Internship in experimental nuclear physics

Conceptual Design of a Target Ion Source System for the Development of the ^{39}Ca+ Beam for the MORA Experiment

The *Matter's Origin from RadioActivity* (MORA [1, 2]) experiment aims to search for signatures of CP violation in the nuclear beta decay that could help explain the matter-antimatter asymmetry observed in the Universe. The most sensitive and complementary isotopes for this search for physics beyond the Standard Model are ^{23}Mg and ^{39}Ca.
MORA is currently taking data at the University of Jyväskylä, where both isotopes are produced with beam intensities of approximately 10^5 particles per second (pps). At GANIL, where the experiment is expected to reach its highest sensitivity, beam intensities exceeding 10^7 pps are anticipated. While such intensities have already been achieved for ^{23}Mg, they remain out of reach for ^{39}Ca due to the chemical reactivity of calcium, which makes it a particularly challenging element to handle.
The objective of this Master's thesis is to develop a conceptual design of a Target Ion Source System (TISS) optimized for the production of a $^{39}Ca^{+}$ beam. The design will be based on the highly innovative TULIP system [3], which has demonstrated excellent performances in producing short-lived exotic isotopes of Rb. Adapting TULIP to operate with fragmentation targets will open promising new avenues for the production of intense exotic beams at GANIL.
This work will be conducted within the Radioactive Beam R&D team at GANIL, in close collaboration with experts in target and ion source development. Participation in data-taking campaigns at Jyväskylä—where a different production technique is employed—will be encouraged to gain complementary experimental experience.
The work can be continued in the frame of a PhD thesis is funded by the ANR ACCLAIM MORA project, see https://mora.ganil-spiral2.eu/.

[1] P. Delahaye, E. Liénard, I. Moore, M. Benali, M. L. Bissel, L. Canete, T. Eronen, A. Falkowski, X. Fléchard, M. Gonzalez-Alonso, W. Gins, R. P. D. Groote, A. Jokinen, A. Kankainen, M. Kowalska, N. Lecesne, R. Leroy, Y. Merrer, G. Neyens, et al., "The MORA project," *Hyperfine Interact.,* no. 240, pp. 63 - 75, 2019.

[2] N. Goyal, A. Singh, S. Daumas-Tschopp, L. M. Motilla Martinez, G. Ban, V. Bosquet, J. F. Cam, P. Chauveau, S. K. Chinthakayala, G. Fremont, R. P. De Groote, F. de Oliveira Santos, T. Eronen, A. Falkowski, X. Flechard, et al., "Performance of the MORA Apparatus for Testing Time-Reversal Invariance," *Eur. Phys. J. A (2025) 61: 221,* 2025.

[3] P. Jardin, M. MacCormick, V. Bosquet, P. Chauveau, S. Damoy, P. Delahaye, M. Dubois, M. Fadil, M. Lalande, C. Michel and J. C. Thomas, "Sub-millisecond atom-to-ion transformation in the TULIP ISOL system," *Nucl. Instrum. Meth. A,* vol. 1055, p. 168332, 2023.

Expected skills
The M2 student has to be interested in experimental physics, solving engineering problems in challenging contexts, and knowledgeable in programming (python, C, C++ or other langages). The M2 student will be part of the TISS development group and of the MORA team at GANIL.

This work leads to a PhD-thesis.

Contact: Pierre Delahaye
Phone: +33 (0)2 31 45 44 56 mail: pierre.delahaye@ganil.fr