Advances in dynamic aperture and loss calculations for the SIS100

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This report describes our progress in dynamic aperture (DA) calculations and beam loss, in particular a scaling law with error strength. The new lattice of the SIS100 [1] has magnet apertures larger than in those used in [2]: semi-axes 60×32.5 mm in quadrupoles and 65×32.5 mm in bending magnets. The modeling of the lattice nonlinearities for the lower magnet excitation is as in [3]. To choose a working point we first inspect the tune diagram including all the systematic resonances up to 5^{th} order, and random error resonances up to the 3^{rd} order (Fig. 1a). We choose

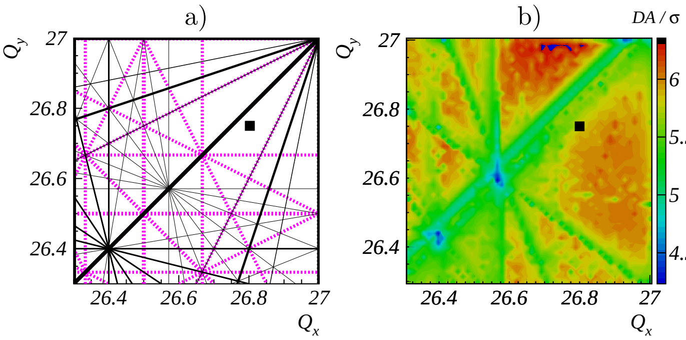

Figure 1: a) Tune diagram with systematic (black) and error resonances (pink). b) Dynamic Aperture for 10^4 turns. The marker shows in both pictures the preliminary working point.

the preliminary working point $Q_{x0/y0} = 26.8/26.75$ which allows an ideal tunespread of $\Delta Q_y = 0.25$. The effective DA limitation is, however estimated performing a scan of DA with $\Delta p/p = 0$ over the tune diagram (Fig. 1b). The definition of DA is as in [3]. The DA is here rescaled as usual to a beam of equal rms emittances of $\epsilon = 8.75$ mm-mrad. The DA shrinks in correspondence of the coupling resonance $Q_x = Q_y$. A cluster of 7^{th} order resonances is found at the point $Q_x = Q_y = 26.57$ and a trace of 5^{th} order resonances is found at $Q_x = Q_y = 26.4$. For $Q_{x0/y0}$ we find a DA of 5.4σ. The influence of quality of magnetic field on this result is estimated as follow: we consider as working ansatz a rescaling of the bend multipoles b_n^0 reported in Fig. 2a according to $b_n = f b_n^0$. The DA is computed for 10^4 turns with a scaling factor $0.1 < f < 10$ (Fig. 2b). In red we plot a fit of the function $D = D_1 f^c$;

a)

n	b_n^0(fit)
3	1.65
5	-1.41×10^{-1}
7	2.43×10^{-2}
9	6.67×10^{-4}
11	7.7×10^{-4}
13	1.75×10^{-4}

units 10^{-4}, $R_{ref} = 25$ mm

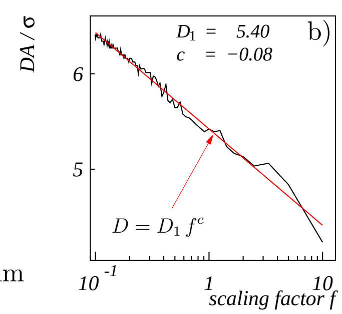

Figure 2: a) Multipoles used in the bending magnet; b) DA vs scaling of multipoles for the chosen working point.

the parameters D_1, c for $Q_{x0/y0}$ are given in Fig. 2b). This scaling holds only for values of DA inside the magnet aperture. This fit law suggests how the magnet quality should be improved in order to improve the DA. For example, an improvement of 10% of DA requires $f = 0.3$. By constrast an extension of the scaling law in [4] shows that the DA induced **only** by the nonlinear component of order $n + 1$ is $D = D_1 f^{-1/(n-1)}$. We infer that the high order components are responsible for DA correction. The effect of random errors in the strength of the nonlinear component on DA at 10^4 turns for $Q_{x0/y0}$ has been studied as well. To each magnet a strength $b_n = b_n^0(1 + 0.1\xi)$ has been given [5]. Here ξ is a Gaussian random variable with unitary variance. The study of random error effects has been made using 400 error sets. The distribution of DA is peaked at 5σ with width 0.42σ. The impact of a DA of 5.4σ on beam loss has been evaluated by tracking for 10^5 turns a 2D Gaussian beam of 2000 macroparticles with $\epsilon_x = 50$ mm-mrad, $\epsilon_y = 20$ mm-mrad (at 2σ). The local pipe aperture has been consistent with each lattice element aperture. We found an initial loss of 1% which is consistent with the acceptance 161/47 mm-mrad. We finally explored the space charge induced effects for this lattice and working point. The simulation with only systematic error [3] was made with a frozen space charge modeling of a Gaussian bunch with 2000 macroparticles. A synchrotron oscillation takes 1000 turns. The detailes of this method and its benchmark versus an experiment are discussed in [6]. The maximum tuneshift for this test bunch is $\Delta Q_{x/y} = 0.41/0.26$. In

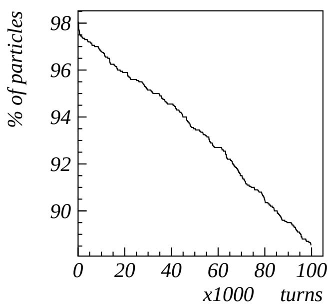

Figure 3: Bunch intensity vs storage time.

Fig. 3a we plot the beam intensity vs storage time, 12% of the ions are lost in 10^5 turns. With respect to the loss prediction reported in [7] we find a substantial increase of beam loss. For minimizing beam loss a careful choice of the working point and a scraping of the distribution tails in a system with collimations is required.

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[7] G. Franchetti, I. Hofmann, EPAC 2004.