# 201 MHz NCRF: Studies and Plans

**Derun Li**

Center for Beam Physics
Lawrence Berkeley National Laboratory

MUTAC Review at LBNL
April 26, 2005

# Collaborators

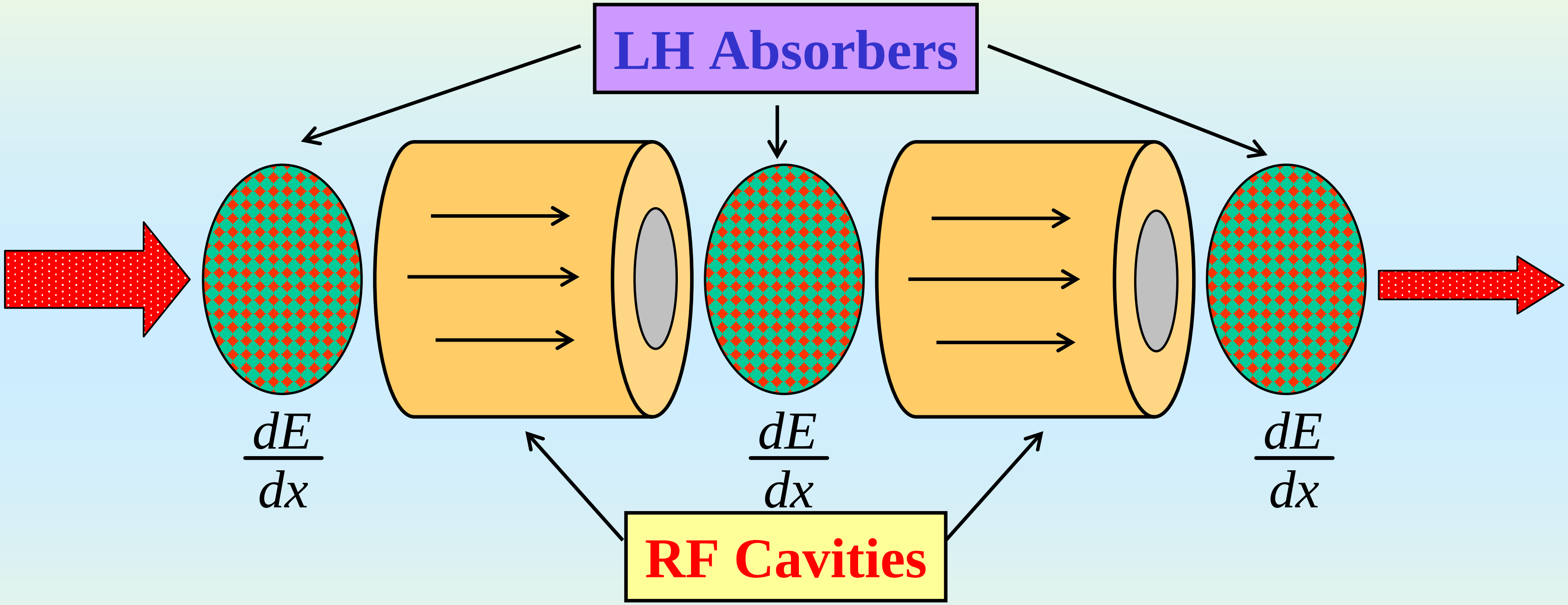
R. MacGill, J. Staples, S. Virostek, M. Zisman
Lawrence Berkeley National Laboratory
J. Norem
Argonne National Laboratory
A. Bross, A. Moretti, Z. Qian
Fermi National Accelerator Laboratory
R. Rimmer, L. Phillips, G. Wu
Jefferson National Laboratory
M. Alsharo'a, Y. Torun
Illinois Institute of Technology
D. Summers
University of Mississippi
W. Lau, S. Yang
Oxford University, UK

# Outline

- Introduction
- 201 MHz cavity
  - Cavity design concept
  - Fabrication status
    - Cavity body, ports, coupler, supporting structure, and …
  - Progress on curved Be windows
    - 21-cm curved Be windows for 201 MHz cavity
- Components for MICE
- Summary

# Introduction

## Ionization cooling principle




– Strong magnetic field to confine muon beams
– Lose energy in LH absorbers
– High gradient RF cavities to compensate for lost longitudinal energy

# Introduction (cont'd)

## Requirements of RF cavities for cooling of

- Intense muon beams
  - Have short lifetime and large phase space
  - Interact weakly with matter
- Confined in focusing channels

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- High gradients
  - 16+ MV/m at 201 MHz and 34 MV/m at 805 MHz
- Normal conducting
  - Rounded "pillbox" cavity
  - <u>Large</u> and <u>thin</u> <u>Be</u> foils (low-Z) to terminate RF fields

→ High cavity shunt impedance
  - Lower peak surface field
  - High accelerating efficiency with independent phase control
  - Less RF power

# Introduction (Cont'd)

## NCRF R&D Program

- Develop highest possible NC accelerating structure to meet the requirements for NF or MC
- Prototype of 201 MHz cavity with curved Be windows
  - Completed cavity design
  - Cavity fabrication almost finished and will be shipped to MTA, FNAL
  - Significant progress in FEA modeling and fabrication of curved Be windows
  - Test plan in progress
- Experimental studies at 805 MHz with and without external magnetic fields up to 4-Tesla (J. Norem's talk)
  - 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 button study at MTA, FNAL soon
    - Test of new materials/surface coating versus RF breakdown field
    - Termination of cavity iris: grids and curved Be windows

# The 201 MHz Cavity Concept

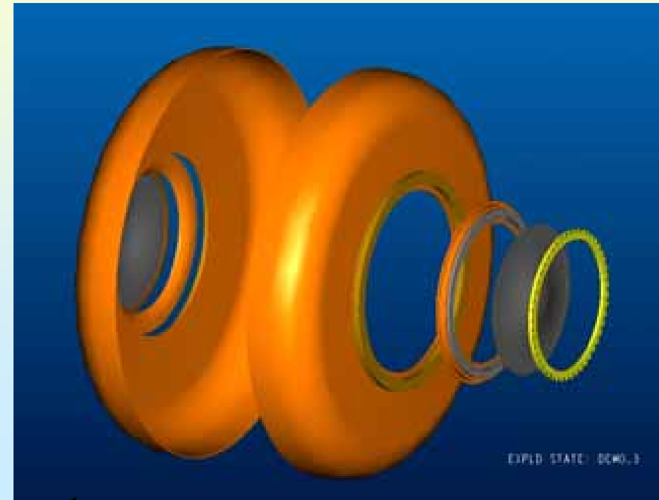
**Goal:** 201-MHz at ~ 16+ MV/m in a few-Tesla magnetic field

## Cavity and its sub-components

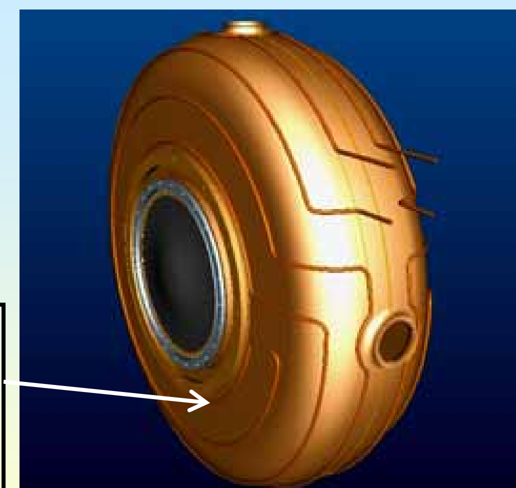
Cavity dimension:

Diameter: 1.2 m, Gap: 0.43 m, Iris Radius: 0.21 m

- Cavity body + water cooling lines
- Four ports and flanges
- RF loop couplers
- Cavity support structure
- Cavity tuners
- Ceramic RF windows (~ 4")
- Curved Be windows
- Possible LN temperature operation



Cavity design concept



Layout of water cooling lines on cavity

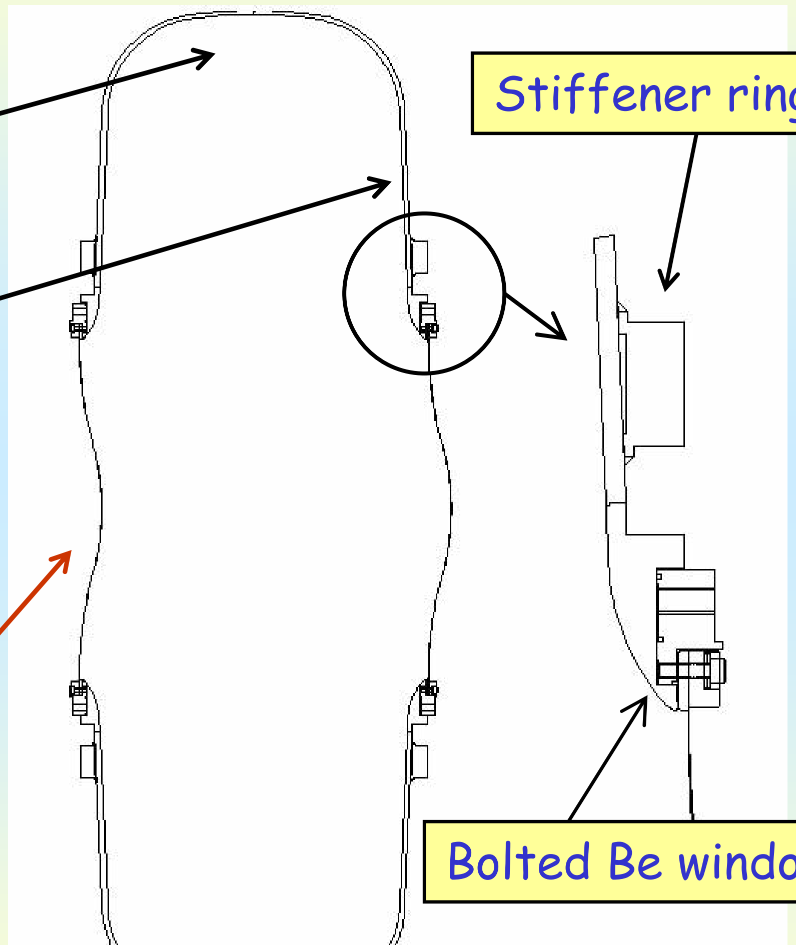
# The cavity body profile

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 in the same direction to terminate RF fields at the iris




**Low peak surface field and easy fabrication**

# The cavity parameters

## The cavity design parameters

- Frequency: 201.25 MHz and $\beta = 0.87$
- 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 $Q_0$, filling time of 3 times time constant )
- Average power dissipation per cavity ~ 8.4 kW
- Average power dissipation per Be window ~ 100 watts

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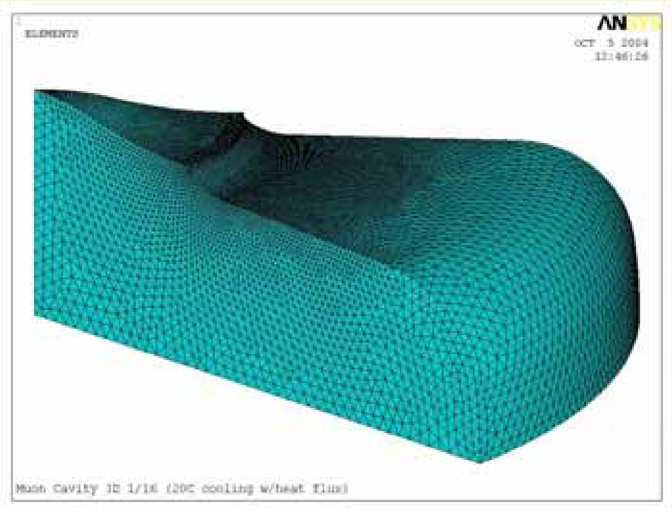
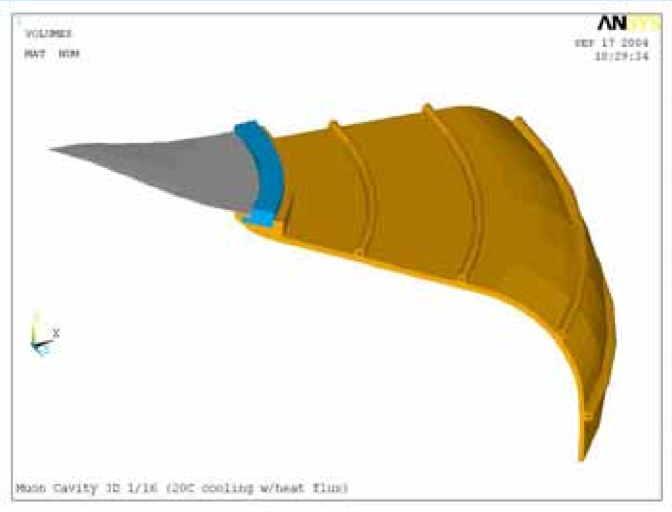
Muon Collaboration

# Finite Element Analysis



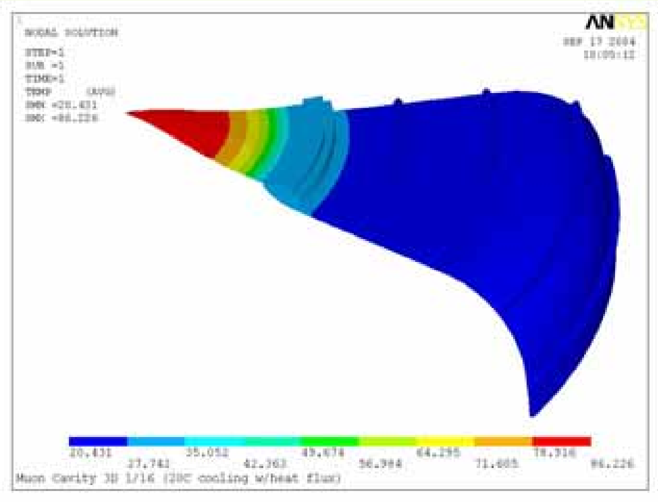



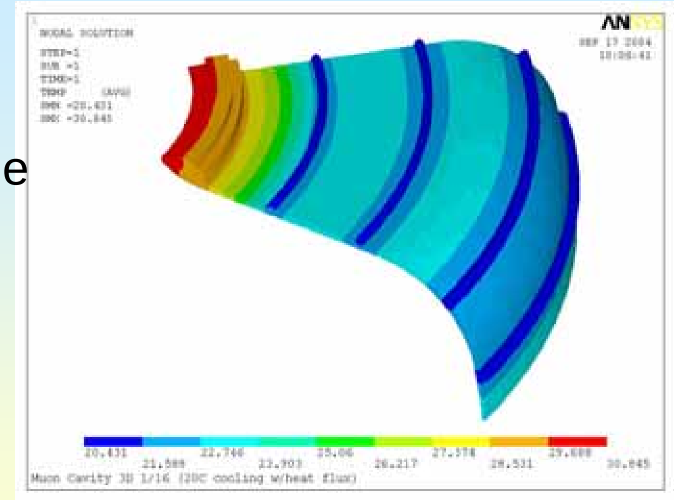

The thermal solution provides temperature distribution throughout the cavity and the beryllium window

The peak temperature occurs at the center of the beryllium window (86 ºC)

FEA helps to determine designs for:

→ Cooling tubes
→ Be window thickness



# 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**

# Curved Be Windows for 201 MHz Cavity

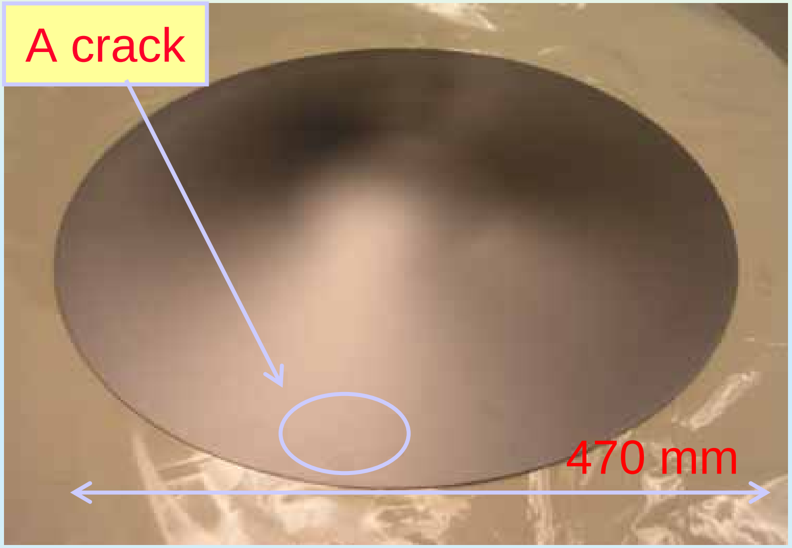
- Succeeded in two curved Be windows for the 805-MHz cavity
- Placed purchase order of three Be windows for 201-MHz cavity:

  0.38 mm thick, 420 mm diameter

  at Brush-Wellman (~100 watts per window with ΔT~ 55 degrees at nominal Study-II parameters)
- Window is formed by applying a die at elevated temperature
- Copper frame is brazed to Be window
- Be windows will be Ti-N coated

Brush-Wellman attempted twice so far:
- warping (1st one)
- cracking (2nd one) on edge, but still can be used
- Very confident for future ones

– Present a perfect conducting BC for RF.
– Min. scattering and mechanically strong




~ 470 mm diameter curved Be window for the 201 MHz cavity formed

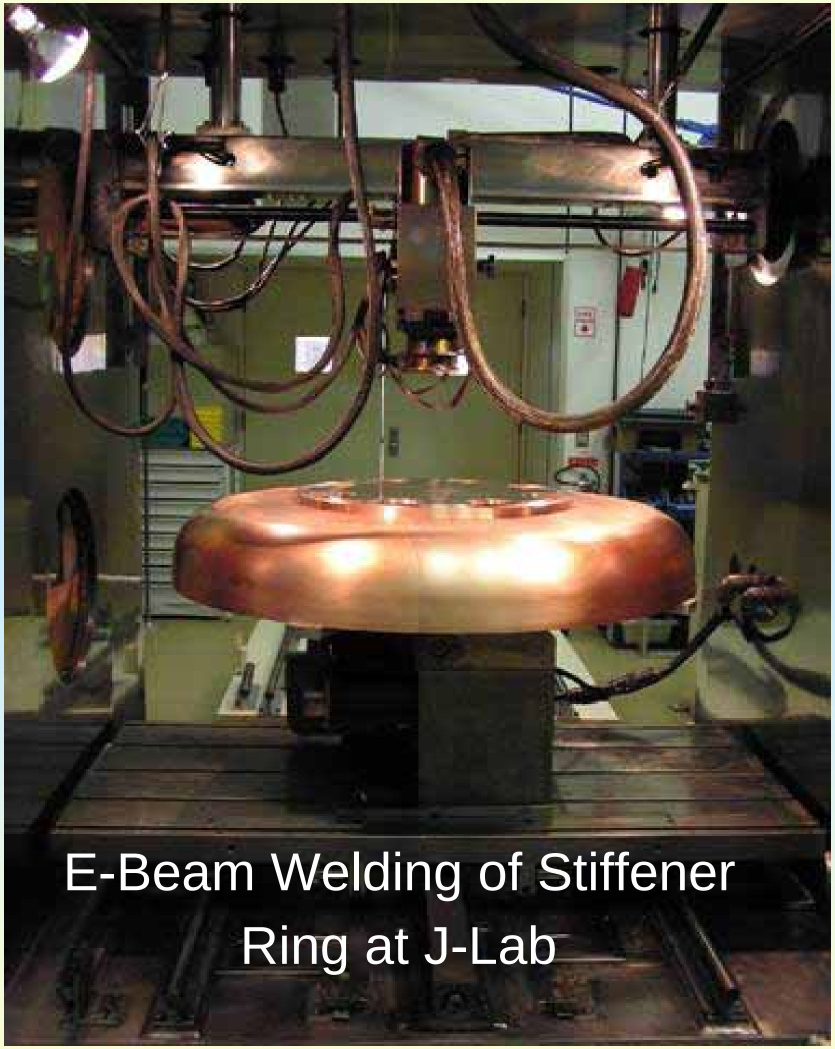
at Brush-Wellman.

This window has a crack on the edge, but still can be used (brazed under Cu frame).

# Curved Be Window with Cu Frame

First successful curved Be window (21-cm radius and 0.38 mm thick) with brazed copper frames

# The Cavity Fabrication

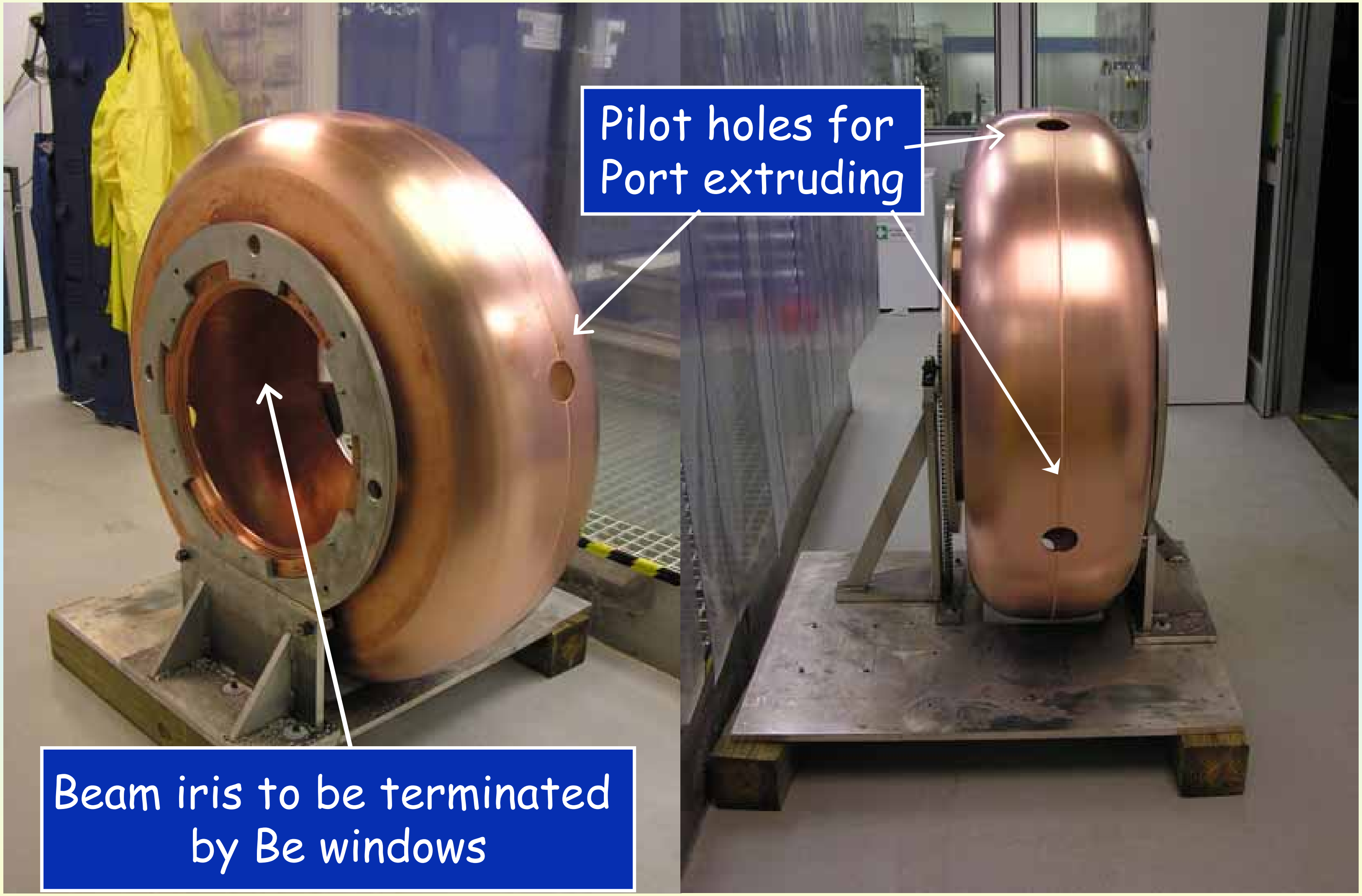


E-Beam Welding of Stiffener Ring at J-Lab

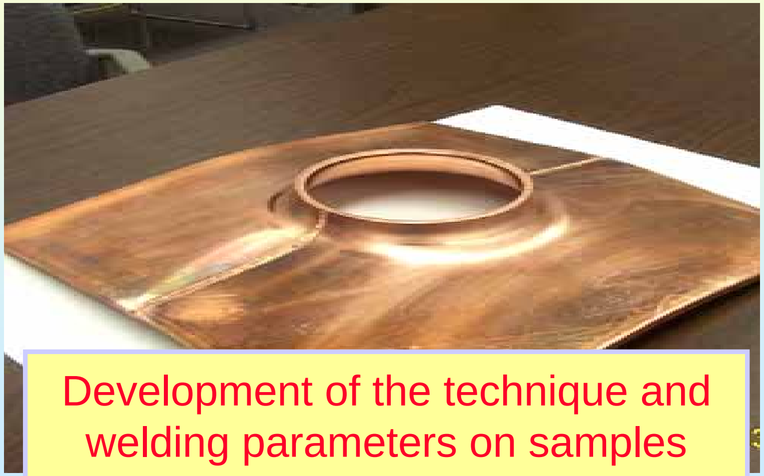
Finished equator welding


We have successfully developed extruding technique for port pulling over e-beam joints

# Nose welding and Port extruding



# Port extruding and Flange Welding




Local annealing of ports

Cavity ports being extruded (pulled)

Extruded port

E-beam welding of the port flange

Finished cavity port

# TIG Braze of Cooling Tubes

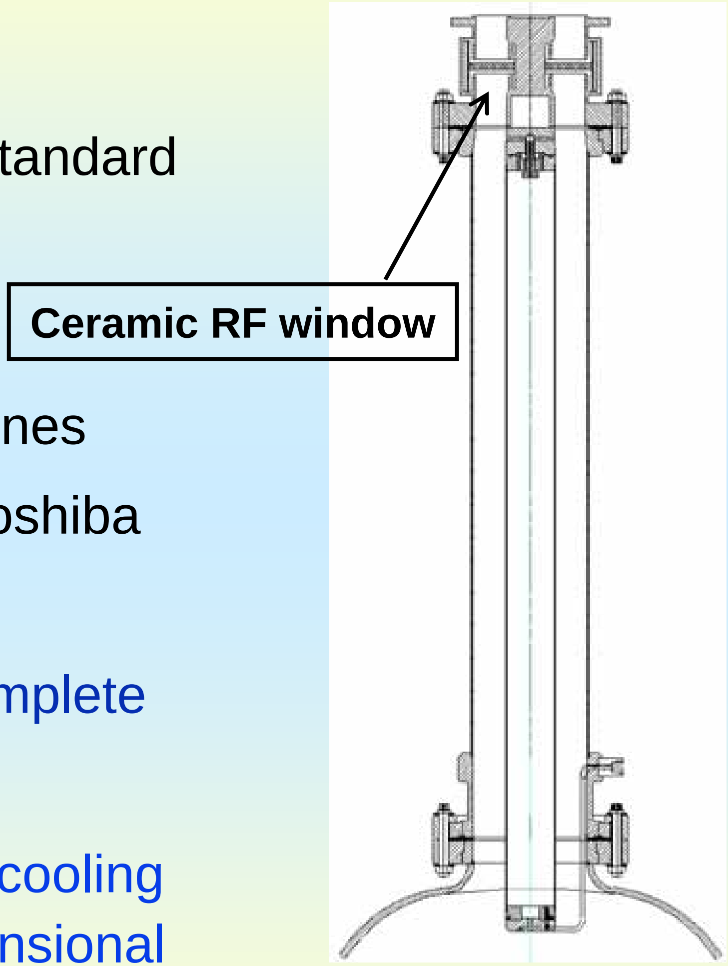
Requirement:
- Good thermal conduction
- No distortion on the cavity body
- Welding material
- Welding speed and temperature

We have developed the technique and achieved the design goal

*Silicon-Bronze with helium gas torch + argon gas flowing in the cooling tubes*

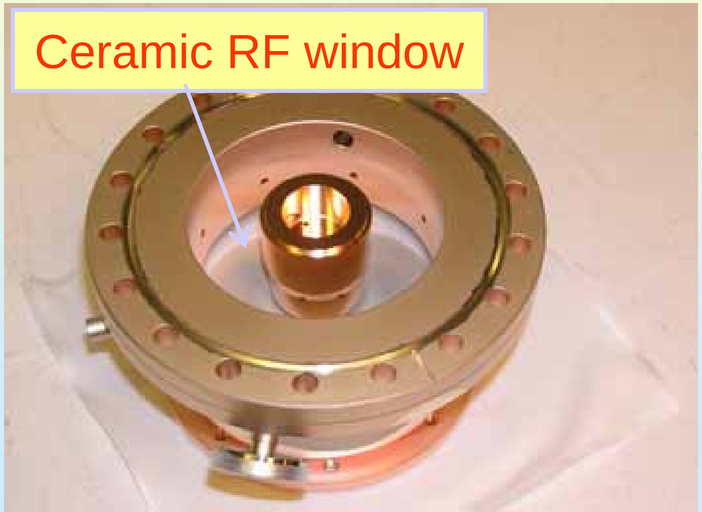
# RF Coupler Design

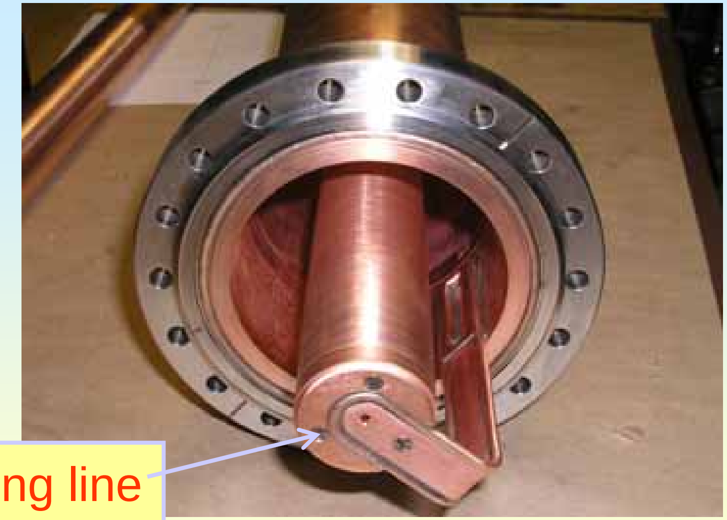
- Loop coupler at critical coupling
- Prototype coupling loop design uses standard off-the-shelf copper co-ax
- Parts were joined by torch brazing
- Coupling loop has integrated cooling lines
- ☺ Two SNS style RF windows mfg. by Toshiba received (no cost to us !)
- Two couplers with RF windows are complete and ready for high power
- Bellows connection required on MICE cooling channel (Study-II) for thermal and dimensional reasons




Loop Coupler Design

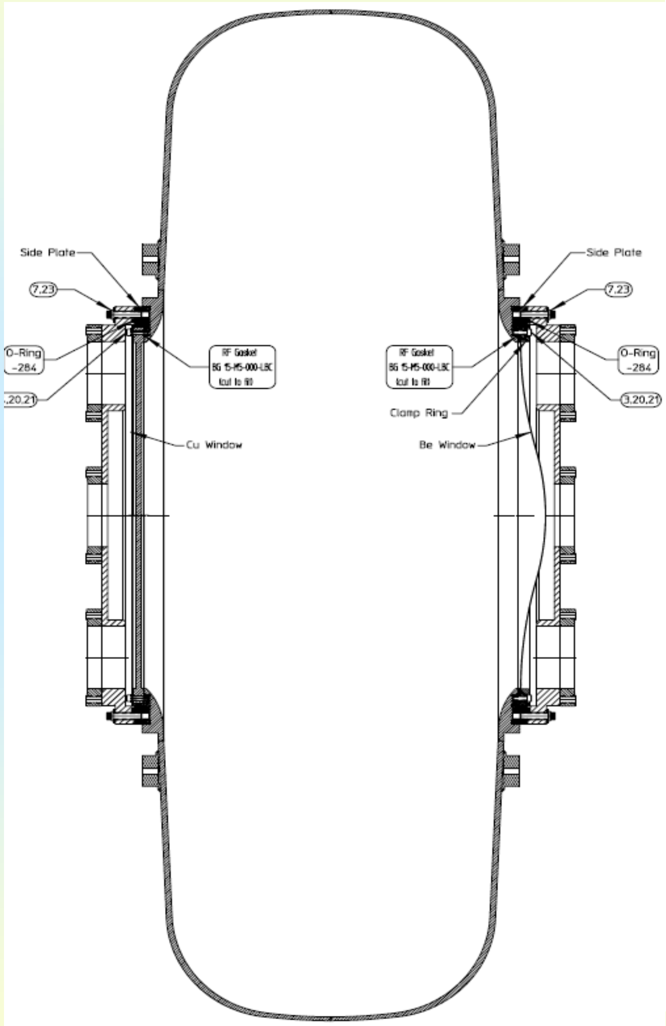
# Fabrication of the Coupler

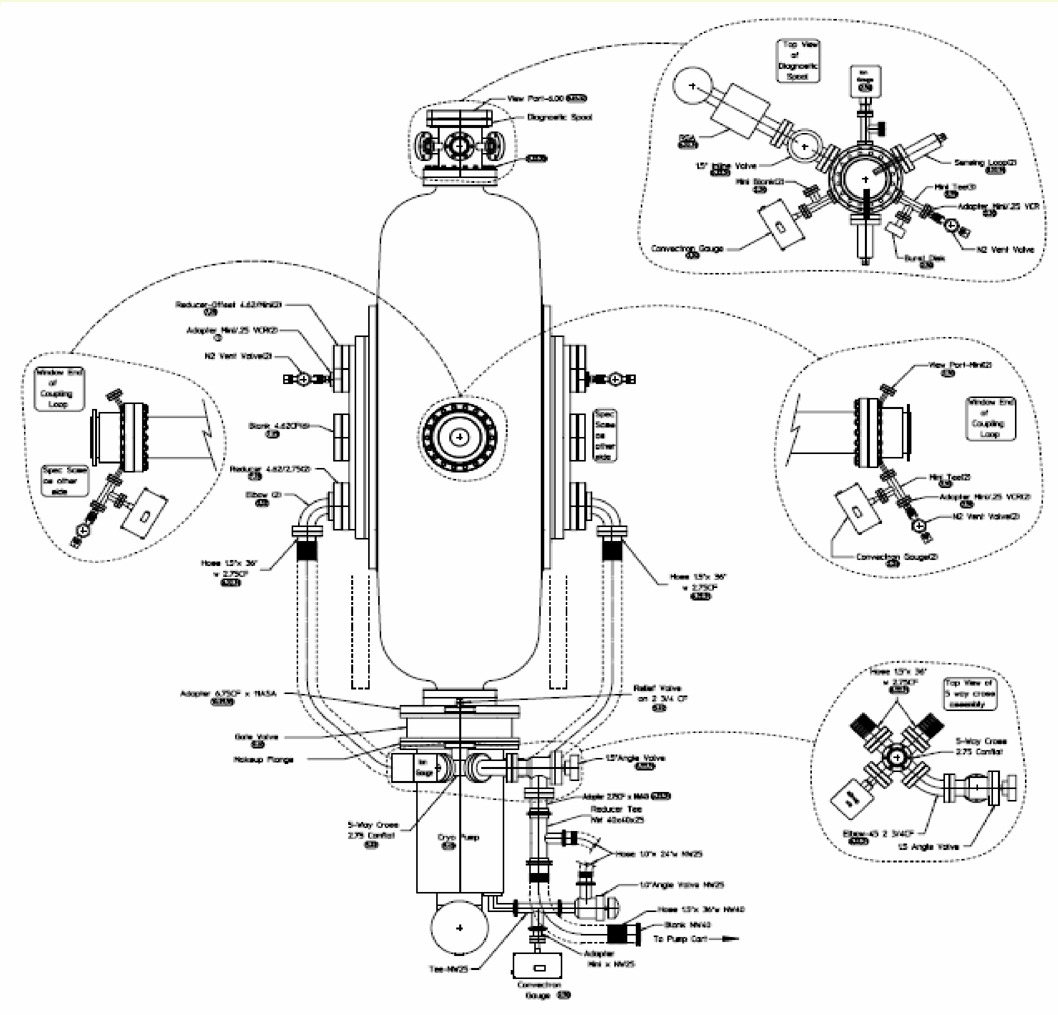



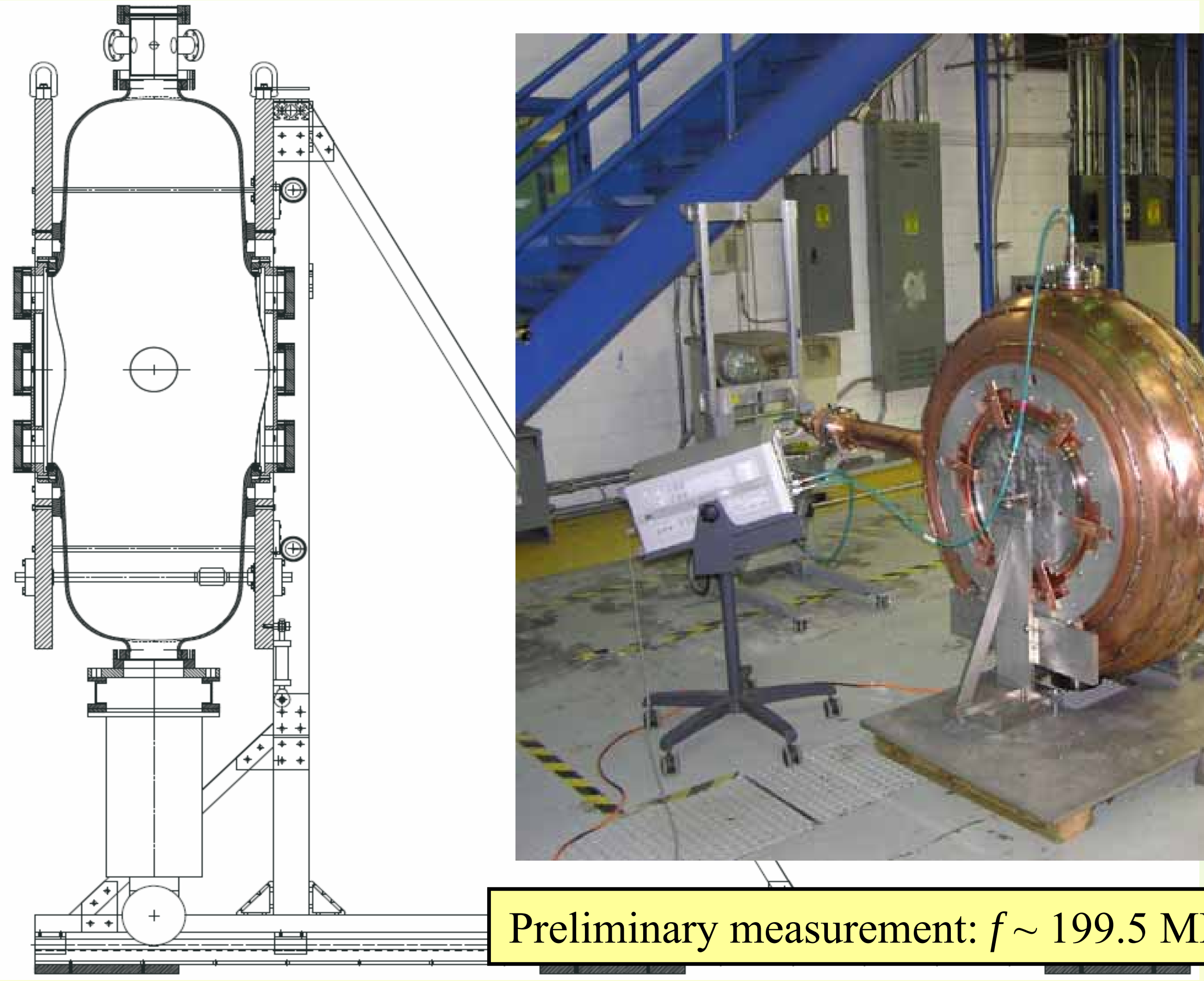

- The coupling can be adjusted by rotating the loop
- Water cooling line goes around the loop

# The cavity with all sub-components



# The Cavity & Supporting Structure



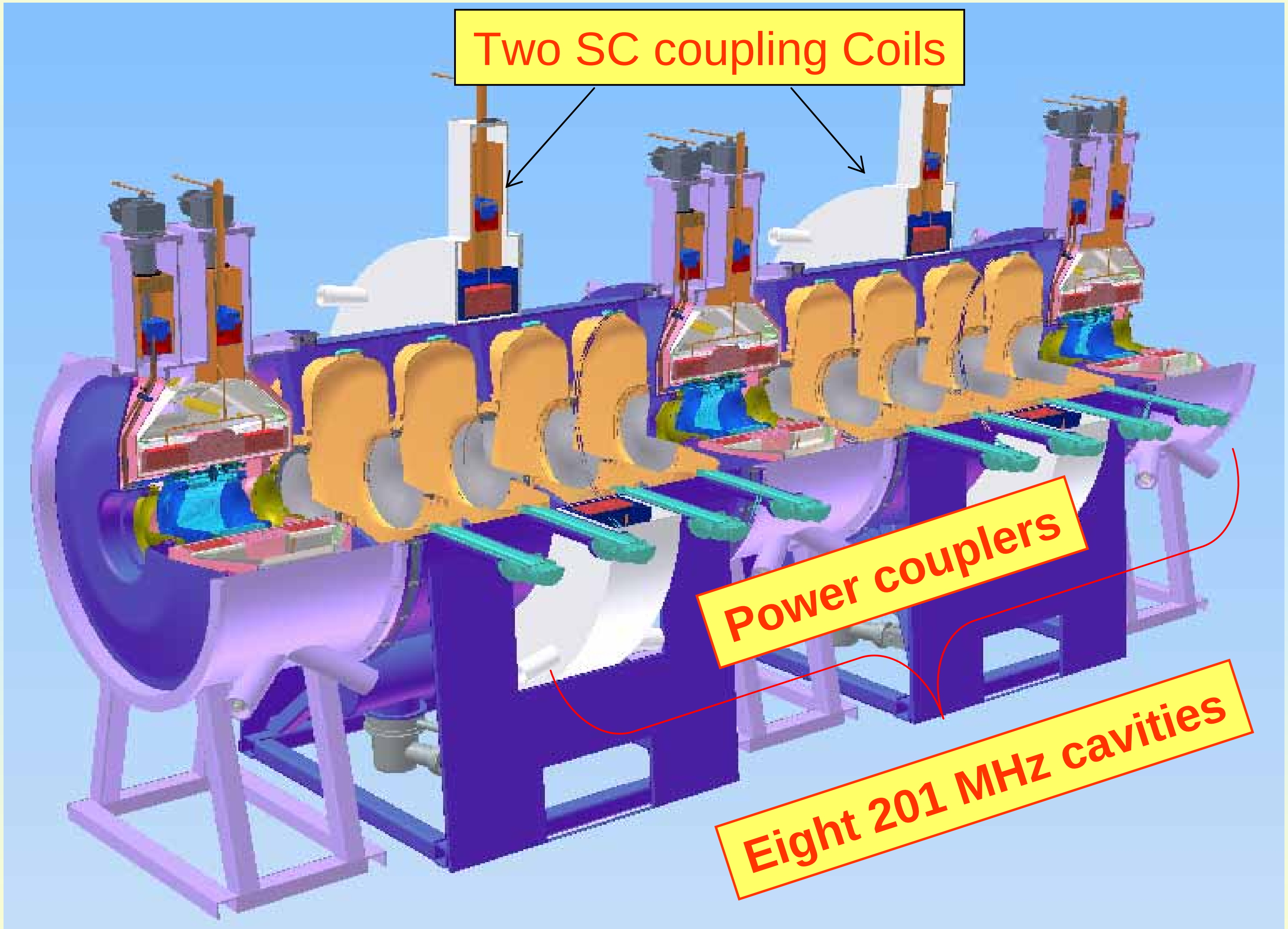
Preliminary measurement: $f \sim 199.5$ MHz with $\beta_C\,(\max) \sim 5$

# Cavity Status and Plans



- RF couplers with ceramic RF windows are ready and will be high power conditioned at SNS in two weeks
- Curved Be windows expect to arrive soon
- Assembly with RF couplers and low power measurements
- Cavity being cleaned now and will be EP this week
- Support structure and tuners being assembled at J-Lab
- Expect to ship the cavity to MTA in May-2005
- High power tests with flat copper and curved Be windows
- Detailed plans on high power test in progress

# Components for MICE



# Summary

- Progress in 201 MHz NCRF cavity R&D
  - 201 MHz cavity prototype fabrication
  - Be window: FEA modeling, prototype and fabrication
  - Cavity sub-components and diagnostics
  - Cavity tuners and support structures
- Unexpected delays due to fabrication difficulties
- The 201 MHz cavity being shipped to MTA, FNAL next month for high power tests
- The 201 MHz cavity has been used as baseline design for MICE