NNV section for (astro)particle physics fall meeting

Friday, 7 November 2025 - Friday, 7 November 2025

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Book of Abstracts

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Constraining the sources of ultra-high-energy cosmic rays with experimental measurements

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Ultra-high-energy cosmic rays (UHECRs) are the most energetic particles known - and yet their origin is still an open question. However, leveraging the precision and accumulated statistics of the largest observatory in the world, the Pierre Auger Observatory, it is now possible to set constraints on the sources of UHECRs. The spectrum and mass composition measurements at the highest energies can be well described by a population of extragalactic, homogeneously distributed sources.
Utilizing additionally the observed anisotropy in the UHECR arrival directions - and interpreting it using models of the Galactic magnetic field that deflects UHECRs on their way to us - even more powerful constraints on the density and distribution of sources can be placed. The status and possible interpretation of UHECR measurements will be reviewed in this presentation.

Parallel Sessions (I) / 38

1Bit HHL for particle track reconstruction

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Although linear system solvers are not currently part of **particle track reconstruction** workflow, our work demonstrates how a lightweight quantum linear solver, such as the Harrow-Hassidim-Lloyd (HHL) could be adapted to this context. The HHL quantum algorithm for solving linear systems promises exponential speed-up. We present a novel variant, **1-bit HHL**, which reduces phase estimation to a single bit of precision. This simplification replaces costly eigenvalue inversion with a binary-controlled operation, significantly lowering qubit and gate requirements. The method achieves a favorable trade-off between efficiency and accuracy, providing a potential path toward near-term quantum applications in high-energy physics.

Plenary session / 39

MYRRHA and its driver accelerator

Authors: Adrian Fabich[None]; Hamid Aït Abderrahim[None]; Ulrich Dorda[None]

MYRRHA is the first Accelerator Driven System (ADS) to be built, consisting of a subcritical nuclear reactor driven by a high power linear accelerator, for the demonstration of transmutation of nuclear waste at pre-industrial scale. With the subcritical concentration of fission material, the nuclear reaction is sustained by the particle accelerator only.
The MYRRHA design for an ADS is based on a 4mA, 600 MeV CW superconducting proton linac. The first stage towards its realization is called MINERVA and was approved in 2018 to be constructed by SCK CEN in Belgium. This consist of a 4mA 100MeV superconducting linac as well as two independent target stations, one for radio-isotope research and production of radio-isotopes for medical purposes, the other one for fusion materials research. The extension of the superconducting linac to 600 MeV is in the conceptual design stage, with a planned implementation until the early 2030s.
This contribution presents the main design choices and current status of the overall project parts (civil engineering, particle accelerator and target facilities).

Parallel Sessions (I) / 40

Performance and efficiency measurement of a transformer-based quark gluon jet tagger in the ATLAS experiment

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In this talk a deep learning approach based on the transformer architecture is presented to distinguish jets originating from quarks or gluons.
The algorithm is defined to operate on jets with transverse momentum $p_{\mathrm{T}} > 20$ GeV and pseudorapidity $|\eta| < 4.5$ and takes as inputs the jet constituents, using information from the ATLAS detector tracker and calorimeter.
The algorithm performance is evaluated in data analyzing final states with two jets produced in proton-proton collisions at $\sqrt{s} = 13$ TeV and 13.6 TeV recorded by the ATLAS detector during Run 2 and Run 3 of the LHC.
Two methods are employed to define distributions associated to quark- or gluon-initiated jets in data: a matrix method fully based on Monte Carlo simulation and a new approach named jet topics which has a reduced dependence on the assumed modelling of the physics process under study.
The quark/gluon identification efficiency is measured in data and, for the 50\% quark identification efficiency working point, is found to vary with respect to the simulated one from 0.85 to 1.18 for quark-initiated jets and from 0.67 to 1.01 for gluon-initiated jets.
The uncertainties on the measurement estimated with the new jet topics method are found to be smaller than the ones estimated with the matrix method, with up to 20\% reduction in systematic uncertainties in some phase space regions.
This talk reports advances in the identification of jets initiated by quarks or gluons, providing a robust tool for precision Standard Model measurements and searches for new physics at the LHC.

Parallel Sessions (II) / 41

A Gravitational-Wave Signature of Deconfined Quark Matter in Neutron Stars

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Quantum chromodynamics predicts a phase transition from hadronic matter to deconfined quarks at extreme densities, yet its exact nature remains uncertain. Neutron stars offer a unique opportunity to probe this transition, but bulk properties—mass, radius and tidal deformability—provide only indirect signatures, which require many detections to resolve and are ineffective if the discontinuity exists at lower densities. In this talk, I report on a *smoking-gun* gravitational-wave signature of a first-order phase transition, identifiable in a single event: the resonant tidal excitation of an interface mode. I demonstrate the detectability of this resonance using general-relativistic perturbation calculations for an ensemble of nuclear-matter equations of state informed by chiral effective field theory. The results suggest that this signature is within reach of third-generation interferometers and may even be observable with LIGO A+ in sufficiently loud events.

Parallel Sessions (III) / 42

Axion-mediated dark matter direct detection

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The quantum field theory of dark matter scattering has been extensively explored for numerous direct detection experiments. However, pseudoscalar-mediated interactions, such as those involving axion-like particles, have received comparatively little attention, primarily because they are both spin-dependent and momentum-suppressed. In this talk, I will discuss how several theoretical mechanisms can enhance these otherwise elusive interactions. For instance, loop effects can convert a spin-dependent and momentum-suppressed interaction at tree level into a spin-independent one. Flavor-changing couplings can further increase the scattering rate and thus detectability. I will demonstrate that current experiments, such as XENONnT, are already sensitive to parts of the pseudoscalar-mediated dark matter parameter space.

Parallel Sessions (I) / **43**

Sensitivity estimates of the VH(cc) process in the Lorentz-boosted regime

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Following the first measurements of the Higgs couplings to vector bosons and third-generation fermions at the LHC, it is essential to probe the Higgs couplings to second-generation fermions, such as the charm quark. Motivated by the increased performance of flavour identification algorithms, this work presents the first sensitivity estimates of the VH(cc) process in the Lorentz-boosted regime, utilizing Run-2 simulation samples at 13 TeV. As a baseline approach, we developed an indirect boosted flavour-tagger by tagging variable-radius track-jets using the state-of-the-art Run-2 flavour-tagger DL1r, which led to an estimated 18% significance improvement at pTV > 400 GeV. To improve upon this, the deployment of the next-generation boosted flavour-tagger GN2X allows for higher signal efficiency with increased background rejection. We further improved event selection by optimizing the GN2X-based Hcc-discriminant, resulting in up to 10% sensitivity gain. Additionally, the application of a boosted decision tree using six event-level and six subjet-level variables resulted in sensitivity gains up to 50%. To correct for differences between the flavour-tagger efficiency in simulation and data, we applied an in-situ calibration, increasing the VH(cc) signal strength uncertainty by an additional 8.5%. Accounting for the calibration, the expected VH(cc) signal strength is found to be 1.00 ± 4.98. Overall, the boosted approach demonstrates substantial improvements over resolved methods in the high-pT regime. Numerous opportunities for further advancements remain, including (pseudo-)continuous flavour-tagging, advanced MVA techniques, and the integration of Run-3 collision data.

Parallel Sessions (I) / **44**

Towards measuring $B_c^+ \to \tau^+\nu_\tau$ at LHCb

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The first experimental measurement of the leptonic decay $B_c^+ \to \tau^+\nu_\tau$ is eagerly awaited by the high energy particle physics community.
Such a measurement provides a sensitive probe of physics beyond the Standard Model and complements the measurements of $\mathcal{R}(D)$ and $\mathcal{R}(D^*)$, which show puzzling differences with the Standard

Model predictions, as both probe the $b \to c\tau\nu$ quark-level transition. However, the measurement of $B_c^+ \to \tau^+\nu_\tau$ at LHCb is experimentally challenging due to the presence of neutrinos and large backgrounds from hadronic decays and material interactions.

This work presents the first steps towards measuring the branching ratio of $B_c^+ \to \tau^+\nu_\tau$ using the data collected by LHCb since 2024. To suppress the hadronic background, a dedicated algorithm is applied that searches for hits in the silicon sensors of the Vertex Locator (VELO) consistent with the crossing of the charged B_c^+ meson or the τ^+ lepton. However, exploring the first data, a significant source of background originating from vertices produced by hadronic interactions with the VELO detector material was found. These material-induced events are studied in detail, and dedicated techniques are applied to distinguish them from genuine b-hadron decays.

Parallel Sessions (II) / 45

Reconstruction of Higgs Boson Pairs in the 4b Final State using Machine Learning

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In the search for new particles beyond the Standard Model, a promising channel involves the decay of a heavy resonance into a pair of Higgs bosons, each subsequently decaying into a bottom quark-antiquark pair: $X \to YH \to 4b$. A major challenge in reconstructing this signal is determining which jets originate from which Higgs boson. In this talk, I will present my work on reconstructing Higgs boson pairs using a boosted decision tree (BDT) trained on kinematic features, focusing on the topology where quarks from each Higgs boson decay are well separated. I will show that this machine learning approach performs better than the traditional mass-based method, both in correctly identifying the true jet pairings and in reducing the probability of selecting incorrect ones. Additionally, the BDT reproduces the expected Higgs boson mass distributions more reliably. These results highlight the potential of multivariate techniques to enhance sensitivity in searches for extended Higgs sectors at high-energy colliders such as the LHC.

Parallel Sessions (II) / 46

Radio detection and interferometry at the Pierre Auger Observatory

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High-energy cosmic rays constantly bombard Earth's atmosphere from outer space, initiating particle cascades called air showers. The Pierre Auger Observatory is the largest observatory in the world dedicated to detecting these air showers. It consists of more than 1,600 surface detectors distributed over an area of 3,000 km². Recently, the surface detectors underwent a major upgrade, called AugerPrime, which enables, among other things, the detection of radio signals emitted by the air showers. Detection with radio waves opens up the possibility of using interferometry to reconstruct key parameters of the air showers with high precision, such as the shower axis and the depth of the shower maximum, X_{max}. Currently, the observatory is being prepared to implement this technique. In this presentation, we will show the AugerPrime upgrade and highlight the interferometry technique, as well as the plans and efforts that have been made to implement it in the Pierre Auger Observatory.

Parallel Sessions (III) / 47

Analyzing GW231109_235456 and its potential implications for nuclear physics and multi-messenger astronomy

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Due to their scientific importance, e.g., in the fields of nuclear physics and cosmology, the scientific community is eagerly waiting to detect more neutron star mergers.
Motivated by this, we study the gravitational-wave trigger GW231109_235456, a sub-threshold neutron star merger candidate observed in the first part of the fourth observing run of the LIGO–Virgo–KAGRA collaboration.
Assuming the trigger is of astrophysical origin, we analyze it using state-of-the-art waveform models and investigate the robustness of the inferred source parameters under different prior choices in Bayesian inference.
Using our findings, we assess the implications for the nuclear equation of state.
Combining GW170817 and GW190425 with GW231109_235456, we estimate that the radius of a $1.4\,M_\odot$ neutron star should be $R_{1.4} = 12.07^{+1.08}_{-1.19}$ km, compared to $12.21^{+1.06}_{-1.37}$ km from GW170817 alone, at the 90% credible level.
We find that the remnant most likely collapsed promptly to a black hole and that, because of the large distance, a possible kilonova connected to the merger was noticeably dimmer than AT2017gfo.
In our projections for the future, we simulate a similar event using the upcoming generation of gravitational-wave detectors. Our findings indicate that we can constrain the neutron star radius with an accuracy of 400 meters using the Einstein Telescope alone, or 300 meters when combined with the Cosmic Explorer, both at 90% credibility.

Parallel Sessions (II) / 48

Status of the NEXT experiment

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The aim of the NEXT experiment in Groningen is the study of the decay properties and masses of Neutron rich EXotic heavy nuclei produced in multi-nucleon Transfer reactions. This type of reaction comes with the experimental challenge of a wide angular distribution of the reaction products.

To overcome this challenge, the NEXT experiment uses a solenoid separator to separate and to focus the reaction products into the low energy beam line. In the low energy beam line the ions are cooled and bunched in preparation for mass measurements in a Multi-Reflection Time-of-Flight Mass Spectrometer. The NEXT experiment has been fully constructed and the preparation for the first beam on target experiments are ongoing. In this presentation an overview of the current status of the experiment will be given.

Parallel Sessions (III) / 49

The study of proton-emitting nuclei near the magic N=82 neutron shell closure

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Proton radioactivity provides a unique probe of nuclear structure far from stability and for odd-Z elements it is expected to be the decay mode that determines the limit of observability for neutron deficient nuclei. Establishing these boundaries of observability and identifying the nuclear structure at these limits is a long-standing challenge in nuclear physics. The nuclei in the region of the N=82 shell closure are expected to be the most nearly spherical proton emitters and therefore a benchmark for theoretical models of this decay mode [1,2]. These odd-Z nuclei are known to have low-lying isomeric states, which are often substantially longer-lived than the ground states in these nuclei, due to the strong increase of proton-decay half-lives with the orbital angular momentum of the emitted proton. In these cases the isomeric states all have a configuration involving a proton in the πh11/2 orbital, while in the ground states the protons are in either a πs1/2 or πd3/2 orbital. This allows the observation of the isomeric states in proton-emitting nuclei where the ground state is too short-lived to be observed with current experimental techniques, for example 159Re [3]. Additional interest in these nuclei comes from the possibility of microsecond multiparticle isomers that are analogous to those seen in their lighter isotones [4].

The aim of this work was to search for new, and clarify the nature of known proton radioactivities in the region of the N=82 shell closure, and to search for possible isomeric states in these nuclei. The searches were performed at the University of Jyväskylä in Finland. The nuclei of interest were produced by fusion-evaporation reactions induced by a 58Ni beam bombarding isotopically enriched 102Pd and 106Cd targets. The evaporation residues were separated in flight using the Mass Analysing

Recoil Apparatus (MARA) [5] and implanted into a double-sided silicon strip detector (DSSD), which was used to measure proton and alpha decays. The DSSD was surrounded by an array of germanium detectors to allow isomer gamma decays to be observed. An overview of the results from the analysis of these data will be presented.

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Background free detection of BaF for eEDM searches

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The NL-eEDM collaboration aims to probe the CP-violating electron electric dipole moment (eEDM) using BaF molecules [1]. The measurement requires frequency-dependent hyperfine state detection. In the current scheme [2], the fluorescent light is not distinguishable from the probe light, resulting in the scattered light from the probe laser dominating the background. We introduce a new laser induced fluorescence detection scheme, in which molecules are excited to the DΣ state with blue light, and a pair of infrared photons is detected. We will present spectroscopy results of this transition, and evaluate its influence on the sensitivity to the eEDM using BaF.

[1] The NL-eEDM collaboration, "Measuring the electric dipole moment of the electron in BaF", European Physical Journal D 72, 197, (2018)
[2] The NL-eEDM collaboration, "Spin-precession method for sensitive electric dipole moment searches", Physical Review A, 110, (2024)

Parallel Sessions (II) / 51

Towards measuring the electron's electric dipole moment using trapped molecules

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The permanent electric dipole moment (EDM) of a fundamental particle is a CP violating property, and can be used as a sensitive probe for physics beyond the Standard Model (BSM). The electron leaves a greatly enhanced EDM signature when bound to a heavy polar molecule. This has allowed molecular precision measurements to explore well into the parameter space of BSM theories. A next generation of electron EDM experiments will be performed using trapped polyatomic molecules, which offer longer coherence times and reduced systematic effects [1]. We have investigated the main challenges and requirements needed to realise a competitive measurement using trapped BaOH molecules [2,3]. In this talk I will outline our approach, which is capable of testing the Standard Model reaching for PeV energy scales.

[1] Anderegg et al., Science 382, 665-668 (2023).
[2] Bause et al., Phys. Rev. A 111, 062815 (2025).
[3] Schellenberg et al., arXiv:2507.17521 (2025).

Parallel Sessions (III) / 52

Quantum entanglement in HWW decays

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We present a preliminary study of quantum entanglement in the $H \to WW^* \to e\nu\mu\nu$ channel using simulation data from the ATLAS experiment. Our study focuses on the dominant gluon-gluon fusion production mode of the Standard Model Higgs boson and its second-greatest decay channel at the Standard Model mass. Exploiting the scalar property of the Standard Model Higgs boson and the $V - A$ structure of weak interactions, we perform Bell tests using the CGLMP inequality via projective measurements of the final state leptons. At the truth level, we first analyze the ensemble averages and distributions of observables relevant to the entanglement study, then investigate the effects of experimental selections. In practical application, we must overcome the missing kinematic information due to neutrinos in the final state in order to reconstruct the rest frames of the Higgs and both ⊠ bosons. This study presents two approaches to reconstructing four-momenta of intermediate particles: an analytical approximation method and a neural network regression model. Our findings show that the neural network regression model significantly outperforms analytical approximations. Finally, we analyze the results of the entanglement observables calculated using predictions from the proposed neural network regression
model.

Parallel Sessions (II) / 53

Extending Neural Likelihood Estimators for Gravitational-Wave Data Analysis through Transfer Learning

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Since the first detection of a gravitational wave (GW) in 2015, more than 300 confident detections have been made, making data analysis increasingly computationally demanding. As the next generation of ground-based detectors is expected to increase the number of detections by three orders of magnitude, new and efficient inference methods are needed. A Neural Likelihood Estimator (NLE) has recently been applied to real GW data for the first time. This approach, in which the NLE is trained on the fly, demonstrates that neural networks can robustly approximate likelihood functions for GW parameter estimation, achieving posterior inference with up to two orders of magnitude fewer likelihood evaluations than traditional Bayesian methods.

We provide an overview of FLEX, a FLEXible NLE, and present robustness tests and features validating its use over an extensive range of parameters. We will show that transfer learning between NLEs trained on different waveform models can further reduce both training time and the number of required likelihood evaluations, while maintaining convergence and accuracy.

These findings highlight the potential of neural likelihood methods as fast, flexible, and scalable tools for gravitational-wave inference in the era of large-scale GW astronomy.

Parallel Sessions (III) / 54

From Detection to Flavour Tagging: Supporting Four-Top Quarks Analyses in ATLAS

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The identification of hadronic jets originating by either bottom, charm or light quarks, called flavor tagging, is a fundamental technique in many analyses at the LHC. Since 2017, this has been performed using deep learning models based on graph neural networks architecture, leveraging information from the inner tracking detector and the calorimeters. Accurate tagging is especially critical for identifying jets produced in rare processes such as the simultaneous production of four top quarks, where distinguishing signal from background is particularly challenging. In this talk, I will give an overview of light jet flavor tagging and discuss how uncertainties in tagging performance and efficiencies can significantly impact the precision of such measurements.

Parallel Sessions (III) / 55

Simulation and Characterization of fast and radiation hard 3D sensors

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The High-Luminosity LHC will subject vertex detectors to unprecedented radiation levels, requiring sensors that can withstand fluences up to 10^{17} n_{eq}/cm^2 while maintaining excellent spatial and temporal resolution. This work presents the development of 3D silicon pixel sensors for the second upgrade of the LHCb Vertex Locator (VELO). Unlike planar sensors, 3D sensors feature columnar electrodes etched through the silicon bulk, significantly reducing charge collection distances. This geometry provides both enhanced radiation tolerance and faster charge collection times, making them ideal candidates for high-rate, high-radiation environments.

To identify optimal 3D sensor geometries that meet the VELO upgrade requirements, an automated simulation pipeline is being developed to explore the large parameter space of sensor designs. Key design parameters under investigation include column diameter and spacing, sensor thickness, doping profiles, isolation structures (p-stop vs. p-spray), and electrode geometry variations for both single-sided and double-sided fabrication processes. Studies have focused on optimizing breakdown voltage, capacitance, and electric field distributions to maximize timing performance when coupled to the PicoPix fast-timing ASIC. In this talk, the results so far obtained, as well as ongoing and future studies will be discussed.

The simulation pipeline integrates multiple software tools and is currently halfway through completion, linking sensor geometry optimization, charge transport modeling, and readout electronics response. First comparisons between testbeam data and simulation results are expected soon. Once completed, the full pipeline will predict the complete hybrid sensor response when coupled to the PicoPix ASIC, enabling comprehensive optimization of the sensor-ASIC system. Experimental validation is performed through laboratory measurements as well as testbeam campaigns at CERN's SPS using the Timepix4 telescope.

Plenary session / 56

Primordial non-Gaussianities: What are they, why do we care, and how do we measure them

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In this talk, I will explain why primordial non-Gaussianities are considered to be one of the most exciting targets in cosmology, on par with primordial gravitational waves (and certainly more exciting than the Hubble tension!). Primordial non-Gaussianities cause the initial conditions to contain moments beyond the variance or power spectrum (second moment) and can be caused by a variety of mechanisms, including multiple (scalar) fields in the early universe or the presence of massive particles. Current leading upper limits on the primordial non-Gaussianity are derived from measuring the bispectrum (skewness) of the cosmic microwave background (CMB), the oldest light in our universe. While a detection is certainly possible within the next few years, the strength of the signal is empirically small. A possible detection would benefit from measuring as many (linear) modes as possible, where modes can be considered samples of independent measurements (due to the cosmological principle). I will explain how such signatures are typically measured and provide an update on the current status of state-of-the-art CMB experiments. Unfortunately, while the CMB currently provides the strongest upper limits on non-Gaussianity, due to the two-dimensional nature of the CMB as a last-scattering surface, the number of cosmological modes is finite. Future observations of the 21cm radiation field could, in principle, provide many more modes, but besides massive foregrounds, I will explain that even under ideal circumstances, there are limitations. I will further allude to adopting machine learning to mitigate some of these limitations.

Plenary session / 57

Quark-gluon plasma and the physics of light ion collisions at the Large Hadron Collider

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n 2010 the Large Hadron Collider collided for the first time lead ions with a Lorentz gamma factor exceeding 1000. Such ultrarelativistic collisions create a quark-gluon plasma with an extremely high temperature. I will explain the basic physics of such collisions and then showcase very new results of similar collisions of oxygen and neon that were just performed last summer. Oxygen and neon nuclei are much smaller than lead and can therefore provide us answers to pressing questions on the tiniest droplets of quark-gluon plasma that we can currently imagine. It also allows us to study how these light nuclei are shaped in a way that was never possible before.