MARS status report for 2022-2023

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This year, we continued the program of providing rare isotope beams (RIBs) for the physics program at the Cyclotron Institute at Texas A&M University with the Momentum Achromat Recoil Separator (MARS) [1]. The MARS beam line was utilized in 6 separate experimental runs for various experiments involving rare isotope beams.

Several experiments with rare isotope beams were conducted with ions that had been developed in previous years. A summary of these RIBs is given in Table I. ^{12}N was produced for an experiment of Professor Rogachev's group in collaboration with experimenters from Brazil. There was a ^{6}He beam made for an experiment with Professor Lee Sobotka's group from Washington University in St. Louis (WUSTL). A ^{11}Be beam was produced for Greg Christian's group and Dr. Shuya Ota for a transfer reaction measurement. The ^{14}O for Professor Rogachev's group was used in an experiment in collaboration with a group from the Institute of Basic Science (IBS) in South Korea. A higher energy ^{14}O beam was also developed for the WUSTL group. It will be used in an upcoming experiment later in 2023. Finally, a ^{13}B beam was produced for Professor Rogachev's group for a transfer reaction measurement with TexAT.

Table I. Summary of MARS RIBs for 2022-2023.

RIB beam	**Reaction**	**Production Rate (eV/nC)**	**Purity**	**Intensity on Target (est.)**
^{12}N	^{10}B+^{3}He at 10.2 MeV/u(Transfer)	7.3 eV/nC	~44%	~2*10^{3} p/s
^{6}He	$^{2}H(^{7}Li,^{6}He)^{3}He$ (Transfer)	126 eV/nC	~69%)	5*10^{4} p/s (~10^{5} possible)
^{11}Be	^{13}C+^{9}Be at 30 MeV/u (Frag.)	78 eV/nC	~70%	~10^{4} p/s
^{14}O	p(^{14}N,^{14}O)n at 17 MeV/u (Transfer)	322 eV/nC	~75%	~2*105 p/s
^{14}O	p(^{14}N,^{14}O)n at 9.1 MeV/u (Transfer)	207 eV/nC	100%	1.8*10^{5} p/s
^{13}B	^{15}N+^{9}Be at 30 MeV/u (Frag.)	54 eV/nC	82%	~10^{4} p/s

During the ^{12}N experiment with the Rogachev group / Brazil collaboration, the MARS liquid nitrogen cooled gas production target had several sudden failures of the HAVAR windows. This was due to the interaction of the primary beam (^{10}B) with the epoxy used to seal the windows. The damage to the epoxy seal was evident from discoloration of the seal in the region where the beam had heated it. The failure of the epoxy seal had been an ongoing problem and occurred most often when low energy, high intensity primary beam from the K150 cyclotron was used for the production of RIBs. In the 2021-2022 year, an aluminum collimator with a 0.6 inch diameter hole, designed by A. Saastamoinen, was added to the front of the gas target to attempt to address this problem by blocking any beam tails from entering the target. However, gas window failures continued to occur. The only way to prevent the gas window failure was to use lower beam intensity, which severely limited the RIB intensities that could be available.

Following the ^{12}N experiment, A. Saastamoinen painted the 0.6 inch diameter collimator with a mixture of ZnS and glue, such that any beam tails impinging on the gas target could be observed via camera during beam tuning and during the course of the experiment. The resulting painted collimator is shown in Fig. 1. During the subsequent experiments with ^{6}He and ^{14}O RIB production, it was observed that, while it was possible to have the primary beam centered on the MARS quadrupole magnet by adjusting only the upstream dipole magnet MARSBLD1, that adjustment forced the path of the primary beam to hit the right hand side of the gas target, as seen with the new painted collimator. It is now believed that this was the cause of the repeated gas target window failures.

With the help of the painted collimator, a new optics beam tune was developed where both the upstream dipole magnets, the “Indiana” magnet and the MARSBLD1, are adjusted in tandem to obtain a primary beam tune where 1) the primary beam is centered on the gas target and 2) the primary beam is centered with respect to the first quadrupole doublet of MARS. For the K150 cyclotron beam, the adjustment is typically 1-2 A lower on “Indiana” magnet (Spectrograph power supply) and up to 30 A lower on MARSBLD1. A similar adjustment for the beam from the K500 beam is also needed, but the parameters of that adjustment are still being determined.

The adjustments to the primary beam optics have resulted in less failures of the gas cell windows and improved primary beam intensities on target. Transmission of up to 50% from the cyclotron FC02 to target has been obtained, whereas typical transmissions were less than 25% previously. Record measured intensities of 700 pnA for ^{7}Li and 220 pnA for ^{14}N were observed on the MARS coffin faraday cup without corresponding window failures.

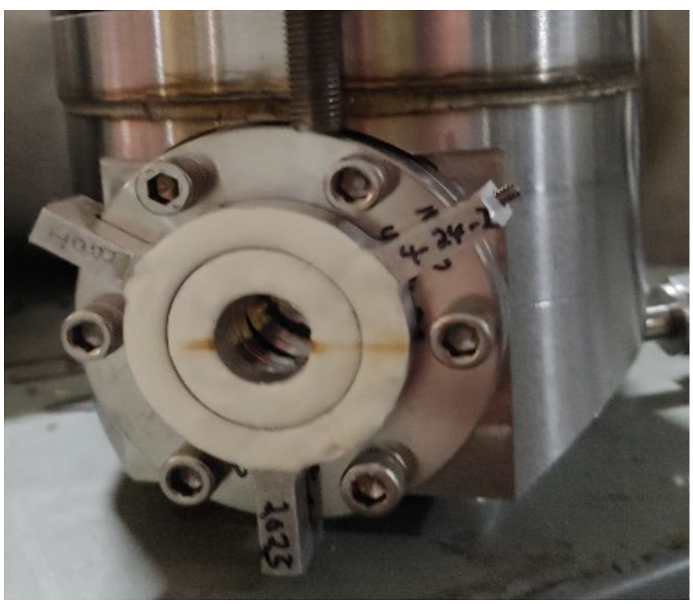

Fig. 1. The new collimator for the MARS gas target painted with ZnS / glue mixture. A brown line from the beam hitting the collimator during tuning is visible across the face of the collimator.

[1] R.E. Tribble, R.H. Burch and C.A. Gagliardi, Nucl. Instrum. Methods Phys. Res. **A285**, 441 (1989).