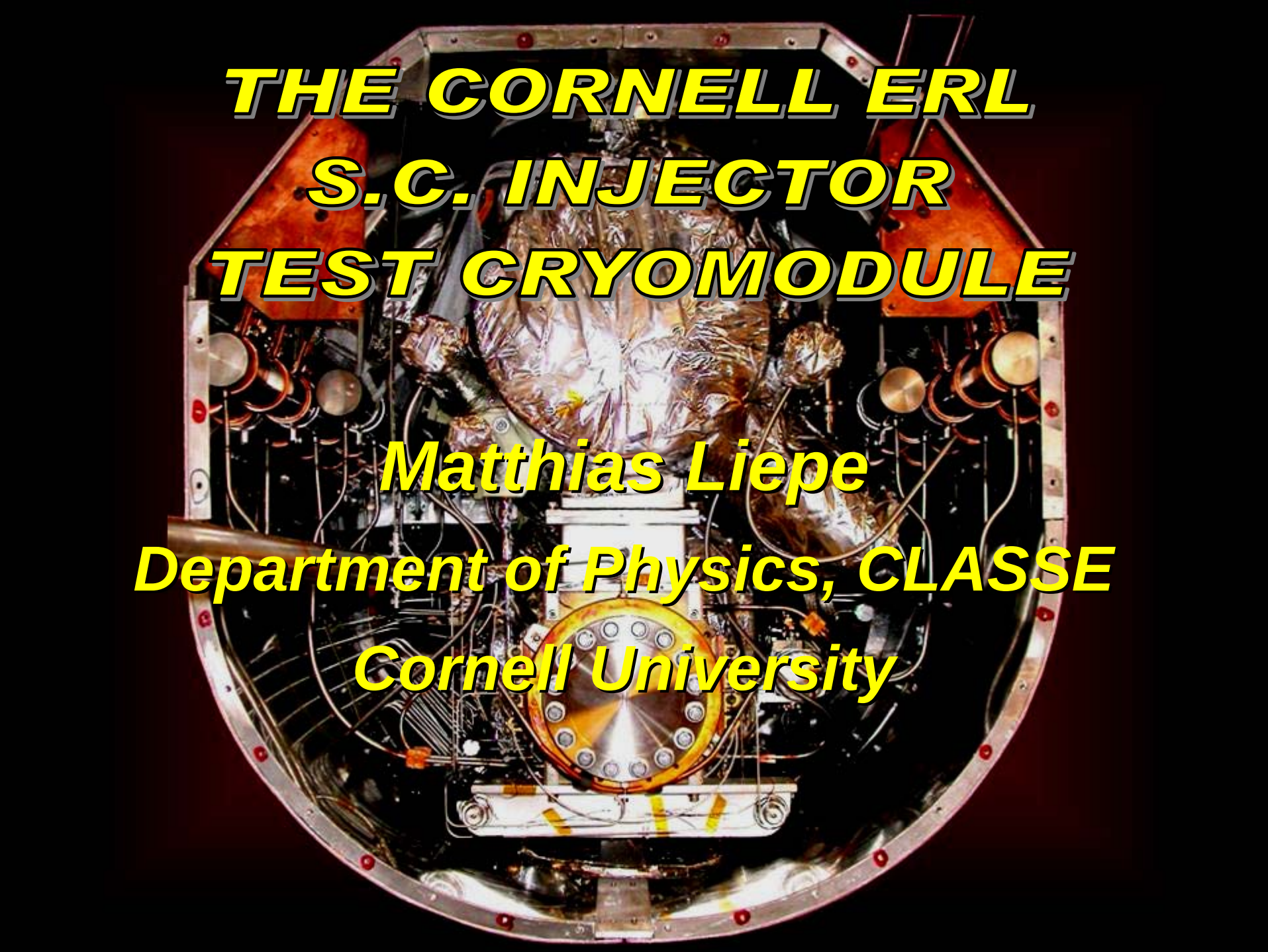

THE CORNELL ERL S.C. INJECTOR TEST CRYOMODULE

Matthias Liepe

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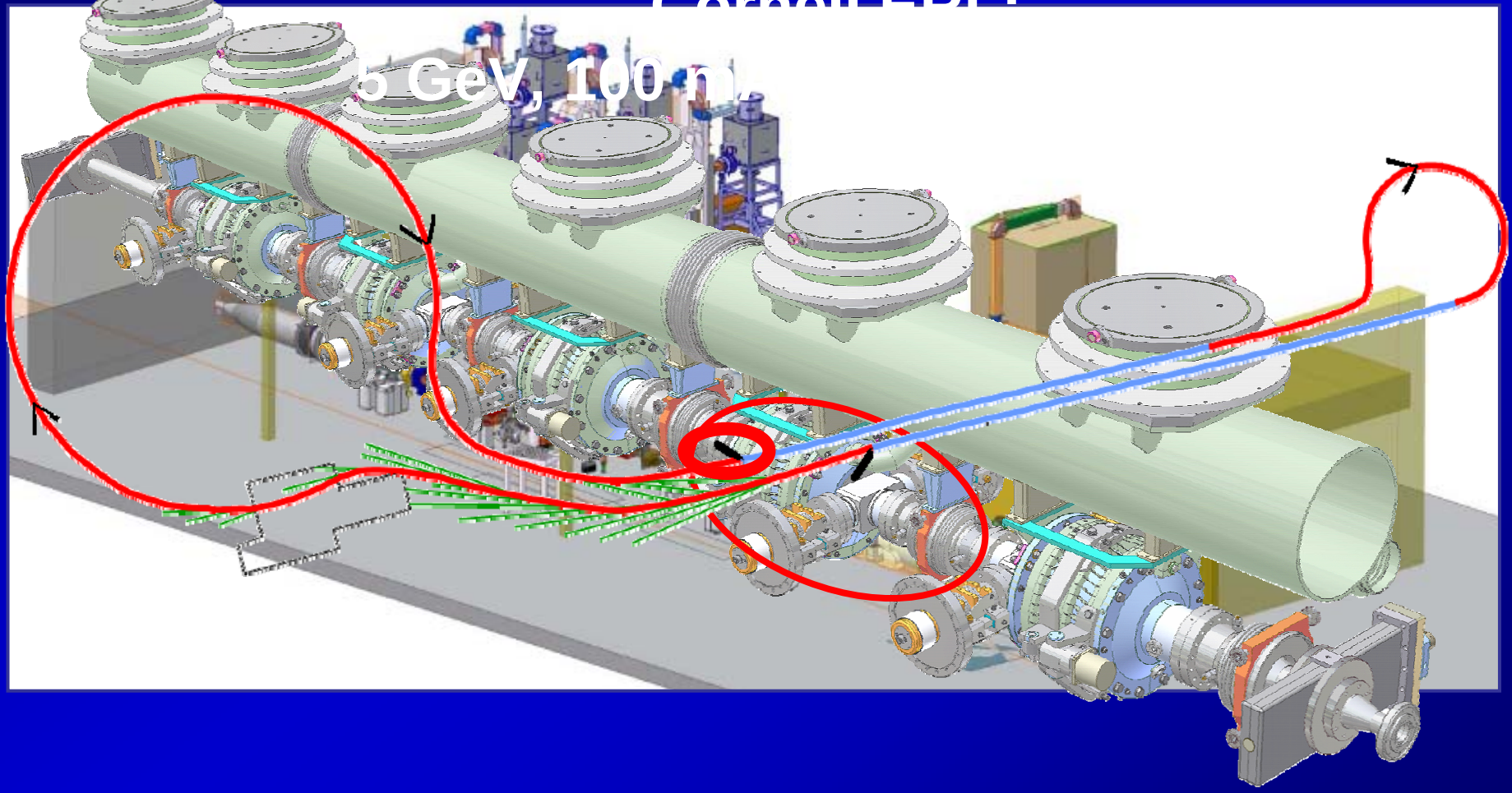
Cornell University

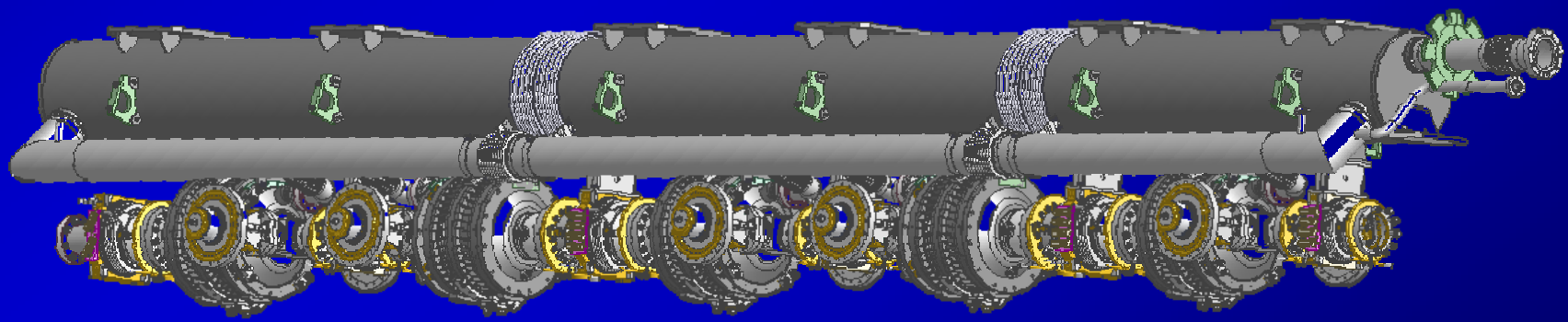
A 100 mA SRF Injector Cryomodule for the Cornell ERL X-ray Light Source



Injector Beam Requirements and SRF Answers

- E = 5-15 MeV
- beam power ≤ 0.5 MW
- max current 0.1 A
- q = 0.01- 0.4 nC
- ε_n = 0.1-1 mm-mrad

- five SRF 2-cell cavities
- symmetric beam line
  - twin coax input couplers
  - round beam line absorbers
- beam line HOM loads for aggressive HOM damping
- cold cavity fine-alignment

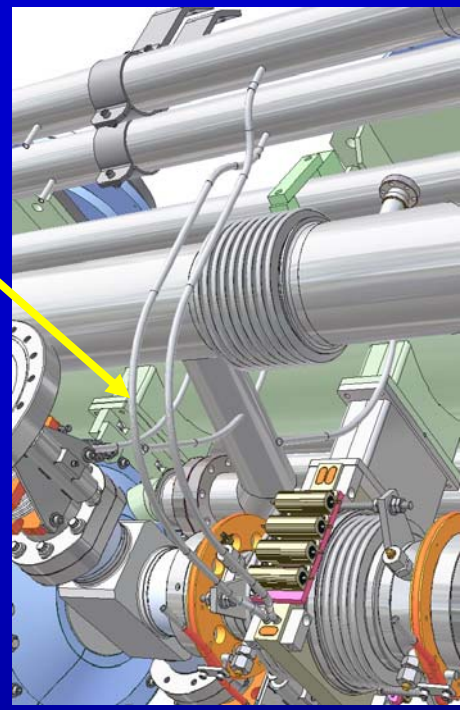


Design Philosophy

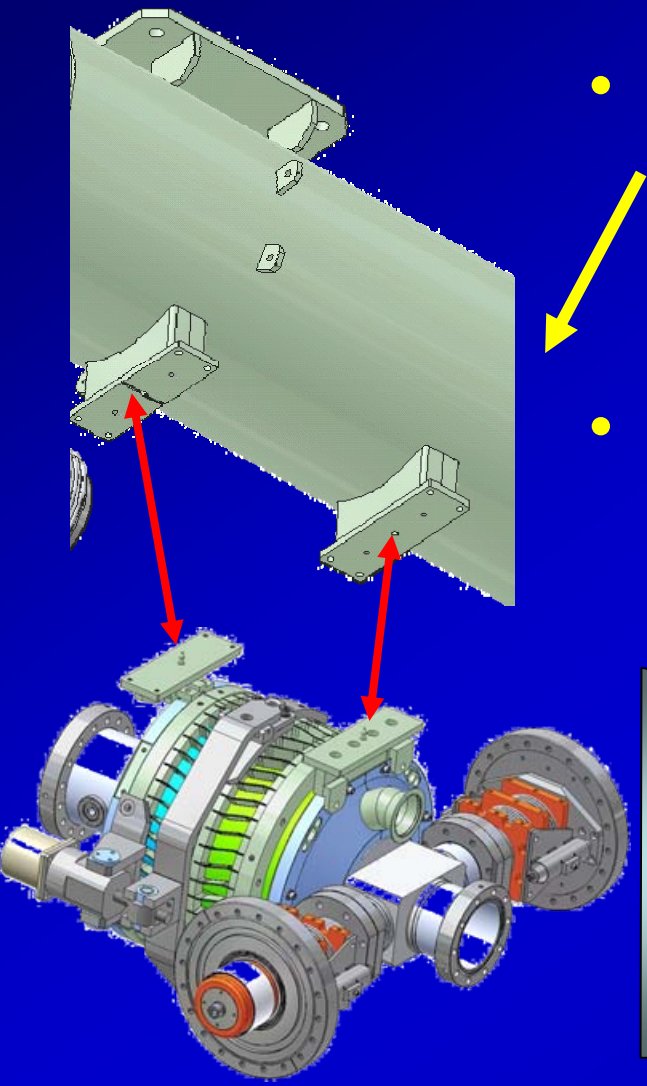
- Use the same cryomodule concept in ERL injector and main linac.
- Cryomodule concept based on the well established TTF cryomodule
  - Cavities supported by large diameter Helium-gas return pipe (HGRP)
- Significant modifications for ERL specific needs:
  - high cryo loads at 1.8K (cavity), 5K and 80K (HOM power, input couplers), high Q_0, HOM loads, …
- Continue simplification and cost reduction

Design Modifications and Innovations

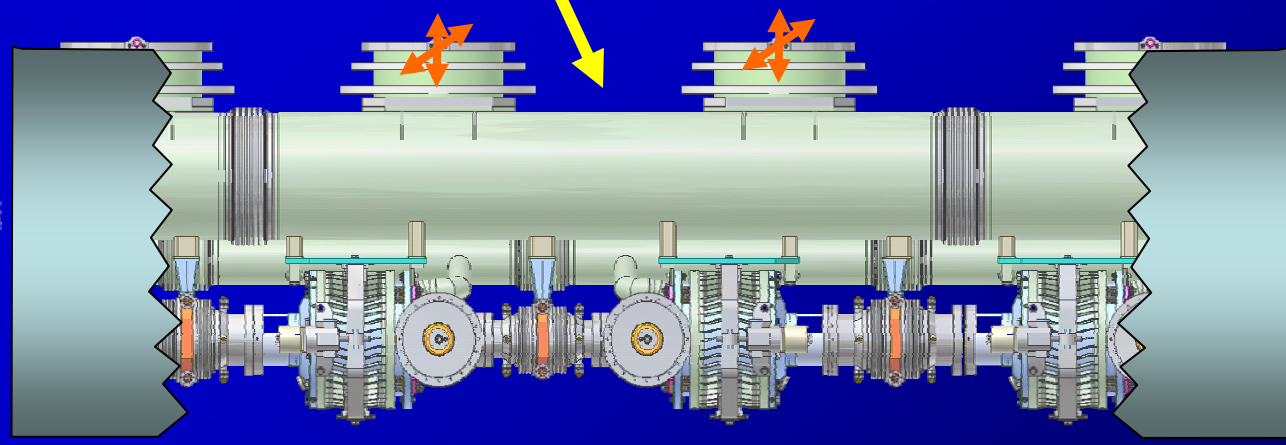
- **Changes compared to TTF cryomodule:**
  - Increase diameter of 2-phase 2K He pipe for CW cavity operation
  - Direct gas cooling of chosen 5K and 80K intercept points with He-gas flow through small heat exchangers
  - HOM absorbers between cavities.
  - 3 layers of magnetic shielding for high Q_o
  - No 5K shield, only a 5K cooling manifold.
  - Tuner stepper easily replaceable while string is in cryomodule
  - New end-cap and feed-cap concept with reduced length
  - In-situ bake for input couplers, no further atmosphere exposure, *no pre-conditioning*



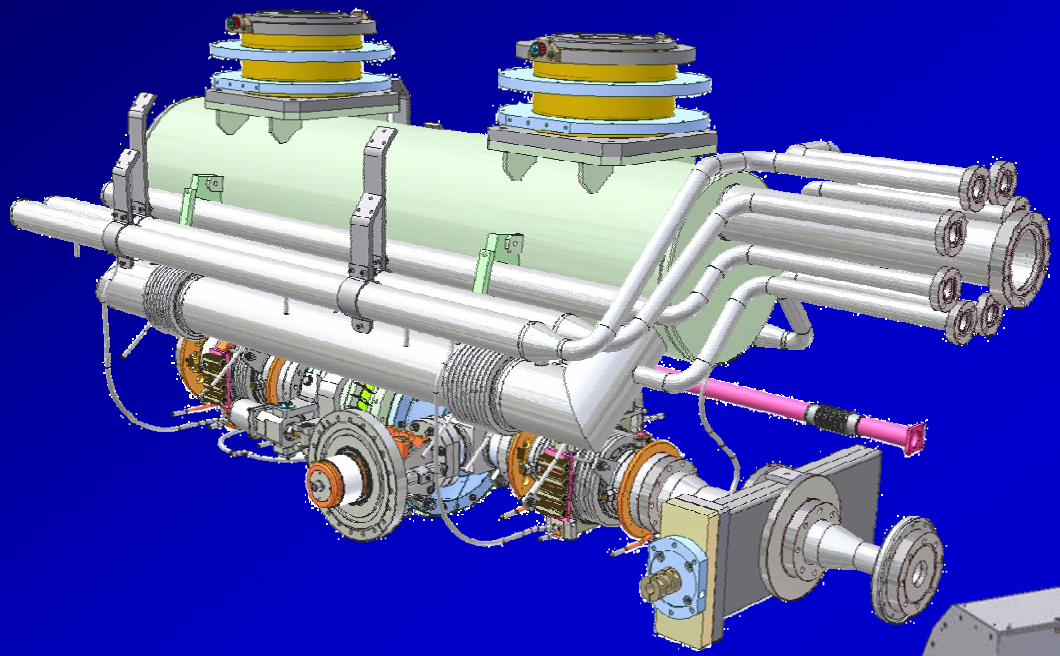
Fixed Cavity and HOM Load Supports



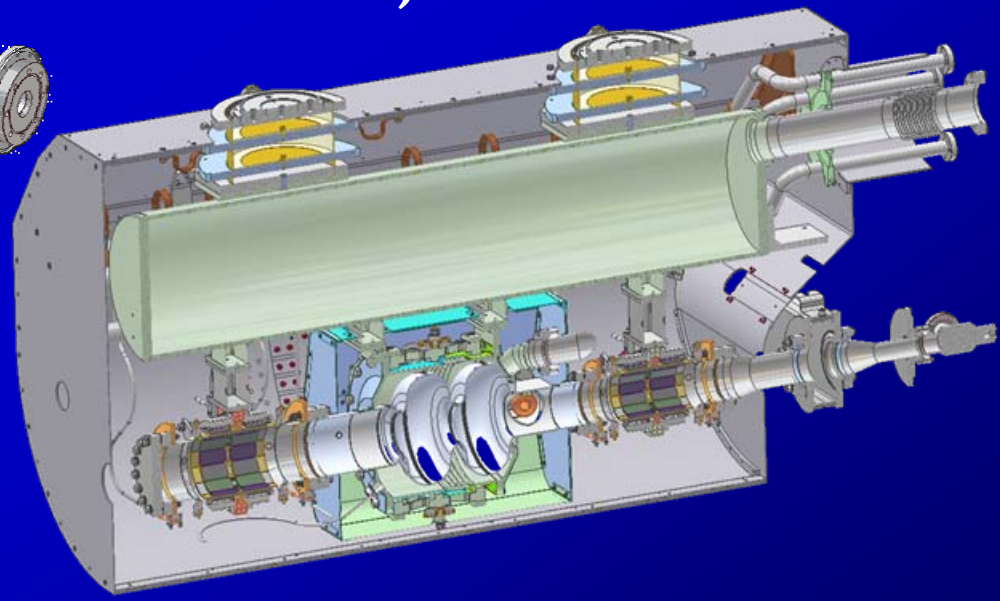
- Precision fixed surfaces between the beamline components and the HGRP ⇒ easy "self" alignment
- Cavity-subunits can be fine-aligned while cavities are at 2K (if required)



Along the Way: The Test Cryomodule



- *Single* cavity test version of full injector module
  - Same concept,…
  - … just shorter

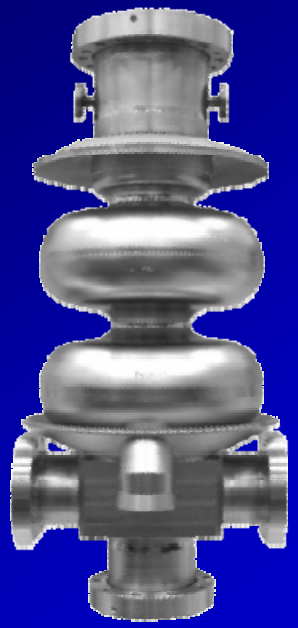


- Vacuum vessel can be used later as an ERL main linac cavity test cryomodule
- Assembly in progress

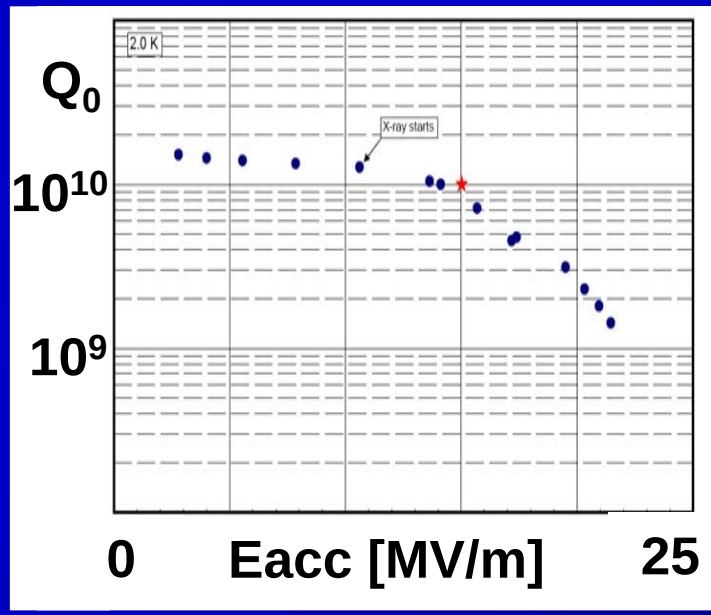
The Beam Line Components:

Design, Fabrication and Test

Superconducting 1.3 GHz 2-cell Cavities



- Brazed conflat flanges
- Twin-input coupler
- 6 cavities fabricated and tested in house
- Only BCP, no 800C
- All cavities meet 15 MV/m spec



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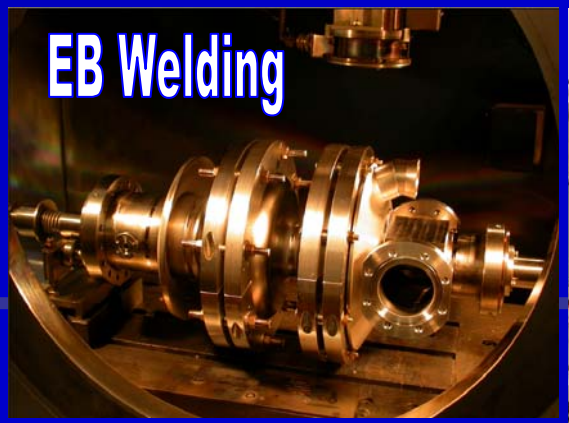
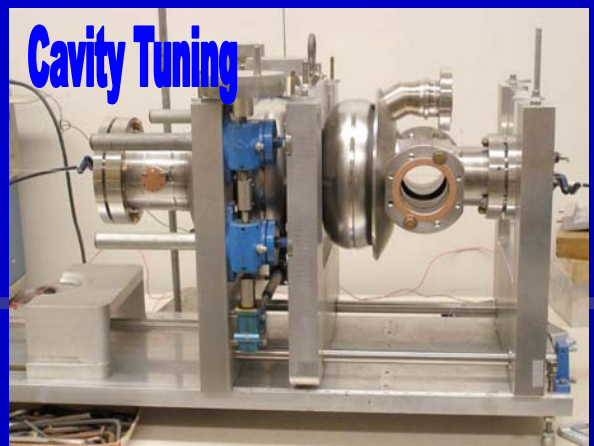
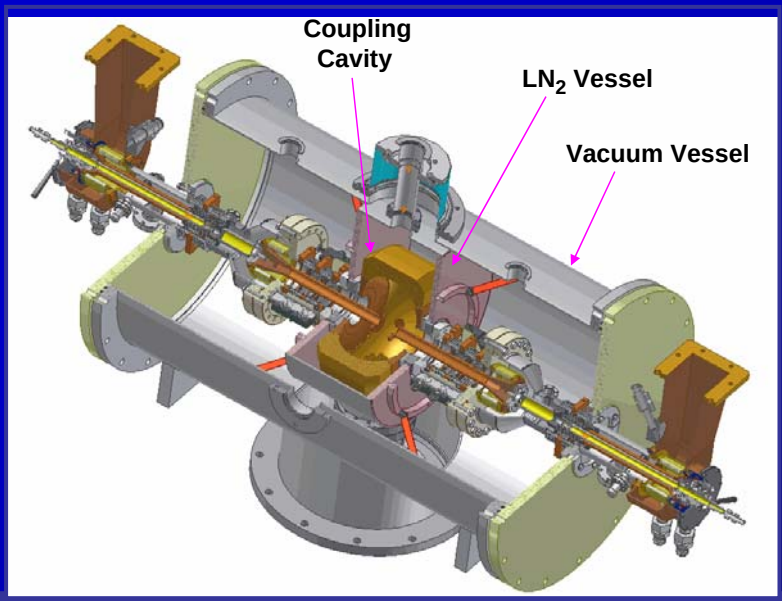




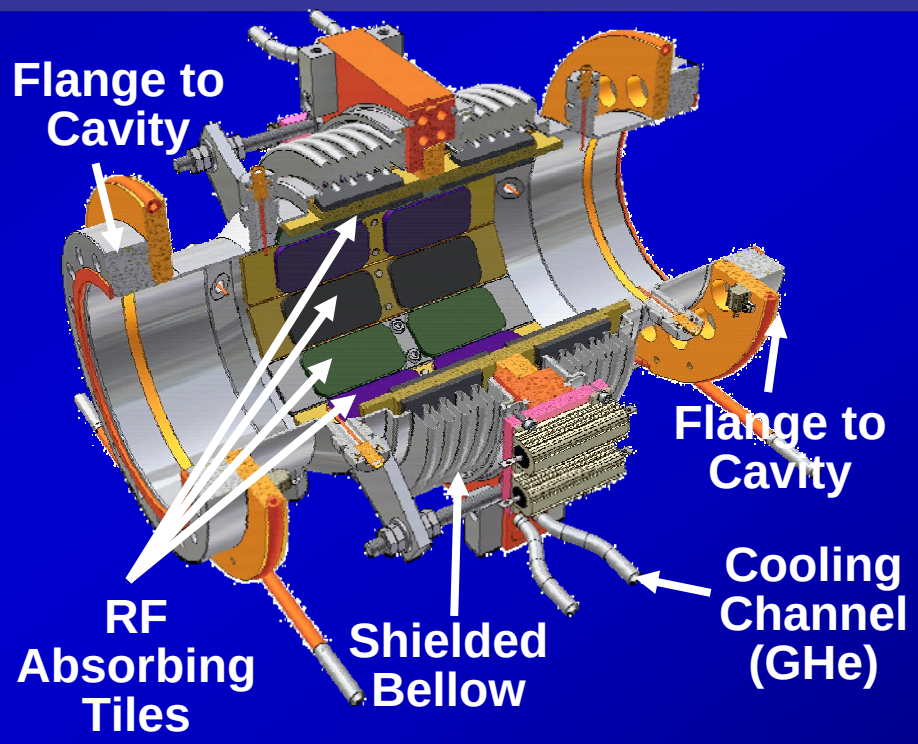
Coaxial Input Couplers

- Design for high cw power > 50 kW
- 2 prototypes tested up to 50 kW cw, 80 kW pulsed
- 10 couplers ordered with further improved cooling

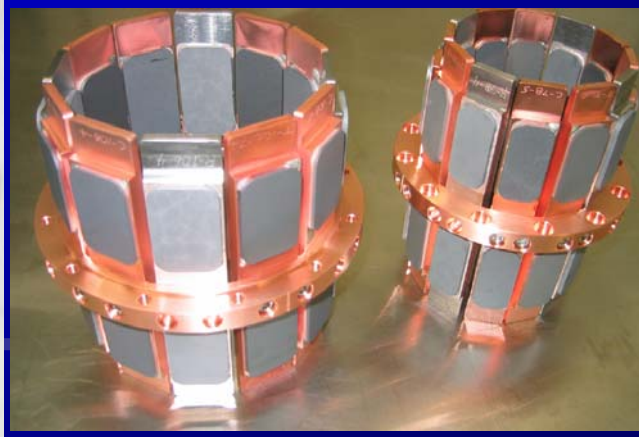


Beam Line HOM Loads

Power per load	26 W (200 W max)
HOM frequency range	1.4 – 100 GHz
Operating temperature	80 K
Coolant	He Gas
RF absorbing tiles	TT2, Co2Z, Ceralloy

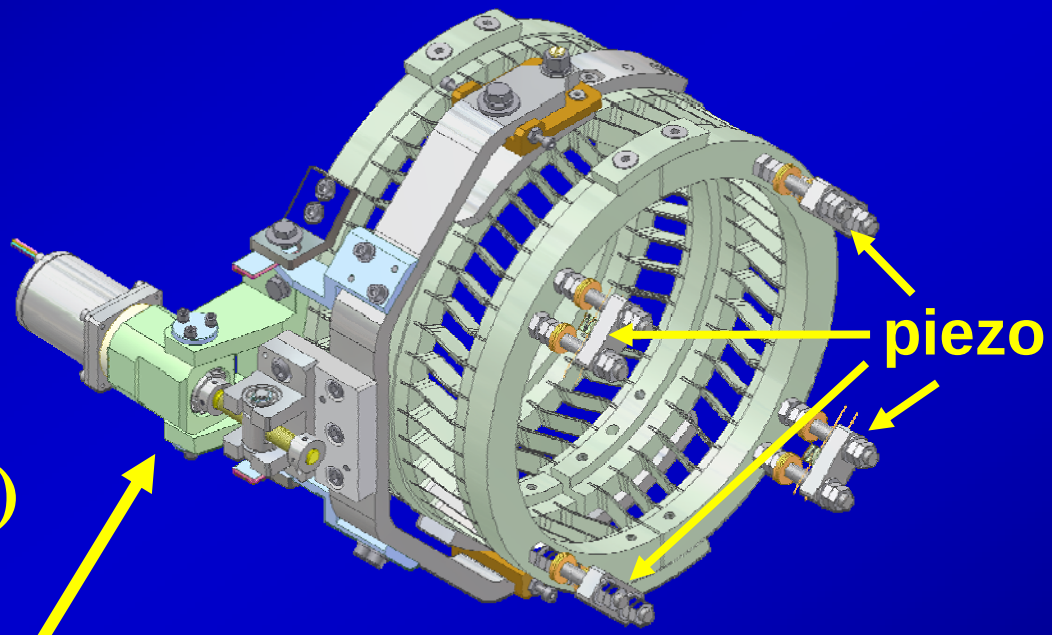


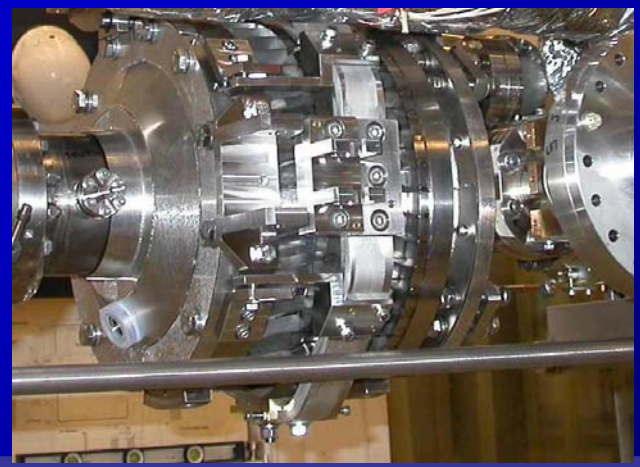
- 2 proto-types fab'ed by Cornell
- 6 production loads fab'ed by industry



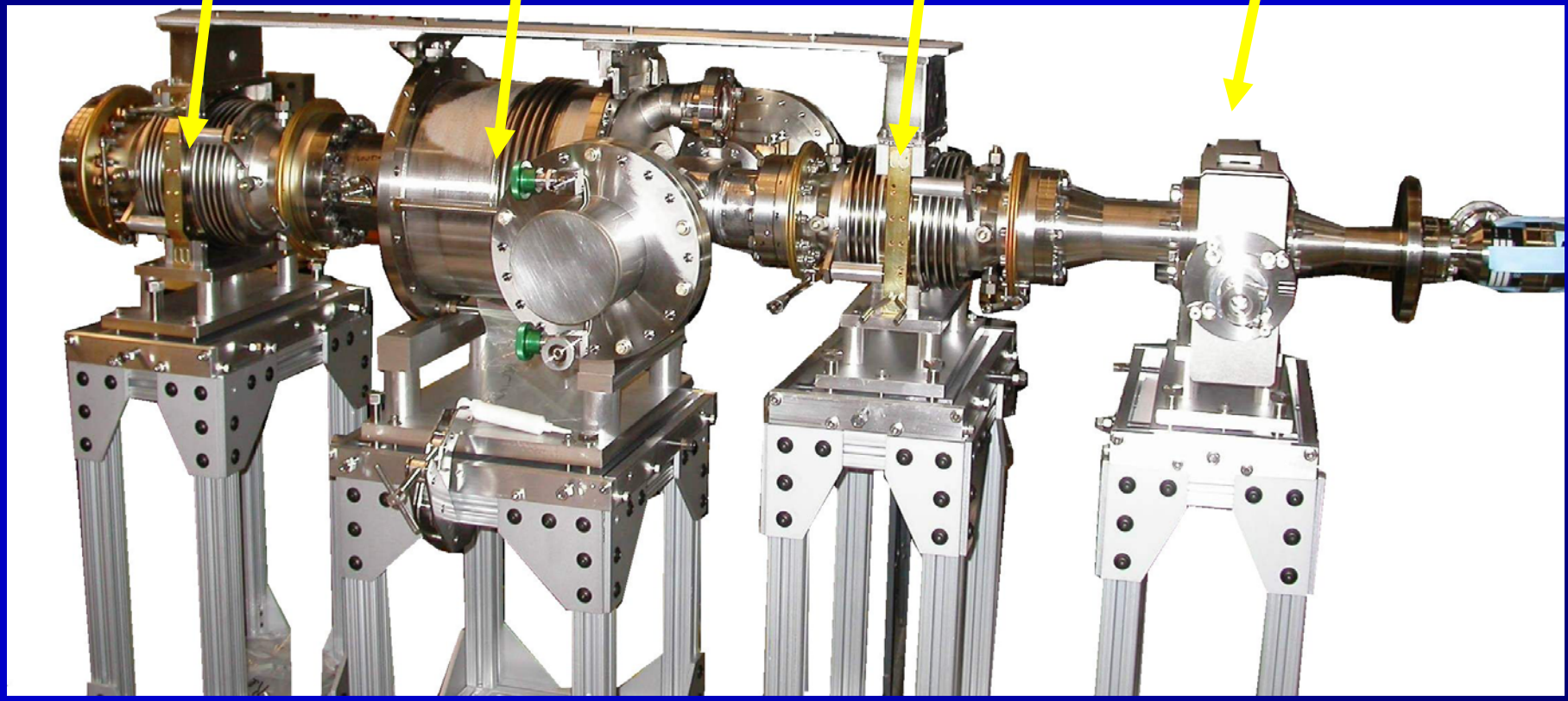
Frequency Tuners

- Modification of the INFN blade tuner
- Added piezos for microphonics compensation (R&D)
- Stepper motor easily replaceable while cavity string is in cryomodule
- 6 units fabricated





Finished Beam Line for Test Module



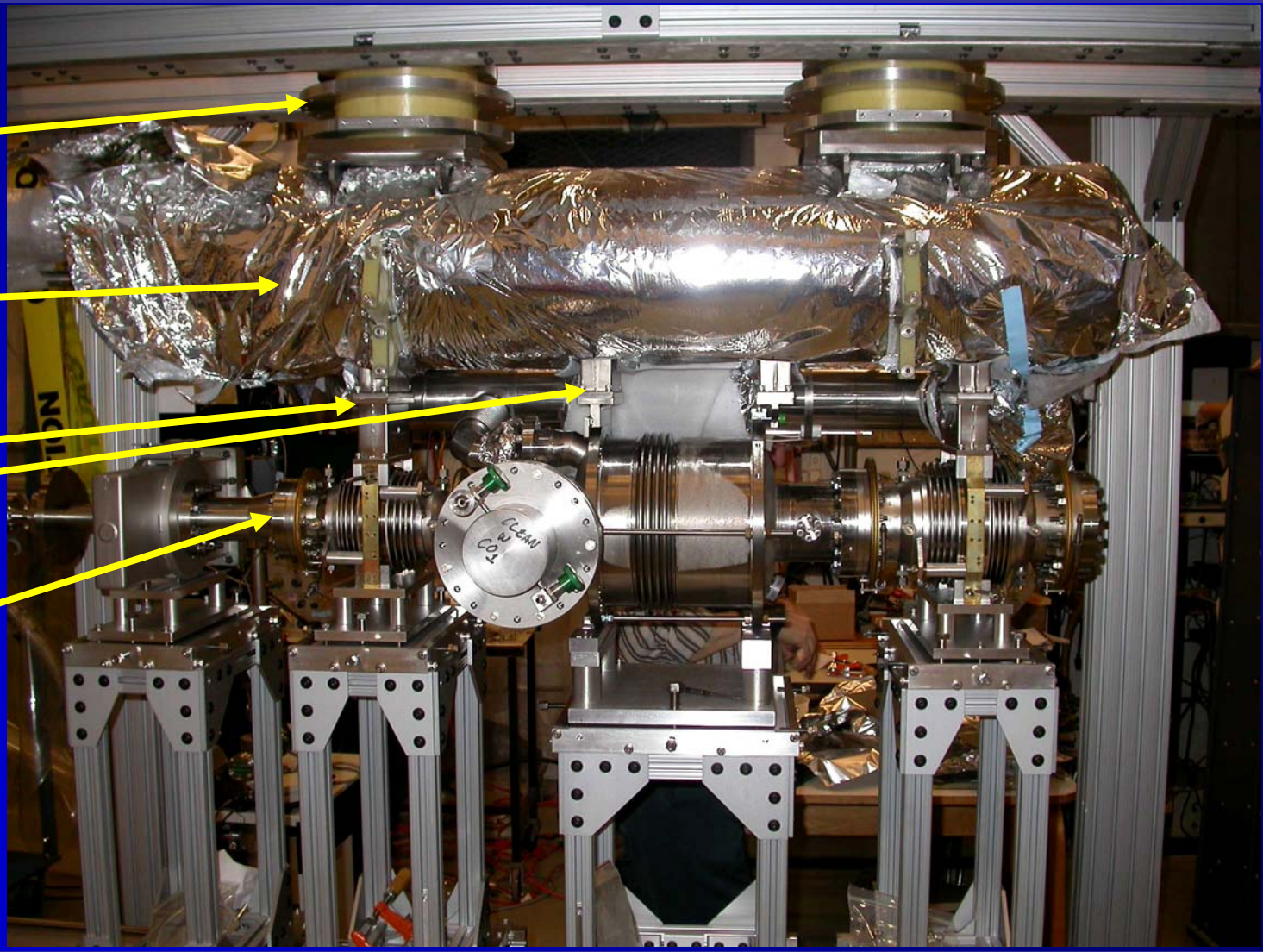
The Test Cryomodule:

Assembly

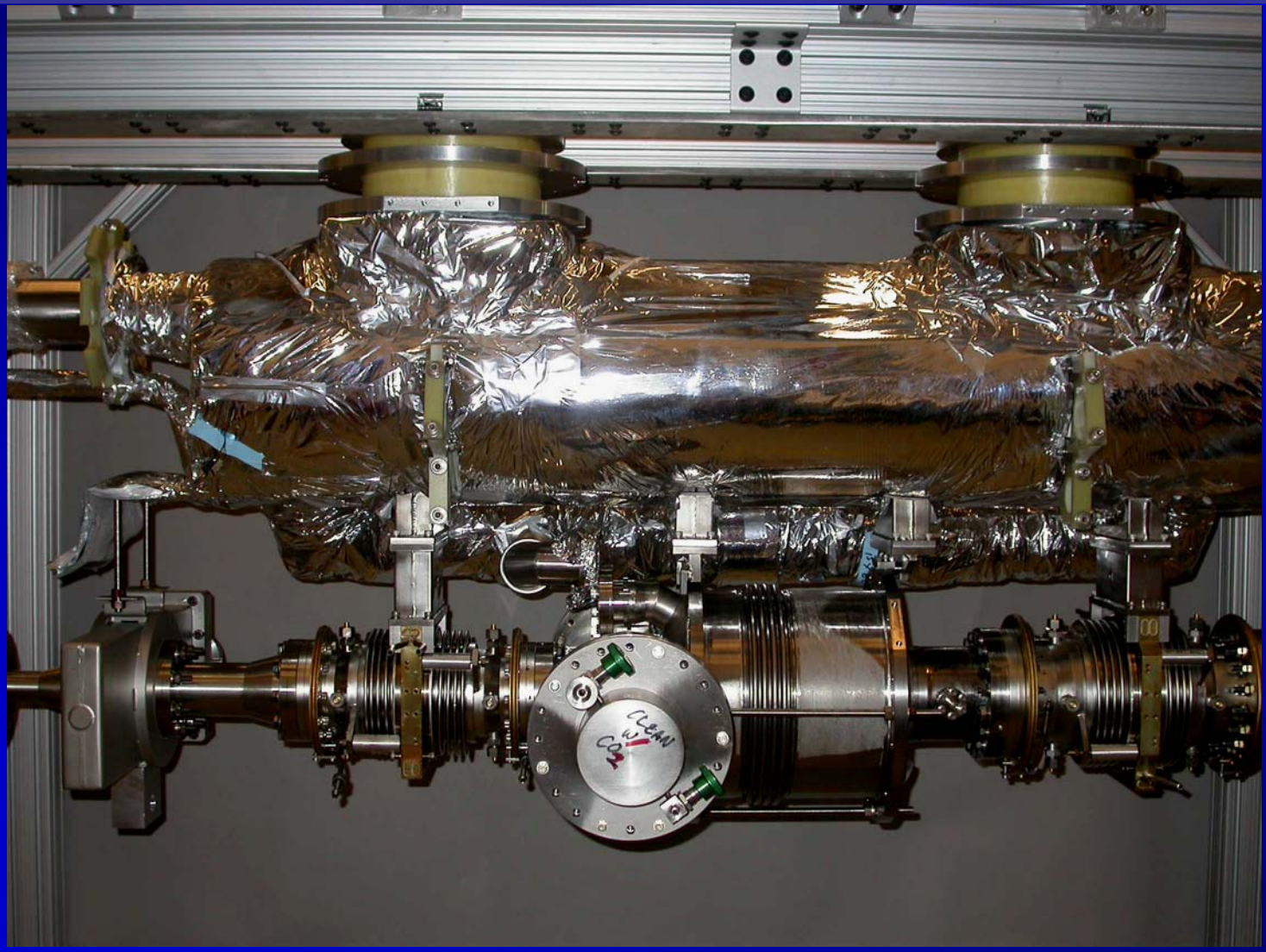
Test Cryomodule Assembly

Helium-gas return pipe; serves also as main beam line support structure

Mounting of Beam Line to HGRP



Beam Line supported by HGRP

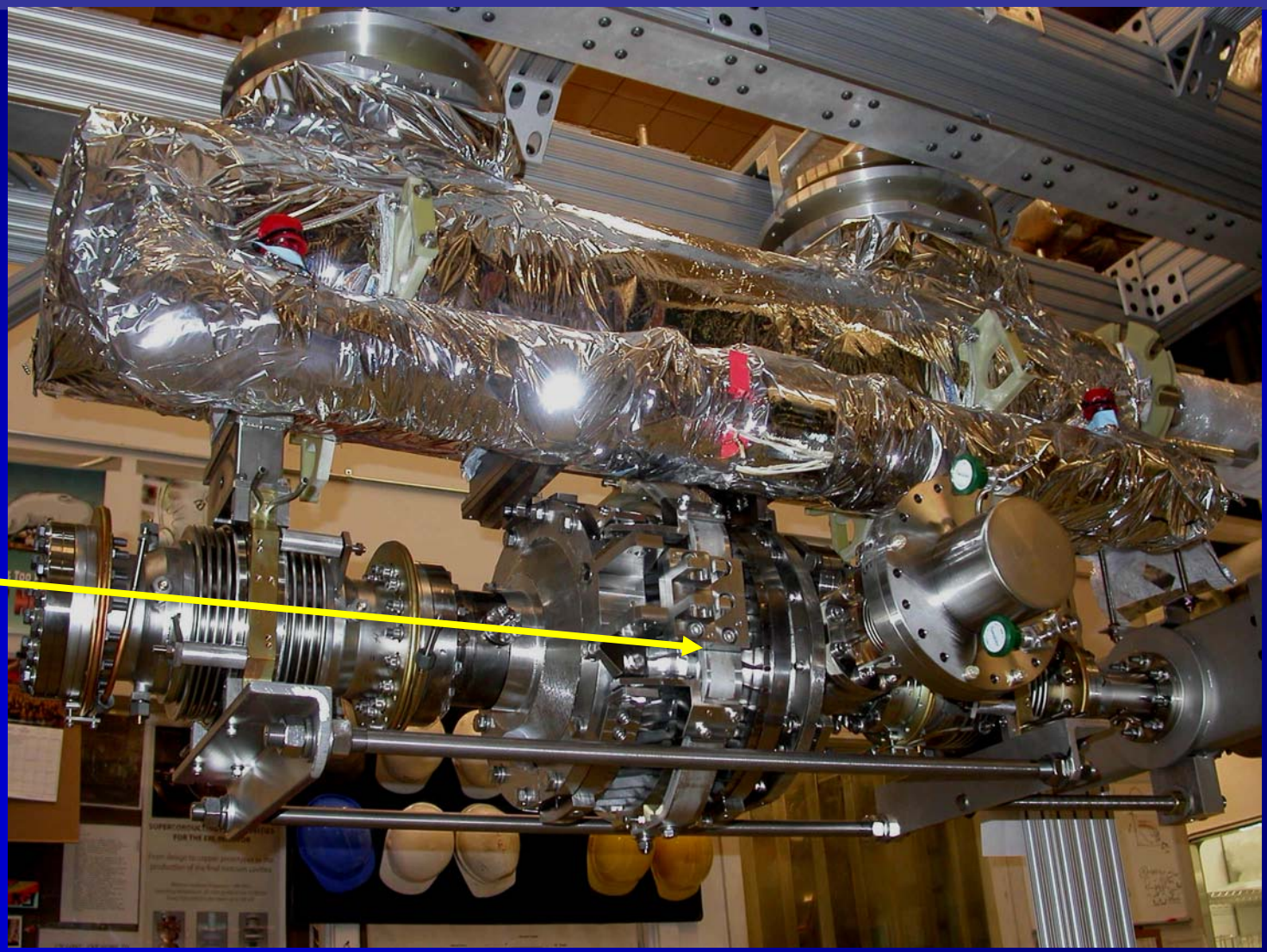


120C Cavity and Coupler Bake (cold part)

In-situ bake for cold and warm couplers, no further atmosphere exposure, no pre-conditioning

Add Magnetic Shield I, Frequency Tuner

Cavity frequency tuner with magnetic shield below blades



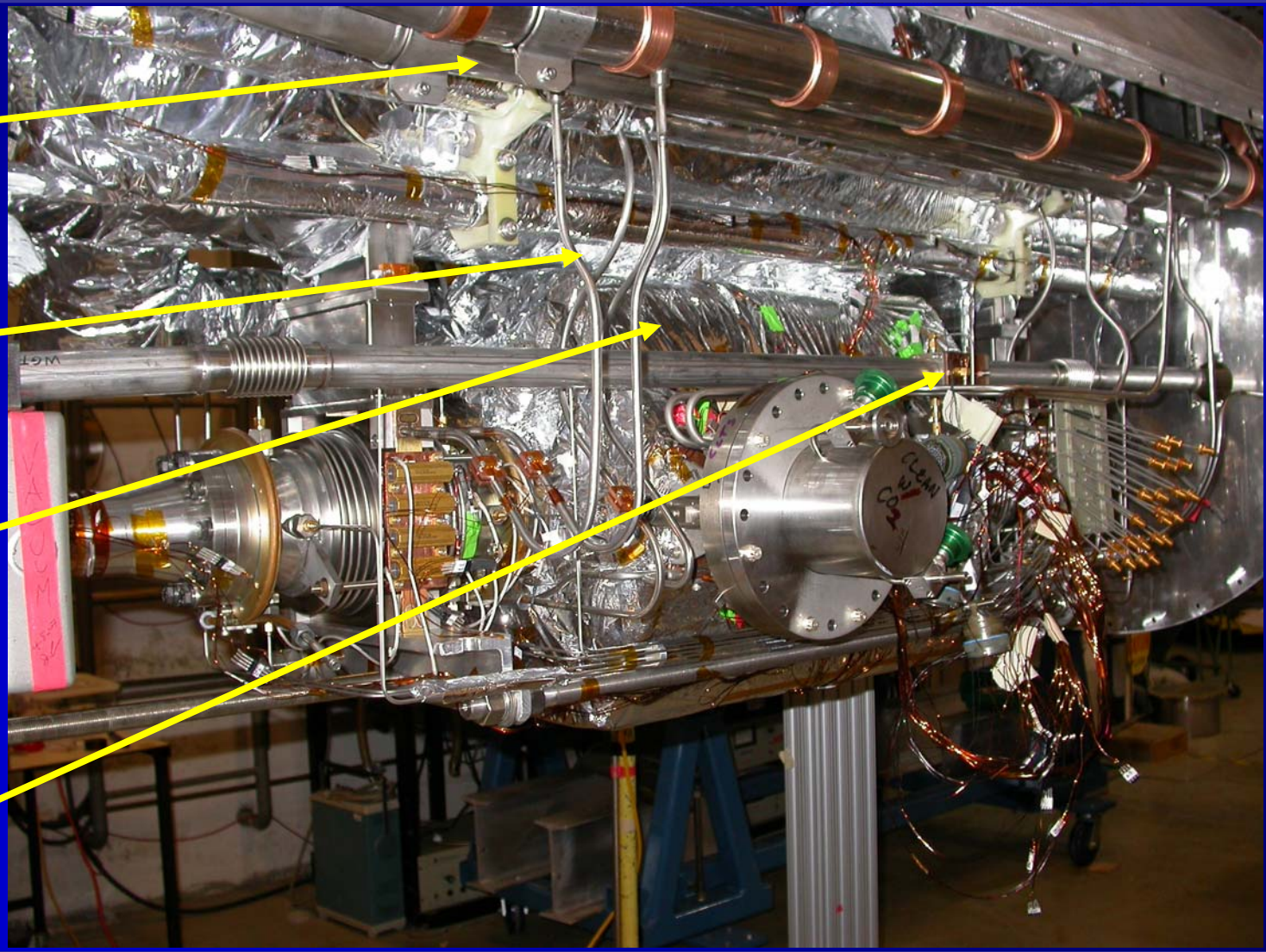
Add 5K and 80K Cryogenic Pipes, Wire Position Monitor, Magnetic Shield II, Cables, …

5K and 80K supply / return pipes

¼" cryogen distribution tubes

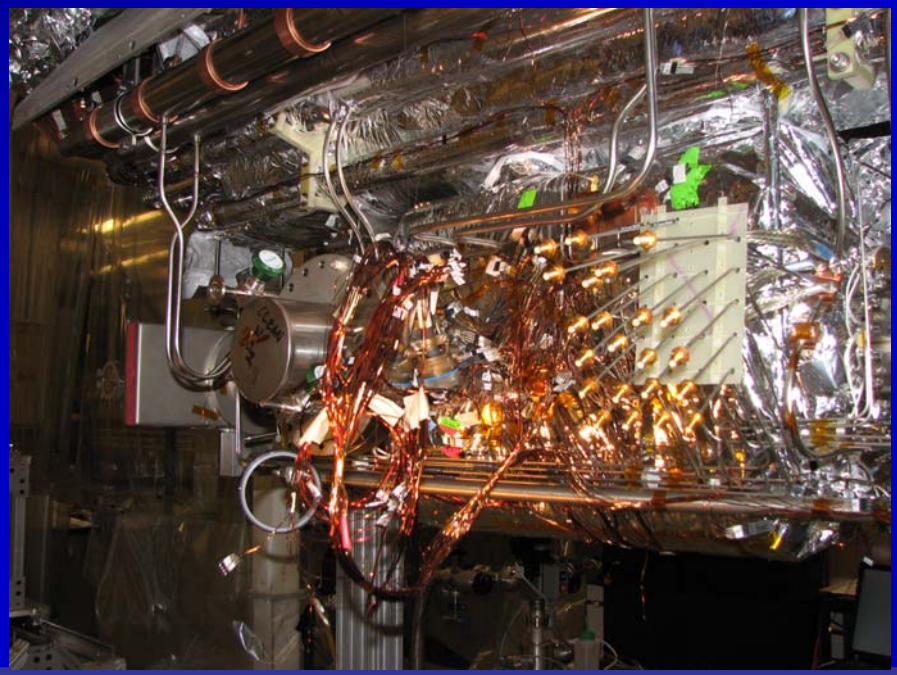
Second magnetic shield around cavity

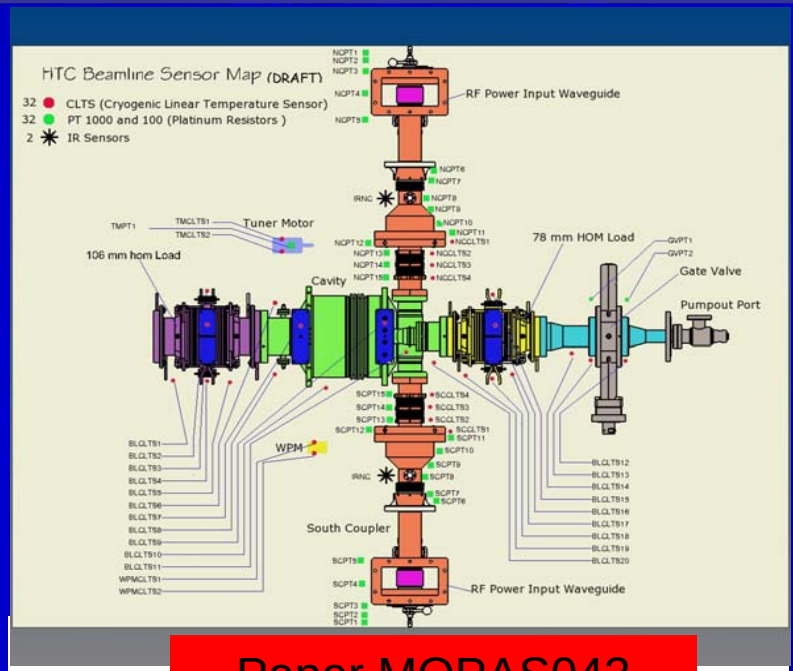
Wire position monitor block mounted to cavity



Cryomodule Instrumentation

- 90 sensors (T, He-level, …)
- 5 heaters (2K, 5K, 80K)
- *In-situ coupler bake*
- 22 RF cables





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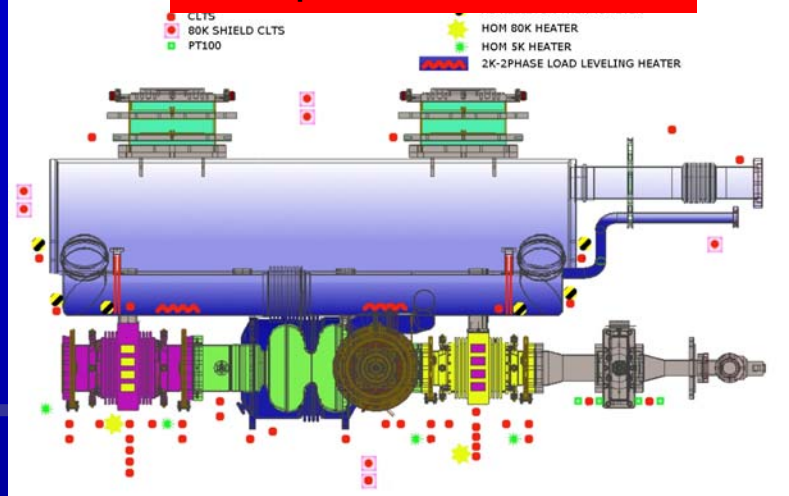
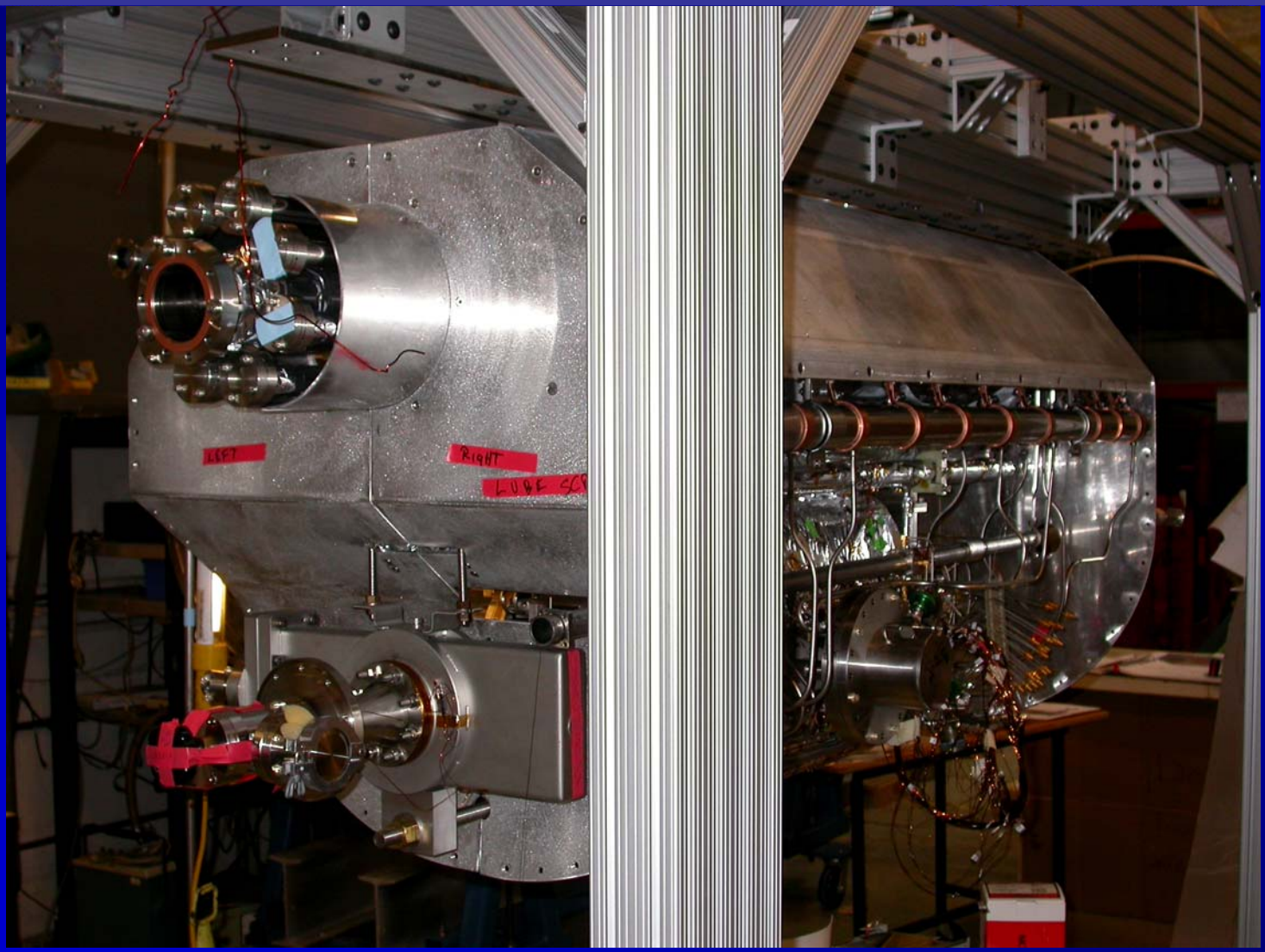


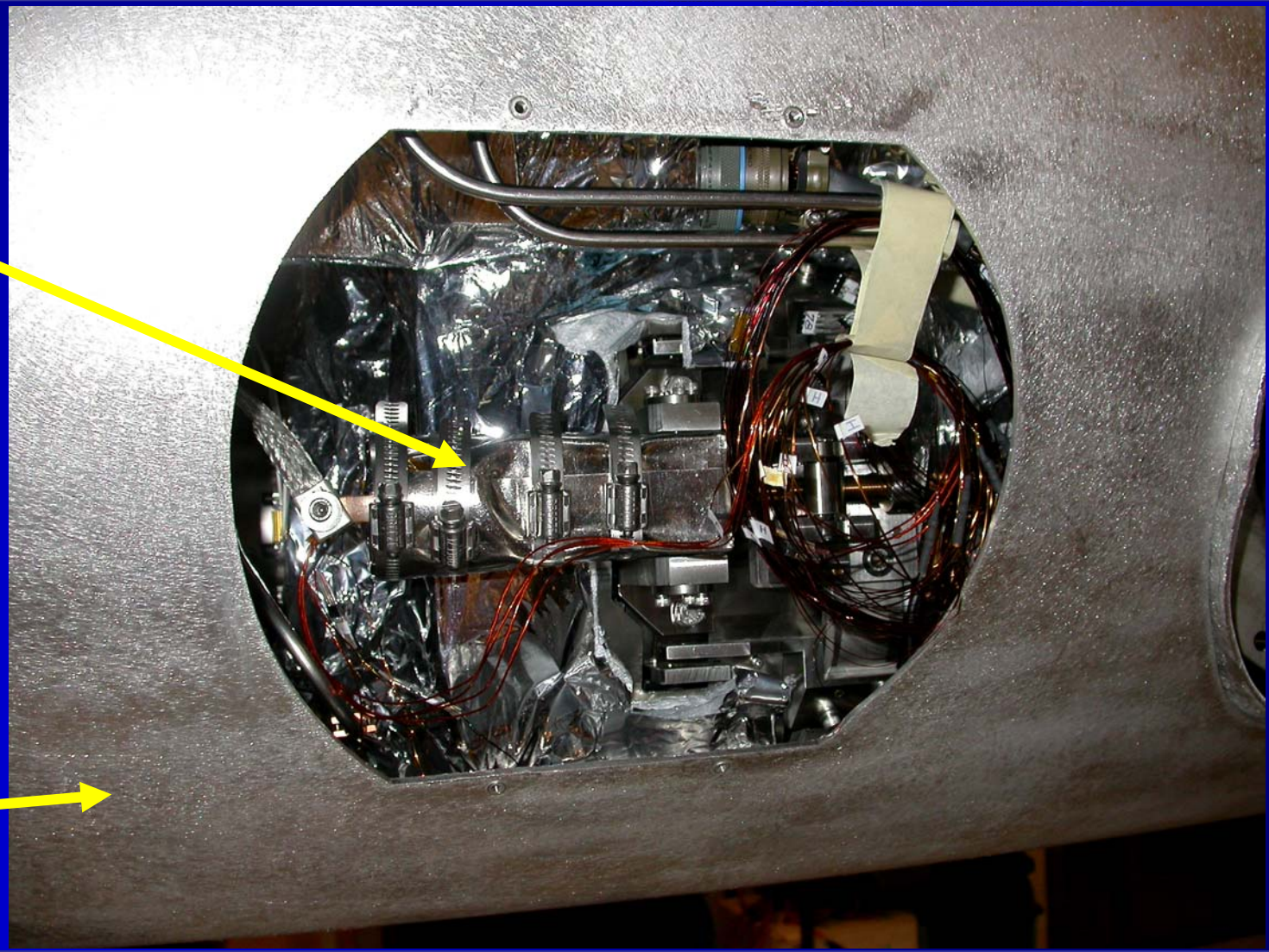
Add 80K Thermal Shield



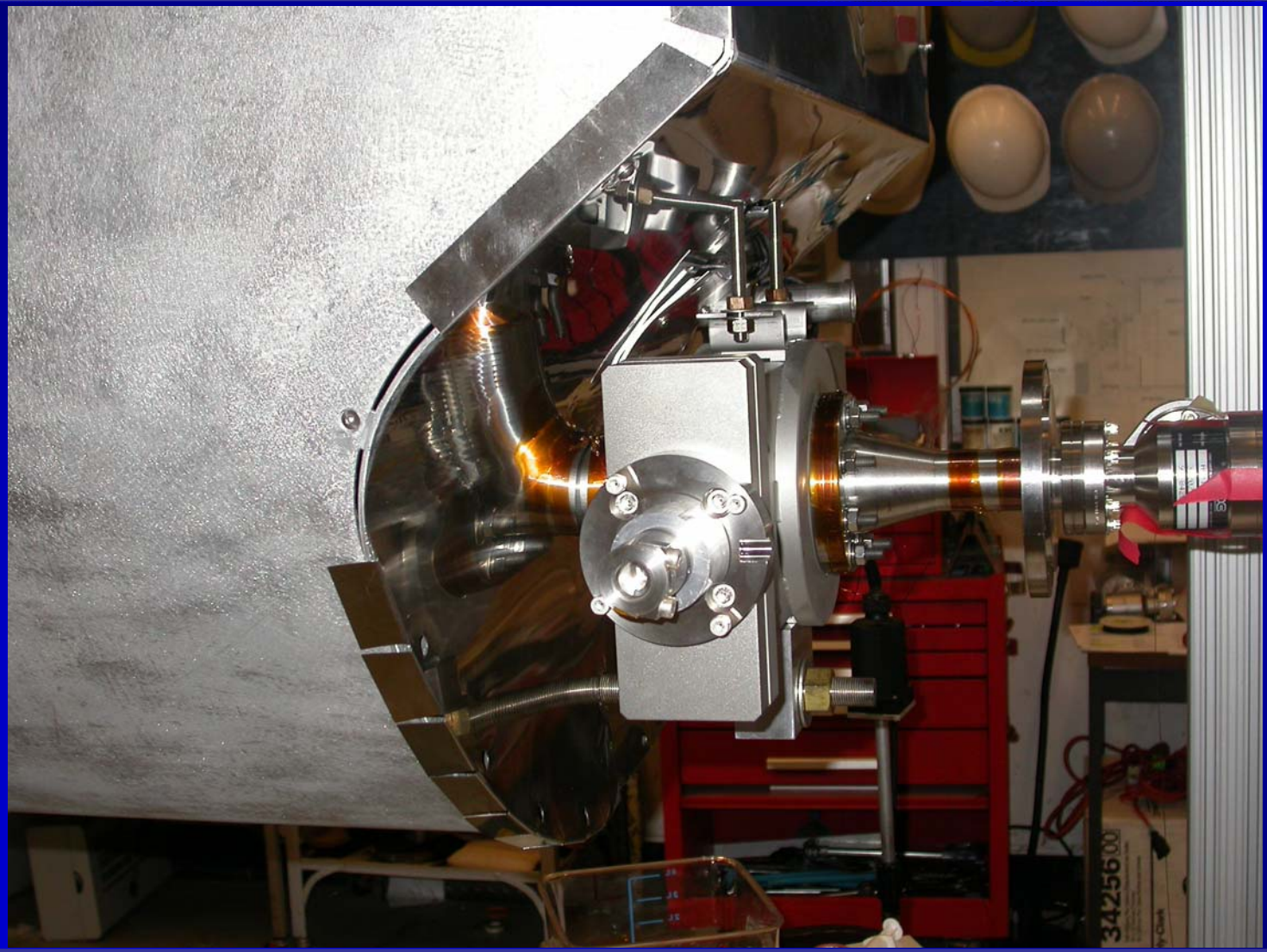
Tuner Motor Access Port in 80K Shield

Tuner stepper easily replaceable while string is in cryomodule

80K thermal shield

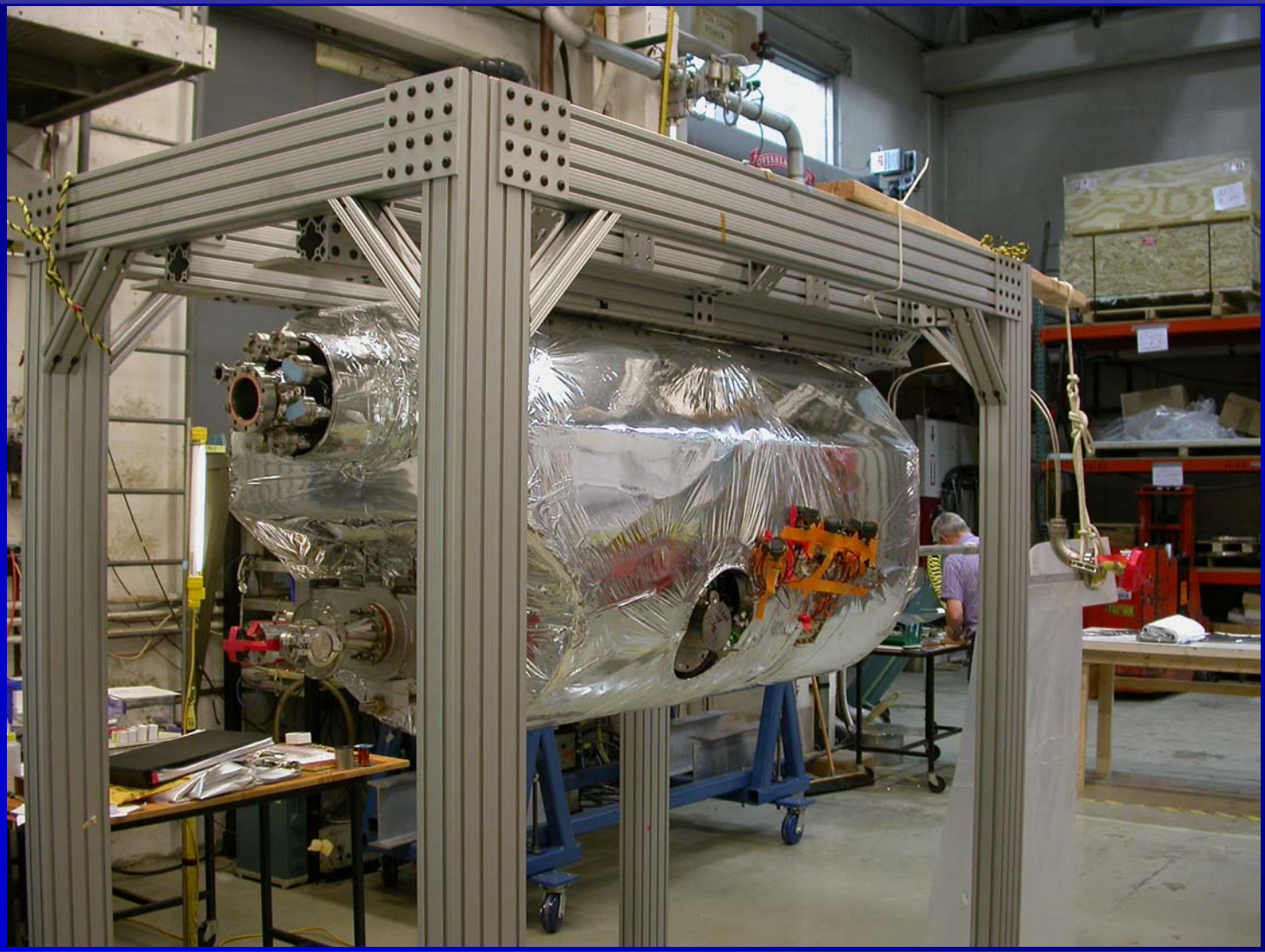


Gate Valve inside of Module with outside Drive



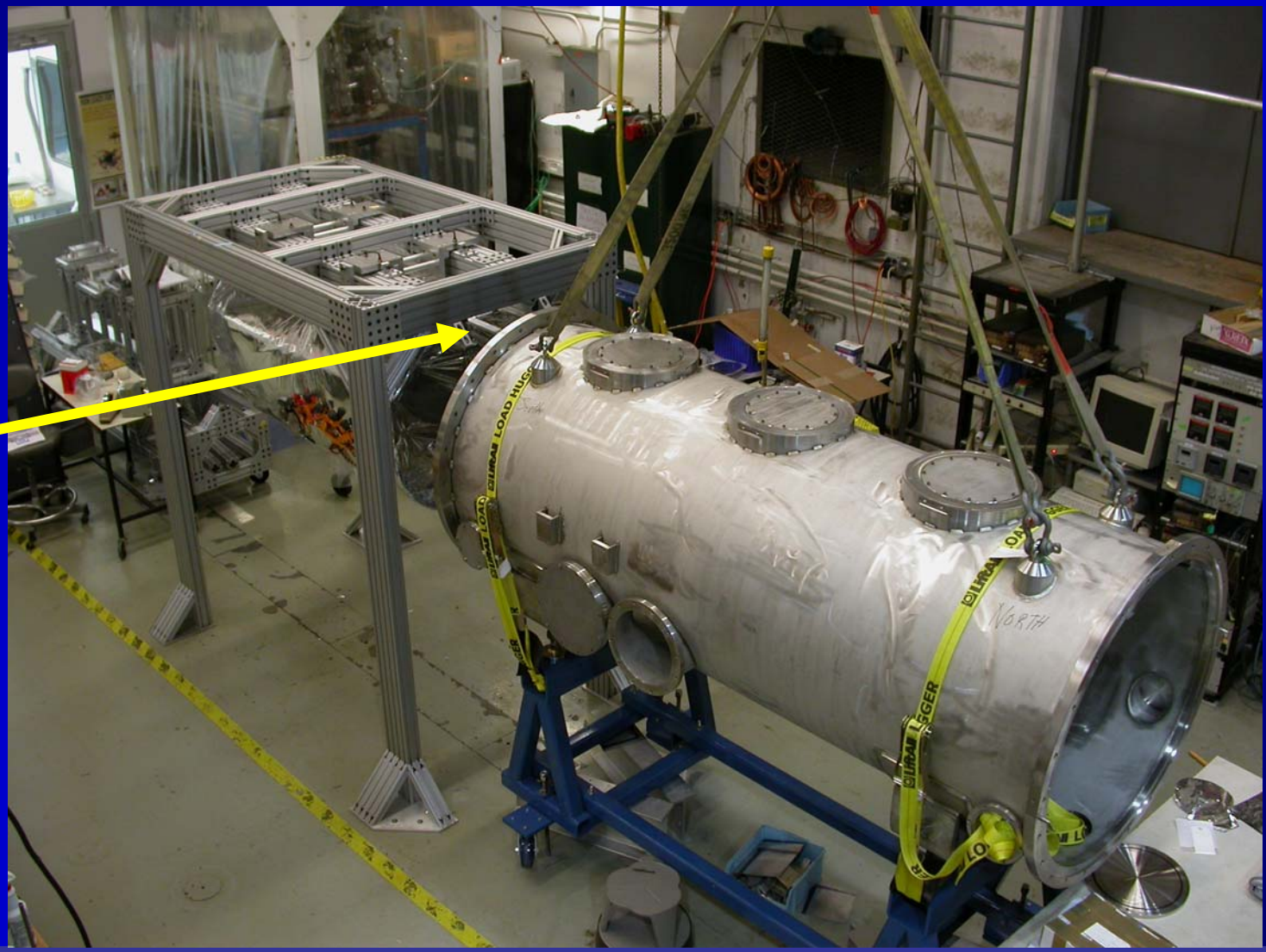
Add Magnetic Shield III

Add Superinsulation

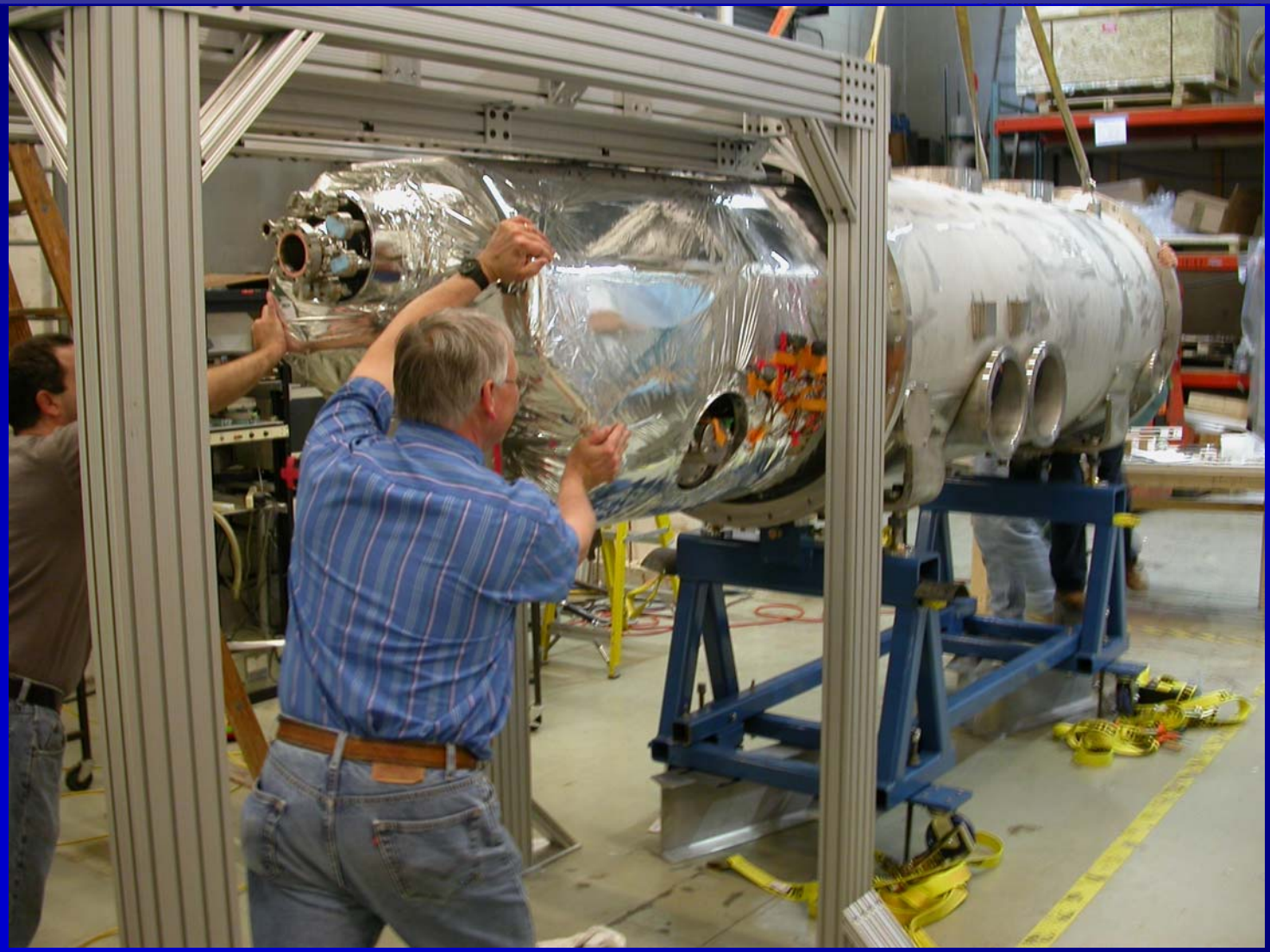


Align Cold Mass and Vacuum Vessel

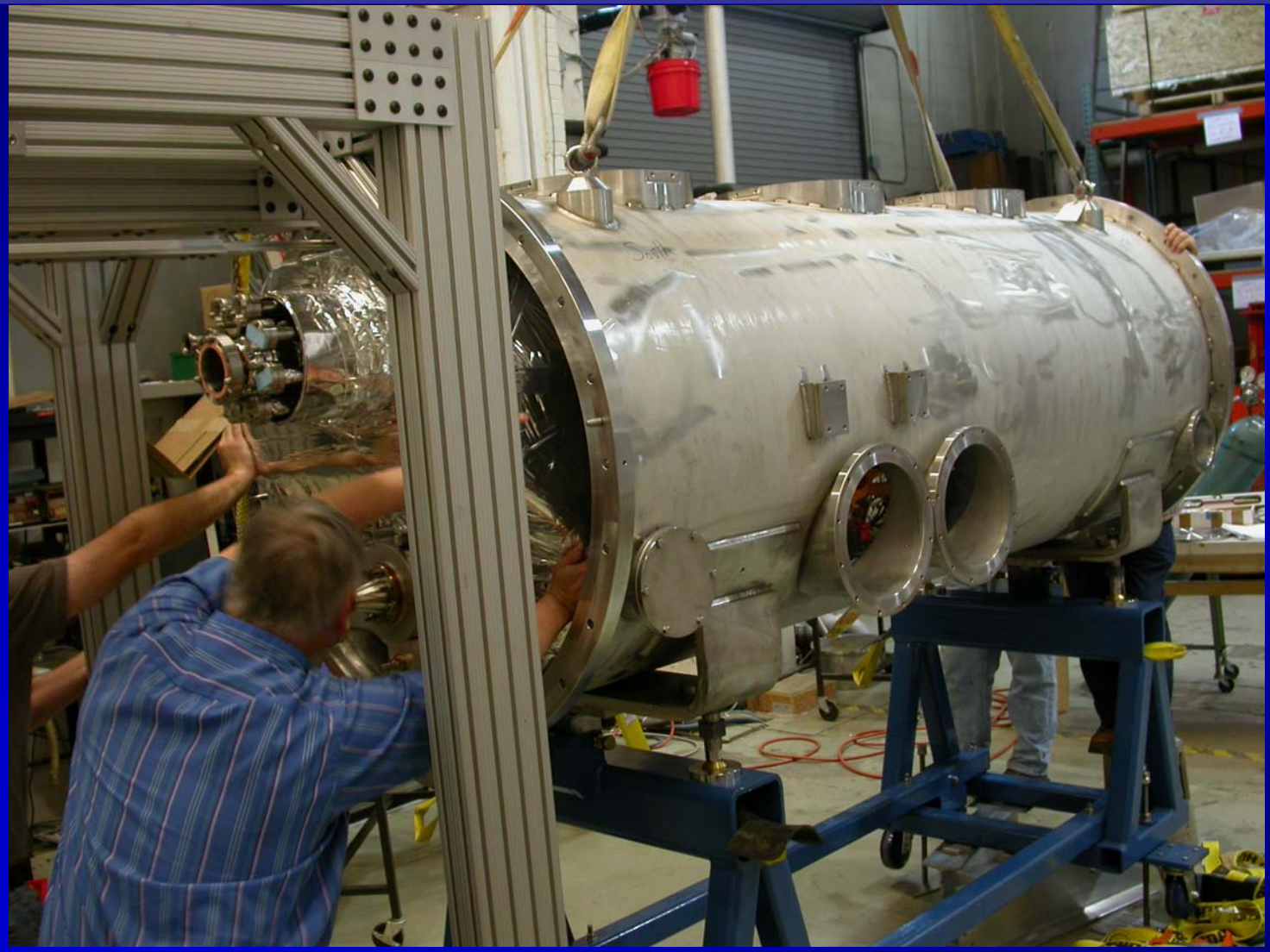
Rail system to slide cold-mass into vacuum vessel



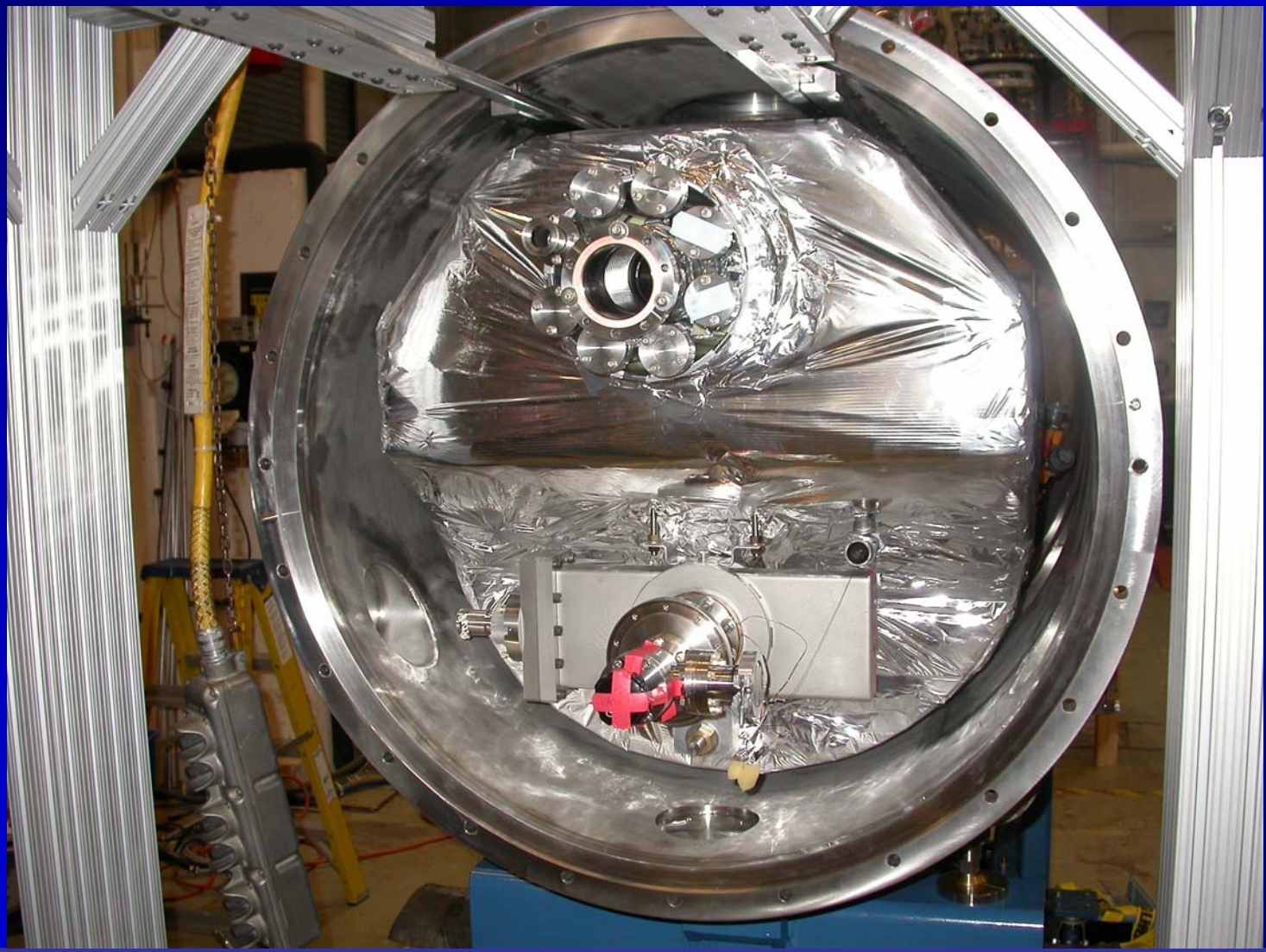
Slide Cold-Mass into Vacuum Vessel



…keep going



Done

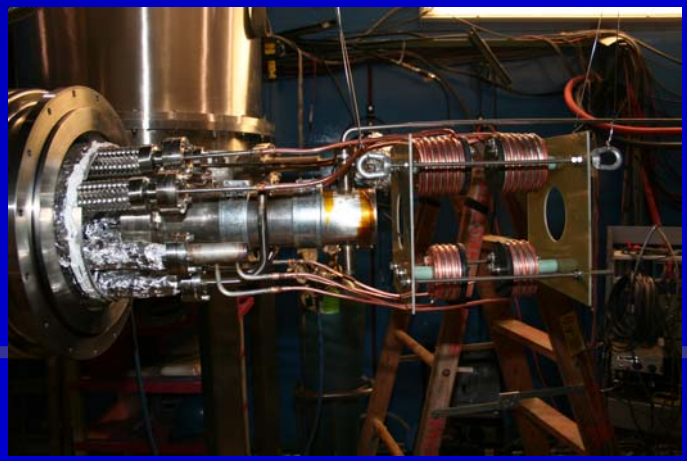


Insight from the Assembly

- First assembly revealed no significant design problems
- Fast, easy assembly (once we had all parts…)
- Fixed alignment concept works well
- Full 3D modeling (including assembly drawings) extremely helpful
- Tight tolerances are cost drivers ⇒ spec carefully!
- Several small improvements have been applied to the full injector module design to reduce cost further

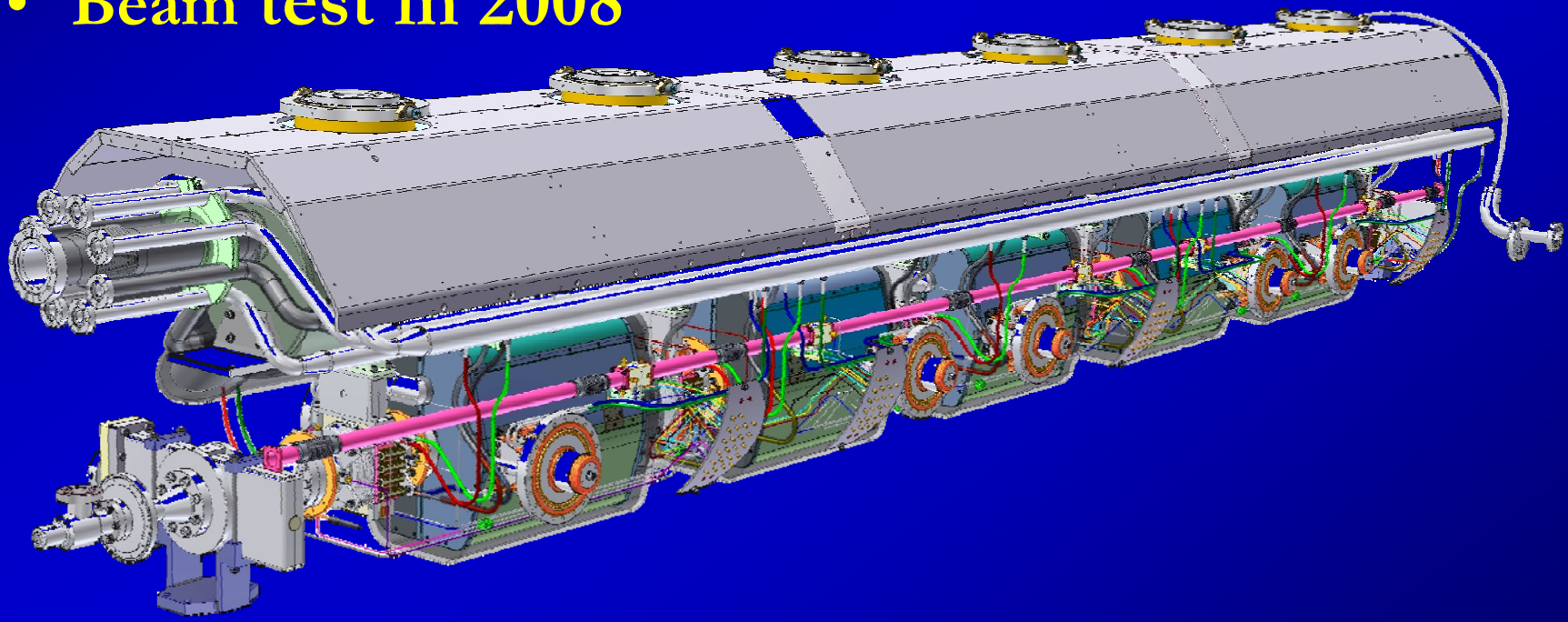
Getting Ready for Test

- 135 kW cw power klystron (e2v)
- Cold-box with 2K, 5K, 80K heat exchanger
- 50 W @ 1.8K pumping skid/ refrigerator



What's next?

- Test-cryomodule test 7/07
- Full injector cryomodule assembly 8/07 – 1/08 (all cryo-vessel parts have been ordered)
- Beam test in 2008



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