Internship in nuclear instrumentation

The PILGRIM mass spectrometer: towards high accuracy mass measurements for exotic nuclei at S^3

The internship aims at contributing to the commissioning of a mass spectrometer system, which will be part of the S3 – Low Energy Branch (S3 LEB) apparatus. S3 is the Super Separator Spectrometer, which will be one of the main facilities of SPIRAL2 at GANIL for producing a wide range of radioactive isotopes, allowing to study their nuclear properties. The S3-LEB consists of: a gas cell, which stops and neutralizes the reaction residues; a laser – ionization region where laser spectroscopy can be performed; a series of buffer gas filled RFQs for ion cooling; and the mass spectrometer Piège à Ions Linéaire du Ganil pour la Résolution des Isotopes en Masse (PILGRIM). PILGRIM will both enable an unambiguous identification and counting of the exotic isotopes produced at S3 and a rapid and accurate measurement of their mass. This ensemble of gas-cell and mass spectrometer is built, installed and is presently being commissioned in LPC Caen.

PILGRIM is a Multi-Reflection Time-of-Flight Mass Spectrometer (MR-ToF-MS). Ions injected as a bunch are stored between two electrostatic mirrors, and then ejected towards a time-of-flight detector for a precise mass analysis. The set of electrodes permits achieving a time-of-flight focusing to minimize the extracted bunch width, for highest mass resolution. So far, PILGRIM has been commissioned independently using chopped beams from an off-line ion source [1]. With this simple setup, resolving powers as high as 140,000 and mass measurement accuracies of $\lesssim 10^{-7}$ were obtained. The goal of the internship will be to test the coupling of PILGRIM to S3-LEB, which will deliver the ions in the form of bunches from its final RFQ, a necessary step for the use at S3. The performance of PILGRIM in mass separation and its mass measurement accuracy will have to be investigated with respect to the bunch properties, energy and time-of-flight distributions, also known as longitudinal emittance, as a function of the RF parameters. Different upgrades will be also studied to enable further improvement of the performances of PILGRIM, aiming at making it one of the best mass spectrometers of its kind:

- Replacing the present ion detector with one providing a higher ion detection efficiency (up to 100% compared to $\lesssim$50%).
- Replacing the present high voltage switches with faster ones, to enable a more flexible mode of operation of PILGRIM,
- Implementing a voltage stabilization system permitting to achieve mass resolving powers above 200,000 over long durations (see for example [2]).

The internship work will therefore be quite enriching and diverse, allowing the development of skills with broad applicability and will be very valuable for the S3-LEB community. The S3 LEB is developed in collaboration between different groups from France (LPC Caen, IPNO, GANIL) and Belgium (IKS Leuven) and will attract other physicists from Europe. Good communication skills are therefore recommended.

[1] Blaise-Maël Retailleau, PhD thesis of the University of Normandy, un spectromètre de masse par temps de vol pour S3, et brisure de symétrie d'isopin dans le 38K, https://tel.archives-ouvertes.fr/tel-03259311

[2] F. Wienholtz et al., Improved stability of multi-reflection time-of-flight mass spectrometers through passive and active voltage stabilization, NIM B 463(2020)348.

Expected skills
Experimental physics, good communication skills, Programming C++/python
This work can be pursued by a PhD-thesis (SHELA project)

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