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Zoom

Book of Abstracts

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Flavour Anomalies

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The *flavour anomalies* are discrepancies observed between the experimental data and the Standard Model (SM) predictions and their detection forms the strongest evidence for the existence of New Physics (NP) in current collider data. These anomalies are revealed in quark-level transitions, such as the $b \to s\, l^+l^-$ transitions, which are highly suppressed in the SM and can only occur via loop diagrams. NP could be manifest by the introduction of new exotic particles, such as a heavier gauge boson Z' or leptoquarks, which could allow the existence of these decays at tree level.

A particularly sensitive realization of the aforementioned transitions is the $B^0 \to K^{*0}\mu^+\mu^-$ decay. Its angular analysis allows one to measure several parameters which are sensitive to different NP sources. This process is at the center of the detected flavour anomalies : several tensions with the SM were found during Run 1 by the LHCb, ATLAS and Belle Collaborations. Despite the large statistics collected during Run 1, the results were dominated by statistical uncertainties. The analysis of the data collected during Run 2 will allow to increase the precision of the measurements given the much higher luminosities achieved and to confirm or falsify the observed discrepancies.

The work of this thesis will be concerned with the study of this decay using data collected by the CMS detector during the full Run 2. The main goal will be to measure the decay branching fraction. The work has the potential to significantly contribute to the CMS exploration of the alluring *flavour anomalies.*

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Evaluation of the potential of a gamma-ray observatory to detect astrophysical neutrinos

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The discovery of high-energy astrophysical neutrinos has the potential to open a new window to study violent phenomena in our Universe, such as gamma-ray bursts, and to pose stringent tests to fundamental interactions. However, due to their low interaction cross-section, few experiments in the world can detect these particles.
The Southern Wide-field Gamma-ray Observatory (SWGO) project aims to monitor the Southern sky in very-high-energy gamma rays. This detector is planned to cover a huge area with detection units based on the water-Cherenkov detection technology, thus being favorable for the detection of high-energy neutrinos.
While promising, the idea to use a gamma-ray observatory to detect high-energy neutrinos has to be better assessed via simulations and considerations regarding the cross section and flux of astrophysical neutrinos. The main goal is to evaluate the validity of using this detector setup to perform these measurements and to determine the sensitivity of SWGO to a flux of astrophysical neutrinos as a function of their energy.

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End-to-end simulation of satellite-based quantum key distribution

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Recent advances in quantum computing and number theory have put a threat on RSA protocols and other modern public-key cryptosystems, challenging the overall fragility of the classical channels. In contrast, quantum key distribution (QKD) offers to restore security and confidentiality of the information even with eavesdropping, through the basic principles of the quantum world. However, there are still a number of problems to be addressed in this field, mainly the trade-off between security, distance, and secret key rates.
To address this situation, this work will be namely focusing on a space to ground QKD simulator between a satellite (*Quantsat*) and a ground station, going all the way from hardware-in-loop testing to a mission concept creation, allowing to validate future space missions and experiments to be proposed under this field.

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Novel Optimization Strategies for Clinical FLASH Proton Therapy

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Over decades, the number of patients diagnosed with cancer has been increasing, with expectations for the numbers to continue to rise in the future. The use of ionizing radiation for cancer treatment - radiotherapy - has become quite important as around 50% of all cancer patients have an indication for it. Treatments with radiotherapy are associated with side effects, arising from unavoidable damage to healthy tissue, which research on the field has been trying to reduce.

A new way of achieving reduced healthy tissue toxicity has been identified by biological studies, through an effect demonstrated by cells when irradiated with a high dose, for a very short time, using a very high dose-rate - the FLASH effect. Combined with precision irradiation techniques, namely proton therapy, the potential for substantially improved plans is great.

As the FLASH biological mechanism is still not understood, it's difficult to evaluate and compare different FLASH-compatible plans and so different metrics have been suggested. This project aims at building a framework for evaluation and comparison of FLASH-compatible proton therapy treatment plans, with focus on implementing strategies for optimization of metrics under a clinical treatment planning software. Evaluation is to be performed on stereotactic lung treatment plans.

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Measurement of the features of the muon number distribution using the MARTA engineering array

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Extensive air showers offer a unique opportunity to study high energy hadronic interactions, tune up-to-date hadronic interaction models and determine the origin and acceleration mechanisms of ultra-high-energy cosmic rays, through the analysis of shower observables and shower reconstruction. We recently showed that the muon number distribution in showers with low muonic content has a feature that can be used to constrain the production cross-section of neutral pions emerging from the first proton-Air interaction. However, the detection of muons is not easily disentangled from the detection of electromagnetic particles in current cosmic ray experiments. The goal of this presentation is then to propose the measurement of the mentioned feature using the MARTA engineering array and assess to which precision this measurement can be achieved, complementing the theoretical work we previously published.

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Nonlinear optics with ultrashort mid-infrared laser pulses

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In the past two decades, there has been a growing interest and investment in the study of ultrafast optics in the mid-infrared (MIR 2-12 μm) region. Mainly because most gaseous and biomolecules have their fundamental vibrational absorptions within this range, leaving distinctive spectral fingerprints of key importance for industrial, medical, and scientific applications.
The first generation of high-energy and high-efficiency laser sources in the MIR region has only a few years of existence and Instituto Superior Técnico (IST) has recently installed one of these new state-of-the-art laser sources. This thesis aims to explore this new laser system, particularly its characterization and the development of the first series of experiments. These will consist of Super-Continuum Generation (SCG) and High-Harmonic Generation (HHG) and will be performed at the Laboratory for Intense Lasers (L2I) in IST. A numerical simulation will then support the experimental results.
By the end of the thesis, it is expected to present this work at an international conference and co-author a paper in an international scientific journal.

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Scalar Mixing in New Physics Models

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The discovery of the Higgs boson in 2012 was an important achievement in particle physics. This scalar particle is essential in the Standard Model to explain the mass of the other particles. However, there is nothing in the theory that restricts the scalar sector of the Standard Model to have only one particle. Therefore, theoretical physicists are trying to understand what are the consequences of adding more particles to this part of the Standard Model and if this extensions are in agreement with the experimental data.
A formalism was developed by Grimus and Neufeld to work with a general model where an arbitrary

number of scalar singlets and doublets are added to the scalar sector of the Standard Model. In my thesis I will first extend this formalism to work also with models with scalar triplets and, on a second stage, I will compute some physical observables using this extended formalism.

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Neutrino masses and the origin of matter through leptogenesis

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During his presentation on "The Theory of Electrons and Positrons", Paul Dirac described how quantum mechanics and relativity made possible the prediction of the positron. After pointing out the apparent symmetry between positive and negative charge, he hinted that the universe could consist of equal amounts of matter and anti-matter but, for some unknown reason, human experience is confined almost entirely to matter. Notwithstanding, the symmetry between particles and antiparticles is firmly established in collider physics, which naturally poses the question of why the observed universe is composed nearly exclusively of matter, in contrast to little or no primordial antimatter. Despite its remarkable success in describing many of the inner workings of Nature at its most fundamental level, the Standard Model struggles to explain the existence of a biased Universe. A compelling possibility is that the baryon asymmetry of the Universe is generated dinamically, a scenario that is known as baryogenesis, which implies the non-conservation of the baryon number. In the past thirty to forty years, several mechanisms for baryogenesis have been put forth: GUT baryogenesis, electroweak baryogenesis, Affleck-Dine mechanism, spontaneous baryogenesis. Nonetheless, the most compelling one is the mechanism of baryogenesis via leptogenesis, first proposed by Fukugita and Yanagida, whose simplest and theoretically best motivated realization is within the seesaw mechanism of neutrino masses.
The objective of this work shall be to analyze the viability of leptogenesis, considering a model based on modular symmetries, by means of which we will determine the BAU and neutrino parameters, followed by a phenomenological analysis.

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Towards the Space-time Picture of a QCD Parton Shower

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Ultra-relativistic heavy ion collisions, such as those in the Large Hadron Collider (LHC) or the Relativistic Heavy-Ion Collider (RHIC), have unlocked an extensive scientific program. Namely, the production of Quark-Gluon Plasma (QGP) offers many opportunities, from the study of early universe dynamics, to the phase diagram of Quantum Chromodynamics (QCD), and the study of QCD in extreme conditions.
Given the rapid evolution of the QGP, on the yoctosecond scale, its properties are accessed through the products of heavy ion collisions. The successive parton showers can be explored by the clustering of the final state hadrons into jets. This allows for the study of jet quenching in the QGP, which can be used to access the medium evolution.
As seen in recent developments, jet clustering algorithms can be used to access the space-time structure of the parton showers, unlocking an experimental treatment of the medium evolution. However, theoretical descriptions rest on the use of coordinate space while event generators, used for phenomenological studies, reflect the momentum space evolution of parton showers.
The aim of this work is therefore to develop a simple Monte Carlo Event Generator in coordinate space, paving the way to a full treatment of QCD showers and their modification by the presence of the QGP.

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Mini magnetospheres in the laboratory

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Ion-scale magnetospheres have been observed around comets, weakly magnetized asteroids, and localized regions on the Moon. These mini magnetospheres provide a unique environment to study kinetic-scale plasma physics, in particular in the collisionless regime. To study these systems, the space and astrophysical plasma community have produced, in the last years, multiple experiments in laboratory, as for example, the ones performed on the Large Plasma Device facility (LAPD), at UCLA.

For the MSc Thesis, we will build analytical and numerical models with collisionless particle-in-cell (PIC) simulations of laboratory-produced magnetospheres, to describe the coupling of laser-produced and magnetized plasmas and determine the properties of their interaction with magnetic obstacles. This work will not only contribute to interpret results from recent experiments, but also to support the design of future experimental studies.

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Neutrino interaction with solid state 2D plasma

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The neutrino is one of the most 'shy' particle that nature created, it's almost massless and has no electric charge. That leads to a really low interaction between neutrino and matter, nevertheless they are important in many scenarios and studying them we can test our models. Nowadays, the detection of neutrino is based on the scattering mediated by W boson that leads to a charged lepton who is revealed by measuring its Cherenkov radiation. My work is to study the interaction between neutrino and electrons plasma with the goal to increase the sensibility of the detection.

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Electron-positron production in extreme fields

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Electron-positron pair production is one of the most important problems in extreme plasma physics. Thanks to the recent advances in laser technology, these can now be created in the lab using the most intense lasers in the world. If all other parameters are equal, more pairs are expected with a higher laser intensity. However, if the total energy of the laser pulse is fixed, there will be a trade-off between the size of the effective interaction volume and the peak intensity. This work will extend analytical scaling laws for pair production in realistic laser-electron beam scattering, previously derived assuming an ideal plane-wave description; it will also propose optimal and innovative solutions for upcoming experiments, as well as investigate applications of quantum algorithms in extreme plasma physics.

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Cr-doped Ga2O3 for radiation detection

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In the field of radiotherapy, one of the major challenges is the accurate in-vivo measurement of the supplied radiation dose. In this context, chromium-doped gallium oxide is an interesting material due to its attractive electrical and optical properties. On the one hand, it is known to be a radiation hard, highly transparent wide bandgap semiconductor with fast scintillation. On the other hand, when irradiated with energetic ion beams, this semiconductor displays a red luminescence assigned to intraionic transitions of chromium at oxidation state 3+ within the first biological window that spans the range of wavelengths from 700 to 950 nm. Moreover, the yield of this red emission is enhanced by the defects that are created during the irradiation. Thus, this material presents a great potential for complementary systems of electric and optical dosimetry. The main purpose of this work is to understand the defect creation mechanisms and their role in the optical activation of the chromium ions, via ion beam-induced luminescence and thermoluminescence measurements, with the goal of developing an optical dosimeter.

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Signatures of Quantum Chaos in Many Body Systems

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Quantum Chaos studies how quantum chaotic dynamics emerges from a classical chaotic system when the action can no longer be considered much larger than $\hbar$. In a seminal work, Peres considered a quantity, now called Loschmidt echo, as a measure of sensibility and reversibility of quantum evolution. For quantum chaotic dynamics the decay of the Loschmidt echo with time can be related to the Lyapunov exponent of the underlying classical system. This relation has mostly been explored for systems containing a few degrees of freedom, typically a single particle, where the semi-classical limit is well defined. However, much less is known about the many-body case, where many degrees of freedom strongly interact. In this project, we propose to study signatures of Quantum Chaos in systems containing a few degrees of freedom with a simple semi-classical analog obtained by taking the thermodynamic limit. Perhaps the simplest examples of this class are collective spin models. However, such systems correspond to a single classical degree of freedom and thus lack a classical chaotic regime. A simple generalization which does exhibit chaos is the two coupled collective spins, i.e. SU(2)×SU(2) and for this reason this system is the central subject of this work. The connection between integrable and chaotic behaviour in a mixed dynamics frame is also studied for the spectral statistics of the system.

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Use of MHD Activity for Disruption Prediction in Tokamaks

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Tokamak plasma disruptions are a threat in achieving a stable controlled nuclear fusion device, thus being very important to consider the development and interconnection between disruption alarm systems and mitigation control systems. In absence of a cohesive theoretical framework based on MHD theory that contains all possible activiy that can precede a disruption, several studies have been applied to tackle this issue. The development of mode locking has been identified as one of the most predictive features. In this work, we intend to go beyond the locked mode to identify other MHD modes that may be relevant for disruption prediction, using Machine Learning and Deep Learning based models and techniques. Additional MHD based features will be relevant to correlate with other phenomena.
Summing up, this work intends to offer a more detailed insight into the processes that cause disruptions in tokamaks, as well as a robust disruption prediction model that can be analysed and potentially be implemented in current and future tokamaks, helping to solve one of the great challenges that are imposed in achieving a stable controlled nuclear fusion device.

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The First Sample of Extinction Laws for Supernova Cosmology

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Type Ia supernovae are a set of important cosmological objects that can be used as distance indicators. This is because their luminosity can be calibrated by applying some empirical corrections, which then allows us to compute their distance to us. One of these corrections is based on a color-luminosity relation, which is in part due to the effect interstellar dust has on the emitted light. This correction is usually obtained from a fit to a large population of supernovae and is thus assumed to be universal. However, it has been shown that dust properties can vary in the Universe and thus, by assuming a universal dust effect, we are committing a gross generalization, the impact of which is still unknown. The objective of this work is therefore to obtain the individual dust contributions for each element in a group of well known supernovae, which can be done by looking at photometric data for their host galaxies. We can then use these values to obtain new distance calibrations, allowing us to evaluate the impact of assuming a universal dust effect.

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New Ideas for physics beyond the Standard Model

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Even though it is one of the most successful theories in all of physics, the Standard Model (SM) of particle physics cannot be a final theory. Some experimental results, ranging from the detection of B meson decays that should involve flavour changing neutral currents, to the detection of neutrino oscillations, seem to point to the existence of new physics beyond the SM. The introduction of very heavy vector-like quarks and the addition of right-handed neutrinos in the framework of Majorana neutrinos are two promising proposals that seem to be able to accommodate some the experimental results.
With these extensions in mind, in the electroweak sector, this work aims to find new symmetries or ansatzes that could constrain the form of the fermion mass matrices, reducing the free parameters of the theory while generating the observed experimental results. The study of the possible implications of these promising extensions on CP violation will be another focus of this work.

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Probing the nature of dark matter using stars

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In the last decades, the fields of cosmology, theoretical astrophysics and particle physics have come across one of the most enduring problems in physics of modern times: the search for the origin and nature of dark matter particles. Numerous studies have compared and combined in a self-consistent way the most powerful cosmic probes: the cosmic microwave background, galaxy redshift surveys, galaxy cluster number counts, type Ia supernovae, and galaxy peculiar velocities. All the studies have led cosmologists to conclude that we live in a flat accelerating Universe, dominated by cold dark matter and by dark energy. Although dark energy is a relatively new problem in cosmology, the dark matter problem has been around for quite some time, without any plausible solution so far. This project proposes using stars as a new method to study the properties of dark matter, complementing that way the international efforts to solve the dark matter problem.

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A Monte Carlo based study of the FLASH effect in radiotherapy with protons

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According to the World Health Organization, cancer is the second leading cause of death globally, right after cardiovascular diseases. Thus, there is a great interest in the continuous study of this disease, not only aiming at an earlier diagnosis but at more effective treatment options.
This project focuses on radiotherapy, a treatment option commonly considered for tumour treatment in which the tumour cells are targeted with ionizing radiation, damaging the cancer cells and eventually leading to their death. Due to its ionizing effects, radiotherapy may also induce serious toxicity effects in the patients and drastically affect their quality of life. In this context, Flash radiotherapy has shown promising results since multiple pre-clinical studies have shown that the delivery of radiation at significantly greater dose rates than the ones conventionally considered, may lead to a reduction in the toxicity effects induced in the surrounding healthy cells, while maintaining an effective tumour control.
The present work will provide a first overview of my Master's dissertation topic, which will focus on the implementation of a multi-beam treatment planning for Flash therapy using protons.

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A Computational Model for Radiotherapy Studies with Proton Mini-Beams

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Radiotherapy is a cornerstone of both curative and palliative cancer care. It is estimated that half of all cancer patients will receive radiotherapy during the course of their treatment. However, radiotherapy is severely limited by radiation-induced toxicities. Irradiation of noncancerous "normal" tissues during the course of therapeutic radiation can result in a range of side effects including self-limited acute toxicities, mild chronic symptoms, or severe organ dysfunction. These side effects of the used radiation treatments are the reason that the research for new types of radiation treatments continue to be investigated.
Mini-beam radiotherapy is a new type of radiotherapy that has been presenting very good results in the reduction of the effects of radiation in healthy tissues. This new type of treatment, studied with for both X-ray and proton therapy, uses a combination of spatial fractionation of the dose and millimetric filed sizes. In mini-beam radiotherapy the tumor is both radiated with very high doses and low doses. The main goal of this work is to develop a new computational model for mini-beam radiotherapy and compare the results with previous studies, to help understand how it is possible that parts of the tumor that receive almost no dose show sterilization of the cancer cells and lower ability to multiply and spread, what ultimate leads the tumor to shrink.

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Polarization patterns in the sky and their influence in astronomical observations

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The perfect conditions of an astronomical observation assume a sky free of light contamination. Moonlight sky polarization can also be a source of systematic errors in polarimetric studies and must be considered.
Sun's radiation, reflected by the moon, passes through Earth's atmosphere and the light interacts with her. That leads to polarization patterns. A model to characterize the observed moonlight polarization includes the localization of the observatory, the light wavelength and the composition and density of the atmosphere. Such a model for the moonlight polarization will help plan observations and correct the background moonlight polarization.
In this talk, some of the concepts and objectives in this model's construction will be summarized and explained.

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An analysis of the Portuguese energy storage strategy based on the Choquet multiple criteria preference aggregation model

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With the increase of renewable energy generation, and their problems related to output instability, storage systems must be implemented in parallel to account for this effect. For this reason, a model to rank the various available options is developed for the several sectors of the energy storage market, as well as a methodologically similar model for the purpose of strategic energy public policy, with the government as the main decision-maker. Beyond a critical review of the results, a robustness analysis will be performed, in order to ensure that the obtained results are credible and valid, serving as the foundation for future decisions.

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Characterization of ultrashort mid-infrared laser pulses using frequency resolved optical gating

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The past decade has witnessed the emergence of ultrashort laser systems in the mid-infrared range (2 – 10 μm). This has brought several new challenges to this field, beginning with the pulse determination. Indeed, to measure an event in time, a shorter one is needed to compare it with, but these ultrashort pulses are the shortest events ever created, measuring at most 100 fs. Pulse retrieval techniques in the near infrared have already been explored for a while now and diagnostic equipment is presently commercially available. This is, however, still not the case for lasers in mid-infrared, mainly due to the lack of market.
The Institute for Plasmas and Nuclear Fusion (IPFN) has recently installed a novel 3 μm laser and it is the goal of this thesis to determine the full temporal characterization of the laser pulses of this new system using the frequency resolved optical gating technique. The work will be conducted in the Laboratory for Intense Lasers (L2I) at Instituto Superior Técnico (IST).

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Magnetoresistive sensors for industrial positioning applications

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Almost every industry of the present day requires accurate solutions for metrology and positioning. There are several techniques that can be used, using different devices working under different physical principles. Each having their own strengths and weaknesses, they aim, however, towards the same goal: accurate and reliable positioning with high resolution. The suitability of each device will vary on the requirements of the task (type of environment, minimum resolution, among others), but this also means versatility is of some value as the device can be used in a widespread range of situations. Magnetoresistive sensors combined with magnetic scales to form a magnetic encoder, provide very accurate positioning systems with high resolution. The focus of the work will be optimizing AMR sensors for positioning applications. These sensors offer solutions with low power consumption and low prices.

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Energy transfer pathways in CO Plasma

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The main goal of this work is to study ⊠⊠ plasmas, and their energy transfer mechanisms. As we will see, these mechanisms are fundamental for the study/understanding of CO2 conversion, which is one of the missing pieces to efficiently produce fuels or other useful chemical components from greenhouse gases. I will state the importance of this topic in more detail, while addressing the advantages of using plasma technology.

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Superradiance in Binaries

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One of the most astounding predictions of General Relativity is the existence of Black Holes. They are known to be possible places to probe the existence and nature of Dark Matter. Black Hole binaries are also expected to serve as detectors of this matter, but the lack of solutions to Einstein's field equations makes it hard to study how in fact these systems interact with this matter. We must then find alternative ways of studying this systems. By means of the fluid dynamics - GR connection, we aim at developing toy models that might give us some insight into the behaviour of such complex systems.

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Some Theorectical Aspects of Multi-Higgs Models

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The Standard Model (SM) of Particle Physics describes the fundamental forces in nature. It accounts for all observed subatomic particles and even predicted the existence of the Higgs boson, which was observed for the first time in 2012. However it also has its shortcomings, such as the inability to explain why there are three generations of fermions, the values of fermion masses, including neutrino masses, the baryonic asymmetry in the universe, or the existence of dark matter (DM). The development of Multi-Higgs models intends to address these problems. It consists essentially in an extension of the scalar sector of the Standard Model by N scalars. In this thesis, we study the Dark Matter problem. We start by studying the theoretical aspects of extended scalar sectors. We will then use those results to develop models for DM consistent with the existent experimental constraints.

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Multi-Higgs Doublet Models

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In recent years, symmetric models with 3 Higgs doublets (3HDMs) have been studied in order to address shortcomings in the Standard Model. This thesis focuses on the mass spectra predicted by some of these 3HDMs, in cases where the symmetries are softly-broken.

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Cryptanalysis for trusted nodes in quantum key distribution

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One of the major challenges of **quantum key distribution (QKD)** is the limited distance at which the communicating parties (Alice and Bob) can be. To mitigate this effect, **trusted nodes** are established, where the key is reconstructed and resent to more distant locations. But even though these nodes are trusted, they are still open to certain types of attacks, namely to the so-called "**side-channel attacks**", which can be exploited by quantum hackers.
The goal of this thesis is to calculate the limit of information which can be disclosed to an eavesdropper (Eve) in these trusted nodes while maintaining the key renewal perfectly secure. Moreover, we shall determine the impact of the number of trusted nodes on the key generation rate, assuming an upper limit of information disclosed by each node. We will also consider concrete QKD implementations at Instituto de Telecomunicações, based on optical fiber and on free space.

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Quasi-disorder Effects in Topological Systems

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The search and study of topological properties of matter has proved fruitful in recent years in research in materials science and condensed matter physics. Superconductors have long been a focus of interest due to their promising applications. Superconductors with intrinsic topological properties, in particular, have recently attracted theoretical and experimental interest due to phenomena associated with the appearance of surface/edge Majorana modes. One of the question that arises is how it is possible to disturb the exotic phases that have been observed in these materials with non-trivial characteristics, and what further effects may arise from perturbing topological systems. The main goal of this work is to study quantum topological systems, in particular topological superconductors, and how topological phases and modes are affected in the presence of quasi-disorder.

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Family Symmetries and the Flavour Problem

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Why are there three families of quarks and leptons and the mass hierarchies and mixing matrices so different for these two types of particles? And why does the gauge sector have only a few parameters while the flavour sector has a much larger set of external parameters? These are still some unanswered questions by the Standard Model, the current model of particle physics. Their solution might be in the introduction of discrete family symmetries. In my master thesis, I will use multiple modular symmetries to construct a high energy theory, which is then broken to a low energy model with a single modular symmetry. This scheme allows multiple moduli fields to acquire different VEV's, leading to the realisation of different mass textures in the charged lepton and neutrino sectors. It is then possible to obtain a realistic mixing matrix and mass hierarchies for the leptons using a much smaller set of free parameters.

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Confronting MultiHiggs models with experiment

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The Higgs particle was predicted in 1964 and discovered at CERN on July 2012, earning Higgs and Englert the 2013 Physics Nobel Prize. This is a spin zero particle (scalar), necessary to give masses to the all other massive particles in the Standard Model of Electroweak interactions. But, there is no fundamental reason why there should be only one such scalar. In this project, one wishes to confront Multi-Higgs models with current experimental data, possibly including models with extended gauge sectors.

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From Light-Front Wave Functions to Parton Distribution Functions

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Parton Distribution Functions have been a fundamental part in the calculation of experimental quantities that involve hadrons. Current understanding comes from experimental fits to data and other techniques such as Lattice QCD. We propose an alternative way of calculating the Parton Distribution Functions directly from the theory via Light-Front Wave Functions, integrated directly from the Bethe-Salpeter Wave Function. The mathematical details and prescriptions are developed for a simple scalar model to be later applied to QCD.

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Development of GPU-Accelerated Trigger Algorithms for the ATLAS Experiment at the LHC

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The LHC is the highest energy particle accelerator ever built. The gigantic ATLAS experiment records proton and ion collisions produced by the LHC to study the most fundamental matter particles and the forces between them. A major upgrade, expected for the years 2025-26, will increase the LHC collision rate up to a factor 7 with respect to the nominal values, to allow acquiring a huge amount of data and pushing the limits of our understanding of Nature.
The online event selection system (trigger) is a crucial part of the experiment. It analyses in real time, the 40 MHz event rate, selecting only the potentially interesting collisions for later analysis. After the LHC upgrade, the estimated increase in collision rate, and consequently event size, lead to much longer event reconstruction times, that are not matched by the slower expected growth in computing power at fixed cost. This implies a change in paradigm, increasing parallelism in computer architecture, using concurrency and multithreading and/or hardware accelerators, such as GPUs or FPGAs for handling suitable algorithmic code.
The first ATLAS Trigger GPU prototype was implemented and evaluated in 2015-16 1. The LIP Portuguese team was responsible for the calorimeter reconstruction algorithms. The results obtained

showed the potential gain but also the limitations of the architecture and implementation done.
The objective of this Master thesis project is to contribute to the development, optimisation and performance studies of the second calorimeter reconstruction Trigger GPU prototype.
The development will be done within the new concurrent ATLAS reconstruction framework AthenaMT, using CUDA and C++ programming languages, in collaboration with researches from CERN and other European institutions involved in this effort.

References:
1 P. Conde Muíño on behalf of the ATLAS Collaboration, "Multi-threaded algorithms for GPGPU in the ATLAS High Level Trigger", J. Phys.: Conf. Ser. 898 (2017) 032003.

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Development of a Magnetic Camera for Barcode and QR Magnetic Identification Tag Readout

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Bar-codes allow the storage of information along a 1D vector, while QR Codes allow the storage along a 2D Matrix, containing a much higher information density.

Both are very used in industry and trade and normally employ optical reading systems, given that nowadays it is also possible to do the reading using the Smartphone câmara.

We seek to develop a magnetic câmara constiting of an array of magnetic sensors that can do the reading (line-by-line or 2D) of Bar-Codes and QR Codes printed in magnetic ink.

While the optical reading systems are more efficient and already represent a standard industry, the magnetic systems allow encoding and transmission of secret information, having possible applications in industry, business and security systems.

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Uptake and depth distribution in cells of metal-based complexes for therapeutic applications

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TBA