The Design and Commissioning of the Accelerator System of the Rare Isotope Re-accelerator - ReA3

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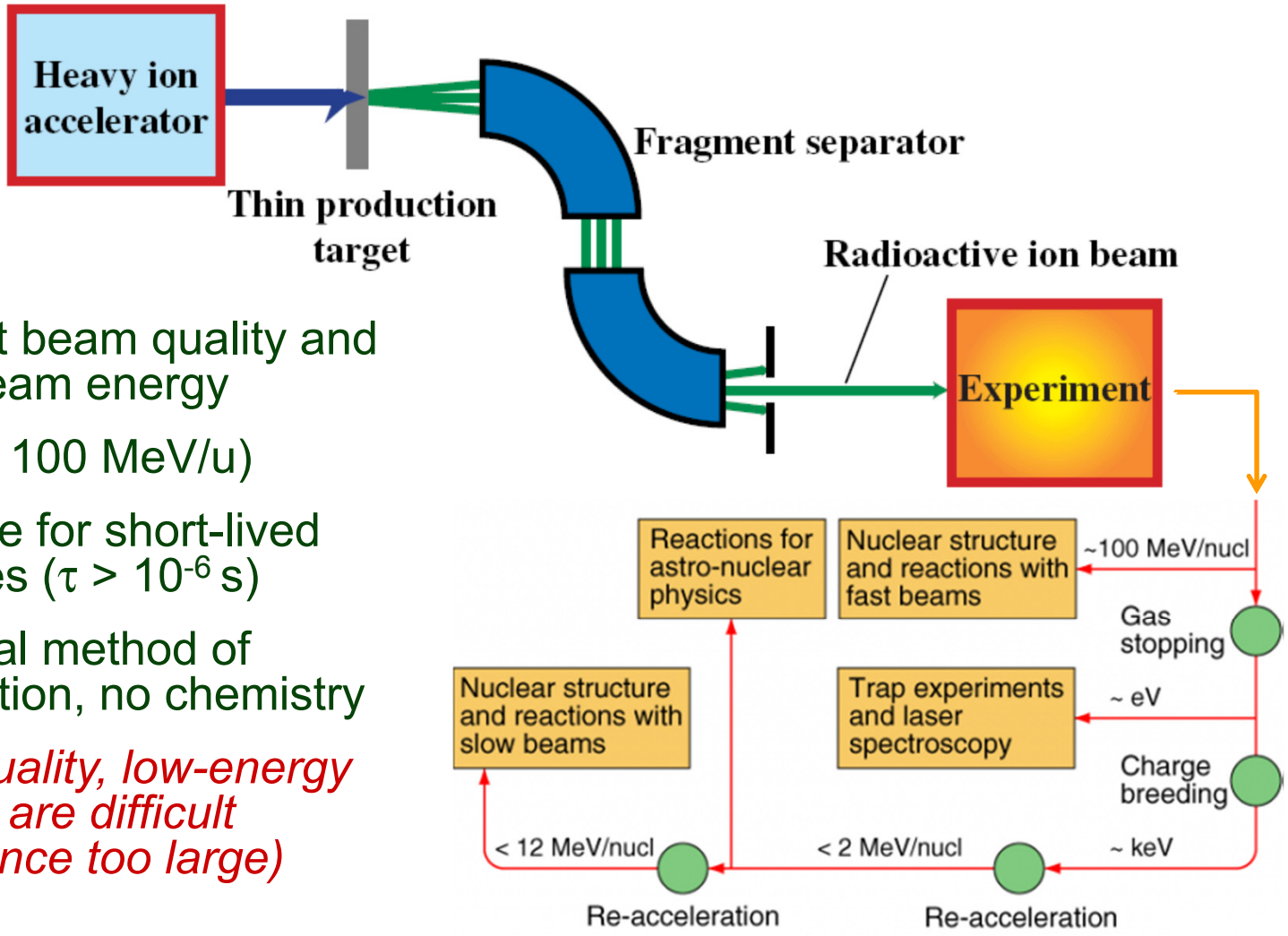
U.S. DEPARTMENT OF ENERGY
Office of Science

NSCL and FRIB Laboratory at Michigan State University

- NSCL is funded by the U.S. National Science Foundation as a user facility to produce rare isotope beams for research and education in nuclear science, nuclear astrophysics, accelerator physics, and societal applications
- FRIB, currently being designed and established at MSU, will be a national user facility funded by the U.S. Department of Energy Office of Science
- NSCL will transition into FRIB eventually

Rare Isotope Beam Productions by Projectile Fragmentation



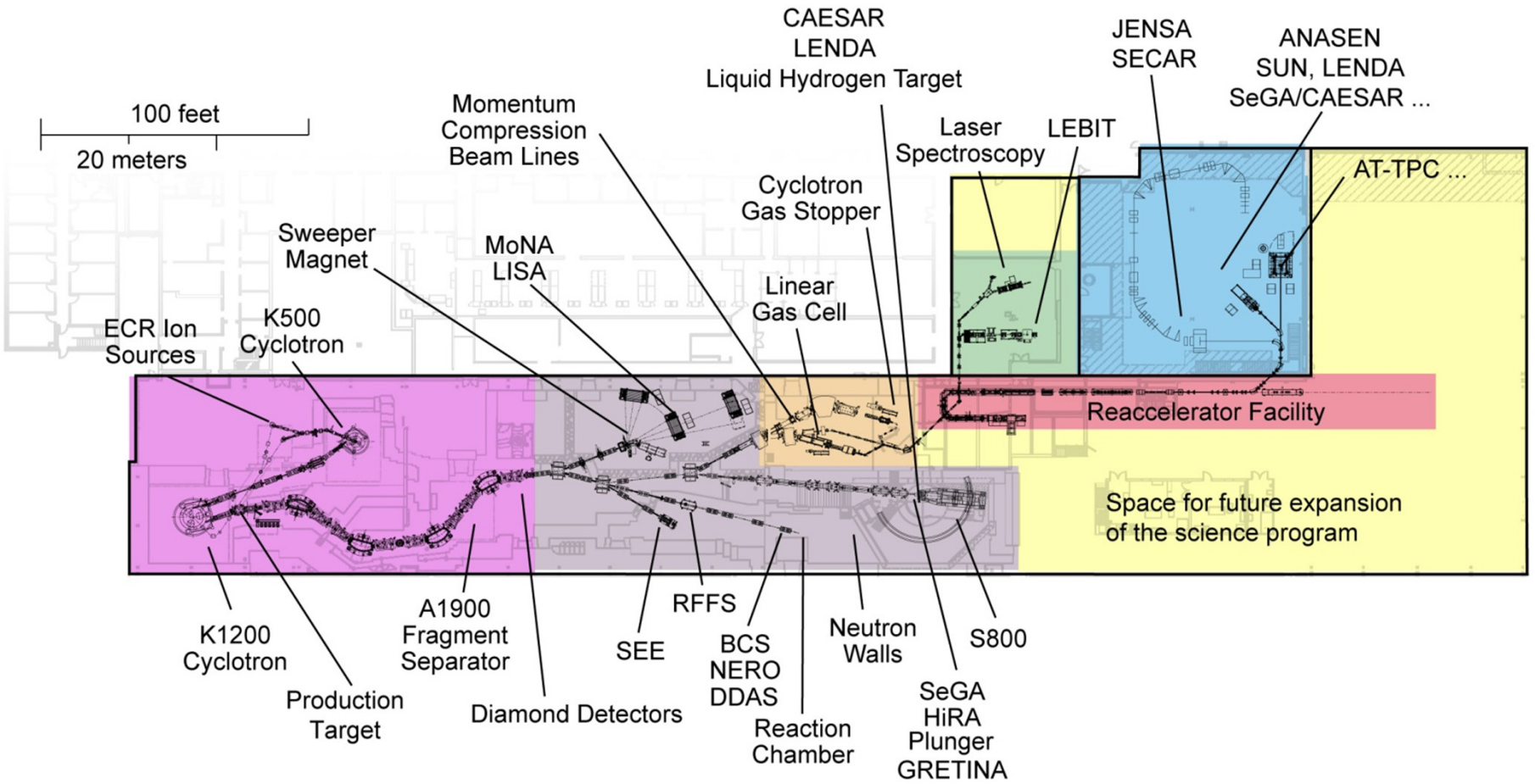
- Modest beam quality and high beam energy

  (E/A ~ 100 MeV/u)
- Suitable for short-lived isotopes ($\tau > 10^{-6}$ s)
- Physical method of separation, no chemistry
- *High quality, low-energy beams are difficult (emittance too large)*

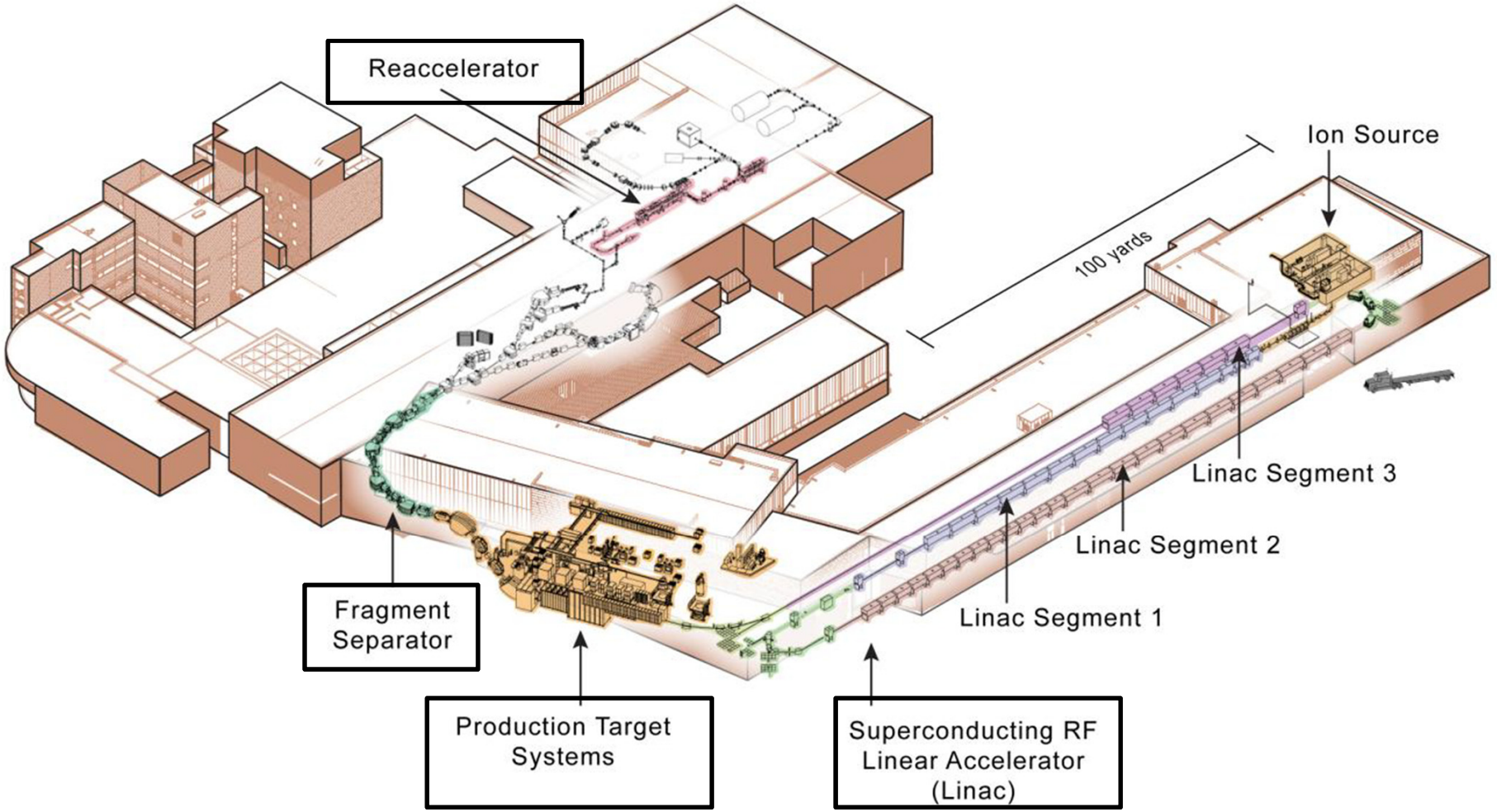
Strong Demands for High Quality, Low-Energy RIBs

- Nuclear astrophysics
  - Better interpretation of X-ray bursts and novae observations
  - Origin of p-nuclei
  - Supernovae modeling
- High quality low energy RIBs allow:
  - Reaction measurements at astrophysical energies
  - Indirect techniques to obtain astrophysical rates
- Nuclear physics
  - Shell structure evolution away from stability
  - Understanding pairing, shapes, cluster structure and collectivity of exotic nuclei
  - Reaction of exotic nuclei
- High quality low energy RIBs allow:
  - Transfer reactions
  - Multi-step Coulomb excitation
  - Fusion evaporation reactions

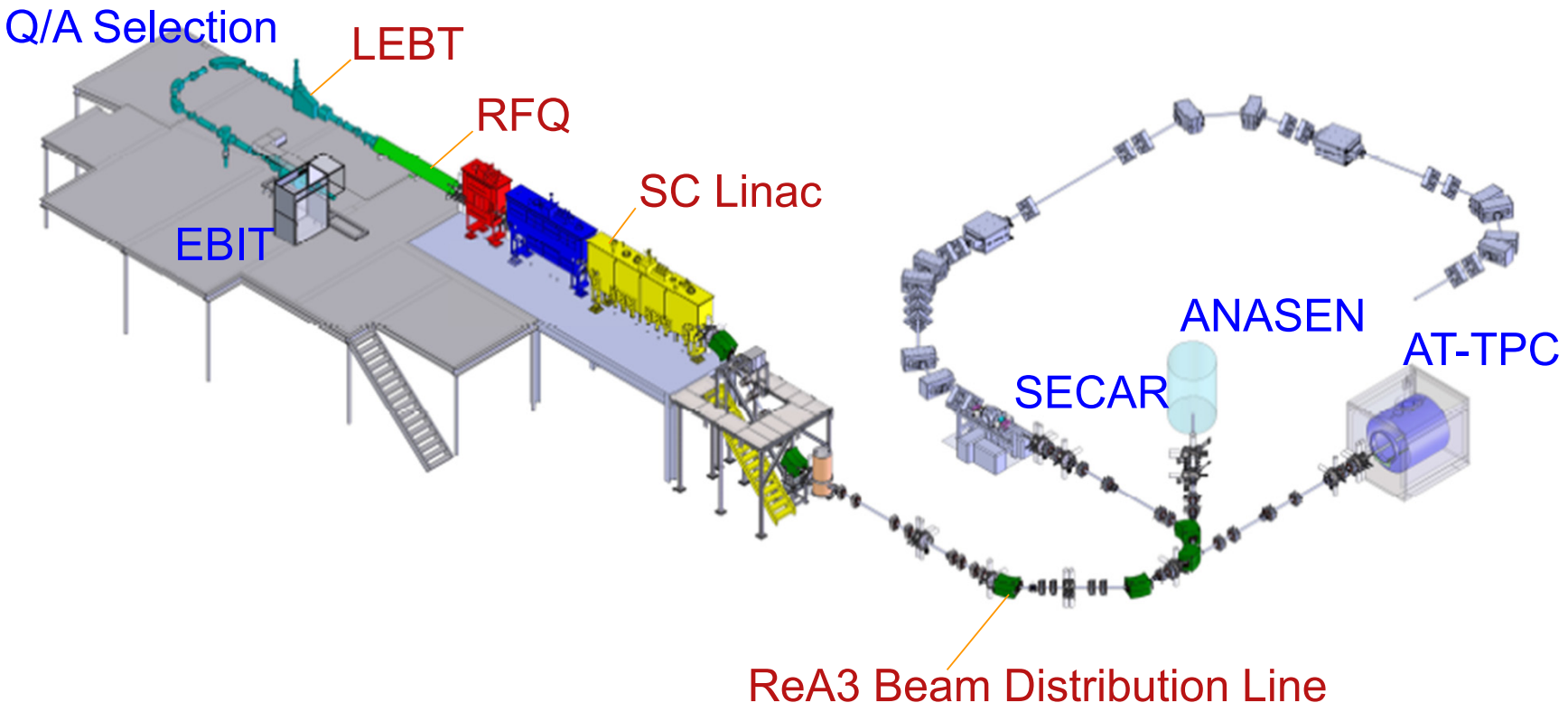
Current NSCL Facility Layout



Future FRIB Layout

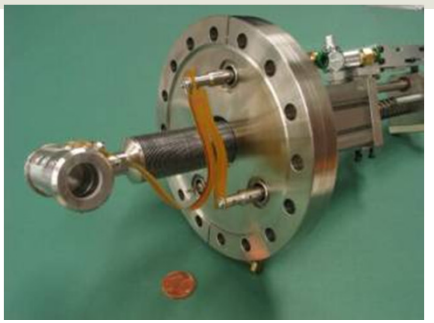


3MeV/u Re-accelerator - ReA3 Layout

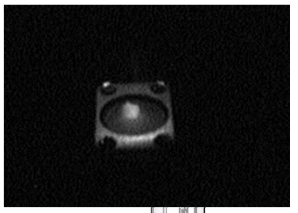


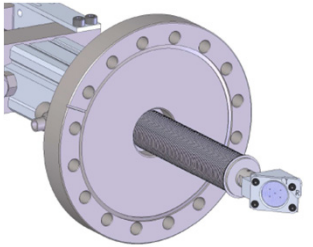
LEBT/RFQ

Offline Ion Source ($^4He^{1+}$)



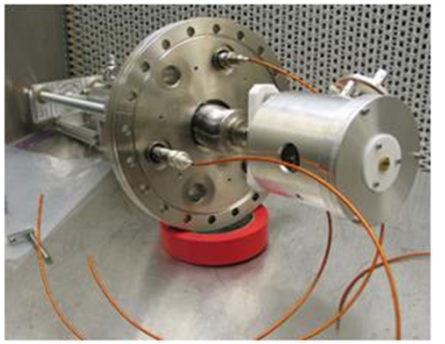
Faraday cup





CaF viewer

Bunch length monitor



Multi-harmonic buncher

RFQ

Beam transport to the RFQ:

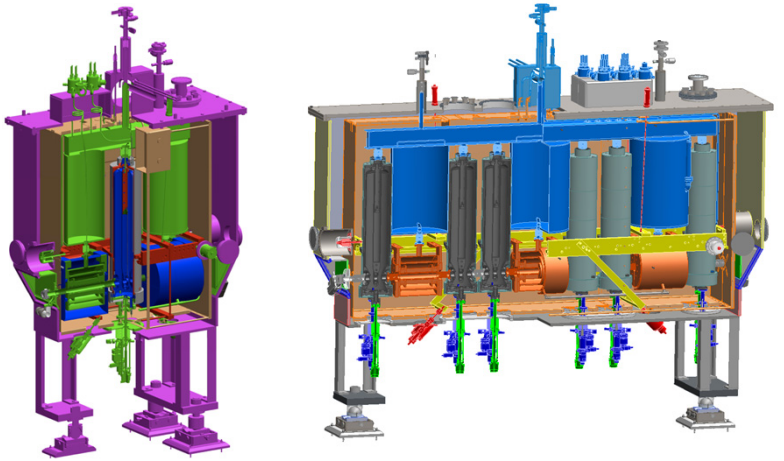
- Beam bunching
- Transverse beam matching

ReA3 SRF Cryomodules

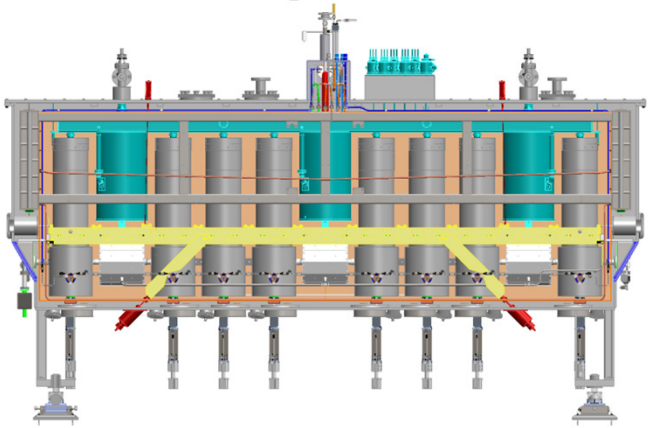
ReA3 -

- 3 ReA3 Cryomodules
- 15 cavities
- 2 cavity types (QWR)
  - Beta=0.041 & 0.085
  - Prototypes for FRIB
- 8 solenoids
  - Same as used in FRIB
- 1st two cryomodules installed In 2010
- 3rd cryomodule under development, will be installed Early 2013

β = 0.041 modules

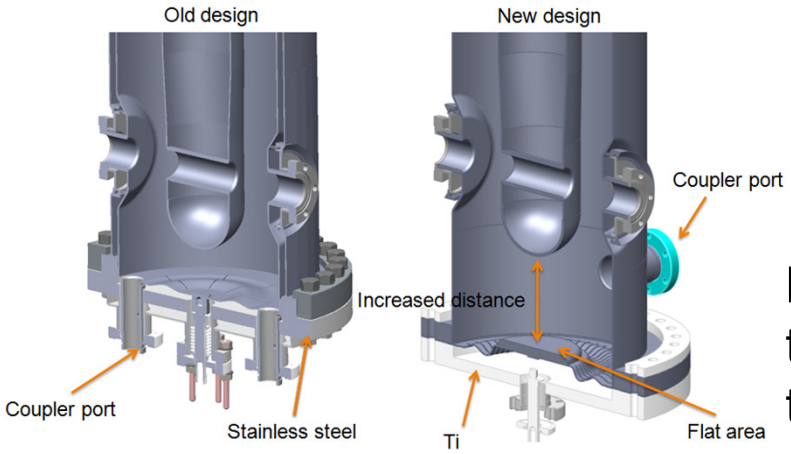


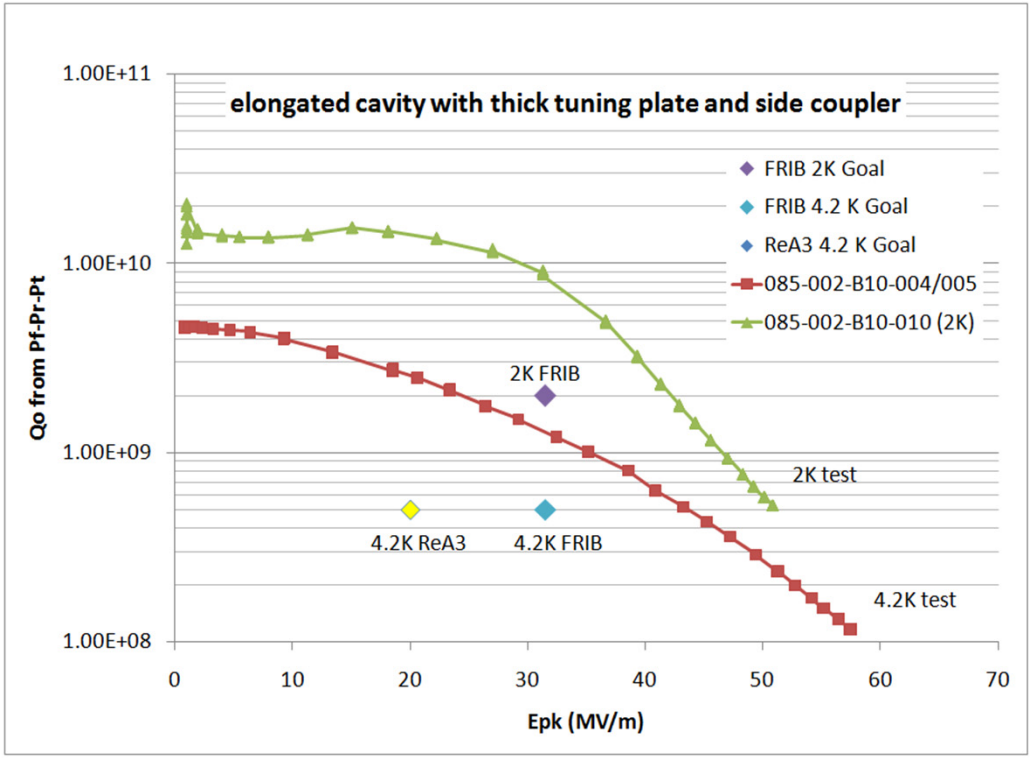
β = 0.085 module



Design Changes of β=0.085 QWR

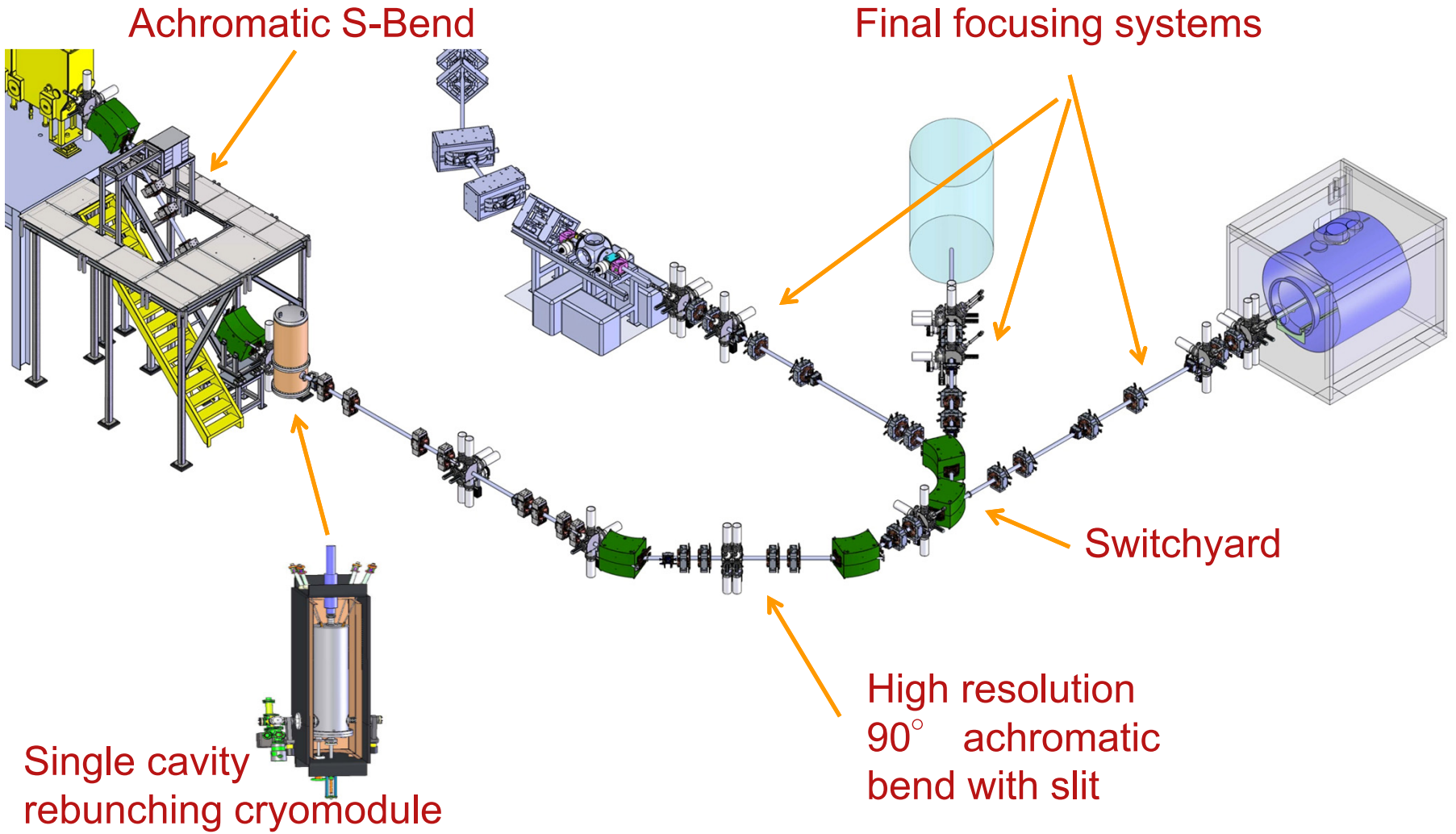
- Old design modified to improve performance reliability
- New design of the rf joint
- Rf couplers moved to the side
- Increased distance from inner conductor to tuning plate





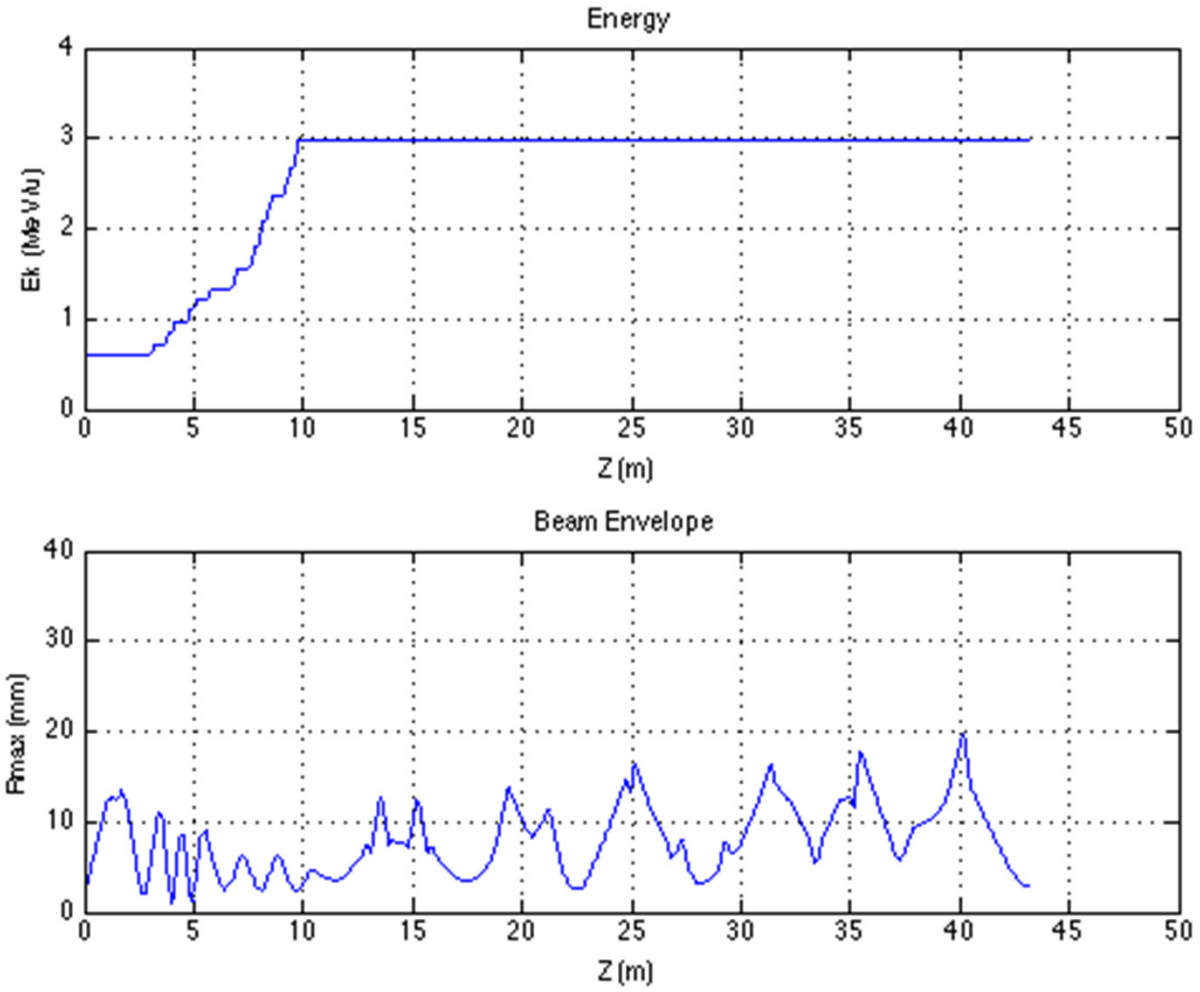
Both ReA3 and FRIB requirements more than fulfilled in testing naked cavities with the new rf joint design and side coupler

ReA3 beam Distribution Line



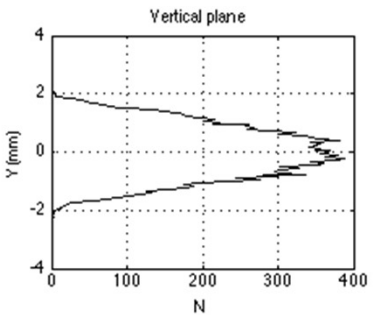
ReA3 Beam Dynamics Simulations (1)

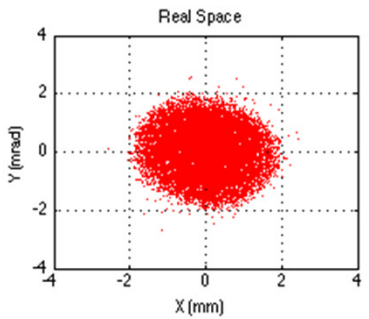
Maintain beam quality – minimize emittance growth

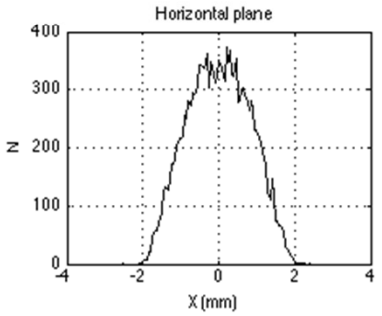


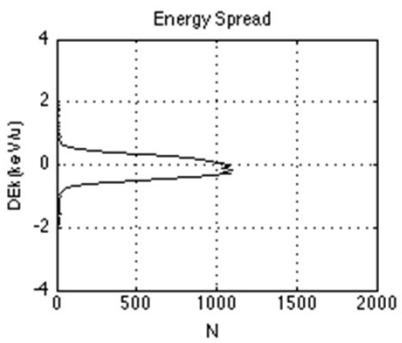
ReA3 Beam Dynamics Simulations (2)

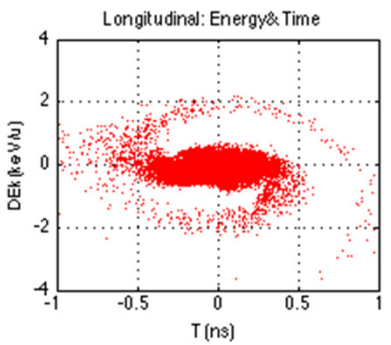
Meeting beam-on-target requirements

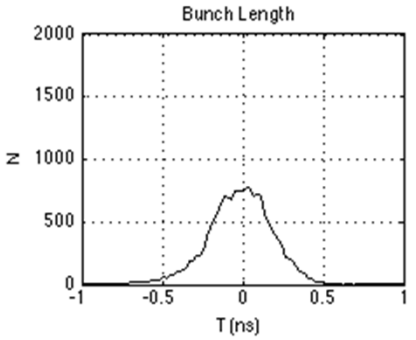






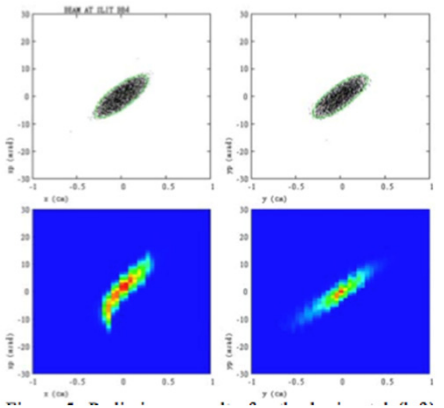






Beam size: ~ 2mm
Energy spread: ~ 1 keV/u
Bunch length: ~ 1 ns

ReA3 Commissioning ongoing



Q/A Selection

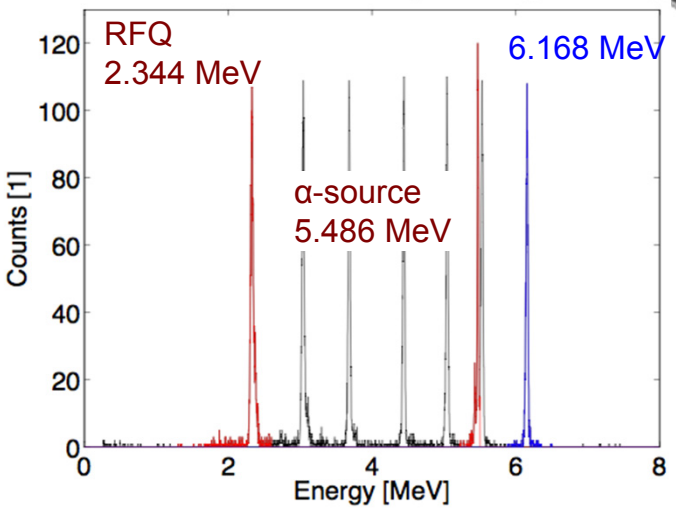
LEBT

RFQ

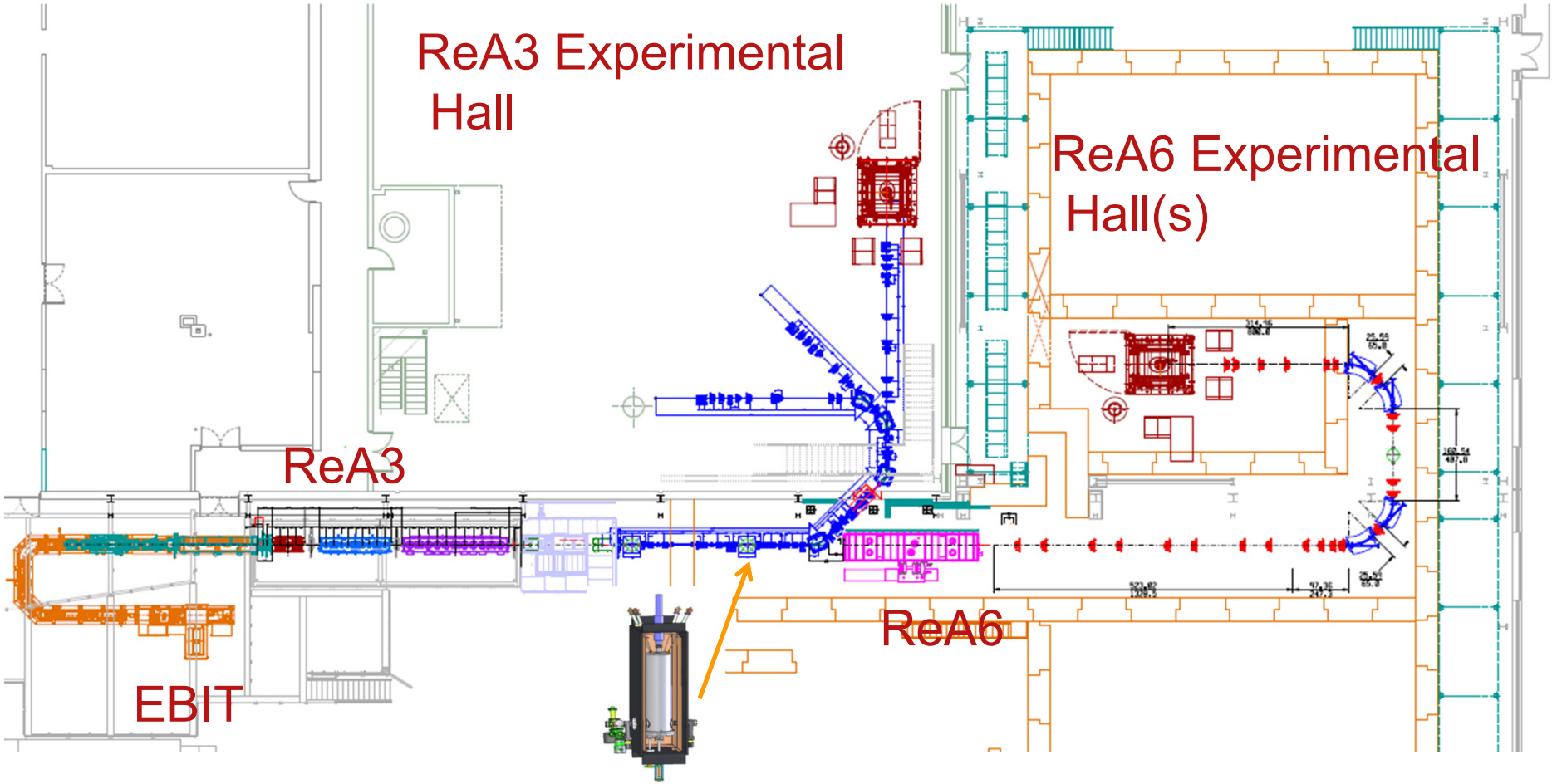
EBIT

Two beta=0.041 Cryomodules

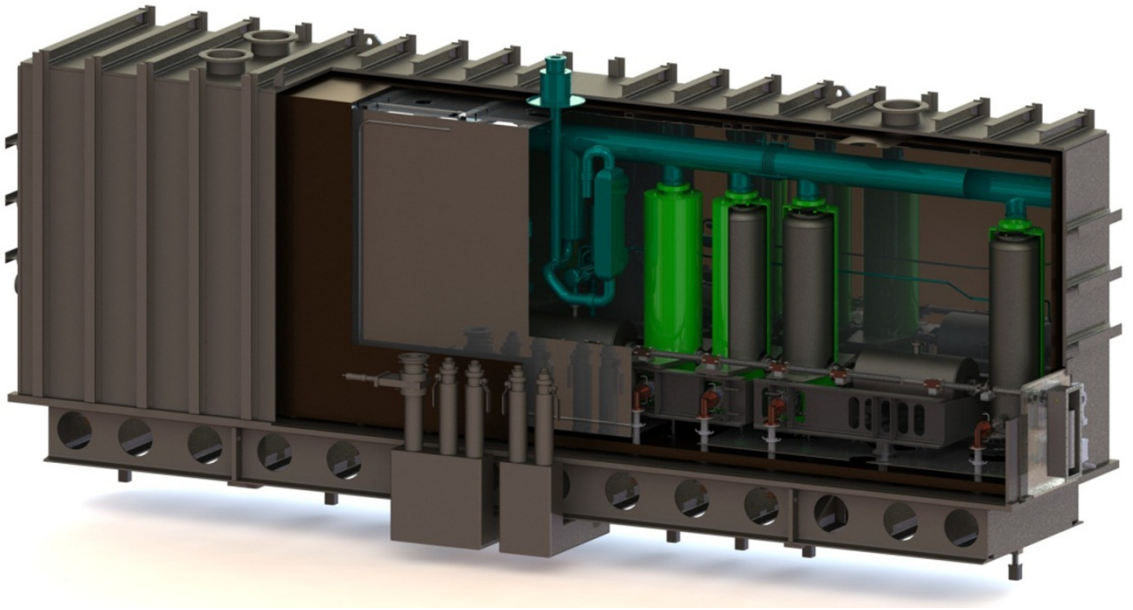
L-Line Deck Extension



Energy Upgrade Phase I - ReA6



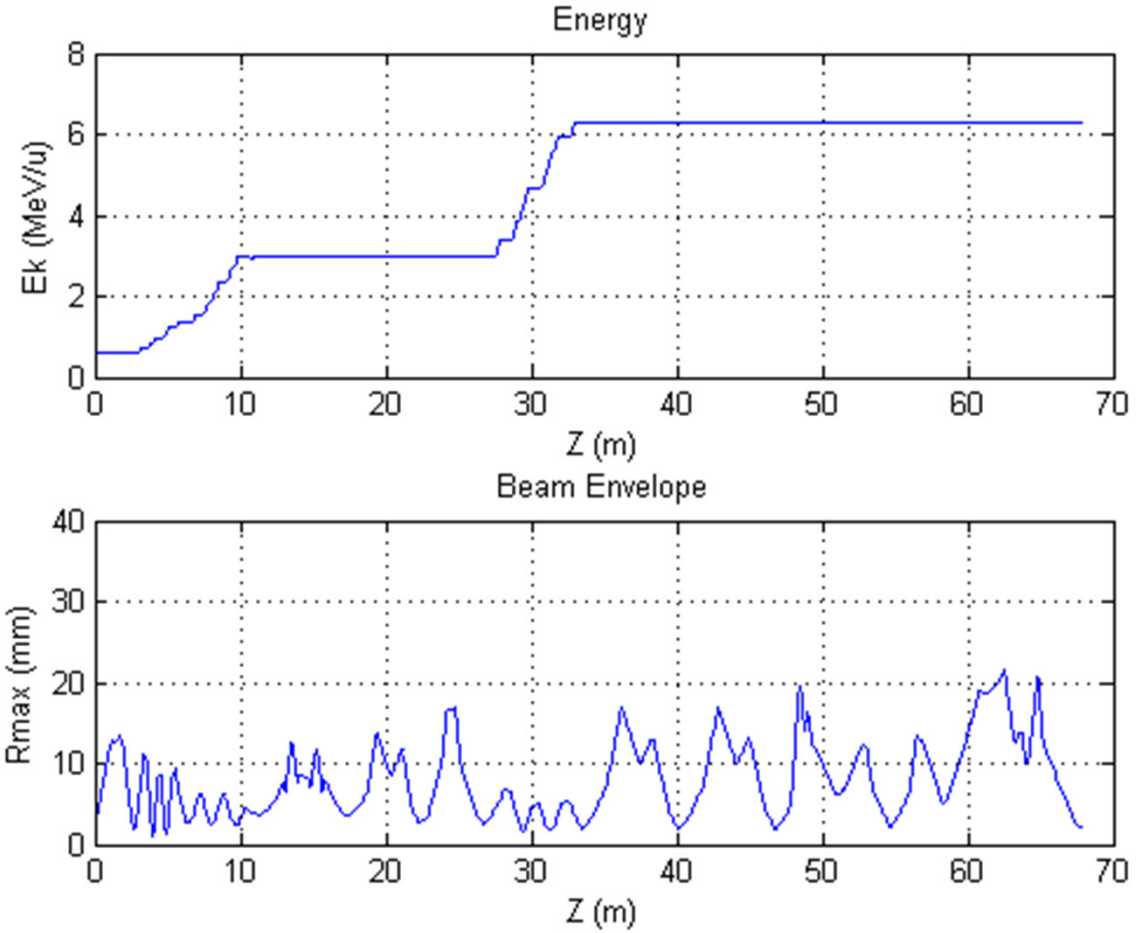
ReA6 Accelerating Cryomodules



- 4th generation beta=0.085 QWR cavities
- 8 cavities
- 3 SC solenoid magnets with X/Y dipole correctors
- 3 Cold beam position monitors
- ~ 6 m long
- FRIB Linac Segment I will use same cryomodules (11)

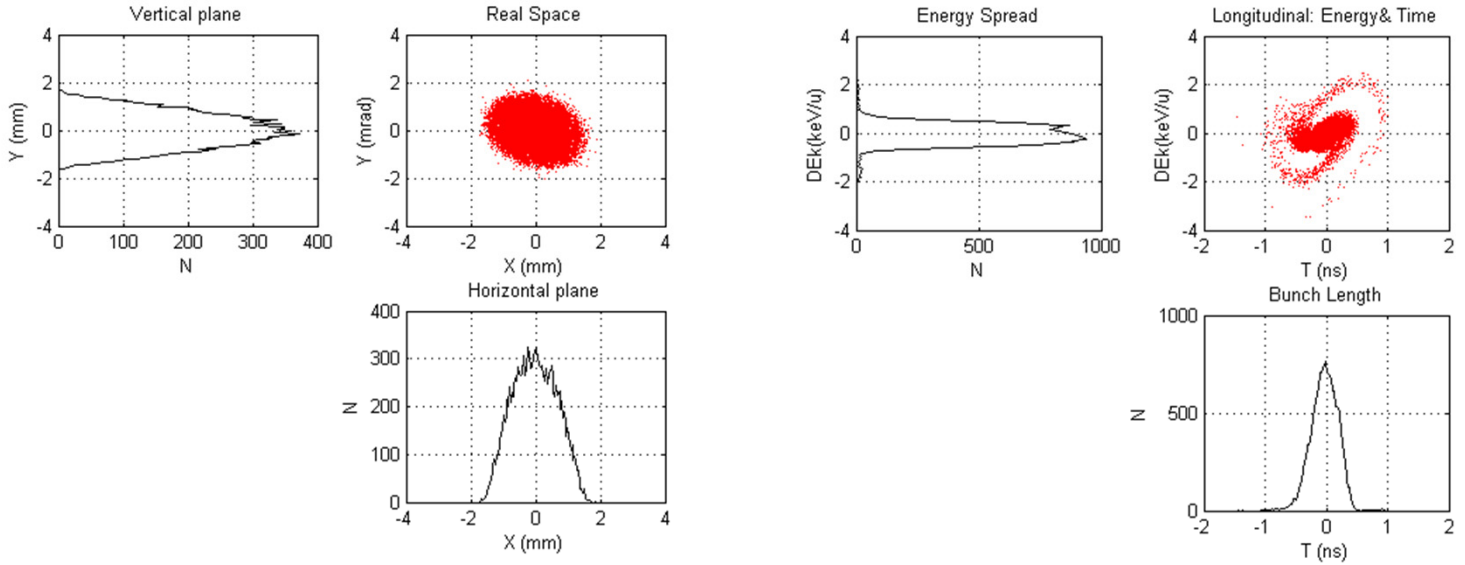
ReA6 Beam Dynamics Simulations (1)

Maintain beam quality – minimize emittance growth



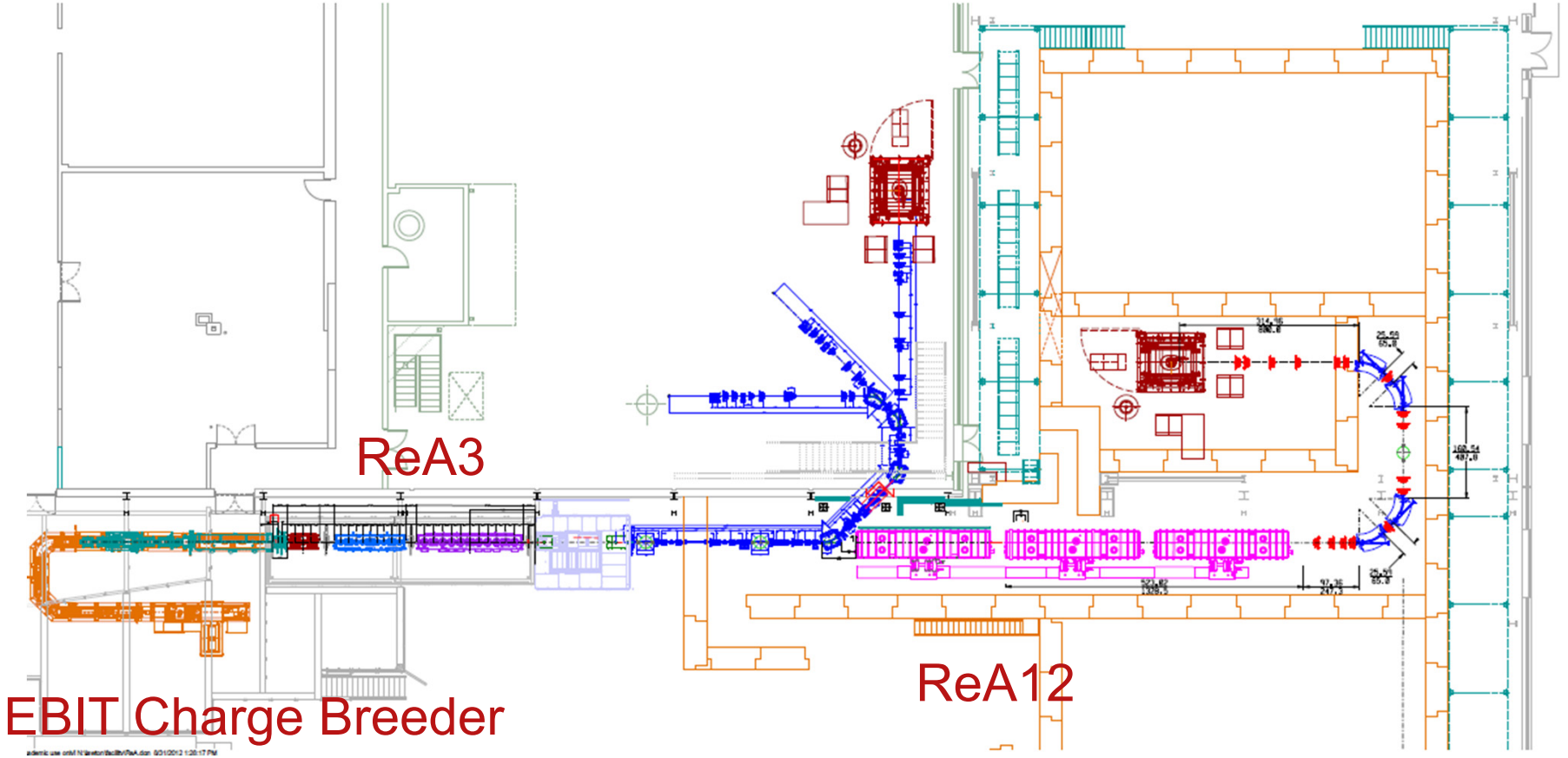
ReA6 Beam Dynamics Simulations (2)

Meeting beam-on-target requirements

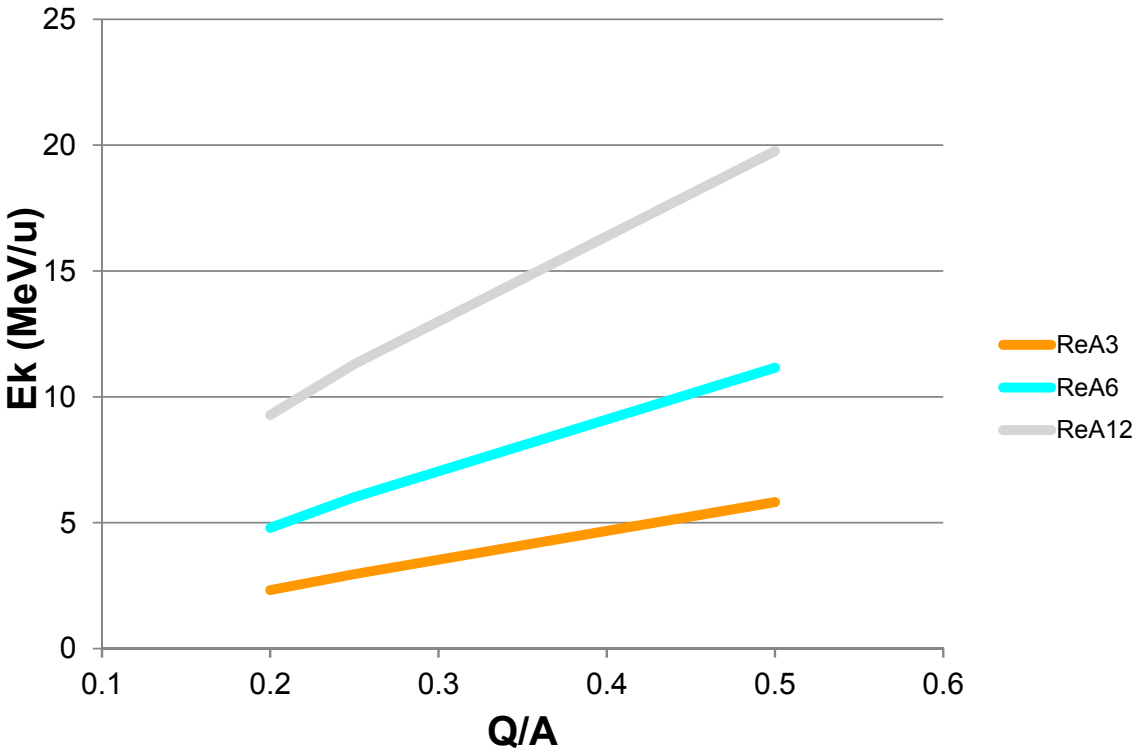


Beam size: ~ 2mm
Energy spread: ~ 1 keV/u
Bunch length: ~ 1 ns

Energy Upgrade Phase II - ReA12



ReA3/ReA6/ReA12 Performance



Summary

- The Re-Accelerators at the NSCL will provide a new low energy high quality RIBs facility for nuclear astrophysics and nuclear science.
- Construction and commissioning underway.
- Installation of ReA3 completed FY2013
- Radioactive ion beam commissioning runs 2013
- First beamline into ReA3 hall 5/2013
- Energy upgrade phase I started
  - ReA6 Cryomodule fabrication has started, completion planned 2014