A RECOIL SEPARATOR FOR ASTROPHYSICS AT THE ADVANCED ISOL FACILITY

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The direct measurement of proton and alpha capture reactions on radioactive species can significantly improve the understanding of a number of astrophysical events such as novae, supernovae, and X-ray bursts, and will be an important experimental program at the Advanced ISOL Facility. Recoil Separators are ideally suited for measuring these reactions in inverse kinematics - using a radioactive heavy ion beam and a hydrogen or helium target - since they offer the possibility of focusing 100% of a given charge state of the capture reaction recoils onto a detector system. The experimental challenge is to maintain a high transmission of the capture reaction heavy recoils while maximizing the rejection of the primary beam. This is difficult because of the small mass and momentum difference between the projectiles and recoils. It is also difficult because all of the projectiles enter the separator, and the projectiles therefore have an intensity 10^{10} - 10^{15} times larger than the recoil intensity. The scattered beam rejection is enhanced by filtering out particles on the basis of both velocity and M/Q, which necessitates the use of either velocity filters combined with magnetic dipoles, or a combination of electric and magnetic dipole elements. Additionally, placing two arrangements of such devices back-to-back, but in reverse order, can cancel important ion-optical aberrations at the final focal plane. An outline design based on these principles has been made for a separator for the Advanced ISOL facility. The separator, which will utilize elements of the existing Daresbury Recoil Separator along with seven new quadrupole and two new dipole magnets, is shown in Figure 1.

Additionally, we drew up general specifications for an Astrophysics Recoil Separator which were presented at the LBNL Workshop on Instrumentation for the Advanced ISOL Facility. These specifications, which are included in the workshop final report, are as follows:

a. High transport efficiency for a relatively small solid angle (due to the inverse kinematics, the maximum angles of the ejectiles are not exceeding a few degrees); approximately 100% transmission per charge state of recoils is desired.

b. High beam purification: beam rejection of 10^{-12} (hopefully 10^{-15}) by the separator alone for proton capture reactions over a broad mass range of beams.

c. Relatively low mass resolution is required ($M/\delta M$ less than or approximately equal to 200)

d. Target chamber capable of accommodating a variety of detector arrays of Si (or other) detectors for (p,p), (p,α), etc. measurements.

e. The ability to accommodate gas targets (both jets and extended targets).

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f. The capability of running with different ion optical modes for reactions with different kinematics.

g. Incorporation of careful beam handling upstream of the separator (e.g., clean recoil beam with small dispersion and no beam halo).

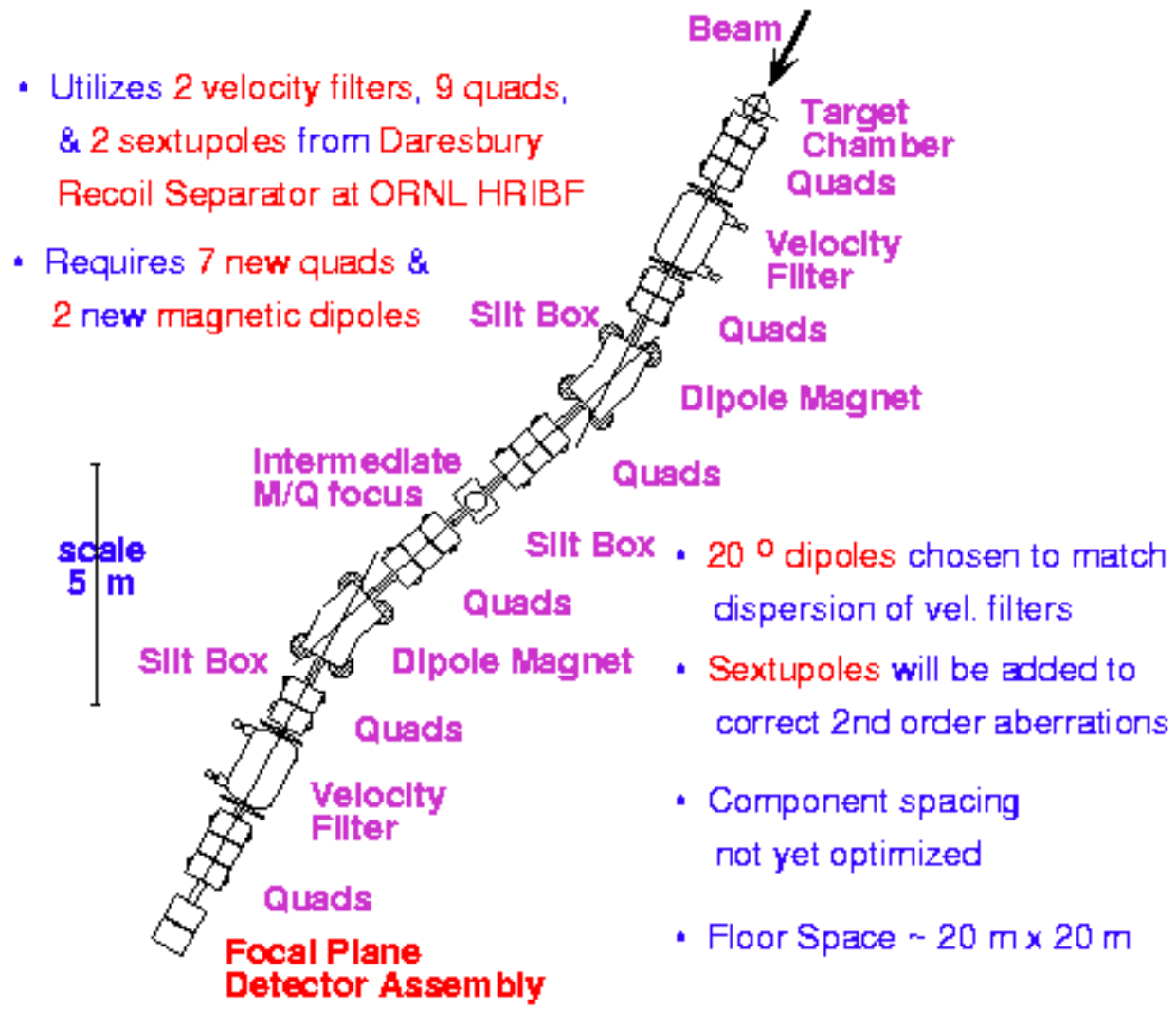

Figure 1: A Recoil Separator for the Advanced ISOL Facility