G^0 Backward Angle Cryotarget Alignment (BASED ON PRELIMINARY DATA)

Lars Hannelius and Greg Smith

November 30, 2005

This report describes the alignment of the G^0 cryotarget and the calibration of the target motion mechanism for the G^0 backward angle run. The alignment and calibration were performed on November 18, 2005 with the target warm and sitting on the floor of hall C. The radiator target position was adjusted on November 21, 2005 by Greg Smith with the same survey setup. In both cases the JLab survey group was headed by Jim Dahlberg.

1 Coordinate System and Survey Points

All measurements were performed in a right-handed coordinate system with $+z$ corresponding to the downstream direction along the beamline, $+x$ corresponding to beam left, and $+y$ corresponding to beam up (see Fig. 1). The origin of the coordinate system was taken to be the center of the beamline, which in turn was determined relative to the downstream flange of the target service module. A post-installation adjustment of the target positions may be necessary since the "ideal" beamline may not correspond to the true beamline once the service module is bolted onto the SMS.

The x and y coordinates of the hydrogen cell axis relative to the beamline were measured in three locations: at the upstream end of the helium cell flange, at a circle drawn near the upstream end of the hydrogen cell, and at a circle drawn near the downstream end of the hydrogen cell (see Fig. 2). The same survey locations were used for the forward angle. The precision of a single measurement on the upstream and downstream circles was about 0.1 mm.

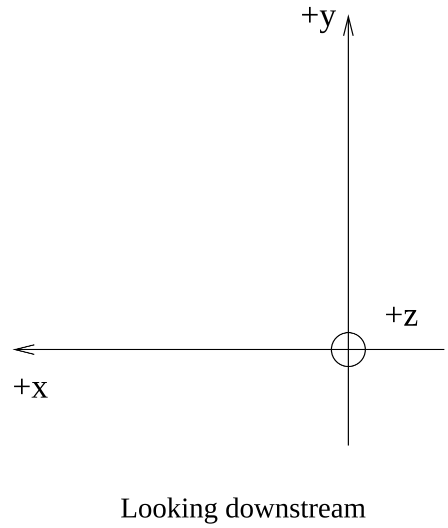

Figure 1: Coordinate system.

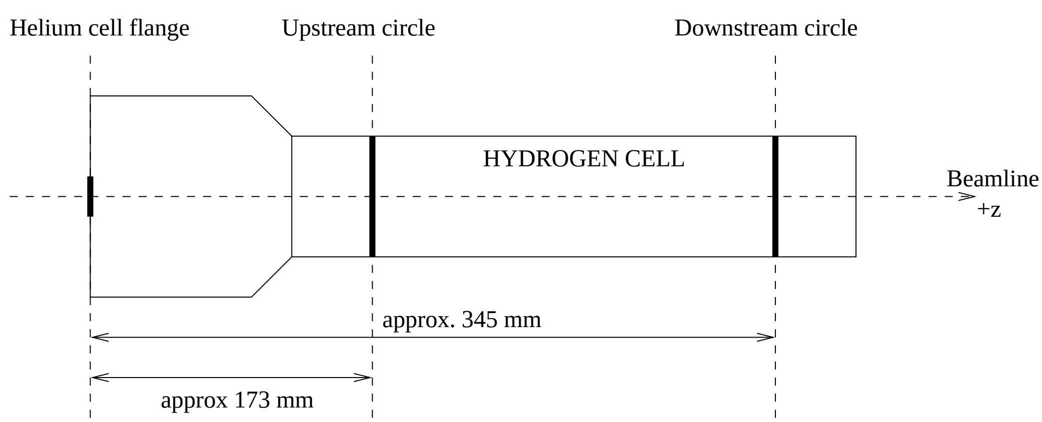

Figure 2: The locations of the three survey points on the target cell.

2 Target Positions

In addition to finding the actuator encoder values corresponding to beam on the hydrogen cell, the alignment also involved determining the actuator encoder values for the target out of beam, beam on the carbon target, beam on the hole target, beam on the aluminum target (a spot on the dummy target frame), and beam on the tungsten radiator located on the target loop. For the radiator and the aluminum target the survey precision was about 0.5 mm because only a single point was measured. The actuator encoder values for the 6 target positions are shown below:

Position	X_{UP}	Y_{UP}	X_{DOWN}	Y_{DOWN}	x-ref (date)
hydrogen	4033	7055	4563	2495	4 (11-18-2005)
carbon	2527	3522	6729	2252	57 (11-18-2005)
hole	3958	3524	4672	2252	58 (11-18-2005)
aluminum	3597	4045	5188	1443	59 (11-18-2005)
radiator	2079	3414	5603	2408	11 (11-28-2005)
out of beam	4033	2651	4548	1065	61 (11-18-2005)

The last column gives the cross-reference to the position data recorded by the survey group. The x and y coordinates of the targets centers are within 0.5 mm of the beamline. A rough sketch of the dummy target frame and its three targets is shown in Fig. 3.

3 Calibration of Actuators

The target motion mechanism was calibrated for displacements about the "hydrogen cell in beam" position: Each of the four actuators was varied over nearly its full range of motion while keeping the other three actuator encoders fixed at their "hydrogen cell in beam" values. The target cell position was surveyed after each change in the actuator encoder values. A total of 47 data points were collected. The data are shown in Figs. 4, 5, 6, and 7. One observes a small nonlinear coupling between x and y.

The dependence of the target position on the actuator encoder values was fit to a model with a constant, a linear, and a quadratic term:

$$y = c + Ax + Bx^2, \tag{1}$$

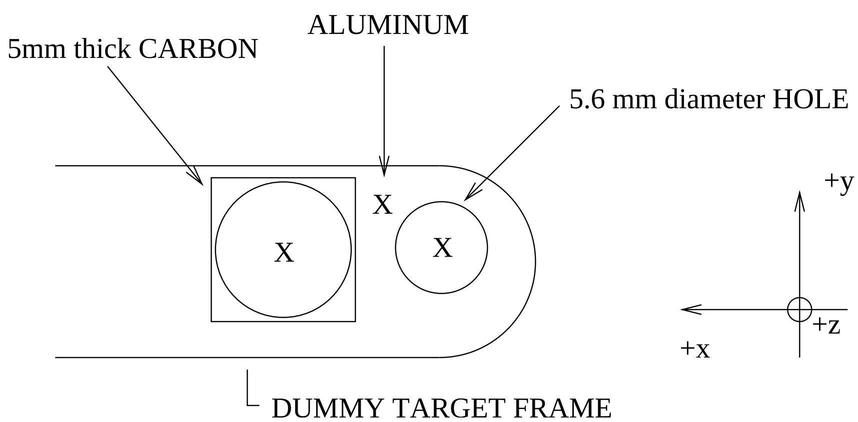

Figure 3: A rough sketch of the dummy target frame and the three target positions located on it. The view is from upstream looking downstream. The carbon target is attached to the upstream side of the dummy target frame.

where

$$y = \begin{pmatrix} x_{\text{helium}} \\ y_{\text{helium}} \\ x_{\text{upstream}} \\ y_{\text{upstream}} \\ x_{\text{downstream}} \\ y_{\text{downstream}} \end{pmatrix} \tag{2}$$

is a 6-by-1 column vector denoting the x and y coordinates of the three survey points with respect to the beamline,

$$x = \begin{pmatrix} X_{\text{UP}} \\ Y_{\text{UP}} \\ X_{\text{DOWN}} \\ Y_{\text{DOWN}} \end{pmatrix}, \qquad x^2 = \begin{pmatrix} X^2_{\text{UP}} \\ Y^2_{\text{UP}} \\ X^2_{\text{DOWN}} \\ Y^2_{\text{DOWN}} \end{pmatrix} \tag{3}$$

are 4-by-1 column vectors denoting the actuator encoder values and their squares, the parameter c is a 6-by-1 column vector, and the parameters A, B are 6-by-4 matrices. A linear regression of the data to Eq. (1) yielded the

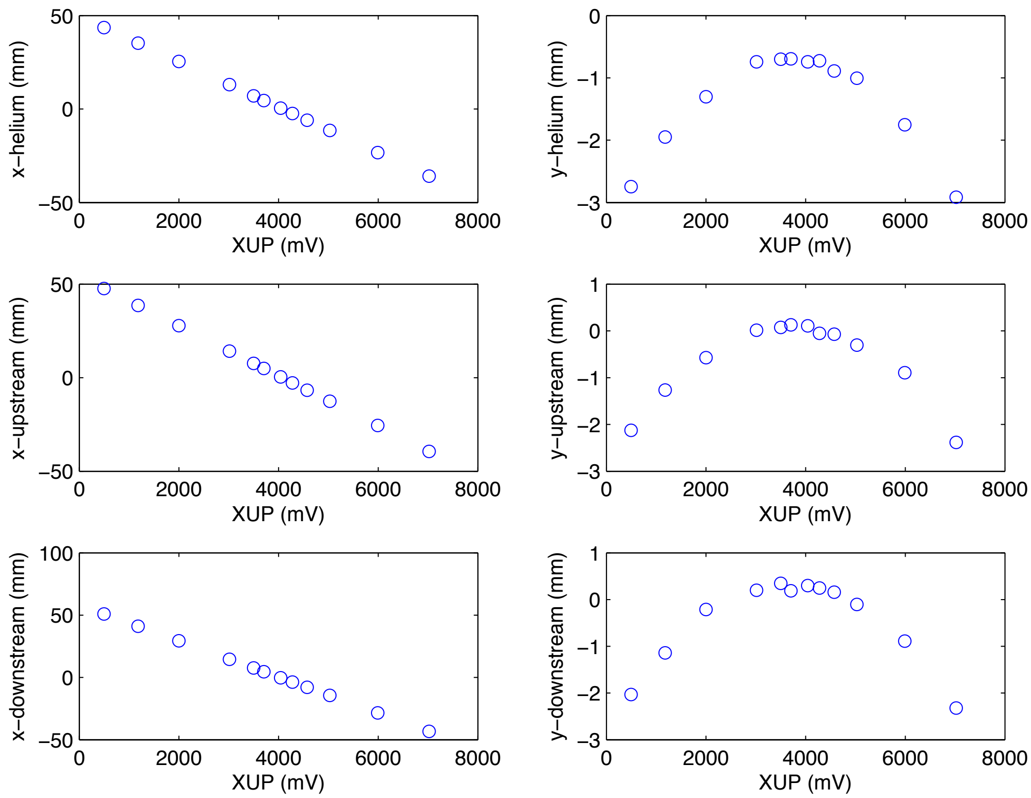

Figure 4: Target position versus $X_{\rm UP}$ actuator encoder value with the other actuators fixed at their "hydrogen cell in beam" values.

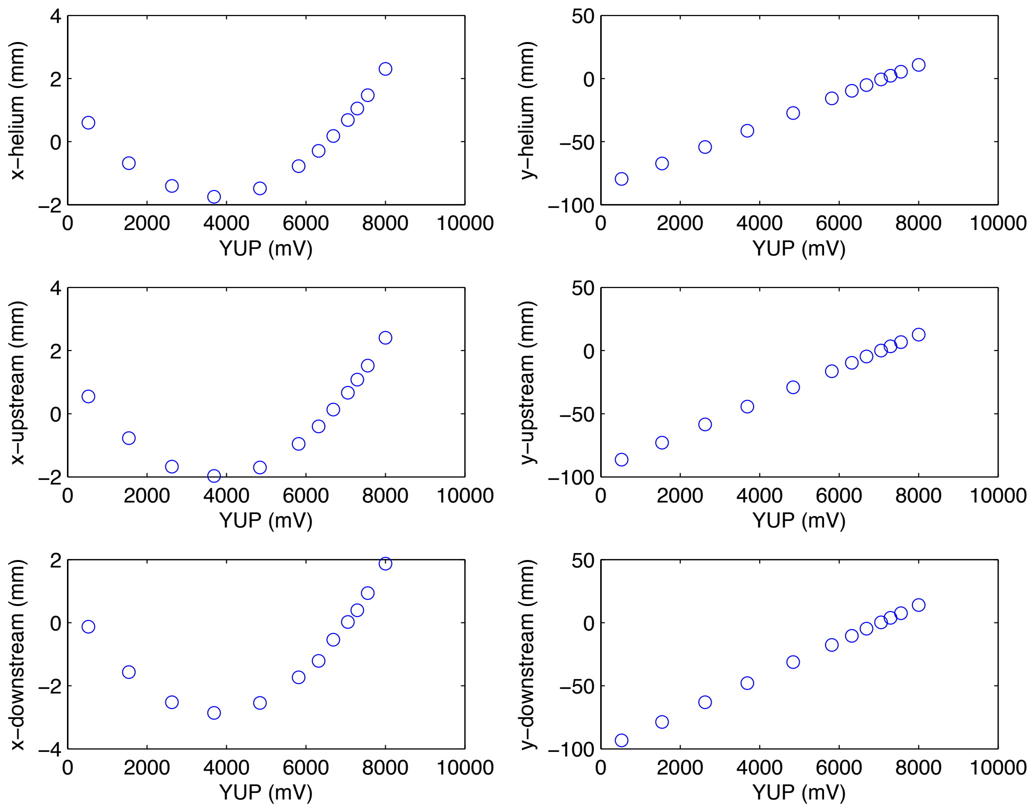

Figure 5: Target position versus Y_{UP} actuator encoder value with the other actuators fixed at their "hydrogen cell in beam" values.

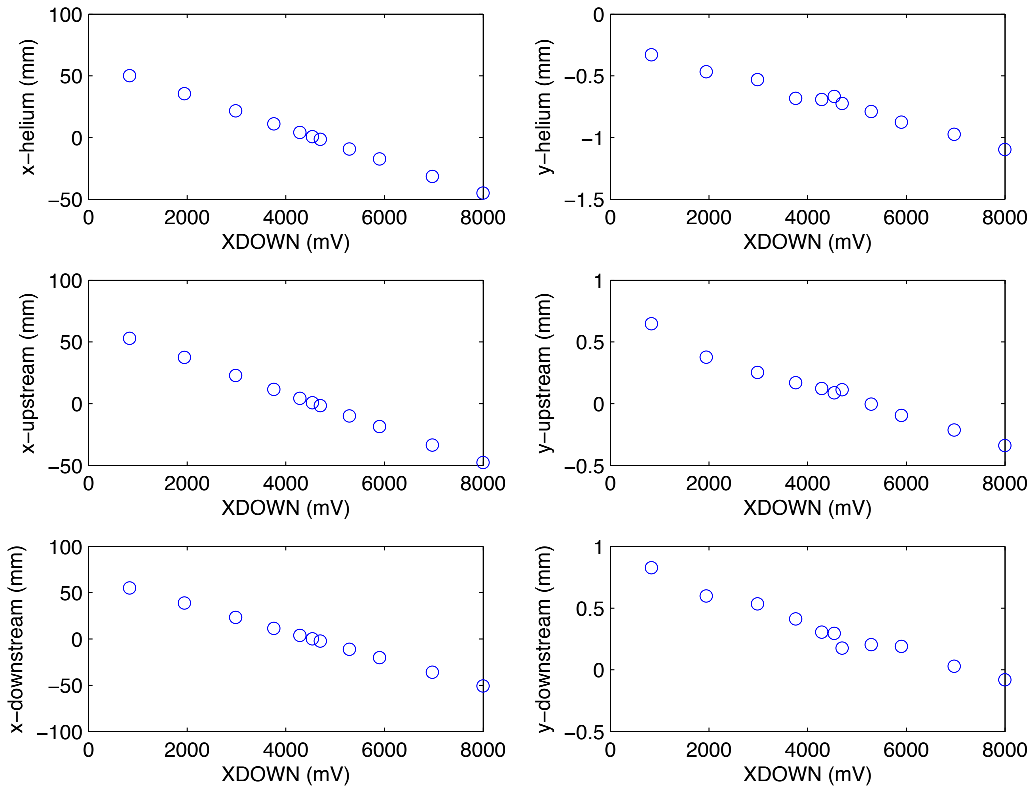

Figure 6: Target position versus X_{DOWN} actuator encoder value with the other actuators fixed at their "hydrogen cell in beam" values.

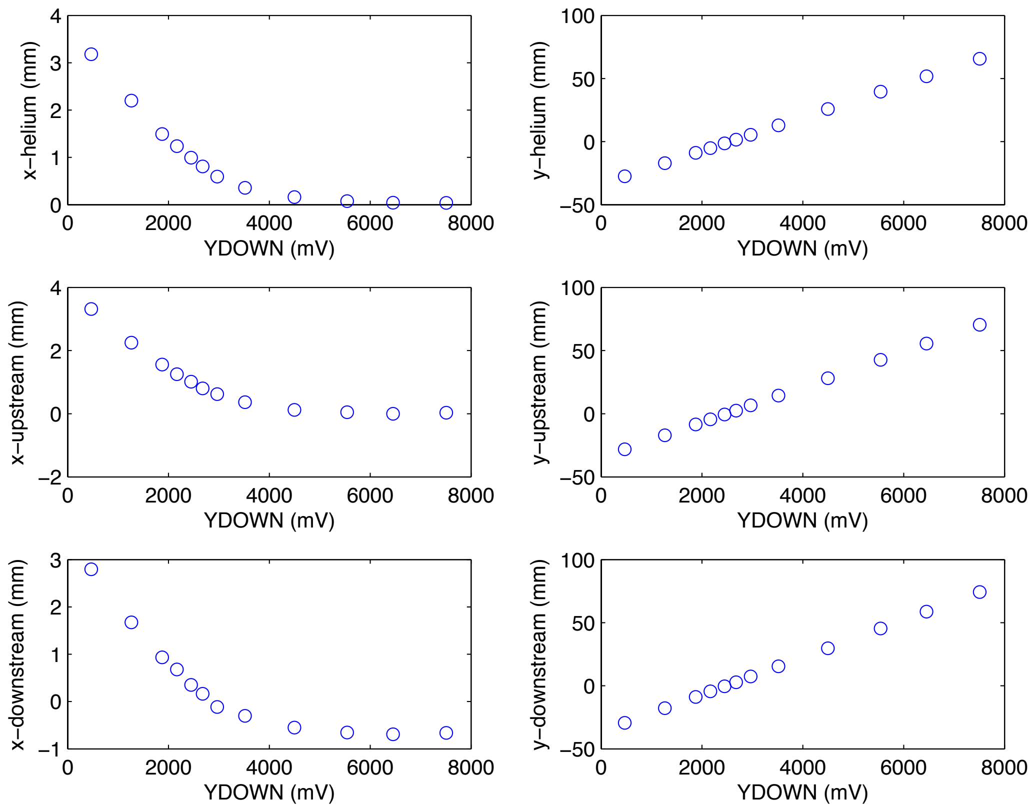

Figure 7: Target position versus Y_{DOWN} actuator encoder value with the other actuators fixed at their "hydrogen cell in beam" values.

following values:

$$c = \begin{pmatrix} 113.7407 \\ -120.9096 \\ 121.9648 \\ -130.2715 \\ 129.3771 \\ -139.8093 \end{pmatrix} \text{mm}, \tag{4}$$

$$A = \begin{pmatrix} -0.0121 & -0.0017 & -0.0133 & -0.0015 \\ 0.0015 & 0.0120 & -0.0002 & 0.0132 \\ -0.0132 & -0.0018 & -0.0140 & -0.0016 \\ 0.0016 & 0.0132 & -0.0002 & 0.0139 \\ -0.0144 & -0.0020 & -0.0148 & -0.0017 \\ 0.0017 & 0.0143 & -0.0002 & 0.0147 \end{pmatrix} \frac{\text{mm}}{\text{mV}}, \tag{5}$$

$$B = 10^{-6} \times \begin{pmatrix} -0.0131 & 0.2258 & 0.0008 & 0.1438 \\ -0.2032 & 0.0061 & 0.0058 & 0.0019 \\ -0.0133 & 0.2464 & -0.0020 & 0.1518 \\ -0.2223 & -0.0008 & 0.0099 & 0.0065 \\ -0.0128 & 0.2657 & -0.0007 & 0.1602 \\ -0.2381 & 0.0045 & 0.0109 & 0.0039 \end{pmatrix} \frac{\text{mm}}{(\text{mV})^2}. \tag{6}$$

The fit residuals are shown in Fig. 8. The precision in x it is better than 0.5 mm, while in y it is better than 0.2 mm.

3.1 Linearized Model

In order to follow the convention used in the G^0 commissioning and forward angle runs the model in Eq. (1) was linearized about the "hydrogen cell in beam" position and restricted to predicting only the upstream and downstream circle positions. This simplified model is written as

$$\delta y' = A'(\delta x), \tag{7}$$

where

$$\delta y' = \begin{pmatrix} \delta x_{\text{downstream}} \\ \delta x_{\text{upstream}} \\ \delta y_{\text{downstream}} \\ \delta y_{\text{upstream}} \end{pmatrix}, \qquad \delta x = \begin{pmatrix} \delta X_{\text{UP}} \\ \delta Y_{\text{UP}} \\ \delta X_{\text{DOWN}} \\ \delta Y_{\text{DOWN}} \end{pmatrix}, \tag{8}$$

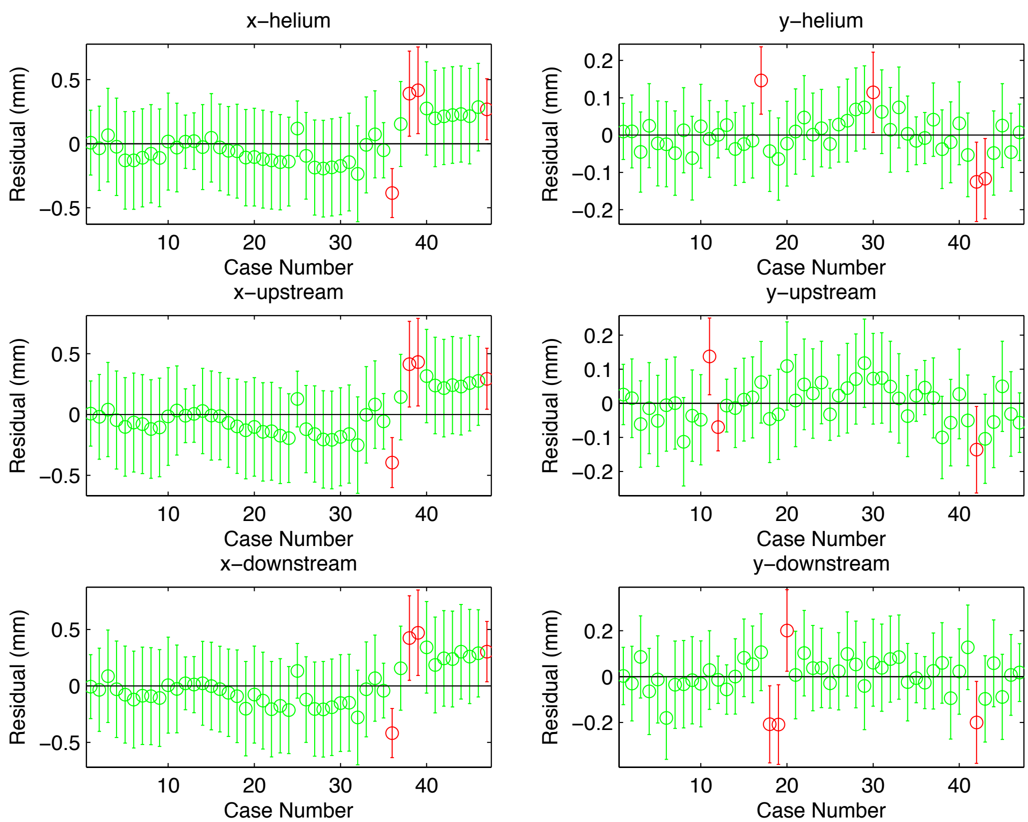

Figure 8: Fit residuals for the model given by Eq. (1). The errorbars correspond to a 95% CL.

represent the *changes* in the position and actuator encoder values, and

$$A' = \begin{pmatrix} -14.4538 & 1.7817 & -14.7991 & -0.8667 \\ -13.3398 & 1.6510 & -14.0659 & -0.8225 \\ -0.1721 & 14.3526 & -0.1202 & 14.7229 \\ -0.1469 & 13.2235 & -0.1270 & 13.9675 \end{pmatrix} \frac{\mu\text{m}}{\text{mV}} \tag{9}$$

is the slope matrix. Note the change in coordinate units from mm to μm. From Eq. (9) one finds that the changes in the actuator encoder values needed for a 1 mm parallel displacement of the target cell are:

Displacement	δX_{UP}	δX_{DOWN}
1 mm right	-126	+188
1 mm left	+126	-188

Displacement	δY_{UP}	δY_{DOWN}
1 mm up	-131	+195
1 mm down	+131	-195

The cross terms are small and can be ignored.