T10 Beam Studies & Beam Simulations

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Geneva, 22.09.2017

Summer Student Report
for the
East Area, Cern

Contents

Chapter 1

Simulation

In order to effectively use the beam line, the program Transport [1] was used to calculate the particles trajectory. Transport uses matrixes known from optics with the R_{1i} (horizontal displacement) and R_{2i} (horizontal angle) terms refering to the x axis, R_{3i} (vertical displacement) and R_{4i} (vertical angle) terms refering to the y axis, R5i (path length difference to central orbit) and R6i refering to the momentum deviation. The focus point is defined as the point where the position is independant of the angle thus R_{12} and R_{34}=0. This is not necessarly the thinnest place of the beam (beam waist). As quadropoles only can focus in one plane this means, that two dipoles have to be varied simultaneously (in this case QFO4 and QDE5). As 1.1 shows the magnet strengths from 8 which are also based on experience differed from the calculated ones and for the later measurement the given currents were used, as these have worked well in the past.

Focus	Calc. QFO4	QFO4 8	Calc. QDE5	QDE5 8
0m	8.9857	7.8971	10.7421	10.6077
2m	8.4119	7.2446	9.1543	8.4739
5m	7.8648	6.659	7.9227	7.0352
7.5m	7.5618	6.3477	7.3314	6.3985
10m	7.3384	6.1236	6.9296	5.9833
11.5m	7.2304	6.0168	6.7447	5.7964
12.5m	7.1666	5.9543	6.6383	5.7734
13.5m	7.1085	5.8973	6.543	5.5957
15m	7.0304	5.8211	6.4171	5.372

Table 1.1: Focus in respekt to Delay Wire Chamber, all magnet strengths in Kilogaus

1.1 MADX

Transport has some problems that make it sup-optimal to work with:

- due to its high age it is no longer actively supported and does no get updated
- all of it's dipole magnets are sector magnets, whereas most beams use rectangular magnets (sector magnets have an additional focusing effect, but are harder to produce)
- beam properties other than the matrix elements are difficult to produce

Thus it is planned to recode the files into Madx[2]. For this report the T10 beamfile was reprogrammed, with the goal being to reproduce the results from Transport (so sector bending magnets were used as well as collimators were ignored)

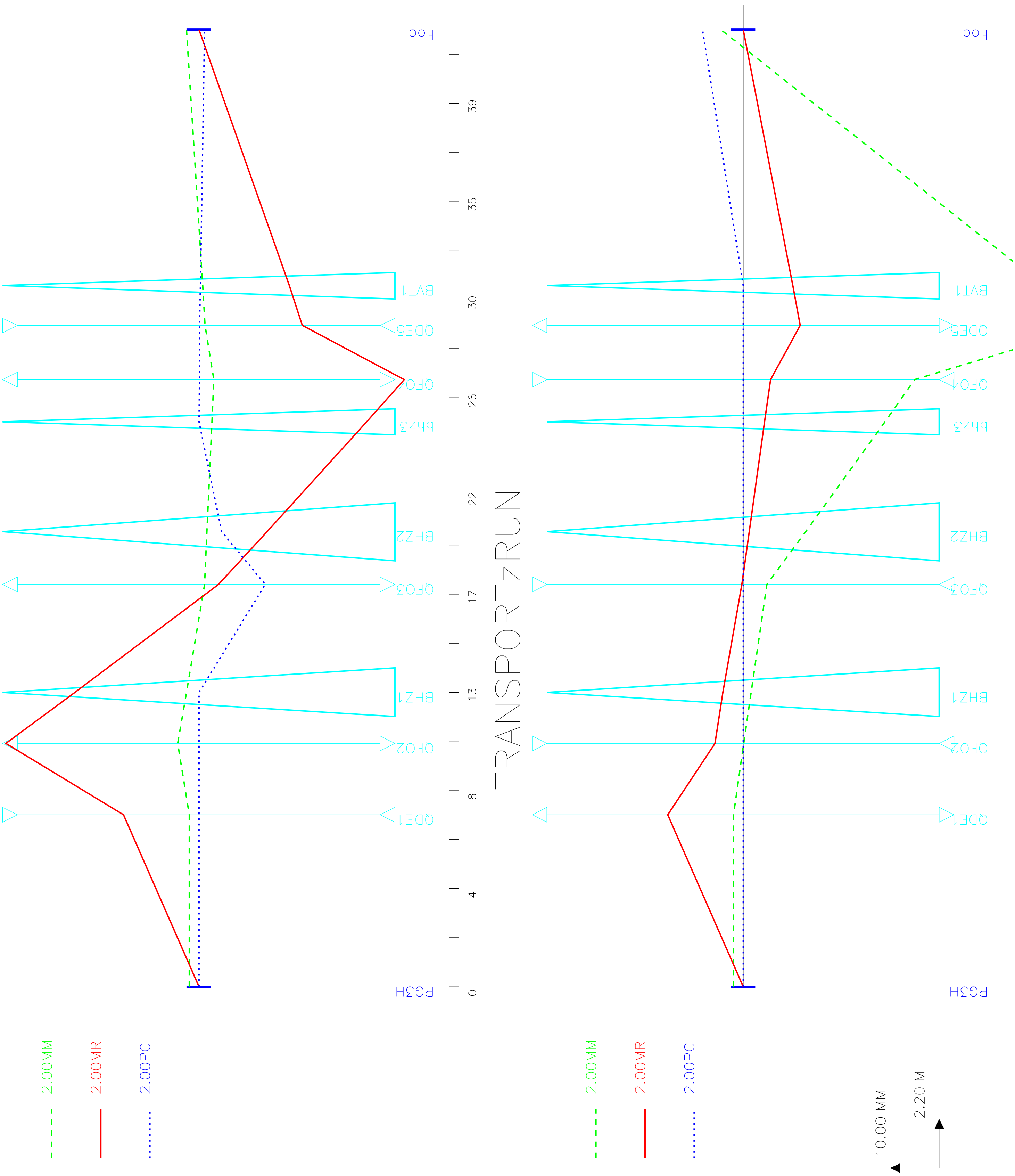
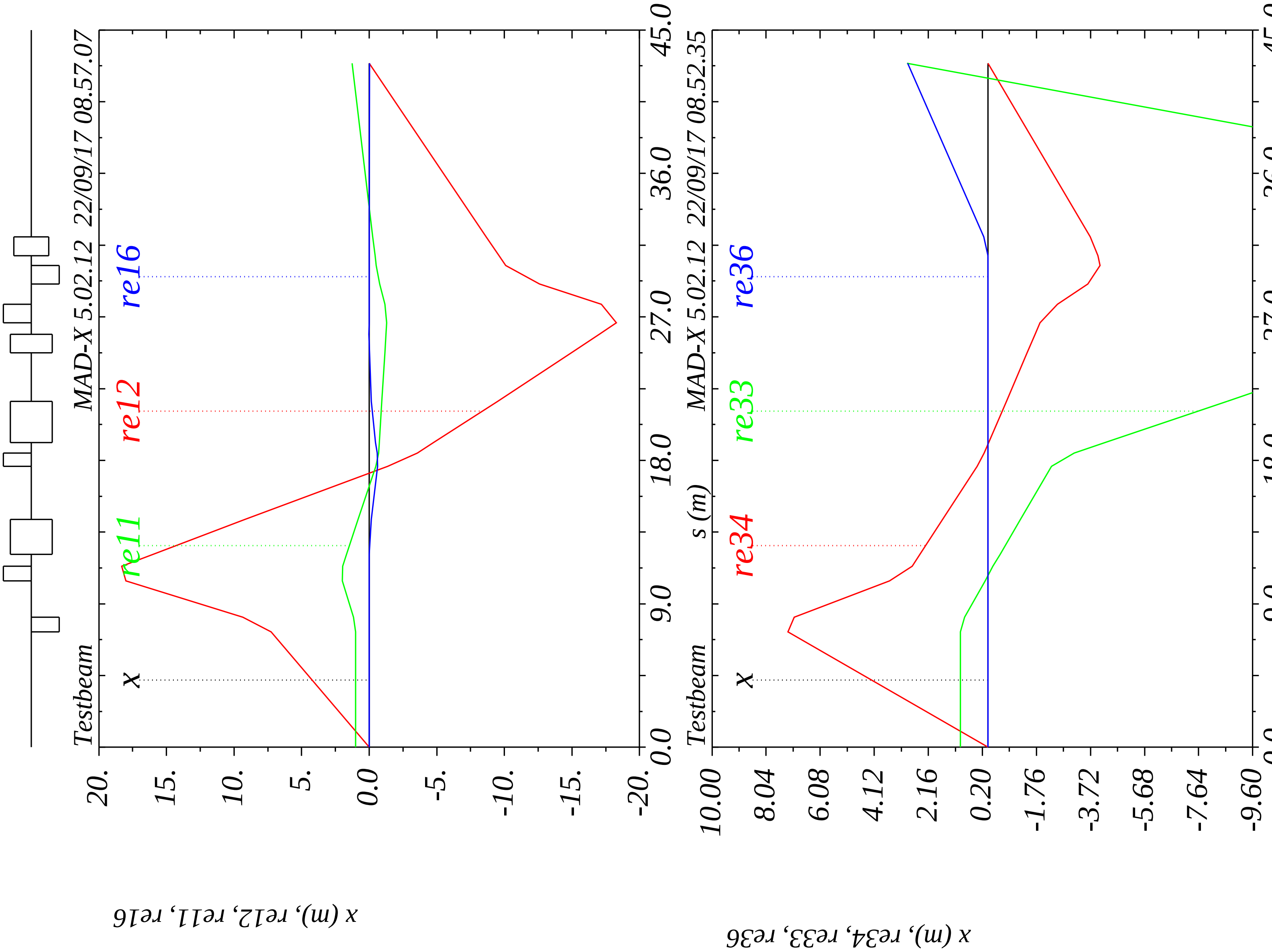


Figure 1.1: R_{11},R_{12},R_{16}on the left and R_{33},R_{34},R_{36}on the right



(a) vertical axis (b) horizontal axis

Figure 1.2: Matrix elements in MAD-X

Chapter 2

Measurement and Instrumentation

2.1 EAST AREA

The East Area provides secondary beams stemming from protons colliding with a fixed target. The protons, which are provided by the Proton Synchrotron, have an energy of 24GeV, an intensity of up to $3 * 10^{11}$ with a spill lasting around 0.4s. After the protons have interacted with the target, the secondary particles type and momentum are selected by dipole magnets and collimators and split the particles into several beam lines. For example one can produce a pure muon beam by closing the collimators completely. For the project we only worked at the T10 beam and used a 6GeV proton beam and used the recommended magnet settings from the Cesar file 8, only changing two quadropoles (QFO4 and QDE5) to focus and two dipoles (BHZ3 and BVT1) to steer the beam onto the telescope.

2.2 AZALEA TELESCOPE

The telescope [3] consists of six pixel detector planes made up of Mimosa26 sensor chips as well as 2 double scintillators on either end which provide triggering with the Trigger Logic Unit. The planes have a pixel size of 18.4*18.4μm^2 and were grouped into two groups of three about one meter apart to provide a larger lever for measuring the angles of tracks 2.1. In hindsight this might have measuring the angles more difficult and one should use the planes spread evenly for future studies.

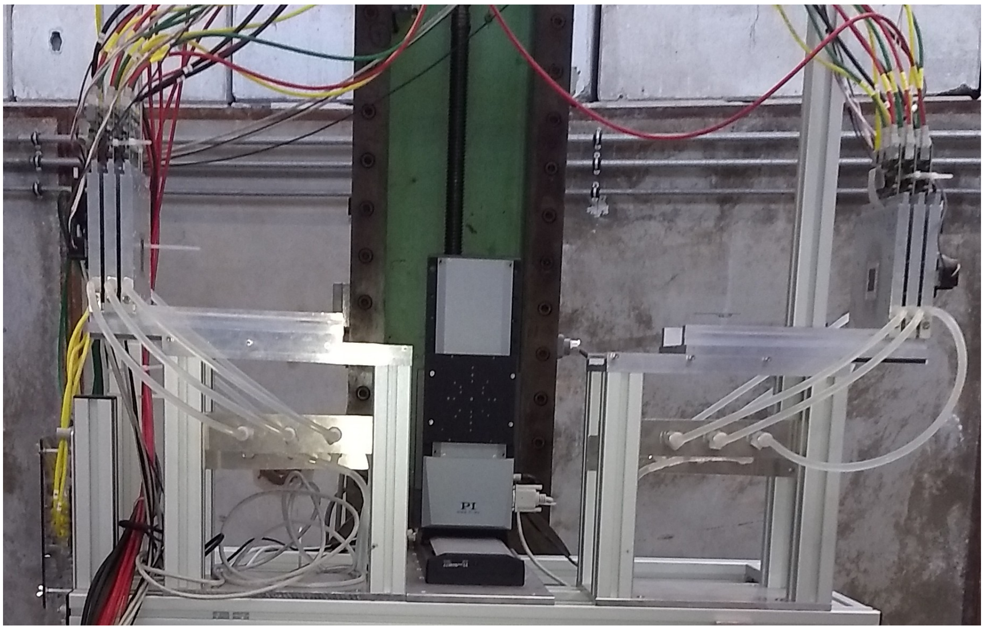


Figure 2.1: The AZALEA telescope mounted at T10

In the data discussed here the collimators where also changed. From Figures 2.2 and 2.3 the currents of -342A for BHZ3 and -255A for BVT1 were chosen, with only the horizontal collimator MCH1 being set to $\pm 10mm$ as closing the vertical collimator MCV1 failed to improve the shape of the intensity when closed further. The improvements for MCH1 can be traced back to a decrease of the momentum spread.

2.3 Analysis

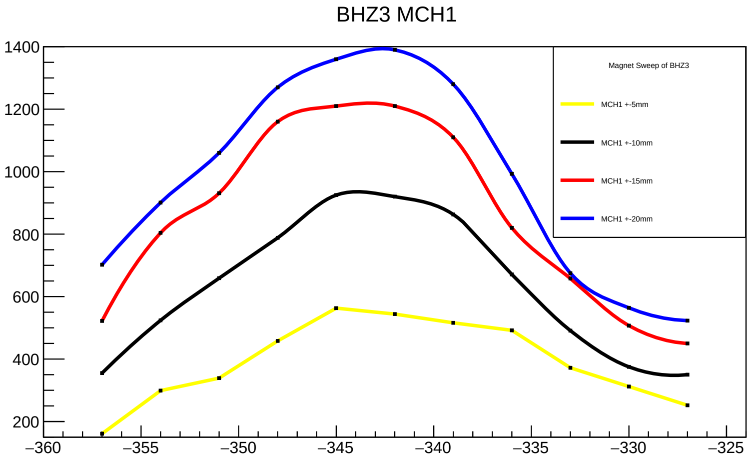
In order to measure the position of the focus point of the beam we assume following points:

- The beam waist (point with the smallest beam size) is the also the focus point (R12 and R34 terms in beam matrix are zero).
- We can reconstruct the position of the focus point using full track information of the telescope.
- Although the beam is roughly 3cm*3cm big the 2cm*1cm pixel planes will capture enough information.

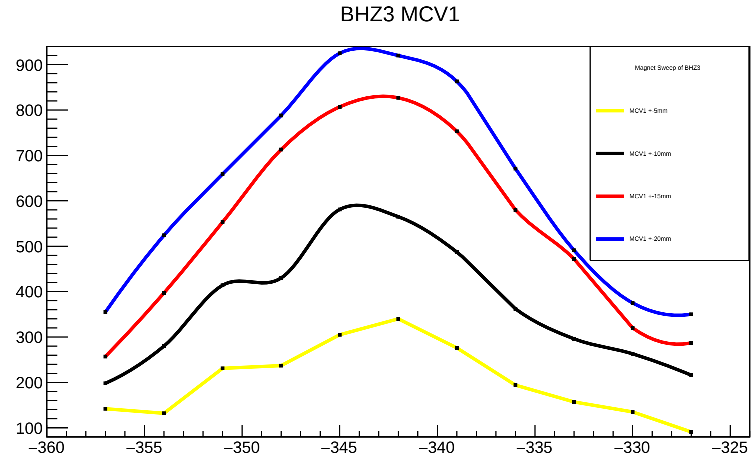
This means that we also assume, that effects of multiple coulomb scattering (MCS) can be ignored as well as that the R_{11} and R_{33} matrix terms are small enough to notice when R_{12} and R_{34} are zero.

2.3.1 Position of Focus

To determine the focus position each data set with different magnet strengths was analysed seperatly. The x and y postions ($xPos_0$, $yPos_0$) of reconstructed tracks

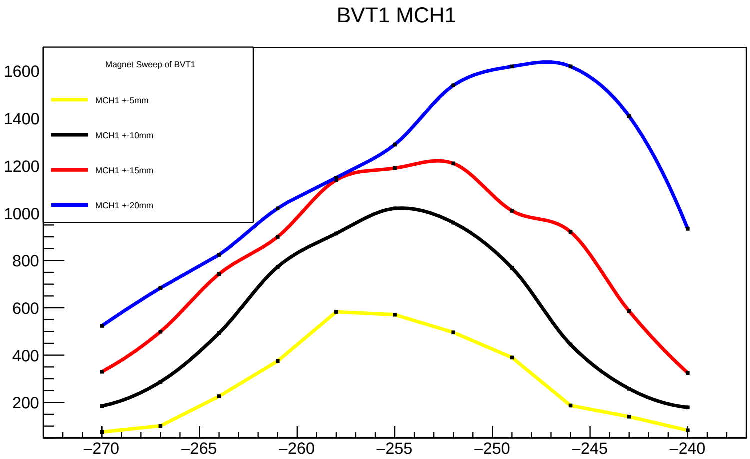


(a) Change of horizontal collimator

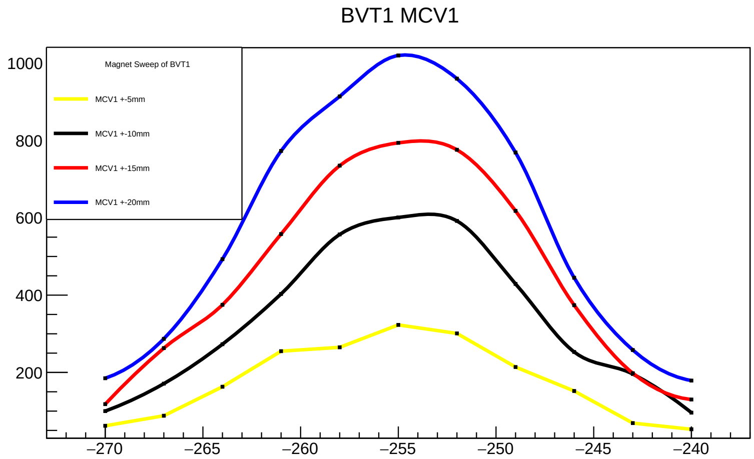


(b) Change of vertical collimator

Figure 2.2: Sweep with horizontal bending magnet



(a) Change of horizontal collimator



(b) Change of vertical collimator

Figure 2.3: Sweep with vertical bending magnet

where extended using the angles (dxdz, dydz) leading to $xPos_l = xPos_0 + dxdz * l$. In ten centimeters interval a gaussian fit of the transverse position was made. The measured sigma of the fit was the filled into a histogram which was fitted with a square function ($f = [0] + [1] * (x - [2])^2$). The position of the minima (equal to [2]) should be at the place the beam was focused. However [2] didn't move by the same amount as the focus was moved 2.1. In all of the measurements the position 0 on the z axis is at plane 0 of the telescope with positve numbers being along the beam line. This means that the Delay Wire Chamber is at -9m and the end of the beamline at +6m

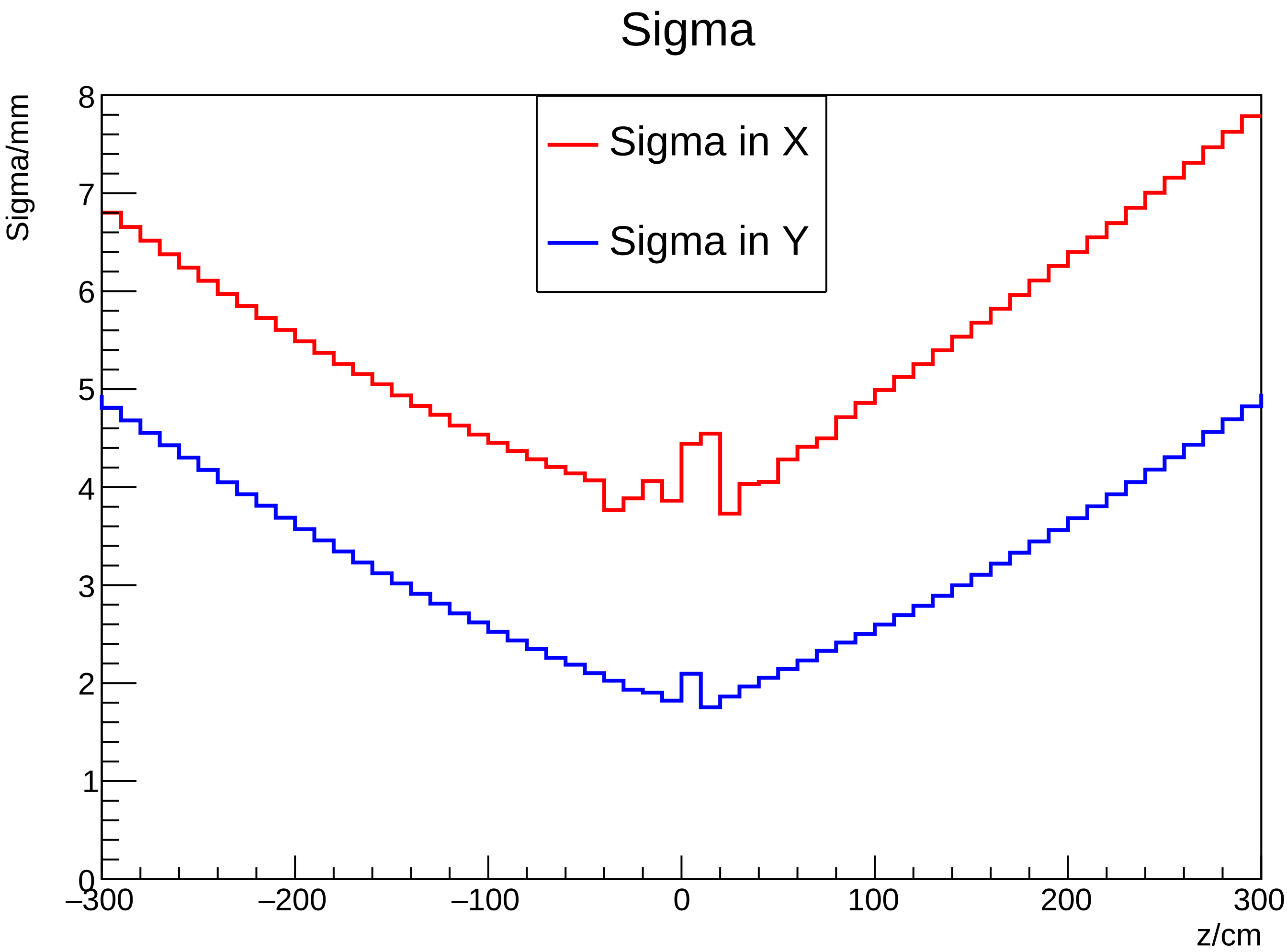


Figure 2.4: Measurement of the σ. Actual focus should be at +600cm.

Position of focus	Measured focus in X	Measured focus in Y
-400	16.12	6.27
100	24.73	22.65
600	30.31	29.74

Table 2.1: Focus points given in cm. Actual focus according to

2.3.2 Quadropole Scan

As one can see from Table 2.1 the focus was moving towards the right direction so a grid scan with QFO4 and QDE5 was made in order to analyze this movement. The region, QFO4: 250-275A and QDE5: 235-275A, scanned should provide focal points from ≈ -1.5m to 6m and was scanned in 5A steps for 10minutes each. Figures 2.6 and 2.5 show the overall expected general behavior with the slight discrepancies easily explained with statistical fluctuations from the short run time. QF04 focuses in x (focus) and defocuses in y whereas QDE5 has the exact opposite effect.

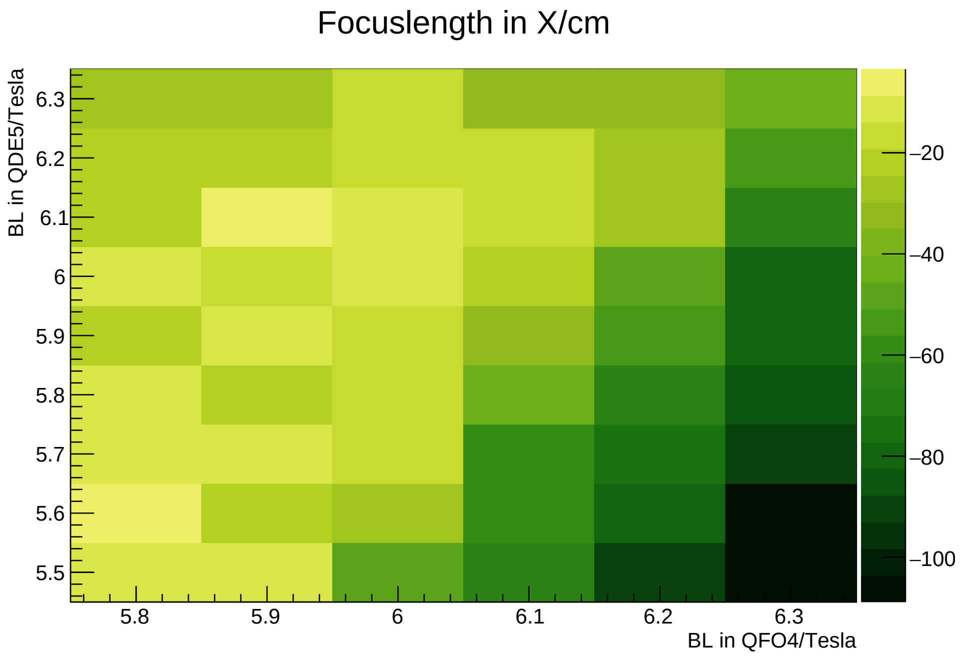


Figure 2.5: Measurement of the focus in x

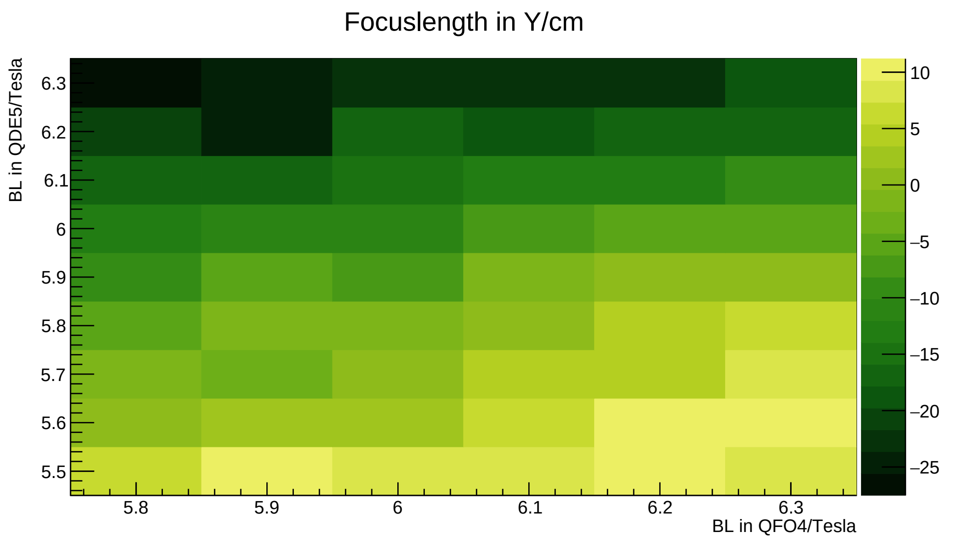


Figure 2.6: Measurement of the focus in y

2.4 Conclusion

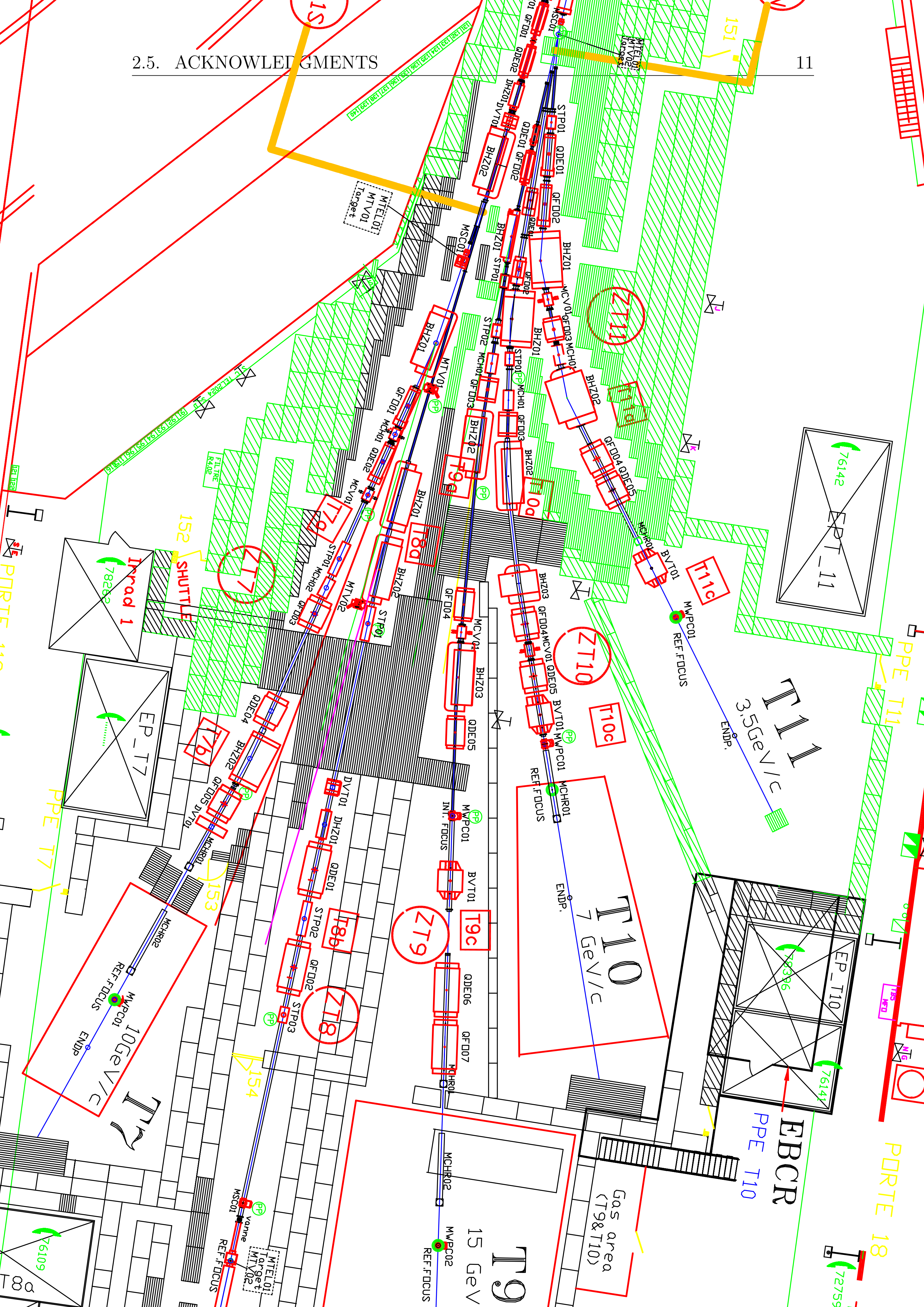
Overall the measurement of the focus point was not possible. This is most likely due to the fact, that the beam spot does not fit into the telescope planes. Other possible reasons (or factors that could worsen the result):

- Multiple-Coulomb Scattering: Between the AZALEA-telescope and the target were multiple other experiments on which the particles can scatter. As the beam had a relatively low energy MCS effects could be improved by doing the same experiment at T9 were one has an empty beamline and higher energy.
- The measurement of the angles was off as the planes were grouped together on either end and the measurement could be improved by distancing the planes evenly see [2.2]

Once the focus is measureable it will be interesting to see by how much MAD-X and Transport deviate from reality. Especially Transport should have a larger error as explained in [1.1]. The MAD-X code also still has to be extended with collimators and using the right kind of dipole.

2.5 Acknowledgments

I would like to thank my supervisors, Dr. Johannes Bernhard and Maarten Van Dijk, for their patient guidance, encouragement and advice they have provided throughout my time as their student. I would also like to thank Dr. Lau Gatignon for his help with Transport, Dr. Marcel Rosenthal and Dr. Alexander Gerbershagen for their help with MAD-X and Dr. André Rummler in helping Maarten and me set up the telescope.


T11
3,5GeV/c
T10
7 GeV/c
T9
15 GeV
T7
10GeV/c
ZT11
ZT10
ZT9
ZT8
ZT7
T11a
T11c
T10a
T10c
T9a
T9c
T8a
T8b
T7a
T7b
EP_T11
EP_T10
EP_T7
Irrad 1
SHUTTLE
EBCR
PPE T10
PPE T11
PPE T7
PORTE 18
Gas area
(T9&T10)
MWPC01
REF.FOCUS
ENDP.
INT. FOCUS
MTEL01
MTV01
Target
7614?
7614?
7828?
7609
T8a
BHZ01
BHZ02
BHZ03
QFO01
QFO02
QFO03
QFO04
QFO05
QDE01
QDE02
QDE04
QDE05
QDE06
QFO07
STP01
STP02
STP03
MCV01
MCH01
MCHR01
MCHR02
BVT01
DVT01
DHZ01
MSC01
MWPC02
vanne

CURRENTS FOR T10 TEST BEAM

After tuning on 14 September 2012

p							XDWC +2 m			XDWC+12.5 m		Focus at XDWC	
GeV/c	QDE1	QFO2	BHZ1	QFO3	BHZ2	BHZ3	QFO4	QDE5	BVT1	QFO4	QDE5	QFO4	QDE5
1.00	83.55	89.44	108.93	49.77	56.24	55.36	52.33	61.21	41.70	43.01	41.70	57.04	76.62
1.50	125.78	134.72	163.24	74.5	84.36	83.04	78.49	91.81	62.55	64.51	62.55	85.56	114.93
2.00	168.55	180.65	217.42	99.53	112.48	110.72	104.65	122.41	83.40	86.01	83.40	114.08	153.24
2.50	212.02	227.45	271.4	124.41	140.60	138.40	130.82	153.01	104.25	107.52	104.25	142.60	191.55
3.00	256.37	275.30	325.34	149.30	168.72	166.08	156.98	183.62	125.10	129.02	125.10	171.12	229.85
3.50	301.74	324.39	379.22	174.18	196.84	193.76	183.14	214.22	145.95	150.52	145.95	199.64	268.16
4.00	348.24	374.85	433.22	199.06	224.96	221.43	209.31	244.82	166.80	172.02	166.80	228.16	307.25
4.50	396.00	426.81	487.57	223.95	253.08	249.11	235.47	275.42	187.65	193.53	187.65	256.68	349.66
5.00	445.14	480.44	542.57	248.83	281.20	276.79	261.63	306.78	208.50	215.03	208.50	285.23	396.64
5.50	495.79	536.05	598.70	273.71	309.32	304.47	287.87	340.30	229.36	236.53	229.35	314.98	450.07
6.00	548.29	594.35	656.65	298.60	337.44	332.15	315.24	376.55	250.21	258.04	250.20	346.72	513.70
6.50	603.35	657.16	717.51	323.93	368.43	366.57	344.29	416.30	271.06	279.54	271.05	380.93	597.43
							Standard			Table		Beam studies	

Figure 8: Currents used during data taking from [5]

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