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201-MHz RF Cavity Construction (Plan) for MICE

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NFMCC Meeting
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Outline

- **MICE Cavity Design**
  - **Based on the design of 201-MHz cavity for MUCOOL**
    - **Cavity body**
    - **Ports for power coupler, vacuum and probes**
    - **RF power loop coupler and ceramic RF window**
    - **Curved Beryllium window**
    - **Tuners**
    - **Interface and integration with RFCC module**
- **Summary**
  - **Status and fabrication plan**
    - **Techniques developed for MUCOOL cavity**
      - **Spinning, port extruding, curved Be windows, RF couplers**

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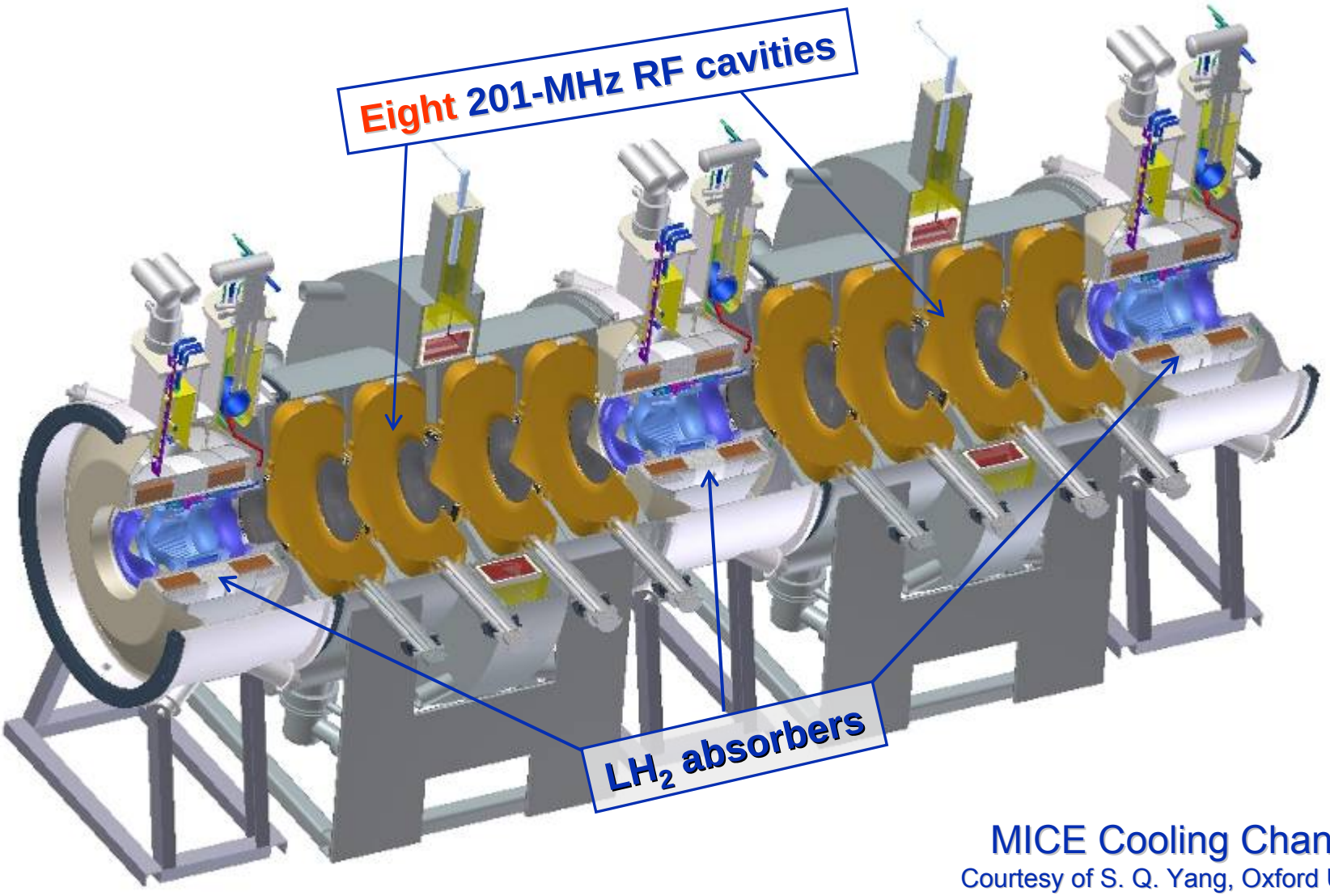
MICE Cooling Channel



MICE Cooling Channel
Courtesy of S. Q. Yang, Oxford Univ.

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MICE RF Cavity

- Eight 201-MHz cavities + with materials for two more spares
- Baseline design: 201-MHz for MUCOOL, but
  - Cavity body profile needs to be modified
    - Resonant frequency
    - Better estimation of spring back after spinning
  - Port extruding
    - Port interface is different from the MUCOOL cavity
  - RF coupler and ceramic window
    - Same as the MUCOOL cavity with Toshiba ceramic windows for SNS
  - Curved Beryllium windows
    - Modified design to better control silver alloy flow during the brazing
  - Tuners and interface with RFCC module
  - Post-processing: Water cooling pipes, cleaning (EP & water rinsing), low power measurement, tuning, assembly and shipping

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Cavity Design Parameters

- **The cavity design parameters**
  - Frequency: 201.25 MHz
  - $\beta = 0.87$
  - Shunt impedance (VT^2/P): ~ 22 MΩ/m
  - Quality factor (Q_0): ~ 53,500
  - Be window radius and thickness: 21-cm and 0.38-mm
- **Nominal parameters for cooling channels in a muon collider or a neutrino factory and MICE**
  - ~ 16 MV/m (**~ 8 MV/m**) peak accelerating field
  - Peak input RF power ~ **4.6 MW** (**~ 1 MW**) per cavity (85% of Q_0, 3τ filling)
  - Average power dissipation per cavity ~ **8.4 kW** **(~ 1 kW at 1 Hz repetition rate and 1 ms pulse length)**
  - Average power dissipation per Be window

    ~ 100 watts **(~ 12 watts)**

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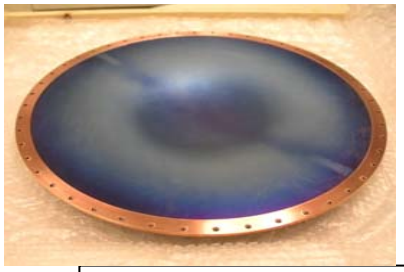
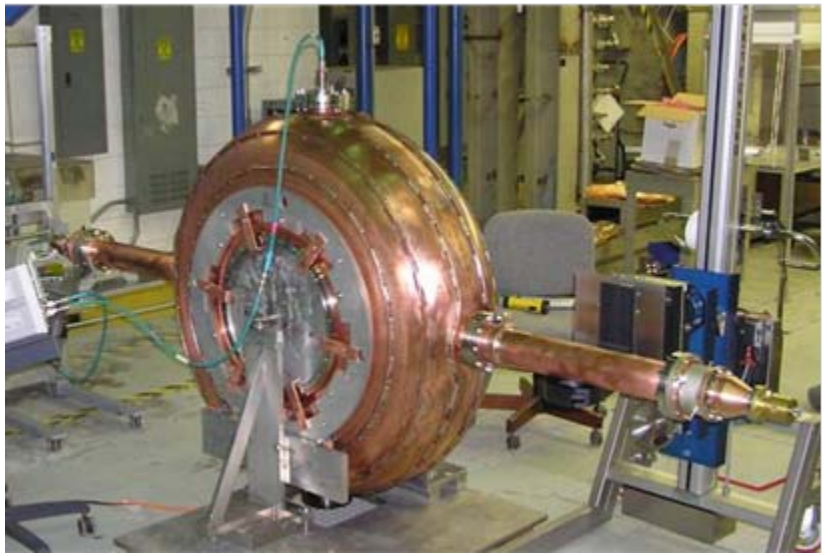
MUCOOL Cavity Review





- Design and engineering at LBNL
- Half shells spun at Acme in Minnesota
- Parts made in Univ. of Mississippi and LBNL
- E-beam welding & port-pulling, cleaning and EP at J-Lab, NASA
- Coupler tests at SNS, Oak Ridge National Lab
- Final assembly and high power tests at MTA, FNAL (March-2006) and reached 16-MV/m without external magnetic field

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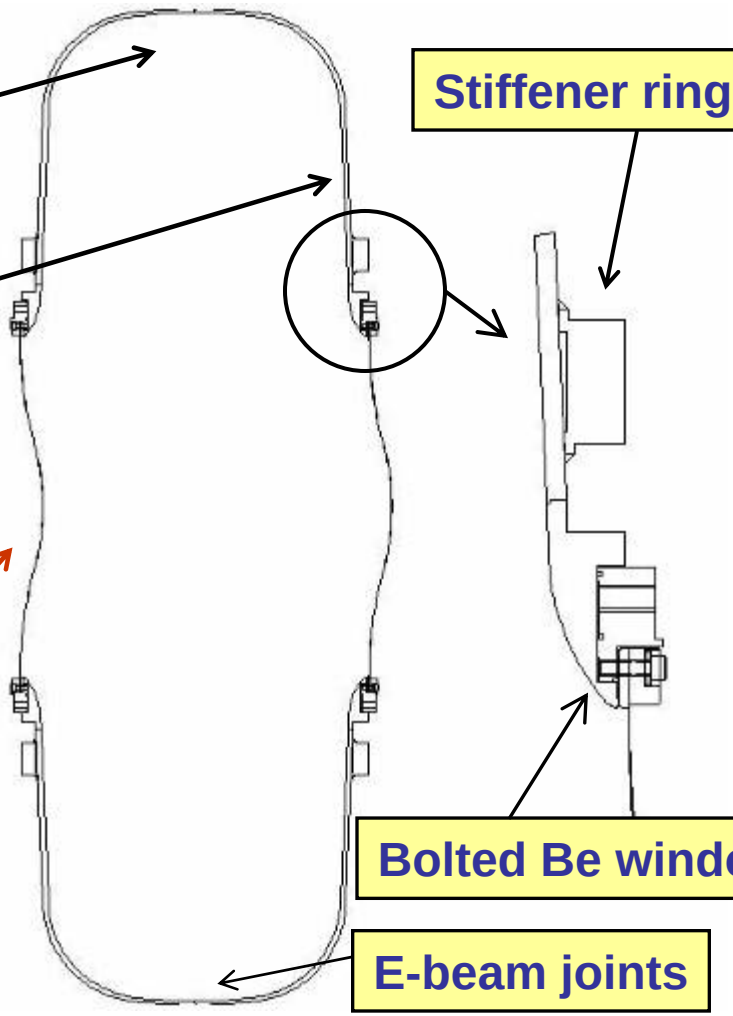
The Cavity Body Profile

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

Cavity Body

- MUCOOL cavity frequency is slightly lower than 200-MHz, but within the bandwidth of RF source
  - Mechanical (fixed) tuners available and tested in air
- MICE cavities
  - Target frequency is 201.250-MHz
  - One RF source (tube) powers more than one cavity
  - Each cavity will be made (spinning) to frequency very close to 201-MHz
    - Modifying the existing mold used for MUCOOL cavity
    - A new mold (could be new materials)
  - 3D simulations to predict the frequency shifts by ports, curved Be windows and thermal contraction (LN operation)
  - Conceptual tuner designs (fine tuning)

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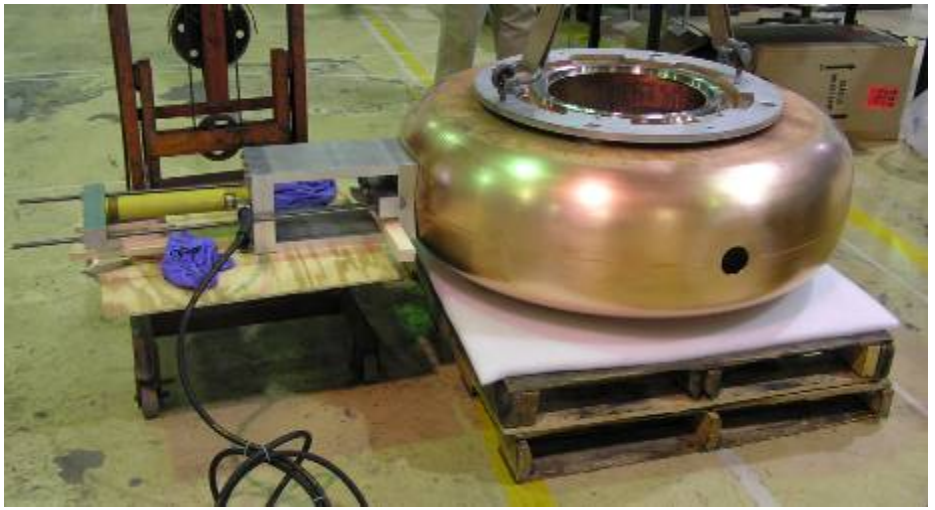
Ports Extruding and Flanges

Local annealing of ports



Cavity ports being extruded (pulled)

Extruded port

Port flange e-beam weld

Finished cavity port

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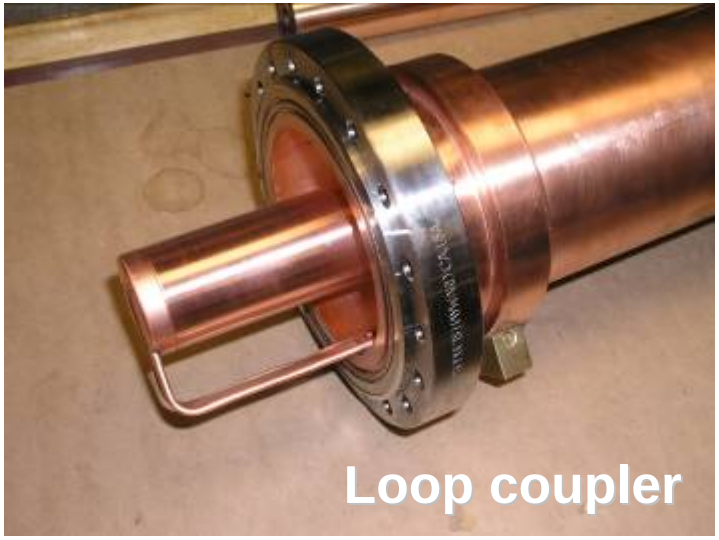
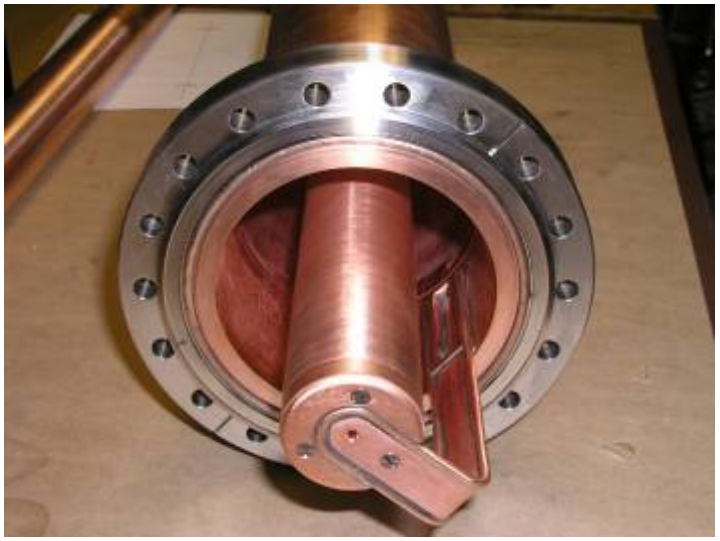
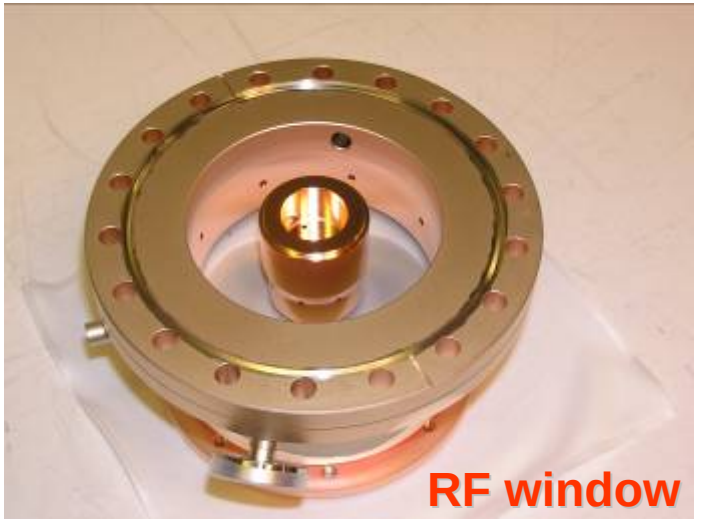
Fabrication of the Coupler





- The coupling can be adjusted by rotating the loop
- Water cooling line goes around the loop
- RF ceramic windows from Toshiba Company



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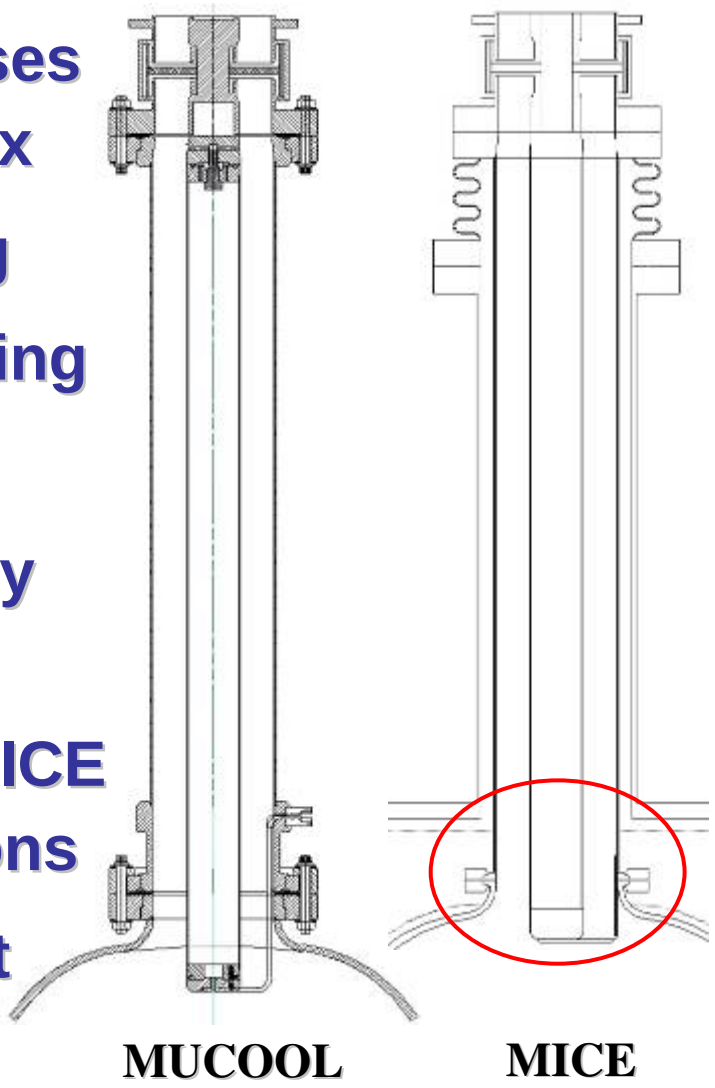
RF Coupling Loop Design

- Prototype coupling loop design uses standard off-the-shelf copper co-ax
- Parts to be joined by torch brazing
- Coupling loop has integrated cooling

  (Possible off-shelf components?)
- Two SNS style RF windows mfg. by Toshiba received (no cost!)
- Bellows connection required on MICE for thermal and dimensional reasons
- Need to integrate with MICE layout



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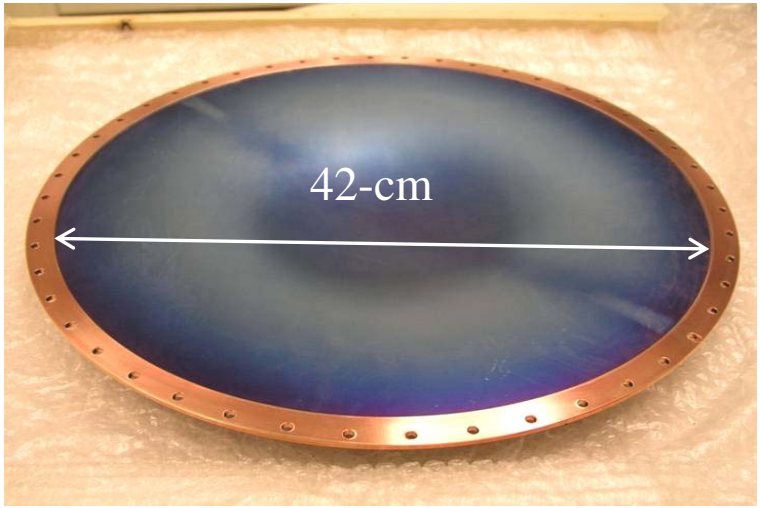
Curved Be Windows

- **We have made two windows available so far**
  - 21-cm and 0.38-mm thick
  - ***Good*** braze (between annular frames and foil)
  - Achieved ~ 95 % of the designed profile
  - Thin Ti-N coatings
- **The windows were HP tested at MTA, Fermilab**



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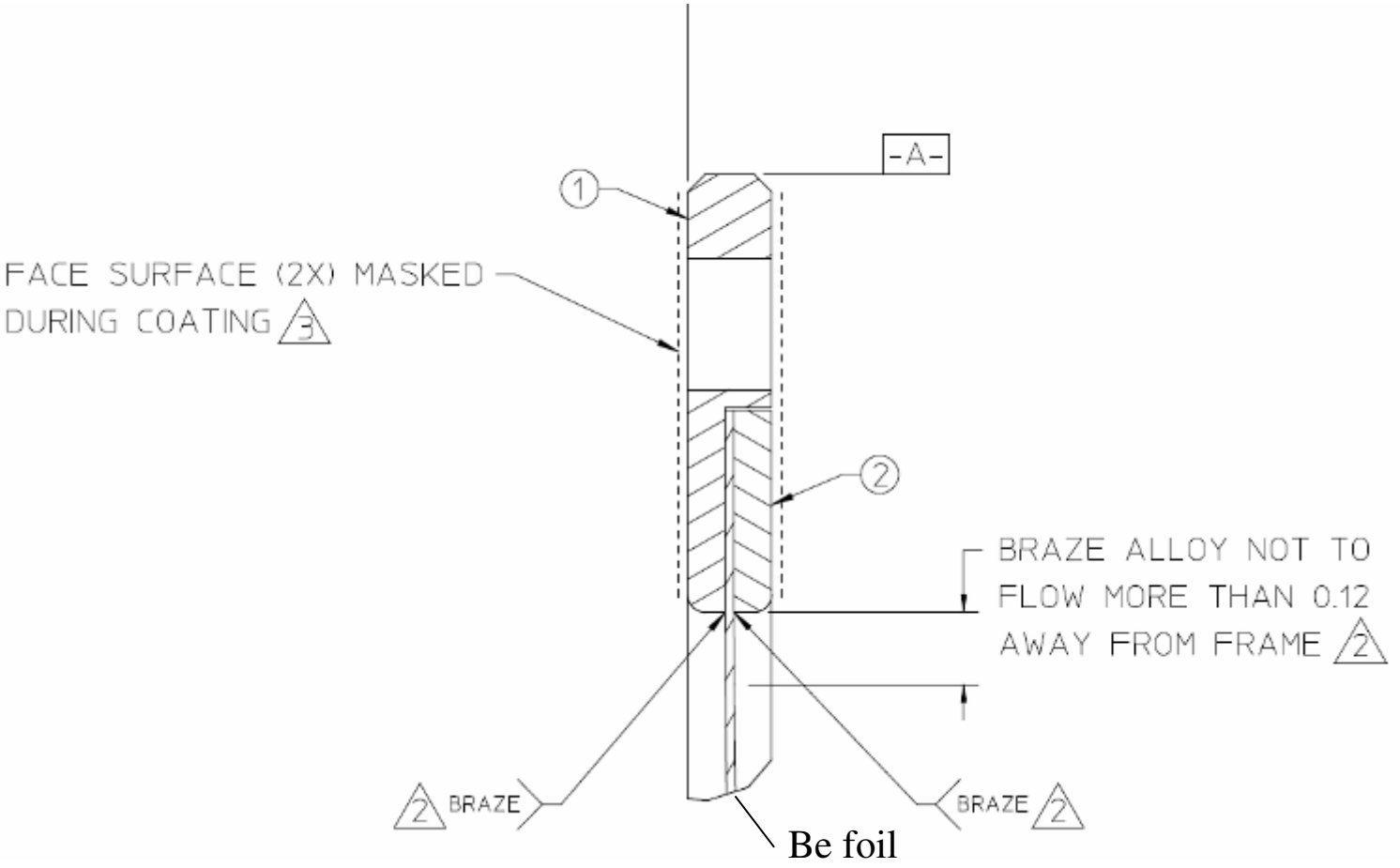
Beryllium Window Update

- **Improved design for better brazing (based on suggestions from Brush-Wellman Company)**



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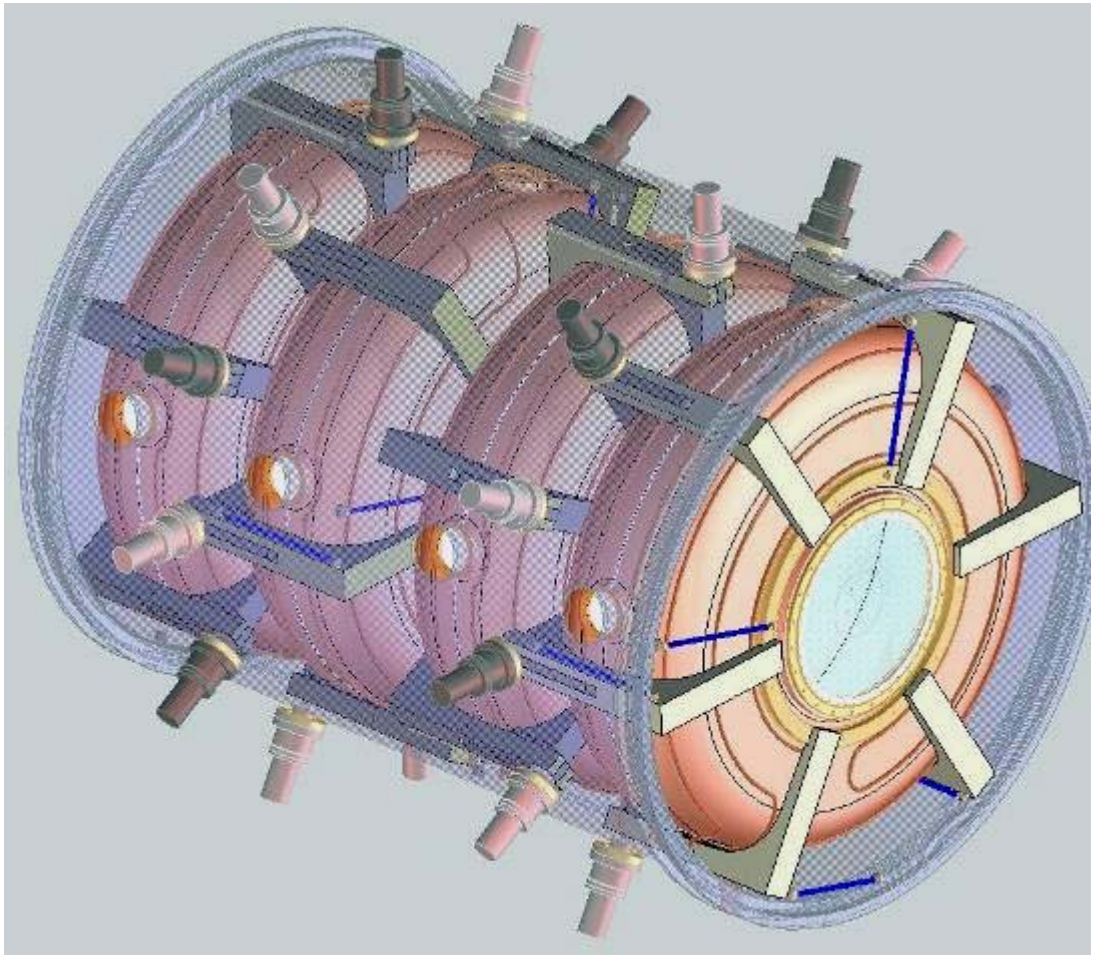
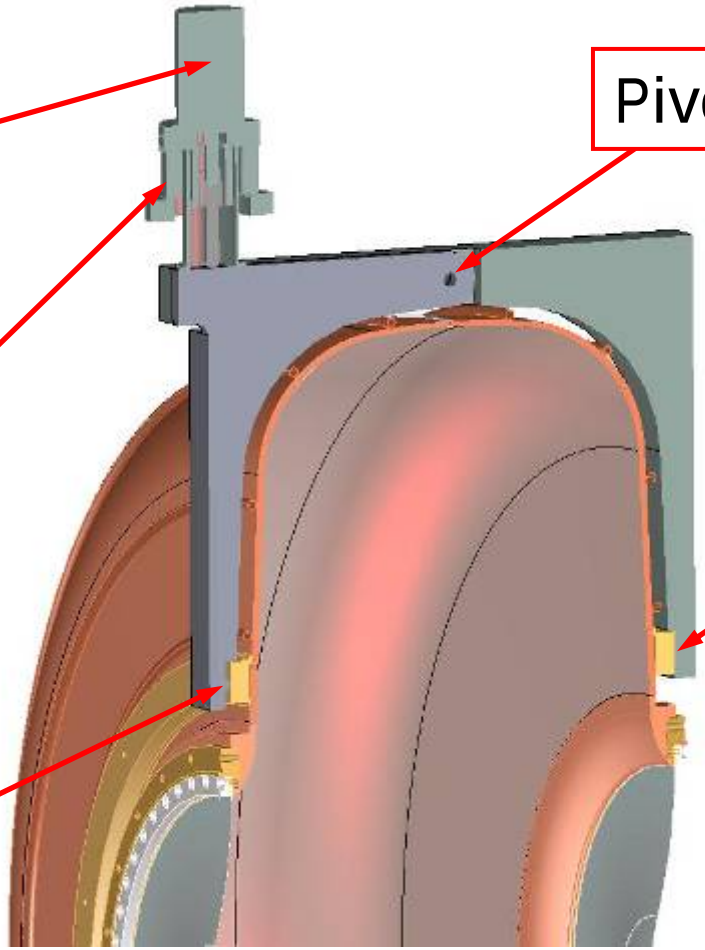
Tuners for MICE Cavities

Four 201-MHz cavities in each RFCC module; one tuner assembly (six sets of tuners) on each cavity.



- **Clocking of tuner position between adjacent cavities avoids interference**
- **Actuators offset from cavity center plane due to width of coupling coil**
- **Soft connection only (bellows) between tuner/actuators and vacuum vessel shell**

Tuner Section View



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MUCOOL Cavity Tuners

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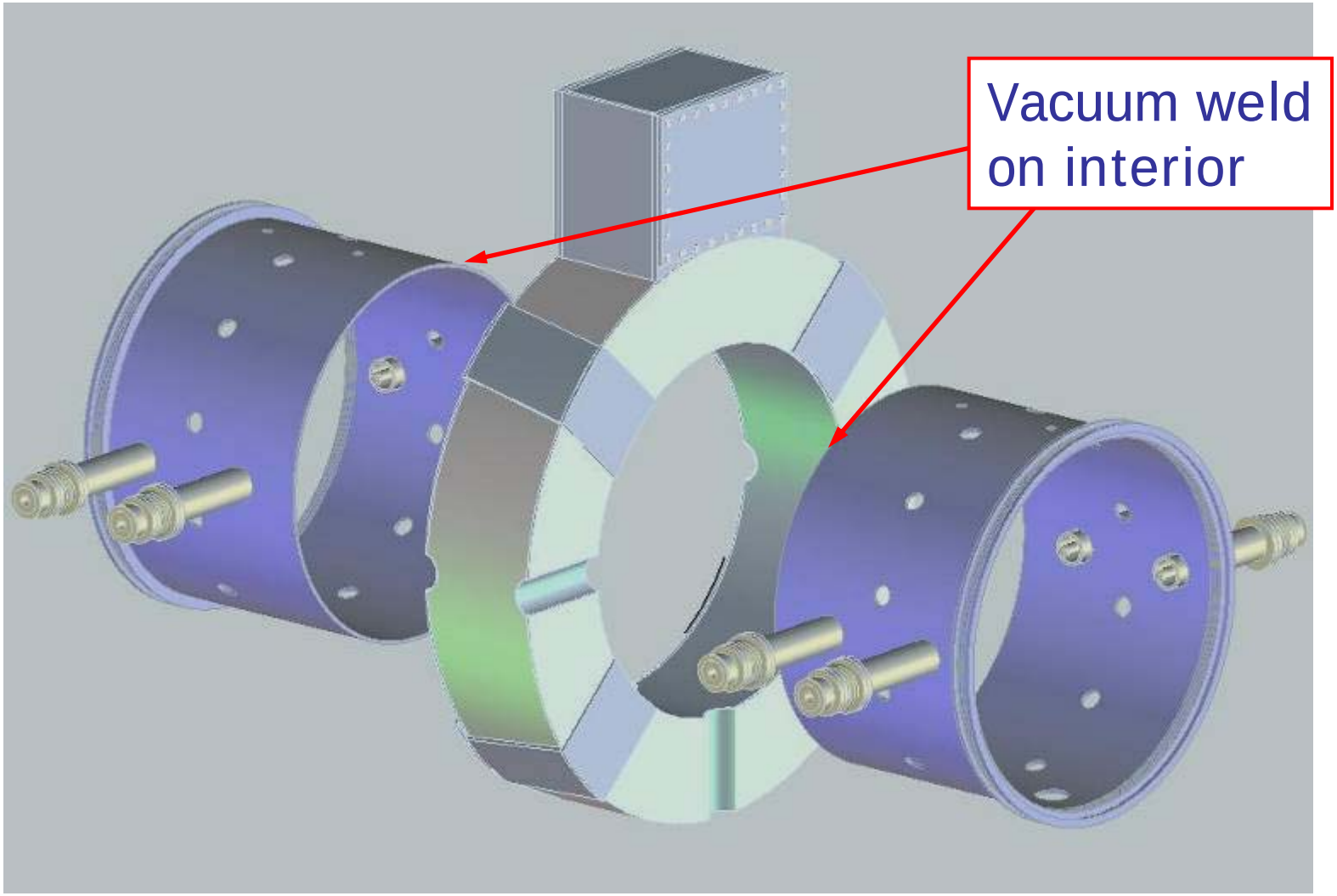
Integration to RFCC Module

RF couplers, vacuum, RF probes, tuners, water cooling pipes



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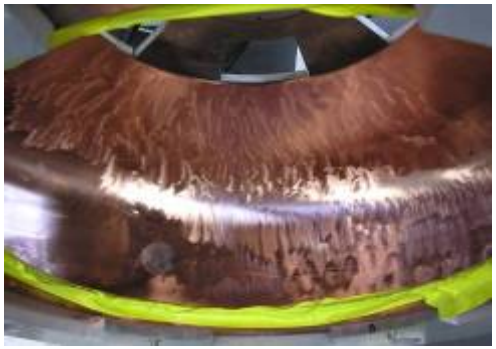
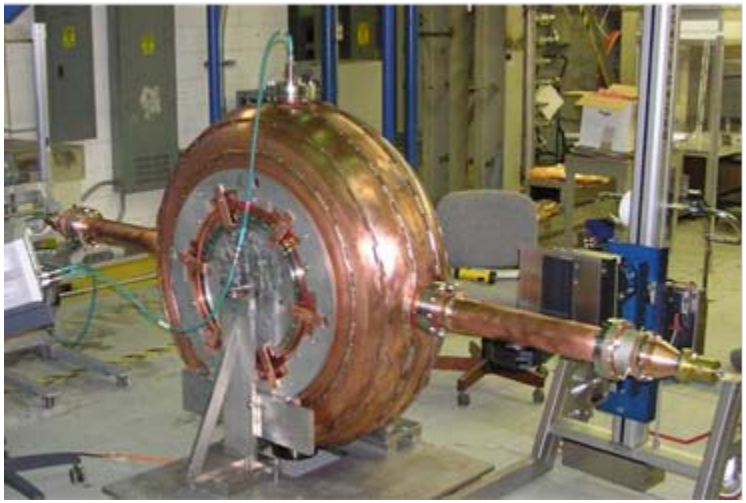
Post-Processing

- Cavity cleaning and assembly
- Low power RF measurements and shipping





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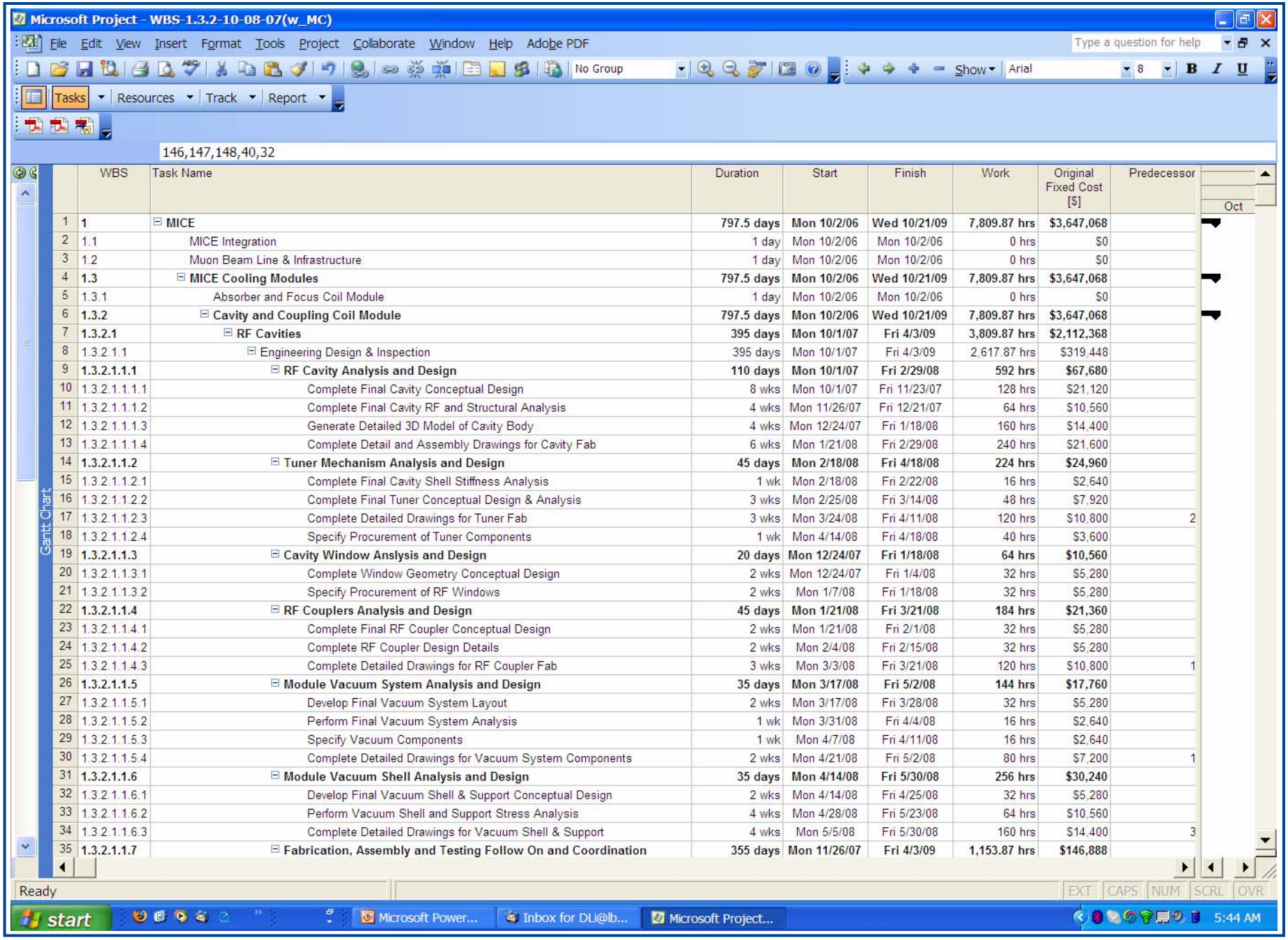
Summary

- **Status**
  - Cavity design modifications have started
    - ✓ Cavity body profile and analysis (RF, thermal [watering cool + possible LN operation], mechanical, vacuum, …)
    - ✓ Modified Be window designs, ready to place PO
    - Tuners and interface with RFCC module
  - Apply successful techniques developed from MUCOOL cavity R&D and look for possible simplifications
    - Spinning, port extruding and post-processing
  - Re-qualify venders (spinning, e-beam welding, port extruding and post-processing) with our supervision
    - US vendors: NIOWAVE, …
    - HIT in China
    - ✓ Brush-Wellman for Be windows
    - ✓ Toshiba for ceramic RF windows
- **Design and Fabrication Plan**
  - Design review ~ June 2008 (MICE CM21 at DL)
  - Schedule has been developed (~ by early 2010)



	WBS	Task Name	Duration	Start	Finish	Work	Original Fixed Cost [$]	Predecessor
1	**1**	**MICE**	**797.5 days**	**Mon 10/2/06**	**Wed 10/21/09**	**7,809.87 hrs**	**$3,647,068**	
2	1.1	MICE Integration	1 day	Mon 10/2/06	Mon 10/2/06	0 hrs	$0	
3	1.2	Muon Beam Line & Infrastructure	1 day	Mon 10/2/06	Mon 10/2/06	0 hrs	$0	
4	**1.3**	**MICE Cooling Modules**	**797.5 days**	**Mon 10/2/06**	**Wed 10/21/09**	**7,809.87 hrs**	**$3,647,068**	
5	1.3.1	Absorber and Focus Coil Module	1 day	Mon 10/2/06	Mon 10/2/06	0 hrs	$0	
6	**1.3.2**	**Cavity and Coupling Coil Module**	**797.5 days**	**Mon 10/2/06**	**Wed 10/21/09**	**7,809.87 hrs**	**$3,647,068**	
7	**1.3.2.1**	**RF Cavities**	**395 days**	**Mon 10/1/07**	**Fri 4/3/09**	**3,809.87 hrs**	**$2,112,368**	
8	1.3.2.1.1	Engineering Design & Inspection	395 days	Mon 10/1/07	Fri 4/3/09	2,617.87 hrs	$319,448	
9	**1.3.2.1.1.1**	**RF Cavity Analysis and Design**	**110 days**	**Mon 10/1/07**	**Fri 2/29/08**	**592 hrs**	**$67,680**	
10	1.3.2.1.1.1.1	Complete Final Cavity Conceptual Design	8 wks	Mon 10/1/07	Fri 11/23/07	128 hrs	$21,120	
11	1.3.2.1.1.1.2	Complete Final Cavity RF and Structural Analysis	4 wks	Mon 11/26/07	Fri 12/21/07	64 hrs	$10,560	
12	1.3.2.1.1.1.3	Generate Detailed 3D Model of Cavity Body	4 wks	Mon 12/24/07	Fri 1/18/08	160 hrs	$14,400	
13	1.3.2.1.1.1.4	Complete Detail and Assembly Drawings for Cavity Fab	6 wks	Mon 1/21/08	Fri 2/29/08	240 hrs	$21,600	
14	**1.3.2.1.1.2**	**Tuner Mechanism Analysis and Design**	**45 days**	**Mon 2/18/08**	**Fri 4/18/08**	**224 hrs**	**$24,960**	
15	1.3.2.1.1.2.1	Complete Final Cavity Shell Stiffness Analysis	1 wk	Mon 2/18/08	Fri 2/22/08	16 hrs	$2,640	
16	1.3.2.1.1.2.2	Complete Final Tuner Conceptual Design & Analysis	3 wks	Mon 2/25/08	Fri 3/14/08	48 hrs	$7,920	
17	1.3.2.1.1.2.3	Complete Detailed Drawings for Tuner Fab	3 wks	Mon 3/24/08	Fri 4/11/08	120 hrs	$10,800	2
18	1.3.2.1.1.2.4	Specify Procurement of Tuner Components	1 wk	Mon 4/14/08	Fri 4/18/08	40 hrs	$3,600	
19	**1.3.2.1.1.3**	**Cavity Window Anslysis and Design**	**20 days**	**Mon 12/24/07**	**Fri 1/18/08**	**64 hrs**	**$10,560**	
20	1.3.2.1.1.3.1	Complete Window Geometry Conceptual Design	2 wks	Mon 12/24/07	Fri 1/4/08	32 hrs	$5,280	
21	1.3.2.1.1.3.2	Specify Procurement of RF Windows	2 wks	Mon 1/7/08	Fri 1/18/08	32 hrs	$5,280	
22	**1.3.2.1.1.4**	**RF Couplers Analysis and Design**	**45 days**	**Mon 1/21/08**	**Fri 3/21/08**	**184 hrs**	**$21,360**	
23	1.3.2.1.1.4.1	Complete Final RF Coupler Conceptual Design	2 wks	Mon 1/21/08	Fri 2/1/08	32 hrs	$5,280	
24	1.3.2.1.1.4.2	Complete RF Coupler Design Details	2 wks	Mon 2/4/08	Fri 2/15/08	32 hrs	$5,280	
25	1.3.2.1.1.4.3	Complete Detailed Drawings for RF Coupler Fab	3 wks	Mon 3/3/08	Fri 3/21/08	120 hrs	$10,800	1
26	**1.3.2.1.1.5**	**Module Vacuum System Analysis and Design**	**35 days**	**Mon 3/17/08**	**Fri 5/2/08**	**144 hrs**	**$17,760**	
27	1.3.2.1.1.5.1	Develop Final Vacuum System Layout	2 wks	Mon 3/17/08	Fri 3/28/08	32 hrs	$5,280	
28	1.3.2.1.1.5.2	Perform Final Vacuum System Analysis	1 wk	Mon 3/31/08	Fri 4/4/08	16 hrs	$2,640	
29	1.3.2.1.1.5.3	Specify Vacuum Components	1 wk	Mon 4/7/08	Fri 4/11/08	16 hrs	$2,640	
30	1.3.2.1.1.5.4	Complete Detailed Drawings for Vacuum System Components	2 wks	Mon 4/21/08	Fri 5/2/08	80 hrs	$7,200	1
31	**1.3.2.1.1.6**	**Module Vacuum Shell Analysis and Design**	**35 days**	**Mon 4/14/08**	**Fri 5/30/08**	**256 hrs**	**$30,240**	
32	1.3.2.1.1.6.1	Develop Final Vacuum Shell & Support Conceptual Design	2 wks	Mon 4/14/08	Fri 4/25/08	32 hrs	$5,280	
33	1.3.2.1.1.6.2	Perform Vacuum Shell and Support Stress Analysis	4 wks	Mon 4/28/08	Fri 5/23/08	64 hrs	$10,560	
34	1.3.2.1.1.6.3	Complete Detailed Drawings for Vacuum Shell & Support	4 wks	Mon 5/5/08	Fri 5/30/08	160 hrs	$14,400	3
35	**1.3.2.1.1.7**	**Fabrication, Assembly and Testing Follow On and Coordination**	**355 days**	**Mon 11/26/07**	**Fri 4/3/09**	**1,153.87 hrs**	**$146,888**	