# N-pact meeting 2025

Thursday 19 June 2025 - Friday 20 June 2025

# Book of Abstracts

# Contents

**Talks** / **2**

## Dark pions at next-to-leading order

**Authors:** Daniil Krichevskiy[1]; Helena Kolesova[1]; Suchita Kulkarni[2]

[1] *University of Stavanger*

[2] *University of Graz*

**Corresponding Authors:** helena.kolesova@uis.no, daniil.krichevskiy@uis.no, suchita.kulkarni@cern.ch

QCD-like theories are of interest in various areas of beyond-Standard-Model phenomenology, including composite Higgs models and strongly interacting pionic dark matter. The low-energy effective field theories provide a framework for describing the dynamics of such strongly coupled gauge theories.
In this work, we present next-to-leading order (NLO) expressions for masses, condensates, decay constants, and scattering amplitudes in the chiral expansion of QCD-like theories with $N_f = 2$ quarks of different masses in both real and pseudoreal representations. These results offer a systematic approach for analyzing the impact of NLO corrections in such theories.
We apply the NLO formulas for masses, decay constants, and the scattering length to fit existing lattice spectroscopic and scattering data, extracting the NLO low-energy constants (LECs) of the $SU(4) \to Sp(4)$ theory. With these estimates, we refine previous NLO analyses and confirm that NLO contributions play a crucial role in determining the viable parameter space for strongly interacting massive particle (SIMP) dark matter.

**Talks** / **4**

## Color superconductivity and non-strange hybrid stars

**Author:** Mathias Pavely Nødtvedt[1]

**Co-author:** Jens Oluf Andersen

[1] *Norwegian University of Science and Technology (NTNU)*

**Corresponding Authors:** mathias.p.nodtvedt@ntnu.no, jensoa@ntnu.no

In this talk I will discuss the three-flavor quark-meson model including color superconductivity, with emphasis on the 2SC and CFL phases. We extend the quark-meson model to the quark meson diquark model. This is a renormalizable low energy effective model that describes the superconductive phases of QCD. We calculate the thermodynamic potential including quark loops. We map out the phase diagram in the $\mu_B$-$T$ plane and sketch how one can apply this model to compact stars. We will present results for the speed of sound, mass-radius relationship, and tidal deformability of non-strange hybrid stars.

**Talks** / **5**

## Interactions of accelerated dark matter with nuclei and implications for DUNE

**Author:** Helena Kolešová[1]

[1] *University of Stavanger*

**Corresponding Author:** kolesova.hel@gmail.com

Halo dark matter particles with sub-GeV masses do not possess sufficient kinetic energy to induce detectable recoils of heavy nuclei, direct detection experiments, hence, loose sensitivity to such light dark matter. Dark matter particles can be, however, accelerated by different mechanisms and even light dark matter can then provide observable signatures. These signatures include not only coherent dark matter-nucleus scattering, but also scattering off individual nucleons or deep inelastic scattering. The latter processes can be detected by neutrino experiments and we demonstrate their importance on the example of dark matter accelerated by scattering with galactic cosmic rays that might be observed by the DUNE experiment.

**Welcome / 6**

## Welcome

**Corresponding Author:** jensoa@ntnu.no

**Talks / 7**

## Curious case of the maximum energy distribution of cosmic-ray accelerators

**Author:** Domenik Ehlert[1]

**Co-authors:** Foteini Oikonomou [2]; Michael Unger [3]

[1] *Norwegian University of Science and Technology*

[2] *NTNU*

[3] *Karlsruhe Institute for Technology*

**Corresponding Authors:** foteini.oikonomou@ntnu.no, domenik.ehlert@proton.me, michael.unger@cern.ch

Ultra-high-energy cosmic rays (UHECRs) are atomic nuclei that reach Earth with energies of up to several hundred exaelectronvolts. Identifying their sources is a key challenge in high-energy astrophysics. Motivated by the fact that candidate astrophysical accelerators exhibit high diversity in terms of their relevant properties, such as luminosity and Lorentz factor, we study the compatibility of a population of sources with non-identical maximum cosmic-ray energy with the observed energy spectrum and composition of UHECRs at Earth. We find that the allowed source-to-source variance of the maximum energy must be low to describe the data. This suggests that the UHECR flux at Earth is dominated by a single source or that a mechanism exists that naturally aligns the maximum energy of all contributing sources.

**Talks / 8**

## Effective field theory dualities from the classical equations of motion

**Author:** Tomas Brauner[1]

[1] *University of Stavanger*

**Corresponding Author:** tomas.brauner@uis.no

The modern amplitude program has not only introduced computationally efficient methods for particle scattering but also revealed surprisingly close relationships between seemingly disparate theories, such as Yang-Mills theory and general relativity. In this talk, I will present a novel type of

duality that connects known effective field theories for massless scalars. This duality relates the physics of pions to Yang-Mills theory coupled to a specific scalar sector. Additionally, pions interacting with a gravitational field will be shown to be equivalent to two exceptional effective theories relevant for cosmology: the Dirac-Born-Infeld theory and the special Galileon theory. These duality maps enable the connection of both perturbative scattering amplitudes and exact classical solutions across different theories.

**Talks / 10**

## Higgs mediated Neutralino pair production in the Next-to-Minimal Supersymmetric Standard model

**Author:** Sofiya Sianiuta[1]

**Co-author:** Are Raklev [2]

[1] *Norwegian University of Science and Technology*

[2] *University of Oslo (NO)*

**Corresponding Authors:** sian.sofiya@gmail.com, are.rachlow@cern.ch

The Next-to-Minimal supersymmetric Standard Model (NMSSM) is a phenomenologically motivated supersymmetric model that includes a gauge-singlet superfield, two $SU(2)$ Higgs doublets and a set of five neutrally charged fermions (neutralinos). Thus, NMSSM can be used to study the properties of extended Higgs sectors and dark matter candidates. We target the union of these two and compute the cross section for Higgs mediated neutralino pair production in proton-proton collisions, to the leading order in the Yukawa coupling and with $\mathcal{O}(\alpha_s)$ Standard Model corrections in the QCD coupling. We assume all Higgs sector parameters to be real and evaluate the resulting cross section in the cNMSSM.1 benchmark scenario in which the lightest neutralino is stable, gauge-singlet–like and with feeble Yukawa couplings to the Higgs bosons. In addition, the lightest Higgs bosons have small decay widths which provides significant resonance enhancement if they are included in the kinematic domain. Our results explore the phenomenological implications of cNMSSM.1 and the prospects of observability of the neutralinos at the Large Hadron Collider.

**Talks / 11**

## PT2GWFinder: a Handy Tool for Cosmological Phase Transitions and Gravitational Waves

**Authors:** António Morais[1]; Marco Finetti[2]; Marco Matteini[3]; Miha Nemevsek[4]; Vedran Brdar[None]

[1] *University of Aveiro*

[2] *Aveiro University*

[3] *Jožef Stefan Institute*

[4] *Jožef Stefan Institute and University of Ljubljana*

**Corresponding Authors:** mfinetti@ua.pt, miha.nemevsek@ijs.si, aapmorais@ua.pt, marcomatteini1996@gmail.com, vedran.brdar@northwestern.edu

The baryon asymmetry problem remains a crucial challenge in particle physics and cosmology. Electroweak baryogenesis, a leading mechanism to produce the matter-antimatter asymmetry we observe today, requires an extension of the Standard Model to achieve a sufficiently strong first-order phase transition (FOPT). Besides representing a target for several future-generation colliders, such Beyond the Standard Model (BSM) theories carry the potential to generate, through a thermal phase transition, gravitational waves (GWs) detectable by future space-based detectors.

Despite growing interest in the problem, publicly available code for studying different BSM scenarios is limited, with the leading tools being *CosmoTransitions*, *PhaseTracer* and *BSMPT*. While they offer powerful methods for model building, there remains a need for an accessible tool that enables the study of FOPTs in a simple and straightforward manner.
We are releasing a fully Mathematica-based paclet to fill the gap, offering a user-friendly and fully automated tool to derive phase transition and gravitational wave parameters. To compute the Euclidean tunneling action, the paclet exploits the recently developed FindBounce, which implements the polygonal bounce method.
The user provides any scalar potential in the form $V(\phi, T)$, where $\phi$ is the field direction in which a FOPT is expected, and the paclet automates the following steps:
- multiple phase tracing methods
- identification of first order phase transitions
- construction of a semi-analytical fit function for the bounce action $S_3/T(T)$
- computation of phase transition parameters: nucleation and percolation temperatures, strength, duration, …
- derivation of GW spectra from templates found in the literature.

Although designed to work with any given thermal potential, we offer additional tools to construct thermal potentials both in the daisy-resummation and dimensional reduction approaches. Specifically, the paclet is intended to interface smoothly with DRalgo, a Mathematica tool implementing dimensional reduction and thermal effective field theory computations.
The tool has been tested on a variety of single-field models, including the dark Abelian Higgs and a coupled fluid-field model. This presentation will cover current results and future development plans, showcasing the potential for this new paclet to become an invaluable resource in the field of cosmological phase transitions.

**Talks** / **12**

# Blazars as a potential source of very-high-energy astrophysical neutrinos

**Author:** Egor Podlesnyi[1]

**Co-author:** Foteini Oikonomou [2]

[1] *Norwegian University of Science and Technology (NTNU)*

[2] *NTNU*

**Corresponding Authors:** egor.podlesnyi@ntnu.no, foteini.oikonomou@ntnu.no

Since the discovery of very-high-energy (E ≥ 100 TeV) astrophysical neutrinos in the 2010s by the *IceCube* neutrino observatory, their origin remains largely unknown. In our work, we investigate blazars —active galaxies with their relativistic jets pointing very close to the Earth —as potential sources of the neutrinos observed by *IceCube*. We use the brightest blazar flare in blazar 3C 454.3 that occurred in November 2010, when it became the most luminous object in the whole gamma-ray sky, as a testbed. We analyse a rich set of then-collected multi-wavelength data (from infrared to gamma-ray range) and model the flare in order to predict the expected neutrino flux from similar blazar flares and use the publicly available catalogue of the detected *IceCube* neutrinos to test our theoretical predictions.

**Talks** / **13**

# Compact Stars with the Quark-Meson Model

**Author:** Carl Fredrik Andresen[1]

[1] *University of Oslo*

**Corresponding Author:** carlfan@uio.no

To predict mass maxima for spherically symmetric compact stars, we use the Tolman-Oppenheimer-Volkoff equation together with an equation of state (EoS). The EoS relates the pressure and energy density, and can be derived for different types of matter. We expect nuclear matter EoSs to break down for a large enough energy density, a threshold which may be surpassed as one approaches the center of a compact star. At very large energy densities, perturbative QCD can be used to describe quark matter. For energy densities between these two extremes, we need another EoS. Therefore, we use the Quark-Meson (QM) model, a phenomenological model with quark degrees of freedom. The two-flavor QM model yields compact star mass maxima of approximately 2 solar masses, which is comparable to the most massive observed compact stars.

**Talks / 14**

## The SIMP and the vector meson

**Author:** Halvor Melkild[1]

[1] *University of Oslo*

**Corresponding Author:** halvor.melkild@fys.uio.no

The so-called "strongly interacting massive particles" (SIMPs) refer to a class of dark matter candidates with the relic abundance set by the $3 \to 2$ interactions which allows for dark matter with sub-GeV masses, not yet strongly constrained by direct detection experiments. Interestingly, SIMP dark matter features relatively strong self-interactions that may explain the small-scale structure puzzles. We investigate the realisation of SIMP models where dark pions form dark matter, protected from decay by dark flavour symmetries. We observe that the freeze-out mechanism for the dark pions depends sensitively on the masses of heavier states present, such as dark vector mesons. We improve on existing results by using recent lattice simulations connecting the masses of dark pions and vector mesons.

**Talks / 15**

## Update of gravitational waves

**Author:** Alex Nielsen[1]

[1] *University of Stavanger*

**Corresponding Author:** alex.b.nielsen@uis.no

This will be a brief update on progress in gravitational wave observations, focussing on the LIGO, Virgo and KAGRA detectors. Prospects for observing gravitational-wave transients in the future will also be discussed.

**16**

## Modeling Gravitational Waves via Post-Newtonian Expansion and Geometric Optics

**Author:** Kristine de Boer[None]

**Corresponding Author:** kristdbo@stud.ntnu.no

Two complementary approximation frameworks are explored for modeling gravitational waves in general relativity. The first part develops the shortwave formalism, which treats gravitational radiation as high-frequency perturbations propagating on a slowly varying background spacetime. This approach enables the derivation of a gauge-invariant effective stress-energy tensor and allows for the study of energy and momentum transport in the far-field region. The second part focuses on the post-Newtonian (PN) expansion, a slow-motion approximation applicable in the near zone around compact sources. Using 1PN corrections to the two-body problem, expressions for periastron precession and orbital period decay are derived and evaluated. The predicted periastron shift for the binary PSR B1913+16, discovered by Taylor and Hulse in 1974, agrees closely with observations, and the theoretical orbital period decay rate matches the corrected observed value with high precision. Numerical modeling of the accumulated arrival time shift over several decades has been performed for both PSR B1913+16 and PSR J0737–3039A/B, yielding results that closely track the observed pulsar timing data. A central result is the accurate modeling of the double pulsar system PSR J0737–3039A/B, where numerical predictions from the PN expansion show excellent agreement with observed timing data. In this system, the deviation between the PN and weak-field predictions becomes clearly visible over time, demonstrating that relativistic corrections captured by the PN formalism are not only necessary, but critical for describing the dynamics of strongly gravitating binaries. Together, the PN and shortwave frameworks provide a coherent and effective approach for understanding both the generation and propagation of gravitational waves in curved spacetime.