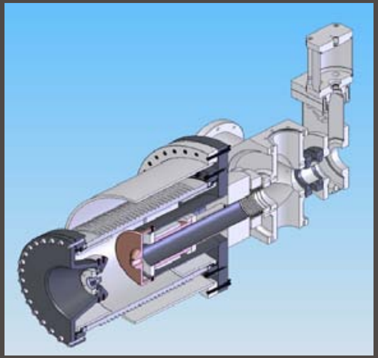
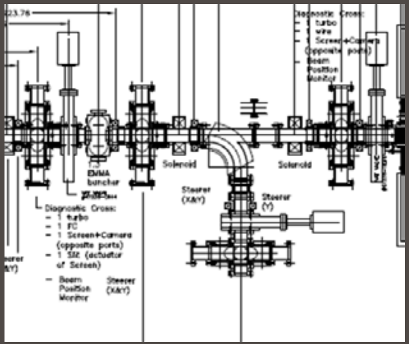
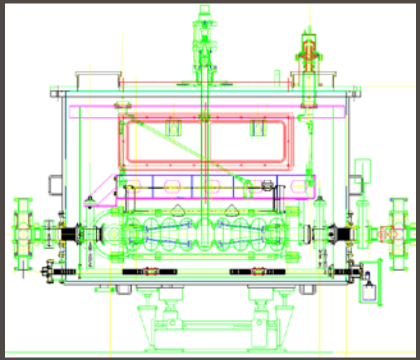
Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

Electron linac photo-fission driver for rare isotope program at TRIUMF



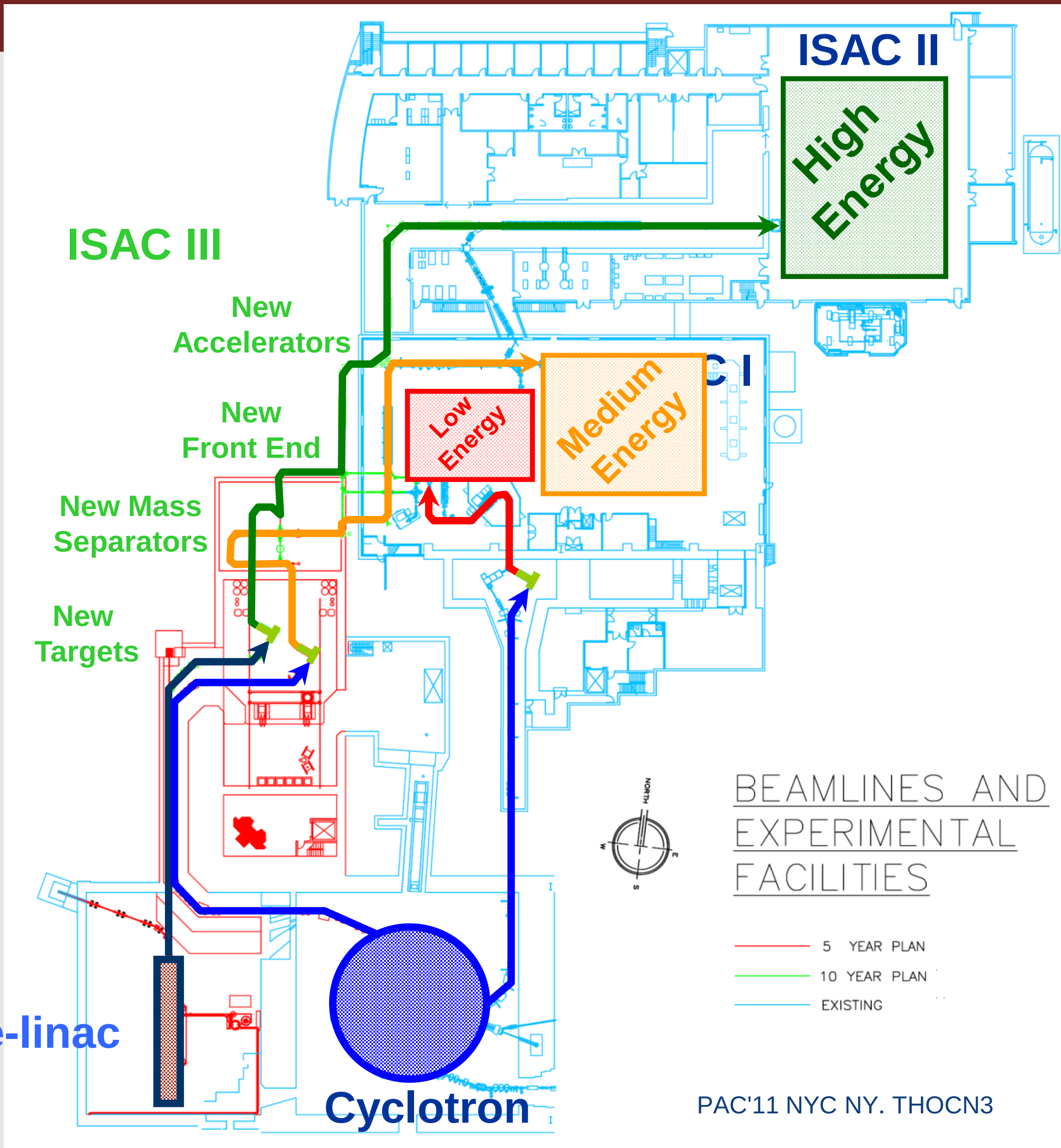




2011 March 31

Shane Koscielniak & e-linac team

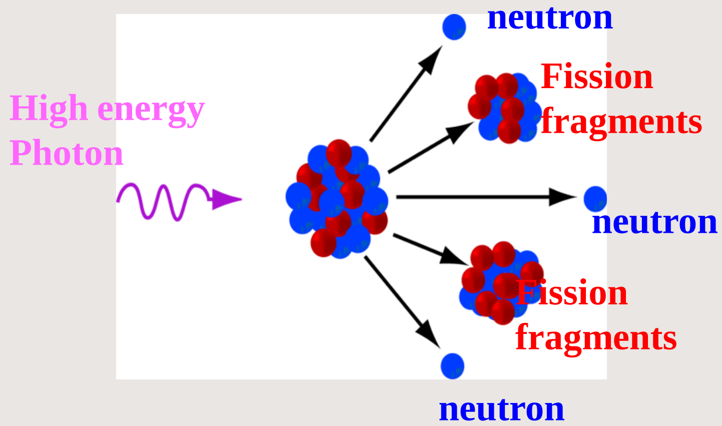
ARIEL Project 10-Year Plan: Motivation



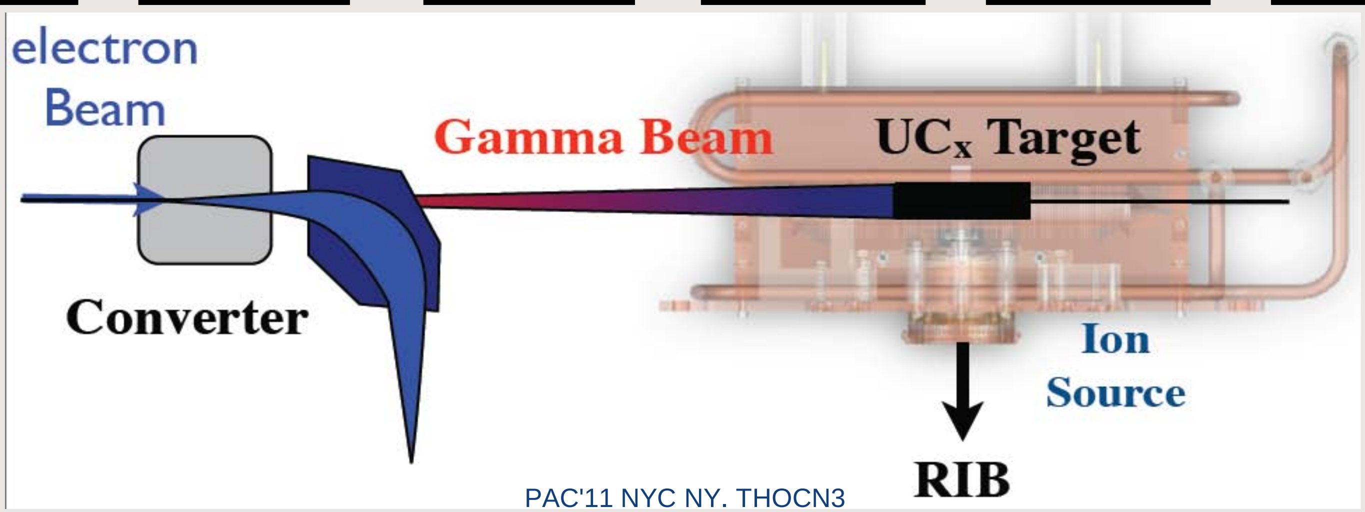
- To substantially expand RIB program with:
  - three simultaneous beams
  - increased number of hours delivered per year
  - new beam species
  - increased beam development capabilities
- New complementary electron linac (e-linac) driver for photo-fission
- New proton beamline
- New target stations and front end
- Staged installation

Photo-fission production of Rare Isotope Beams

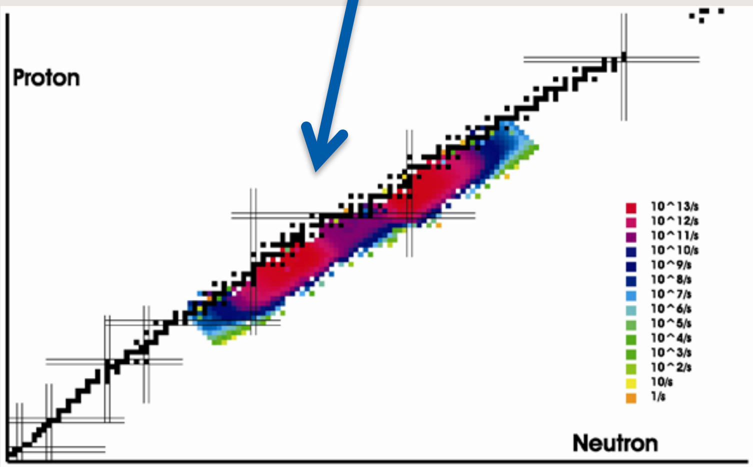
Photofission of ^{238}U was proposed by W. T. Diamond (Chalk River) in 1999 as an alternative production method for RIB.

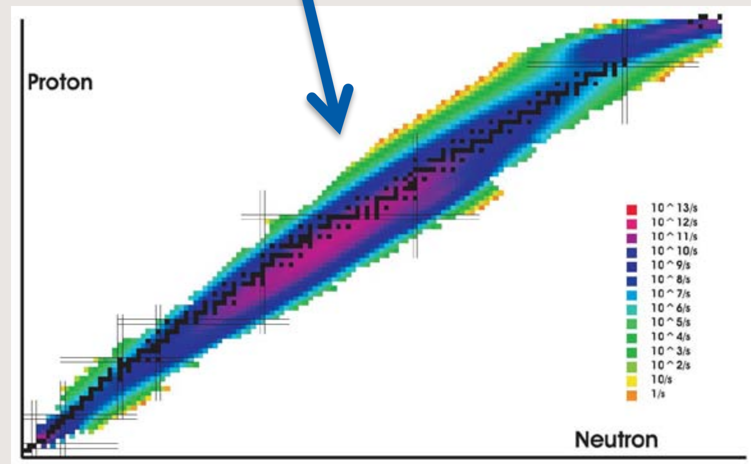


E-linac → Electron-Photon Converter → ^{238}U Target → Ion Source → Mass Separator → RIB User



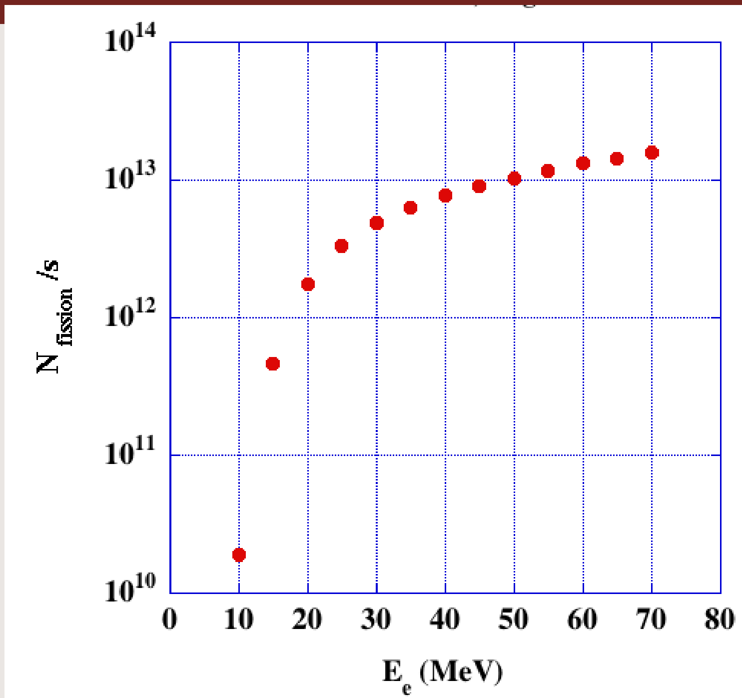
Why photo-fission, rather than proton driver?





- Smaller range & depth of products, with emphasis on neutron rich species.
- BUT lower isobaric contamination, lower activation, easier remote handling.
- Fission rate/e << rate/p. But easily compensated in source; 10 mA gun easy.
- β=v/c=1 from the start. Single RF structure throughout, lowers cost.

E-Linac Physics Requirements



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

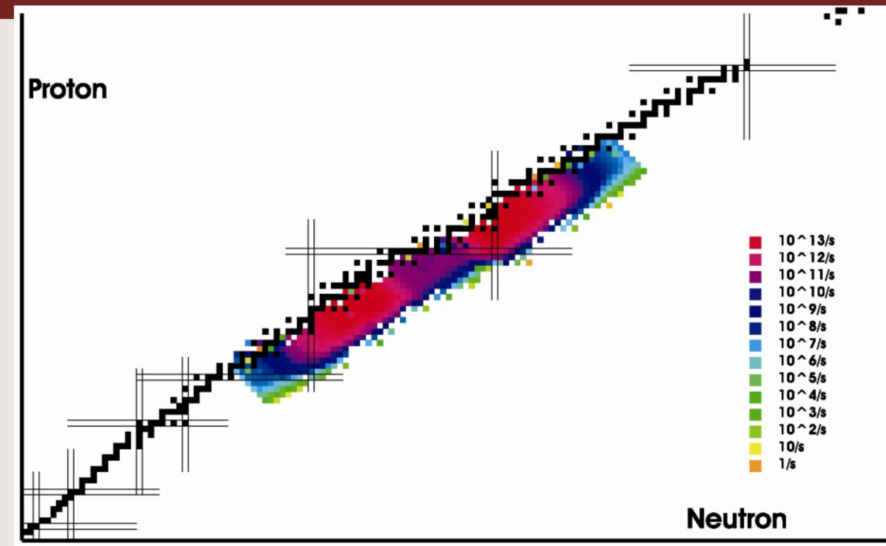


Photo-fission products distribution using 50 MeV 10 mA electrons on Hg convertor & UC_x target

For in-target fissions up to 5×10^{13}/s

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

ARIEL Funding

- July 2009 CFI awarded funds for e-linac- with release contingent upon matching funds for labour (NRC) and buildings (Province).
- April 2010, the NRC contribution to Five Year Plan became known: TRIUMF funded at level of M$222 over 5 years.
- June 2010 Province (B.C.) awarded funds for ARIEL building.
- Jan 2011 MoUs with CFI partner Universities complete

2010 June 22nd:
Red letter day

Key Milestones:

- Injector Cryomodule test with beam: 2012 Nov
- Accelerator Cryomodule equipment test: 2014 June
- ACM test with 100kW electron beam: Jan 2015

TRIUMF

E-Linac: Accelerator Overview

Power levels as in 2017

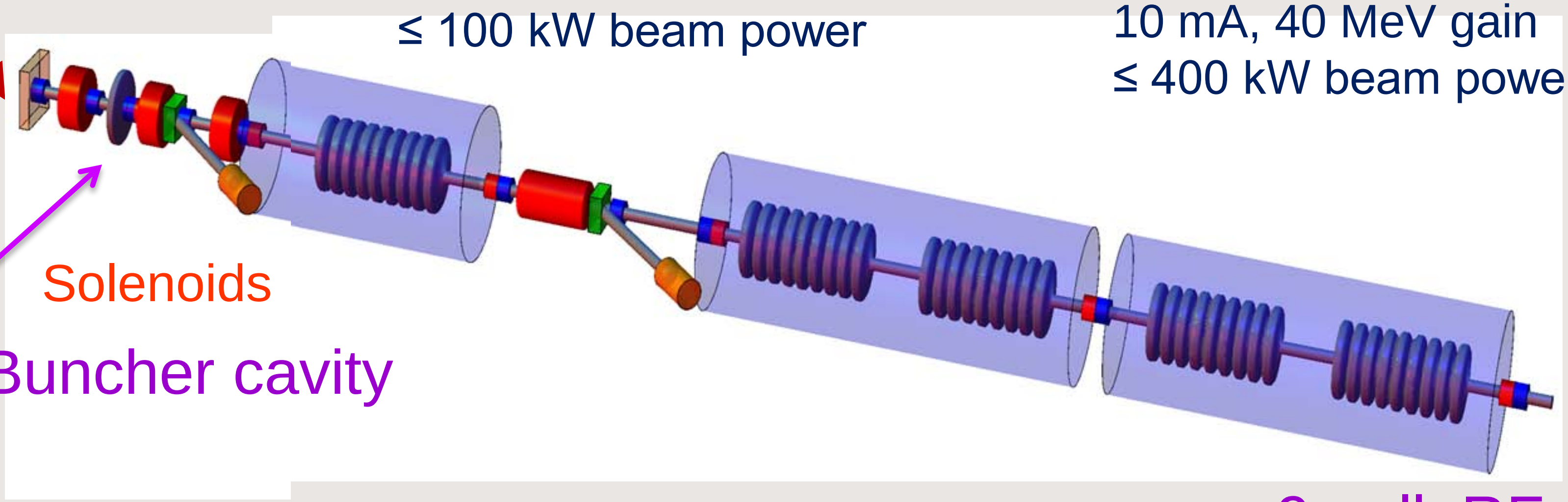
300 keV Thermionic gun: triode operation at 650 MHz

Injector:

$Q \geq 10^{10}$ @10 MV/m,
10 mA, 5-10 MeV gain
≤ 100 kW beam power

Main linac:

Two cryomodules
Two cavities/module,
$Q \geq 10^{10}$ @10 MV/m,
10 mA, 40 MeV gain
≤ 400 kW beam power



Solenoids

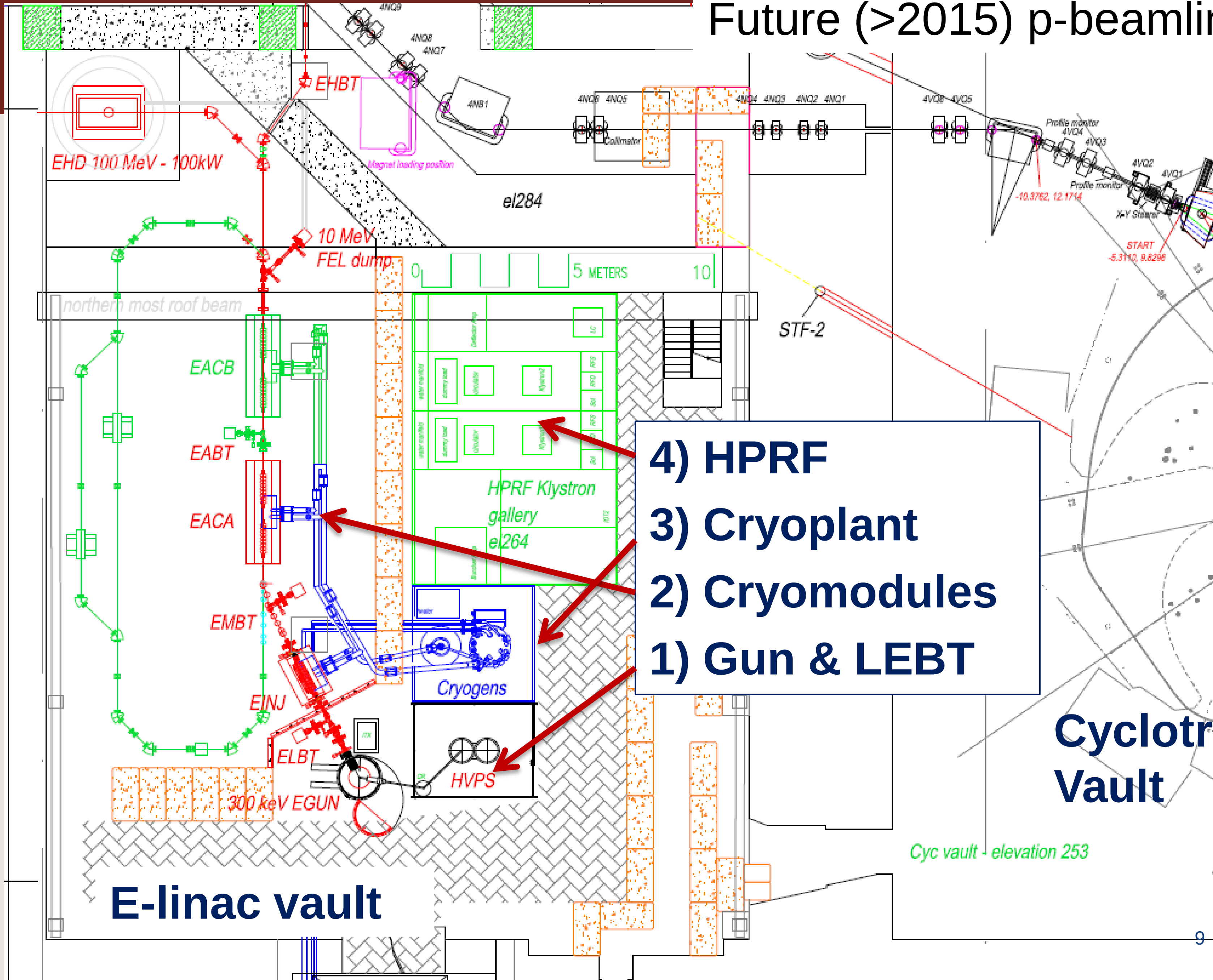
NC Buncher cavity

9-cell, RF Cavities

Division into injector & main linacs allows:

- **Possible expansion for:**
  - **Energy Recovery (ERL) or Energy Doubler (RLA)**
  - **Add return arcs to make a ring.**

Future (>2015) p-beamline



4) HPRF

3) Cryoplant

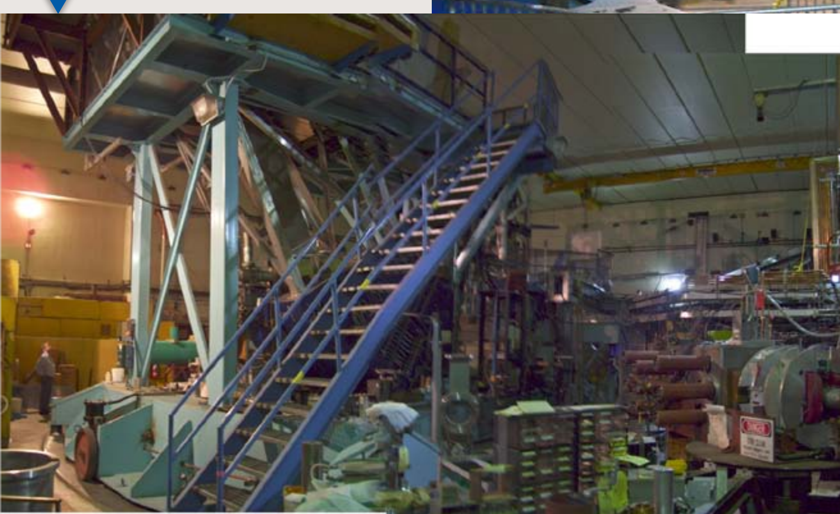
2) Cryomodules

1) Gun & LEBT

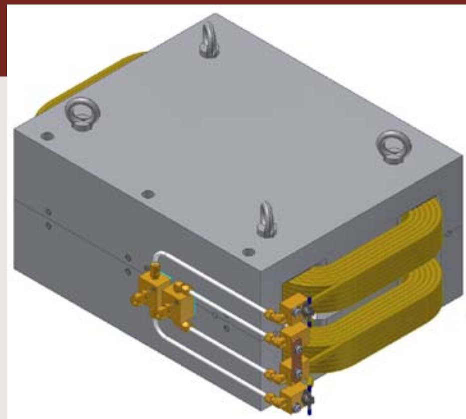
Former Proton Hall being cleaned out and refurbished as electron linac vault

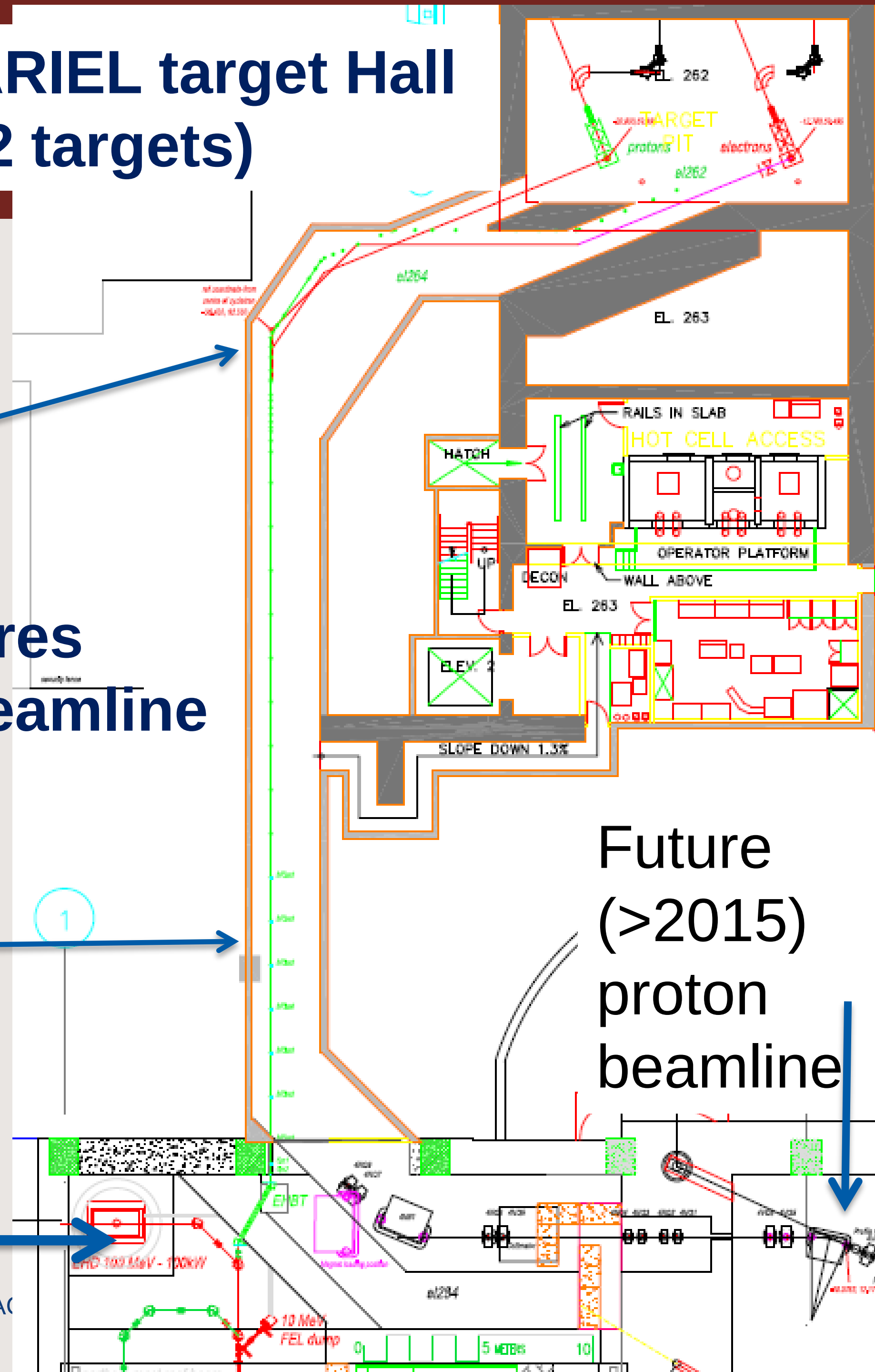
After

Before

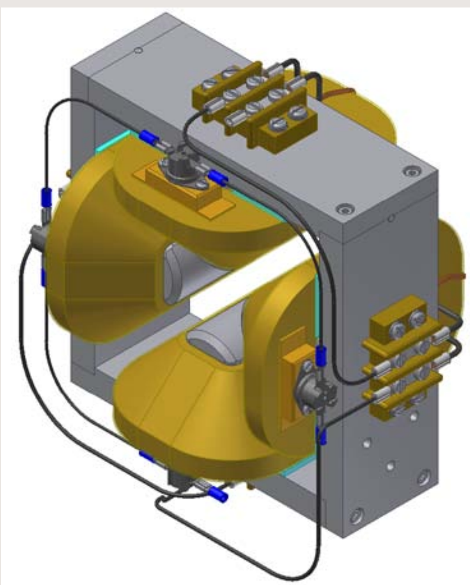


ARIEL target Hall (2 targets)





80 metres long beamline

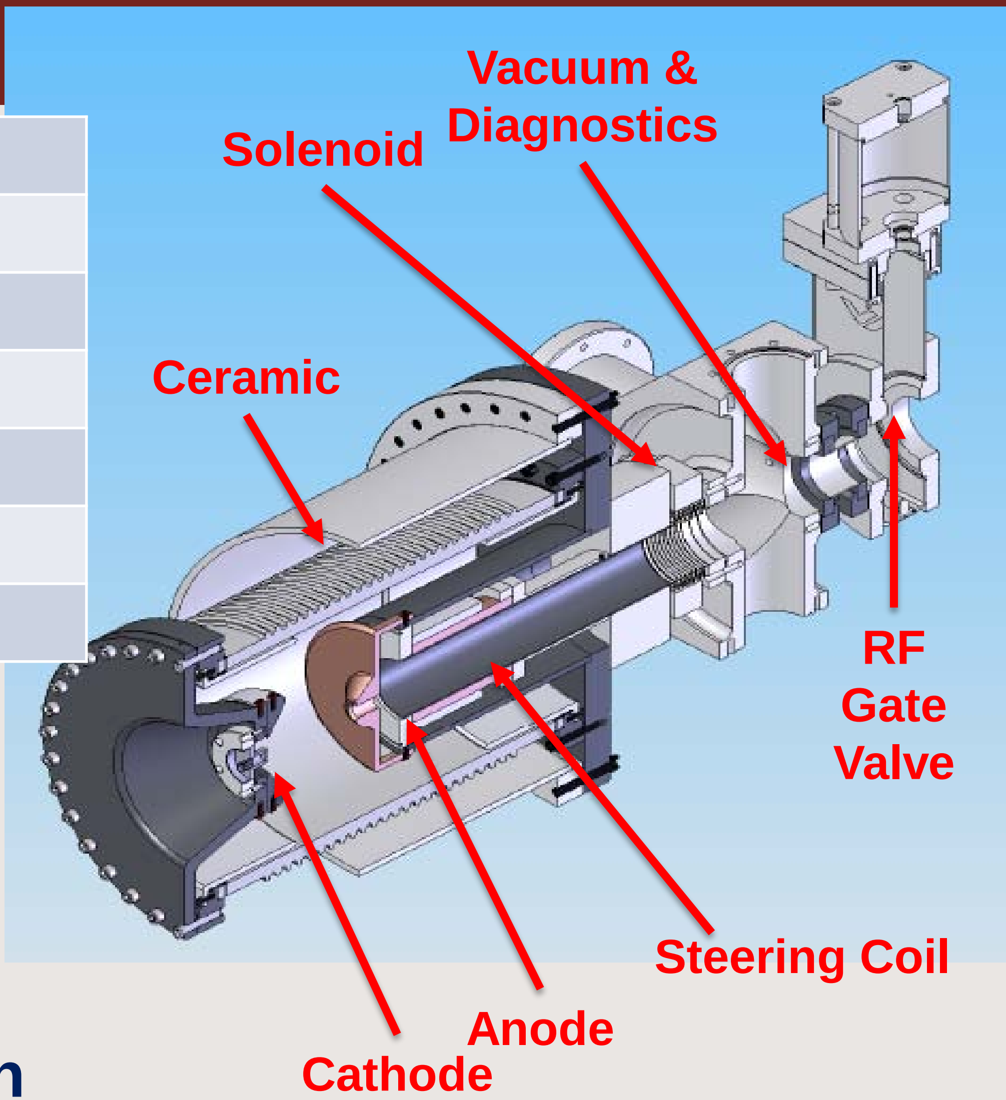


Future (>2015) proton beamline

Electron linac vault

300 keV Thermionic Gun Specifications

Beam energy	300 keV
Average current	10 mA
Modulation freq	650 MHz
Bunch length (FW)	16 deg
Bunch charge	16 pC
Energy spread	1keV FW
Emittance (1 σ)	5μm normalized



e-gun on HV platform in N2/SF6 gas mix at 2 atm.

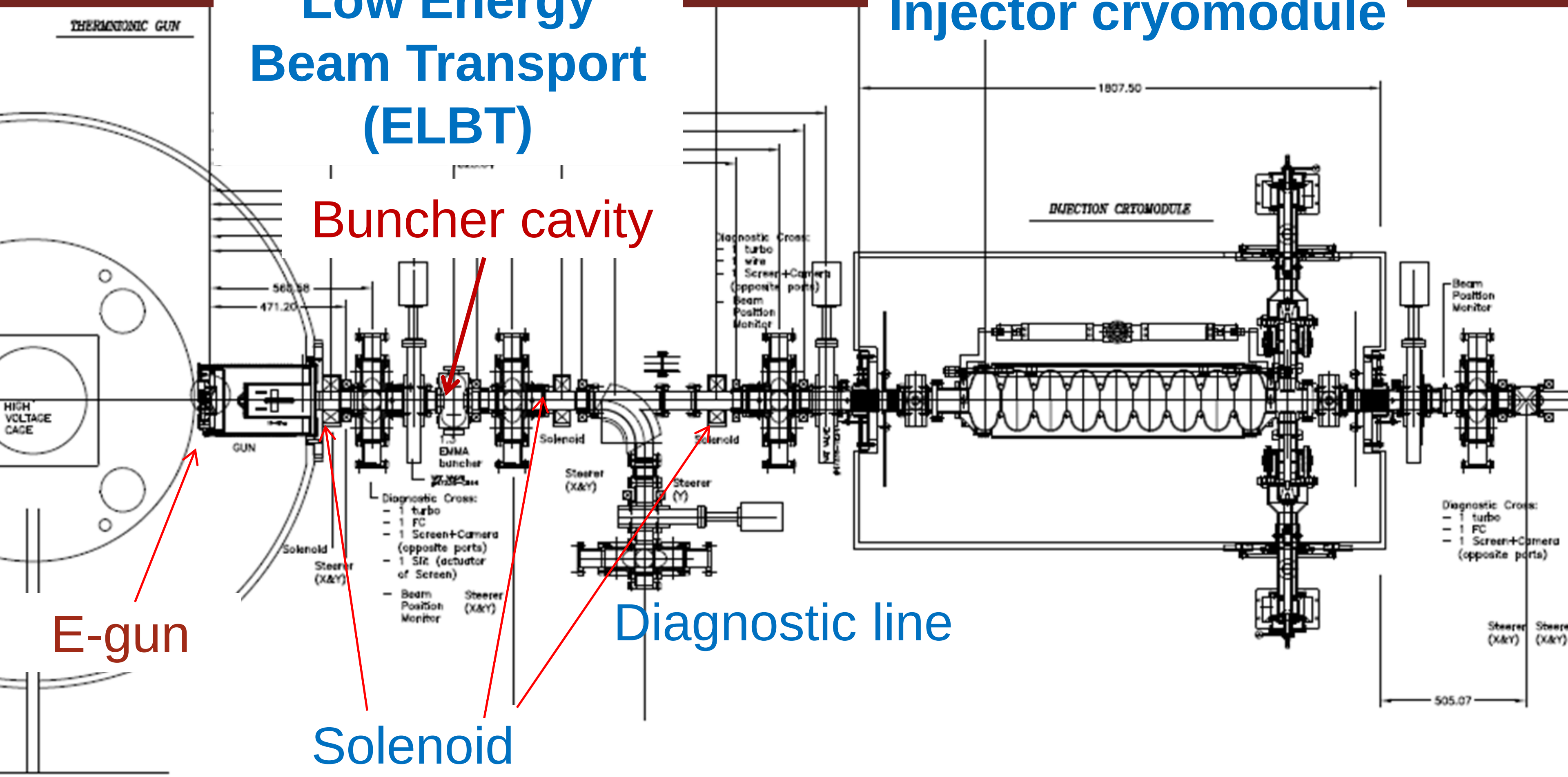
TUP017: Conceptual Design of the Elinac 300 keV Gun

Main components of e-linac Injector

Low Energy Beam Transport (ELBT)

Injector cryomodule

Buncher cavity



E-gun

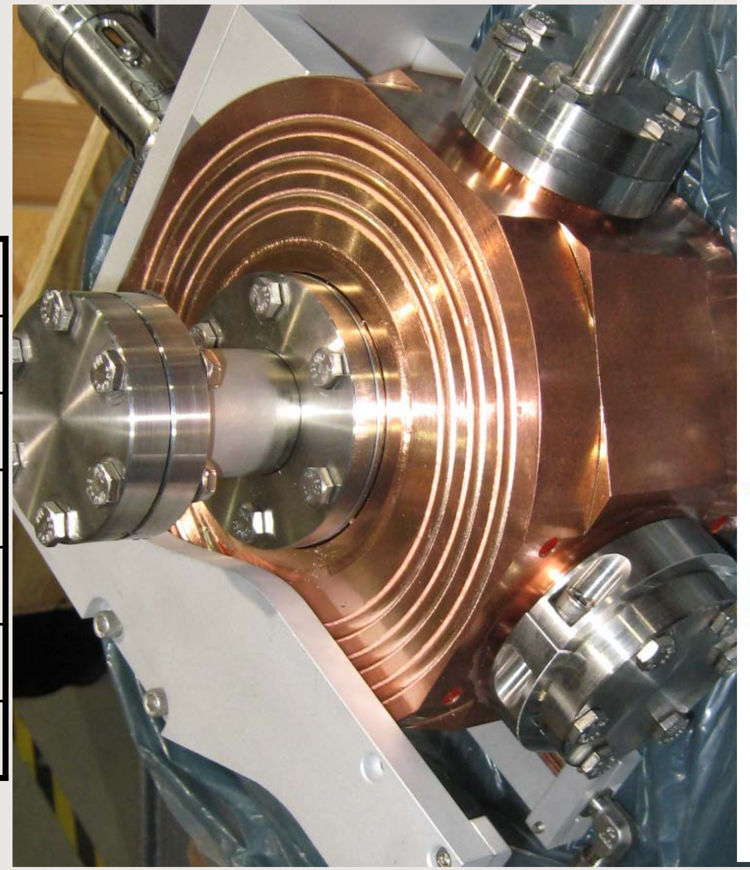
Diagnostic line

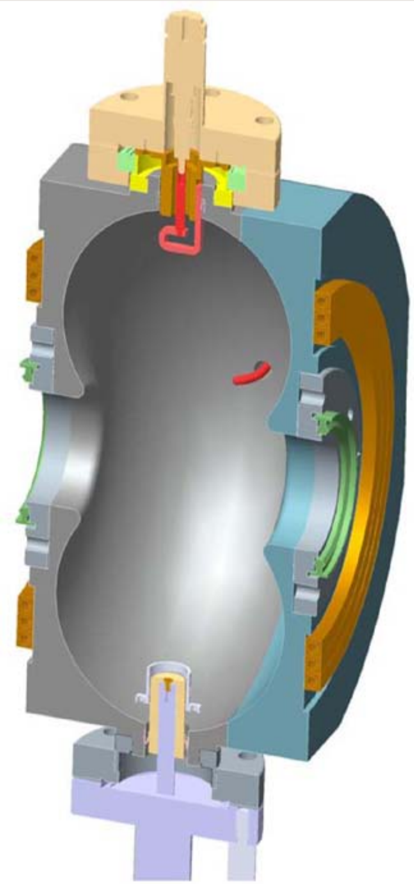
Solenoid magnets for focusing being re-designed.

1.3 GHz NC Buncher – matches beam to 9-cell cavity

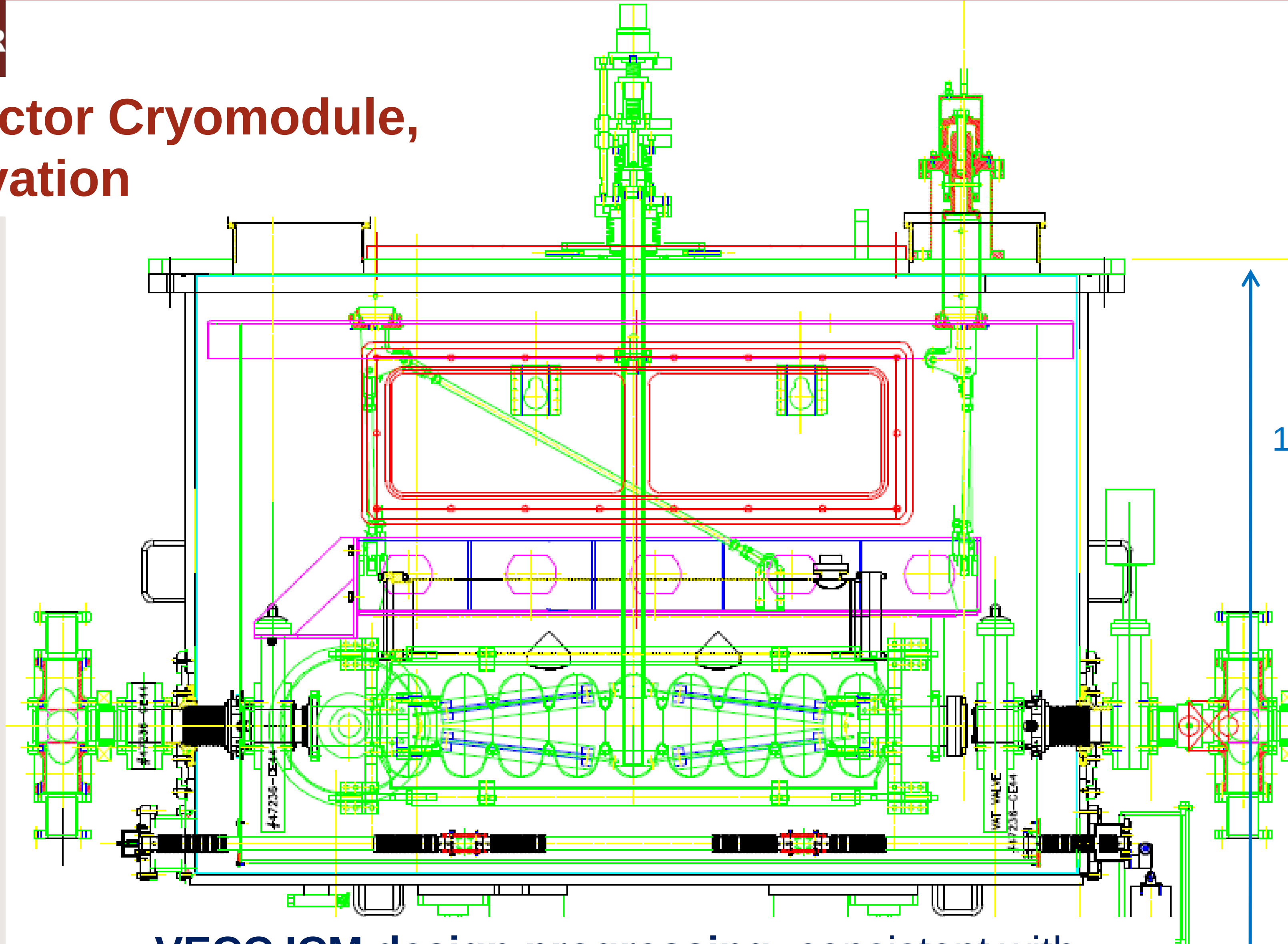
- On site November 2009
- Daresbury EMMA design purchased from Niowave

Parameter	value
Frequency (GHz)	1.300
Shunt resistance	4.3 (MΩ)
Realistic (80%)	3.44 (MΩ)
Q_0	23,000
R/Q	147
Tuning (MHz)	-4 to +1.5





Injector Cryomodule, elevation

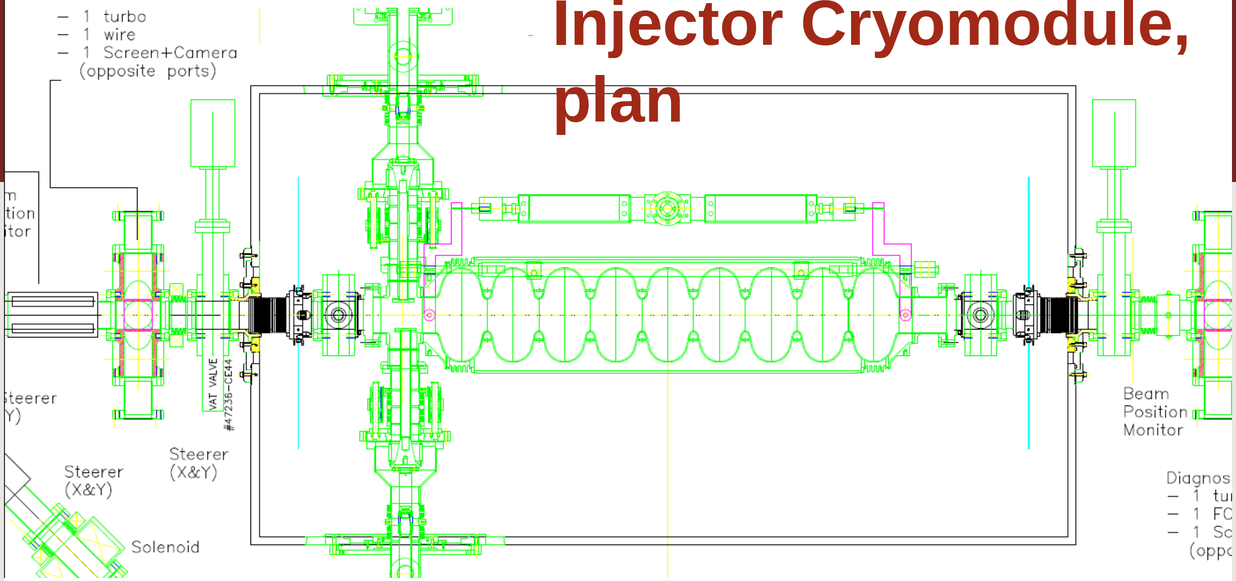


1.717 m

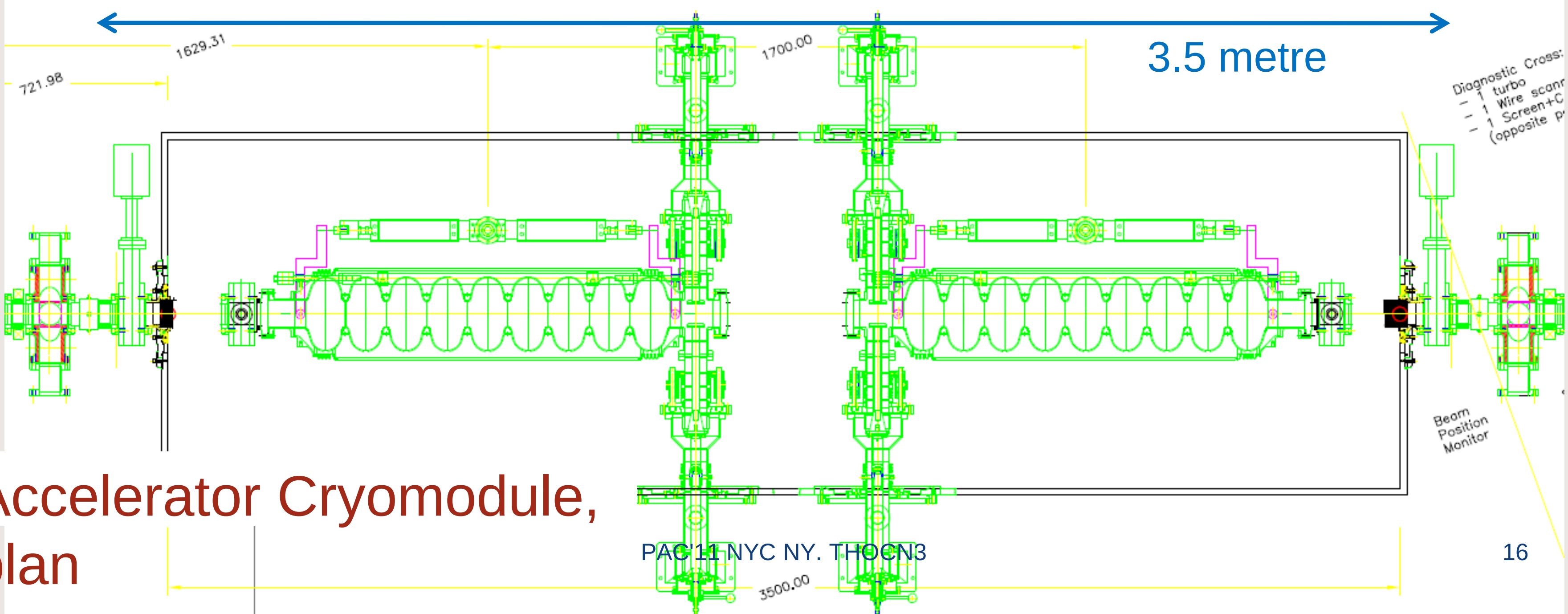
0.762 m

- **VECC ICM design progressing:** consistent with small static and large dynamic heat loads.
- Borrows many features from successful ISAC-II CMs
- Such as top-loading CM

Injector Cryomodule, plan

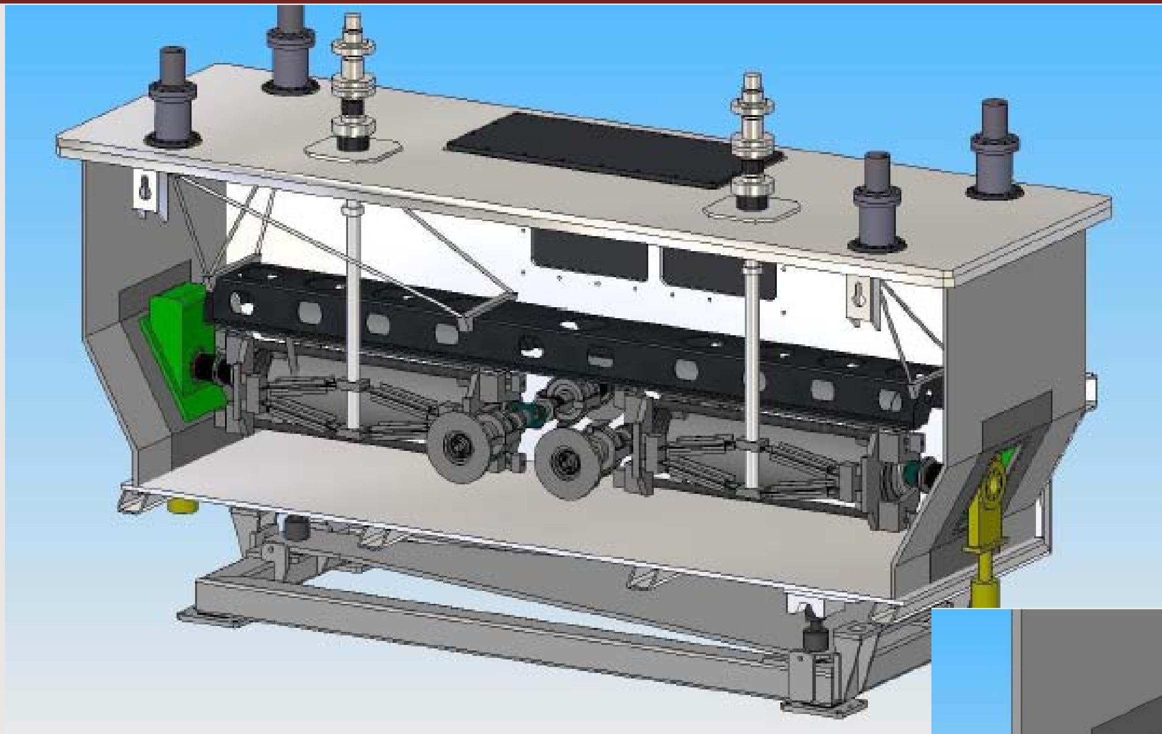


Single-cavity ICM prototypes most of the features of the two-cavity ACM design

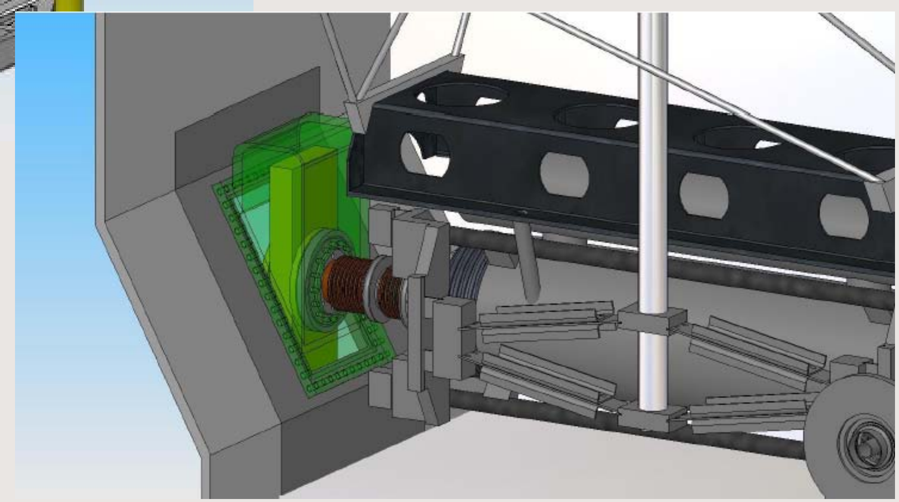


Accelerator Cryomodule, plan

Accelerator Cryomodule
ISO View With Tank Side Removed

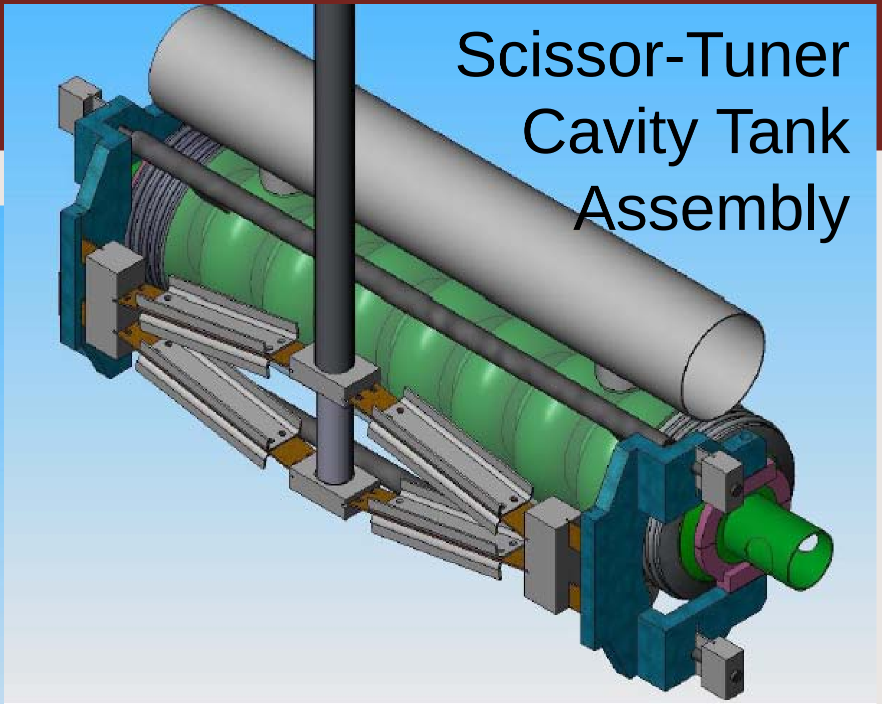


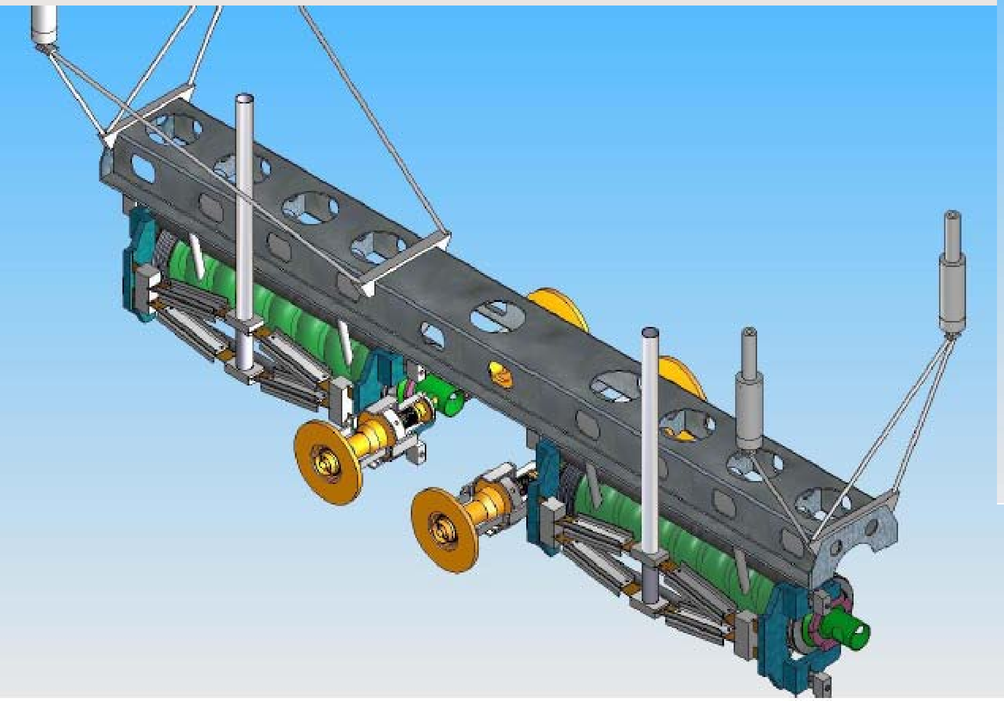
ACM 27Deg. Tank Warm/cold Transition Ends



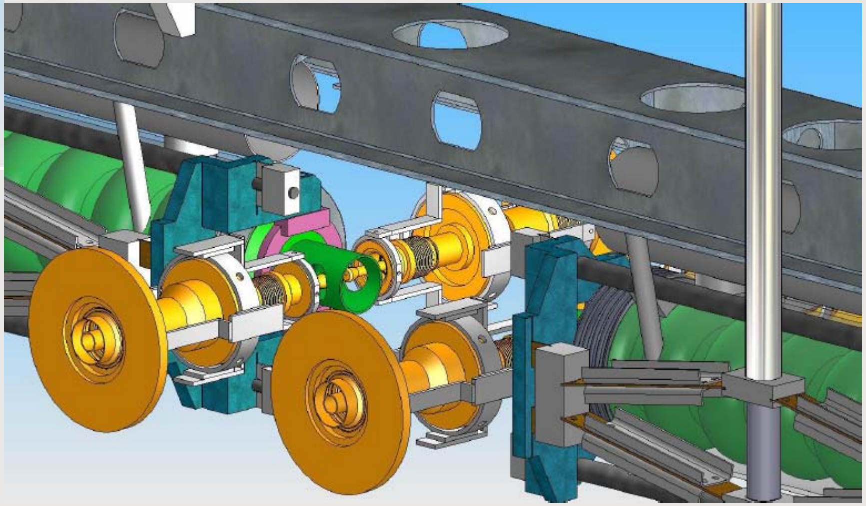
- Cold mass (cavity string and 2-phase helium pipe) supported from strong back
- Strong back held in place by support posts strung from the lid

Final strong-back cold-mass design



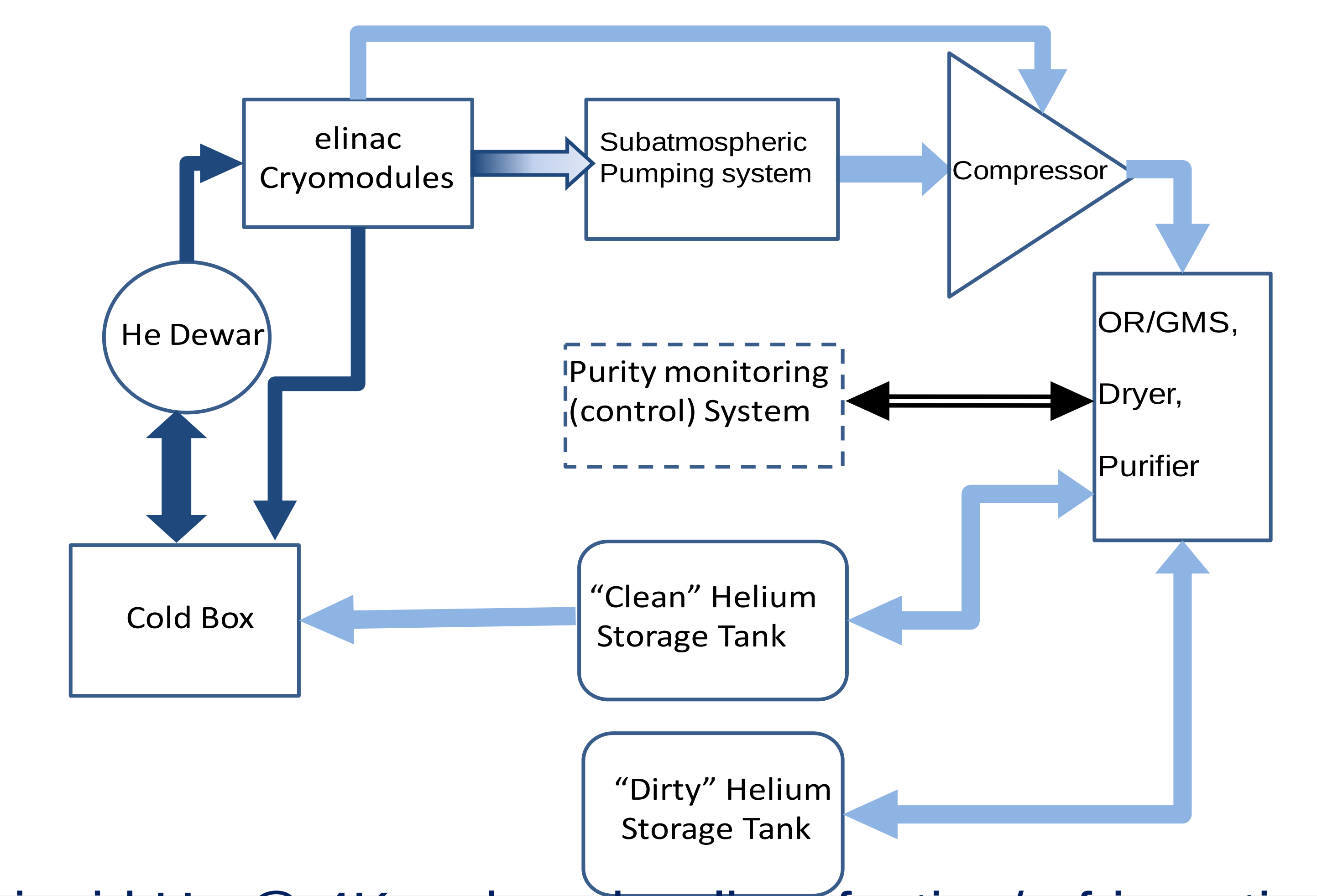


TUP027: The SRF Program for e-Linac at TRIUMF



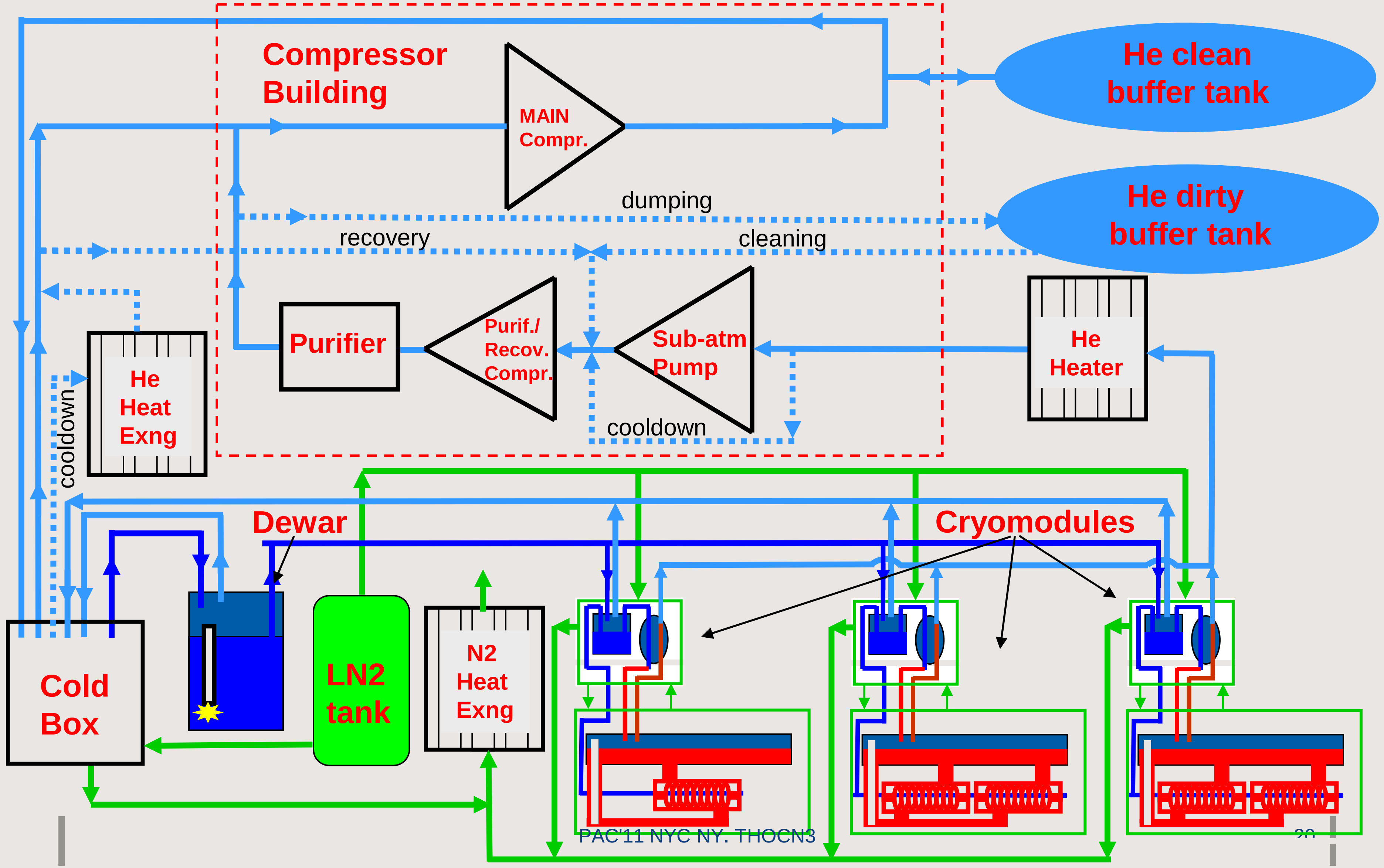
New Coupler Region Design

Simplified block diagram for e-Linac He Cryogenic System

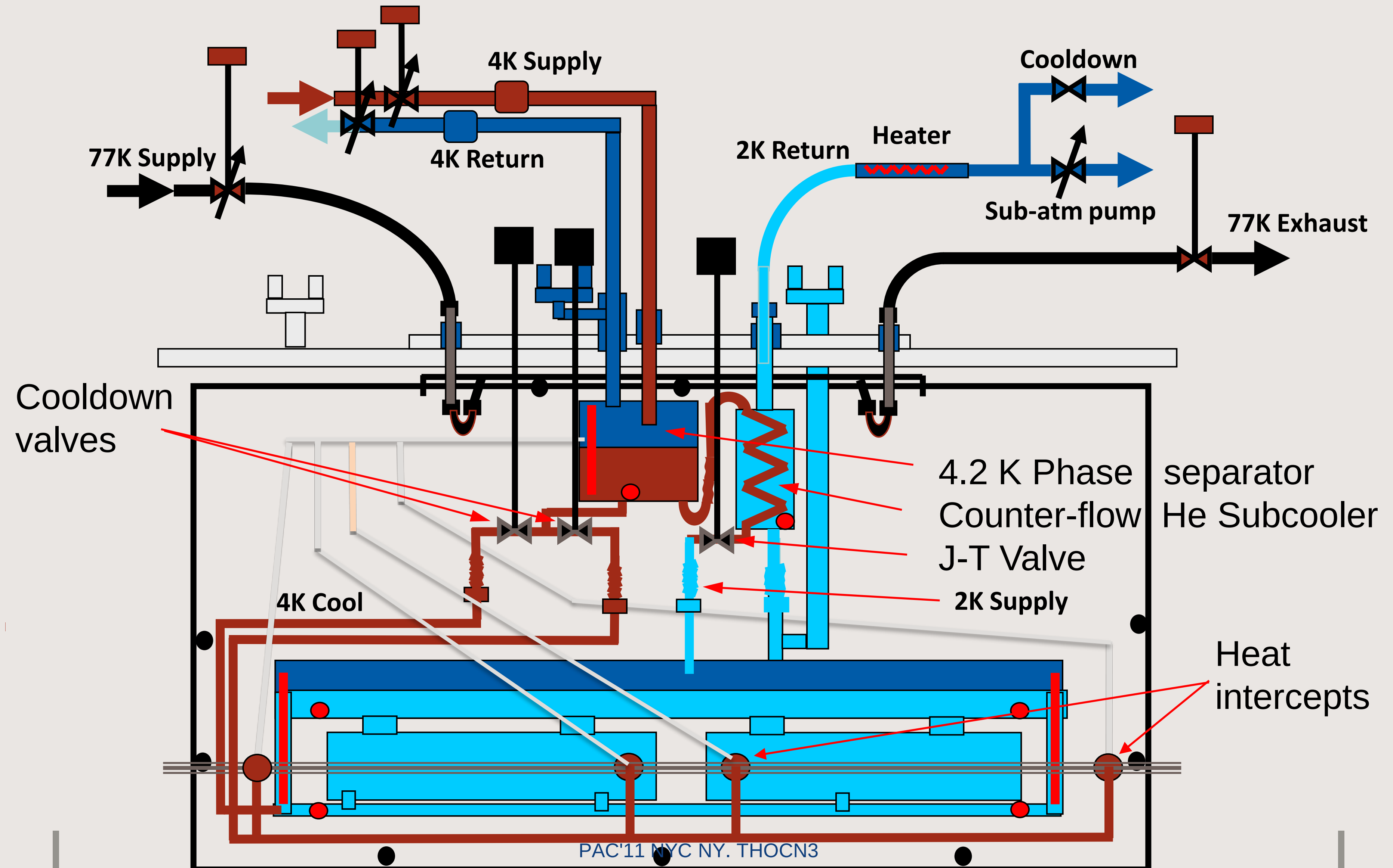


- Liquid He @ 4K – closed re-liquefaction/refrigeration loop
- Liquid He @ 2K – produced in cryomodules by sub-atmospheric pumping

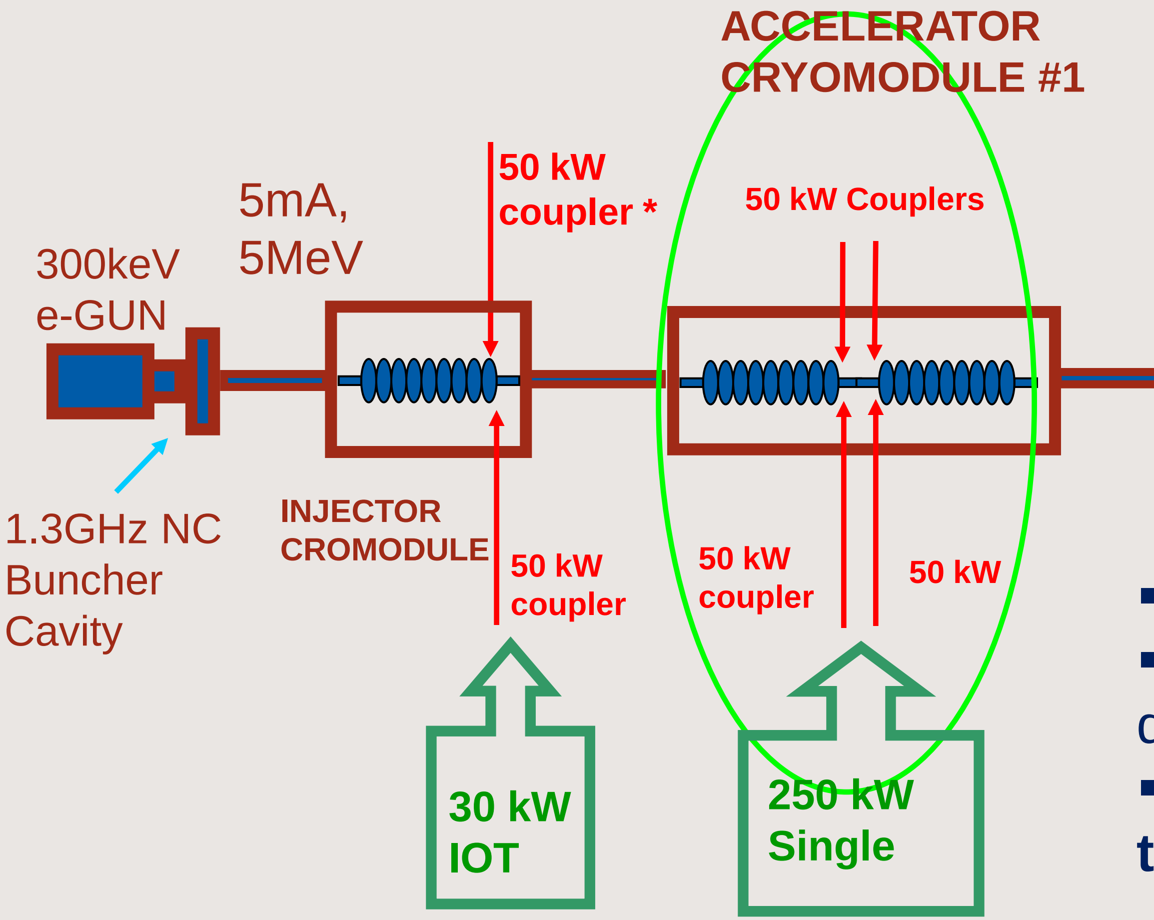
E-linac Cryogenic System Block Diagram

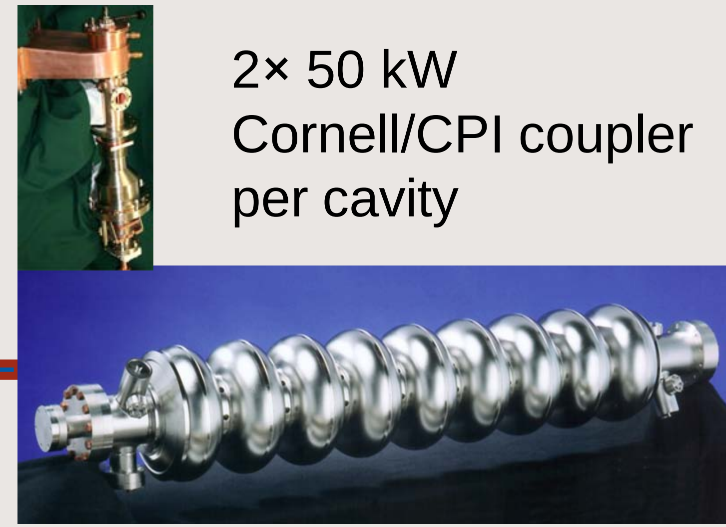


Cryomodule Schematic Diagram



HPRF staging: 5mA, 25 MeV Date: 2014



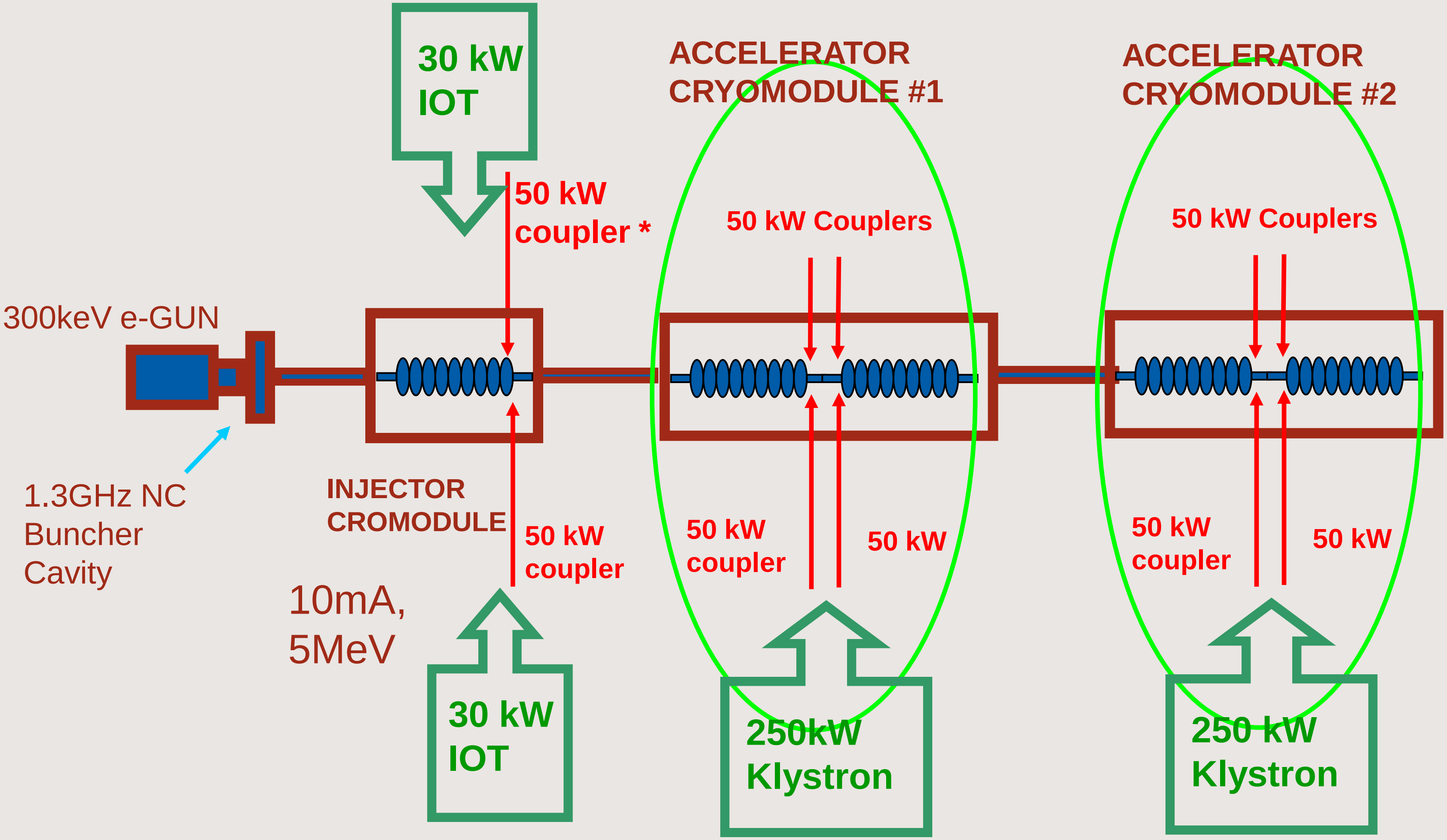


2× 50 kW Cornell/CPI coupler per cavity

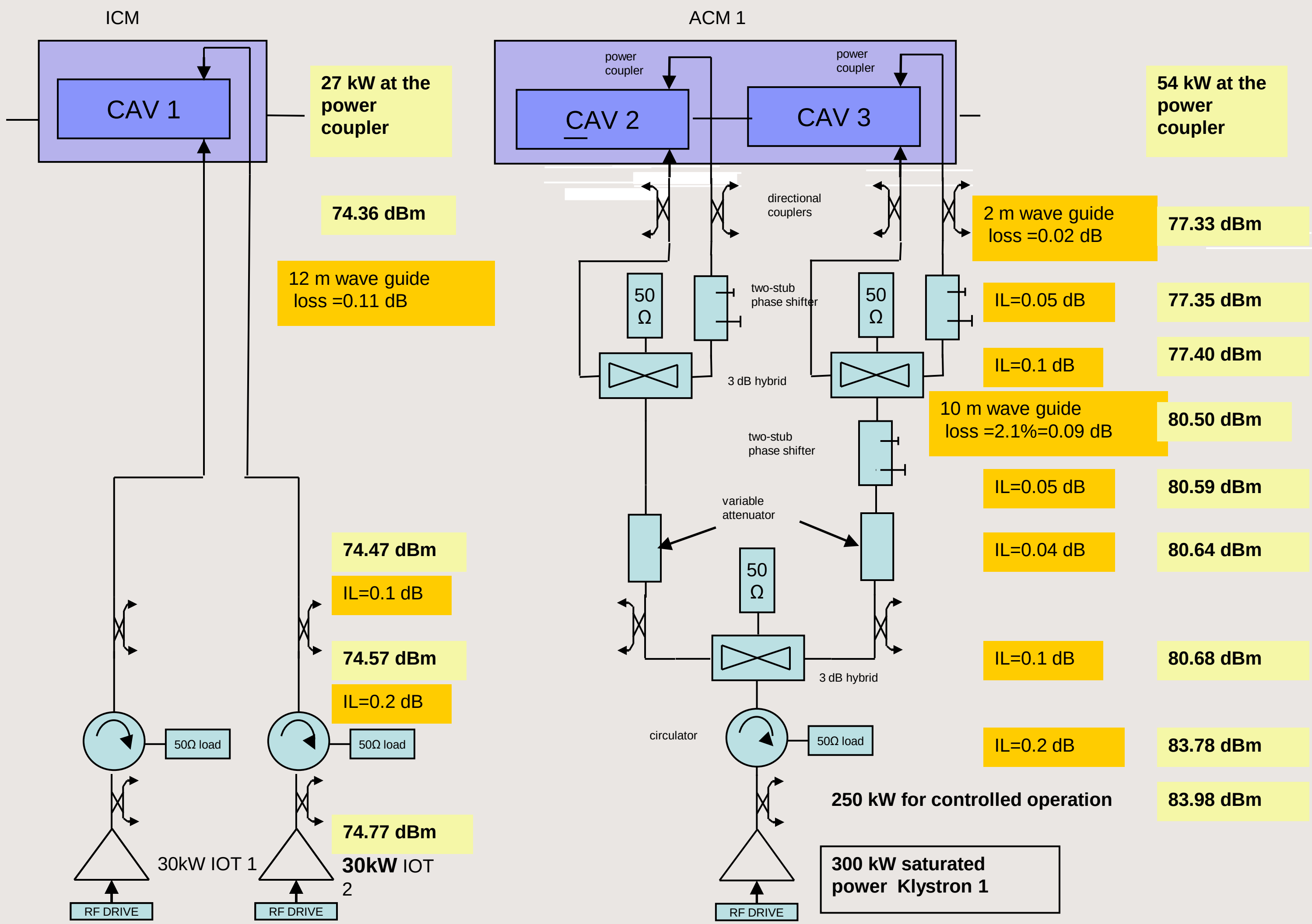
- Modified TTF style cavity
- HOM damping for 1st and 3rd dipole pass bands
- **TUP026: Cavity Design for the TRIUMF e-linac**

250 kW Klystron

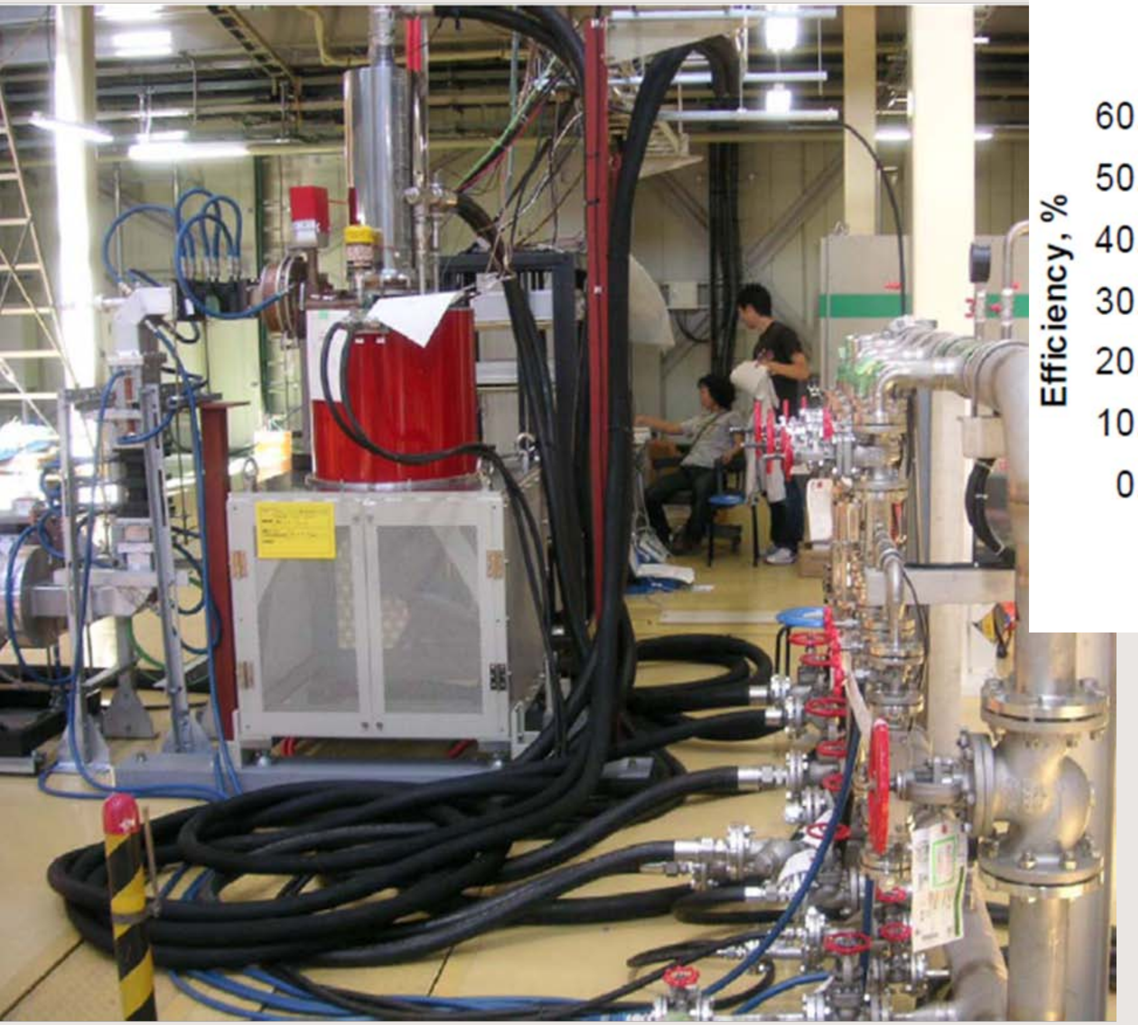
HPRF staging: 10 mA, 50 MeV Date: 2017

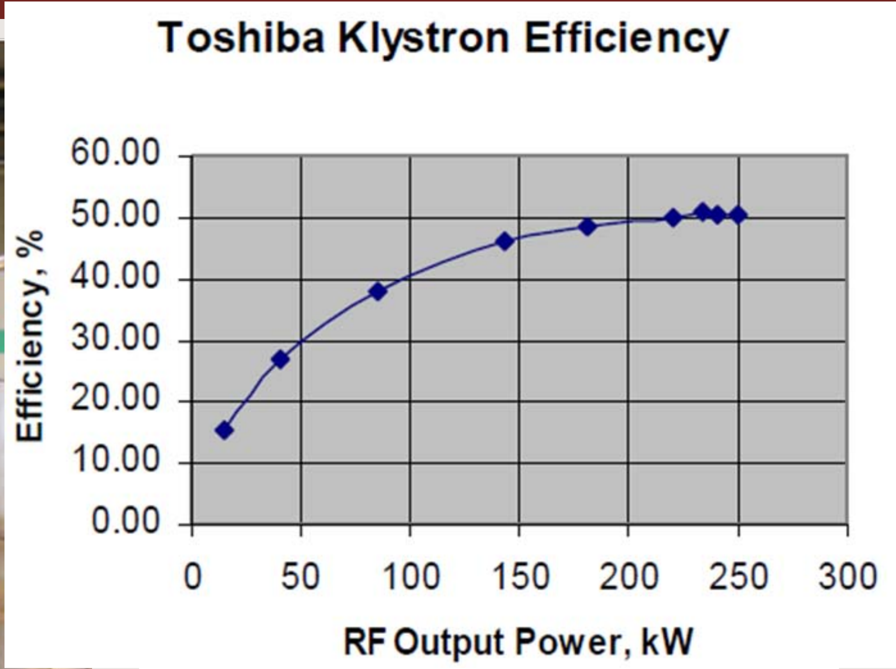


HPRF System Schematic



Candidate klystron: 1.3 GHz 300 kW at KEK





Under tested at KEK since 2010 Sept. Amiya Mitra present for 1st tests. Presently achieved 280 kW.

Ground Breaking News, 2011 March 28

Relocation of Stores & RH – make way for ARIEL