Production and separation of new secondary beams ^{30}P and ^{27}P

E. Simmons, L. Trache, B. Roeder, M. McCleskey, A. Spiridon, and R. E. Tribble

The Momentum Achromat Recoil Spectrometer (MARS) at TAMU was used for the production and separation of both ^{30}P and ^{27}P. The nuclear astrophysical motivation for studying ^{30}P is its importance in explosive hydrogen burning in novae. The reaction rate for its radiative proton capture is known only with large uncertainty. This reaction, like others our group has previously studied in the sd-shell is dominated by capture through low-energy resonances, and is thus, very difficult to study directly. An indirect method to study this reaction was done previously through the beta-delayed proton and gamma decay of ^{31}Cl. Another reaction of interest is ^{30}P(d,p)^{31}S, which we intend to measure in inverse kinematics with TECSA.

Similarly, there is a nuclear astrophysical motivation for the production of ^{27}P. It was, shortly after this production test, used in another beta-delayed proton and gamma decay experiment. The experiment was done in order to study the destruction reaction of ^{26m}Al(p,γ)^{27}Si*. The discovery in 1982 of the 1.809 MeV gamma-ray line for the decay of ^{26}Al was the first key proof of ongoing nucleosysnthesis in the Galaxy. However, many things are still not clearly understood, for example, such as the provenience and abundance of ^{26}Al in our Galaxy.

The Production and Separation of ^{30}P

For the production and separation of ^{30}P, the primary beam from the K500 superconducting cyclotron was ^{30}Si at 18 MeV/u. The fragment of interest, ^{30}P, is created when the primary beam struck the hydrogen gas cell target (kept at 2 atm and liquid nitrogen temperature) and a (p,n) charge-exchange reaction occurrs.

The separation of exotic ^{30}P from the other fragments was performed in MARS. By the time ^{30}P reached our target detector it was at an energy of 14.2 MeV/u. After optimizing magnet settings we found that the best rate was between 10,500 and 11,000 events/nC with the coffin slits at ±1.0 cm. The total impurities were about 4%, most of which was ^{28}Si (having the same magnetic rigidity as ^{30}P meant that we could not get rid of all of it, but only minimize it as much as possible with different slits. See Figure 1). With primary beam from an enriched silane gas, we expect to be able to obtain a secondary ^{30}P beam of about 10^6 pps, which will make a TECSA experiment possible.

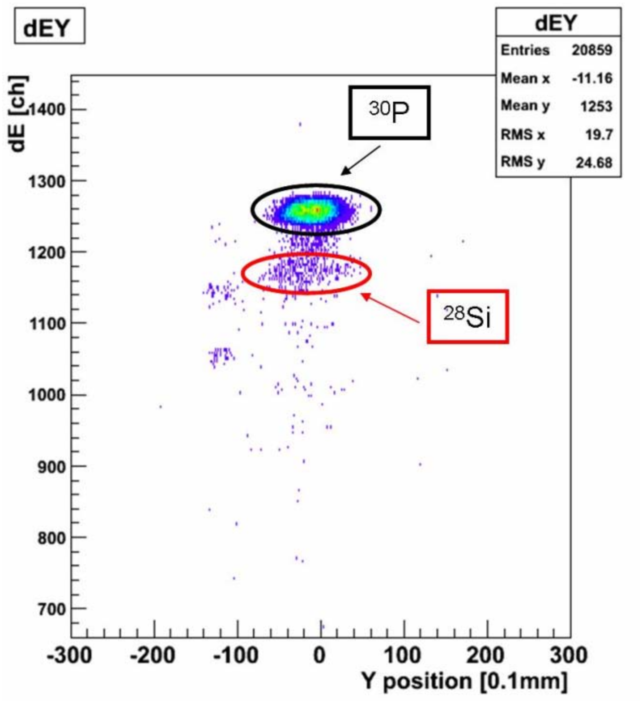

FIG. 1. Results from the ^{30}P Production and Separation.

The Production and Separation of ^{27}P

The second production test performed using MARS during this same experiment, was the production and separation of ^{27}P, using a 40 MeV/u ^{28}Si beam from the K500 superconducting cyclotron. This ^{28}Si beam hit our hydrogen gas cell target, kept at p = 2 atm and liquid nitrogen temperature, and a fusion evaporation (p,2n) reaction produced the ^{27}P fragments of interest. The exotic secondary beam was then taken through MARS and ^{27}P was separated out of the mix. By the time it reached the target detector ^{27}P had an energy of about 34 MeV/u. The final rate on our detector was about 6 events per enC measured in the coffin or about 85 per pnC for a momentum spread of +/-0.6% obtained with the coffin slits open at +/-1.0 cm. The total rate at the target detector was around 3000 pps, in line with other rates we obtained for T_z=-3/2 nuclei in this region.

The test also showed that we had about 28% total impurities, most of which was ^{24}Al, slipping in from the neighboring N=Z-2 line of nuclei. This ^{24}Al impurity could later be diminished to below 10% by closing acceptance slits, sometimes at the expense of the production of ^{27}P. However, as at the same rigidity, ^{24}Al has a longer range in Si, with about 60 μm, which will put it out of our implantation detector and will not contribute in the proton spectra, but will be stopped in the back beta-detector and will give impurity peaks (identifiable though!) in the gamma-ray spectra. However, this ^{24}Al impurity was actually to our advantage in experiment. We were able to use it for extended energy and efficiency calibrations (up to 8 MeV) for the high purity germanium detectors.

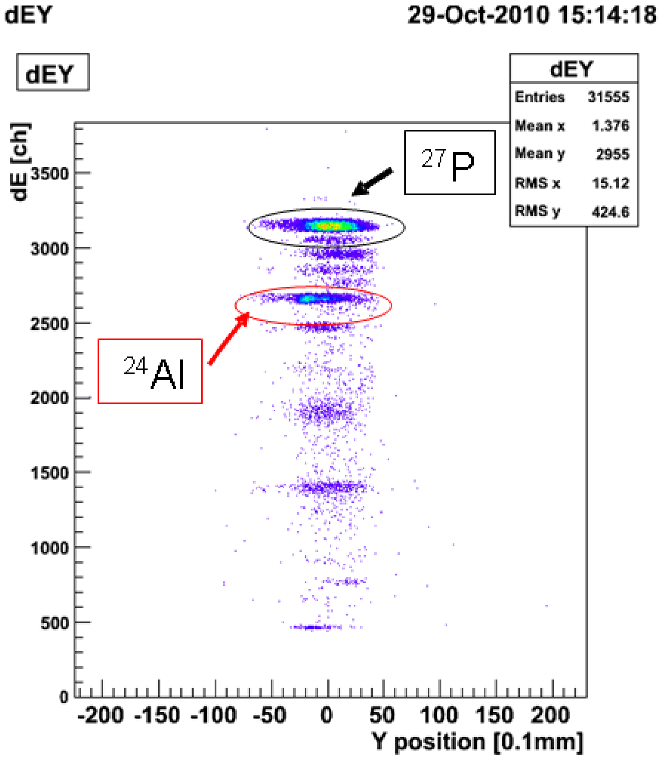

FIG. 2. Final tuning results for ^{27}P production test.