Extraction Beam Lines for COSY-Jülich

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Abstract

The cooler synchrotron COSY [1] will accelerate protons from 40 MeV up to 2.5 GeV. The 3 experimental areas at the COSY Jülich cooler synchrotron require for the extracted beams a very small and stable beam spot at the target positions. The beam size has to be demagnified from the extraction point - the exit of the magnetic extraction septum - to the target by a factor of about 20 for the two areas, accommodating the BIG KARL spectrometer as well as the Time-of-Flight experiment. The beam lines consist of an achromat directly behind the extraction followed by a system of demagnifying triplets ($R_{11} \approx R_{33} \approx 1/20$).

I. BEAM PARAMETERS AT EXTRACTION

For the TRANSPORT calculations the COSY tune with $Q_x = Q_y = 3.38$ and the corresponding TWISS parameters of tab. 1 have been used.

Tab. 1: TWISS Parameters at Extraction for the COSY - Tune (Q_x/Q_y) = 3.38/3.38)

$\beta_x = 7.2$ m	$\beta_y = 12.7$ m
$\alpha_x = 0.14$	$\alpha_y = 0.07$

It was assumed that the angular dispersion vanishes at extraction point ($R_{26} = 0$); the radial dispersion $D_x = R_{16}$ was varied in a rather large range : $0 \leq D_x \leq 5$ m.
From the values of the β-function at extraction the TRANSPORT beam parameters are readily obtained from the assumed momentum dependent beam emittance $E = \pi \cdot \varepsilon$. They are listed in tab. 2.

Tab. 2: Beam Parameters for the TRANSPORT Runs. (The values are derived from the TWISS parameters listed in Tab. 1.)

ε [mm mr]	x [mm]	x' [mrad]	y [mm]	y' [mrad]
5	6.0	0.840	7.97	0.629
2.5	4.243	0.595	5.635	0.445
1	2.683	0.376	3.564	0.281

Since the TWISS parameters $\alpha_{x,y}$ are finite at extraction point, we assumed for the TRANSPORT calculations there the corresponding matrix elements $R_{12} = 0.14$ mm/mrad and $R_{34} = 0.07$ mm/mrad. For the beam a momentum of p = 3.3 GeV/c was assumed, for the momentum spread dp/p = ± 0.25%. The TRANSPORT parameters for the beam are calculated for the different beamlines.

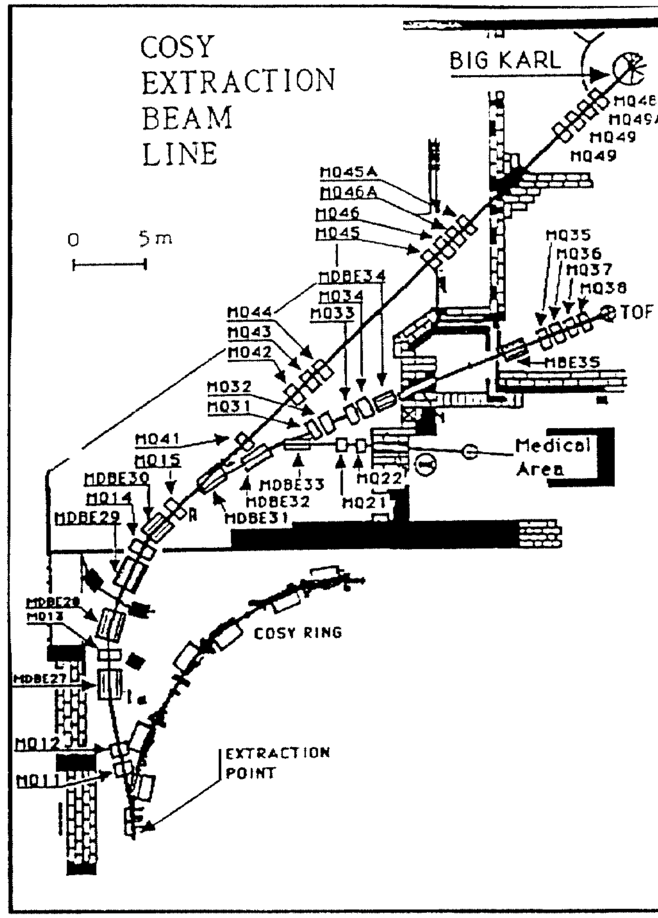


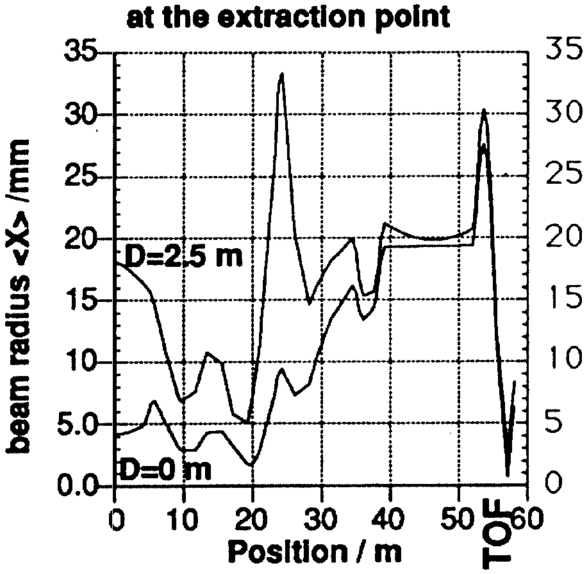
Fig. 1: Layout of the experimental areas at COSY

Figure 1 shows the actual layout for the external beam lines.

II. THE FODO FRONT SECTION

The front end system of the extraction beam line is designed to achieve a dispersion free beam at the end. It consists of a matching quadrupol doublet followed by 4 combined function bending magnets. The magnets have a gradient of n = ±12.88.in TRANSPORT notation. The front end system should be able to compensate for different dispersions at the extraction point. This works for $0 \leq D_x \leq 5$ m.In fig.2 the beam envelopes are shown for two different values of D. This demonstrates the independence of the beam radius from the unknown dispersion at the extraction point.

Fig. 2 : Horizontal beam radius for dispersions of D=0 and D=2.5 at the extraction point



III. RESULTS OF THE TRANSPORT CALCULATIONS

1. EXTERNAL BEAMLINE 2 - MEDICAL AREA

The beam acceptance of beamline 2 was assumed to be $\varepsilon_x = \varepsilon_y = 2.5$ mm·mrad. The beam dimension at the target position was specified to be:

$$x = y < \pm 2 \text{ mm}$$

Therefore as optical solution a doubly achromatic waist in both coordinates has been specified. Compared to the earlier design [2] two further quadrupole singlets - 3MQ21 and 3MQ22 - have been added.
The gradients of the quadrupoles of beamline 2 for a beam momentum of p = 3.3 GeV/c and for different dispersions at extraction are summarized in tab. 3, the resulting beam dimension at the target position is contained in tab. 4, again for different values of the beam dispersion.

Tab. 3: Gradients for the Quadrupoles of Beamline 2 for p = 3.3 GeV/c and different Dispersions at Extraction.

D	3MQ11	3MQ12	3MQ13	3MQ15 3MQ14	3MQ21	3MQ22
[m]	[T/m]	[T/m]	[T/m]	[T/m]	[T/m]	[T/m]
0	- 3.31	11.00	3.733	- 7.58	-10.07	8.72
1.25	- 6.16	10.64	4.980	- 8.02	-10.19	7.80
2.50	- 6.80	10.37	5.927	- 8.50	-10.35	9.13
5.00	- 5.96	9.32	7.273	- 9.16	-10.36	11.33

Tab. 4 : Beam Radii at the Target of Beamline 2.

D	Mom. spr.	x	y
[m]	dp/p [%]	[mm]	[mm]
0	0.5	1.86	2.01
1.25	0.5	2.97	2.46
1.25	0.1	2.27	2.46
2.5	0.5	3.41	1.88
2.5	0.1	3.25	1.88
5.0	0.5	2.21	1.46

2. EXTERNAL BEAMLINE 3
TIME - OF - FLIGHT = TOF

Also for this beamline we have assumed an arbitrary emittance of $\varepsilon_x = \varepsilon_y = 2.5$ mm·mrad. Compared to the previous concept two additional vertical bending magnets - 3MBE34 and 3MBE35 - had to be included to enable hoisting the beam by 80 cm at the TOF - target position. An ion optical consequence is a small but finite vertical dispersion. The beam dimensions, radially and axially at the target position, were specified by the experiment to be

$$x, y < \pm 1 \text{ mm}.$$

The results of the Transport calculation are plotted in fig. 2 for two different dispersions.
The gradients for the quadrupoles of the TOF - beamline are listed in tab. 5, the beam dimension at the target position in tab. 6, for the different values of the beam dispersion at extraction and a beam momentum of p = 3.3 GeV/c.

Tab. 5: Gradients of the Quadrupoles of Beamline 3 (TOF) at p = 3.3 GeV/c for different Dispersions at Extraction.

D	MQ11	MQ12	MQ13 MQ14	MQ15	MQ31 MQ34	MQ32 MQ33	MQ35 MQ38	MQ36 MQ37
[m]	[T/m]	[T/m]	[T/m]	[T/m]	[T/m]	[T/m]	[T/m]	[T/m]
0	6.08	-1.40	3.86	-4.21	5.41	-4.78	-9.14	8.56
1.25	3.86	0.15	3.60	-4.23	5.48	-4.81	-9.14	8.56
2.50	5.08	-2.07	5.06	-6.29	5.33	-4.70	-9.23	8.63
5.0	4.16	-1.19	4.25	-6.10	5.49	-4.77	-9.35	8.70

Tab. 6 : Beam Radii at the TOF Target for different Dispersions(D) at Extraction Point and D_{TOF} at the Target

D	dp/p	x	y	D_{TOF}
[m]	[%]	[mm]	[mm]	[m]
0	0.5	0.51	0.72	-0.73
1.25	0.5	0.75	0.81	1.5
2.5	0.5	2.74	1.79	-0.42
2.5	0.1	0.56	0.52	-0.42
5.0	0.5	2.16	0.58	-0.80
5.0	0.1	0.50	0.52	-0.80

3. EXTERNAL BEAMLINE 4
BIG KARL SPECTROGRAPH

For this beamline again an emittance of $\varepsilon_x = \varepsilon_y = 2.5$mm·mrad has been assumed. The gradients of the quadrupoles of the BIG KARL beamline are listed in tab. 7, the beam dimensions and divergences at the target are contained in tab. 8, for different values of the beam dispersion and for a beam momentum of p = 3.3 GeV/c.

Tab. 7: Gradients of the Quadrupoles of Beamline 4 (BIG KARL) at p = 3.3 GeV/c.

D	0,00	1,25	2,50	5,00	m
MQ11	4,31	1,38	0,57	2,33	T/m
MQ12	-1,58	1,23	2,27	1,07	T/m
MQ13=MQ14	5,09	4,13	3,29	3,49	T/m
MQ15	0,88	3,11	5,69	5,95	T/m
MQ41	-5,52	-5,03	-5,65	1,81	T/m
MQ42	1,38	7,24	2,27	-7,16	T/m
MQ43	10,0	8,36	4,62	-0,82	T/m
MQ44	-10,0	-5,98	-2,12	8,30	T/m
MQ45=MQ45A	5,56	6,36	6,49	6,54	T/m
MQ46=MQ46A	-4,91	-5,60	-5,64	-5,98	T/m
MQ48=MQ48A	8,12	8,15	8,16	8,09	T/m
MQ49=MQ49A	-7,51	-7,50	-7,46	-7,42	T/m

Tab. 8: Beamradii and -divergences at the BIG KARL Target for different Dispersions at Extraction.

D [m]	Mom.spr. dp/p [%]	x [mm]	x' [mrad]	y [mm]	y' [mrad]
0	0.5	0.50	5.76	0.50	5.94
1.25	0.5	0.52	5.05	0.51	5.01
2.5	0.5	0.53	5.44	0.47	7.04
5.0	0.5	1.43	7.15	0.43	6.92
5.0	0.1	0.45	7.14	0.43	6.92

IV. REFERENCES

[1] R. Maier and U. Pfister,"The COSY-Jülich project, March 1992 status", to appear in the proceedings of this conference

[2] C.A.Wiedner, S. Martin "COSY - Strahlführung zu den externen Strahlplätzen 2, 3, 4 und BIG KARL", COSY-note No. 84, KFA Jülich, September 1989