Assembly and Testing of the Forward Time-of-Flight Panel-1b for CLAS12

April 26th, 2012

Introduction

The Experimental Nuclear Physics Group at the University of South Carolina has been involved in hardware construction and physics analysis as part of the CLAS collaboration and one of its founding members. We are excited about the opportunity to push the strong interaction research with the energy-upgraded electron beam at Jefferson Lab and particularly the proposed and planned physics program with the CLAS12 detector. We have committed to assemble, instrument, and test the Forward Time-of-Flight Panel-1b detector as part of the new CLAS12 spectrometer, as described in the Memorandum of Understanding between Jefferson Lab (JSA) and the University of South Carolina that was signed in November 2010.

We have extensive experience in assembling large time-of-flight (TOF) detectors based on developing, building, and successfully running the ELAN (ELektronstreuung An Nukleonen) TOF spectrometer, including full lifecycle electronic module development, at ELSA (ELectron Stretcher Accelerator) in Bonn, Germany [1]. We also have extensive design, development, and prototyping experience with individual Forward Time-of-Flight Panel-1b scintillation detectors, where we exceeded the CLAS12 design requirements, see FTOF12 Technical Review Document presented in November 2009 [2] and the project wiki pages [3]. This document fulfills the information request in Section 1.7 of the Statement of Work of this RFP under the solicitation number JSA-11-R297094.

a. Assembly and Storage Spaces

The University of South Carolina Research Foundation (USCRF) through the Experimental Nuclear Physics Group will provide lab space of at least 1122 ft^2 for the Panel-1b FTOF project. This includes storage, test, and assembly areas. A key aspect required on-site at the University of South Carolina to carry out the assembly effort is the availability of assembly space with a minimum floor area of 16 ft x 16 ft and at least 16 ft high. This area is the central assembly area for gluing, wrapping, and mounting. Additional areas provided by USCRF are designated separated areas for PMT and magnetic-shield testing, for validation and verification of the required specifications through detailed six-bar measurements of all identical-length scintillators, for data analysis, and office space for the key personnel.

All scintillators sent by the manufacturer, backing structures for pairs of

[1] BONN-IR-90-34 (Master's Thesis) and BONN-MS-97-04 (Technical Note)
[2] http://www.physics.sc.edu/~gothe/research/pub/FToF12-review-11-09.pdf
[3] http://clasweb.jlab.org/wiki//index.php/CLAS12_Time-of-Flight

scintillators, and additional support structures for shipping have to be stored individually or in assembled units at USC before they are transported to Jefferson Lab. For this purpose, a dedicated shelving system will be installed. Since the shelving system should be capable of holding fully assembled units, the shelf-spacing calculation was performed for this maximum-spacing scenario. In each sector, the FTOF panel-1b subsystem contains 64 scintillators (384 overall), with cross-sections of 6 cm by 6 cm, and lengths ranging, including PMTs and shielding, from roughly 50 cm to 400 cm. The backing structures and shipping support structures add 6 cm each to the vertical space needed for storage. Thus, the shelving system must have shelves of 430-cm length and 18-cm accessible height. An additional 7 cm in height was allowed for the shelf material and clearance for reaching inside. To accommodate easy handling of stored units, a 65-cm shelf depth was chosen.

b. Key Personnel

The Principal Investigator (PI) for this project is Prof. Ralf W. Gothe. He is designated as the USC FTOF assembly manager and is supported by Gleb Fedotov and Evan Phelps (or to be named), who are fully integrated and knowledgeable secondary contacts. In case of short-term inaccessibility of the assembly manager, the secondary contacts will fill in. In the eventuality that the assembly manager will no longer be able to fulfill his duties, the Co-PI Prof. Steffen Strauch will fulfill his responsibilities.

c. Contingency and Assembly Plan

In the event of NIM-, VME-, or HV-related malfunctions, to guarantee quickest recovery time, JLab will provide replacements until necessary parts are repaired. In the event of other six-bar testing station equipment malfunctions (DAQ system, analysis workstation, LabView or analysis software, etc.) or PMT testing station equipment malfunctions (DAQ system, analysis workstation, software, Helmholtz coils, power supplies, CAMAC, etc.), USC FTOF panel-1b key personnel will expedite resolution. In the event of custom tooling malfunction (assembly windmill, centering tools, six-bar testing rack, cutting tools, etc.), USC FTOF panel-1b key personnel and USC workshop personnel will expedite resolution.

In the event of assembly or testing technician unscheduled absence, USC Experimental Nuclear Physics Group graduate students will substitute as needed. The contingency plan for assembly manager absence is laid out in Section b, Key Personnel, of this document.

The assembly process is task-oriented and organized into multiple parallel task tracks, allowing for flexible scheduling of small task groups. Technicians will be trained for each assigned task track. A detailed manual, troubleshooting guide, and quality assurance plan for each task track will be available and routinely maintained for each task track. A task track expert will always be approachable in case of any further problems.

Receiving and Storage

- Crew size: 2-3 for scintillators, depending on length.
- Shipping crate or box assessment with photo-documentation.
- Unpacking but not unwrapping the protective film provided by the manufacturer.
- Individual scintillator damage assessment with photo-documentation.
- Database entry with assessment notes, photo-documentation, and manufacturer supplied information. All subsequent task entries will refer to this baseline entry.
- Verify that all identification labels are present before storage.
- Store on the designated shelf of the incoming material storage area.

- Crew size: 1 for PMTs.
- Shipping crate or box assessment with photo-documentation.
- Unpacking but keeping the individual protective boxes provided by the manufacturer.
- Individual PMT damage assessment with photo-documentation.
- Database entry with assessment notes, photo-documentation, and manufacturer supplied information. All subsequent task entries will refer to this baseline entry.
- Verify that all identification labels are present on box and PMT before storage.
- Re-box individual PMTs and store on the designated shelf of the PMT cabinet.

- Crew size: 2-3 for backing structures, depending on length.
- Shipping crate or box assessment with photo-documentation.
- Unpacking and individual backing structure damage assessment with photo-documentation.
- Label with unique identifier composed of sector number and the corresponding odd number between 1, most inner and shortest, and 63, most outer and longest backing structure.
- Database entry with assessment notes, photo-documentation, and manufacturer supplied information. All subsequent task entries will refer to this baseline entry.
- Verify that all identification labels are present before storage.
- Store on the designated shelf of the incoming material storage area.

- Crew size: 1 for stoppers and mu-metal shielding.
- Shipping crate or box assessment with photo-documentation.
- Unpacking and individual item damage assessment with photo-documentation.
- Verify numbers of left-end stoppers, right-end stoppers, and screws.
- Label left- and right-end stoppers.
- Verify that mu-metal shielding dimensions are within specifications and that edges facing the scintillators are rounded.

- Label left- and right-end mu-metal shielding.
- Database entry with assessment notes, photo-documentation, and manufacturer supplied information.
- Verify that all labels are present before storage.
- Store on the designated shelf of the PMT cabinet.

- Crew size: 1 for incidentals, such as scintillator glue, various tapes, syringes, glue-mixing containers, etc.
- Shipping crate or box assessment with photo-documentation.
- Unpacking and individual item damage assessment with photo-documentation.
- Verify contents.
- Database entry with assessment notes, photo-documentation, and manufacturer supplied information.
- Verify that all labels are present before storage.
- Store in the designated area.

PMT Testing

- Crew size: 1
- <u>AT NO TIME SHOULD THE BOX BE OPEN WHILE THE HV IS ON!</u>
- <u>AT NO TIME SHOULD HV EXCEED 1750!</u>
- Unpack PMT and load PMT into and close black box, insert Sr-90 source into designated cavity as needed, and connect HV (do NOT turn it on yet) and signal cables.
- Apply optical grease to PMT as needed.
- Pull back and secure the sled
- Insert the PMT into the box with the ground oriented up and carefully press the PMT forward against the scintillator until flush, as indicated by the oozing of the grease from around the PMT
- Secure PMT in black box using rubber bands and release the sled allowing it to slide forward.
- 1500V dark current
  - Set the HV to 1500V, be as accurate as possible when setting the voltage for this and all other steps. After configuring the electronics, take Dark Current measurements for 1500V.
    - Remove the source.
    - Feed the anode signal into the Linear FiFo; one output going to the discriminator with a threshold of 10mV and output directly to a visual scalar. The second output should go to the oscilloscope.
    - For scalar measurements, remove the VETO for 100 seconds and record the count on the scalar
    - For Oscilloscope measurements, set vertical scale to 20mV, adjust trigger to 10mV, and take a range of frequency values and average
- 1500V ADC
  - Record (ADC mean – offset mean).

- Perform 2 times.
- For ADC measurements use the voltage splitter at 1500V even if not needed

- Baseline ADC
  - adjust HV to baseline
  - Record (ADC mean – offset mean).
  - Perform 2 times.
  - For ADC measurements use the voltage splitter even if not needed
- Baseline rate of events
  - Feed the anode signal with source into Linear FiFo; one output going to the discriminator with a threshold of 10mV and output directly to a visual scalar. The second output should go to the oscilloscope.
    - For scalar measurements, remove the VETO for 100 seconds and record the count on the scalar
    - For Oscilloscope measurements, set vertical scale to 20mV, adjust trigger to 10mV, and take a range of frequency values and average
- Baseline dark current
  - Feed the anode signal into the Linear FiFo; one output going to the discriminator with a threshold of 10mV and output directly to a visual scalar. The second output should go to the oscilloscope.
    - For scalar measurements, remove the VETO for 100 seconds and record the count on the scalar
    - For Oscilloscope measurements, set vertical scale to 20mV, adjust trigger to 10mV, and take a range of frequency values and average
- Baseline snapshot
- 1500 snapshot
- 1700 snapshot
- 1500 rate of events
  - Feed the anode signal with source into the Linear FiFo; one output going to the discriminator with a threshold of 10mV and output directly to a visual scalar. The second output should go to the oscilloscope.
    - For scalar measurements, remove the VETO for 100 seconds and record the count on the scalar
    - For Oscilloscope measurements, set vertical scale to 20mV, adjust trigger to 10mV, and take a range of frequency values and average
- 1500 dark current
  - Feed the anode signal into the Linear FiFo; one output going to the discriminator with a threshold of 10mV and output directly to a visual scalar. The second output should go to the oscilloscope.
    - For scalar measurements, remove the VETO for 100 seconds and record the count on the scalar
    - For Oscilloscope measurements, set vertical scale to 20mV, adjust trigger to 10mV, and take a range of frequency values and average
- Rise time
  - Plug into oscilloscope and read off the numbers

- Note: All measurements using the splitter or attenuators will result in values that are one half (for the splitter) or a fraction of (variable based on the attenuator) their actual value
- Add test results and notes to corresponding database entry. All measurements should have corresponding Oscilloscope snapshots and histograms where applicable.
- Remove any grease from black box at end of day.

Counter Assembly

- Crew size: 2-3, depending on length.
- Prepare and clean workbench area, and retrieve six identical-length scintillators from storage area.
- Use latex gloves before further handling the scintillators.
- Remove protective film only at the end faces of the scintillators.
- Each end of the scintillator is fitted with black tape (hereon referred to as “anticookie”), which masks the corners while leaving a circular window that extends one millimeter into the area that will be covered by the PMT. Apply anticookie end window.
- Mask the scintillator around top edges of protective tape with electrical tape slightly above the top edge. Fold the tape down to prevent glue driping.
- Place the scintillators Diamond cut side facing you horizontally into the windmill frame while maintaining a balanced load.
- Pressurize the air pistons to 40 psi to secure the scintillators in place.
- Use the hydraulic lift to raise the windmill frame, clearing it for rotation, and rotate so that the scintillators are vertically aligned.
- Secure height and rotation angle, and keep the compressor powered.
- Mount centering tool with open side facing you. Leave a 1.5 cm gap between the top of the scintillator and the centering tool for easy centering.
- Extract 7.4 ml of each of scintillator glue and 2.4 ml of catalyst using disposable syringes and squirt the content into a disposable mixing container.
- Mix and pour glue into a capped syringe with its stopper removed and mount it into one of the base holes in the vacuum chamber and seal.
- Close all valves and open valve to chamber from pump. Evacuate chamber to -30 psi. Close valve, turn pump off, and wait for 2 minutes. Open release valve on pump farthest from chamber to protect pump from condensation. Open release valve on chamber to restore pressure, and wait 2 minutes. Close all valves.
- Wrap paper towel around bottom base of centering to catch excess glue.
- Prepare PMT for glueing.
- Place stopper in syringe and squeeze out any remaining air from tip.
- Apply approximately 1 ml of glue to the top end of a scintillator, straight down in the center of the anticookie.
- Check for bubbles in glue. If bubbles are found reapply glue.
- Lower the PMT in a rotating motion through the centering tools slowly onto the

scintillators ensuring that copper on PMT points to front left corner.

- Continue process till all PMTs are mounted checking the syringe for any glue bubbles near the tip. If glue bubbles are present in the syringe you must remix new glue to ensure there are no bubbles.
- Using an Allen wrench set width of centering tools to center PMT if needed.
- Look in open area of centering tool to make sure the PMT is centered, then center between diamond-tooled side with gloved fingers. Re-verify centering of molded side with eyes.
- Distribute 3 wires evenly about PMT.
- After at least 12 hrs, rotate the windmill frame with the scintillators by 180^o, and repeat the gluing process.
- After at least 12 hrs, rotate the windmill frame into the horizontal, turn off the air compressor, and release the pressure.
- Prepare and clean workbench area, and move one counter onto the workbench.
- Create a single counter label that includes the manufacturer-provided identification numbers for the scintillator and the PMTs, as well as a position-dependent number *i* from 1, most inner and shortest, to 64, most outer and longest scintillator.
- Check that PMT orientations align with each other.
  - If the PMTs do not align with each other they must be re-glued.
  - If the PMTs align with each other but are offset from center you may continue.
- File the corners of the diamond cut ledge to further protect wrapping.
- File the corners smooth with a fine file.
- Blow scintillator with compressed air to remove dust.
- Remove black electric tape from ends of scintillator.
- Remove protective film, keep track of the new counter label, and remember that you will not be able to attach the new label until the entire wrapping procedure is concluded.
- Perform detailed scintillator visual inspection, and record all inclusions, bubbles, scratches, cloudy areas, refraction index changes, or any other anomalies with their respective sizes and coordinates.
- Identify diamond-tool-finished (defining the height) and molded (defining the width) sides. The molded side should be face up and defines the front of the scintillator.
  - For previously non-centered but aligned PMT pairs it will be important to orientate the bar such that the side with the greatest gap between the PMT and the edge of the bar be face up denoting the front of the scintillator.
- File corner edges of scintillators to protect light tight wrapping. Using a flat coarse file file the corner down 4 mm; Only file away from the anticookie during this step.
- Log progress in check sheet.
- Cut the Mylar film to length, and wrap the counter in a single layer. Apply the transparent tape only on one molded side, which so defines the front side.

- Trim the Mylar film to the length of the scintillator.
- Cut the Tedlar film in half with the spool-mounted cutting tool.
- Cut the Tedlar film to length (scintillator length plus 20 cm on each end), and wrap the counter tightly and wrinkle-free in three layers. Retain the film tension with electrical tape, secured only on the front side. Finish it off with a layer of the 5-cm wide, thin, black tape running the full length of the Tedlar sheet.
- Apply the counter label to the center of the front side and cover with evenly cut clear tape.
- Record width and height every 20 cm and the overall length and straightness. Verify whether they are within specifications. Add inspection notes and measurements to corresponding scintillator database entry.
- Wrap 2 layers of electrical tape around PMT ~3 cm from edge of scintillator and at end near wires.
- Firmly pigtail the Tedlar film as close as reasonably possible to the PMT HV divider in the center with the electrical tape, trim the Tedlar to 3 cm from the PMT HV divider, and finish the pigtail by wrapping the electrical tape around the bundled Tedlar and cables extending to 5 cm beyond the PMT HV divider.
- Check that the ends closest to the PMT of the Tedlar pigtail are less than 15.5mm in diameter.
- Zip tie wires tightly using pliers at base of PMT and trim excess.
- Blow work area clear before starting new bar.
- Before loading the first bar into the six-bar testing rack, ensure that the previous counter control measurement has been signed off. If the rack is still loaded, stop the measurement, turn off the individual HV channels, unplug the HV, anode, and dynode cables, and unload the six-bar rack, storing each counter on the designated shelf in the storage area.
- Load the counter into the six-bar testing rack with the bottom side facing the wall.
- Add the new counter in the database by associating the entries of the two PMTs with that of the scintillator.
- Repeat the inspection and wrapping procedure for the remaining scintillators.

Counter Control Measurements

- Crew size: 1-2
- Ensure that the six counters are properly aligned and secured in the six-bar rack.
- Connect HV, anode, and dynode cables, each set from top-left, labeled 1 to bottom-right, labeled 12.
- Apply baseline voltages according to PMT testing task database entries.
- Verify that the anode and dynode signals on the oscilloscope match the nominal documented pulse-shape distribution.
- Verify that the dark current is independent of light on/off status.
- Start LabVIEW VI "Calibration Stack Reader.vi" to begin Calibration run.
- Start LabVEIW VI "Histogram Grapher.vi". Check that channels match PMTs

on the first tab labeled Data map and press confirmation button.

- Move to the ADC tab and plot histograms by holding down the "Plot ADC DATA" button. Adjust voltage till histograms leading edge lines up with read line on all graphs. Restart both programs between each run.
- Move to TDC tab and check for consistency between each channel. If not consult task expert.
- Further help is available by pushing the Instructions button in the lower left corner of program or ask the task expert if any discrepancies remain.
- Close previous VIs and Start the LabVIEW VI "24 hour ComboStackReader.splitter.noproc.vi" to start a 24 hour run. First create a file name specific to your current task by pressing the "Enter File Name" button then hit start.
- Enter your name on screen.
- Enter your name and start time in the log book at the computer station.
- The program will run for 24 hours then create a new file every subsequent day automatically until stopped. A green light will turn on when the first 24 hours has passed. The automated analysis system will automatically process the collected data and store the results and histograms into the database when the run is complete.

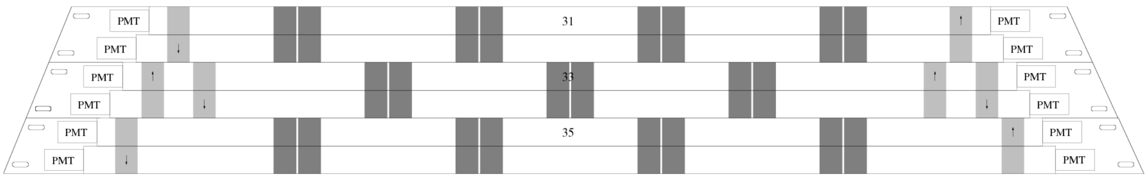
Counter Control Analysis and Sign-off

- Crew size: 1
- Verify that the automated analysis process is complete and that the corresponding files and database entries are present.
- Verify control histograms and spot-check database entries according to interactive checklist application, as described in more detail in Section f, Quality Assurance Plan, of this document.
- At the end of the interactive checklist, the application will request sign off and will store all responses with the user's id.
- If sign off is not warranted, the task expert must be consulted for resolution.

Backing Structure and Two-Counter Assembly

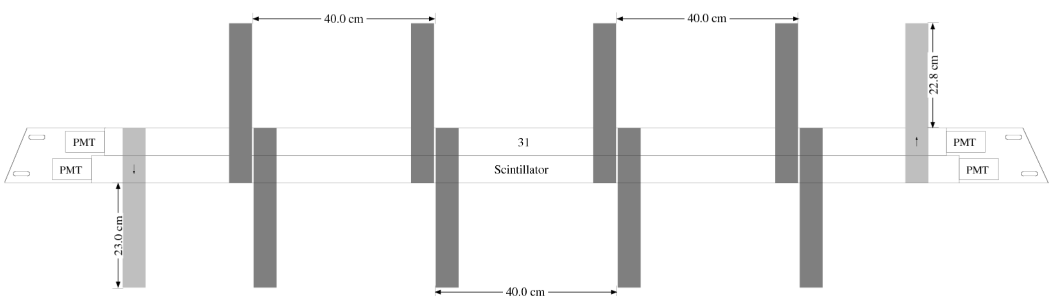
- Crew size: 2-3 depending on length.
- Prepare and clean workbench area, and retrieve an odd-*i* backing structure
- Consult database and diagram to find corresponding counters, *i* and *i+1*.
- Retrieve a pair of both the left and right stoppers, 16 screws, and, if required by the assembly plan, 4 mu-metal shields.
- Add a new two-counter assembly to the database by associating these two counters and this backing structure.
- Mount left stoppers for sectors 3, 4, and 5 in their most outward positions and for sectors 1, 2, and 6 with screws slit-centered.
- Mount right stoppers for sectors 1, 2, and 6 in their most outward positions and for sectors 3, 4, and 5 with screws slit-centered.

– Prepare the backing structure for taping by first marking the placement for taping onto the structure itself. Refer to the overall diagram for the taping pattern for the current backing structure. The tape-loop pairs are at intervals of 40 cm for long counters and 20 cm for short counters (30cm gap between tape-loop pairs). Mark additional single loops at each end following the pattern on the full diagram.



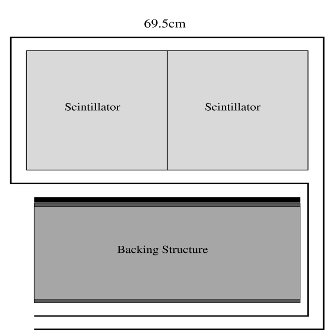
– Apply the single-sided rubber tape to the front of the backing structure in the 30cm gap between the tape-loop pair markings. The rubber tape should be measured out to 29cm and placed directly between tape-loop pairs with a half cm tolerance to the loop pairs.

– Suspend the backing structure between 2 stools/sawhorses and clamp it to them. This will allow you to freely tape the structure.
– Prepare tape-loop pairs, starting from the center of the backing structure. Tape loops of adjacent backing structures must be offset to avoid overlap, so backing structures 1, 5, 9, ... must have tape-loop pairs starting at the center, and 3, 7, 11, ... must have two central tape-loop pairs equidistant from the center (15cm).

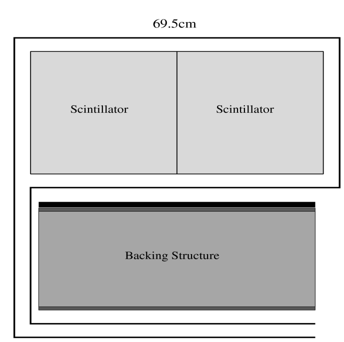


Place the tape-loop pairs in the areas previously marked for them . Each long (short) pair consists of two 5 cm x 65 cm (2.5 cm x 65 cm) bi-directional, double-sided fiberglass tape loops, running side-by-side extending from the back corner along the back, the side, and then across the top surfaces in opposite directions, the remaining length should overhang in preparation for the two counter pairs, as diagrammed on previous diagram, and displayed in the work area.

- An additional single tape loop must be added to the far ends of each backing structure. The loop orientation (left-handed or right-handed) will depend on the large full diagram.
- Place the longer counter onto the backing structure and orient it into its proper position. Lay the smaller counter next to it and mark its proper position onto the larger counter. This will act as a guide when taping them together.
- **Caution: Tape is extremely adhesive and must be handled with care, and placed accurately.** Apply the double-sided, high-tack polyester film tape along the length of the top diamond-tool-finished scintillator side of the shorter, lower, odd-numbered counter, remove the tape's protective film, and center and attach the bottom diamond-tool-finished scintillator side of the longer, upper, even-numbered counter using the marks as a guide.
- Remove the protective film of the tape loops.
- Place the two-counter unit onto the backing structure, ensuring that it is positioned so that the edge of each counter's scintillator is 1 mm from the stoppers that have slit-centered screws.
- Continue by tightly wrapping each tape loop’s remaining length around the two-counter unit and back under the backing structure, completely overlapping with the first segment of the tape loop. Work as a team simultaneously on opposing tape-loop pair sides to avoid Tedlar wrinkles, especially on the top and bottom diamond-tool-finished sides, which will be stacked.

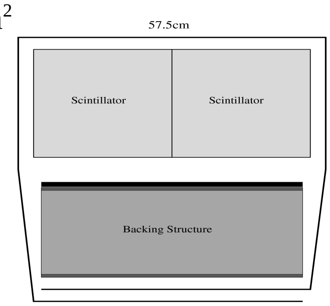


Inner Lefthanded Loop: "Fiberglass Tape"



Inner Righthanded Loop: "Fiberglass Tape"

- Finish each tape-loop pair by applying a 12.7 x 53 cm^2 single-sided, red Mylar tape loop, with both ends terminating on the back of the backing structure, to cover the double-sided fiberglass tape.
- Ensure that the slit-centered stoppers are placed and secured at 1 mm from the scintillator end faces, and reposition the most outward-mounted stoppers at 5 mm from the opposite scintillator end faces.
- Store the backing structure counter assembly in the designated storage area.



d. Milestone Schedule and Construction Timeline

	Milestone	Date Relative to Contract Award
1	Setup of assembly space at USC	1 month
2	Readiness review at USC	1 month
3	PMT/divider testing start	0.5 month
4	Scintillator testing start	1.5 month
5	Phase 1 assembly start (first 5units)	4 month
6	Phase 1 assembly end	9 months
7	Phase 2 assembly start (next 42 units)	9 months
8	Phase 2 assembly end	31 months
9	Phase 3 assembly start (last 17 units)	31 months
10	JLab Acceptance Test preparation start	33 months
11	Phase 3 assembly end	36 months
12	JLab Acceptance Test preparation end	36 months
13	Panel-1b counters delivered to JLab	36 months
14	Sector assembly start	37 months
15	Sector assembly end	38 months
16	Counter baseline measurements complete	39 months
17	Panel-1b assembly and testing complete	40 months

Notes:

1) 3 “PMT/divider testing start” also depends on the availability of first article PMTs.

2) 4 “Scintillator testing start” also depends on the availability of first article scintillators.

3) 5 “Phase 1 assembly start” also depends on the availability of first charge

deliveries of PMTs and scintillators.

4) A “unit” refers to a set of six identical-length scintillators.

e. Construction Budget Estimates

	Description	Labor	Material	Non-Labor	Basis
1	PMT/divider 1st article testing	$5822			12 m-w
2	Scintillator 1st article testing	$5822			12 m-w
3	USC panel-1b support tests	$5822			12 m-w
4	Construction training	$3639			7.5 m-w
5	Misc. test system parts		$3850		Materials
6	Database and automated software	$135000			Post-doc salary
7	Supervisor travel (Gothe)			$19000	$3k/yr*3 + $10k*1
8	Develop construction tooling		$16800		Materials+shop charges
9	PMT/divider order QA	$9316			19.2 m-w
10	Phase 1 construction materials		$20000		Incidentals/Consumables
11	Phase 1 counter construction (5 units)	$9364			19.3 m-w
12	Phase 2 construction materials		$20000		Incidentals/Consumables
13	Phase 2 counter construction (42 units)	$52644			108.5 m-w
14	Phase 3 construction materials		$20000		Incidentals/Consumables
15	Phase 3 counter construction (17 units)	$10674			22.0 m-w
16	Load counters for transport	$8151			16.8 m-w
17	USC personnel @ JLab (housing+per diem)			$39960	
18	USC personnel @ JLab (travel)			$2491	
19	Prepare JLab construction space	$5822			12 m-w
20	Setup FTOF DAQ and test station	$10,674			22 m-w
21	Unload counters	$3,882			8 m-w
22	QA and counter repair	$5822			12 m-w
23	Mount counters to support frames	$3493			7.2 m-w
24	Panel-1b baseline measurements	$11645			24 m-w
	Totals: $429693	**$287592**	**$80650**	**$61451**	

Notes:

1) Cost of packing and shipping of counters from USC to JLab to be paid for separately by JLab.

2) USC overhead rate agreement = 11.5%.

3) USC fringe benefit rate = 1.1% for workers compensation.

4) The post-doc labor charge is based on 100% FTE for 2011, 50% FTE for 2012-2013, and 25% FTE for 2014. The charge includes overhead and fringe benefits.

5) All hourly manpower charges are based on an average labor rate over the duration of the project of $12.13/hr that includes fringe benefits.

f. Quality Assurance Plan

Process-inherent quality assurance measures are integrated into the task tracks' documented procedures and checklists, and regular process reviews and database audits ensure adherence and ensure that potential problems are identified as early as possible in the process. Additionally, QA technicians, who review measurements and results, are trained to compare key quantitative and visual attributes of all characteristic histograms produced during the analysis process to their nominal counterparts. For the final-product quality assurance, QA technicians inspect distinct six-bar measurement results to verify that the required specifications are met by establishing individual counter properties in a step-by-step approach guided by the automated analysis and quality assurance program.

- Log into the quality assurance program, and select the database entry that corresponds to the data under review and was automatically created during the 30-minute calibration run. The system requires a user response to each following step.
- Compare 10-ns cable delay signal time distribution to the documented nominal timing control TDC histogram.
- Compare NIM electronics delay signal time distribution to the documented nominal NIM electronics control TDC histogram.
- Compare individual measured signal time distributions to the documented nominal TDC histograms.
- Compare individual offset integrated charge distributions to the documented nominal QDC offset histograms.
- Compare individual integrated charge distributions to the documented nominal QDC histograms.
- Compare individual position-specific two-dimensional time-walk parameter distributions and fits to the documented nominal time-walk parameterization histograms and fits according to the corresponding counter length.
- Compare individual position-dependent time-walk parameter graphs and fits to the documented nominal time-walk graphs and fits according to the corresponding counter length.
- Compare individual position-dependent time resolution graphs and fits to the documented nominal time resolution graph and fit according to the corresponding counter length.
- Compare individual QDC versus TDC difference distributions and fits to the documented nominal two-dimensional light attenuation histograms and fits according to the corresponding counter length.
- Verify that measured time-walk parameters, effective speed of light, attenuation length, and minimum/maximum/average time resolution are within documented

nominal accepted ranges according to the corresponding counter length.
- Review responses, adding additional notes if necessary, and confirm with electronic signature that the results were reviewed and accepted.

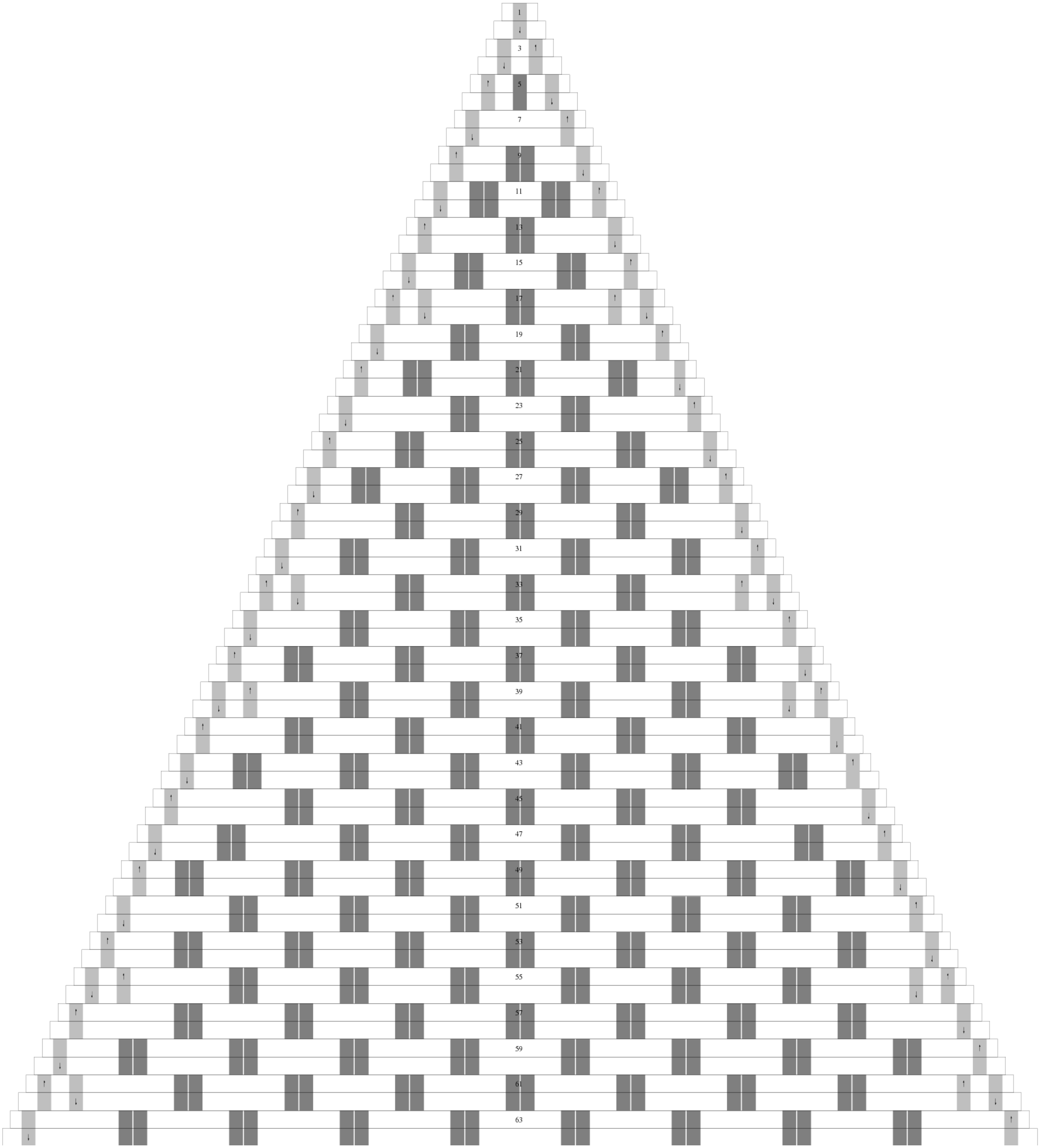
All tests and results will be available online and reported to Jefferson Lab during bi-weekly progress meetings.

g. JLab Assembly and Acceptance Test Plan

Cables and electronics to carry out the 6 six-bar method measurements simultaneously will be provided by JLab three months prior to shipment and will be configured and tested by USC key personnel, assisted by JLab personnel prior to shipment. In a sufficient assembly and testing area provided by JLab, USC Experimental Nuclear Physics Group personnel, assisted by JLab personnel, will mount the 32 backing structure two-counter assemblies of a specific sector into the corresponding sector frame. After all six sectors are mounted, they will be stacked horizontally, aligning each identical-length counter sextuplet. Signal and HV cables for 6 counter sextuplets will be hooked up, and a 24-hour measurement will be prepared and carried out as described in Section c, Contingency and Assembly Plan, of this document. After the automated analysis system processes the data and populates the database, the results are reviewed by a QA technician as described in Section f, Quality Assurance Plan, of this document, with the exception that the documented nominal histograms and graphs are substituted with the previously established histograms and graphs of each individual counter.

h. Shipping and Storage Plan

During counter construction, USCRF will provide sufficient climate-controlled storage areas for all components, individually and assembled. Storage areas, storage plans, and shipping plans are further described in Sections a and c, Assembly and Storage Spaces and Contingency and Assembly Plan, of this document, as well as in Section 5 of the Statement of Work. USC will build shock-damping shipping support structures in consultation with the JLab lead project engineer and mount backing structure two-counter assemblies onto the structures, which will, in turn, be fixated in a single layer onto the bed of an air-ride equipped eighteen-wheeler. Packing and shipping will be arranged by USC key personnel and charged separately to JLab. As required by Section g, JLab Assembly and Acceptance Test Plan, JLab will provide sufficient space for single-layer storage of 192 backing structure two-counter assemblies adjacent to assembly and testing space for at least one horizontally placed, fully cabled sector and required electronics for the time of the JLab assembly period.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