5th Project MEFT Workshop

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Zoom

Book of Abstracts

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Flight data analysis of the BERM radiation monitoraboard the BepiColombo mission to Mercury

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BepiColombo, one of ESA's cornerstone missions, launched in 2018, will study the composition, geophysics, atmosphere, magnetosphere and history of Mercury. On board of one of Bepi's spacecrafts is the BERM radiation monitor, that will complement the scientific investigations of the Hermean environment, by providing measurments of the energetic particle population.
The effect of radiation, both in terms of electromagnetic waves and particles, is one of the major technological impacts of planetary space weather on spacecraft instruments and on the ground. The monitoring and comprehension of the dynamics of radiation in space is therefore a crucial step of space exploration.
This thesis work aims to characterize BERM and to study its sensitivity to solar energetic particles, as well as analyzing the data it obtains during the cruise phase and the first Mercury flyby.

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Defect and Strain Profiles caused by Ion Implantation in GaN

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Gallium Nitride (GaN) is a wide bandgap semiconductor, with a broad range of optical and electric applications. One field of particular interest is the area of power electronics, as group III nitrides are handled as an energy-efficient alternative for the currently used silicon power devices. Indeed, GaN technology has matured during the last two decades promising huge energy savings if widely adopted in electronic and optoelectronic devices.

Nevertheless, several materials and processing challenges are still limiting the wide introduction of GaN devices in the power electronics market. One example is the usage of ion implantation for doping the materials and enhancing some of its properties. However, during this process, a lot of damage is created in the material, hampering their efficiency. This damage includes the creation of defects and strain in the samples, whose formation mechanisms are not still completely understood, making their study an important subject.

In this work, I will study the defect and strain profiles in GaN samples, implanted with Eu and Si, using Rutherford Backscattering Spectrometry/Channeling and X-Ray Diffraction. Analytical models and Monte Carlo simulations will be used to try to fit the obtained experimental data, and develop a model based on these techniques that provides a more accurate description of the data, and so, of the physical processes behind them. In the end, I expect to provide a better understanding for the mechanisms of damage formation, as well as alternatives that may help reduce the strain and the defects.

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Studying the properties of axion dark matter using massive stars

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Dark matter makes up 25% of the energy-mass budget of the Universe, about five times more than bayonic matter, and yet we still don't know what it is made of. Nonetheless, phenomena such as gravitational lensing, the abnormally fast rotation of galaxies, as well as density perturbations in the cosmic microwave background radiation have provided not only evidence of this type of matter, but hints about the characteristics of its fundamental particles as well. Even so, the mistery of dark matter has been puzzling scientists for decades now, with multiple hypothetical particles being proposed, one of them being the axion. The axion is a very light particle that was originally proposed as a solution to the conservation of charge and parity problem of the strong force. Despite multiple efforts to detect this "invisible" boson, no experimental evidence has been found. But all is not lost, the silver lining is that several constrains on the axion's mass, as well as its coupling constants have been set, opening the door to new challenges.
The present work aims to contribute to this exclusion process by setting constraints provided by the interior structure and evolution of massive stars.

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Interactive Solar Electric Rickshaw

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As the world develops, it is inevitable that society has to adapt to the changes that occur. One of the sectors that is experiencing such developments is the transportation sector. As the global warming and climate change concerns increase, it is important to turn our attention to cleaner energies and create ways to ease the adaptation to these changes.

With that in mind, the scientific proposal of this thesis revolves around a fully solar electric rickshaw. The purpose of the implementation of solar photovoltaic panels on the electric rickshaw is to assist the vehicle operation and autonomy by charging the battery pack. Throughout this process, changes in the vehicle instrumentation will be carried out to optimize the interaction between the vehicle, the battery pack and the solar photovoltaic panels.

Apart from such optimization, multiple sensors and communication technologies will be integrated in order to create an interactive dashboard destined for the vehicle occupants. This dashboard will be mainly oriented towards an energy management system that will provide information on general details of the trip and on how the system of solar photovoltaic panels and battery pack translates to environmental and economical contributions.

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Solar assisted-electric rickshaw construction and assessment

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In recent times, electric vehicles (EVS) are becoming more commonplace in transportation sector, and the reasons behind this are many. The most eminent one is their contribution in reducing greenhouse gas (GHG) emissions. However, battery recharging and range anxiety have been the Achilles heel of electric vehicle due to the low density and high mass of batteries in comparison with fuel. Therefore, initiatives and analysis focused on electric vehicles integration powered by renewables is

currently a desirable solution to shift away from these problems. Under this framework, this thesis proposes a development and evaluation of an electric rickshaw (also known as tuk tuk in Portugal) as an alternative to conventional rickshaws to assists in the batteries recharging.

The goal is to investigate the impacts of the overall performance of solar technology on an electric rickshaw and its benefits in terms of savings.

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Coupling of multiple plasma stages for a Proton Driven Plasma Wakefield Accelerator

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Particle accelerators have many important applications, one of them being the study of fundamental particles and the forces that act between them. Although we have a good understanding of the current Standard Model, we also know that there is still a lot to learn, and to do so we need particles with more energy, and thus we need to improve current particle accelerators.

The use of plasmas in particle accelerators has been proposed by many, as they are able to support larger electric fields which means that they are able to transfer more energy to particles. At CERN, the AWAKE experiment is developing a plasma based accelerator by using a proton beam to create these large electric fields, which we call plasma wakefields.
Some of the advantages of using proton beams to create plasma wakefields is that available proton beams have a lot of energy, and thus are able to create large electric fields, but available proton beam's size is too large for these wakefields to efficiently accelerate other particles, so the AWAKE experiment needs to couple two plasma stages (one for reducing the beam's size and the other to create the accelerating fields) in order to create an efficient accelerator.

The main goal will be to use computer simulations to study the implications of coupling these two stages and study the main effects on the accelerating fields.

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Testing the radiation resistance of CIGS solar cells for space applications

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One of the main power sources available in space for powering satellites and spacecrafts is the sun. Photovoltaic systems can be installed to convert the incident sunlight into usable electrical power, but they need to be able to operate in harsh space environments with strong radiation fields, extreme temperature changes and in vacuum. In this context, CIGS solar cells (based on thin films of Cu(In,Ga)Se2) are a promising technology due to their radiation hardness, low cost and high stowability, while reaching a power conversion efficiency similar to that of the mainstream crystalline Silicon solar cells.
This work intends to test the effects of particle and gamma radiation on CIGS solar cells, and to develop CIGS interface passivation methods that can mitigate the resulting degradation of the cell. Furthermore, annealing studies of the irradiated samples will be performed to evaluate the temperature conditions upon which the self-healing mechanisms most efficiently restore the cell from radiation-induced damage.

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Dark Matter Searches at the LHC

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A recent paper has interpreted the GW190521 signal, detected with the LIGO and Virgo detectors, as being a merger of two Proca stars composed of a vector boson with a mass of the order 10^-13 eV. This particle can be considered as a dark matter candidate. The Higgs Characterization model can be used to produce a similar particle, and consequently simulate its detection at the LHC.
In this talk, I will first briefly introduce the history and known properties of dark matter, then explain how a particle physics model can be made to include dark matter particles and how these would be detected at the LHC. Finally, I will outline how I will be simulating these detections in my master's thesis project.

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The soft-hard antenna spectrum in presence of a QGP

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The modification of colour coherence effects in QCD radiation due to the presence of a QGP has been the focus of an extensive theoretical effort in the last decade. The fundamental building block of this effort is the computation of the interference emission of a gluon from a pair of partons (quarks or gluons) with a common direct ancestor, what is usually referred as the antenna spectrum. Understanding of the antenna spectrum forms the backbone of event generators where interference effects much be encoded in a probabilistic language. Current state-of-the art event generators that simulate the interaction of jets with QGP fail short of accurately accounting for QGP induced modifications of the antenna interference pattern. Going beyond the current status requires lifting several approximations in the standard in-QGP antenna calculations, particularly by addressing the case in which the interfering partons carry very different energy (soft-hard antenna).

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Accretion disks around compact objects

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Accretion disks are a flattened band of spinning matter around a massive central object such as a black hole. While a black hole, by definition, does not emit any radiation, an accretion disk does. Its spectrum depends, among other things, on the properties of the surrounding spacetime. This makes them very useful astrophysical objects for testing general relativity, probing spacetime, and studying the properties of the central compact object. The most prominent emission line of an accretion disk is the fluorescent line of Iron. In theory the peak would be very narrow in energy but due to non-relativistic (Doppler), special relativistic (beaming) and general relativistic effects (gravitational red-shift) the line is not a spike but a skewed and asymmetric profile. The profile of the line allow us to probe spacetime around the disk but can also be use to compute the black hole's spin. The main goal of my thesis is to use accretion disks and Fe iron line profiles to test alternative spacetime theories, focusing my work in boson stars.

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Production of single-cycle laser pulses through nonlinear pulse compression

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Today, most ultrashort lasers are already capable of producing pulses in the order of dozens of femtoseconds using mode-locked Ti:Sapphire oscillators. This pulses have paved the way to the emergence of attosecond science by enabling the generation of XUV pulses of several tenths of attoseconds duration via high-harmonic generation. This ultrashort pulses are the tools of choice for exploring electron dynamics inside atoms, molecules and solids or in nanostructures and they are necessary for understanding fundamental phenomena like magnetism or charge migration inside molecules.
In the Voxel laboratory we will implement a setup to shorten the 35fs pulse that currently exists in the lab into the sub 5fs regime using a state of the art method: after the existing a amplifier we will put the pulse through a Hollow Fiber Compressor to broaden the bandwidth, and then a compressor/metrology d-scan system from *Sphere Ultrafast Photonics* to simultaneously measure and optimize (i.e., re-compress) the pulse.
After getting such ultrashort pulses, we plan on designing a Fourier Holography experimental setup, a technique that utilizes attosecond soft x-ray pulses to image nanometer-scale objects so as to take advantage of the ultrashort pulses created.

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Magnetic Current Imaging of defects in Integrated Circuits using a MR scanning system

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The new packaging solutions introduced by semiconductor device manufacturers require powerful, accurate and true 3D failure localization techniques to yield Non-Destructive Failure Analysis (FA) useful in this new era of increasingly complex microelectronic devices. Magnetic Current Imaging (MCI) is one such technique that relies on the reconstruction of the current path inside a faulty Device-Under-Test (DUT) from the magnetic fields created in its surroundings, to non-destructively inspect it for the presence of physical defects or electrical malfunctions, such as short circuits.

State-of-the-art Magnetic Tunnel Junctions developed at INESC-MN are a very interesting option to perform magnetic field sensing in MCI, compared to the current commercial options that rely on a combination of a SQUID and single GMR sensors mounted on the tip of a scanning probe. This is mostly due to their high sensitivity to the magnetic field and their very small size, which enables scanning at very high spatial resolution when near the surface of the DUT.

In a partnership with Neocera, LLC, I propose to work on a new design of a MCI system, which is based uniquely on MTJ sensors mounted on a scanning probe tip. The goal is to enhance the accessible spatial resolution obtained with magnetic scans in Failure Analysis without compromising the SNR, to better perform fault isolation in devices where the average defect size is increasingly smaller.

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Explorations into Charged Black Holes Collisions

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One of the most interesting and staggering solutions of the Einstein equation is the black hole. In recent years, numerical relativity has experienced a tremendous growth, generating a wealth of information about astrophysical black hole binaries; however, few studies explore the physics of charged black hole binaries. The goal of this thesis is to study, numerically, the dynamics of such systems, from head-on collisions to orbiting binaries and advance our understanding of strong-field gravitation and electromagnetism in this largely unexplored territory.

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Time Resolved Opacity Maps of Warm Dense Titanium

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Measurements of photon absorption as a solid turns into a plasma were taken and will be studied (Warm Dense Model). A femtosecond IR laser was used for isochoric heating. The changes in absorption are measured by an independent XUV probe pulse that allows for 50fs temporal resolution and a CCD is used for spatial resolution as well. A drop in opacity is found, at first glance consistent with theoretical predictions. A 2D map of the opacity was obtained for each shot, for the first time, significantly increasing the amount of data available to constrain the competing plasma and "hot condensed matter models" in this region.