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Update on 201-MHz RF Cavity Construction (Plan) for MICE

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Lawrence Berkeley National Laboratory**

**MICE-20th Collaboration Meeting
RAL, UK
February 10 – 13, 2008**

Outline

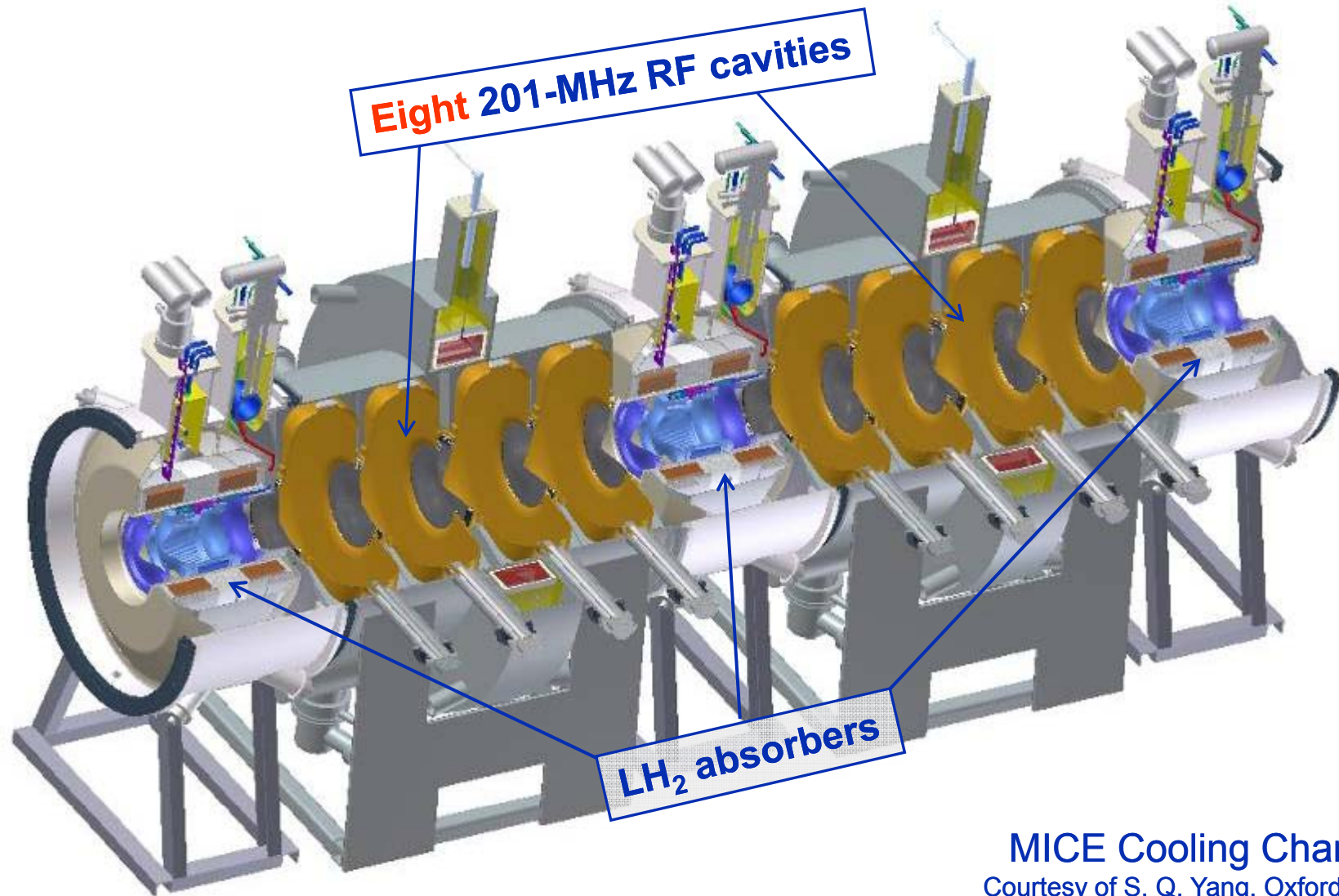


- **MICE Cavity Design**
 - **Based on the design of 201-MHz cavity for MUCOOL**
 - Cavity body
 - Ports for power coupler, vacuum and probes
 - RF power loop coupler and ceramic RF window
 - Curved Beryllium window
 - Tuners
 - Interface and integration with RFCC module
- **Summary**
 - **Status and 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**

Cavity Design Parameters

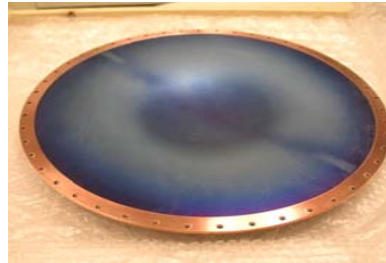


- **The cavity design parameters**
 - Frequency: 201.25 MHz
 - $\beta = 0.87$
 - Shunt impedance (VT^2/P): $\sim 22 \text{ M}\Omega/\text{m}$
 - Quality factor (Q_0): $\sim 53,500$
 - Be window radius and thickness: 21-cm and 0.38-mm
- **Nominal parameters for cooling channels in a muon collider or a neutrino factory and MICE**
 - $\sim 16 \text{ MV/m}$ ($\sim 8 \text{ MV/m}$) peak accelerating field
 - Peak input RF power $\sim 4.6 \text{ MW}$ ($\sim 1 \text{ MW}$) per cavity (85% of Q_0 , 3τ filling)
 - Average power dissipation per cavity $\sim 8.4 \text{ kW}$ ($\sim 1 \text{ kW}$ at 1 Hz repetition rate and 1 ms pulse length)
 - Average power dissipation per Be window
 $\sim 100 \text{ watts}$ ($\sim 12 \text{ watts}$)



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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 ($\pm \sim 6^\circ$)
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

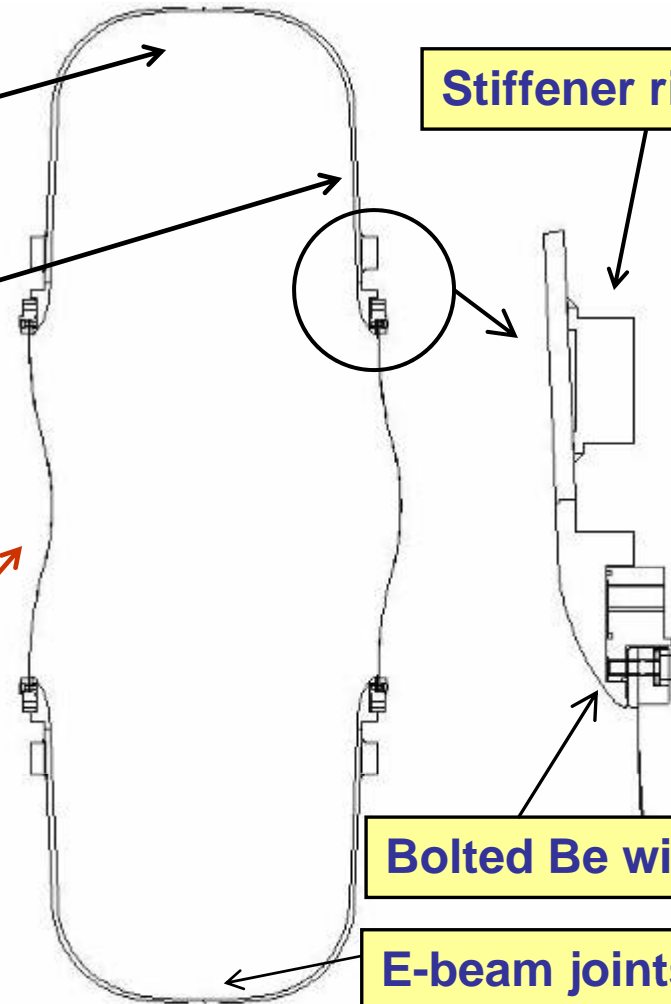
De-mountable pre-curved Be windows pointing in the same direction to terminate RF fields at the iris

Stiffener ring

Bolted Be window

E-beam joints

Low peak surface field and easy fabrication



Cavity Body

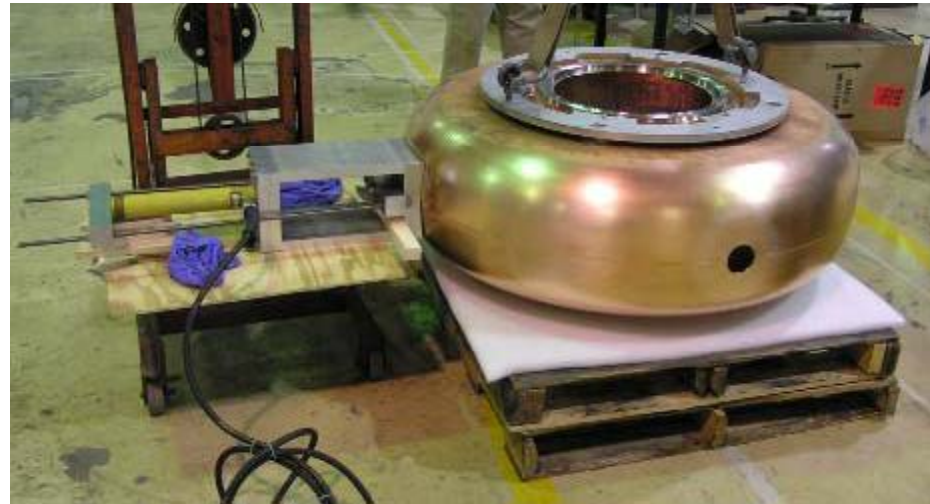


- **MUCOOL cavity frequency is slightly lower than 200-MHz (as long as within bandwidth of RF source)**
 - Mechanical (fixed) tuners available and tested
- **MICE cavities**
 - Target frequency is 201.250-MHz
 - One RF source (tube) powers more than one cavity
 - Each cavity will be made (spinning) to frequency very close to 201-MHz by modifying the mold used for spinning
 - Frequency shifts by ports and curved Be windows
 - Conceptual tuner designs (fine tuning)

Ports Extruding and Flanges



Local annealing of ports



Cavity ports being extruded (pulled)



Extruded port

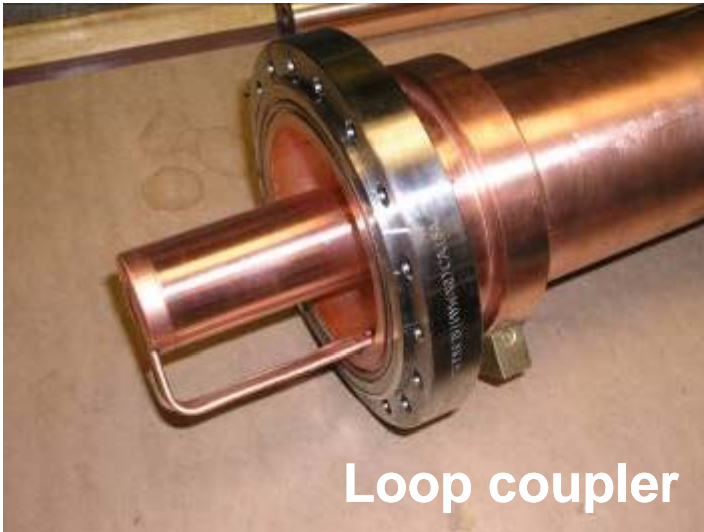


Port flange e-beam weld



Finished cavity port

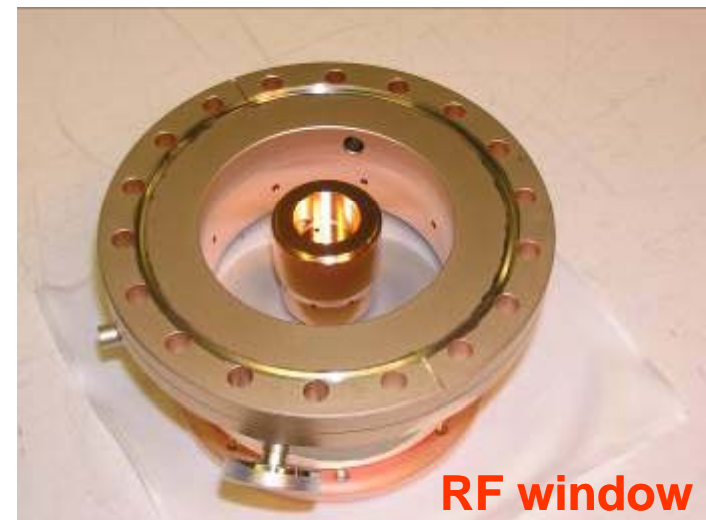
Fabrication of the Coupler



Loop coupler



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



RF window

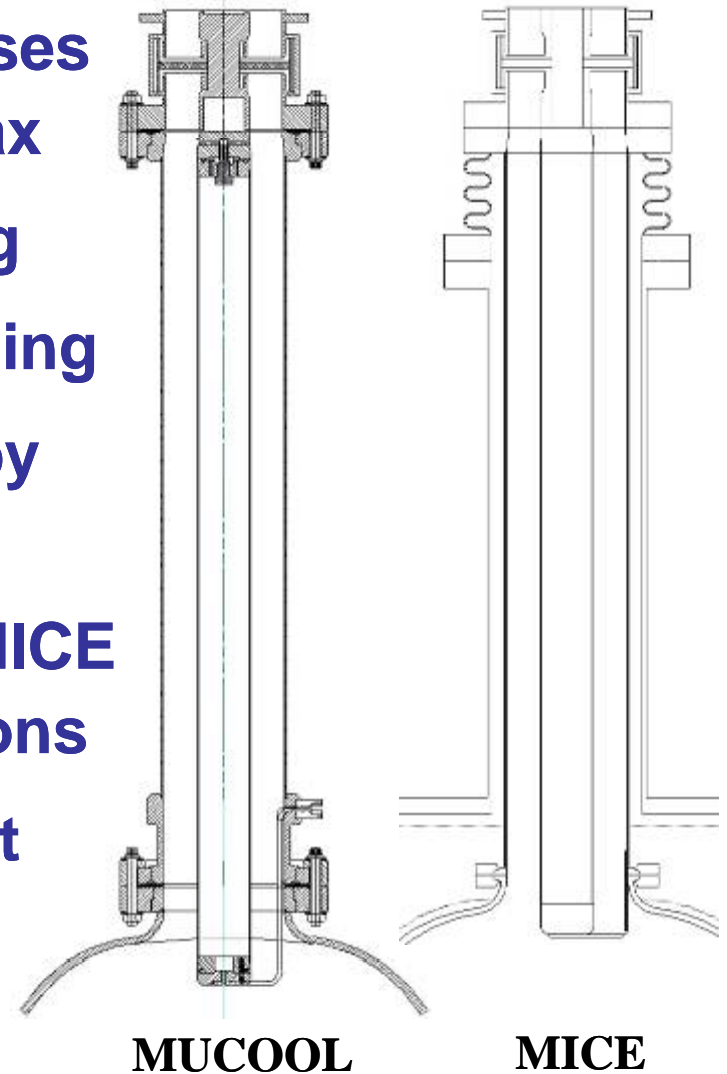


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RF Coupling Loop Design



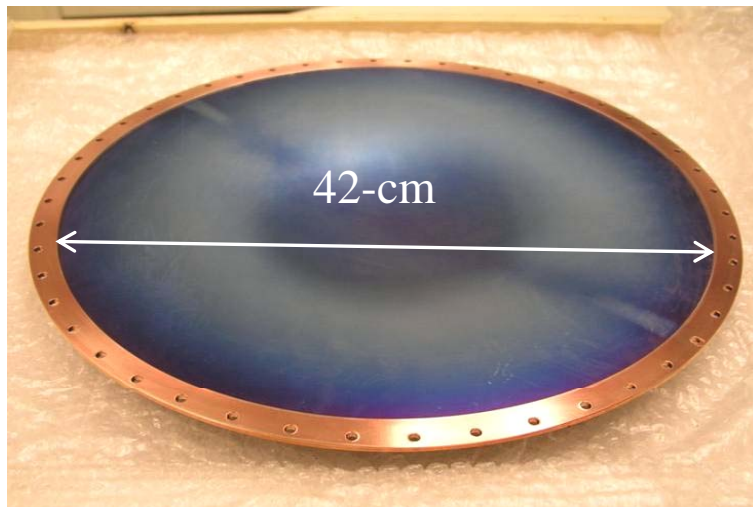
- Prototype coupling loop design uses standard off-the-shelf copper co-ax
- Parts to be joined by torch brazing
- Coupling loop has integrated cooling
- Two SNS style RF windows mfg. by Toshiba received (no cost!)
- Bellows connection required on MICE for thermal and dimensional reasons
- Need to integrate with MICE layout



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



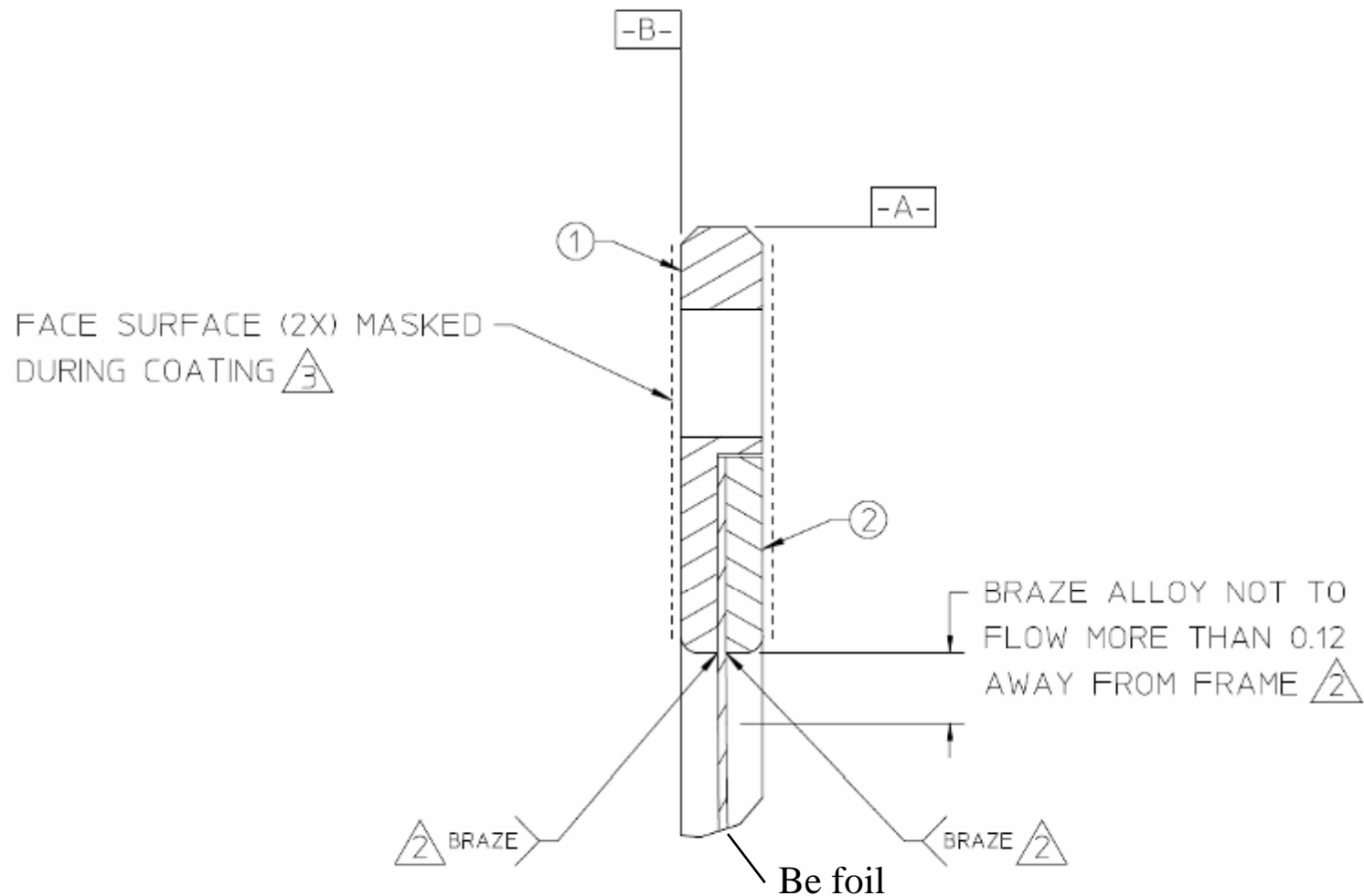


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Beryllium Window Update



- Improved design for better brazing



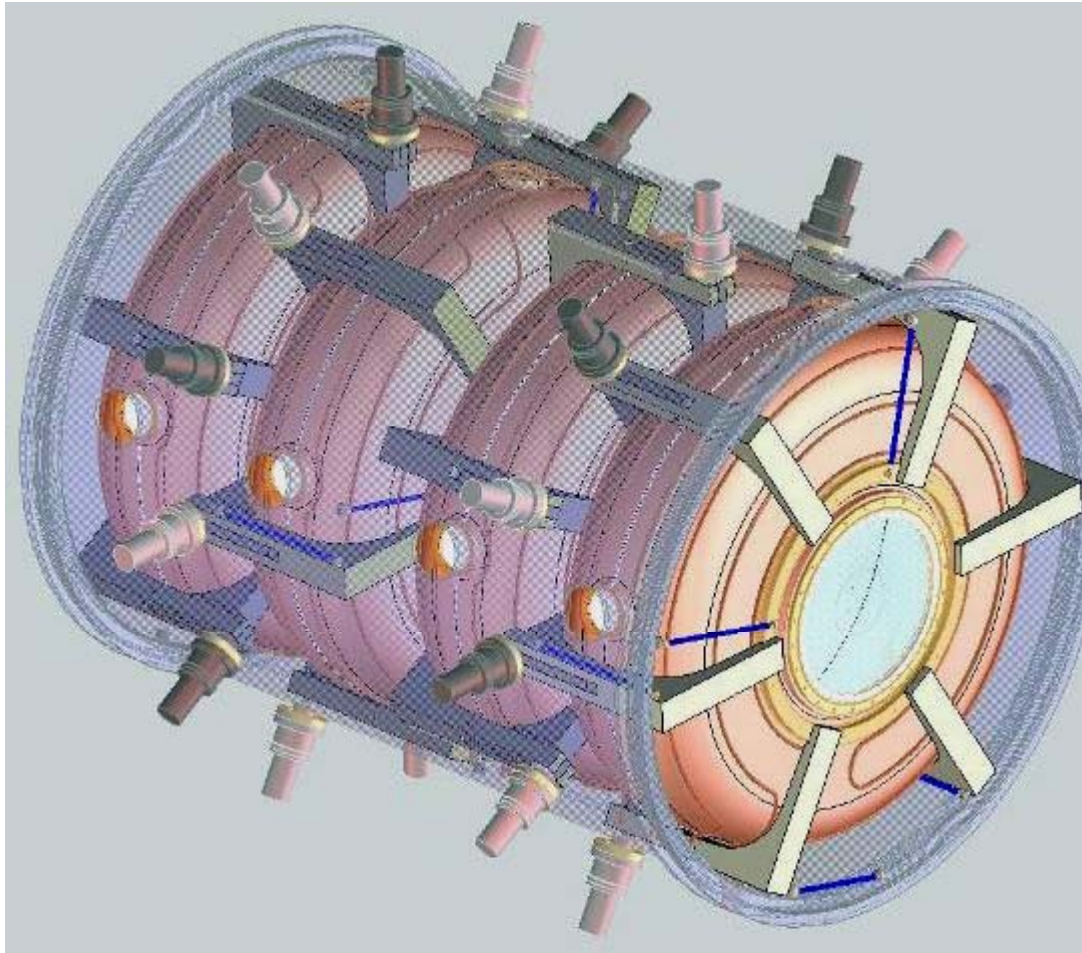


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Tuners for MICE Cavities



Four 201-MHz cavities in each RFCC module; one tuner assembly on each cavity.

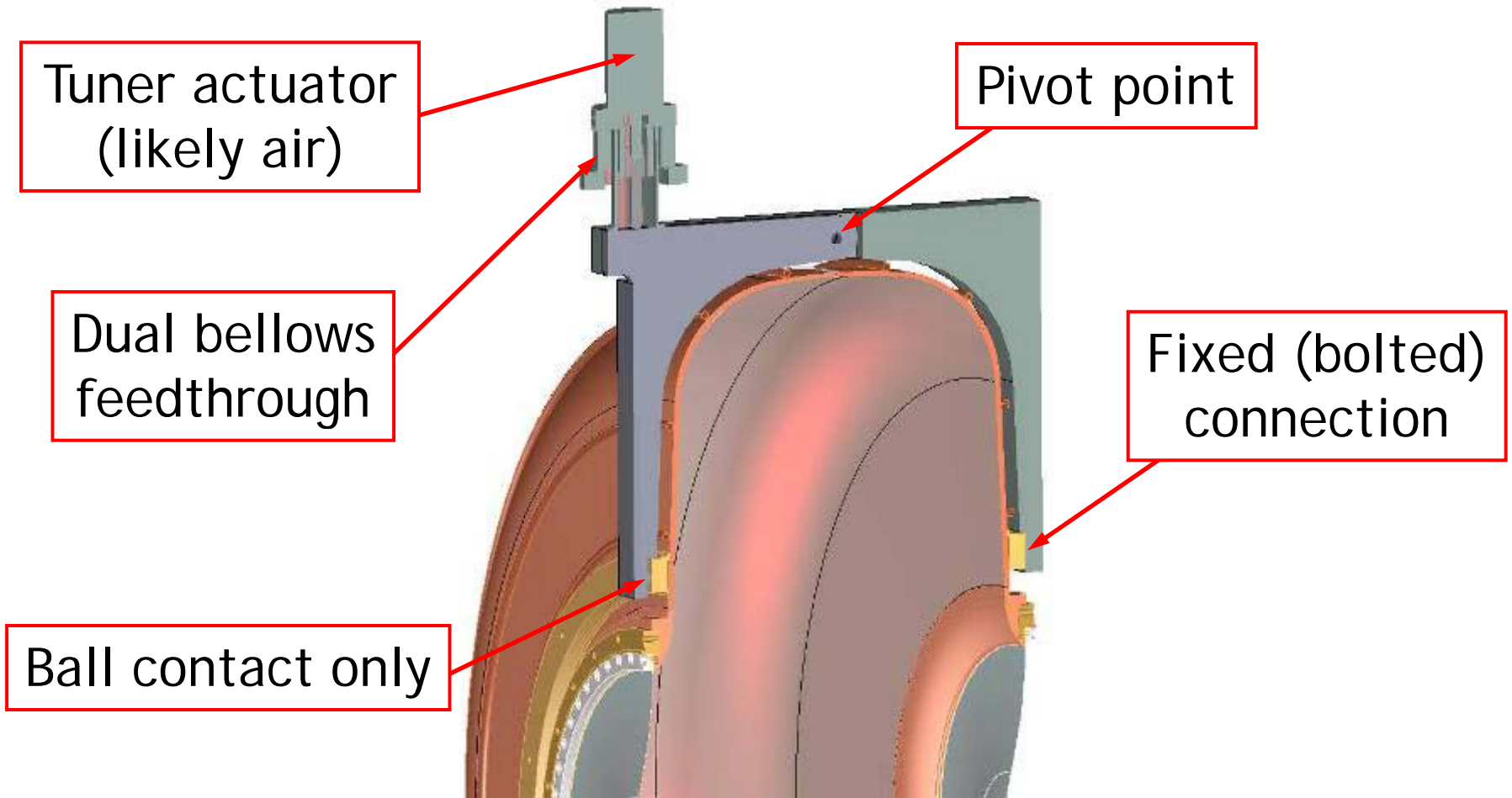


- Clocking of tuner position between adjacent cavities avoids interference
- Actuators offset from cavity center plane due to width of coupling coil
- Soft connection only (bellows) between tuner/actuators and vacuum vessel shell



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Tuner Section View





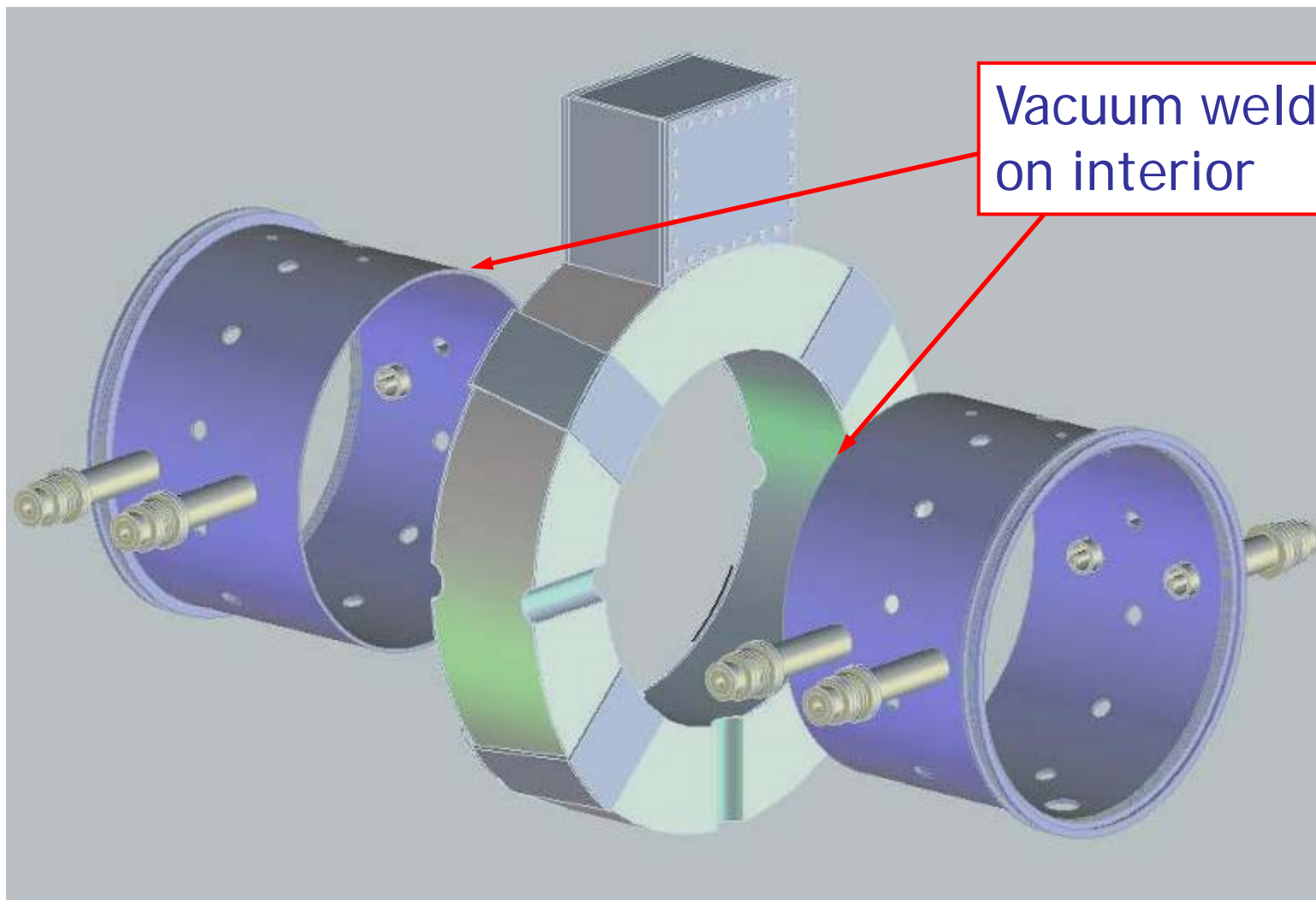
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MUCOOL Cavity Tuners



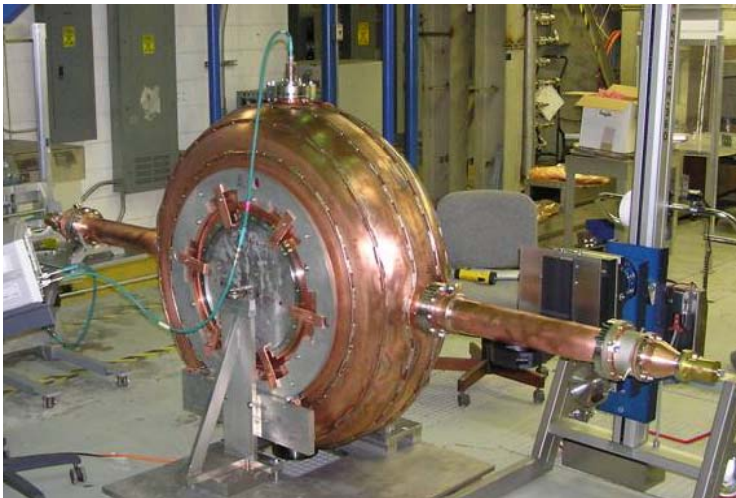
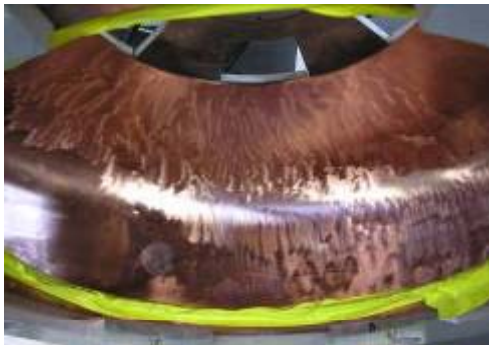
Integration to RFCC Module

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



Post-Processing

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





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Summary



- **Status**
 - **Cavity design modifications**
 - ✓ Cavity body profile
 - ✓ Modified Be window designs
 - Tuners and interface with RFCC module
 - **Apply successful techniques developed from MUCOOL cavity R&D**
 - Spinning, port extruding and post-processing
 - **Re-qualify vendors (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 ~ May 2008
 - Schedule has been developed (~ by early 2010)

Microsoft Project - WBS-1.3.2-10-08-07(w_MC)

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Tasks Resources Track Report

146,147,148,40,32

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

Ready

EXT CAPS NUM SCRL OVR

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