# A NEW CLASS OF SUPERCONDUCTING STRUCTURES FOR THE DEFLECTION AND CRABBING OF PARTICLE BEAMS

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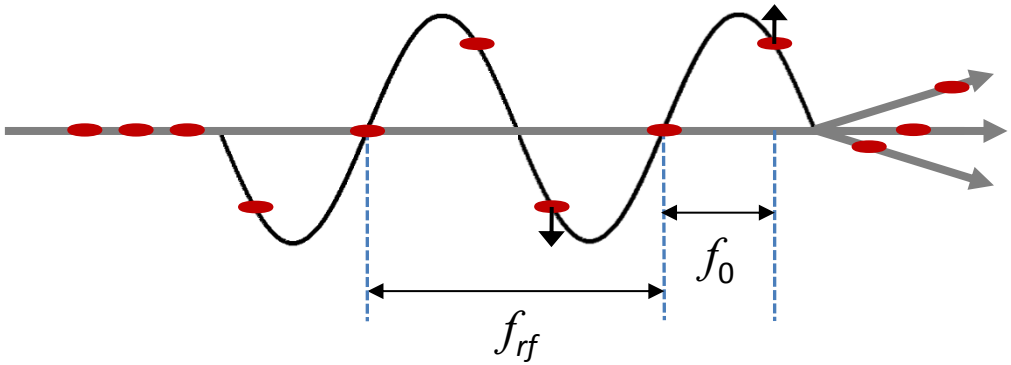
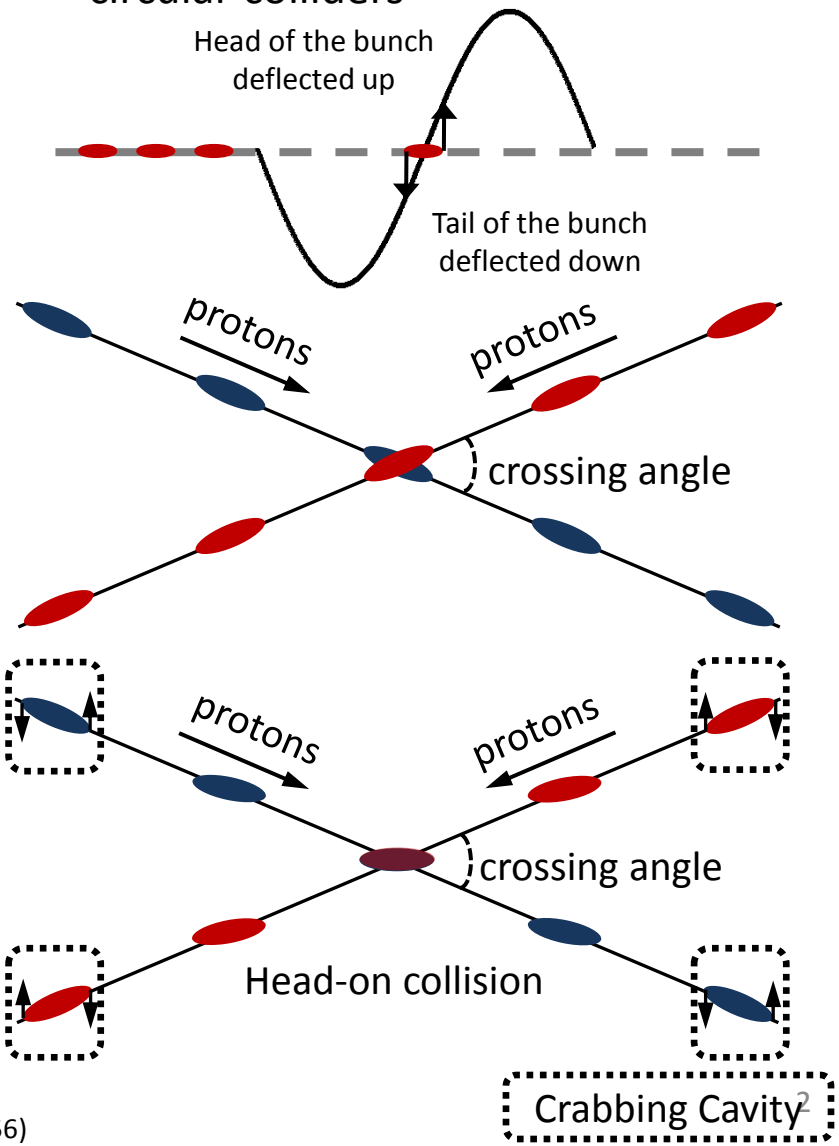
MAY 07, 2015

# DEFLECTION AND CRABBING OF BUNCHES

- Separation or merging of multiple beams




- Luminosity management in linear or circular colliders



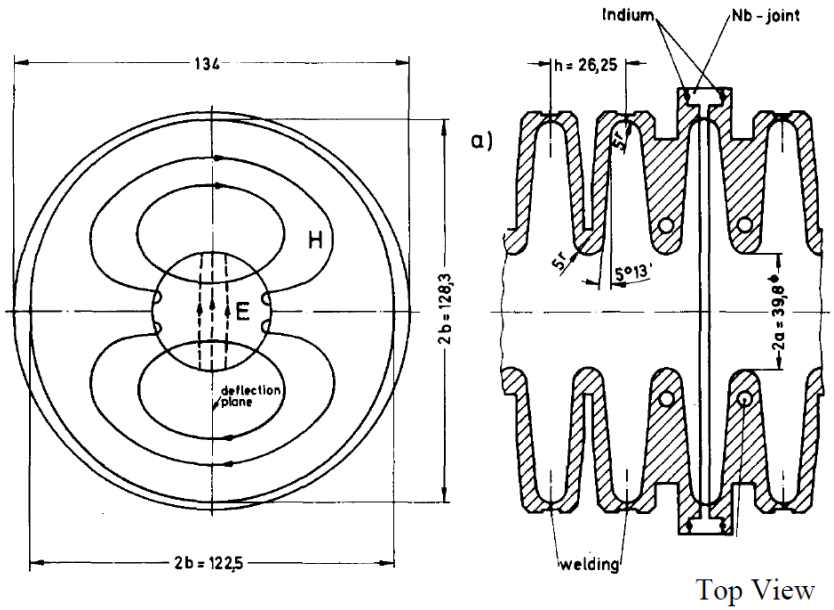

## Other Applications

- Emittance exchange in beams
  - Change of emittances between longitudinal and transverse plane
- X-ray pulse compression
  - Generation of compressed x-ray beams
- Beam diagnostics
  - Bunch length measurements



W. K. H. Panofsky and W. A. Wenzel, Rev. Sci. Instrum. **27**, 967 (1956)

# FIRST SUPERCONDUCTING DEFLECTING AND CRABBING CAVITY



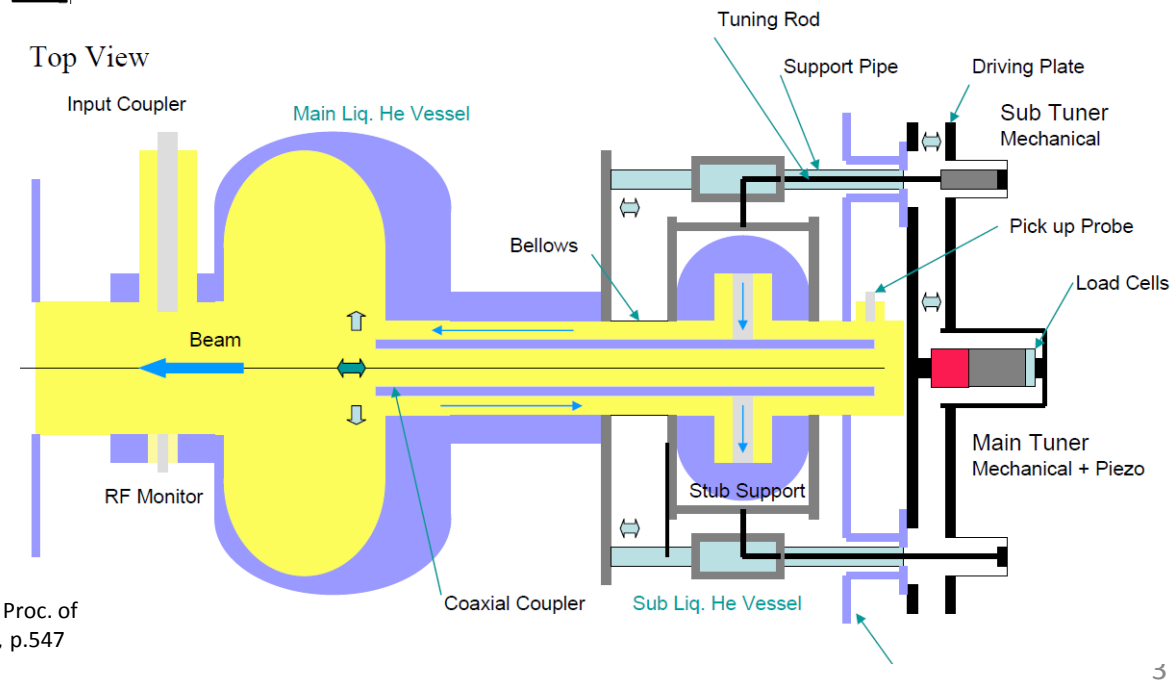

## 2.865 GHz Karlsruhe/CERN RF Separator*

- Designed 1970, operated 1977-1981
- 104 cells
- At IHEP since 1998
- Operating mode: bi-periodic $TM_{110}$ mode

* A. Citron et al., NIM 164, 31-55, (1979)

## 508.9 MHz KEK Crabbing Cavity#

- Operating mode: $TM_{110}$ mode
- Required transverse deflection: 1.44 MV
- Operation: 2007-2010




#K. Hosoyama et al, "Crab Cavity for KEKB", Proc. of the 7th Workshop on RF Superconductivity, p.547 (1998)

# MOTIVATION FOR THIS WORK

- A need for compact low frequency cavities for both deflecting and crabbing applications
- Look to a solution beyond TM110 type cavities
- With improved performance with respect to
  - Electromagnetic properties
  - Field quality
  - Higher order mode properties

# PARALLEL-BAR DEFLECTING CAVITY

- Operates in a TEM-like mode

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **12**, 062002 (2009)

## New compact TEM-type deflecting and crabbing rf structure

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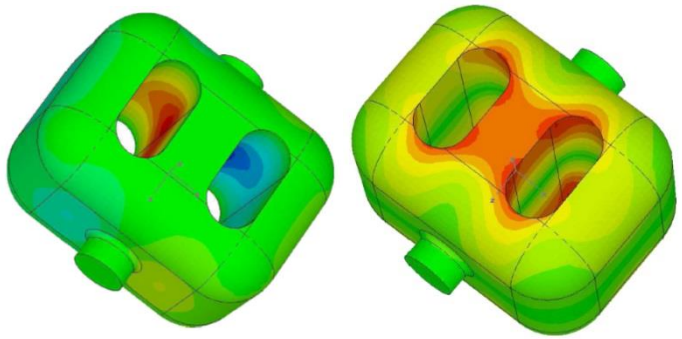
(Received 23 March 2009; published 18 June 2009)

A new type of rf structure for the deflection and crabbing of particle beams is presented. The structure is comprised of a number of parallel TEM resonant lines operating in opposing phase from each other. One of its advantages is its compactness compared to conventional crabbing cavities operating in the $TM_{110}$ mode, thus allowing low frequency designs. This geometry would also be effective for the deflection of beams propagating at velocities substantially less than that of light.

DOI: 10.1103/PhysRevSTAB.12.062002 PACS numbers: 29.27.Ac, 41.85.Ar, 41.85.Ct



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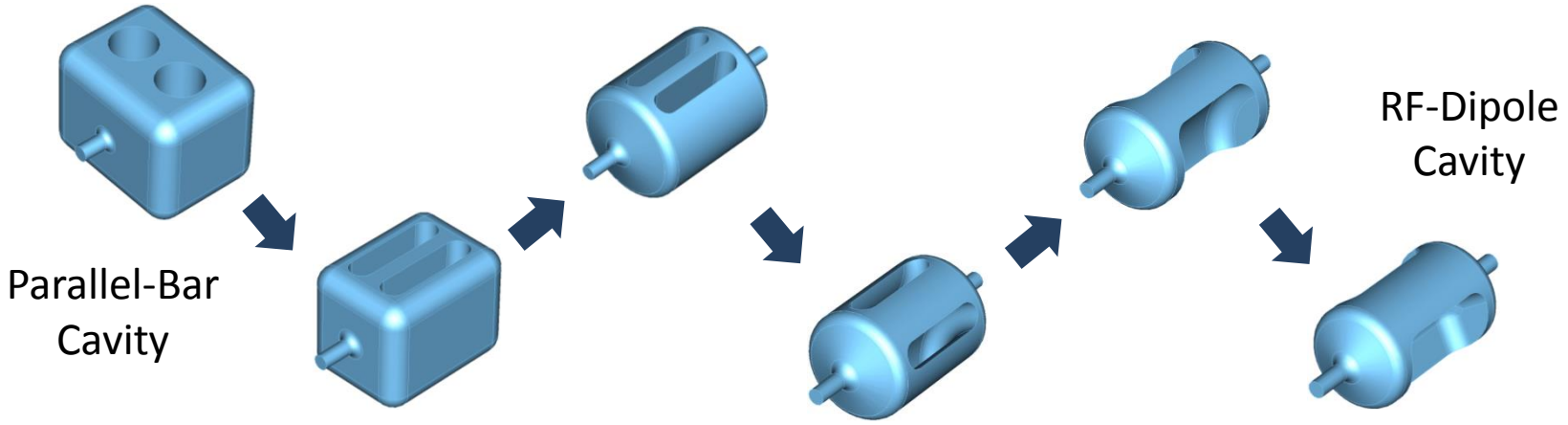
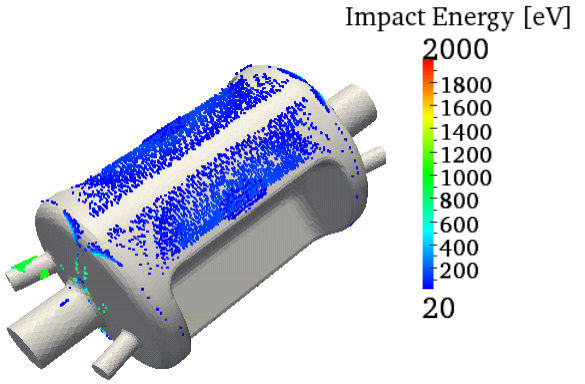
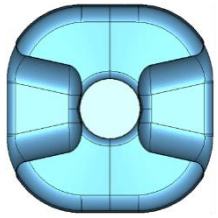
# DESIGN EVOLUTION AND OPTIMIZATION




- Aspects of optimization
  - Low and balanced peak surface fields
  - No lower order or same order mode
  - Wide separation in higher order mode spectrum
  - Robustness of the design
  - Ease of cavity processing
  - Absence of multipacting barriers
  - Optimized geometry to reduce higher order multipole components

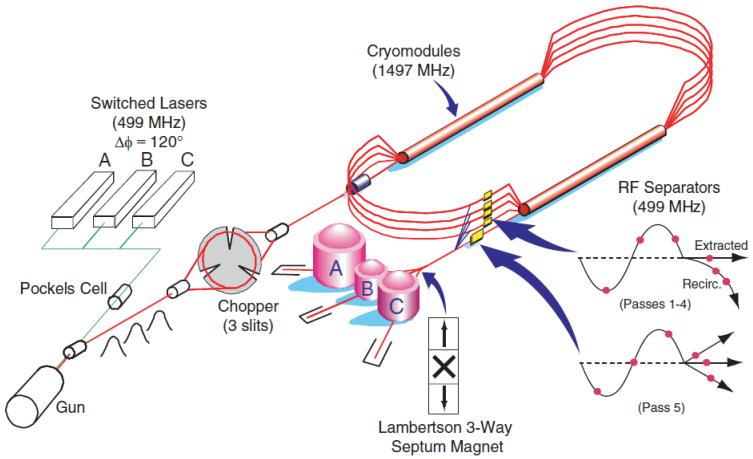


# PROOF-OF-PRINCIPLE RF-DIPOLE CAVITIES

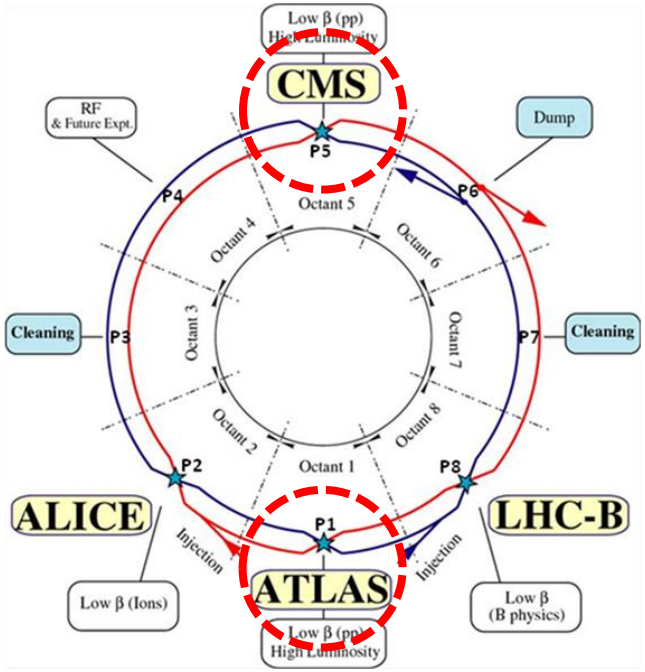
**499 MHz Deflecting Cavity for Jefferson Lab 12 GeV Upgrade**

**400 MHz Crabbing Cavity for LHC High Luminosity Upgrade**



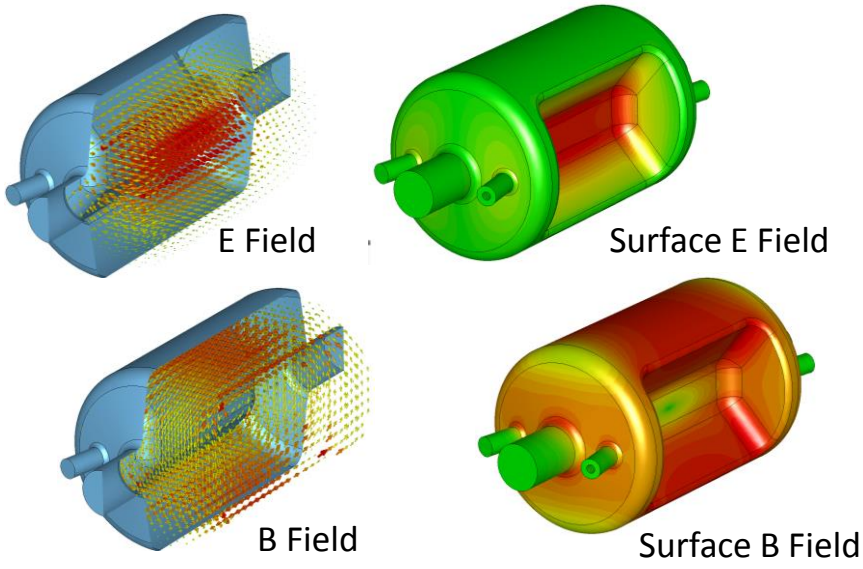

Deflecting voltage – 3.3 MV

- 13.4 MV per beam per side
- 3.4 MV per cavity
- Two crabbing systems



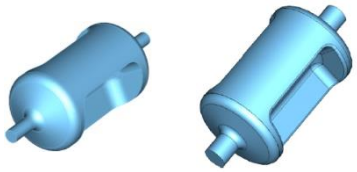
# RF – DIPOLE CAVITY

## EM Design




- Operates in TE11-like mode
- Low and balanced peak surface fields at a high net transverse voltage
- High shunt impedance
- No lower order modes
- First HOM 1.5 times fundamental mode

## RF Properties

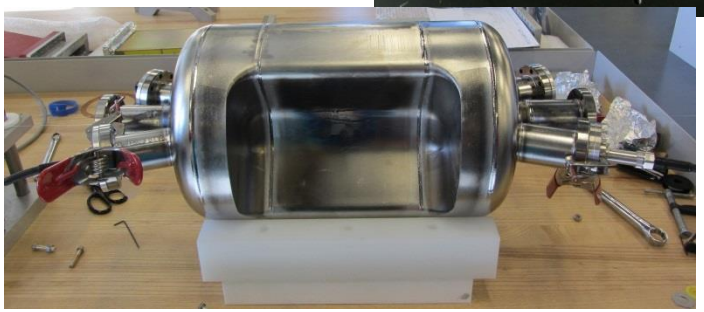


| **Frequency** | **499.0** | **400.0** | **MHz** |
|---|---|---|---|
| Nearest HOM | 777.0 | 589.5 | MHz |
| $E_p^*$ | 2.86 | 3.9 | MV/m |
| $B_p^*$ | 4.38 | 7.13 | mT |
| $B_p^*/E_p^*$ | 1.53 | 1.83 | mT/(MV/m) |
| $[R/Q]_T$ | 982.5 | 287.0 | Ω |
| Geometrical Factor ($G$) | 105.9 | 140.9 | Ω |
| $R_T R_S$ | $1.0\times10^5$ | $4.0\times10^4$ | $\Omega^2$ |
| At $E_T^* = 1$ MV/m | | | |

# FABRICATION

499 MHz Deflecting Cavity

Fabricated at Jefferson Lab

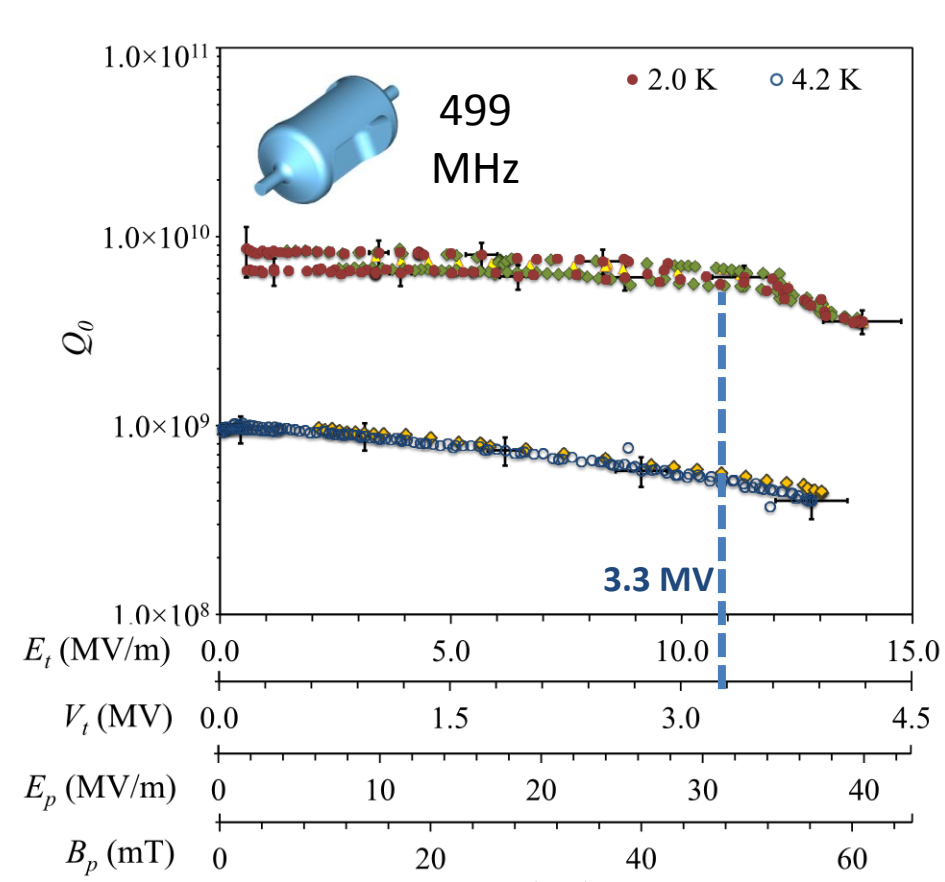


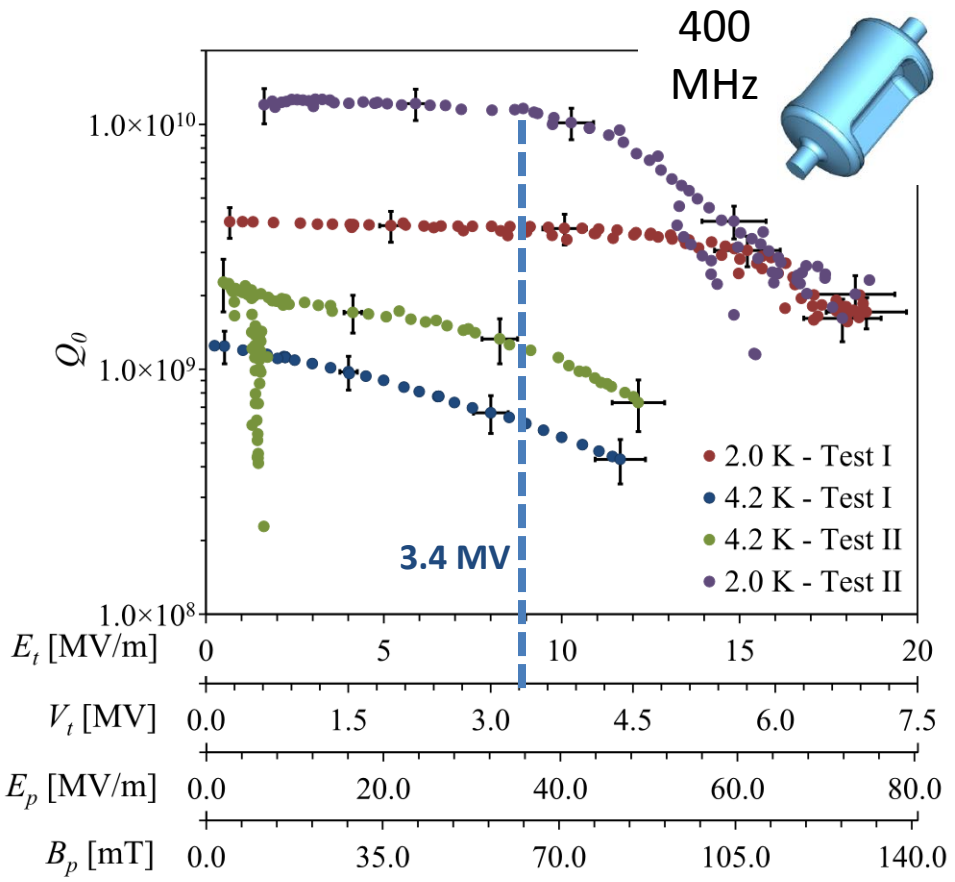
400 MHz Crabbing Cavity

Fabricated at Niowave Inc.

# RF-DIPOLE CAVITY TEST RESULTS

- RF tests performed at vertical test facility at Jefferson Lab
- Cavities reached high transverse gradients far in excess of requirements
- Multipacting levels processed easily and did not reoccur

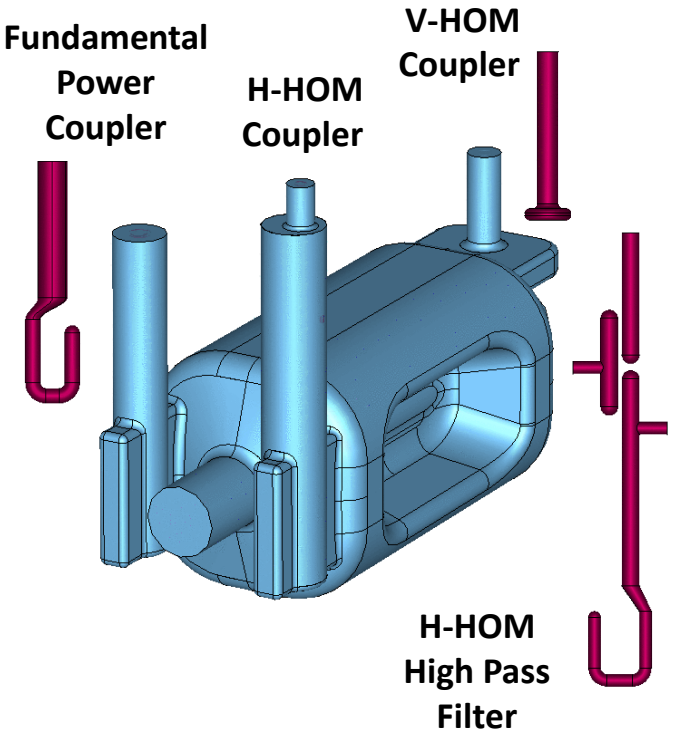


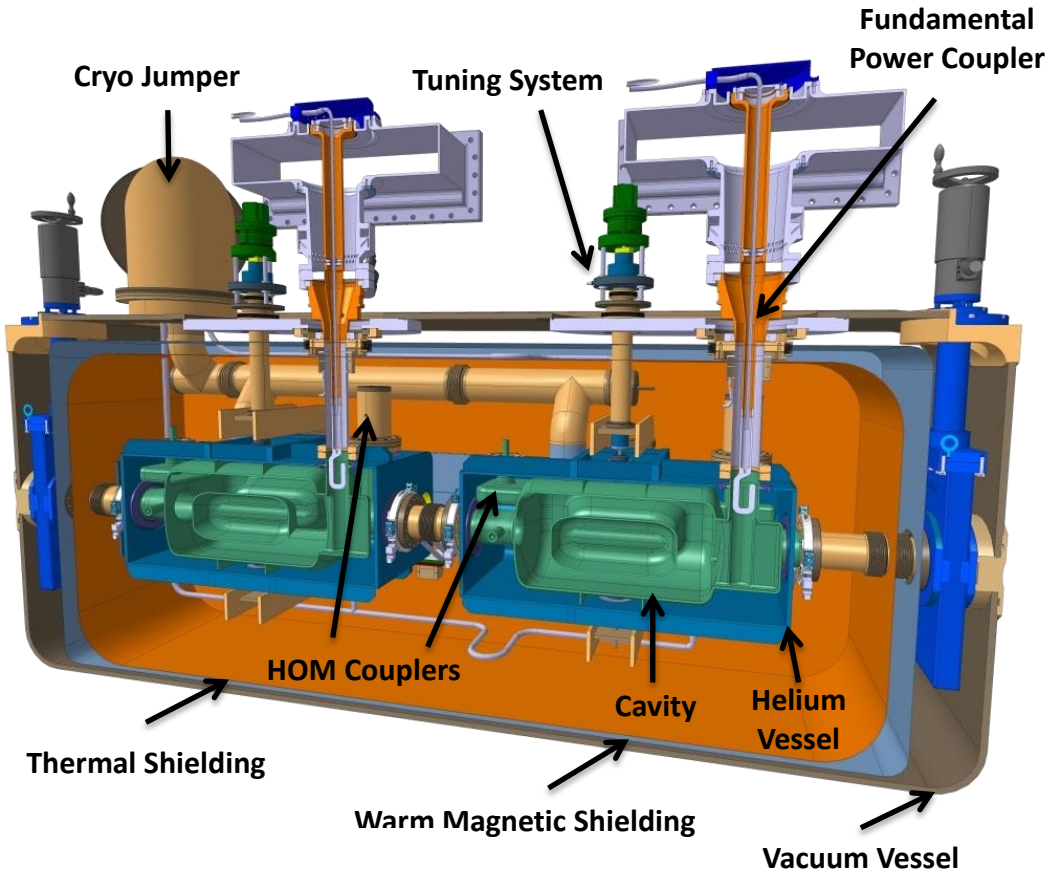




**Proof-of-Principle cavities performed exceedingly well**

# CRABBING CAVITY FOR LHC HIGH-LUMINOSITY UPGRADE

- Integrate cavities in cryomodule for SPS test to begin in 2017
- Design and build LHC prototype cryomodules (2017-2020)
- Build production cryomodule (2020-2023)
- Installation (2023-24)



# SUMMARY

- New accelerator applications had performance and dimensional requirements beyond state of the art
- A new class of compact deflecting/crabbing cavities has been designed, fabricated and tested successfully
- Can be implemented in many accelerator applications
- Performance of these cavities exceeds previous designs
  - Low surface fields
  - High shunt impedance
  - No lower order modes and well separated fundamental mode
  - Multipacting well controlled

# ACKNOWLEDGEMENT


- My Advisor: Prof. Jean Delayen
- ODU – Chris Hopper, Alex Castilla, Kevin Mitchell
- JLab – HyeKyoung Park, Peter Kneisel, Tom Powers, Kirk Davis, Geoff Krafft,
- SLAC – Zenghai Li, Lixin Ge
- Niowave – Terry Grimm, Dmitry Gorelov, Chase Boulware, Nick Miller

❖ DOE High Energy Physics
❖ DOE Nuclear Physics

❖ Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177
❖ *US Department of Energy through the US LHC Accelerator Research Program (LARP). The research leading to these results has received funding from the European Commission under the FP7 project HiLumi LHC, GA no. 284404, co-funded by the DoE, USA and KEK, Japan*

THANK YOU