Quarter Wave Crab Cavity Design and Status

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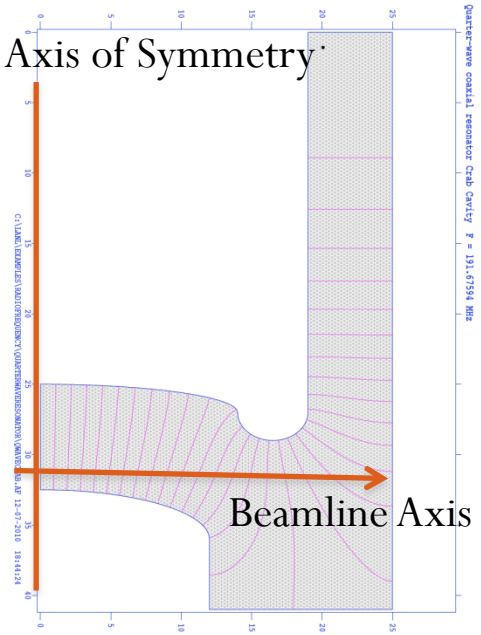
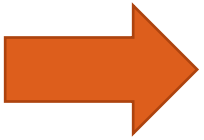
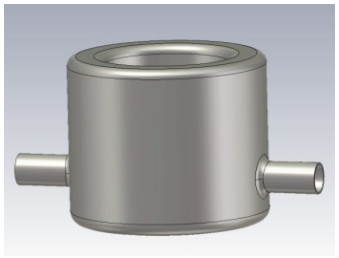
Outline

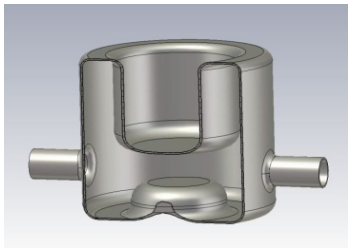
- The original idea
- Optimization
- Cavity parameters
- Higher Order Mode (HOM) damping
- Multipacting
- Existing Quarter Wave Resonators (QWR)
- Future plan
- Summary

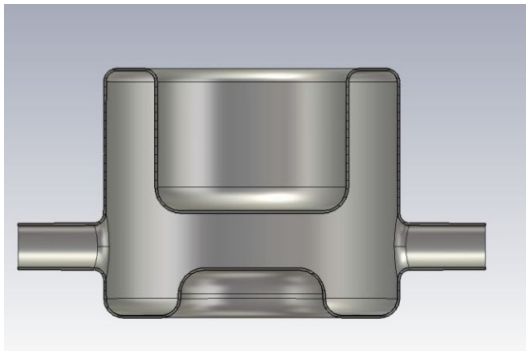
The Original Idea











	Crabbing (fundamental) mode freq.	1st HOM	Cavity length	Cavity width	Beam pipe diameter	Deflecting voltage	Epeak	Bpeak	R_t/Q	Accelerating voltage
Unit	MHz	MHz	cm	cm	cm	MV	MV/m	MV/m	Ω	MV
QW crab cavity	400	625	34	17.4/7	10	3.8	34	13	167	0.3

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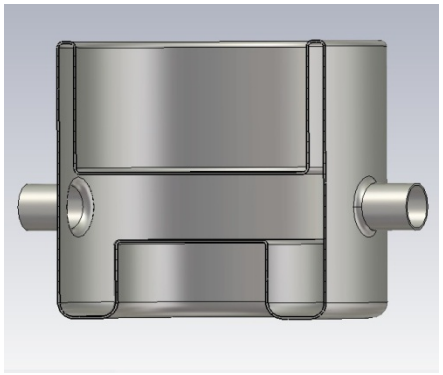
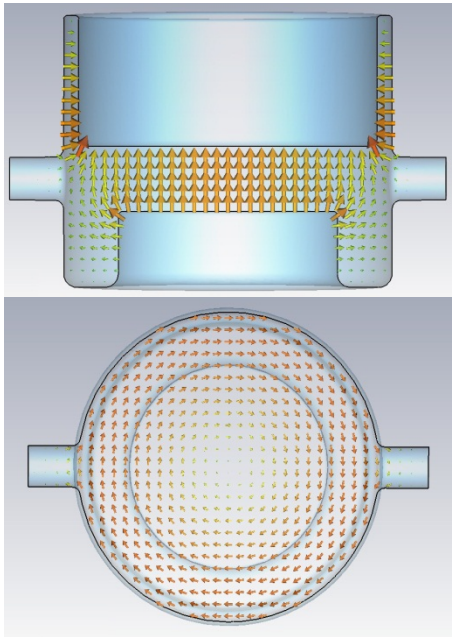
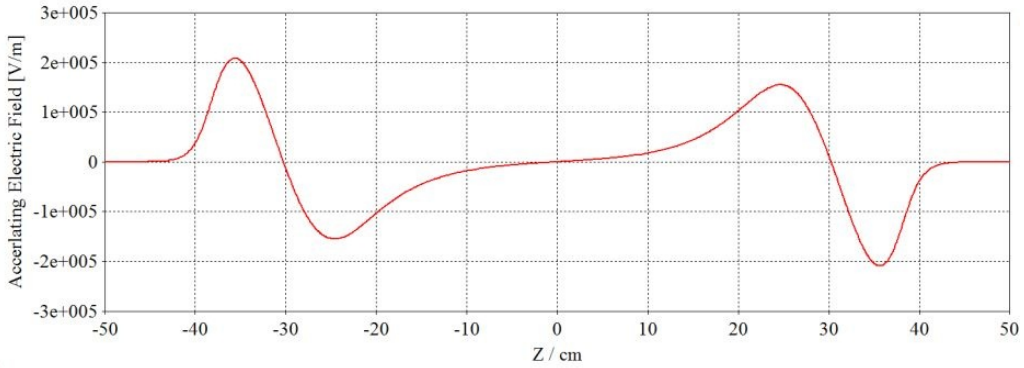
For eRHIC







Accelerating field along the beam axis.

Q.Wu et al. @ SRF11

$$\frac{\partial}{\partial z}p_{\perp} = \nabla_{\perp} p_z \quad \Rightarrow \quad V_y = \left| \left(\frac{c}{\omega}\right) \int_{-L/2}^{L/2} (-i) \nabla_y E_z \, dz \right|$$

$$V_{acc} = \left| \int_{-L/2}^{L/2} E_z(r=0,z) e^{-ikz} \, dz \right|$$

	Unit	QW crab cavity
Crab mode frequency	MHz	181
Nearest other mode frequency	MHz	251
Cavity length	cm	75.2
Cavity width	cm	38.1/25.1
Diameter of large electrode	cm	68.6
Diameter of small electrode	cm	50.2
Height of large electrode	cm	30.6
Height of small electrode	cm	17.6
Deflecting voltage*	MV	6.1
Peak surface electric field*	MV/m	39
Stored energy*	J	100
R_t/Q	Ω	291
Accelerating voltage*	MV	0**

*: Normalized to 100 mT peak magnetic field.
**: For beam pipe radius of 5 cm.

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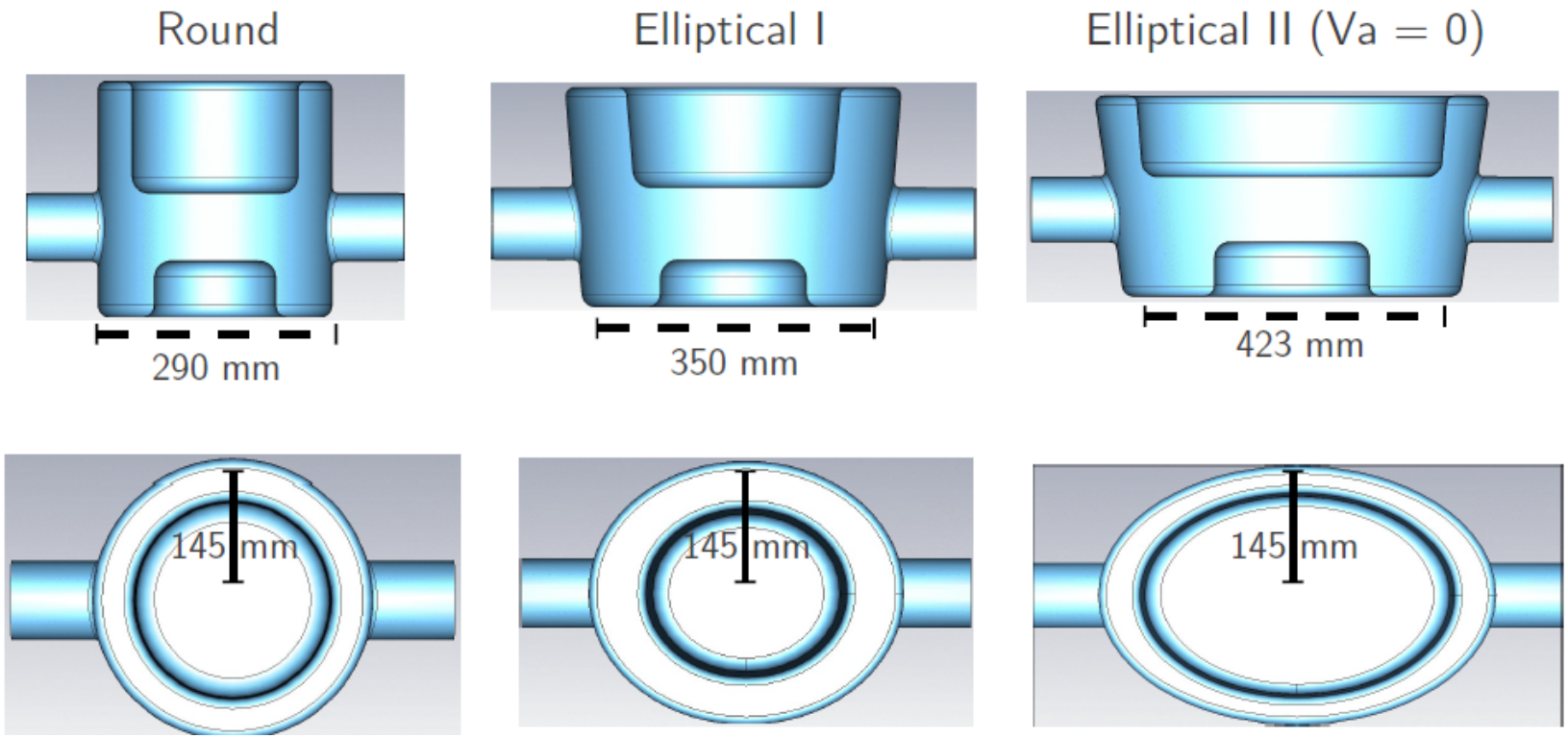
Optimization for LHC

- Deflection mode frequency: 400MHz
- Aperture: 84mm
- Deflection voltage per cavity: 3MV
- Max cavity envelop (width and height): 150mm
- Low peak fields
- High Rt/Q
- None or reasonable acceleration voltage
- Simple fabrication

Three versions



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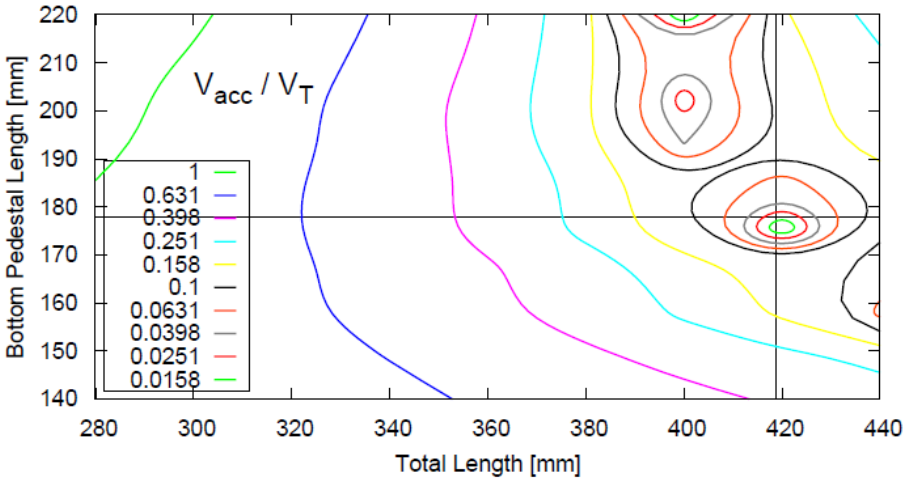
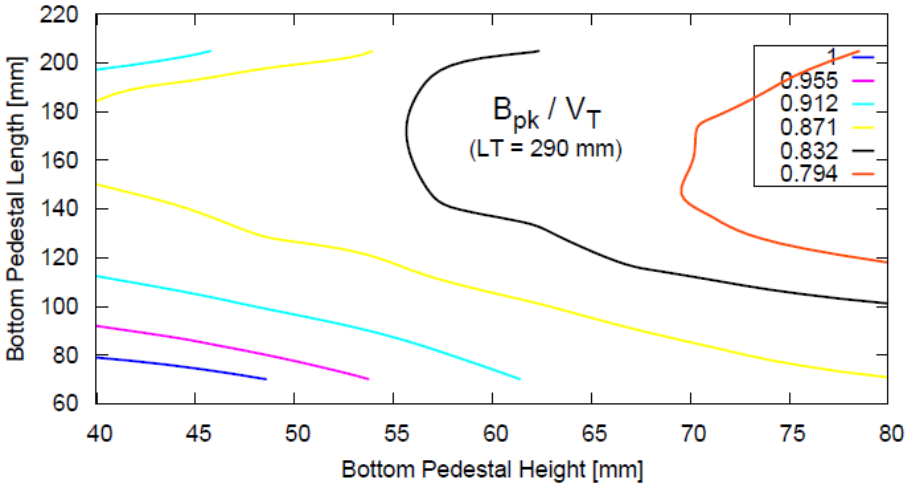
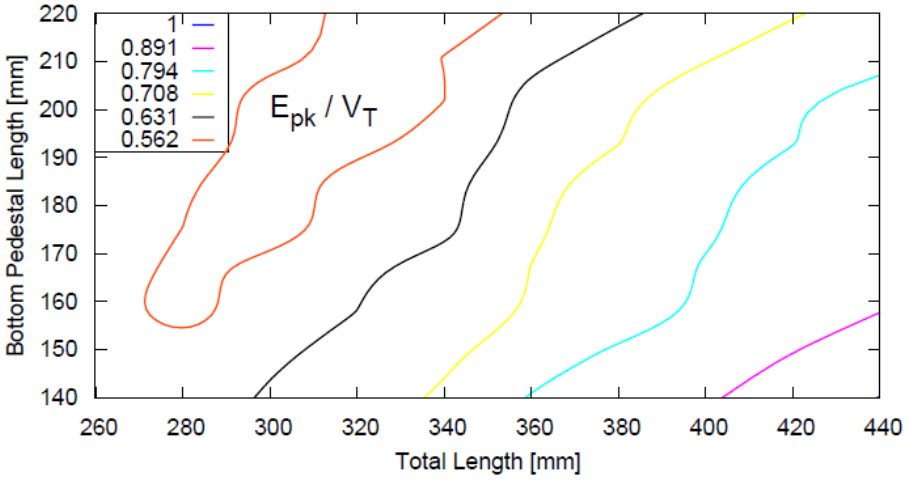
Optimization

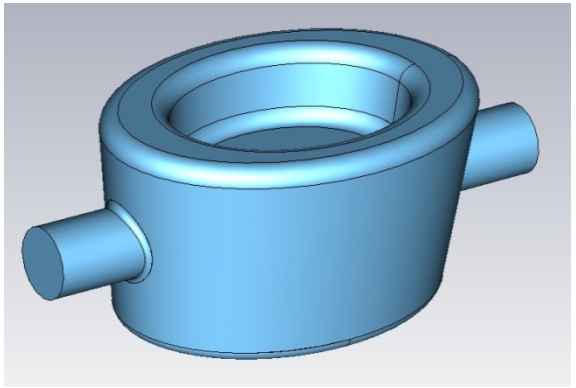


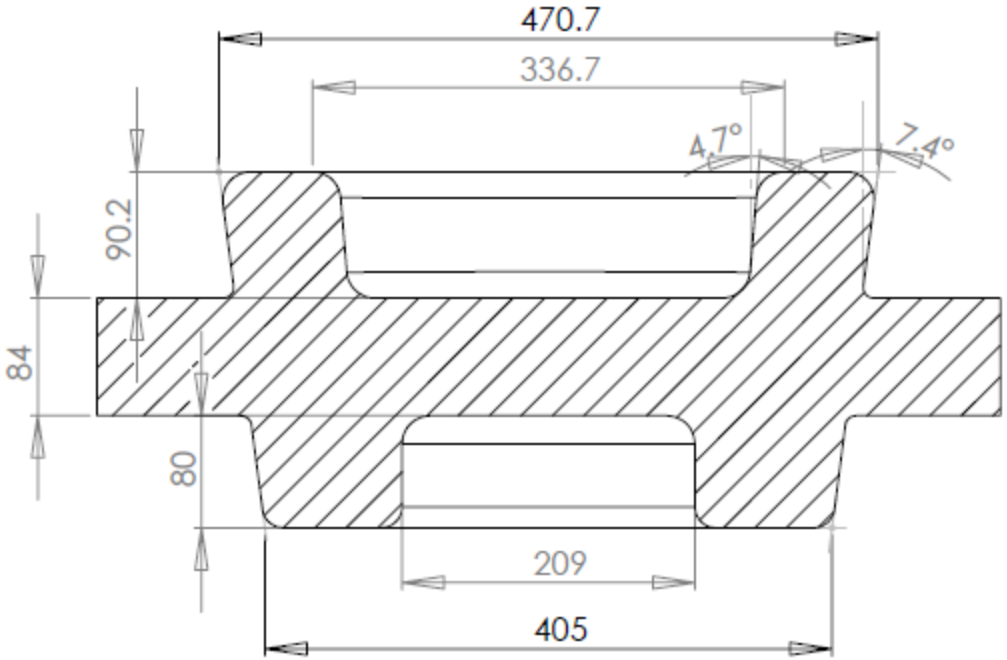


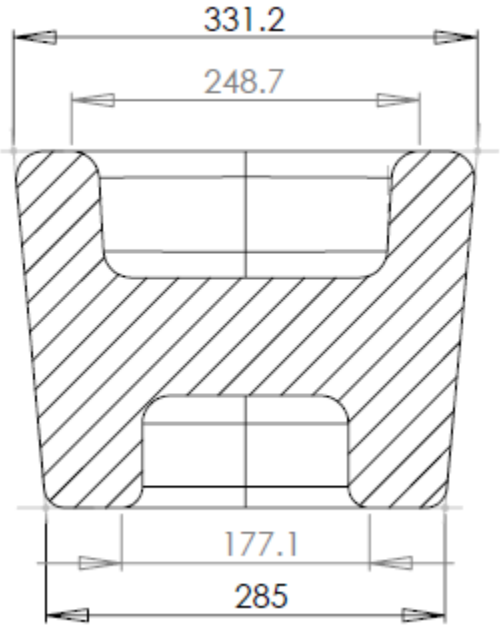


R. Calaga @ IPAC12

Cavity Parameters







unit: mm

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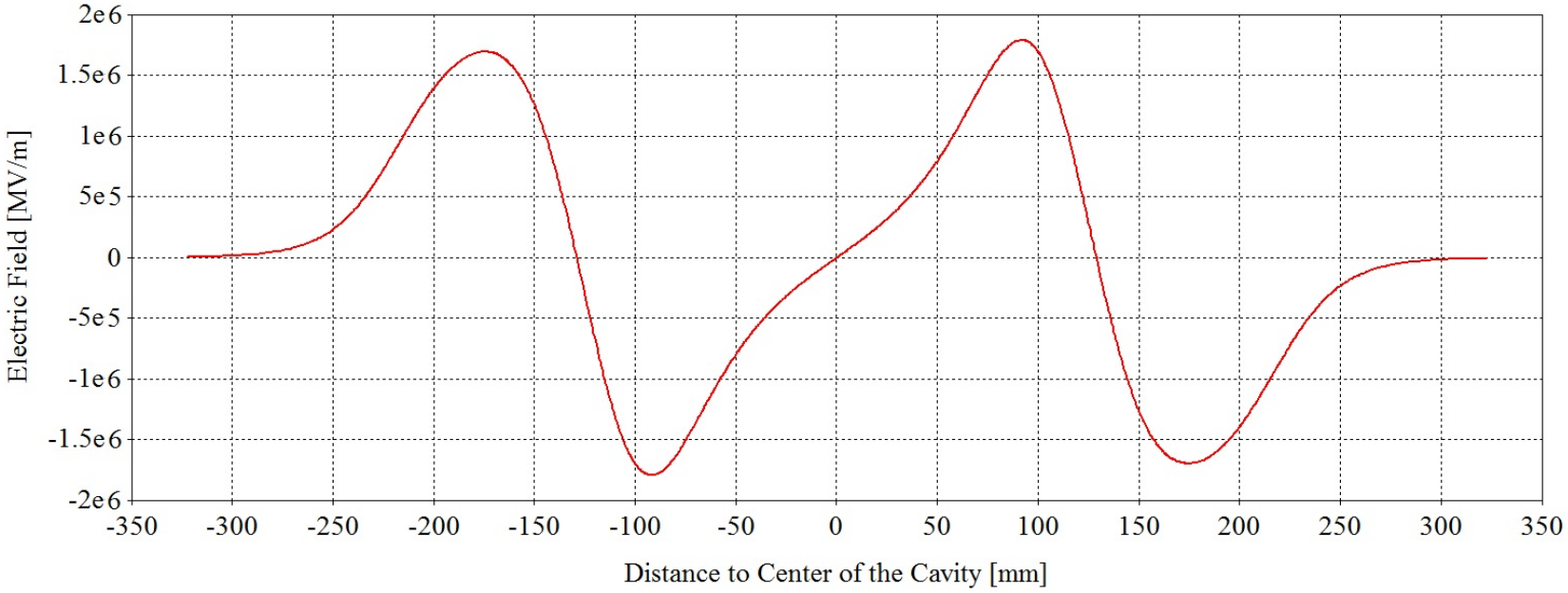
Cavity Field

Peak longitudinal electric field of fundamental mode with 3MV vertical deflection voltage

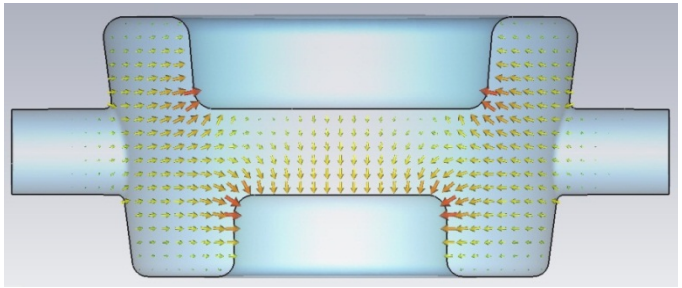


Another option for cancelling the acceleration voltage would be slightly offset the cavity in the deflection direction during installation. A few mm would be enough.

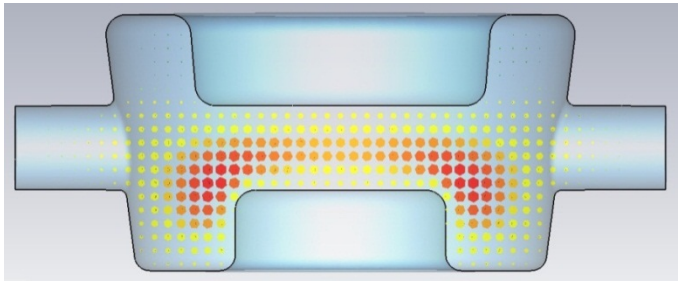
Cavity Parameters

	Unit	Optimized QWCC
Fundamental Mode Frequency	MHz	400
Nearest Mode Frequency	MHz	657
Vertical Deflection Voltage	MV	3
Rt/Q (Fund. Mode)	Ohm	341
Epeak	MV/m	44
Bpeak	mT	60
Vacc	MV	0.12
Energy Content	J	10.6

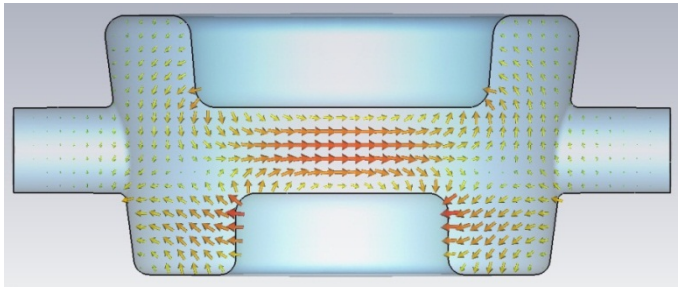
Electric field



deflection mode

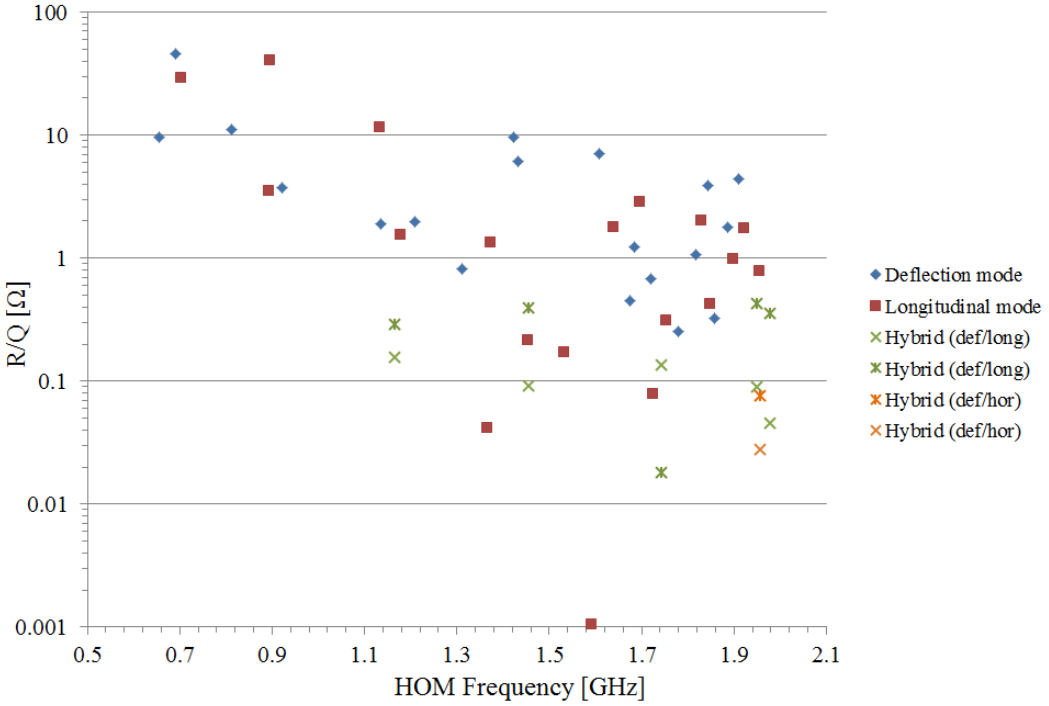


horizontal mode



longitudinal mode

HOMs



HOM Damping

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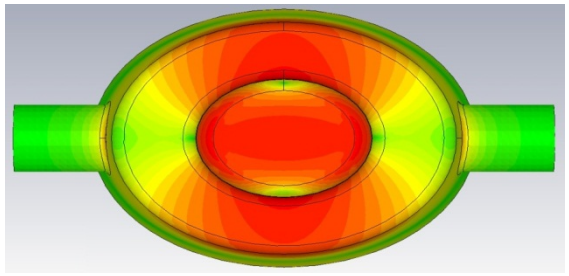
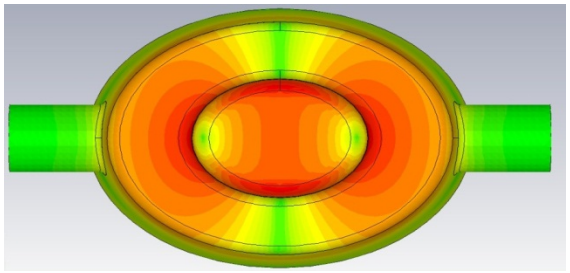
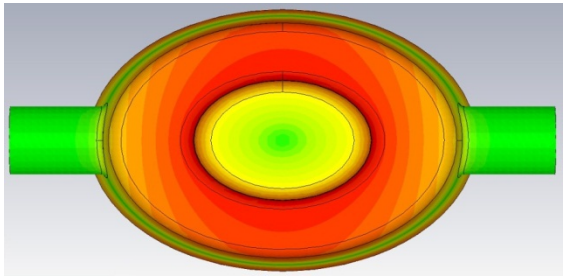


0.657GHz

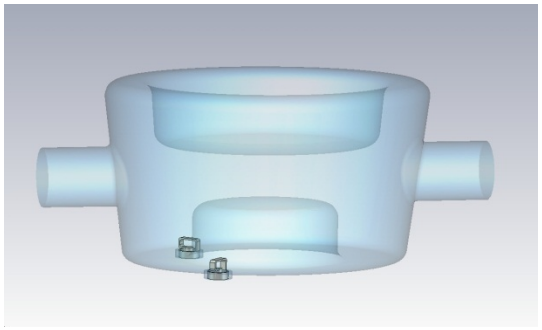


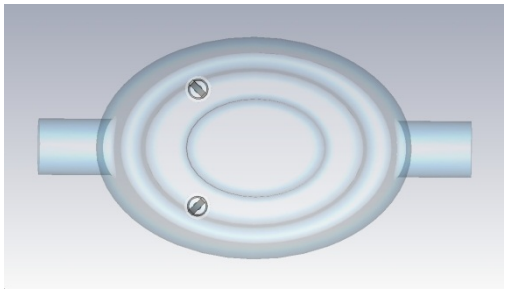
0.812GHz

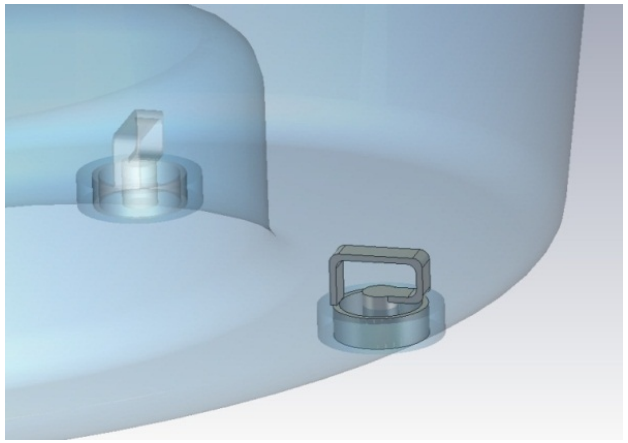


0.893GHz

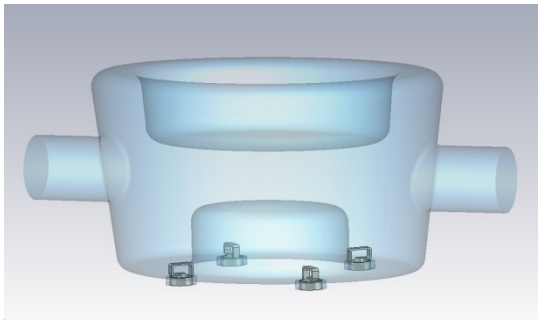
HOM Damping I

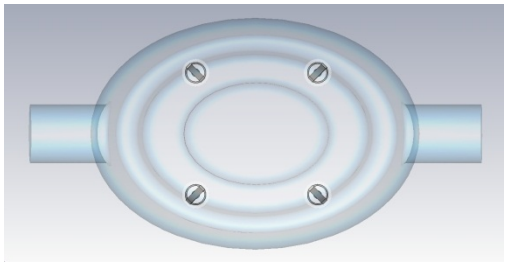






HOM Damping II



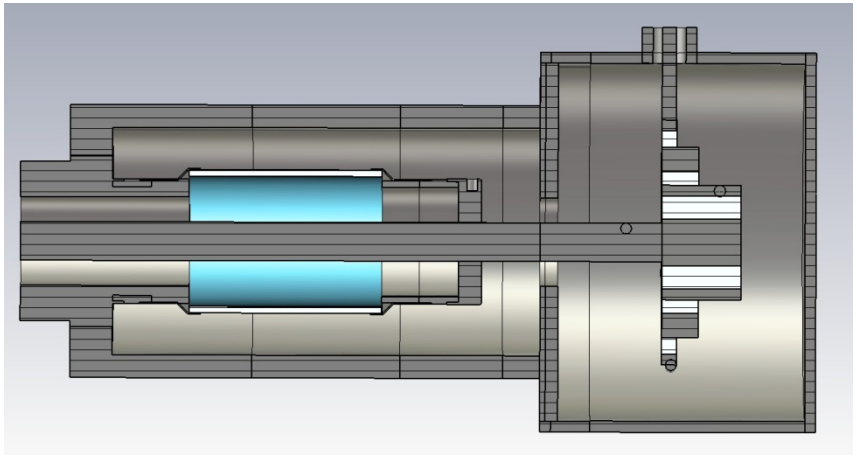


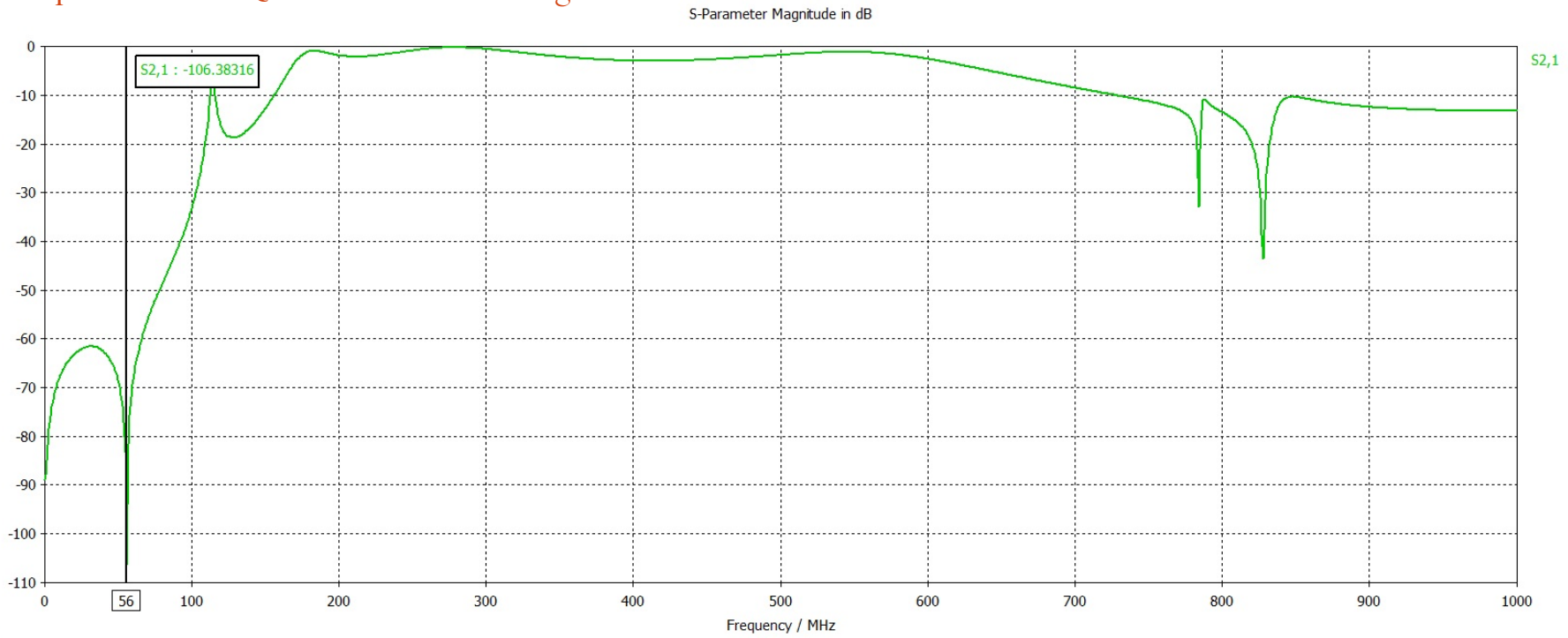
HOM Damping

HOM frequency [GHz]	Mode Config.	R/Q [Ω]	Qext - I	Qext - II
0.656	Deflection	9.6	664	340
0.690	Deflection	45.7	2.7e6	1.8e6
0.702	Horizontal	29.0	2180	1118
0.812	Deflection	11.2	581	307
0.893	Horizontal	3.5	404	306
0.896	Horizontal	40.3	2930	1240
0.922	Deflection	3.8	27386	14170
1.132	Horizontal	11.55	85496	41164
1.136	Deflection	1.89	2619	1867

High-Pass Filter

- We have successfully designed high-pass filter for 56MHz QWR at BNL. The reflection for fundamental mode is below -100dB. This first HOM is 168MHz, and the reflection has decreased to -5dB.
- With such experience, high performance high-pass filter for QWCC should be straight forward.





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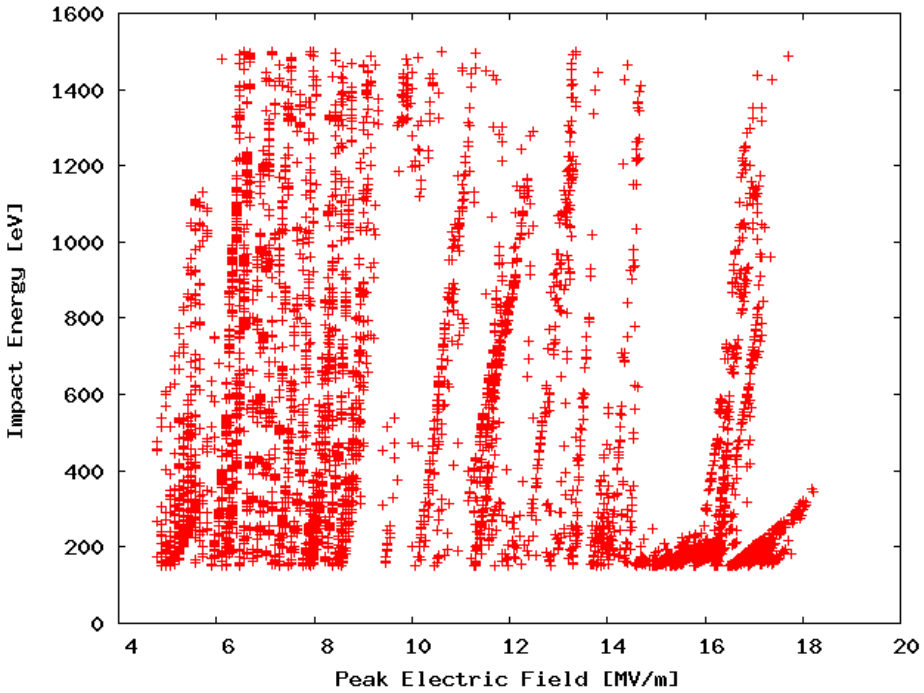
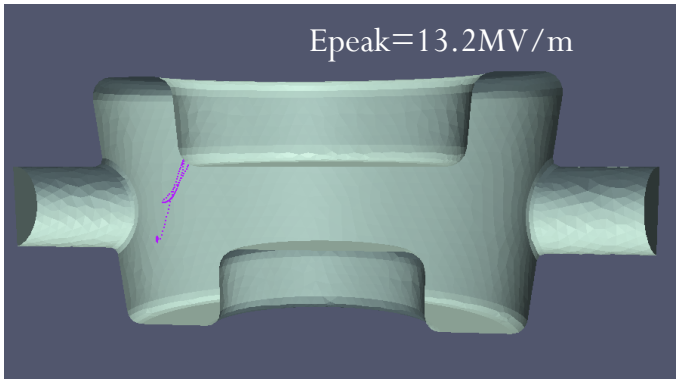
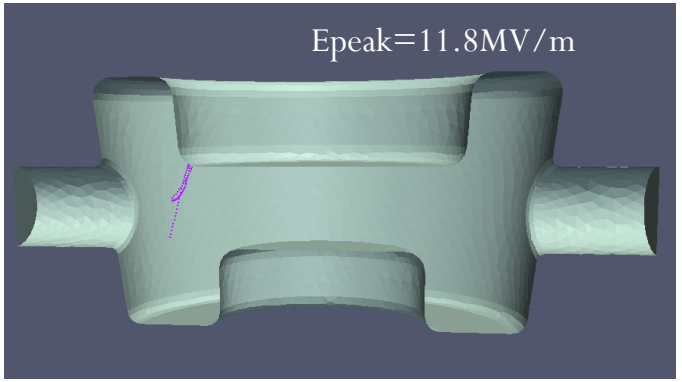
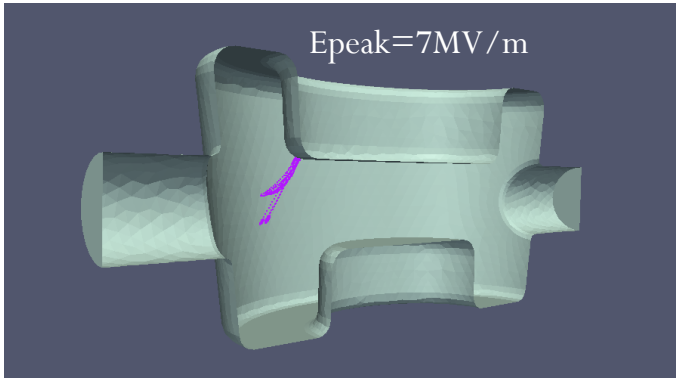
Multipacting

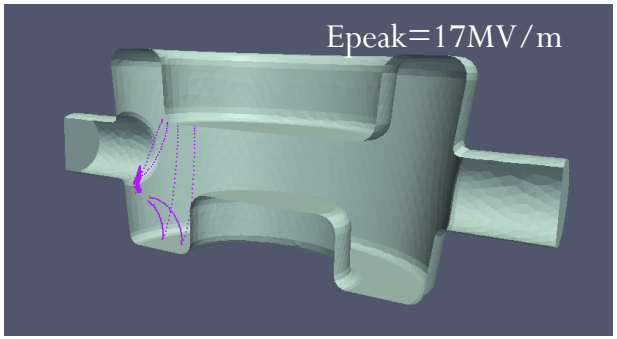
Results from TRACK3P



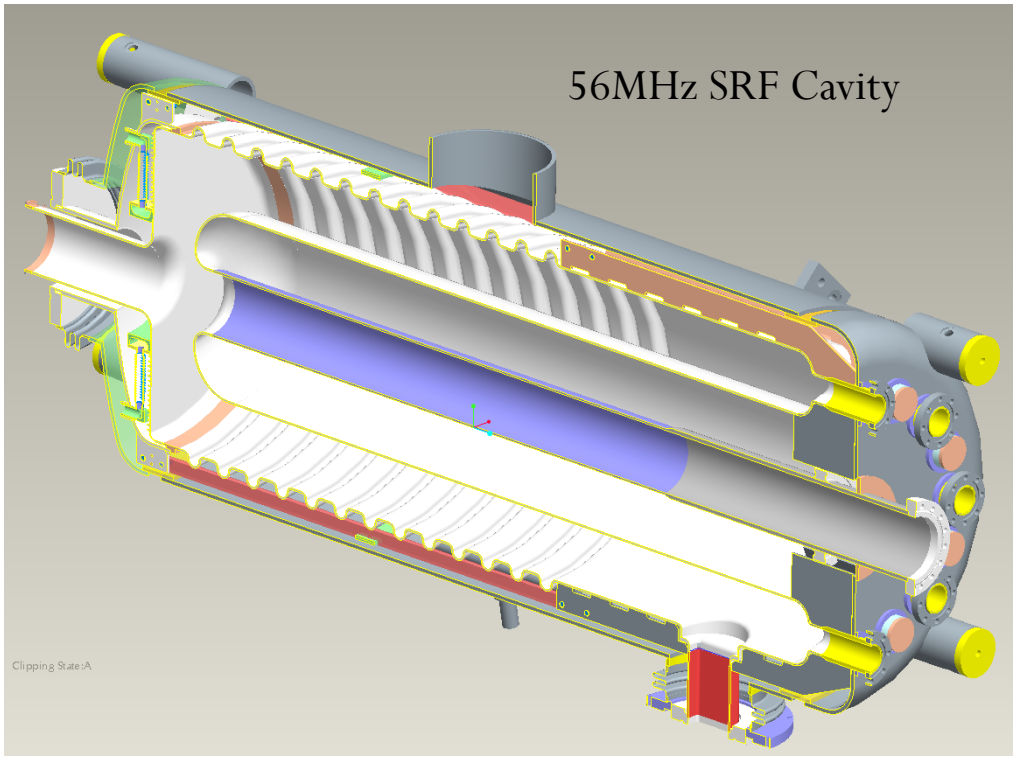


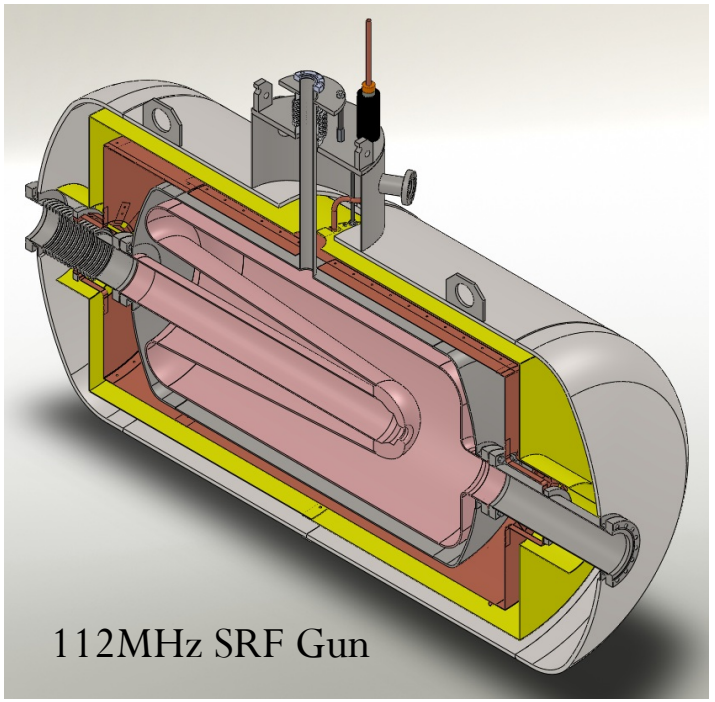


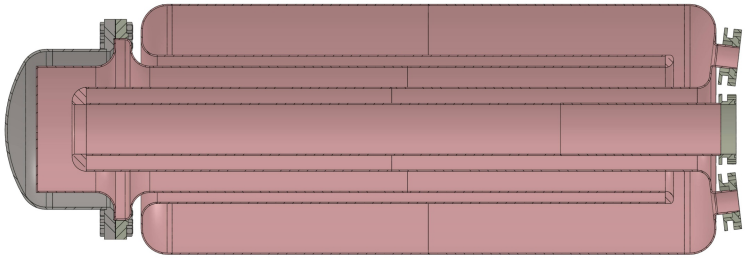




QWRs for BNL







28MHz SRF Cavity

QWRs around the world

R. Calaga et. al. @ LHC-CC11

Plan for 2012-2013

- 0.1 FTE + 1 postdoc
- The optimization of the cavity is complete.
- Statement of Work has been prepared for fabrication of a prototype Nb cavity, will be released in May
- We expect the fabrication to be complete at the end of calendar year 2012
- Chemistry and HPR will be done by April 2013
- Vertical testing, first without HOM couplers then with HOM couplers will be carried out through the end of August 2013
- The testing will be focused on
  - Deflection voltage
  - HOMs
  - Peak fields
  - Possible multipacting

Prototype fabrication and testing

- Fabrication and testing of the cavity and its various RF couplers (FPC, pick-up, HOM) will include:
  - Cavity fabrication
  - HOM coupler (two units)
  - Fundamental Power Coupler and pickup
  - Chemistry and HPR
  - Vertical testing (3 rounds)
  - Electronics
- BNL contributions to the program would be one HOM coupler, motion system for the FPC, parts for the fabrication of the FPC and pickup, vertical testing, and electronics.

Summary

- The QWCC is a new approach for deflecting particles. It is a compact design with high Rt/Q.
- The cavity can provide 3MV of deflection voltage while the peak fields are maintained in a safe level.
- It is optimized for LHC installation so that no conflict to the adjacent beamlines.
- Large separation between fundamental deflection mode and 1st HOM simplifies the design in HOM damping scheme and high-pass filter design.
- Multipacting studies are in progress.
- Further optimization can, as always, led us to better performance.
- We are looking forward to testing the prototype Nb cavity in the year of 2013.

Reference

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- R. Calaga, presentation, LHC-CC11, CERN, Nov 14-15, 2011
- Q. Wu, S. Belomestnykh, I. Ben-Zvi, *Novel deflecting cavity design for eRHIC,* Proceedings of the SRF11, Chicago, IL, July 25-29, 2011
- Q. Wu and I. Ben-Zvi, Simulation of the high-pass filter for 56mhz cavity for RHIC, Kyoto, Japan, May 23-28, 2012
- K. Ko et al, "Advances in Parallel Electromagnetic Codes for Accelerator Science and Development", LINAC2010, Tsukuba, Japan.