Survey Results for the BigBite Spectrometer

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This document contains the results from surveys taken for the BigBite spectrometer during the G_E^n experiment. Results pertain to the two surveys taken immediately before and after the experiment began. The raw survey information is taken from the survey group and interpreted into the frame of interest. Small corrections are then made against tracking.

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In this document we refer to the first survey as A1041 (Appendix B), taken at the beginning of the experiment and the second survey as A1067 (Appendix C), taken at the end of the experiment.

The change between the two settings occured between the first and second kinematic points beginning on March 9, 2006. This shift can be taken to occur between runs 2782 and 2783.

1 Coordinate Systems

There are three coordinate systems of interest:

LAB Coordinates - Hall coordinate system where y goes against gravity, z is in the direction of the beam, and x is to the left when looking down the beam

Target Coordinates - Origin at the center of the target. x goes with gravity, z is parallel to the ground in the direction towards the center of the BigBite drift chambers. y is to the left looking down z

Detector Coordinates - Origin specified by center of the first plane of the drift chambers. x is "down" in the dispersion direction, z is in the nominal direction of particles such that z = 0 is defined by the first plane of the chamber. y is defined so we have a right handed coordinate system.

Plane Coordinates - One dimensional coordinate system where the origin is specified by nominal center of the plane and axis runs perpendicular to wires. Positive goes with increasing wire number (generally "with" $x_{detector}$).

2 Survey to Database

What is recorded in the survey are the positions of the centers and corners of all three chambers in the Hall coordinate system. For the beginning of the experiment, we also have the position of the front face of the BigBite magnet.

The method used is to translate the information from the surveys (given in LAB coordinates) into the coordinate systems of interest. This was done by specifying rotations such that the rotations would place the chambers into their nominal positions, namely the vector normal to each of the planes running parallel with the $z_{detector}$ axis. Normal vectors of the planes are determined by crossproducts of the vector from the chamber center to two adjacent corners. Survey results were deemed in agreement by measurements performed independently by Eugene Chudakov (see Appendix D).

Once the planes were oriented properly, the center of the chambers are translated such that the center of chamber 1 represents the origin in the detector coordinate system. At this point, further, minor, adjustments to the planes are done by looking at track residuals and a reconstructed carbon foil target. These adjustments correct for the last two chamber origins shifted off the $z_{detector}$ axis.

Further adjustments are a possibility. As of the writing of this document, there are no corrections made to the chambers not lying in parallel planes nor have corrections been added to account for rotations about the $z_{detector}$ axis (roll).

3 Coplanarity of Chamber Corners

Since all 4 corners of the chambers were given, there is a choice of four different normal vectors. If all four corners are coplanar, all choices are equivalent, though this must be verified. To do this, we considered the arc cosine of the dot product between the four resulting unit normal vectors for each chamber.

As shown in tables 1 and 2 these are in good agreement with each other, as all the corners are within a milliradian agreement.

Chamber 1 (mrad)				
	Top	Right	Bottom	Left
Top	—	0.000	0.050	0.050
Right	0.000	—	0.050	0.050
Bottom	0.050	0.050	—	0.000
Left	0.050	0.050	0.000	—
Chamber 2 (mrad)				
	Top	Right	Bottom	Left
Top	—	0.136	0.099	0.117
Right	0.136	—	0.117	0.234
Bottom	0.099	0.117	—	0.136
Left	0.117	0.234	0.136	—
Chamber 3 (mrad)				
	Top	Right	Bottom	Left
Top	—	0.005	0.043	0.046
Right	0.005	—	0.046	0.049
Bottom	0.043	0.046	—	0.005
Left	0.046	0.049	0.005	—

Table 1: Angular difference between cross products generated by adjacent corners for first survey.

4 Determination of Rotations

Our goal is to now determine the central angle and pitch of the chambers. These two angles contain identical information to the two polar angles necessary to describe the orientation of the chambers in space.

Chamber 1 (mrad)				
	Top	Right	Bottom	Left
Top	—	0.079	0.177	0.115
Right	0.079	—	0.115	0.086
Bottom	0.177	0.115	—	0.079
Left	0.115	0.086	0.079	—

Chamber 2 (mrad)				
	Top	Right	Bottom	Left
Top	—	0.033	0.077	0.050
Right	0.033	—	0.050	0.035
Bottom	0.077	0.050	—	0.033
Left	0.050	0.035	0.033	—

Chamber 3 (mrad)				
	Top	Right	Bottom	Left
Top	—	0.267	0.501	0.277
Right	0.267	—	0.277	0.209
Bottom	0.501	0.277	—	0.266
Left	0.277	0.209	0.266	—

Table 2: Angular difference between cross products generated by adjacent corners for second survey.

4.1 Central Angle

The central angle was found by attempting to minimize the arc cosine of the dot product between the unit vector along the $z_{detector}$ axis and the unit chamber normal. Since we have not calculated the pitch, $-10.0°$ was assumed. The points to minimize are shown in figures 1 and 2. Results for the final angles of -56.26° and -51.59° for the first and second survey, respectively are shown in tables 5 and 6.

BigBite Central Angle: -56.26°	
Chamber	Angular Difference (mrad)
1	1.073
2	1.064
3	1.073

Table 3: Angular difference between chamber normal vectors and central ray for varying central angle from first survey. A pitch of -10.0° was assumed.

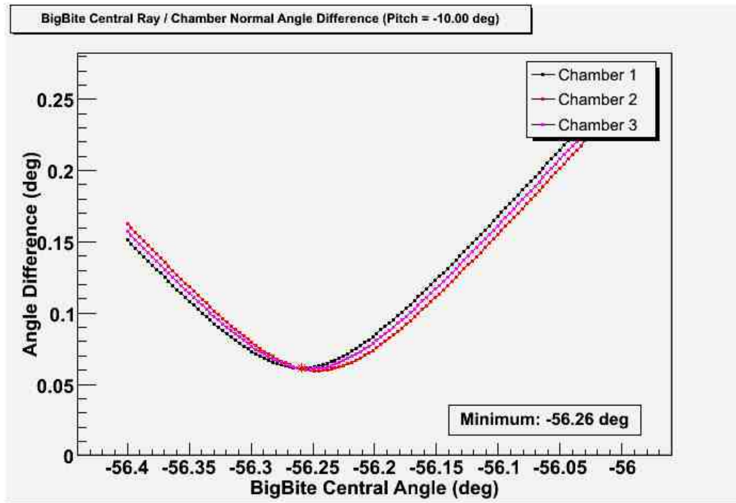

Figure 1: Angular difference for several assumed central angles for the three chambers for the first survey. The minimum of chamber 1 is taken as the true central angle.

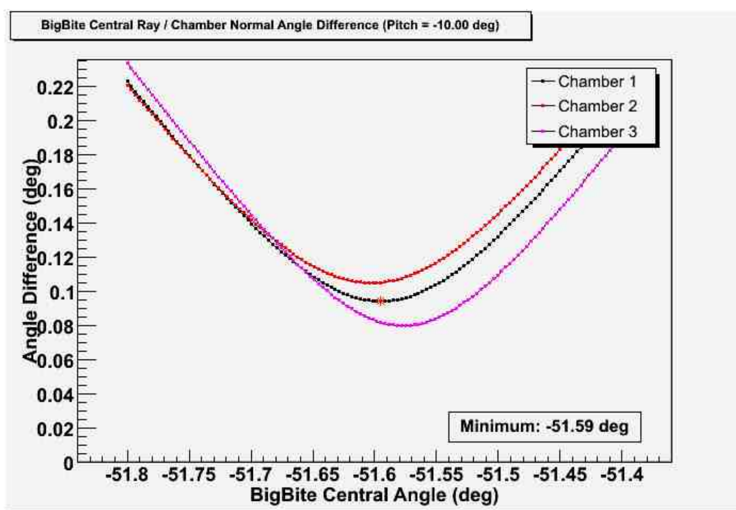

Figure 2: Angular difference for several assumed central angles for the three chambers for the second survey. The minimum of chamber 1 is taken as the true central angle.

BigBite Central Angle: -51.59°	
Chamber	Angular Difference (mrad)
1	1.649
2	1.840
3	1.432

Table 4: Angular difference between chamber normal vectors and central ray for varying central angle from second survey. A pitch of -10.0° was assumed.

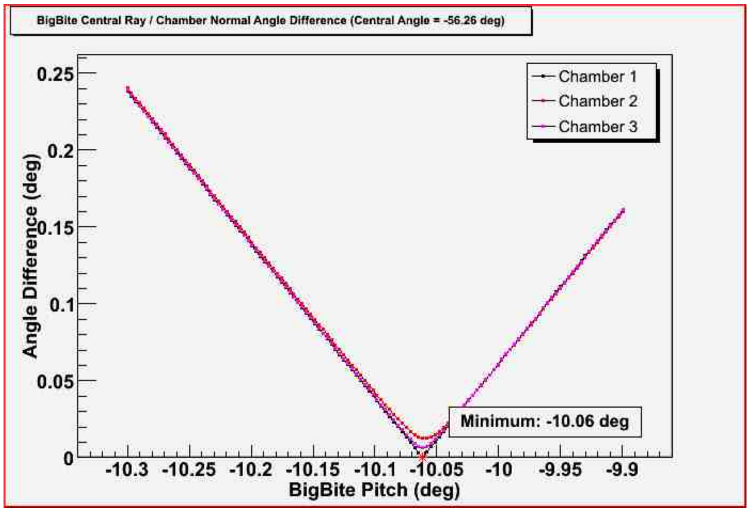

Figure 3: Angular difference for several pitches for the three chambers for the first survey. The minimum of chamber 1 is taken as the true pitch.

4.2 Pitch

Using the central angle found, we then adjust the pitch to once again minimize the arc cosine of the dot product between the unit vector along the $z_{detector}$ axis and the unit chamber normal.

BigBite Pitch: -10.06°	
Chamber	Angular Difference (mrad)
1	0.007
2	0.222
3	0.112

Table 5: Angular difference between chamber normal vectors and central ray for varying pitch from first survey. A central angle of -56.26° was used.

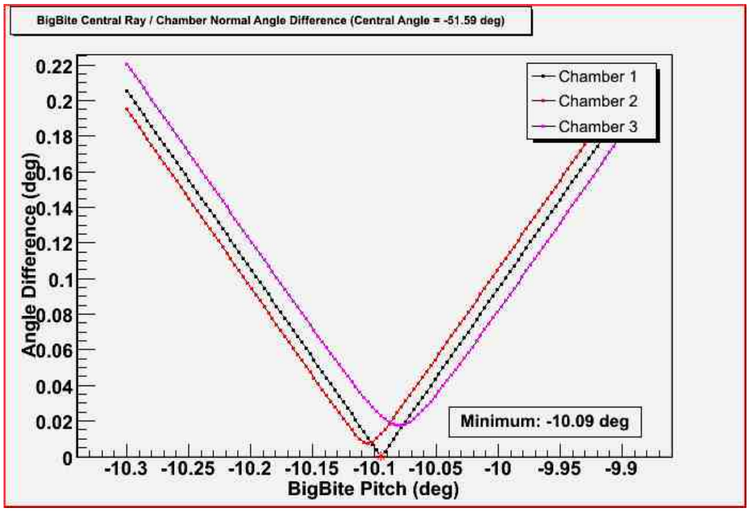

Figure 4: Angular difference for several pitches for the three chambers for the second survey. The minimum of chamber 1 is taken as the true pitch.

BigBite Pitch: -10.09°	
Chamber	Angular Difference (mrad)
1	0.009
2	0.223
3	0.404

Table 6: Angular difference between chamber normal vectors and central ray for varying pitch from second survey. A central angle of -51.59° was used.

4.3 Individual Chamber Rotations (Roll)

The roll of each chamber is determined by by interpolating a central point on each side of the chamber. Since we have four sides to consider on each, we can measure four separate values. These were done by translating the four corners for each chamber, averaging adjacent corner vectors, and looking at the deviation of the azimuthal angle ϕ from an ideal orientation. Results are in tables 7 and 8. The corrections do not appear to be large for chambers 1 and 2. Corrections may be considered for chamber 3.

These numbers have not been entered into the database nor have they been verified against data.

5 Determination of Translations

Translations were done by the choosing the proper translation such that the $z_{detector}$ axis coincides with the center of the first chamber. Results are in table 9 and 10.

Chamber	Top	Left	Bottom	Right	Average
1	0.039	0.049	0.042	0.041	0.043
2	-0.050	-0.050	-0.050	-0.047	-0.049
3	-0.162	-0.139	-0.163	-0.150	-0.153

Table 7: Necessary angular adjustments to wire orientation from first survey. Units are degrees

Chamber	Top	Left	Bottom	Right	Average
1	0.040	0.043	0.041	0.046	0.042
2	-0.064	-0.064	-0.064	-0.064	-0.064
3	-0.18	-0.196	-0.181	-0.197	-0.189

Table 8: Necessary angular adjustments to wire orientation from second survey. Units are degrees

	X (m)	Y (m)	Z (m)
Detector Offset	0.0046	-0.1672	2.2547
Chamber 1 Center	0.0000	0.0000	0.0000
Chamber 2 Center	0.0086	0.0002	0.3587
Chamber 3 Center	0.0008	-0.0020	0.7050

Table 9: Detector offset in target coordinate system and chamber centers in detector coordinates from first survey.

	X (m)	Y (m)	Z (m)
Detector Offset	0.0078	-0.1687	2.2532
Chamber 1 Center	0.0000	0.0000	0.0000
Chamber 2 Center	0.0093	0.0003	0.3588
Chamber 3 Center	0.0023	-0.0018	0.7055

Table 10: Detector offset in target coordinate system and chamber centers in detector coordinates from second survey.

6 Adjustments by Tracking

Adjustments to positions of the second and third chamber were done by making adjustments such that residuals became centered. These corrections were produced by hand. A list of plane $z_{detector}$ and first wire positions in the plane coordinate system can be found in table 11. The residuals for all planes can be seen in figure 5.

Corrections can be made to the z_{target} origin using carbon foils data by adjusting z_{target} such that the center foil reconstructs to $z_{LAB} = 0$. This has been done for the final kinematics and was determined to be $z_{target} = 0.005$m. This remains to be calculated for the remaining kinematics. The carbon foils are shown in figure 6.

Chamber	Plane	x_1 Position (m)	$z_{detector}$ (m)
1	U1	-0.7025	0.0000
1	U2	-0.6975	0.0064
1	X1	-0.7025	0.0128
1	X2	-0.7075	0.0224
1	V1	-0.7025	0.0288
1	V2	-0.6975	0.0352
2	U3	-0.9927	0.3598
2	X3	-0.9975	0.3662
2	V3	-0.9939	0.3825
3	U4	-1.0023	0.7444
3	U5	-0.9973	0.7385
3	X4	-1.0136	0.7316
3	X5	-1.0085	0.7178
3	V4	-1.0031	0.7109
3	V5	-0.9981	0.7050

Table 11: A list of plane z positions and starting wire positions

7 Magnet Center

The center of the BigBite magnet was measured once at the beginning of the experiment (Appendix A). As we have now calculated the central angle of the spectrometer at this time, we can determine the center of the magnet in the target reference frame. We are only interested in the z_{target} position for the effective bend plane model we use. This was determined to be 1.415m. From the front face to the magnetic midplane along the median line was taken to be 0.325m (figure 7).

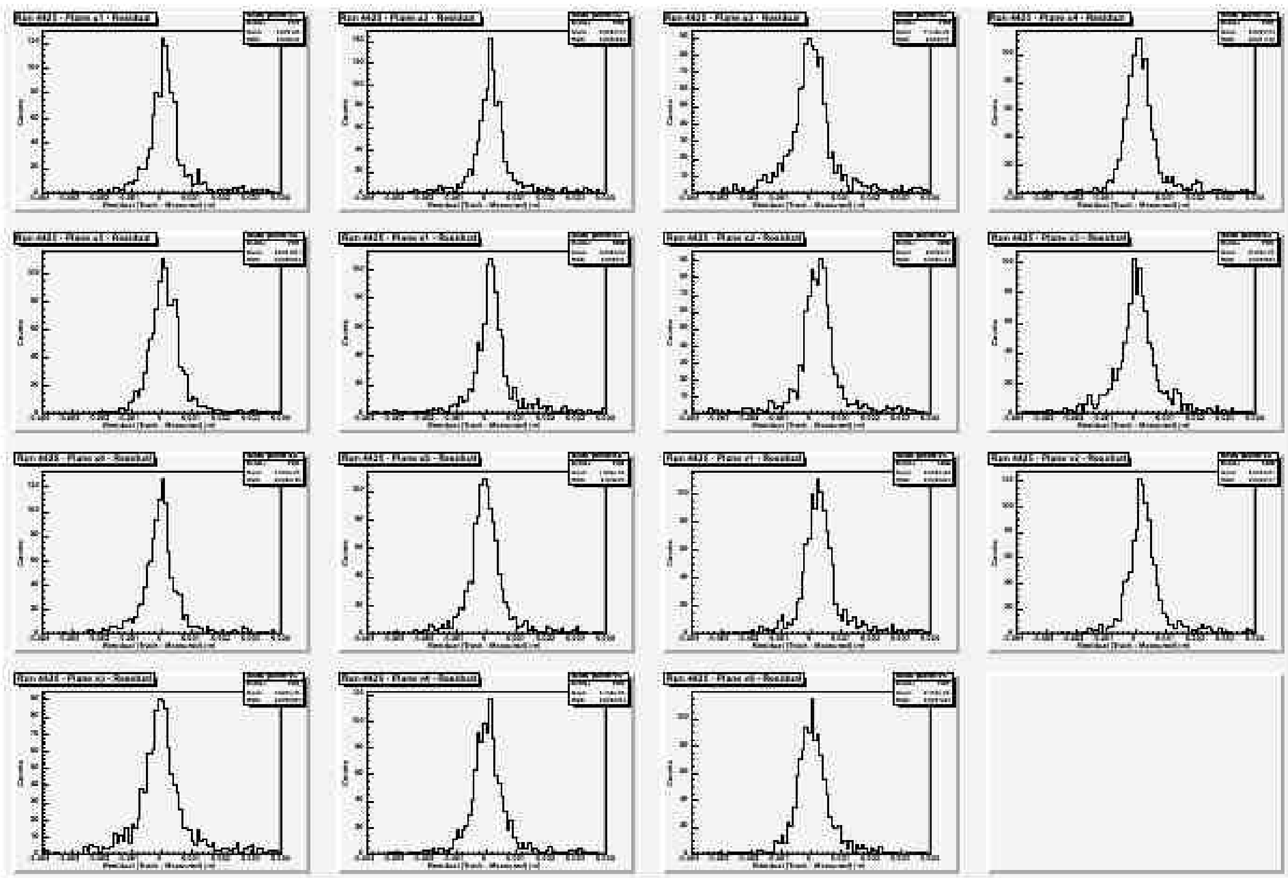

Figure 5: Tracking residuals for all planes

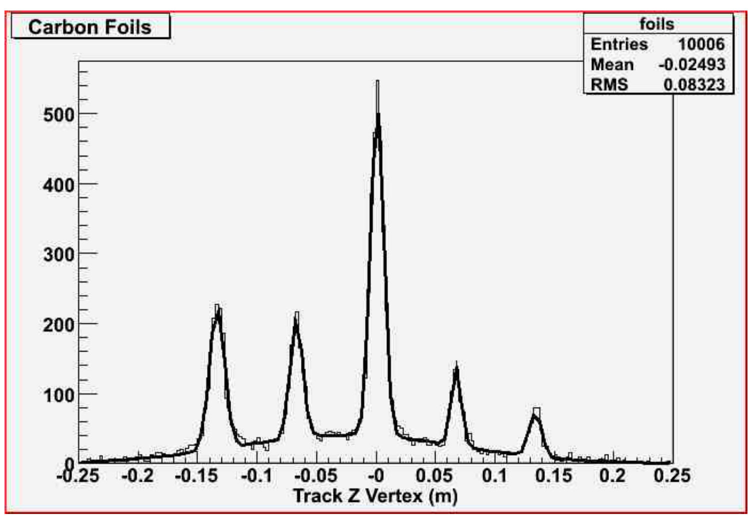

Figure 6: Reconstructed carbon foil target.

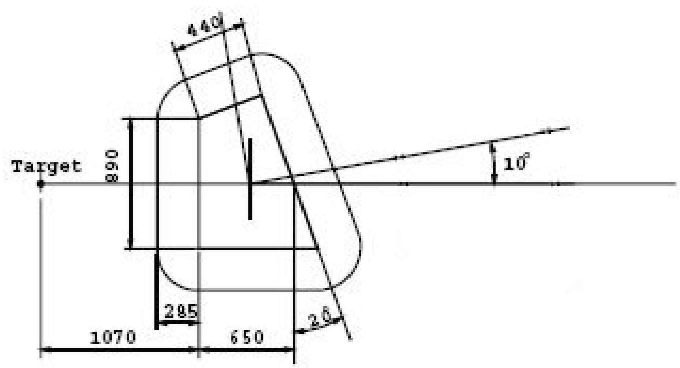

Figure 7: BigBite magnet

A Survey Report A1039r - BigBite and Magnet

Jefferson Lab Alignment Group

Data Transmittal

TO: E. Chudakov. B. Wojtsekhowski, E. Folts, J. LeRose		**DATE:** 08 Feb 2006
FROM: Kelly Tremblay	**Checked:**	**# :** A1039r

DETAILS: Data: m:\algin\data\step2b\halla\bigbite\060207a

The Hall A Gen 2 experiment Big Bite magnet and detector assemblies were surveyed February 7th, 2006. The assembly was located at the ideal angle of 56.5° clockwise looking downstream from the standard Hall A target. The magnet origin is located 1.1 meters from the hall target and is the front face of the steel core. The origin for the detector is the front face of the assembly. The coordinate system shown is in millimeters with the hall A target center being the origin, +z being the downstream along the main beamline, +x being transverse beam left and +y being up. The angular results are in degrees, with the +yaw being clockwise about the y axis, +pitch is positive counter clockwise about the x axis and +roll is clockwise about the z axis.

	Ideal			Found			Deltas bfs		
	Z	X	Y	z	x	y	dz	dx	dy
Magnet	607.1	-917.3	0.0	594.5	-913.5	-0.3	-10.1	-8.4	-0.3
Detector	1252.8	-1892.8	151.6	1255.6	-1872.6	164.8	-15.3	13.5	13.2
	Ideal Angles			Found Angles			Delta Angles		
	Yaw	Pitch	Roll	Yaw	Pitch	Roll	dYaw	dPitch	dRoll
Magnet	56.50	0.00	0.00	56.26	-0.35	0.06	-0.24	-0.35	0.06
Detector	56.50	10.00	0.00	56.21	10.05	-0.09	-0.29	0.05	-0.09

B Survey Report A1041 - BigBite Drift Chambers

Jefferson Lab Alignment Group

Data Transmittal

TO: Eugene Chudakov. Bogdan Wojtsekhowski. John LeRose	**DATE:** 22 Feb 2006
FROM: Chris Curtis	**Checked:**
	# : A1041

DETAILS: Data: m:\algin\data\step2b\halla\bigbite\060214a

Given below are the results of the Big Bite detector survey carried out on February 14th, 2006. The center of each of the three chambers is shown, together with the four corners of each detector plane. This information is derived from the as found location survey of the external fiducials (Feb 14th), and the fiducialization survey carried out after the planes were shimmed on December 22nd. Some distortion of the external fiducials was apparent between these two surveys. The coordinates are in millimeters, with the Hall A target as origin, +z being downstream along the main beamline, +x being transverse beam left, and +y being up with respect to gravity (not pitched).

	Z	X	Y
Ch1 Center	1256.2	-1872.4	167.1
Ch1 Bot L	1682.0	-1776.7	-717.4
Ch1 Top L	1506.5	-1516.4	1052.2
Ch1 Bot R	1005.9	-2228.4	-718.0
Ch1 Top R	830.5	-1968.1	1051.5
Ch2 Center	1453.4	-2167.2	221.3
Ch2 Bot L	1989.4	-2063.2	-970.0
Ch2 Top L	1756.6	-1710.7	1411.8
Ch2 Bot R	1150.4	-2623.7	-969.1
Ch2 Top R	917.3	-2271.4	1412.6
Ch3 Center	1640.2	-2450.9	289.5
Ch3 Bot L	2174.7	-2348.2	-902.9
Ch3 Top L	1945.5	-1993.1	1479.3
Ch3 Bot R	1334.8	-2908.9	-900.9
Ch3 Top R	1105.8	-2553.5	1482.3

C Survey Report A1067 - BigBite Drift Chambers

Jefferson Lab Alignment Group

Data Transmittal

TO: Eugene Chudakov, Bogdan Wojtsekhowski, John LeRose		**DATE:** 07 Jul 2006
FROM: James Dahlberg	**Checked:**	**# :** A1067

DETAILS: Data: m:\algin\data\step2b\halla\gen\060516a

Note: The previous data transmittal #A1061 was incorrectly referenced to the May 10th survey and is actually for the May 16th survey. A revised DT for #A1061 will be published.

Given below are the results of the Big Bite detector survey carried out on May 10th, 2006. The center of each of the three chambers is shown, together with the four corners of each detector plane. This information is derived from the as found location survey of the external fiducials (May 10th), and the fiducialization survey carried out after the detector was shifted from the running position on May 16th. The coordinates are in millimeters, with the Hall A target as origin, +z being downstream along the main beam line, +x being transverse beam left, and +y being up with respect to gravity (not pitched).

	Z	X	Y
Ch1 center	1405.89	-1760.85	168.66
Ch1 topbr	988.98	-1890.52	1053.03
Ch1 topbl	1626.12	-1385.20	1053.73
Ch1 botbr	1185.66	-2136.42	-716.39
Ch1 botbl	1822.82	-1631.27	-715.75
Ch2 center	1626.60	-2038.74	222.40
Ch2 topbr	1100.28	-2185.05	1413.64
Ch2 topbl	1891.38	-1558.27	1412.66
Ch2 botbr	1361.80	-2519.17	-967.79
Ch2 botbl	2152.94	-1892.49	-968.91
Ch3 center	1836.25	-2306.59	290.00
Ch3 topbr	1312.07	-2451.56	1483.09
Ch3 topbl	2103.32	-1825.05	1479.51
Ch3 botbr	1569.20	-2788.47	-899.66
Ch3 botbl	2360.41	-2161.27	-902.95

D Measurments by Eugene Chudakov

http://hallaweb.jlab.org/experiment/E02-013/surveys.html
August 18, 2006

Additional BB Measurements

Knowing the BB detector angle with an accuracy of about 1 mrad is important for the experiment. Therefore, additionally to the surveys performed by the survey group, simple independent measurements of the detector angle were made. These mesurements utilized the angle marks on the floor of the hall. The marks, made by the survey group, are normally used for positioning the HRS (spectrometers). They are located on two arcs with radii of about 10 m and 16 m. The accuracy of a mark is about 1 mm. The angle Θ (around Y) of a line drawn through two marks, indicating the same angle, is known to an accuracy of about 1mm/6m = 0.2 mrad. We selected such a line, close to the center of the BB position, and marked a parallel line, at a distance of 43 inches = 1092.2 mm. Then, we measured the distance to the chambers aluminum frames from this line. Knowing the frames' widths (32 inches for DC1 and 39.75 inches for DC2-3) we can find out what is the Θ angle of a line drawn through the chambers centers. The procedure is illustrated on this picture.

Our BB detector measurements

The coordinate system is the MRS, turned around Y, that Z axis looks along the BB axis. The angle of the detector is the angle between the projection of a line crossing the chamber centers, at a certain Y_{BB} (this is the coordinate along the chambers, in the dispersive plane, looking up), on the floor, and the median line on the floor. The median line is drawn at the assumed BB angle. ΔX is the measured distance from the median line to the detector center (positive, when the center is closer to the beam dump). ΔX does not take into account the tilt of the line of sight with respect to the median line $\Delta\Theta$ (see below). $\Delta\Theta$ is the derived detector angle with respect to the median line (positive if it goes away from the beam). The 'side' indicates from which side of BB, looking along the particles, the measurement was done. The line of sight could be tilted with respect to the median line, deliberately or not. The angle is indicated by $\Delta\Theta$. Measurement #9 was done with aluminum shielding on the BB left side, while measurement #10 was done with the shielding removed.

						ΔX, mm			$\Delta\Theta$, mrad		
#	Date	Θ° median	side	Y_{BB},mm	$\Delta\Theta$ mrad	DC1	DC2	DC3	DC3-DC1	DC3-DC2	DC2-DC1
5	2006/02/23	56.5	right	-880.	0.0	13.00	13.14	1 0.58	3.88	6.26	-0.70
6	2006/02/23	56.5	right	-880.	-2.9	62.27	61.81	57.94	4.03	6.51	-0.76
7	2006/02/23	56.5	right	-880.	2.6	-35.51	-35.67	-37.11	3.58	6.13	-1.33
11	2006/02/23	56.5	right	-130.	0.0	-	12.60	11.31	-	3.14	-
8	2006/05/02	52.0	right	-880.	0.0	25.00	25.90	23.91	1.75	4.83	-4.20
9	2006/05/10	52.0	right	-880.	0.0	25.40	25.60	24.21	1.91	3.38	-0.93
10	2006/05/10	52.0	right	-880.	0.0	25.30	25.60	23.81	2.39	4.35	-1.40

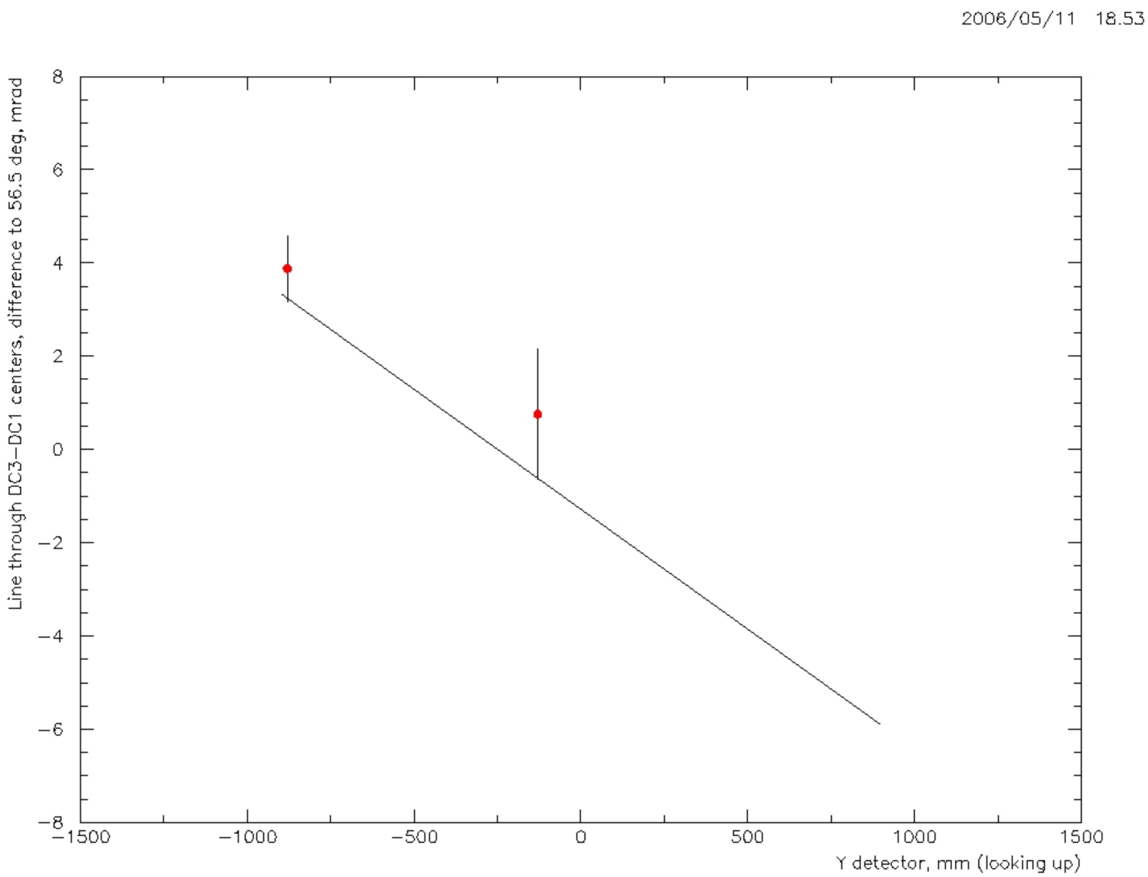

Figure 8: Survey Comparison

The standard deviation for $\Delta\Theta$ is about 0.7 mrad for DC3-DC1 and 1.4 mrad for DC3-DC2. These results are consistent with the surveyers results (figure 8). Here, we used the DC3-DC1 angle. At Y_{BB}=-880 mm we used the measurement #5. For Y_{BB}=-130 mm (measurement #11) we were not able to measure DC1. In order to convert the result to DC3-DC1 we took $\Delta\Theta$ DC3-DC1(#11) $\approx$ $\Delta\Theta$ DC3-DC1(#5) + $\Delta\Theta$DC3-DC2(#11) - $\Delta\Theta$ DC3-DC2(#5) = 0.76 mrad.