Conceptual Design of a High Sensitive Versatile Schottky Sensor

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The Collector Ring at FAIR (CR) is a high acceptance ring that features three modes of operation:

- Stochastic precooling of antiprotons from the antiproton target at a fixed kinetic energy of 3 GeV to be delivered to the RESR storage ring
- Stochastic precooling of secondary rare isotope beams from the fragment separator (SuperFRS) at a fixed kinetic energy of 740 MeV/u to be delivered to the RESR storage ring
- Mass measurements of short-lived secondary rare isotope beams from the SuperFRS in the isochronous mode

Table 1: Parameters of the CR

Parameter	Antiprotons	Rare Isotopes
Velocity	0.971 c	0.83 c
Kinetic energy	3 GeV	750 MeV/u
Frequency slip factor η	-0.011	0.186
Revolution frequency	1.37 MHz	1.17 MHz
Bunch length (inj.)	50 ns	20 ns
Bunch length (extr.)	400 ns	200 ns
Momentum acceptance	±3%	±1.5%

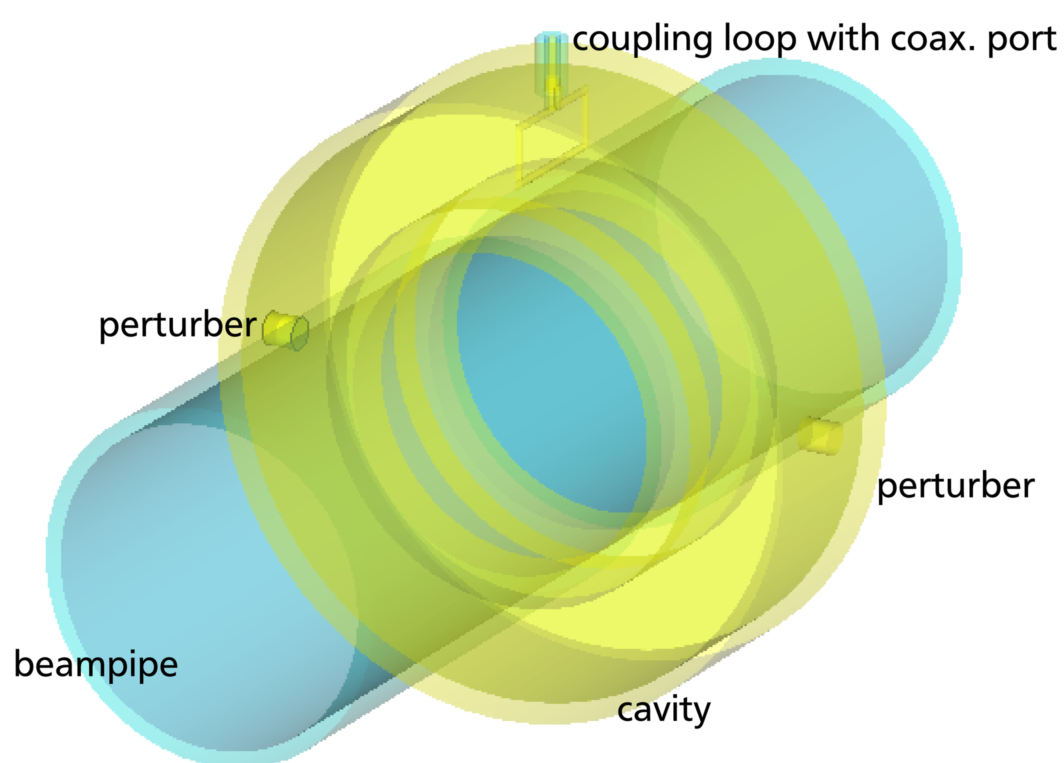
For beam optimizations in all three modes a sensitive Schottky setup is required to monitor very low beam intensities down to single particles.

Variable coupling to adjust the loaded Q

Tuning to compensate fabrication tolerances and temperature changes

Ceramic window shielding the vacuum and allow movable parts under non-vacuum conditions

Geometry as simple as possible for fabrication



Prototype design of a tunable sensor cavity modeled in CST Microwave Studio. Two perturbers are included at the left and right, as well as a coupling loop with coaxial feedthrough on top.

Materials: copper, steel
Dimensions: cavity radius = 60 cm, length = 12 cm
beampipe radius = 20 cm
Quality factor: $Q_{unloaded}$ = 18930, Q_{loaded} = 150

Schottky noise is used to measure beam parameters such as momentum spread, revolution frequency and tune

Schottky noise is distibuted to hamonic bands. The amplitude is following 1/f while the width is increasing with the harmonic number.

At a certain frequency the bands will start to overlap

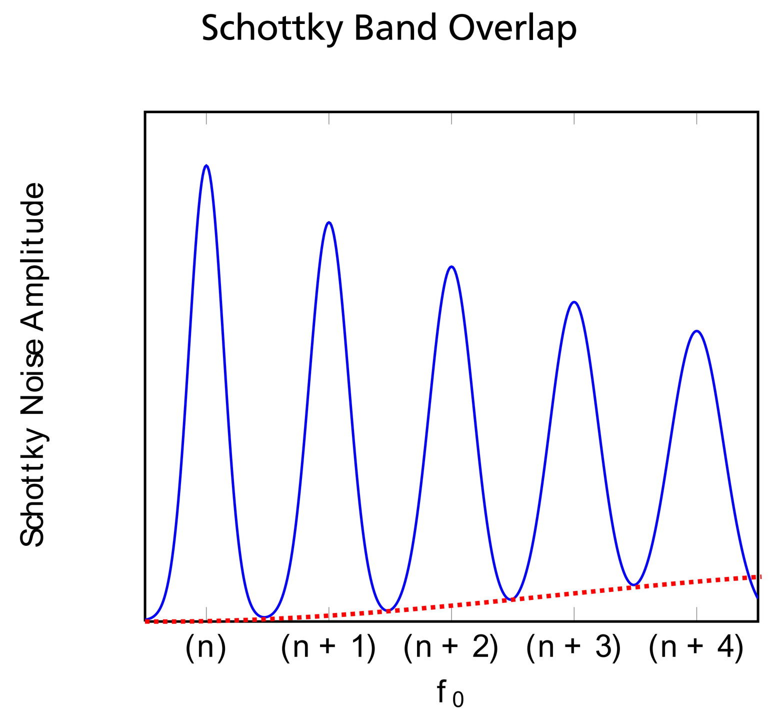


Table 2: Schottky Noise Parameters

Case	$\Delta p/p$	η	h	$h \cdot f_r$
Antiprotons	±3%	-0.011	1010	1384 MHz
Rare Isotopes	±1.5%	0.186	119.47	139 MHz

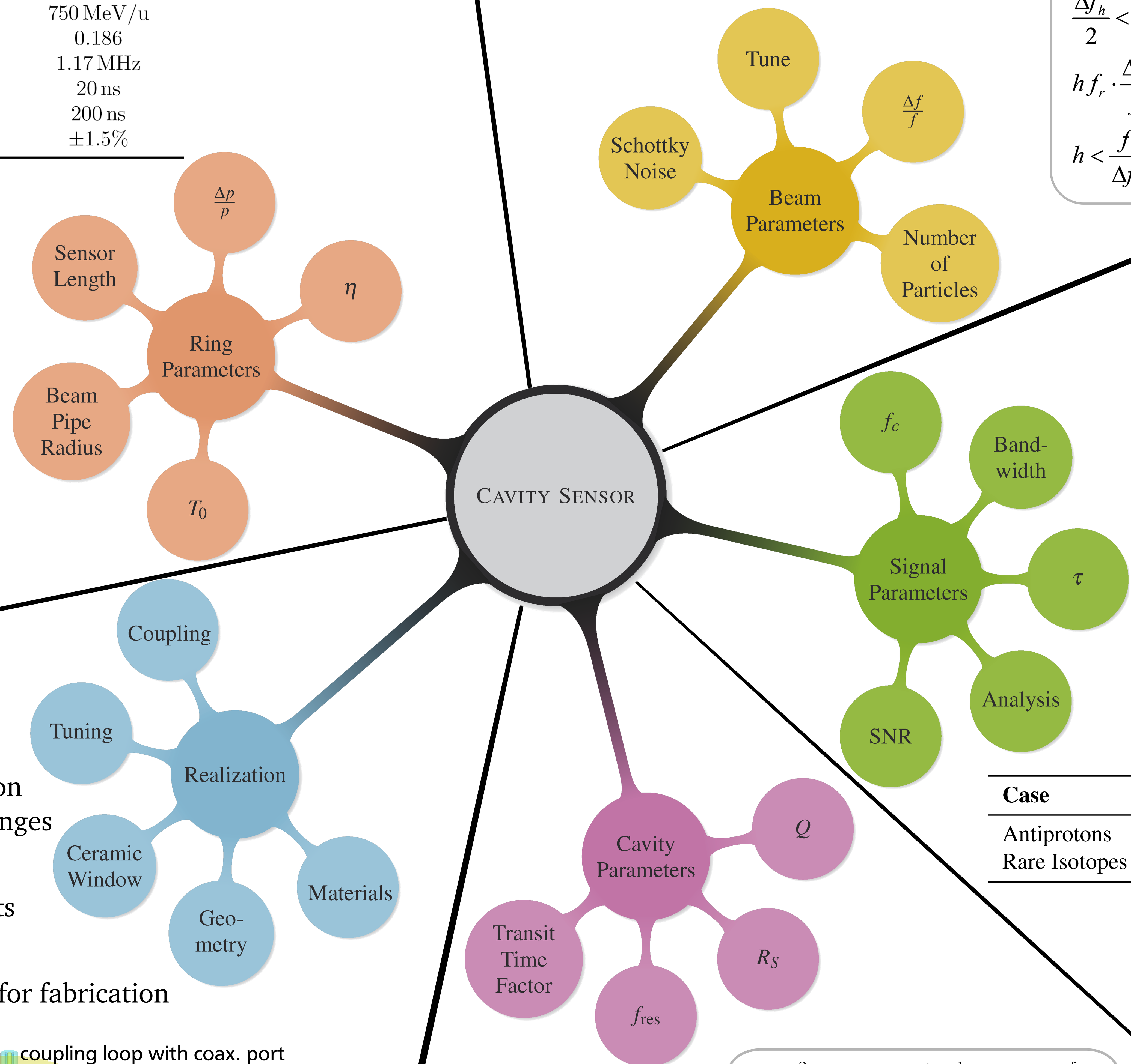
$$\Delta f_h = h f_r \cdot \frac{\Delta f}{f}$$

$$\frac{\Delta f_h}{2} < \frac{f_r}{2}$$

$$h f_r \cdot \frac{\Delta f}{f} < f_0$$

$$h < \frac{f}{\Delta f}$$

$$\frac{\Delta f}{f} = \eta \cdot \frac{\Delta p}{p}$$



Goal:
Maximized signal to noise ratio SNR at certain bandwidth and center frequency

Dependencies on the measurement devices and amplifiers

For turn-by-turn measurements the time response is important

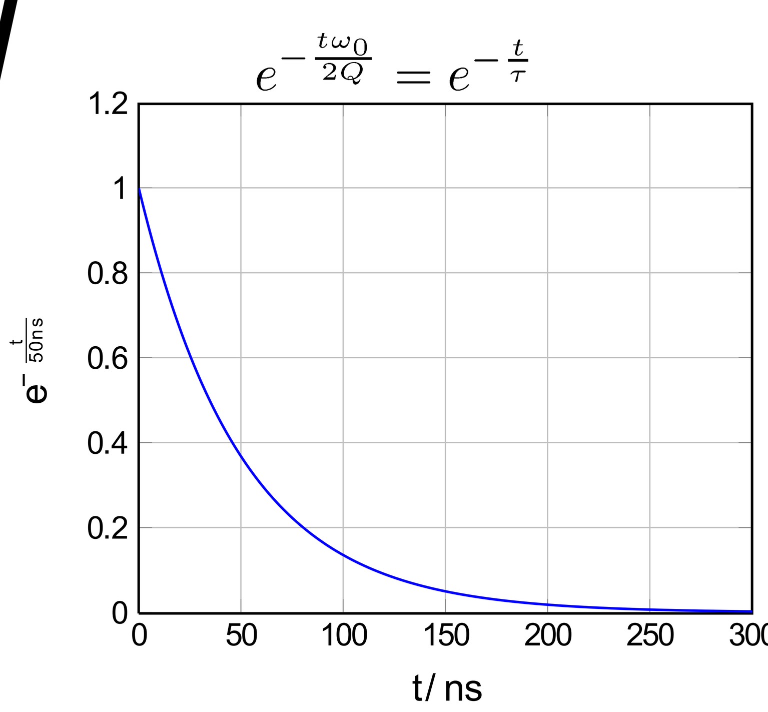
Table 3: Signal Parameters

Case	f_c	BW	T_0
Antiprotons	$h \cdot 1.37$ MHz	0.099%	730 ns
Rare Isotopes	$h \cdot 1.17$ MHz	0.837%	855 ns

$$Q = \frac{2\pi \cdot \text{avr. energy stored}}{\text{energy dissipated /cycle}} \text{ and } Q = \frac{f_r}{\Delta f_{3dB}}$$

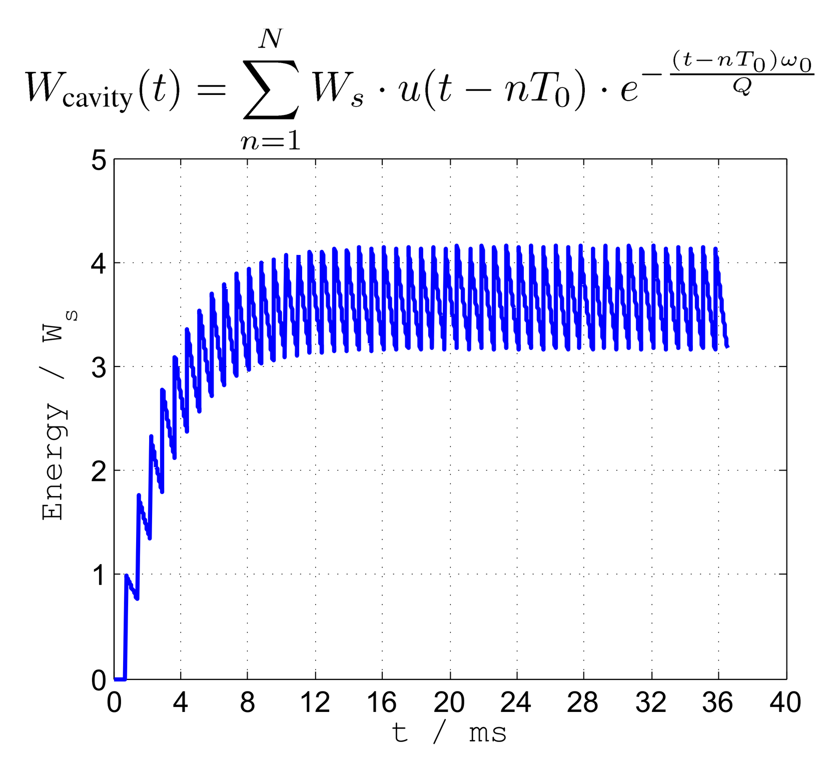
$$Q_{\text{loaded, max}} = \frac{T_0\,\omega_r}{2\,\ln(100)}$$

$$e^{-\frac{t\omega_0}{2Q}} = e^{-\frac{t}{\tau}}$$



Field decay for Q=20 and f_r=130 MHz

$$W_{\text{cavity}}(t) = \sum_{n=1}^{N} W_s \cdot u(t - nT_0) \cdot e^{-\frac{(t-nT_0)\omega_0}{Q}}$$



Energy stored inside the cavity for Q=5000, f_r=300 MHz T_0=(1.37 MHz)$^{-1}$

- Q optimization regarding: bandwidth (Q_{max}=1010 and Q_{max}=119) time constant (Q_{max}=68 and Q_{max}=76), and mode of operation
- High R_S
- Resonance frequency at center frequency

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