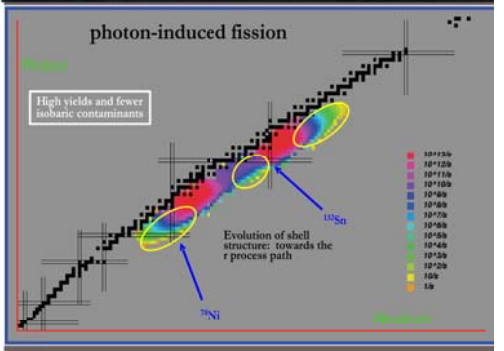
TRIUMF

Canada's National Laboratory for Particle and Nuclear Physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

ARIEL: TRIUMF's Advanced Rare IsotopE Laboratory



IPAC'11

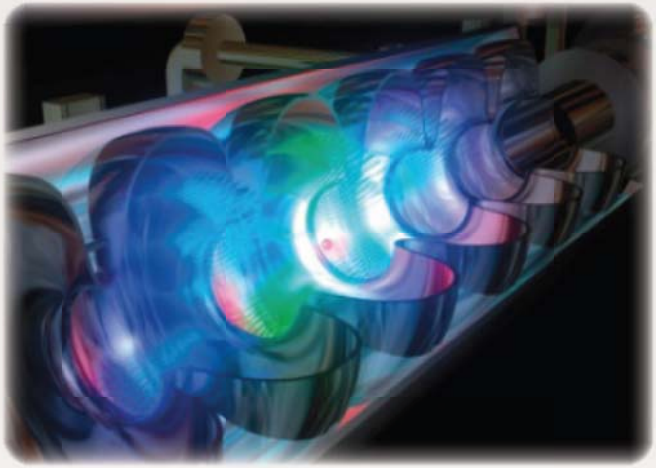
2nd International Particle Accelerator Conference
4 – 9 September 2011

Owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council Canada
Propriété d'un consortium d'universités canadiennes, géré en co-entreprise à partir d'une contribution administrée par le Conseil national de recherches Canada

ARIEL

TRIUMF ARIEL

ADVANCED RARE ISOTOPE LABORATORY

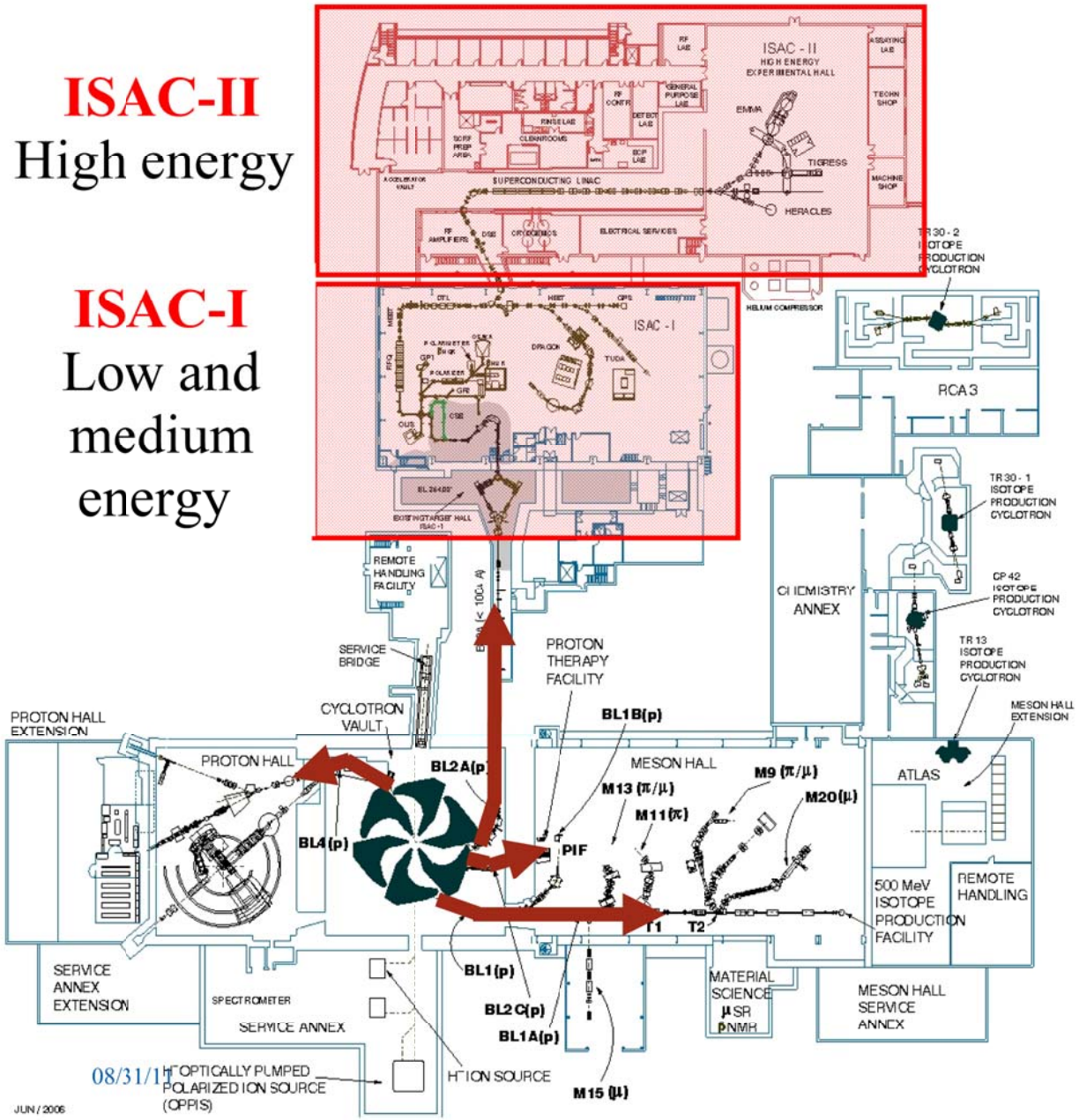


ARIEL will be TRIUMF's flagship Rare Isotope Beam facility for the production of isotopes for physics and medicine. ARIEL uses proton-induced spallation and electron-driven photo-fission of ISOL targets for the production of short-lived, rare isotopes that are delivered to multiple experiments simultaneously at the ISAC facility.

ISAC-I & ISAC-II Rare Isotope Beam Facilities

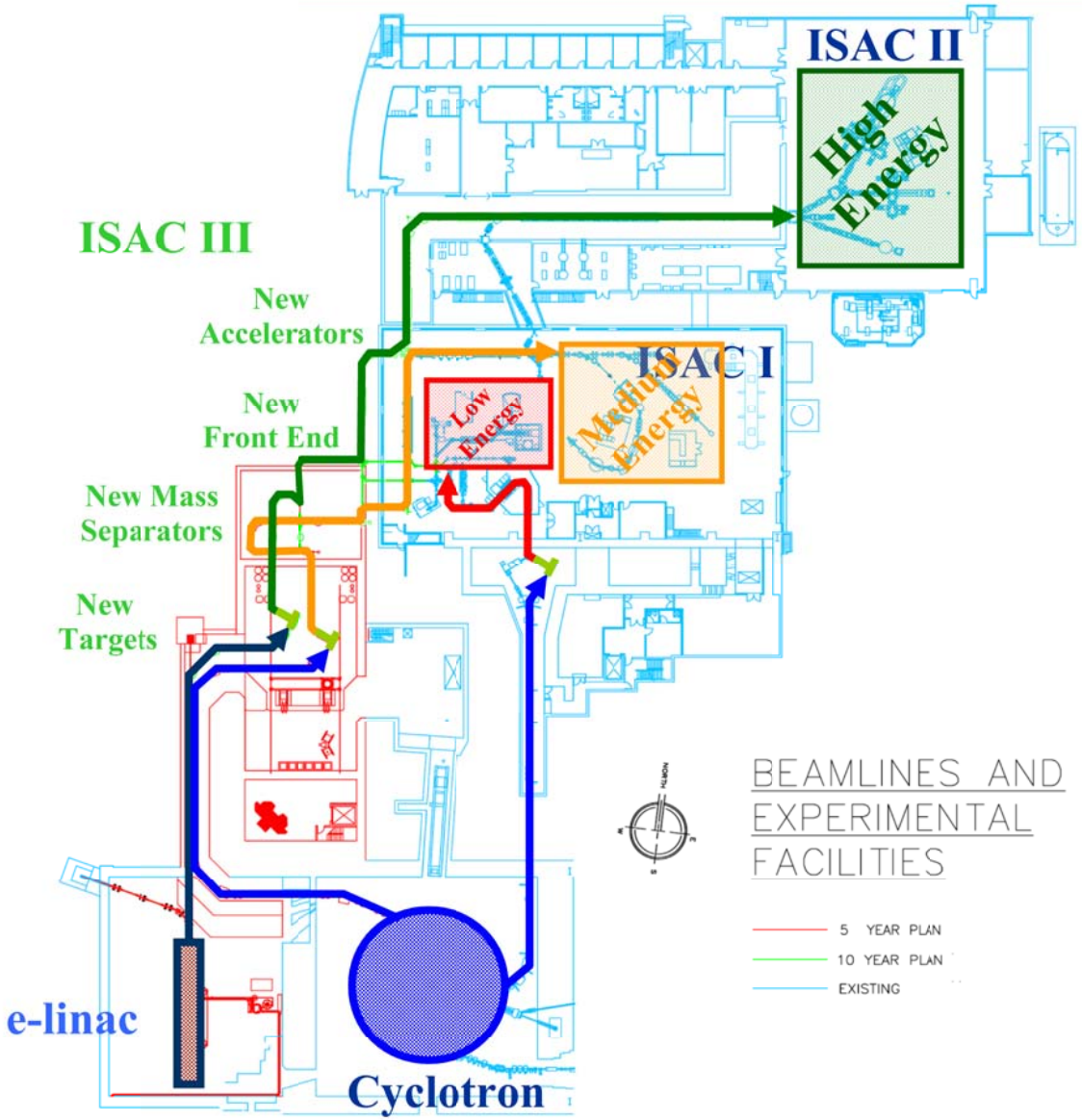
ISAC-II
High energy

ISAC-I
Low and medium energy



- 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

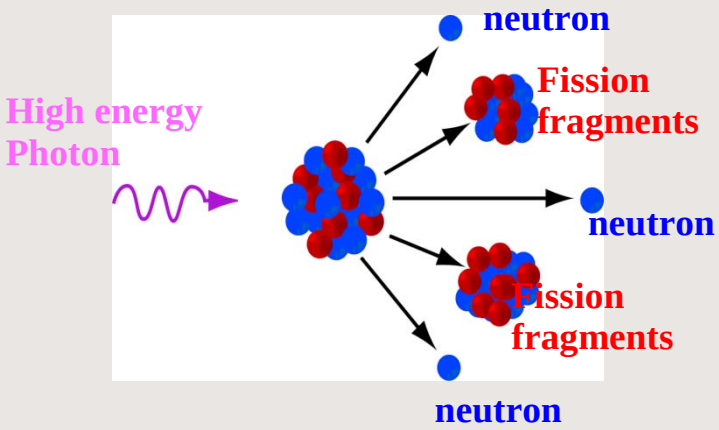


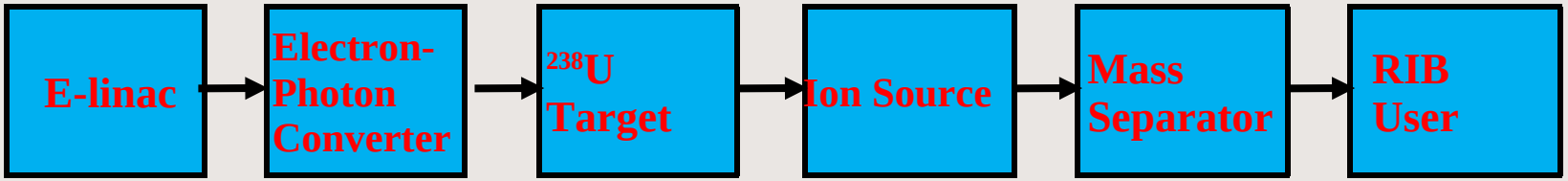
- Goal is to substantially expand rare isotope beam program with:
  - three simultaneous beams
  - increased number of hours delivered per year
  - new beam species
  - increased beam development capabilities

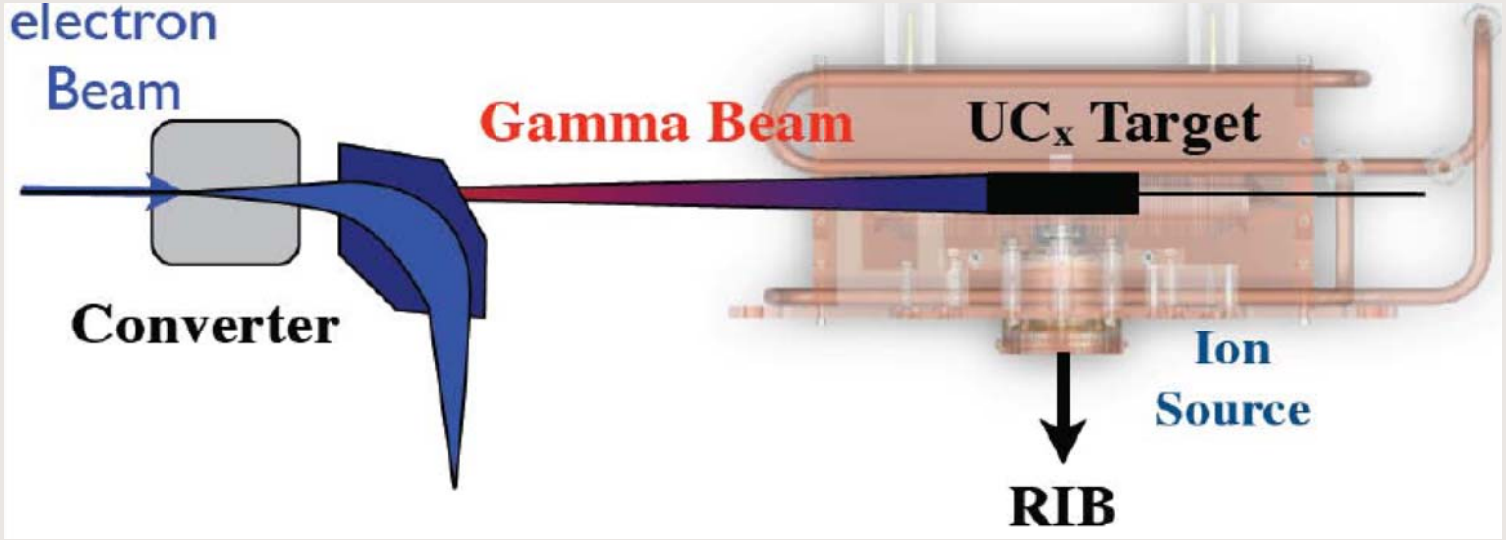
- New complementary e-driver for photo-fission
- New proton beamline
- New target stations and front end
- Staged installation

Photo-fission production of Rare Isotope Beams

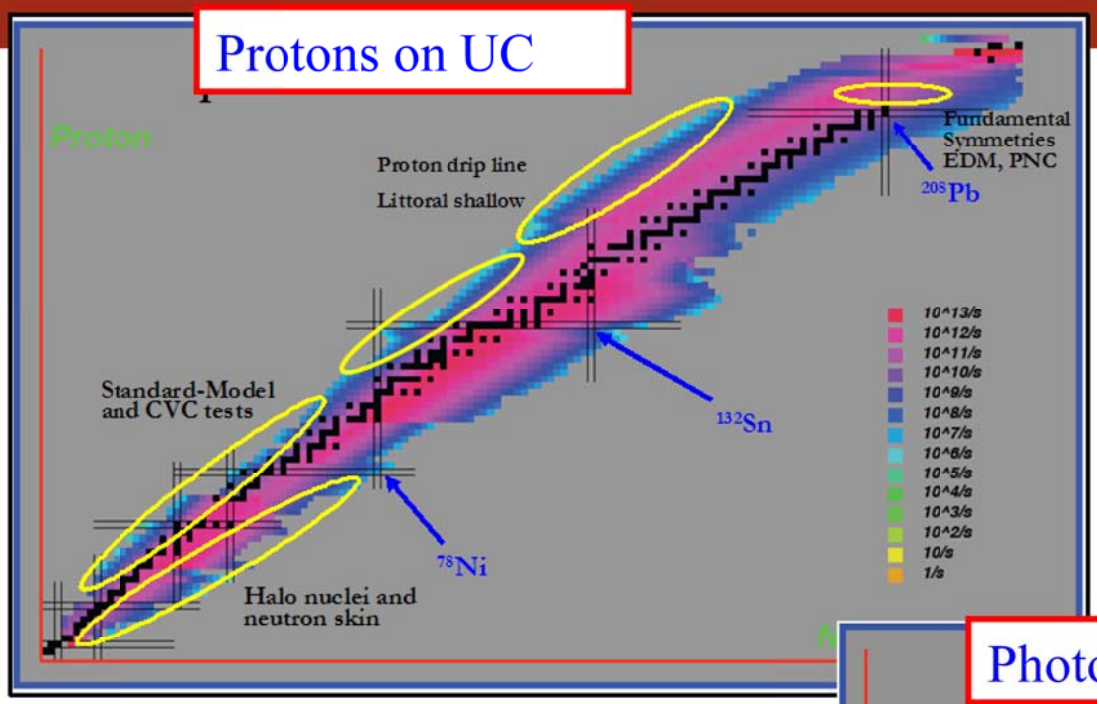
Photofission of ^{238}U was proposed by W. T. Diamond (Chalk River) in 1999 as an alternative production method for RIB.

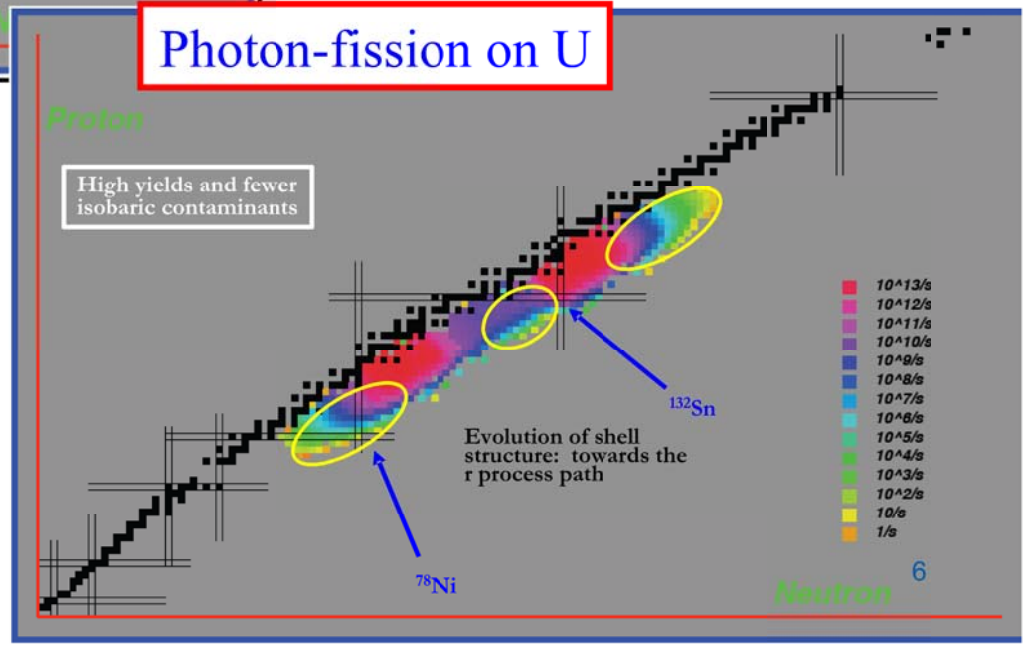




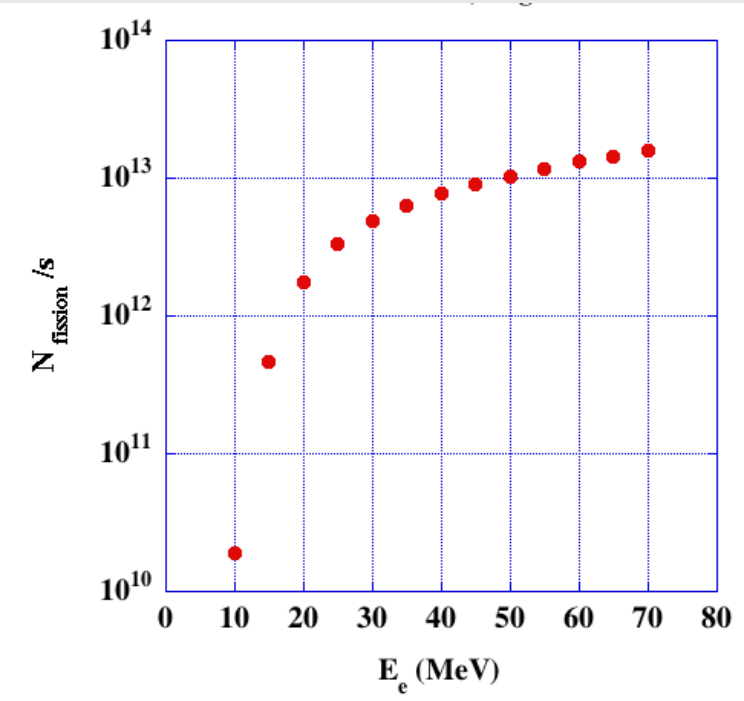


Nuclear Science at TRIUMF in 2015 and Beyond





e-Linac Physics Requirements



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

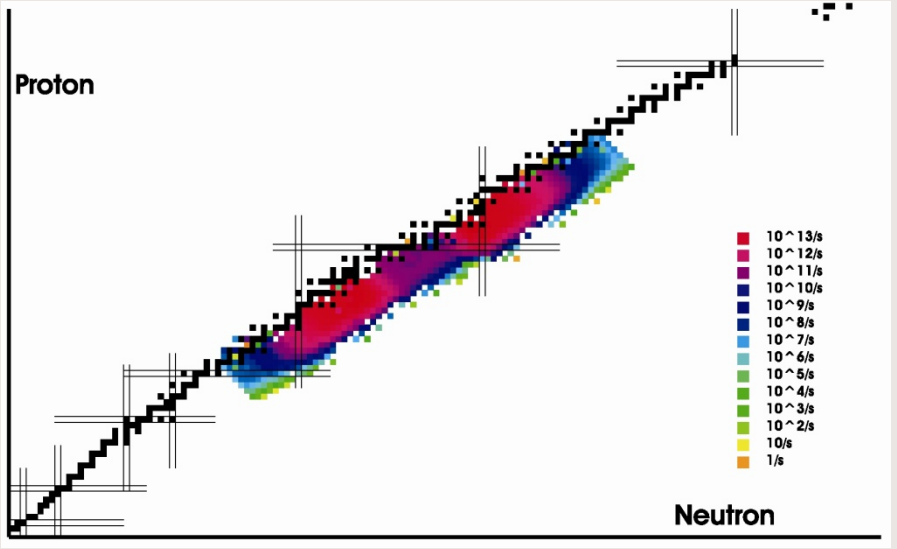
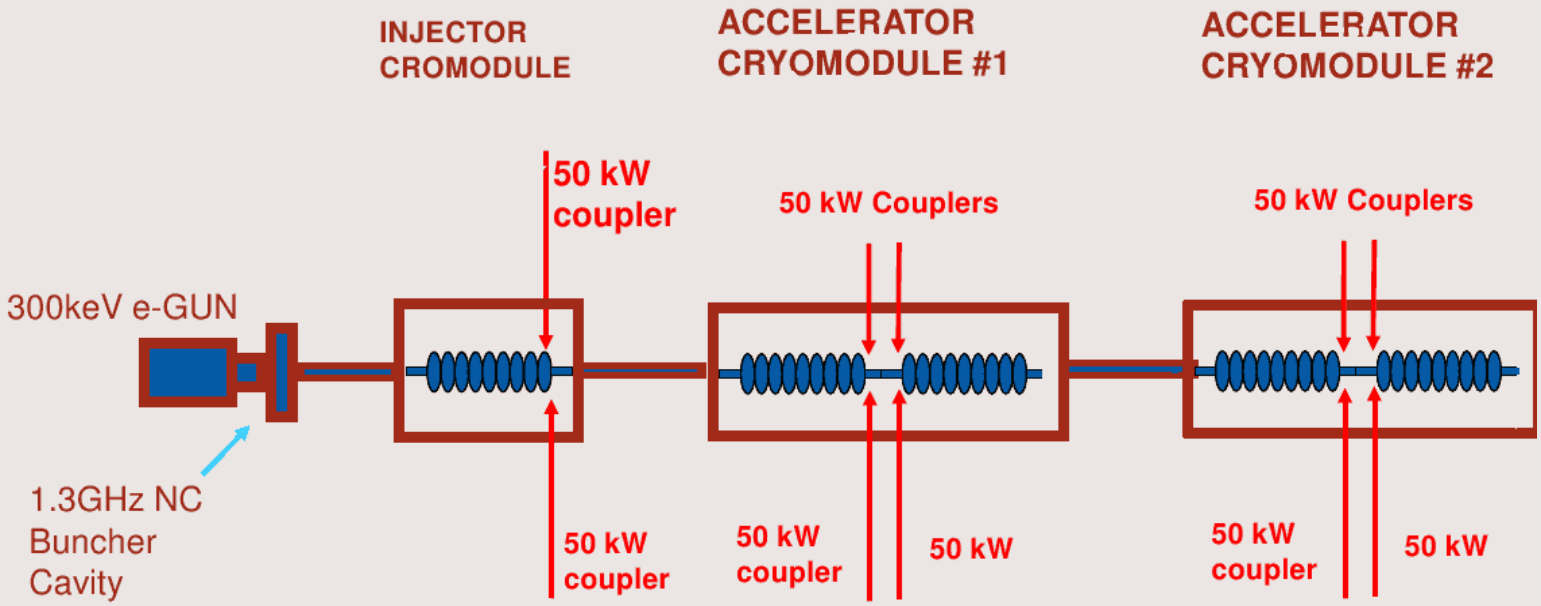


Photo-fission products using 50 MeV 10 mA electrons on to Hg convertor & UC_x target.

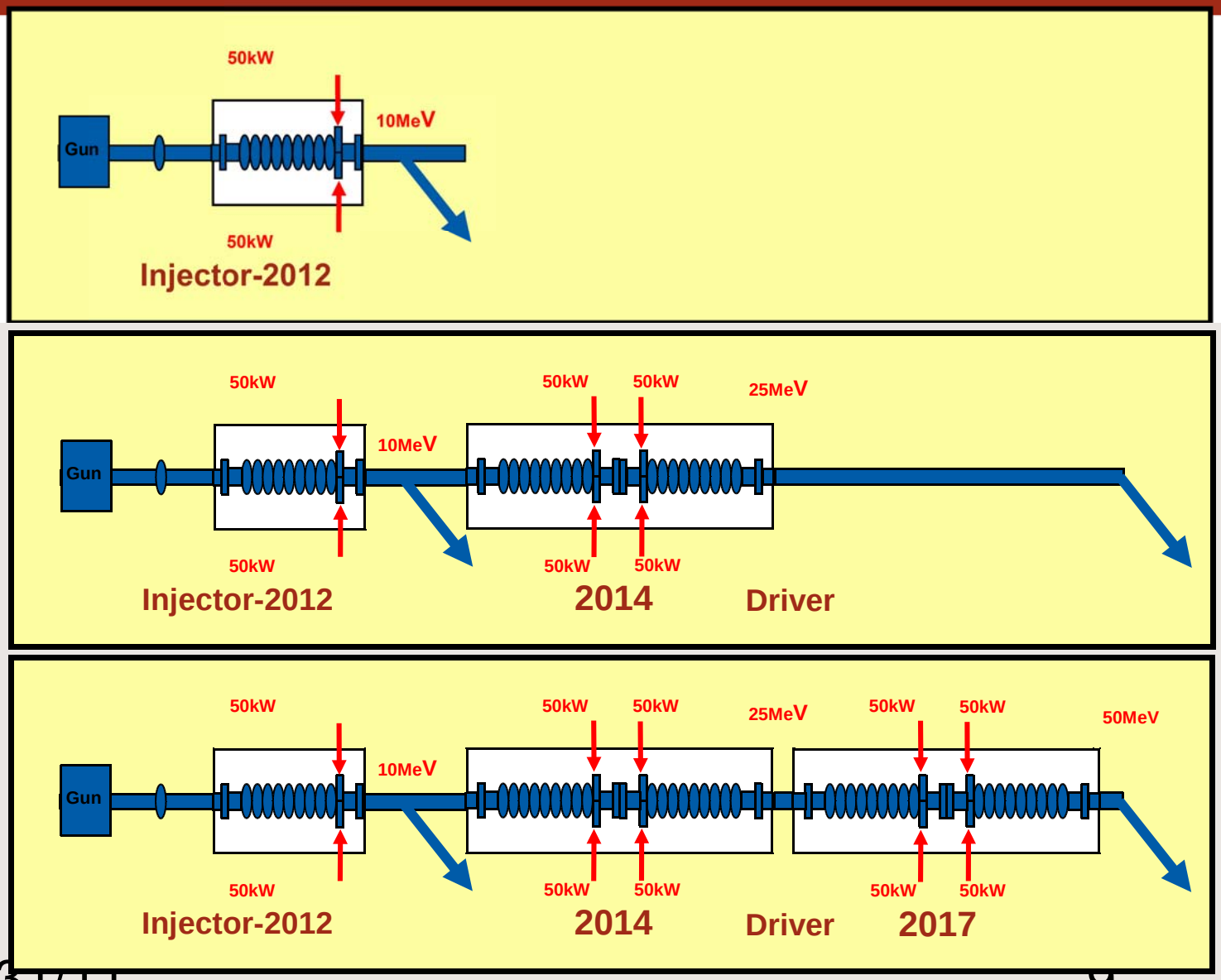
Kinetic energy (MeV)	50
Average current (mA)	10
Duty Factor	100%
Beam Power (MW)	0.5

e-Linac: MW-class Superconducting Electron Accelerator at TRIUMF



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).

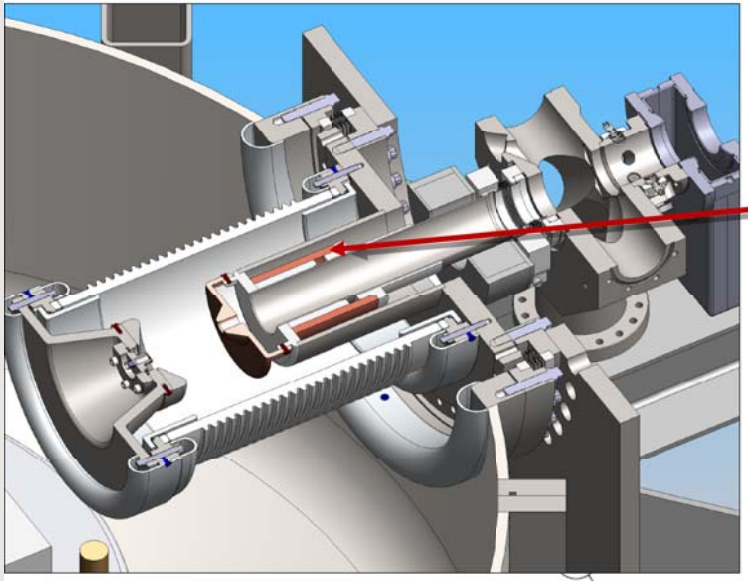
TRIUMF e-Linac Staging



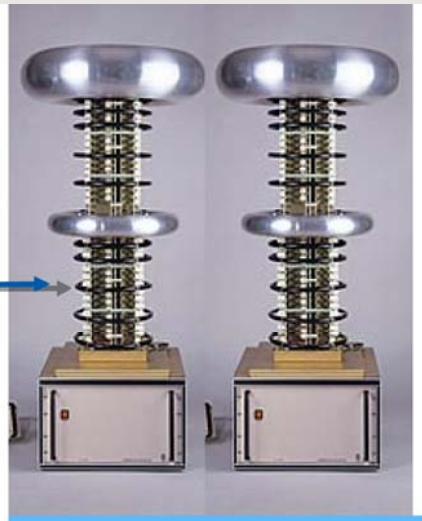
VECC Collaboration

- 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

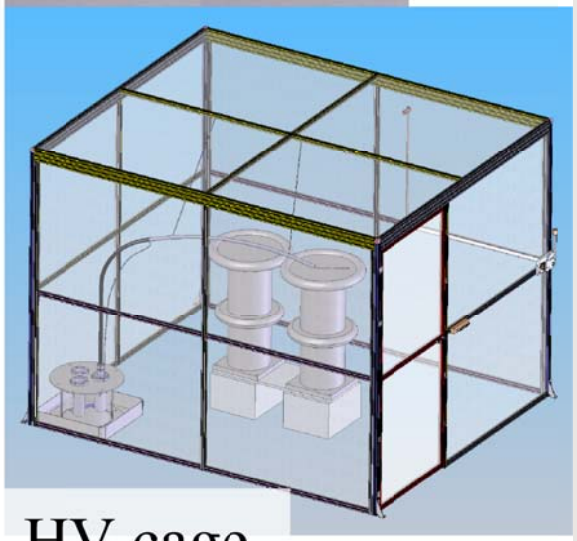
300 keV Thermionic Gun



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

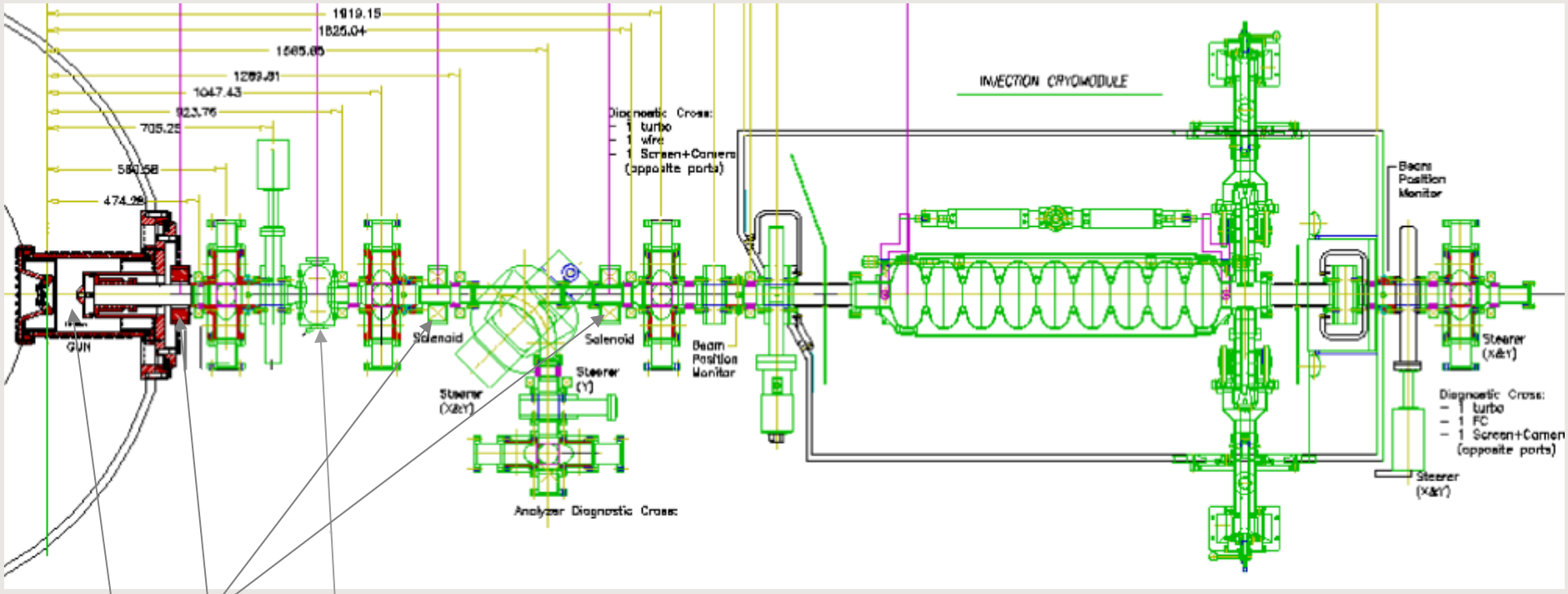


Critical path:
Electrodes,
Gun vessel.
Project Completion:
2012 Feb.



HV cage

Low Energy Transport, ICM



e-Gun

Solenoid

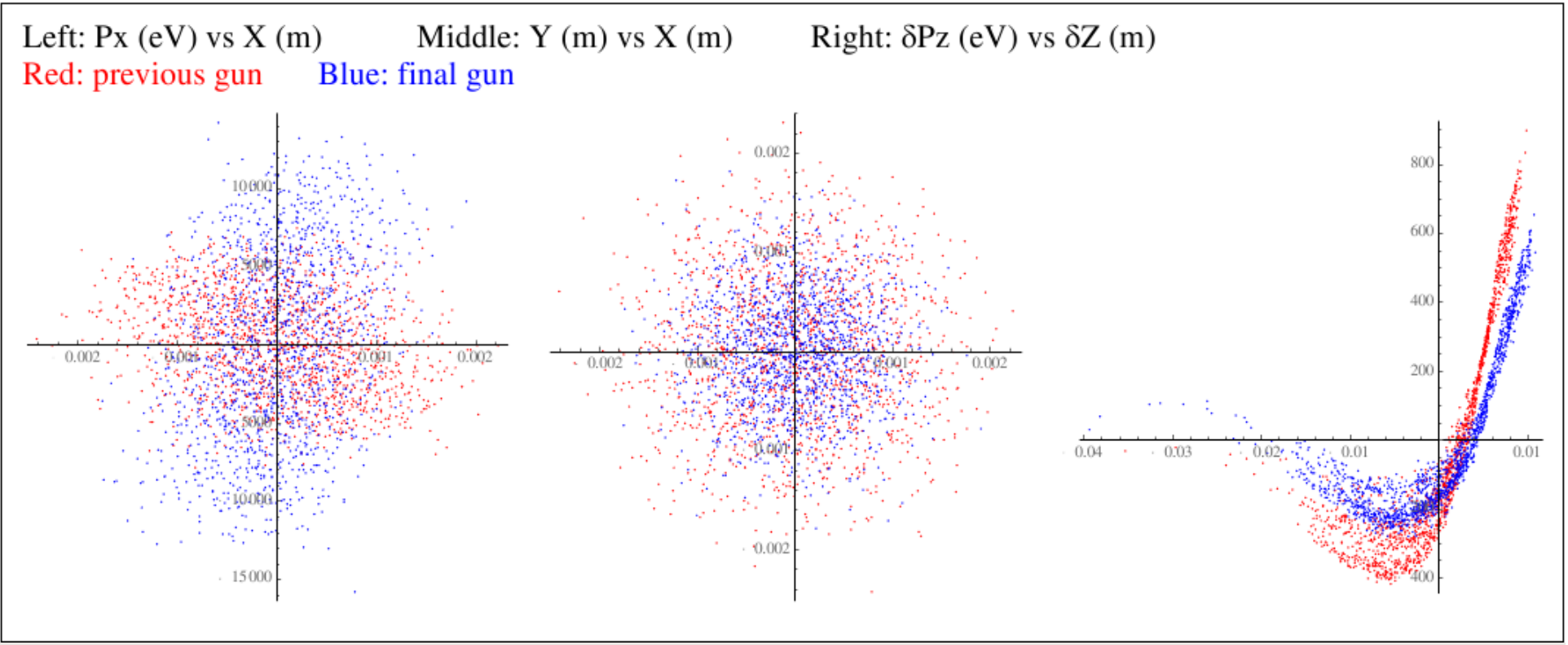
Buncher

Analyzer

IC
M

Gun, Optics, Layout Optimization

– performed using a genetic algorithm (Bazarov, Sinclair 2005)



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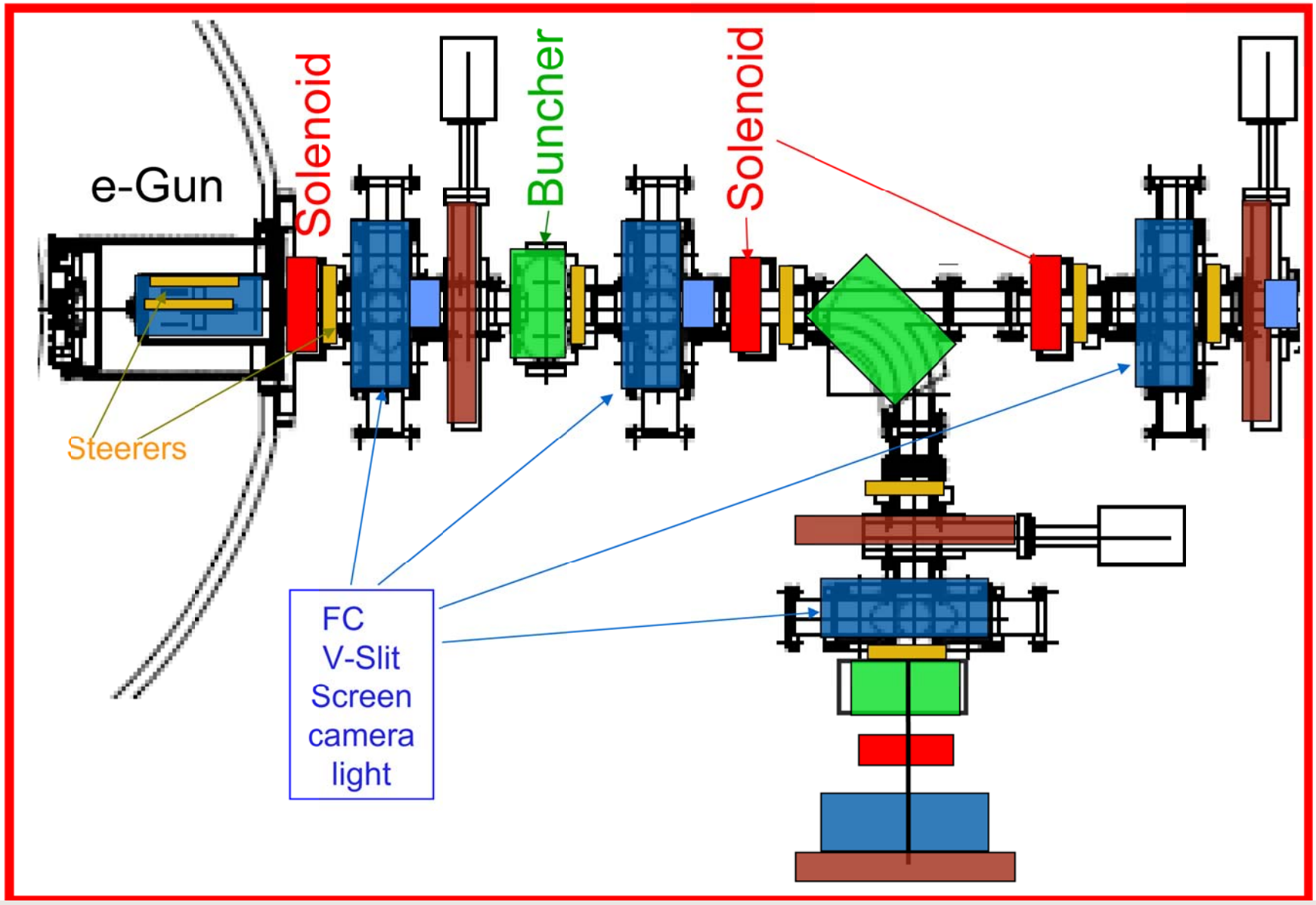
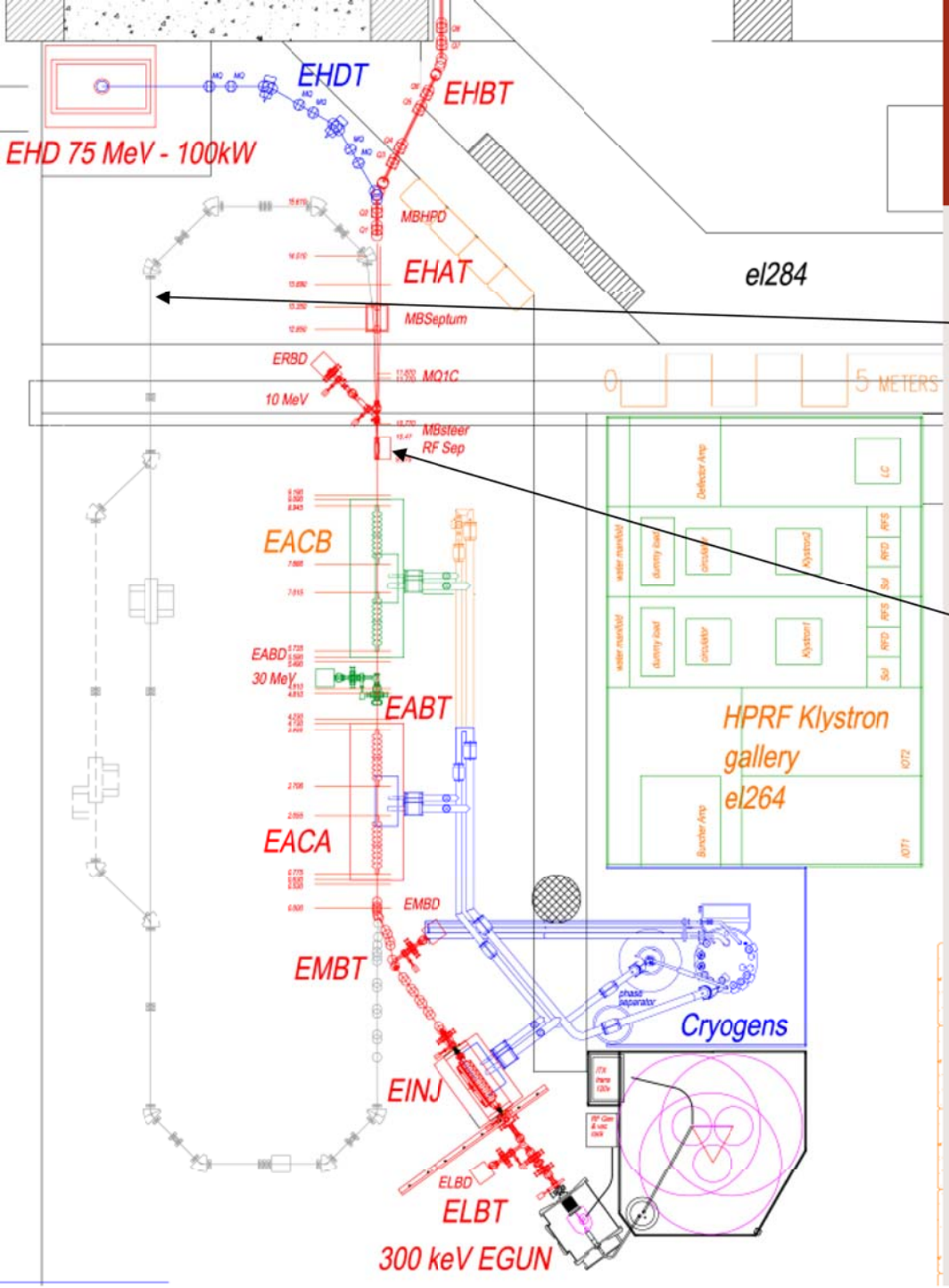
VECC Gun/LEBT Layout



Layout

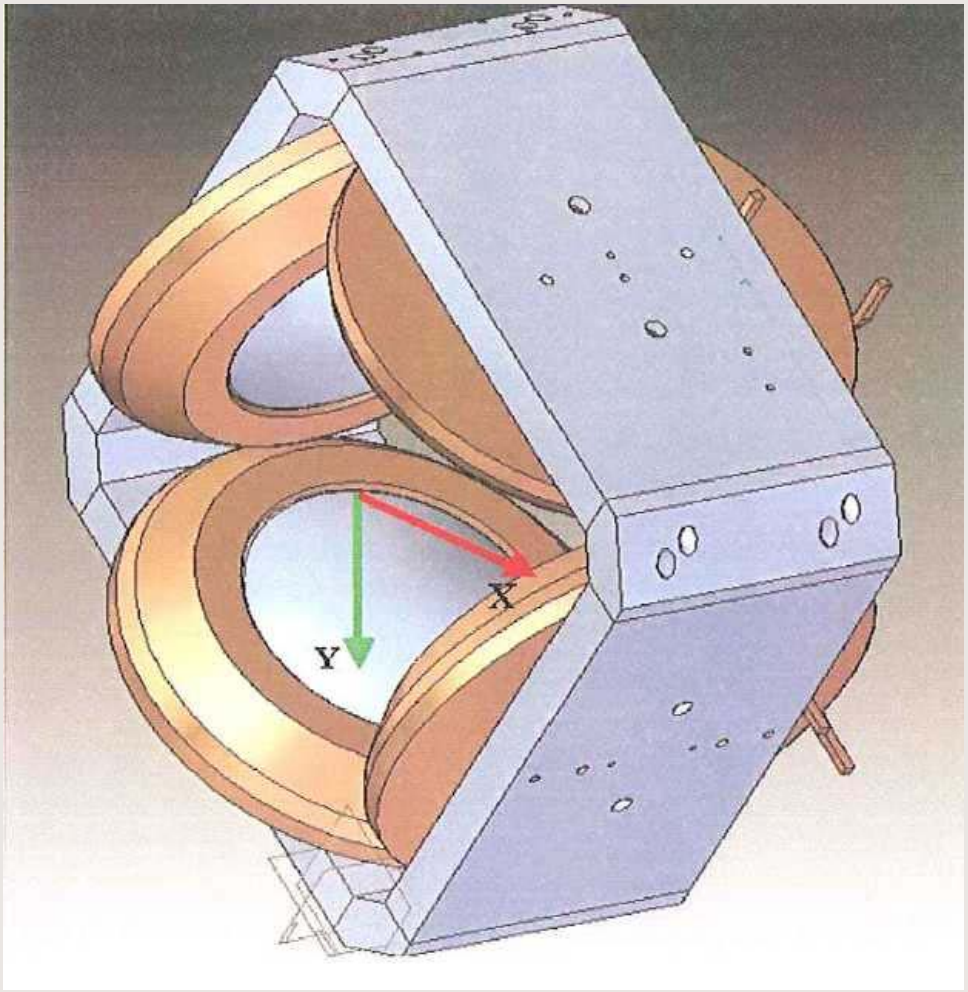


Note the (gray) ERL. In order to share with photofission, this requires an rf deflector.

10MeV, 50MeV Transport

RMS Emittance = 5μm, so σ ≈ 1mm.

There are 76 quadru-poles, aperture diameter 52mm. As they are weak, most will be very short (yoke length = aperture dia.) with spherical poles.. Most will be air-cooled.



Transport

For details on tranport, 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

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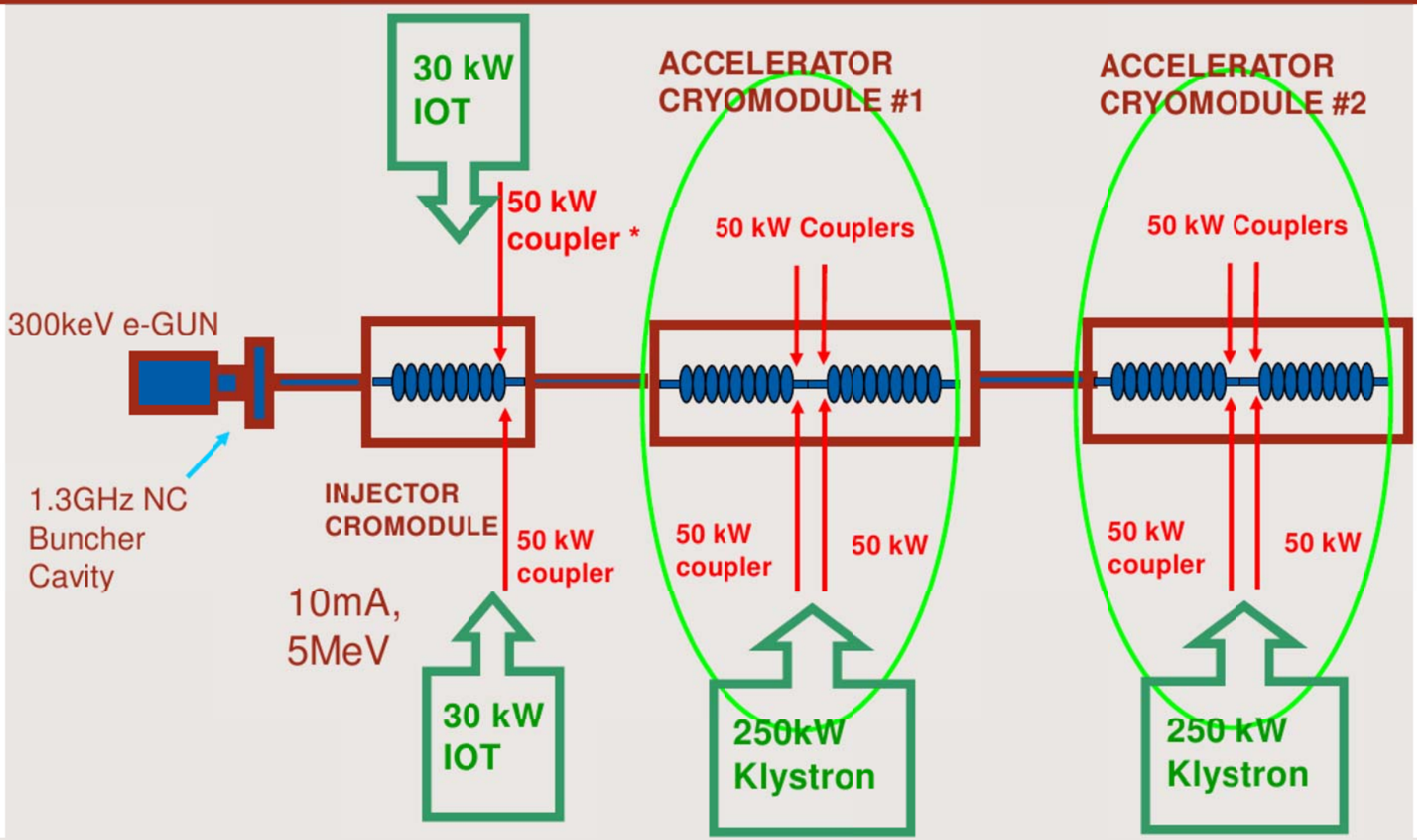
Beam Physics Challenges

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

RF Layout


30 kW
IOT
ACCELERATOR
CRYOMODULE #1
ACCELERATOR
CRYOMODULE #2
50 kW
coupler *
50 kW Couplers
50 kW Couplers
300keV e-GUN
1.3GHz NC
Buncher
Cavity
INJECTOR
CROMODULE
50 kW
coupler
50 kW
coupler
50 kW
50 kW
coupler
50 kW
10mA,
5MeV
30 kW
IOT
250kW
Klystron
250 kW
Klystron

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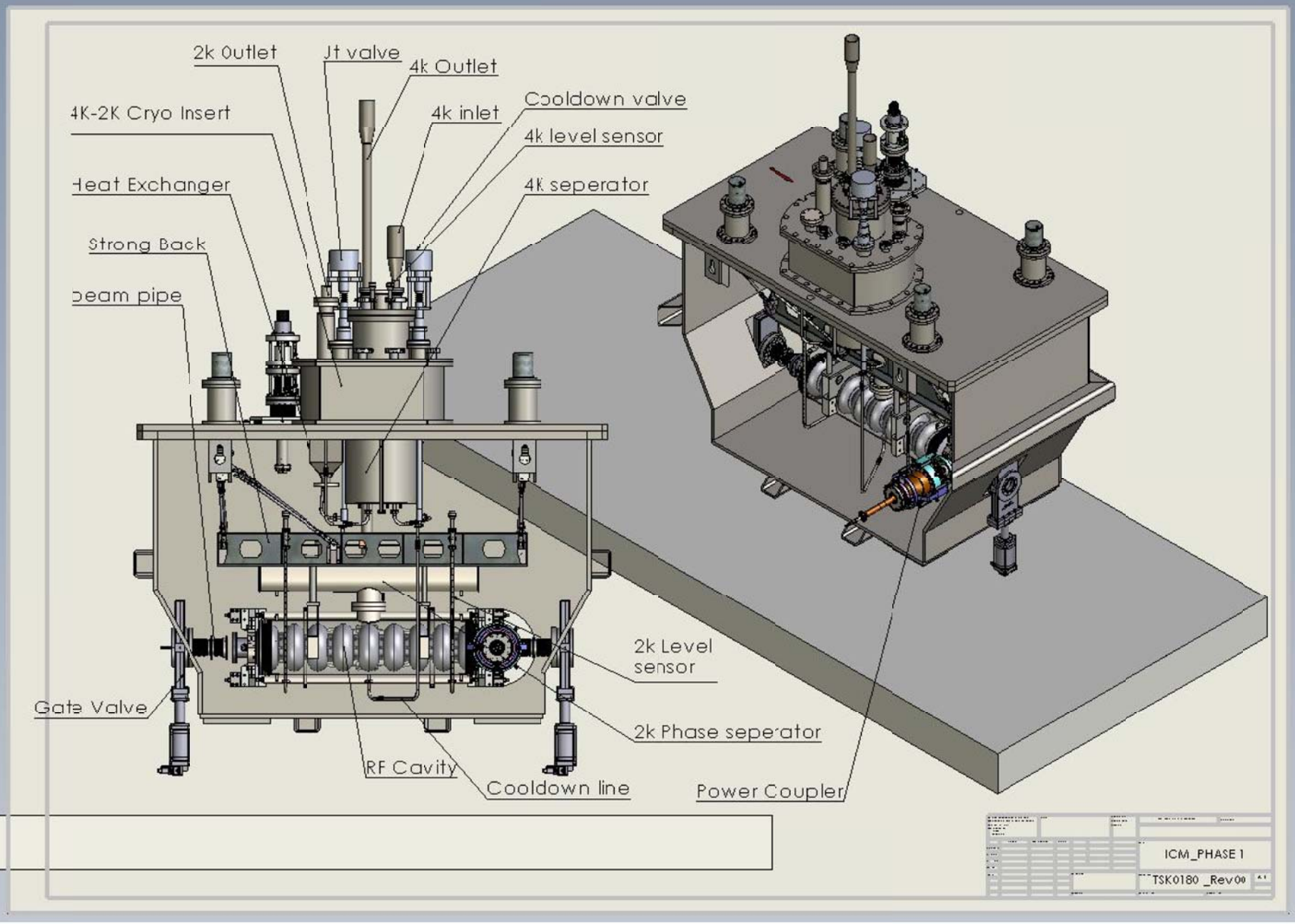
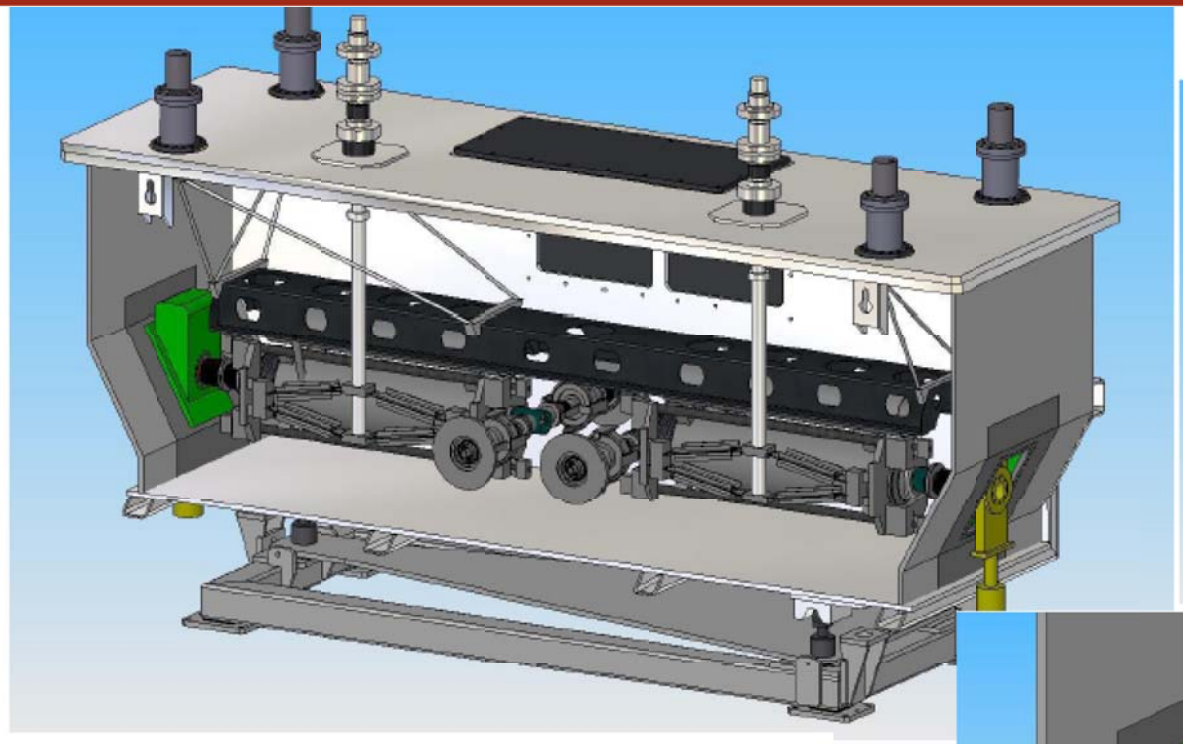
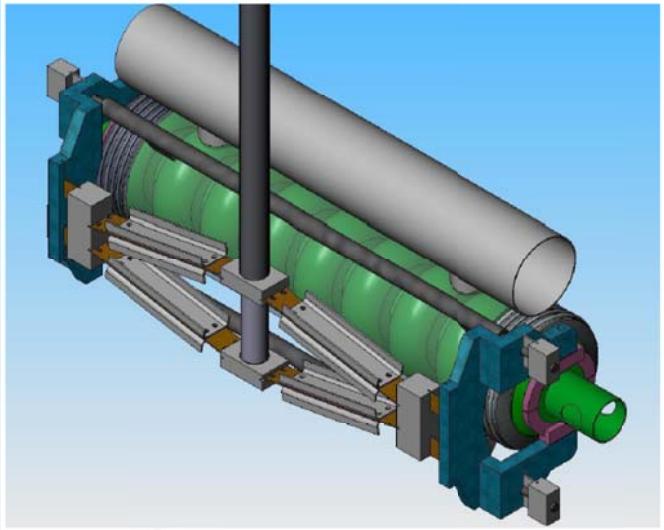
Injector Cryo Module

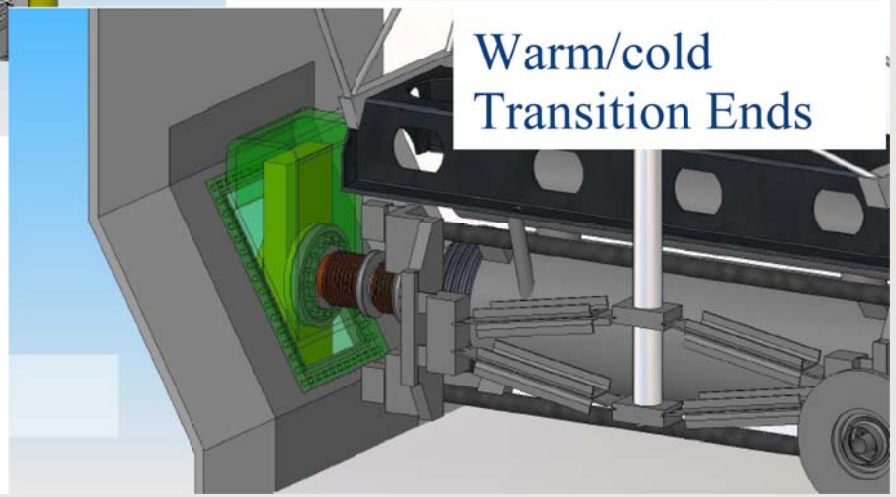


Accelerator Cryomodule



Scissor-Tuner Assembly





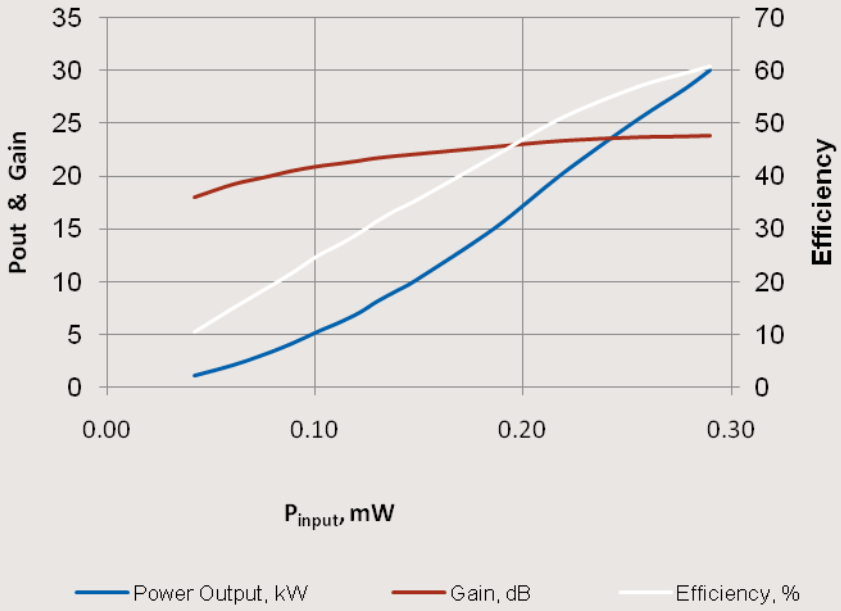
Warm/cold
Transition Ends

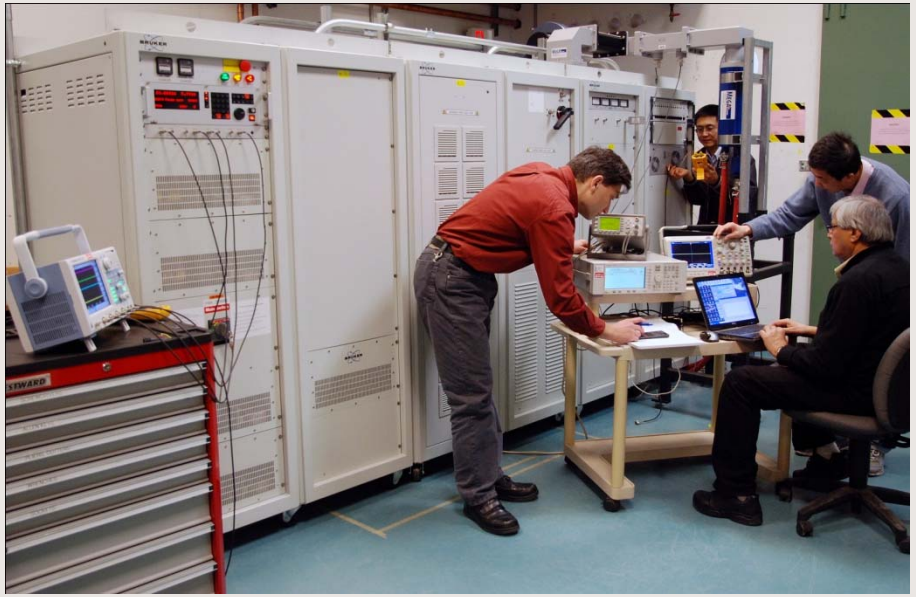
two-cavity ACM design

Accelerator CM equipment test: 2014 Feb

30 kW IOT Transmitter

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.

E-linac papers at this conference

MOPC126: *High Power RF System for TRIUMF E-Linac Injector* – A. Mitra, Z. Ang, S. Calic, S. Koscielniak, R. Laxdal, R.Shanks, Q. Zheng

MOPS047: *Studies of Transverse Single-pass Beam Breakup in E-Linac* – D. Kaltchev, R. Baartman, Y.-C. Chao, P. Kolb, S. Koscielniak, Lia Merminga, A. Mitra, V. Zvyagintsev

E-linac major equipment procurement

- 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.

e-Linac: A "green" Accelerator

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
} ~10 MW heat generated
Presently using ~3000 litres/min through cooling towers => ~6 MW

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!

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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