The beam passing through the cavity excites some RF modes. The signal voltage of the monopole mode is proportional to beam intensity and does not depend on the beam position. Dipole mode voltage is proportional to the distance of the beam from the centre axis of the monitor.

Arranged around the beam tube, the cavity is composed of a mechanical structure with four orthogonal feedthroughs (or antennas). Main RF characteristics for a cavity:
- Frequencies
- Coupling Q
- R/Q

Due to tolerances in machining, welding and mounting, some small distortions of the cavity symmetry are generated. A beam displacement in the ‘x’ direction gives not only a reading in that direction but also a non zero reading in the orthogonal direction ‘y’.

This asymmetry is called cross talk.

Resolution

Resolution : RMS value related to the minimum position difference that can be statistically resolved.
- Position signal

\[ V_{\text{signal}} = \sqrt{\frac{\text{Noise}_n^2 + \text{Noise}_p^2}{2}} \]

- Noise determined by the thermal noise and the noise from signal processing channel

Thermal noise : \[ P_n = k_B T \times \text{BW} \]

\( k_B \) = Boltzmann’s constant (1.38*10^-23 J/K), BW (Hz) = bandwidth of the signal processing channel, and \( T \) (K) = room temperature.

Noise from the signal processing:

\[ P_p = N_F \times G \times P_n \]

\( N_F \) = total noise figure of the signal processing channel, \( G \) = gain of the signal processing and \( P_n \) = thermal noise.

Example: Pill box cavity
Re-entrant BPM (1)

Re-entrant cavity BPM installed in a warm section on the FLASH linac.

RF Characteristics of the BPM

- Resonant modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>f (MHz)</th>
<th>Q</th>
<th>Resonant modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monopole</td>
<td></td>
<td></td>
<td>Calculated</td>
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<td>Measured</td>
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</tr>
</tbody>
</table>

- Q determined by HFSS with matched feedthroughs.
- With Matlab and the HFSS calculator, we computed R/Q ratio.
- $R = \frac{1}{2\pi f} \int_{-\infty}^{\infty} e^{i\omega t} dt$ and known.
- Difference on Q factors can be explained by the boundary conditions which are not the same during the measurements in laboratory and in the tunnel.

Re-entrant Cavity (2)

- It is arranged around the beam tube and forms a coaxial line which is short circuited at one end.
- The cavity is fabricated with stainless steel as compact as possible:
  - 170 mm length, 76 mm aperture.

RF Cavity and Fields (1)

Monopole mode ($f = 1255$ MHz)
- Simulated with HFSS

Dipole mode ($f = 1724$ MHz)
- Simulated with HFSS

Signal Processing (2)

RF signal after Band pass Filter on channel 1
- Possibility bunch to bunch measurements

Time Resolution

Damping time is given by the following formula:
$$\tau = \frac{1}{\sqrt{2 \pi f \Delta f}}$$

With
- $f$: dipole mode frequency
- $Q_l$: loaded quality factor for the dipole mode

RF signal measured at one pickup
- Possibility bunch to bunch measurements
Beam tests on the BPM

- Calculate for each steerer setting, the relative beam position in using a transfer matrix between steerer and BPM.
- The beam tests were carried out at room temperature and are encouraging.

- Good linearity in a range +/- 5 mm

- Resolution measurement: correlation of the reading of one BPM in one plane against the readings of all other BPMs in the same plane (using linear regression).
- RMS resolution around 4 µm on the Y channel and 8 µm on the X channel.

Reentrant cavity designed for the probe beam of CTF3

- Beam pipe (I)
- Gap (II)
- Coaxial cylinder (III)