Design of the Scintillator Counters for the MINERνA Neutrino Detector

A thesis submitted in partial fulfillment of the requirement
for the degree of Bachelors of Science in Physics from
The College of William and Mary in Virginia.

by

Meghan Colleen Snyder

Advisor: Dr. Jeff Nelson

Williamsburg, VA
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Abstract:

MINERvA is a high statistics neutrino scattering experiment approved to run in the NuMI neutrino beamline at the Fermi National Accelerator Laboratory. The hexagonally shaped detector will be placed in the beamline directly in front of the MINOS Near Detector at Fermilab, increasing the precision of MINOS data by reducing systematic errors in the measured delta mass squared interval. There are 30,000 scintillator counters in the MINERvA detector design. Developing a robust detector design using safe materials that can be assembled with minimum labor is essential for the successful construction of the detector. With the use of calculations and measurements, designs for the major component materials for the Inner and Outer Detector were evaluated and costed based on quotes from various venders and documented. Parts and supplies for initial design tests were ordered for prototyping in the spring semester. Designs for scintillator cutting tables were designed. A prototype of the Inner Detector cutting table was assembled and used to make a prototype of a miniature plane of the Inner Detector.

Acknowledgements:

I would first like to thank my advisor, Dr. Jeff Nelson for the opportunity to get involved on such a remarkable project as MINERνA, and for putting up with my countless questions over the past two years. You have introduced me to a field of physics that has captured my attention, proven to me that I have chosen the right major, and made me grin at the mention of the word ‘neutrino’. Thanks to Rita Schneider for all of her time spent analyzing my data while testing and gathering her own. To the MINERυA collaboration, thank you for trusting me with the responsibility to test and develop new techniques for the production of this detector and for all of the help you have given me along the way.

Contents:

1. MINERνA:

MINERνA is a project consisting of a new fine-grained detector to be built in the NuMI neutrino beamline directly in front of the MINOS Near Detector in the MINOS Hall at Fermilab. Such a detector will improve our knowledge of low energy neutrino interactions in the range of 1 to 18 GeV. The MINOS experiment will study neutrino interactions occurring in the 2 to 5 GeV region using a much coarser detector than MINERνA, producing less detailed information about the interactions. Implementation of the MINERνA detector will increase the precision of the MINOS data and reduce systematic errors in the measured delta mass squared interval. *Figure 1* is a schematic diagram of the positioning of the new detector in relation to the Near Detector in MINOS hall.

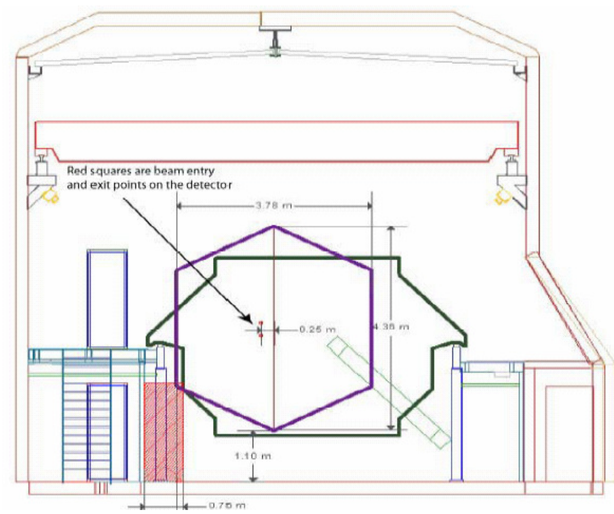
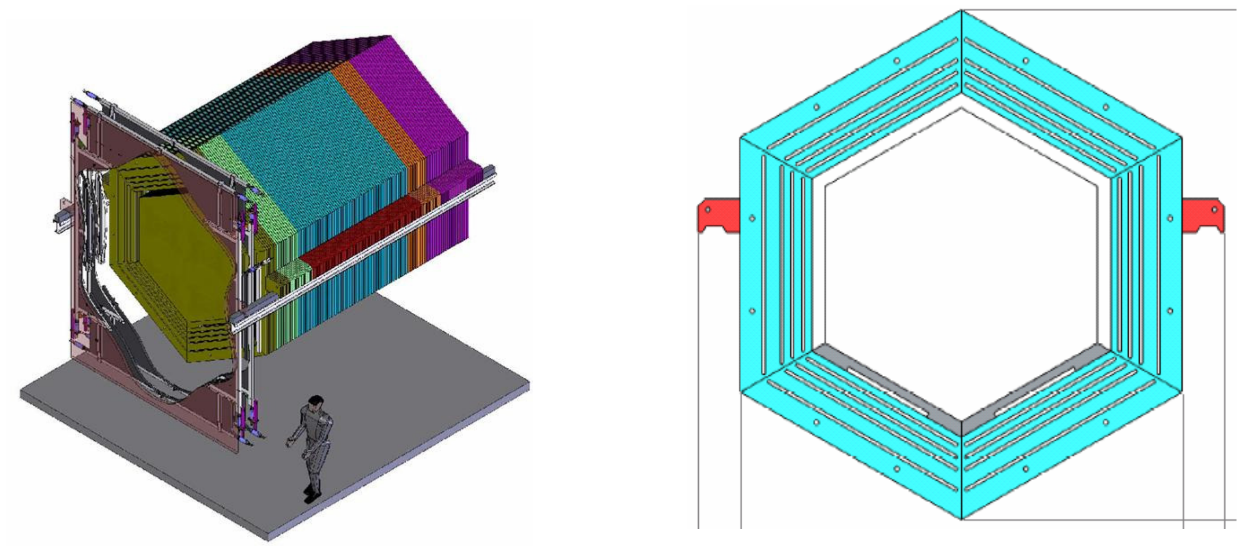


Figure 1: Schematic diagram of the MINERνA detector in relation to the Near Detector.

The MINERνA detector is shown as the smaller hexagon while the Near Detector is shown as the irregular octagonal shape behind. Note that the new detector would be placed in front of the Near Detector, with the neutrinos produced from the NuMI beam first passing through MINERνA before proceeding onward to the Near Detector. An isometric view of the MINERνA detector is shown in *Figure 2a*. The hexagonally shaped MINERνA detector will be composed of a totally active Inner Detector, constructed from 196 triangular arrays of scintillation counters. The Outer

Detector portion of the hexagon will be composed of six trapezoids of steel (towers) and scintillator acting as a sampling calorimeter. The Outer Detector is shown schematically in *Figure 2b.*



(a) *(b)*

Figure 2: a) Isometric view of the MINERνA detector.
b) Schematic drawing of Outer Detector.

1.2 Scintillators and PMTs

The MINERνA scintillator is made of polystyrene doped with organic molecules (POP and POPOP). As charged particles travel through the plastic, electrons are ionized. As these electrons return to their ground state, they release a photon of blue light that travels through the scintillator impacting the WLS (wavelength shifting) fiber, which transforms the blue photon into a green photon. The green photons are emitted isotropically. The collected green photons pass down the length of the fiber where they strike a photomultiplier tube (PMT). Approximately four photoelectrons (PE) are produced when a relativistic muon passes through one layer of MINOS scintillator. A strip is a single piece of scintillator of a given length.

The flux of photons is converted into electrons in the photodetector. The photomultiplier tube is made up of two individual portions. The initial charge, which is emitted by the photocathode, is amplified by the 11 dynodes of the PMT. At each dynode, more electrons are "kicked off," resulting in the production of 10^6 electrons from each original PE.

As photons travel through the fibers to the PMT, only a fraction of them are actually detected. The process through which these photons are converted into electrons and pass through the dynode chain is random. Thus, the ADC spectrum is represented by a Poisson distribution. This equation is given by:

$$P(n ; \mu) = \frac{\mu^n e^{-\mu}}{n!} \quad ,$$

where $\mu = mq$, μ is the mean number of PEs at the first dynode, m is the mean number of photons striking the photocathode, and q is the quantum efficiency of the photocathode. $P(n ; \mu)$ is the probability of n PEs being observed if their mean is μ.

Assuming that more than one photoelectron reaches the first dynode, (approximately four do in the MINOS strips) and assuming their amplifications are independent, then the output charge distribution can be approximated by the Gaussian distribution given by the equation:

$$G_1(x) = \frac{1}{\sigma_1\sqrt{2\pi}} \exp\left(-\frac{(x-Q_1)^2}{2\sigma_1^{\ 2}}\right)$$

where σ_1^2 is the variance, Q_1 is the mean, and x is the random variable.

The arrangement of MINOS scintillator strips limits the determination of a muon interaction to two dimensions. For each plane of scintillator, only one strip is hit by a particle. When the detectors were designed and assembled, the direction of the scintillator strips alternated every other plane. Strips were secured to a steel plane diagonally across the face from the top left to the bottom right. The next plane had its strips secured perpendicularly to that of the previous plane (diagonally across the face from top right to bottom left). This orthogonality allows the exact location of the interaction to be determined by two hit strips in adjacent planes.

MINERυA, however, is striving for a more detailed and accurate positioning system in which the scintillator is arranged in three directions. This arrangement helps solve ambiguities if there are more than a couple of particles passing through the same plane. This has led to the design of a new scintillating array (See F*igure 3*).

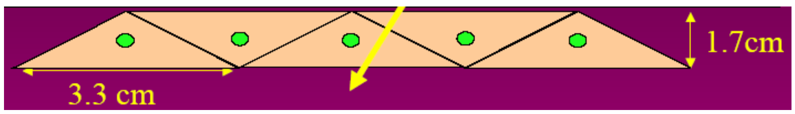


Figure 3: diagram of how the triangular strips are placed to form an array.

Each triangular strip has a base of 3.3cm and a height of 1.7cm, as shown in *Figure 4*. A hole for the fiber is in the center of the triangular piece. A 1.2mm fiber will be used to collect the scintillation light as in MINOS.

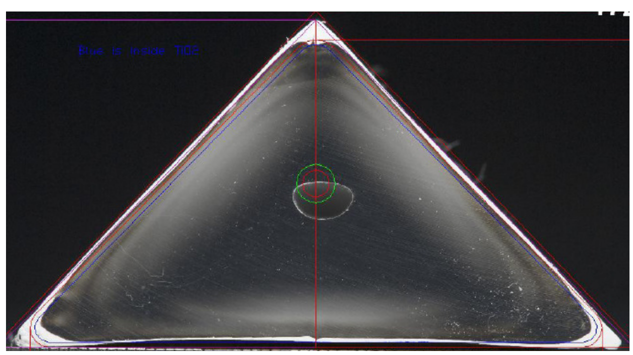


Figure 4: MINERvA scintillator strip (end view) with TiO_2 *extrusion.*

Using this triangular array, the location of the event can be found with significantly improved resolution. As a charged particle passes through the array (see the arrow in *Figure 3*) it strikes two scintillating triangles. As this occurs, light that is emitted from the ionization of the electrons in the polystyrene goes to both fibers (one in each of the triangles), called light sharing. Based on the ratio of the light output read from each of these strips, the exact trajectory of the particle can be determined.

2 Designing the MINERνA Scintillation Counters

Currently, MINERνA is in the R&D phase and attempting to secure funding. Quantities, such as the size, shape, thicknesses, and/or flame properties for components of the Inner and Outer detector have been determined for each plane and tower. The inner detector is composed of 127 strips of scintillator, collectively wrapped in Lexan, a polycarbonate, light-tight material which will keep the light produced in an interaction contained to its plane. For each plane, the top and bottom are wrapped, as well as a web of material which will weave through every three

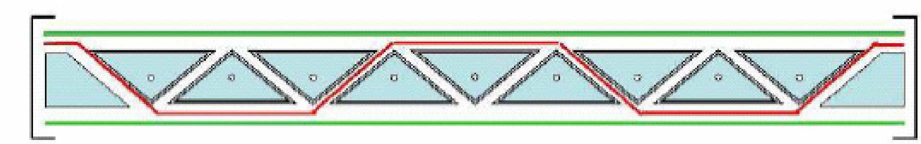


Figure 5: The weaving of the Lexan material through the array of triangular scintillator.

triangular strips of the plane, as shown in *Figure 5*. Extra Lexan material for end covers, which keeps light in at the edges of the plane are also taken into account. The quantity of epoxy needed to adhere the Lexan to the scintillator has been calculated using the dimensions of the plane and scintillator strips. The thickness that was used in this calculation was extrapolated from quantities reported by Jim Grudzinski from Argonne National Lab that were used in the MINOS detector.

Epoxy used to hold the WLS fibers in the scintillator as well as provide better optical coupling has been studied. By increasing the amount of light that is received by the PMT from the fibers, better determination of the particle's position and more precise particle tracking results that are obtained.

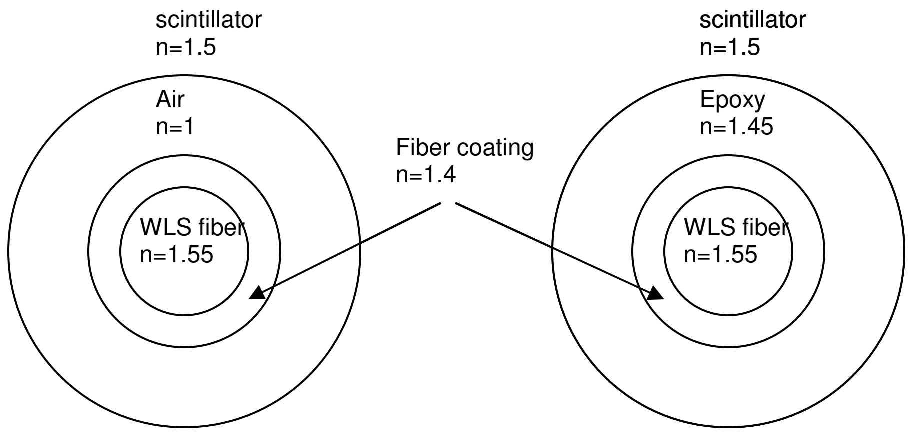


Figure 5: diagram of indexes of refraction

Figure 5 above shows a diagram of the hole of each scintillator, with the index of refraction n, equal to 1.5 for the strip, 1 for air, 1.4 for the WLS fiber cladding, and n=1.55 for the center of the fiber. It is unlikely that all of the photons produced inside the scintillator (n = 1.5) will pass to the WLS fiber through internal reflection in the diagram on the left of F*igure 5* due to the large difference in the indexes of refraction. This diagram represents the case where there is no epoxy in the hole. The diagram on the right shows the indexes of refraction after the epoxy has been injected into the hole. Notice that the index of refraction of the epoxy is 1.45, between the index of the scintillator and the cladding of the fiber. This increases the number of photons transferred to the fiber from the scintillator, increasing light yields. The reflection coefficient can be determined from the following equation.

$$r = \frac{n_2 - n_1}{n_2 + n_1}$$

where r is the reflection coefficient and n is the index of refraction.

Two brands of optical epoxy were compared using light tests to determine the best epoxy for light transmission. Prior to co-extrusion, scintillator was coated with reflective paint for preliminary testing. In order to verify that the scintillating arrays would perform as designed, a Vertical Slice Test (VST) was performed at Fermilab using half-meter strips, which would be painted. Lights tests were also used on scintillator with different paints to determine the best paint for light yield. These tests are described below.

2.1 Fiber Tests

Light outputs were determined for two types of WLS fibers, blacked and mirrored. As light enters the WLS fibers, it propagates forward and backward. In the blacked fibers, whose ends were marked black, the light traveled backward and was absorbed in the black, not reflected in the forward direction. A mirrored surface was placed at the end of the fiber, allowing for the backward light to be collected, producing a higher light yield. *Figure 6* shows the data using coextruded strips with no epoxy and no RTV, with current in nA on the x-axis.

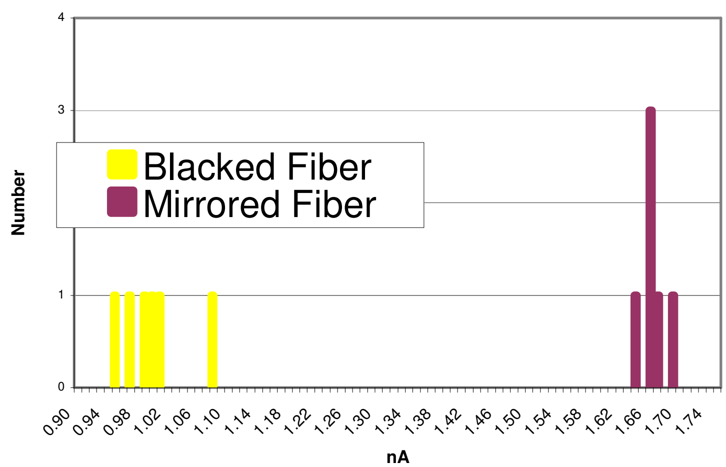


Figure 6: Light output (in nA) between blacked and mirrored fibers.

The mirrored fibers produced a light output increase of 66% compared to the blacked fibers. The ratio of glue to no glue for coextruded strips using 815C and TETA are shown in *Figures 7 and 8* below for the mirrored and blacked fibers. The average light ratio of glue to no glue for blacked fibers is 1.49±0.02 with an RMS of 0.042. The average light ratio for the mirrored fibers is

1.51±0.03 with an RMS of 0.062. This data shows that the light ratio of glue to no glue is independent of whether the fibers are mirrored or not.

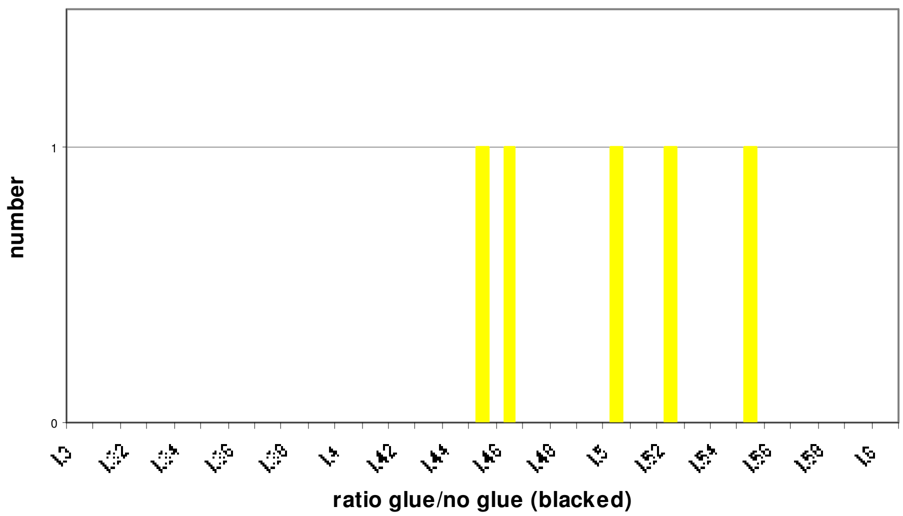


Figure 7: ratio of glue/no glue for blacked fiber.

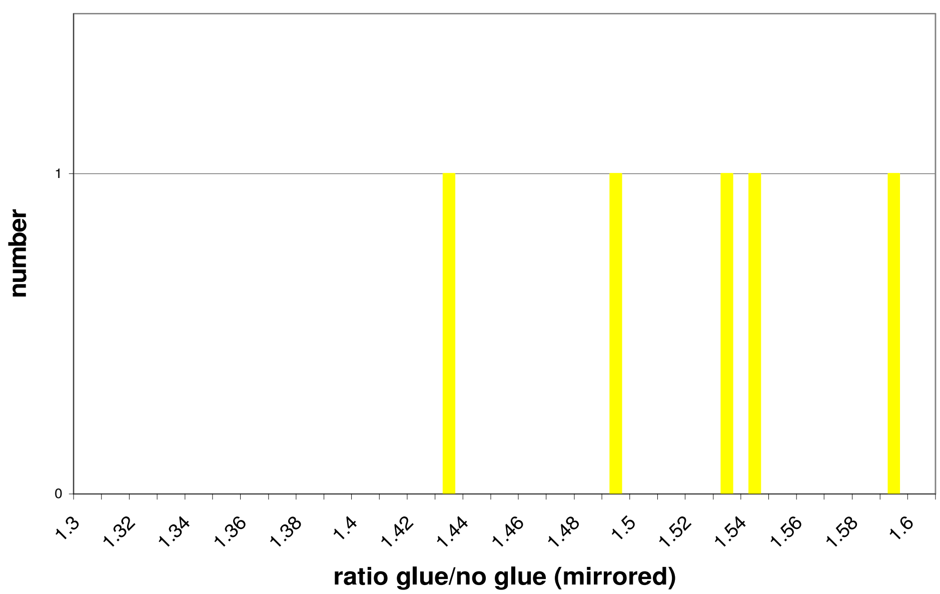


Figure 8: ratio of glue/no glue for mirrored fiber.

2.2 Epoxy and Paint Tests

Two brands of paint and optical epoxy were compared using light tests in a light box. The paint would be used for preliminary testing of the scintillating arrays, while the optical epoxy would be chosen for the assembly process. The two brands of paint were Eljen, a latex based paint which is applied smoothly, and Bicron, a clumpier, thicker paint. Six half-meter strips were painted with Bicron, and two with Eljen.

The two brands of epoxy that were tested were 815C and TETA (resin and curing agent) and Eljen epoxy (2-part epoxy). The 815C and TETA combination is the same epoxy that was used in MINOS with a 30 minute pot life. The Eljen has a higher viscosity than the 815C epoxy but with an hour pot life.

Three of the six Bicron painted strips were epoxied with 815C and TETA, with the remaining three epoxied with Eljen epoxy. One of the Eljen painted strips was epoxied with the 815C while the other was with the Eljen epoxy. All of the epoxied strips were injected at 30 psi using the same glue injection process which is described in Appendix B.

A dark box containing a collimated Cs-137 source was used for testing the light output of the epoxied strips. The strip being tested was sandwiched between two non-painted strips used to support the holder for the Cesium source (See *Figure 9*).

The source holder was placed 20 cm from the injection site for each test. The fiber traveled from the scintillator to the PMT, which sent signals to a computer programmed to return the corrected PMT value for the current (see *Figure 10*). The computer program took 20 data values and averaged them as the "corrected PMT" value. Five tests were performed on each

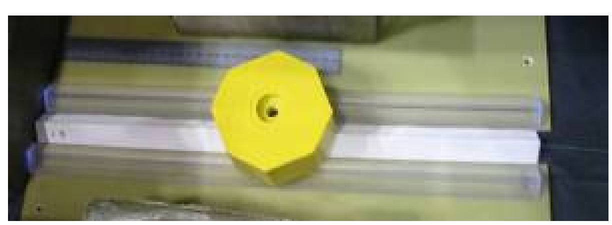


Figure 9: light test setup.

strip with data recorded in the table below.

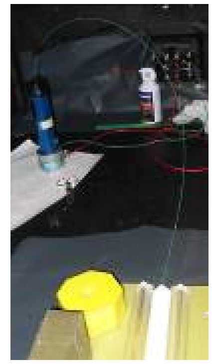


Figure 10: More setup.

2.2.1 Data

Paint	Epoxy	Avg. PMT signal (nA) No glue	Glue	Avg. Glue	Ratio = glue/no glue Avg. Light Increase
Bicron	Eljen	18.663	26.843	26.476	1.429
		18.508	26.020		
		18.428	26.564		
Bicron	815C	19.708	26.998	25.591	1.315
		18.690	23.063		
		19.913	26.712		
Eljen	Eljen	13.492	17.858	17.858	1.324
Eljen	815C	12.89	17.774	17.774	1.379

For scintillator with 815C epoxy, the light yield ratio of Eljen to Bicron paint is 0.695. The light yield ratio for the Eljen epoxy is 0.675.

Coating, Epoxy	AVG	% RMS
Coex. 815C	1.50 ± .03	3.3%
Bicron, Eljen epoxy	1.43 ± .01	1.4%
Coex. Eljen epoxy	1.40 ± .03	4.5%
Eljen paint, 815C	1.38	n/a
Eljen paint, Eljen epoxy	1.32	n/a
Bicron, 815C	1.32 ± .04	5.5%

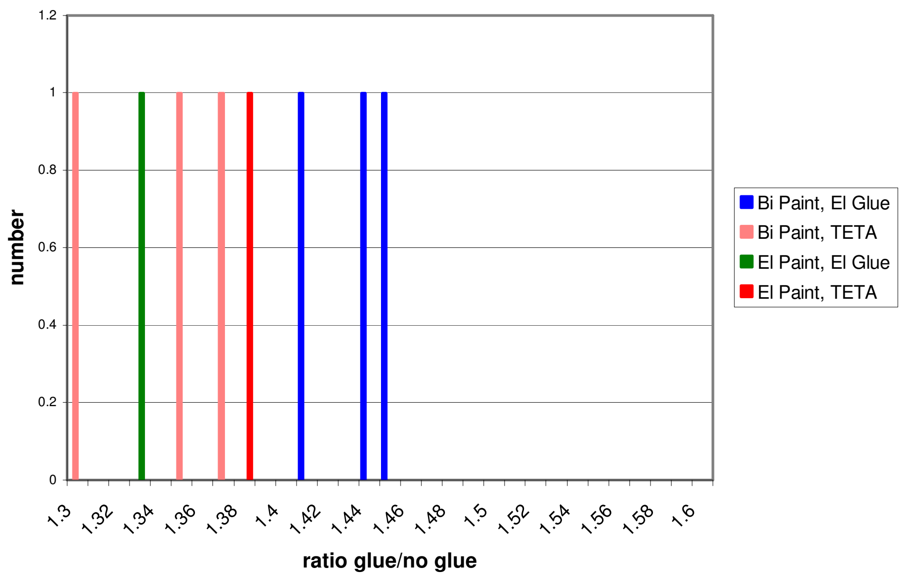


Figure 11: ratio of glue/no glue for Bicron and Eljen paint and 815C and Eljen epoxy.

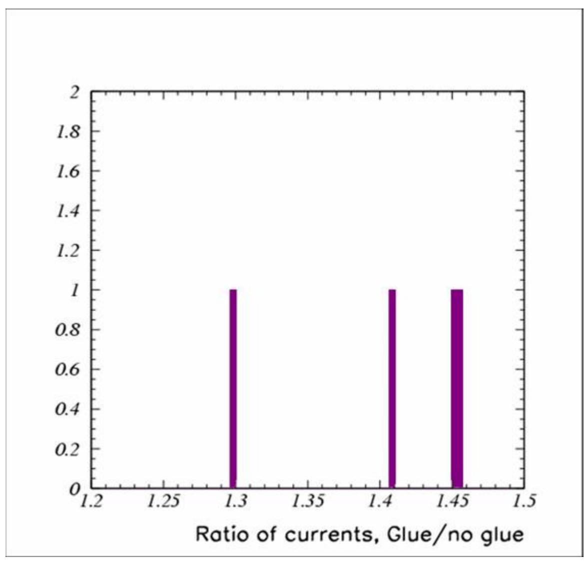


Figure 12: Eljen epoxy with coextruded scintillator.

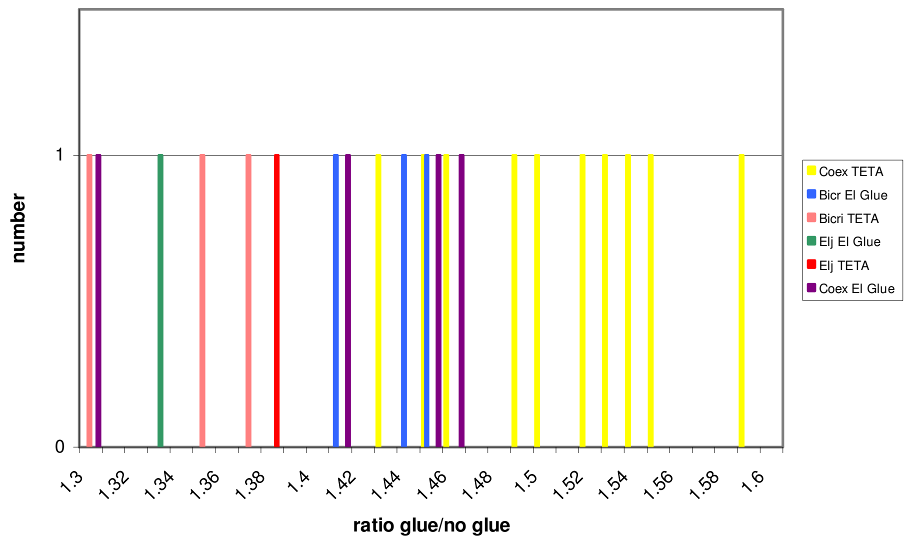


Figure 13: ratio of glue/no glue for all the scintillator tested.

2.2.2 Results

2.2.2.1 Paint

There is a 30% difference in light yields between the two paints. Due to Eljen's latex-based consistency, it was hoped that it would be used to paint the scintillator for the Vertical Slice Test. However, the data showed that the Bicron paint is a much better reflective coating proving that it should be used for the Test instead, in spite of its potential for being clumpy.

This testing between paints was performed preceding the fall semester, when coextruded strips of scintillator were not able to be used in the Vertical Slice Test. Once coextruded strips were available in the fall, they were tested for average light yields and compared to retested Bicron and Eljen painted strips. *Figure 13* above shows the ratio of glue to no glue for the coextruded strips and 815C in yellow, ranging from 1.43 to 1.59, with an average of 1.50±0.03. Note the increase in light yield between the coextruded (1.50±0.03) and the painted strips (Eljen was 1.39 and Bicron was 1.32±0.04).

2.2.2.2 Epoxy

The average light yield between glued and unglued fibers was a factor of 1.43±0.01 higher for Bicron painted strips with Eljen epoxy. The average light yield increase for Bicron painted strips with 815C epoxy was 1.32±0.04. However, with the Eljen paint, the 815C had a slightly higher light increase than the Eljen epoxy. Other issues also contributed to the epoxy decision including their viscosity. The Eljen epoxy is more viscous than the 815C. A problem with higher viscosity epoxies is an increased time to epoxy each strip. It is optimal to reduce the amount of time required to epoxy each strip due to a maximum strip length of approximately three meters.

Coextruded pieces of scintillator were tested, using both 815C and the Eljen epoxy. The coextruded pieces with 815C had an average light ratio of 1.50±0.03 with a percent RMS of 3.3%. The coextruded pieces with Eljen epoxy had an average light ratio of 1.40±0.03 with a percent RMS of 4.5%. The highest light increase was the coextruded scintillator with 815C and TETA. All of the data is shown above.

2.2.3 Conclusions

Light tests showed that Bicron is a better reflective coating than Eljen paint for MINERνA scintillator with a difference of approximately 30 percent. The second Vertical Slice Test, performed at Fermilab, used Bicron paint because of these findings. The coextruded scintillator has a much light yield compared to either of the paints. Due to this and the availability of the coextruded strips, the new Vertical Slice Test will use coextruded strips. The use of coextruded scintillator for the detector was the original plan. This data simply solidifies our choice in using the coextruded strips for optimal light yield and collection.

These same light tests showed that Eljen epoxy had a greater average light increase between glued and not glued strips that were painted with Bicron paint. The 815C epoxy had a slightly greater light increase for the strips painted with Eljen rather than the Bicron paint. Due to the success of the 815C epoxy in MINOS combined with the large difference in the light yields using the coextruded strips between 815C and Eljen epoxy (1.50±0.03 compared to 1.40±0.03), the 815C will be used in the construction of MINERνA scintillator planes.

2.3 Epoxy Injection Methods

While injecting epoxy into the scintillator, it became clear that the epoxy had a tendency to flow out of the injection site, instead of progressing down the length of the fiber in the hole. To alleviate this 'backflow' of epoxy, different forms of caulking and RTV were tested to determine the best end seal. RTV proved a better end seal.

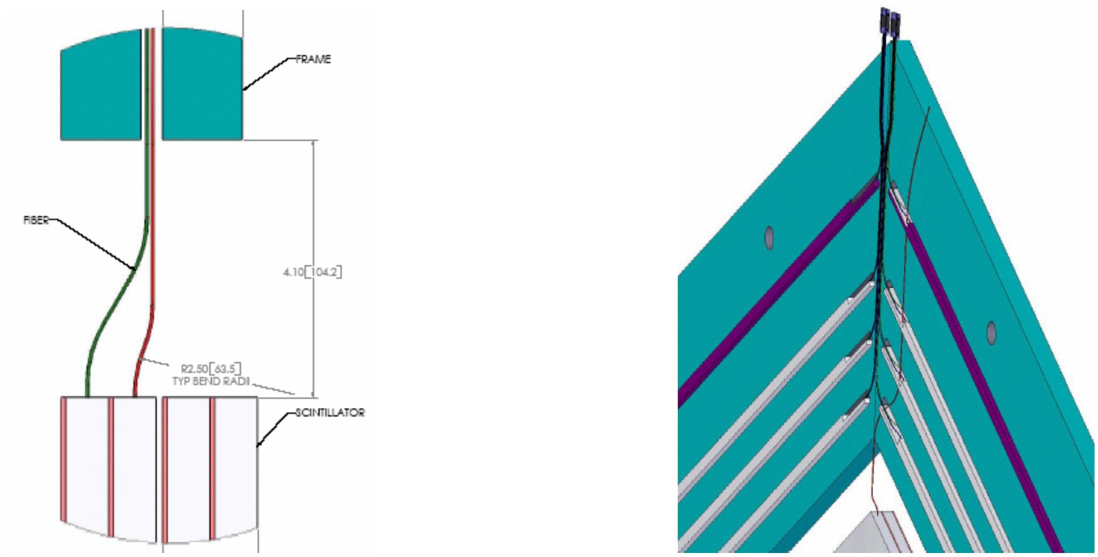
RTV is placed on the end of the strip of scintillator completely covering the fiber hole. This is allowed to cure for 24 hours. The epoxy is the same as that used for MINOS. The resin is 815C (Epon 815C) and the hardener is TETA (Epi-Cure 3234). The proportions are 100/14 (with 100 grams resin for 14 grams TETA). Once the appropriate batch size is determined, the resin and hardener are mixed together using either a digital weight scale or a triple-beam balance.

The epoxy is then put in vacuum to remove the air bubbles produced during mixing. Once still, the epoxy is poured into a 30cc syringe followed by a stopper. The fiber is then put in the hole in preparation for injection. An air driven glue machine is used with a foot pedal for regulating the pressure. A barrel adapter kit connects the syringe to the glue machine. A needle is then attached to the end of the syringe and is inserted into the hole in the scintillator by puncturing the RTV. With the pressure adjusted on the glue machine, the epoxy is injected into the scintillator. An instruction manual for the epoxy injection process was written and can be found in the Appendix B.

2.4 Fiber Guidance

Research has been done for products which will provide rigidity and support for guiding the WLS fibers from the scintillator to the PMT. Foamed PVC will be used to guide the fibers from the scintillator onto the steel towers between each plane for both the inner and outer detector. The fiber path for the Inner Detector is shown in *Figure 14a* below. The foam will be designed and shaped to insure that the fiber follows the designated path (as outlined in *Figure 14a*) and remains in that position as it leaves the scintillator and travels over the steel towers to the PMT (shown in *Figure 15*). The fibers in the Outer Detector scintillator will be routed over a portion of the tower to the PMT, as shown in *Figure 14b*.

To keep the fibers of the Inner Detector from tangling and to provide support across the steel towers, a reinforced plastic Canvex sheet will be used as a "routing substrate" (*Figure 15*). This same Canvex material will be heat sealed and taped together to form a "sleeve" or "routing cover" which will encapsulate the fiber guiding it across the steel towers, creating a light-tight environment for the fibers of each plane.



(a) *(b)*

Figure 14: a) fiber route from Inner Detector scintillator onto the steel tower using foamed PVC. b) fiber route from Outer Detector scintillator onto the steel tower surface.

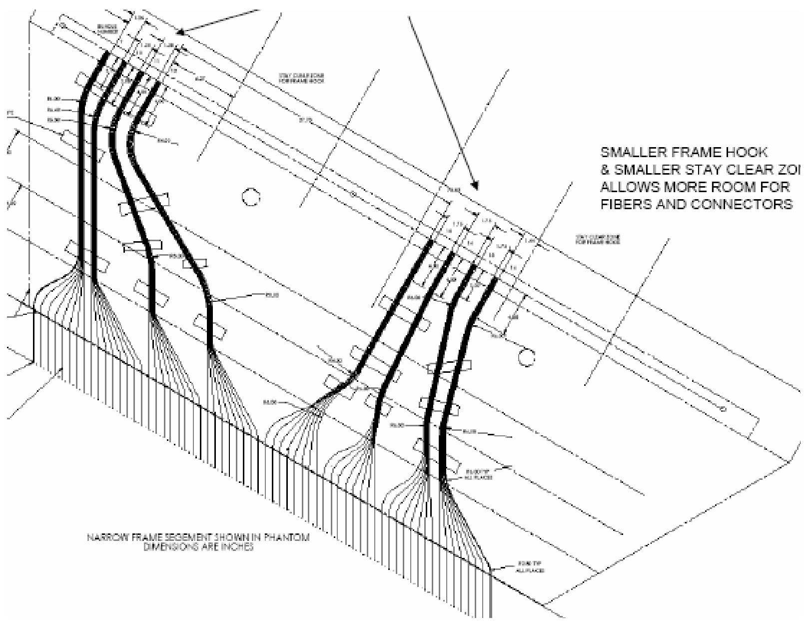


Figure 15: Route of the Inner Detector fibers over the steel towers (fibers are held in place on a Routing substrate the same shape as the towers).

For each of these quantities, quotes from vendors have been filed and inserted into a technical memo that the Department of Energy calls a BOE (Basis of Estimate) detailing the costs and supporting documentation of each item of a single MINERvA scintillator plane. The document summarizes the costs of each plane of the detector into two main headings, the Inner Detector Planes and the Outer Detector Towers. Each heading is further divided into components that will be procured through William and Mary and through our collaborators at Hampton University, listing the materials, designs, and prices for each.

Not only have the quantities for the components of each design been calculated, but the methods by which each design will be manufactured have been defined. The PVC foam will be cut into specific dimensions and machined into their final shapes in the William and Mary shop. Canvex will be cut into shapes for the Routing Substrate and Routing Cover and pre-sealed by a vendor. The costs associated with these methods for manufacturing are also documented in the BOE.

A final cost is determined to be $109k for 208 Inner Detector planes, while the final cost for 684 towers of the Outer Detector is $33k, with a 46% cost contingency. The Basis of Estimate for the Inner Detector can be found in Appendix C.

3 Prototyping:

Nine scintillator strips were cut into a trapezoidal array and assembled into a prototype of a plane of the Inner Detector (see *Figure 16*). Lexan was epoxied to the top and bottom of the array as well as weaved every three strips to create the web, providing stability to the plane. PVC foam pieces were cut, glued together, and attached to the array for the fibers to be guided out. The prototype will be vacuum cured when components arrive at WM which are currently being shipped.

Each scintillator strip shipped to William and Mary will need to be cut at a designated length to form the trapezoidal shape. A cutting table will be used to cut the scintillator. *Figure 17* shows the prototype of this cutting table that was designed and created for use with a circular saw. A diagram for the cutting table is shown in Appendix A. The parts for the table were ordered and are currently being fabricated in the WM machine shop.

Figure 16: trapezoid of scintillator array.

Figure 17: prototype of cutting table

4 REFERENCES:

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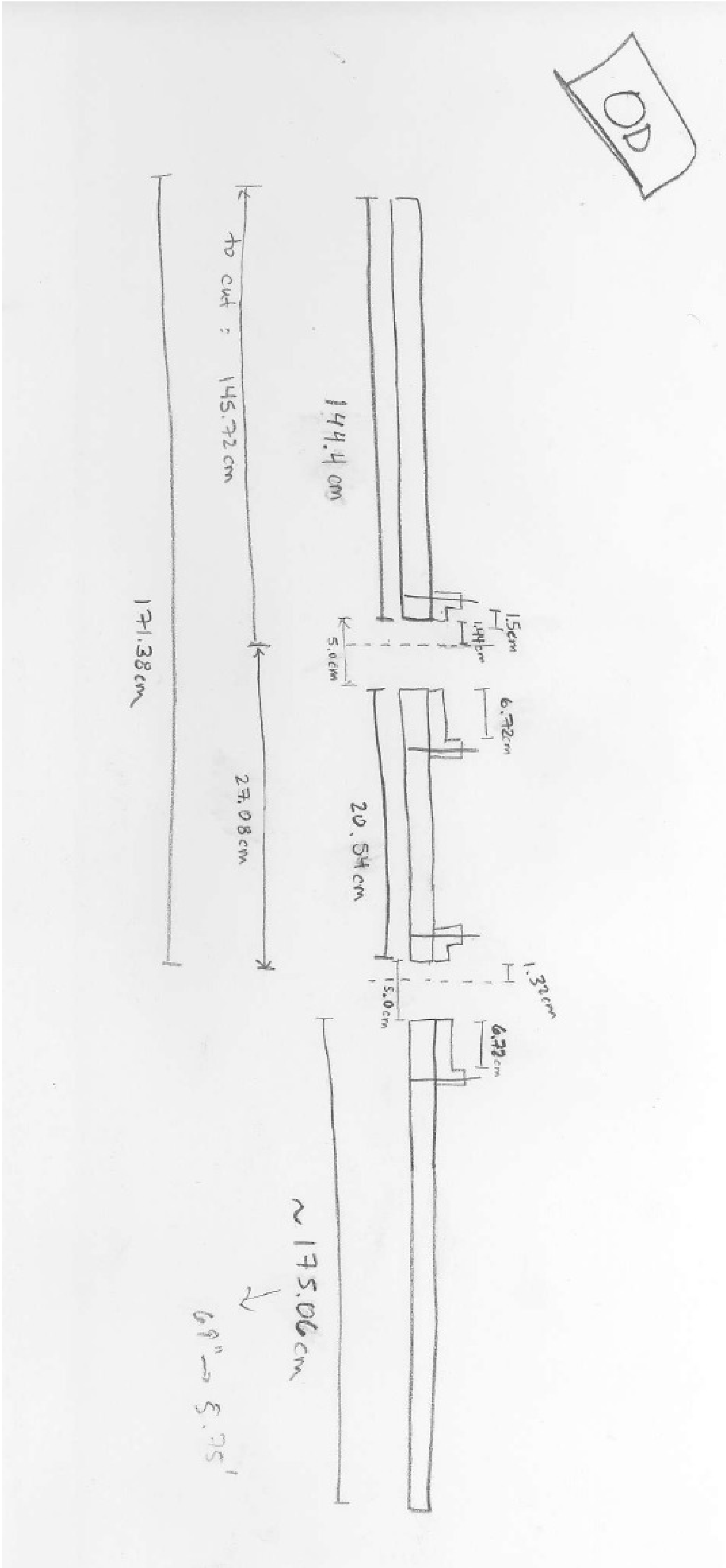
5 Appendix A

OD Scintillator Cutting Table Design



6 Appendix B

Physics Department The College of William and Mary	**GLUE INSTRUCTION**	
TITLE: EFD Glue Machine Injection Process	REVISION: **1**	DOCUMENT NO.:
EFFECTIVE DATE: **January 25, 2006**	PAGE	SIGNATURE: Meghan Snyder

Purpose: To describe the process for Glue Injection into the MINERvA scintillator using the EFD glue machine.

References:

EPON 815C Resin Material Safety Data Sheet
EPICURE 3234 Curing Agent (TETA) Material Safety Data Sheet

Action:

1. Material Requirements

1.1. Miller-Stephenson EPON 815C Resin - one (1) Quart Unit
1.2. Miller-Stephenson EPICURE Curing Agent 3234 (TETA) – one (1) Quart Unit
1.3. Scintillator pieces
1.4. WLS fiber (1.2mm)
1.5. RTV
1.6. Triple-Beam Balance or Digital Scale
1.7. 8oz cup for mixing
1.8. Mixing sticks (skewers)
1.9. Masking Tape
1.10. Vacuum Pump
1.11. 30cc Syringe – one (1)
1.12. 30cc Piston – one (1)
1.13. 30cc Syringe Adapter assembly – one (1)
1.14. Gauge 20 Pink Precision stainless steel tip – one (1)
1.15. EFD Mixing Machine
1.16. EFD foot peddle or hand button attachment
1.17. Plastic tubing for air supply
1.18. Small ring clamps
1.19. Small Phillips head screwdriver
1.20. Disposal wipes

2. Safety Equipment Required

2.1. Plastic gloves
2.2. Safety glasses
2.3. Closed Toe Shoes

3. Work Area Preparation

3.1. Inspect quarts of epoxy components (resin and curing agent).
3.2. Make sure scale is balanced.
3.3. Check that all components for glue machine are present.
3.4. Put ChemWipes (or aluminum foil) down on work surface to protect against epoxy.

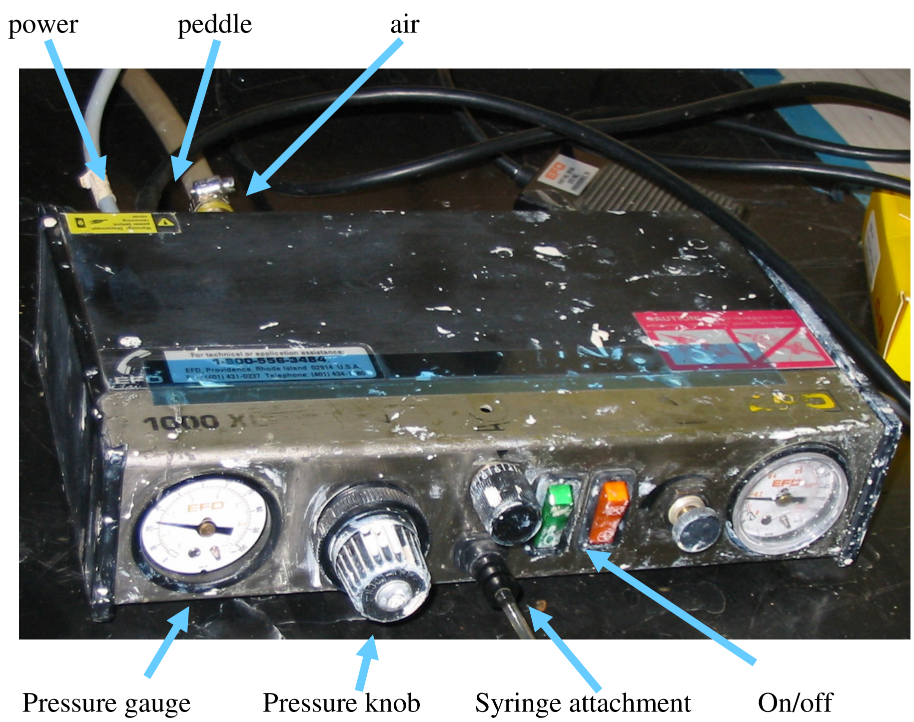
Note: material to be mixed per manufacturer's recommendations

4. Scintillator Preparation

4.1. Determine the length of scintillator that will be used.
4.2. Cut scintillator with band saw if scintillator needs to be cut into smaller pieces.
4.3. On the smooth end of the scintillator, apply a generous quantity of RTV, completely covering the hole. Allow to cure for 24 hours before injection attempts.

5. Assemble EFD Mixing Machine

5.1. Plug the machine in (power) (on back on machine).
5.2. Attach the foot peddle or hand button to the back of the machine.
5.3. Attach the Syringe Adapter to the front of the machine.
  5.3.1. It should twist in.
5.4. Attach the tubing to the wall air supply and the copper nozzle on the back of the machine.
  5.4.1. Tighten the tubing with ring clamps using the screwdriver – make sure it's REALLY tight – otherwise it might explode off.
  5.4.2. Turn air on.



6. Mixing Epoxy and Syringe Filling

6.1. Wearing safety goggles, measure out the epoxy components (815C and TETA) using the triple beam balance.

6.1.1. Use the proportion of 100g 815C resin to 14g TETA. (Don't forget to take into account the mass of the cup used to mix in).

6.2. Mix the epoxy until it is well incorporated.

6.3. Using the vacuum pump pull as many air bubbles out of the epoxy as possible.

6.3.1. A gauge should show that the pressure inside is approximately 0.5 atm.

6.4. Transfer the epoxy from the cup into the 30cc syringe, with tip already screwed on end.

6.4.1. Run the epoxy down the side, avoiding air bubbles wherever possible.

6.4.2. Good idea to plug the end of the tip with your finger to keep it from running out while the syringe is filling.

6.5. When all epoxy is in syringe, push stopper inside syringe to the level of the epoxy so there are no air bubbles.

6.6. Attach the syringe adapter (yellow top) to the top of the syringe.

7. Injection process

7.1. Set the pressure gauge on the machine to the designated pressure for injection.

7.2. Insert the fiber into the scintillator, leaving several inches at the end.
7.3. Take the end of the fiber gently to the table or work surface to make sure the fiber does not move during injection.
7.4. Puncture the needle tip through the RTV into the hole, careful around the fiber.
7.5. Making sure that the needle tip is completely inside the scintillator and is firmly pressed against the RTV to make sure of no back-leakage, press the foot peddle or hand/finger button to start injection, being sure to have it pressed the entire time for the epoxy to flow to the end of the scintillator (don't stop in the process of injection – it will cause unnecessary air bubbles).

7.6. Turn air off. Remove yellow syringe adapter from syringe. Press the foot peddle/hand button to dispel of excess air in the tubing.
7.7. Let the epoxy dry/cure for at least an hour before handling. More air bubbles appear as it is left to cure.

8. Clean Up

8.1. Allow for the syringe to dry for an hour before discarding.
8.2. After an hour, the masking tape may be taken up from the fibers.
   8.2.1. The epoxy should have set enough for the fibers to remain in place.
8.3. Discard of the ChemWipes, etc that were used.
8.4. Turn mixing machine off and disconnect all attachments.

MATERIAL USE RECORD SHEET

Date	Time	Scintillator lengths and quantity	815C Weight	TETA Weight	Waste Weight (mix cup & material)

7 Appendix C

Minerva Basis of Estimate

WBS 3: Scintillator Plane Assembly

I. General Information

Task Name: WBS 3.2.2 Acquire Inner Detector Plane Components

Unique ID Number: 1339

Date of Estimate: December, 2005

Estimate Generator: J.K. Nelson & M.C. Snyder

Cost Category:
Fixed
x SWF

Comments: This BOE covers all of WBS 3.2.2

Vendor Quote Number if Applicable: Many

Drawing Reference Number or Attachment: ____________

Costing Method: Mixture of methods (mostly quotations)

Total Task Cost: $ 106,502

Contingency & Method: Various

II. Cost Estimate Breakdown

The costs per plane are broken down by institution and to L5 tasks at follows:

		$/plane
3.2.2	**ID plane**	**$512.03**
3.2.2.1	**ID Plane Components at William & Mary**	**$385.23**
3.2.2.1.1	Procure light sealing components for ID Modules	**$ 48.72**
3.2.2.1.2	Procure ID scintillator readout routing parts	**$ 34.20**
3.2.2.1.3	Purchase ID scintillator adhesive	**$120.51**
3.2.2.1.4	Procure WLS fiber OD routing components	**$144.93**
3.2.2.1.5	Purchase ID optical coupling	**$ 36.87**
3.2.2.2	**ID Plane Components at Hampton**	**$126.80**
3.2.2.2.1	Purchase ID package materials	**$ 48.22**
3.2.2.2.2	Purchase scintillator detailing and curing components	**$ 18.67**
3.2.2.2.3	Purchase ID mounting hardware	**$ 59.92**

The L6 breakdown is shown in the following table:

		$/plane
3.2.2	**ID plane**	**$ 512.03**
3.2.2.1	**ID Plane Components at William & Mary**	**$ 385.23**
3.2.2.1.1	**Procure light sealing components for ID Modules**	**$ 48.72**
	Side rails	$ 24.20
	Side seals	$ 0.32
	End shim	$ 24.20
3.2.2.1.2	**Procure ID scintillator readout routing parts**	**$ 34.20**
	Purchase material	$ 24.20
	Machine material	$ 10.00
3.2.2.1.3	**Purchase ID scintillator adhesive**	**$ 120.51**
	Fastenal A	$ 52.58
	Fastenal B	$ 52.95
	Gluing consumables (plunger, nozzle)	$ 4.98
	Consumables (plastic trowels, Kim wipes, disposable holding cans)	$ 10.00
3.2.2.1.4	**Procure WLS fiber OD routing components**	**$ 144.93**
	Routing substrates	$ 7.80
	Routing covers	$ 15.60
	Routing covers transit tape	$ 51.00
	Carpet tape	$ 2.53
	Purchase routing supports	$ 30.00
	Machine routing supports	$ 4.00
	Purchase connector box mounts	$ 30.00
	Machine connector box mounts	$ 4.00
3.2.2.1.5	**Purchase ID optical coupling**	**$ 36.87**
	Teta (hardener)	$ 5.36
	815C (epoxy)	$ 27.45
	Mixer heads	$ 1.38
	Reflector paint	$ 0.68
	Cleaning supplies (razor, solvent, reamer, wet-dry sand paper)	$ 2.00
3.2.2.2	**ID Plane Components at Hampton**	**$ 126.80**
3.2.2.2.1	**Purchase ID package materials**	**$ 48.22**
	Upper skin	$ 15.50
	Lower skin	$ 15.50
	Web	$ 15.50
	End covers	$ 1.72
3.2.2.2.2	**Purchase scintillator detailing and curing components**	**$ 18.67**
	Vacuum tape	$ 8.89
	Plastic sheeting	$ 3.99
	RTV	$ 2.20
	Black tape	$ 1.50
	Al tape	$ 1.33
	Zip locks	$ 0.75
3.2.2.2.3	**Purchase ID mounting hardware**	**$ 59.92**
	H clips	$ 46.87
	Adhesive	$ 7.80
	Steel wool	$ 0.25
	Alcohol and Kim wipes	$ 5.00

From the per plane costs, the costs of each of the task in WBS 3.2.2 were computed by multiplying by the number of planes required for the task. In the entire L3 task, 208 planes worth of material are purchased. These costs are broken down and their basis explained in the following sections.

WBS	**3.2.2.1.1.1**
Item:	Side Rails
Cost:	$24.20
Vendor:	Total Plastics Inc
Type:	Quote in quantity (FY06$)
Contingency:	40%
Reason:	Technical risk; uncertainty in fire safety approval

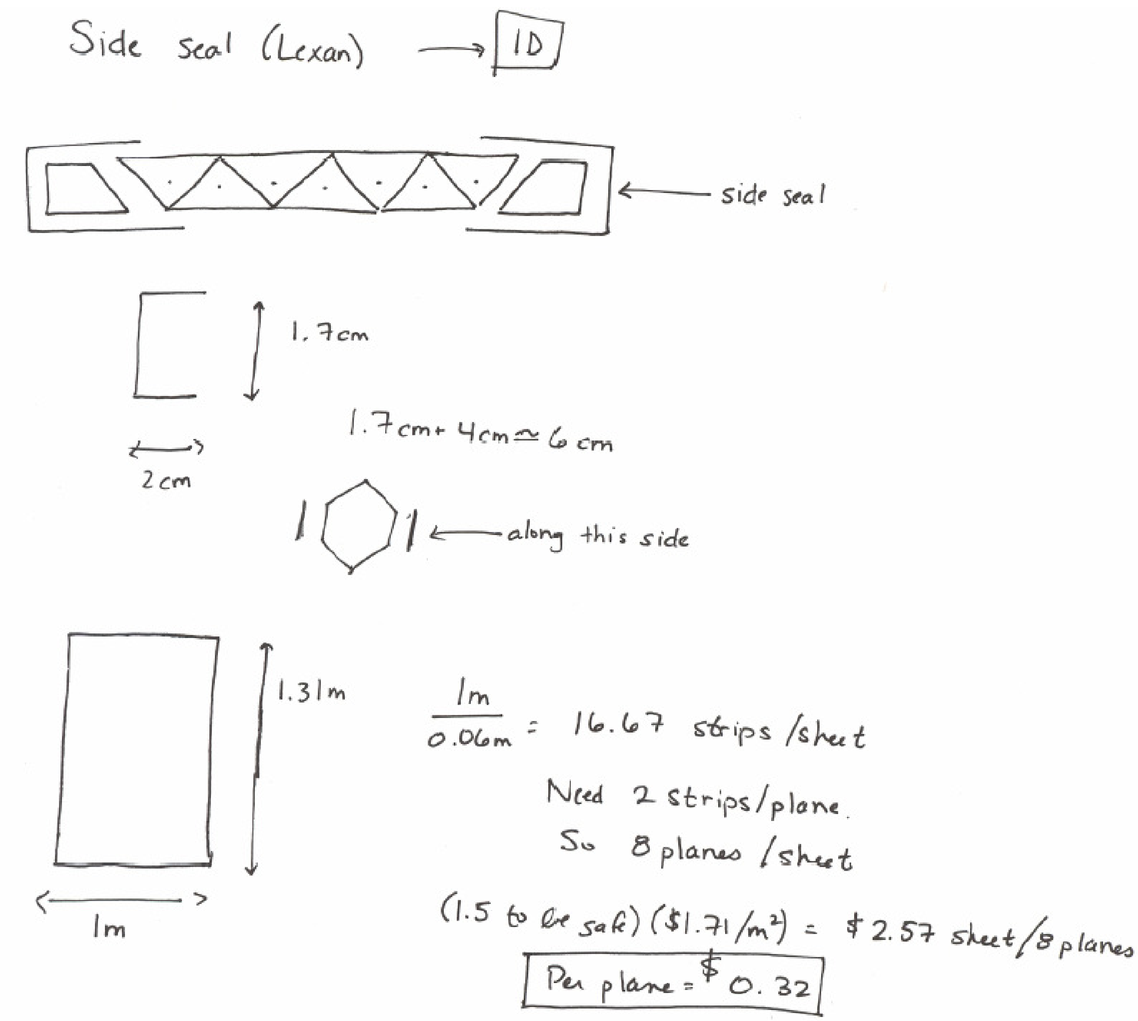
Estimate Details:

These parts are made from Intefoam brand foamed PVC, parts rough cut by Total Plastics Inc. (See Quote 1 at the end of the document) for a 5ft x 8ft part is $42.93. They also quote a cut per part cost of $6.05. Four of these parts are required to make the rails for a plane. Delivery is 2-3 weeks. The later quote is used for the BOE.

A second quote (#2) was also received from Modern Plastics, Inc for 4ft wide sheets of $38 (uncut).

WBS **3.2.2.1.1.2**
Item: Side Seals
Cost: $0.32
Vendor: Piedmont Plastics:
Type: Quote in quantity (FY06$)
Contingency: 30%
Reason: Technical risk; uncertainty in material thickness
Estimate Details:

A quote for 10 mil FR700 black fire retardant Lexan polycarbonate roles was received from Eric Christy at Hampton. The quote is for one meter width rolls of 150m, and with a cost per roll of $256.70 (from Piedmont Plastics). The cost per square meter of the material is $1.71. The math is shown below. Note 50% waste in rough cutting is assumed.



WBS	**3.2.2.1.1.3**
Item:	End Shim
Cost:	$ 24.20
Vendor:	Total Plastics Inc
Type:	Quote in quantity (FY06$)
Contingency:	40%
Reason:	Technical risk; uncertainty in safety approval
Estimate Details:	

These parts are made from Intefoam brand foamed PVC, parts rough cut by Total Plastics Inc. (See Quote 1 at the end of the document) for a 5ft x 8ft part is $42.93. They also quote a cut per part cost of $6.05. Four of these parts are required to make the end shims for a plane. Delivery is 2-3 weeks. The later quote is used for the BOE.

A second quote (#2) was also received from Modern Plastics, Inc for 4ft wide sheets of $38 (uncut).

WBS	**3.2.2.1.2.1**
Item:	Purchase readout routing material
Cost:	$ 24.20
Vendor:	Total Plastics Inc
Type:	Quote in quantity (FY06$)
Contingency:	40%
Reason:	Technical risk; uncertainty in fire safety approval
Estimate Details:	

These parts are made from Intefoam brand foamed PVC, parts rough cut by Total Plastics Inc. (See Quote 1 at the end of the document) for a 5ft x 8ft part is $42.93. They also quote a cut per part cost of $6.05. Four of these parts are required to make the readout routing plates for a plane. Delivery is 2-3 weeks. The later quote is used for the BOE.

A second quote (#2) was also received from Modern Plastics, Inc for 4ft wide sheets of $38 (uncut).

WBS	**3.2.2.1.2.2**
Item:	Machine readout routing material
Cost:	$ 10.00
Vendor:	W&M Machine Shop
Type:	Estimate based on machining time (FY06$)
Contingency:	40%
Reason:	Technical risk; uncertainty in fire safety approval
Estimate Details:	Assume that the 8 parts are machined in 21 minutes at a G&SA loaded hourly rate of $28.60. This is the time to load the mill.

WBS	**3.2.2.1.3.1**
Item:	Scotch-Weld 2216 (Fastenal A)
Cost:	$ 57.36 (updated after the roll up and director's review freeze)
Vendor:	3M
Type:	Quote in quantity (FY06$)
Contingency:	40%
Reason:	Technical risk; uncertainty in used quantity; petroleum volatility
Estimate Details:	

This adhesive was used by MINOS to attach their module skins to the surface of their scintillator. Jim Grudzinski from Argonne was the MINOS scintillator factory manager for the NuMI project. His group measured the average amount of adhesive used in the middle of their production. They used 3mil of epoxy.

In a MINERvA plane there is a top skin (214.4cm wide), a bottom (214.4cm wide), and a web that weaves between the top and the bottom (249.2cm wide). The average length for the parts is 200cm yielding a surface area to glue of $13.56m^2$. This corresponds to a volume of 2.07 liter or 0.55 gal per plane. Including some allowance for waste we cost 0.6 gal/plane. Adhesive is a 50:50 mix of each component (also see the next item).

The quote is attached as Quote #3.

(delivery time 30-45 days)		Scotch-Weld 2216			
1 plane = .6 gallons			0.3	of each part	
3M: 1 gallon	$ 412.29	$ 226.76			
Fastenal A	$ 956.00	$/5 gal	$ 91.20	$/gal	$ 57.36

WBS	**3.2.2.1.3.2**
Item:	Fastenal B
Cost:	$ 57.77 (updated after the roll up and director's review freeze)
Vendor:	3M
Type:	Quote in quantity (FY06$)
Contingency:	40%
Reason:	Technical risk; uncertainty in used quantity; petroleum volatility
Estimate Details:	

This adhesive was used by MINOS to attach their module skins to the surface of their scintillator. Jim Grudzinski from Argonne was the MINOS scintillator factory manager for the NuMI project. We cost 0.6 gal/plane. Adhesive is a 50:50 mix of each component.

(delivery time 30-45 days)		Scotch-Weld 2216			
1 plane = .6 gallons			0.3	of each part	
3M: 1 gallon	$ 412.29	$ 226.76			
Fastenal B	$ 962.75	$/5 gal	$ 192.55	$/gal	$ 57.77

WBS **3.2.2.1.3.3**
Item: Gluing consumables (plunger, nozzle)
Cost: $ 4.98
Vendor: Industrial General Store
Type: Quote in quantity (FY06$)
Contingency: 100%
Reason: Uncertainty in rate of consumption
Estimate Details: We'll use a nozzle and plunger on each plane. (The applicator is reusable.) Quotes for cases:

EPX Pneumatic Mixing Nozzle (50 ml)	$ 808.90	for a case of 1200 or $0.68 per unit
EPX 1:1 Plunger 9161	$ 43.10	for a case of 10 or $4.20 per unit

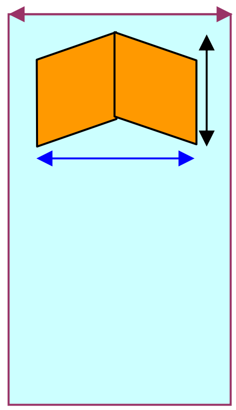
(Note: small inconsistency: 1200 units are too many. We have a new quote of $77.70 for 72 or $1.08 per unit. This will be fixed.)

WBS **3.2.2.1.3.4**
Item: Consumables (plastic trowels, Kim wipes, disposable containers)
Cost: $ 10.00
Type: Physicist estimate (JKN, FY06)
Contingency: 100%
Reason: Physicist estimate of materials used to keep clean while mixing and applying the adhesive.

WBS **3.2.2.1.4.1**
Item: Routing substrates
Cost: $ 7.80
Vendor: Americover
Type: Quote in quantity (FY06$)
Contingency: 50%
Reason: Uncertainty in safety approval
Estimate Details:

The quoted material is 12mil black Canvex CB12WB reinforced plastic sheeting. The required parts are nested as shown below. The results is a cost per part of $7.80

(304.8cm roll width)



Piece size + 6" = 167.86 cm
entire roll: 3048cm long

3048/167.86 = 18.158
can fit ~ 18 pieces/roll
Quote 25 rolls (12'x100') @ $140.40/each

WBS **3.2.2.1.4.2**
Item: Routing covers
WBS 3.2.2.1.4.2
Cost: $ 15.60
Vendor: Americover
Type: Quote in quantity (FY06$)
Contingency: 50%
Reason: Uncertainty in safety approval
Estimate Details:

The quoted material is 12mil black Canvex CB12WB reinforced plastic sheeting. The required parts are nested as shown below. The detailed calculation is shown in the previous item. There is a top and bottom cover so the cost per 2 parts is $15.60.

WBS **3.2.2.1.4.3**
Item: Routing covers transit tape
Cost: $ 51.00
Vendor: Catalog
Contingency: 50%
Reason: Technical: need to try with Lexan (designed for poly)
Estimate Details:

This seal runs on the top and bottom layer along two edges of a scintillator plane to attach the routing covers to the plane’s skins. Additional is used around the WLS connector boxes. A cost was found of $21 for a 4” by 100ft roll. A total of 21m of material is assumed per plane. (Note: the cost will be lower in the next round of costing the. The current cost it too high for this basis.)

WBS	**3.2.2.1.4.4**
Item:	Carpet tape
Cost:	$ 2.53
Vendor:	Manderscheid Equipment & Supply
Type:	Quote in quantity (FY06$)
Contingency:	50%
Reason:	Technical: need to try with actual materials
Estimate Details:	

This runs in certain location on the routing cover to constrain the WLS fibers to their routing paths. A very conservative net length of 11.2m of material per plane is assumed.
(See Quote 4.)

Description	3M Double Coated Polyester Film Tape - 4 mil
3M UPC Product Number	21200037641
Size	36 yd x 1/2 in
Units per Carton	72
List Price per Carton	$526.10

WBS	**3.2.2.1.4.5**
Item:	Purchase routing supports
Cost:	$ 30.00
Vendor:	Catalog in small quantities (AL flat bar)
Type:	Physicist estimate (JKN, FY06)
Contingency:	50%
Reason:	Based on incomplete design
Estimate Details:	Assume enough material to reach from the plane edge to beyond the edge of the OD. Assumes 8 per plane.

WBS	**3.2.2.1.4.6**
Item:	Machine routing supports
Cost:	$ 4.00
Vendor:	
Type:	Physicist estimate (JKN, FY06)
Contingency:	100%
Reason:	Based on incomplete design
Estimate Details:	Job is to cut the piece on a band saw and drill two holes on 8 parts. Assume 25 minutes of undergraduate labor.

WBS	**3.2.2.1.4.7**
Item:	Purchase connector box mounts
Cost:	$ 30.00
Vendor:	Physicist estimate (JKN, FY06)

Type:	Catalog in small quantities (AL flat bar)
Contingency:	50%
Reason:	Based on incomplete design
Estimate Details:	Assume enough material line two sides of the OD.

WBS	**3.2.2.1.4.8**
Item:	Machine connector box mounts
Cost:	$ 4.00
Vendor:	J.K. Nelson
Type:	Physicist estimate (JKN, FY06)
Contingency:	100%
Reason:	Based on incomplete design
Estimate Details:	Job is to cut the piece on a band saw and drill two holes on 8 parts. Assume 25 minutes of undergraduate labor.

WBS	**3.2.2.1.5.1**
Item:	Optical epoxy - EPON (815C)
Cost:	$ 30.82 (Recosted after schedule frozen for director's review)
Vendor:	Miller-Stephenson Chemical Company, Inc
Type:	Quote in quantity (FY06$)
Contingency:	40%
Reason:	Uncertainty in used quantity (due to unknown hole dia.)
Estimate Details:	

Cost per 5 gallon pail given over phone 6/30/05. Assumes 50% waste. Note: This is an updated quote from that in the 12/05 director's review. Old quotes were on 1 gal containers. Compute volume of epoxy to glue fibers into a plane:

Π*(0.2cm)^2*(200cm)*(128)		3216.991	cm^3	hole cross section
Π*(0.12cm)^2*(200cm)*(128)		1158.117	cm^3	fiber cross section
	epoxy volume	2058.874	ml	
		2.1	l (round up to 0.1)	
	waste 50%	3.15	L	
		0.8	gal (round up to 0.1)	
1:14 ratio	93%	0.747	gallons 815C	

	$/5gal	price/plane
price/gallon	$ 206.40	$ 30.82

WBS	**3.2.2.1.5.2**
Item:	Epoxy hardener - TETA (Epi-Cure 3234)
Cost:	$ 2.65
	(Recosted after schedule frozen for director's review)
Vendor:	Miller-Stephenson Chemical Company, Inc
Type:	Quote in quantity (FY06$)
Contingency:	40%
Reason:	uncertainty in used quantity (due to unknown hole dia.)

Estimate Details:

Cost per 5 gallon pail given over phone 6/30/05. Assumes 50% waste. Note: This is an updated quote from that in the 12/05 director's review. Old quotes were on 1 gal containers. Compute volume of epoxy to glue fibers into a plane:

Π*(0.2cm)^2*(200cm)*(128)		3216.991	cm^3	hole cross section
Π*(0.12cm)^2*(200cm)*(128)		1158.117	cm^3	fiber cross section
	epoxy volume	2058.874	ml	
		2.1	l (round up to 0.1)	
	waste 50%	3.15	L	
		0.8	gal (round up to 0.1)	
1:14 ratio	7%	0.053	gallons TETA	

	$/5gal	price/plane
price/gallon	$ 248.80	$ 2.65

WBS	**3.2.2.1.5.3**
Item:	mixer heads
Cost:	$ 1.38
Vendor:	
Type:	Scaled from MINOS actual use (via Keith Ruddick, FY02)
Contingency:	50%
Reason:	MINOS extrapolation on quantities

Estimate Details:

These 10mm mixer nozzles are used on the automated glue machine. They used to cost $1.38 for MNOS and we assume they have extrapolated. One is used per plane. (Note: this should be requited since it's in FY02 units.)

WBS	**3.2.2.1.5.4**
Item:	Reflector paint
Cost:	$ 0.68
Vendor:	
Type:	Scaled from MINOS actual use (via Keith Ruddick, FY05)
Contingency:	50%

Reason: MINOS extrapolation on quantities
Estimate Details: Use reflector plane on the ends of the strip get more uniform light output. Smaller are than MINOS. Was $130.00 per can and MINOS used 26 cans. We use a similar amount but produce many less units.

WBS 3.2.2.1.5.5
Item: cleaning supplies (razor, solvent, reamer, wet-dry sand paper)
Cost: $ 2.00
Vendor:
Type: Physicist estimate (JKN, FY06)
Contingency: 100%
Reason: guess
Estimate Details: Physicist estimate of materials used to keep clean after each day's running of the glue machine. Assume one clean up per plane.

WBS 3.2.2.2.1.1
Item: upper skin
Cost: $ 15.50
Vendor: Piedmont Plastics
Type: Quote in quantity (FY06$)
Contingency: 30%
Reason: uncertainty in material thickness
Estimate Details:
A quote for 10 mil FR700 black fire retardant Lexan polycarbonate roles was received from Eric Christy at Hampton. The quote is for one meter width rolls of 150m with a cost per roll of $256.70 (from Piedmont Plastics). The cost per square meter of the material is $1.71. An area of a layer is assumed to be and there is 9m^2.

WBS 3.2.2.2.1.2
Item: lower skin
Cost: $ 15.50
Vendor: Piedmont Plastics
Type: Quote in quantity (FY06$)
Contingency: 30%
Reason:
Estimate Details:

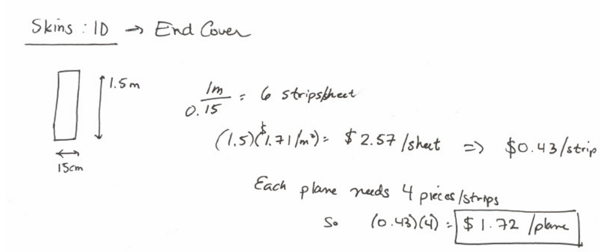
A quote for 10 mil FR700 black fire retardant Lexan polycarbonate roles was received from Eric Christy at Hampton. The quote is for one meter width rolls of 150m with a cost per roll of $256.70 (from Piedmont Plastics). The cost per square meter of the material is $1.71. An area of a layer is assumed to be and there is 9m^2.

WBS **3.2.2.2.1.3**
Item: web
Cost: $ 15.50
Vendor: Piedmont Plastics
Type: Quote in quantity (FY06$)
Contingency: 30%
Reason:
Estimate Details:

A quote for 10 mil FR700 black fire retardant Lexan polycarbonate roles was received from Eric Christy at Hampton. The quote is for one meter width rolls of 150m with a cost per roll of $256.70 (from Piedmont Plastics). The cost per square meter of the material is $1.71. An area of a layer is assumed to be and there is 9m^2.

WBS **3.2.2.2.1.4**
Item: end covers
Cost: $ 1.72
Vendor: Piedmont Plastics
Type: Quote in quantity (FY06$)
Reason: uncertainty in material thickness
Contingency: 30%
Estimate Details:

A quote for 10 mil FR700 black fire retardant Lexan polycarbonate roles was received from Eric Christy at Hampton. The quote is for one meter width rolls of 150m, and with a cost per roll of $256.70 (from Piedmont Plastics). The cost per square meter of the material is $1.71. The math is shown below. Note 50% waste in rough cutting is assumed.



WBS **3.2.2.2.2.1**
Item: vacuum tape
Cost: $ 8.89
Vendor:
Type: Scaled from MINOS actual use (via Keith Ruddick, FY05)
Contingency: 50%
Reason: MINOS extrapolation on quantities
Estimate Details: Used to seal the edges of a plastic sheet over the assemblies so they can be vacuum cured. It was purchased in cases at $130.00 per case for MINOS, which used 334 cases. We use a same amount per unit area of detector and assume a cost of $146.32.

WBS **3.2.2.2.2.2**
Item: plastic sheeting
Cost: $ 3.99
Vendor:
Type: Scaled from MINOS actual use (via Keith Ruddick, FY05)
Contingency: 50%
Reason: MINOS extrapolation on quantities
Estimate Details: Used to cover the assemblies so they can be vacuum cured. It was purchased in cases at $9.90 per roll for MINOS, which used 1968 rolls. We use a same amount per unit area of detector and assume a cost of $11.14.

WBS **3.2.2.2.2.3**
Item: RTV
Cost: $ 2.20
Vendor:
Type: Scaled from MINOS actual use (via Keith Ruddick, FY05)
Contingency: 50%
Reason: MINOS extrapolation on quantities
Estimate Details: Used to seal the edges of the assemblies. It was purchased in cartridges at $4.42 per unit for MINOS, which used 1588 units. It was purchased in tubes at $2.57 per unit for MINOS, which used 1260 units. We use a same amount per unit area of detector and assume a cost of $8.71 and $5.06.

WBS **3.2.2.2.2.4**
Item: Black electrical tape
Cost: $ 1.50
Type: Scaled from MINOS actual use (via Keith Ruddick, FY05)
Contingency: 50%
Reason: MINOS extrapolation on quantities
Estimate Details: Used to seal the edges of the assemblies and repair light leaks. It was purchased in 1.5" rolls at $12.65 per unit for MINOS, which used 500 units. It was purchased in 0.75" rolls at $2.57 per unit for MINOS, which used 388 units. We use a same amount per unit area of detector and assume a cost of $24.92 and $5.06.

WBS **3.2.2.2.2.5**
Item: Al tape
Cost: $ 1.33
Vendor:
Type: Scaled from MINOS actual use (via Keith Ruddick, FY05)
Contingency: 50%
Reason: MINOS extrapolation on quantities

Estimate Details: Used to seal down the electrical tape to ensure the corners didn't peel up. It was purchased in 2" rolls at $29.60 per unit for MINOS, which used 220 units. We use a same amount per unit area of detector and assume a cost of $58.30.

WBS **3.2.2.2.2.6**
Item: zip locks
Cost: $ 0.75
Vendor:
Type: Physicist estimate (JKN, FY06)
Contingency: 50%
Reason:
Estimate Details: A protective cover taped over the optical connectors.

WBS **3.2.2.2.3.1**
Item: h clips
Cost: $ 46.87
Vendor:
Type: Scaled from MINOS actual use (via Tom Chase, FY05)
Contingency: 50%
Reason: MINOS extrapolation on quantities
Estimate Details: Assumes an amortized die cost of $8,500 divided by 8 planes and 8 clips at $0.75 per clip.

WBS **3.2.2.2.3.2**
Item: Hclip adhesive
Cost: $ 7.80
Vendor:
Type: Scaled from MINOS actual use (via Keith Ruddick, FY05)
Contingency: 50%
Reason: MINOS extrapolation on quantities
Estimate Details: This adhesive is DP810 which MINOS bought 2096 tubes at $9.08 per unit. We assume the twice the number of brackets per unit area. We use a $17.88 unit cost and a cost per plane of $7.80.

WBS	**3.2.2.2.3.3**
Item:	steel wool
Cost:	$ 0.25
Vendor:	
Type:	Physicist estimate (JKN, FY06)
Contingency:	100%
Reason:	Physicist estimate
Estimate Details:	Use a pad of steel wool to clear the surface of the chip to get good adhesion. The estimate assumes cleaning of 6 clips per plane.

WBS	**3.2.2.2.3.4**
Item:	alcohol and Kim wipes
Cost:	$ 5.00
Vendor:	
Type:	Physicist estimate (JKN, FY06)
Contingency:	100%
Reason:	Uncertainty in usage; no cost basis
Estimate Details:	Physicist estimate of materials used to clean the clips surface and to clean the skins where the clips mount. The estimate assumes cleaning of 12 mounting point locations per plane.

III. Contingency Breakdown

Contingencies are base on the bottom up estimates outlined above... The L4 task they are summarized in the following tables:

		$/plane	Cont
3.2.2	**ID plane**	**$ 512.03**	45%
3.2.2.x	**ID Plane Components at William & Mary**	**$ 385.23**	46%
3.2.2.x.1	Procure light sealing components for ID Modules	**$ 48.72**	40%
3.2.2.x.2	Procure ID scintillator readout routing parts	**$ 34.20**	40%
3.2.2.x.3	Purchase ID scintillator adhesive	**$ 120.51**	45%
3.2.2.x.4	Procure WLS fiber OD routing components	**$ 144.93**	50%
3.2.2.x.5	Purchase ID optical coupling	**$ 36.87**	45%
3.2.2.y	**ID Plane Components 1 - 20 at Hampton**	**$ 126.80**	42%
3.2.2.y.1	Purchase ID package materials (1-20)	**$ 48.22**	30%
3.2.2.y.2	Purchase scintillator detailing and curing components (1-20)	**$ 18.67**	50%
3.2.2.y.3	Purchase ID mounting hardware (1-20)	**$ 59.92**	50%

IV. Time Estimates

Cost is basically a labor time estimate, so the time estimates are detailed and justified above in sections II and III. 45 days is the longest lead item. We expect to have some parts in had to accelerate this process to 8 weeks.

Comments (earliest can be started, or must finish by, how can speed up, etc):

1. Quote

757 221 3540

Total Plastics Inc. ™

A subsidiary of A. M. Castle & Co.

"REQUOTE"

X	5424 PULASKI HIGHWAY BALTIMORE, MD 21205 PH: 410.483.1122 OR 800.492.4595 FX: 410.483.1493
	431 AMITY ROAD HARRISBURG, PA 17111 PH: 717.231.6510 OR 800.442.6839 FX: 717.231.6519
	780-G PINE VALLEY RD. PITTSBURGH, PA 15239 PH: 724.327.3030 OR 877.338.6825 FX: 724.327.3434

QUOTATION

Company: COLLEGE OF WILLIAM & MARY   Date: 10/03/05

Address:

Representative: Megan Snyder

Quantity	Material	Price
	IT IS OUR PLEASURE TO "REQUOTE" YOU AS FOLLOWS:	
40 shts	Black PVC Foam 6mm x 60 x 96 (TO YLD APPROX 850 PCS)	$ 56.75/sht
	Delv: as of today approx 2 wks	$2270
850 pcs	SAME MATL/CUT PER DWG	$ 6.05/pc
	Delv: as of today approx 2-3 wks	$5142.50
	PLUS FREIGHT	$ 80.00(approx)
	THANK YOU FOR GIVING TPI THE OPPORTUNITY	
	TO BE OF SERVICE	

FOB: Delivery:

Darlene E Brodka (signature)

Signature Darlene E Brodka   CC: EPR/JS

Sheet/Rod
Tube/Film
Fabricated Parts
YSAFMTPI104

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website: www.totalplastics.com

2. Quote

Sep 16 05 10:39a p.1

Modern Plastics, Inc.
Quotation/Fax Order Form

MODERN plastics IAPD MEMBER
www.modernplastics.com

DATE
09/16/05

Please refer to below QUOTE NUMBER

Quote# Q1228375

Terms: BELOW
F.O.B. BPT

Quoted by: DAVID ALTIERI
203 333-3128

TO
MEGHAN SNYDER
COLLEGE OF WILLIAM AND MARY
DEPT OF PHYSICS
WILLIAMSBURG, VA 33187
757-672-1103
757-221-3540 (Fax)

☐ 678 Howard Avenue, Bridgeport, CT 06605-057, (203) 333-3128, FAX: (203) 333-4625
☐ 1300 Jefferson Blvd, Warwick, RI 02886-2527, (401) 732-0415, FAX: (401) 732-5847
☐ 56 Pulaski Street, Peabody, MA 01960-1830, (978) 531-3154, FAX: (978) 531-2362
☐ 710 Berkshire Avenue, Springfield, MA 01109-100, (413) 785-1671, FAX: (413) 736-6365

We are pleased to quote on your requirements as follows:

Part Number and Product Description	Quantity	Price/Un	UN	Extension
SIM6BLACKINTE * 6 mm 48 x96 BLACK INTEFOAM PVC SHEET FOB: Delivered Delivery: Net30 Upon approved credit Note: This quotation is good for 30 days.	175	42.930	EA	7512.75

Standard cut tolerance: +/- .062"
Prices are firm thirty-days from Quotation date, unless otherwise stated.

Last Page
Quote# Q1228375

Quotation Total
$ 7,512.75

Would you like to place this order? ☐ YES!

Your Purchase Order No: ____________ **Date/Signature:** ____________

Did you make any changes to above quotation? ☐ YES (simply type or write in any changes)

Any further instructions? ____________

Please fax to above number and your order will be promptly shipped.

For complete details on quote terms Go to: http://www.modernplastics.com/disclaimer.htm

3. Quote

FASTENAL®
INDUSTRIAL & CONSTRUCTION SUPPLIES

Price Quotation

November 2, 200

WILLIAM & MARY
P.O. BOX 8795
Williamsburg, VA 23187

Phone: 757-672-1103
Fax: 757-221-3540

ATTN: Megan

Account: WLVA0142
Quote #: 17098
Job #:

Expiration Date: 12/2/05
PO #: 3M

PART NO	CUST PART	DESCRIPTION	QUANTITY	PRICE PER HUNDRED	EXTENDED PRICE
<Cust part desc>		55 Gallon Epoxy Adhesive 2216 Translucent Part A. 3M Part 02120020927	1	999,553.00	9,995.53
<Cust part desc>		Part B Base for Epoxy Adhesive 55 gallon	1	973,152.00	9,731.52
<Cust part desc>		5 Gallon Containers PART A	1	95,600.25	956.00
<Cust part desc>		5 Gallon Containers PART B	1	96,275.25	962.75
				Shipping & Handling	254.14
			USD	TOTAL	21,899.94

Comment:
This is a made to order item from 3M. Please allow 30-45 days to receive. This will ship direct via CCX.

Thank you,
FASTENAL
465 Merrimac Trail

Williamsburg, VA 23185
Phone: (757)258-2635
Fax: (757)258-2636
E-mail: vawia@stores.fastenal.com

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ORM-QT01

Page 1

4. Quote

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15 % additional volume discount.

Search returned 12 results: 415

3M UPC Product Number	Description	Size	Grade	Units Per Carton	List Price	List Price per Carton	Purchase
21200037641	3M Double Coated Polyester Film Tape - 4 mil	36 yd x 1/2 in	415	72	$7.31	$526.10	Buy

5. Quote

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- 5424 Pulaski Highway
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- Ph: 410.483.1122
- **Fx: 410.483.1493**

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- Elk Grove Village, IL 60007
- Ph: 847.593.5000
- **Fx: 847.593.5333**

☐ **CLEVELAND**
- 17851 Englewood Dr.
- Middleburg Hts., OH 44130
- Ph: 440.891.1140
- **Fx: 440.891.1145**

☐ **DETROIT**
- 1661 Northfield Dr.
- Rochester Hills, MI 48309
- Ph: 248.299.9500
- **Fx: 248.299.4330**

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- Grand Rapids, MI 49519
- Ph: 616.530.0055
- **Fx: 616.530.0852**

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- Fort Wayne, IN 46825
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- **Fx: 260.490.3600**

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- Harrisburg, PA 17111
- Ph: 717.231.6510
- **Fx: 717.231.6519**

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- Indianapolis, IN 46226
- Ph: 317.543.3540
- **Fx: 317.543.3553**

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- 2810 N. Burdick St.
- Kalamazoo, MI 49004
- Ph: 269.344.0009
- **Fx: 269.344.0711**

☐ **PITTSBURGH**
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- Pittsburgh, PA 15233
- Ph: 412.322.1072
- **Fx: 412.322.2678**

☐ **NEW YORK**
- 606 Franklin Ave
- Mount Vernon, NY 10550
- Ph: 914.664.9023
- **Fx: 914.664.9311**

☐ **TAMPA**
- 203 Kelsey Lane, Suite F
- Tampa, FL 33619
- Ph: 813.283.1200
- **Fx: 813.283.1212**

Total™ Plastics Inc.
A subsidiary of A. M. Castle & Co.
www.totalplastics.com

TPI® Facsimile Message

Date: 9/16/2005

To: College of William & Mary Fax Number: 757-672-0103
757-221-3540

Attention: Megan Snyder Page 1 of 1

From: Ed Randolph

☐ Urgent ☒ For Review ☐ Please Comment ☐ Please Reply

165 pcs - Black 6mm x 48 x 96
FOAM PVC $38.00 EACH
OR =$6270

165 pcs - White 6mm x 48 x 96
FOAM PVC 34.20 EACH

Physics Dept.

Freight $80.00 Approx.

Williamsburg VA.

YSAFMFAX

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