

High power coupler at BNL

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Outline

➤ 704 MHz 500 kW CW Fundamental power coupler for R&D ERL SRF gun and now booster cavity of the LeREC.

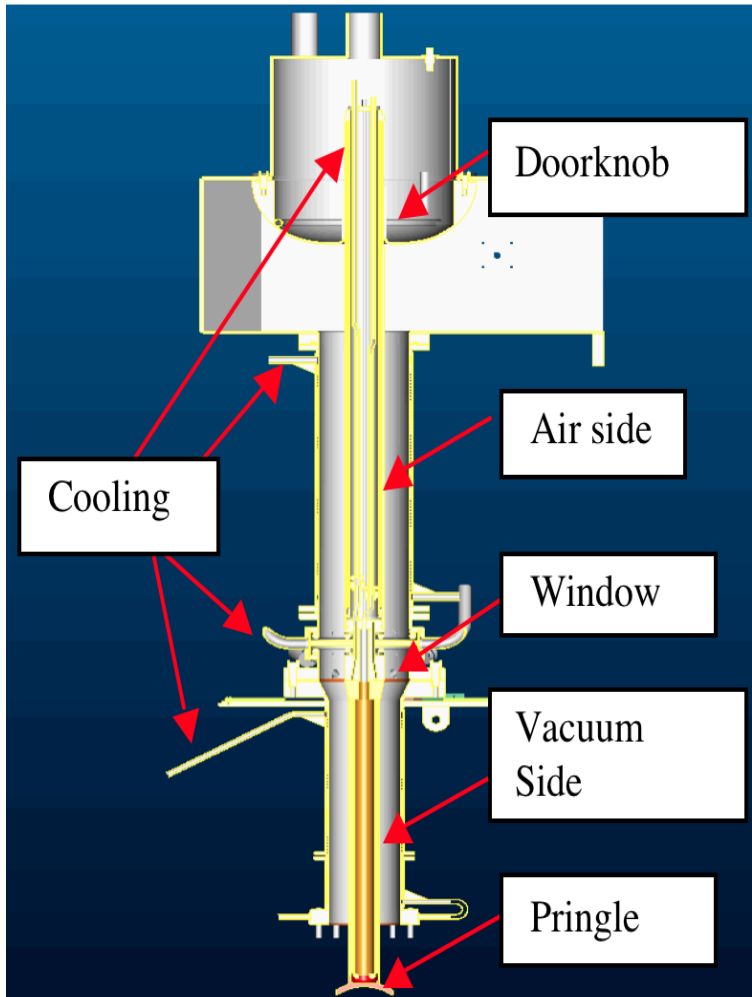
- These two couplers were conditioned and operated for 2.5 years.
- It was taking apart to repair the cavity. Getting ready to re-condition it.

➤ 20 kW Toshiba FPC for 704 MHz 5-cell cavity

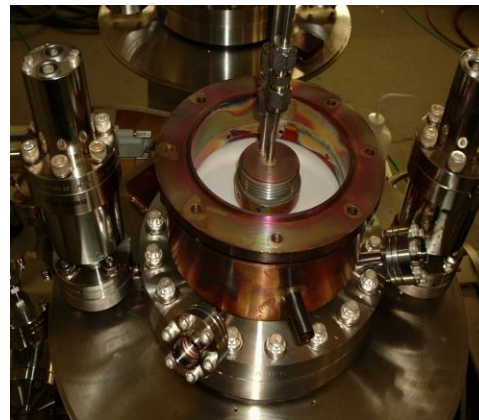
- This coupler was conditioned in-situ, and operated in the run16.
- It was taking apart to repair the cavity.

➤ Summary

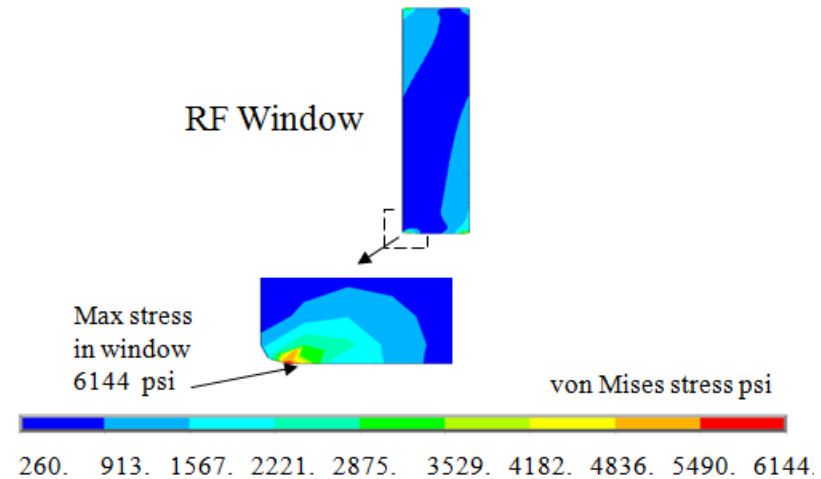
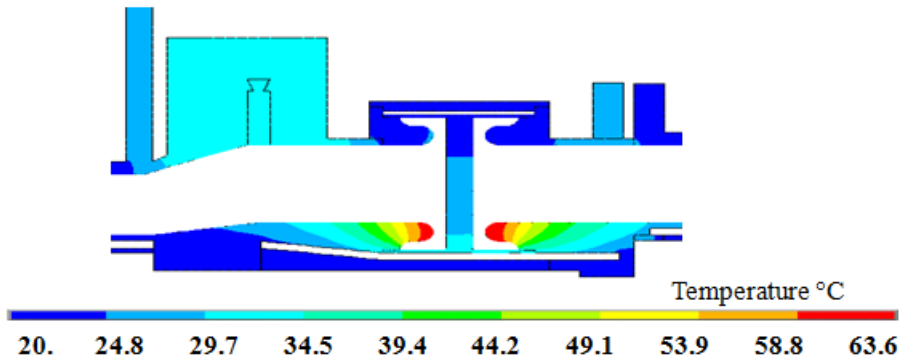
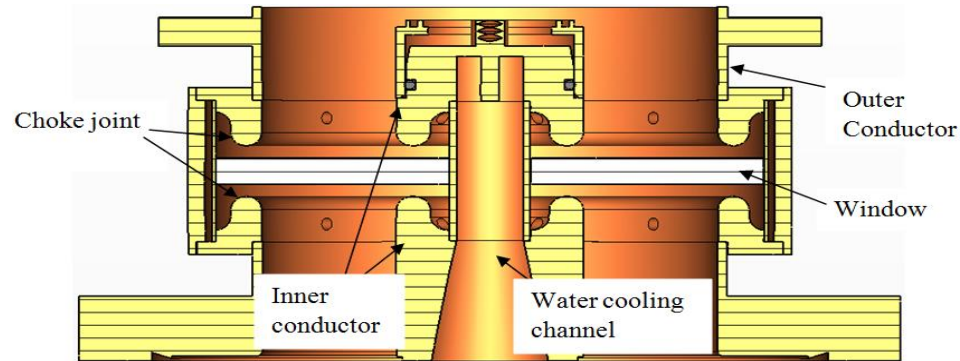
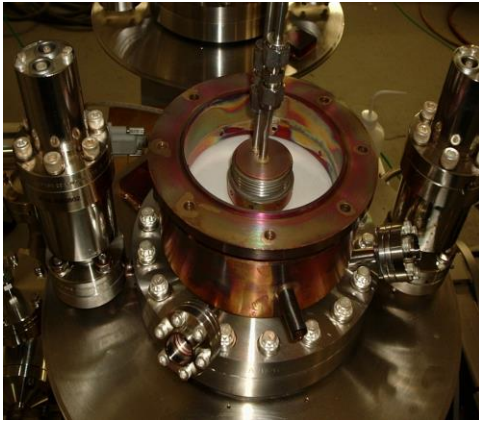
500 kW CW Fundamental power coupler



- 500-kW coaxial fundamental power (FPC) coupler belongs to the family of TRISTAN/KEKB/SNS couplers.
- Two couplers will provide up to 1 MW of RF power to the R&D ERL SRF gun.
- FPC has a planar Berillia window.
- Inside the cryostat the copper-plated stainless steel outer conductor is cooled by helium gas.
- Copper inner conductor is cooled by water.
- Air-side inner and outer conductors are cooled by water.
- Window assembly has ports for vacuum gauges and arc detectors.
- Doorknob transition to WR1500.
- Pringle-shaped tip of the antenna to enhance coupling (similar to that of Cornell ERL injector).
- Designed by AES, manufactured by CPI/Beverly.

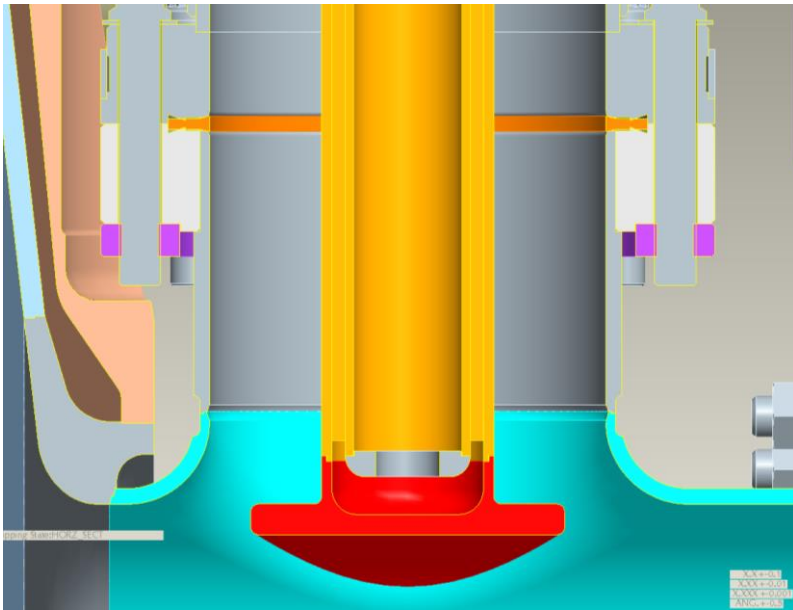


BeO window

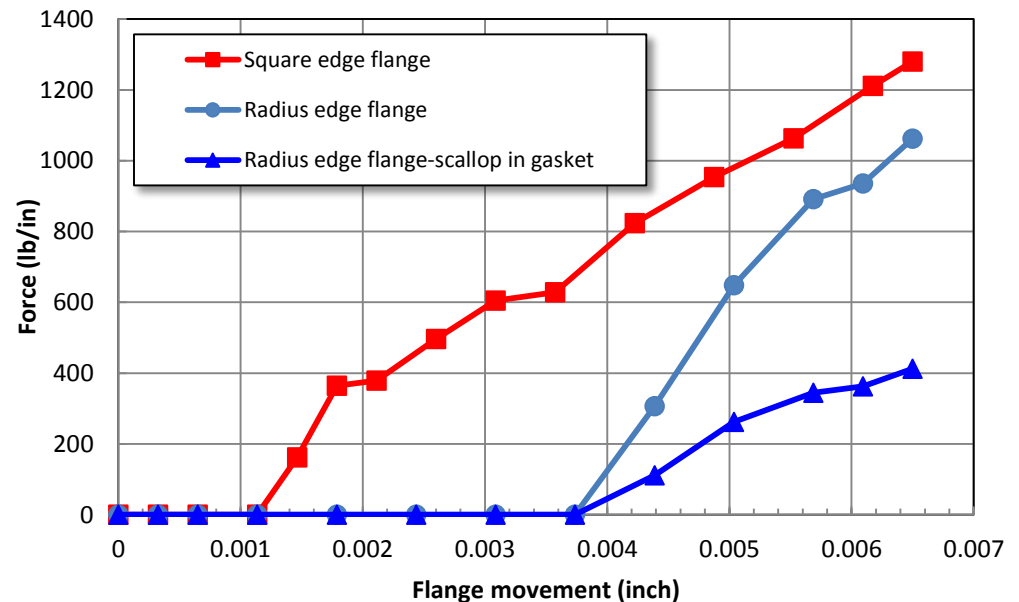
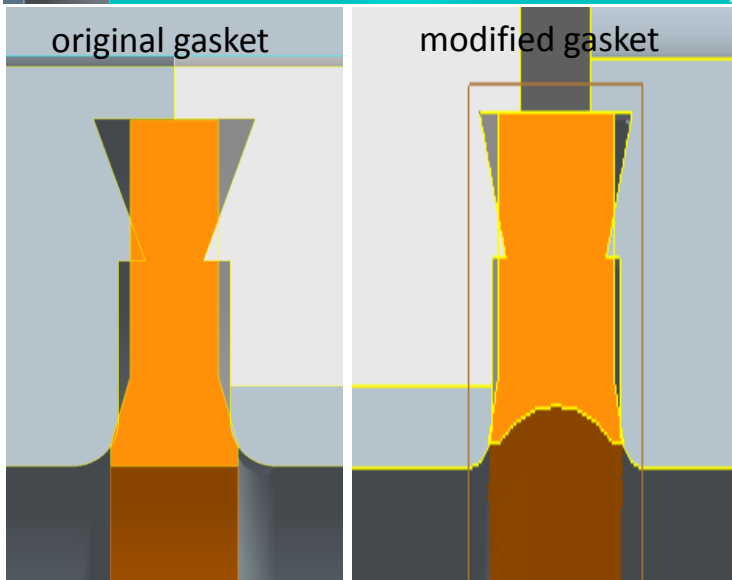


- ❖ The design was done by collaboration of AES and BNL
- ❖ 1 MW transmitted power was used in simulations. Water cooling (9.6psi for window) make sure the temperature rise less than 0.1°C.
- ❖ The maximum stress at the window is 6144 psi from the heat load and ambient pressure, which is approximately one third of the tensile strength of BeO.

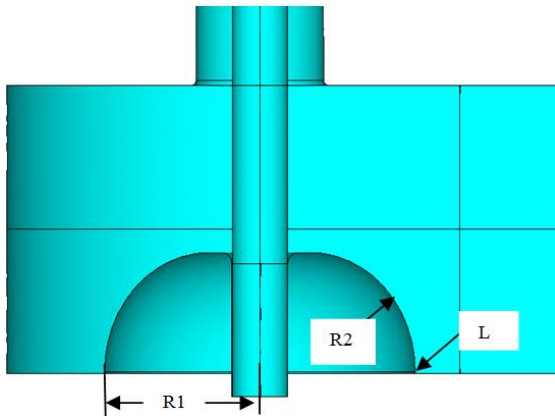
Conflat gasket with RF seal



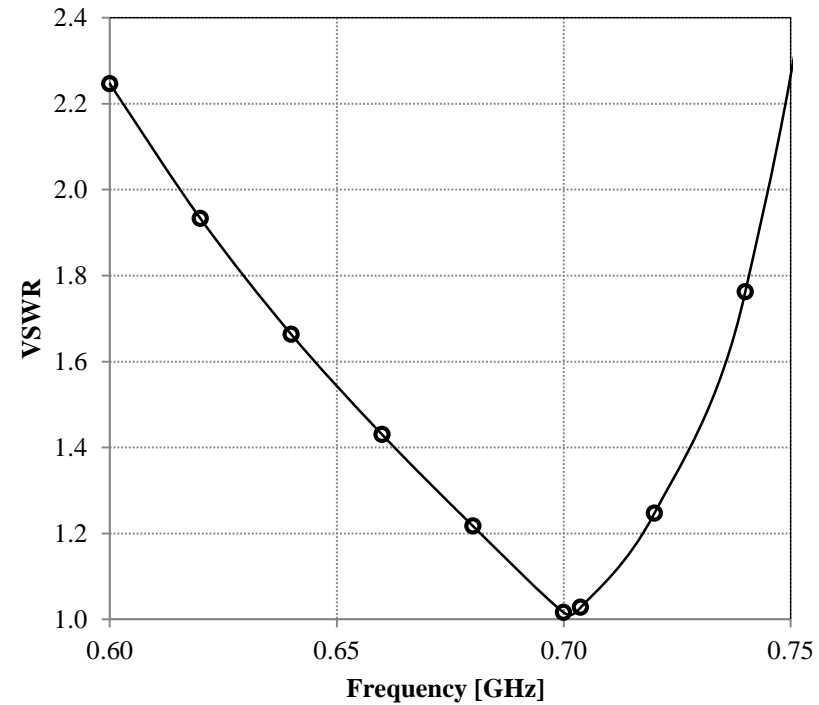
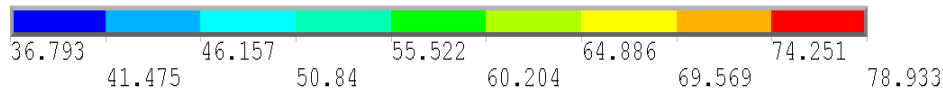
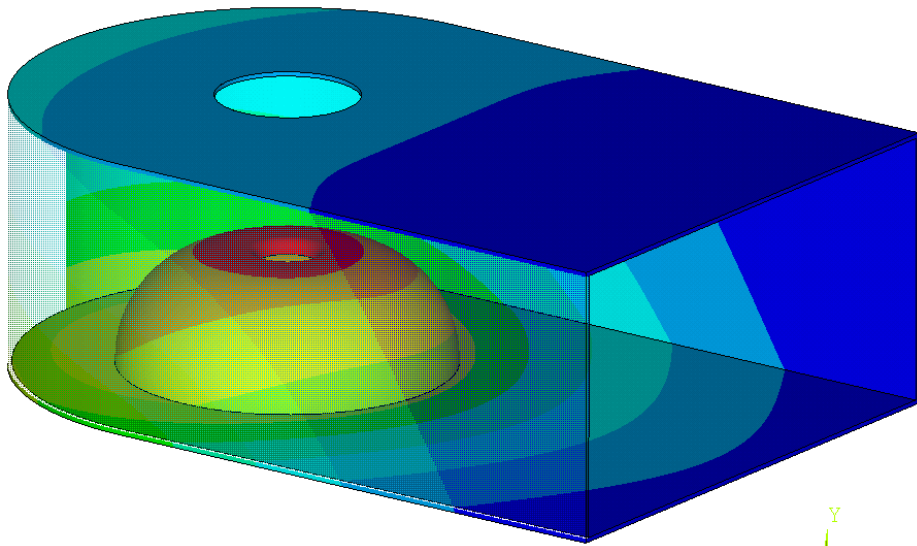
- A custom Conflat gasket with RF seal is used between the FPC and the SRF gun cavity.
- We have found that the original gasket was difficult to seal as the flanges had to crush the gasket in two places, which required very high force.
- A modification was proposed to alleviate the problem. It is used now on the SRF gun cavity/FPC interface.
- We may use similar gaskets in the future for beam pipe seals.



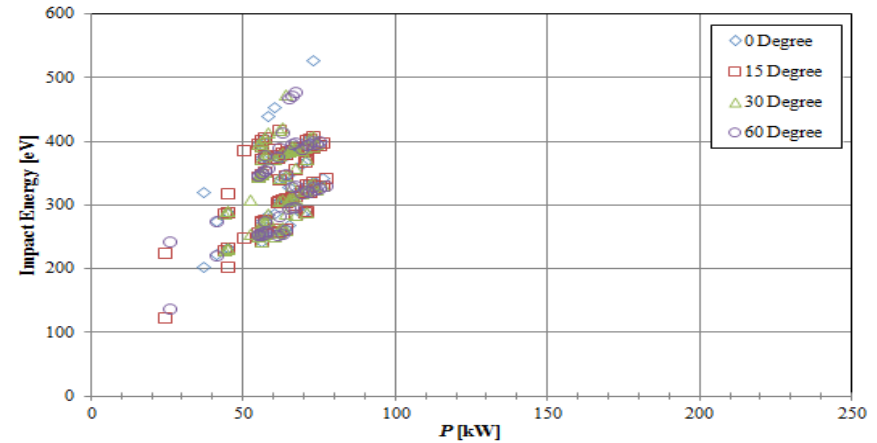
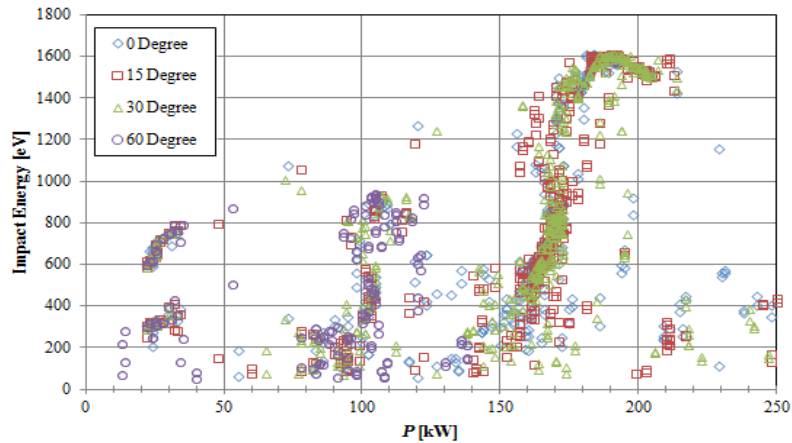
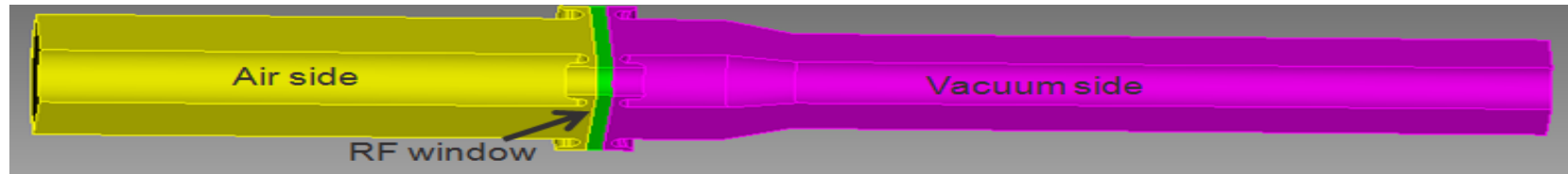
Doorknob



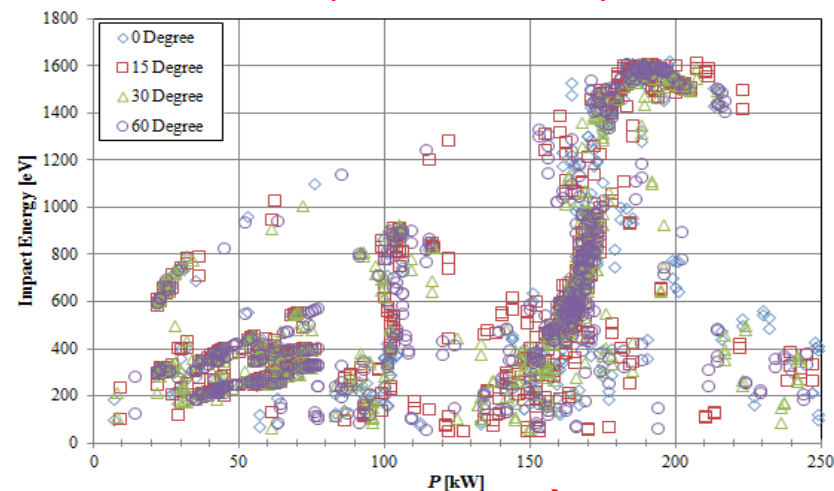
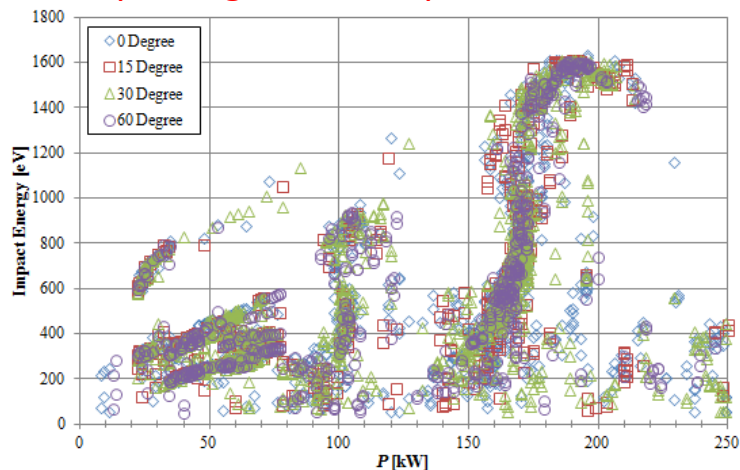
- 1 MW transmitted power was used in simulations.
- 1 GPM water flowing around the inner corner of the doorknob to keep the temperature (72°C) increase $<1^{\circ}\text{C}$.



Multipacting simulation

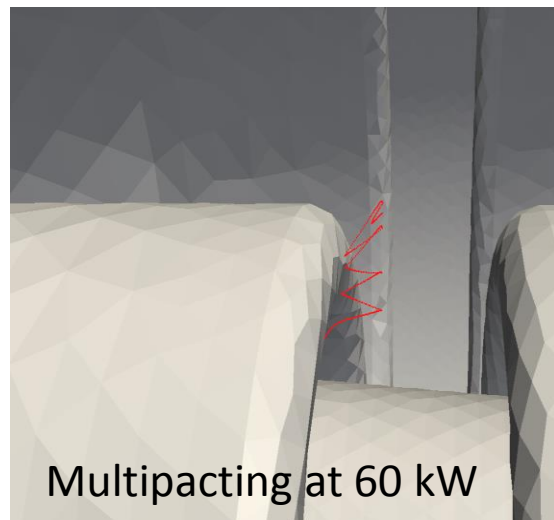
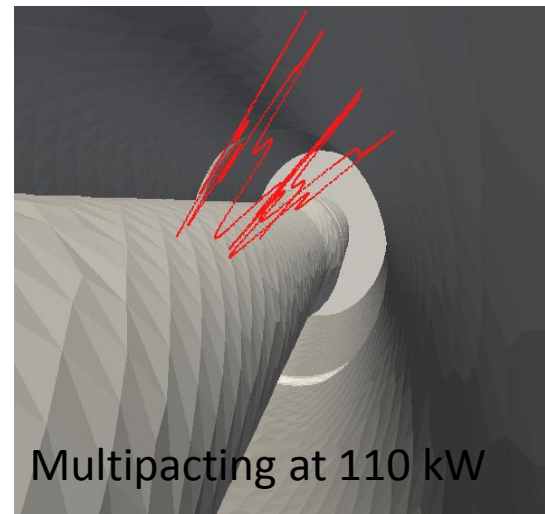
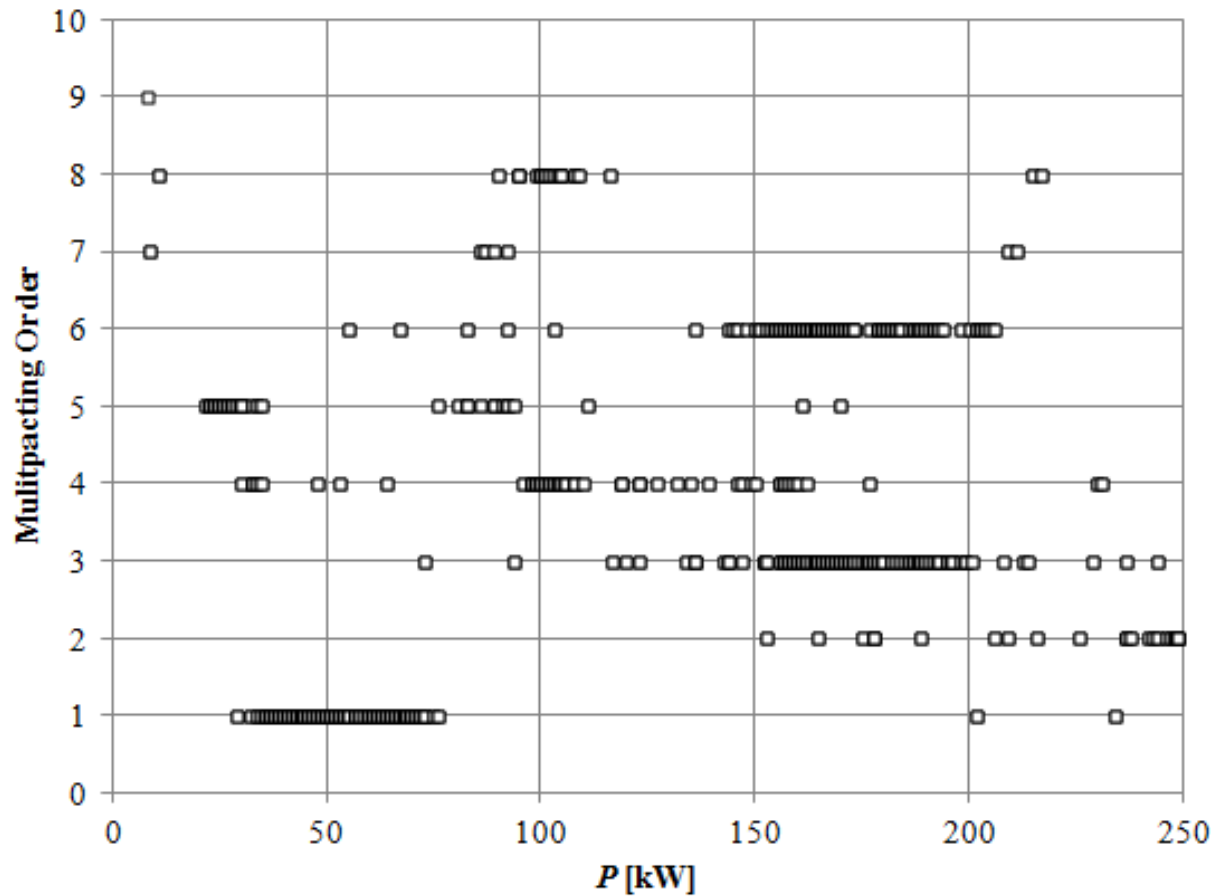


Multipacting in the coupler: left - vacuum side, right - window → no phase sensitivity

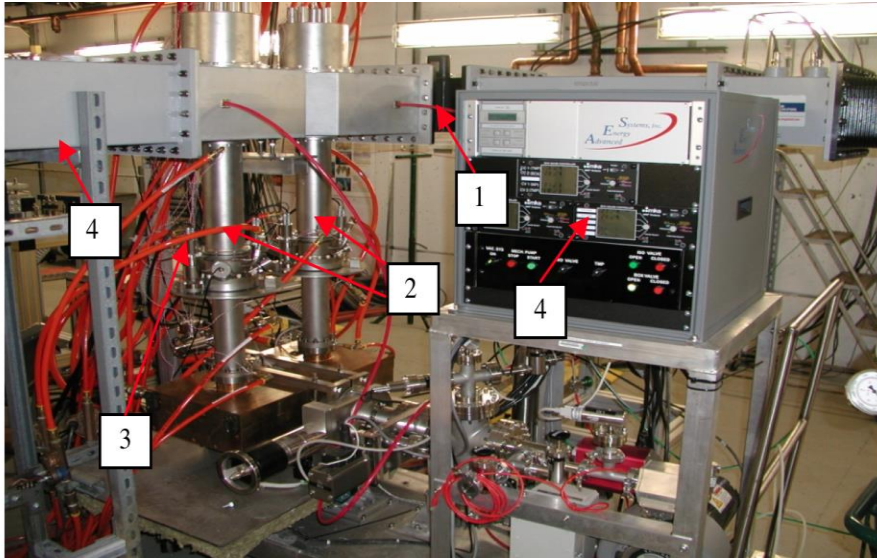


Multipacting simulation at different frequencies: left - 703.9 MHz, right - 703.75 MHz → not much frequency sensitivity for MP zone, but time consuming is different for different frequency

Multipacting simulation: Results



FPC conditioning

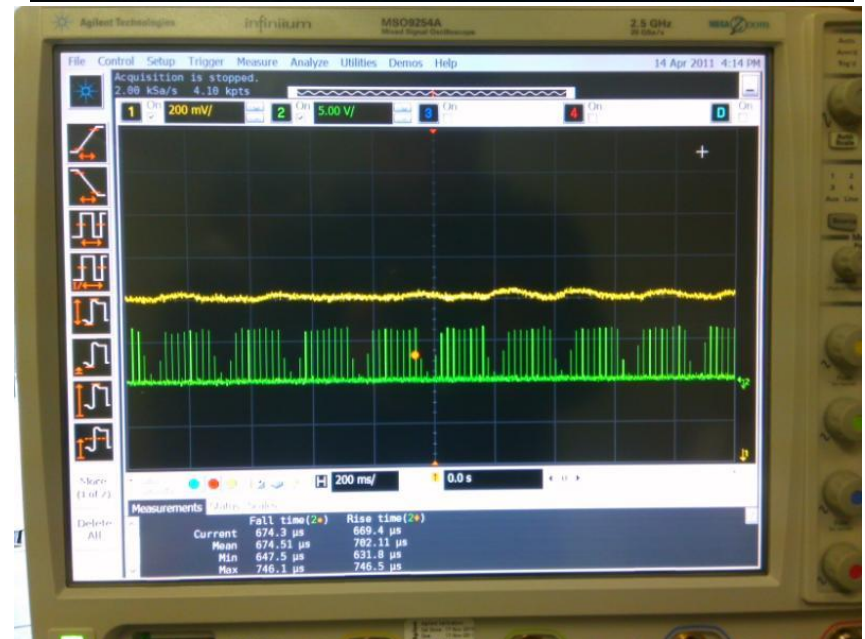
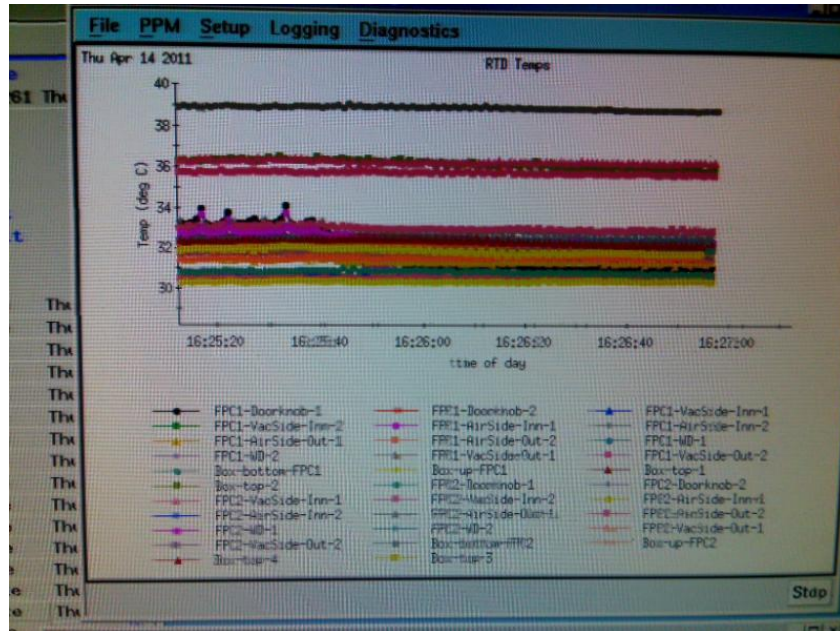
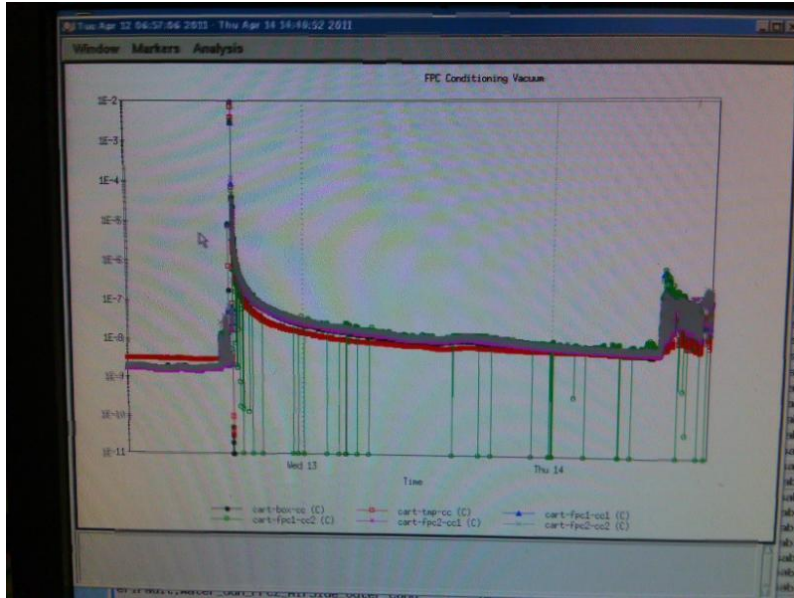


FPCs for conditioning set up: 1 - waveguide connecting to 1 MW klystron, 2 - two FPCs, 3 - cooling hoses, 4 - waveguide phase shifter and a short plate.

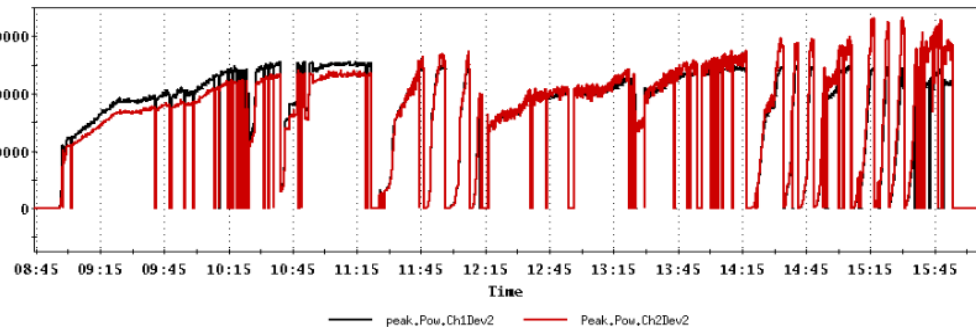
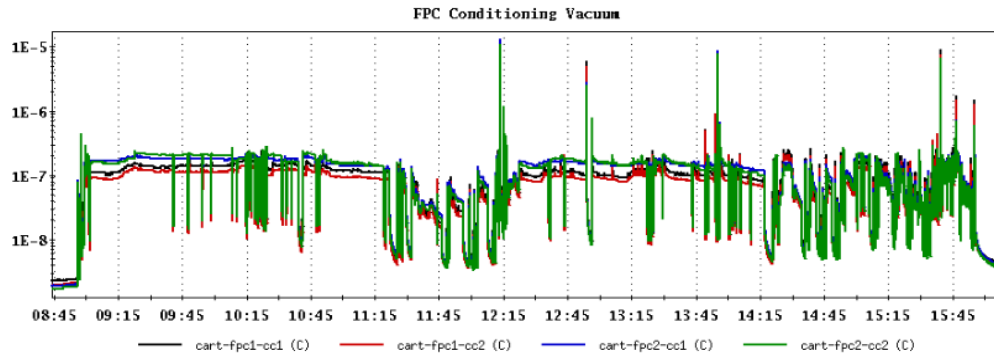
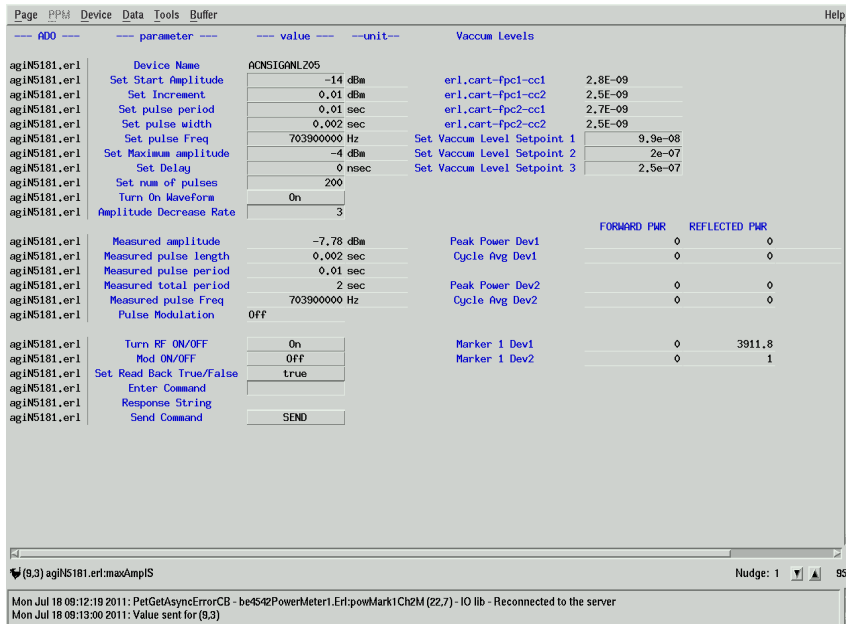
- The FPC conditioning cart and FPCs were assembled at AES.
- All components were cleaned in an ultrasonic bath and dried with dust-free nitrogen gas.
- The window assemblies were also rinsed with DI water to reduce concentration of dust particles and contaminants trapped in the window.
- The assembly of vacuum components was carried out in a class 10 clean room at AES.

- The first thing after the cart arrival at BNL was vacuum bake at 200°C for about 20 hours.
- With a thermal-insulation box, it takes 7 hours to ramp the temperature up to 200°C (RF window temperature). The stand stays at this temperature for 20 hours. Then the temperature is ramped down at a rate of 15°C/hr. The vacuum reached 7.3E-9 Torr immediately after baking and to 3E-9 Torr after several days of pumping.
- The S-parameters were measured.
- Finally, the FPCs were connected to the klystron output at one end, and the phase shifter terminated by a short plate at the other end.

Watching the signals

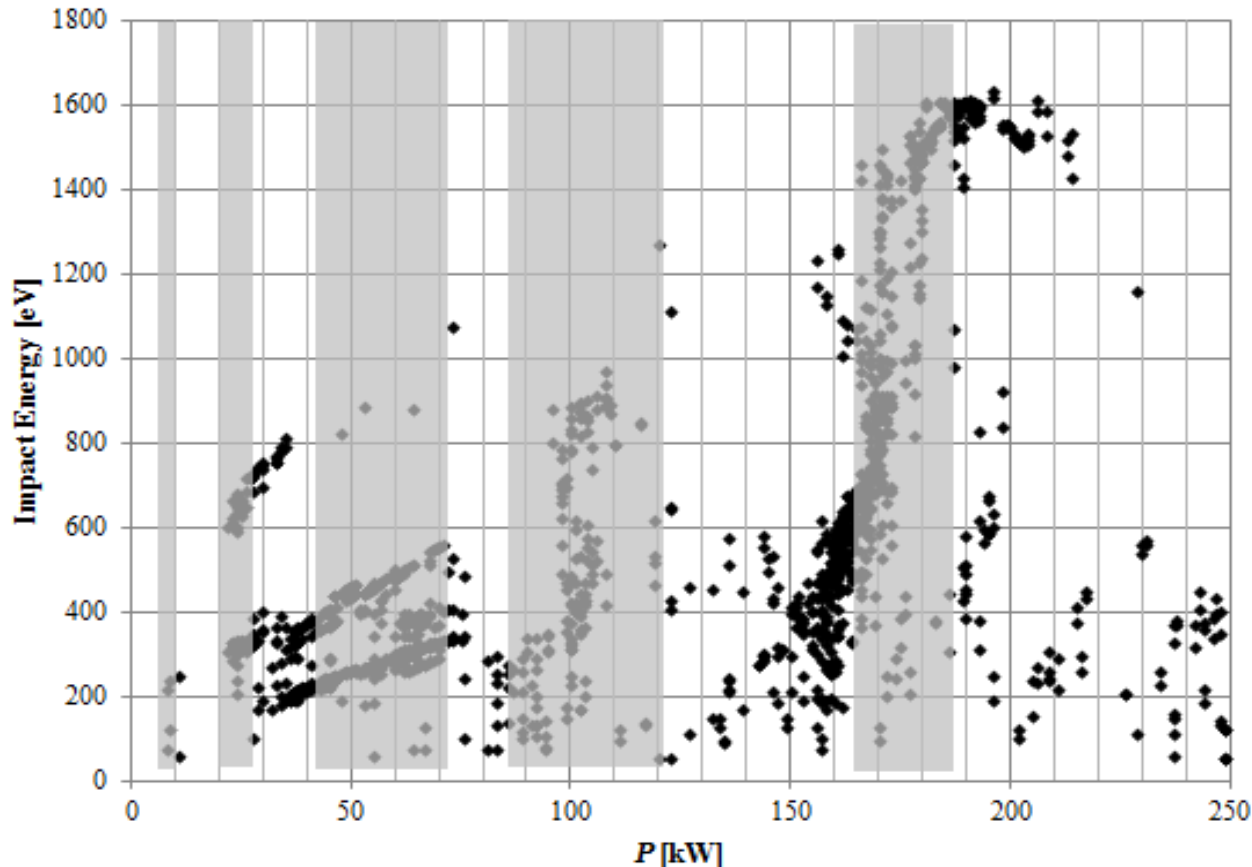


FPC conditioning: Multipacting observed



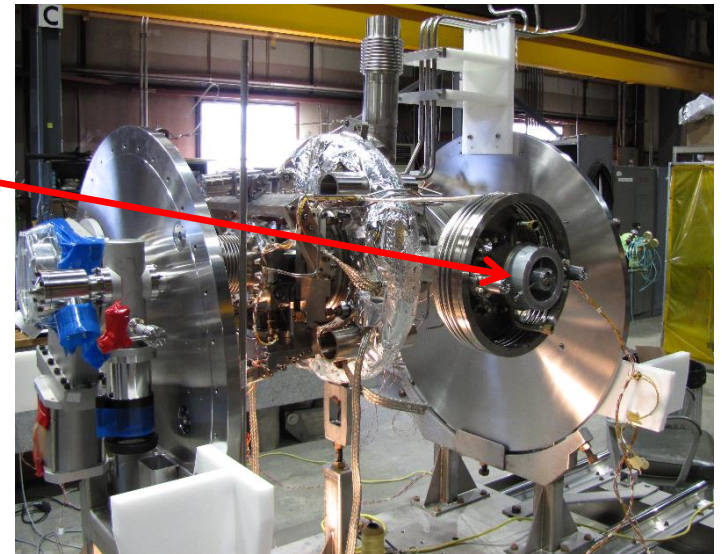
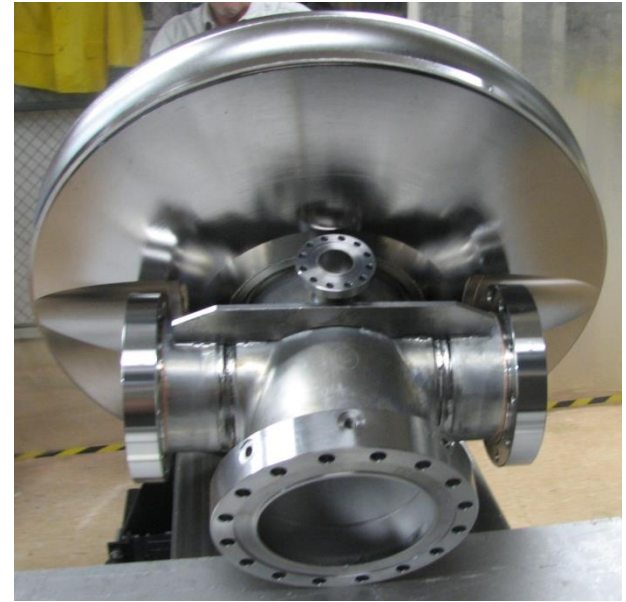
- The FPC conditioning began in various pulse modes, from 100 μ s / 10 ms to 2 ms / 10 ms pulse length / period, followed by CW mode with gradual increase of RF power to the maximum value.
- Multipacting zones at 8 to 10 kW, 16 to 25 kW, 40 to 70 kW, 85 to 120 kW and about 165 to 185 kW. Above 185 kW, there was a lot of out gassing.
- For different RF phases (every 10°), the processing went similar and the conditioning time was close except for the very first run, which took most of the test time to ramp up the RF power and it was much shorter time for the later runs.

Comparison of simulation and test

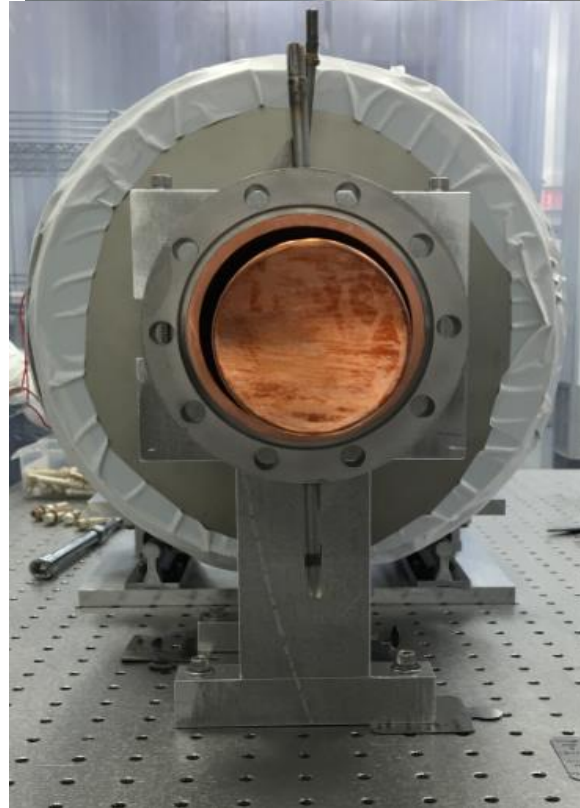


- ✓ Simulation shows multipacting will happen at the RF power level about are 8 to 10 kW, 16 to 25 kW, 40 to 70 kW, 85 to 120 kW and about 165 to 185 kW. All these featuresd were observed in the experiments
- ✓ The simulation also shows that multipacting zone is not sensitive to frequency. However, the strength of multipacting changes with frequency.
- ✓ The multipacting is not sensitivity to the phase, since the multipacting mainly happens in the vacuum side.

FPC operation experience with the cavity

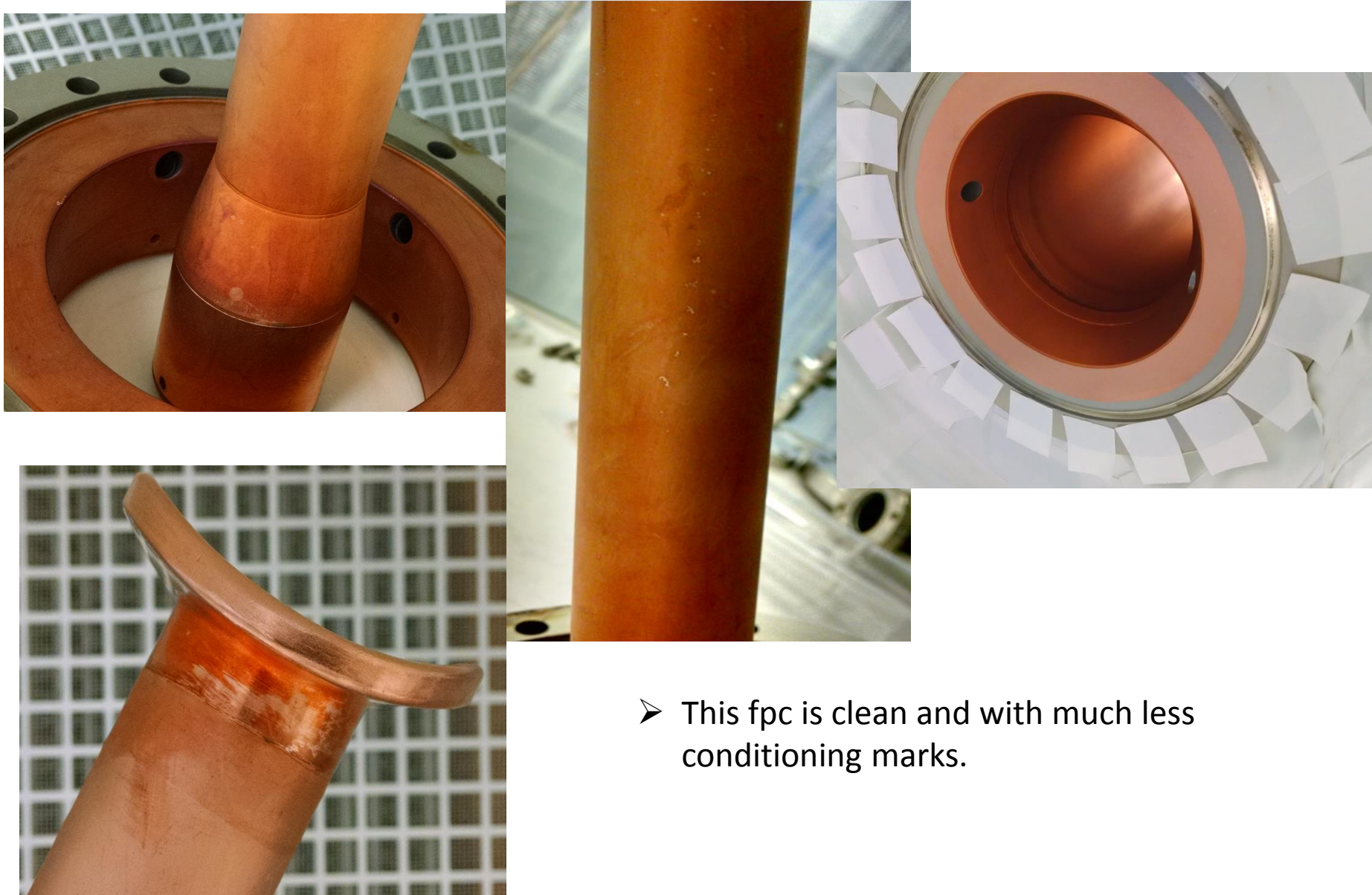


FPC#1 after it was taken apart.



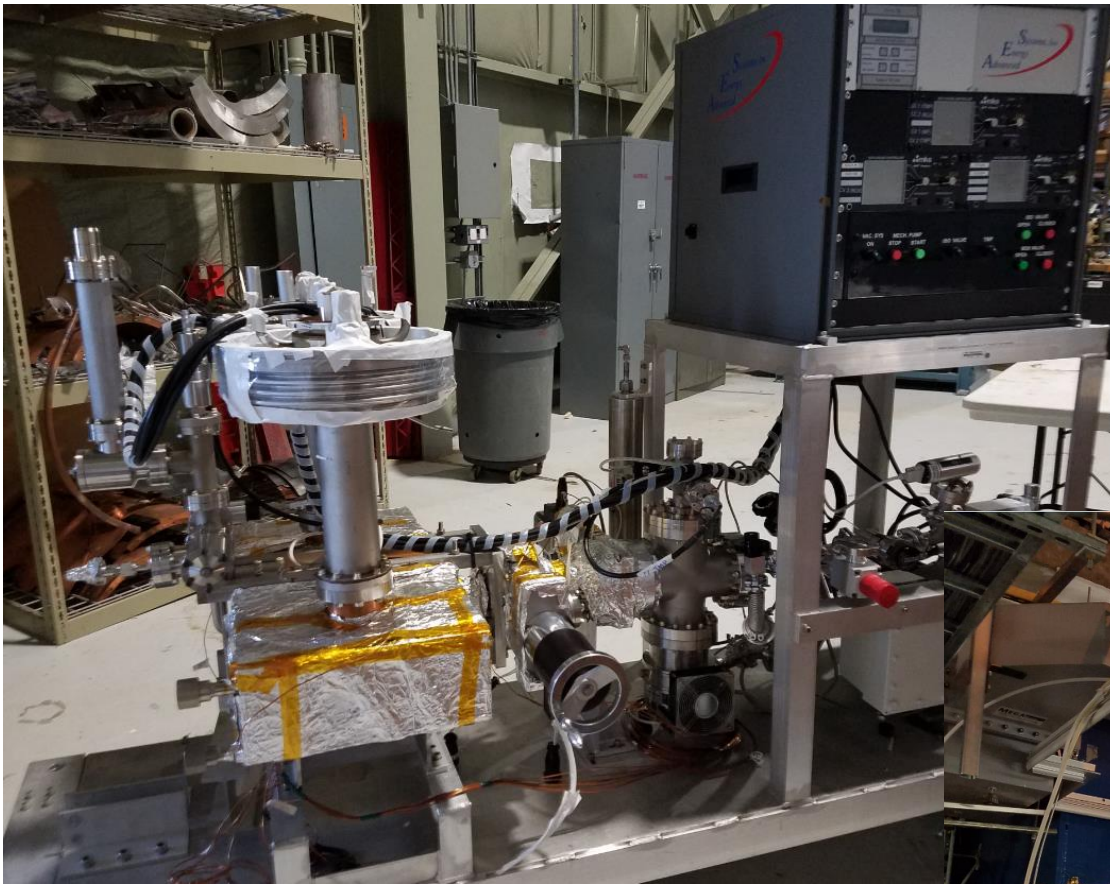
- During test, this FPC were arcing more than the other one.
- It seems that this FPC inner conductor was not built "straight".

FPC#2 after it was taken apart.



- This fpc is clean and with much less conditioning marks.

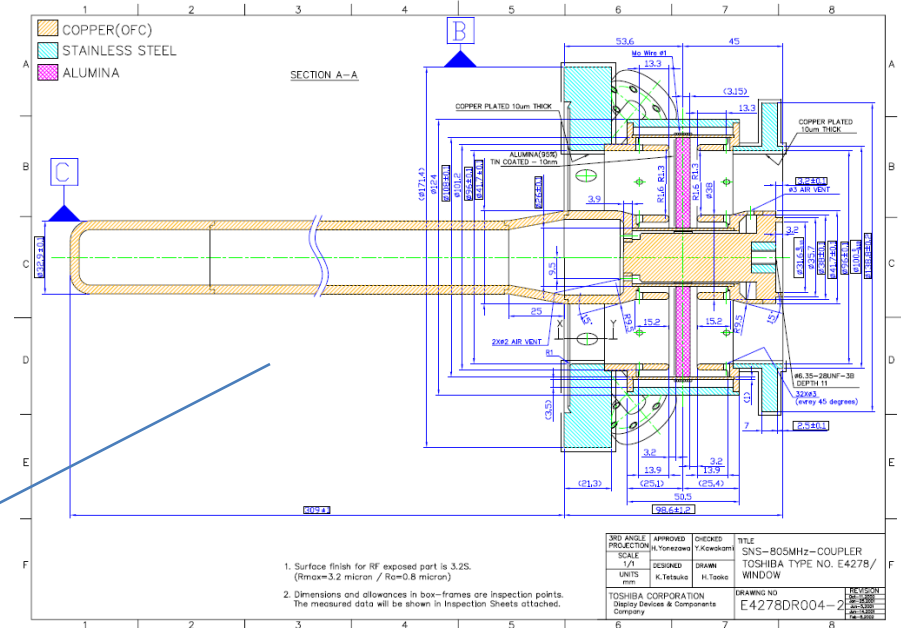
Preparation for re-conditioning the couplers



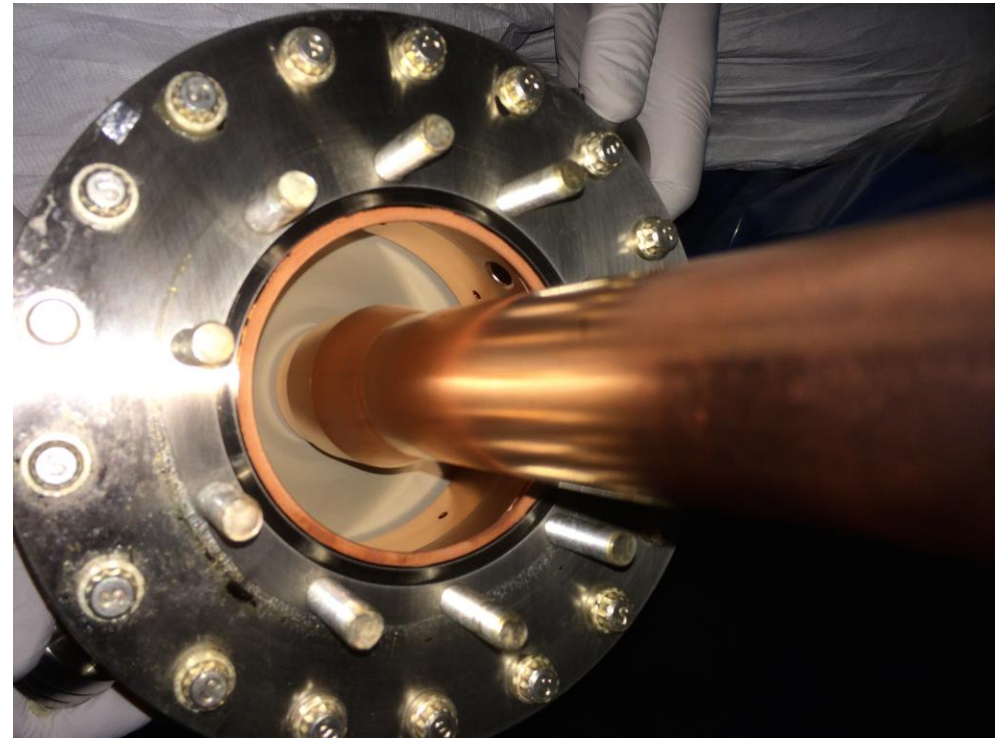
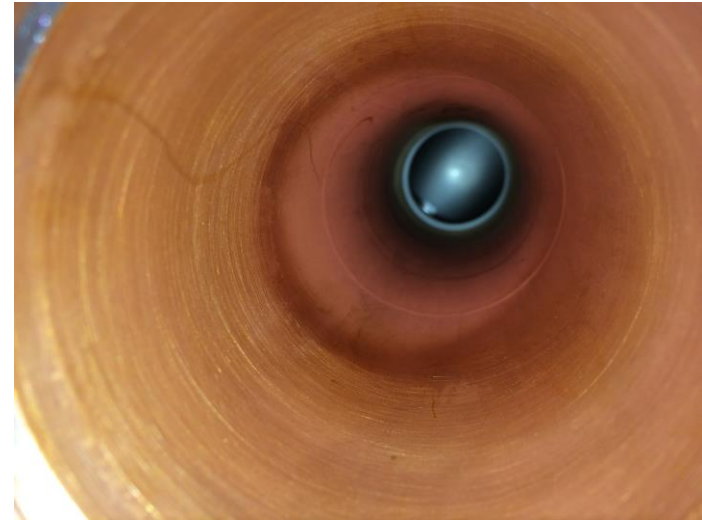
Operation experience on 20 kW Toshiba FPC for 704 MHz BNL3 cavity



Three stub tuner



1. FPC is made by Toshiba, water cooling on the window only.
2. Three stub tuner to adjust the Q_{ext} : $2E7$ to $8.5E6$.
3. FPC was conditioned in-situ, a lot of arcing in pulse mode.
4. As the cavity is contaminated, it is taking apart for BCP and HPR.



➤ The coupler is clean. Where was the arcing?

Summary

- Two 500 kW CW FPC were conditioned, the MP zones agreed with the track3p simulation very well.
- The couplers were commissioned with the cavity for 3 years, and took apart recently to be re-conditioned.
- A modified Conflat gasket with RF contact was designed and become “standard” RF seals.
- A 20 kW Toshiba coupler was commissioned with 704 MHz 5-cell cavity.
- A question: how to locate where arc happens, coupler or cavity?