ARIEL Buildings Construction and Electron Linac Photo-Fission Driver for the Rare Isotope Program at TRIUMF

IPAC’12, 2012 May 21

Yu-Chiu Chao for e-linac team
Motivation – RIB science at ISAC

ARIEL Civil Construction
  - Stores & Badge Buildings
  - Compressor Building
  - ARIEL Targets and RIB Building
  - E-hall renovation

E-linac (the machine)
  - E-Gun
  - ELBT at VECC test area
  - Cryomodules
  - Cryogenic System
  - HPRF

Conclusion
10-Year Vision: expanded RIB program with:

- three simultaneous beams
- increased number of hours delivered per year
- new beam species
- increased beam development capabilities

Implementation:
- Complementary electron linac driver for photo-fission
- New target stations and front end
- New proton beamline
- Staged installation
Site Preparation: demolition, relocation, construction

- 2011 October
- CONGESTED SITE
- Old Stores & RH Demolition
- Excavation and shoring
- Makes way for ARIEL building

New GHe compressor building
New Stores building
New Badge building
Ground Breaking: 2011 March

Completion: 2011 September
New Badge Building

Construction started: 2011 August

Occupancy: 2011 November
Helium Compressor Building

Ground breaking: 2012 March

- Foundations: 2012 May
- Expect occupancy: 2012 December
ARIEL building design

The culmination of an intensive study of what is needed to facilitate smooth and routine RIB delivery.
ARIEL E-linac, IPAC 12, 2012 May 21

ARIEL Layout – below ground

Target Hall
Actinide Annex
Tunnel
Electron Hall
RIB front end
BL4N protons
Cyclotron vault
Excavation started: 2011 November

ARIEL site: 2012 Jan

Building occupancy expected: 2013 April

ARIEL site: 2012 May
Electron Hall Renovation: Cleanout

- Proton hall clean up complete
  2012 Feb
- Construction underway 2012 March
- Expect occupancy 2012 October
Electron Hall Renovation: South shield wall

- Shielding upgrades
- South wall B2 up to ground for ERL/RLA operation.

1st concrete pour 2012/March

Final S. wall pour, 2012/April
Electron Hall Renovation: North shield wall

- Poured-in-place concrete
- N. Wall (shield e-hall from BL4N)

Rebar for N shield wall, 2012/April

1st pour cured 2012/May
300 keV thermionic gun: 650 MHz modulated

**Injector:**
10 mA, 5-10 MeV gain
≤ 100 kW beam power

**Accelerator:**
Two cryomodules
Two cavities/module, 10 mA, 40 MeV gain
≤ 400 kW beam power

ARIEL Phase I:
25 MeV, 200kW

Installed Cryoplant for Phase I & II

ARIEL Phase II:
50 MeV, 500kW
300 kV 10 mA Electron Gun

Gun assembly

- Detail design mostly complete
- Procurements in progress
- Installation begins: 2012 Sept

Many long lead items already delivered:
Ceramic, HVPS, ITX, RF
Cathodes, Steering coils

SF6 Vessel

ARIEL E-linac, IPAC 12, 2012 May 21
Gun Components

- Ceramic Insulator
- Steering Coil
- Cathode
- BeCu Anode
- Solenoid
RF horns and ceramic waveguide

Successful dielectric waveguide R&D program with scale model & HFSS

Transmission optimized at 650 MHz

RF modulation on 100kV prototype makes bunched beam at 650MHz

RF power on grid used to generate duty factors 0.1% to 99.9% at repetition rates 100Hz to 1kHz
ELBT at VECC test stand

Diagnostic Box #1

Buncher

BPM

Allison Scanner.
Test 1 Configuration

University of Victoria View Screen Profile Monitor

100kV e-gun & solenoid

Screen

Slit

Camera

Buncher

Turbo

300 W Faraday cup
VECC ELBT Test1 – 2011 Dec/2012 Feb

Allison emittance scans performed 2012 Feb 09 onward up to 660W beam power at ~20W/mm

Slit scanner profile for various solenoid settings

Chromox Target: ~0.3μA Beam Current - Solenoid Scan

2011 Dec 07: Image of gun electron beam
- Single-cavity EINJ prototypes most features of two-cavity EACA design.
- 2011 June: focus narrowed to completion of EINJ design, and fabrication in 2012
Injector Cryomodule

Cryomodule concept borrows significantly from ISAC-II

Top loading box concept with cavity mounted to strongback that is suspended from struts

Box gives headroom for on-board 2K/4K heat exchanger & 4K separator

- All procurements in hand
- Fabrication underway
- Cavity, 4K/2K insert (75% done)
Injector Cryomodule Detailing

- Detail design complete:
  - Cold mass support (strongback, struts), lid, cold mu-metal, scissor tuner
- Detail design in progress:
  - Tank, warm/cold transition, LN2 shield

Completion milestone: 2012 June 1st
Cavity Status

- 7 cell Cu cavity delivered from PAVAC
- Nine cell cavity design fixed and contract signed
- Tooling optimized
- Four Nb half cells formed and welded

Success: 7 out of 7 PAVAC/TRIUMF single-cells meet requirements
Liquid He @ 2K produced in cryo-modules by SA pumping

Liquid He @ 4K closed re-liquefaction/refrigeration loop

AND 77K LN system for He pre-cool.

- White boxes: TRIUMF responsibility
- Pale blue boxes: cryoplant ordered from Air Liquide Advanced Technology, 2011 Oct
Supplied by ALAT

Helial Cold Box

Main Compressor

Recovery Compressor

Oil removal & Gas Management System

Schedule
2013 March: ALAT cryoplant at TRIUMF
2013 October: commissioned
Successful Final Design Review concluded 2012 May 15
The plant shall demonstrate 3 modes:
- **Mixed Mode**: >130W @ 4.6K and 242 L/h rising level
- **Pure Liquefaction**: 288 L/h at 4.6K in the Dewar rising level
- **Pure Refrigeration**: 600W at 4.6K in the Dewar (expected)

![Graph showing required load line and ALAT load line with mixed mode point]
Other major components

- He buffer tanks: delivery expected 2013 Jan
- Dewar in hand; will widen neck
- He Purifier in design stage
- Cold Helium Distribution System: tender mid 2012
- 2K sub-atmospheric components:
  - Pumps: tender mid 2012
  - He heaters: prototyping

- Tanks rated 15 Bara
- Capacity ~113 m³ each

Accelerator cryomodules

LHe Dewar

Cold Box

He cold distribution and sub-atmospheric line

15 Ω Resistive heater prototype
High Power RF staging: 5mA, 25 MeV in 2014

300keV e-GUN
1.3GHz NC Buncher Cavity

30 kW Inductive Output Tube

5mA, 5MeV
coupler *

5mA, 25MeV

50 kW Couplers

50 kW Klystron

270 kW

50 kW coupler

ACCELERATOR CRYOMODULE #1

50 kW Couplers

50 kW coupler
IOT transmitter will be used for EINJ beam test 2013 Jan;
RF input coupler conditioning (10kW) 2012 March onward

- 2011 June: Tube operated tube in excess of 30kW
- 2011 July: Successful acceptance tests: ran cw at 30 kW for 24 hours, at 25kW for 40 hours and at 20 kW for 7 days without trip.
- Now running routinely
Coupler Conditioning Stand in VECC test area
1.3 GHz 290 kW klystron & HVPS procurement

Require 200kW cw for EACA (2-cavity) cryomodule

- 2011 Aug: 290kW Klystron ordered from CPI, USA
- Coordinated purchase with Helmholtz Zentrum Berlin
- 2012 June: Final design review
- 2012 Nov: klystron factory test

600kW High Voltage Power Supply

- 2012 Feb: Tender issued
- 2012 March: Tender closed
- Vendors under consideration

Klystron predicted CW Power Output vs. RF Input Drive
Conclusion

- Outstanding Progress Across All Areas
- Buildings Construction – on schedule for 2013 April
- Injector Cryomodule beam test – on schedule for 2013 March
- Accelerator Cryomodule beam test – on schedule for 2014 June
Cavity & HOM Damping

- 9 cell cavity
- Inner 7 cells TTF geometry
- Modified end groups for larger coupler & HOM damping

HOM frequency spectrum and shunt resistance for 9-cell cavity

- Minimal damping goal
- Achieved damping
- Ideal damping goal

- HOM damping target set by Regenerative BBU (2-pass)
- 39/35/48 mm iris geometry gives the lowest maximal \((R_d/Q)\times Q_L\)
- Damping by SS ring on coupler end, CESIC ring on tuner end
- All modes \((R_d/Q)\times Q_L < 2\times 10^6 \text{ ohm}\)

Two 50 kW Cornell/CPI coupler per cavity
EINJ: Injector Cryomodule Detailing