

## COSY-Lattice Description

*P. Krejčík, S. Martin, D. Prasuhn, H. Stockhorst and R. Wagner*  
*Kernforschungsanlage Juelich GmbH, D-5170 Juelich, Postfach 1919*

### SUMMARY

The ionoptical lattice design of the cooler storage ring *COSY*-Jülich is discussed with respect to the experimental demands for *high momentum resolution*, *high angular momentum resolution* and *high luminosities* at the internal target station TP1. Since *COSY* will operate as a storage ring chromatic aberrations have to be carefully compensated. It is shown that three families of sextupoles are sufficient to correct both chromaticity and dispersion.

### INTRODUCTION

The cooler storage ring *COSY* [1] is designed to accelerate light ions as well as to operate as a storage ring with internal target or with an extracted beam. These different modes of operation result in distinct requirements which have to be fulfilled by the ionoptical layout of the ring:

- injection energy 40 MeV/A
- maximum energy 2.5 GeV
- ramping to maximum 1.6 sec
- $0.9 \text{ Tm} \leq B\rho \leq 12 \text{ Tm}$

In this contribution we demonstrate the ionoptical flexibility which is necessary to fulfill one of the following experimental requests on the beam properties at the internal target station:

- **high momentum resolution**,
- **high angular momentum resolution**,
- **high luminosities**

Details on the lattice and beam parameters as well as on the layout of the ring can be found in the contribution [1] to this conference.

### IONOPTICAL VERSATILITY

Briefly, the ionoptical layout of *COSY* is based on a sixfold symmetry realized by six mechanically identical periods. Each of the periods consists of two mirror symmetrical half cells with two bending magnets and two quadrupoles in each half. The focusing structure per period is thus given by

$$QU1-Bend-QU2-Bend-|Bend-QU2-Bend-QU1.$$

This structure is interrupted by two straight sections to gain free space for experimental setups. To prevent distortions on the lattice functions each straight section is telescopic with a phase advance of  $2\pi$ . The focusing structure of each period will be achieved with two independent quadrupole families *QU1* and *QU2*. The quadrupole strengths for a stable particle motion may be changed to achieve a phase advance  $\mu$  per period in the range  $12^\circ \leq \mu \leq 180^\circ$  in both planes corresponding to a tune variation between 2.2 and 4.9 (Fig. 1).

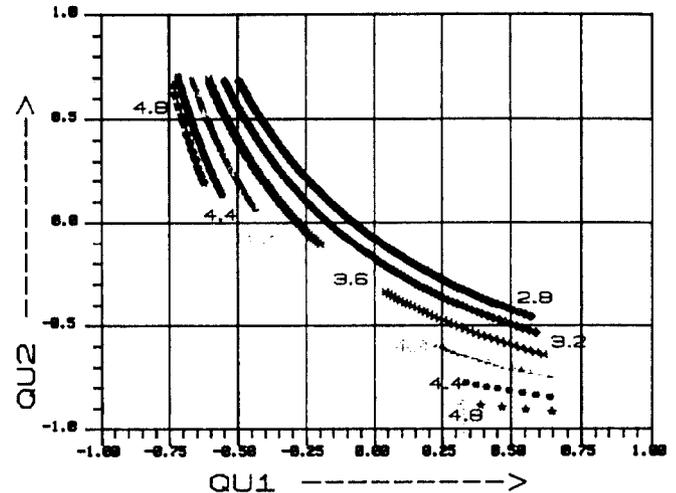


Fig. 1a: Lines of constant horizontal tune versus quadrupole strengths [ $1/m^2$ ].

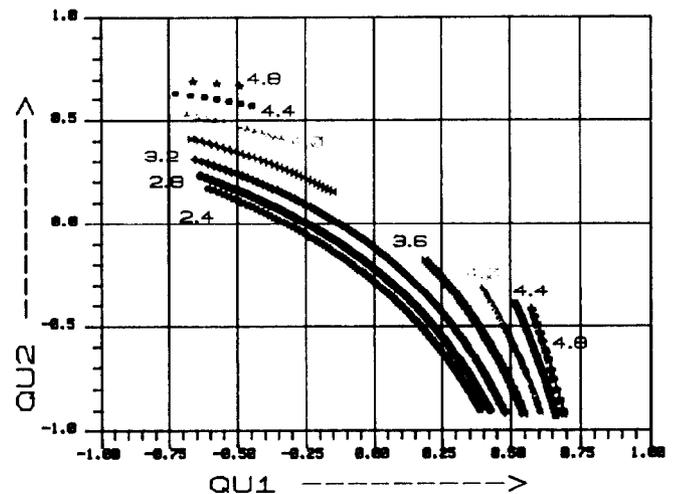


Fig. 1b: Lines of constant vertical tune versus quadrupole strengths [ $1/m^2$ ].

The figure resembles the usual Necktie-diagram with the exception that the waist is broadened towards negative *QU2*-strengths due the additional vertical focusing caused by the edges of the rectangular dipole magnets [1,2].

Since *COSY* will be operated as a storage ring with internal target special care has to be taken on the emittance growth due to angular straggling by Coulomb scattering. To first order the emittance growth  $\Delta\epsilon_n$  after *n* turns is proportional to the  $\beta$ -function at the target [3]:

$$\Delta\epsilon_n = \epsilon_n - \epsilon_0 = \frac{n}{2} \cdot \beta \cdot \theta_{rms}^2$$

where  $\epsilon_0$  denotes the start emittance and the RMS-width of the scattering angle is given by  $\theta_{rms}$ . Therefore, as low as possible  $\beta$ -functions in both the horizontal and vertical plane are necessary at the target station.

Various lines of constant  $\beta$ -functions covering the wide range  $0.5m \leq \beta \leq 20m$  in the horizontal and vertical plane are plotted in Fig. 2 with respect to the tunes corresponding to the stable area in Fig. 1. Overlapping curves of different  $\beta$ -values are visible. This is obviously according to Fig. 1 since different quadrupole settings exist which generate the same working point  $(Q_x, Q_z)$ . The ionoptical conditions are however changed. Besides we mention that in the same way the acceptance of the ring may be varied at one working point.

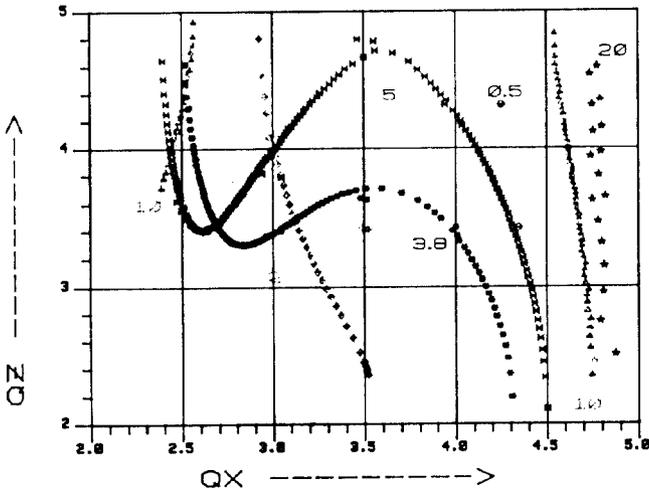


Fig. 2a: Lines of constant horizontal  $\beta$ -values [m] at the target station TP1 versus tune.

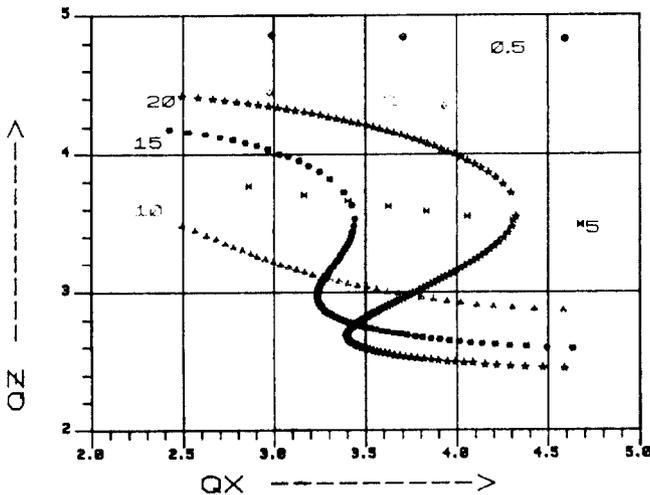


Fig. 2b: Lines of constant vertical  $\beta$ -values [m] at the target station TP1 versus tune.

The figures demonstrate the ionoptical versatility of COSY. However it should be pointed out that not all  $\beta$ -values can be simultaneously realized in both planes. E.g. it is not possible to choose  $\beta \leq 1m$  in both planes simultaneously.

By way of contrast, experiments with high angular resolution require as large as possible  $\beta$ -values since the primary beam divergence is given by

$$\theta_{beam} = \sqrt{\epsilon \cdot (1 + \alpha^2) / \beta}$$

Here,  $\alpha$  is determined via the derivative of the  $\beta$ -function:  $-2\alpha = d\beta/ds$ . The versatility of COSY allows to choose a high  $\beta$  in the horizontal and a low  $\beta$  in the vertical plane thereby taking account for the lower vertical acceptance [1].

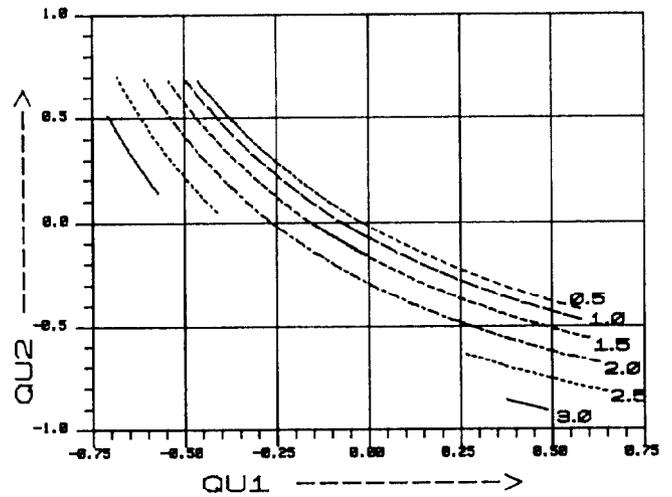


Fig. 3a: Lines of constant  $\gamma_{tr}$  versus quadrupole strength.

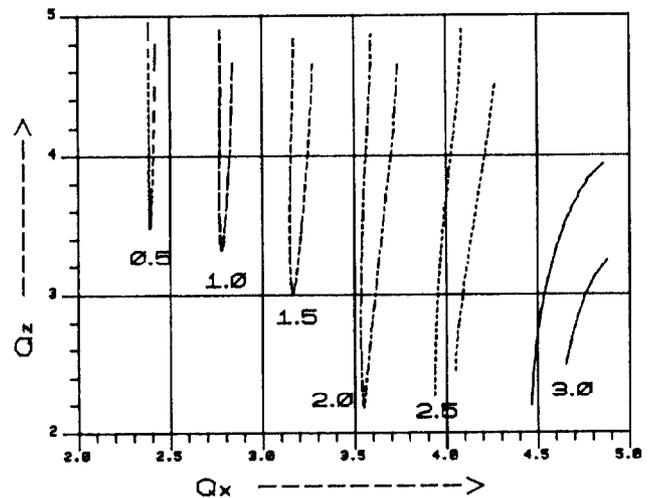


Fig. 3b: Lines of constant  $\gamma_{tr}$  versus tune.

As outlined in [4] the **momentum resolution** depends on the parameter  $D^2/\beta$ . A momentum resolution of the order of  $10^4$  can be obtained with an emittance  $\epsilon = 0.1 \pi$  mm mrad and  $D^2/\beta \approx 50$  m. The emittance may only be influenced by cooling or by well located slits. However, the versatility of the *COSY* lattice design allows  $D^2/\beta$  values in a wide range up to 500 m.

On special interest in stochastic cooling is the mixing number and its dependence on energy and  $\gamma_{tr}$  as outlined in a contributed paper [5]. As shown in Fig. 3,  $\gamma_{tr}$  may be varied in the range between 0.5 and 3.0.

### CHROMATICITY CORRECTION

The linear lattice functions along the ring are shown in Fig. 4 for a *DFPD* quadrupole structure at the working point  $(Q_x, Q_z) = (3.867, 4.119)$ . In this case three families of quadrupoles are used to match the dispersion to zero in the long straight sections.

Chromatic aberrations due to a tune spread caused by particles with different momenta have to be carefully compensated in order to avoid particle loss during the storage mode. In the linear lattice design a great effort was done to

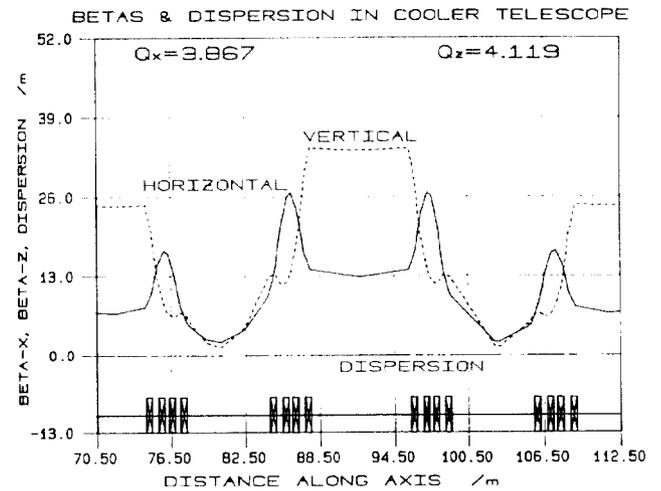
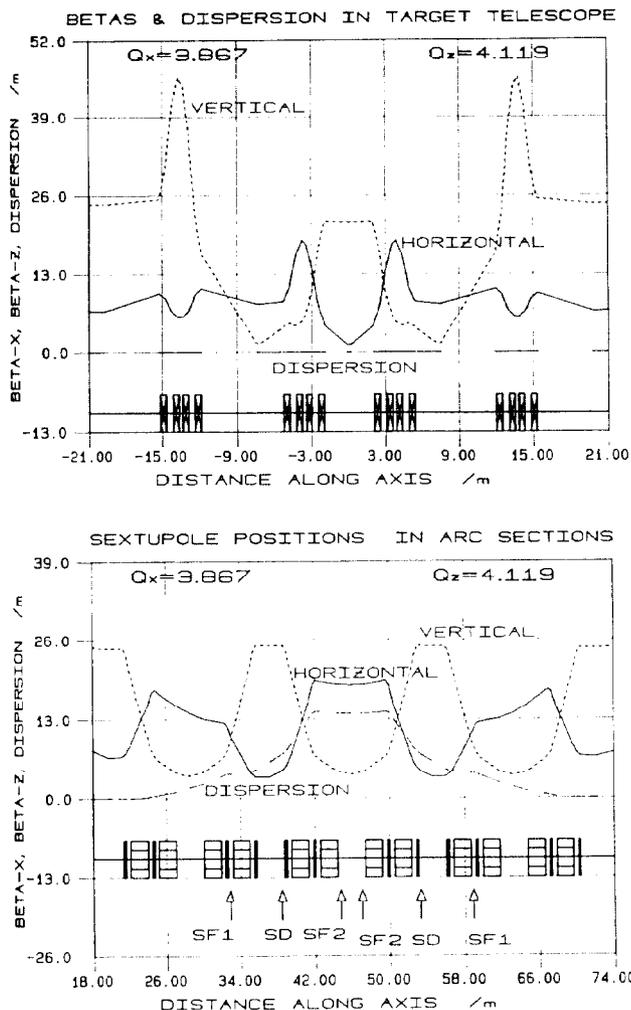


Fig. 4:  $\beta$ -functions and dispersion in different sections of the ring as indicated in the figure. The arrows indicate the positions of the sextupoles.

achieve straight sections with zero dispersion. This is an essential option for stochastic cooling and guarantees that the beam is always in the center of the stochastic pickups. The cooling rate is also affected by the beam size in the kickers so here the dispersion should also be as low as possible. Therefore, a proper chromaticity and dispersion correction is to be done. It turns out that three families of sextupoles (*SF1*, *SF2*, *SD*) are sufficient to correct both horizontal (*F*-sextupoles) and vertical (*D*-sextupoles) chromaticity. They are located at positions where the dispersion is not too small and the  $\beta$ -function is sufficiently large (Fig. 4b). Only relatively low sextupole strengths ( $k < 1 \text{ m}^{-3}$ ) are therefore needed. Thus, a coupling of the horizontal and vertical motion can be kept low.

In the absence of errors, the dispersion correction to 1<sup>st</sup> and 2<sup>nd</sup> order results in a change of beam position with momentum of less than 0.1 mm over a 1% momentum range. For the working point given above the tune variation in the same momentum range is  $\Delta Q_x \approx 0.01$  and  $\Delta Q_z \approx 0.03$ .

In addition, large amplitude behavior have been investigated. Numerical tracking studies over 1024 turns have shown that the particle motion remains stable. Further investigations will be done.

### REFERENCES

- [1] U. Pfister, Status of the COSY-Jülich, this conference. LS 05
- [2] U. Bechstedt et al., this conference NP 014
- [3] S. Martin et al., Nucl. Instr. and Meth. in Phys. Res. **A236** (1985) 249
- [4] D. Prasuhn, Jül-Spez-382 (1986)
- [5] N. Bongers et al., this conference MP 152