

Commissioning of CARIBU EBIS Charge Breeder Sub-systems

S. Kondrashev, C. Dickerson, A. Levand, P.N. Ostroumov,
R. Vondrasek, A. Pikin, G.I. Kuznetsov, M.A. Batazova

June 20, 2012

Content

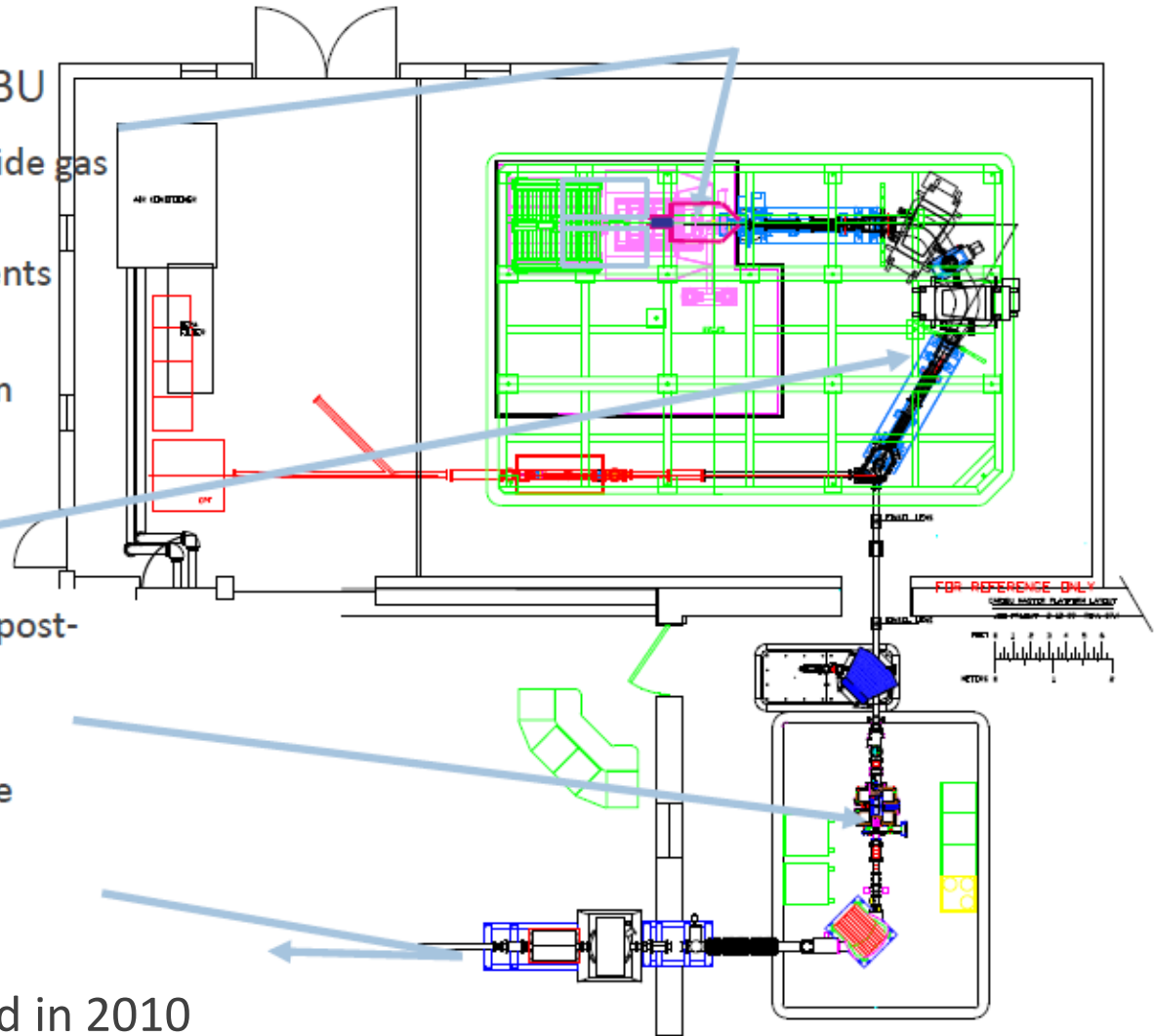
- Parameters of CARIBU
- Motivation for EBIS charge breeder
- Design and parameters of CARIBU EBIS charge breeder
- Commissioning of EBIS charge breeder sub-systems:
 - 6 T superconducting solenoid
 - high-perveance e-gun
- Summary



CARIBU - Californium Rare Ion Breeder Upgrade

Main components of CARIBU

- "ion source" is ^{252}Cf source inside gas catcher / RFQ cooler
 - Thermalizes fission fragments
 - Extracts all species quickly
 - Forms low emittance beam
- Isobar separator
 - Purifies beam
- Charge breeder
 - Increases charge state for post-acceleration
- Post-accelerator
 - ATLAS with energy upgrade



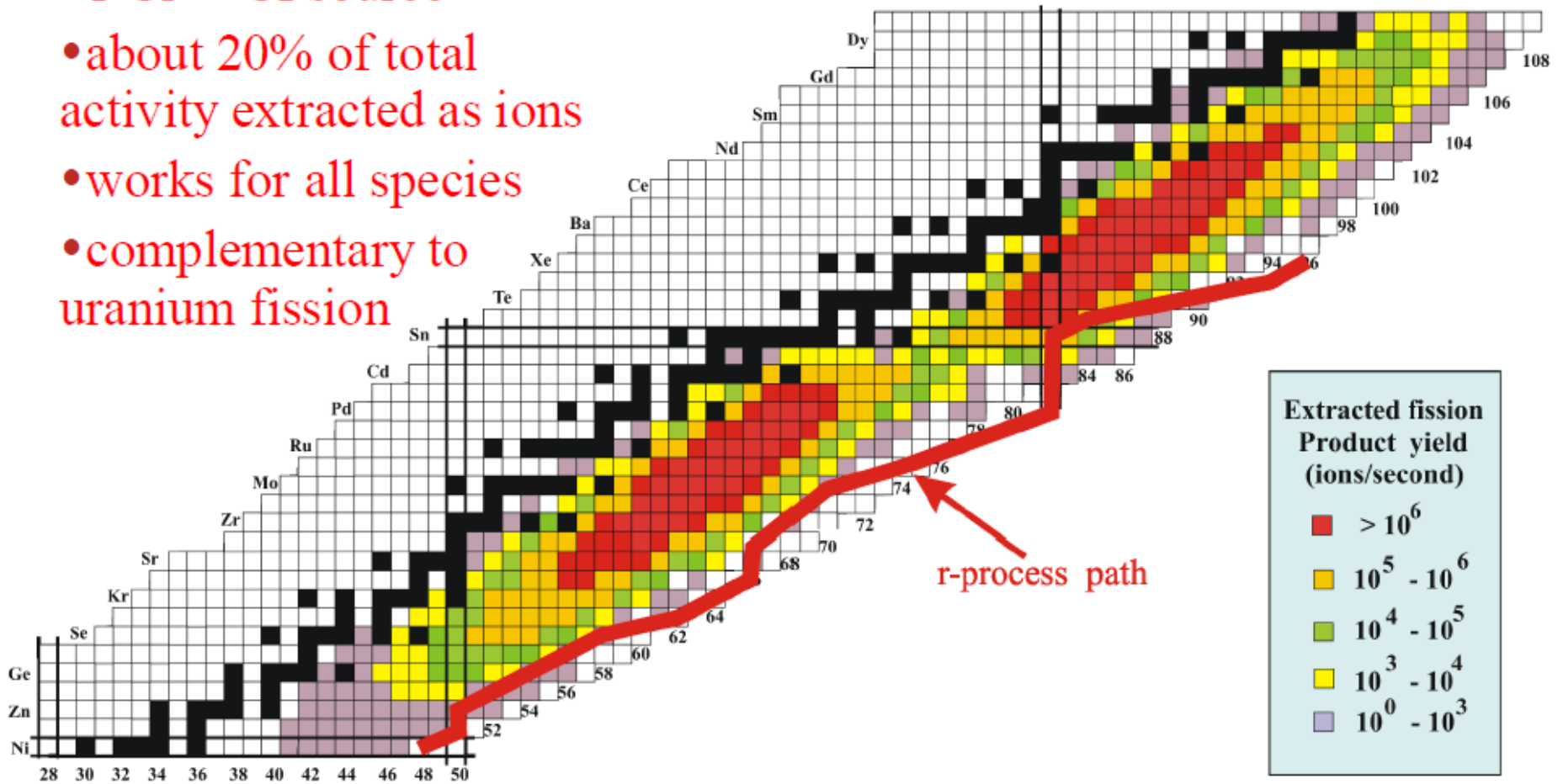
CARIBU was commissioned in 2010

Sergey Kondrashev, Commissioning of CARIBU EBIS Charge Breeder Sub-systems, HIAT 2012, June 20, 2012



CARIBU Isotope Yield at Low Energy (50 kV)

- 1 Ci ^{252}Cf source
- about 20% of total activity extracted as ions
- works for all species
- complementary to uranium fission



Sergey Kondrashev, Commissioning of CARIBU EBIS Charge Breeder Sub-systems, HIAT 2012, June 20, 2012



CARIBU EBIS Charge Breeder

EBIS vs ECR:

- Higher breeding efficiency (about factor 2)
- Better purity of beams (several orders)
- Shorter breeding time (factor 5-10)

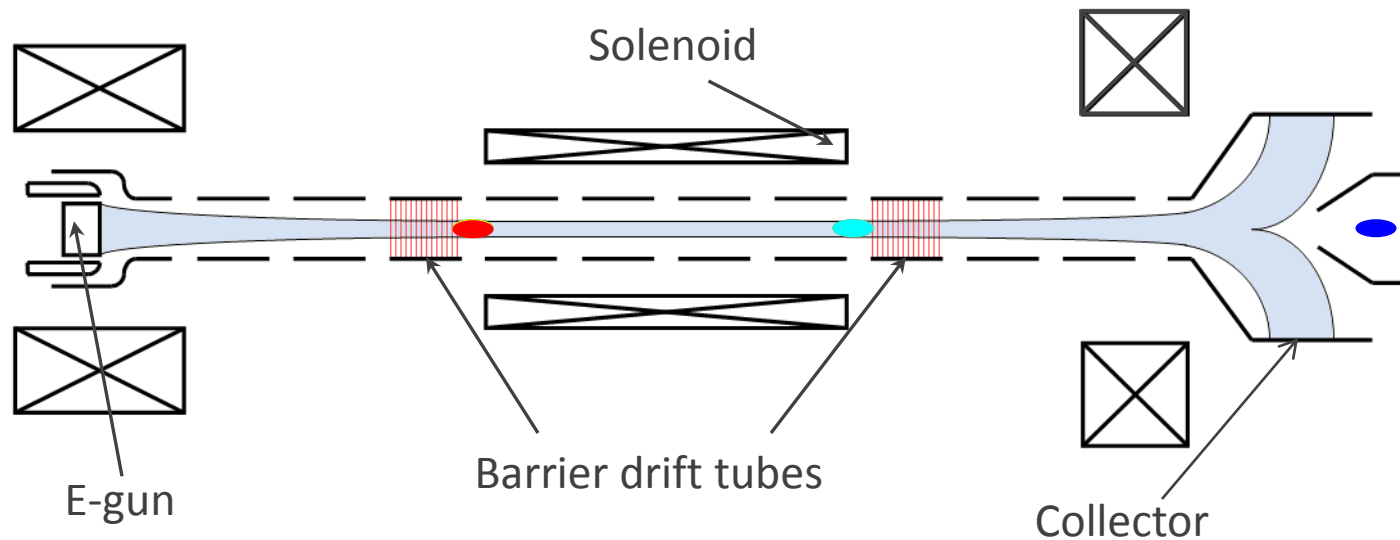
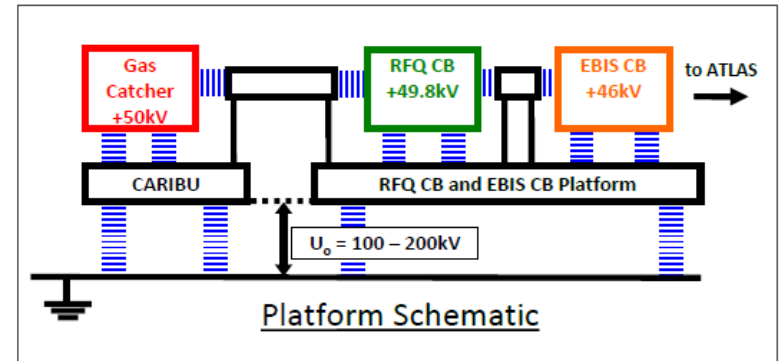
Choice for CARIBU:

- “Classical” EBIS
 - Proven technology (REXEBIS, CERN)
 - Higher acceptance (larger electron beam size) than in case of EBIT
- BNL RHIC and Test EBIS are prototypes (the most advanced EBIS technology nowadays)



EBIS Charge Breeder - Principle of Operation

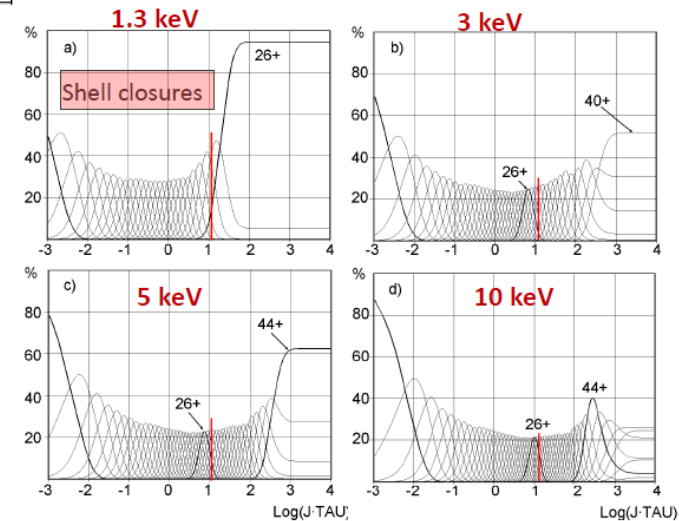
- 1+ ions are accumulated in the RFQ cooler-buncher
- Injection time $\sim 10 \mu\text{s}$
- Breeding time $\sim 33 \text{ ms}$
- Extraction time $\sim 10 \mu\text{s}$ can be adjusted if necessary
- Repeat with the rate of 30 Hz
- Transverse confinement is achieved by electron beam space charge
- Longitudinal confinement is provided by drift tube potentials



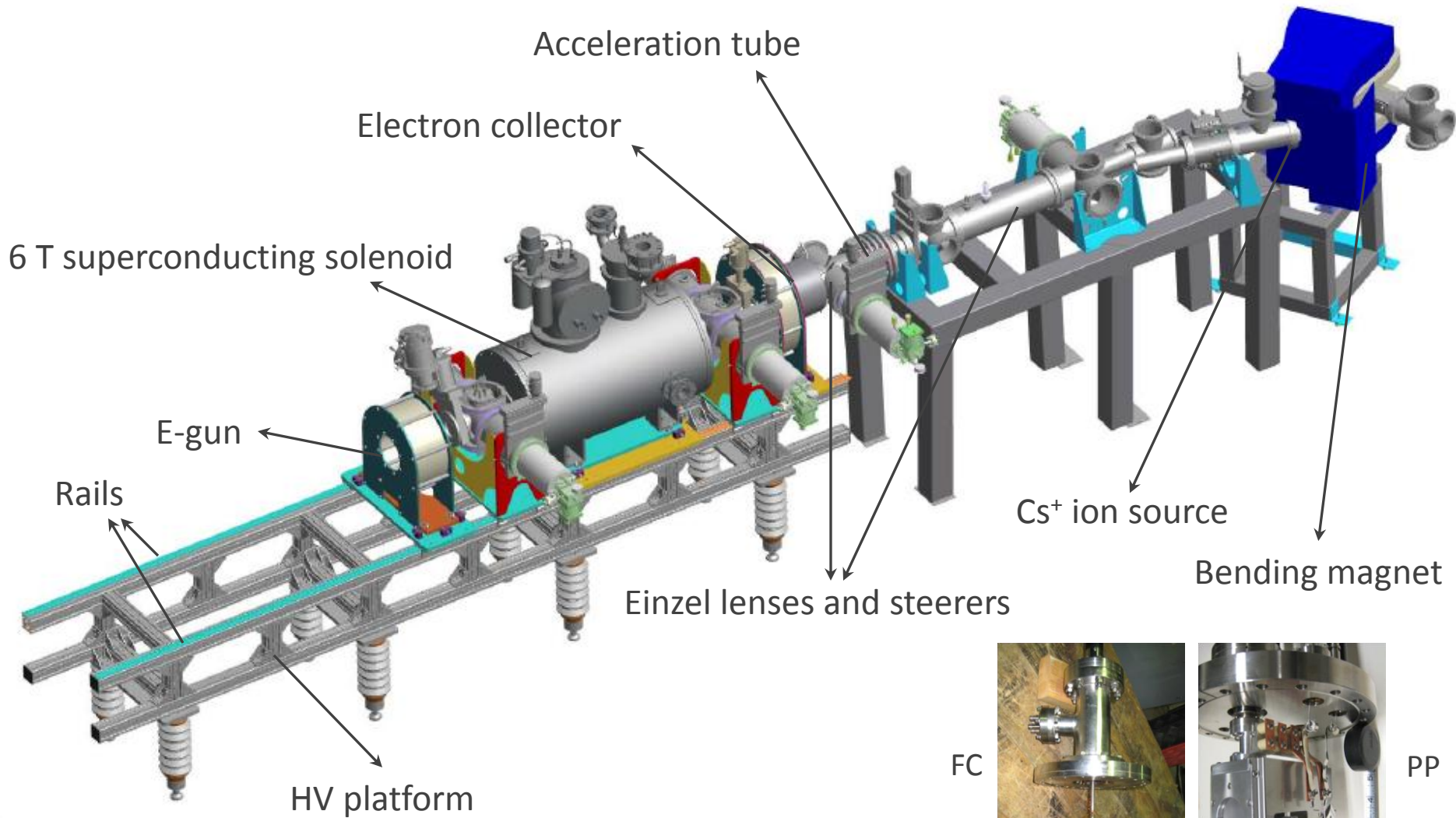
Main Parameters of CARIBU EBIS Charge Breeder

Parameter	Low current e-gun	High current e-gun
Superconducting solenoid: length/ field	1 m/6 T	1 m/6 T
Diameter of the IrCe thermocathode	1.6 mm	4 mm
Electron beam current	0.2 A	2 A
Electron beam energy	~ 2 keV	~ 5 keV
Electron beam diameter in the trap	~ 230 μm	~ 580 μm
Electron beam current density in the trap	~480 A/cm ²	~750 A/cm ²
Ion trap length	0.5 m	0.5 m
Trap capacity (in elementary charges)	~ 4•10 ¹⁰	~ 2•10 ¹¹

Low current e-gun will be used to study efficiency gain at shell closures



Off-line Commissioning Configuration



FC



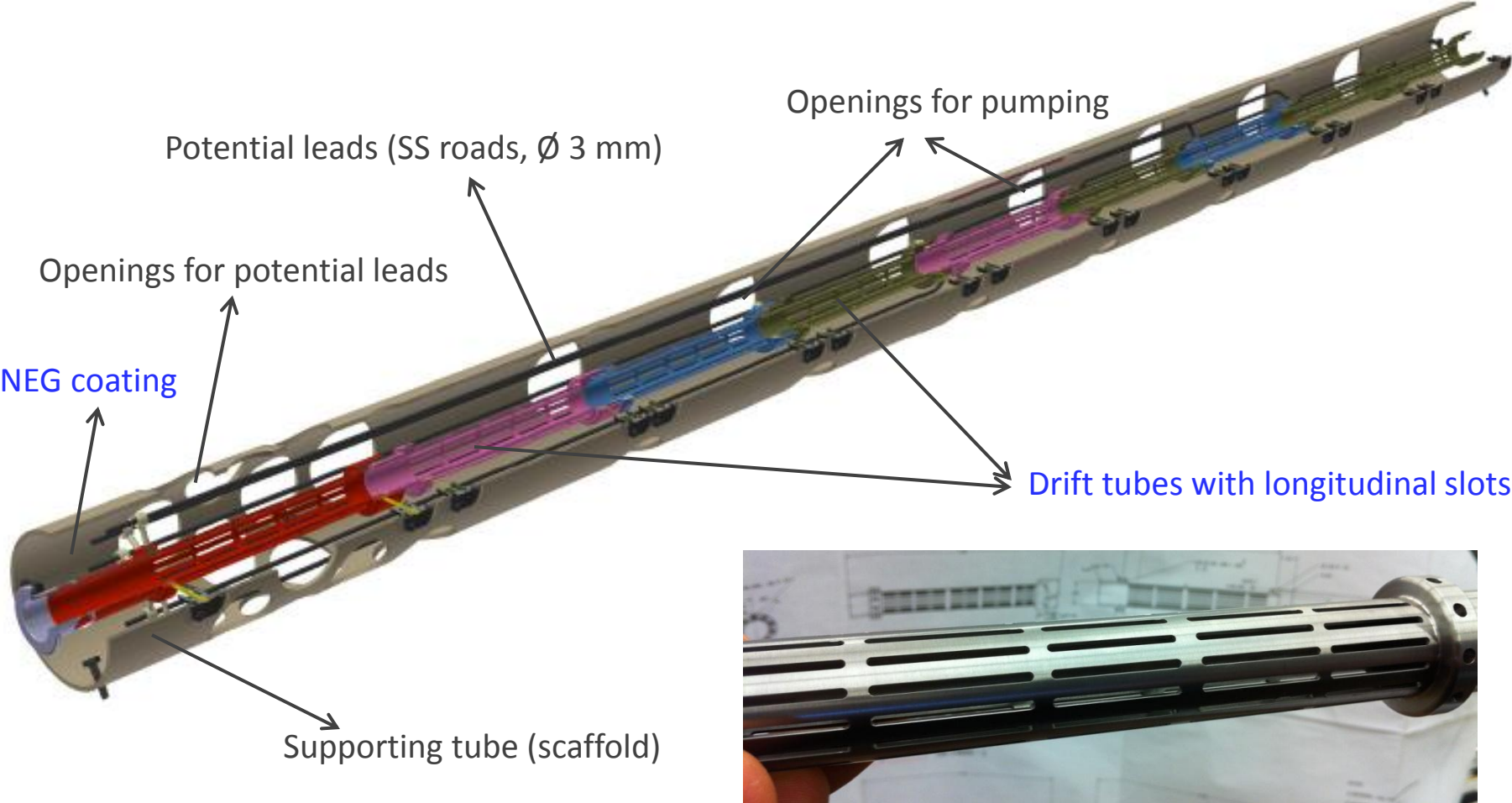
PP



Sergey Kondrashev, Commissioning of CARIBU EBIS Charge Breeder Sub-systems, HIAT 2012, June 20, 2012



Drift Tube Structure



Sergey Kondrashev, Commissioning of CARIBU EBIS Charge Breeder Sub-systems, HIAT 2012, June 20, 2012



Commissioning of 6 T Superconducting Solenoid

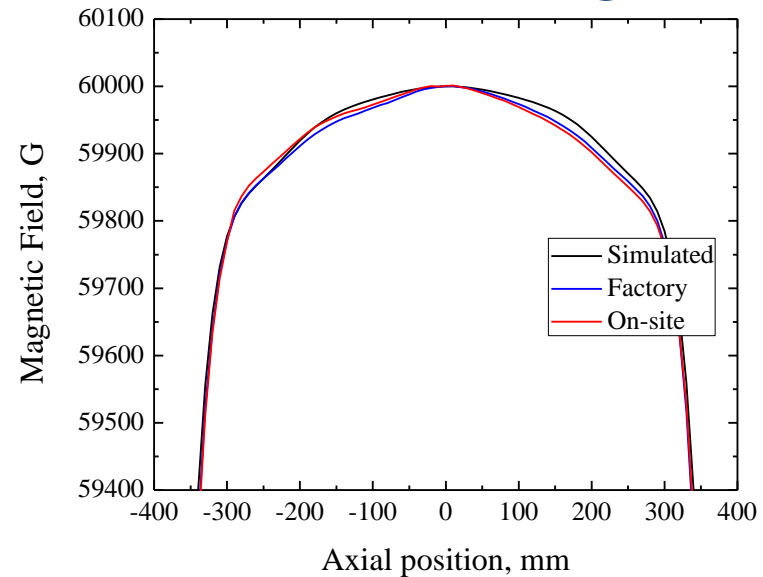
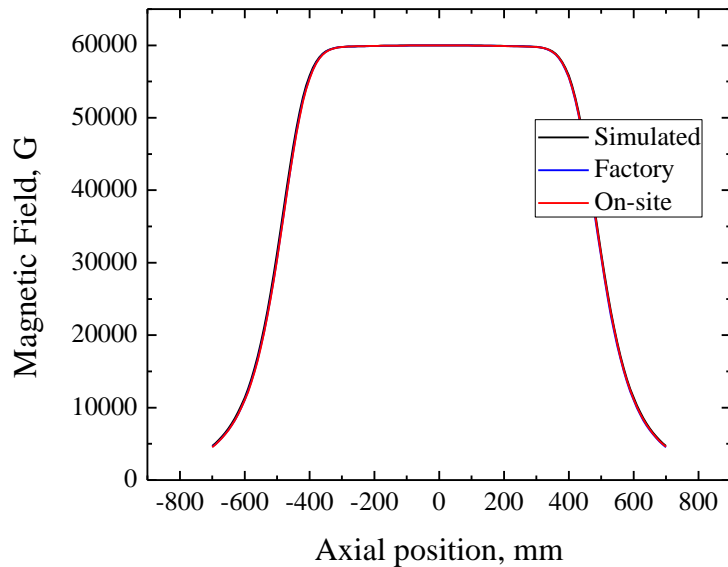
- Unshielded solenoid with warm bore
- Supplier: Cryomagnetics, Inc.
- Delivered: October 2011

6 T solenoid installed at HV platform
In final position for on-site
commissioning

Magnetic axis was aligned with
mechanical axis of warm bore
in real magnetic environment



Results of 6 T Solenoid Commissioning



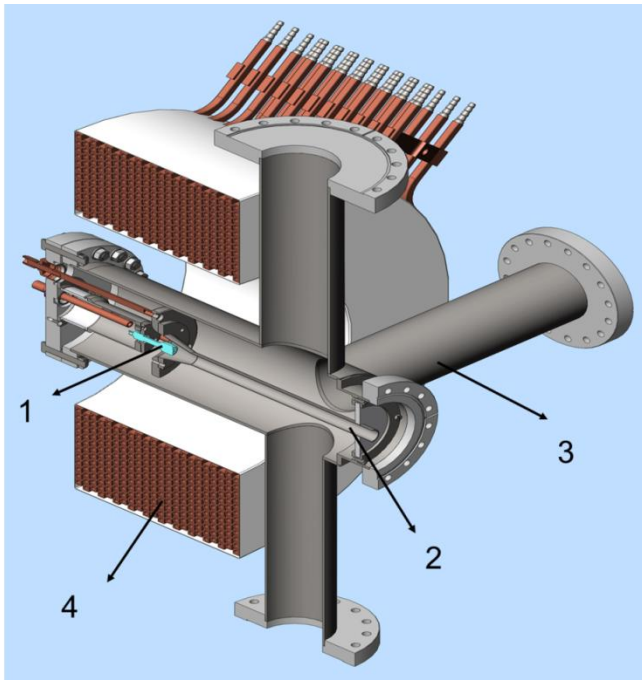
Parameter	Specification	Measurements
Central Field	6.0 T	6.05 T @ 82.66 A
Maximum Field	6.6 T	6.6 T @ 90.17 A
Charge Time to 6 T	70 min	70 min
Field Homogeneity	$\pm 0.4\%$ over ± 30 cm on axis	$\pm 0.2\%$ over ± 30 cm on axis
Coil Inductance	195 H	193 H
Field Decay Rate	< 1 ppm/hour	< 0.01 ppm/hour

Sergey Kondrashev, Commissioning of CARIBU EBIS Charge Breeder Sub-systems, HIAT 2012, June 20, 2012

Electron Guns

Supplier: BINP (Novosibirsk, Russia)

Delivered: April 2012



Engineering model of e-gun (1 – IrCe thermionic cathode, 2 – anode, 3 – vacuum chamber, 4 – magnetic coil)

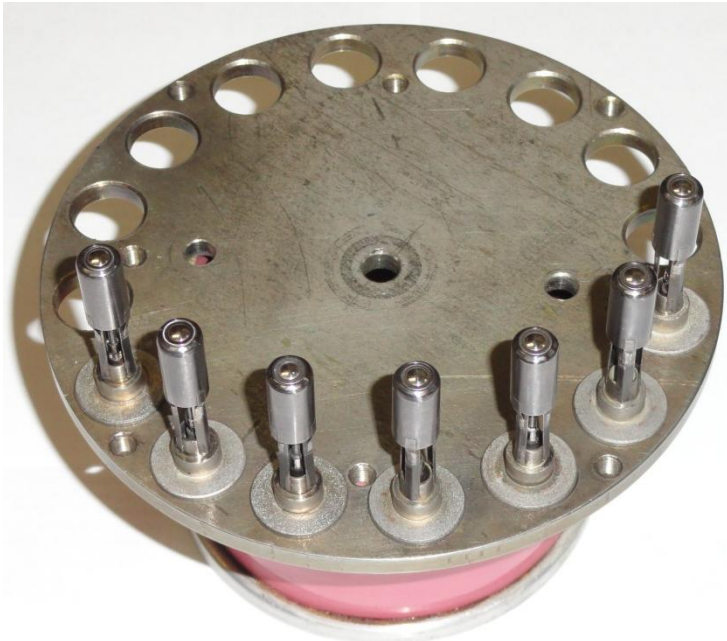
Parameter	CARIBU (high current)	CARIBU (low current)
Current	Up to 2 A	Up to 0.2 A
Current density at the cathode	10–15 A/cm ²	10–15 A/cm ²
Magnetic field at the cathode surface	~ 0.15 T	~ 0.15 T
Cathode material	IrCe	IrCe
Cathode diameter	4 mm	1.6 mm
Radius of cathode convex surface	6.6 mm	1.8 mm
Expected cathode lifetime	~ 20000 hours	~ 20000 hours

IrCe thermionic cathodes demonstrated the longest live time

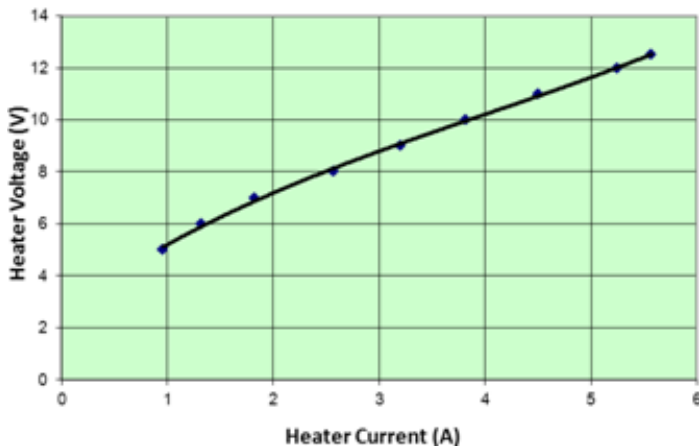
2 A and 0.2 A e-guns are exchangeable by exchanging cathode units



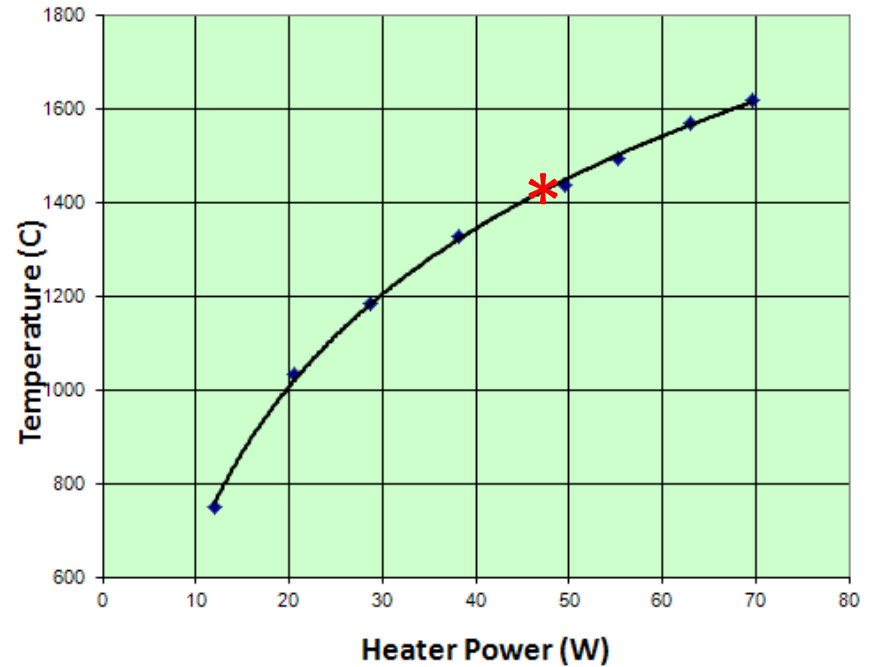
IrCe Thermionic Cathodes Tests



Current-Voltage Heater Curve (4 mm diameter cathode)



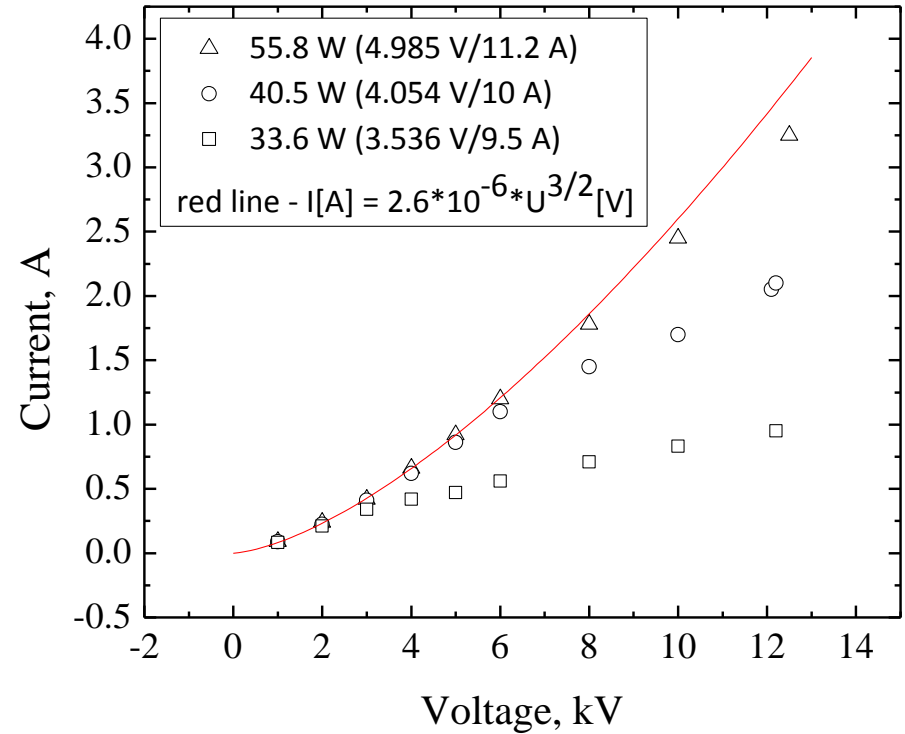
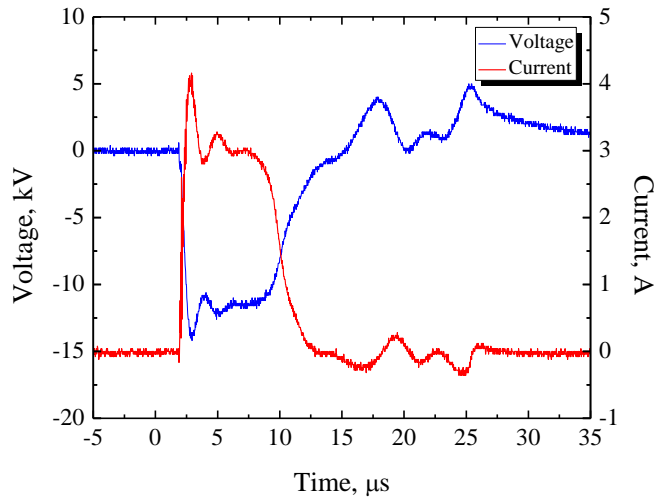
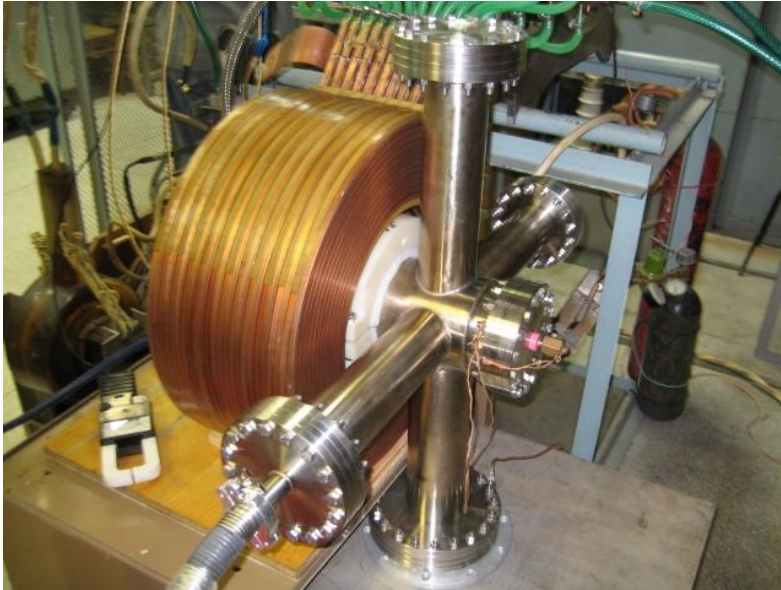
Brightness Surface Temperature



Sergey Kondrashev, Commissioning of CARIBU EBIS Charge Breeder Sub-systems, HIAT 2012, June 20, 2012



E-gun Commissioning Results



Perveance is about $2 \cdot 10^{-6} \text{ A/V}^{3/2}$

Summary

- EBIS charge breeder is an excellent choice for acceleration of CARIBU beams
- Design of CARIBU EBIS charge breeder has been completed and manufacturing of different components is in progress
- 6 T superconducting solenoid and high-perveance e-gun have been recently commissioned and met all specified parameters

