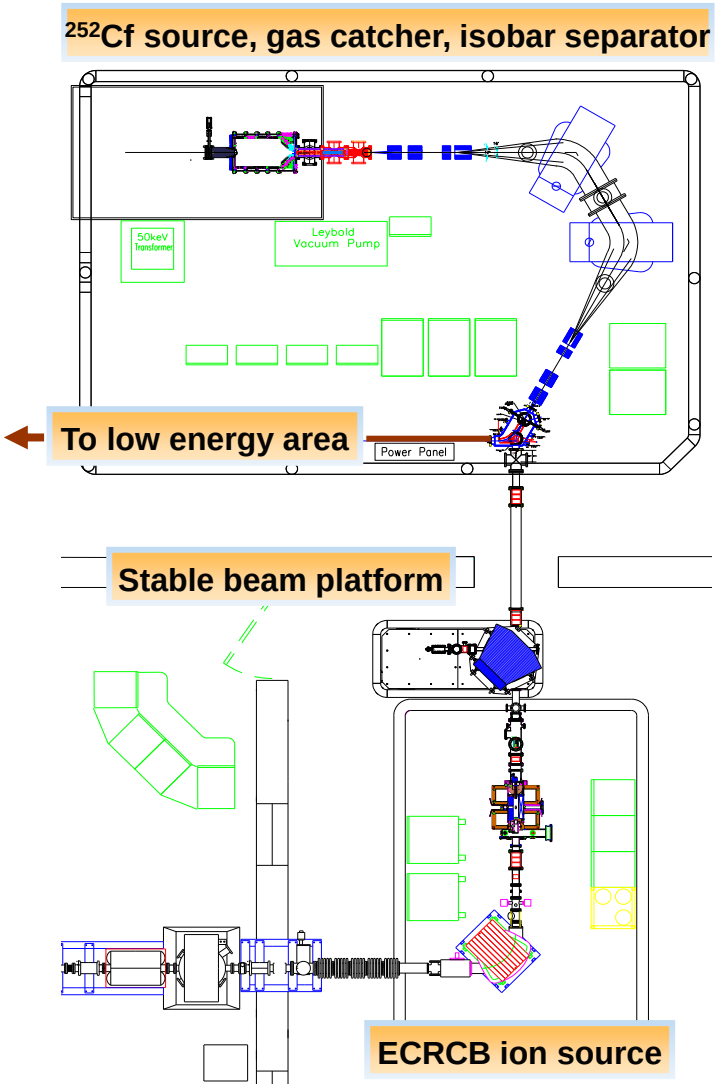
Low-contamination Rare and Exotic Beams (at CARIBU)

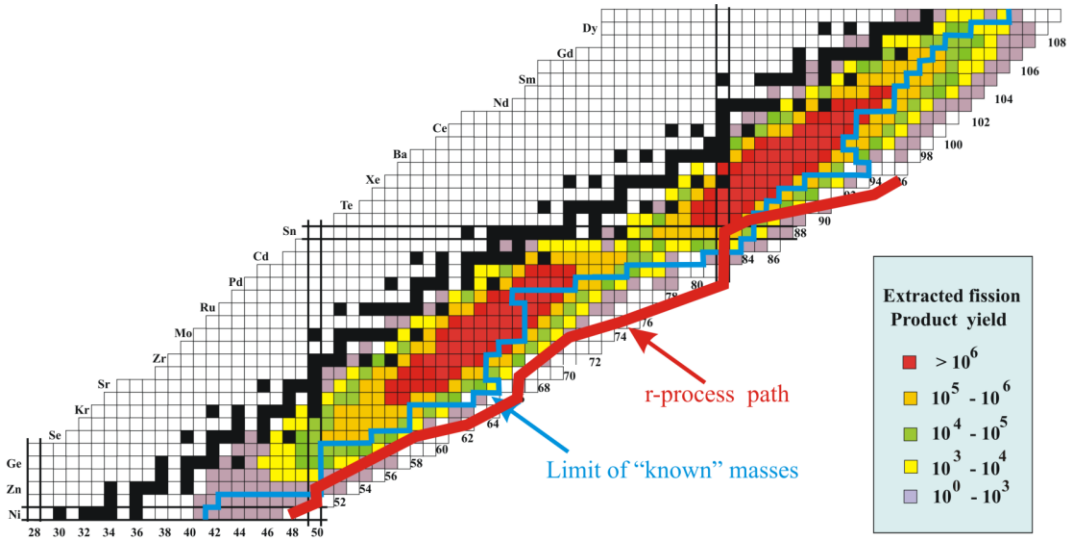
Sergey Kondrashev

October 16, 2012

CARIBU - Californium Rare Ion Breeder Upgrade



- ^{252}Cf fission source provides radioactive species (80 – 160 a.m.u)
  - 500 mCi source installed September 5, 2012
- High quality beam out of gas catcher
  - Energy spread of 1 eV
  - Emittance of 3 π mm mrad
- Stopped beams and reaccelerated beams up to 15 MeV/u
- Highest yields are in the mid-mass species
  - Above Germanium, below Dysprosium



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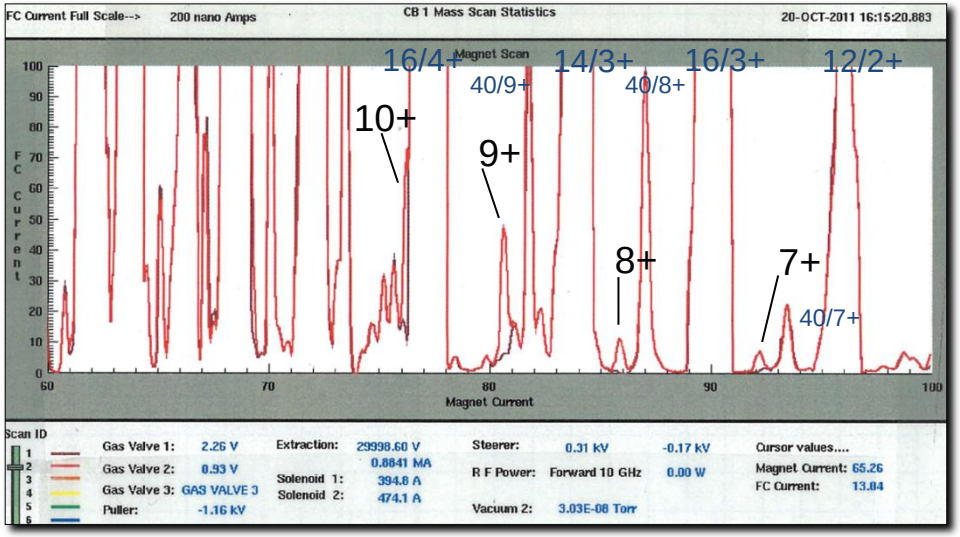
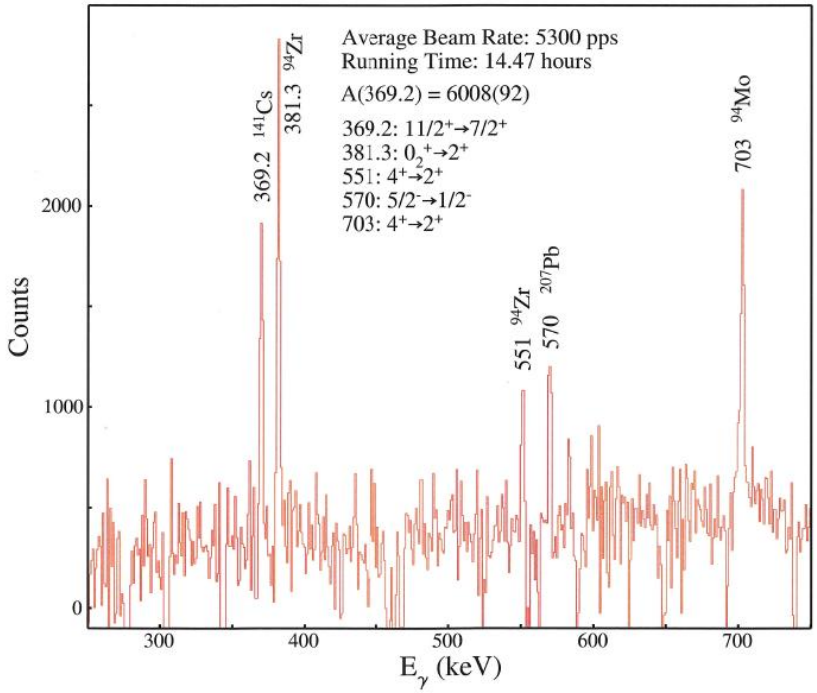
From "Messy" Beam at CB Output to "Clean" Post-accelerated Beam

At output of ANL ECR CB



Mass scan of background plasma constituents and charge bred ^{39}K beam showing peaks for 7+, 8+, 9+, and 10+ (courtesy of Rick Vondrasek).

Post-accelerated ^{141}Cs RI beam



(courtesy of Rick Vondrasek)

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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)	~ $4 \cdot 10^{10}$	~ $2 \cdot 10^{11}$

- (q/A) ≥ 1/7 at CB output
- Warm bore superconducting solenoid
- Low-current e-gun to study efficiency gain at shell closures
- BNL Test and RHIC EBIS were used as prototypes

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Sources of Beam Contamination in EBIS/T CB

- Residual gas atoms and molecules
- Evaporated atoms of e-gun cathode, cathode heater and surrounding elements
- Electron beam induced desorption from collector walls
- Highly-charged ion induced desorption from drift tube walls

Only the first source of contamination is relatively easy to control.

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How to Purify Charge-bred Ion Beam?

- Separation of different species in LEBT (ATLAS LEBT - two 90° bending magnets, mass separation is about 500)
- Separation in linear accelerator? No, typical mass separation less than 100 (ATLAS linac doesn't provide further purification)
- Choose q/A of charge-bred rare isotope with the lowest intensity of surrounding background within LEBT resolution – easy to implement for EBIS CB by changing breeding time
- Residual pressure in the trap should be as low as possible to minimize background, although in many cases it can be not the main source of local contamination

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Vacuum System of CARIBU EBIS CB

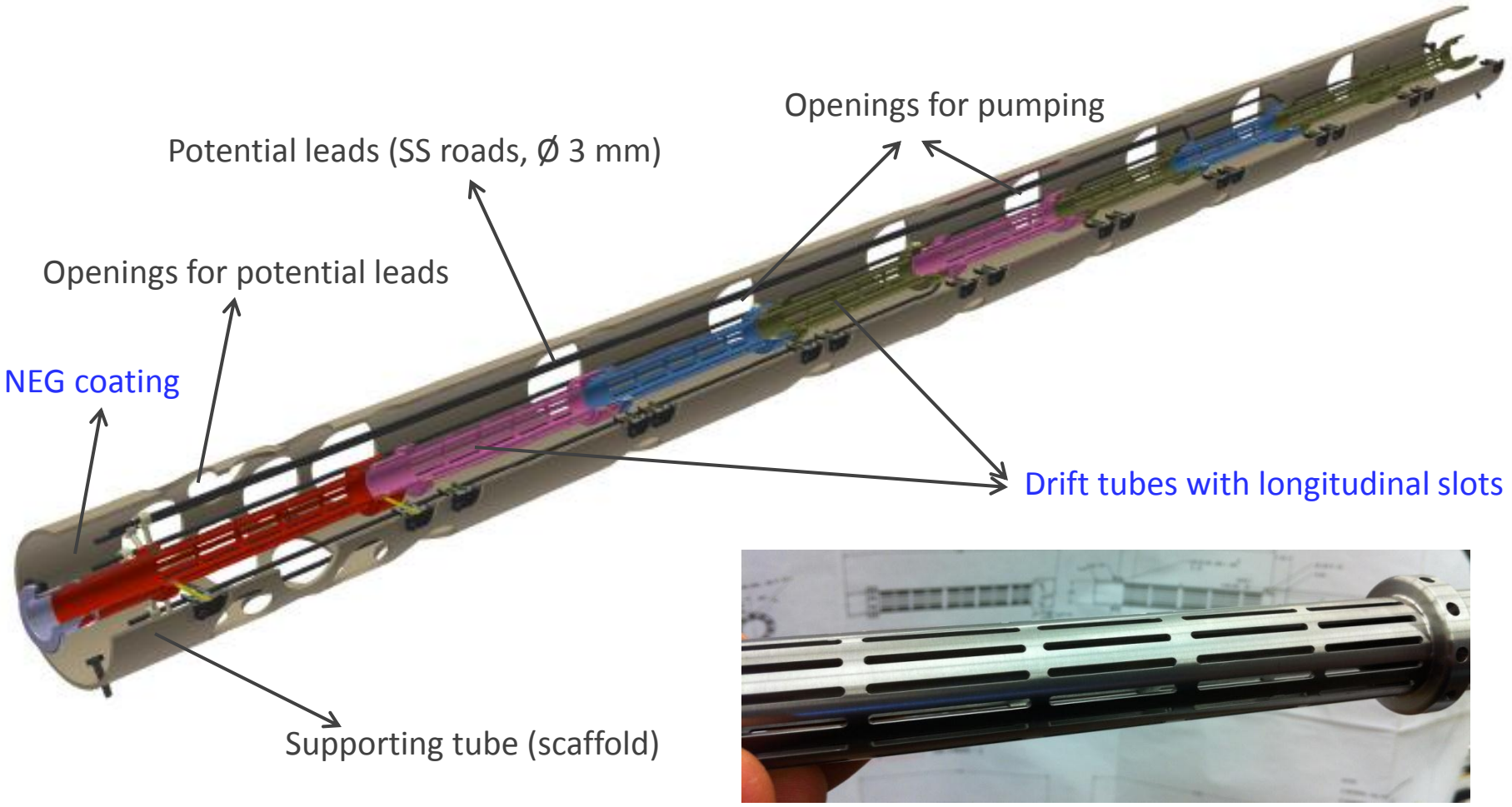
Similar to BNL RHIC EBIS:

- TMP and cryopump on each side of the trap
- Differential pumping between trap and heavily outgassing e-gun and collector chambers

Additional features:

- Drift tubes with longitudinal slots to enhance trap vacuum conductance
- NEG coating of trap supporting tube

CARIBU EBIS CB Drift Tube Structure



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Number of Residual Gas Ions Inside CARIBU EBIS CB Trap

- Number of atoms/molecules ionized within 30 ms breeding cycle **~ $2 \cdot 10^8$** for residual gas pressure in the trap ~ 10^{-10} mbar
- Trap capacity (for 2 A electron beam) **~ 10^{11}** elementary charges
- Ratio of total charge of residual gas ions to trap capacity **is independent on electron beam current**, if electron beam current density in the trap is the same
- Degree of trap neutralization by residual gas ions **is less than few percent** already at trap pressure ~ 10^{-10} mbar
- Residual gas ions **are a major part of charge-bred beam** at trap pressure ~ 10^{-10} mbar
- Trap pressure **~ 10^{-12} mbar** is required for the most intense rare isotopes to become a major part of the beam

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