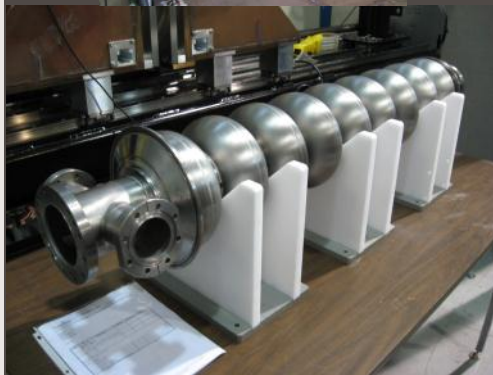
TRIUMF

Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

TRIUMF ARIEL E-linac



NA-PAC, Pasadena CA, 2013 Sept 30

Shane Koscielniak

For e-linac team

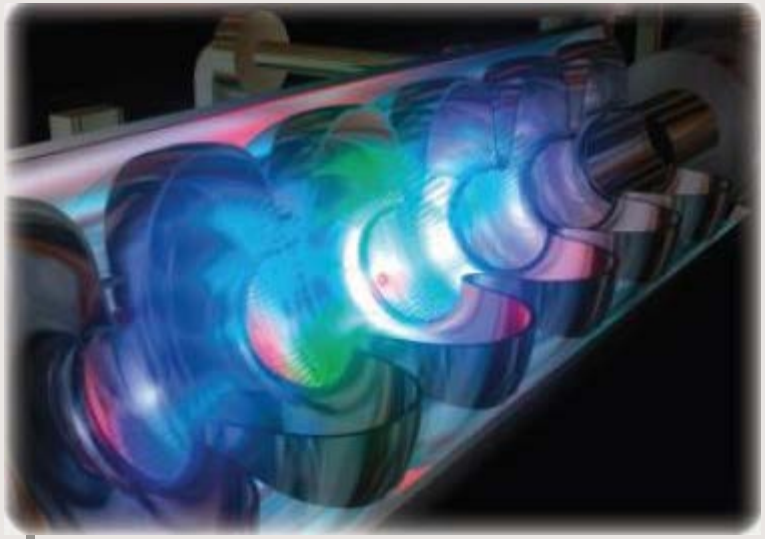
E-linac Update: Outline

- Introduction
- ARIEL Construction
- Cryogenic & HPRF
- E-gun & Beamlines
- Cryomodules & SRF
- Conclusion

ARIEL Mission Statement

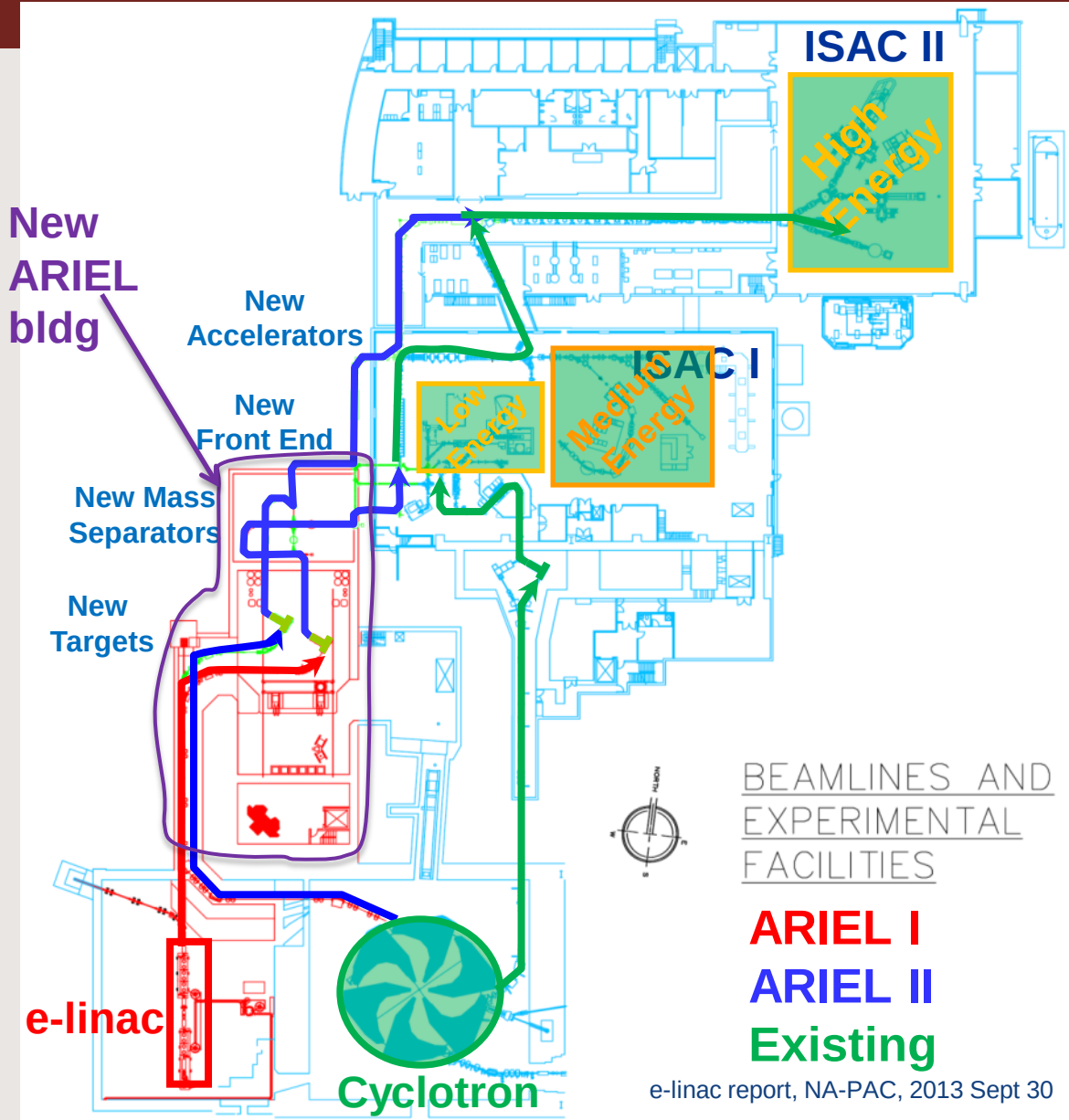
The primary mission of ARIEL is to deliver unprecedented intensities of rare, short-lived exotic isotopes, and in particular those with extreme neutron excess, to simultaneous and multiple experiments, at the existing and world-leading ISAC accelerator complex.

Courtesy Greg Hackman (TRIUMF staff scientist)



A secondary mission of ARIEL is to anticipate future uses of e-linac technologies such as free electron lasers, and including commercial uses such as the production of medical isotopes by photo-fission.

ARIEL eliminates bottle-neck & triples RIB science



10-Year Vision: expanded RIB program with:

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

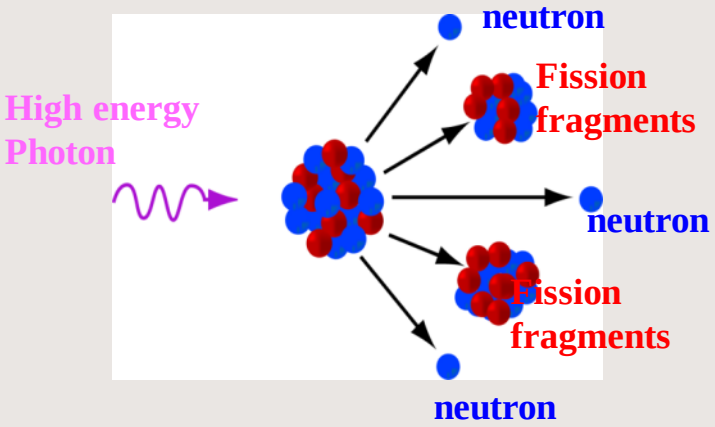
Implementation:

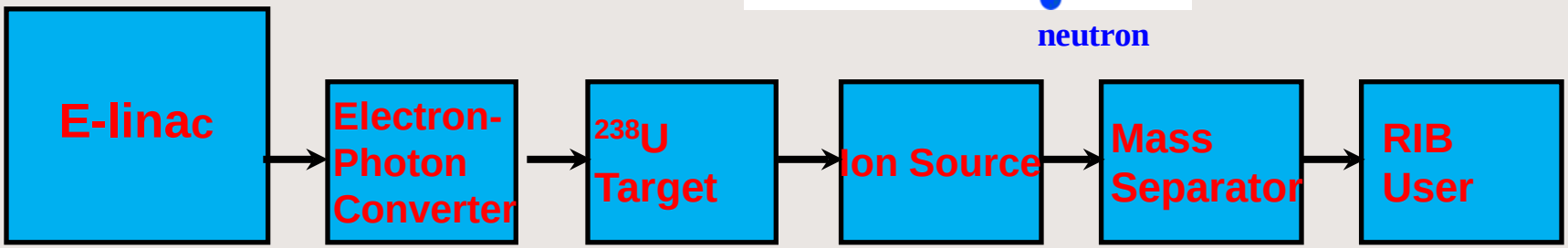
- Complementary electron linac driver for photo-fission
- New target stations and front end
- New proton beamline
- Staged installation

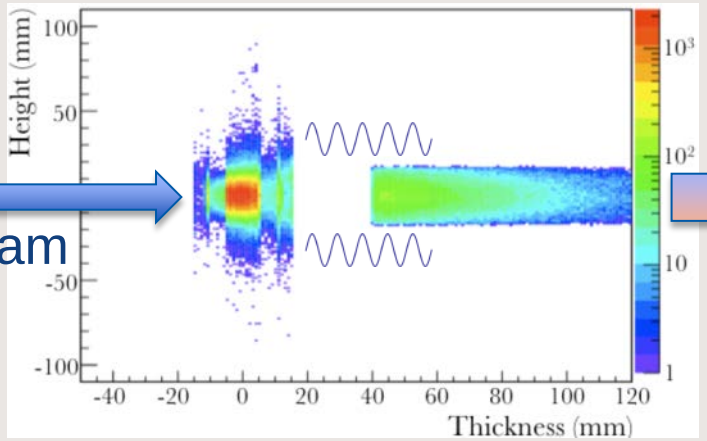
e-linac report, NA-PAC, 2013 Sept 30

Photo-fission production of Rare Isotope Beams

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







E-beam

RIB & neutrons, γs

ARIEL Construction Complete

ARIEL Target Hall Complete

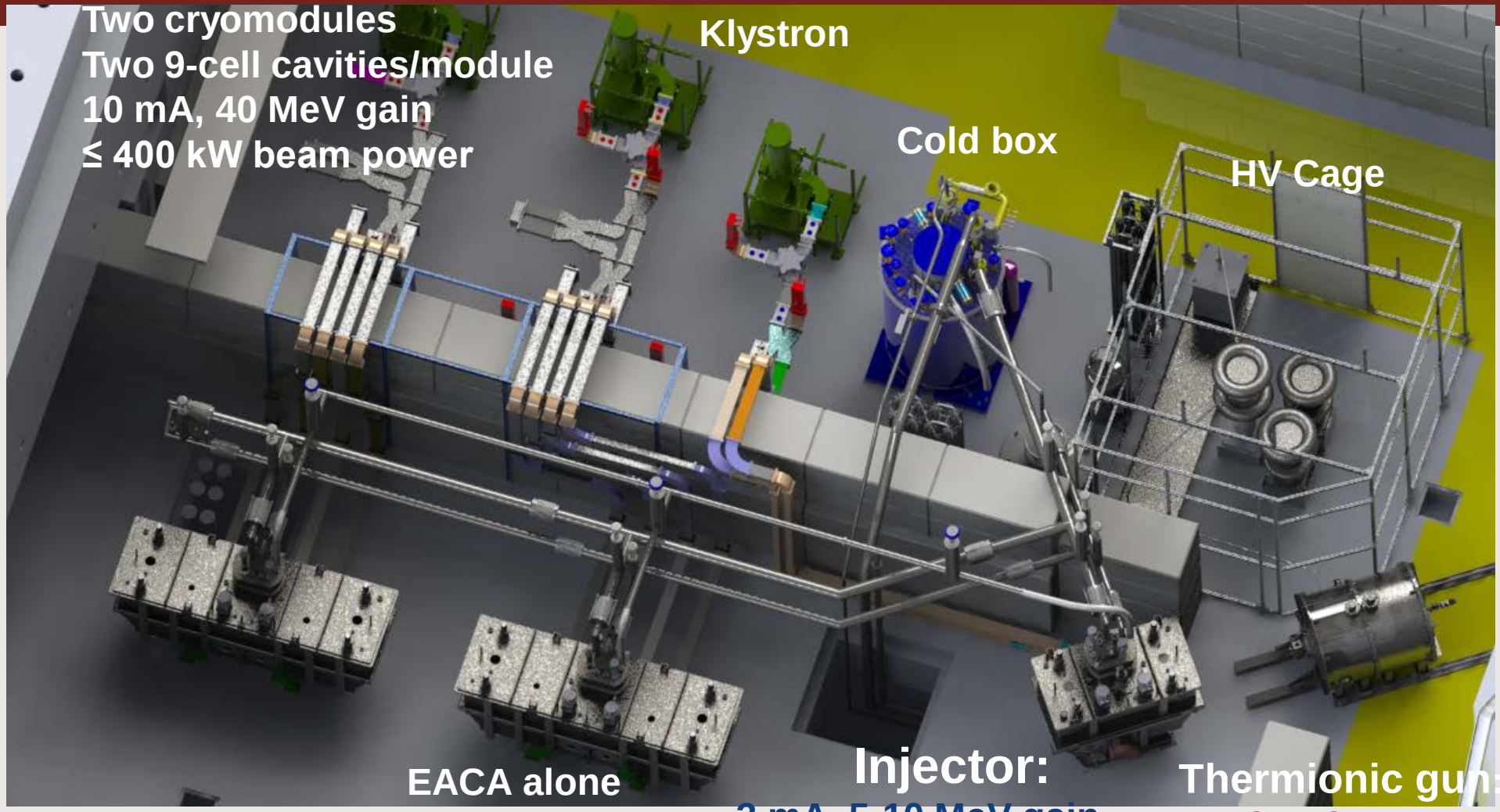
All hands mtg 2013 Aug 2nd

Provisional Occupancy Request to UBC: August 1st (with exclusion areas)

E-Linac in e-hall

Accelerator

Two cryomodules
Two 9-cell cavities/module
10 mA, 40 MeV gain
≤ 400 kW beam power



EACA alone
installed 2014
July 10

Injector:
3 mA, 5-10 MeV gain
≤ 30 kW beam power

Thermionic gun:
300 keV in SF6;
650 MHz

Helium Compressor Building Complete

Services:
Water - 90%
HVAC - 90%
Electrical - done
Service Air - done
Data - done
Controls - 70%

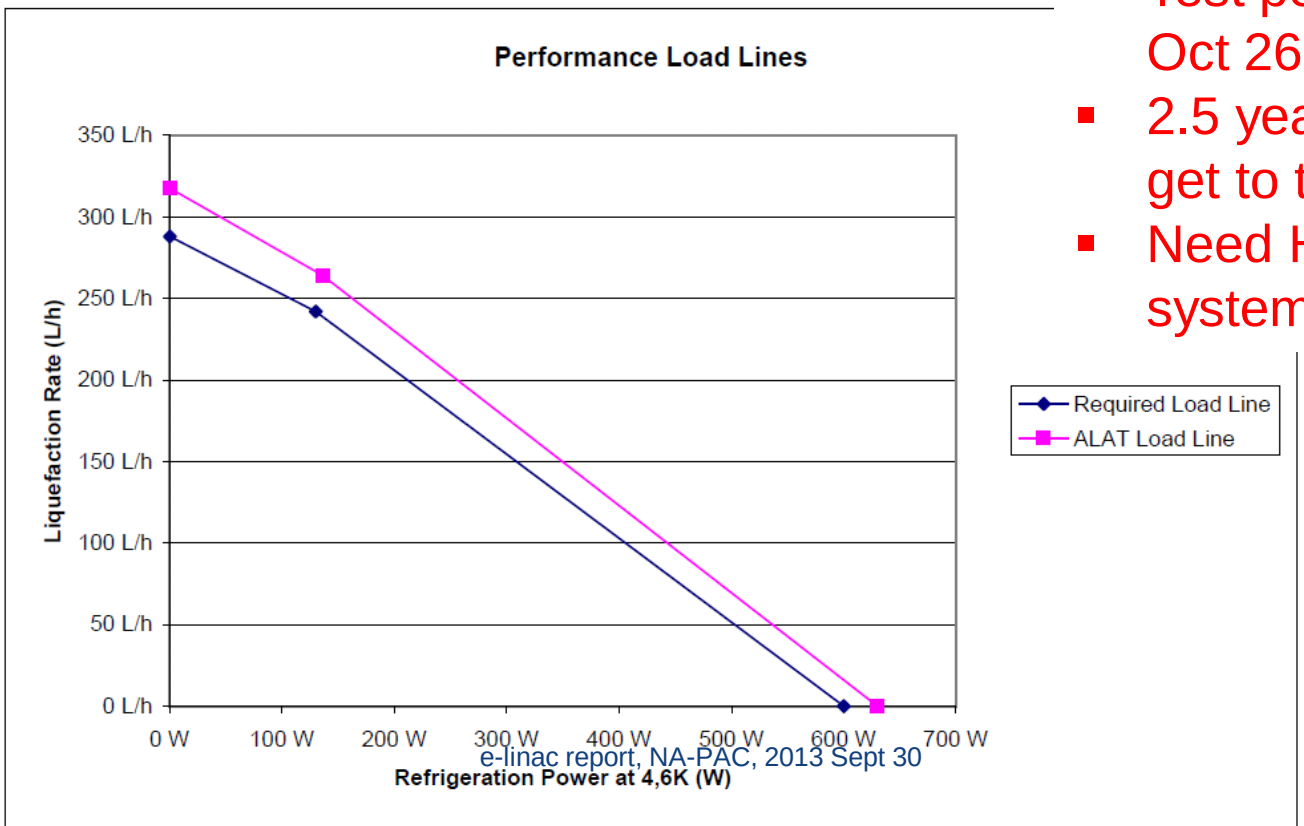
Connected to UPS & emergency power 2013 July 05

Cryogenic Plant 4K Acceptance Test

	Specification (with LN2)		ALAT Process				COMMENTS		
			With LN2		Without LN2*		LN2 Consum.	Compr. Flow	Joule-Thomson Expansion **
	REF.	LIQ.	REF.	LIQ.	REF.	LIQ.			
100% Liquefaction	0 W	288 L/h	0 W	318 L/h			113.2 L/h	90 g/s	simple
Guaranteed Mixed mode	130 W	242 L/h	136 W	264 L/h			98.0 L/h	93 g/s	simple
Mixed mode 2*	NA	NA							
Mixed mode 3*	NA	NA							
Mixed mode 4*	NA	NA							
100% Refrigeration	600 W	0 L/h	630 W	0 L/h			28.1 L/h	90 g/s	double

*Calculation in progress : All modes without LN2 + Mixed modes 2,3 and 4 with LN2

** The JT expansion type (simple or double) is chosen, so as to optimise the performance.



- Test performed Oct 26 – Nov 18
- 2.5 years effort to get to this point
- Need He and LN2 systems

Cryogenic System Status

Required for ALAT acceptance test 2013 Oct

Helium Refrigerator/Liquefier:

- ALAT Cold box – services connected.
- Main & recovery compressor – installed, prepped for start-up Oct.
- ALAT Oil removal and gas management system – installed
- He Dewar – refurbished, flange and heater ready
- He buffer tank – installed, 4bar He gas for start-up Oct.
- Purifier and absorbers (MoU with FNAL)

Helium Distribution System:

- Cold transfer lines – delivery expected 2013 Dec
- Warm piping – complete/installed
- Sub-atmospheric Line – tender documents in progress

2K sub-atmospheric components:

- SA Pumps - delivered, tested
- He SAL HEX – delivery expected Oct 18th

Liquid nitrogen system

- LN2 distribution to cryomodules – RFQ in progress
- Transfer lines (prefabricated) – installed
- Phase separator & Ambient vaporizer – installed
- LN2 storage tank - existing

Dewar received 2012 Dec.
Dewar and LN2 Phase separator instrumented & installed.
Remaining: controls.

4K Cold box delivered 2013 March 28
Services installed and 95% ready for acceptance test.
Remaining tasks: Pumping & purging; Turbines installation.

GHe System installation

Factory test complete, 2013 Feb 05

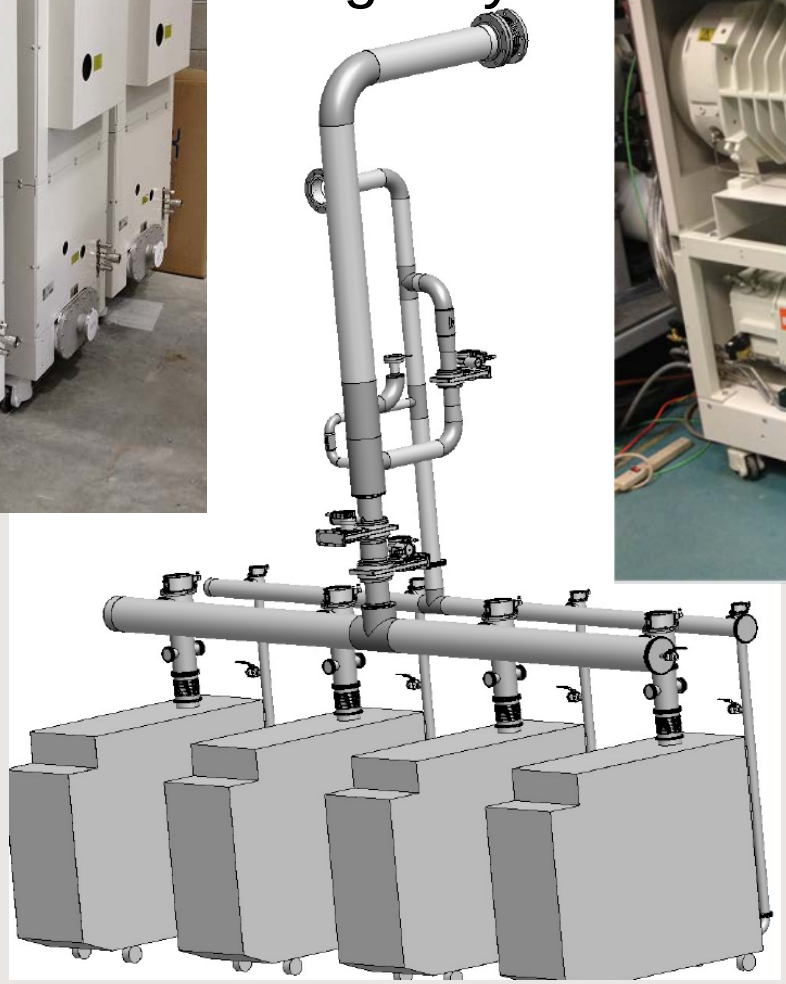
ALAT Oil Removal & He gas management system
Delivered 2013 March 28

Kaeser compressors Delivered 2013 Jan 31

- CSA approval August 2nd for B2L control cabinets.
- Electrical hook up Aug 21-23rd for Kaeser.

2K Subatmospheric helium pumps

Design layout



4 BUSCH Combi DS3010-He pumping units **delivered to TRIUMF March 15.** Helium throughput ~1.4 g/s at 24 mBar each

Test of the pumping unit at SRF facility

Roots blower & screw type backing pump

Vaporizers, warm He, LN2 piping for e-hall and CB installed & connected

e-hall LN2 vaporizer installed & connected to GN2 exhaust piping

Warm He piping installed

GHe storage tank leak-tested, evacuated and flushed with helium. Building an inventory for the compressors start-up.
LN2 vaporizer is operational – sending flow of GN2 to dry carbon beds of ORS.

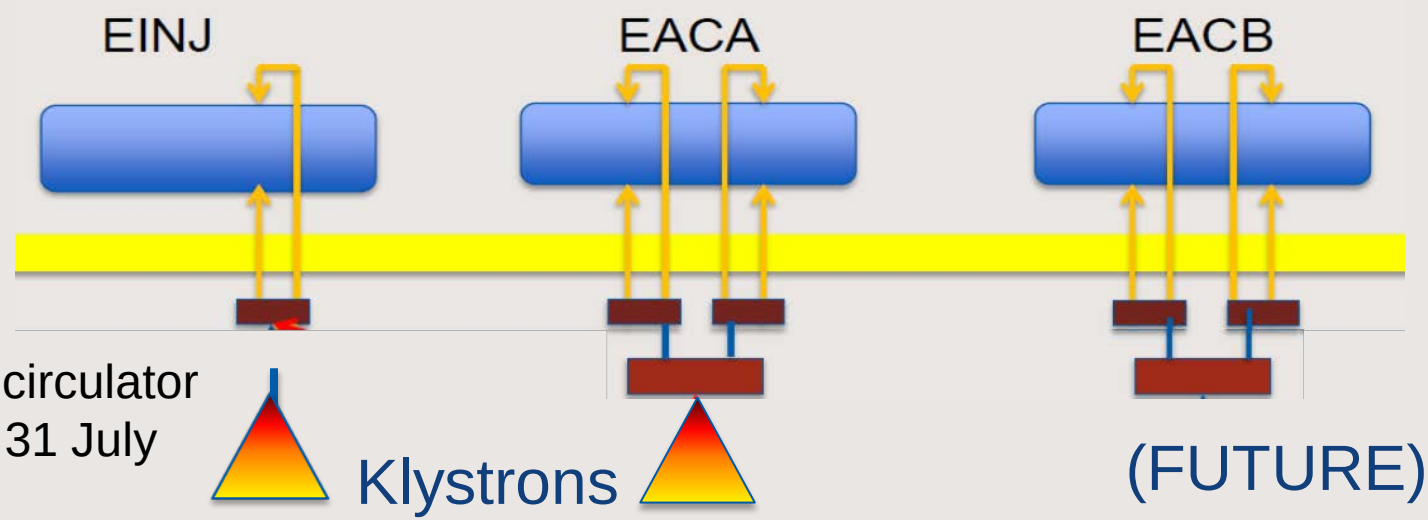
Cryogenic System Milestones

- **Warm Piping complete: 2013 Sep 23**
- **Cold box cool down start: 2013 Oct 26**
- **ALAT tests complete: 2013 Nov 18**
- **NEXT STEP: 2K test in e-hall needs:**
- Cryomodules with 4K/2K insert in e-hall
- LHe-2-CMs distributn lines complete & tested: 2014 Jan 12
- LN2-2-CMs distrib lines complete & tested: 2014 March 15
- 2K SAL in e-hall complete & vac tested: 2014 June 1
- Cryo-system commissioning complete: 2014 July 1

E-linac: High Power RF (WEPHO01)

Two 290 kW klystron and HVPS ordered.

- 1st klystron provides 100 kW rf for EINJ beam test May 2014.
- 2nd klystron provides 200 kW rf for EACA beam test Sept 2014.



Milestones

- EINJ klystron/HVPS 300kW RF test to dummy load: 2013 Oct 21-25
- HPRF test to EINJ waveguide load complete: 2014 Jan 29
- EACA klystron and HVPS acceptance test complete: 2014 June 13

290 kW klystron procurement

CPI Factory Test

- Started 2013 Jan 04
- 300kW achieved Jan 21
- 150kW parameters also established.

Peter, Thomas, Amiya, Stevo

klystron e-hall installation

Arrived TRIUMF: 2013 March 21

Installed June 21

- 2013 Aug 7th: 300 kW Power divider received
- 2013 Sept 17: The 300 kW circulator and water cooled waveguide loads received; Sept 25: installed
- 3 Stub Phase Shifter spec in progress
- Snubber from CPI, USA is expected Oct 1st (previously received damaged; returned July 19)

klystron HVPS installation

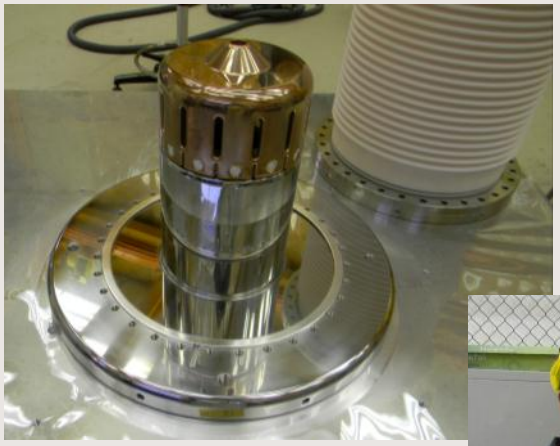
A. Mitra, A. Sphiger of Ampegon, and R. Shanks.

600kW 65kV Power Supply

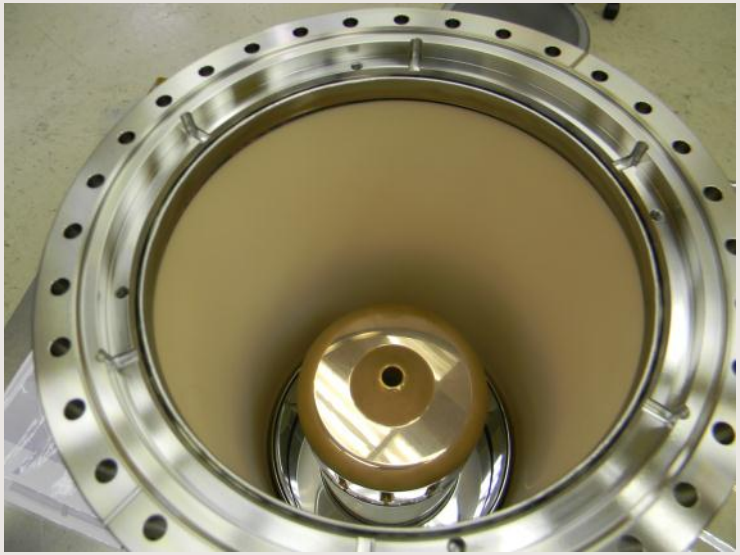
- HVPS uses IGBT-based, pulse step modulators (PSM)
- PM-14-10-VR is based on modulator PSM12-2400 for DESY XFEL
- 2013 May 29: Factory test
- Received Aug 14.
- Installed Aug 21.
- Commissioning October.

- Powered with UPS, and communication between KPS and PLC established – Sept 12
- 720 kV transformer energized via Siemens 12.5 kV Switchgear – Sept 21
- PLC to EPICS to be done
- Water cooling for KPS complete and interlocked.

300kV thermionic Gun

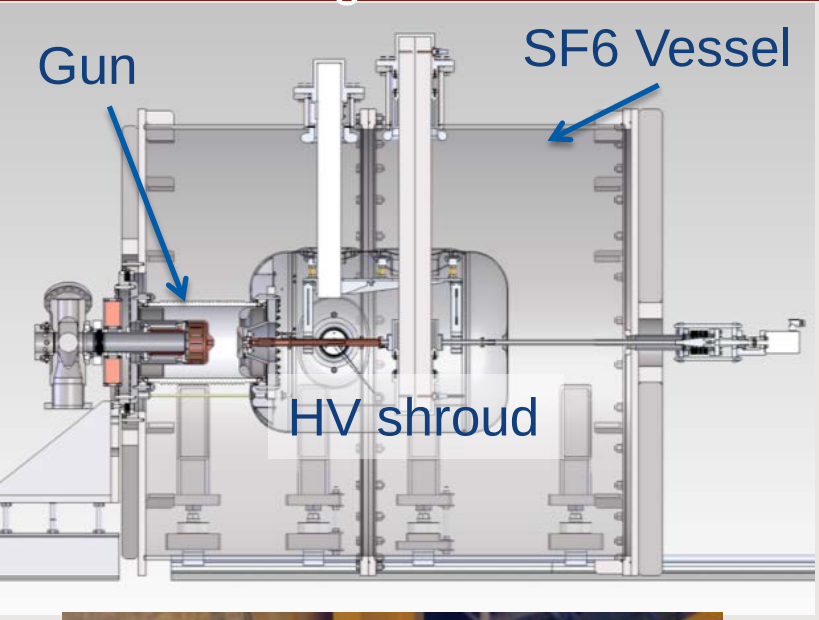


Assembled
2013 May 08



SF6 Vessel & HV shroud

Waveguide



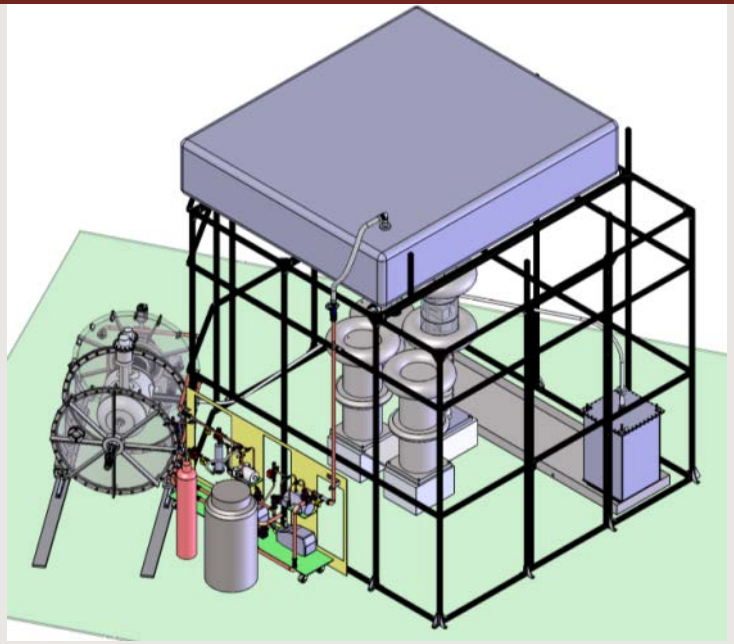
- 2013 May 17: Vessel delivered.
- May 24-3: Gun Installation

Aug 16: Ceramic waveguide & RF impedance tuner almost complete

2013 June 10: reached 10^{-9} Torr after 180 C bake

2013 Sept 07: Shroud sub-assy installed

300keV Gun progress

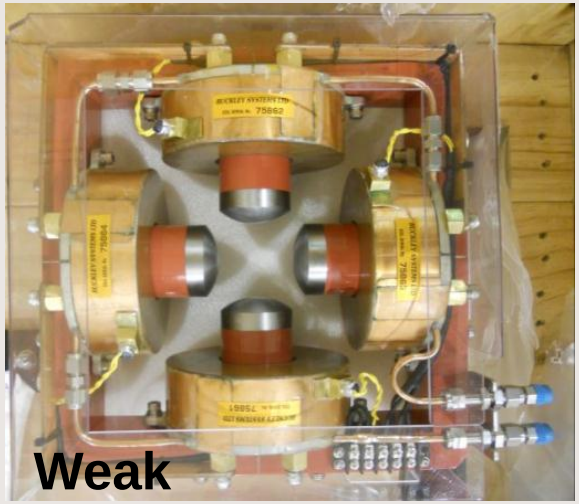


- HV cage installed May 27
- HV applied 2013 Oct 02
- Results pending…

Quadrupoles Magnets (WEZBB1)

Type	Weak	Medium	Strong
K value (Tesla)	≤0.2	0.2≤K≤0.7	0.9≤K≤1.3
Quantity	36	35	9

Prototypes received: 2013 Feb 28
First shipment: 2013 June 06
Last shipment: 2013 August 02



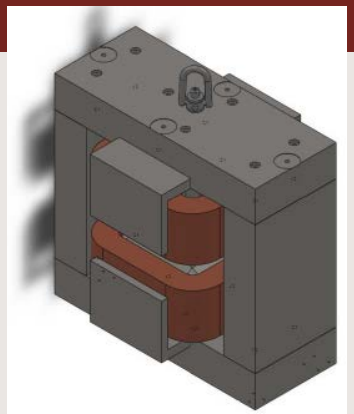
Medium

Strong

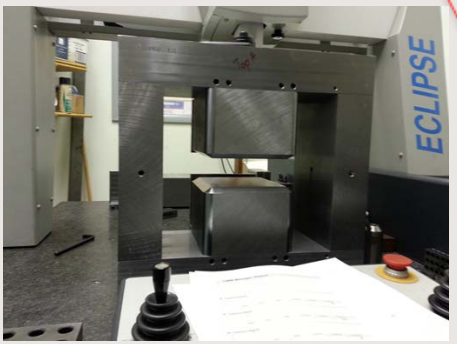
Beamline System milestones

- EMBT installed and equipment tested: 2014 May 01
- EHAT/EHDT installed, connected, tested: 2014 June 12
- EHBT in tunnel installed & equipment tested: 2014 Sept 30

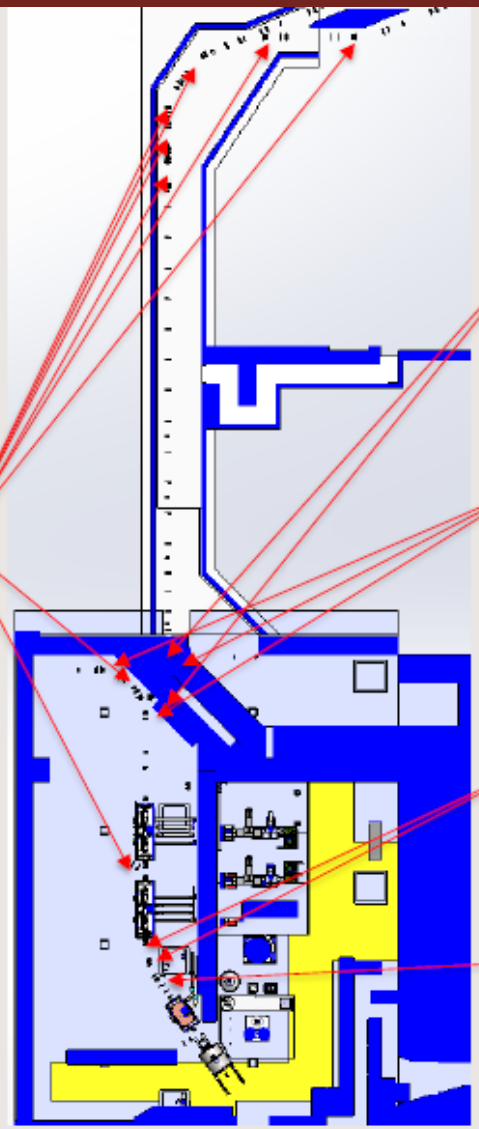
Dipole Magnets



S34 (qty=8)
Delivery
November 2013



Everson Tesla S34
Sept 24 yoke
measurements



DLVD (qty=2)
DN under review
Tender: October

Y30 (qty=3)
Contract let
Sept 23

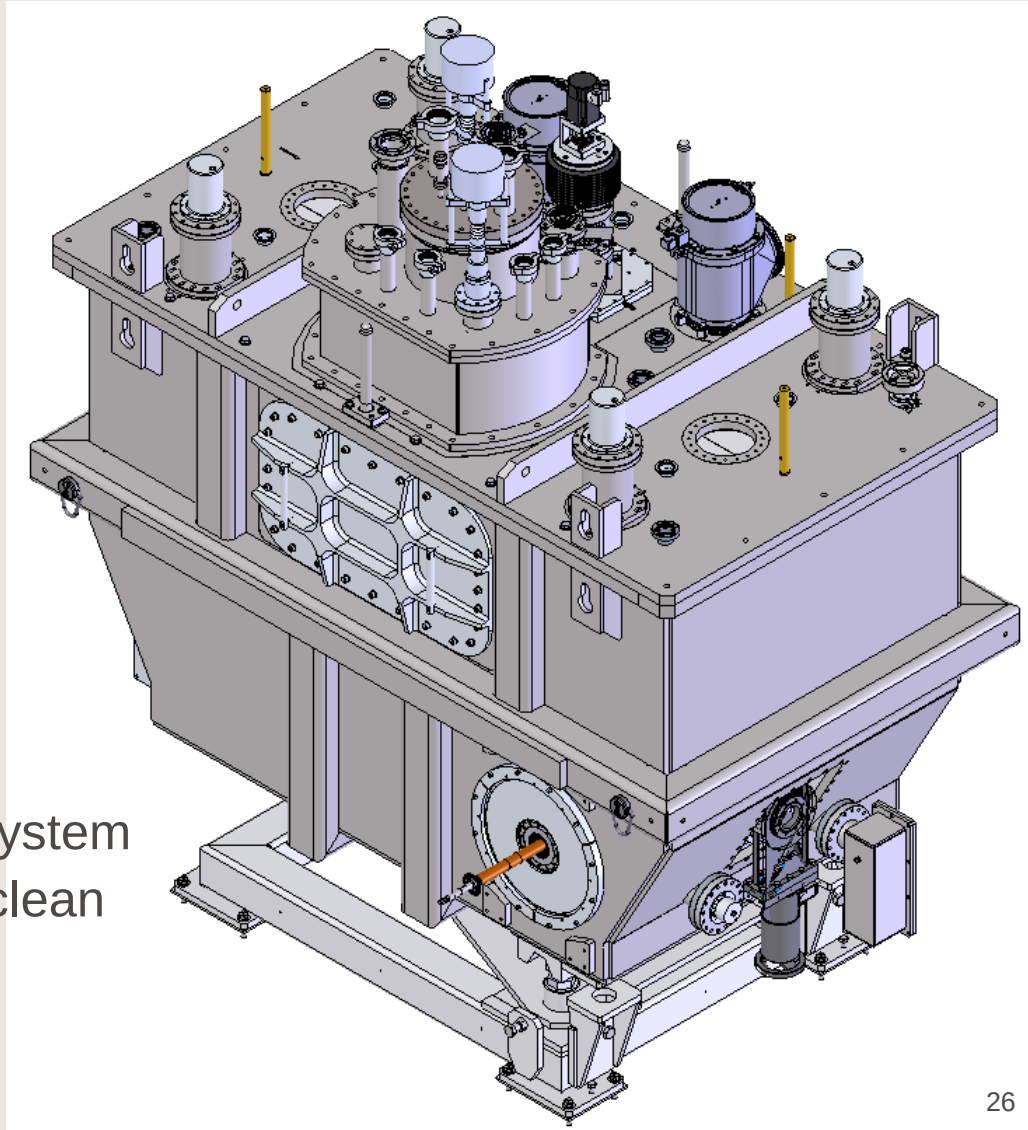
EMBT (qty=2)
Received 20th
June 2013

EMBD:MB0
(qty=1)
Received Jan

Injector Cryomodule Progress

All sub-assemblies are detailed and fabricated:

- Lid
- Tank (Vacuum vessel)
- EINJ Stand
- LN2 thermal shield
- Warm & Cold Mu-Metal
- Strong-back cavity support
- 2K Reservoir
- 4K/2K insert
- Tuner
- Warm Cold Transition (WCT)
- Wire Position Monitor (WPM) system
- Jigs/Fixture for alignment and clean room assembly

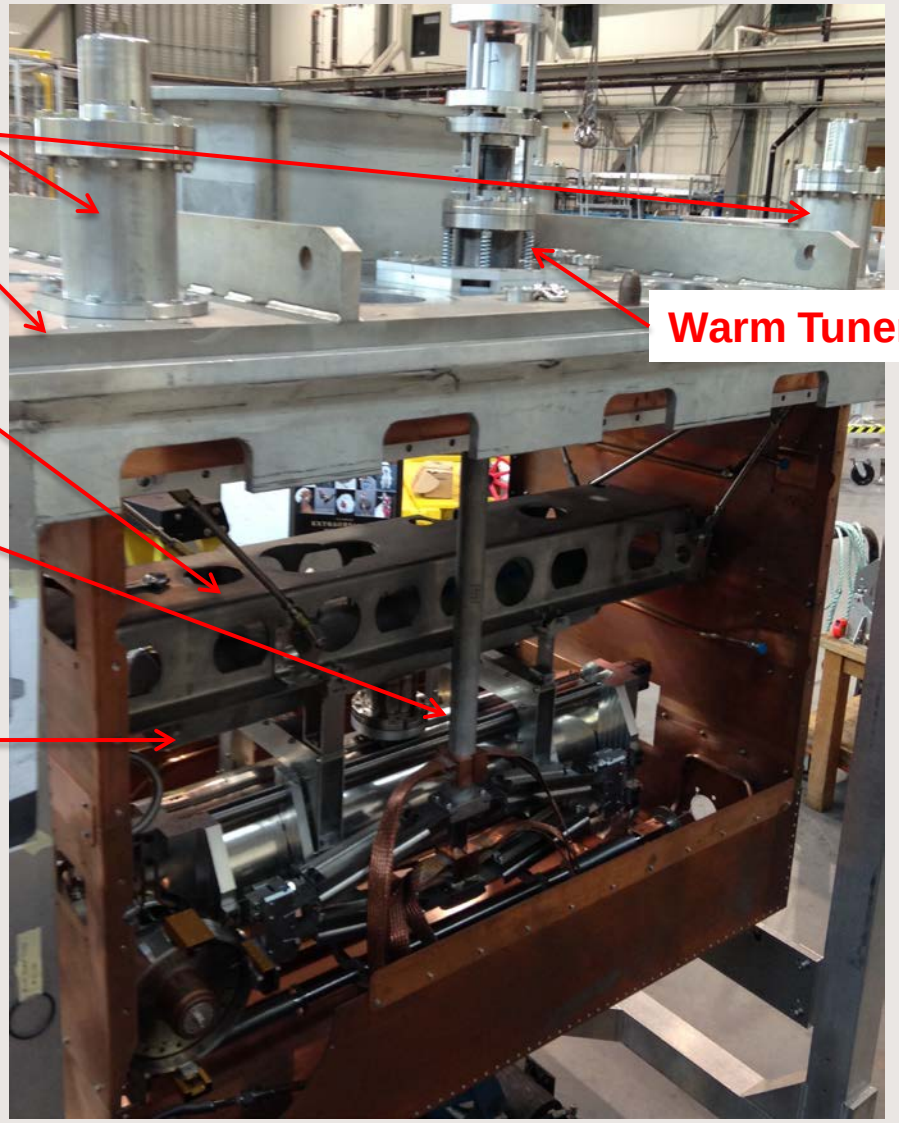


Mock-Up Assembly Status

Sub-Assemblies:

- Support Towers: Assembled and used in assembly.
- Lid: Leak checked with tank and used for assembly.
- Strut and Strong-back: Fully assembled and integrated with lid and cavity, no problems during assembly.
- Cold Tuner: Tested and assembled into Mock-Up, some minor interferences fixed in-situ and updated in design.
- Warm Tuner: Tested and assembled and integrated with cold tuner.
- 2K Reservoir: Leak checked and integrated with mock-up assembly.

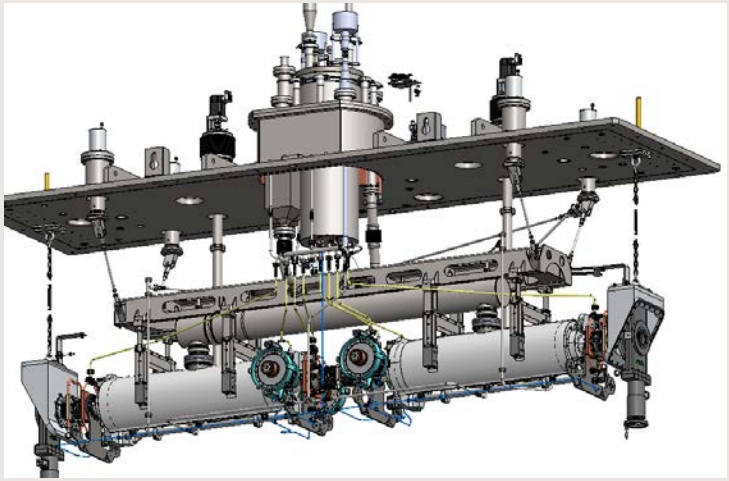
A mock-up is used to study assembly and ensure all parts will assemble and operate during final assembly with no interferences or conflicts.

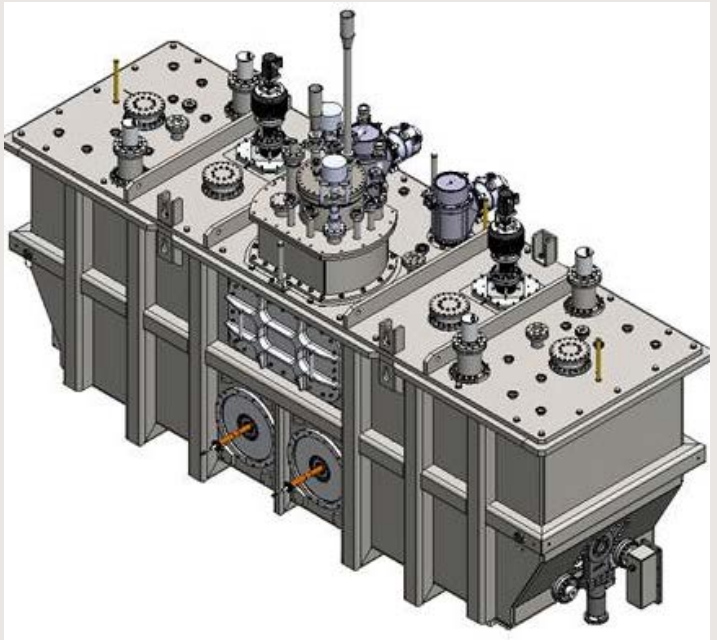


Accelerator Cryomodule Design Progress

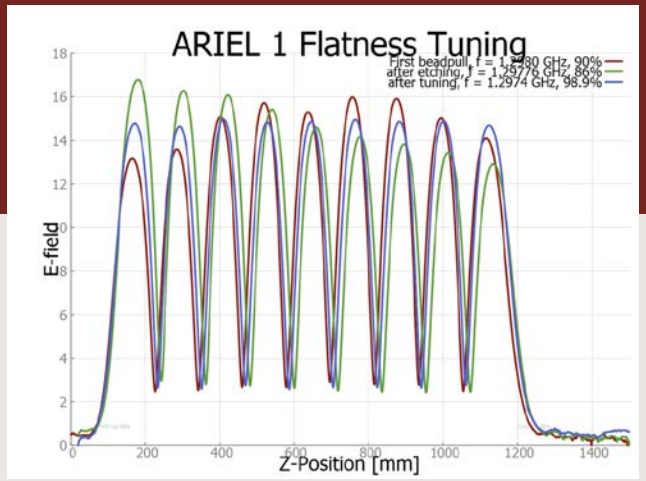
Design Tasks >95% complete

- Tank and Lid complete.
- Fabrication contract awarded June 26
- Strong-back and cavity support engineering & detailing complete.
- LN2 shield design & detailing complete.
- Intercavity transition detailing complete.
- 2K Reservoir detailing complete; finalizing burst disk.
- Tank stand detailing expected complete Oct 11th .
- Design completion 2013 October.





E-linac Nb Cavities



ARIEL1:

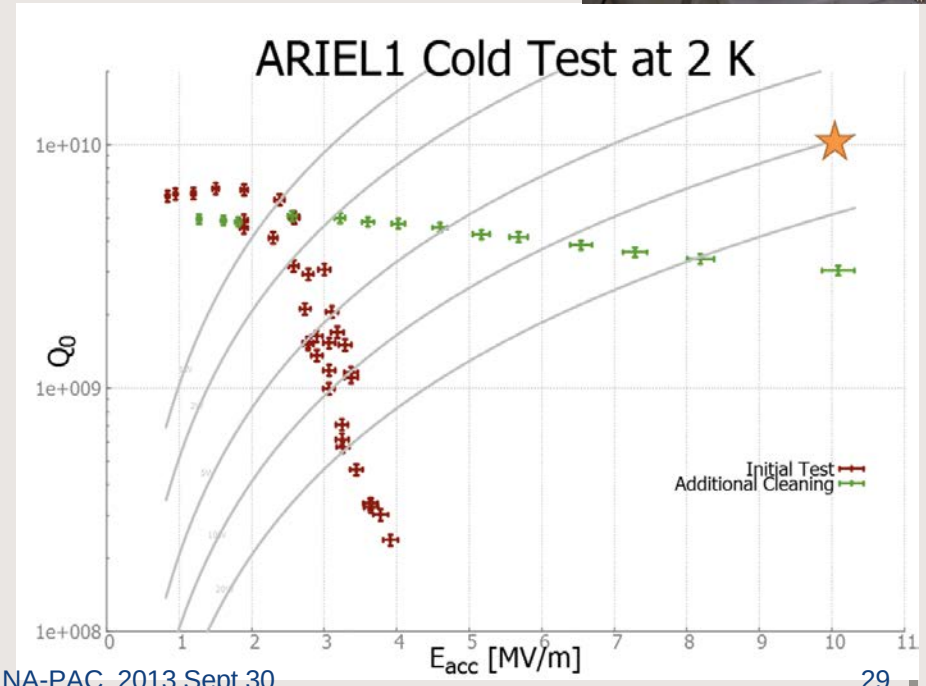
- Delivered 2013 May 28
- Cell frequency tuning complete
- 10 MV/m reached, with Q 3×10^9
- Limited by cryogenics (no quench, no field emission after cleaning)
- Next step: degassing at FNAL to increase Q and release Hydrogen
  - 4h@800C with Nb caps

ARIEL2:

- Fabricated, etched & tuned
- Ready for testing

ARIEL3

- Cells fabricated, in production



Conclusion

- Truly Outstanding Progress Across All Areas
  - ARIEL Building Occupancy: 2013 Aug 02
  - Cryogenic Plant Acceptance Test: Oct 26 – Nov 18
  - Klystron & HVPS Acceptance Test: Oct 21 - 25
- Future Milestones
  - E-gun complete: 2013 Nov
  - Injector Cryomodule beam test: 2013 Dec
  - Accelerator Cryomodule beam test: 2014 Sept

TRIUMF

Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

Thank you!
Merci!

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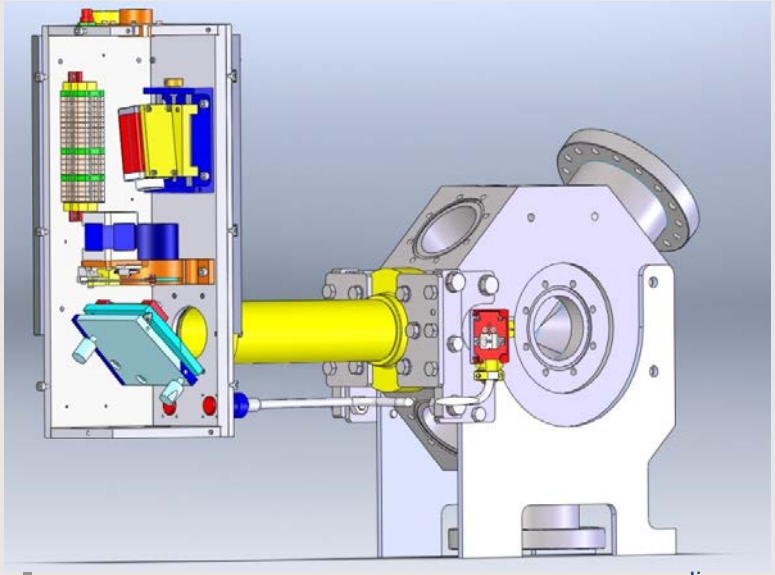
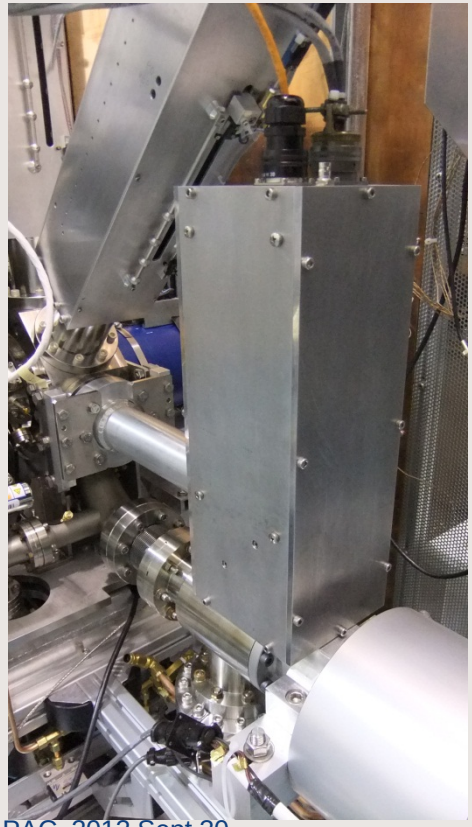
Propriété d'un consortium d'universités canadiennes, géré en co-entreprise à partir d'une contribution administrée par le Conseil national de recherches Canada

Beam Profile Monitors

17 constructed



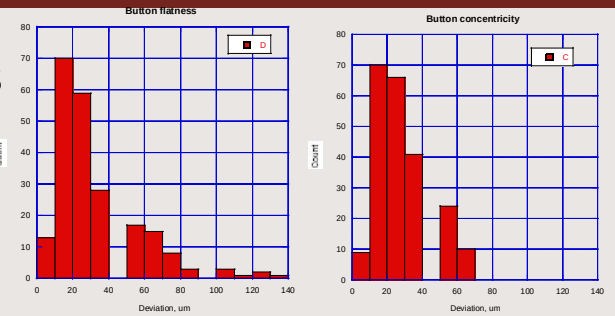
Prototype camera box and screen at ELBT test area



Ladder with targets

Beam Position Monitors

All 220 button electrodes received from Kyocera & dimensionally inspected.

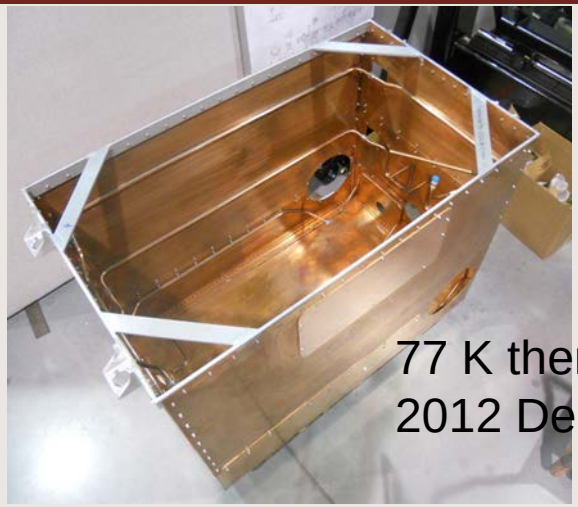


BPM Electronics

- Operates in pulse and CW modes. Fresh data available each microsecond.
- Three blocks: commercial front-end to down convert the input 650MHz signals to the IF frequency, a 14-bit ADC and a Spartan-6 FPGA for the digital signal demodulation and filtering.
- Electronics is assembled inside a 1U rack enclosure and currently in production.
- Need 56 units.
- 3 complete, 7 more in assembly.

Injector Cryomodule Subassembly Status

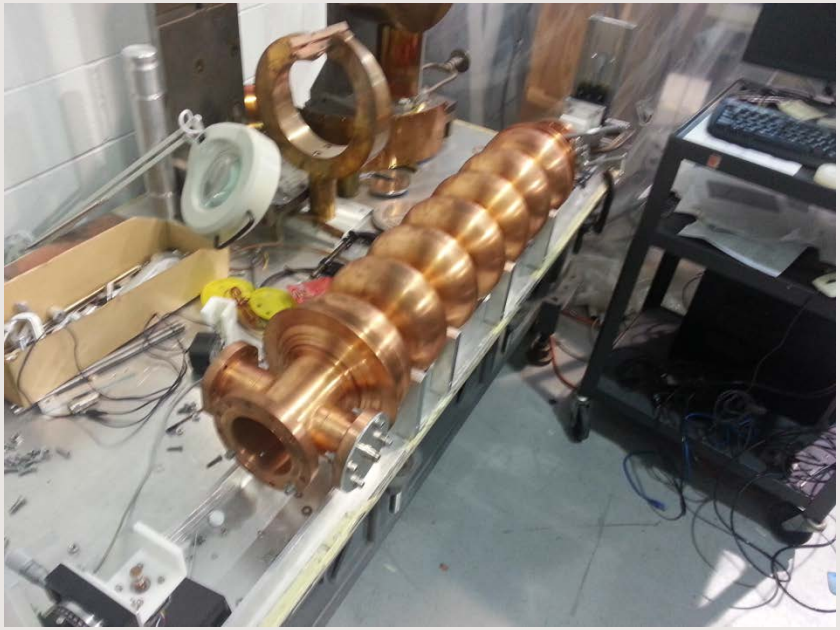
- **Tank and Lid (2)**: Completed and leak checked. Mu-metal lining installed
- **Tank Stand (1)**: Completed.
- Warm mu metal installed in tank and lid
- LN2 shield complete

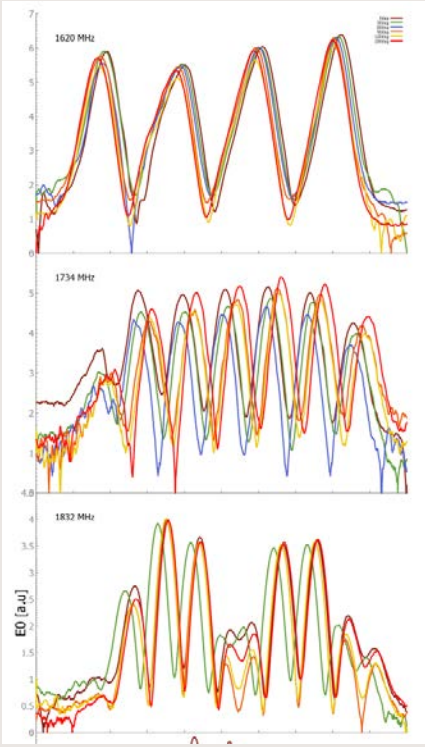


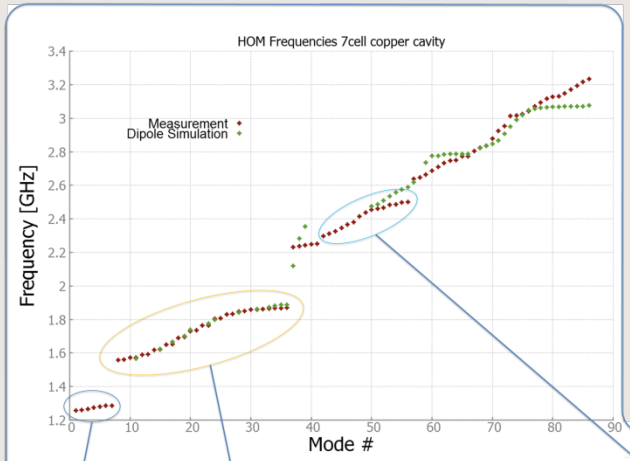
77 K thermal shield
2012 Dec 21

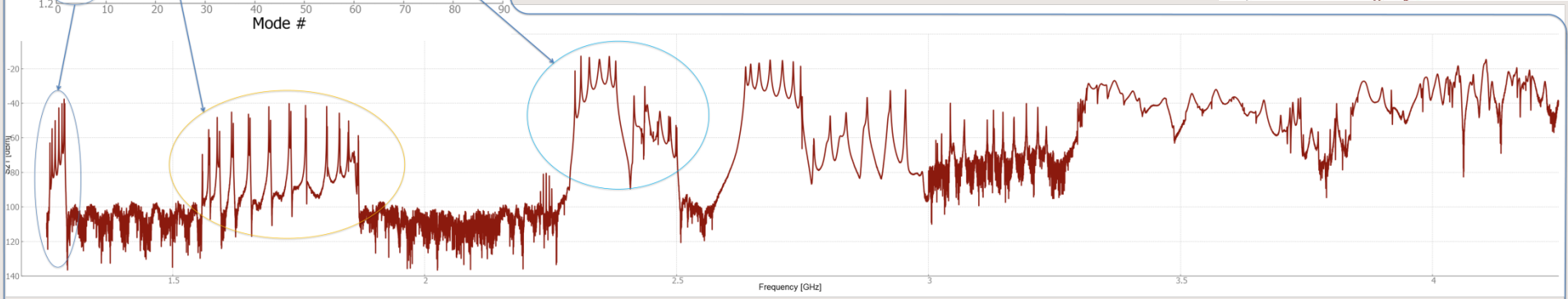
Copper 7 cell cavity: HOM measurements & bead pulls

Goal of the cavity design is to reduce the highest shunt impedance of any dipole HOM to 10^6 Ω or less.



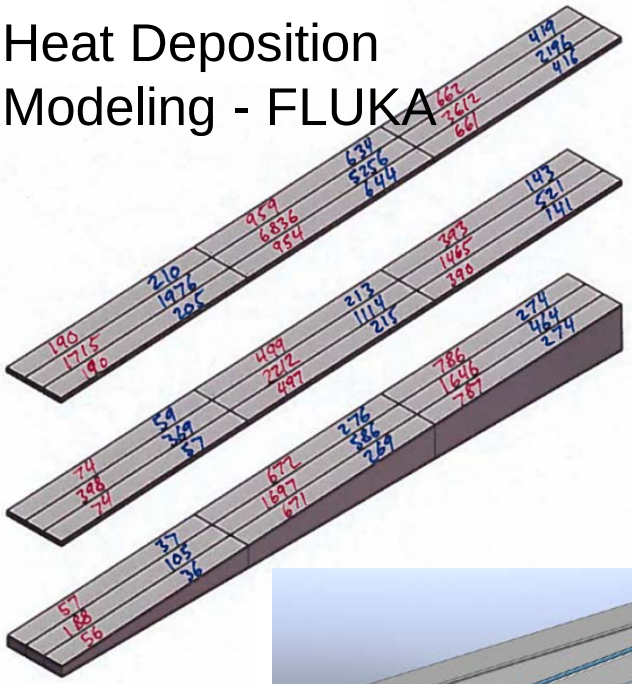


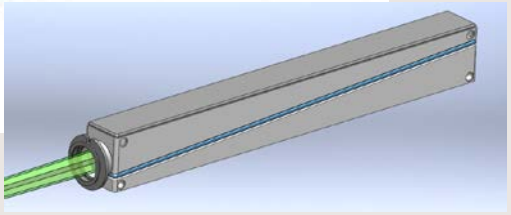




100kW tuning dump

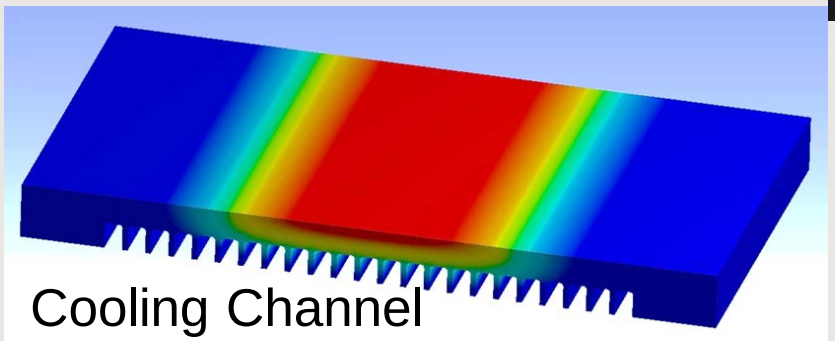
Heat Deposition Modeling - FLUKA





- Design review July 12
- Water package review October
- Tight schedule for May? 2014

BD Body Mockup ½-size

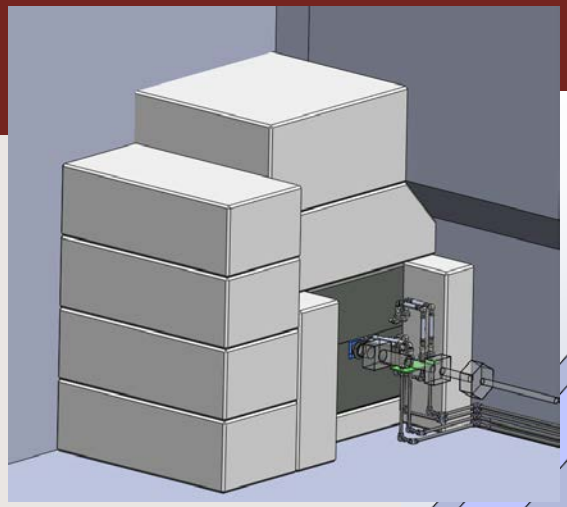


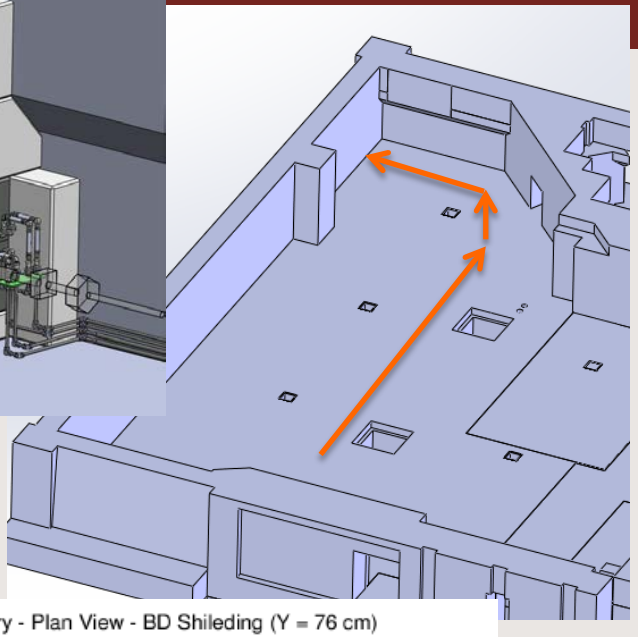
Cooling Channel Optimization

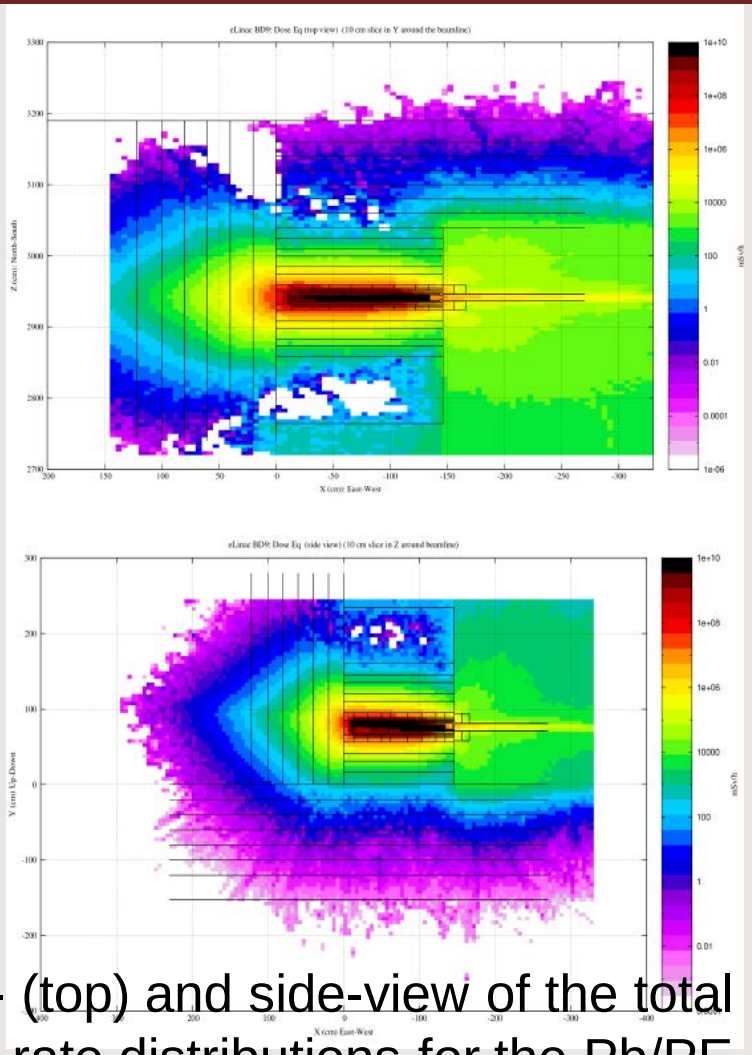
Welding completed on mockup

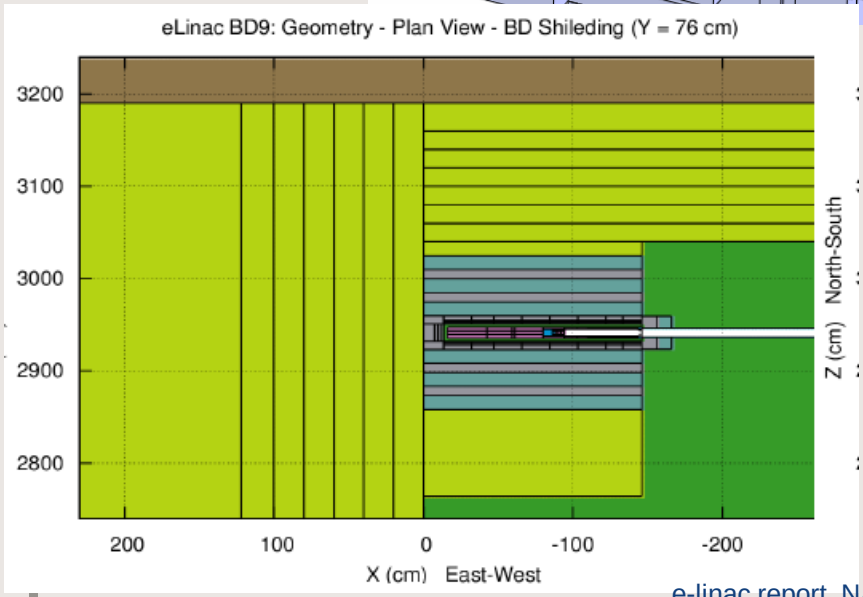
- 0.4mm lift at front and rear - correctable
- No twisting or sidewise bending of vessel
- Leak tight: 0.5*10-9 cc/sec leak rate on Varian after 3 mins

Beam dump shielding



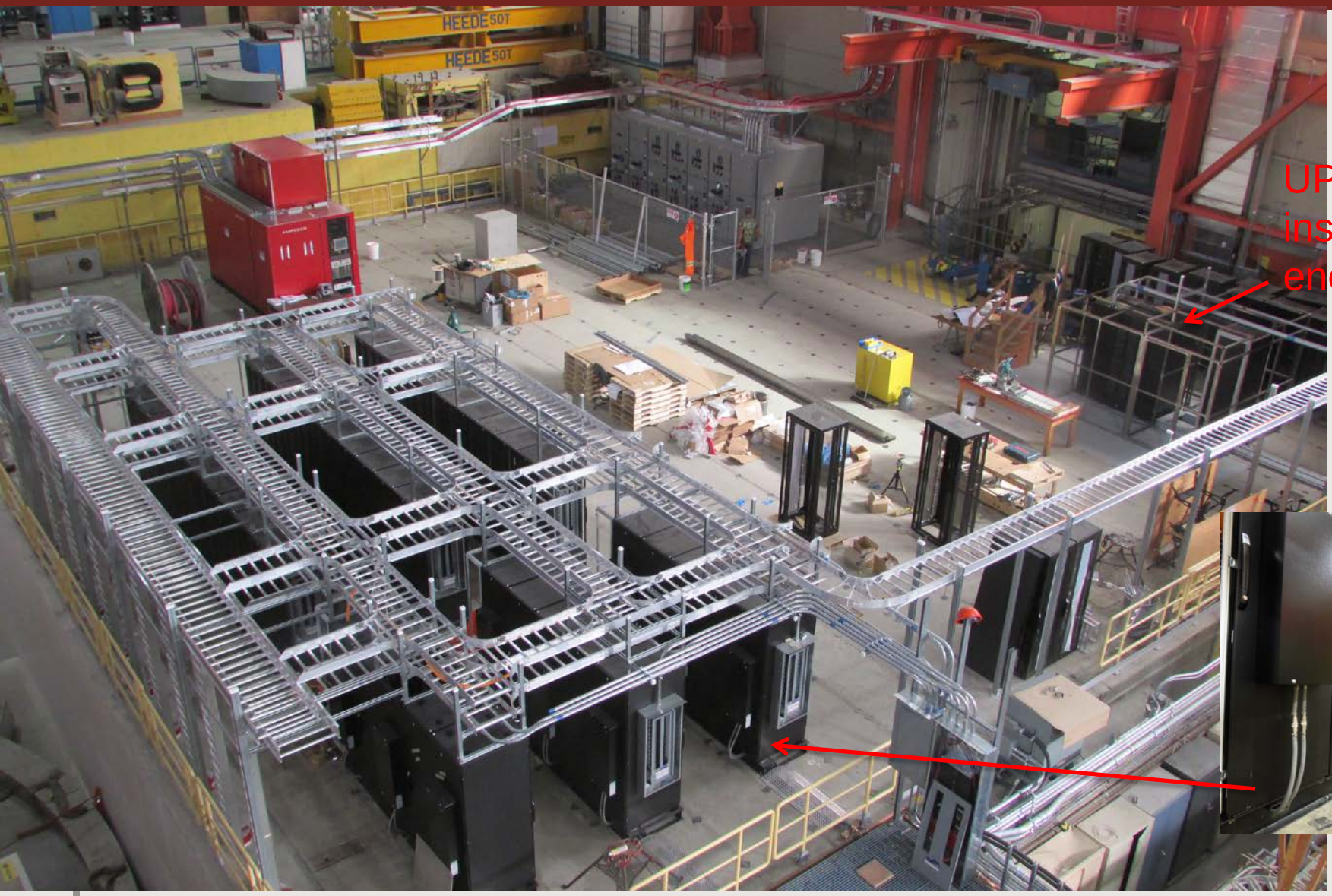






Plan- (top) and side-view of the total dose rate distributions for the Pb/PE layer shielding configuration.

E-hall Roof beams Cable trays & LCW Cooling Piping System Complete



UPS installed, energized