A High Rigidity Spectrometer for FRIB

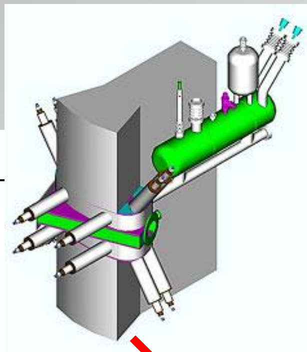
Goal

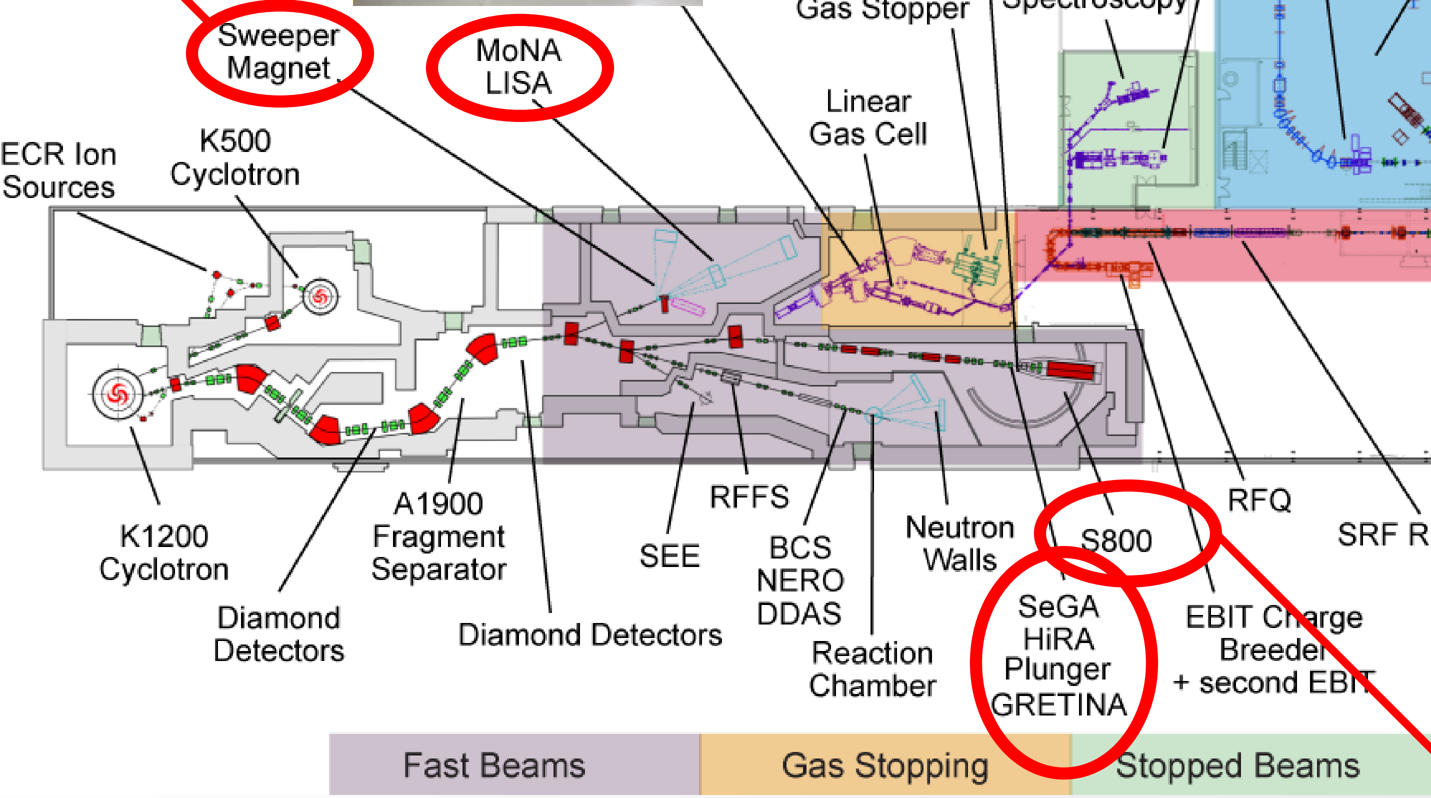
To design and build a High Rigidity Spectrometer and associated infrastructure at FRIB that provides users with access to beams of the rarest isotopes at the highest yields produced by in-flight fragmentation. The spectrometer should provide a flexible and efficient environment for performing state-of-the-art experiments with a wide variety of auxiliary detection systems, using fast rare isotope beams transported with minimal losses from the FRIB fragment separator.

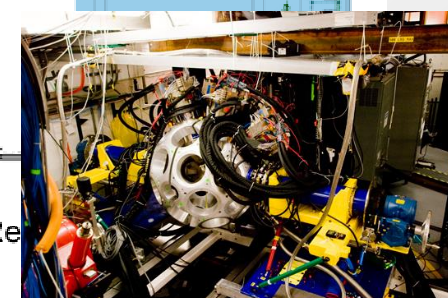
HRS Workshop - July 10/11, 2014 - Agenda

		start	length
Opening Reception - July 10th - NSCL Atrium		19:00	
Workshop - July 11th - Room 1221A/B			
Breakfast		8:00	0:30
Overview & Introduction	Remco Zegers	8:30	0:30 (20+10 for discussion)
Pre-conceptual designs	Thomas Baumann	9:00	1:00 (30+30)
SAMURAI@RIBF	Hideaki Otsu	10:00	0:30 (20+10)
Break		10:30	0:15
SHARAQ@RIBF	Georg Berg	10:45	0:30 (20+10)
Fragment Separator	Mauricio Portillo	11:15	0:20 (15+5)
HRS + MoNA-LISA	Jim Brown	11:35	0:20 (15+5)
EoS studies at the HRS	Zach Kohley	11:55	0:20 (15+5)
Lunch Break		12:15	1:00
Time-of-flight mass measurements at the HRS	Wolfgang Mittig	13:15	0:20 (15+5)
High-Z knockout experiments and resolution requirements	Daniel Bazin	13:35	0:20 (15+5)
Extending our reach of N=Z nuclei with the HRS	Andrew Rogers	13:55	0:20 (15+5)
Lifetime measurements at the HRS	Hiro Iwasaki	14:15	0:20 (15+5)
Inelastic Scattering experiments (tentative)	Chris Campbell	14:35	0:20 (15+5)
Break		14:55	0:15 (15+5)
prompt gamma spectroscopy and decay spectroscopy	Heather Crawford	15:10	0:20 (15+5)
Isoscalar giant resonances	Umesh Garg	15:30	0:20 (15+5)
Spin-isopin studies at the HRS	Remco Zegers	15:50	0:20 (15+5)
Discussion on white paper and Town meeting		16:10	0:50
Finish		17:00	

Spectrometers for fast beams at NSCL

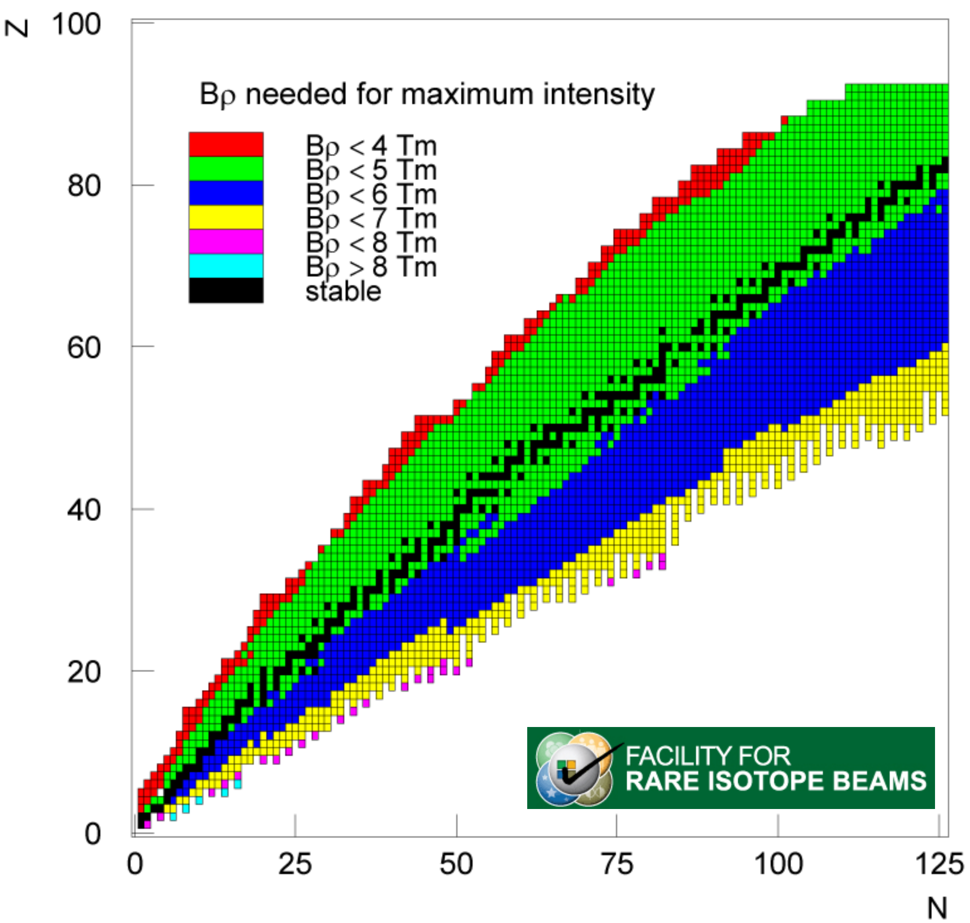






The magnetic rigidity of the S800 and Sweeper are limited to ~4 Tm.

By being able to perform experiments at rigidities at which maximum production yield is achieved, the HRS will strongly enhance the scientific output from FRIB, and will open new opportunities by allowing for experiments at higher and a wider range of beam energies.



Optimum rigidities for performing experiments with neutron-rich rare isotopes are beyond the capabilities of the S800 and Sweeper magnets.

Besides a loss in intensity, lowering the beam energy (either by starting with a lower primary beam energy, or slowing down the fragments) increases the level of contamination from other species and/or charge-states.

FRIB energy upgrade from 200 MeV/u to 400 MeV/u

High Discovery Potential

Experiments with fast beams allow for experiments closest to the neutron drip line

About 50% of NSAC RIB Taskforce benchmarks require experiments with fast beams (About 50% of experiments at NSCL require S800 spectrometer or sweeper magnet)

The program with the HRS at FRIB will maximize the output from other high-priority and very significant investments by DOE and NSF, such as GRET(IN)A and MoNA-LISA.

Total reaction/interaction measurements
Projectile fragmentation and in-flight fission
Invariant-mass spectroscopy
Time-of-flight mass measurements
Charge-exchange reactions
Life-time studies
Giant Resonance studies

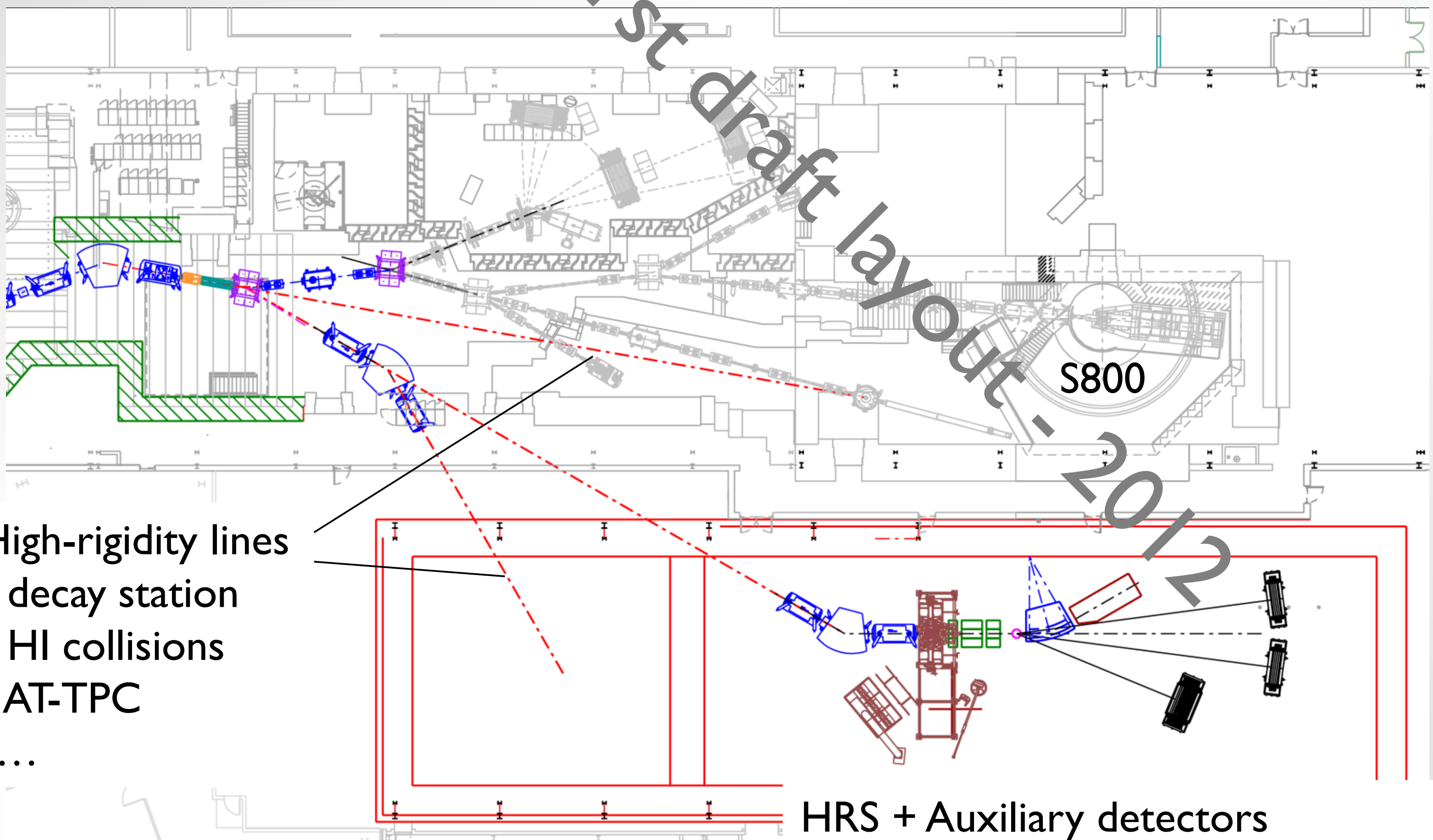
Knockout reactions
Quasifree scattering
Electromagnetic excitations
Elastic scattering
Inelastic scattering
Heavy-ion multifragmentation reactions
...

Fast-beams at FRIB

High Rigidity Spectrometer Replaces sweeper	S800	Multi-purpose station(s)
• High-Rigidity • Medium resolution • Variety of auxiliary detectors-maximize beam opportunities	• Medium rigidity (experiments at 50-100 MeV/u) • High resolution • Auxiliary detectors	• Decay Station • Heavy-ions collisions • AT-TPC • …

Be cognizant of the prospect that experiments with fast beams at FRIB should aim at, more so than ever, fully utilizing the available beam time. With the design of the HRS we have the opportunity to maximize the ways in which can study multiple channels simultaneously.

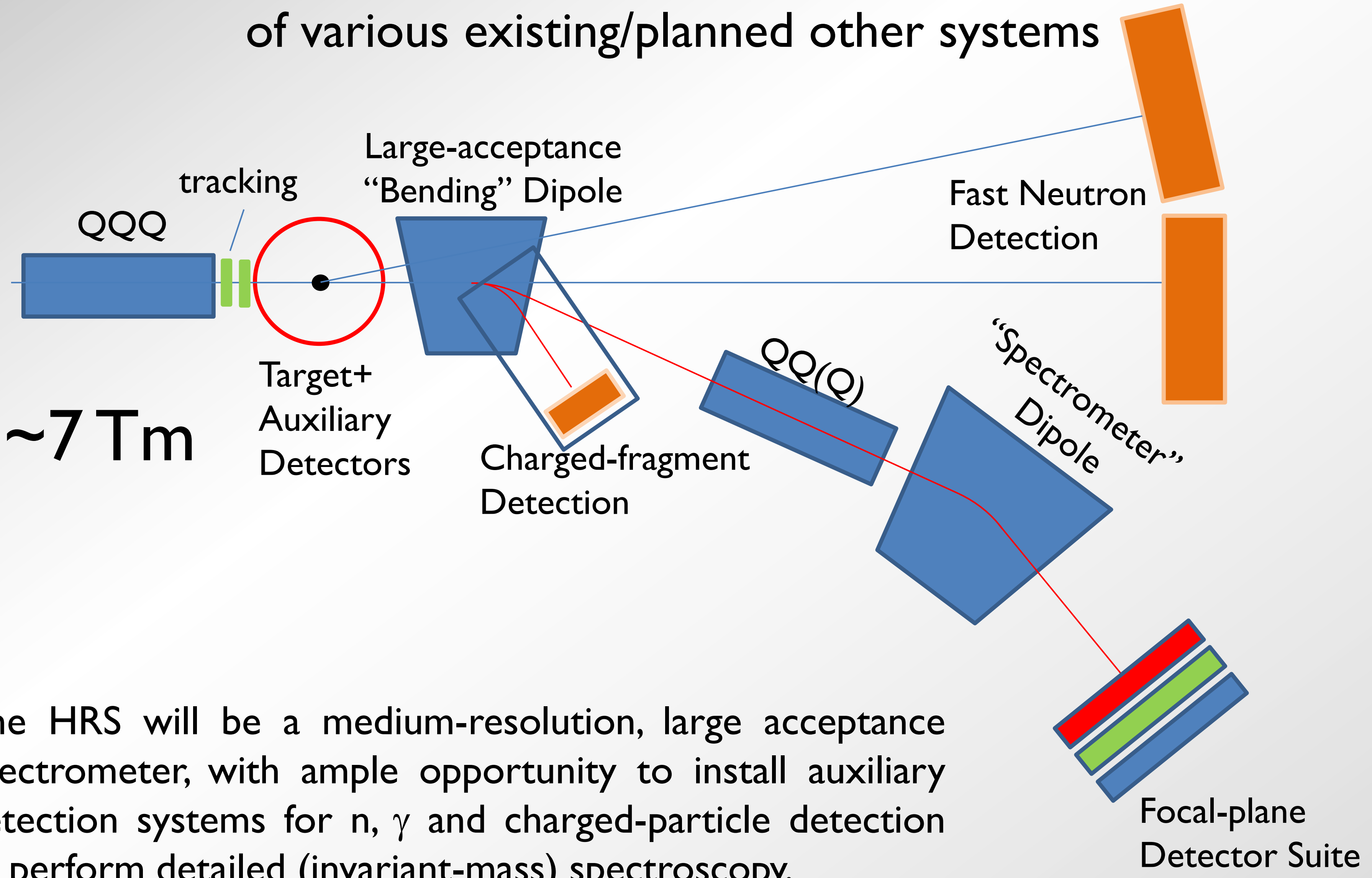
Strategic investment in laboratory infrastructure allows for the development of a high-quality and versatile experimental area for the HRS



High-rigidity lines
- decay station
- HI collisions
- AT-TPC
- …

HRS + Auxiliary detectors
(MoNA-LISA, GRET(IN)A, AT-TPC,etc.)

A very schematic layout discussed in the 2013 users meeting evolved from an earlier preliminary design and considerations of various existing/planned other systems

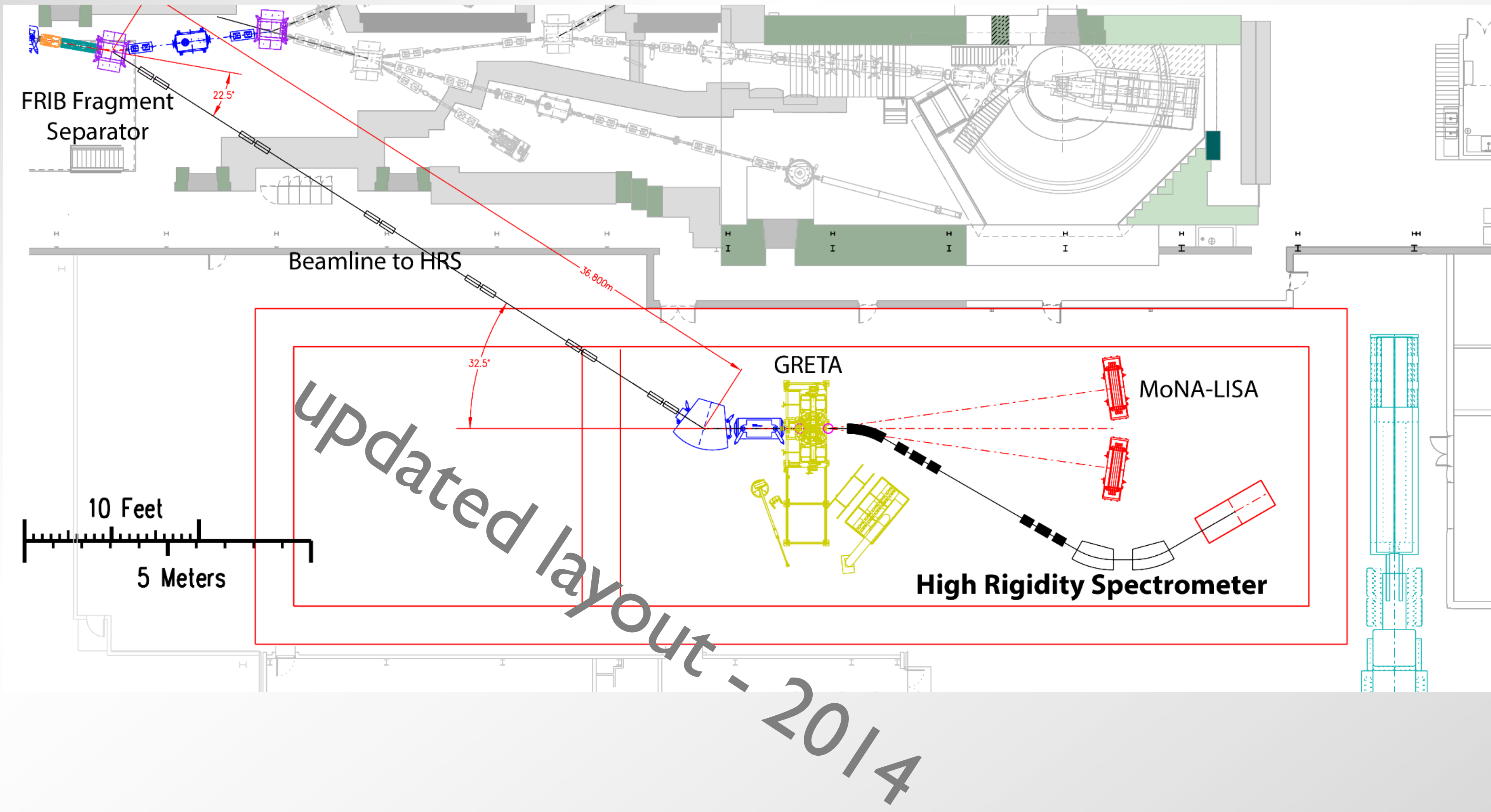


The HRS will be a medium-resolution, large acceptance spectrometer, with ample opportunity to install auxiliary detection systems for n, γ and charged-particle detection to perform detailed (invariant-mass) spectroscopy.

Basic properties

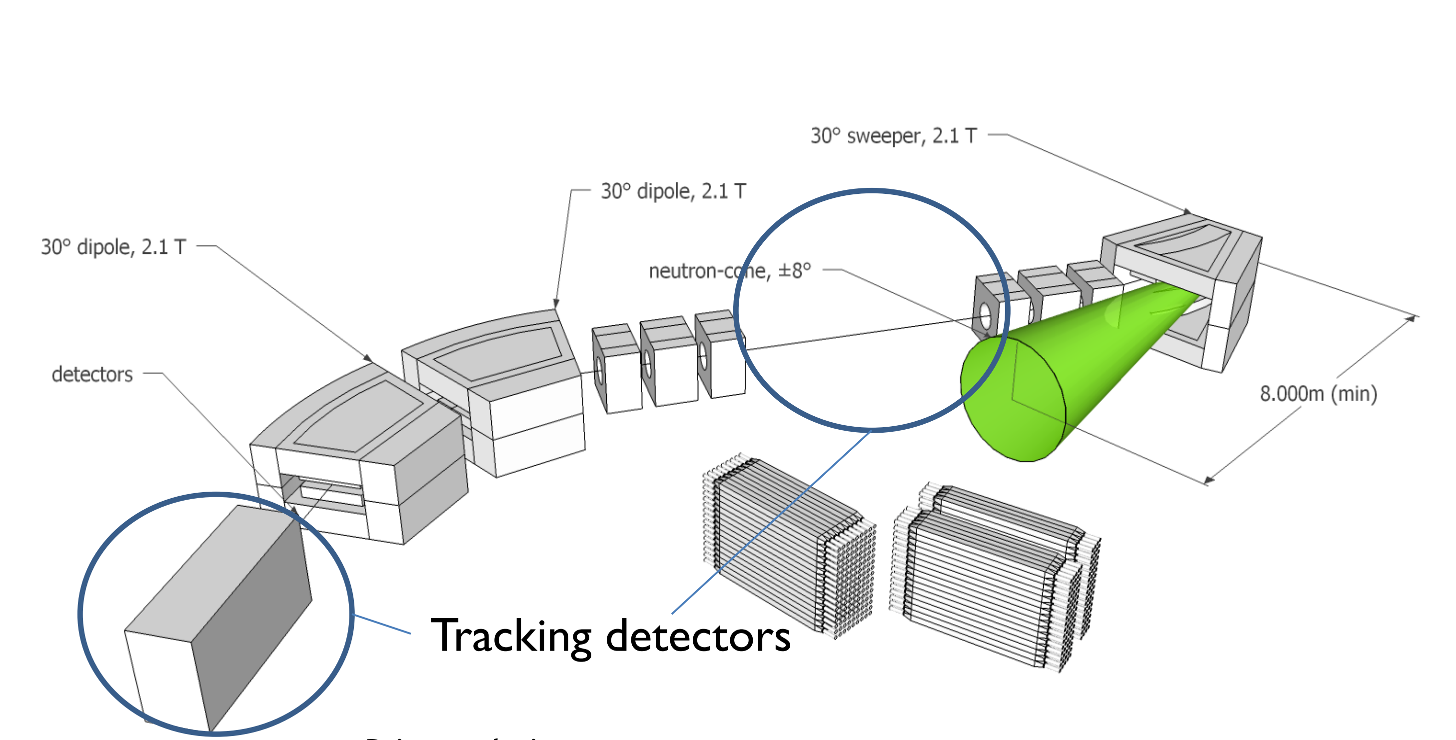
- Medium momentum resolution
- Good mass resolution for heavy masses (A~200 and above)
- Large acceptances – comparable to S800
- Large gap for detection of decay neutrons
- Versatile target station for auxiliary detectors (limit fringe fields)
- Beam line must carry large fraction of RI from fragment separator to HRS
- Possibility to track beams
- Possibility to reject unreacted beam after target
- Possibility to detect light charged particles after target
- …

Pre-conceptual design and layout-2014



Pre-conceptual base design

details in talk by Thomas Baumann

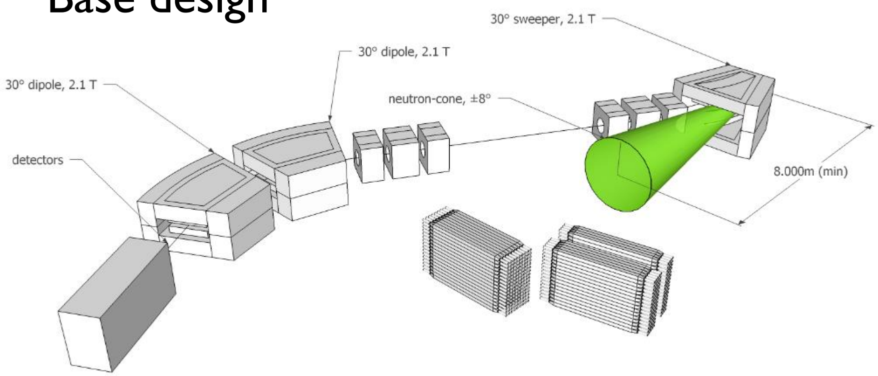


Primary design parameters	
Maximum Magnetic Rigidity	8 Tm
Acceptance	10 msr
Momentum acceptance	10%
Momentum resolution	1 in 5000
Ion-optical features	Image after sweeper stage for removing beam
Dispersion	7 cm/%
Sweeper	30° bending angle, B_{max} = 2.1 T, gap size: 60 cm
Spectrometer Dipoles	2x30° bending angle, B_{max} = 2.1 T, gap size: 12 cm
Quadrupoles	based on FSQ7/8 design for FRIB separator, ~50cm maximum bore

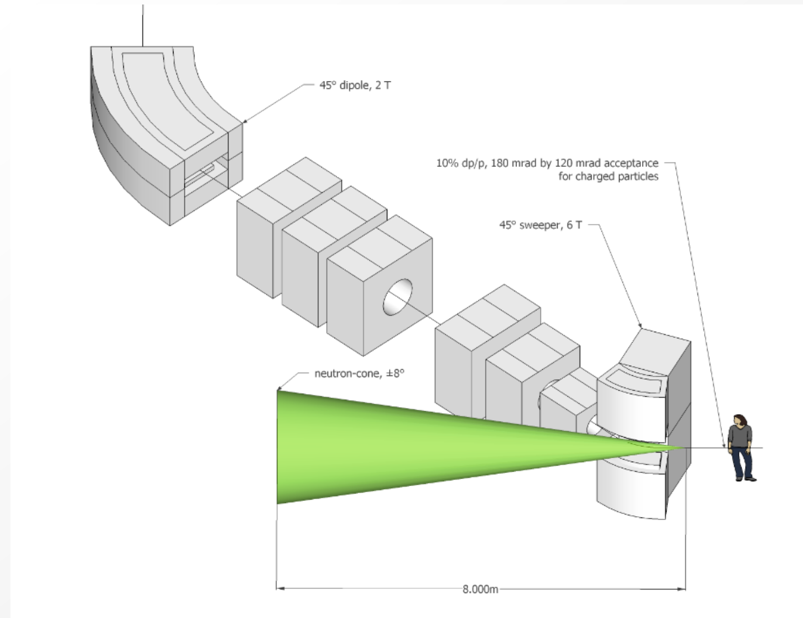
Base design and alternatives

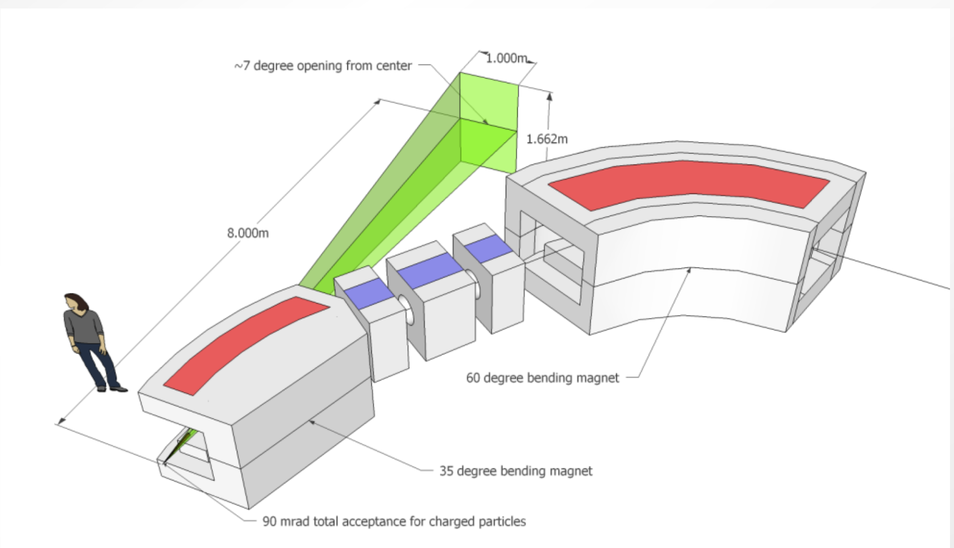
details in talk by Thomas Baumann

Base design



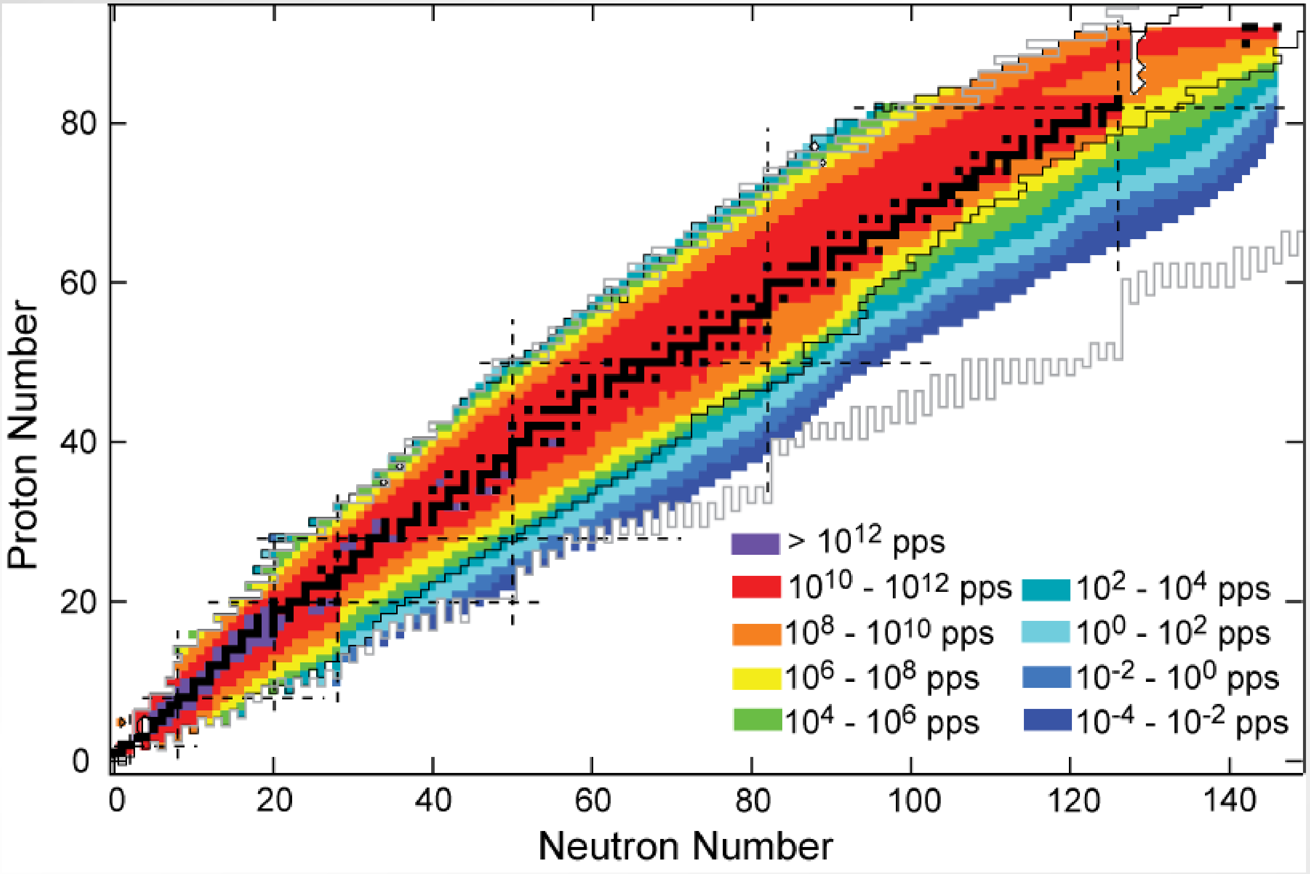
High-field sweeper alternative





Simplified two-stage alternative

FRIB @ 400 MeV/u: dripline closely approached for high A



Cost estimates

	Equipment	Labor	Total	Including contingency	Note
Beam line	$3.9M	$4.8M	$8.7M	$11.4M	Includes switching dipole, 6 doublets, beam line dipole and quadrupole triplet, and associated infrastructure
HRS	$4.1M	$8.3M	$12.4M	$17.8M	Includes sweeper dipole, 2 quadrupole triplets and 2 spectrometer dipoles, and associated infrastructure and detectors
Total	**$8.0M**	**$13.1M**	**$21.1M**	**$29.1M**	

Labor estimates for design, manufacturing, installation and project management are included. A 30% contingency is assumed for magnets with the technical scope well established – a 50% contingency is assumed for the HRS sweeper and 2 spectrometer dipole magnets for which the uncertainties are larger at present.

Excludes construction of building which costs $10M (+$1M contingency), including the utility infrastructure, radiation shielding/interlocks and overhead crane.

Long-Range Plan, Town-meeting and white paper

- White-paper serves as input for Long-Range Plan
- Must have close to a final version by Town Meeting – final input can be collected there
- Draft Whitepaper ready by end of July
- Input requested – can build on some existing documents