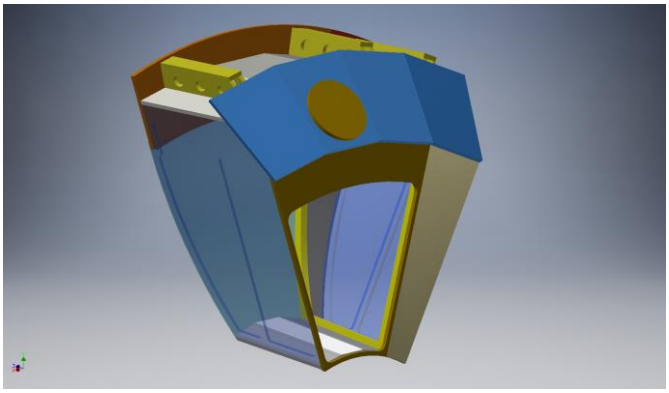
Cost basis of SoLID Heavy Gas Cerenkov (HGC)

SoLID HGC group

1.1.3 Design and Procedures of HGC

1.1.3.1 Tank and front thin window

The design of tank and front thin window needs to satisfy JLab pressure system requirement as mentioned in the SoLID Project WBS Dictionary. The Duke group of Prof. Haiyan Gao and the University of Regina (UofR) group of Prof. Garth Huber have been working on designing and building a prototype of one supersector which is 1/10 of the full HGC detector. The initial thin window design and test are completed. The tank prototype design by Duke is completed and the construction by UofR will start soon. The goal of the prototype is to understand its structure integrity and study how to make it gas tight with internal gas pressure ~1.7atm. Even though this is not the final design, this work provided us the necessary experience to estimate the labor needed for the final design of tank and front thin window.



HGC prototype design

1.1.3.2 Magnetic shielding and reflection cone

During the tank prototype design, the magnetic shielding and reflection cone are also designed at a preliminary stage to be compatible with the tank design. This experience informed us of the labor needed to finish their final design.

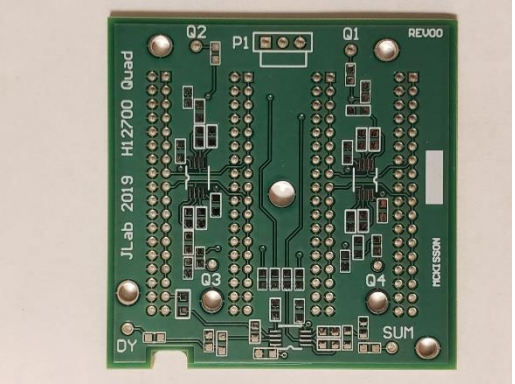
1.1.3.3 Gas system

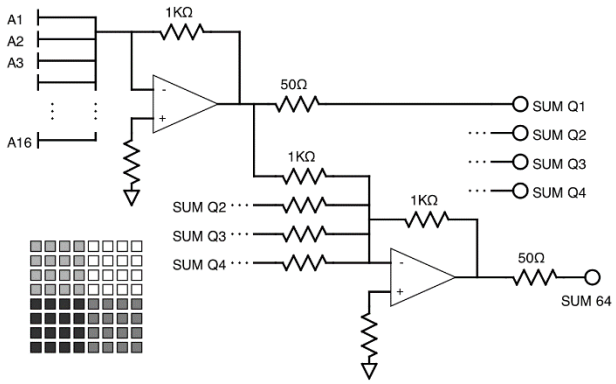
JLab has designed and built the heavy gas system for CLAS Cerenkov detector in Hall B more than 20 years ago. It includes gas filling, collection and purifying units. Recently, it was upgraded for CLAS12 Low Threshold Cerenkov Counter (LTCC) to reach a recovery efficiency >90%. And the amount gas it needs to process (a few hundred kg) is similar to what SoLID HGC needs. The factor that the SoLID HGC operating pressure at ~1.7atm is different from the LTCC operating pressure at slightly above atmospheric pressure will be taken into account in the design. The extensive engineering experience at JLab allows us to estimate the design labor for the gas system.

1.1.3.4 Sum readout

SoLID HGC uses MAPMTs as photonsensor, similar to SoLID Light Gas Cerenkov (LGC) detector. The sum readout includes both a set of electronic board to read out MAPMT signal and the mechanic support for the readout assembly to be mounted inside the magnetic shielding and reflection cone. The JLab detector group has designed and built a preliminary electronic board to sum all 64 pixels of MAPMT as showed in the figure below. We are starting to test the board and it's expected to have several design iteration to reach final design. During the tank prototype design, we also did a preliminary design of the

mechanic support of readout system to make sure it is compatible. This work provided the necessary experience to estimate the design labor for sum readout.





MAPMT preliminary sum board

1.2.3 Construction of HGC

1.2.3.1 Tank and front thin window

The labor and procurement for building the tank and front thin windows are based on the experience of building large pressured vessels with thin windows among the groups responsible for the project. The UofR group has built the JLab Hall C SHMS HGC which is also made of a large cylinder Al vessel. SHMS HGC is designed to operate at the internal pressure between 0.3 atm and 1 atm, while SoLID HGC will operate at ~1.7 atm. It has a 40mil thin front Al window of diameter 66 inch or 167cm, which are much larger than SoLID HGC front window. The Duke group has designed the Hall B PRad vacuum tank with the same window size as that of SHMS HGC and used same tooling to build. JLab engineering group has overseen these two pressure systems and also other similar systems at JLab. The design and construction of the prototype tank and front thin window also gives us direct information to help estimate the labor and materials needed for the full detector. Most parts of the tank will be built by vendors and the labor we need is for window fabrication, the vessel assembly and leak testing at UofR. The vessel cost estimate is based on the SHMS HGC vessel construction cost, scaled by the relative size of the detector. A much better estimate should be available in the next several months, as the vessel prototyping moves to its next stage. The cost estimate for the thin window is based on prototype window material and labor costs.

1.2.3.2 Mirrors

HGC mirror blanks, coating and assembly will be the same as those of LGC mirrors. The cost can be scaled by mirror area and HGC has about 75% of LGC's mirror area. Please refer to LGC cost basis for more details.

1.2.3.2.1 Mirror blanks

The mirror blanks are estimates based on a light weight carbon-fiber design which will maintain rigidity for optical purpose and minimum material budget.

1.2.3.2.2 Mirror coating

The mirror coating is estimated by pre-coated flexible reflective film and securing the film to smooth mirror blanks.

1.2.3.2.3 Mirror assembly

The mirror assembly refer to the labor and materials needed to apply the reflective film with adhesive to the mirror blanks in a clean room environment.

1.2.3.3 Magnetic Shielding and reflection cone

1.2.3.3.1 Magnetic Shielding

The magnetic shielding cone needs to shield the 20x20 cm square photon sensor assembly to reduce the magnetic field from the expected ~100G. The preliminary design has one or two layers of low carbon steel as outer layer and one Mu-metal as inner layer to maximum the shield performance. We have tested two layers of low carbon steel to reach nearly a factor 4 of field reduction, which will only cause a few percent PMT gain loss and already satisfy the requirement. We think adding additional layer of Mu-metal to improve it even further. We are talking to vendors who are specialized in magnetic shielding and experts working with large magnetic shielding for other Cerenkov detectors. The shielding cones will be built by vendors and we will test them and assemble together reflection cone and readout. A quote is attached.

1.2.3.3.2 Reflection cone

The reflection cones will be used to collect lights from mirrors onto the photosensors. The current plan is to use Al coated polycarbonate Lexan film attached to the magnetic shielding cones. The same reflective film with good reflectivity has been used for the reflection layer for the CLAS12 LTCC mirrors and JLab has extensive experience working with vendors on those films. We need labor to attach the film to inner layer of magnetic shielding cones to form the reflection cones. A quote of the film is attached.

1.2.3.4 PMTs and Coating

1.2.3.4.1 PMTs

64 pixels 2 inch square shaped MAPMT from Hamamatsu (model H12700-03) is the current default choice for photosensor because it works in moderate magnetic field and can be assembled into large array. 16 MAPMTs will form a 4x4 array in one sector. Total 480 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 LGC to get a bulk pricing, if in the end H12700-03 were chosen.

1.2.3.4.2 PMT coating

To enhance the photon detection efficiency near 200nm UV range where most of Cerenkov light is, the MAPMTs will be coated with the wave-length shifting chemical p-Terphenyl. The LGC group from Temple and ANL has extensive experience with coating regular PMT for CLAS12 LTCC and test coating on MAPMT. The cost is based on their work and experience.

1.2.3.5 Gas and Gas System

1.2.3.5.1 Gas System

The SoLID HGC gas system will be built in Hall A following the experience of CLAS12 LTCC gas system in Hall B. The purifying unit can be shared between the two because it only needs to operate at the gas recovering stage and there are buffer tanks in place for both detectors if there is any conflict in time. The gas filling and collecting units will be built by JLab engineers and technicians who are very experienced. The labor and procurement needed are all estimated according to the experience.

1.2.3.5.2 Gas for Testing, Commissioning and Initial Operation

The choice of heavy gas for SoLID HGC is C4F8. A recent test in Summer 2019 using the SHMS HGC in Hall C at JLab, which is also sensitive to photons above 200 nm, has shown that the C4F8 performance with additional 10\% pressure is comparable to the commonly used heavy gas C4F8O. Following the ESH&Q policy, we will minimize its use with a recycling gas system and keep a record of the quantity used. The gas is commonly available from many suppliers. We have quote for $80/kg in bulk. For an entire volume of 20m3 at 1.7atm, 2000kg C4F8 gas is needed for testing, commissioning and initial operation. A quote is attached.

1.2.3.6 Sum Readout

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 that the 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 have experience of building mechanic support structure for MAPMT to form photosensor assembly. Our estimation of the 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 MAPMTs under magnetic field and other detectors at JLab using those MAPMTs in their running will provide useful information. Our labor will be mainly used for testing those MAPMTs with electronic boards as a part of the SoLID DAQ system, while collaborating with the LGC group. An detailed estimation is attached

1.2.3.7 Testing and Installation

We will start to test individual components like mirrors, magnetic shielding and reflection cones, MAPMTs and readout as soon as they are made available. After tanks and front thin windows are built at UofR, they will be shipped to JLab. Other components will be mounted into the tanks in a test lab for initial optical alignment, assembly and gas leak test. We will also conduct cosmic ray tests. Each of half a toroid will be transported into Hall A and mounted onto the supporting rails of the SoLID magnet endcap after other downstream subsystems are installed. The gas system and tanks will be connected and final gas leak test will be carried out before filling heavy gas. The cabling from the readout to SoLID DAQ mainframe will be made and the final optical alignment will be performed before it is ready for commission. Our estimation of the material and labor needed for testing and installation are based on the experience with SHMS HGC and CLAS12 LTCC.

Reference:

1. quote for magnetic shielding

2. quote for reflection film for reflection cone

3. estimation of sum readout electronics cost

4. quote for C4F8

1. quote for magnetic shielding

(All prices below come from Magnetic Shield Corp.)

Material (Thickness)	Price (USD)
NETIC (1.27 mm)	53.10
NETIC (2.41 mm)	92.70
Co-NETIC (0.76 mm)	351.45
Co-NETIC (1.57 mm)	703.65
MuMetal Foil (30.48 cm wide, price is by foot)	71.95

The NETIC sheet comes in 30” x 14” (76.2 cm x 35.56 cm)
The Co-NETIC sheet comes 30” x 14” (76.2 cm x 38.1 cm)

A two-layer shield of 2.41 mm NETIC and 1.57 mm Co-NETIC was recommended. We could construct the shield (with endcap) using four pieces of the thicker variety of NETIC and Co-NETIC. This would put the price for the materials at:

$$4 \times (\$92.70) + 4 \times (\$703.65) = \$3185.40$$

The quote for the full shield with forming, welding and final stage annealing was $5224.00.

2. quote for reflection film for reflection cone

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 49°C 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

www.evaporatedcoatings.com

3. estimation of sum readout electronics cost

From Jack McKisson at JLab detector group on Jan 10, 2019

The estimates can be roughly broken down as follows
for the 480 H12700 sum amp boards (perhaps grouped rather than individual, so fewer than 480 separate pieces)
~15K PCB costs 480 identical boards populated, assembled tested
~10K preamp ICs, resistors capacitors
~15K PCB connectors power and signal (reduced 50% if soldered, but higher assembly labor)
~5K wire for power and signal (highly design dependent)
~20K feed through connectors (highly design dependent)
~25K In-house labor (mounting assemblies to MAPMTS and into mechanical)
~10K contingency

4. quote for C4F8

C4F8 is available in bulk from many suppliers. The quote (~$80/kg) below is from Airgas which was used for Hall C beam test

Quote For: 2734633
DUKE UNIVERSITY - FFSC
124 SCIENCE DR
DURHAM NC 27708-9976

Sold To: 2761675
DUKE UNIVERSITY/ACCTS PAYABLE DEPT
324 BLACKWELL ST STE 800
DURHAM NC 27701-3689

Quote Number	2008127030
Quote Date	04/22/2019
Prepared By	Rick Bullock
Contact Phone	+1 919-544-9699
PO Number	FFSC
Release Number	
Ordered By	Zhiwen

Item	Material/Description	Plant	Order Qty	UM	Vol/Wt	UM	Unit Price	UM	Ext Price
10	**R3 CP80** C318 OCTAFLUOROCYCLOBUTANE CP GR 3.8 SIZE 80 20LBS CGA 660	S304	1	CL	20	LBS	**945.00**	CL	**945.00**
20	**PF CP5P** PERFLUOROPROPANE CP GR 2.5 SIZE 5LBS CGA 510	S304	1	CL	5	LBS	**410.00**	CL	**410.00**
30	**R3 CP200** C318 OCTAFLUOROCYCLOBUTANE CP SIZE 200 110LBS CGA 660	S304	1	CL	110	LBS	**3,854.00**	CL	**3,854.00**

Incoterms	Airgas Truck
Shipping Method	Airgas Truck
Payment Terms	NET 30

Quote Amount	5,209.00
Sales Tax	0.00
Quote Total	5,209.00

PLEASE REFER TO THIS QUOTATION WHEN ORDERING.
Terms and pricing are valid for a limited time only.