Status of the Fermilab Cold BPM R&D

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Current BPM R&D Status

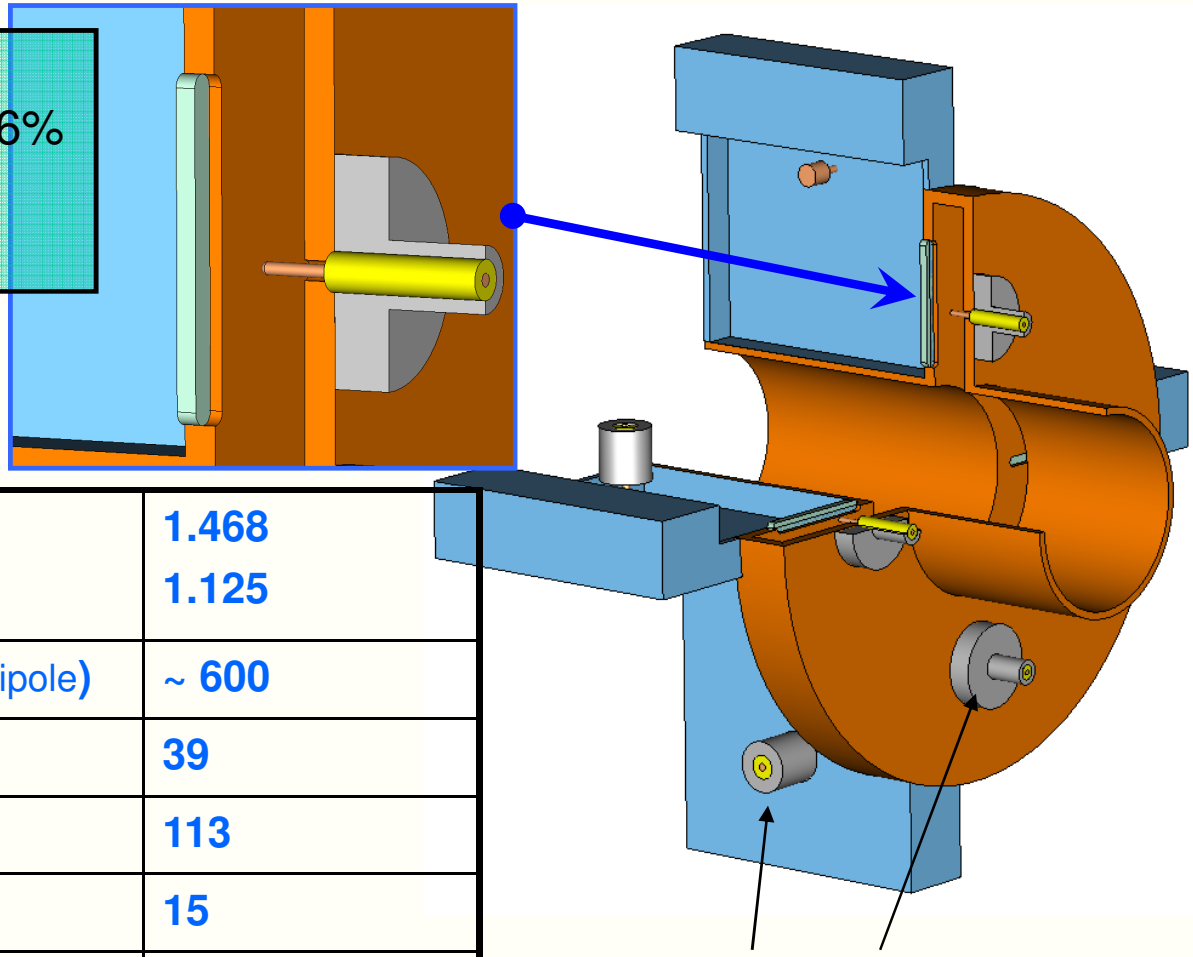
- **SLOW, but moving…**
  - Fermilab mid-term focus:
    energy frontier (ILC) -> intensity frontier (Project X)
  - R&D activities:
    - ILC test accelerator at NML (ILC-like 3 MHz e-beam)
    - HINS: Project X front-end R&D (high intensity H^- beam, 325 MHz)
  - Project X (neutrino, kaon & muon physics), based on ILC SCRF:
    - 2 GeV SCRF CW linac & RCS (ICD-2, preferred, 162.5 MHz H^- beam)
    - 8 GeV SCRF pulsed linac (ICD-1, 325 MHz H^- beam)
- **Cold BPM**
  - Project X does not need an ultra high resolution BPM
  - ILCTA(NML) CM1 & CM2: button style BPM pickup
  - BUT: Continue common-mode free
    cold cavity BPM R&D at Fermilab!

Cold BPM for an ILC Cryomodule

- **ILC beam parameters, e.g.**
  - Macro pulse length t_{pulse} = 800 µs
  - Bunch-to-bunch spacing $\Delta t_b \approx 370$ ns
  - Nominal bunch charge = 3.2 nC
- **Beam dynamic requirements**
  - < 1 µm resolution, single bunch (emittance preservation, beam jitter sources)
  - Absolute accuracy < 300 µm
  - Sufficient dynamic range (intensity & position) and linearity
- **Cryomodule quad/BPM package**
  - Limited real estate, 78 mm beam pipe diameter!
  - Operation at cryogenic temperatures (2-10 K)
  - Clean-room class 100 and UHV certification

Fermilab L-Band Design

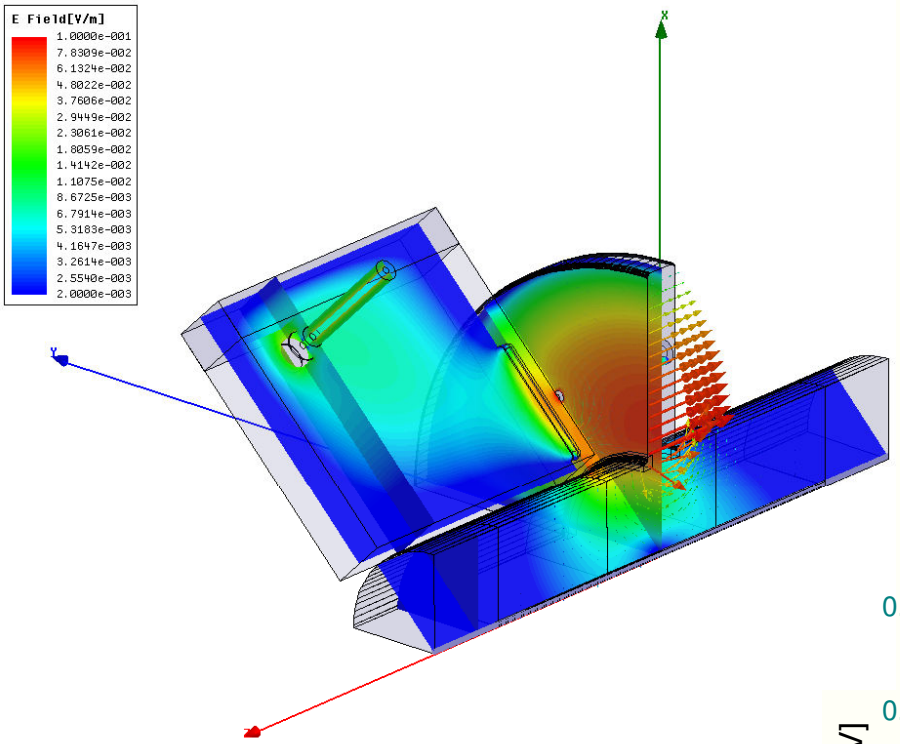
Window –
Ceramic brick of alumina 96%
$\varepsilon_r = 9.4$
Size: 51x4x3 mm



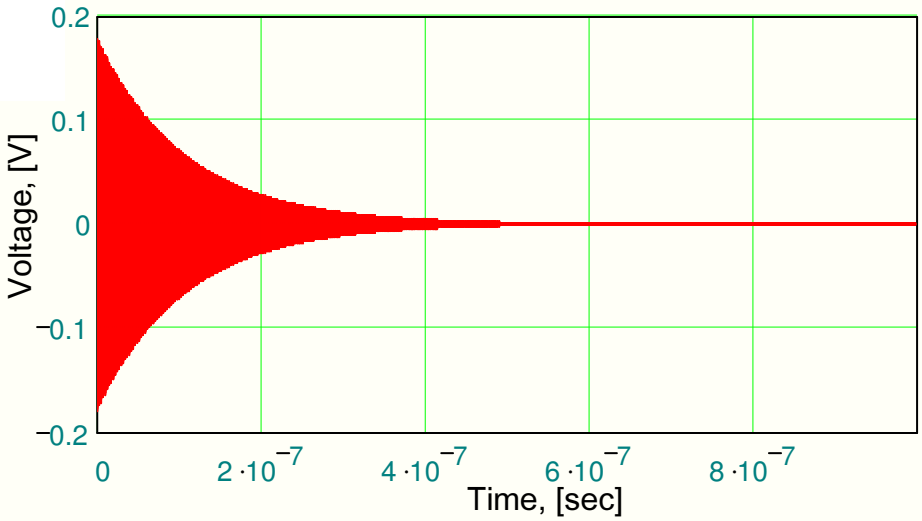
Frequency, GHz, dipole	**1.468**
monopole	**1.125**
Loaded Q (both monopole and dipole)	**~ 600**
Beam pipe radius, mm	**39**
Cell radius, mm	**113**
Cell gap, mm	**15**
Waveguide, mm	**122x110x25**
Coupling slot, mm	**51x4x3**

N type receptacles,
50 Ohm

HFSS Simulations: Dipole Mode

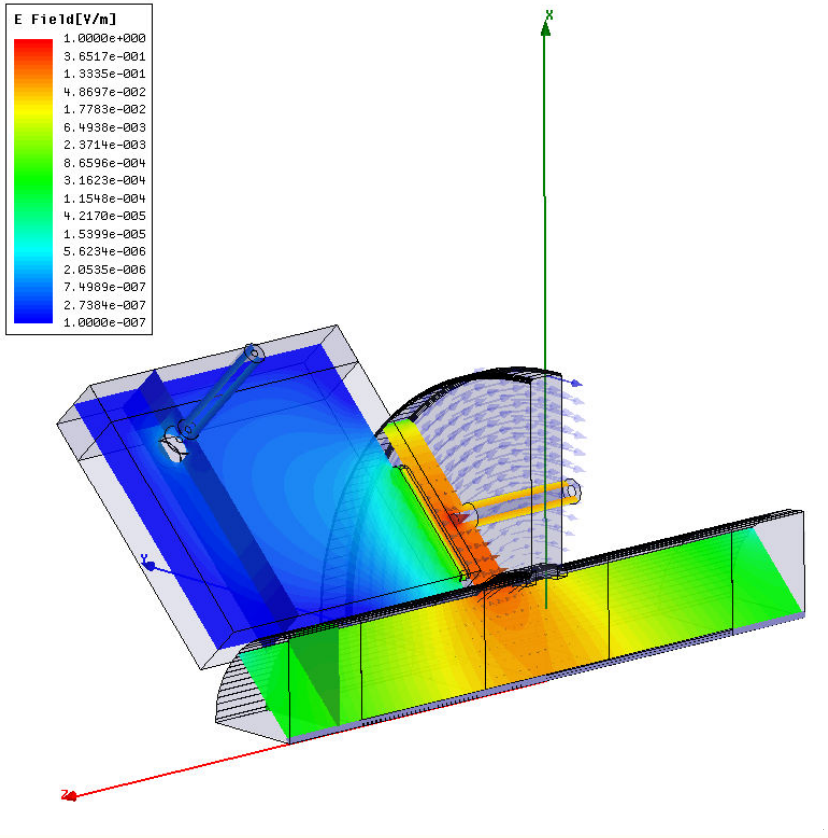


Frequency, [GHz]	1.480
Q, External Q, Surface (Cu) Q, Ceramic(AL_2O_3)	500 22000 5600
Test charge, [coulomb] (X=0, Y=1mm)	1E-9
Stored energy, [joule]	5.9.0E-11
Output Voltage at T=0*, [V]	0.24

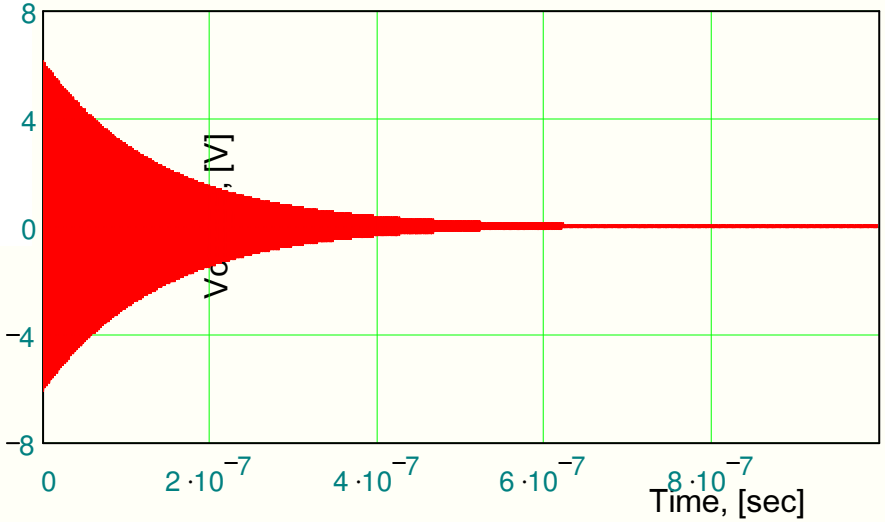


* Normalized to 50 Ohm,
The total signal combines with two ports

Simulations: Monopole Mode

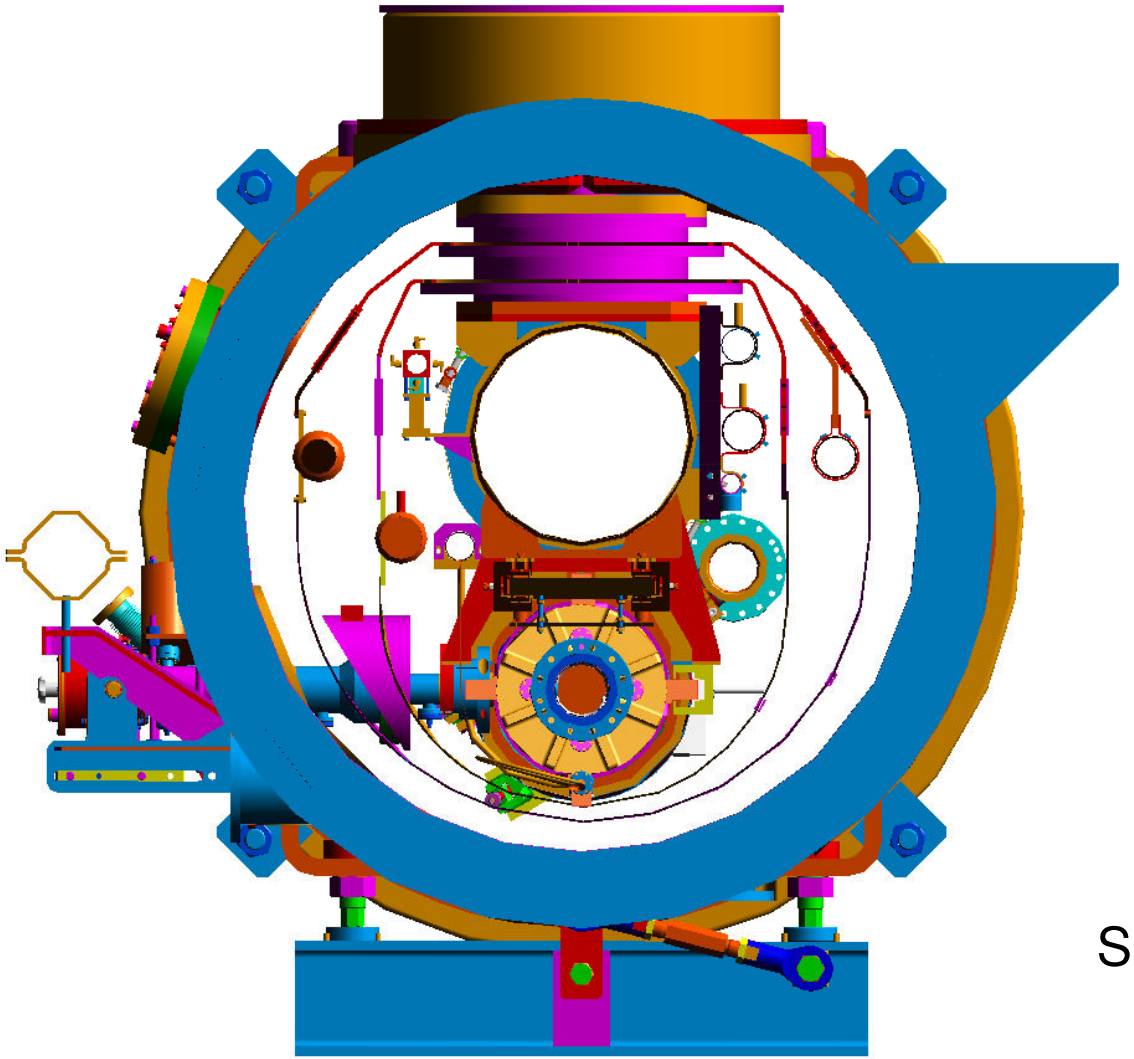


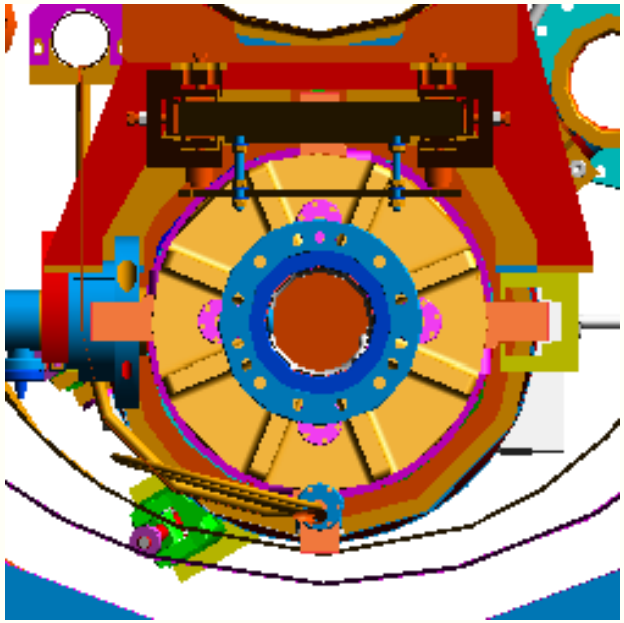
Frequency, [GHz]	1.120
Q, External Q, Surface (Cu) Q, Ceramic(AL_2O_3)	550 19500 7.9E6
Test charge, [coulomb] (X=0, Y=1mm)	1E-9
Stored energy, [joule]	6.1E-8
Output Voltage at T=0*, [V]	6.1
Coupling with TM_{11} port, Output Voltage at T=0*, [V]	5.6E-5



* Normalized to 50 Ohm,
The total signal combines with four ports

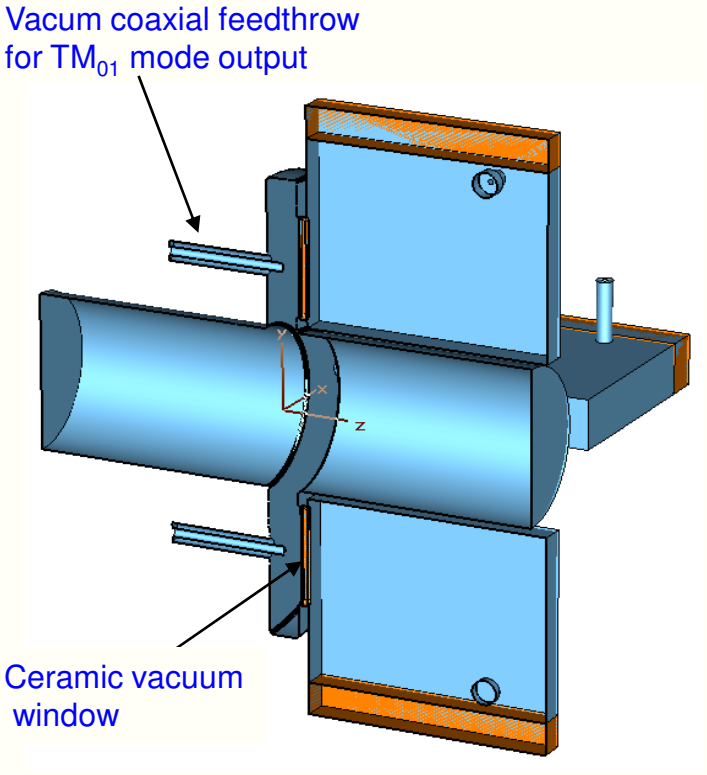
CM Type III+ BPM Real-Estate

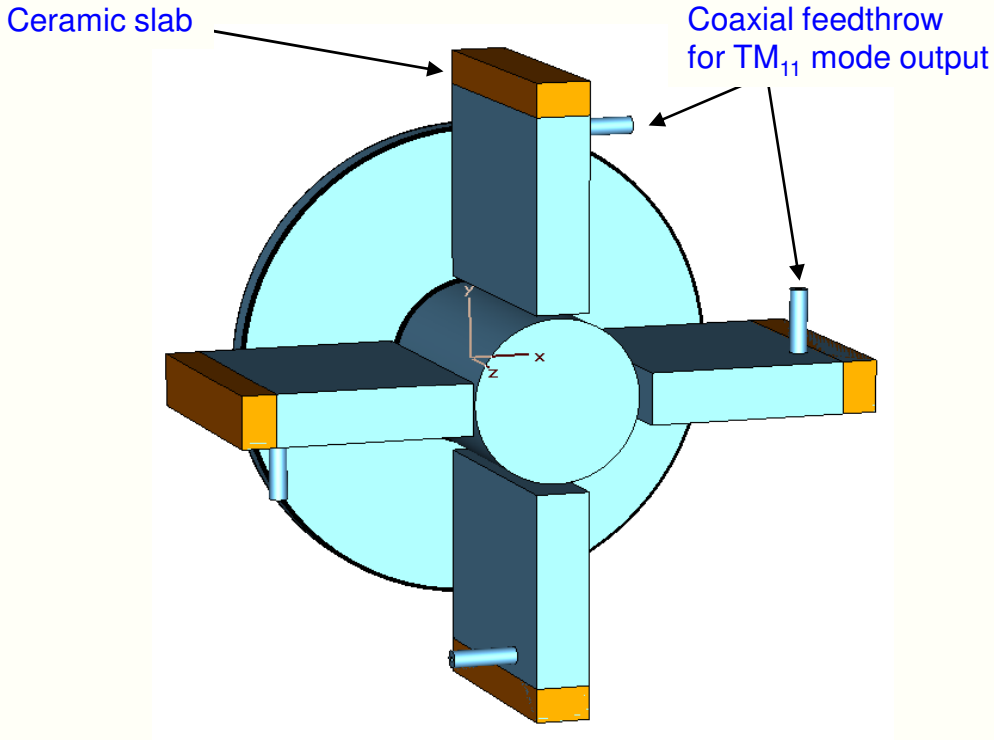




Section View showing BPM

Shortened Waveguides

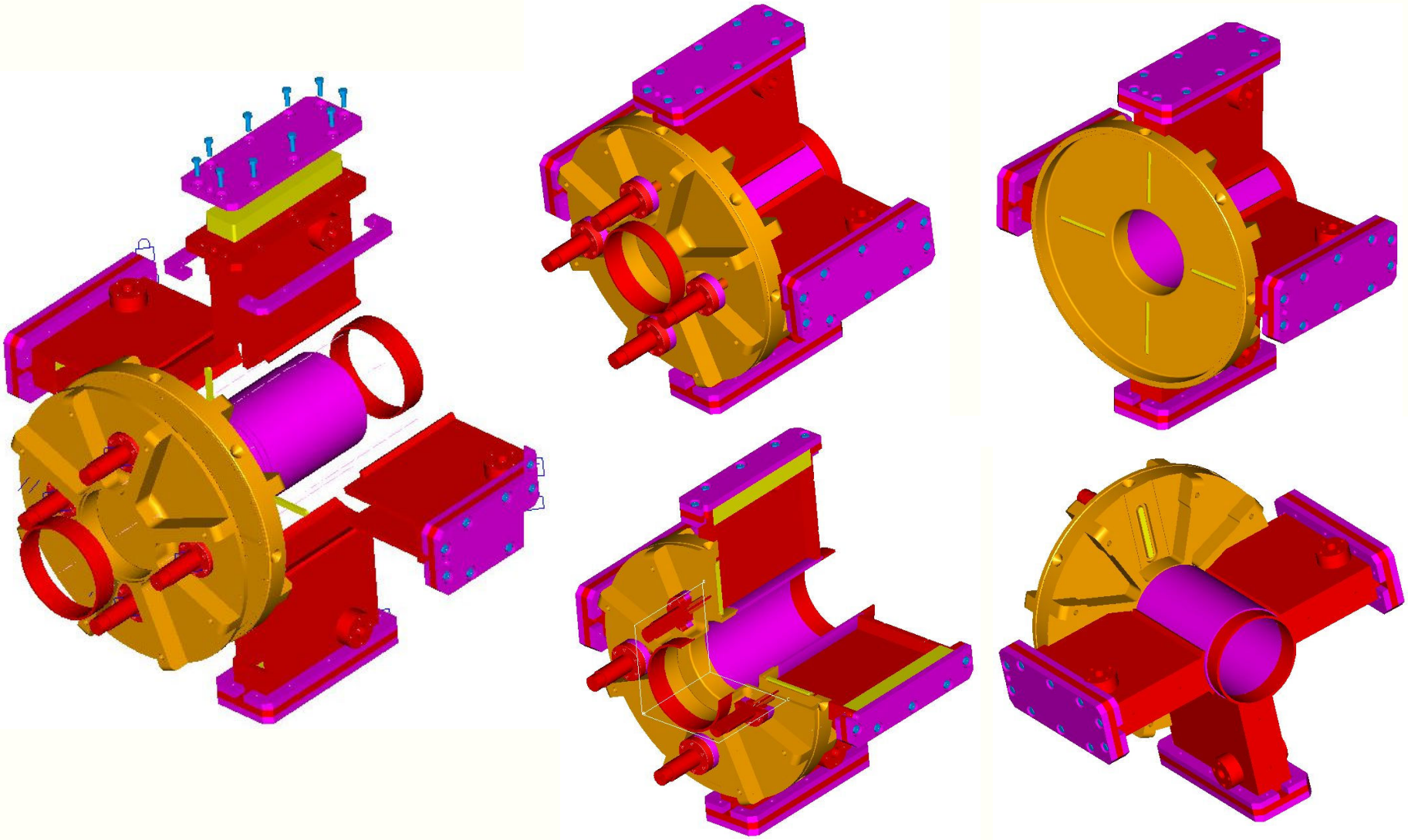


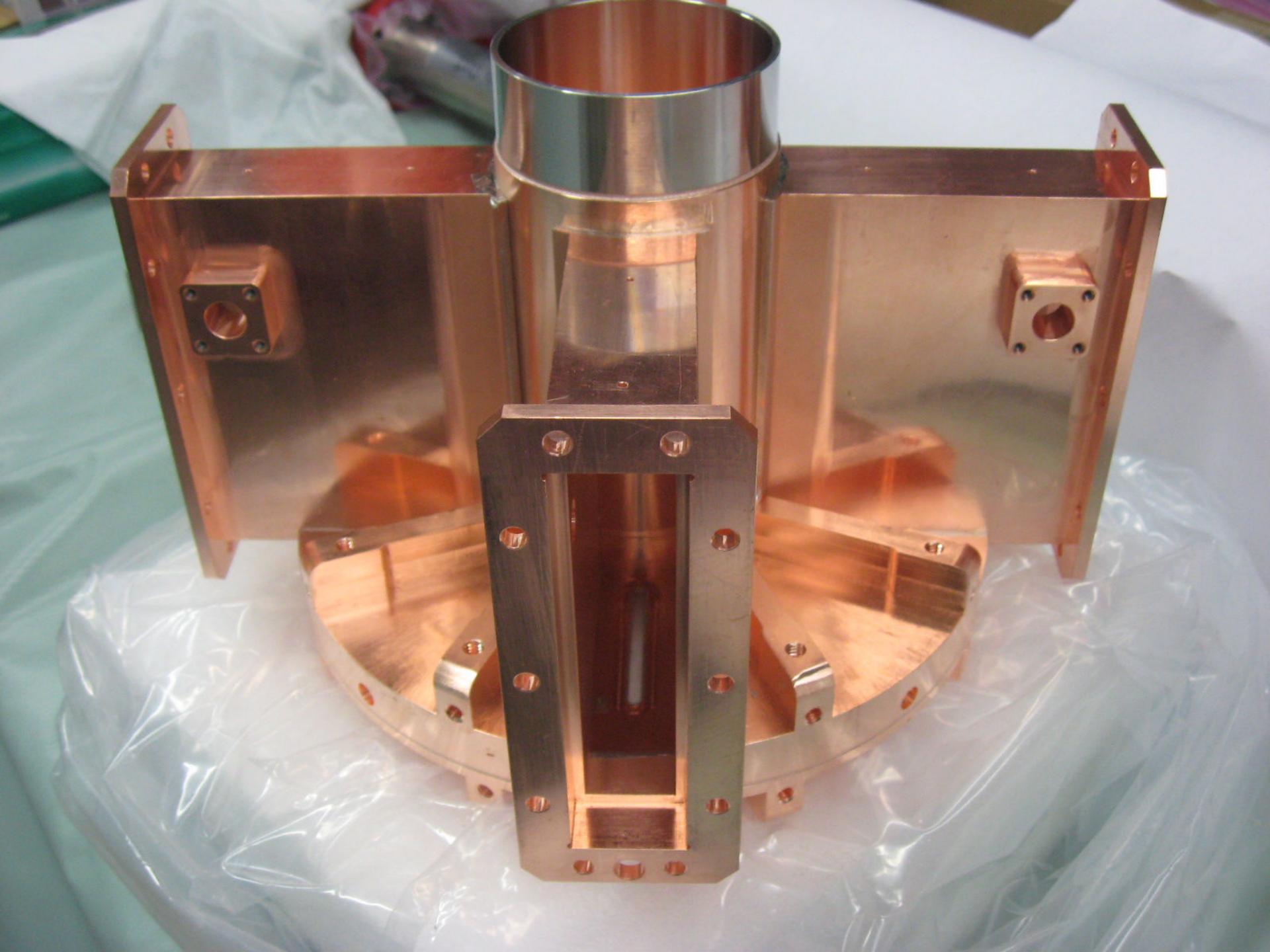


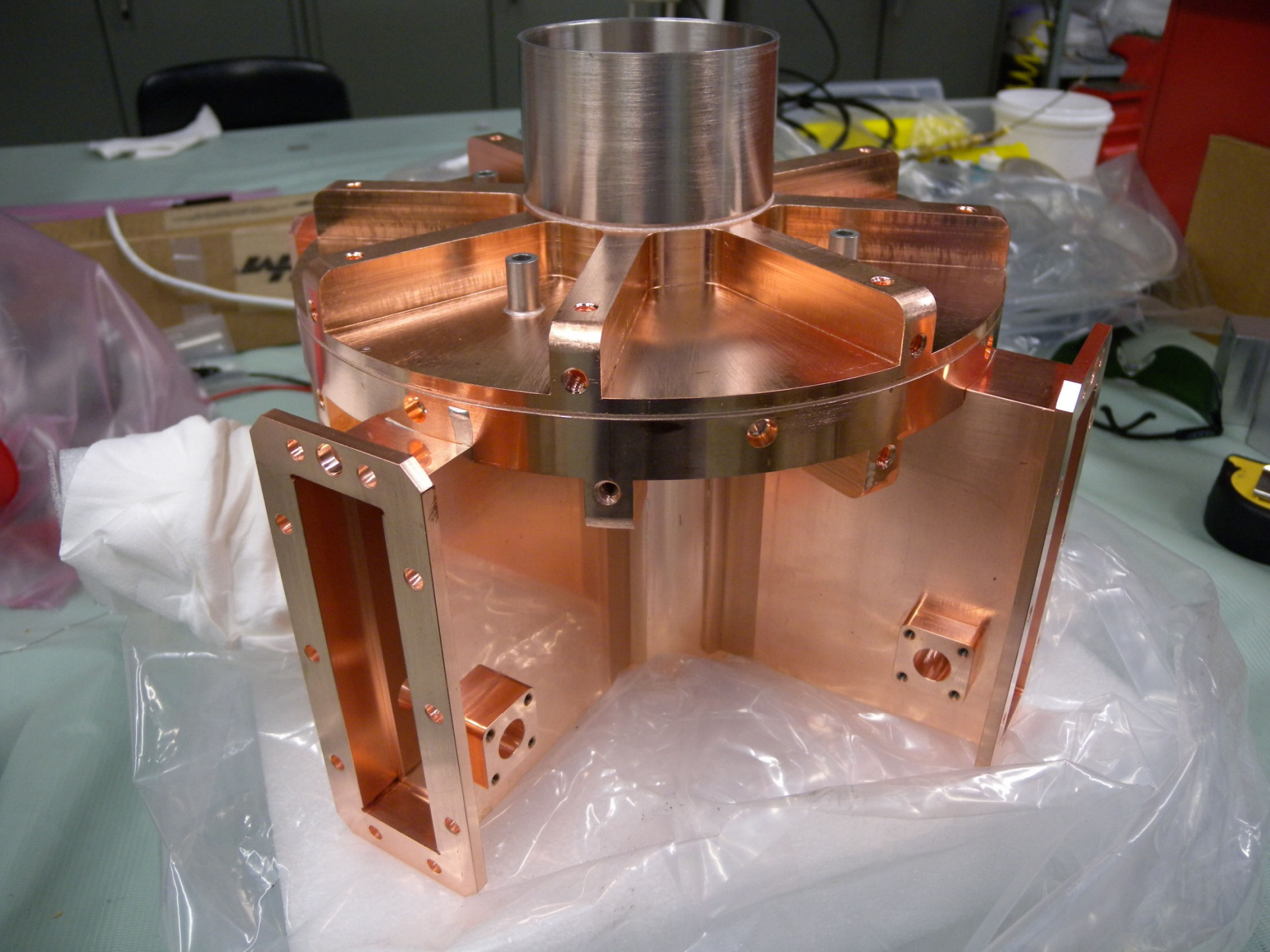
Cavity diameter: 113 mm
Gap length: 15 mm
Pipe diameter: 78 mm
Waveguide: 120 x 25 mm

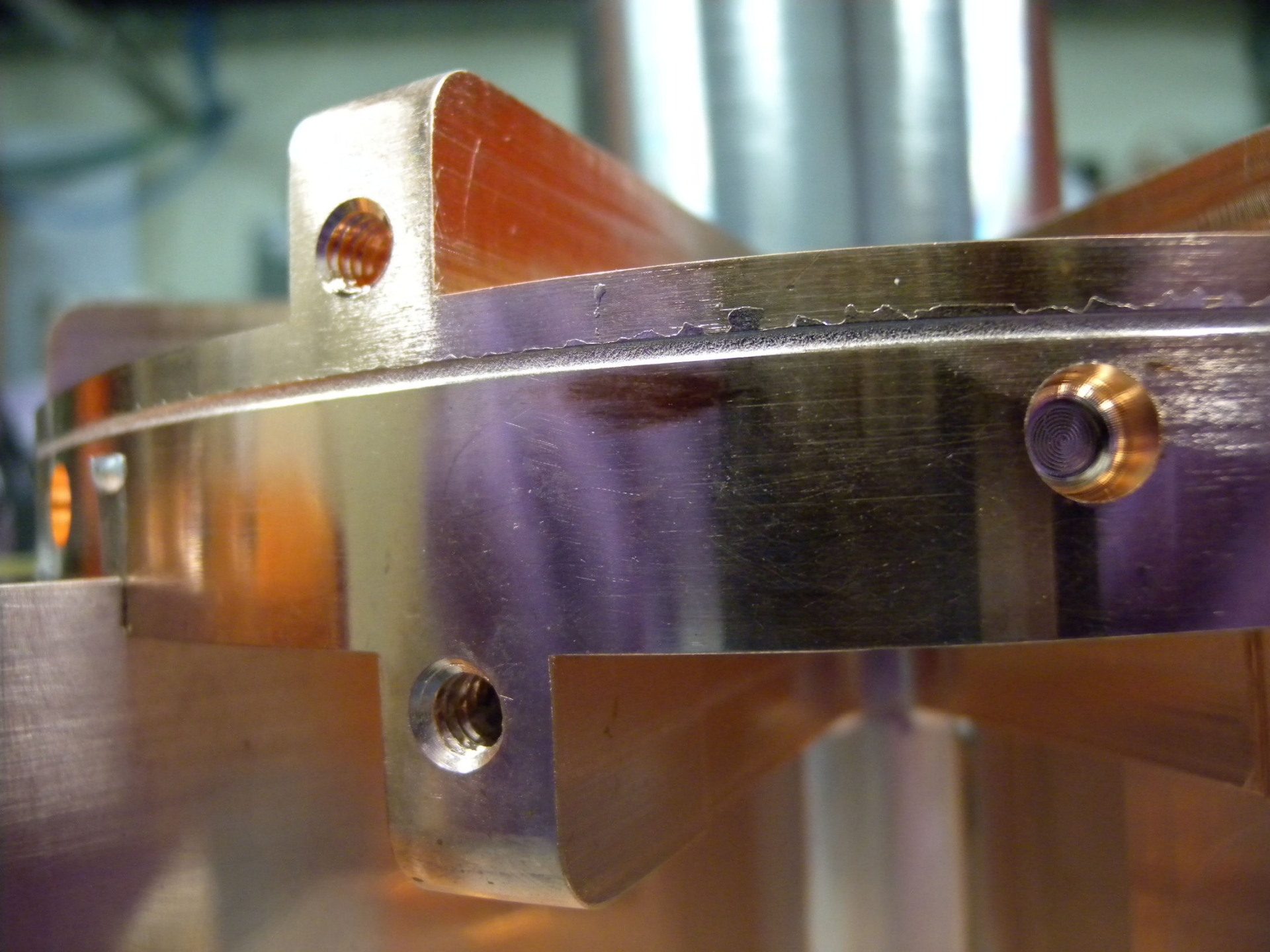
Features:
1. Ceramic (Al_2O_3) brazed vacuum windows
2. Common TM_{11} and TM_{01} cavity
3. Symmetrical signal processing
4. Time resolution: 1 μs (bunch by buch)
5 . Position resolution: < 1 μm (± 1 mm)

Construction Details





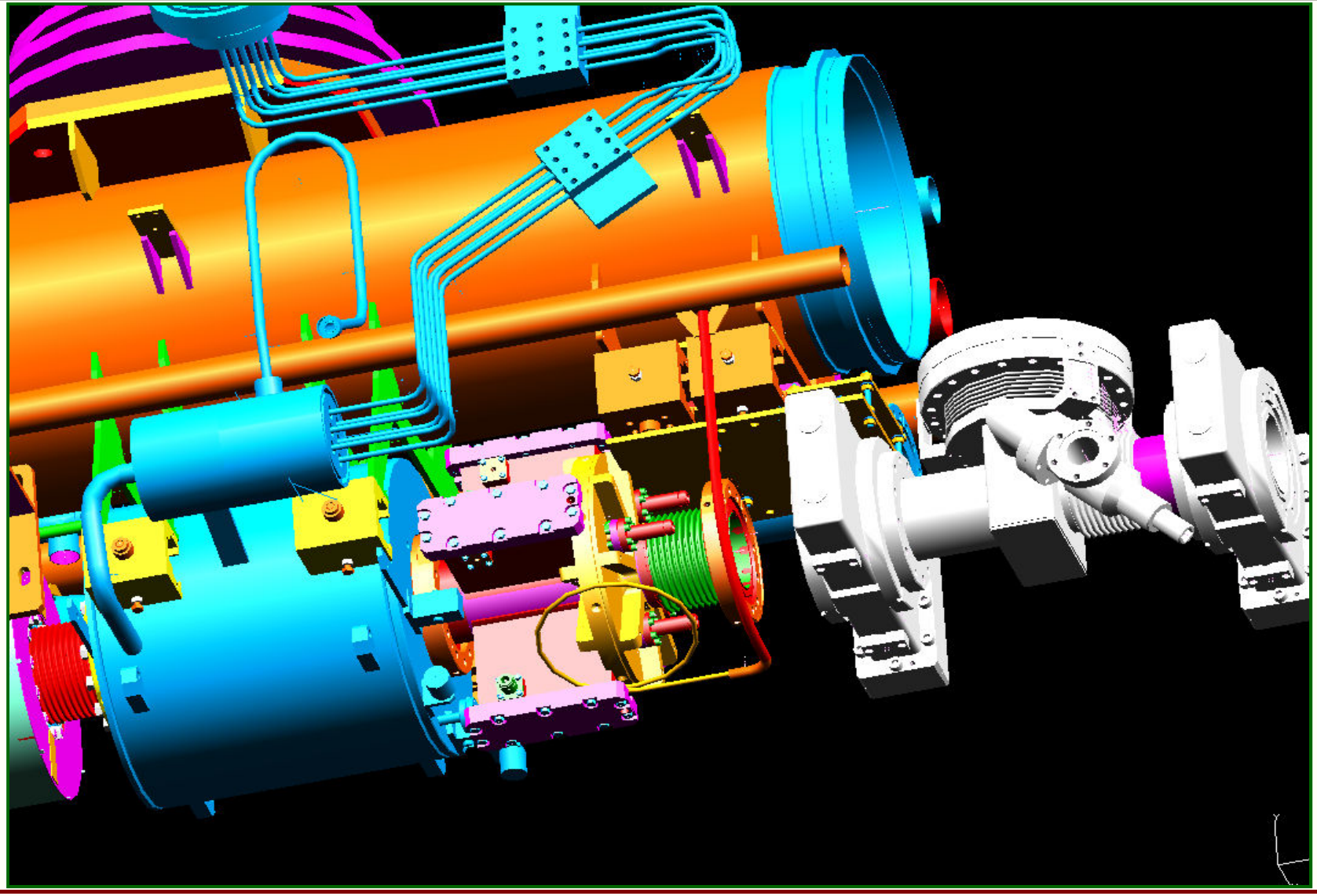




Next Steps…

- All brazing procedures successfully completed!
- Finalize cavity BPM
  - Waveguide lids (ceramics are ready for installation)
  - Weld monopole mode signal feedtrough flange adapters
  - Mount dipole mode signal ports
- Setup for RF measurements
  - Check / tune resonant frequencies and Q-value
  - Tune to minimize xy cross talk (dimples)
- Complete BPM for beam tests
  - Weld beam pipe and flanges
  - Vacuum certification
- This prototype ILC cavity BPM has “warm” dimensions
  - To be tested in a warm accelerator environment, e.g. A0PI, ATF

Cold ILC BPM in a Type III+ CM



Cold Button BPM for NML CM2