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Estimating a Linear Optics of BTS

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This is a short summary of the machine study done by W. Byrne and H. Nishimura on January 10. 2004. All the simulation was done by using TracyBTS that you can find my note #204.

The BTS beam transport line has been working for over 11 years without any serious problem. We know that its performance is sufficient for the current mode of operation. However, it is also true that it has never been seriously modeled simply because there was no need. There is no real document describing how it was designed and commissioned.

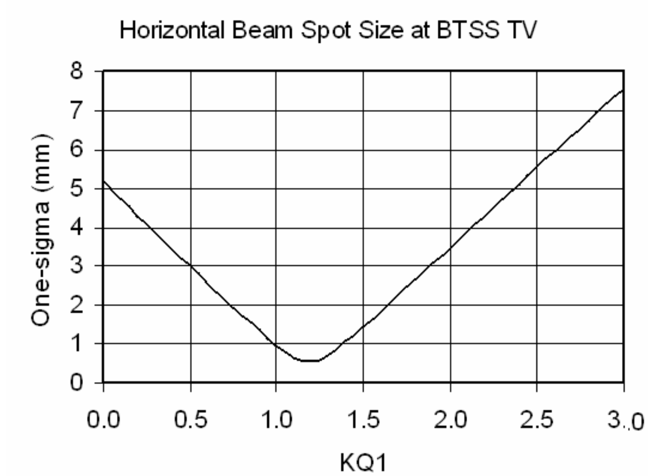
Quad	I (A)
Q1	48.810
Q2.1	21.310
Q2.2	9.390
Q3.1	18.420
Q3.2	57.650
Q4	66.170
Q5.1	81.580
Q5.2	84.270
Q6.1	54.320
Q6.2	58.300
Q7	50.212

Let us try to estimate the optics by using the nominal setting shown right without taking the transfer function figured from the literature.

The input is the ratio of the settings of these 11 quadrupole magnets that are supposed to be identical.

The very first step is to make a rough estimation of the transfer function to start with. We turned off Q2.1, Q2.2 and B1 so that the extracted beam can directly hit the TV monitor just after B1 that is turned off. We can measure the beam size by changing Q1.

The linear model gives us the following plot that has a minimum at KQ1=1.186.



The measurement by WB and HN gave the minimum width at 38.6 A. Again, the error bar is large as we do not have frame grabber for the beam size measurement.

The tentative transfer function is 1.186 / 38.6 = 3.073 E-2.

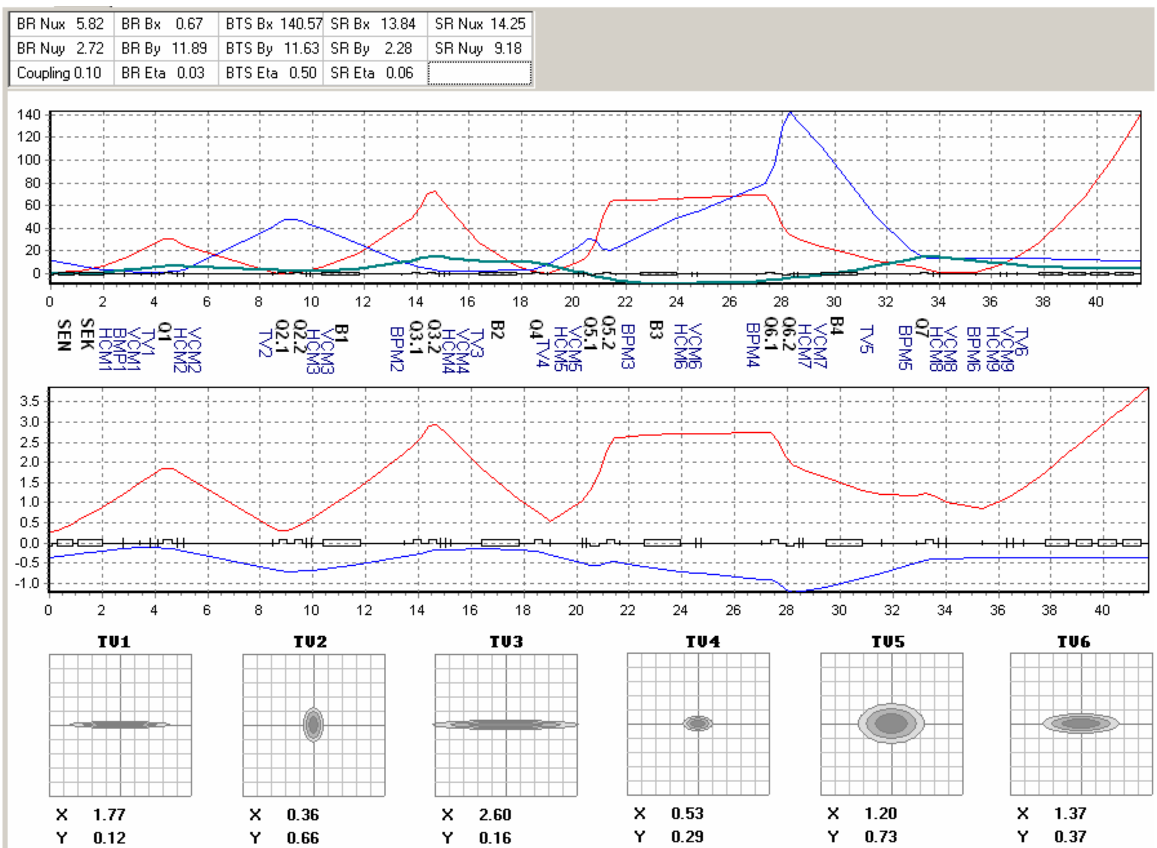
By using this constant, we have the first guess of the K vlaues. Let us call this set as K0.

Quad	I (A)	K0
Q1	48.810	1.500
Q2.1	21.310	-0.655
Q2.2	9.390	-0.289
Q3.1	18.420	-0.566
Q3.2	57.650	1.772
Q4	66.170	2.033
Q5.1	81.580	-2.507
Q5.2	84.270	2.590
Q6.1	54.320	1.669
Q6.2	58.300	-1.792
Q7	50.212	1.543

The optics is not so bad except the horizontal beta function at the end. Here, the question is the dependence on the value of the transfer function as it is based on our very rough measurement.

Here comes the scaling! Let us scale all the quad strength by keeping the ratio. Check is there is any reasonable optics in the neighborhood.

It is very interesting to point out that the 6 % increase of all the quads leads to a quite nice optics shown on the next page.



note: The emittance is the natural emittance of BR at 1.5 GeV. The coupling is 10 %.

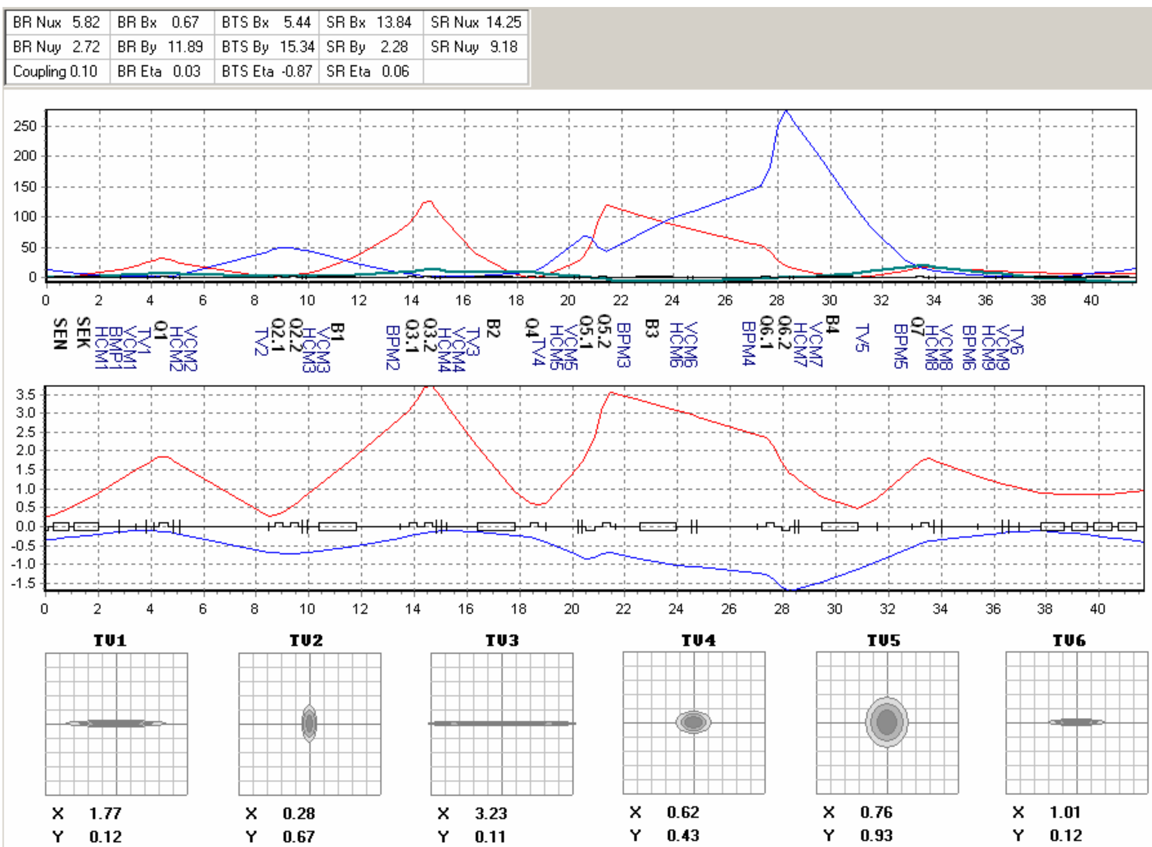
Quad	I (A)	K0	K1
Q1	48.810	1.500	1.590
Q2.1	21.310	-0.655	-0.694
Q2.2	9.390	-0.289	-0.306
Q3.1	18.420	-0.566	-0.600
Q3.2	57.650	1.772	1.878
Q4	66.170	2.033	2.155
Q5.1	81.580	-2.507	-2.657
Q5.2	84.270	2.590	2.745
Q6.1	54.320	1.669	1.769
Q6.2	58.300	-1.792	-1.900
Q7	50.212	1.543	1.636

The initial setting of K0 is increased by 6 % to give K1. The transfer function is:

1 A --> K = 3,257 E-2

This scaling gives very small values of beta and dispersion functions at the end.

It should be emphasized that it is not a trivial task to find a solution like this.

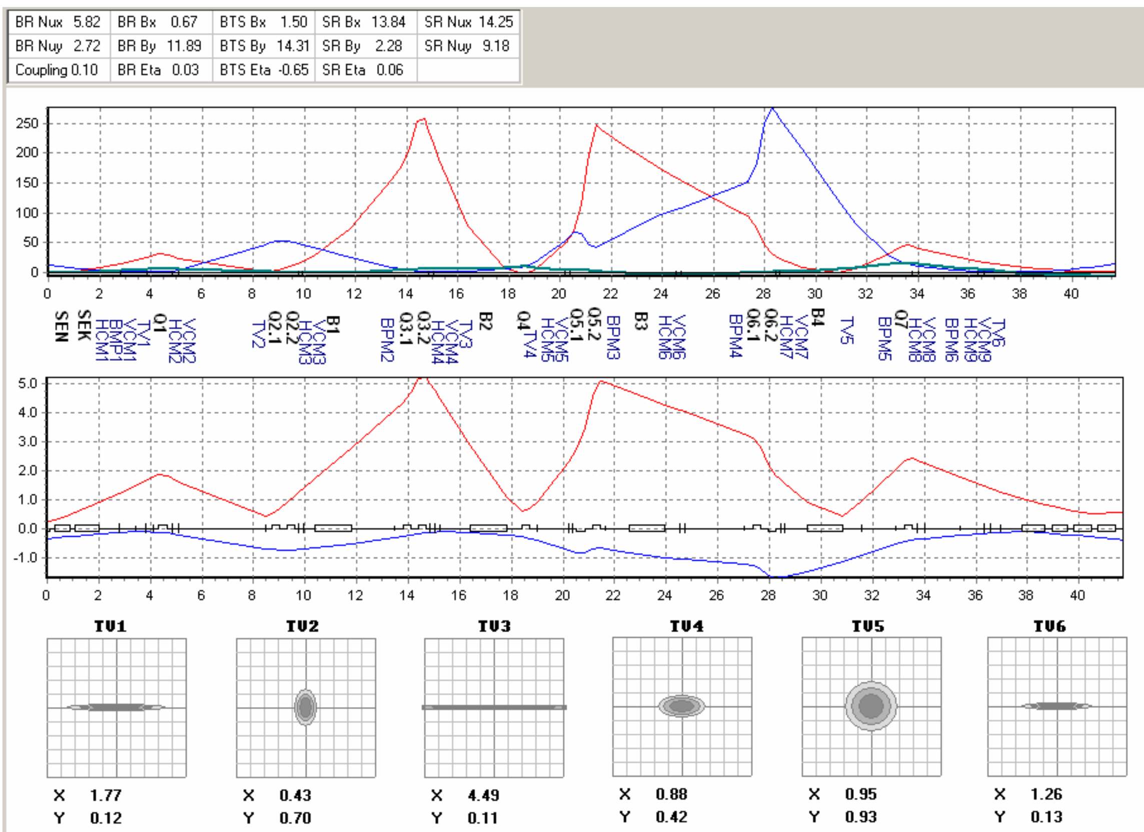


The vertical beta has a peak higher than 250 m. However, it is acceptable because of the beam size.

Quad	I (A)	K0	K1	K2
Q1	48.810	1.500	1.590	1.750
Q2.1	21.310	-0.655	-0.694	-0.694
Q2.2	9.390	-0.289	-0.306	-0.306
Q3.1	18.420	-0.566	-0.600	-0.600
Q3.2	57.650	1.772	1.878	1.878
Q4	66.170	2.033	2.155	2.155
Q5.1	81.580	-2.507	-2.657	-2.657
Q5.2	84.270	2.590	2.745	2.745
Q6.1	54.320	1.669	1.769	1.769
Q6.2	58.300	-1.792	-1.900	-1.900
Q7	50.212	1.543	1.636	1.636

It is worth pointing out that Q1 is the most effective knob to adjust the final beam size. By simply increasing Q1 by 10 %, we can even decrease horizontal beta down to 10 %.

Assuming that K1 is the current optics, we are suggesting just increase Q1 by 10% to see the effect on the injection efficiency in a context of our previous note.



Summary

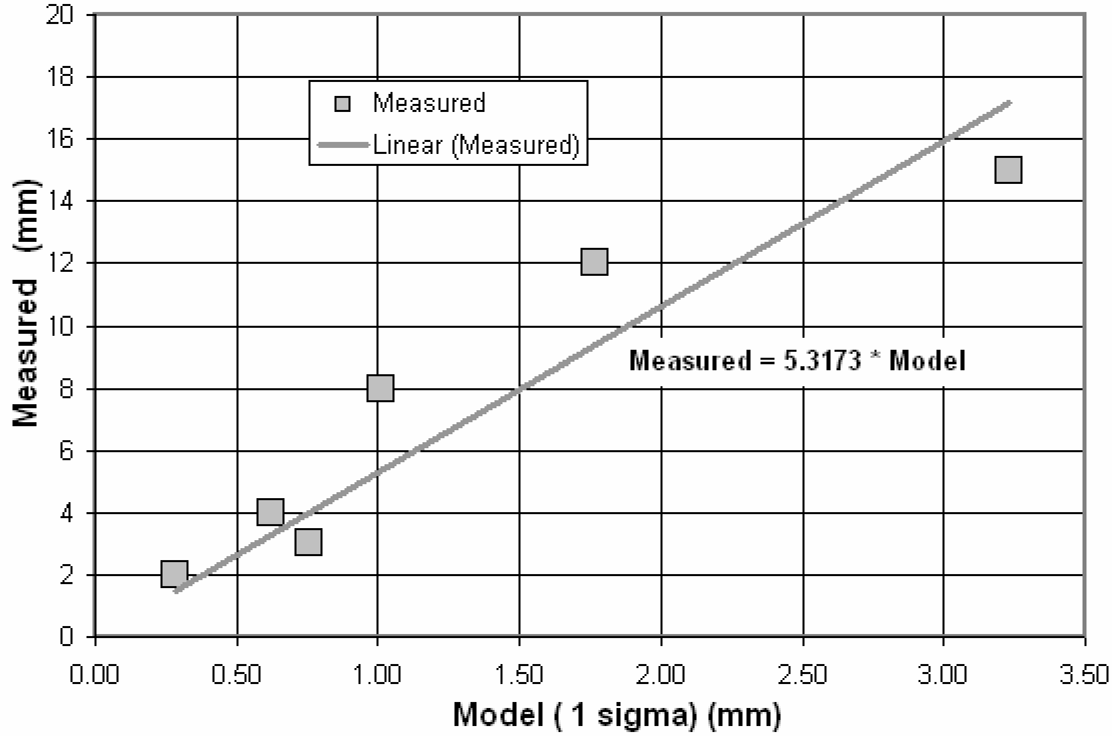
N	Quad	I (A)	K0	K1	K2
1	Q1	48.810	1.500	1.590	1.750
2	Q2.1	21.310	-0.655	-0.694	-0.694
3	Q2.2	9.390	-0.289	-0.306	-0.306
4	Q3.1	18.420	-0.566	-0.600	-0.600
5	Q3.2	57.650	1.772	1.878	1.878
6	Q4	66.170	2.033	2.155	2.155
7	Q5.1	81.580	-2.507	-2.657	-2.657
8	Q5.2	84.270	2.590	2.745	2.745
9	Q6.1	54.320	1.669	1.769	1.769
10	Q6.2	58.300	-1.792	-1.900	-1.900
11	Q7	50.212	1.543	1.636	1.636
		BetaH	140.570	5.44	1.99
		BetaY	11.630	15.34	6.59
		EtaH	0.500	0.06	0.19
		X1	1.77	1.77	1.77
		X2	0.36	0.28	0.43
		X3	2.60	3.23	4.49
		X4	0.53	0.62	0.88
		X5	1.20	0.76	0.95
		X6	1.37	1.01	1.26
		Y1	0.12	0.12	0.12
		Y2	0.66	0.67	0.70
		Y3	0.16	0.11	0.11
		Y4	0.29	0.43	0.42
		Y5	0.73	0.93	0.93
		Y6	0.37	0.12	0.13

X and Y are the one sigma values at each TV screen.

Here is the comparison with the measured beam size measured by our organic frame grabbers on the next page. If the frame grabber reads the full width as 5.3 sigma, the result shows reasonable agreement.

The precise beam size measurement by using the real frame grabber is truly needed!

** We have! Sep 5, 2006



This is the old plot. Bt using a frame grabber, we must update it!