HELIOS @ FRIB Questionaire

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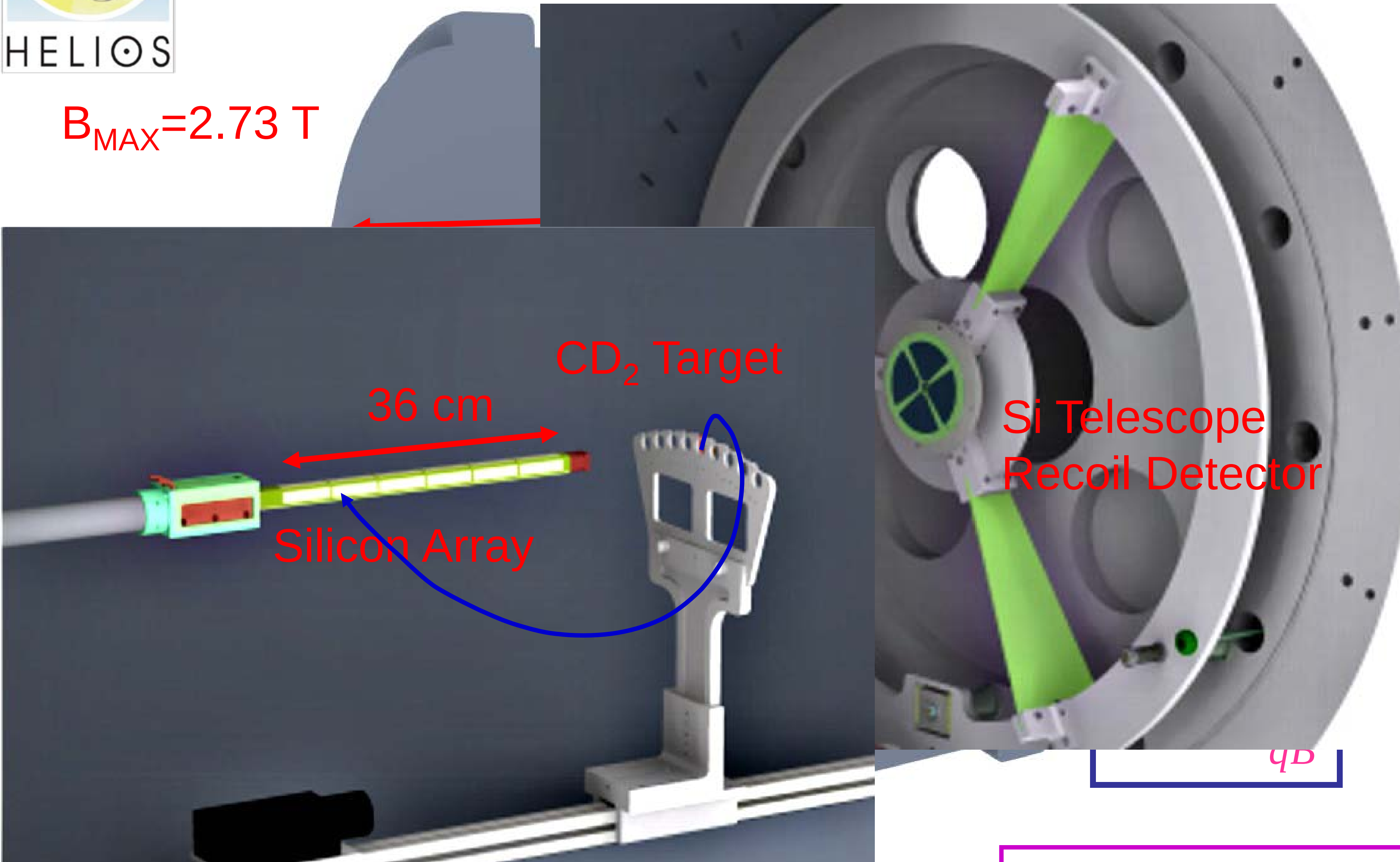
HELIcal Orbit Spectrometer -HELIOS

B_{MAX}=2.73 T



NIM A **580**, 1290 (2007)

Floor plan in ReA12 experimental area

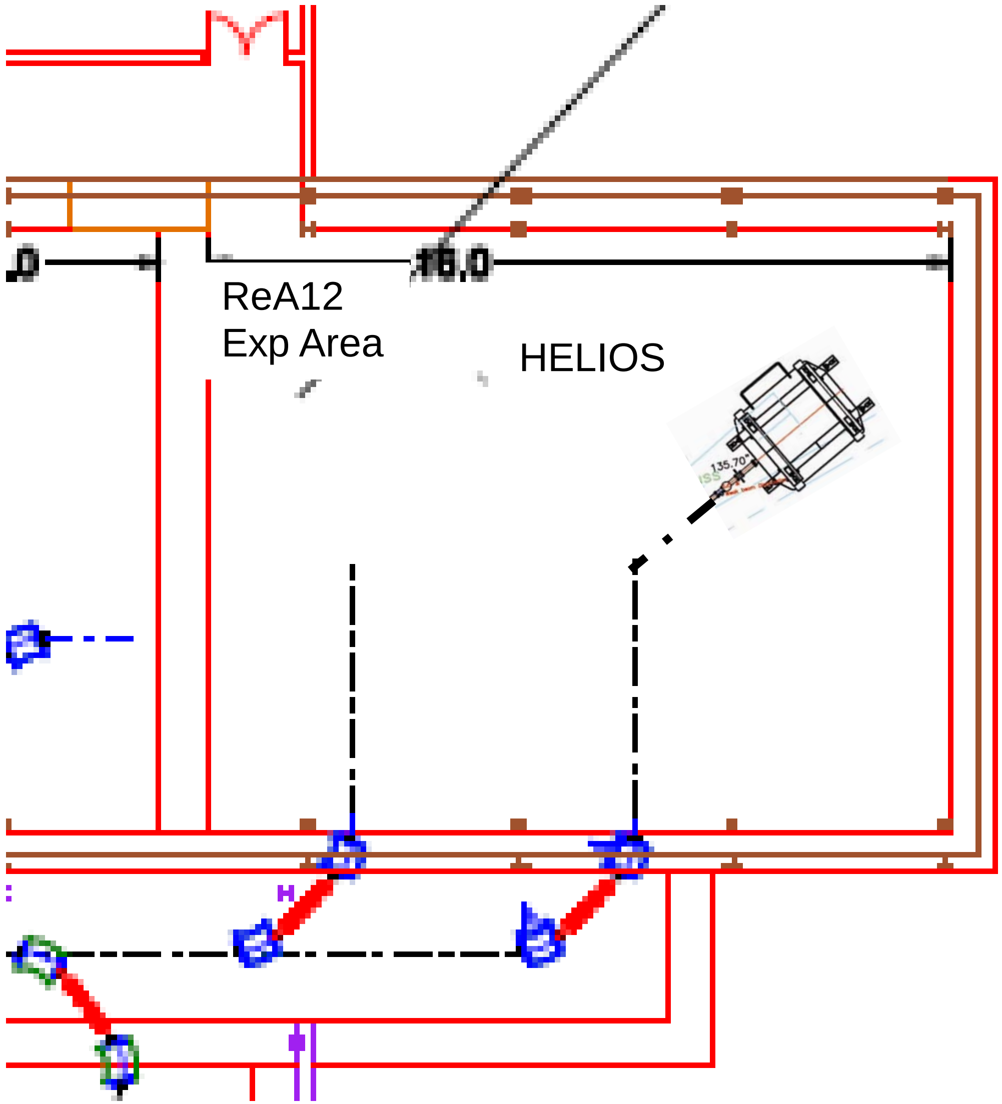


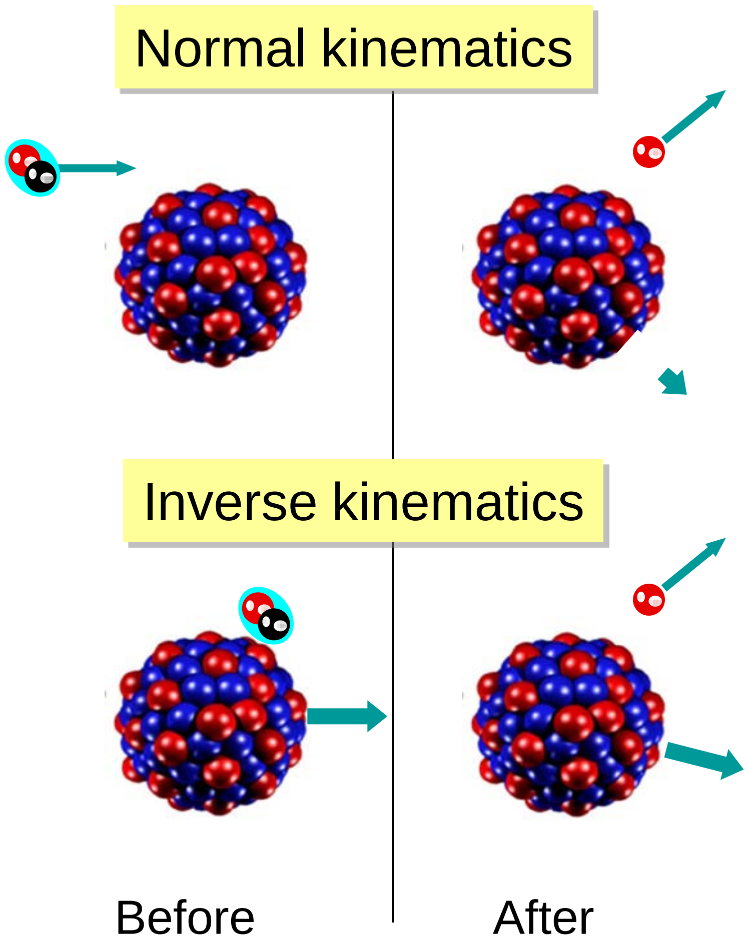
Figure to indicate necessary floorspace

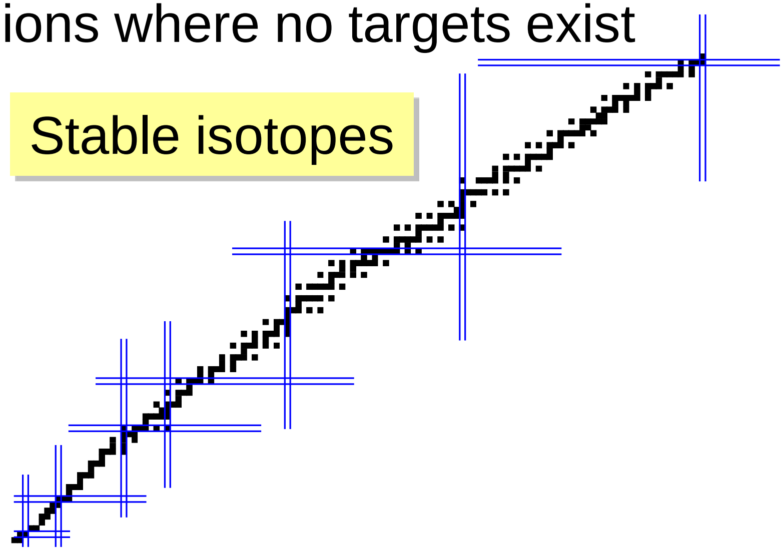
What is the primary physics motivation and experimental capability of the proposed instrument and why is this important for FRIB science?

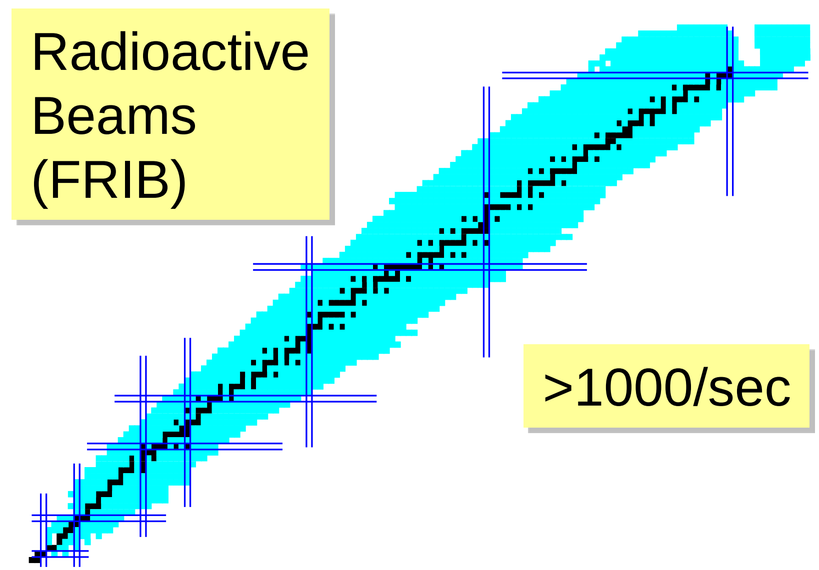
- The primary physics motivation for this device is to study nucleon transfer and scattering reactions in inverse kinematics. The experimental capability of the device is to detect light charged particles such as protons, deuterons, tritons, 3He, and alpha particles.
- The kinematic correlations of the light particles are directly translated from the center-of-mass system, and the resolution of excited states in the residual nuclei is considerably better than can be achieved with silicon-detector arrays measuring at fixed angles in the laboratory. This instrument allows for a wide range of nuclear structure and reaction studies using re-accelerated exotic beams from the FRIB facility. Areas of particular interest is the single particle structure and correlations in very neutron-rich nuclei in order to refine our understanding of such nuclei. Neutron transfer reactions can also provide information about radiative neutron-capture processes of interest for astrophysics with respect to the r-process.

Inverse kinematics – wide applications

- Precision studies of nuclei in regions where no targets exist







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 device has the capability to measure transfer and scattering reactions with better resolution than is possible with setups using only arrays of segmented silicon detectors. This improvement in resolution applies to reactions producing particles in both the forward and backward hemispheres. This instrument can operate in a stand-alone mode, or with detectors to observe the recoiling heavy partner. The recoil detector can be an internal set of silicon detector telescopes, an external gas ionization counter, *or more sophisticated recoil spectrometer*. The device could be used with beams from the ReA3 facility, or its higher-energy extensions before the full implementation of FRIB. An existing device of this type is operational now at the ATLAS facility at Argonne National Laboratory.

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 device utilizes a large-bore (~1 m diameter) high-field (B~ 3T) solenoid to transport particles from a target positioned on the solenoid axis, to a compact array of position-sensitive silicon detectors centered on the solenoid axis, either upstream or downstream of the target. The energy, time of flight, and distance from the target are recorded. The *flight time measures the mass-to-charge ratio of the detected particle*, and the energy-position correlation yields the center-of-mass energy and angle for the detected particle. The resolution in the cm frame is limited only by the intrinsic silicon detector resolution and the spread in beam energy from the target. For (d,p) reactions, the observed excitation-energy resolution is better than 100 keV. The conceptual design of this device is fixed.

Re-Accelerator requirements

- Beam pulse width: $\Delta T \sim 1$ ns
- Beam microstructure: ~100 ns between pulses

What is the current stage of development of your project ?

- A device of this type is in operation now at the ATLAS facility at Argonne National Laboratory. A new gas ionization chamber recoil detector will be installed there in 2010. A new device requires the procurement of a new solenoid magnet, and construction of associated mechanical components, including chamber flanges, beam line, silicon detector procurement and silicon detector array construction, etc. Design drawings exist for the device already in operation.
- The existing device was constructed as a demonstration device. A larger bore, higher field magnet is needed for the FRIB program to collect particles with large m/q (~3, e.g. tritons).

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

- The replacement cost of a the existing device at ANL is approximately $2M.
- A new device with larger, high-field magnet and fully instrumented silicon detectors is approximately $4M.
- Possible funding sources include the Department of Energy, or the National Science Foundation (MRI program?)

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

- A.H. Wuosmaa, Western Michigan University   Alan.Wuosmaa@wmich.edu
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- K.E. Rehm, Argonne National Laboratory
- J.P. Schiffer, Argonne National Laboratory
- R. V. F. Janssens, Argonne National Laboratory
- H. Y. Lee, Los Alamos National Laboratory
- A. Macchiavelli, Lawrence Berkeley Natl. Lab.
- W. Lynch, Michigan State University
- M.B.Tsang, Michigan State University
- D. Bardayan, Oar Ridge National Laboratory
- J. Escher, Lawrence Livermore Natl. Lab.
- J. Blackmon, Louisiana State University
- J.A. Cizewski, Rutgers University
- Kate Jones, University Of Tennessee
- R. Kozub, Tennessee Technical University
- R. Krucken, Munich
- S.J. Freeman, Manchester University
- Steven Pain, University of West Scotland
- R. Kanungo, St. Mary’s University

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?)

- A collaboration has been in place since Sept 2004, to construct and commission the existing HELIOS device. The collaboration holds weekly meetings with typically 10 participants.
- A web page describing the device exists at the ANL ATLAS web site.

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

- The final design was arrived at based on extensive simulations, including various detector and magnetic field configurations. The result was driven by a few, simple design considerations that optimize center-of-mass energy resolution, acceptance, etc. It is a fortunate fact that the parameters for the demonstrator device (field strength, magnetic field homogeneity, bore size etc.) are close to those of modern MRI medical imagining devices, such that suitable magnets are available commercially. A stronger, larger magnet is preferable for the FRIB implementation of the concept.

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

- A variety of different silicon-detector arrays exist to study nucleon transfer reactions. All rely on the approach of detecting particles at a fixed laboratory angle. One device dedicated to (d,p) reactions at low bombarding energies is the ORRUBA detector at HRIBF.
- The physics goals are similar but the characteristics and approach are very different.
- Apart from HELIOS, there is no comparable spectrometer in existence anywhere.

Conclusions

- Concept has been proven experimentally for (d,p) reactions
- The approach opens a large area of research for transfer and scattering reactions in inverse kinematics at FRIB
- Coupling to a recoil separator capable of providing A and Z identification will enhance its capabilities
- Possibilities exist for gamma-ray detection
- A collaboration for FRIB implementation is forming