# Theory and Experiment in High Energy Physics

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HUN-REN Wigner Research Centre for Physics, Budapest, Hungary

# Book of Abstracts

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**Short talks** / **1**

# Exclusion bounds for neutral gauge bosons

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We study how the recent experimental results constrain the gauge sectors of $U(1)$ extensions of the standard model using a novel representation of the parameter space. We determine the bounds on the mixing angle between the massive gauge bosons, or equivalently, the new gauge coupling as a function of the mass $M_{Z'}$ of the new neutral gauge boson $Z'$ in the approximate range $(10^{-2}, 10^{4})$ GeV/$c^2$. We consider the most stringent bounds obtained from direct searches for the $Z'$. We also exhibit the allowed parameter space by comparing the predicted and measured values of the $\rho$ parameter and those of the mass of the $W$ boson. Finally, we discuss the prospects of $Z'$ searches at future colliders. This work is presently submitted for publication, the corresponding preprint can be found at arXiv:2402.14786.

**Short talks** / **2**

# Studies of ATLAS Forward Proton (AFP) ToF performance with Run-3 data

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The analysis of the early LHC Run-3 data was performed. Efficiencies and resolutions for the ATLAS Forward Proton (AFP) Time-of-Flight (ToF) detector were studied with different methods. In addition, these performance studies of the ToF data included the proton-proton vertex reconstruction using matching of ToF and central ATLAS vertex position. After a calibration, a preliminary resolution of the vertex reconstruction was determined with a low-mu ATLAS run.

**Short talks** / **3**

# Anomalous dimensions for hard exclusive processes

**Author:** Sam Van Thurenhout[1]

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We give an overview of recent developments in the computation of the anomalous dimension matrix of composite operators in non-forward kinematics. The elements of this matrix determine the

scale dependence of non-perturbative parton distributions such as the generalized parton distribution functions. The latter provide important information about hadronic structure and are accessible experimentally in hard exclusive scattering processes like deeply-virtual Compton scattering. Particular emphasis will be put on a recently developed method that exploits consistency relations for the anomalous dimension matrix which follow from the renormalization structure of the operators.

**Short talks** / **4**

## Exact quark mass corrections to Higgs production in association with a jet

**Author:** Gabor Somogyi[1]

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In this talk, we present the computation of the next-to-leading order QCD corrections to the production of a Higgs boson in association with a jet at the LHC, including the exact dependence on the masses of quarks circulating in heavy-quark loops. The NLO corrections are computed including the top-quark mass and the bottom-quark mass as well. We show results in the on-shell mass scheme as well as a running mass renormalisation scheme.

**Public plenary** / **5**

## Cosmic Muography

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Naturally occuring cosmic particles, mostly muons, reach the Earth surface continuously and nearly uniformly, and due to their high energy can cross as much as 10-1000m of rock. Since muons propagate along straight lines, one can use these particles for imaging the internal density structure of large objects. More than five decades ago, this method has been used to search for hidden chambers in a pyramid, and subsequently to study various challenging structures: mines, caves, volcanoes, nuclear reactors. Since the turn of the last century, there has been a rapid increase of interest towards muon imaging –with a new research field, called "Muography"emerging –and the application possibilities broadened along with drastic reduction of instrumentation cost, at improved detection efficiency, portability and imaging resolution. The most relevant application possibilities include mining, archeology, volcanology, nuclear industry and border control. Measurements related to volcanology span three continents, and revealed magma movement and erosion effects.

Mining applications allow cost reduction (less drilling) and improved operational safety, thus contributing to a sustainable future.

Muography is not only becoming a consistent research field, but there is an international community which facilitates information exchange, critical assessment of the quality of new results, and promotes technology transfer towards an increasing number of industrial partners.

**Public plenary** / **6**

## Superweak extension of the standard model

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**Short talks** / **10**

## Strong coupling expansion of determinant observables in N=4 SYM

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A special class of observables in N=4 and N=2 SYM can be expressed as determinants of semi-infinite matrices. At strong coupling, the expansion of these observables are asymptotic. The perturbative coefficients was already determined in the literature. We have established a method to systematically calculate the non-perturbative part as well. It is based on the fact that the elements of the defining matrices are given by truncated Bessel kernels. Their structure provide several constraints to the observables in forms of differential and integral equations. Using them and the analyticity properties of the kernel the entire asymptotic series can be determined.

**Short talks** / **11**

## Trajectory reconstruction for proton computed tomography with machine learning

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Hadrontherapy is an alternative way of treating cancer. This method utilizes the Bragg peak of protons to destroy cancerous cells while minimize the harm in the healthy ones. The aim of Hadrontherapy is to beam in protons that deposits most of their energy inside the tumor.
Proton Computed Tomography (pCT) is a method for calculating relative stopping powers on protons in the body of a patient. It can help to optimize the dosage planning for Hadrontherapy.
In my research the goal is to be able to process the signals from the detector layers and then predict the scattering angle from the incoming protons and their kinetic energy before entering the detector system.

**Short talks** / **12**

## Luminosity measurements using the ATLAS Forward Proton (AFP) detector

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The latest results of luminosity measurements using the AFP detector are presented.

**Short talks** / **13**

## Can Rotation Solve the Hubble Puzzle?

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The Hubble constant H0 is a key parameter determining the rate of the Universe's expansion. Presently, the discrepancy between the low and high redshift measurements of H0 is the highest significance tension within the concordance ΛCDM paradigm. We show that a rotating dark-fluid variant of the concordance model resolves this tension with an angular velocity today ω0 ⊠ 10−3 Gyr-1.Curiously, this is approximately also the fastest rotation with a tangential velocity less than the speed of light at the horizon.

**Short talks** / **14**

## Image Reconstruction with Proton CT

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One of the most successful treatments in cancer therapy is proton therapy, with radiation planning being a key element. Photon CT is commonly used for this purpose; however, it does not provide sufficiently accurate information about the range of protons. Therefore, proton CT imaging is more favorable for radiation planning. Due to the Coulomb scattering of protons, it is important to calculate the Relative Stopping Power at the voxel level (thus, appropriate handling of trajectories is also required), for which several algorithms have been developed. The aim of my research is to test, further develop and optimize a software package using the Richardson-Lucy algorithm developed in the Bergen Proton CT Collaboration.
The simulations necessary for the research were performed using the Geant4 and Gate software. I optimized the framework using the Richardson-Lucy algorithm with appropriate methods for faster and more efficient operation. I tested the operation of the algorithm and image reconstruction on phantoms developed to measure the performance of medical imaging systems at different energies. During my work, I managed to optimize the algorithm reducing the runtime. Based on the evaluation of phantom reconstruction, I found that the algorithm operates with the desired accuracy.
Among my long-term goals are further optimization and achieving clinical usability (including further reducing runtime).

**Short talks** / **15**

## Jet substructure measurements in heavy-ion collisions

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High-energy collisions of heavy ions produce hot and dense strongly coupled matter, the so-called quark–gluon plasma (QGP). Jets, which are collimated particle sprays resulting from parton fragmentation, are modified by the QGP. The loss of jet momentum in the hot and dense medium, called jet quenching, was one of the first tell-tale signs of the presence of QGP. Jet quenching alone, however, is not enough to fully understand the energy loss mechanisms of jets within the plasma. With systematic jet substructure measurements, however, not only can we investigate the energy loss of the color charge, but we can also learn about the length scales that are resolvable by the QGP, or determine whether the plasma has an emergent quasiparticle structure. This contribution summarizes some of the most interesting results of the ATLAS, CMS, and ALICE experiments at the LHC, which contribute to answering these questions and extend our knowledge of the non-perturbative regime of quantum chromodynamics.

**Short talks** / **16**

## Probing hadron-quark phase transition in twin stars using f-modes

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Although it is conjectured that a phase transition from hadronic to deconfined quark matter is possible in the ultrahigh density environment in Neutron Stars, the nature of such a transition is still unknown. Depending on whether there is a sharp or slow phase transition, one may expect a third family of stable compact stars or "twin stars"to appear, with the same mass but different radii compared to Neutron stars. The possibility of identifying twin stars using astrophysical observations has been a subject of interest, which has gained further momentum with the recent detection of gravitational waves from binary neutron stars. In this work, we investigate for the first time the prospect of probing the nature of hadron-quark phase transition with future detection of gravitational waves from unstable fundamental (f-) mode oscillations in Neutron Stars. By employing a recently developed model that parametrizes the nature of the hadron-quark phase transition via "pasta phases", we calculate f-mode characteristics within a full general relativistic formalism. We then recover the stellar properties from the detected mode parameters using Universal Relations in GW asteroseismology. Our investigations suggest that the detection of gravitational waves emanating from the f-modes with the third-generation gravitational wave detectors offers a promising scenario for confirming the existence of the twin stars. We also estimate the various uncertainties associated with the determination of the mode parameters and conclude that these uncertainties make the situation more challenging to identify the nature of the hadron-quark phase transition.

**Public plenary** / **17**

## Rare Kaon Decays and Searches for BSM Physics

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We shall summarize why searches for Beyond Standard Model (BSM) Physics signals in rare kaon decays make sense. In the second part of the talk the latest results from the NA62 Experiment at CERN will be discussed.

**Public plenary** / **20**

## Precision luminometry for tests of the Standard Model at (HL-)LHC

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The most precise measurements of Standard Model processes, including the production of W, Z and Higgs bosons, as well as top quark pairs, require a luminosity precision better than 1% per year at the HL-LHC. The expected harsh experimental conditions with up to 200 interactions per bunch crossing will make this extremely challenging. I summarise the state-of-the-art in luminometry touching new studies of the beam-beam electromagnetic interactions using multiparticle tracking simulations of the intense bunched beams, improved experimental techniques to limit the van der Meer calibration biases, the emittance scan method and Z boson counting to improve integration systematics at the LHC, and the development of new instrumentation for the upgraded CMS detector at HL-LHC.

**Public plenary** / **21**

## AdS/CFT and integrability

**Author:** Zoltan Bajnok[1]

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In my talk I will give an overview of the duality linking the maximally supersymmetric four dimensional gauge theory to superstrings propagating on the product of the five dimensional sphere and the the five dimensional anti de Sitter space. Special emphasis will be put on the integrable description. In particular, I will explain the philosophy of the integrable approach and explain how it actually works. I will give details on how the scaling dimensions of the conformal gauge theory can be calculated.

**Public plenary** / **22**

## Neutrino Oscillation Experiments - Review

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The discovery of neutrino oscillation marked a paradigm shift in particle physics, fundamentally altering our understanding of neutrinos and their properties. The neutrino oscillation experiments have unraveled the neutrino mixing picture by detecting neutrinos from various sources. Three neutrino mixing framework is firmly established and neutrino physics is going through its precision era. This talk provides an overview of the
of the achievements of past and ongoing neutrino oscillation experiments, and discuss the potential of future neutrino oscillation experiments to pin down the remaining unanswered questions about neutrino.

**Short talks / 23**

## Mesons in medium (in Hadron-Nucleus reactions)

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Since dileptons can leave the dense phase of a reaction without distortion, their observation may allow us to observe in\,-\,medium effects on mesons produced in hadron induced reaction. The masses of the low lying charmonium states, the $J/\Psi$, $\Psi(3686)$, and $\Psi(3770)$ are shifted downwards due to the second order Stark effect. In hadron + \text{Au}$collisions at 6\text{-}20\ GeV we study their in-medium propagation. The time evolution of the spectral functions of these charmonium states is studied with a BUU type tr$ $medium mass shift can be observed in the dilepton spectrum, therefore, we may gain information about the magnitude of th$ $medium effect on \rho and \omega mesons can be observed by studying their interference contributing to the dilepton spectra$ \$ induced reactions at 1-2 GeV pion beam energies. This may be observed in JPARC.

**Short talks / 24**

## CERN lpGBT: Merging Timing, Data, and Control of Detectors

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The presentation shows the recent evolution of the data, trigger and control links in HEP experiments, using the CERN ALICE detector as an example. It gives an introduction of the CERN GBT/lpGBT protocol and their implementation in a radiation environment, the versatile link optical components, and some back-end interface cards (CRU, FELIX) that make the integration of the connected systems possible.

**Short talks / 25**

## Search for Axion-Like-Particle (ALP) with the ATLAS Forward Proton (AFP) Detector with Di-photons

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A search for forward proton scattering in association with light-by-light scattering mediated by an axion-like particle is presented, using the ATLAS Forward Proton spectrometer to detect scattered protons and the central ATLAS detector to detect pairs of outgoing photons. Proton-proton collision data recorded in 2017 at a centre-of-mass energy of √ s =13 TeV were analysed, corresponding to an integrated luminosity of 14.6 fb−1. A total of 441 candidate signal events were selected. A search was made for a narrow resonance in the diphoton mass distribution, corresponding to an axion-like particle (ALP) with mass in the range 150-1600 GeV. No excess is observed above a smooth background. Upper limits on the production cross section of a narrow resonance are set as a function of the mass, and are interpreted as upper limits on the ALP production coupling constant, assuming 100% decay branching ratio into a photon pair. The inferred upper limit on the coupling constant is in the range 0.04-0.09 TeV−1 at 95% confidence level.