



## Internship in experimental nuclear physics

---

### Space-Charge Effects On the Transmission of Bunched Ion Beams

---

The *Matter's Origin from RadioActivity* (MORA [1, 2]) experiment searches 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  $^{23}\text{Mg}$  and  $^{39}\text{Ca}$ .

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.

To effectively transport and inject these radioactive ions into the MORA setup, the beams are converted from a continuous ion stream into temporally narrow, dense ion bursts, also known as bunches, by using a device called a Radiofrequency Quadrupole Cooler Buncher (RFQ-CB). At the University of Jyväskylä, MORA uses the so-called “minibuncher” [3] to perform such a conversion. However, it was observed that the transmission efficiency of the bunches decreases as a function of the number of ions in the bunch, for numbers as low as a few  $10^5$ . One hypothesis for the source of these losses is that the Coulomb repulsion drives the ions apart, losing some of them inside the beamline.

The objective of this M2 project is to study and report these transmission losses by simulating the transport of ion bunches in SIMION, utilizing its in-built Poisson equation solver to account for space-charge effects. This work will be conducted within the MORA project at GANIL.

For more information, 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. Fléchar, 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] V.A. Virtanen, T. Eronen, A. Kankainen, O. Beliuskina, P. Campbell, R. Delaplanche, Z. Ge, R.P. de Groote, M. Hukkanen, A. Jaries, R. Kronholm, I.D. Moore, A. Raggio, A. de Roubin, J. Ruotsalainen, M. Schuh, “Miniaturised cooler-buncher for reduction of longitudinal emittance at IGISOL” *NIM-A* 1072: 170186, 2025

#### **Expected skills**

The M2 student is expected to be interested in experimental physics, to have a firm grip on the basics of electromagnetism, and to have prior experience in programming, for example, in python, lua, C++, or in other comparable language.

This work does not lead to a PhD-thesis.

**Contact:** Ville Virtanen and Pierre Delahaye  
emails: [ville.virtanen@ganil.fr](mailto:ville.virtanen@ganil.fr) and [pierre.delahaye@ganil.fr](mailto:pierre.delahaye@ganil.fr)