# Box Cavity Magnetic Insulation

**NTMCC Collaboration Meeting**

**University of Mississippi, Oxford, Miss.**

**01/13/10**

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**Fermilab**

# Outline :

- Acknowledgements.
- Box Cavity Details.
- HFSS Models  of orthogonal and Parallel cavities.
- Set of cavity drawings.
- Light Spectrometer and waveguide rotation layout.
- Specifications.
- Qo, Resonant Impedance, Power requirements, peak surface fields.
- Peak electric Field contours.
- Pictures of the orthogonal and network analyzer setup.
- New and different RF Cavity Commissioning Proposal.
- Summary.

# Acknowledgements of the people who have contributed to this project.

Tim Hamerla– Fermilab

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Moses Chung– Fermilab

Dazhang Huang—IIT.

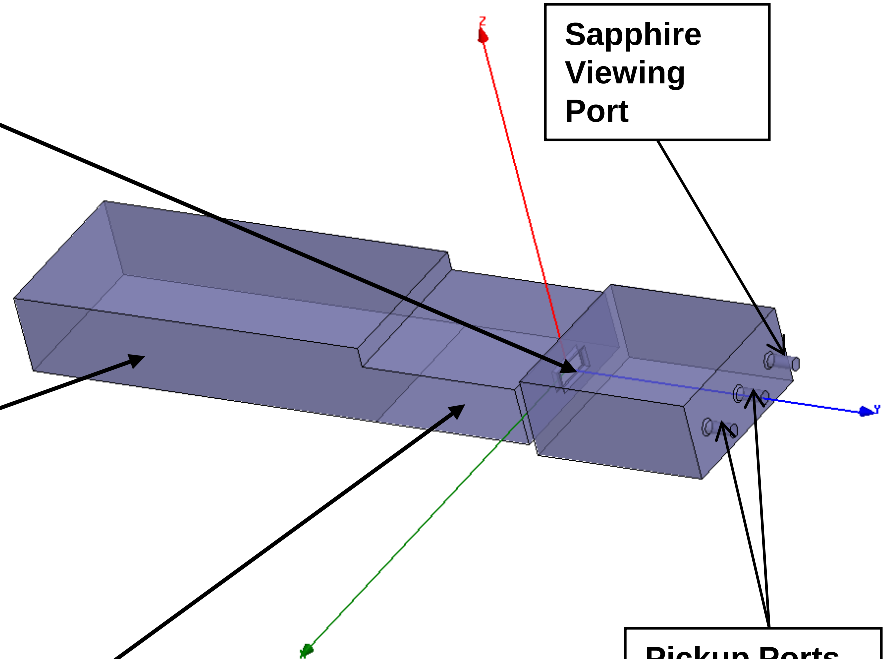
## Box Cavity construction and measurements Summary:

- **The orthogonal box cavity is made of 101 OFE copper plates. Interior Parts and the aperture were machined to 32 μ inch finish. Two hydrogen brazing cycles were required to complete the cavity. Two cross Field cavities were produced. The HFSS simulation coupling aperture design has been machined into the cavities. The first test cavity has been found to be vacuum tight; measurements were made on the cavity with a network analyzer; results were in agreement with HFSS simulation. The cavity and its support structure have been designed for 0 to 12 Degree rotation. The second cavity is currently undergoing finishing processing.**
- **A cold RF test has been performed using a tapered waveguide coupler to determine Fo, Qo and coupling factor. The cavity matched the HFSS simulation without the need for any trimming of the aperture.**
- **A special compound curved waveguide vacuum tin seal has been successfully designed to attach the cavity to the LBL waveguide coupler and cavity.**
- **Vacuum system, drive waveguides, 2 RF cavity pick-ups and sapphire viewing window will be attached; after calibration testing will begin at 90 Degrees.**
- **We have decided to build one parallel box. The detailed design is very similar to the orthogonal box cavity and is about 95 % completed.**

# Orthogonal E and H Cavity Coupled to the Waveguide

**Rectangular Coupling aperture with rounded edges**

**Sapphire Viewing Port**



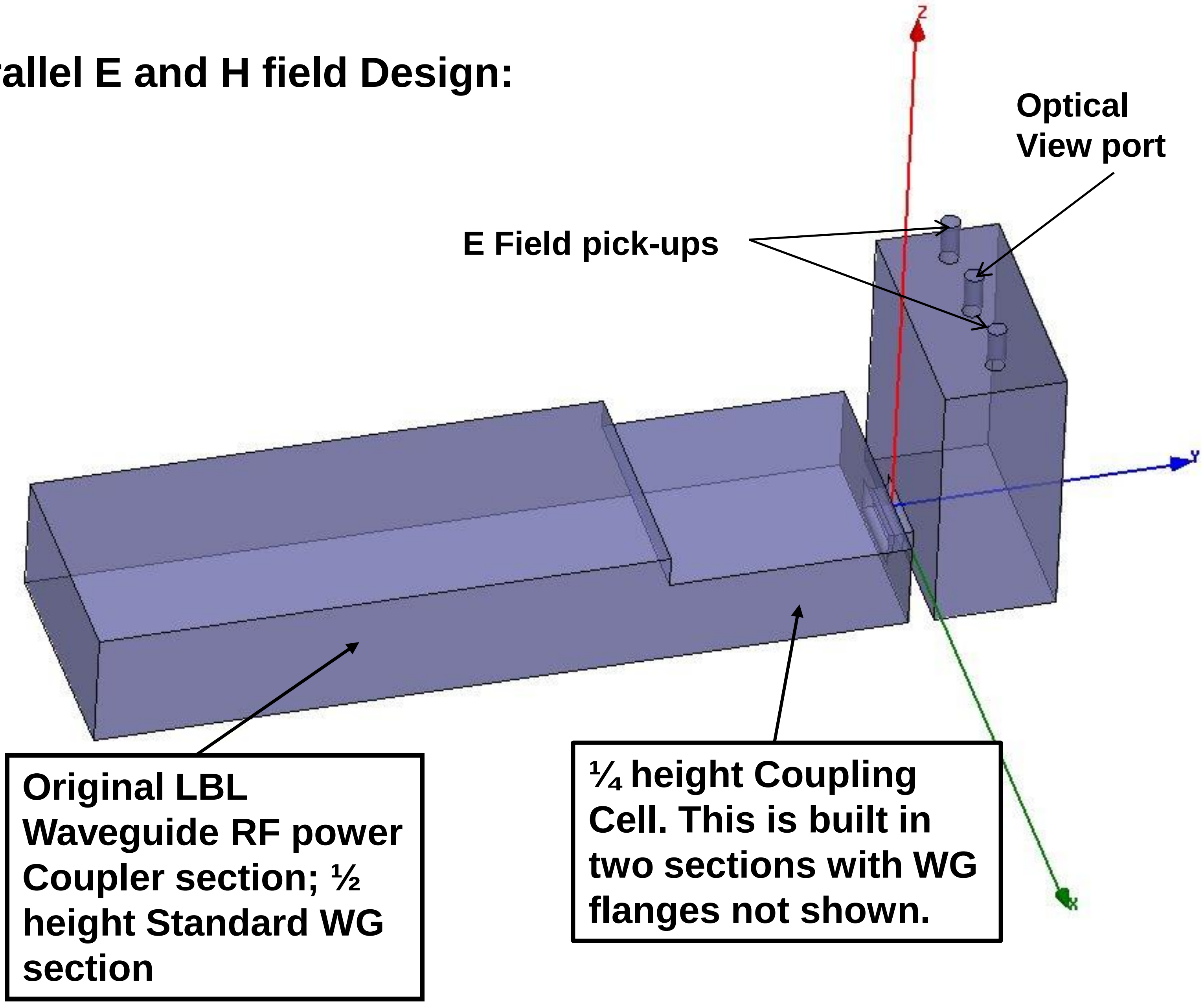
**Original LBL Waveguide RF power Coupler section; ½ height Standard WG section**

**Pickup Ports**

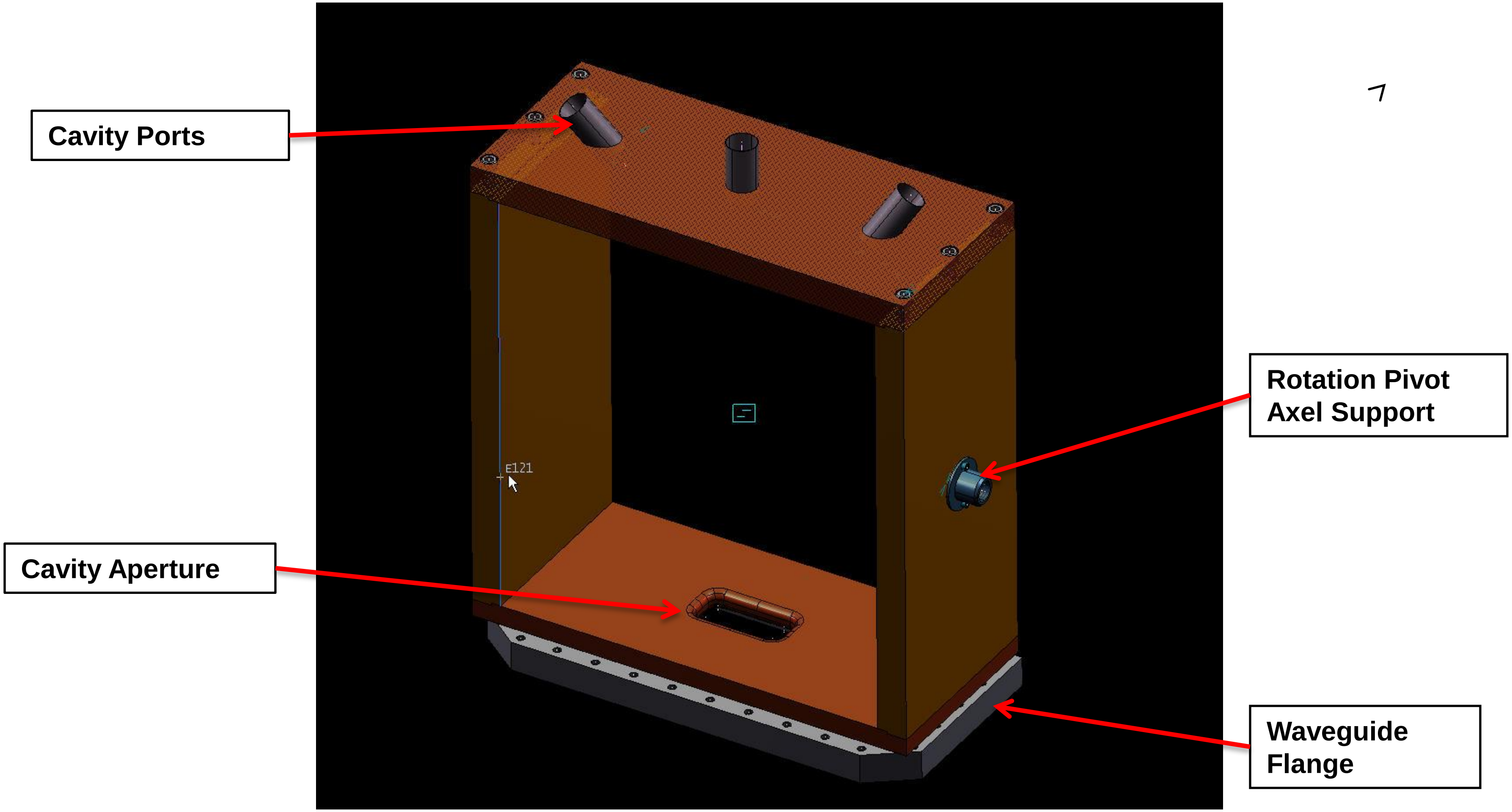
**¼ height Coupling Cell. This is built in two sections with WG; flanges not shown.**

## HFSS Model RF cavity and WG coupler

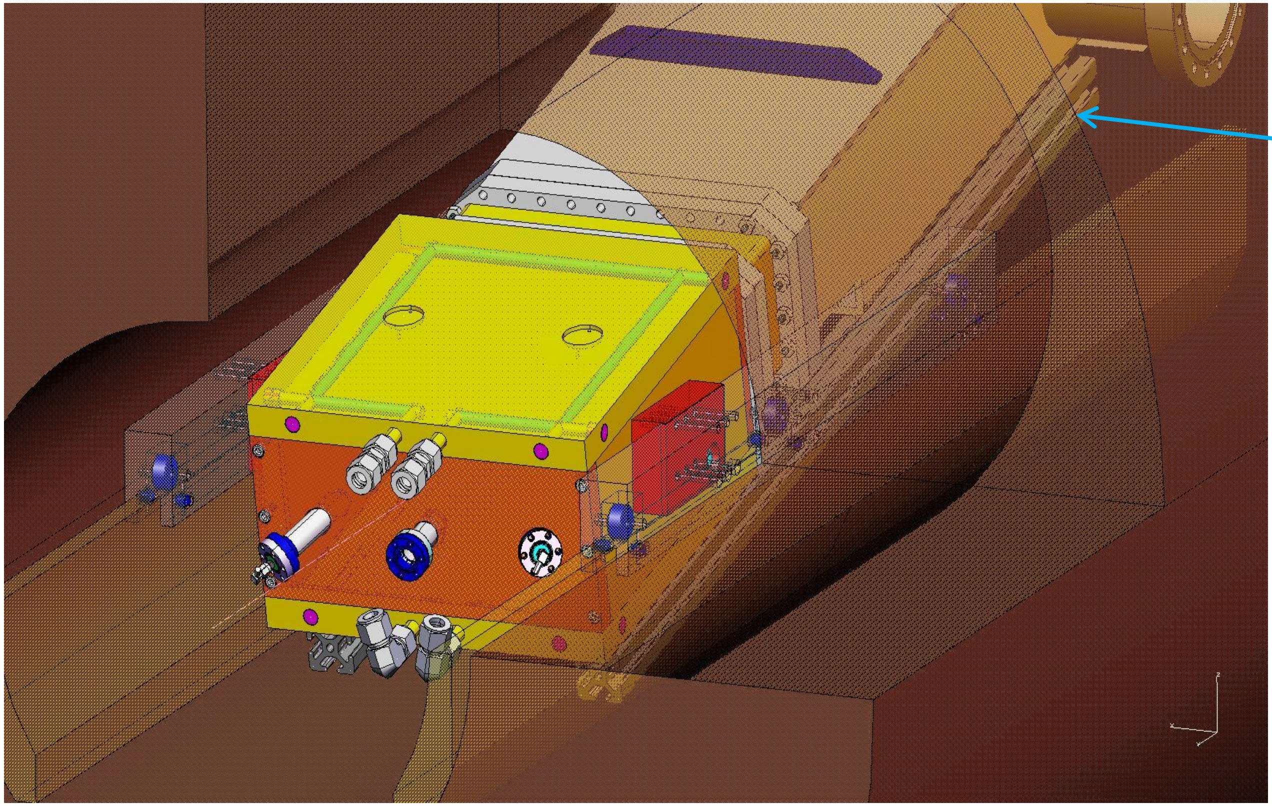
## Parallel E and H field Design:



# Open View of the orthogonal Box cavity



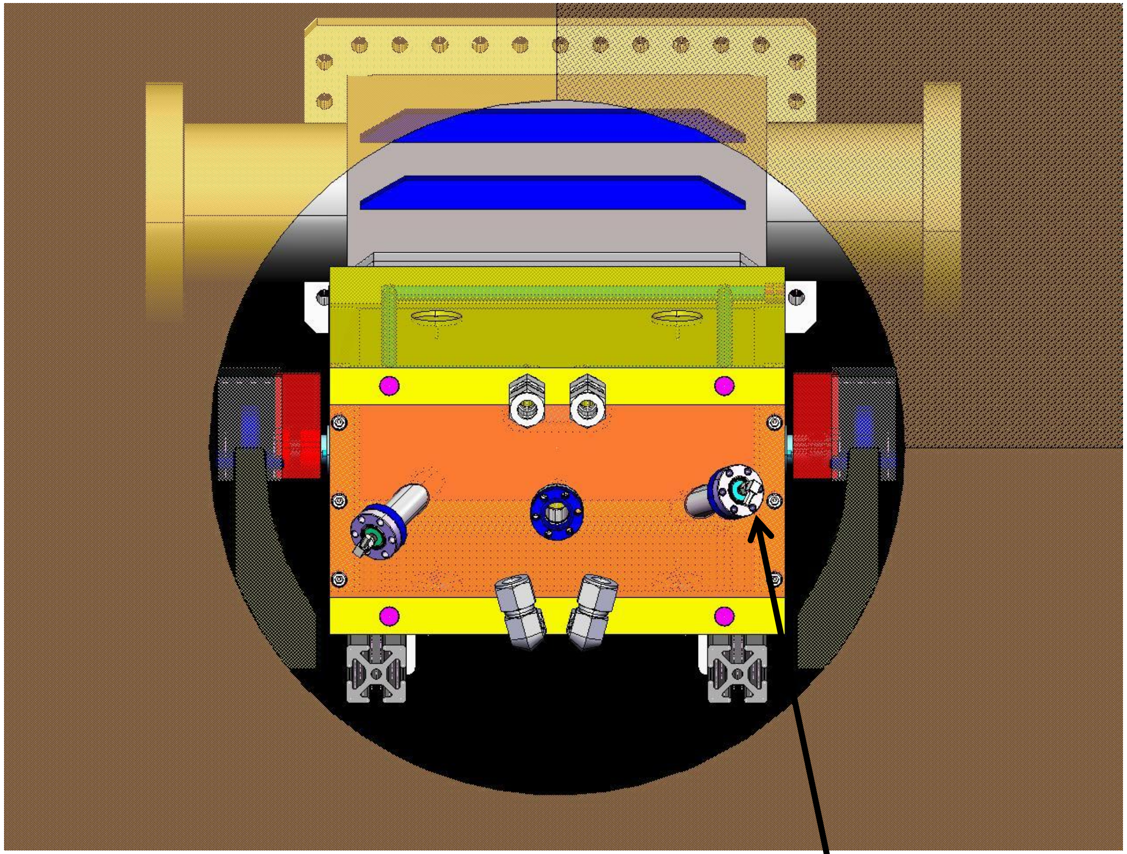
## Box Cavity Attached to Waveguide in the magnet Showing Water cooling path and fittings, pickup ports and some of Support structure.



Magnet support structure

# End View of The cavity in the Magnet

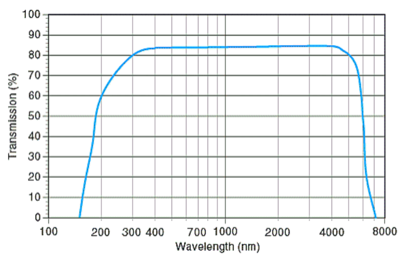
Magnet cavity support structure and external support transfer table parts are in the shop and should be completed this week. Pre-assemble and integrations of parts to the cavity is scheduled in the A0 clean room for the end of this week. The set-up and calibration in the MTA hall is scheduled for the last week in January. First operations to begin first or second week of February and should take several weeks.



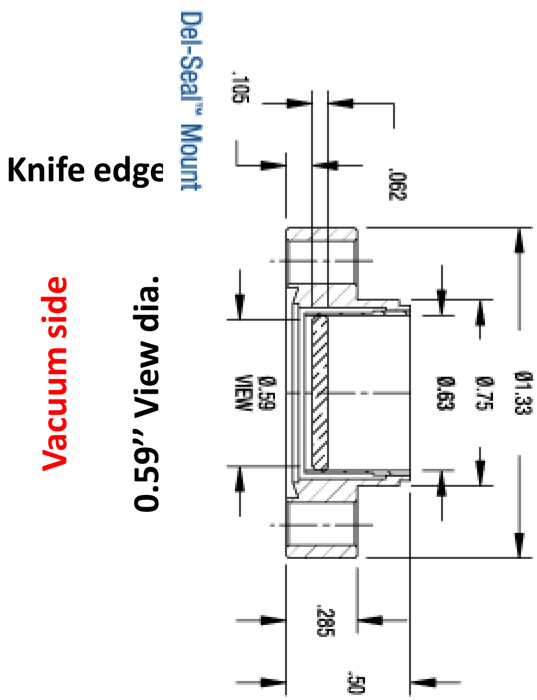
Optical sapphire window location for the light emission spectrometer study

# Schematic of the optical diagnostics

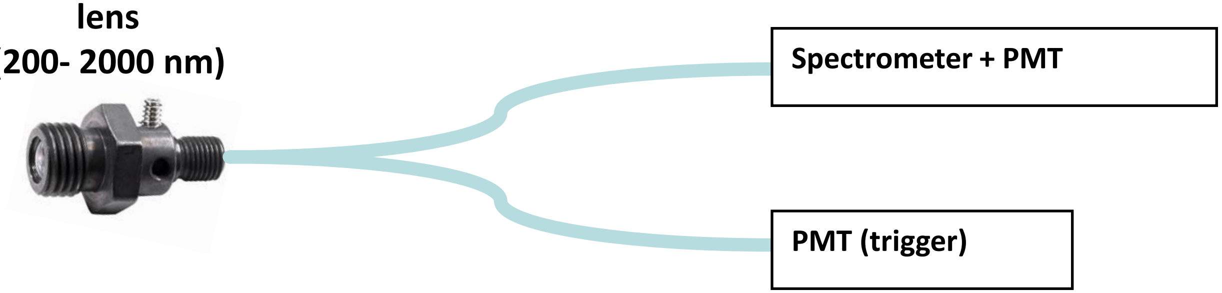
Sapphire spectrum



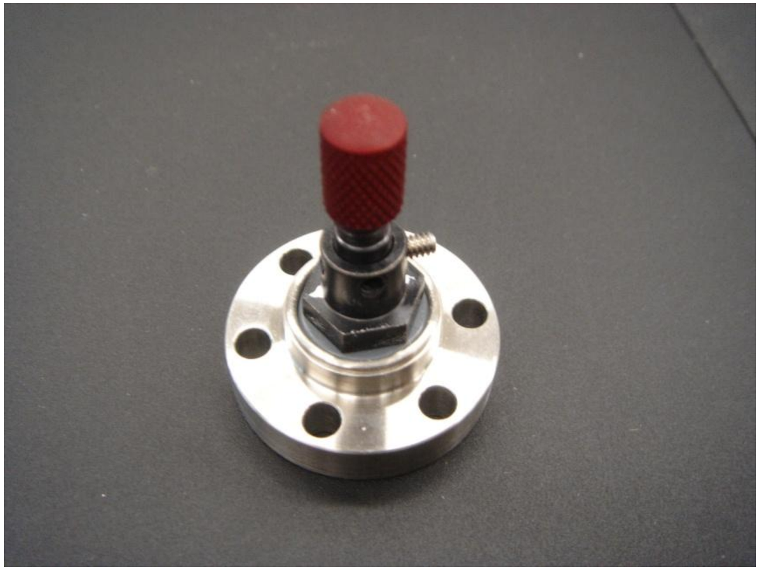

**To investigate the breakdown characteristics of the box cavity using visible light emission, we are going to use the optical diagnostic system used on the HPRF cavity experiments.**
**Since PMT's, optical fibers, and spectrometer are all already available from the HPRF experiment, we only need add an optical window and fiber coupler.**




UV/VIS Collimating lens (200- 2000 nm)

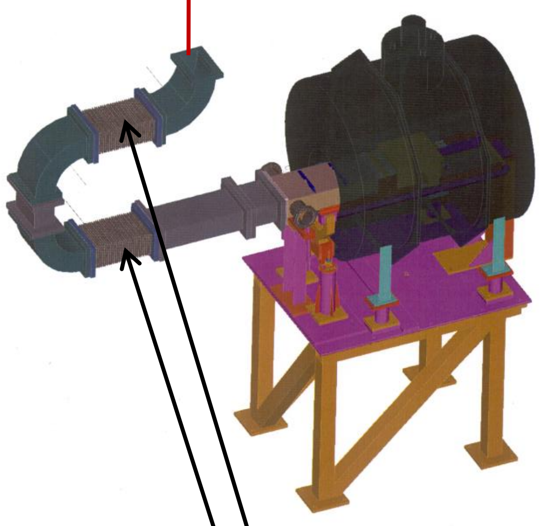


# Photos of the window and lens assembly



# Layout of the Rotation Waveguide attachment

**The waveguide rotation apparatus design consists (3) 90 Deg Ekbows, (2) Straight sections of WG and (2) 0.46 m Flexible WG sections. A precision digital level which reads tilt angles in degrees will be use the measure rotation angle.**



# Specifications

**The following are some of the specs for the square cavity:**

**Tolerance of parts = ± 0.005"** ***(Parts were machined to +/- .0015 inches)***

**Inside finish = 30 u inches**

**Average power = 5 kW with half the power dissipated equally on the Top and bottom plates the remainder almost equally on the 4 sides.**

**Pick-up ports: Three min-ConFlat vacuum feed-thru ports in the side opposite the coupling aperture, 2 with field pick-up loops and one with a Sapphire vacuum viewing window on a mini Con Flat flange.**

**Temperature: Max. temperature on inside surface of the un-cooled coupler aperture is +37.2 ° C at 5 kW with room temperature water circulating in the cooling tubes. The other max temperatures are at center of top and bottom plates is 38.1 ° C and 43.1 ° C on the long side plate.**

**Rotation Angle: 90 + Δ12 Degrees, need to lower the center of cavity vertically 3.8 cm to achieve 15 Degrees.**

# Calculated Parameters of the cavity and cavity dimensions

**HFSS normalizes all parameters to 1 W of input power to the waveguide coupler and solves for the frequency, gradient, coupling factor, Qo (in cavity mode) etc.**

**1W produces a gradient of 25 kV/m by scaling:**

**25 MV/m would take 1 MW ideal.**

**The Impedance across the center of the cavity is**

**Imp =9.5 MΩ.**

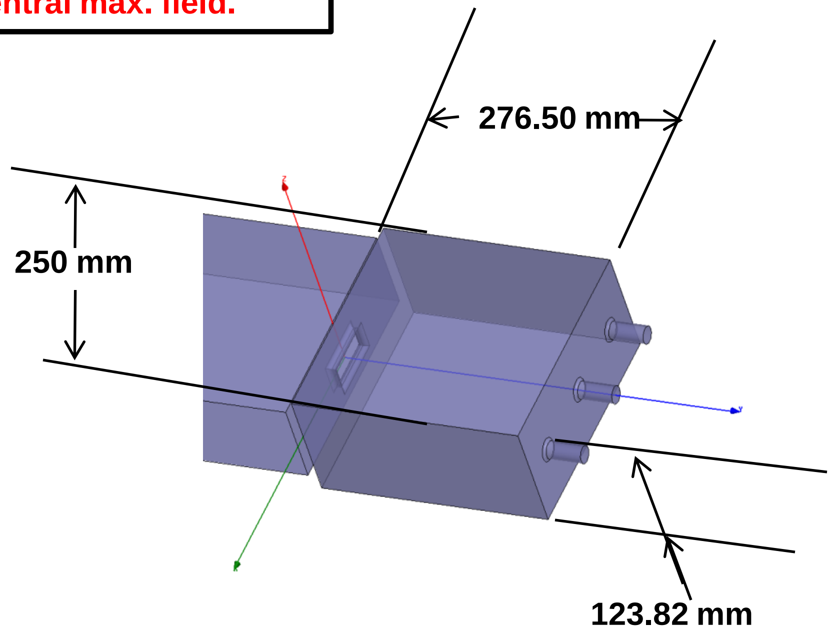
**This is the resistance across the center of the cavity given by**

**Imp = (gap Voltage)²/1 W.**

**This uses the peak voltage and is in agreement with SuperFish and most published accelerator designs.**

**Qo = 27,400.**

**Aperture Fields about a factor 4 lower than central max. field.**



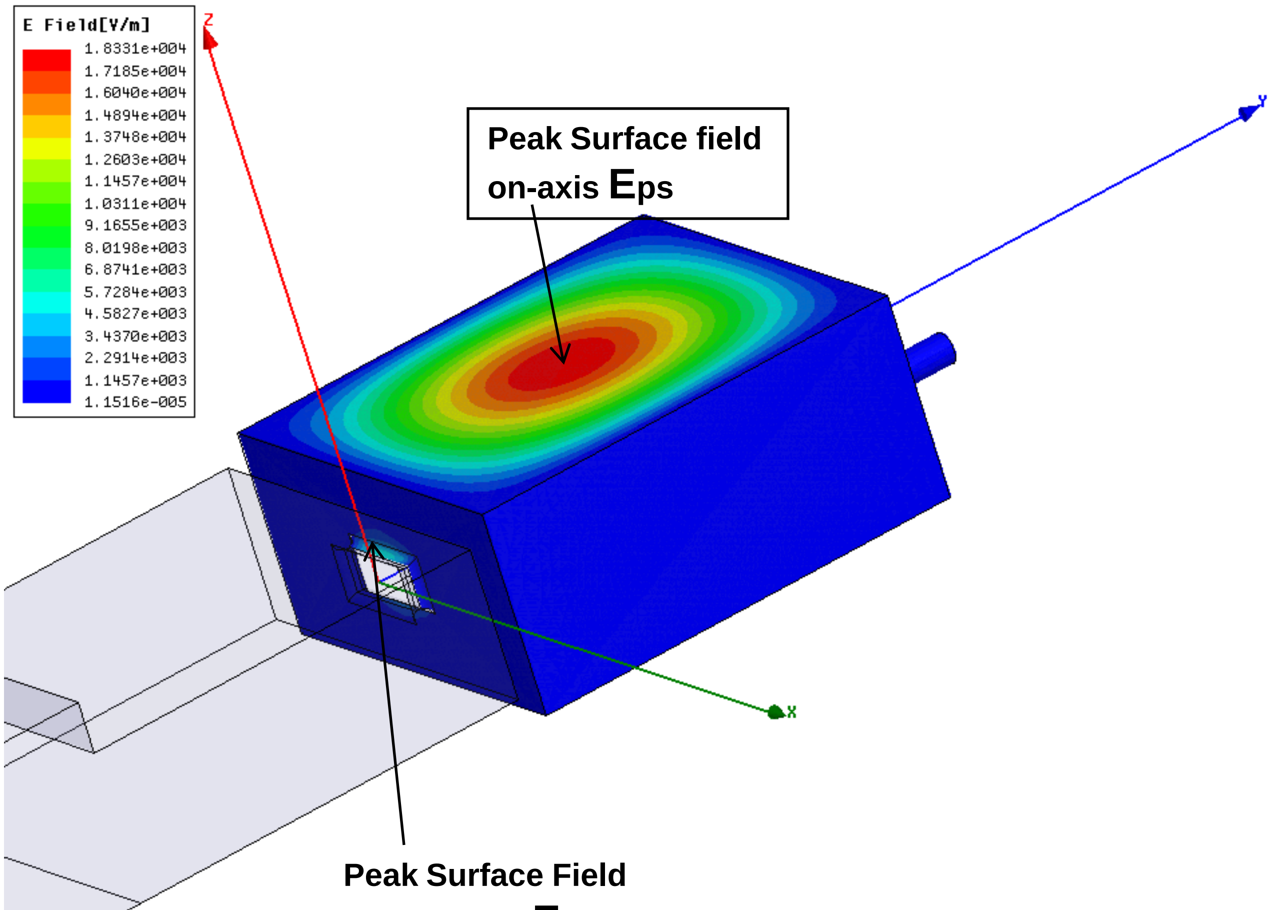
# Orthogonal Cavity Electric Field Simulation

**Note 1:**

**Ratio Eps/ Epa= 3.5 for orthogonal case.**

***Note 2:***

**Ratio Eps/ Epa= 2 for parallel case. This should be considered when determining the pre RF commissioning of the cavities (LBL or Box cavity) with flat windows without buttons and without the presence of the magnetic field.**




**Peak Surface Field on Aperture Epa**

# Picture of the Orthogonal Box Cavity in A0 Test Lab connected to the End ¼ height Waveguide Coupling Cell after successful Vacuum Leak Check

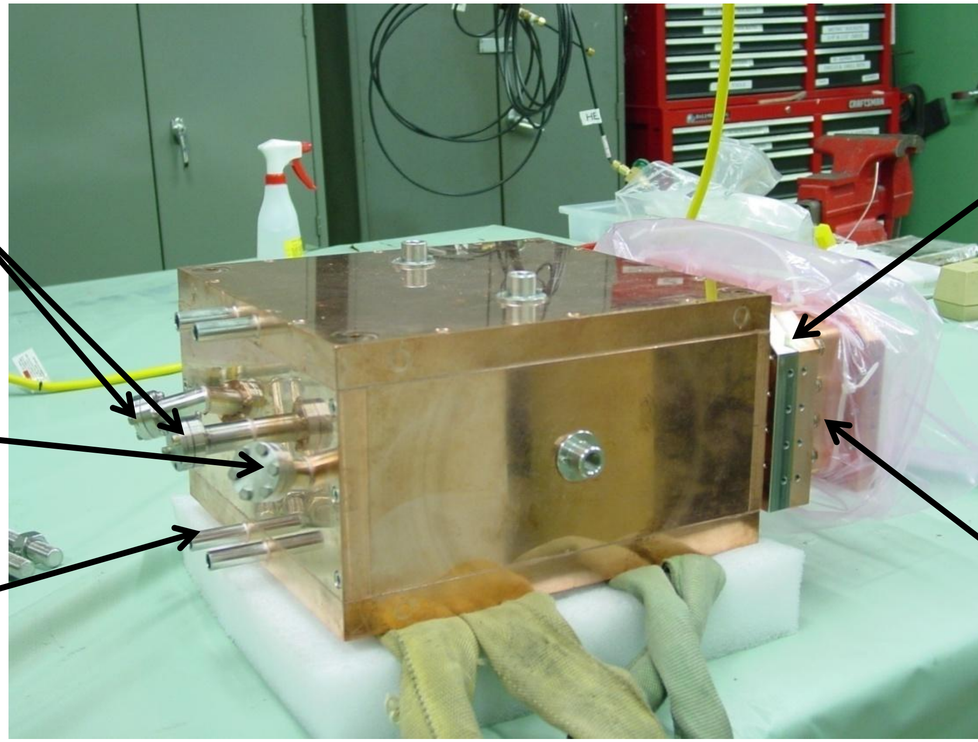



**Figure 1**

# Box Cavity attached to Tapered waveguide coupler and type N connector to WG Adapter.

**Network analyzer measurements:**

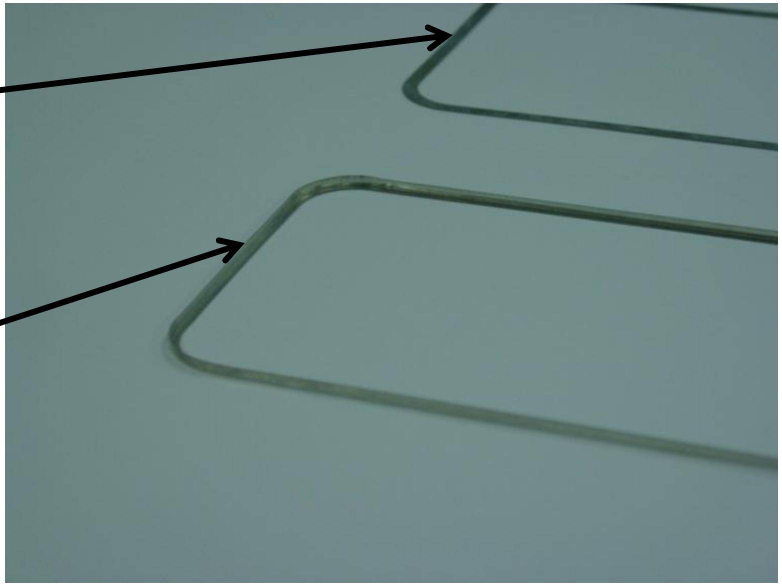
- **Fo = 805.08 MHz;**
  **Simulation Fo=896.2 MHz**
- **Qo= 26,400;**
  **Simulation Qo= 27,400**
- **β= 0.9 coupling factor;**
  **Simulation β= 1.06.**
  - **These values are preliminary and may change when attached to the LBL stepped WG coupler and mounted in the magnet.**


Type N to WG Adapter | Tapered WG Coupler | ¼ height WG Coupling Cell | Cavity

# Tin vacuum Seal comparison

Standard Flat 10 mil thick tin seal

Special compound 10 mil thick vacuum seal with ½ round edge which gives it added strength.



Comparison of the two seals supported by some of the tooling pieces.

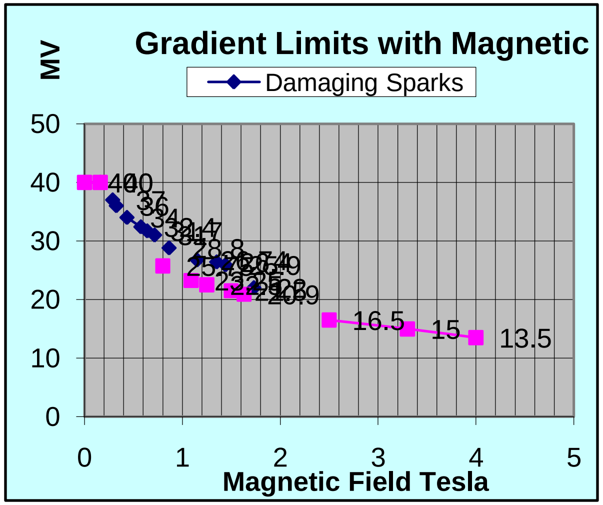
# New and Different RF Cavity Commissioning proposal

**I would like to RF commission ether the LBL cavity or the Box cavity or both starting with the 3 T high magnet field breakdown limit. Using the magnetic breakdown curve as our guide, RF commission say to 10 to 15 % above the curve, 16.5 to 17.25 MV/m without the magnetic field. After this turn-on the magnetic to 3 T and RF commission the cavity with the magnetic field to its limit.**

**Reduce the magnetic field to say 2 T and rf commission again 10 to 15 % above the 2.75 T breakdown curve; increase the magnetic field to 2.75 T and RF commission with field upto its limit. This should be repeated until we trace out the whole curve down to say 0.25 T. In the past, we took the data by Increasing magnetic field in steps of 0.25 T upto 3 T. However in the past, we RF commissioned to 36 MV/m before RF commissioning with the magnetic field and we started this commissioning at 0.25 T. In this case, the reason we do not want to go to zero magnetic field is the charging and discharging time of the magnet are to long about 2 hours.**

**I especially want to do this for the orthogonal cavity. I am of the opinion now, that it does help much to RF commission the cavity or cavities without the magnetic to very high gradient. All this does create pits that interfere with the magnetic field commissioning results later.**

**At this time it looks as if the box cavity and the 5 T magnet will be operational at about the same time in February. We should, however, RF commission the cavity at a low safe valve of 16.5 to 17.25 MV/m several days (2.5 M pulses) before commissioning with the magnetic field. *We have noted large improvements in breakdown limit of vacuum cavity in our linac with very very long RF running times.***



# Summary

- **The orthogonal cavities should be operational the first or second week of February. It has a Ratio Eps/ Epa= 4.**

- **The design of the parallel cavity is about 95 % completed. It has a Ratio Eps/ Epa= 2 and can be completed in about 3 months with high laboratory priority. The copper and long lead time items are on hand.**

- **The assembly of the cavity with its support parts will take place in the A0 clean room and then transported to the MTA hall.**

- **Inspections of spark damager will take place in the upgrated MTA cleanroom.**