ISLA: Isochronous Spectrometer with Large Acceptance

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

This instrument is intended for the re-accelerated radioactive beams of ReA12, at energies varying between 1 and 12 MeV/u. It would provide a unique combination between very high M/Q resolution for precise identification of the reaction products, and large acceptances to achieve high transmission efficiency. This device would be essential to the science conducted using reactions at energies around the Coulomb barrier, such as fusion-evaporation, deep-inelastic, or Coulomb excitation. It is especially well adapted to the use of low intensity, re-accelerated radioactive beams provided by the ReA12 accelerator fed first by the NSCL driver, then the FRIB driver. Some of the the broad physics motivations covered by this device are changes in shell structure, states of high angular momentum, study of fission barrier, or decay studies of drip-line proton-rich nuclei.

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 unique capabilities of ISLA can be enumerated in the following list:

- high resolution M/Q tagging using time-of-flight and isochronous design - from 1/1000 to 1/10000 depending on the time-of-flight and RF bunch size. Existing spectrometers have typically around 1/300 M/Q resolution.
- large acceptances (both geometrical and momentum) combined with small image at focal plane. Spectrometers with large acceptances usually have large focal planes.
- vertical incoming beam swinger with large angular range (0° - 60°).

ISLA can be used in conjunction with other instruments, both around the target location (typically with gamma-ray detector arrays such as Gretina or Greta), and at the final focal plane (typically implantation and decay observation setups).

The beam rejection is accomplished by the magnetic rigidity selection of the spectrometer, and at the intermediate dispersive focal plane for the beam charge states falling into the acceptance. The rejection requirements are less stringent than on spectrometers using stable beam, because the intensities of re-accelerated radioactive beams from ReA12 are relatively low (< 10^8 pps). This instrument can be used at NSCL after the completion of the ReA12 accelerator.

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 ISLA spectrometer is composed of 4 identical dipoles bending in the same direction, for which it is possible to realize a point-to-point isochronous solution between object and image (see fig. 1). The performances are summarized below:

- Acceptances: 63 msr (± 200 mrad horizontal, ± 80 mrad vertical), ± 5% momentum.

- Resolution: M/Q 1/4,700 without aberration correction, 1/10,000 with correction.
- Beam size at image: within ± 10 mm in both planes
- Maximum rigidity: 3.2 T.m.

The high resolution M/Q relies on the time-of-flight measurement between the final focal plane detectors and the RF signal of the ReA12 accelerator. Depending on the velocity of the reaction products, various bunching schemes of the ReA12 linac can be employed to adjust the M/Q acceptance and resolution (see https://groups.frib.msu.edu/group/project/bunching-optimization).

4)What is the current stage of development of your project ?

This project is at the Concept Development stage. The conceptual and basic optics designs of ISLA are close to final (see https://groups.frib.msu.edu/group/project/optics-studies). Calculations of high order aberrations and their effect on the M/Q resolution have been performed, but they ultimately depend on the choice of magnet technology. The next step will consist on an exploration of these choices, their cost and feasibility estimates. A preliminary discussion can be found in these pages (https://groups.frib.msu.edu/group/project/magnet-studies).

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

The main cost comes from the 4 large gap dipoles, for which a design based on iron-free magnets has been estimated at $5.5M of procurement. A preliminary approximate cost has been evaluated at $11M, including parts and labor. A detailed budget is posted on our web site at https://groups.frib.msu.edu/node/50.

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

The ISLA working group has presently 26 members from 7 institutions: NSCL/MSU, RIKEN, LBNL, Florida State U., ORNL, ANL, and LNS (Italy). The conveners are D. Bazin (bazin@nscl.msu.edu) and W. Mittig (mittig@nscl.msu.edu).

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?)

Several meetings and visits by collaborators, as well as seminars have happened. The main communication tool is the web site (https://groups.frib.msu.edu/group/isla). This site provides information to anyone, and allows members to discuss topics in a blog-like format.

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

Designs similar to existing spectrometers such as the FMA (Argonne) or VAMOS (GANIL) were considered, but none covers all the advantages offered by the ISLA design: large acceptances, small aberrations, high M/Q resolution and small beam size at focal plane.

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

- FMA at Argonne National Laboratory.
- RMS at Oak Ridge National Laboratory.

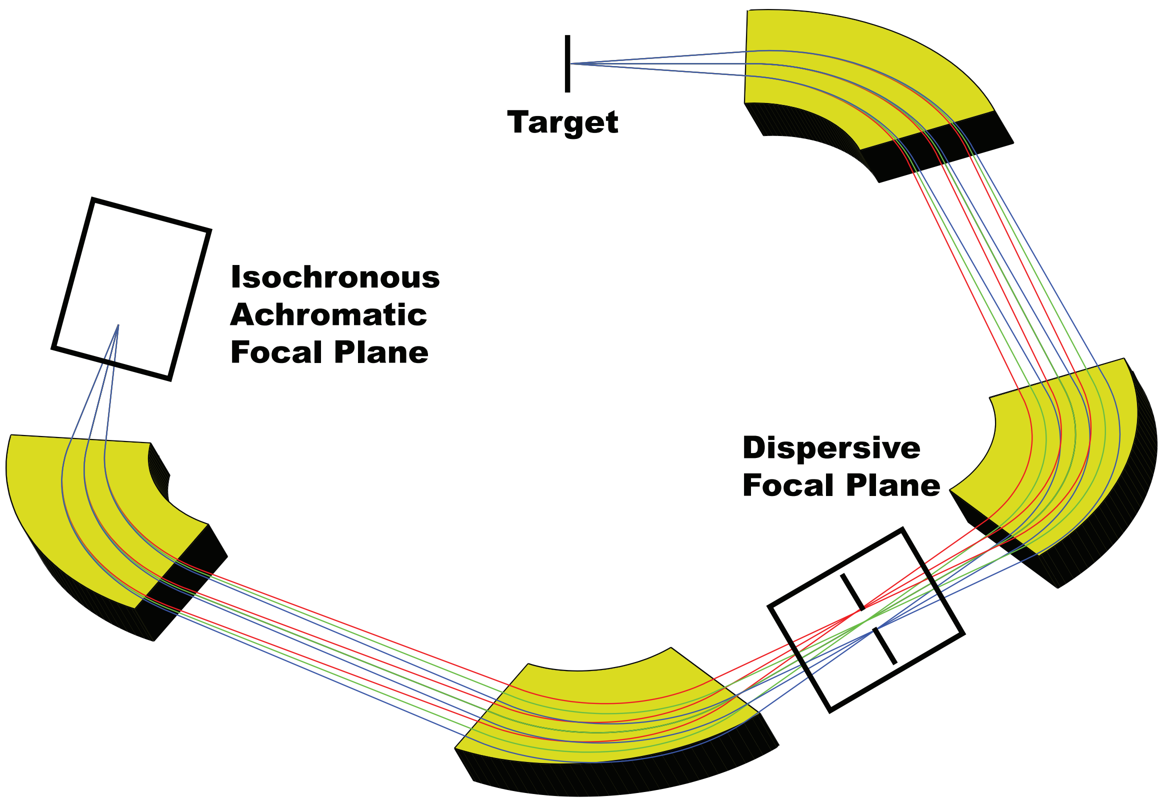

Fig. 1: Conceptual design of ISLA. The spectrometer is composed of 4 bending sections each made of a single dipole magnet and drift lengths. The main advantages of this design are the high M/Q resolution, combined with large geometrical and momentum acceptances. Thanks to the isochronous optics, the time-of-flight is a direct measurement of the M/Q, regardless of the momentum of the particles. The dispersive focal plane located at the symmetry point provides a convenient way to block unwanted charge states of the beam which fall within the momentum acceptance. A vertical beam swinger (no shown in this figure) allows to rotate in the incoming radioactive beam on the reaction target. All reaction products selected by the spectrometer are tightly focused at the final isochronous focal plane, which greatly facilitates implantation-decay types of experiments.

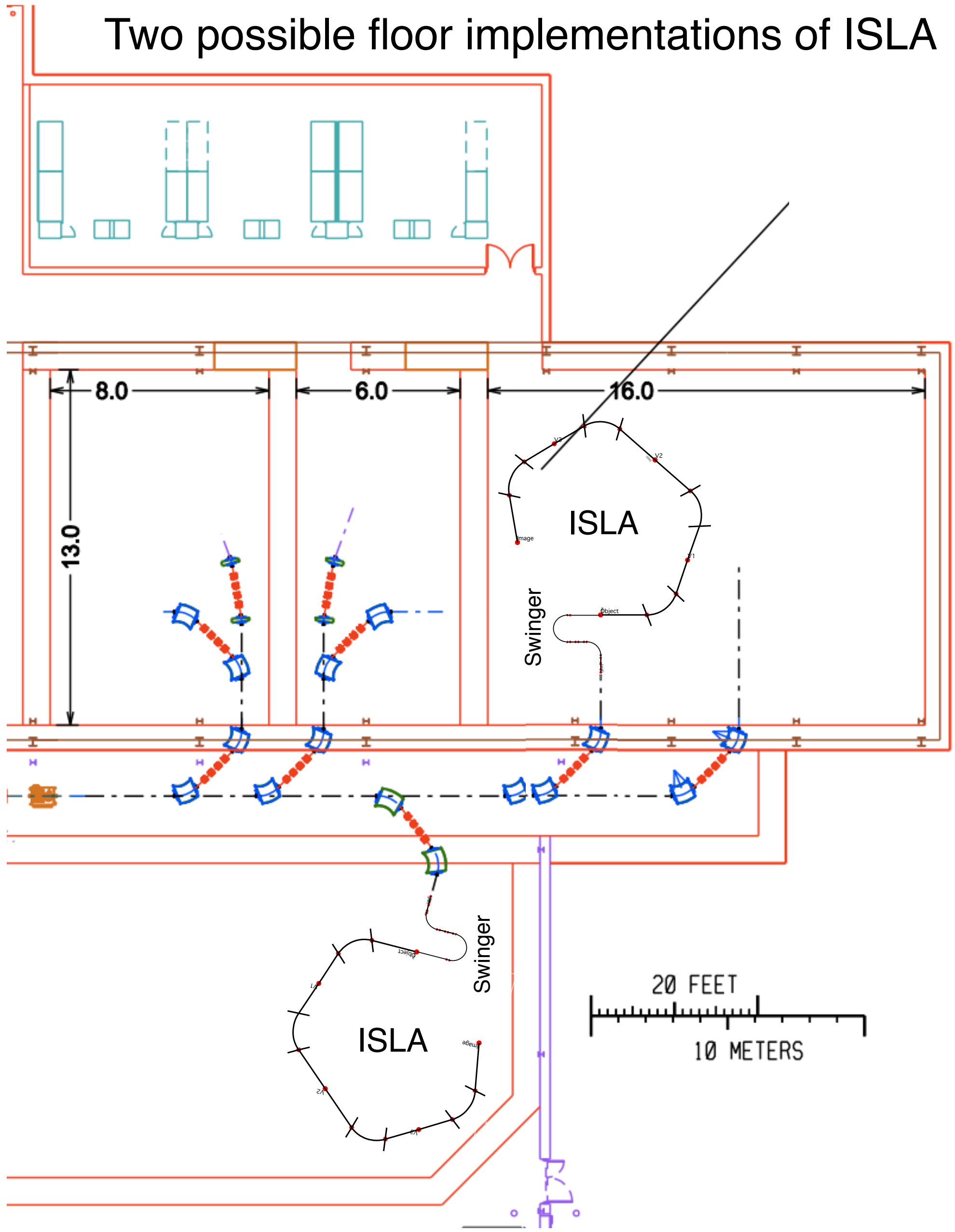

Fig. 2: Possible floor implementations of the ISLA spectrometer in the ReA12 experimental area. The spectrometer and its beam swinger are schematically drawn to scale.