Research activity
Electromagnetic Moments In Exotic Nuclei

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1 Project

The project is built around the recently developed and commissioned plunger device OUPS (Orsay Universal Plunger System), built by a collaboration between two of the P2IO laboratories (CSNSM and IPN Orsay). This project also includes participation from IRFU. A Plunger instrument is typically used to perform lifetime measurement of excited states in nuclei with lifetimes in the ps range but can also be used to measure g-factors. However this last point requires further development. The project consists in the improvement of calibration and analysis tools and the development of new techniques and targets for the plunger in order to further develop the Orsay Plunger as a complete tool to measure lifetimes and g factors of excited states.
The successful development of the collaboration around the electromagnetic moments in exotic nuclei will secure this much needed expertise in France and create the opportunity of a strong 'pôle d'excellence' for the electromagnetic moments and transition probabilities studies among three of the nuclear physics laboratories of P2IO. This will provide the possibility for the collaboration to take a leading role at nowadays available (GANIL, ISOLDE) and near-future (SPIRAL2, HIE-ISOLDE) world class radioactive beam facilities.

2 Description of work achieved

Electromagnetic moments are crucial observables in nuclear physics as they give access to the excited states nuclear wave functions using the well-known electromagnetic transition operators. They are thus very important to validate nuclear structure theories and particularly to disentangle competing theoretical models. This happens typically in the regions of the nuclear chart where there is considerable modifications of the nuclear structure with nucleon number or excitation energy.

2.1 Static electromagnetic moment

The static moments are of key importance since the wave function of a single state is involved in the estimation of their expectation values. In order to measure these observables with radioactive ion beams (RIB), new techniques have to be developed. The Time Dependent Recoil In Vacuum technique (TDRIV) has been used in the 70's for g-factor measurements in the *sd*-nuclei, with a plunger device equipped with a stopper foil. The hyperfine interaction couples the nuclear and electronic spins and causes a precession of their nuclear moments about the total (atomic+nuclear) spin of the free ion. This precession has a frequency that is proportional to the magnitude of the nuclear g-factor. However, in the case of Radioactive Ion Beams, the ions cannot be stopped inside the zone viewed by the γ-ray detectors, and the stopper foil of the plunger has to be replaced by a thin foil that resets the electron configuration.

Using γ-recoil coincidence, we were able to measure the perturbed angular correlation and hence the g-factor of ^{24}Mg with a precision of $\sim 3\%$. The obtained result is in good agreement with the shell-model calculation in this region and is in fairly good agreement with the previous measurement in this nucleus. A new experiment to extend this measurement into more neutron rich nuclei, up to ^{28}Mg has been proposed to and accepted by the ALTO advisory committee. This new experiment will be performed in the second semester of 2014. Moreover, as this first measurement was successful, another experiment is planned to probe the feasibility of this technique not only with H-like ions but also with Na-like, which will give us access to a new region of nuclei. This new technique will also be used during the physics campaign of the new generation γ-ray array AGATA at GANIL in 2015 with the OUPS plunger.

2.2 Dynamic electromagnetic moment

The dynamic moments are related to the expectation value of the electromagnetic decay operator between two states of the nucleus. Using the beam delivered by the ALTO tandem (Orsay, France) the ORGAM array, composed of ten Compton suppressed Ge-detectors and the OUPS plunger, we were able to extract for the first time the lifetimes of the two first excited states of the neutron deficient ^{170}Os. The obtained lifetimes for the 2_1^+ and 4_1^+ in ^{170}Os follow nicely the systematics and are in agreement with the hypothesis of a shape transition from well deformed prolate shape at the neutron mid-shell ($N = 104$) to near spherical shape at the neutron shell closure ($N = 82$). The comparison of the experimentally obtained lifetimes and theoretical predictions are currently in progress.

2.3 New development

During the post-doc period the feasibility of lifetime measurements after incomplete fusion reactions was probed, where the break-up of the weakly-bound nucleus occurs before the fusion of one of the break-up component with the target or projectile. This kind of reaction was extensively used in direct kinematic for γ-spectroscopy studies to populate moderately neutron-rich nuclei at high spin. However, for lifetime measurements using the RDDS method, the inverse kinematics is more suitable as Doppler broadening of the peaks due to recoil emission cone will be reduced. Using the particle detector developed at CSNSM for the TDRIV method, we were able to construct particle-γ coincidence and thus obtain cleaner recoil identification. This experiment was performed last December using a ^{70}Zn beam delivered by the Tandem from the ALTO facility impinging on a Li target, especially developed for this experiment in collaboration with the target laboratory of the IPN. The first results indicate a strong population of Ga isotopes when the coincidence between particle and γ-rays is requested.

3 Publications

The publication on the results obtained within this project are currently being written. In particular on the first measurement of magnetic moment using the TDRIV method with the Orsay Plunger [2] and the measurement of lifetimes in the neutron-deficient ^{170}Os [1]. We also recently published a paper [3] on the optimization of the plunger setup for experiment with new generation γ-ray array like for example AGATA. In parallel to these activities, A. Goasduff have been involved in several experiments, which led to the following publications :

[1] A. Goasduff *et al.*, In preparation for Phys. Rev. C.

[2] A. Kusoglu *et al.*, In preparation for Phys. Rev. C.

[3] A. Goasduff *et al.*, Accepted for publication, Nucl. Instr. Meth. A

[4] A. M. Stefanini *et al.* Phys. Lett. B **728**, 639 (2014).

[5] A. Goasduff *et al.*, Phys. Rev. C **89**, 014305 (2014).

[6] S. Szilner *et al.*, Phys. Rev. C **87**, 054322 (2013).

[7] G. Montagnoli *et al.*, Phys. Rev. C **87**, 014611 (2013).

[8] S. Szilner *et al.*, Acta Phys. Pol. B **44**, 417 (2013).

4 Relevance of the project within P2IO

The Orsay Universal Plunger System developed at CSNSM in collaboration with IPN, is an important tool for the future experiment that will be performed not only at ATLO but also in at GANIL with the presence of the European new generation γ-ray array AGATA. The development that have been performed during this project, in particular the development of new targets and the prove of feasibility of new techniques such as TDRIV, are of particular importance for the visibility of the ALTO facility and the collaboration consolidated within the P2IO framework.

Altogether, the work performed during this project has strongly contributed to deepen the know-how and knowledge already present in the collaboration, which is now considered as one of 'pôle d'excellence' for the experimental electromagnetic moment determination in Europe.

5 For end of contract post-docs : position after P2IO

At the end of his contract, A. Goasduff will start an INFN fellowship at the Legnaro National Laboratory (Italy). This new contract should start on October 1^{st}, 2014.