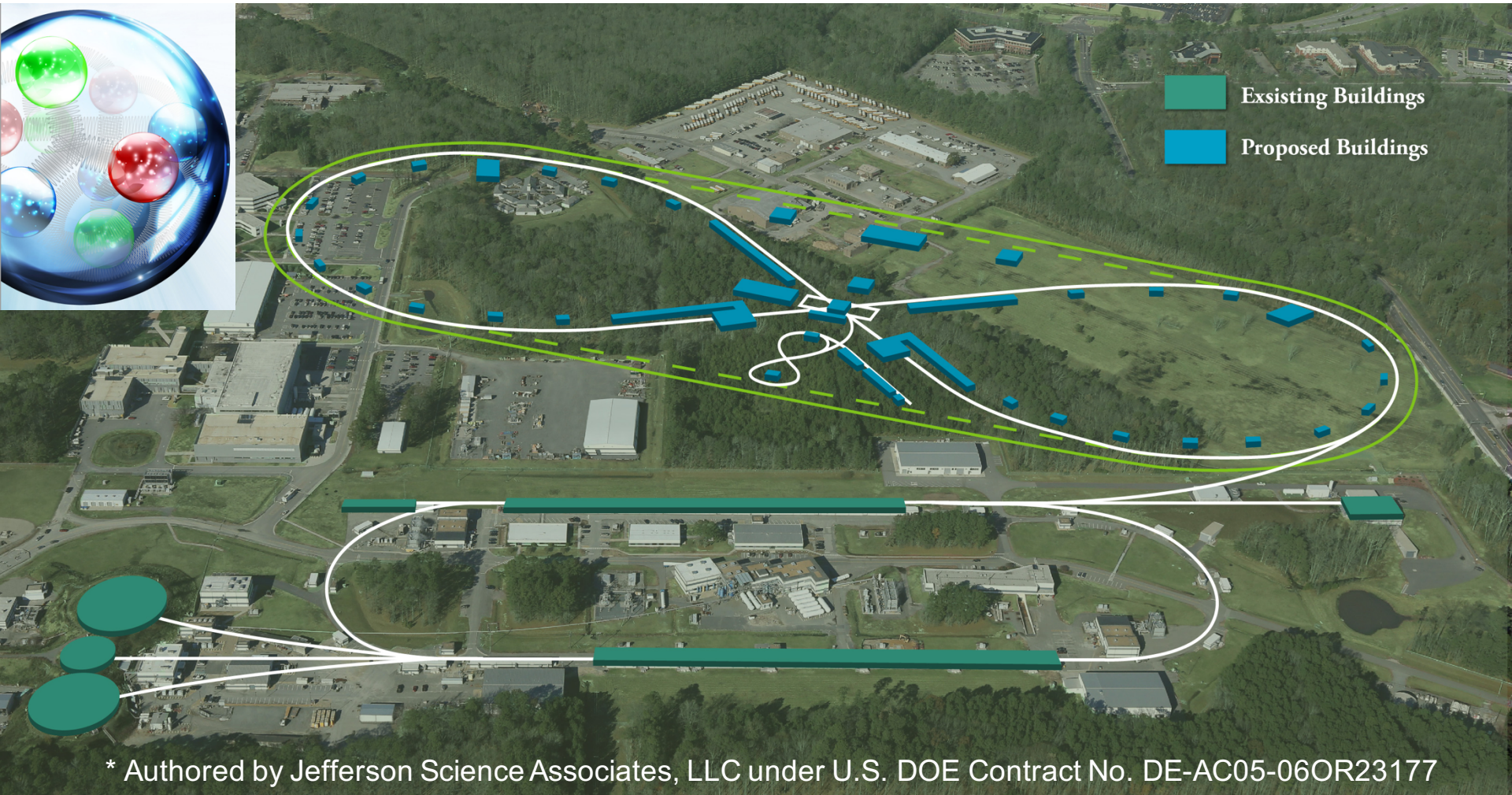
800 MHz SRF Cavity status

R. Rimmer, J. Henry, F. Marhauser, L. Turlington



* Authored by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177

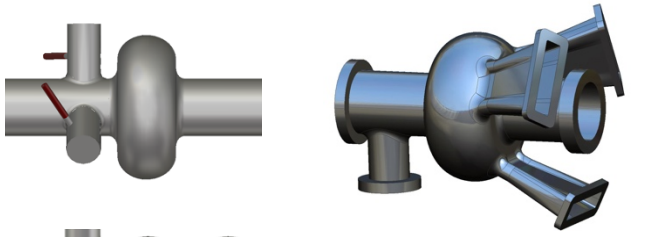
Outline

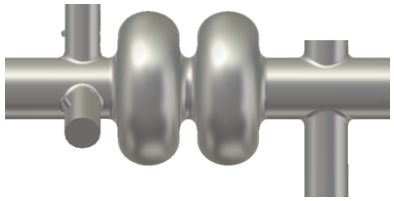
- LHeC (PERLE) cavity development context
- Requirements
- Design philosophy
  - Cell shape optimization (see Frank Marhauser's talk)
  - HOM damping (see Frank Marhauser's talk)
- 952.6 MHz prototype cavity status
- 800 MHz cavity status and plans
- SNS-like Cryostat update
- Conclusions
- "strong" bunched-beam electron cooling
- Modular Cryostat update

LHeC cavity design context:

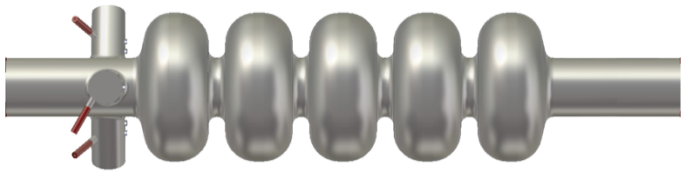
FCC and EIC cavities for low and high energy

	V_tot	n_bunch	I_beam	σ	E_turnloss
FCC-hh	0.032		500		
Z	0.4 / 0.2	30180 / 91500	1450	0.9/1.6	0.03
W	0.8	5260	152	2	0.33
H	3	780	30	2	1.67
t	10	81	6.6	2.1	7.55



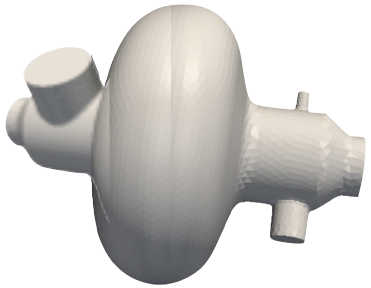


952.6 MHz



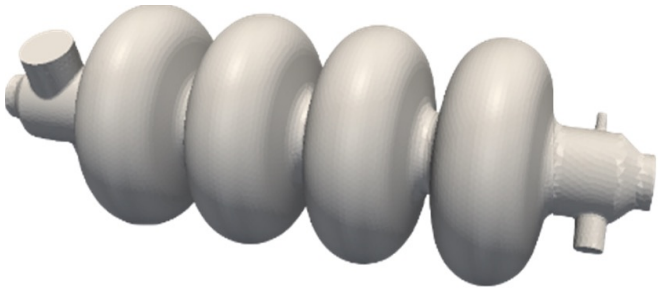
Jlab cavities with coax and on-cell dampers

O. Brunner, FCC Week 2016, Rome

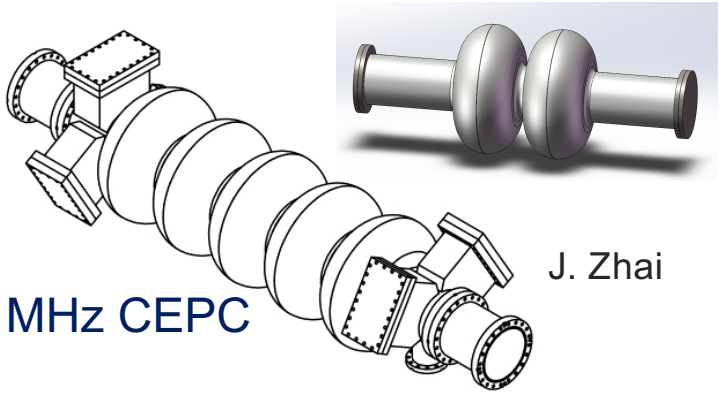


400MHz,

1 cell,
Nb/Cu



400/800 MHz, multi-cells, Nb/Cu

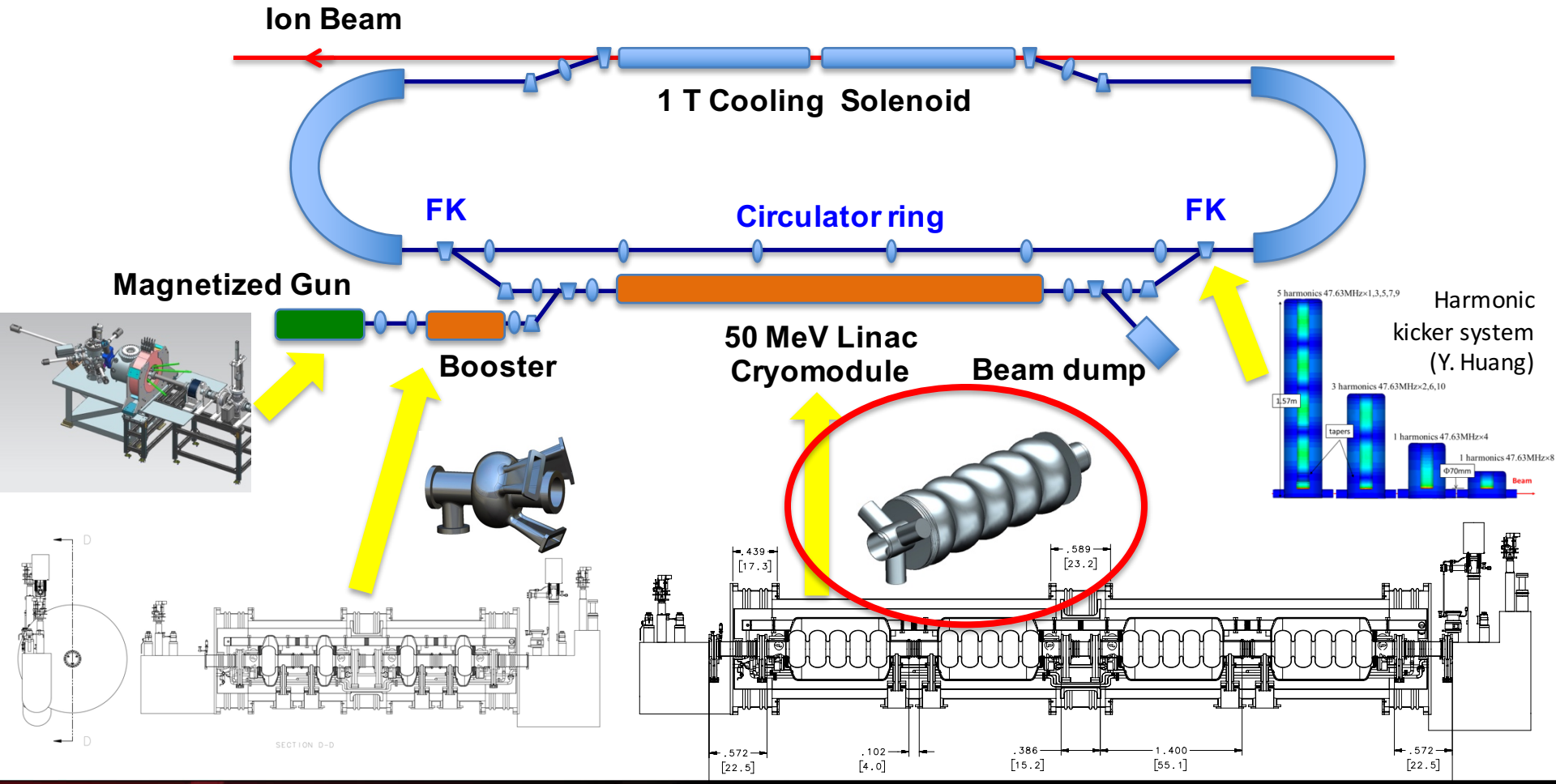


650 MHz CEPC

J. Zhai

JLEIC "Strong" bunched-beam cooling

- Electrons circulate 10 to 30 turns in **circulator ring**, fed by an **ERL current?**
- Beam current and bunch repetition frequency reduced by a factor of 10 to 30
- **Fast kickers (FK)** needed with rise and fall-off times of a fraction of a ns



Cavity parameters

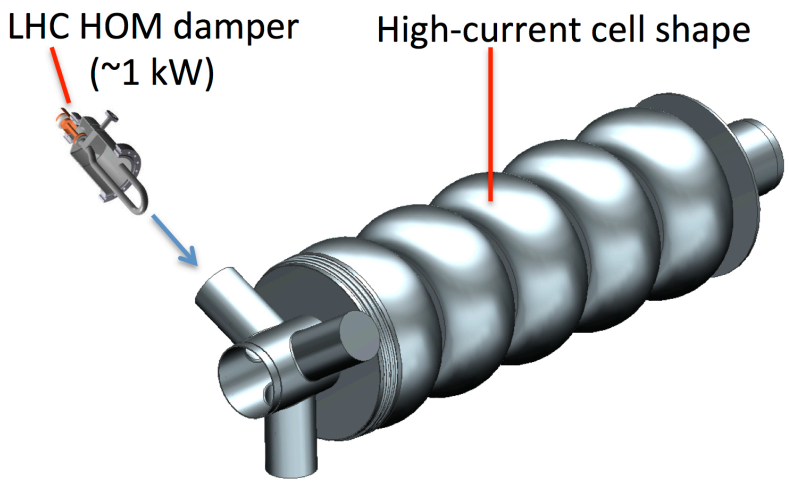
- Table of parameters from PERLE CDR

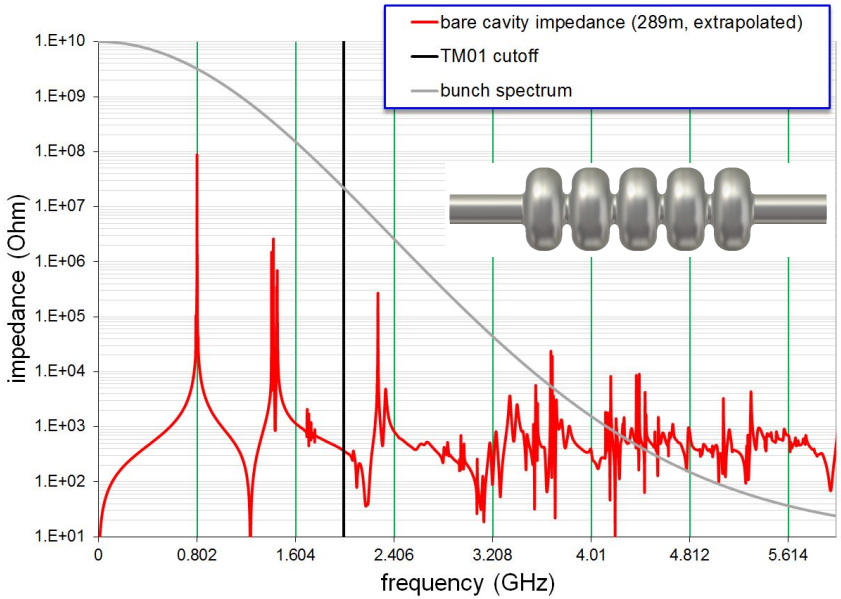
Iris	MHz	115	130	150	160
Parameter	Unit	$Jlab_1$	$Jlab_2$	$CERN_1$	$CERN_2$
Frequency	MHz	802	802	801.58	801.58
L_{active}	mm	922.14	917.911	935	935
$R/Q = V_{eff}^2/(\omega W)$	Ω	583.435	523.956	430	393
Integrated k_{loss}	V/pC	3.198	2.742	2.894	2.626
(R/Q)/cell	Ω	116.687	104.7912	86	78.6
G	Ω	273.2	274.717	276	283
(R/Q) · G /cell	Ω^2	31877	28788	23736	22244
Equator diameter	mm	323.1	328.0	350.2	350.2
Wall angle	degree	0	0	14	12.5
E_{pk}/E_{acc}		2.07	2.26	2.26	2.40
B_{pk}/E_{acc}	$10^{-9}s/m$	4.00	4.20	4.77	4.92
k_{cc}	%	2.14	3.21	4.47	5.75
N^2/k_{cc}		1168	778	559	435
cutoff TE_{11}	GHz	1.53	1.35	1.17	1.10
cutoff TM_{01}	GHz	2.00	1.77	1.53	1.43
E_{acc}	MV/m	20.3	20.4	20.0	20.0
E_{pk}	MV/m	42.0	46.1	45.1	48.0
B_{pk}	mT	81.1	85.5	95.4	98.3

Design philosophy: cell shape

Closely follow JLEIC 952.6 MHz cavity design (based on previous 750 MHz high current ERL 5-cell).

- Optimize for HOM spectrum in the cell (avoid RF lines)
- Strong cell to cell coupling
- Good efficiency
- Acceptable surface fields
- Low multipacting impact energy



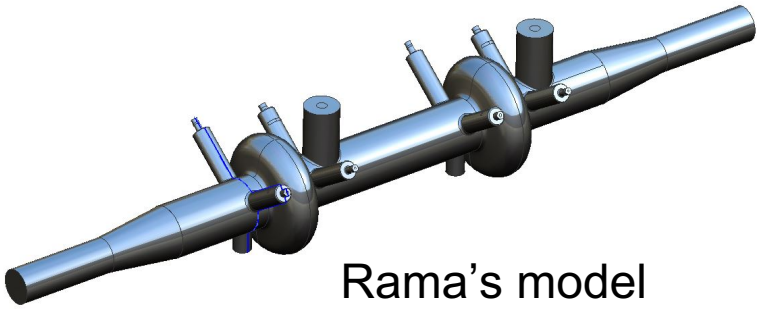


Design philosophy: HOM damping

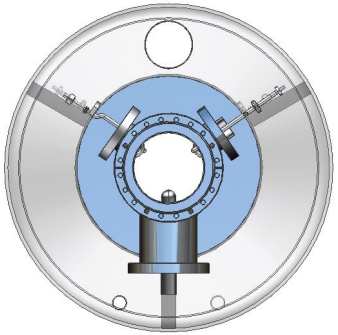
Evaluate scaled LHC type coupler and HOM dampers (Rama's model)

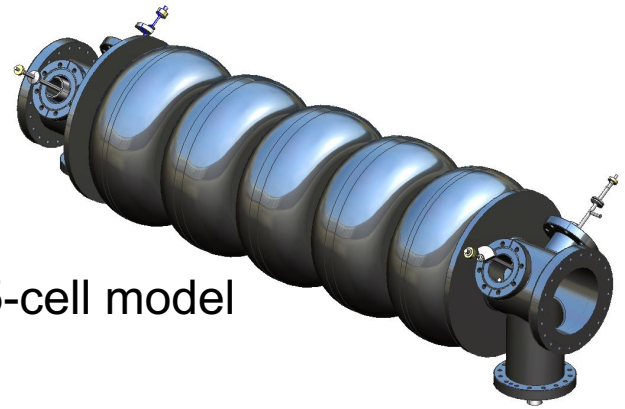
- LHC power coupler is well proven but may be overkill
- JLab FEL waveguide dampers may be overkill*
- LHC HOM dampers are somewhat narrow band (tuned)
- High power capability (~1 kW), active cooling
- Demountable
- Evaluate scaled TESLA couplers in the same location

See Frank's talk



Rama's model



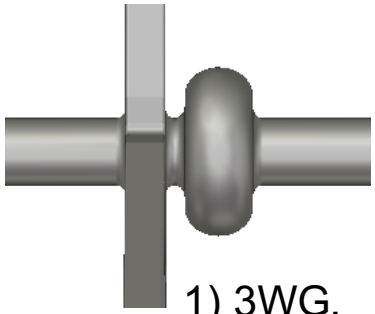


5-cell model

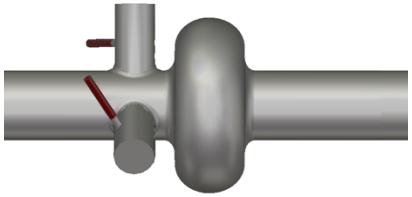
* Or not, depending on filling pattern

Jlab 952.6 MHz cavity current status

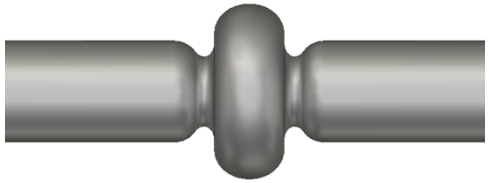
- New 952.6 MHz high-current cavity shape developed
- 1-cell prototype in progress
- HOM damping schemes under evaluation
- Full RF system parameter tables defined



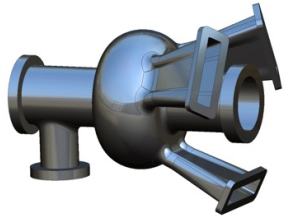
1) 3WG.



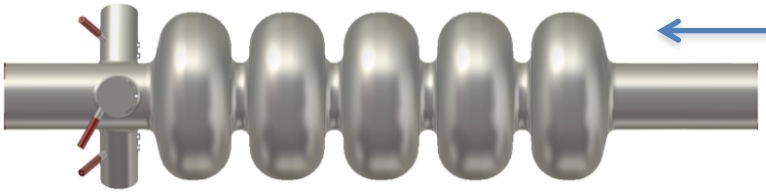
2) 3 x coax dampers.



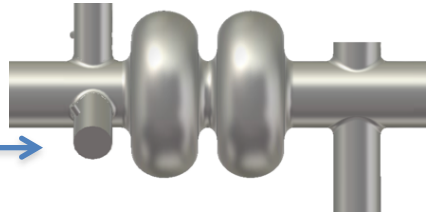
3) enlarged beam pipes (ref)



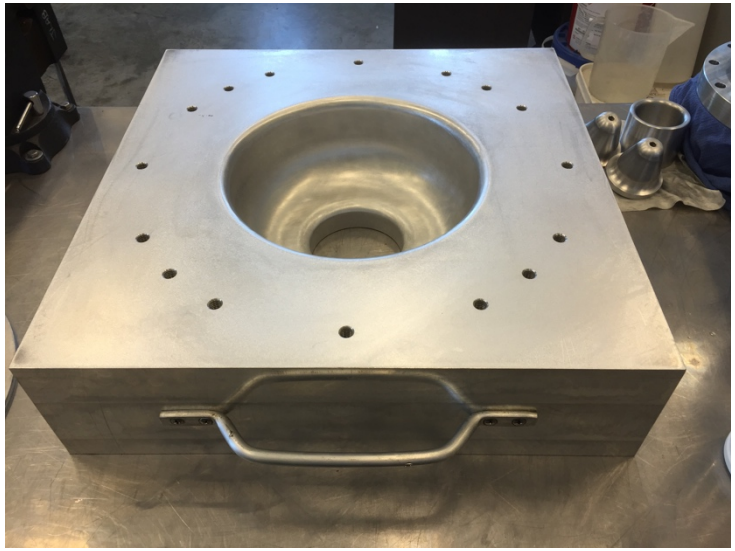
4) on-cell dampers



Cooler needs **5-cells** in the ERL, 1-cells in the injector. Ion ring might use **2-cells**



First 952.6 MHz test pressings



800 MHz cavity status and plans

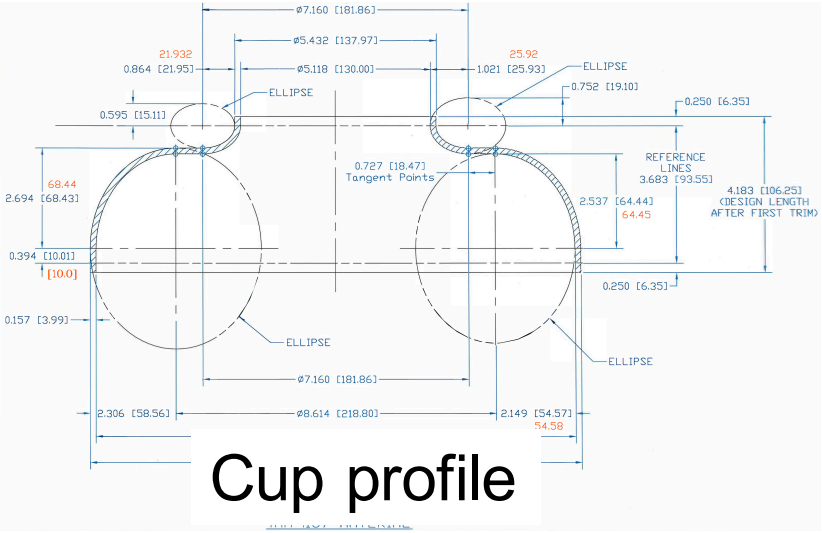
- Cell shape design complete (F. Marhauser talk)
- Preliminary port locations proposed
- Die set designed and out for bids
- Blank size determined by scaling from JLEIC cavity

- To do:
- Develop bill of materials for CERN
- Test dies with Aluminum or copper disks
- Fabricate 1 or more Cu 1-cells for coating at CERN
- 1-cell Nb prototype (with or without ports?)
- 5-cell Nb prototype with ports

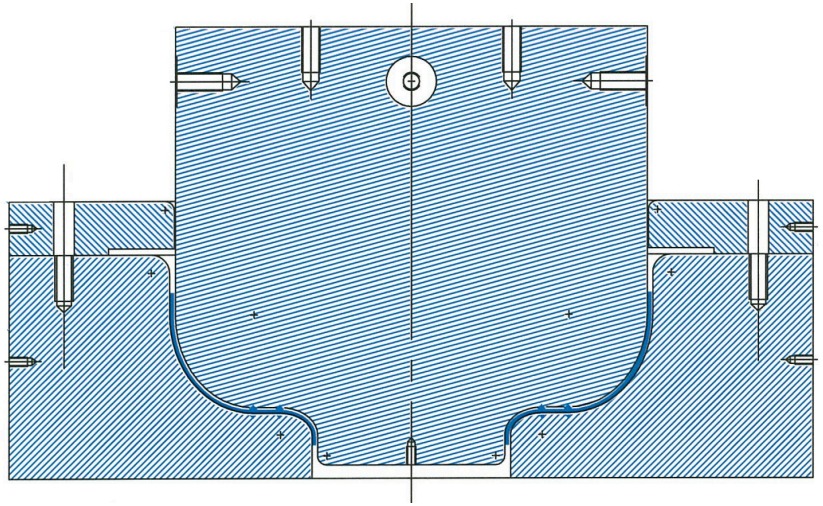
- Optional:
- Integration into SNS type cryomodule
- Cost estimate for PERLE requirements

802.58 MHz die set

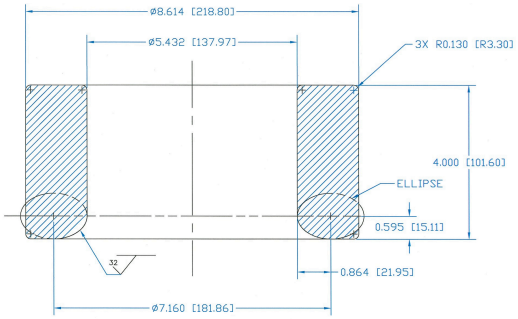
Out for bid…



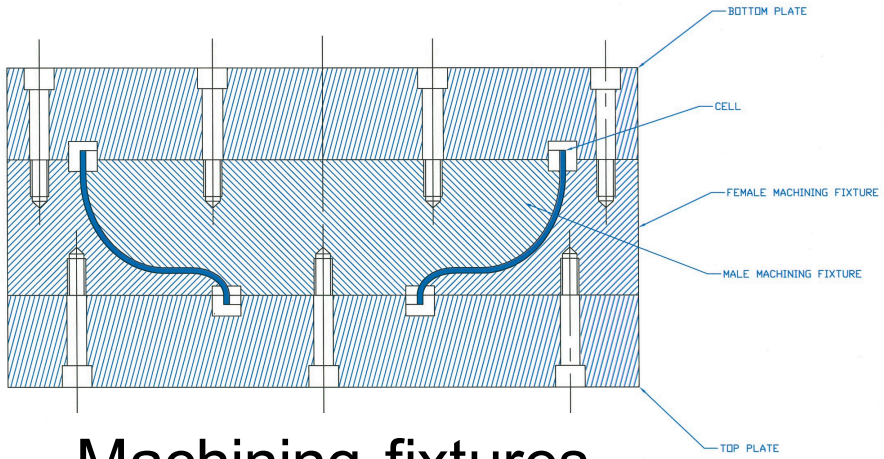
Cup profile



Forming dies



Coining fixture



Machining fixtures

Plan forward

Fabricate dies. Q2 FY17

Test dies with Al or Cu disks, check dimensions etc.

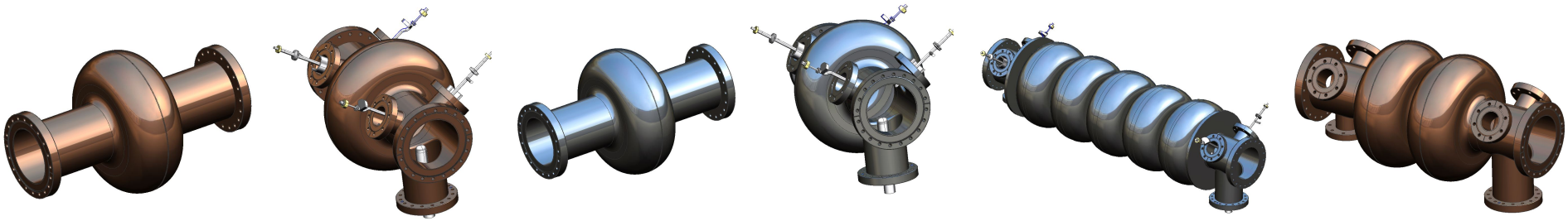
Fabricate one or more copper 1-cell cavities. Q3 FY17

- Check tuning procedure and useful for CERN coating tests
- Can add ports for development of HOM couplers

Fabricate one bare Nb single cell. Q3 FY17

- Validate frequency, Qo and gradient
- Option to make one large grain single cell

Fabricate bare 5-cell cavity (no He vessel) with ports. Q4 FY17

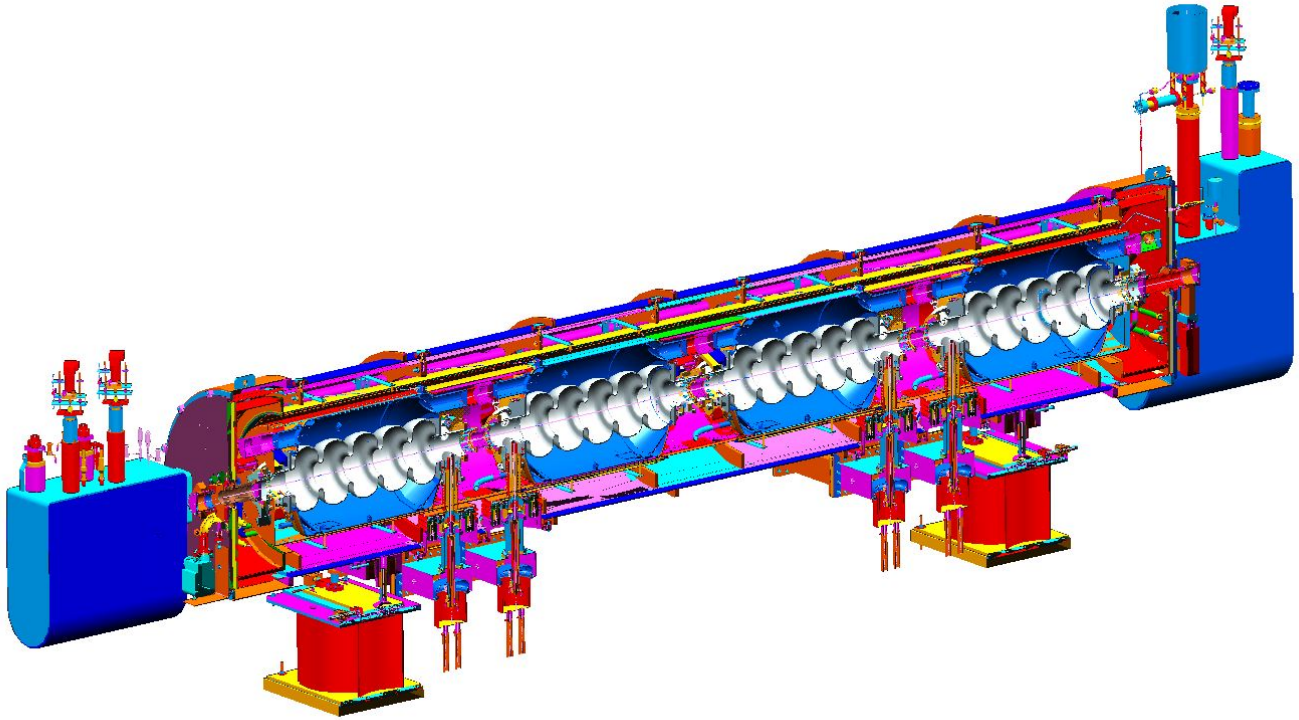


✔ ? ✔ ? ✔ ?

✔ = in plan, **?** = option

SNS like cryomodule

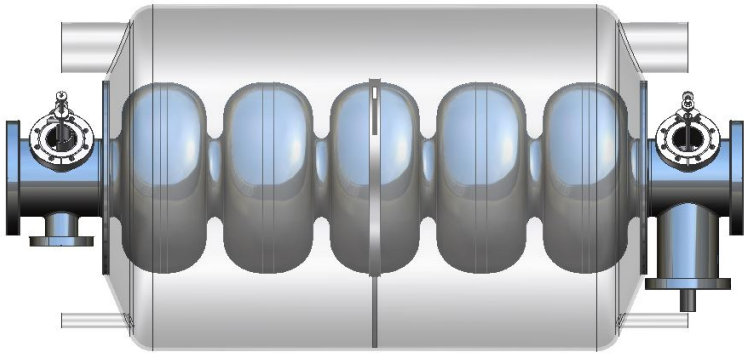
Cavity fits well in SNS type (805 MHz) cryomodule
Cost and fabrication processes well understood
Some updates for pressure code have been made by ORNL
Plans to build new modules for SNS Power Upgrade
Fresh cost estimate in hand, can be adapted to PERLE

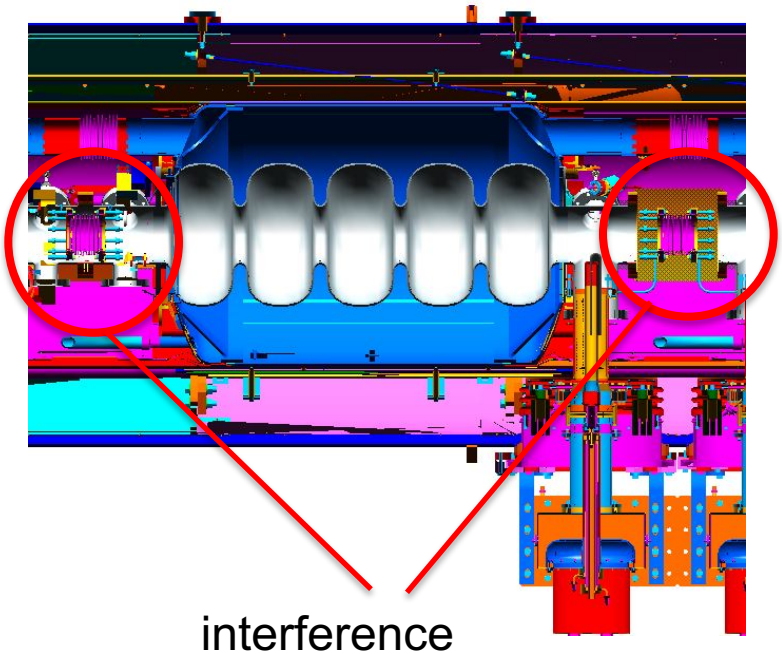


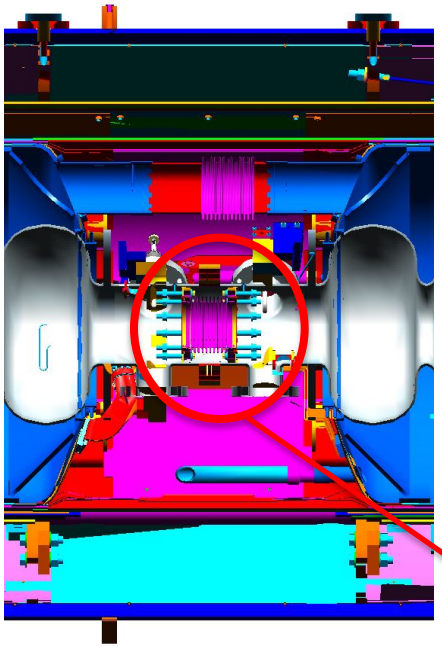
SNS-like cryomodule

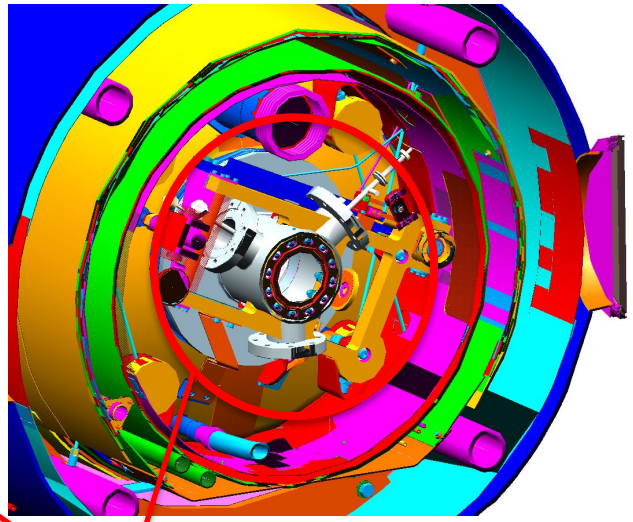
Some detail changes needed:

- Helium vessel bellows
- Cavity interconnects
- FPC (SNS version is smaller)
- Tuner interference with HOM loads



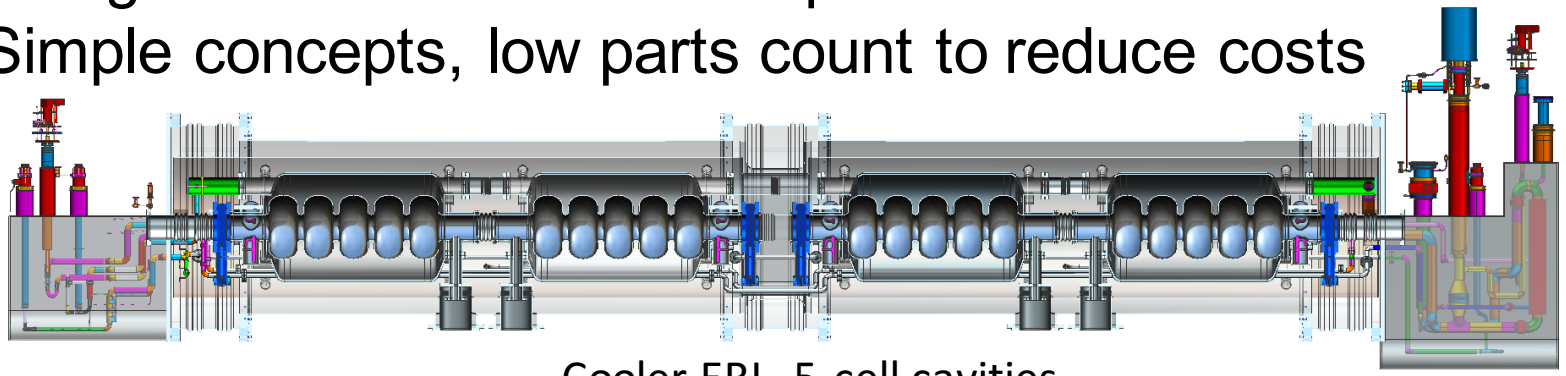




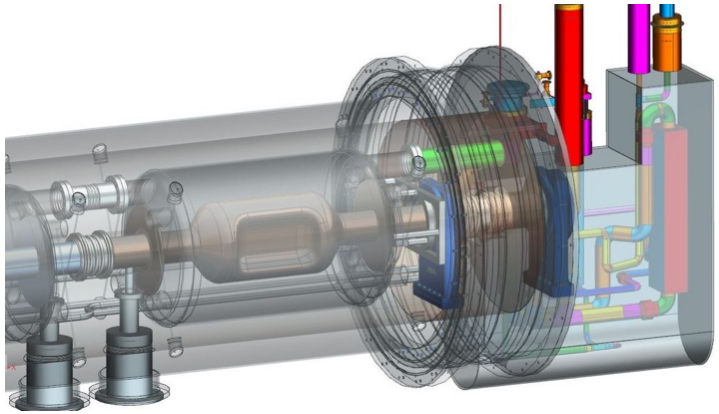


Jlab Modular Cryostat

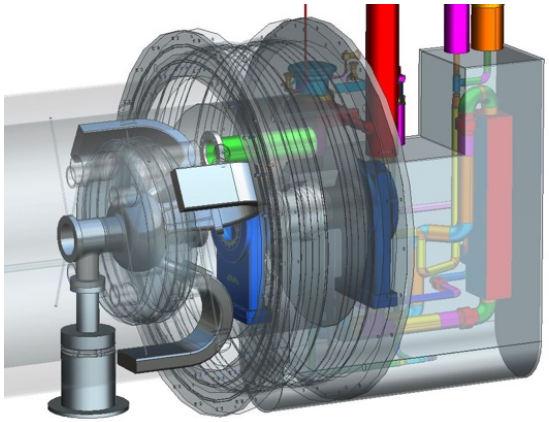
- Take the best features of previous JLab designs
- Modular approach to hold various different cavities
- Design suitable for industrial production
- Simple concepts, low parts count to reduce costs



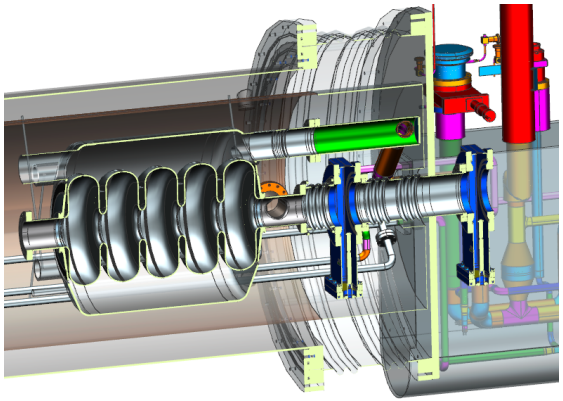
Cooler ERL, 5-cell cavities



476.3 MHz Crab cavity



On-cell damper concept



β=0.6 650 MHz cavity

Conclusions

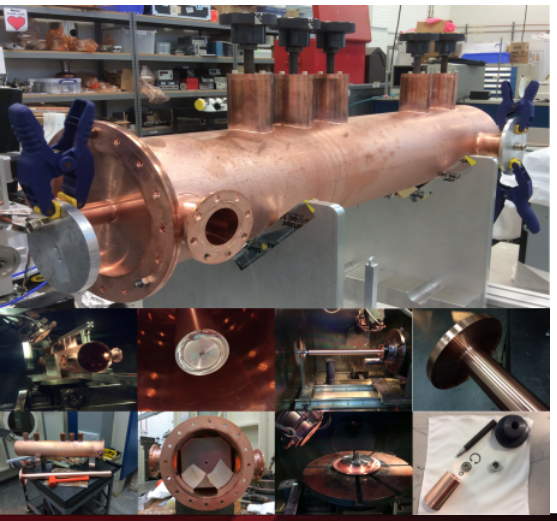
- JLEIC 952.6 MHz RF cavity is progressing
- 802.58 MHz cavity is following a step behind
- Optimized cell shape is done
- HOM damping analysis in progress
- 802.58 MHz dies designed, out for bids
- Insertion into SNS-type cryomodule looks straightforward
  - Minor changes needed
  - Tooling in hand, costs well understood
- Damped cavities may work for other projects
  - e.g. FCC-hh

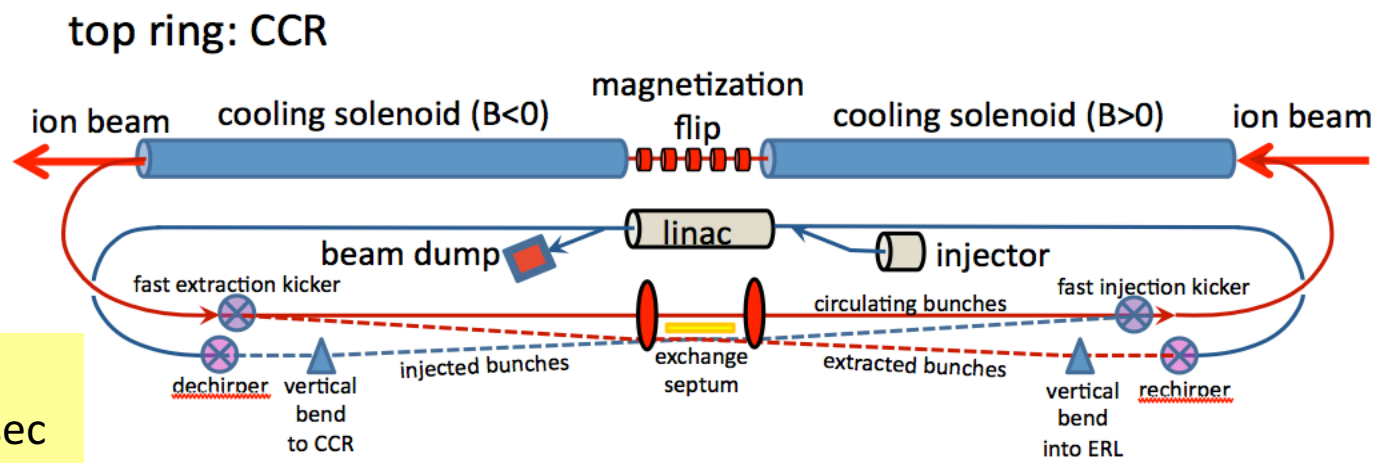
Backup

Baseline: strong cooling

ERL cooler +
Multi-turn circulator ring

Enabling technologies :
Fast kickers, risetime <1 nsec
Magnetized source ~75mA



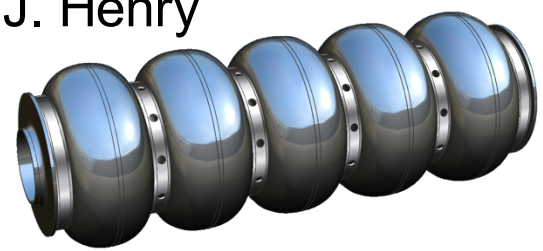


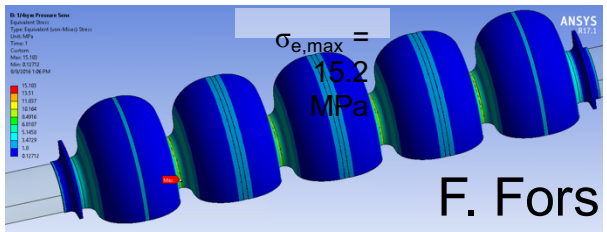
Electron energy	MeV	up to 55
Bunch charge	nC	3.2
Turns in circulator ring	turn	~20
Current in CCR/ERL	A	1.5/0.075
Bunch repetition	MHz	476
Cooling section length	m	60
RMS Bunch length	cm	3
Energy spread	10^{-4}	3
Cooling solenoid field	T	1
Cooling section length	m	2x30

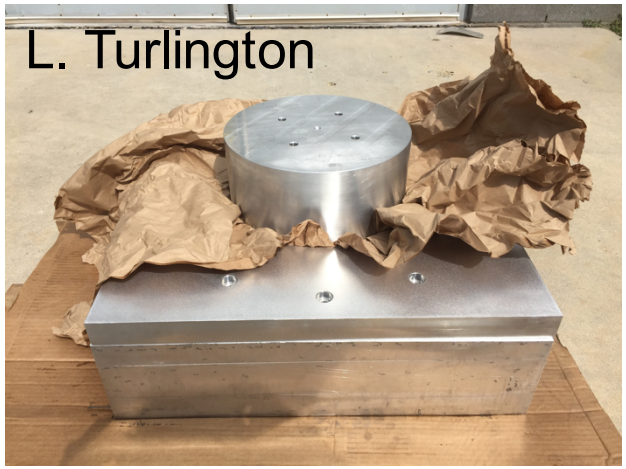
952.6 MHz cavity prototype

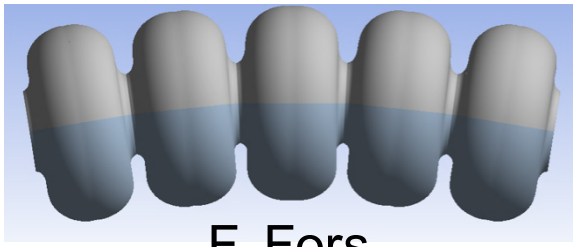
- Preliminary engineering analysis is complete
- Cell and beam tube dies (110mm) have been fabricated
- Test blanks have been pressed
- **End group design** will be chosen based on simulations
- Impedance requirements (Q spec)
- HOM power (i-ring, e-ring, ERL)
- Will produce single-cell first (possibly using ingot material)

J. Henry

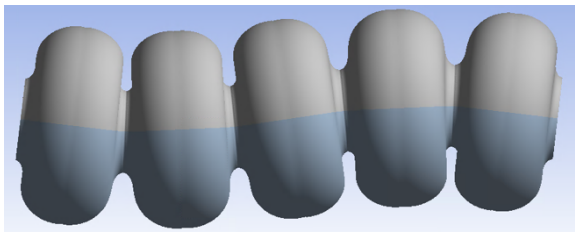






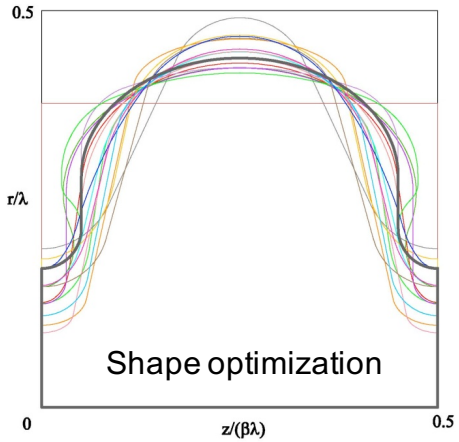


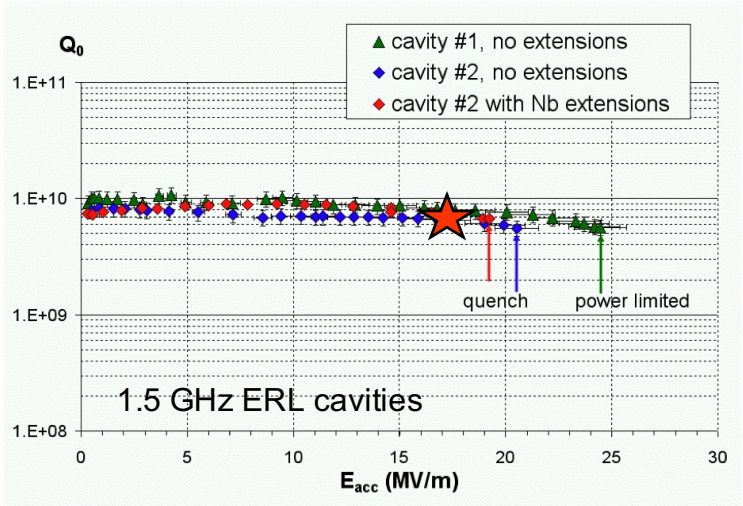
F. Fors

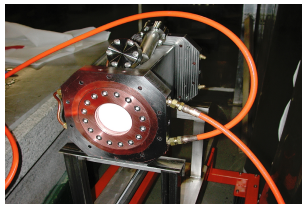


JLab high-current cavities

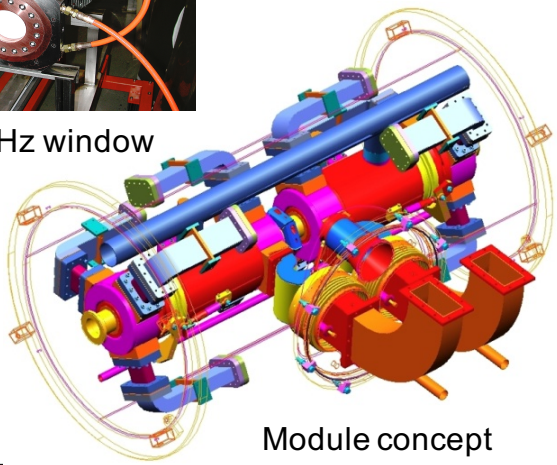
- Two 1.5 GHz, one 750 MHz prototypes built and tested
  - Results exceed requirements for 4th gen. light source
  - High power RF window demonstrated to > 60 kW CW



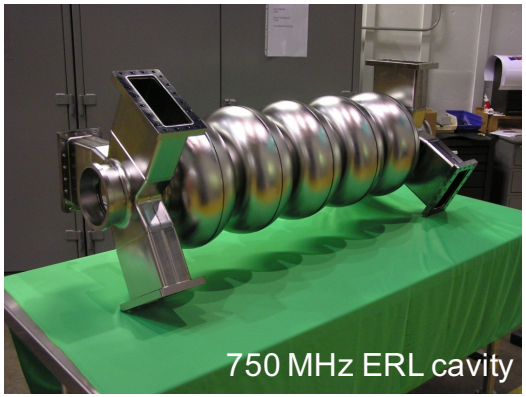


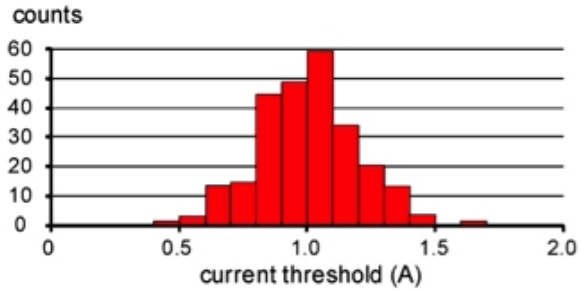


1.5 GHz window



Module concept





BBU simulations for 1.5 GHz ERL

JLab high current cryomodule

- JLab 750 MHz ERL module (based on modified SNS layout)
- Very large apertures (halo!) Very high BBU threshold
- Waveguide HOM dampers with high power loads