ARIEL: TRIUMF’s Advanced Rare IsotopoPE Laboratory

2nd International Particle Accelerator Conference
4 – 9 September 2011
ARIEL will be TRIUMF's flagship Rare Isotope Beam facility for the production of isotopes for physics and medicine. ARIEL uses proton-induced spallation and electron-driven photo-fission of ISOL targets for the production of short-lived, rare isotopes that are delivered to multiple experiments simultaneously at the ISAC facility.
ISAC-I & ISAC-II Rare Isotope Beam Facilities

- ISOL facility with highest power driver beam
- Most intense beams of certain species
- Single user facility (single driver, two target stations)
- Fourteen world-class experiments on the floor in three areas: low, medium, high energy
ARIEL Project: Motivation

- Goal is to substantially expand rare isotope beam program with:
  - three simultaneous beams
  - increased number of hours delivered per year
  - new beam species
  - increased beam development capabilities

- New complementary e-driver for photo-fission
- New proton beamline
- New target stations and front end
- Staged installation
Photofission of $^{238}$U was proposed by W. T. Diamond (Chalk River) in 1999 as an alternative production method for RIB.
Nuclear Science at TRIUMF in 2015 and Beyond

Protons on UC

Photon-fission on U

08/31/11
Photo-fission products using 50 MeV 10 mA electrons on to Hg convertor & UC\textsubscript{x} target.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinetic energy (MeV)</td>
<td>50</td>
</tr>
<tr>
<td>Average current (mA)</td>
<td>10</td>
</tr>
<tr>
<td>Duty Factor</td>
<td>100%</td>
</tr>
<tr>
<td>Beam Power (MW)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Number of photo-fission/s vs. electron energy for 100 kW e-beam on Ta convertor and U target.

For up to $10^{14}$ fissions/s

08/31/11
The present e-linac design concept, based on 1.3 GHz Superconducting RF technology (SRF) in CW operation, offers flexibility, possibility for expansion to other applications (Free Electron Laser, Energy Recovery Linac).
VECC Collaboration

- TRIUMF and VECC (Variable Energy Cyclotron Center, Kolkata, India) are collaborating on a 50MeV high intensity (10mA) cw electron linac for the production of radioactive ions through photo-fission
  - First stage is design and construction of two Injector Cryomodules (ICM) to 10MeV and 30kW beam test

- MoU of $6.2M scope was signed August 2008. Allows:
  - Early start of e-Linac project
  - Early system integration tests with beam
  - Additional resources – both manpower and cash

- Progress to date is excellent
300 keV Thermionic Gun

Critical path: Electrodes, Gun vessel.

Long lead items ordered:
RF Cathodes, Steering coils, HVPS, Ceramic

HV cage
Low Energy Transport, ICM

- e-Gun
- Solenoid
- Buncher
- Analyzer
- IC
- M

ACOT, 2011 May 13
– performed using a genetic algorithm (Bazarov, Sinclair 2005)
Note the (gray) ERL. In order to share with photofission, this requires an rf deflector.
RMS Emittance = 5μm, so \( \sigma \approx 1\text{mm} \).

There are 76 quadrupoles, aperture diameter 52mm. As they are weak, most will be very short (yoke length = aperture dia.) with spherical poles. Most will be air-cooled.
For details on transport, including switching between targets and a future ERL, see:

**WEPC002:** *RF Separator and Septum Layout Concepts for Simultaneous Beams to RIB and FEL Users At ARIEL* – Yu-Chiu Chao, Chris Gong, Shane Koscielniak

Also of interest:

**WEPC003:** *Low-Beta Empirical Models used in Online Model and High Level Applications* – Yu-Chiu Chao, Gabriel Goh
Beam Physics Challenges

• 0.5 MW electrons requires careful control of losses (few Watts per meter; even less in superconducting cavities).
• Too high density on target means developing a failsafe rastering scheme (>~1 kHz).
• Need non-intercepting diagnostics and a pulsing scheme to safely raise beam power without destabilizing the rf.
• Electron gun with clean 650 MHz-modulated grid.
• Control of beam alignment in spite of large (3 Gauss) stray ambient magnetic field.
• …
Injector Cryo Module

- 2k Outlet
- Jt valve
- 4k Outlet
- 4K-2K Cryo Insert
- Heat Exchanger
- Strong Back
- Beam pipe
- Gate Valve
- RF Cavity
- Cooldown line
- Cooldown valve
- 4k level sensor
- 4k separator
- 2k Level sensor
- 2k Phase separator
- Power Coupler
two-cavity ACM design

Accelerator CM equipment test: 2014 Feb
The IOT transmitter has been able to produce 30 kW output power on a regular basis. It has been kept running cw at 30 kW for 24 hours, at 25kW for 40 hours and at 20 kW for 7 days without a single trip.

The 30 kW IOT transmitter will be used for the coupler test. Initially rf power will be limited to 10 kW cw for rf conditioning and thermal test of the couplers.

300 kW klystron contract has been awarded to CPI (Development is in collaboration with BESSY)

HVPS draft specification document nears completion.

Cryoplant tender was sent out in June. Two companies are bidding on the contract. Order will be placed beginning of September.

Quadrupole design package has been placed with D-Pace.
Goals:
- Use the e-Linac as a proof-of-principle demonstration of recovery of waste heat from a real system.
- Aim at “greening” all TRIUMF accelerators.

Actively working with UBC Sustainability Office, collaborators in Lund.

Requirement: 0.5 MW beam power
~15% overall accelerator efficiency
=> 3.3 MW total power required

=> ~3 MW heat generated

0.5 MW beam power on target
0.3 MW dissipated in converter

Cyclotron: 5 MW
ISAC: 1.5 MW
e-Linac and ARIEL Targets: 3.3 MW

Presently using ~3000 litres/min through cooling towers => ~6 MW

~10 MW heat generated
Acknowledgements

At TRIUMF:
Ames, Austen, Baartman, Ballard, Beard, Bylinsky, Chao, Clark, Dale, Drozdoff, Emmens, Fong, Hurst, Kaltchev, Khan, Koveshnikov, Koscielniak, Laxdal, Levy, Louie, Mammarela, Merminga, Mitra, Mitrovic, Morrey, Preddy, Reeve, Ries, Richards, Rowbotham, Sitnikov, Teodoropol, Trinczek, Trudel, Verzilov, Waraich, Yosifov, Zvyagintsev.

At U.Vic:
Karlen, Abernathy, Birney. Langstaff, Storey.
Thank you!

Merci!
Time line (funding)

• Funded now:
  – CFI & TRIUMF Manpower: e-linac
  – Provincial Government: ARIEL Buildings

• Exploring funding to complete in this 5YP:
  – Electron Target Station
  – ARIEL Front-end for ISAC

• Next five-year plan:
  – Proton Beam line
  – Proton/electron target
  – 2nd ARIEL Front-end for ISAC