Skew-quadrupole correctors for SIS100

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The need for the skew-quadrupole correctors in SIS100 is related to the compensation of the 2nd-order coupling resonances, and to the adjustments of the global linear $x-y$ coupling.

Number of the skew-quadrupole correctors

There are two resonant lines which should be affected simultaneously, thus the absolute minimum is 4 magnets. Since the tune split is rather small in SIS100 (~ 0.1), and because of the sector symmetry, at least <u>6 magnets</u> are needed.

Number of the normal-quadrupole correctors

The number of the <u>12 normal-quadrupole correctors</u> should not be reduced. Additionally to the compensation of the four half-integer resonances, the important function of these correctors will be the compensation of beta beating in SIS100.

Positions of the skew-quadrupole correctors

Since 12 normal-quadrupole correctors are all needed, the skew-quadropoles can not be combined within the 12 corrector nested magnet system. The positions of the missing dipoles at the arc ends can be considered for the skew-quadrupole correctors. In the arc beginning, the beta functions for the fast-extraction ion lattice at the missing dipoles are $\beta_x \approx 8...6\,\mathrm{m}$ and $\beta_y \approx 11...16\,\mathrm{m}$. In the arc end, the beta function at the missing dipoles are $\beta_x \approx 16...11\,\mathrm{m}$ and $\beta_y \approx 6...8\,\mathrm{m}$. For the linear coupling, both planes are equally important, thus no preference between the arc beginning and the arc end can be recognized.

Strength of the skew-quadrupole correctors

Two main skew-quadrupole error sources are considered. The tilt of the main quadrupoles produces the rms angle $\sigma_\theta = \sqrt{2}\sigma_x/w_q = \sqrt{2} \times 1\,\mathrm{mm}/350\,\mathrm{mm} = 0.004$. The resulting skew-quadrupole gradient is

$$\frac{J_1}{K_1} = \sin(2\sigma_\theta) = 0.008 \ ,$$

where $K_1 \approx 0.2\,\mathrm{m}^{-2}$ is the gradient of the main quadrupoles.

The statistical maximum accumulated global error for the 99.7% confidence is

$$\Sigma J_1 = \sqrt{N_{\mathrm{magnet}}}\ J_1 \times 3 = \sqrt{168} \times 0.008 \times 0.2\,\mathrm{m}^{-2} \times 3 = 0.06\,\mathrm{m}^{-2} \ .$$

Assuming that the 6 corrector magnets should cover the global error, and taking into account that the corrector magnet length is $L_\mathrm{c} = 0.75\,\mathrm{m}$ and the main quadrupole magnet length is $L_\mathrm{m} = 1.3\,\mathrm{m}$,

$$g_\mathrm{skew} = \frac{\Sigma J_1}{6} B\rho \frac{L_\mathrm{m}}{L_\mathrm{c}} = \frac{0.06\,\mathrm{m}^{-2}}{6} \times 100\ \mathrm{Tm} \times \frac{1.3\,\mathrm{m}}{0.75\,\mathrm{m}} = \underline{1.7\ \mathrm{T/m}}\ .$$

This is to compare with the maximum gradient of the normal-quadrupole corrector magnets,

$$g_\mathrm{max} = 0.75\,\mathrm{T/m}\ .$$

The skew-quadrupole strength estimation is conservative for the highest rigidity, thus the skew-quadrupole correctors with the same gradient as the normal-quadrupole correctors might be sufficient.

The second error source is the skew-quadrupole component in the main dipole magnets. The FoS magnet indicated $a_2 \approx 2$ units. The corresponding global error is

$$\Sigma J_1 = \sqrt{N_\mathrm{magnet}}\ J_1 \times 3 = \sqrt{108} \times 2.2 \times 10^{-4}\,\mathrm{m}^{-2} \times 3 = 0.007\,\mathrm{m}^{-2}\ ,$$

which is an order of magnitude smaller than the effect of the main quadrupole tilt.

Accuracy of the current supply for the skew-quadrupole correctors

The smallest reliable current change needed for the skew-quadrupole correctors should correspond to the single error source from an individual dipole magnet,

$$\Delta J_1 = 7 \times 10^{-4}\,\mathrm{m}^{-2}\ ,$$

which corresponds to $\underline{\approx 1\% \text{ of the maximal gradient}}$.