## Production of a New Radioactive Beam $^{12}$N with MARS

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The reaction rate for the radiative proton capture on the drip line nucleus $^{12}$N is currently under investigation at the Cyclotron Institute using an indirect method. This reaction is important in the hot proton-proton chain of H burning in supermassive stars [1]. We intend to use the $^{14}$N($^{12}$N,$^{13}$O)$^{13}$C proton transfer reaction to extract the asymptotic normalization coefficient (ANC) for the virtual decay $^{13}$O->$^{12}$N + p, and calculate from it the direct component of the astrophysical S-factor. A primary beam of $^{12}$C from the K500 superconducting cyclotron is used to produce in-flight radioactive $^{12}$N which is separated from other reaction products with the recoil spectrometer MARS. In early spring 2006, we studied the production and separation of $^{12}$N, in preparation for the run in May of 2006.

Here we report on the production rate of the $^{12}$N secondary beam, developed at the Cyclotron for the first time. A host of possible production reactions –$^{12}$C(p,n)$^{12}$N, $^{14}$N(p,t)$^{12}$N, $^{12}$C($^{3}$He,t)$^{12}$N, $^{10}$B($^{3}$He,n)$^{12}$N– were considered to be studied in inverse kinematics. According to past measurements for these reactions [2], the ones more feasible for the energy regime of interest appeared to be $^{12}$C(p,n)$^{12}$N and $^{10}$B($^{3}$He,n)$^{12}$N, with production cross sections of the order of a few mb. We chose to investigate the (p,n) reaction mechanism, used also successfully at MARS in the production of $^{7}$Be, $^{11}$C, $^{13}$N, $^{14}$O beams, and for which one benefits from a more forward focus that is propitious to the MARS acceptance [3].

We have used a primary beam of $^{12}$C at 23 MeV/u impinging on a $LN_2$ cooled $H_2$ gas cell. The secondary $^{12}$N nuclei have been produced in the H($^{12}$C,$^{12}$N)n reaction. The entrance and exit windows of the gas cell were made of havar foil of 4 μm each and the pressure in the cell was p=1.5 atm. Due to the large negative Q-value of the reaction $Q_{(p,n)}$=-18.12 MeV, the energy of the primary beam has to be large. Therefore the energy of the recoiling products, which is larger than needed for the secondary proton transfer reaction (10-12 MeV/u), needs to be degrade it behind the production target. A 250-μm-thick Al foil was put behind the target cell as an energy degrader. Various production scenarios such as charge exchange around 0° (forward angle solution), around 180° (backward angle solution) or the fusion-evaporation mechanism were considered and the production was measured for each. To quantify the influence of the multiple scattering in the Al degrader foil, we have determined the production rate with and without it in place. We have found its influence to be marginal. MARS was tuned for each case and the $^{12}$N production was determined by counting the $^{12}$N yield in the target detector relative to the primary beam integrated in the Faraday cup in the coffin of MARS. The target detector used was a 300 μm 16 strip position sensitive Si detector. The secondary beam was tuned at very low intensities of the primary beam to restrict the bombarding rate to be below 100 Hz. The procedure has been described elsewhere [4]. The results are summarized in Table I. Obviously, the forward angle solution gives the largest production rate. With this productivity we expect to have secondary beams of around $10^5$ pps. We will use this method for the main run in May 2006.

**TableI.** Summary of results for $^{12}$N production.

| **Production mechanism** | **degrader** | **E/A ($^{12}$N) [MeV/u]** | **$N_{ev}$($^{12}$N) [events/nC]** |
|---|---|---|---|
| *forward angle solution* | 250 μm Al | 13.1 | 185 |
| *backward angle solution* | 250 μm Al | 9.5 | 40 |
| *fusion-evaporation* | 250 μm Al | 11.4 | 33 |
| *forward angle solution* | none | 19.6 | 173 |


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