Cost Basis for SoLID Light Gas Cherenkov (LGC)

SoLID LGC group

1.1.2 Design and Procedures for LGC

All estimates of design time come from Temple University's Mechanical Engineer and his experience designing and constructing the SANE Cherenkov detector for Jefferson Lab.

1.1.2.1 Adjustable Mirror System

In order to accommodate two different incident particle angles between PVDIS (22 to 35 deg from a central Z-vertex 270 cm away) and SIDIS (8.0 to 15.0 deg from a vertex 520 cm away), All 30 inner mirrors must be adjusted between experiments such that the reflected Cherenkov light in both configurations falls into the PMT detector acceptance. This is achieved by rotating each mirror by an angle of approximately 8 deg inward about the mirror's inner-most edge (or edge closest to the beam-line).

1.1.2.2 Tank and Plumbing

The main body of the tank remains identical between PVDIS and SIDIS configurations, and has a length roughly 105 cm with an inner radius of 71 to 85 cm, and an outer radius of 265 cm. When in the SIDIS or J/psi configuration, an additional tank 'snout' is attached upstream of the main tank inside the additional space evacuated by the baffle system. This tank snout adds an additional 107 cm of length to the tank with an inner radius of 58 to 71 cm, and an outer radius of 127 to 144 cm. The tank will use a "pump-and-dump" method of gassing with N2, and sit at slightly above atmospheric pressure to avoid gas contamination.

1.1.2.3 Support and Mounting

The Cherenkov tank front and back windows will be divided into six radial sections. Between each pair of sections will be two thin rectangular aluminum support spokes, one to support and frame the upstream side of the tank and another to support and frame the downstream side. Both spokes are positioned and aligned to minimize the probability of tracks passing through the support material. Additionally, both spokes are interconnected at the outer radius of the tank, outside of the desired physics acceptance, by a solid arc-shaped plane to increase the rigidity of the frame and provide additional support for mounting the photosensor assemblies. The space between the upstream and downstream spokes will remain open to maximize Cherenkov light collection. The combined frame itself will be mounted to the back wall of the downstream magnet housing, to support the full weight of the LGC detector.

1.2.2 Light Gas Cherenkov

1.2.2.1 Tank and Support

All personnel time estimates for tank and support construction are from engineering judgement on the scale and time-frame of production, with experience building large scale projects and Cherenkov detectors, including the SANE Cherenkov used at Jefferson Lab.

1.2.2.1.1 Gas System

Cost estimates are based on general plumbing hardware and machining estimates for custom pieces. Engineering Judgement is estimated by scaling costs from construction of the SANE Cherenkov detector. Also included in estimates is all automated pressure systems combined with slow control readout. An estimated year of construction/testing time is required to deliver a gas-tight, semi-automated, and pressurized system.

1.2.2.1.2 Windows/Frame/Support

Window costs are estimated from discussions with vendors for PVF window material, with frame and support estimates from general machining and hardware cost. The entire load baring system capable of maintaining precision optics within the gas cavity, including an adjustable mirror rotation system and a removable snout for added gas in the SIDIS configuration is included in the estimates for materials and manpower. Most of the physical construction of the LGC tank falls into this category.

1.2.2.1.3 Integration/Assembly

This category covers the complete assembly of the Cherenkov detector. The assembly of the mirrors and photosensor arrays are defined in their own sub-category, then those assembled components must be integrated into the full tank detector. All costs listed for this category are for manpower alone, and estimates are based on requirements for other projects similar in scale. Since mirrors and photosensors will be produced and tested in their own time-frame, it is expected that a rolling influx of sub-assemblies will define the total duration of the project. Initial "assembly-level" calibration of mirrors and photosensor arrays will also be preformed under this category.

1.2.2.2 Mirrors

1.2.2.2.1 Mirror Blanks

Original estimates for mirror blanks came from the company Composite Mirror Applications (CMA), who had reliably produced mirrors for the LHCb RICH and the CLAS12 RICH detectors. Unfortunately, CMA discoed an error in their estimate calculation, and recently revised their estimates with an increase of 300+%. Following this discovery, alternative mirror companies were explored. Estimates for blanks of similar optical quality from other vendors were found to be similar in price to the newer quotes from CMA. To minimize costs, alternative designs were considered. With the discovery of reflective coated Lexan, which was used to refurbish the CLAS Cherenkov mirrors for use in the LTCC, the need for optically polished blanks was removed. An optical quality polish of the blank surface was the most often the driving factor in cost for the mirror blanks. Latest cost estimates come from correspondence with carbon-fiber fabrication companies (Rock West Composites and ProTech Composites). ROM estimates put spherical segment fabrication at around $3k to $7k per mirror (depending on thickness of carbon), with additional costs (~$50k) for tooling and engineering design.

There are two alternatives to purchasing spherical blanks. The first is to purchase flat fiber-glass panels and re-shape them with heat to the appropriate curvature. This would involve using an industrial oven and a machined mold for shape. A second option would be to mold the fiberglass cloth from scratch. Material plus labor estimates put total cost around $7k per mirror segment. A lead time of one year is expected in both the primary and alternative procurement.

1.2.2.2.2 Mirror Coating

The mirrors will be covered with pre-coated Lexan film. This film will either be purchased directly from ECI, or coated in-house at Stoney Brook University. Estimates and order time come from quotes and email exchanges with Evaporated Coatings incorporated.

1.2.2.2.3 Mirror Assembly

Before assembly, any additional cutting/ drilling will bee preformed, along with attaching any additional mounting hardware necessary. The mirrors will need to be assembled in a clean-room environment, with each spherical blank coated with adhesive, and the Lexan film carefully attached. The mirrors will then be stored in a clean environment until they are ready for mounting inside the main tank. Estimates in time are from conversations with the CLAS12 LTCC group's experience refurbishing CLAS mirrors.

1.2.2.3 Photosensor Detector Array

1.2.2.3.1 Photosensors

Two inch square MaPMTs with 64 pixels from Hamamatsu (model H12700-03) is the current default choice for photosensor. It works in moderate magnetic field and can be assembled into a 3x3 square array. Total 270 MAPMTs will be needed for 30 sectors. Preliminary quote from the Hamamatsu Corporation has $3000 per MAPMT and we plan to make purchase together with HGC to get bulk pricing. The time-frame comes from email-exchange with Hamamatsu representatives.

An alternative technology may be available when photosensors are ultimately purchased for the SoLID detectors. Newer Micro-channel plate photomultipliers (MCPMTs) or large area picosecond photon detectors (LAPPDs) may be a cost comparable solution, with the added benefit of little to no performance impact inside of magnetic fields and increased sensitive area for photon collection. Such photosensors would remove the need for magnetic shielding and reflective focusing cones at the detector face. Although these devices are in the prototyping stage today, they should not be ruled out as alternatives to MaPMTs when funds are allocated for photosensor purchase.

1.2.2.3.2 Photosensor Coating

The photosensors discussed in section 1.2.2.3.1 all have a photon detection efficiency that drops as photons increase in energy from the visible to the ultra-UV range. By coating the photosensors with a wavelength shifting substrate (p-Terphenyl) higher energy photons can be absorbed and near-instantly remitted at a lower energy. Since the Cherenkov radiation spectrum is decaying roughly exponentially in emitted photon energy, even a small gain in the UV can increase the photoelectron yield significantly. The CLAS12 LTCC PMTs were successfully coated with p-Terphenyl by Temple University before commissioning.   Costs and total time are estimated from this experience.

1.2.2.3.3 Summing Electronics

The JLab detector group has extensive experience in both design and working with vendors on producing electronic boards for PMT signal processing. The preliminary version of electronic board JLab detector group designed and built to sum all 64 pixels of MAPMT provides a good base to estimate the cost of final boards and their accessories. Both CLAS12 RICH and GLUEX DIRC has experience of building mechanic support structure for MAPMT to form photosensor assembly. Our estimation of construction of mechanic support is based on those experience and informed by our preliminary design in the prototype stage. Both our past experience of testing those MAPMT under magnetic field and other detectors at JLab using those MAPMT in their running will provide useful information. Since the photosensor model is common between both groups, collaboration with the HGC group is expected with testing and integrating the summing electronics into the DAQ readout. Time estimates come from discussions with the JLab detector group.

1.2.2.3.4 Mu-Metal Shielding

The magnetic shield for each MaPMT is required to keep the total field in all directions below 50 gauss. Each shield is cylindrical in design and the MaPMT sits near the center and perpendicular to the long-axis of the cylinder. The cost estimates and expected delivery time for this level of magnetic shielding come from two separate vendors (Amuneal and The Magnetic Shield Corporation).

1.2.2.3.5 Reflective Cones

The reflective cones for the LGC will be constructed from machined aluminum or custom glassand coated with reflective Lexan film in a similar method to the mirror coating outlined in section 1.2.2.2.1 and 1.2.2.2.2.   Costs are estimated from machining estimates of cones plus ECI quotes for reflective Lexan coating. Time estimates includes machining time and Lexan strip order time.

1.2.2.3.6 Array Assembly

All components of the arrays (photosensor mount, photosensors, sum readout electronics, mu-metal shields, and reflective cones (including attaching the reflective film) will need to be assembled and made ready for testing and integration into the larger sector inside the tank. Manpower effort is estimated from experience with similar assembly projects (SANE Cherenkov and various prototype cherenkov detectors).

1.2.2.4 Transport, Travel, and Testing

1.2.2.4.1 Transport

Costs are estimated from transport of similar large, fragile equipment from Temple University to Jefferson Lab (SANE Cherenkov, Helium target cells, prototype cherenkovs).

1.2.2.4.2 Travel

Costs are estimated from general travel costs for students and workers to interface with scientists and engineers at Jefferson Lab.

1.2.2.4.3 Testing

Almost all components of construction will need to bye tested for quality before assembly. The majority of requested manpower outside of engineering/technician work falls into this category. Estimates are from prior prototype and detector construction/commissioning.

Appendix A: Quotes and Correspondence

A1) ECI quotation for reflective strips

A2) Mu-Metal magnetic shields from Magnetic Shield corporation

A3) Correspondence with CMA for (revised) mirror estimate

A4) Correspondence with Rockwest Composites for Carbon-fiber mirror blanks.

A5) Correspondence with Hamamatsu for MaPMTs

A1: ECI quotation for reflective strips

eci
evaporated coatings inc

2365 Maryland Road
Willow Grove, PA 19090
USA

(215) 659-3080
(215) 659-1275 fax
bmonti@evapcoat.com

To: Zhiwen Zhao   Company: Jefferson Lab   Date: August 2018   Quotation # 18080805
CC: Michael Paolone

Thank you for your request for ***quotation for ECI supplying custom, UV-enhanced aluminum mirrored Lexan optics!*** We are pleased to propose the following for your consideration:

Unit	Total Quantity	Additional Details	USD Price
Each	180	All Item A	$ 190.55 each
Each	150	All Item C	$ 345.05 each
1 Lot	2 – 4	1 – 2 item A and 1 – 2 item C	$ 2,965.00/lot
1 Lot	3 – 4	All Item A	$ 2,355.00/lot
1 Lot	8 – 10	All Item A	$ 2,750.00/lot
1 Lot	2 – 3	All Item C	$ 2,545.00/lot
1 Lot	4 – 6	All Item C	$ 3,115.00/lot

Description

Item A) 9" x 36" x 0.010" (nom) thick 8010 Lexan/polycarbonate sheet. Item C) 10" x 36" x 0.050-.060" (nom) thick 9034HO Lexan/polycarbonate sheet. All items supplied coated on one side with #801PP Front-surface, UV-enhanced aluminum mirror optimized for Rmax @ 200-600nm for 0° AOI & Air. Reflectivity(R) ≥ 85% @350-600nm; R ≥ 80%@250-350nm; Best Effort for R ≥ 80% @ 200-250nm. Fixture/Holding (uncoated) areas will be located on the 9" or 10" edges only, the same as previously done. ECI will process small witness slides with mirrors and test witness slides to confirm coating run results. Curves provided showing reflectivity from 200-600nm. Coating will meet Humidity Test exposure in air for 24-hours at a temperature of 49ºC and 95% relative humidity, plus Adhesion Test with 3M Scotch Brand No.610 tape placed on the coated surface and removed slowly. Coated surface can be protected with a temporary, short term masking layer. As discussed, the protective masking is only meant for short term use, and should be removed as soon as possible in a timeframe less than or equal to maximum anticipated assembly period. (Est ~ 3 months or less) Alternately, mirrors can be wrapped or interleaved with soft optical tissue to protect mirror surface for longer term storage. Mirrors should be stored in a climate controlled environment and not be exposed to elevated heat, extreme cold, significant humidity, pressures, caustics, acids, solvents, or other avoidable contaminants.

The prices quoted are F.O.B. Willow Grove, Pennsylvania, and your payment terms are Net 30 Days. Payment may also be made by credit card. Deliveries can begin 6-8 weeks after receipt of your order, then continue per a mutually agreed upon schedule, as applicable. Please contact us about any expedited delivery requirements, so we may do our best to meet your needs. We appreciate the opportunity to be helpful to you and your business!

Sincerely,
Barbara M. Monti
Senior Technical Sales

evaporated coatings inc
THIN FILM COATING SOLUTIONS

A2: Mu-Metal magnetic shields from Magnetic Shield Corporation

Hello Michael,
As requested the pricing for the tubes that we've been discussing is as follows:

Product: 0.040" thick x 9.055 " ID X 9.055" long MuMETAL Tube
Qty: 32
Price: $263.22 ea.

Product: 0.080" thick x 9.055 " ID X 9.055" long MuMETAL Tube
Qty: 32
Price: $464.94 ea.

Lead Time: 4 weeks
Freight: F.O.B. Bensenville, IL.

Thanks again Michael and please do not hesitate to let me know if there is anything that I can do to help.

Regards,

Terry Lannon – Regional Sales Manager
Magnetic Shield Corporation
Ph: 630-766-7800
Fx: 630-766-2813
www.magnetic-shield.com

A3: Correspondence with CMA for (revised) mirror estimate

Hi Zhiwen,

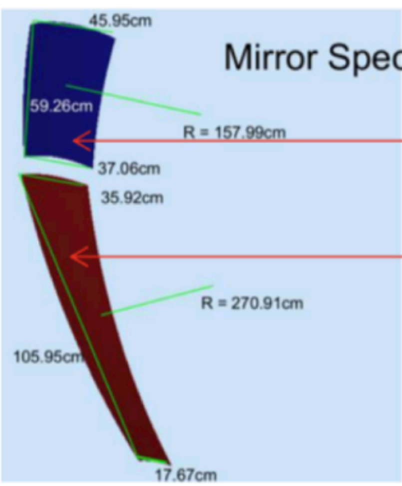
Sorry, a bit tough to quote for 4-5 years out. The ROM cost is $3,075K of which $450K is the mandrels. The metric including NRE is $75K/m2, which is consistent with our other program costs. We will supply a formal quote as we get closer to a contract.

Thanks Zhiwen.

-Bob-

$3M for both LGC and HGC

Mirror Specs



Mirror 1: Qty: 32, Area ≈ 0.27m2, mirror weight est: 1.4kg

Mirror 2: Qty. 32, Area ≈ 0.38m2, mirror weight est: 1.9kg

21m2 x $75k/m2 = $1.575M

Total Area: ~21m^2

Total Mirror Weight: ~35kg

A4) Correspondence with Rockwest Composites for Carbon-fiber mirror blanks.

Tom Preece tom.preece@rockwestcomposites.com via rwc1.onmicrosoft.com Jun 4, 2019, 12:48 PM

to me

Understood Michael – I reviewed the relatively loose spec/tolerances needed (that you noted in the inquiry) with our engineers but perhaps they are erring on the side of caution or too caught up in past experience.

Cost will depend on the thickness requirements, but if I guess at something like 0.125" thick then the weight per set is roughly 3.5 lbs. At $50/Lb for std modulus carbon prepreg that comes out to $175 per set in material cost. If labor is high and material cost is 1/10 the total cost, then that comes out to $1750 per set (obviously much less than $50k!).

These numbers are so far apart that I worry about you using $1750 for your ROM. But obviously this project is very dependent upon the specs required.

Perhaps once you've got a formal set of drawings/specs you can send over and we can do a formal quote? Hopefully you've got something to go with for now….

Thanks

Tom Preece
V.P., Business Development & Marketing
Direct: 858.537.6260 ext. 103
Mobile: 760.419.2380
Email: tom.preece@rockwestcomposites.com

Rock West Composites

1602 Precision Park Lane • San Diego, CA 92173
Ph: 858.537.6260 • Fx: 858.537.6265

Tom Preece tom.preece@rockwestcomposites.com via rwc1.onmicrosoft.com Jun 21, 2019, 11:48 AM

to me

Hi Michael, we actually just quoted a reflector program of similar geometry. If I plug in the 3.5lbs of material per set to that quote (is that approximately the weight?) , I come in around $4600 per set. I still don't see any thicknesses or firm requirements on the drawings, so this is my best guess at this time. Hope this helps…

Tom Preece
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Rock West COMPOSITES

1602 Precision Park Lane • San Diego, CA 92173
Ph: 858.537.6260 • Fx: 858.537.6265

A5: Correspondence with Hamamatsu for MaPMTs

Dear Zhiwen,

Sorry for the long delay, and many thanks for your patience! Hamamatsu Japan got back to me with production cost info for the following performance selections:

i. H12700B-03 SEL2: total dark current = 5nA max. @ 1KV & gain = 8E5 min. @ 1KV
ii. H12700B-03 SEL3: total dark current = 5nA max. @ 1KV & gain = 1.5E6 min. @ 1KV

Here are current budgetary unit price estimates of the above options for purchase qty. ranges of 200-499 and 500-999 units, respectively:

SEL2: $2750 | $2600
SEL3: $3200 | $3050

I hope you find the above pricing info helpful for your planning needs. Don't hesitate to let me know if you have any question about the above info or if I can help you with anything else.

Kind Regards,

Ardavan Ghassemi
Big Science Account Manager
HAMAMATSU CORPORATION
Phone: 908-252-7632