



## PIP-II Couplers: Lessons Learned

J. Helsper

TESLA Technology Collaboration Meeting

5-8 December 2023

PIP-II is a partnership of:



US-DOE



India-DAE



Italy-INFN



UK-STFC-UKRI



France-CEA, CNRS/IN2P3



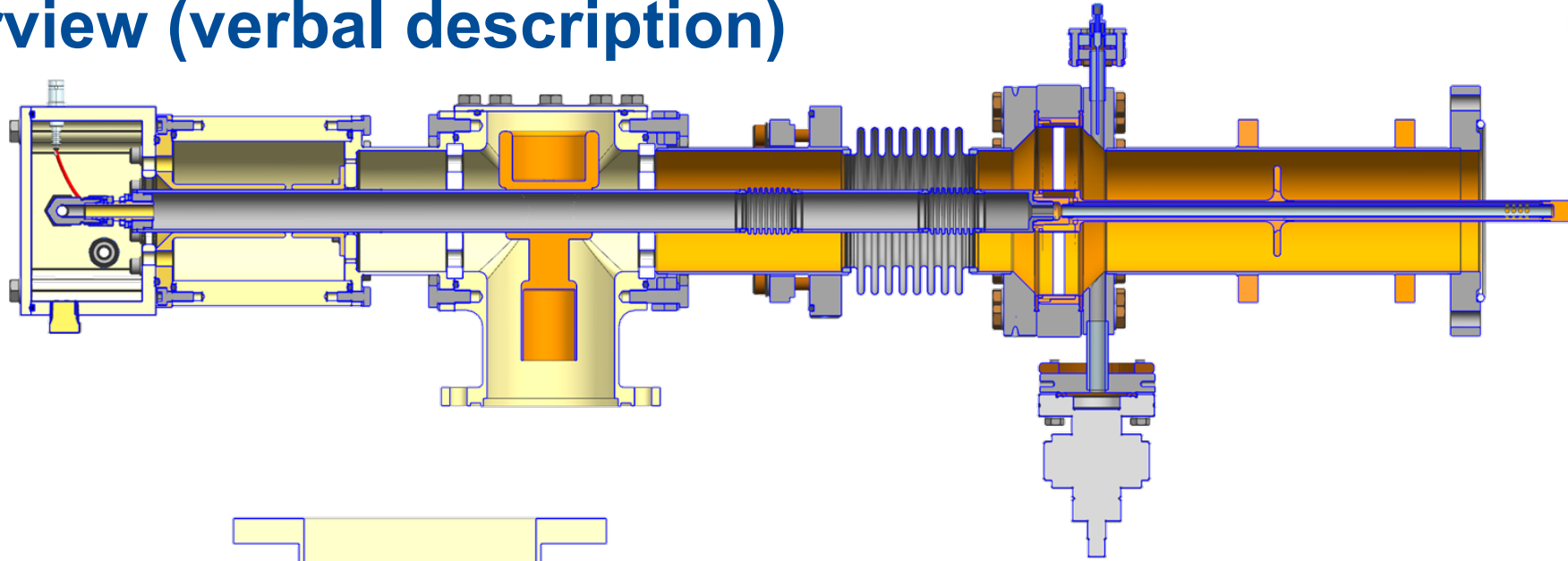
Poland-WUST, WUT, TUL

# Outline

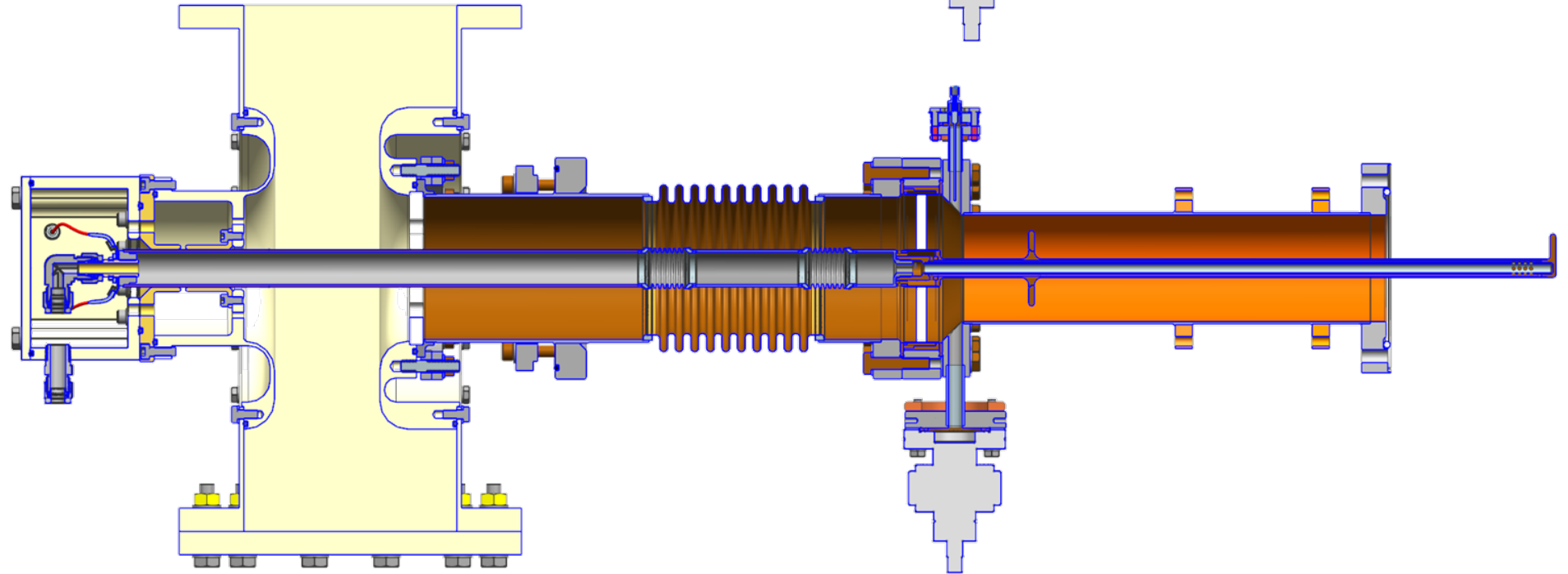
- Coupler Design Overview
- High Voltage Bias
- Ti-N Coating
- CT Scanning
- Cold Cathode Gauges

# Design Overview (verbal description)

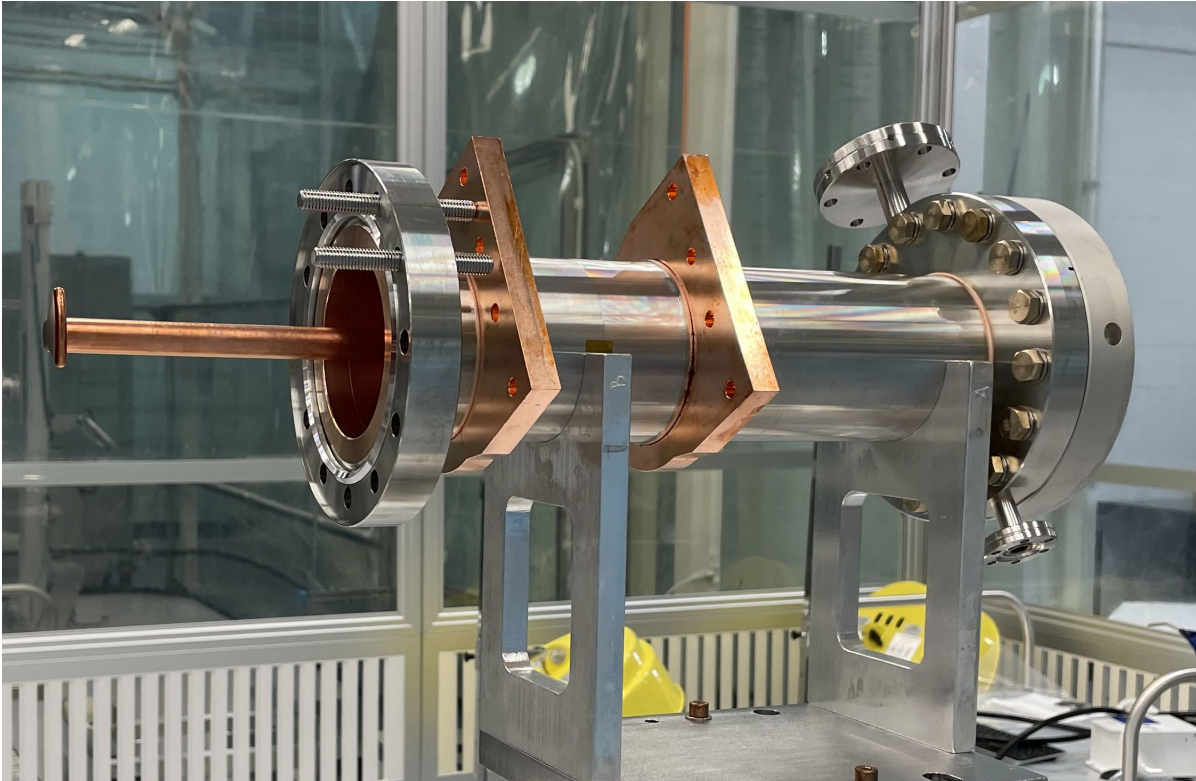
325 MHz



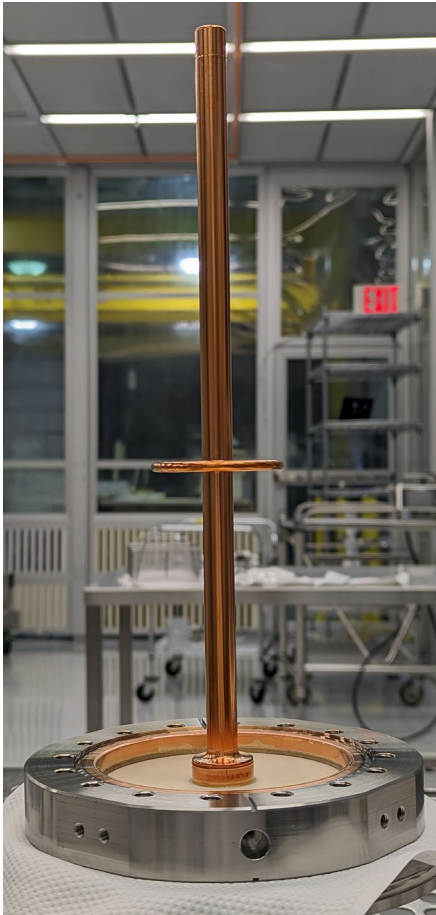
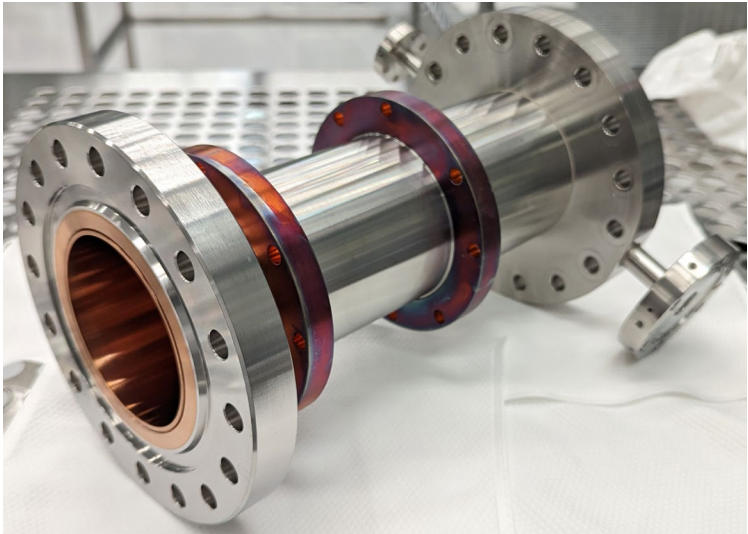
650 MHz



# Couplers As-Built



650 MHz



325 MHz

# High Voltage Bias

# High Voltage Bias

High Voltage Bias (4.5 kV 650 MHz, 3.7 kV 325 MHz) is ALWAYS used

- Warm RF testing + Cryomodule operation

## Warm RF Testing

- Simulations show the HV should be enough to suppress fully, but RF Conditioning is still needed for high power levels
- 650MHz conditioned to 50 kW CW, 325 MHz conditioned to 12 kW CW
- No MP after conditioning

## Cryomodule Operations

- 1 ms response time for interruption of HV Bias to RF power OFF
- No MP detected during pHB650 CM Testing (38 kW CW)
- Minimal if any RF conditioning was needed for couplers

# Ti-N Coating

# Ti-N Coating

## 325 MHz Results:

- Ti-N Coating made no significant improvement for coupler conditioning or Multipacting

## 650 MHz Results:

- Pending warm RF test of 2x Ti-N Couplers
- Performed cold test on LB650 cavity up to 30 kW with HV Bias
  - Performed tests on losing HV Bias when operating at full power
  - No problems with stored energy in cavity creating Multipacting

## Production Coupler Plan

- Ti-N coating is not planned for use on PIP-II production couplers; only HV Bias
- Subject to change if new results from 650 MHz tests; option open for coating



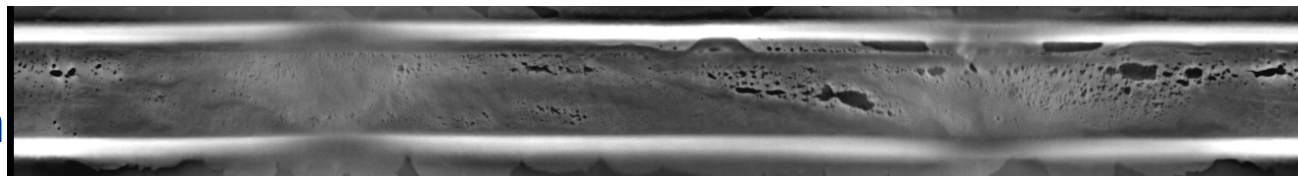
# CT Scanning

# Computed Tomography Scanning

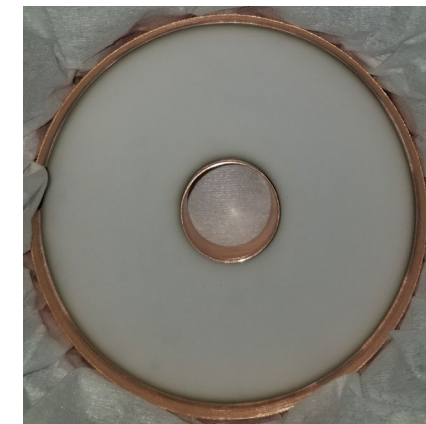
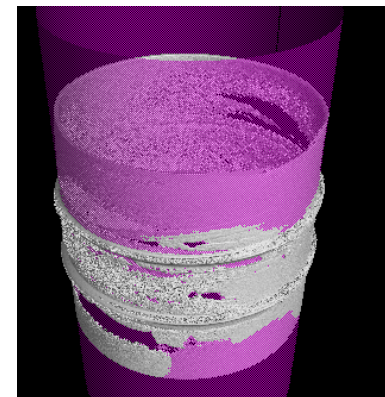
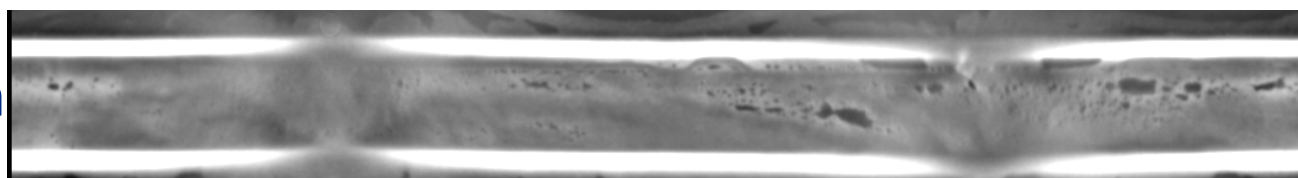
## ppSSR2 Ceramic Window CT Scans

- Only ceramic with brazed copper sleeves (can NOT scan w/ flange)
- Inner Braze: 20 microns resolution. Outer Braze: 71 microns

20 um



71 um



- Dark spots are thought to be braze voids – attempts to confirm this were inconclusive

## Production Plan

- Build a database with a record for each coupler
  - Not planning to use as disqualification measure as of now

Others: CT Scanning experience / comments on Ceramic Braze QC?

# Cold Cathode Gauges

# Cold Cathode Gauges



- Every coupler has a Pfeiffer cold cathode gauge
  - Useful for Warm RF testing (vacuum spike – multipactor)
  - Thought to be useful for leak detection during Cryomodule operation
- With CM string at in  $1e-10$  –  $1e-9$  range, after a few months, gauges went ‘offline’ and can not be woken up
  - Operating in CM insulating vacuum
  - Thoughts as to why? Current hypothesis is the Penning electron field ‘sputtered out’
  - Anyone with similar experience? (failure / operating long term in  $e-10$  / in insulating vac)

No activity noted during pHB650 testing

## Production Plans

- Use of CCG in production string is under discussion

# Final Slide

These topics were presented:

- Coupler Design Overview
- High Voltage Bias
- Ti-N Coating
- CT Scanning
- Cold Cathode Gauges

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</showcase/pip-ii/>



## UV Dye Penetrant Checked Ceramic Window (thanks Sandry Wallon!)



# Discussion (speaker will take notes)

## Ti-N Coating

- Notes

## High Voltage Bias

- Notes

## CT Scanning

- Notes

## Cold Cathode Gauges

- Notes