Cold Test Results of the ISAC-II Medium Beta High Gradient Cryomodule

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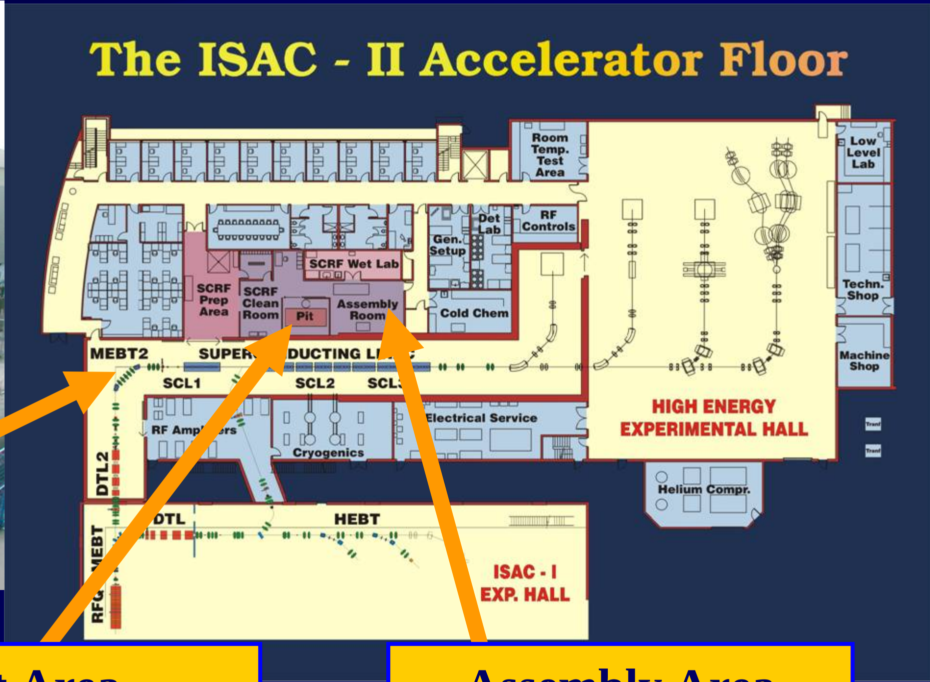
TRIUMF, Vancouver, Canada

Outline:

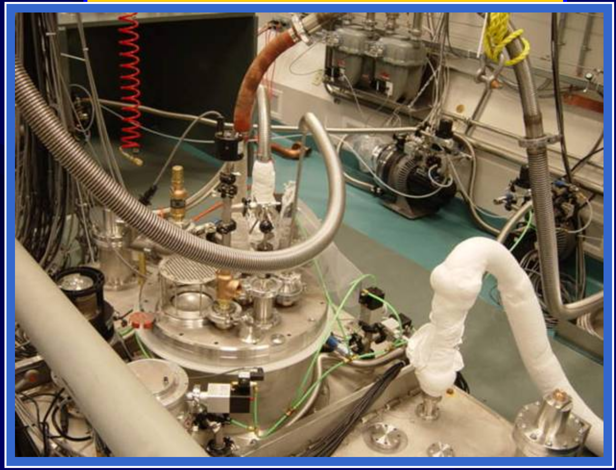
- Overview
- Cryomodule
  - Developments/Hardware
- Results

ISAC-II Building



Linac Vault

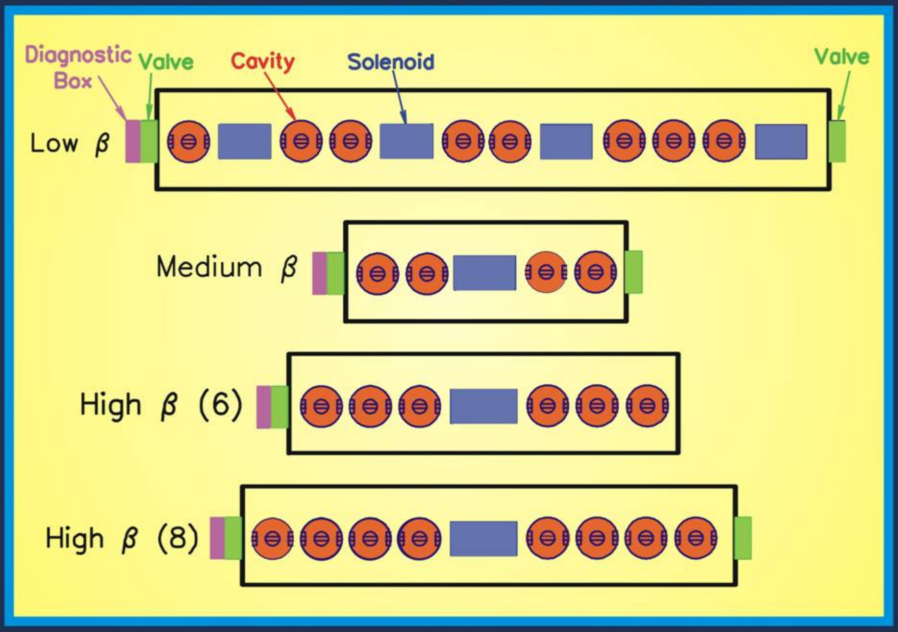
Test Area



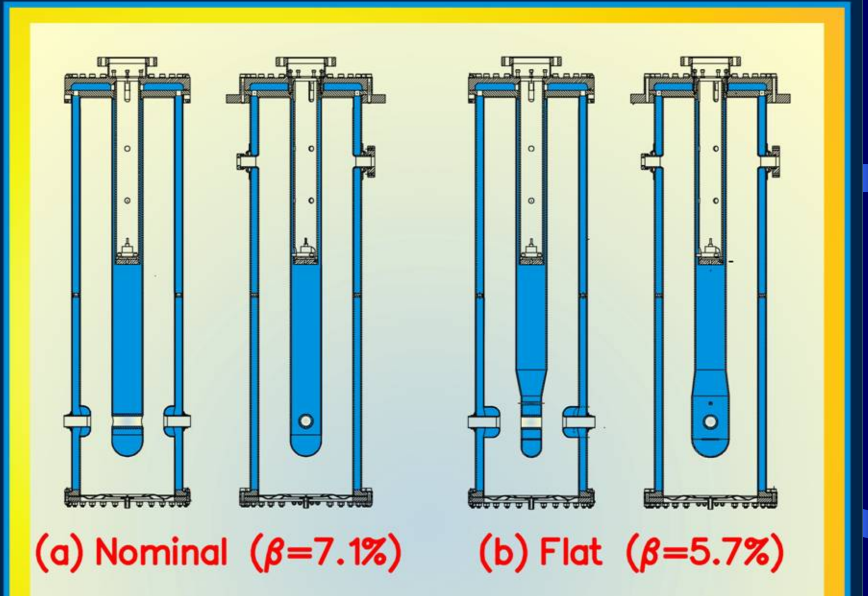
Assembly Area

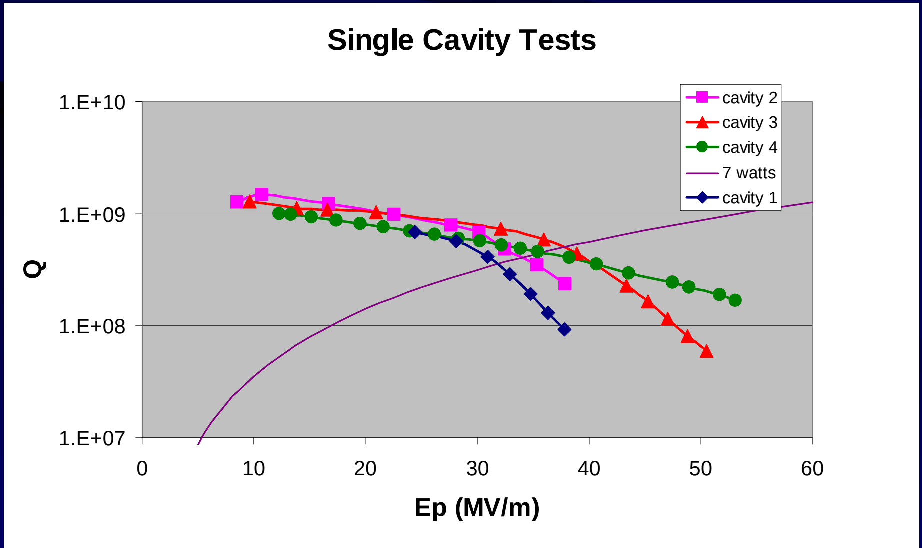
ISAC-II SC Linac

ISAC-II Cryomodules



Medium Beta Cavities

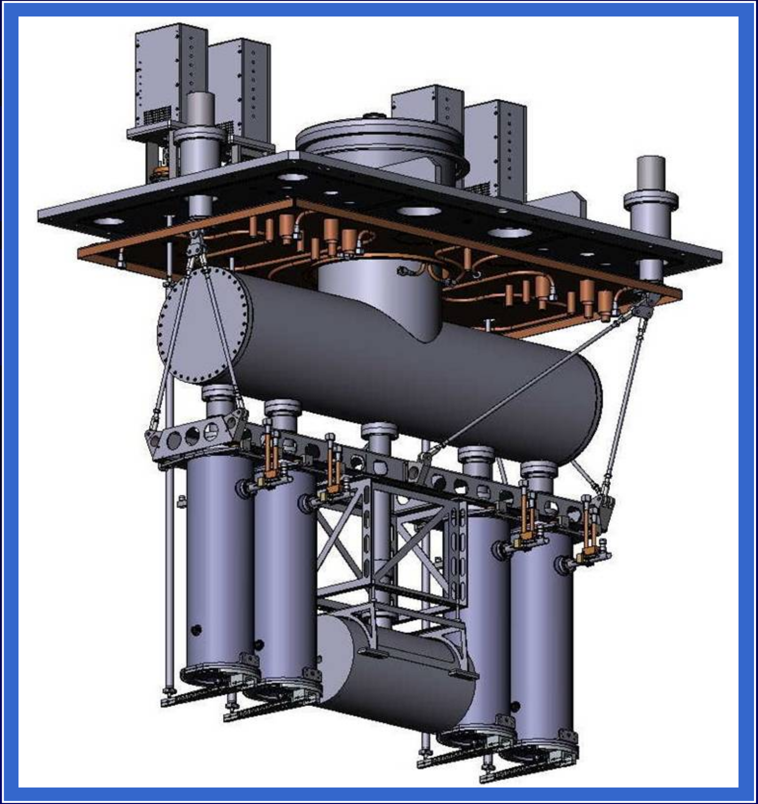




Section	β_0 (%)	f_{RF} MHz	No.	E_p MV/m	E_a MV/m
Low β	4.2	70.7	8	25	5
Med β	**5.7**	**106**	**8**	**30**	**6**
	7.1	**106**	**12**	**30**	**6**
High β	10.4	141	20	30	6

Medium Beta Cryomodule

- Design Features
  - Stainless steel vacuum enclosure
  - LN2 cooled copper shield
  - mu metal for magnetic field suppression

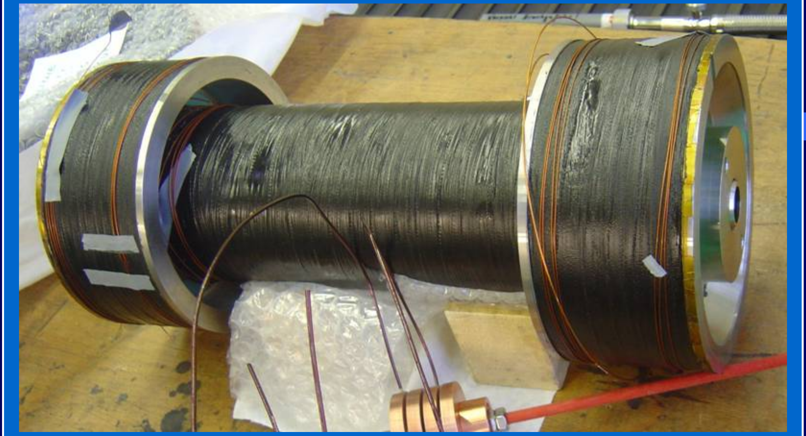


Lid Assembly in Assembly Frame

Superconducting Solenoids

- Focussing in the SC Linac is provided by superconducting solenoids (B≤9T)
- End fringe fields controlled with active `bucking' coils ($B_{cavity} \leq 0.1T$)
- Production Medium and High beta solenoids in fabrication at Accel
  - See table for specifications

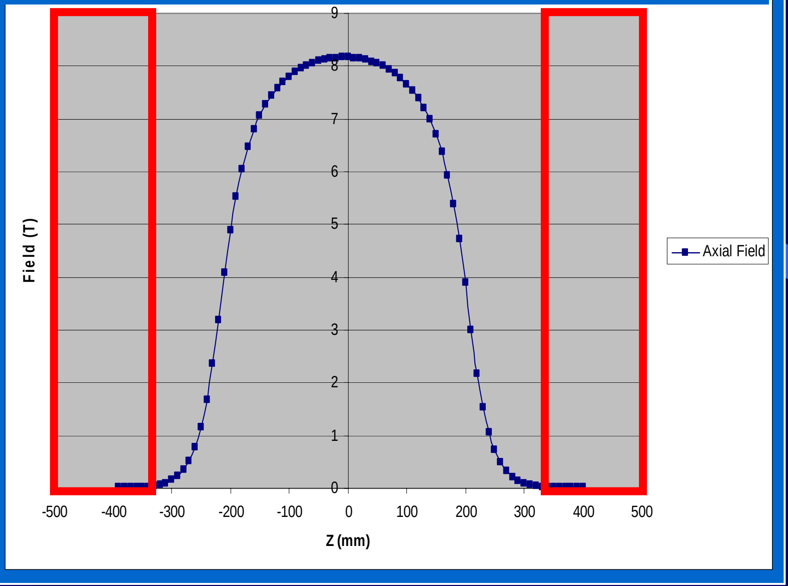
Prototype Solenoid at Accel



Specifications

	Low β	Med β	High β
Field	9T	9T	9T
Bore	26mm	26mm	26mm
Number	4	5	3
Eff. Length	16cm	34cm	45cm

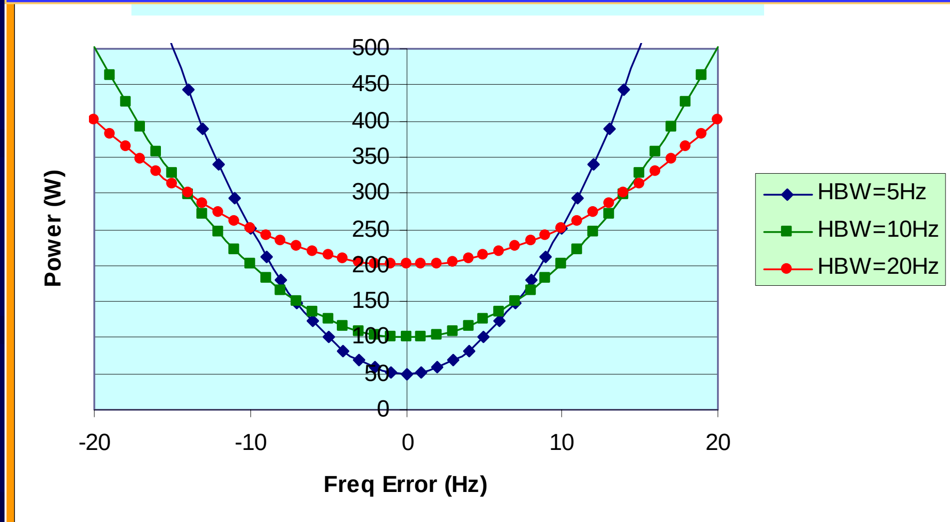
Axial Field



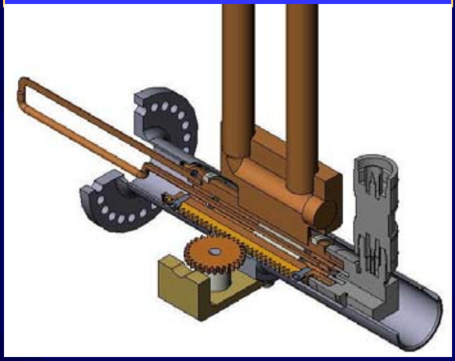
RF Systems

- RF power
  - Provide useable bandwidth by overcoupling
  - Require P_f=200W at cavity for $f_{1/2}$=20Hz at E_a=6MV/m, β=200
- Coupling loop
  - Developed LN2 cooled loop
  - <0.5W to LHe for P_f=250W
- Mechanical tuner
  - Precise (0.3~Hz), fast (>50Hz/sec) tuner with dynamic range of 8kHz and coarse range of 32kHz
- Tuning plate
  - Spun, slotted, `oil-can' tuning plate to improve tuning range

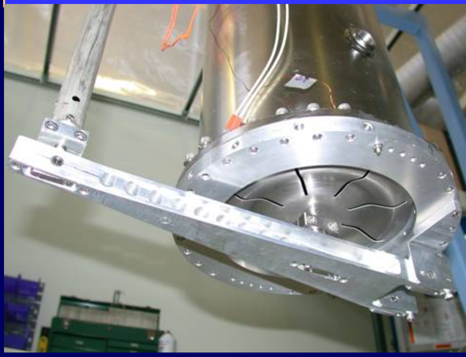
Forward power required for Ea=6MV/m and given bandwidth



Coupling Loop

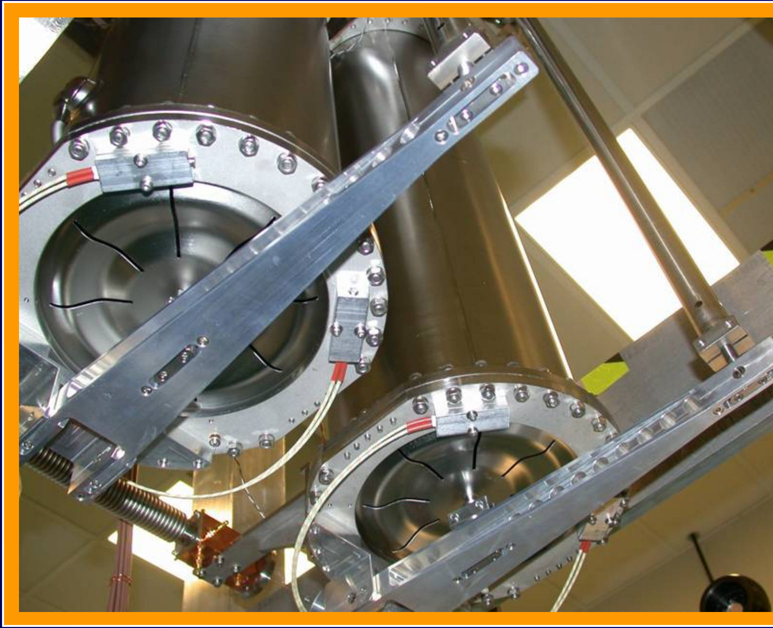


Mechanical Tuner

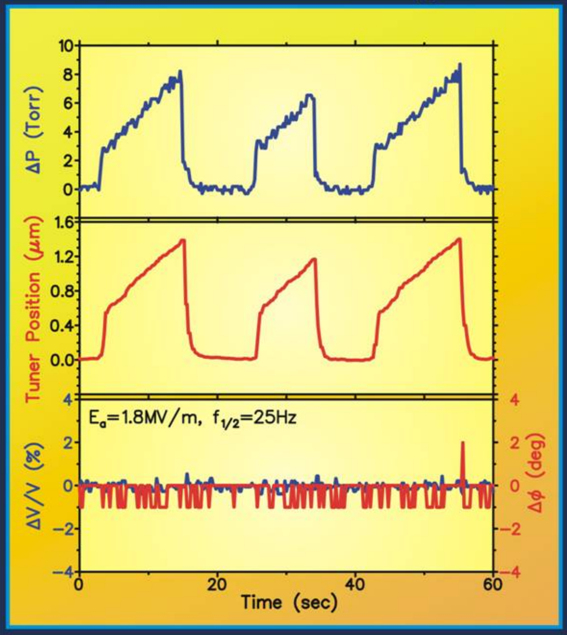


ISAC-II Mechanical Tuner

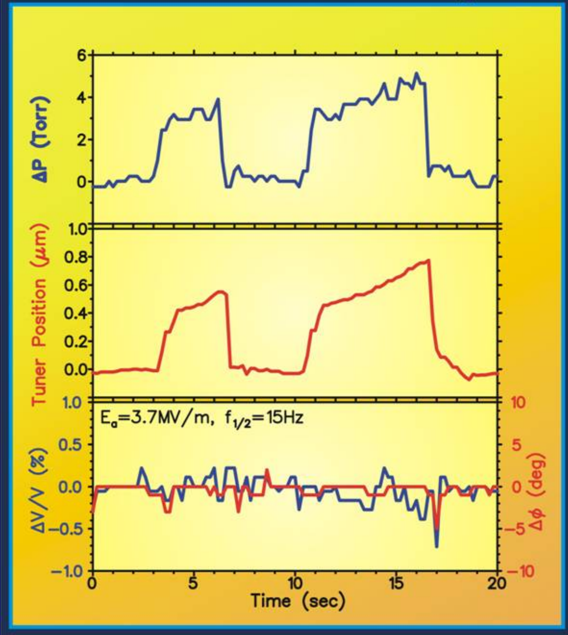
- Deflects niobium tuning plate at base of cavity (6 Hz/μm)
- Lever mechanism with zero backlash hinges and stiff rod connected to precision linear motor (Kollmorgan) in air
- In cold tests control loop was phase locked and tuner maintained frequency during rapid forced helium pressure fluctuations up to 60Hz/sec



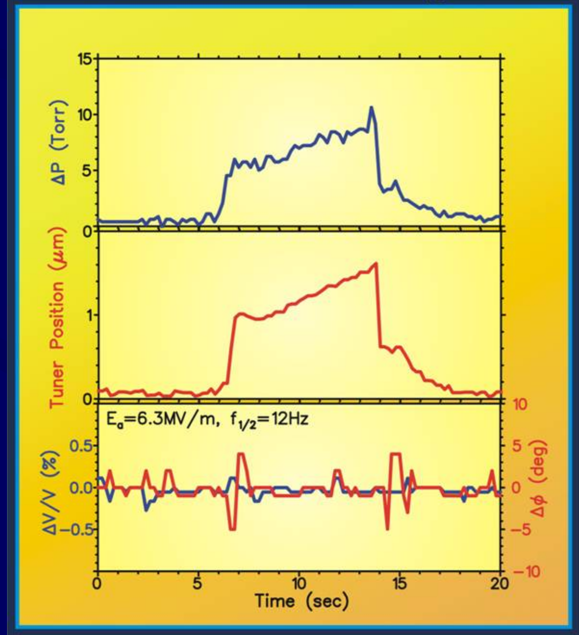
Low Field (E_a=1.8MV/m), $f_{1/2}$=25Hz



Moderate Field (E_a=3.7MV/m), $f_{1/2}$=15Hz



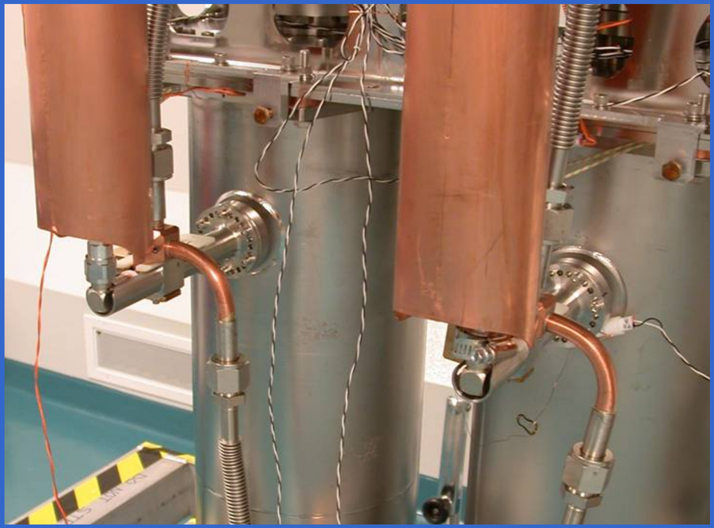
High Field (E_a=6.3MV/m), $f_{1/2}$=12Hz

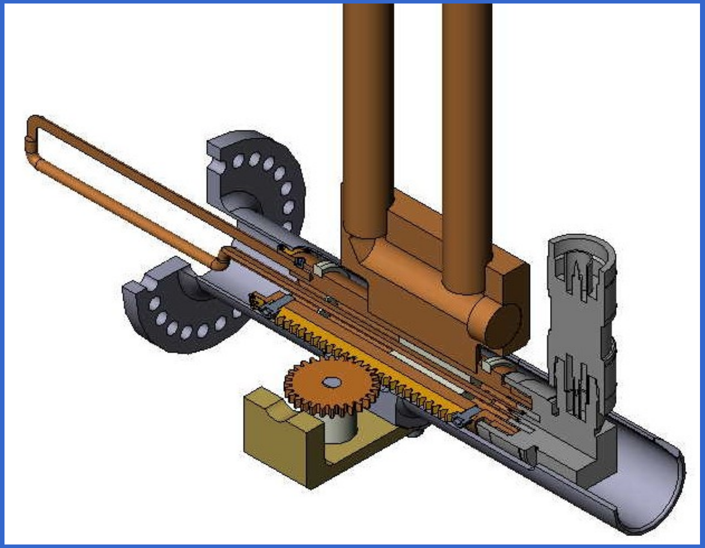


Coupling Loop with Direct Cooling

- Developed from INFN Legnaro adjustable coupling loop
- Modifications
  - ✓Stainless steel body for thermal isolation
  - ✓Copper outer conductor thermally anchored to copper LN2 cooled heat exchange block
  - ✓Aluminum Nitride dielectric inserts thermally anchor the inner conductor to the outer conductor
  - ✓Removed fingerstock to control microdust

✓Achieved <0.5W helium heating with P_f=250W

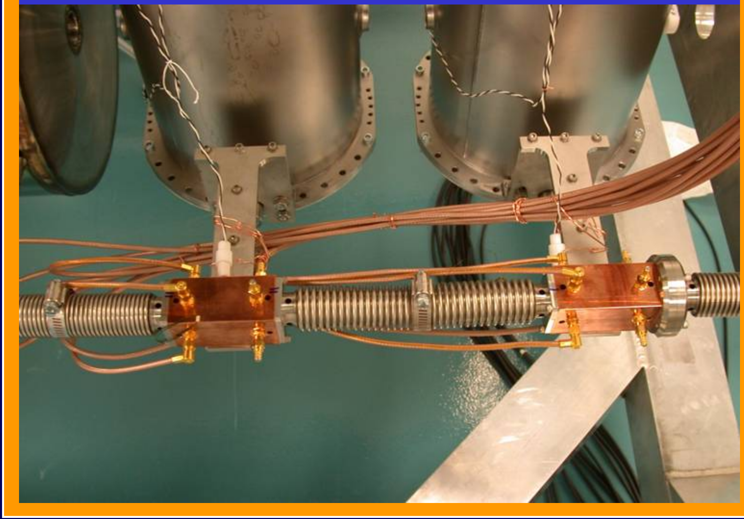




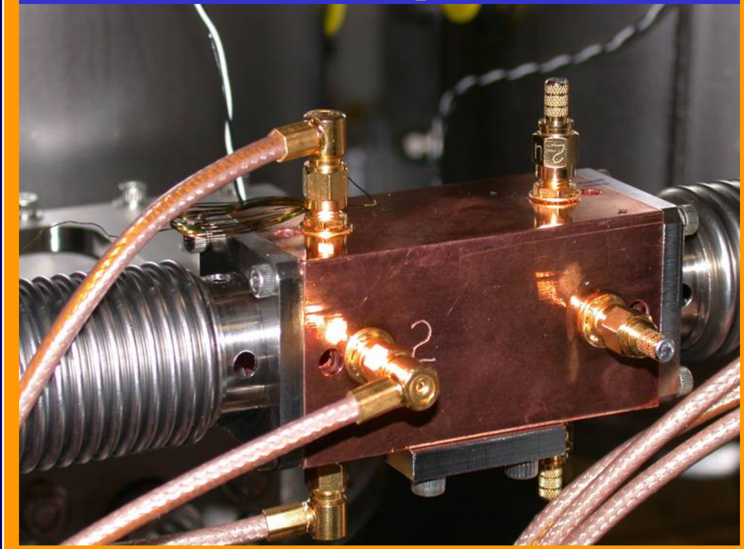
Cryomodule Alignment

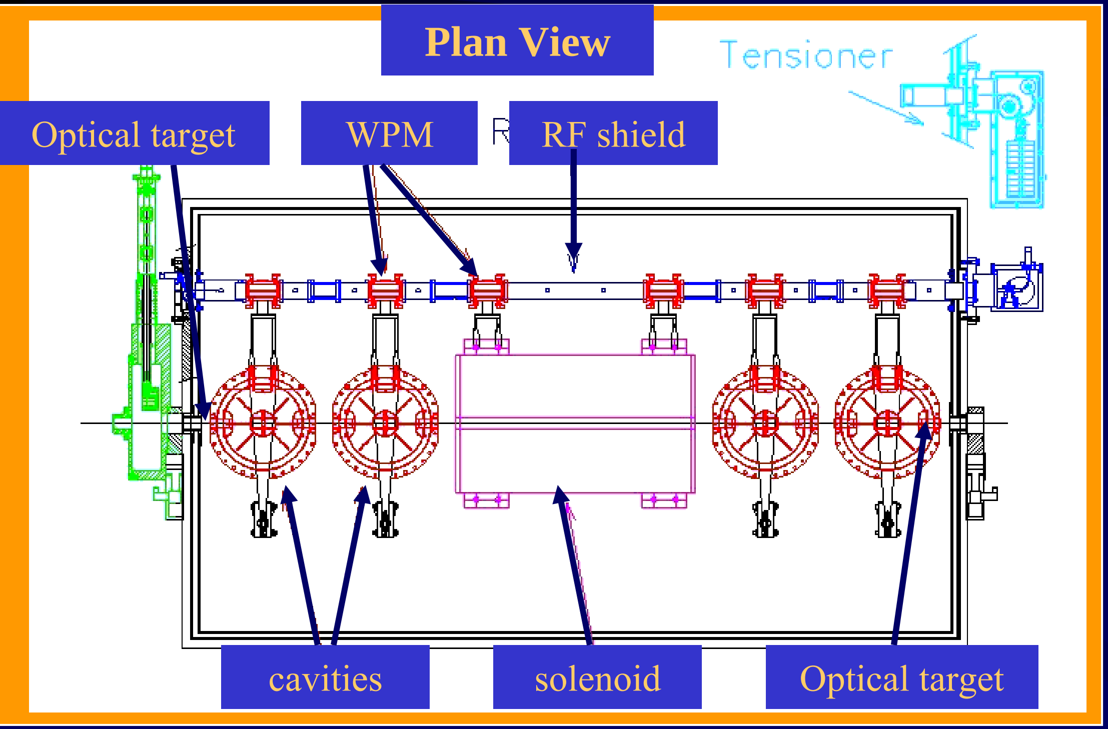
- **the tolerance on solenoid and cavity misalignments are ±200 µm and ±400 µm respectively**
- we have collaborated with INFN Milano on the development of a Wire Position Monitor for cold alignment with precision of 20 µm
  - Stripline monitor attached to each device driven by rf signal along a reference wire

WPM Monitors on Cavities



Wire Position Stripline Monitor

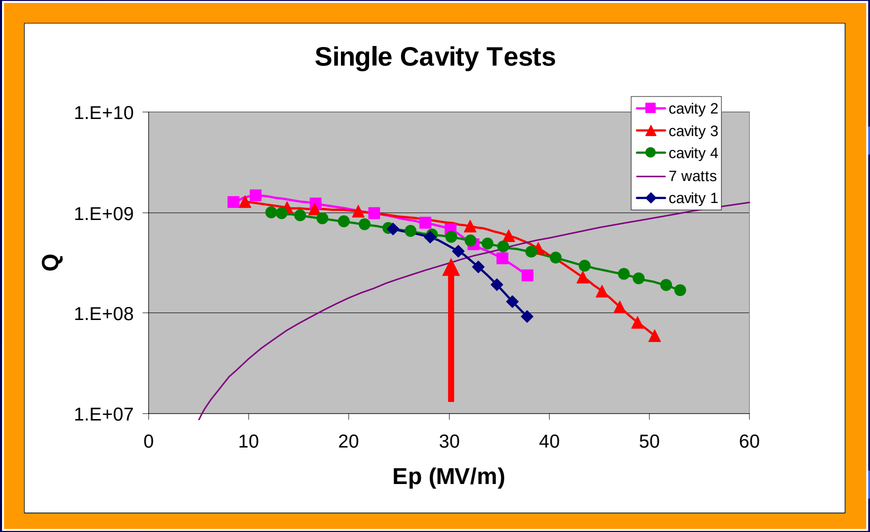


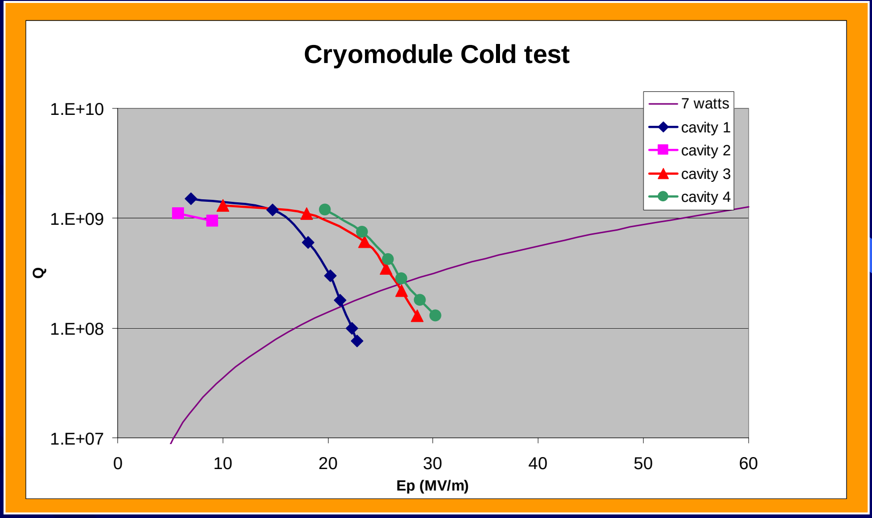


Cryomodule Cold Test – June 2004

Cavity Performance

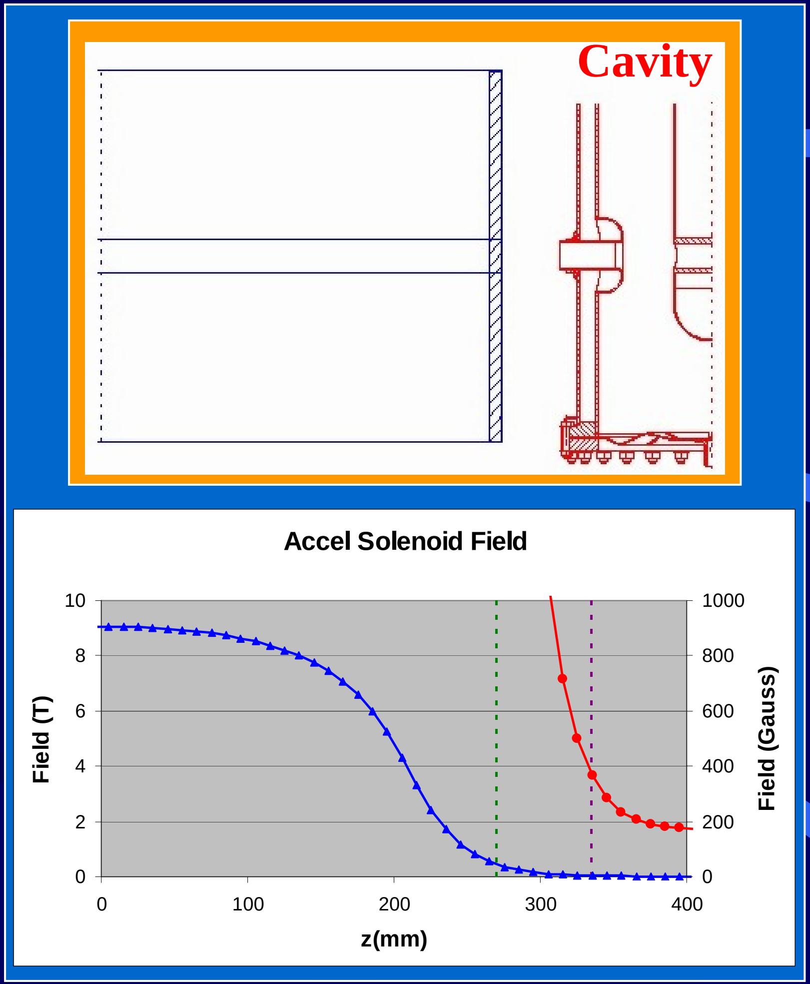
- •All cavities locked at reference frequency
- •Three cavities locked simultaneously
  - •Hardware problem with one control board
- •Low level Q values all >1e9
  - •Mu metal field reduction is adequate
- •Field emission at high field
  - •Cavities not rinsed prior to test
  - •Require more conditioning time





Solenoid Test

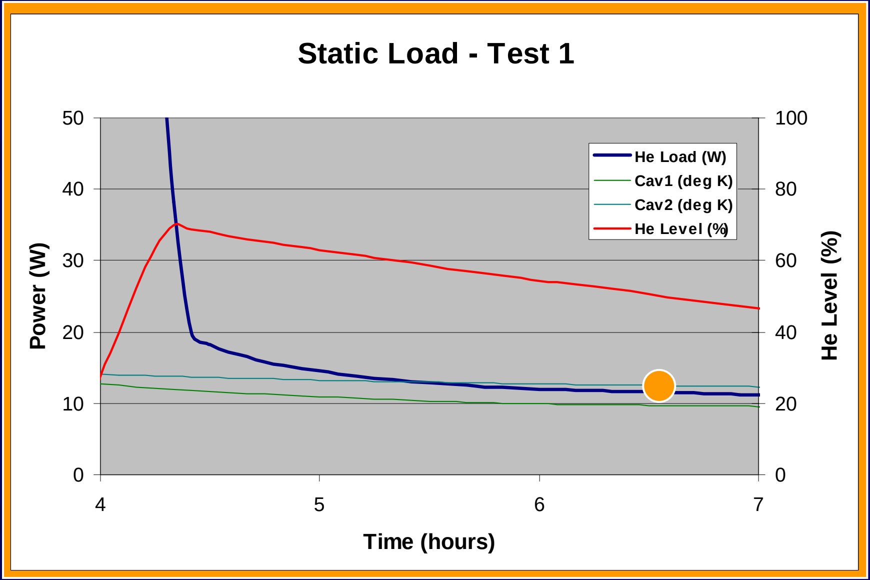
- Base Q's measured before solenoid test
- Ramp up solenoid to 9T
    - Cavities 2 and 3 on
    - No quench of cavities or solenoid
    - No change in cavity Q
- Cold mass warmed above transition
- Q's measured after second cooldown
    - No change; Q>1e9
    - Residual field tolerable



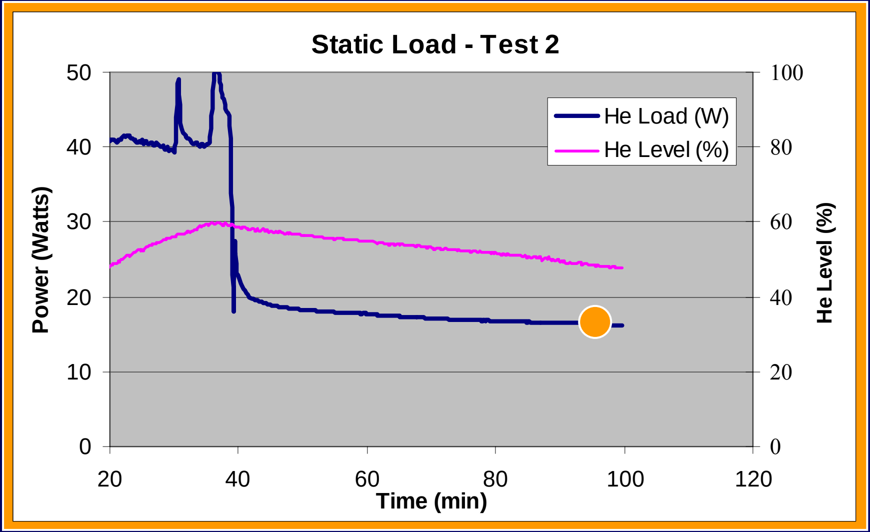
No negative impact on cavities from operation of solenoid

Cryomodule Static Load

- April 25 – First cooldown
  - 200ltr LHe accumulated in cryomodule
  - After thermalization boil-off equivalent to **11W** static load



- July 2 – Second cooldown
  - 180ltr LHe accumulated in cryomodule
  - After thermalization boil-off equivalent to **16W** static load



Conclusion

- First cryomodule rf cold test was very successful
- Highlights
  - All cavity Q’s >1e9
  - All cavities locked
  - Three cavities locked simultaneously with solenoid on
  - Solenoid ramped to 9T
  - No impact of solenoid on cavity performance from operating field or from remnant fields
  - Static load within design limits - 16W

ISAC-II Contributions

- MOP86 – Cryomodule Cold Test – R. Laxdal
- MOP86 – RF Coupling Loop Design – R. Poirier
- MOP89 – Wire Position Monitor – B. Rawnsley
- TUP77 – RF Control System – K. Fong
- TU104 – ISAC Overview/Plans – P. Schmor
- THP14 – Cryomodule Engineering – G. Stanford
- THP14 – High Beta Cavity Design – R. Laxdal