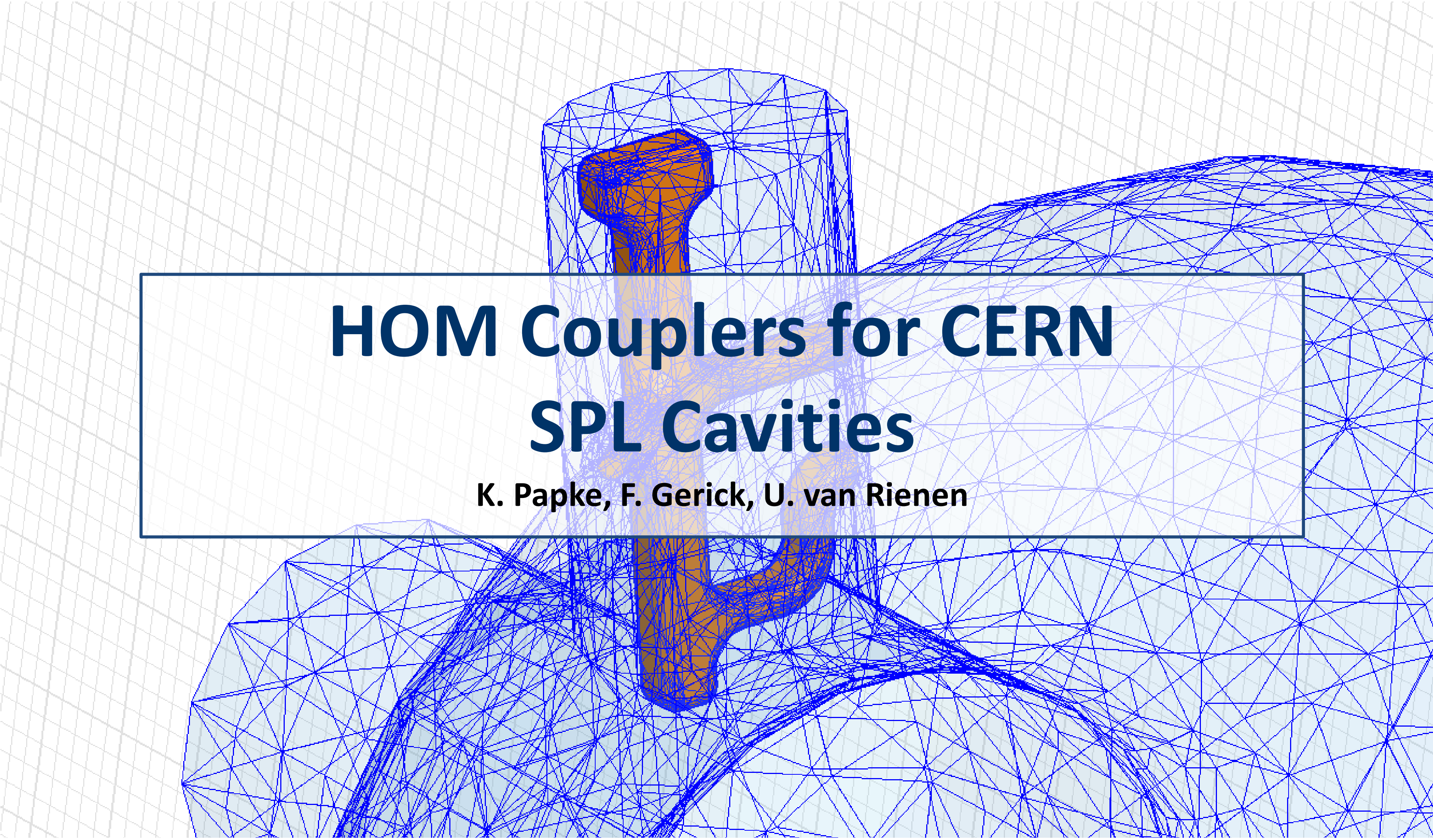
HOM Couplers for CERN SPL Cavities

K. Papke, F. Gerick, U. van Rienen



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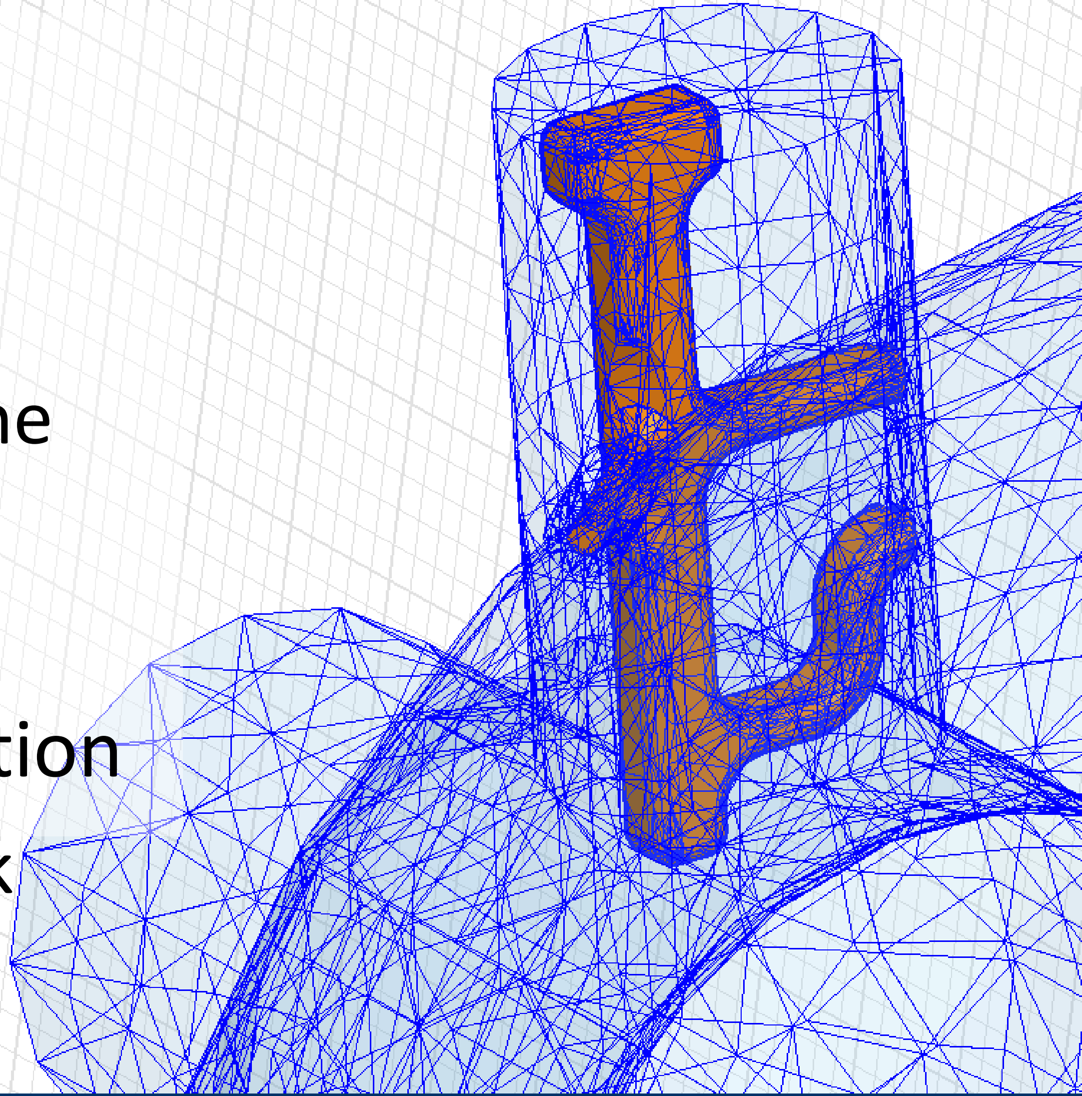
Outline

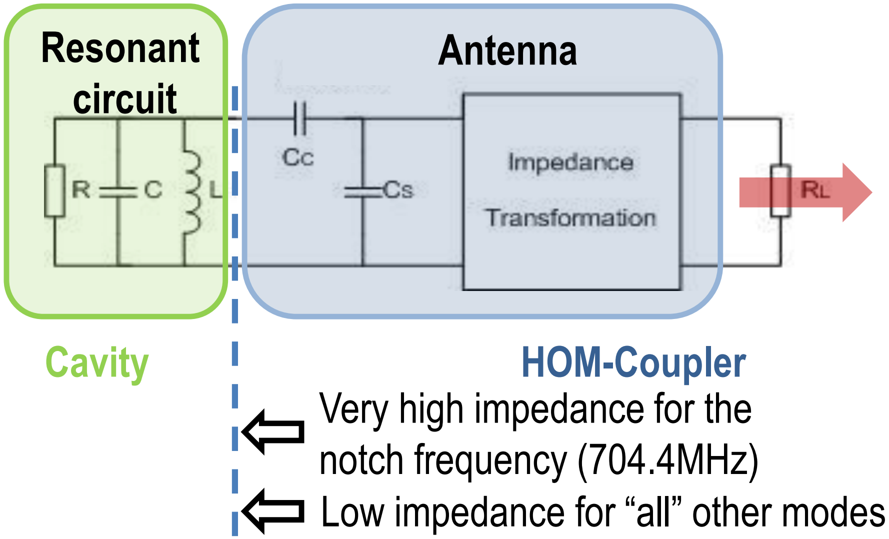
- Overview
- Design approaches
- RF Characteristic
- Measurements of the Prototype
- Multipacting
- Heat Loss Investigation
- Summary & Outlook

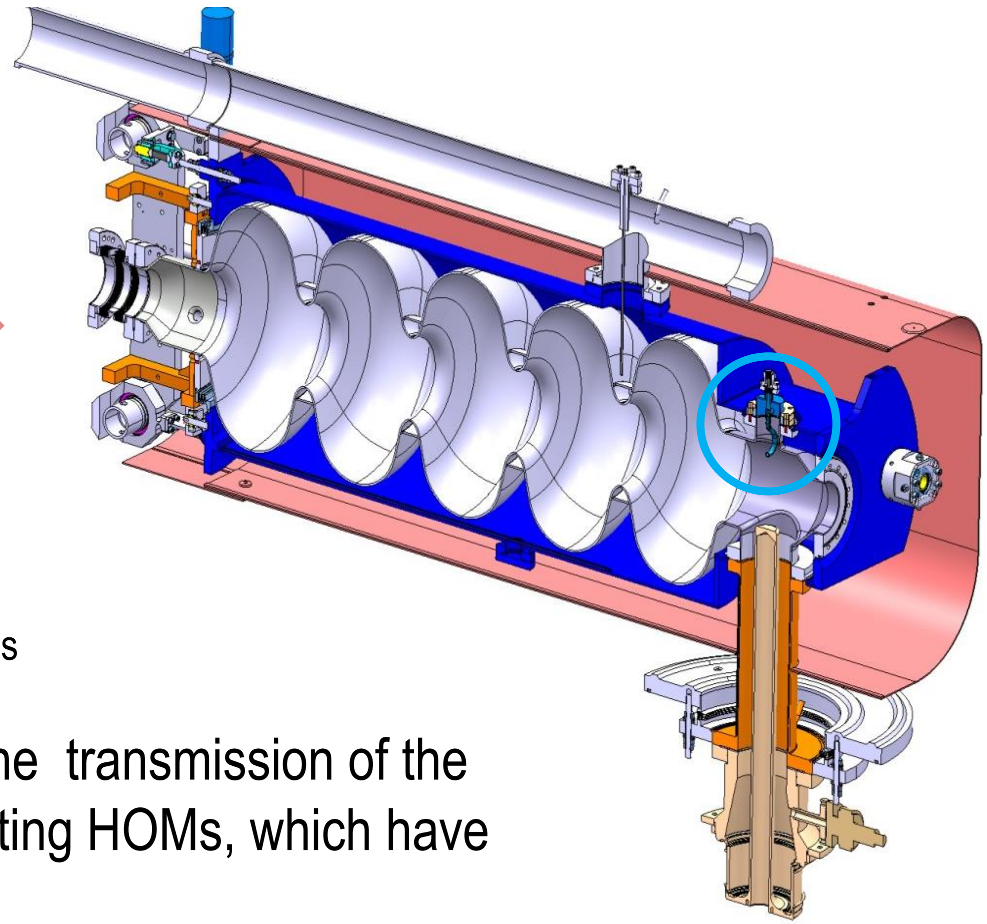


Overview

CERN Universität Rostock Traditio et Innovatio

- HOM-Coupler used to extract or dissipate unwanted, higher order modes in the cavity induced by the beam





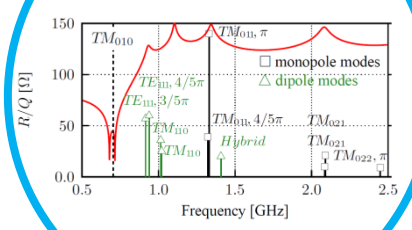
- Design goal of HOM filter: block the transmission of the accelerating mode, while transmitting HOMs, which have significant (R/Q) values

O. Capatina, SPL Seminar 2012

Overview

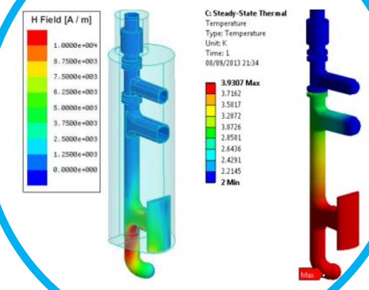
- Number of factors such as RF transmission behaviour, power dissipation, multipacting sensitivity, field emission, heat loss, mechanical restrictions

RF characteristics

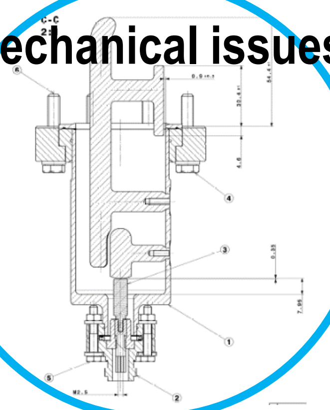


Design Approach for HOM coupler

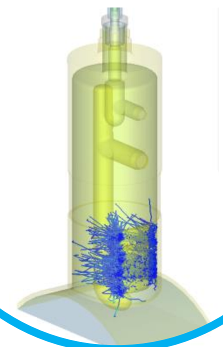
Heat loss



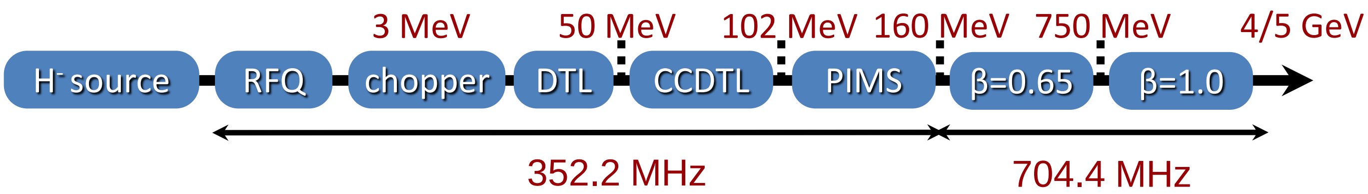
Mechanical issues



Multipacting



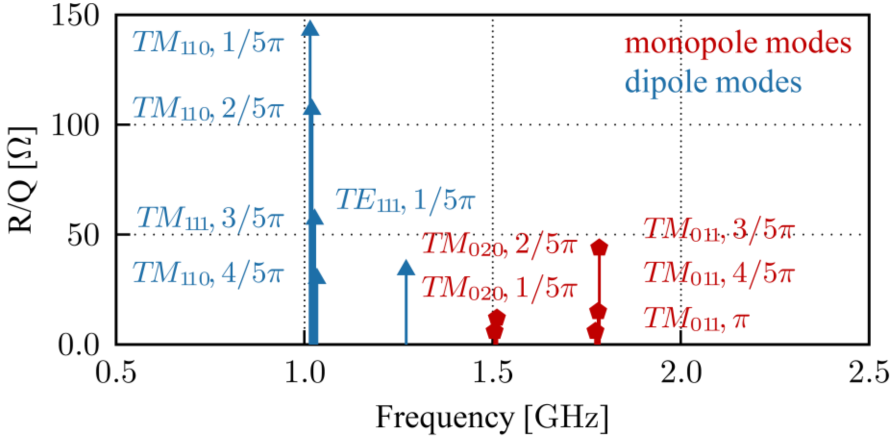
Overview



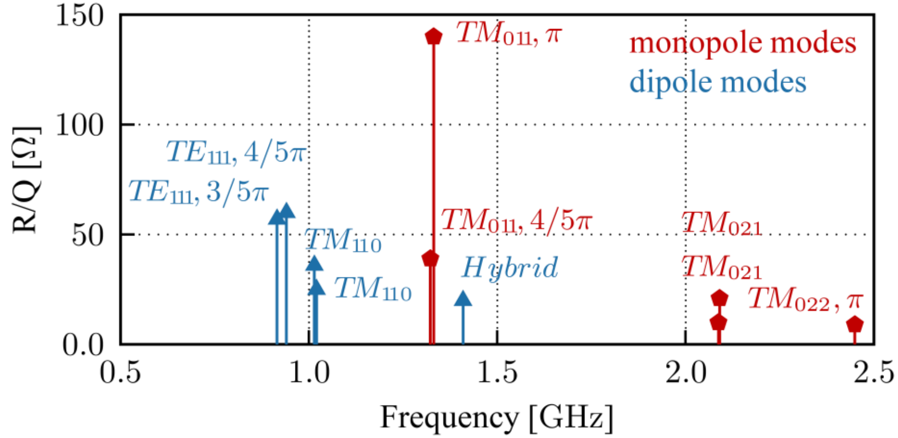
Schematic layout of the linac
(Conceptual design of the SPL II)

- For SPL dipole HOMs are considered less problematic
- In case of recirculators or synchrotrons should be also considered
- Design goal for relevant HOMs: **Qext < 10^5**
- HOM spectra for the medium and high beta Cavities:

Medium beta cavity (beta = 0.65)

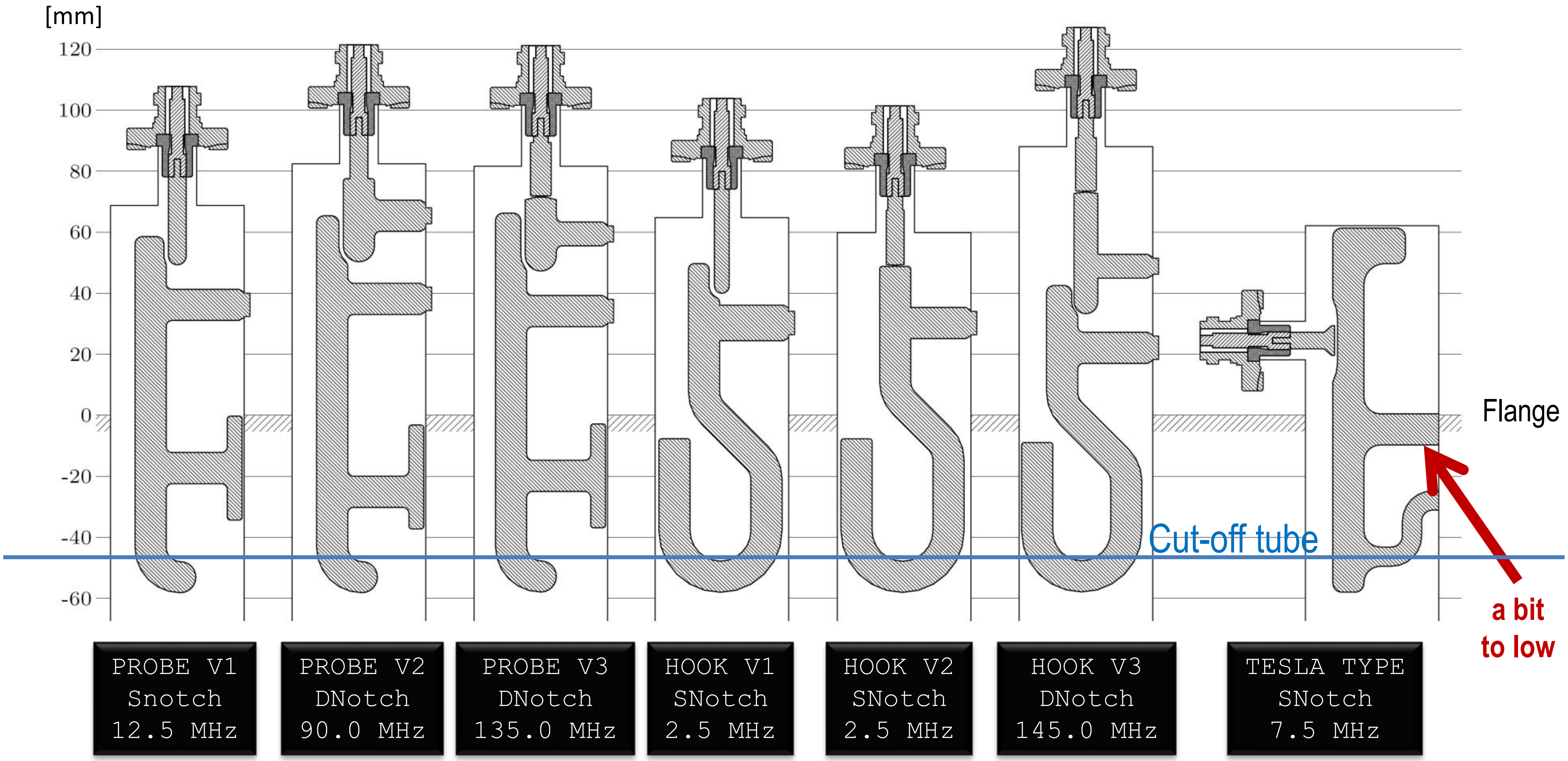


High beta cavity (beta = 1)



M.Schuh, F. Gerigk. "Influence of higher order modes on the beam stability in the high power superconducting proton linac", Phys. Rev. ST Accel. Beams, 2011

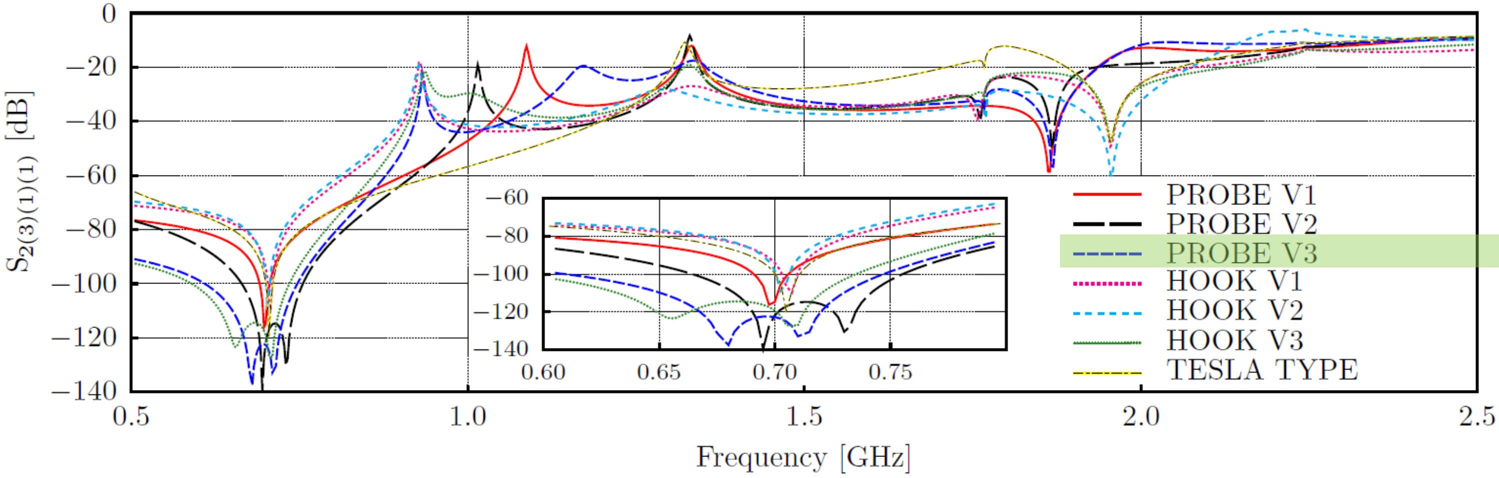
Design Approaches



- Single notch designs easier to fabricate but they are more sensitive and have a lower selectivity
- Hook designs have a better coupling to dipole modes/ Probe designs better for monopole modes
- Notch filter of the TESLA design nicely tunable but design is not reasonable for SPL cavity

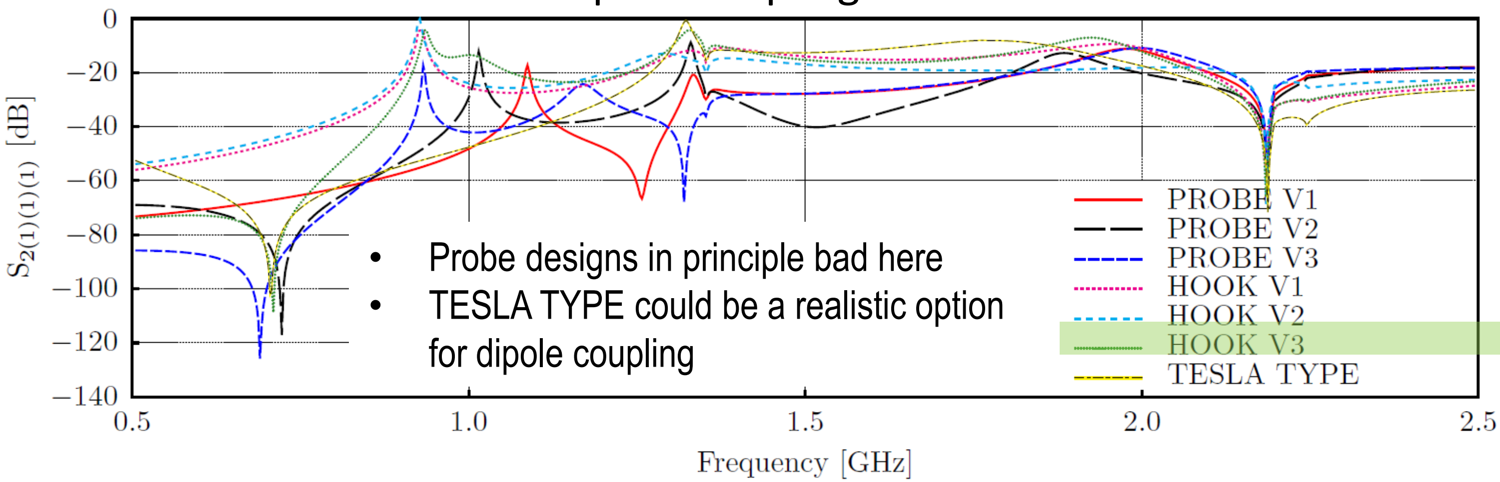
RF Characteristics

Monopole Coupling



Best option

Dipole Coupling



- Probe designs in principle bad here
- TESLA TYPE could be a realistic option for dipole coupling

Best option

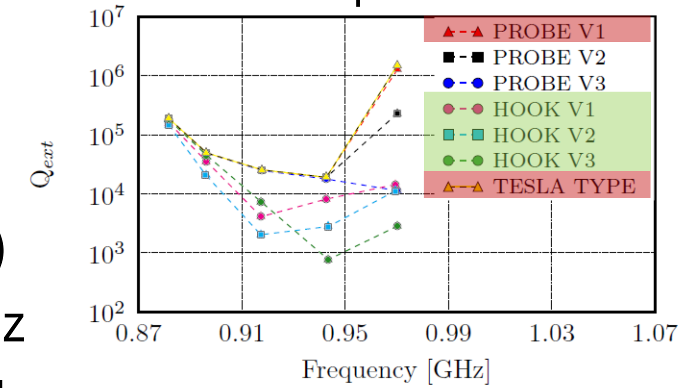
RF Characteristics

Qext in comparison

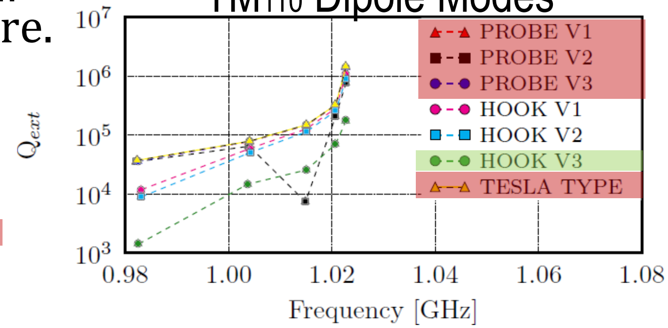
- Simulation using 2 couplers with a penetration of 20 mm
- Shows different coupling behavior for hook and probe designs and their preferences (dipole-/ monopole modes)
- HOOK V3, TESLA comparable good between 1.3 – 2 GHz
- Best choices taking into account the notch filter bandwidth:
  - **PROBE V3 and HOOK V3**

Type equation here.

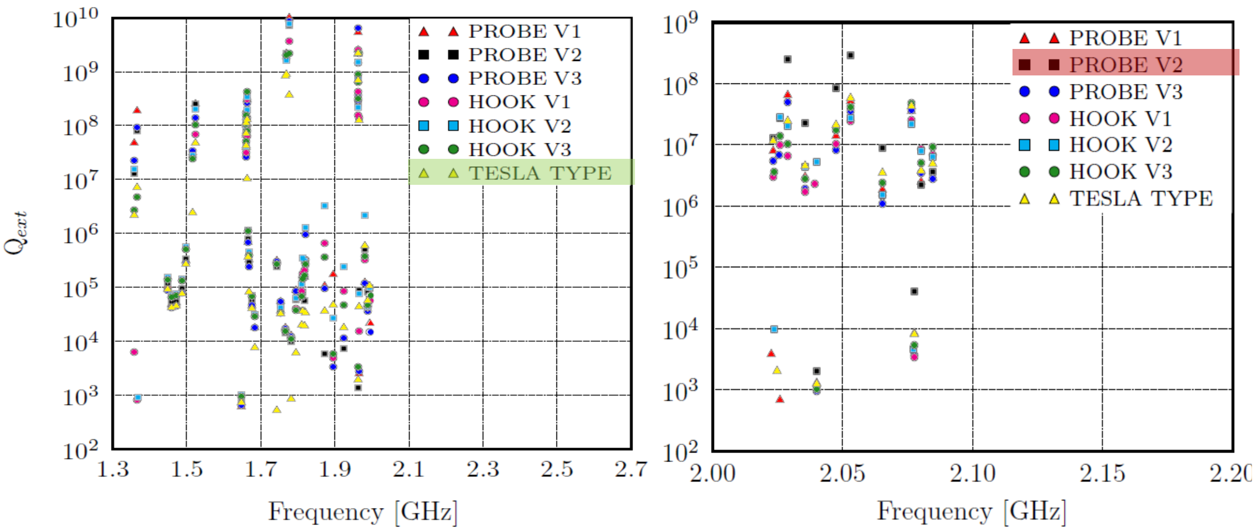
TE_{111} Dipole Modes



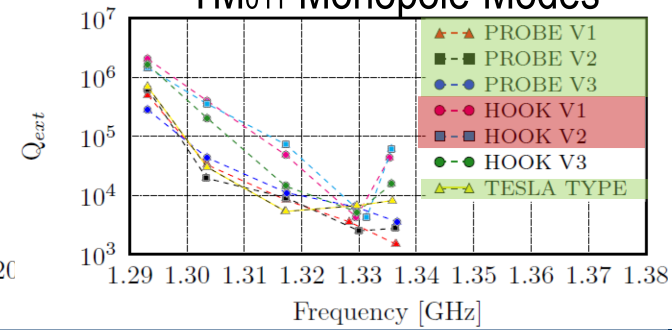
TM_{110} Dipole Modes



Modes between 1.3 and 2.1 GHz

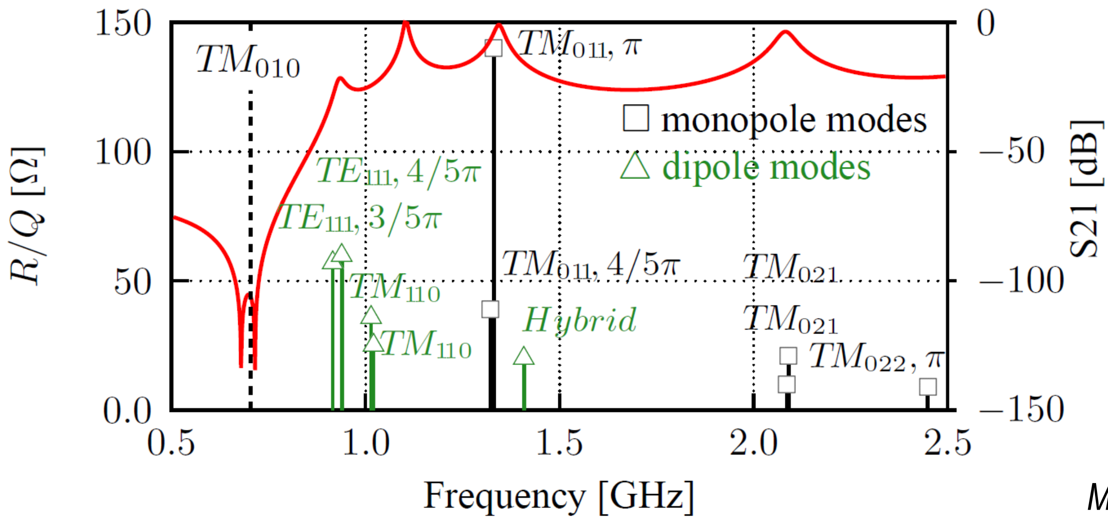


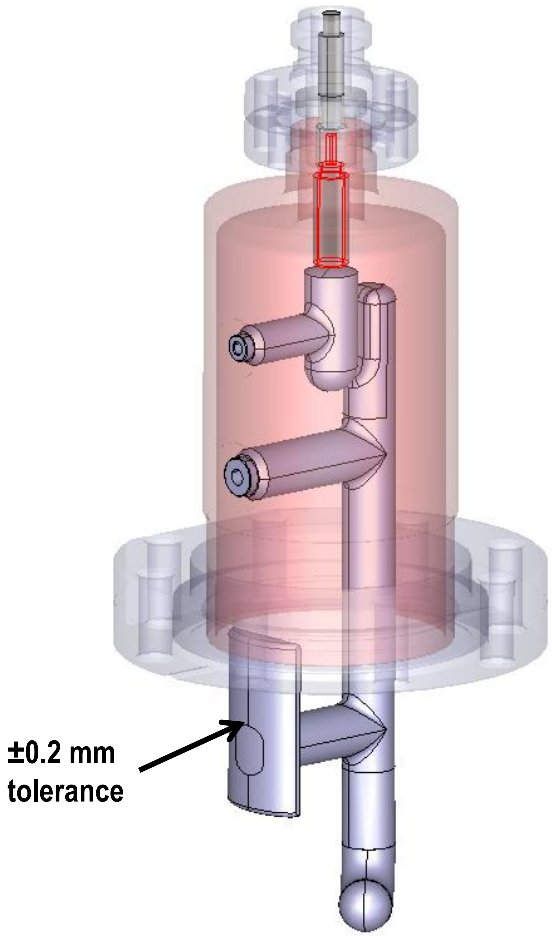
TM_{011} Monopole Modes



Prototype

- As the 1st Prototype the Probe Coupler (V3) with 3 stages was chosen
  - Notch filter with a relative high bandwidth (135 MHz @-100dB) and therefore very robust
  - High selectivity (steep transition between stop band and or notch filter and pass band)
  - Best coupling to the monopole HOMs at 1.3GHz.
  - No active cooling of the antenna necessary.

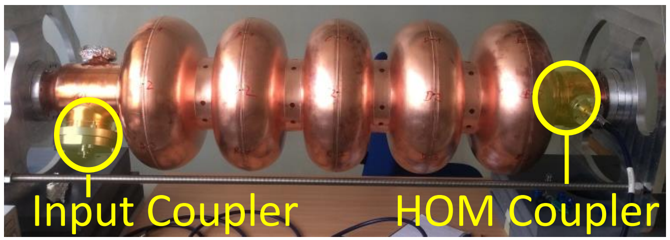




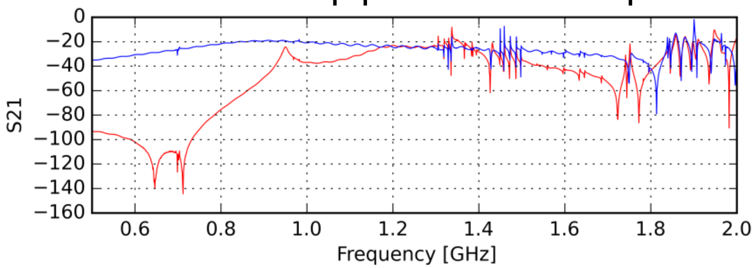
Mechanical Design by T. Renaglia, F. Pillon, N. Alonso

Prototype

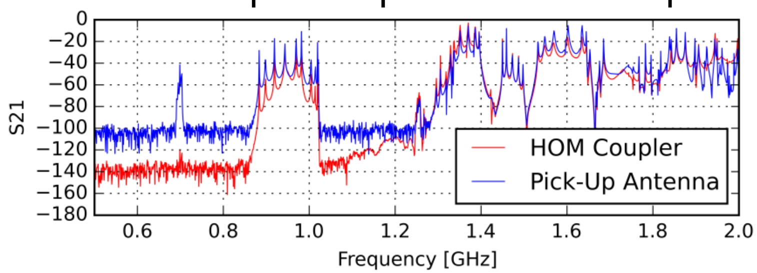
- The first prototype is a 3D print made of plastic and then copper coated Surface
- Coupler tested on a copper SPL cavity in different setups (angle/ penetration depth)
- Easy tunable due to the rotatable plastic flange

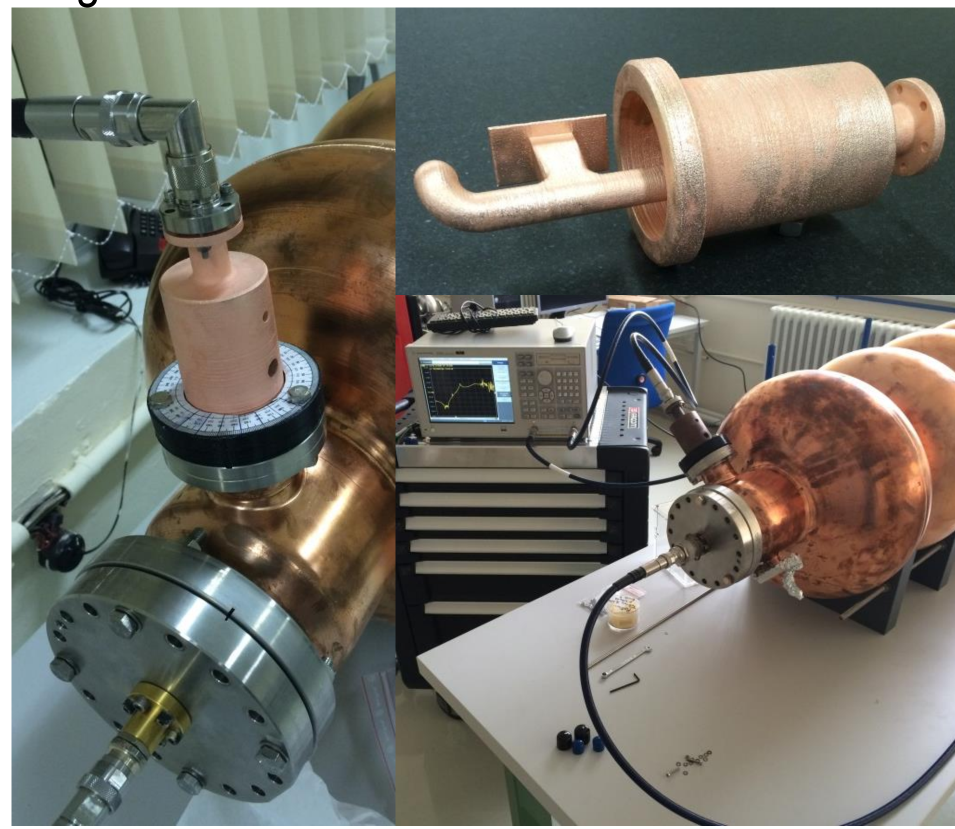


S_{21} from beam pipe to HOM coupler



S_{21} from Input coupler to HOM coupler



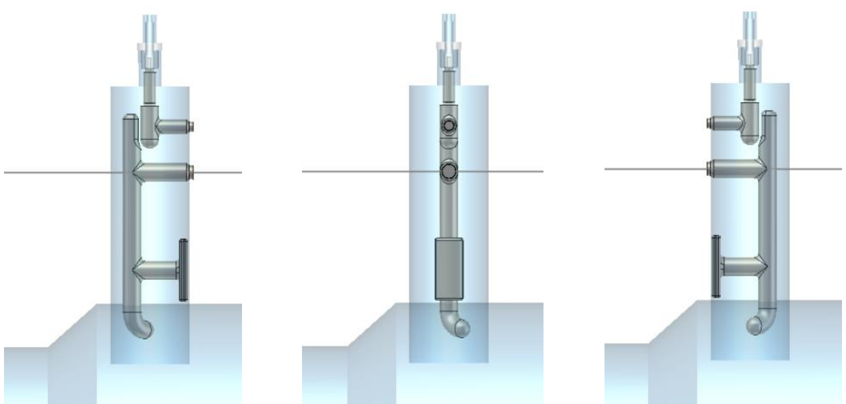


Plastic prototype coated with copper

Prototype

Investigations for the HOMs

- Q external measurements for different coupler orientation with respect to the beam line
- For TM011 @1.331 GHz big influence in the positive angel range
- Taken into consideration the most important modes an angle of **30 deg** is the best choice

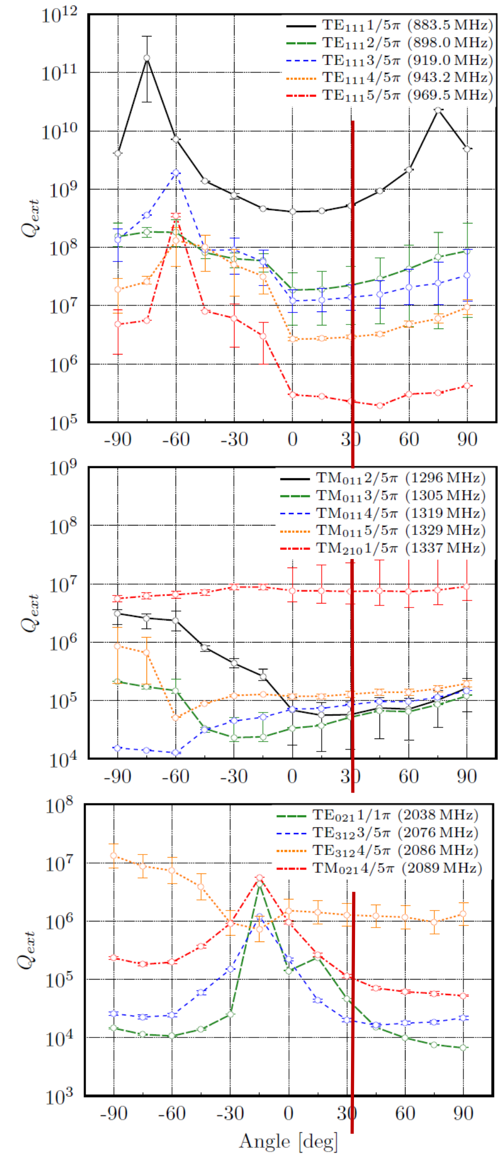


-90 deg   0 deg   90 deg

TE_{111} Dipole Modes:

TM_{011} Monopole Modes:

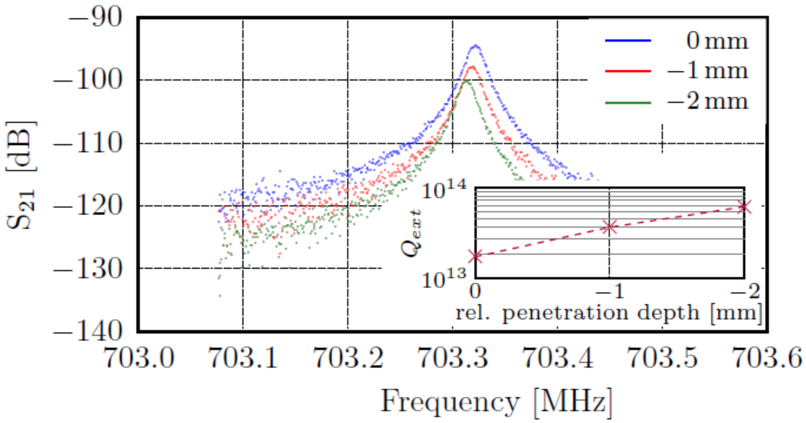
TE_{021} and TM_{021} Monopole Modes:

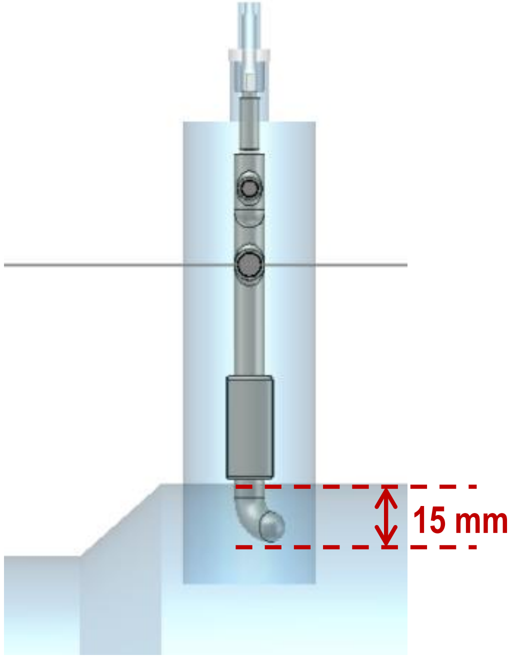


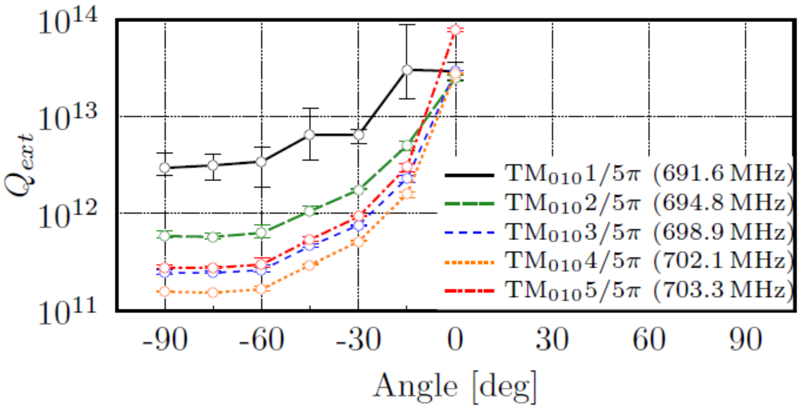
Prototype

Investigations for the accelerating mode

- Q external measurements for different coupler penetration and angles
- Default penetration depth: **15 mm**
- An angle > 0 deg is preferable





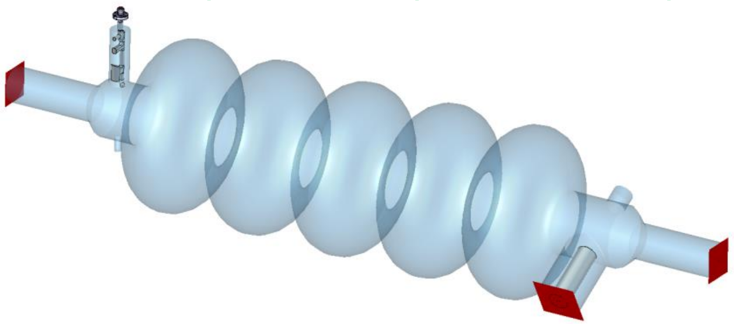


Prototype

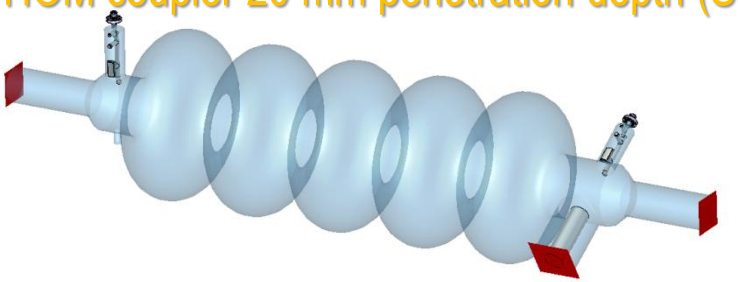
Comparison with simulations (CST MWS)

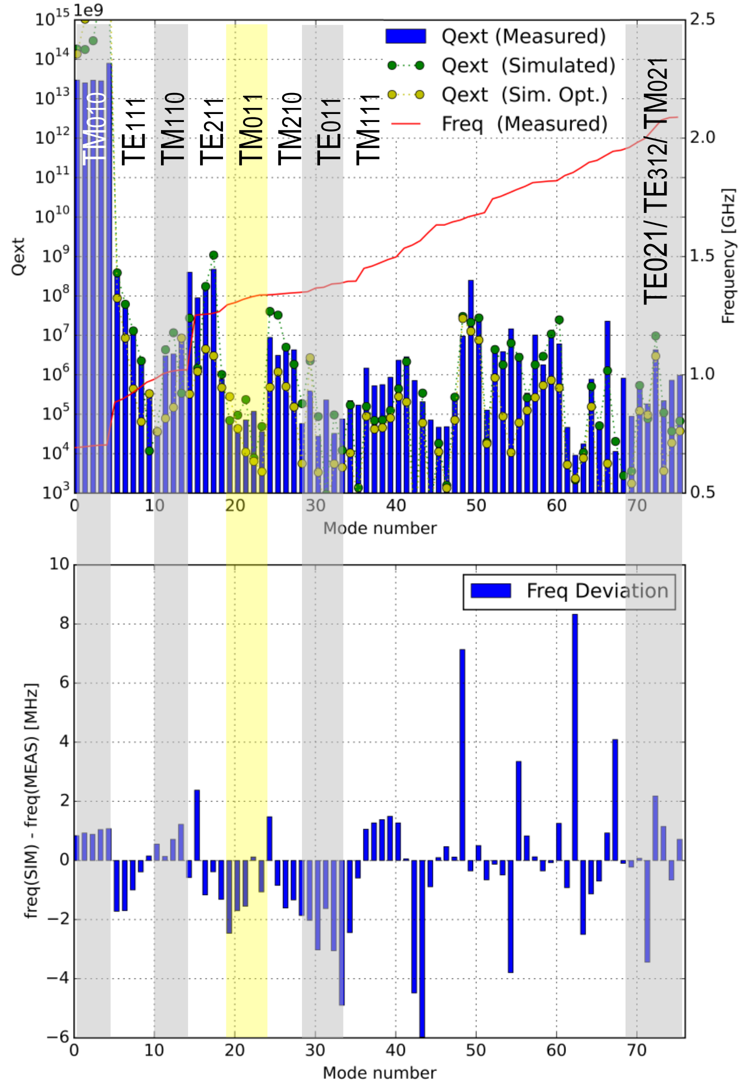
- $|\Delta Qext| < 0.75$ orders of magnitude
- $|\Delta f| < 1.5$ MHz (Cavity used for tuning tests before)
- Using 2 couplers with an increased penetration depth reduces Qext by >1 order of magnitude but maintains the notch filter performance sufficiently

1 HOM coupler 15 mm penetration depth (Simulated)



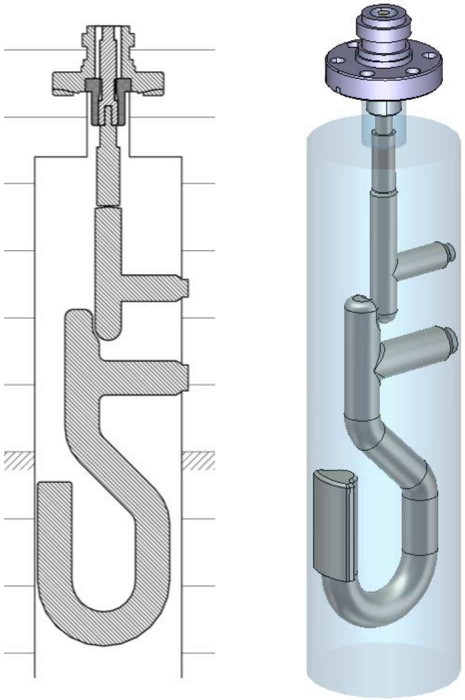
2 HOM coupler 20 mm penetration depth (Sim. Opt.)



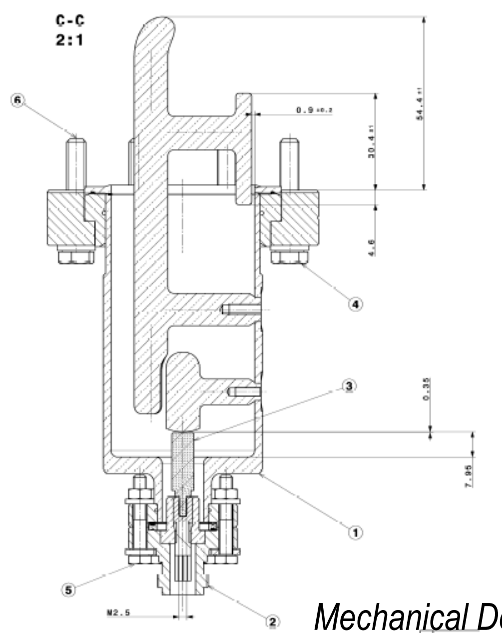


- 2nd 3D printed prototype will be tested on the copper cavity as well (HOOK V3)
- Bulk copper prototype of the probe coupler is been fabricating (05/2015)
- Latter one is foreseen for leakage test, warm and cold tests cavities and multipacting analysis

HOOK V3 (2nd 3D Print)



PROBE V3 (bulk copper)



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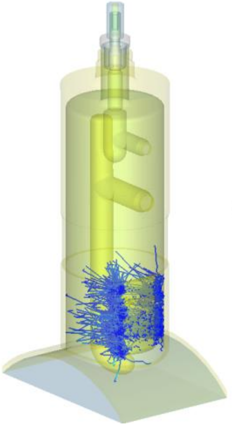
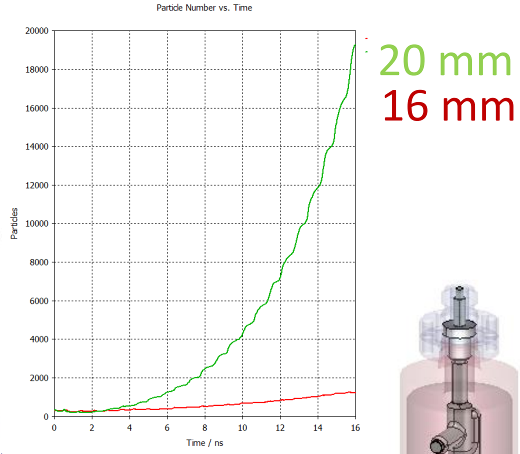
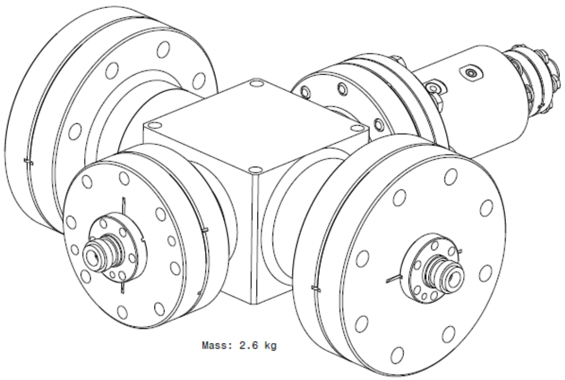
Multipacting

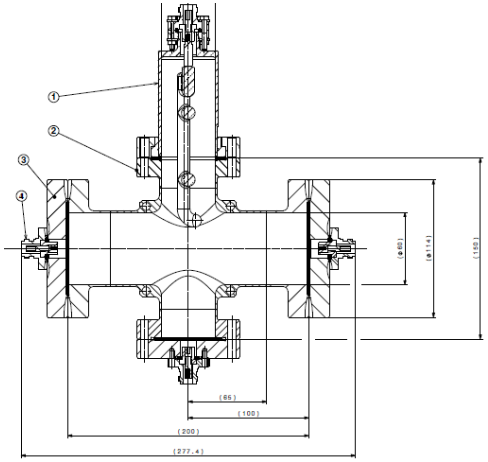
- Different parts of the Coupler have been investigated separately (CST)
- Most critical part are the plate sides of the notch capacitor
- Different materials tested to classify between hard and soft barriers
- Test facility (Cross) in fabrication to locate MP experimentally using the bulk copper prototype

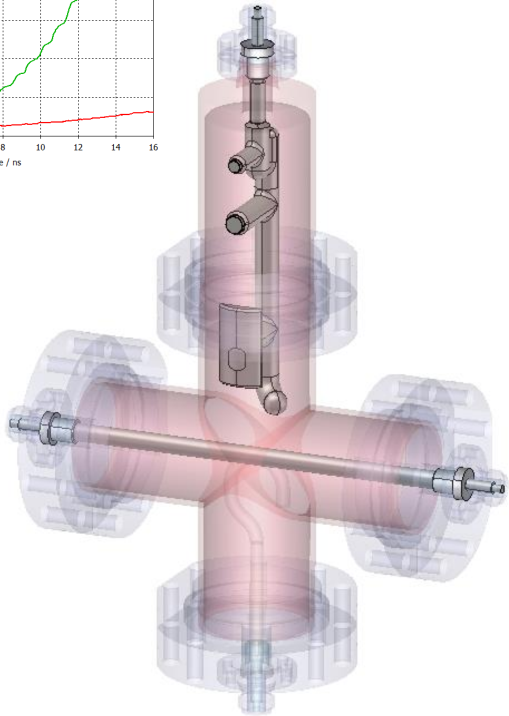
Influence of the notch capacitor width











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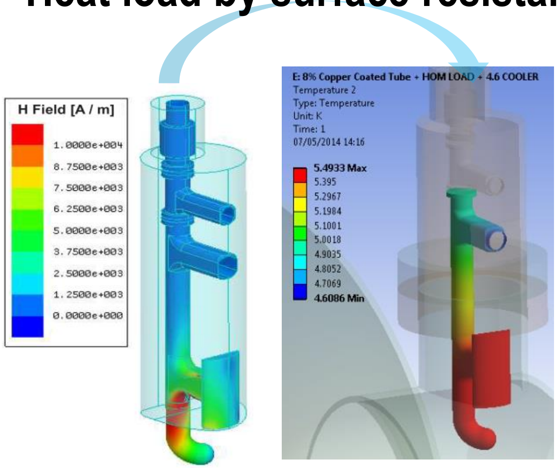
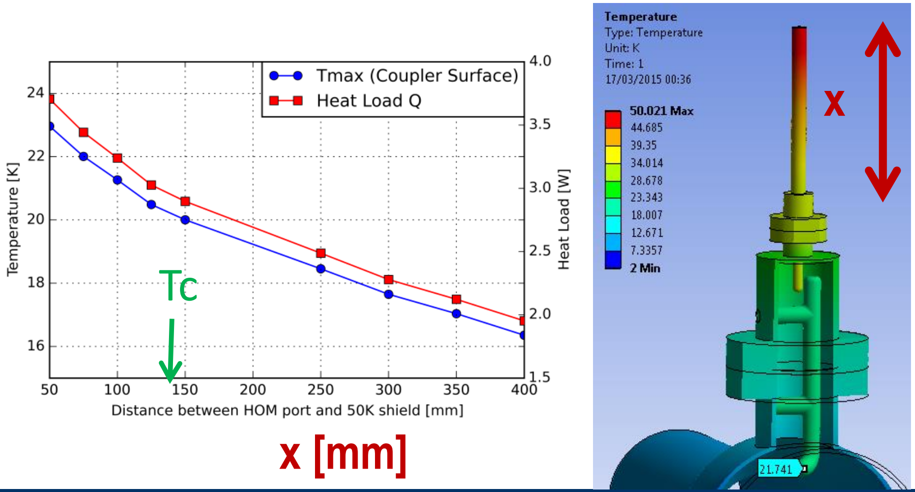
Heat Loss Investigation

- Coupled Simulation performed by HFSS (EM Field calculation) and ANSYS result in moderate (a heat flow of <100 mW at the outer tube surface is sufficient to keep the coupler superconductive)
- Heat load due to the feed through dominates and results in several watts for the heat sink (~3W) around the coupler tube

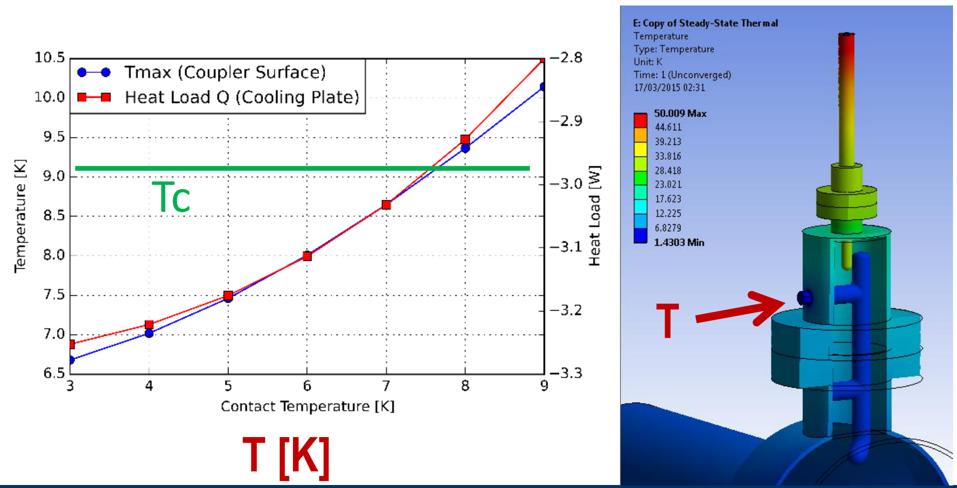
Heat load by surface resistance



Heat load by feed through without cooling



Heat load by feed through with cooling



Summary and Outlook

- 1st prototype successfully tested and verified the RF simulations
- Further Investigations and verification for multipacting barriers
- 2nd 3D printed prototype will be tested on a the copper SPL cavities (HOOK V3) for comparison
- Bulk copper prototype foreseen for warm and cold tests, tuning tests, contraction analysis, vacuum leakage test and multipacting location
- Frequency and Q factor sensitivity of selected HOMs will be investigated for the high beta cavity using the tuning bench

Thank you for your attention