Measurement of Switchyard Phase Space 18Aug05

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Abstract

An attempt is made to measure the vertical emmittance and lattice functions at the upstream of Q102 in Switchyard. The technique is explained, data is tabulated, and the results are shown.

A trim magnet (VT102), located upstream of Q102, was also varied in attempt to directly measure the quadrupole gradient. However, the lateral motion of the beam was not suffient to yield meaningfull results (and, therefore, no further mention will be made). I assume that momentum spread is negligable.

1 Technique.

The quadrupole Q102 is followed by a long drift space, then a SWIC. In principle, by varying the quadrupole and measuring the resulting profile, one can fit for the phase space (and thus derive the emittance and lattice functions).

Consider the well-know equation:

$$\mathbf{s}^f = \mathbf{R}\,\mathbf{s}^i\,\mathbf{R}^T$$

Expanding for s^f_{11} yields:

$$s^f_{11} = s^i_{11} r^2_{11} + 2 s^i_{12} r_{11} r_{12} + s^i_{22} r^2_{12} \tag{1}$$

Thus, if the quadrupole strength and size, the distance from the quadrupole to the SWIC, and the beam size, were all known perfectly, one could determine the initial phase space of the beam by measuring the final beam width at three different quadrupole currents. In practice, one would make several measurements and fit the data.

The emittance and lattice functions are then derived by:

$$\epsilon_p = \sqrt{det\begin{pmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{pmatrix}}$$

$$\beta = \sigma_{11}/\epsilon$$
$$\alpha = \sigma_{12}/\epsilon$$

current [amp]	width [mm]	number	spread [mm]
-10.	4.28	2	0.14
-5.	2.97	3	0.24
0.	2.01	4	0.14
+5.	1.00	3	0.05
+10.	1.66	3	0.06

Table 1: Summary of data for phase space measurement. The quadrupole setting is listed – a positive setting indicates focusing in the horizontal plane. The listed beam width is the 1σ beam width.

β	172.9	18.4	m
α	0.639	0.104	
$\epsilon_{p(1\sigma)}$	2.52×10^{-8}	2.22×10^{-8}	m radian
$\epsilon_{N(95\%)}$	$19.3\,\pi$	$1.7\,\pi$	mm mradian

Table 2: The calculated emittances are the 1σ phisical and 95% normalized emittance. Errors are calculated by propagating the spread in SWIC measurements.

2 Data

Data was taken at five different currents for Q201. This data is listed in Table 1. Also listed is the quadrupole strength, number of measurements at each current, and spread.

3 Results

The results are shown in Tables 2 and 3. As seen in Figure 1, the predicted beam widths match the measured beam widths quite well ($\chi^2/df = 0.12$).

Q102 current [amp]	S200VS data [mm]	fit [mm]
-10	4.28 ± 0.14	4.33 ± 0.15
-5	2.97 ± 0.24	3.09 ± 0.16
0	2.01 ± 0.14	1.76 ± 0.19
+5	1.00 ± 0.05	1.02 ± 0.19
+10	1.66 ± 0.06	1.64 ± 0.12

Table 3: Measured beam width and beam width calculated from fitted parameters.

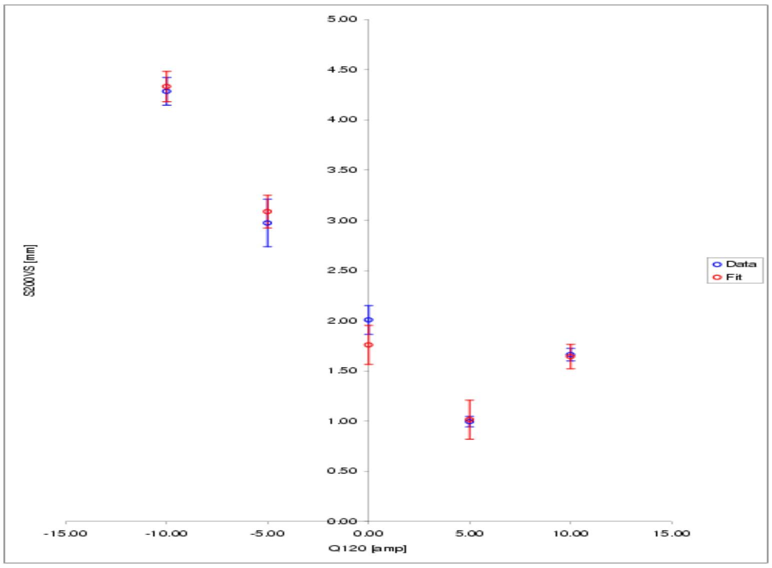

Figure 1: Comparison of measured and predicted beam widths as a function of quadrupole strength.

4 Conclusion

By varying the quadrupole current and measuring the beam width, one may determine the phase space of the incoming beam. The measured and predicted beam widths are in good agreement. A further test would be to propagate the beam further along the beamline.