Acceleration of $H^-$ ions for the Cyclotron Institute Upgrade Project

Juan Olvera
Angelo State University

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Outline

- Why we need the K150 Cyclotron
- Original plans for proton (H+) beam via ECR2
- Problems with proton extraction using ECR2
- Enter the H⁻ Source
- Other upgrades done to K150 Cyclotron
- Future work
- Acknowledgments
- References
Why K150 is Needed

• New concept using Rare Isotope Accelerator (RIA)

• First proposed experiment:

\[ p + \frac{27}{13}Al_{14} \rightarrow n + \frac{27}{14}Si_{13} \]

• Requirements for this reaction:
  • Proton current of 14\(\mu\)A at extraction
  • Proton current of 10\(\mu\)A on target
  • Proton beam energy of 30MeV on Al target
Initial Plan for Proton Production

- Original plan called for use of the Electron Cyclotron Resonance (ECR2) source

- ECR2 source removes electrons, produces H+ Ions (protons) before injection into cyclotron

- H+ are injected into the cyclotron and accelerated
K150 Injection Line
Extraction Problems

- Activation of deflector
  - Loss of run time
  - Safety hazard – secondary radiation

- Extraction efficiency of deflector
  - Approximately 50% loss of beam at best
## Activation of Deflector

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity (mCi)</th>
<th>Dose Rate (mRem/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 min</td>
<td>1168.108</td>
<td>52144.3</td>
</tr>
<tr>
<td>1 hour</td>
<td>1028.649</td>
<td>45918.9</td>
</tr>
<tr>
<td>1 day</td>
<td>686.216</td>
<td>30632.7</td>
</tr>
<tr>
<td>3 days</td>
<td>390.27</td>
<td>17421.7</td>
</tr>
<tr>
<td>5 days</td>
<td>265.811</td>
<td>11865.8</td>
</tr>
<tr>
<td>Na-22 gamma source</td>
<td>0.1</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Rad worker limit: 5000mRem/year

Distance: .5 meters
Activation of Deflector

Hole for the injection line

Sky shine problem

Cyclotron iron

Roof planks

Concrete wall (7')
Solutions

• Build a special deflector for protons
  • Need one for each proton energy, ideally
  • Approximately 80KV bias needed – HV danger
  • HV Sparking – degrades surface, less deflection

• Build deflector from pure Aluminum
  • Excessive heat – complicates maintenance

• Make ions via an H⁻ source
  • Best option
Enter the H-Source

- 100% extraction efficiency from cyclotron
- No need for deflector - reduces secondary radiation
- No danger of HV – no sparking, less maintenance
- Allows production of high intensity proton and deuteron beams
H-Source Placement

Source

Source

Spool & steering magnet
Proton (H⁺) Production

- H⁻ ion collides with Carbon foil 2 microns thick
- Electrons are stripped away
- Proton (H⁺) emerges from collision
Extraction of Protons
But How to Get H⁻ Ions?

Excited Molecules

Dissociative Attachment

\[ e_{\text{hot}} + H_2 \rightarrow e + H_2(v'') \]

\[ e_{\text{cold}} + H_2(v'') \rightarrow H + H^- \]
Source “Tilt” suggested by Olli Tarvainen, JYFL

- Plasma Electrode
- Puller with e- Dump Magnets
- Einzel Lens
- H- ions
- e-
Quick Recap

Source
Results From First Test

- 24.5µA at extraction for a brief moment
- 10µA at extraction, sustained – vacuum problems
- 60+ hours of filament use without failure
Other Upgrades to the K150

- Installed spool, steering magnet, and platform
- Raised water cooling system – reduced clutter
- Installed door switches in HV cage – safety precaution
- Installed safety cage to isolate HV near source
- Installed gas lines, air lines, electrode covers, helped wire some interlock lines
Future Work

- Test beam focusing, throughput down the beam line

- Joe Brinkley will develop program to optimize beam from source

- Improve ion source – filament is limiting factor
  - Inductively coupled rf-discharge
    - Eliminates filament
  - Inductively heated thermionic emission cathode
    - Extends the lifetime of the filament – further development needed
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References

- Clark, Henry. “Project Management Plan for the Cyclotron Institute Upgrade at Texas A&M University”


Questions?