Design and use of a new implantation station for beta-delayed decay experiments

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Several experiments involving beta-delayed proton- and alpha-decays have been studied by our group, with collaborators, using the Momentum Achromat Recoil Spectrometer (MARS) at TAMU. So far, ^{23}Al, ^{31}Cl, ^{20}Mg, ^{20}Na have been investigated and most recently ^{27}P. Investigation of beta-delayed proton decay is being used as an indirect method to study astrophysical reactions that would otherwise be beyond our current capabilities to study directly in the laboratory. What are of interest are resonances in the proton-capture cross sections. We study them by decay spectroscopy, measuring simultaneously beta-delayed protons and gammas.

The experimental technique developed by our group to effectively do these experiments involves implanting the parent nucleus (^{23}Al, ^{31}Cl, ^{20}Mg or ^{27}P) in the center of a thin Si detector (referred to as the proton (or alpha) detector). One, or in some cases two HpGe detectors are used, placed on either side of the proton detector, at 90 degrees to the beam axis. A telescope setup is used for the Si detector arrangement; a thin (45-65 μm) double sided Si strip detector (DSSSD), the p-detector, sandwiched between two thick (300μm to 1 mm) Si detectors (referred to here as the β-detectors) allows us to measure protons (or alphas). The beta-detectors help to reduce the background in the analysis. The precise implantation, in the middle of a very thin detector, can be obtained due to the combination of good momentum control in MARS and of the ability to controllably change the angle of an Al degrader foil that is placed inside the implantation station, right in front of the Si detectors. Pulsing the beam from the cyclotron allows us to measure, simultaneously, the β-p and β-γ coincidences. See Fig. 1 for a general layout used for these experiments.

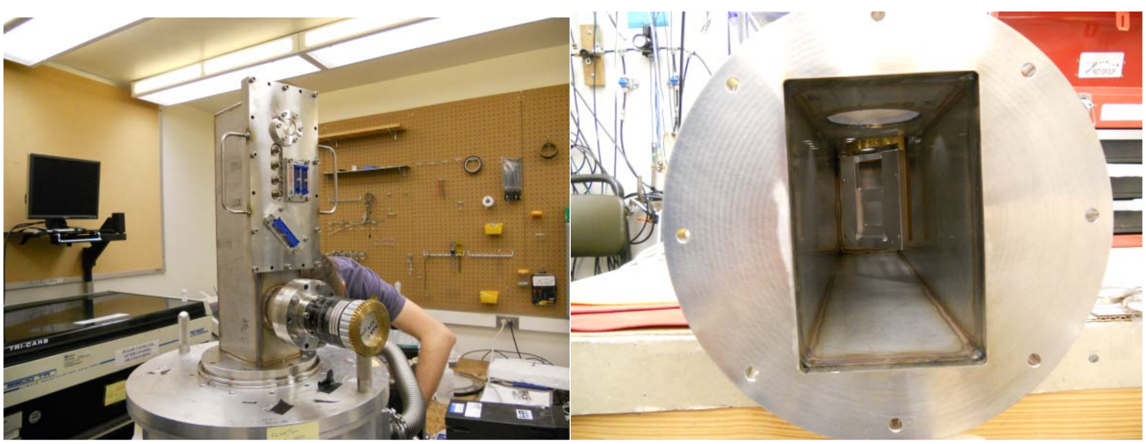

FIG. 1. New Implantation Station. Picture on the right shows the view point of the beam.

A new implantation-decay station was designed and built this year, replacing the one used before in the ^{23}Al and ^{31}Cl decay studies. First and foremost we wanted to be able to move the HpGe detectors in even closer to the Si detectors where the implantation and decay occur. This decrease in distance alone (3” to 2”) results in an approximate 50% increase in solid angle (when using two HpGe’s). Changing from a cylindrical chamber to a rectangular one also allows the HpGe’s to be placed flush with the chamber side. Originally we wanted to make this new chamber entirely out of Aluminum, but due to the way in which it had to be welded (tight corners) and the dimensions of the actual welding tools, it was not physically possible to make unless we used stainless steel. Estimates showed that, at the energies we are interested in, the change in material does not cost us that much in efficiency (for example, 70% (SS) verses 85% (Al) transmission for 200 keV photons, and the higher the gamma-ray energy, the more equal the transmissions become).

The change from 6” diameter chamber to a rectangular chamber 4” wide and 6” tall required a complete rearrangement of water pipes used for cooling the detector telescope and of electric feed through locations. Attention was paid to make sure that no cables or pipes would be in the path of the beam either as a hindrance or as a potential for scattering. The inclusion of the rotating degrader motor (interchangeable with the old implantation station) made this a complete, self contained chamber. As before, the Si detectors are placed at a 45 degree angle to the path of the beam in order to increase the amount of Si the beam encounters and simplify the gamma-ray transmission to the Ge detectors. This chamber design also allows for either the BB2 or the W1 type DSSD detectors to be used for the proton detector (both made by Micron Semiconductor). Also, a beta detector can be placed on either side of the proton detector without coming in contact with the side of the chamber. All Si detectors, as before, are attached to a brass stand that is cooled by flowing cool water through pipes that are welded to the back of this stand. This brass stand is placed on a plastic part that is then secured to the top plate of the chamber in order to try to maintain electrical isolation (even though the detector cables go through the BNC feed through connections). Handle bars were added to the top plate to make it easier to remove and change detectors throughout the experiment.

At the same time a new stand was designed and built to permit two HpGe gamma-ray detectors to be positioned easily, in a close and reproducible geometry.

In November 2010 the most recent beta-delayed proton decay experiment (^{27}P) used successfully this implantation station. Analysis of the data is underway, and so far the improvement in efficiency is clear. It is hoped that future experiments required proton detections in addition to gamma spectroscopy will find this implantation station useful.