The Beam Phase Monitor for CLIC and CTF3

Pick-up Design

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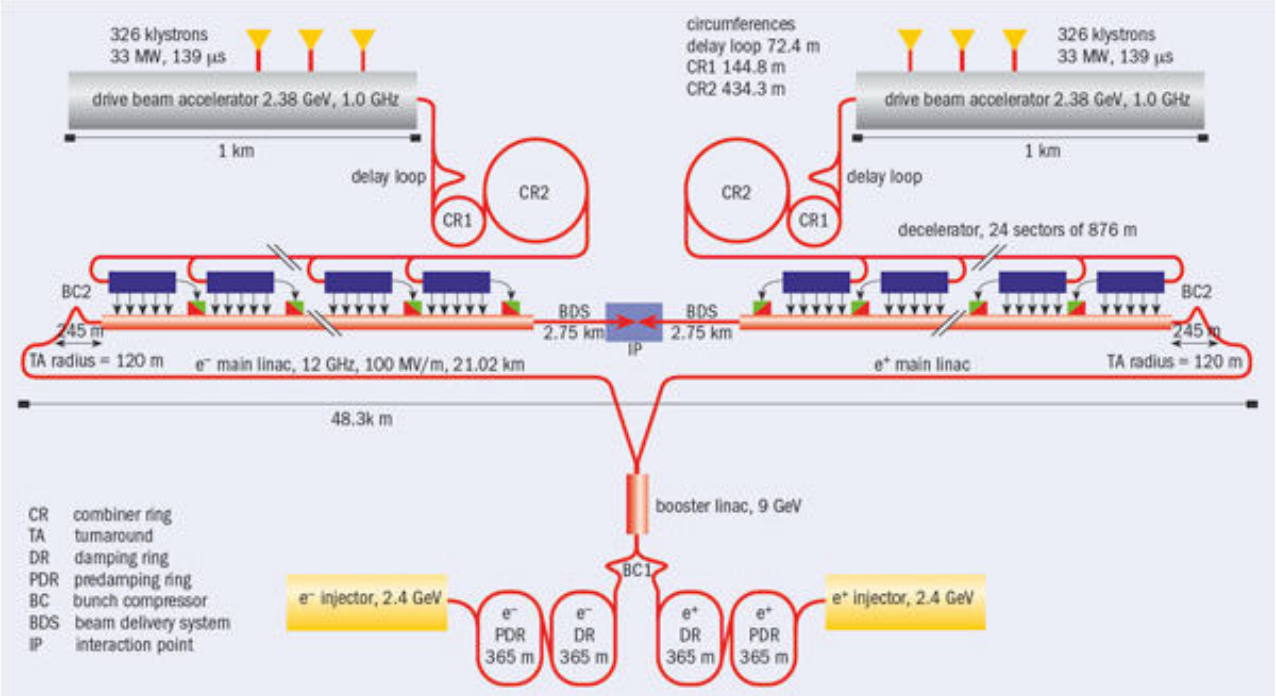
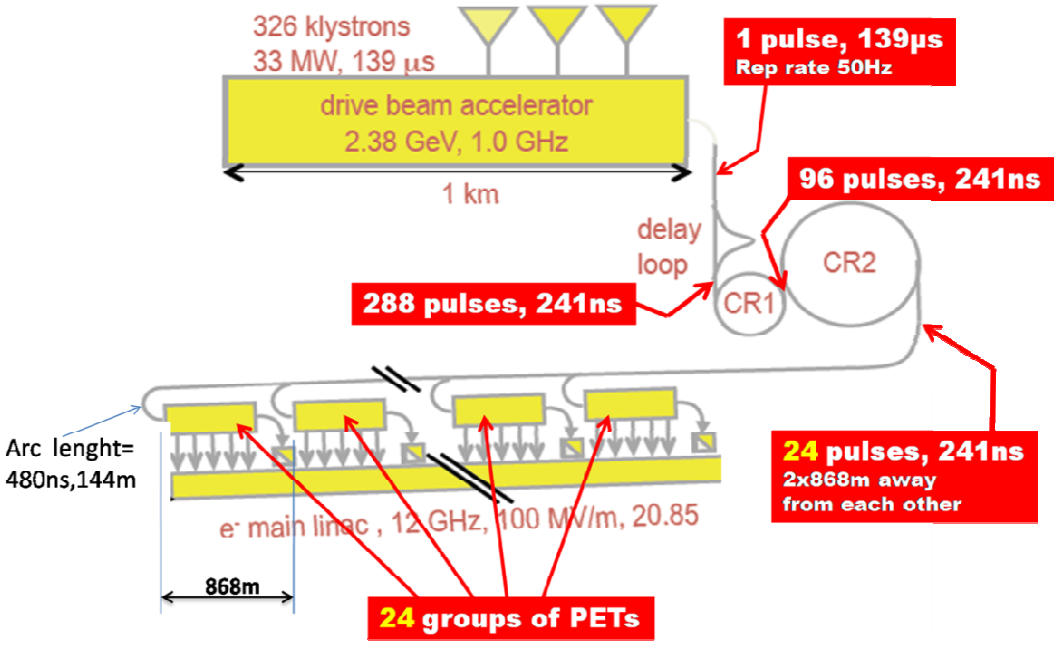
EuCARD
WP9: NC Linac
Task 5: Drive Beam Phase Control

Phase error control

- In the two beam acceleration scheme is important to synchronize precisely the Main Beam with respect to the RF power produced by the Drive Beam.
- Timing errors lead to energy variations in the Main Linac and would have an impact on the collider performance (luminosity reduction).



- Control of the drive beam phase errors within about 0.1° (23fs @ 12GHz).
- Feedback and/or feedforward systems needed.
- Time measurements of both beams, comparison and correction of the Drive Beam phase (correction with RF deflectors, fast kickers, varying the energy before the final drive beam bunch arcs…).



Drive beam phase control system

Each pulse coming out of the CR2 goes into a different decelerator group.

Possible solution:
Separate longitudinal feedforward for each group of decelerators.
Rep rate 50Hz.

System bandwidth requirements:

- Supposing detection and correction of Drive Beam phase jitter respectively before and after the arc, the available time to correct the phase of each pulse as a whole is, at least, the time for covering the arc (480ns).
- For intra-pulse phase correction within the 241 ns pulses, should be much faster.
- Upper limit is the Main Linac accelerating structure filling time (they could not follow faster variations of the input RF). $\tau_{f\ mainlinac}$ **= 20÷30ns**

A **beam phase arrival monitor** is essential component of the system.

Phase monitor main requirements

- Resolution of the order of 20 fs.
- Very low coupling impedance due to the high beam current.
- Rejection, by means of proper designed filters, of RF noise and weak fields in the beam pipe that otherwise could affect the measurements.
- Detection is done at 12 GHz.
- $\tau_{f\ monitor} \approx 10ns = 2Q/\omega \rightarrow Q \approx 380$, BW $\approx 30MHz$.

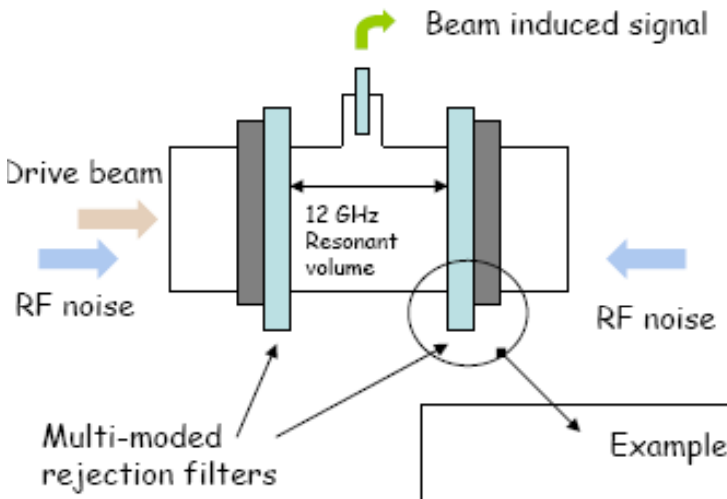
Prototype pick-up design

- The design of a possible pick-up has started.
- It could be tested in the CTF3 and installed in the chicane region, before the Delay Loop, where the vacuum pipe diameter is 40mm.
- Design followed the concepts already developed by **Igor Syratchev**.

12 GHz low impedance noise-free pick-up concept

Igor Syratchev

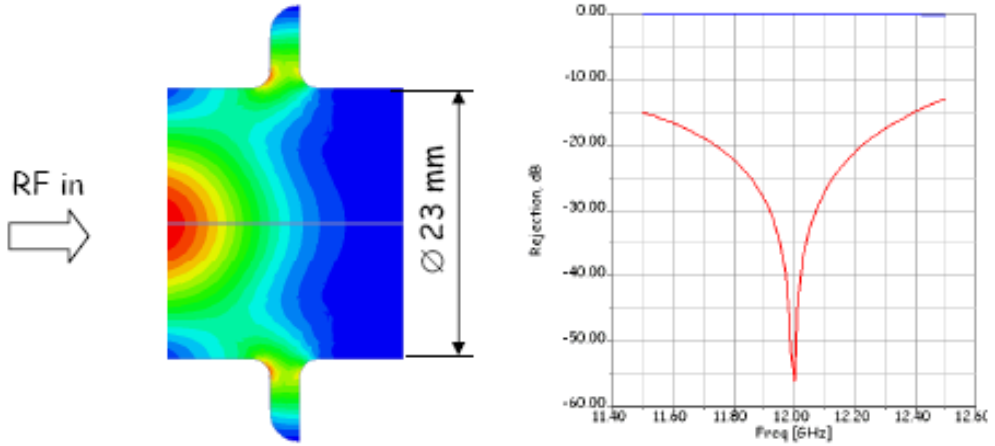
Schematic view of the 12 GHz pick-up concept



Considerations:

1. We have to keep big aperture of the pick up (I used 23 mm – similar to one in the PETS).
2. Low impedance!
3. The sensitivity of the device will depends on the RF nose rejection level
4. We need a resonant volume anyway (Q loaded to be defined)

Example: TM01 choke-type rejection filter

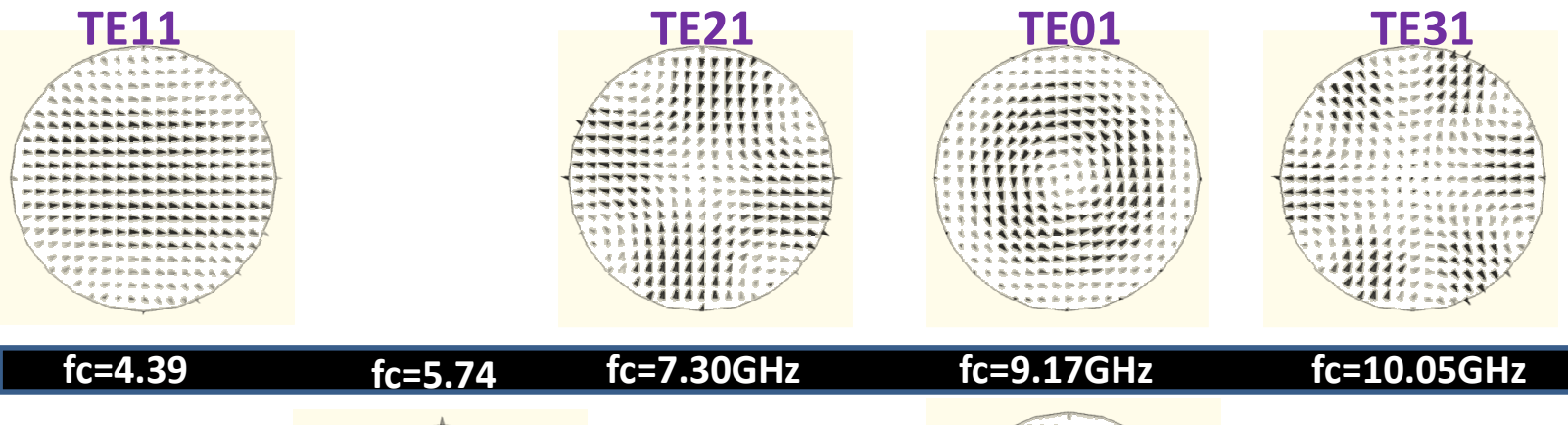


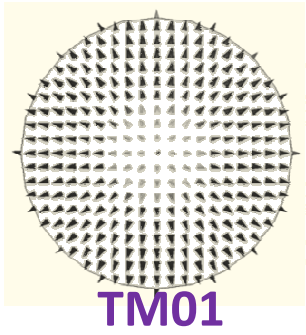
RF noise and wakefields

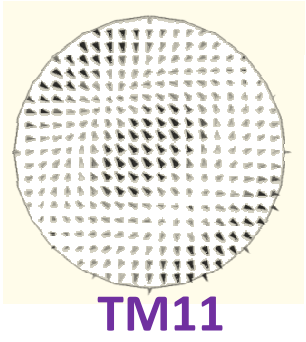
At 12 GHz, 6 modes can propagate in a Ø=40mm pipe.

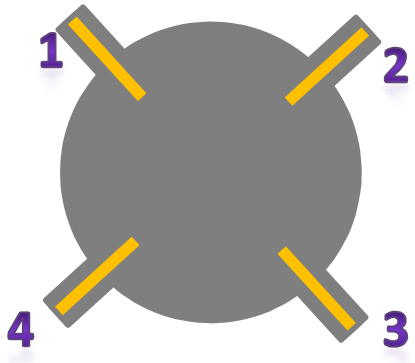
A smaller pipe cross section would be useful to reduce the no. of modes.

Pick-up must reject the RF noise propagating in any possible combination of them.









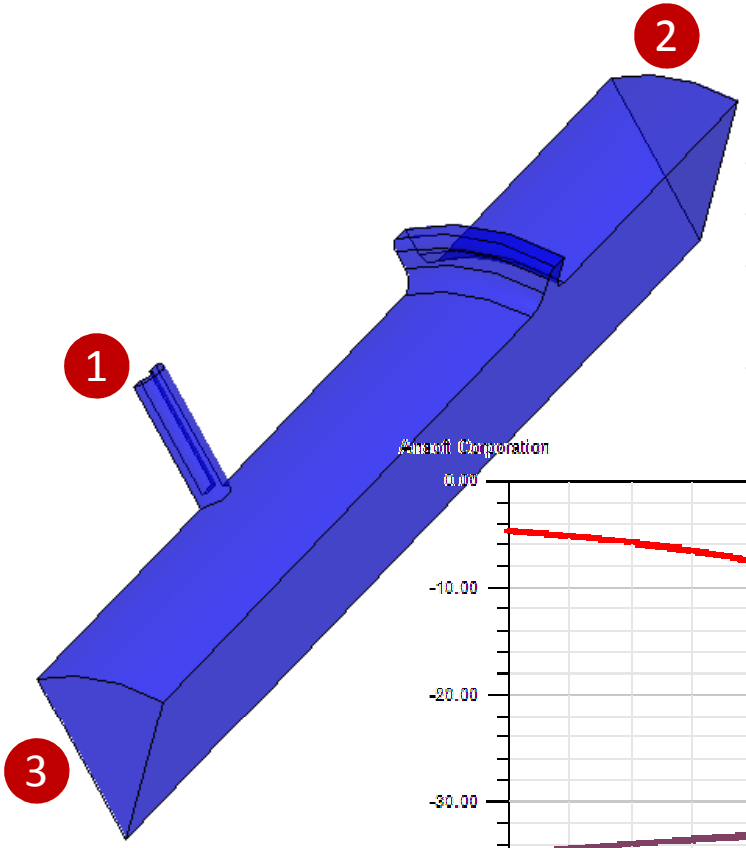
V1+V2+V3+V4 { ≠ 0, TM01

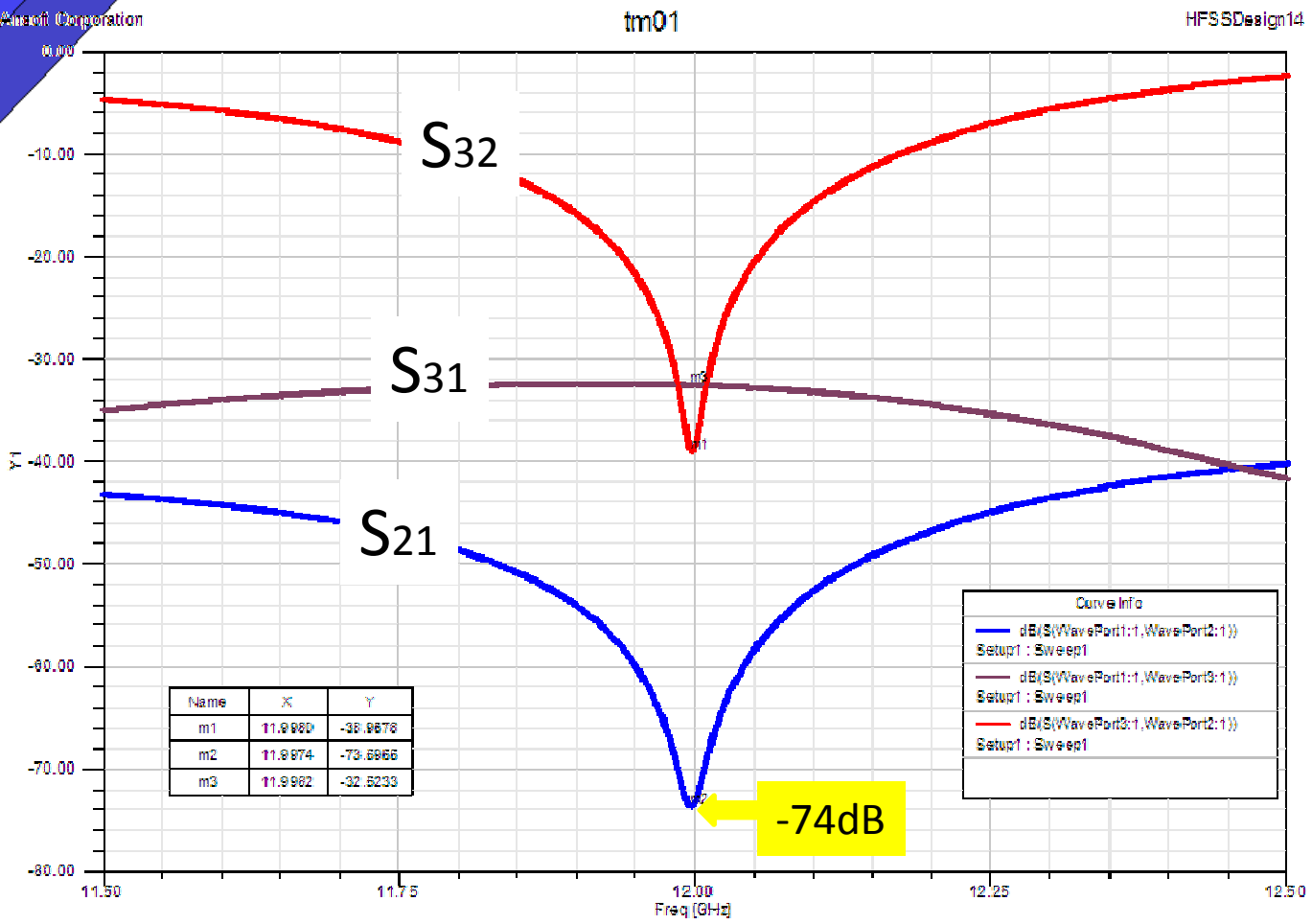
= 0 , TE11, TE21, TE01, TM 11, TE31

This could be a first partial filtering

Notch filter for TM01

- Centered at 12 GHz, rejection is ≈-40dB.
- Pipe to single antenna coupling ≈ -45dB.
- Different kind of signal pick-up than coax antenna can be considered. Example: waveguide inserted in the pipe.
- No rejection of the other 5 modes in this frequency span.





The “double mirror”

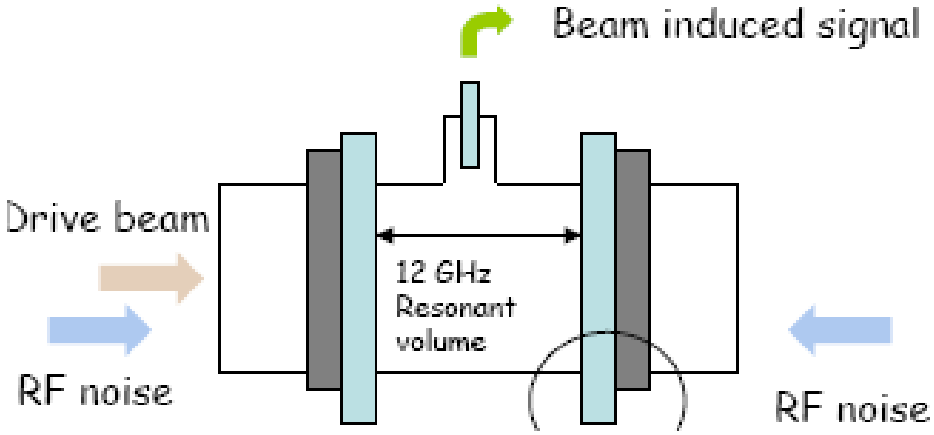
RF noise has to be filtered at both the pick-up sides.

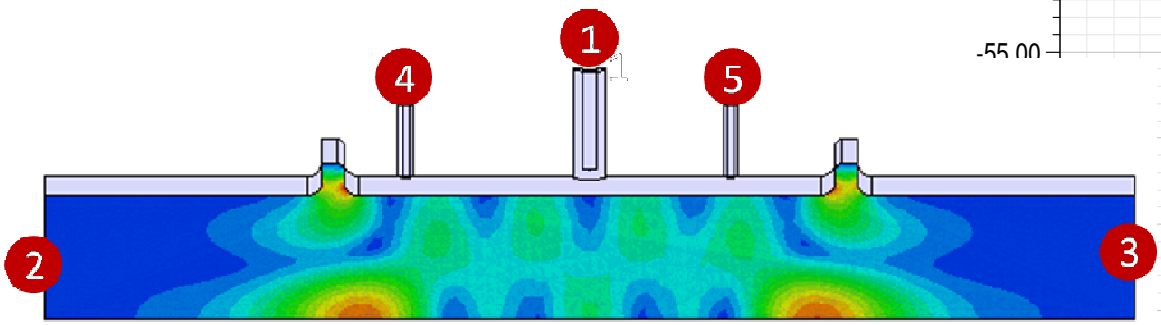
12 GHz component of beam generated field after the first filter could be reflected back by the second filter and detected again.

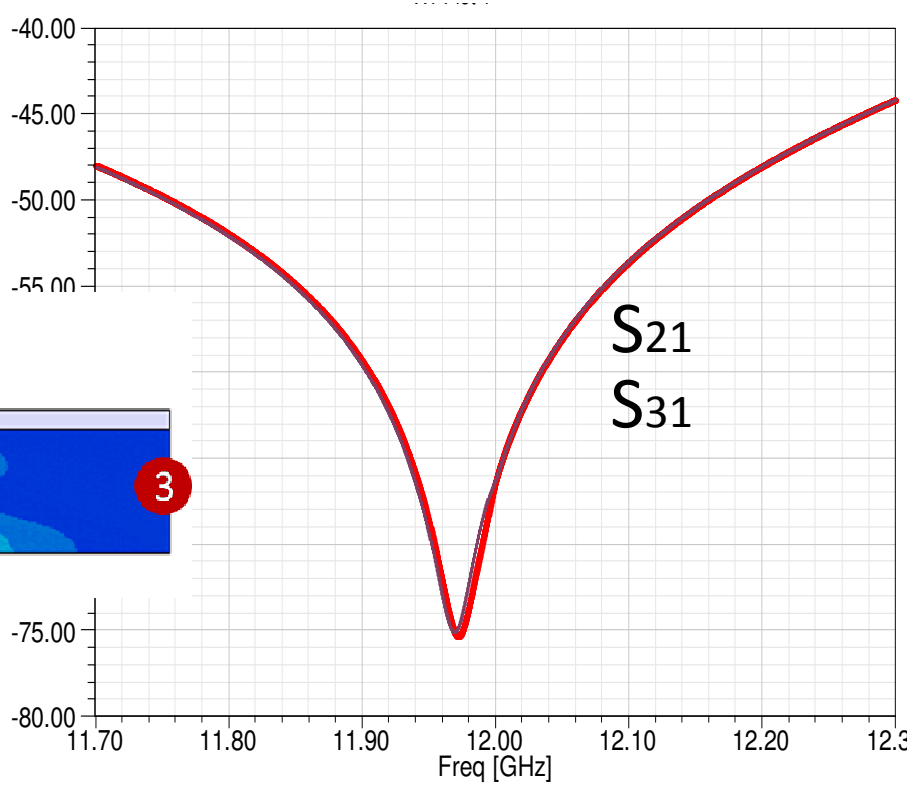
Multi-reflection process could start and affect measurement.

Unless the distance between the filters is chosen to define a volume resonating at 12 GHz.

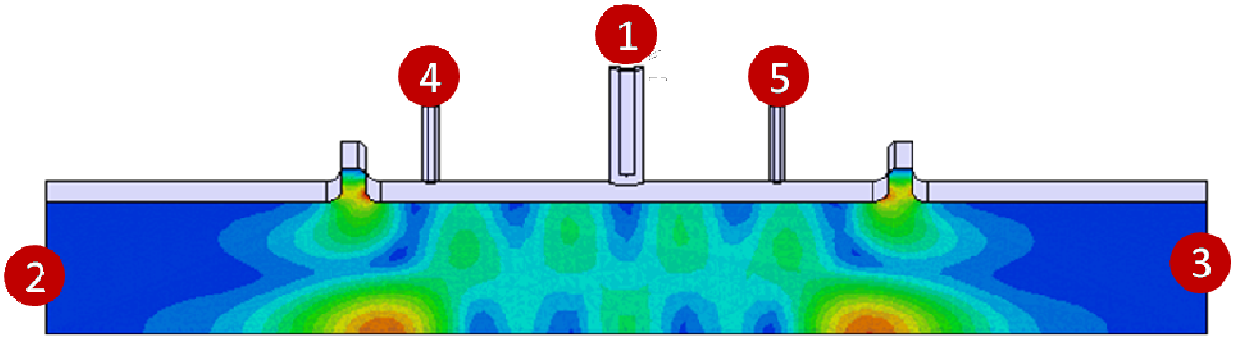
The pick-up is positioned in correspondence of zero crossing standing wave field.



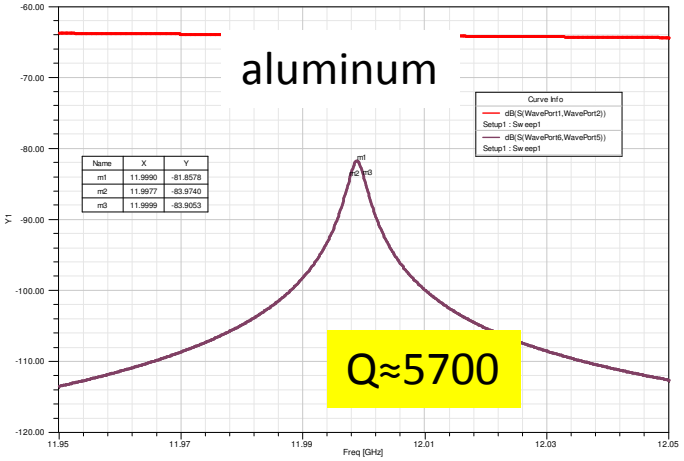


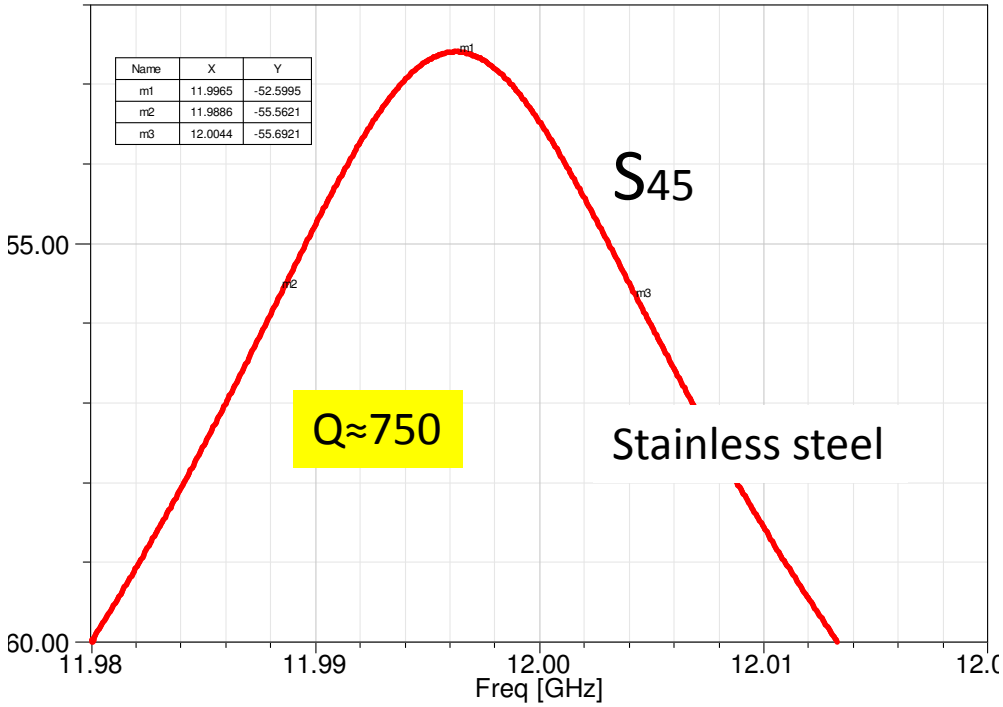


The pick-up output is of the order of few Watts, when the beam current is of the order of tens of Ampere.



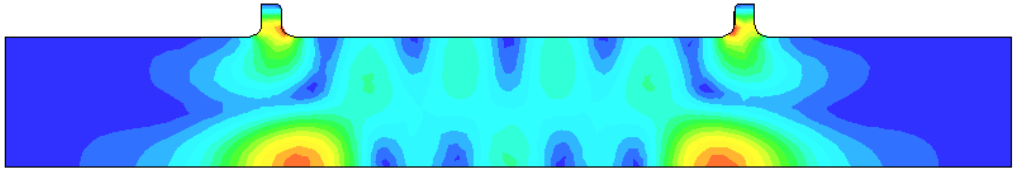
Q evaluation



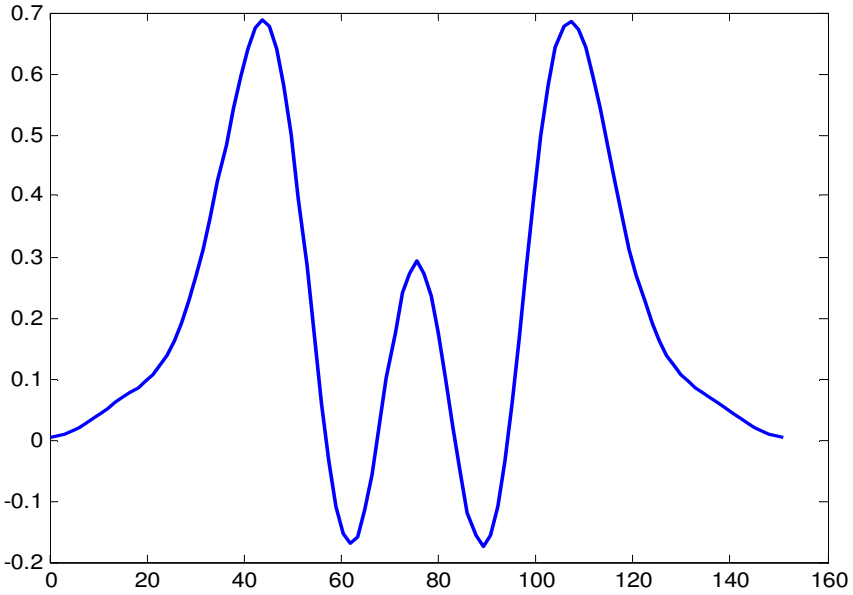


If a larger BW is necessary Q could be further lowered deteriorating the monitor surfaces roughness or introducing damping.

Impedance evaluation



field generated by the beam at 12 GHz



Longitudinal component of E field along the axis structure

R/Q=10.2 Ω

Average dissipate power ≈ 30W, @I=30 A

A more exhaustive impedance evaluation has to be performed. Take into account beam/structure interaction at all the frequencies. Needs of appropriate codes (GdfidL).

Further filtering of the modes other than TM01 with notches

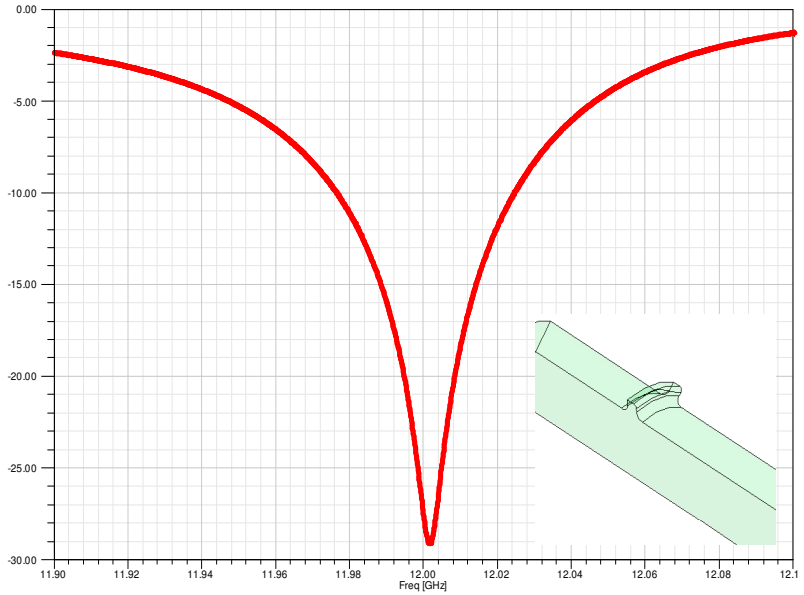
Is rejection of TE11, TE21, TE01, TM11, TE31 by out of phase combination of the 4 ports outputs enough?

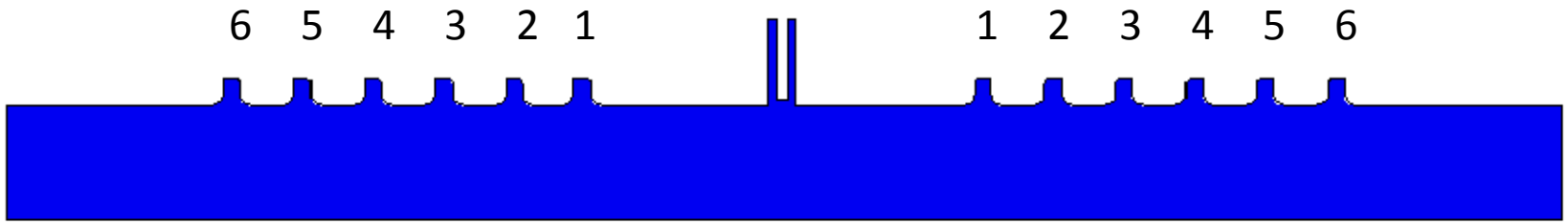
What is the contribution of differences in the 4 channels (antenna couplings, misalignements and asymmetries, cables, combiner,...) ?

Dedicated filters for each one of these modes could be necessary.

The plot shows the retuned filter geometry for notching the TE21 mode.

Notch retuned for TE21





This could be the final layout of the monitor

How choose the distances between notch pairs?
Have them to define resonant volumes like in the the case of TM01?
In principle TE modes should not be excited and TM11 is excited only in case of off axis trajectory.

Next steps

- Complete the design
    1. Study for multimode notch filters
    2. Impedance evaluation
    3. Fine tuning of Q, notch frequency and “cavity” frequency.
- Mechanical drawings
- Construction
- Lab tests and measurements

Still according to EuCARD task schedule.

Conclusion

- Importance of precise controlling the phase jitter of drive beam.
- Phase monitor essential component for feedforward or feedback systems.

- Pick-up design in progress.
- Main criteria fixed.
- According to the obtained results the adopted solution seems feasible.
- A lot still to do to get a detailed design ready for construction.

Thanks to Igor Syratchev, R. Corsini, D. Alesini, C. Biscari and A. Ghigo for very helpful discussions .