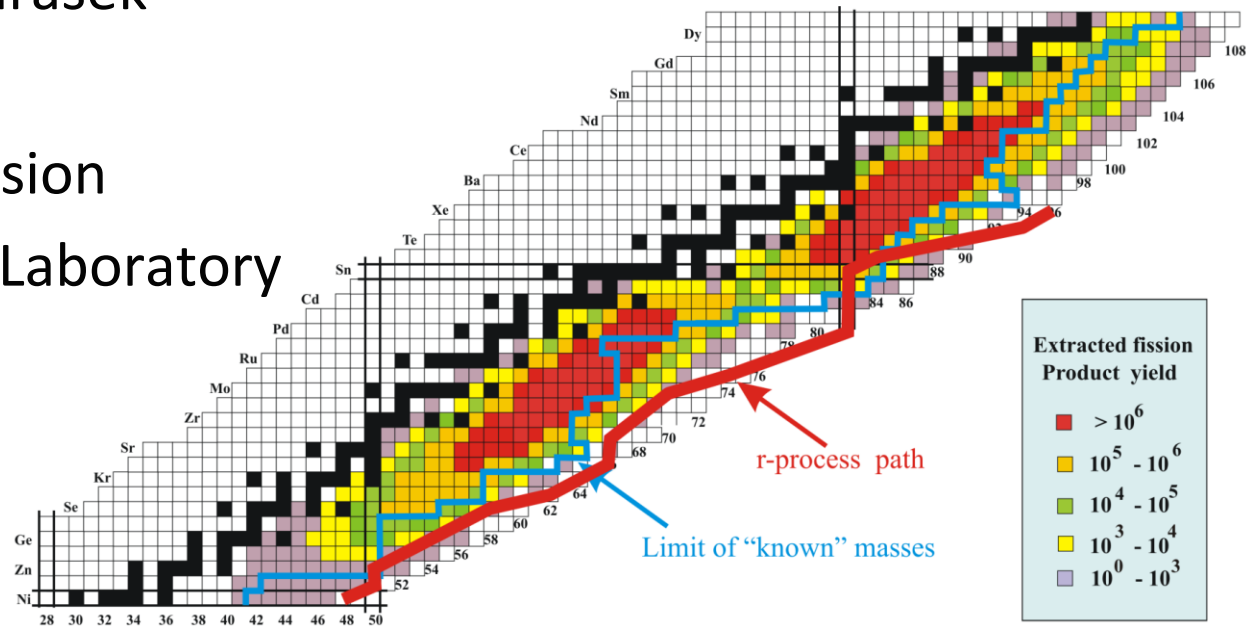


CARIBU Charge Breeding

Richard Vondrasek

Physics Division

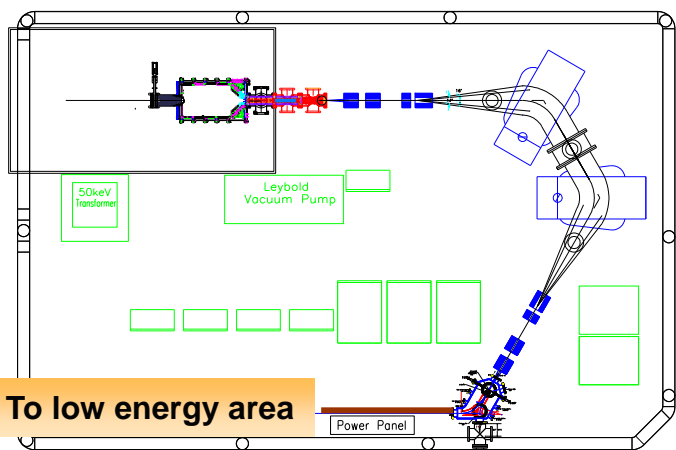
Argonne National Laboratory



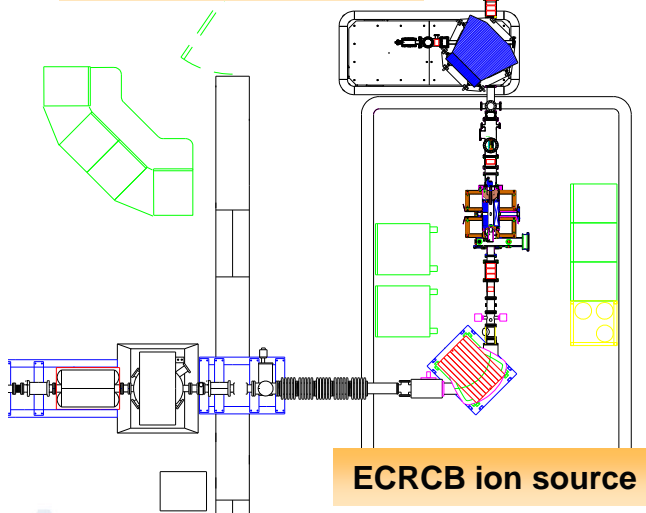
- CARIBU ECR charge breeder
- Charge breeding results
- Areas of investigation

CARIBU - Californium Rare Ion Breeder Upgrade

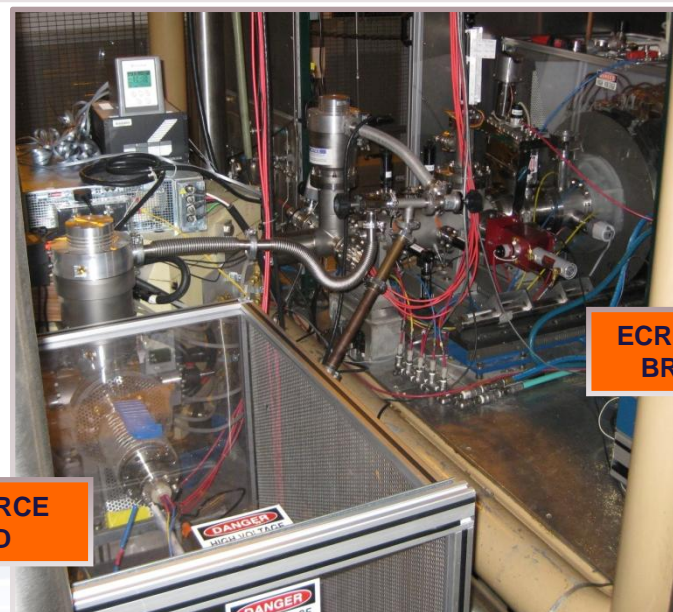
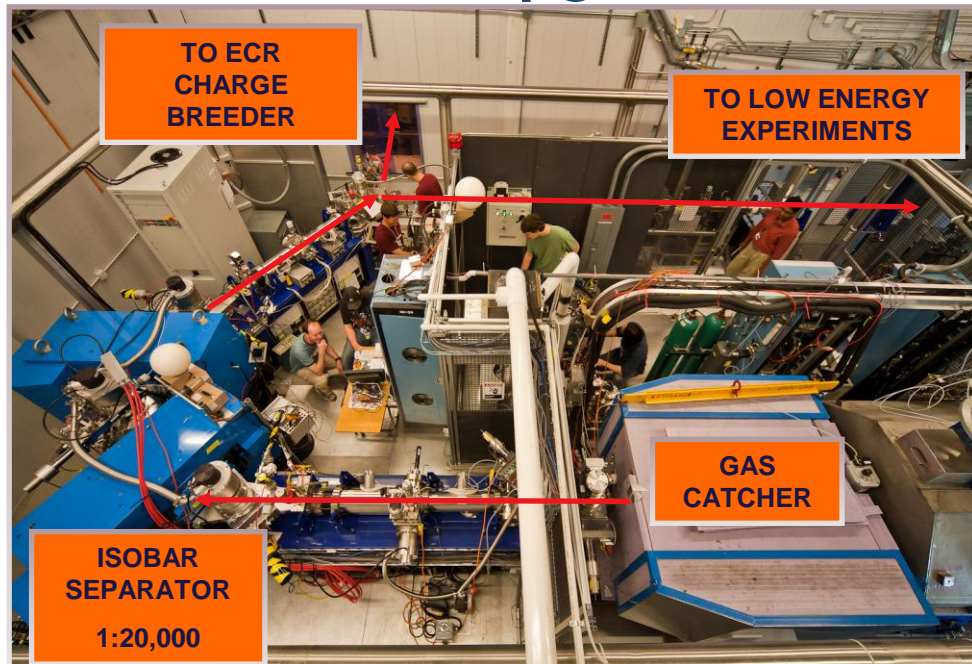
^{252}Cf source, gas catcher, isobar separator



Stable beam platform



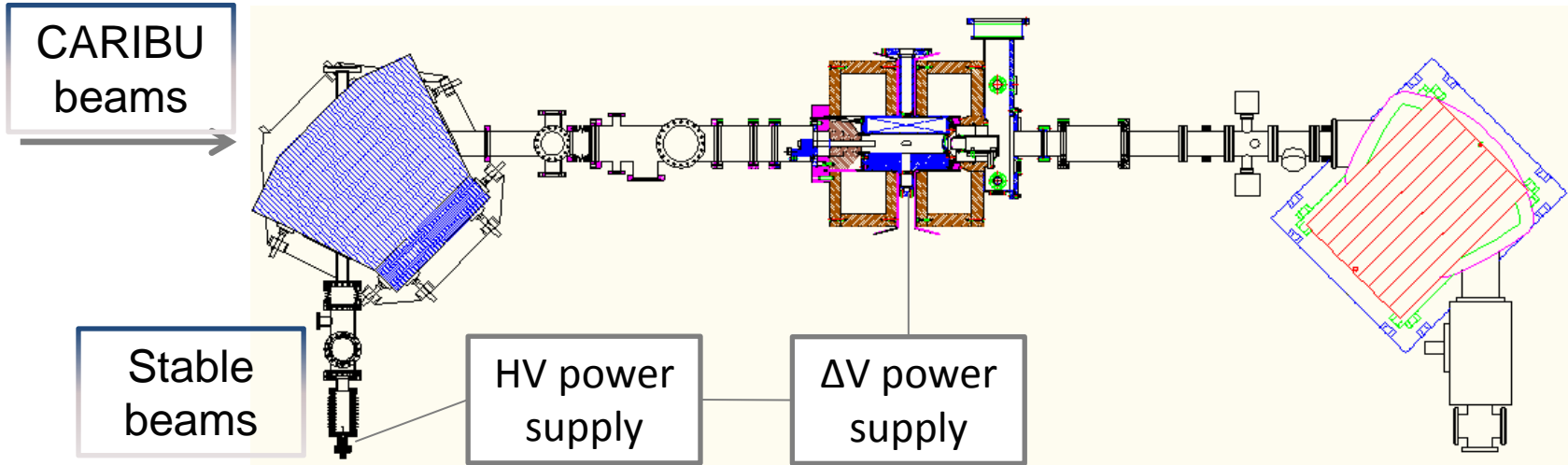
ECRCB ion source



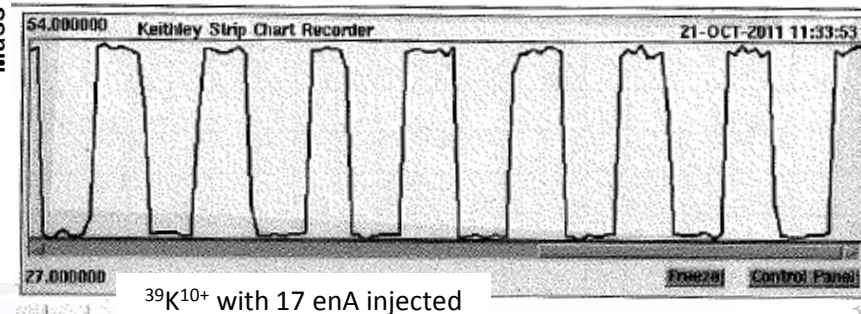
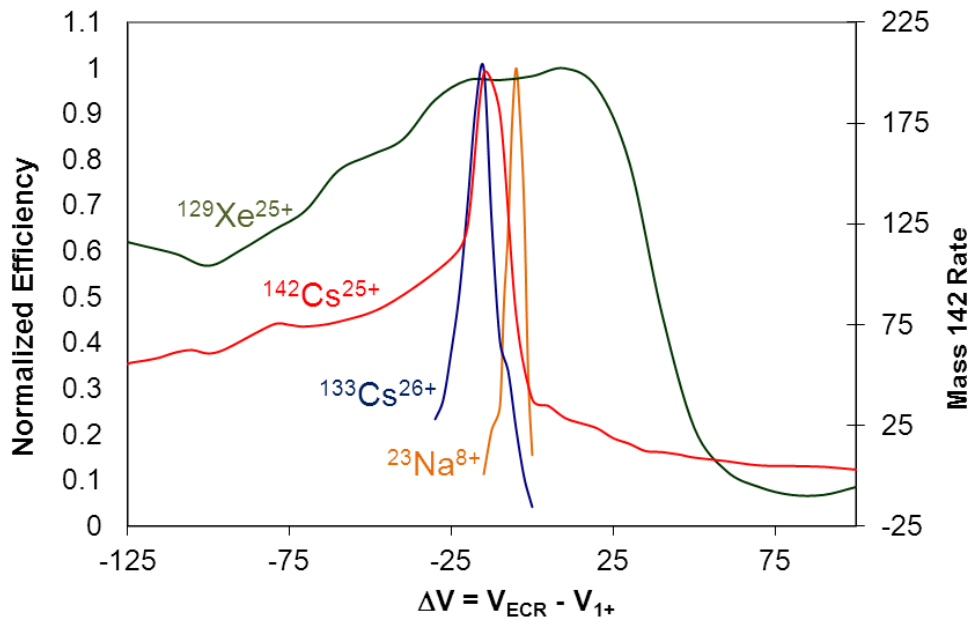
1+ SOURCE HEAD



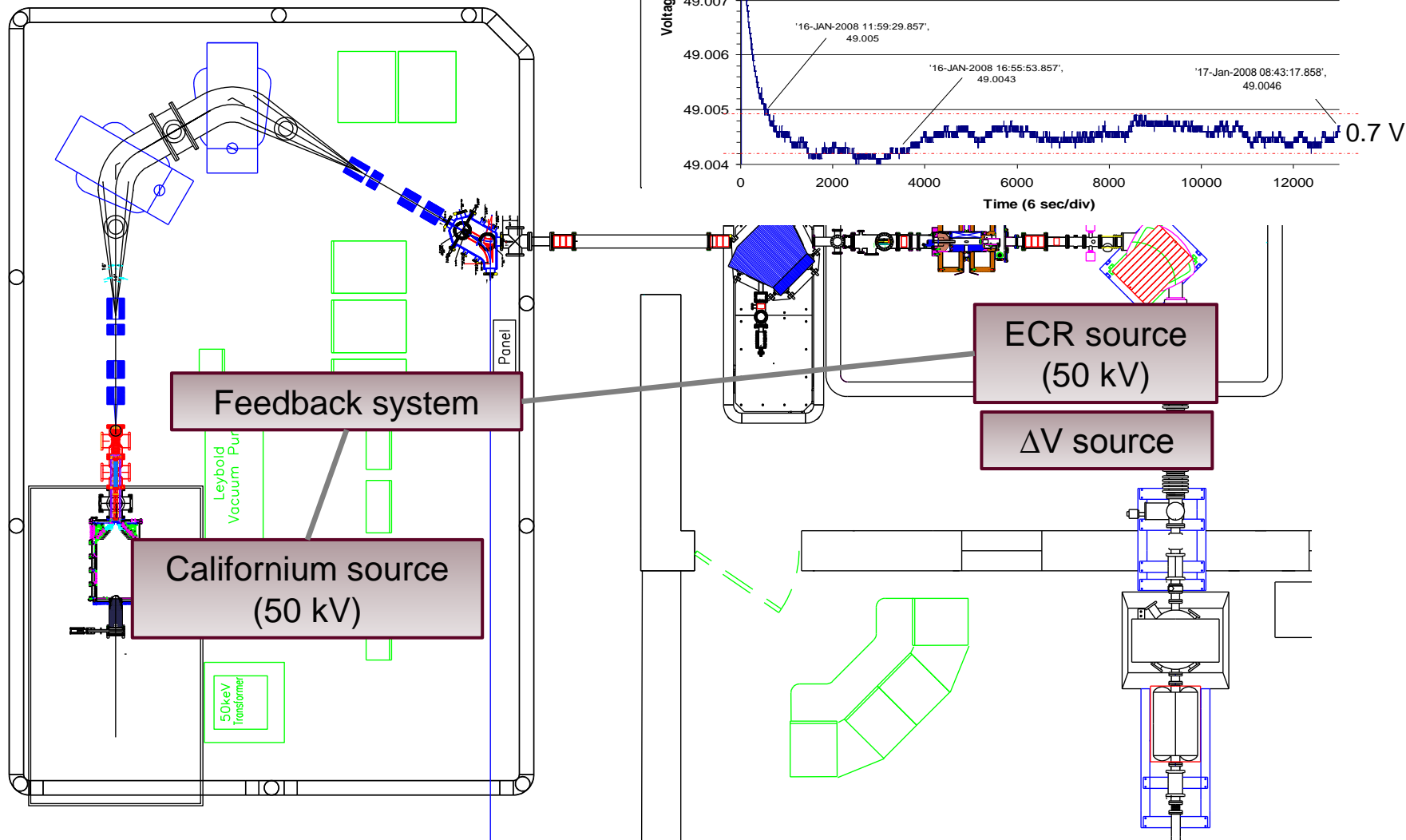
Charge breeding with ECR source



- Efficient stopping of the 1+ ions requires precise control of the ΔV
 - ΔV of stable beams from surface source and radioactive species from CARIBU are similar
 - Small supply for stable beams, separate 50 kV supplies for CARIBU breeding

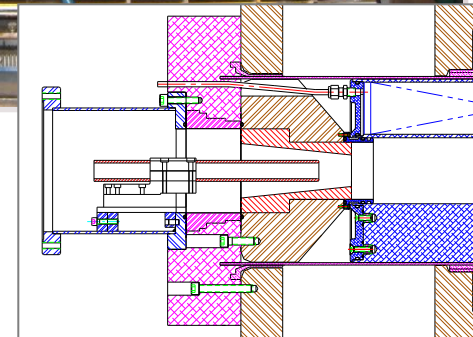
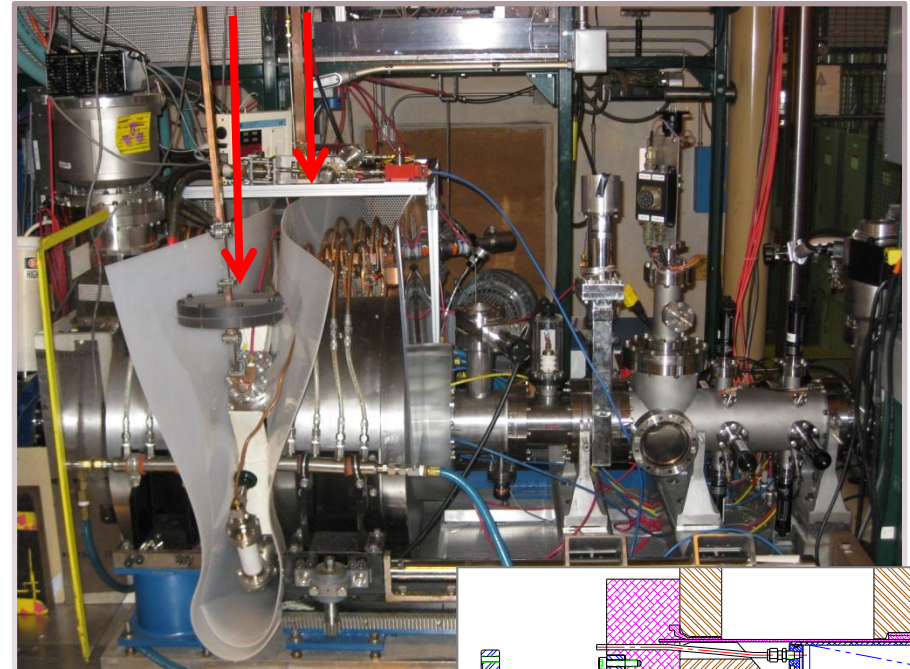


High voltage relationships



ECR charge breeder

- Multiple frequency operation
 - Klystron: 10.44 GHz, 2 kW
 - TWTA: 11→13 GHz, 0.5 kW
- Open hexapole structure
 - RF is injected radially
 - Uniform iron in the injection region for symmetrical fields
 - Improved pumping to the plasma chamber region
 - Base pressure: 2×10^{-8} mbar
 - Operation: 7×10^{-8} mbar
 - Extraction pressure: 4×10^{-8} mbar
- Movable grounded tube
 - 2.5 cm of travel
- 50 kV high voltage isolation



	Design value	Running condition
B_{inj}	1.31 T	1.16 T
B_{min}	0.31	0.27
B_{ext}	0.85	0.83
$B_{(radial)}$		0.86 T
Last closed surface		0.61 T

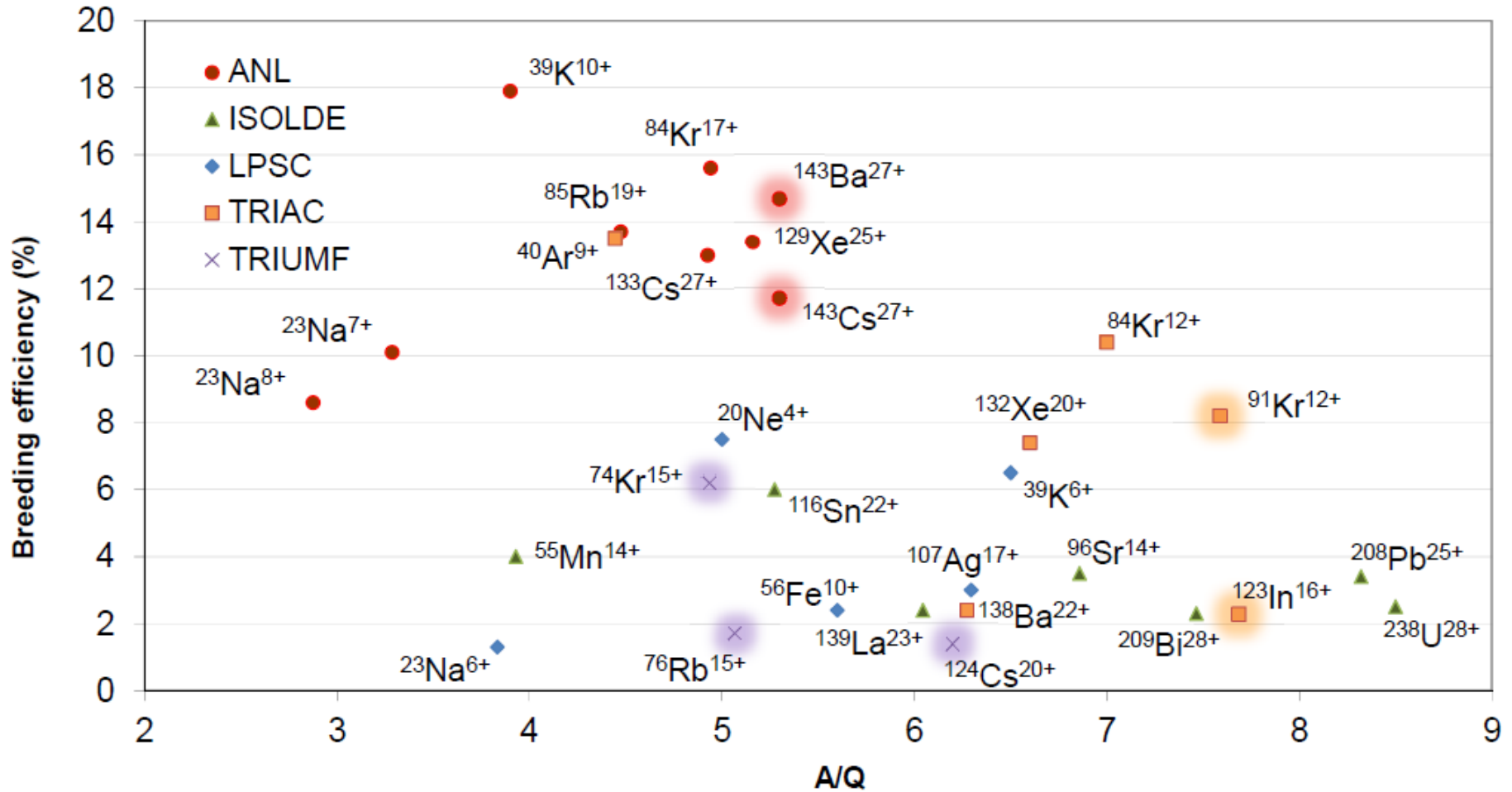
Charge breeding results

Ion		Efficiency (%)	A/Q
⁸⁴ Kr	17+	15.6	4.94
⁸⁵ Rb	19+	13.7	4.47
¹²⁹ Xe	25+	13.4	5.16
¹³³ Cs	27+	13.0	4.93
¹⁴³ Cs (1+)	27+	11.7	5.30
($t_{1/2} = 1.79$ s)	27+	14.7	5.30
¹⁴³ Ba (2+)			
($t_{1/2} = 14.33$ s)			

Ion		Efficiency (%)	A/Q
²³ Na	6+	6.6	3.83
	7+	10.1	3.29
	8+	8.6	2.87
³⁹ K	9+	3.4	2.56
	7+	3.0	5.57
	8+	4.9	4.87
	9+	15.6	4.33
	10+	17.9	3.90

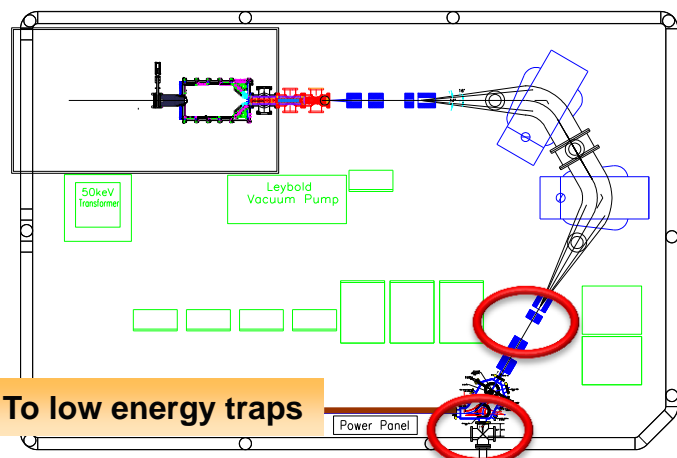
- Multiple frequency operation
- 30 → 36 kV extraction
- Helium plasma for Na and K, oxygen for all others
- For sodium injected 12.6 enA of Na-23
- With sodium, He-4 was replaced with He-3
 - No improvement
 - Adding oxygen did not help
- 13.8% breeding efficiency for ³⁹K¹⁰⁺ with 16.5 nA injected
 - Adding oxygen to the helium mixing gas was not beneficial
- Breeding time was 150 msec for ³⁹K⁹⁺ and 160 msec for ³⁹K¹⁰⁺

Worldwide charge breeding results

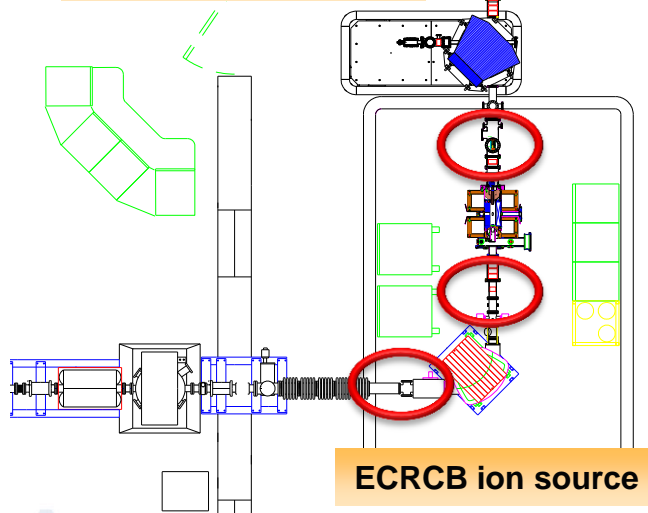


Radioactive beam tuning

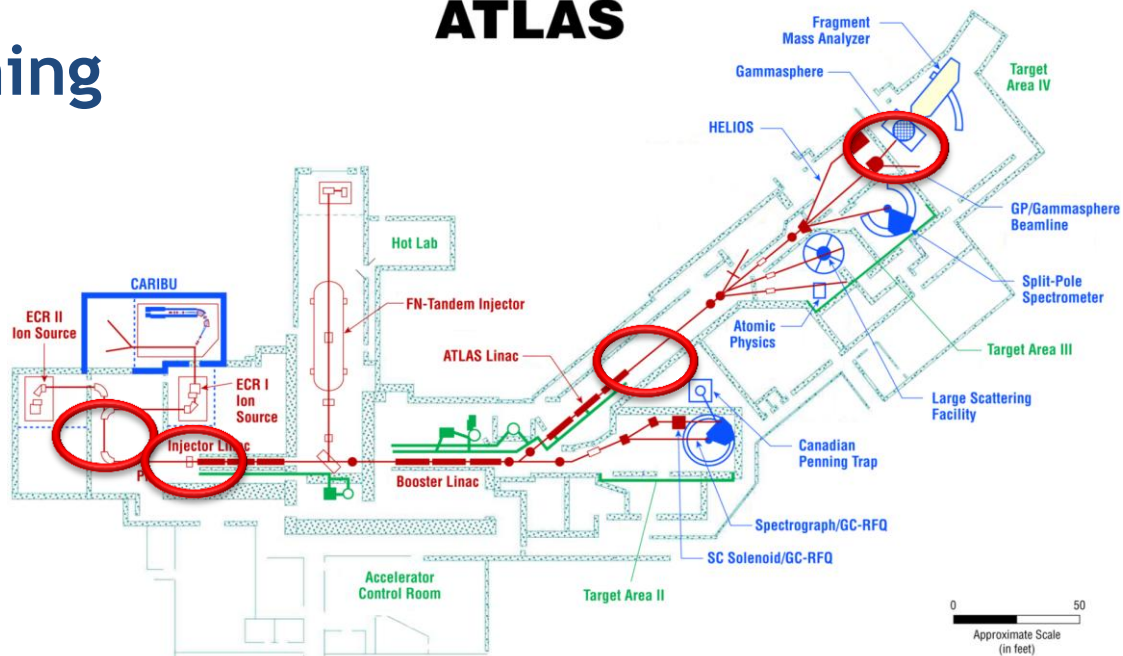
^{252}Cf source, gas catcher, isobar separator



Stable beam platform



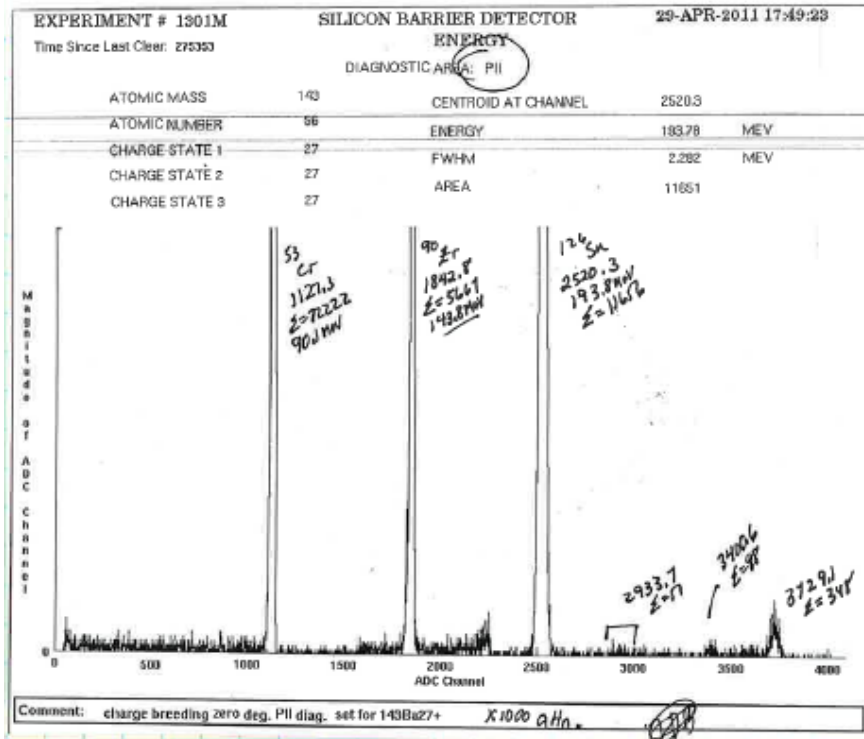
ATLAS



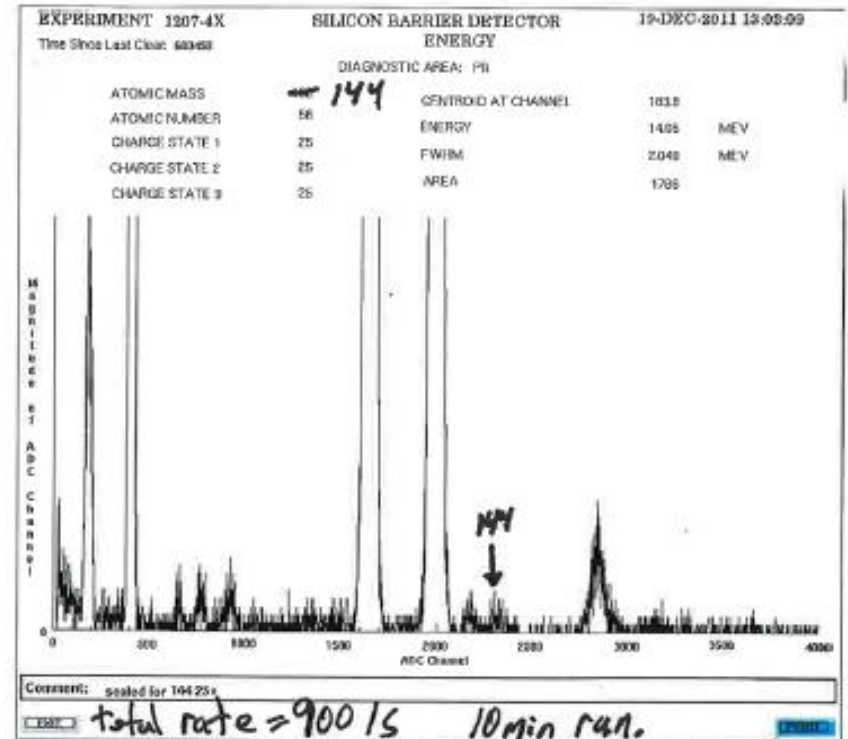
- Accelerator is first tuned with a stable guide beam from the ECRCB which has a similar q/m as the radioactive beam
- All machine elements are then scaled to the desired q/m with no tuning after scaling
- Beta decay of the fission products are monitored on surface barrier detectors placed at key locations
- Tune out of ECRCB for stable guide beam and radioactive charge bred ions are different

Beam contaminants

- Many species are extracted from the ECRCB, but there are many q/m combinations which can yield a relatively clean spectrum



- A = 143, Q = 25+
 - Total rate: 66,000 Hz
- A = 143, Q = 27+
 - Total rate: 330,000 Hz



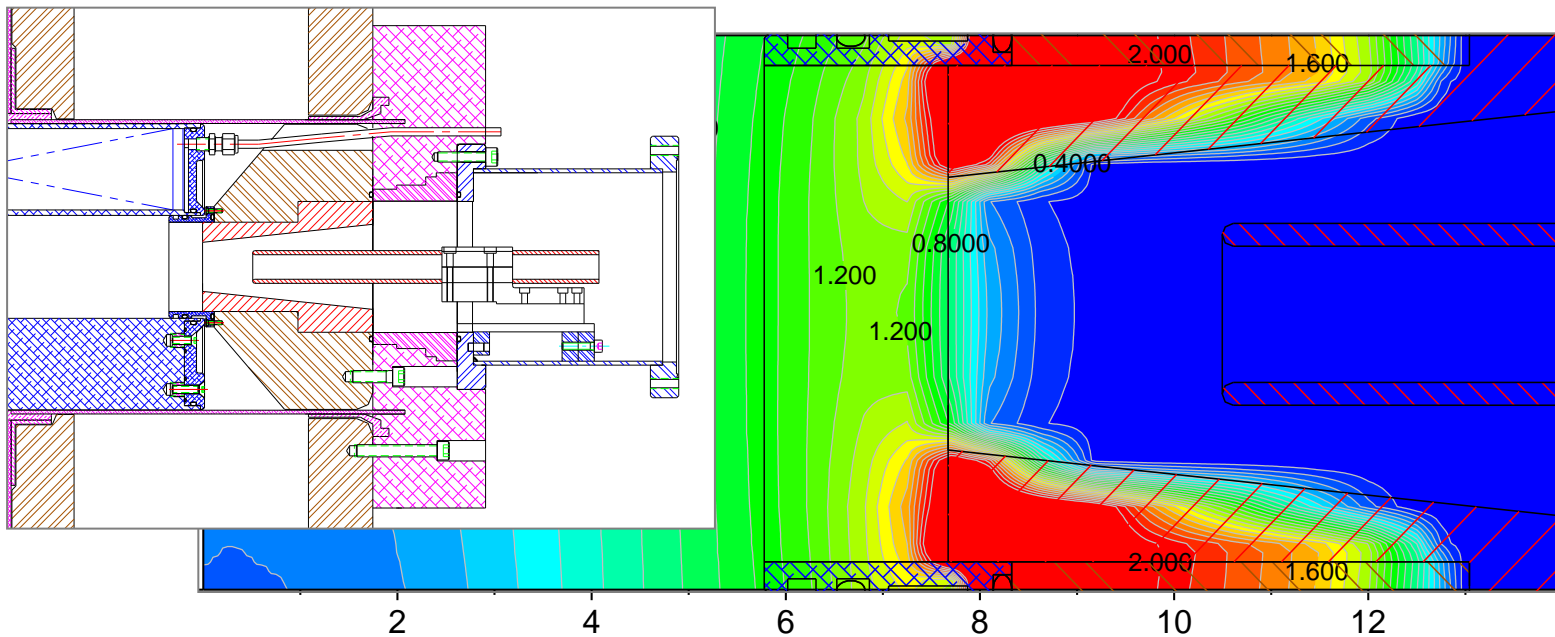
- A = 144, Q = 25+
 - Total rate: 900 Hz
- A = 144, Q = 26+
 - Total rate: 10,000 Hz

Beam contaminants - quartz liner

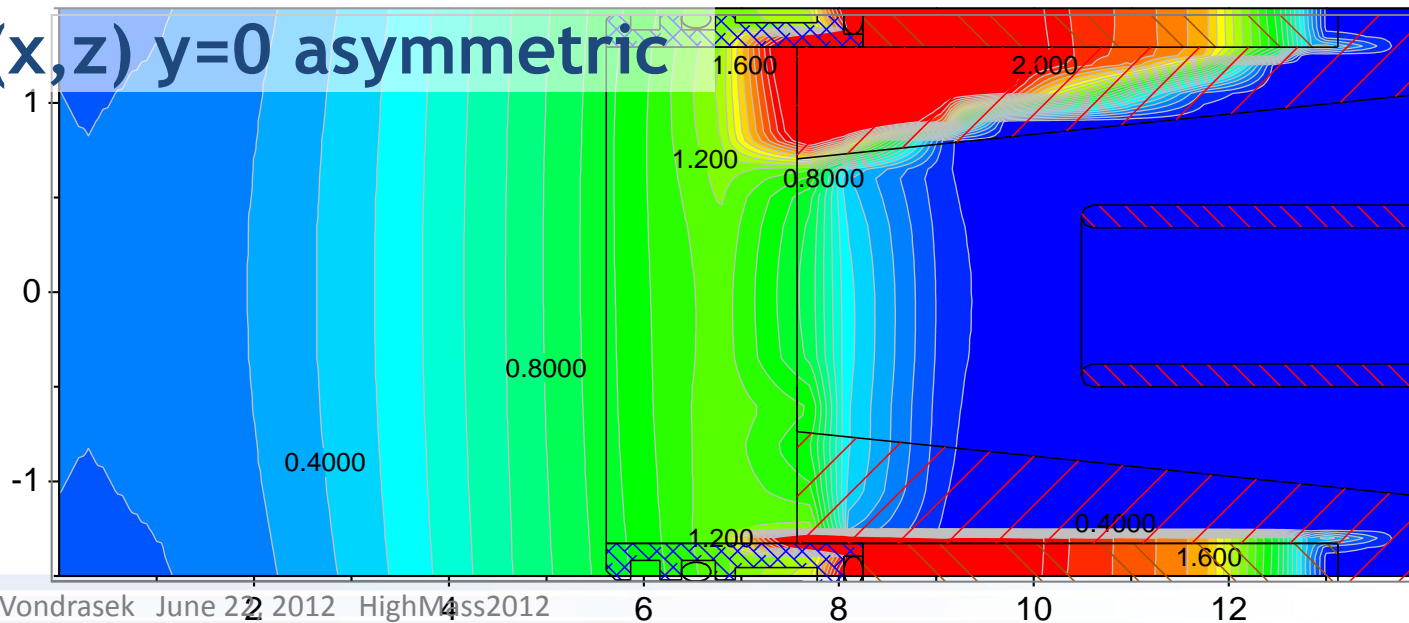
- Have installed a quartz liner
- Similar to one used for Ar-39 AMS work
 - There it reduced the K-39 background by factor of 100
- Have not yet fully characterized its usefulness in background reduction for ECRCB
 - Initial tests show an improvement but no firm numbers
 - Liners can be troublesome
 - High pressure rinsing or coating may be better but will require disassembling the source



$B_z(x,z)$ $y=0$ symmetric

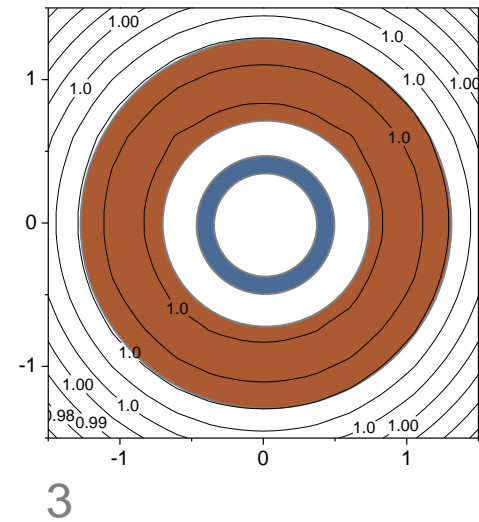
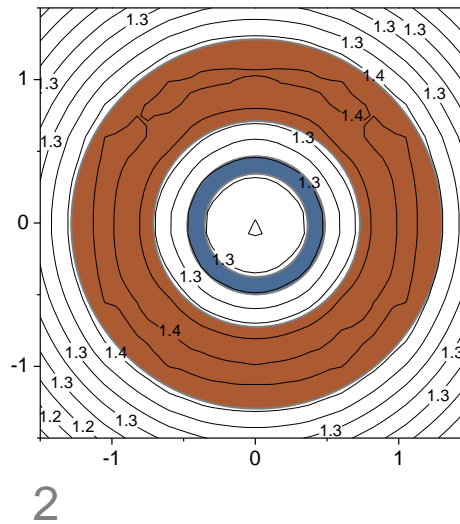
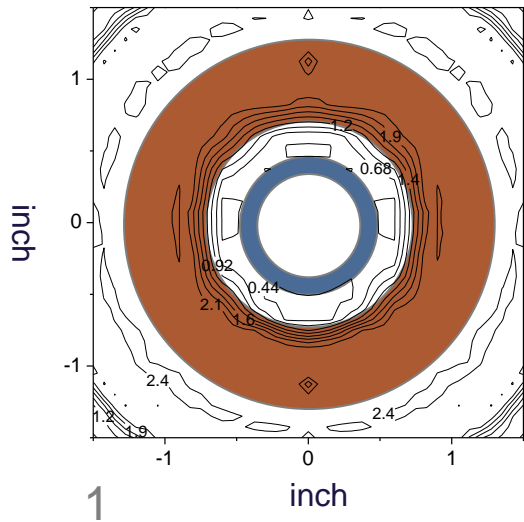


$B_z(x,z)$ $y=0$ asymmetric

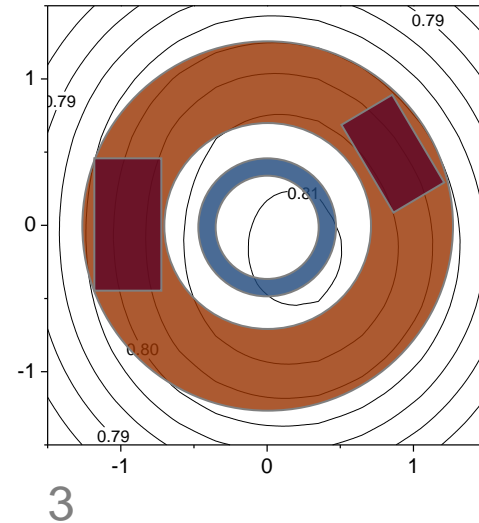
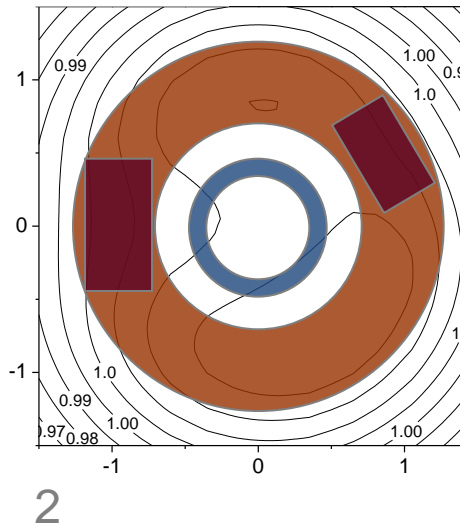
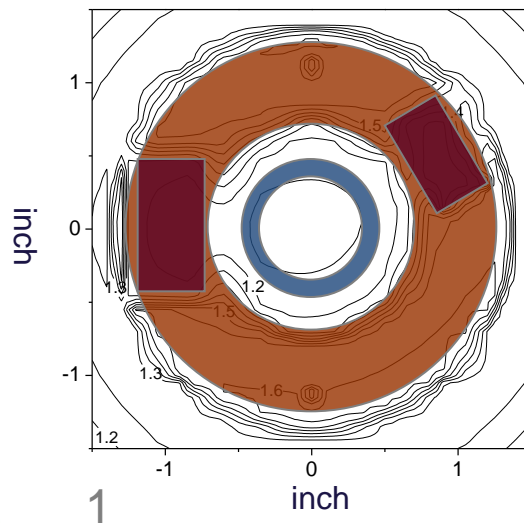


Injection B field profile

$B_z(x,y)$ symmetric

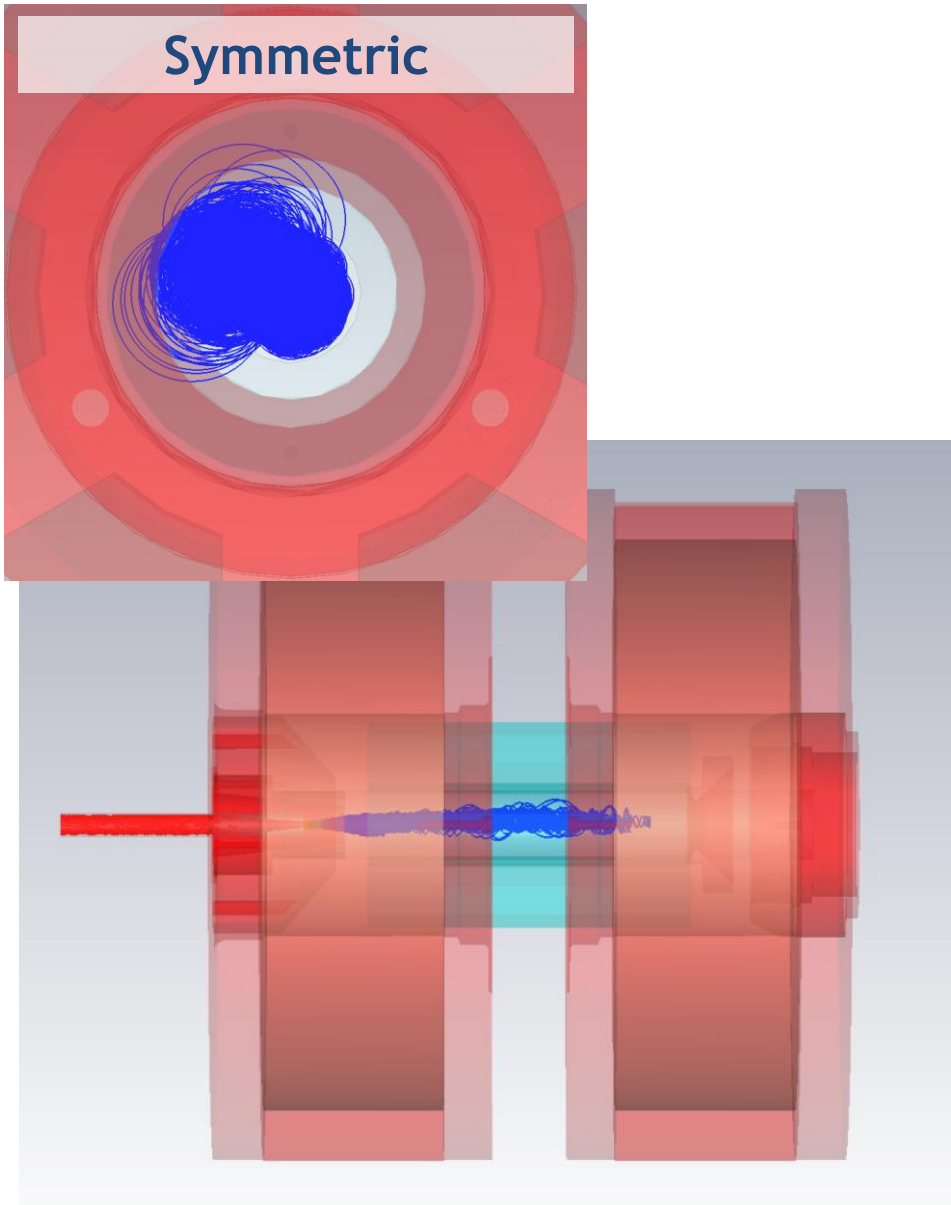


$B_z(x,y)$ asymmetric

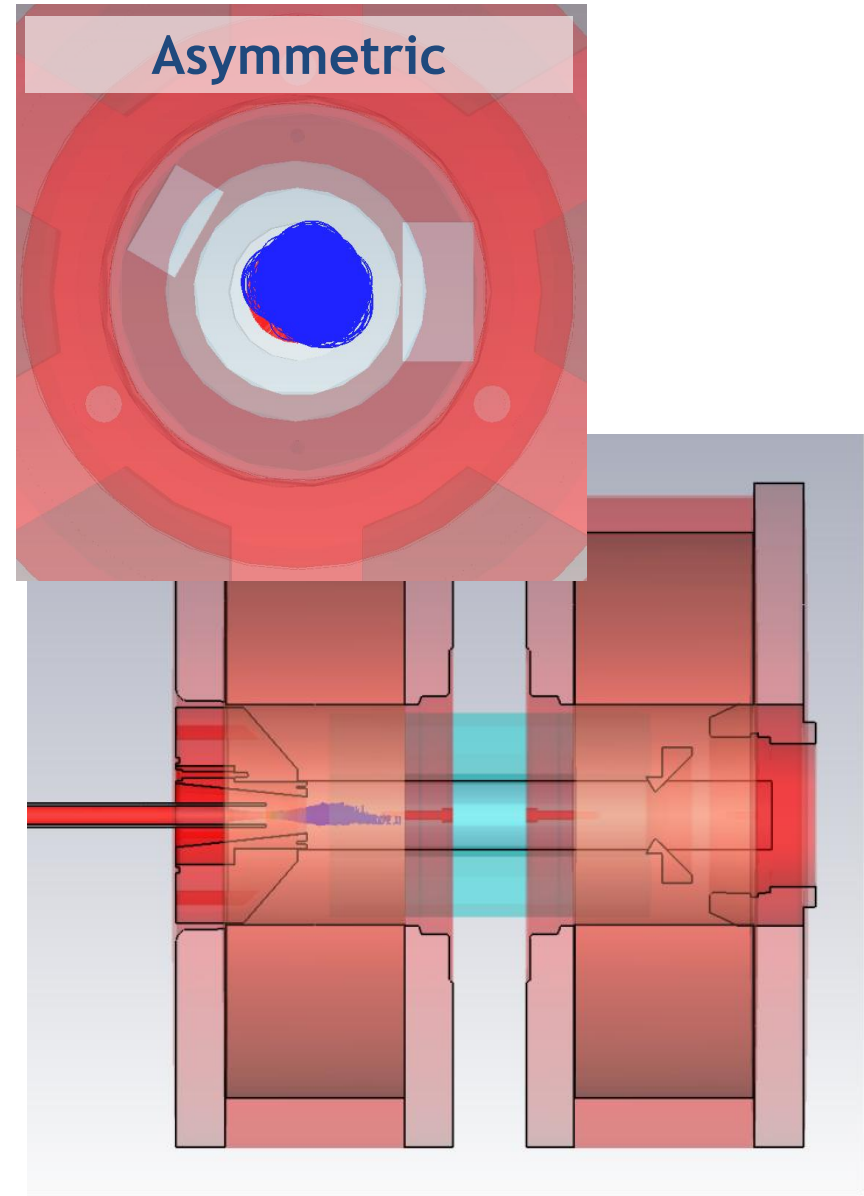


$^{133}\text{Cs}^{1+}$ Injection

Symmetric



Asymmetric



ECR charge breeder development tasks

- Better understanding of the difference between stable and radioactive beam tunes with regard to the charge breeder
- Improve the beam purity from the ECRCB
 - Quartz liner has been installed
 - Fully characterize
 - Does make operation a bit more difficult
 - Changed over to high purity aluminum components
 - This has reduced iron component
 - Remove the grounded tube
 - Aluminum coat the iron plug