# quarter wave resonators for beta~1 Accelerators

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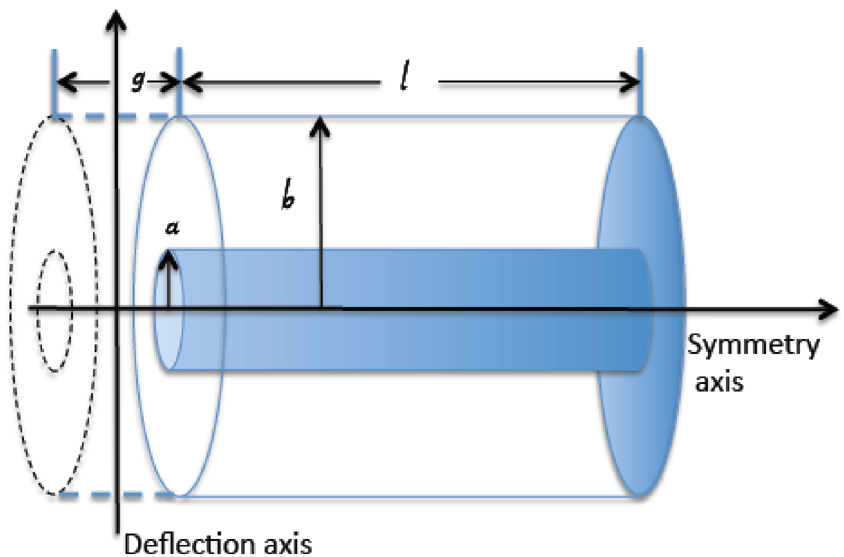
# Why the QWR?

- Most compact structure.
- Extremely high mechanical stability.
- No Same Order Mode (SOM).
- The first HOM is a factor of 2 to 3 in frequency above the fundamental crabbing mode, very easy to damp.
- Simple fabrication, coupling and tuning.

# QWR Schematic




$$Z_0 = \frac{\eta}{2\pi} \ln \frac{b}{a}$$

$\eta$=377Ω

$$R_{sh} / Q = \frac{4Z_0}{\pi}$$

$$\Gamma = QR_s = \frac{2\pi\eta}{\lambda} \frac{\ln(b/a)}{a^{-1} + b^{-1}}$$

$$\frac{R_t}{Q} = \frac{4\pi a^2 Z_0}{g^2}$$

$$E_P \geq \frac{V}{a \cdot \ln(b/a)}$$

$$H_p = \frac{1}{\eta} \frac{V}{a \ln \frac{b}{a}}$$

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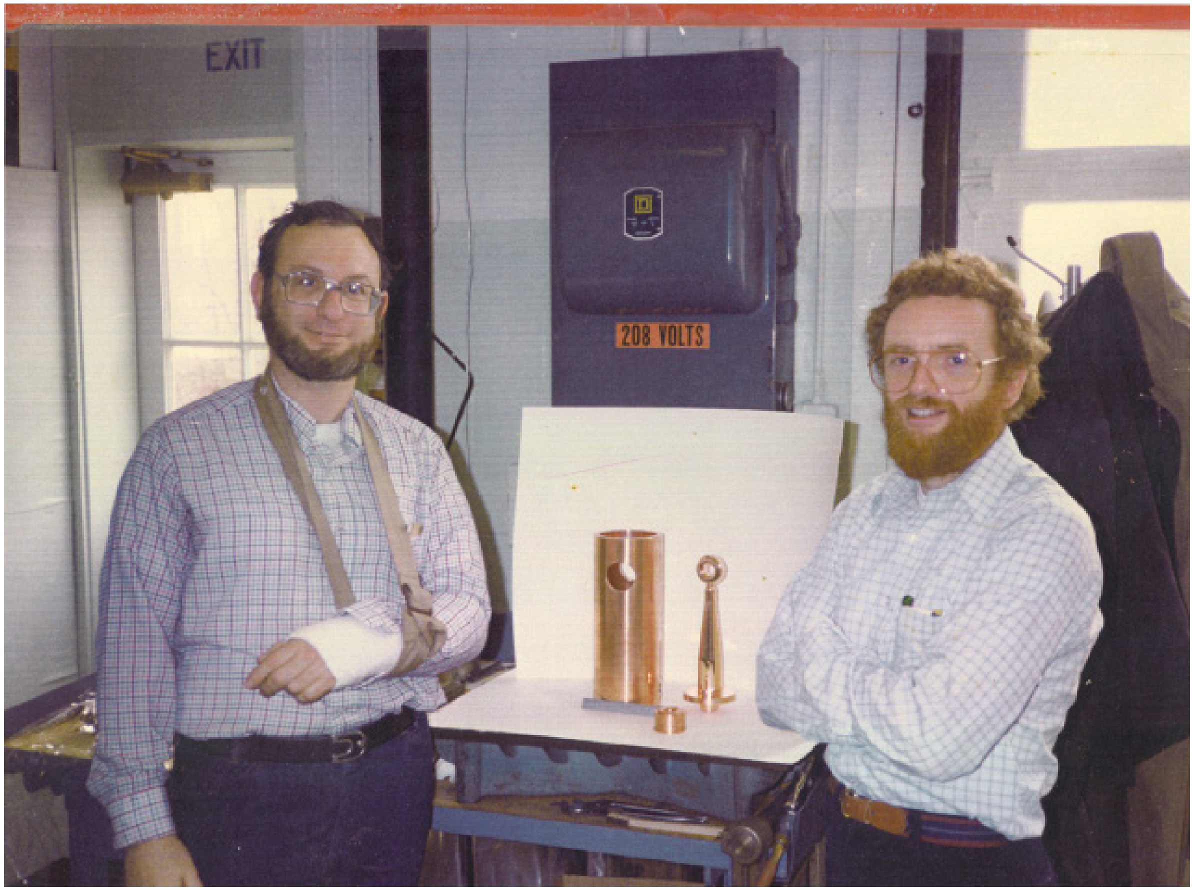
# SRF Quarter Wave Resonators are well known and are quite compact




The first superconducting Quarter Wave Resonator, ca. 1981. The frequency is 300 MHz.

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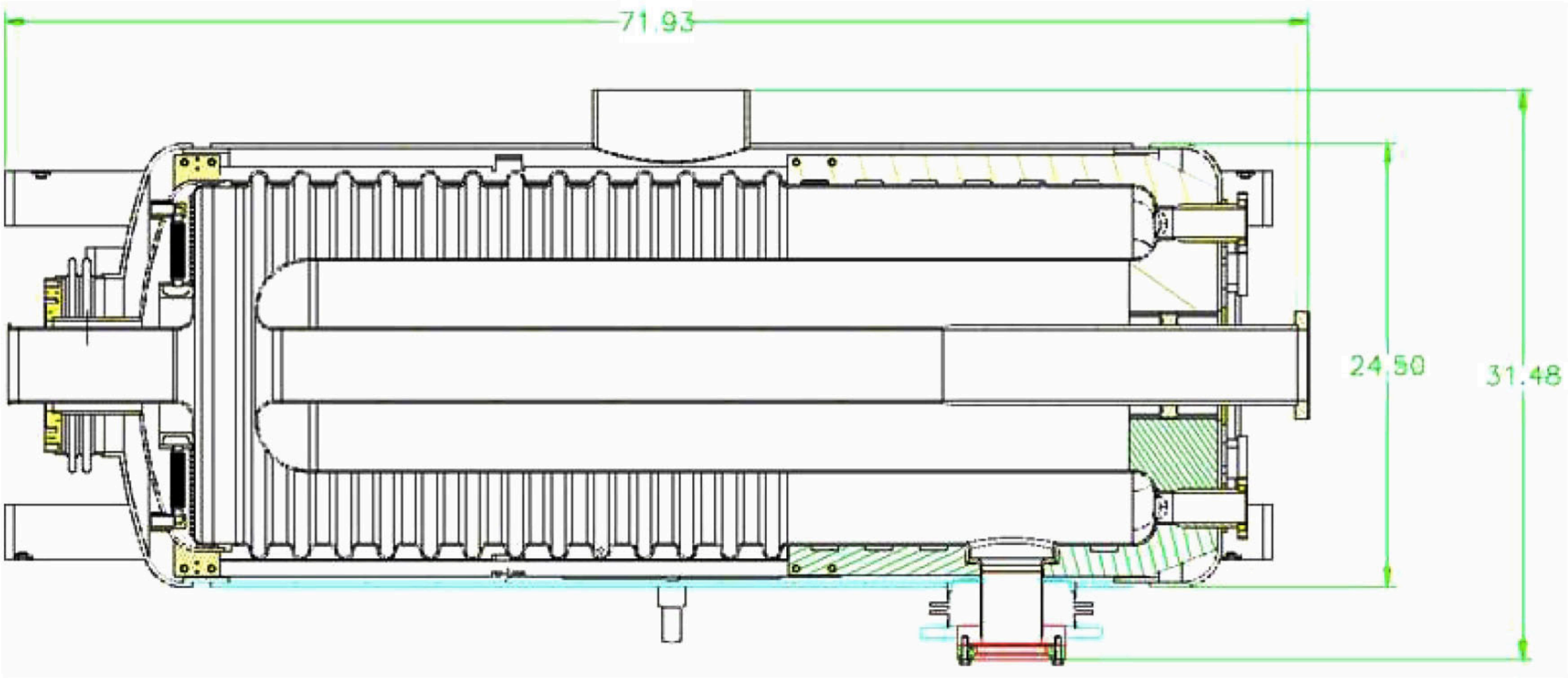
# SUPRESSION OF MULTIPACTING




DAMAYANTI NAIK AND ILAN BEN-ZVI Phys. Rev. ST Accel. Beams 13, 052001 (2010)

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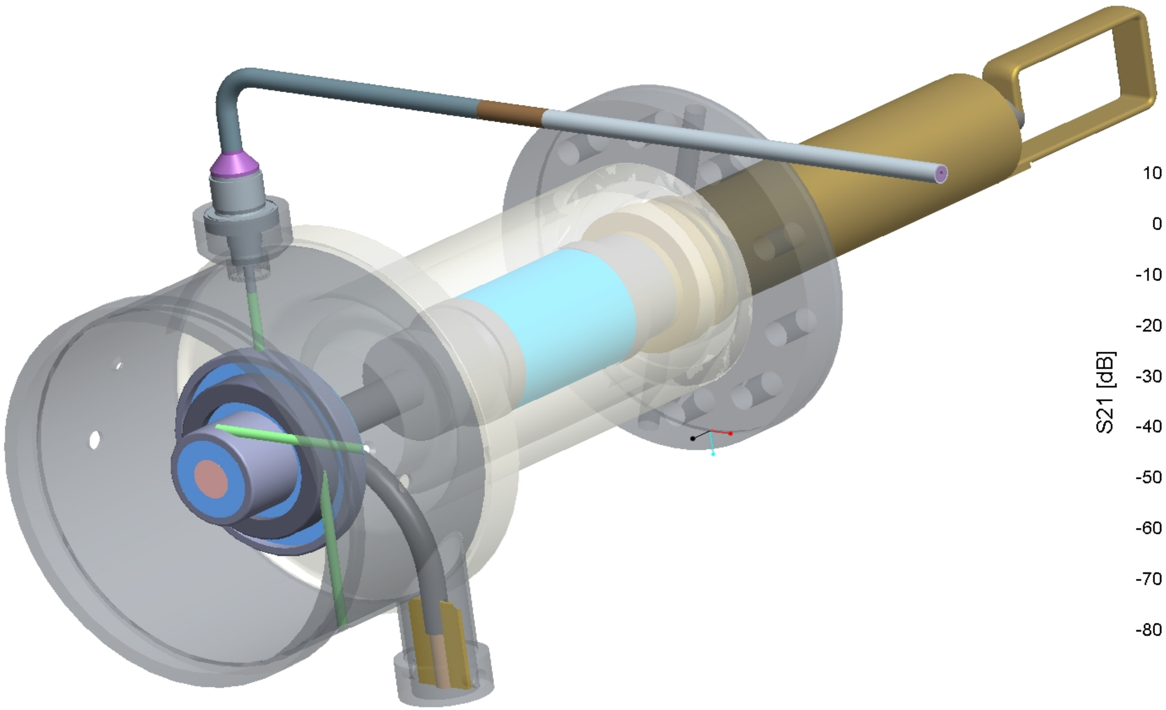
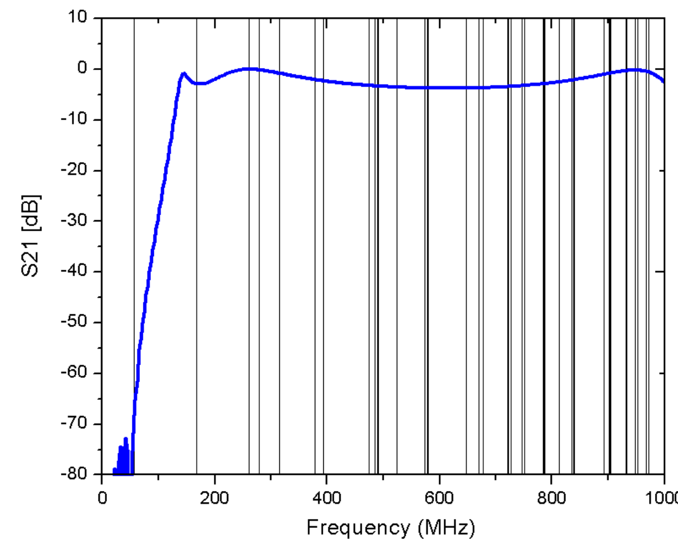
# A HOM damper with an integral high-pass filter for QWR






Q. Wu and I. Ben-Zvi, Optimization of Higher Order Mode Dampers in the 56 MHz SRF Cavity for RHIC, Proceeding of IPAC'10, Kyoto, Japan

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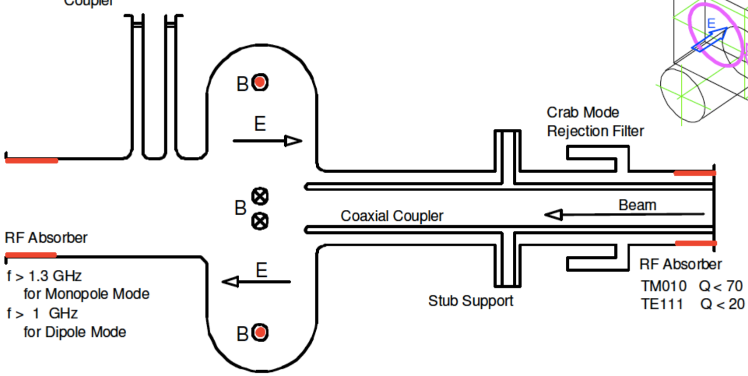
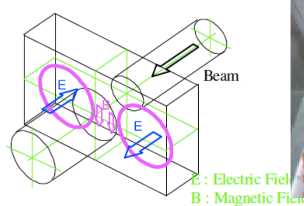
# Crab Cavities

- Big issue: Damping of LOM, SOM, HOM made simple.
- Big Issue: Size.

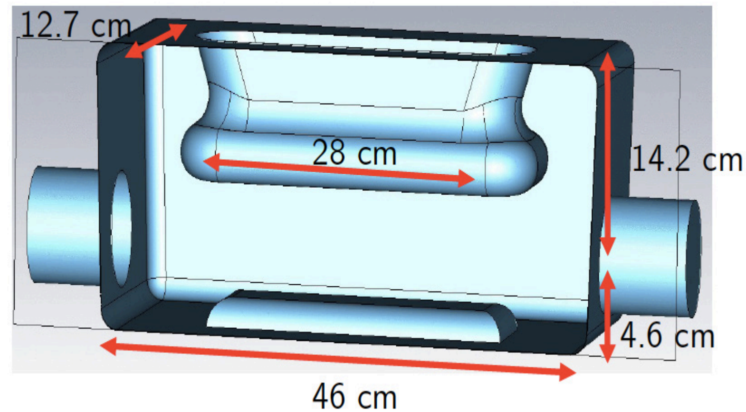


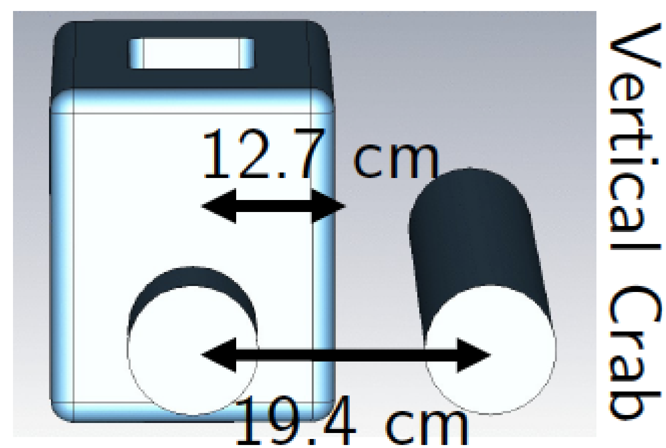




KEKB Crab cavity at 500 MHz

# Initial LHC QWR crab cavity design
# Rama Calaga

- 400 MHz
- Very easy fit into LHC
- Nearest other mode is well separated at 675 MHz
- $V_t$~2.5 MV @110 mT and 48 MV/m surface fields, Rt/Q of 132 Ω

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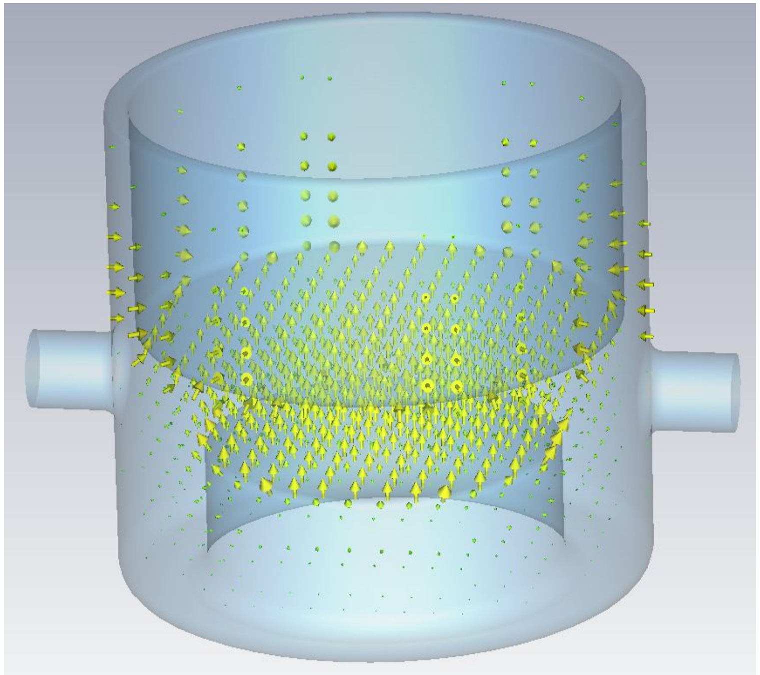
# eRHIC crab cavity initial design
# Qiong Wu (THPO007)

- 181 MHz (and harmonics)
- No acceleration

| QWR crab cavity for RHIC | Units | MWS |
|---|---|---|
| Crab mode frequency | MHz | 181 |
| Nearest other mode | MHz | 251 |
| Length (along beam line) | cm | 75.2 |
| Width (long /short parts) | cm | 38.1/25.1 |
| Deflecting voltage* | MV | 6.1 |
| Peak surface electric field* | MV/m | 39 |
| Stored energy* | Joules | 100 |
| Rt/Q (Engineering def.) | Ohms | 291 |
| Accelerating voltage* | kV | <1 |

*) At peak surface magnetic field of 100 mT



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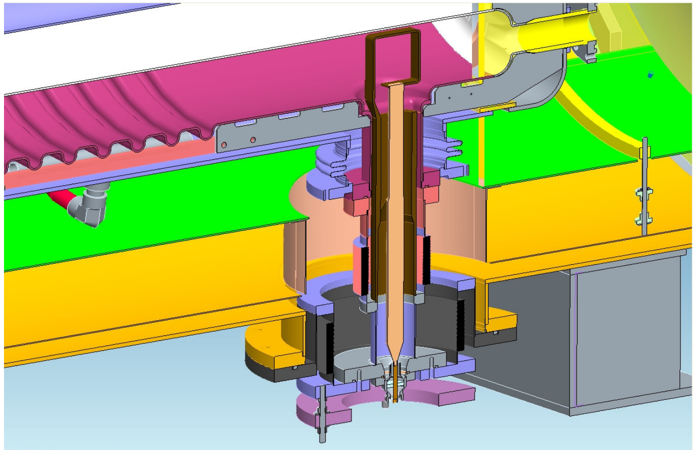
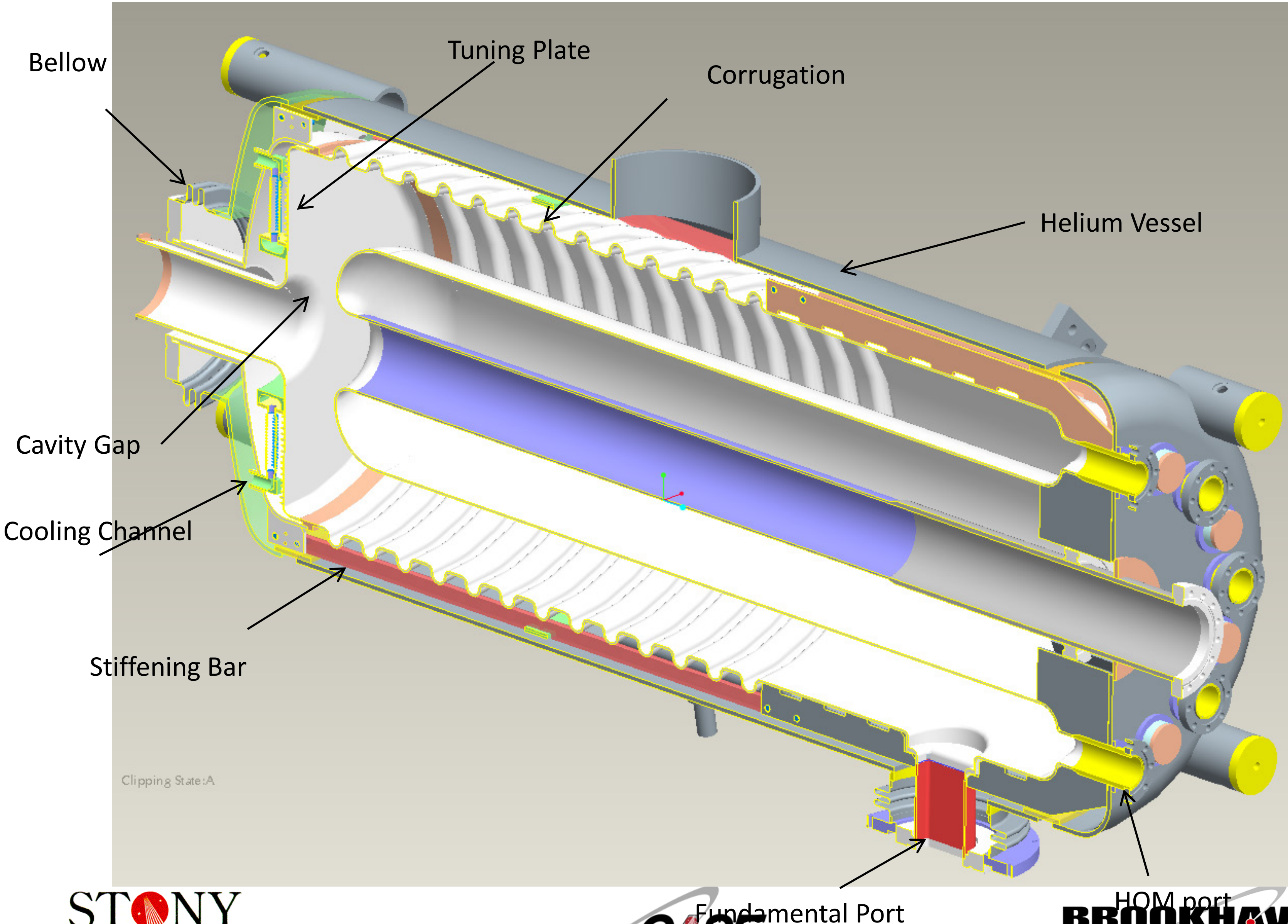
# RHIC 56 MHz Storage Cavity

- Heavily damped HOM
- Variable fundamental damping
- 2 MV, beam driven
- 1 kW RF for amplitude lock
- Multipacting suppressed



# 56 MHz SRF Cavity for beam storage at RHIC

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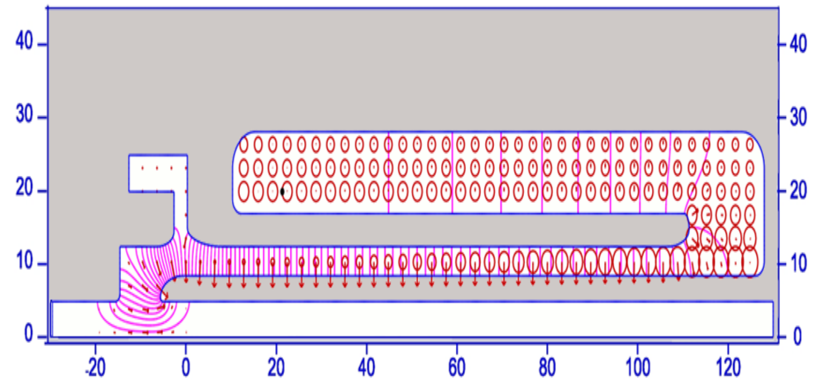
# RHIC 28 MHz Accelerating cavity

- SBIR at Niowave
- Very low frequency
- Very large tuning range
- Folded structure
- Very challenging!




| | |
|---|---|
| Cavities for RHIC | 4 |
| Frequency | 28.1 MHz |
| Gap voltage | 600 kV |
| Tuning range | 200 kHz |
| Tuning rate | 22 kHz/s |
| Aperture | 0.1 m |

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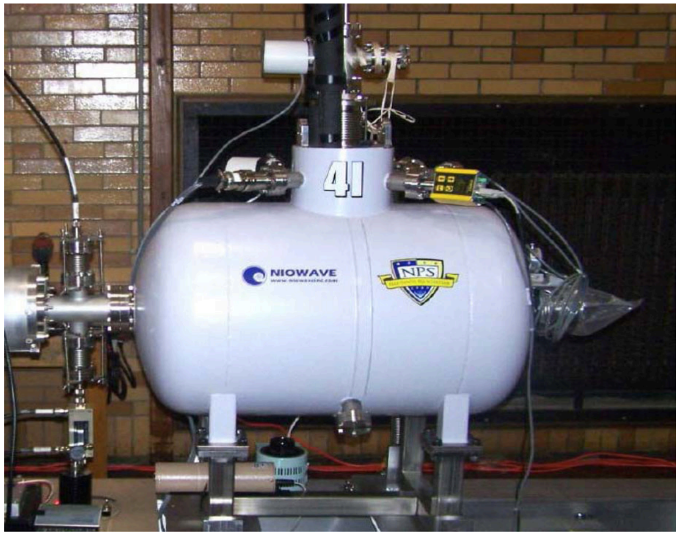
# SRF electron guns

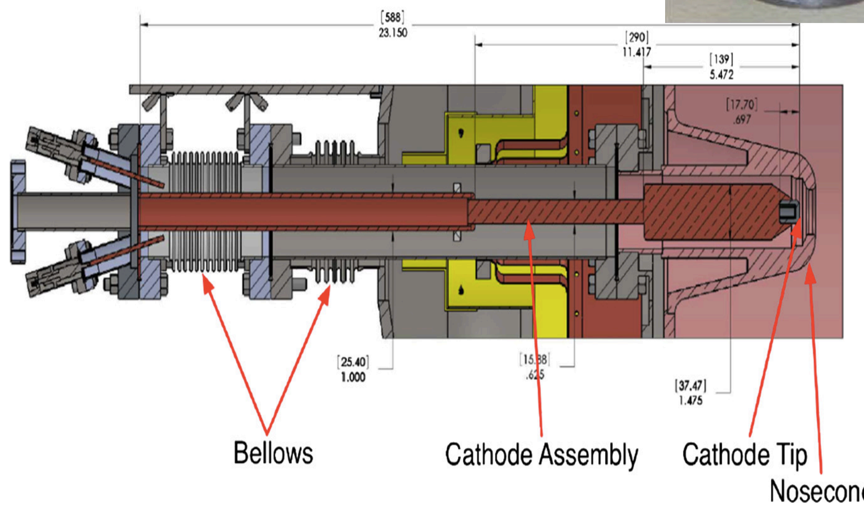
- Fast growing application for QWR, 3 so far.
- Important for various applications, in particular CW high-brightness beams for FELs and ERLs.
- Niowave in collaboration with various institutes.
- Quick design – to – test cycle.
- At this conference, also talk by Sergey Belomestnykh MOPO055

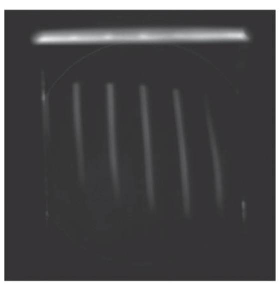
# BNL-U. Wisc.-NPS-Niowave SRF Gun Parameters

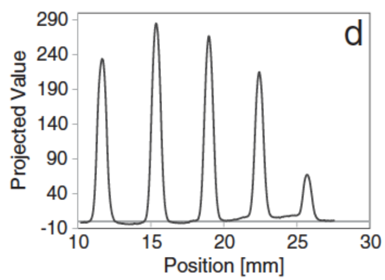
| Parameter | Units | BNL | U. Wi. | NPS |
|---|---|---|---|---|
| Frequency | MHz | 112 | 200 | 500 |
| Aperture (beam tube) | cm | 10 | 10 | 6.35 |
| Cavity Diameter | cm | 42 | 60 | 24 |
| Cavity Length | cm | 110 | 50.3 | 20.3 |
| Planned beam energy | MeV | 2 | 4 | 1.2 |
| Peak electric field MV/m | 38 | 53 | 51 | |
| Peak magnetic field | mT | 73 | 80.4 | 78 |
| Peak / cathode field | - | 2.63 | 1.31 | 1.8 |
| QRs (geometry factor) | Ω | 38 | 85 | 125 |
| R/Q (linac definition) | Ω | 126 | 147 | 195 |
| Q0 (no cathode, 4.5K) | $x10^9$ | 3.7 | 3.3 | 1.2 |

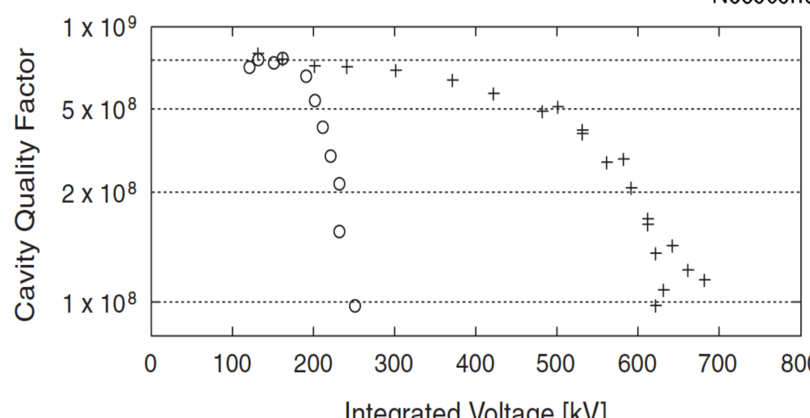
# NPS 500 MHz gun



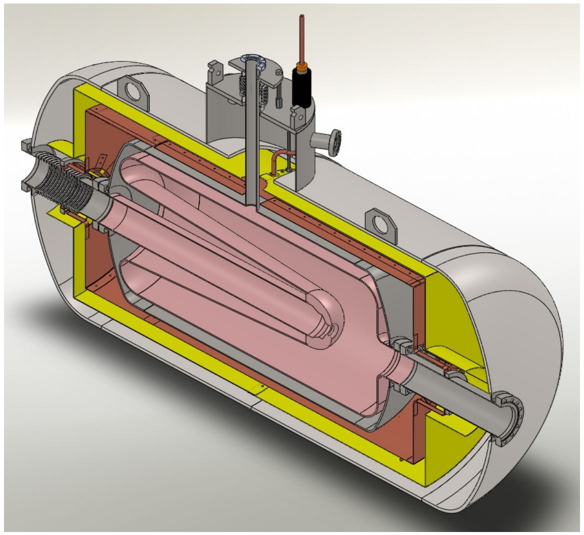



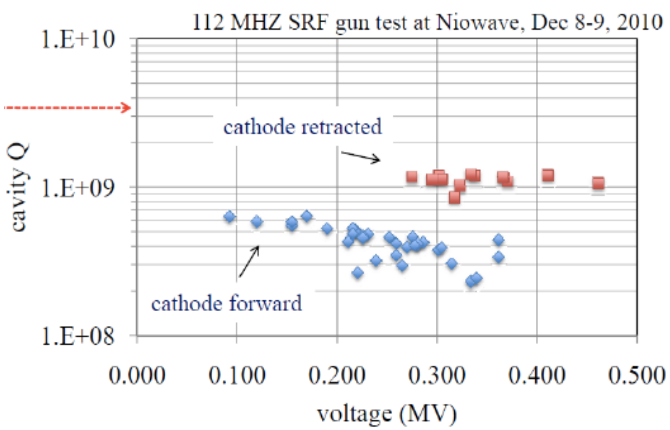



PRST-AB **14**, 053501 (2011)

# BNL 112 MHz gun






S. Belomestnykh et al, proc. PAC11

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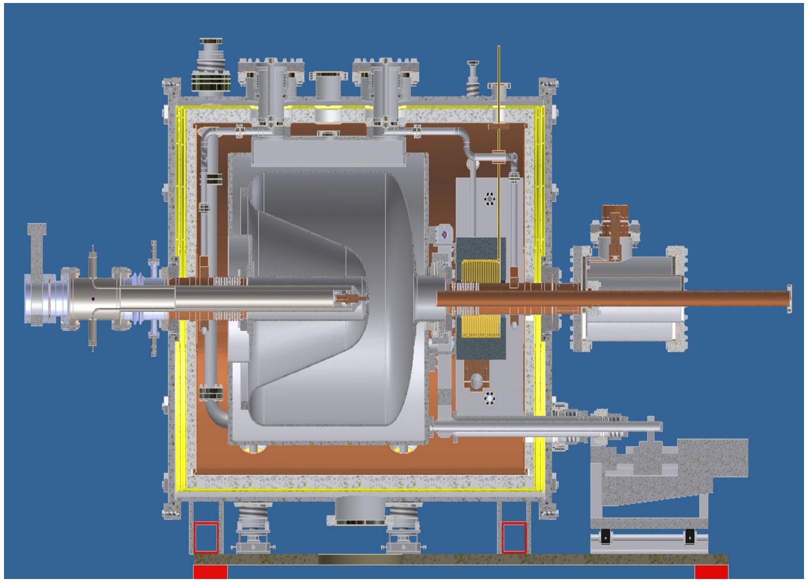
# U. Wisconsin 200 MHz gun

- BES funded design for a seeded VUV/soft X-ray Free Electron Laser
- Gun is being fabricated at Niowave with testing beginning next year.



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# In closing

- The QWR is a simple, ultra-compact, stable and efficient.
- It is a very popular cavity for low β applications.
- The Superconducting QWR is recently finding many applications for very high β.
- These applications include crab cavities, storage ring accelerating and storage cavities and electron guns.
- An enormous advantage in these applications is the outstanding separation of the unwanted modes.