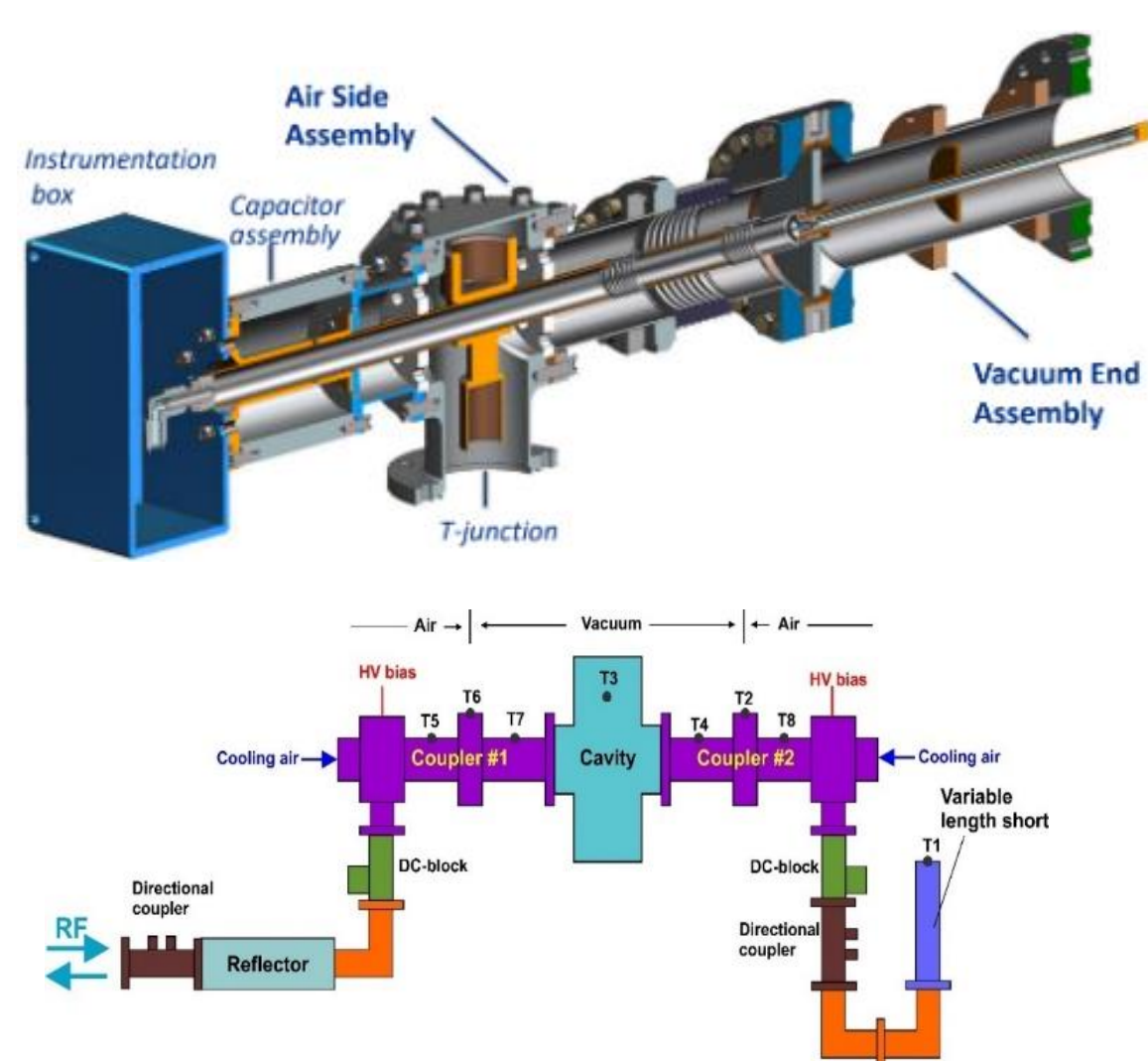


## ABSTRACT

Fundamental 325 MHz power couplers are designed, built and tested for SSR cavities in PIP-II project [1]. Couplers should work in CW mode at power level 7.5kW w/o beam and ~15 kW with the 2 mA beam. At pre-production stage we built and tested 6 couplers, produced by CPI (FNAL) and PMB (IJCLab) and 4 more couplers will be tested soon. Two of tested couplers had TiN coated ceramic window. In warm test stand two couplers were mounted on the coupling chamber and tested in SW regime at full reflection with phase controlled by position of short and reflection insert. Couplers were tested at pulse mode (up to 25kW) and cw mode (12kW) with HV bias or without bias. Test results demonstrated that 3.5 kV DC bias completely suppresses multipactor in coupler. Vacuum activity in coupler was controlled by e-pickups and build-in vacuum gauges, located near the vacuum side of window. Power processing without DC bias was done for several couplers with and without TiN coating on ceramic window. Test results are presented and discussing in paper.

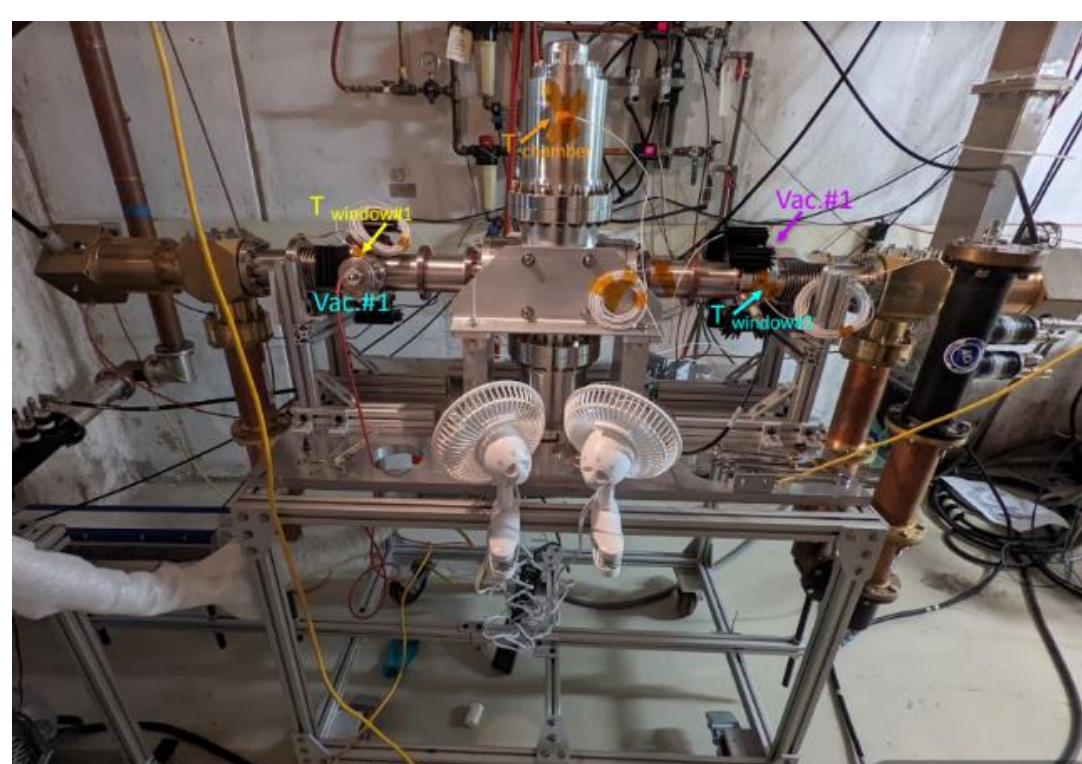
## COUPLER RF POWER PROCESSING



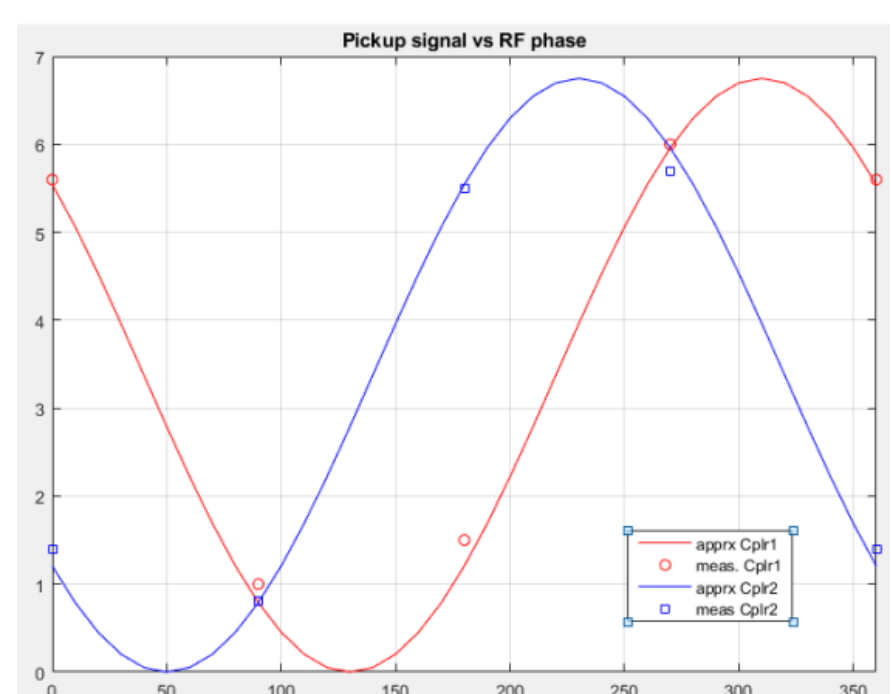
Mechanical design of the pre-production 325 MHz coupler. CPI built 5 full assemblies and 1 vacuum antenna assy:

- 4 couplers built by IJCLab at MPB- two vacuum ends delivered to FNAL, one tested
- six of them assembled in ppHB650 and tested
- One tested in STC with LB650 cavity.

Schematic of RF system in coupler test stand. Resonance conditions between movable reflector and short create allow to get >30-40 kW in SW, using 8 kW SSA: gain x (4-6)



Two vacuum ends assembled on coupling cavity in clean room, pumped, leak checked and baked 120C 48hrs. Air parts assembled in test stand cave. Each vacuum part of the coupler have pick-up and vacuum gauge to use for MP diagnostics and RF amplitude near window. Coupler antennas and windows cooled by air flow.



E-field measurements by e-pickup near window as a function of reflection phase.

### Testing Protocol

Testing requirements for SSR2 couplers: 12kW CW with full reflection at arbitrary reflection phase (0°, 90°, 180°, 270°) (TRS). For each phase configuration:

- Pulse: 10; 100; 300; 500 ms; ramp to 25kW; stay few minutes at max power.
- CW mode: ramp to 12kW. Stay >1 hours to reach equilibrium temperature.

### Conditions/interlock

- Air flow rate ~3 g/s per coupler
- External air cooling: radiators on window flange, 2 fans for cooling
- DC bias 3.5kV – each coupler (separate PS).
- Vacuum interlocks 2.e-6 Torr for each vacuum gauges
- Ceramic flange temperature, interlock ~140°F

### Diagnostics

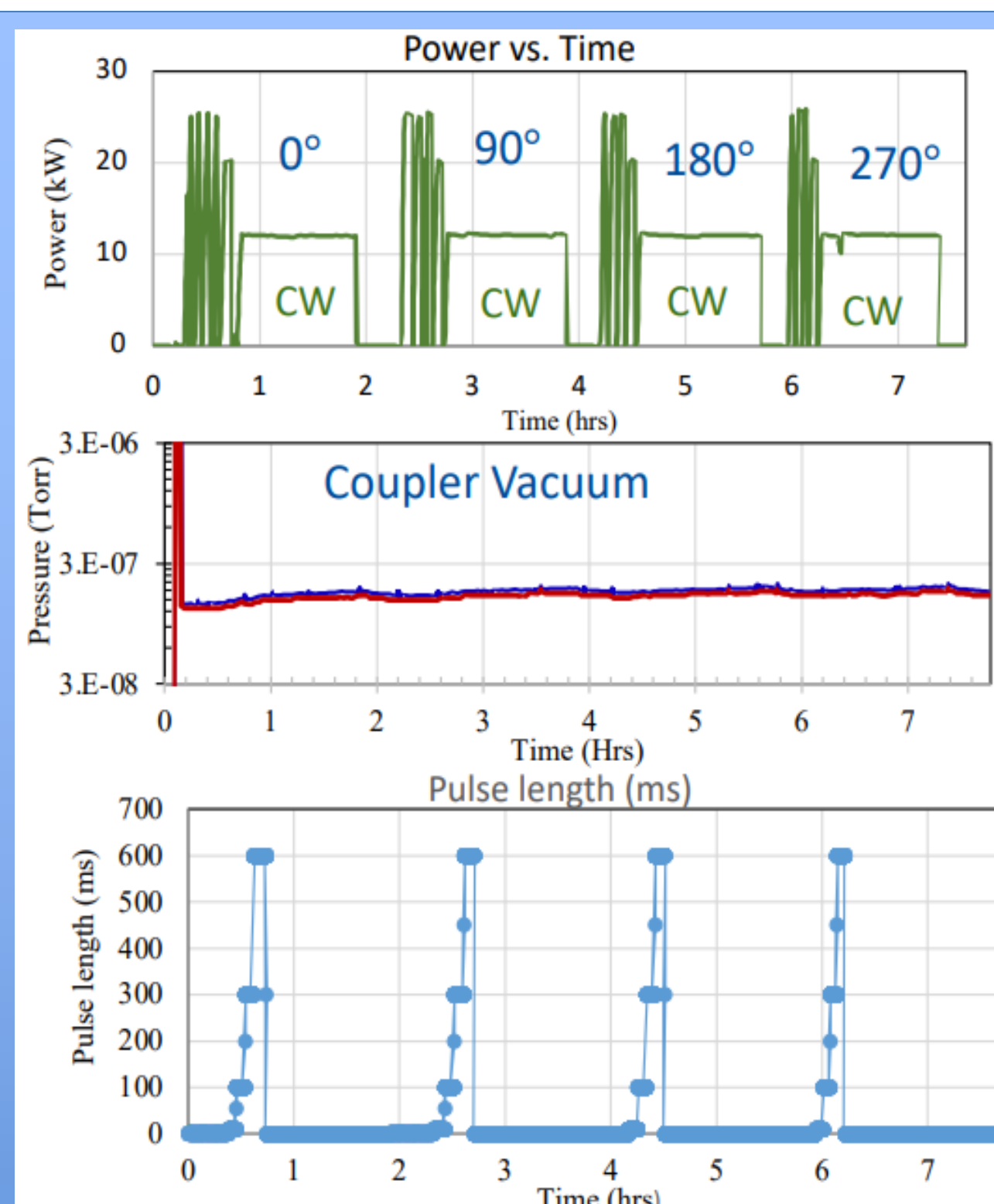
- Vacuum: 2 vacuum gauges on couplers + vacuum gauge in pumping line
- Temperature: window flanges (2), coupling cavity (1), DC blocks (2);
- DC bias: voltage and current
- pick-up probe (2) signal

## Proton Improvement Plan-II

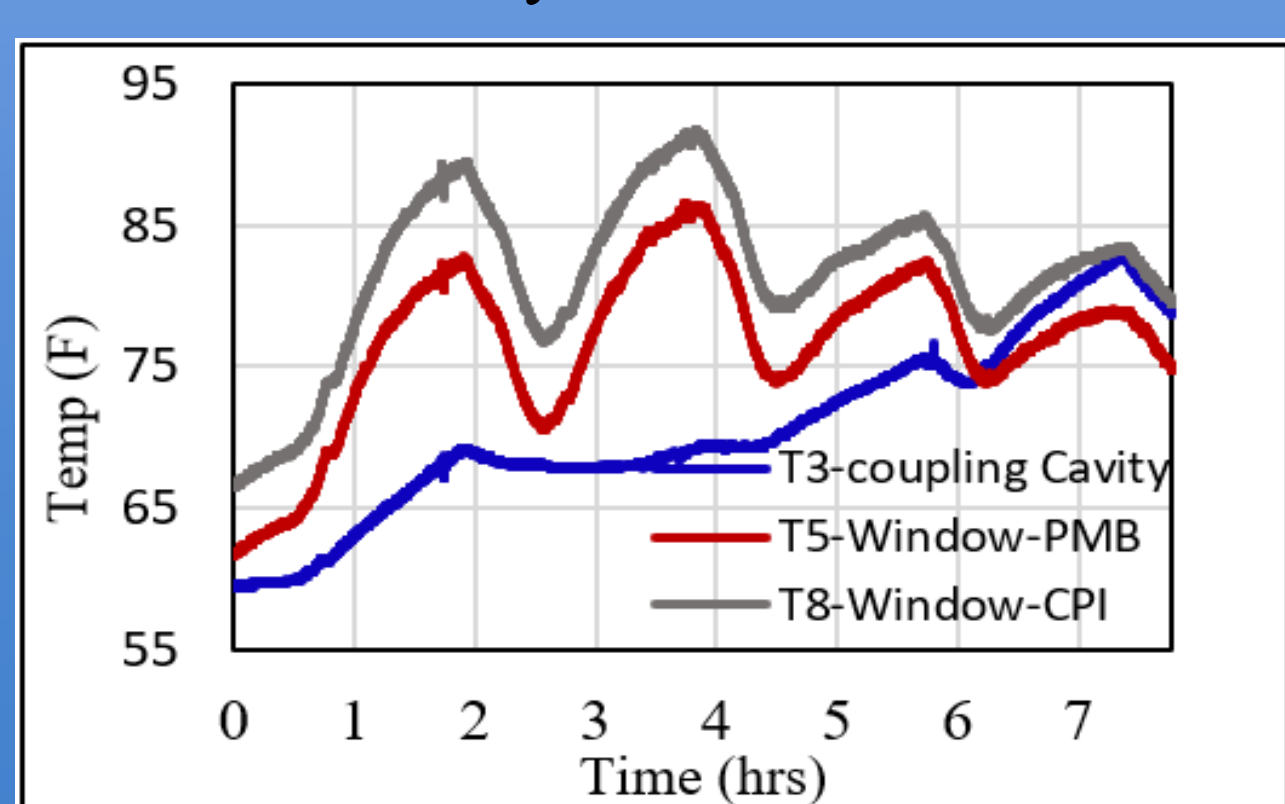


## TEST RESULTS

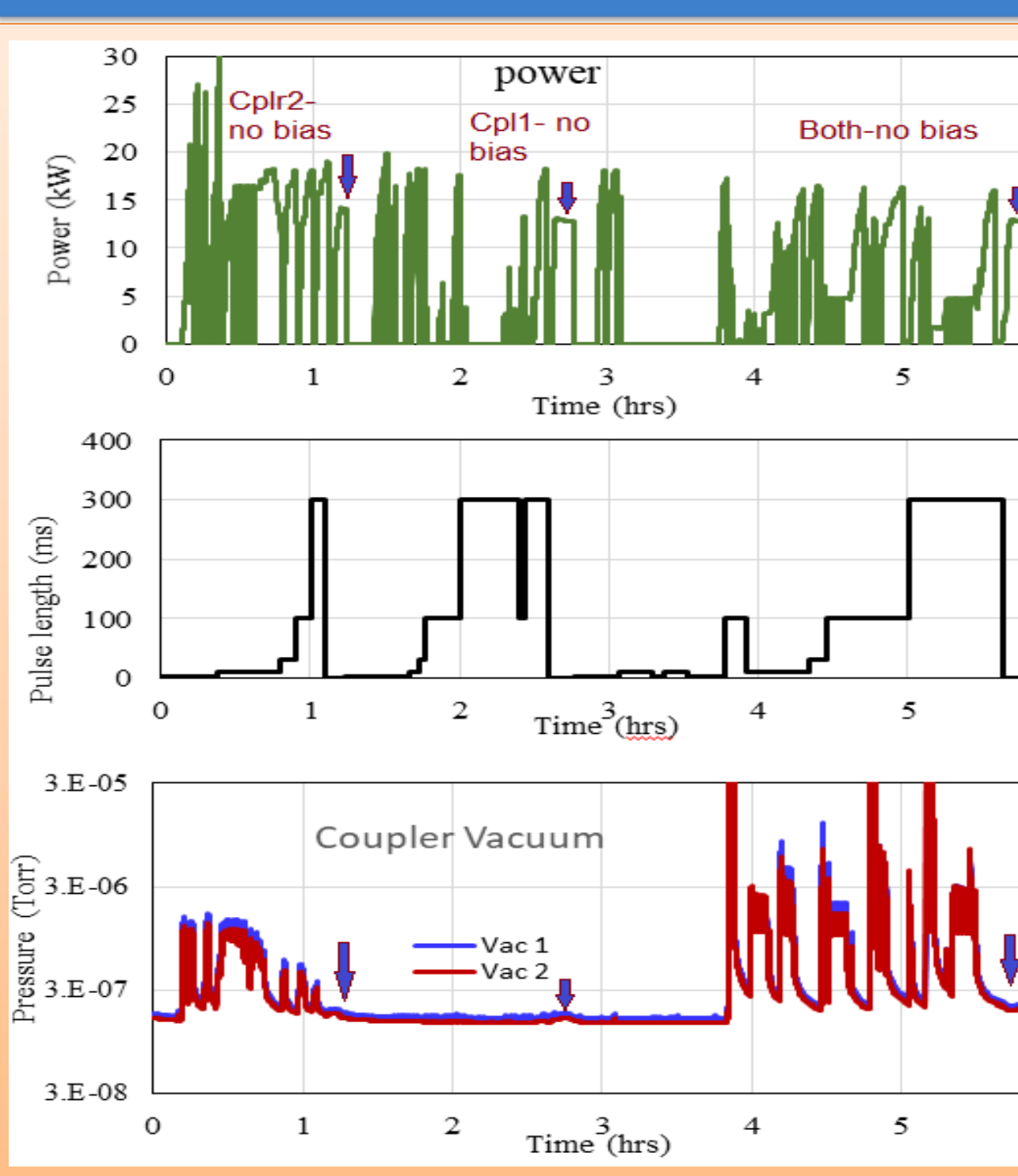
### 1. Power processing with HV bias



No MP activity with DC bias ON.



Temperature of the window flanges and coupling cavity vs. reflection phase.



### Future testing plans

- Two remaining couplers with deformed antennas (CPI and PMB) are preparing for test. For that coupling elements in cavity are modified to increase gap between antenna and fixture.
- Other two couplers from IJCLab (expected delivery in June) also will be tested after inspection.

### 2. Power processing w/o HV bias (coated + uncoated)

After completing RF qualification test two assemblies, with one uncoated and one TiN coated ceramics were power processed without DC bias on one or both couplers. Goal of these studies to demonstrate that we can effectively clean coupler by outgassing surface by MP discharge.

#### Processing Protocol:

For each reflection phase we run three cases:

- No bias on TiN coated ceramic only (Cplr2)
- No bias on uncoated ceramic only (Cplr1)
- No bias on both couplers

For each case we start with short pulse increasing power and the go to CW mode

- Pulse mode: 1,3,10,30,100,300,600ms, Pmax=16-20 kW
- CW mode; Pmax = 12-13 kW

During MP processing power was ramping keep vacuum near interlock level 2.e-6 Torr.

### RESULTS

For 1<sup>st</sup> pair (couplers 3&6, CPI) full processing time ~80 hours, including: Phase 270° ~ 60 hours; Phase 0° ~ 14 hours; Phase 90° = 2.5 hours; Phase 180° = 2.5 hours. Most MP activity for first phase and short pulses. Final check – 12 kW in CW mode. One can see that most time was spent for first reflection phase, for last two reflection phases processing done much quickly. MP activity was not processed completely for at least one phase, still some residual MP activity remains.

For 2<sup>nd</sup> pair couplers (CPI uncoated; PMB coated) total processing time was around 30 hours, including: Phase 0° = 10 hours; Phase 90° = 11 hours; Phase 180° = 6 hours; Phase 270° = 3 hours. Figure shows history of power processing for 180°. Arrows shows 12kW CW run (no MP activity in both couplers w/o bias). In last run for 270° reflection phase no any MP activity was seen in pulse or CW mode.

Inspection of the ceramic after heavy power processing does not indicate any degradation or discoloration. We concluded that after processing it can be used for cavity installation.

History of power processing without DC bias. Reflection phase 180°. Arrows shows time of CW operation at 12kW.

## SUMMARY

- In summary, the ppSSR2 325 MHz couplers procured by both FNAL and IJCLAB met the technical requirements necessary to be used as part of the ppSSR2 CM String. Six couplers (including two with TiN coated ceramic windows) were already successfully qualified in warm test stand with DC bias at specified 12kW CW power and four reflection phases. Additional 4 couplers (3 of them from IJCLab) will be tested this summer.
- Two ppSSR2 couplers with TiN coating on vacuum side of ceramic window (CPI and PMB) were also high power (HP) processed without DC bias on coupler warm test stand. In each test we used one TiN coated and one uncoated coupler and switched off bias for one of them or both. After pulse processing at ~20kW, both couplers were cleaned and does not show MP at 12kW CW without bias for all 4 reflection phases. Total processing time was ~30 hours for one test and ~80 hours for the second test. With a small statistics we could not clearly conclude that TiN coated ceramic perform better than uncoated in HP tests.