Beam-line 4 Initial Parameters of Beam

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1 Objective

BL4A3 was brought back for test runs, after being out of operation for 10 years since late 1990s. The primary objective is to investigate the initial conditions of beam down to the beamline and offer a reference for the future BL4N design. Three tunes were therefore tested of energies of 493, 497 and 451 MeV, and beam profiles were measured using the available multi-wire ionization chamber monitors (harps) through the beam-line. However, optics calculations cannot achieve good agreement with these measured beam sizes, particularly from the half-way downwards. In order to minimize uncertainties, caused by such as vacuum leak, aged harps, quads roll errors, etc, it was decided to focus on the the front end making measurements, instead of flying through the whole beam-line.

2 Measurements and Fits

I performed the measurements at upstream of the first dipole 4VB1, where there are 3 quadrupoles 4VQ1,4VQ2,4VQ3 and 2 harps 4VM1,4VM2. See Fig.1. 4VQ1 was completely off due to problems with it; 4VQ3 was in a position of $\sim 45°$ rotated from the normal position. I took 2 series of measurements at 497 MeV: the first series was having Q3 set to 0 A, and then varying Q2 settings from 0 to 240 A in a step of 10 A; whereas the second series was with Q2 set to 0, but varying Q3 from 0 to 200 A. At each setting, I recorded the beam profiles at 4VM2. The stripper foil used in the measurements was a carbon wire of diameter 0.001 inch, and the foil was only partially dipped into the beam vertically, so it was pulling out very small amount of beam ($< 1\mu$A) down to the beam-line.

From the profiles measured I calculated the 2rms beam sizes. See Table 1. Should be noted that these calculated sizes have $\sim \pm 10\%$ uncertainty for the noise cut. I got 50 parameters of beam size in total for the first series measurements, and 40 parameters for the second series. These data were then fitted in the beam optics calculations with `TRANSOPTR` to find the initial conditions of beam hitting on the foil. There are 7 initial parameters to be determined from the fit: (α_x, β_x, ϵ_x; α_y, β_y, ϵ_y; $\delta p/p$), where $\sqrt{\beta_x \epsilon_x} \leq 0.001$ inch; ϵ_y (vertical emittance) is known for sure below $1\,\pi$mm-mrad. Besides, α_y and β_y both are depending on the value of ϵ_y because the foil was only partially dipped vertically. To this end, I used the `COMA` simulated ϵ_y dependencies of α_y and β_y in the fits. So, the solution to be sought is over-determined. The cyclotron fringe field transfer matrix used was calculated with `STRIPUBC`.

The fit is good. See Table 1 for the results. Table 2 lists the σ matrix (2rms) of beam at the exit of combination magnet. Also, calculation results appear that horizontally the beam size is not sensitive to the emittance, instead, it's dominated by the energy spread.

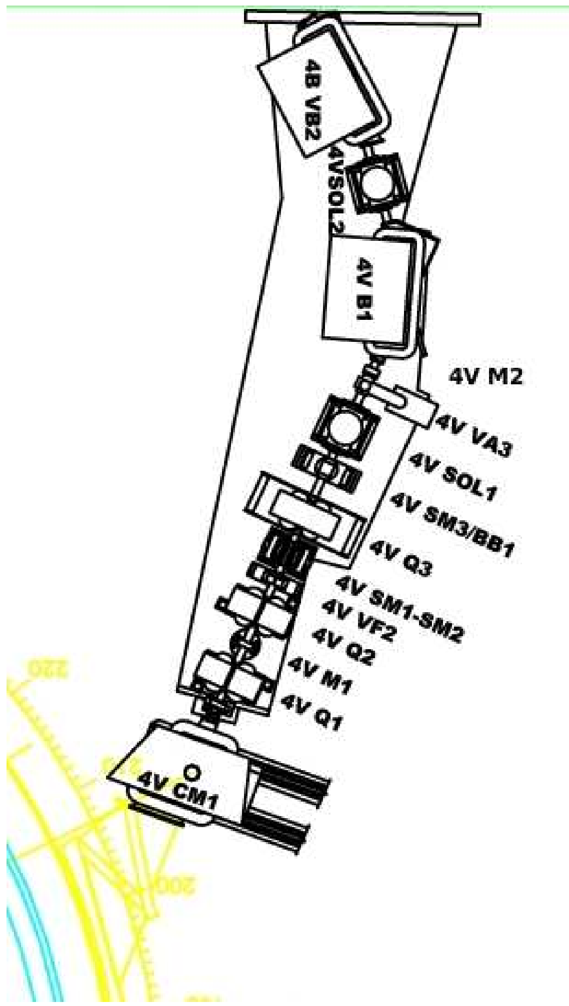

Figure 1: *Layout of BL4 front end.*

Table 2 Sigma-matrix of beam at the exit of combination magnet

	Diagonal	Off-Diagonals (Normalized Form)				
x(cm)	0.35973					
theta(mrad)	0.38176	0.78347				
y(cm)	0.75552	0.00000	0.00000			
phi(mrad)	1.23442	0.00000	0.00000	0.97745		
l(cm)	70.00000	0.00000	0.00000	0.00000	0.00000	
delta(%)	0.12580	0.49267	0.88696	0.00000	0.00000	0.00000

Table 1 Measured and calculated beam sizes (2rms)

Q2 (A)	Q3 (A)	Horiz. Meas. (cm)	Horiz. Calc. (cm)	Vert. Meas. (cm)	Vert. Calc. (cm)
0.0	0	0.54	0.54	1.35	1.41
10.0		0.58	0.59	1.24	1.27
20.0		0.62	0.65	1.14	1.14
30.0		0.64	0.71	1.02	1.00
40.0		0.74	0.77	0.87	0.87
50.0		0.79	0.83	0.77	0.73
60.0		0.82	0.89	0.63	0.60
70.0		0.95	0.95	0.51	0.47
80.0		0.97	1.02	0.36	0.34
90.0		1.05	1.08	0.27	0.21
100.0		1.20	1.14	0.20	0.10
110.0		1.23	1.20	0.19	0.10
120.0		1.26	1.26	0.29	0.21
130.0		1.25	1.33	0.41	0.33
140.0		1.26	1.39	0.58	0.45
150.0		1.24	1.45	0.71	0.58
160.0		1.30	1.52	0.81	0.70
170.0		1.30	1.58	0.90	0.83
180.0		1.37	1.65	1.01	0.95
190.0		1.37	1.71	1.17	1.08
200.0		1.37	1.78	1.29	1.20
210.0		1.40	1.84	1.41	1.32
220.0		1.39	1.91	1.48	1.44
230.0		1.46	1.97	1.47	1.56
240.0		1.48	2.04	1.51	1.68
0	10.0	0.52	0.54	1.37	1.43
	20.0	0.54	0.56	1.34	1.45
	30.0	0.59	0.60	1.33	1.47
	40.0	0.66	0.65	1.34	1.49
	50.0	0.76	0.71	1.37	1.51
	60.0	0.83	0.78	1.39	1.53
	70.0	0.87	0.85	1.42	1.56
	80.0	0.98	0.93	1.42	1.58
	90.0	1.11	1.01	1.44	1.61
	100.0	1.20	1.10	1.47	1.64
	110.0	1.27	1.18	1.48	1.67
	120.0	1.34	1.27	1.50	1.70
	130.0	1.40	1.36	1.53	1.74
	140.0	1.50	1.46	1.55	1.77
	150.0	1.56	1.55	1.58	1.81
	160.0	1.59	1.64	1.63	1.84
	170.0	1.67	1.74	1.67	1.88
	180.0	1.75	1.83	1.70	1.92
	190.0	1.87	1.92	1.75	1.95
	200.0	1.93	2.02	1.78	1.99