SRF: Cavity design for FCC

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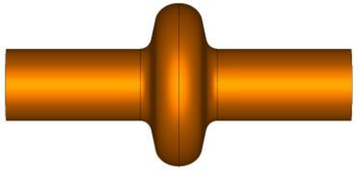
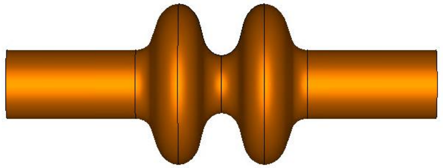
Many thanks to F. Peauger, E. Montesinos and all FCC-ee colleagues

Proposed updates on SRF system

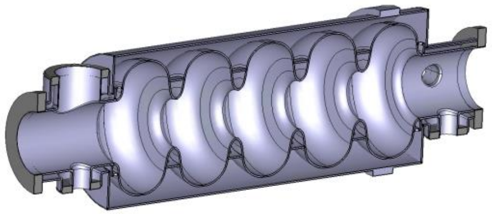
Baseline



Z: 112 cavities
400 MHz 1-cell Nb/Cu, 4.5 K

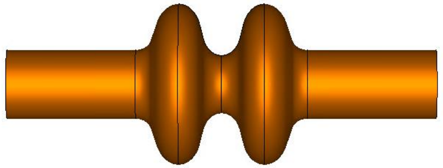


W, H: 264 cavities
400 MHz 2-cell Nb/Cu, 4.5 K



$t\bar{t}$ collider and boosters: 1028 cavities
800 MHz 5-cell Bulk Nb, 2 K

Proposed update

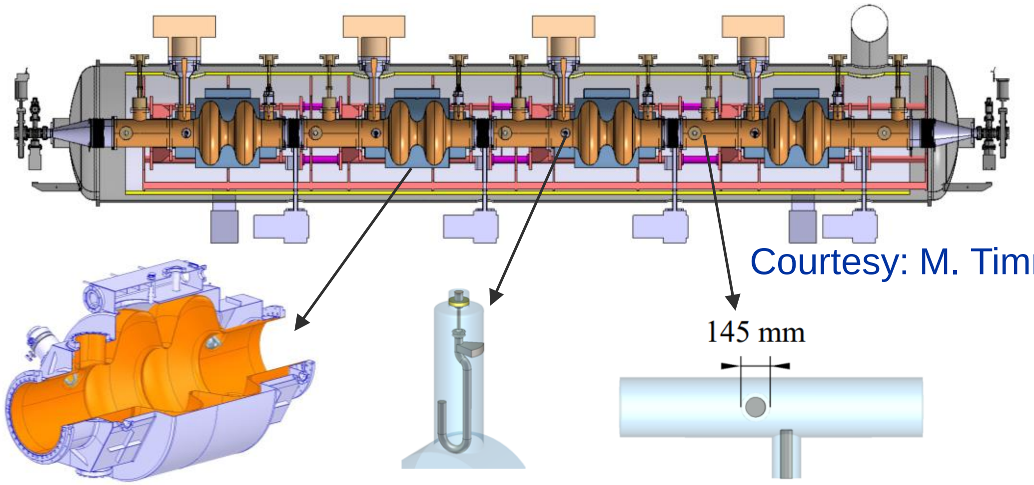


Z, W, H: 264 cavities
400 MHz 2-cell Nb/Cu, 4.5 K
Goal: $Q_0 = 3.3 \times 10^9$ at $E_{\mathrm{acc}} = 13.2\ \mathrm{MV/m}$

$t\bar{t}$ collider and boosters: 860 cavities
800 MHz 6-cell Bulk Nb, 2 K
Goal: $Q_0 = 3.8 \times 10^{10}$ at $E_{\mathrm{acc}} = 24.5\ \mathrm{MV/m}$

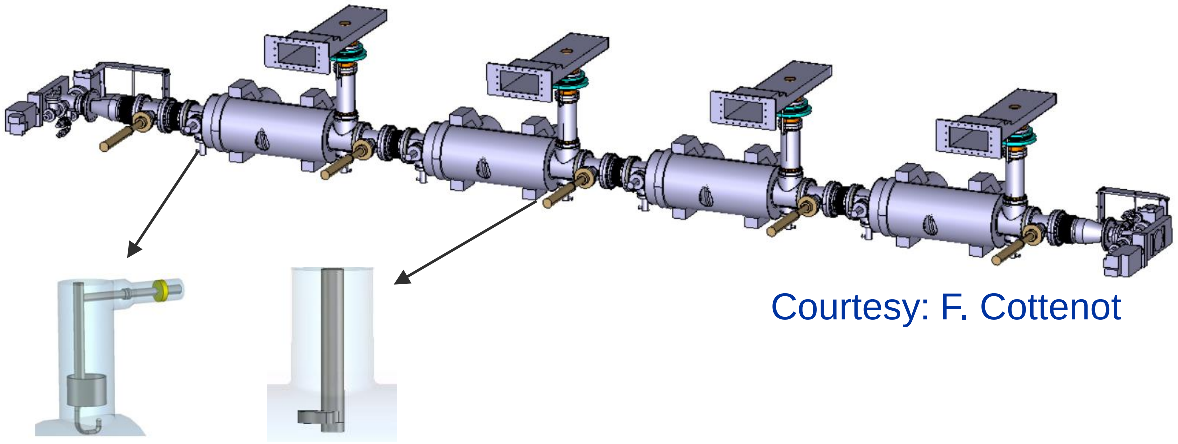
HOM couplers in cryomodules

400 MHz module



Courtesy: M. Timmins

800 MHz module

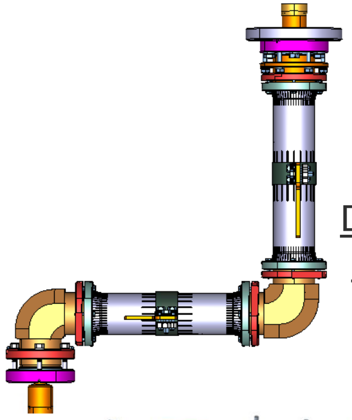


Courtesy: F. Cottenot

- Two hook-type coaxial couplers are used for dipole mode damping, with two coaxial lines for high-power HOM extraction
- The possibility of using FRT is being studied, with additional port and space requirements to be considered
- Can a larger radius taper be implemented to reduce the total resulting HOM power?

- Study the optimum distance between cavities, the location of the broadband impedance extractor, and trapped HOM impedance for the 6-cell cavity
- Electro-mechanical calculations with the helium vessel and frequency tuner to determine tuning and perturbation sensitivity
- Evaluate the possibility of using the same beam pipe diameter between modules

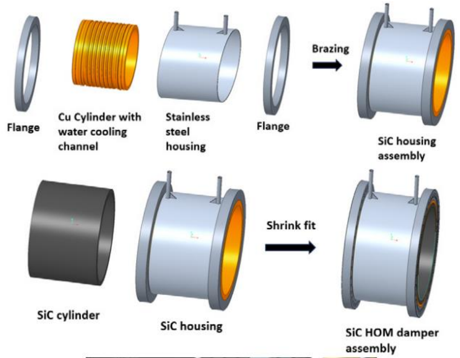
Beam line absorber vs coaxial coupler

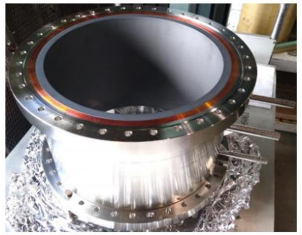


DQW cavity coaxial line

- **Coaxial line:**
  - Extracts and damps HOMs outside the cryomodule, with a more complex design but less direct exposure to beam vacuum. Lower cryogenic load due to thermal isolation
  - The dielectric window decreases transmission efficiency and serves as a fragile point prone to failure or degradation over time
  - **The detailed design for the 400 MHz and 800 MHz coaxial lines needs to be developed**

- **Beam line absorber (BLA):**
  - Absorbs HOMs inside the cryomodule, with efficient broadband damping but higher self-heating
  - Increased risk of vacuum pollution since components are in direct contact with the beam vacuum. Careful material selection is crucial → limited experience here at CERN
  - Simpler design but direct access to the BLA inside the cryomodule for maintenance is not possible.
  - For high-power HOMs thermal shielding inside the module is critical to manage heat load and protect nearby components
  - PERLE plans to use BLA at 800 MHz — their operational experience, along with insights from other labs, will guide better decision-making
  - **The possibility of using BLA in/between cryomodules to be checked**



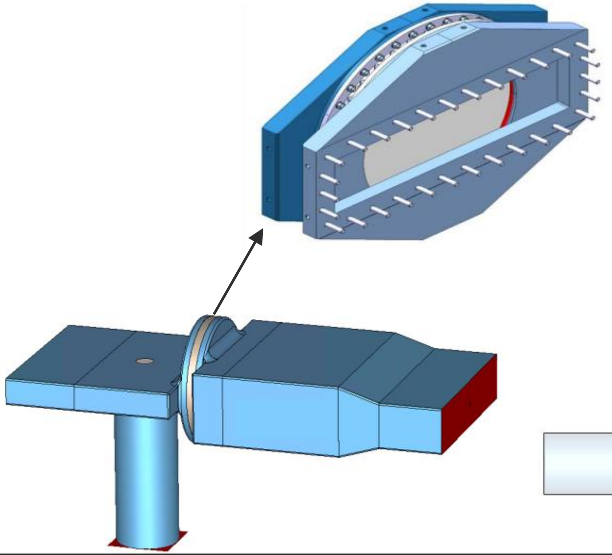


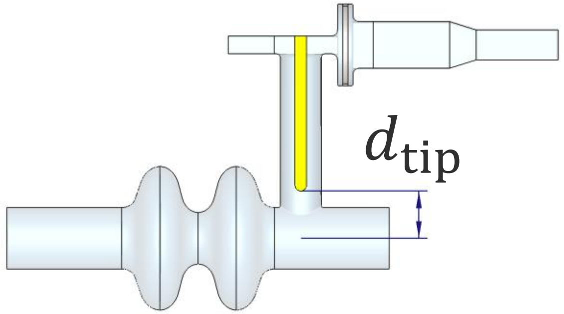
EIC BLA

Fundamental power coupler

400 MHz:

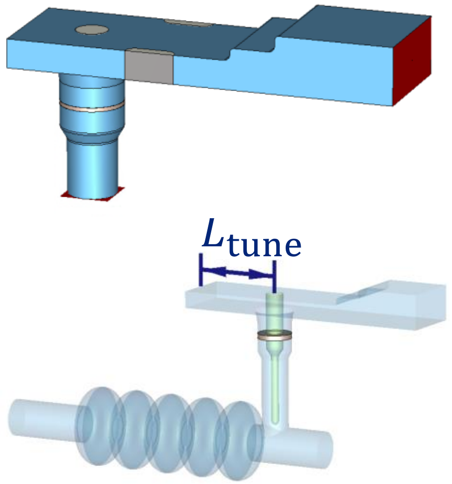
- High power (1 MW) FPC with LINAC4-type window → Q_{ext} variation by changing d_{tip} and the WG in front of the window
- The range of the required Q_{ext} and input power for each working point depends on the feasibility and conditions of the reverse-phase scheme

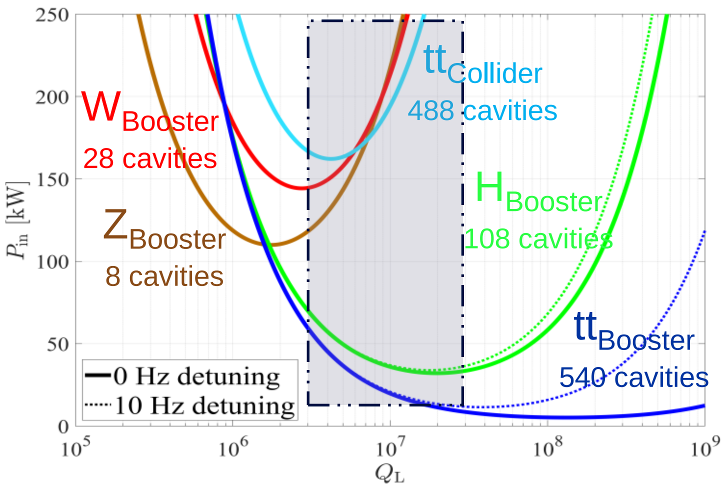




800 MHz:

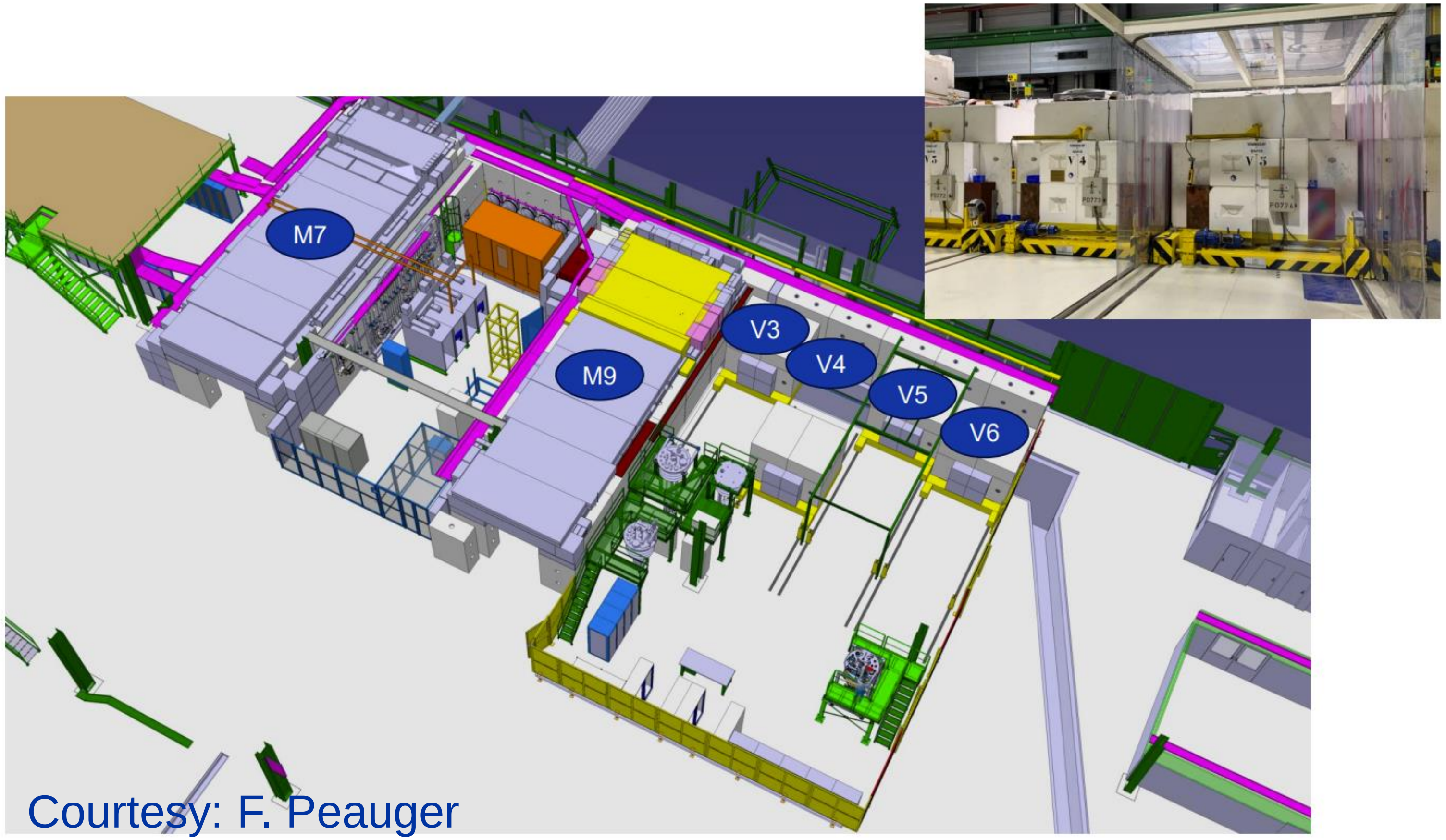
- The same type of FPC with coaxial disk window is considered at 800 MHz for all working points capable of handling 200 kW
- L_{tune} on the air-side is varied to cover Q_{ext} by around one order of magnitude
- The exact range of input power and Q_{ext} will be determined based on the selection of either the 5-cell or 6-cell scheme





SM18 cold testing benches

- Two horizontal test stand: recently renovated M9 for 4.5 K tests, and M7 for 800 MHz 2 K measurements
- RF sources needed for high power 400 MHz and 800 MHz tests
  - Space and RF source limitations → integration between M7 and M9
  - Electrical infrastructure upgrade to supply 1 MW klystrons
- Field flatness measurement bench development, cleanroom work upgrade, tooling and handling of equipment from one station to another to be defined



Courtesy: F. Peauger

Main challenges with advanced RF parameters

400 MHz 2-cell at Z

- Transient beam loading management with twice higher R/Q
- Transverse feedback system against coupled bunch instabilities becomes mandatory
- Risks of beam instabilities with 0-mode of the cavity
- Higher HOM power losses (32.9 → ~40 kW per CM)
- Q_{ext} of 1.2e4 at Z is difficult with present FPC design where antenna tip is fixed and Q_{ext} is tuned in the waveguides → increase of peak surface fields on the FPC side. Reverse phase operation can relax this constraint

See I. Karpov's talk

800 MHz 6-cells

- Max RF power 800 MHz increases close to the limit of 200 kW
- Trapped modes in the 4-cavity string module to be checked
- Investigate the possibility of using BLA
- High Q_L which does not help for cavity control (Lorentz force detuning, microphonics)
- Compatibility with present infrastructures (chemical benches, furnaces, HPR cabinets, …) with a cavity length of **~1.5 m from flange to flange**

The goal is to finish studying these limits by the end of 2024

Courtesy: F. Peauger