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Hall A Cryogenic and Dummy Targets Information

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Abstract

This report describes the cryotargets and the aluminum dummy targets. A total error of 0.1% in the target length was achieved. The density of the liquid hydrogen target at 19 K and 26 psia is 0.07230±0.00007 g/cm^3. The density of the liquid deuterium target at 22 K and 22 psia is 0.1670±0.0005 g/cm^3.

Contents

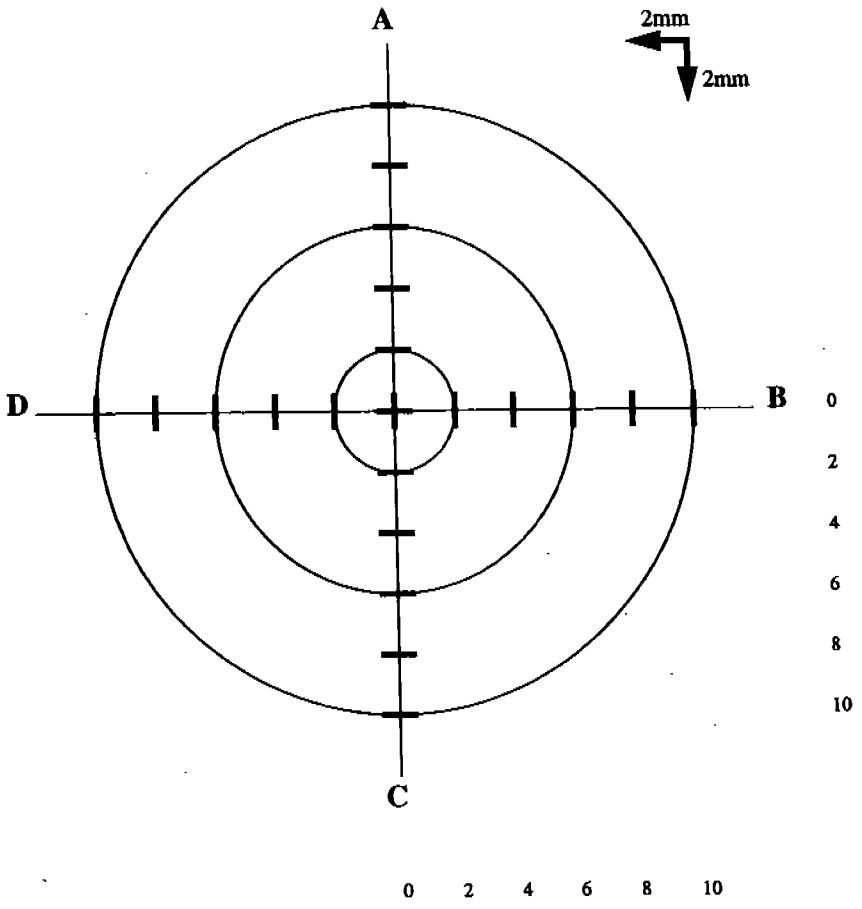

Figure 1: *Measurement points on the downstream window.*

1 Target Length

1.1 Upstream and Downstream windows

The thickness of the downstream window was measured in Dec 96 and Jan 97 using the Coordinate Measurement Machine (CMM). The results are listed in Table 1. Figure 1 shows the measurement points on the downstream window. The thickness of the upstream window is 2.8 mil for all the cells.

Beer Can #		0	2	4	6	8	10	Edge
Cell Block #1 [Loop 1]								
11 [15 cm]	A	4.2	4.4	4.4	4.5	4.4	4.7	5.2
	B		4.5	4.4	4.5	4.8	4.8	5.2
	C		4.4	4.6	4.6	4.6	4.7	5.0
	D		4.6	4.4	4.4	4.6	4.8	5.5
16 [4 cm]	A	4.6	4.8	4.7	4.8	4.9	4.9	5.6
	B		4.7	4.8	4.8	5.0	5.1	5.4
	C		4.7	4.8	4.7	4.7	4.7	4.7
	D		4.5	4.7	4.7	4.8	4.8	5.5
Cell Block #2 [Loop 2]								
3 [15 cm]	A	3.7	3.8	3.8	3.7	3.9	3.9	4.4
	B		3.7	3.9	3.8	3.9	3.9	5.2
	C		3.7	3.8	3.8	3.9	4.0	5.3
	D		3.6	3.6	3.7	3.8	3.9	4.7
8 [4 cm]	A	3.5	3.6	3.6	3.8	3.7	3.8	4.5
	B		3.6	3.7	3.7	3.6	3.8	4.5
	C		3.6	3.7	3.6	3.8	3.9	4.5
	D		3.6	3.8	3.8	3.7	3.8	4.7
Cell Block #3 [Loop 3]								
1 [15 cm]	A	3.8	3.8	3.9	3.9	4.1	4.2	5.1
	B		3.8	3.7	3.9	4.0	4.1	4.8
	C		3.8	3.9	3.7	3.9	4.3	6.4
	D		3.9	3.9	4.0	4.0	4.1	4.9
17 [4 cm]	A	3.6	3.8	3.7	3.9	4.0	4.0	4.2
	B		3.8	4.0	3.7	3.9	4.0	4.4
	C		3.8	3.8	4.0	3.9	4.2	4.5
	D		3.8	4.0	3.9	3.8	4.1	4.4
Cell Block #4 [Spare]								
4 [15 cm]	A	3.9	3.8	3.8	3.7	3.9	4.0	4.6
	B		3.8	3.6	3.9	4.0	4.1	4.5
	C		4.1	3.9	3.9	4.1	4.0	4.4
	D		3.9	4.1	4.1	4.1	4.1	4.4
18 [4 cm]	A	3.8	3.8	3.8	3.7	3.8	3.6	2.9
	B		3.9	4.0	3.9	4.0	4.1	4.1
	C		3.9	4.1	4.1	4.3	4.2	4.6
	D		3.9	3.9	3.9	4.0	4.1	4.4

Table 1: Downstream window thickness in mils.

1.2 CMM Measurement

Four cell blocks were measured and each cell block consisted of two targets. The measurements were performed in the Test Lab using a Mituoyo Coordinate Measurement Machine (CMM) model number B-70H. The CMM was operated by Jim Dahlberg from the Alignment group.

The coordinate system was determined by fitting a cylinder to six points along the upstream window tube. A 0.7488 inch stylist was used so the probe extended past the extension rod which had a diameter of 0.5 inches. While fitting the cylinder, three points were hit near the front of the tube and three near the rear. The x-z plane was determined by hitting four points on the tube base, thus, establishing the origin of y at the front of the tube base. The x and z axes were aligned by hitting two z measurements at the top of the cell block. The stylus was qualified at the beginning of the measurement, at each subsequent stylus change, and at the changing of the direction of the probe. The qualification consisted of hitting five points on a standard two inch sphere. This determined the diameter of the stylus and was the reference point for the measurements. During each cell block measurement, the length of a calibration rod (ideal = 12.0001 in) was measured and found to be within 1 mil.

Figure 2 show the points measured on the upstream and downstream windows at 25 psig. This is the coordinate system while looking downstream. The measurements were made along the x axis and the z axis. The values of these points for each target are in Appendix A.1. In addition to the measurement values, the length is calculated as well as the center of the target. In addition, both targets of Cell Block #1 were measured at x=z=0 at 0, 20, 25, 30 psig. These measurements are shown in Tables 2 and 3 and Figures 3 and 4. The data for each of these targets had to be corrected to the proper operating pressure. Note that the amount of bulging is less for the upstream window. This is because the diameter of the upstream window (1.00 in) is less than the diameter of the downstream window (2.55 in).

15 cm target

Upstream =	0	9.0496	Downstream =	0	14.9338
	20	9.0469		20	14.9457
	25	9.0466		25	14.9478
	30	9.0461		30	14.9499
				25	14.9475
				20	14.9450
	0	9.0497		0	14.9337

Table 2: Cell Block #1 window bulging versus pressure.

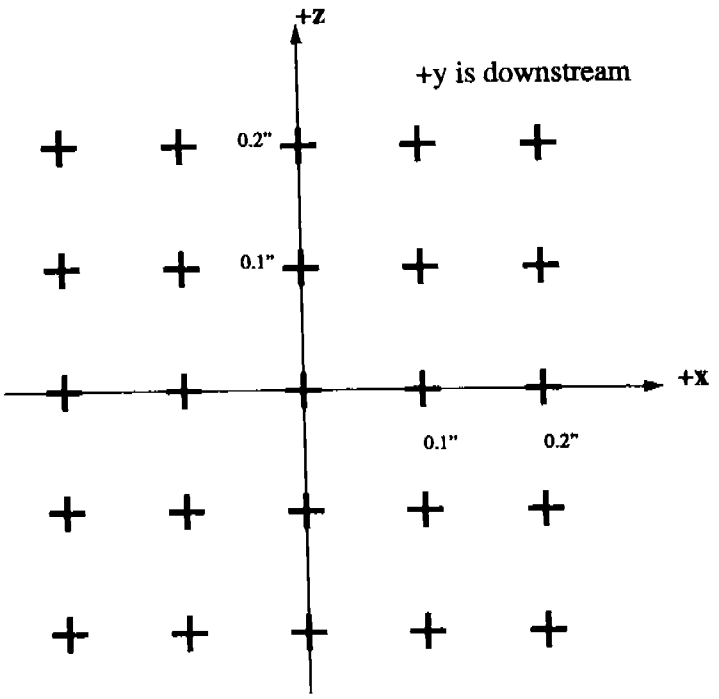

Figure 2: *Target length measurement points on the upstream and downstream windows.*

4 cm target

	0	11.2265		0	12.7594
	20	11.2195		20	12.7707
	25	11.2188		25	12.7723
Upstream =	30	11.2182	Downstream =	30	12.7745
				25	12.7720
				20	12.7702
	0	11.2282		0	12.7593

Table 3: Cell Block #1 window bulging versus pressure.

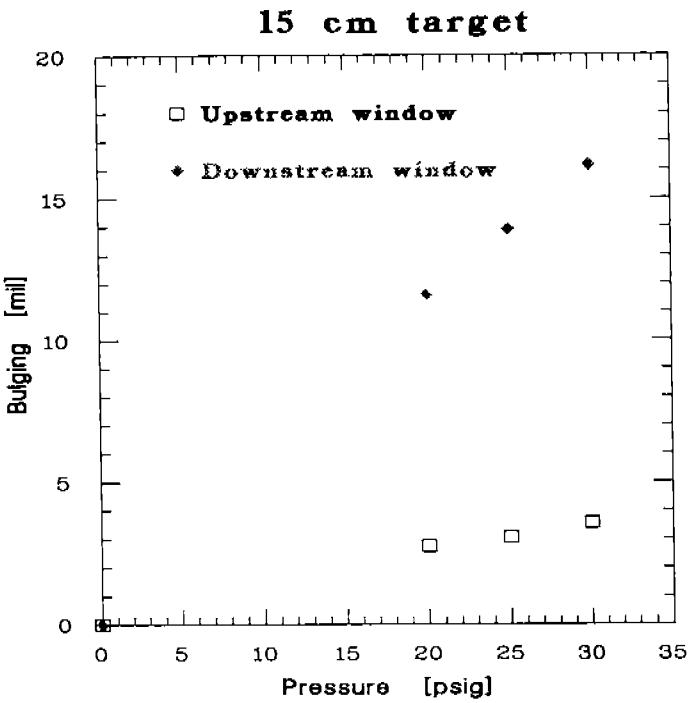

Figure 3: *Cell Block #1 window bulging versus pressure.*

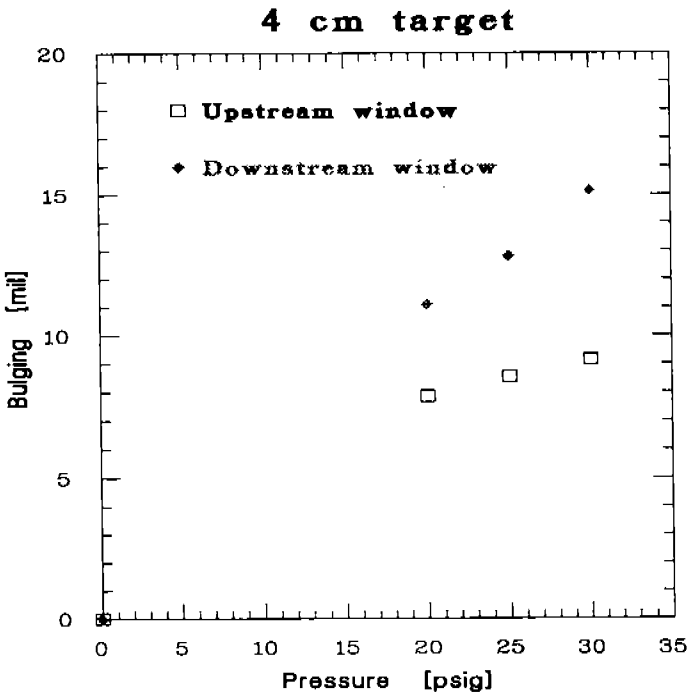

Figure 4: *Cell Block # 1 window bulging versus pressure.*

1.3 Target Length

Table 4 lists the cryogenic target lengths at their centers (without the windows). These length have been corrected for the operating pressure (22 psia for loop 1 and loop 3 and 26 psia for loop 2) and for thermal contraction (about 0.4% at 20 K). Since the cell windows are convex, the beam position on the target affects the length. If a more quantitative description of beam induced length change is needed, fits to the length measurement can be provided.

Note: Target cell side wall thickness is 0.007±0.001 in.
Target cell diameter is 2.55 in.
Upstream window tube diameter is 1.60 in.

Target loop	Cell	Cold Length	Upstream Window Thickness	Downstream Window Thickness
1	15 cm	14.91±0.02	0.0071±0.0003	0.0107±0.0005
	4 cm	3.91±0.01	0.0071±0.0003	0.0117±0.0005
2	15 cm	14.95±0.02	0.0071±0.0003	0.0094±0.0005
	4 cm	3.78±0.01	0.0071±0.0003	0.0089±0.0005
3	15 cm	14.94±0.02	0.0071±0.0003	0.0097±0.0005
	4 cm	3.93±0.01	0.0071±0.0003	0.0091±0.0005

Table 4: Cryotarget dimensions (cm).

The error on the target length calculation (without beam) is $\sim$ 0.1% and is due mainly to the uncertainty of the thermal contraction. With beam the error is much larger, about 0.1-1.0%. The length of the target depends on how much accurate we know where the beam pass through the target and at what angle. On running the cryogenic target the beam must be rastered, this makes the beam spot large enough that the target length changes over different places on the beam spot and some kind of averaging would be necessary.

Sources of errors in determining the target length are:

1. Negligible target length measurement error.
2. Thermal contraction error ($\sim$ 0.1%).
3. Knowledge of where beam travels through target ($\sim$ 0.1-1.0%).

2 Target Density

The liquid hydrogen target operating temperature is 19 K and the operating temperature for the liquid deuterium target is 22 K. These temperatures are determined by a resistance measurement of two LakeShore Cernox resistors for each loop. The resistors were calibrated by LakeShore and the calibration data were loaded into Oxford ITC^{502}'s which converted the resistance to temperature. The liquid hydrogen target operating pressure is 26 psia and the operating pressure for liquid deuterium is 22 psia. The pressure for each loop was measured by two pressure transducers, one is in the gas fill line and the other is in the return line. Table 5 lists the densities of H_2 and D_2.

Target Liquid	Temperature	Pressure	Density (g/cm^3)
Hydrogen	19.00 K	26.0 psia	0.07230±0.00007
Deuterium	22.00 K	22.0 psia	0.1670±0.0005

Table 5: Target density (para H_2 and normal D_2).

The error in the density calculation (without beam) is $\sim$ 0.1% for H_2 and 0.3% for D_2 and is due mainly to the uncertainty of the equations of state.
Sources of errors in determining the target density are:

1. Error resulting from the temperature and pressure determination

   - $\sim$ 50 mK absolute error from Cernox resistors in the operating temperature region. This corresponds to an error of less than 0.1% for the density of both H_2 and D_2.
     $[\frac{1}{\rho}\frac{d\rho_L}{dT} = 1.5\%\ \mathrm{K}^{-1}]$
   - $\sim$ 0.2-0.3 psi absolute error from pressure transducers. This corresponds to an error of less than 0.1% for the density of both H_2 and D_2.
     $[\frac{1}{\rho}\frac{d\rho_L}{dP} = 0.01\%\ \mathrm{psia}^{-1}]$

2. Ortho-Para Modifications: different relative orientations of the two nuclear spins in the diatomic molecules H_2 and D_2 give rise to the molecular modification designated by the prefixes ortho and para. The equilibrium ortho-para composition is temperature dependent. The high temperature concentration of hydrogen, closely approached at room temperature and known as "normal" hydrogen, is 75% ortho-hydrogen (nuclear spins in the same direction) and 25% para-hydrogen (nuclear spins in opposite directions). The high temperature equilibrium composition of deuterium is 67% ortho and 33% para.

   - For D_2, No difference in P-ρ-T values for different ortho-para modifications could be observed [1].

- On the other hand the density of ortho-para mixtures of hydrogen will vary very little and the differences in density between normal and pure para-hydrogen is about 0.5-0.7% (normal hydrogen has the larger density). At 19 K, the equilibrium concentration is almost 100% para. The assumption that the target liquid hydrogen is in equilibrium is valid since the hydrogen has some impurities which act as catalysts for ortho-para conversion and the time scale is long enough for conversion to equilibrium; the experiment ran for 60 days. Thus, the error in the hydrogen target density due to ortho-para modifications is negligible.

3. Error coming from the equations of state
   - $\sim 0.3\%$ relative error on density for D_2 [1]
   - $\sim 0.1\%$ relative error on density for H_2 [2]
4. Beam induced local boiling (to be determined experimentally).

3 Dummy Targets

	Upstream Window	Downstream Window
Al Alloy	5052	3004
Density (g/cm^3)	2.68	2.71
Thickness (mil)	2.8	4.0
X_o (g/cm^2)	23.85	24.12
Radiation Length	0.0008	0.0011

Table 6: Upstream and downstream windows thickness and material. Note: for the downstream window this is the average thickness.

Target	10 cm Dummy		15 cm Dummy		4 cm Dummy	
	upst	dnst	upst	dnst	upst	dnst
Al Alloy	6061	6061	6061	6061	6061	6061
Density (g/cm^3)	2.71	2.71	2.71	2.71	2.71	2.71
Thickness (mil)	36.95	36.60	38.85	38.85	12.60	12.25
X_o (g/cm^2)	24.12	24.12	24.12	24.12	24.12	24.12
Radiation Length	0.0105	0.0104	0.0111	0.0111	0.0036	0.0035

Table 7: Dummy target thickness and material.

Dummy Target	Z position of upstream foil	Z position of downstream foil	Cold distance between center of foils
10 cm	-47.77±0.2 mm	+51.86±0.2 mm	9.96±0.03 cm
15 cm	-73.15±0.2 mm	+76.31±0.2 mm	14.95±0.04 cm
4 cm	-17.79±0.2 mm	+22.47±0.2 mm	4.03±0.01 cm

Table 8: Dummy target Z position and length.

4 Positioning and Survey

Below are the results of hall A solid and cryogenic target survey performed on Sep 1997 [3]. The distances are in millimeters and are in a right handed coordinate system looking downstream (see note below). Also included is the Z location of the dummy targets and collimator. These dimensions are relative to the center of the cryo cells as specified, they are not as set location in the beam line. The pitch of the relevant cryo cell and its location in the beam line would have to be considered to obtain this information.

Note: +X = Beam left
+Y = high
+Z = downstream
+pitch = up looking downstream
+yaw = clockwise looking down

Target	Z (mm) ±0.2	X (mm) ±0.2	Y (mm) ±0.2	pitch (mr) ±1.0	yaw (mr) ±1.0	Encoder
Cryo 1 [L1 15 cm]	+0.69	-0.12	-0.37	+3.2	-1.2	6873658
Cryo 2 [L1 4 cm]	+0.99	-0.08	-0.41	+4.1	+1.5	6158394
Cryo 3 [L2 15 cm]	+1.40	-0.18	-0.36	+1.9	+1.7	5345338
Cryo 4 [L2 4 cm]	+0.68	-0.14	-0.43	+2.5	+1.3	4630074
Cryo 5 [L3 15 cm]	+2.03	-0.12	-0.32	+4.1	+0.1	3817018
Cryo 6 [L3 4 cm]	+2.11	-0.07	-0.39	+3.0	+1.5	3101754
Solid 3 [Al]	+2.85	-1.05	+0.30	—	+0.9	463520

Repeatability check

Cryo 1 [L1 15 cm]	+0.56	-0.05	-0.33	+3.1	-0.1	6873658
Cryo 6 [L3 4 cm]	+2.05	-0.05	-0.37	+2.8	+0.6	3101754

Centerline of dummy target foil relative to cryo 6 (based on center of cryo cell 304.77 mm from upstream face)

10 cm upstream	-50.08 mm
10 cm downstream	+49.95 mm
15 cm upstream	-75.56 mm
15 cm downstream	+75.50 mm
4 cm upstream	-19.98 mm
4 cm downstream	+20.44 mm

Collimator relative to cryo 1 (based on center of cryo cell 304.70 mm from upstream face)

upstream face	-157.37 mm

The final survey positions are in Appendix A.2. These numbers are corrected for cold contraction and movement of the target ladder due to putting the scattering chamber under vacuum.

References

[1] NBS Report 9276.

[2] NBS Report N76-11297 (1975).

[3] J. Dahlberg, Jefferson Lab Alignment Group (1997).

A Appendix

A.1 Profile of Target Warm Length

Cell Block # 1 [Loop 1]

15 cm Target Warm Length at 25 psig

x(in)	z(in)	Upstream Window y(in)	Downstream Window y(in)	Target Length (cm)	% Diff from x=z=0	Center of Target (in)
0.2	0.2	9.0766	14.9372	14.886	-0.71	12.0069
0.2	0.1	9.0643	14.9415	14.928	-0.43	12.0029
0.2	0.0	9.0596	14.9427	14.943	-0.33	12.0012
0.2	-0.1	9.0619	14.9416	14.934	-0.39	12.0018
0.2	-0.2	9.0712	14.9384	14.903	-0.59	12.0048
0.1	-0.2	9.0593	14.9417	14.941	-0.34	12.0005
0.1	-0.1	9.0504	14.9448	14.972	-0.13	11.9976
0.1	0.0	9.0482	14.9460	14.980	-0.08	11.9971
0.1	0.1	9.0529	14.9449	14.966	-0.17	11.9989
0.1	0.2	9.0646	14.9414	14.927	-0.43	12.0030
0.0	0.2	9.0600	14.9429	14.943	-0.33	12.0015
0.0	0.1	9.0484	14.9463	14.981	-0.07	11.9974
0.0	0.0	9.0448	14.9471	14.992	00.00	11.9960
0.0	-0.1	9.0460	14.9460	14.986	-0.04	11.9960
0.0	-0.2	9.0550	14.9432	14.956	-0.24	11.9991
-0.1	-0.2	9.0576	14.9417	14.946	-0.31	11.9997
-0.1	-0.1	9.0487	14.9450	14.977	-0.10	11.9967
-0.1	0.0	9.0464	14.9464	14.986	-0.04	11.9964
-0.1	0.1	9.0513	14.9453	14.971	-0.14	11.9983
-0.1	0.2	9.0629	14.9418	14.932	-0.40	12.0024
-0.2	0.2	9.0729	14.9397	14.902	-0.60	12.0063
-0.2	0.1	9.0611	14.9420	14.937	-0.37	12.0016
-0.2	0.0	9.0562	14.9430	14.952	-0.27	11.9996
-0.2	-0.1	9.0585	14.9416	14.943	-0.33	12.0001
-0.2	-0.2	9.0675	14.9381	14.911	-0.54	12.0028

Cell Block # 1 [Loop 1]

4 cm Target Warm Length at 25 psig

x(in)	z(in)	Upstream Window y(in)	Downstream Window y(in)	Target Length (cm)	% Diff from x=z=0	Center of Target (in)
0.2	0.2	11.2476	12.7613	3.845	-2.66	12.0045
0.2	0.1	11.2358	12.7648	3.884	-1.67	12.0003
0.2	0.0	11.2315	12.7661	3.898	-1.23	11.9988
0.2	-0.1	11.2344	12.7653	3.888	-1.57	11.9999
0.2	-0.2	11.2450	12.7620	3.853	-2.46	12.0035
0.1	-0.2	11.2326	12.7664	3.896	-1.37	11.9995
0.1	-0.1	11.2224	12.7693	3.929	-0.53	11.9959
0.1	0.0	11.2197	12.7699	3.938	-0.30	11.9948
0.1	0.1	11.2239	12.7684	3.923	-0.68	11.9962
0.1	0.2	11.2355	12.7647	3.884	-1.67	12.0001
0.0	0.2	11.2307	12.7661	3.900	-1.27	11.9984
0.0	0.1	11.2194	12.7699	3.938	-0.30	11.9947
0.0	0.0	11.2164	12.7717	3.950	00.00	11.9941
0.0	-0.1	11.2189	12.7711	3.943	-0.18	11.9950
0.0	-0.2	11.2280	12.7686	3.913	-0.94	11.9983
-0.1	-0.2	11.2309	12.7683	3.905	-1.14	11.9996
-0.1	-0.1	11.2211	12.7708	3.936	-0.35	11.9960
-0.1	0.0	11.2179	12.7712	3.945	-0.13	11.9946
-0.1	0.1	11.2220	12.7695	3.931	-0.48	11.9958
-0.1	0.2	11.2335	12.7656	3.892	-0.81	11.9996
-0.2	0.2	11.2436	12.7625	3.858	-2.33	12.0031
-0.2	0.1	11.2321	12.7666	3.898	-1.32	11.9994
-0.2	0.0	11.2276	12.7686	3.914	-0.91	11.9981
-0.2	-0.1	11.2310	12.7683	3.905	-1.14	11.9997
-0.2	-0.2	11.2413	12.7656	3.872	-1.97	12.0035

Cell Block # 2 [Loop 2]

15 cm Target Warm Length at 25 psig

x(in)	z(in)	Upstream Window y(in)	Downstream Window y(in)	Target Length (cm)	% Diff from x=z=0	Center of Target (in)
0.2	0.2	9.0711	14.9547	14.944	-0.56	12.0129
0.2	0.1	9.0517	14.9582	15.003	-0.17	12.0050
0.2	0.0	9.0493	14.9593	15.011	-0.11	12.0043
0.2	-0.1	9.0592	14.9579	14.983	-0.30	12.0086
0.2	-0.2	9.0728	14.9537	14.937	-0.61	12.0133
0.1	-0.2	9.0648	14.9577	14.968	-0.40	12.0113
0.1	-0.1	9.0546	14.9619	15.005	-0.15	12.0083
0.1	0.0	9.0515	14.9633	15.016	-0.08	12.0074
0.1	0.1	9.0548	14.9624	15.005	-0.15	12.0086
0.1	0.2	9.0647	14.9586	14.971	-0.38	12.0117
0.0	0.2	9.0617	14.9599	14.981	-0.31	12.0108
0.0	0.1	9.0513	14.9636	15.017	-0.07	12.0075
0.0	0.0	9.0480	14.9647	15.028	00.00	12.0064
0.0	-0.1	9.0516	14.9639	15.017	-0.07	12.0078
0.0	-0.2	9.0614	14.9590	14.980	-0.32	12.0102
-0.1	-0.2	9.0653	14.9579	14.967	-0.41	12.0116
-0.1	-0.1	9.0551	14.9623	15.004	-0.16	12.0087
-0.1	0.0	9.0515	14.9635	15.016	-0.08	12.0075
-0.1	0.1	9.0547	14.9623	15.005	-0.15	12.0085
-0.1	0.2	9.0653	14.9583	14.968	-0.40	12.0118
-0.2	0.2	9.0759	14.9544	14.931	-0.65	12.0152
-0.2	0.1	9.0652	14.9582	14.968	-0.40	12.0117
-0.2	0.0	9.0620	14.9591	14.979	-0.33	12.0106
-0.2	-0.1	9.0657	14.9578	14.966	-0.41	12.0118
-0.2	-0.2	9.0759	14.9534	14.929	-0.66	12.0147

Cell Block # 2 [Loop 2]

4 cm Target Warm Length at 25 psig

x(in)	z(in)	Upstream Window y(in)	Downstream Window y(in)	Target Length (cm)	% Diff from x=z=0	Center of Target (in)
0.2	0.2	11.2481	12.7093	3.711	-2.65	11.9787
0.2	0.1	11.2369	12.7131	3.750	-1.63	11.9750
0.2	0.0	11.2324	12.7136	3.762	-1.31	11.9730
0.2	-0.1	11.2324	12.7120	3.758	-1.42	11.9722
0.2	-0.2	11.2447	12.7076	3.716	-2.52	11.9762
0.1	-0.2	11.2341	12.7126	3.755	-1.50	11.9734
0.1	-0.1	11.2249	12.7167	3.789	-0.60	11.9708
0.1	0.0	11.2222	12.7188	3.801	-0.29	11.9705
0.1	0.1	11.2267	12.7169	3.785	-0.71	11.9718
0.1	0.2	11.2376	12.7134	3.749	-1.65	11.9755
0.0	0.2	11.2340	12.7147	3.761	-1.34	11.9744
0.0	0.1	11.2230	12.7186	3.799	-0.34	11.9708
0.0	0.0	11.2191	12.7198	3.812	00.00	11.9695
0.0	-0.1	11.2215	12.7178	3.801	-0.29	11.9697
0.0	-0.2	11.2307	12.7137	3.767	-1.18	11.9722
-0.1	-0.2	11.2346	12.7130	3.755	-1.50	11.9738
-0.1	-0.1	11.2251	12.7174	3.790	-0.58	11.9713
-0.1	0.0	11.2223	12.7186	3.801	-0.29	11.9705
-0.1	0.1	11.2265	12.7174	3.787	-0.66	11.9720
-0.1	0.2	11.2378	12.7142	3.750	-1.63	11.9760
-0.2	0.2	11.2484	12.7096	3.711	-2.65	11.9790
-0.2	0.1	11.2368	12.7134	3.751	-1.60	11.9751
-0.2	0.0	11.2325	12.7155	3.767	-1.18	11.9740
-0.2	-0.1	11.2355	12.7134	3.754	-1.52	11.9745
-0.2	-0.2	11.2449	12.7094	3.720	-2.41	11.9772

Cell Block # 3 [Loop 3]

15 cm Target Warm Length at 25 psig

x(in)	z(in)	Upstream Window y(in)	Downstream Window y(in)	Target Length (cm)	% Diff from x=z=0	Center of Target (in)
0.2	0.2	9.0765	14.9558	14.933	-0.63	12.0162
0.2	0.1	9.0662	14.9592	14.968	-0.40	12.0127
0.2	0.0	9.0630	14.9599	14.978	-0.33	12.0115
0.2	-0.1	9.0663	14.9582	14.965	-0.42	12.0123
0.2	-0.2	9.0751	14.9540	14.932	-0.64	12.0101
0.1	-0.2	9.0635	14.9579	14.972	-0.37	12.0107
0.1	-0.1	9.0555	14.9624	15.004	-0.16	12.0090
0.1	0.0	9.0528	14.9644	15.015	-0.09	12.0086
0.1	0.1	9.0559	14.9636	15.006	-0.15	12.0098
0.1	0.2	9.0659	14.9601	14.971	-0.38	12.0130
0.0	0.2	9.0626	14.9620	14.984	-0.29	12.0123
0.0	0.1	9.0526	14.9652	15.018	-0.07	12.0089
0.0	0.0	9.0492	14.9659	15.028	00.00	12.0078
0.0	-0.1	9.0501	14.9638	15.021	-0.05	12.0070
0.0	-0.2	9.0614	14.9594	14.981	-0.31	12.0104
-0.1	-0.2	9.0664	14.9581	14.965	-0.42	12.0123
-0.1	-0.1	9.0541	14.9627	15.008	-0.13	12.0084
-0.1	0.0	9.0521	14.9648	15.018	-0.07	12.0085
-0.1	0.1	9.0562	14.9641	15.006	-0.15	12.0102
-0.1	0.2	9.0661	14.9609	14.973	-0.37	12.0135
-0.2	0.2	9.0770	14.9569	14.935	-0.62	12.0170
-0.2	0.1	9.0668	14.9603	14.969	-0.39	12.0136
-0.2	0.0	9.0614	14.9610	14.985	-0.29	12.0112
-0.2	-0.1	9.0667	14.9588	14.966	-0.41	12.0128
-0.2	-0.2	9.0769	14.9540	14.928	-0.67	12.0155

Cell Block # 3 [Loop 3]

4 cm Target Warm Length at 25 psig

x(in)	z(in)	Upstream Window y(in)	Downstream Window y(in)	Target Length (cm)	% Diff from x=z=0	Center of Target (in)
0.2	0.2	11.2448	12.7872	3.918	-1.14	12.0160
0.2	0.1	11.2351	12.7712	3.902	-1.54	12.0032
0.2	0.0	11.2320	12.7728	3.914	-1.24	12.0024
0.2	-0.1	11.2356	12.7710	3.900	-1.59	12.0033
0.2	-0.2	11.2459	12.7665	3.862	-2.55	12.0062
0.1	-0.2	11.2357	12.7713	3.900	-1.59	12.0035
0.1	-0.1	11.2255	12.7757	3.938	-0.63	12.0006
0.1	0.0	11.2218	12.7772	3.951	-0.30	11.9995
0.1	0.1	11.2248	12.7758	3.940	-0.58	12.0003
0.1	0.2	11.2345	12.7715	3.904	-1.49	12.0030
0.0	0.2	11.2314	12.7731	3.916	-1.19	12.0023
0.0	0.1	11.2215	12.7774	3.952	-0.28	11.9995
0.0	0.0	11.2185	12.7789	3.963	00.00	11.9987
0.0	-0.1	11.2221	12.7774	3.950	-0.33	11.9998
0.0	-0.2	11.2328	12.7730	3.912	-1.29	12.0029
-0.1	-0.2	11.2360	12.7720	3.901	-1.56	12.0040
-0.1	-0.1	11.2255	12.7761	3.939	-0.61	12.0008
-0.1	0.0	11.2218	12.7776	3.952	-0.28	11.9997
-0.1	0.1	11.2250	12.7762	3.940	-0.58	12.0006
-0.1	0.2	11.2350	12.7719	3.904	-1.49	12.0035
-0.2	0.2	11.2457	12.7677	3.866	-2.45	12.0067
-0.2	0.1	11.2354	12.7719	3.903	-1.51	12.0037
-0.2	0.0	11.2323	12.7736	3.915	-1.21	12.0030
-0.2	-0.1	11.2359	12.7722	3.902	-1.54	12.0041
-0.2	-0.2	11.2465	12.7682	3.865	-2.47	12.0074

Cell Block # 4 [Spare]

15 cm Target Warm Length at 25 psig

x(in)	z(in)	Upstream Window y(in)	Downstream Window y(in)	Target Length (cm)	% Diff from x=z=0	Center of Target (in)
0.2	0.2	9.0791	14.9479	14.907	-0.63	12.0135
0.2	0.1	9.0689	14.9519	14.943	-0.39	12.0104
0.2	0.0	9.0652	14.9535	14.956	-0.31	12.0094
0.2	-0.1	9.0678	14.9524	14.947	-0.37	12.0101
0.2	-0.2	9.0778	14.9487	14.912	-0.60	12.0133
0.1	-0.2	9.0681	14.9527	14.947	-0.37	12.0104
0.1	-0.1	9.0586	14.9565	14.981	-0.14	12.0076
0.1	0.0	9.0554	14.9577	14.992	-0.07	12.0066
0.1	0.1	9.0590	14.9561	14.979	-0.15	12.0076
0.1	0.2	9.0695	14.9518	14.941	-0.41	12.0107
0.0	0.2	9.0662	14.9533	14.953	-0.33	12.0098
0.0	0.1	9.0560	14.9574	14.990	-0.08	12.0067
0.0	0.0	9.0524	14.9588	15.002	00.00	12.0056
0.0	-0.1	9.0554	14.9577	14.992	-0.07	12.0066
0.0	-0.2	9.0651	14.9540	14.958	-0.29	12.0096
-0.1	-0.2	9.0686	14.9525	14.945	-0.38	12.0106
-0.1	-0.1	9.0590	14.9561	14.979	-0.15	12.0076
-0.1	0.0	9.0559	14.9573	14.990	-0.08	12.0066
-0.1	0.1	9.0595	14.9557	14.976	-0.17	12.0076
-0.1	0.2	9.0699	14.9518	14.940	-0.41	12.0109
-0.2	0.2	9.0803	14.9475	14.903	-0.66	12.0139
-0.2	0.1	9.0698	14.9514	14.939	-0.42	12.0106
-0.2	0.0	9.0663	14.9530	14.952	-0.33	12.0097
-0.2	-0.1	9.0693	14.9518	14.942	-0.40	12.0106
-0.2	-0.2	9.0790	14.9483	14.908	-0.63	12.0137

Cell Block # 4 [Spare]

4 cm Target Warm Length at 25 psig

x(in)	z(in)	Upstream Window y(in)	Downstream Window y(in)	Target Length (cm)	% Diff from x=z=0	Center of Target (in)
0.2	0.2	11.2546	12.7304	3.749	-2.60	11.9925
0.2	0.1	11.2442	12.7344	3.785	-1.66	11.9893
0.2	0.0	11.2411	12.7360	3.797	-1.35	11.9886
0.2	-0.1	11.2442	12.7352	3.787	-1.61	11.9897
0.2	-0.2	11.2537	12.7316	3.754	-2.47	11.9927
0.1	-0.2	11.2432	12.7360	3.792	-1.48	11.9896
0.1	-0.1	11.2338	12.7392	3.824	-0.65	11.9865
0.1	0.0	11.2307	12.7400	3.834	-0.39	11.9854
0.1	0.1	11.2338	12.7385	3.822	-0.70	11.9862
0.1	0.2	11.2438	12.7341	3.785	-1.66	11.9890
0.0	0.2	11.2398	12.7357	3.800	-1.27	11.9878
0.0	0.1	11.2299	12.7401	3.836	-0.34	11.9850
0.0	0.0	11.2266	12.7418	3.849	00.00	11.9842
0.0	-0.1	11.2288	12.7411	3.839	-0.26	11.9855
0.0	-0.2	11.2392	12.7378	3.806	-1.12	11.9885
-0.1	-0.2	11.2421	12.7373	3.798	-1.33	11.9897
-0.1	-0.1	11.2325	12.7404	3.830	-0.49	11.9865
-0.1	0.0	11.2292	12.7410	3.840	-0.23	11.9851
-0.1	0.1	11.2326	12.7390	3.826	-0.60	11.9858
-0.1	0.2	11.2425	12.7347	3.790	-1.53	11.9886
-0.2	0.2	11.2517	12.7312	3.758	-2.36	11.9915
-0.2	0.1	11.2409	12.7356	3.797	-1.35	11.9883
-0.2	0.0	11.2381	12.7377	3.809	-1.04	11.9879
-0.2	-0.1	11.2416	12.7371	3.799	-1.30	11.9894
-0.2	-0.2	11.2515	12.7338	3.765	-2.18	11.9927

A.2 Final Survey Summary

Oct. 5/97

Target	Encoder
L1 15cm	6870747
L1 4cm	6158344
L2 15cm	5348541
L2 4cm	4636138
L3 15cm	3826334
L3 4cm	3113931
Dummy 10cm	2586417
Dummy 10cm	2197834
Dummy 4cm	1809251
Raster 2mm	1048449
Raster Center	1011324
Raster 1mm	979299
12C	752269
Al	493213
BeO	234157
Empty	-24898
Home	-46820

Notes:

- The beam will pass 2.141 mm below the center of Empty target when the target lifter is in HOME position

- The survey results correction is: # move cryo cells up by 0.38 mm
  # move solid target down by 0.30 mm
  [compared with the initial survey, 1 mm = 10240]

- The vacuum correction is to move the whole target up by 20500 encoder

- The cold contraction correction is to move the top of the solid target ladder down by 44000. Thus, each target must be moved down by 44000 + 0.4% * (encoder of top solid target ladder - target encoder)

A.3 Miscellaneous

- The experiment E91026 requires a 15 cm deuterium target with a collimator to collimate the cell block and the downstream window for the backward angle (144.5°) measurement of the magnetic form factor of the deuteron, $B(Q^2)$. Loop 1 was modified for this purpose and was used as deuterium target form Oct 11 to Oct 27, 1997. The collimator reduced the 15 cm target to 9.3014 cm (3.0656 cm upstream and 6.2358 cm downstream). The details of the collimator can be found in the drawing # 65630-D-54010-50. During the whole experiment period loop 2 was filled with hydrogen and from Oct 27 till the end of the experiment loop 3 was filled with deuterium.

- The exit window on the scattering chamber was covered with 16 mil Al sheet (alloy = 5052-H34, density = 2.68 g/cm^3).

- Each beer can was rapped with four layers of super isolation. Each layer consisted of one sheet of Al (thickness = 0.25 mil) and three sheets of fiber glass (thickness = 1.0 mil each).

- In Feb 1998, the scattering chamber was opened. A visual survey of the beam spot on the downstream windows showed a systematic offset of the beam vertical position on all the cells. The beam was hitting the cells at around 2 to 3 mm below the center of the downstream window. The beam spot was centered horizontally.

- Soild targets thickness and material:

Target	C	Al	BeO
Thickness	40.0±0.1 mil	40.0±0.5 mil	20.0±0.5 mil
Dimensions	1.00×0.75 in	1.00×0.75 in	1.00×0.75 in
Density	223.20±0.14 mg/cm^2	2.71 g/cm^3	—