Doctoral INPhINIT - INCOMING Fellowship Programme 2020 Call for applications

Position: Unveiling the interior of neutron stars with the R3B experiment at FAIR

Leader: Dolores Cortina (d.cortina@usc.es)

Centre description

The Galician Institute for High Energy Physics (Instituto Galego de Física de Altas Enerxías, IGFAE) is a joint research institute of the University of Santiago de Compostela and Xunta de Galicia (the Galician Autonomous Government). It was officially created on July 2, 1999. The main goal of the Institute is to coordinate and foster the scientific and technical research in the field of High Energy Physics, Particle and Nuclear Physics and related areas as Astrophysics, Medical Physics and Instrumentation. Of primary importance is the planning and promotion of the relation with large experimental facilities, especially with CERN, GSI/FAIR and the Pierre Auger Observatory at present.

The experimental groups at IGFAE coordinate the Spanish participation in the LHCb Collaboration at CERN, the Spanish participation in the Pierre Auger Observatory, as well as the Spanish participation in the GSI/FAIR nuclear facility. Members of the Institute have a relevant participation in the LHCb upgrade planning, in the LHeC project development and planning, etc. In the last couple of years, a new line has also been open with the building of a new facility (LaserPET) at the University of Santiago de Compostela aiming to produce radioisotopes for medical use by a laser-induced plasma accelerator. Moreover, the theory section of the Institute holds an excellent international reputation, with participation in different international committees, invitations to plenary talks and large-impact publications.

Research project and research line description

Reactions induced by Relativistic Radioactive Beams offer unique opportunities to synthesize in the laboratory nuclear matter similar to the one that constitutes neutron stars (NS).

Neutron-rich nuclei at the NS outer crust, neutron matter at the inner crust or hyper-matter at the NS core, can be produced and investigated with the R3B (http://www.gsi.de/r3b) experiment at FAIR (http://fair-center.eu). R3B is a versatile experimental setup providing a complete identification of all final nuclei, nucleons and gamma rays produced in nuclear reactions induced by relativistic radioactive beams. This setup is being built by an international collaboration of around 250 scientists from twelve different countries. During FAIR phase 0 (2019-2021) the R3B experiment will make use of the existing GSI facilities to initiate the above-mentioned program. Once FAIR will be completed, around 2025, R3B will profit from the unprecedented capabilities of this new international facility in terms of the variety and intensity of the delivered ion beams.

The Experimental Group of Nuclei and Particles at IGFAE has a recognized trajectory in the field of Nuclear Physics with highly skilled scientists with an outstanding international impact. GENP scientists have led cutting-edge experiments in the most relevant accelerator facilities in Nuclear Physics (GSI, GANIL, CERN/n_ToF, etc). Since 2008 GENP plays a leading role in the new R3B experiment. GENP scientists have led the design and construction of the CALIFA gamma and proton calorimeter for the R3B target area, have an outstanding contribution to the data sorting and simulations software development and coordinate some of the physics proposals for data taking. Moreover, one of the group members is since recently the spokesperson of the R3B experiment.

Job description

FAIR-phase0 (2019), will deliver beams of exotic nuclei to the R3B experiment. Those beams, in particular, n-rich nuclei, will be used to investigate the nature of the nuclear matter as it manifests at different depths in neutron stars, or the matter synthesized in neutron star merger events, as the one detected last year by the LIGO/Virgo experiments. The first data taking campaigns will focus on:

- Constraining the symmetry energy term of the equation of state for the neutron-rich matter. Measurements of the total reaction and charge-exchange cross-sections of neutron-rich tin isotopes will allow us to determine the neutron-skin thickness, the difference between the proton and neutron radial distributions, which has been shown to be sensitive to the symmetry energy.

- Short-range correlations in the nucleon-nucleon interaction. The recent observation of a sizeable amount high momentum neutron-proton pairs in n-rich nuclei with the CLAS experiment at JLAB demonstrates the existence of short-range correlations having a known impact in the cooling mechanism of neutron stars. The R3B experiments will use quasi-free proton and nucleon knock-out reactions with n-rich nuclei to investigate the nature of those correlations.
- Fission of nuclei far from stability. The electromagnetic signal associated to the neutron star merger detected in 2017 confirmed that those events trigger the r-process nucleosynthesis of the heaviest elements of the periodic table. The fission of those nuclei plays a decisive role in the final nature and abundance of those heavy neutron-rich nuclei. R3B will investigate the fission of some of these very exotic nuclear species.

Moreover, the R3B experiment offers also opportunities for candidates with a more technical profile interested in:

- Advanced scintillator materials for the detection of gamma rays, neutrons and charged particles.
- Big data and machine learning techniques for the data sorting of the R3B experiment.