AstroBox – a new type of low energy proton detector

E. Simmons, M. McCleskey, A. Spiridon, L. Trache, B. Roeder, R. E. Tribble
E. Pollacco,[1] M. Kebbiri,[1] and G. Pascovici[2]
[1]*Service de Physique Nucleaire, CEA Saclay, France*
[2]*Institut fuer Kernphysik der Universitaet zu Koeln, Cologne, Germany*

We worked hard in the last four years to measure very low proton energies from β-delayed proton decays, motivated by our interest in nuclear astrophysics (NA) studies. In many reactions important in H-burning involving radiative proton capture on sd-shell nuclei or heavier, resonances dominate. We aim at evaluating their contribution by studying these resonances and their properties (energy, spin and parity, resonance strength) by populating them from the beta decay of exotic nuclei that we produce and separate with MARS. These are excited states above the proton threshold in daughter nuclei that may decay by gamma-rays or by proton emission. Only the states within the Gamow window are important in NA, and this means very low proton energies: below 200-300-400 keV, depending on the temperature of the stellar process. Our first solution was to implant the proton emitting nuclei in very thin (use used 45-65 umm) double sided Si strip detectors [1]. With this technique we could measure efficiently and without much background protons with energies Ep=400-1500 keV and we could reach as low as Ep=200 keV from the decay of ^{23}Al through a careful subtraction of the important background created at low energies by the positrons from the β continuum [2]. However, the very large background in the 100-300 keV energy region and the limited resolution did impair our searches for states with small proton branchings. We realized recently an important breakthrough by using a new type of proton detector that we call AstroBox. It is based on a gas detector using micromegas [3] electron amplifiers and was designed and assembled together with specialists at CEA Saclay. The micromegas were produced at CERN. The principle of the measurement remains similar with the one used with Si detectors: the source nuclei are stopped (“implanted”) in the active volume of the detector (with the detector turned off) for a period equal to about two half-lives, after which the beam is turned off and the detector is turned on for the same period. The central detector, 5 mm in diameter, is surrounded by an ‘outer’ detector, 10 cm OD, split in four sectors (which may be connected into two or even one signal only). In March 2011 we have did the first test of the detector and its working principle, using the same β-delayed proton emitter ^{23}Al. Figure 1 shows a summary of results. The left side shows a 2-dimensional spectrum of the center detector and of the detector surrounding it (outer), which was used to tune the implantation in the source in the desired space. The right hand side shows a proton spectrum measured in the center detector. It shows a spectacular reduction of the beta background, which was restricted to energies below Ep~80 keV, a good separation of the proton peaks around 200-270 keV observed before [2], and an improved resolution. While we can confirm the observations made in Ref. 2, due to this much reduced background and the better resolution, we could also clearly observe the proton peak corresponding to the proton decay of the isobaric analog state of ^{23}Al. We note that this decay is isospin forbidden in first order, a fact that results in a very weak proton branching, and its observation can give information about isospin mixing in these nuclei.

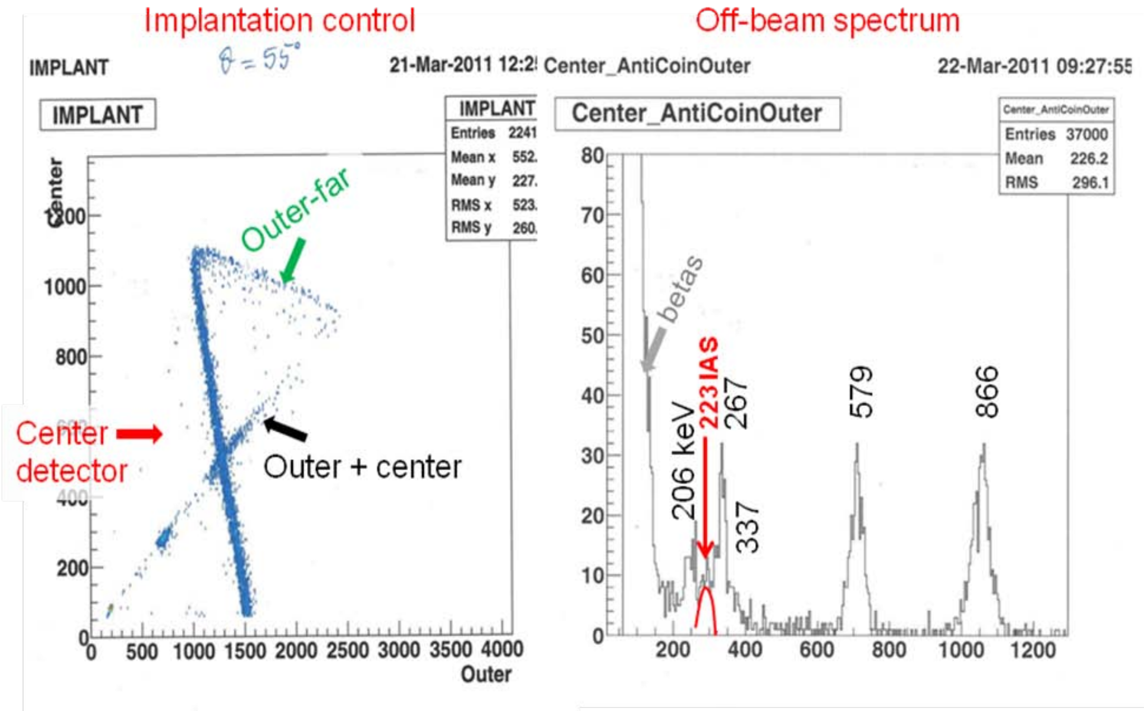

FIG. 1. Summary of the two phases of the experiment. On the left the implantation control phase, showing that most of ^{23}Al is implanted in the center region. Right side: proton spectrum from the decay of ^{23}Al. It was obtained in about 2 hours of beamtime. The energies marked are in keV.

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