BNL 3 Cavity Design

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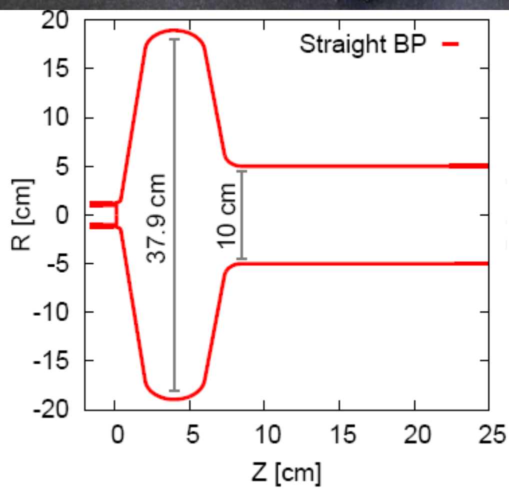
(BNL and Stony Brook University, Long Island, New York).

The BNL High-Current R&D ERL

- Aimed at pushing the limits for beam current: 0.5 amperes and developing ERL technologies
- Testing of novel components and techniques:
  - Superconducting electron gun
  - Diamond amplified photocathode
  - Z-bend ERL beam merging
  - High-current SRF cavity at 703.75 MHz
  - Diagnostics and more.
- Collaboration with AES

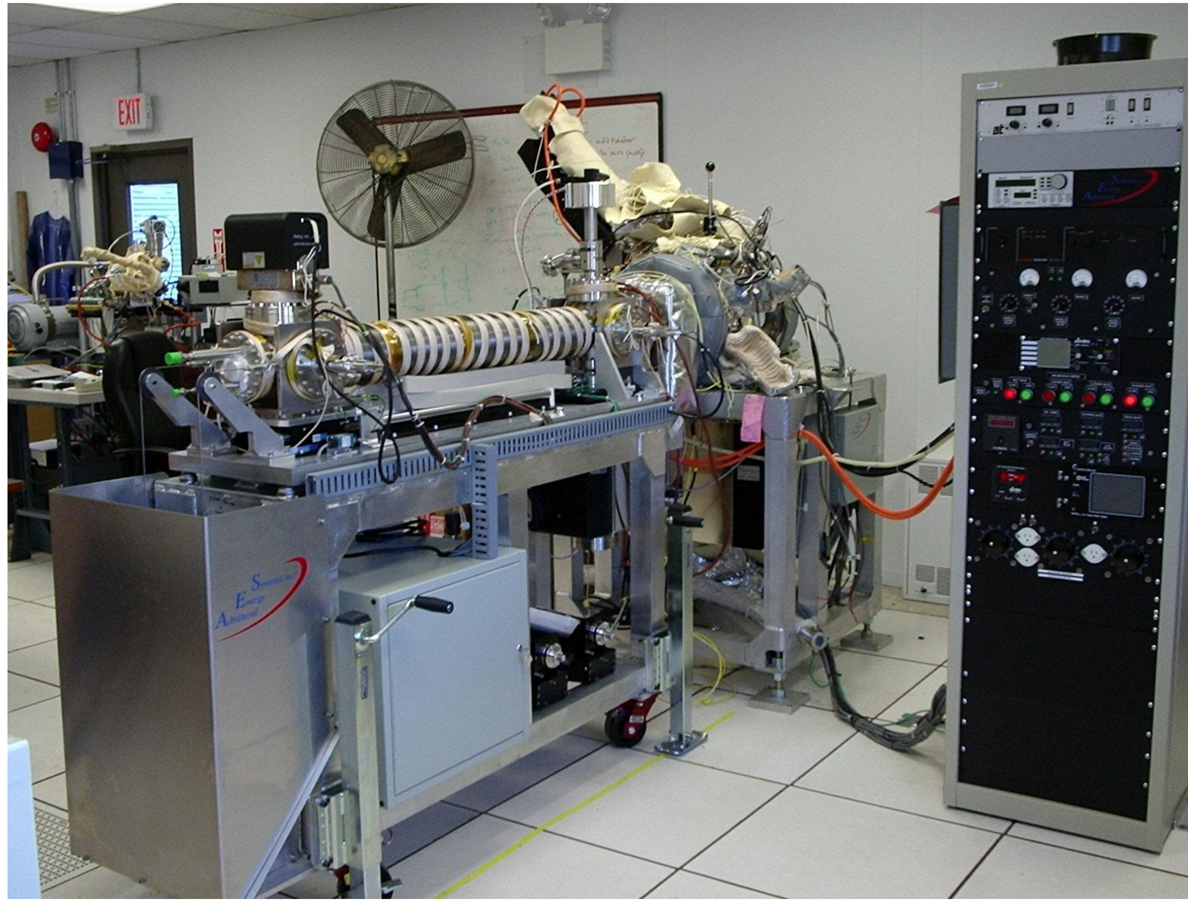
SRF Gun

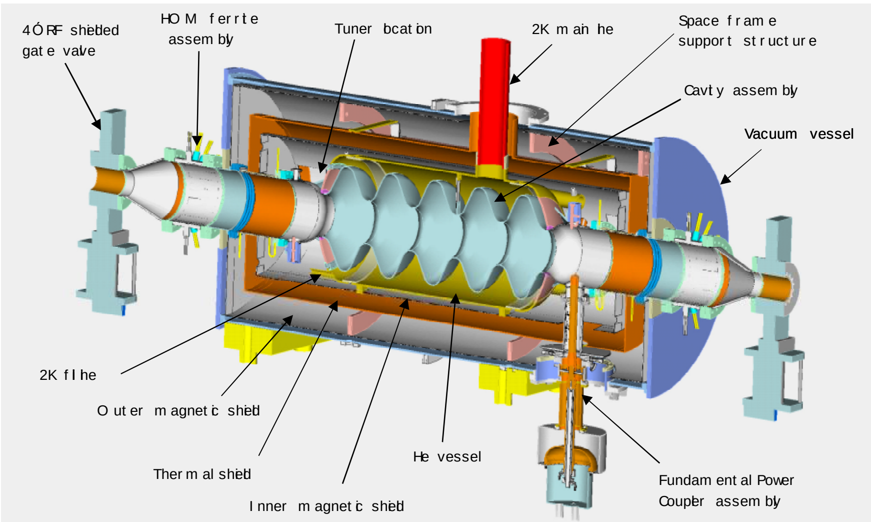


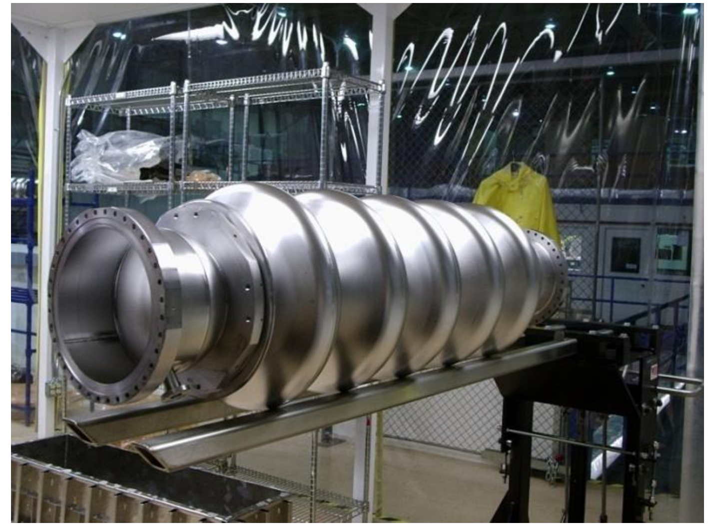
Parameter	Units	Value
Frequency	MHz	703.75
Iris radius	cm	5
Equator Diameter	cm	37.9
Cavity length	cm	25
Beam kinetic energy	MeV	2
Peak electric field	MV/m	35.7
Peak magnetic field	A/m	58740
Stored energy	Joule	8.37
QR_s (geometry factor)	Ω	35.2
R/Q	Ω	96
Q_e (external Q)		37000
Power input	MW	1
Maximum current	mA	500
Emittance at 1.4 nC	µm rms normalized	1.4
Cathode recess	mm	1
Cathode spot size	mm diameter	5
Emission phase	Degrees	25
Longitudinal loss factor	V/pC	0.7
Transverse loss factor	V/pC/m	32

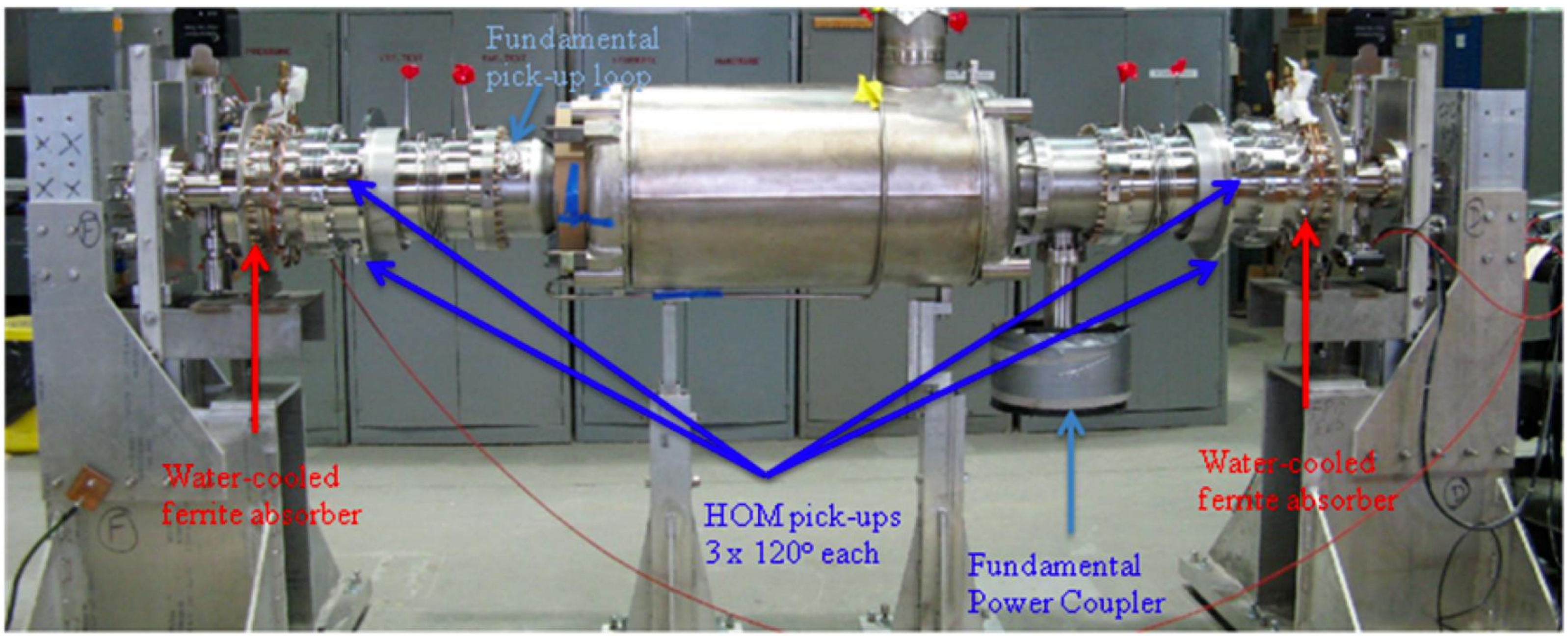
Load-lock 3rd Gen Deposition System

- •Multi-alkaline capability
- •Base pressure $1x10^{-10}$ Torr
- •System designed to eliminate cross contamination of sources
- •Provides for quicker source exchange
- •2 UHV transport systems with LN_2 cooling capability

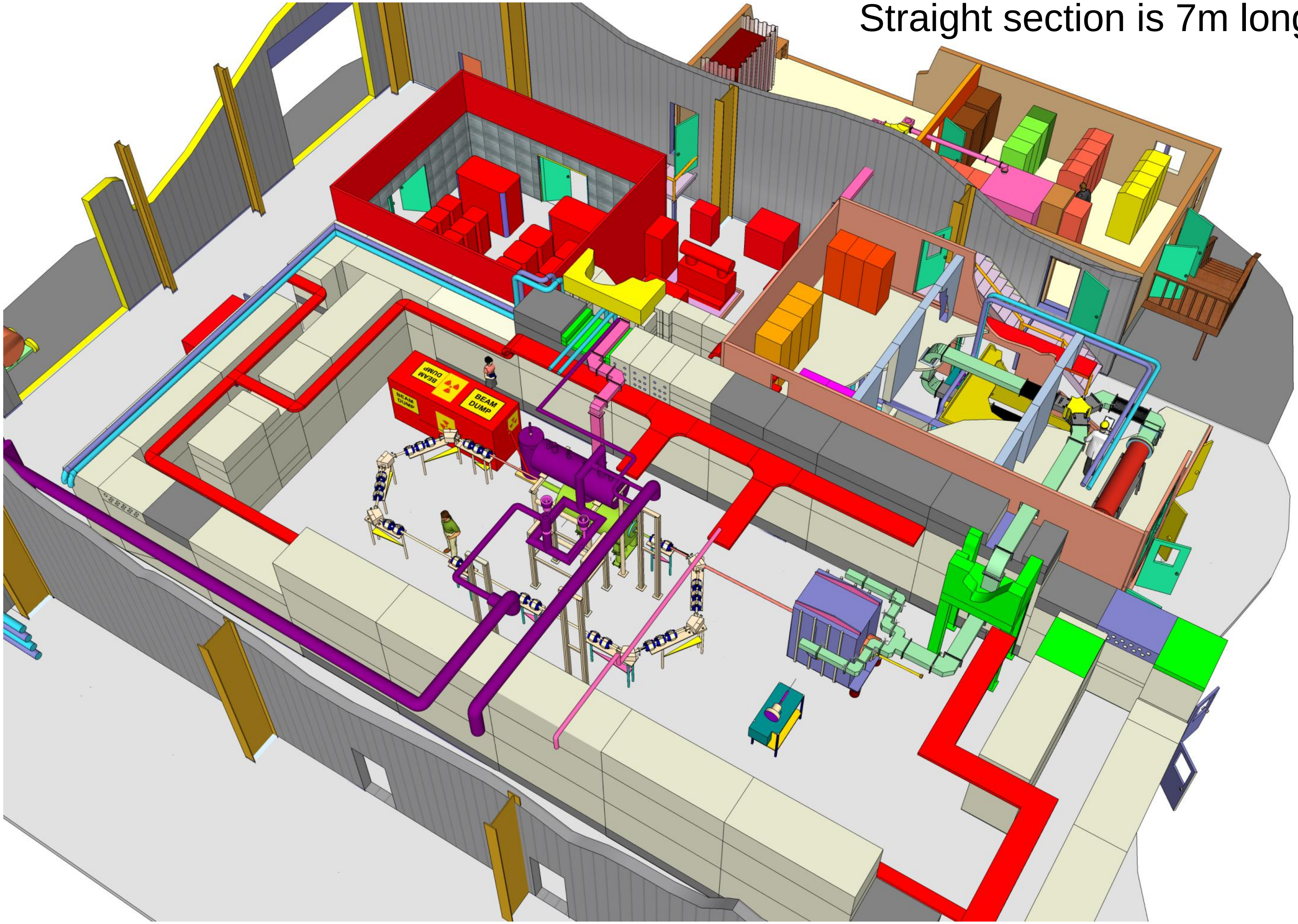


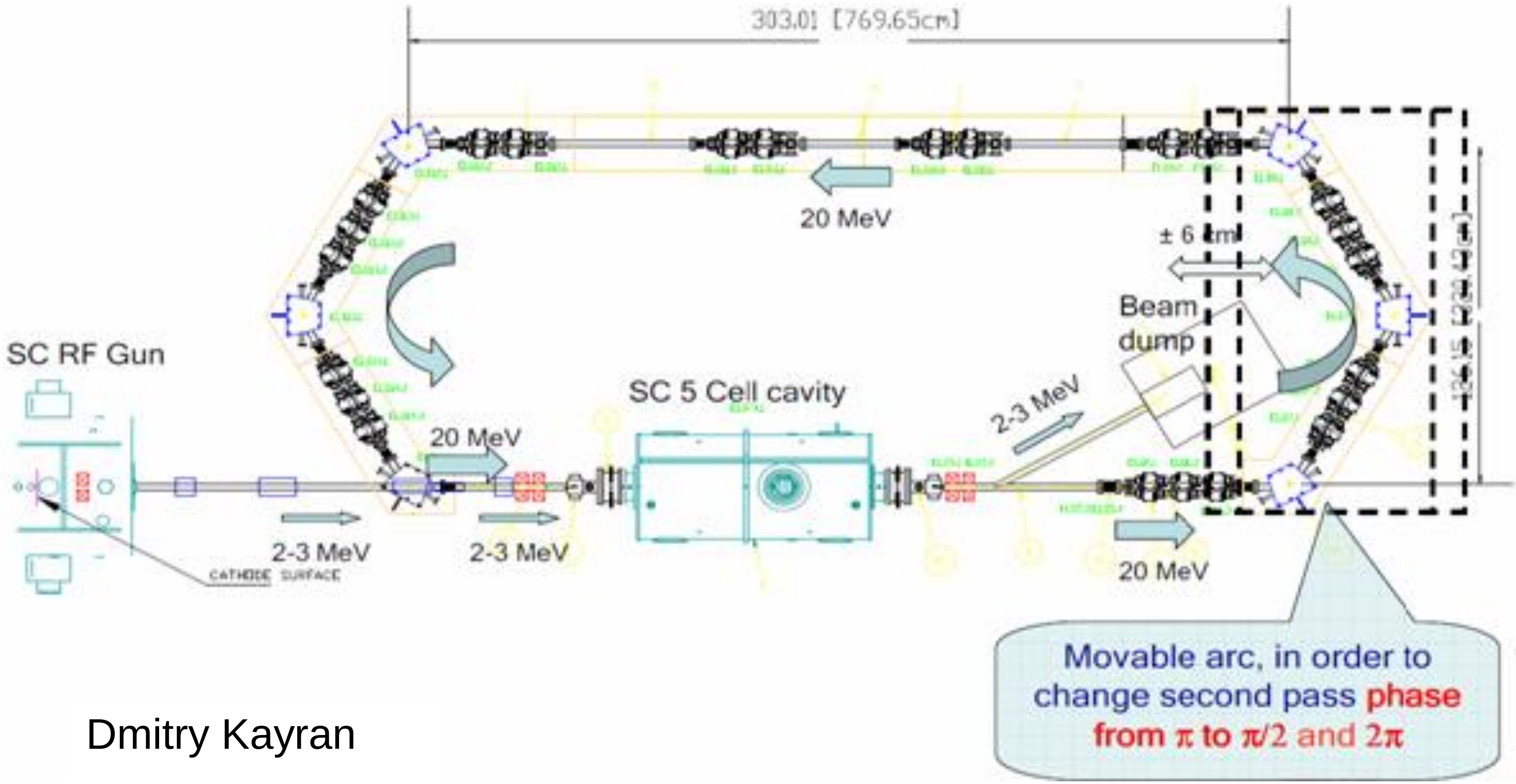

4Ó RF shielded gate valve
HO M ferrite assembly
Tuner bcat bn
2K main line
Space frame support structure
Cavity assembly
Vacuum vessel
2K fill line
Outer magnetic shield
Thermal shield
He vessel
Inner magnetic shield
Fundamental Power Coupler assembly




Fundamental pick-up loop
Water-cooled ferrite absorber
HOM pick-ups 3 x 120° each
Fundamental Power Coupler
Water-cooled ferrite absorber

ERL layout.
Straight section is 7m long



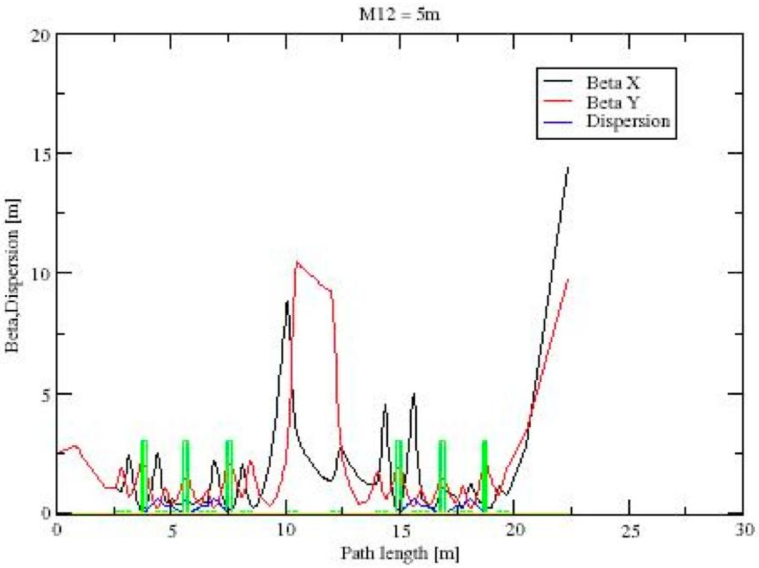


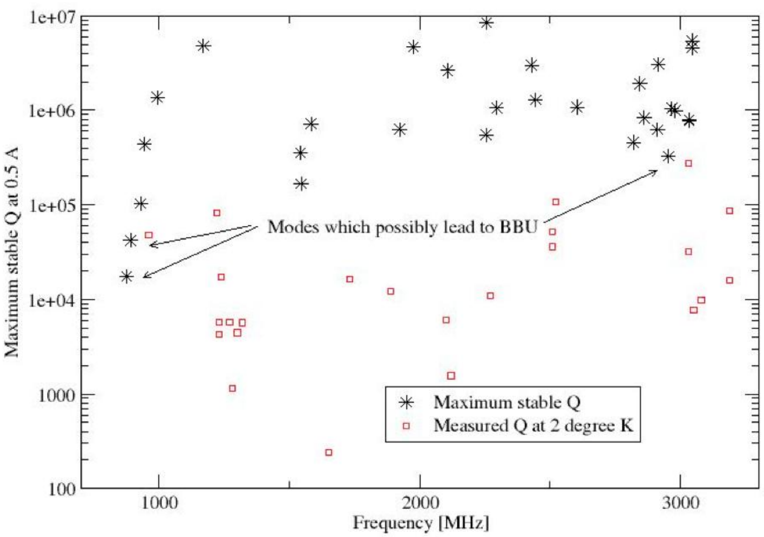
Dmitry Kayran

ERL Beam Design Parameters

	R&D ERL design		BNL ERL projects requirements				
	High Current	High charge	PoP CeC Test *)		Pre-cooling @ 40GeV	MEeRHIC	eRHIC 10/20
Charge per bunch, nC	**0.7**	**5**	**5**	**5**	**14 (9x1.56)**	**5**	**18/3.5**
Energy maximum/injection, MeV	20/2.5	20/3.0	21/3	21/3	21/3	4000/5	10000/5 20000/5
R.m.s. Normalized emittances ex/ey, mm*mrad	**1.4/1.4**	**4.8/5.3**	**5**	**5**	**3**	**7-73**	**77**
R.m.s. Energy spread, $\delta E/E$	3.5×10^{-3}	1×10^{-2}	1.5×10^{-3}	1.5×10^{-3}	$8\ 10^{-4}$	2×10^{-3}	1×10^{-3}
R.m.s. Bunch length, ps	18	31	30	30	30	6.7	30
Bunch rep-rate, MHz	700	9.383	0.078	9.383	9.383	9.383	14.1
Gun/dumped ave. current, mA	500	50	0.4	50	130	50	260/50
Linac average current, mA	**500**	**50**	**0.4**	**0.4/50**	**130**	**300**	**2600/500**
Injected/ejected beam power, MW	1.0	0.150	0.0012	0.15	0.390	0.250	1.3/0.250
Numbers of passes	1	1	1	1	1	3	5

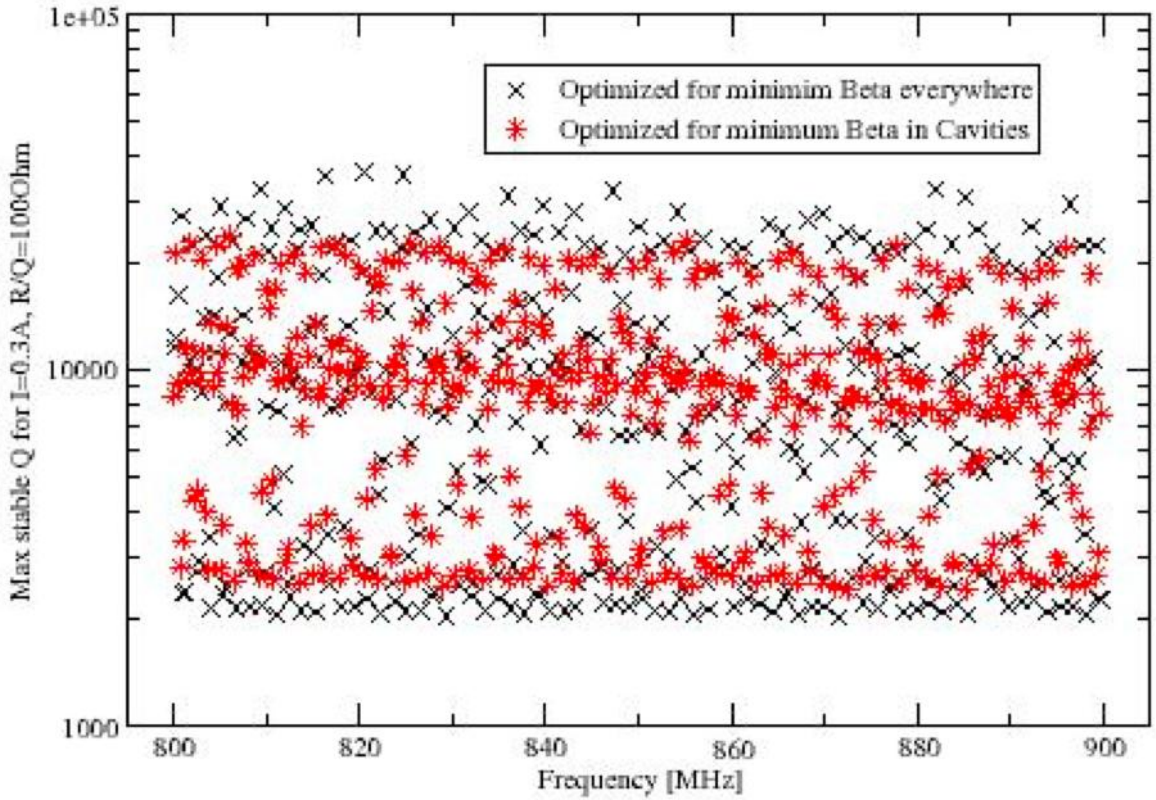
R&D ERL in mode aiming to cause BBU



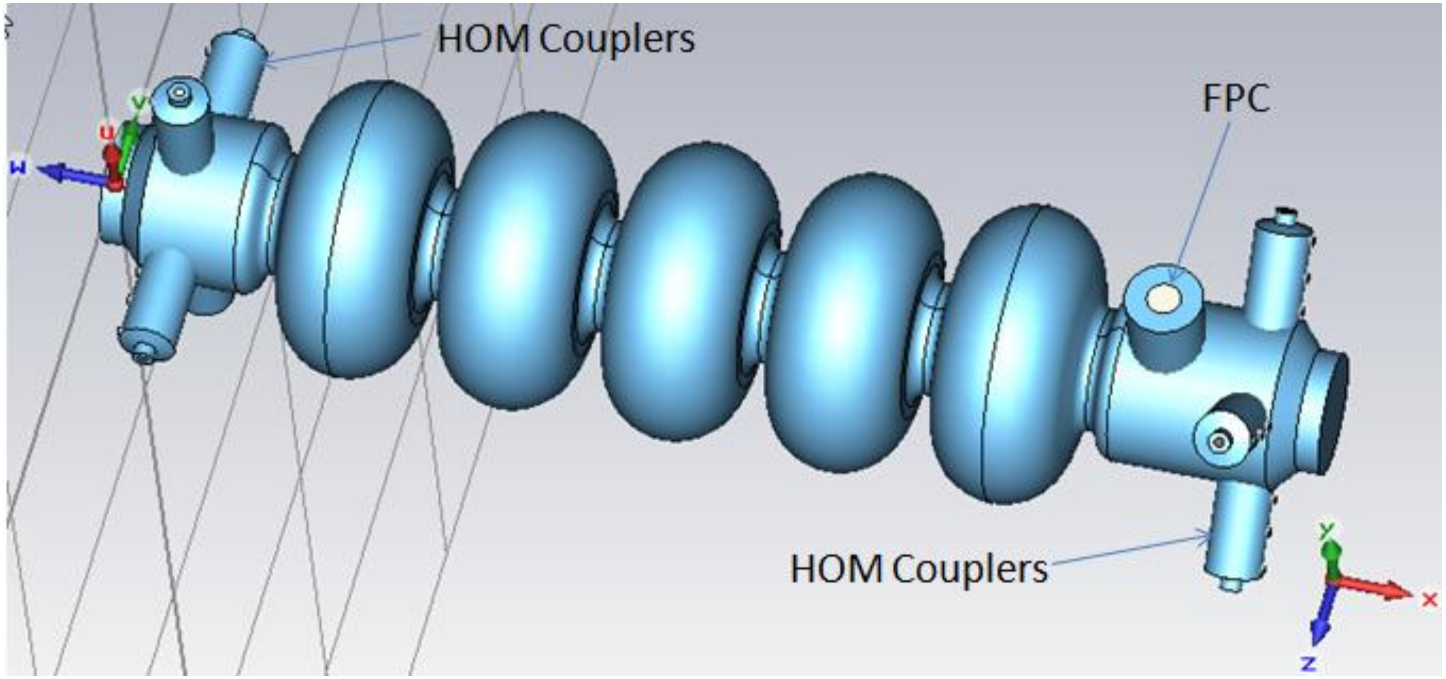


Dmitry Kayran, Harald Hahn, Lee Hammons, Jorg Kewisch.

Maximum stable Q in 4 GeV 3-pass ERL, at 0.3 A and a single dipole HOM with *R/Q*=100 Ω. These numbers are arbitrarily selected to demonstrate the application of the BBU code. Jorg Kewisch.



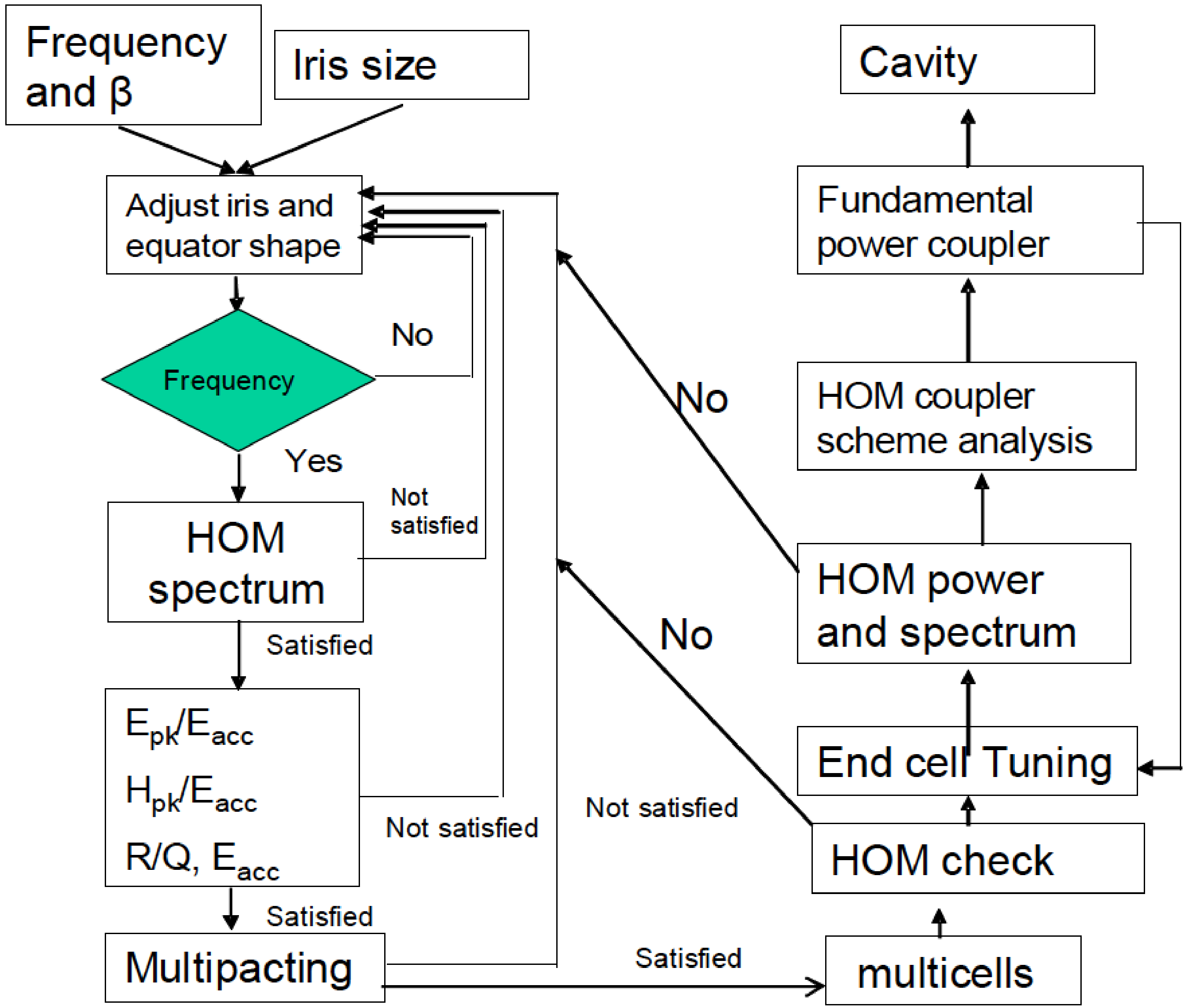
Design of new ERL cavity
Wencan Xu

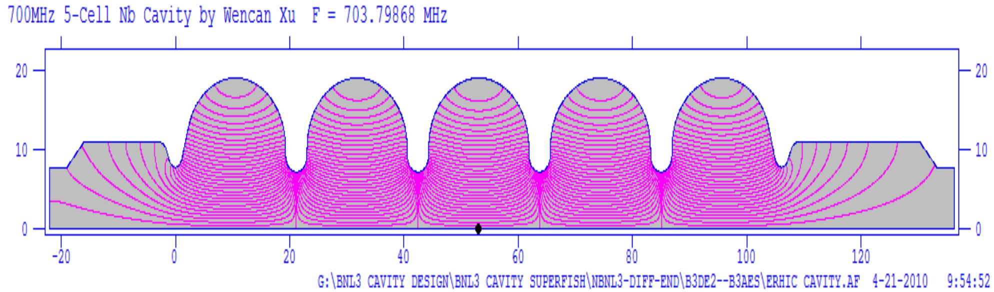


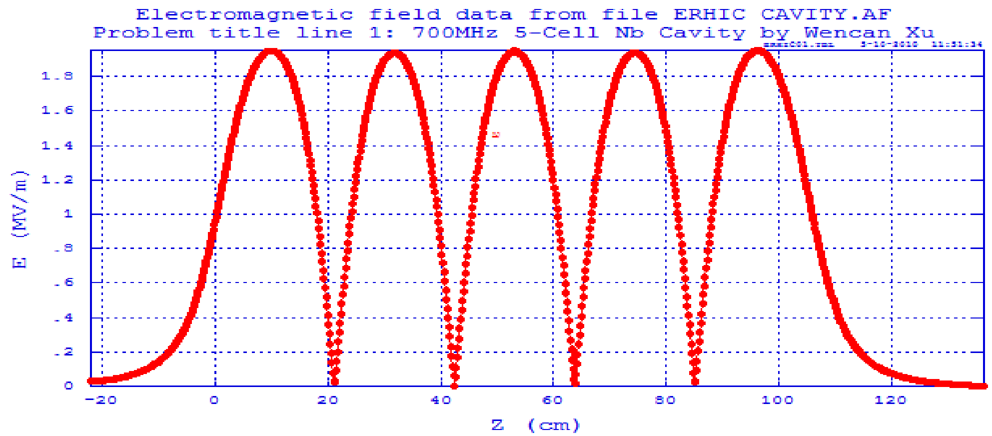
Hallmarks: Improved SRF properties and HOM damping.
Use pick-up probes rather than ferrites or waveguides.
HOM power conducted through coax lines to room temperature loads.

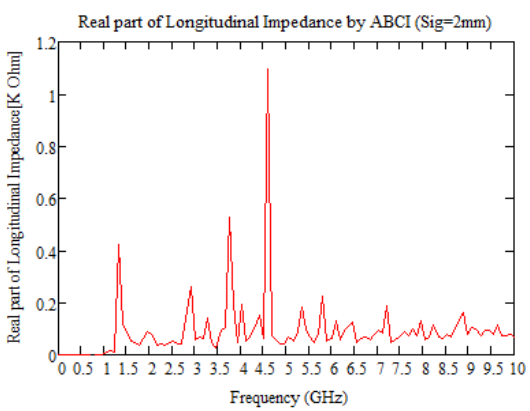
Steps of SC cavity design

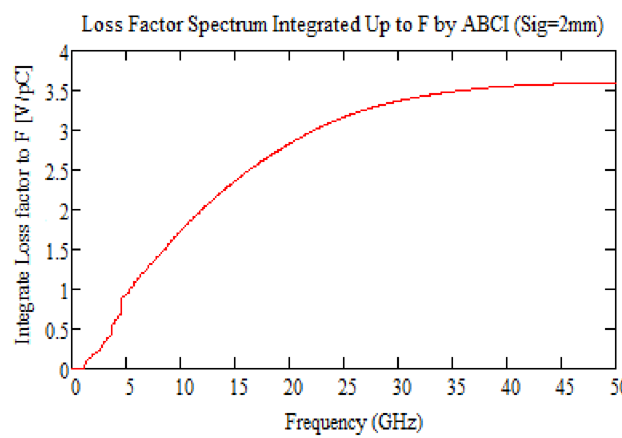
Wencan Xu




700MHz 5-Cell Nb Cavity by Wencan Xu F = 703.79868 MHz
G:\BNL3 CAVITY DESIGN\BNL3 CAVITY SUPERFISH\NBNL3-DIFF-END\B3DE2--B3AES\ERHIC CAVITY.AF 4-21-2010 9:54:52


Electromagnetic field data from file ERHIC CAVITY.AF
Problem title line 1: 700MHz 5-Cell Nb Cavity by Wencan Xu
E (MV/m)
Z (cm)


Real part of Longitudinal Impedance by ABCI (Sig=2mm)
Real part of Longitudinal Impedance[K Ohm]
Frequency (GHz)


Loss Factor Spectrum Integrated Up to F by ABCI (Sig=2mm)
Integrate Loss factor to F [V/pC]
Frequency (GHz)

Comparison: New and original

Parameters	BNL I	BNL III
Frequency [MHZ]	704	703.79
beta	1	1
Cells No.	5	5
Geometry Factor	**225**	**283**
(R/Q)/cell [Ω/cell]	**80.8**	**101.26**
Epeak/Eacc	1.97	2.46
Bpeak/Eacc [mT/MV/m]	**5.78**	**4.26**
Coupling factor [%]	3.00	3.02
Length (cm)	152	144 (SPL), 160 (eRHIC)
Beam pipe radius (mm)	120	110

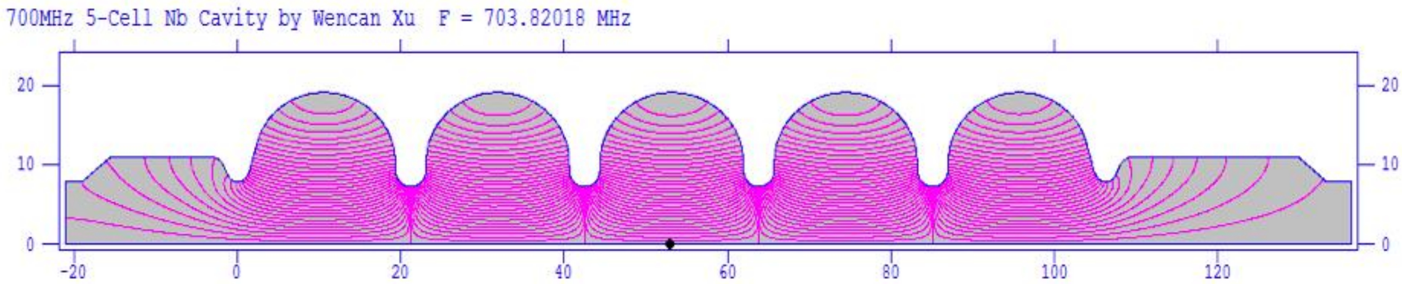
Comparison to other cavities

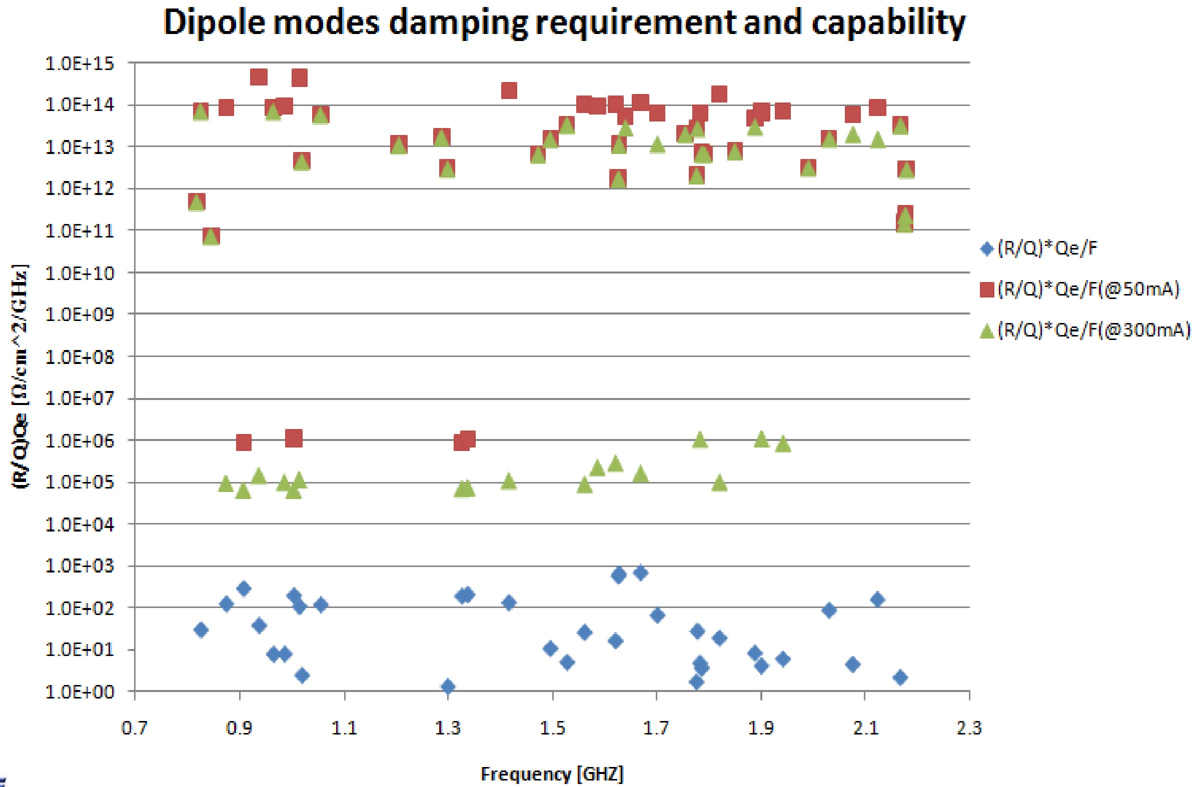
Cavity	Freq.(MHz)	beta	cell No.	Geometry factor	(R/Q) Ohm/cell	(R/Q)*G /cell	Epeak/Eacc	Bpeak/Eacc (mT/MV/m)	Kcc(%)
TESLA	1300	1	9	270.00	115.10	31077.00	2.00	4.26	1.87
ILC-LL	1300	1	9	284.00	133.70	37970.80	2.51	3.58	2.38
ANL	1407.7	1	5	276.00	93.40	25778.40	2.62	4.19	
Jlab-High current	750	1	5	279.40	104.30	29141.42	2.44	4.18	3.26
BNLI	704	1	5	225.00	80.80	18180.00	1.97	5.78	3.00
BNLII	704.4	1	5	275.94	101.70	28063.10	2.17	4.49	2.99
BNL3	703.82	1	5	283.53	101.53	28786.71	2.46	4.26	3.02

HOM trapping

Comparing Qext of HOM spectrum (f<1.5GHz)							
Range	BNL2(Et=0)				MeRHIC cavity(Both Et=0&Ht=0)		
>10^8	2-Sextupole	1- TE011			None	None	None
>10^7	2-TE011	1-Sextu			None	None	None
>10^6	1-TE011				1-Sextu		
>10^5	7-Quad	2-Sextupole			5-Sextu		
>10^4	2-Dipole				2-Quad	3-Monpole	1-Sextu
>10^3	6-Dipole				2-Dipole	12-modes: Se, Qo, Mon	
Comments	Several dangerous High-Q TE-modes				No dangerous high Q modes		

Performance in terms of BBU





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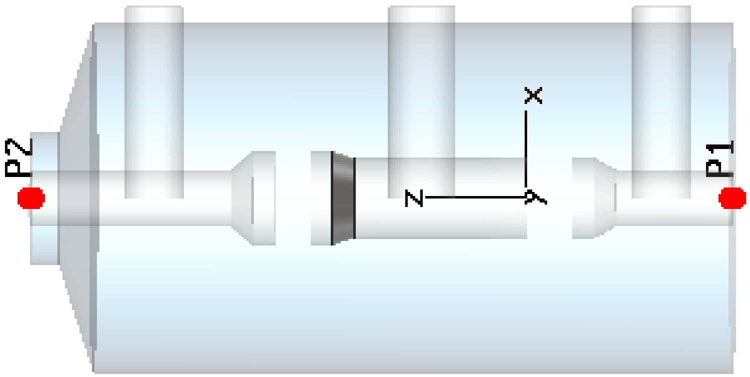
U.S. DEPARTMENT OF ENERGY

I. Ben-Zvi

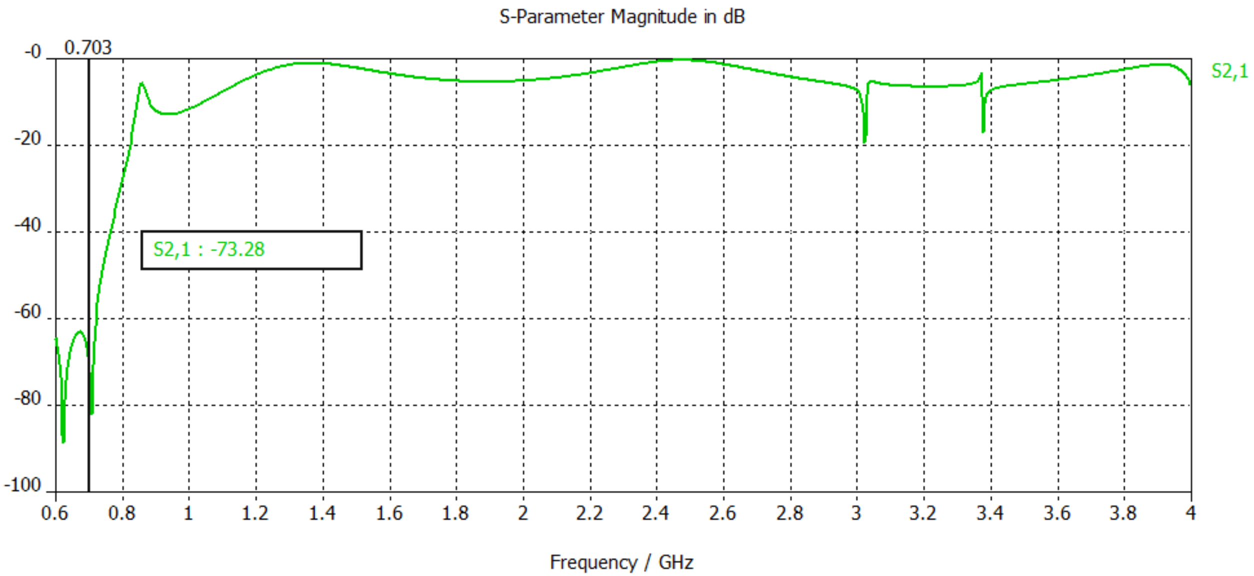
BROOKHAVEN
NATIONAL LABORATORY

Band-stop filter design

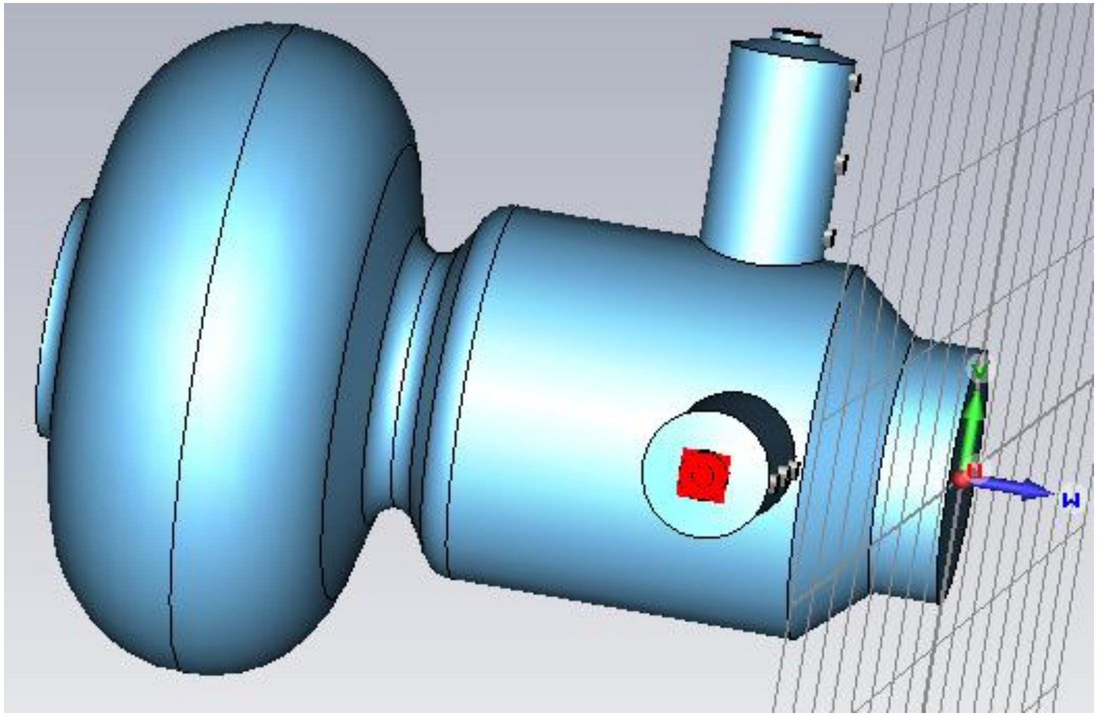
Wencan Xu



A band-stop filter is simpler and safer than a notch filter.

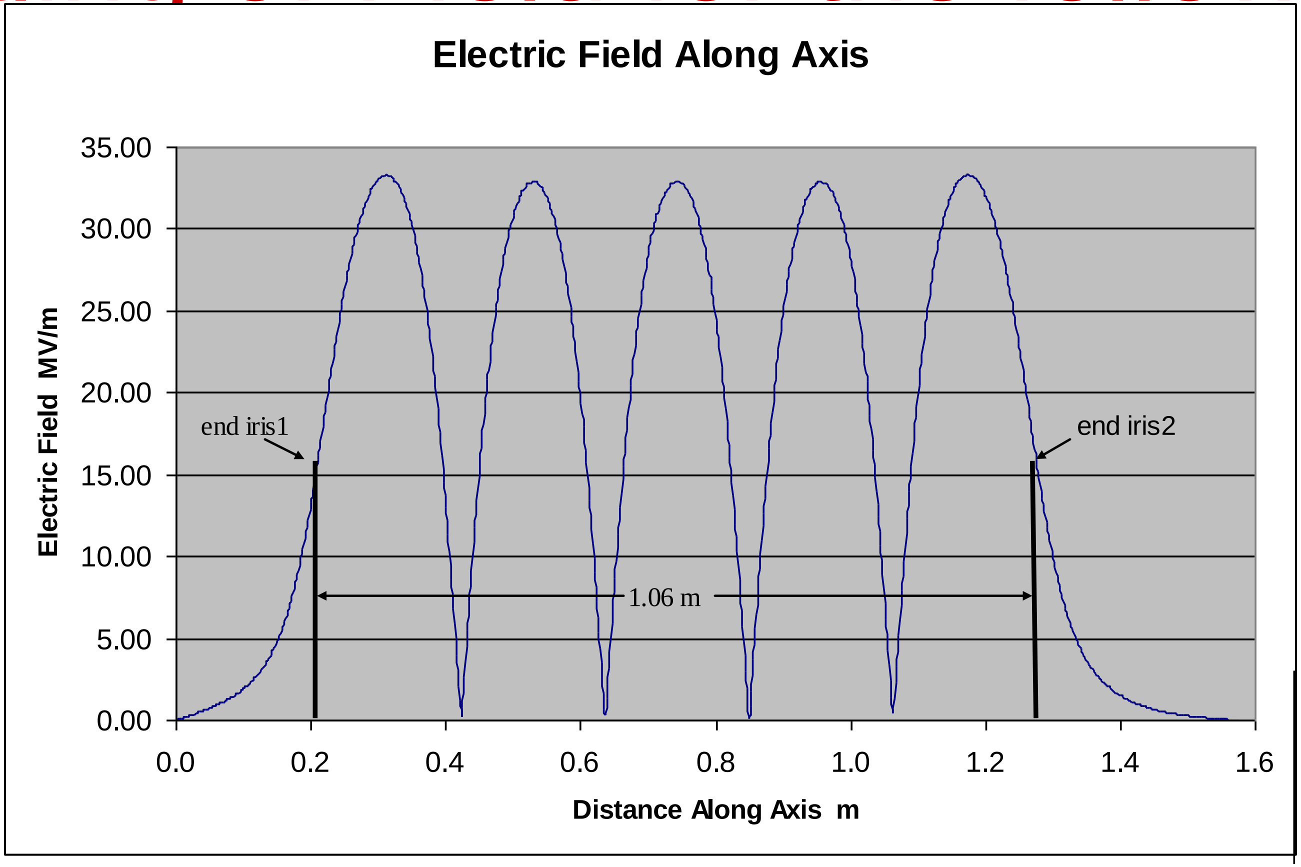


Single cell with band pass filter



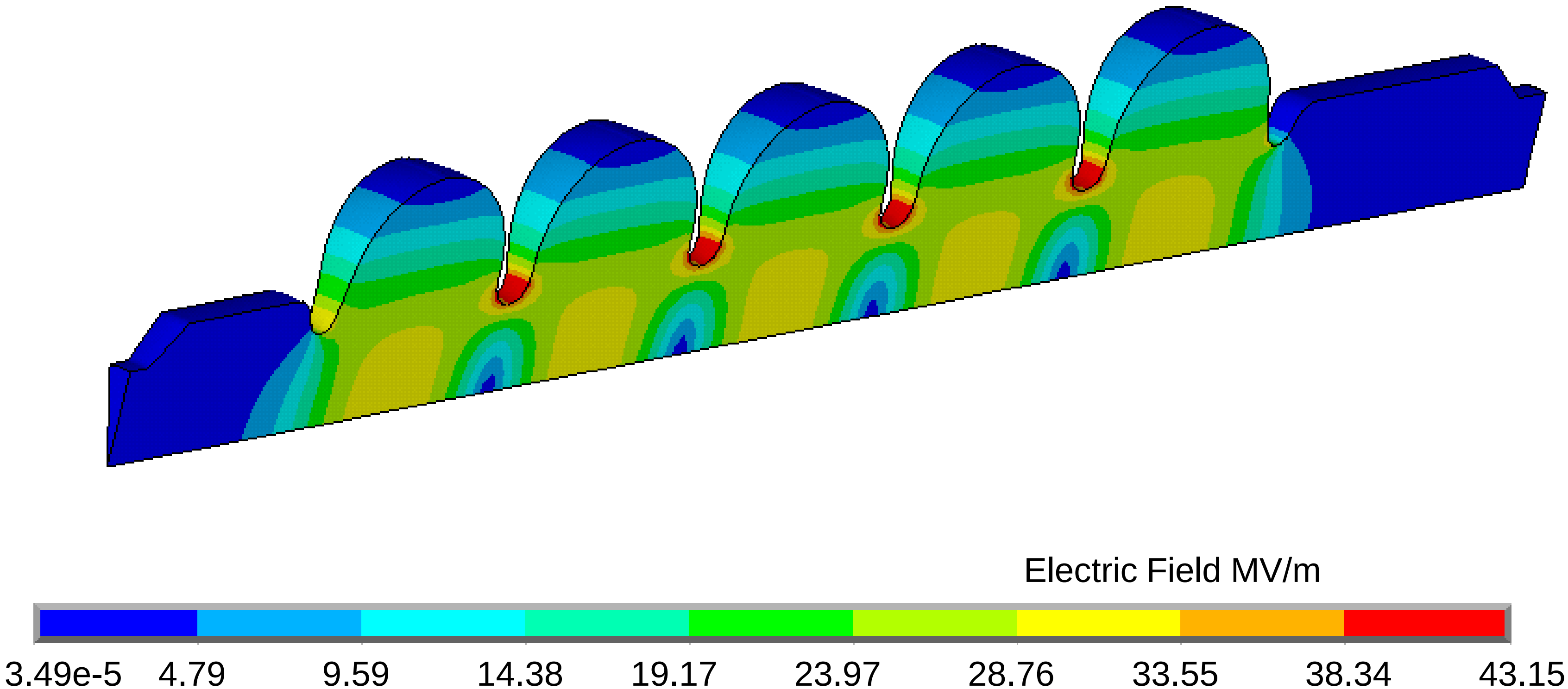
Mode	two HOM on beamtube BE with BP port	
	Frequency	External Q
F-mode	0.7037	3.460E+10
D-mode	0.8318	7.754E+03
	0.831826	4.404E+03
	0.92358	3.808E+02
	0.925749	3.854E+02
	0.9838	3.876E+03
	0.9847	2.711E+03
	1.19535	1.305E+03
	1.19583	1.403E+03
Q-mode	1.19659	1.242E+06
	1.1967	2.790E+05
	1.2636	8.843E+04

Scaling of Field for the following

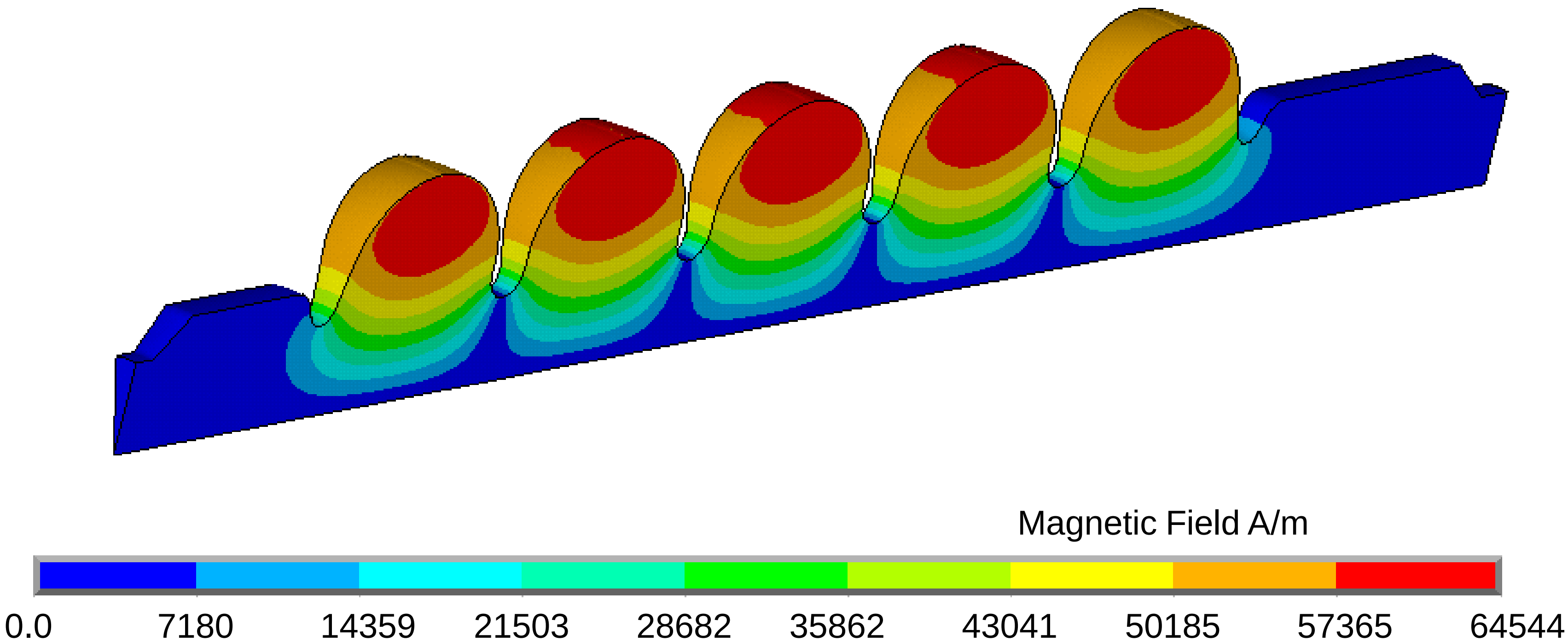


$$25 \text{ MeV} = \int_{\text{end iris1}}^{\text{end iris2}} E_z \partial_z$$

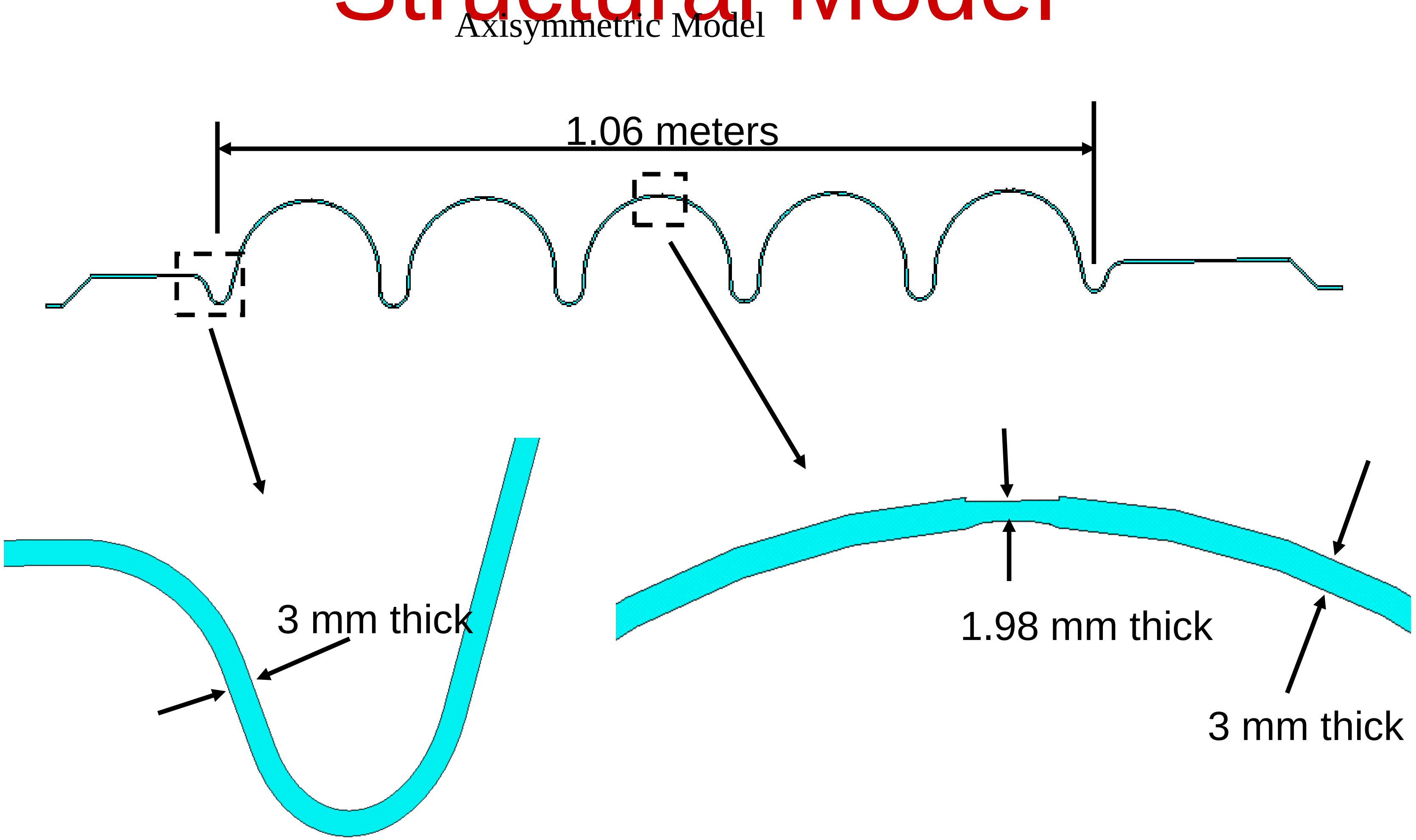
Electric field



Magnetic field

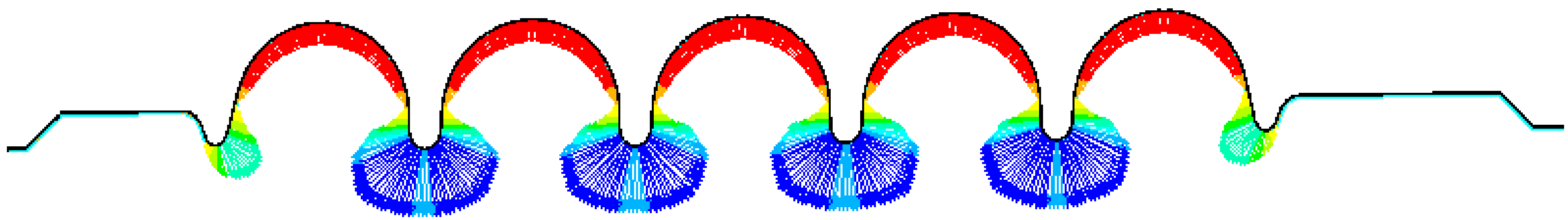


Structural Model



Lorentz Pressure

$$P_{Lorentz} = \frac{1}{4}\left(\mu_O H^2 - \varepsilon_O E^2\right)$$

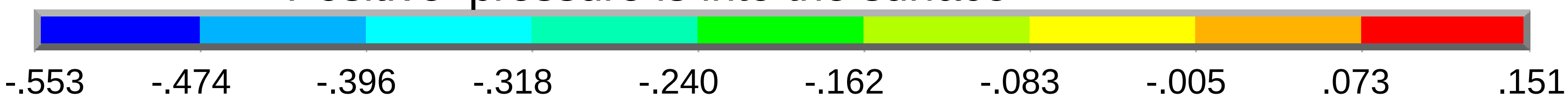


$$\partial f = -K_L E^2_{acc}$$

When K_L is positive the frequency shift is negative

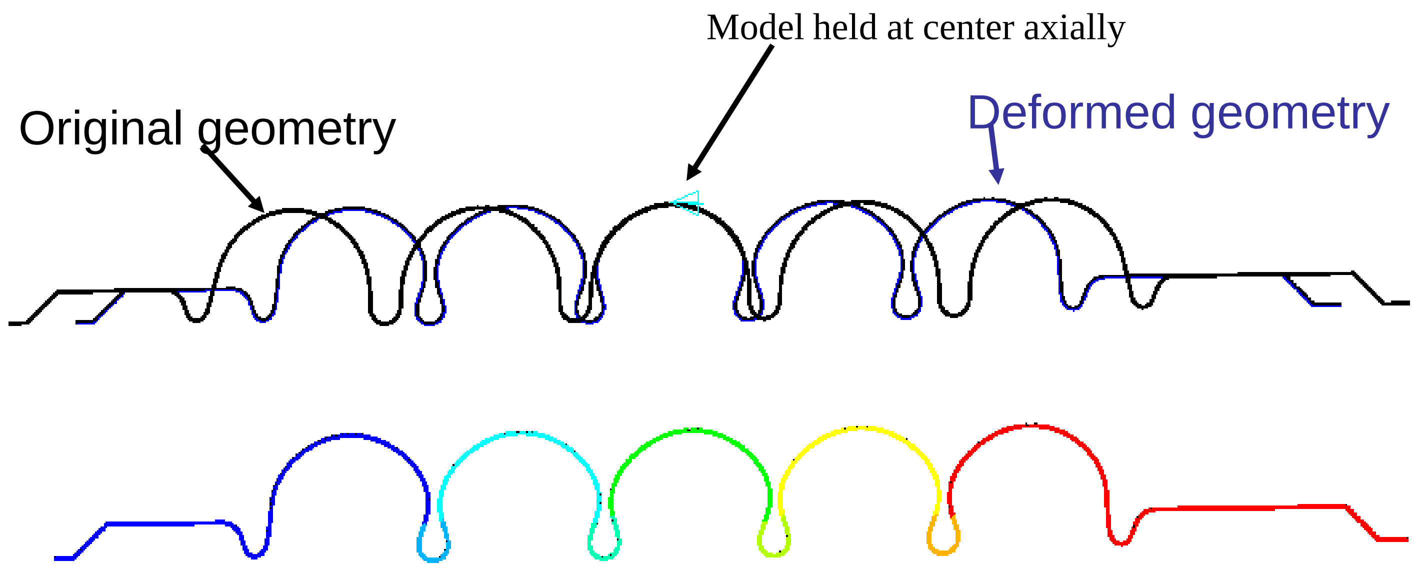
Positive pressure is into the surface

Lorentz Pressure psi

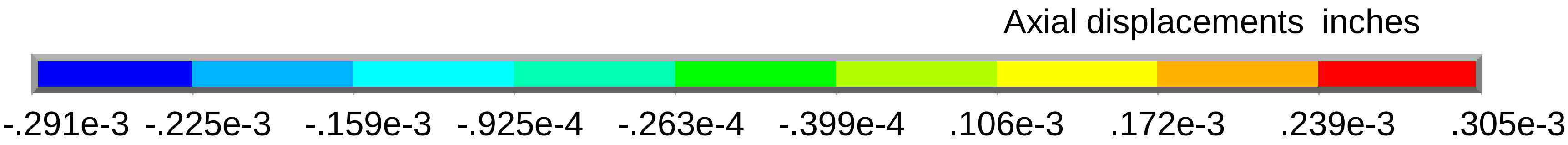


Model Deflection

Axisymmetric Model   Free – Free Boundaries



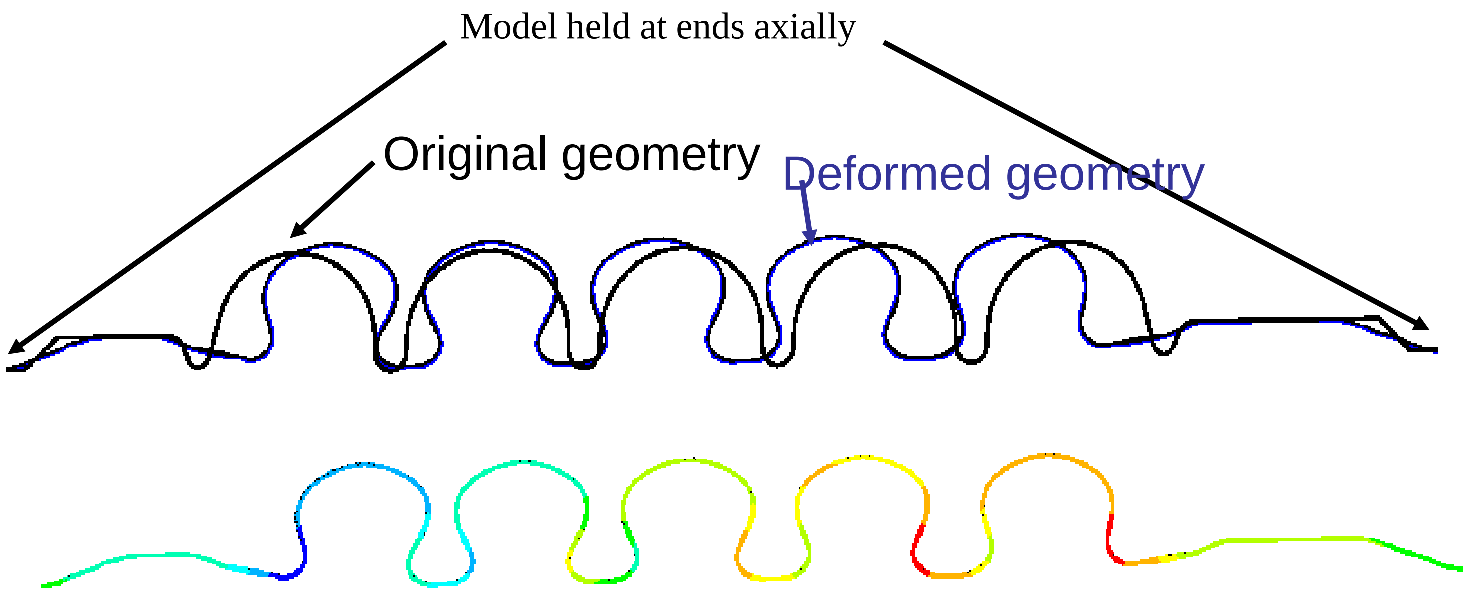
Lorentz Detuning Coefficient 4.01 Hz/(MV/m)^2



Model Deflection

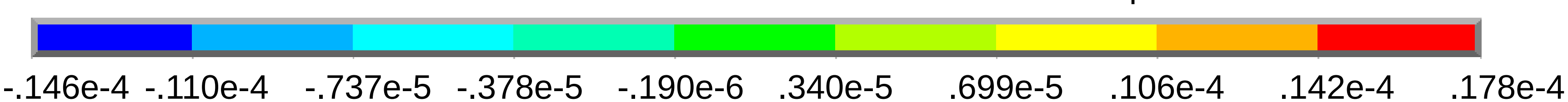
Axisymmetric Model

Fixed – Fixed Boundaries

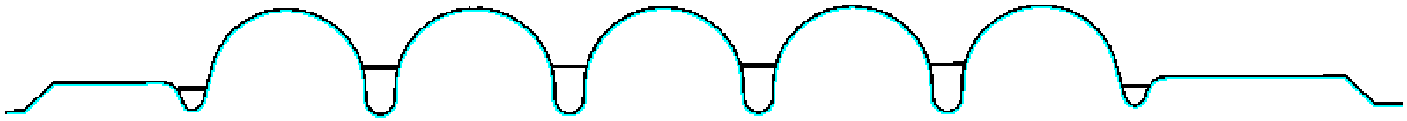


Lorentz Detuning Coefficient .579 Hz/(MV/m)^2

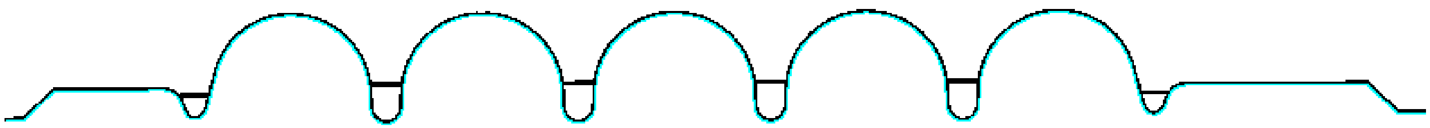
Axial displacements inches



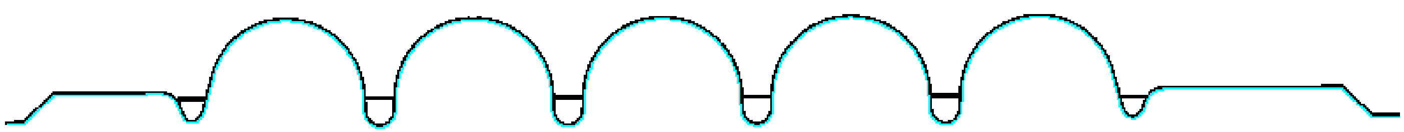
Location of Stiffeners



10.45 cm Center stiffeners at radius of 12.78 cm 10.45 cm

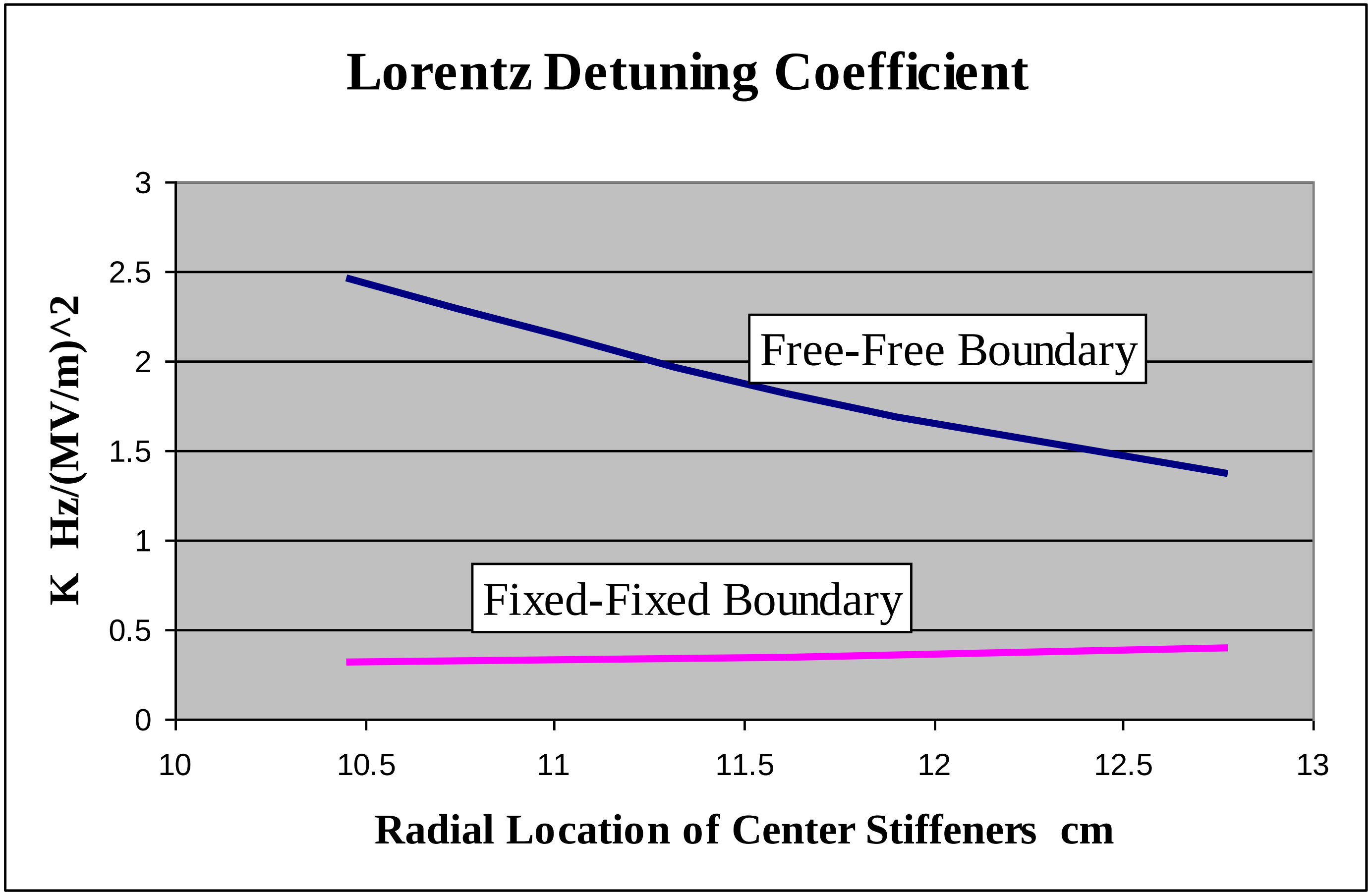


10.45 cm Center stiffeners at radius of 11.61 cm 10.45 cm

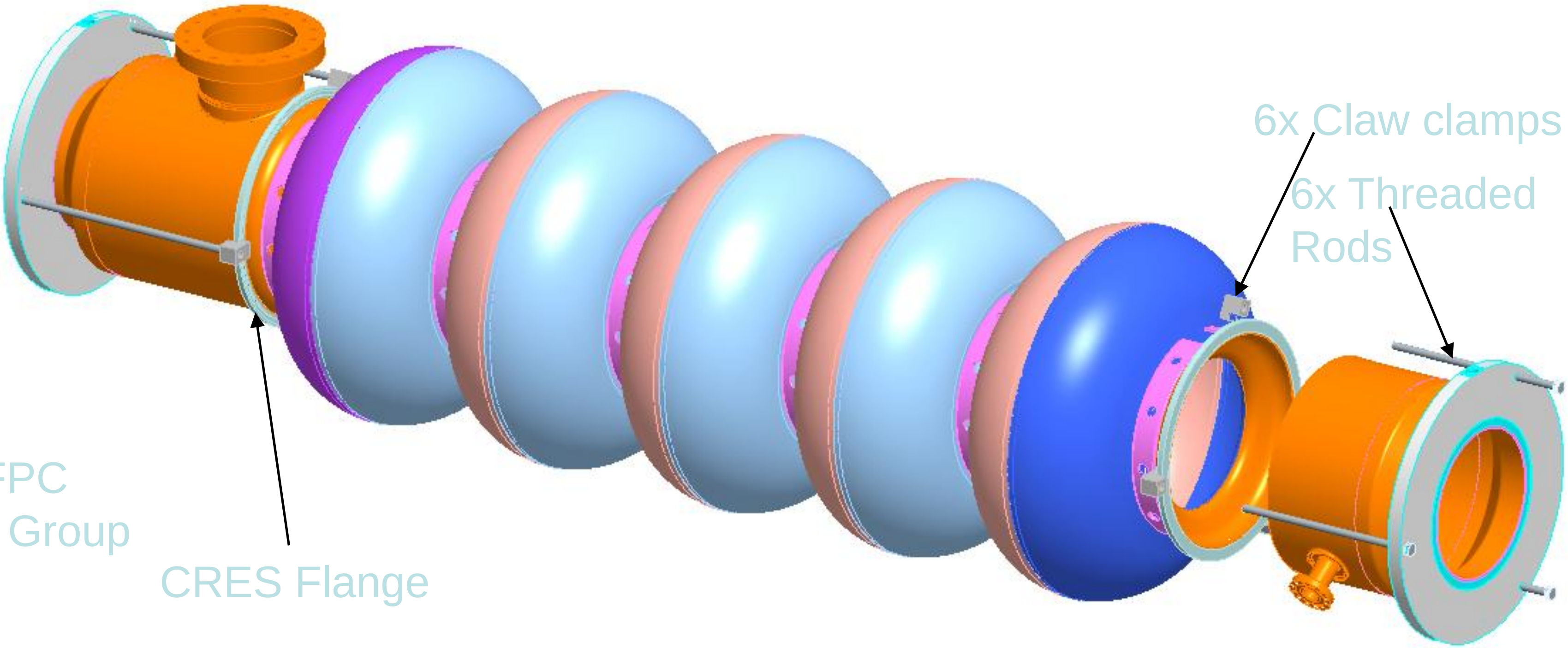


Stiffeners centered at radius of 10.45 cm

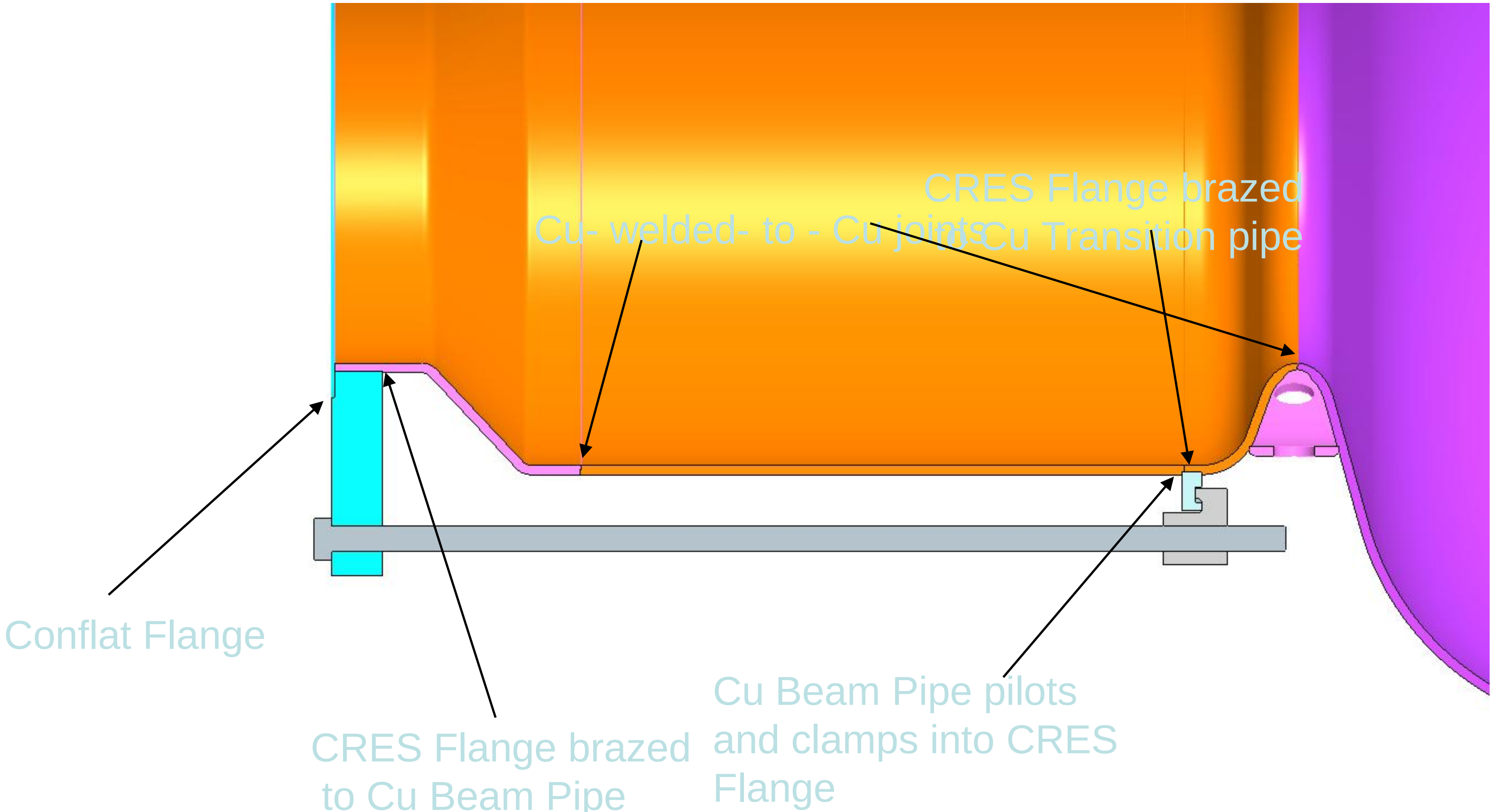
Lorentz Coefficient for Different Stiffener Locations



Design of a copper prototype (AES)



Beam Pipe joints



SUMMARY

- A new R&D ERL is in advanced construction
- ERL is a test-bed for high current technologies
- Development of new cavity
- New features:
  - Better SRF performance
  - Probe with coax line and band-stop filter
- The result - a universal 704 MHz cavity.