Recent Performance of the Argonne National Laboratory ECR Charge Breeder

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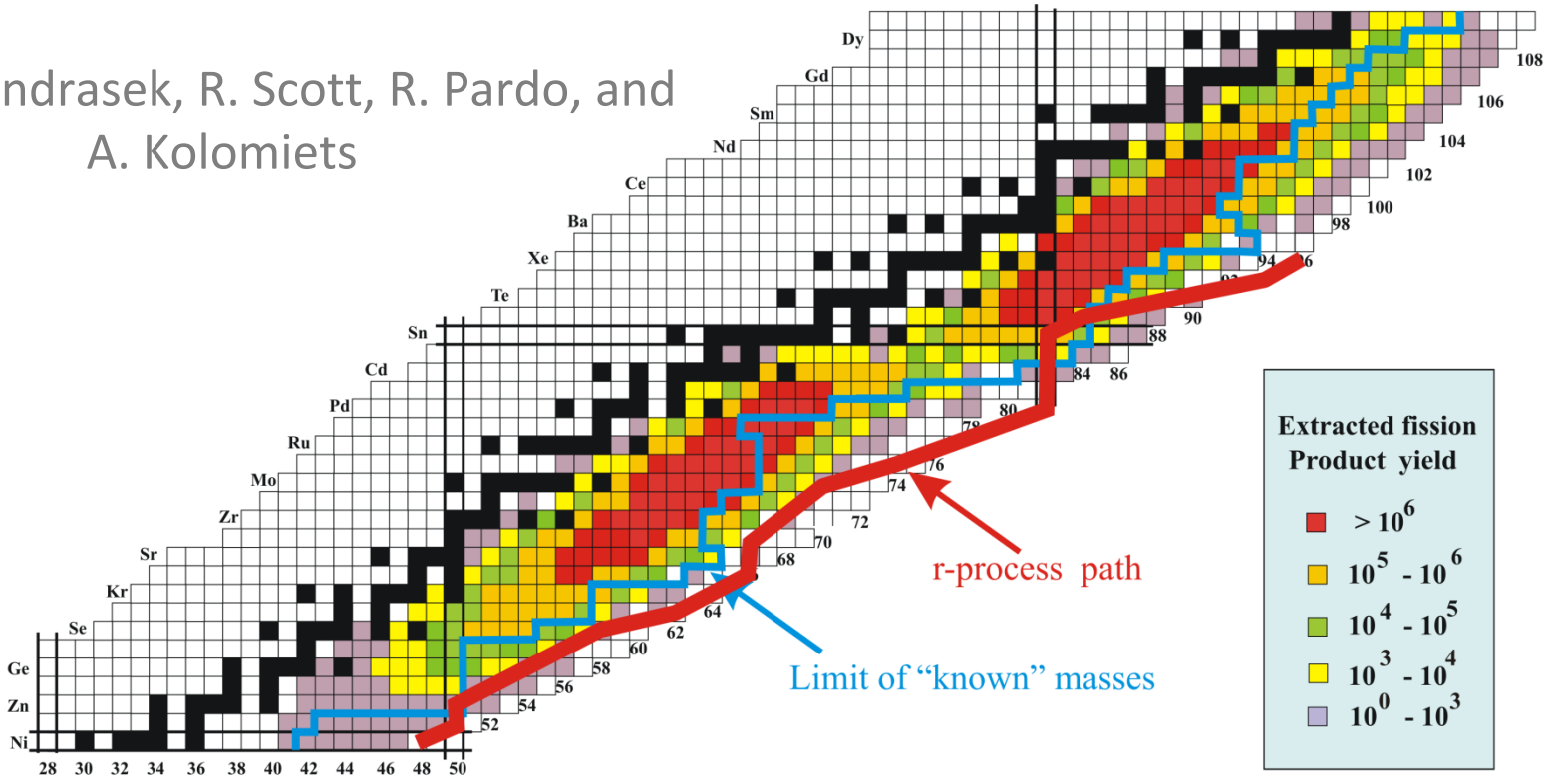
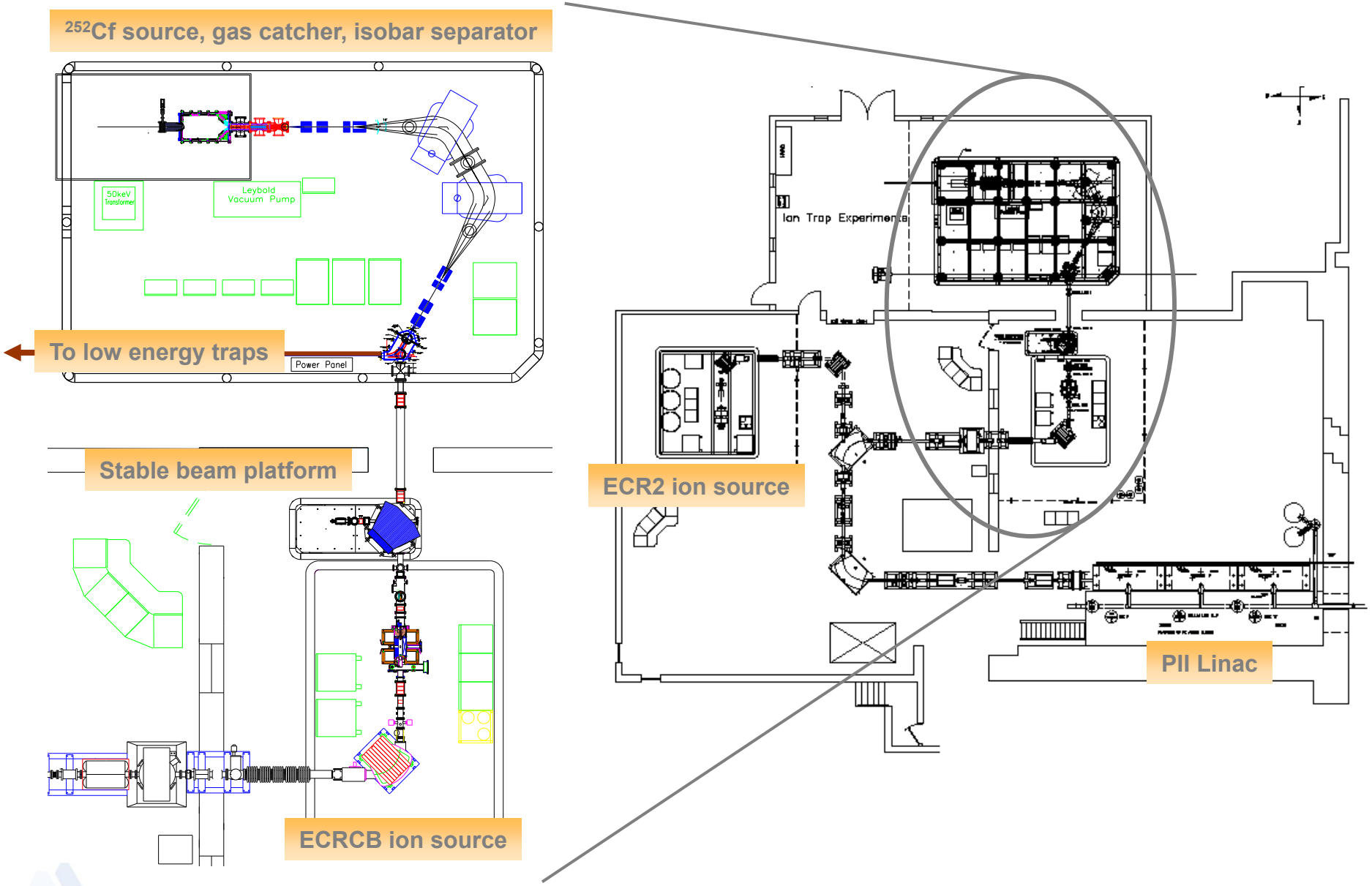
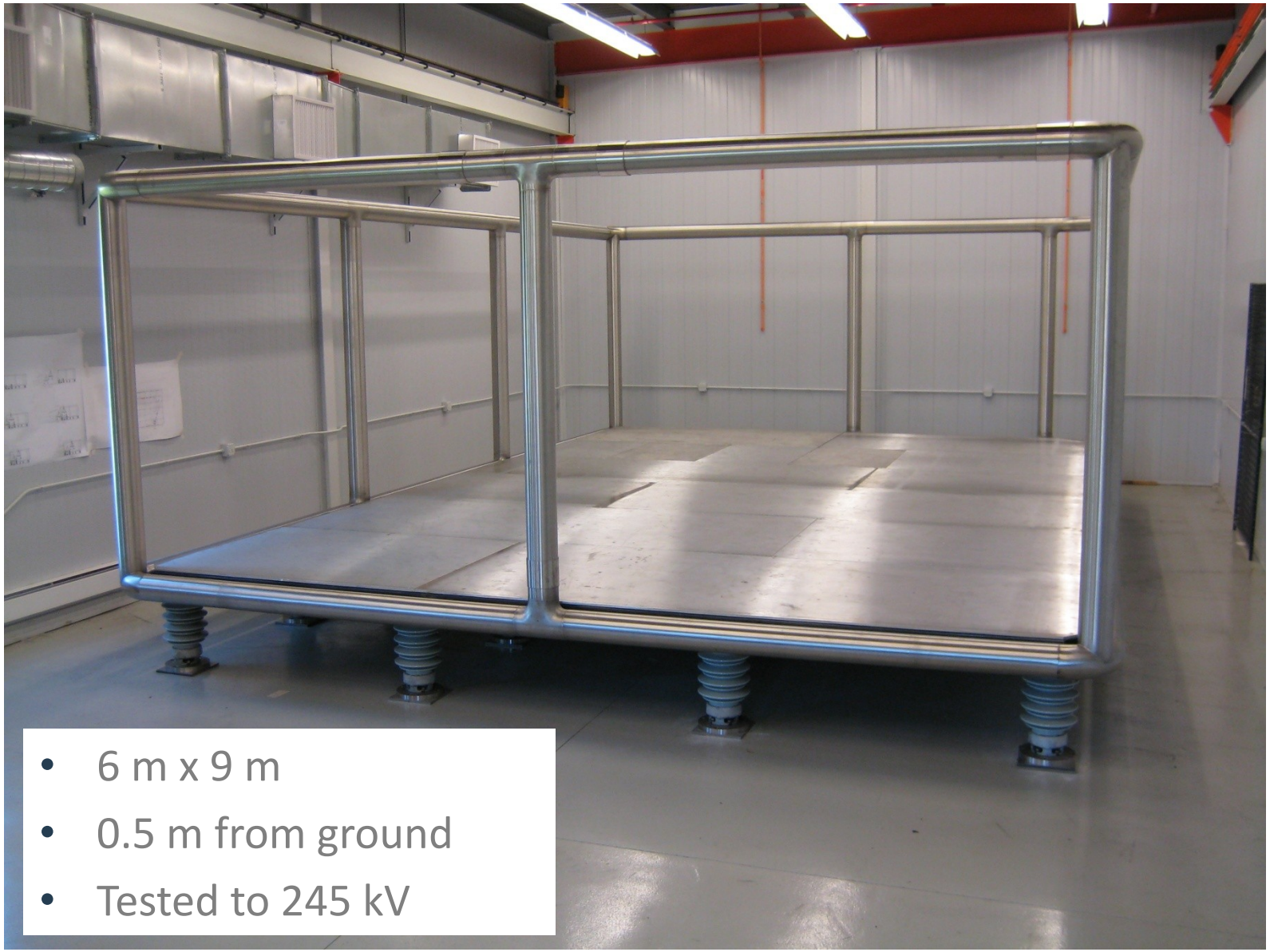


CARIBU layout

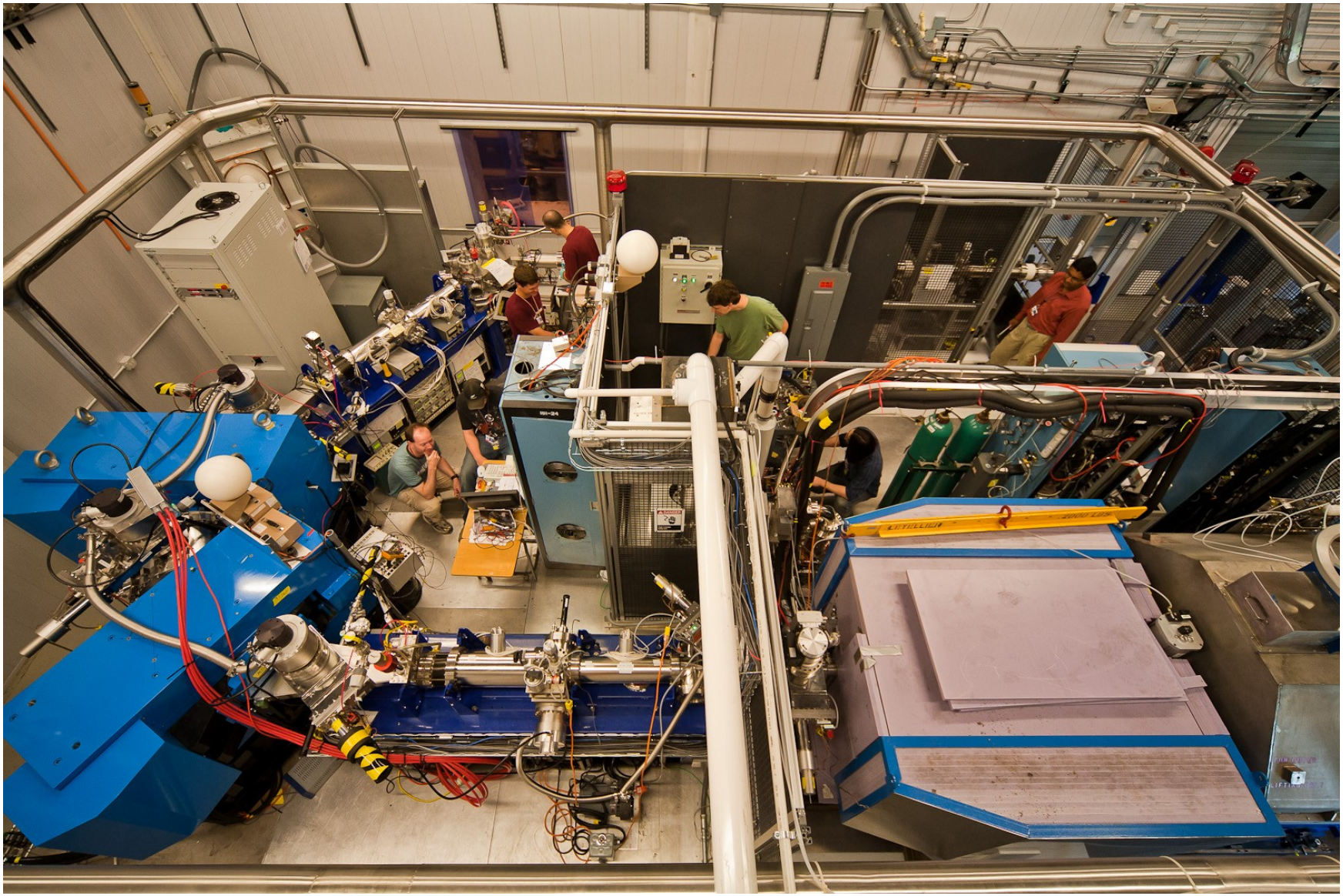


CARIBU - 2008



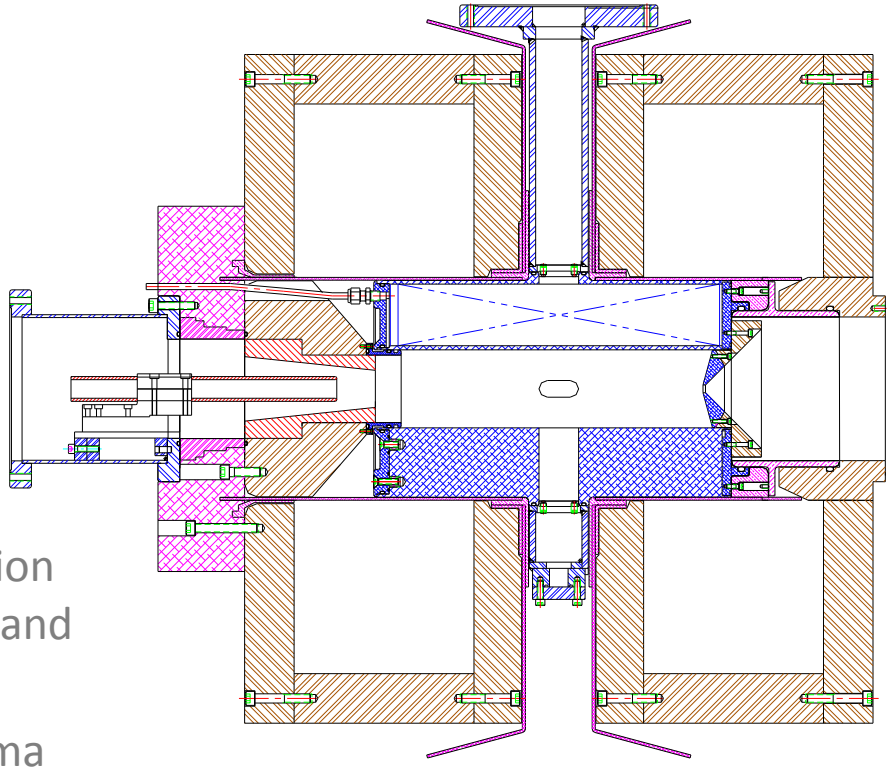
- 6 m x 9 m
- 0.5 m from ground
- Tested to 245 kV

CARIBU – 2010



ECR charge breeder

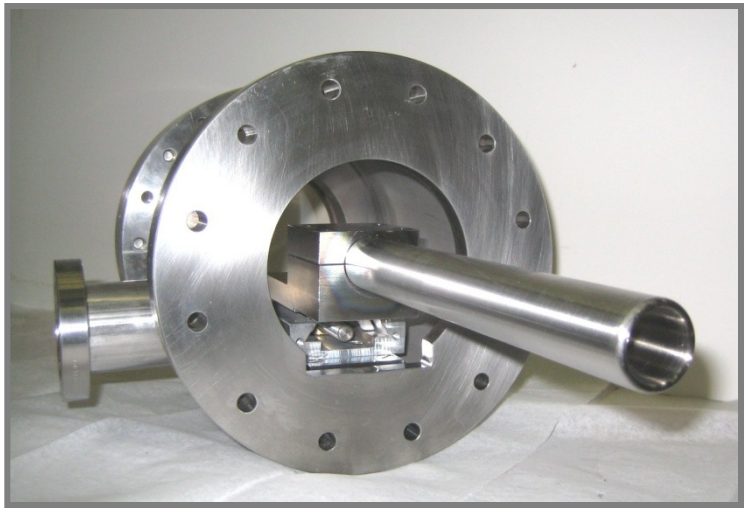
- Multiple frequency operation
  - Klystron: 10.44 GHz, 2 kW
  - TWTA: 11→13 GHz, 0.5 kW
- Open hexapole structure
  - RF is injected radially
  - Allows more iron in the injection region for improved magnetic confinement and symmetrical fields
  - Provides better pumping to the plasma chamber region
    - Source base pressure: 2×10^{-8} mbar
    - Operates at 8.0×10^{-8} to 2.0×10^{-7} mbar
    - Extraction pressure: 4×10^{-8} mbar
- HV isolation
  - Source operates in charge breeding mode at 50 kV
  - Source assembly has been tested to 65 kV without plasma

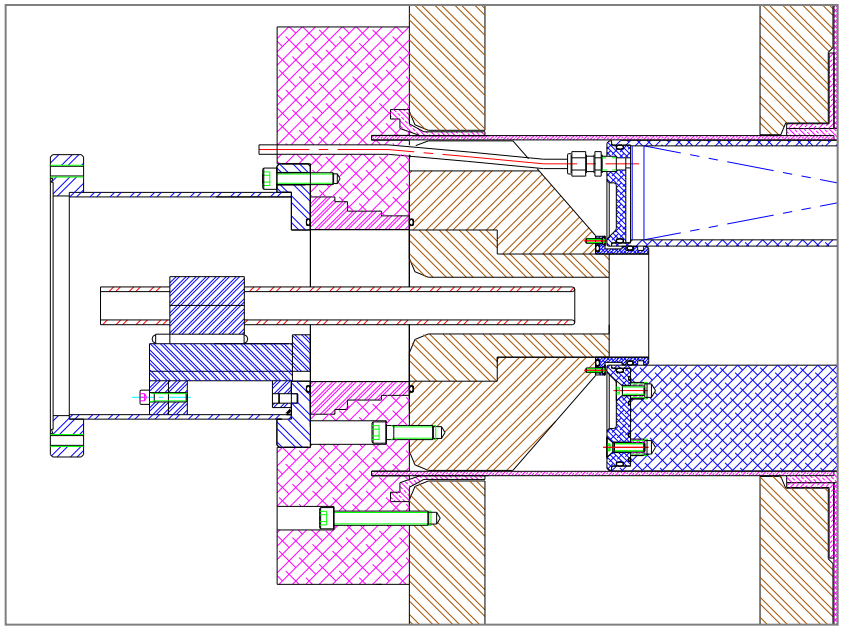


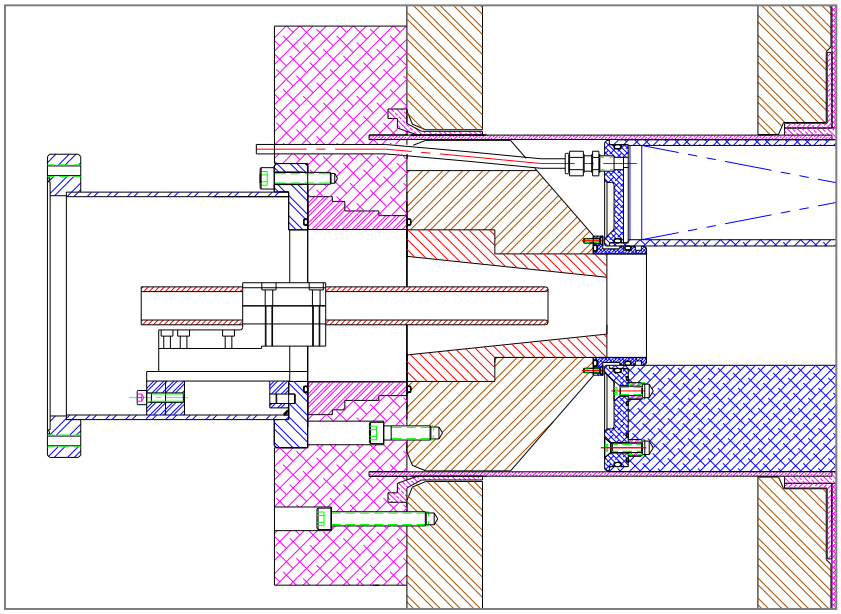
Design value	Running condition
B_{inj} 1.31 T	1.16 T
B_{min} 0.31	0.27
B_{ext} 0.85	0.83
$B_{(radial)}$	0.86 T
Last closed surface	0.61 T

1+ injection

- Reshaped iron in the injection region due to Penning discharges
  - Breakdown occurred at 30 kV even without plasma present
  - Gap was too small but the iron was designed to be easily removable
- Stainless steel transfer tube
  - Linear slide with 30 mm travel







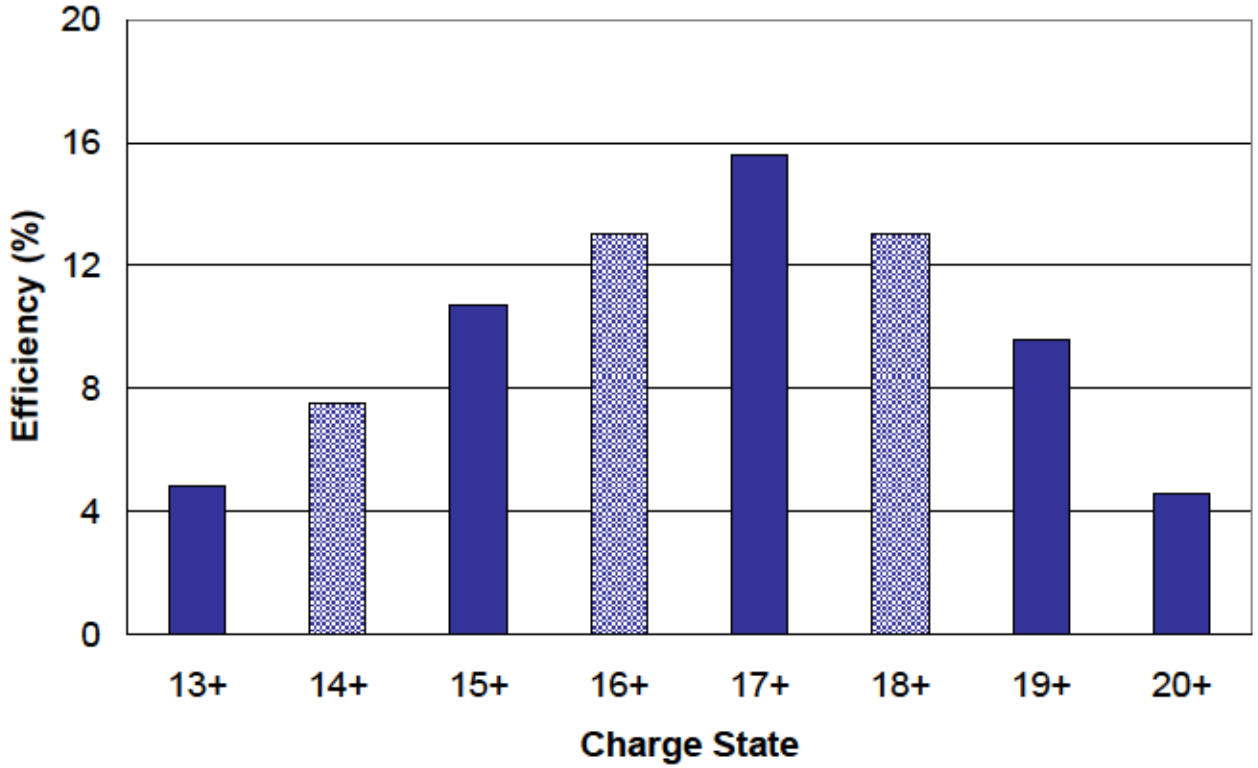
Charge breeding results

- All results are with two-frequency operation
- Oxygen support gas

Ion Species	1+ Intensity (nA)	n+ Charge State	Efficiency (%)	Global Efficiency (%)	Breeding Time (msec)
Kr-86	19.0	17+	15.6	77	
Rb-85	5.0	19+	11.9	57	200
Xe-129	12.5	25+	13.4	63	~250
Cs-133	21.5	20+	2.9		

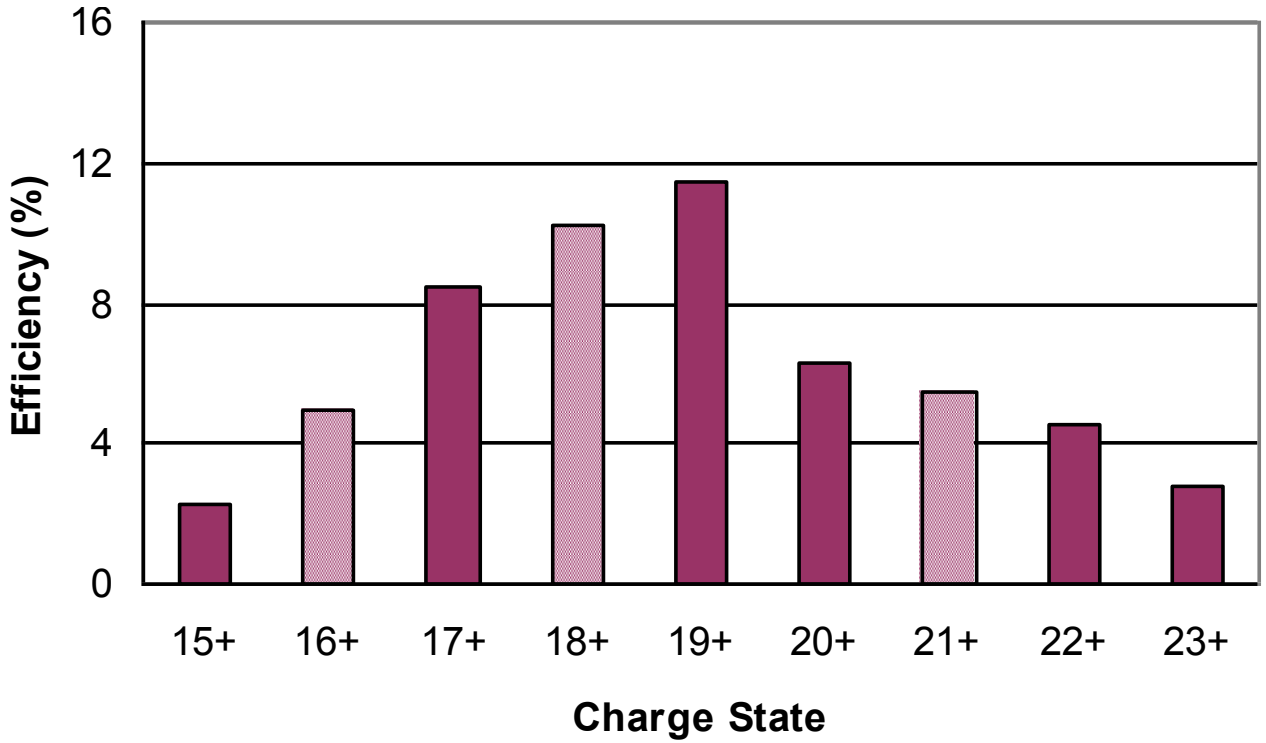
Kr-86 charge breeding

- RF discharge source operated with helium and ^{nat}Kr
  - The analysis system allowed clear identification of all masses
  - Typically injected 20 nA of $^{86}Kr^{+}$ into the charge breeder
- Operated source in two-frequency mode
  - 10.44 GHz at 105 W, 11.90 Ghz at 278 W



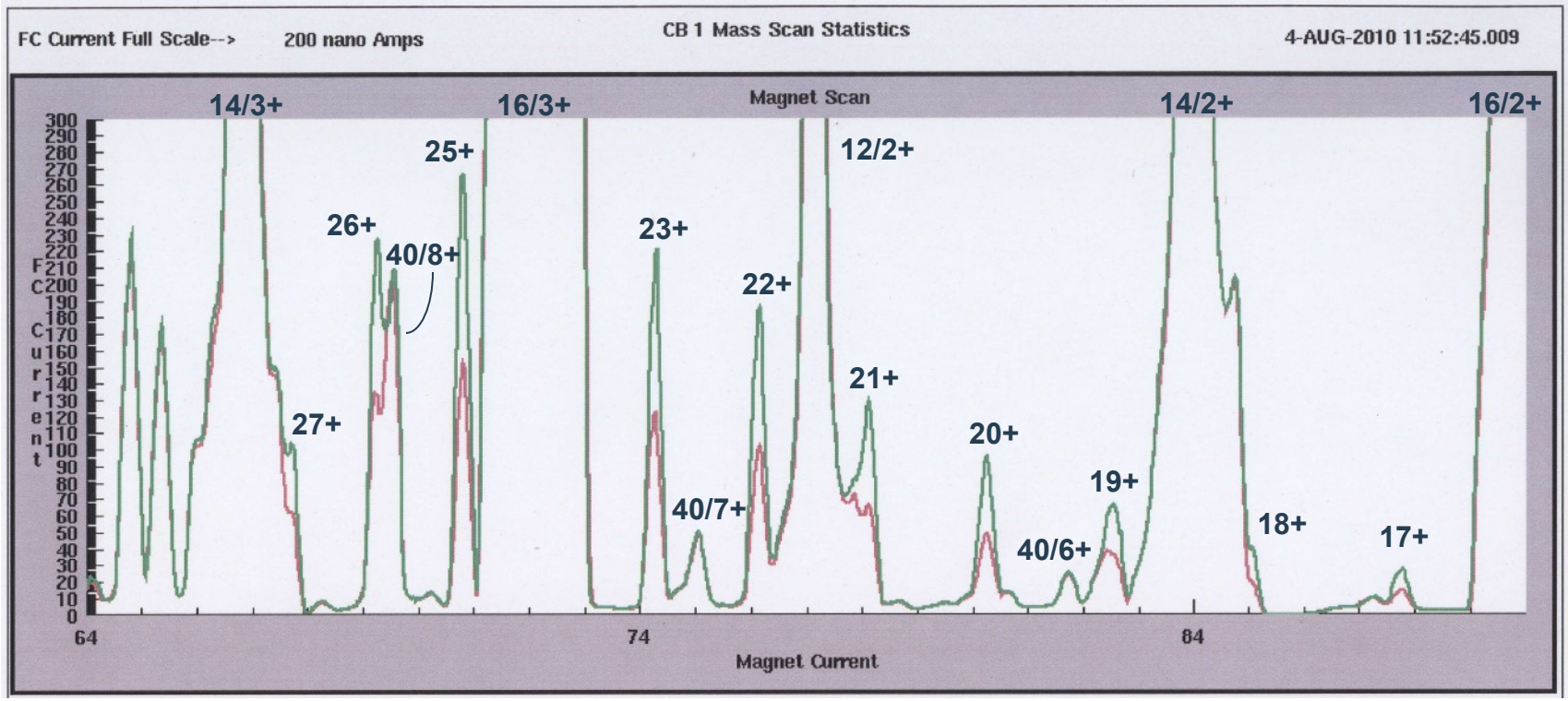
Rb-85 charge breeding

- Surface ionization source
  - Produced up to 500 nA of $^{85}Rb^{+}$
  - Typically injected 10 nA of $^{85}Rb^{+}$ into the charge breeder
- Operated source in two-frequency mode
  - 10.44 GHz at 105 W, 11.90 Ghz at 278 W



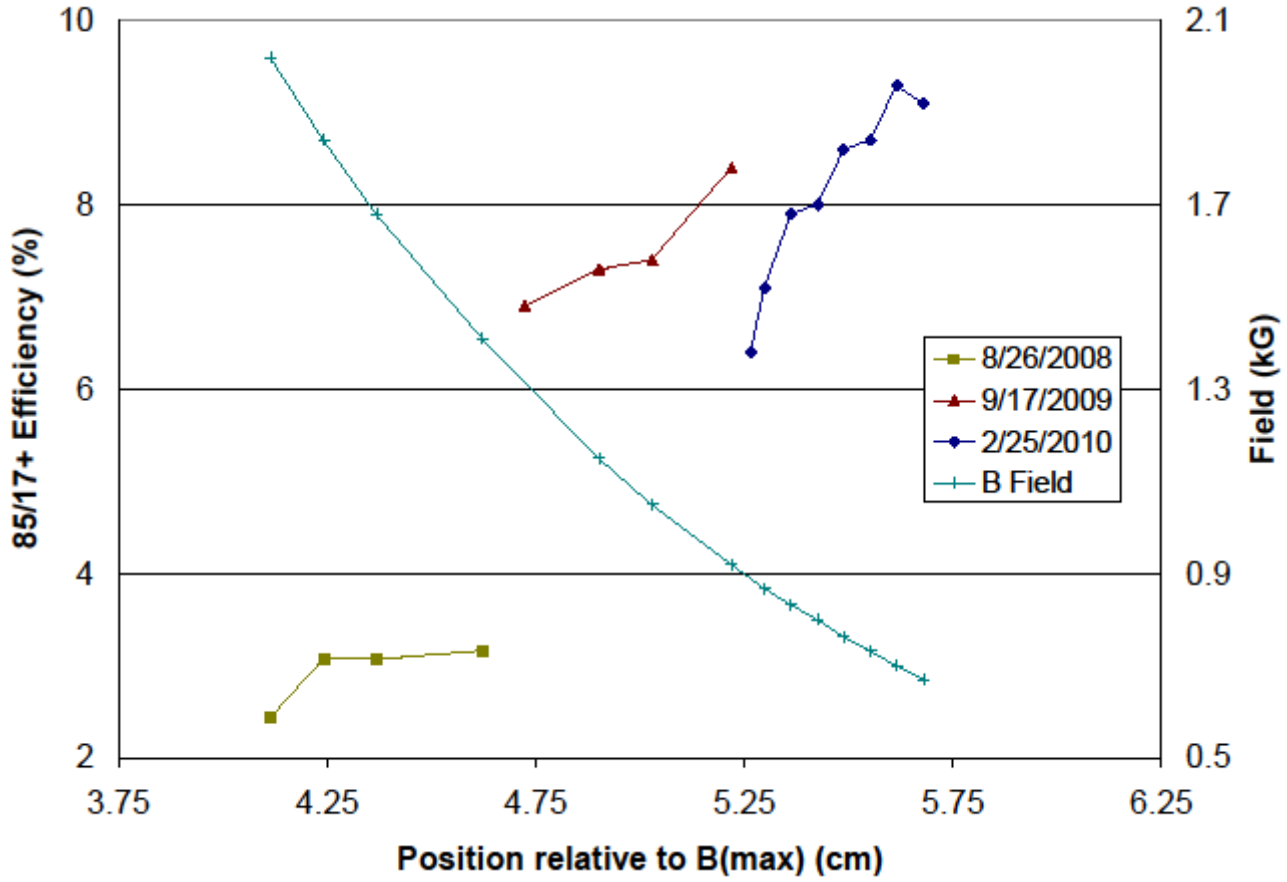
Xe-129 charge breeding

- RF discharge source operated with helium and Xe-129 (98%)
  - Maximum output was 100 nA of $^{129}Xe^{+}$
  - Typically injected 20 nA into the charge breeder
  - Neutral Xe-129 migrated from the RF source into the ECR charge breeder



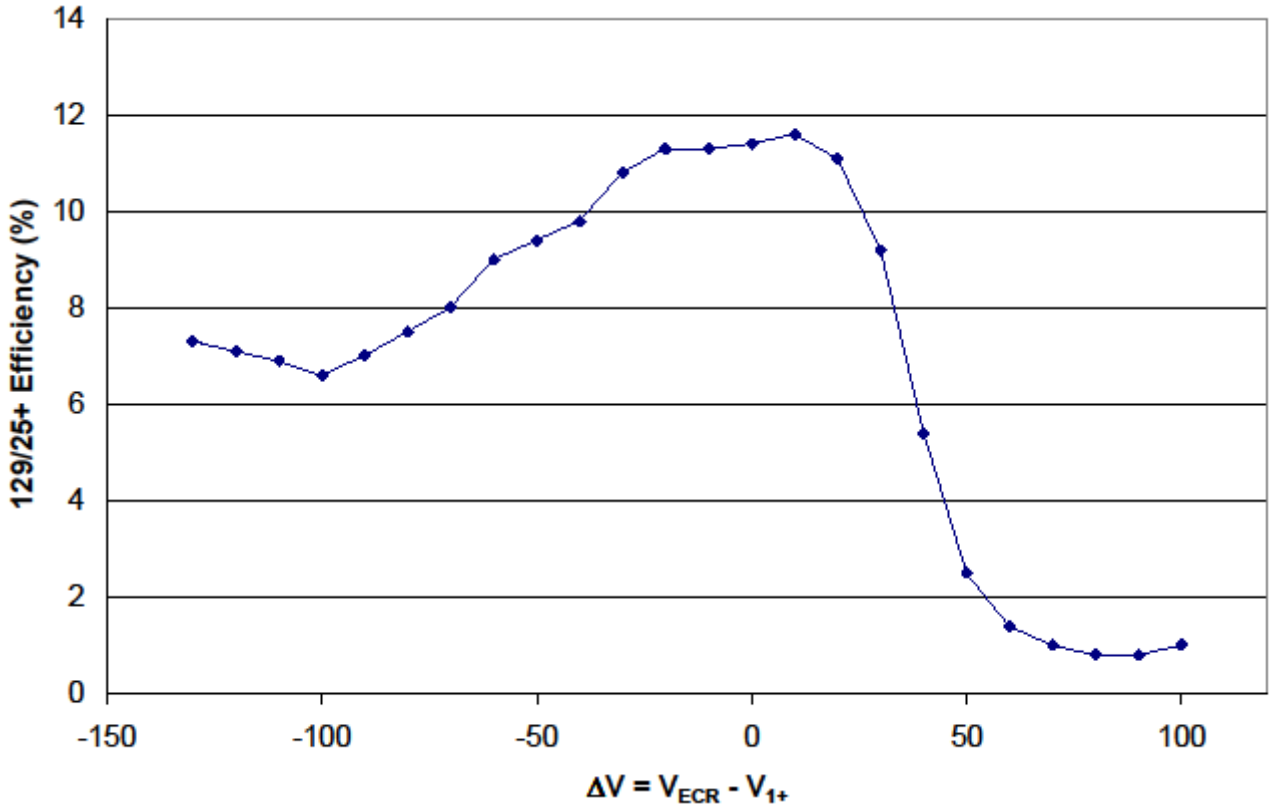
Transfer tube position

- Efficiency of $^{85}Rb^{17+}$ as a function of the transfer tube position
  - Position indicates the distance from B_{max} to the end of the transfer tube
  - Three different data sets from 2008, 2009 and 2010



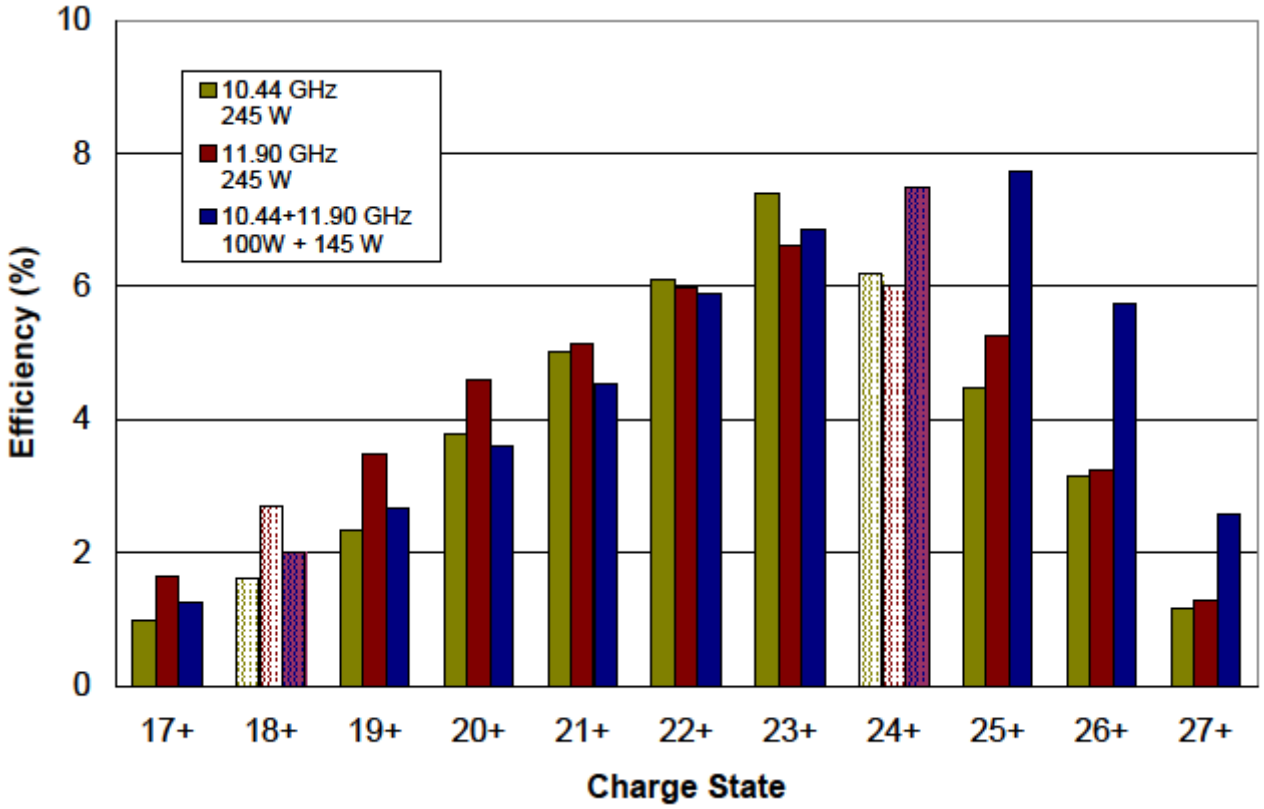
ΔV optimization

- Efficiency of $^{129}Xe^{25+}$ as a function of the potential difference between the RF discharge source and the ECR charge breeder
  - Optimum ΔV was typically +10 V (ECR charge breeder higher than 1+ source) with a large acceptance window
  - For surface ionization source with Rb-85, ΔV was typically -15 V (ECR charge breeder lower than 1+ source) with an acceptance window of ~5 V



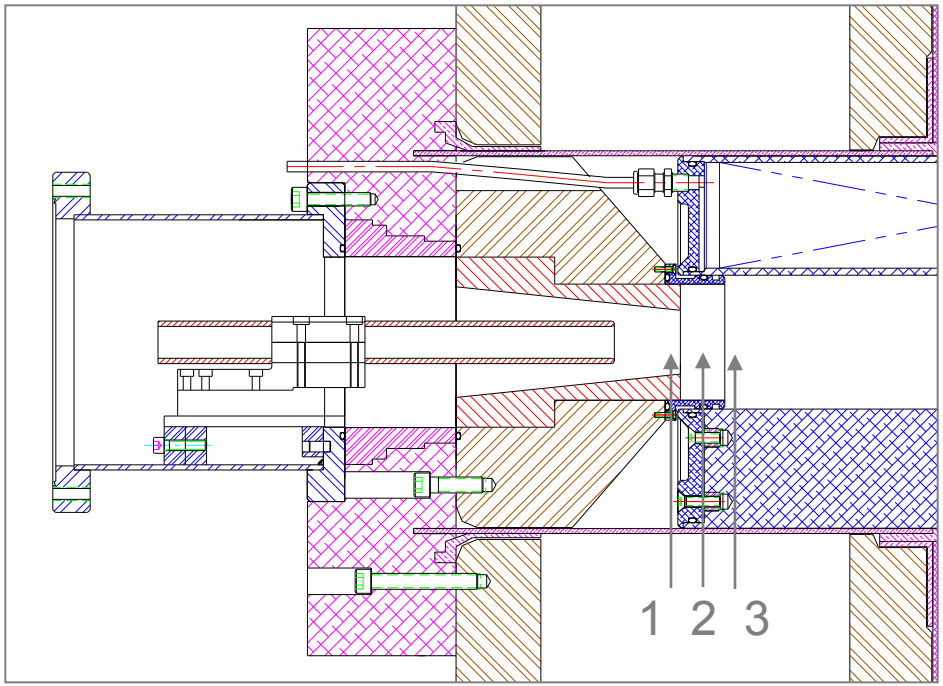
Multiple frequency operation

- Efficiency of Xe-129 as a function of power distribution
  - $^{129}Xe^{+}$ beam intensity of 65 nA
  - Kept the total amount of RF power constant (245 W, 10.44 and/or 11.90 GHz)
  - Slight tuning of source on $^{129}Xe^{25+}$ between the various configurations



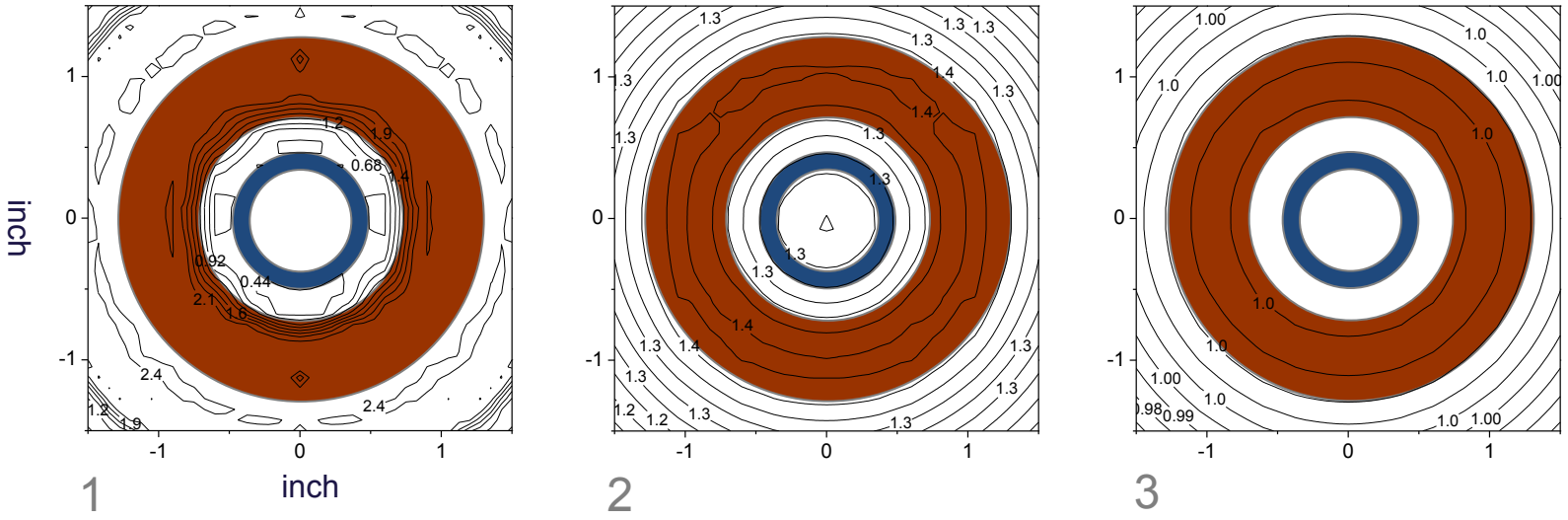
Injection B field profile

- Radial RF injection maintains field symmetry
- Axial RF injection means that slots have to be cut into the iron plug for the waveguides
  - Leads to field asymmetry in the injection region
  - Simulations done with CST EM Studio using source operating parameters to look at the B field profiles
  - Presently setting up particle tracing simulation to compare the two cases

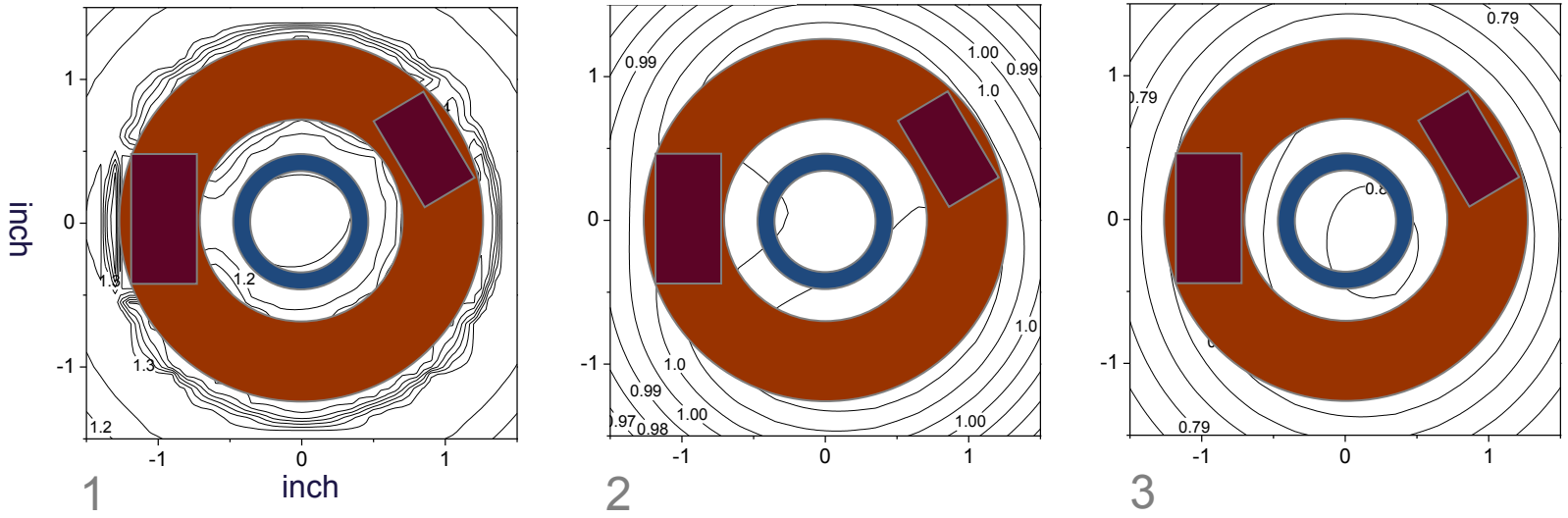


Injection B field profile

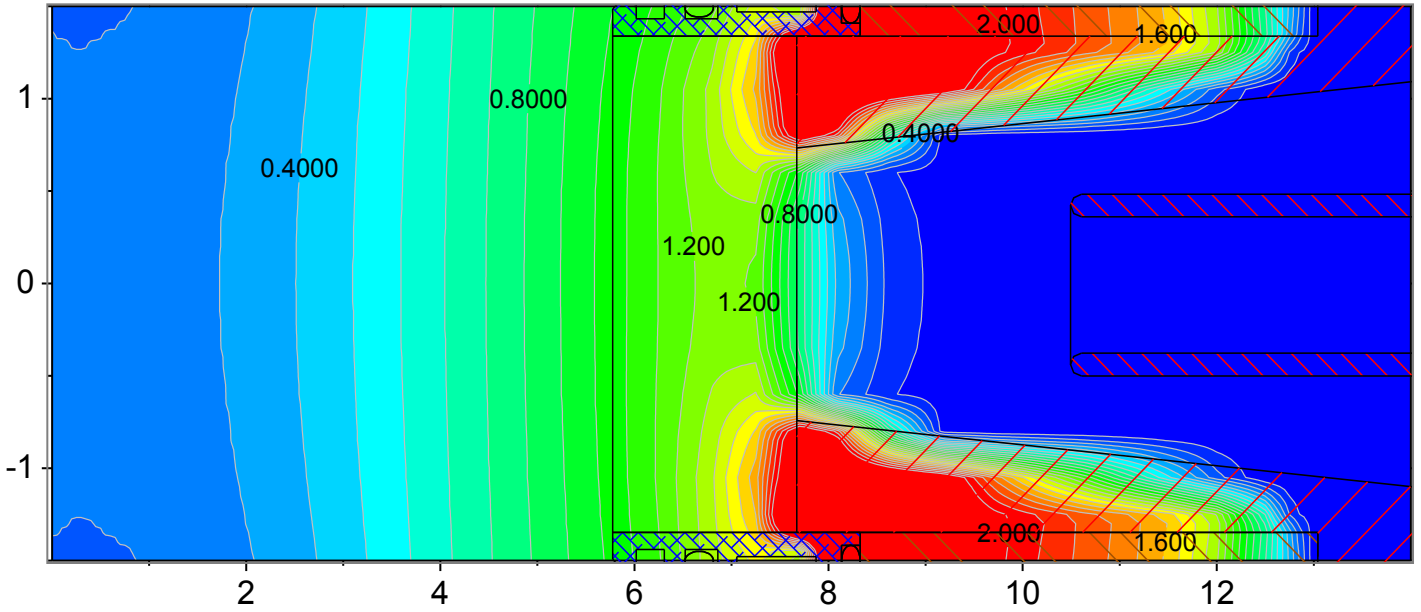
B_z (x,y) symmetric



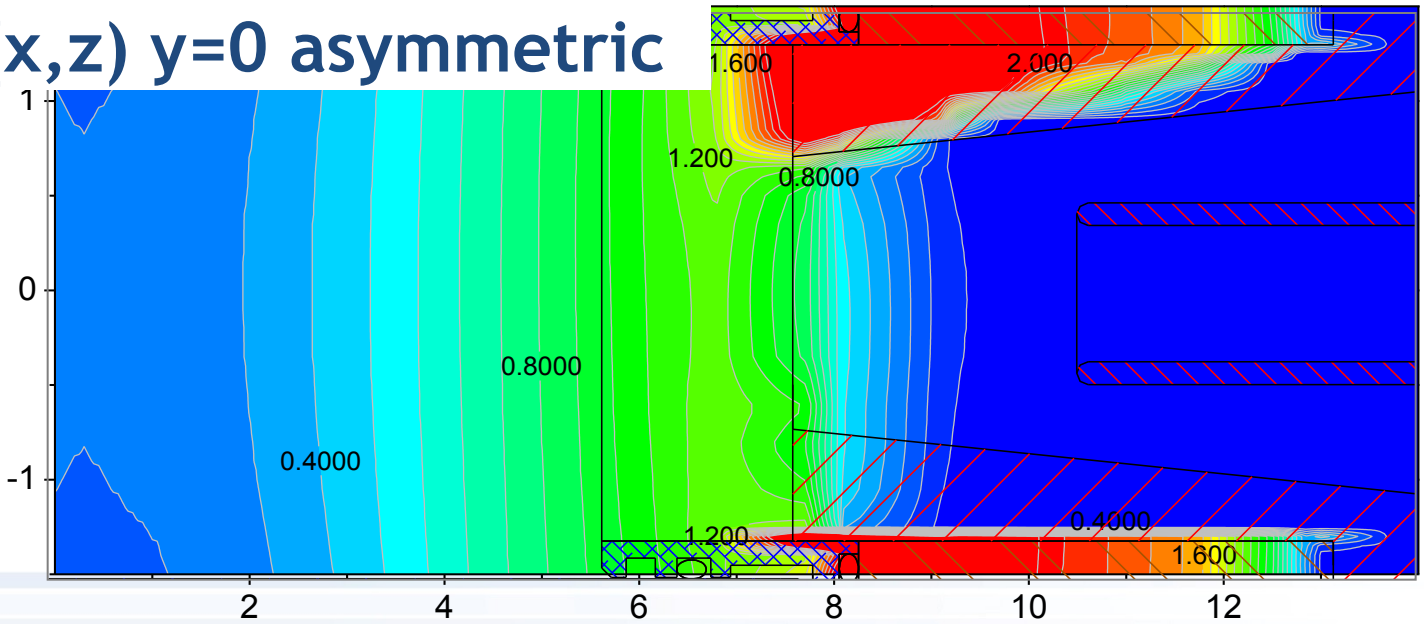
B_z (x,y) asymmetric



B_z (x,z) y=0 symmetric



B_z (x,z) y=0 asymmetric



Next activities

- Commission CARIBU project
  - First run occurred last week with Ba-143
    - Identified activity after isobar separator but not at high energy end of accelerator
      - » Next run is scheduled for October 2010

- Build an EBIS for charge breeding
  - Collaboration with Brookhaven National Laboratory