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Study of 2-proton radioactivity with ACTAR TPC

(proposal for PhD grant)

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After the discovery of the 2-proton radioactivity process [1,2], and the experimental studies performed on ^{45}***Fe***, ^{48}***Ni*** and ^{54}***Zn*** nuclei [3,4] (mainly at GANIL, France) and more recently on ^{67}***Kr*** [5,6] (at RIKEN, Japan) by the "Exotic Nuclei" group of CENBG [7], the current proposal addresses the study of the decay mechanism of this exotic radioactivity process with the new ACTAR TPC device.

The 2-proton radioactivity, that was already predicted in the 60's [8], has been experimentally evidenced only in the years 2000 [1,2], for nuclei beyond the proton *drip-line* with respect to nuclear binding forces. These very exotic nuclei can only be produced at *projectile fragmentation* facilities and the associated fragments separators (such as LISE at GANIL, FRS at GSI or BigRIPS at RIKEN). The experiments that allowed for the discovery of this exotic decay mode used the standard implantation-decay technique in silicon detectors. Since no information about individual protons can be measured with this technique, the 2-proton radioactivity was deduced indirectly from global decay information: half-life, transition energy, decay of the daughter nucleus… In order to better study the emission dynamics and perform nuclear structure studies, in the framework of various theoretical approaches [9,10,11], the angular and energy correlations between the emitted protons has to be measured. New detectors, based on *time projection chambers* (TPC) principle, have been developed in this purpose. The first correlation measurements could be achieved in experiments using these detectors [12,13,14].
A new instrument has been recently developed by the ACTAR TPC collaboration [15,16]. This detector has been designed for a full 3D reconstruction of the energy deposit along the tracks of charged particles produced in nuclear reactions ("active target" mode) or emitted in exotic radioactive decays such as 2-proton radioactivity. In order to cover a large scientific field, the device has been designed with 2 geometries, in order to measure different reactions and tracks topologies. The first version of the detector has been successfully used in a recent GANIL experiment: the tracks from protons of 0.7 to 2.5 *MeV* have been recorded, in the decay of isomeric states in ^{53}***Co*** and ^{54}***Ni***.

An experiment aiming to measure proton-proton correlations in the decay of ^{48}***Ni*** (or ^{54}***Zn***) with ACTAR TPC has been accepted by the GANIL PAC. This experiment that may take place in early 2020 will be the main topic of the proposed PhD position. A similar experiment has also been accepted at RIKEN on the decay of ^{67}***Kr***.

The expected work for this PhD is:

- to participate to the tests and validation of the 2nd geometry of the ACTAR TPC detector, that will be available in the 2nd half of 2019; this should allow to get familiar with the ACTAR TPC device and its associated electronics (a demonstrator version is also available at CENBG);
- to be fully involved in the preparation and the running of the GANIL experiment;
- to analyze the experimental data from this experiment: an strong involvement on the online/nearly analysis during the experiment represents an important preliminary analysis work;
- in the case the RIKEN experiment is scheduled, to contribute to the preparation and running of this experiment.

It should be noticed that an important part of the work will be devoted to the analysis of complex and large experiment data sets. In addition to the fragments identification (that will be performed using relatively standard techniques), it will be necessary to improve or develop the tracking algorithms. It is therefore recommended to be familiar with ROOT analysis environment and C++ programming.

The group is involved in various other experiment works in fundamental nuclear research. A (limited) contribution to these works, especially in experiment participation, is more than welcome.

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Suggested readings

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