Cavity type BPM for the CLIC drive beam decelerator (concept)

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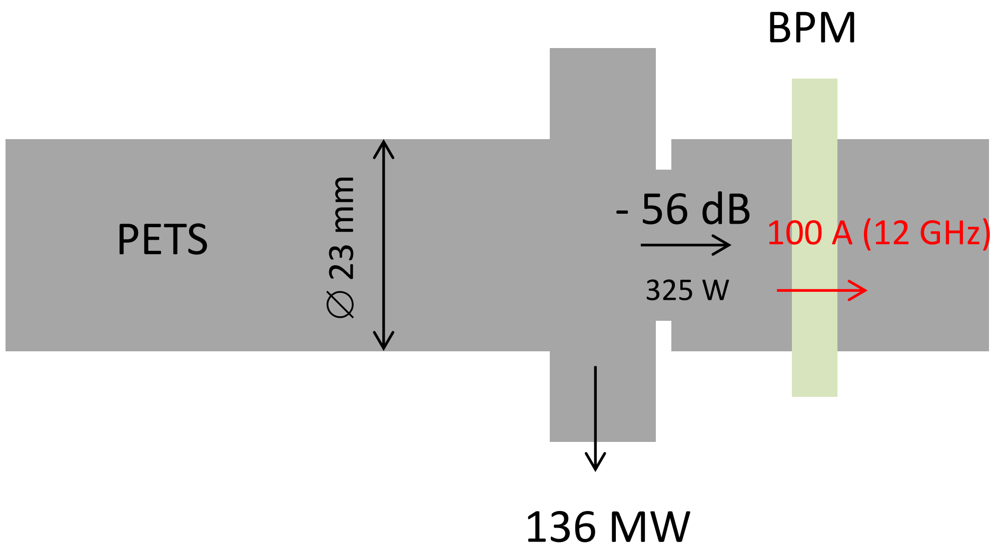
The main objective of the study was to provide design of the compact cavity BPM with submicron position resolution and <10 ns time resolution.

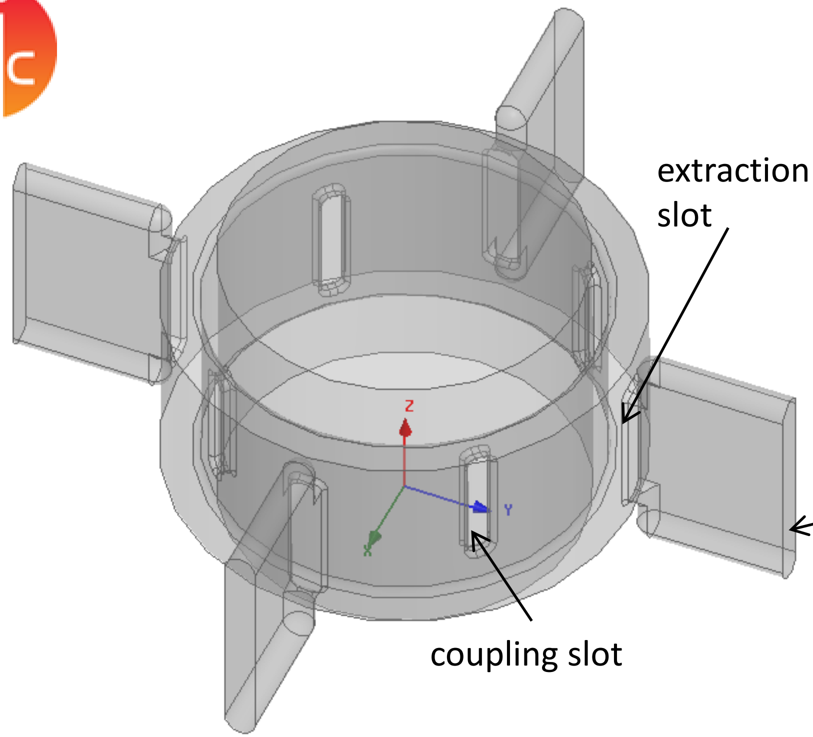


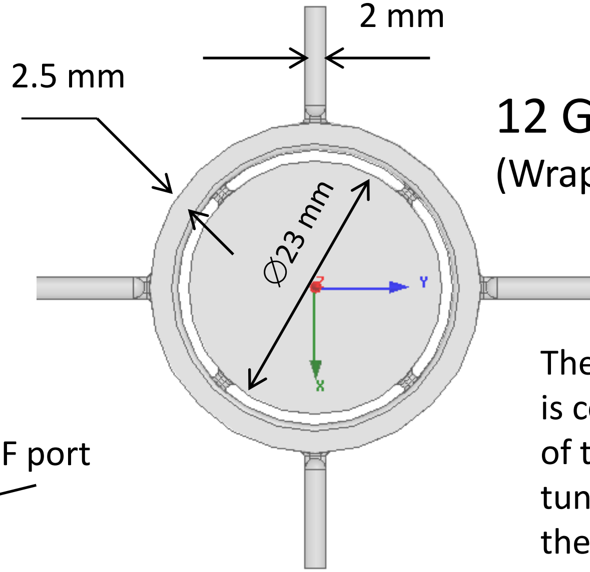
The Main challenges:

- The cavity BPM should operate at beam frequency (12 GHz). The use of higher harmonics (24,36 GHz....) does not look appropriate due to relatively big volume of the cavity. Thus the BPM design should provide extremely high isolation (< - 150 dB) of the RF power generated in the PETS itself.
- Beam aperture is extremely big (practically ~ wavelength). How to avoid the operation at the high radial number mode? For any possible cavity configuration, it is clear that the monopole mode frequency will be very close (few 100 MHz) to the operating one.

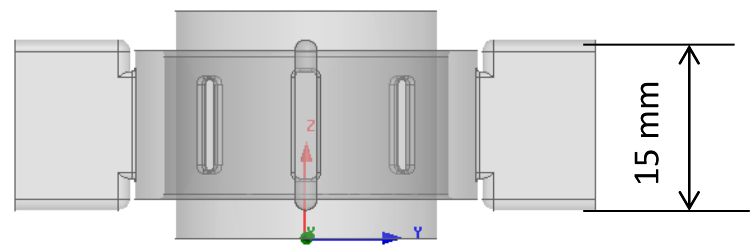
12 GHz PETS BPM concept.

(Wrapped around waveguide)

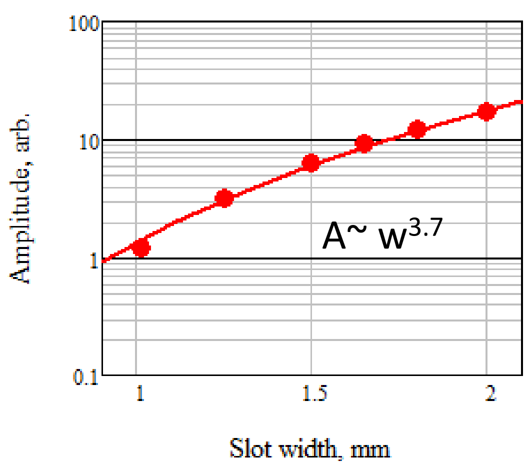




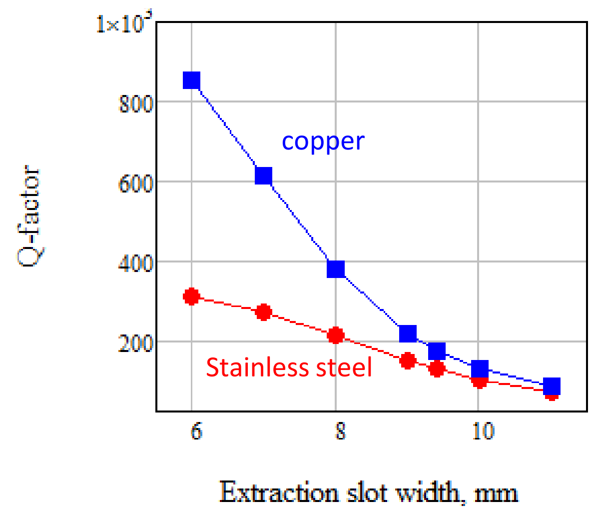
The external Q-factor of he cavity is controlled by the width/height of the extraction slot. It can be tuned in a very wide range (see the graph)



Dipole beam signal coupling (port signal amplitude) vs. coupling slot width



Using the symmetry properties of the modes, the longitudinal coupling and extraction slots can do the job.



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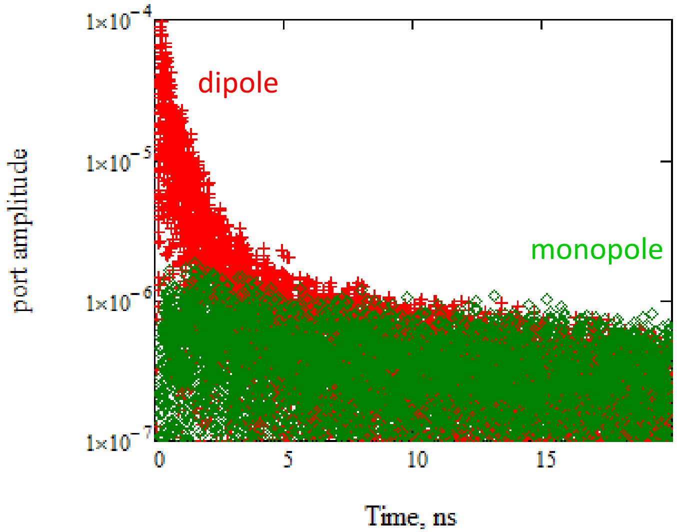
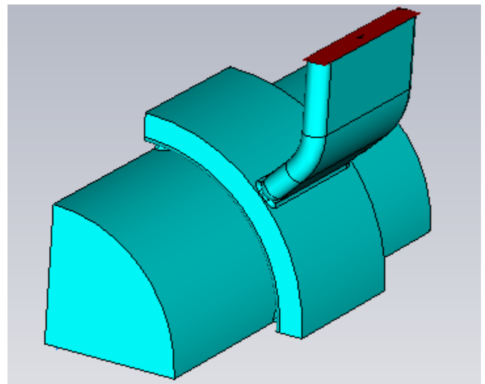
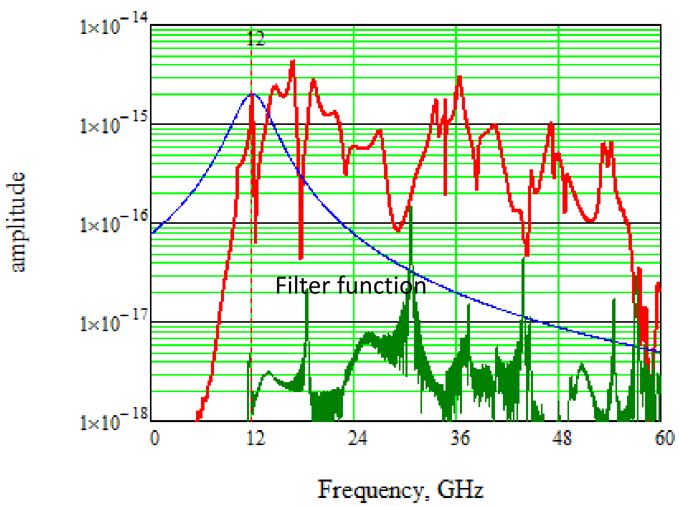
Simulations with beam

Port signals, single bunch

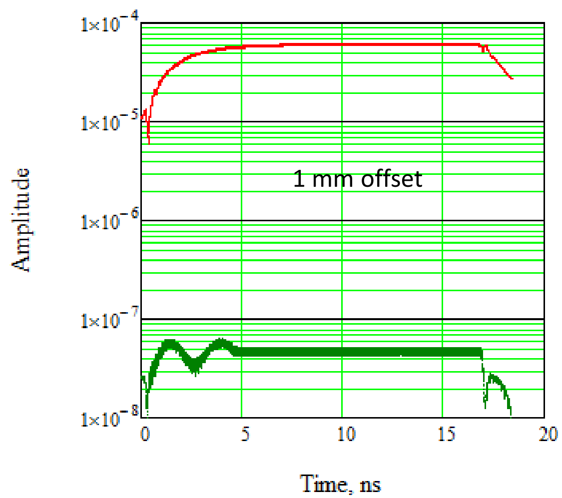


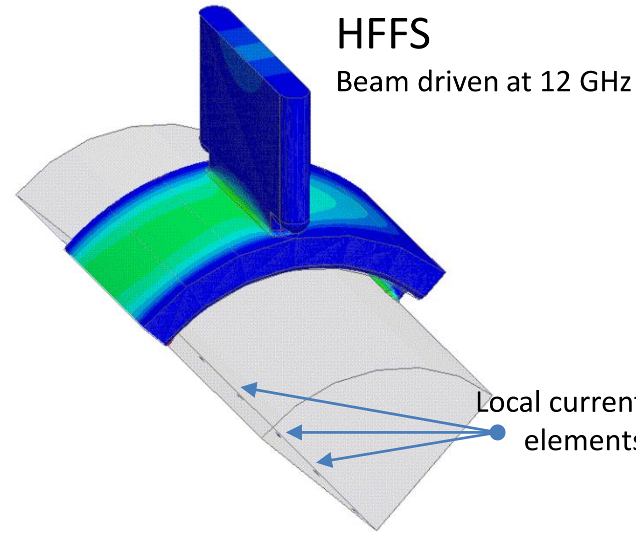
CST studio





Port signals (filtered)
Multi-bunch at 12 GHz





- Big cavity volume results in the rather dense dipole modes spectrum. Special care should be taken (the cavity shape, damping?) to avoid resonant conditions at harmonics of 12 GHz.
- Beam driven simulations showed that <0.7 μm resolution can be achieved.
- BPM has very low beam impedance (wakefields).
- For given design the transient time is about 6 ns.

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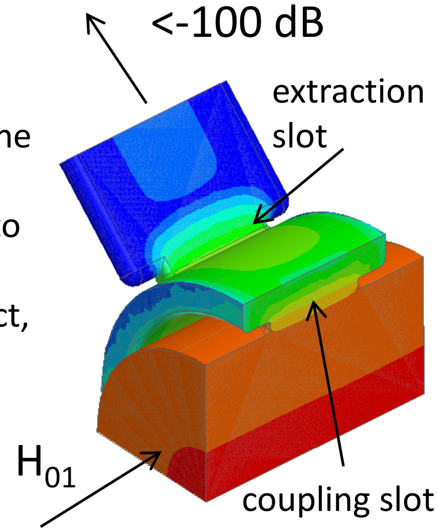
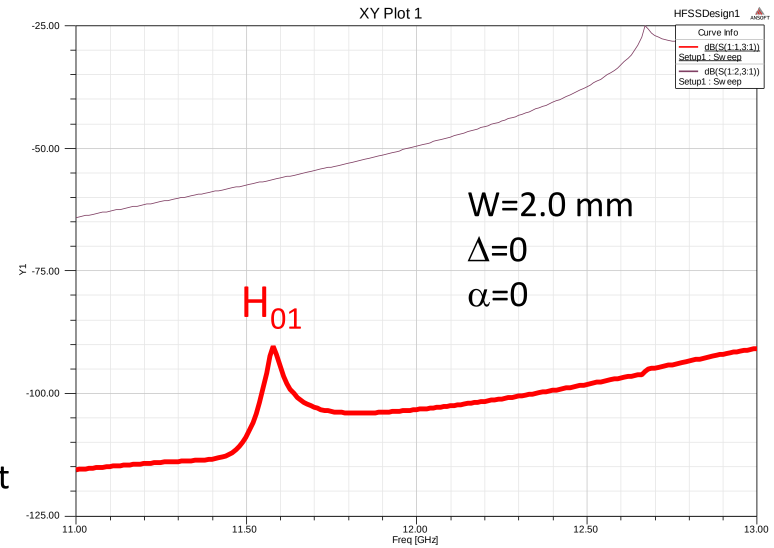
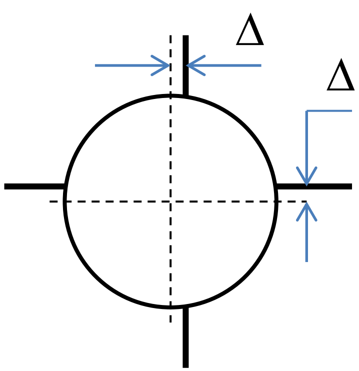
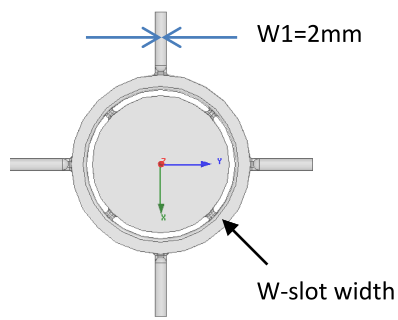
Symmetrical mode (H_{01}) isolation #1

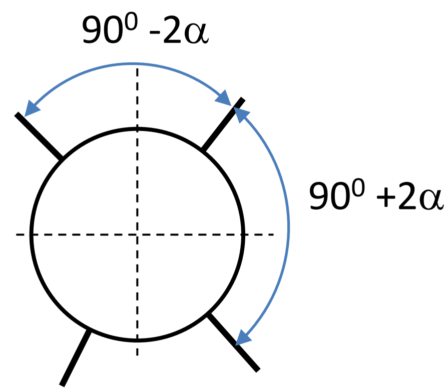
Isolation of the H01 mode follows the coupling and extraction longitudinal slots arrangements, when the symmetry of the mode allows for extremely high mode rejection. Normally this method is sensitive to the fabrication errors. In our case, the high group velocity in the circular waveguide reduces this effect, so that even rather coarse errors can be accepted.











Δ =0.5mm -90.6 dB ← W=2.0 mm: - 104 dB

W= 1.5mm: - 115 dB → α =1.0^0: -100 dB

W=1.0 mm: - 125 dB

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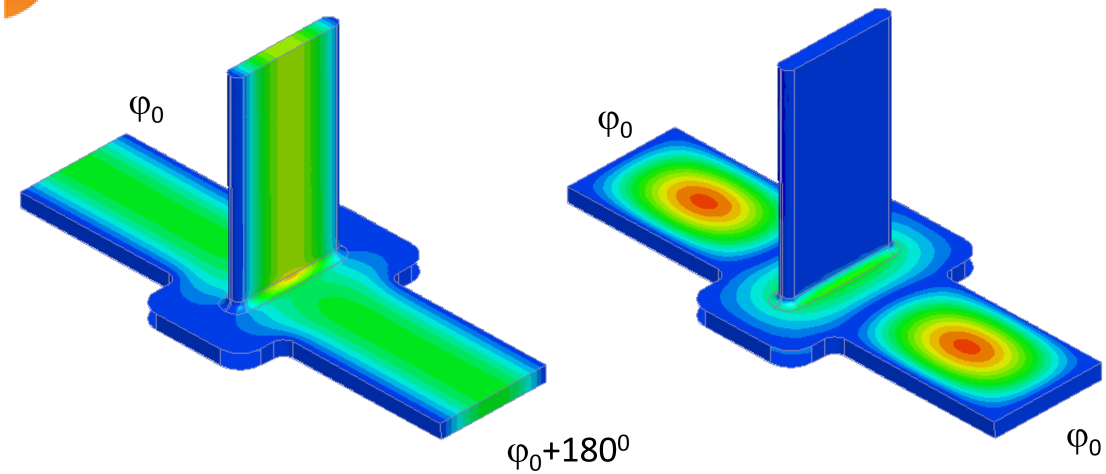
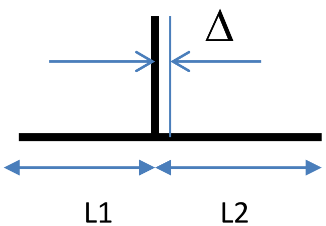
Symmetrical mode (H_{01}) isolation #2

Dipole mode (extraction) monopole mode (rejection)

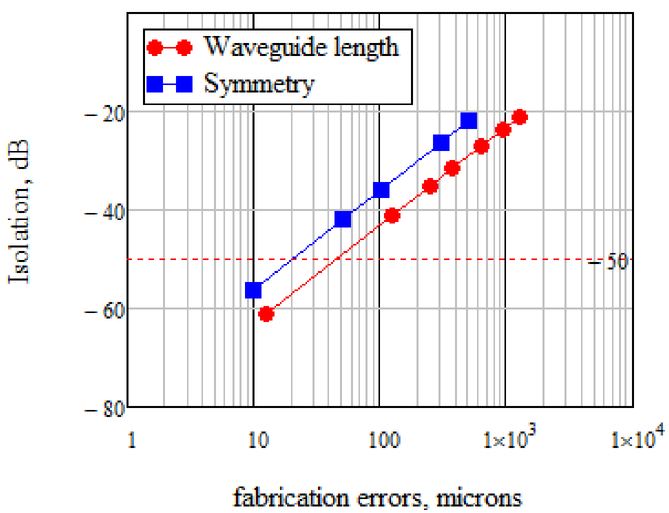


- Together with PETS coupler isolation (-56 dB) and slot symmetry (-100 dB), the overall rejection of the generated RF power in PETS technically could be less than -200 dB (10^{-12} W).

- The same arguments can be used for the beam position detection, when the common mode signal will be reduced by at least 100 times (- 40 dB) at 12 GHz. Thus the nanometre range resolution can be obtained or/and the fabrication tolerances can be relaxed.



Effect of typical fabrication errors:
-Waveguide length: L1≠L2 (Δ=0)
-Symmetry; Δ≠0 (L1=L2)



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The proposed concept of the cavity BPM for the high frequency, big aperture ($2a/\lambda \sim 1$) application can provide submicron resolution in a presence of the strong RF background. Such a concept can be also adapted to the other applications.

As for the future development, next subjects should be addressed:
- Cavity design is needed to be revised to avoid the resonances at harmonics of 12 GHz.
-The coupling slot configuration (width and thickness) and slots number should be optimized to reduce further down coupling to the monopole mode.
- The extraction slots geometry and cavity material should be chosen following the required filling time.
- Fabrication errors analysis should be done, as well as integrated analyses including electronic equipment.