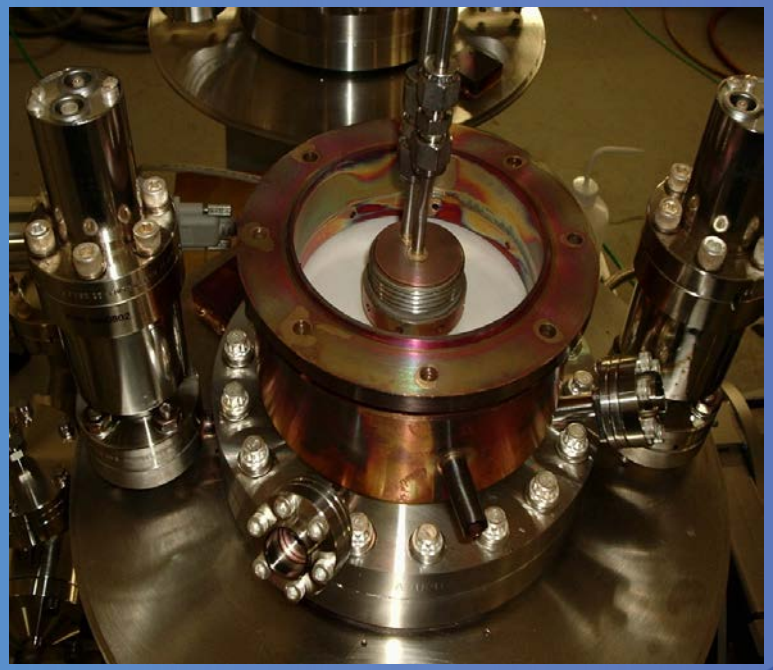
Fundamental power couplers for the ERL prototype SRF gun at BNL



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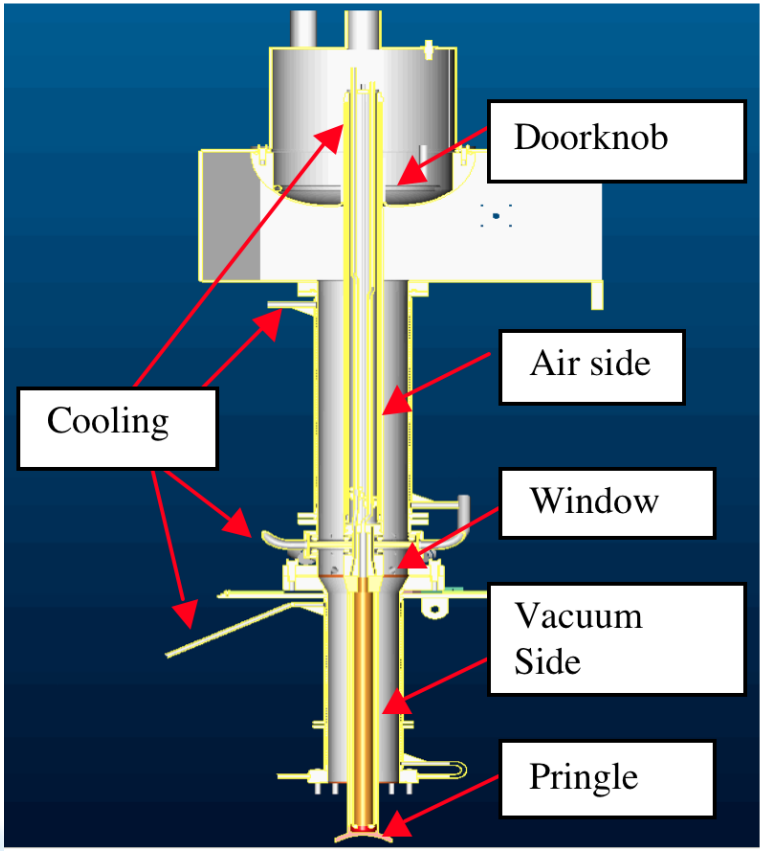
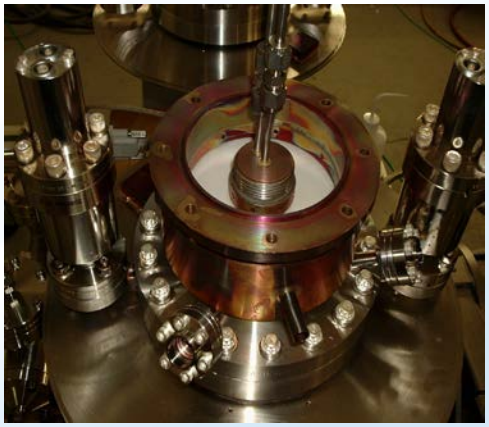
AES: M. Cole, G. White

SLAC: Liling Xiao, Lixin Ge, Kwok Ko

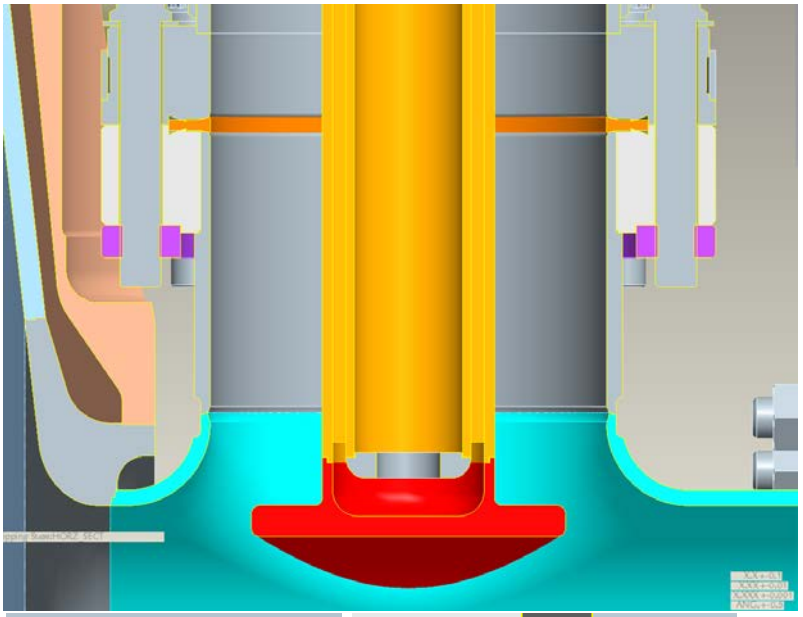
FPC for the prototype ERL SRF gun

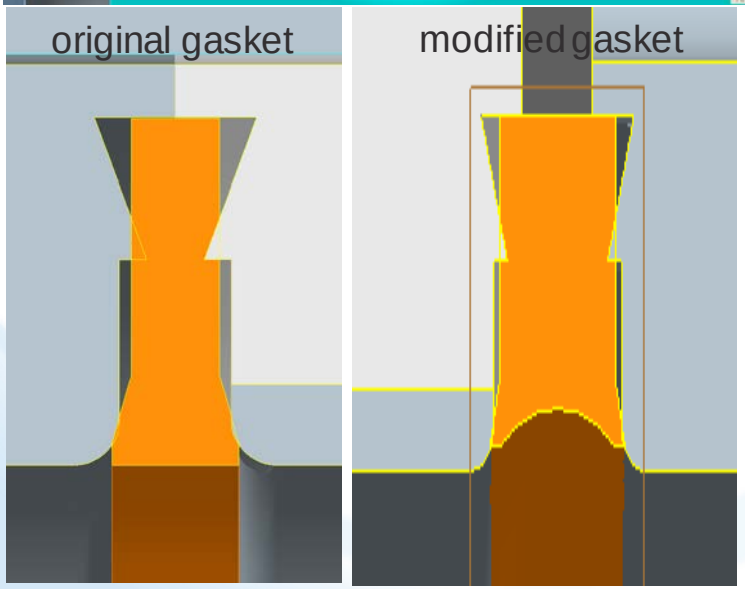


- 500-kW coaxial fundamental power (FPC)coupler belongs to the family of TRISTAN/KEKB/SNS couplers.
- Two couplers will provide up to 1 MW of RF power to the R&D ERL SRF gun.
- FPC has a planar berillia window.
- Inside the cryostat the copper-plated stainless steel outer conductor is cooled by helium 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.

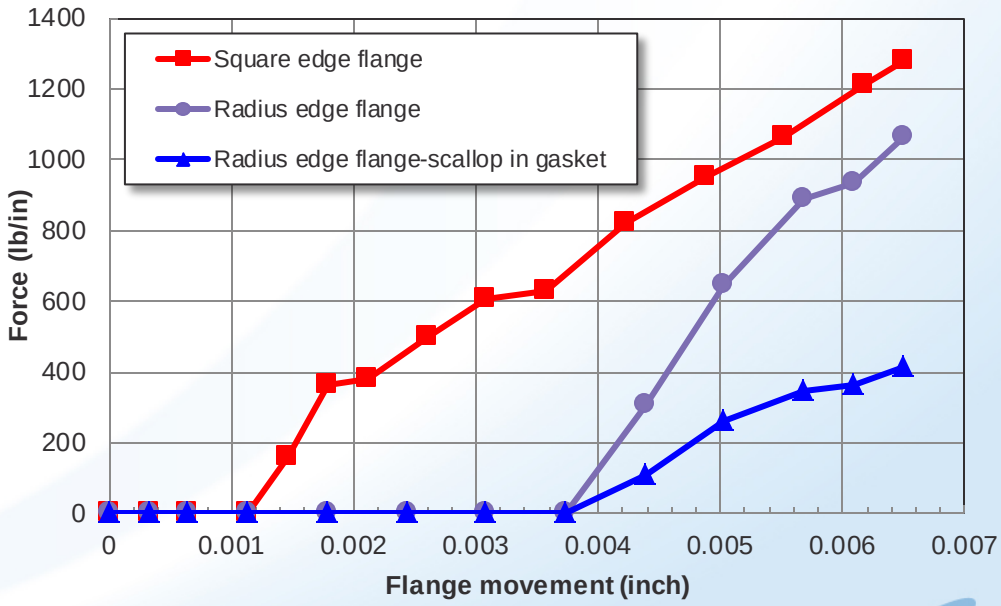


Conflat gasket with RF seal

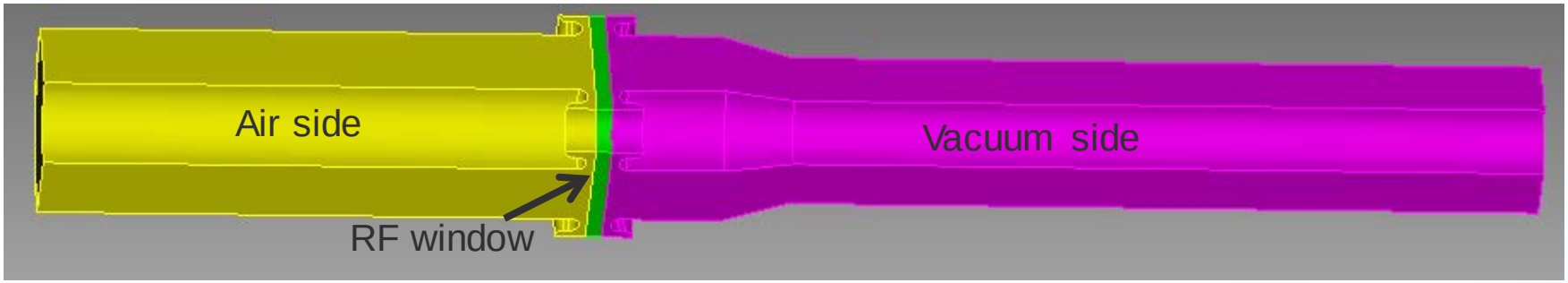




- A custom Conflat gasket with RF seal is used between the FPC and the SRF gun cavity.
- We have found that the original gasket was difficult to seal as the flanges had to crush the gasket in two places, which required very high force.
- A modification was proposed to alleviate the problem. It is used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

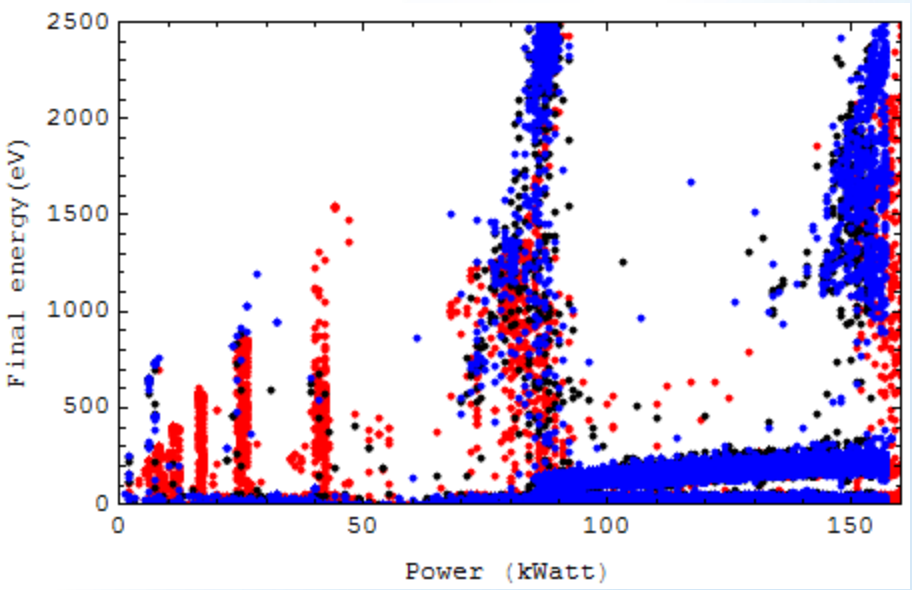


Simulations of multipacting with Track3P



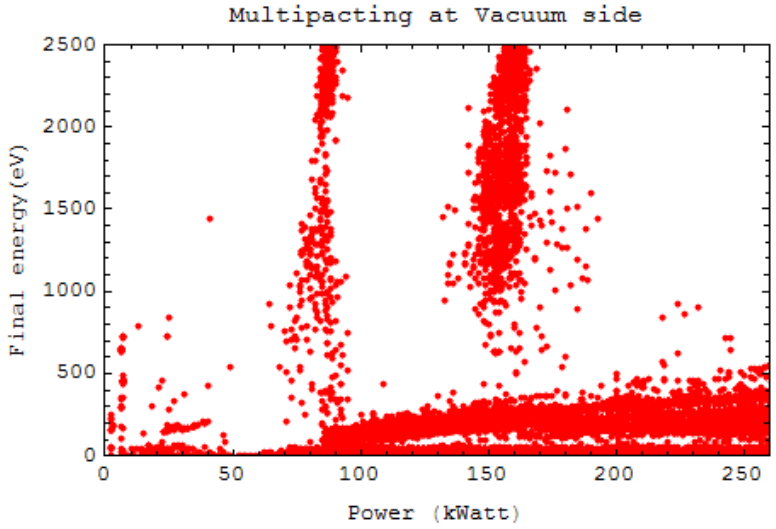
- The simulations were carried out for the FPC conditioning setup: standing wave, full reflection at different phases .
- MP was found in the coaxial line, but not at the window ➔ MP zones are not sensitive to the RF pahse of reflecting wave.
- MP is predicted at RF power levels about 4 kW, 16 kW, 25 kW, 80 kW and 160 kW.
- Zones are not sensitive to the RF frequency. However, the strength of multipacting varies with the frequency change.

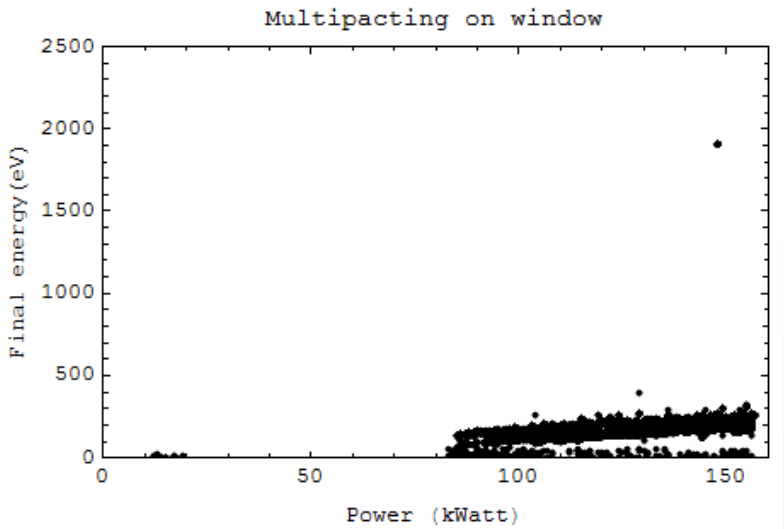
MP simulation at different reflection phase:
red - 0, black - π/9, blue - π/6



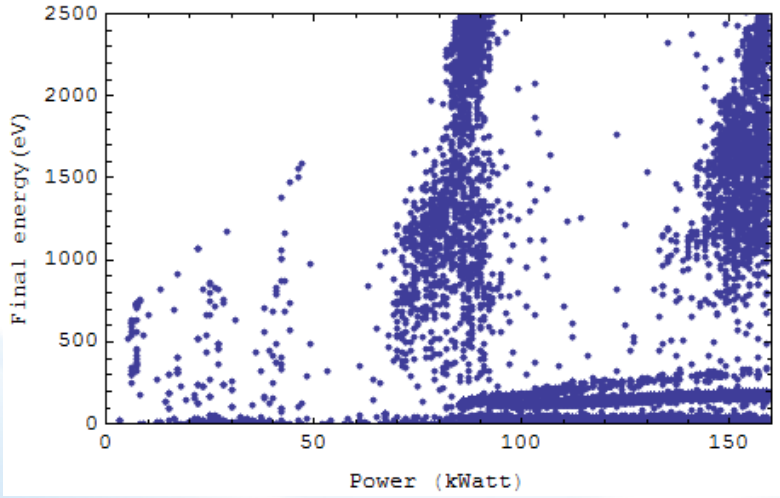
More simulations results

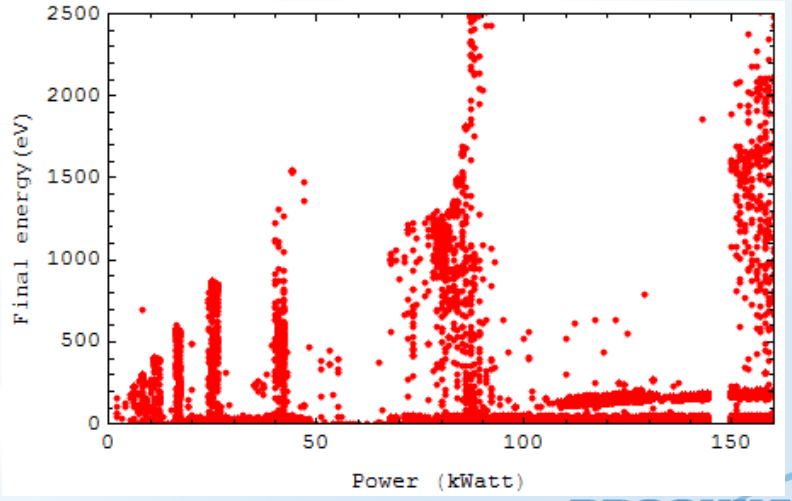
Left - vacuum side coaxial line, right – window



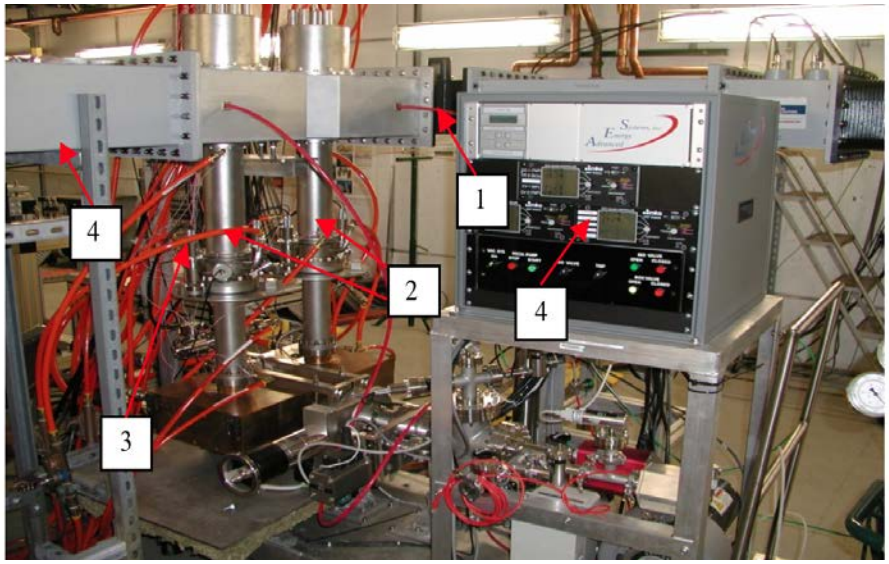


Simulations at different frequencies: left - 703.9 MHz, right - 703.75 MHz





FPC conditioning set up

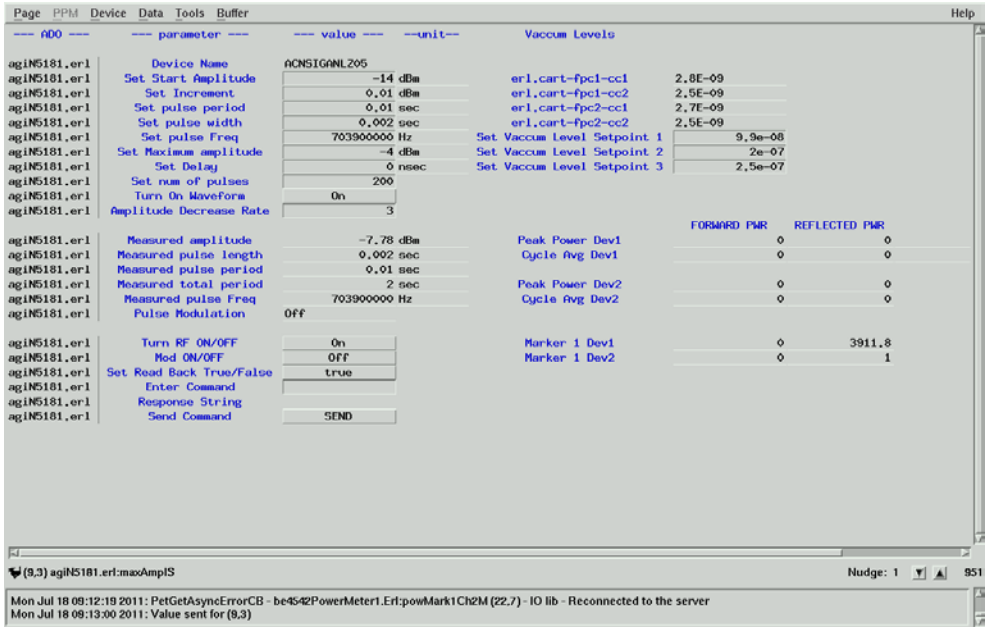


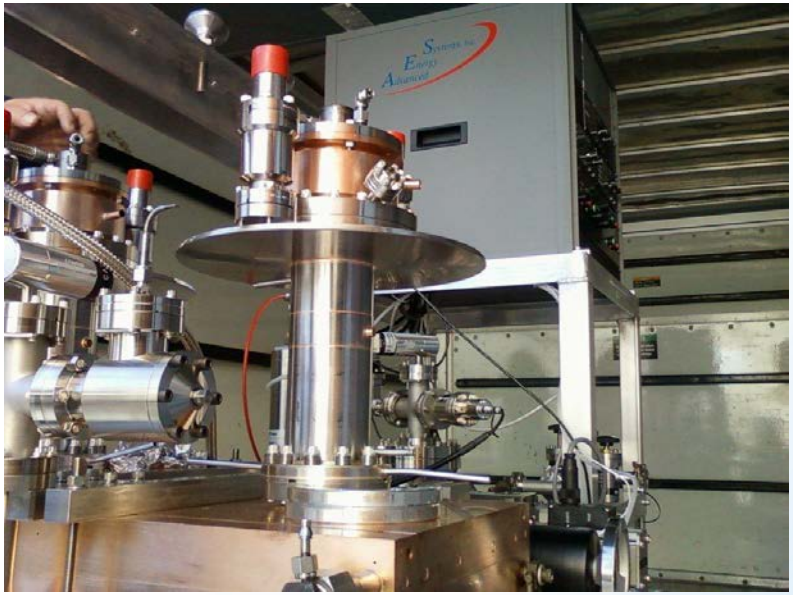
FPCs for conditioning set up: 1 - waveguide connecting to 1 MW klystron, 2 - two FPCs, 3 - cooling hoses, 4 – waveguide phase shifter and a short plate.

- 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 neasured.
- 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.

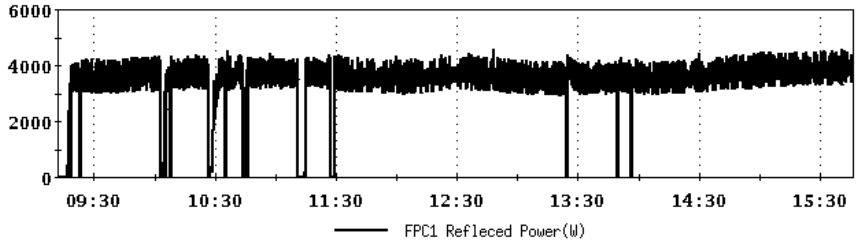
FPC conditioning

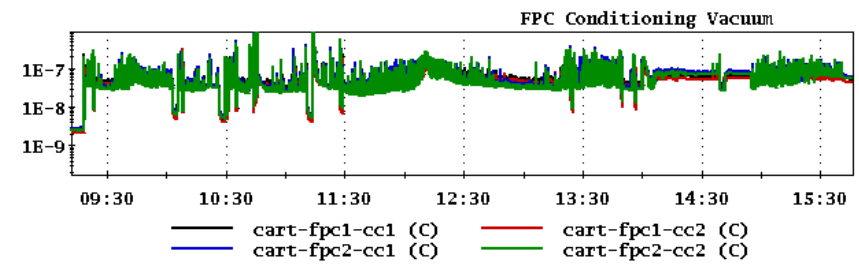




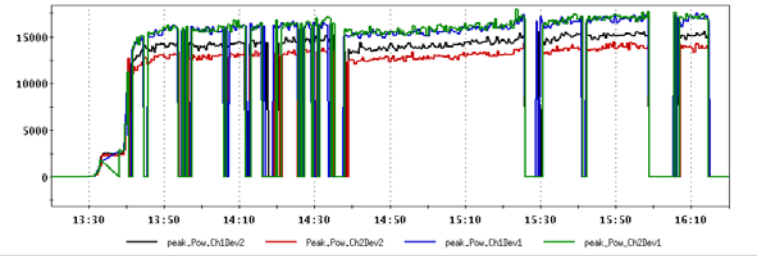
- Conditioning is performed in standing wave mode.
- It begins in various pulse modes, from 100 μs/10 ms to 2 ms/10 ms pulse length/period, followed by the CW mode with gradual increase of RF power to the maximum value.
- The phase shifting up to 45 degrees is performed via the remotely controlled phase shifter.
- The output of the klystron is controlled by a computer program with feedback on vacuum.
- RF power was limited to 125 kW in CW mode to keep local field levels at standing wave maximum the same as they would be at 500 kW.
- RF power in pulse mode was up to 250 kW (limited by the klystron collector).

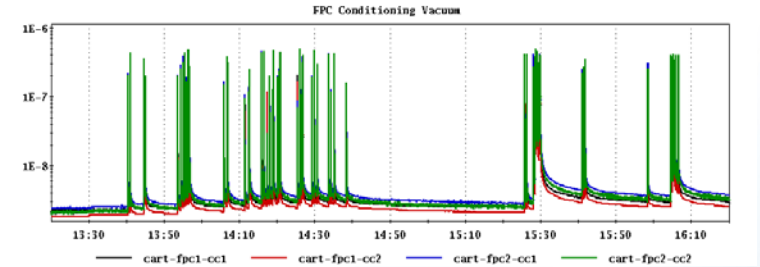
FPC conditioning: MP zones



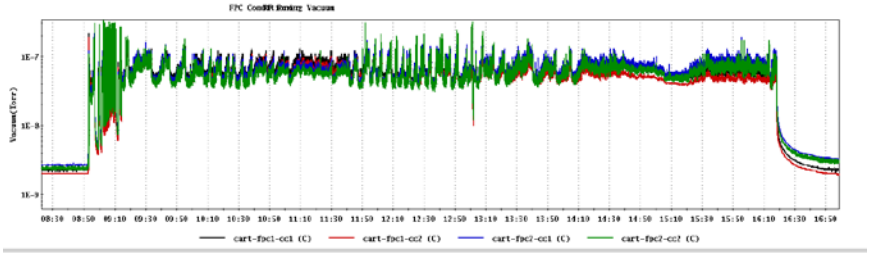


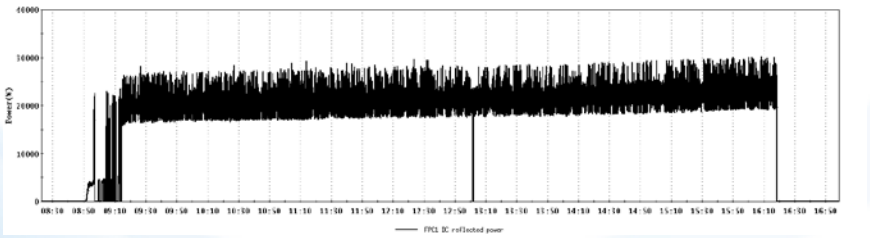
(a) MP at 4-6 kW



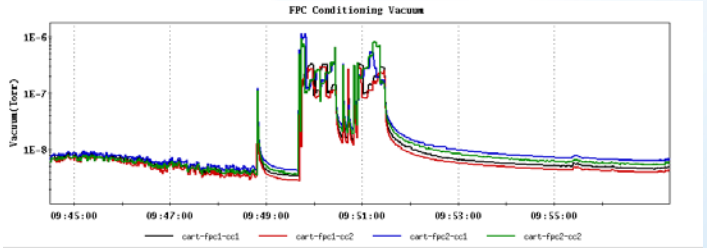


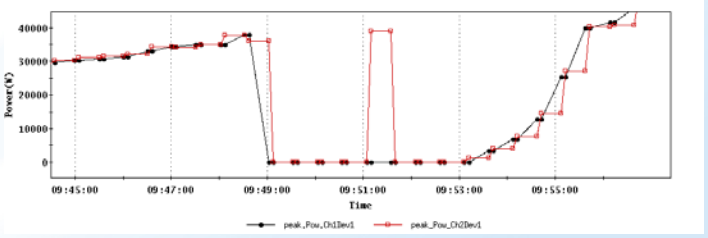
(b) MP at 16-18 kW





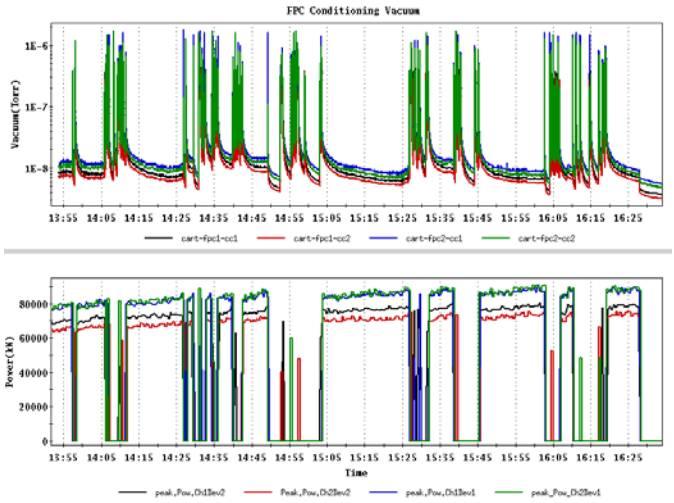
(c) MP at 25 kW



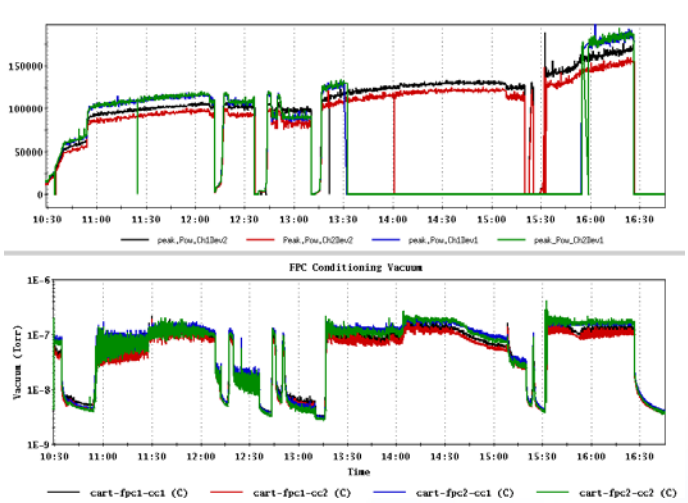


(d) MP at 40 kW

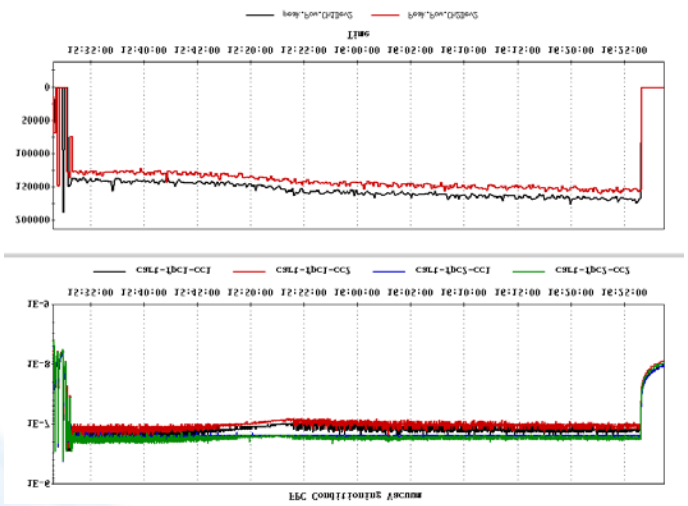
FPC conditioning: MP zones (2)



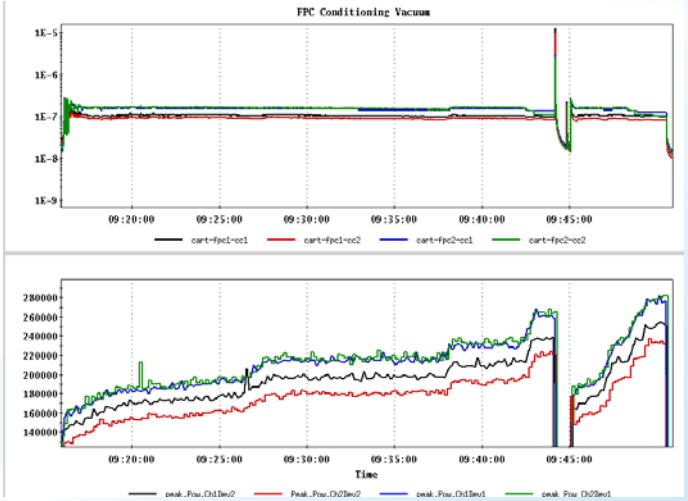
(e) MP at 80 kW



(f) MP at 100 kW

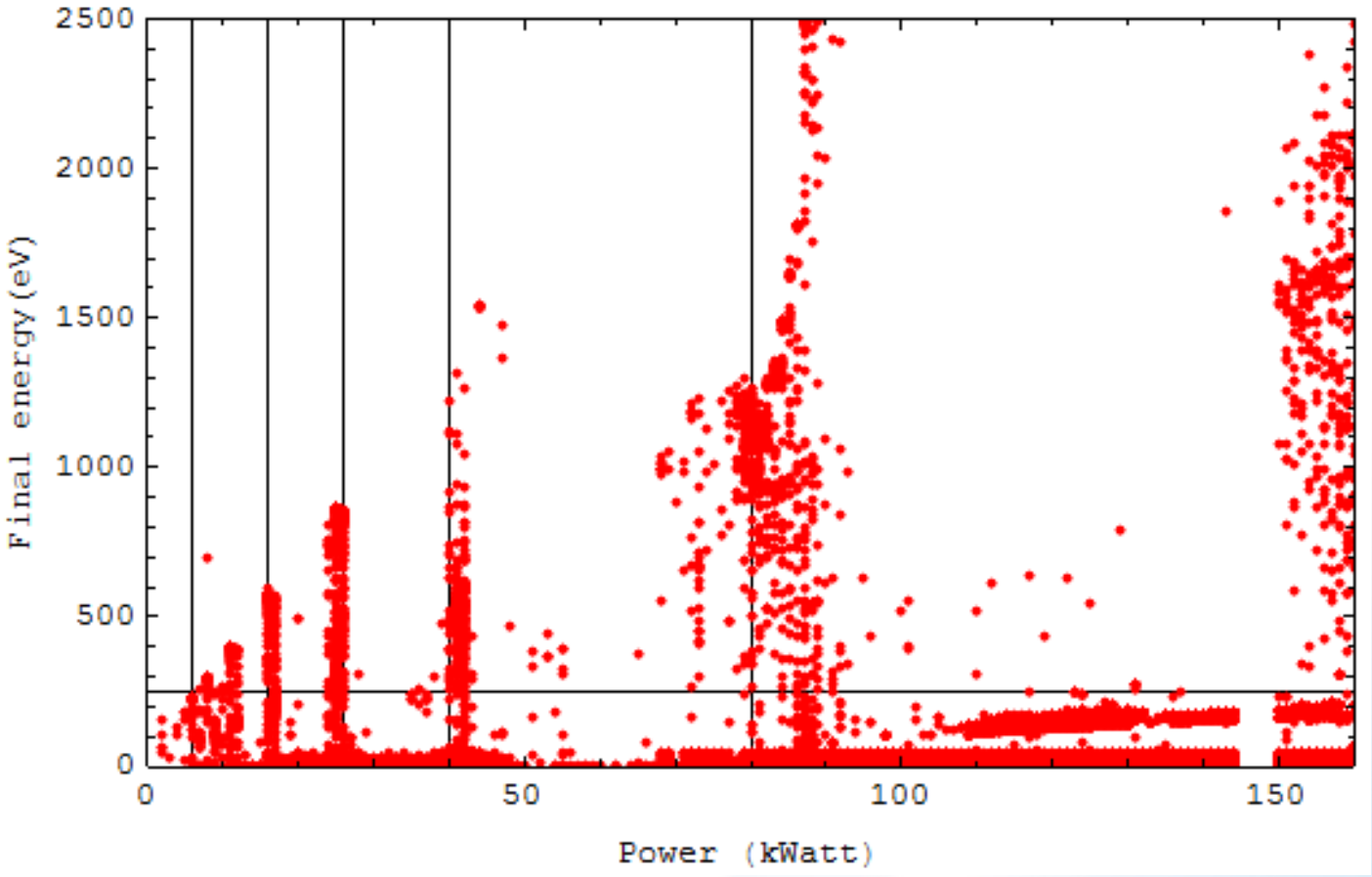


(g) MP and outgassing at 160 kW



(h) outgassing at higher input power

Comparison with simulations



- Simulations predicted multipacting at RF power levels about 4 kW, 16 kW, 25 kW, 80 kW, and 160 kW.
- A lot of electron activity is predicted above 100 kW, which can be responsible for outgassing.
- These is exactly what was observed in the experiment.

Summary

- We have successfully tested 500-kW FPCs for the R&D ERL SRF gun.
- The test was in a standing wave mode with full reflection.
- Maximum power was set to 250 kW in pulse mode (limited by klystron collector) and 125 kW in CW (administrative limit).
- Observed MP barriers were in very good agreement with those predicted by simulations with Track3P.
- A modified Conflat gasket with RF contact was designed and may be useful for beam pipe seals.