An Electron Linac Photo-Fission Driver for the Rare Isotope Program at TRIUMF

Outline

• Introduction
• Baseline design
• Beam dynamics study
• Schedule
• Summary
E-Linac Motivation/Impact

- New Science: Nuclear physics with neutron-rich RIBs
- Clean radioisotope beams
- Complementary & independent RIB driver
  - Enhanced science output: multiple beams to multiple users
  - Steady RIB production: staggered E-Linac & cyclotron shutdowns
- Leverages valuable existing infrastructure:
  - Proton Hall: available shielded vault with services
  - World-class RIB multiple experimental stations
  - Expands SCRF in-house expertise
- Prepares Canada for SCRF projects world-wide (ILC, CERN-SPL)
- Qualifies commercial partner (PAVAC) to build SCRF cavities.
What is photo fission?

Production efficiency: one γ-photon for three electrons (30 MeV)

Photo-fission cross-section high for 15 MeV γ due to Giant Dipole Resonance
TRIUMF 5-year plan: ARIEL project – new isotope production facility for ISAC expansion
The requirement:

\[ 50 \text{ MeV} \times 10 \text{ mA} = \frac{1}{2} \text{ MW beam power} \]

### E-Linac Beam Specification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunch charge (pC)</td>
<td>16</td>
</tr>
<tr>
<td>Bunch repetition rate (GHz)</td>
<td>0.65</td>
</tr>
<tr>
<td>Radio frequency (GHz)</td>
<td>1.3</td>
</tr>
<tr>
<td>Average current (mA)</td>
<td>10</td>
</tr>
<tr>
<td>Kinetic energy (MeV)</td>
<td>50</td>
</tr>
<tr>
<td>Beam power (MW)</td>
<td>0.5</td>
</tr>
<tr>
<td>Duty Factor</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Practical considerations (beam diagnostics) motivate bunch rep rate**

<table>
<thead>
<tr>
<th>Bunch vital statistics</th>
<th>inject</th>
<th>eject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized emittance ((\mu\text{m}))</td>
<td>&lt;30(\pi)</td>
<td>&lt;100(\pi)</td>
</tr>
<tr>
<td>Longitudinal emittance (eV.ns)</td>
<td>&lt;20(\pi)</td>
<td>&lt;40(\pi)</td>
</tr>
<tr>
<td>Bunch length (FW), inject (ps)</td>
<td>&lt;170</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Energy spread (FW)</td>
<td>&lt;1 keV</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

Not critical; beam dumped on target
HP RF building block for e-linac

130 kW klystron

50 kW coupler

50 kW coupler

E-linac RF unit = 100 kW/cavity
E-linac layout

Division into injector & main linacs allows:

- Possible expansion for:
  - Energy Recovery Linac (ERL) – e.g. 10 mA, 80 MeV
  - Recirculating Linear Accelerator (RLA) – e.g. 2 mA, 160 MeV
Beam dynamics: 100 kV - 50 MeV low charge (16pC)

Curves represent results of capture section optimization

Beam portraits at the linac exit
Energy spread (3 rms): 0.32%
Bunch length (3 rms): 6.4 ps

Beam dynamics posters: Thursday: TH6PFP097; Friday: FR5PFP075
Beam dynamics (continued)
**Electron Source**

**Thermionic gun** – inexpensive, simple, low maintenance

NIST/JLab electron gun was donated to TRIUMF

Being converted from diode to triode

RF modulated gun avoids chopping and high power beam dump at linac start

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**Longitudinal emittance simulation (SIMION 3D) at the gun exit**

**Electron gun development stand**
Cavity Development with PAVAC

• PAVAC is a local company with EBW expertise
  – Now produces 20 QW 141MHz cavities for ISAC-II
• PAVAC to produce two single cells by summer 2009
  – Dies sourced from FNAL/RRCAT
  – Forming and welding tests underway (in copper and Nb)
Collaboration with VECC*

- Same goal: build electron linac for RIB
- Share resources
- Signed MOU in 2008
- Scope: build and test with beam at TRIUMF two Injector Cryo-Modules (ICM) at 10MeV/50kW

* VECC=Variable Energy Cyclotron Centre (Kolcata, India)

TRIUMF/VECC collaboration poster: MO6RFP090
The Schedule

- **July 2009**
  - Conceptual design
  - Single cavity of beta=1 prototyping and test
- **December 2009**
  - ICM design
- **November 2010**
  - Assemble ICM1
- **May 2011**
  - Beam test with ICM1 in ISAC-II
  - Build e-linac infrastructure in Proton Hall
- **December 2011**
  - Test ICM2 in Proton Hall
- **July 2013**
  - E-linac beam test at 25 MeV
- **November 2013**
  - Ready for RIB production
- **2017**
  - E-linac beam test at full energy and full power
Summary

- E-linac is a major new RIB source, complementary to cyclotron
- Opens new science horizons with neutron-rich RIB
- L-band SCRF cost effective MW-class fission driver
- Capitalization on world-wide SRF R&D
- Light source technology test bed
- Allows participation in other SRF projects (e.g. SPL, ILC etc.)