

## Separator for Unique Products of Experiments with Radioactive Beams - SUPERB

### **1. What is the primary physics motivation and experimental capability of the proposed instrument and why is this important for FRIB science?**

Reaccelerated radioactive beams at FRIB will offer unique opportunities for studies of exotic nuclei. In recent years electromagnetic mass separators played essential role in dramatic advances in nuclear structure far from the line of stability at stable beam facilities worldwide. They separated exotic reaction products from unreacted beam and dispersed them according to their mass to charge state ratio. In conjunction with a suite of focal plane detectors they provided full identification of the recoiling reaction products. A similar device will be indispensable for in-beam gamma-ray spectroscopy or decay studies of exotic nuclei produced in fusion-evaporation reactions with reaccelerated radioactive beams at FRIB.

### **2. What are the unique capabilities of this device that are not available in existing equipment? Is this instrument stand alone or is it to be used (solely or partially) in conjunction with other instruments. Could it be used at NSCL or other laboratories before FRIB?**

The proposed separator will be used with reaccelerated beams in connection with an in-beam gamma-ray array and an implantation-decay station. The device would be primarily located in the Rea12 experimental area. Compared to existing electromagnetic mass separators it would have a much larger M/Q acceptance, i.e., it would transport more charge states, resulting in much larger overall efficiency.

### **3. Describe the instrument in some detail – how does it meet the scientific requirements and what are the (estimated) performance specifications? Be brief but as detailed as you can. Is the design fixed or are multiple options still being discussed and encouraged?**

The design of the proposed Separator for Unique Products of Experiments with Radioactive Beams (SUPERB) is based on the S3 separator designed by S. Manikonda and J. Nolen from the Argonne Accelerator group together with collaborators from France. The S3 separator will be used with the SPIRAL2 facility at GANIL which will deliver intense stable beams. The S3 separator consists of two sections: the momentum achromat for beam suppression and the mass separator. For experiments with relatively low intensity radioactive beams the beam suppression is not as important and the mass separator section alone will be sufficient. Compared to other electromagnetic separators the S3 separator has a much larger M/Q acceptance. For example, for experiments in the  $^{100}\text{Sn}$  region mass as many as 5 charge states are transported, compared to the usual 2-3, resulting with an overall efficiency exceeding 50% of all recoils. Similar or better efficiency is expected for the  $^{63}\text{Ga}+^{40}\text{Ca}$  or  $^{75}\text{Rb}+^{28}\text{Si}\rightarrow^{100}\text{Sn}+p2n$  reactions with radioactive beams at 3.3 MeV/n.

SUPERB will consist of an electric dipole and a magnetic dipole each sandwiched between two quadrupole triplets. According to optics calculations it will have an angular acceptance of +/-50 mrad in both planes, Bp acceptance of +/-10%, a magnetic rigidity of 2 Tm, an electric rigidity of 12 MV and a mass resolution of more than 1/300(FWHM). The distance between the target and the first quadrupole is ~1m which is sufficient to accommodate a Ge array. The overall length of the currently considered device is ~14m and fits within 4.5mX13m rectangle. A possible location is shown on the attached FRIB layout with ample space for both an in-beam Ge array and a decay station.

The final design details and size might change slightly when the performance of the mass separator is optimized for use without the momentum achromat.

**4. What is the current stage of development of your project?**

The design of the S3 separator is in final stages. The S3 project is to be funded from several sources including French government agencies. A DOE FOA proposal to collaborate on the design and construction of SPIRAL2, the S3 separator, and experimental equipment was approved. The S3 separator is expected to be commissioned in 2013. Experience with the S3 separator will be directly applicable to the proposed separator. The engineering and manufacturing costs will be lower since identical elements could be used to construct SUPERB.

**5. What is the approximate cost of the project: discuss possible sources of funding.**

Based on the estimates for the S3 separator the total cost of the proposed separator, the beam line and vacuum equipment included, would be about \$4M.

**6. Please provide a brief list of collaborators and institutions. Spokesperson(s) provide contact info.**

J. Nolen, S. Manikonda, D. Seweryniak ANL, A.M. Amthor GANIL, plus interested members of the larger S3 team, and other interested collaborators world-wide.

**7. Please can you outline how your collaboration has been developing your project and how you are growing your collaboration (How many meetings? Participants?, Circular mailings? Have you a web-site?)**

The core of the group are members of the S3 collaboration. It is our intention to use the experience gained from the design and commissioning of the S3 separator for the construction of SUPERB. We meet frequently to discuss various design issues.

**8. Did you consider alternative designs? What alternatives were considered? How did you arrive at a final design?**

The S3 group compared all existing and proposed mass separators for acceptance, beam rejection, and mass resolution. From these studies the present Momentum Achromat, Mass Separator concept emerged for use with intense stable beams. The mass separator section of S3 appears well optimized for use with radioactive beams if physical separation of the mass channels is required. There are significant differences between the proposed electromagnetic mass separator and the ISLA separator. SUPERB offers 2 times larger M/Q acceptance, physical separation between nuclei with different mass numbers. Also no time reference is required to obtain mass information. ISLA exhibits much larger solid angle and higher rigidity. However, for fusion-evaporation reactions the rigidities of the proposed separator are sufficient. One could also consider having a second set of electrodes with a smaller gap to accommodate experiments in inverse kinematics which require higher electric rigidity. In many ways the ISLA and SUPERB concepts are complementary.

**9. What existing equipment exists in the US Community that has similar goals and characteristics, even if inferior in performance.**

The Fragment Mass Analyzer at the Argonne National Laboratory and the Recoil Mass Separator at the Oak Ridge National Laboratory have been successfully used for fusion-evaporation reactions with stable beams for more than a decade. The EMMA separator for research with reaccelerated beams at TRIUMF is under construction.