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NSCL

Investigation of ion injection into the MSU charge-breeder electron beam ion trap

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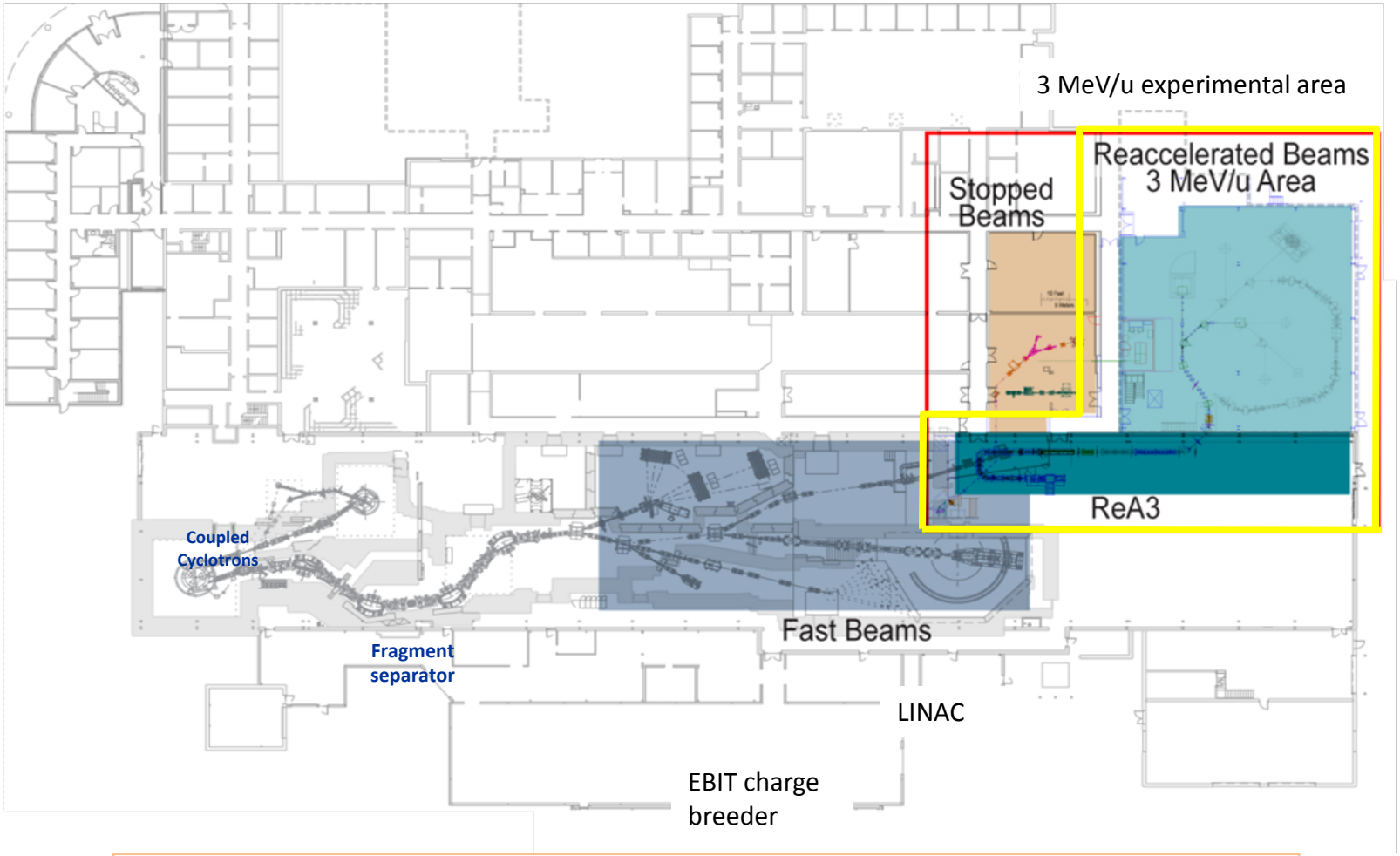
International Workshop on Stopping and Manipulation of Ions

March 21-24, 2010

Outline

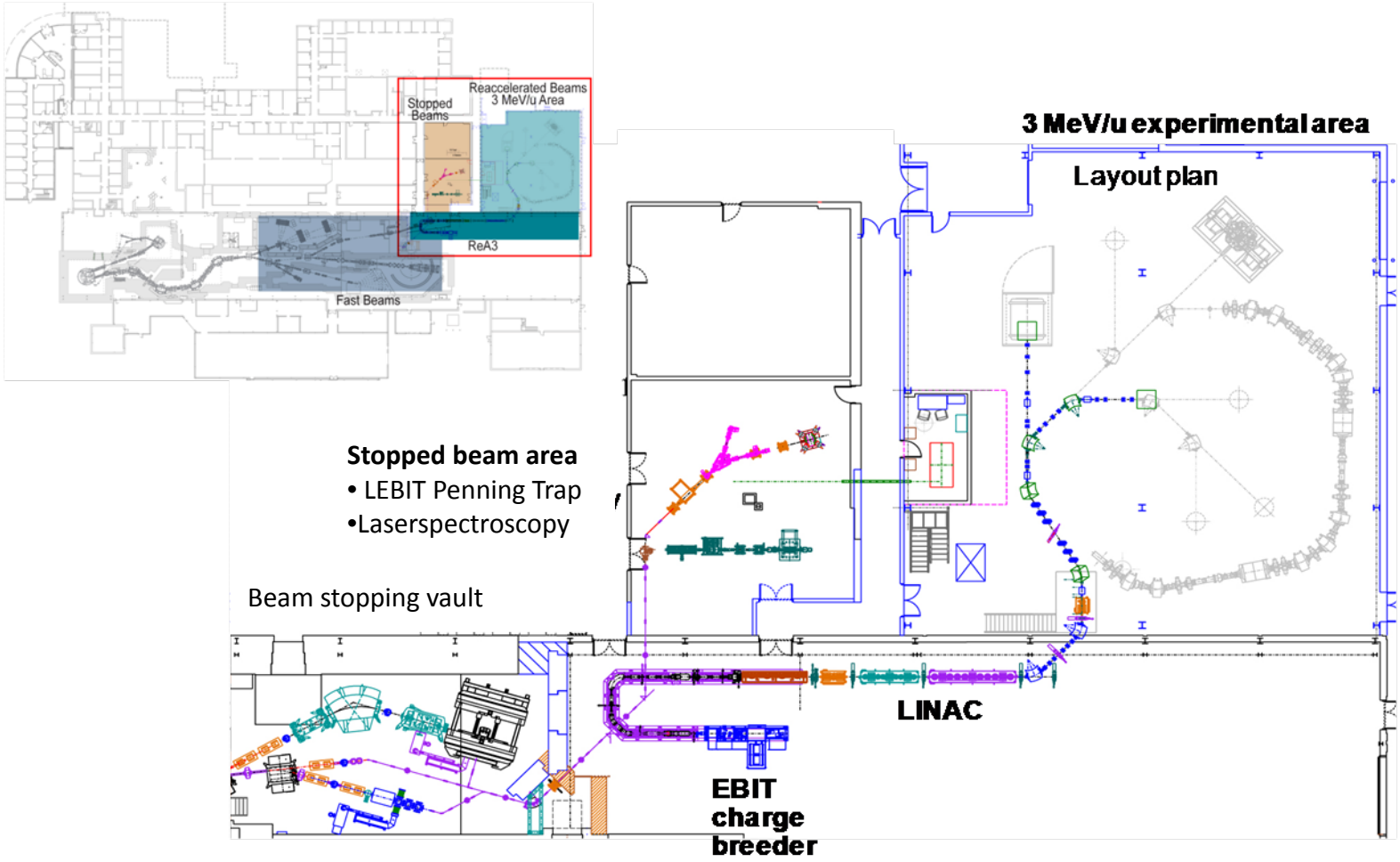
- ReA3 project
- MSU EBIT
- Injection calculation
- Status and outlook

ReA3 location in NSCL

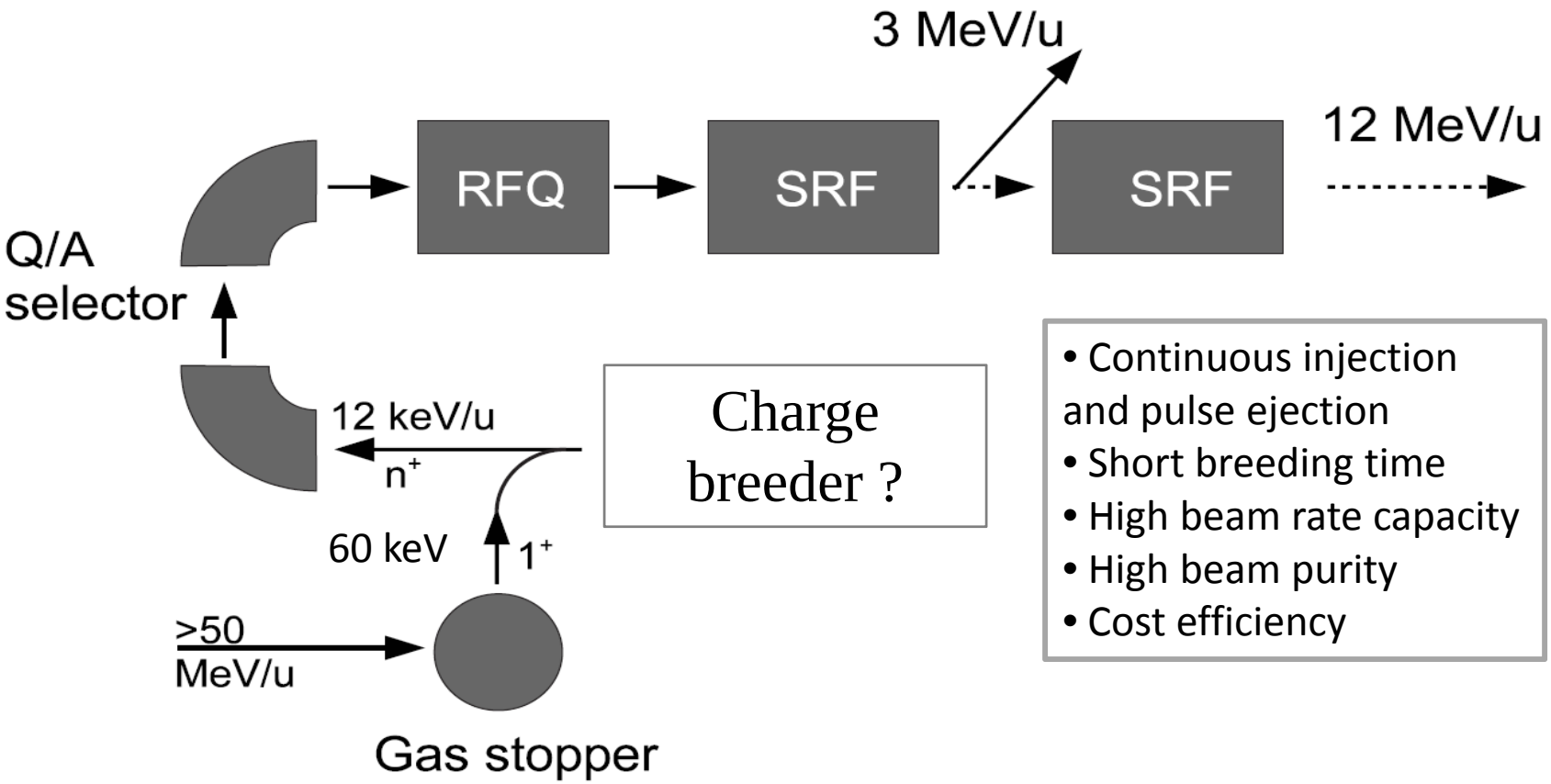


new science opportunities with rare isotopes from projectile fragmentation

- Nuclear astrophysics: key reactions at near-stellar energies
- Nuclear structure via Coulomb excitation or transfer reactions


Reaccelerated Beams
3 MeV/u Area
Stopped Beams
ReA3
Fast Beams
3 MeV/u experimental area
Layout plan
Stopped beam area
• LEBIT Penning Trap
•Laserspectroscopy
Beam stopping vault
LINAC
EBIT
charge
breeder

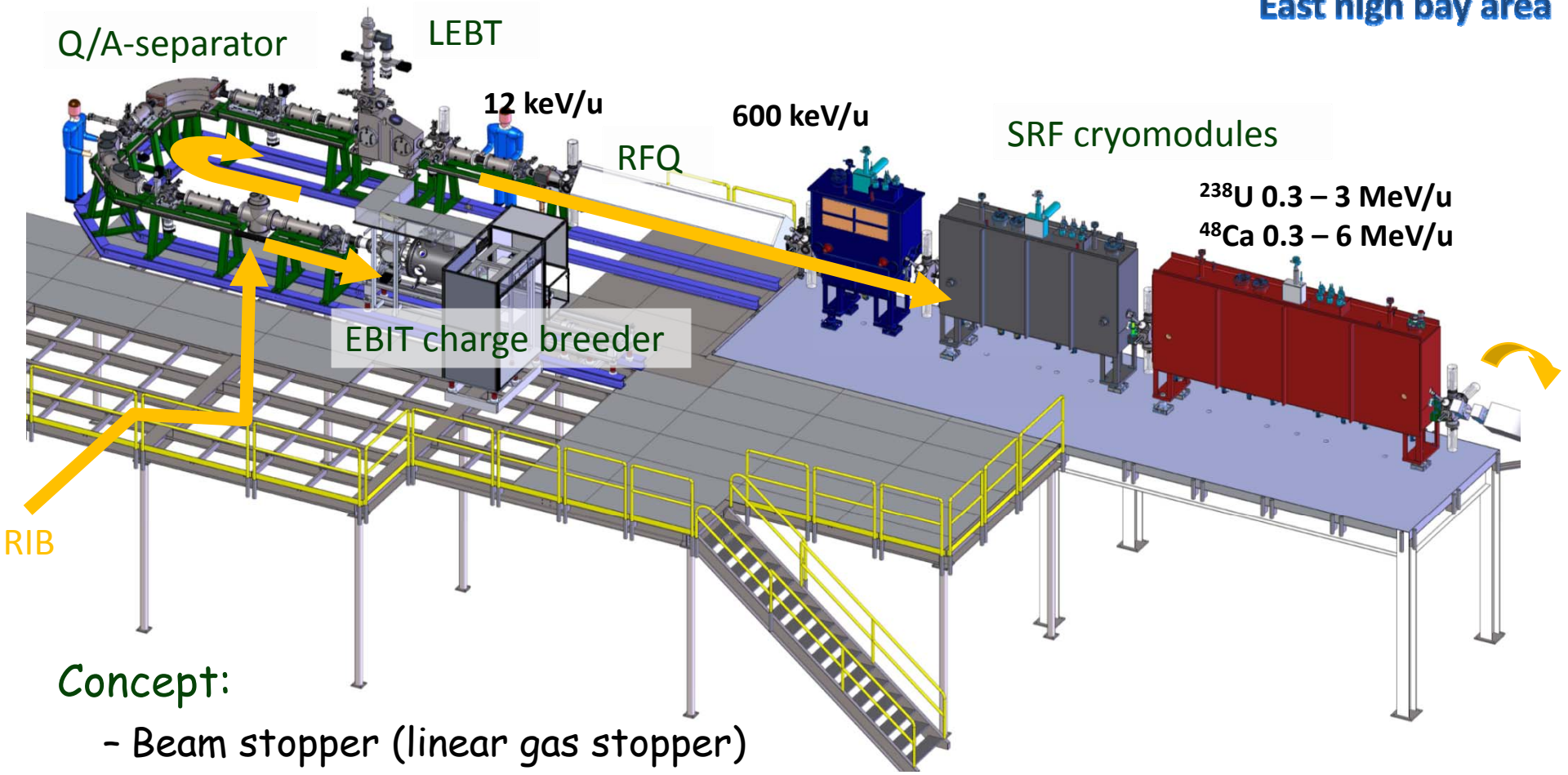
New reaccelerator for rare isotopes ReA3



Charge breeder ?

- Continuous injection and pulse ejection
- Short breeding time
- High beam rate capacity
- High beam purity
- Cost efficiency

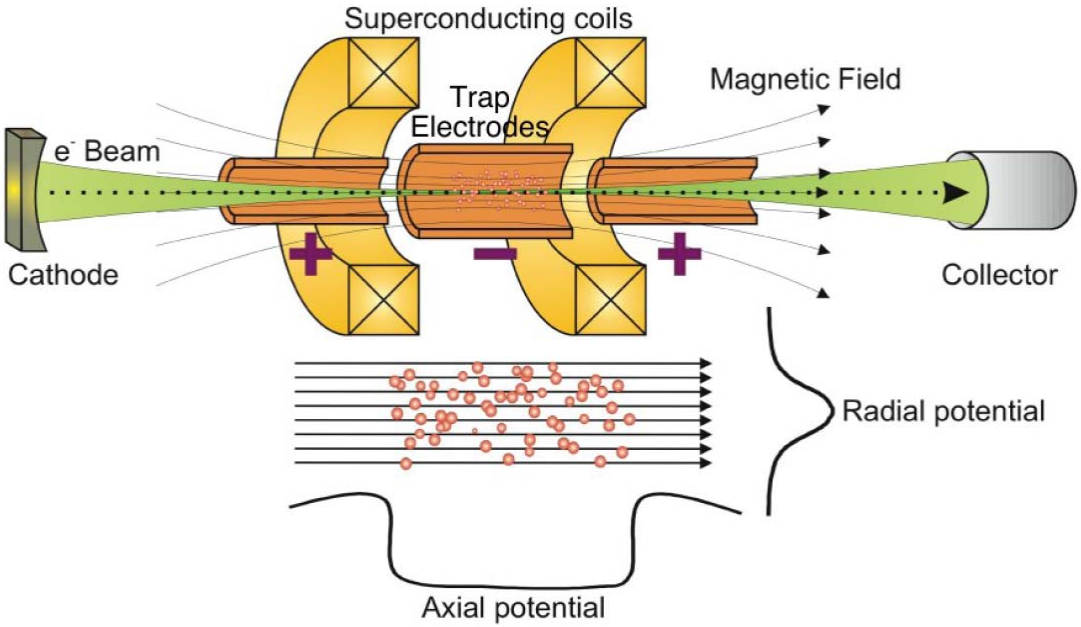
East high bay area



Concept:

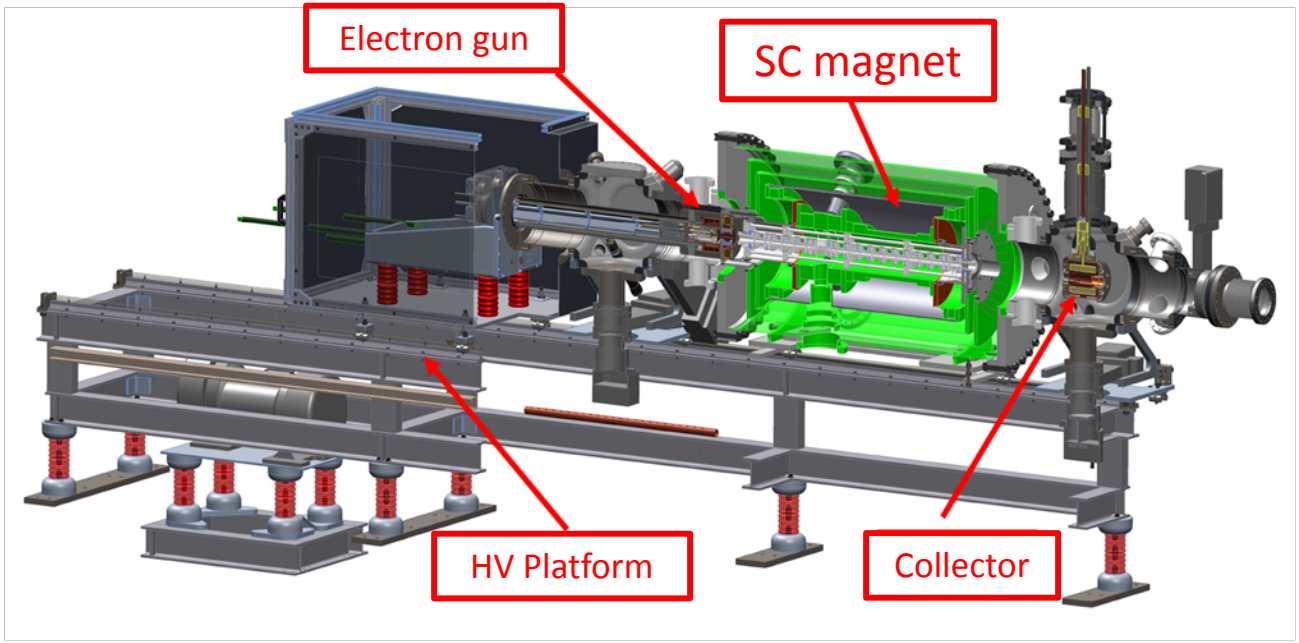
- Beam stopper (linear gas stopper)
- High-intensity electron beam ion trap (EBIT) as $1^+ \rightarrow n^+$ charge breeder
- Room temperature RFQ and Superconducting RF Quarter Wave Resonators in cryomodules, f = 80.5 MHz

Principle of EBIT



Electron beam radius : $r_e(r_c , E_e , I_e , B)$

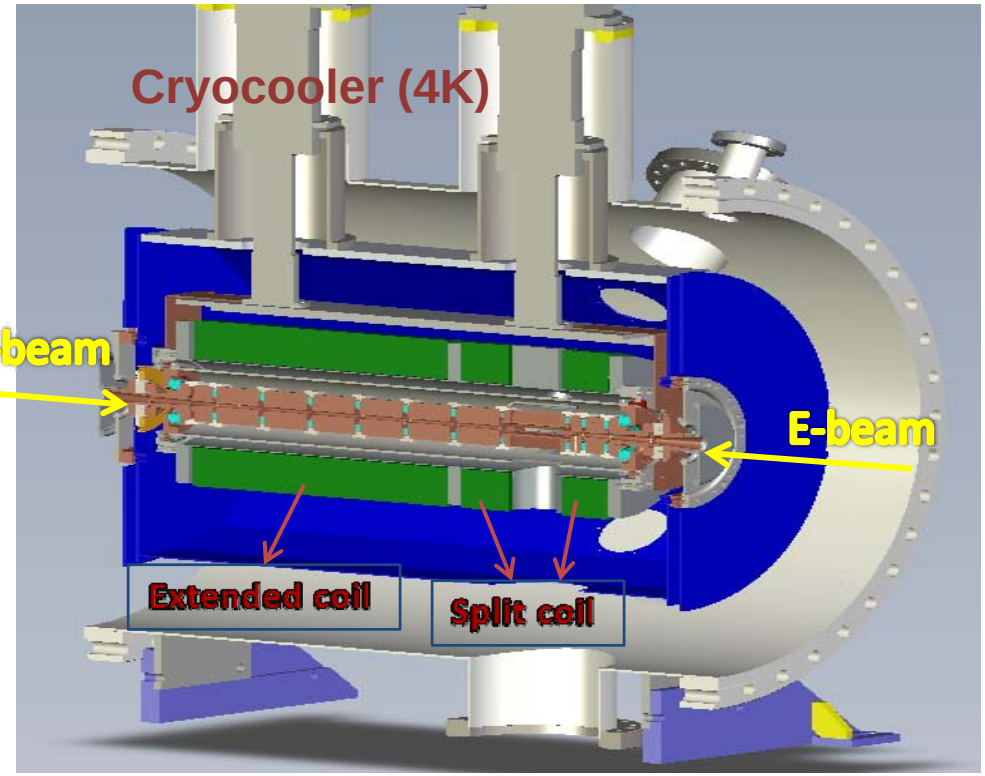
With r_c =1.5 mm, E_e =5 keV, I_e =2 A, B=6 T; **r_e = 27 μm**



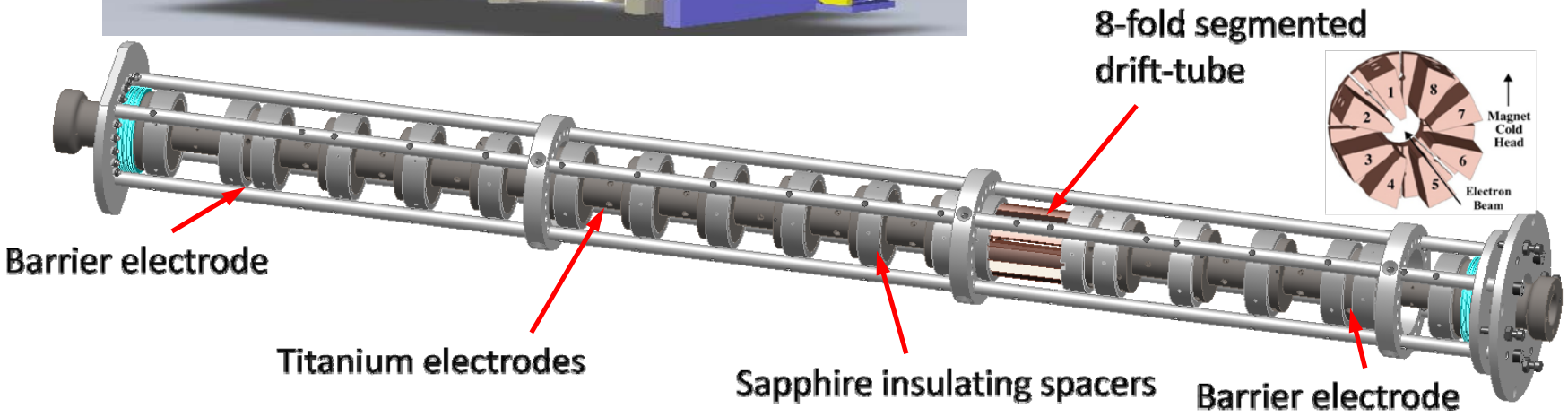
Superior performance:

- High beam current: >2.5 A
- High current density: > 10^4 A/cm^2
- Length of trap: 0.8 m
- Stored charge: 10^{10} positive charges
- Sophisticated magnetic field structure , up to 6 T

Trap electrode and magnet structure

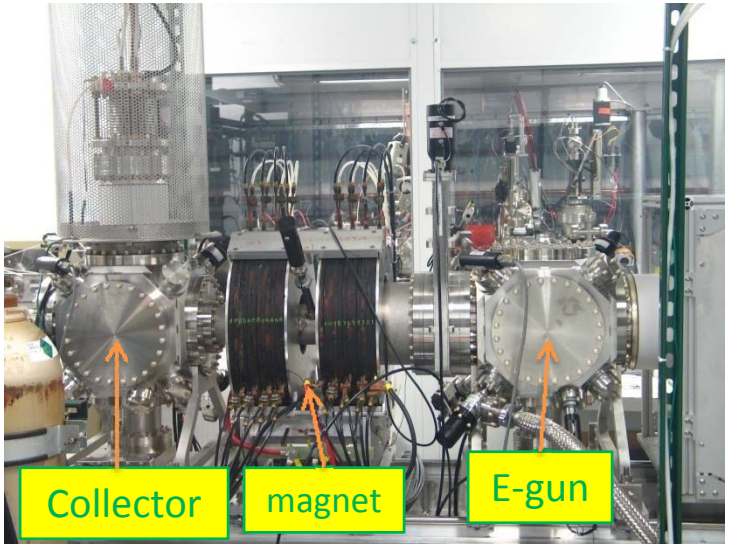


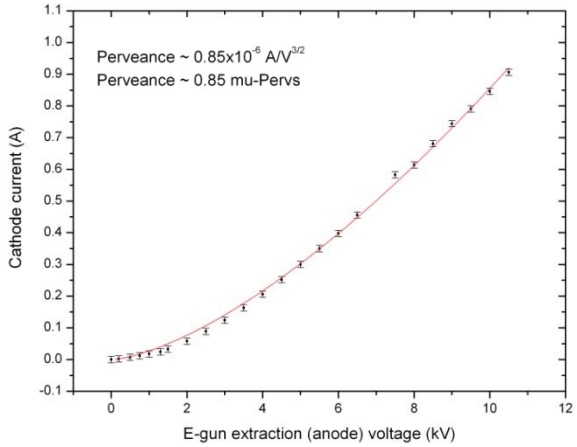
- 21 electrodes with 10mm inner diameter
- 10 μs barrier switch
- Sapphire insulator



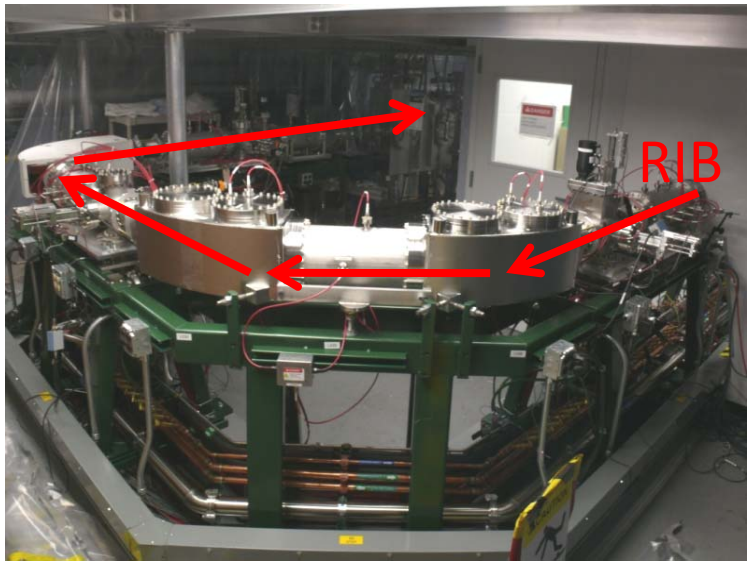
EBIT and Q/A separator commissioning

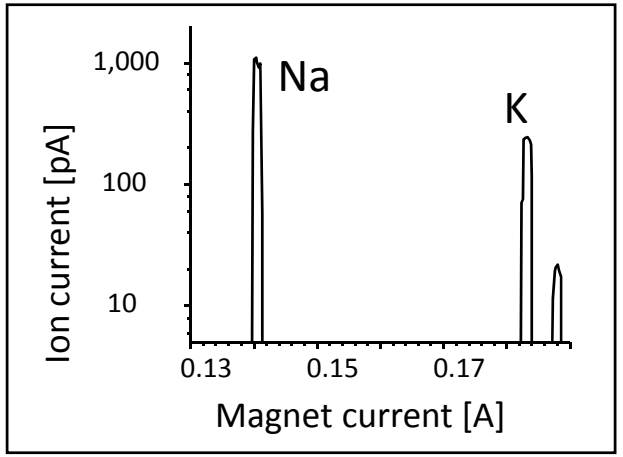
E-gun commissioning setup with temporary 0.4T magnet



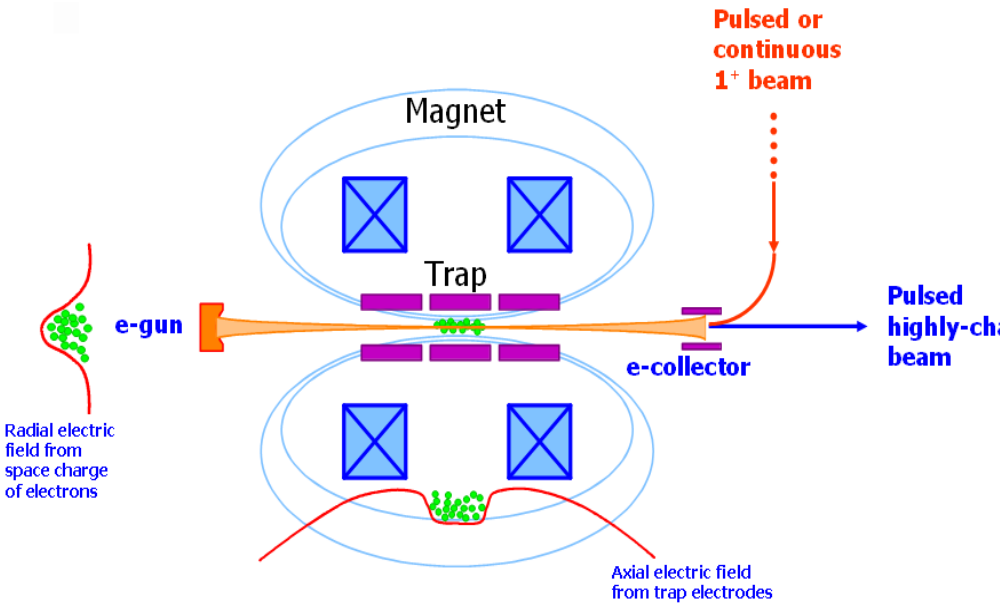


Achromatic Q/A separator

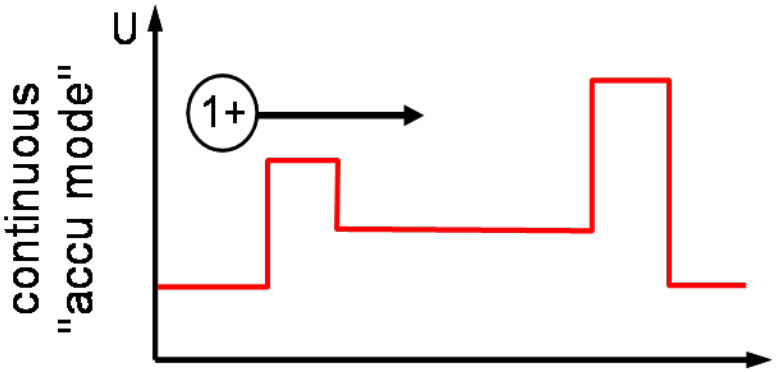


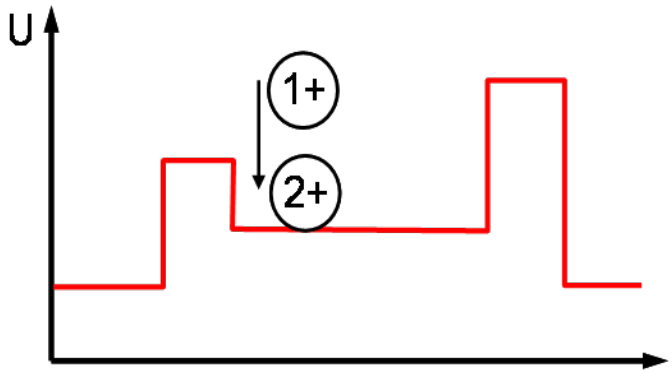


Injection concept

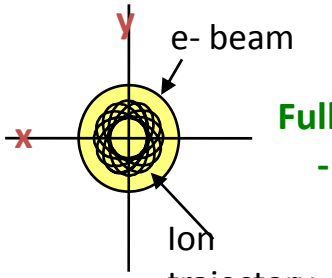


- Unique features:
  - Continuous injection of ions
    - ➢high capture rate
  - Variable extraction duty cycle
    - ➢ μs pulse to quasi-continuous

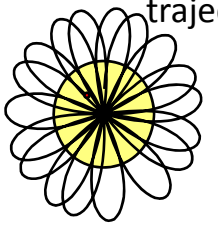




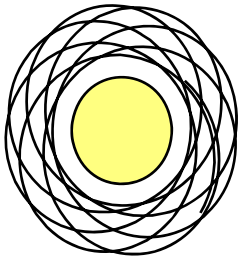
Capture probability vs Emittance



Full overlap,
- ideal !

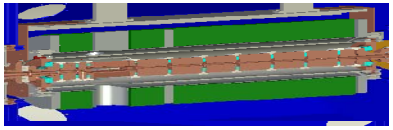


Partial overlap
- nice, but bad !

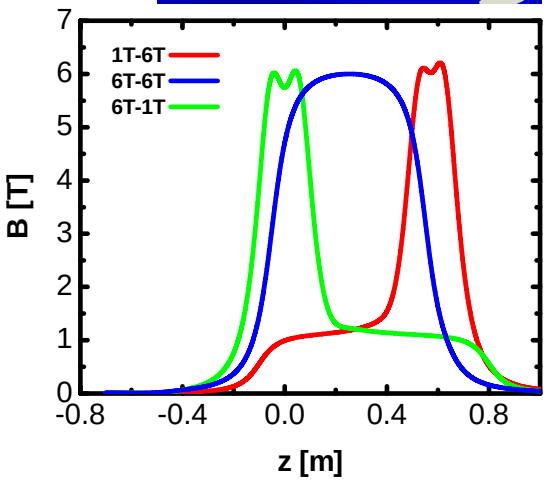


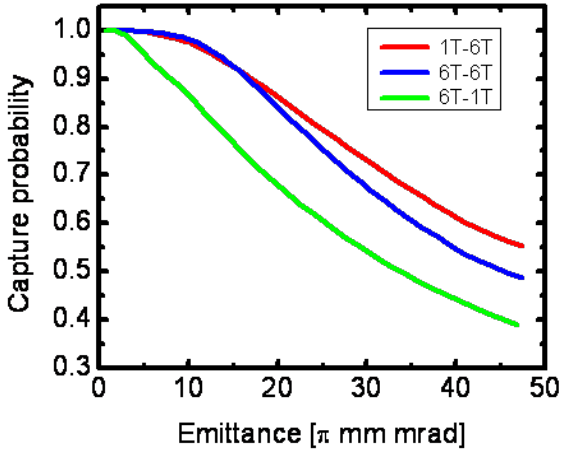
No overlap
- no capture

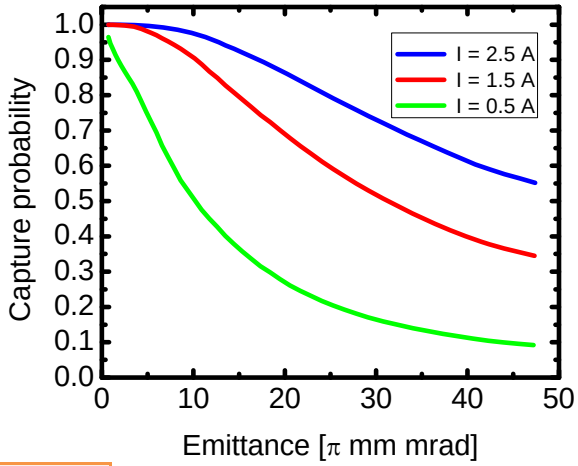
Collector



E-gun





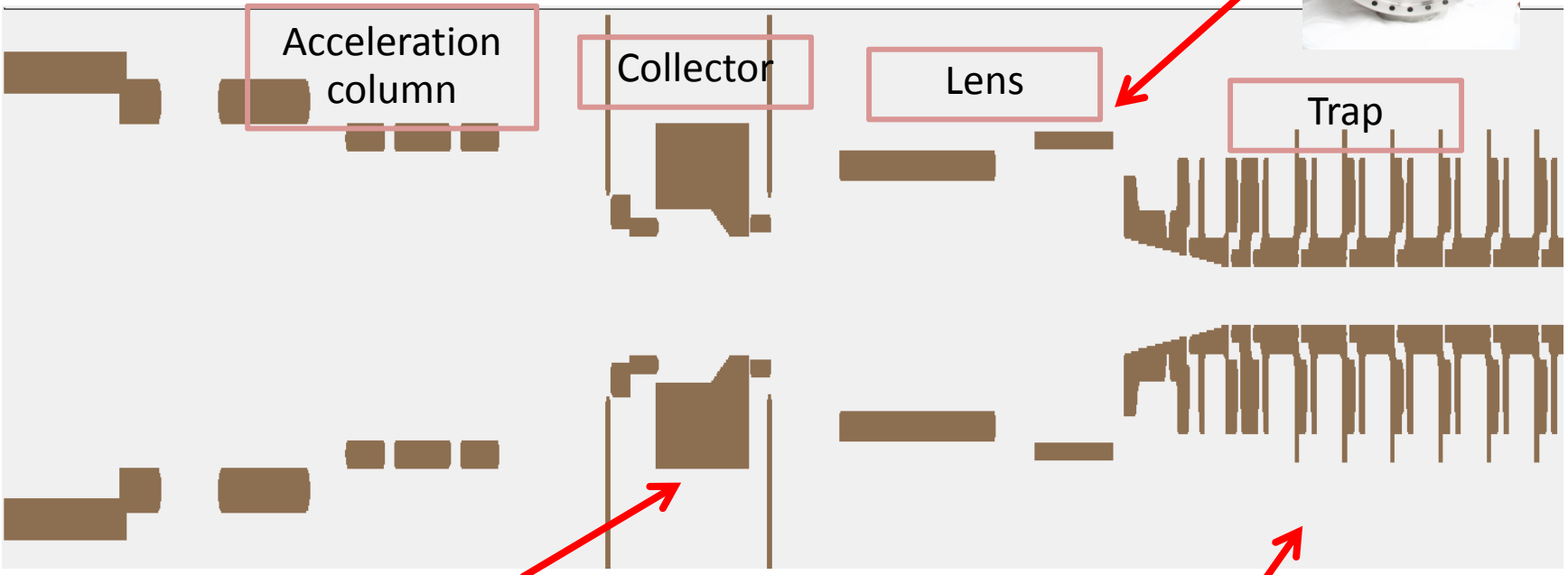


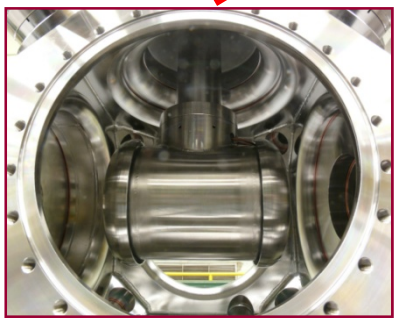
Importance of overlap
of electron and ion beam for capture of ion beam

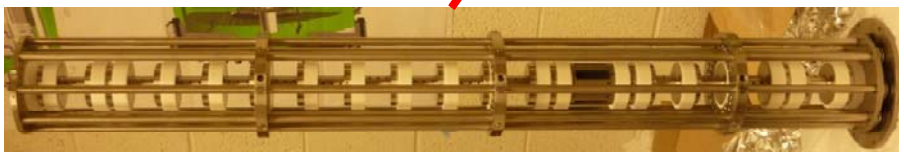
Large radius (low magnetic field)	High capture rate but long breeding time
Small radius (high magnetic field)	Low capture rate but short breeding time

Injection calculation

The simulation follow the real geometry and number of electrodes



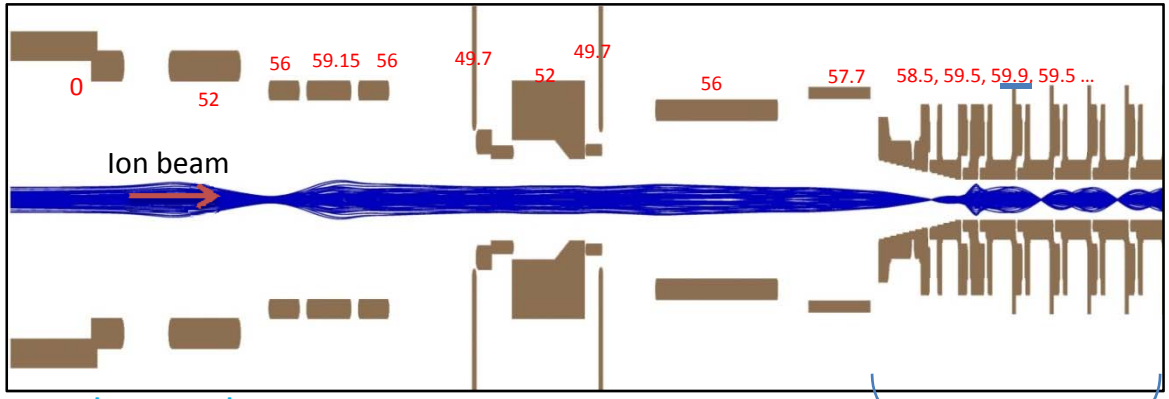




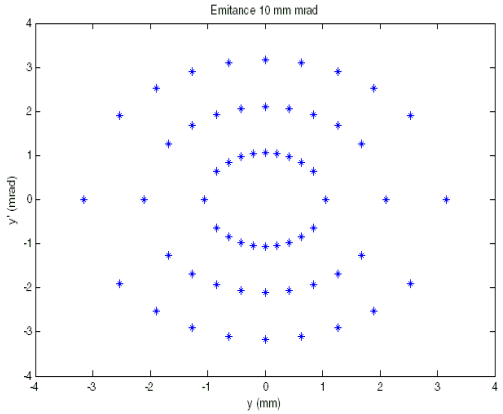
1 T-6T calculation

Goal : Minimum radial energy!

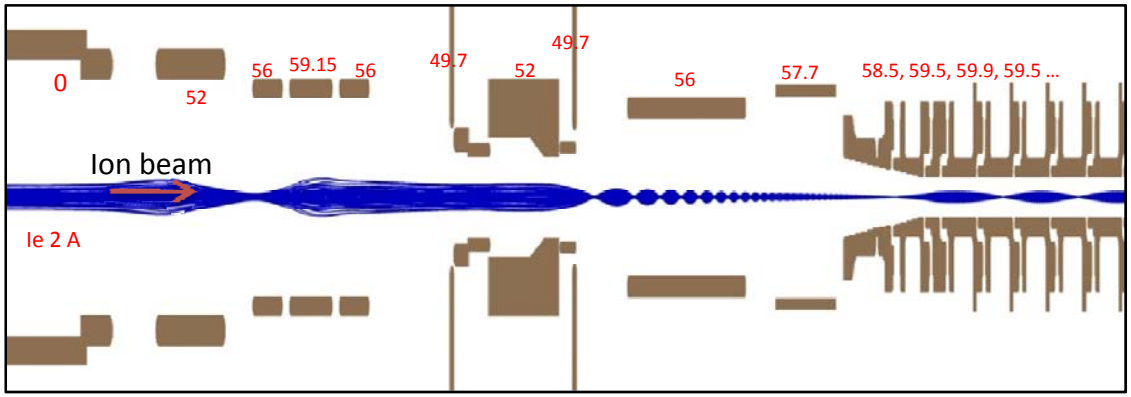
Injected beam with $\varepsilon = 10\pi$ mm mrad



No electron beam

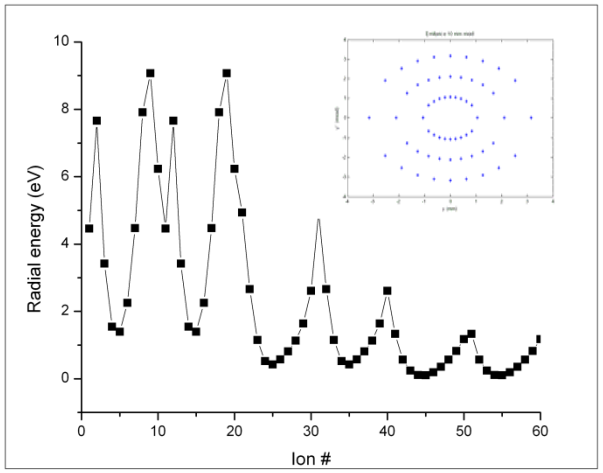


Collector **Trap**



E-beam

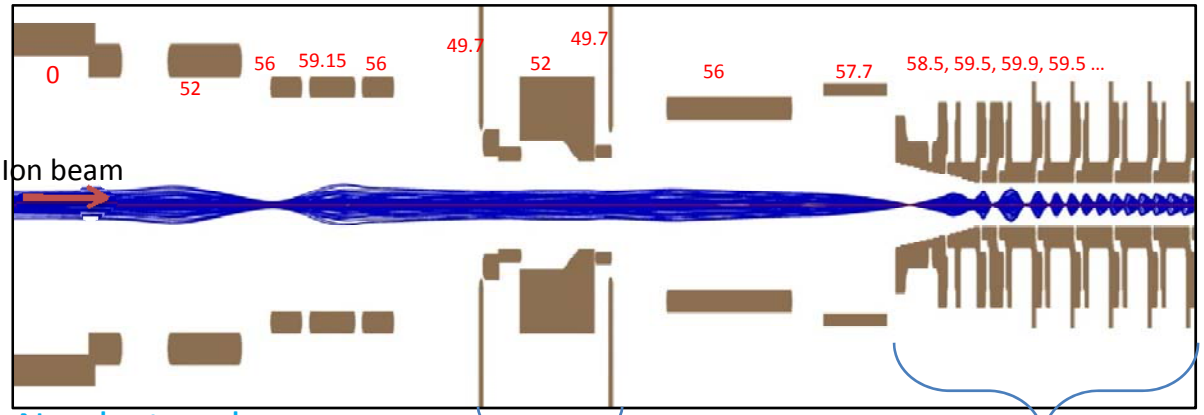
With electron beam 2 A



No electron beam

Ion beam: A=40 u, Q=1, 60 keV
Electron beam: 5 keV

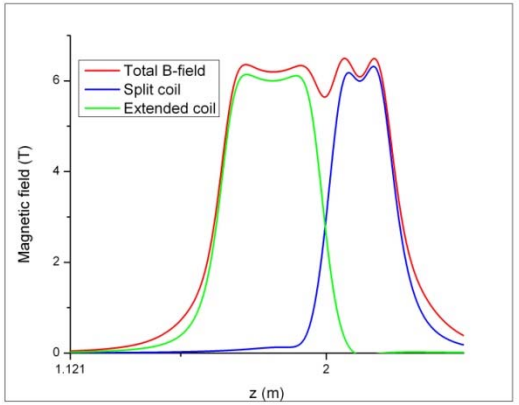
6 T-6T calculation

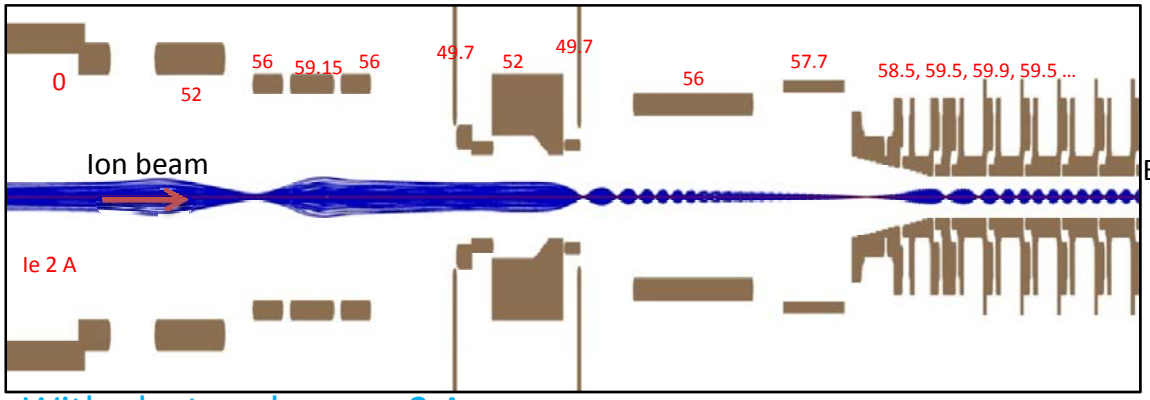


No electron beam

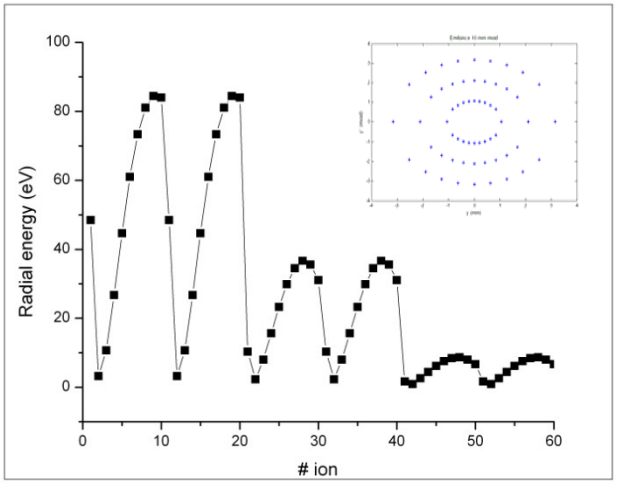
Collector

Trap





With electron beam = 2 A



No electron beam

Ion beam: A=40 u, Q=1, 60 keV
Electron beam: 5 keV

Status and outlook

- ✓ Electron gun and collector have been constructed and successfully tested
- ✓ Trap and related parts has been built
- Superconducting magnet is coming soon
- Monte Carlo simulation for charge state evolution with the real setup
- Optimize ion beam injection to get a highest efficiency
- First charge breeding by the end of 2010 !!!

Thank You For Your Attention