MARS status report for 2017-2018:
Tuning of rare isotope beams of ^{59}Fe, ^{42}Ti, ^{10}C, ^{8}B, ^{8}Li, ^{35}K, and ^{32}Cl

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This year, we continued the program of providing rare isotope beams for the physics program at the Cyclotron Institute at Texas A&M University with the Momentum Achromat Recoil Separator (MARS) [1]. ^{10}C and ^{42}Ti beams provided to Dr. Hardy's research group were prepared for their continuing studies of super-allowed β-decay. ^{8}B and ^{10}C beams at lower energy around 8 MeV/u were prepared for experiments with Dr. Rogachev's research group in collaboration with the University of São Paulo in Brazil. An ^{59}Fe beam was developed for Dr. Yennello's group. Beams of ^{8}B and ^{8}Li were tuned for Dr. Rogachev's group as part of the commissioning run for the new TexAT detector. Finally, beams of ^{35}K and ^{32}Cl beam were made for Dr. Tribble's group for their continuing studies of β-delayed proton decay with the Astrobox2 detector.

With the exception of ^{59}Fe, most of the beams made this year were made before and reported in annual reports from previous years [2,3]. A summary of the ^{59}Fe beam preparation results is given in this report.

An ^{59}Fe beam has been requested by Dr. Yennello's group for an experiment in collaboration with Los Alamos National Laboratory. Despite the long half-life of ^{59}Fe, which would make it a candidate for production via neutron capture in a reactor, the in-flight production method with MARS may be preferred for the experiment due to safety concerns. In the beam production test, two reactions were investigated using beams from the K500 cyclotron: d(^{59}Co,^{59}Fe)2p at 13 MeV/u and d(^{58}Fe,^{59}Fe)p at 11 MeV/u. A third possible reaction, ^{9}Be(^{61}Ni,^{59}Fe)X (2p-removal) was also proposed but not investigated due to the cost of the ^{61}Ni isotope.

For the d(^{59}Co,^{59}Fe)2p case, ^{59}Co at 13 MeV/u bombarded the MARS gas target filled with 0.5 atm of D_2 gas at 77K. A 1 mil thick Al degrader was placed after the target, but before MARS, to attempt to separate the ^{59}Fe from the ^{59}Co primary beam via energy loss and magnetic rigidity. This method would have produced ^{59}Fe secondary beam via a direct transfer reaction with an energy of about 8.0 MeV/u, as desired by the experimenters. However, due to the low beam energy, the reaction products were not fully stripped of their electrons and were difficult to identify separated from the charge states of the primary beam. A reaction product was identified in between the 4 charge states of the beam using a passive, 1 mil Al degrader in front of the silicon detector at the focal plane. The energy loss through this degrader suggested this product was more consistent with an excited state of the ^{59}Co, not with ^{59}Fe. Due to the inconclusive results, and the difficulty in separating the ^{59}Fe from the charge states of the ^{59}Co primary beam, this production method was abandoned.

For the d(^{58}Fe,^{59}Fe)p case, ^{58}Fe at 11 MeV/u bombarded the MARS gas target filled with 0.5 atm of D_2 gas at 77K. This setup produced a ^{59}Fe secondary beam via a direct transfer reaction with an energy of 7.5 MeV/u. As with the previous reaction, the reaction products were not fully stripped of their electrons and charge states 23+ through 26+ were populated. It was noted in this case, however, that mass-59 reaction products were separated from the ^{58}Fe primary beam charge states by about 1 cm at the focal plane. Thus, the ^{58}Fe charge states could be mostly blocked with the focal plane slits of MARS. To identify the ^{59}Fe, the mass-59 reaction products were centered on the 1 mm thick position sensitive silicon detector, and then a 1 mil thick passive aluminum degrader was placed in front of the detector. This allowed a separation via energy loss between ^{59}Co, produced from d(^{58}Fe,^{59}Co)n and ^{59}Fe from the (d,p) reaction. Once this separation was achieved in the spectrum, then the rigidity of MARS was tuned until the production of ^{59}Fe was optimized at the focal plane. The resulting beam tune, with the focal plane slits inserted and the 1 mil aluminum degrader inserted in front of the detector, is shown in Fig. 1.

The best tune for ^{59}Fe gave about 650 eV/nC for ^{59}Fe^{23+}. The total secondary beam was composed of 80% ^{59}Fe, 7% ^{59}Co and 13% ^{57}Co, where the latter two isotopes could not be separated. Some low-mass background was also present in the beam. With 40 enA of ^{58}Fe beam on the faraday cup at the exit of the cyclotron, a rate of 42 kHz was observed for this secondary beam on a scintillator at the MARS focal plane, implying about 30 kHz of ^{59}Fe was possible. With these parameters, a rate of about 10^5 particles/sec ^{59}Fe would be possible with about 3 times more primary beam on target. 100-200 nA of ^{58}Fe primary beam should be achievable if the ^{58}Fe is produced with an oven in the ECR source instead of via sputtering, as was done for this test run.

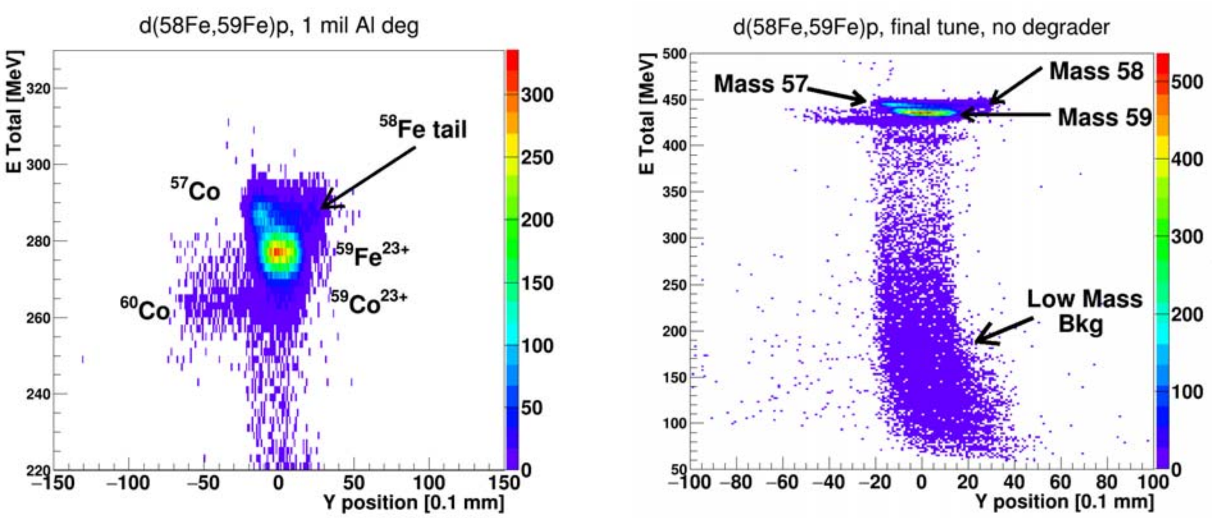

FIG. 1. Resulting secondary beam for d(^{58}Fe,^{59}Fe^{23+})p. The MARS rigidity tune has been optimized for the ^{59}Fe production. To obtain the left spectrum, a 1 mil Al degrader was placed in front of the silicon detector so that the products could be identified via energy loss in the spectrum. See text for further explanation.

[1] R.E. Tribble, R.H. Burch, and C.A. Gagliardi, Nucl. Instrum. Methods Phys. Res. A**285**, 441 (1989).

[2] B.T. Roeder *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. IV-25;

[3] B.T. Roeder *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2016-2017), p. IV-23.