TAGGING OF ISOBARS USING ENERGY LOSS AND TIME OF FLIGHT MEASUREMENTS

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One expects isobaric contaminants to be present in beams delivered at radioactive ion beam (RIB) facilities. A mixture of beams with similar mass to charge ratios with equal rigidity from a fragmentation source or isobars that escape separation in beams delivered from an ISOL source introduce significant amounts of isobaric contamination. Since isobars are very close in mass their separation is not an easy task. Magnetic separation at the level of 1:20,000 can be attained for beams with low emmitance. Using an ionization chamber to tag the beam charge (for mass resolved beams) can be effective for low count rates. This paper describes the application of a passive absorber and time of flight measurements to isobar tagging. Predictions of resolving power with this method are compared to measurements in several cases and limits to it's applicability are discussed.

At energies well below 1 GeV/nucleon the energy lost by the moving ion is due to ionization of the medium's atoms. This energy loss is approximated by the Bethe-Bloch formula [1]:

$$\frac{dE}{dx} = \frac{4\pi\ N_0 z^2 e^4}{mv^2}\frac{Z}{A}[\ln(\frac{2mv^2}{I(1-\beta^2)}) - \beta^2]$$

The projectile dependence in this formula is through the nuclear charge, z, and kinetic energy, mv^2. Therefore the fractional difference in energy loss suffered by two neighboring isobars moving at the same speed is given approximately by $2/z$. For the case of $z = 28$ nuclei (^{56}Ni and ^{56}Co) this amounts to about 7% relative separation. If the amount of energy lost by the ions in the absorber is also a significant fraction ($0.1 \leq p \leq 0.5$) of the total particle energy, the difference in isobar energies as they emerge from the absorber becomes significant and detectable ($0.007 \leq \Delta E/E \leq 0.035$ in the above case). After neighboring isobars pass the absorber the difference in momentum or velocity between them is such that a magnetic separator or a time of flight measurement with modest resolution can effectively separate the isobars.

Effective separation can be achieved when energy loss is near 30% of the incident energy and uncertainty due to absorber inhomogeneity is kept well below 0.5%. To this end a gas absorber with two thin mylar window foils supported by a wire frame is used. The detector arrangement used for the measurements reported here is shown in Figure 1. The time resolution is near 200ps fwhm and most of the spreading in the measured velocity spectra originates from energy straggling of the beam [2]. Figure 2 compares calculated and measured energy spread and energy loss difference for isobars passing the gas abosrber (i.e no appreciable spread due to absorber inhomogeneity). Measurements were done with separated ^{132}Te. The results show that at this energy separation is possible but not complete. Results of post-absorber velocity spectra for a mixture of A=132 isotopes, produced by the HRIBF fission source and accelerated to 450 MeV [3], are shown in Figure 3 confirming that the predicted degree of separation is indeed attainable.

References

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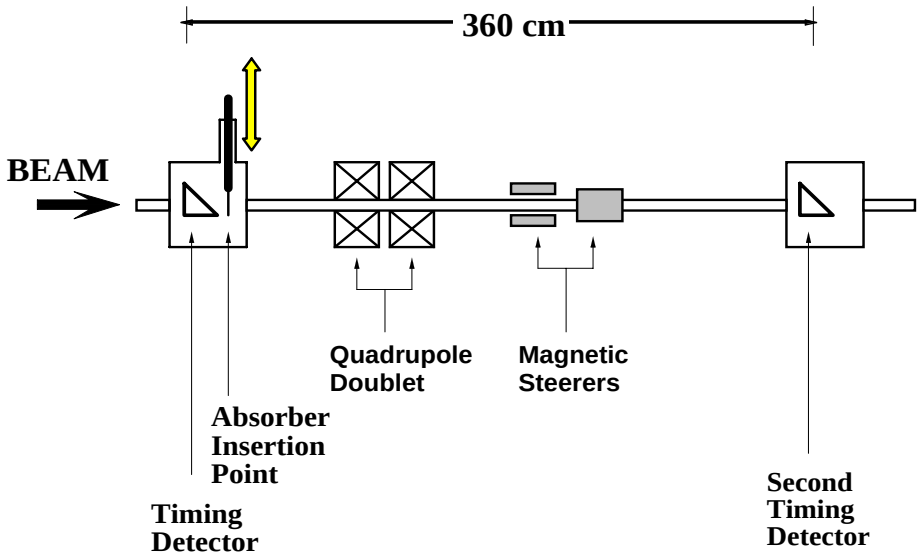

Figure 1: Beam line setup for studying isobar tagging.

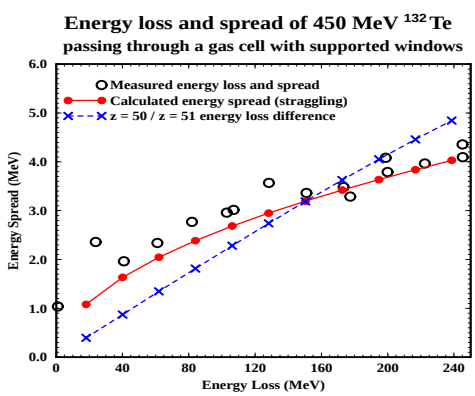

Figure 2: Measured and calculated energy spread for 450 MeV ^{132}Te passing through the gas cell and the anticipated [4] separation for $z = 51$ and $z = 52$ isobars.

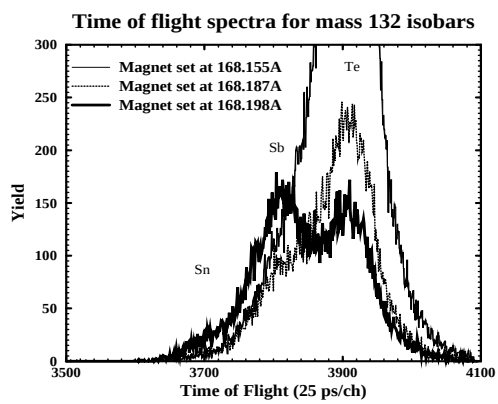

Figure 3: Time of flight spectra for a mixture of accelerated ^{132}Te, ^{132}Sb and ^{132}Sn with different field settings of the second stage isobar separation magnet at the HRIBF ion source.