Fabrication Status of the first 802 MHz Prototype Cavities for PERLE

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LHeC Workshop CERN

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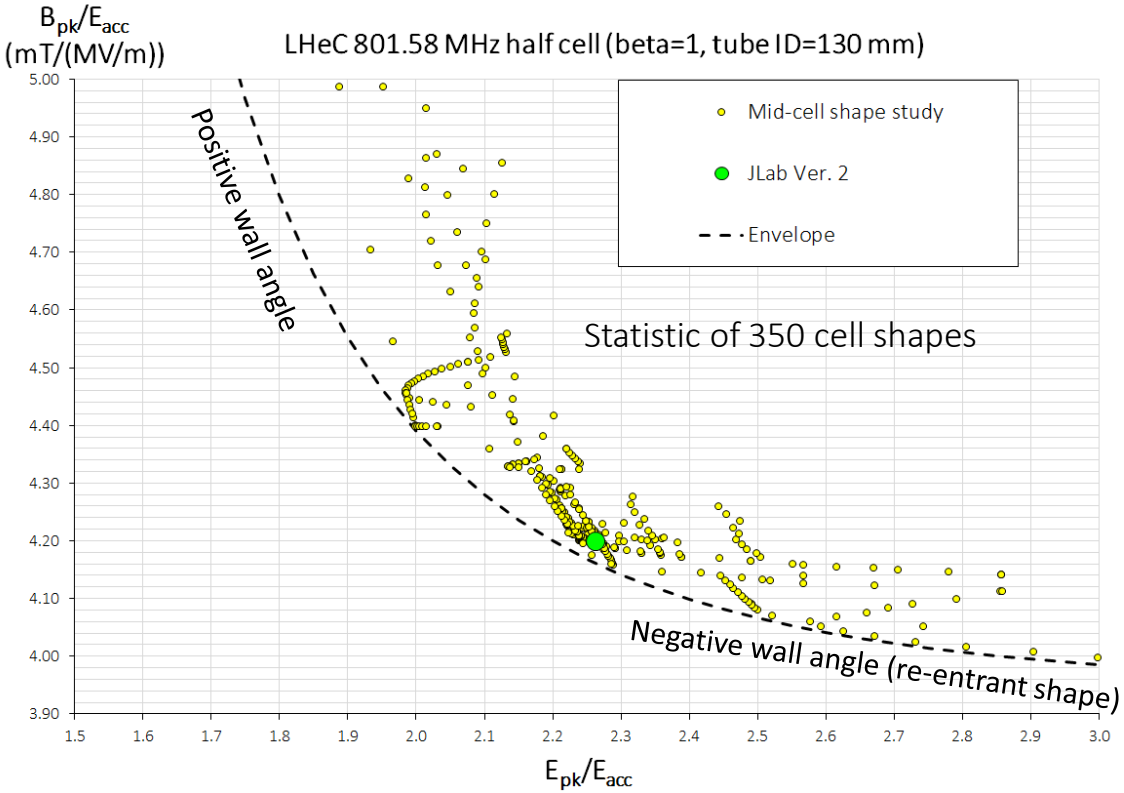
Overview

- Jefferson Lab has a contract with CERN to build
  - One single-cell fine-grain niobium 802 MHz cavity (manufactured)
  - Two single-cell OFHC 802 MHz cavities
  - One 5-cell fine-grain 802 MHz cavity
  - The remaining cavities are advancing rapidly
- In addition, Jefferson Lab has looked into:
  - Higher Order Mode (HOM) coupler design
  - Cryomodule design
  - This design work is preliminary
    - Funding is required to make more progress

Surface Peak Fields

- At E_{acc} = 20 MV/m → B_{pk} ~ 84 mT (B_{pk}/E_{acc} ~ 4.2 mT/(MV/m))
  - Avoids potential Q_0-slope
- Risk at 20 MV/m is field emission, small E_{pk}/E_{acc} can become important
- Main parameter to minimize peak field ratios is cavity iris diameter (ID) → small ID
- However, if ID is too small, HOM-damping can be compromised



ID: 130 mm (fixed)

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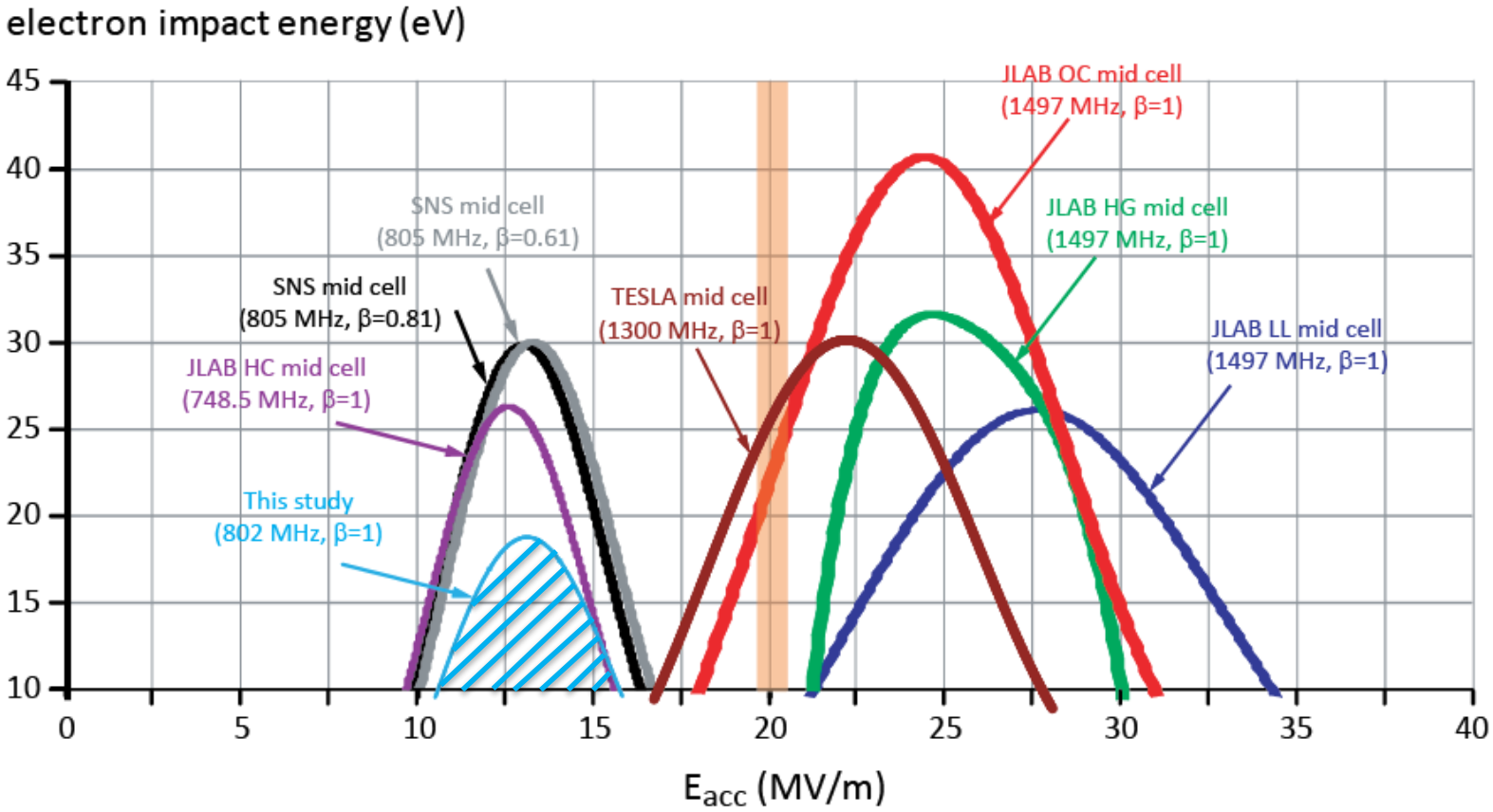
Typical Cell Multipacting Barrier

- Flatter equator in JLab's design lowers secondary impact energy



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Parameter Table for Cavity Versions

Parameter	Unit	Value	Value	Value
Cavity type		JLab/PERLE	CERN Ver. 1	CERN Ver. 2
Frequency	MHz	801.58		
Number of cells		5		
L_{active}	mm	917.9	935	935
Long. loss factor (2 mm rms bunch length)	V/pC	2.742	2.894	2.626
$R/Q = V_{eff}^2/(\omega*W)$	Ω	523.9	430	393
R/Q/cell	Ω	104.7	86.0	78.6
G	Ω	274.6	276	283
R/Q·G/cell		28788	23736	22244
Eq. Diameter	mm	328.0	350.2	350.2
Iris Diameter	mm	130	150	160
Tube Diameter	mm	130	150	160
Eq./Iris ratio		2.52	2.19	2.19
Wall angle (mid-cell)	degree	0	12.5	12.5
E_{peak}/E_{acc} (mid-cell)		2.26	2.26	2.40
B_{peak}/E_{acc} (mid-cell)	mT/(MV/m)	4.20	4.77	4.92
k_{cc}	%	3.21	4.47	5.75
N^2/k_{cc}		7.78	5.59	4.35
cutoff TE_{11}	GHz	1.35	1.17	1.10
cutoff TM_{01}	GHz	1.77	1.53	1.43

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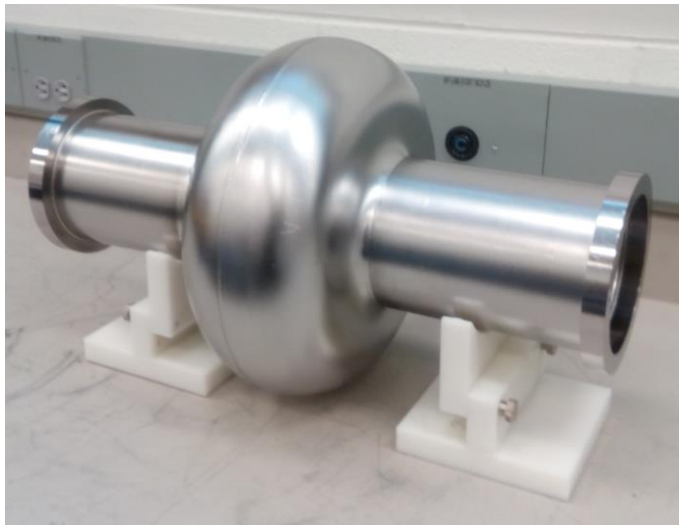
Deliverables (based on SOW with CERN)



- First 802 MHz Niobium single-cell cavity has been completed at JLab, the cavity is now being post-processed prior to vertical RF testing

- 2 copper 802 MHz cavities will be produced for R&D purposes and will be sent to CERN

One bare Niobium five-cell 802 MHz design is being fabricated, completion expected by end of Sept. 2017

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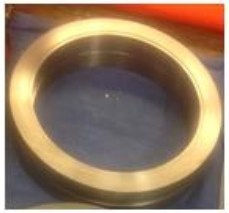
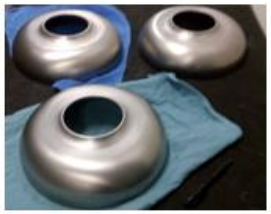
Status of Deliverables

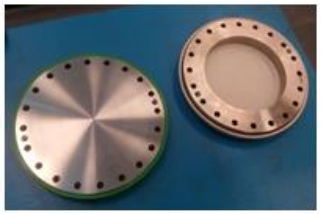
Cavity	Qty.	Material	Half cells deep-drawn	Beam Tubes deep-drawn/ rolled	Flanges machined	End group EBW (end cell + tube + flange)	Dumb-bells EBW	Machining/ Trimming	Cavity EBW
1-cell	1	FG Nb	2/2	2/2	2/2 NbTi flanges	2/2	n/a	done	done
1-cell	2	OFHC Cu	4/4	4/4 not EB-welded and machined	4/4 SS 316 LN	not yet started	n/a	equator trimming after EBW	-
5-cell	1	FG Nb	10/10	2/2	2/2 NbTi flanges	2/2	4/4	in progress	-







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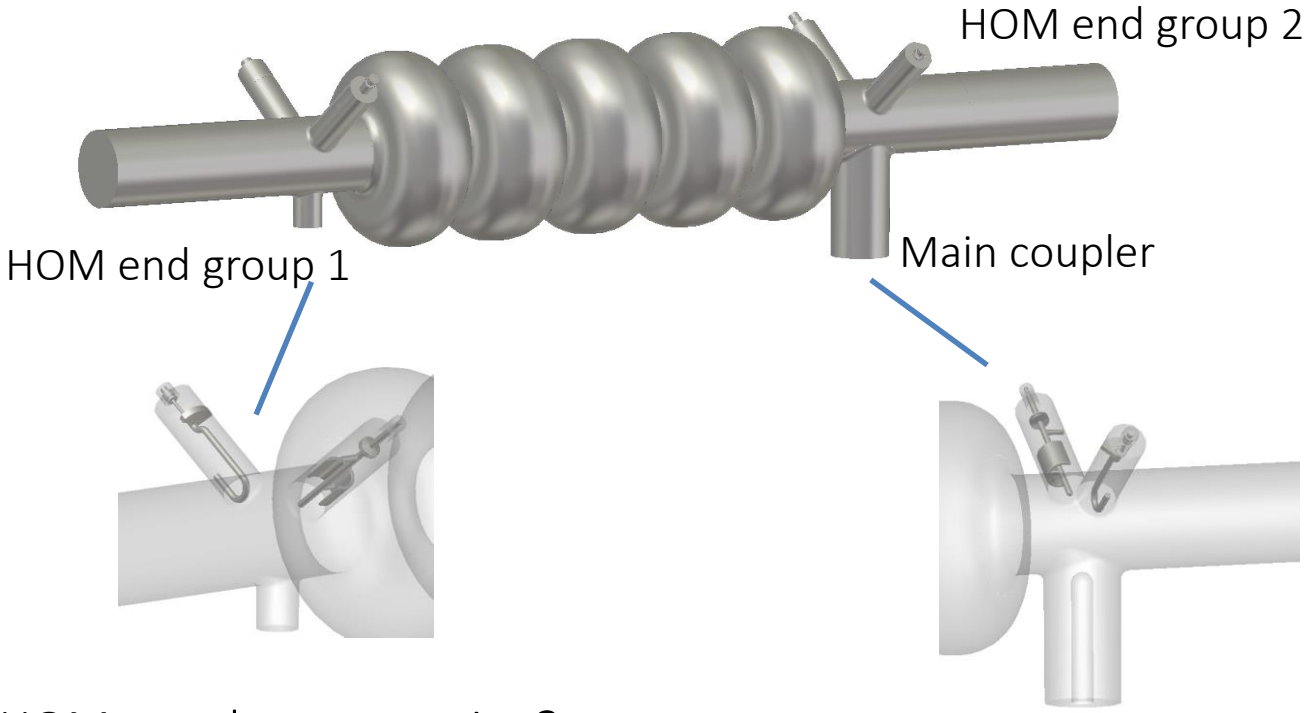
Which HOM-Coupler Technology ?

- First approach should be to utilize existing coupler technology, but this needs scaling to new frequency and tube ID
- For instance: scale LHC HOM couplers (and FPC)



- 4 HOM couplers per cavity ?
  - LHC-type coaxial loop coupler is narrowband coupler for dipole modes
  - LHC-type coaxial antenna/capacitive coupler is more broadband

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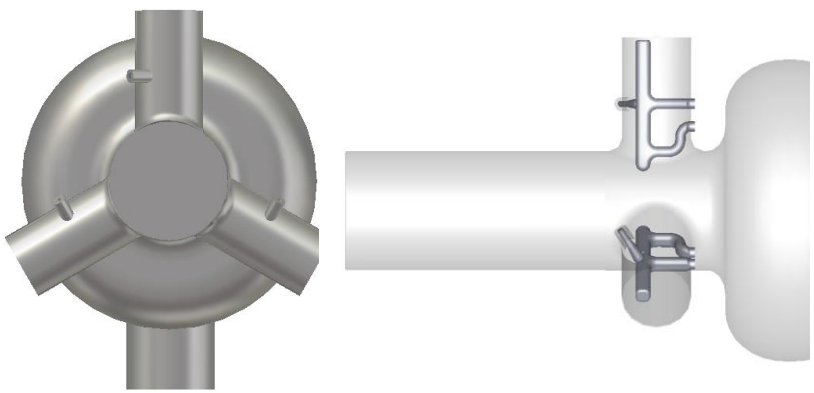
Which HOM-Coupler Technology ?

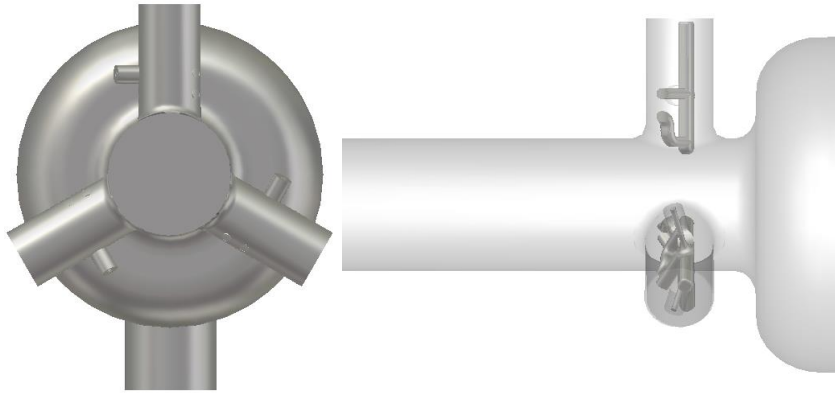
- A better solution would be utilizing 3 couplers for HOM end group
- Minimizes dependence on mode polarization

HOM end group

Main coupler



Scaled JLab-type couplers



Scaled TESLA-type coaxial couplers

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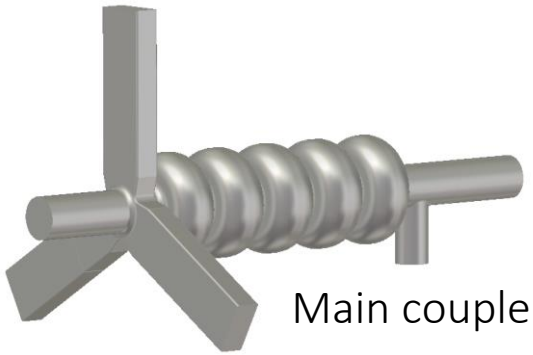
Which HOM-Coupler Technology ?

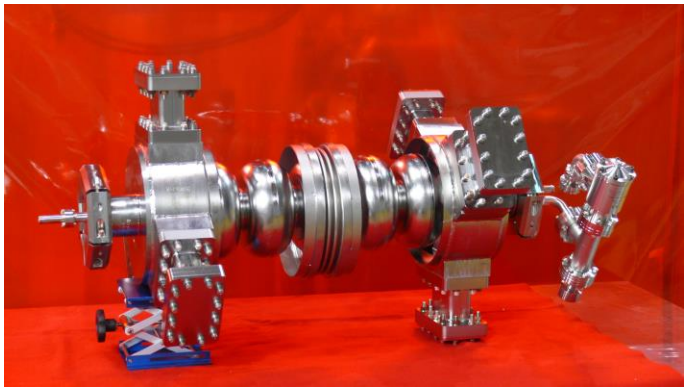
- HOM waveguides only required if beam current increases significantly

HOM end group



Main coupler

Scaled JLab High Current (HC) waveguide couplers



1.5 GHz HC cavity prototype

750 MHz HC cavity prototype

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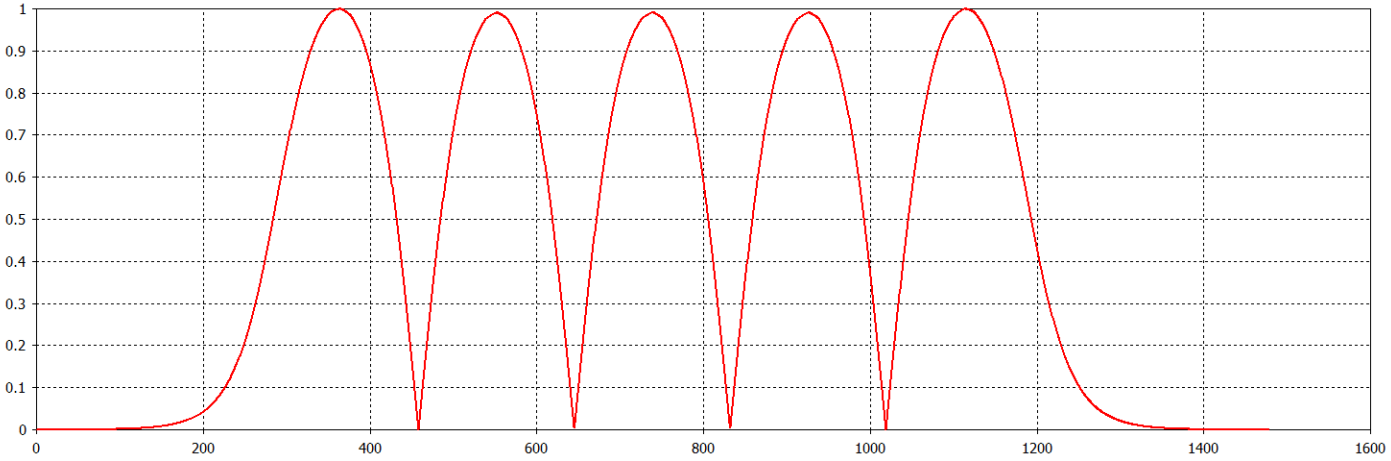
JLab/PERLE

- For the prototype PERLE cavity we have chosen a single-die design (end cells are trimmed shorter)
- PERLE cavity identical to CERN FCC prototype under construction
- Optimized for high current operation

On axis |Ez|



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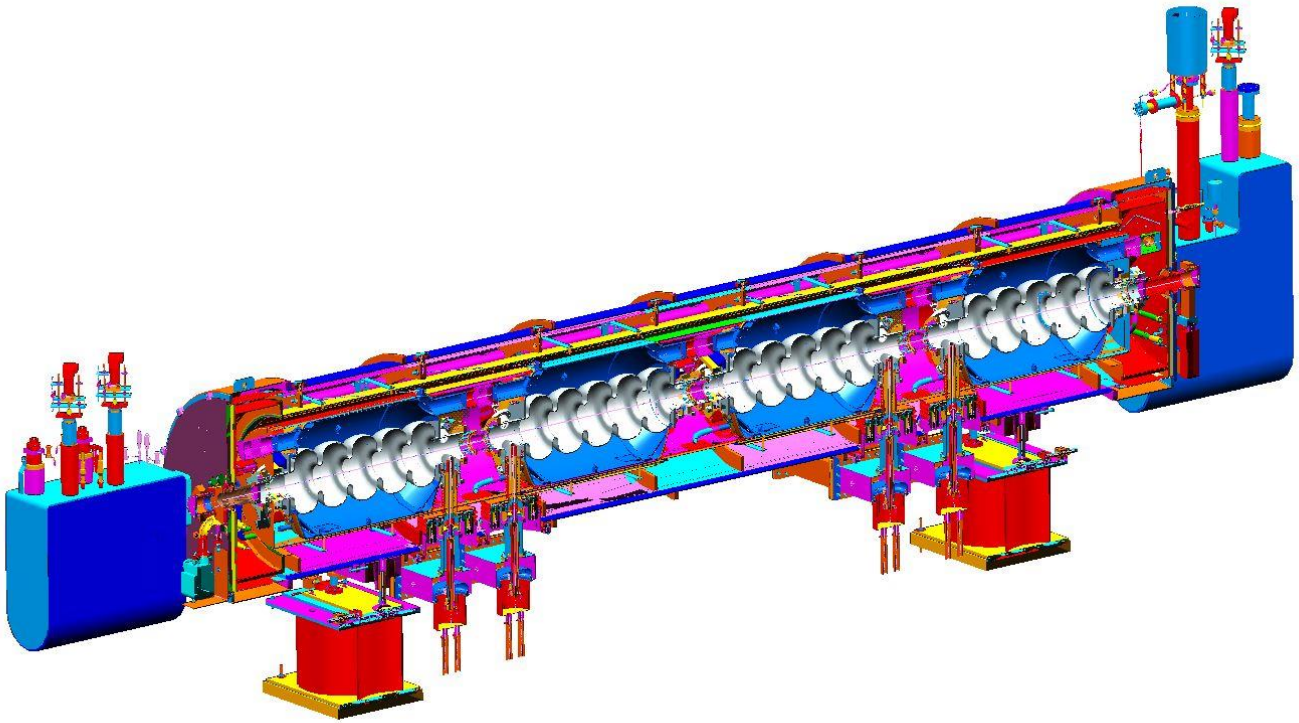
SNS-like cryomodule

- Cavity fits well in SNS type (805 MHz) cryomodule
- Cost and fabrication processes well understood
- Some updates for pressure code have been made by ORNL
- Plans prepared to build new modules for SNS Power Upgrade
- Fresh cost estimate in hand, can be adapted to PERLE



Bob Rimmer

Summary

- CERN FCC cavity prototypes are progressing well
  - Expected completion in September 2017
  - Cutting off the beam tubes from the bare 5-cell cavity and welding new end groups to the cavity to investigate HOM-damping scenarios would be a good next step
- Preliminary evaluation of HOM's has been carried out
  - Either coax or waveguide would work (waveguide is probably overkill)
  - Three couplers should be sufficient (needs to be checked)
  - Strong cell-to-cell coupling is good for HOM damping
- Design for PERLE cavity is identical to CERN FCC cavity
  - Ready for detailed end group design work
  - Prototype cavity could be built 6 months after funding becomes available if CERN 5-cell prototype cavity is modified
    - One year would be required starting from scratch
- Jefferson Lab will provide a budgetary estimate for an SNS-type cryomodule for PERLE