Ernest Orlando Lawrence Berkeley National Laboratory

fact Muon Collaboration

NCRF R&D Programs and Plans

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Outline

- Introduction
- Experimental study at 805 MHz
  - Pillbox cavity with demountable windows
  - Cavity iris termination: foils and grids
  - Surface damage study with a button in the cavity
- 201 MHz cavity
  - Cavity design
  - Fabrication status
  - Progress on curved Be windows
    - FEA modeling and prototype for 805 MHz cavity
  - 21-cm curved Be windows
- Components for MICE
- Summary

Demand for high gradient RF

Technical challenges

- Muon beam is unstable, and has short decay time (~ 2 μs at rest)
  - Muon beam is created with LARGE 6-D phase space
  - Strong external magnetic field needed to confine muon beams
  - Muon beam manipulation must be done **quickly,** including **cooling**

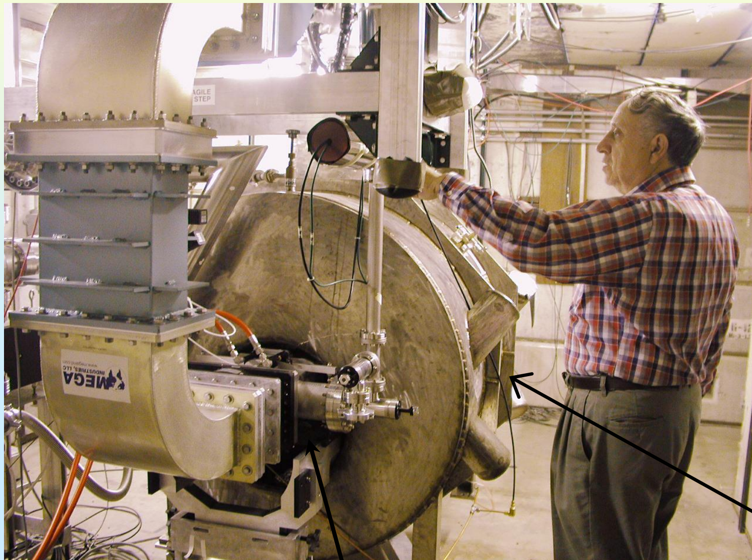
→ Highest possible gradient NC RF cavity !

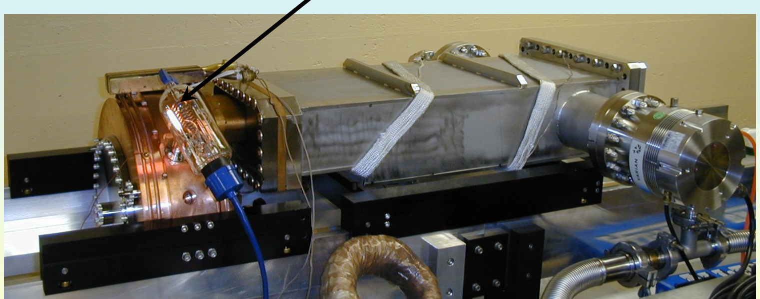
- Requirements of RF cavity for muon beam
  - High cavity shunt impedance, high gradient and high field
    - Gradient at 201 MHz: ~ 16 MV/m [Kilpatrick: 15 MV/m]
    - Gradient at 805 MHz: ~ 30 MV/m [Kilpatrick: 26 MV/m]
  - RF cavity without [beam] iris
    - Higher shunt impedance
    - Lower peak surface field
    - Independent phase control, higher transit factor
    - **We choose RF cavity with irises terminated by windows or grids**

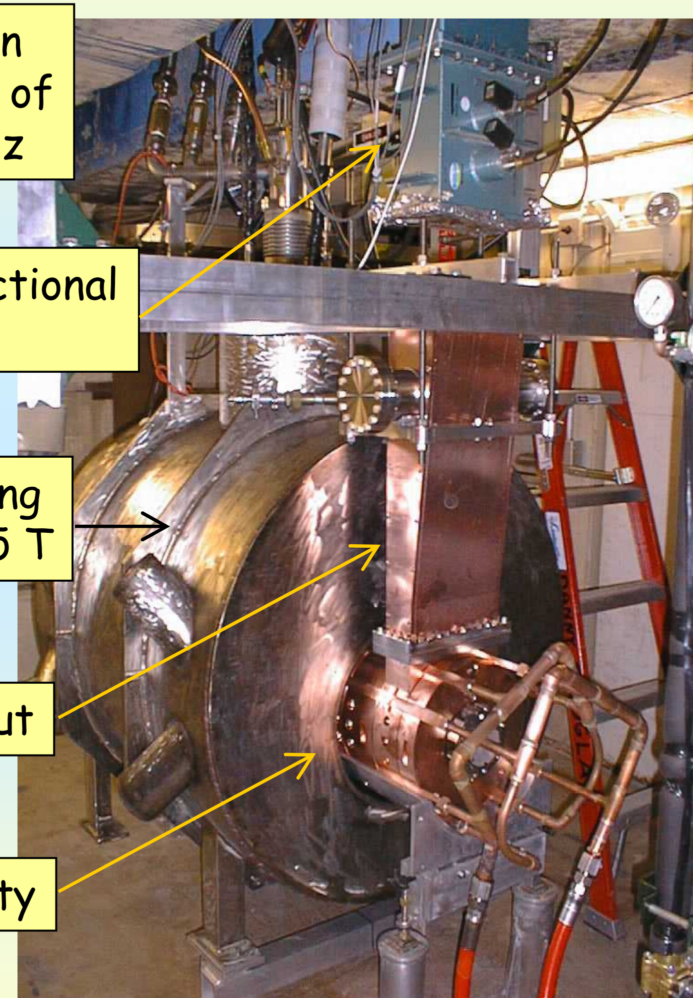
NC RF R&D programs

- Experimental studies at 805 MHz with and without external magnetic fields up to 4-Tesla
  - Finished open 5-cell cavity test at Lab G
  - Designed, fabricated and tested pillbox-like cavity with demountable windows at Lab G
  - Will resume the study at MTA, FNAL soon
    - Test of new materials/surface coating versus RF breakdown field
    - Termination of cavity iris: grids and curved Be windows
- Prototype of 201 MHz cavity with curved Be windows
  - Completed cavity design
  - Cavity fabrication going well
  - Significant progress in FEA modeling on Be windows and grids
  - Ready to make 21-cm curved Be windows

Test setup at Lab G, FNAL







12 MW klystron with capability of 50 μs and 15 Hz

Waveguide directional coupler

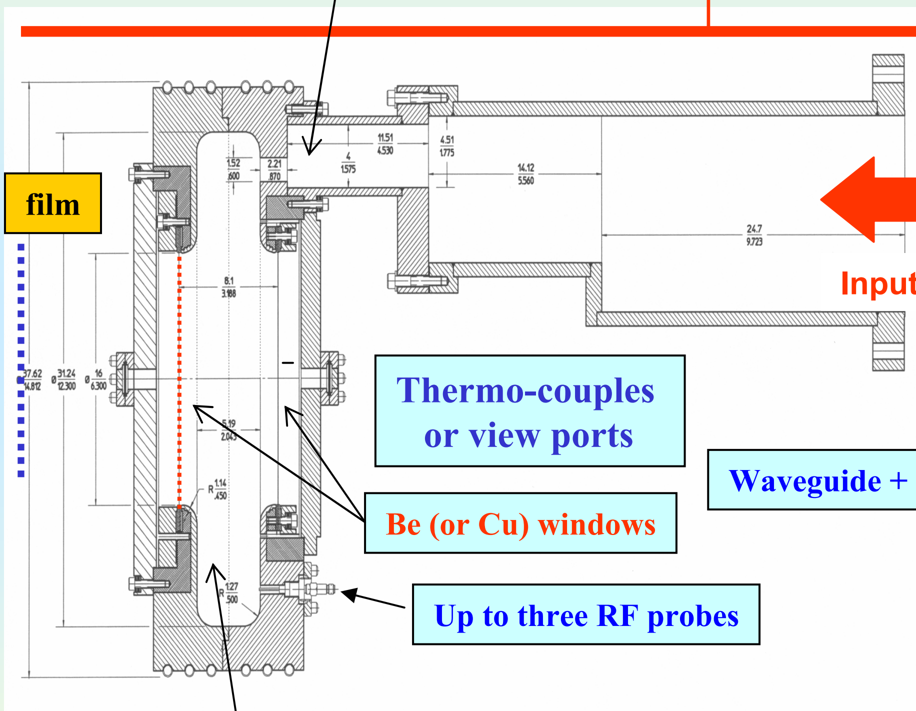
Superconducting solenoid up to 5 T

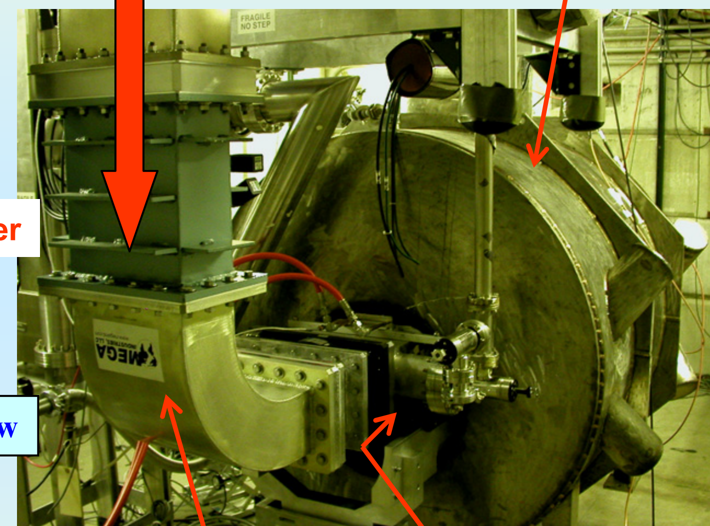
805 MHz pillbox cavity with windows

Waveguide Input

Open 5-cell cavity

Test setup for the pillbox cavity





Coupler

Superconducting magnet

Up to 12 MW peak power

SC Solenoid

film

Input RF Power

Thermo-couples or view ports

Waveguide + RF window

Be (or Cu) windows

Up to three RF probes

805 MHz cavity inside the solenoid

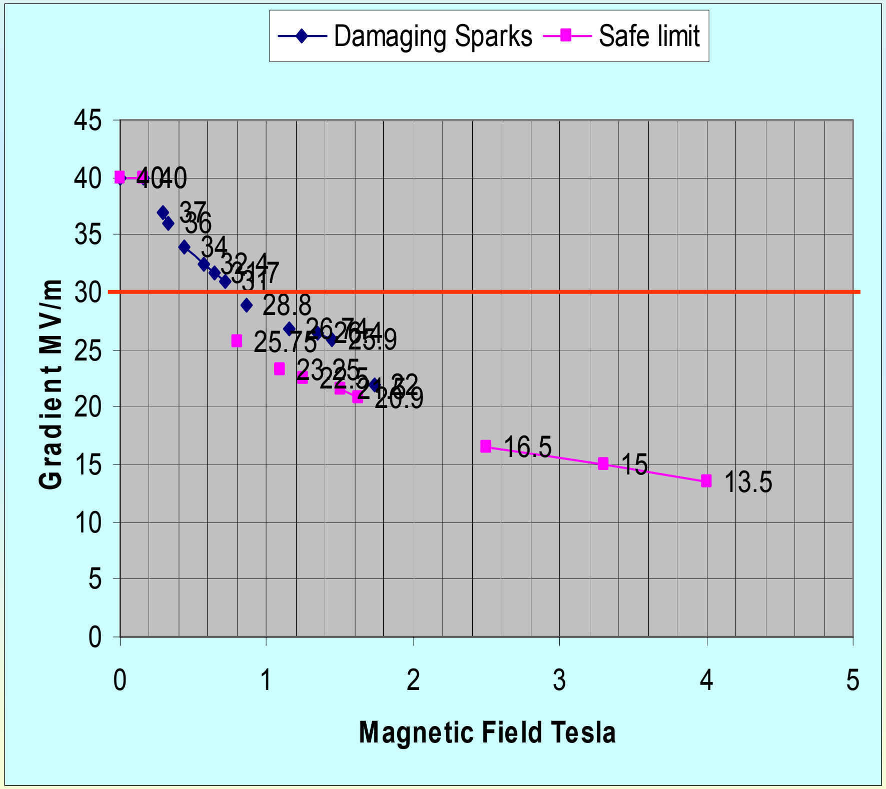
Pillbox cavity

Three more view ports on the equator

Input RF Waveguide

805 MHz cavity tests

We have conducted experimental studies at 805 MHz for nearly three years at Lab G, FNAL



- Open 5-cell cavity reached 25 MV/m gradient (54 MV/m surface field)
  - Large dark current with surface and window damage
- Pillbox cavity test has exceeded its design gradient of 30 MV/m with no magnetic field and reached up to 40 MV/m
- Thin Be windows with TiN-coated surface have been tested versus magnetic fields up to 4 Tesla
  - No surface damage was found on the Be windows
  - Little multipacting was observed; accelerating gradient limit is a function of the external magnetic field

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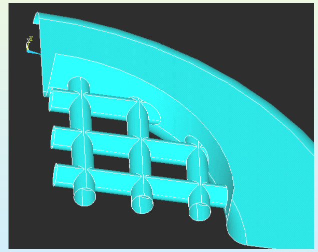
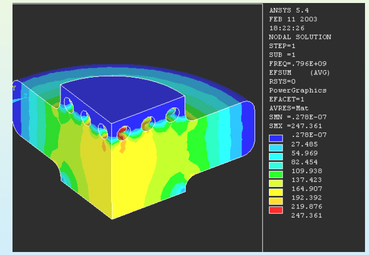
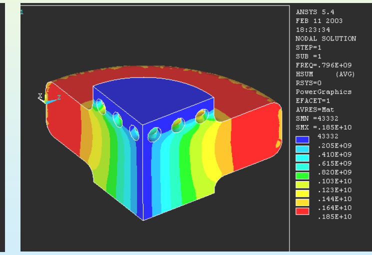
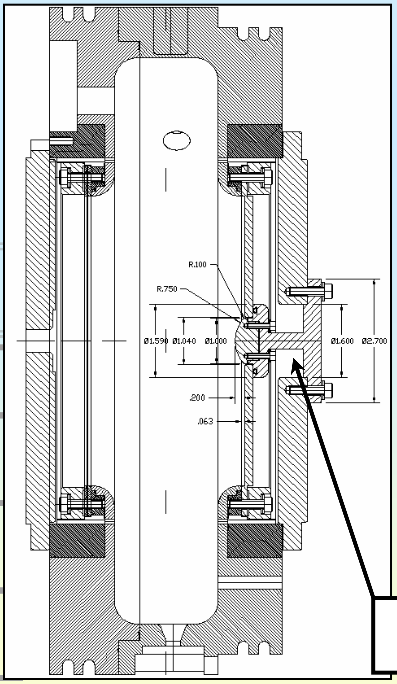
Grid tube & button study

- ANSYS study of grid tube design and prototype for 805 MHz pillbox cavity (M. Alsharo'a's Ph.D thesis)
  - Tests at MTA soon
  - Field enhancement between 1.4 & 3.6
  - RF Heating on tubes

Grid Model	Electric Field	Magnetic Field
		

Maximum Surface Field Enhancement

Grid \ Tube DIA (cm)	0.50	1.00	1.25	1.50
4x4-Connected	3.60			
4x4 -Waffle	2.30	1.80		
6x6 -Waffle		1.64	1.40	1.39
6x6 Middle-Concentrated/Waffle		1.40		



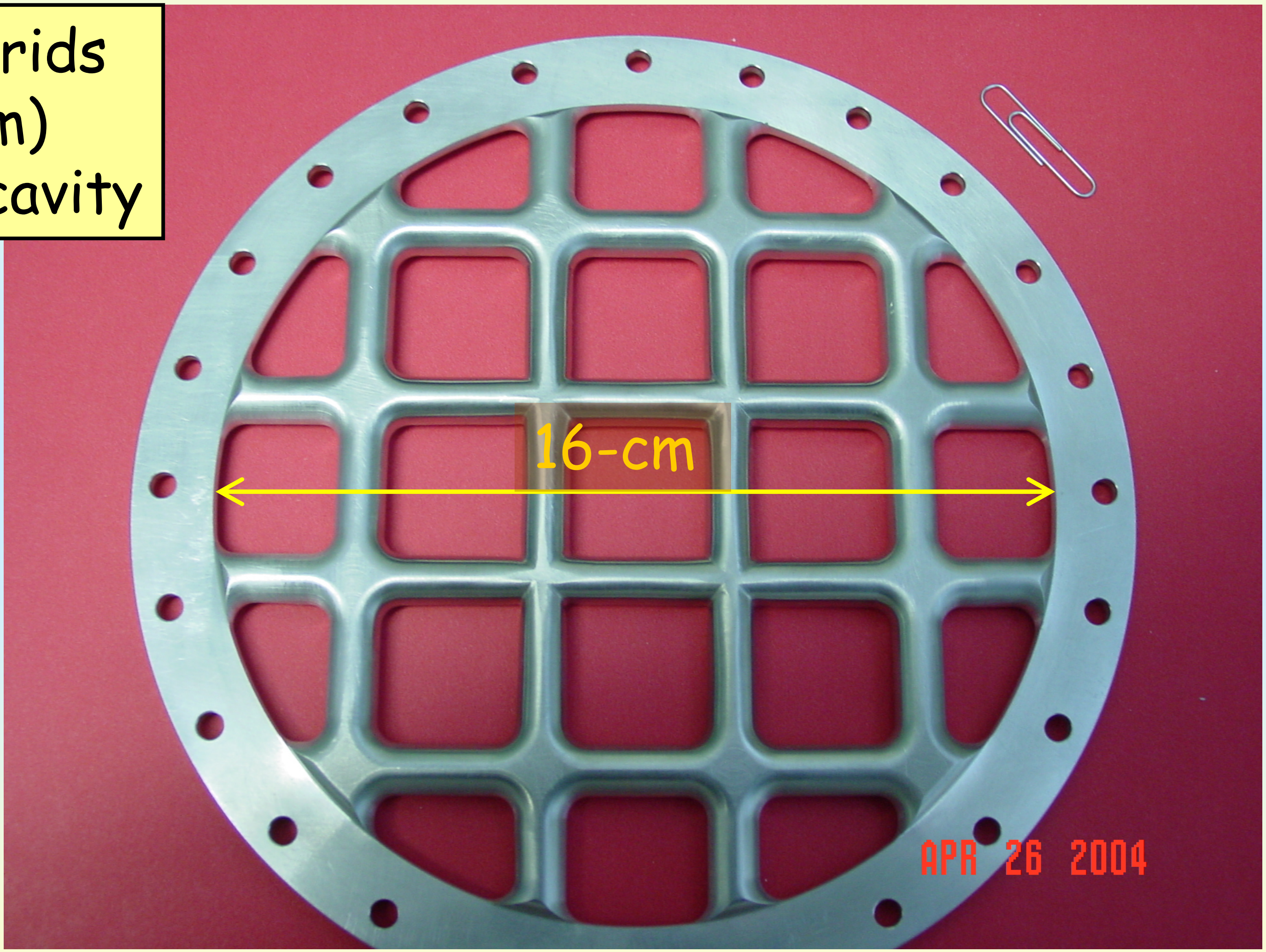
Demountable button

Button study

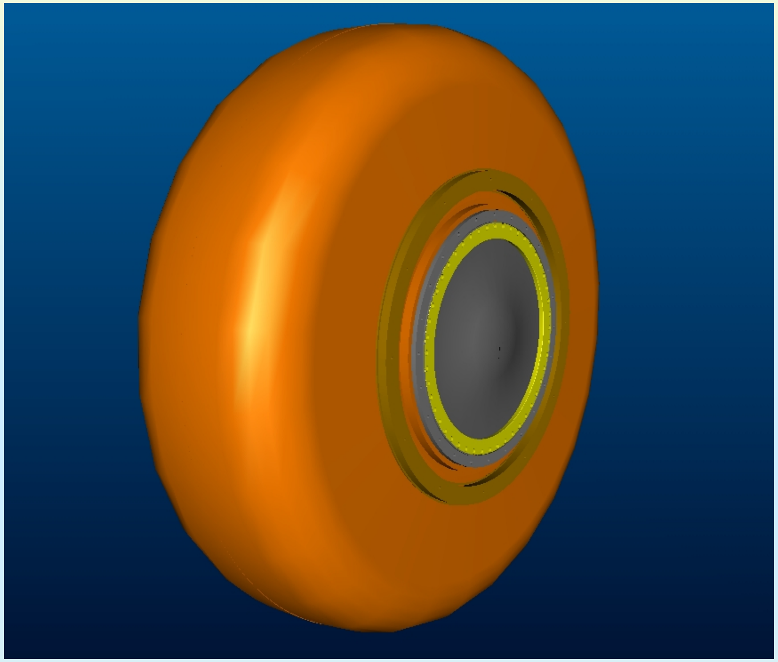
- Completed design
- ~ 70% of peak surface field enhancement with ~ 0.5 MHz shift
- Ready for fabrication
- New material
- Different surface coatings

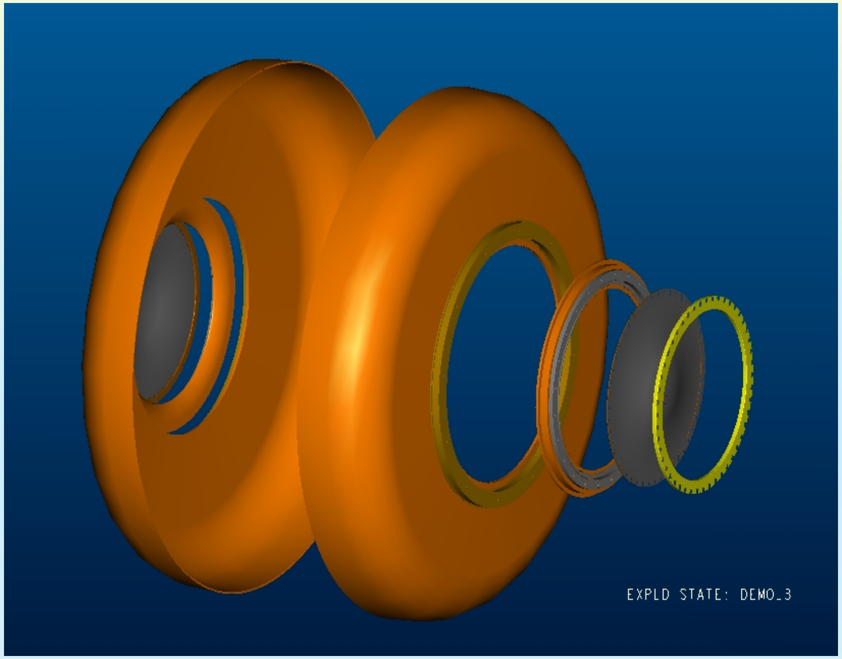
Grids Prototype

Prototype of grids (solid Aluminum) for 805 MHz cavity



201 MHz cavity concept





Spinning of half shells using thin Cu sheets and e-beam welding to join the shells. Four ports across the e-beam joint at equator.

Cavity design uses pre-curved Be windows, but also accommodates different windows or grids.

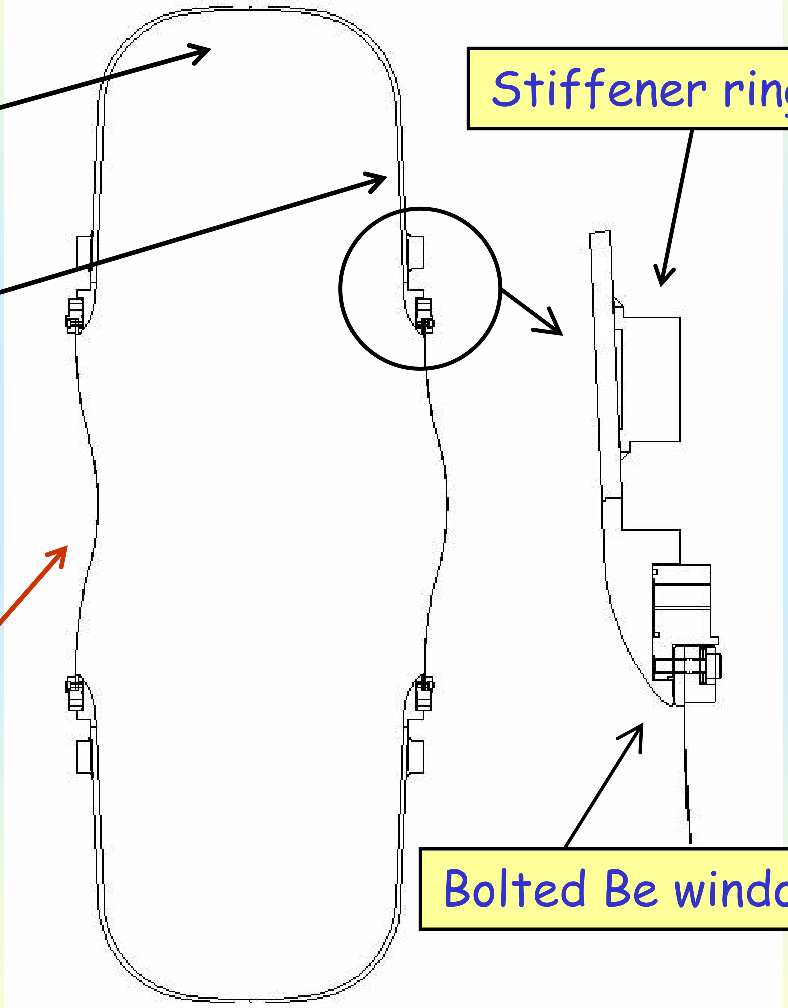
The cavity body profile

Spherical section at the equator to ease addition of ports (± ~ 6°)
Elliptical-like (two circles) nose to reduce peak surface field

2° tilt angle

6-mm Cu sheet permits spinning technique and mechanical tuners similar to SCRF ones

De-mountable pre-curved Be windows pointing to the same direction to terminate RF fields at the iris



Stiffener ring

Bolted Be window

The cavity parameters

The cavity design parameters

- Frequency: 201.25 MHz
- β = 0.87
- Shunt impedance (V_T^2/P): ~ 22 MΩ/m
- Quality factor (Q_0): ~ 53,000
- Curved Be window radius and thickness: 21-cm and 0.38-mm (better performance with significant savings, compared to pre-tensioned flat Be windows)

Nominal parameters for a cooling channel in a neutrino factory

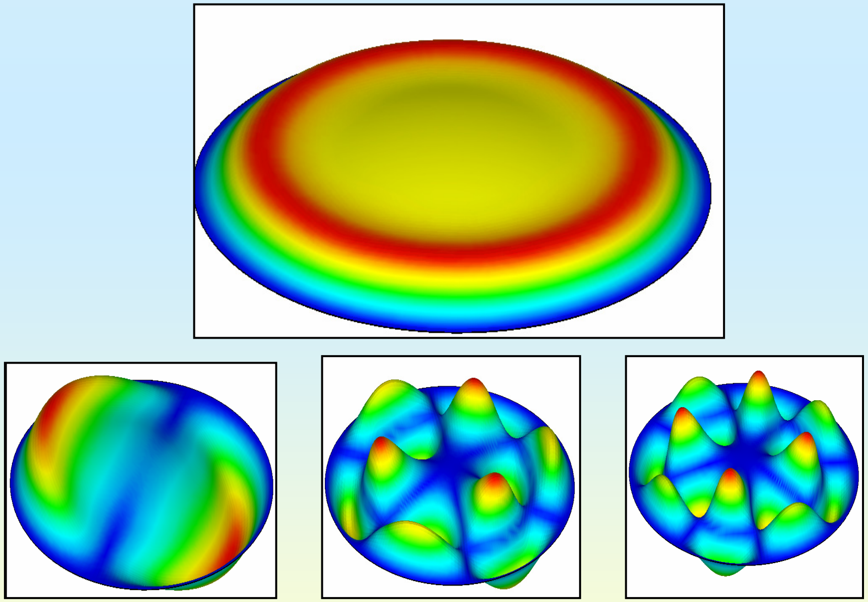
- Up to 17 MV/m peak accelerating field
- Peak input RF power ~ 4.6 MW per cavity (85% of Q_0, 3τ filling)
- Average power dissipation per cavity ~ 8.4 kW
- Average power dissipation per Be window ~ 100 watts

Window for muon RF cavity

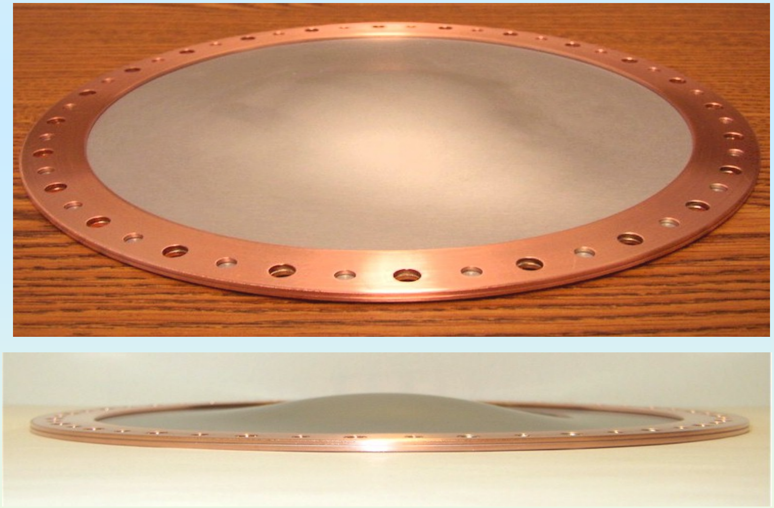
- Performance for an ideal window
  - Transparent to muon beams
    - Low-Z material
  - Perfect electric boundary to RF field
    - Good electrical conductivity
  - Mechanical strength and stability
    - No detuning of cavity frequency under RF heating
- Beryllium is a good material for windows
  - High electrical & thermal conductivity with strong mechanical strength and low-Z
- Engineering solutions being explored
  - Thin, flat Be foils (pre-tensioned)
  - Pre-curved Be foils
  - Grids (Ph.D thesis of M. Alshaor'a at IIT)

Be window R&D

- Designed, fabricated and tested pre-tensioned flat Be windows
  - They work, but expensive; balance between thickness & RF gradient
- Progress on FEA modeling and engineering design of all approaches
- Fabricated pre-curved windows of S.S. and Be for 805 MHz cavity
- Ready to make 21-cm radius pre-curved Be windows for 201 MHz cavity



ANSYS simulations: mechanical vibration modes



Fabricated pre-curved Be window:
16-cm in diameter and 0.254 mm thick

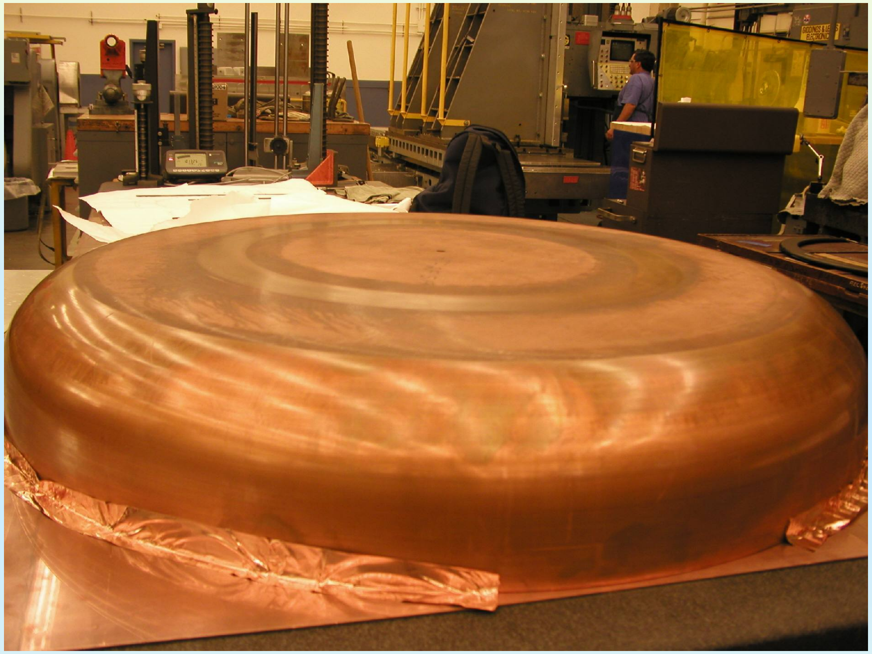
201 MHz cavity fabrication: spinning at ACME

An example of using spinning technique !

Spinning a bowl

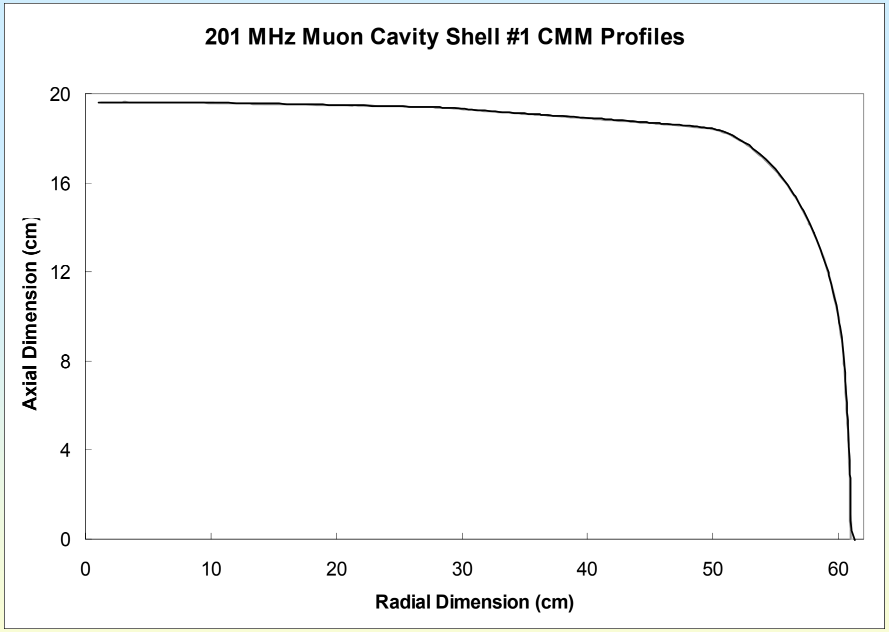
Spinning tools

RF & CMM measurements at LBNL



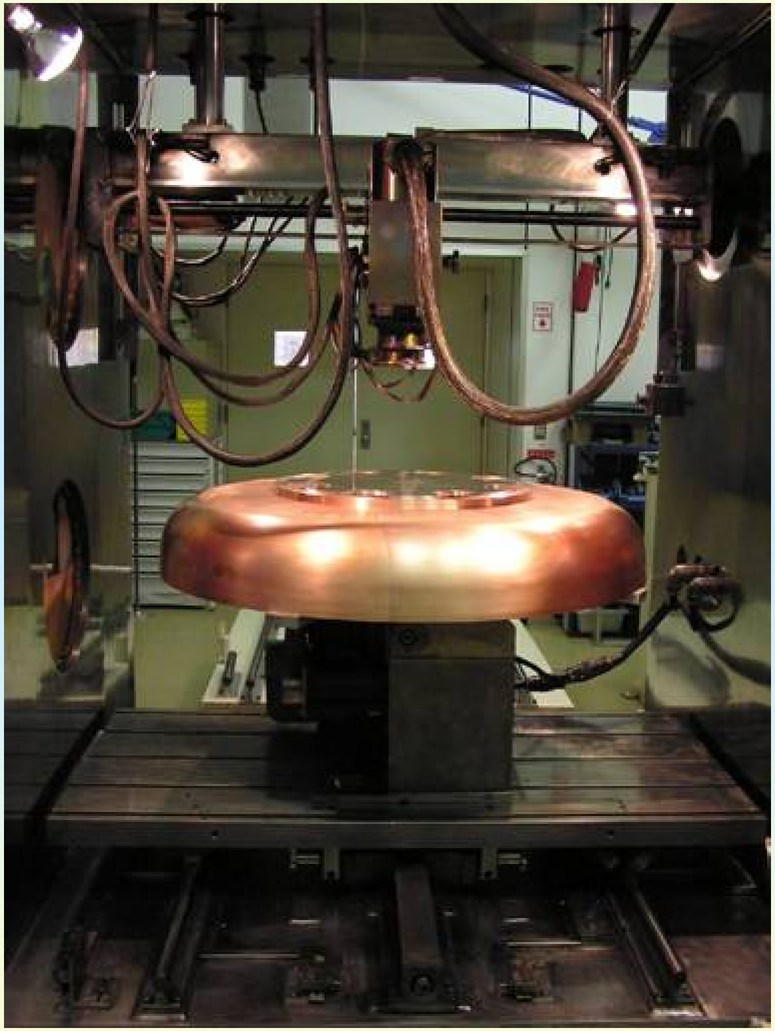
3 CMM scans per half shell conducted at 0°, 45°, 90°, respectively.

Measured frequency: 196.97 MHz
(simulated frequency: 197.32 MHz)



CMM scans, RF frequency and Q measurements of half shells; Cu tape for better RF contacts.

E-Beam welding at JLab



Preparation for e-beam welding of the stiffener ring (left); after the e-beam Welding (above)

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Recent progress for the welding

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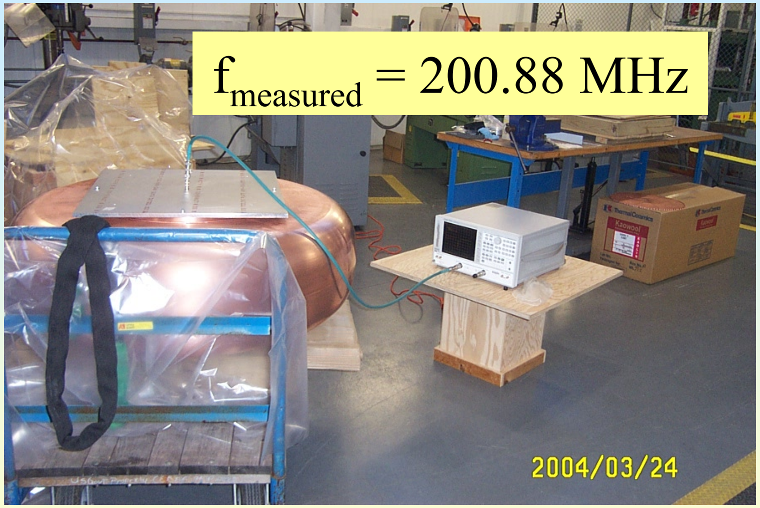
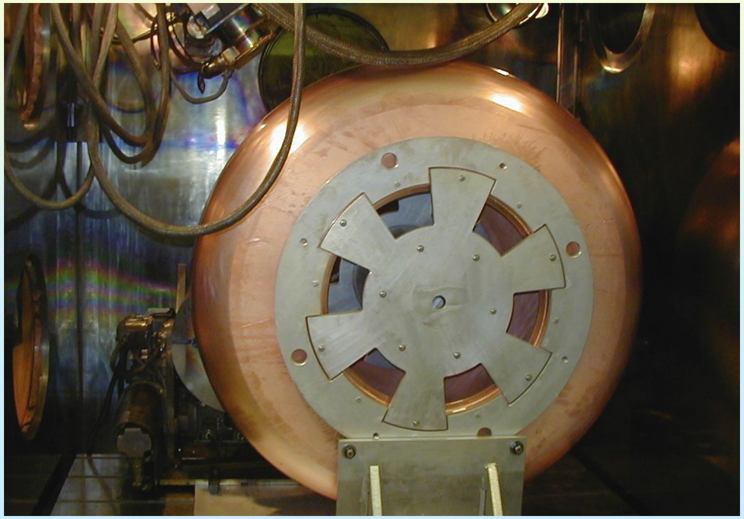
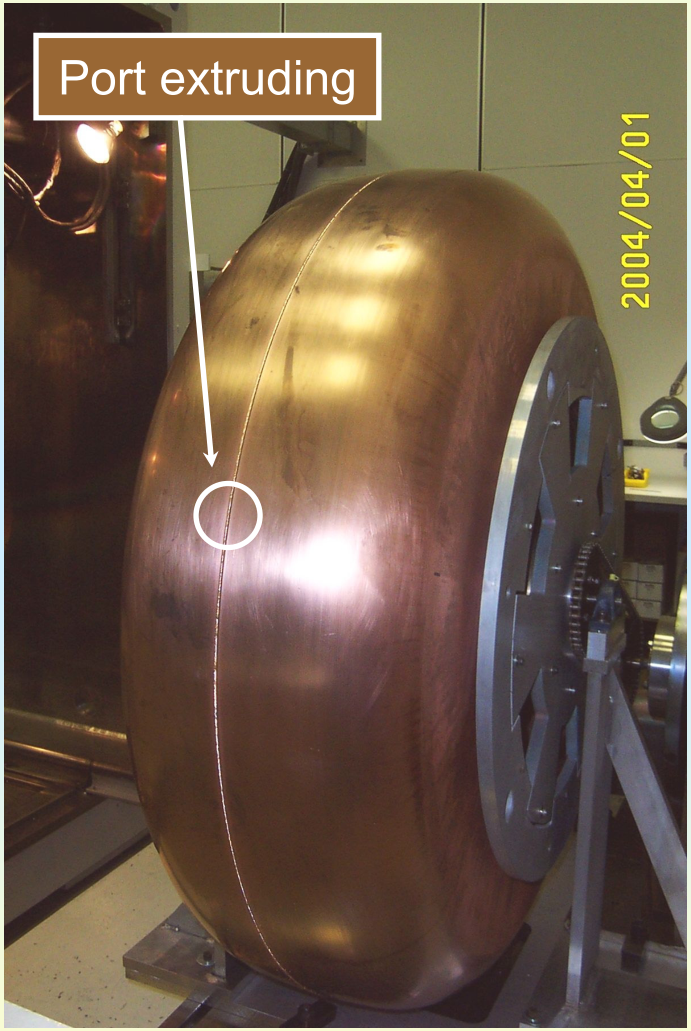


Preparation for equator welding

Equator welding





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Extruding tests at JLab

We have successfully developed techniques to extrude ports across e-beam welded joints.

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201 MHz cavity status

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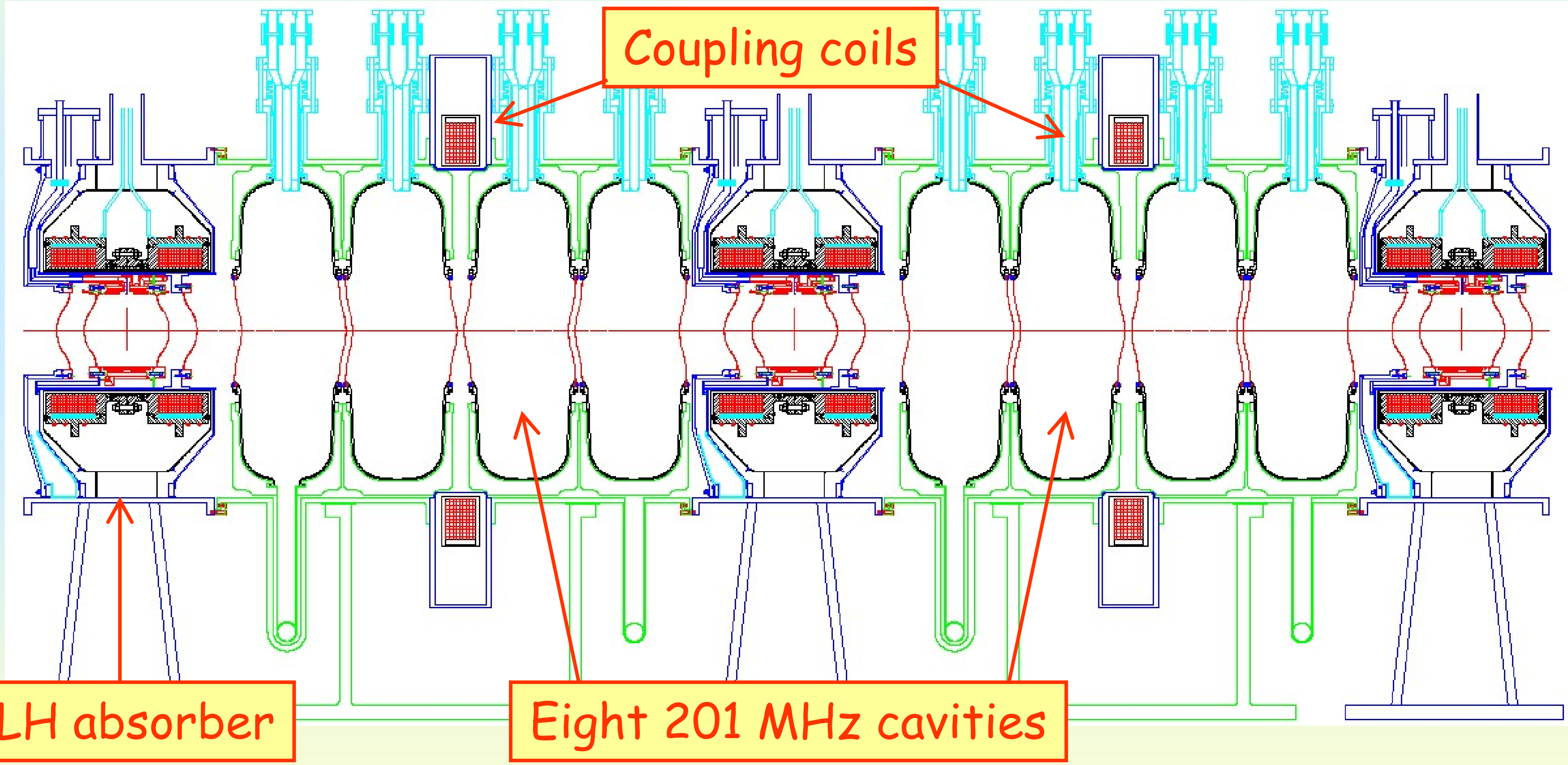
- ✓ Four half shells have been formed by spinning
- ✓ Cu stiffener rings were e-beam welded to two half shells
- ✓ The shells were mechanically cleaned at JLab
- ✓ Shells are ready for machining prior to e –beam welding of equator joint
- ✓ Equator weld fixturing has been fabricated at LBNL
- ✓ Cavity nose piece rings (Univ. of Mississippi) have been brazed at LBNL
- ✓ Conceptual design of RF loop coupler
- ✓ E-beam welding of equator joint
- ❑ Extruding four ports
- ❑ Nose pieces
- ❑ Chemical cleaning and electro-polishing of the cavity
- ❑ Pre-curved Be windows

The cavity should be ready for test in MTA at Fermilab this fall

Components for MICE

Eight 201 MHz RF cavities with curved Be windows for the cooling channel



Summary

- **Good progress on NC RF R&D programs**
  - Experimental study at 805 MHz
  - 201 MHz cavity prototype
  - Be window: FEA modeling and prototype
- **805 MHz pillbox cavity tests progress well at Lab G and provide valuable operation experience and experimental data that will benefit accelerator community**
- **Experimental study using the 805 MHz cavity will be resumed once the cavity and the SC magnet are moved to MTA, FNAL.**
- **201 MHz test cavity fabrication progressing well; ready for testing this fall (2004)**
- **The 201 MHz cavity has been used as baseline design for MICE**