LOW-ENERGY LOW-INTENSITY DIAGNOSTICS FOR REA3 @ NSCL/MSU

DIAGNOSTICS FOR THE NEEDS OF FRIB

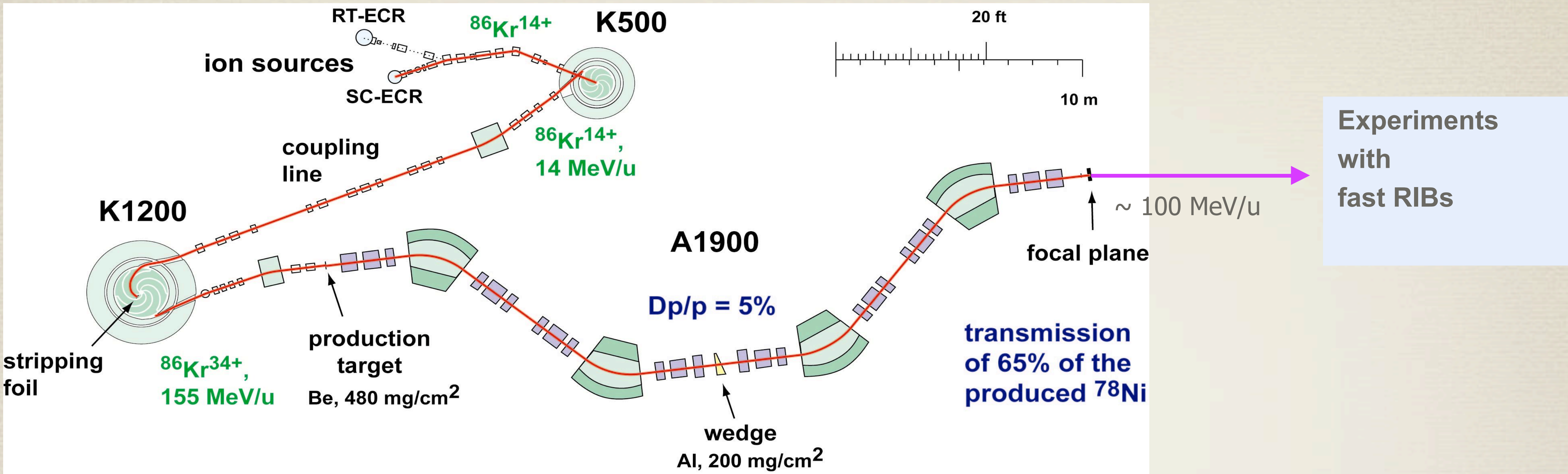
G. Perdikakis for the ReA3 team

NSCL

MICHIGAN STATE UNIVERSITY

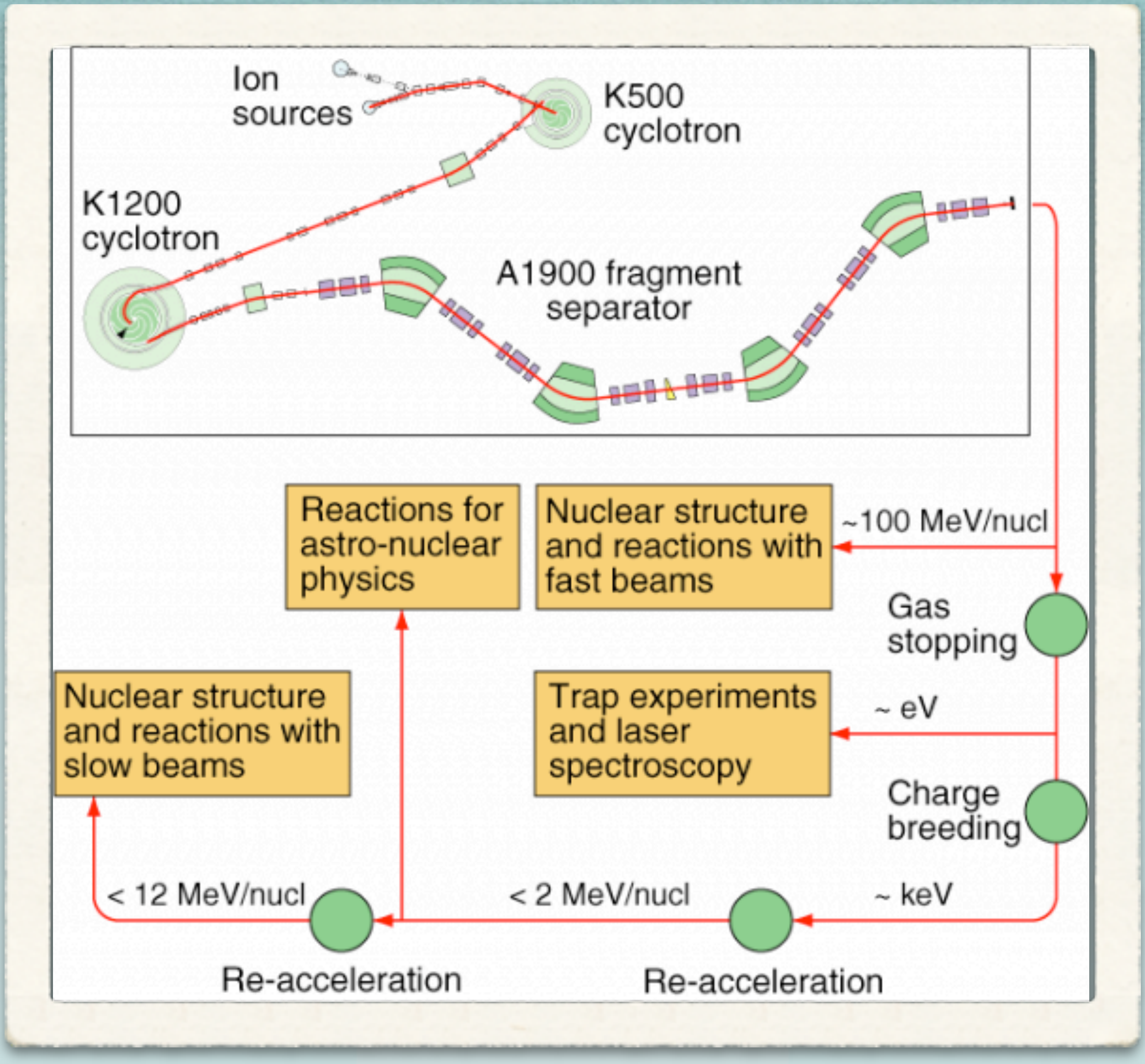
Advancing Knowledge. Transforming Lives.

National Superconducting Cyclotron Laboratory



- Cyclotron-based facility
- Fast Radioactive Beams by projectile fragmentation
- Fragments Energy ~ 100MeV/u

Science opportunities @ ReA3

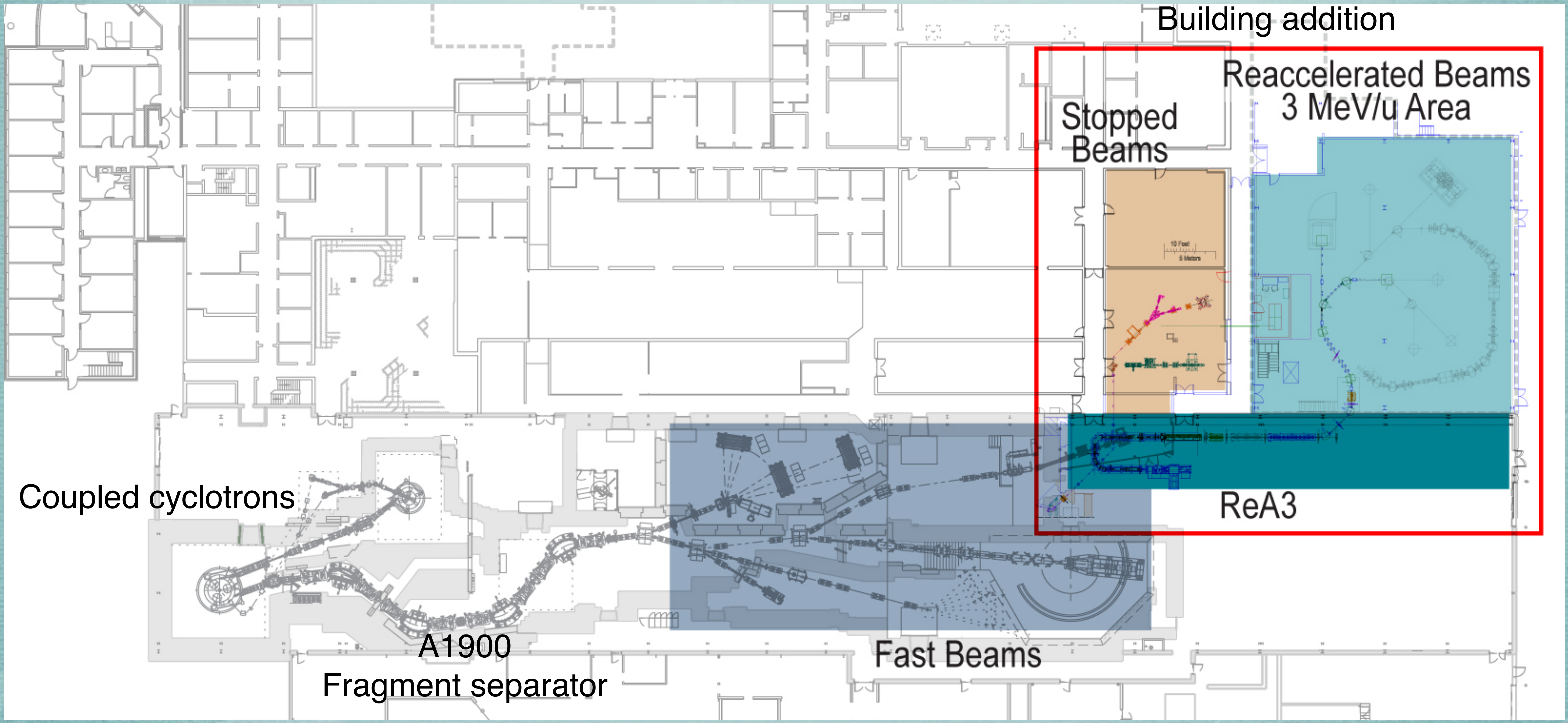


- ReA3 part of FRIB - to be extended to 12 MeV/u (ReA12)
- Allows to develop techniques and programs before FRIB operation

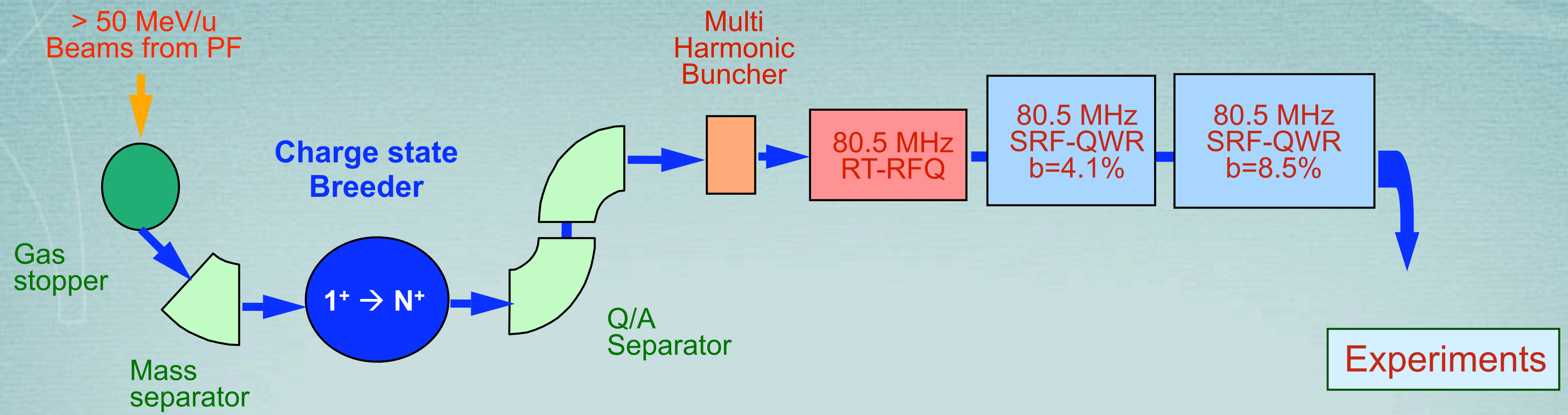
to be completed in 2010

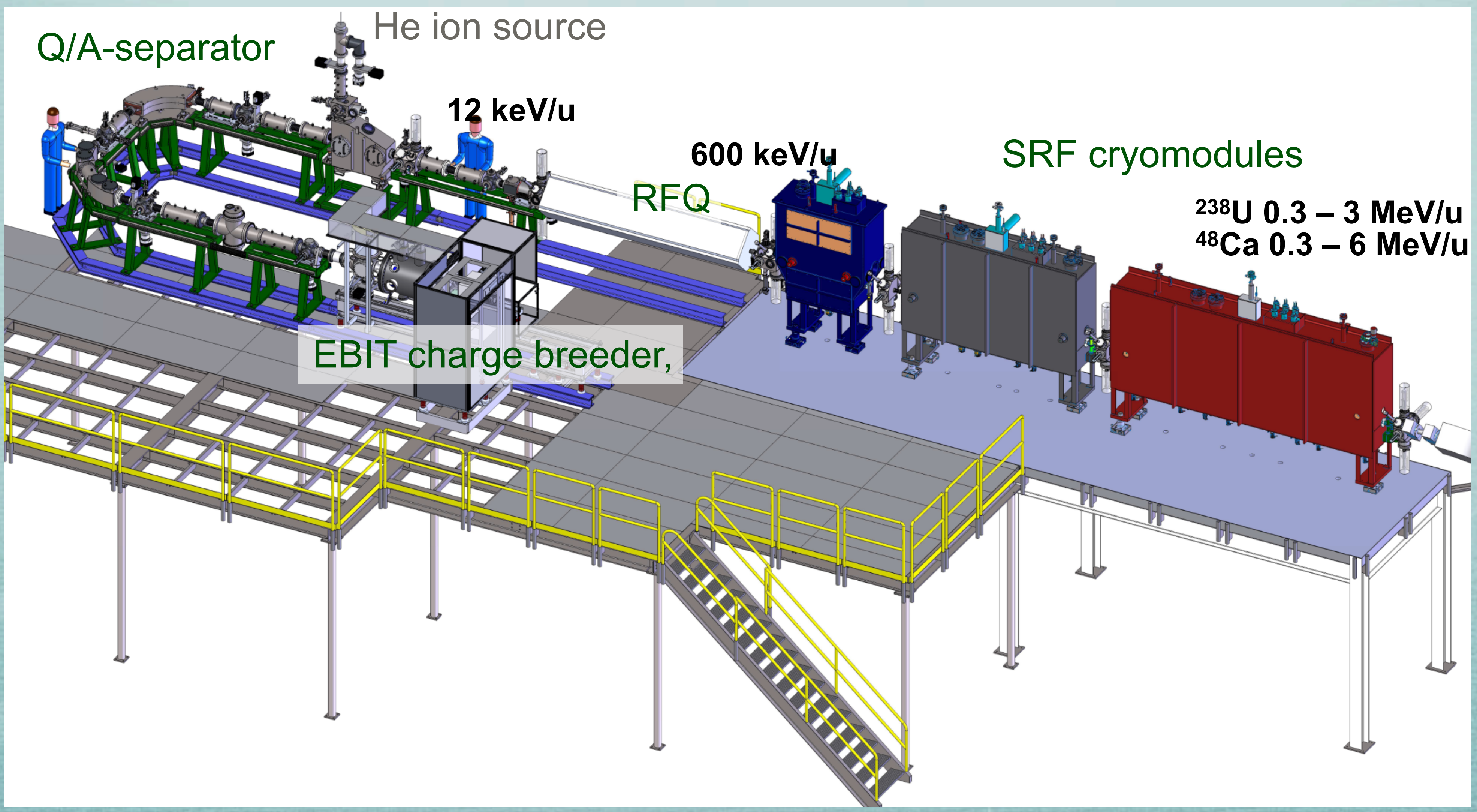
ReA3 at the Coupled Cyclotron Facility

- Coupled cyclotrons beams : ~ 100 MeV/u
- ReA3 beams : 0.3 - 3 MeV/u for Q/A=1/4 rare isotope beams



THE REA3 CONCEPT





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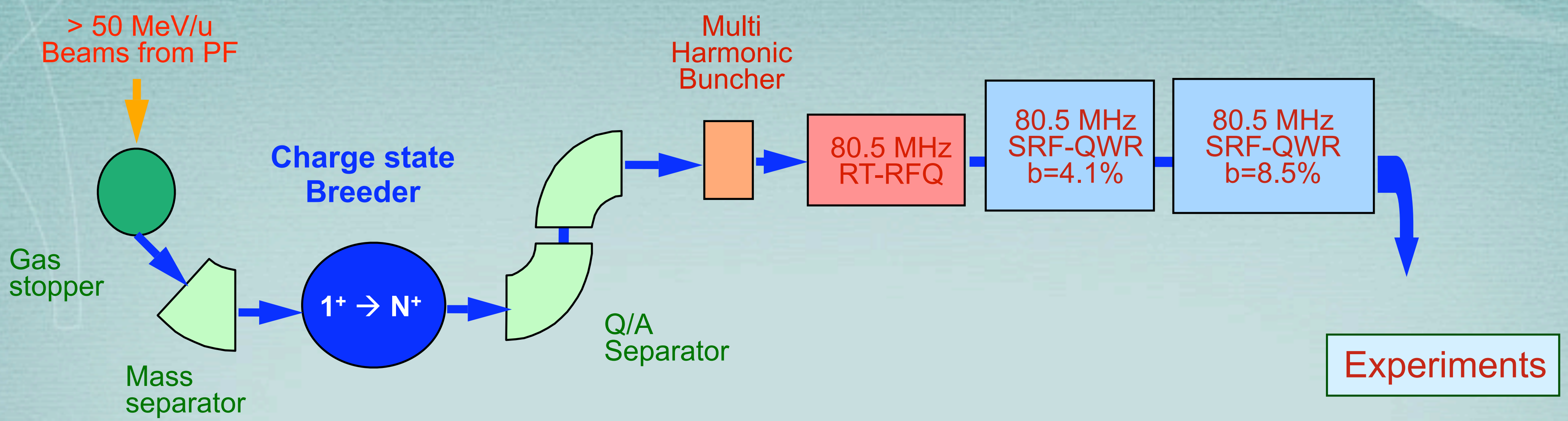

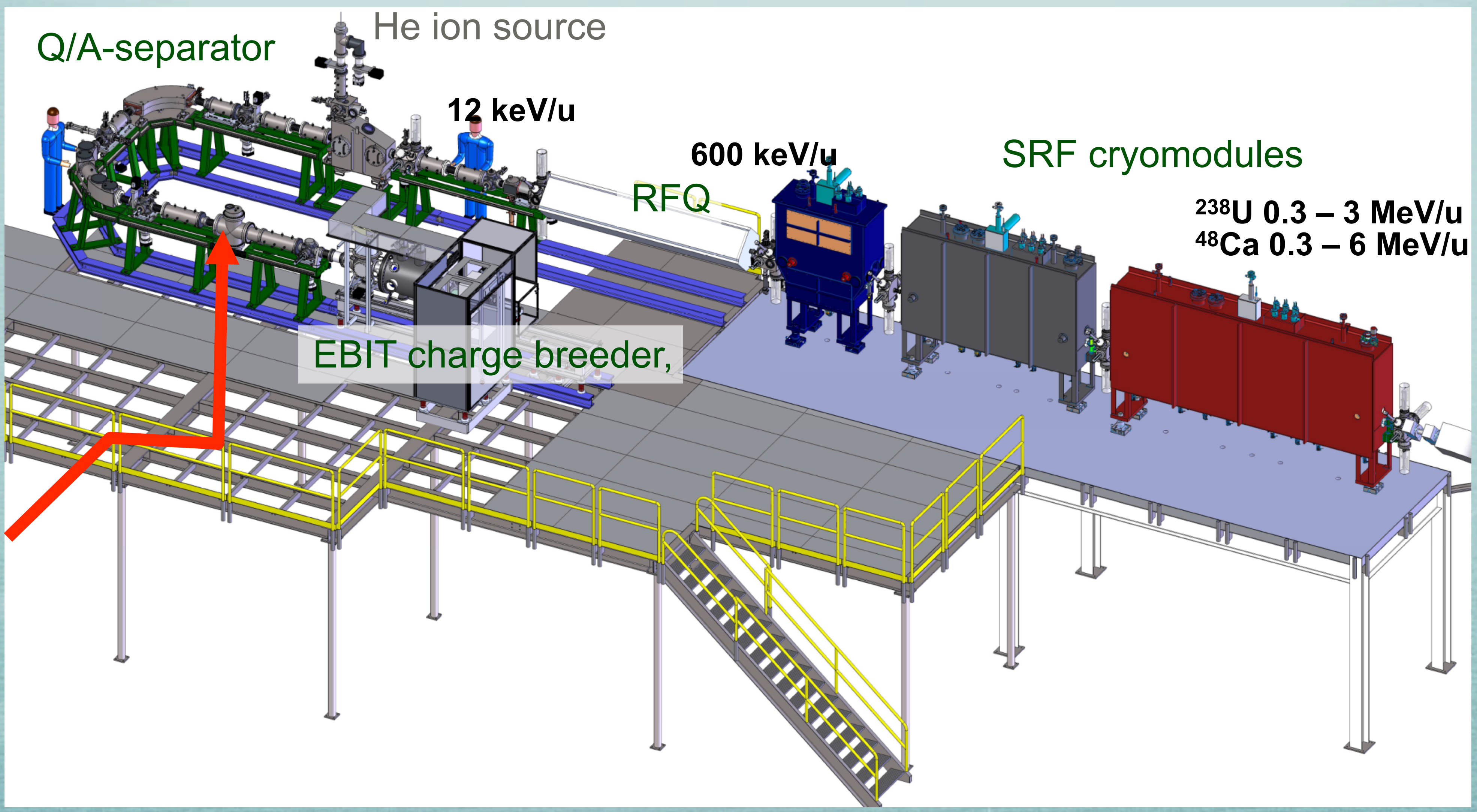

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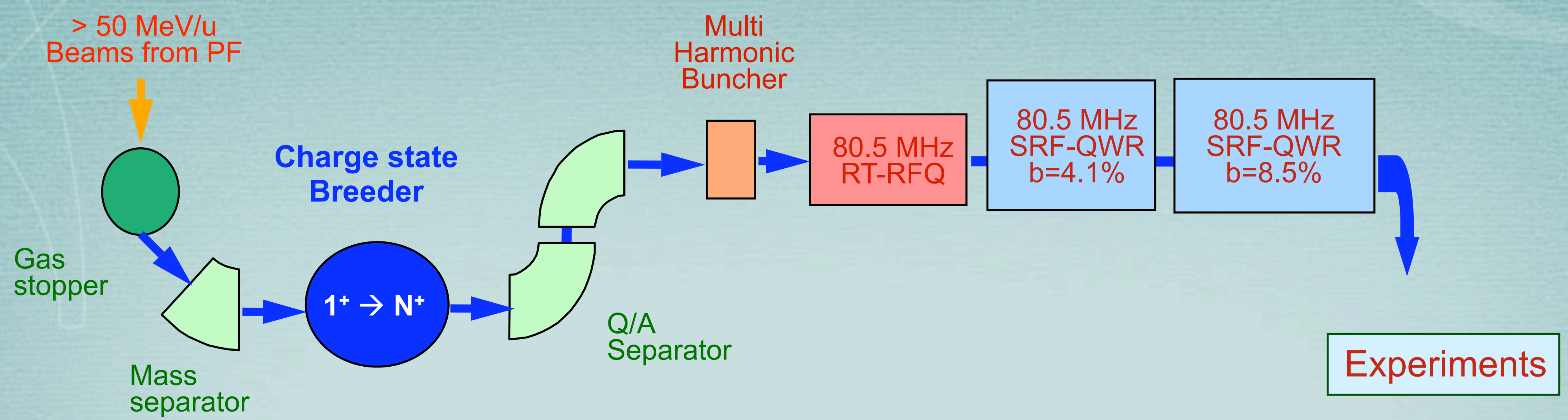

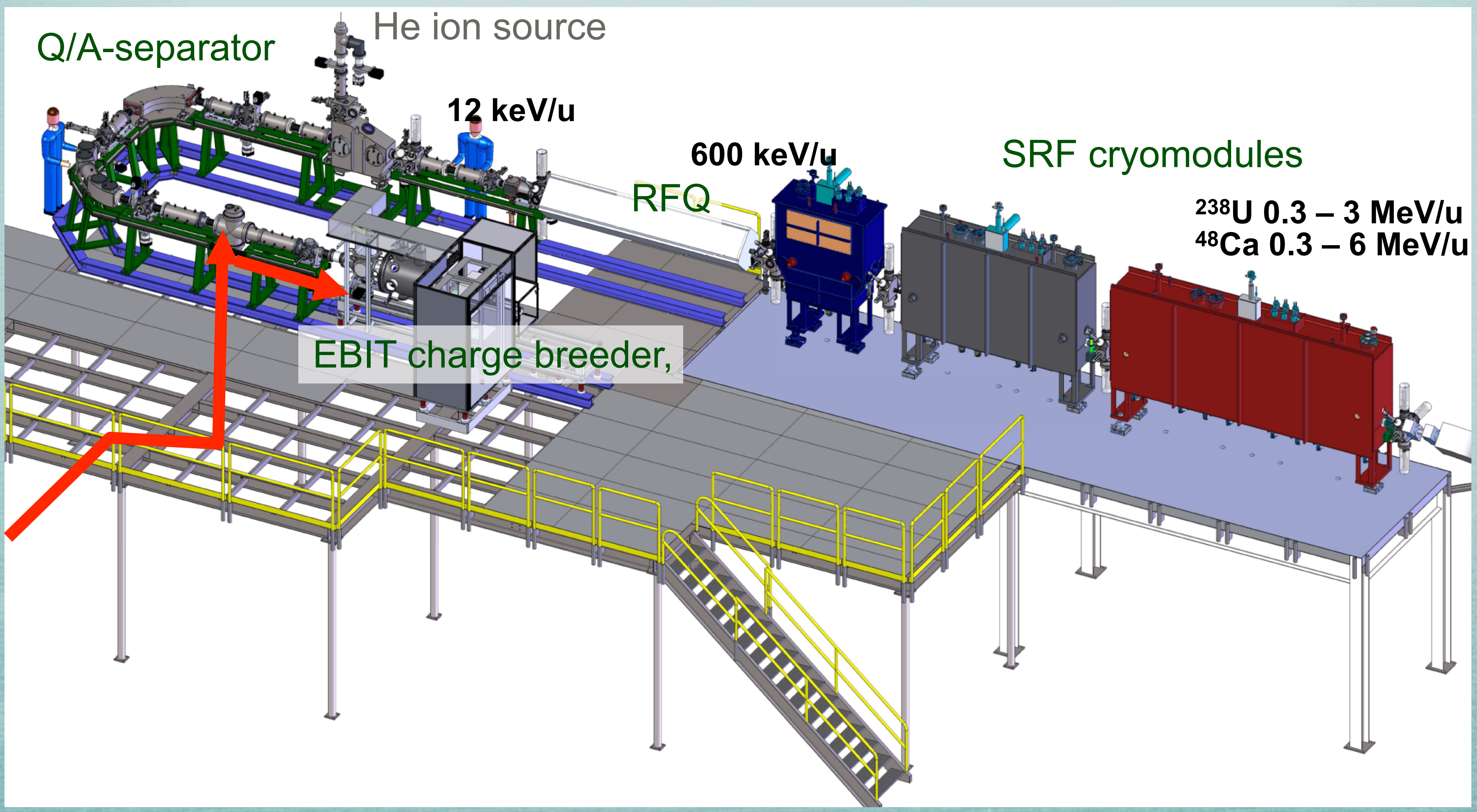

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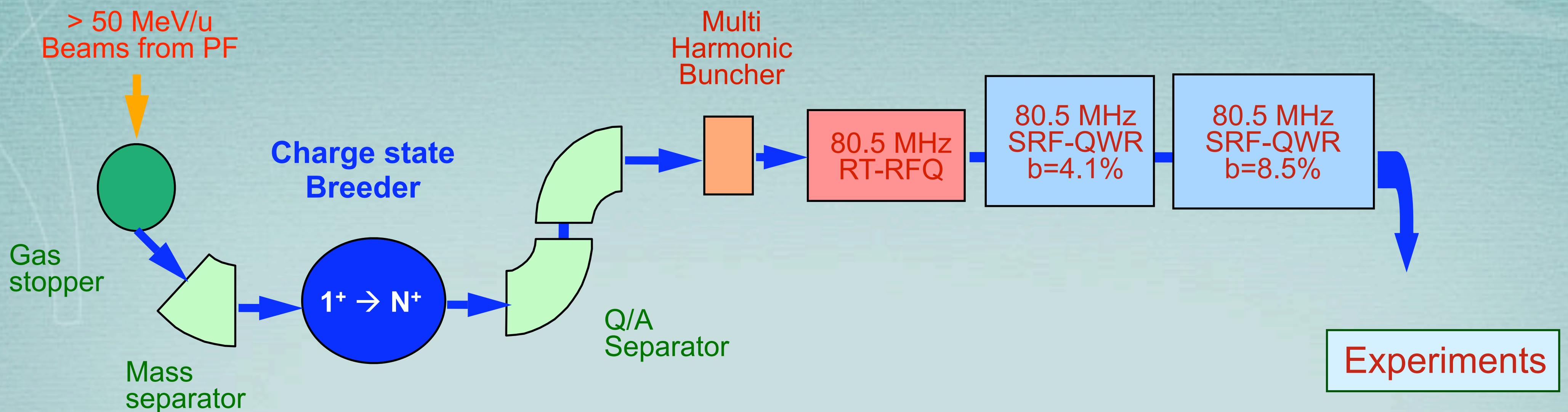

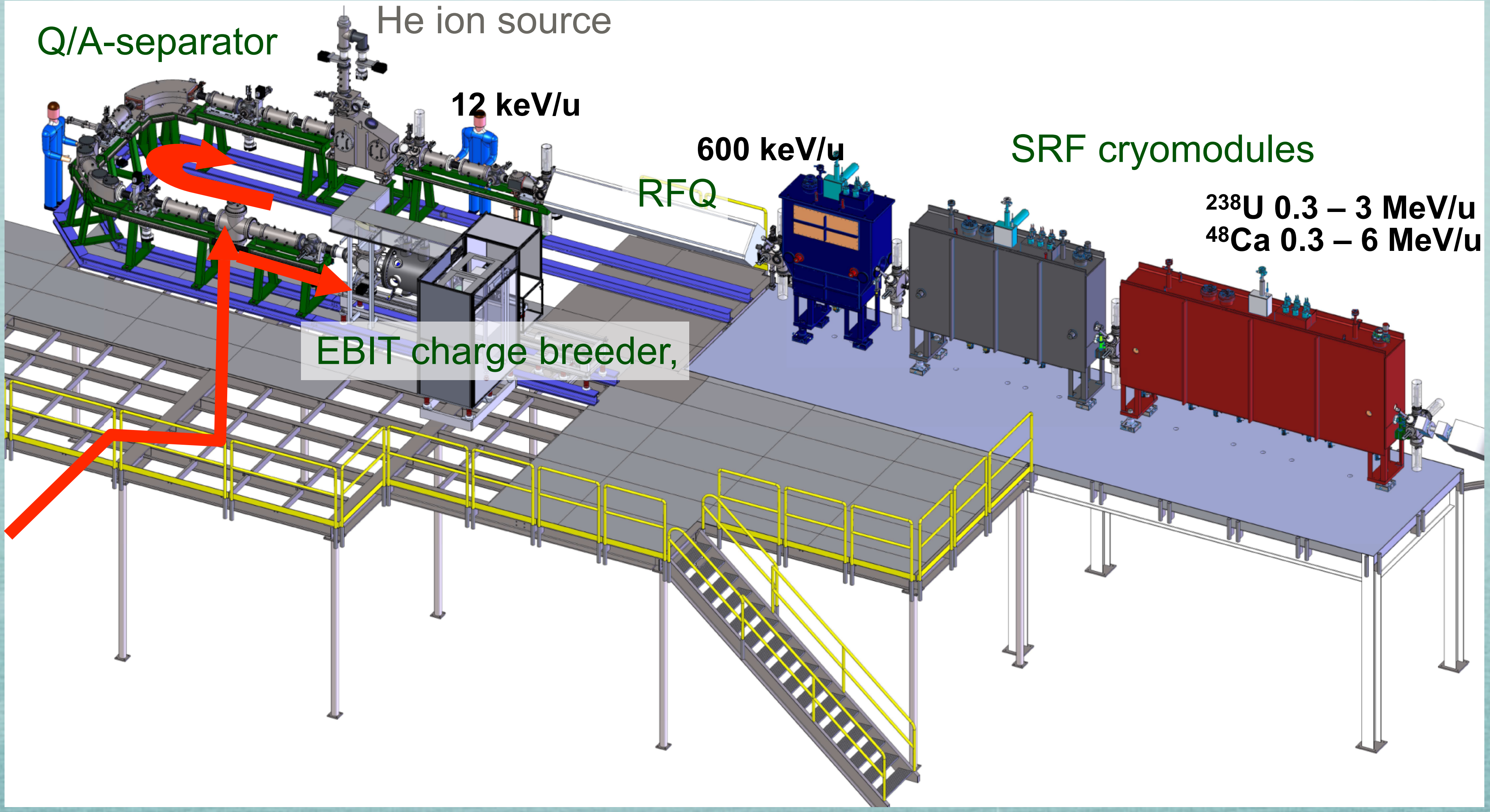

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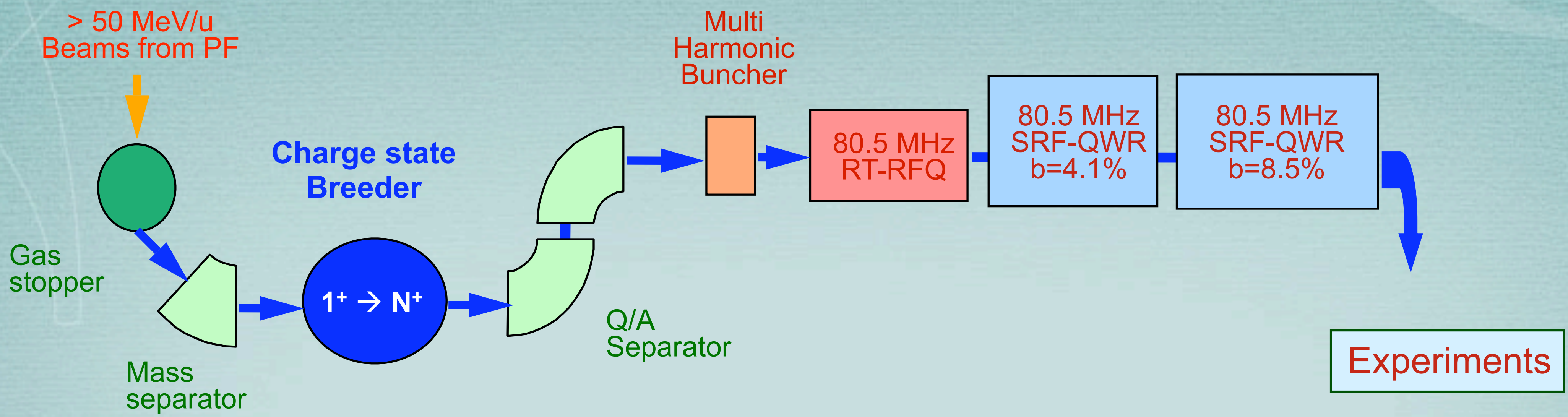

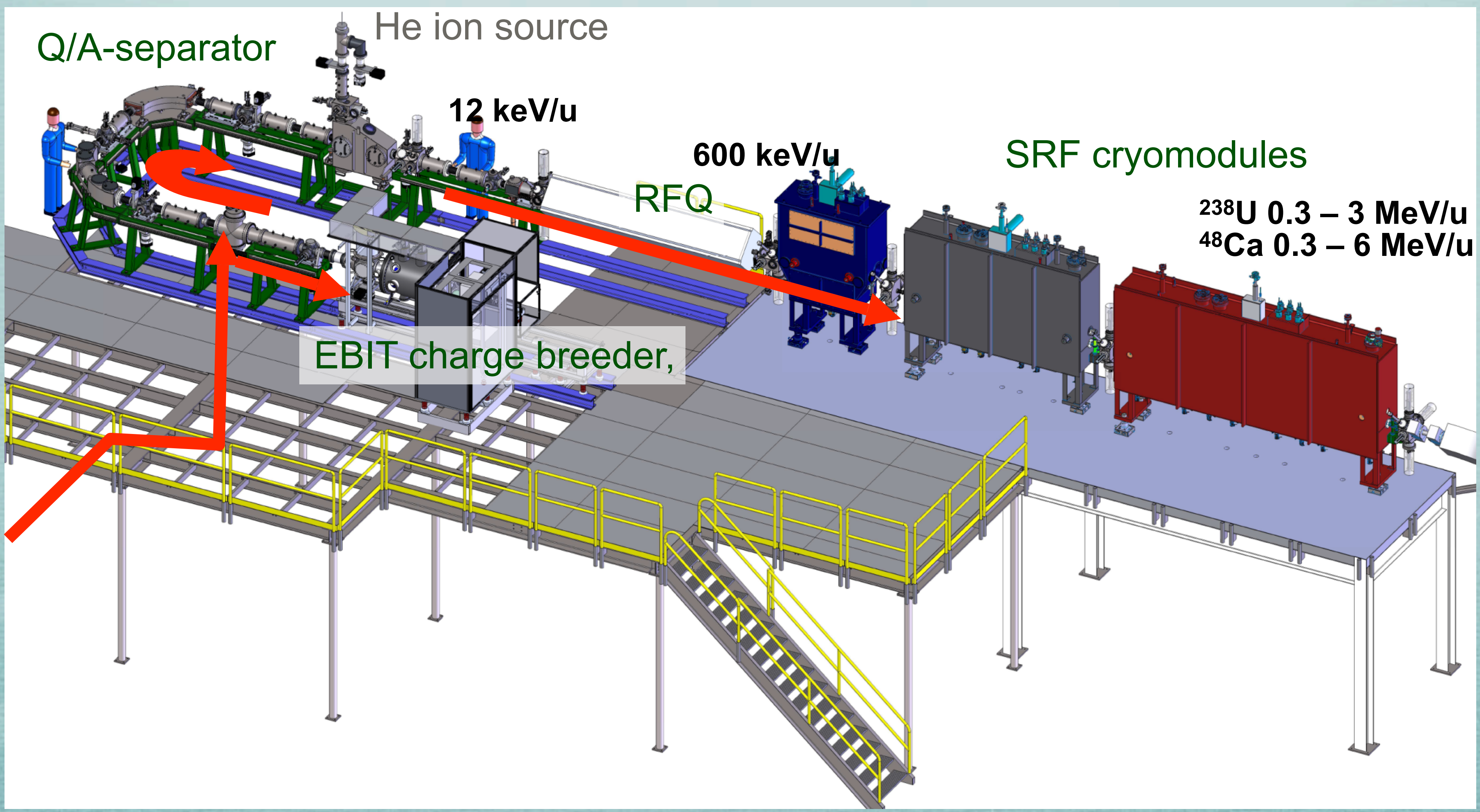

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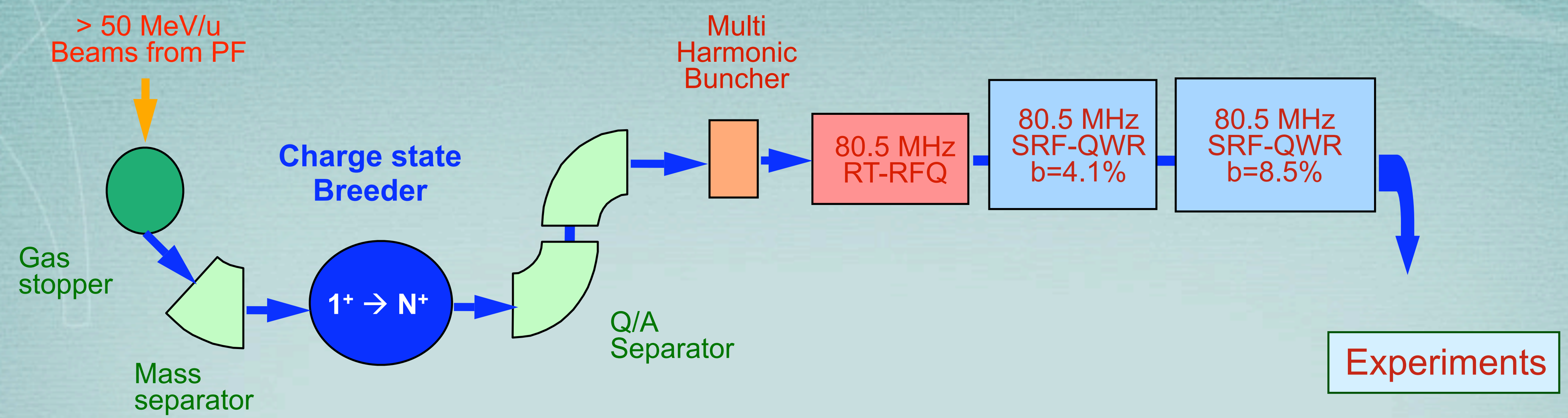
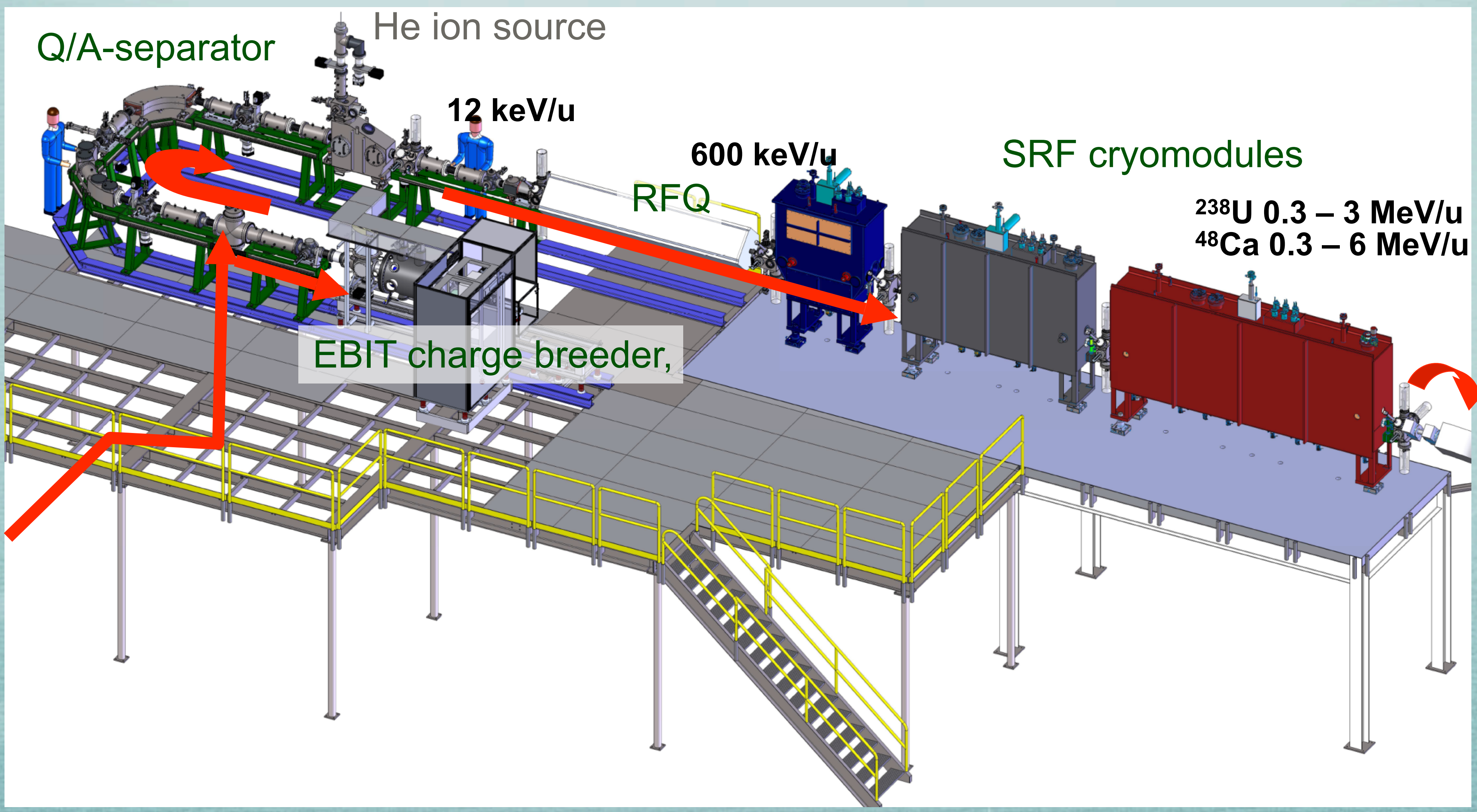
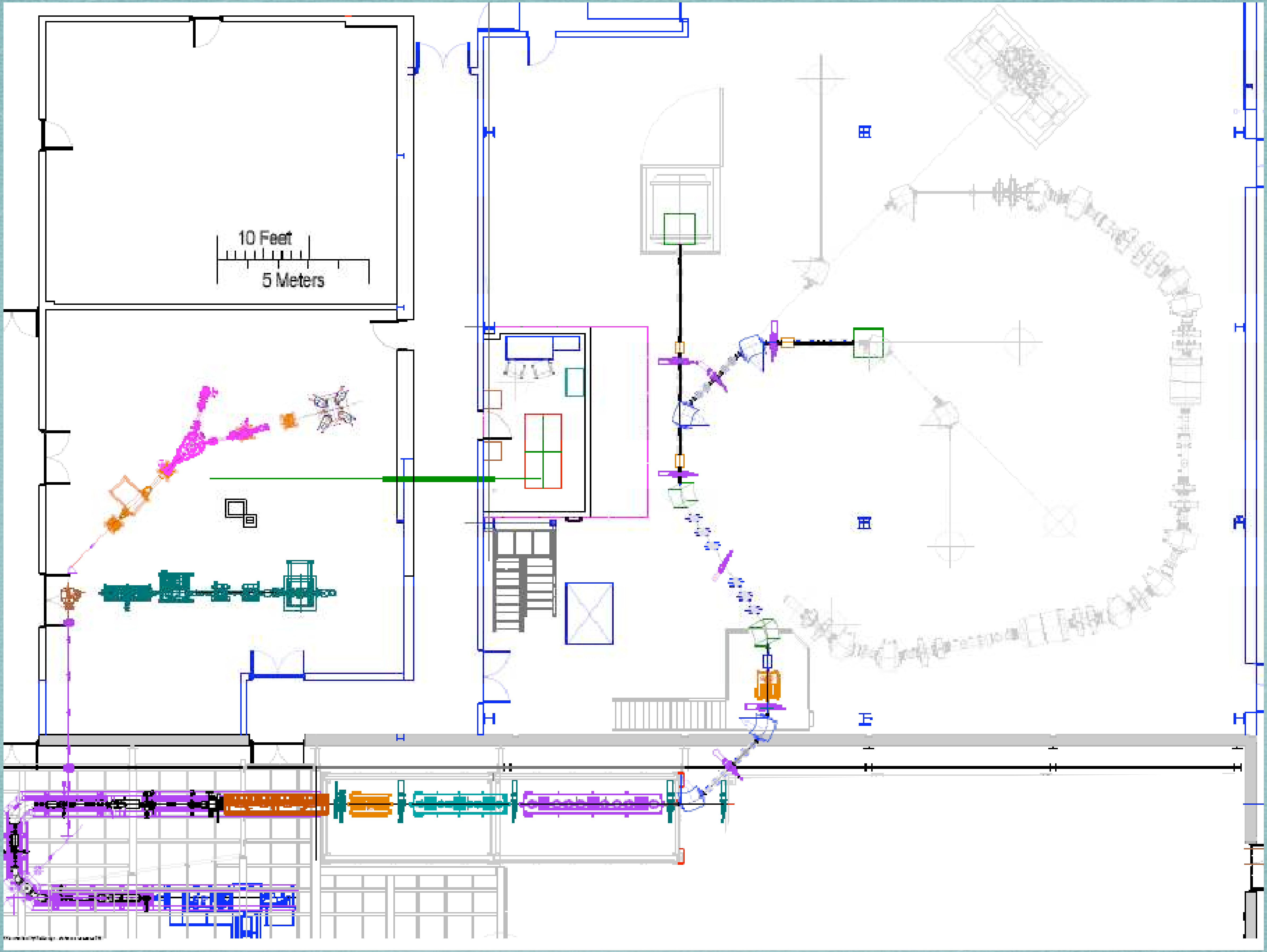





10 Feet
5 Meters

Beam Phase Space

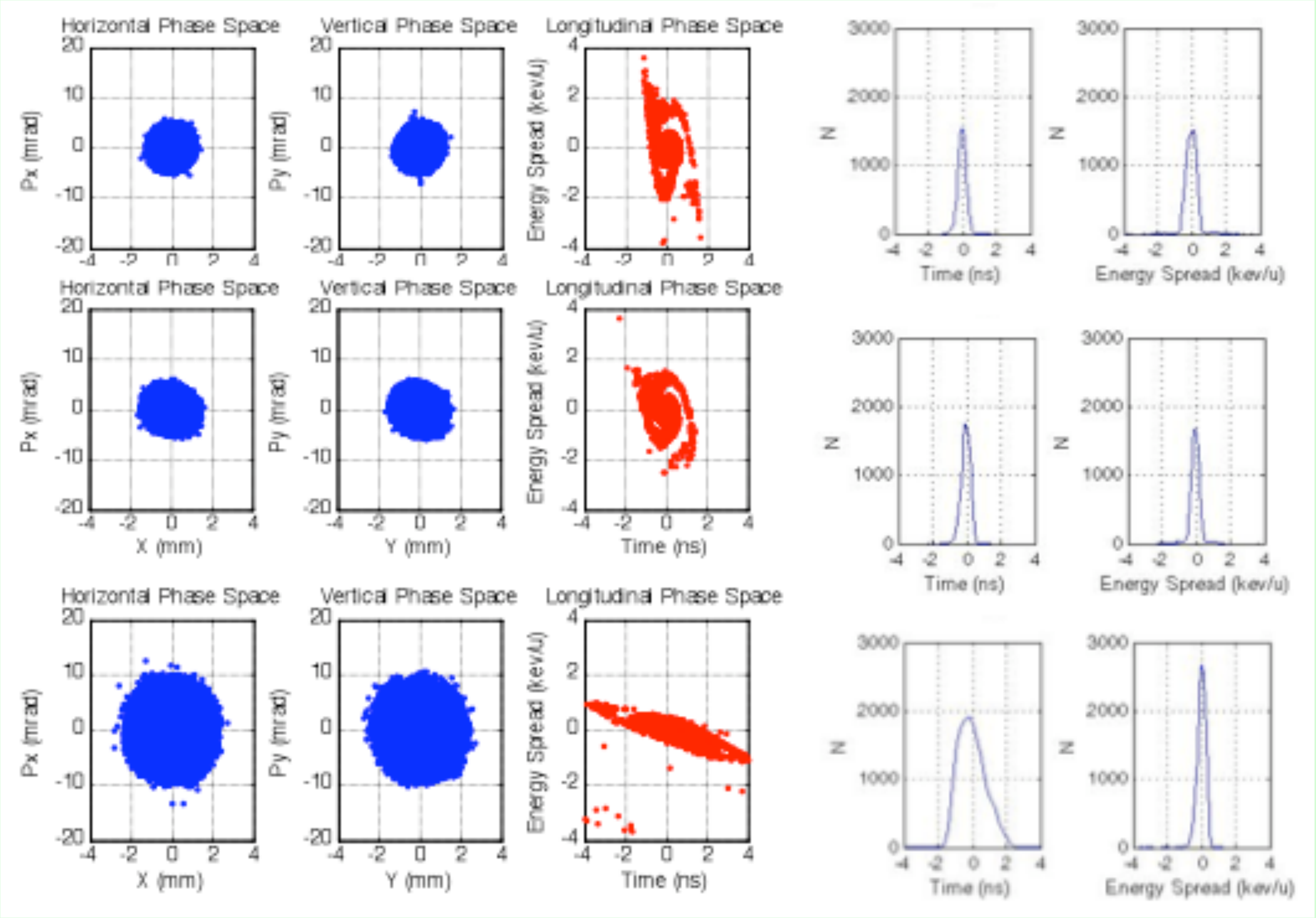
- Q/A=0.25

On target

4.6 MeV/u

3.0 MeV/u

0.3 MeV/u



2-4 mm

1-2 ns – keV/u

Challenges for ReA3 diagnostics

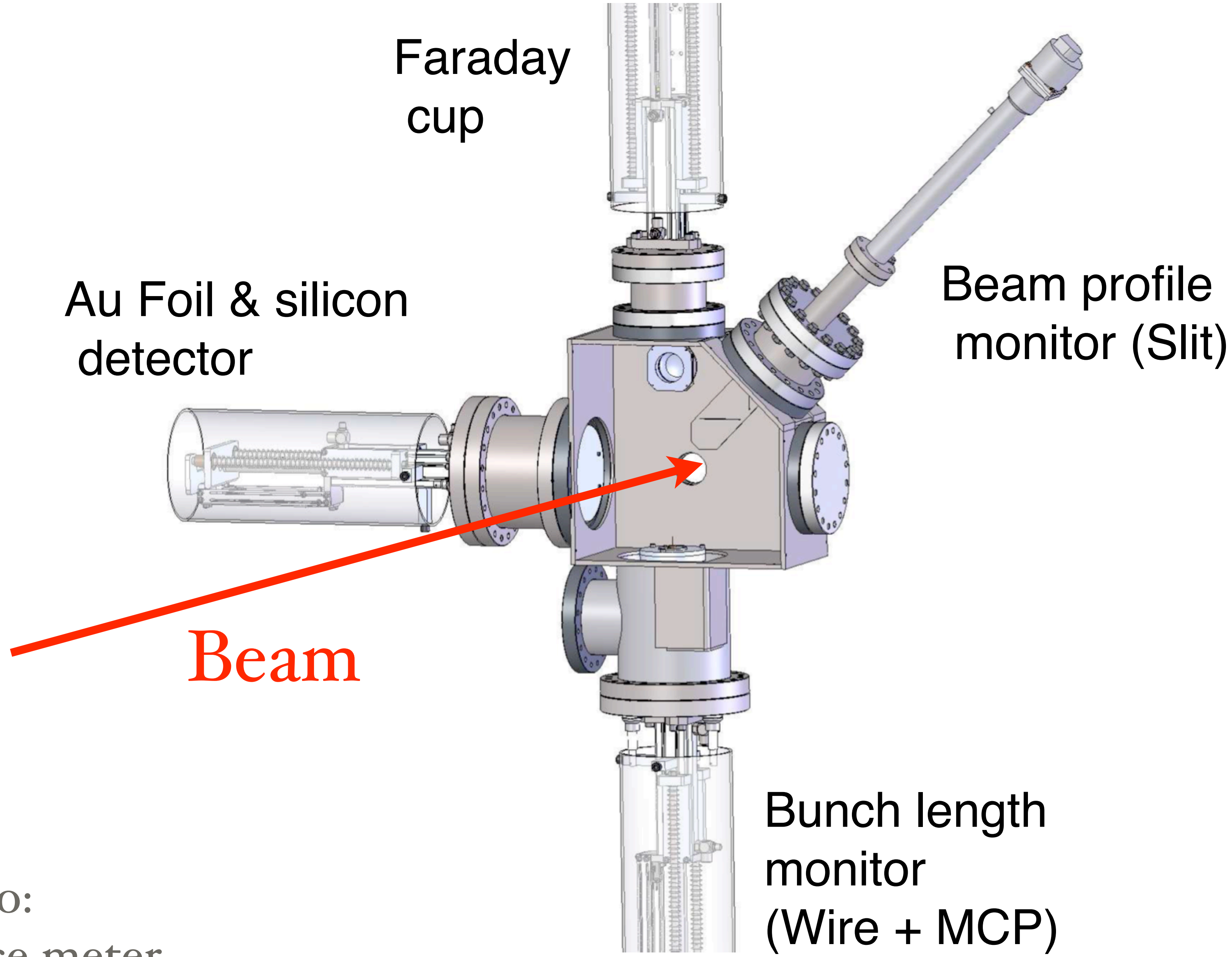
* Intensity of radioactive beam < 10^6 pps
* Broad range of projectile mass and energy
* Energy loss limiting
* High Resolution required
* Tuning with higher intensity stable beam

Diagnostics wish-list for ReA3

* **Detect presence of radioactive beam**
* **Measure beam properties**
    * Beam rate
    * Time structure (pulse width) – longitudinal emittance
    * Transverse profiles— transverse emittance
    * Energy
* **Facilitate optimizing cavity voltage and phase**
* **Facilitate transport to experiment**

Analog beam for setting accelerator

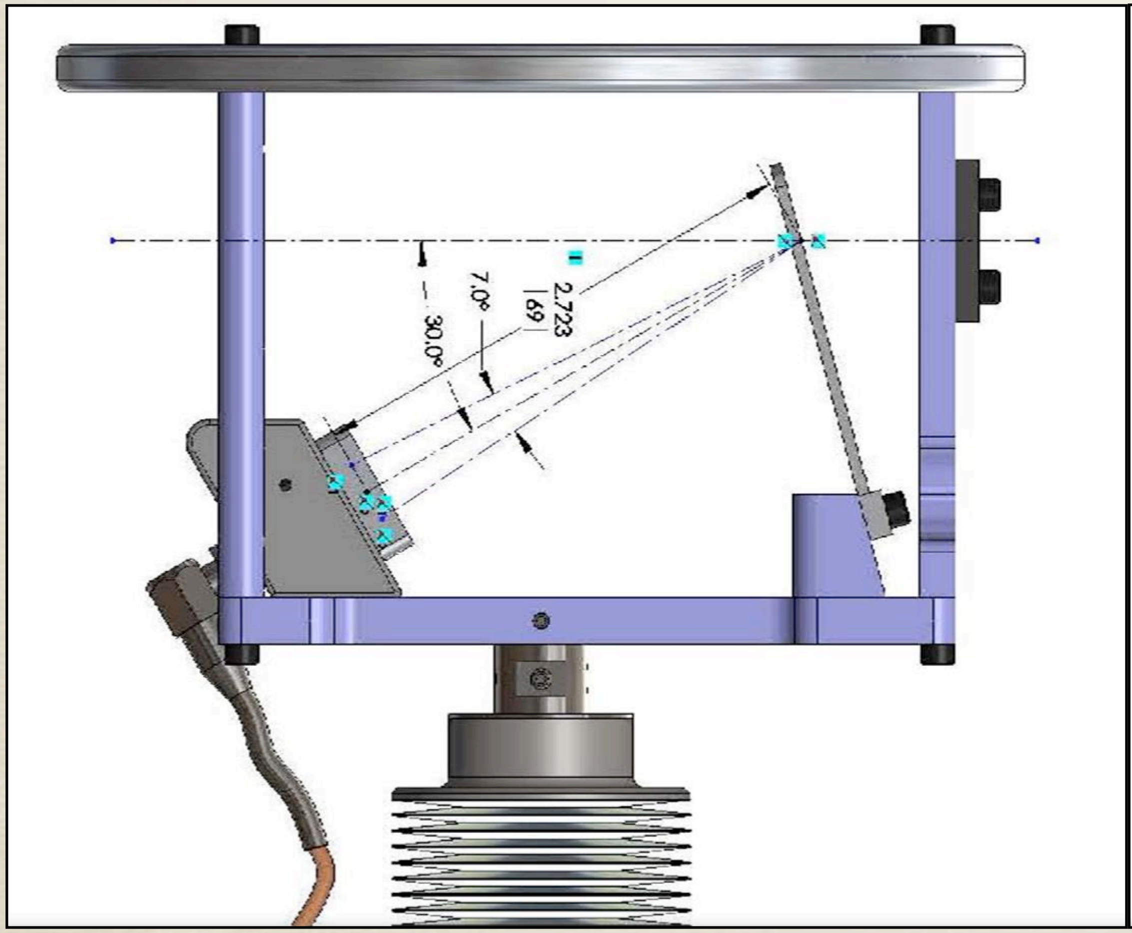
* Beam provided from the stable ion source
* Same Q/A as the radioactive ion
* Charge breeding done in EBIT
* ReA3 is tuned up using the stable ion beam with intensity ~ nA

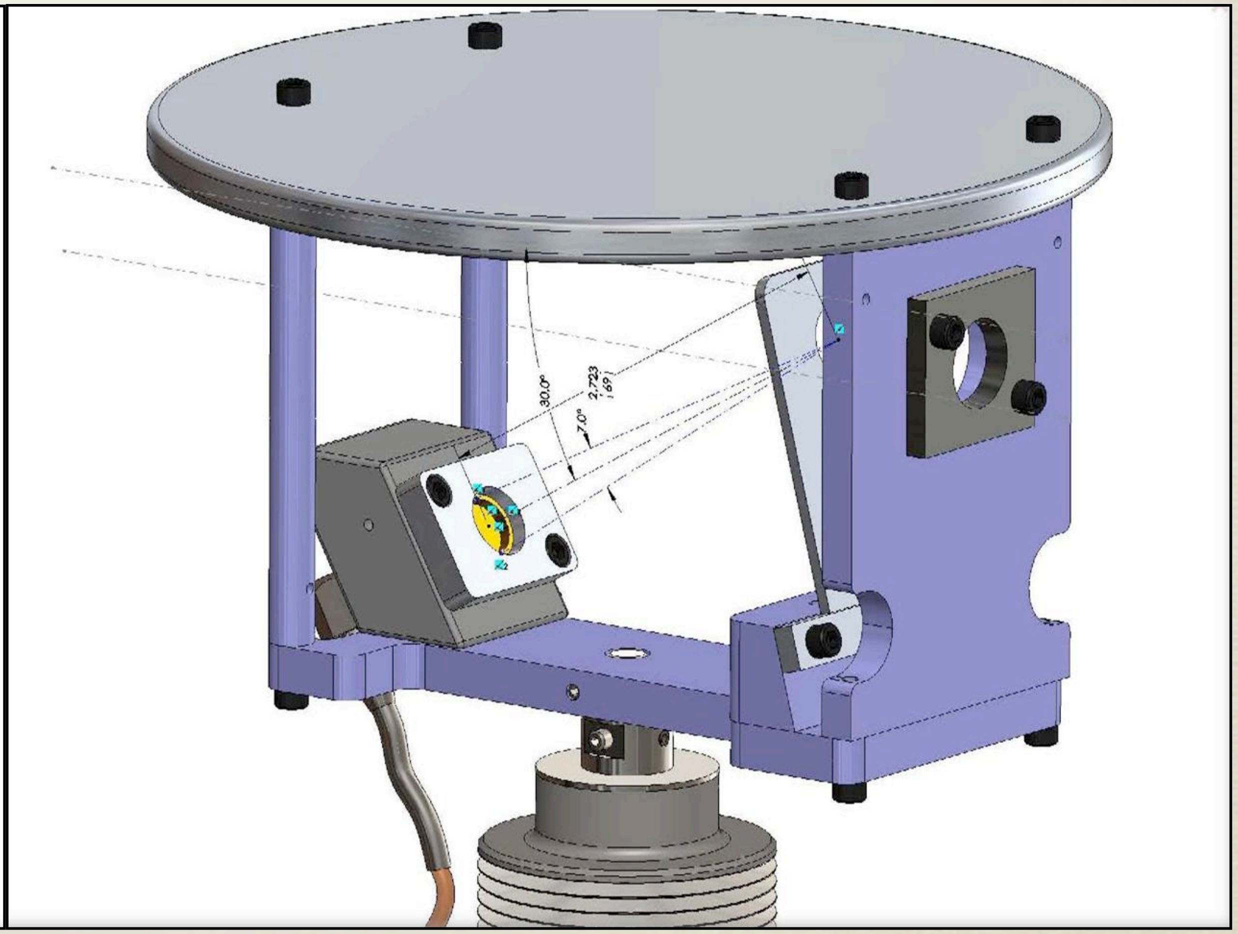


also:
Emittance meter
YAG viewer plate
MCP+phosphor screen
Decay counter

Elastic Scattering Detector

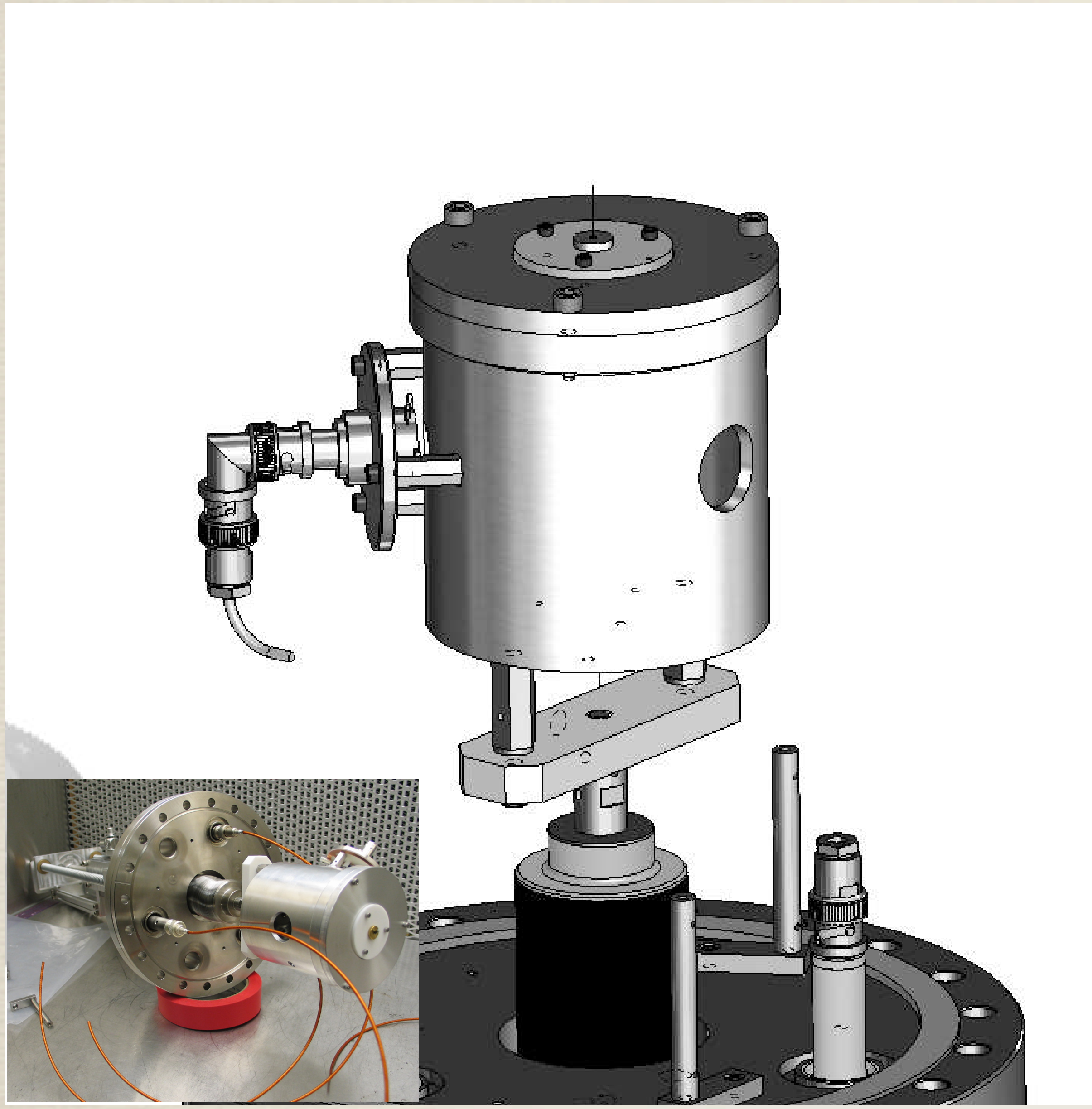
- 40 nm Gold foil @ 15° to the beam
- PIPS Si detector @ 30° to beam
- Phasing of Cavities
- Energy measurement
- Fair timing resolution (down to 200ps)



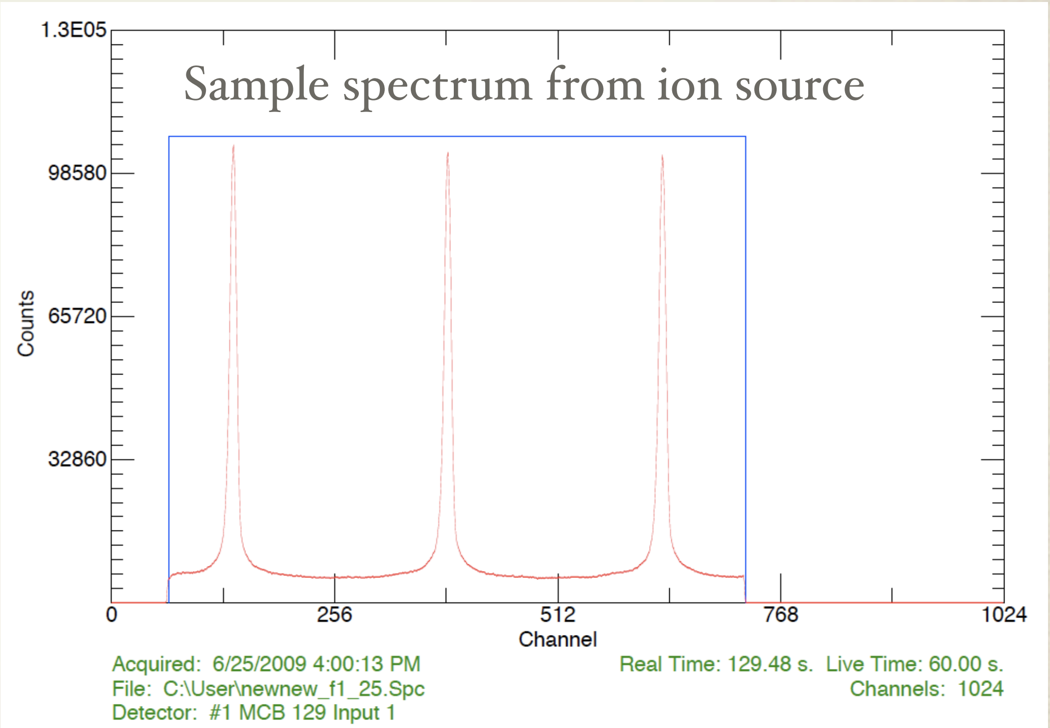


Design based on TRIUMF diagnostics

Timing Wire Detector



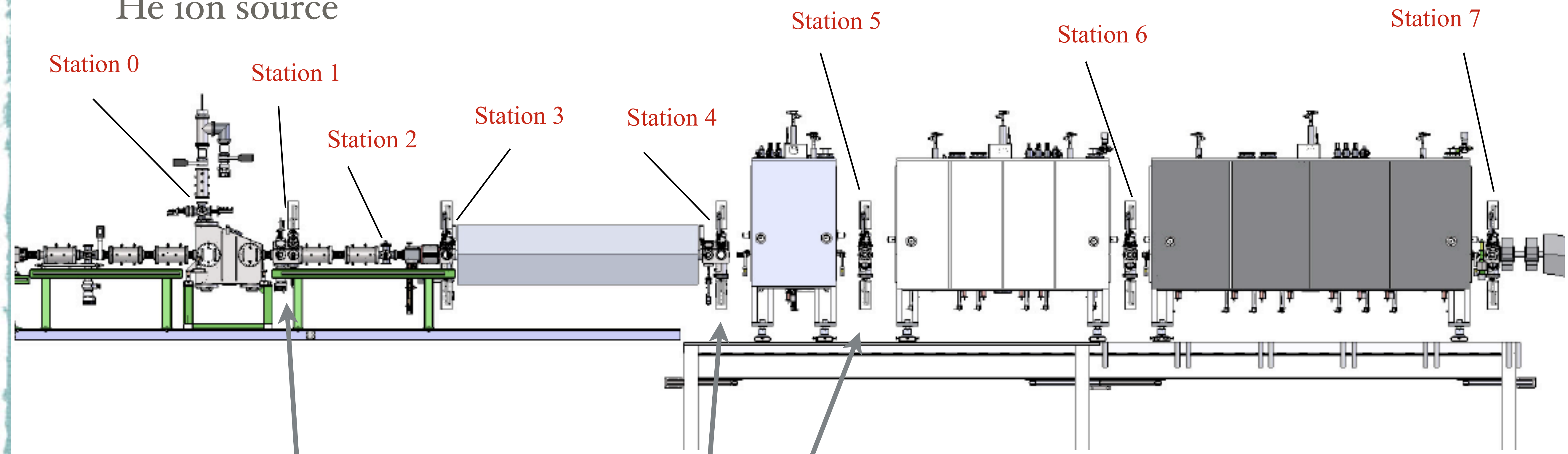
- Thin Nb Wire + MCP detector
- Time resolution < 100ps possible
- Longitudinal Phase-Space
- Energy by Time-of-Flight



Design based on TRIUMF diagnostics

Low Energy Beam Transport

He ion source

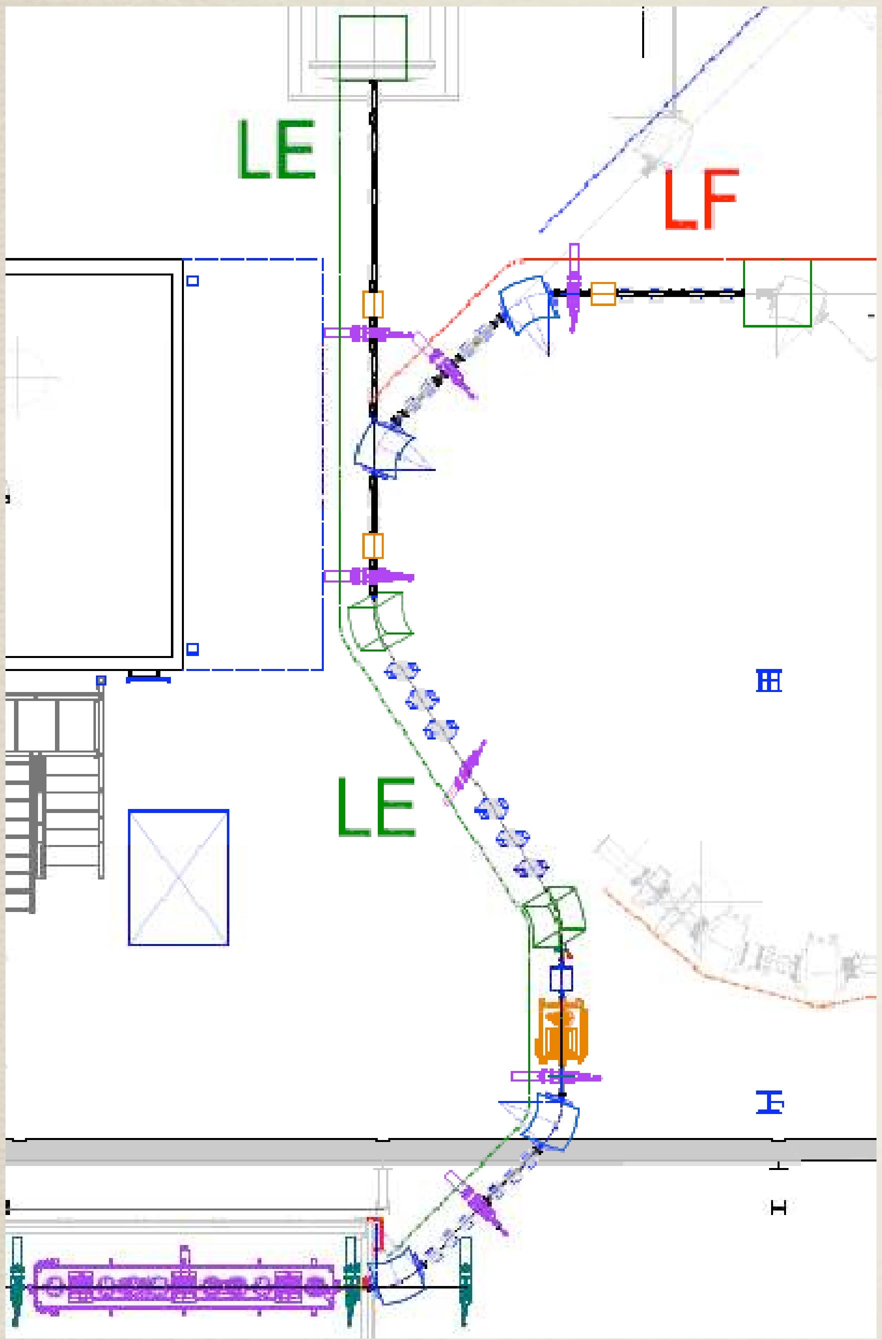


- **Emittance meter**
- **MCP + Phosphor screen**
- **Decay counter**

- **Collimation slits and apertures**

Station	Devices
0	Faraday cup, attenuator, viewer
1	Faraday cup, attenuator, viewer, decay counter, MCP phosphor, emittance
2	viewer
3	Faraday cup, movable slit, timing
4	Faraday cup, movable slit, timing, 4-jaw slit, attenuator
5	Faraday cup, movable slit, timing, foil and Si det., defining aperture
6	Faraday cup, movable slit, timing, foil and Si det.
7	Faraday cup, movable slit, timing, foil and Si det.

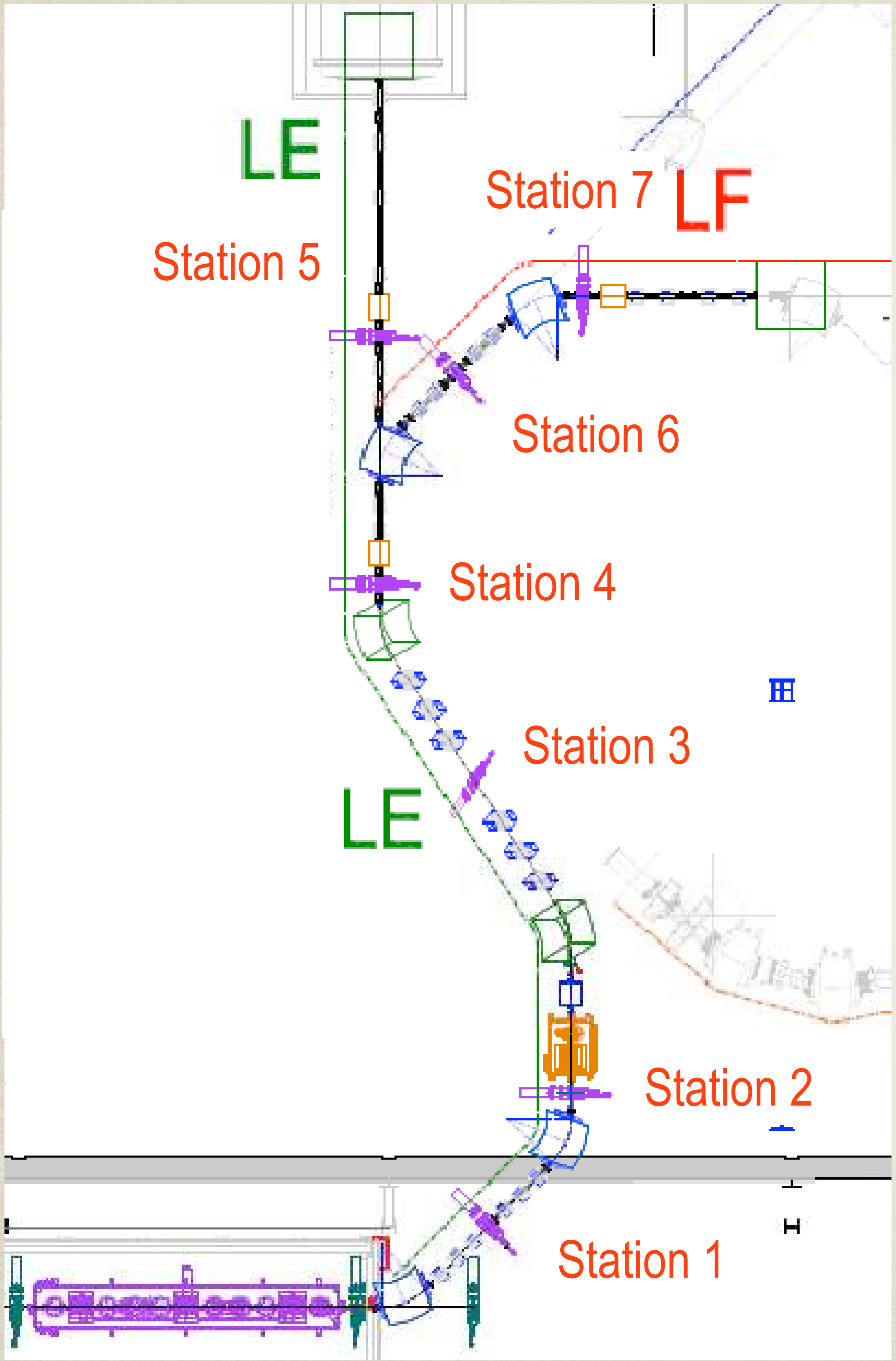
High Energy Beam Transport



Wish-list

- **Measure radioactive beam properties**
  - Beam rate
  - Time structure (pulse width) – longitudinal emittance
  - Transverse profiles— transverse emittance
  - Energy distribution of beam
  - Purity and Particle identification of beam species

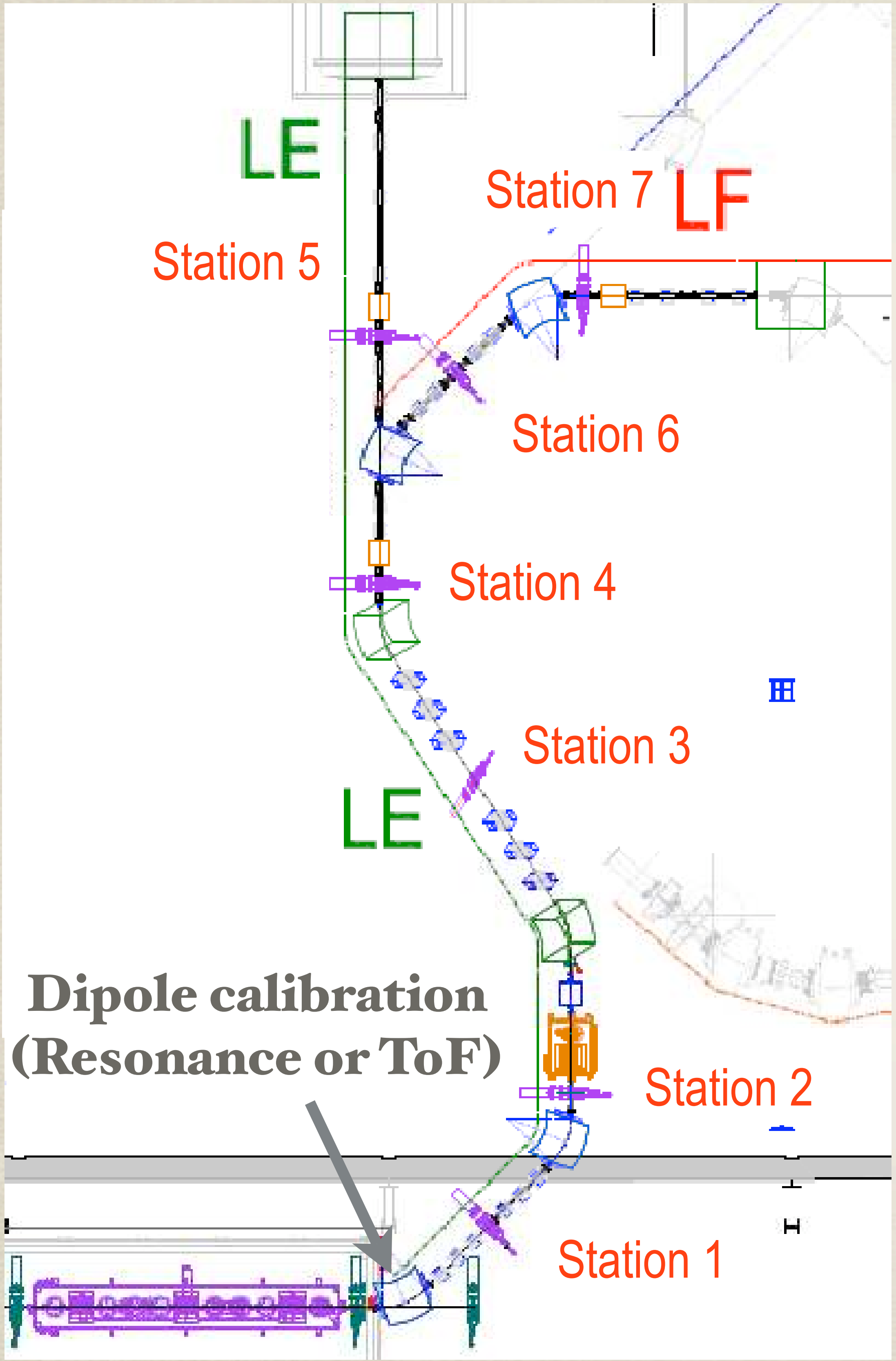
High Energy Beam Transport



Name	Diagnostics device
DP1	VP, FC, Collimation Aperture
DP2	FC, SL, WC, FS
DP3	VP, FC
DP4	VP, FC, WC
DP5	VP, FC
DP6	VP, FC, Collimation Aperture
DP7	VP, FC

VP: Viewer/Camera
WC: Wire and cylinder
SL: Movable slit
FS: Foil + SI detector
FC: Faraday Cup

High Energy Beam Transport



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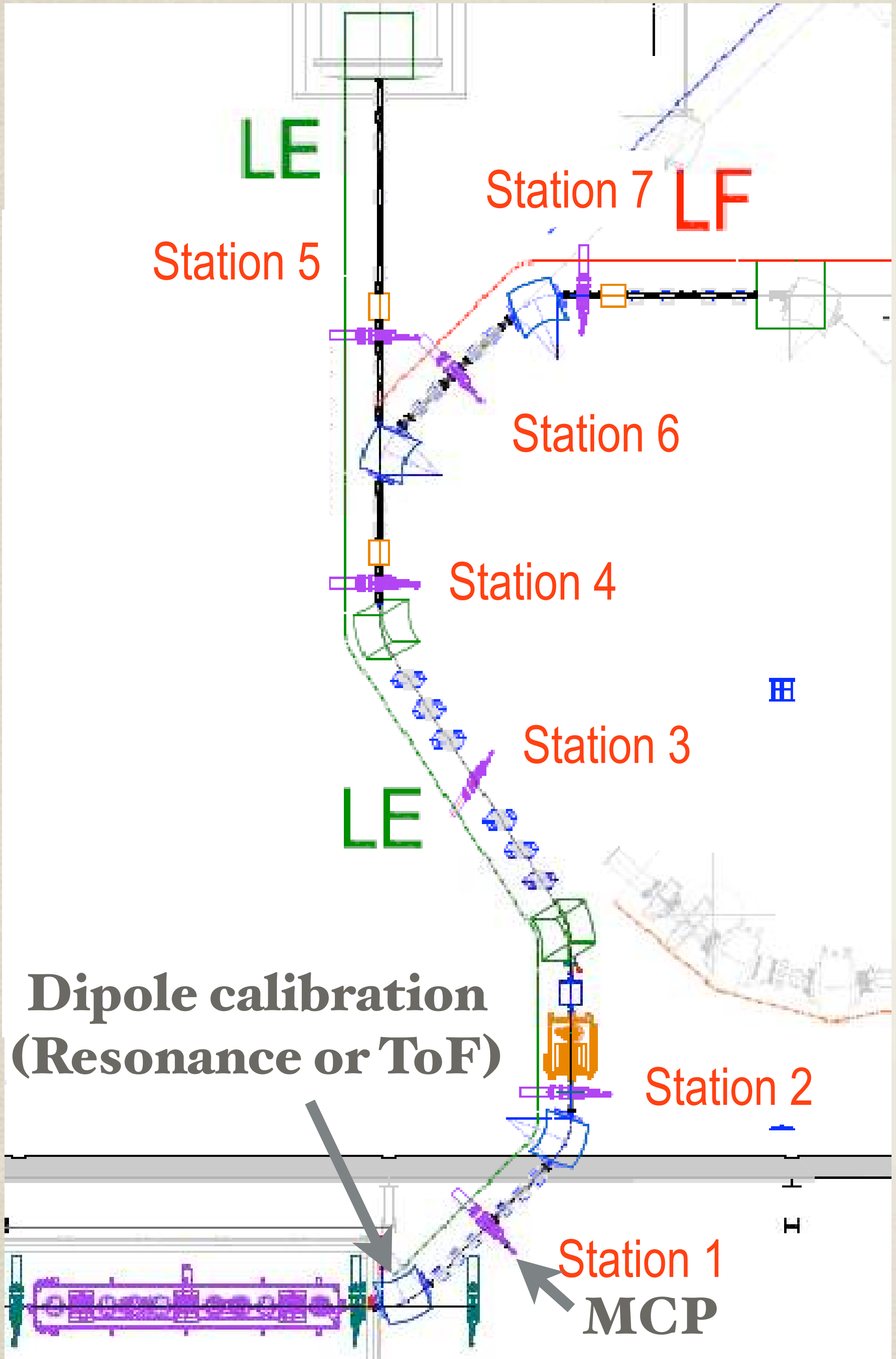

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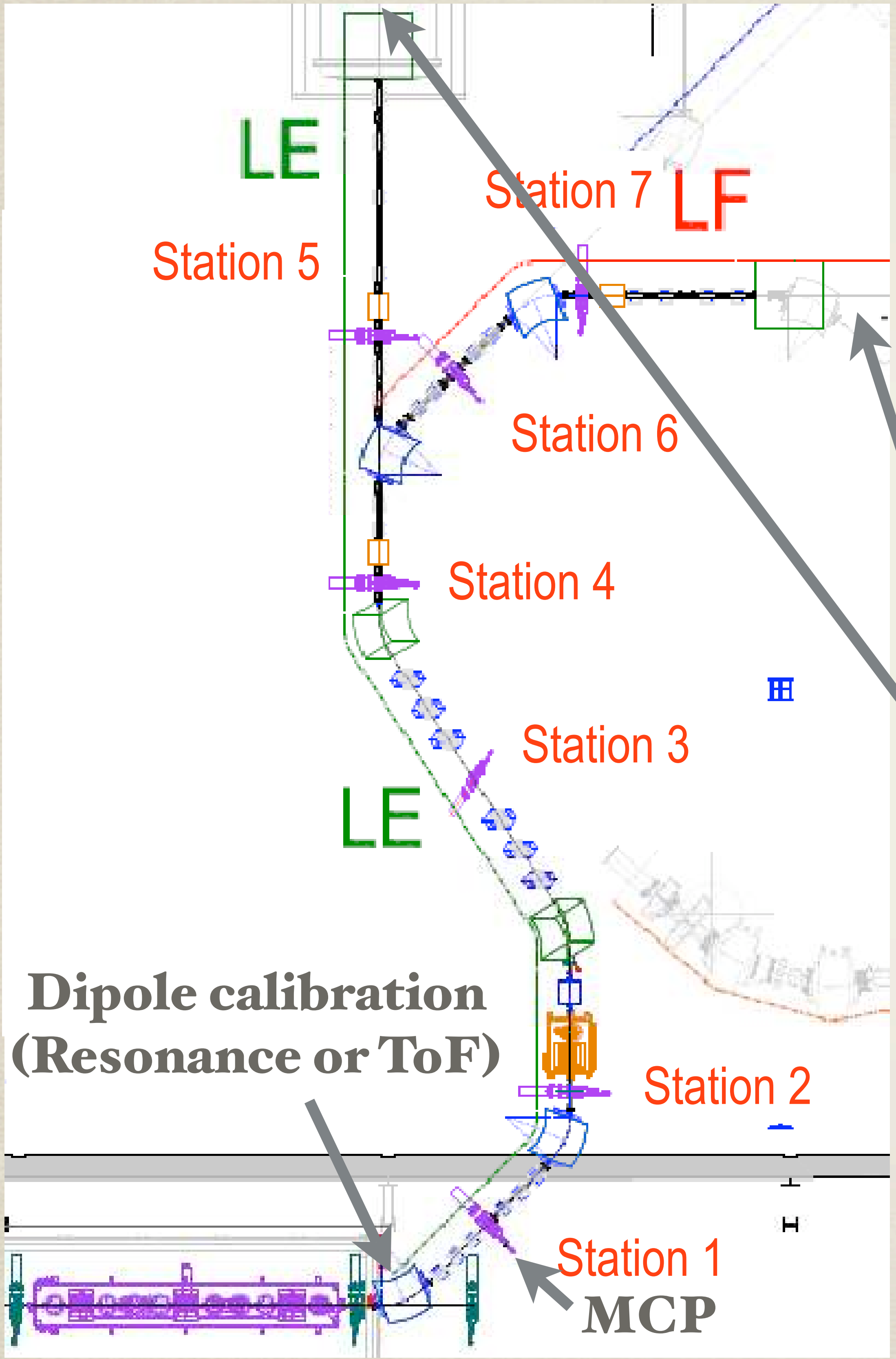

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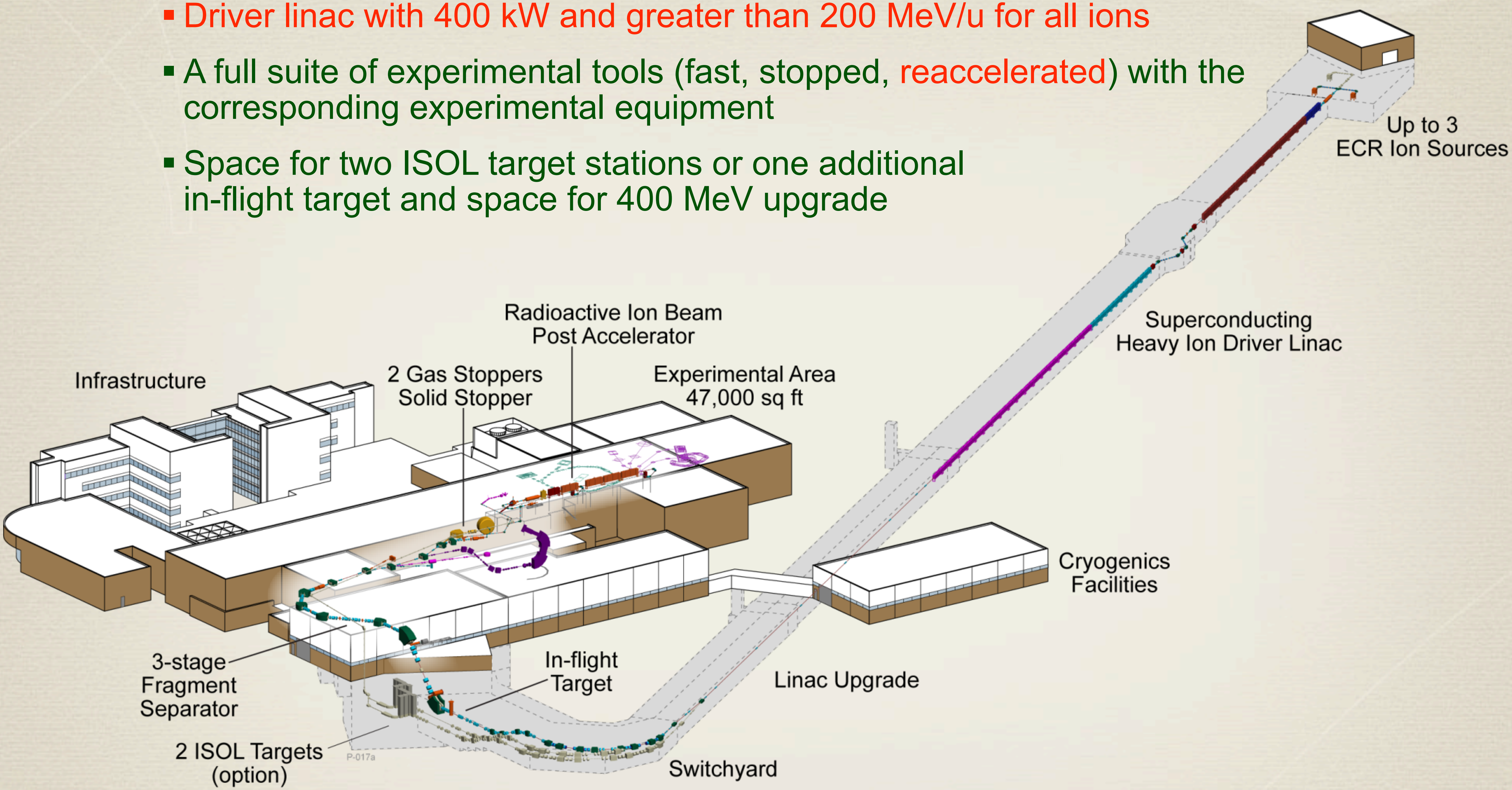
+ **General Purpose Diagnostic Station**
  - Segmented Anode Ionization Chamber
  - PID by differential energy loss
  - Event by event diagnostic

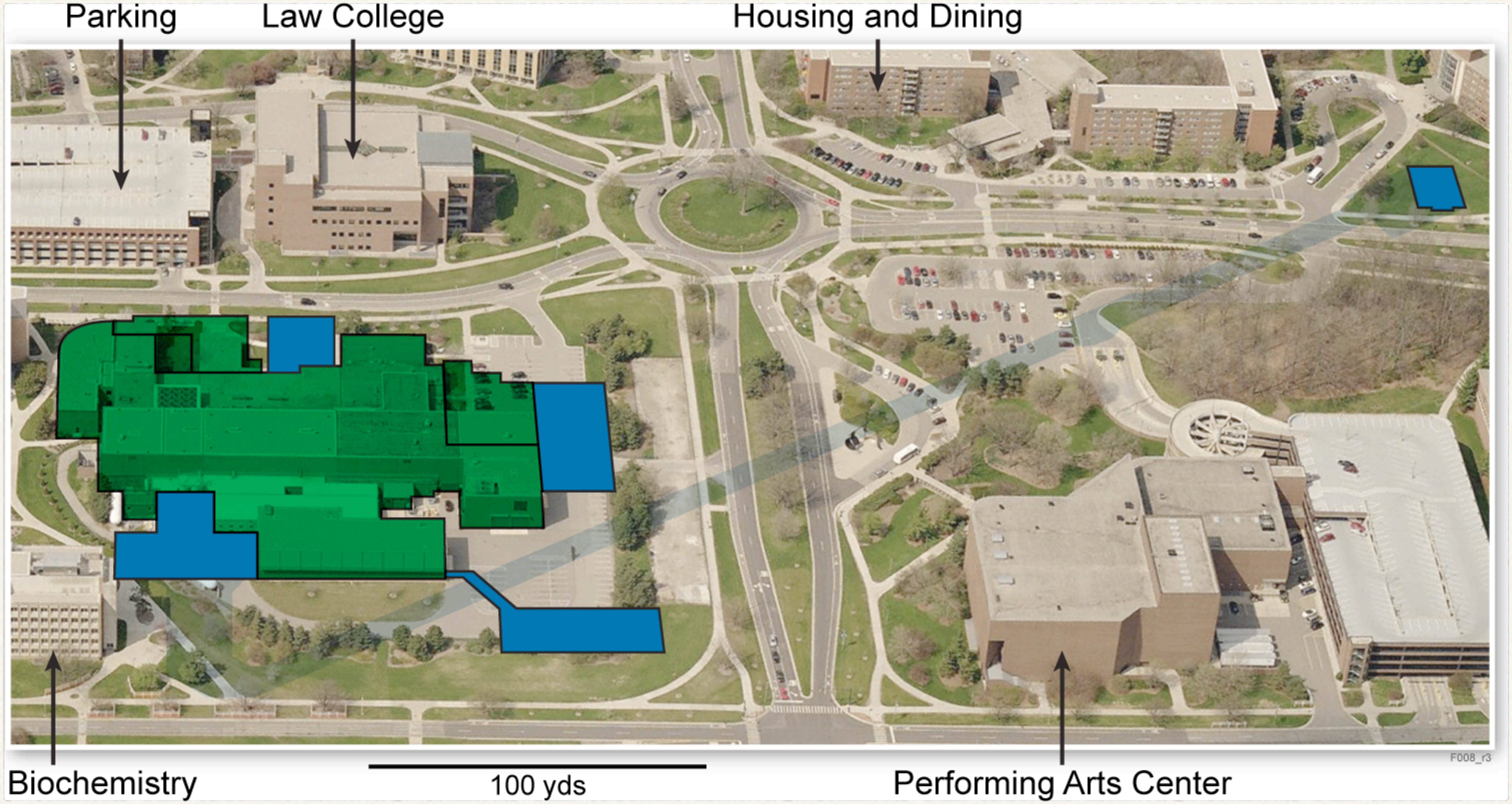
Linac commissioning in mid-2010

FRIB General Features

- Driver linac with 400 kW and greater than 200 MeV/u for all ions
- A full suite of experimental tools (fast, stopped, reaccelerated) with the corresponding experimental equipment
- Space for two ISOL target stations or one additional in-flight target and space for 400 MeV upgrade

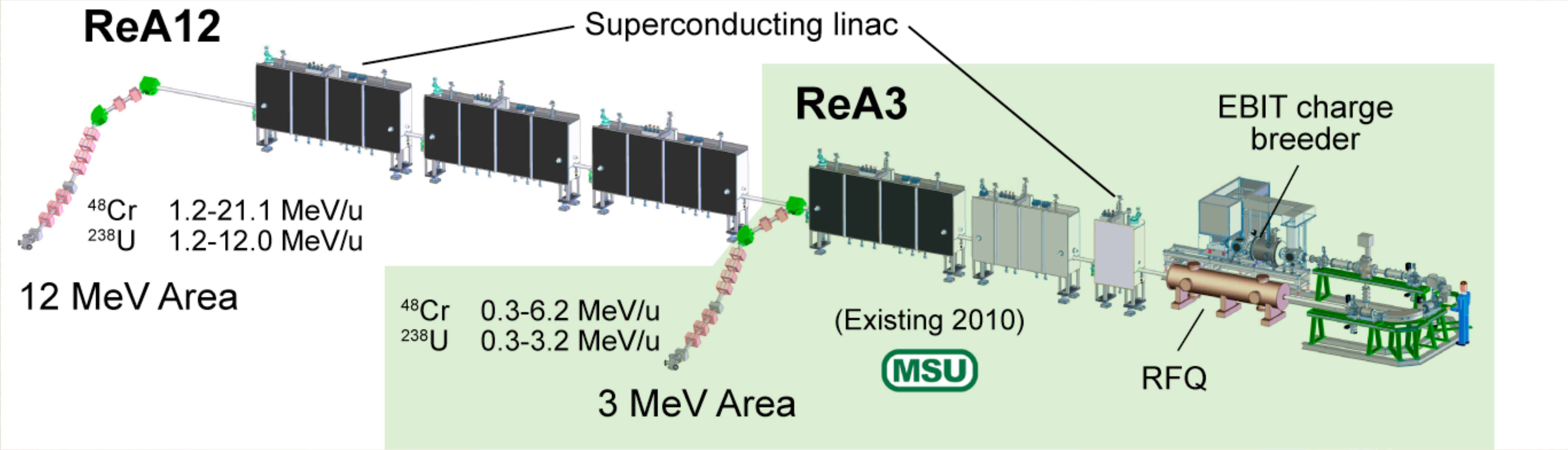


FRIB @ MSU Campus



- Green – existing
- Blue - new

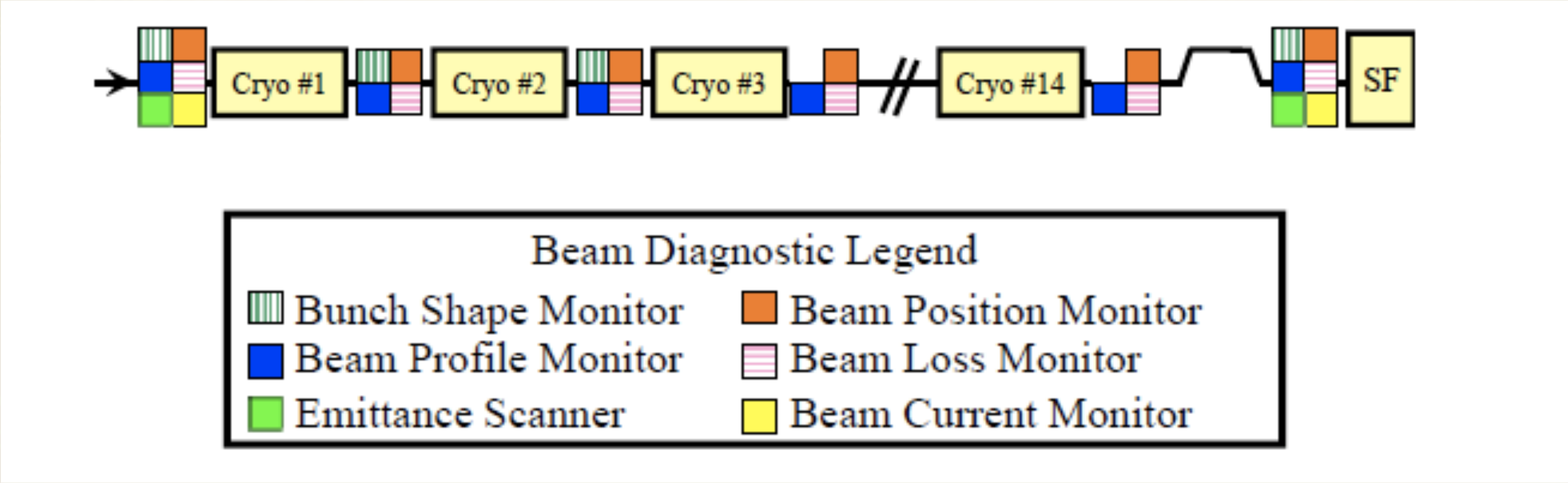
Upgrade ReA3 to ReA12



Special needs of FRIB

- High Power accelerator (400Kw at exit of Linac)
- Beam loss tolerance of ≤ 1W/m (i.e ≤ $2.5x10^{-6}$/m fractional loss at exit)
- Fast detection of Beam loss accidents
- Long linac with many SRFcavities
- Suboptimal performance critical. Has to be detectable by diagnostics

Conceptual design of Diagnostics for Segment 1



Diagnostics system currently being designed

Important elements:

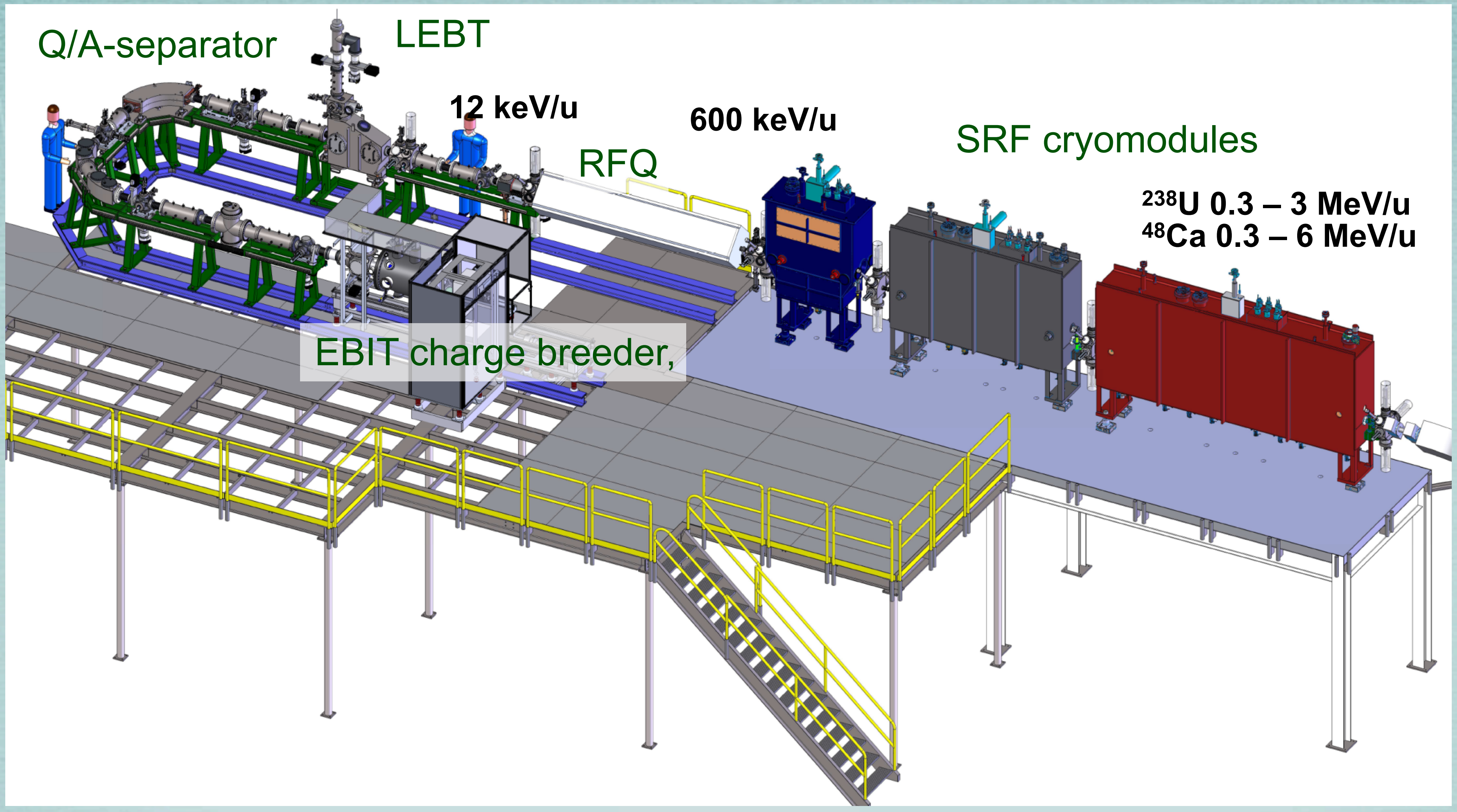
- Beam Dynamics simulations for critical operation scenarios
- Radiation transport simulations
- Final linac design
- Upgrade possibilities?

Conclusions

* Diagnostics important for ReA3 linac tuning
* Special diagnostics needed for RIB experiments
* ReA3 Linac + Diagnostics under construction
* Commissioning in 2010 with stable beam
* First RIB experiments in 2011
* FRIB diagnostics a challenge - design kicked off
* Stay tuned ...

THE END

NEW REACCELERATOR FOR RARE ISOTOPES REA3



Modern ion linac:

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

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

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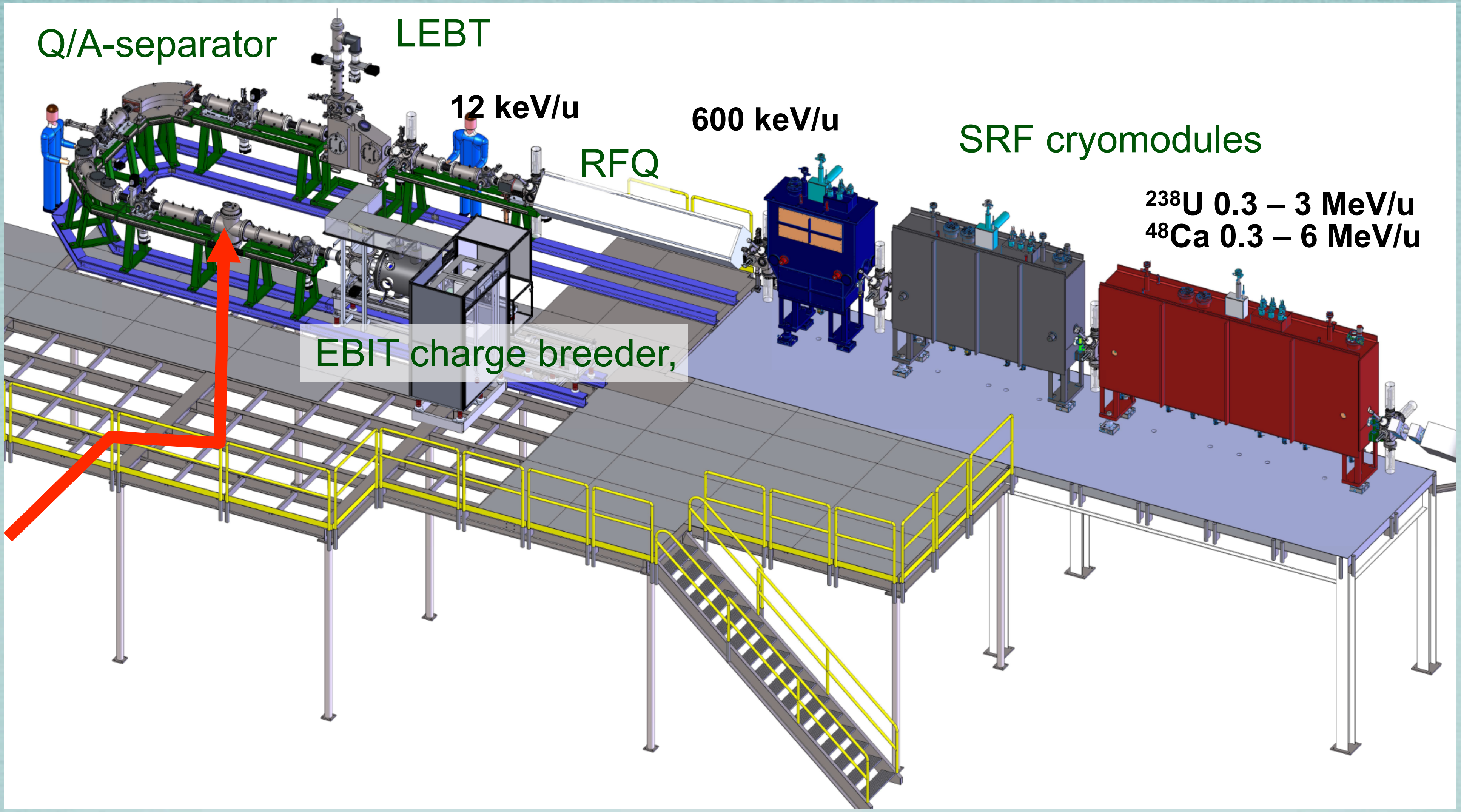

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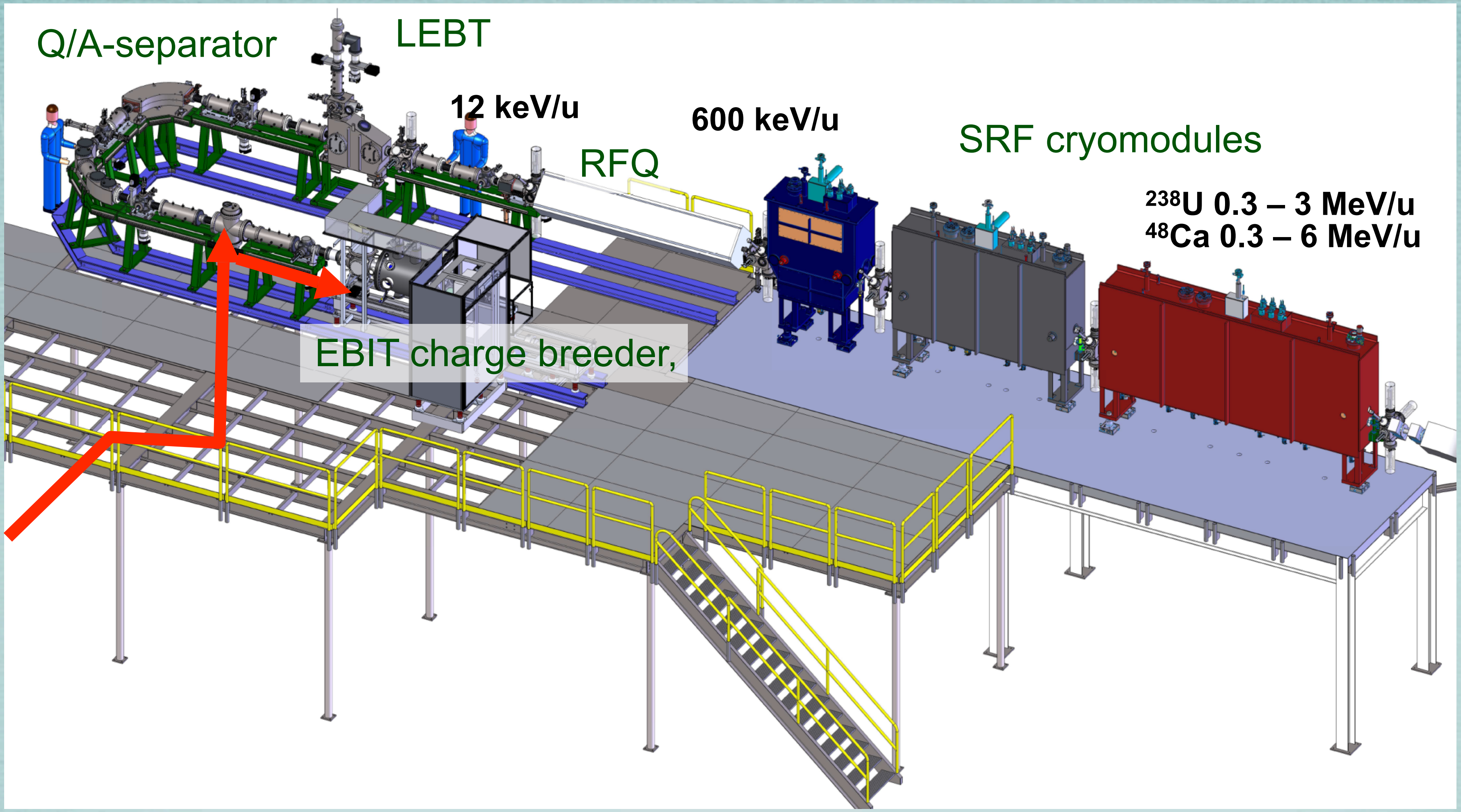

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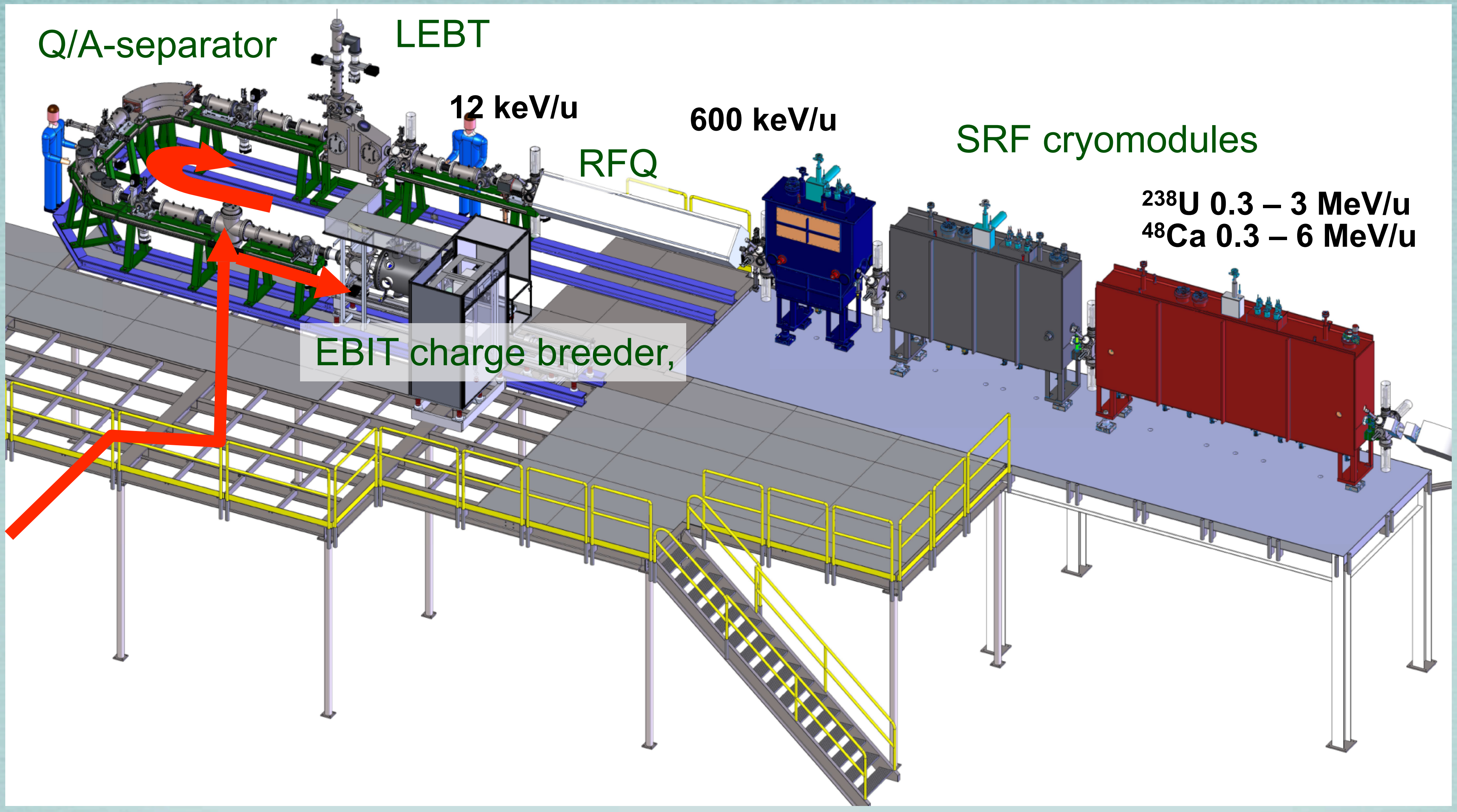

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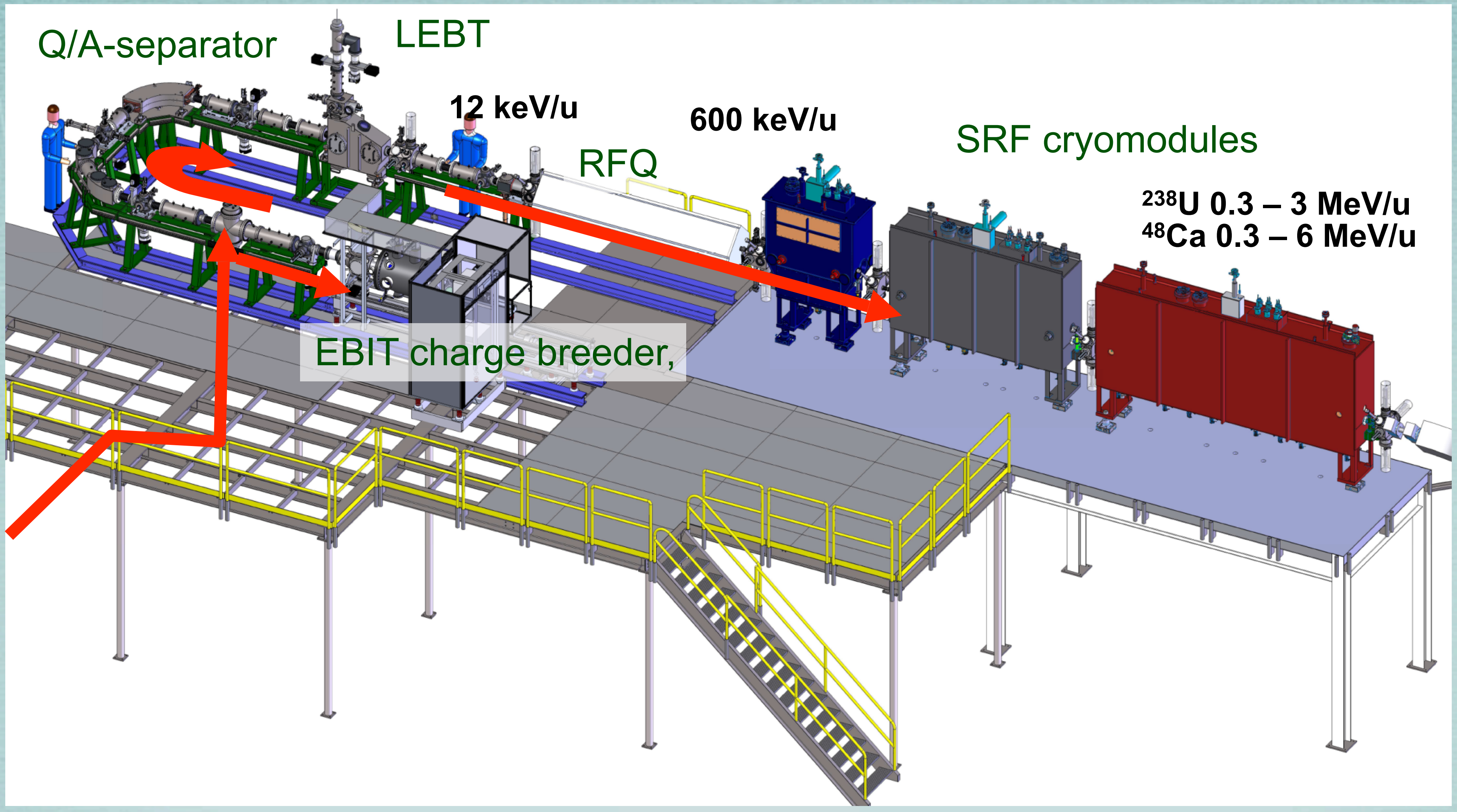

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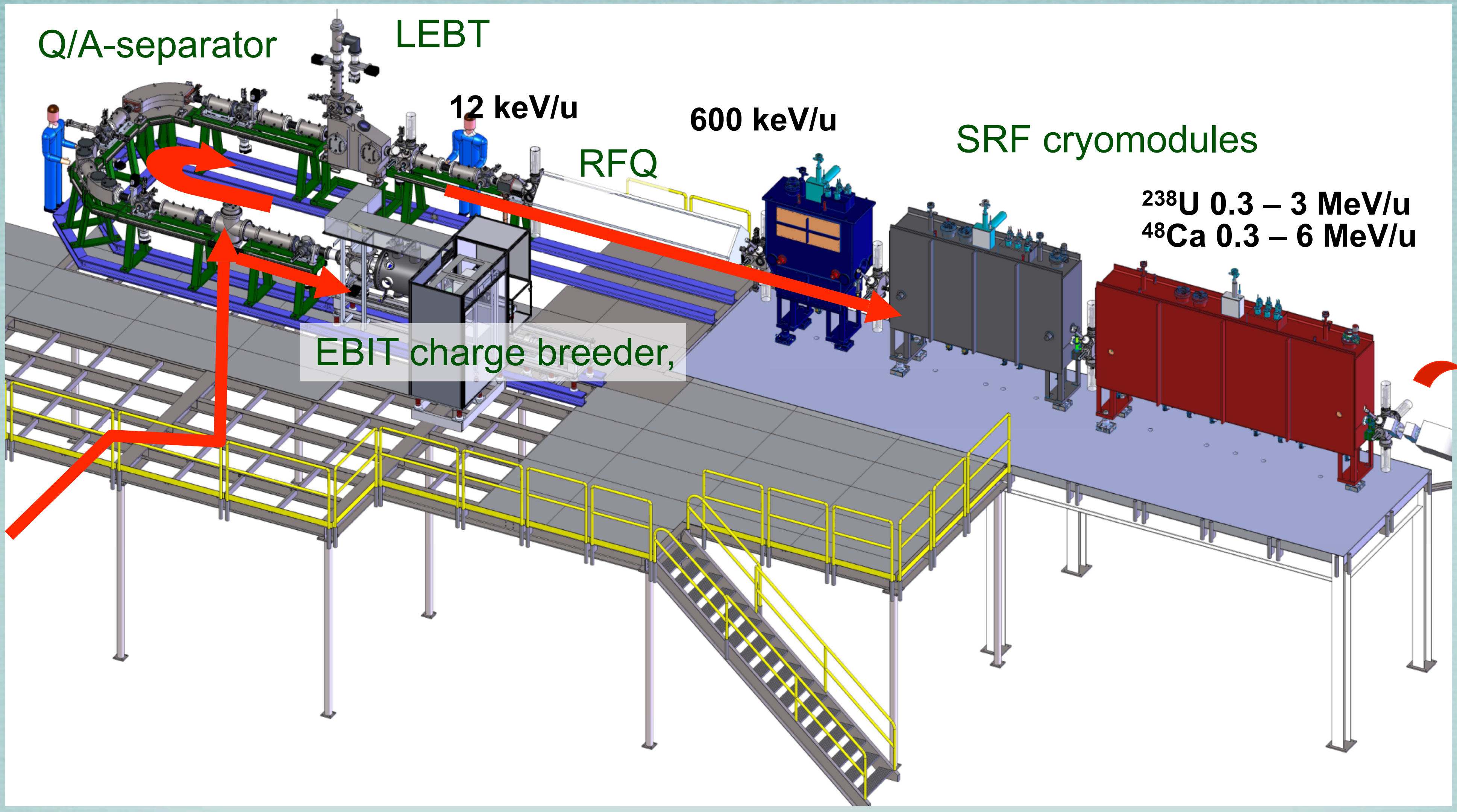

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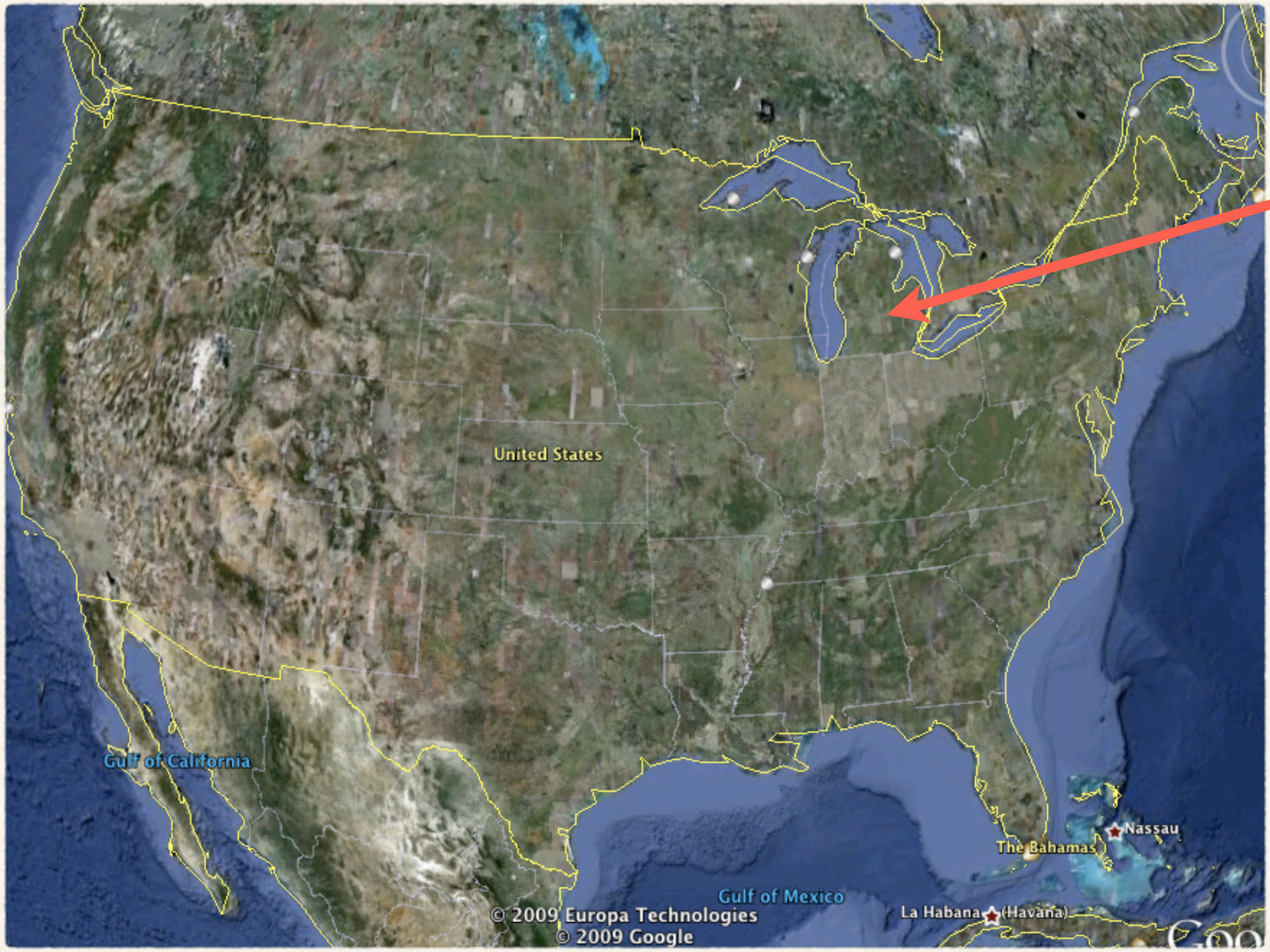


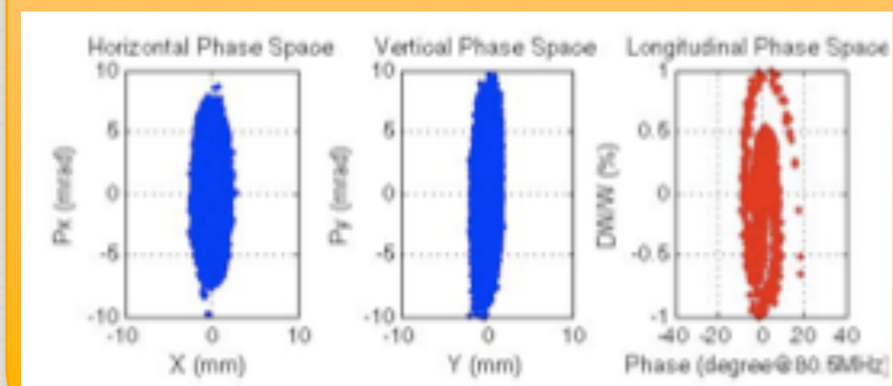
MSU location

Input Beam Parameters *(From EBIT)*	
Energy	12 keV/u
Q/A	0.2 – 0.4
Transverse Emittance (normalized)	0.6 π mm-mrad
Energy Spread	± 0.2 %
Output Beam Parameters *(On target)*	
Energy Variability	From 0.3 to 3.0 MeV/u
Bunch Width on Target	~ 1 ns
Energy Spread on Target	~ 1 keV/u
Beam Size on Target	~ 1 mm

Beam Phase Spaces

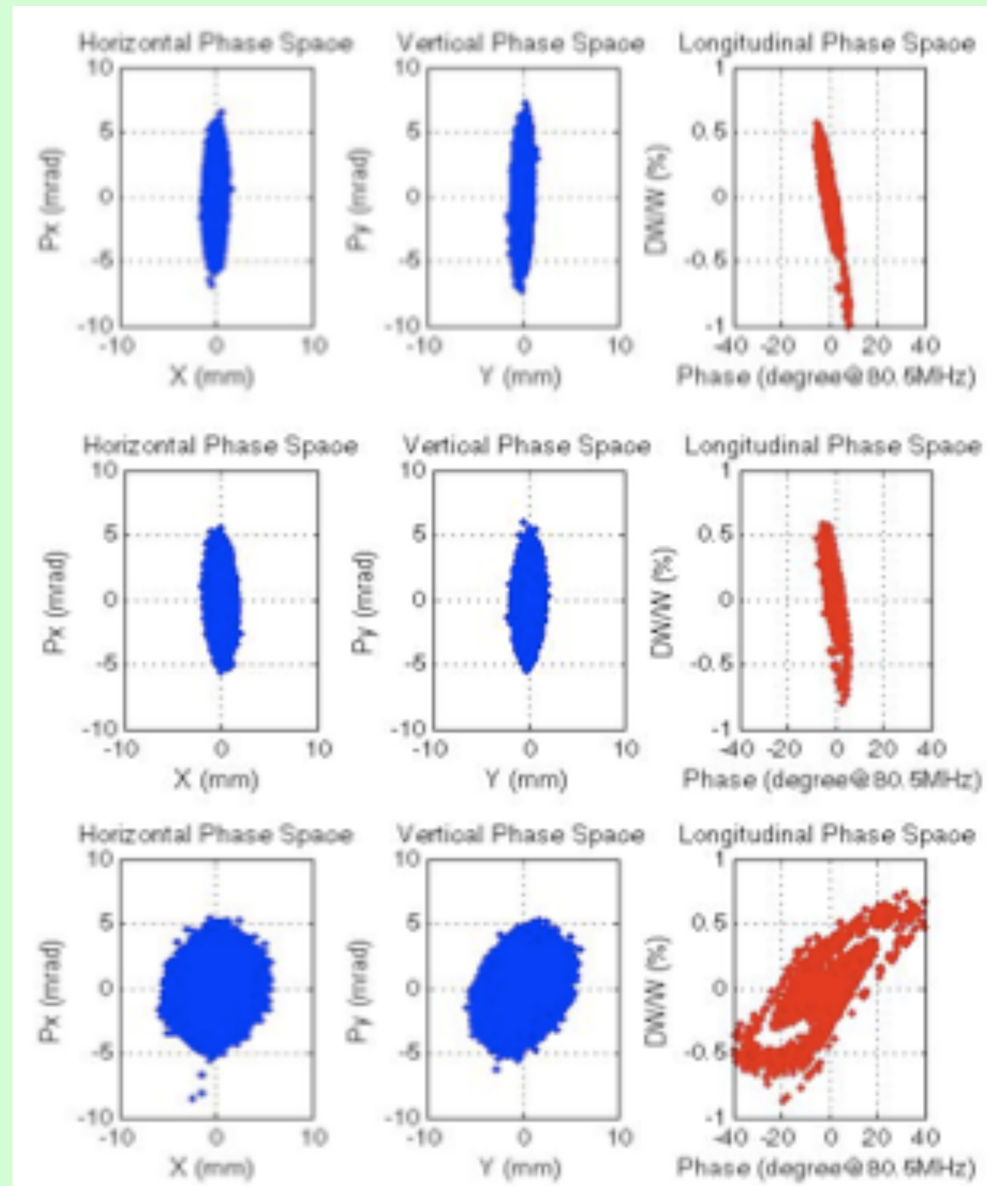
- Q/A=0.25

RFQ exit



0.6 MeV/u

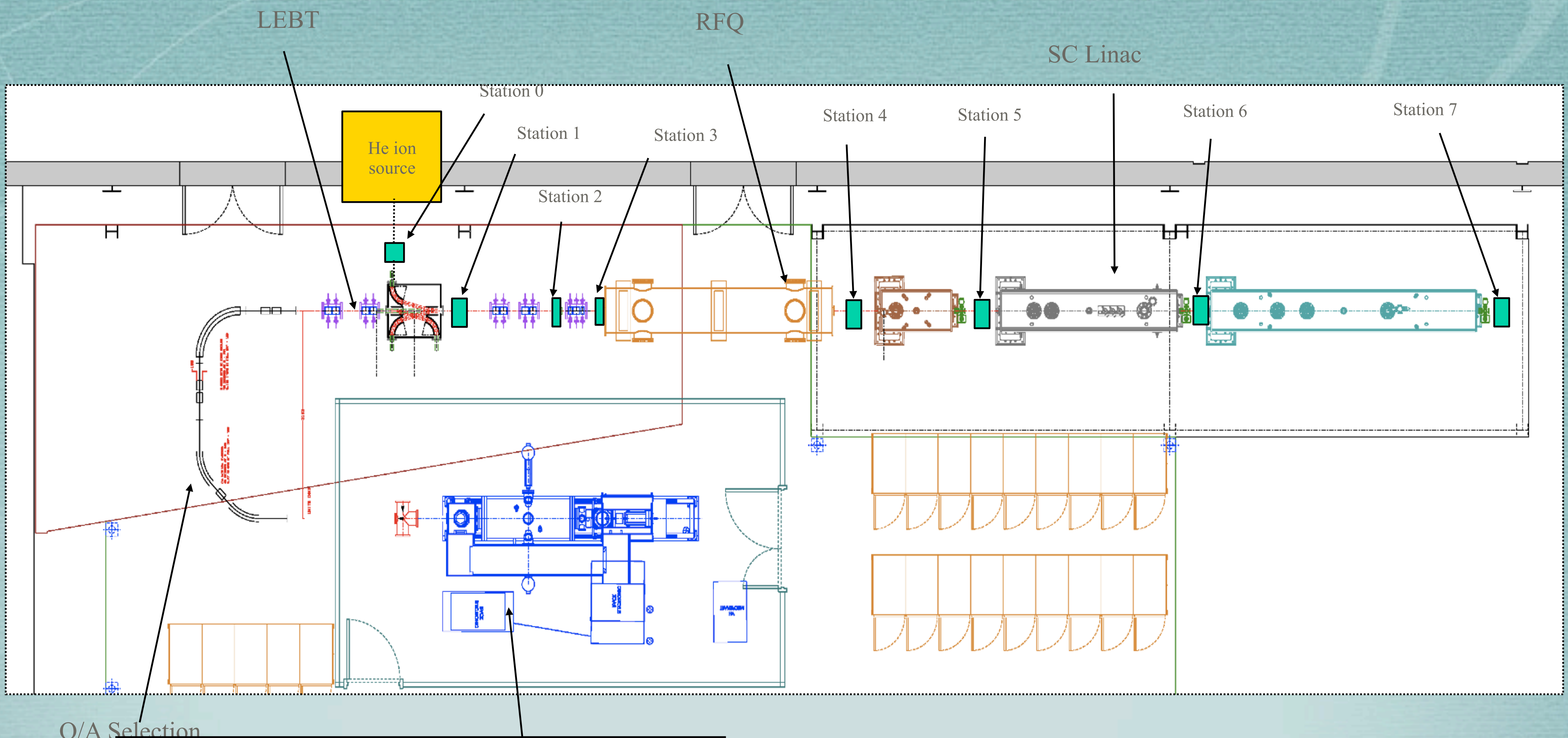
LINAC exit



4.6 MeV/u

3.0 MeV/u

0.3 MeV/u



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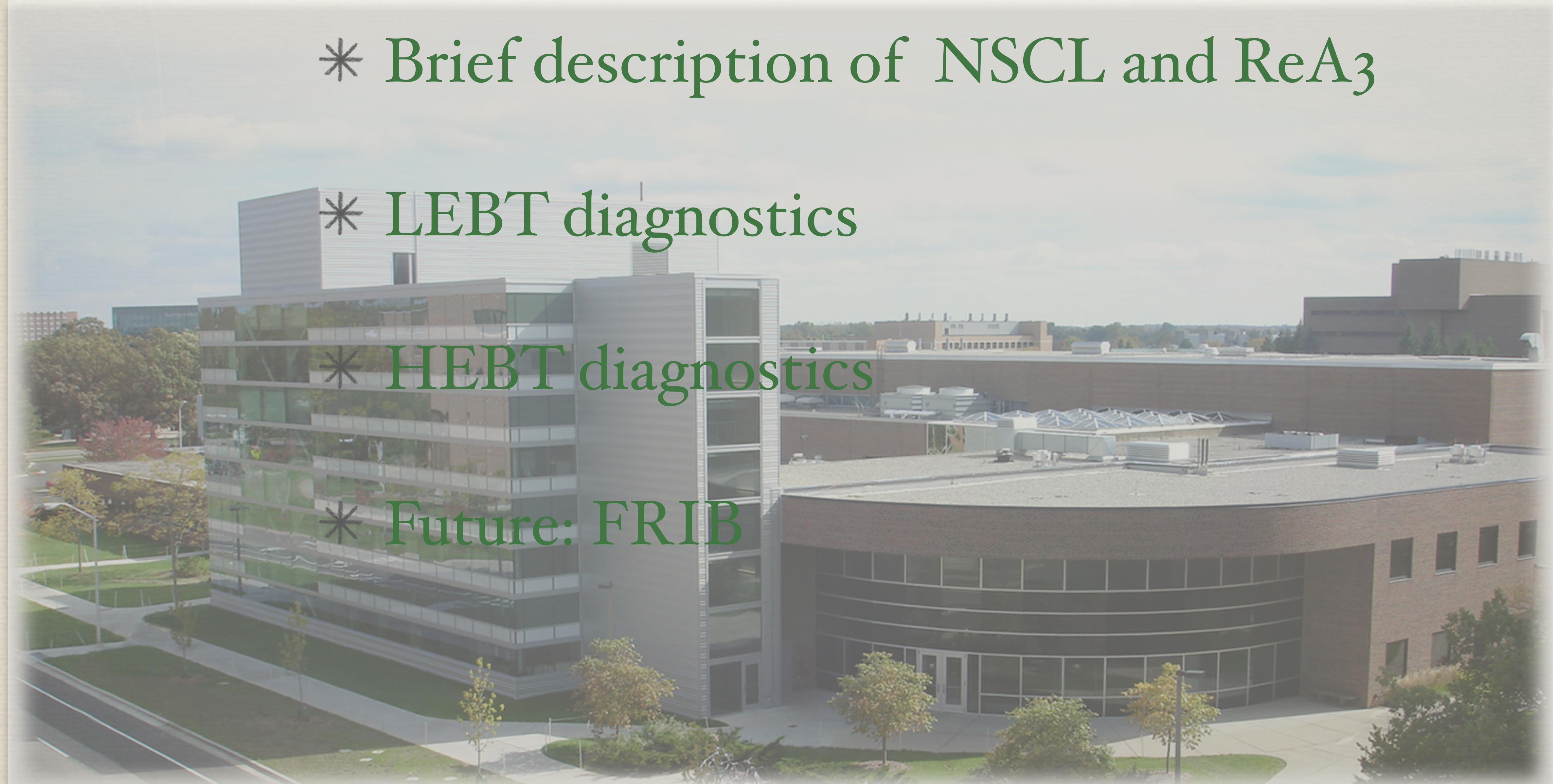
Diagnostics wish-list for commissioning (stable beam)

- **Measure beam properties**
  - Beam current
  - Time structure (pulse width) – longitudinal emittance
  - Transverse profiles— transverse emittance
  - Energy
- **Facilitate optimizing cavity voltage and phase**

Outline



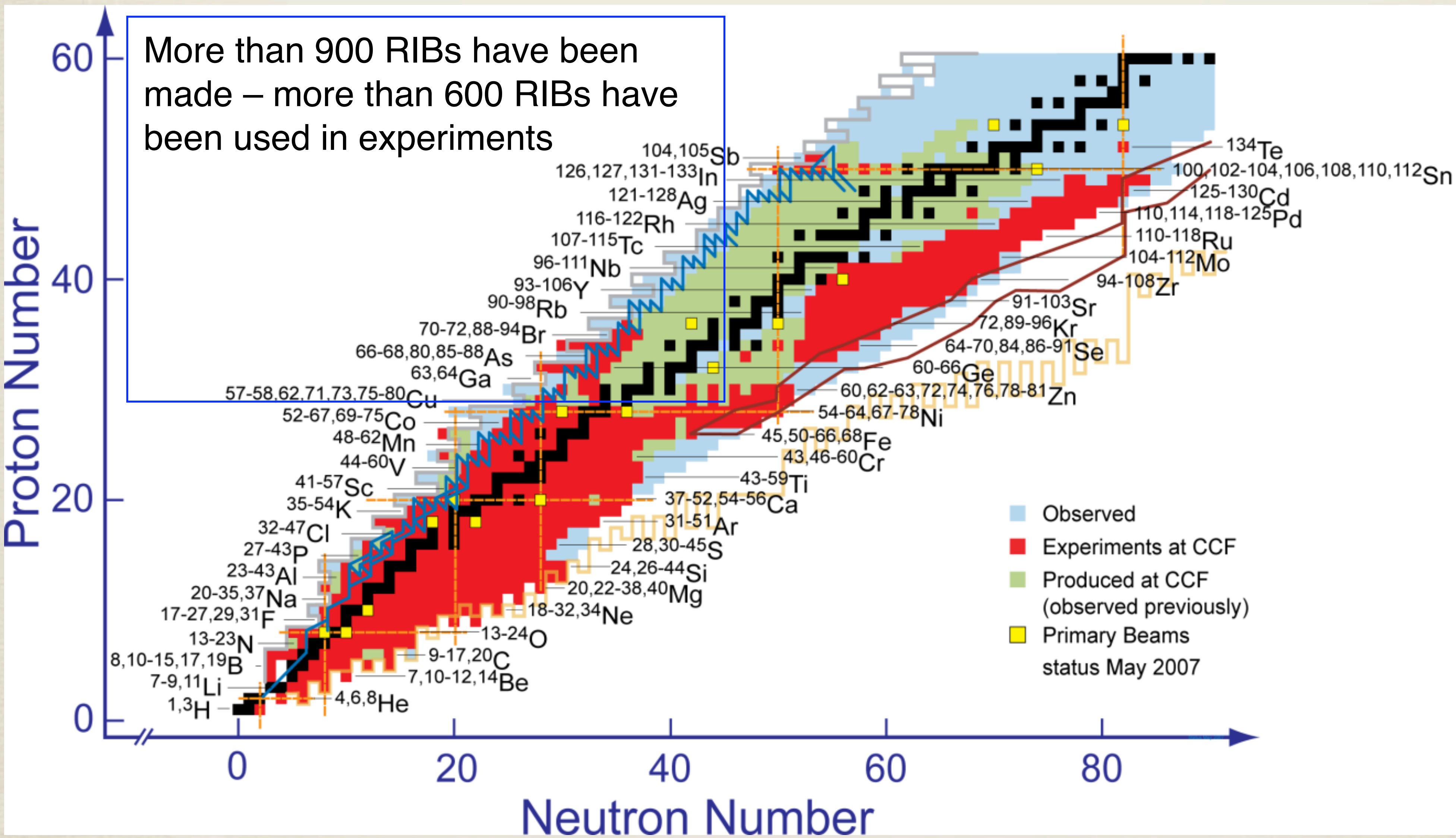
- Brief description of NSCL and ReA3
- LEBT diagnostics
- HEBT diagnostics
- Future: FRIB

Why reaccelerated beams at the NSCL?

–NSCL has already successful program with stopped beams

– LEBIT facility for Penning trap mass spectrometry of projectile fragments

– Laser spectroscopy under preparation



• New science opportunities with rare isotopes @ ReA3