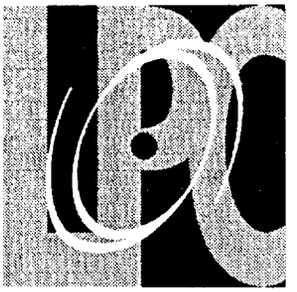

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Y_{target} optimization for E93050 experiment
Part I : $Q^2 = 1$ GeV^2

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VCS Collaboration-E93050

PCCF RI 9816

Y_{target} optimization for E93050 experiment

Part I : $Q^2 = 1$ GeV^2

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LPC-Clermont-Fd

November 24 th 1998

VCS Collaboration-E93050

This document summarizes the Espace y_{tg} optimization that has been performed for experiment E93050 at $Q^2 = 1$ GeV^2. The method and results are presented. The Y tensor elements that we obtain can be used for first pass analysis, although a more refined analysis may need futher optimized optic elements.

1 Introduction

To analyse with ESPACE, we use a file called database. This file is separated in two parts : one for the lepton arm and the second for the hadron arm. In each part, the database begins with some coefficients (like TDC offsets) related to the detector package. After, we find the coefficients of the optic tensor. This tensor is used to calculate the coordinates at the target (θ_{tg}, ϕ_{tg}, y_{tg} and δ) from the focal plan coordinates (θ_{fp}, ϕ_{fp}, y_{fp} and x_{fp}). (we note $\delta = \frac{p-p_0}{p_0}$).

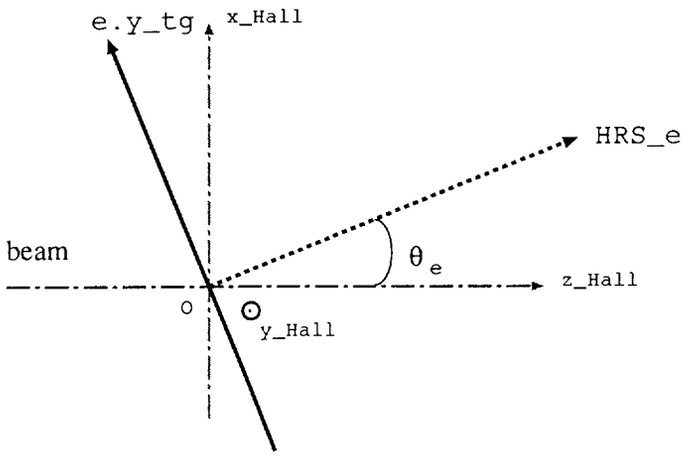


Figure 1: Coordinate system at the target for the lepton arm. The view is in horizontal plane. (X,Y,Z are axis in Hall A frame).

$$y_{tg} = \Sigma_{ijkl}\ Y_{ijkl}\ x_{fp}^{i}\ \theta_{fp}^{j}\ y_{fp}^{k}\ \phi_{fp}^{l}$$

$$\phi_{tg} = \Sigma_{ijkl}\ P_{ijkl}\ x_{fp}^{i}\ \theta_{fp}^{j}\ y_{fp}^{k}\ \phi_{fp}^{l}$$

$$\theta_{tg} = \Sigma_{ijkl}\ T_{ijkl}\ x_{fp}^{i}\ \theta_{fp}^{j}\ y_{fp}^{k}\ \phi_{fp}^{l}$$

$$\delta = \Sigma_{ijkl}\ D_{ijkl}\ x_{fp}^{i}\ \theta_{fp}^{j}\ y_{fp}^{k}\ \phi_{fp}^{l}$$

The coefficients (Y_{ijkl}, P_{ijkl}, T_{ijkl} and D_{ijkl}) are written in the database. Of course, the resolution of physics variables (like vertex point coordinates, momentum and angles, but also missing mass ... etc) depends on the coefficients. Because optical properties of the spectrometers may change with the central momentum value (due to saturation of magnetic field), we have to optimize the coefficients for the momentum of our setting. The subject of this document is the optimization of y_{tg} for our first VCS setting, at $Q^2 = 1$ GeV^2.

Electron arm	$P_e = 3.50$ GeV $\theta_e = 15.40^{\ 0}$
Hadron arm	$P_p = 1.17$ GeV $\theta_p = 54.30^{\ 0}$

y_{tg} is the track coordinate reconstructed at the target, along the horizontal axis perpendicular to the spectrometer axis (see fig 1).

2 Inputs for y_{tg} optimization

We use E93050 runs which were taken with ^{12}C or Dummy target (4, 10, 15 cm). These targets are equivalent to seven thin foils covering the range [-75, +75] mm on the beam axis.

We need to predict where these foils should be seen by the spectrometer on y_{tg} axis: let's call $\bar{Y}_1$,... $\bar{Y}_7$ these predicted values. They must be typed into the input file for Espace y_{tg} optimization. (see section 7)

The $\bar{Y}$ values are computed from 3 quantities :

- 1)^{12}C and Dummy targets absolute positioning in Hall A frame, i.e. the location of the seven thin foils along the Z_{Hall} axis.
- 2) the average beam position on target, along the X_{Hall} axis.
- 3) the spectrometer horizontal offset in Hall A frame.

So, we need to know these 3 quantities with good accuracy. The next three sections explain how we calculate each item.

Then, the formula to get $\bar{Y}$ is given together with all numerical values.

3 Target positioning for E93050

3.1 Computation of target position on z axis in Hall A frame.

Our computation is based on the following target survey data:

- ref.[1] = Riad's paper Jlab TN 97-008
- ref.[2] = survey of Febr. 13th 1998 (emitted on March 13th 19998)
- ref.[3] = survey of August 28th 1998 (emitted on Oct. 9th 1998)

and several discussions with Jiang-Ping CHEN.

3.1.1 Dummy targets

In ref.[1] page 13, we have the positions of the 3 dummy targets (warm) relative to the target "cryo6". [1] We calculate target center z_{center} w.r.t. cryo6, and total target length in table 1.

target	z_{center} relative to Cryo6	length
E 04cm	(-19.98 + 20.44)/2 = +0.230 mm	40.42 mm
E 10cm	(-50.08 + 49.95)/2 = -0.065 mm	100.03 mm
E 15cm	(-75.56 + 74.50)/2 = -0.530 mm	150.06 mm

Table 1: dummy targets position (warm) relative to cryo6 .

Using now the surveys of ref.[2] and [3], we can calculate the Cryo6 (warm) average position in the Hall A frame. You can find different notations for the target names: see Table 2. Cryo6 is "CRYO3B" in ref.[2] and [3].

target type	name in ref.[1]	name in ref.[2]
Loop 1 (LD2) (15 cm)	cryo 1	cryo 1T
Loop 1 (LD2) (04 cm)	cryo 2	cryo 1B
Loop 2 (LH2) (15 cm)	cryo 3	cryo 2T
Loop 2 (LH2) (04 cm)	cryo 4	cryo 2B
Loop 3 (LD2) (15 cm)	cryo 5	cryo 3T
Loop 3 (LD2) (04 cm)	cryo 6	cryo 3B
Aluminium target (solid)	Solid 3	hasol3

Table 2: Usual target names.

From ref.[2] we average the four DZ values of CRYO3B and change the sign, because it's written that these numbers "represent the amount the target would have to move to be at the ideal location".

DZ(CRYO3BA) = -0.89 mm
DZ(CRYO3BB) = -1.09 mm
DZ(CRYO3BC) = -1.19 mm
DZ(CRYO3BD) = -1.10 mm

$\Rightarrow$ $z_{average}$(cryo6 Feb.98) = $-1\times$ (- 0.89 - 1.09 - 1.19 - 1.10) /4 = +1.07 mm .

[1] Beware: in ref.[1] p.13 there is a misprint. $Z_{downstream}$ of Empty 15 cm target should read + 74.50 mm instead of + 75.5 mm [7].

In ref.[3] we don't have the position of the Cryo6. But we can see that all the targets moved by +0.85 mm from the Feb 98 survey (=ref.[2]). Then the new position of the center of Cryo6 in August 98 is :

$$z_{average}(\text{cryo6 Aug.98}) = 1.07 + 0.85 = 1.92 \text{ mm}.$$

We take the average of these two positions as the best value for the cryo6 center position on z axis in the Hall A frame during the experiment:

$$z_{center}(\text{cryo6}) = (1.07 + 1.92) \ / \ 2 = 1.495 \text{ mm} \simeq 1.500 \text{ mm}.$$

So we get the dummy targets center (warm) in Hall A frame in Table 3.

target	warm target Z_{center} in Hall A system
E 04cm	(+0.230 + 1.500)= +1.730 mm
E 10cm	(-0.065 + 1.500)= +1.435 mm
E 15cm	(-0.530 + 1.500) = +0.970 mm

Table 3: Z position for dummy targets center (warm) in Hall A system.

During the cooldown, it was observed that target moved upstream on z axis by 1.50 mm. We supposed that all targets have the same global motion [4].

(upstream means in the negative direction of the Hall z axis). So we get the dummy targets center (cold) in Hall A frame in Table 4. Accidentally, because this upstream translation exactly compensates the value of z_{center}(cryo6), we get for the dummy targets center (cold) in Hall A frame the same numbers as in Table 1. We can compute the target cold length either from ref.[1] page 11 or from the warm length and the contraction factor of aluminum during cooldown (=0.4%). Results for cold targets are shown in Table 4.

target	Z_{center} position after cooldown in Hall A system	total length (cold) along Z
E 04cm	+0.230 mm	40.26 mm
E 10cm	-0.065 mm	99.63 mm
E 15cm	-0.530 mm	149.46 mm

Table 4: Z_{center} of dummy targets (cold) in Hall A system, and target length.

Then, we can calculate the position of the "foils", i.e. the endcaps of each target: see table 5.

target	$z_{upstream}$ (mm) $z_{downstream}$ (mm)
E 04cm	z_u = 0.230 - (40.26/2) = -19.90 z_d = 0.230 + (40.26/2) = +20.36
E 10cm	z_u = -0.065 - (99.63/2) = -49.88 z_d = -0.065 + (99.63/2) = +49.75
E 15cm	z_u = -0.530 - (149.46/2) = -75.26 z_d = -0.530 + (149.46/2) = +74.20

Table 5: Foils position in Hall A system (cold targets).

3.1.2 Solid target : ^{12}C

For this foil, the number given by the survey is relative to the Hall A system, but represents the amount the target would have to move to be at the ideal location.

We suppose that all the solid targets centers are aligned [4]. Then, z_{carbon} is equal to $z_{aluminum}$ [2]

From ref.[2] :

DZ(HASOL3C) = -1.48 mm
DZ(HASOL3D) = -1.86 mm $\Rightarrow$ Average = - 1.67 mm,
equivalent to z_{carbon}(Feb.98) = + 1.67 mm in Hall A frame.

From ref.[3]:

DZ(HASOL3C) = -2.83 mm
DZ(HASOL3D) = -3.14 mm $\Rightarrow$ Average = - 2.99 mm,
equivalent to z_{carbon}(Aug.98) = + 2.99 mm in Hall A frame.

Averaging these two values of z_{carbon}, we find that the ^{12}C target position on z axis in Hall A system is +2.33 mm (warm). After the global motion due to cooldown (1.5 mm upstream), we have :

$$z_{carbon} = \mathbf{2.33 - 1.50 = +0.83\ mm} \quad \textbf{in the Hall A system.}$$

[2]Beware : on ref.[2], there was a typo in the survey sheet: the HASOL4 should be HASOL3, which is the aluminum target. [4]

4 Average horizontal beam position in Hall A frame

With Espace, we can obtain the average beam position on X_{Hall} axis. We check the results given by Espace with GEO code [5] (which can determine beam position from CODA events and also from EPICS events). For the y_{tg} optimization, we used 4 runs :

```
e_93050_1464.dat (12C target)
e_93050_1468.dat (Dummy target 4 cm)
e_93050_1478.dat (Dummy target 10 cm)
e_93050_1486.dat (Dummy target 15 cm).
```

The beam average for these 4 runs is given in table 6.

target	$beam\_x$ (mm)
^{12}C	+0.050
E 04cm	+0.075
E 10cm	-0.050
E 15cm	-0.060

Table 6: Beam average position in Hall A frame found with Espace and GEO.

5 Spectrometer offsets (horizontal)

In the horizontal plane (X_{Hall}, Z_{Hall}), the spectrometer's mispointing is given by the value of HPM-MAG variable as an output of the survey code written by Javier GOMEZ [6]. HPM-MAG represents the oriented distance OO' on figure 9, for both spectrometers. [3]

For both spectrometers, HPM-MAG is positive when the spectrometer axis points upstream of the origin of Hall A frame.

For the electron arm, we used "calib.set = 0" in Javier's survey code [6], because our analysis of E93050 data in its present state suggests that it is the correct calibration set for the E-Arm horizontal LVDT. Offsets values are given in table 7.

[3] Horizontal offsets (x_{offset} and z_{offset}) that enter in the header file of Espace are defined as the projection of OO' on X_{Hall} and Z_{Hall} axis in Hall A frame (see fig. 9). So we have :
$x_{offset} = (HPM - MAG) * cos(\theta_{HRS})$ (E-Arm)
$x_{offset} = -(HPM - MAG) * cos(\theta_{HRS})$ (H-Arm)

target	HPM-MAG E arm	HPM-MAG H arm	X_{offset} E arm	X_{offset} H arm
^{12}C	4.21	1.33	4.057	-0.778
E 04cm	4.21	1.33	4.058	-0.778
E 10cm	4.21	1.33	4.055	-0.778
E 15cm	4.20	1.33	4.053	-0.778

Table 7: Spectrometer offsets in Hall A frame given by Survey code. (all values are in mm.)

6 Computation of predicted $\bar{Y}$

Now, we know the quantities :

- z_{target} : location of a foil on Z_{Hall} axis
- beam_x average
- x_{offset} of both spectrometers

On figures 7, 8 and 9 (Appendix A) you can see the influence of these 3 quantities on the target position reconstruction on y_{tg} axis.

As these 3 inputs are independent, y_{tg} position is the sum of these 3 offsets.

The analytical formula to obtain $\bar{Y}$ is the following :

electron arm	$\bar{Y} = cos(\theta_{HRS}) * beam\_x - z_{target} * sin(\theta_{HRS}) - \frac{x_{offset}}{cos(\theta_{HRS})}$
hadron arm	$\bar{Y} = cos(\theta_{HRS}) * beam\_x + z_{target} * sin(\theta_{HRS}) - \frac{x_{offset}}{cos(\theta_{HRS})}$

where θ_{HRS} is the nominal spectrometer angle ($\theta_{HRS} > 0$)

Using informations from table 5 for z_{target}, table 6 for beam_x and table 7 for x_{offset}, we can calculate now the $\bar{Y}$ on y_{tg} axis for each foil (see table 8) for the electron arm : $\theta_{HRS_e} = 15.399^0$

For the hadron arm, considering angular setting ($\theta_{hadron} = 54.301\ ^0$) and spectrometer acceptance, only 5 thin targets could be reconstructed (the E-15cm is not seen). We find the values of table 9.

In E-arm, the two endcaps of one target are seen very asymetrically on y_{tg} axis, due to the large spectrometer offset (of the order of 4 mm). In H-arm, the asymetry between two endcaps is smaller because HPM-MAG is smaller (of the order of 1 mm).

target	$\bar{Y}$
^{12}C	$\bar{Y}_{1e}$ = -4.38
E 04cm	(upstream) $\bar{Y}_{2e}$ = +1.15 downstream $\bar{Y}_{3e}$ = -9.54
E 10cm	(upstream) $\bar{Y}_{4e}$ = +8.99 (downstream) $\bar{Y}_{5e}$ = -17.46
E 15cm	(upstream) $\bar{Y}_{6e}$ =+15.72 (downstream) $\bar{Y}_{7e}$ = -23.96

Table 8: $\bar{Y}$ theoretical position for seven foils in electron arm. (all values are in mm.)

target	$\bar{Y}$
^{12}C	$\bar{Y}_{1h}$ = 2.040
E 04cm	(upstream) $\bar{Y}_{2h}$ = -14.78 (downstream) $\bar{Y}_{3h}$ = +17.91
E 10cm	(upstream) $\bar{Y}_{4h}$ = -39.20 (downstream) $\bar{Y}_{5h}$ = +41.71

Table 9: $\bar{Y}$ theoretical position for five foils in hadron arm. (all values are in mm.)

7 Input file for the optimization.

To optimize the coordinate *spec_e.y_tg* with Espace, we need to have such a file. Below is the input file we have used.

```
 4 1
-0.0400        0.0400        1.00 cut_1464
-0.0400        0.0400        1.00 cut_1468
-0.0400        0.0400        1.00 cut_1478
-0.0400        0.0400        1.00 cut_1486
1
-0.00396    -0.00438 0.003
2
-0.00956    -0.00954      0.003
 0.00133     0.00115      0.003
2
-0.01740    -0.01746      0.003
 0.00872     0.00899      0.003
```

```
2
-0.02410    -0.02396       0.003
 0.01492     0.01572       0.003
```

File content is explained in table 10.

line number	written value	what this value means
line 1	4	number of run
	1	choice of fit mode (keep equal to 1)
line 2 $\rightarrow$ 5	-0.0400	$(\frac{\delta p}{p})_{minimum}$
	+0.0400	$(\frac{\delta p}{p})_{maximum}$
	1.0000	full width half max on $\frac{\delta p}{p}$
	cut_1464	logical variable (defined in kumac file run)
line 6	1	number of the foil
line 7	-0.00396	y_{tg} experimental position
	-0.00438	y_{tg} theoretical (calculated) position
	0.003	full width half max on y_{tg} experimental

Table 10: Explanation of input file content.

Then the optimization can begin....

8 Results.

8.1 Electron arm

Figure 2 represents the coordinate y_{tg} for the electron arm before and after optimization. The big difference between these two databases (non-optimized and optimized) is the reconstructed length of the dummy targets. We can calculate the theoretical length of dummy target, and measure the length experimentally, before and after optimization (see table 11.) The experimental length on y_{tg} is the distance between the endcap positions. We measured the y_{tg} position as the central value of full width half max for each endcap's histogram (using "locate" in paw). We estimate that the error with this method is :

```
+/- 0.3 mm for electron arm (= +/- 1 bin)
+/- 0.5 mm for the hadron arm (= +/- 1 bin).
```

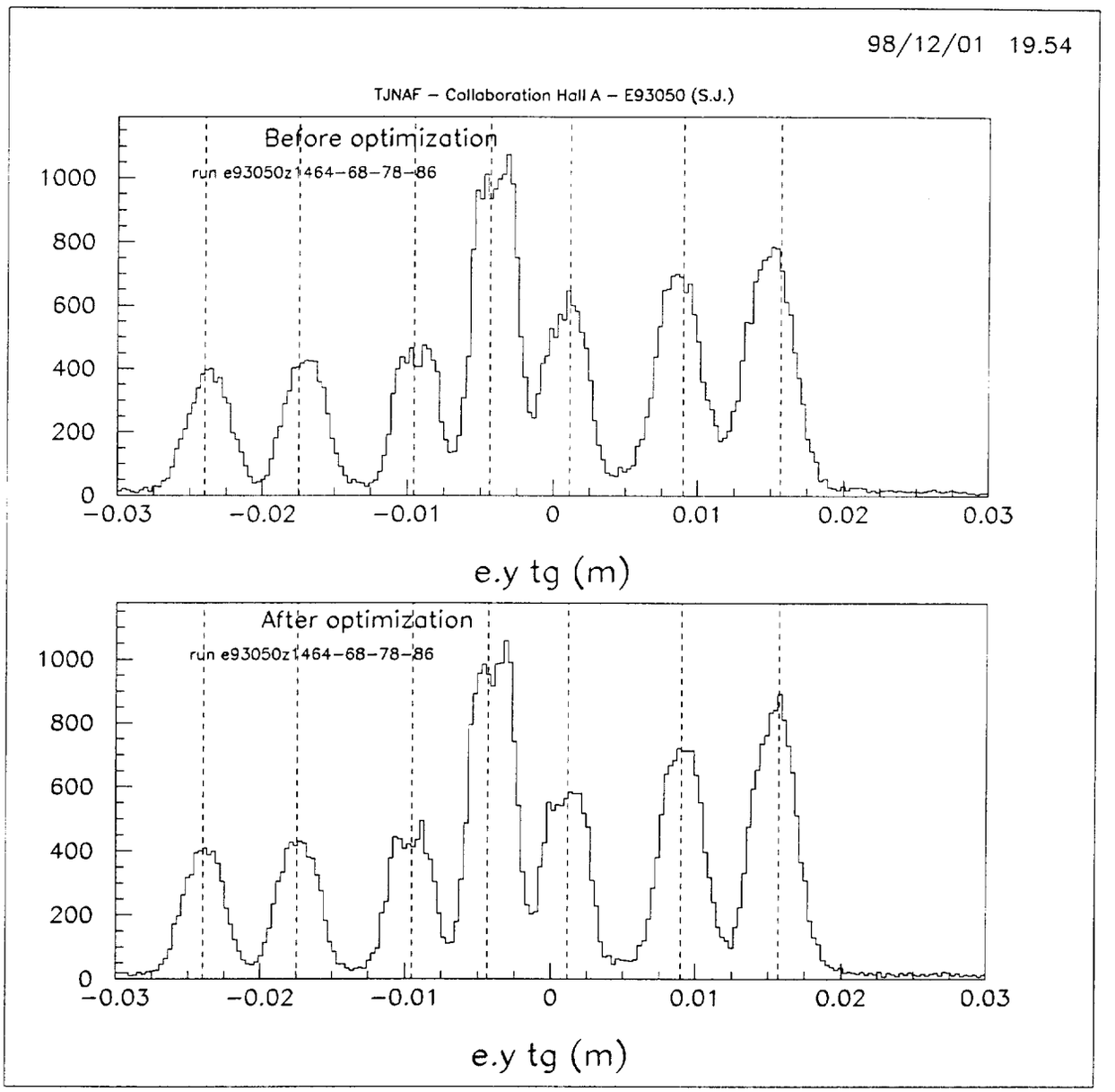


Figure 2: Position for 7 thin targets on y_{tg} axis in electron spectrometer system. The dashed line represents the theoretical position on y_{tg} axis ($= \bar{Y}$ in the text.)

target	Theoretical length	Experimental length before optimization	$\frac{L_{th}-Lexp}{L_{th}}$ before optimization	Experimental length after optimization	$\frac{L_{th}-Lexp}{L_{th}}$ after optimization
E 04cm	10.7	10.3	3.7 %	10.6	0.9 %
E 10cm	26.5	25.7	3.0 %	26.4	0.4 %
E 15cm	39.7	38.7	2.5 %	39.3	1.0 %

Table 11: Dummy target length on y_{tg} axis, theoretical and experimental, before and after optimization. (all values are in mm.)

8.2 Hadron arm

Figure 3 represents the coordinate y_{tg}, before and after optimization, for the hadron arm. We can see that these thin foils aren't close to predicted positions before optimization.

For the 10 cm dummy target experimental length on y_{tg} axis before optimization (see table 12), the scale is 10 % too small. You can see that the length reconstruction with optimized database is better : now, we have just 2% optical error .

target	Theoretical length	Experimental length before optimization	$\frac{L_{th}-Lexp}{L_{th}}$ before optimization	Experimental length after optimization	$\frac{L_{th}-Lexp}{L_{th}}$ after optimization
E 04cm	32.7	32.5	0.6 %	32.8	0.3 %
E 10cm	80.9	73.2	9.5 %	80.1	1.0 %

Table 12: Dummy target length on y_{tg} axis, theoretical and experimental, before and after optimization. (all values are in mm.)

8.3 Some checks of the results

After an y_{tg} optimization, we have to check that there are no big correlations left between all focal plane coordinates (x_{fp}, y_{fp}, θ_{fp} and ϕ_{fp}) and y_{tg}. We can check also a non-correlation with the other target variables : δp, θ_{tg} and ϕ_{tg}.

During experiment E93050, we used a raster for the beam (variation on X_{Hall} axis). As you can see on fig 7 in Appendix A, the variation of the beam on X_{Hall} axis is

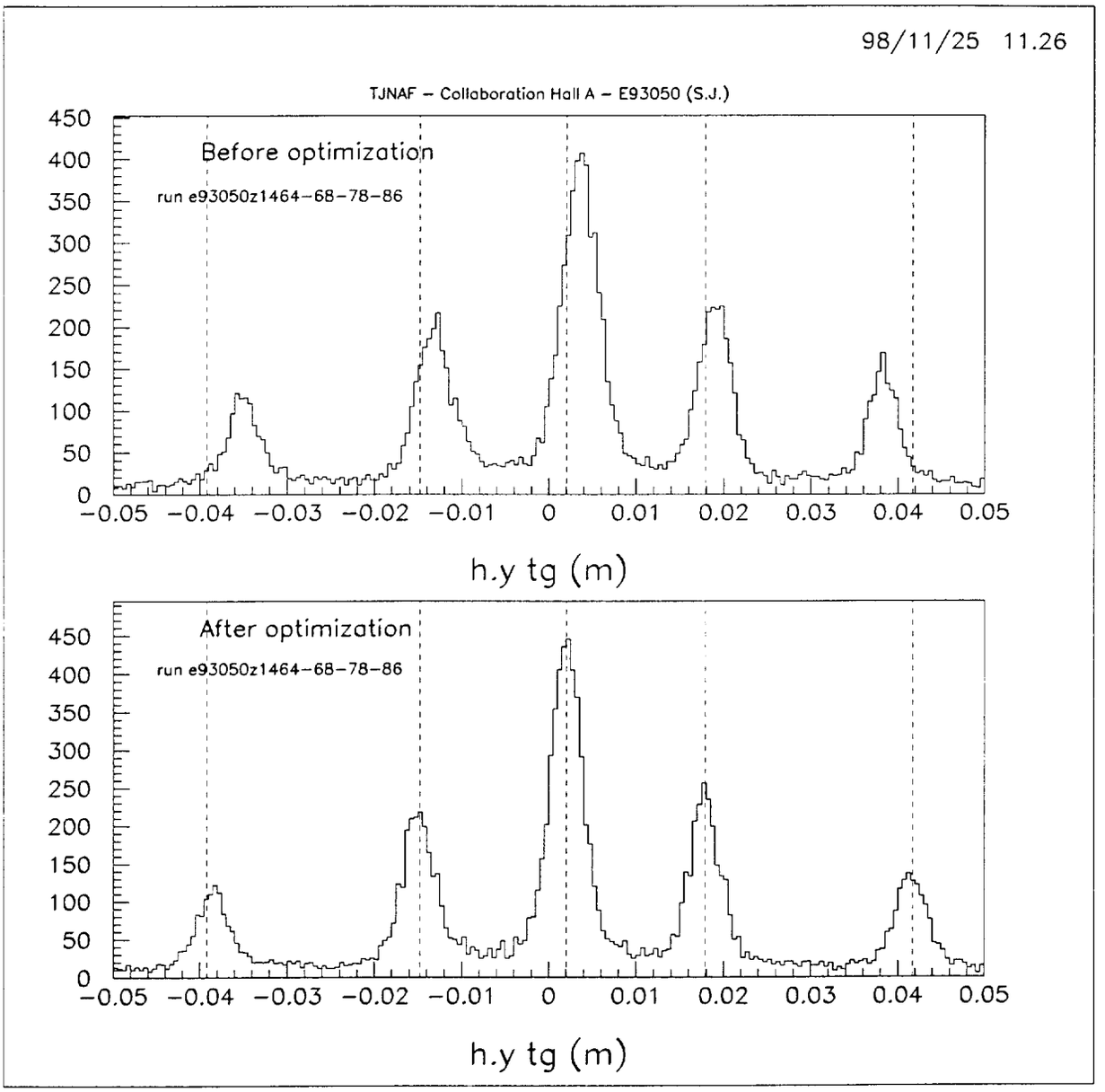


Figure 3: Position for 5 thin targets on y_{tg} axis in hadron spectrometer system. The dashed line represents the theoretical position on y_{tg} axis ($= \bar{Y}$ in the text).

important for the electron arm to determine the vertex point position on y_{tg} axis. The raster amplitude increases the full width half max of the y_{tg} peak. To see a correlation, it's more easy if foil reconstruction is as thin as possible.

This is why we use the Z_{Hall} axis instead of y_{tg} axis : the correlation, if we have it, is kept and the raster influence is removed.

With Espace, it's possible to reconstruct the vertex with the beam and spectrometer informations. Espace has several definitions for the vertex point :

- definition 1 : both spectrometers : twoarm_z(x)
- definition 2 : one spectrometer and the beam : spec_e.reactz(x) and spec_h.reactz(x)
- definition 3 : a weighted average of spec_e.reactz and spec_h.reactz : react_z

Figure 4 represents the two first vertex point reconstruction possibilities.

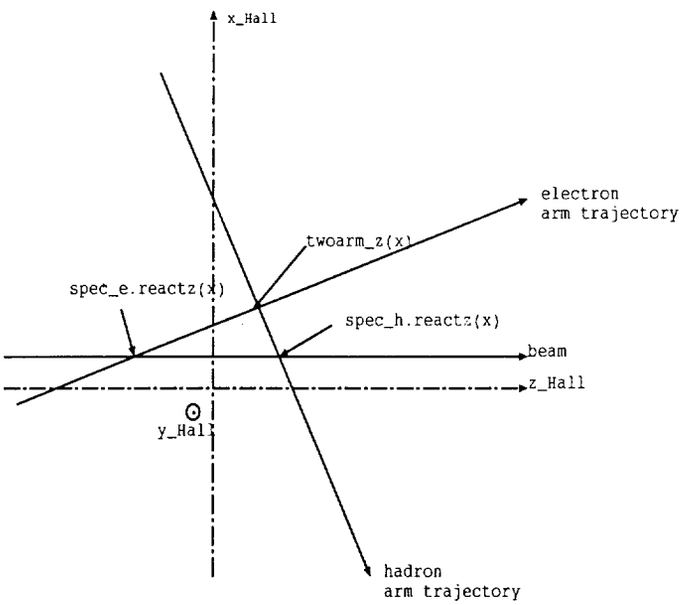


Figure 4: Definition of the vertex variables in Espace.

For this study we want to check the electron and hadron arm separately. Then we'd rather have the vertex point reconstructed with information from one spectrometer and the beam. Consequently, we used definition # 2, and on figs 5 and 6, we called the variables : e.reactz (for spec_e.reactz) and h.reactz (for spec_h.reactz).

Normally, the target reconstruction on z axis should be independent of the focal plane variables. As an example, we can see on fig 5 that with non optimized database, we have some correlations between the z coordinate of the foil and the non dispersive coordinate , $y_{focalplane}$, for the hadron arm.

Figure 6 represents the same plot, but after optimization. The correlation has mostly disappeared.

You can find in Appendix B, the new coefficients Y_{jkl} for the electron and hadron part of the database.

Caution : these Y elements go with the values of y000 elements. Normally, Y000 coefficients are not allowed (due to Dirichlet symmetry), but it seems all hadron arm databases have such coefficients. Probably we will have to go one step further, by optimizing the y000 coefficients in such a way that Y000 coefficients are no longer necessary. For the moment, we did not modify at all the y000 elements; we kept the existing ones. For hadron arm, our y000line is identical to the one in the "standard" database db_e2000_h1000 of JC GAO and Nilanga Liyanage. For electron arm, our y000 line is slightly different from the one in db_e2000_h1000.

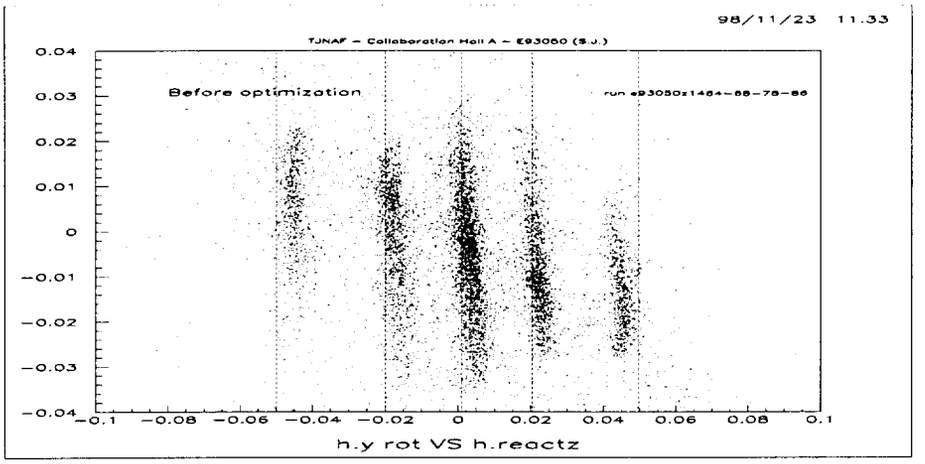


Figure 5: Hadron arm : non dispersive coordinate ($y_{focalplane}$) as a function of z_{HallA} coordinate before optimization .

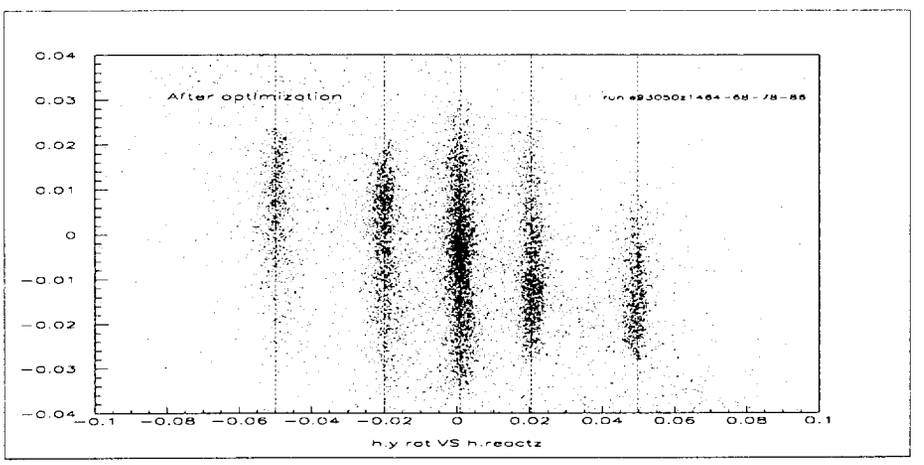


Figure 6: Hadron arm : non dispersive coordinate ($y_{focalplane}$) as a function of z_{HallA} coordinate after optimization .

Appendix A.

The target position in spectrometer system, depends of 3 inputs. You can see the influence of these 3 inputs of the position on y_{tg} axis. (see fig 7, fig 8 and fig 9)

Attention : for the beam and target position influence, O stays at the center of spectrometer frame (figs 7 and 8). But for the spectrometer offset influence, O' becomes the center of spectrometer frame (fig 9).

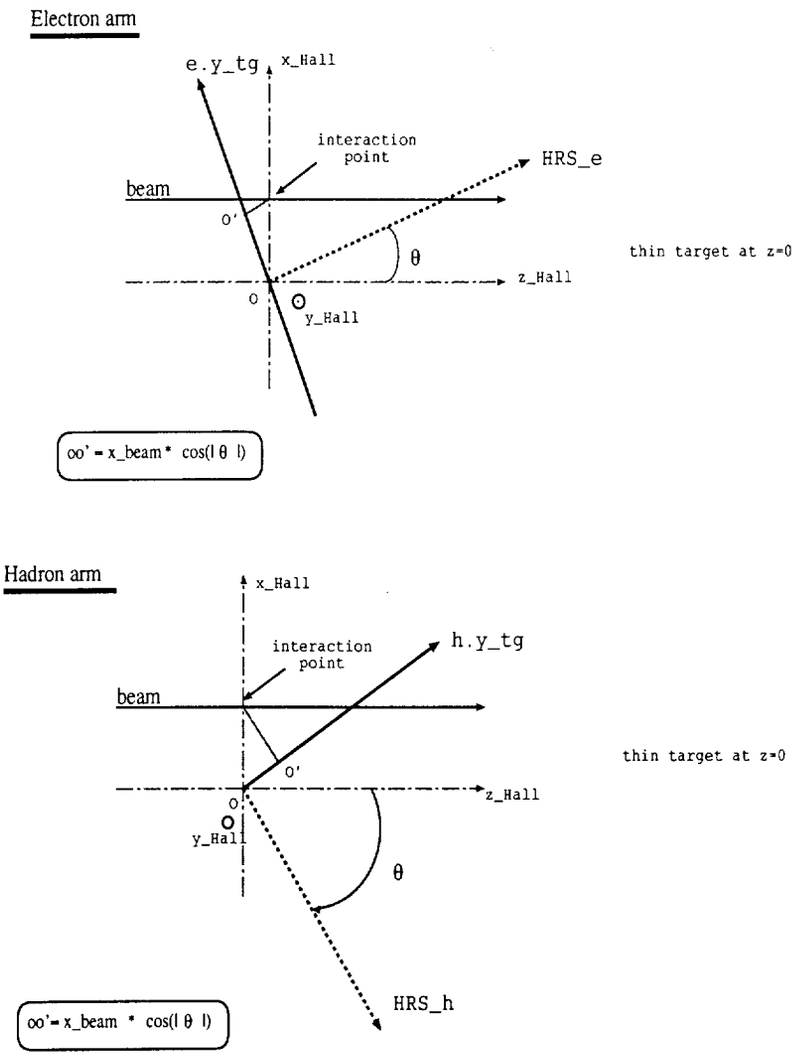


Figure 7: Influence of the beam average position on the y coordinate. O represents the center of spectrometer frame and O' is where the interaction point is seen by the spectrometer.

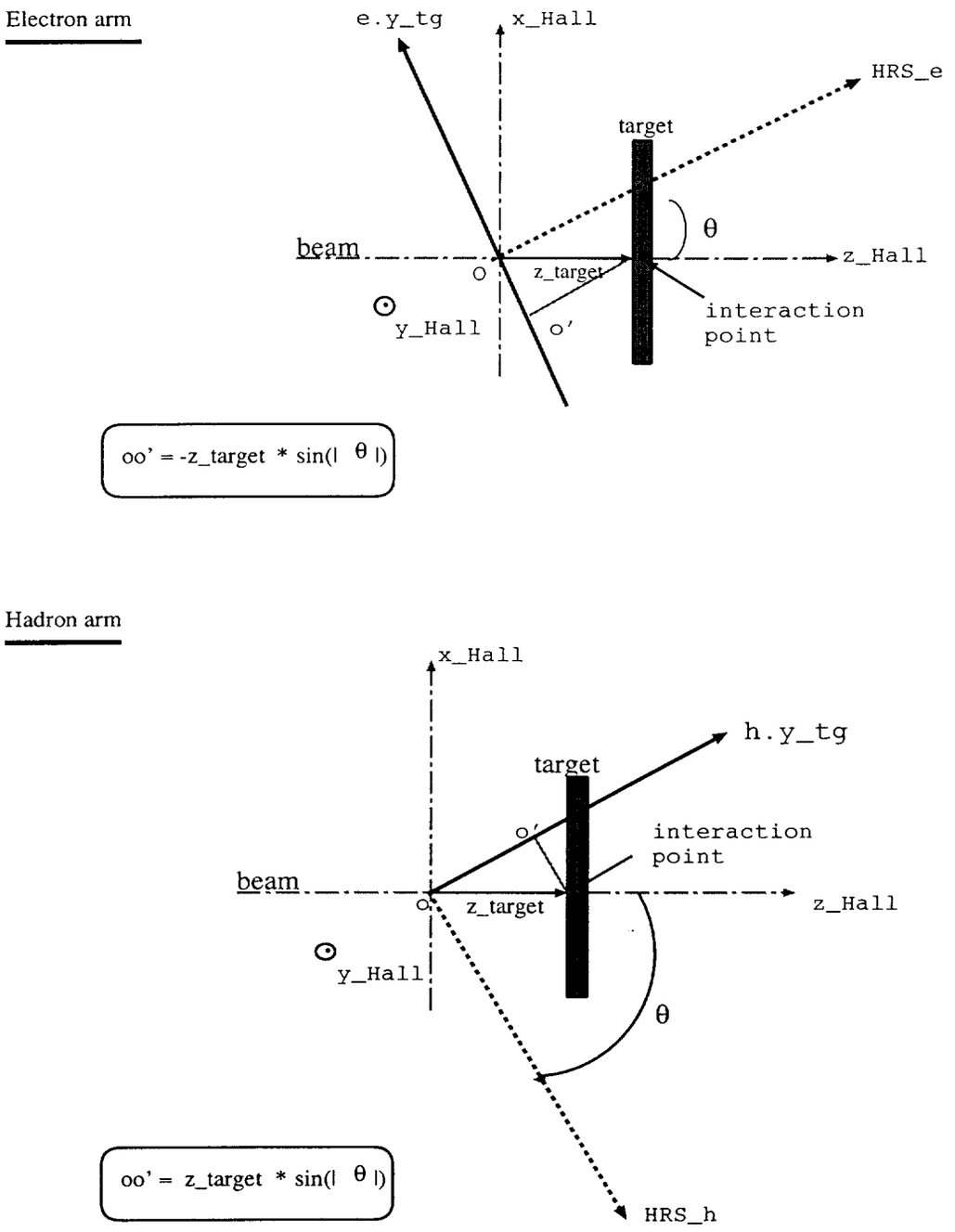
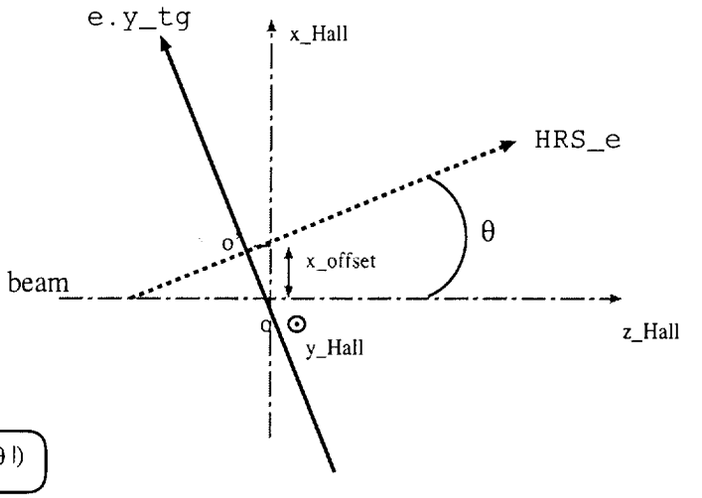


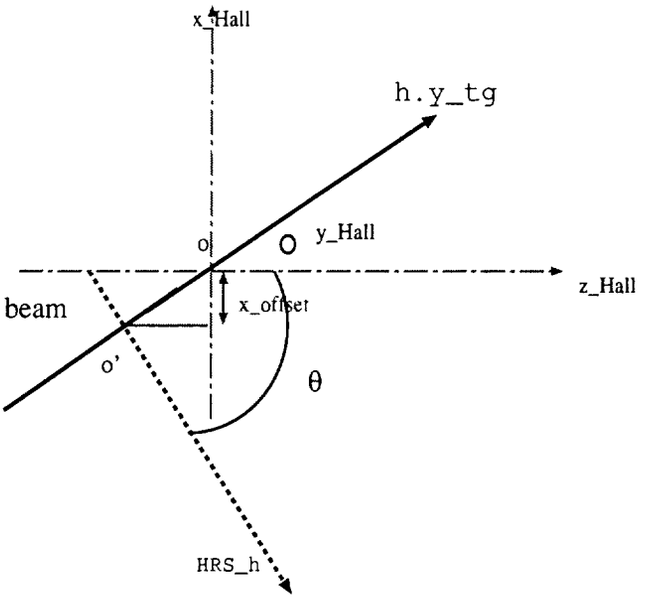
Figure 8: Influence of the target position on the y coordinate. O represents the center of spectrometer frame and O' is where the interaction point is seen by the spectrometer.

Electron arm



o'o= - x_offset / cos(| θ |)

Hadron arm



o'o= - x_offset / cos(| θ |)

Figure 9: Influence of the spectrometer offset on the y coordinate. O' represents the center of spectrometer frame. O is at the same times the true interaction point and the interaction point seen by the spectrometer.

Appendix B.

Optimized Y_{jkl} coefficients in the database of Espace.

Electron arm

```
0 0 0 0 -7.9853E-03  3.2838E-03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 y000

0 0 0 1  7.0286E-01 -1.3258E+00 -7.1899E-01  1.7952E-01   .0000E+00   .0000E+00   .0000E+00 Y001
0 0 1 0 -1.2018E+00 -7.6833E-01  1.7602E-01   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y010
0 1 1 0 -1.2126E+01 -2.7081E+00 -2.7950E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y110
0 1 0 1 -5.4045E-01 -5.5970E+00 -6.7633E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y101
0 0 1 2  1.0779E+02 -1.6963E+02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y012
0 0 0 3  1.9650E+00  1.3416E+02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y003
0 2 0 1  4.5545E+02  1.8975E+02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y201
0 2 1 0  3.1359E+02 -7.6984E+01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y210
0 0 3 0  7.0567E+01  1.3741E+01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y030
0 0 2 1 -4.9750E+01  9.5108E+01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y021
0 1 0 3 -2.6534E+02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y103
0 1 3 0  1.0400E+03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y130
0 1 1 2  1.8785E+03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y112
0 3 0 1  3.4370E+03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y301
0 3 1 0  2.3195E+03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y310
0 1 2 1 -3.3073E+03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y121
```

Hadron arm

```
0 0 0 0 -2.8496E-03 -2.0963E-03  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 y000

0 0 0 0 -5.0515E-03  5.4609E-03 -1.1243E-03  2.9127E-04  1.0548E-02   .0000E+00   .0000E+00 Y000
0 0 0 1  7.6764E-01 -1.1992E+00 -5.9207E-01   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y001
0 0 1 0 -1.2674E+00 -7.6271E-01  1.1909E-01  2.6228E-01   .0000E+00   .0000E+00   .0000E+00 Y010
0 1 1 0 -1.4291E+01  8.5405E-01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y110
0 1 0 1 -2.2068E+00 -7.8024E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y101
0 0 1 2  2.1252E+00 -1.2997E+02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y012
0 0 0 3 -9.7720E+00  1.1325E+01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y003
0 2 0 1  4.1827E+02  5.4107E+01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y201
0 2 1 0  2.7941E+02 -9.7705E+01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y210
0 0 3 0  9.7512E+01  4.6016E+01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y030
0 0 2 1 -5.2374E+01  8.3545E+01   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y021
0 1 0 3  1.1045E+03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y103
0 1 3 0 -1.4921E+02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y130
0 1 1 2  6.8173E+02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y112
0 3 0 1  5.5300E+03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y301
0 3 1 0  3.8057E+03   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00 Y310
```

References

[1] Hall A Cryogenic and Dummy Targets Information : Jlab TN 97-008

[2] target survey of Febr. 13th 1998 (emitted on March 13th 1998)

[3] target survey of August 28th 1998 (emitted on Oct. 9th 1998)

[4] Jiang-Ping CHEN private communications

[5] GEO code : G.Laveissiere, LPC and private communications.

[6] Survey code "align3v2" written by Javier GOMEZ, Hall A collaboration .

[7] Riad Suleiman private communications.