BEAM PARAMETERS AT THE INTERNAL TARGET POSITIONS FOR EXPERIMENTS IN COSY - JULICH

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Abstract

At the internal target positions in COSY both foil and gas targets can be installed. With internal foil targets very high luminosity can be achieved but also sufficiently high luminosity can be obtained with polarized storage cell targets or atomic beam targets because of the high intensity of the circulating beam. For optimum experimental conditions the ring acceptances should be large and the beta functions at the target position should be small. The ring acceptances depend on the maximum beta functions in the COSY ring and on its apertures.

1 INTRODUCTION

The COSY Julich cooler synchrotron and storage ring provides a number of internal target places [1].Two of them have been considered as a place for the ANKE spectrometer installation: TPA and TP2 [2]. The TPA target place is in the cooler straight section in the COSY ring between quadrupoles MQT28 and MQT29 [3]. The TP2 target place is in the target straight section in the COSY ring between quadrupoles MQT12 and MQT13. All targets will be installed between dipole magnets D1 and D2 in the ANKE spectrometer.

The solid target for the experiment COSY#13 [4] is located at the TP1 place in the middle of the target straight section.

In the following we will discuss beam parameters at internal target positions for experiments planned with the ANKE spectrometer and for the COSY#13 project. Results of the MAD calculations will be presented.

2 PARAMETER DEFINITION

The horizontal aperture of the COSY ring is 75 mm both in straight and arc sections. So the COSY geometrical acceptance in the horizontal direction is equal to $a_x = 75*75/\beta_x^{max}$, where β_x^{max} is the maximum of the horizontal β function in the ring.

The vertical aperture is equal to 75 mm in the straight sections and 30 mm in the arc sections. So when calculating the vertical COSY acceptance we have taken as the vertical geometrical acceptance

$$a_y = \min\left(30*30/\beta_{y,a}^{max},\ 75*75/\beta_{y,t}^{max}\right),$$

where $\beta_{y,a}^{max}$ and $\beta_{y,t}^{max}$ are the maximum vertical β functions in the arc and telescope sections, respectively.

The maximum current in the quadrupole coils is 550 A. The length L for arc quadrupoles is 0.372 m and for telescope quadrupoles is 0.62 m. The quadrupole coefficient is calculated as $K_1 = 0.29979*S/L/p$, where S is a quadrupole strength and p is the proton momentum. For the maximum proton momentum p=3.3 GeV/c, available in the COSY ring, the maximum quadrupole coefficient is equal to $K_1 = 0.816\ m^{-2}$ for arc quadrupoles and $K_1 = 0.856\ m^{-2}$ for telescope quadrupoles.

The acceptance radii are:

$$S_x = \sqrt{a_x \cdot \beta_x^T}, \qquad S_y = \sqrt{a_y \cdot \beta_y^T}$$

where: πa_x, πa_y - are the horizontal and vertical acceptances of COSY, respectively; β_x^T, β_y^T - the β functions at the target position.

For optimum experimental conditions the ring acceptances should be large and the beta functions at the target position should be small. We define the following figure of merit:

$$M = \frac{1}{\frac{\beta_x}{a_x} + \frac{\beta_y}{a_y}}$$

Good experimental conditions are achieved for large values of M.

For solid targets [5] we require to have good filling of the ring, low Coulomb scattering to minimize particle loss and reasonably small S_y (for COSY#13 the rate is $\propto S_y^{-1}$). For the foil target we introduce the following parameter which includes both figures of merit:

$$F = M_{inj} \cdot M_F$$

where M_{inj} is the figure of merit at the injection point and M_F is the figure of merit at the foil target position. As long as the number N of protons is far below the space charge limit, N is proportional to M_{inj}. To have good filling of the ring, M_{inj} should then be as large as possible. To have a small particle loss in the ring, M_F should be as large as possible. So we look for a maximum value of the F parameter to find the best experimental conditions for foil targets. At the space charge limit, $F \propto M_F$.

In case of a polarized storage cell target it is important to have a high density and good filling of the ring. For a rigid cell, the target dimensions must be $\geq 2S_x$ and $\geq 2S_y$, respectively. The density in a storage cell target is roughly proportional to l^2/d^3, where l is the length of the storage cell and d is its diameter. For a fixed value of l, the density in a target is roughly proportional to $(\sqrt{S_x \cdot S_y})^{-3}$. As in case of the foil target we look for the figure of merit and include the properties of the injection point. We can then define a parameter:

$$G\_S = \frac{M_{inj}}{(\sqrt{S_x \cdot S_y})^3}$$

which should become maximum for maximum luminosity.

As reference values we use data for the standard COSY working point of tunes Q_x=3.63 and Q_y=3.55. The tunes are set by changing the strength of the quadrupoles.

3 MAD CALCULATIONS

The MAD code [6] was used to calculate the COSY beam parameters of the actual standard working point and to look for the optimum quadrupole settings necessary for ANKE and COSY#13 experiments.

The following quantities were calculated and analysed: the β functions for horizontal and vertical plane, the horizontal tune Q_x, the vertical tune Q_y, the gamma transition γ_{tr}, the phase functions μ for both planes, the dispersion function in the horizontal plane (the dispersion in the vertical plane is 0), the geometrical horizontal acceptance a_x, the geometrical vertical acceptance a_y.

From the values calculated by the MAD code the following parameters were obtained: the figure of merit M_{inj} at the injection point, the figure of merit M_T at the target position (both for foil and gas target), the acceptance radii S_x and S_y, the parameter F and G_S for foil and gas targets, respectively.

For the foil target placed at TP1 for COSY#13 the calculations were stopped when F was 102 times higher than for the standard COSY quadrupole set-up. A still higher value seems achievable.

For TP2 two different internal target types are considered: a polarized storage cell target and a foil target. The gas target is put at s=32.02 m and the foil target at s=32.51 m along the COSY ring. The injection point to the COSY ring is at s=0. For the foil target, the MAD calculations were stopped when the parameter F reached the value 18 times higher than for the standard COSY quadrupole set-up but the limit in calculations has not been reached. For the gas targets at the TP2 position the maximum value of the parameter G_S was reached for the almost circular shape of the target cell with S_x~S_y~4 mm.

For the TPA place and the gas target, calculations were made for all planned target positions: close to D1 (s = 125.29 m), between D1 and D2 (s = 125.76 m), close to D2 (s = 126.24 m) [7]. The foil target is placed at s = 126.24 m. The injection point to the COSY ring is at s = 0. For the TPA position and the foil target, the MAD calculations were stopped when the parameter F reached the value 24 times higher than for the standard COSY quadrupole set-up but still it is possible to continue calculations. For the gas targets at this position the maximum value of the parameter G_S was reached for the target cell with S_x~6 mm and S_y~4 mm.

In Tables 1 and 2 the beam parameters for the standard actual COSY quadrupole set-up and some results of calculated optimum parameters are presented.

The layout of the COSY ring with all considered internal target places is shown in Fig.1 including new power supplies proposed for the ANKE installation at the TPA target place.

Table 1. Calculated beam parameters for standard actual COSY quadrupole set-up

β_x^{max} = 43.8 m $\beta_{y,a}^{max}$ = 57.3 m $\beta_{y,t}^{max}$ = 38.4m

a_x = 128.3 π mm mrad a_y = 15.7 π mm mrad

Q_x = 3.630 Q_y = 3.550

γ_{tr} = - 2.03 M_{inj} = 1.1

maximum dispersion = 27.6 m

QUANTITY	TP1 foil at s=24.87	TP2		TPA	
		gas at s=32.02	foil at s=32.51	gas at s=125.76	foil at s=126.24
β_x (m)	19.8	1.6	1.5	4.3	3.5
β_y (m)	18.7	5.5	4.2	5.0	4.7
M_T	0.7	2.8	3.6	2.8	3.1
S_x (mm)	50.5	14.5	14.0	23.5	21.1
S_y (mm)	17.2	9.3	8.1	8.9	8.6
F G_S	0.80	 0.69	3.88	 0.36	3.29
dispersion at target (m)	19.1	1.6	-0.1	6.5	5.1

$\beta_{y,a}^{max}$, $\beta_{y,t}^{max}$ - maximum vertical β functions in the arc and telescope sections, respectively

Table 2. The calculated optimum beam parameters for gas and foil targets for TP1, TP2 and TPA target places in the COSY ring

QUANTITY	TP1 foil at s=24.87	TP2		TPA	
		gas at s=32.02	foil at s=32.51	gas at s=125.76	foil at s=126.24
β_x (m)	7.0	0.5	2.3	1.0	2.6
β_y (m)	1.3	1.6	1.6	1.3	1.5
a_x (π mm mrad)	278.0	30.3	221.7	34.6	174.1
a_y (π mm mrad)	44.8	9.3	33.3	10.0	38.2
Q_x	3.689	3.627	3.320	3.526	3.547
Q_y	3.234	3.871	4.120	4.401	4.137
γ_{tr}	2.11	-1.97	1.45	1.84	1.82
M_{inj}	4.5	0.4	4.1	0.7	4.3
M_T	18.3	5.4	17.6	6.1	18.7
S_x (mm)	44.0	4.0	22.5	5.9	21.3
S_y (mm)	7.7	3.8	7.2	3.6	7.5
F G_S	81.66	7.17	71.44	6.85	80.58
dispersion at target (m)	-8.3	2.4	-0.3	-0.7	-0.6
maximum dispersion (m)	11.8	51.9	27.1	14.4	11.0

4 REFERENCES

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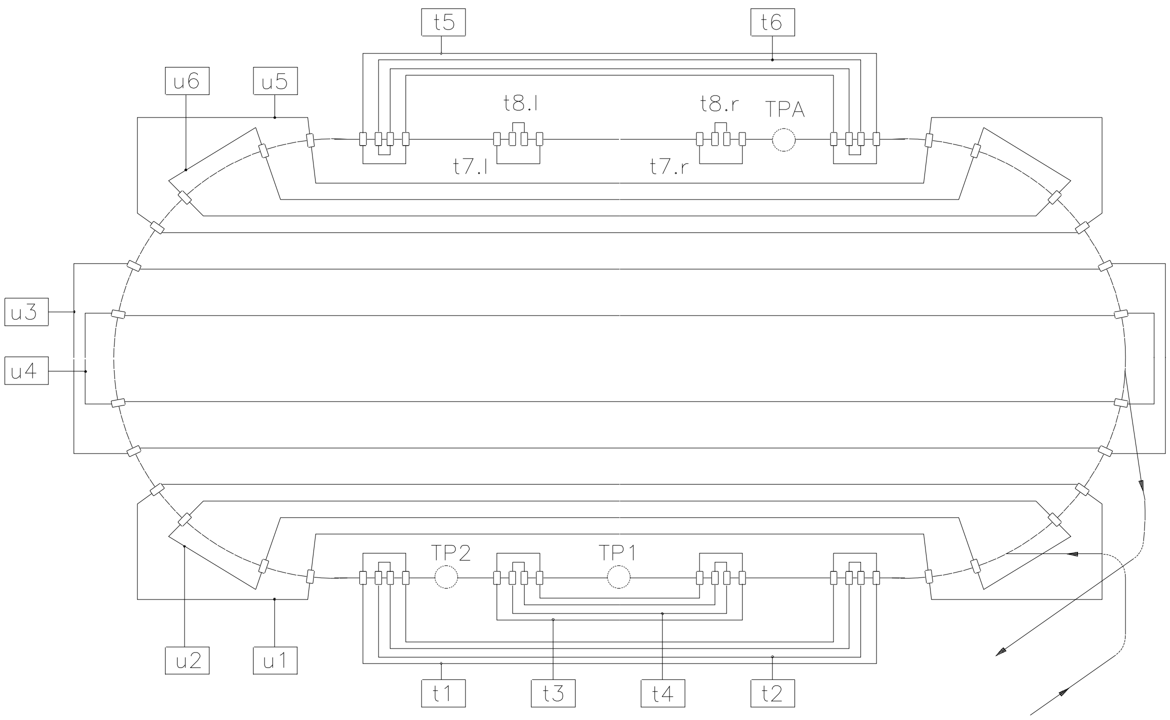

Figure 1. The COSY ring with new power supplies proposed for the ANKE installation at the target place TPA (u_1,...,u_6 - power supplies for arc quadrupoles, t_1,...,t_6 - existing power supplies for telescope quadrupoles, t_{7_l}, t_{7_r}, t_{8_l} and t_{8_r} - new power supplies proposed for ANKE, instead of existing t_7 and t_8)