The Accelerator System for ReA3 – the New Re-accelerated RIBs Facility at MSU

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on behalf of the NSCL ReA3 team

U.S. Department of Energy Office of Science
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Michigan State University

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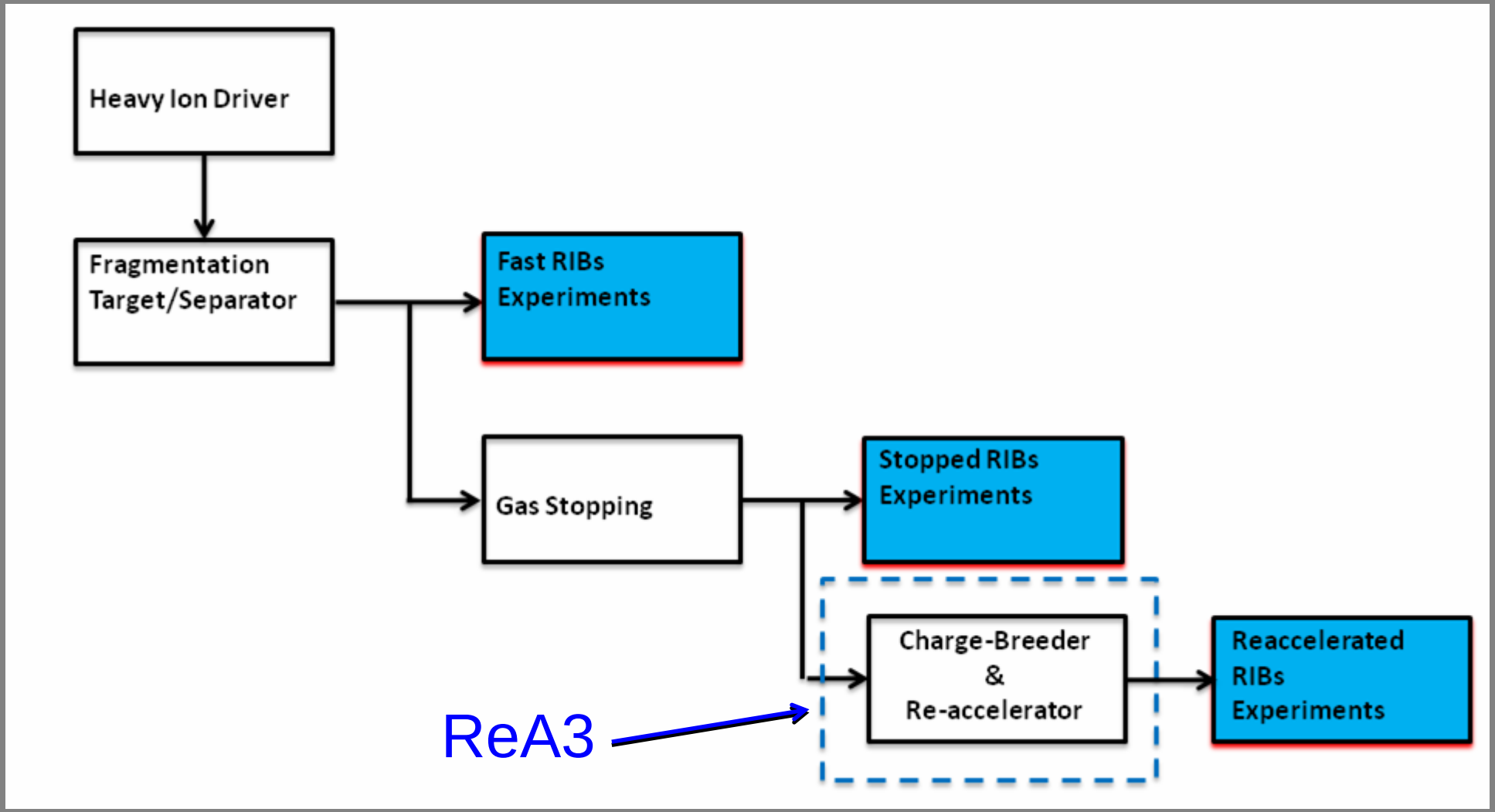
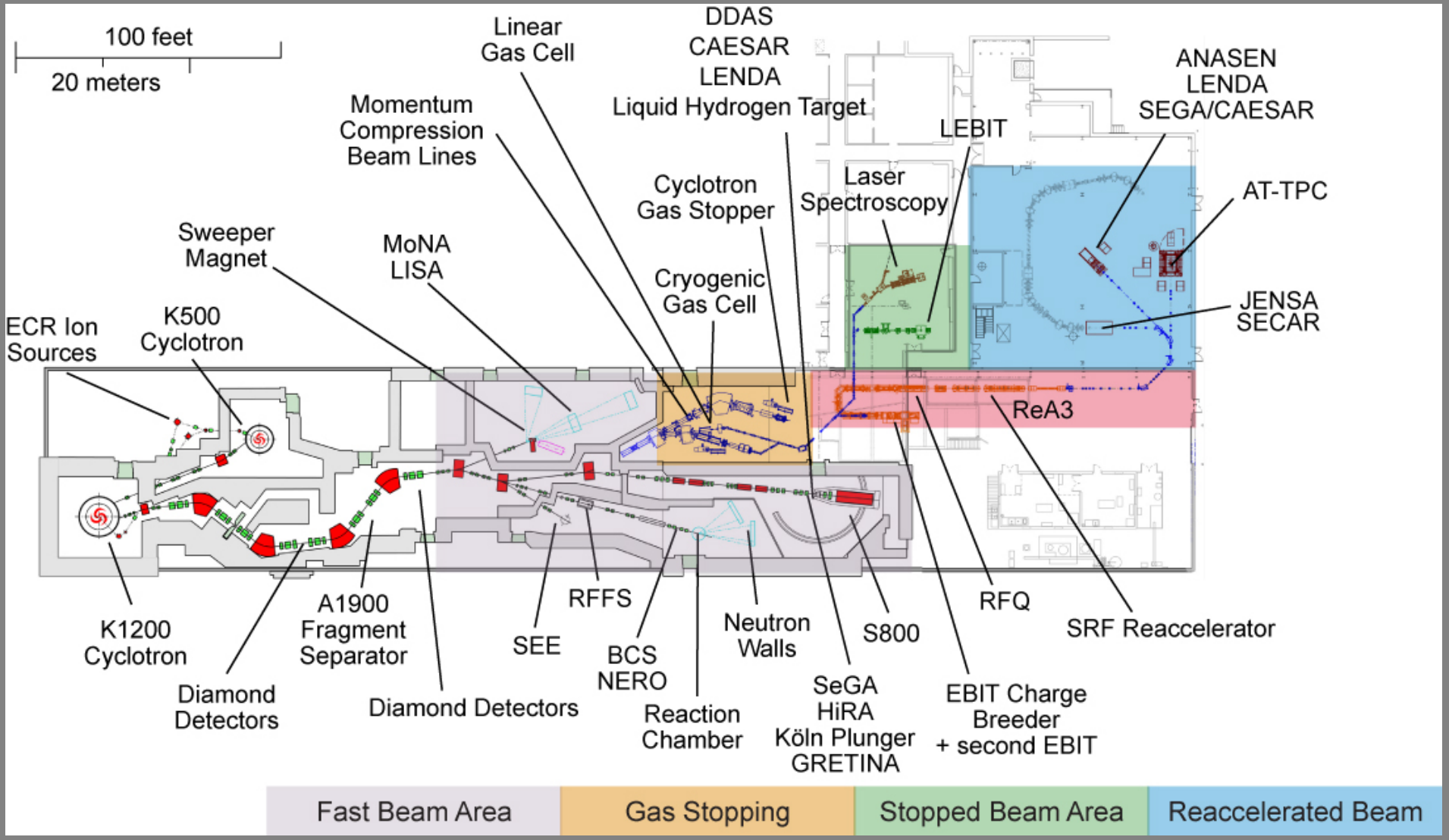
Production of RIBs by Projectile Fragmentation at NSCL



NSCL Present Facility Layout



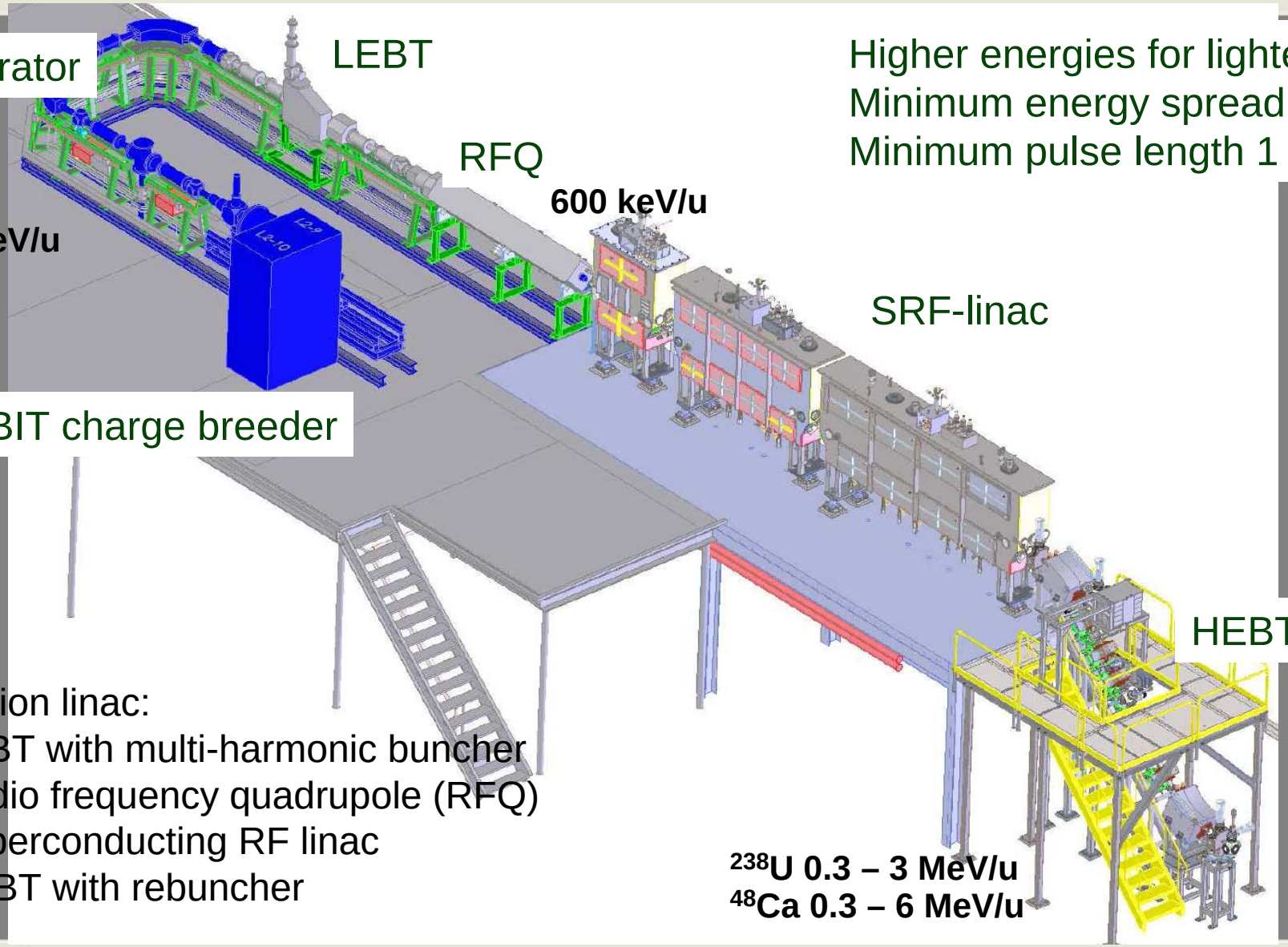
Facility for Rare Isotope Beams (FRIB)

- >200 MeV/u for all ions
- 400kW
- Superconducting driver linac
- Three-stage fragmentation separator
- Successfully passed DOE CD-1 review
- To be completed in ~2018

ReA3 Connections to CCF and FRIB

- ReA3 will be operated as a radioactive beam reaccelerator for the Coupled Cyclotron Facility in the coming years
- ReA3 will be operated as a radioactive beam reaccelerator for FRIB once the FRIB driver linac is operational and replaces the coupled cyclotrons
- ReA3 shares similar technology as the FRIB driver linac
  - Low energy beam lines for ion beams
  - RFQ
  - SRF linac
- ReA3 will provide valuable experience to FRIB for tuning strategies, particularly for SRF linac phasing strategy and development of beam tuning applications

ReA3 platform



Higher energies for lighter ions
Minimum energy spread 1keV
Minimum pulse length 1 ns

Modern ion linac:

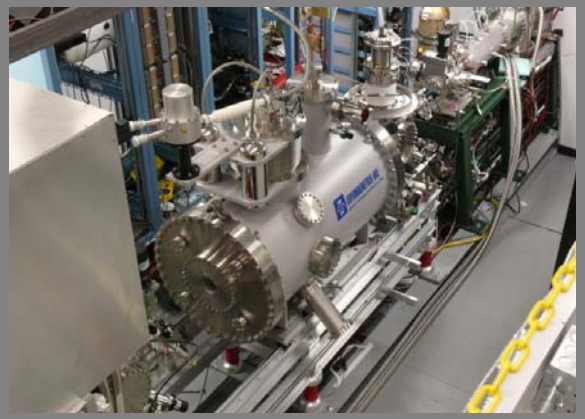
- LEBT with multi-harmonic buncher
- Radio frequency quadrupole (RFQ)
- Superconducting RF linac
- HEBT with rebuncher

^{238}U 0.3 – 3 MeV/u
^{48}Ca 0.3 – 6 MeV/u

ReA3 platform

ReA3 hardware

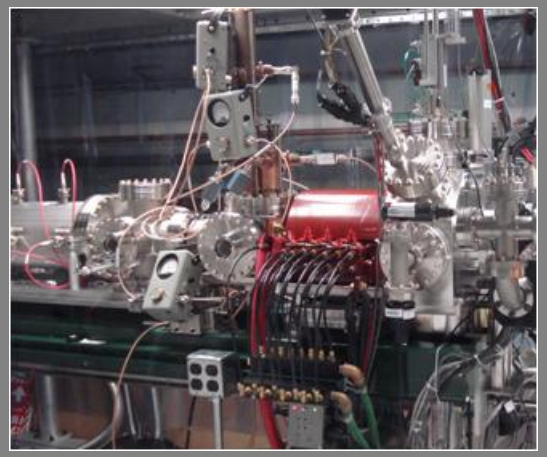
EBIT Charge Breeder



Q/A Separator

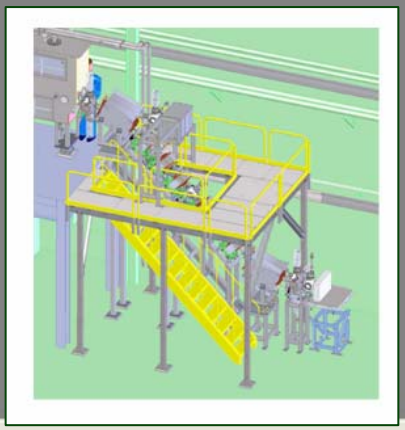
SC Linac

LEBT



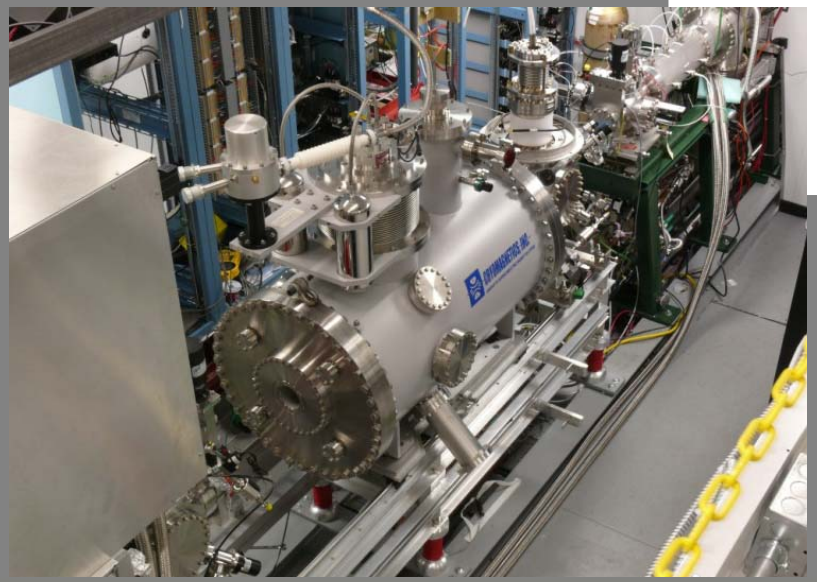
RFQ

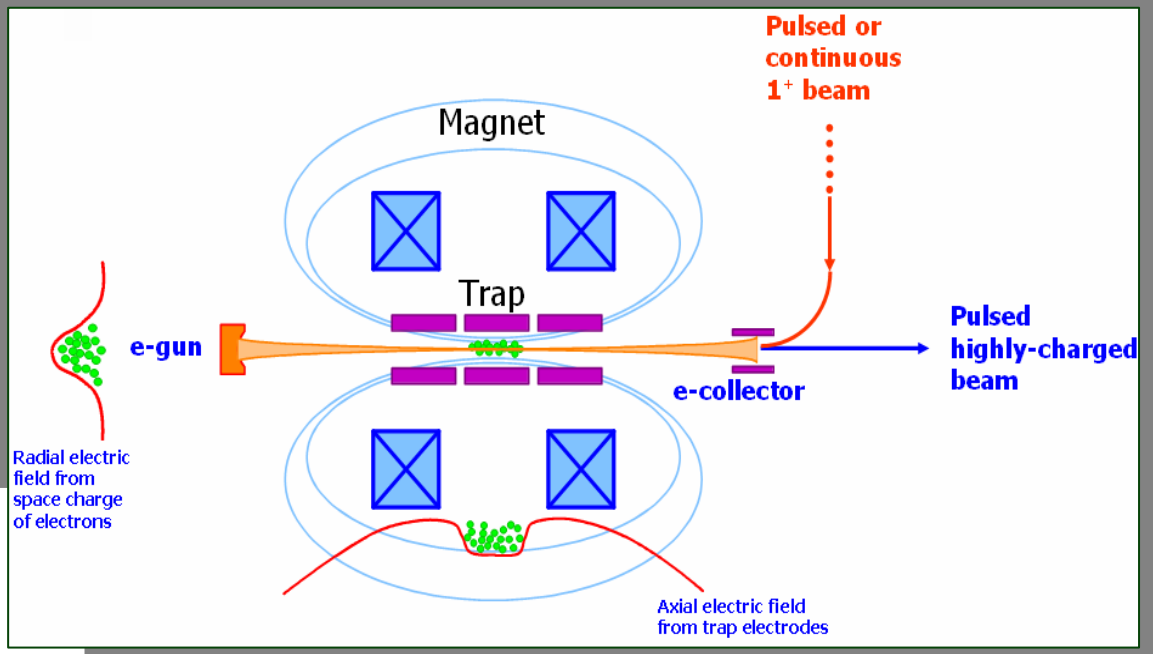
HEBT



ReA3 – EBIT charge breeder

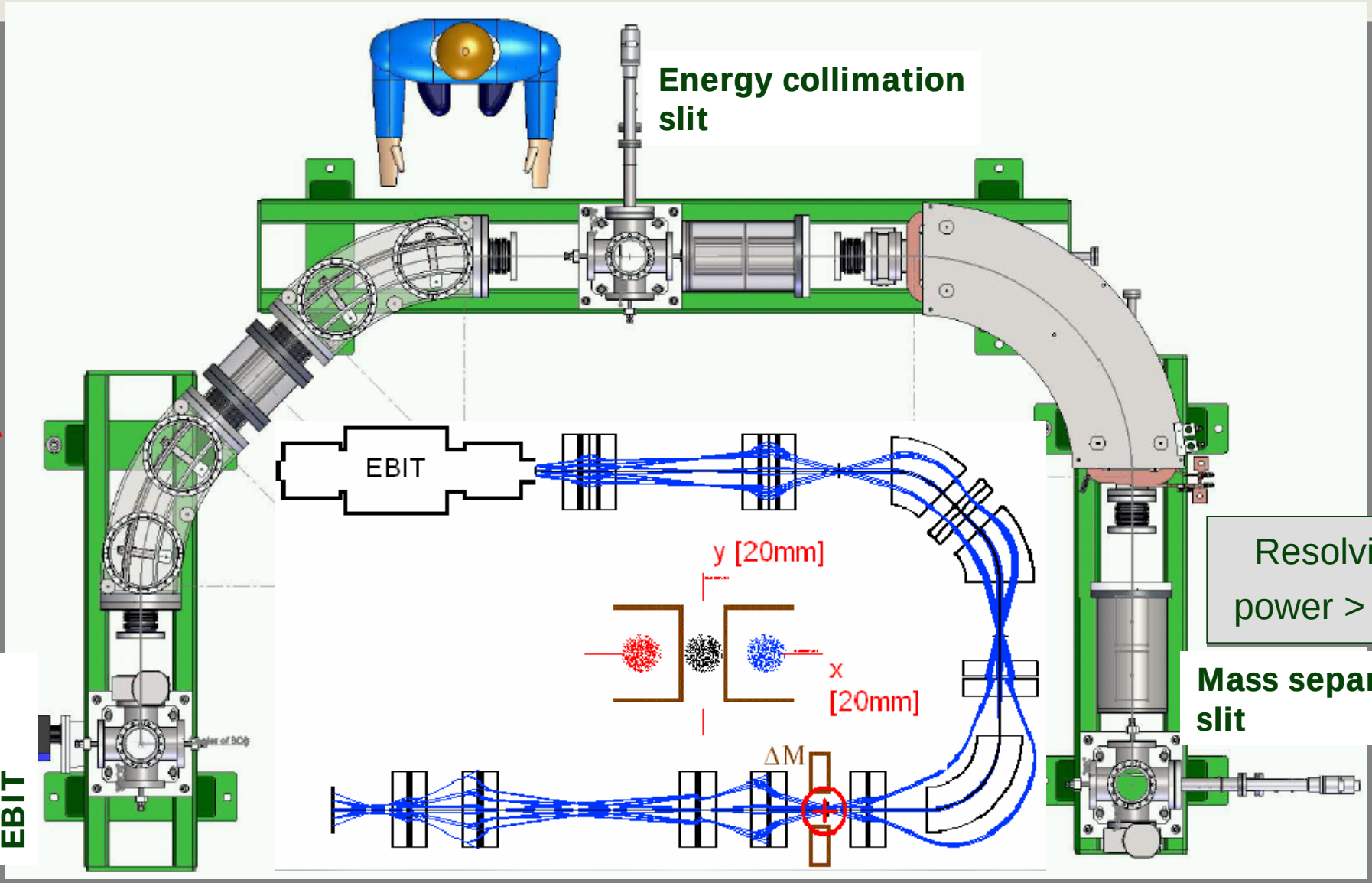
- Unique features:
  - Continuous injection of ions
    - » high capture rate
  - Variable extraction duty cycle
    - » μs pulse to quasi-continuous
  - Short breeding time (<10 ms)
  - High efficiency
    - > 50% in a single charge state





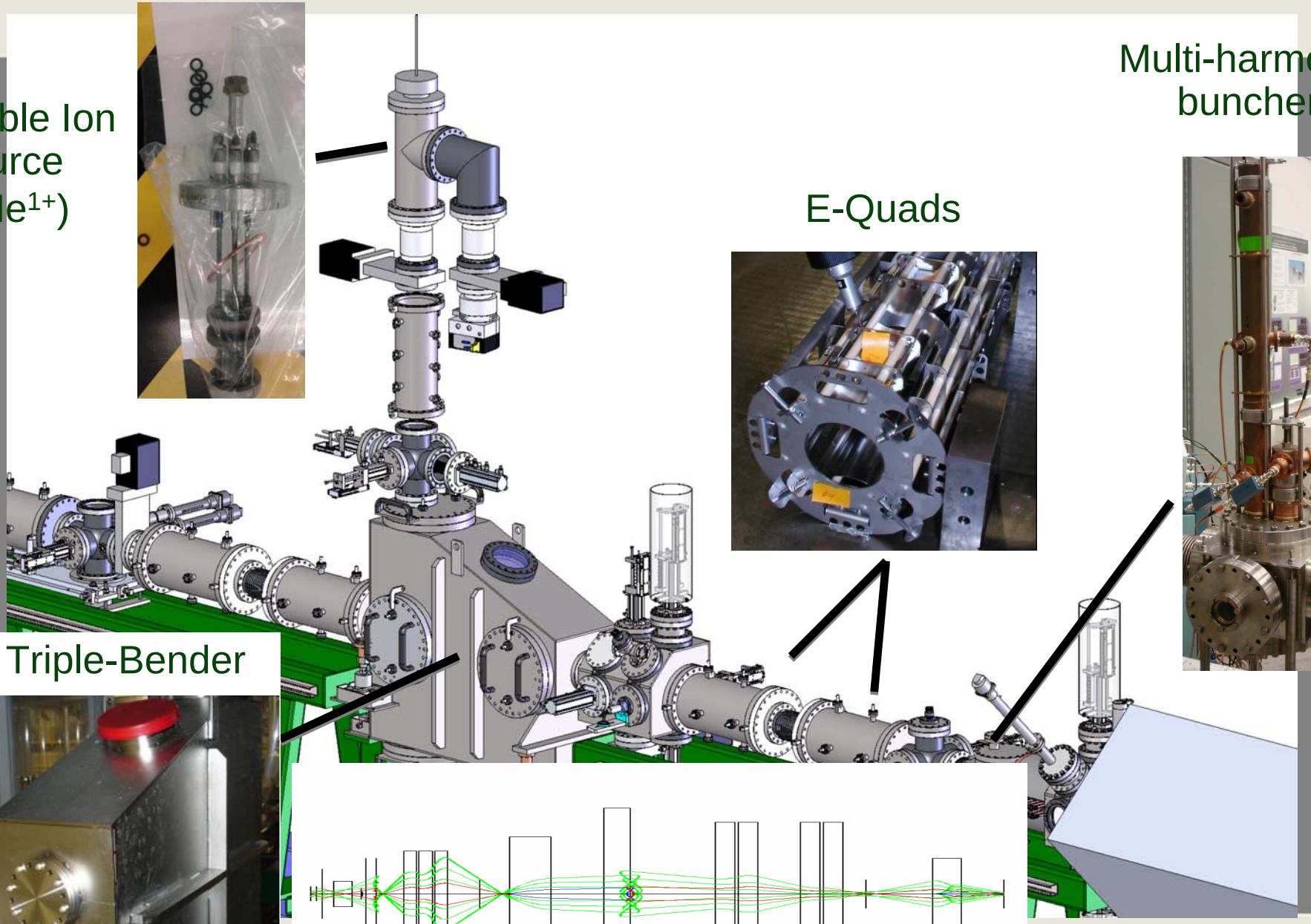
EBIT installation will be completed in October,
Simulations are performed to optimize performance,
Injection tests end of 2010!

Achromatic Q/A-separator



Low energy beam transport (LEBT)

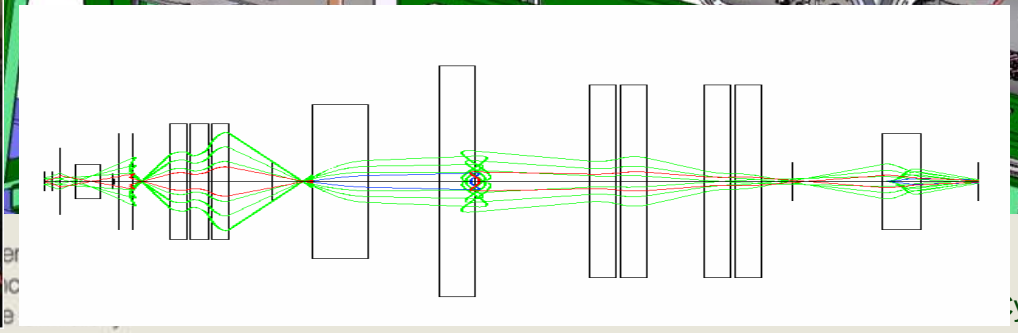
Stable Ion Source ($^4He^{1+}$)



Multi-harmonic buncher

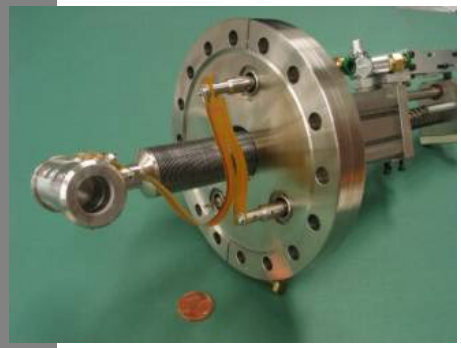
E-Quads

Triple-Bender



Beam Diagnostics (LEBT)

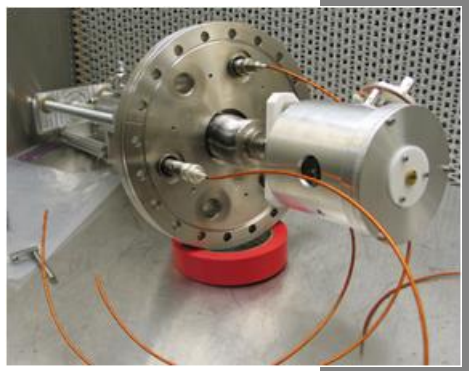
Faraday cup



CaF viewer

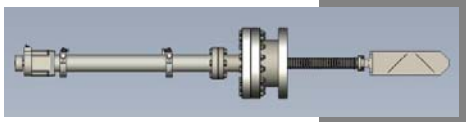
MCP viewer

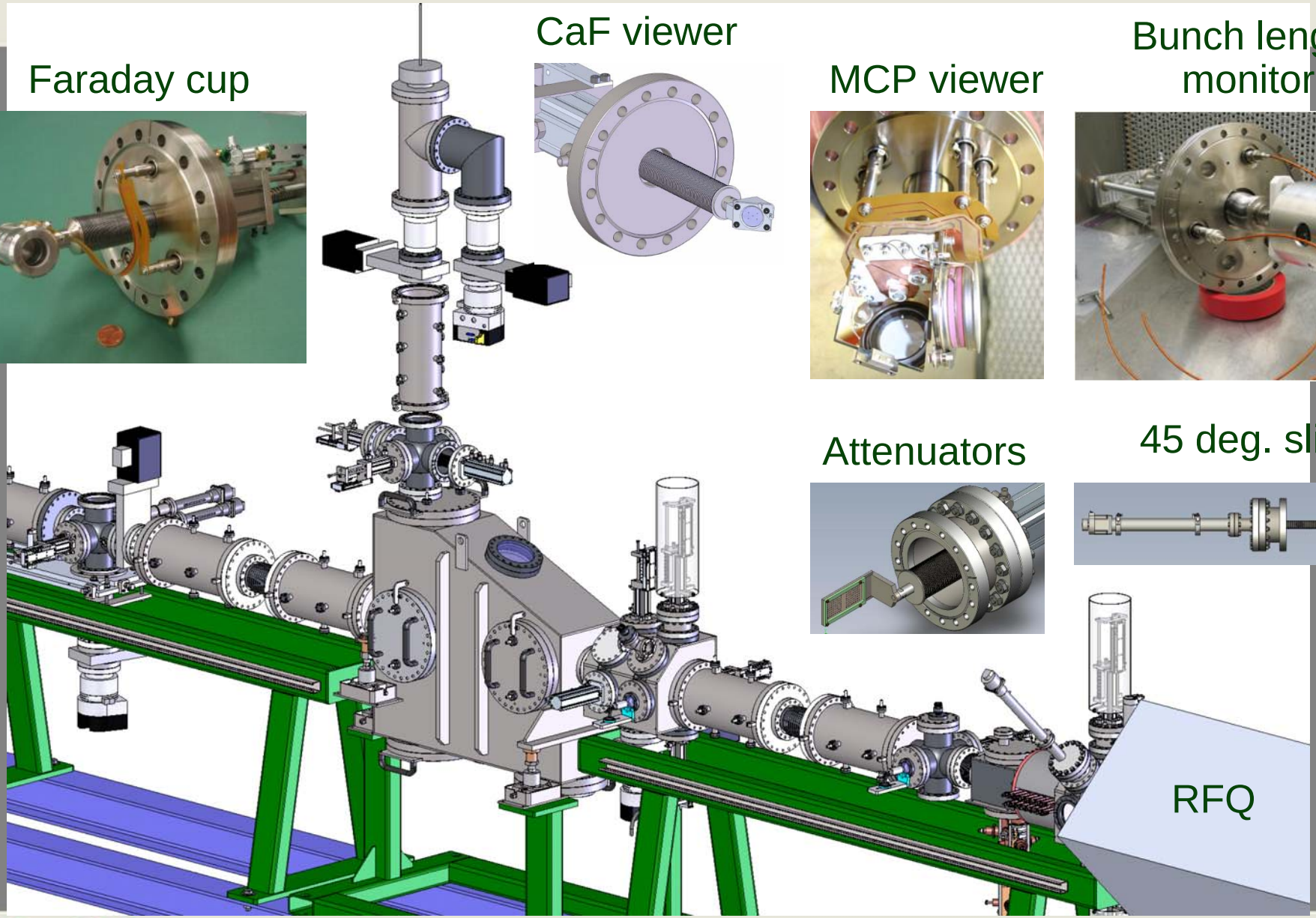
Bunch length monitor



Attenuators

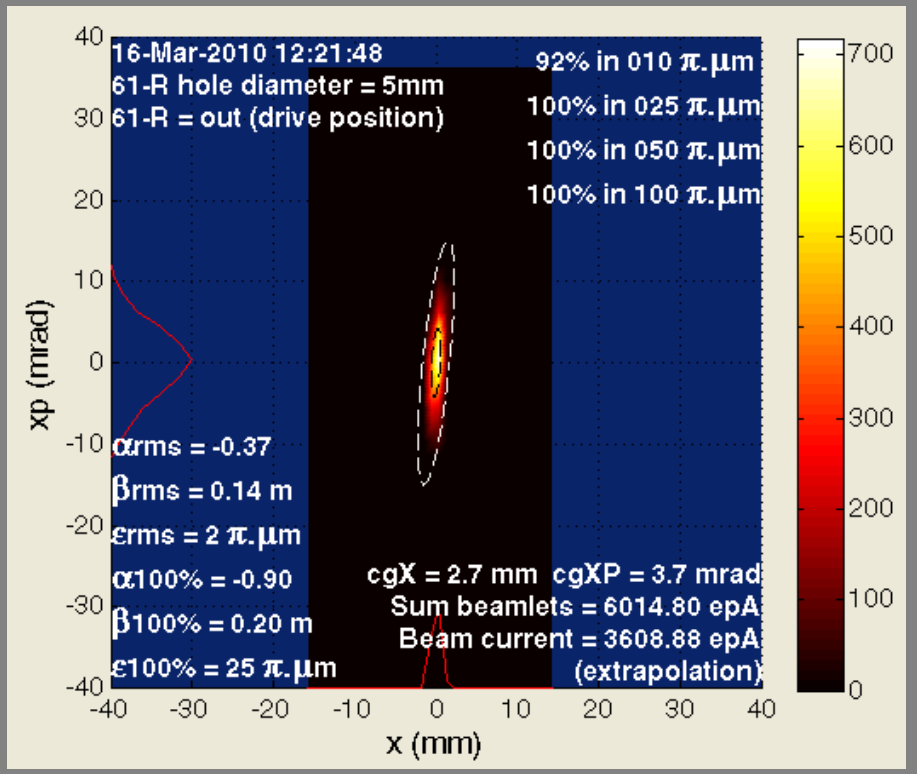
45 deg. slit

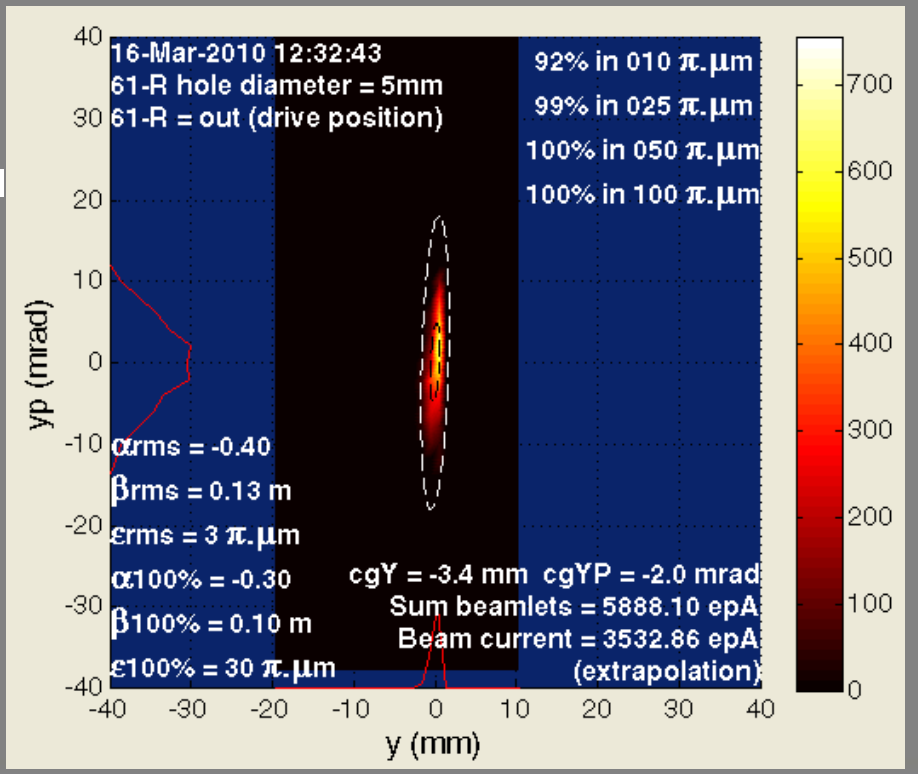




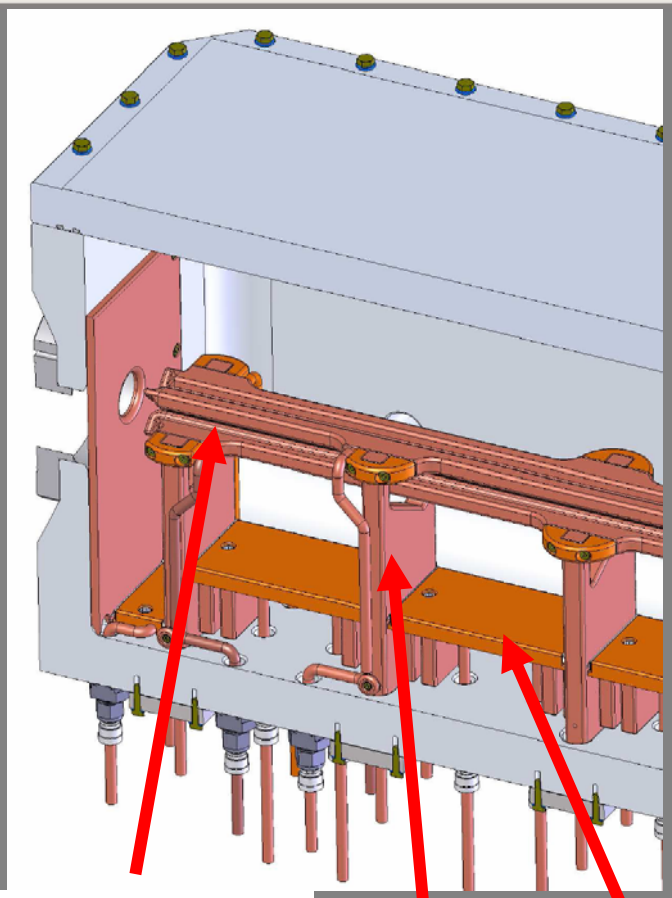
Emittance Scans

- RFQ transverse acceptance >
  - ε_n = 1.0 π-mm-mrad
  - ε_g = 200 π-mm-mrad (@ RFQ input energy of 12 keV/u)
- Desired twiss parameters α = 0.6 and β = 0.06 m
  - Measured beam emittances fit into RFQ transverse acceptance





RT 4-rod RFQ



rods (milled from Cu profiles)

stem

tuning plate

New design:

- Al-tank (no copper plating required)
- Simple adjustment of tuning plates, no alignment required
- High power operation

RFQ installed in beam line,
Conditioning started,
Beam tests in September 2010!

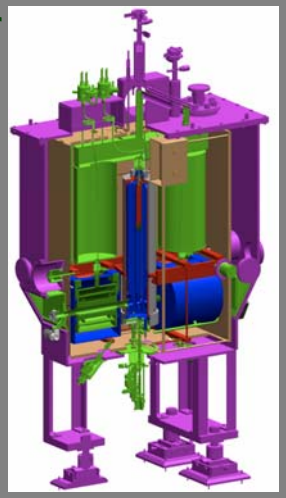
ReA3 SRF-cryomodules

ReA3 -

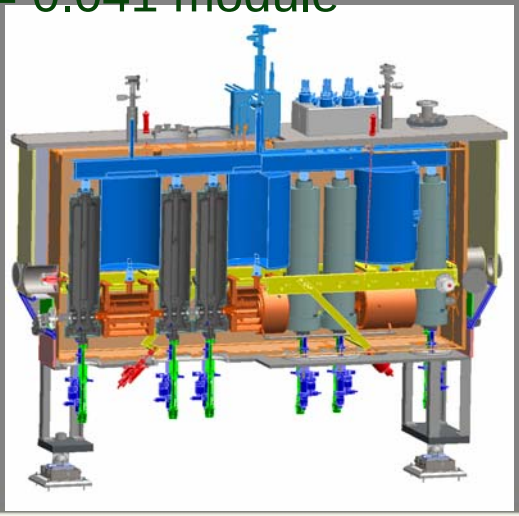
- 3 ReA3 Cryomodules
- 15 cavities
- 2 cavity types (QWR)
  - Beta=0.041 & 0.085
  - Same as FRIB design
- 8 solenoids
  - Same as used in FRIB

First two cryomodules completed, third in progress to be completed Q2FY2011

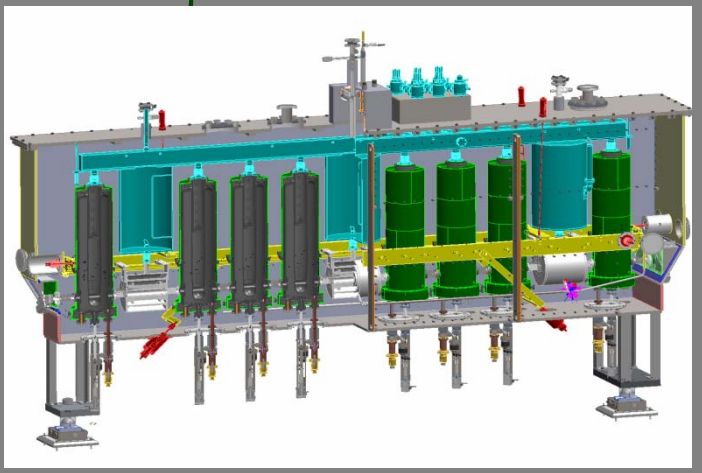
re-buncher



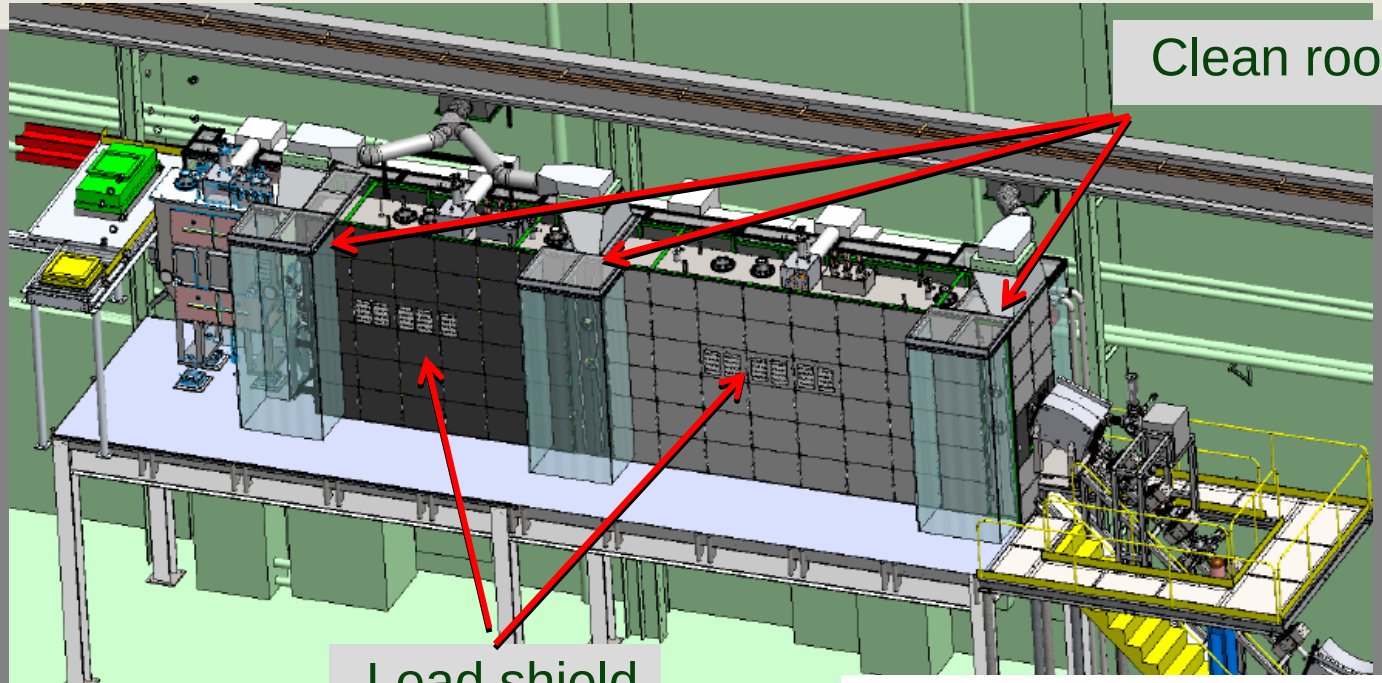
β = 0.041 module



β = 0.085 module

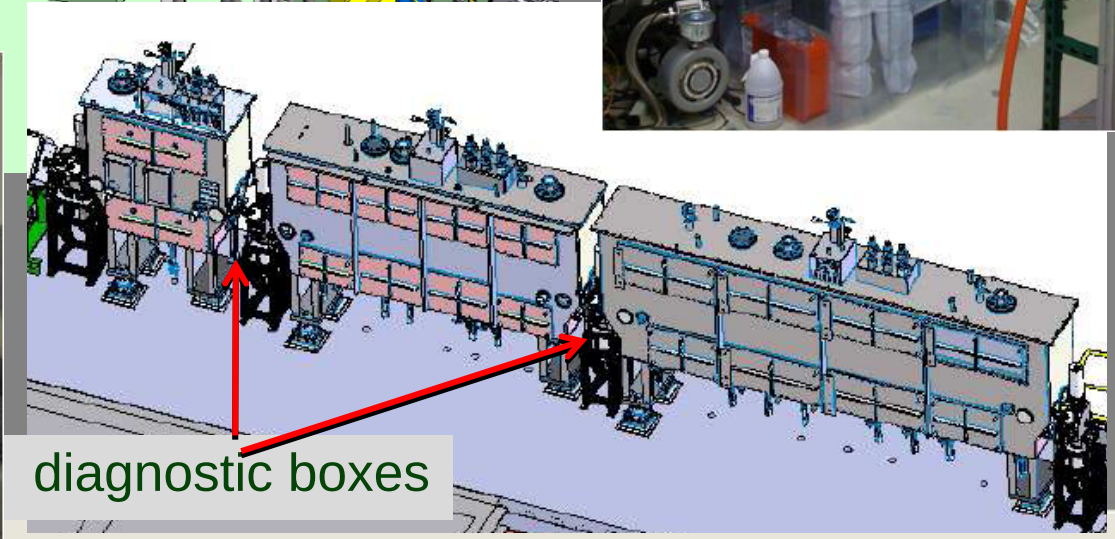


SRF-LINAC infrastructure



Clean rooms

Lead shield



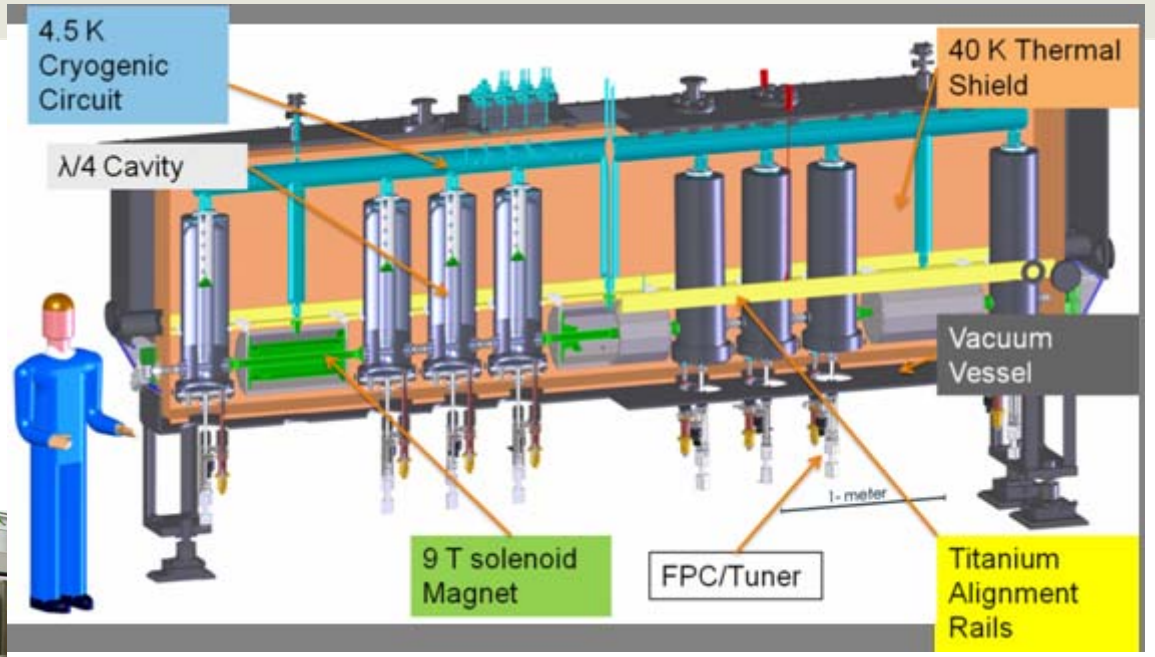
diagnostic boxes

Building cryomodules!

Clean room assembly of cold mass required!

Cold-mass ReA3 Cryomodule

Cryogenic Distribution System



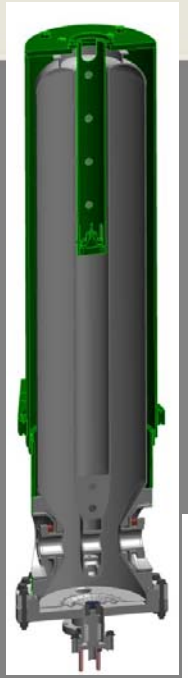
Performance tests of cavities and solenoids.

Thermal Shield

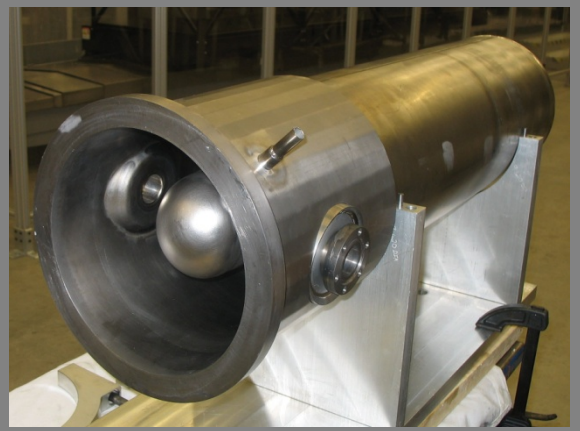
Vacuum Vessel ReA3 design

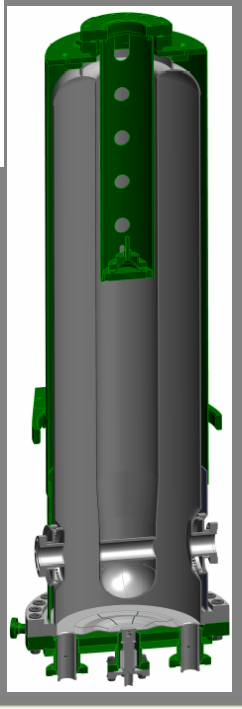
ReA3 – QWRs testing

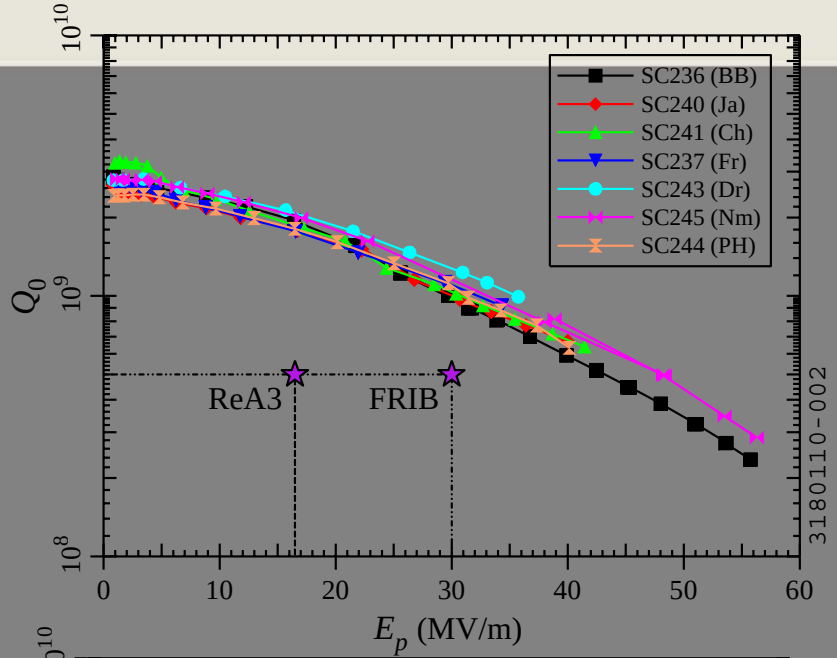
β_{opt}=0.041

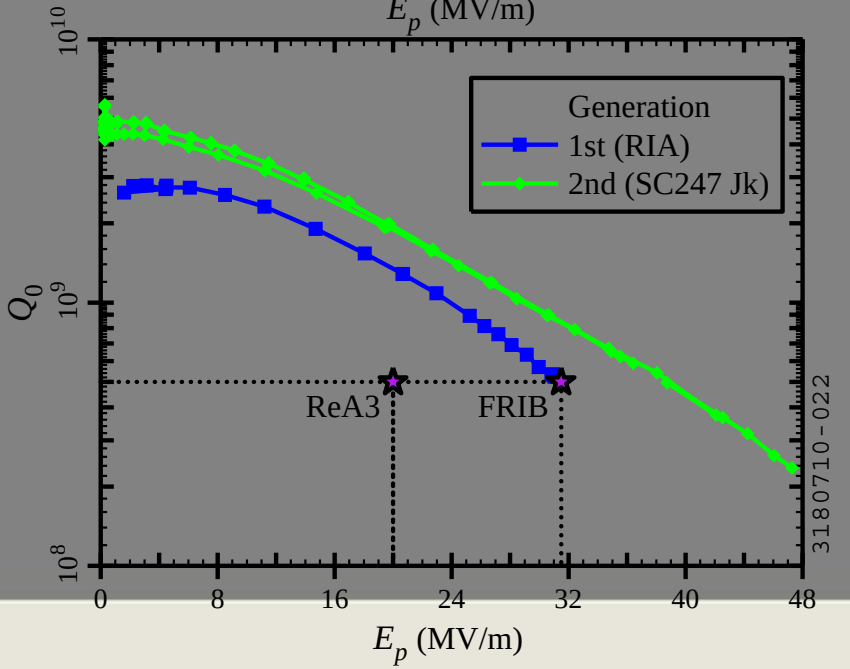


β_{opt}=0.085

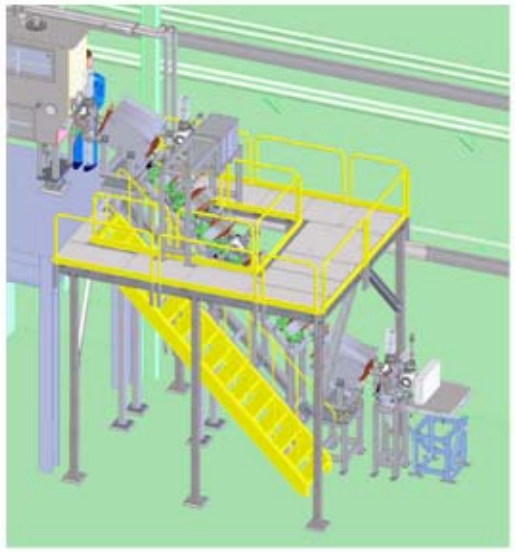


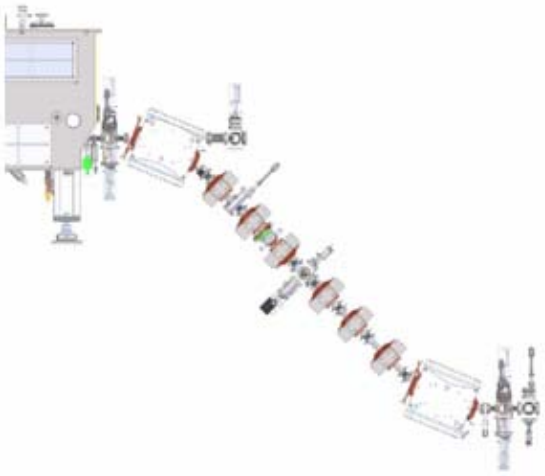






ReA3 High Energy Beam Transport (HEBT)





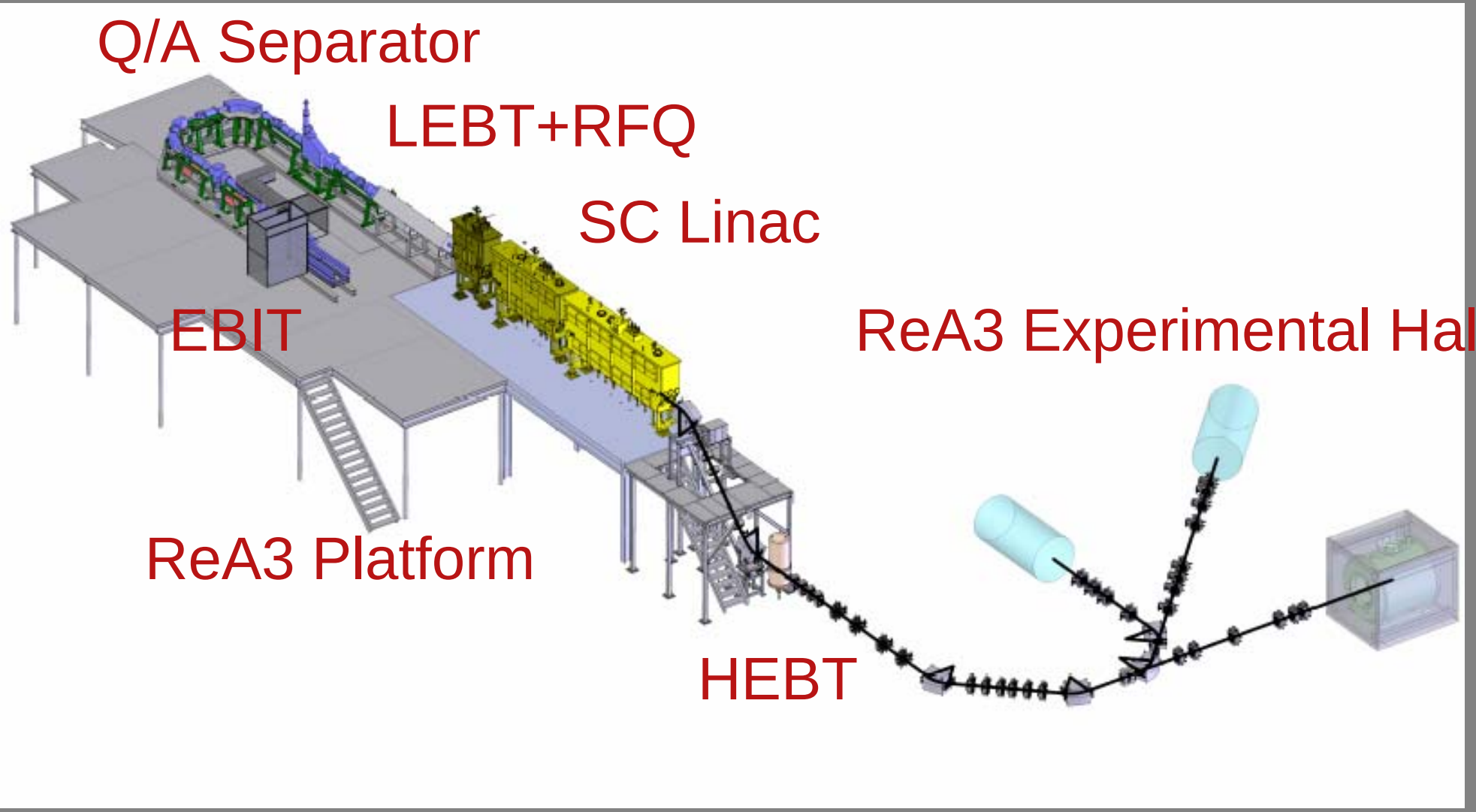
- Beam dynamics design completed
- Mechanical design of S-bend completed
- Magnets in production
- Completed end of 2010

- Beam dynamics design completed
- Design of Re-buncher cryomodule started
- Completed end of 2011

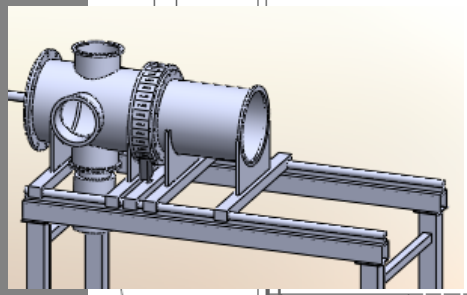
β=0.041 QWR Re-buncher

ReA3 Platform

ReA3 Facility Layout



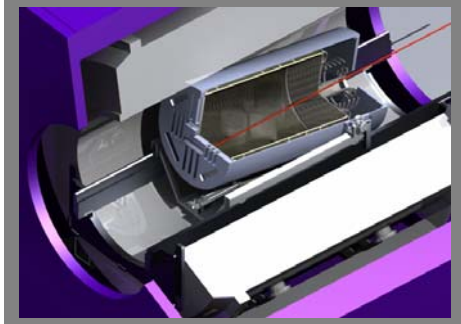
Strong interests using ReA3 RIBs for nuclear astrophysics experiments



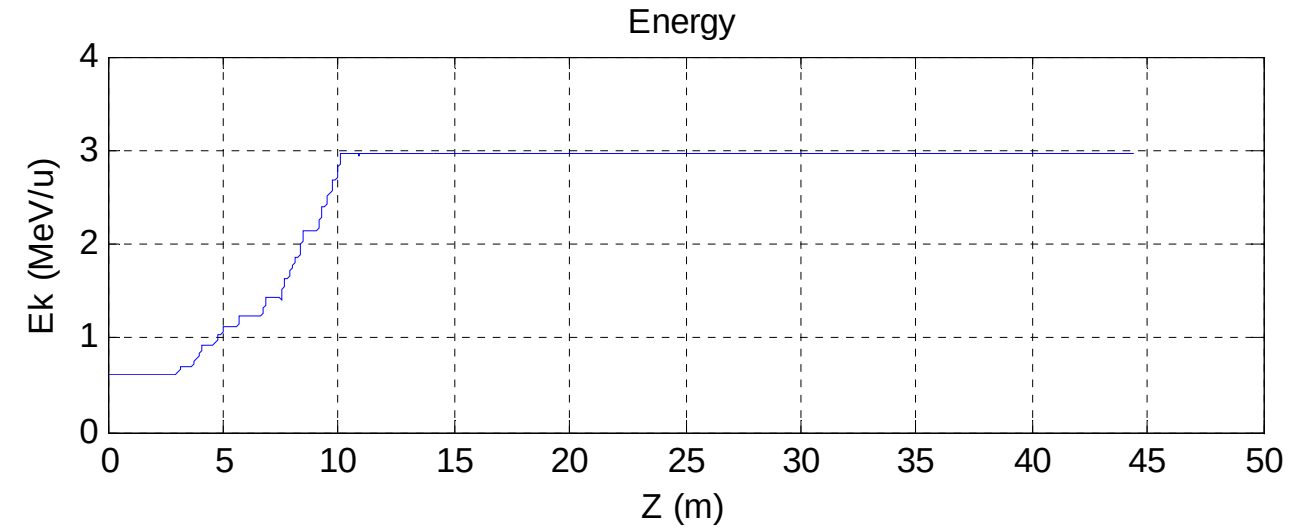
ANSEN
SeGA
CAESAR

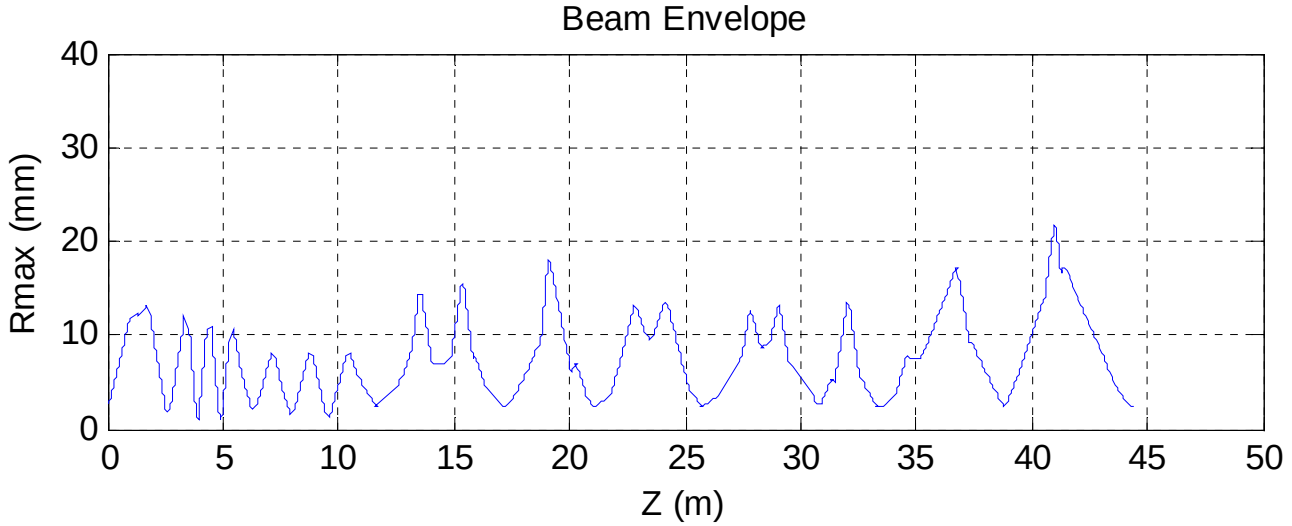
JENSA
SECAR

AT-TPC

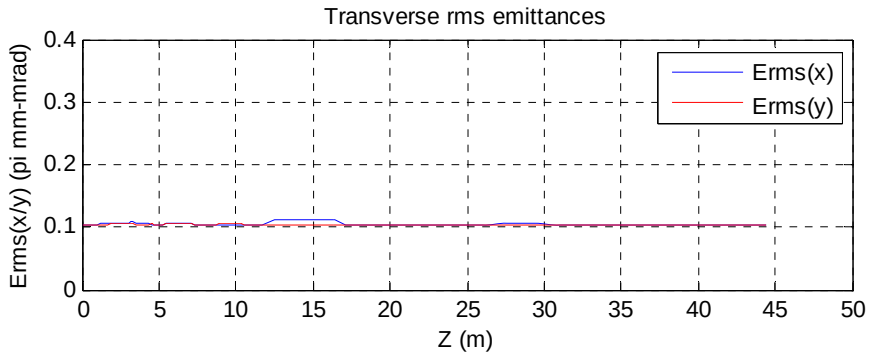


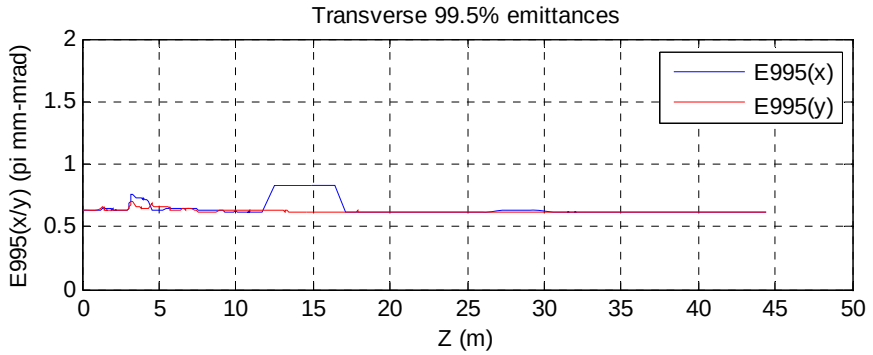
ReA3 Beam Simulations

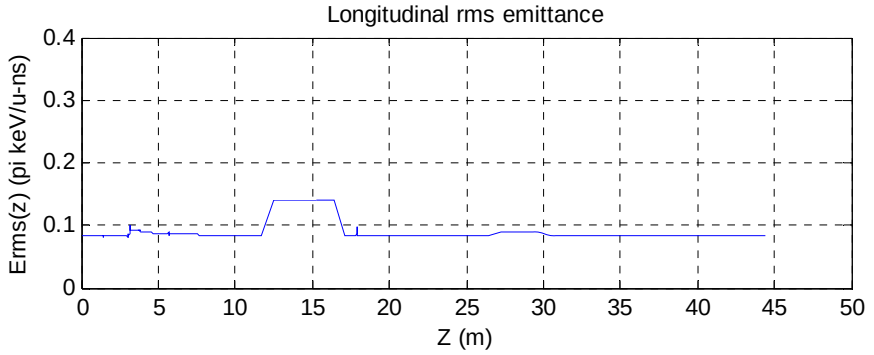


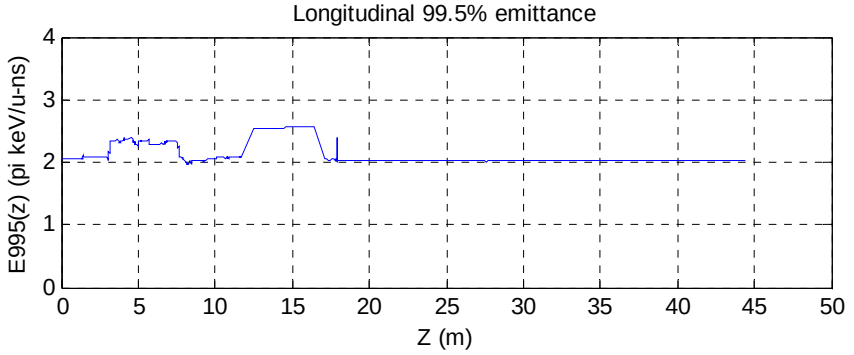


ReA3 Beam Simulations

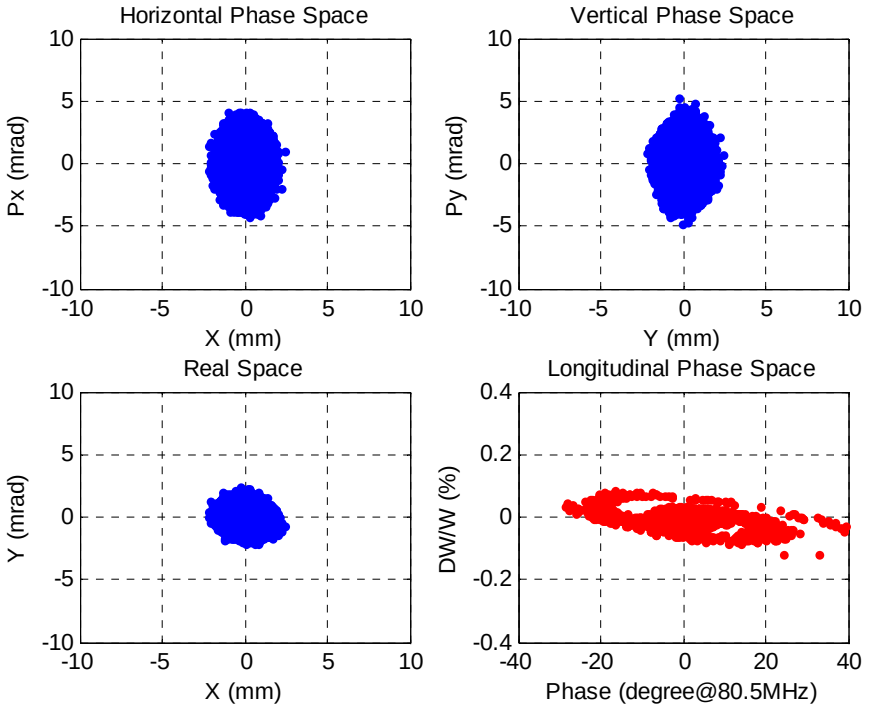


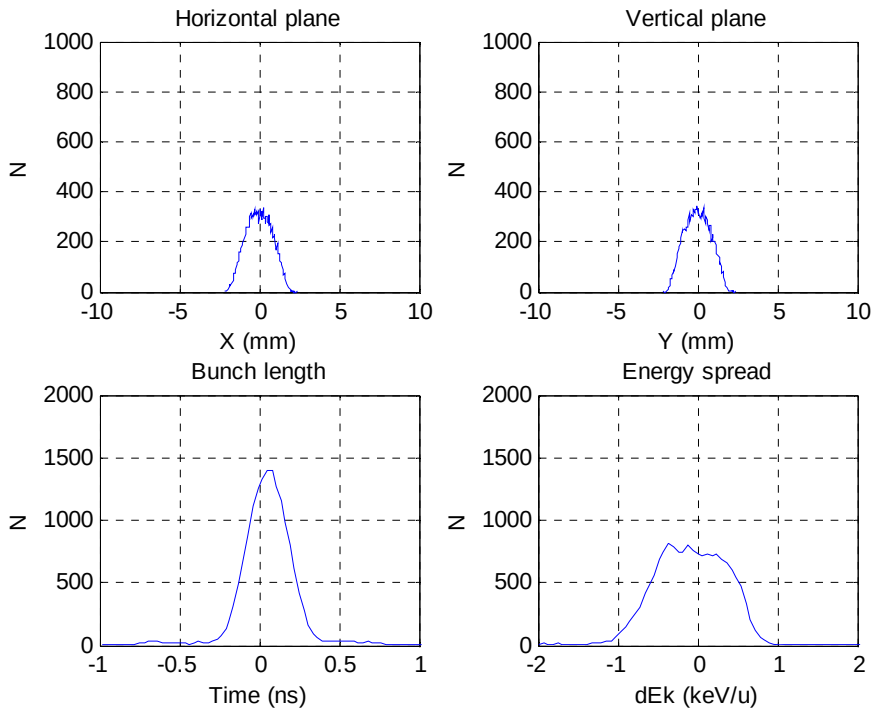




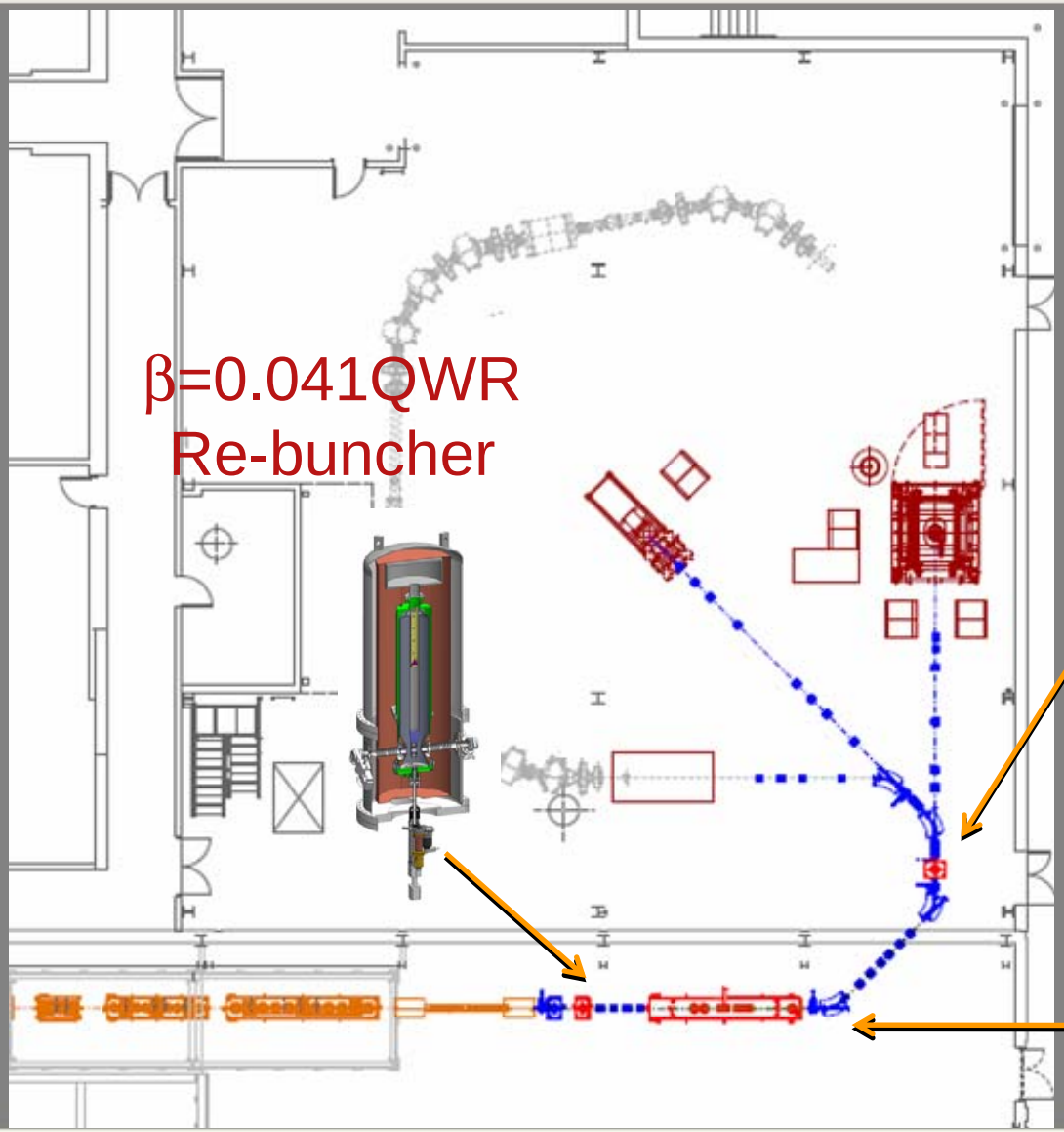


ReA3 Beam Simulations

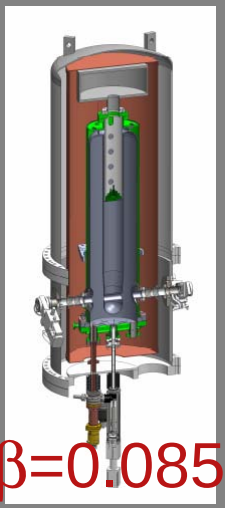




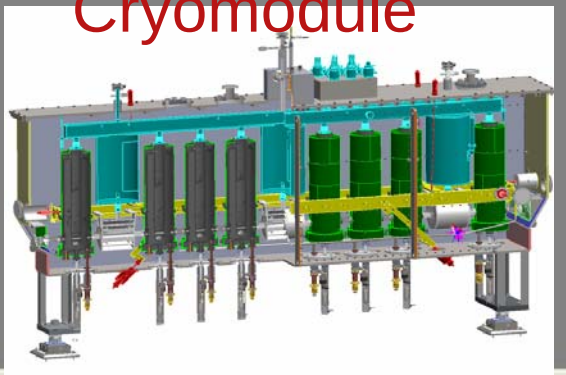
ReA3 to ReA6 Upgrade



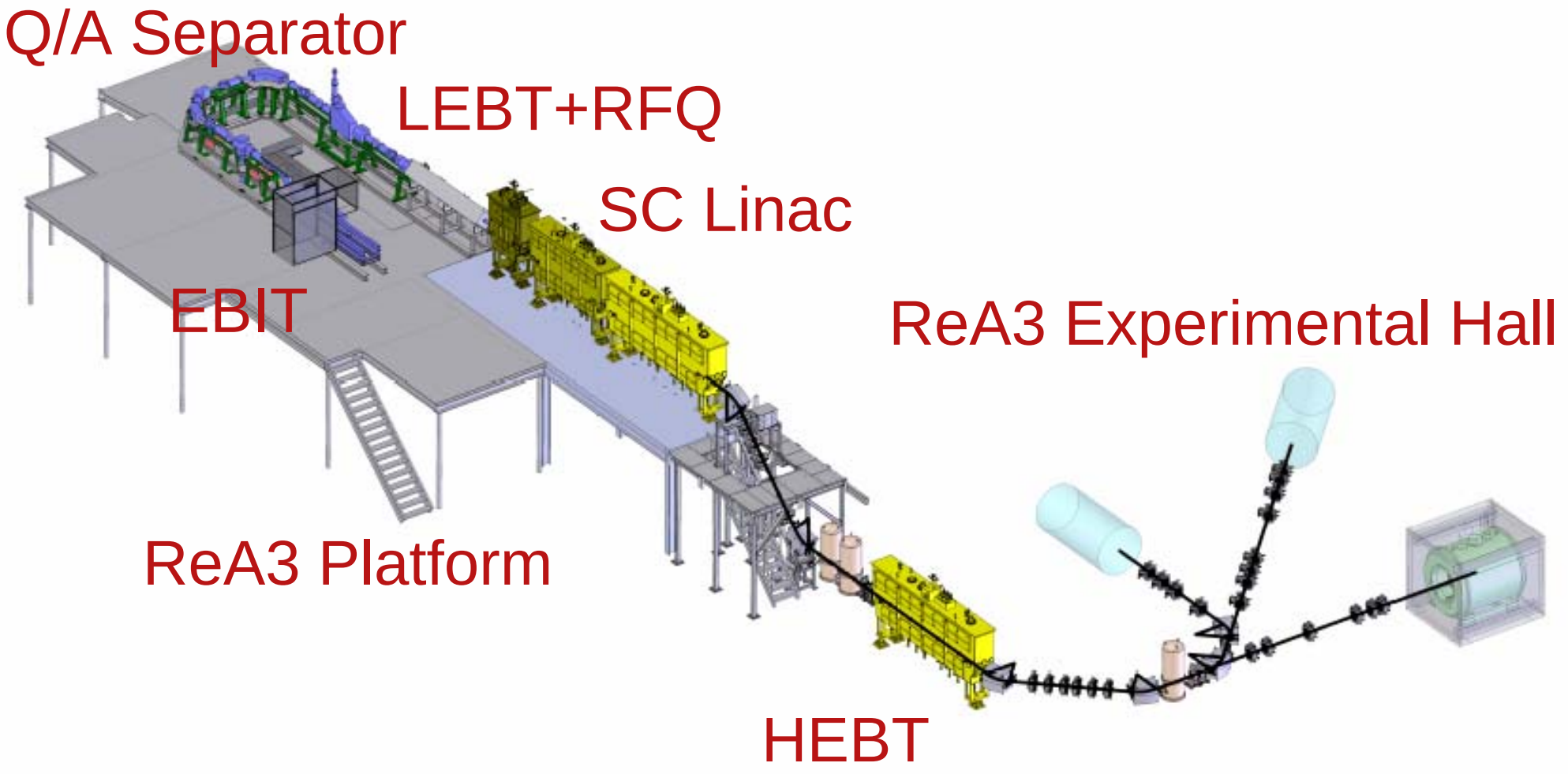
β=0.085 QWR
Re-buncher



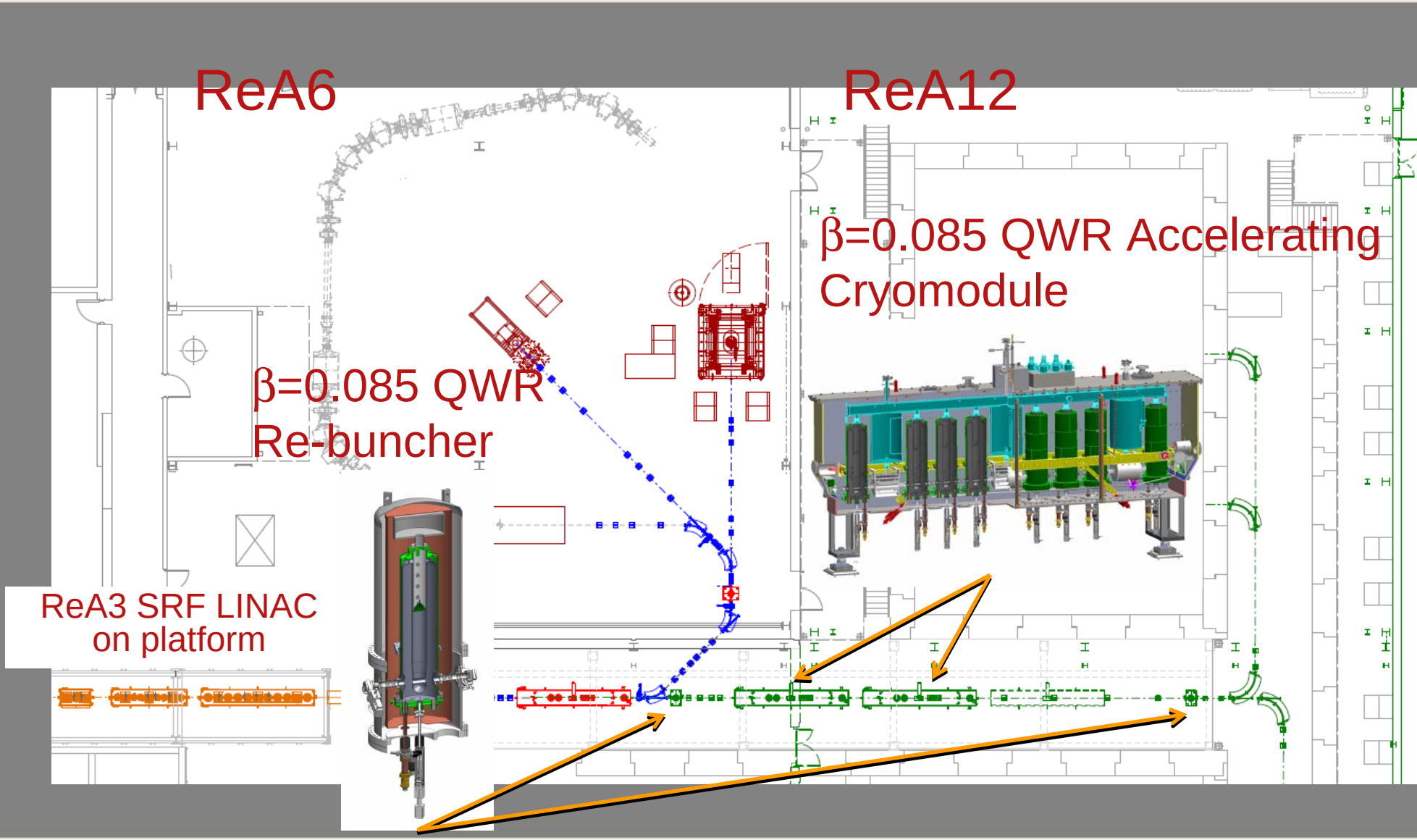
β=0.085 QWR
Accelerating
Cryomodule



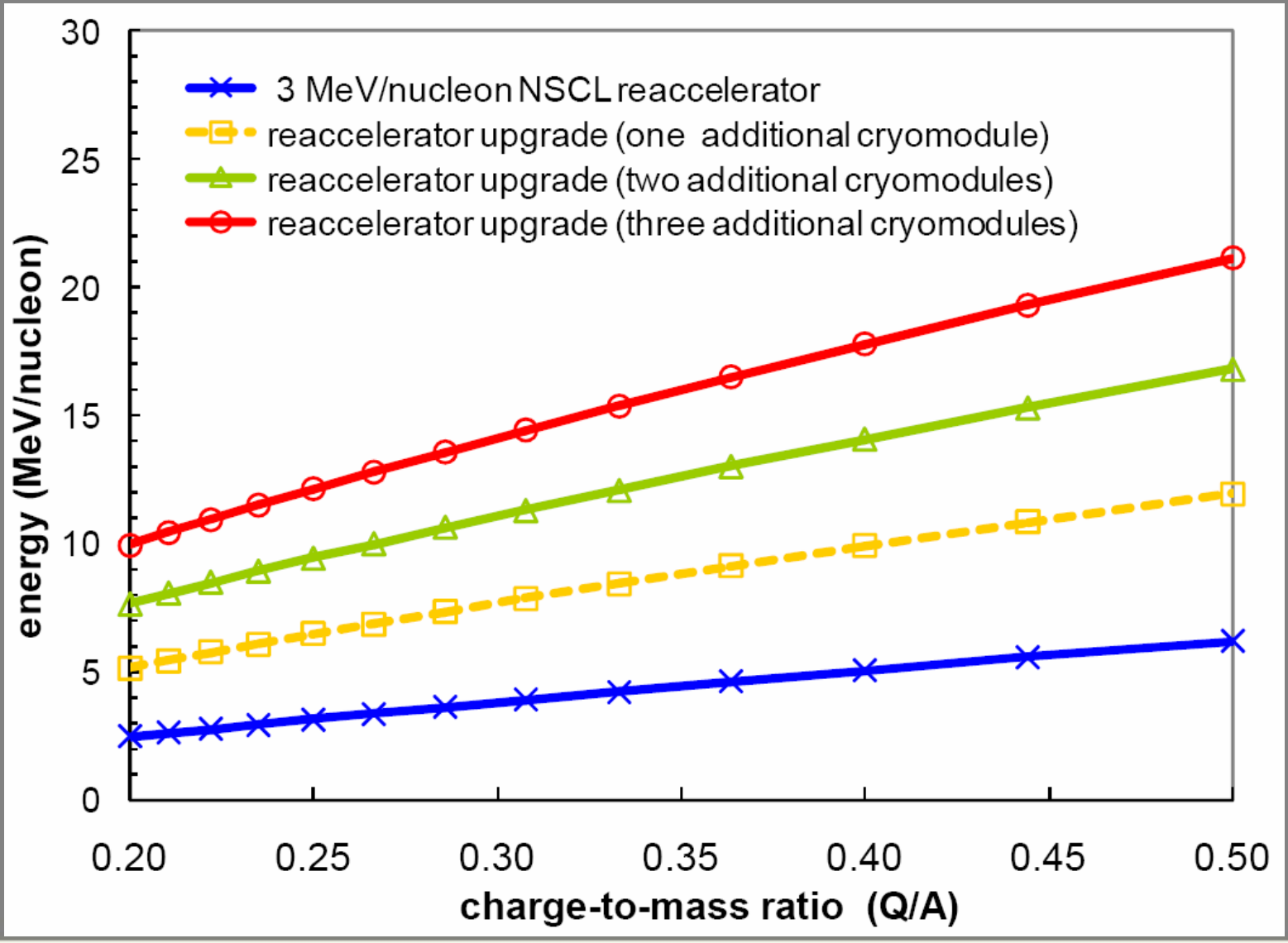
ReA6 Facility Layout



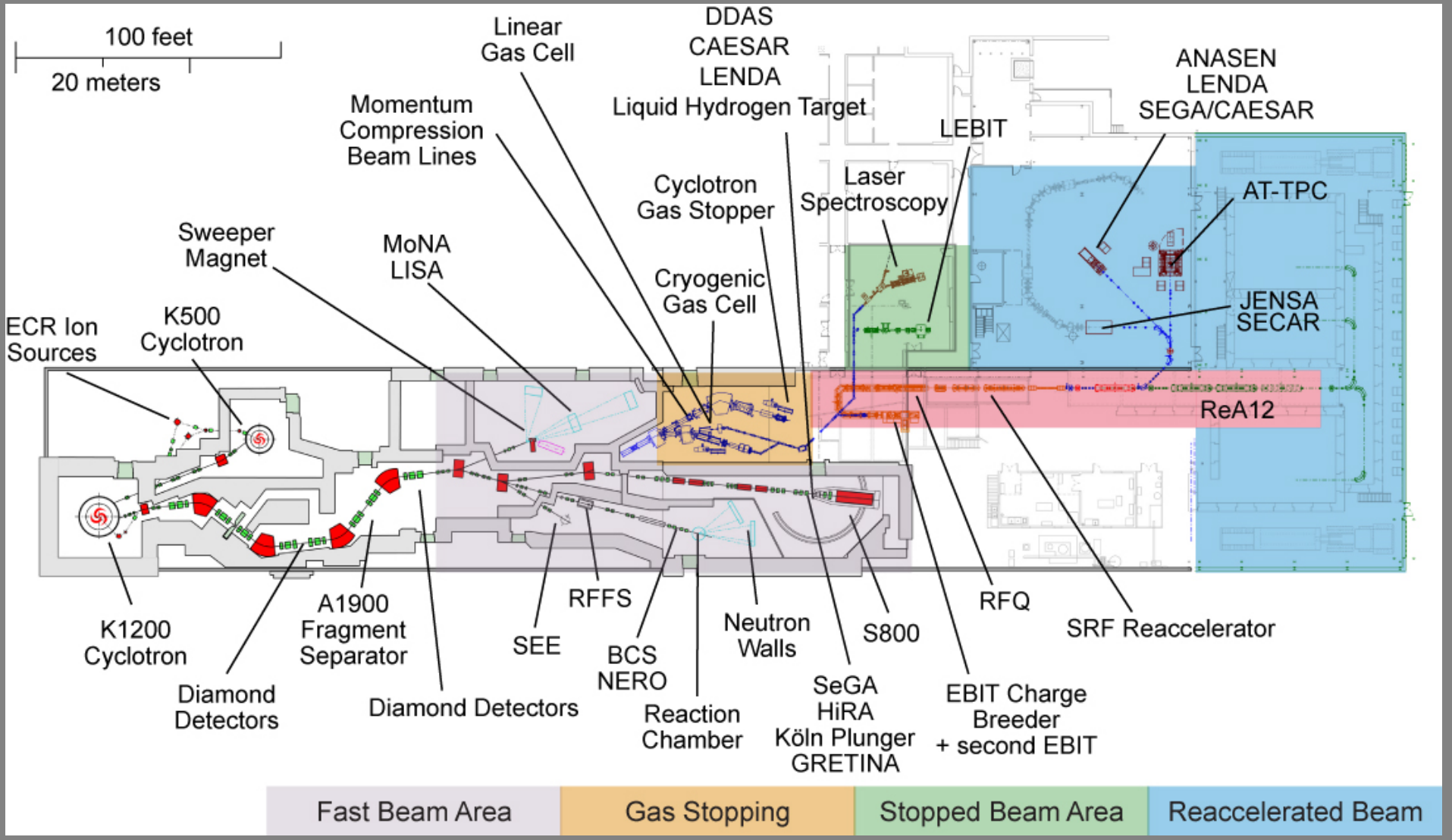
ReA6 to ReA12 Upgrade



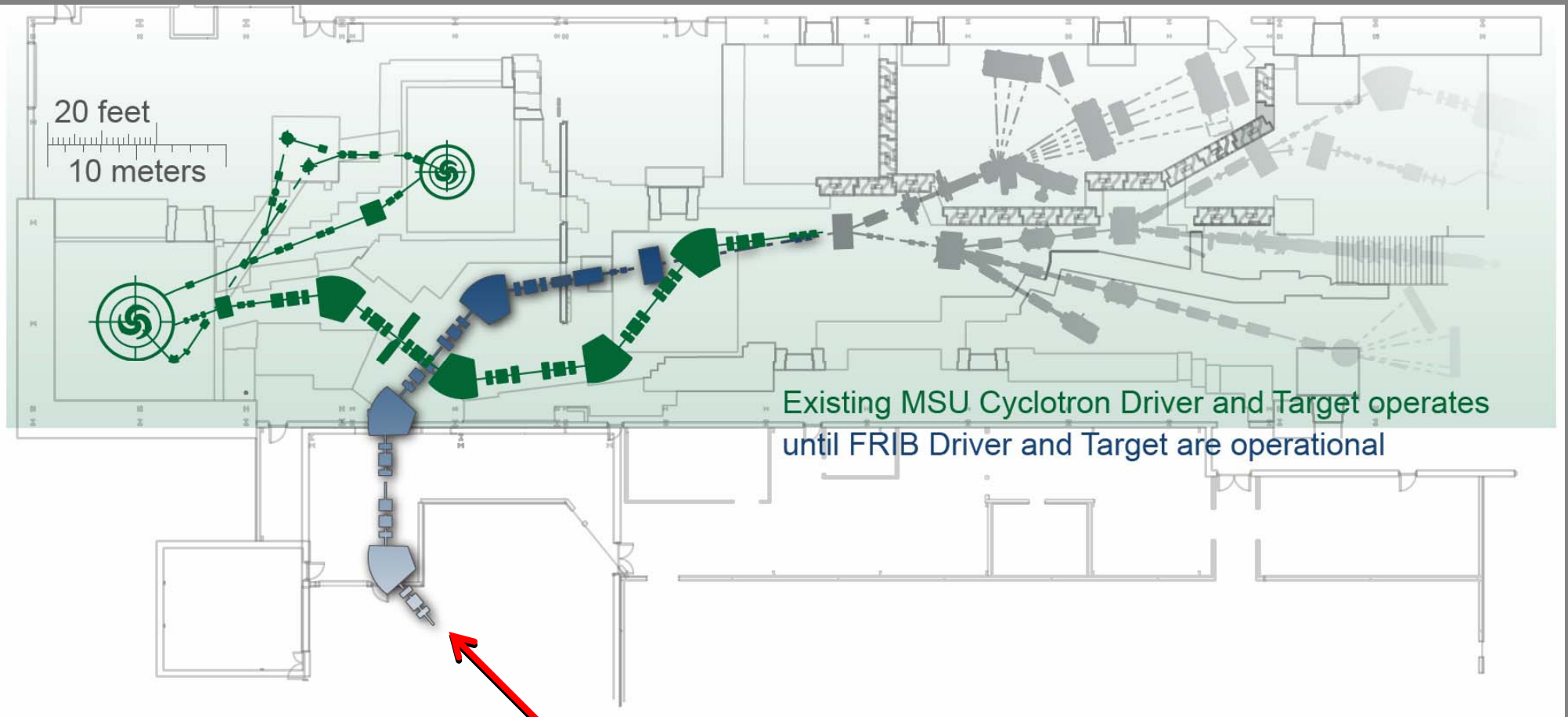
Re-Accelerator Energy Increase with Additional Cryomodules



NSCL Pre-FRIB (2016) Facility Layout



Fast, Stopped, and Re-accelerated RIBs at NSCL with FRIB



RIBs from FRIB

Summary ReA3 status

- Test of EBIT electron beam system done, magnet commissioned, assembly ongoing → first operation October
- Q/A-separator beam commissioning completed
- LEBT beam commissioning is presently performed
- RFQ tuning completed, conditioning ongoing, first beam tests in early September 2010
- SRF-linac:
  - re-buncher rf-tests completed, first beam tests in conjunction with RFQ beam commissioning
  - $\beta = 0.041$ module installed, hardware tests are being performed
  - $\beta = 0.085$ under construction
- Accelerated stable beams → end of 2010
- Reaccelerated beams in 2011