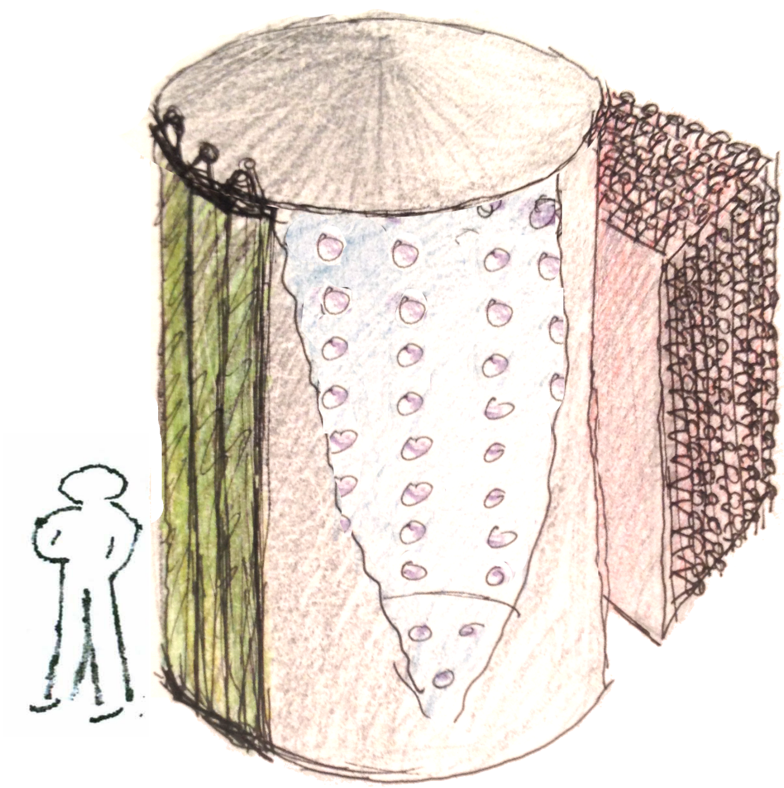
DIRECTORATE

TECHNICAL SCOPE OF WORK
FOR THE 2015 FERMILAB SCIBOONE HALL PROGRAM
T-1063
ANNIE
The Accelerator Neutrino Neutron Interaction Experiment

Tuesday 22$^{\mathrm{nd}}$ December, 2015



Contents

Introduction

This is a technical scope of work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of ANL; BNL; Iowa State; Ohio State; University of Sheffield; U Chicago; UC Davis; UC Irvine; and Queen Mary University of London who have committed to participate in beam tests to be carried out during the FY 2016 Fermilab SciBooNE Hall program.

The TSW is intended primarily for the purpose of recording expectations for budget estimates and work allocations for Fermilab, the funding agencies and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to modify this scope of work to reflect such required adjustments. Actual contractual obligations will be set forth in separate documents.

This TSW fulfills Article 1 (facilities and scope of work) of the User Agreements signed (or still to be signed) by an authorized representative of each institution collaborating on this experiment.

Description of the Tests:

The long term goal of ANNIE is to measure final state neutron yields from neutrino interactions in water, as a function of the kinematic properties (and types) of the interactions. This Technical Scope of Work document, outlines the goal of ANNIE Run I: a measurement to quantify and understand neutron backgrounds.

Several sources introduce neutron backgrounds to the ANNIE detector. A continuum of ambient neutrons from cosmic radiation and long-lived isotopes will be present, but can be largely suppressed by strict time cuts around the beam window, and characterized with data from an off-beam trigger. Neutrinos from the BNB can interact with dirt and rock upstream of the experimental hall, producing a correlated neutron background. While this background may appear slow with respect to the prompt component of an event, it is fast on the time scale of Gd neutron captures.

An initial estimate of the neutron flux from neutrino interactions in and outside the tank was obtained from simulations performed by Robert Hatcher (FNAL), using fluxes provided by Zarko Pavlovic (FNAL). For the neutrino interactions that occur in the tank approximately 49.2% of these interactions yield one or more neutrons. The simulation leads to an expectation of one neutron arising from interactions outside the tank, within in the building itself or the surrounding dirt, for every $\sim$87 spills. The kinetic energy spectrum of the neutrons on the left of Fig 1 is dominated by a spike of thermalized neutrons in the first bin. The spatial distribution of dirt events that contribute to the flux is shown on the right of Fig 1.

An additional neutron background is that of sky-shine, namely secondary neutrons produced at targets and beam stops that leak onto the atmosphere and make it into the detector after undergoing multiple scatterings. Preliminary results from SciBooNE indicate an observable excess of events after the beam time window with a clear dependency on the height. Fig. 2 shows the distributions of the vertical-component for reconstructed vertices of events with at least one track, in three different time windows: before, during and after the BNB spill. Events appearing in the before window correspond to mostly cosmic background, whereas events in the after window have a combination

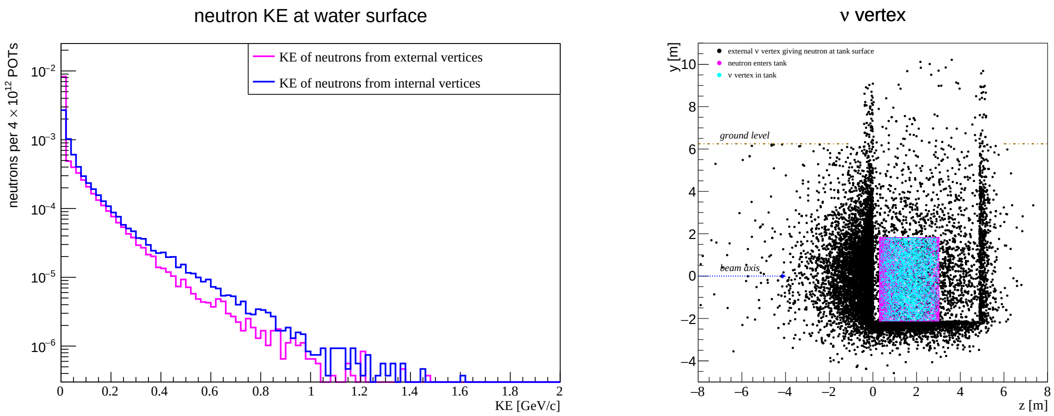


Figure 1: LEFT: Kinetic Energy spectrum of the neutrons reaching the water in the tank from outside (magenta) and those originating from neutrino vertices within the tank (blue). RIGHT: The distribution of neutrino vertices that contribute neutrons that reach the tank (black points). Magenta points are where the neutrons enter the tank. Neutrino interactions inside the tank are cyan.

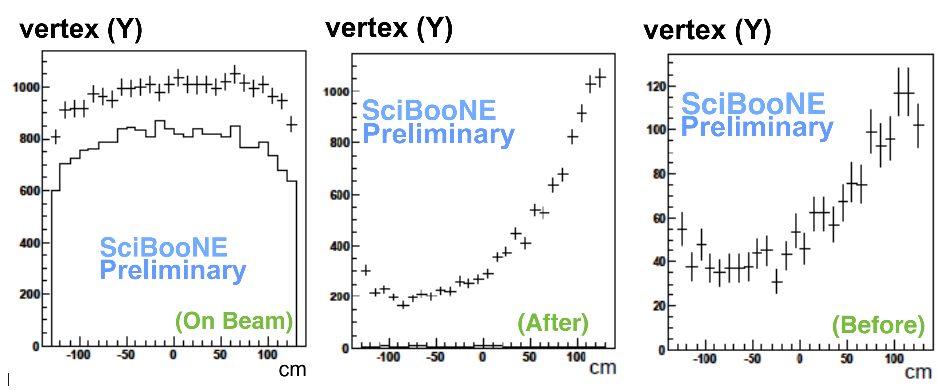


Figure 2: Vertical position of the reconstructed vertices in the SciBoone experiment. LEFT: before the beam time window ($-2 \leq t < 0 \mu s$). CENTER: during the beam spill ($0 \leq t \leq 2 \mu s$). RIGHT: after the beam time window ($2 < t < 20 \mu s$).

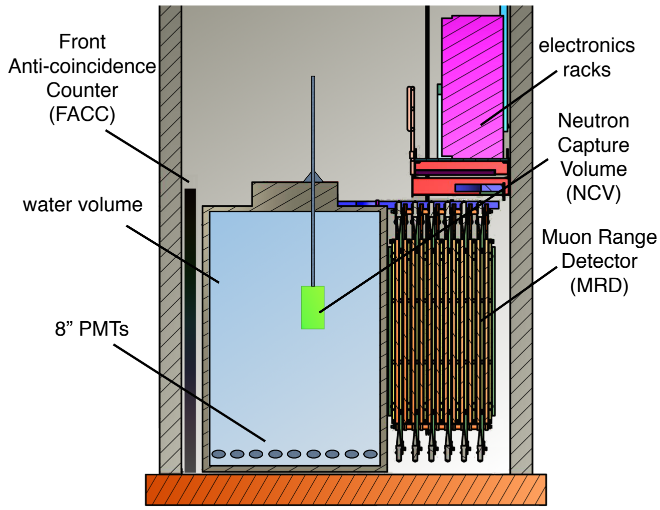


Figure 3: A concept drawing of the ANNIE detector system.

of cosmic and sky-shine interactions. Note that the longer time window in the right-most figures affecting overall normalization. The y-dependence of the event count in the detector suggests that the optimization of the fiducial volume allows for the reduction of skyshine and cosmic related backgrounds.

The approved phase I of ANNIE will measure the neutron backgrounds directly in the target water volume as a function of distance distance from the wall and the top of the detector. The non-uniformities in neutron capture can be measured by limiting the Gd-loaded water volume to a smaller portion of the total water volume. A Gd-loaded transparent target will moved from top to bottom and in the beam direction, for beam-on events with no interaction and the water volume and for bunches with full-contained interactions.

Overview of the Detector:

A concept drawing of the ANNIE Run I detector is shown in Fig 3. The main volume consists of an upright cylindrical tank (10 ft diameter x 13 ft tall), initially filled with 30 tons of ultra-pure water. A smaller Neutron Capture Volume (NCV), consisting of a transparent acrylic vessel loaded with Gd-enhance scintillator oil, will be lowered into the water. The Gd enhances the neutron-capture cross section of the target and produces a detectable (8 MeV) photon signal within a much shorter time frame than that of hydrogen (20 μs vs. 200 μs). Neutrons that thermalize in this sub-volume will be detectable from the high light yields of scintillating oil, collected by an array of 60 upward-facing 8" (Hamamatsu) PMTs at the bottom of the tank. Position dependence of the neutron rates from different overburdents of water can be studied by raising and lowering the NCV and traslating it along the beam axis. Muons entering and exiting the tank will be tagged using muon paddles in a newly installed Forward Veto detector and several recommissioned layers of the existing Muon Range Detector (MRD) from SciBooNE.

I Personnel and Institutions

Co-Spokespersons: Mayly Sanchez and Matt Wetstein
Fermilab Experiment Liaison Officer: Bill Lee

The group members at present are:

	Insitution	country	User	Rank/Position
1.1	ANL	USA	Robert Wagner	Scientist
1.2	BNL	USA	Minfang Yeh	Scientist
1.3	ISU	USA	F Krennrich M Sanchez A Weinstein M Wetstein	Professor Professor Professor Professor
1.3	U Chicago	USA	H Frisch	Professor
1.4	UC Davis	USA	R Svoboda	Professor
1.5	U Sheffield	UK	M Malek	Lecturer
1.6	QMUL	UK	F Di Lodovico	Professor
1.7	UC Irvine	USA	H Sobel M Smy	Professor Scientist
1.7	Berkeley	US	G Orebi Gann	Professor
1.3	FNAL	USA	B Lee A Kreymer G Savage E Ramberg	Scientist Scientist Scientist Scientist
1.8	Ohio State University	US	J Beacom	Professor

II Experimental Area, Beams, and Detector Overview

II.1 Location

The apparatus under test will be located in the SciBooNE Hall.

The main water tank, which is 10 ft in diameter is to be placed on the center line of the beam. At 13 ft high, the top of the tank is roughly level with the first balcony at the 732 ft level. Additional staging space at FNAL will be required. A work table has been arranged for a limited R&D effort at Lab 7 and is detailed in a separate TSW. Work on the tank will require a space with a high bay door taller than 13 ft and floor space to accommodate at least two times the 10 ft footprint of the tank. Sufficient floor space for muon paddle refurbishment is also requested. This staging area will likely be at the D0 Assembly Building (DAB).

II.1.1 Area Infrastructure

ANNIE will require a source of clean water. The strategy employed to create extremely clear water has been to remove all suspended solids, dissolved gases, ions, and biologics from solution via a series of filtration elements. These include microfiltration filters, degasifiers (vacuum and/or membrane type), reverse osmosis membranes (RO), deionization resins (DI), and exposure to intense ultraviolet light (UV). The water in the detector will be periodically recirculated through the filtration system. This is necessary as transparency-impairing materials are steadily leaching into the chemically active ultra-pure water.

Water can be brought in by hose from MI8 or nearby spigot, although a pump may be require to maintain a reasonable flow rate. Laboratory water is not sufficiently pure for the ANNIE recirculation system and will need to be pre-cleaned. Nalco-Crossbow Water can provide a water filtration system for ∼$3k. After passing through the pallet-mounted water filters system, clean water will go directly into the ANNIE tank. There it will be subject to further purification through a skid mounted filtration system provided by UC Davis and located at second level of the hall. This system comes with a pump capable of bringing the water out of the tank and up to surface level. Once cleaned, the water can be pumped out of the tank and stored for reuse during later runs.

The ANNIE water volume requires a source of dry nitrogen in order to suppress the growth of biologics in the water. This nitrogen will be bubbled through the water during fill. After the fill, a blanket of nitrogen, from gas bottles installed outside the hall, will be maintained above the surface of the water. The flow rate will be kept as low as necessary to maintain a pure N_2 environment, with only one gas bottle in use at a time. Oxygen Depletion Hazard (ODH) is not expected to be an issue.

Other requirements include:

- Cable trays: Cabling and trays for the MRD are already installed as sufficient. Some additional trays will be required for the forward veto and water volume.
- Power for rack electronics: Given similar power needs to SciBooNE, this requirement will likely be met by the power infrastructure already in the hall.
- Network access: ANNIEs needs can be met by an existing fiber connection, but may require an upgraded switch.

- Beam signal (already available).
- Crane Access.
- Computing resources (described in a separate TSW).

The necessary infrastructure to accommodate the tank and allow access from the second floor is show in VII.0.12. A steel access platform as been designed for this purpose.

II.2 Beam

Beam Sharing The experiment will run parasitically to the Short Baseline Neutrino Program

II.3 Detector Overview

Area Infrastructure Location of the experiment, SciBooNE, is depicted in Appendix I.

There are three major detector systems in ANNIE Run I:

- An existing Muon Range Detector (MRD) from SciBooNE, consisting of alternating layers of 2-inch steel and scintillator paddles and designed to measure the energies and angles of stopped muons.
- A forward veto, designed to detect and reject muons produced in the dirt upstream of the detector.
- The main water target, ultimately used to detect neutrino interactions, but used in Run I to study background neutrons.

  There are 6 major structural elements of the water volume that need to be either designed or built:

  - **water tank**: a 10 ft (dia) x 13 ft (height) upright cylindrical steel water tank
  - **inner structure**: an octangular prism structure attached to the top of the tank, consisting of a steel frame and PMT-mounted PVC panels.
  - **PMT support structure**: the parts necessary to mount and support PMTs on the PVC panels.
  - **access platform**: a structure, with balcony, surrounding the tank in ANNIE Hall, allowing collborators to climb onto and access the top of the tank.
  - **staging platform**: the structure build at the staging area to support the top of the water tank and inner structure, while collaborators mount PMT panels.
  - **neutron capture volume (NCV)**: The acrylic vessel, containing Gd-loaded liquid scintillator, to be placed and moved within the tank volume.

II.4 Forward Veto

The forward veto consists of two layers of muon paddles, inherited from the CDF experiment, mounted on the wall with aluminum 80-20 extrusions. The detector system is installed and shown in Fig 4. The paddles are tested and in working condition. Cabling remains to be installed.

Figure 4: The ANNIE Forward Veto.

Signal and HV cables will need to be made. An existing stock of 1-ended cables from MC8 can be used for the purpose. Connectors will need to be purchased and attached. The HV connectors will be attached by a tech, but ANNIE collaborators can make the BNC cables, with some training. Technical support will be needed to install the necessary cable trays and strain reliefs to run the cables to the second-floor racks. A map of the planned cable paths is shown in Fig 5.

II.5 Water Target

The ANNIE water volume consists of an upright, welded steel storage tank, 10 ft (dia) x 13 ft (height, not including the top), shown in Fig 6. A water tight, plastic liner will be placed in the tank, both to protect the Gd-loaded water in future runs and to serve as secondary containment. The tank and PMT inner structure are designed to fulfill the requirements described in Appendix IV: Tank Requirements.

Fermilab engineering will cut off the top of the tank. Once the top is removed, additional support will be needed to maintain roundness. Rolled angle stock will be welded on to support this roundness, allowing the tank to be kept in the staging location (the DAB), even with the top detached. The angled reinforcement will also serve to flange the joint where the two pieces will be bolted back together.

The tank lid will bolted on top of a self-supporting, octagonal stainless steel PMT inner structure. This inner structure, pictured in Fig 7, is designed to support as many as the 200 PMTs expected for ANNIE Run II. In ANNIE Run I, there will be only 60 8-inch PMTs, mounted facing upward on the bottom of the frame. The frame is designed to support both the weight of the phototubes in gravity as well as the buoyant forces in water. Cabling and plumbing can run up this inner structure, to feedthroughs on the top. The structure will also hold the narrow submersible pump used for the water circulation system. Installation and future modifications to the detector configuration will be made to this structure when its removed from the tank and placed standing on its own.

The tank lid will require the addition of feedthroughs for cabling, gas exchange, and water circula-

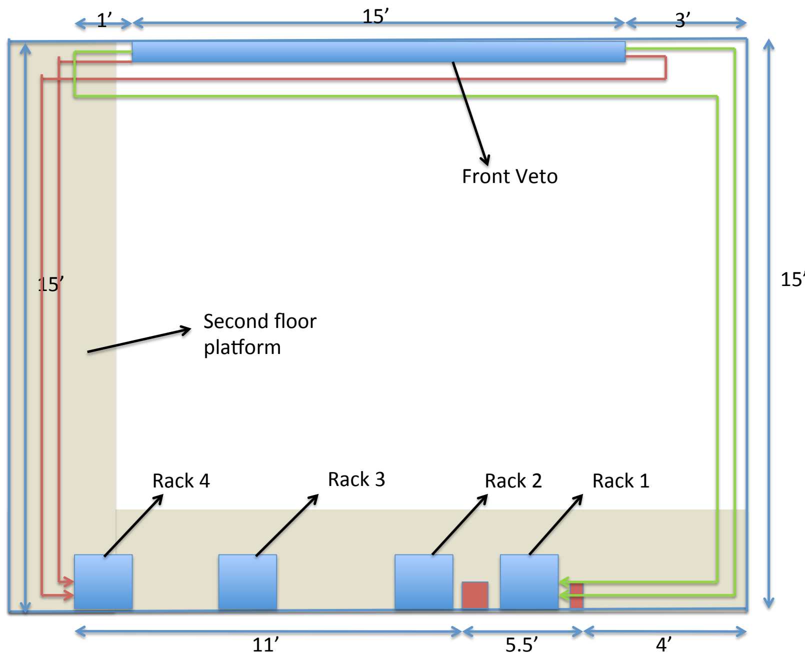


Figure 5: Cable paths of the HV (red) and signal (green) cables for the Forward Veto.

tion. The hatch will need to be modified with a slot to accommodate the NCV. The water target, with all feedthroughs and head attached, must be light tight.

The ANNIE PMTs will be mounted on sheets of black PVC, using standard hardware and designed in a way to allow easy collaborator assembly. The PMT will be pressed into a circular opening in the PVC panel with a silicon rubber o-ring placed between. The o-ring will protect the tube and accommodate stresses from thermal expansion (contraction) or some distortion under mechanical stress. The panel will grip the tube at its center of buoyancy, making possible both upward facing and sideways orientations. The tubes will be held to the panels by either acrylic rings (which have been costed in this TSW) or flexible wires, following the design used by MicroBooNE (both options are shown in Fig 9. Mounting of the PMTs and attachment of the panels to the steel inner structure will be performed by ANNIE collaborators. Welding and attachment of the steel structure will be performed by Fermilab technicians.

In ANNIE phase I, neutron detection will be made possible by captures in a small sub-volume containing Gd-loaded scintillator. This Neutron Capture Volume (NCV) will consist of a transparent acrylic vessel, housed in a steel support frame. The NCV will be weighted to have a slightly negative net buoyancy. The height of the vessel will be adjusted by a winch and cable, passing through a slot in the top of the hatch. Some translation along the beam direction can be achieved by sliding the winch along the length of the slot.

II.6 The Muon Range Detector (MRD)

ANNIE makes use of an existing MRD that remains mostly intact in the experimental hall. The MRD is a steel and plastic scintillator sandwich detector, designed to range GeV-scale muons and provide directional information. The electronics and high voltage (both for the MRD and photosensors in the water volume) will be provided by Fermilab PREP for the duration of the experiment. Several layers of muon paddles and PMTs are absent; Fermilab has agreed to provide

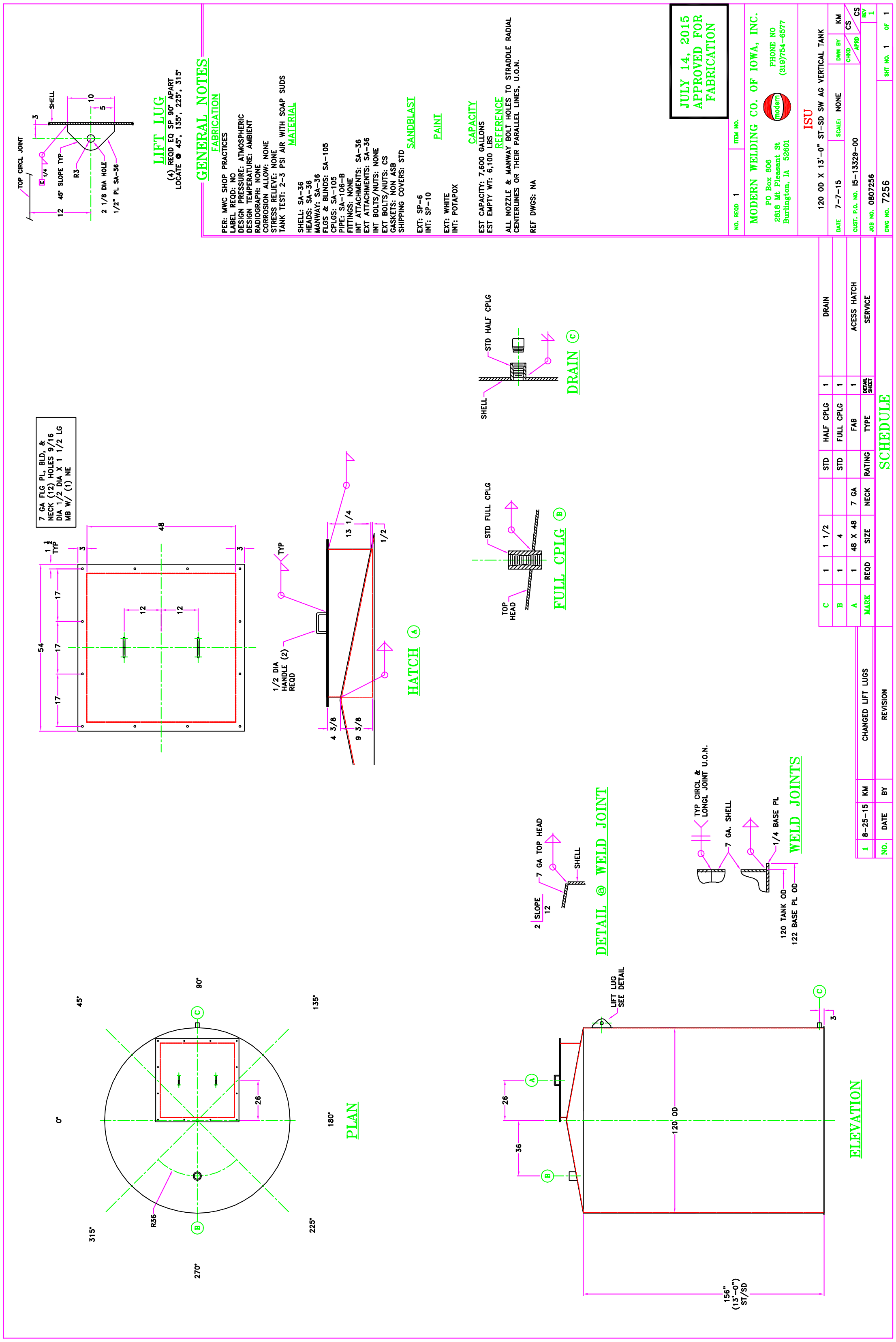


Figure 6: Blueprint of the ANNIE tank.

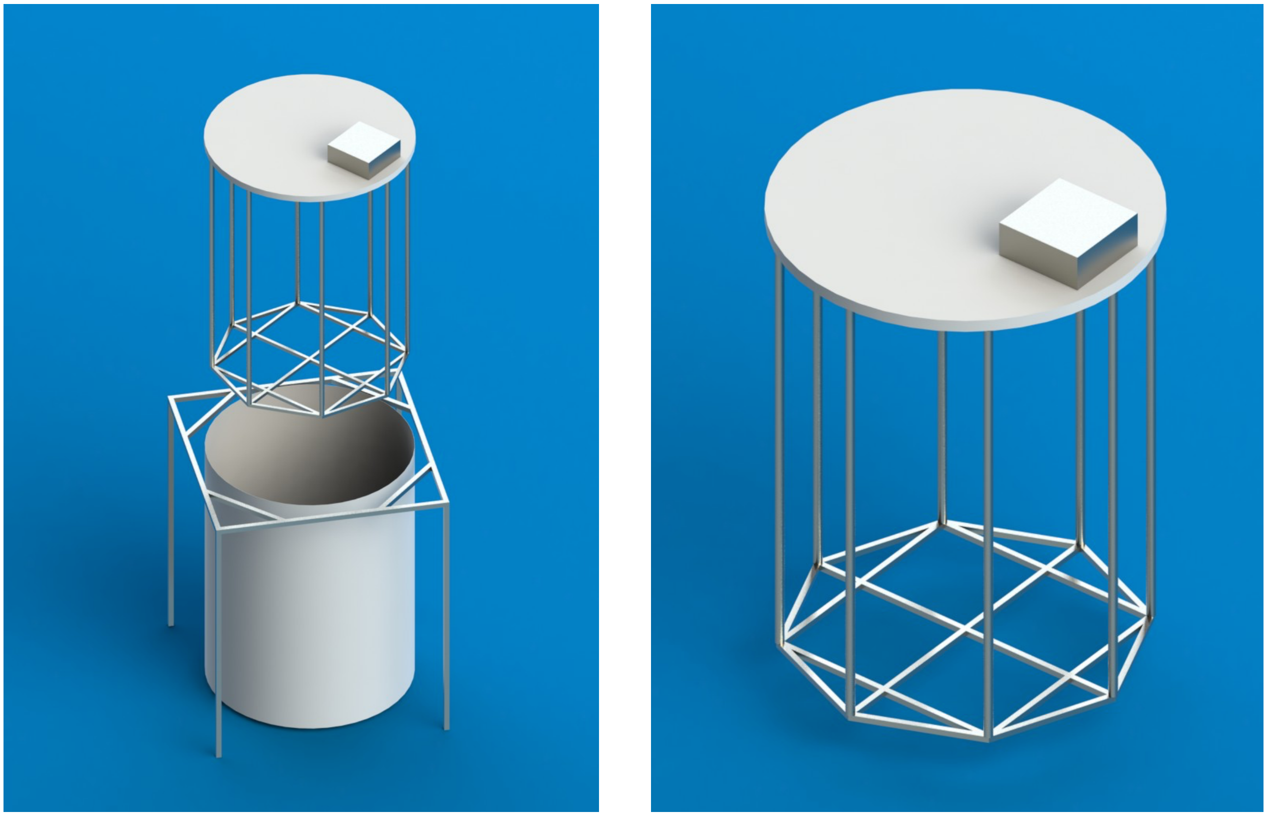


Figure 7: Two views of the ANNIE inner structure.

Figure 8: Two views of the NCV vessel.

Figure 9: Two PMT holder designs.

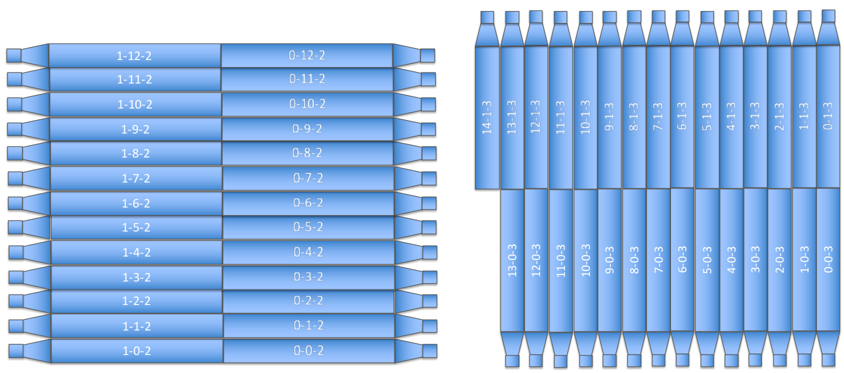


Figure 10: Schematic of MRD layers 2 (LEFT) and 3 (RIGHT).

materials and instructional support to the ANNIE collaboration to replace the missing paddles. A fraction of the MRD will be made operational for Phase I of ANNIE in early fall.
Accommodating the ANNIE water tank necessitated the removal of inactive steel plane from the front of the detector. It is estimated from MC simulations that the effect of this modification will be small.

For Run I the plan is to operate only the first two instrumented layers of the MRD, one horizontal plane (layer 2) and one vertical (layer 3). These two planes are pictured in Fig 10. As shown in the figure, 1 muon paddle is missing. In addition, collaborators have identified 3 nonfunctioning PMTs among these two layers. Where possible, the bases for these PMTs should be further looked at and repaired.

Once the ANNIE Phase I detector is operational, ANNIE collaborators request support in rebuilding missing Muon paddles, to replace missing layers in Phase II. The paddles themselves are available on site. However, a stock of 2-inch PMTs will need to be identified, as the missing phototubes were returned to Stonybrook and KSU.

II.7 Photomultipier Tubes

Photodetection in ANNIE Run I will be provided by of 60 8 Hamamatsu PMTs, from a stock of Super-K spares belonging to UC Irvine. These PMTs are complete with water proof bases, and have already been tested for basic QA. All that remains is to attach water proof cabling. This work will be done at Irvine, with cables, connectors, and shrink tubing purchased using the requested ANNIE budget.

II.8 Electronics

The ANNIE electronics consist of three readout systems, corresponding to the three primary detector elements: (1) small PMTs in the veto and MRD (2) large area PMTs in the water volume, and (3) LAPPDs. The large PMTs and LAPPDs in the water volume will rely on two readout systems developed by U Chicago. LAPPDs will be instrumented with electronics built around the PSEC4 chip. PMT signals will be split. Part of the split signal will be sent sent to the same PSEC4 electronics. The other part will be sent to VME-based FADC cards developed at UC for the KOTO experiment in Japan. These systems can be supported with expertise outside the lab, although interest within the lab in developing expertise around these robust, high performance systems is also welcome.

The Muon Range Detector, Forward Veto, and any other veto or cosmic muon paddles will nominally rely on the same FADC system as the PMTs in the water volume. In Run I it is only necessary to operate the 26 scintillator paddles and between 1 and two layers (26-52 channels) of the MRD. These signals will be combined through an analog OR and sent to a few spare FADC channels on the KOTO boards. Once this nominal readout is working, the ANNIE collaboration intends to recommission the CAMAC-based MRD electronics used by the SciBooNE collaboration and available through PREP. Some layers of the MRD and veto will be sent to both the FADC and CAMAC systems for redundancy and relative timing.
The 8 phototubes instrumenting the ANNIE water volume are operated at positive HV with a single cable for both power and signal. Splitter boxes will be necessary to separate the PMT signal and the HV. These splitter boxes are being designed and built at IA State. Schematics and actual modules will be shared with ES&H for appropriate review and feedback.
The FADC system borrowed from the KOTO collaboration will constitute the main backbone of the ANNIE Run I electronics. The PSEC and CAMAC systems will be phased in, only after the primary readout and DAQ are successfully recording data.

ANNIE will use a CAEN system (available in PREP) to provide the positive and negative high voltages necessary for operation. A stock of 6 A734P cards would suffice to power the 62 large PMTs in the water volume and the 26 positive HV PMTs in the MRD. ANNIERun I will also need 26 negative HV channels for the Forward Veto and another 52 channels to power at least two layers of the MRD. There are likely a sufficient number of the right cards available. The collaboration is checking on the current draw of the tubes to determine the parameters needed. The collaboration is looking A832N and A932AN models, in particular. Many of the negative HV supplies have high-density connectors and will need appropriate cables fanning out to patch panels with HV connectors. These cables have been located, but will likely require safety reviews.

The layout, crate protection, power needs, and custom designs will need to be carefully reviewed with guidance from ES&H. The ANNIE electronics group will maintain frequent contact with the necessary experts, in preparation for an ORC review.

III Schedule for ANNIE Phase I

We have developed an schedule with the goal of beginning data taking in mid-March. This will allow sufficient data collection to occur by the summer shutdown of the Booster beam. The main activities on-going on each week for mid-November to mid-March are described below. The main leads in each activity are shown in parentheses.

- **Milestone Week November 16:** Finalize tank modification design and PMT structure (FNAL engineering).
- Weeks November 16 - December 14: Prototype PMT holder (FNAL engineering).
- Weeks November 16 - December 14: PMT testing and cabling work (UC Irvine).
- **Milestone Week December 14:** Ship PMTs from UC Irvine to FNAL.
- Weeks November 30 - December 14: Tank Modification work (FNAL engineering/tech).
- *Procurement/Milestone Week December 7:* Order liner (final decision on color required).
- *Procurement/Milestone Week December 14:* Order PMT structure materials (final design of PMT holder decision required).
- Weeks January 4 - January 11: Build PMT structure (FNAL engineering/tech).
- Weeks January 4 - January 11: Test PMTS / Develop Installation of PMT Modules Procedures (ANNIE collaboration).
- Weeks January 4 - January 25: Populate and test electronic racks (ANNIE collaborators). Preliminary ORC review.
- Weeks January 4 - January 18: Attach connectors to HV and BNC cables for forward veto (ANNIE), install cables and cable trays in hall (FNAL engineering/tech).
- *Procurement Week January 4:* Order NCV materials (UC Davies)
- Week January 18 - January 25: Install liner, test lowering PMT structure into tank, move tank (FNAL engineering/tech).
- Weeks January 18 - January 25: Assemble and install PMT modules (ANNIE collaborators).
- Weeks February 1 - February 8: Building platform around the tank at SciBooNE hall (FNAL engineering/tech).
- Weeks February 1 - February 8: Continue assembly and installation of PMT modules (ANNIE collaborators).
- Weeks February 1 - February 8: Continue to Populate/test electronic racks (ANNIE collaborators).
- **Milestone Week February 8:** Final ORC review on electronics.
- Weeks February 1 - February 8: Build NCV (UC Davies)
- **Milestone Week February 15:** Ship NCV from UC Davies to FNAL.

- Week February 15: Transport of PMT structure to SciBooNE hall (FNAL engineering/tech).
- **Milestone Week February 22:** Completed transport and lowering of structure in the hall.
- Week February 22: Cable connecting, DAQ testing (ANNIE collaborators).
- Week February 29: Testing PMTS, cabling, DAQ in situ, check for light leaks (ANNIE collaborators).
- Week February 29: Dark detector commissioning (ANNIE collaborators).
- Procurement Week February 29: Setup water skid
- **Milestone Week March 7:** Filling the tank and detector commissioning with water (ANNIE collaborators).
- **Milestone Week March 14:** Install and commissioning of NCV (ANNIE collaborators).
- **Milestone Week March 21:** Data taking begins.

III.1 Table of ANNIE Related Activities

Activity	**Performed By**	**Location**	**Dates**
MRD and forward veto testing	ANNIE collab	SciBooNE	ongoing
prototype PMT holder	FNAL tech	DAB	Nov 16 - Dec 14
PMT testing and cabling	UC Irvine	offsite	Nov 16 - Dec 14
tank modification work	FNAL tech	DAB	Nov 30 - Dec 14
build PMT inner structure	FNAL tech	DAB	Jan 4 - Jan 11
on-site PMT testing	ANNIE collab	DAB	Jan 4 - Jan 11
populate electronics racks	ANNIE collab	SciBooNE	Jan 4 - Jan 25
attach connectors to veto cables	ANNIE collab	DAB	Jan 4 - Jan 18
cable installation for veto	FNAL tech	SciBooNE	Jan 18 - Jan 25
install plastic tank liner	ANNIE/FNAL	DAB	Jan 18 - Jan 25
test lower inner structure into tank	FNAL tech	DAB	Jan 18 - Jan 25
move tank to SciBooNE	FNAL tech	DAB/SciBooNE	end of Jan
assemble and mount PMT modules	ANNIE collab	DAB	Jan 18 - Jan 25
build NCV	UC Davis	offsite	Feb 1 - Feb 8
construction of access platform	FNAL tech	SciBooNE	Feb 1 - Feb 8
continued work on racks	ANNIE collab	SciBooNE	Feb 1 - Feb 8
move inner structure to SciBooNE	FNAL tech	DAB/SciBooNE	week of Feb 22
cabling and DAQ testing	ANNIE collab	SciBooNE	week of Feb 22
in situ PMT testing	ANNIE collab	SciBooNE	week of Feb 22
dark detector commissioning	ANNIE collab	SciBooNE	week of Feb 29
setup water skid	outside techs	SciBooNE	week of Feb 29
water fill and commissioning	ANNIE/FNAL	SciBooNE	week of March 7
installation of NCV	ANNIE	SciBooNE	week of March 14
data taking	ANNIE	SciBooNE	March 21 -
electronics upgrades	ANNIE	SciBooNE	Summer 2016
paddle-making for MRD	ANNIE/FNAL	DAB	Summer 2016

IV Responsibilities by Institution - Non Fermilab

IV.0.1 UC Davis

- Installation and maintenance of the Forward Veto
- Operation and monitoring of the water system

IV.0.2 UC Irvine

- Provide 62 spare Super-K 8 PMTs
- Testing of PMTs
- Engineering for water proof cabling

IV.0.3 University of Chicago

- Design of the PSEC central card
- Support of PSEC4 electronics
- Expertise on LAPPD technology and fast timing

IV.0.4 Iowa State

- Electronics development (VME-based FADC system)
- Testing and operation of LAPPDs
- Simulations and reconstruction

IV.0.5 Queen Mary University of London

- Electronics and DAQ
- Simulations and reconstruction

IV.0.6 Argonne National Laboratory

- Expertise with 6cm glass MCPs

IV.0.7 Sheffield University

- Simulations and reconstruction

IV.0.8 Berkeley

- Mechanical Engineering
- Simulations and reconstruction

V Responsibilities by Institution - Fermilab

V.1 Fermilab Accelerator Division:

V.1.1 Use of BNB as outlined in Section II.

V.1.2 Maintenance of all existing standard beam line elements, instrumentation, controls, clock distribution, and power supplies.

V.1.3 Connection to ACNET console and remote logging should be made available.

V.1.4 A beam-on-target trigger signal to insert into the experiment data stream

V.2 Fermilab Neutrino Division:

V.2.1 The efforts in this TSW will make use of the SciBooNE Hall as given in Section II. The Fermilab ND Operations Support Group will be responsible for coordinating overall activities in the SciBooNE Hall. [0.5 FTE/week]

V.2.2 A console at ROC WEST for shifts and remote monitoring.

V.2.3 Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary.

V.2.4 Provide safety training as necessary, with assistance from the ESH&Q Section.

V.2.5 Update/create ITNAs for users on the experiment.

V.2.6 Initiate the ESH&Q Operational Readiness Clearance Review and any other required safety reviews.

V.2.7 Support from Bill Lee and Geoff Savage [30 FTE-days]

V.3 Fermilab Particle Physics Division:

V.3.1 Technical support to remove roof and assist in moving experimental equipment into and out of SciBooNE Hall. [3.0 FTE/day/roof-removal]

V.3.2 Additional technical support for moving equipment.

V.3.3 Mechanical design work. [10.0 FTE-days tech labor],[20.0 FTE-days engineering]

V.3.4 Construction work on the tank. [88.0 FTE-days tech labor], [10.0 FTE-days engineering], [11.0 FTE-days welding]

V.3.5 Mechanical support on the MRD and veto. [11.0 FTE-days tech labor]

V.3.6 Support on other systems (water skid, plumbing, cable trays, crate support). [12.0 FTE-days tech labor], [5.0 FTE-days engineering]

V.3.7 Conduct a NEPA review of the experiment.

V.4 Fermilab Scientific Computing Division

V.4.1 Internet access in the SciBooNE Hall.

V.4.2 See Appendix II for summary of PREP equipment pool needs.

V.5 Fermilab ESH&Q Section

V.5.1 Assistance with safety reviews.

V.5.2 Provide safety training, with assistance from ND/PPD, as necessary for experimenters. [0.2 FTE]

V.6 Fermilab Collaborators

Bill Lee, Arthur Kreymer, Geoff Savage, Rob Hatcher.

VI Summary Of Costs

task	tech labor (person-days)	engineering	welder	OSG	days	peron-days/days
Design structure	10	20				
tank						
finite element undestanding of tank top		4			5	0.8
clear area for cutting top	6				2	3
prepare top, add lift lugs,	2		1		1	3
cut top off	4				1	4
weld rolled angle iron			2		1	2
assemble feedthroughs/ports/slot in hatch	6				2	3
build/weld inner structure	30		5		10	3.5
attach top	3				1	3
place liner in tank	3				1	3
attach dummy PMTs to structure (collaborators?)					1	0
test fit structure	3				1	3
attach PMTs to structure (collaborators)					15	0
move tank to SciBooNE	4				1	4
assemble platform	20	6	3		10	2.9
move structure to SciBooNE	6				1	6
cut slit in hatch	1					
veto/mrd						
cable making	2					
setup cable tray in SciBoone	9				3	3
Other						
put water skid in SciBooNE	3				1	3
plumb skid to tank	3				1	3
additional cable tray	6				2	3
VME crate/ Power Supply		5				
Total	**121**	**35**	**11**	**30**		

System	Component	Institution	Quantity	Cost/item	Estimate	Source of estimate	
TANK	rolled angle	FNAL	1	$1,682.00	$1,682.00	Jim at 11/03 meeting	
	steel extrusions	FNAL	1	$2,498.00	$2,498.00	Jim via NAPCO Steel	
	access platform	FNAL	1	$1,500.00	$1,500.00	Jim in original engineering estimate	
	liner	FNAL	1	$4,650.00	$4,650.00	Kentain Rep.	
	other	FNAL	1	$500.00	$500.00	best guess feedthroughs/ports materials	
						SUM=	$10,830.00
PMT SUPPORTS	PVC sheets	FNAL	1	$3,000.00	$3,000.00	matt guess	twice the cost of covering the 80 sq ft of the bottom
	Acrylic rings	FNAL	130	$22.50	$2,925.00	watchman	
	other hardware	FNAL	1	$1,000.00	$1,000.00	conservative guess	
						SUM=	$6,925.00
PMTS	cables	Irvine	1	$1,720.00	$1,720.00	M Smy	
	HV connectors	Irvine	130	$21.00	$2,730.00	M Smy	
	shrink tube	Irvine	70	$9.00	$630.00	M Smy	
	shipping PMTs	Irvine	60	$50.00	$3,000.00	M Smy	
						SUM=	$8,080.00
WATER SYSTEM	water delivery		1.25	$2,500.00	$3,125.00	B Svoboda	9ft scaled to 10 ft
	replacement DI cartridges & filters		1	$500.00	$500.00	B Svoboda	for skid
	other						
						SUM=	$3,625.00
NCV	steel bridal	UC Davis	1	$635.00	$635.00	D Hermer (Davis)	
	stell basket	UC Davis	1	$600.00	$600.00	D Hermer (Davis)	
	acrylic plate	UC Davis	1	$340.00	$340.00	D Hermer (Davis)	
	acrylic tube	UC Davis	1	$1,700.00	$1,700.00	D Hermer (Davis)	
	stainless wire and wench	UC Davis	1	$700.00	$700.00	D Hermer (Davis)	
	other hardware	UC Davis	1	$500.00	$500.00	D Hermer (Davis)	
	engineering (60 hours)	UC Davis	60	$64.00	$3,840.00	D Hermer (Davis)	
	shipping + tax	UC Davis	1	$1,500.00	$1,500.00	D Hermer (Davis)	
						SUM=	$9,815.00
GAS SYSTEM	gas?		0	$0.00	$0.00		negligible
	other		0	$0.00	$0.00		
						SUM=	$0.00
ELECTRONICS	HV pick-off boards	ISU	64	$16.00	$1,024.00	Jonathan quote	with contingency
	RMS 1 pps signal and timecc	ISU	1	$500.00	$500.00	Jonathan quote	
	Receiver with internal discipli	ISU	1	$1,000.00	$1,000.00	Jonathan quote	
	Cables	ISU	0	$0.00	$0.00	don't think we need them	
	HV connectors	ISU	96	$20.00	$1,920.00	From proposal	60+26+Extra
	BNC connectors	ISU	96	$8.00	$768.00	From proposal	60+26+Extra
	Crate	FNAL/ISU	2	$10,000.00	$20,000.00		will evaluate one in D0 so this is contigency cost/might need a spare
	VME power supply	ISU	1	$1,100.00	$1,100.00	Jonathan quote	
						SUM=	$26,312.00
Gd LOADED SCINTILLATOR	shipping of Gd Scintillator	LANL	1	$ 500.00	$ 500.00		
	disposal of Gd Scintillator	FNAL	1	$ 150.00	$ 150.00		assuming 55 gallon drum
						SUM=	$650.00
DAQ computers		FNAL	3	$6,000.00	$18,000.00	Geoff quote	
Network switch		FNAL	1	$4,000.00	$4,000.00	Geoff quote	

Grand Total	$66,237.00
20% contingency	$79,484.40
Grand Total (with DAQ)	$82,557.00
20% contingency	$99,068.40

VII General Considerations

VII.0.1

The responsibilities of the Spokesperson and the procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Researchers": (http://www.fnal.gov/directorate/PFX/PFX.pdf). The Spokesperson agrees to those responsibilities and to ensure that the experimenters all follow the described procedures.

VII.0.2

To carry out the experiment a number of Environmental, Safety and Health (ESH&Q) reviews are necessary. This includes creating an Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The Spokesperson will follow those procedures in a timely manner, as well as any other requirements put forth by the Divisions Safety Officer.

VII.0.3

The Spokesperson will ensure at least one person is present at the Fermilab Test Beam Facility whenever beam is delivered and that this person is knowledgeable about the experiments hazards.

VII.0.4

All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ESH&Q section.

VII.0.5

All items in the Fermilab Policy on Computing will be followed by the experimenters. (http://computing.fnal.gov/cd/policy/cpolicy.pdf).

VII.0.6

The Spokesperson will undertake to ensure that no PREP or computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Scientific Computing Division management. The Spokesperson also undertakes to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Sector management.

VII.0.7

The experimenters will be responsible for maintaining both the electronics and the computing hardware supplied by them for the experiment. Fermilab will be responsible for repair and maintenance of the Fermilab-supplied electronics listed in Appendix II. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

VII.0.8

An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters Meeting.

VII.0.9

The co-spokespersons are the official contact and are responsible for forwarding all pertinent information to the rest of the group, arranging for their training, and requesting ORC or any other necessary approvals for the experiment to run.

VII.0.10

The spokesperson, or designee, will generate a one-page summary of the experiments use of the Test Beam facility during the fiscal year, to be included in the annual SciBooNE Report Fermilab submits to the DOE.

At the completion of the experiment:

VII.0.11

The Spokesperson is responsible for the return of all PREP equipment, computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the Spokesperson will be required to furnish, in writing, an explanation for any non-return.

VII.0.12

The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ESH&Q requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters unless removal requires facilities and personnel not able to be supplied by them, such a rigging, crane operation, etc.

Signatures

________________________________ Tuesday 22$^{\mathrm{nd}}$ December, 2015

Mayly Sanchez, Experiment Spokesperson

________________________________ Tuesday 22$^{\mathrm{nd}}$ December, 2015

Matt Wetstein, Experiment Spokesperson

The following people have read this TSW:

______________________________ Tuesday 22^{nd} December, 2015

Bill Lee, SciBooNE Facility Manager

______________________________ Tuesday 22^{nd} December, 2015

Angela Aparicio, ND ES&H DSO

______________________________ Tuesday 22^{nd} December, 2015

Jonathan Lewis, PPD Engineering & Support

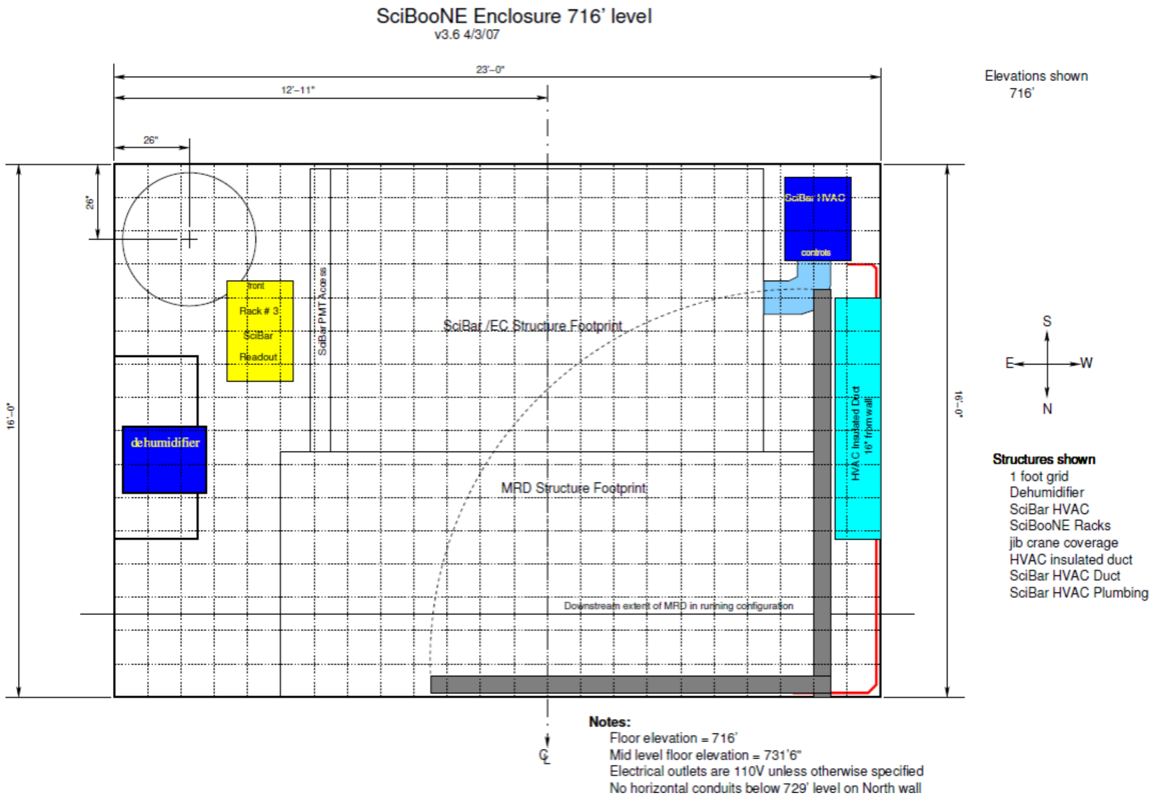
______________________________ Tuesday 22^{nd} December, 2015

Patricia McBride, PPD Division Head

______________________________ Tuesday 22^{nd} December, 2015

Regina Rameika, ND Division Head

Appendix I: SciBooNE Area Layout



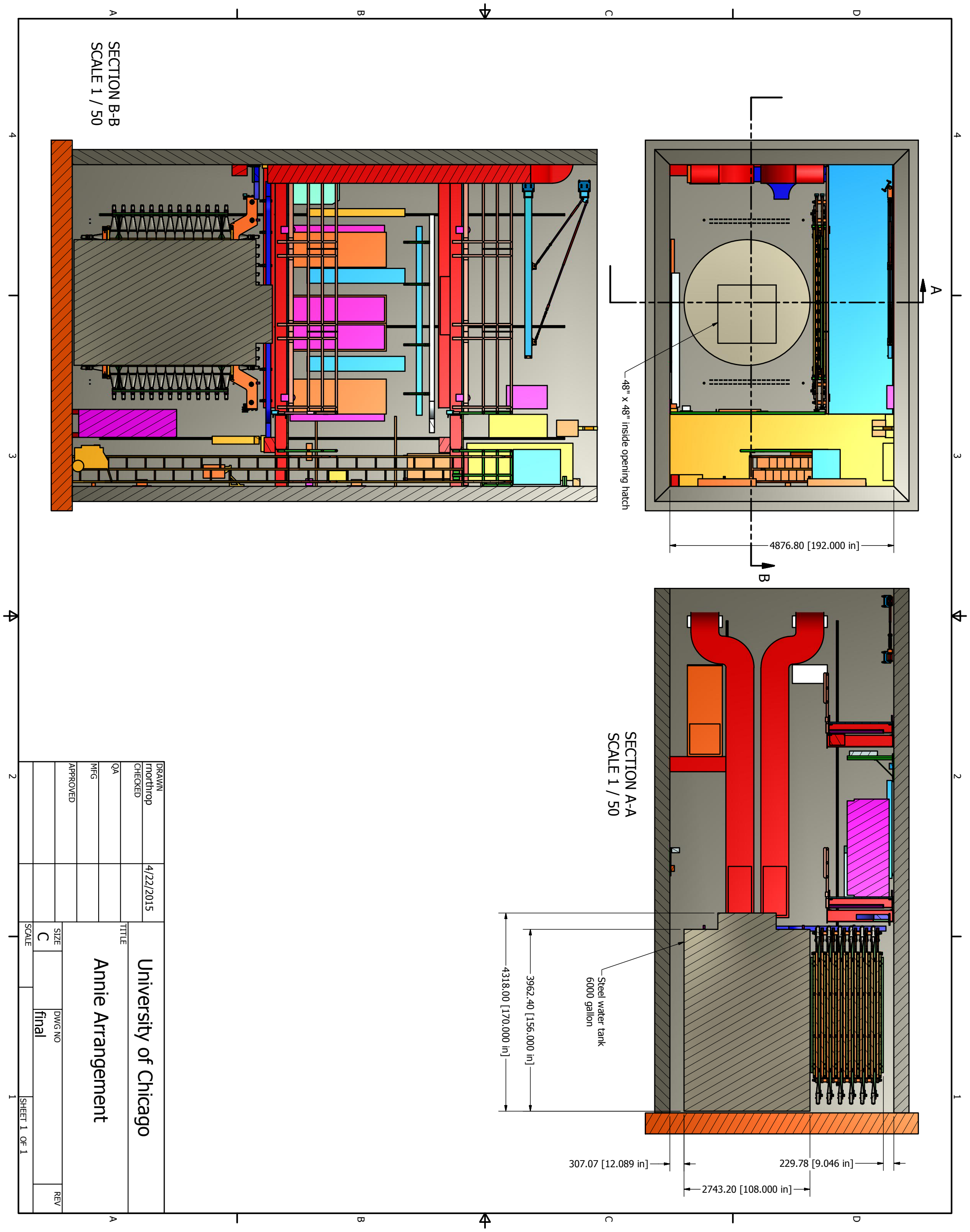


Figure 11: Layout of ANNIE in the experimental hall.

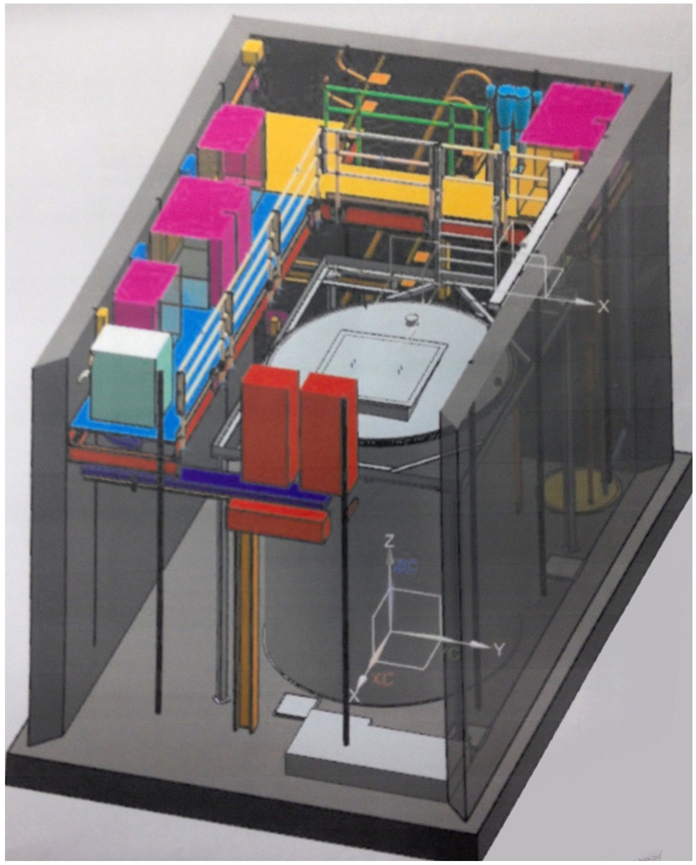


Figure 12: A view of ANNIE with the access platform.

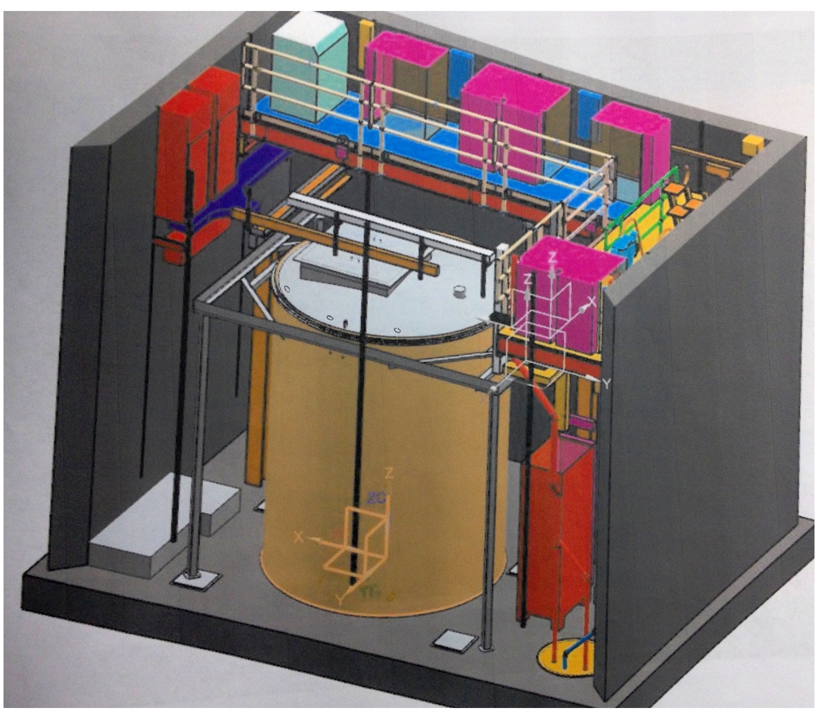


Figure 13: A view of ANNIE with the access platform.

Appendix II: Equipment Needs

Provided by experimenters:

The ANNIE collaboration has provided the tank, 8 PMTs, pickoff boxes, most of the VME-based and PSEC4-based electronics, veto support structure, and water system.

Equipment Pool and PPD items needed for Fermilab test beam, on the first day of setup.

PREP EQUIPMENT POOL:

QTY (Run I)	QTY (Run II)	Description	Status
27	27	LeCroy 4300B/610 ADCs (16 ch/card)	1 in hand, 55 ready for issue
27	27	LeCroy 4413 discriminators (16 ch/card)	1 in hand
14	14	LeCroy 3377 TDCs (32 ch/card)	1 in hand, 100 returned from user
3	3	WIENER CCUSB cards	3 in hand
5	5	BIRA:6700C CAMAC crate	1 in hand, 16 returned from user
5	5	BIRA: 6700P (POWER SUPPLY,CRATE,CAMAC)	1 in hand, 1 ready for issue, 15 returned from user
5	5	BIRA: 6700F (FAN,CRATE,CAMAC)	1 in hand, 1 ready for issue, 15 returned from user
3	3	CAEN: SY527 (POWER SUPPLY,UNIVERSAL MULTICHANNEL)	1 in hand, 12 returned from user
6	10	CAEN: A734P (POD,HV,16 CH,+3KV@3MA)	9 in hand
4	20	CAEN: A938AN (NEG,HV,16 CH,-6KV@1.2MA)	5 units returned from user

Some additional equipment in the form of standard NIM cards may also be requested.

Appendix III: Hazard Identification

ANNIE hazards include the operation of High Voltage systems to power PMTs. Some electronics, such as the pick-off boxes for the PMTs in the water volume, will be non-commercial. The VME system requires non-standard 7.5V power and necessitates a modified crate. All non-commercial electronics will be closely communicated and reviewed with ES&H. The Nitrogen blanket will be kept at as low of a flow rate as possible and will nominally be delivered by a single gas bottle at a time. ODH concerns are not anticipated. The Neutron Capture Volume will be filled with Gd-loaded scintillating oil. This system will also be designed and built in close contact with ES&H.

Flammables (Gases or Liquids)		**Gasses**		**Hazardous Chemicals**		**Other Hazardous / Toxic Materials**
Type:		Type:	**Nitrogen**		Cyanide plating materials	List hazardous/toxic materials planned for use in a beam line or an experimental enclosure:
Flow rate:		Flow rate:	**low**		Hydrofluoric Acid	
Capacity:		Capacity:			Methane	
Radioactive Sources		**Target Materials**			photographic developers	
	Permanent Installation		Beryllium (Be)		PolyChlorinatedBiphenyls	
	Temporary Use		Lithium (Li)		Scintillation Oil	**X**
Type:			Mercury (Hg)		TEA	
Strength:			Lead (Pb)		TMAE	
Lasers			Tungsten (W)		Other:	**Gadolinium Chloride**
	Permanent installation		Uranium (U)			
	Temporary installation		Other:	**Nuclear Materials**		
	Calibration	**Electrical Equipment**		Name:		
	Alignment		Cryo/Electrical devices	Weight:		
Type:			Capacitor Banks	**Mechanical Structures**		
Wattage:		**X**	High Voltage (50V)	**X**	Lifting Devices	
MFR Class:			Exposed Equipment over 50 V		Motion Controllers	
		X	Non-commercial/Non-PREP	**X**	Scaffolding/ Elevated Platforms	
		X	Modified Commercial/PREP		Other:	
Vacuum Vessels		**Pressure Vessels**		**Cryogenics**		
Inside Diameter:	**8”**	Inside Diameter:			Beam line magnets	
Operating Pressure:	**13’ water**	Operating Pressure:			Analysis magnets	
Window Material:	**glass**	Window Material:			Target	
Window Thickness:	**2-4 mm**	Window Thickness:			Bubble chamber	

Appendix IV: Tank Requirements

Constraints:

1. Material costs should be low.
2. Should require minimal custom machining/welding to be done by FNAL technical.
3. Design of the PMT supports and attachment to the inner structure should be bolt-together, capable of assembly by ANNIE collaborators with minimal training.

Requirements:

1. The tank must be able to hold 30 tons of Gd-loaded water. The fill line should fall within roughly 6 of the 13ft level.
2. The tank must be capable of water fill and emptying once or twice per run period.
3. The tank should be modified to hold roundness with its top detached, both in the SciBooNE hall and in the staging area
4. The joint between the tank and lid must be light tight.
5. The top of the tank should provide a tight seal for the nitrogen blanket.
6. The inner structure is designed to meet the Run I ANNIE specifications, but should be compatible with (or adaptable to) Run II and future runs.
7. The inner structure must be able to hold 60-200 (8",10", and 11") PMTs in addition to 20 LAPPDs. Only 60 8-PMTs will be required in Run I. The PMTs must be located close to the boundaries of the tank, but with a safe 2 clearance.
   (a) The sides of the inner should allow 2 inch clearance for the largest side-mounted tubes: 10 Hamamatsu R7081
   (b) The top and bottom of the inner structure should allow 2 clearance for the largest bottom mounted tubes: 11" ETEL D784KFL
8. It should be possible to lower the top of the inner structure in Run II, so as to provide more of a buffer-layer of water.
9. The top of the inner structure should accommodate the hatch opening.
10. The inner structure must withstand buoyant forces in a water filled tank and gravity in an empty tank.
11. The inner structure should be capable of standing upright outside of the tank.
12. All materials in tank including those of the inner structure, PMT holders and liner must be Gd sulfate loaded water compatible.
13. Modifications to the inner structure will occur on 4-7 occasions over 4 years:
   (a) two major installations - the Run I and Run II PMT coverages.
   (b) several (2-3) stages of LAPPD installation.

(c) possibility of access for repairs - 2 emergency accesses.

14. It must be possible to safely transport and lower the PMT-mounted structure, without jeopardizing the PMTs (robust to possible dynamic forces as well as protecting the PMT bases).
15. Protections should be provided to prevent banging of the structure when lowered into the tank.
16. The hatch must be accessible for NCV installation.
17. It should be possible to walk on the top of the tank.
18. PMT holders should be compatible with the structure, simple to assemble, rigid, adaptable to 3 possible PMT sizes: 8in (Run I), 10in (Run II), and 11in PMTs (Run II).
19. PMT holders should support upward, downward, and sideways orientations.
20. In later runs there will be a stock of Large Area Picosecond Photodetectors (LAPPDs) attached to the inner structure. LAPPDs are small square vacuum tiles with an 8"x8" footprint, less than 1in thick.
    (a) Buoyant forces should be symmetric and negligible.
    (b) The waterproof housing is not yet designed but is expected to have a slightly larger, approximately 14inx14inx6in footprint.
    (c) The design of the LAPPD housing can be adapted for compatibility with the inner structure.