Calculation of the quadrupole moment $\sigma_x^2 - \sigma_y^2$ for an asymmetrical Pick-up*

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Introduction

This report presents the simulation results for an asymmetric pick-up installed at GSI SIS-18. The pick-up is planned to be used as transverse beam size oscillations monitor at SIS-18, and possibly as a transverse emittance monitor [1] in future. The properties of the pick-up are studied in order to evaluate its usage as a quadrupole moment monitor. Further, a comparison of signal processing methods such as traditional difference over sum, log-ratio and modified log-ratio [2] with respect to the suppression of beam position contribution in the quadrupole moment $\sigma_x^2 - \sigma_y^2$ is presented.

Simulations and Results

Quadrupole signal for a centred beam

Assuming that the beam is long compared to the pick-up electrode, the pick-up properties are determined electrostatically with the simulation software CST EM Studio (Electrostatics solver). The quadrupolar signal $\Xi$ for traditional diff-over-sum method is defined as $(R + L - T - B)/(R + L + T + B)$ where $R$, $L$, $T$ and $B$ are the voltages induced on the respective pick-up plates. It is calculated for a range of quadrupole moment such that transverse horizontal beam radius $\sigma_x$ is varied from 7.5 mm to 50 mm while vertical beam radius $\sigma_y$ is 7.5 mm.

![Figure 1: Quadrupole signal for a centred beam.](image)

Figure 1: Left: front view of the pick-up design; right: quadrupole signal $\Xi$ using the diff over sum method; $\sigma_y/b = 0.075, 0.075 \leq \sigma_x/b \leq 0.5, \Xi = \sigma = 0, b = 100.3$ mm, $a = 35.3$ mm.

Figure 1 shows that the quadrupole signal is not linear in the whole range of the beam dimension used for the simulation. However, in the range covering typical SIS-18 beam dimensions, i.e. $0 \leq (\sigma_x^2 - \sigma_y^2)/b^2 \leq 0.05$, the curve fits well with a straight line (linear regression with the coefficient of determination $R^2 = 0.9997$), as shown by dotted line in Fig. 1. The slope $m$ and the zero point $(\sigma_x^2 - \sigma_y^2)\sigma$ of the fitted line are 0.678 and 0.4593, respectively.

Effect of the beam position $(\Xi, \sigma)$

Now, taking into account the beam position in the quadrupole signal, the beam dimension can be obtained simply by Eq. (1).

$$\frac{\sigma_x^2 - \sigma_y^2}{b^2} = \frac{\Xi}{m} + (\sigma_x^2 - \sigma_y^2)\sigma_0 - n \left(\frac{x^2 - y^2}{b^2}\right) \quad (1)$$

![Figure 2: Relative error of the pick-up values of $(\sigma_x^2 - \sigma_y^2)/b^2$ at $\Xi/b = 0.075, \sigma_0/b = 0.05; b = 100.3$ mm](image)

Figure 2: Relative error of the pick-up values of $(\sigma_x^2 - \sigma_y^2)/b^2$ at $\Xi/b = 0.075, \sigma_0/b = 0.05; b = 100.3$ mm

In Fig. 2, the relative errors in the calculated quadrupole moment for a variation of $\sigma_x$ in the range of 7.5 mm to 22.5 mm with a constant $\sigma_y = 7.5$ mm and beam position $(\Xi = 7.5$ mm, $\sigma_0 = 5$ mm) using different processing methods are shown.

Conclusions

In the beam size range of interest, the quadrupole signal calculated using the asymmetric pick-up is found to have a linear dependence on quadrupole moment for a centred beam. The dependence of quadrupole moment on beam position is studied by three signal processing methods. The modified log-ratio method shows the least influence of beam position on the quadrupole moment.

References


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