Development of a Transversely Sensitive Resonator as a Schottky Noise Detector for CR at FAIR

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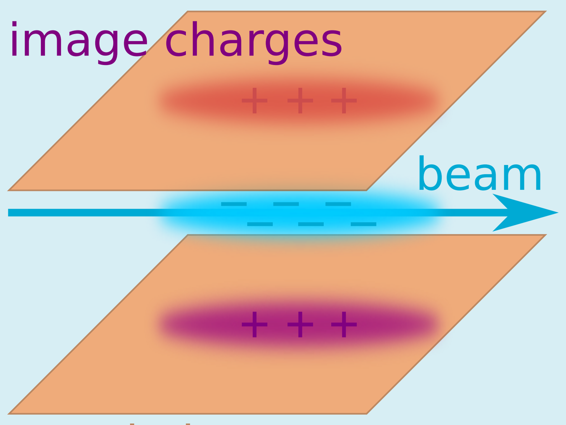
Schottky Noise

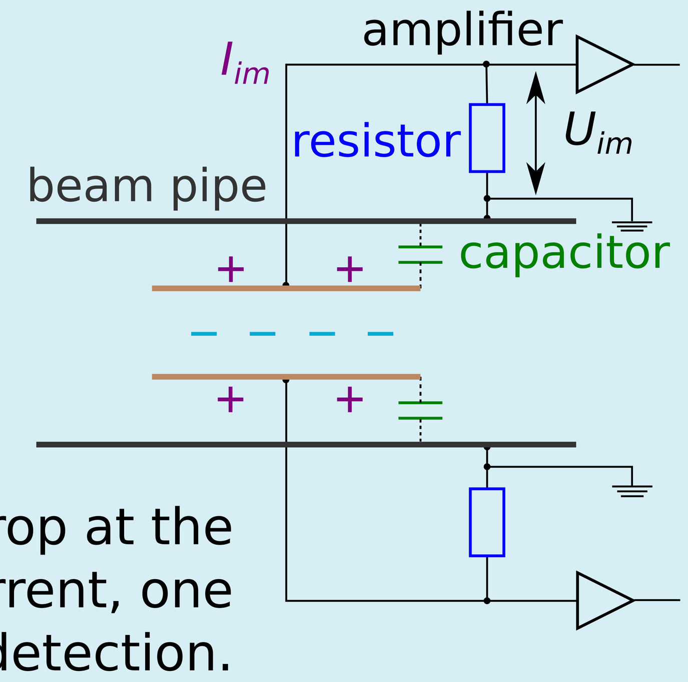
Schottky noise is named after Walter Schottky who conducted pioneering investigation on fluctuation in direct current [1]. The noise originates from the discrete nature of electric charge, thus relates to particle number in a beam. It may be dominant when the particle number is sufficiently small so that uncertainties of particle states, due to Poisson distribution, are significant.

Walter H. Schottky

Principle of Detection

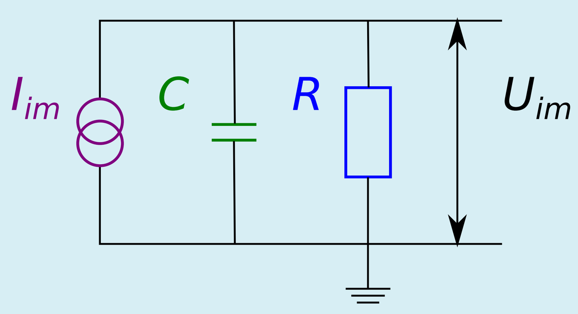


When a beam of charged ions passes through a pair of parallel metal plates, it will induce image charges on the surface of each plate [2].

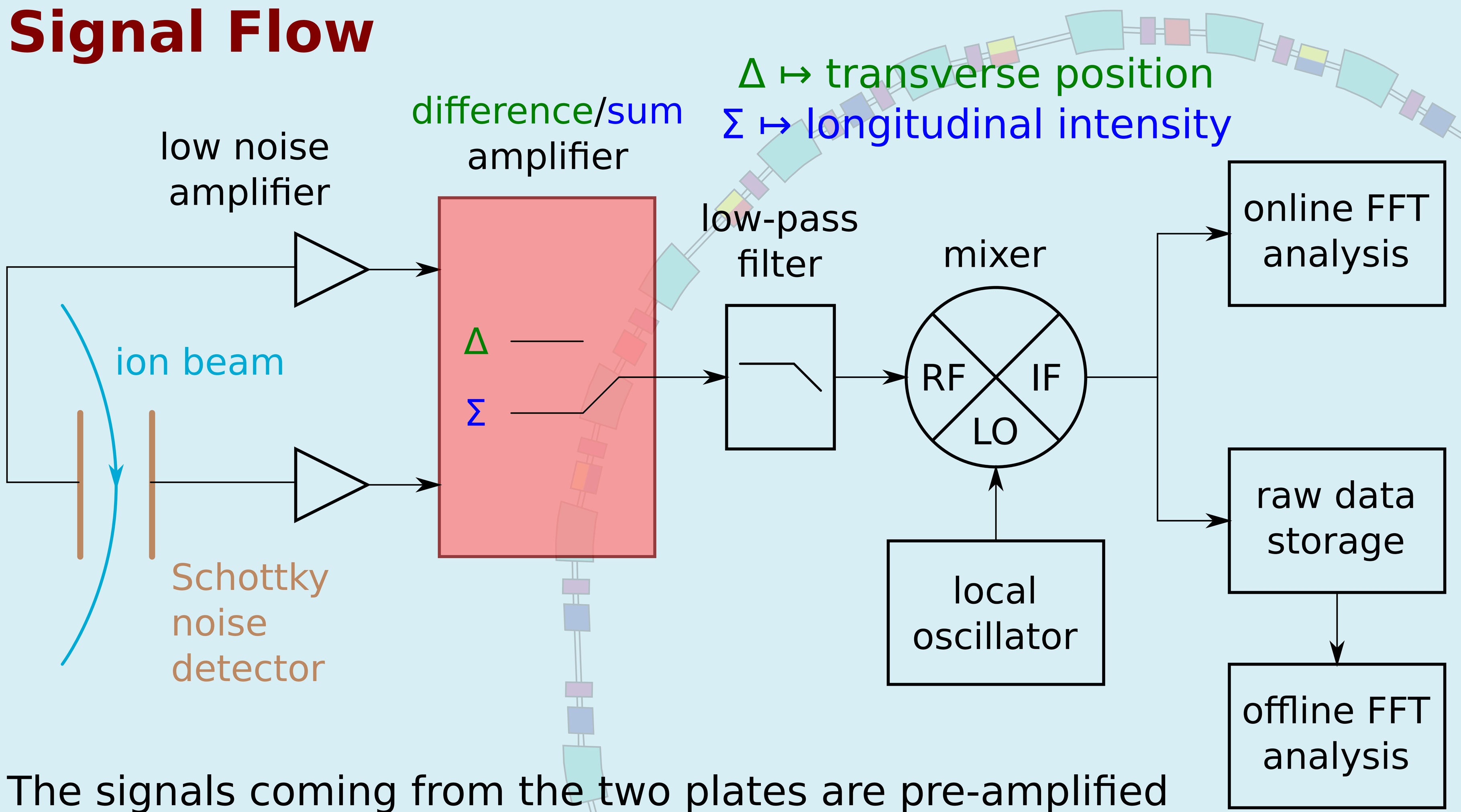


By measuring the voltage drop at the resistor caused by the image current, one can achieve a non-destructive beam detection.

Equivalent Circuit



Signal Flow



The signals coming from the two plates are pre-amplified by low noise amplifiers, then switched to either difference or sum amplifier, depending on specific purpose.

Capacitive Pickup

The photo presents one typical configuration of a capacitive pickup used as Schottky noise detector. It was designed by U. Schaaf in 1991 [3], and mounted into Experimental Storage Ring (ESR) at GSI.

The capacitive pickup is able to monitor both intensity and position of a beam, which makes it widely used in beam diagnostics, e.g. used as Beam Position Monitor (BPM).

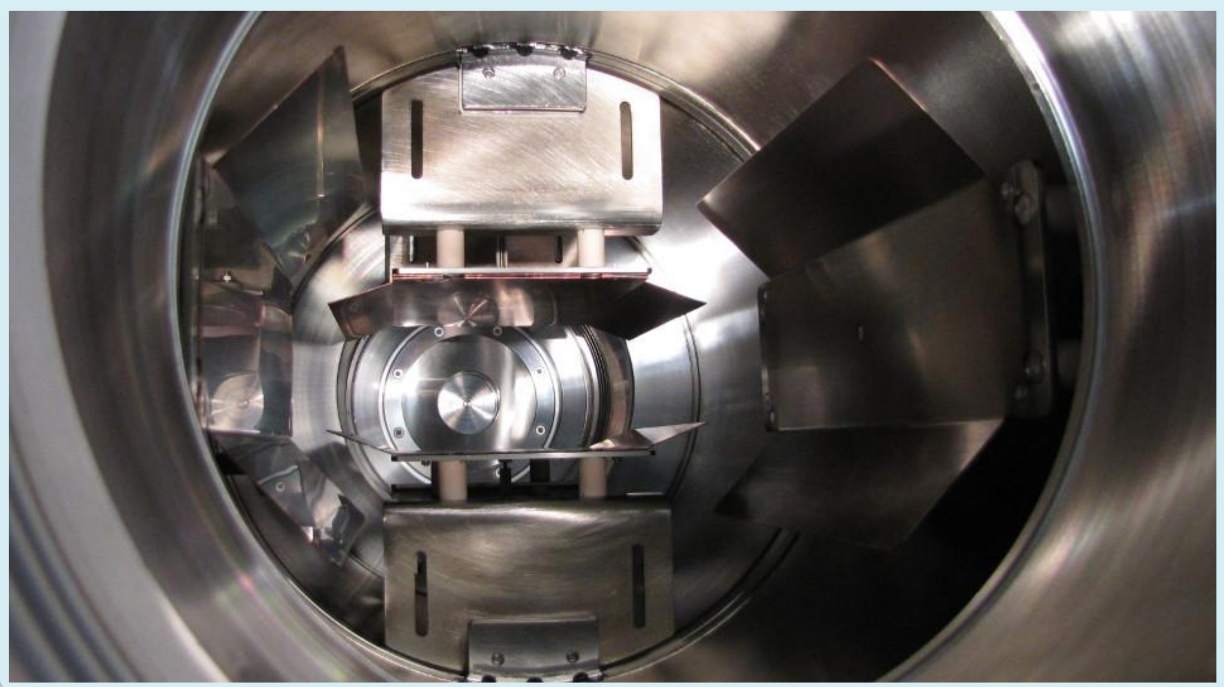


image courtesy of P. Petri

Pillbox Resonator

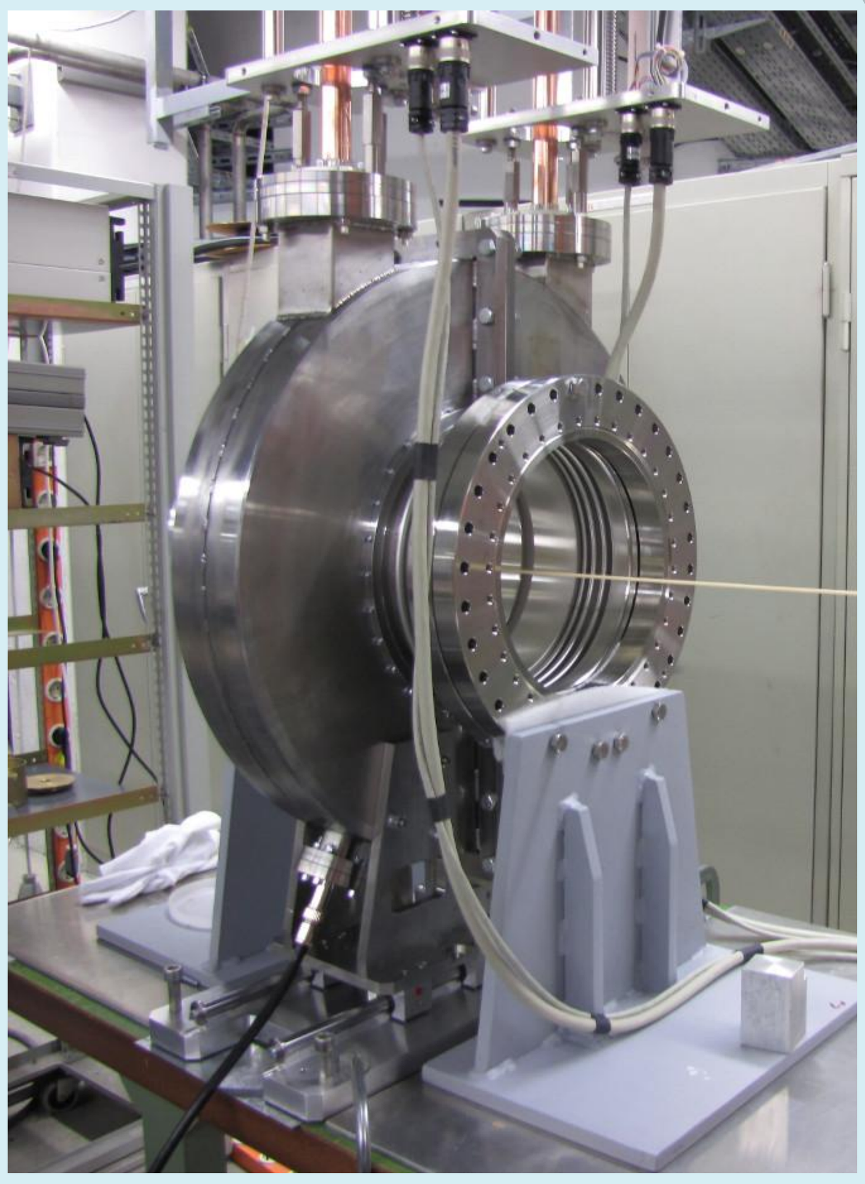
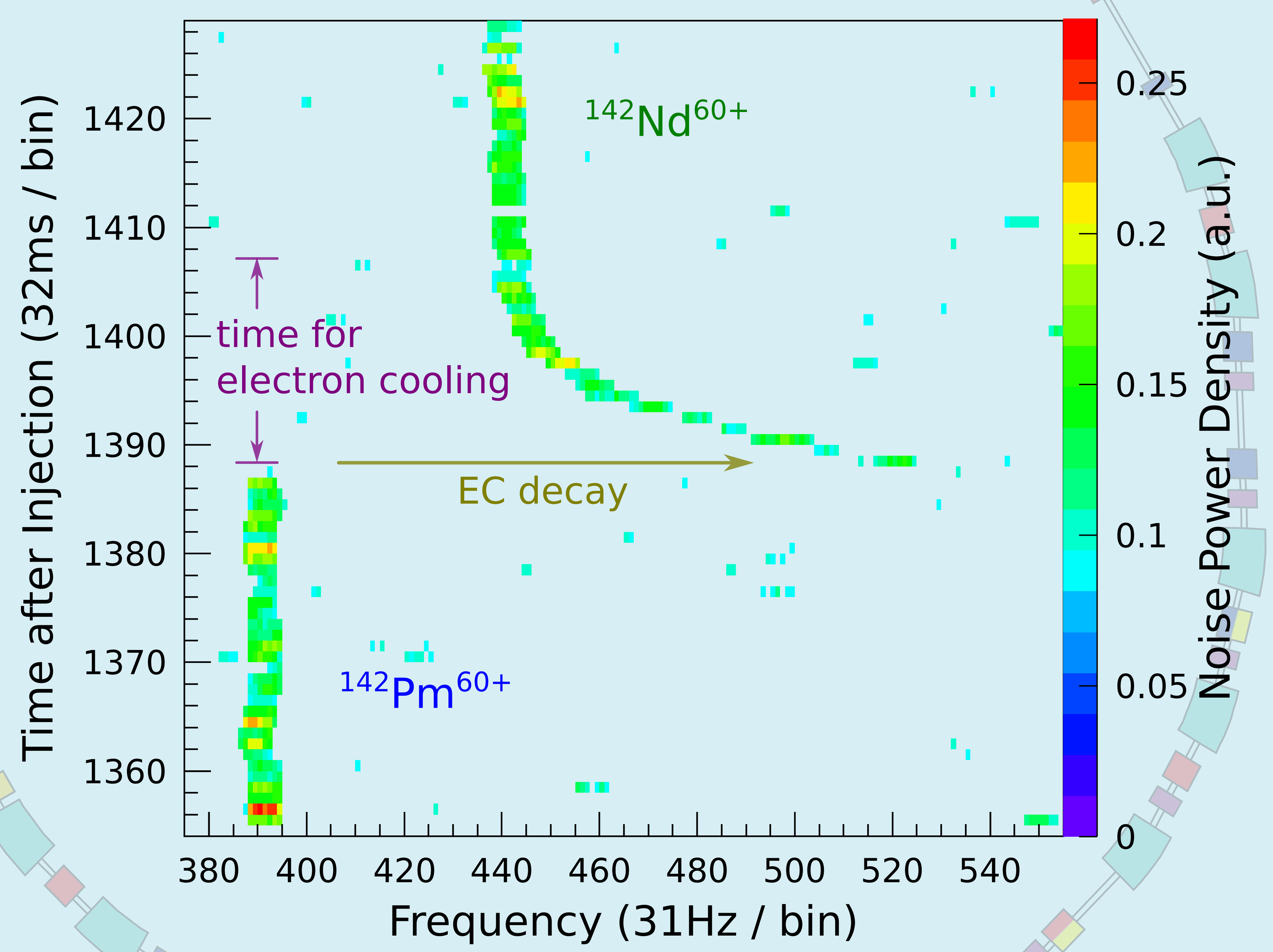


image courtesy of P. Petri

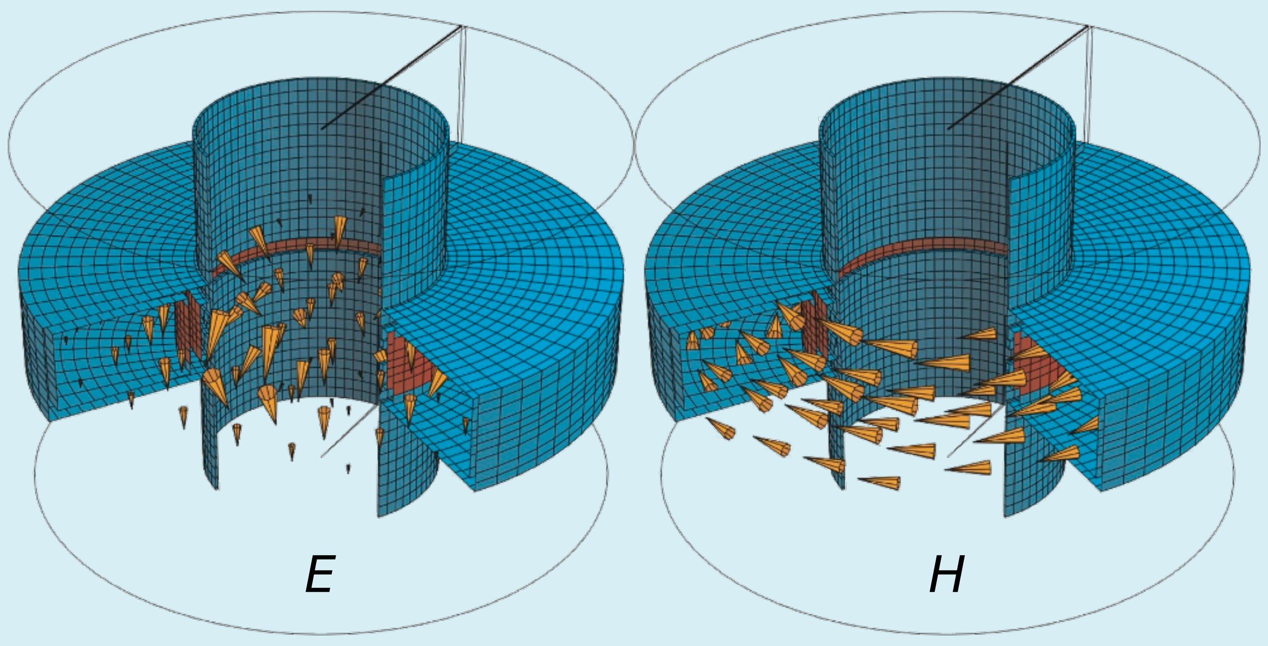
Another kind of a Schottky noise detector, which is shown on the left, was also designed for and built into ESR in 2010 [4].

It is a pillbox-like RF resonator with cylindrical cavity, which operates at the fundamental eigenmode of EM fields, i.e. monopole mode.



Time resolved Schottky spectrogram depicting EC decay process of one single ion stored in ESR

The Schottky noise signals were detected by the pillbox resonator during an experiment conducted at ESR in 2010. Thanks to resonating structure, the sensitivity of pillbox resonator is enhanced by a factor of 100 compared to the capacitive pickup.

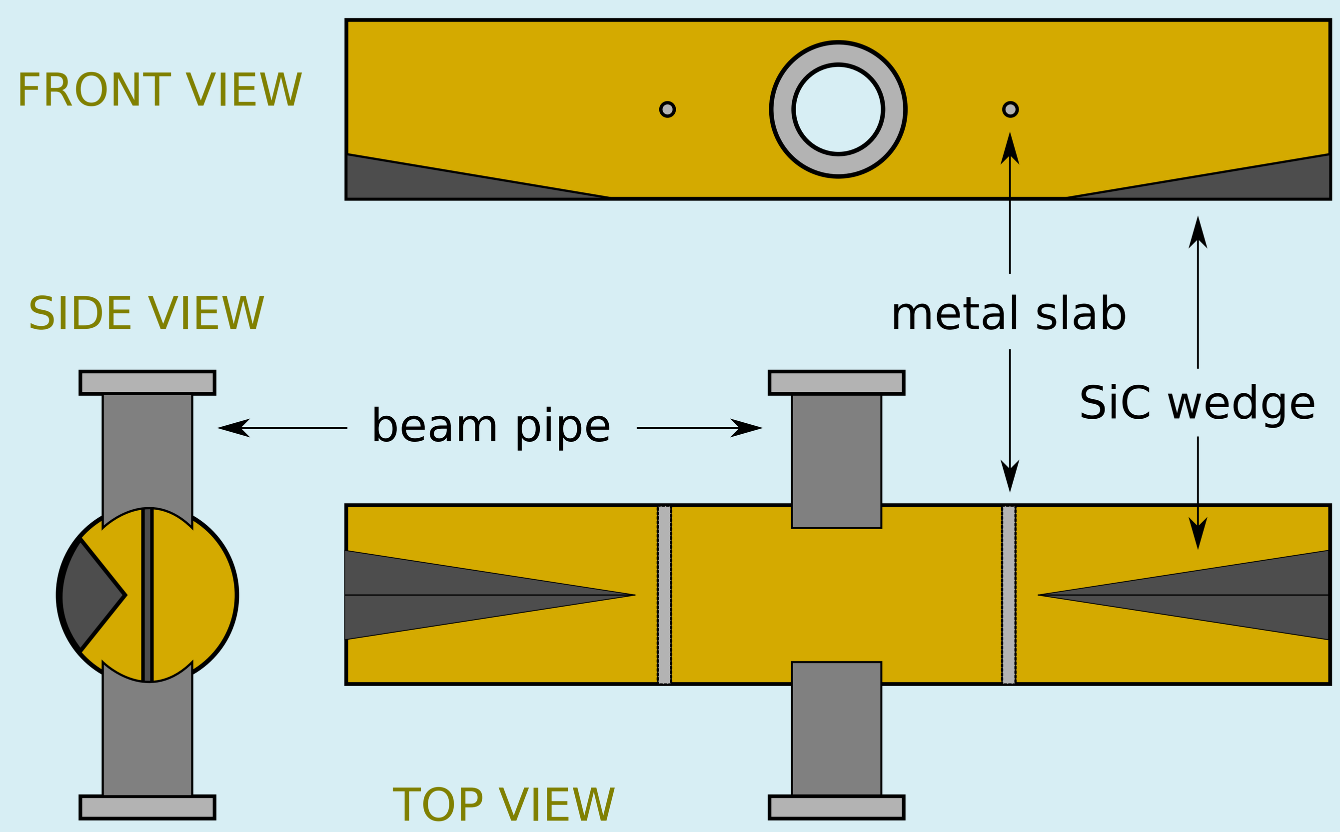


Since both electric and magnetic fields of the monopole mode are cylindrically symmetric, all points on a concentric circle are equivalent [5]. As a result, the pillbox resonator is insensitive to transverse directions.

Outlook

To meet the requirement for accurate position measurements of single stored ions in the Collector Ring (CR), a new Schottky noise detector that is sensitive to both longitudinal and transverse directions has been proposed.

In order to distinguish transverse displacements of ions, higher order eigenmodes, such as dipole mode, are necessary. Different shapes of RF resonators must be taken into account to suppress monopole mode. The configuration of one candidate is sketched below [6].



References

[1] W. Schottky, *Ann. Phys. (Berlin)* **362**, 541 (1918). [2] P. Forck, "Lecture Notes on Beam Instrumentation and Diagnostics", *Joint University Accelerator School* (2012). [3] U. Schaaf, Ph.D. thesis, *Frankfurt University* (1991). [4] F. Nolden *et al.*, *Nucl. Instrum. Meth. A* **659**, 69 (2011). [5] M. S. Sanjari, Ph.D. thesis, *Frankfurt University* (2013). [6] O. Kester and P. Hülsmann, Proposal, *Forschungsverbund SPARC* (2011).

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