Beam Based Alignment at the Cooler Synchrotron (COSY)

Tim Wagner for the JEDI Collaboration
RWTH Aachen University & Forschungszentrum Jülich

Motivation

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

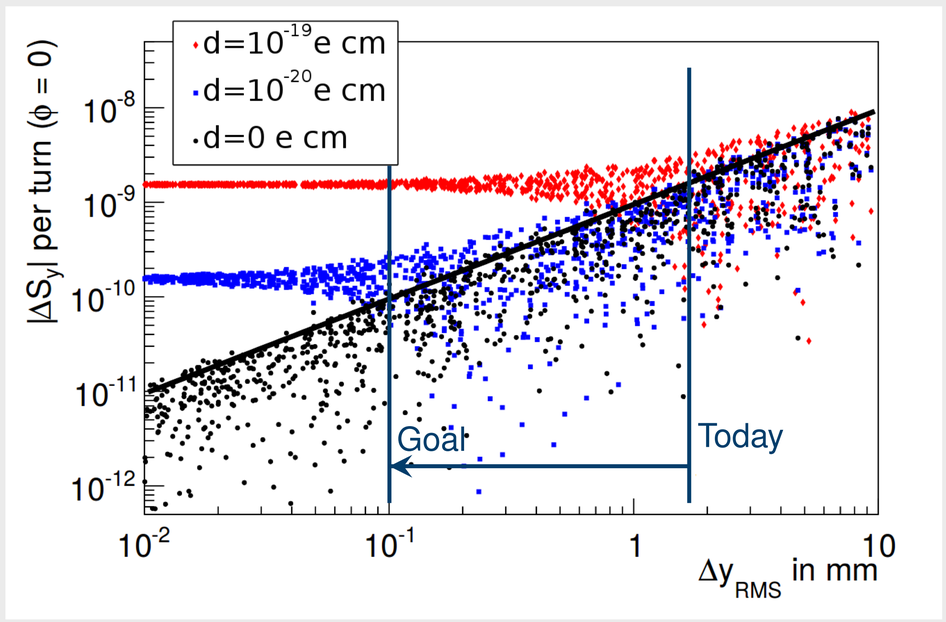


Figure: Spin buildup $|\Delta S_y|$ for different EDM values depending on the orbit RMS Δy_{RMS}[1]. The spin buildup is the measure for the EDM and freezes out at some point. The contribution due to misalignments dominates for large orbit RMS, but keeps decreasing for smaller orbit RMS until the EDM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

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

- Minimized with the following merit function:

$$f = \frac{1}{N_{\mathrm{BPM}}}\sum_{i=1}^{N_{\mathrm{BPM}}}(x_i(+\Delta k) - x_i(-\Delta k))^2$$
$$f \propto (\Delta x(s))^2 \propto (x(s_0))^2$$

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

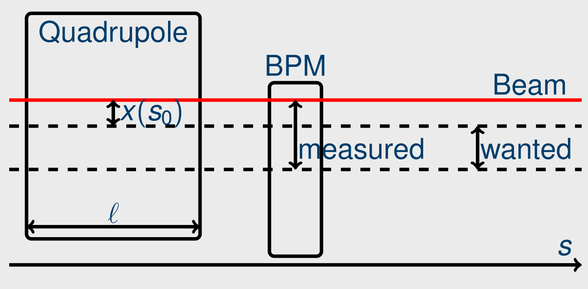
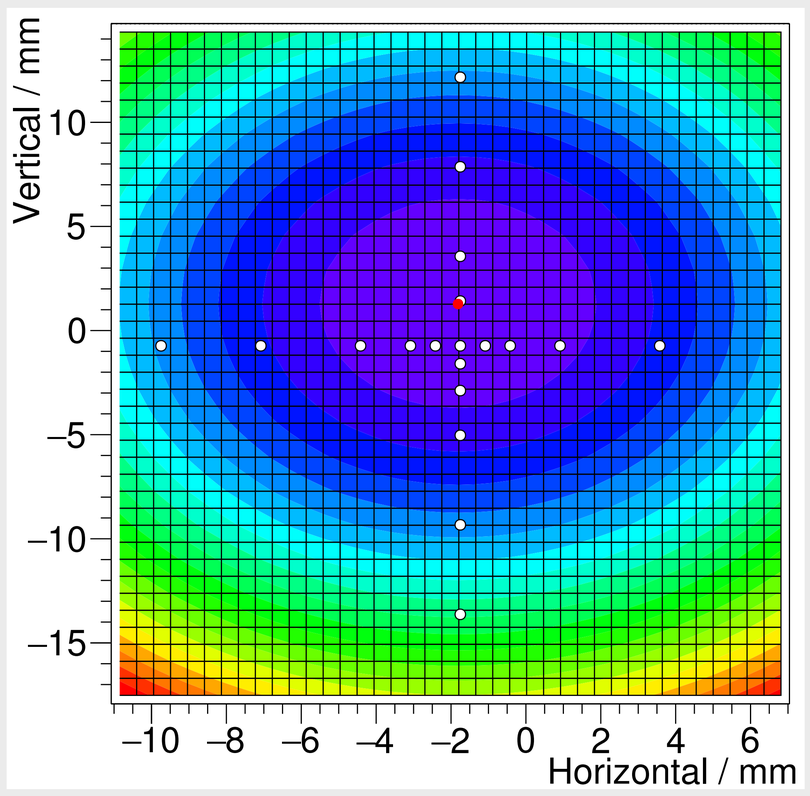


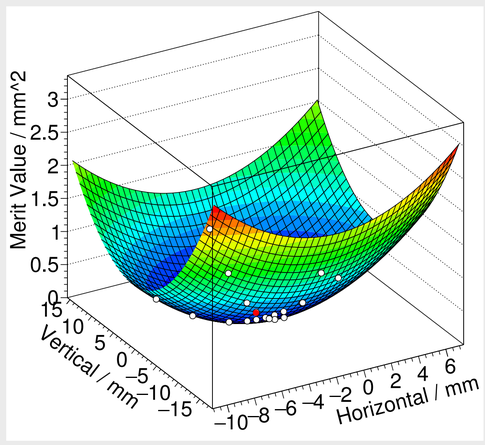
Figure: Sketch of one quadrupole and BPM and some of the parameters in the equation above. In addition the measured position and the wanted position is indicated.

Results

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



(a) Top view



(b) Side view

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 ± 0.01) mm horizontally and (1.15 ± 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

[1] M. S. Rosenthal. “Experimental Benchmarking of Spin Tracking Algorithms for Electric Dipole Moment Searches at the Cooler Synchrotron COSY”. PhD thesis. RWTH Aachen University, 2016.

[2] G. Portmann et al. “Automated beam based alignment of the ALS quadrupoles”. In: *Conf. Proc.* C950501 (1996), pp. 2693–2695.

Contact: Tim Wagner - t.wagner@fz-juelich.de