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DESIGN OF T10 (ALICE) FOR EHNL

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1. Constraints, design and needs of the new T10 line.

1.1 General and vicinity constraints.

The new T10 shall fit the geometry as defined in EHNL5 document (ref. 1.), with adequate optical characteristics and no incidence on T11 which we will keep untouched. The consequences on T9 should be minimal and compatible with its own requirements and solutions. It is desirable to reuse the presently available magnets and power supplies as far as practical.

This T10 line will be mainly dedicated to tests of the LHC ALICE experiment, the maximum momentum being raised to 7 GeV/c in agreement with the ALICE team, from its present 5 GeV/c. Higher momentum could not be handled in the specified geometry and/or without alteration of the T11 line.

The design should guarantee good and reproducible beam quality at the experimental focus, within its expected useable range. The optical design is an adaptation of the classical double monochromator scheme, with its known favourable quality/complexity ratio. Its proper optimisation is, however, far from trivial, but the work investment is concentrated at design time, with comparative ease of operation however, once the line have been properly commissioned.

1.2 Geometry and momentum adaptation.

In the present line, the limiting elements are mainly the two bending magnets BHZ01 and BHZ02. Increasing the momentum implies a reduction of their deflexion. A change of magnet type can not be envisaged as there is no available stronger magnets.

The line is unmodified from the target up to and inclusive to the analyser magnet BHZ01. The deflexion of this magnet is reduced from 200 to 140 mrad to cope with the increased momentum. The recombiner magnet shall retain the 200 mrad deflexion with an early rotation point to match the final destination line in the ALICE experimental area. The present BHZ02 can only provide 149 mrad at 7 GeV/c, so we added an M100 magnet (BHZ03) to handle the complement. These two magnets will be separated by the shielding wall; laying the stronger one first will place the experimental line at the required location.

The vertical dipole BVT02 had to be slightly moved upstream of its present longitudinal location to make space for the last doublet and the vertical acceptance collimator. This rises the line level to 2.505m instead of the previously published 2.5 m.

1.3 Optical design.

Dispersion control : done with field lens QFO03 and angle of BHZ03, with proper attention to the needed shielding space and the final experimental line location. Horizontal dispersion is suppressed beyond BHZ03.

Intermediate focus : horizontal in the mid plane of the momentum slit, vertical in the principal object plane of the field lens QFO03 (diverging plane) for minimum sensitivity; tuneable elements QDE01 and QFO02. The doublet sign is needed to contain the beam with respect to BHZ01 gap size.

Final focus : strictly done with QFO04 and QDE05 once the upstream optics is defined. The spacing has been increased to insert the vertical acceptance collimator; this also reduce the needed forces in the lenses.

The resulting geometry, once all matching and cross checks are done, can be found in Table 2. The nominal optics (first order) is shown on fig. 1.

1.4 Needed magnetic resources and power supplies.

All the magnets, quadrupoles and their associated power supplies are recovered from the present line and reused under conditions quite similar than now. Some of the power dissipation are higher than at present and the increased cooling needs have to be taken into account. Details can be found in Table 3.

The only additional element is a M100 magnet called BHZ03 and its associated power supply. No parts are liberated, ancillary equipment are also reused.

M-name	Magnet	I max	P max (kW)	Flow (l/min)
QDE01	Q801[a]	669	99	71
QFO02	Q802[a]	782	143	103
BHZ01	MC207[a]	784	227	163
QFO03	QFS13[a]	366	11	8
BHZ02	MC201[a]	784	227	163
BHZ03	M100[b]	347	23	16
QFO04	Q108[a]	456	33	23
QDE05	Q109[a]	639	55	40
BVT02	M117[a]	236	12	9
Total			**830**	**600**

Table 1. Magnets, power and required water flow.

a/ magnet and power supply already exist in the present T10 line, no change required

b/ the magnet type only is defined, a new magnet and a power supply should be installed

Remark : the quoted power takes into account the DC resistance of the magnet at a mean coil temperature of 35° Celsius. It neglect wiring losses and efficiency of the power converters. The water flow is given for a 20° Celsius temperature rise (~36 m^3/h); it may be lower if a higher temperature rise is acceptable.

1.5 Ancillary equipment.

- Momentum collimator : same as now at almost the same location, in the target area.
- Vertical acceptance collimator : same as now, moved in the secondary area between the lenses of the last doublet to make it efficient. The beam is already filtered by the various acceptance limitations upstream and the maximum expected beam intensity (~10^7/spill) is deemed acceptable by the radiation protection group.
- Beam stopper : will be renovated and replaced close to its present location, inside the target area
- Shielding: moved downstream to make space for BHZ03, total thickness 2.4 m.

1.6 Monitoring devices.

The effective devices installed have still to be discussed with the beam diagnostics group for availability, feasibility and performances; our wish list is however quite clear :

- MWPC or equivalent devices at line end and at the vicinity of experimental focus. Resolution in the order of 2 or 4 mm seems adequate.
- Some kind of intensity measurement would be very useful. It should reflect the effective intensity delivered to the experiment and impose minimal degradation of the beam quality. Its location and type is open to discussion.

1.7 Line vacuum.

The line is expected to be under crude vacuum (< 10 Pa) from the upstream face of QDE01 up to the downstream face of BVT02 (just after the separating wall). This will ensure minimal multiple scattering in air and vacuum windows.

Reported by TRANPLT/SRV program [std units: L(m), S(m), Field(kG)] Run at 17.07.34 11/11/96
Initial coord. at Sx=Sy=Sz=0, Ax=pi/2, Ay=0, Az=-pi/2
Bend coord. given at Xing point of straight lines
Angle to the left or to the up side is >0
Z axis stands as the altitude
Program version 1.1 - any complain to JYH (CERN)

Start Ax,Ay,Az (radians)=			1.7370	-.1662	-1.5326					
Name	dSl	S.lgth	S.x	S.y	S.z	B.pos	Length	Field	deg	rad
_TV7	.000	.000	2076.407	2182.183	1.326	.000				
*QDE1	7.700	7.700	2083.995	2180.910	1.620	7.700	.900	-8.9518		
*QFO2	3.200	10.900	2087.148	2180.381	1.743	10.900	.900	9.9569		
>BHZ1	2.302	13.202	2089.417	2180.000	1.831	13.200	2.180	14.9951	8.0214	.1400
_BS	1.832	15.034	2091.247	2179.952	1.901	15.030				
_CH75	1.745	16.779	2092.990	2179.906	1.967	16.775				
*QFO3	.940	17.869	2094.078	2179.878	2.009	17.865	.840	7.6434		
>BHZ2	2.062	19.930	2096.137	2179.824	2.088	19.925	2.180	14.9951	8.0214	.1400
>BHZ3	4.812	24.742	2100.915	2180.370	2.272	24.735	1.160	10.6545	3.0327	.0529
*QFO4	1.880	26.622	2102.767	2180.682	2.344	26.615	1.160	7.5057		
_CV46	1.210	27.832	2103.960	2180.882	2.390	27.825				
*QDE5	.980	29.042	2105.152	2181.083	2.436	29.035	1.160	-9.1652		
>BVT2	1.795	30.837	2106.921	2181.381	2.505	30.830	1.180	7.5664	-2.1909	-.0382
_Foc	3.470	34.308	2110.343	2181.957	2.505	34.300				
_ENDP	5.000	39.308	2115.274	2182.787	2.505	39.300				
Final Ax,Ay,Az (radians)=			1.4041	.1667	-1.5708					

BHZ1	H	140	mrad left
BHZ2	H	140	mrad left
BHZ3	H	52.931	mrad left
BVT2	V	38.238	mrad down

EHNL5D T10new v5.1 7.0 GeV/c 4/11/96 "

Table 2. Geometry of the new T10 line, version 5.1

Required power, kW										Line total
Momentum	ZT10.QDE01	ZT10.QFO02	ZT10.BHZ01	ZT10.QFO03	ZT10.BHZ02	ZT10.BHZ03	ZT10.QFO04	ZT10.QDE05	ZT10.BVT02	
1.00	1.57	1.94	4.39	0.21	4.39	0.48	0.61	0.91	0.25	14.74
1.50	3.56	4.41	9.86	0.46	9.86	1.07	1.37	2.04	0.56	33.20
2.00	6.39	7.94	17.49	0.82	17.49	1.89	2.44	3.64	0.99	59.09
2.50	10.11	12.61	27.26	1.27	27.26	2.93	3.81	5.70	1.55	92.50
3.00	14.78	18.50	39.16	1.83	39.16	4.19	5.50	8.23	2.21	133.58
3.50	20.48	25.74	53.21	2.49	53.21	5.66	7.51	11.27	3.00	182.56
4.00	27.29	34.44	69.44	3.25	69.44	7.34	9.84	14.84	3.89	239.79
4.50	35.31	44.74	87.96	4.12	87.96	9.25	12.53	19.01	4.90	305.77
5.00	44.63	56.82	108.93	5.10	108.93	11.39	15.59	23.87	6.01	381.27
5.50	55.39	70.97	132.63	6.21	132.63	13.80	19.05	29.55	7.24	467.48
6.00	67.79	87.77	159.54	7.46	159.54	16.52	22.97	36.31	8.59	566.49
6.50	82.18	108.77	190.49	8.89	190.49	19.60	27.43	44.58	10.06	682.49
7.00	99.38	142.82	227.01	10.53	227.01	23.12	32.54	55.30	11.65	829.36

Table 3. Computed power in magnets function of momentum for the nominal focus.

2. Precomputed behaviour of the T10 line.

This chapter presents what is to be expected from the modified T10 line. Some of the values may change slightly during implementation and will have to be confirmed at commissioning time.

Characteristics of the beam T10.

Maximum design momentum		7.0 GeV/c
Length at reference focus[1]		34.3 m
Beam height		2.505 m
Production angle from target	H	61.06 mrad
	V	8.24 mrad
	total	61.6 mrad

Horizontal angular acceptance[2] (in QFO02)	4.85 mrad
Vertical angular acceptance[2] (in QDE01)	12.4 mrad
solid angle acceptance[3]	189 μsr

Horizontal magnification at momentum slit	0.3
Momentum slit displacement	5.0 mm for 1% Δp/p
Theoretical momentum resolution[4]	0.24%

Optical characteristics at reference focus (minimum Δp/p, multiple scattering not included).

dispersion (/% Δp/p)	H	0 mm/ 0 mrad (first order full correction)
	V	1.33 mm/ 0.38 mrad
magnification from target	H	0.84
	V	0.62

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1 Reference focus is located 3.47 m downstream of the last magnet centre (vertical dipole)

2 The physical aperture limit is inside the first two quadrupoles, inner radius of 92 mm.

3 The aperture limit is an ellipse with semi-axis 35.2*89.8 (mm, H*V) at the entrance face of the first quadrupole, located 7.25m from the target plane.

4 For an effective production target of 4*4 mm^2.

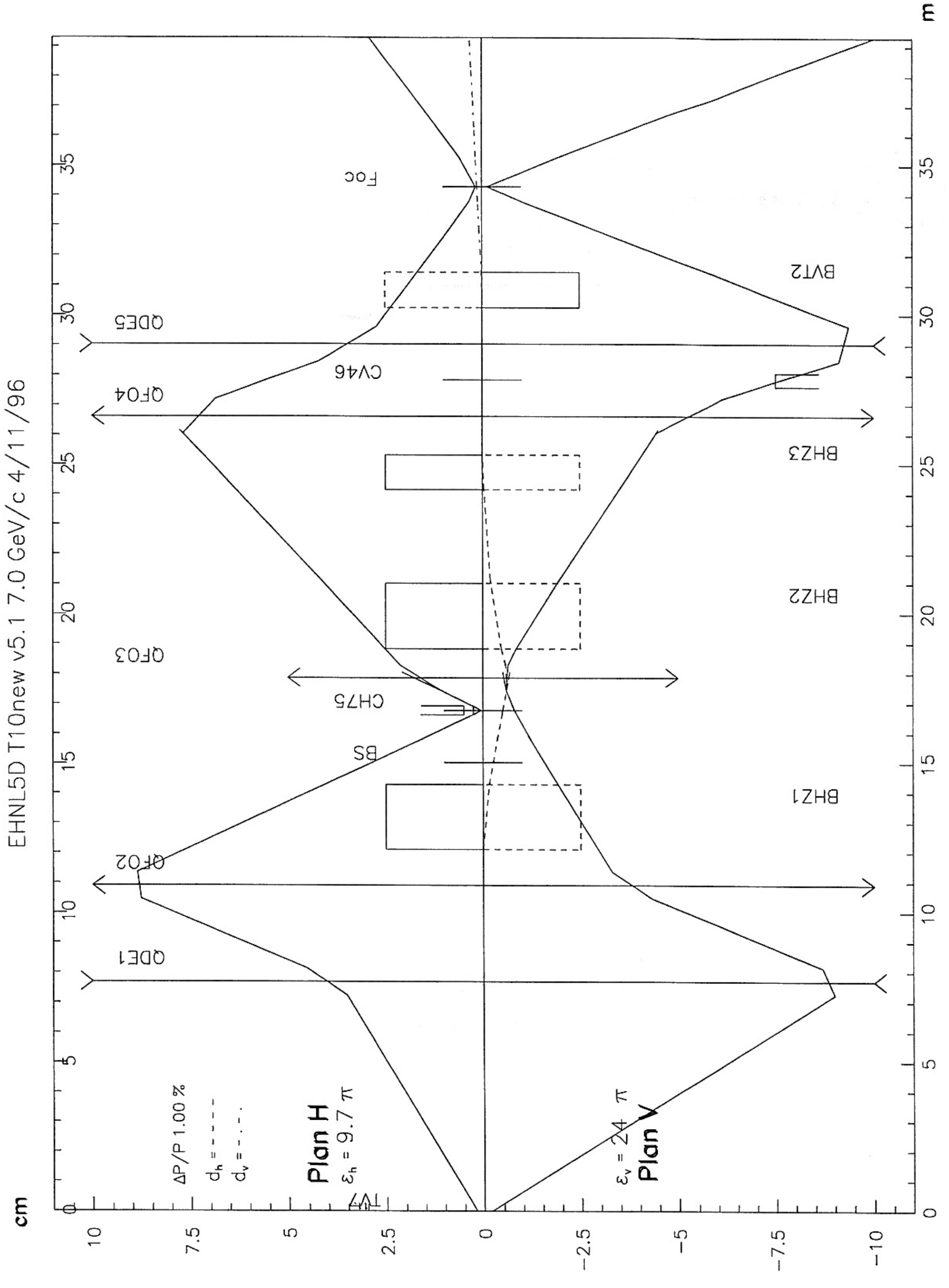


Fig 1. First order optics for the T10 line (nominal focus).

Momentum	ZT10.QDE01	ZT10.QFO02	ZT10.BHZ01	ZT10.QFO03	ZT10.BHZ02	ZT10.BHZ03	ZT10.QFO04	ZT10.QDE05	ZT10.BVT02
							nominal foc	nominal foc	
1.00	84.44	93.98	108.93	52.65	108.93	47.74	53.83	65.74	34.53
1.50	127.13	141.62	163.25	78.91	163.25	71.41	80.76	98.64	51.71
2.00	170.37	190.02	217.42	105.10	217.42	94.88	107.72	131.61	68.81
2.50	214.34	239.41	271.44	131.24	271.44	118.14	134.74	164.70	85.80
3.00	259.21	290.02	325.34	157.33	325.34	141.20	161.84	198.01	102.69
3.50	305.13	342.04	379.23	183.42	379.23	164.10	189.07	231.67	119.46
4.00	352.23	395.63	433.23	209.59	433.23	186.95	216.52	265.87	136.12
4.50	400.62	450.94	487.57	235.92	487.57	209.84	244.26	300.89	152.70
5.00	450.41	508.22	542.58	262.57	542.58	232.93	272.43	337.11	169.23
5.50	501.79	567.99	598.71	289.71	598.71	256.39	301.18	375.11	185.73
6.00	555.11	631.62	656.65	317.60	656.65	280.47	330.74	415.81	202.25
6.50	611.19	703.15	717.52	346.61	717.52	305.48	361.41	460.77	218.84
7.00	672.11	805.71	783.28	377.28	783.28	331.83	393.63	513.17	235.57

Table 4. Computed currents for the nominal focus, function of momentum.

Momentum	ZT10.QFO04	ZT10.QDE05	ZT10.QFO04	ZT10.QDE05	ZT10.QFO04	ZT10.QDE05	ZT10.QFO04	ZT10.QDE05	ZT10.QFO04	ZT10.QDE05
	nominal foc	nominal foc	+2.5 m	+2.5 m	+5 m	+5 m	+7.5 m	+7.5 m	+10 m	+10 m
1.00	53.83	65.74	49.56	54.21	46.84	48.23	44.94	44.55	43.53	42.04
1.50	80.76	98.64	74.35	81.33	70.26	72.36	67.41	66.83	65.31	63.07
2.00	107.72	131.61	99.17	108.48	93.71	96.50	89.90	89.13	87.09	84.11
2.50	134.74	164.70	124.02	135.69	117.18	120.68	112.42	111.45	108.90	105.17
3.00	161.84	198.01	148.93	162.98	140.70	144.91	134.98	133.81	130.74	126.25
3.50	189.07	231.67	173.93	190.42	164.30	169.23	157.59	156.22	152.64	147.39
4.00	216.52	265.87	199.08	218.07	188.00	193.67	180.30	178.73	174.61	168.58
4.50	244.26	300.89	224.42	246.03	211.86	218.29	203.13	201.35	196.70	189.88
5.00	272.43	337.11	250.05	274.43	235.93	243.15	226.14	224.14	218.93	211.30
5.50	301.18	375.11	276.06	303.43	260.29	268.34	249.38	247.16	241.36	232.88
6.00	330.74	415.81	302.59	333.28	285.03	293.99	272.93	270.48	264.06	254.70
6.50	361.41	460.77	329.81	364.28	310.28	320.23	296.90	294.18	287.11	276.80
7.00	393.63	513.17	357.97	396.90	336.21	347.27	321.40	318.40	310.61	299.28

Table 5. Computed currents in the last doublet, function of momentum and distance from the nominal focus.

Beam intensity and structure.

Intensity of various particle species will be almost identical as presently as the source itself is unmodified, data can be found in ref. 2 (given for 2.10^{11} p at 24 GeV/c on standard target and 5mm half width of the momentum slit). Extrapolation to higher momentum has to be guessed at this time.

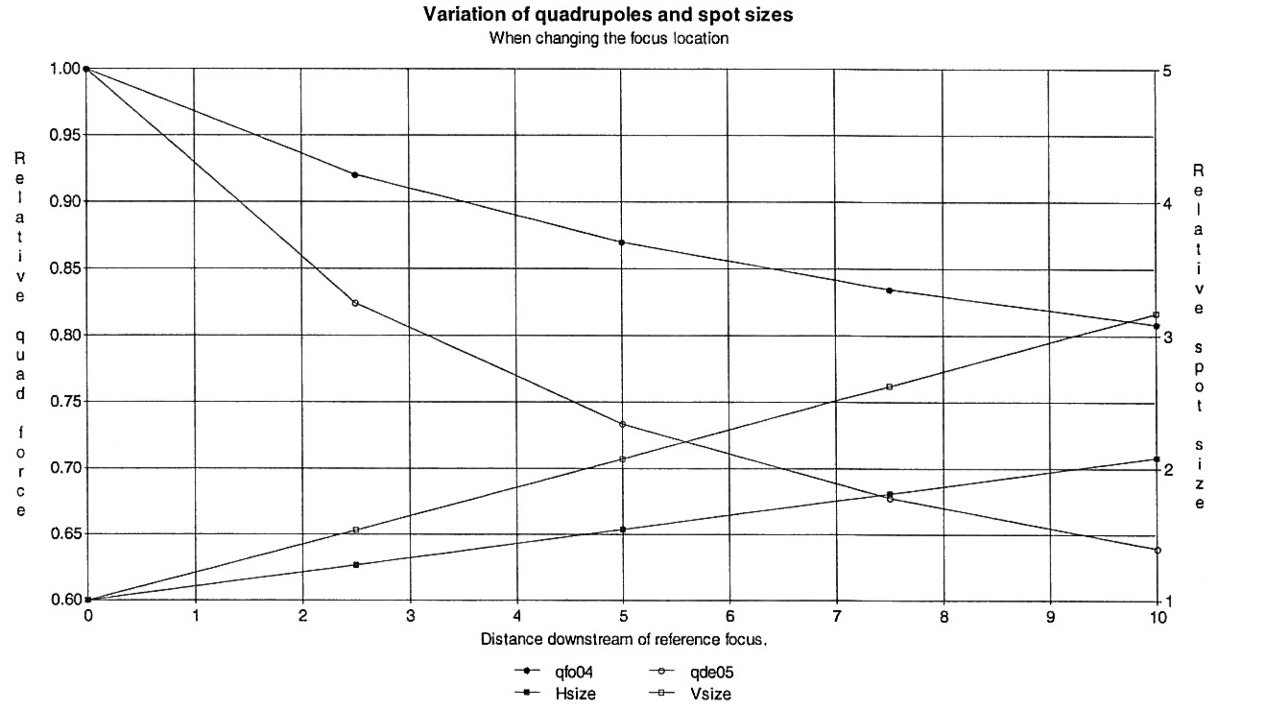
The standard beam on target comes from the slow extraction of a PS coasting beam with a spill time around 350 ms. The target and the line are transparent to the impinging time structure down to the ns level.

Line tuning.

It can be done with the help of tables 4 and 5. By convention, magnets are wired such that all polarities are the same as the selected particle species (i.e. all positive currents for protons). Final beam focusing and steering can be done with the last four magnets (BHZ03, QFO04, QDE05 and BVT02). The first part is dedicated to momentum analysis and playing with it is strongly discouraged as the resulting optical behaviour will be less than ideal.

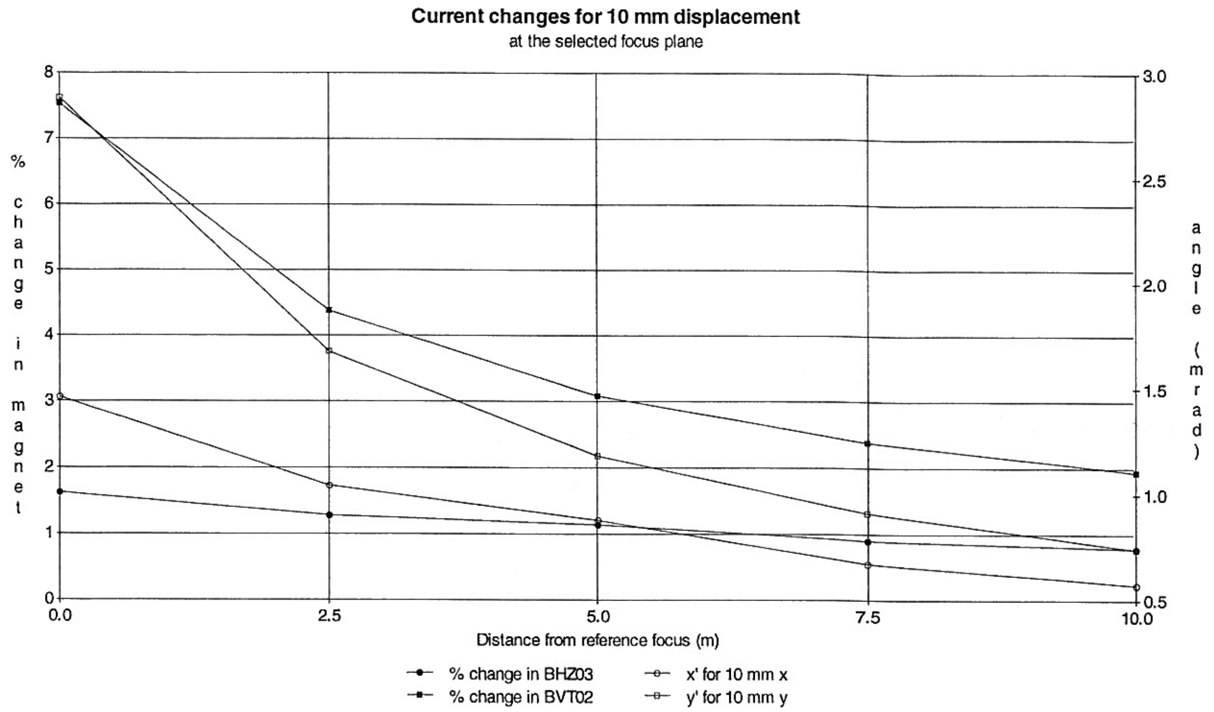
Focusing.

Table 5 should be used to move the longitudinal location of the focus, both foci H and V are in the same plane. Distances refer to the nominal focus which is marked in the zone. The tuning of the last doublet and the expected beam behaviour (spot sizes at focus) is graphically illustrated below; note that quadrupolar forces change as shown, not their currents which are non linear in the high momentum range.



H and V steering.

Uses BHZ03 for horizontal move, BVT02 for vertical move. The expected sensitivities are illustrated in the next figure (% change of current in magnet for 10 mm move); only small displacements are allowable (~50mm in H, ~20mm in V) as these changes imply some modification in the corresponding dispersion.

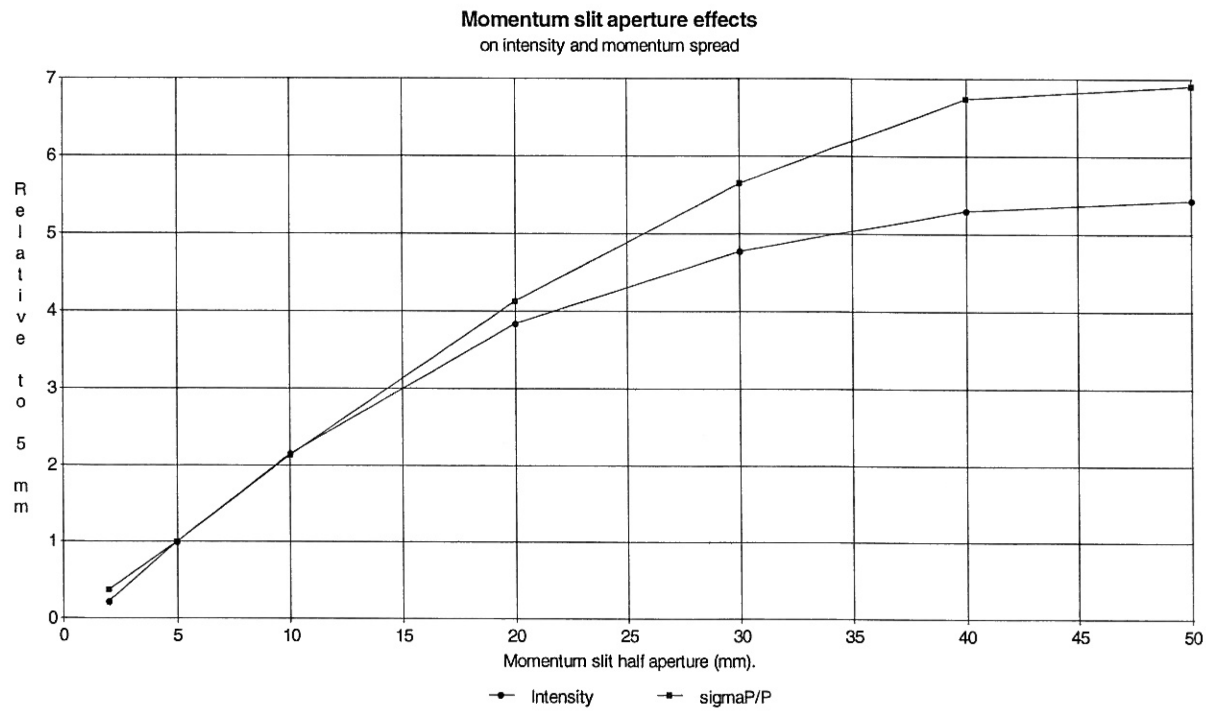


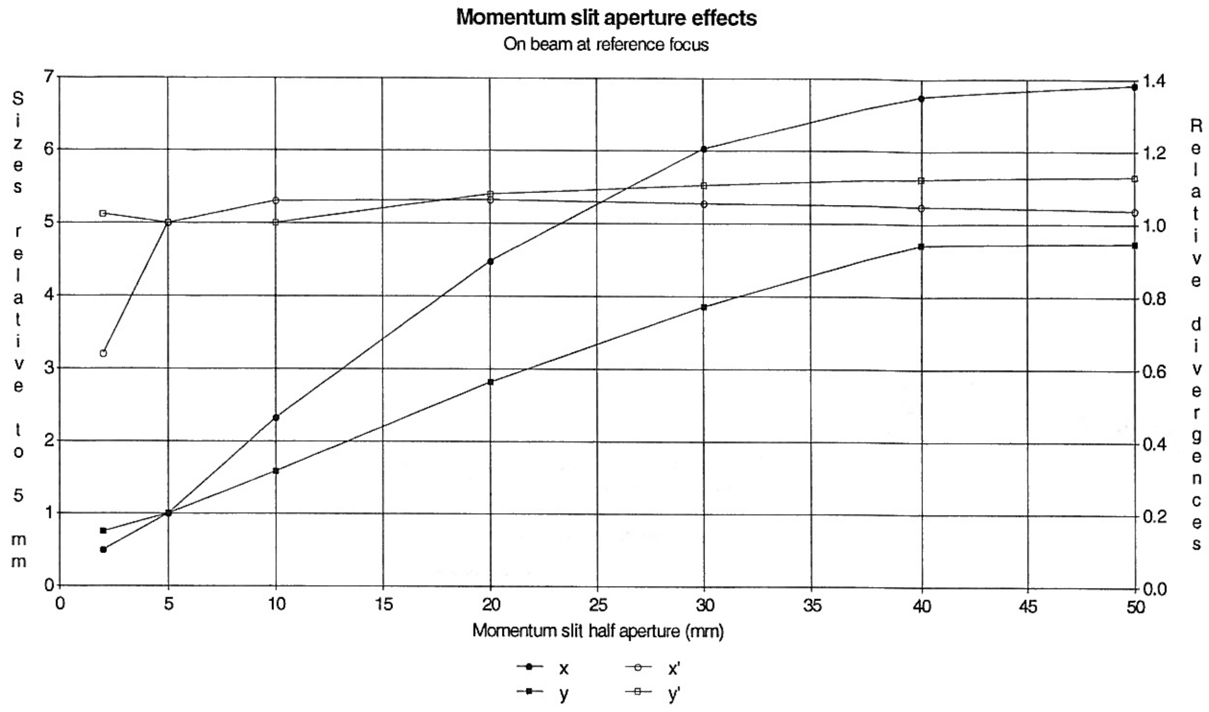
Collimators effects (intensity and momentum spread tuning).

The following graphs are summaries from TURTLE runs; each point has a statistic uncertainty of 2 to 4% due the finite sample size. Reference points for the collimators are :

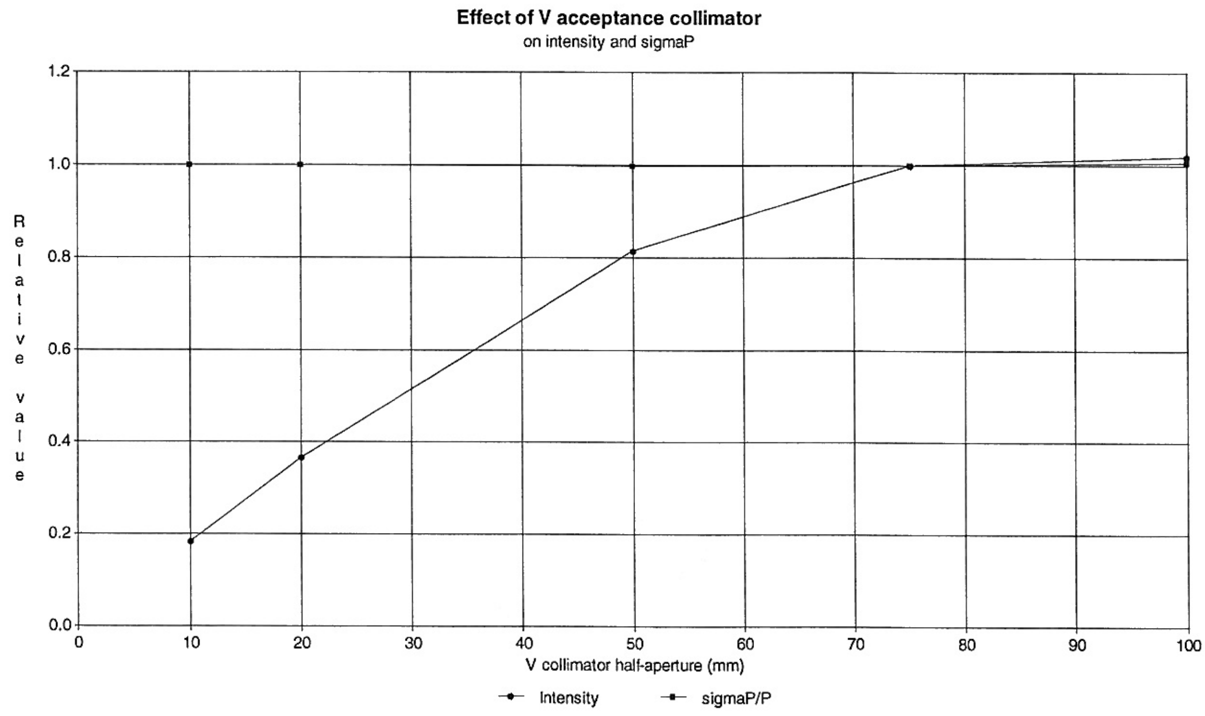
- 5 mm half-width for the momentum slit (σ_p/p ~0.47%).
- Vertical acceptance collimator fully open (in this case > 75 mm for each jaw).

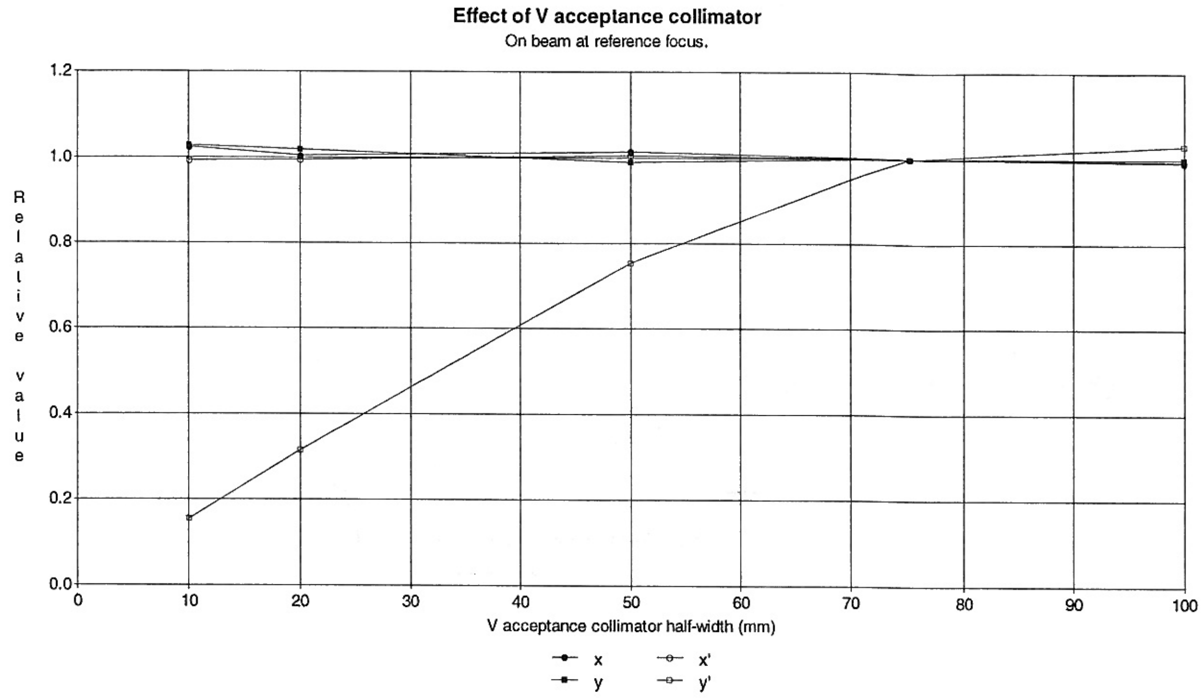
Collimators are supposed to be set symmetrical with respect to the beam axis as they should always be.





Observed changes in spot sizes are mainly due to optics chromatism and not to the small residual dispersion at the focus, although not insignificant in the V plane (y,y'). The drop in H divergence below 6 mm is caused by the finite length of the slit.

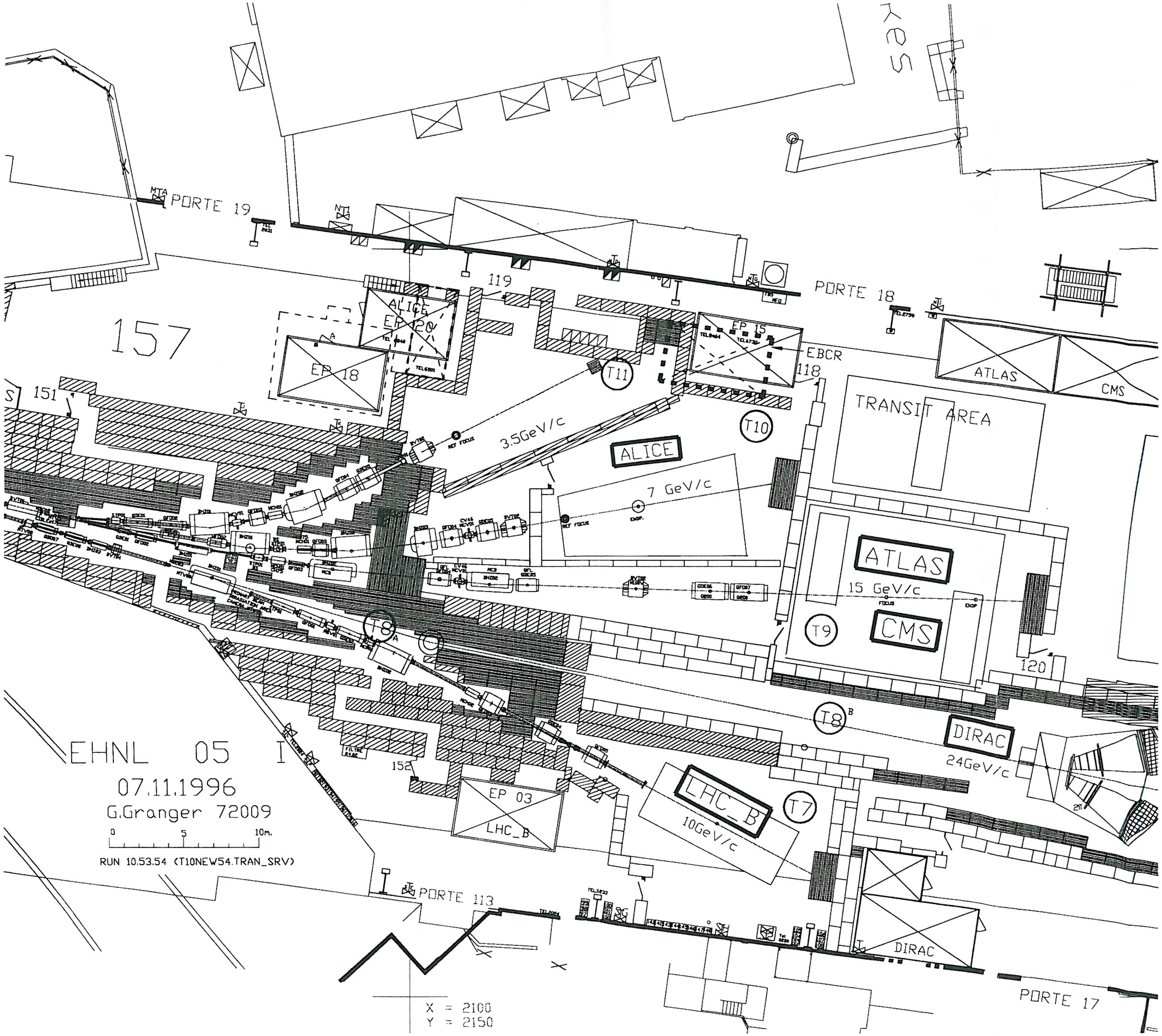




References:

1 EHNL_5 Proposal for the Beam lines & Areas for Tests and Experiments in the East Hall. PS/PA/Note 96-28. J.-Y. Hémery.

2 Secondary Beams for Tests in the PS East Experimental Area. PS/PA/Note 93-21. Edited by D.J. Simon, revised by L. Durieu.


PORTE 19
PORTE 18
PORTE 17
PORTE 113
157
ALICE EP 120
EP 18
EP 15
EBCR
118
119
151
152
120
T11
T10
T9
T8
T7
3.5GeV/c
7 GeV/c
15 GeV/c
24GeV/c
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ALICE
ATLAS
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