CLAS12 Forward Time-of-Flight Survey Requirements

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ftof_survey.tex

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Abstract

This document details the survey requirements and plans for the CLAS12 Forward Time-of-Flight System (FTOF).

1 FTOF Overview

The CLAS12 detector in Hall B at Jefferson Laboratory is built around a six-coil toroidal magnet that divides the active detection area into six azimuthal regions called sectors. Each sector subtends an azimuthal range of 60° from the mid-plane of one coil to the mid-plane of the adjacent coil. The sector mid-plane is an imaginary plane that bisects the azimuth of each sector.

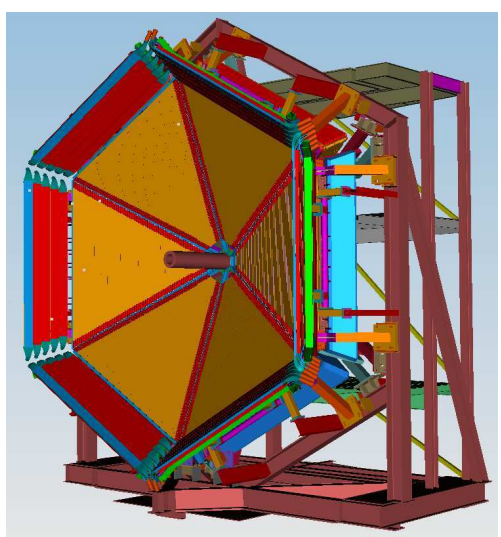

Figure 1: View of the FTOF system for CLAS12. The panel-1b counter arrays are shown in orange and the panel-2 counter arrays, mounted about the perimeter of the Forward Carriage, are shown in red. The panel-1a counter arrays mounted just downstream of the panel-1b are not visible in this picture. The Forward Carriage is roughly 10 m across.

The Forward Time-of-Flight System (or FTOF) is a major component of the CLAS12 forward detector used to measure the time-of-flight of charged particles emerging from interactions in the target. The average path length from the target to the FTOF counters is roughly 7 m. In each of the six sectors of CLAS12, the FTOF system is comprised of three sets of counters arrays, referred to as panels, named panel-1a, panel-1b, and panel-2. Each panel consists of an array of rectangular scintillators with a photomultiplier tube (PMT) on each end. The panel-1a and panel-1b arrays are mounted on the Forward Carriage in Hall B, with panel-1a positioned immediately behind panel-1b. These two triangular-shaped arrays of counters cover the angular range from roughly 5° to 35°. Panel-1a is installed immediately upstream of the new Preshower Calorimeter (PCAL). The panel-2 counter arrays are positioned at larger angles (roughly 35° to 45°) and are mounted about the perimeter of the Forward Carriage. The positioning of the different FTOF detector arrays on the Forward Carriage is shown in Fig. 1.

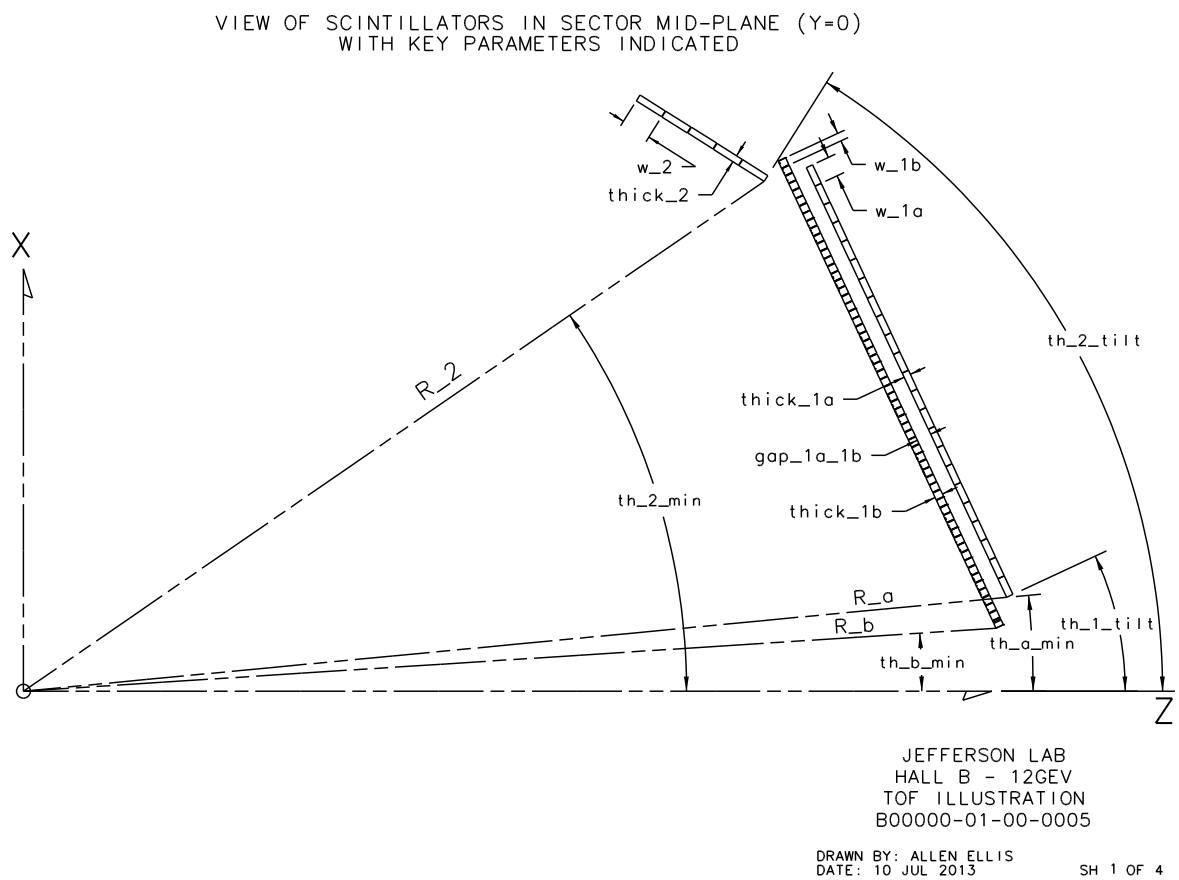

Figure 2: View of FTOF scintillators for panel-1a, panel-1b, and panel-2 in the sector mid-plane with the key parameters indicated for a single representative sector.

2 FTOF Geometry

2.1 Model Geometry

The geometry for each FTOF array is specified by a limited set of parameters. Figure 2 shows a view of the scintillator arrays in a single representative sector. This view is in the sector mid-plane and the key parameters used to specify the geometry are indicated. These parameters include:

- **R_a** - distance from the nominal CLAS12 center to the small angle upstream edge of panel-1a counter #1.
- **R_b** - distance from the nominal CLAS12 center to the small angle upstream edge of panel-1b counter #1.
- **th_a_min** - polar angle of the ray marking R_a.
- **th_b_min** - polar angle of the ray marking R_b.
- **th_1_tilt** - tilt angle of the panel-1a and panel-1b arrays relative to the electron beamline.
- **thick_1a** - thickness of the panel-1a scintillators.
- **w_1a** - width of the panel-1a scintillators.
- **thick_1b** - thickness of the panel-1b scintillators.
- **w_1b** - width of the panel-1b scintillators.
- **gap_1a_1b** - separation between panel-1a and panel-1b.
- **R_2** - distance from the nominal CLAS12 center to the small angle upstream edge of panel-2 counter #1.
- **th_2_min** - polar angle of the ray marking R_2.
- **th_2_tilt** - tilt angle of the panel-2 array relative to a line perpendicular to the electron beamline.
- **thick_2** - thickness of the panel-2 scintillators.
- **w_2** - width of the panel-2 scintillators.
- **gap_1a** - gap between neighboring panel-1a counters (not shown).
- **gap_1b** - gap between neighboring panel-1b counters (not shown).
- **gap_2** - gap between neighboring panel-2 counters (not shown).

The nominal values of the FTOF geometry parameters from the design model are listed in Table 1. Note that there are two values listed for gap_1b. The smaller value is the gap between counters mounted to a single backing structure and the larger value is the gap between counters on neighboring backing structures. Tables 6, 7, and 8 in the Appendix (Section 4) contain a listing of the coordinates of the center point on the upstream face of each scintillator in panel-1a, panel-1b, and panel-2 in Sector 1 (see Fig. 3)for the CLAS12 sector naming convention) calculated using these values. The coordinates are listed in the Hall B coordinate system with the z-axis along the electron beamline pointing downstream, the x-axis pointing toward beam left, and the y-axis pointing upward, thus defining a right-handed coordinate system. The origin is located at the center of the nominal CLAS12 target position.

Parameter	Nominal Value
R_a	726.689 cm
R_b	717.236 cm
th_a_min	5.453°
th_b_min	3.667°
th_1_tilt	25°
thick_1a	5.08 cm
w_1a	15.01 cm
thick_1b	6.0 cm
w_1b	6.0 cm
gap_1a_1b	10.717 cm
R_2	659.71 cm
th_2_min	34.698°
th_2_tilt	58.11°
thick_2	5.08 cm
w_2	22.0 cm
gap_1a	0.1384 cm
gap_1b	0.04 cm, 0.200 cm
gap_2	0.302 cm

Table 1: Table of the nominal geometry parameters for the CLAS12 FTOF detector system.

2.1.1 Scintillator Lengths

The nominal scintillator layout and naming convention for panel-1a, panel-1b, and panel-2 are shown in Figs. 4, 5, and 6, respectively. The panel-1a arrays each contain 23 counters, the panel-1b arrays each contain 62 counters, and the panel-2 arrays each contain 5 counters. The lengths of the individual bars are given in Tables 2, 3, and 4.

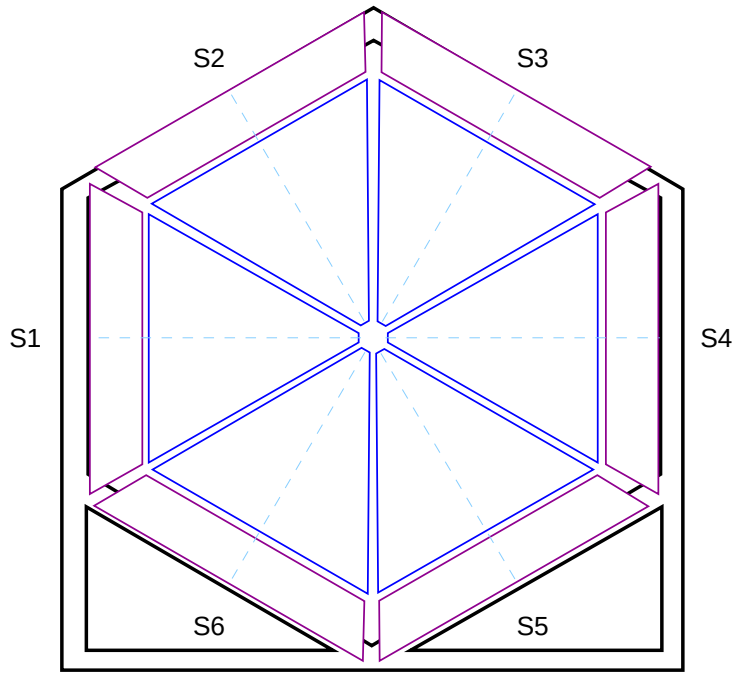

Figure 3: View of the upstream face of the Forward Carriage in Hall B showing the CLAS12 sector naming conversion for Sector 1 (S1) through Sector 6 (S6). The dashed lines denote the mid-planes for each sector.

Counter	Length (cm)	Counter	Length (cm)	Counter	Length (cm)
1	32.3	11	185.8	21	344.4
2	48.1	12	201.7	22	360.2
3	64.0	13	217.6	23	376.1
4	79.8	14	233.4		
5	95.7	15	249.3		
6	106.6	16	265.1		
7	122.4	17	281.0		
8	138.3	18	296.8		
9	154.1	19	312.7		
10	170.0	20	328.5		

Table 2: FTOF panel-1a counter lengths (cm) for each scintillator. Each panel-1a scintillator is 15.0 cm wide.

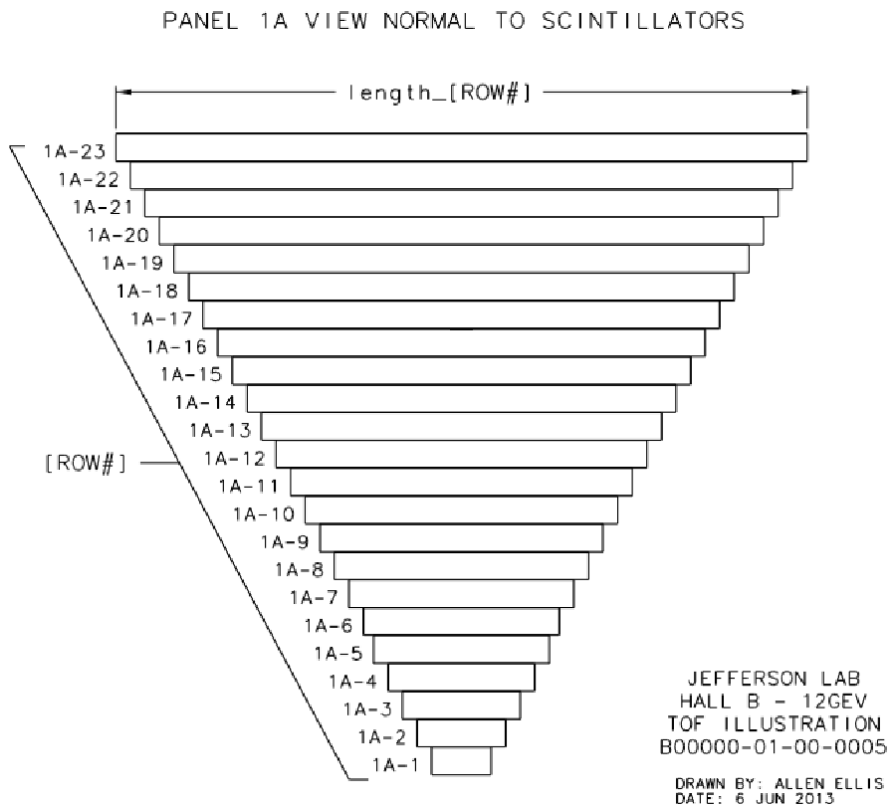

Figure 4: View of the face of a generic FTOF panel-1a array showing the numbering scheme for the 23 scintillators that make up the counters in each of the six sectors of CLAS12.

Counter	Length (cm)	Counter	Length (cm)	Counter	Length (cm)	Counter	Length (cm)
1	17.27	17	119.75	33	222.22	49	324.69
2	23.62	18	126.10	34	228.57	50	331.04
3	30.08	19	132.56	35	235.03	51	337.50
4	36.43	20	138.91	36	241.38	52	343.85
5	42.89	21	145.37	37	247.84	53	350.31
6	49.24	22	151.72	38	254.19	54	356.66
7	55.70	23	158.17	39	260.65	55	363.12
8	62.05	24	164.52	40	267.00	56	369.47
9	68.51	25	170.98	41	273.46	57	375.93
10	74.86	26	177.33	42	279.81	58	382.28
11	81.32	27	183.79	43	286.27	59	388.74
12	87.67	28	190.14	44	292.62	60	395.09
13	94.13	29	196.60	45	299.08	61	401.55
14	100.48	30	202.95	46	305.43	62	407.90
15	106.94	31	209.41	47	311.88		
16	113.29	32	215.76	48	318.23		

Table 3: FTOF panel-1b counter lengths (cm) for each scintillator. Each panel-1b scintillator is 6.0 cm wide.

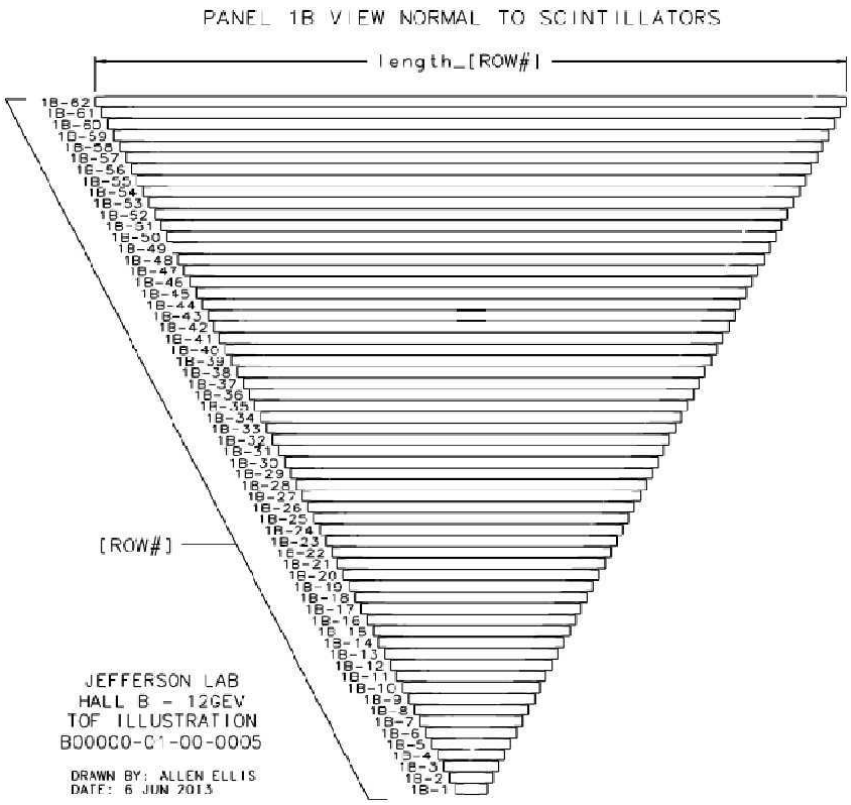

Figure 5: View of the face of a generic FTOF panel-1b array showing the numbering scheme for the 62 scintillators that make up the counters in each of the six sectors of CLAS12.

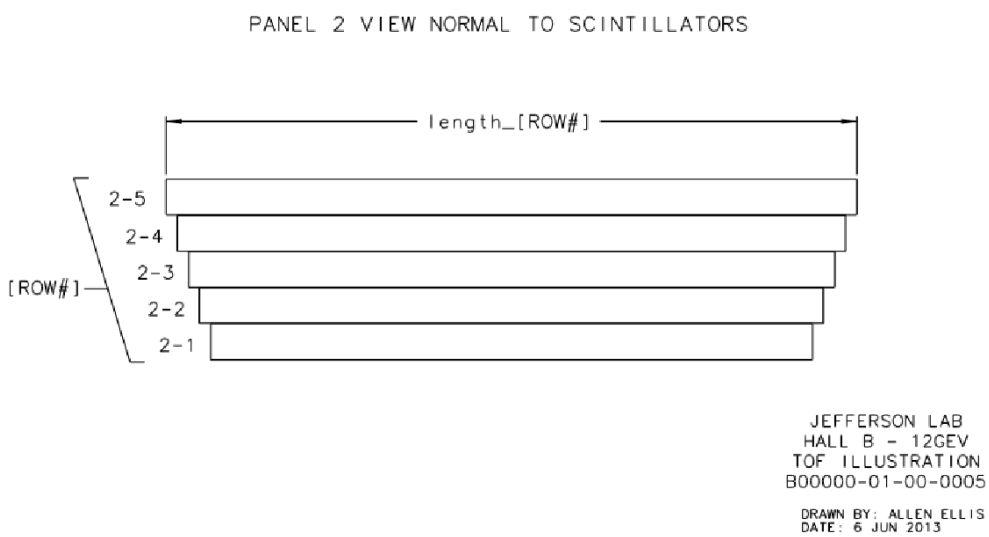

Figure 6: View of the face of a generic FTOF panel-2 array showing the numbering scheme for the 5 scintillators that make up the counters in each of the six sectors of CLAS12.

Counter	Length (cm)
1	371.3
2	385.0
3	398.7
4	412.5
5	426.2

Table 4: FTOF panel-2 counter lengths (cm) for each scintillator. Each panel-2 scintillator is 22.0 cm wide.

2.2 Nominal Geometry

The positioning of the individual FTOF scintillators shown in Fig. 2 is based on the design model. The true positioning of the bars must account for the material layers that are wrapped around the bare scintillator material, as well as the nominal gaps between the bars as they are placed on their mounting frames. To determine the nominal bar positioning on the frames, we use the known thicknesses of the wrapping materials for each bar and the average counter-to-counter gaps determined from the assembled arrays.

To specify the FTOF geometry we introduce a sector-based coordinate system for each array defined as in Fig. 7. Here the X' axis lies along the sector mid-plane, the Y' axis lies along the small-angle edge of the scintillator closest to the beamline (called the inner edge), and the Z' axis goes into the page. To determine the nominal geometry and positioning of the FTOF scintillators on the counter frames, the overall radial extent of each counter array along the X' axis must be known. The values from direct measurements of the counters on their associated frames are given in Table 5. The last two rows of Table 5 show the average overall radial extent and the standard deviation σ of the sector-to-sector variations for each of the different FTOF arrays.

	Array Radial Width (cm)		
Sector	Panel-1a	Panel-1b	Panel-2
1	349.409	379.254	110.966
2	348.774	379.413	110.569
3	348.774	379.254	110.966
4	349.568	379.095	110.808
5	349.409	379.254	110.808
6	349.488	379.095	110.728
Avg.	349.237	379.228	110.733
σ	0.33	0.11	0.24

Table 5: Overall sector radial extent (cm) for each of the FTOF panel-1a, panel-1b, and panel-2 arrays, including the computed average and standard deviation values.

From the information included in Table 5 on the overall radial extents (W^{rad}) of each counter array, along with knowledge of the wrapping materials and how the counters are stacked on the frames, the nominal gap between each of the counters on the frames can be

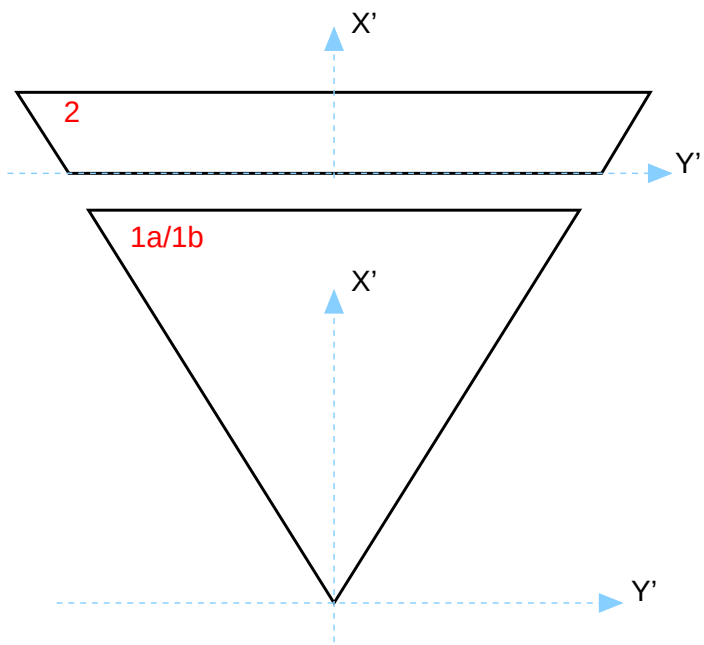

Figure 7: Definition of the X', Y', Z' local coordinate system for each panel-1a, panel-1b, and panel-2 counter array. In this scheme, the scintillators run parallel to the Y' axis and the Z' axis goes into the page.

computed and compared to a sampling of the measured values. The average gap between counters can be determined by the following formula for panel-1a and panel-2:

$$W_{1a,2} \;=\; (N_c \cdot W_c) + (2 \cdot t_{material} \cdot N_c) + (N_c - 1) \cdot gap. \tag{1}$$

For panel-1b the appropriate formula is given by:

$$W_{1b} \;=\; (N_c \cdot W_c) + (2 \cdot t_{material} \cdot N_c) + (N_c/2 - 1) \cdot gap. \tag{2}$$

In these expressions, the overall panel radial extents ($W_{1a,1b,2}$) come from the average values given in Table 5, N_c is the number of counters in each panel (panel-1a = 23, panel-1b = 62, panel-2 = 5), W_c is the nominal width of the bare scintillators in each array (panel-1a = 15.0 cm, panel-1b = 6.0 cm, panel-2 = 22.0 cm), $t_{material}$ is the wrapping material thickness on each side of the counters, and *gap* is the nominal counter-to-counter gap on each frame. Note that for panel-1b, the pairs of counters on a single backing structure have no gap between the scintillators except for the wrapping materials. The separation between counters on different backing structures of panel-1b is given by the value of *gap*.

For panel-1a and panel-2 the wrapping materials include:

- 1 layer of 0.0094 in (0.02388 cm) thick Kapton,
- 2 layers of 0.001 in (0.00254 cm) thick aluminum foil,
- $t_{material}$ = 0.02896 cm (total thickness per side).

For panel-1b, the wrapping materials include:

- 3 layers of 0.0015 in (0.00381 cm) thick Tedlar,
- 1 layer of 0.0003 in (0.00076 cm) thick aluminized Polyester film,
- $t_{material} = 0.01219$ cm (total thickness per side).

Using Eqs. (1) and (2), this gives the following nominal average counter-to-counter gap values:

- Panel-1a: $gap = 0.132$ cm,
- Panel-1b: $gap = 0.191$ cm (gap between counter pairs as noted above),
- Panel-2 : $gap = 0.111$ cm.

The computed gaps can be compared against a sampling of the measured counter-to-counter gaps. For panel-1a, the typical measured gaps fell into the range from 0.127 cm to 0.152 cm. For panel-1b, the typical measured gaps were in the range from 0.127 cm to 0.203 cm. For panel-2, the typical measured gaps fell into the range from 0.076 cm to 0.254 cm. The measured gaps are reasonably consistent with the values computed for these gaps.

3 Survey Plans

In order to account for differences between the as-built/as-installed geometry of the FTOF arrays in each sector relative to the nominal geometry, the absolute locations of the arrays need to be determined by the JLab Survey Group. The basic survey procedure involves determining the location of each of the FTOF arrays after installation relative to fixed monuments on the Forward Carriage. After the Forward Carriage is moved into its nominal physics running position, the fixed survey monuments are then located relative to the nominal Hall B coordinate system. This coordinate system has its z-axis along the electron beam line pointing downstream, its x-axis pointing toward beam left along the mid-plane of Sector 1, and its y-axis pointing upward. The origin of this right-handed coordinate system is located at the nominal CLAS12 target center. The survey information is then used to determine the absolute positions of the individual FTOF arrays.

The survey information will be used to determine position offsets for each FTOF array, $\Delta X'$, $\Delta Y'$, and $\Delta Z'$, in the local sector-based coordinate system, representing the shift in the position of the array relative to its nominal position in the CLAS12 model. The information from survey will also be used to determine the rotation angles of each array about its different coordinate axes. These rotation angles are referred to as pitch, yaw, and roll, where θ_{pitch} is the pitch angle for rotations about the Y' axis, θ_{yaw} is the yaw angle for rotations about the X' axis, and θ_{roll} is the roll angle for rotations about the Z' axis. Thus the survey results for each FTOF array in each sector should amount to six quantities, the offsets $\Delta X'$, $\Delta Y'$, and $\Delta Z'$, and the rotations θ_{pitch}, θ_{yaw}, and θ_{roll}.

The nominal position of the individual FTOF counters for panel-1a, panel-1b, and panel-2 in each of the sectors of CLAS12 will be specified through the FTOF *Geometry Service*,

which is based on the information included in Section 2. However, the FTOF positioning determined from the *Geometry Service* software will include the position and angle offsets to account for the information provided by the counter survey data.

The procedure to determine the positions of the scintillators in each panel-1a and panel-1b FTOF array will include the following steps:

1. Prior to installation of the individual FTOF arrays on the Forward Carriage, survey markers for use with the Survey Group's laser tracker (a coordinate measuring machine) will be attached to the support frames of the panel-1a and panel-1b arrays. The nominal plan is to attach the hardware for two markers in the nose and two markers in the rear of each mounting frame. These markers allow for precise determination of their associated (x, y, z) coordinates. These markers will be fiducialized relative to the scintillators such that they can be used to locate the counter positions after they are surveyed.

2. After installation of the panel-1a and panel-1b arrays on the Forward Carriage, the survey measurements using the laser tracker will include sighting the installed survey markers on each sector frame. These markers will enable quick checks of the arrays in the future after servicing work that requires removal of the arrays.

3. Survey measurements will define the plane of the counters. This is done by holding the target of the laser tracker against the upstream face of the counters. At least ten points sampled (reasonably) uniformly over the surface of each array will allow for a fit of the data to determine the counter plane. This data can also be used to determine θ_{pitch} and θ_{yaw}.

4. Survey measurements will define the edges of the first and last counters in each array. This is done by locating the target of the laser tracker as it is placed in several locations along the inner edge of counter #1 and several locations along the outer edge of the last counter. This information will determine the extents in X' of each array and can be used to determine θ_{roll}.

5. The final survey measurements will locate the ends of the light-tight boots of panel-1a (just at the end of the cylindrical portion of the boot) and the ends of the shield boxes for panel-1b. Measurements will be taken using the target of the laser tracker at roughly six PMTs on each side of each array. This information can also be used to determine θ_{yaw}.

The survey of the panel-2 arrays will follow a different approach as the support frames are not visible from the upstream side of the arrays and because the ends of the counters are not well defined given the attachment of the curved light guides and the presence of the light-tight wrapping. The survey measurements will include the following steps:

1. After installation of the panel-2 arrays on the Forward Carriage, survey measurements will define the plane of the counters. This is done by holding the target of the laser tracker against the upstream face of the counters. At least six points sampled (reasonably) uniformly over the surface of each array will allow for a fit of the data to determine the counter plane. This data can also be used to determine θ_{pitch} and θ_{yaw}.

2. Survey measurements will define the edges of the first and last counters in each array. This is done by locating the target of the laser tracker as it is placed in several locations along the inner edge of counter #1 and several locations along the outer edge of counter #5. This information will determine the extents in X' of each array and can also be used to determine θ_{roll}.

3. The center-lines of the counters will be determined by measuring the support frames. The center-line of the frames will be used as the center-line of the counters. Note that the center-lines determined in this manner can be cross-checked against the crude center-lines marked on the counters. Additional survey holes will be drilled into the frames to fiducialize the panels on the Forward Carriage.

3.1 Required Survey Accuracy

The requirement is to have survey numbers that allow for determination of the absolute positioning of the individual FTOF counters to the level of 5 mm in all coordinates. This specification is based on the requirement that the counter position uncertainty contributes no more than 50% to the overall reconstructed mass uncertainty for charged hadrons. With the flight time from the target to the FTOF system given by:

$$t = L/(\beta c), \tag{3}$$

with L the path length, c the speed of light, and β the hadron velocity given by:

$$\beta = \frac{p}{\sqrt{p^2 + m^2}}, \tag{4}$$

the reconstructed hadron mass in the CLAS12 system can be written as:

$$m = \sqrt{p^2 \left(\frac{t^2 - L^2}{L^2} \right)}. \tag{5}$$

From this expression, the relative uncertainty in the reconstructed mass $\Delta m/m$ is given by:

$$\left(\frac{\Delta m}{m} \right)^2 = \left(\frac{\Delta p}{p} \right)^2 + \gamma^4 \left[\left(\frac{\Delta L}{L} \right)^2 + \left(\frac{\Delta t}{t} \right)^2 \right]. \tag{6}$$

Thus the relative uncertainty on the reconstructed hadron mass has contributions from three sources, the relative uncertainties of the particle momentum p, the path length L, and the flight time t.

Figure 8 shows calculations of the three different contributions to the overall mass resolution from Eq. (6) (in % of the overall resolution), assuming a reconstructed momentum resolution of 1% from the DC system and a timing resolution of 50 ps from the FTOF system (both typical values expected for CLAS12 measurements), with three different assumptions for the path length uncertainty of 1 mm, 5 mm, and 10 mm. Calculations were carried out for pions, kaons, and protons. Fig. 8 shows that with a path length uncertainty (or absolute FTOF counter position uncertainty) of 5 mm, the requirement that the path length uncertainty be no more than 50% of the overall mass resolution can be met. Under these

conditions, the reconstructed hadron mass resolution is dominated by the FTOF timing measurement, except for low momentum kaons and protons where the momentum resolution is the dominant contribution.

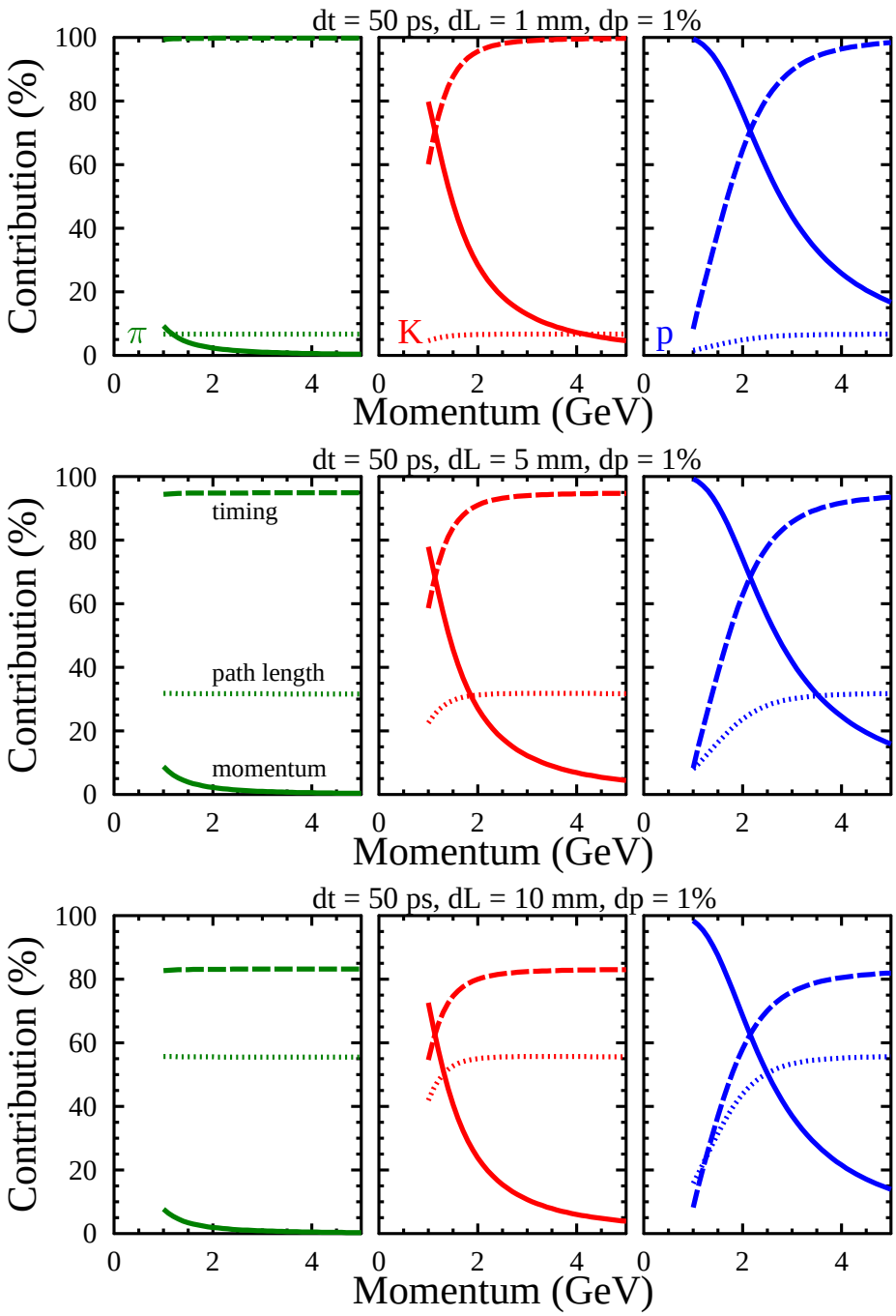

Figure 8: Calculations of the different contributions to the reconstructed hadron mass as a function of hadron momentum for pions (left), kaons (middle), and protons (right). The vertical axis represents the relative contribution to the overall mass resolution (in %) for each of the three terms of Eq. (6), the time resolution uncertainty (dashed lines), path length uncertainty (dotted lines), and momentum resolution (solid lines). The calculations assume a time resolution of 50 ps and a momentum resolution of 1%. The path length uncertainties considered are 1 mm (top), 5 mm (middle), and 10 mm (bottom).

4 Appendix

Using the values in Table 1 the x and z coordinates at the center of the upstream face of each bar can be computed for counter N using:

<u>Panel-1a & Panel-2</u>

$$x = R\sin(th\_min) + [(N-1)(t+gap) + 0.5t]\cos(th\_tilt) \tag{7}$$
$$z = R\cos(th\_min) - [(N-1)(t+gap) + 0.5t]\sin(th\_tilt) \tag{8}$$

<u>Panel-1b</u>

$$N_{pair} = (mod(N,2)+N)/2, \qquad N_{member} = mod(N+1,2) \tag{9}$$
$$x = R\sin(th\_min) + [(2t+gap_1+gap_2)(N_{pair}-1) + (t+gap_1)N_{member} + 0.5t]\cos(th\_tilt) \tag{10}$$
$$z = R\cos(th\_min) - [(2t+gap_1+gap_2)(N_{pair}-1) + (t+gap_1)N_{member} + 0.5t]\sin(th\_tilt) \tag{11}$$

Counter	x (cm)	y (cm)	z (cm)	R (cm)
1	75.859	-0.076	720.228	724.212
2	89.590	-0.079	713.826	719.426
3	103.320	-0.082	707.423	714.928
4	117.050	-0.085	701.021	710.725
5	130.781	-0.088	694.618	706.822
6	144.511	-0.091	688.215	703.224
7	158.241	-0.093	681.813	699.935
8	171.972	-0.096	675.410	696.960
9	185.702	-0.099	669.008	694.303
10	199.433	-0.102	662.605	691.967
11	213.163	-0.105	656.203	689.957
12	226.893	-0.108	649.800	688.274
13	240.624	-0.111	643.397	686.921
14	254.354	-0.114	636.995	685.900
15	268.085	-0.117	630.592	685.212
16	281.815	-0.120	624.190	684.859
17	295.545	-0.123	617.787	684.841
18	309.276	-0.125	611.384	685.159
19	323.006	-0.128	604.982	685.810
20	336.736	-0.131	598.579	686.796
21	350.467	-0.134	592.177	688.114
22	364.197	-0.137	585.774	689.761
23	377.928	-0.140	579.372	691.737

Table 6: Table of the nominal coordinates in the Hall B coordinate system locating the center point on the upstream face of the scintillators for each FTOF counter in panel-1a for Sector 1.

Counter	x (cm)	y (cm)	z (cm)	R (cm)	Counter	x (cm)	y (cm)	z (cm)	R (cm)
1	48.592	0.029	714.500	716.150	32	220.464	0.029	634.354	671.573
2	54.066	0.029	711.947	713.997	33	226.083	0.029	631.734	670.971
3	59.685	0.029	709.327	711.833	34	231.557	0.029	629.182	670.439
4	65.159	0.029	706.774	709.771	35	237.176	0.029	626.561	669.949
5	70.778	0.029	704.154	707.702	36	242.650	0.029	624.009	669.527
6	76.252	0.029	701.601	705.733	37	248.269	0.029	621.388	669.150
7	81.871	0.029	698.981	703.760	38	253.743	0.029	618.836	668.837
8	87.345	0.029	696.429	701.885	39	259.363	0.029	616.216	668.574
9	92.964	0.029	693.808	700.009	40	264.837	0.029	613.663	668.372
10	98.439	0.029	691.256	698.230	41	270.456	0.029	611.043	668.221
11	104.058	0.029	688.635	696.453	42	275.930	0.029	608.490	668.130
12	109.532	0.029	686.083	694.771	43	281.549	0.029	605.870	668.093
13	115.151	0.029	683.463	693.095	44	287.023	0.029	603.317	668.112
14	120.625	0.029	680.910	691.512	45	292.642	0.029	600.697	668.189
15	126.244	0.029	678.290	689.938	46	298.116	0.029	598.144	668.319
16	131.718	0.029	675.737	688.455	47	303.735	0.029	595.524	668.509
17	137.337	0.029	673.117	686.985	48	309.209	0.029	592.972	668.749
18	142.811	0.029	670.564	685.603	49	314.829	0.029	590.351	669.053
19	148.430	0.029	667.944	684.237	50	320.303	0.029	587.799	669.404
20	153.905	0.029	665.391	682.959	51	325.922	0.029	585.179	669.820
21	159.524	0.029	662.771	681.699	52	331.396	0.029	582.626	670.281
22	164.998	0.029	660.219	680.524	53	337.015	0.029	580.006	670.810
23	170.617	0.029	657.598	679.372	54	342.489	0.029	577.453	671.380
24	176.091	0.029	655.046	678.302	55	348.108	0.029	574.833	672.021
25	181.710	0.029	652.426	677.257	56	353.582	0.029	572.280	672.700
26	187.184	0.029	649.873	676.293	57	359.201	0.029	569.660	673.452
27	192.803	0.029	647.253	675.359	58	364.676	0.029	567.107	674.240
28	198.277	0.029	644.700	674.501	59	370.295	0.029	564.487	675.103
29	203.896	0.029	642.080	673.677	60	375.769	0.029	561.935	675.997
30	209.371	0.029	639.527	672.927	61	381.388	0.029	559.314	676.971
31	214.990	0.029	636.907	672.214	62	386.862	0.029	556.762	677.972

Table 7: Table of the nominal coordinates in the Hall B coordinate system locating the center point on the upstream face of the scintillators for each FTOF counter in panel-1b for Sector 1.

Counter	x (cm)	y (cm)	z (cm)	R (cm)
1	381.349	0.000	533.050	655.416
2	393.129	0.000	514.117	647.200
3	404.909	0.000	495.185	639.656
4	416.689	0.000	476.252	632.808
5	428.469	0.000	457.319	626.679

Table 8: Table of the nominal coordinates in the Hall B coordinate system locating the center point on the upstream face of the scintillators for each FTOF counter in panel-2 for Sector 1.