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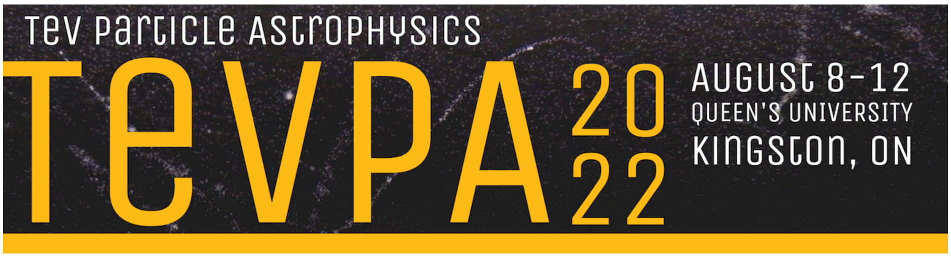

Book of Abstracts

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Gravitational Wave and Multimessenger / 6

Neutrino follow-up with the Zwicky Transient Facility: Results from the first 24 campaigns

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The Zwicky Transient Transient Facility (ZTF) performs a systematic neutrino follow-up program, searching for optical counterparts to high-energy neutrinos with dedicated Target-of-Opportunity observations. Since first light in March 2018, ZTF has taken prompt observations for 24 high-quality neutrino alerts from the IceCube Neutrino Observatory, with a median latency of 12.2 hours from initial neutrino detection. I will summarise the results of this program, and the implications for the origin of astrophysical neutrinos.

Collaboration name:

ZTF

Dark Matter / 7

Using small-scale lensing anisotropies to constrain dark matter.

Authors: Birendra Dhanasingham[1]; Francis-Yan Cyr-Racine[1]

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Strong gravitational lensing provides a promising way to look for clues to the elusive particle nature of dark matter. Indeed, subtle perturbations to lensed images can reveal the dark-matter distribution on sub-galactic scales. In addition to the subhalos of the main lens, a significant contribution to these perturbations comes from dark matter halos along the line-of-sight between the observer and the source. Handling these multiplane lensing effects is computationally expensive. Here we introduce a new approach called "effective multiplane gravitational lensing" to study the collective effect of line-of-sight halos and main-lens dark matter substructure on extended lensed arcs. In this approach, the lens mapping between the source and image planes can be fully characterized by two "effective" lensing potentials encompassing the complete structure of the deflection field, and the line-of-sight halos and main-lens substructure contribute differently to each potential. Using this approach, we point out that line-of-sight halos between the observer and the source imprint a previously unstudied quadrupolar signature in the two-point correlation function of the effective convergence field. Our approach based on this anisotropic signal has the potential to statistically distinguish the line-of-sight halo contribution to lensing perturbations from that of main-lens subhalos in a strongly lensed system, hence significantly improving the constraint on dark matter from strong gravitational lensing.

Collaboration name:

Dark Matter / 8

Assessing the Impact of Hydrogen Absorption on the Characteristics of the Galactic Center Excess

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We present a new reconstruction of the distribution of atomic hydrogen in the inner Galaxy that is based on explicit radiation-transport modelling of line and continuum emission and a gas-flow model in the barred Galaxy that provides distance resolution for lines of sight toward the Galactic Center. The main benefits of the new gas model are, a), the ability to reproduce the negative line signals seen with the HI4PI survey and, b), the accounting for gas that primarily manifests itself through absorption.

We apply the new model of Galactic atomic hydrogen to an analysis of the diffuse gamma-ray emission from the inner Galaxy, for which an excess at a few GeV was reported that may be related to dark matter. We find with high significance an improved fit to the diffuse gamma-ray emission observed with the Fermi-LAT, if our new HI model is used to estimate the cosmic-ray induced diffuse gamma-ray emission. The fit still requires a nuclear bulge at high significance. Once this is included there is no evidence for a dark-matter signal, be it cuspy or cored. But an additional so-called boxy bulge is still favoured by the data.
This finding is robust under the variation of various parameters, for example the excitation temperature of atomic hydrogen, and a number of tests for systematic issues.

Collaboration name:

Dark Matter / 10

Primordial Black Hole Dark Matter in the Context of Extra Dimensions

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The addition of spatial dimensions compactified to submillimeter scales serves as an elegant solution to the hierarchy problem. As a consequence of such large extra dimensions, is the possibility of producing primordial black holes (PBHs) from high-energy collisions in the early universe, leading to a novel source of dark matter. While four-dimensional PBHs have been extensively studied, they have received little attention in the context of extra dimensions. We derive the full cosmological history including creation and evolution of these PBHs, adapting and extending previous analyses of four-dimensional PBHs. We combine constraints from Big Bang Nucleosynthesis, the Cosmic Microwave Background, the Cosmic X-ray Background, and galactic centre gamma-rays. In addition to finding strong constraints on a large portion of available parameter space, we find that in the case of two extra dimensions, asteroid-mass (˜ 10^{20} g) black holes could be created in the early universe and survive until today, potentially comprising the entirety of the observed dark matter abundance.

Collaboration name:

Gamma Rays / 13

Unresolved sources naturally contribute to PeV γ-ray diffuse emission observed by Tibet ASγ

Authors: Flavio Zuccarini[1]; Vittoria Vecchiotti[2]; Francesco Lorenzo Villante[1]; Giulia Pagliaroli[3]

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The Tibet ASγ experiment provided the first measurement of the total diffuse gamma-ray emission from the Galactic disk in the sub-PeV energy range.
Based on analysis of the TeV sources included in the HGPS catalogue, we predict the expected contribution of unresolved pulsar-powered sources in the two angular windows of the Galactic plane observed by Tibet ASγ.
We show that the sum of this additional diffuse component due to unresolved sources and the truly diffuse emission, produced by the interaction of Cosmic Rays (CRs) with the interstellar medium, well saturates the Tibet data, without the need to introduce a progressive hardening of the cosmic-ray spectrum toward the Galactic centre.
We also investigate the typical age of these sources and we show that a relevant contribution is provided by relatively young PWNe with age ranging between $t \sim (7-33)$ kyr, depending on the sky region considered.
Finally, we estimate that CTA will be able to detect about 280 (140) pulsar-powered sources in the whole Galaxy for a typical source size is 10˜pc (40˜pc).

Collaboration name:

Dark Matter / 14

Direct detection of light new species from evaporating primordial black holes

Author: Marco Chianese[1]

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The direct detection of sub-GeV dark matter interacting with nucleons is hampered by the low recoil energies induced by scatterings in the detectors. This experimental difficulty is avoided in the scenario of boosted dark matter where a component of dark matter particles is endowed with large kinetic energies. In this talk, I will show that the current evaporation of primordial black holes with masses from 10^{14} to 10^{16} g is a source of boosted light dark matter with energies of tens to hundreds of MeV. Focusing on the XENON1T experiment, these relativistic dark matter particles could give rise to a signal orders of magnitude larger than the present upper bounds. Therefore, this allows to significantly constrain the combined parameter space of primordial black holes and sub-GeV dark matter. In the presence of primordial black holes with a mass of 10^{15} g and an abundance compatible with present bounds, the limits on DM-nucleon cross-section are improved by four orders of magnitude. I will also discuss the case of DM-electron interactions.

Collaboration name:

Extragalactic Sources / 15

Gamma-ray and neutrino emissions from star-forming and star-burst galaxies

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Experimental observations have demonstrated a strong correlation between star-forming processes and gamma-ray luminosities. However, the very nature of these emissions is still under debate. Certainly, star-forming and starfurst galaxies (SFGs and SBGs) are well-motivated astrophysical emitters of gamma-rays and neutrinos through hadronic collisions. In this talk, I will present several updates on their non-thermal radiations, revisiting both their point-like and cumulative (diffuse) emission properties. From the point-like side, I will discuss the potentialities of future gamma-ray (CTA, SWGO) and neutrino (KM3NeT/ARCA, IceCube-gen2) telescopes to quantitively scrutinize their gamma-ray and neutrino expectations from different cosmic-ray transport models. From the diffuse perspective, I will investigate a model based on a data-driven blending of spectral indexes, thereby capturing the observed changes in the properties of individual emitters. Strikingly, SFGs and SBGs can explain up to 40% of the diffuse HESE data, while remaining consistent with gamma-ray limits on non-blazar sources.

Collaboration name:

Dark Matter / 16

Novel Model Independent Constraints on Dark Matter and Cosmic Neutrinos

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In this talk, we present model-independent constraints on dark matter and cosmic neutrinos through gravitational interactions on asteroidal objects. The bounds only rely on the matter density around the trajectories of the asteroids. The new bounds are model-independent but are most meaningful in constraining dark matter and cosmic neutrino scenarios with significant clustering.
We also discuss the studies of constraining cosmologically interesting modified gravity models.

Collaboration name:

Neutrinos / 17

Point sources of ultra-high-energy neutrinos: minimalist predictions for near-future discovery

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The detection of ultra-high-energy neutrinos, with energies above 100 PeV, is requisite to fully understand the high-energy Universe. Their discovery might soon be within reach of upcoming neutrino telescopes, yet in-depth discovery forecasts for their astrophysical sources are largely unavailable. We present a robust framework to compute the statistical significance of source discovery via the detection of neutrino multiplets,
i.e., neutrinos clustered around a position in the sky. Our methods are experiment-based—i.e., independent of flux predictions—conservative—i.e., they adopt the maximum allowed background of diffuse neutrinos—and comprehensive—i.e., they account for non-neutrino backgrounds, neutrino attenuation inside the Earth, and the angular response of the detector. We focus on neutrino radiodetection in IceCube-Gen2, via state-of-the-art simulation. To discover a source with 5σ significance, IceCube-Gen2 will need to detect a triplet, at best, and an octuplet, at worst, depending on whether the source is steady-state or transient, and on its position in the sky. The number of discovered sources carries significant information on the properties of the source population, and the discovery of a neutrino multiplet can trigger searches for electromagnetic sources. Our framework is easy to implement and adaptable to other upcoming neutrino telescopes.

Collaboration name:

Cosmic Rays / 18

Direct Detection of TeV—PeV Cosmic Rays in Space

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We present the first results of the ERC PeVSPACE project, aimed at fundamentally improving the precision of direct cosmic ray measurements at the highest energies –in the TeV–PeV range, on DArk Matter Particle Explorer (DAMPE) and High Energy Radiation Detector (HERD) experiments.

DAMPE and HERD provide a unique opportunity of directly probing cosmic ray spectra close to the "knee". However, such measurements stumble against a critical limitation –dominating systematics uncertainties related to particle reconstruction& identification and hadronic simulations at the highest energies. The goal of our research is to overcome these challenges through the development of novel tracking and particle identification techniques, as well as improved hadronic simulations, using for the first time the state-of-the-art Artificial Intelligence approach.

First, we give a brief overview of the DAMPE and HERD missions, focusing on the main challenges of direct Cosmic Ray detection at TeV—PeV. Then we present the developed techniques and demonstrate their first application on the analysis of DAMPE data at the highest energies.

Collaboration name:

DAMPE

Gamma Rays / 20

Implications from 3-dimensional modeling of gamma-ray signatures in the Galactic Center

Author: Julien Dörner[1]

Co-authors: Anna Franckowiak [2]; Horst Fichtner [1]; Julia Tjus ; Mario R. Hoerbe [2]; Mehmet Guenduez [3]; Paul-Simon Blomenkamp [1]

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The Galactic Center (GC) region has been intensively studied in gamma-rays in the past decades. Fermi LAT has discovered a GeV excess which is not fully understood, and the first detection of a *PeVatron* by H.E.S.S. indicates the existence of cosmic ray sources providing energies up to a PeV or higher. The emission of TeV gamma rays in the GC is affected by the source position and the distribution of the gas, photons and magnetic field within this region.
For the first time we model the TeV emission in a realistic three-dimensional distribution of gas as well as photon fields and use a complex magnetic field comprising the large-scale field structure and small-scale imprints of molecular clouds as well as non-thermal filaments. Additionally, we test different anisotropies of the diffusion tensor defined by the ratio of the diffusion coefficients perpendicular and parallel to the local magnetic field direction. For comparison we compute a two-dimensional gamma-ray distribution and compare it with H.E.S.S. measurements.

Collaboration name:

Neutrinos / **22**

Latest results from the CUORE experiment

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The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for $0\nu\beta\beta$ decay that has been able to reach the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO2 crystals arranged in a compact cylindrical structure of 19 towers. CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and in April 2021 released its 3rd result of the search for $0\nu\beta\beta$, corresponding to a tonne-year of TeO2 exposure. This is the largest amount of data ever acquired with a solid state detector and the most sensitive measurement of $0\nu\beta\beta$ decay in 130Te ever conducted, with a median exclusion sensitivity of 2.8×10ˆ25 yr. We find no evidence of $0\nu\beta\beta$ decay and set a lower bound of 2.2 ×10ˆ25 yr at a 90% credibility interval on the 130Te half-life for this process. In this talk, we present the current status of CUORE search for $0\nu\beta\beta$ with the updated statistics of one tonne-yr. We finally give an update of the CUORE background model and the measurement of the 130Te $2\nu\beta\beta$ decay half-life, study performed using an exposure of 300.7 kg·yr.

Collaboration name:

CUORE

Galactic Sources / **23**

TeV neutrinos from dense winds in Novae

Authors: Andrzej Śmiałkowski[1]; Wlodek Bednarek[None]

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We investigate the hypothesis that hadrons are accelerated as a result of the reconnection of the White Dwarf magnetic field during the initial dense and fast wind in Nova explosion. Hadrons are expected to interact efficiently with a dense matter of the wind producing neutrinos with TeV energies. We estimate the muon neutrino event rates in the IceCube telescope in the case of a few Novae. For isotropic emission of neutrinos, those event rates are unlikely to be detected with the present detector. However, in the case of anisotropic emission of neutrinos and for favourable location of the observer, some neutrino events might be detected not only from the class of Novae recently detected in the GeV gamma-rays by the Fermi-LAT telescope but also from novae not detected in gamma-rays.

Collaboration name:

Dark Matter / 25

Global fits of s-channel simplified models for dark matter with GAMBIT

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Dark matter candidates can arise from a wide range of extensions to the Standard Model. Simplified models with a small number of new particles allow for the optimisation and interpretation of dark matter and collider experiments, without the need for a UV-complete theory. In this talk, I will discuss the results from a recent GAMBIT study of global constraints on vector-mediated simplified dark matter models. I will cover several models with differing spins of the dark matter candidate. Along with these constraints, I will provide new unitarity bounds from the self-scattering of vector dark matter and discuss their effect on collider constraints.

Collaboration name:

GAMBIT

Dark Matter / 26

Dark Matter decay to neutrinos

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Dark matter (DM) particles are predicted to decay into Standard Model particles which would produce signals of neutrinos, gamma-rays, and other secondary particles. Neutrinos provide an avenue to probe astrophysical sources of DM particles. We review the decay of dark matter into neutrinos over a range of dark matter masses from MeV/c2 to ZeV/c2. We examine the expected contributions to the neutrino flux at current and upcoming neutrino and gamma-ray experiments, such as Hyper-Kamiokande, DUNE, CTA, TAMBO, and IceCube Gen-2. We consider galactic and extragalactic signals of decay processes into neutrino pairs, yielding constraints on the dark matter decay lifetime that ranges from tau ~ 1.2×10ˆ21 s at 10 MeV/c2 to 1.5x10ˆ29 s at 1 PeV/c2.

Collaboration name:

Dark Matter / **27**

Constraining Dark Matter Decays at the keV Scale with the NuSTAR Observatory

Author: Brandon Roach[1]

Co-authors: Steven Rossland [2]; Kenny Chun Yu Ng [3]; Kerstin Perez [1]; John Beacom [4]; Brian Grefenstette [5]; Shunsaku Horiuchi [6]; Roman Krivonos [7]; Daniel Wik [2]

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Dark matter at the keV scale has become an active topic in the last decade. The NuSTAR x-ray observatory, with its energy bandpass 3–150 keV and wide-angle aperture for unfocused x-rays, is an ideal platform to search for decaying keV-scale dark matter, e.g. sterile neutrinos. Previous NuSTAR analyses constrained much of the sterile-neutrino parameter space for masses ˜10–40 keV, improving upon previous instruments by nearly an order of magnitude, but were generally limited at lower masses by the irreducible instrument background. After reviewing our group's previous NuSTAR analyses, I will describe our recent efforts to apply novel background-rejection and modeling techniques to long-exposure spectra of the Milky Way halo, further constraining the parameter space for 6–40 keV sterile neutrinos. These improvements will allow NuSTAR to begin to test some of the models of the 3.5-keV anomaly.

Collaboration name:

Cosmology / **28**

An Effective Field Theory of 21 cm Radiation with Redshift Space Distortions

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With the prospect of detecting the cosmological 21 cm signal from the epoch of reionization just over the horizon, methods for extracting maximal cosmological information from this signal are increasingly timely. I will discuss recent work to further develop the effective field theory (EFT) for the 21 cm brightness temperature field during the epoch of reionization, incorporating renormalized bias and a treatment of redshift space distortions. To validate our theoretical treatment, we fit the predicted EFT Fourier-space shapes to the Thesan suite of hydrodynamical simulations of reionization at the field level, where the considerable number of modes prevents overfitting. We find agreement at the level of a few percent between the 21 cm power spectrum from the EFT fits and simulations over the wavenumber range $k < 0.8$ h/Mpc and neutral fraction $x_{\mathrm{HI}} > 0.4$ that is imminently measurable by the Hydrogen Epoch of Reionization Array (HERA). The ability of the EFT to describe the 21 cm signal extends to simulations that have different astrophysical prescriptions for reionization as well as simulations with interacting dark matter. We provide physical interpretations for the various bias parameters and test these interpretation against the different simulations, and find that simulations with the largest bubble sizes are perturbative over the smallest ranges of x_{HI}.

Collaboration name:

Neutrinos / **30**

Tau Appearance from High-Energy Neutrino Interactions

Author: Pavel Zhelnin[None]

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High-energy muon and electron neutrinos yield a non-negligible flux of tau neutrinos as they propagate through Earth. In this talk, the impact of this additional component in the PeV and EeV energy regimes is addressed for the first time. This contribution is predicted to be significantly larger than the atmospheric background above 300 TeV, and so effects future cosmic tau neutrino flux discovery in current/future neutrino telescopes. Further we demonstrate that Earth-skimming neutrino experiments, designed to observe tau neutrinos, will be sensitive to cosmogenic neutrinos, even in extreme scenarios without a primary tau neutrino component.

Collaboration name:

Neutrinos / **31**

LEGEND-1000: a future ton-scale experiment for Neutrinoless Double Beta Decay

Author: Michele Morella[None]

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LEGEND-1000 [1] is a next-generation ton-scale experiment searching for neutrinoless double beta decay ($0\nu\beta\beta$) of ^{76}Ge using p-type, high-purity ICPC germanium semiconductor detectors. The experiment is based on 1000 kg of Ge detectors enriched to more than 90% in ^{76}Ge. The detectors are operated submerged in liquid argon (LAr), which act as a cooling medium and, through the detection of its scintillation light by a system of light-guiding fibers coupled to SiPMs, as active shield. Germanium detectors are intrinsically very pure and have a high density allowing to deploy substantial mass in limited volumes. The excellent energy resolution of germanium detectors (about

0.12% FWHM @ $Q_{\beta\beta}$) allows the identification of a peak at $Q_{\beta\beta}$ while pulse shape analysis makes background discrimination based on event topology possible. LEGEND-1000 is going to be installed in an underground laboratory to reduce direct and induced backgrounds from cosmic rays. The baseline design assumes LEGEND-1000 to be installed in the SNOLAB cryopit. A similar design could be set up at the alternative LNGS site. The goal for LEGEND-1000 is to have a background level of less than 1×10^{-5} cts/(keV kg yr). With an exposure of about 10 ton yr, this allows to probe $0\nu\beta\beta$ decay half-life of ^{76}Ge beyond 10^{28} years with a 99.7% CL discovery sensitivity. This corresponds to a full coverage of $m_{\beta\beta}$ values suggested by a possible inverted neutrinos mass ordering.
The goals, design and background reduction strategies of LEGEND-1000 will be presented.

[1] LEGEND-1000 PreConceptual Design Report, LEGEND Collaboration, N. Abgrall et al., arXiv:2107.11462 [physics.ins-det]

Collaboration name:

LEGEND

Neutrinos / 32

MUTE: A Modern Calculation for Deep Underground and Underwater Muons

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I present a new, open-source, pure Python program, MUTE (MUon inTensity codE) (A. Fedynitch, W. Woodley, M.-C. Piro 2022 *ApJ* 928 27). MUTE combines the state-of-the-art codes MCEq (Matrix Cascade Equation) and PROPOSAL (PRopagator with Optimal Precision and Optimised Speed for All Leptons) to compute the cosmic ray cascades in the atmosphere and the propagation of muons through matter in separate steps. It is both efficient and flexible, as the most recent theoretical models can be changed in the code independently of each other. Using these tools, MUTE provides forward predictions for muon spectra in deep underground and underwater laboratories, accurately characterising the uncertainties arising from hadron production models. The implications are that if high-energy atmospheric neutrino flux uncertainties are cross-calibrated with the underground muon intensity data, there is considerable potential for them to be reduced from 40% down to approximately 10%. MUTE can be also used for laboratories located in mines or under mountains. The control of theoretical uncertainties allows us to accurately predict the total muon rates and their seasonal variations, and derive muon-induced backgrounds in underground Dark Matter and neutrino detectors.

Collaboration name:

Cosmic Rays / 33

Potential measurement of the primary cosmic-ray proton spectrum between 40 TeV and a few hundred TeV with the Tibet hybrid experiment (Tibet-III + MD)

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We are observing extensive air showers using the Tibet-III air shower array and the undergound water-Cherenkov Muon Detector array (MD) to measure the chemical composition of cosmic rays around the knee energy region. We have developed a method to select air showers induced by primary protons with the energy between 40 TeV and 630 TeV by using the number of muons detected by the MD in each shower. The detector's sensitivity for primary proton spectra was evaluated by Monte Carlo simulations assuming different primary cosmic ray composition models and interaction models. Using the number of muons detected by the MD, it was found that the protons could be selected with 90% purity. The systematic errors including the model uncertainty is sufficient to study the shape of proton spectra. We will also report results from the analysis of observed data with the new method.

Collaboration name:

Tibet ASg

Neutrinos / **34**

Search for correlations between high-energy neutrinos and blazars with IceCube

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The IceCube Neutrino Observatory is the world largest neutrino telescope, instrumenting one cubic kilometer of Antarctic ice. IceCube started its operation in 2011 and a diffuse flux of neutrinos was discovered in 2013. To this day the sources of those neutrinos are still largely unknown. One of the most promising source candidates are blazars, Active Galactic Nuclei with jets aligned towards Earth.

In 2018 IceCube reported the first observation of a high-energy neutrino with a high probability of being astrophysical in origin (neutrino alert), IC170922A, in spatial and temporal coincidence with blazar TXS 0506+056. To determine if blazars produce high-energy neutrinos all correlations between blazars and neutrino alerts can be combined into a global p-value by performing a stacking analysis. Here we present the results obtained with 2089 blazars from the incremental version of the Fourth Catalog of Active Galactic Nuclei detected by Fermi-LAT (4LAC-DR2, for Data Release 2) and 275 neutrinos detected by IceCube between 2011 and 2020 that would have passed the neutrino alert criteria.

Collaboration name:

IceCube

Cosmic Rays / **36**

Force-Field Model of Galactic Cosmic Ray Propagation in the Inner Heliosphere

Author: Jung-Tsung Li[1]

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We investigate the effect of inertial range magnetohydrodynamic turbulence to the 1-dimensional force-field model. Using well established quasilinear theory together with the recently available magnetic power spectrum from Parker Solar Probe, we perform calculations of parallel diffusion coefficient, modulation potential and galactic cosmic ray flux in the inner heliosphere. The model applies to solar ecliptic plane only and does not include particle drifts and full adiabatic energy loss. Our model shows a rigidity-dependent modulation at low particle rigidity from including the inertial range power spectrum and a rigidity-independent modulation at high rigidity from including $1/f$ noise in which the latter agrees with neutron monitor measurements. We find a substantial cosmic ray flux reduction for particle kinetic energy less than 10 GeV compared to the previous analytical treatments, which only consider $1/f$ noise for the magnetic power spectrum. Comparison of the model with the measurements of galactic cosmic ray radial gradients is presented.

Collaboration name:

Extragalactic Sources / 38

Probing the multiwavelength emission scenario of GRB 190114C

Authors: Andrew Taylor[1]; Marc Klinger[2]; Sylvia Jiechen Zhu[None]; Donggeun Tak[None]

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The multiwavelength observation of GRB 190114C, an extremely bright gamma-ray burst (GRB), opens a new window for studying the emission mechanism of GRBs. The Very-High-Energy (VHE; >100 GeV) detection by MAGIC suggested the inverse Compton process as the emission mechanism for the VHE gamma rays during the early afterglow phase of the burst. However, other VHE GRB detections have casted doubt on this scenario as the inverse Compton emission has not been clearly observed in other bursts. Furthermore, in GRB190114C, only a limited number of statistical and systematic studies on the emission scenario have been performed. Here, we perform the full likelihood analysis with the multiwavelength dataset: Swift-XRT, Swift-BAT, Fermi-GBM, Fermi-LAT, and MAGIC. We compute the statistical preference of the combined synchrotron and synchrotron self-Compton (SSC) model over the synchrotron-only model, and check the stability of this preference.

Collaboration name:

Galactic Sources / 39

Gone with the breeze: A subsonic solution to the Fermi bubbles problem

Co-authors: Donna Rodgers-Lee [1]; Andrew Taylor [2]

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More than a decade after their discovery, the mechanism behind the Fermi bubbles features is still elusive. The two main models considered for the advection of cosmic-rays (CRs) are a jet model for leptonic process or wind model for hadronic process. An alternative has been proposed where CRs, produced by pp collisions, are both diffused and advected by a Galactic breeze, ie a subsonic outflow. The first results provided a flat surface brightness in the same range than observations. The breeze profile took the form of a divergence-free outflow. In this paper we push the model further by using an hydrodynamic code introducing a divergence conduction to adiabatic losses for the γ-ray emission.

Collaboration name:

Dark Matter / 40

The General AntiParticle Spectrometer - Search for Dark Matter using Cosmic-ray Antinuclei

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The GAPS experiment is designed to conduct a dark matter search by measuring low-energy cosmic-ray antinuclei (antiprotons, antideuterons, antihelium) with a novel detection approach. For the case of antiprotons, a high-statistics measurement in the unexplored low-energy range will be conducted. In contrast, not a single cosmic antideuteron has been detected by any experiment thus far. However, well-motivated theories beyond the standard model of particle physics contain viable dark matter candidates, which could lead to a significant enhancement of the antideuteron flux due to annihilation of dark matter particles. This flux contribution is calculated to be especially large at low energies, which leads to a high discovery potential for GAPS. This antideuteron search is essentially background free because the theoretically predicted antideuteron flux resulting from secondary interactions of cosmic rays with the interstellar gas is very low. Furthermore, the search for low-energy antihelium-3 and antihelium-4 promises an even lower secondary background and can also be performed with GAPS. The experiment is designed to achieve its goals via a series of long-duration balloon flights at high altitude in Antarctica. GAPS is currently under construction and preparing for the first flight. The presentation will briefly review the theoretical status, introduce the GAPS experiment and its capabilities, and report on the construction and instrument performance status.

Collaboration name:

GAPS

Galactic Sources / 41

Hadronic origin of gamma-ray emission from nova RS Oph revealed by the MAGIC telescopes

Authors: Julian Sitarek[None]; Vandad Fallah Ramazani[1]; David Green[None]; Francesco Leone[None]; Ruben Lopez-Coto[2]; Alicia Lopez-Oramas[None]

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RS Ophiuchi (RS Oph) is a recurrent symbiotic nova. Its latest outburst, on 8th of August 2021, brought to the first detection of this class of sources in very-high-energy (above 100GeV) gamma rays. We present the MAGIC observations of RS Oph during this event, triggered by the Fermi-LAT detection of high energy gamma rays from this source. We characterize the emission from one day after the optical detection. We perform modeling of the gamma-ray spectrum with both leptonic and hadronic models, supported by simultaneous optical observations. We find strong evidence for the hadronic origin of the emission and discuss its implications for the contribution to the Galactic Cosmic Rays.

Collaboration name:

MAGIC

Extragalactic Sources / 42

Galactic halo magnetic fields and UHECRs deflections

Authors: Andrew Taylor[1]; Vasundhara Shaw[None]; Arjen van Vliet[2]

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The paths of cosmic rays are deflected upon passing through the Galactic magnetic field structure. The strength of the deflections that these cosmic rays undergo is dependent on the strength and structure of the Galactic magnetic field. Unfortunately, our knowledge of the Galactic magnetic field is very limited, especially when considering the fields present in the Galactic halo region. In this talk, I wish to motivate the importance of the Galactic halo magnetic fields not only from the point of view of radio observations but also for ultra high energy cosmic ray propagation.

The observations from eROSITA and FERMI-LAT show clear evidence of large extended structures out in the Galactic halo region, with a total energy of up to ˜1056ergs seen in thermal X-rays. However, most of the widely used Galactic magnetic field models focus predominantly on the Galactic disc rather than the halo. In Ref.˜[1] we motivate a toy magnetic field model for the Galactic halo. We use this model, in combination with an analytic expression for the non-thermal electron distribution, to generate synthetic polarised synchrotron maps and compare them with 30 GHz Planck data. By enforcing equipartition between the magnetic field and non-thermal particles, we obtain constraints on the parameters of our model and utilise these constraints to create arrival direction maps for ultra high energy cosmic rays. We conclude that present uncertainties in the field strengths can have major consequences on the arrival directions of the cosmic rays and thereby the source localisation.

[1] V. Shaw, A. van Vliet, A. M. Taylor, arXiv:2202.06780

Collaboration name:

Neutrinos / 43

Measurement of the Astrophysical Diffuse Flux Spectrum using Muon Neutrino Events with a Contained Vertex in IceCube

Co-authors: Sarah Mancina [1]; ALBRECHT KARLE [2]

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The IceCube Neutrino Observatory is a cubic kilometer-sized detector designed to detect astrophysical neutrinos. However, cosmic rays interacting in the atmosphere produce a significant number of muons in the southern equatorial sky. This work outlines a new dataset with large background rejection and high signal efficiency using a boosted decision tree. This dataset is also effective at rejecting atmospheric neutrinos that are often accompanied with muons; this so-called self-veto effect allows us to reject atmospheric neutrinos in the southern sky significantly. We search for muon neutrinos that undergo a charged current interaction within the detector volume resulting in a neutrino energy resolution of ~25%. In addition, our selection techniques target muon neutrinos giving us a median angular resolution of 1 degree. The excellent signal purity and event properties of this dataset allow us to measure the astrophysical diffuse flux between 5 TeV and 1 PeV. We show this as a measurement of the astrophysical diffuse flux modeled as a single power law. We also show measurements of the flux assuming more complex models such as broken and piecewise power laws.

Collaboration name:

IceCube Collaboration

Neutrinos / **44**

Galactic and Extragalactic Southern Sky Neutrino Source Searches with IceCube Starting Track Events in the 1 to 100 TeV Energy Range.

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Astrophysical neutrinos are an important piece of the TeV multimessenger astrophysics puzzle. However, the significant background of atmospheric neutrinos seen in our neutrino observatories makes it difficult to study neutrino sources below 100 TeV in the southern sky Looking for starting events from the southern sky with IceCube allows us to reject not only events from incoming atmospheric muons but also atmospheric neutrinos that are escorted into the detector by muons from the same shower. This creates a muon neutrino sample of a purity that can only be achieved with throughgoing events above an energy of 100 Tev in the 1 to 100 TeV range. In our sample presented here, we specifically look for well-localized tracks generated by muon neutrino interactions occurring inside the detector. With this sample we search over the full sky for significant neutrino point sources. We also look for neutrino emission from bright GeV gamma ray extragalactic sources, TeV gamma ray galactic plane sources, and diffuse neutrino emission from cosmic ray interactions in the Galactic Plane.

Collaboration name:

IceCube

Neutrinos / **45**

IceCube Matter-Enhanced Sterile Neutrino Searches

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The IceCube Neutrino Observatory has sensitivity to sterile neutrino oscillations through matter-enhanced oscillation occurring in the few TeV energy range for eV^2-scale mass-squared splittings. I will present previous measurements of these effects in ν_μ disappearance, which has strong sensitivity to the mixing angle θ_{24} via $\bar{\nu}_\mu \to \bar{\nu}_s$ transitions. I will also discuss ongoing work towards measuring the sterile neutrino mixing angles θ_{14}, θ_{24}, and θ_{34} through the previously unexplored $\bar{\nu}_\mu \to \bar{\nu}_e$ and $\bar{\nu}_\mu \to \bar{\nu}_\tau$ cascade appearance channels.

Collaboration name:

IceCube

Dark Matter / **46**

Signatures of primordial black hole dark matter at DUNE and THEIA

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Co-authors: Mariam Tórtola [1]; Pablo Martinez-Mirave [2]

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Primordial black holes (PBHs) are a potential dark matter candidate whose masses can span over many orders of magnitude. If they have masses in the 10ˆ15 – 10ˆ17 g range, they can emit sizeable fluxes of MeV neutrinos through evaporation via Hawking radiation. We explore the possibility of detecting light (non-)rotating PBHs with future neutrino experiments DUNE and THEIA. We will show that they will be able to set competitive constraints on PBH dark matter, thus providing complementary probes in a part of the PBH parameter space currently constrained mainly by photon data.

Collaboration name:

Galactic Sources / **47**

Detection of very-high-energy gamma rays from RS Ophiuchi by the prototype Large-Sized Telescope for the Cherenkov Telescope Array

Author: Yukiho Kobayashi[1]

Co-authors: Arnau Aguasca-Cabot [2]; Mabel Bernardos [3]; David Green [4]; Rubén López-Coto [3]

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The Cherenkov Telescope Array (CTA) will be the next-generation ground-based gamma-ray observatory, and will achieve unprecedented sensitivity in the energy range between 20 GeV and 300 TeV. The Large-Sized Telescopes (LSTs) provide the best sensitivity in the lowest part of the CTA energy range. The prototype LST (LST-1) for CTA was inaugurated in 2018, on La Palma, the northern site of CTA. LST-1 is currently finishing its commissioning phase and starting scientific observations. During its commissioning, LST-1 has observed various sources, including transient phenomena. Among them, LST-1 performed observations of the outburst of RS Ophiuchi, a recurrent nova in the Galaxy, in August 2021. The currently operating gamma-ray telescopes have reported the detection of very-high-energy gamma rays from the burst, which are the first reports of detection of very-high-energy gamma-ray emission from a nova. Our analysis of the LST-1 observations of RS Ophiuchi shows that LST-1 also achieved the detection of the nova. We will present the status of our analysis of the LST-1 observations of RS Ophiuchi.

Collaboration name:

Cherenkov Telescope Array

Dark Matter / **48**

Constraining resonant dark matter self-interactions with strong gravitational lenses

Author: Daniel Gilman[None]

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Dark matter halos and subhalos less massive than 10ˆ9 solar masses hold the key to understanding the nature of dark matter, including its formation mechanism, particle mass, and possible interactions. In particular, self-interacting dark matter (SIDM) prescribes a dynamic evolution of halo density profiles that distinguishes it from cold dark matter. This process begins with core formation, and ends with gravothermal catastrophe, or core collapse. Core collapse transforms halos into extremely efficient gravitational lenses. Focusing on SIDM with attractive interaction potentials, I will argue that resonances in the cross section, which increase its amplitude by over an order of magnitude, can trigger core collapse in low-mass subhalos and field halos. By analyzing the relative image magnifications of quadruply-imaged quasars, I will present constraints on the abundance of core-collapsed halos and field halos, and cast this inference in terms of resonant SIDM. I will conclude by discussing future prospects for this kind of analysis with forthcoming data from JWST.

Collaboration name:

Dark Matter / **49**

The semi-visible dark photon

Author: Matheus Hostert[1]

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Light dark sectors can explain the existence of dark matter and, if the new fermions carry lepton number, may also generate light neutrino masses. We revisit models where the dark photon A' couples to multiple generations of dark fermions. The decays A' are semi-visible: they contain visible particles but come accompanied by missing energy. We will show that these models can provide an explanation for the g-2 of muon and that they can lead to the effective violation of lepton flavor universality in B decays.

Collaboration name:

Extragalactic Sources / 52

A multi-wavelength spectral characterization of gamma-ray emitting extreme BL Lacertae blazar candidates hidden in Fermi-LAT data.

Authors: Mireia Nievas[None]; Alberto Dominguez[1]; Aryeh Louis Brill[2]; Graziano Chiaro[3]; Giovanni La Mura[4]; Vaidehi Paliya[5]

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Blazars are key-elements in the understanding of the extragalactic Universe from the astroparticle physics point of view. These sources are jetted radio-loud active galactic nuclei dominated by non-thermal emission that extends across the electromagnetic spectrum. Their emission is a proof of cosmic particle acceleration and the production of ultra-relativistic particles within their physical structure. An intriguing subset of blazars is known as extreme high-synchrotron-peak (EHSP) blazars, whose gamma-ray emission is expected to peak at TeV energies, yet surprisingly their numbers are scarce in very high energy source catalogs. In this talk, we show a model-driven methodology to search for classical EHSP blazars based on data from NASA's Fermi Gamma-ray Space Telescope in addition to archival radio, optical, and X-ray data. This strategy allows us to study their physical properties. Our main results are (1) finding 17 new EHSP blazars, increasing significantly their number, (2) that only 2 of them seem to be detectable by TeV telescopes, and (3) interestingly, these 2 objects are outliers relative to their magnetic versus kinetic energy density. We discuss some interpretations of these results.

Collaboration name:

Cosmology / 53

Hubble distancing: Focusing on distance measurements in cosmology

Author: Kylar Greene[1]

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The Hubble-Lemaitre tension is currently one of the most important questions in cosmology. Most of the focus so far has been on reconciling the Hubble constant value inferred from detailed cosmic microwave background measurement with that from the local distance ladder. This emphasis on one number – namely H0 – misses the fact that the tension fundamentally arises from disagreements of distance measurements. To be successful, a proposed cosmological model must accurately fit these distances rather than simply infer a given value of H0. Using the newly developed likelihood package 'distanceladder', which integrates the local distance ladder into MontePython, we show that focusing on H0 at the expense of distances can lead to the spurious detection of new physics in models which change late-time cosmology. As such, we encourage the observational cosmology community to make their actual distance measurements broadly available to model builders instead of simply quoting their derived Hubble constant values.

Collaboration name:

Gravitational Wave and Multimessenger / 55

Searches for IceCube-neutrino counterparts to gravitational wave events

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The IceCube Neutrino Observatory at the South Pole has detected an astrophysical flux of high-energy neutrinos. Searches for the sources of these astrophysical neutrinos are performed with these detections which have energies above several 100s of GeV. A dense infill array called DeepCore lowers IceCube's energy threshold to a few GeV, enabling additional searches for low-energy astrophysical transients. Compact binary mergers can leave their gravitational-wave signatures in the LIGO and Virgo detectors, and could be a possible source of astrophysical neutrinos. Here, we will focus on neutrino follow-up searches of gravitational-wave transients detected by LIGO-Virgo. We present analyses that search for high (>1 TeV) and low (<1 TeV) energy neutrino counterparts from the O1, O2 and O3 runs of LIGO-Virgo. The sensitivities of these analyses, and the unblinded results, will be discussed.

Collaboration name:

IceCube Collaboration

Dark Matter / 56

The CYGNO experiment, a directional detector for direct Dark Matter searches

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We are going to present the CYGNO/INITIUM project, an experiment that emerges as a new approach for directional Dark Matter searches using a gaseous TPC with the purpose of detecting low

mass (0.5-50 GeV) WIMPS and performing solar neutrino spectroscopy. This project distinguishes itself by the use of He:CF_4, a low-density gas mixture sensitive to both spin dependent and independent interactions, at atmospheric pressure and with optical readout. The final objective of the CYGNO/INITIUM project is to install a $O(1)$ m^3 demonstrator at the Laboratori Nazionali del Grand Sasso (LNGS) by 2024-2026. This will act as a demonstrator of the technology, performance, and scalability of the project.

The signal formation in our detector starts with a particle interaction inside the gas volume which is followed by the ionization of the gas and drift of the newly generated electrons. The amplification plane is composed by a stack of three Gas Electron Multipliers (GEMs), where the primary electrons are amplified. The readout is carried out through the combined use of a scientific CMOS camera and PMTs which record the light produced at the amplification stage due to excitation (and posterior de-excitation) of the gas molecules that occur during the electron avalanche process. By merging the information of the two-dimensional projection (X-Y) obtained with a sCMOS camera and the light time profile (dZ) reconstructed using the PMT signal, it is possible to perform a 3D reconstruction of the ionizing events. The high granularity and fast sensors also provide a detailed reconstruction of the energy deposition over a path length which enables topology, directional and head-to-tail recognition.

We will demonstrate the latest results concerning energy resolution, particle identification, and 3D tracking capabilities obtained with our latest 50 L prototype, LIME, recently installed underground. We will also discuss our most recent R&D progresses carried out with a smaller prototype focused on the improvement of the light production and experimental technique.

Collaboration name:

CYGNO/INITIUM

Dark Matter / 58

Searching for Axionlike Particles from Gamma-ray Bursts with Fermi

Author: Milena Crnogorcevic[None]

Co-authors: Regina Caputo [1]; Manuel Meyer [2]; Nicola Omodei ; Michael Gustafsson

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Axion-like particles (ALPs) are a well-motivated candidate for constituting a significant fraction of dark matter. They are produced in high-energy environments, such as core-collapse supernovae (CCSNe), and could undergo conversion into gamma-rays in the presence of an external magnetic field, with a characteristic spectrum peaking in the 30–100-MeV energy range. CCSNe are often invoked as progenitors of ordinary long gamma-ray bursts (GRBs), allowing us to conduct a search for potential ALP spectral signatures using GRB observations with Fermi Large Area Telescope (LAT). We conduct a data-driven sensitivity analysis to find the distance limit for a hypothetical ALP detection with the LAT's low-energy (LLE) technique which, in contrast to the standard LAT analysis, allows for a a larger effective area for energies down to 30˜MeV. We select a candidate sample of twenty-four GRBs and carry out a model comparison analysis in which we consider different GRB spectral models with and without an ALP signal component. We also consider any precursor GRB emission in the standard and LLE data. Here, we summarize the statistical methods used in our analysis and the underlying physical assumptions, the feasibility of the upper limits on ALP coupling from our model comparison results, and an outlook on future MeV instruments in the context of ALP searches.

Collaboration name:

Fermi LAT

Cosmic Rays / 59

The Surface Array Enhancement of the IceCube Neutrino Observatory

Authors: Dennis Soldin[None]; Roxanne Turcotte-Tardif[None]; Frank Schröder[None]

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The IceTop array, located at the surface of the IceCube Neutrino Observatory, is currently used as a veto for the in-ice neutrino detector as well as a cosmic ray detector. Built from 162 ice Cherenkov tanks, its sensitivity has been reducing over the operational years due to snow accumulation on the tanks. In order to mitigate this issue as well as further increase the accuracy of cosmic-ray measurements, an enhancement is planned in the next few years. It consists of an array of scintillation panels and radio antennas that will be deployed within the whole IceTop footprint. Upgrading IceTop with radio antennas will provide X_{max} measurements, a variable widely used to reconstruct the cosmic-ray chemical composition. The scintillators will reduce the detection threshold down to hundreds of TeVs. Combined, the scintillators, the antennas, the ice-Cherenkov tanks, and the in-ice detector will provide a unique tool for understanding air-shower particle physics and the composition of cosmic rays in the energy range around 10^{14}eV to 10^{18}eV. In January 2020, a prototype station with 3 antennas and 8 scintillation panels was deployed. In this talk, I will describe the surface array enhancement and demonstrate the performance of the prototype station.

Collaboration name:

IceCube

Gravitational Wave and Multimessenger / 60

Astrometric Gravitational-Wave Detection via Stellar Interferometry

Author: Michael A. Fedderke[1]

Co-authors: Peter W. Graham [2]; Bruce Macintosh [2]; Surjeet Rajendran [1]

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In this talk, I will evaluate the potential for gravitational-wave (GW) detection in the frequency band from 10 nHz to 1 μHz using extremely high-precision astrometry of a small number of stars. In particular, I will argue that non-magnetic, photometrically stable hot white dwarfs (WD) located at $\sim$ kpc distances may be optimal targets for this approach. Previous studies of astrometric GW detection have focused on the potential for less precise surveys of large numbers of stars; this work provides an alternative optimization approach to this problem. Interesting GW sources in this band are expected at characteristic strains around $h_c \sim 10^{-17} \times (\mu\text{Hz}/f_{\text{GW}})$. The astrometric angular precision required to see these sources is $\Delta\theta \sim h_c$ after integrating for a time $T \sim 1/f_{\text{GW}}$. I will show that jitter in the photometric center of WD of this type due to starspots is bounded to be small enough to permit this high-precision, small-N approach. I will also discuss possible noise arising from stellar reflex motion induced by orbiting objects and show how it can be mitigated. The only plausible technology able to achieve the requisite astrometric precision is a space-based stellar interferometer. I will outline how such a future mission with few-meter-scale collecting dishes and

baselines of $\mathcal{O}(100\text{km})$ is sufficient to achieve the target precision. This collector size is broadly in line with the collectors proposed for some formation-flown, space-based astrometer or optical synthetic-aperature imaging-array concepts proposed for other science reasons. The proposed baseline is however somewhat larger than the km-scale baselines discussed for those concepts, but there is no fundamental technical obstacle to utilizing such baselines. A mission of this type thus also holds the promise of being one of the few ways to access interesting GW sources in this band.

Collaboration name:

Dark Matter / 61

Mirror Stars and other probes of Dark Complexity

Author: David Curtin[1]

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Complex Dark Sectors are theories of hidden particles and forces that could constitute all or part of dark matter but have non-minimal interactions between them, such as dark analogues of electromagnetism of the strong force. These scenarios are predicted by many highly motivated extensions of the Standard Model that solve fundamental mysteries like the hierarchy problem, but are notoriously difficult to study due to the complex nature of the resulting dark matter subcomponents on cosmological and astrophysical scales. I will discuss one robust consequence of dark complexity, Mirror Stars, which are dark compact objects of atomic dark matter that can be observed due to emissions from regular matter they capture from the interstellar medium. This opens up a new frontier in the search for dark matter using telescope surveys, and motivates understanding the behaviour of complex dark matter in great detail. I then discuss other signatures of Mirror Stars in gravitational lensing and gravitational wave observations, and close with an update on the world's first atomic dark matter N-body simulations which will greatly enhance our understanding of complex dark matter dynamics in our galaxy.

Collaboration name:

Neutrinos / 63

Neutrino Oscillations with IceCube and the IceCube Upgrade

Author: David Jason Koskinen[None]

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Neutrino oscillations remain the sole laboratory signals of Beyond the Standard Model physics and the IceCube Neutrino Observatory detects tens of thousands of atmospheric neutrinos per year which are used for oscillation analyses. Beyond particle physics, neutrino oscillations play an important role for interpreting any astrophysical neutrino fluxes, due to the impact of oscillations over cosmic distances. In this talk I will present the leading oscillation results from IceCube DeepCore (including muon neutrino disappearance and tau neutrino appearance) as well as the prospects for the upcoming IceCube Upgrade; a low energy extension to the existing array.

Collaboration name:

IceCube

Dark Matter / 64

Searching for inelastic dark matter with future laboratory experiments

Author: Marco Taoso[None]

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We consider a dark sector containing a pair of almost degenerate states coupled to the Standard Model via a portal interaction. The lightest state can be a dark matter candidate, while the heaviest one is long-lived, and its decays offer new testable signals at accelerator experiments. We study the prospects for the detection of this scenario at proposed LHC experiments (e.g. FASER and MATHUSLA) and at beam-dump facilities. We explore both cases of a light dark photon mediator, and of an heavy (>O(1) TeV) vector portal. We show that future experiments can test large portions of parameter space currently unexplored, and that they are complementary to future High-Luminosity LHC searches.

Collaboration name:

Dark Matter / 65

DarkSide-20k experiment and its veto

Author: Marek Bohdan Walczak[1]

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The Technical Design of the DarkSide-20k experiment has been finalised and the detector construction in the Gran Sasso National Laboratory in Italy starts this year. The experiment is designed to observe WIPMs scattering from argon atoms in 20 tonnes of the liquid argon target. Scintillation light generated during the interaction is detected by planes of Silicon photomultipliers (SiPMs). The experiment will maintain negligible background level thanks to its novel neutron veto design.
In this talk I will introduce the DarkSide-20k experiment and in particular the neutron veto. I will also present the status of the ongoing tests of the veto SiPMs.

Collaboration name:

The Global Argon Dark Matter Collaboration

Dark Matter / 66

Latest results from DEAP-3600

Author: Simon Viel[1]

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The latest results from DEAP-3600 will be presented, including the best constraints on TeV-scale mass dark matter scattering in argon, and world-leading constraints on Planck-scale mass dark matter. DEAP-3600 is located at SNOLAB, 2 km underground in Sudbury, Ontario. This spherical detector consists of 3.3 tonnes of liquid argon in a large ultralow-background acrylic cryostat instrumented with 255 photomultiplier tubes. The broad physics programme of DEAP-3600 will be presented, including measurements and searches for new physics.

Collaboration name:

DEAP

Dark Matter / 67

Simulation and Indirect Detection of Dark Glueball Showers

Author: Caleb Gemmell[1]

Co-authors: David Curtin [1]; Christopher Verhaaren [2]

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Parton showers are part and parcel of particle phenomenology, but what in the case of a confining dark sector with no light quarks below the confinement scale? Then the only available hadronic states are 'glueballs', composite gluon states. To date, there have been very few quantitative studies of dark shower signatures with glueball final states, despite the fact they commonly appear in motivated BSM theories such as neutral naturalness, and are prominent LLP candidates. This is due to the fact that commonly used hadronisation models, such as the Lund model, are no longer valid. We found that significant progress can be made despite the non-perturbative uncertainties. In this talk I will outline a method of simulating the formation of glueballs from a perturbative gluon shower, and how we handle the hadronisation process. This simulation has allowed us to study a variety of dark glueball phenomena quantitatively for the first time, including the indirect detection of DM annihilating into dark glueballs that then decay into the SM. Additionally, since the glueball decays depend on a range of operators, information on the UV completion of the sector may be able to be determined from multimessenger analysis of a potential signal. The `GlueShower` simulation code is additionally publicly available for use by the BSM community.

Collaboration name:

Neutrinos / 69

Neutrino Astronomy with KM3NeT/ARCA

Author: Rasa Muller[None]

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Neutrino astronomy is a rapidly evolving discipline probed by large-volume neutrino detectors such as the ones being built by the KM3NeT collaboration in the Mediterranean Sea together instrumenting a cubic kilometre of seawater. ARCA is the high-energy unit of this network. In its full configuration of 230 lines with > 10ˆ5 photomultiplier tubes installed, it will be sensitive to neutrinos in the 10ˆ2 - 10ˆ8 GeV energy range with sub-degree angular resolution and even sub 0.1° for E > 20 TeV. Since May 2021 KM3NeT has been taking data with more than 6 lines. In this contribution an update will be given of the most recent astrophysics results with the ARCA detector, among which the responses to prompt alerts in a multi-messenger network, and the sensitivity of ARCA to a cosmic diffuse neutrino flux and to point sources in the sky.

Collaboration name:

KM3NeT

Neutrinos / 70

Ultrahigh-energy cosmic-ray induced gamma-ray and neutrino fluxes from blazars

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Blazars are potential candidates of cosmic-ray acceleration up to ultrahigh energies (> 1 EeV). For an efficient cosmic-ray injection from blazars, ⊠⊠ collisions with the extragalactic background light and cosmic microwave background can produce gamma-ray and neutrino fluxes in the TeV and PeV-EeV energies, respectively. Such a line-of-sight cosmogenic gamma-ray flux can contribute to the spectra measured by ground-based air-Cherenkov telescopes from individual blazars, while PeV-EeV neutrinos form a "guaranteed"component in addition to any sub-PeV neutrinos produced in the blazar jet and as detected by IceCube. We calculate line-of-sight cosmogenic fluxes from the blazars TXS 0506+056, PKS 1502+106 and GB6 J1040+0617, which have been associated with IceCube neutrino events. We discuss conditions required for detection of these fluxes by current and upcoming gamma-ray and neutrino telescopes.

Collaboration name:

Extragalactic Sources / 71

Gamma-ray and neutrino emission from radiatively inefficient accretion flows

Author: Shigeo Kimura[None]

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The origins of cosmic MeV gamma-ray and high-energy neutrino backgrounds have been veiled in mystery since their discoveries. In this talk, I will propose raidiatively inefficient accretion flows in low-luminosity active galactic nuclei (AGN) as the common source of these backgrounds. Thermal electrons in low-luminosity AGN emit MeV gamma-rays by the Comptonization process, while non-thermal protons accelerated by stochastic acceleration can produce PeV neutrinos via hadronic interactions. With the contributions by luminous AGN, accretion flows onto supermassive black holes can contribute to a broad range of high-energy backgrounds (keV-MeV for photons and TeV-PeV for neutrinos). I also discuss point-source detectability by future MeV gamma-ray and high-energy neutrino experiments.

Collaboration name:

Dark Matter / 72

A global analysis of decaying ALPs

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Axion-like particles (ALPs) decaying before the time of recombination can have strong implications in a range of cosmological and astrophysical observations. In this talk I present a global analysis of a model of decaying ALP, focusing specifically on their coupling to photons. Exploiting the multidisciplinary nature of the GAMBIT framework, we combine state-of-the-art calculations of the irreducible ALP freeze-in abundance, primordial element abundances (including photodisintegration through ALP decays), CMB spectral distortions and temperature anisotropies, and astrophysical constraints from supernovae and stellar cooling. Most notable among the interesting results that I will present are a definite lower bound on the ALP mass, and a surprising improvement of the fit to the primordial abundances compared to vanilla ΛCDM.

Collaboration name:

Dark Matter / **73**

Searching for the fundamental nature of dark matter in the cosmic large-scale structure

Authors: Cora Dvorkin[None]; Hiranya Peiris[None]; Keir Rogers[None]

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The fundamental nature of dark matter so far eludes direct detection experiments, but it has left its imprint in the large-scale structure (LSS) of the Universe. Extracting this information requires accurate modelling of structure formation and careful handling of astrophysical uncertainties. I will present new bounds using the LSS on two compelling dark matter scenarios that are otherwise beyond the reach of direct detection. Ultra-light axion dark matter, particles with very low mass and astrophysically-sized wavelengths, is produced in high-energy models like string theory (”axiverse”). I will rule out axions that are proposed to resolve the so-called cold dark matter “small-scale crisis” (mass ˜ 10ˆ-22 eV) using the Lyman-alpha forest (mass > 2 x 10ˆ-20 eV at 95% c.l.), but demonstrate how a mixed axion dark matter model (as produced in the string axiverse) could resolve the S_8 tension (mass ˜ 10ˆ-25 eV) using Planck, ACT and SPT CMB data and BOSS galaxy multipoles. Further, I will set the strongest limits to-date on the dark matter − proton cross section for dark matter particles lighter than a proton (mass < GeV). The LSS model involves one-loop perturbation theory, a non-cold dark matter halo model and, to capture the smallest scales, a machine learning model called an “emulator”, trained using hydrodynamical simulations and an active learning technique called Bayesian optimisation.

Collaboration name:

Dark Matter / **74**

Searching for Dark Matter with the DAMIC at SNOLAB Experiment

Author: Ian Lawson[None]

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The DAMIC experiment at SNOLAB uses thick, fully-depleted, scientific grade charge-coupled devices (CCDs) to search for the interactions between proposed dark matter particles in the galactic halo and the ordinary silicon atoms in the detector. DAMIC CCDs operate with an extremely low instrument noise and dark current, making them particularly sensitive to ionization signals expected

from low-mass dark matter particles. This talk will focus on results from the 11 kg day exposure with traditional CCDs, including the strictest limits on the WIMP-nucleon scattering cross section for a silicon target. We will discuss the recent upgrade of the SNOLAB apparatus with two (~9 g each) skipper CCDs that allow for a sub-electron readout noise and therefore a lower detector threshold. We are actively acquiring data at SNOLAB with these upgraded CCDs to directly probe the previously observed excess. Furthermore, we will discuss the recent progress at DAMIC-M and the future of CCDs as a dark matter search device with the Oscura experiment, which will aim to build a large array of CCDs with a total exposure of 30 kg-yr. This research and development effort is now in the design phase with a goal to start construction in late 2024.

Collaboration name:

DAMIC

Gravitational Wave and Multimessenger / 75

Prediction of high-energy neutrino signals associated with gravitational waves: effects of kilonova photons

Author: Riki Matsui[None]

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GW170817 revealed that binary neutron star mergers are accompanied by jets, which are the origin of short gamma-ray bursts (sGRBs), but the production mechanism and dissipation regions of the jets are still unknown. The X-ray lightcurves of sGRBs have extended emission components lasting for 100-1000 seconds, which are considered to be evidence of prolonged engine activity of the jet. Jets by prolonged engine activity should propagate inside the ejecta of neutron star mergers and interact with photons of kilonova, an optical transient powered by radio-active decay of neutron-rich elements. We calculate neutrino emission from jets by prolonged engine activity, considering interaction between kilonova photons and cosmic rays accelerated in jets. We find that observation of neutrino signals associated with gravitational waves are highly probable for 10-years of operation by the future project, IceCube-Gen2 with second generation gravitational wave detectors. Also, we show that probability to observe such neutrino signals does not depend on the Lorentz factor of the jets, and we can constrain the values of dissipation radius of jets by neutrino signals.

Collaboration name:

Dark Matter / 76

General Dark Matter-Electron Interactions in Detector Materials

Author: Einar Urdshals[None]

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We develop a novel formalism to describe the scattering of dark matter (DM) particles by electrons bound in detector materials such as silicon, germanium and graphene for a general form of the underlying DM-electron interaction. By applying non-relativistic effective field theory methods, we find that the DM and material physics factorise into a handful of DM and material "response functions". The former are obtained by taking the non-relativistic limit of the free amplitude for DM-electron scattering, whereas the latter are expressed in terms electron wave-function overlap integrals and obtained using Density Functional Theory. To illustrate the potential of our formalism, we predict scattering rates for DM-electron interactions that were not accurately tractable before, such as the magnetic dipole interaction.

Collaboration name:

Extragalactic Sources / 77

Absorption features in gamma-ray spectra of BL Lac objects

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Absorption and emission lines in the optical spectrum are typically used to investigate the presence of large-scale environments in active galactic nuclei. In BL Lac objects, this approach is hampered by the dominant non-thermal continuum of their relativistic jet, which prevents us from identifying the thermal emission of the photon fields produced by such large-scale structures.
However, these photon fields may eventually interact with the gamma rays traveling in the blazar jet, and produce observable effects. In our contribution, we discuss this indirect method that may help to unveil the presence of ambient structures in BL Lac objects through the analysis of their gamma-ray spectrum. Passing through structures at different distances from the black hole, gamma rays of the jet interact with the corresponding photon fields via gamma-gamma pair production, producing absorption features in their spectral energy distribution. An interaction of the gamma-ray photons with a narrow-line region producing optical-UV seed photons may reduce the observed gamma-ray flux and cause absorption features at a few hundreds GeV.
Sources with spectra reaching TeV energies, such as high synchrotron-peaked BL Lac objects (HBLs) and extreme HBLs (EHBLs, extreme blazars), may represent exceptional probes to investigate this topic. At this scope, we discuss recent observations of sources that may show evidence of such absorption features in their gamma-ray spectra.
Finally, we examine how sub-TeV absorption features in the spectra of BL Lac objects may affect their broadband modeling, and eventually represent a powerful diagnostic tool to constrain the gamma-ray production site and the jet environment.

Collaboration name:

Gamma Rays / 78

First Science Results from the Large-Sized Telescope prototype for The Cherenkov Telescope Array

Author: David Green[None]

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The Large-Sized Telescopes (LSTs) of the Cherenkov Telescope Array (CTA) are designed to maximize the performance of gamma-ray studies for low energies, rapid telescope re-pointing, large field of view, and unprecedented flux sensitivity. The LST will dominate the performance of the CTA Observatory between 20 GeV and 150 GeV. The prototype of the LST telescopes (LST-1) was inaugurated in 2018 at the CTA Northern site on the island of La Palma, Canary Islands, Spain and has taken over 200 hours of commissioning data on various astrophysical sources. We report on the

first physics results obtained with the LST-1 including the detection of several active galactic nuclei, including 1ES 0647+250 with a redshift greater than 0.3, and Galactic sources such as the Galactic Center.

Collaboration name:

CTA LST Project

Cosmic Rays / 82

The mechanism of efficient electron acceleration at parallel non-relativistic shocks

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Thermal electrons cannot directly participate in the process of diffusive acceleration at electron-ion shocks because their Larmor radii are smaller than the shock transition width: this is the well-known electron injection problem of diffusive shock acceleration. Instead, an efficient pre-acceleration process must exist that scatters electrons off of electromagnetic fluctuations on scales much shorter than the ion gyro radius. The recently found intermediate-scale instability provides a natural way to produce such fluctuations in parallel shocks. The instability drives comoving (with the upstream plasma) ion-cyclotron waves at the shock front and only operates when the drift speed is smaller than half of the electron Alfvén speed. Here, we perform particle-in-cell simulations with the SHARP code to study the impact of this instability on electron acceleration at parallel non-relativistic, electron-ion shocks. To this end, we compare a shock simulation in which the intermediate-scale instability is expected to grow to simulations where it is suppressed. In particular, the simulation with an Alfvénic Mach number large enough to quench the intermediate instability shows a great reduction (by two orders of magnitude) of the electron acceleration efficiency. Moreover, the simulation with a reduced ion-to-electron mass ratio (where the intermediate instability is also suppressed) not only artificially precludes electron acceleration but also results in erroneous electron and ion heating in the downstream and shock transition regions. This finding opens up a promising route for a plasma physical understanding of diffusive shock acceleration of electrons, which necessarily requires realistic mass ratios in simulations of collisionless electron-ion shocks.

Collaboration name:

Dark Matter / 84

Velocity-dependent dark matter annihilation from simulations

Authors: Azadeh Fattahi[1]; Carlos Frenk[1]; Erin Piccirillo[2]; Louis Strigari[3]; Nassim Bozorgnia[4]; Federico Marinacci[5]; Julio Navarro[6]; Kyle Oman[1]; Robert Grand[7]

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If the dark matter annihilation cross section is velocity dependent, the dark matter pair-wise relative velocity distribution enters into the calculation of the annihilation signals and the so-called J-factors. Studies of velocity-dependent dark matter annihilation commonly rely on simplified analytic models for the dark matter phase space distribution, which need to be tested against cosmological simulations. I will present the dark matter density profiles and relative velocity distributions extracted from state-of-the-art hydrodynamical simulations of Milky Way-like galaxies. I will then discuss the J-factors and expected annihilation signals from the Milky Way, dark matter subhalos, and Milky Way dwarf spheroidal analogues for velocity-dependent annihilation models.

Collaboration name:

Neutrinos / 85

Status of the Radar Echo Telescope

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We present the current status of the Radar Echo Telescope, an instrument to detect neutrinos of the highest energies. First, we present the status of the Radar Echo Telescope for Cosmic Rays (RET-CR), a prototype instrument that seeks to test the radar echo method in nature, using the in-ice cascade produced by the core of a cosmic-ray air shower as it impacts the ice. We present the current hardware, firmware, and software development toward an upcoming deployment. Next, we present the development status of the Radar Echo Telescope for Neutrinos (RET-N), an eventual full-scale neutrino detector. We present updated sensitivity studies for RET-N.

Collaboration name:

Radar Echo Telescope

Dark Matter / 86

Dark Matter from Monogem: Constraints on Velocity-Dependent Dark Matter-Nucleus Scattering

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Direct detection experiments set strong constraints on dark matter-nucleus scattering, but are typically limited to probing dark matter velocities of order 10ˆ-3 c. If there exists a sub-population of dark matter with much larger velocity, considering this population could make direct detection experiments sensitive to smaller dark matter mass, while also improving their sensitivity to cross sections that scale strongly with velocity, as in nonrelativistic effective field theory. We show that supernova shocks, traveling at speeds much larger than typical dark matter velocities in the Milky Way, could produce a small but detectable flux of energetic dark matter particles. We use this observation to set competitive constraints on effective operators that scale strongly with dark matter velocity.

Collaboration name:

Dark Matter / 88

Constraining axion-like particles with the diffuse gamma-ray flux measured by the Large High Altitude Air Shower Observatory

Authors: Pierluca Carenza[None]; Marco Chianese[None]; Damiano Fiorillo[1]; Leonardo Mastrototaro[None]; Gennaro Miele[2]; Alessandro Mirizzi[None]; Daniele MONTANINO[None]

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The detection of very high-energy neutrinos by the IceCube experiment supports the existence of a comparable gamma-ray counterpart from the same cosmic accelerators. Under the likely assumption that the sources of these particles are of extra-galactic origin, even for transparent sources the photon flux would be significantly absorbed during its propagation over cosmic distances. However, in the presence of photon mixing with ultra-light axion-like-particles (ALPs), this expectation would be strongly modified. Notably, photon-ALP conversions in the source would produce an ALP flux which propagates unimpeded in the extra-galactic space without being absorbed. Then, the back-conversion of ALPs in the Galactic magnetic field leads to a diffuse high-energy photon flux. In this context, the recent detection of the diffuse high-energy photon flux by the Large High Altitude Air Shower Observatory (LHAASO) allows us to exclude at the 95% CL an ALP-photon coupling $g_{a\gamma} > 3.0 - 6.0 \times 10^{-11}\ \mathrm{GeV}^{-1}$ for $m_a < 4 \times 10^{-7}\ \mathrm{eV}$, depending on the magnetic field in the source and on the original gamma-ray spectrum.This new bound is complementary with other ALP constraints from very-high-energy gamma-ray experiments and the sensitivity of future experiments.

Collaboration name:

Dark Matter / 89

Discovering Composite Dark Matter with the Migdal Effect

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An intriguing possibility for dark matter is that it formed bound states in the early Universe, in a scenario called 'composite' dark matter, much like the Standard Model fundamental particles formed nucleons, nuclei and atoms. One of the simplest composite dark matter models consists of dark fermions bound together by a real scalar field. Composite states that are massive enough source scalar fields so intense that nuclei, if coupled to this force, can recoil upon contact to energies capable of ionization through the Migdal effect. Combined with the large sizes of these composites, the ionization signal produced by their transit at dark matter experiments is detectable even for minuscule couplings between nuclei and the dark matter. In this talk, I will discuss the discovery prospects of composite states at noble element detectors like Xenon-1T and other underground experiments.

Collaboration name:

Extragalactic Sources / 90

Electron pre-acceleration through Stochastic Shock Drift Acceleration at shocks in merging galaxy clusters

Authors: Jacek Niemiec[1]; Karol Fulat[2]; Martin Pohl[3]; Masahiro Hoshino[4]; Oleh Kobzar[5]; Shuichi Matsukiyo[6]; Stella Boula[1]; Takanobu Amano[4]

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Particle pre-acceleration remains an important unresolved problem in the diffusive shock acceleration (DSA) theory. This mechanism acting at merger shocks in galaxy clusters is thought to produce relativistic electrons that form the so-called radio relics detected in radio and X-ray. DSA at merger shocks may also generate high- and ultra-high-energy cosmic rays and associated gamma-ray emission and neutrinos. We report on our recent studies of electron pre-acceleration in nonrelativistic shocks with low Mach numbers propagating in hot intracluster medium. We use large-scale fully kinetic 2D and hybrid-kinetic 2D and 3D numerical simulations that allow us to investigate the effects of the ion-scale rippling of the shock front and the multi-scale turbulence in the shock transition and downstream. We demonstrate that electron injection to DSA can be provided through stochastic shock-drift acceleration (SSDA) process, in which electrons are confined in the shock transition by pitch-angle scattering off turbulence and gain energy from the motional electric field. Through analysis of multi-scale turbulence in the shock at different pre-shock conditions we demonstrate a crucial role of the shock rippling in electron acceleration via SSDA.

Collaboration name:

Particle Physics / 92

Electromagnetic radiation from axion condensates in a time dependent magnetic field

Authors: Lars Sivertsen[1]; Srimoyee Sen[1]

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Axions produced in the early universe can form bound clumps of Bose Einstein condensates, which are in some cases well described by a classical field with a single dominant angular frequency, close to the axion mass. In the vicinity of external electromagnetic fields, these axion clumps will start to radiate energy due to the axion-photon coupling. We will here consider the electromagnetic radiation from axion condensates in the background of an alternating magnetic field, such as the ones found around rotating neutron stars, orbiting binaries and merging neutron stars. We find that a resonant peak in radiation can occur when the frequency of the alternating magnetic field is comparable to the axion mass scale. More interestingly, in situations where the frequency of the alternating magnetic field itself changes with time, as can be the case in binary mergers due to steady increase in orbital frequency, the resonant peak in radiation may occur for a range of axion mass scales scanned by the time-varying magnetic field frequency.

Collaboration name:

Extragalactic Sources / 93

Multi-messenger characterization of Mrk501 during historically low X-ray and γ-ray activity

Authors: Axel Arbet-Engels[1]; David Paneque[1]; Lea Alina Heckmann[1]; Matteo Cerruti[2]; Narek Sahakyan[3]; Sargis Gasparyan[3]

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As highly energetic physics laboratories, blazars are prime candidates to reveal the mysteries of the most energetic parts of our universe. For many of them, the very-high-energy (>0.2 TeV, VHE) γ-ray band as well as the X-ray bands are especially interesting since they host the most variable part of their emission.

We present a multiwavelength (MWL) data set of Mrk 501 obtained from 2017 to 2020 revealing a historically low activity in exactly these bands. Using the comprehensive VHE data set collected by the two MAGIC telescopes, we can identify a low-state lasting for two years with a stable and historically low VHE flux (>0.2 TeV) of 5% that of the Crab Nebula. We use this unprecedented opportunity to investigate, additionally using constraints set by public IceCube data, the nature of the low-state which can be attributed to the MWL emission of leptonic, lepto-hadronic as well as purely hadronic scenarios. This potential baseline emission can be explained by a standing shock while the more variable emission before the low-state can be connected to an additional traveling shock region. The patterns appearing in this variable emission show a significant correlation between VHE γ-rays and X-rays for the first time also during low activity states for Mrk 501. Extending the data set to 12 years, we identify several significant correlations, such as a correlated behavior between HE γ-rays and X-rays supporting a common origin between these bands and the claim that the variable emission originates from relativistic leptons.

Collaboration name:

for the Multi-wavelength collaborators and the MAGIC and Fermi-LAT-Collaboration

Extragalactic Sources / 94

High-energy gamma-rays from magnetically arrested disks in nearby radio galaxies

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The origins of the GeV gamma-rays from nearby radio galaxies are unknown. Hadronic emission from magnetically arrested disks (MADs) around central black holes (BHs) is proposed as a possible scenario. Particles are accelerated in the MAD by magnetic reconnection and stochastic turbulence acceleration. We investigate the feature of the radio galaxies that can be explained by the MAD model. We pick up the fifteen brightest radio galaxies in the GeV band from the Fermi 4LAC-DR2 catalog and apply the MAD model. We find that we can explain the GeV data by the MAD model if

the accretion rate is lower than 0.1% of the Eddington rate. For a higher accretion rate, GeV gamma-rays are absorbed by the two-photon interaction due to copious low-energy photons. This causes the MAD model to fail to reproduce the GeV data. We also apply the MAD model to Sgr A*and find that the GeV-TeV gamma-rays observed at the Galactic center do not come from the MAD of Sgr A.*

Collaboration name:

Extragalactic Sources / 95

Intergalactic magnetic field studies by means of the gamma-ray emission from GRB 190114C

Author: Paolo Da Vela[1]

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The origin of the large-scale magnetic fields in the Universe is one of the long-standing problem in cosmology. To discriminate among the different explanations it is crucial to measure the intergalactic magnetic field (IGMF) in the voids among the galaxies. Gamma-rays coming from extragalactic sources can be used to constrain the IGMF due to their interaction with the intergalactic medium. Particularly, strong transients allow to constrain very weak IGMFs. We use CRPropa3 to propagate the measured very-high energy (E > 100 GeV) spectrum from GRB 190114C in the intergalactic medium. We then compute the expected cascade emission in the GeV domain for different IGMF settings and compare it with the Fermi/LAT limits for different exposure times.

Collaboration name:

Gamma Rays / 96

The SST-1M gamma-ray mini-array - results of early operations

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We present first results of the commissioning data of two Single-Mirror Small-Sized Telescopes (SST-1M) for detection of gamma rays with the imaging air Cherenkov technique. SST-1M adopts a Davies-Cotton optics and a fully digitising silicon photomultipliers (SiPM) based camera. SST-1M telescopes have a lightweight and compact structure with 4 m-diameter mirror dish composed of 18 hexagonal glass mirrors and the focal ratio of 1.4. Their innovative cameras have a wide field-of-view of 9.1◦ and employ digital electronics with fully digital trigger and readout architecture and highly performing large-area SiPM with dedicated slow control. The SST-1M telescopes are optimized to provide gamma-ray sensitivity above 500 GeV in stereo mode. They are designed for operation in harsh environment with minimal maintenance and they already allow fully robotic operation. The

SST-1M mini-array is installed at the Ondřejov Observatory in the Czech Republic and undergoes commissioning and validation during which first remote observations of astronomical objects are performed. In our presentation we will report on the status of the project, present first results of early science operations, and discuss future prospects.

Collaboration name:

SST-1M

Gamma Rays / 97

HAWC Observations of Gamma rays from the Quiescent Sun

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Galactic cosmic rays interact with the Sun's atmosphere to produce gamma rays via pion decay up to at least 100 GeV. The role of solar magnetic fields in modulating and enhancing the flux of these gamma rays is not completely understood, and can be further elucidated with a broadband spectrum extending into the TeV range. The HAWC observatory is a ground-based array of photo-detectors sensitive to cosmic rays and gamma-ray showers between 300 GeV and ˜ 100 TeV. Using six years of data with an improved reconstruction and analysis, we present the results of a search for gamma rays from the Sun. Our work hints at a new component of high energy emission largely independent of the solar cycle.

Collaboration name:

HAWC

Galactic Sources / 100

Where are hadronic PeVatrons? –Constraints and Prospects

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The high flux of hadronic cosmic rays and the detection of bright gamma-ray sources suggest a tight connection between them, which implies that Galactic neutrino sources must exist. However, none have been detected. Where are they? We outline constraints on the properties of hadronic PeVatrons based on the existing data. We introduce a new population-based approach, calibrated to the observed cosmic-ray flux and demanding consistency with measurements of gamma-ray sources, diffuse flux, and neutrino non-detection. We make new predictions and discuss the implications of detections or non-detections. We also define the detector requirements to definitively test the origins of the Milky Way's hadronic cosmic-ray sources.

Collaboration name:

Gravitational Wave and Multimessenger / 101

Searching for Gamma- and hard X-ray Counterparts to Gravitational-wave events in GWTC-3 with Fermi-GBM and Swift-BAT

Authors: Cori Fletcher[1]; Joshua Wood[2]; Milena Crnogorcevic[None]

Co-authors: Peter Veres [3]; James DeLaunay [4]; Aaron Tohuvavohu [5]; Rachel Hamburg [3]

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The era of multi-messenger astronomy began with the gravitational-wave detection of the binary neutron-star merger, GW170817, in coincidence with a short gamma-ray burst, GRB 170817A. One of its primary goals is a detection of another coincidence of gravitational and electromagnentic emission. With that in mind, we present a follow-up search for excess emission of gamma-rays with the Fermi Gamma-ray Burst Monitor (Fermi-GBM), and that of hard X-rays with the Swift Burst Alert Telescope (Swift-BAT), in spatial and temporal correspondence to gravitational-wave events reported by LIGO/Virgo/Kagra (LVK) Collaboration. We utilize Fermi-GBM on-board triggers and sub-threshold searches in combination with Swift-BAT rate data to determine whether there is any statistically significant excess emission around the given gravitational-wave trigger. We report no new joint detections to date; however, we place joint flux upper-limits, allowing us to constrain the current theoretical models that describe the production of gamma- and X-rays in these environments.

Collaboration name:

Galactic Sources / 103

Anisotropic diffusion cannot explain TeV halos

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TeV halos have become a new class of astrophysical objects which were not predicted before their recent observation. They offer evidence that diffusion around sources (concretely, pulsars) is not compatible with the effective average diffusion that our models predict for the Galaxy. This directly impacts Galaxy formation, our knowledge of the propagation process throughout the Galaxy and our models of acceleration of charged particles by astrophysical sources like supernova remnants (SNRs) or Pulsar Wind Nebulae (PWN).
In this talk we show that, while anisotropic models may explain a unique source such as Geminga, the phase space of such solutions is very small and they are unable to simultaneously explain the size and approximate radial symmetry of the TeV halo population. Furthermore, we note that this conclusion holds for any CR-powered source (hadronic or leptonic), implying more generally that anisotropic diffusion does not dominate the propagation of particles near energetic sources (at least, below hundreds of TeV) because of the self-generated turbulence.

Collaboration name:

Gamma Rays / 105

Status, performance and results of the Large-Sized Telescope prototype for the Cherenkov Telescope Array

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The Cherenkov Telescope Array (CTA) will be the next generation ground-based observatory for gamma-ray astronomy and will consist of Imaging Atmospheric Cherenkov Telescopes (IACTs) distributed over two sites, one in the northern and one in the southern hemisphere. CTA will detect gamma rays from 20 GeV to 300 TeV by means of three different telescope sizes. The sub-array of four Larged-Sized Telescopes (LSTs) at the CTA-North site at La Palma (Spain) aims at detecting gamma rays at lower energies, especially between 20 GeV and 100 GeV. The first LST (LST-1) was completed in 2018 and three more will be built in the next three years. In this presentation we report on the status of the LSTs as well as the progress of the commissioning of the LST-1. We will also show the achieved performance of the telescope on standard sources such as the Crab Nebula and Crab pulsar.

Collaboration name:

CTA-LST Project

Dark Matter / 106

Search for gamma-ray spectral lines from Dark Matter annihilation in the Galactic Centre region with MAGIC

Authors: Daniel Kerszberg[None]; Tomohiro Inada[1]; Moritz Hütten[2]; Javier Rico[None]; Masahiro Teshima[None]; Kazunori Kohri[3]; Nagisa Hiroshima[None]

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The Galactic Centre (GC) region is a promising target for dark matter (DM) search due to the size of its halo and proximity. We report on the search for DM spectral gamma-ray lines in the GC region up to gamma-ray energies of 100 TeV with the MAGIC telescopes, located on the island of La Palma (Spain). We present the results obtained with more than 200 hours of large-zenith angle observations of the GC region with MAGIC, which allow us to derive limits on the DM annihilation cross-section at high particle masses (<5×10^(-28) cm^3 s^-1 at 1 TeV and <1×10^(-25) cm^3 s^-1 at 100 TeV for cuspy dark matter profile), improving the best current constraints above 20 TeV. We also study the impact of a cored dDM profile on our limits. Finally we use our results to constrain super-symmetric wino models.

Collaboration name:

MAGIC

Extragalactic Sources / 108

A robust lower bound on intergalactic magnetic fields from Fermi/LAT and MAGIC observations of 1ES 0229+200

Authors: Ievgen Vovk[None]; Paolo Da Vela[1]; Alexander Korochkin[2]; Andrii Neronov[None]; Dmitri Semikoz[None]; Antonio Stamerra[3]

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Secondary gamma-ray emission from distant TeV sources induced by the effects of propagation of gamma rays through the intergalactic medium could be used to probe the intergalactic magnetic field (IGMF). A proper realization of this opportunity requires a knowledge on the evolution of the source luminosity from GeV to TeV energies over the relevant period of time. Here we use a sample of MAGIC, H.E.S.S., VERITAS and Fermi/LAT observations to trace the evolution of the hard-spectrum blazar 1ES0229+200 in the GeV-TeV band over one-and-a-half decade in time. This allows us to make a precise prediction of the timing properties of the time-delayed secondary gamma-ray flux, removing the largest source of uncertainty for IGMF probing. We further show that the non-detection of such a secondary emission in the Fermi/LAT energy band yields a robust lower bound on the strength of IGMF.

Collaboration name:

MAGIC collaboration

Neutrinos / 109

Search for High-Energy Neutrinos from TDE-like Flares with Ice-Cube

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The collected data of IceCube, a cubic kilometre neutrino detector array in the antarctic ice, reveal a diffuse flux of astrophysical neutrinos. The sources of these neutrinos however have yet to be discovered. Recently, high-energy neutrino alerts, sent out by IceCube in real time, were observed in coincidence with two (likely) Tidal Disruption Events (TDEs). A follow-up study found a broader sample of TDE-like flares, radiation outbursts from supermassive black holes that accrete at an enhanced rate, to be correlated at 3.7σ with IceCube's high-energy neutrino alerts. This does suggest a correlation also at lower energies. In this contribution I will present studies of a stacking analysis looking for IceCube neutrinos from these TDE-like flares, using the same catalogue and a sample of muon track events, testing the correlation at energies from $\mathcal{O}(100)$ GeV to $\mathcal{O}(10)$ TeV.

Collaboration name:

IceCube

Dark Matter / 112

Impact of the particle physics model on dark matter indirect detection limits

Authors: Björn Herrmann[1]; Celine Armand[None]

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Cosmological and astrophysical probes suggest that dark matter (DM) would make up for 85\% of the total matter content of the Universe. However, the determination of its nature remains one of the greatest challenges of fundamental physics. Assuming the ΛCDM model, Weakly Interacting Massive Particles (WIMPs) would annihilate into Standard Model particles, such as γ rays, which could be detected by ground-based telescopes. Dwarf spheroidal galaxies represent promising targets for such indirect searches as they are assumed to be highly dark matter dominated with the absence of astrophysical sources nearby. So far, previous studies have presented upper limits on the annihilation cross section $\langle\sigma v\rangle$ assuming single exclusive annihilation channels. In this work, we consider more realistic particle physics models and take into account their complete annihilation pattern in order to study their impact on the derivation of the upper limits on the dark matter annihilation cross section. We use mock data for the Cherenkov Telescope Array (CTA) simulating the observations of two promising dwarf spheroidal galaxies, Sculptor and Draco. We show the impact of considering the full decay pattern within two phenomenologically viable particle physics models.

Collaboration name:

Cosmic Rays / 113

The FLUKA cross sections for cosmic-ray propagation studies

Authors: Nicola Mazziotta[1]; Pedro De la Torre Luque[None]

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While the accuracy of current cosmic-ray (CR) data allows us to carry out precise tests of our models of propagation of charged particles in the Galaxy, the precision of cross sections data for the production of secondary particles (secondary CRs, neutrinos, gamma rays) is very poor, considerably limiting these tests. Given that most of the calculations of these cross sections from fundamental models of particle interactions are in disagreement with data, we rely on parameterizations fitted to the very scarce and uncertain experimental data.

In the last years, the FLUKA Monte Carlo nuclear toolkit has been optimized to be used in different kinds of CR studies and has been extensively tested against data. In this talk, we present new sets of spallation cross sections of CR interactions in the Galaxy, both inelastic and inclusive, computed with FLUKA. Furthermore, these cross sections have been implemented in the DRAGON2 code to characterize the spectra of CR nuclei up to Z=26 (Iron) and study the main propagation parameters predicted from the spectra of secondary CRs such as B, Be and Li. These results and their implications will be discussed in the talk.

Collaboration name:

Neutrinos / 116

Methods for a consistent treatment of systematic uncertainties in a combined analysis of IceCube's high energy neutrino data

Author: Richard Naab[1]

Co-author: Erik Ganster [2]

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The IceCube Neutrino Observatory has been observing a diffuse astrophysical neutrino flux, measuring the energy spectrum and flavor composition in different detection channels. With about 10 years of data, we combine the detection channels focused on the event topologies of tracks and cascades to measure the energy spectrum and flavor composition with improved precision compared to the individual channels. The high statistics data samples require rigorous treatment of systematic uncertainties, which we aim to achieve with the so-called SnowStorm method, recently developed within the IceCube collaboration. This technique involves a continuous variation of systematics parameters during the detector simulation and requires a dedicated analysis approach. We present the validation of this method for the purpose of measuring the energy spectrum and flavor composition. The treatment of uncertainties on the atmospheric backgrounds entering the measurement as well as the method of combining the data samples is discussed.

Collaboration name:

IceCube

Cosmic Rays / 118

Antiproton Flux and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS

Author: Zhili Weng[1]

[1] *Massachusetts Inst. of Technology (US)*

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Latest results by AMS on the fluxes and flux ratios of charged elementary particles in the absolute rigidity range from 1 up to 2000 GV reveal unique properties of cosmic charged elementary particles. In the absolute rigidity range ˜60 to ˜500 GV, the antiproton flux and proton flux have nearly identical rigidity dependence. This behavior indicates an excess of high energy antiprotons compared with secondary antiprotons produced from the collision of cosmic rays. More importantly, from ˜60 to ˜500 GV the antiproton flux and positron flux show identical rigidity dependence. The positron-to-antiproton flux ratio is independent of energy and its value is determined to be a factor of 2 with percent accuracy. This unexpected observation indicates a common origin of high energy antiprotons and positrons in the cosmos.

Collaboration name:

AMS

Dark Matter / 119

Combined dark matter searches towards dwarf spheroidal galaxies with Fermi-LAT, HAWC, H.E.S.S., MAGIC, and VERITAS

Authors: Benjamin Zitzer[None]; Celine Armand[None]; Chiara Giuri[None]; Dan Salaza[None]; Daniel Kerszberg[None]; Elisa Pueschel[None]; Emmanuel Moulin[None]; Eric Charles[None]; Javier Rico[None]; Kristen Tollefson[None]; Louise Oakes[None]; Lucia Rinchiuso[None]; Mattia Di Mauro[None]; Pat Harding[None]; Tjark Miener[None]; Vincent Poireau[None]

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Cosmological and astrophysical observations suggest that 85% of the total matter of the Universe is made of Dark Matter (DM). However, its nature remains one of the most challenging and fundamental open questions of particle physics. Assuming particle DM, this exotic form of matter cannot consist of Standard Model (SM) particles. Many models have been developed to attempt unraveling the nature of DM such as Weakly Interacting Massive Particles (WIMPs), the most favored particle candidates. WIMP annihilations and decay could produce SM particles which in turn hadronize and decay to give SM secondaries such as high energy γ rays. In the framework of indirect DM search, observations of promising targets are used to search for signatures of DM annihilation. Among these, the dwarf spheroidal galaxies (dSphs) are commonly favored owing to their expected high DM content and negligible astrophysical background. In this work, we present the very first combination of 20 dSph observations, performed by the Fermi-LAT, HAWC, H.E.S.S., MAGIC, and VERITAS collaborations in order to maximize the sensitivity of DM searches and improve the current results. We use a joint maximum likelihood approach combining each experiment's individual analysis to derive more constraining upper limits on the WIMP DM self-annihilation cross-section as a function of DM particle mass. We present new DM constraints over the widest mass range ever reported, extending from 5 GeV to 100 TeV thanks to the combination of these five different γ-ray instruments.

Collaboration name:

Neutrinos / 120

A combined analysis of the diffuse astrophysical neutrino flux using IceCube's high-energy through-going muon tracks and cascades

Author: Erik Ganster[1]

Co-author: Richard Naab [2]

[1] *RWTH Aachen University*

[2] *DESY Zeuthen*

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The IceCube Neutrino Observatory has been observing a diffuse flux of high-energy astrophysical neutrinos in multiple detection channels since 2013. These detection channels are complementary with respect to event topologies such as muon tracks and cascades, the sensitive energy range, and backgrounds. In this analysis we combine two of these channels, through-going muon tracks and contained cascades, into a single fit of IceCube's high energy neutrino data which will lead the way towards a global picture of the astrophysical neutrino flux. The complementary properties of the two event samples reduce the overall uncertainties in signal and background, allowing for a consistent measurement of the astrophysical neutrino flux properties: measuring the energy spectrum and flavor composition as well as challenging the widely used single power-law flux model. We will present an approach for this combined fit with a decade of IceCube data.

Collaboration name:

IceCube

Cosmic Rays / 121

Unique Properties of the 3rd Group of Cosmic Rays: Results from the Alpha Magnetic Spectrometer

Author: Valerio Formato[1]

[1] *INFN - Sezione di Roma Tor Vergata*

Corresponding Author: valerio.formato@cern.ch

Cosmic Nitrogen, Sodium, and Aluminum nuclei are a combination of primaries, produced at cosmic-ray sources, and secondaries resulting from collisions of heavier primary cosmic rays with the interstellar medium. We present high statistics measurements of the N, Na and Al rigidity spectra. We discuss the properties and composition of their spectra and present a novel model-independent determination of their abundance ratios at the source. The systematic comparison with the latest GALPROP cosmic ray model is presented.

Collaboration name:

AMS-02 collaboration

Cosmic Rays / **122**

Towards Understanding the Origin of Cosmic-Ray Positrons

Author: Zhili Weng[1]

[1] *Massachusetts Inst. of Technology (US)*

Corresponding Author: zhili.weng@cern.ch

Precision measurements of cosmic ray positrons are presented up to 1.4 TeV based on 3.4 million positrons collected by the Alpha Magnetic Spectrometer on the International Space Station. The positron flux exhibits complex energy dependence. Its distinctive properties are: (a) a significant excess starting from 24.2 GeV compared to the lower-energy, power-law trend; (b) a sharp drop-off above 268 GeV; (c) in the entire energy range the positron flux is well described by the sum of a term associated with the positrons produced in the collision of cosmic rays, which dominates at low energies, and a new source term of positrons, which dominates at high energies; and (d) a finite energy cutoff of the source term at 887 GeV is established with a significance of 4.5σ. These experimental data on cosmic ray positrons show that, at high energies, they predominantly originate either from dark matter annihilation or from new astrophysical sources.

Collaboration name:

AMS

Galactic Sources / **123**

VERITAS observations of gamma-ray binary systems.

Author: Jamie Holder[None]

Corresponding Author: jholder@physics.udel.edu

The VERITAS imaging atmospheric Cherenkov telescope array has been operating regularly since 2007. One of the key science programs for VERITAS throughout its lifetime has been searching for and monitoring gamma-ray binary systems. These systems are comprised of a massive star and a compact object, either black hole or neutron star, with the peak energy output of their emission occuring in the high or very high energy gamma-ray band, above 1 GeV. Gamma-ray binary observations now constitute some of the largest datasets in the VERITAS archive. We will summarize the status and results here, including observations of the GeV-faint binary HESS J0632+057, the bright gamma-ray binary LS I + 61 303, and the 50-year period pulsar/Be-star binary PSR J2032+4127/MT91 213.

Collaboration name:

The VERITAS Collaboration

Dark Matter / 124

Q-monopole-ball: a topological and nontopological soliton

Author: Nicholas Orlofsky[1]

Co-authors: Yang Bai [2]; Sida Lu [3]

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Magnetic monopoles and Q-balls are examples of topological and nontopological solitons, respectively. A new soliton state with both topological and nontopological charges is shown to also exist, given a monopole sector with a portal coupling to an additional scalar field S with a global U(1) symmetry. This new state, the Q-monopole-ball, is more stable than an isolated Q-ball made of only S particles, and it could be stable against fissioning into monopoles and free S particles. Stable Q-monopole-balls can contain large magnetic charges, providing a novel nongravitational mechanism for binding like-charged monopoles together. They could be produced from a phase transition in the early universe and account for all dark matter.

Collaboration name:

Cosmic Rays / 125

Unique Properties of Cosmic H, He, Li and Be Isotopes

Authors: Jiahui Wei[1]; Carlos Delgado Mendez[2]; Francesco Dimiccoli[3]; Javier Berdugo Perez[2]; Fernando De Carvalho Barao[4]; Laurent Yves Marie Derome[5]; Francesca Giovacchini[2]; Mercedes Paniccia[6]

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[2] *Centro de Investigaciones Energéticas Medioambientales y Tec. (ES)*

[3] *Universita degli Studi di Trento and INFN (IT)*

[4] *LIP Laboratorio de Instrumentacao e Fisica Experimental de Particulas (PT)*

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We present high statistics measurements of cosmic H, He, Li and Be isotopes based on 10 years of AMS data.

Collaboration name:

AMS

Cosmic Rays / 126

Unique Properties of Primary Cosmic Rays: Results from the Alpha Magnetic Spectrometer

Author: Yi Jia[1]

[1] *Massachusetts Inst. of Technology (US)*

Corresponding Author: yi.jia@cern.ch

We present high statistics measurements of primary cosmic rays from Proton to Iron based on 10 Years AMS data. The properties of primary cosmic ray fluxes are discussed. The systematic comparison with the latest GALPROP cosmic ray model is presented.

Collaboration name:

AMS

Dark Matter / 127

Towards Understanding the Origin of Cosmic-Ray Electrons

Authors: Valerio Vagelli[1]; Valerio Vagelli[2]

[1] *ASI and INFN-Perugia (IT)*

[2] *Italian Space Agency (ASI) and INFN*

Corresponding Authors: valerio.vagelli@cern.ch, valerio.vagelli@asi.it

Precision results on cosmic-ray electrons are presented in the energy range from 0.5 GeV to 2.0 TeV based on 50 million electrons collected by the Alpha Magnetic Spectrometer on the International Space Station. In the entire energy range the electron and positron spectra have distinctly different magnitudes and energy dependences. At medium energies, the electron flux exhibits a significant excess starting from 49.5 GeV compared to the lower energy trends, but the nature of this excess is different from the positron flux excess above 24.2 GeV. At high energies, our data show that the electron spectrum can be best described by the sum of two power law components and a positron source term. This is the first indication of the existence of identical charge symmetric source term both in the positron and in the electron spectra and, as a consequence, the existence of new physics.

Collaboration name:

AMS-02 collaboration

Cosmic Rays / 128

Precision Measurement of Daily Electron, Positron, Proton, and Helium Fluxes with the Alpha Magnetic Spectrometer

Author: Yi Jia[1]

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The detailed measurement of the daily electron, positron, proton, and helium fluxes based on 10 year data from May 20, 2011 to May 2, 2021 with the Alpha Magnetic Spectrometer on the International Space Station, is presented.

Collaboration name:

AMS

Neutrinos / 129

Exploring neutrino-matter interactions at the EeV energy frontier

Author: Victor Branco Valera Baca[None]

Co-authors: Mauricio Bustamante [1]; Christian Glaser

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The measurement of high-energy neutrino-matter interactions furthers our knowledge of nucleon structure and allows us to test proposals beyond the Standard Model: the higher the energy, the more piercing the probe. Ultra-high-energy (UHE) cosmic neutrinos, with EeV-scale energies (1 EeV = 10^{18} eV), offer the ultimate high-energy probes of neutrino physics. For fifty years, they have evaded detection. Fortunately, upcoming neutrino telescopes have a real chance of discovering them. We perform the first detailed study of the UHE neutrino-nucleon cross-section measurement capabilities, geared to IceCube-Gen2, the planned upgrade of the IceCube neutrino telescope. The sensitivity to the cross section stems form the effect of in-Earth attenuation on the UHE neutrino flux. We work with several models of the UHE ν flux proposed in the literature. In this way, we span the parameter space from pessimistic to optimistic scenarios. To relax the model dependence of our analysis we measure both the cross-section and the flux normalization. Hence, the spectral shape of the ν flux is the only assumed information. Further, we study the dependence of the results on the detector characteristics. This includes the exposure time, angular resolution, radio antenna type. We find that, for the highest flux models, the UHE neutrino-nucleon cross section will be measured to within the theory uncertainty in the cross-section prediction.

Collaboration name:

Dark Matter / 130

Global fit of Non-relativistic Effective Operator Dark Matter using Solar Neutrinos

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In the search for particle dark matter (DM) the most prominent model is the Weakly Interacting Massive Particle (WIMP). This work uses Non-Relativistic Effective Operators (NREOs) from corresponding effective field theory (EFT) to describe WIMP DM interactions. The advantage of the NREO formalism is its ability to describe interactions outside the typical spin dependent and spin independent couplings. Should particle DM have some weak interaction with baryonic matter, the DM would interact with the matter found in the Sun and other massive bodies. When the DM scatters to velocities below the local escape velocity of such a body, this results in gravitational capture. The NREO formalism can allow for elements like iron to dominate capture rates in the Sun despite their low abundance. This solar DM constraint can be combined with direct detection (DD) experiments to complement their constraints. This is done using the Global And Modular BSM Inference Tool (GAMBIT) to allow for a global analysis of the current state of DM detection using the NREO formalism. GAMBIT is able to simultaneously consider Solar capture of DM along with current DD experiments to preform a novel analysis of the parameter space for WIMP DM.

Collaboration name:

Extragalactic Sources / 131

Closing In on The MeV Gap - An Introduction to Compton Spectrometer and Imager (COSI)

Author: Jarred Roberts[1]

Co-authors: John Tomsick [2]; Steven Boggs [1]; Zoglauer Andreas [2]; Thomas Siegert [3]; Jacqueline Beechert [2]; Hadar Lazar [2]; Eric Wulf [4]; Chris Karwin [5]

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The Compton Spectrometer and Imager (COSI) is a Small Explorer (SMEX) satellite mission selected by NASA for development. COSI is a wide-field telescope designed to survey the entire gamma-ray sky at 0.2-5 MeV. It provides imaging, spectroscopy, and polarimetry of astrophysical sources, and its germanium detectors provide excellent energy resolution for emission line studies. The science goals for COSI include studies of 511 keV emission from antimatter annihilation in the Galaxy, mapping radioactive elements from nucleosynthesis, determining emission mechanisms and source geometries with polarization, and detecting and localizing multimessenger sources. The instantaneous field of view for the germanium detectors is 25% of the sky, and they are surrounded on the sides and bottom by active shields, providing background rejection as well as allowing for detection of gamma-ray bursts or other gamma-ray flares over most of the sky. In addition, with improved sensitivity over previous missions, COSI's all-sky MeV survey explores new discovery space. In this presentation, an overview of the COSI science and instrument design will be covered, as well as some insights into the detector readout instrumentation and data analysis pipeline tools, currently being developed for the satellite mission.

Collaboration name:

COSI

Cosmic Rays / 132

Unique Properties of Secondary Cosmic Rays: Results from the Alpha Magneti Spectrometer

Author: Yao Chen[1]

[1] *Shandong Institute of Advanced Technology (SDIAT) (CN)*

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We present high statistics measurements of the secondary cosmic rays Lithium, Beryllium, Boron, and Fluorine based on 10 years of AMS data. The properties of the secondary cosmic ray fluxes and their ratios to the primary cosmic rays Li/C, Be/C, B/C, Li/O, Be/O, B/O, and F/Si are discussed. The systematic comparison with the latest GALPROP cosmic ray model is presented.

Collaboration name:

The Alpha Magnetic Spectrometer

Cosmic Rays / 133

Isotopic composition of cosmic rays with the HELIX balloon project

Author: Keith McBride[None]

Co-authors: Nahee Park ; Scott Wakely ; Stephane Coutu [1]; James Beatty [2]; Gregory Tarle [3]; David Hanna [4]; Patrick Allison [2]; Noah William Green [5]; Hyebin Jeon [6]; JIm Musser [7]; Scott Lowry Nutter [8]; Stephan O'Brien ; Makoto Tabata [9]; Brandon Kunkler [7]; Lucas Beaufore [10]; Mark Gebhard [7]; Rostom Mbarek [10]; Gerard Visser [7]; Monong Yu [1]; Samuel Mognet [1]; Yu Chen [1]; Zach Siegel [10]

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Galactic cosmic ray nuclei have been measured at the GeV and TeV scale, confirming a diverse set of elemental species. These measurements heavily impact our understanding of both Galactic accelerator candidates and cosmic ray propagation. Light cosmic ray isotope abundances deliver a

crucial and independent measurement on the latter. Long-lived unstable nuclei such as beryllium-10 provide a unique cosmic ray lifetime measurement, related to the size of the propagation halo in the Milky Way. I will present the High Energy Light Isotope eXperiment (HELIX), a balloon-borne magnet spectrometer that directly measures a cosmic ray's charge, magnetic rigidity, and velocity to identify the isotope. A high-precision drift chamber tracker in a 1 Tesla magnetic field is used for rigidity measurements and time-of-flight scintillator paddles are used for charge measurements, as well as velocity at lower energies. At higher energies, velocity is measured with an aerogel-based ring-imaging Cherenkov detector. For the sought-after beryllium isotope measurements, HELIX will detect hundreds of events in the energy range of 0.2 GeV/n to 3 GeV/n in a single Antarctic Long Duration Balloon flight. I will present an update and overview on the payload including science goals and possible plans for a first launch.

Collaboration name:

HELIX - High Energy Light Isotope eXperiment

Cosmic Rays / 134

Observation of Cosmic-Ray Anisotropy with Ten Years of IceCube Data

Authors: Rasha Abbasi[1]; Paolo Desiati[2]; Juan Carlos Diaz Velez[3]; Frank McNally[None]

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The complete IceCube Observatory has collected over 620 billion cosmic-ray induced muon events from May 2011 to May 2021. These unprecedented statistics make it possible to observe significant structure in the cosmic-ray arrival direction distribution at both higher cosmic-ray energies and smaller angular scales. Combined with improved simulation and systematics, we can provide a newly detailed assessment of the energy- and time-dependence of the cosmic-ray anisotropy in the Southern Hemisphere. We present the preliminary results from a study with the extended event sample.

Collaboration name:

IceCube Collaboration

Gravitational Wave and Multimessenger / 135

Recent updates on the VERITAS multimessenger program: searching for electromagnetic counterparts of high-energy neutrino and gravitational-wave events

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The origin of IceCube astrophysical neutrinos is an important question in astrophysics and neutrino science, and the real-time follow-up of neutrino events in the very-high-energy (VHE, E > 100 GeV) gamma-ray band is a promising way to locate neutrino sources. In 2017, evidence was presented that a flaring gamma-ray blazar, TXS 0506+056, was in spatial and temporal coincidence with the high-energy neutrino IceCube-170922A detected by IceCube. As a part of an active gamma-ray follow-up observation program of IceCube neutrino alerts, VERITAS performed observations of TXS 0506+056 in the VHE gamma-ray band and has continued this program in the following years. In a similar way, the importance of searching for gamma-ray counterparts is well demonstrated by the first detection of gravitational waves from a neutron star merger by LIGO/Virgo in 2017, which was greatly benefited from the concurrent detection of a gamma-ray burst. Searching for VHE gamma-ray counterparts will be one of the major goals of multimessenger astronomy for the near future. This presentation will describe the IceCube neutrino and gravitational-wave events follow-up program by VERITAS. We will present recent results of searching for VHE gamma-ray counterparts associated with neutrino and gravitational wave events. A subset of events will be presented with multiwavelength data as highlights.

Collaboration name:

VERITAS (Very Energetic Radiation Imaging Telescope Array System)

Galactic Sources / 136

Searching for TeV emission from Galactic PeVatrons with VERITAS

Author: Bangale P., for the VERITAS Collaboration.[1]

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Galactic PeVatrons are astrophysical sources accelerating particles up to a few PeV ($\sim 10^{15}$ eV). The primary identification of both electron and proton PeVatrons is gamma-ray radiation at ultra-high energies (UHE, E$>$100 TeV). Recently, LHAASO detected 14 steady gamma-ray sources with photon energies above 100 TeV and up to 1.4 PeV. Most of these sources contain possible source associations, such as supernova remnants, pulsar wind nebulae, and stellar clusters. However, two sources are without any source association. Therefore, multiwavelength observations are required to identify the PeVatrons responsible for the UHE gamma rays, understand the source morphology and association, and shed light on the emission processes. Here, we will present the status of VERITAS observations of the PeVatron candidates identified by LHAASO and also discuss the VERITAS PeVatron search in general.

Collaboration name:

VERITAS Collaboration

Cosmic Rays / 137

Properties of Heavy Nuclei in South Atlantic Anomaly region

Authors: Alberto Oliva[1]; Francesca Giovacchini[2]; Martha Liliana Valencia Otero[3]

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The Alpha Magnetic Spectrometer collected over 150 billion cosmic rays events during the first 8.5 years of operation aboard the International Space Station. A component of Z>2 ions with rigidities below the rigidity cutoff and located in the South Atlantic Anomaly have been measured both in the down-going and up-going direction.

Collaboration name:

AMS

Gravitational Wave and Multimessenger / 138

Neutrino Emission during Supermassive and stellar mass Binary Black Hole Mergers

Author: Ilja Jaroschewski[1]

Co-authors: Julia Becker Tjus [1]; Peter L. Biermann [2]

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The diffuse astrophysical neutrino flux was first detected by IceCube in 2013. With the high-probability association of a high-energy neutrino to the blazar TXS0506+056 in 2017 and several more neutrino-blazar associations since then, there is an indication that at least a non-negligible part of this diffuse neutrino flux originates from blazars.
As over ninety stellar mass binary black hole mergers were already detected via gravitational waves, with more to come, there are strong indications that supermassive black holes in galaxy centers, and thus blazars, also merge and have undergone at least one merger in their lifetime. Such a merger is almost always accompanied by a change of observable jet direction, leading to interactions of a preceding jet with surrounding molecular clouds and therefore neutrino productions.
By creating a connection between the emitted energy in form of neutrinos and gravitational waves in each merger of binary supermassive and stellar mass black holes, we estimate their contributions to the diffuse neutrino flux that is measured by IceCube. As neutrino production is directly connected to high energy cosmic ray interactions, the contribution of these sources to the injection rate of cosmic rays is established.

Collaboration name:

Extragalactic Sources / 139

VERITAS Observations of Fast Radio Bursts

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Gamma-ray observations of extreme astrophysical transient phenomena continue to play an important role in understanding both the physical emission mechanisms in these sources and their contribution to the cosmic-ray population. One transient class that continues to expand, but remains difficult to understand, are Fast Radio Bursts (FRBs). Due to their sporadic and short-lived emission (˜ms), capturing multi-wavelength data for these sources has proven challenging, and there still remain relatively few simultaneous measurements. Imaging Atmospheric Cherenkov Telescopes like VERITAS naturally carry with them a high sensitivity to rapid events compared to other instruments, and as future generations of telescopes begin to come online, understanding the challenges and techniques for these observations is critically important. In this talk, I will summarize the VERITAS FRB program including simultaneous observation of three new bursts in 2021 from FRB20180916B, and ongoing work with 6 other repeating FRBs. VERITAS's rapid optical observations of these sources will also be presented.

Collaboration name:

VERITAS

Neutrinos / 142

Simulating neutrino echoes induced by secret neutrino interactions

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Beyond the Standard Model (BSM) interactions in the neutrino sector have been of much interest in cosmology and astroparticle physics. We developed a Monte Carlo code to investigate the neutrino time delay distribution caused by BSM interactions en route to the observer. While we find excellent agreement for small optical depths, the optically thick limit show features that are not described by simple analytical estimates. With this code, we can understand the effects of cosmological redshift, neutrino spectra and flavors. The code can be used to probe BSM interactions in current neutrino detectors such as IceCube and Super-Kamiokande, as well as future detectors.

Collaboration name:

Cosmic Rays / 144

Testing the universality of cosmic-ray nuclei from protons to oxygen with AMS-02

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The AMS-02 experiment has provided high-precision measurements of several cosmic-ray (CR) species. I plan to review the implication of the CR measurements of antiprotons, protons, helium, helium 3, boron, carbon, nitrogen, and oxygen. The achieved percent-level accuracy allows us, for example,

to investigate different CR propagation scenarios or to study the universality of CR acceleration, a property expected in the standard scenario of CR shock acceleration. I want to discuss two viable but competing propagation scenarios: The first scenario has a break in the diffusion coefficient at a few GVs and includes reacceleration, while the second uses reacceleration and employs breaks in the power law of the primary injection spectra. I intend to carefully address the impact of systematic uncertainties on our analyses, emphasizing those arising from nuclear production cross-sections of secondaries and correlations in the CR data.

Collaboration name:

Galactic Sources / 145

The formation of gamma-ray halos around supernova remnants through particle escape

Authors: Iurii Sushch[1]; Robert B.[None]; martin pohl[None]

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Supernova remnants (SNRs) are known to accelerate particles to relativistic energies, from the detection of nonthermal emission. The particularities of the acceleration mechanism are still debated. Here, we discuss how particle escape modifies the observable spectra as well as morphological features that might be revealed by the observational progress from radio to gamma-ray energies.

We use our time-dependent acceleration code RATPaC to study the formation of extended gamma-ray halos around supernova remnants and the morphological implications that arise when the high-energetic particles start to escape from the remnant.

We find a strong difference in the morphology of the gamma-ray emission from supernova remnants at later stages, dependent on the emission process. At early times, both the inverse-Compton and the Pion-decay morphology are shell-like. However, as soon as the maximum-energy of the freshly accelerated particles starts to fall, the inverse-Compton morphology starts to become center-filled, whereas the Pion-decay morphology keeps its shell-like structure. Both emission-spectra show a spectral softening caused by the escape of the highest-energetic particles. Escaping high-energy electrons start to form an emission halo around the remnant at this time. There are good prospects for detecting this spectrally hard emission with the future Cerenkov Telescope Array, as there are for detecting variations in the gamma-ray spectral index across the interior of the remnant. Due to the projection effects there is no significant variation of the spectral index expected with current-generation of gamma-ray observatories.

Collaboration name:

Galactic Sources / 147

Gamma-ray emission from young supernova remnants in dense, structured circumstellar environments

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Supernova remnants are known to accelerate cosmic rays from the detection of non-thermal emission of radio waves, X-rays, and gamma rays. The presence of cut-offs in the gamma-ray spectra of several young SNRs led to the idea that the highest energies might only be achieved during the very initial stages of a remnant's evolution. Unfortunately, the gamma-ray luminosity is assumed to peak in the first weeks after the Supernova explosion where strong γγ absorption attenuates the observable signal. Here, we investigate to which extend the interaction of SNR-shocks with dense structures in the medium around red supergiant (RSG) and luminous blue variable (LBV) stars can boost the gamma-ray emission moths to years after the explosion.

We use the time-dependent acceleration code RATPaC to study the acceleration of cosmic rays in supernovae expanding into dense environments around massive stars. We performed spherically symmetric 1-D simulations in which we simultaneously solve the transport equations for cosmic rays, magnetic turbulence, and the hydrodynamical flow of the thermal plasma in the test-particle limit.

We investigated typical parameters of the circumstellar medium (CSM) in the freely expanding winds around RSG and LBV stars and added dense structures that arise from episodes of highly-enhanced mass-loss in case of LBV or photoionization-shells in the case of RSG progenitors.

We find that the interactions with the dense structures happens typically after a few months for LBV progenitors and a few years for RSG progenitors. During the interaction stage, the γγ absorption by photons emitted from the Supernova's photosphere became negligible. The gamma-ray luminosity of the interacting SNRs can surpass the internal/unabsorbed peak-luminosity that arises shortly after the explosion by a factor of up to 10 for the parameters that we explored. As a consequence, the observable flux can be 100 times higher compared to the signal expected shortly after the explosion where γγ absorption is important and where most gamma-ray observatories search for transient signals from these Supernovae.

Collaboration name:

Extragalactic Sources / 148

The MAGIC view of gamma-ray bursts at very high energies

Author: Alessio Berti[1]

Co-authors: Alberto Javier Castro-Tirado [2]; Antonio Stamerra [3]; David Paneque [4]; Davide Miceli [5]; Elena Moretti ; Francesco Longo [6]; Katsuaki Asano [7]; Kenta Terauchi [8]; Koji Noda [7]; Lara Nava [3]; Manuel Artero [9]; Michele Palatiello [10]; Razmik Mirzoyan [4]; Satoshi Fukami [11]; Serena Loporchio [12]; Stefano Covino [3]; Susumu Inoue [13]; Yusuke Suda [14]; Željka Bošnjak [15]

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After almost two decades of searches, in January 2019, MAGIC unambiguously detected TeV emission from the gamma-ray burst GRB 190114C. This long-awaited detection marked the beginning of the very high energy (VHE, $E > 100$ GeV) era for GRB studies. After this historical achievement, the MAGIC collaboration continued its effort in the follow-up of GRBs. In December 2020, MAGIC detected GRB 201216C, a long GRB at redshift $z = 1.1$, and got a strong hint of detection for GRB 201015A, a relatively low luminosity GRB. Together with the evidence of emission from the short GRB 160821B, these results confirm MAGIC as one of the best instruments for studying GRBs in the VHE range. They also lead to interesting questions about the universality of TeV emission in different (sub-)classes of GRBs, or the modeling of such emission in a unified theoretical scenario. In this contribution, we will present the status of the MAGIC GRB follow-up program. In particular, we will focus on the physical implications of GRB results at VHE and the open questions for which more detected GRBs are needed. Finally, we will give some prospects for future GRB studies with MAGIC, showing how this instrument will contribute even more to this new exciting branch of GRB physics.

Collaboration name:

MAGIC

Extragalactic Sources / 150

A preliminary population study of gamma ray bursts detected in the very high energy domain

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Gamma-ray burst (GRB) emission in the very high energy (VHE, E>100GeV) band has been discussed and theorized for many years, but has eluded for a long time the observations. Only in the last years the Cherenkov telescopes MAGIC and H.E.S.S. have unequivocally proven that VHE GRB afterglow radiation is produced up to a few TeV for at least a (sub-)class of GRBs. This newly opened TeV spectral window is providing unprecedented information on the physical processes involved and on several aspects of GRB afterglow physics, including particle acceleration mechanisms, and properties of the GRB environment. Modeling of multi-wavelength data performed with numerical code have been extensively used in order to probe such open questions of GRB afterglow physics. In this contribution we will address the question why these GRBs have been detected in the VHE domain, whether they have peculiar properties or they show some common behavior which may be at the basis of the production of TeV radiation. We will then show preliminary studies of the observed and the intrinsic properties of this first population of GRBs at VHE, highlighting their similarities and differences, and discussing how they compare to the whole population.

Collaboration name:

Dark Matter / 151

A machine learning approach to searching dark matter subhalos in Fermi-LAT sources

Author: Kathrin Nippel[None]

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Using the data from the Large Area Telescope (LAT), the Fermi-LAT collaboration continuously updates their catalogs, which now contain a few thousands of detected gamma-ray sources. Among them, around one third are of not yet identified origin, and they could contain signals from established source types or, most intriguing, new source types such as dark matter subhalos producing gamma-rays from dark matter self-annihilation. This possibility has been extensively investigated, finding competitive constraints on dark matter properties. Moreover, it has been shown that neural networks provide powerful methods to predict the classification of gamma-ray sources.
In this contribution we apply state-of-the-art machine learning methods for classification and anomaly detection to the gamma-ray sources in Fermi-LAT catalogs with the aim of identifying possible candidates of exotic gamma-ray sources, namely dark matter subhalos. By using established models from both N-body simulations and semi-analytical approaches for the subhalo distribution, we first simulate the properties of dark matter subhalo gamma-ray sources. We then carefully assess the detectability of this sample by using Fermi-LAT analysis tools. We present preliminary results of our machine learning analysis performed on the unidentified sources in the 4FGL-DR3.

Collaboration name:

Galactic Sources / 152

Supernova remnants at TeV energies with VERITAS

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The origin of the cosmic rays (CRs) is a complex problem that requires a proper understanding of the CR's acceleration, diffusion, and radiation mechanisms. However, observations suggest that these properties of CRs depend highly on the initial supernova explosion conditions and the structure of the ambient material into which a supernova remnant (SNR) expands. Therefore, a source-by-source study is essential to probe the acceleration, diffusion, and radiation processes. With VERITAS, we have deep exposure to young and middle-aged SNRs such as Cas A and IC 443. We will show detailed spectral and morphological studies from these SNRs in GeV-TeV gamma-ray energies, which eventually can help us understand CRs acceleration and radiation mechanisms.

Collaboration name:

VERITAS

Galactic Sources / 154

MAGIC observations of the putative PeVatron SNR G106.3+2.7 in the proximity of the Boomerang PWN

Authors: Marcel Strzys[1]; Tomohiko Oka[2]; Takayuki Saito[1]; Hidetoshi Kubo[1]

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The supernova remnant SNR G106.3+2.7 in the proximity of the Boomerang PWN has recently gained a lot of attention due to the emission above 100 TeV detected by HAWC, Tibet ASγ, and LHAASO. This SNR shows a characteristic comet-like morphology in radio observations, with a head and a tail. Due to the limited angular resolution of air shower experiments, it is not clear if the emission comes from the head, where an energetic pulsar wind nebula is located, or from the tail, where a clump of molecular cloud is present. The MAGIC telescopes, with an angular resolution better than 0.1 degrees, observed G106.3+2.7 for 122 hours and found a significant gamma-ray excess elongated along the axis of the comet shape. We performed a spectro-morphological analysis, and found the spectrum of the tail to be harder than the one in the head. This suggests that the 100 TeV emission detected by air shower experiments is from the tail. The multi-wavelength spectrum of the tail emission favors proton acceleration up to energies of ˜1 PeV, while the emission mechanism of the head could be both hadronic or leptonic.

Collaboration name:

MAGIC Collaboration

Galactic Sources / **155**

Spectrum of Pairs injected by Geminga into the Interstellar Medium

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The recent detection of the Geminga PWN by HAWC in the multi-TeV band allows us to infer precious information about the transport of pairs in the immediate surroundings of the pulsar and on the spectrum of pairs contributed by a Geminga-like pulsar to the spectrum of pairs in the cosmic radiation. Moreover, this detection allows us to address the issue of how typical are the so-called TeV halos associated to PWNe. Our calculations confirm the need to have suppressed diffusion within 30-50 pc around the pulsar, and are used here to infer precious constraints on the spectrum of pairs accelerated at the termination shock: more specifically, we discuss the conditions under which such spectrum is consistent with that typically expected in a PWN. Finally, we discuss the implications of the existence of a TeV halo around Geminga in terms of acceleration of protons in the pulsar environment, a topic of profound relevance for the whole field of particle acceleration and physics of pulsars.

Collaboration name:

Cosmology / **157**

Intergalactic medium as a probe of fundamental physics

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Most of the volume of the Universe consists of the Intergalactic Medium (IGM), space between collapsed structures like galaxies and galaxy clusters. Extragalactic photons and charged particles that propagate through the Universe spend most of their time in the IGM and can be influenced by its properties. In this talk, I will present a few examples of how we can study fundamental physics from IGM-particles interaction. These include constraints on new light feebly interacting particles as dark photons and axions, as well as the properties of the Intergalactic Magnetic Field (IGMF). If the IGMF contains a primordial component, it can have unique information about the processes in the Early Universe. However, the powerful galactic feedback processes can affect the observed properties of the IGMF. I will discuss how both the upper bounds on the IGMF, obtained using radio astronomy, and the lower bounds, obtained by gamma-ray astronomy, are affected by these processes and the prospect of measuring the volume-filling component of the IGMF using future CTA and SKA data.

Collaboration name:

Galactic Sources / 158

Analysis of High-mass X-ray Binary LS 5339 at Highest energy with HAWC

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LS 5039 is a high mass X-ray binary with an orbital periodicity of 3.9 days located about 1.5 degrees from the galactic plane. Previously, the H.E.S.S. telescope detected very high energy gamma-ray emissions from this source and measured the spectral energy in a broad inferior conjunction phase (0.45<phi<0.9) and a complimentary superior conjunction phase. However, the behavior of the emission spectrum beyond tens of TeV remains unclear. The High-Altitude Water Cherenkov (HAWC) gamma-ray observatory recently disentangled gamma-ray emission of LS 5039 from the emission of other objects in a complex galactic plane region using a multi-source model fit. An artificial neural network was applied to reconstruct the energies of the gamma-rays. The preliminary HAWC measurement shows that the spectral energy distribution of LS 5039 extends beyond tens of TeV without suppression. In a further analysis, the fluxes in the superior and inferior conjunction phases are measured separately. We will present these flux measurements between ~1 TeV and >100 TeV.

Collaboration name:

HAWC

Gamma Rays / 159

Comparison between PeVatron candidates in the HAWC and LHAASO Data Sets

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The search for the PeVatrons is one of the most important goals of the very-high-energy gamma-ray community. Gamma-rays of energies >100 TeV are produced by particles previously accelerated to PeV energies in astrophysical sources and point back to them because they are not deflected by galactic magnetic fields. Last year, LHAASO published a list of 12 sources emitting gamma rays of energy >100 TeV, which had been preceded by a publication of a list of nine sources emitting > ˜60 TeV gamma-rays by the High-Altitude Water Cherenkov (HAWC) observatory. HAWC recently released a new data set (pass 5). With more accumulated statistics and better angular resolution, more PeVatron candidates were identified in this data set. We will present preliminary results from this PeVatron search and compare HAWC with LHAASO measurements.

Collaboration name:

HAWC

Dark Matter / 162

Axion dark matter-induced echo of supernova remnants

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Axions and axion-like particles (ALPs) are a theoretically promising dark matter candidate. In the presence of radio emissions from bright astrophysical sources, nonrelativistic ALPs can undergo stimulated decay to two nearly back-to-back photons, giving bright radio sources counterimages ("echoes") in nearly the exact opposite spatial direction. These echoes are spectrally distinct, and travel galactic distances to allow one to look back in time. In this talk, I will present a recent work showing that ALP-induced echoes of supernova remnants may be bright enough to be detectable by current radio telescopes, and their non-detection may be able to set the strongest limits to date on ALP dark matter in the 1-10 μeV mass range where there are gaps in coverage in past experiments.

Collaboration name:

Extragalactic Sources / 163

Multiwavelength observations of the extreme HBL H 1426+428

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H 1426+428 is a, so called, extreme high-frequency-peaked BL Lac object (extreme HBL) located at a redshift of z = 0.129 that was detected on a number of occasions by the previous generation of ground-based gamma-ray telescopes (Whipple, CAT and HEGRA), with its VHE flux ranging up to 80% of the Crab Nebula (Crab Units, CU) above a few hundred GeV. Current-generation TeV observatories (VERITAS, MAGIC) have, however, only reported low-flux detections with the flux typically ranging from 1-3% CU. In this contribution we report the results of a multi-year monitoring program with VERITAS covering the period 2008-2016, which revealed an average steady flux of ˜2% CU, with no variability detected on timescales of days to years. We incorporate multi-wavelength data including optical, Swift UVOT, Swift XRT, Swift BAT, and Fermi-LAT, and construct and model the time-averaged spectral energy distribution, constraining the low state of this extreme HBL. Additionally, in 2021 VERITAS detected a significantly elevated state of H 1426+428 compared to the 2008-2016 data sets and conducted an intensive observation program. During this period, no cutoff is detected in the observed TeV energy spectrum up to at least 6 TeV. The results of this period are presented along with contemporaneous Swift XRT and NuSTAR observations.

Collaboration name:

VERITAS

Dark Matter / 165

Cosmology of Atomic Dark Matter with CLASS

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In the atomic dark matter scenario, a fraction of the dark matter can exist as a dark plasma of dark sector particles charged under their own gauge force, coupled to a dark radiation bath until a relatively late recombination. This process can leave observable imprints on the CMB and matter power spectrum of the universe, distinct from ΛCDM. We present an upgraded version of the numerical Boltzmann solver code CLASS that can compute the cosmological history in an atomic dark matter scenario, as well as constraints on the atomic dark matter parameters from CMB and LSS observations.

Collaboration name:

Cosmic Rays / 166

Precision Measurement of the Monthly Proton, Helum, Carbon and Oxygen Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station

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Cosmic Rays (CR) inside the Heliosphere interact with the solar wind and with the interplanetary magnetic field, resulting in a temporal variation of the cosmic ray intensity near Earth for rigidities up to few tens of GV. This variation is known as Solar Modulation. Previous AMS results on proton and helium spectra showed how the two fluxes behave differently in time. To better understand these unexpected results, one could therefore study to the next most abundant species. In this contribution, the precision measurements of the monthly proton, helium, carbon and oxygen fluxes for the period from May 2011 to Nov 2019 with the Alpha Magnetic Spectrometer on the International Space Station are presented. The detailed temporal variations of the fluxes are shown up to rigidities of 60 GV. The time dependence of the C/O, He/(C+O), p/(C+O), and p/He are also presented and their implication on the shape of the nuclei LIS is discussed.

Collaboration name:

AMS Collaboration

Dark Matter / 167

Searching for Secluded Dark Matter with Present and Future Gamma-ray Observatories

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The true nature of the largest matter density component of the Universe, the so-called dark matter, is one of the most elusive problems of Physics. One primary candidate to explain dark matter are Weakly Interacting Massive Particles (WIMPs), as they provide the right relic density with a cross-section at the electroweak scale, however, up-to-date no WIMP signals were observed until now. Secluded models are good alternatives to the standard ones. In this case, instead of a direct annihilation to the standard model (SM) particles, the dark matter annihilates into mediators which subsequently decay into SM particles. In this way, secluded models may avoid the stringent limits from direct searches, and, at the same time, be probed by indirect detection experiments. In this talk, we will present the sensitivity of several gamma-ray instruments (current and future), including Fermi-LAT, H.E.S.S., CTA, and SWGO, to secluded dark matter annihilations in several targets, such as the inner galactic halo, dwarf spheroidal galaxies and the sun, covering a wide range dark matter masses, from tens of GeV to hundreds of TeV. In particular, the combination of present and future observatories will be able to probe cross-sections below the thermal relic value for dark matter particles in the whole mass range between 100 GeV and 100 TeV or between 100 GeV and ~40 TeV depending on the annihilation channel.

Collaboration name:

Dark Matter / 168

A new path for dark matter searches: cross-correlation between gamma rays and gravitational tracers

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Dark matter in cosmic structures is expected to produce signals that originate from its particle-like nature, among which the electromagnetic emission represents a relevant opportunity. However, this emission is very faint and contributes only to the unresolved background radiation. This background emission is isotropic at first order, but exhibits a degree of anisotropy since it originates from clustered dark matter haloes. This fact implies that the anisotropies in the radiation field will be correlated to the matter distribution in the Universe.

One method to measure these anisotropies is the cross-correlation technique. In particular, we want to correlate gamma rays, indirectly produced by dark matter particles, with a gravitational tracer of the matter distribution. A positive signal in this cross-correlation channel would be the evidence that dark matter is made up of new elementary particles and is not a manifestation of an alternative theories of gravity.

I will describe this promising technique and some interesting applications to several gravitational tracers (neutral hydrogen, galaxies, cosmic shear). This technique can also be extended to include cosmic voids as a new probe for indirect detection of dark matter.

Collaboration name:

Dark Matter / 170

Jeans Model Beyond Spherical Symmetry

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The isothermal Jeans model is a semi-analytical approach to modelling galaxies and galaxy clusters with self-interacting dark matter (SIDM) that has been shown to work remarkably well. Recent studies have found great success testing Jeans model predictions for SIDM halos against both observations and simulations while assuming spherical symmetry. In the presence of baryons SIDM halos are known to depart from spherical symmetry, therefore we present a theoretical framework for relaxing symmetry assumptions and extending the Jeans model to higher dimensions. We confront 2D Jeans model predictions to SIDM-plus-baryons simulations of halos with a (velocity-independent) cross-section of $\sigma/m \sim 1\ cm^2/g$, showing that the model predicts the correct order of magnitude for the cross-section as well as matching halo shape observables in the intermediate region where the effects of SIDM become dominant.

Collaboration name:

Neutrinos / 171

Direction Reconstruction for the Radar Echo Telescope for Neutrinos (RET-N)

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The Radar Echo Telescope for Neutrinos (RET-N) is a proposed experiment to detect neutrinos with energies above ˜10 PeV utilizing the radar echo method in polar ice. RET-N will consist of a phased-array radio transmitter and an array of receivers, aiming to detect the ionization trail from an ultra-high-energy neutrino interaction in-ice via active radar sounding. The received signal is a function of the transmitted signal (including any modulation), array geometry, geometry of the reflection, and propagation effects from the ice. In this talk we discuss properties of the radar signal and how we will use these properties to reconstruct the incident neutrino's arrival direction. These methods will be tested in the pathfinder experiment for RET-N, the Radar Echo Telescope for Cosmic Rays (RET-CR).

Collaboration name:

Radar Echo Telescope (RET)

Neutrinos / 172

Recent progress towards a 5-station neutrino search with ARA

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The Askaryan Radio Array (ARA) in Antarctica is designed to detect >10 PeV neutrinos through the radiation emitted by the particle showers they initiate. ARA consists of five stations each made up of 8 horizontally-polarized and 8 vertically-polarized antennas deployed on 4 strings in the Antarctic ice. These antennas detect the radio frequency pulses associated with Askaryan emission. An additional parallel experiment with a compact array of antennas that can be used together as a phased array has been collecting data in parallel with the existing ARA5 station since 2018. This detector is made up of a single string of 9 tightly-spaced antennas and benefits from a much lower threshold trigger and higher analysis efficiency than the traditional ARA stations. We report here on efforts towards a combined 5-station and phased array analysis search for diffuse neutrinos. An analysis of the full dataset from the five traditional stations alone would represent a five-fold increase in the total exposure over the previous ARA result that used eight station-years. Further, due to its larger effective volume, the phased array dataset will provide an additional, substantial increase to the overall exposure despite its relatively short livetime. Together this analysis will result in ARA's most sensitive neutrino search to date.

Collaboration name:

ARA Collaboration

Galactic Sources / 173

Broadband X-ray Study of the Galactic Microquasar W50/SS433, a Galactic PeVatron Candidate

Author: Brydyn Mac Intyre[1]

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W50/SS433 is a complex and fascinating system that represents an important test bed for many astrophysical processes. Powered by the microquasar SS 433, the W50 nebula —classified as a supernova remnant with an unusual double-lobed morphology reminiscent of a Manatee —has been proposed to be a Galactic PeVatron candidate; a scenario that has been recently revived with the detection of very high energy TeV emission with HAWC. We present the first NuSTAR and XMM-Newton observations of the inner eastern lobe of W50, combined with archival Chandra and XMM-Newton observations spanning various regions across the eastern lobe. We resolve and characterize hard non-thermal X-ray emission detected up to 30 keV, originating from a knotty, few-arcminute size, head region located ~29 pc east of SS 433, and constrain its photon index to 1.58+/-0.05 (0.5-30 keV). The index gradually steepens away from SS 433 and all the way out to the radio ear (at ~96 pc east of SS 433) where soft thermal X-ray emission dominates. The unusually hard index and blobby structure seen from the 'head'of the eastern jet is similar to what is observed in pulsar wind nebulae as well as in extragalactic AGN jets, and challenges classical particle acceleration processes. We conclude with an outlook on upcoming and future modelling and observational studies of this system that continues to puzzle and fascinate a diverse range of researchers even more than 40 years into its discovery.

Collaboration name:

W50 Collaboration

Dark Matter / 174

The KDK experiment: measuring a rare decay of potassium relevant to dark matter searches

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Potassium-40 (40K) is a naturally-occurring radioactive isotope. It is a background in rare-event searches, plays a role in geochronology, and has a nuclear structure of interest to theorists. This radionuclide decays mainly by beta emission to calcium, and by electron-capture to an excited state of argon. The electron-capture decay of 40K directly to the ground state of argon has never been measured, and predicted intensities are highly variable (0–0.22%). This poorly understood intensity may impact the interpretation of the DAMA claim of dark matter discovery by constraining the signal modulation fraction [1]. The KDK (potassium decay) experiment is carrying out the first measurement of this electron-capture branch, using a novel setup at Oak Ridge National Labs [2]. KDK deploys a very sensitive inner detector to trigger on the ~keV radiation emitted by both forms of electron capture, surrounded by a very efficient veto to distinguish between the decays to ground state and those to the excited state. We report on our latest experimental results and the process of opening the blind data set.

[1] Pradler et al, Physics Letters B 720 (2013) 399–404, http://dx.doi.org/10.1016/j.physletb.2013.02.033

[2] Stukel et al, Nuclear Inst. and Methods in Physics Research, A 1012 (2021) 165593, https://doi.org/10.1016/j.nima.2021.165593

Collaboration name:

KDK

Dark Matter / 175

The NEWS-G light Dark Matter search experiment: Results of a methane gas physics campaign

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The NEWS-G direct dark matter search experiment uses spherical proportional counters (SPC) with light noble gasses to explore low WIMP masses. The current iteration of the experiment consists of a large 140 cm diameter SPC installed at SNOLAB with a new sensor design, and lots of improvements in detector performance and data quality. Before its installation at SNOLAB, the detector was operated with 135 mbar pure methane gas at the LSM, with a temporary water shield, offering a hydrogen-rich target and reduced backgrounds. We present results from a 10-day physics campaign in these conditions, including calibrations of the detector response down to the single ionization regime.

Collaboration name:

NEWS-G

Neutrinos / 176

A model independent framework for measuring the neutrino-nucleon cross section at UHE neutrino detectors

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At the highest energies, the neutrino nucleon cross-section σ can only be measured via interaction of ultrahigh energy (UHE) neutrinos with target particles in the Earth. The energies involved ($E_\nu \geq 10^{16}$ eV) probe $\sqrt{s}$ higher than anything possible at current colliders. Measurement of σ at these energies will directly probe new physics models. Many current and future detectors are planned to detect these UHE neutrinos. In this talk we present a model independent framework for evaluating how well these many different instruments can measure σ for any arbitrary neutrino flux, what the required detector resolutions are, and what statistics will be needed. We find that with modest numbers of neutrinos and achievable energy and angular resolutions, measurement of σ is possible in the near future with the broad spectrum of upcoming UHE neutrino detectors.

Collaboration name:

Dark Matter / 179

Revisiting the Gamma-Ray Galactic Center Excess with Multi-Messenger Observations

Author: Ilias Cholis[1]

Co-authors: Yi-Ming Zhong [2]; Samuel McDermott [3]; Joseph Surdutovich [4]

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The Galactic Center Excess (GCE) remains one of the most intriguing discoveries from the Fermi Large Area Telescope (LAT) observations. I will revisit the characteristics of the GCE by using a new set of high-resolution galactic diffuse gamma-ray emission templates. This diffuse emission, which accounts for the bulk of the observed gamma rays, is ultimately due to cosmic-ray interactions with the interstellar medium. Using recent high-precision cosmic-ray observations, in addition to the continuing Fermi-LAT observations and observations from lower energy photons, we constrain the properties of the galactic diffuse emission. I will describe a large set of diffuse gamma-ray emission templates which account for a very wide range of initial assumptions on the physical conditions in the inner galaxy. The updated GCE spectral and morphological properties have an impact on its interpretations. In particular, a high-energy tail is found at higher significance than previously reported. This tail is very prominent in the northern hemisphere, and less so in the southern hemisphere. This strongly affects one prominent interpretation of the excess: known millisecond pulsars are incapable of producing this high-energy emission, even in the relatively softer southern hemisphere, and are therefore disfavored as the sole explanation of the GCE. The annihilation of dark matter particles of mass 40^{+10}_{-7} GeV (95% CL) to b quarks with a cross-section of $\sigma v = 1.4^{+0.6}_{-0.3} \times 10^{-26}$ cm^{3}s^{-1} provides a good fit to the excess especially in the relatively cleaner southern sky. Dark matter of the same mass range annihilating to b quarks or heavier dark matter particles annihilating to heavier Standard Model bosons can combine with a subdominant millisecond pulsars component to provide a good fit to the southern hemisphere emission as well, as can a broken power-law spectrum which would be related to recent cosmic-ray burst activity.

Collaboration name:

Gamma Rays / 180

Southern Wide-field Gamma-ray Observatory (SWGO)

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HAWC and LHAASO provided a new look at the gamma-ray sky. With high sensitivity through the use of the water-Cherenkov particle detection method, these instruments have been able to achieve unprecedented sensitivity and have detected gamma rays up to 1 PeV. Their wide fields and continuous operation make them highly complementary to CTA and other IACTs. The Southern Wide-field Gamma-ray Observatory (SWGO) collaboration is a project under development to build a next-generation water-Cherenkov gamma-ray instrument in the southern hemisphere to expand wide-field coverage to the southern sky, the location of the central region of our galaxy. SWGO aims to be both higher and larger than HAWC and LHAASO and is re-examining the detector design to develop an optimal combination of background rejection and angular resolution. I will summarize the design and optimization process and present information on our prototype detector designs, with emphasis on how we can extend the sensitivity. Additionally, I will provide an overview of the goals and current status of this project.

Collaboration name:

SWGO Collaboration

Gravitational Wave and Multimessenger / 182

GW follow-up in the VHE domain with H.E.S.S.

Authors: Fabian Schüssler[1]; Sylvia Jiechen Zhu[None]; Halim Ashkar[None]; Heike Prokoph[None]; Ruslan Konno[None]

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Since the first detection of Gravitational-Wave (GW) events in 2015, scientists have been searching for their multimessenger counterparts. Major facilities are taking part in these searches by following up GW events upon their detection. In 2017, the first and only confirmed electromagnetic counterpart to a GW event was found coincident with the neutron star merger GW170817. The High Energy Stereoscopic System (H.E.S.S.) is a ground-based experiment dedicated to the observation of very high energy (VHE) gamma rays. Since 2015, H.E.S.S. has been actively taking part in the global search for the counterparts of GW events by following up the most promising GW events. In this contribution we report on the H.E.S.S. GW follow-up observations, the analysis results and the derived prospects. Although no VHE counterparts have been detected, H.E.S.S. is the first instrument to constrain the short-term and long-term VHE emission from neutron star mergers by observing GW170817. These observations allow us to place lower limits on the magnetic field in the remnants of the coalescence. The H.E.S.S. observations also place the first constraints on the VHE emission from four binary black hole mergers. The increased rate of GW event detection foreseen for the upcoming runs will increase the ability of H.E.S.S. to observe GW events across various timescales after the detection and place even stronger limits on the VHE emission of such events.

Collaboration name:

H.E.S.S. Collaboration

Extragalactic Sources / 183

Constraining Axion-Like Particles with HAWC Observations of TeV Blazars

Authors: Katherine Freese[1]; Sunniva Jacobsen[None]; Tim Linden[None]

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Axion-like particles (ALPs) are a broad class of pseudo-scalar bosons that generically arise from broken symmetries in extensions of the standard model. In many scenarios, ALPs can mix with photons in regions with high magnetic fields. Photons from distant sources can mix with ALPs, which then travel unattenuated through the Universe, before they mix back to photons in the Milky Way galactic magnetic field. Thus, photons can traverse regions where their signals would normally be blocked or attenuated.
In this talk, I will present the results, and necessary background, of a paper where we use TeV γ-ray observations of distant blazars, made by the HAWC collaboration, to constrain models of ALPs. We use 7 TeV upper limits provided by HAWC to find new constraints on the ALP parameter space that

are competitive with, or better than, leading terrestrial and astrophysical constraints in the relevant mass range.

Collaboration name:

Dark Matter / 184

Dark Matter Annihilations in Massive Stars: A New Lease on Life?

Author: Joshua Ziegler[None]

Co-author: Katherine Freese [1]

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Stars whose initial mass is between approximately 150 and 240 $M_\odot$ face a fate of complete explosion in a pair instability supernova (PISN). However, by injecting energy into the star, it may be possible in some cases to avoid this fate. We outline conditions on this energy injection which can lead to the survival or incomplete explosion of the star, and we discuss how dark matter annihilations throughout a star may offer one mechanism to provide this energy. Finally, we begin to explore the range of energy conditions which may allow stars to avoid PISN.

Collaboration name:

Dark Matter / 187

Measuring dark matter subhalos in strong lenses with truncated marginal neural ratio estimation

Authors: Adam Coogan[None]; Camila Correa[1]; Christoph Weniger[None]; Kosio Karchev[2]; Noemi Anau Montel[None]

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Strongly-lensed galaxies are a unique laboratory for probing dark matter substructure and testing the fundamental assumptions of the ΛCDM paradigm. However, the statistical difficulties with analyzing such observations are formidable, requiring disentangling the source galaxy's light from the lens'mass distribution and marginalizing over different substructure configurations. In this talk I present a new approach to this problem based on a simulation-based inference method called truncated marginal neural ratio estimation (TMNRE). I will explain how TMNRE enables measuring both the properties of individual subhalos and directly the parameters of the subhalo mass function, overcoming limitations of likelihood-based analyses. I will show initial results based on mock data and argue that such techniques pave the way to measuring the fundamental properties of dark matter from both existing lensing images and the large amounts of data new telescopes will generate in the coming few years.

Collaboration name:

Dark Matter / 189

Search for Dark Matter with the PICO Experiment

Author: Guillaume Giroux[1]

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The PICO collaboration searches for WIMPs using large superheated liquid detectors, or bubble chambers. Recent results from the complete exposure of the PICO-60 C_3F_8 detector at SNOLAB set the world's most stringent limits on WIMP-proton spin-dependent interactions. I will present the current status of the construction and physics potential of the next generation, tonne-scale experiment at SNOLAB: PICO-500.

Collaboration name:

PICO

Dark Matter / 190

Faint light of old neutron stars from dark matter capture and detectability at the James Webb Space Telescope

Authors: Brijesh Kanodia[1]; M.S.N. Kumar[2]; Raghuveer Garani[3]; Shiuli Chatterjee[None]; Rajeev Kumar Jain[4]; Sudhir Kumar Vempati[None]

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Neutron stars (NS) of age >10ˆ9 yrs exhaust thermal and rotational energies and cool down to temperatures below \mathcal{O}(100) K. Accretion of particle dark matter (DM) by such NS can heat them up through kinetic and annihilation processes. This increases the NS surface temperature to a maximum of \sim 2600 K in the best case scenario. The maximum accretion rate depends on the DM ambient density and velocity dispersion, and on the NS equation of state and their velocity distributions. Upon scanning over these variables, we find that the effective surface temperature varies at most by \sim 40\%. Black body spectrum of such warm NS peak at near infrared wavelengths with magnitudes in the range potentially detectable by the James Webb Space Telescope (JWST). Using the JWST exposure time calculator, we demonstrate that NS with surface temperatures \gtrsim 2400 K, located at a distance of 10 pc can be detected through the F150W2 (F322W2) filters of the NIRCAM instrument at SNR \gtrsim 10 (5) within 24 hours of exposure time.

Collaboration name:

Neutrinos / 191

Propagation of Cosmic Rays in Plasmoids of AGN Jets-Implications for Multimessenger Predictions

Authors: Fabian Schüssler[1]; Ilja Jaroschewski[2]; Julia Becker Tjus[2]; Marcel Schroller[2]; Mario Hörbe[2]; Patrick Reichherzer[2]; Wolfgang Rhode[3]

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With the successful detection of cosmic high-energy neutrinos and the first high-probability association of such a neutrino to the blazar TXS 0506+056 leads to the anticipation that active galactic nuclei could soon be identified as point source emitters of high-energy neutrinos. This opens up new challenges for a joint explanation of the observed electromagnetic spectrum together with neutrinos. Modeling the charged, relativistic particles responsible for the different emissions achieves such an explanation.

In this work, we analyze the propagation regimes of cosmic rays, which are crucial constituents, in a relativistic plasmoid traveling along the jet axis. It is shown that in the considered energy range of high-energy photon and neutrino emission, the transition between diffusive and ballistic propagation significantly influences not only the spectral energy distribution but also the lightcurve of blazar flares

Collaboration name:

Particle Physics / 192

Flavor and CP Violation from a QCD-like Hidden Sector

Authors: Daniel Stolarski[1]; Wafia Bensalem[1]

[1] *Carleton University*

Confining hidden sectors at the GeV scale are well motivated by asymmetric
dark matter and naturalness considerations and can also give interesting collider signatures. Here we study such sectors connected to the Standard Model by a TeV scale mediator charged under both QCD and the dark force. Such a mediator admits a Yukawa
coupling between quarks and dark quarks which is generically flavour and CP violating.
We show that in contrast to expectation, electric dipole moments do not place a strong
constraint on this scenario even with O(1) CP-violating phases. We also quantitatively
explore constraints from $\Delta F = 1, 2$ processes as a function of the number of dark quark
flavours. Finally, we describe the reach of upcoming measurements at Belle-II and KOTO,
and we propose new CP-odd observables in rare meson decays that may be sensitive to the
CP-violating nature of the dark sector

Collaboration name:

Dark Matter / 193

Hunting for Sub-GeV DM with the SENSEI experiment

Author: Erez Etzion[1]

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The SENSEI Experiment leads the direct-detection searches for sub-GeV dark matter (DM) using the novel Skipper-CCD sensors. The Skipper-CCDs can provide repetitive non-destructive readouts of a single pixel's charge reducing the noise to a negligible level and reaching a single electron distinction. Already with the small-scale prototype runs, SENSEI achieved the lowest rates in silicon detectors of events containing single, pair, three, or four electrons, and reached world-leading sensitivity for a large range of low-mass DM masses.
We will present recent results from low-mass prototype runs on the surface and in the MINOS cavern at the Fermi National Accelerator and the commissioning of the O(100-gram) SENSEI experiment at SNOLAB.

Collaboration name:

SENSEI

Dark Matter / 194

Warm dark matter searches from the Galactic halo

Author: Ariane Dekker[1]

[1] *University of Amsterdam*

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Warm dark matter (WDM) could explain some small-scale structure observations that have challenged the cold dark matter (CDM) model, as warm particles suppress structure formation due to free streaming effects. Observing small-scale structure thus provides a valuable way to distinguish between CDM and WDM. In this talk, I will present a semi-analytical model of the dark matter substructure evolution, with which we estimated the number of satellite galaxies in the Milky Way. I will discuss stringent constraints on WDM models based on the observed number of satellites in the Milky Way.
Moreover, warm particles such as sterile neutrinos and axion-like particles can decay into photons, which are consequently detectable by X-ray telescopes. eROSITA will perform an all-sky X-ray survey, of which I will present its sensitivity to identify dark matter decay with narrow X-ray line emission.

Collaboration name:

Dark Matter / 195

Hidden dynamics of a sub-component dark matter

Authors: Ayuki Kamada[1]; Seodong Shin[2]; Heejung Kim[3]; Jong-Chul Park[4]

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We emphasize the distinctive cosmological dynamics in multi-component dark-matter scenarios and its impact in probing a sub-dominant component of dark matter.

The dynamics originates from the conversion among different dark-matter components.
We find that the temperature of the self-interacting sub-component dark matter is significantly enhanced by the dark-matter annihilation into the sub-component.
The same annihilation sharply increases the required annihilation cross section for the sub-component as we consider a smaller relative abundance fraction among the dark-matter species.
Because of the enhanced temperature and annihilation cross section of the sub-component, contrary to a naive expectation, it can be easier to detect the sub-component with smaller abundance fractions in dark-matter direct/indirect-detection experiments and cosmological observations.
Combining with the current results of accelerator-based experiments, the abundance fractions smaller than $10\,\%$ are strongly disfavored;
we demonstrate this by taking a dark photon portal scenario as an example.
Nevertheless, for the abundance fraction larger than $10\,\%$, the warm dark-matter constraints on the sub-dominant component at sub-GeV mass scale can be complementary to the parameter space probed by accelerator-based experiments.

Collaboration name:

Dark Matter / 196

Cosmic-ray Neutrino Boosted Dark Matter (νBDM)

Author: Jong-Chul Park[1]

Co-authors: Yongsoo Jho [2]; Seong Chan Park [2]; Po-Yen Tseng [3]

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We propose a novel mechanism of boosting dark matter by cosmic-ray neutrinos. The new mechanism is so significant that the arriving flux of cosmic-ray neutrino boosted dark matter (νBDM) lighter than O(1) MeV on Earth substantially larger than the one of the cosmic-ray electron boosted dark matter. Therefore, νBDM can dominantly contribute in direct detection experiments. We derive conservative but still stringent bounds and future sensitivity limits for νBDM from advanced underground dark matter and neutrino experiments such as XENON1T/nT, LZ, Borexino, and JUNO.

Collaboration name:

Cosmology / 198

A Poisson Log-Normal Framework for Cosmological Parameter Inference Using Dark Sirens

Author: J. Leo Kim[1]

Co-authors: Ghazal Geshnizjani [2]; Supranta Sarma Boruah [3]; William Gregory Dallaway [2]

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We present a novel statistical framework to infer cosmological parameters from cosmological surveys, based on a Bayesian forward modelling of correlated Poisson processes. In particular, given catalogs of galaxies and standard sirens, we compute the posterior distributions for cosmological parameters by assuming that the detection of standard sirens follow a spatial Poisson process that samples an underlying random log-normal density field. This framework has several computational and mathematical advantages when compared to the usual Gaussian scenario, such as eliminating the need for the inverse of very large matrices. We validate the accuracy of this method using mock catalogs, and show that it is in reasonable agreement with recent forecasts that use Gaussian approximations to the likelihood functions, while providing a more realistic description of the non-Gaussian tails of the posterior probability distributions for inferred cosmological parameters.

Collaboration name:

Dark Matter / 199

The SABRE South Experiment at the Stawell Underground Physics Laboratory

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The SABRE (Sodium iodide with Active Background REjection) experiment aims to detect an annual rate modulation from dark matter interactions in ultra-high purity NaI(Tl) crystals in order to provide a model independent test of the signal observed by DAMA/LIBRA. It is made up of two separate detectors; SABRE South located at the Stawell Underground Physics Laboratory (SUPL), in regional Victoria, Australia, and SABRE North at the Laboratori Nazionali del Gran Sasso (LNGS).

SABRE South is designed to disentangle seasonal or site-related effects from the dark matter-like modulated signal by using an active veto and muon detection system. Ultra-high purity NaI(Tl) crystals are immersed in a linear alkyl benzene (LAB) based liquid scintillator veto, further surrounded by passive steel and polyethylene shielding and a plastic scintillator muon veto. Significant work has been undertaken to understand and mitigate the background processes, that take into account radiation from the detector materials, from both intrinsic and cosmogenic activated processes, and to understand the performance of both the crystal and veto systems.

SUPL is a newly built facility located 1024 m underground (˜2900 m water equivalent) within the Stawell Gold Mine and its construction will be completed by mid-2022. The laboratory will house rare event physics searches, including the upcoming SABRE dark matter experiment, as well as measurement facilities to support low background physics experiments and applications such as radiobiology and quantum computing. The SABRE South detector assembly is planned to start once SUPL is finalised, and its commissioning is expected to occur in 2023.

This talk will report on the design of SUPL design and its current status, as well as the general status of the SABRE South assembly.

Collaboration name:

SABRE

Dark Matter / 200

The DarkSide-20k TPC and underground argon cryogenic system

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Darkside-20k will exploit the physical and chemical properties of liquid argon housed within a large dual-phase time project chamber (TPC) in its direct search for dark matter. The TPC will utilize a compact, integrated design with many novel features to enable the 20t fiducial volume of underground argon. Underground argon (UAr) is sourced from underground CO2 wells and depleted in the radioactive isotope 39-Ar, greatly enhancing the experimental sensitivity to dark matter interactions. Sourcing and transporting O(100 t) of UAr for DarkSide-20k is costly, and a dedicated single-closed-loop cryogenic system has been designed, constructed, and tested to handle the valuable UAr. We present an overview of the DarkSide-20k TPC design and the first results from the UAr cryogenic system.

Collaboration name:

DarkSide

Dark Matter / **201**

Search for dark matter signatures with ANTARES and KM3NeT

Author: Sara Rebecca Gozzini[None]

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Extraterrestrial neutrinos can be used as messengers to probe the presence of dark matter particles in the Milky Way. Indeed, sizable fluxes of high-energy neutrinos are expected from pair annihilation and decay of dark matter in regions where it accumulates to a high density. Massive celestial bodies such as the Sun and the very large reservoir at the Galactic Centre are inside the field of view of neutrino telescopes installed in the Mediterranean Sea. ANTARES was operated for 16 years and was recently decommisisoned, and KM3NeT is currently taking its first data with 10 detection lines for its low energy sub-detector ORCA, and 8 lines for its high energy sub-detector ARCA. A search for signatures of Weakly Interacting Massive Particles (WIMPs) has been performed in 14 years of all-flavour neutrino data, yielding competitive upper limits on the strength of WIMP annihilation. Other non-WIMP landscapes, such as model predicting heavy dark matter candidates, have been tested with dedicated searches in ANTARES data. The current results with the first installed KM3NeT unit will be discussed.

Collaboration name:

ANTARES and KM3NeT Collaborations

Dark Matter / **202**

Dark Matter-neutrino interactions through a one-loop diagram

Authors: Aaron Vincent[1]; Karen Macías Cárdenas[1]; Gopolang Mohlabeng[2]

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[2] *University of California, Irvine*

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The nature of Dark Matter is an ongoing and relevant object of study in astroparticle physics. Despite our best efforts to identify its possible particle properties, the results have been null, which has led to a plethora of models describing viable connections to the Standard Model. In particular, loop models of Dark Matter, like the scotogenic model, have received attention in the last decade but their phenomenology in regard to Dark Matter interactions with neutrinos in the Early Universe has not been widely studied. We aim to explore whether parameters of a one-loop model with Scalar Dark Matter-neutrino interactions such as the dark matter mass, the scattering cross-section, and the couplings can be constrained by Early Universe data like the Lyman-alpha forest, Cosmic Microwave Background anisotropies and the Matter Power Spectrum, and give rise to the observed relic abundance.

Collaboration name:

Dark Matter / 203

The Status of the Galactic Center Excess

Author: Dan Hooper[1]

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A bright and statistically significant flux of GeV-scale gamma rays has been detected from the region surrounding the Galactic Center. While the spectrum, angular distribution, and intensity of this signal is consistent with the predictions of annihilating dark matter matter particles, it has also been suggested that these gamma rays could potentially be produced by a large population of millisecond pulsars. In this talk, I'll review the arguments for each of these interpretations, and discuss the current status of the hunt for the annihilation products of dark matter.

Collaboration name:

Galactic Sources / 204

Multi-wavelength study of the galactic PeVatron candidate LHAASO J2108+5157

Author: Jakub Jurysek[1]

Co-authors: Andrea Tramacere [1]; Dominik Eckert [1]; Giorgio Pirola [2]; Matteo Balbo [1]; Roland Walter [1]

[1] *University of Geneva - Department of Astronomy*

[2] *Max-Planck-Institut fur Physik*

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LHAASO J2108+5157 is the first gamma-ray source directly discovered in the Ultra-High-Energy band by the LHAASO collaboration. Two molecular clouds identified in the direction towards LHAASO J2108+5157 make the source a promising galactic PeVatron candidate. In 2021, the Large-Sized Telescope prototype (LST-1) of the Cherenkov Telescope Array (CTA) Observatory performed observations of LHAASO J2108+5157, establishing constraining upper limits on the source emission

in the multi-TeV band. Target of Opportunity XMM-Newton observations were also carried out in 2021, leading to strong constraints on the source X-ray emission. In this contribution, we will present multi-wavelength modeling of data from various instruments and discuss possible scenarios for the high energy emission of the source.

Collaboration name:

the CTA-LST Project

Plenary session / 205

High-Energy Neutrinos: A New Trail Towards New Physics

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Collaboration name:

Plenary session / 207

The ANTARES adventure

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Collaboration name:

Plenary session / 208

Young Stellar Clusters: a new player in the field of Cosmic Ray origin

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The origin of Galactic cosmic rays (CR) is still a matter of debate. Supernova remnants (SNR) remains the best candidates thanks to their kinetic luminosity and a well studied acceleration mechanism, the diffusive shock acceleration, which has been shown to efficiently work at the SNR forward shocks. However, recently their ability to accelerate particles up to PeV energies, as required from direct detection of local CRs, have been questioned both from an observational point of view as well as from a theoretical prospective. Only very rare and powerful SNRs seem to be able to reach PeV energies, posing a serious challenge to the entire SNR paradigm. The last decade has also seen the rise of a new class of potential CR sources, namely Young Stellar Clusters (YSC), supported by observations showing high energy gamma-ray emission in coincidence with several YSCs. Indeed, powerful winds from massive stars embedded in YSC produce large wind blown bubble where the conditions to accelerate PeV particles may be reached. In this talk I will critical discuss this hypothesis presenting the status of theoretical models and future prospectives for gamma-ray observation of YSCs with upcoming facilities.

Collaboration name:

Plenary session / 209

Dark Matter in Celestial Objects

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Collaboration name:

Plenary session / 210

Dark Matter in Extreme Environments

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Collaboration name:

Plenary session / 211

Counting your dark matter halos

Collaboration name:

Plenary session / 212

Neutrinos and Cosmic rays from Tidal Disruption Events

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Collaboration name:

Plenary session / 213

Precision neutrino physics with liquid scintillator detectors

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Collaboration name:

Plenary session / 214

Cusps, Cores and Kinematics: Modelling Gas in Galaxies to Measure Dark Matter

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Plenary session / 215

Searches for new particles in bound solar orbits

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Plenary session / 216

Measurements of Galactic Gamma-Ray Sources with Imaging Atmospheric Cherenkov Telescopes

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Collaboration name:

Plenary session / 217

Cosmology and Fundamental Physics with (Extreme) Blazars

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Collaboration name:

Plenary session / 218

Pulsar Timing Arrays: The Next Window to Open on the Gravitational-Wave Universe

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Galaxy mergers are a standard aspect of galaxy formation and evolution, and most (likely all) large galaxies contain supermassive black holes. As part of the merging process, the supermassive black holes should in-spiral together and eventually merge, generating a background of gravitational radiation in the nanohertz to microhertz regime. An array of precisely timed pulsars spread across the sky can form a galactic-scale gravitational wave detector in the nanohertz band. I describe the current efforts to develop and extend the pulsar timing array concept, together with recent limits

which have emerged from international efforts to constrain astrophysical phenomena at the heart of supermassive black hole mergers.

Collaboration name:

Plenary session / 219

Neutrinos from blazars five years after the IC170922A / TXS0506+056 event

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Collaboration name:

Plenary session / 221

A decade of discoveries with Cherenkov neutrino telescopes

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Collaboration name:

Plenary session / 222

Radio Detection of Ultra-High Energy Neutrinos

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Collaboration name:

Plenary session / 223

Very to Ultra-High-Energy Gamma-ray Astrophysics with Ground-Based Particle Detection Arrays

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Collaboration name:

Plenary session / 224

Search for ”Light” Dark Matter and CEvNS with NEWS-G and SBC experiments

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Collaboration name:

Plenary session / 225

Direct detection of dark matter at higher masses

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Collaboration name:

Plenary session / 226

Astroparticle Physics with the Forward Physics Facility at the High-Luminosity LHC

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High-energy collisions at the High-Luminosity Large Hadron Collider (HL-LHC) will pro- duce an enormous flux of particles along the beam collision axis that is not accessible by existing LHC experiments. Multi-particle production in the far-forward region is of par- ticular interest for astroparticle physics. High-energy cosmic rays produce large particle cascades in the atmosphere, extensive air showers (EAS), which are driven by hadron-ion collisions under low momentum transfer in the non-perturbative regime of QCD. Thus, the understanding of high-energy hadronic interactions in the forward region is crucial for the interpretation of EAS data and for the estimation of backgrounds for searches of astrophysical neutrinos. The Forward Physics Facility (FPF) is a proposal to build a new underground cavern at the HL-LHC which will host a variety of far-forward ex- periments to detect particles outside the acceptance of the existing LHC experiments. We will present the current status of plans for the FPF and highlight the synergies with astroparticle physics. We will discuss how measurements at the FPF will improve the modeling of high-energy hadronic interactions in the atmosphere and thereby reduce the associated uncertainties of measurements in the context of multi-messenger astrophysics. In addition, we will explore the connection between searches for new physics at the FPF and the understanding of the nature of Dark Matter in the Universe.

Collaboration name:

Plenary session / 227

The Universe as a Lab for Dark Matter Physics

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Collaboration name:

Plenary session / 228

The All-sky Medium-Energy Gamma-ray Observatory eXplorer: AMEGO-X

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Collaboration name:

Plenary session / 229

Latest results and the upgrade of the Pierre Auger Observatory

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Collaboration name:

Plenary session / 230

Overview of the recent results and future developments of the Telescope Array experiment

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Collaboration name:

Plenary session / 231

Direct Detection of Low Mass Fast Moving Dark Matter

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Low mass fast moving/energetic dark matter (DM) is very well motivated and has been a subject of attention in the literature. These fast-moving particles can gain enough kinetic energy to pass the thresholds of some Large volume terrestrial detectors. For instance, fast-moving or "boosted" DM can account for the recent excess in electron recoil events observed by the XENON1T detector, due to its velocity being large enough to give rise to ~keV recoil electrons. An explanation from ambient DM seems challenging otherwise. In this talk, I will focus on "boosted" DM which is a byproduct of the annihilation of heavier, ambient, dark sector partners. I will present on-going work in which the atomic effects are considered and show that, in the case of fast-moving DM, the limits can change depending on the electron ionization form factor used.

Collaboration name:

KC Kong, Haider Alhazmi, Doojin Kim, Jong-Chul Park & Seodong Shin

Neutrinos / **232**

Towards Powerful Probes of Neutrino Self-Interactions in Supernovae

Authors: Christopher Hirata[1]; Ivan Esteban[1]; John Beacom[1]; Po Wen Chang[1]; Todd Thompson[2]

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Neutrinos remain mysterious. As an example, enhanced self-interactions (νSI), which would have broad implications, are allowed. At the high neutrino densities within core-collapse supernovae, νSI should be important, but robust observables have been lacking. We show that νSI make neutrinos form a tightly coupled fluid that expands under relativistic hydrodynamics. The outflow becomes either a burst or a steady-state wind; which occurs here is uncertain. Though the diffusive environment where neutrinos are produced may make a wind more likely, further work is needed to determine when each case is realized. In the burst-outflow case, νSI increase the duration of the neutrino signal, and even a simple analysis of SN 1987A data has powerful sensitivity. For the wind-outflow case, we discuss several promising ideas that may lead to new observables. Combined, these results are important steps towards solving the 35-year-old puzzle of how νSI affect supernovae.

Collaboration name:

Dark Matter / **233**

Ab initio calculations of structure factors for dark matter searches

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We present converged ab initio calculations [1] of structure factors for elastic spin-dependent WIMP scattering off all nuclei used in dark matter direct-detection searches: 19F, 23Na, 27Al, 29Si, 73Ge, 127I, 129Xe, and 131Xe. From a set of established two- and three-nucleon interactions derived within chiral effective field theory, we construct consistent WIMP-nucleon currents at the one-body level, including effects from axial- vector two-body currents. We then apply the in-medium similarity renormalization group to construct effective valence-space Hamiltonians and consistently transformed operators of nuclear responses. Combining the recent advances of natural orbitals with three-nucleon forces expressed in large spaces, we obtain basis-space converged structure factors even in heavy nuclei. Generally, results are consistent with previous calculations, but in certain cases can differ by as much as 80-90% at low momentum transfer.

[1]. Ab initio structure factors for spin-dependent dark matter direct detection. B.S. Hu, et al. Phys. Rev. Lett. 128 (2022) 072502. arXiv:2109.00193.

Collaboration name:

Dark Matter / 234

First dark matter search result from the LZ experiment

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The LUX-ZEPLIN (LZ) experiment is a direct dark matter detector hosted at the Sanford Underground Research Facility in Lead, South Dakota. LZ's central detector is a dual-phase time projection chamber containing 7-tonnes of liquid xenon. This is aided by a xenon skin detector and a liquid scintillator-based outer detector to veto events inconsistent with dark matter.
Results from LZ's first search for Weakly Interacting Massive Particles (WIMPs) with an exposure of 60 live days were recently published, with the data being consistent with a background-only hypothesis. This has set new limits on the spin-independent WIMP-nucleon cross-section.
This talk will provide an overview of the experiment and report on its status, including a discussion of the first result.

Collaboration name:

LUX ZEPLIN

Cosmic Rays / 235

The High Energy cosmic Radiation Detector

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The High Energy cosmic-Radiation Detection (HERD) facility is one of several space astronomy payloads onboard the future Chinese Space Station (CSS), planned for operation starting around 2027 for about 10 years. HERD is a China-led mission with key European contributions led by Italy. The primary scientific objectives of HERD are: Indirect dark matter search with unprecedented sensitivity; precise cosmic ray spectrum and composition measurements up to the knee energy; gamma-ray monitoring and full sky survey. HERD is composed of five scientific instruments. The central one (CALO) is a homogeneous, almost cubic calorimeter made of about 7500 LYSO cubic crystals and capable of accepting particles incident on its top face and four lateral faces. All the five sides of CALO are covered by layers of fiber trackers (FIT), plastic scintillators (PS) and silicon charge detectors (SCD), from inside out. Additionally, a transition radiation detector is located on one lateral face for energy calibration of TeV particles. The total weight of HERD is about 4 tons. This design results in an effective geometric factor more than one order of magnitude larger than that of previous missions, and also excellent lepton/hadron separation capabilities thanks to the 3D nature of the calorimeter. The novel design and key specifications of HERD instruments have been successfully verified with four beam tests at the CERN SPS.

Collaboration name:

Neutrinos / 236

The Pacific Ocean Neutrino Experiment

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The Pacific Ocean Neutrino Experiment (P-ONE) is a proposed cubic kilometre class neutrino telescope two hundred kilometres off the coast of Vancouver Island, Canada. A partnership with Ocean Network Canada (ONC) brings extensive knowledge, experience, and infrastructure to build a novel large-scale neutrino telescope in the ocean. P-ONE's primary scientific goals are to advance the field of neutrino astronomy, test fundamental physics at TeV to PeV energies, and contribute to multi-messenger astronomy. P-ONE is currently developing the first mooring line (P-ONE 1) to be expanded to a 10-line demonstrator. The demonstrator will observe the first neutrinos in the ocean environment, test new photo-detector modules and calibration methods, and pave the way for a 70-line P-ONE telescope. P-ONE provides a unique opportunity for interdisciplinary collaboration with oceanographers, marine biologists and climate scientists. The design, abilities and current status of the P-ONE demonstrator are shown.

Collaboration name:

P-ONE

Particle Physics / 237

GAMBIT update

Authors: Csaba Balazs[None]; The GAMBIT Community[None]

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I give an update on GAMBIT, the Global And Modular BSM Inference Tool. After briefly describing the main features of the GAMBIT code, I highlight why GAMBIT is a promising framework to isolate sign of physics beyond the standard models (BSM) of particle physics and cosmology. Then I show the latest GAMBIT results for a model where the gravitino, and the neutralinos and charginos are the only light sparticles in the Minimal Supersymmetric Standard Model.

Collaboration name:

The GAMBIT Community