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memorandum

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SUBJECT: MODIFIED SNS DTL TANK 1 D-PLATE LAYOUT

Simulations have been completed to determine the beam envelopes and emittances as a function of z-distance along the beam axis from the DTL Tank 1 endwall for a modified layout of the D-plate. A 10,000 macroparticle RFQ distribution was transported through the MEBT and Tank 1 followed by a 3m drift to simulate beam transport through the D-plate. The proposed D-plate length is 3m from the tank endwall to the end of the beam stop. Various modifications to the D-plate layout have been assumed:

1) A BPM has been added upstream of the Gate Valve.
2) An electomagnetic quadrupole (EMQ) was added to the D-plate centered at z= 44.16 cm.
3) The slit positions have been moved to z=70 cm. The collectors are still at z= 165 cm.
4) The steering magnet position has been moved and is centered at z =85 cm.

The new D-plate device positions of interest are summarized in Table 1 below. Not all new device locations are listed. The results presented below will be used to determine the optimal device locations, the required measurement resolutions, and required beam stop geometry.

Table 1 – D-plate devices and their longitudinal locations.

Z-Position (cm)	Device
0.0	Tank 1 Endwall
29.05	Gate Valve
44.16	EMQ
70.0	Wire Scanner
70.0	View Screen
70.0	Slits (x and y)
85.0	Steering Magnet
165.0	Collectors (x and y)
245.0	Segmented Halo Scraper
250.0-300.0	Beam Stop

Beam Envelopes

The results presented here are to be compared with those presented in our previous memorandum [1]. Our goal in adding an EMQ to the D-plate layout was to allow for additional beam focusing and thereby control the emittance growth and the beam size, if possible. Two tuning solutions for the EMQ were determined. The first was chosen such that the x- and y-rms beam sizes are approximately identical at the position of the slits. This allows the slits to be identical in width for both x- and y-emittance measurements. Table 2 compares the rms beam sizes at the slit position (z= 70 cm) for the two cases: 1) Without EMQ and 2) With EMQ. For this tuning solution, the EMQ gradient required is 1380 G/cm assuming an effective length of 10.16 cm (4 inches). Figure 1 shows the rms beam sizes and Fig. 2 shows the total beam sizes as a function of distance from the Tank 1 endwall. As can be seen, a waist in y now exists at approximately z= 120 cm due to the effect of the EMQ. Since the collector position is still assumed to be at z= 165 cm this should present no problems in measuring the emittance. The emittance and rms beam size measurement resolutions should be acceptable for these beam envelopes and should be identical to those quoted in Ref. 1. Table 3 summarizes the simulation results for this tuning solution.

Figure 3 shows the transverse emittances as a function of distance from the Tank 1 endwall. Both the xx′- and yy′-emittances are seen to grow significantly after z= 100 cm. This is to be compared with z=70 cm for the previous layout that did not include the EMQ. Therefore, the inclusion of the EMQ does allow some control of the emittance growth (over an additional 30 cm in the z-direction) while also allowing adjustment of the beam size at the slit position. If the goal is to measure emittances very similar to the tank output emittances, positioning the slit at z=70 cm still seems to be a good choice. Assuming a slit position of z=70 cm and a slit width of 0.1 mm, approximately 5% accuracy in position should be achievable. Assuming x and y slit positions at z= 70 cm and the collectors at z=165 cm, the angular resolution achievable should be approximately 0.8 mrad.

Table 2 – Comparison of the rms beam sizes at the slit location (z= 70 cm) with and without the EMQ. The EMQ gradient and effective length is 1380 G-cm and 10.16 cm, respectively.

	Without EMQ	EMQ
x-rms	0.1574	0.2025 cm
y-rms	0.4824	0.2082 cm

The second tuning solution that was determined is one that produces nearly identical rms beam sizes at the beam stop location. Table 4 summarizes the simulation results for this tuning solution. An EMQ gradient of 2020 G/cm assuming the same effective length as before (4 inches). Figure 4 shows the rms beam size as a function of distance from the Tank 1 endwall. Note the nearly identical rms beam sizes in both x and y at the beam stop

Table 3 – Simulation results for equal rms beam sizes at the slits (z=70 cm).

Z (cm)	W (MeV)	Exn, (cm-mrad)	Eyn (cm-mrad)	Epz (deg-MeV)	Epzn (cm-mrad)	xrms (cm)	yrms (cm)	xmax (cm)	ymax (cm)
1.75	7.5230	0.02537	0.02375	0.12304	0.02667	0.1803	0.0999	0.6938	0.3439
10	7.5230	0.02555	0.02352	0.12253	0.02656	0.1382	0.1362	0.5099	0.4909
20	7.5230	0.02573	0.02321	0.12219	0.02649	0.0926	0.1851	0.3052	0.6809
34	7.5230	0.02567	0.02307	0.12273	0.02661	0.0488	0.2610	0.2498	0.9510
39.08	7.5230	0.02563	0.02320	0.12345	0.02676	0.0473	0.2904	0.2405	1.0501
49.24	7.5230	0.02558	0.02381	0.12549	0.02720	0.0803	0.2974	0.3994	1.0559
59.40	7.5230	0.02559	0.02460	0.12751	0.02764	0.1382	0.2526	0.6938	0.8691
70	7.5230	0.02572	0.02525	0.12953	0.02808	0.2025	0.2082	1.0078	0.6758
85	7.5230	0.02618	0.02579	0.13226	0.02867	0.2971	0.1495	1.4647	0.4175
90	7.5230	0.02641	0.02588	0.13315	0.02886	0.3294	0.1312	1.6172	0.3573
100	7.5230	0.02695	0.02594	0.13489	0.02924	0.3948	0.0971	1.9229	0.2833
110	7.5230	0.02762	0.02591	0.13661	0.02961	0.4611	0.0691	2.2290	0.2142
120	7.5230	0.02849	0.02585	0.13853	0.03003	0.5284	0.0553	2.5356	0.3168
130	7.5230	0.02961	0.02579	0.14097	0.03056	0.5964	0.0645	2.8427	0.4718
140	7.5230	0.03085	0.02577	0.14359	0.03113	0.6651	0.0900	3.1502	0.6269
150	7.5230	0.03207	0.02579	0.14601	0.03165	0.7344	0.1221	3.4579	0.7822
160	7.5230	0.03322	0.02585	0.14815	0.03212	0.8040	0.1571	3.7658	0.9375
165	7.5230	0.03376	0.02590	0.14912	0.03233	0.8390	0.1751	3.9198	1.0203
170	7.5230	0.03428	0.02595	0.15003	0.03252	0.8741	0.1934	4.0739	1.1097
180	7.5230	0.03525	0.02606	0.15168	0.03288	0.9444	0.2306	4.3821	1.2885
190	7.5230	0.03615	0.02618	0.15316	0.03320	1.0149	0.2683	4.6904	1.4673
200	7.5230	0.03697	0.02631	0.15448	0.03349	1.0857	0.3065	4.9989	1.6463
210	7.5230	0.03774	0.02644	0.15569	0.03375	1.1566	0.3449	5.3074	1.8253
220	7.5230	0.03845	0.02657	0.15679	0.03399	1.2277	0.3836	5.6160	2.0043
230	7.5230	0.03911	0.02671	0.15780	0.03421	1.2989	0.4225	5.9246	2.1834
240	7.5230	0.03974	0.02684	0.15873	0.03441	1.3703	0.4615	6.2333	2.3626
250	7.5230	0.04032	0.02697	0.15960	0.03460	1.4417	0.5007	6.5421	2.5418
260	7.5230	0.04088	0.02709	0.16041	0.03477	1.5132	0.5400	6.8509	2.7210
270	7.5230	0.04140	0.02722	0.16117	0.03494	1.5848	0.5794	7.1597	2.9003
280	7.5230	0.04190	0.02734	0.16189	0.03509	1.6565	0.6189	7.4686	3.0796
290	7.5230	0.04237	0.02746	0.16256	0.03524	1.7283	0.6584	7.7775	3.2589
300	7.5230	0.04282	0.02758	0.16320	0.03538	1.8001	0.6981	8.0864	3.4382

Table 4 – Simulation results for equal rms beam sizes at the beam stop (z=300 cm).

Z (cm)	W (MeV)	Exn, (cm-mrad)	Eyn (cm-mrad)	Epz (deg-MeV)	Epzn (cm-mrad)	xrms (cm)	yrms (cm)	xmax (cm)	ymax (cm)

1.75	7.5230	0.02537	0.02375	0.12304	0.02667	0.1803	0.0999	0.6938	0.3439	-

10	7.5230	0.02555	0.02352	0.12253	0.02656	0.1382	0.1362	0.5099	0.4909	-

20	7.5230	0.02573	0.02321	0.12219	0.02649	0.0926	0.1851	0.3052	0.6809 -
34	7.5230	0.02567	0.02307	0.12273	0.02661	0.0488	0.2610	0.2498	0.9510
39.08	7.5230	0.02563	0.02320	0.12345	0.02676	0.0473	0.2904	0.2405	1.0501
49.24	7.5230	0.02558	0.02380	0.12549	0.02720	0.0847	0.2734	0.4194	0.9698
59.40	7.5230	0.02559	0.02450	0.12766	0.02767	0.1521	0.1827	0.7623	0.6185
70	7.5230	0.02582	0.02492	0.13020	0.02823	0.2263	0.0916	1.1209	0.2606
85	7.5230	0.02701	0.02493	0.13568	0.02941	0.3357	0.0454	1.6348	0.2768
90	7.5230	0.02759	0.02502	0.13768	0.02985	0.3732	0.0847	1.8091	0.4297
100	7.5230	0.02858	0.02530	0.14047	0.03045	0.4491	0.1688	2.1583	0.7722
110	7.5230	0.02940	0.02562	0.14241	0.03087	0.5258	0.2548	2.5078	1.1150
120	7.5230	0.03009	0.02594	0.14388	0.03119	0.6030	0.3415	2.8575	1.4581
130	7.5230	0.03069	0.02625	0.14506	0.03145	0.6806	0.4288	3.2074	1.8014
140	7.5230	0.03122	0.02655	0.14603	0.03166	0.7585	0.5164	3.5574	2.1448
150	7.5230	0.03169	0.02683	0.14685	0.03183	0.8366	0.6042	3.9075	2.4884
160	7.5230	0.03212	0.02709	0.14756	0.03199	0.9149	0.6922	4.2577	2.8320
165	7.5230	0.03232	0.02722	0.14788	0.03206	0.9541	0.7363	4.4328	3.0038
170	7.5230	0.03251	0.02735	0.14818	0.03212	0.9933	0.7804	4.6079	3.1757
180	7.5230	0.03287	0.02759	0.14874	0.03224	1.0719	0.8687	4.9582	3.5195
190	7.5230	0.03320	0.02782	0.14924	0.03235	1.1505	0.9571	5.3085	3.8633
200	7.5230	0.03351	0.02804	0.14970	0.03245	1.2293	1.0456	5.6589	4.2071
210	7.5230	0.03380	0.02825	0.15011	0.03254	1.3081	1.1342	6.0092	4.5510
220	7.5230	0.03407	0.02845	0.15049	0.03262	1.3870	1.2229	6.3596	4.8949
230	7.5230	0.03432	0.02864	0.15085	0.03270	1.4659	1.3116	6.7101	5.2389
240	7.5230	0.03456	0.02883	0.15118	0.03277	1.5449	1.4004	7.0605	5.5828
250	7.5230	0.03479	0.02901	0.15149	0.03284	1.6240	1.4892	7.4110	5.9268
260	7.5230	0.03501	0.02918	0.15178	0.03290	1.7030	1.5780	7.7615	6.2709
270	7.5230	0.03522	0.02935	0.15205	0.03296	1.7822	1.6669	8.1119	6.6149
280	7.5230	0.03542	0.02951	0.15231	0.03302	1.8613	1.7559	8.4625	6.9590
290	7.5230	0.03561	0.02966	0.15255	0.03307	1.9405	1.8448	8.8130	7.3030
300	7.5230	0.03579	0.02981	0.15278	0.03312	2.0197	1.9338	9.1635	7.6471

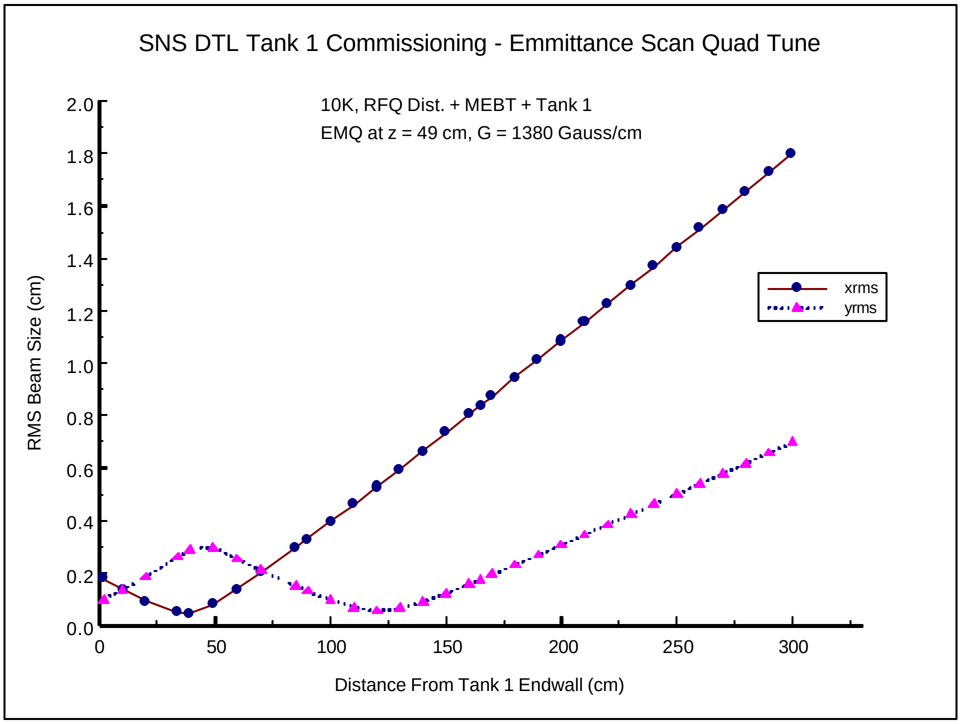

Figure 1 –RMS beam size as a function of distance from the Tank 1 endwall.

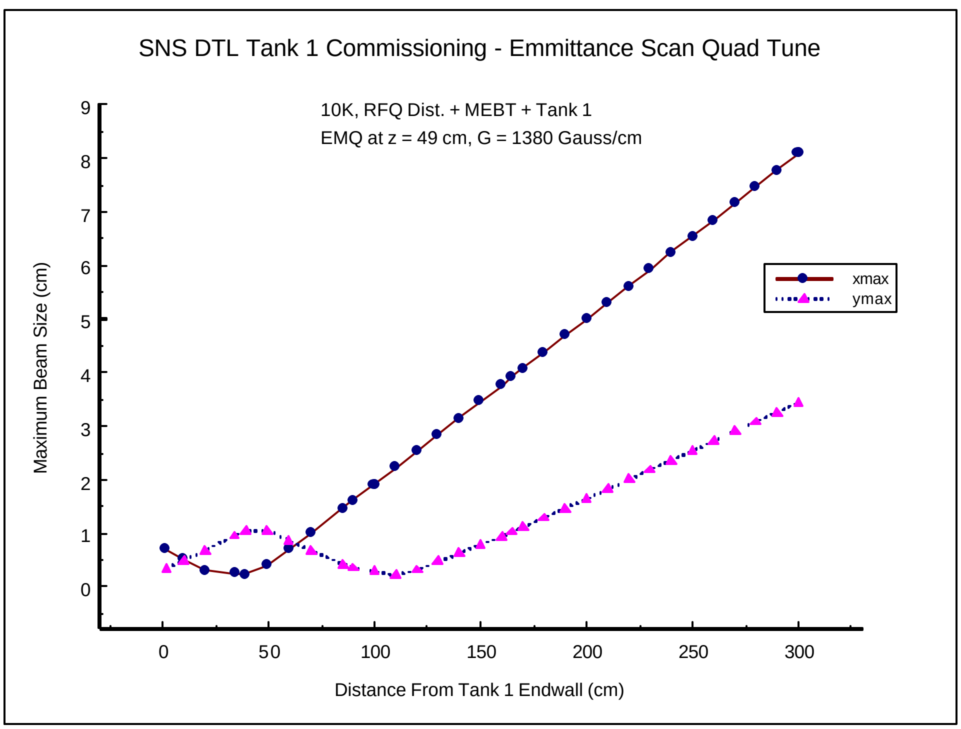

Figure 2 – Total beam size as a function of distance from the Tank 1 endwall.

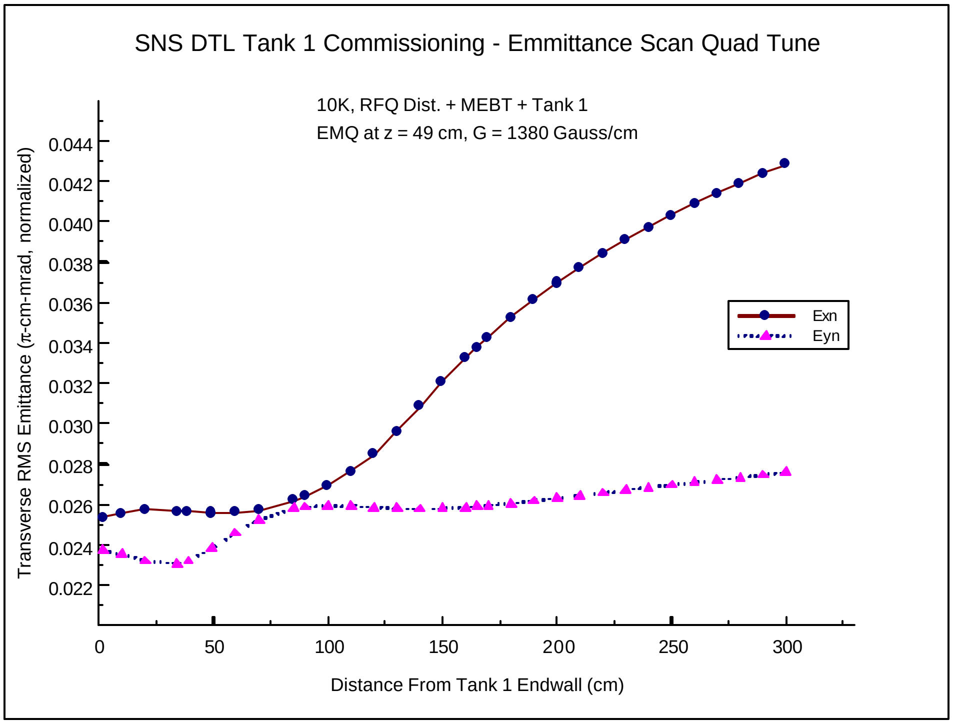

Figure 3 – RMS emittances as a function of distance from the Tank 1 endwall.

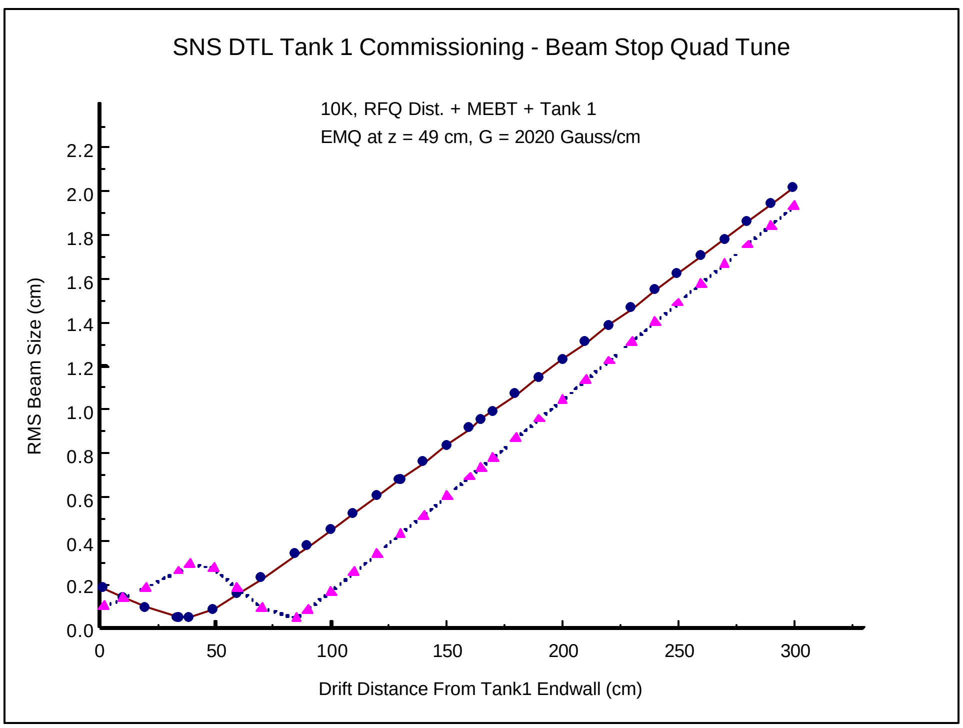

Figure 4 –RMS beam size as a function of distance from the Tank 1 endwall for the beam stop tune.

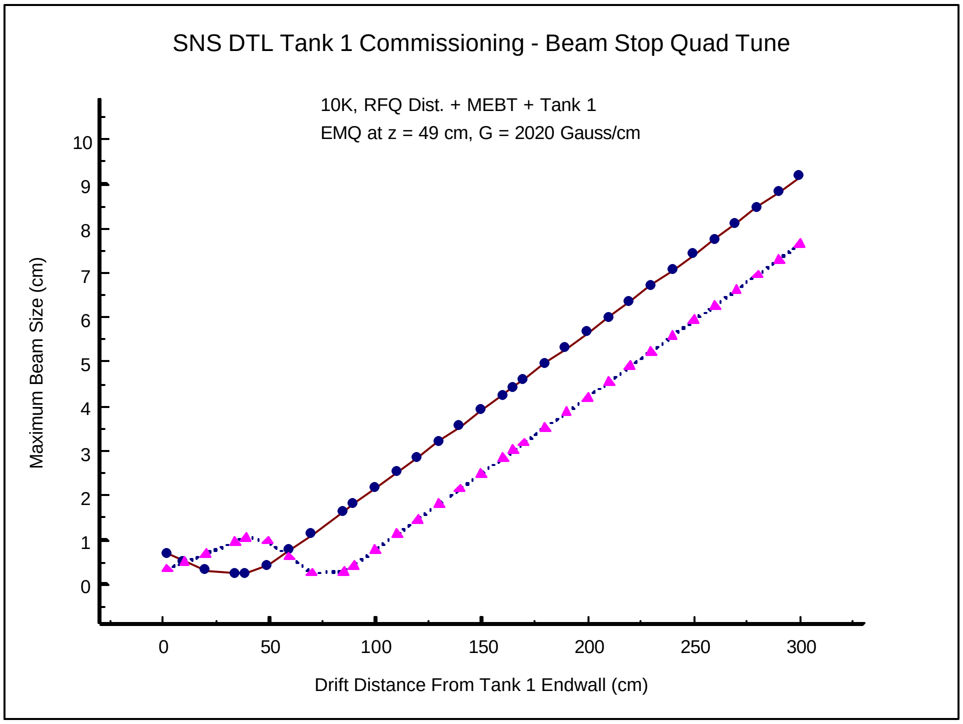

Figure 5 – Maximum beam size as a function of distance from the Tank 1 endwall for the beam stop tune.

(3 m). Figure 5 shows the maximum beam sizes at the beam stop.

Steering Magnet Effectiveness

Table 1 shows the new steering magnet position at z=85 cm. The maximum steering angle proposed for this magnet is 10 mrad. Just as before, the centroid of the beam distribution out of the DTL was offset by 0.25 cm in both x- and y-positions. Because of the additional steering of the offset beam by the quadrupole, the centroid displacements are expected to be larger than in our previously discussed D-plate layout. For example, the rms beam centroids are displaced approximately 0.20 cm and 2.17 in x and y, respectively, assuming no steering magnet corrector scheme for the 1380 G/cm EMQ setting. Steering magnet GL-products of 550 G-cm and 4000 G-cm for x and y, respectively, will be required to correct these offsets at the new steering magnet position.

Beam Distribution at the Beam Stop

Figure 6 shows the beam distributions and the xy-plot at the beam stop (z=300 cm) for the second tuning solution. Note the nearly identical x- and y-distributions. Based on the results shown here and in Fig. 5, the aperture radius of the beam stop should be increased to at least 10 cm to intercept 100% of the beam. This assumes the beam is steered on-axis when it hits the beam stop.

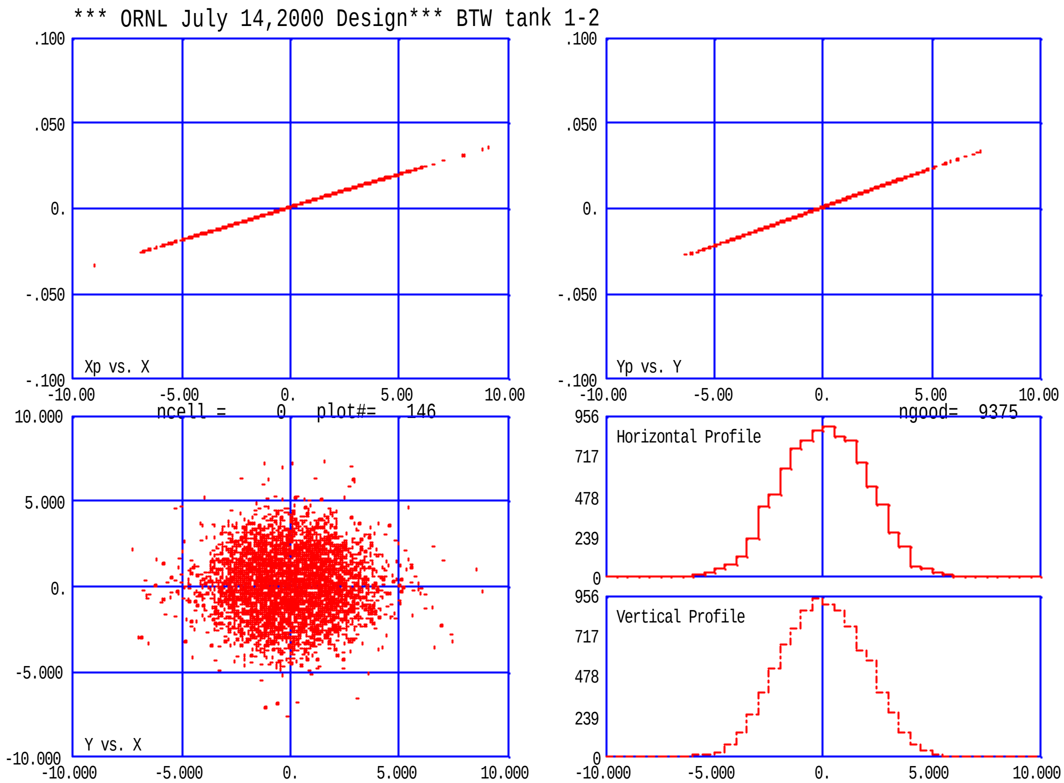

Figure 6 - Beam distribution at the beam stop (z=300 cm).

Summary and Recommendations

1) The usefulness of the addition of an EMQ to the D-plate layout has been demonstrated. However, two operational modes will exist when making measurements. The first mode will be a low-power (low rep-rate, short pulse) mode for making emittance measurements. This mode will use the first tuning solution that will give identical x- and y-rms beam sizes at the slits. The second mode will require the slits and collectors to be removed and the EMQ adjusted to the second tuning solution to give the larger, but equal x- and y-rms beam sizes at the beam stop. This will be the high-power (full duty factor) mode. The approximate position of the EMQ should be z= 44.0 cm to use the solutions demonstrated here.
2) Steering magnet position at z= 85 cm with a maximum steering GL-product of 4000 G-cm (approximately 10 mrad bend) should be acceptable.
3) Collectors positioned at z= 165 cm should provide adequate angular resolution for the emittance measurements.
4) The minimum radial aperture of the beam stop should be increased to 10.0 cm.

References

[1] R. Garnett, "SNS DTL Tank 1 D-Plate Supporting Simulations," Los Alamos National Laboratory Memorandum, LANSCE-1:00-084, September 21, 2000.

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