ECR3 PREPARATION FOR C-14 ION BEAMS AT ATLAS

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WEZZO03
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East Lansing, Michigan

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- 24/7 operation
- >5000 hours/year on target
- DOE National User Facility
- 2018 operations
  - 80% Stable ECR2
  - 20% CARIBU/EBIS
- 3 accelerating sections, stripping avail. PII, Booster
- Max. energy 17 MeV/u

https://www.anl.gov/atlas/about-atlas
**ECR3 INSTALLATION**

**BIE100 ECR ion source**

- Fulfill two needs:
  - Production of C-14 after 7 year hiatus
  - 2\(^{nd}\) source of stable beams

- All permanent magnets
- Small footprint
- Majority of parts re-used
- Capable of 2\(^{nd}\) frequency
  - 12.75-14.5 GHz

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**ECR3 Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_{in}/B_{min}/B_{ext}$</td>
<td>1.27 / 0.42 / 0.65 T</td>
</tr>
<tr>
<td>$B_{rad}$</td>
<td>1.0 T</td>
</tr>
<tr>
<td>PC dimensions</td>
<td>$d = 6.4 \text{ cm} / L = 17.5 \text{ cm}$</td>
</tr>
<tr>
<td>TWTA</td>
<td>11-13 GHz/300 W</td>
</tr>
<tr>
<td>Source HV</td>
<td>$\leq 15 \text{ kV}$</td>
</tr>
<tr>
<td>Platform HV</td>
<td>$\leq 200 \text{ kV}$</td>
</tr>
</tbody>
</table>

* D. Z. Xie, RSI Vol. 73, No. 2 [DOI; 10.1063/1.1429320]
ECR3 C-14 PLANNING

Carbon-14 experiment requirements:

- Energy \(210\,\text{MeV}\)
- Intensity \(100\,\text{pnA at target}\)
- Beam contamination \(\text{C-14:N-14} \geq 4:1\)

ATLAS facility goal:

- Consumption rate as low as possible
  - Reduce radioactive contamination
  - Reduce cost
ECR3 ENERGY VERIFICATION

C-14 experiment requirement: Energy 210 MeV

- Used in-house energy prediction application
- Determined 3 linac configurations that will yield required energy

<table>
<thead>
<tr>
<th>Source</th>
<th>PII Stripping Energy</th>
<th>Fraction</th>
<th>Maximum Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>q</td>
<td>25.7 [MeV]</td>
<td>3+</td>
<td>122.2</td>
</tr>
<tr>
<td>3+</td>
<td>25.7 [MeV]</td>
<td>6+ 0.4</td>
<td>210.8</td>
</tr>
<tr>
<td>4+</td>
<td>27.9 [MeV]</td>
<td>4+</td>
<td>156.3</td>
</tr>
<tr>
<td>4+</td>
<td>27.9 [MeV]</td>
<td>6+ 0.4</td>
<td>212.3</td>
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<tr>
<td>5+</td>
<td>30.6 [MeV]</td>
<td>6+</td>
<td>214.3</td>
</tr>
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</table>
ECR3 INTENSITY VERIFICATION

C-14 experiment requirement: Intensity 100 pnA at target

- Calculate source intensity required with
  - 20% transmission to target
  - 40% stripping efficiency

- Beam tests with C-13 ethylene gas
  - C-12
    - m/q conflicts 3+,6+
    - Competing background carbon
  - Limited gas and RF input (100W)
    - lens sparking

<table>
<thead>
<tr>
<th>Source</th>
<th>Transmission</th>
<th>Target</th>
<th>I [pnA]</th>
<th>[%]</th>
<th>q</th>
<th>I [pnA]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3+</td>
<td>1250</td>
<td>6+</td>
<td>100</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4+</td>
<td>1250</td>
<td>6+</td>
<td>100</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6+</td>
<td>500</td>
<td>6+</td>
<td>100</td>
<td>20</td>
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<tr>
<td>6+</td>
<td>500</td>
<td>20</td>
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<table>
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<tr>
<th>Required Source</th>
<th>Achieved Source</th>
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<tbody>
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<td>I [pnA]</td>
</tr>
<tr>
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<td>1250</td>
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<td>--</td>
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ECR3 NITROGEN CONTAMINATION

C-14 experiment requirement: $C:N \geq 4:1$

- Measured $^{13}C:{^{14}N}$ ratio to predict $^{14}C:{^{14}N}$
- Foil stripping fraction into 6+ favors N over C
  - Chart C:N is corrected (20% lower)
- Helium support favors N over C
  - Results do not use a support gas
- Ratio/intensity improve with more ethylene input
ECR3 C-14 CONSUMPTION RATE

ATLAS facility goal: as low as achievable

- Maintain experiment requirements
- Minimize radioactive contamination
- Lower cost to the facility

- 4+ rate is ~50% higher than 4+ at the required intensity
SUMMARY

- ECR3 has been installed and commissioned at ATLAS
- ECR3 will provide flexibility to ATLAS and C-14 ion beams
- ECR3 at ATLAS will meet all C-14 experiment requirements

Thank you for your attention.