Optical Flexibility Of The *COSY*-Jülich Storage Ring

K. Bongardt, S. Martin, P.F.M. Meads, D. Prasuhn, H. Stockhorst and R. Wagner
Kernforschungsanlage Jülich GmbH, D-5170 Jülich, Postfach 1913, FRG

SUMMARY

The lattice of the cooler synchrotron and storage ring *COSY* is designed in a way to guarantee a wide range of ionoptical flexibility. The decoupling of the bending and straight sections in *COSY* is generally discussed. The magnifications of the telescopic straight sections are independent from the working point in the arcs. For different 2π-phase advance telescopes the magnifications are given in both planes. For a special working point ($Q_x=Q_y=4.25$) the variation of the dispersion, the betafunctions and γ_{tr} are presented.

INTRODUCTION

The cooler storage ring *COSY* /1,2/ is designed to accelerate light ions as well as to operate as a cooler storage ring with internal target or with an extracted beam. These different modes of oparation result in distinct requirements which have to be fulfilled by the ionoptical layout of the ring /3/. One example is the variation of the dispersion between zero and a finite value in the straight sections.

DECOUPLING BETWEEN STRAIGHT SECTIONS AND ARCS

The cooler storage ring *COSY* consists of two identical 180^0 arcs separated by two 40 m long straight sections. In one straight section the rf cavities and the electron cooling device are located (*cooler telescope*) whereas the other one (*target telescope*) contains the target stations for internal experiments.
The telescopes are built up by two mirror symmetrical arrangements having telescopic behaviour with the magnifications m_x and m_y. The total 2π-phase advance and the overal 1:1 imaging due to mirror symmetry of the telescopes guarantees first order decoupling of the arcs and the straight sections. Therefore the magnifications are independent from the lattice parameters in the arcs. Each of the telescopes consists of 16 mechanically identical quadrupoles grouped in four units. The four quadrupoles in each unit are excited by two power supplies. The $\beta_{x,y}$-values and the dispersion D_x in the middle of each telescope are given by

$$D_x^T = m_x \cdot D_x^0 \qquad (1)$$

$$\beta_x^T = (m_x)^2 \cdot \beta_x^0 \qquad (2)$$

$$\beta_y^T = (m_y)^2 \cdot \beta_y^0 \qquad (3)$$

where $\beta_{x,y}^0$, D_x^0 are the values at the end of the arc.

Determination of m_x and m_y

In **Figure 1** and **2** the absolute values m_x and m_y are plotted for the *cooler telescope* and the *target telescope* for possible quadrupole settings. The magnifications for all triplet **T** (+--+) or doublet-doublet **D-D** (+-+-) combinations of an unit are shown.

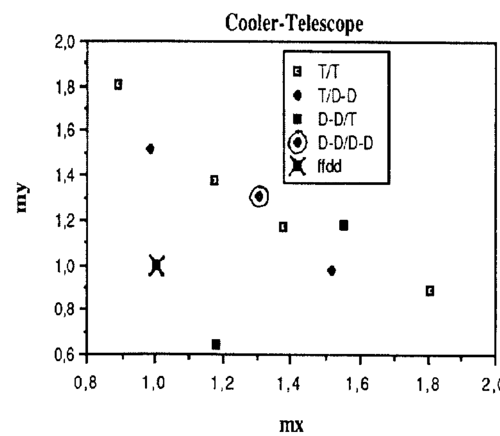

Fig. 1: Magnifications in the cooler telescope for different quadrupole settings

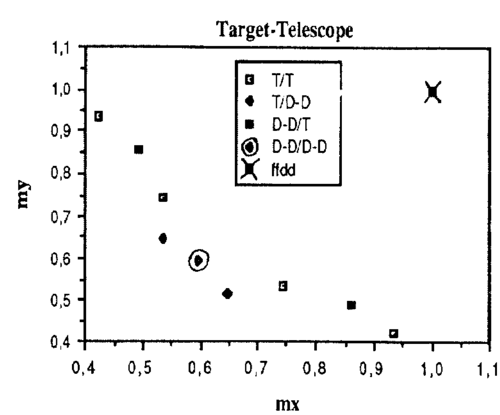

Fig. 2: Magnifications in the target telescope for different quadrupole settings

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The quadrupoles with plus or minus polarity normally have different field strengths. In the *target telescope* the magnifications are smaller than in the *cooler telescope* due to the smaller spacing of the two central units. In addition one **ffdd** (++--) setting with equal field strengths of all quadrupoles in both telescope is included. Here the magnifications are equal in both telescopes. This leads to large but still acceptable betafunctions.
In **Table 1** and **2** the maximum particle energies for the different configurations are summarized for an upper limit of 7.5 T/m for the field gradient. The evaluated **ffdd** combination with 2π-phase advance allows acceleration up to the highest energy of *COSY*.

Tab. 1 and 2:

Cooler-Telescope

Different Operation Modes for 2π-Phase Advance:

Mode	Q1 Q2 Q3 Q4	Q5 Q6 Q7 Q8	N	T_{max} (GeV)
I	T	T	4	2.0
II	D-D	T	2	1.0
III	T	D-D	2	0.8
IV	D-D	D-D	1	0.8
V	f f d d	f f d d	1	4.0

Target-Telescope

Different Operation Modes for 2π-Phase Advance:

Mode	Q1 Q2 Q3 Q4	Q5 Q6 Q7 Q8	N	T_{max} (GeV)
I	T	T	4	1.8
II	D-D	T	2	0.7
III	T	D-D	2	1.1
IV	D-D	D-D	1	0.7
V	f f d d	f f d d	1	4.0

where **N** gives the number of possible combinations with different magnifications.
T Triplet
D Doublet
T_{max} is calculated for the field gradient of 7.5 T/m

Determination of $\beta^0_{x,y}$, D^0_x

In order to determine the values $\beta^T_{x,y}$ and D^T_x at the target station the $\beta^0_{x,y}$ and D^0_x -values at the end of the arcs have to be known. Each arc consists of three unit cells with the following structure:

Q1-B-Q2-B-B-Q2-B-Q1

for the unit cells 1 and 3 and

Q1-B-Q3-B-B-Q3-B-Q1

for unit cell 2.
B: 15^0 bending magnet
Qi: quadrupole

The arcs are mirror symmetric about the center of the second unit cell.
The following investigations are done for the tune $Q_x = Q_y = 4.25$ in order to achieve relatively large acceptances and to allow third order resonace extraction The actual working point will be shifted slightly to avoid the fourth order sum resonances
Figure 3 shows the variation of D^0_x as a function of the quadrupole settings in the arc. If we limit the field gradient to 7.5 T/m only the range $0 \le D^0_x \le 4$m is allowed for the highest energy of 2.5 GeV. **Figure 4** shows the betafunctions at the end of the arcs as a function of the dispersion.

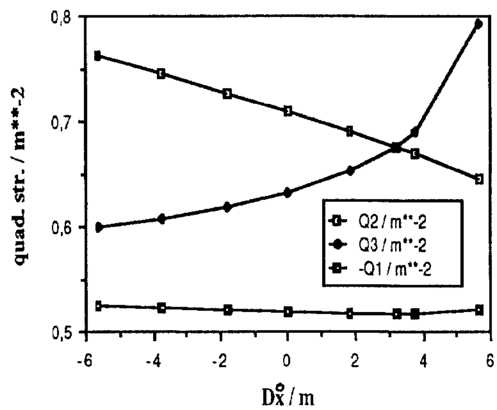

Fig. 3: The setting of the unit cell quadrupoles as a function of the dispersion at the end of the arcs

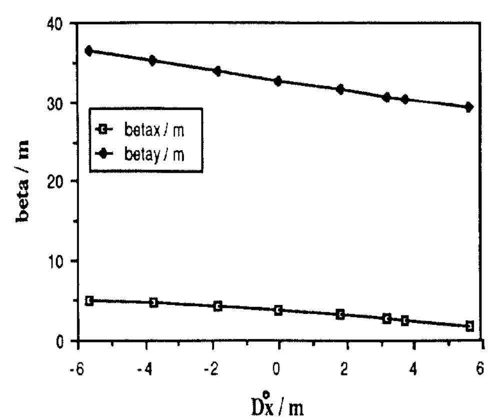

Fig. 4: Horizontal and vertical betafunctions as a function of the dispersion at the end of the arcs

To achieve certain values $\beta^T_{x,y}$ and D^T_x at the target location the possible magnifications m_x and m_y (**Figure 1** and **2**) have to be combined with $\beta^0_{x,y}$ and D^0_x (**Figure 3** and **4**) according to equations

1 to 3. This demonstrates quite clearly the flexible layout of the *COSY* machine.

Figures 5 and **6** show the maximum dispersion and β-values in the arcs. The position of the maximum values in the arcs varies for different quadrupole settings. In both cases the minima correspond to three identical unit cells per arc (Q2 = Q3). For an achromatic beam in the telescopes the lattice functions become relatively large.

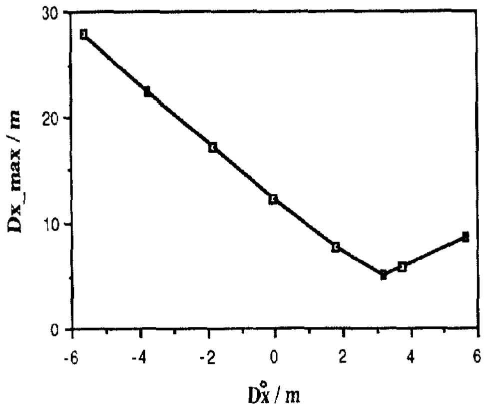

Fig. 5: Maximum dispersion in the arcs as a function of the dispersion at the end of the arcs

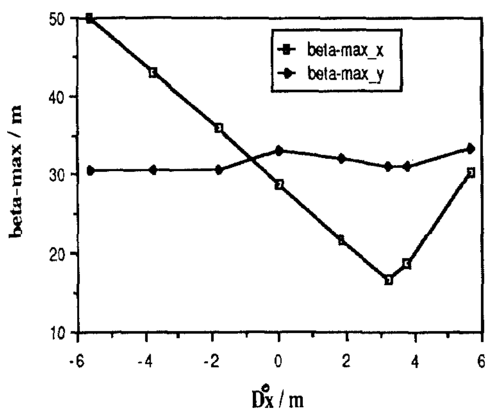

Fig. 6: Maximum β-values in the arcs as a function of the dispersion at the end of the arcs

Figure 7 displays the variation of γ_{tr} for the different D_x^0-values. In the region $2m \leq D_x^0 \leq 4m$, γ_{tr} is nearly constant, whereas in the region $D_x^0 \leq 2m$ a change of γ_{tr} by 0.1 can be achieved by changing the quadrupole gradients Q2 and Q3 by less than 5% (see **Figure 3**). Such a γ_{tr} jump can be done faster than the approximate 50 msec time interval needed for increasing γ by 0.1 due to acceleration.

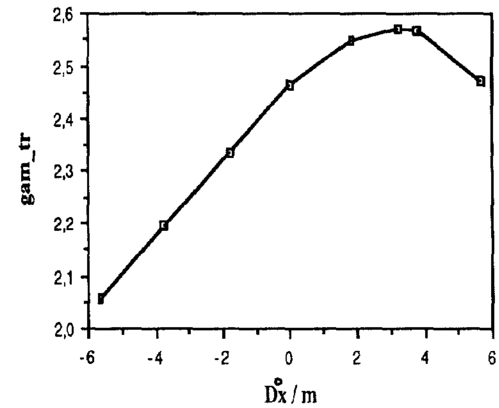

Fig. 7: γ_{tr} as a function of the dispersion at the end of the arcs

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