S800 RAY-RECONSTRUCTION

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The S800 spectrograph has been designed with minimal high order correction magnets or edges. The two exceptions are a sextupole winding in the second quadrupole and trim coils in the dipoles. This choice was deliberate in order to limit the cost and take advantage of analytical correction of the aberrations. The correction method is based on the ion optics code COSY Infinity which can calculate a matrix of polynomials between the coordinates of any two locations along a defined beamline. This matrix of polynomials is referred to as a 'map' in the following, and can be easily inverted. From the coordinates of each particle measured in the focal plane, an inverted map can therefore provide the coordinates of the same particle at the target location. Under the assumption of a point-like source in the dispersive plane at the target location, the energy and scattering angle of each particle can be calculated as shown below:

$$x_i = 0 \longrightarrow \begin{pmatrix} \theta_i \\ y_i \\ \phi_i \\ \delta_i \end{pmatrix} = S^{-1} \begin{pmatrix} x_f \\ \theta_f \\ y_f \\ \phi_f \end{pmatrix} \longrightarrow \Theta_{scat} = \arctan\sqrt{\tan(\theta_i)^2 + \tan(\phi_i + \phi_{S800})^2}$$

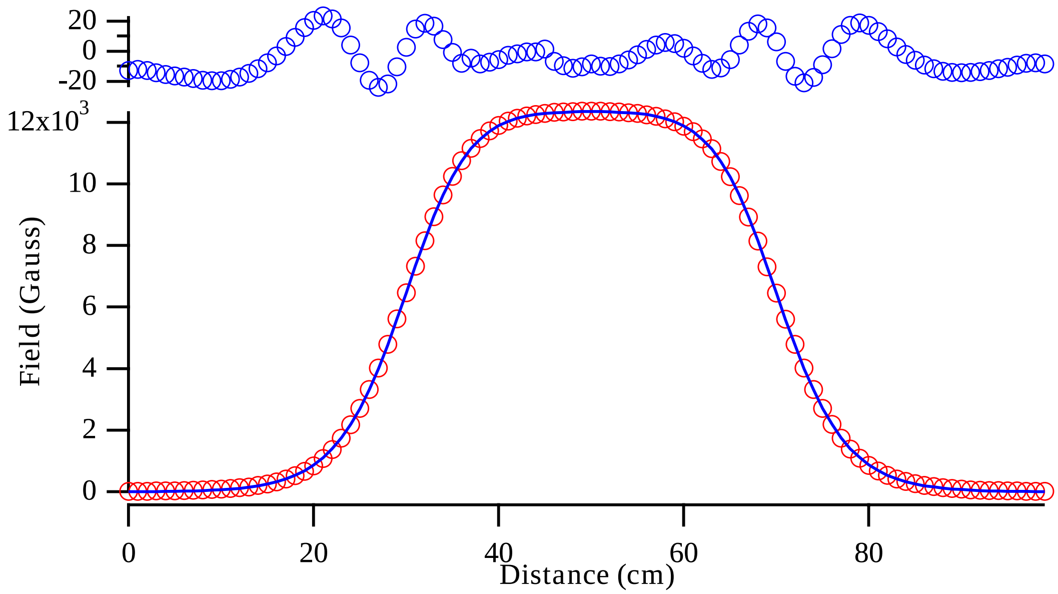
where S^{-1} stands for the 'inverse' map, ϕ_{S800} the angle of the spectrograph, and the indices i and f for the initial (target) and final (focal plane) coordinates respectively. The inverse map contains the aberrations of the spectrograph up to a given order. The contributions of aberrations above order 5 are smaller than 500 μm, and therefore higher orders are normally not used.

The successful correction of the spectrograph's aberrations relies on several requirements which must be fulfilled simultaneously:

1. Precise positioning of the magnets and detectors according to CAD specifications.
2. Accurate calibration of the position detectors (CRDCs) in the focal plane.
3. Appropriate models of the magnetic fields, especially in the fringe fields regions.

If the first two requirements are easily met (the calibrations are done for each experiment by inserting a mask in front of the detectors), the 3rd one is on the other hand more difficult to achieve because it relies only on the measured field maps. Early attempts of reconstruction tried to use the field map itself to integrate the trajectory of particles within COSY Infinity, but failed due to residual noise and instabilities in the data. Only analytical functions could be used reliably to calculate high order field derivatives, especially away from the mid-plane of the dipoles. Enge functions are well-suited to model the fringe field of magnets. An example of modeling the field of the first quadrupole (Q1) is shown in the figure. The top graph shows the residuals between the data and the fitted Enge functions in Gauss. The oscillations are due to the nature of the Enge function which uses a polynomial. Their amplitude however, is only on the order of 0.4 % of the maximum field.

The same procedure is used for Q2 and the two dipoles. In addition, the effective lengthes of each magnet are calculated for each Bρ setting. The resulting parameters are then injected into COSY Infinity, which starts by a first order calculation to verify the x focussing at the focal plane location. If that requirement is not met, it then adjusts the position of the focal plane accordingly, in order to reproduce



the experimental conditions. The adjustments are usually less than 1 cm in absolute value. Finally, the calculation to 5^{th} order is performed.

An example of the result obtained with this method is illustrated in the report on S800 operations. A resolution of 1 part in 2,200 in energy is obtained whereas one would have expected 1 part in 4,000 in that experiment. The reasons for the missing factor of 2 are most likely the accuracy of the models used to simulate the fields in the magnets. Further improvements of these models are on the way. They include a better simulation of the field in the interior of the dipoles, as well as on the outer fringe field regions where the fields from different magnet overlap.