From Cu to Nb:
towards the fabrication of the dressed cavity

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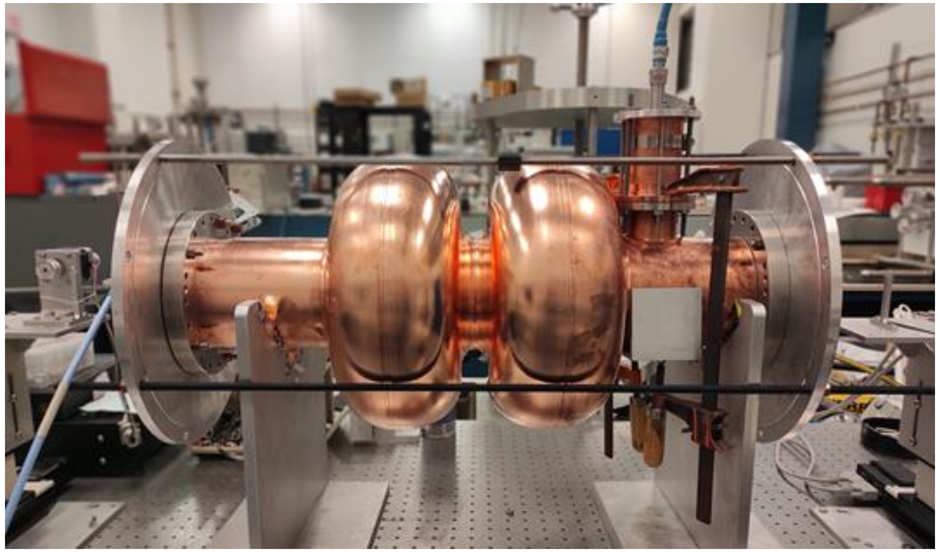
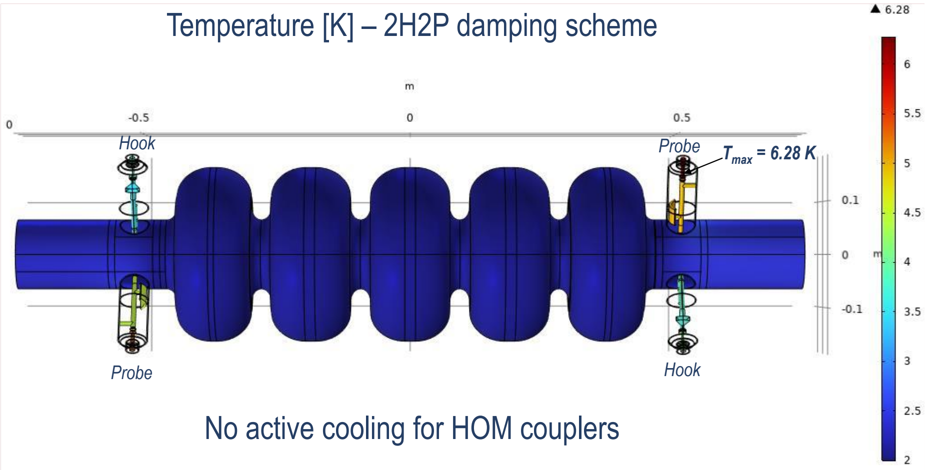
JLab

C. Barbagallo, IJCLab

Progress on copper cavity

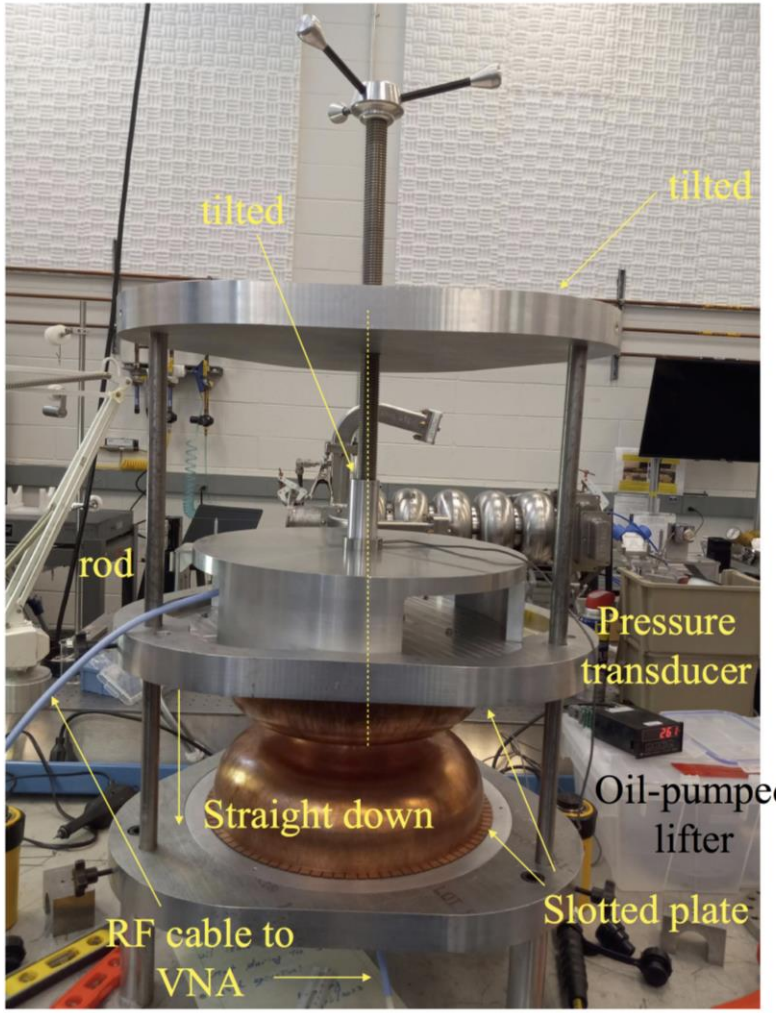


2-cell copper model



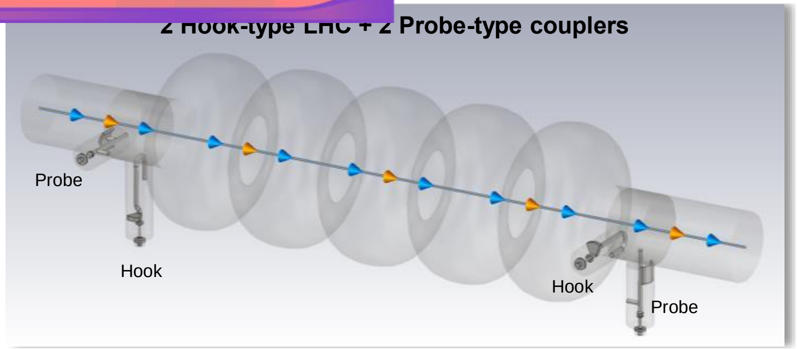
Thermal study

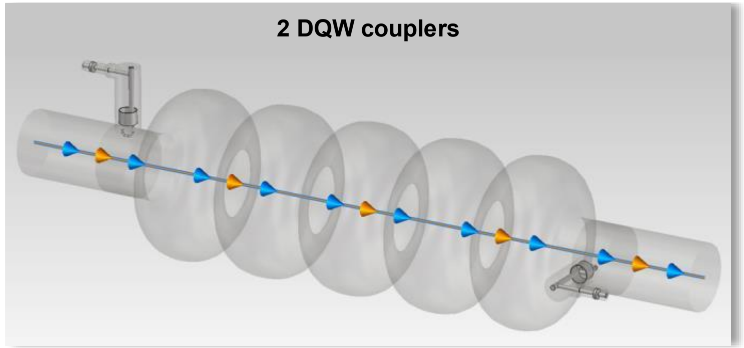
Do we need BLA's?

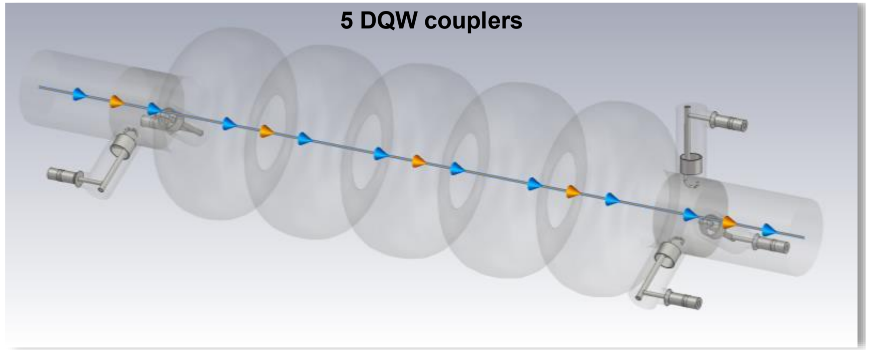


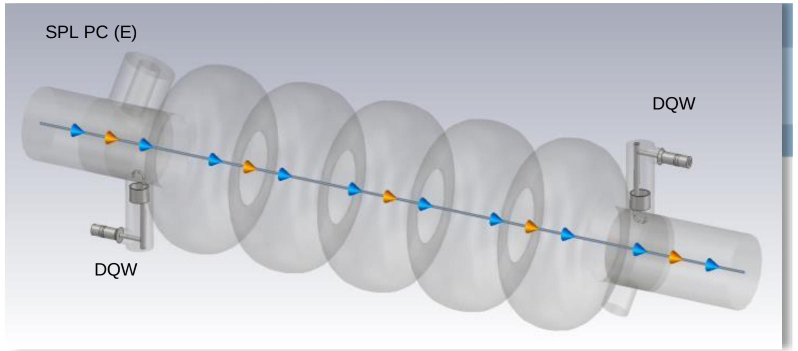
Dumbbell tuning for copper 5-cell

M study: Carmelo



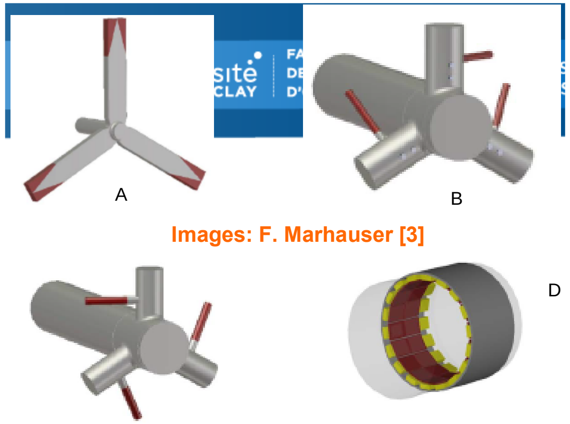






Other suitable HOM-damping schemes :

- •Rectangular waveguide dampers (A)
- •JLab-Type coaxial couplers (B)
- •TESLA-Type coaxial couplers (C)
- •Add absorbers in cavity-interconnecting beam tubes (D)
- •Coupling through Fundamental Power Coupler (E)

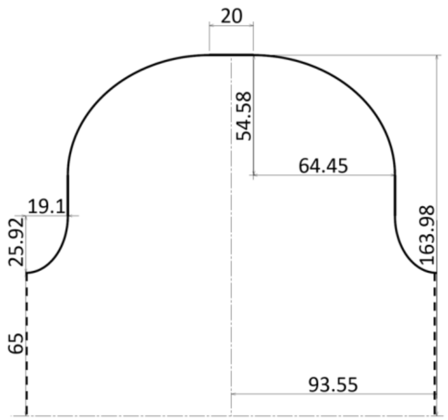


Images: F. Marhauser [3]

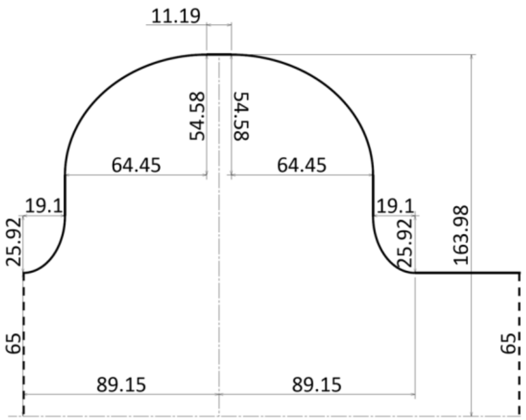
The 5-cell SRF cavity for PERLE

The first 801.58 MHz 5-cell elliptical Nb cavity has already been fabricated and successfully tested at JLab in October 2017 [1].

Cavity Parameters	Unit	Value
Frequency	[MHz]	801.58
Temperature	[K]	2.0
Cavity active length	[mm]	917.9
R/Q	[Ω]	523.9
Geometry Factor (G)	[Ω]	274.6
B_{pk}/E_{acc} (mid-cell)	$[\mathrm{mT/(MV/m)}]$	4.20
E_{pk}/E_{acc} (mid-cell)	[-]	2.26
Cell-to-cell coupling k_{cc}	[%]	3.21
Iris radius	[mm]	65
Beam Pipe radius	[mm]	65
Mid-cell equator diameter	[mm]	328
End-cell equator diameter	[mm]	328
Wall angle	[degree]	0
Cutoff TE_{11}	[GHz]	1.35
Cutoff TM_{01}	[GHz]	1.77



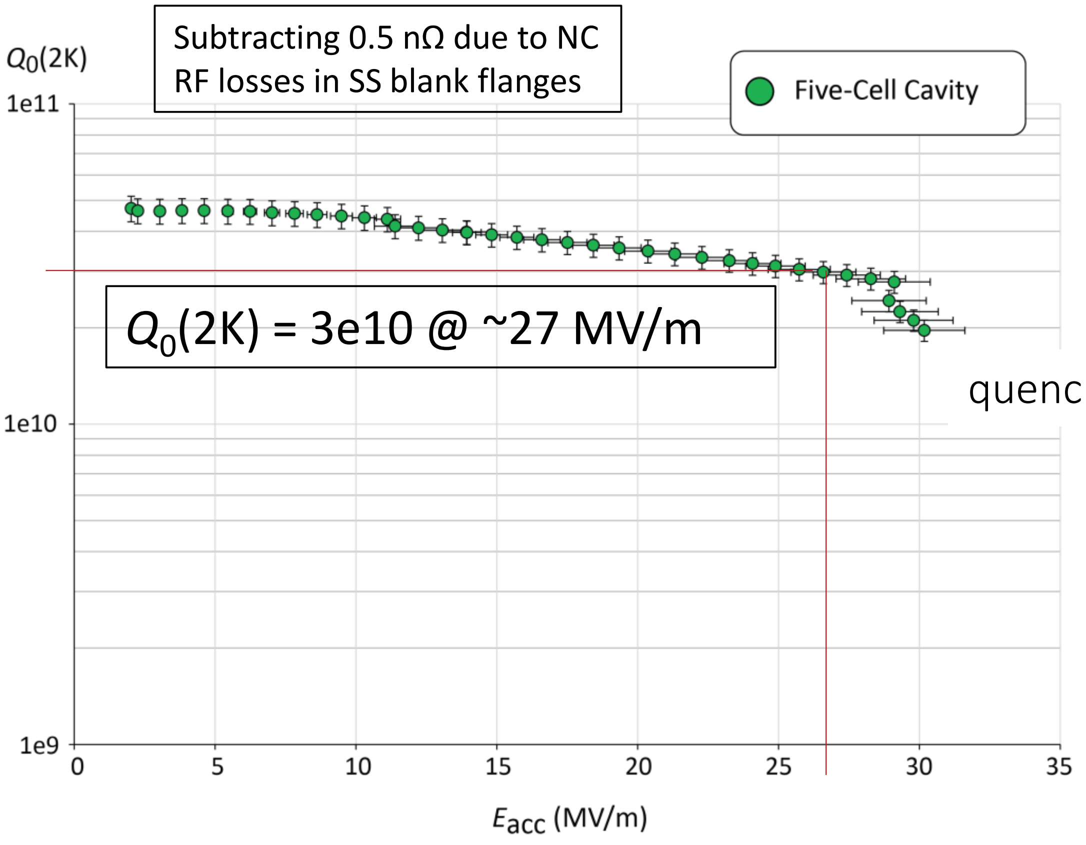
Mid-cell



End-cell

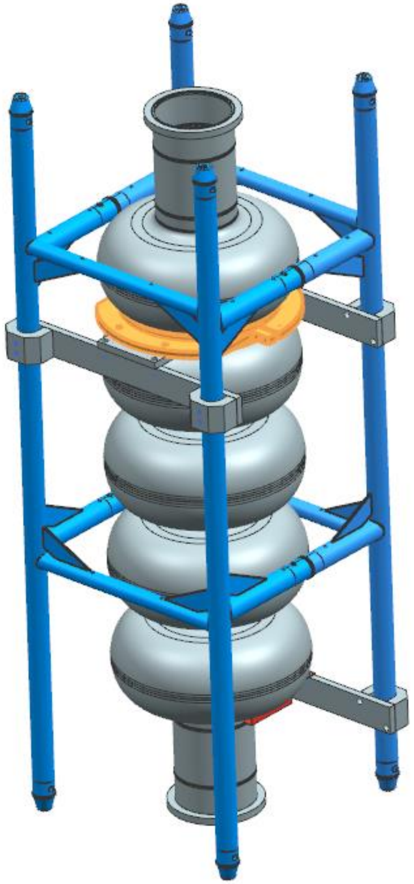
International Workshop on Energy Recovery Linacs (ERL 22), Cornell University, 3-6 October 2022

Final Vertical Test Result at 2K (Five-cell *CRN5*)



quench limit ~30 MV/m

Cavity is now at FNAL for more tests

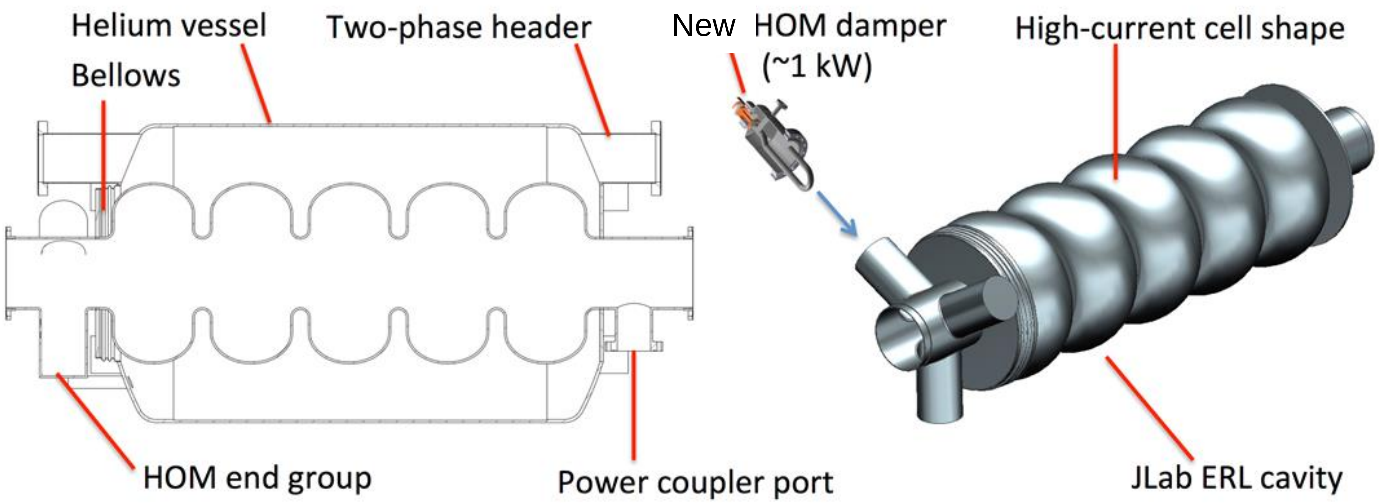


Main post-processing steps

	Unit	CRN5
Bulk BCP	µm	216
High-T heat treatment	°C, hrs.	800, 3
Final EP	µm	30
HPR cycles		4
Low-T bake-out	°C, hrs.	120, 12

ERL roadmap/path forward

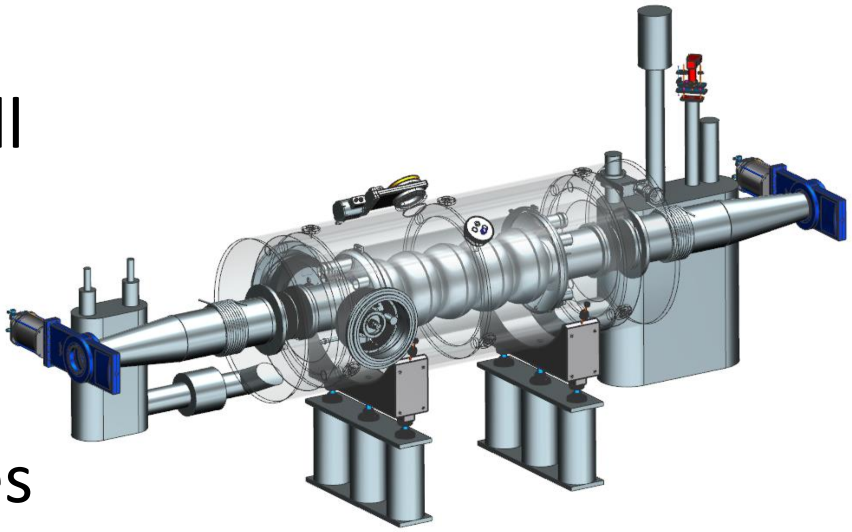
- Develop firm requirements for PERLE
  - BBU thresholds
  - Bunch parameters
  - Fill pattern
- Complete HOM study
  - Carmelo visits to Jlab
  - ~~Determine if new end cells needed~~
- Use Cu models to verify design
- Finalize FPC interface
- Modify Jlab prototype cavity
- Fabricate prototype HOM couplers
- Vertical test at Jlab or CERN
- Integrate into He tank and SPL module
- Build or procure 4 production cavities



Jefferson Lab

EIC Cooler 591 MHz 5-cell

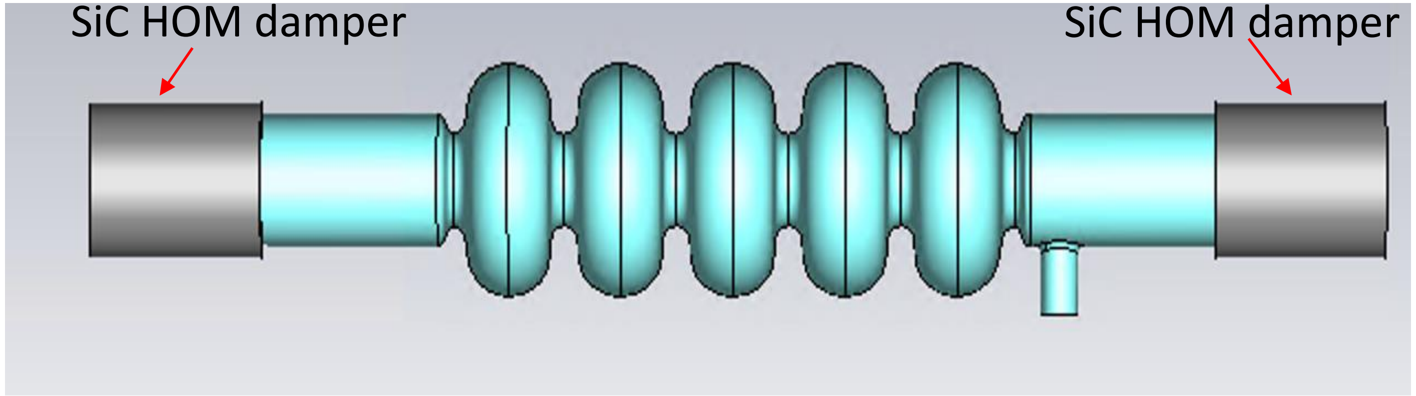
- In CDR common design assumed for HSR, RCA and cooler ERL
- Baseline scaled from ESR 1-cell
  - Warm BLA HOM dampers
  - Symmetric FPC's
  - Long tapers
- ERL has the most 5-cell cavities
  - Lower HOM power
  - Tight space constraints
  - Evaluating other HOM options



591 MHz 5-cellcavity

EIC SRF cavity: 5-cell 591 MHz SRF cavity

- RCS requirements for 5-cell 591 MHz SRF cavity.
  - Total voltage 60 MV for 3 cavities.
  - Ramping of electron bunch energy requires cavity resonant frequency fast tuning up to 4 kHz in ~ 100 ms.
  - Couple bunch instability requires longitudinal impedance < 1.6 M Ω (bunch merging at 1 GeV).
  - Transversal bunch instability requires impedance < 12 MΩ/m.
- Scaled from the high current 650 MHz SRF linac cavity design for eRHIC (previous BNL version of EIC).
- A Copper 650 MHz cavity was built for HOM study.
- A 650 MHz Nb cavity was prototyped, processed and tested vertically up to 18.2 MV, limited by radiation.
- The 650 MHz Nb cavity serves as a practicing cavity for EIC, and we are reprocessing the cavity and retesting the cavity soon.

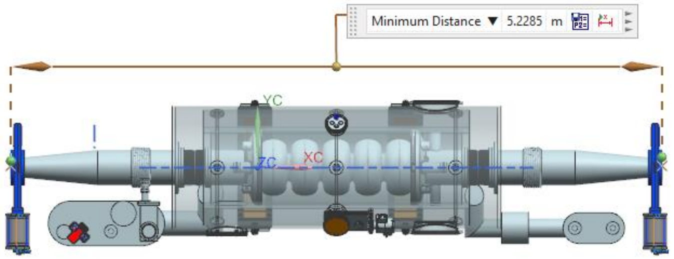


Frequency	591 MHz
R/Q	502 Ω
Geometry factor	273
Epk/Eacc	2.27
Bpk/Eacc	4.42 mT/(MV/m)
Coupling factor	2.8
Wall thickness	4.4 mm
Tuning range	+/- 174 kHz (+/-2mm)
Lorentz detuning factor	0077 Hz/(MV)^2
First modal frequency	> 107 Hz

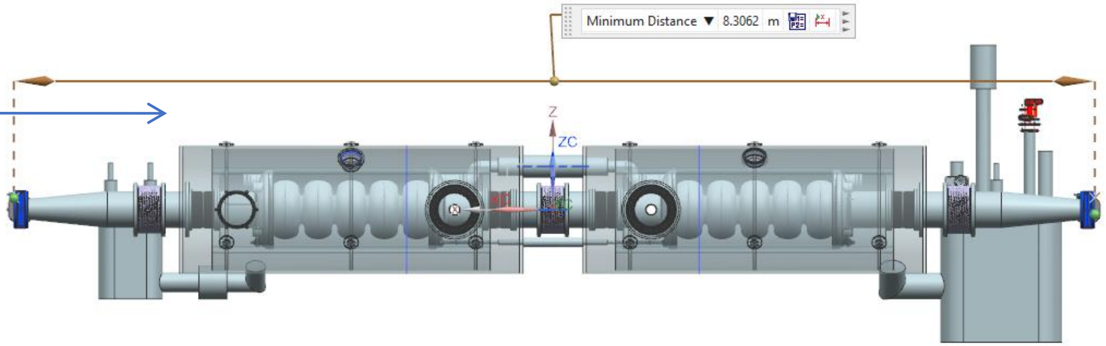
Compact 5-cell options

For 100 mA HSR cavity may be overkill

- Standard 5-cell



- Two per string



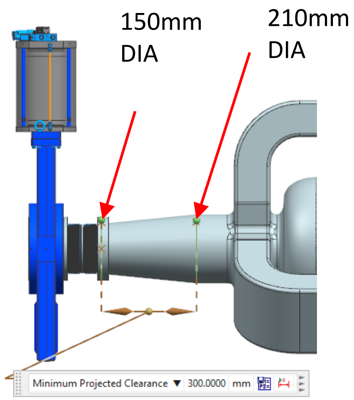
- Compact end groups
    - Waveguide

      JLab, HZB
    - Coaxial

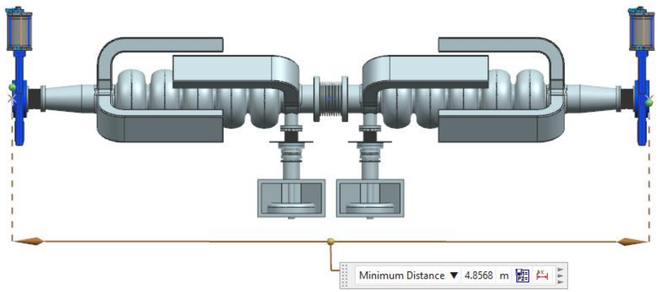
      HERA, LHC,

      TESLA, C100

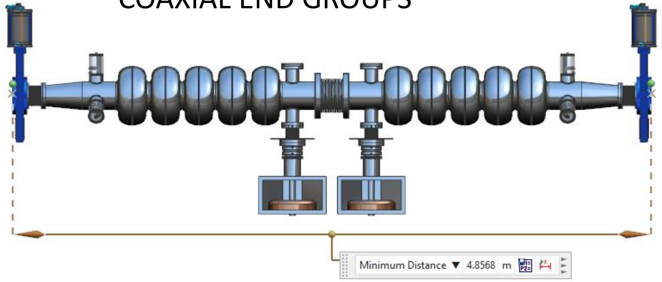
      PERLE



WAVEGUIDE END GROUPS



COAXIAL END GROUPS



- Need more analysis

Conclusions

- Good progress on copper model measurements
- Open questions:
  - Do we need beam line absorbers?
  - How much space is needed for helium tank attachment?
  - Do we need active cooling of antennas?
- Next steps:
  - Validate HOMS on 5-cell copper cavity
  - Prepare for implementing ports on Nb 5-cell
  - Plan for four production cavities
- Strong synergy with EIC cooler ERL

Back up

PERLE CM concept based on SNS cryostat

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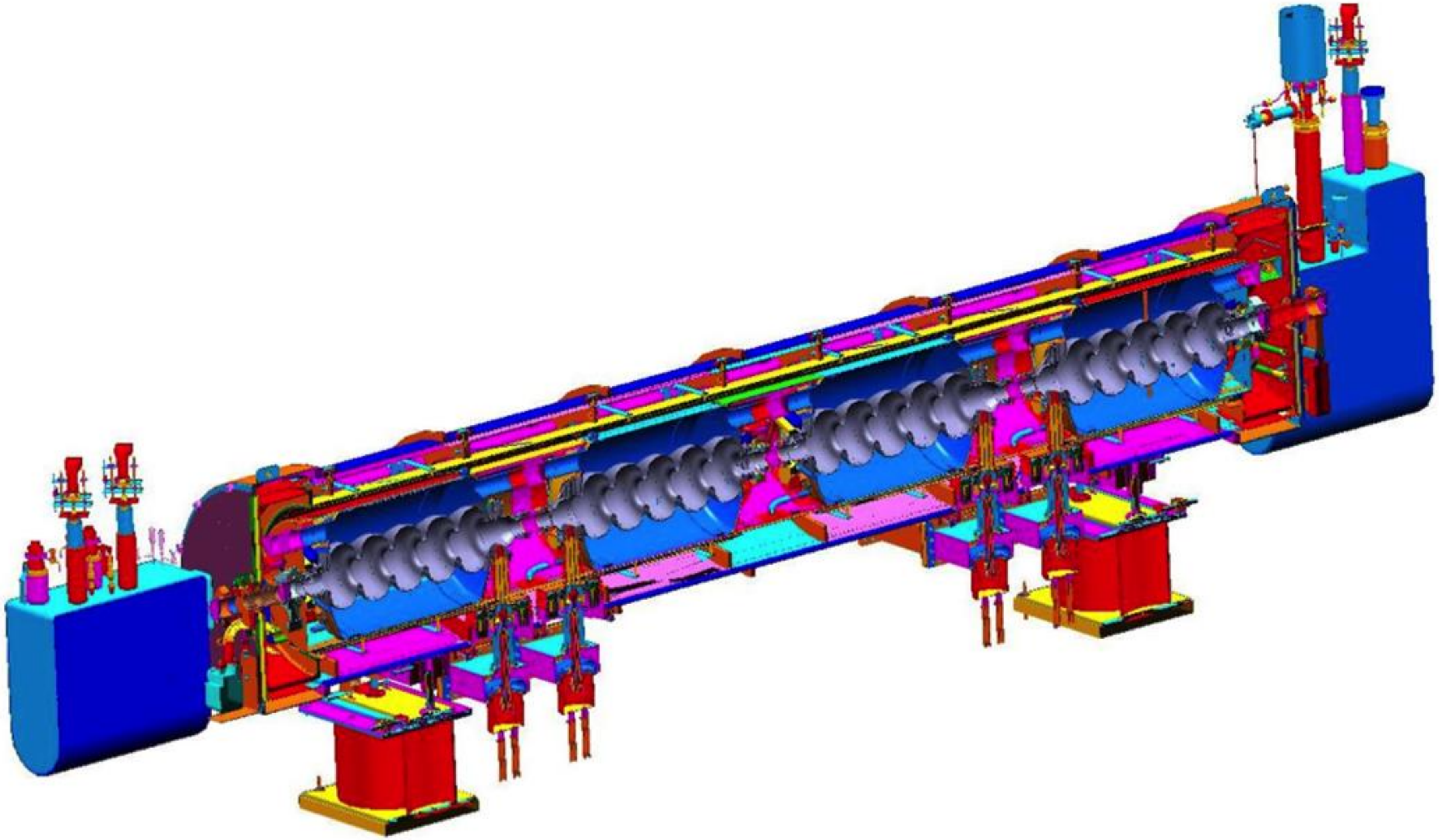
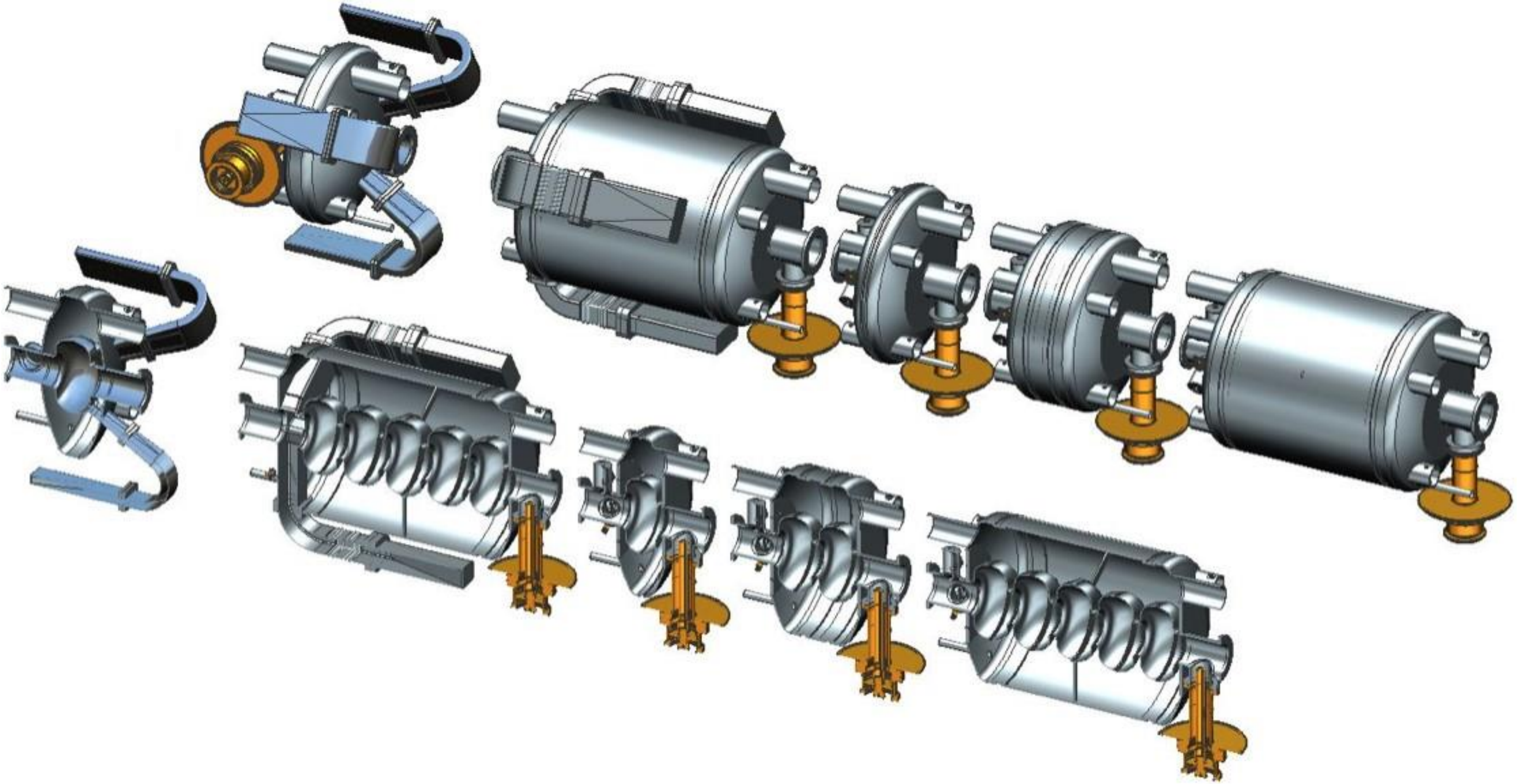
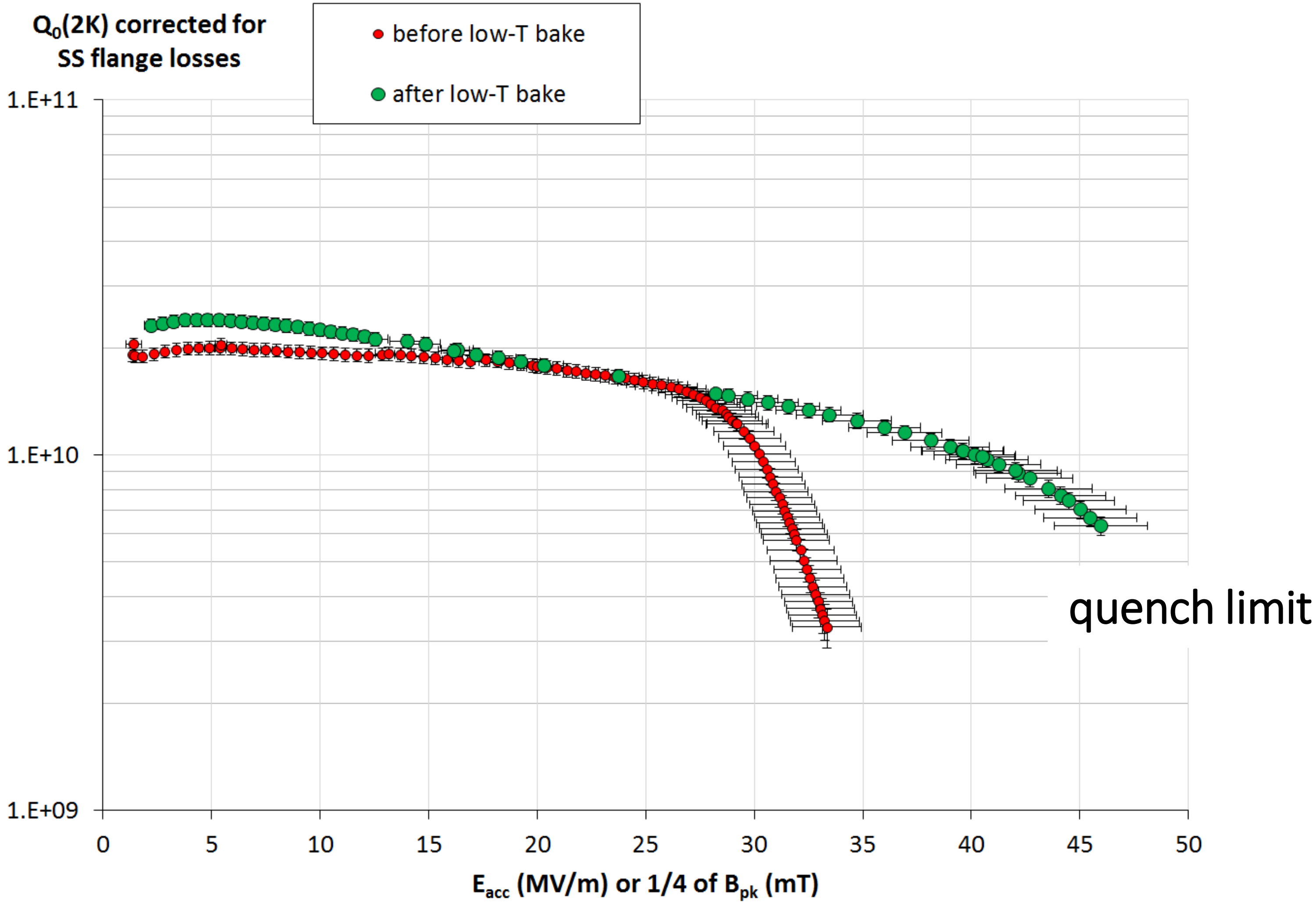


Jlab modular cryostat

Dimensions loosely based on SNS cryomodule

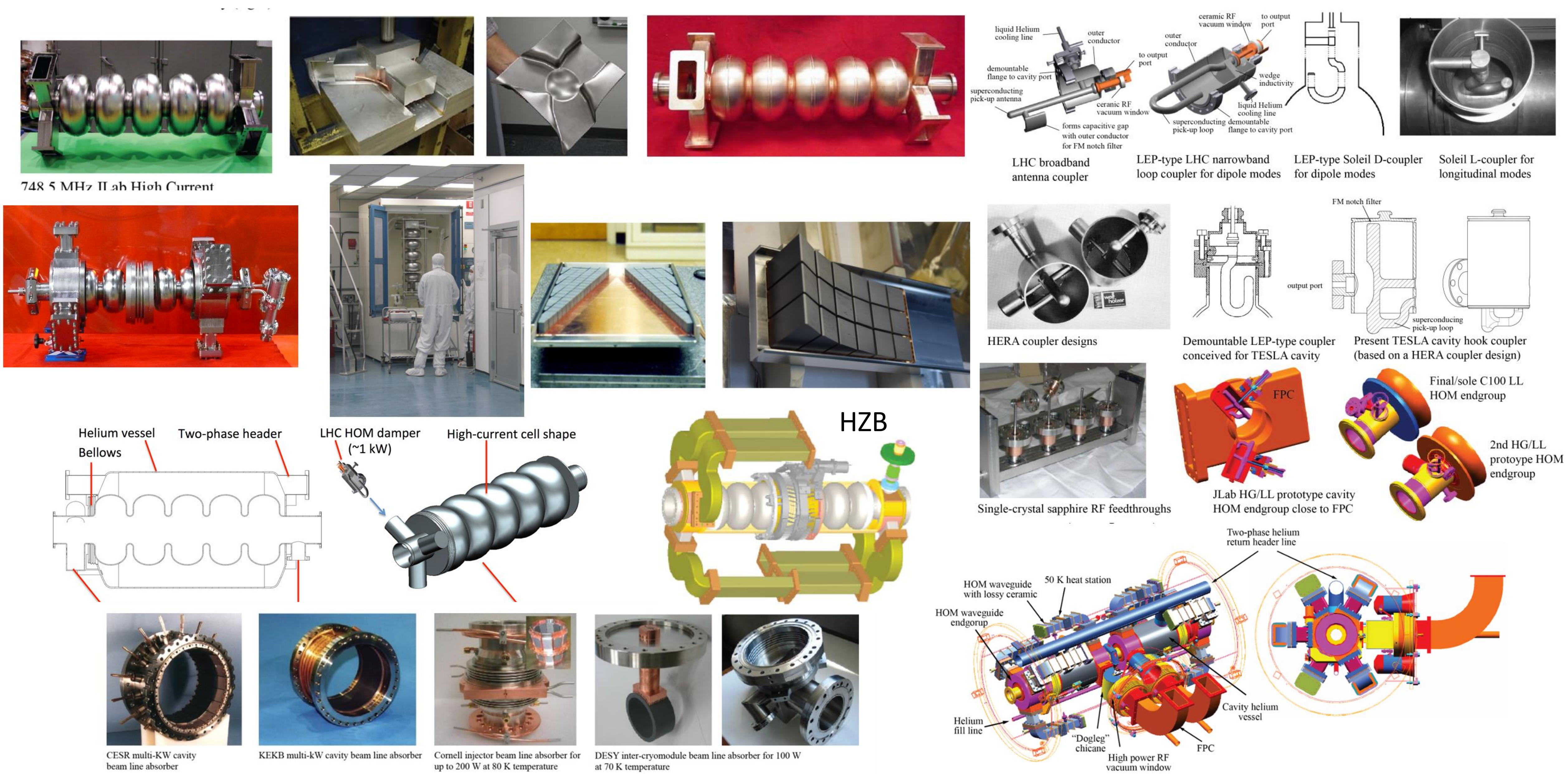


- RF test of **953 MHz** of 1-cell (*EIC1*) cavity



EIC1

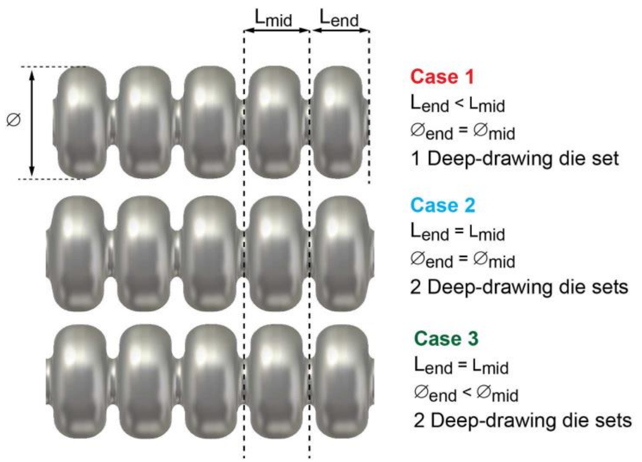
HOM damping options



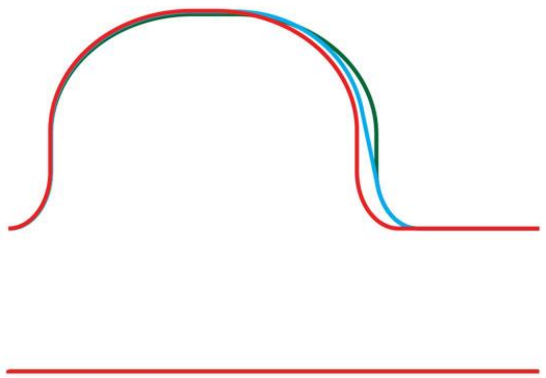
F. Marhauser

New Jlab variants

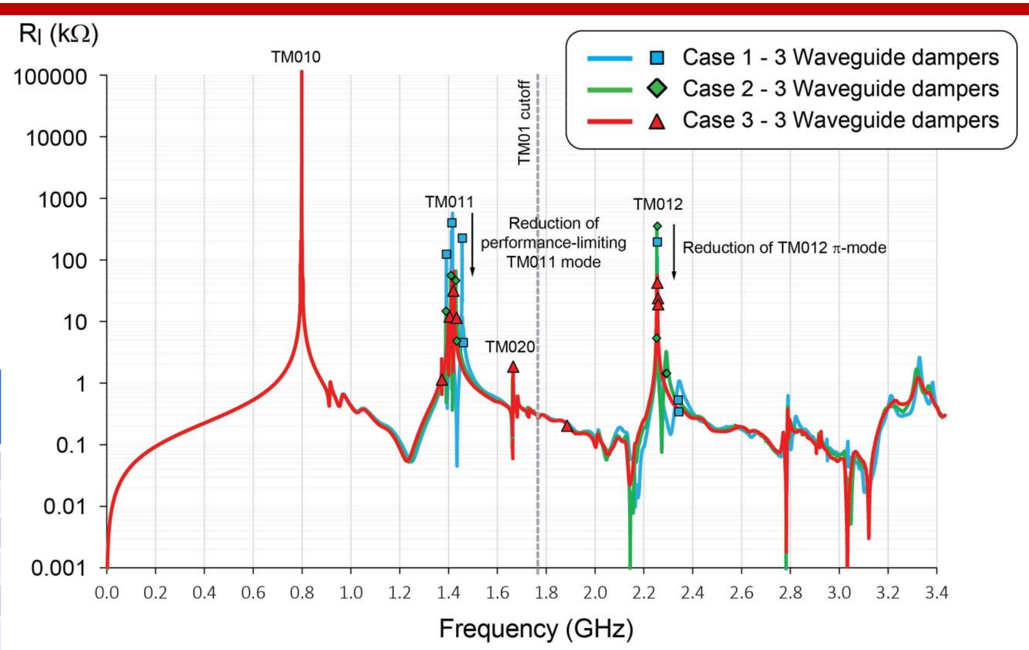
- Modified end cell profiles
- Reduction of TM011 and TM012 modes
- Some increases in dipole modes

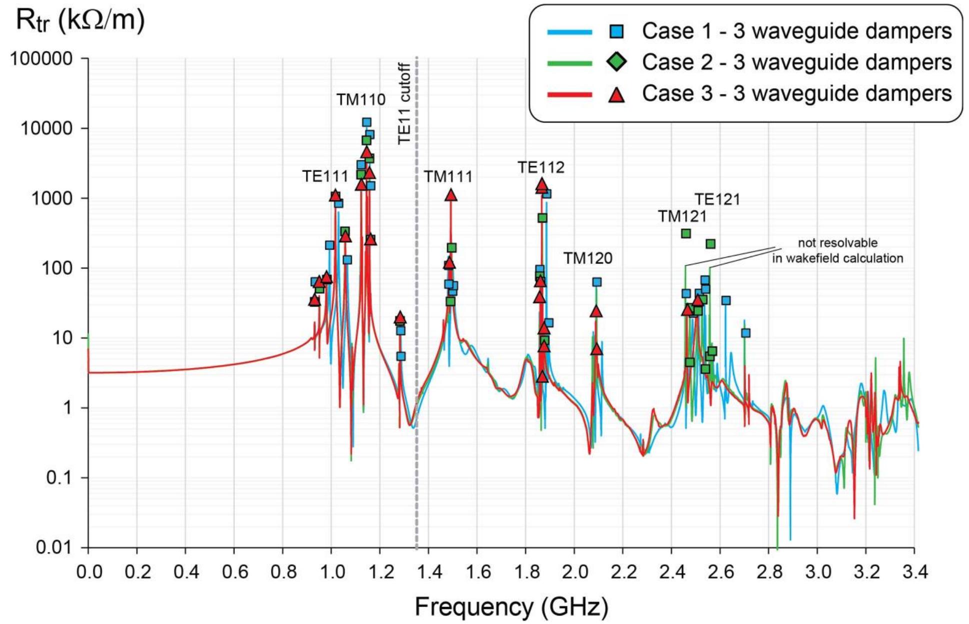


Endcell contours

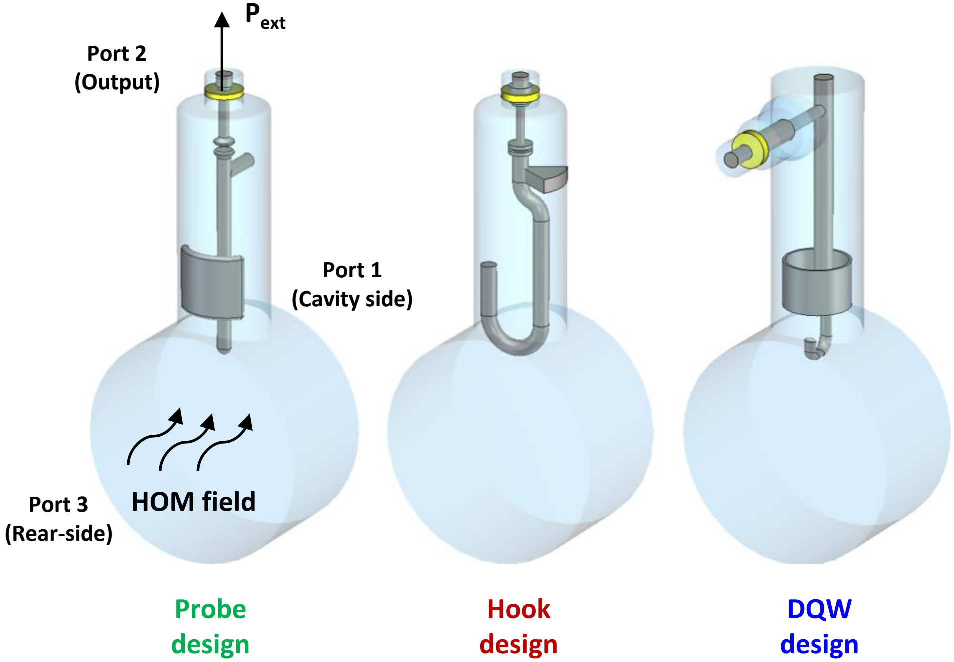


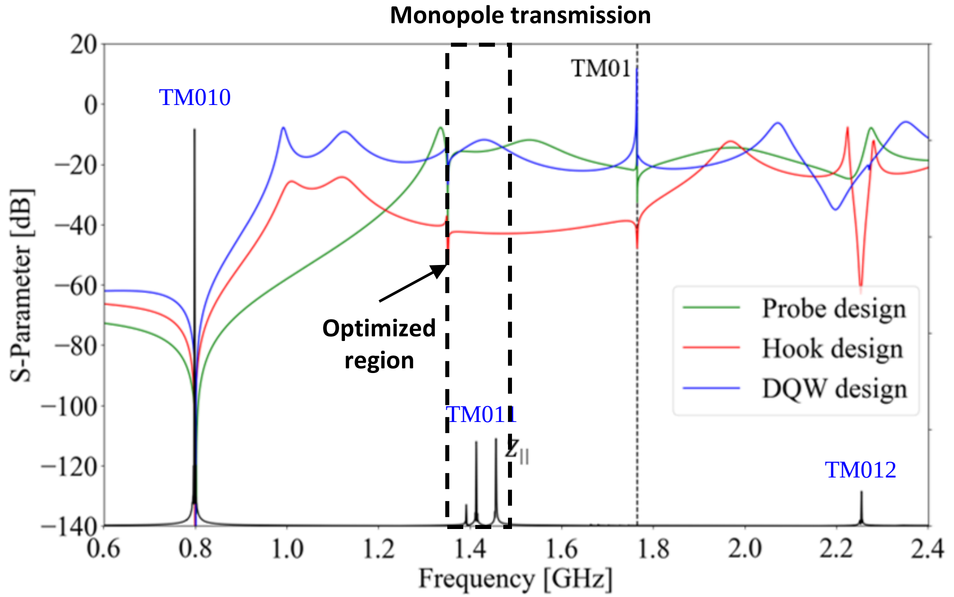
Parameters*	JLab Case 1	JLab Case 2	JLab Case 3
Frequency [MHz]	801.58	801.58	801.58
Number of Cells	5	5	5
Material	Bulk Nb.	Bulk Nb.	Bulk Nb.
Temperature [K]	2.0	2.0	2.0
Cavity active length [mm]	917.911	935.536	935.536
Mid-cell length [mm]	187.107	187.107	187.107
End-cell length [mm]	178.295	187.107	187.107
R/Q [Ω]	524.25	520.63	522.70
(R/Q)/(cell number) [Ω]	104.85	104.13	104.54
Geometry Factor (G) [Ω]	274.505	201.490	278.112
G*(R/Q) [Ω²]	143909.2	149901.7	145369.1
(R/Q)*G/(cell number) [Ω²]	28781.85	29980.35	29073.83
B_{pk}/E_{acc} (mid-cell) [mT/(MV/m)]	4.62	4.70	4.66
E_{pk}/E_{acc} (mid-cell) [-]	2.38	2.30	2.27
Iris radius [mm]	65	65	65
Beam Pipe radius [mm]	65	65	65
Mid-cell equator diameter [mm]	328	328	328
End-cell equator diameter [mm]	328	328	325
Wall angle [degree]	0	11.95	0
Cell-to-cell coupling of mid cells [%]	2.93	2.92	2.91
$k_{\|\|}(\sigma_z = 3\ \mathrm{mm})$ [V/pC]	2.74	2.4	2.74
Cutoff TE11 [GHz]	1.35	1.35	1.35
Cutoff TM01 [GHz]	1.77	1.77	1.77

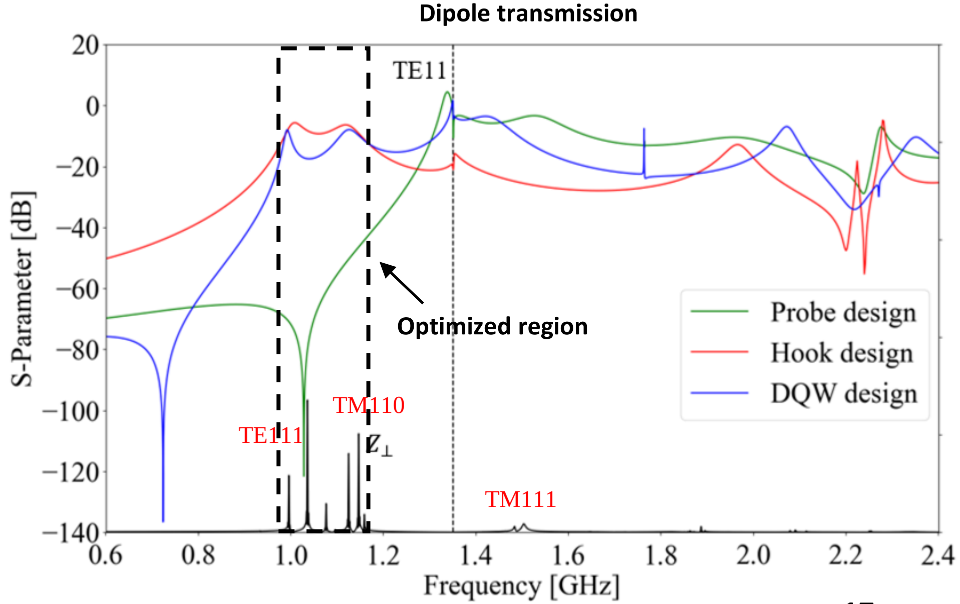




HOM coupler optimization





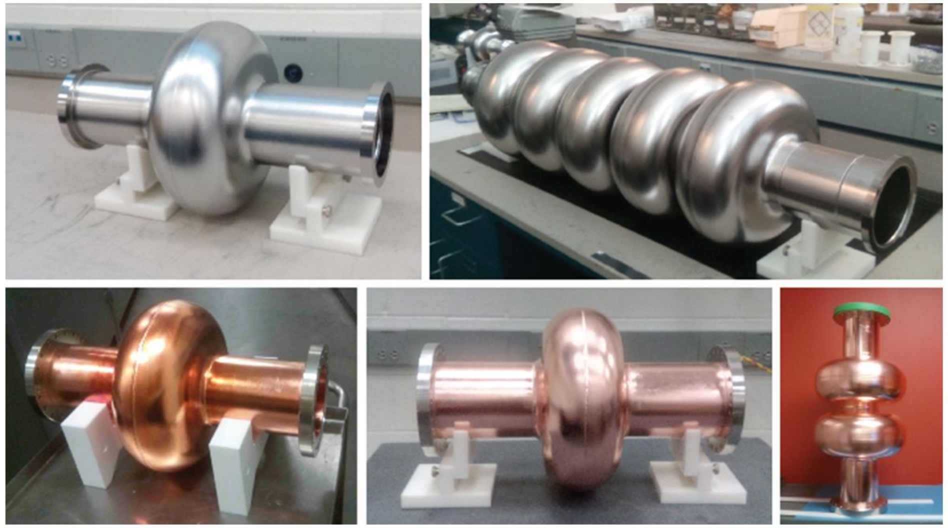


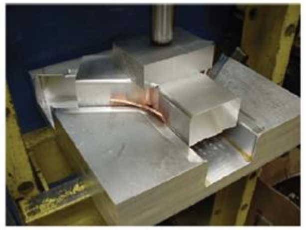
- HOM couplers are geometrically optimized according to the HOM spectrum ($Z_{||}$ and $Z_{\perp}$)
- The S-parameters between the beam pipe port 1 and port 2 at the coaxial output of the coupler are studied.

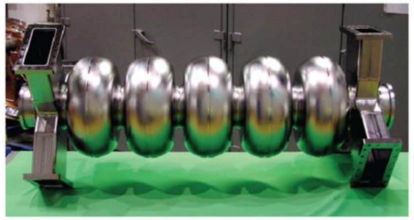
- The DQW coupler exhibits a better monopole coupling for TM010 mode than the probe design.
- The hook coupler provides higher damping of the first two dipole passbands (TE111 and TM110)

Jlab 802.5 MHz prototype (F. Marhauser et. al.)

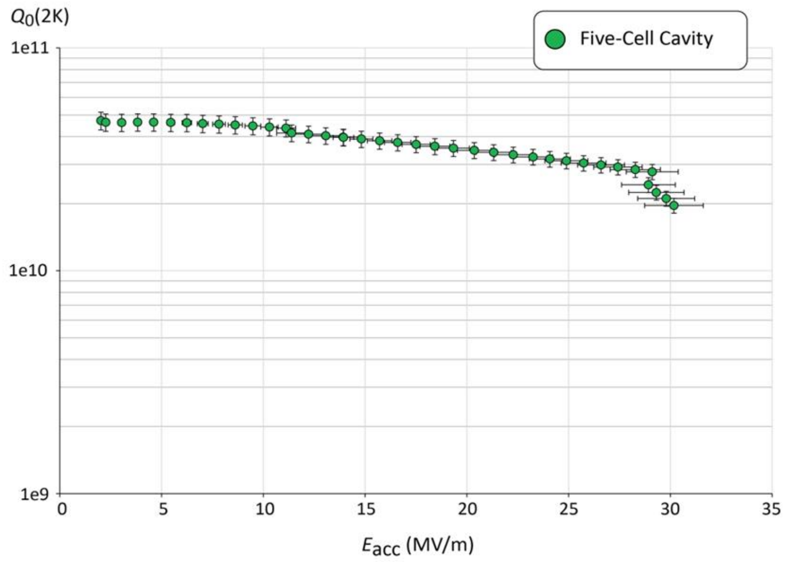
- Shared DNA with Jlab FEL, JLEIC cooler and CEBAF “C75” cavities
- 1-cell and 5-cell Nb prototypes
- 2x Cu 1-cells for thin film coating
- 2-cell Cu “kit” for further HOM development
- End group design was to come from CERN
- Most parts available for PERLE if useful
- Dies and fixtures available at Jlab.







748.5 MHz JLab High Current



192.R. Rimmer et al. The JLab Ampere-Class Cryomodule. *Proceedings of the 12th Workshop on RF Superconductivity (SRF’05)*, 2005.
193.[193] R.A. Rimmer, W. Clemens, D. Forehand, J. Henry, P. Kneisel, K. Macha, F. Marhauser, L. Turlington, and H. Wang. Recent Progress on High-Current SRF Cavities at JLab. *Pro- ceedings of the International Particle Accelerator Conference (IPAC’10)*, 2010.