REGION ONE DRIFT CHAMBER
ANALYSIS OF SURVEY DATA

January 21, 1998
Reinhard Schumacher

CLAS-Note 98-001 (v.1)

The Jefferson Lab survey group performed measurements of the Region One Drift Chamber location inside the CLAS spectrometer on October 3, 1997, prior to the December 1997 e1 run. The raw numbers provided by this group are analyzed in this report to provide positional offsets needed in the drift chamber tracking programs. The raw data are given in Appendix I. The handwritten notes and calculations leading to the results given below are in Appendix II.

The overall accuracy of the survey group numbers seems to be very good. They claim +/- 0.4 mm in Z and +/- 0.15 mm in X and Y. Various cross checks between their results and design numbers unknown to them but known to us indicate that these estimates are on the conservative side.

Region One is supported by two dowel pins at its downstream end which slide into holes in a mating piece attached to the cryostat. At the upstream end the detector has three legs which attach to "landing pads" attached to the cryo-ring at 10, 2, and 6 o'clock. The accuracy of the downstream positioning was determined by how well the mating hole bracket was aligned and attached to the cryostat. Doug Tilles aligned this mating piece with a digital level which had an estimated precision of 1/2 degree. The accuracy of the upstream positioning was determined by how well the cryo-ring was manufactured and aligned to the torus. During installation of Region One it was noted that the cryo-ring was machined to fairly low tolerance, since we could not get the dowel pins in the three legs of Region One to slide simultaneously into their holes. The legs of Region One were made such that the position tolerances of the dowel pins was less than 10 mils, while the mismatches to the cryo-ring were of the order of 1/4". Only one of three dowel pins (the one at 10 o'clock) was inserted, and can be used in the future to ensure excellent reproducibility of the Z chamber position if and when Region One is removed and reinstalled. The upstream end of the detector was not surveyed during the installation process. The upstream positioning was done to eyeball accuracy by equalizing the small (roughly 1/2") gaps between the six sectors and the cryostat. Hence the present survey is the only accurate means of determining the X and Y positioning of the chamber package.

There are 10 fiducial points on the Region One detector package. The upstream end of Region One has four 1/2" tooling balls, mounted at 12, 3, 6, and 9 o'clock on the inner surface and flush with the downstream face of the Boss Ring. Each of the six sectors has a scribed cross on the downstream sector plates which is visible from the upstream end of the detector.

The sighted (X,Y) coordinates for each of the six downstream crosses were fitted to a circle to determine the mean rotation and offset of the downstream end of the detector. The residuals for all sectors were very small, on the order of tens of microns, and the radius of the fitted circle was in excellent agreement with the design value. Thus we have confidence that the downstream positioning is well understood. We found

X offset	0.72 +/- 0.03 mm	
Y offset	-0.29 +/- 0.03 mm	
Rotation	-7.1 +/- 0.8 millirad	(counterclockwise about Z)

where the X and Y offsets refer to the difference between the center of the fitted circle and the CLAS Z-axis which point downstream. Y points opposite to gravity and X points to beam left to form a right-handed coordinate system. The rotation, about 4/10 of a degree, is consistent with the estimated positioning accuracy of the downstream mounting bracket. (The negative value for the rotation is correct for a counterclockwise rotation, but may differ from the definition of rotation angle in the off-line analysis program.)

The upstream tooling balls were used to determine the offset and rotation of the upstream end of the detector in a manner similar to the downstream measurements. The offsets determined from both the vertical and horizontal pairs of tooling balls agreed within errors. We found

X offset	+0.58 +/- 0.1 mm	
Y offset	-1.88 +/- 0.1 mm *	
Rotation	-1.277 +/- .006 millirad	(c.c.w. about z)

The offsets and rotation are again consistent with our estimated positioning accuracy known from the installation period. The offset values basically agree with the memo sent out by Dan Carman on 11-10-97 (see Appendix II), but the number given with the (*) differs in sign. The rotations are given above for the first time.

The measured distance between pairs of tooling balls both horizontally and vertically was consistently 2.2 mm larger than the distance calculated from the Boss ring and tooling ball geometry. We do not understand the reason for this difference, but we do not have complete information about how this part of the survey was done (which part of the tooling ball was targeted, which tooling ball type was actually used, etc). This lack of knowledge was not important in extracting good results below.

Using all the survey points it was possible to estimate the offset of the entire chamber in X, Y, and Z. The design distance in Z from the origin to the downstream scribe marks was 31.000", while the design distance to the upstream tooling balls was 45.265". Using the centerline offsets given above together with these lengths led to the following offset of Region One from the nominal origin. We found

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X offset	+0.66 +/- 0.08 mm
Y offset	-0.94 +/- 0.08 mm
Z offset	-1.40 +/- 0.50 mm
Rotation about X	-0.82 +/- 0.05 mrad
Rotation about Y	+0.07 +/- 0.05 mrad
Rotation about Z	-4.2 +/- 4.1 mrad

****

The rotation about Z is given as the average of the upstream and downstream rotations. Taken on their face, the Z numbers imply a small helical twist to the detector induced by the mounting arrangement, albeit one consistent with our mounting accuracy. The rotations about X and Y are computed from the upstream and downstream centerline offset; alternate values derived using the tooling ball measurements were consistent with these, though with larger estimated uncertainties. The signs of the rotations are defined as positive for clockwise and negative for counterclockwise about their respective axes.

The X and Y offsets given above can be rotated into the sector coordinate system for each sector for the purpose of single-sector tracking. These numbers are as follows (rotation numbers from Rob Feuerbach):

Sector	"X" offset	"Y" offset	"X" rot	"Y" rot	"Z" rot
1	0.66 mm	-0.94 mm	-.82 mr	+.07	-4.2
2	-0.48	-1.04	-.47	-.68	-4.2
3	-1.14	-0.10	+.35	-.75	-4.2
4	-0.66	0.94	+.82	-.07	-4.2
5	0.48	1.04	+.47	+.68	-4.2
6	1.14	0.10	-.35	+.75	-4.2

The raw survey numbers from Appendix I can also be compared with the nominal design values for those numbers. They are (in millimeters):

	Z Survey	X Survey	Y Survey	Z Nominal	X Nominal	Y Nominal
Target	0.00	0.00	0.00			
Downstream Sector						
1	786.21	80.20	-0.92	787.4	79.375	0.000
2	786.33	40.92	68.27	787.4	39.688	68.741
3	786.07	-38.54	68.70	787.4	-39.688	68.741
4	786.23	-78.67	0.30	787.4	-79.375	0.000
5	786.35	-39.50	-68.80	787.4	-39.688	-68.471
6	786.46	39.92	-69.30	787.4	39.688	-68.471
Upstream						
12o'clock	-1152.11	1.30	576.27	-1149.73	0.00	576.00
3 o'clock	-1151.69	-510.13	-1.22	-1149.73	-508.48	0.00
6 o'clock	-1150.69	-0.17	-580.06	-1149.73	0.00	-576.00
9 o'clock	-1151.08	511.31	-2.53	-1149.73	508.48	0.00

In conclusion, the survey data for Region One are mostly consistent with known features of the detector, and internally consistent with themselves. Numbers given here should be suitable for inclusion in the RECSIS or SDA analysis packages. Each time Region One is removed and re-installed in the future, it must be re-surveyed in order to ensure that the true detector location is known.

APPENDIX I

Raw survey data as transmitted from Kelly Tremblay to Robert Feuerbach:

"The following data reports the location of the Hall B CLAS Region 1 chamber tooling balls and scribe locations relative to the the target on October 31st, 1997. The target is defined by Jefferson Lab drawing 66210-E-01738 and our groups original cryostat survey (cira 1995). The data is in millimeters with the origin at the target center, Z axis follows the beam positive towards the dump, X is in the horizontal plane, positive beam left, and Y is positive opposite to gravity. Please note that there is a slight rotation of the entire torus magnet of 4 millirads, clockwise about the Z axis.

Target	Z	X	Y
Beam Target	0.00	0.00	0.00
DownStream Scribe 1 o'clock	786.07	-38.54	68.70
DownStream Scribe 3 o'clock	786.23	-78.67	0.30
DownStream Scribe 5 o'clock	786.35	-39.50	-68.80
DownStream Scribe 7 o'clock	786.46	39.92	-69.30
DownStream Scribe 9 o'clock	786.21	80.20	-0.92
DownStream Scribe 11 o'clock	786.33	40.92	68.27
UpStream Tooling Ball 12o'clock	-1152.11	1.30	576.27
UpStream Tooling Ball 3 o'clock	-1151.69	-510.13	-1.22
UpStream Tooling Ball 6 o'clock	-1150.69	-0.17	-580.06
UpStream Tooling Ball 9 o'clock	-1151.08	511.31	-2.53

The positional accuracy of the points is approximately +/- 0.4 mm in Z, and +/- 0.15 mm in X and Y. Please contact me if you have any questions.
Kelly Tremblay"

APPENDIX II

Handwritten notes by R.A. Schumacher with the detailed calculations.

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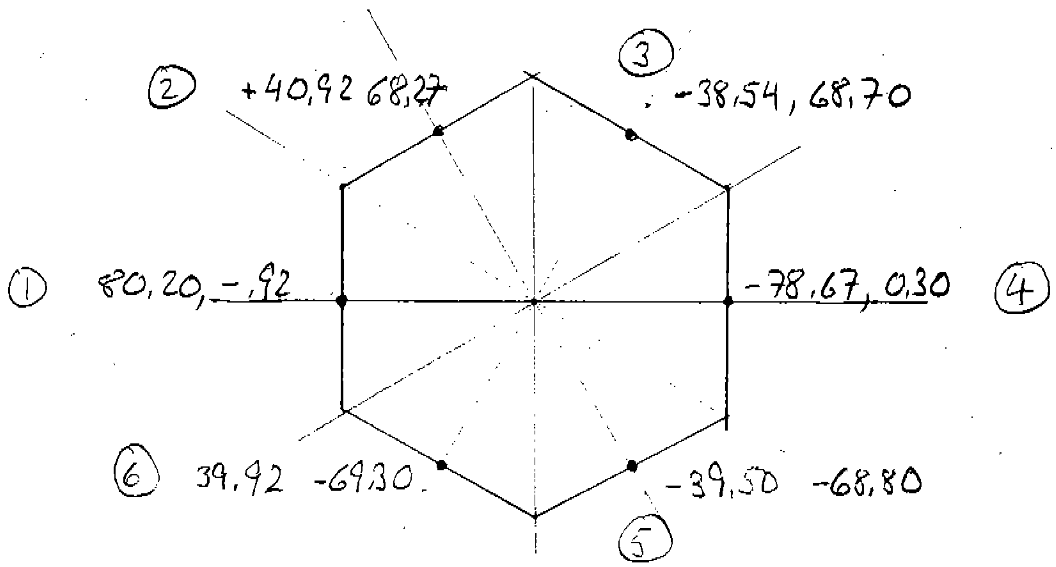
Source file: uquark.phys.cmu.edu::[schumacher.region1]survey.txt

Offset and Rotation of Downstream End of Region I.



Parameters in fit:	Radius	79,42	mm
	Angle	+7,1	mrad
	Xoffset	,72	mm
	Yoffset	-,29	mm

(See fitting program "SURVEYFIT.FOR" on uquark.)
The offsets agree with the 11-10-97 memo, and we now see that the front of the detector is rotated c.c.w. by 7,1 mrad = 0,41°.
± 0,8 mrad

x/y uncertainty ≃ ,15 / 6 = .03 mm

single meas.

number of measurements

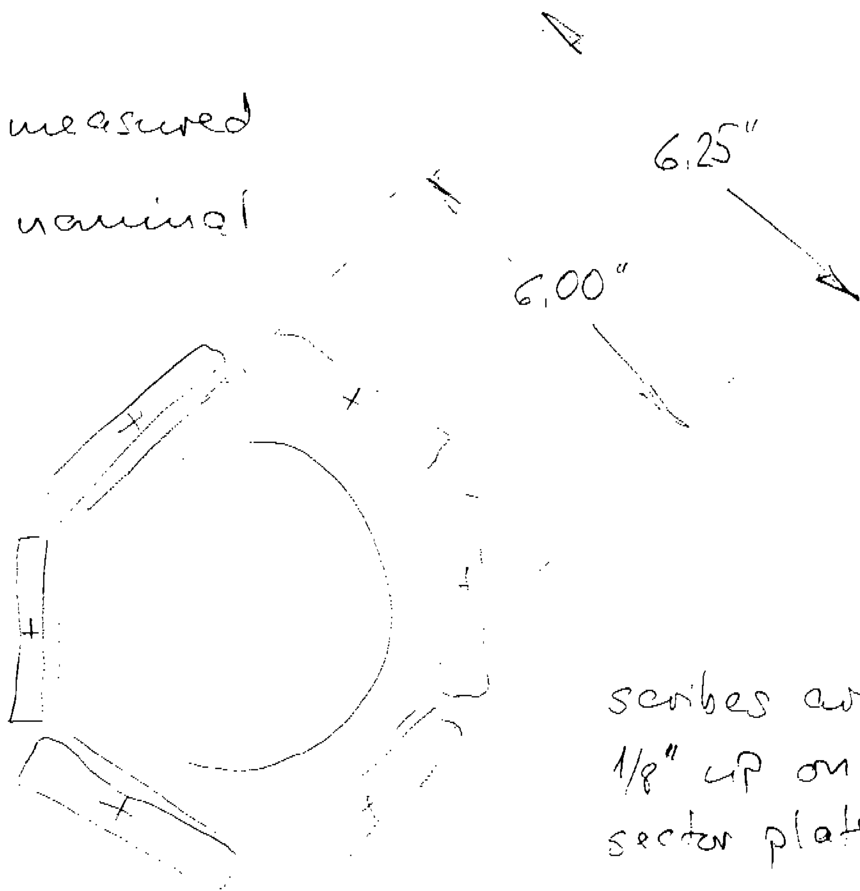
Fit to Region One Survey of Downstream Fiducials

	1	2	3	4	5	6	
X Values:	80.200	40.920	-38.540	-78.670	-39.500	39.920	survey
Y Values:	-0.920	68.270	68.700	0.300	-68.800	-69.300	

10)	79.424	7.107	0.724	-0.293	0.02378
Residuals:	Radius	Angle	X	Y	χ^2

X:	0.055	-0.003	-0.042	0.028	-0.024	-0.026
Y:	-0.063	0.064	-0.071	0.028	-0.009	0.056

$R = \begin{cases} 3.127'' & \text{- measured} \\ 3.125'' & \text{- nominal} \end{cases}$



scribes are
1/8" up on
sector plates

3.125" = 79.375 mm

```
c***************************************************************************
c       SURVEYFIT.FOR
c
c       Fit the Region One survey data for the downstream scribe
c       marks to extract the radius, angle, xoffset and yoffset.
c
c       R. A. Schumacher, 1-14-98, C.M.U.
c
        implicit real*8 (a-h),(o-z)
        logical ifirst
        real*8 xval(6),yval(6),xfit(6),yfit(6),aa(4),astep(4)
        real*8 xres(6),yres(6)
c
c       J_Lab Survey from October 31, 1997
c
        data xval/ 80.20, 40.92, -38.54, -78.67, -39.50,  39.92/
        data yval/ -0.92, 68.27,  68.70,   0.30, -68.80, -69.30/
        data astep/2.0,2.0,2.0,2.0/     !initial step sizes in fit
        data ifirst/.true./
        equivalence (aa(1),radius),(aa(2),angle),(aa(3),xoff),(aa(4),yoff)
c
        open(unit=1,name='surveyfit.txt',status='unknown')
        write(1,10)xval,yval
        write(6,10)xval,yval
10      format(1x,78('_'),/,t15,
        1 'Fit to Region One Survey of Downstream Fiducials',/,
        1 1x,78('_'),/,
        1 1x,'X Values:',6f10.3,/,1x,'Y Values:',6f10.3)
c
c       Initial guesses
c
c       radius = 79.     ! mm
c       angle  = 0.      ! radians
c       xoff   = 0.      ! mm
c       yoff   = 0.      ! mm
        radius = 79.424  ! mm
        angle  = 7.907   ! radians
        xoff   = .724    ! mm
        yoff   = -.293   ! mm
c
        sigma = 0.15     ! mm    survey group estimate
c
        dera = 3.1415926535/180.
        cos60 = .5
        cos30 = sqrt(3.)/2.
        sin60 = cos30
        sin30 = .5
c
c       Do a simple grid search over the four parameters
c
        iter   = 0              !iteration counter
        icount = 0
50      iter = iter + 1
        icount = icount + 1
        do 500 ipar = 1,4
        chi2old = 1000.
c
c       Assume the rotation is internal to the chamber, and that
c       the offsets in X and Y apply to the rotated chamber.
c
70      xfit(1) =  radius
        xfit(2) =  radius * cos60
        xfit(3) = -radius * cos60
        xfit(4) = -radius
        xfit(5) =  xfit(3)
        xfit(6) =  xfit(2)
        yfit(1) =  0
        yfit(2) =  radius * sin60
        yfit(3) =  yfit(2)
        yfit(4) =  yfit(1)
        yfit(5) = -radius * sin60
        yfit(6) =  yfit(5)
        do 100 i=1,6
        xtemp = xfit(i)
        ytemp = yfit(i)
        theta = angle/1000.     !theta is in radians, angle in millirad
```



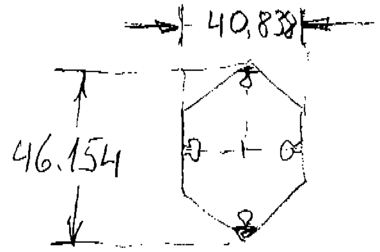
```
        ct = cos(theta)
        st = sin(theta)
        xfit(i) = xtemp * ct + ytemp * st
        yfit(i) = ytemp * ct - xtemp * st
        xfit(i) = xfit(i) + xoff
        yfit(i) = yfit(i) + yoff
100     continue
c
        chi2 = 0.0
        do 120 i = 1,6
        xres(i) = xval(i) - xfit(i)
        yres(i) = yval(i) - yfit(i)
        chi2 = chi2 + (xres(i)*xres(i) + yres(i)*yres(i))/(sigma*sigma)
120     continue
c       chi2 = chi2 / 8.        !12-4=8 is the number of degrees of freedom
        if(ifirst)then
                write(6,510)iter,aa,chi2
                ifirst=.false.
        end if
        delchi2 = chi2 - chi2old
        if(abs(delchi2).lt.0.0001)goto 500      !step next parameter
        if(delchi2.gt.0)then                    !take another step
                astep(ipar) = -astep(ipar)*0.9
        end if
        aa(ipar) = aa(ipar) + astep(ipar)
        chi2old  = chi2
c       write(6,130)ipar,aa,chi2
c130    format(1x,i3,5f10.3)
        goto 70
c
500     continue
c       if(icount.lt.10)then
        if(icount.lt.1)then
                goto 50
        else
                icount = 0
        end if
        write(6,510)iter,aa,chi2
510     format(1x,i3,')',4f10.3,f10.5)
        write(6,520)xres,yres
520     format(1x,'Residuals:',/,1x,'X:',6f10.3,/,1x,'Y:',6f10.3,/)
        write(6,*)'Continue (1=yes,0=no)?'
        read(5,*)igo
        if(igo.eq.1)goto 50
        write(1,510)iter,aa,chi2
        write(1,520)xres,yres
        close(1)
        write(6,*)'All done.'
        call exit
        end
```

Offset of Upstream End of Region I.

Using the tooling ball locations:

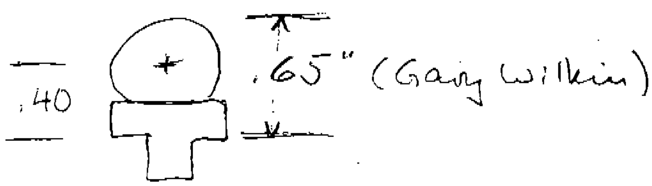
	Σ	ΔX	ΔY.
Horizontal	1021.44	+ .590 mm	− 1.875
Vertical	1156.33	+ .565	− 1.895
		+ 0.58 ± .1	− 1.88 ± .1 *

Nominally, the Boss Ring has 40.838" opening across flats (Sept '92 dwg.)



$(40.838" \times 25.4)/2 = 518.643$ mm

the tooling balls are .65" = 16.51 mm



To the center of the tooling ball: $518.643 - (.4 \times 25.4) = 508.48$ mm

Compare to $1021.44/2 = 510.72$ mm for survey.
The difference is −2.23 mm.

* sign disagrees with Dan Carman's 11-10-97 memo

Vertically:

Boss ring: $\frac{1}{2}46.154'' \times 25.4 - .4 \times 25.4 = 576.00$ mm
(from drawings)

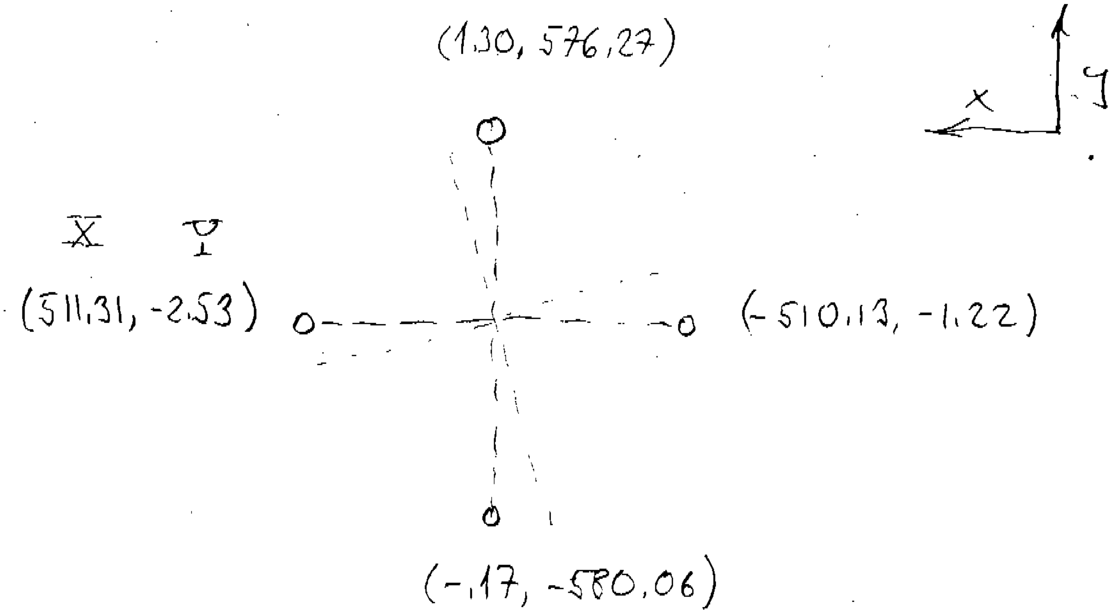
Survey: $\frac{1}{2}(1156.33) = 578.16$

Difference: 2.16 mm.

Thus, in both directions the upstream tooling balls measure −2.2mm from their ideal positions. The size of the two discrepancies is at least consistent.

Rotation of upstream end of chamber.

Tooling ball locations:



horizontal axis: $\frac{\Delta y}{\Delta x} = +1.283 \times 10^{-3}$

$= 1.28$ mrad c.c.w.

vertical axis: $\frac{\Delta y}{\Delta x} = +1.274 \times 10^{-3}$

$= 1.27$ mrad c.c.w.

good agreement

Average: Region I is rotated c.c.w. by

$-1.277 \pm .006$ mrad $= .073°$

at the upstream end.

We note that this is in the opposite sense to the 4 mrad c.w. rotation of the torus.

Also, the downstream end of Region I may have a different rotation ... (see later)

1-13-98
R.A.Sch.

Region I Offset in Z_l

Using Kelly Tremblays 10-31-97 survey:

Mean Z of downstream scribes : $786.275 \pm .135$

Mean Z_l of upstream tooling balls : $-1151.393 \pm .631$

Surveyed distance from scribes to tooling balls:

$(1937.668 \pm .645)$ mm

Design distance from tooling ball center line to sector plate scribe marks, from 2-14-97 notes:

$(76.265'') \times 25.4$ mm/in $= 1937.118$ mm

Thus, the survey value is larger by

$0.550 \pm .645$ mm,

which is consistent, assuming no upstream tilting. The center of Region I is designed to be $31.00'' = 787.4$ mm upstream of the scribe marks. Thus, the detector is

$$787.4 - (786.275 \pm .135) = 1.125 \pm .135 \text{ mm}$$

upstream of its nominal position. Computing for the upstream end we expect:

$$-(45.265'' \times 25.4) - (-1151.393 \pm .6) = 1.662 \pm .6$$

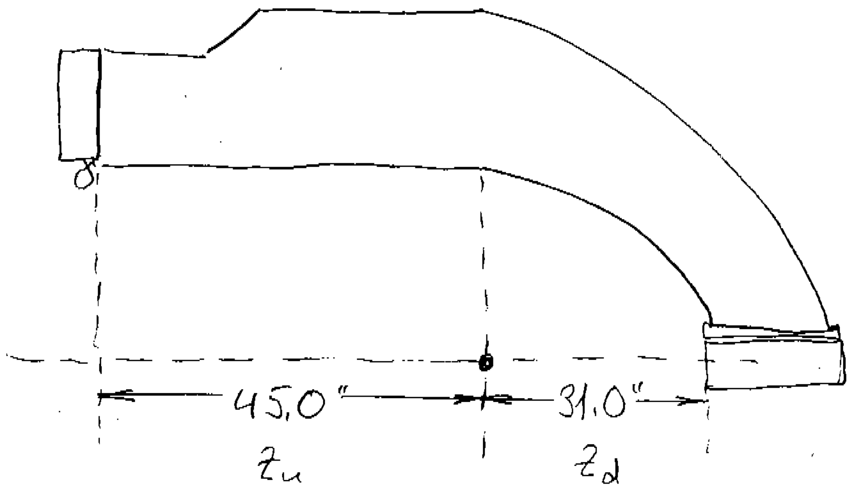
Averaging these two values gives

$$\Delta Z_{l\,\text{Region 1}} = -1.4 \pm .5 \text{ mm}.$$

Position of Region I Geometric Center

	UPSTREAM	DOWNSTREAM	$z = 0$
X	.58 mm	.72 mm	$0.66 \pm \cancel{.03}$ ±.08 mm
Y	−1.88 mm	−.29 mm	$-0.94 \pm \cancel{.03}$ ±.08 mm

at $z_1 = 0$



$$x_0 = x_u + (x_d - x_u)\,\frac{z_u}{z_u + z_d}$$

$$= \underset{\pm .1}{.58} + (\underset{\pm .03}{.72} - \underset{\pm .1}{.58})\,\frac{45}{45+31} = 0.66 \text{ mm}$$

$$y_0 = y_u + (y_d - y_u) \quad ''$$

$$= -1.88 + (-.29 + 1.88)\,.592 = -0.94$$

Net rotation along z:

$\frac{1}{2}(1.3 + 7.1) = -4.2$ mrad ± 4.1 mrad c.c.w.

implies c.c.w. rotation

<u>Rotations about X and Y axes.</u>

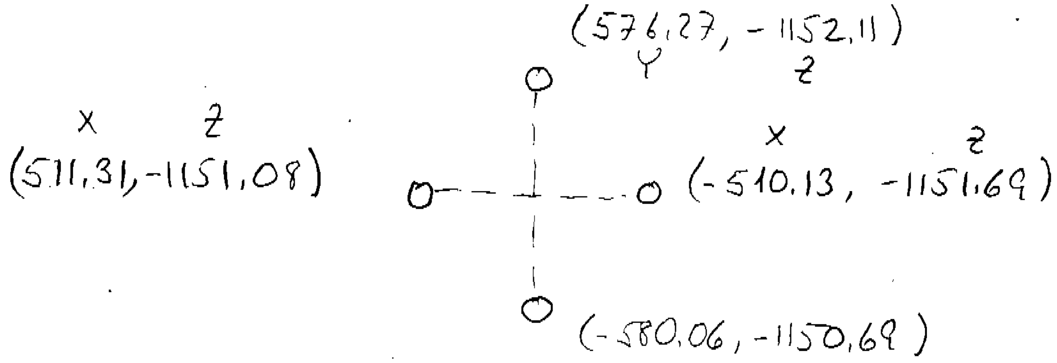
$$\frac{\Delta X}{\Delta Z} = \frac{.72 - .58^{\pm .1}\ \text{mm}}{1937.118\ \text{mm}} = 7.22 \times 10^{-5}\ \text{rad} \pm 5.16 \times 10^{-5}$$

$$\frac{\Delta Y}{\Delta Z} = \frac{-.29 - (-1.88)\ \text{mm}}{1937.118\ \text{mm}} = 8.21 \times 10^{-4}\ \text{rad} \pm 5.16 \times 10^{-5}$$

Thus we have

Θ_x	$-0.82 \pm .05$ millirad	(c.c.w.)
Θ_y	$+0.07 \pm .05$ millirad	(c.w.)
$\langle \Theta_z \rangle$	-4.2 ± 4.1 millirad	(c.c.w.)

Using the Upstream Tooling Balls to Estimate Rotations About X and Y



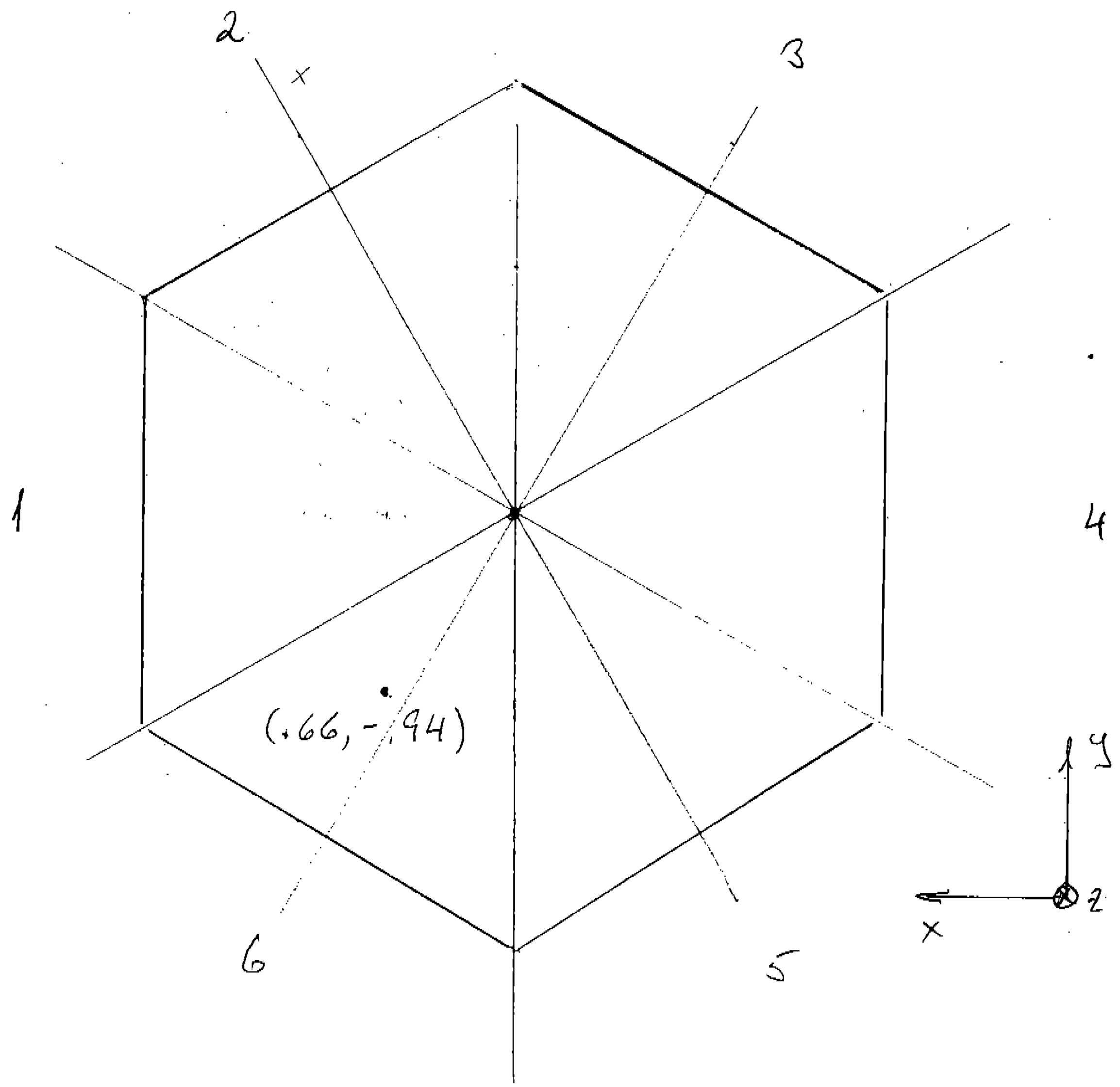
$$\theta_y = \frac{\Delta Z}{\Delta X} = \frac{-.61 \pm \sqrt{2}(.4)}{1021.44} = -(5.97 \pm 5.54) \times 10^{-4}$$

$$= -(0.6 \pm 0.6) \text{ mrad.}$$

$$\theta_x = \frac{\Delta Z}{\Delta Y} = \frac{1.42 \pm .4\sqrt{2}}{1156.33} = (1.23 \pm .49) \times 10^{-3}$$

$$= -(1.2 \pm .5) \text{ mrad}$$

These values are consistent with but less precise than the numbers computed on page 9.



Assume software takes the sector coordinates of hits and <u>adds</u> offsets to them prior to doing rotations to the proper sector location. Each sector is put into the Sector 1 location prior to rotation.

```
xQUARK>t rotate.for
c
c       Quick hack to rotate a coordinate pair to the each of six
c       sector coordinate values.
c
        data xval,yval/.66,-.94/
        data xnot,ynot/79.375,0./
        dera = 3.14159265/180.
        do 100 i=0,360,60
        ccos = cos(i*dera)
        ssin = sin(i*dera)
        x = xval*ccos - yval*ssin
        y = xval*ssin + yval*ccos
        write(6,*)i,x,y
100     continue
        write(6,*)'  '
        do 200 i=0,360,60
        ccos = cos(i*dera)
        ssin = sin(i*dera)
        x = xnot*ccos - ynot*ssin
        y = xnot*ssin + ynot*ccos
        write(6,*)i,x,y
200     continue
        write(6,*)'All done.'
        end
xQUARK>r                                                   Sector
          0  0.6600000      -0.9400000                     1
         60   1.144064       0.1015769                     6
        120  0.4840638        1.041577                     5
        180 -0.6600001       0.9399999                     4
        240  -1.144064      -0.1015769                     3
        300 -0.4840640       -1.041577                     2
        360  0.6600002      -0.9399999                     1

          0   79.37500       0.0000000E+00                 1
         60   39.68750        68.74077                     2
        120  -39.68750        68.74077                     3
        180  -79.37500      -6.9391831E-06                 4
        240  -39.68749       -68.74077                     5
        300   39.68749       -68.74077                     6
        360   79.37500       1.3878366E-05
All done.
```

offset in sector coordinates

nominal scribe mark locations

From: UQUARK::SCHUMACHER 10-NOV-1997 14:28:01.20
To: WILKIN@ERNEST.PHYS.CMU.EDU,FEUERBAC@ERNEST.PHYS.CMU.EDU, MCNABB@ERNEST.PHYS.CMU.EDU
CC: SCHUMACHER
Subj: Region One survey results

November 10, 1997

Hi Dan,

Thanks for the report on the Region One survey results. I assume the deviations you quote are relative to the ideal beam line and target center, and not, for example, relative to the torus only. At the upstream end I'm not surprised we are off by between half and two millimeters, since we never tried to position the upstream end, in our installation haste, to better than eyeball precision (as far as I know). At the downstream end I'd bet our alignment with respect to the torus is much better than the measured deviations of 0.75 (dX) and -.33 (dY). My guess is that the whole torus is offset by those distances.

John McNabb has seen "funny" effects in the reconstruction of pairs of tracks projected back to the target. I'm wondering if a millimeter-ish displacement of Region One in "Y" could account for the effects he sees. Essentially, depending on which pair of sectors he uses to project track pairs he finds systematic offsets on the order of several millimeters (at the target) when he uses the ideal chamber geometry. I'm sure he'd be glad to show you what he's got after he gets to J_Lab today; he will be trying to figure this out in the next week or so.

Regards,
Reinhard

cc Gary, Rob, John

Date: Mon, 10 Nov 1997 12:25:06 -0500 (EST)
From: "Daniel S. Carman" <CARMAN@CEBAF.GOV>
Subject: R1 survey results

November 10, 1997

Reinhard and Gary,

I thought you might be interested in the results from the recent survery of the Region One detector. This sighting was performed by the TJNAF survey group under the direction of Kelly Tremblay and was completed on October 31, 1997.

The results show differences from ideal in mm in a right-handed coordinate system. In this system, z is along the beam and +X is towards beam left. Survey accuracy is estimated to be +/- 0.25 mm for X and Y and 0.5 mm for Z values, with respect to the local monuments.

The midpoint indicated below is the calculated midpoint on a line between the 2 stated tooling balls on Region 1. The best fit center of the downstream scribes is the result of a circle fit to the six scribe centers on the sectors. The calculated torus center is based on a transformation using the fiducials on the upstream cryostat ring.

Location	dZ	dX	dY
Midpt Upstream 6 o'clock and 12 o'clock TB's	n/a	0.57 mm	1.83 mm
Midpt Upstream 3 o'clock and 9 o'clock TB's	n/a	0.59	1.81
Best fit center of downstream scribes	n/a	0.75 = 30 mil	-0.33
Calculated torus center	0.33	1.31	0.03

OLD, OBSOLETE

+.3 mr pitch in X

If you have any questions on this matter, let me know.

Daniel

25.4 mm/mil

-4.0 mr roll about z

-.07 mr yaw about y

← says Mac, 1-13-98