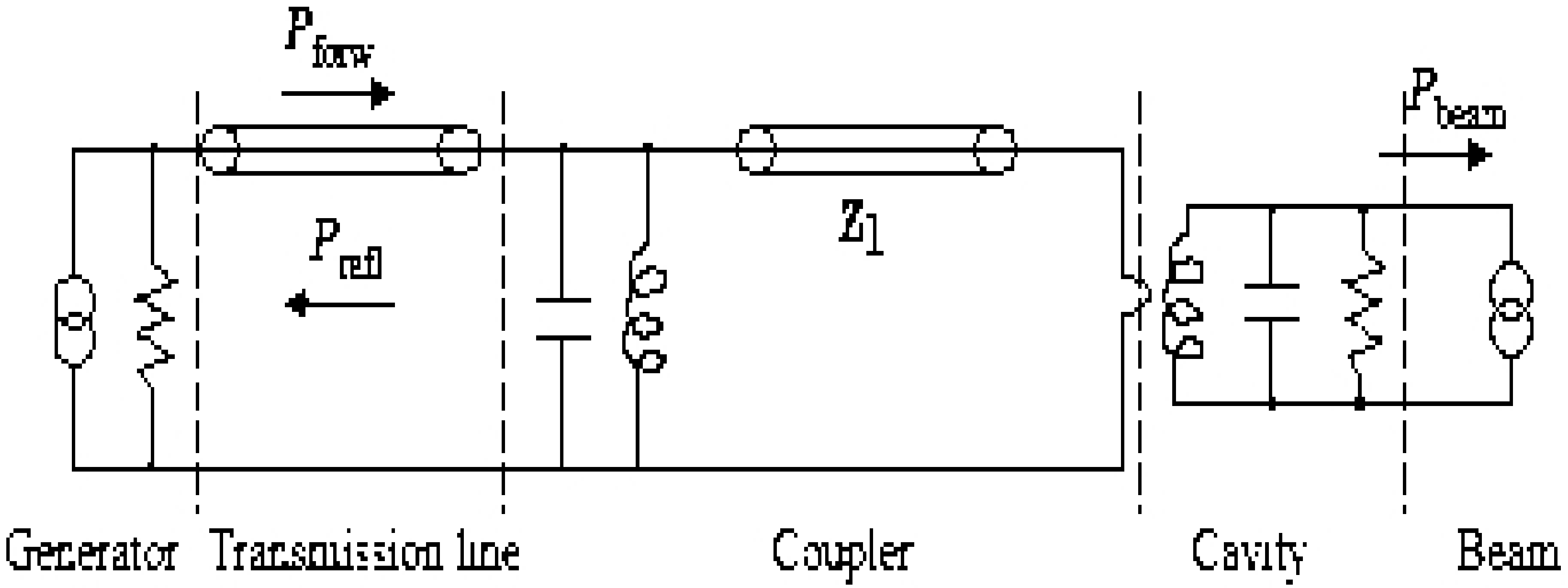
Couplers and Tuners

for low beta cavities

Amit Roy

COUPLER

RF input couplers are passive impedance matching networks designed to efficiently transfer RF power from a source to a beam loaded cavity.



Requirement of couplers

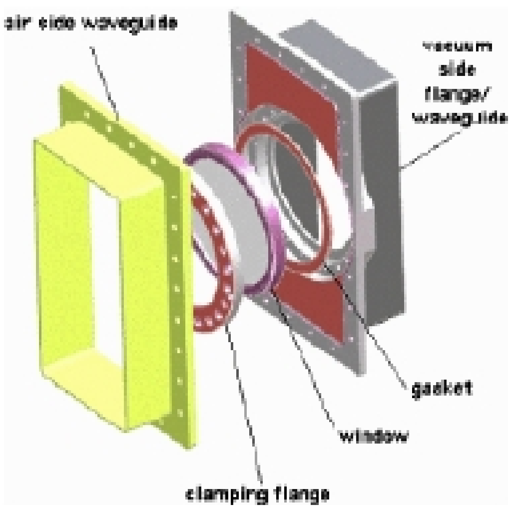
- Good thermal isolation between room temperature end and the cavity end.
- Should itself be efficiently cooled.
- Should be amenable to clean procedures.
- Little or no Multipacting in the coupler.

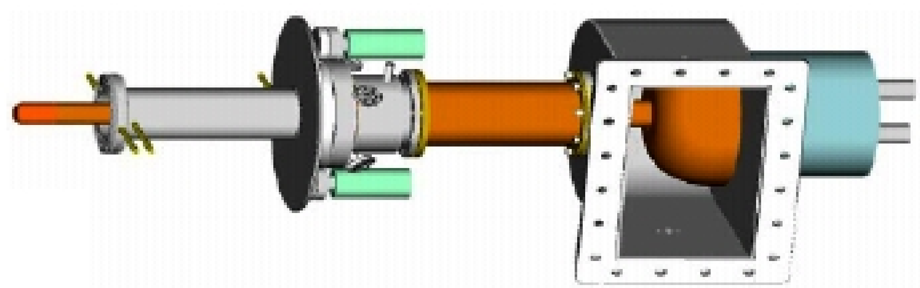
Fixed couplers vs adjustable coupler.
Useful during multipacting of cavities.

Waveguides vs **Coaxial lines** (S.Belomestnykh)

- Simpler design
- Better power handling
- Easier to cool

- More compact
- Smaller heat leak
- Easier to make variable
- Easier to handle multipacting

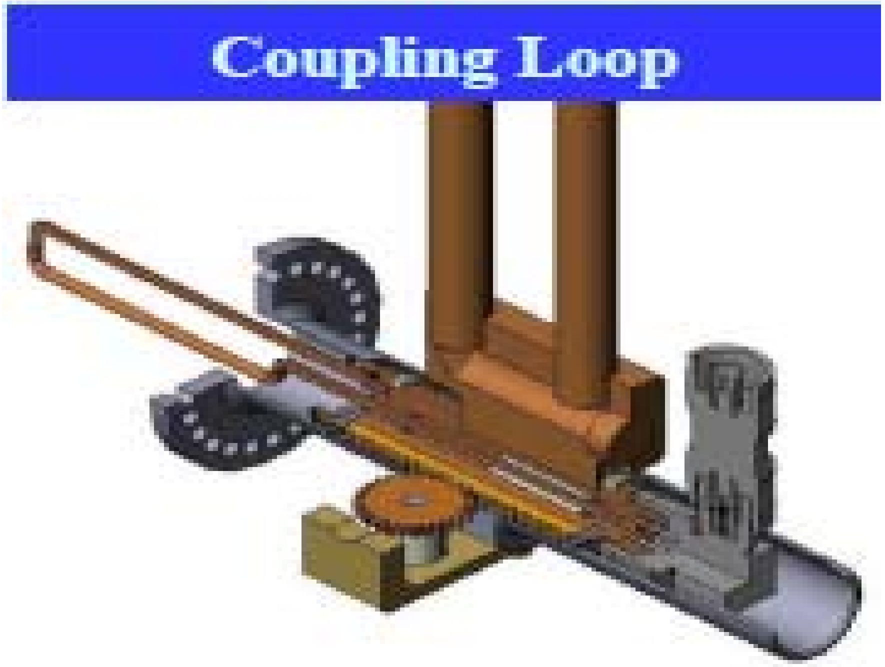


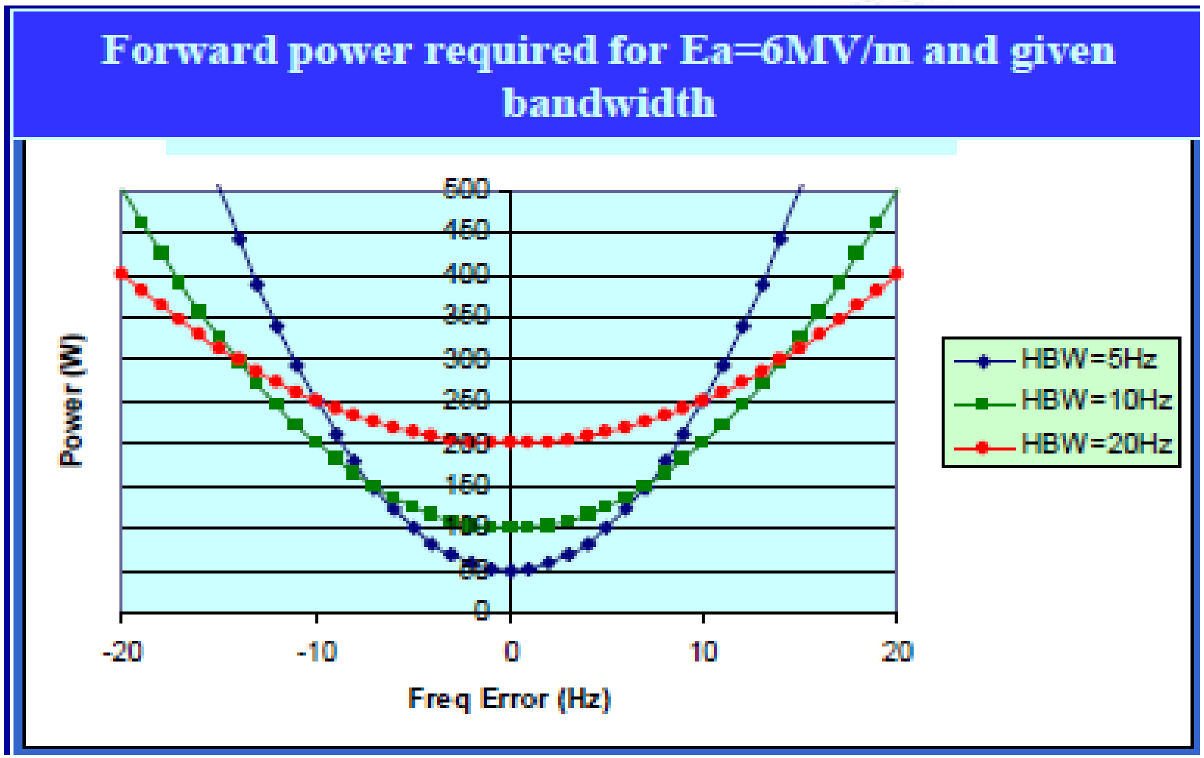


For low beta cavities, coaxial lines have been preferred. For high beta cavities both coax lines and waveguides have been used.

Forward power for control of cavity,

$$P = \pi . U_o . \Delta\omega$$



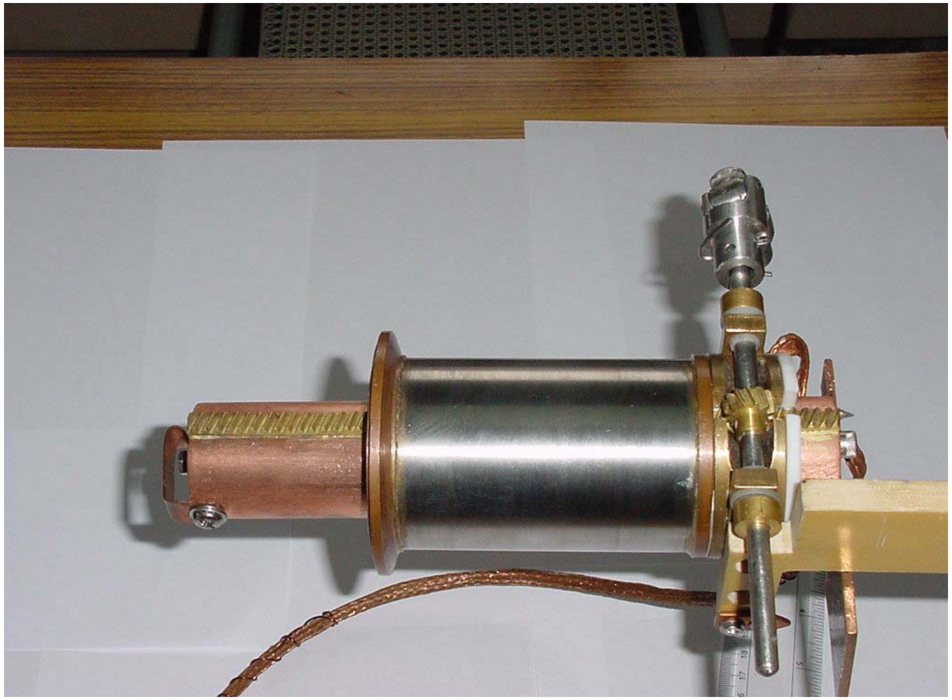


TRIUMF

β = 0.057 & 0.071
P = 250 W

- Cross roller bearings replace teflon guide bushing
- Side loads from LN2 circuit reduced by using center feed
- Thermal tests confirmed design goals
- Smoother travel
- <0.5W from loop to 4K at Pf=200W

TRIUMF



Old Drive

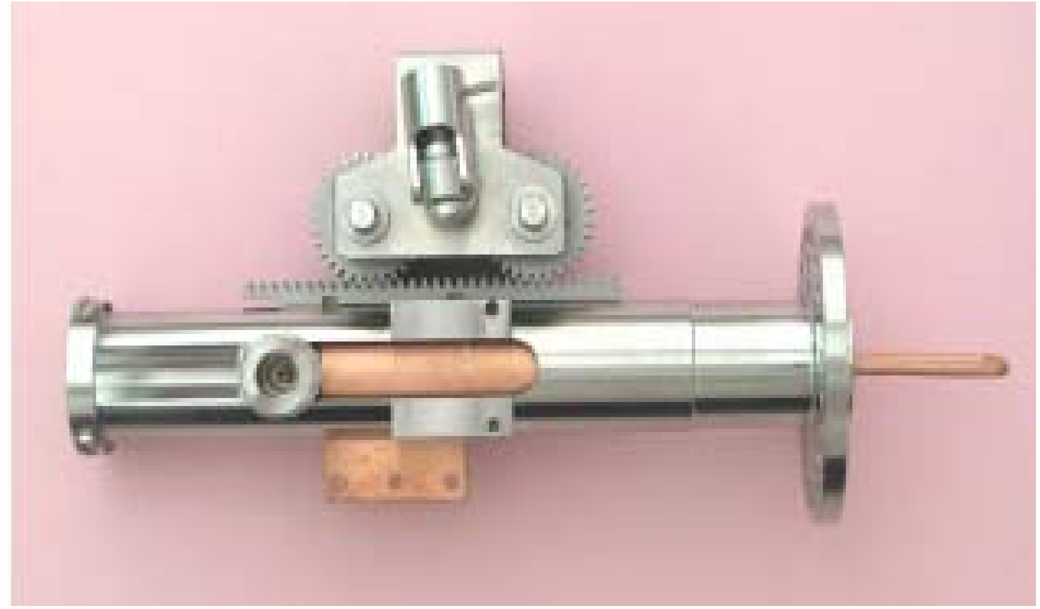
IUAC

$\beta = 0.08$
P 100-150 W
0.5 W at 4.5 K @125 W

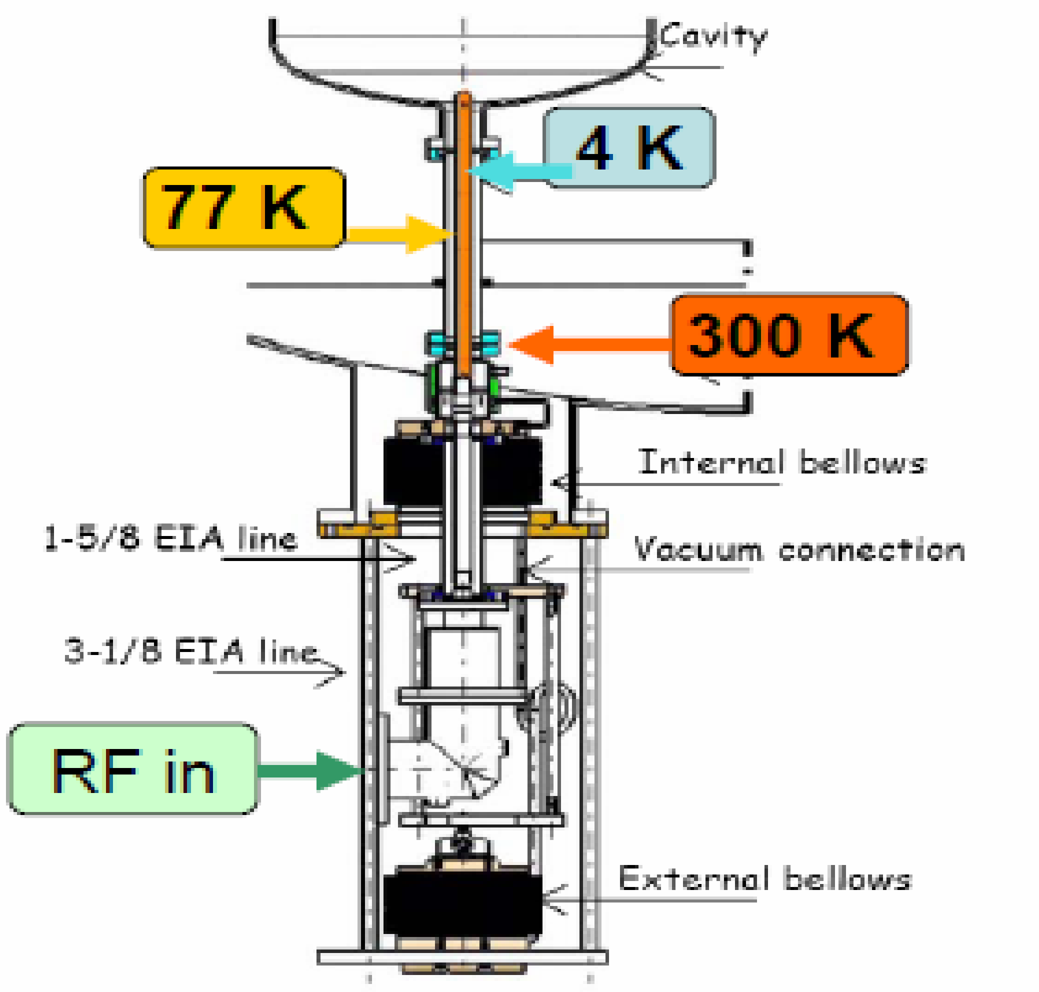
New Drive with
linear & rotary motion

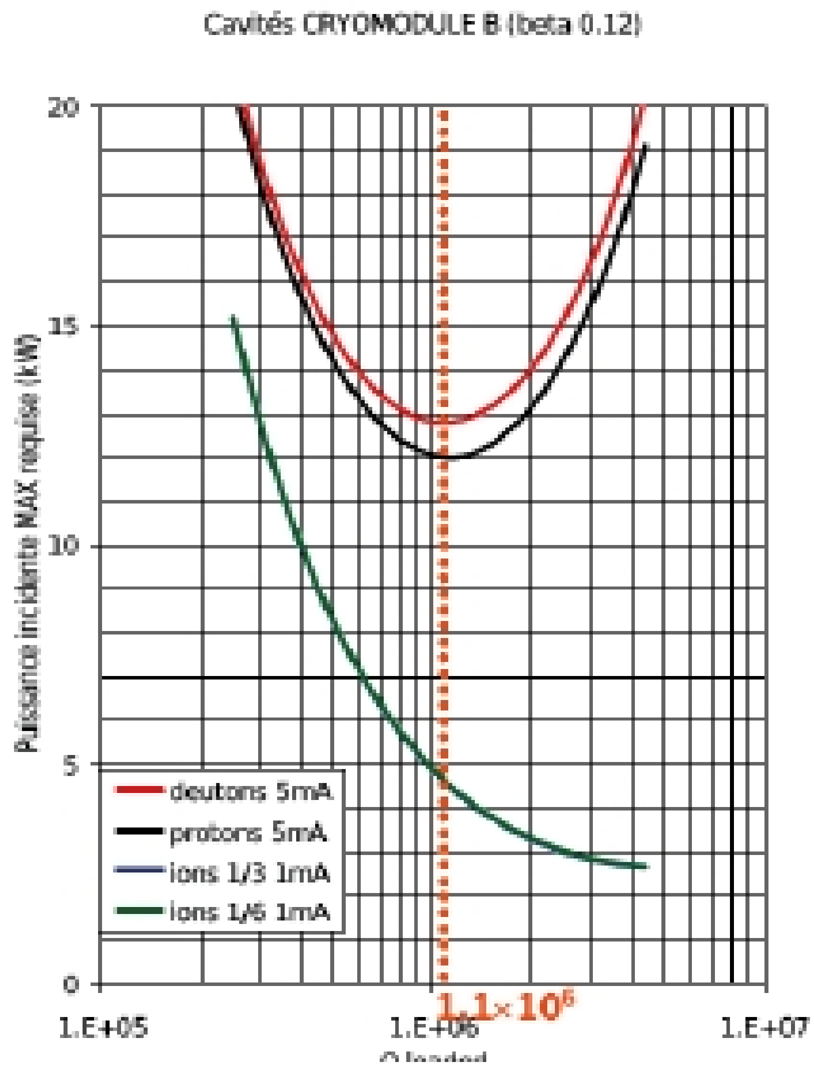
New Drive with
rack & pinion outside

Low-β cavity equipped with new tuner and cooled coupler, ALPI

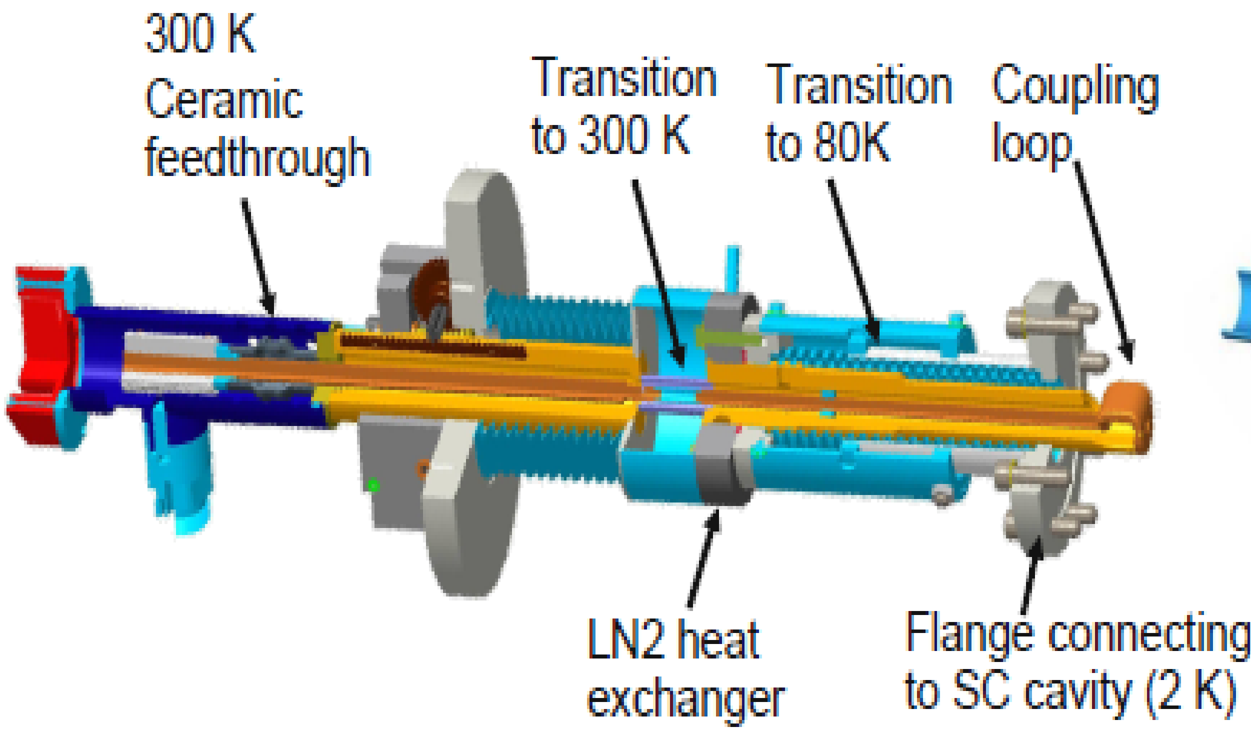


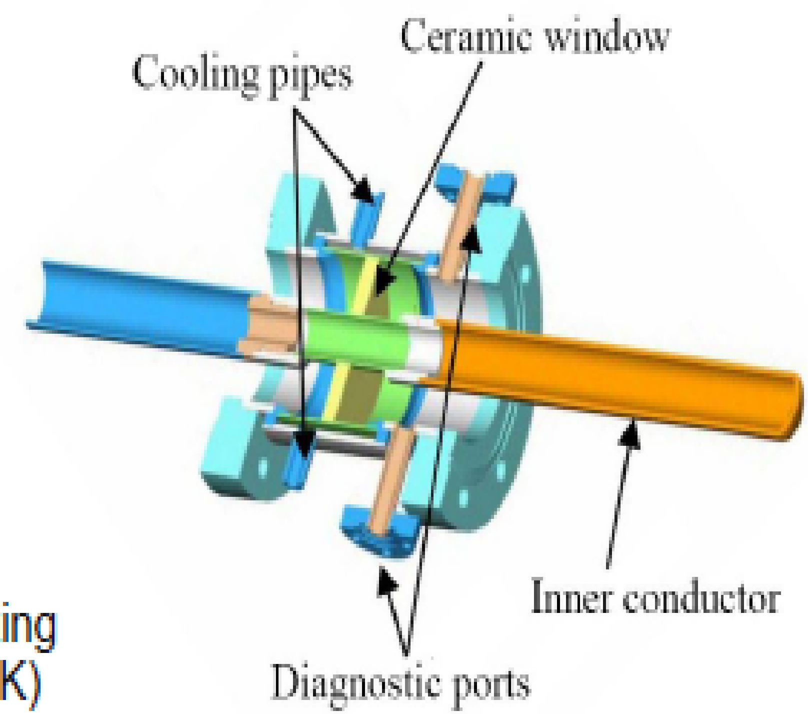
View of the new cooled coupler





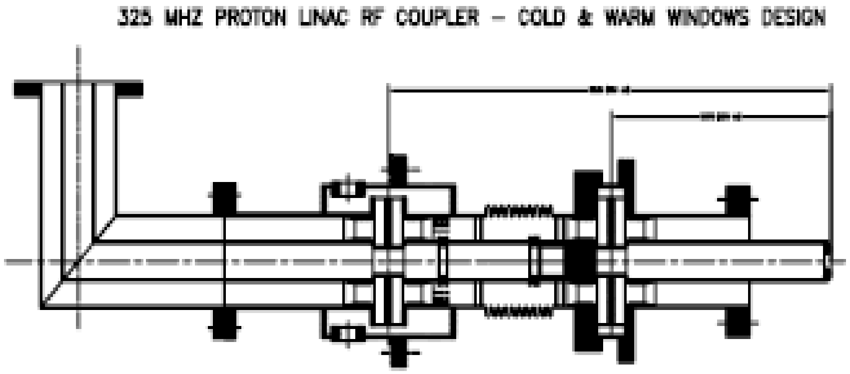
T. Junquera GANIL & IPNO, France, $\beta = 0.12$, P = 20 kW



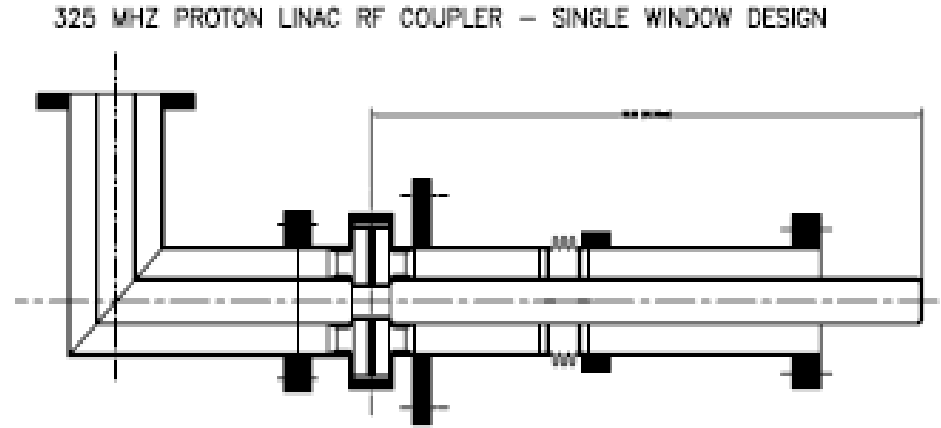


cw inductive power coupler – ANL for spoke cavity
Fully variable over 50 dB

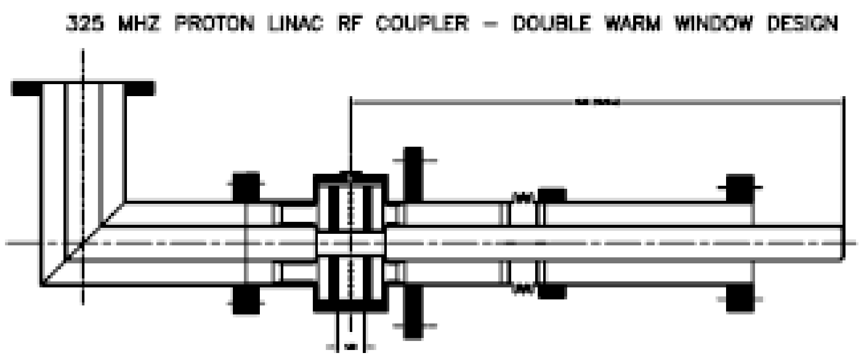
FNAL & AMAC Inc. Newport News, Coupler for Spoke cavity(β =0.22)



RF Coupler with Cold and Warm Windows, Vacuum or Dry Nitrogen between windows.



Single Warm window:



Double Warm Window RF Coupler with Self- kept Vacuum or Dry Nitrogen Fill between Windows

Characteristics	Single Window	Double Warm Windows	Cold and Warm Windows
S11	0.01303	0.00886	0.02484
S12	0.99929	0.99926	0.99892
VSWR	1.0264	1.01788	1.0509
Power loss at Ceramic Window(s), Watts	0.345	0.7072	0.7545
Power loss at metalization (copper), Watts	0.05	0.0667	0.091
Power loss at inner conductor, Watts	2.997	3.145	3.447
Power loss at outer conductor, Watts	1.33	1.384	1.547

Tuners

Detuning of cavities caused by
Coupling of microphonics due to
(i) mechanical vibrations (microphonics & resonances)
(ii) LHe bath pressure fluctuations
Lorentz detuning

Two time scales => Fast and Slow

Slow Tuners
- **Large tuning range (~10s of kHz)**
- **Slow response time (~seconds)**
- **Provide coarse RF frequency control such that all of the cavities are operating approximately at the design frequency.**

Fast Tuners
- **Small tuning ranges (~100s of Hz)**
- **Fast response time (~ ms)**
- **Provide fine RF frequency control to compensate the effects of microphonics and/or the dynamic Lorentz force.**

Slow tuners operated by mechanical deformation of a part of cavity using either stepper motor control or pneumatic control

Wall displacement towards High E field => f ↓

B field => f ↑

Fast Tuners

 Overcoupling to control RF field controls phase and amplitude

– Additional RF power to be supplied

– Useful in applications with heavy beam loading

VCX fast tuners

– Couple an external reactance to the cavity.

– Damp the cavity Q.

– Cavities operating at small stored energy

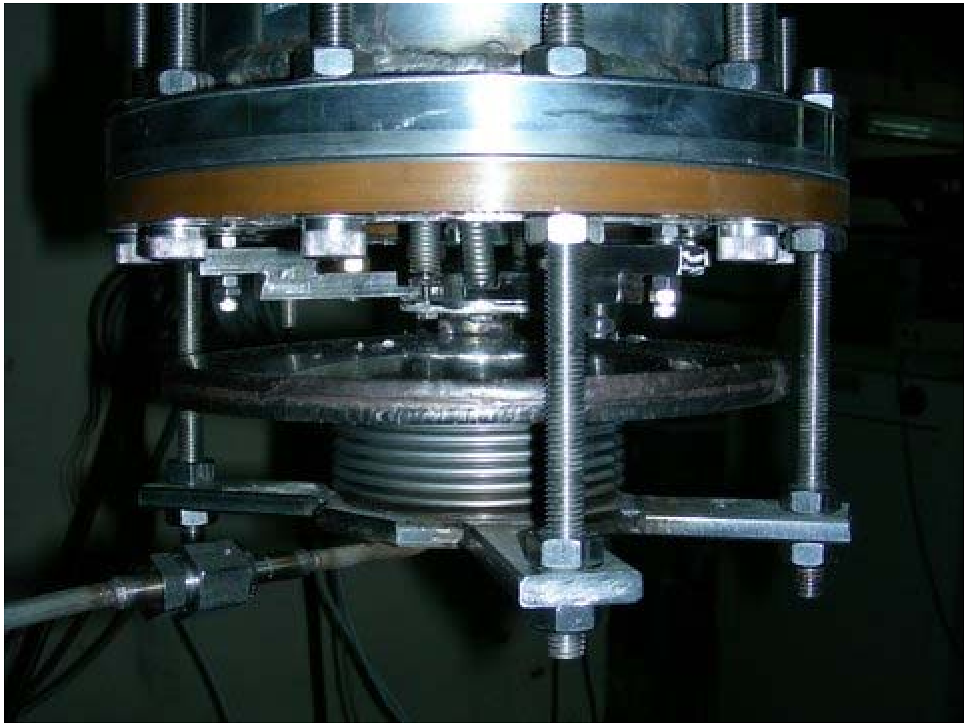
– R&D needed to expand application range

Fast Mechanical Tuners

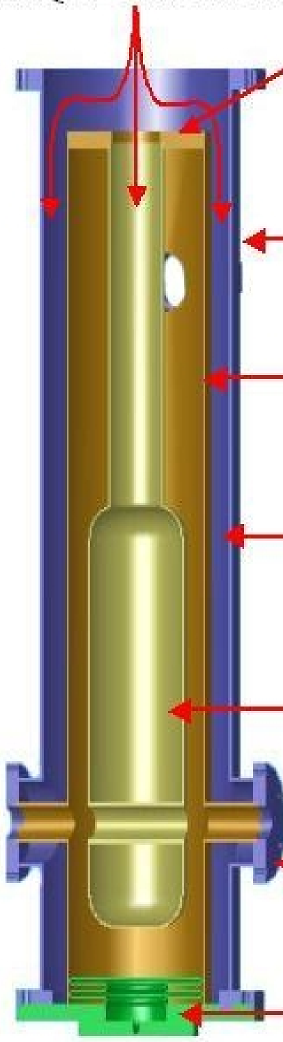
– Deform the cavity to introduce a controllable change in the RF frequency.

– No additional RF power

– The fast mechanical tuner and the cavity are an integral system.



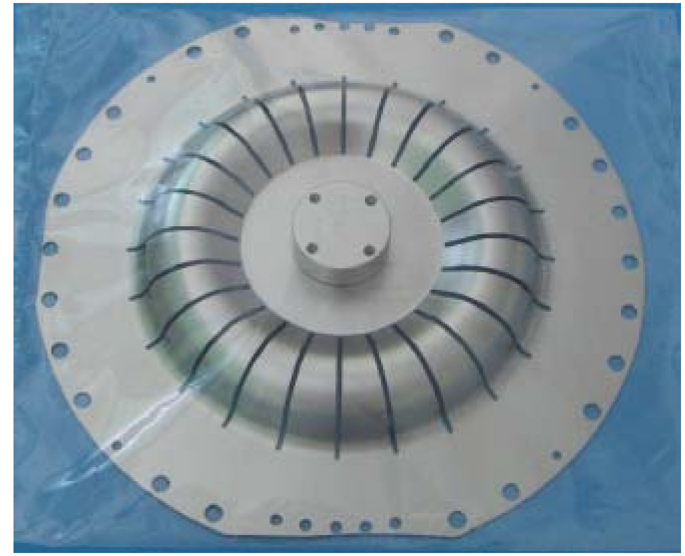
SS bellow for slow-tuner pneumatic control



IUAC

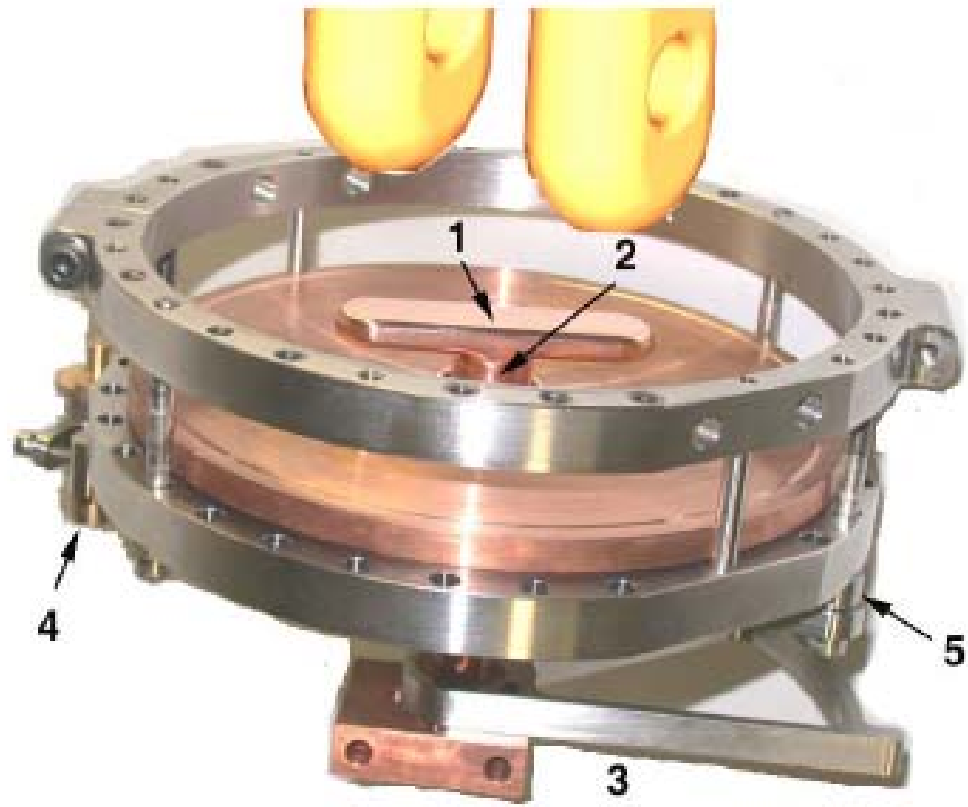
LNL

New tuner assembly

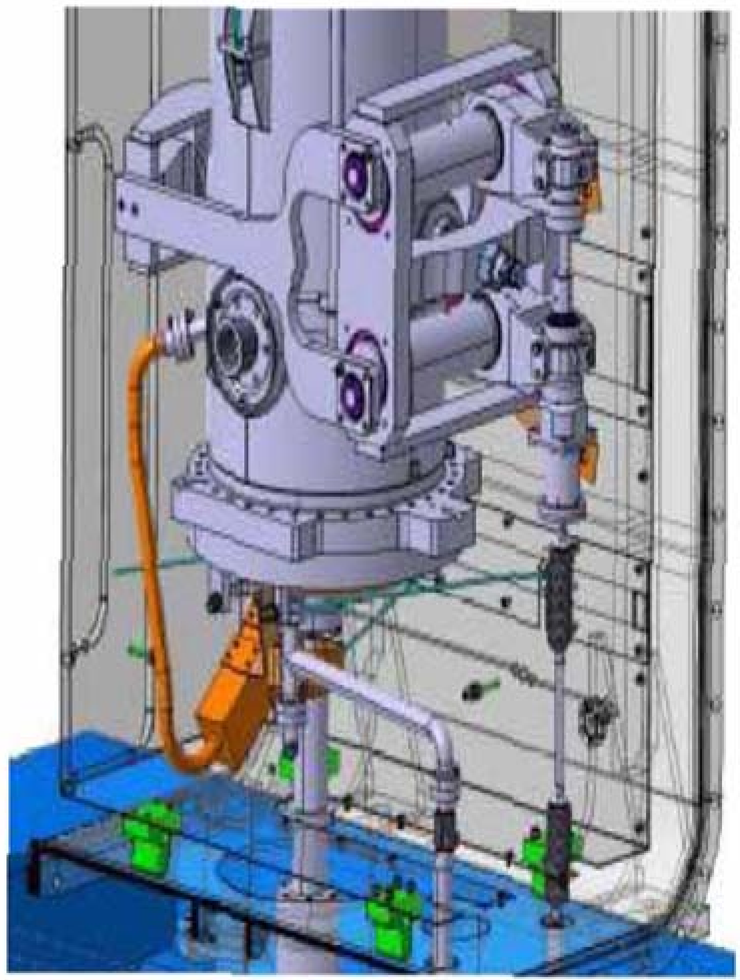


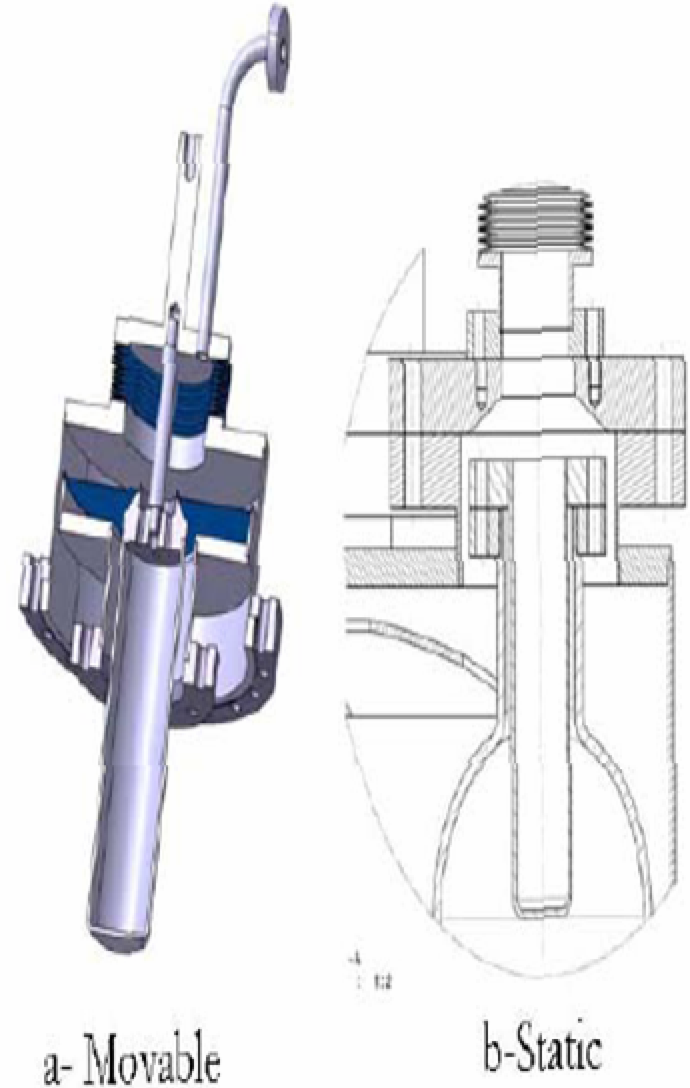
Bulk Nb slotted tuning plate (in a protective plastic bag).

TRIUMF



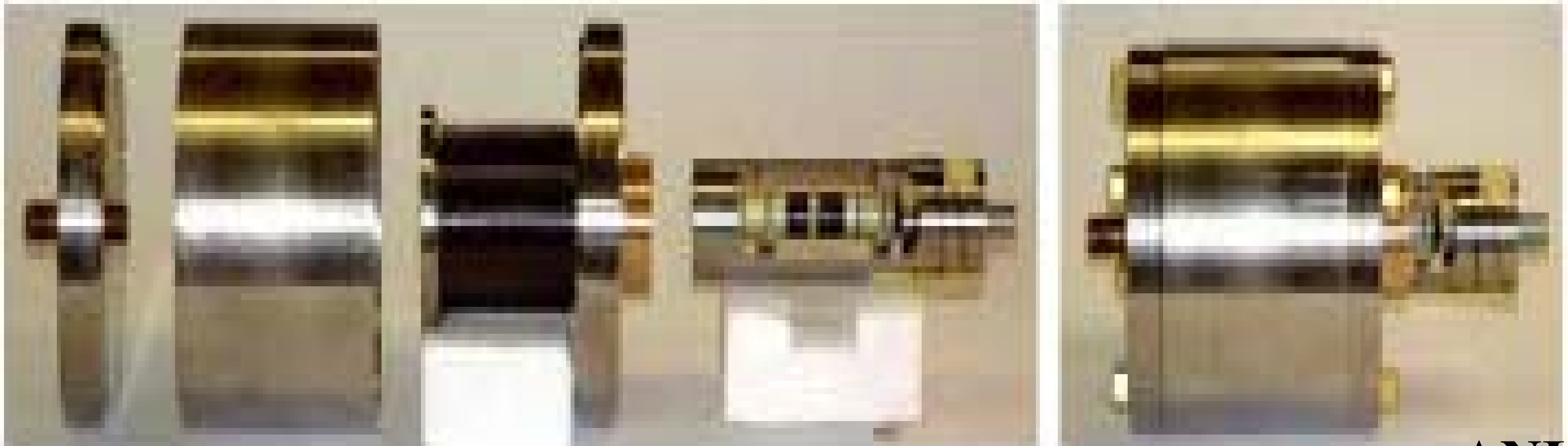
ANU: (Color) Mechanical design of rotary tuner: 1—flat bar with rounded edges; 2—tuner shaft; 3—arc lever arm; 4—driving rotary shaft; 5—coarse tuning inserts.



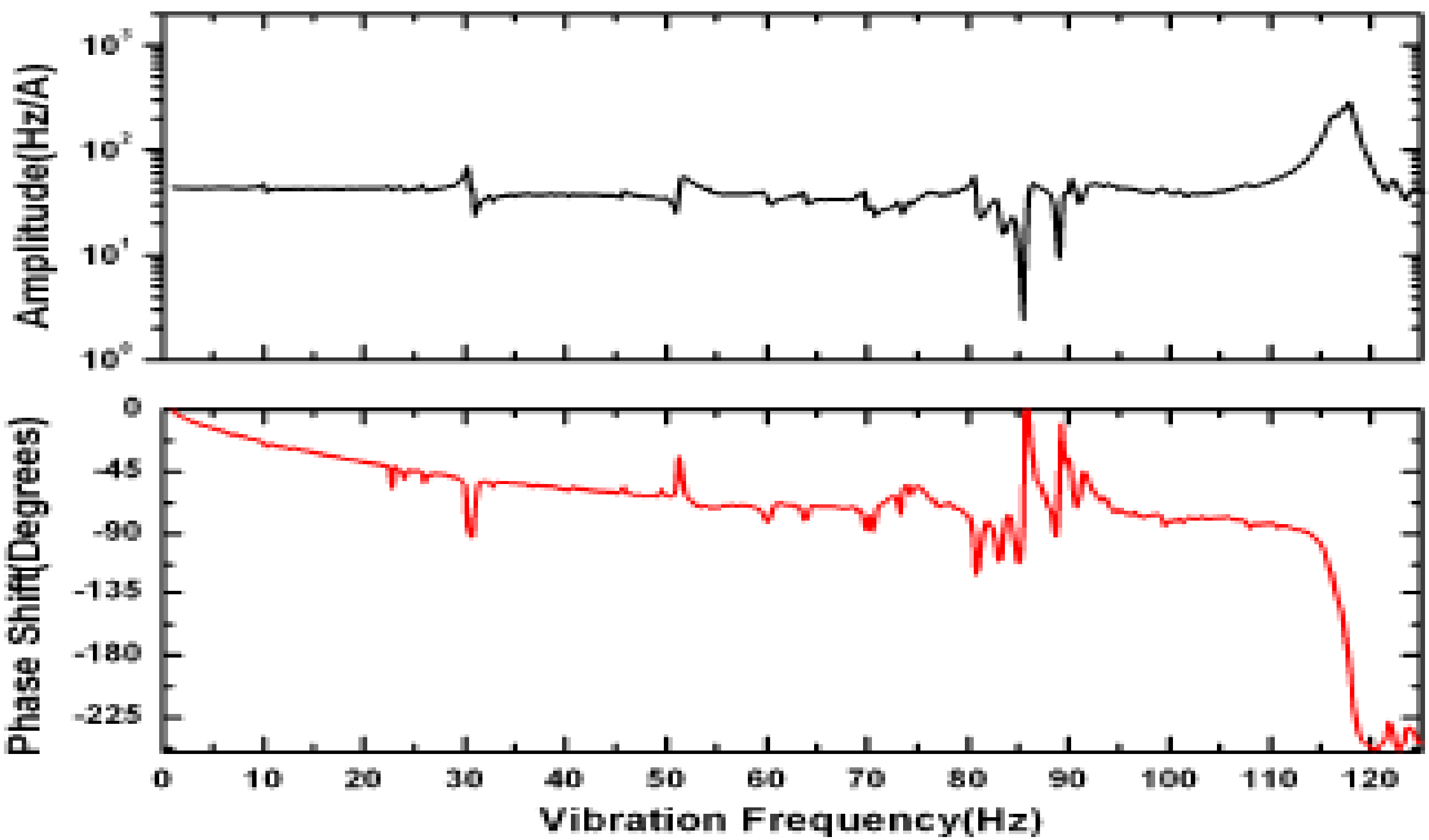


• β 0.07 : mechanical tuner, QWR body deformation
• β 0.12 : plungers on QWR top volume (fixed and movable)

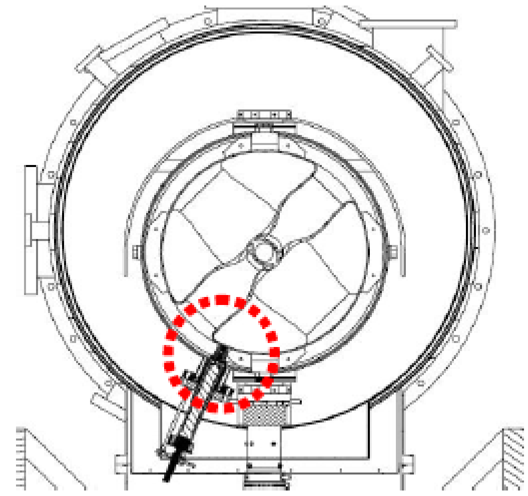
T. Junquera GANIL & IPNO, France



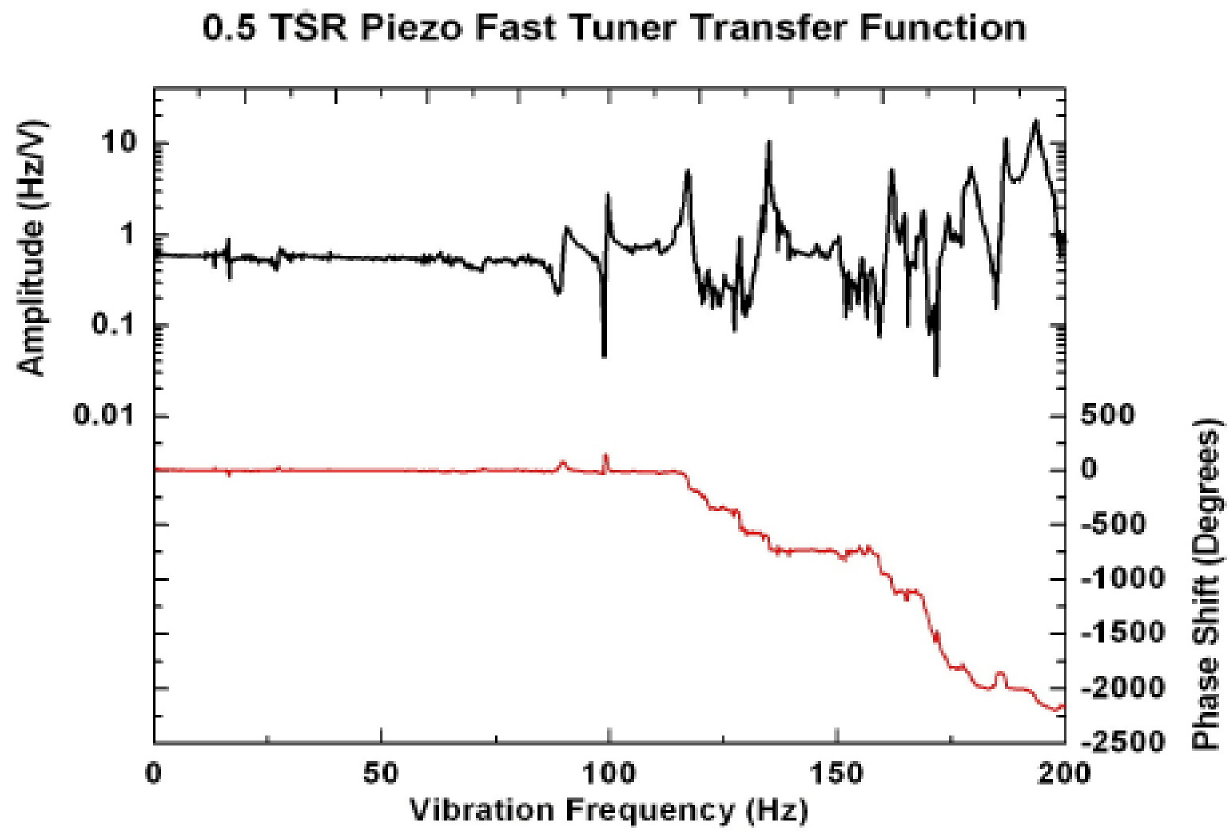
ANL
Magnetostrictive
ner and adjustable
lder.



The mechanically coupled $\beta = 0.5$ TSR and magnetostrictive fast tuner transfer function.



Location (inside dashed line) of the fast tuner in the beta 0.5 triple spoke cavity (drawing from ANL).



Piezoelectric fast tuner transfer function amplitude (top) and relative phase shift (bottom). ANL

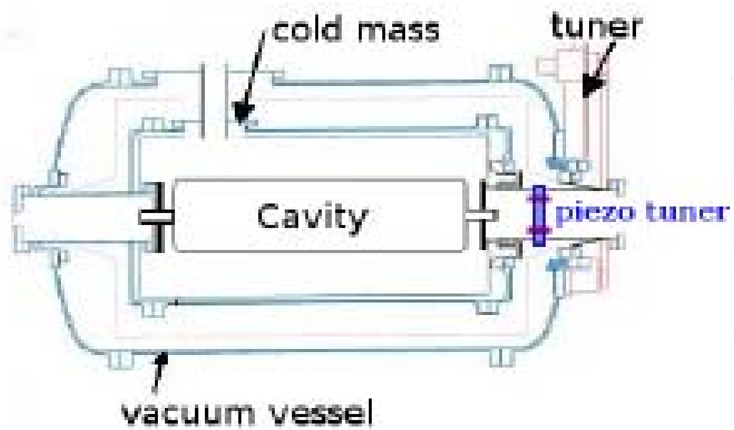
piezoelectric fast tuner guide assembly (above) and bare piezoelectric stack

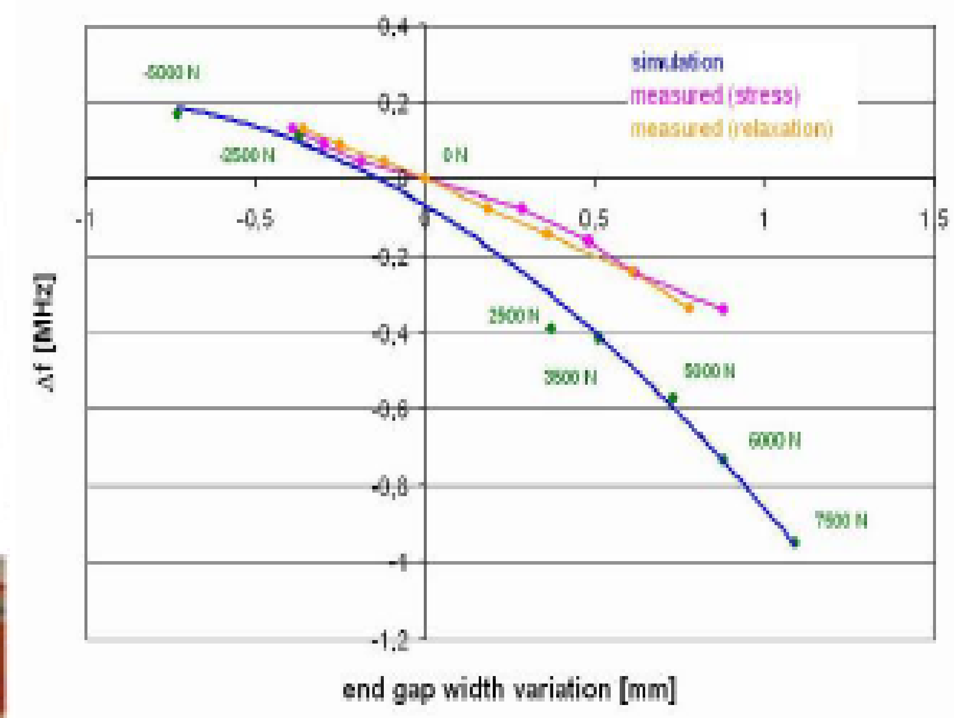
Magnetostrictive actuator designed and built by Energen, Inc.

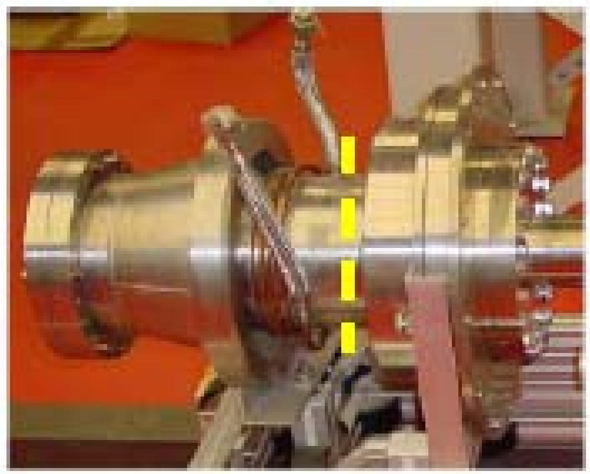
- **Response time ~6ms.**
- **Magnetostrictive rod coaxial with an external solenoid operating at 4K.**
- **Not designed for high frequency operation.**

- **Response time <1ms.**
- **Layered piezo-ceramic material electrically connected in parallel operating at 26K with a resolution of 2nm purchased from APC.**
- **Support structure not optimized for high frequency operation**

Tuner Actuator	Piezoelectric	Magnetostrictive
Operating Temp.	Greater than 4 K	2 to 4 K
Length	Long (6 - 12")	Short (~4")
Stroke @ 4 K	< 10 µm	> 100 µm
Push Force	4000 N	440N

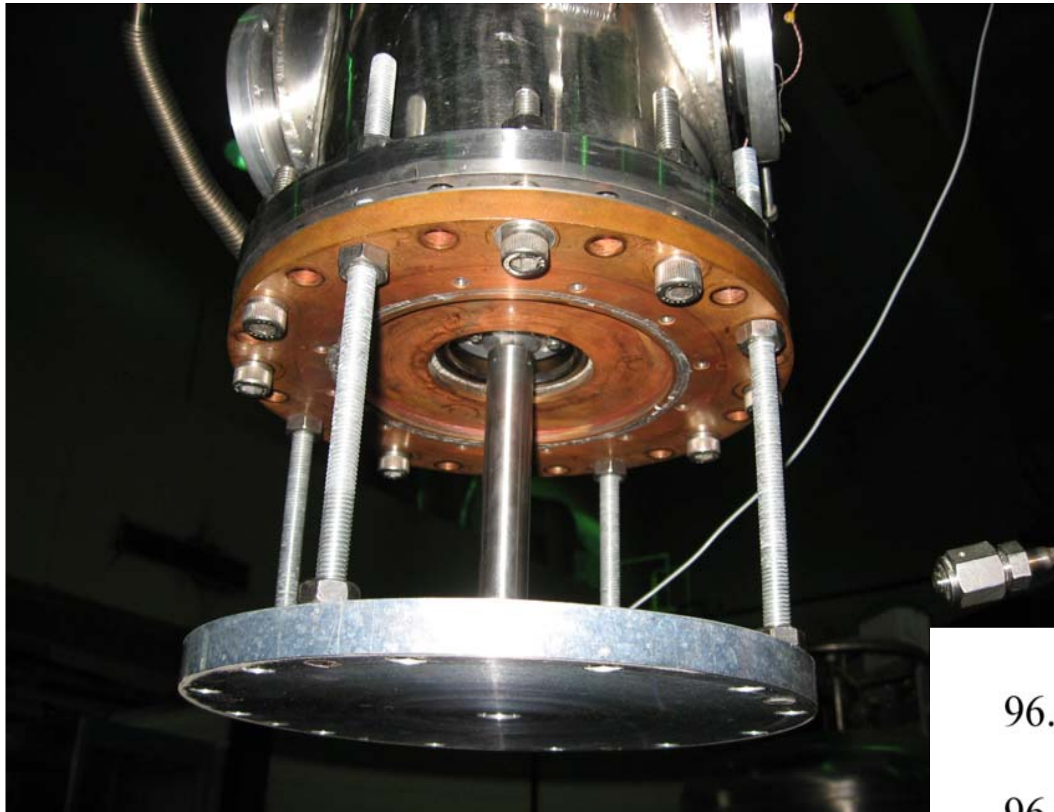


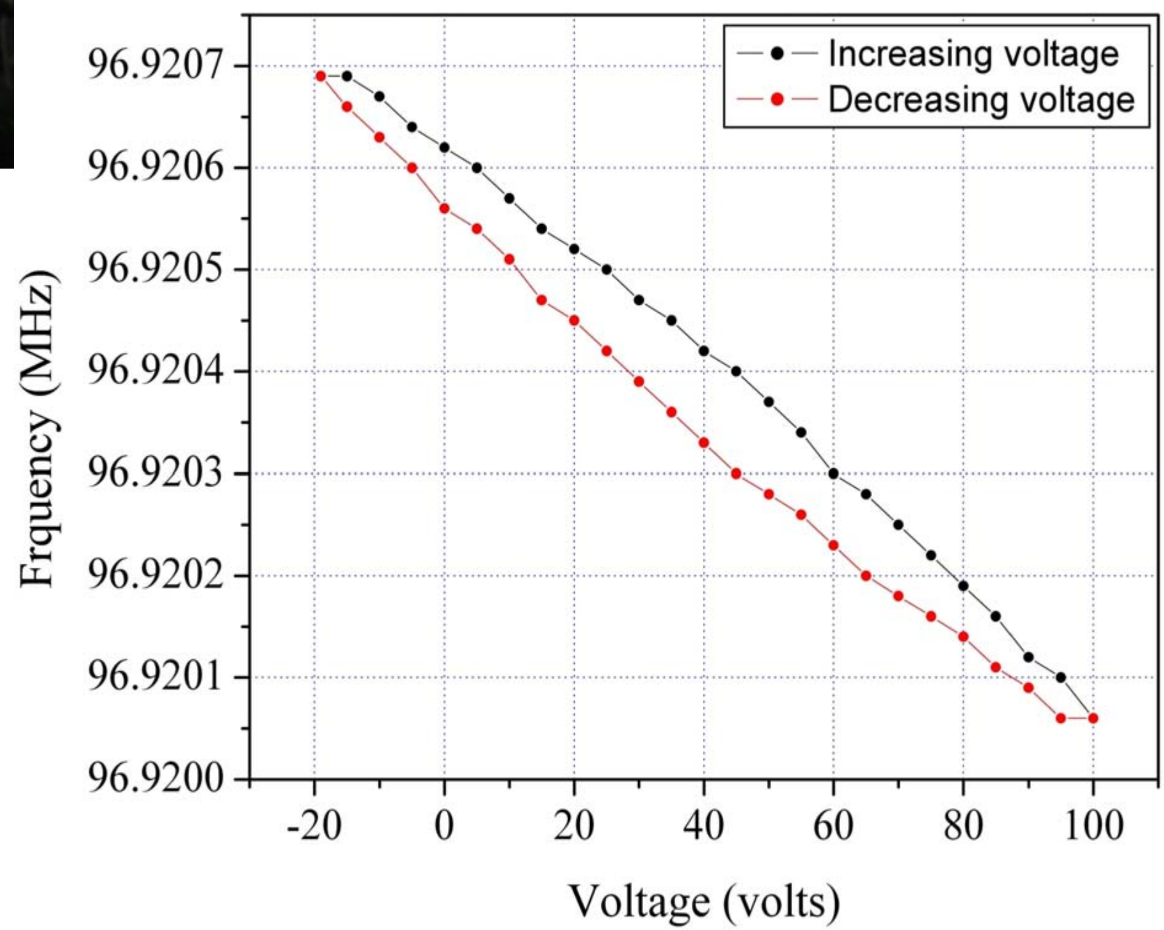




Simulated and measured rf- response.

Scheme of the cryostat with tuner positioning on top right, a piezo from Physical Instruments (PI) top left, the mechanical tuner bottom left and beam pipe were piezo tuner shown in fig. 5 will be included close to the cooling loop in the middle (dotted line).
IAP, J. W. Goethe-Universitaet, Frankfurt, Germany.





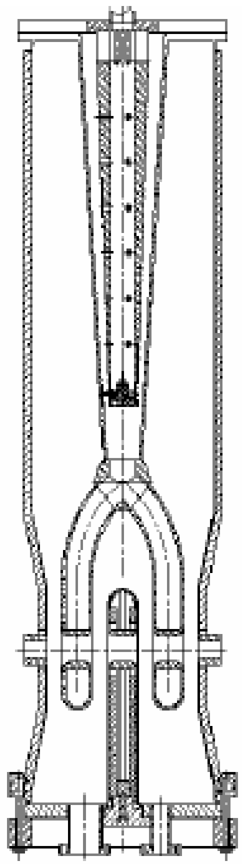
With Piezo Tuner
Δf at 300K = 2.5 kHz

at 4.2K = 0.626 Hz

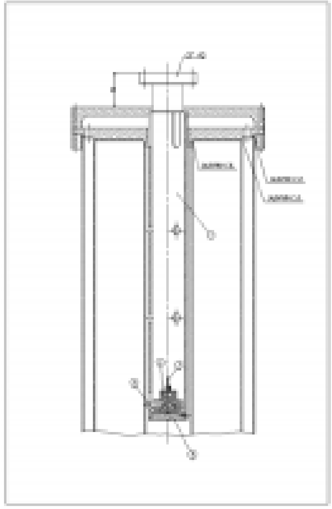
IUAC QWR

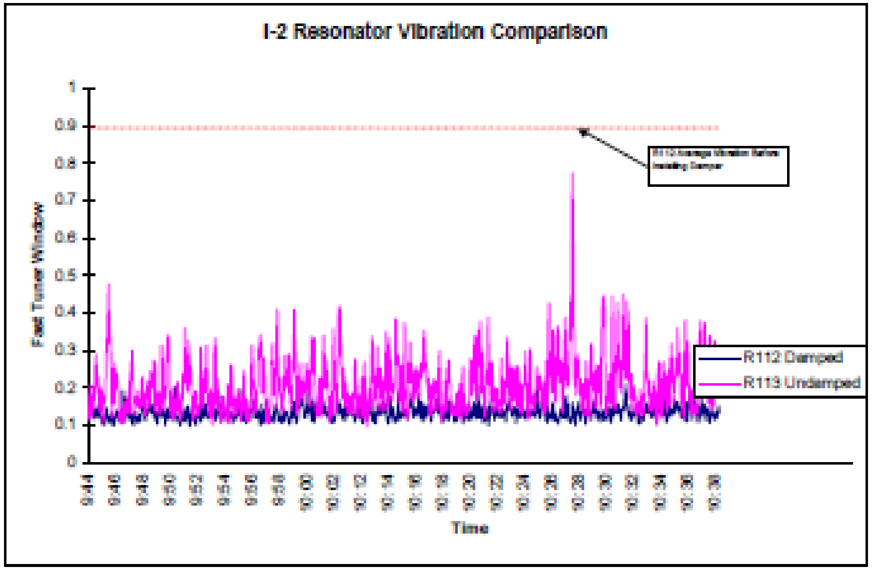
Mechanical vibration dampers

4-gap, 48 MHz QWR with vibration damper



80 MHz QWRs with vibration damper

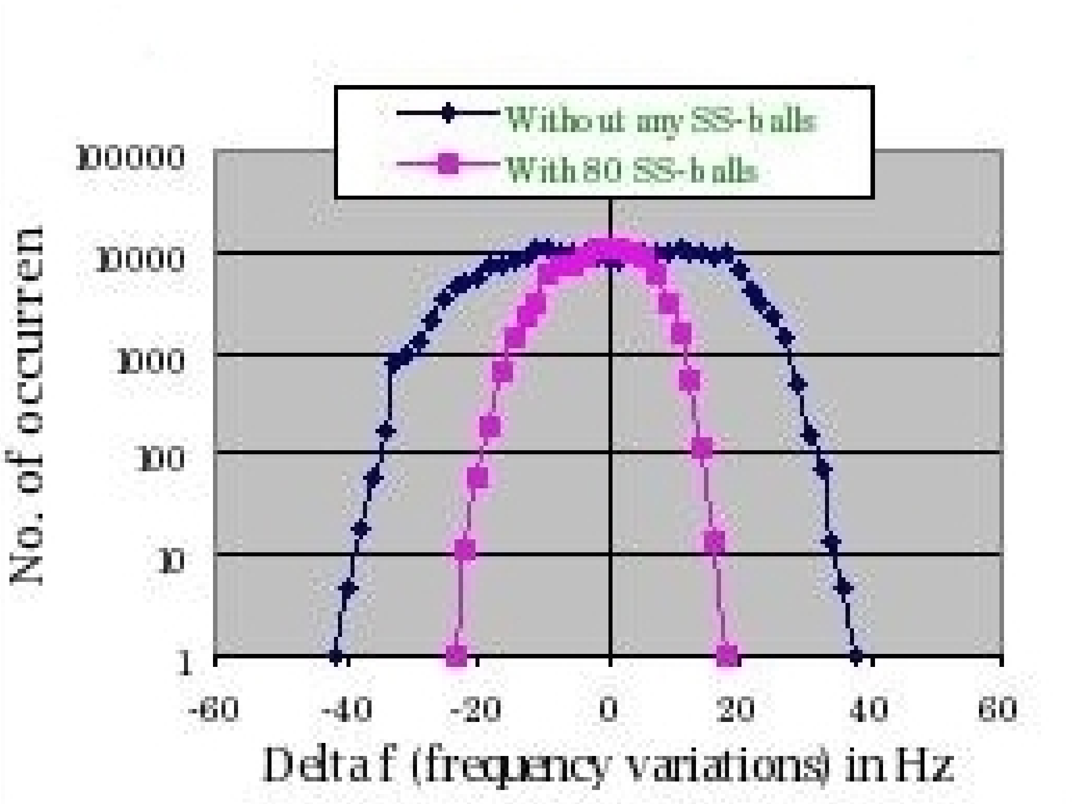


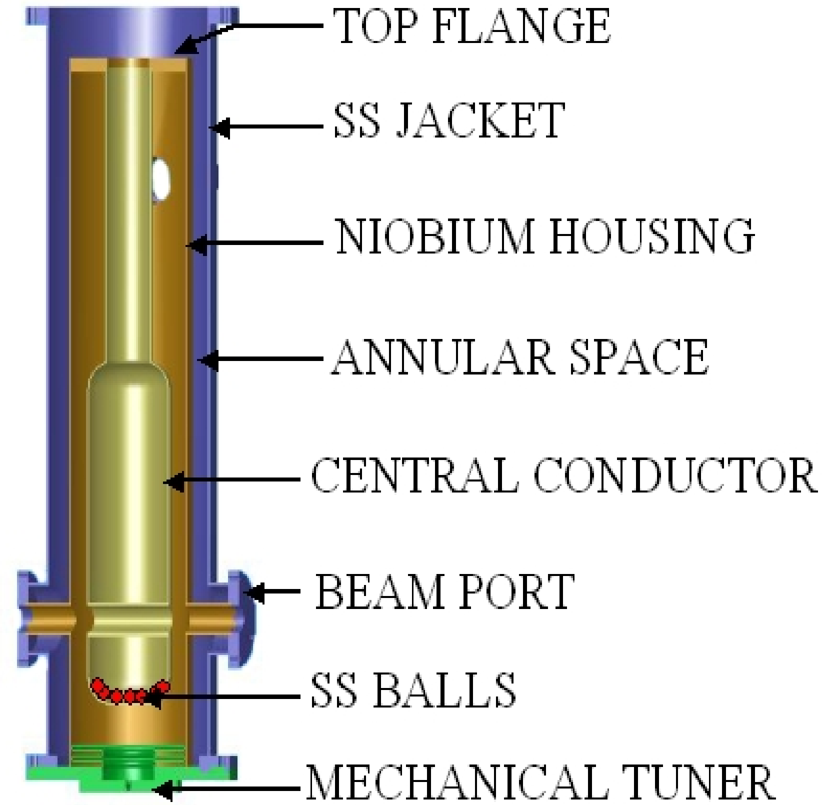


Approx. $\times 10$ attenuation of the vibration amplitude

Vibration dampers are cheap and effective

LNL, TRIUMF, ANL





IUAC mechanical damping of mechanical resonances