Production of new radioactive beams ^{46}V, ^{6}He, ^{20}Mg and ^{13}O with MARS

L. Trache, A. Banu, M. McCleskey, B. Roeder, E. Simmons, A. Spiridon, R. E. Tribble, V. Goldberg, H. I. Park, P. J. Woods,[1] G. Lotay,[1] and D. Shetty[2]

[1]*School of Physics, University of Edinburgh, Edinburgh, United Kingdom,*

[2]*Western Michigan University, Kalamazoo, Michigan*

This year we continued to produce and separate radioactive beams needed for our physics program using the Momentum Achromat Recoil Spectrometer MARS. For years this has become a well-known process and it is typical that MARS tuning takes less than a shift, even for new cases. A few of the beams this year were new and special in one way or another: ^{6}He, ^{13}O, ^{20}Mg, ^{46}V. A few of the parameters and the performances obtained are presented here.

In August 2008, we studied the production and separation of ^{46}V. We used a primary beam of ^{47}Ti accelerated to 30 MeV/u. The target was H_2 gas cooled at LN_2 temperature. The gas cell windows were made of thinnest havar foils we have (0.16- mils=4 μm each) and the pressure inside was 2 atm. The secondary beam of ^{46}V was produced in the fusion-evaporation reaction p(^{47}Ti, ^{46}V)2n. The secondary beam was identified and tuned with a 989μm position sensitive detector in the focal plane of MARS (the "target detector"). Fig. 1 shows the energy loss versus Y position in the target detector, with the final slits SL4 open vertically to ±1.6 cm, before the final separation of ^{46}V. The N=Z+2, N=Z+1 and N=Z lines of isotopes are clearly visible. In the end we have centered the N=Z species in the center of the detector and closed the vertical slits to ±0.40 cm to select the desired species. The final production rate obtained for

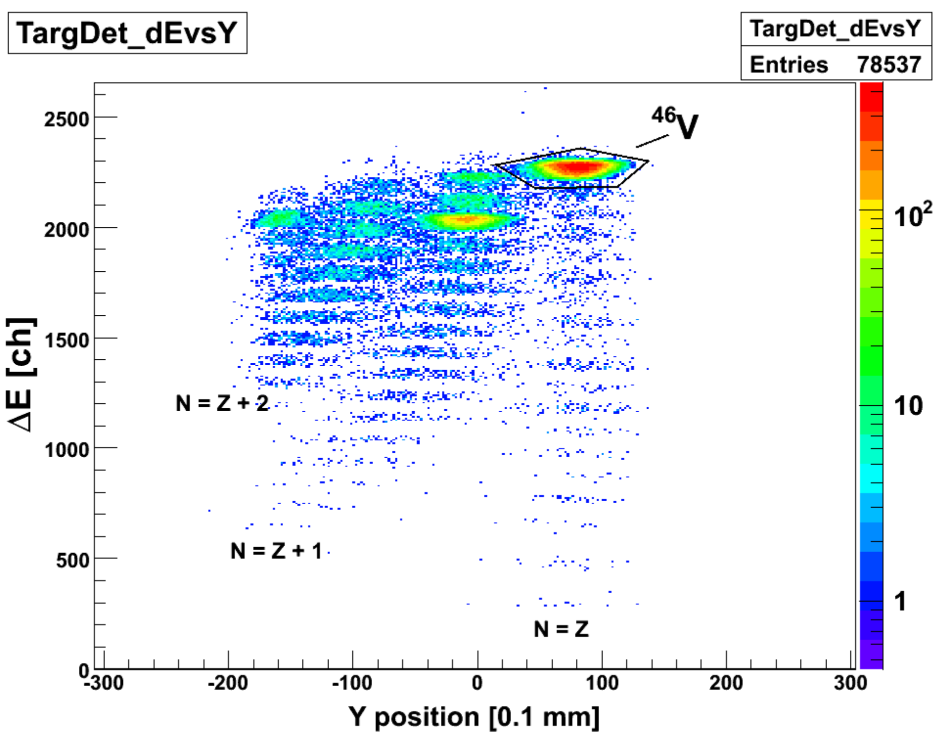

FIG. 1. Production of ^{46}V. Energy loss versus position on Y axis.

^{46}V was 1300 events/nC (incident beam measured in coffin) with 3% impurities. The impurities are due mostly to reactions of the beam with the gas cell windows. Later in the year we have used isotopically enriched ^{47}Ti in the ECR source and increased the energy of the incident beam to 32 MeV/u. We have delivered about 20 kHz of ^{46}V for the group of Prof. J.C. Hardy. They made precision lifetime measurements, part of the on-going program to study superallowed β-decays.

A few months later, we produced and separated ^{6}He. We investigated different production mechanisms with two primary beams: $^{7}Li^{+2}$ at 20 MeV/u and $^{7}Li^{+1}$ at 8 MeV/u. The target was deuterium gas cooled at LN_2 temperature. The gas cell windows were again 0.16 mils thick each and the pressure inside was 1.5 atm. We started with $^{7}Li^{+2}$ as primary beam and we investigated three mechanisms: fragmentation, transfer and fusion-evaporation. The fragmentation reaction ($v_{6He} = v_{7Li}$ at 20 MeV/u) was the only one to yield a significant production rate, 280 ev/nC. With $^{7}Li^{+1}$ as primary beam we investigated the transfer reaction $d(^{7}Li, {}^{6}He_{g.s.}){}^{3}He_{g.s.}$ and observed a production rate for ^{6}He of 233 ev/nC. This beam is intended for experiments proposed by a group from Western Michigan University.

In February 2009, we prepared for another experiment in the series of measurements of β-delayed proton decay of proton-rich nuclei [1]. The aim of this experiment, planned with the group from the University of Edinburgh, is to measure the β-p emission from ^{20}Mg and use these measurements to study the 448 keV resonance, of crucial importance for the $^{19}Ne(p,\gamma)^{20}Na$ reaction in stars. For now, the purpose of the run was to study the production and separation of ^{20}Mg, before starting the decay measurements. The ^{20}Mg beam was obtained from a beam of ^{24}Mg at 48 MeV/u through fragmentation on a 306μm Be target. Fragmentation is not the typical production mechanism used in MARS, so far. The major problems were, as expected, a low production rate for ^{20}Mg and a very large contamination with ^{10}C, of same q/m, which cannot be avoided in the present MARS configuration. After separation with MARS, we have also tried to use Al degraders placed after the target to attempt reducing an observed background scattering (off the degrader ladder?!) and the ^{10}C contamination. We tried two thicknesses for the degrader, 15 mil and 25 mil. The latter gave better ^{20}Mg to ^{10}C ratio, 0.06, and ^{20}Mg production rate, 1.5 ev/pnC. We estimate that even this very low rate obtained will suffice for the proposed experiment and the large contamination with ^{10}C will not affect the off-beam measurement because these ions pass through the thin proton detector, but we intend to try other reactions to find better production rate and purity.

Another challenging secondary beam obtained this year was ^{13}O. We have developed it for the study of the unbound ^{14}F nucleus using the resonant elastic proton scattering in inverse kinematics and the thick target method. We started from a ^{14}N primary beam at 38 MeV/u incident on the H_2 gas-cell at p=3 atm. We have obtained a production rate of 13.2 part/nC and a total rate of about 4000 pps. The purity of the beam was 75% with ^{10}C the main impurity. The intended experiment was performed in two runs in March and April and is described separately [2].

[1] L. Trache *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2007-2008), p.I-11; http://cyclotron.tamu.edu/publications.html

[2] V. Goldberg *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2008-2009), p.I-21.