# Charge-State Boosting for Post-Acceleration

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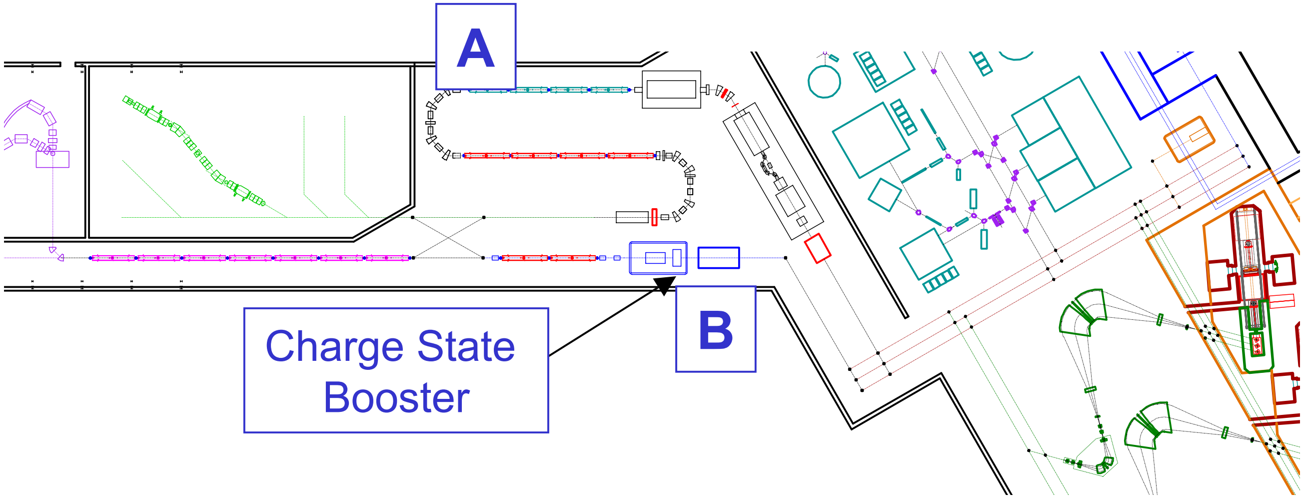


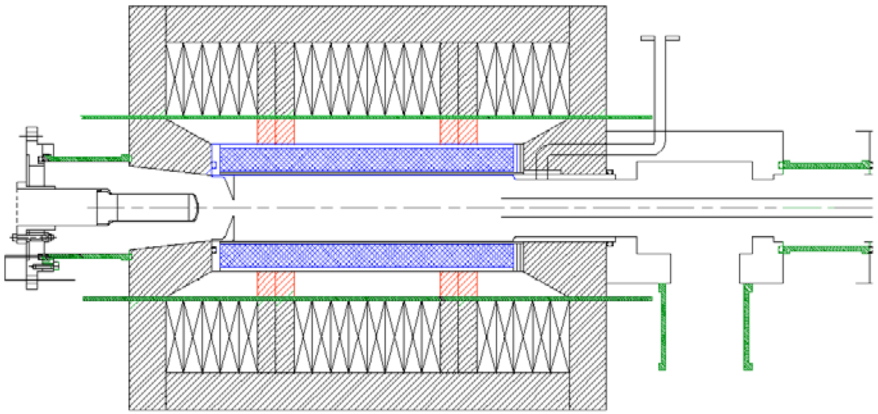

**A** only: A cost saver ! Limitations ?

**A + B**: Increased facility performance – two beams simultaneously for experiments with post-accelerated beams

Options: ECR and EBIS/EBIT devices

# ECR sources for charge state boosting

PHOENIX
(ISN Grenoble, TRIUMF Vancouver)



Tests with stable beams:

**T. Lamy et al., Rev. Sci. Instr. 73 (2002) 717**

Breeding efficiency for $Sn^{1+} \rightarrow Sn^{22+}$ $\eta = 4$ %
Breeding time for $Sn^{19+}$ $\tau = 20$ms
Beam emittance of $\varepsilon_{90\%} = 50\ \pi$ mm mrad for 12-keV Ar-ions

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ISOLDE – ECR tests (EU RTD project Charge Breeding)

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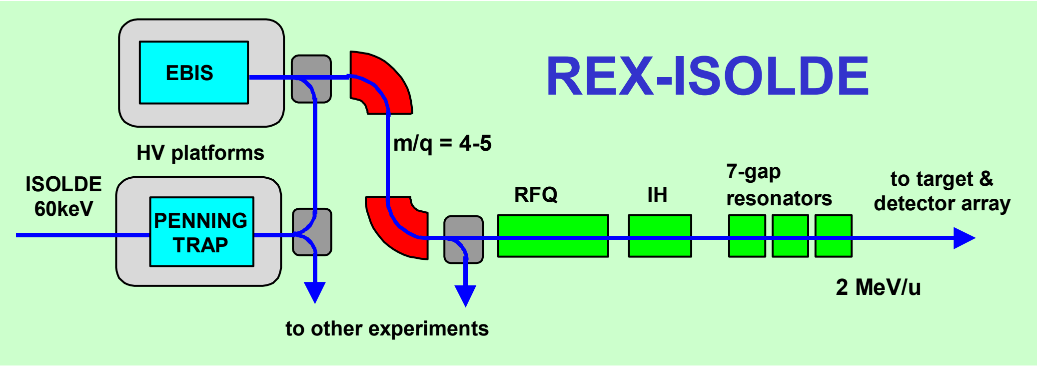
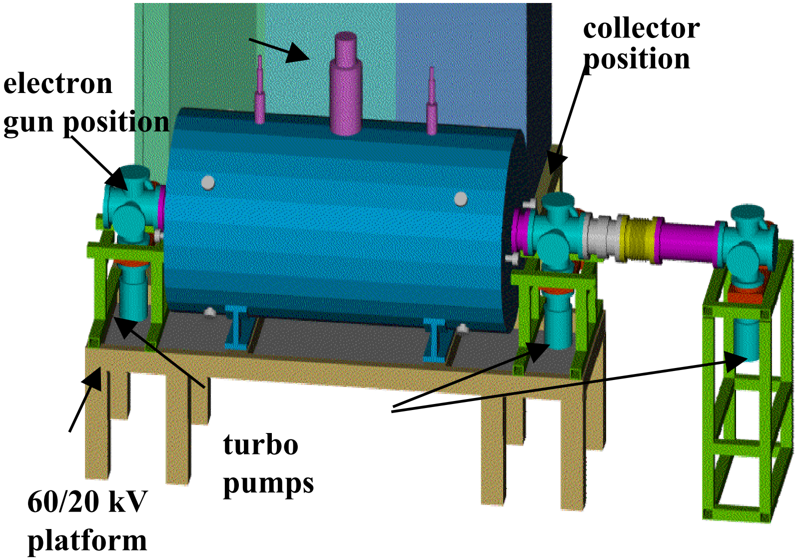
Texas A&M
Don P. May : "Preparations to Investigate Charge Multiplication via 1+ to n+ Scheme in a Large Volume ECR Ion Source"

# Charge State Boosting with EBIS/EBIT devices




REX-ISOLDE is operational




## REX-EBIS

<u>First tests</u>

Breeding time ($Na^{1+} \rightarrow Na^{8+}$) $\tau = 18$ ms
Breeding efficiency $\eta$ = 8-10 % (for peak charge state)
Beam emittance $\varepsilon = 5\,\pi$ mm mrad @ 60 keV
**Requires bunched beams** (←REXTRAP)

$B = 2$ T
$L_{trap} < 0.8$ m
$E_{electron} = 5$ keV
$I_e = 0.5$ A
$j_e = 250$ A/cm$^2$
(tests with 150 mA/cm$^2$)

B.H. Wolf et al., NIM 204 (2003) 428
O. Kester et al., NIM 204 (2003) 20

# Charge State Boosting with EBITs

EBIT vs EBIS: higher electron current density and energy, shorter length

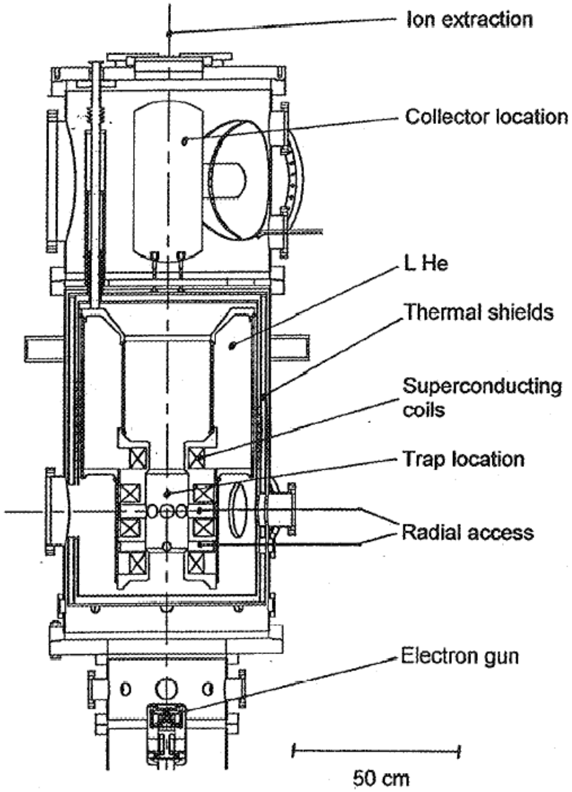
**TITAN, TRIUMF** (J. Dilling et al.) probably with a **FREBIT** like system

J. R. Crespo López-Urrutia, Hyperfine Interactions 127, 497 (2000)

**SuperEBIT, LLNL**

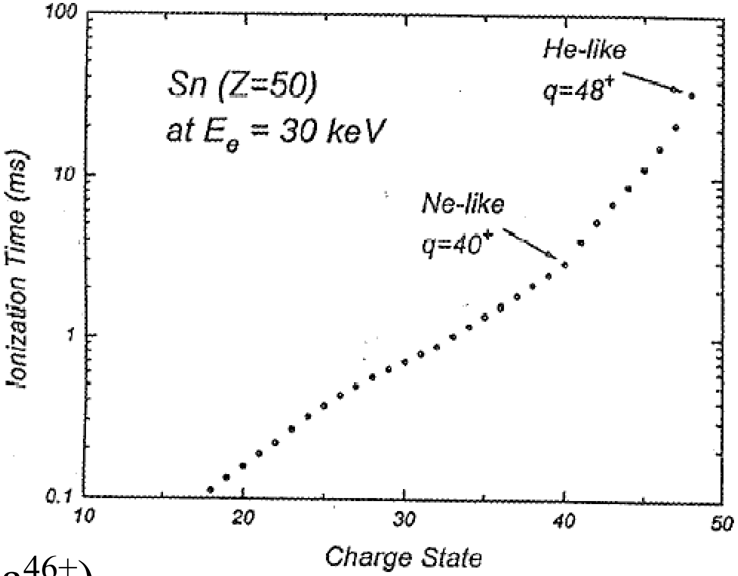
R.E. Marrs and D.R Slaughter
CAARI 15, 1998, AIP Conf Proc. 475 (1999) 322

| | |
|---|---|
| Magnetic field | 6 tesla |
| Electron beam energy | 30 keV |
| Electron beam current | 5 A |
| Beam radius (80% current) | 48 µm |
| Central current density | $1.1 \times 10^5$ A/cm$^2$ |
| Trap length | 25 cm |
| Total electron charges | $7.9 \times 10^{10}$ |



# Expected performance based on SuperEBIT parameters

R.E. Marrs and D.R Slaughter CAARI 15, 1998, AIP Conf Proc. 475 (1999) 322




**Fast capture**

breeding time $1^+ \rightarrow 2^+$ = 10% of travel time through the system

**Short breeding times**

$Sn^{1+} \rightarrow Sn^{40+}$ (Ne-like) $\tau$ = 3 ms

$Sn^{1+} \rightarrow Sn^{48+}$ (He-like) $\tau$ = 34 ms.

**High breeding efficiencies:**

Typical 25%, up to 90% for closed shells ($Ba^{46+}$)

D. Schneider et al., Phys. Rev A44, 3119 (1991)

**Reasonable intensity limit**

$10^{10}$ - $10^{11}$ ions/s for $Sn^{40+}$(estimated).

**Excellent beam emittance**

1 $\pi$ mm mrad at 30 keV. J.W. McDonald et al., Rev. Sci. Instr. 73, 30 (2002)

# Comparison and Conclusion

| *Sn isotopes* | **ECR** | **EBIT** |
|---|---|---|
| Breeding times | 20 ms ($19^+$) | 3 ms ($1^+$- $40^+$) |
| Efficiencies (peak abund.) | 4% ($1^+$-$28^+$) | 25-90% ($1^+$- $40^+$) |
| Intensity limit | > μA | 10-100 nA |
| Emittance @ 60 keV | 20 π mm mrad | 1 π mm mrad |
| Stable beam intensities | large | very low |

The EBIT concept is an option to be considered for charge state boosting at RIA