Considerations for a Cavity-Based Position-Sensitive Heavy Ion Detector for the CR at FAIR

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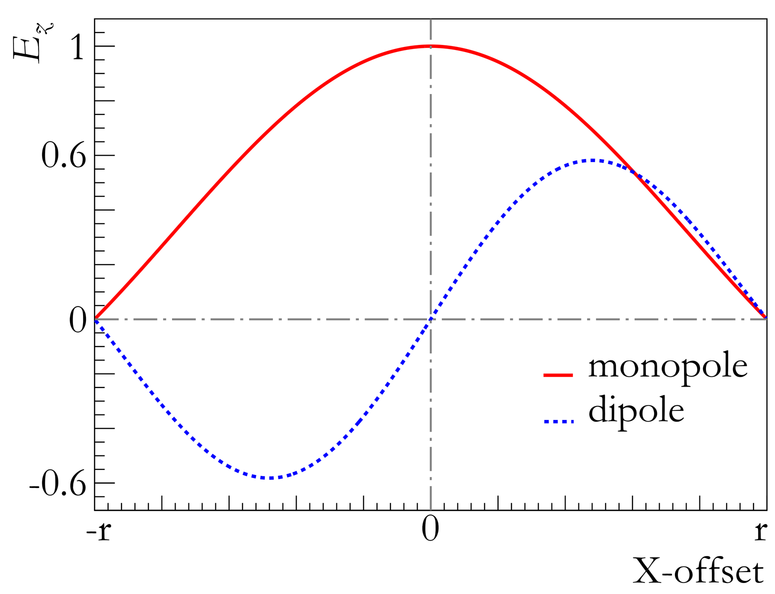
Introduction

The utilization of a resonant structure in design of beam position monitor (BPM) to enhance its sensitivity has a long history of more than half a century. Nowadays cavity-based BPMs, along with capacitive and strip-line monitors, are commonly adopted in many particle accelerators all over the world [1]. Their excellent performance in sensitivity makes them stand out from other types of BPMs, especially in the case of low-current beam monitoring. As an example, a resonant pickup for the detection of heavy ion Schottky noise was mounted into ESR at GSI not so long ago, and has demonstrated its ability of observing dynamic cooling processes of single ions [2]. Based on the previous experiences, we will keep on using cavity scheme for our next generation of heavy ion detector which can discriminate transverse offsets of stored particles in CR.

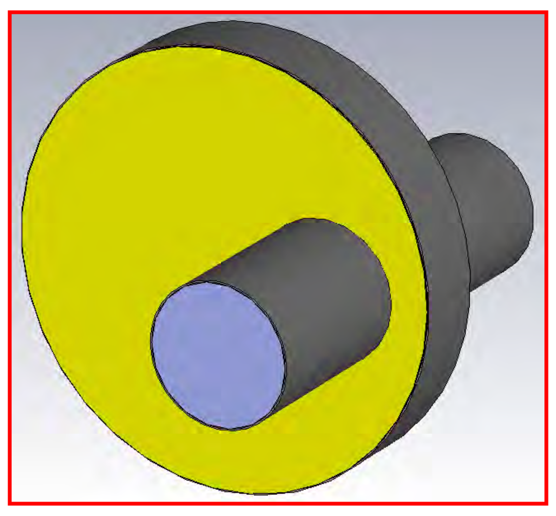
Figures of Merit

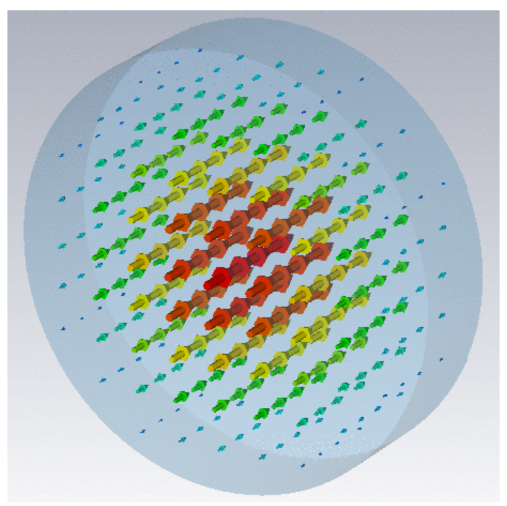
1) Resonant Frequency f_0
at which the standing EM wave resonates in the cavity, determined by cavity geometry
2) Quality Factor Q
reflects how good the cavity is in the sense of keeping EM field in a certain mode
3) Shunt Impedance R
measures the dissipated amount of stored energy given a voltage across two ends of the cavity, quantifies the coupling strength between the beam and the cavity
It is found convenient to use "reduced" shunt impedance R/Q in most cases, since it is material-independent and only determined by cavity geometry [3].

Design

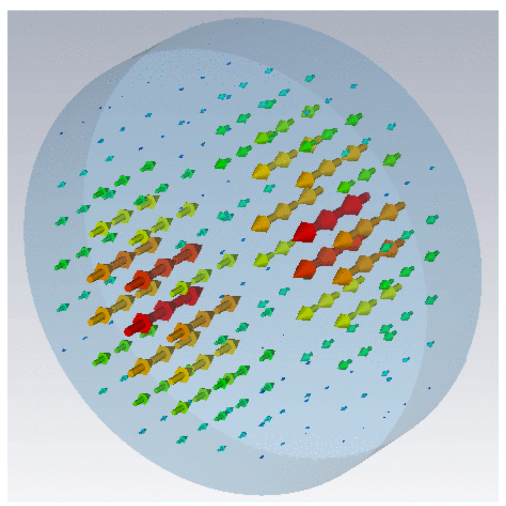


The sloping parts should be used for position detection, which leads to two general designs
1) using dipole mode with pipe on the cavity centre
2) using monopole mode with an off-centred pipe





Monopolar E field

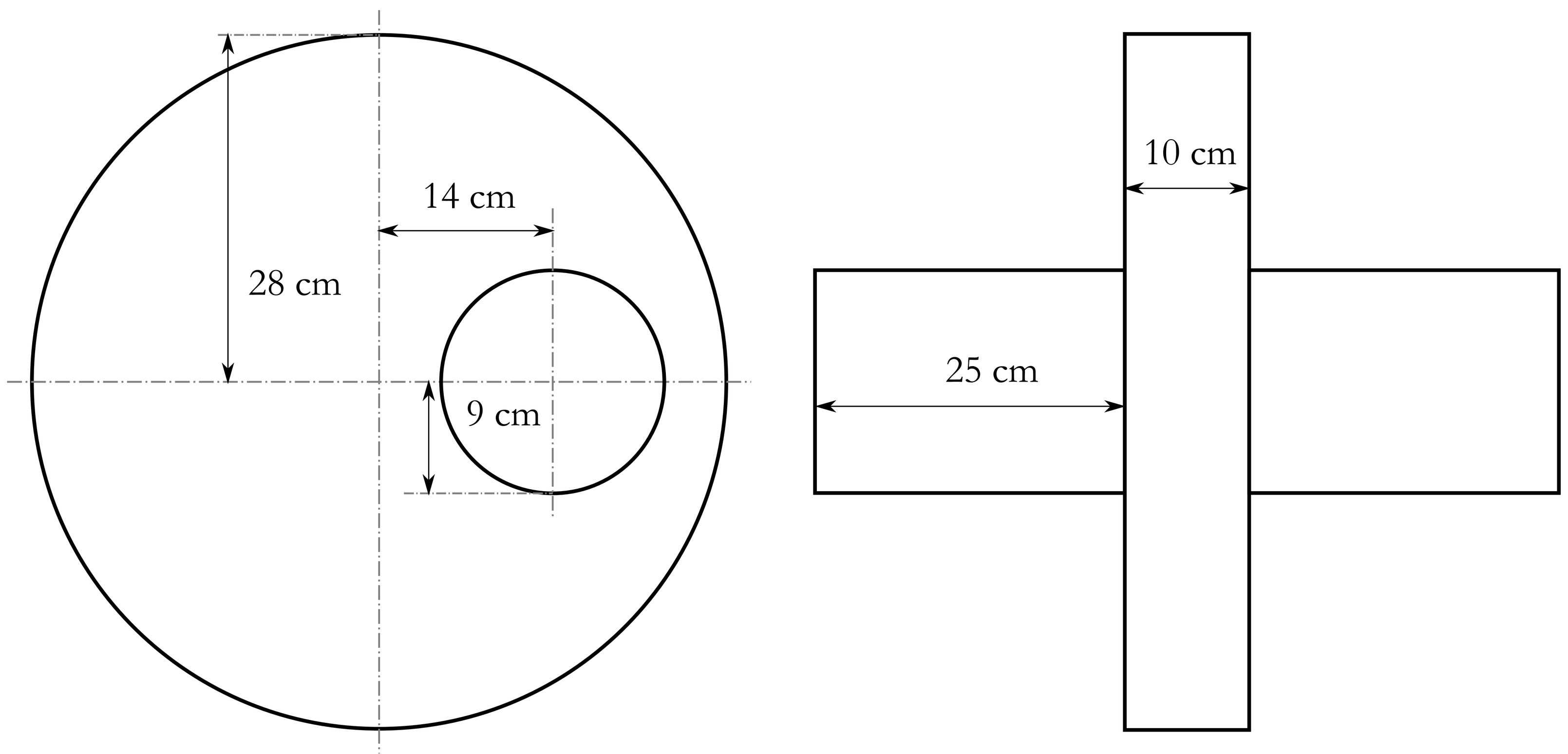


Dipolar E field

Since we are dealing with a large pipe opening and low-intensity beams, design 1 seems to be a great challenge in the following points
- weak coupling signal (noise suppression)
- strong inteference from monopole (parasitic modes elimination)

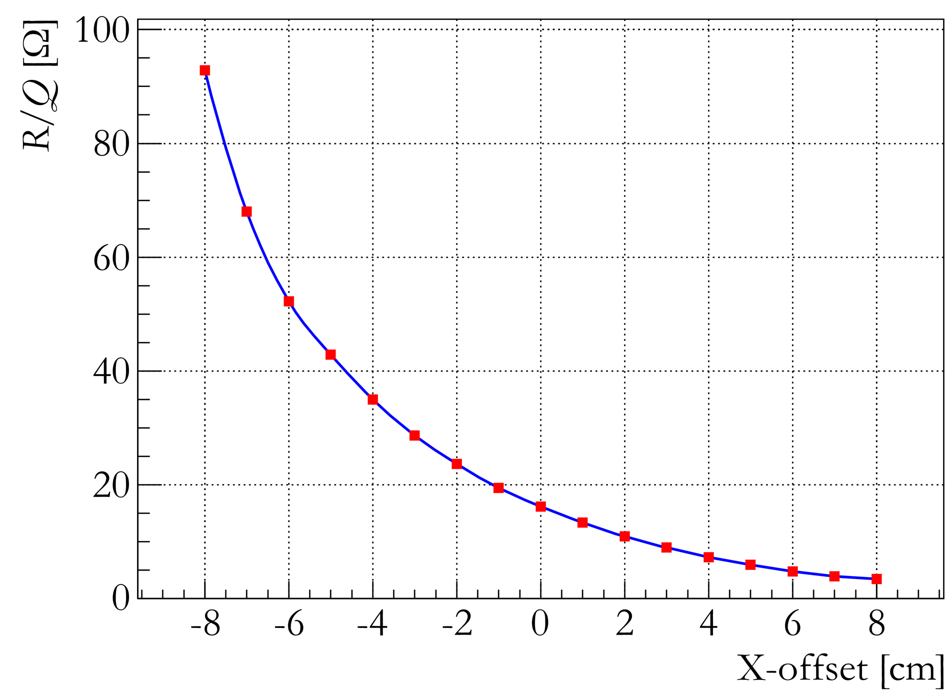
Consequently, we favor design 2 taking advantage of high shunt impedance in monopole mode [4].

Simulation



CST MICROWAVE STUDIO®
- f_0 = 409.77 MHz
- Q = 13673, lossy materials
- R/Q has an average change of 5.6 Ω/cm

A pair of such cavities are placed close but reverse. The transverse position of the beam can be interpreted from the difference of two channels of signals.



References

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