ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Study of the reaction gamma p --> eta pi0 p at GlueX

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UNIVERSITY/RESEARCH CENTER: University of Barcelona (an Italian partner University will also participate, in case someone is interested in this topic)

ABSTRACT

In this project, you will build a Monte-Carlo simulator to generate events for the process according to a given model (and another set of events just with the phase space). From these events you will make histograms to understand the kinematics of the reaction. You will compare the simulated distributions with those extracted by the GlueX detector and adjust the model to capture the features of the real data set. You will fit the events (the generated ones, not the real ones) with the same model with free parameters and get back out the parameters you put in. For the fitting procedure, you will choose between the minimization of the likelihood or the chi-squared. Depending on the progress, at the end, you will may investigate the effect of the detector acceptance. This project can be undertaken by a student with either a more experimental or a more theory background as it involves both data manipulation and modeling. It simulates a real case, the analysis of the photoproduction of eta-pi0 on a nucleon target, currently under investigation by the GlueX collaboration.

TITLE: Dynamically generated resonances in correlation function

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ABSTRACT

This topic is taken by MARTA BOTELLA GARCIA

TITLE: Neutrinoless double-beta decay beyond the closure approximation

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ABSTRACT

Neutrinoless double-beta decay is a special nuclear decay, where two neutrons turn into two protons, and only two electrons are emitted. Thus, two matter particles are emitted without any antimatter, in contrast with the predictions of the standard model of particle physics. The observation of neutrinoless double-beta decay will thus illuminate why the universe is mainly formed by matter instead of equal amounts of matter and antimatter. The decay rate, however, depends on the structure of the initial and final nuclei through a nuclear matrix element. In this work you will calculate nuclear matrix elements for some of the nuclei used in the most advanced experiments worldwide beyond the so-called closure approximation, which involves neglecting the contributions of the intermediate states of the decay.

TITLE: Exploring physics beyond the standard model with nuclei

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ABSTRACT

The standard model of particle physics provides excellent agreement with a very wide set of experimental data. Some of these processes involve atomic nuclei, such as the beta decay of a nucleus, or the conversion of a muon into an electron in a nucleus. At the moment, several experimental groups are measuring these processes with high precision with the aim to test the predictions of the standard model with very precise data. In this work you will calculate nuclear matrix elements for beta decay and muon to electron conversion for the nuclei used in the most advanced experiments. These matrix elements will be combined with other information from the standard model to compare with the results of the experiments.

TITLE: Meson-baryon femtoscopy in proton-proton collisions

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ABSTRACT

Experimental measurements of hadron correlations at particle colliders provide access to the details of the interaction between pairs of particles. Recently, the TROY (T-matrix-based routine for hadron femtoscopy) framework has been developed to obtain predictions for D meson and light meson pairs. The master thesis will consist in the study of new systems of experimental interest integrating baryons within the TROY package, such as the calculation of correlations of D mesons and protons, or pions and protons. The determination of the production weights of the different channels will also be investigated using results from coalescence models, or alternatively, using the statistical resonance model. The goal is to generate predictions for correlation functions potentially accessible by the ALICE collaboration in proton-proton collision experiments and the LHC.

TITLE: Study of hadron interactions from femtoscopic analyses

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ABSTRACT

The study of low-energy interactions between hadrons produced in heavy-ion collision experiments employing femtoscopic techniques has experienced an increased amount of interest in the last few years. This is mostly thanks to the efforts of the ALICE@LHC collaboration that have provided a good amount of high-quality data, from which the properties of two-body interactions can be derived with good precision. This project aims at confronting various meson-baryon interaction models to recent femtoscopic data, employing a momentum-space methodology developed by our group which has already been shown to be successful in the analyses of systems with charm. An especial focus will be put on systems for which the femtoscopy data has obtained intriguing properties, such as the claim of a strongly attractive p-phi interaction, which can even support a bound state.

TITLE: A Variational Approach to Quantum Field Theory

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ABSTRACT

In quantum mechanics, the variational method (VM) provides a rigorous approach to determine the eigenfunction and corresponding energy eigenvalue of an arbitrary quantum Hamiltonian. In practice, some truncation on the space of functions considered in the variational basis leads to the VM producing a rigorous upper bound on the ground state energy. In principle, this approach can also be applied to quantum field theories. While less studied than other approaches, the VM offers the prospect of providing rigorous non-perturbative upper bounds on the energy eigenstates in the theory. In this project, the VM is applied to a scalar field theory in 1+1 dimensions. The low-lying energy spectrum of the theory is extracted using the VM and compared to perturbative predictions, where applicable. **STUDENT: Martí Rovira Pons**

TITLE: Causal transport coefficients of heavy particles

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ABSTRACT

The dynamics of heavy-flavor particles can be described via the Langevin equation. Transport coefficients, obtained from fundamental interactions, are necessary inputs to solve this equation. To be respectful with the special relativity principles, a recent study has considered a causal version of the Langevin equation which requires an additional coefficient, the memory time.
In this project, the nature of the memory time will be studied from the microscopic interactions of heavy-flavor particles. By applying the theory of hydrodynamic fluctuations, this memory time will be extracted for real systems like D mesons or charm quarks, by performing numerical simulations.