Towards technical solutions for HOM dampers, whether we'll need them or not

Discussion topic

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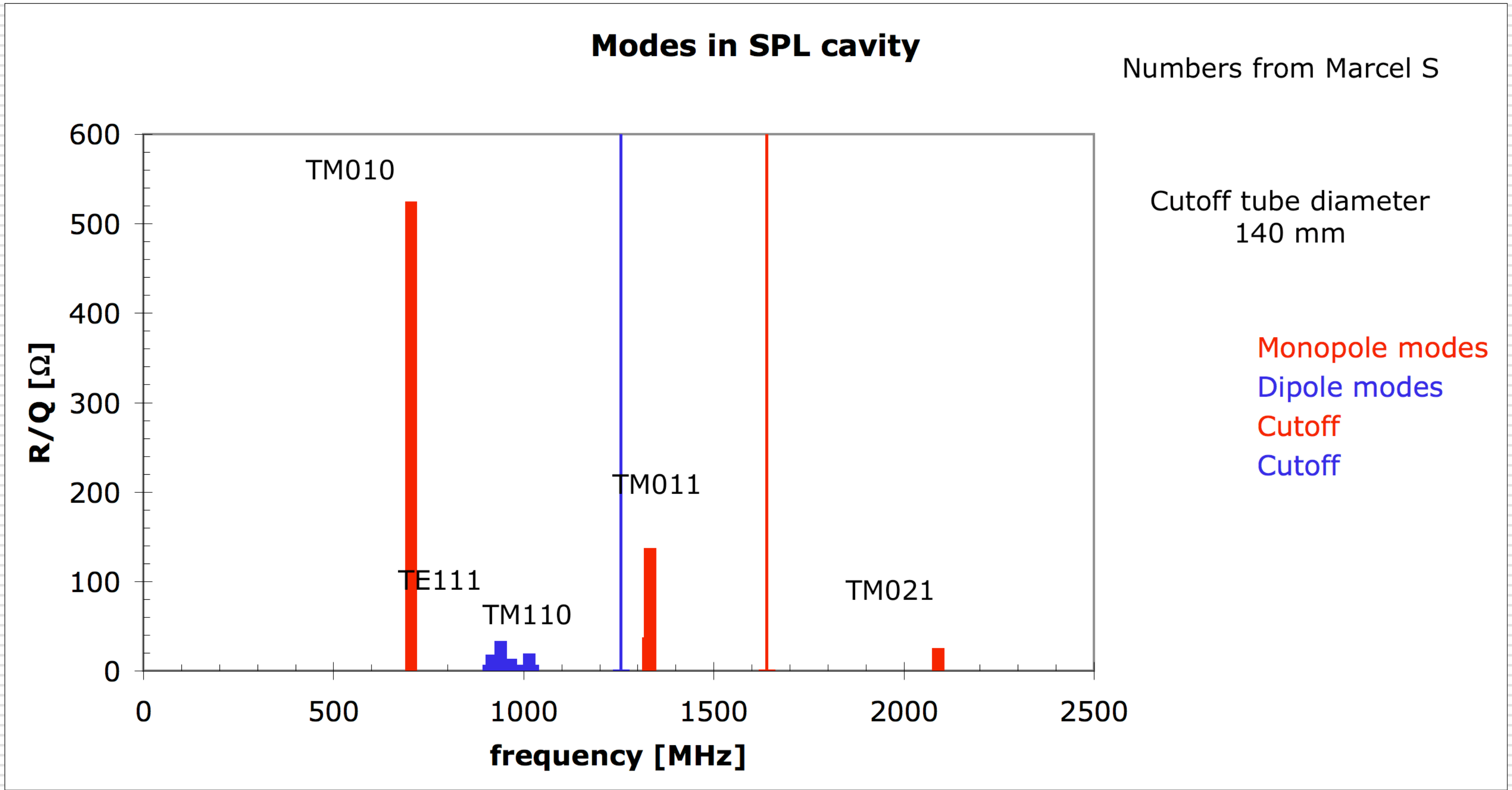
Material mainly based on lecture “Couplers for cavities” by Ernst Haebel

CERN Yellow report CERN-96-03

CAS - CERN Accelerator School : Superconductivity in Particle Accelerators, Hamburg, Germany, 17 - 24 May 1995, pp.231-264

1. What is the HOM spectrum?



2. What is the upper limit of Q_{ext} from BBU point of view?

Is there a clear threshold value of Q_{ext} to avoid BBU?

On what parameters does this threshold depend?

spread in frequency, R/Q, Q

3. What is the upper limit of Q_{ext} from the maximum HOM power point of view?

$$P = \frac{1}{2} \cdot (R/Q) \cdot Q \cdot I^2$$

Sum over all monopole modes assuming 6 % duty cycle (from Marcel S.)

Q_{ext}	10^5	10^6	10^7
ΣP_n [kW] (medium β)	0.1	1.1	11
ΣP_n [kW] (high β)	3	30	300

Can the HOMs be damped by beam tubes?

Tacit supposition: Damping schemes on individual cavity cell excluded

- Can all modes be damped by sufficiently large beam tubes?
  - No, because of unrealistically large beam tube diameters
  - There remain confined modes
    - TM010, TM011
    - TE111, TM110
  - But: Even a mode frequency beyond cutoff is no guarantee for sufficient mode damping -> **trapped modes**

How to deconfine modes?

Open beam tube

OK for single cell cavity, but high cryo-load by thermal radiation

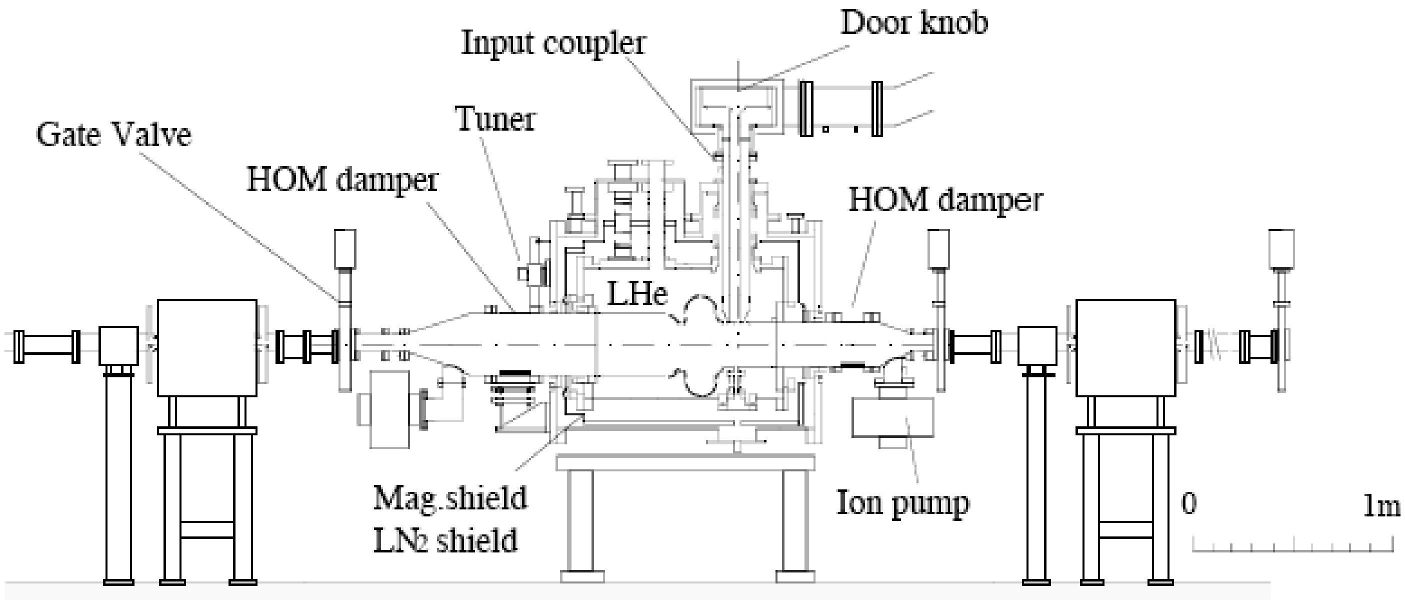


Figure: 1 A sketch of the prototype module in TRISTAN Accumulation Ring.

How to deconfine modes cont'd?

Open beam tube:

Use ridge-shaped beam tubes (Cornell)

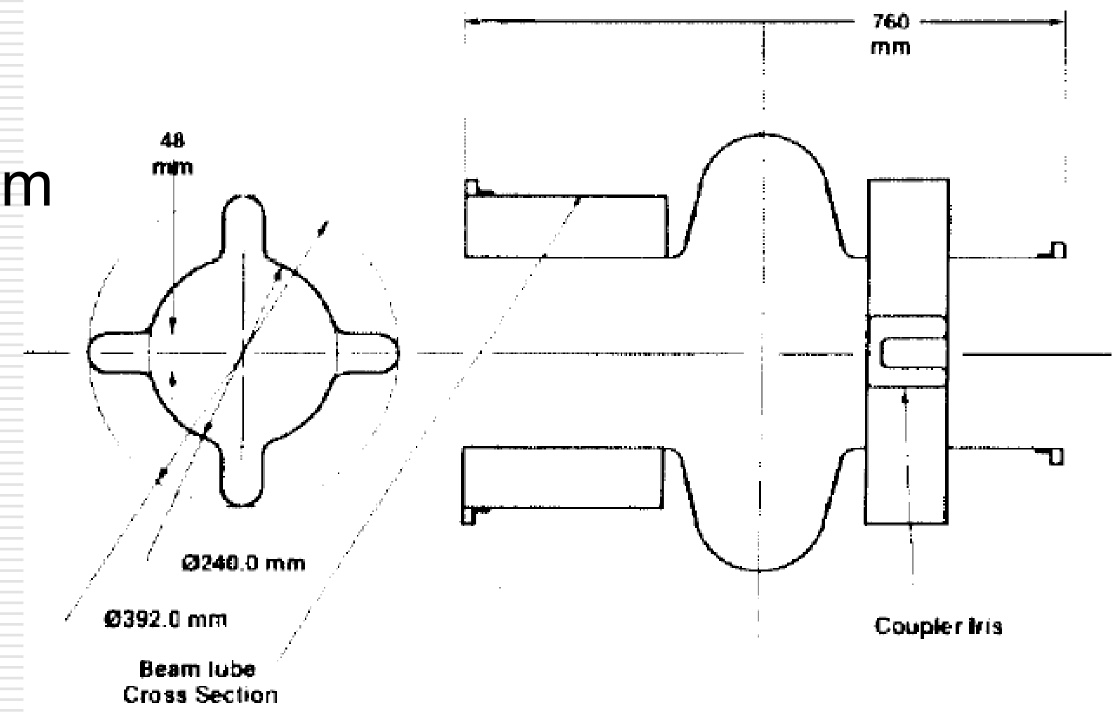


Fig. 3 Fluted beam pipe and input coupler geometries

Beam tube loads?

Ferrites?

- low power handling capacity if cold
- higher power handling capacity if warm
- mechanical and vacuum design not easy

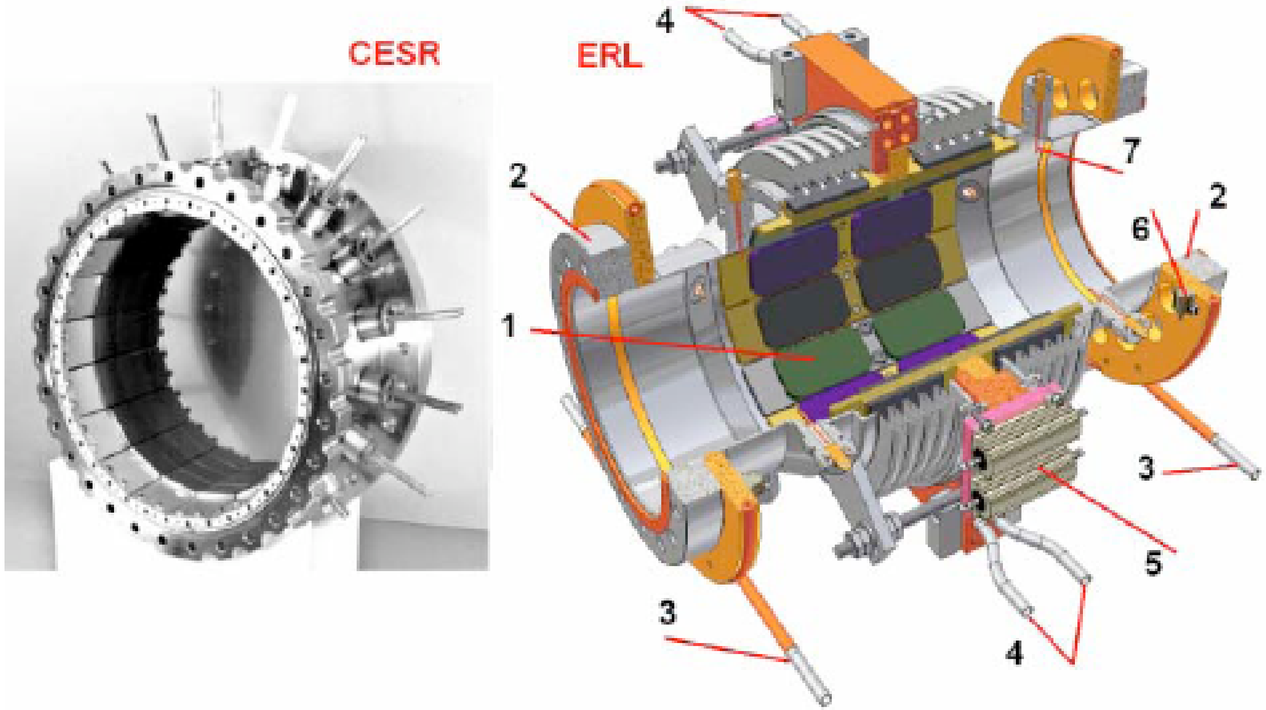


Figure 1: CESR and ERL HOM loads. 1 – absorber plates, 2 – flange to cavity, 3 – 5 K He cooling loop, 4 – 80 K cooling loop, 5 – 80 K heater, 6 – 5 K heaters, 7 – HOM pickup.

Waveguide dampers?

- termination load at room temperature
- fundamental mode rejection by proper choice of waveguide dimensions

- BUT: limited to higher frequencies
- engineering issues: Integration in cryostat not easy, RF windows, heat leaks

Waveguide dampers cont'd?

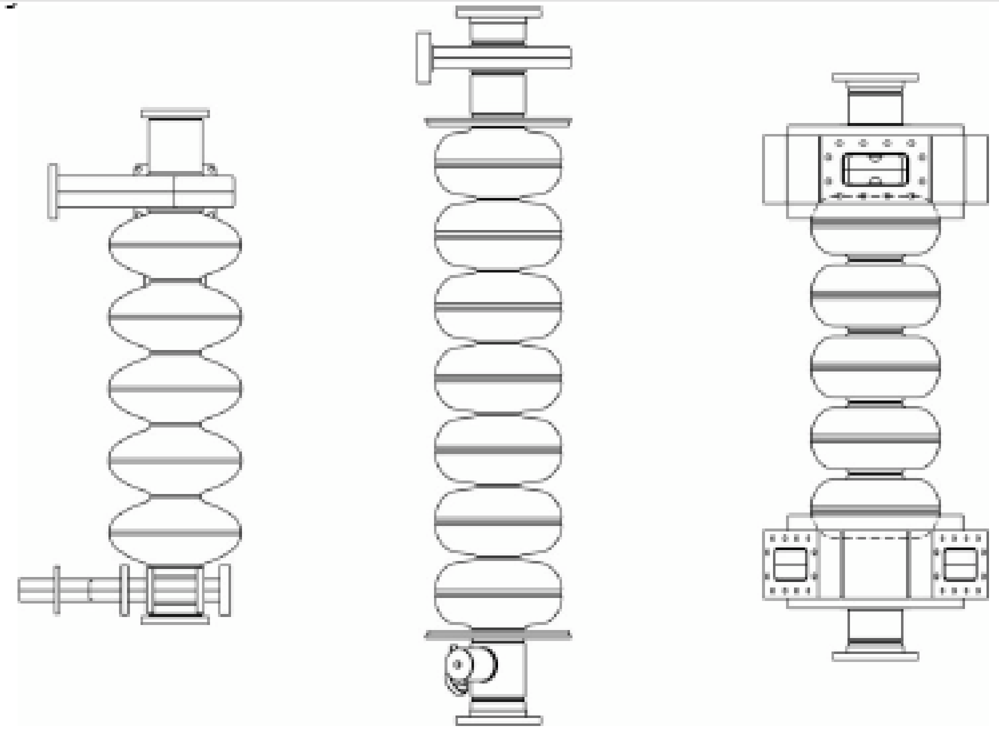


Figure 2: JLab CW cavities for (left) CEBAF, (center) 12 GeV upgrade and (right) high-current.

Coaxial transmission line dampers?

- termination load at room temperature
- options:
  - Non-resonant vs. resonant
  - Probe antennas vs. loop antennas
  - Obtainable Q_{ext}: 5000

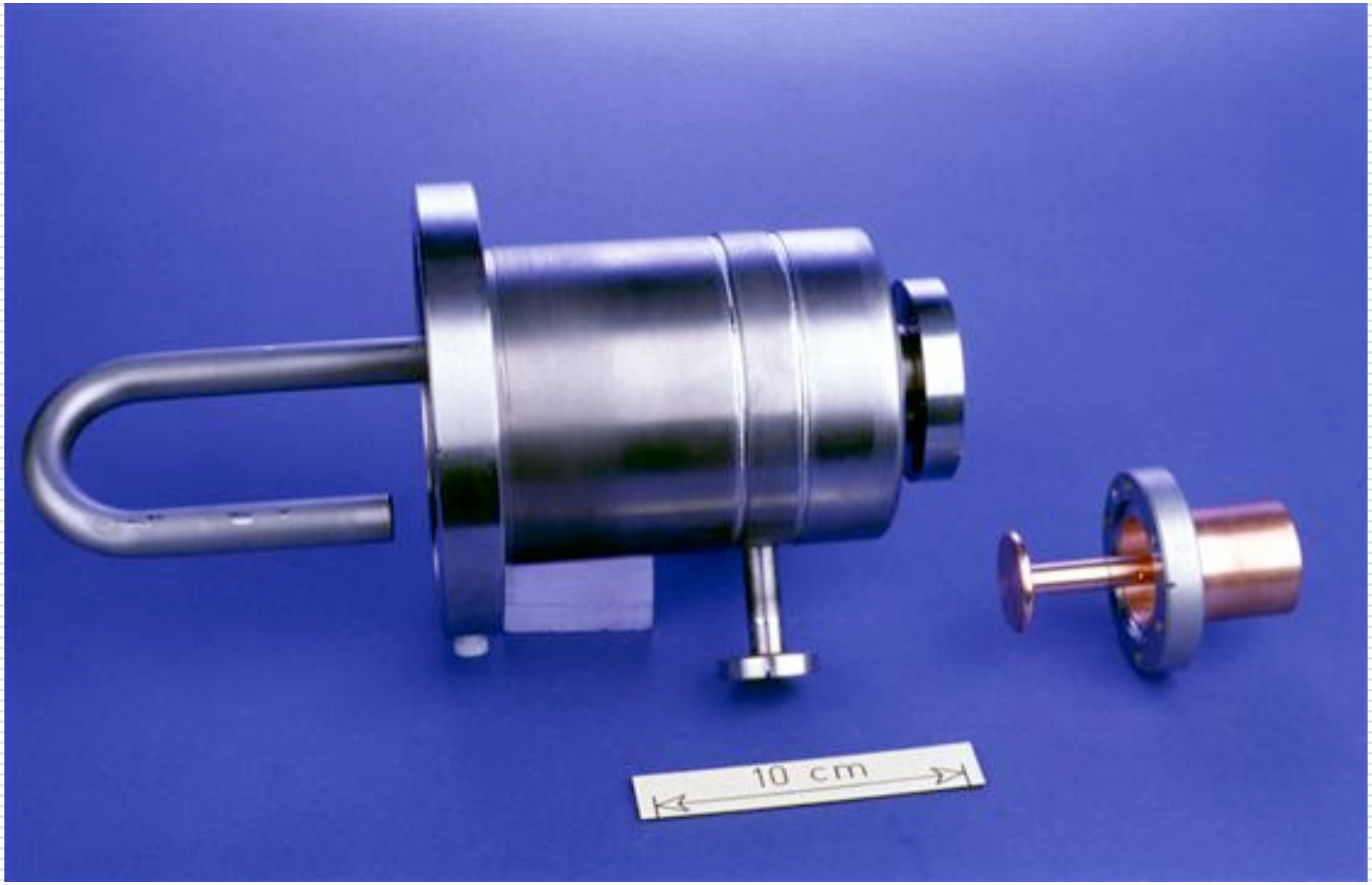
- BUT:
  - they don't have a cut-off frequency, hence need a filter to suppress the FM
  - limitation of coupling strength by unwanted current flow through internal impedances for NON-resonant transmission line couplers
  - must couple to both polarisations of transversal modes

Resonant coaxial transmission line dampers?

- Compensate internal impedances: The HOM coupler becomes a resonator coupled to the cavity resonator. It may have two eigenfrequencies.

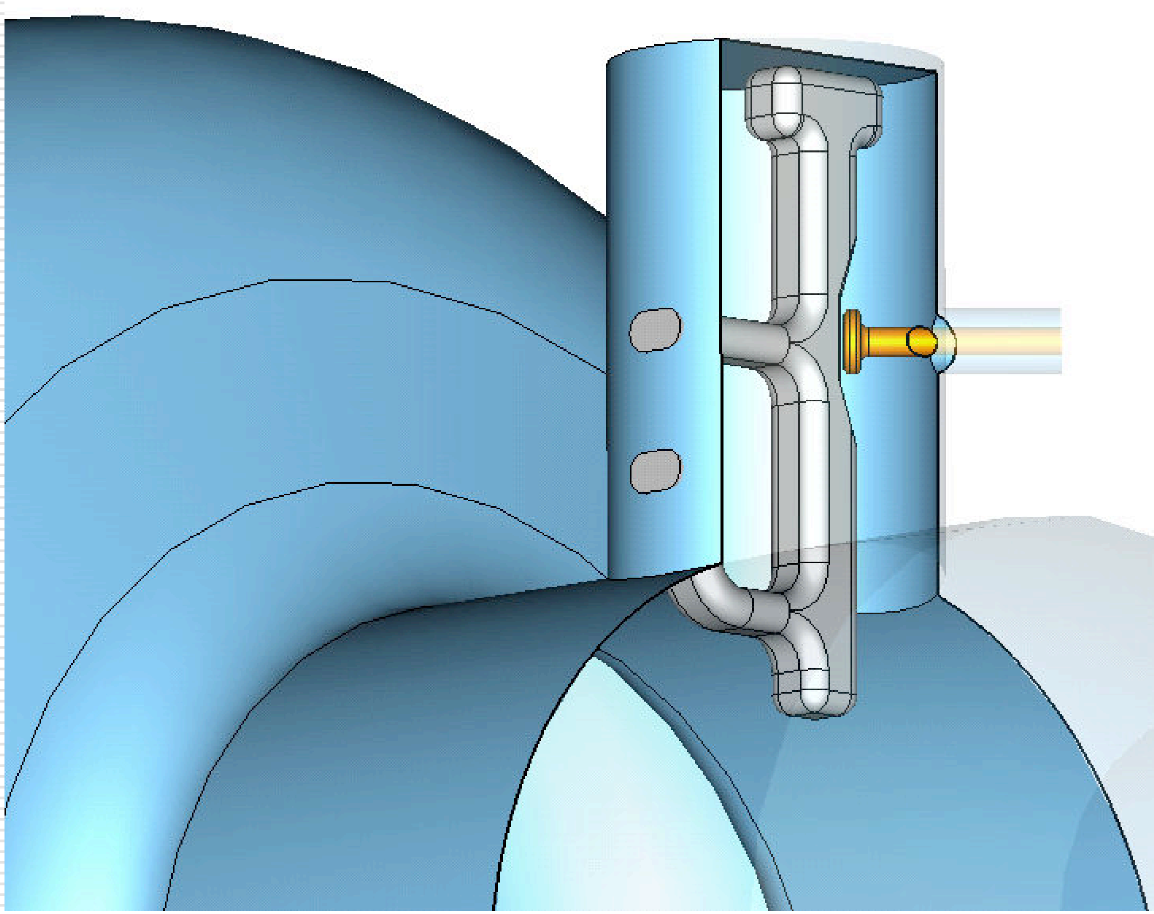
  Obtainable Q_{ext}: 50
- Pros:
  - Couplers with several resonances possible (HERA, LEP, LHC, ILC are of this type)
  - Demountability
  - Fundamental mode rejection:
    - LEP: Fundamental mode E-field rejected by stop-filter in front of HOM coupler
    - Fundamental mode H-field rejected by loop plane perpendicular to cavity axis
    - Risk of detuning of notch filter
- BUT: High currents request for superconducting material prepared under ultra-clean conditions (like the cavity) and lHe cooling
- Prone to electron emission from inside cavity

Technical solution?



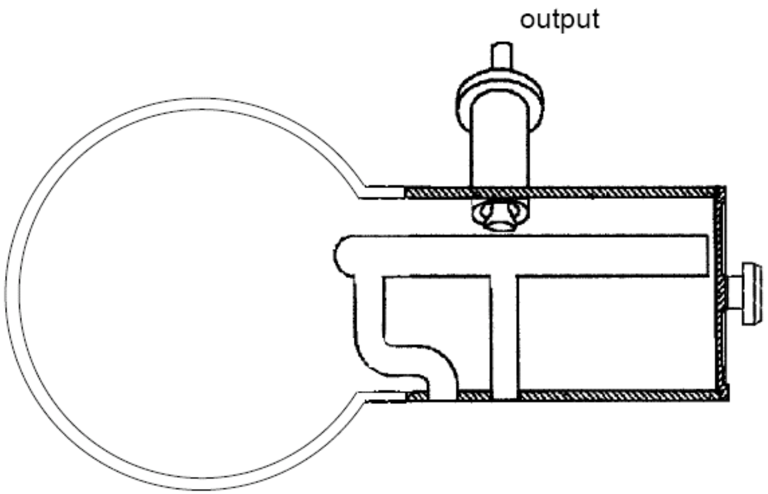
LHC HOM coupler

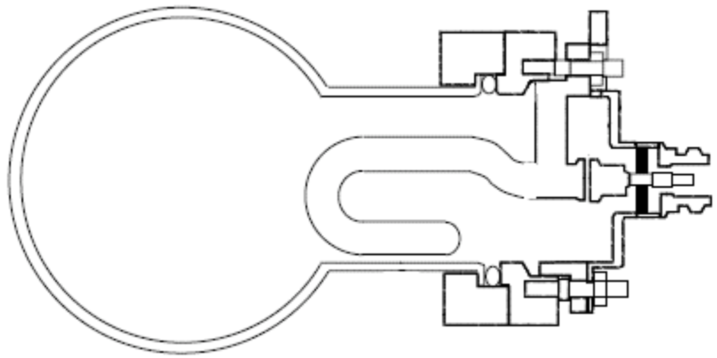
Technical solution cont'd?



SNS HOM coupler

Technical solution cont'd?





TESLA HOM coupler

What are reasonable design criteria for HOM couplers?

1. What is max. tolerable Q_{ext} wrt BBU?
2. Is this Q_{ext} compatible with the max possible RF power throughput?
3. Prone to multipactor, discharges and electron impact?
4. Demountability?
5. Ultra-clean processing possible?
6. Suitable interlocks?
7. Conduction cooling sufficient, or active lHe cooling needed?
8. Both polarisations being damped?
9. Risk of cold leaks to lHe mitigated?
10. …

Possible design?