Dynamic Aperture Studies for SIS100

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This report describes our progress in dynamic aperture (DA) calculations for SIS100 using a preliminary lattice and working point [1]. The tools developed here will be applied to an optimized lattice in the near future.

In the SIS100 the storage of a beam is foreseen, which fills a good fraction of the beam pipe of semi-axes 55×25 mm [1]. Multipolar expansion of the accelerator magnets is used to model lattice nonlinear components. Usually multipoles b_n, a_n are retrieved by integrating the magnetic field over a reference circle of radius R. The standard calculation of b_n, a_n made with $R \leq 25$mm leaves uncertain the accuracy of the reconstructed magnetic field in the far region of the magnet aperture. Alternatively, the multipoles can be obtained through a fit [2] of a truncated multipolar expansion with the bending magnetic field map [3]. The best fitting provides the order of the expansion.

Table 1 shows the multipoles for an SIS100 dipole at 10% excitation computed with standard [3] and fitting procedure (here $a_n = 0$). In order to improve the convergence between the standard and fit b_3, the magnetic field map has been taken in $|x| \leq 50$ mm. The maximum reconstruction error in the grid magnetic field is $\Delta B/B_0 = 0.38 \times 10^{-4}$. We use the fit multipoles to describe the nonlinear components in the center of the SIS100 bends. The effect of the sagitta of 8 mm [4] is included through a proper coordinate shift at the location of the bend nonlinearities. The nonlinear components of the quadrupole fringe field are modeled as well [5]. In Fig. 1a) we plot a cut of the stability domain in the x-y plane. The SIS100 is tuned on the reference working point [1] of $q_{x0} = 15.9$, $q_{y0} = 15.7$. The stability domain is computed in the x-y section with $\beta_x = 7$ m and $\beta_y = 9.3$ m (injection). Each point in the plot represents the initial condition of test particles with $x' = y' = 0$ which are stable (bounded) during the turns correspondent to its grey scale. In red is plotted the beam pipe in the SIS100 bends. In blue is drawn the space section of the beam at 2σ if injected with equilibrated emittances of $\epsilon_{x,rms} = \epsilon_{y,rms} = 8.75$ mm mrad [1]. The DA is defined as the radius (in normalized coordinates) of the largest circle inscribed inside the domain of stable initial conditions [7]. As customary we express the DA in terms of the beam σ, which for equal emittances [1] reads 4.4σ. This result, however, does not account for the imperfections which affect the systematic strength of each magnet nonlinear component. We assume these perturbations are of the same kind for each magnet: with average zero and variance 10% [6] of the systematic strength b_n. By giving each nonlinear component of the SIS100 its perturbed strength, we have formed an error set. For each error set a new DA will be found. We computed the DA for 5×10^4 turns and 97 error sets. These results are shown in the histogram in Fig. 1b). The vertical axes gives the number of sets for which the DA aperture was found to have the value in the correspondent bin in the horizontal axes. In order to estimate beam loss, we have tracked a Gaussian beam of 10^4 test macroparticles with equal emittances over 10^4 turns. In these simulations the beam pipe is an ellipse of 55×25 mm kept constant along the ring. We computed then the percent of beam survival per error set and found a distribution peaked at 97.3% of beam survival with a spread of 0.5%.

Table 1: Standard and best fit multipoles in units of 10^{-4}.

n	b_n(standard)	b_n(fit)	deviation %
3	1.56	1.65	-5.1
5	-1.11×10^{-1}	-1.41×10^{-1}	-21.4
7	1.40×10^{-2}	2.43×10^{-2}	-42.5
9	6.0×10^{-3}	6.67×10^{-4}	800
11	-4.0×10^{-3}	7.7×10^{-4}	-617
13	4.0×10^{-3}	1.75×10^{-4}	2184

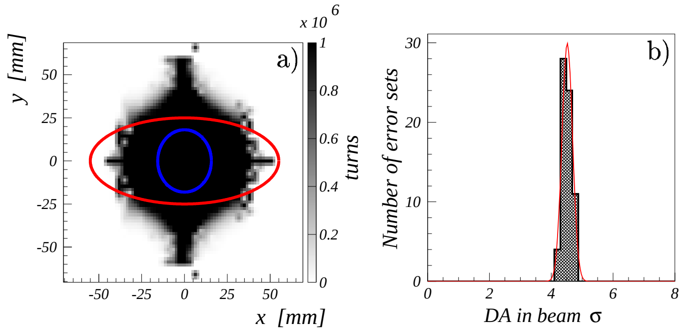

Figure 1: a) Stability domain; b) DA for a beam with $\epsilon_{rms,x,y} = 8.75$ mm mrad as function of bend errors.

Our results for the DA cannot be taken as final values since additional factors need to be taken into account. For a preliminary discussion we adopt the suggested reductions (in %) of Ref. [7]. The additional safety margin of -20% proposed in Ref. [7] appears to be unacceptable here and needs further consideration. We scale in Table 2 the SIS100 DA of 4.4σ for the reference working point. We infer also possible beam loss by simply using a Gaussian cut model. More accurate calculations require the complete set of multipolar component b_n, a_n along the ring and misalignments tolerances. Beam loss predictions including space charge will be computed once a definite working point is chosen.

Table 2: Relation between effective and computed DA.

Source of Uncertainty	Suggestion	DA	% Loss
Sensitivity to initial condition	-10%	3.96	0.3
Time-dependent multipole	-10%	3.65	1.3
Ripple	-10%	3.28	3.6
Space charge	?	?	?

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[6] G. Moritz private comunication.

[7] J. P. Koutchouk, Proc. of 18^{th} PAC. (1999) 372.