THE COSY LATTICE

K. Bongardt, D. Dinev, S. Martin, P.F. Meads, D. Prasuhn , H. Stockhorst and R. Wagner
Forschungszentrum Juelich
Institut für Kernphysik
Postfach 1913, D-5170 Jülich

Abstract

The lattice of the cooler synchrotron COSY-Juelich is designed for a wide range of ion optical flexibility. This is necessary to match the different requirements resulting from the different modes of operation, i.e. electron cooling, stochastic cooling, resonant extraction to external experimental areas, polarization etc. The different demands are discussed and how the COSY lattice is able to fulfill them.

Introduction

After a brief description of the lattice one chosen working point will be discussed in more details. Then a description of the closed orbit correction scheme is presented. Calculation of instability limits and implications for the lattice to improve some of the limitations follow. In the last passage remarks about polarization are given.

General description of the lattice

The general layout of COSY consists of two 180^0 bending sections and two long straight sections [1]. Each of the two bending sections is built out of 3 identical periods with the structure

QU1-Bend-QU2-Bend-Bend-QU2-Bend-QU1

The two straight sections are designed as telescopes with either π or 2π phase advance in each plane and an overall magnification of ± 1. By this the lattice functions in the arc are independent of the telescope setting.

The quadrupoles in the bending sections may be combined to 1 up to 6 families thus giving a wide range of optical flexibility [2]. In the following a detailed discussion of the 3 parameter lattice is given. The 3 parameter lattice has enough flexibility to fulfill all the requests. On the other side it is simple enough for the commissioning.

The 3 parameter lattice

The most important demands on ionoptical conditions in COSY follow from:

- The slow resonant extraction similar to the LEAR ultra slow extraction scheme favours a tune in COSY close to a 3rd order resonance,

- internal target experiments and electron cooling demand small β-functions in the target area and the cooler section [3], respectively;

- transverse stochastic cooling prefers smooth β-functions at the pickup and kicker tanks with 0 or small dispersion [4].

The ionoptical requirements for the stochastic cooling of smooth and sufficiently large β-functions favour a rather small tune in COSY. Together with a tune close to a 3rd order resonance a tune close to 3.38/3.38 is chosen. Fig. 1 shows the variation of γ_{tr} for this tune with three quadrupole families in the bending sections.

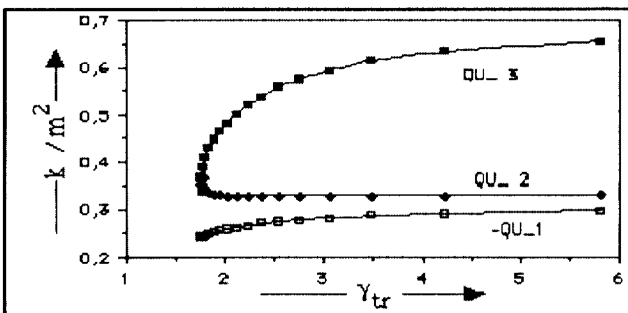

Fig. 1: Quadrupole strength vs. γ_{tr} for the constant tune of 3.38/3.38

In Fig. 2 the lattice functions at the intersection point between bending sections and telescopes are plotted vs. γ_{tr}. From this and the magnifications of the telescopes the optical conditions in the cooler region and the target stations can be calculated [5].

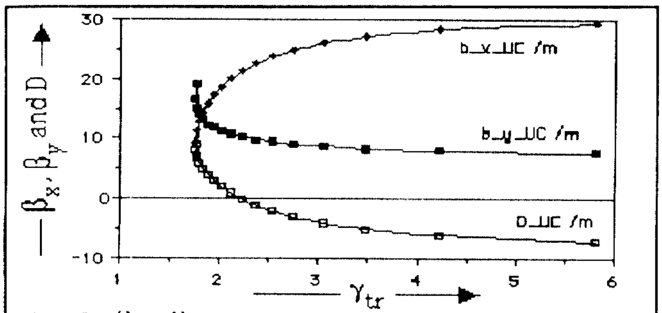

Fig. 2: β_x, β_y and D at the intersection point between arcs and straight sections vs, γ_{tr}.

In Fig. 3 the acceptance limiting lattice functions, i.e. the maximum horizontal β-function and dispersion and the largest vertical β-function in the bending sections, are plotted as function of γ_{tr}.

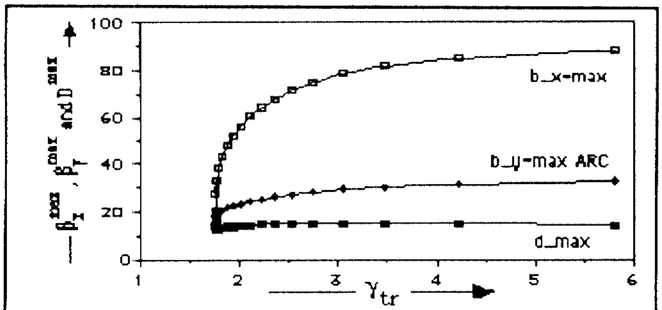

Fig. 3: β_x^{max}, D^{max} and β_y^{max} in the arcs vs. γ_{tr}.

With this and the vacuum chamber dimensions of 150 mm diameter in the straight sections and 150x70 mm^2 in the arcs the acceptances can easily be calculated.

These plots indicate that γ_{tr}-crossing may be avoided by adjusting the quadrupoles. As in the cases of large γ_{tr} the acceptances are limited, careful studies have to be done to evaluate the possibility of changing γ_{tr} continuously during one cycle.

Closed orbit corrections

Closed orbit control will be done with 27 capacitive position monitors for each plane in the ring. For a maximum possible tune of 5 this corresponds to 5 monitors per betatron wavelength. For the closed orbit correction 4 steering magnets per plane will be available in each of the straight sections. In the bending section 7 vertical steering magnets will be installed whereas for the horizontal plane backleg windings on the dipoles will be used as closed orbit correctors. Dipole field errors of $(\Delta B/B)_{rms} = 2 \cdot 10^{-4}$ are expected according to the first field measurements. Taking this into account and additional positioning errors of the quadrupoles of $\Delta x_{rms} = 0.25$ mm and $\Delta \theta_{rms} = 0.3$ mrad a maximum closed orbit deviation of less than 18 mm in the horizontal and less than 14 mm in the vertical plane are expected. Calculations with the program ORBIT demonstrate (fig. 4), that a correction of the closed orbit with a maximum deviation of less than 1 mm is possible.

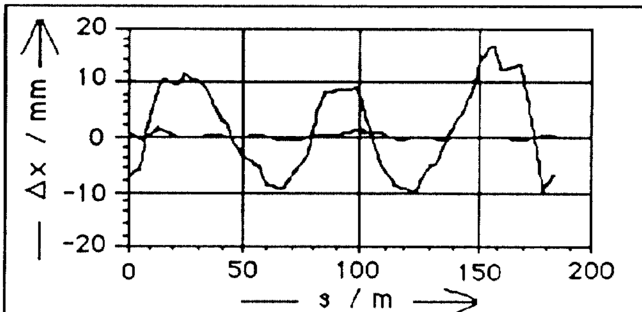

Fig. 4: Horizontal closed orbit deviations with random field and positioning errors and corrected closed orbit.

Instability limits

Space charge effects, resistive wall and microwave instabilities etc. limit the phase space density of the circulating beam. For COSY different energy regimes and different modes of operation have to be taken into account.

Electron cooling at injection energy down to the equilibrium values of about 1 π mm mrad and 10^{-4} in momentum spread [3] would lead to instabilities at high intensities:

The incoherent Laslett tune shift at injection energy amounts to 0.1 for 10^{10} circulating particles within an emittance of 3 π mm mrad. Therefore a heating system has to be installed to limit the equilibrium emittance to the Laslett tune limit for more than 10^{10} circulating protons.

The longitudinal coasting beam instability is no problem for intensities up to 10^{10} stored particles because injection takes place far below γ_{tr}.

The transverse coasting beam instability growth rate is dominated by the low frequency resistive wall contribution. A raise time of 7 s for 10^9 protons is tolerable, whereas for intensities of 10^{10} stored protons a transverse active damping respectively feedback system up to 150 MHz (for $\Delta p/p = 10^{-4}$) or up to 30 MHz (for $\Delta p/p = 5 \cdot 10^{-4}$) is needed.

Work is going on to calculate the emittance dilution coming from the microwave instabilities for the case that γ_{tr} has to be crossed.

Polarization

The physics program at COSY implicates a strong request on polarized beam. As the synchrotron covers a wide range in momentum between 270 and 3300 MeV/c different correction schemes have to be foreseen to overcome the intrinsic and imperfection resonances.

For a vertical tune close to 3.38 there occur 10 intrinsic resonances according to

$$\gamma G = kS \pm Q_y$$

Here, S is the supersymmetry of the lattice and k an integer value. γ is the relativistic factor and G=1.8 for protons.

Simulations with the program DEPOL [6] show that for COSY only the uncorrected S=2 resonances cause emittance depending depolarization. For an emittance of 60 π mm mrad at injection energy the necessary tune jump amounts to about $5 \cdot 10^{-2}$ per turn.

The strongest resonance occurs at $\gamma G = 8 - Q_y$ ($\gamma G = 6 - (Q_y - 2)$) because the two long straight sections have a 2π phase advance and the arcs are built out of 6 almost identical periods. The second strongest one, $\gamma G = 2 + Q_y$ corresponding to S=2, is only reduced by 1/3 in its strength thus indicating that the telescopic sections are not complete spin transparent. The 5 imperfection resonances $\gamma G = k$ will either cause complete spin flip or can be corrected by the described closed orbit correction scheme.

Conclusions

The discussion of the 3 parameter lattice shows, that COSY offers a wide range of ionoptical flexibility to fulfill the different requirements from the experimental as well as from the accelerator point of view.

The closed orbit correction scheme is able to reduce the maximum closed orbit deviations resulting from field and positioning errors below 1 mm. This is sufficient to keep the full geometrical acceptance of the ring available.

The intensity limitations do not seem to cause severe problems if feedback systems are installed.

Polarization can be preserved by closed orbit corrections and by installation of a fast tune jump scheme.

Acknowledgement

The authors thank P. Blüm, University of Karlsruhe, for many stimulating discussions about instabilities and polarization.

References

[1] U. Pfister and R Theenhaus, The COSY-Juelich project, Contribution to this conference

[2] P. Krejcik, S. Martin, D. Prasuhn, H. Stockhorst and R. Wagner, COSY-Lattice description, EPAC 1988, Rome, p. 788

[3] R. Maier, B. Seligmann and J. Stein, Electron cooling in COSY-Juelich, Contribution to this conference

[4] K. Bongardt, S. Martin, D. Prasuhn and H. Stockhorst, Theoretical Analysis of transverse stochastic cooling in the Cooler-Synchrotron COSY, Contribution to this conference

[5] K. Bongardt, S. Martin, P.F.M. Meads, D. Prasuhn, H. Stockhorst and R. Wagner, Optical Flexibility of the COSY-Juelich Storage Ring, PAC 1989, Chicago

[6] E. Courant and R.D. Ruth, BNL Report 51270, 1980