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Status of SC Spoke Cavity Development

(WE302)

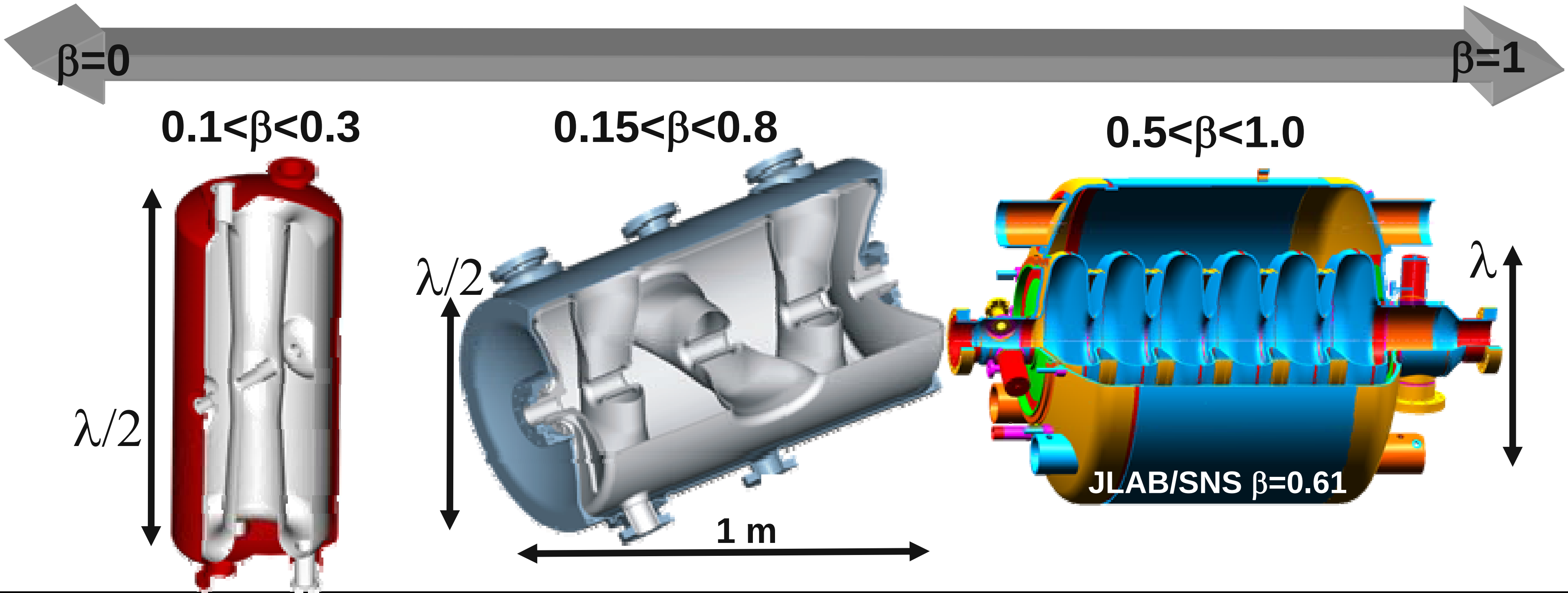
SRF 2007

Oct. 14 -19, 2007, Beijing, China

Speaker: Mike Kelly

SC Linac Technologies for Mid-Beta

SC Cavities	■ Low rf losses → efficient cw operation ■ Short, modular, independently phased → multi-ion flexibility ■ Large bore 4-7 cm → large transverse acceptance ■ High-gradient → compact
SC Spoke Cavities	■ Low frequency → large longitudinal acceptance ■ Mechanically rigid → low microphonics ■ Radial coupling, tuning → high packing factor ■ Sparse mode spectrum → good HOM extraction?



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Outline

I. **Background**
II. **Applications**
III. **Latest Developments**
IV. **Field Performance**
V. **Ancillary Components (Coupler, Tuners)**

THANK YOU

Jean Delayen (JLab)

Guillaume Olry (IPN Orsay)

Zack Conway (ANL/Cornell)

Yvgeny Zaplatine (Jülich)

Alberto Facco (INFN Legnaro)

I. Background
Single-Spoke Cavities for Mid-Beta

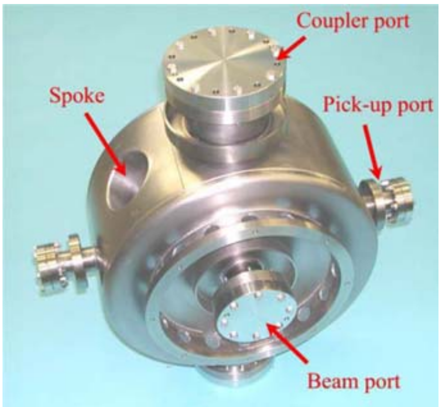
Low-Beta~0.1

1st SC spoke 1991 (funded through SDI)

High-Beta~1.0

850 MHz β=0.28 ANL

340 MHz β=0.29 ANL



350 MHz β=0.175 LANL

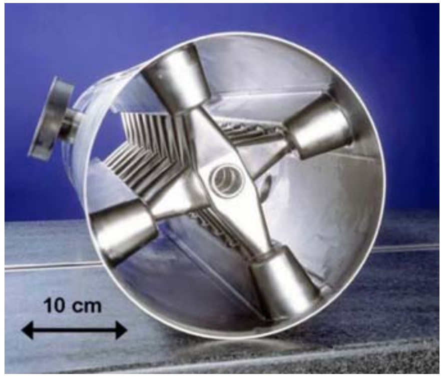
352 MHz β=0.15 IPNO

325 MHz β=0.22 FNAL/Zanon

352 MHz β=0.35 IPNO

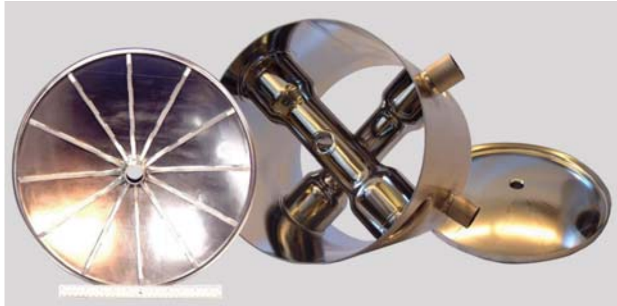
References [1,2,3,4,5]

I. Background
Multi-Spoke Cavities



360 MHz β=0.1 Frankfurt

760 MHz β=0.2 Juelich



345 MHz β=0.40 ANL

345 MHz β=0.50 ANL

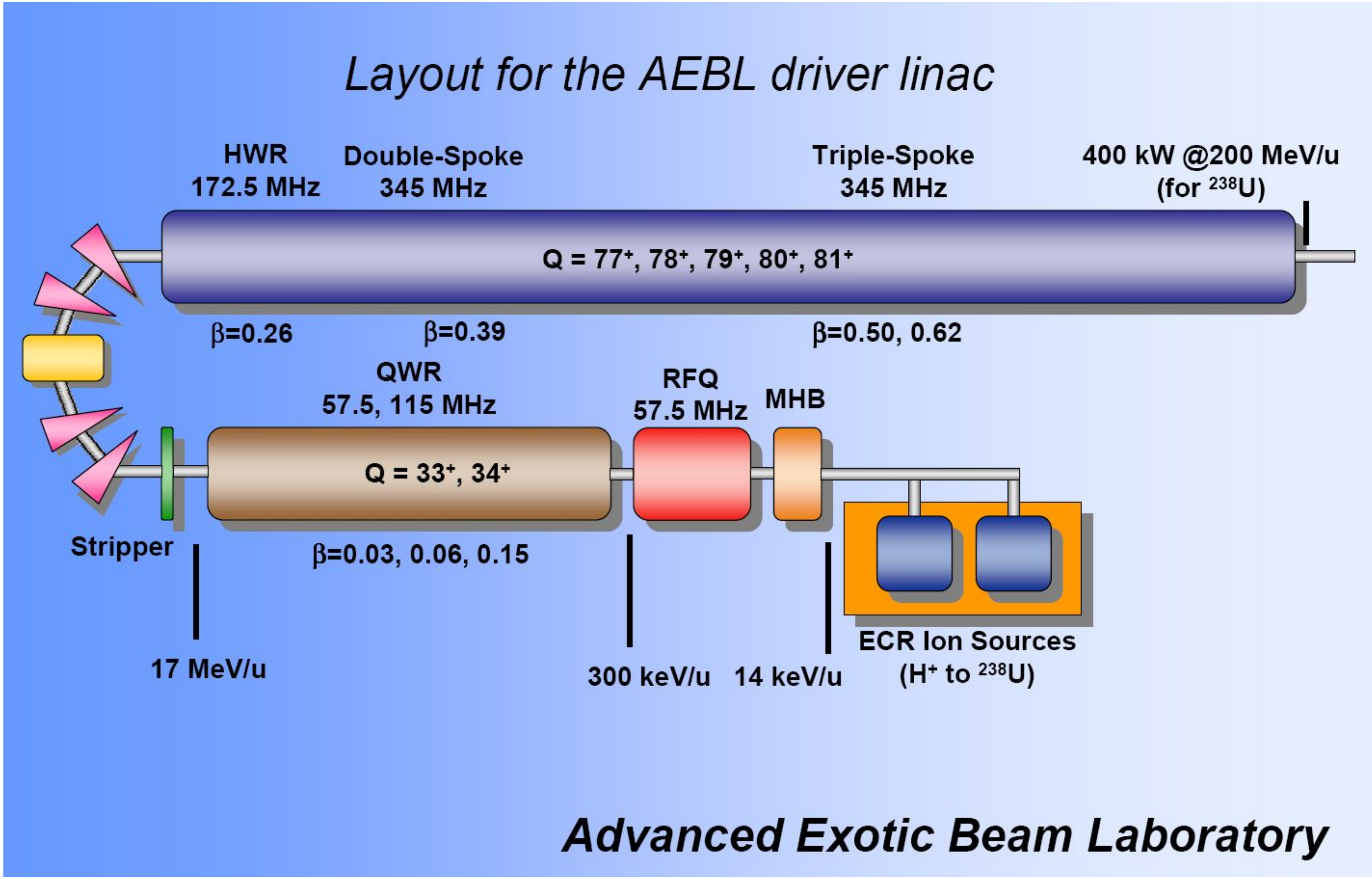
345 MHz β=0.63 ANL

References [6,7,8]

II. Applications
Proposed Spoke (HWR) Cavity Applications

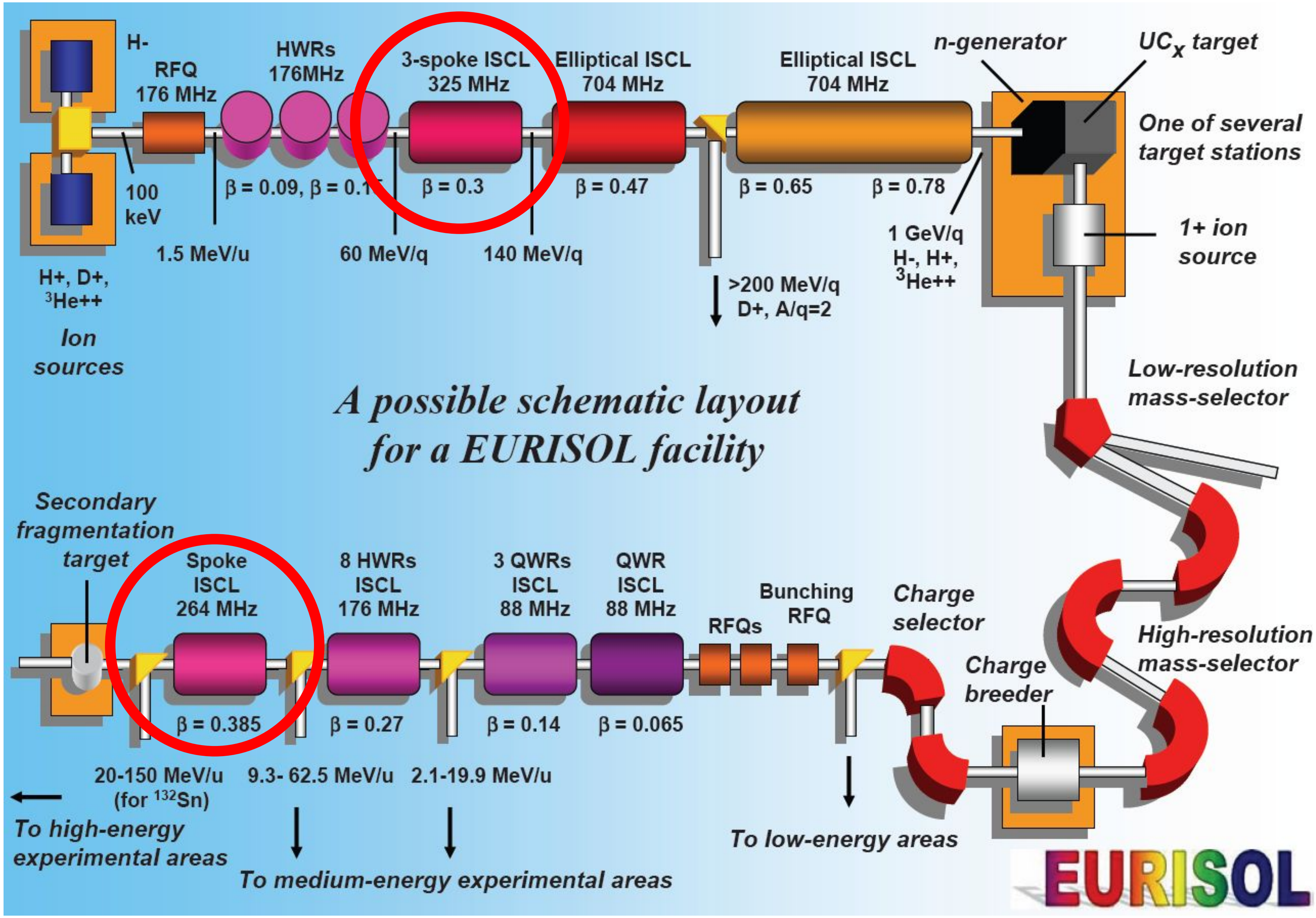
Applications	Frequency (MHz)	Beta (v/c)	Particle type	# of Spoke or HWR Cavities (total cavities)	Duty Factor
AEBL	345	0.4,0.5, 0.62	Proton to Heavy-Ion	134 (207)	CW
ISF	322 (HWR)	0.285, 0.425	Proton to Heavy-Ion	297 (481)	
EURISOL	352	0.3, 0.385	Proton Light-Ion	100-200	
XADS, APT	350	0.17,0.35	Proton	100 (190)	
Project X	325	0.2-0.6		90 (420)	Pulsed
SARAF	176 (HWR)	0.09, 0.15	Proton, Deuteron	42	CW

II. Applications: Spoke –cavity based AEBL



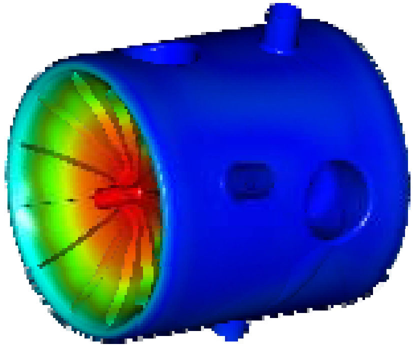
Reference [9]

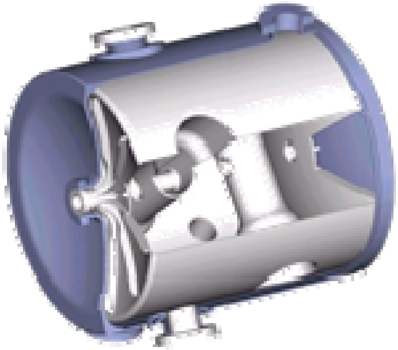
II. Applications: Eurisol



Reference [10]

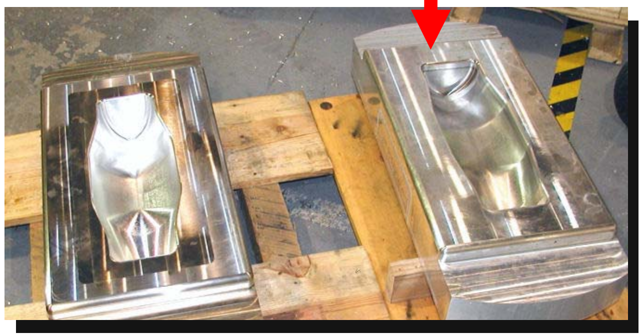
III. Development: Mechanical Design



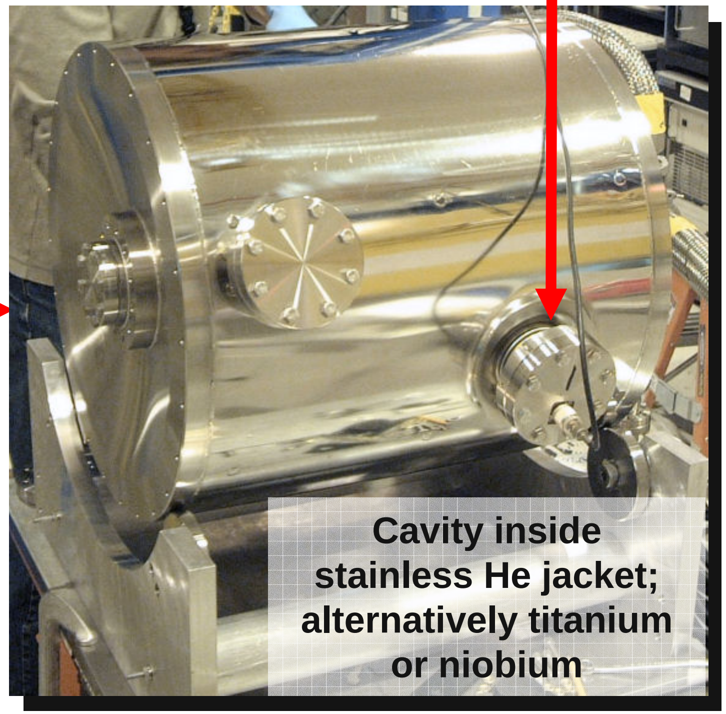


Designed in 3D, using MAFIA Microwave Studio ProE/ANSYS

Niobium-to-stainless braze



3 mm (also 2 and 4 mm) RRR>250 niobium sheet



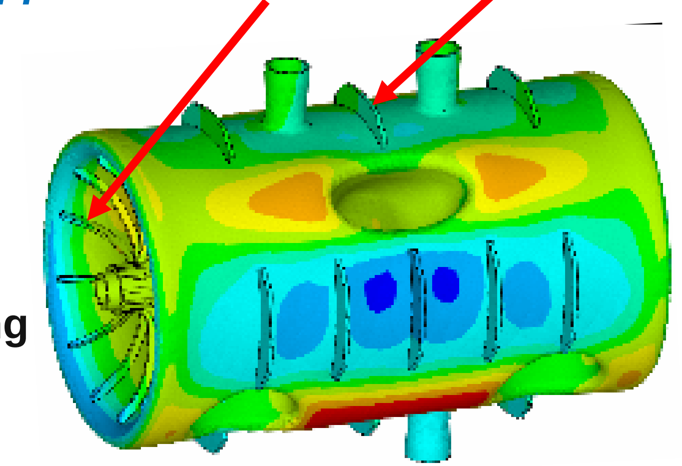
Cavity inside stainless He jacket; alternatively titanium or niobium

Die formed and EB-welded

III. Development: Mechanical Design

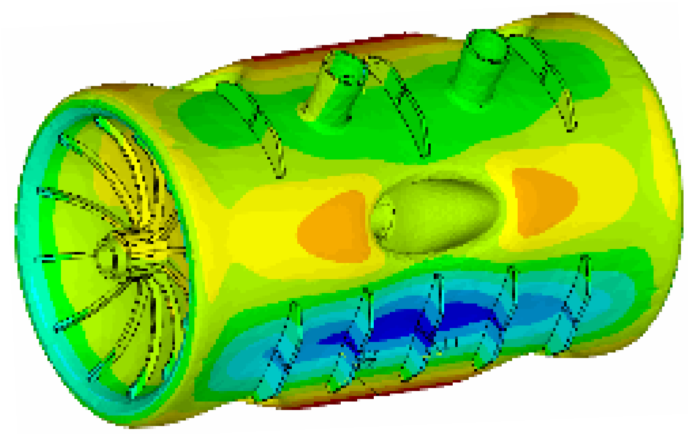
Support ribs in E field and H field to essentially eliminate pressure sensitivity

Before Machining Ribs



Δf/ΔP measured = -12.4 Hz/torr

After Machining Ribs

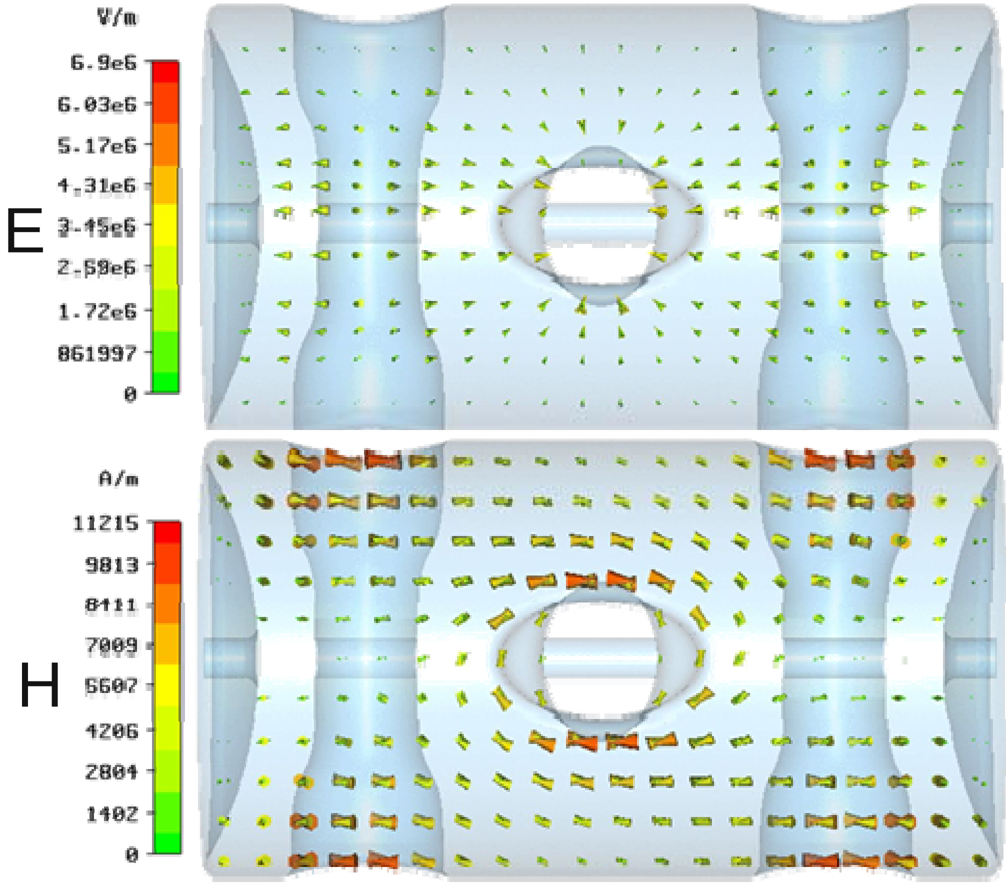


Δf/ΔP = -0.5 Hz/torr

β=0.5 triple-spoke w/ support ribs

III. Development: Electromagnetic Design

Lowest TEM-like mode



Example of Mode Spacing

3-spoke | 9-cell (TESLA)

Mode #	Freq. (MHz)	Δf/f % of f_{ACC}	Freq. (MHz)	Δf/f % of f_{ACC}
1	345		1275.6	1.7
2	365	5.7	1277.6	1.6
3	401	14	1280.7	1.4
4	442	28	1284.5	1.1
5	482	40	1288.5	0.8
6	519.7	51	1292.4	0.5
7	520.2	51	1295.5	0.2
8	534	55	1297.6	0.05
9	619	79	1298.3	
10	679	97		

- **TEM modes strongly coupled; Large mode splitting; No cell tuning needed**
- **Easy radial access; no trapped modes; good for HOM extraction?**

Reference [12]

III. Development: Electromagnetic Design

Intersecting cylinders

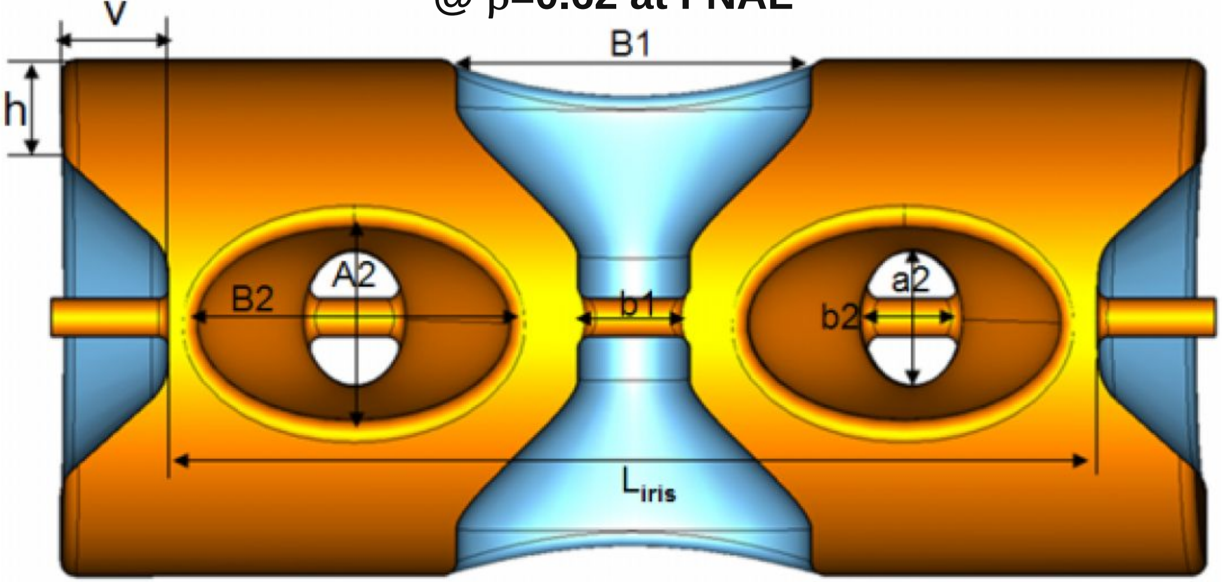
racetrack

expanded spoke base

A "Fully" optimized EM design @ β=0.62 at FNAL

Beta	0.41	0.54	0.62
E_{PEAK}/E_{ACC}	2.7	2.9	2.9
B_{PEAK}/E_{ACC} (mT/MV/m)	6.47	6.66	6.17

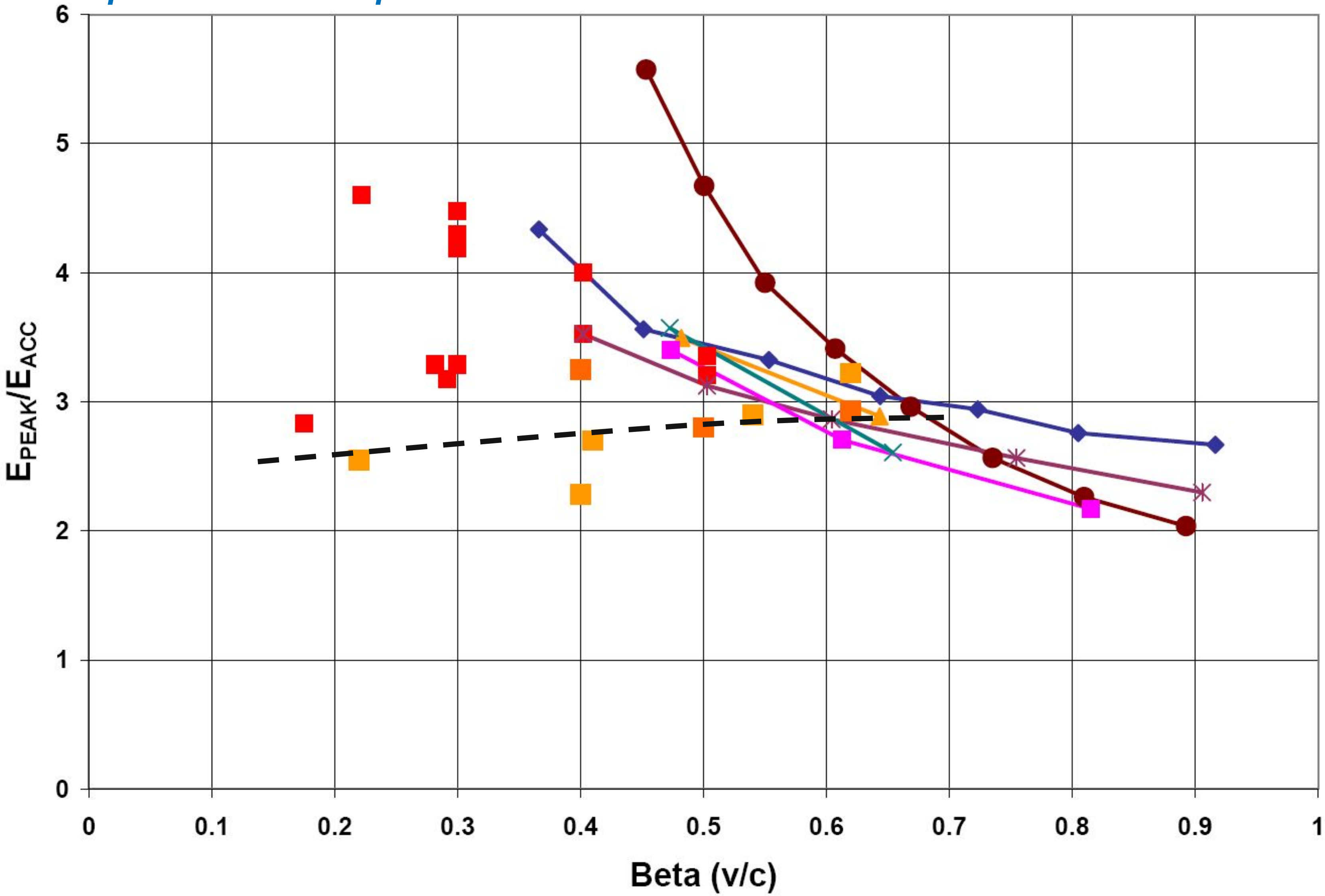
Preliminary ANL calcs.



Reference [13]

III. Development: Optimizing E_{PEAK}

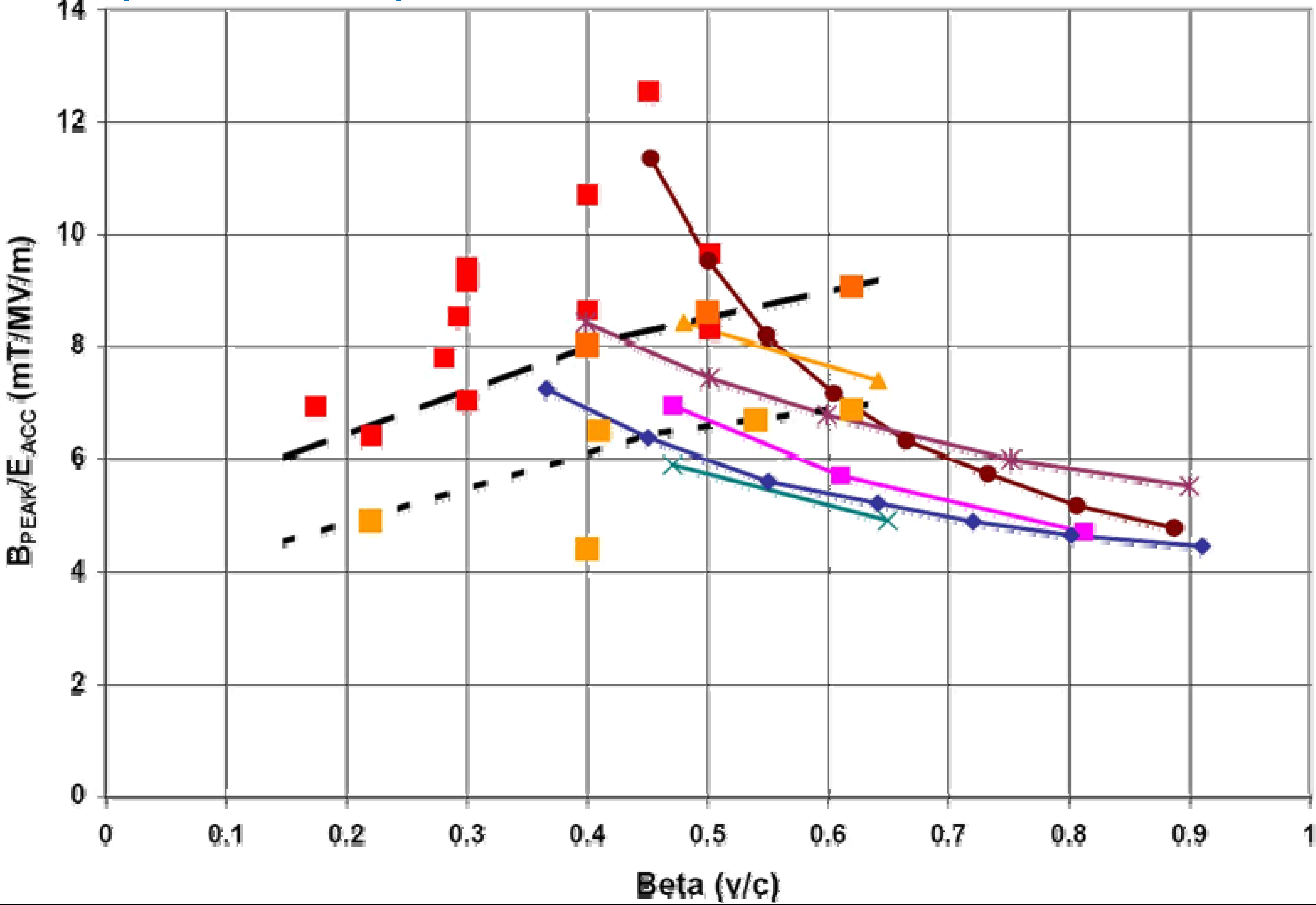
Spoke-cavities → points *E-cell cavities → solid lines*



Reference [14]

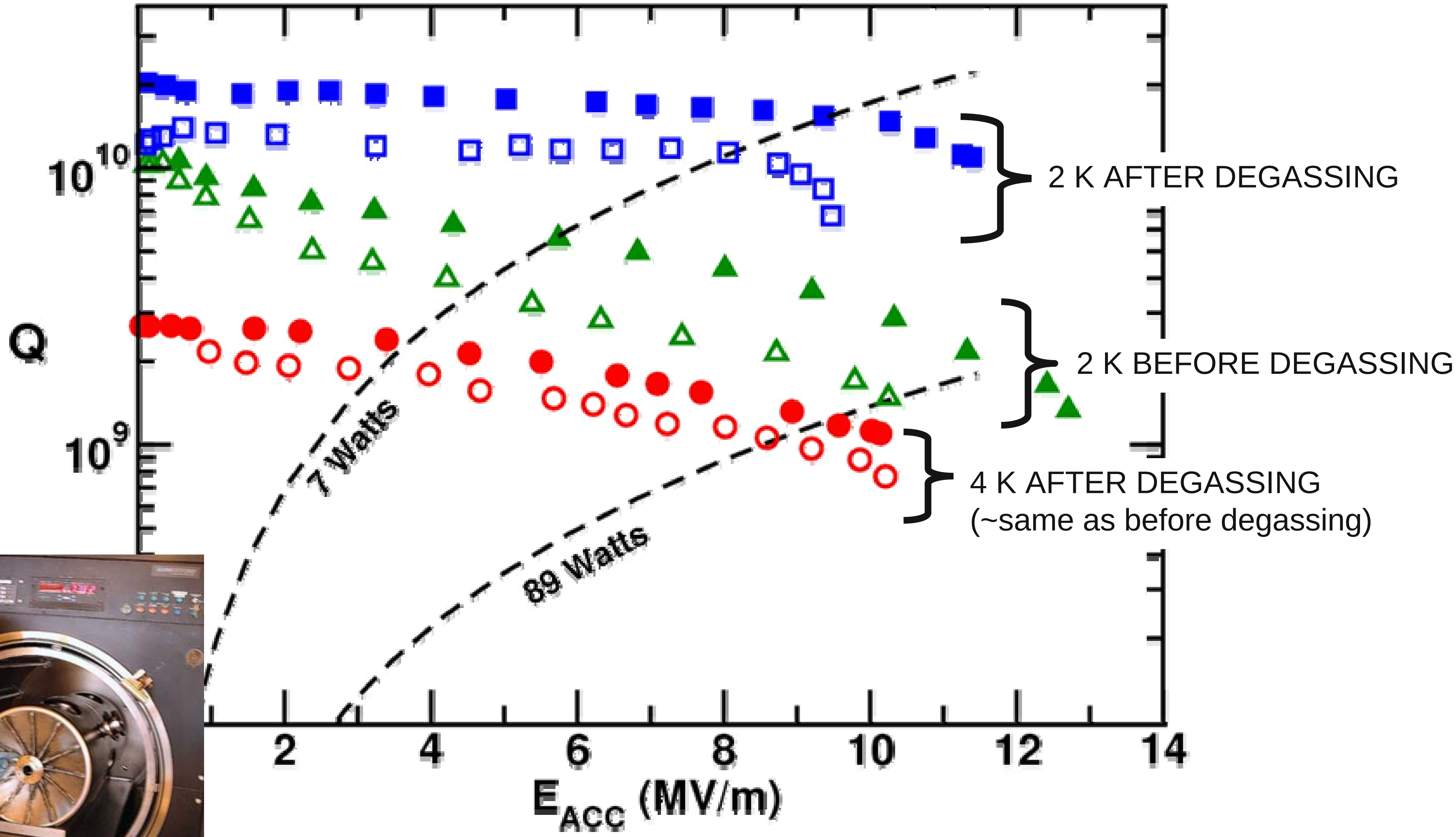
III. Development: Optimizing B_{PEAK}

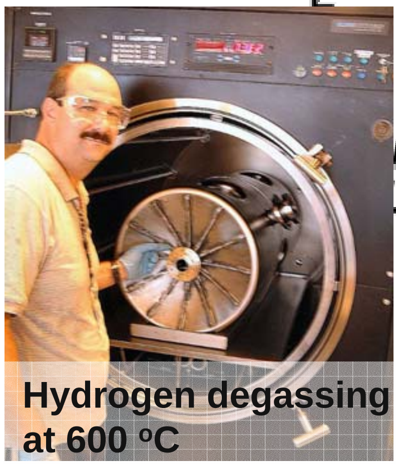
Spoke-cavities → points *E-cell cavities → solid lines*



Reference [14]

IV. Performance: A pair of triple-spoke cavities at 2 Kelvin

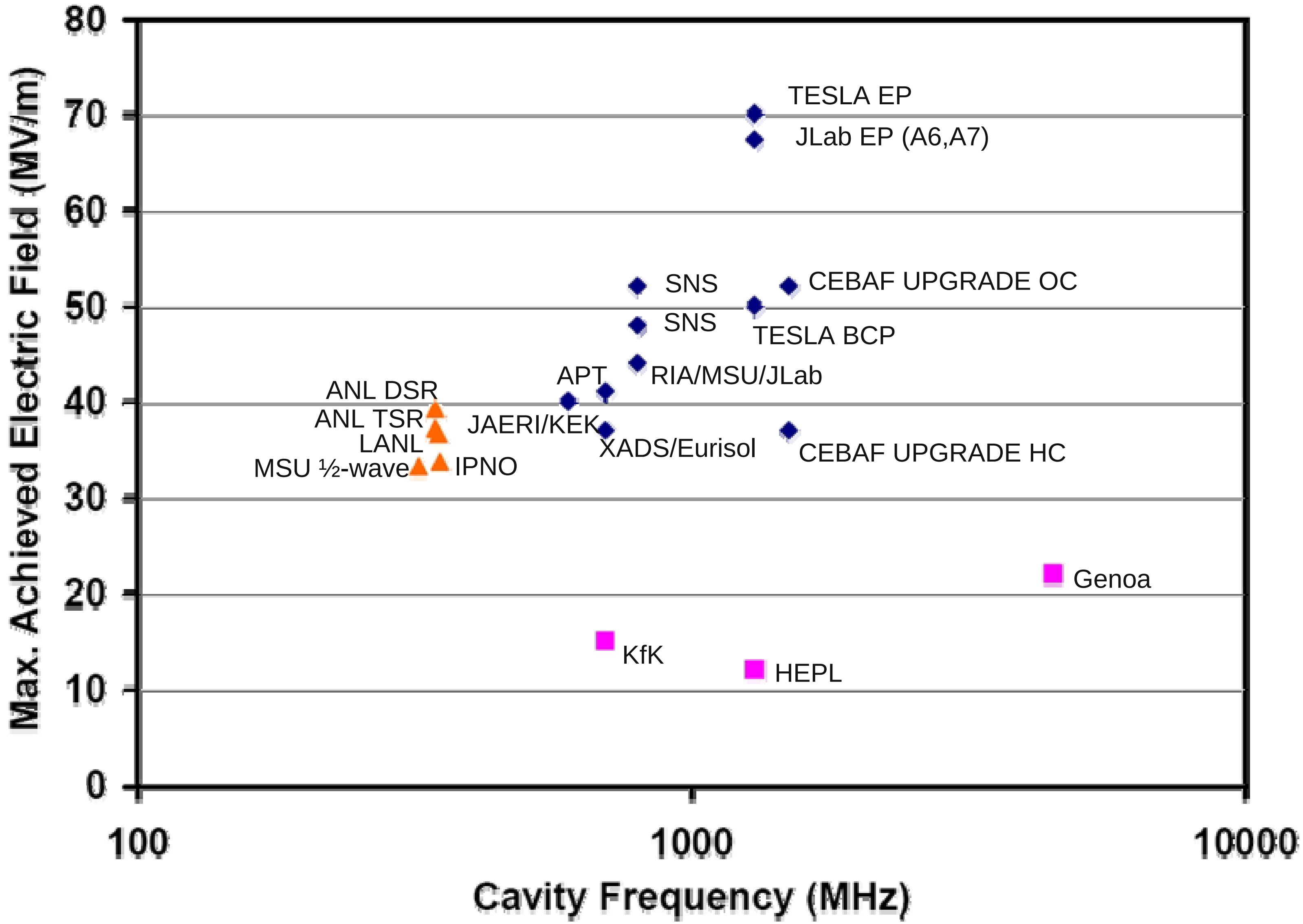




Hydrogen degassing at 600 °C

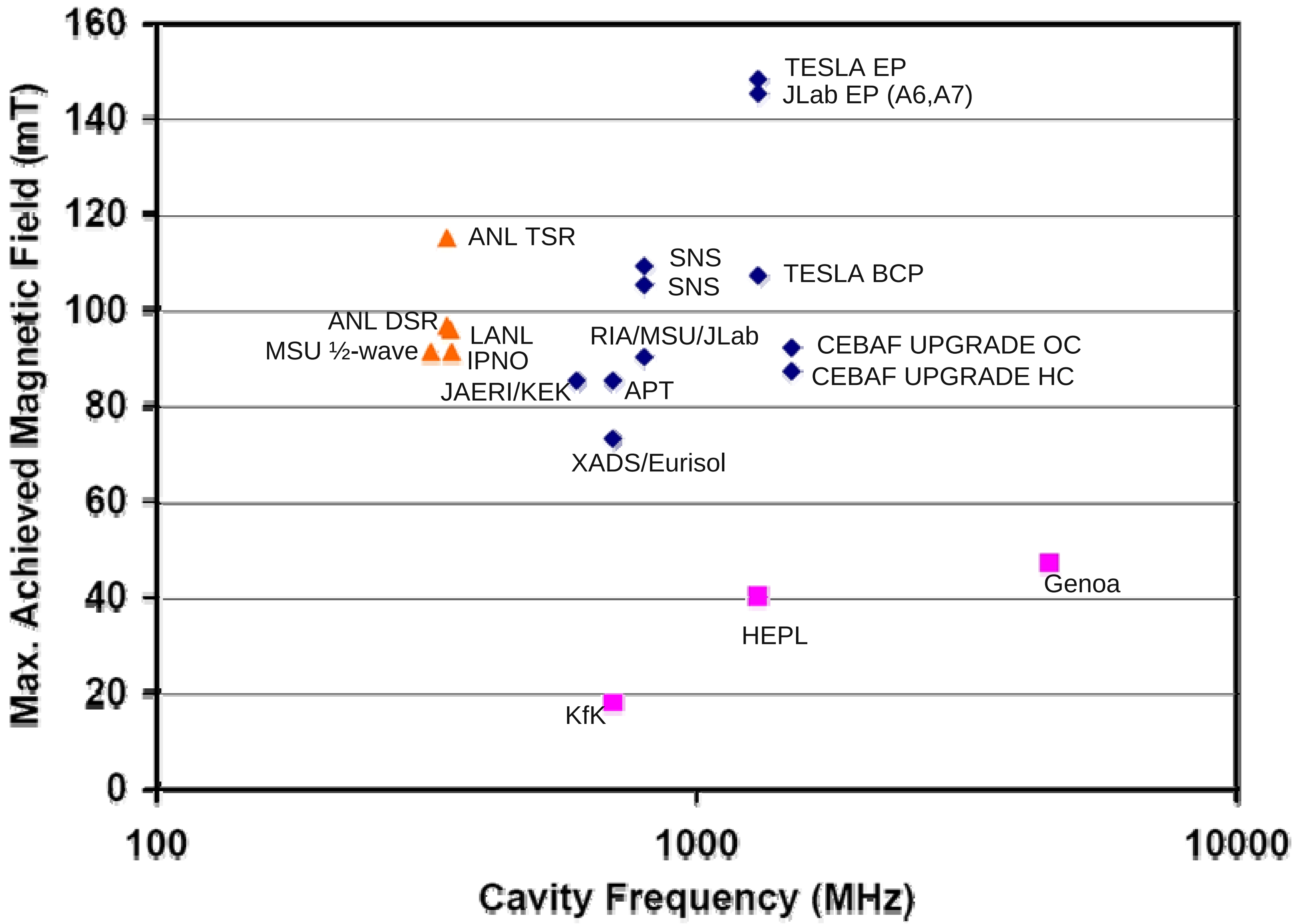
Filled Symbols – Beta=0.62 Triple-spoke Cavity
Open Symbols – Beta=0.50 Triple-spoke Cavity

IV. Performance: Best Values Surface Electric Field



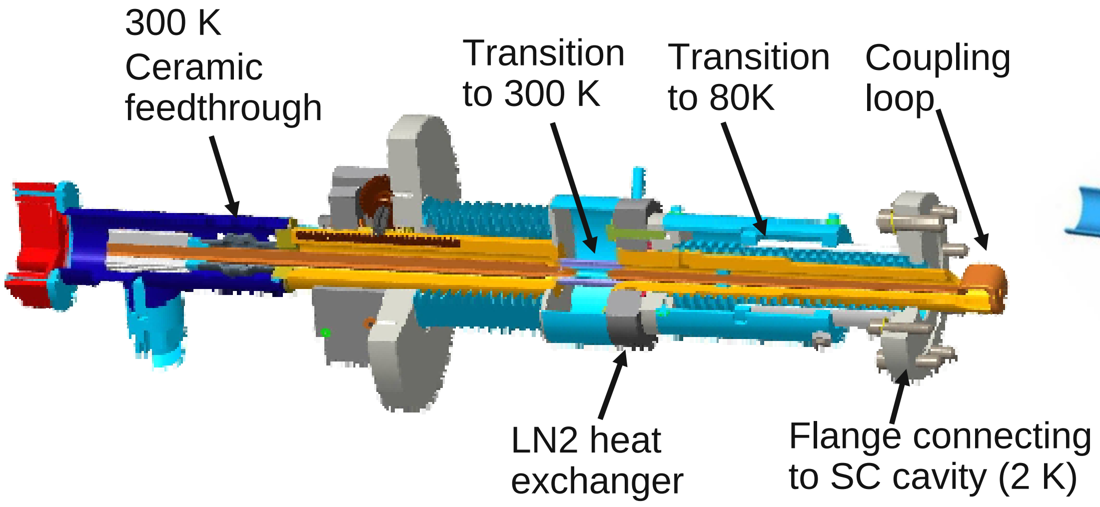
Reference [15]

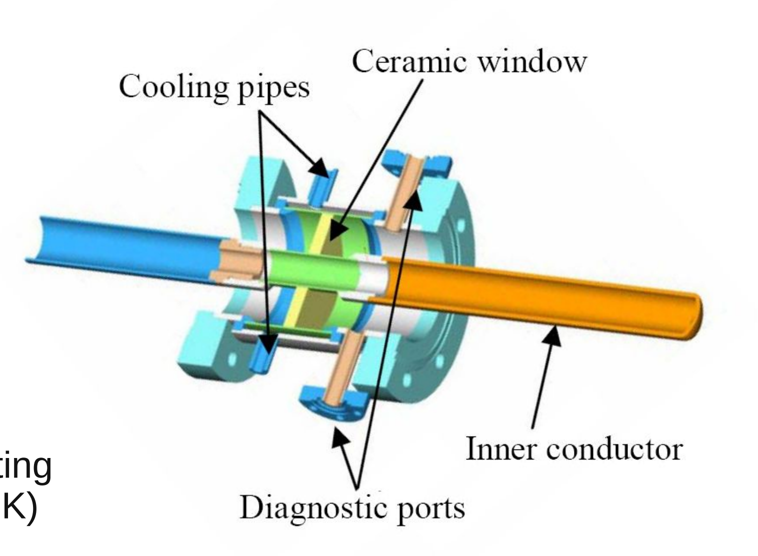
IV. Performance: Best Values Surface Magnetic Field

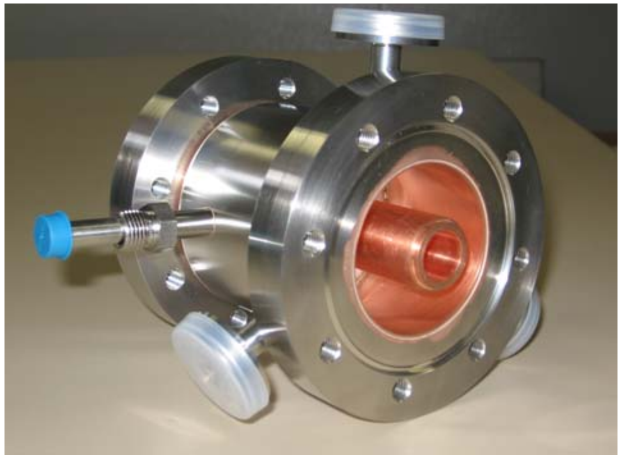


Reference [15]

V. Ancillary components: Couplers





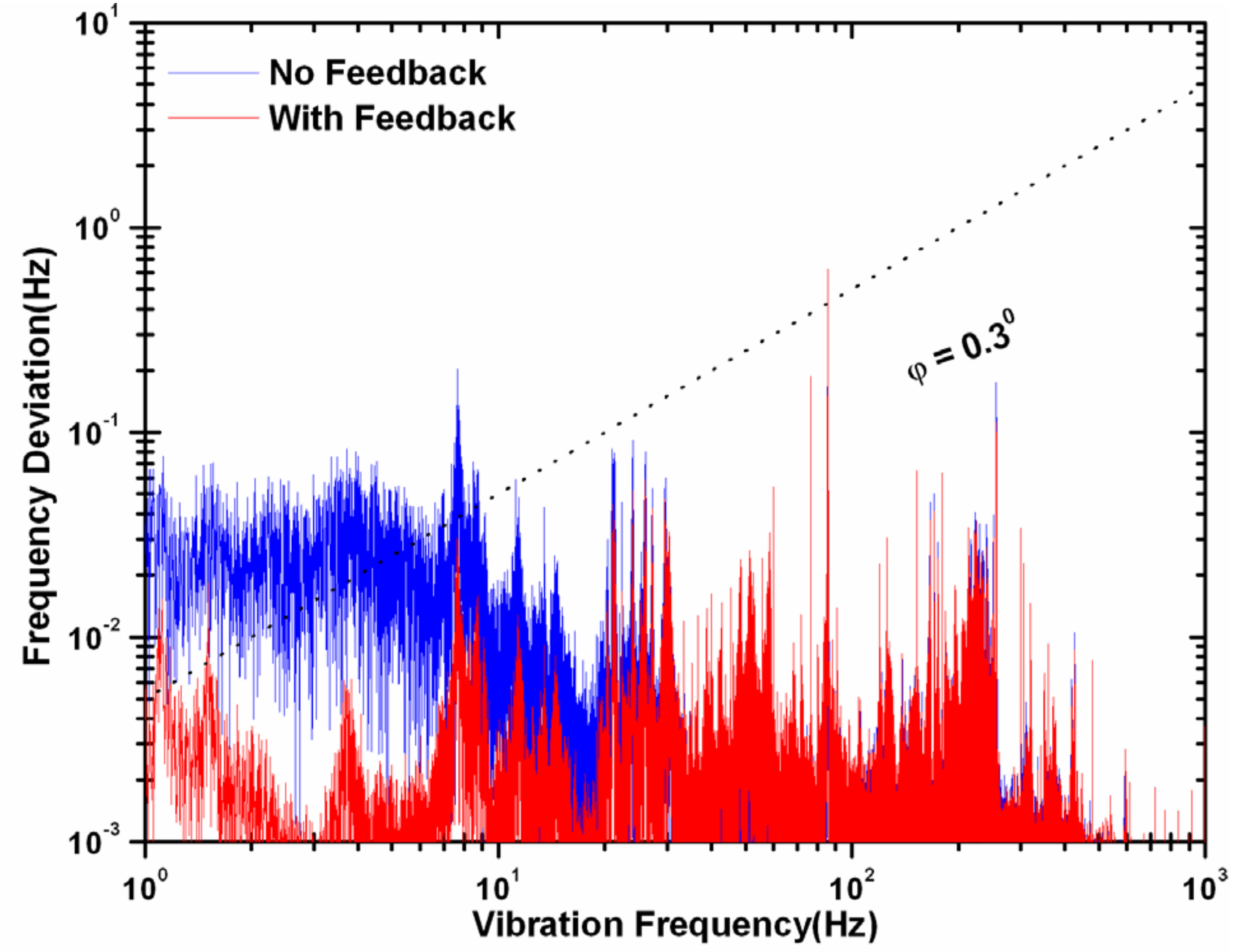


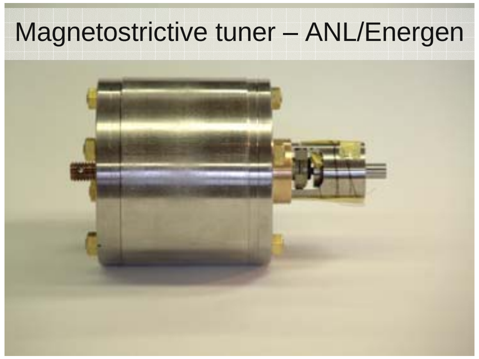
- cw inductive power coupler – ANL
- Fully variable over 50 dB

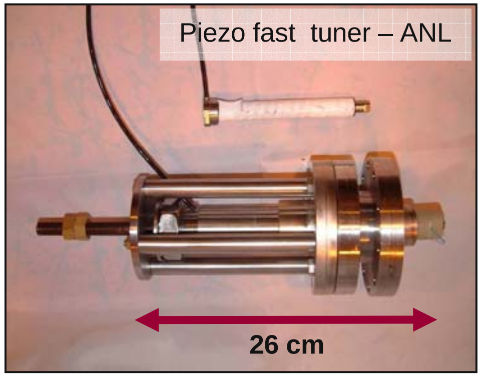
- cw capacitive power coupler (window) – IPN Orsay

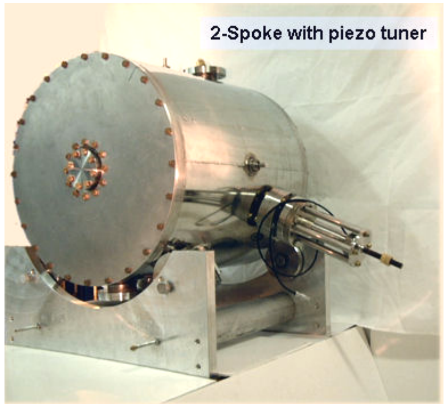
V. Ancillary components: Fast Tuners

Microphonics Damping with a piezoelectric tuner (4 Kelvin)









- Electro-mechancial properties of SC Spoke Cavities – Ph.D. Thesis, Zack Conway

Outlook for SC Spoke Cavities

- Superconducting cavities for the full velocity range required for proton and heavy-ion linacs have been developed

Superconducting Spoke Cavities…

- Span most of the full velocity region
- Have large acceptance, low rf losses, good mechanical properties and operate at high accelerating gradients
- May have interesting applications for electron linacs (very high beam currents, difficult HOM extraction)
- Represent the technology of choice for many intermediate velocity ion linac applications
- Spoke cavities are ready for primetime

References

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- [12] R. Wanzenberg, “Monopole, Dipole and Quadrupole Passbands of the TESLA 9-cell Cavity”, TESLA 2001-33, September 2001
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