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Book of Abstracts

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Spherical accretion of a Vlasov gas to a Kerr black hole

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Astrophysical compact objects are known to attract matter in their surroundings, in a process known as accretion. This is one of the most important contributions to the formation and evolution of large-scale structures such as galaxies, stars and compact objects. In this work, we investigate relativistic collisionless accretion to rotating black holes. First steps towards the implementation of Kerr spacetime in the OSIRIS-GR code are taken and validated, allowing to perform this research with many-particle simulations. Finally, preliminary results for the Kerr effective potentials are obtained numerically outside the equatorial plane for a Vlasov gas, resorting to single-particle simulations.

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Kinetic theory of Fermi-boson systems

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In this work, we explore the dynamics of coupled quantum systems comprising both fermionic and bosonic particles, focusing on their collective behaviors and emergent phenomena in graphene. Conventional research frequently isolates a main species and examines its characteristics either independently of or in equilibrium with nearby species. Here we diverge by studying mixed systems with complex interactions between bosons and fermions, with particular emphasis on bosonic charge density oscillations, called plasmons. We use a kinetic theory framework that quantizes both bosonic and fermionic particles, in contrast to traditional methods that treat fields classically. By incorporating non linear effective forces to couple and correlate the various species, we are able to provide a more thorough understanding of their dynamics. With this kinetic approach we will uncover new modes and instabilities within the plasma dynamics, offering insights into the complex behaviors underpinning coupled fermi-boson systems.

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Isotope studies with the Alpha Magnetic Spectrometer (AMS) - RICH velocity reconstruction features and corrections

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Cosmic rays, high-speed charged particles traversing the universe, yield crucial insights into cosmic phenomena. Understanding the production, acceleration, and propagation of these particles requires analyzing the relative abundances of different isotopes, which relies on precise mass measurements. The Alpha Magnetic Spectrometer (AMS) on the International Space Station provides these measurements, with accuracy dependent on precise velocity data. The Ring Imaging Cherenkov Detector (RICH), a subdetector of AMS, measures particle velocity using the Cherenkov effect. This study proposes enhancing the velocity reconstruction algorithm by incorporating a plastic foil within the RICH as an additional Cherenkov radiator, aiming to boost velocity measurement precision and hence improve isotopic separation.

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Temporal Phenotyping of ALS Patients using Machine Learning

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Amyotrophic Lateral Sclerosis (ALS) is a rapidly progressive neurodegenerative disorder characterized by progressive loss of motor neurons in the brain and spinal cord, leading to muscular weakness and ultimately death. Life expectancy is 3 to 5 years after disease onset, there is no cure and disease heterogeneity make it difficult to understand its underlying mechanisms. This research project aims to enhance the understanding of ALS progression over time through advanced ML techniques, focusing on leveraging longitudinal patient data, including phenotype information and clinical records, to identify distinct phenotypic clusters within ALS trajectories. By adapting and extending existing models such as LATTE and CAMELOT, the research explores novel approaches to capture temporal patterns, feature importance, and cluster assignments in ALS patients. The methodology involves preprocessing steps, classifier performance evaluations, and the incorporation of innovative attention mechanisms to improve interpretability and accuracy in predicting disease outcomes. Through this comprehensive analysis, this study will contribute with valuable information about ALS progression and provide new prognostic information for better patient care and management.

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Using Machine Learning and Fundamental Analysis to Find the Intrinsic Value of Stocks

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Nowadays, the stock market's complexity and volatility pose significant challenges to traditional investment strategies. To address these issues, combining machine learning techniques with fundamental analysis provides a more advanced approach to determining the intrinsic value of stocks. By leveraging models such as Random Forest, Support Vector Machines (SVM), and XGBoost, alongside key financial indicators like the Piotroski F-Score and Altman Z-Score, this method enhances the accuracy of intrinsic value predictions. Analysing financial statement data helps identify companies with strong financial health and long-term growth potential. Additionally, the impact of various investment strategies on portfolio performance is evaluated, particularly in the context of significant price drops, price increases, and deviations from the S&P 500 index. Integrating these advanced analytical tools enables greater precision and
efficiency in investment decision-making, optimising outcomes, and effectively navigating the complexities of today's stock market. This approach is further validated by comparing the performance of constructed portfolios against key financial metrics, including ROI, Sharpe Ratio, Sortino Ratio, and Value at Risk (VaR).

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Muon Energy Spectrum From The Analysis of Inclined Shower Footprint

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There is a discrepancy between the number of muons detected in the Pierre Auger observatory detectors and the ones obtained by air shower simulations. In this work, the GEANT4 simulation code is used to analyse footprints of inclined showers starting from basic simulations without realistic parameters and imposing each parameter one by one in other to better study where the simulations fail to describe the number of muons detected. It is intended to develop an experimental method for evaluating the shower muon energy spectrum taking into account the distortions in the shower footprint caused by the Earth's magnetic field in inclined showers. With access to the shower muon energy spectrum, there is hope to get a better understanding about the interactions in between the development of the shower and possibly find a solution to the mismatch in the number of muons.

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Development of a GATE model for three-dimensional dosimetric estimates of a PET/CT system

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Liver cancer is one of the most commonly diagnosed cancers and a leading cause of cancer-related deaths worldwide due to its high malignancy and typically late diagnosis. Radioembolization (RE) with Yttrium-90 (Y90) loaded glass microspheres is a recent Nuclear Medicine (NM) treatment for unresectable liver tumors. In this procedure, Y90 microspheres are delivered via a microcatheter into the hepatic artery, lodging in the tumor's blood vessels and emitting high-energy beta radiation to induce tumor cell death. However, the risk of radiation damage to healthy liver tissues can potentially lead to liver dysfunction. Accurate absorbed dose calculation is crucial for effective treatment planning and balancing tumour control with normal tissue complications. Therefore, 3D voxel-based dosimetry methods are increasingly explored for their ability to provide personalized dosimetry. These methods operate at the level of each reconstructed voxel, enabling 3D visualization of the tumor-absorbed dose distribution. Monte Carlo GATE (MC-GATE) simulations are the most precise technique for assessing absorbed doses in tissues from a point source of radioactivity. They effectively handle non-uniform activity distributions and heterogeneous tissues using small sub-organ voxel dimensions, allowing simulation of all particle interactions within tissues. This research aims to estimate 3D absorbed dose distributions from non-uniform Y90 activity distributions measured by real PET/CT equipment and compare them with those obtained from MC-GATE simulations towards the optimization of prescribed activities in RE treatment planning.

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Magnetoresistive Devices for Industrial Applications: Improvement of Thermal Robustness

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Magnetoresistive sensors utilize multilayers of magnetic and non-magnetic thin films to convert magnetic field changes into electrical resistance variations. Critical components include the sensing layer and the reference layer, stabilized by an exchange bias with an antiferromagnetic layer. The performance of these sensors is influenced by factors such as layer thickness, material compatibility, and thermal stability. Key attributes—high magnetoresistance ratio, broad linear range, and thermal stability—are tailored for various applications, from biological detection to automotive sensing. Optimizing these characteristics, particularly using MnNi as an antiferromagnet and a soft-pinning strategy, aims to enhance sensor performance in terms of linear range, high-field detection, and thermal stability, advancing the field of magnetoresistive sensor technology.