Beam Based Alignment at the Cooler Synchrotron (COSY)

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Motivation

- An Electric Dipole Moment (EDM) measurement needs the orbit to be as good as possible
- Orbit RMS should be lower than 100 µm

Figure: Spin buildup $|\Delta S_y|$ for different EDM values depending on the orbit RMS $\Delta y_{\text{RMS}}$[1]. The spin buildup is the measure for the EDM and freezes out at some point. The contribution due to misalignments dominates for large orbit RMS, but keeps decreasing for smaller orbit RMS until the EDM signal becomes visible.

Technique

- Use the beam to optimize the beam position inside quadrupole
- Vary quadrupole strength $k$, then observe and minimize orbit change

Orbit change [2] described by:

$$\Delta x(s) = \left(\frac{\Delta k x(s)}{B_p}\right) \left(\frac{1}{1 - k \frac{x(s)}{B_p \rho \tan \pi \nu}}\right) \times \frac{\beta(s) \sqrt{\beta(s_0)}}{2 \sin \pi \nu} \cos(\phi(s) - \phi(s_0) - \pi \nu)$$

- Minimized with the following merit function:

$$f = \frac{1}{N_{\text{BPM}}} \sum_{i=1}^{N_{\text{BPM}}} \left( x_i(\Delta k) - x_i(-\Delta k) \right)^2$$

$$f \propto (\Delta x(s))^2 \propto (x(s_0))^2$$

- Merit function has the shape of a parabola and the minimum is the optimal position in the quadrupole

Results

- Quadrupole strength of quadrupole QT12 varied with the use of back leg windings
- Beam moved inside the quadrupole in horizontal and vertical direction

Figure: Measurement for the beam based alignment. The white dots indicate the measurement points where the merit function was evaluated and the red dot is the minimum, i.e., optimal position, found by the fit. The x- and y-axis are labeled with the corresponding beam offset in mm.

- Optimal position located at ($-1.98 \pm 0.01$) mm horizontally and ($1.15 \pm 0.01$) mm vertically
- Beam Based Alignment with the use of back leg windings works
- Additional quadrupoles have to be made adjustable and the BPM offset has to be measured

References


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