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The Injector Cryomodule for e-Linac at TRIUMF

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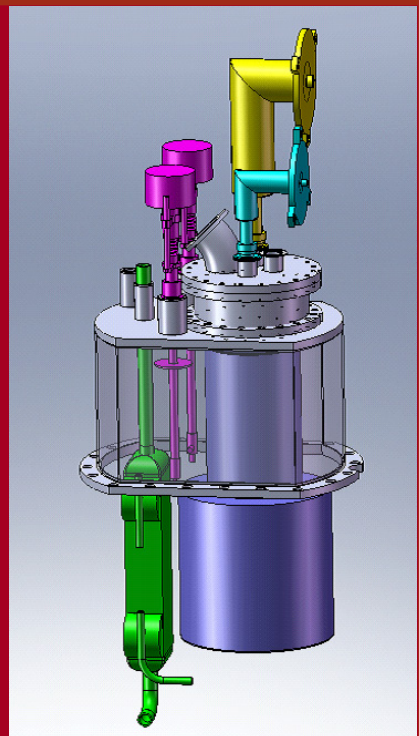
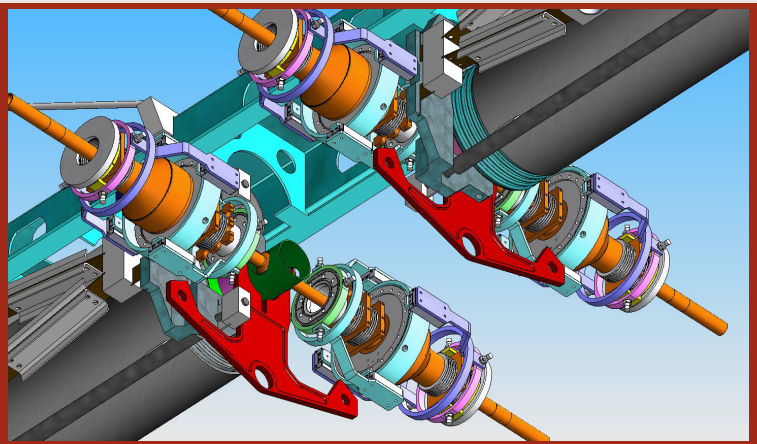
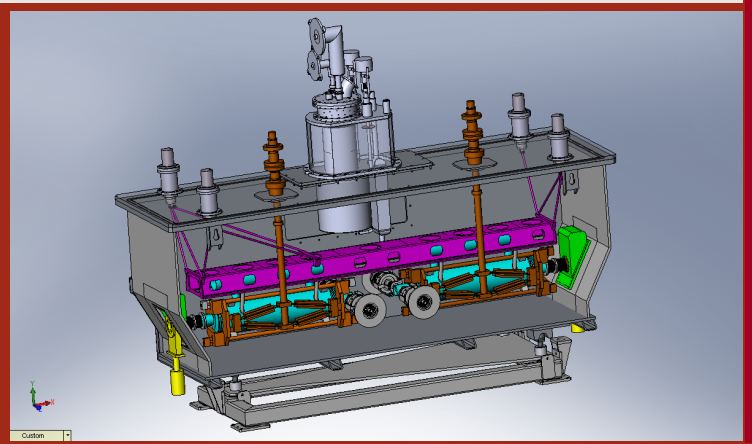
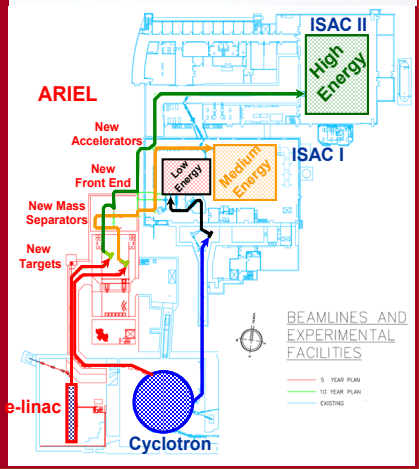
PAC11, WEOCS6, March 30, 2011



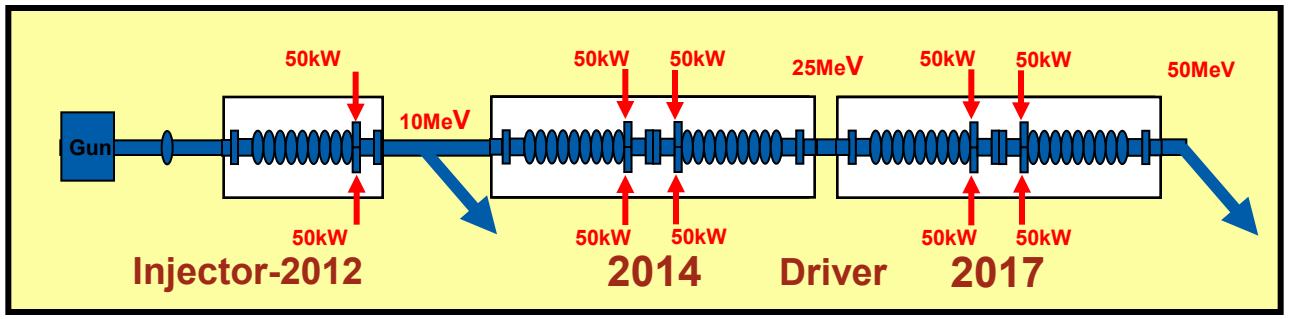






E-Linac Cryomodules

- TRIUMF is building an electron linac (50MeV/10mA) as a second driver for radioactive ion beam production for the ISAC facility
  - **see Shane Koscielniak talk Thursday afternoon for overview**
- E-Linac requires one nine-cell in the injector section and four nine-cell cavities in the accelerator section – choose 1+2+2 cavities/cryomodule
  - **Injector Cryomodule (ICM) to be used as a working prototype for Accelerator Cryomodule (ACM)**
  - **Two ICM's will be built and tested with beam - one for TRIUMF and one for VECC (Kolkata)**
  - **Two cavity ACM fits staging scenarios and is conveniently sized**
- 1.3GHz Cavities require operation at 2K, two cw 50kW power couplers per cavity required to supply beam loading of 100kW/cavity



VECC/TRIUMF Collaboration

ISAC-II Vault

SC LINAC

1 2 3 4 5

Cryoline

2K pumps

30kW IOT System

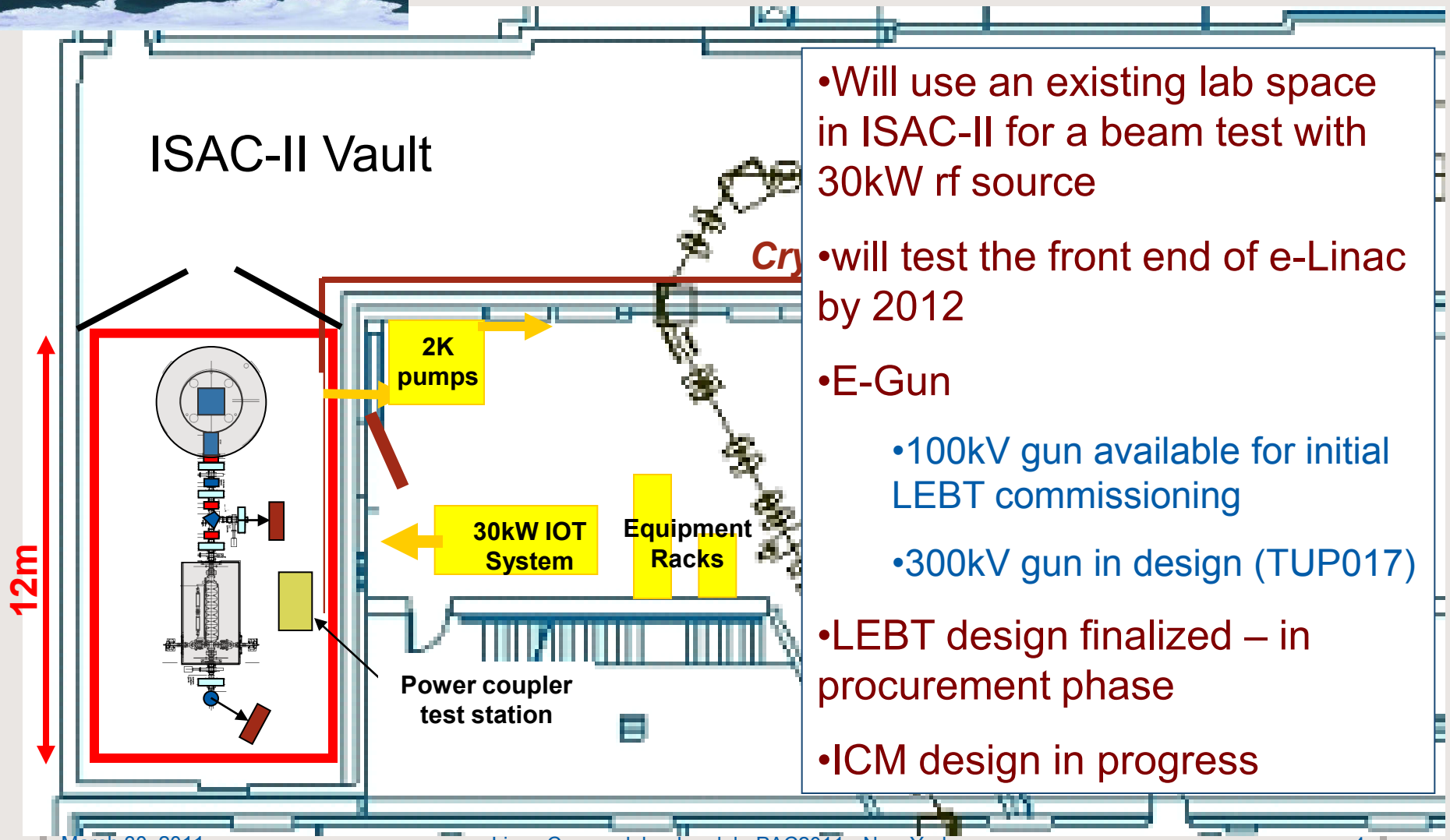
Equipment Racks

CRYOGENICS

Power coupler test station

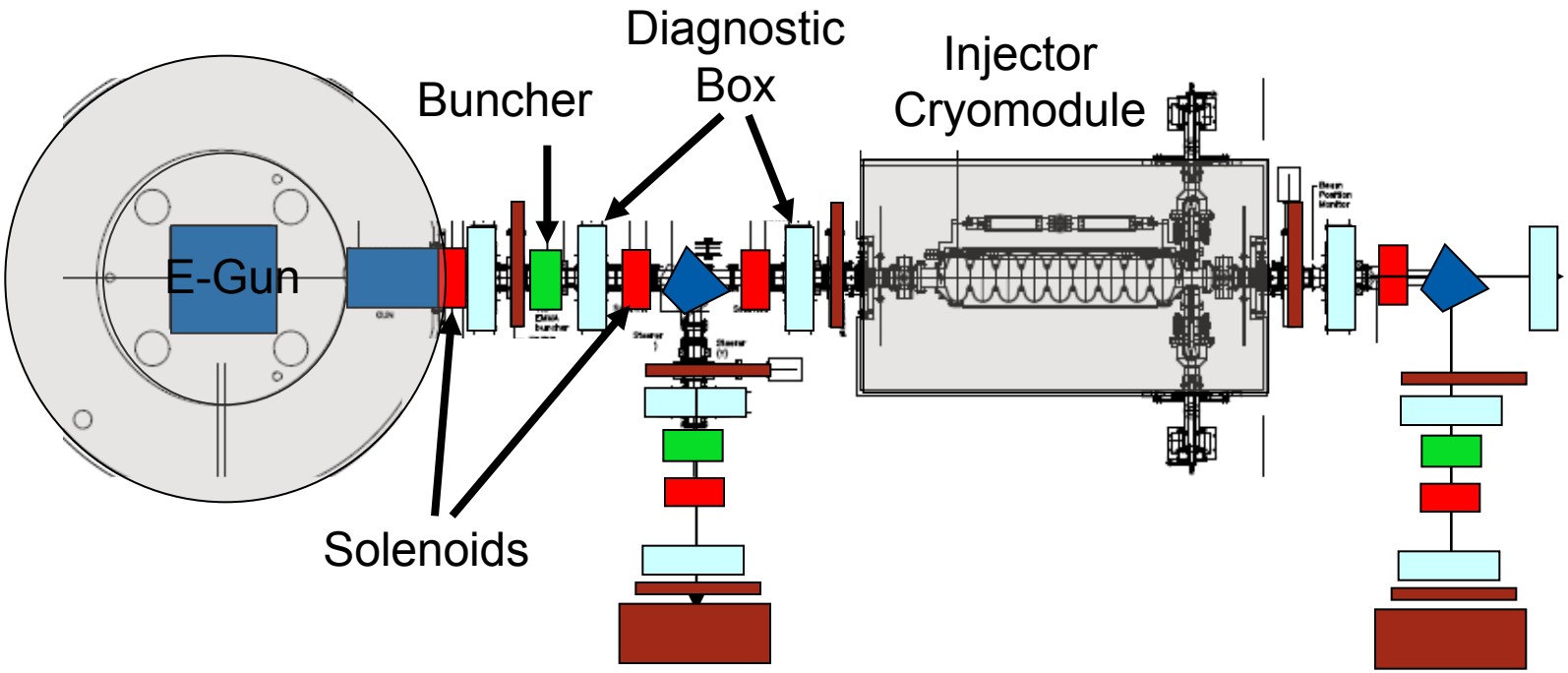
12m

VECC/TRIUMF Collaboration

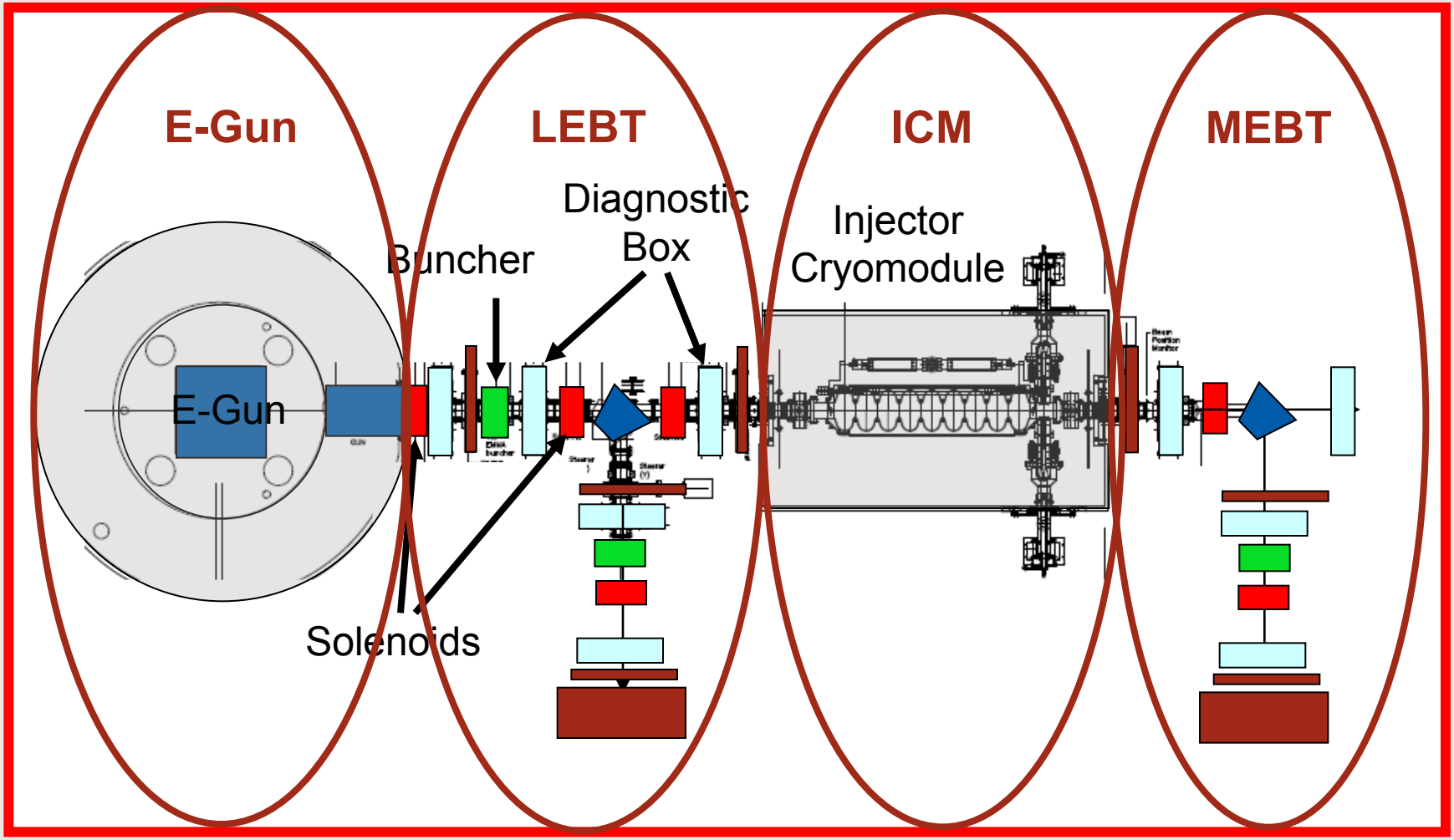


- Will use an existing lab space in ISAC-II for a beam test with 30kW rf source
- will test the front end of e-Linac by 2012
- E-Gun
  - 100kV gun available for initial LEBT commissioning
  - 300kV gun in design (TUP017)
- LEBT design finalized – in procurement phase
- ICM design in progress

Injector Test Layout - 2012

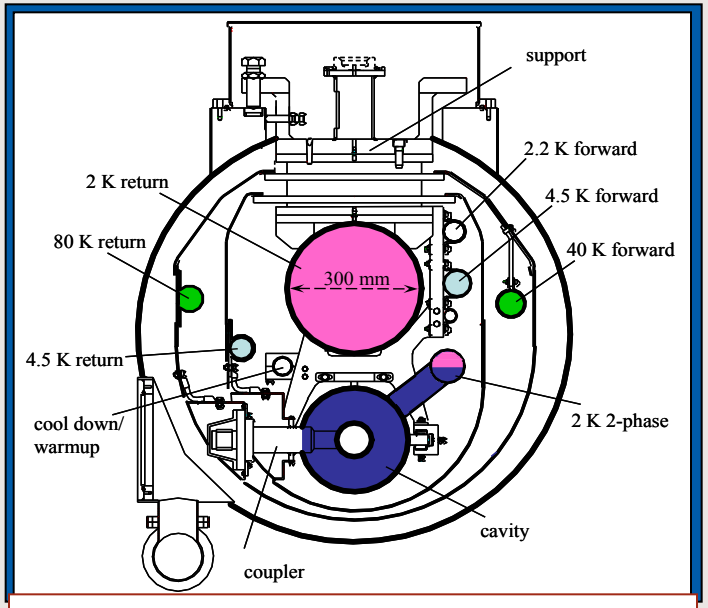


Injector Test Layout - 2012

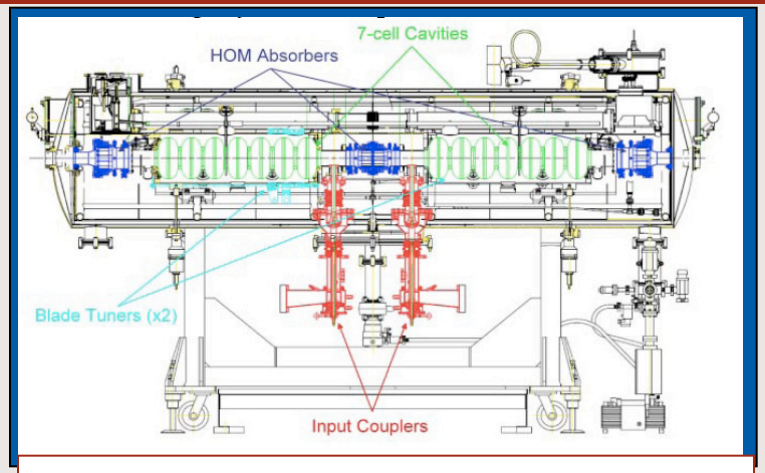


Cryomodule Concepts (end load)

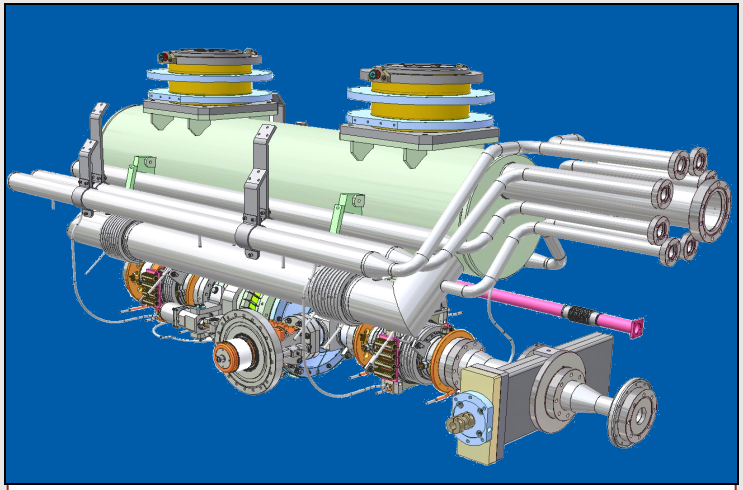
- Typically elliptical cavities housed in pipe like vacuum chambers with cold-mass loaded from one end
- 2K production from custom cold box or local JT expansion valve box



XFEL/ILC Style



Daresbury HI Module (Stanford)



Cornell (after Tesla)

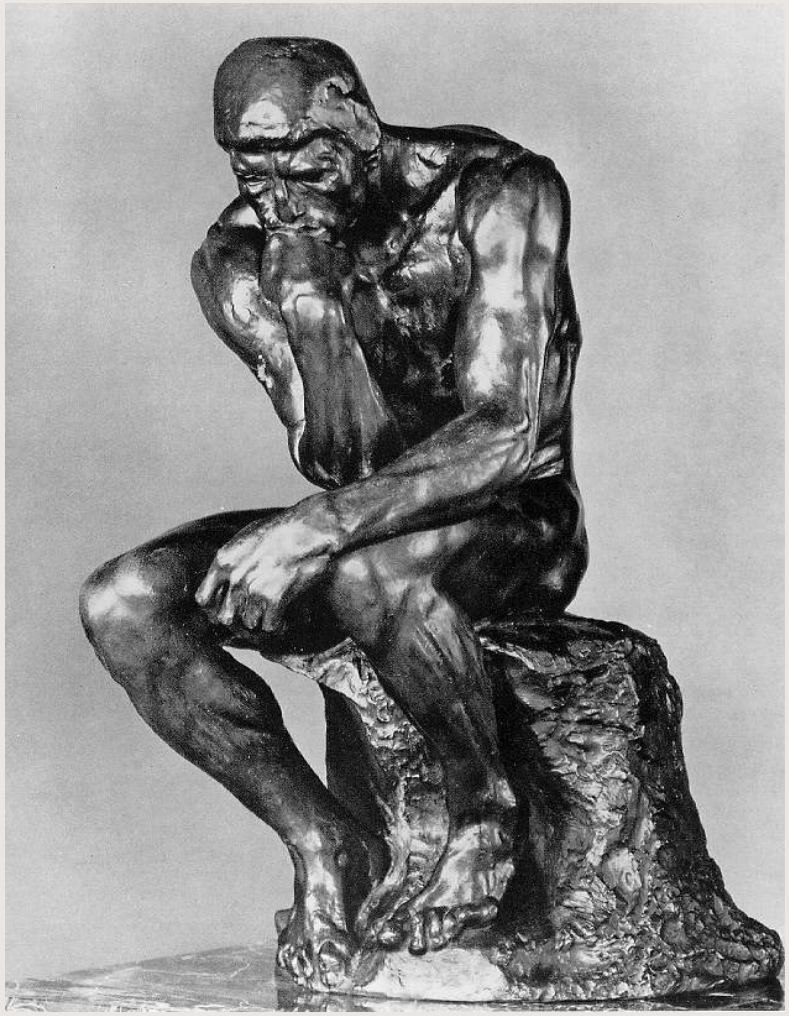
Low beta cryomodules – top load

- Low beta cryomodules tend to utilize the top loading box concept
  - Large transverse cavity dimensions
  - Cavities loaded on strongback
  - 4K helium reservoir/phase separator on board
  - Common or separated vacuum solutions available

ISAC-II top-loading box cryomodule

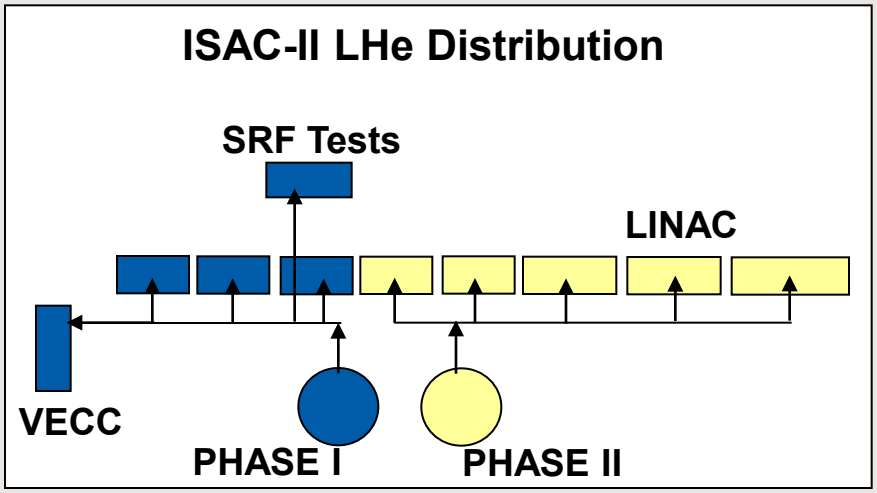
Cryomodule design philosophy

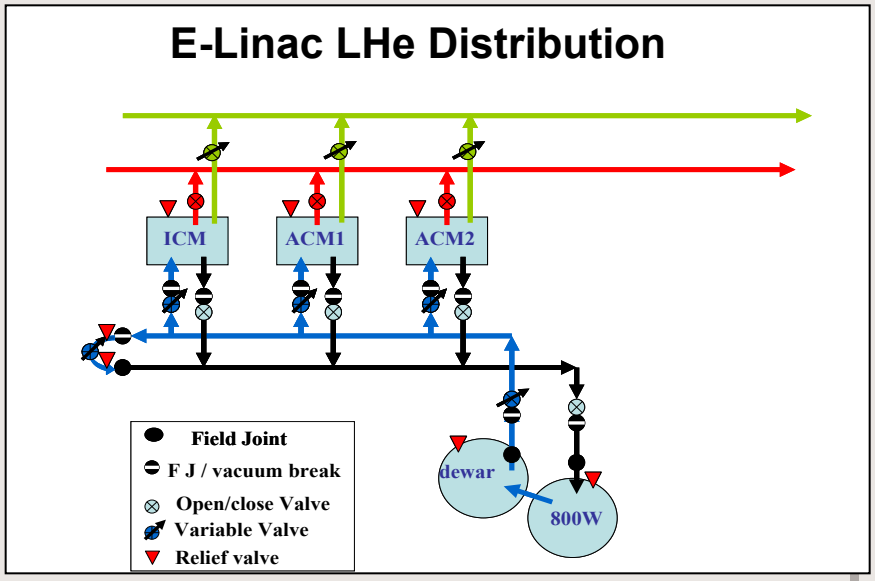
- ICM and ACM's will be installed in stages- ICM will be tested in ISAC-II (4K plant) then delivered to e-Hall
  - Convenient to make each cryomodule self sufficient as far as 2K production – each equipped with heat exchanger and JT valve
- Decide to take advantage of experience with ISAC-II as far as practical to reduce design time and take advantage of existing infrastructure



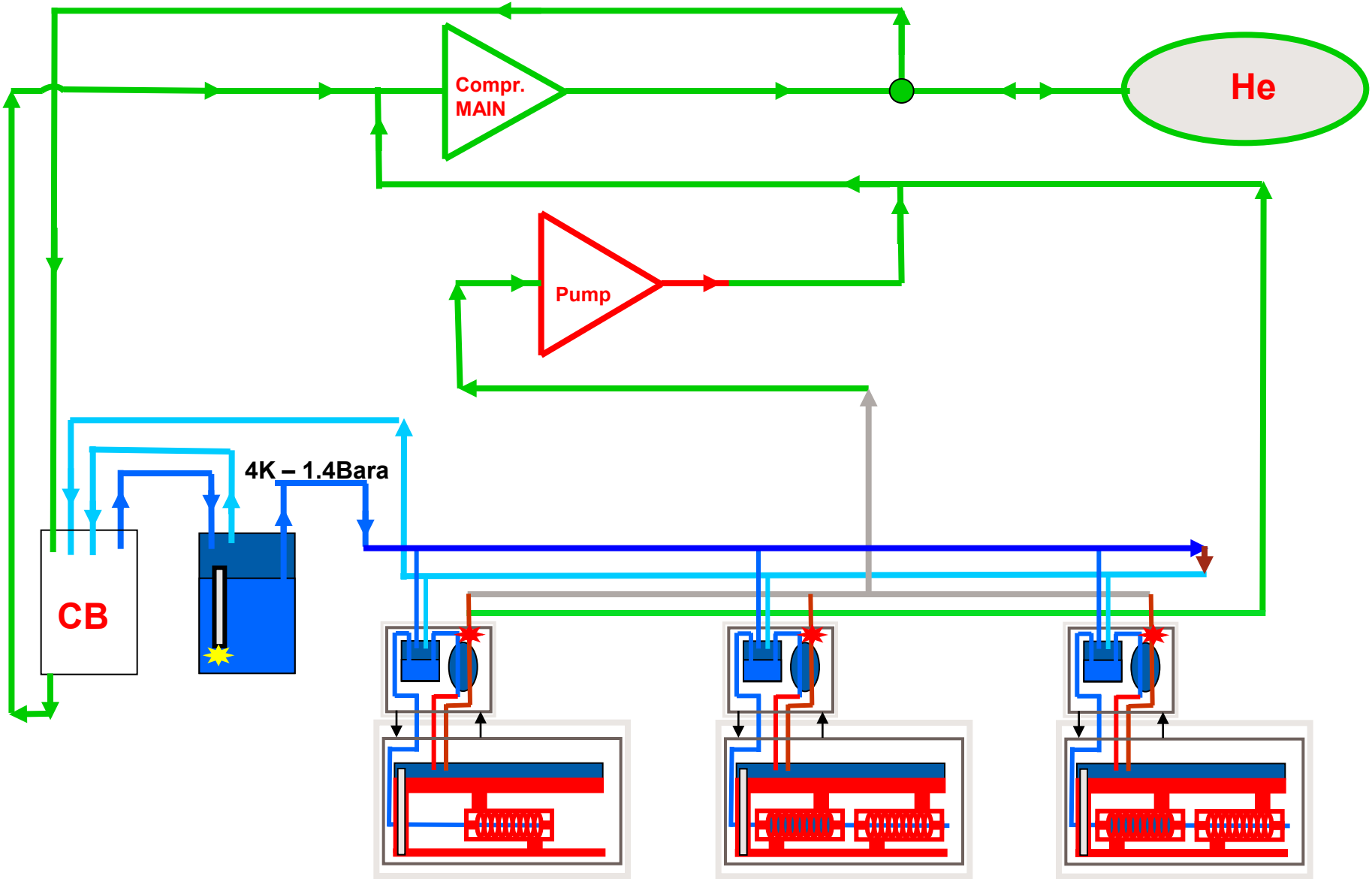
ISAC-II vs e-Linac Cryogenics

- E-Linac cryogenic system borrows significantly from ISAC-II
  - Cold box delivers 4K liquid to a central supply dewar
  - 4K liquid at ~1.3Bar is delivered to a trunk line and distributed in parallel to each of the cryomodules
  - Phase separator in each cryomodule collects 4K liquid with cold vapour returned to the cold box
- Expansion to 2K within each module
  - LHe is expanded in JT valve to produce 2K liquid
  - Sub-atmospheric pumps maintain 30mBar operating pressure



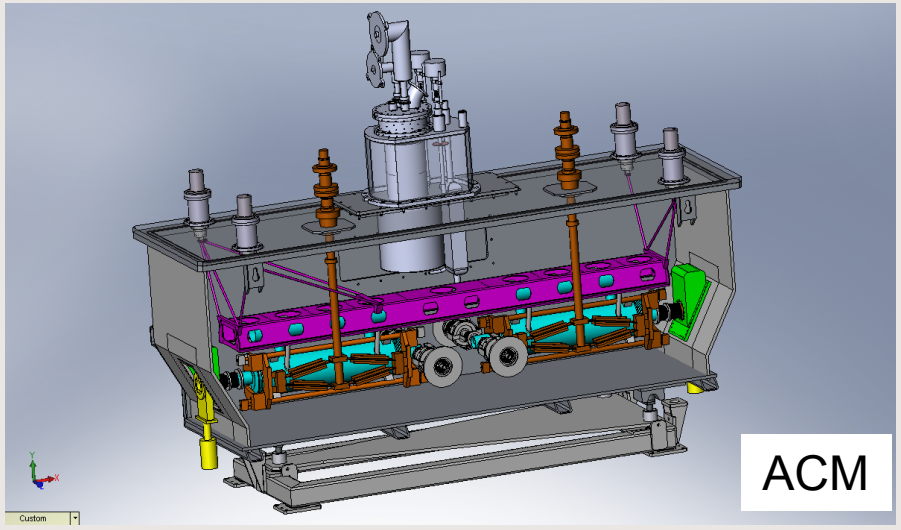


e-Linac cryogenic system

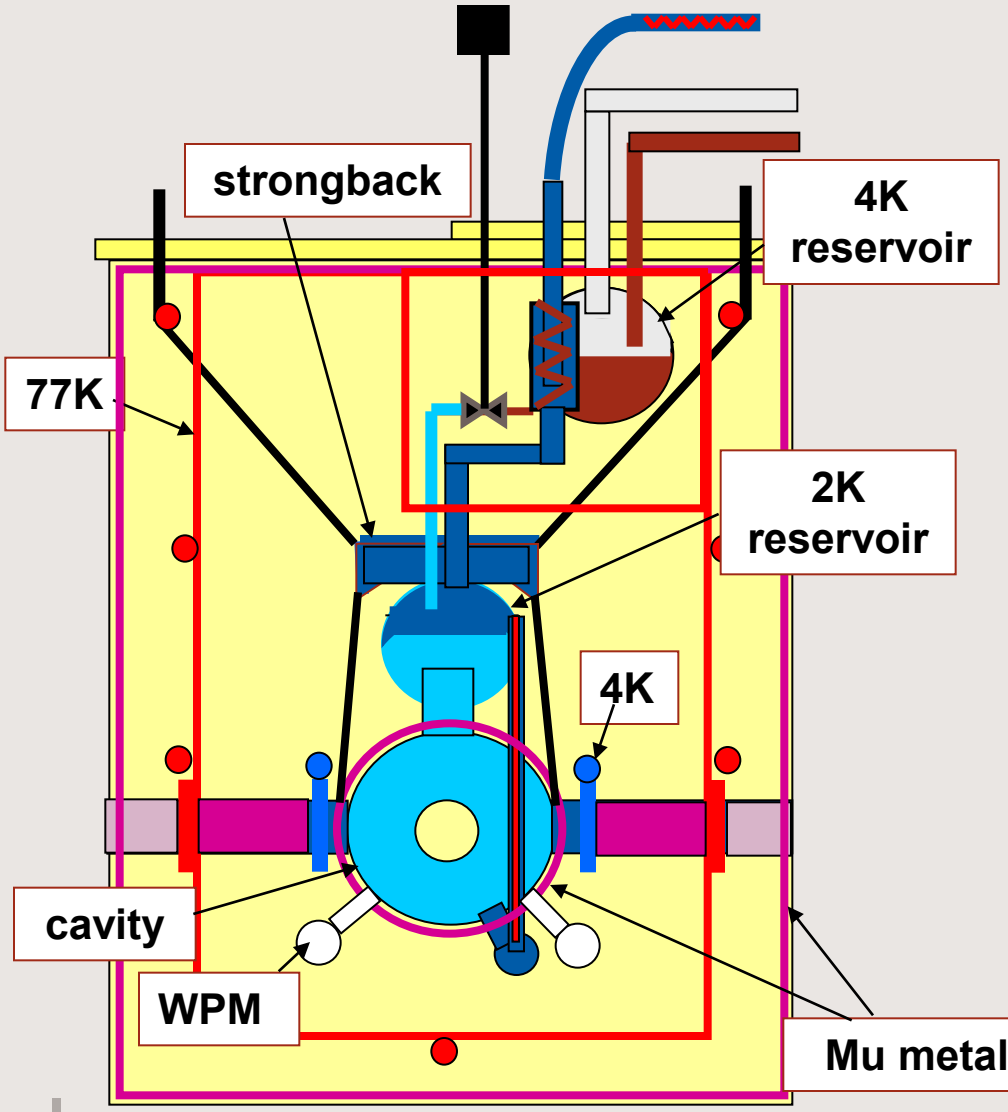


ISAC-II vs e-Linac cryomodule

- E-Linac cryomodule borrows significantly from ISAC-II
  - Top loading box concept
  - Strongback mounted from struts
  - LN2 thermal shield
  - 4K phase separator on board
- Key differences
  - Cold mass operates at 2K
  - Elliptical cavities vs quarter wave cavities
  - MLI ok – separated vacuum

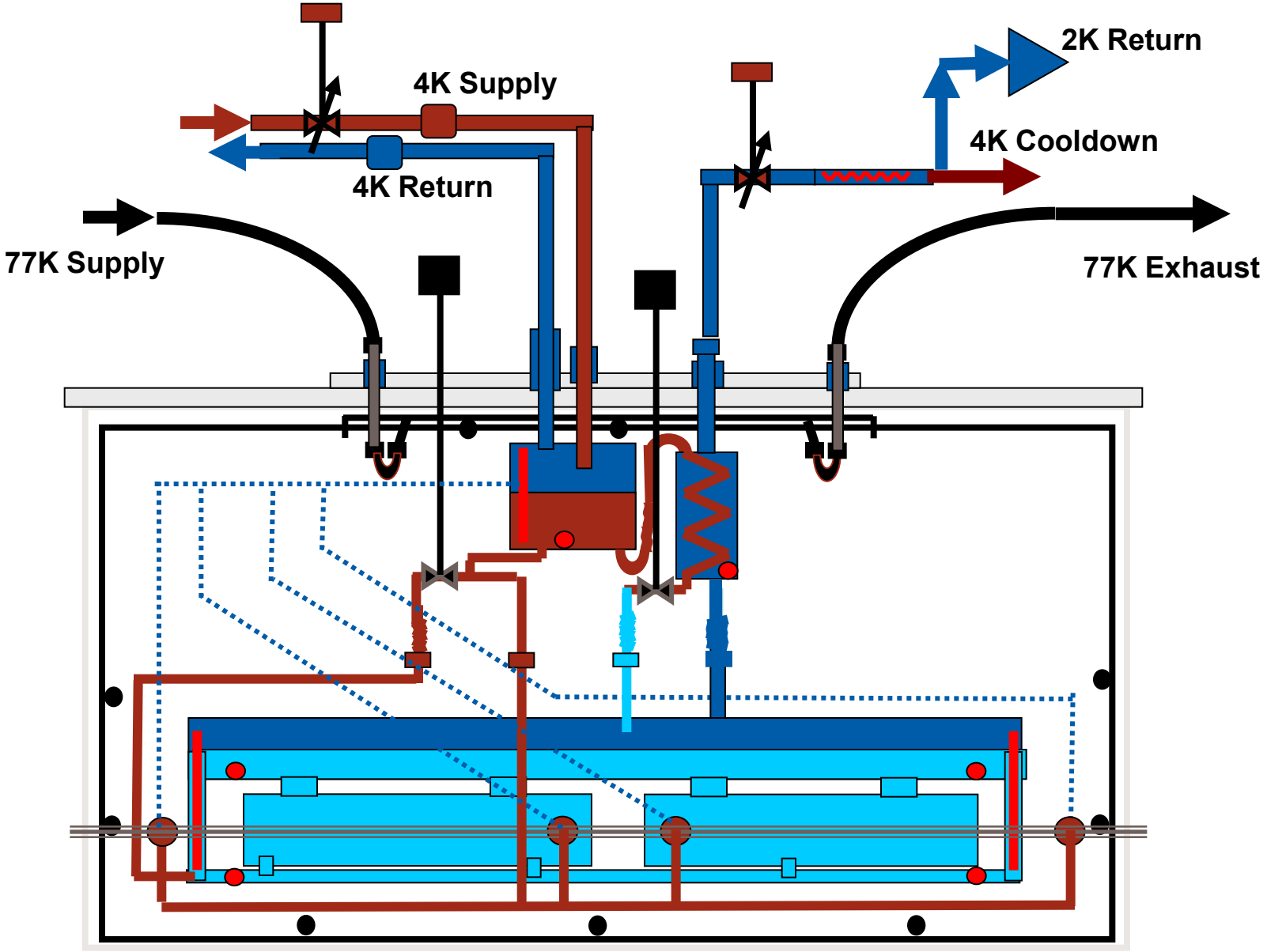


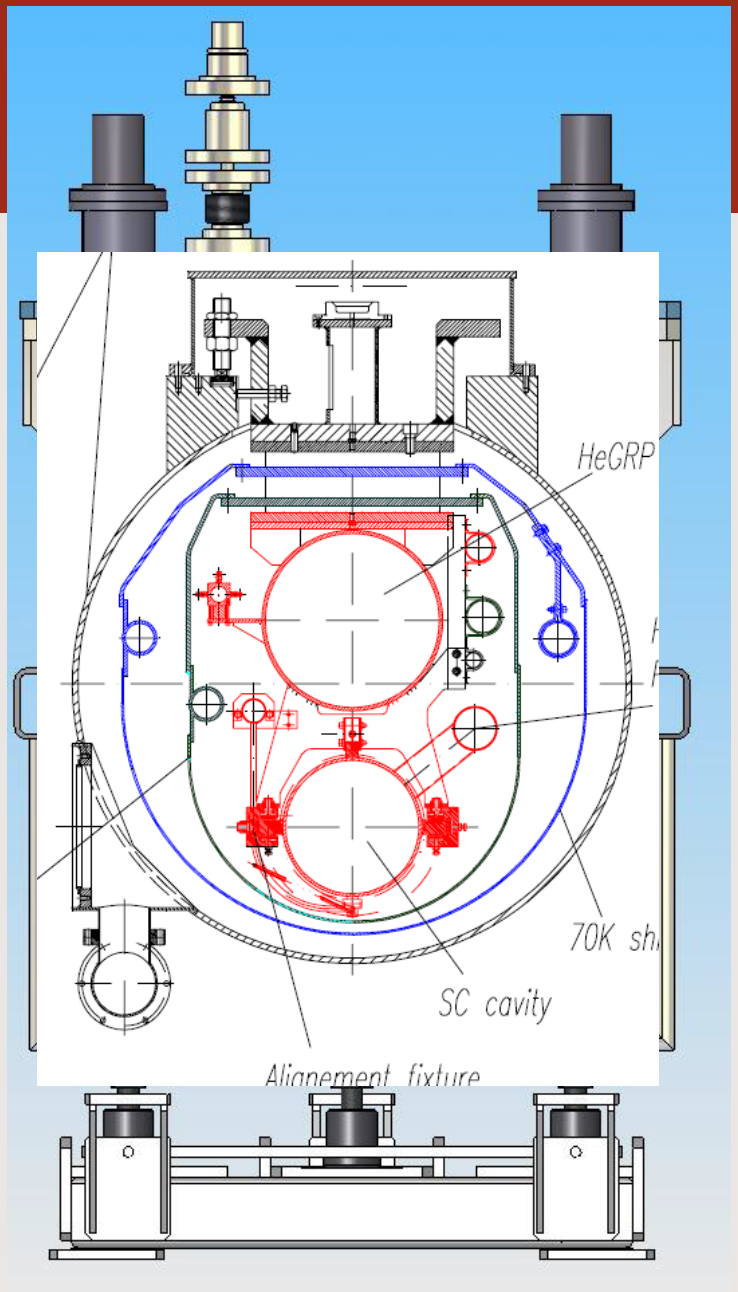
e-Linac Cryomodule features

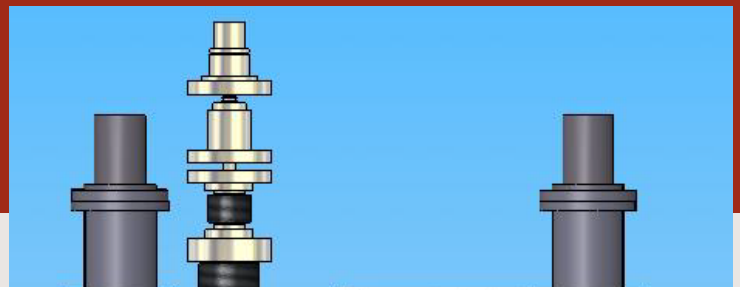


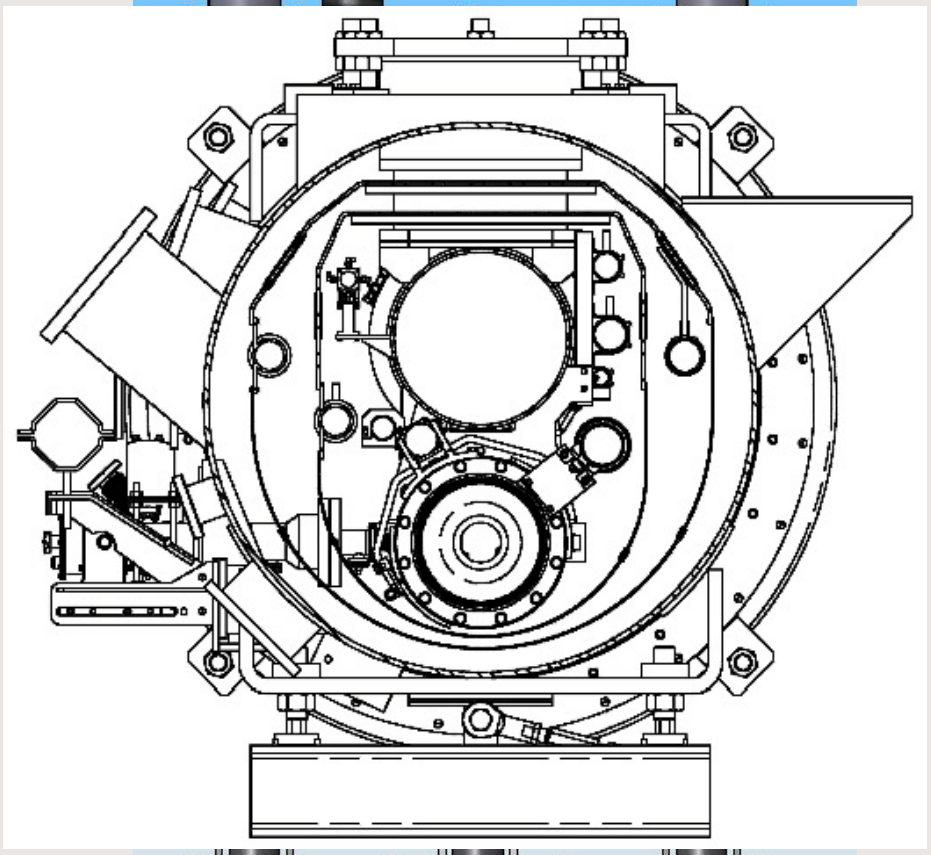
- Top loading box concept
- Cryogenic insert with 4K phase separator JT valve and heat exchanger on board to produce 2K liquid; insert is removable with cryomodule in situ
- Cold mass supported by strong-back
- LN2 cooled thermal shield; 4K circuit for intercepts
- Warm and cold mu-metal
- Pair of alignment pick-ups upstream and downstream of each cavity

Cryogenic Couplings



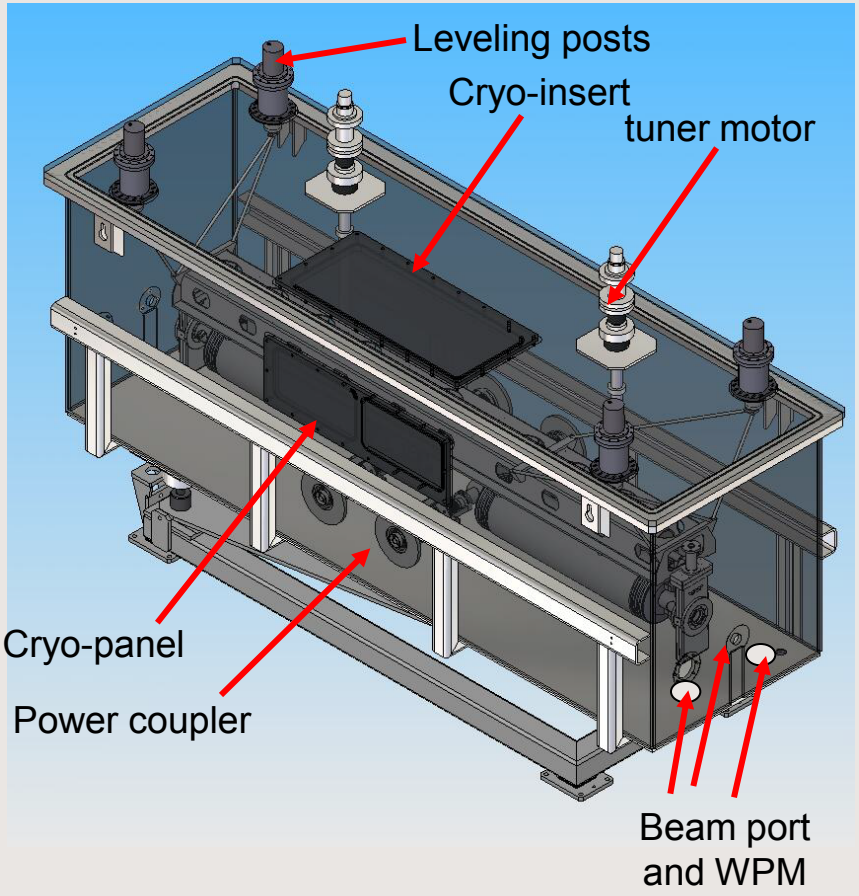

HeGRP
70K sh
SC cavity
Alignement fixture





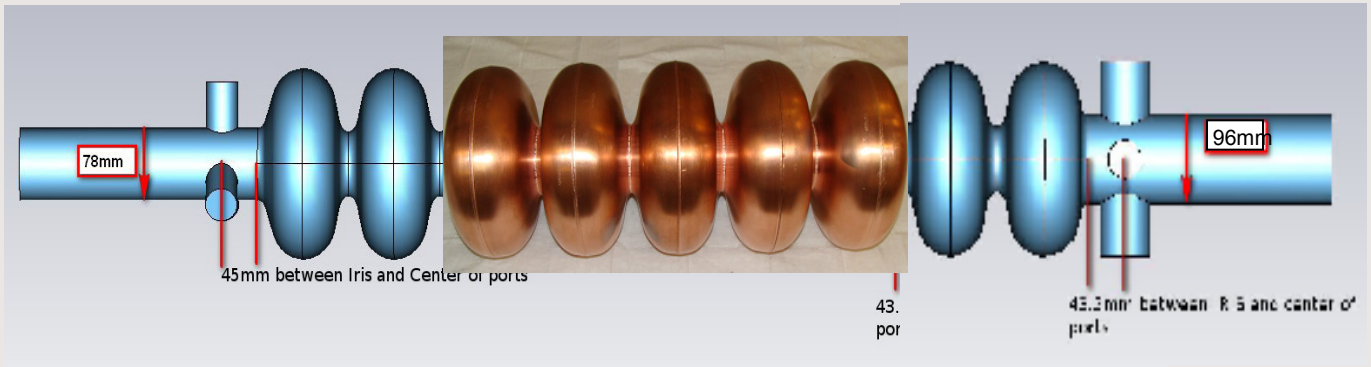
Vacuum chamber

- Stainless steel ribbed enclosure
- window openings for power coupler installation
- End ports for beam pipe, WPM ports and warm isolation valve
- Top opening for cryo insert; side window for cryo-connections
- Top ports for vacuum pumps, WPM cables, tuner actuator, rf pick-ups, diagnostics (temp sensors, heaters, level probes)

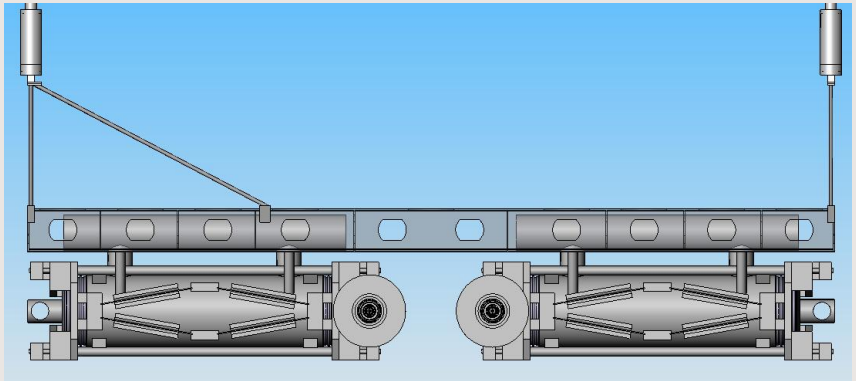


Cavity parameters

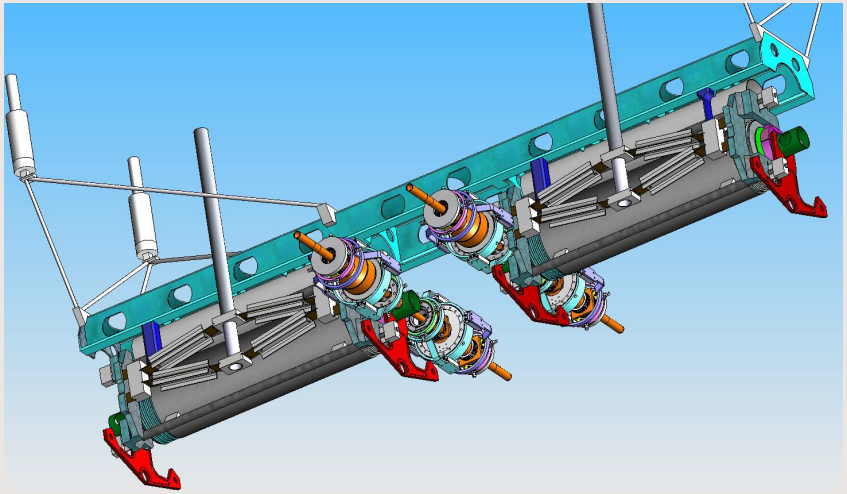
- Baseline cavity is the 1.3GHz Tesla 9-cell bulk niobium cavity
- Two power couplers (50kW cw each) limit $P_{rf} \leq 100$kW per cavity; means $\Delta E \leq 10$MeV for I=10mA – corresponds to Ea=10MV/m design specification – 10W at Q_0=1e10
- End cells are modified to accommodate the large power couplers and mitigate higher order modes driven by high beam current

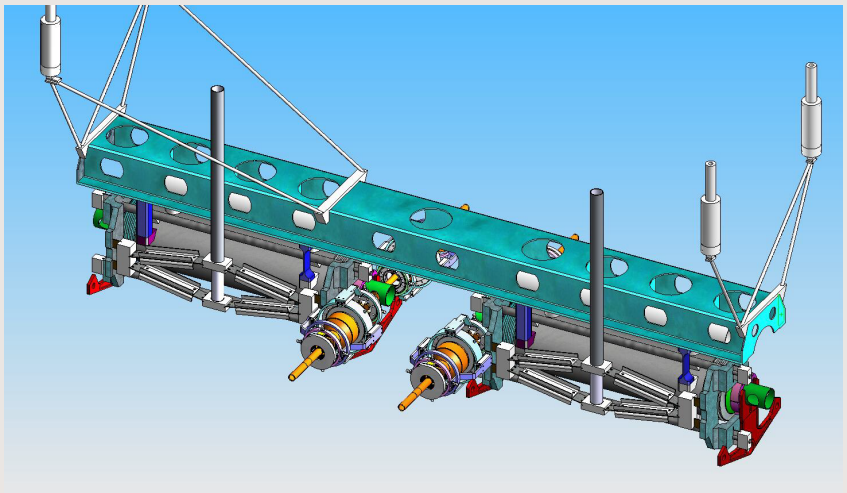


Strongback



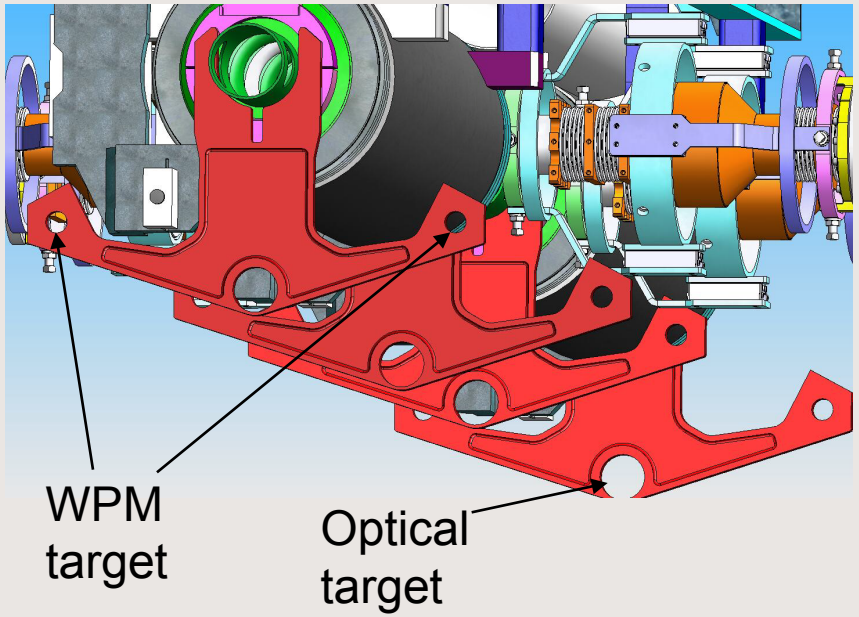
- Cavity sub-assemblies are formed into a hermetically sealed unit (cavity string) bounded by isolation valves and containing cold power coupler, two phase pipe and WPM supports
- The cavity string is then outfitted with magnetic shielding and tuners and then mounted to the strong back for alignment

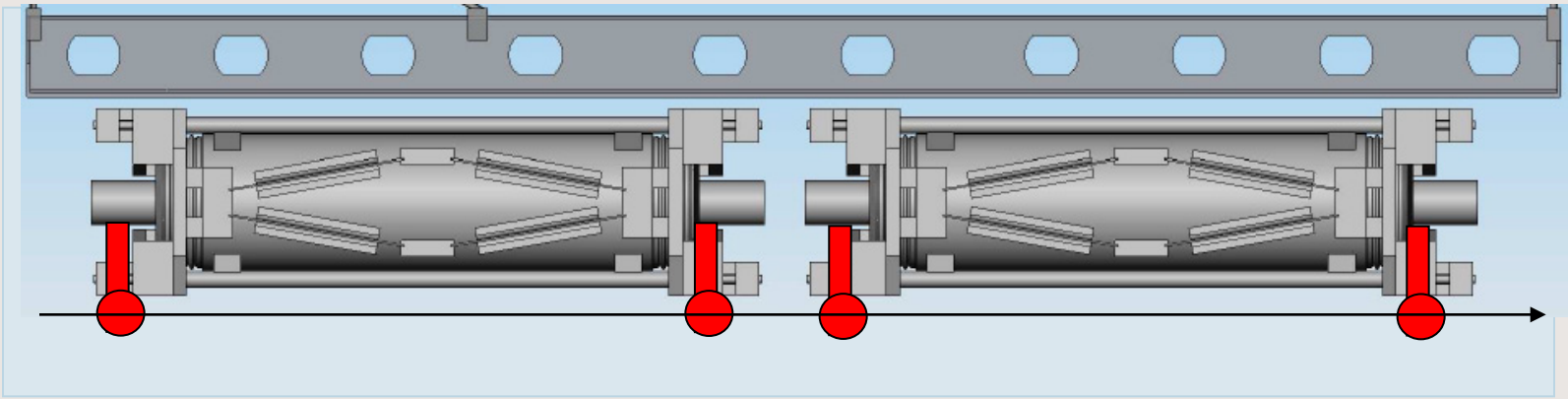




Alignment

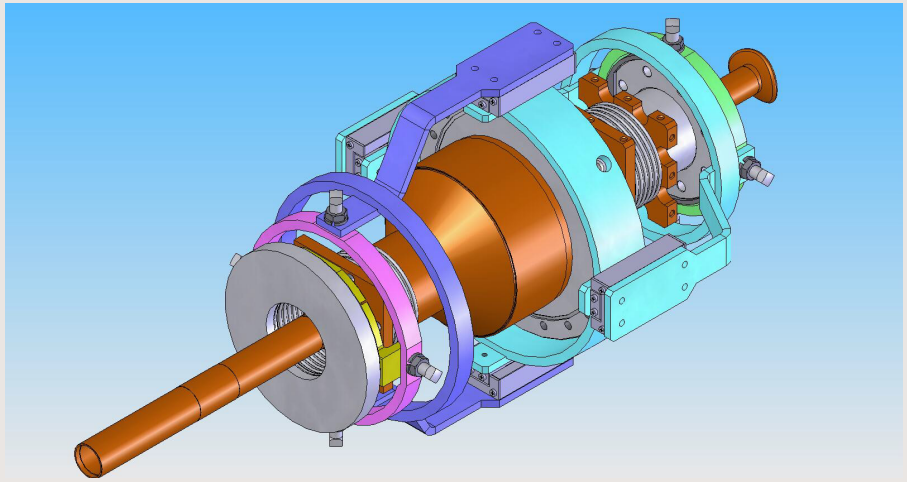
- A pair of alignment brackets are placed upstream and downstream of each cavity fixed to the beam tube and indexed to the beam center
- The brackets can host optical or WPM targets
- Variable mounting supports from cavity to strongback are used to align the targets



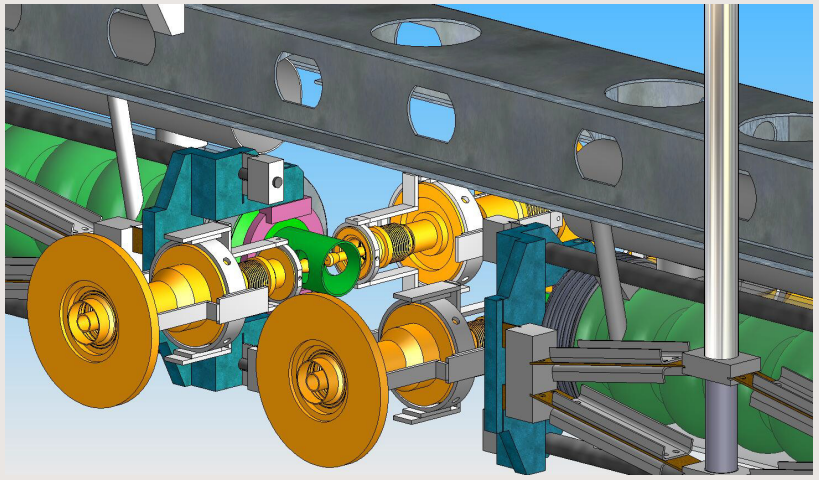


Power coupler gymbal and mock-up

- Need to maintain support for power coupler while allowing it to move under cooldown and maintain low stress on window
  - Design gimbaled support system
  - Making a mock-up tank-flange and power coupler cavity flange to test range of motion of coupler
  - Useful for working out installation of warm coupler end to installed cold part



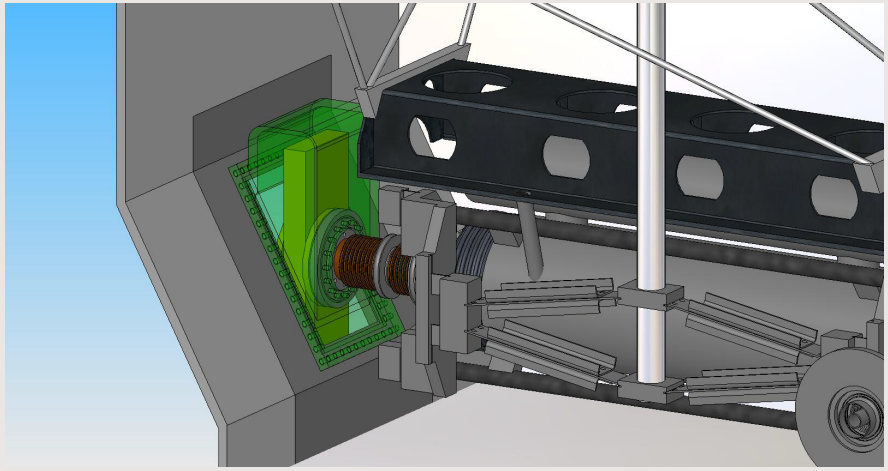
Gimbal support for power coupler



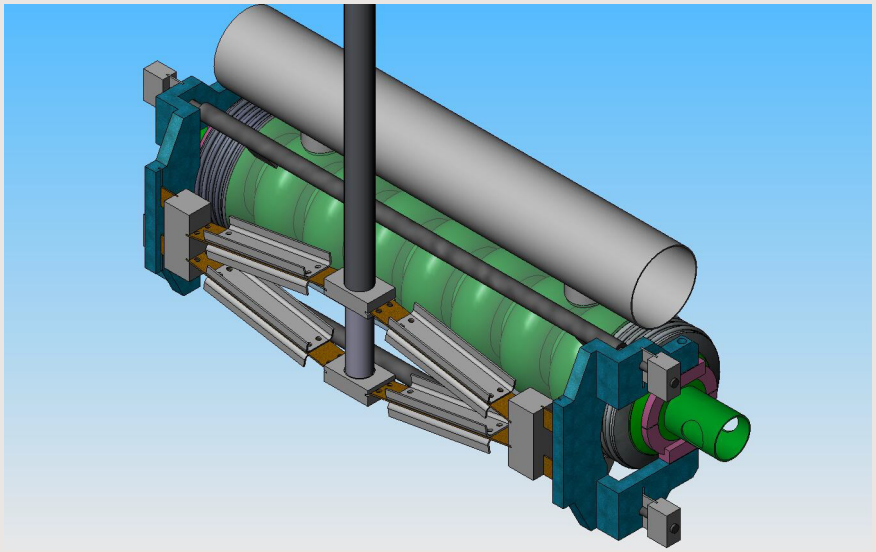
Couplers installed

Cavity tuner and end flange

- End flange
  - Utilize angled end flange and warm isolation valve
  - ie ATLAS Energy upgrade cryomodule

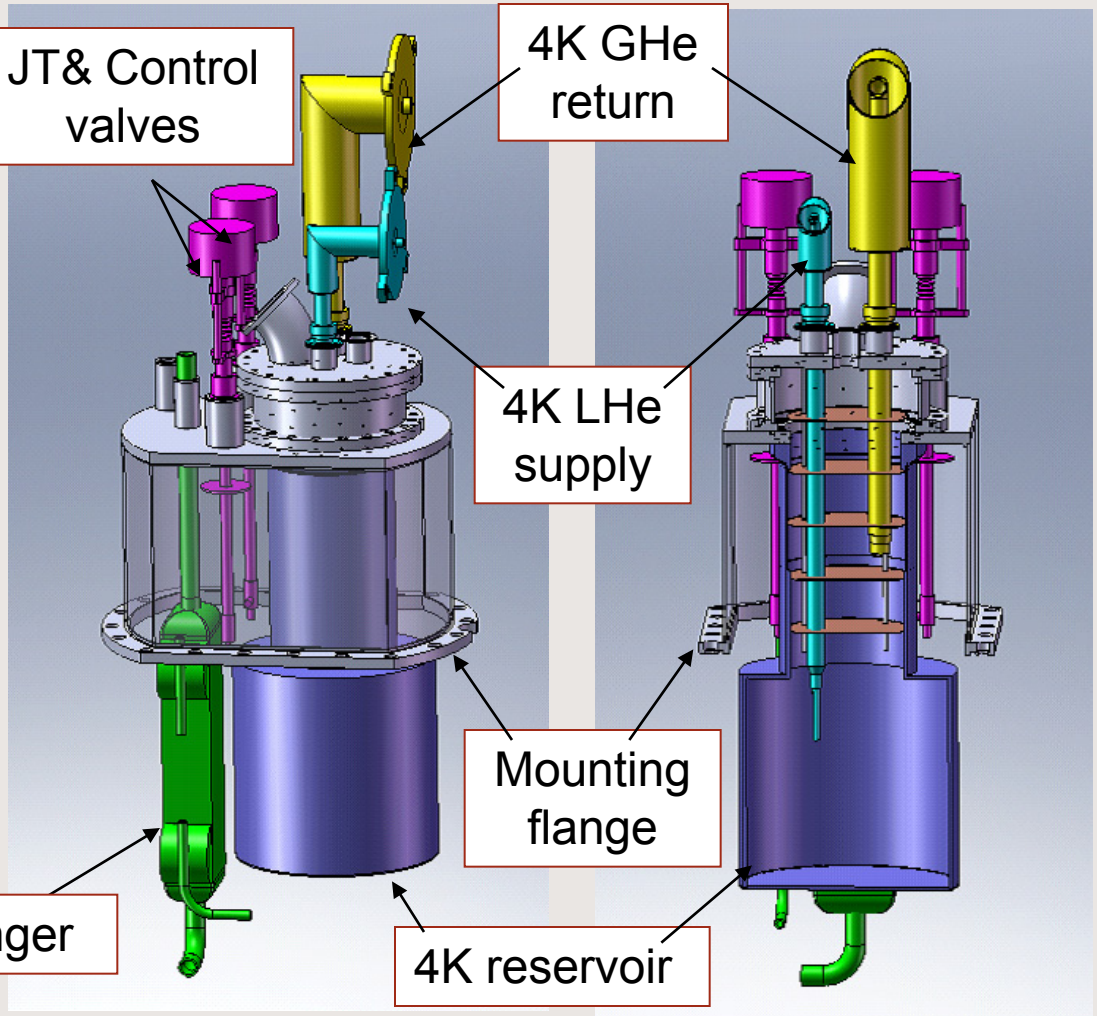


- Cavity tuner
  - Utilize JLab scissor tuner with long actuator and warm motor on top of cryomodule



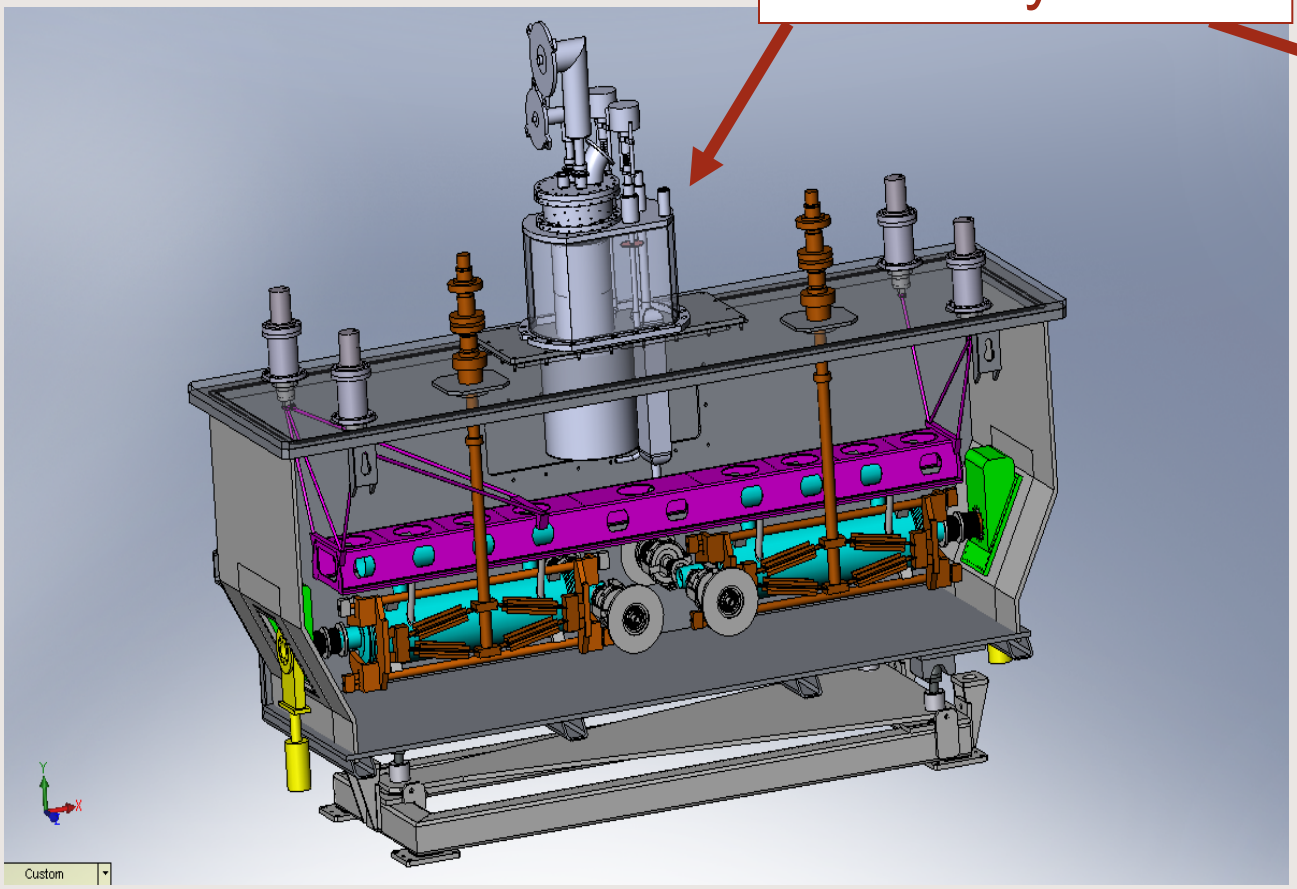
Cryo-insert design

- Design enables prototyping and testing of cryo-insert in existing test cryostat (141MHz cavity cryostat)

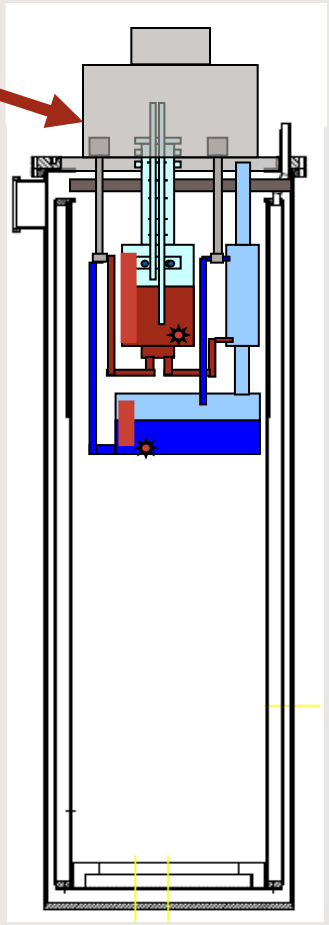


Cryogenic-insert Design

4K/2K cryo-insert



Accelerating Cryomodule



141MHz Test Cryostat

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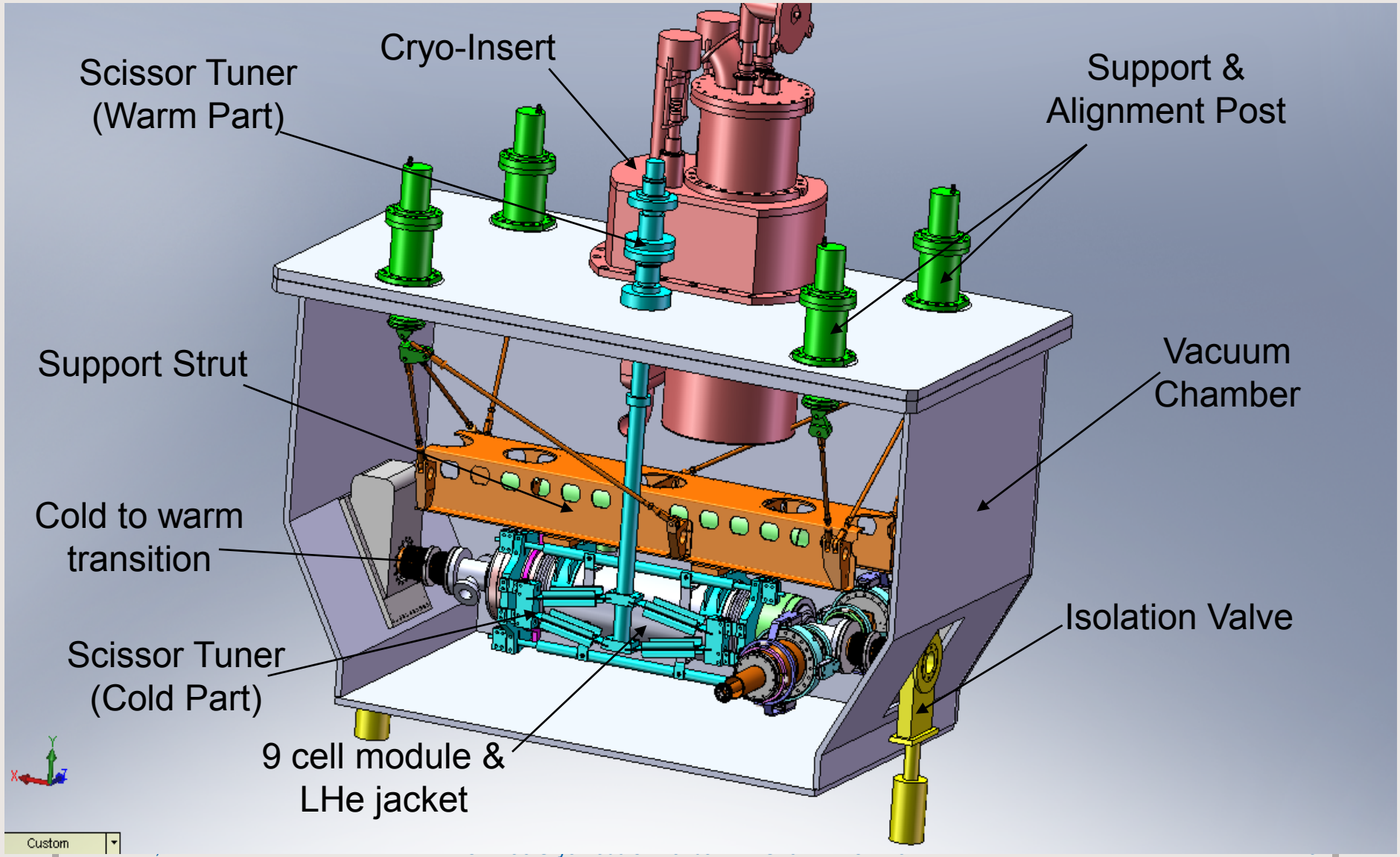
Injector Cryomodule



Summary

- E-Linac cryomodule concept
  - ISAC-II design features incorporated where possible to save engineering time and profit from available infrastructure
  - Cryomodule – top loading box with 4K to 2K production on board
  - 4K cold box delivers 4K liquid at 1.3 Bar in parallel to each cryomodule phase separator
- Status
  - Cavity being prototyped in copper at PAVAC
    - Soon to start fabrication in niobium
  - 4K/2K insert in procurement phase
  - ICM detailed design on-going
  - Plan for a beam test in 2012

Thank You!

Merci!