Natural Sciences and Engineering Research Council of Canada | Conseil de recherches en sciences naturelles et en génie du Canada

Institutional Identifier	
System-ID (for NSERC use only) 125494327	

FORM 101
Application for a Grant
PART I

Date 2009/10/22

Family name of applicant	Given name	Initial(s) of all given names	Personal identification no. (PIN)
Huber	Garth	GM	**Valid** 114664

Institution that will administer the grant	Language of application	Time (in hours per month) to be devoted to the proposed research / activity
Regina	[X] English [ ] French	140

Type of grant applied for	For Strategic Projects, indicate the Target Area and the Research Topic; for Strategic Networks and Strategic Workshops indicate the Target Area.
Research Tools and Instruments - Category 1	

Title of proposal
Heavy Gas Cerenkov detector for Jefferson Lab

Provide a maximum of 10 key words that describe this proposal. Use commas to separate them.
Particle Identification, Cerenkov Radiation, Hadronic Structure, Form Factors, Non-perturbative QCD, Intermediate Energy Nuclear Physics, Electromagnetic Interactions

Research subject code(s)		Area of application code(s)	
Primary	Secondary	Primary	Secondary
3108	3105	1202	1200

CERTIFICATION/REQUIREMENTS

If this proposal involves any of the following, check the box(es) and submit the protocol to the university or college's certification committee.

Research involving : Humans [ ] Human pluripotent stem cells [ ] Animals [ ] Biohazards [ ]

Does any phase of the research described in this proposal a) take place outside an office or laboratory, or b) involve an undertaking as described in Part 1 of Appendix B?

[X] NO [ ] If YES to either question a) or b) – Appendices A and B must be completed

TOTAL AMOUNT REQUESTED FROM NSERC

Year 1	Year 2	Year 3	Year 4	Year 5
148,529	0	0	0	0

SIGNATURES (Refer to instructions "What do signatures mean?")

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors* apply to any grant made pursuant to this application and are hereby accepted by the applicant and the applicant's employing institution.

Applicant

Head of department

Applicant's department, institution, tel. and fax nos., and e-mail

Physics
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Dean of faculty

President of institution
(or representative)

The information collected on this form and appendices will be stored in the Personal Information Bank for the appropriate program.
PROTECTED WHEN COMPLETED

Version française disponible

Canada

Personal identification no. (PIN)	Family name of applicant
Valid 114664	Huber

CO-APPLICANTS

I have read the statement "What do signatures on the application mean?" in the accompanying instructions and agree to it.

PIN, family name and initial(s)	Research/ activity time (hours/month)	Organization	Signature
157269, Hornidge, D.L.	20	Mount Allison	
100124, Sarty, A.J.	10	Saint Mary's	

CO-APPLICANTS' ORGANIZATIONS AND/OR SUPPORTING ORGANIZATIONS (if organization different from page 1)

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors,* as well as the statements "What do signatures on the application mean?" and "Summary of proposal for public release" in the accompanying instructions, apply to any grant made pursuant to this application and are hereby accepted by the organization.

Family name and given name of signing officer, title of position, and name of organization	Signature
Mc Clatchie, Dr. Stephen Provost and Vice-President, Academic and Mount Allison	
Murphy, Dr. Terrence Vice-President, Academic and Research Saint Mary's	

Use additional page(s) if necessary.

Personal identification no. (PIN)	Family name of applicant
Valid 114664	Huber

SUMMARY OF PROPOSAL FOR PUBLIC RELEASE (Use plain language.)
This plain language summary will be available to the public if your proposal is funded. Although it is not mandatory, you may choose to include your business telephone number and/or your e-mail address to facilitate contact with the public and the media about your research.

Business telephone no. (optional):
E-mail address (optional):

One of the central problems of modern physics research concerns our understanding of the building blocks of the atomic nucleus -- the protons, neutrons, and other particles (mesons) that bind them. Notable discoveries have indicated that these particles consist of yet more fundamental constituents, the quarks and gluons. While a very good theoretical framework (called Quantum Chromo-Dynamics, or QCD) is able to describe accurately how quarks and gluons interact at extremely high energies (or, equivalently, when the quarks are very close together), it has been very difficult to apply QCD to lower energy (longer distance) phenomena. The paradox is that the increasing complexity of the quark-gluon interaction as these particles become further apart is critically important to their confinement within the nuclear building blocks, but we cannot perform the QCD calculations necessary to confirm our understanding.

One of the obstacles to our improved comprehension has been a lack of quality data, particularly for the Exclusive Reactions where the system responds coherently to the incoming probe, and so provides the clearest picture of the inner workings of QCD. Existing data in the Deep Inelastic Scattering regime are primarily inclusive in nature, where the system responds incoherently. The Super HMS spectrometer (SHMS), under construction in Jefferson Lab Hall C as part of a major upgrade of its facilities, will make Hall C the only facility in the world capable of exploring Exclusive Reactions up to Q^2~15 GeV^2, and it will do so at an unprecedented luminosity of 10^{39}/s/cm^2. Canadians lead important parts of this new experimental program, such as measurements of the charged pion form factor and scaling studies of pi+ and K+ production. Specifically, this proposal requests funds for the Heavy Gas Cerenkov detector, which is indispensable for these measurements. The Canadian-led experiments all require excellent pion identification, and this detector is solely responsible for providing that information. The detector work builds upon previously developed expertise and provides an excellent training ground for the next generation of scientists.

Other Language Version of Summary (optional).

Personal identification no. (PIN)	Family name of applicant
Valid 114664	Huber

Before completing this section, **read the instructions** and consult the *Use of Grant Funds* section of the NSERC Program Guide for Professors concerning the eligibility of expenditures for the direct costs of research and the regulations governing the use of grant funds.

TOTAL PROPOSED EXPENDITURES (Include cash expenditures only)

	Year 1	Year 2	Year 3	Year 4	Year 5
1) Salaries and benefits					
a) Students	0	0	0	0	0
b) Postdoctoral fellows	0	0	0	0	0
c) Technical/professional assistants	0	0	0	0	0
d)	0	0	0	0	0
2) Equipment or facility					
a) Purchase or rental	179,791	0	0	0	0
b) Operation and maintenance costs	0	0	0	0	0
c) User fees	0	0	0	0	0
3) Materials and supplies	0	0	0	0	0
4) Travel					
a) Conferences	0	0	0	0	0
b) Field work	0	0	0	0	0
c) Collaboration/consultation	0	0	0	0	0
5) Dissemination costs					
a) Publication costs	0	0	0	0	0
b)	0	0	0	0	0
6) Other (specify)					
a)	0	0	0	0	0
b)	0	0	0	0	0
TOTAL PROPOSED EXPENDITURES	179,791	0	0	0	0
Total cash contribution from industry (if applicable)					
Total cash contribution from university (if applicable)					
Total cash contribution from other sources (if applicable)	31,262	0	0	0	0
TOTAL AMOUNT REQUESTED FROM NSERC (transfer to page 1)	148,529	0	0	0	0

1 Detailed Budget Table

Table 1 lists materials, parts, equipment and other technical support costs required to complete the Heavy Gas Čerenkov detector. An overview of the relevant technical aspects of the proposed instrumentation will follow. Detailed information on each budget item in the table is then given.

Table 1: Exchange rates of US$1.00=C$1.10 and SFr1.00=C$1.02, have been assumed for all items where direct pricing in Canadian dollars was not available. These rates are based on the 2008 year-average exchange rates plus bank commission. Tax rates of 5% PST and 1.67% GST have been applied where applicable.

Detailed Budget Table				
Item Description	Number of Items	Cost	NSERC Fraction	NSERC Request (C$)
Pressure Vessel				
1. Cylindrical Vessel	1	C$59,735	1	$59,735
2. Window Hydroforming	3	C$ 569	1	$ 569
Mirrors				
3. Mirrors	10	US$ 7,000	1	$ 8,214
4. Carbon Fiber Backing	6	C$ 5,539	1	$ 5,539
5. Mirror Mounts	4	C$ 7,033	1	$ 7,033
6. Mirror Aluminization	5	SFr 10,000	1	$10,200
Photomultipliers				
7. PMT,mu-Shield,Socket	5	US$ 3,994/ea	1	$23,430
8. Convex Adapters	4	US$ 1,010/ea	1	$ 4,740
9. Spectrosil Windows	4	US$ 1,125/ea	1	$ 5,280
10. PMT Mounting Assembly	4	C$ 5,633	1	$ 5,633
Gas Handling				
11. OctaFluoroTetraHydrofuran C_4F_8O	1,000L (9.2kg)	US$73/kg	0	$ 0 (JLab)
12. Gas System		US$10,000	0	$ 0 (JLab)
Electronics				
13. HV	4 channels	US$ 4,400	0	$ 0 (JLab)
14. DAQ Electronics	8 channels	US$ 3,100	0	$ 0 (JLab)
15. Cables		US$ 1,000	0	$ 0 (JLab)
Miscellaneous				
16. Optical Alignment Jig		C$ 500	1	$ 500
17. Valves & Fittings		C$ 2,239	1	$ 2,239
18. Support Stand		US$10,000	0	$ 0 (JLab)
19. Shipping		C$ 15,417	1	$15,417
Total				$148,529

2 Need and Urgency of the Equipment

The SHMS (Super High Momentum Spectrometer) is an 11 GeV/c superconducting spectrometer being built as one of the major detector components of the Jefferson Lab upgrade. The SHMS will pair with the existing HMS (High Momentum Spectrometer) in Hall C to allow exclusive and semi-inclusive coincidence measurements $(e, e'X)$ to be performed in the deep inelastic scattering regime. Much of the interesting physics is only accessible if at least one of the spectrometers can achieve angles significantly below 10^o. The SHMS will achieve a minimum scattering angle of 5.5^o with acceptable solid angle, and it will do so at high luminosity. The SHMS is designed to achieve a momentum resolution of 0.03%-0.08%, with a momentum acceptance of $-10\% < \delta < +22\%$ (where $\delta = (P - P_{cent})/P_{cent}$), and a solid angle acceptance of 4.5 msr. These characteristics pair well with those of the existing 7.3 GeV/c HMS. Both spectrometers will be rigidly connected to a central pivot, which permits reproducible angular rotation and pointing to the target, two requirements needed to make accurate cross section measurements. The SHMS momentum and target acceptances are designed to be very flat, with performance similar to the HMS. This also simplifies accurate measurements, and facilitates experiments such as Rosenbluth L/T separations, which require a large number of angle and momentum settings. A perspective view of the two spectrometers is shown in the left panel of Fig. 1.

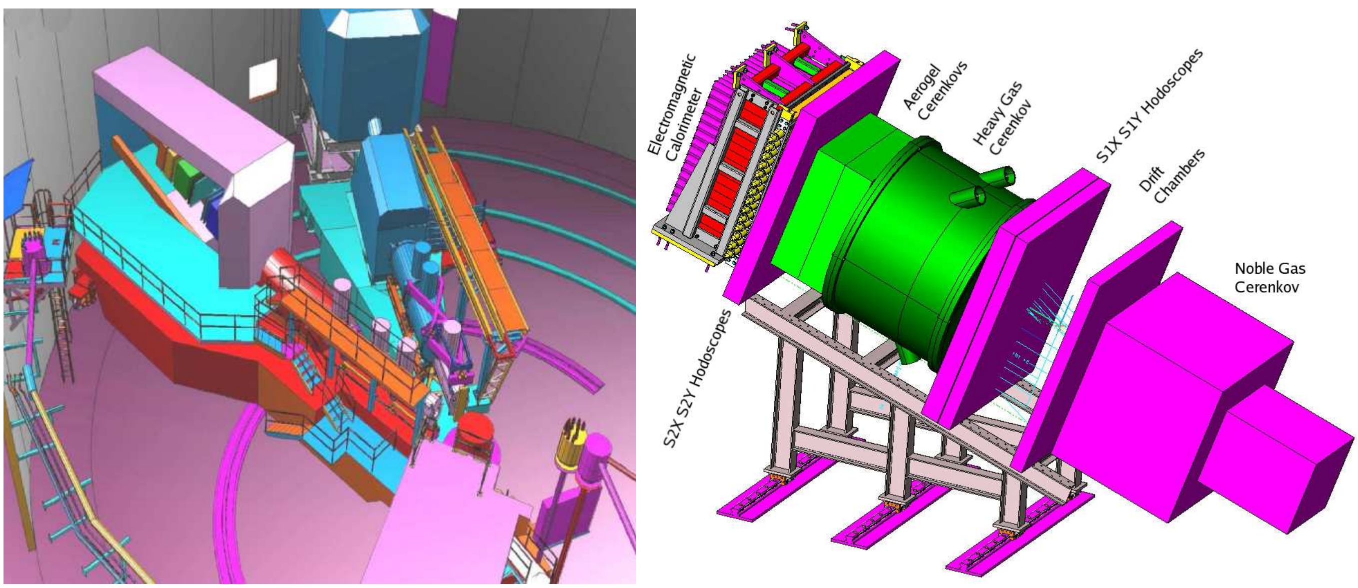

Figure 1: Left: Rendering of the SHMS and HMS spectrometers in Hall C. The electron beam is incident from the lower right of the diagram, and is deposited into a beam dump buried near the upper center of the diagram. The existing HMS is the device on the upper right, while the new SHMS is on the left.
Right: Layout of the SHMS focal plane detectors. Charged particles focused by the magnetic elements of the spectrometer traverse the various detectors, from lower right to upper left in the figure. The Heavy Gas Čerenkov detector is the large cylinder near the center of the figure.

SHMS Particle Identification: Much thought has gone into ensuring the planned suite of tracking and particle identification detectors are adequate to meet the physics goals of the proposed experiments. A side view of the SHMS focal plane detectors is shown in the right panel of Fig. 1.

The SHMS tracking system (two multi-wire drift chambers of 6 planes each) will provide the only measurement of particle momentum and production angle in the spectrometer. Three planes of plastic scintillating hodoscopes and one plane of quartz Čerenkov hodoscopes will provide several essential functions: a trigger which is $> 99.9\%$ efficient for minimum ionizing particles, a means to reject accidental coincidences in multi-arm experiments, and a means to measure the efficiency of the tracking system.

For momenta from 2-11 GeV/c, it becomes increasingly more difficult to distinguish charged particle species by time of flight measurements, and one must rely on other means of particle identification. Electron identification will be accomplished by use of energy measurements in an electromagnetic calorimeter at the end of the detector stack. For measurements at high momentum and low signal to background, this calorimeter will be supplemented with a Noble Gas Čerenkov detector in place of the last section of vacuum pipe just upstream of the first wire chamber. This device, using a Ne-Ar mixture at atmospheric pressure, can have its index of refraction tuned to enhance either $e : \pi$ or $\pi : K$ discrimination at high momentum. At these higher momenta, the multiple scattering due to this added detector will be tolerable.

For hadrons, efficient, high-confidence particle identification (PID) over the entire SHMS momentum range can be provided economically with the appropriate choices of detectors and techniques:

- **~ 1 to ~ 3 GeV/c:** $K : \pi$ separation can be achieved with one Aerogel Čerenkov detector instrumented with appropriately chosen n. A time of flight measurement over the 2.2 m path between the trigger detector planes with a resolution of 200 ps allows one to distinguish p from K at the 3σ level up to 2 GeV/c. At the high end of this range, proton PID can be improved with the use of an additional Aerogel Čerenkov detector with $n = 1.02$.
- **~ 3 to ~ 5.5 GeV/c:** Charged pions will trigger a C_4F_8O Heavy Gas Čerenkov detector. The gas pressure will be adjusted such that K do not radiate. Charged kaons will trigger an Aerogel Čerenkov with $n = 1.02$ to 1.01.
- **~ 5.5 to ~ 11 GeV/c:** Pions will still trigger the C_4F_8O Čerenkov, with pressure reduced to ensure kaons remain below Čerenkov threshold. A Noble Gas Čerenkov filled with an Ar-Ne mixture detector will be inserted upstream of the first drift chamber and provide an additional electron tag.

The Heavy Gas Čerenkov detector presented in this application is the only detector responsible for charged pion identification in the SHMS. As such, it is a critical component of the Canadian-led portion of the SHMS scientific program, such as measurements of the charged pion form factor and scaling studies of exclusive π^+ and K^+ production. All of these experiments require reliable pion identification from 2.2 to 8.5 GeV/c. This detector is also an appropriate Canadian contribution to the SHMS because it makes use of Regina expertise built up in earlier detector projects, such as the Aerogel Čerenkov detector constructed for JLab Hall A, and the Gas Čerenkov detector constructed for TAGX. Indeed, because of this expertise, the design studies of the Heavy Gas Čerenkov are well-advanced.

A particular design challenge is the Čerenkov light collection efficiency, which needs to be both high and uniform across the SHMS focal plane. The Čerenkov cone angle is as large as 3^o (for 7.3 GeV/c pions), and since this is one of the last detectors in the SHMS stack, the incident particle tracks are somewhat divergent. These considerations make it challenging to collect efficiently the generated Čerenkov light, possibly affecting the π identification efficiency below 4.5 GeV/c. Furthermore, JLab's original space allocation for the Heavy Gas Čerenkov in the SHMS detector stack was only 100 cm in length. Our studies showed that it was difficult to focus efficiently the Čerenkov light onto the PMTs within this tight constraint, and that the best light collection efficiency would be obtained with a 130 cm long detector and spherical mirrors of 115 cm radius of curvature. These optical ray trace studies (using the WestGrid computational facility in Vancouver) also provided the mirror and PMT locations and angles used in our design drawings. JLab subsequently increased the length allocation for this detector to 1.3 m. We also performed Geant4 investigations to determine whether parabolic mirrors provide noticeably better light collection than spherical mirrors. An example showing the improved focusing of light onto one of the PMTs is shown in the left panel of Fig. 2. The projected detector performance, shown in the right panel of Fig. 2, indicates a useful lower momentum limit of 3.4 GeV/c, and a minimum pion detection efficiency $> 99\%$ over most of the SHMS momentum range. These pion identification characteristics will allow the experiments discussed in the proposal to meet their scientific objectives.

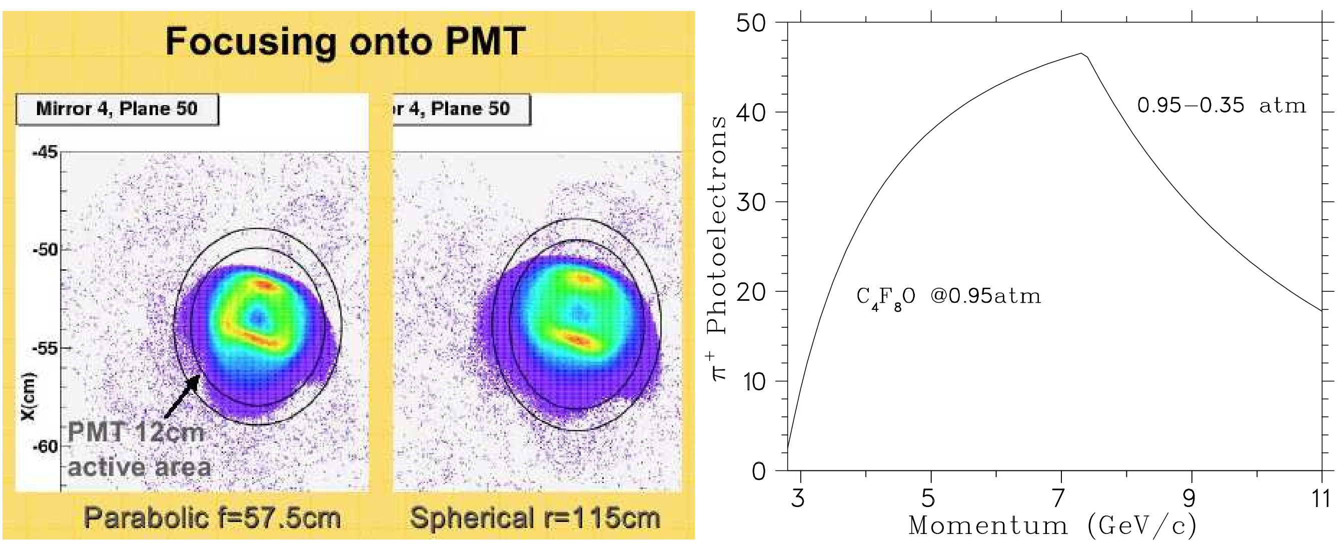

Figure 2: Left: Simulated focus of Čerenkov light onto a 5" PMT by parabolic (left) and spherical (right) mirrors of the same orientation and central radius of curvature. The outer ring indicates the physical diameter of the PMT, while the inner ring indicates the PMT active area. The parabolic mirror provides noticeably improved performance.
Right: Projected number of detected photoelectrons for π^+ incident on the detector. The number of photoelectrons increases with momentum up to 7.3 GeV/c, but decreases thereafter as the radiator gas pressure is reduced from 0.95 atm to 0.35 atm to ensure that kaons remain below Čerenkov threshold.

Timeline: The budget for the entire SHMS project is approximately U.S.$25 million. As of October, 2009, all design for the SHMS superconducting magnets has been completed, and the contracts for the magnets have either all been signed or are in the final stages of vendor discussion. The reference designs for the magnet support carriage and detector shield house have been reviewed externally, and the detailed fabrication engineering contract has been let. The first magnets are expected to be delivered to JLab in the summer of 2011 and will undergo testing prior to SHMS installation and assembly in Hall C in 2012-13.

Funding for the tracking and triggering detectors, as well as the detector support stand, has been secured from the NSF by a consortium of Virginia and North Carolina universities. Procurement and assembly of these detectors has already begun, with this task scheduled to be completed in mid-2012. The HERMES Electromagnetic Calorimeter was donated by the Netherlands for use in the SHMS. The calorimeter blocks and PMTs arrived at JLab in the spring of 2008 and they are presently being refurbished by the Yerevan (Armenia) group. The Noble Gas Čerenkov detector will be built by the University of Virginia, using JLab 12 GeV project funds which have been secured for 2011. Funds for two Aerogel Čerenkov detectors have been requested from the NSF by two U.S. universities but have not yet been secured. Approval of this grant application would complete the planned instrumentation for the SHMS. The application is timely, as its approval would allow a two year construction window for the Heavy Gas Čerenkov prior to cosmics testing and installation on the SHMS.

3 Detailed explanation of budget items

The detailed explanation which follows reflects the design work which has been performed to date in Regina, with helpful input provided by many Jefferson Lab collaborators and Detector Physicist Jan Soukup (University of Alberta CRPP). Following Hall C's customary internal review process, it is anticipated that all designs will be reviewed by the SHMS detector working group prior to procurement, to ensure that all necessary requirements are met.

3.1 Pressure Vessel and Entrance/Exit Windows (Items 1,2)

Since the lowest operating pressure of the C_4F_8O radiator gas is 0.35 atm at 11 GeV/c, the Heavy Gas Čerenkov pressure vessel must be capable of maintaining significantly below-atmospheric pressure for long periods of time. It should also withstand vacuum during gas purging and filling operations. To accommodate these needs, the vessel is proposed to be made from 1 inch thick aluminum alloy sheet (6061, or similar suitable), which is rolled into a cylinder and then welded. Large post-welding-machined end flanges would mate with thin foil entrance and exit windows that would match in shape the end flanges. Two views of the vessel from our detailed design drawings used to solicit vendor quotations are shown in the left panel of Fig. 3. Final engineering drawings of the vessel are expected to be made at no cost by the University of Alberta CRPP. The inner diameter of the vessel is planned to be 1.7 m, and including the end clamps, the vessel length will be 1.275 m. [Allowance for bolt head clearance brings the overall length to the 1.3 m allocated in the SHMS detector stack.] Both vendors have been requested to include a dye test of all welds and a vacuum test of the vessel (using thicker blank-off windows) prior to delivery. One of the blank-off windows is requested to be drilled with the full bolt-hole pattern in order to accommodate item 2, which will be discussed shortly.

The vessel also includes four tubular side ports which will house the PMTs. By allowing the PMTs to straddle the pressure vessel wall (see Fig. 5), the side ports allow the vessel size to be shrunk to the minimum diameter needed to contain the SHMS focal plane envelope. This is necessary due to tight space constraints in the SHMS detector hut. To ensure the side ports maintain proper alignment during welding, their exterior surfaces will first be machined to a snug fit to the mating holes milled in the pressure vessel walls. The tubes will then be slid into position

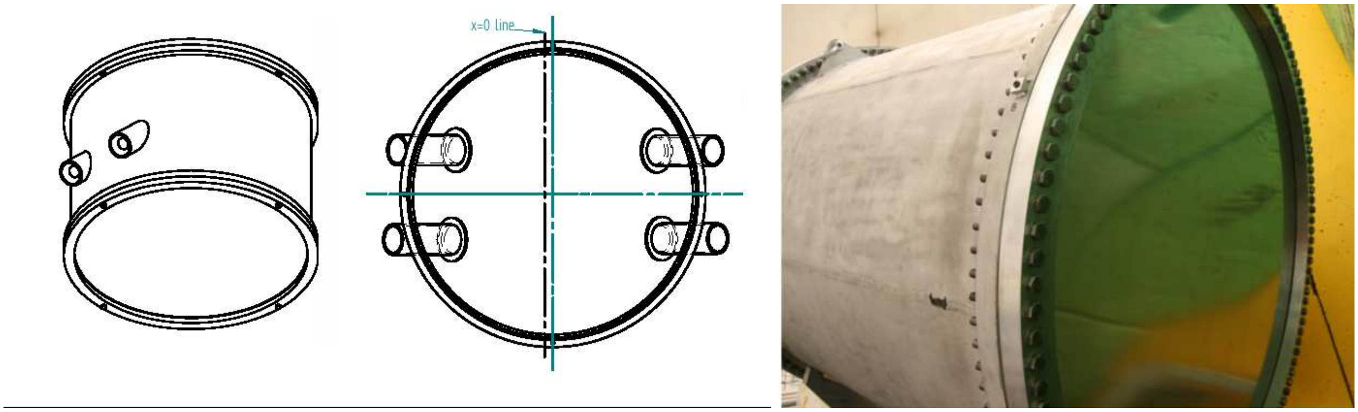

Figure 3: Left: Schematic of the Heavy Gas Čerenkov pressure vessel (item 1).
Right: Photo of the HMS Gas Čerenkov entrance window, which serves as the reference design for this detector. The window is clamped and secured with 120 bolts, with an O-ring seal to the vessel.

and welded in place. The PMTs will view the radiator gas through quartz windows mounted in flanges (with O-ring seals) at the end of each port.

The design of the pressure vessel entrance and exit windows is based on the existing HMS Gas Čerenkov detector shown in the right panel of Fig. 3. The windows must not be excessively thick, as knock-on electrons produced by subthreshold particles traversing the windows will lead to false signals in the detector. These background events can be largely (but not completely) eliminated via a cut on the number of photoelectrons registered by the PMTs. A finite element analysis of the windows is underway at the University of Alberta CRPP, so the design is not yet finalized. Our present design assumes 1 mm thick high tensile strength 7075 aluminum alloy entrance and exit windows clamped to the vessel end flanges in a manner similar to that shown in Fig. 3. Three windows are proposed for fabrication. The third one is reserved for a puncture test, which is expected to be required by JLab as part of the safety and hazard review of the detector prior to installation.

The fabrication of the pressure vessel can be done by a large number of companies in Western Canada. Design drawings of the pressure vessel and clamps were submitted to seven companies, of which only Ross Machine Shop and EBCO Industries chose to submit budgetary quotations for this proposal. Each quotation includes the cylindrical pressure vessel with the four tubular side ports, as well as the two large window clamp rings and the four small nozzle window clamp rings. The quotations also include three entrance windows and all bolts and O-rings. Neither quotation includes any provision for design work by the vendor, nor any part of the mirror or PMT mounting fixtures.

Ross Machine Shop (Regina, SK): This vendor has been contracted to mill the lead-scintillating fiber bars made in Regina for the GlueX Barrel Calorimeter, a different component of the JLab 12 GeV Upgrade. Their $53,384 quotation includes a dye test and vacuum pump-down test of the vessel. Adding PST and GST brings the total to $56,945.

EBCO Industries (Richmond, BC): This is a highly reputable vendor used frequently by TRIUMF. Their quotation of $56,000 (not including tax or shipping) allows for a full helium leak check of the vessel. Adding PST and GST brings this to $59,735.

Although both vendors were supplied with detailed design drawings, they were not final engineering drawings with all bolt holes and construction tolerances specified. The supplied quotations were the result of numerous phone conversations and emails with the estimating officers, to be sure the project requirements were as clear as possible. Overall, the EBCO quotation is more detailed, with suppliers identified for each item, and a helium vacuum leak check included. Therefore, the EBCO Industries quotation has been included in the detailed budget table (item 1).

Window Hydroforming: In order to provide the necessary structural strength, the thin entrance/exit windows will be hydroformed to a concave shape in Regina using a procedure developed at SLAC and used previously for the HMS Gas Čerenkov detector windows. In this case, the window will be clamped to one of the blank-offs used for the pressure vessel vacuum test (using the full 120 bolt pattern), and pressurized with water until the desired curvature is obtained. This is expected to result in an approximate factor of two improvement in the window strength. The only foreseen cost is 16 hours of technician time. The UofR $35/hour labor rate anticipates 50% cost recovery by the university, and so is an implicit subsidy of $35/hour towards this project. Adding GST brings this to $569 (item 2).

3.2 Mirrors, Backing, Mounts and Aluminization (Items 3-6)

Four mirrors of dimension $55{\times}60$ cm^2 are required to span the SHMS focal plane. The mirrors must be thin, to avoid the problem of knock-on electrons for the Aerogel Čerenkovs mounted behind this detector. For the same reason, the assembly to mount the mirrors to the cylindrical vessel walls must also be located outside the beam envelope. These dual requirements pose a considerable design challenge. The mirrors are planned to be made from thin (3 mm) glass, which will be reinforced by a carbon fiber epoxy backing within the beam envelope to provide the necessary structural rigidity. To get a better idea of the planned backing design, a photo of the carbon fiber mirror backing used in the existing SOS Gas Čerenkov detector at JLab is shown in Fig. 4. Although this detector is considerably smaller and simpler than the one discussed here, it has a similar four mirror configuration. The mirrors will then be clamped on two outside edges and mounted to the cylindrical vessel walls via a custom assembly of machined aluminum. The location of the mirror mounting points outside of the beam envelope is indicated in Fig 5.

Mirror Blanks: The quotation by EuropTec USA for the glass mirror blanks is attached. Sheets of plate glass will be cut to the required rectangular shape and then slumped over a mold of the required curvature under vacuum. This company has provided mirrors for a wide variety of Čerenkov detectors at JLab, and so has the necessary expertise. Half of the U.S.$7,000 cost estimate is simply for machining of the mold and set-up costs. The additional price per mirror is relatively small. With no allowance for spares, the four mirrors minimally required for the detector would cost U.S.$5,500 (not including shipping or taxes). For a mere U.S.$1,500 extra, six additional spares can be acquired. This is well worth the cost, as it allows us to perform a series of spot-size and Ronchi tests on the mirrors to select those with the fewest optical distortions for aluminization. The Ronchi test was used to test the HERA-B RICH mirrors, and involves placing a line grating near the mirror radius of curvature and looking for distortions in the reflected image. Performing these tests and writing them up as a formal report would make an excellent student project.

The attached email from EuropTec indicates that no significant cost increment is expected for parabolic ($f = 57.5$ cm) versus spherical ($R = 2f$=115 cm) mirrors. Adding PST and GST to their quotation brings the total to C$8,214 for ten mirrors (item 3).

Stiffening Brackets: The mirror carbon fiber backing and stiffening brackets are planned to be designed and fabricated at the UofR Science Machine Shop. This will allow us to select efficiently

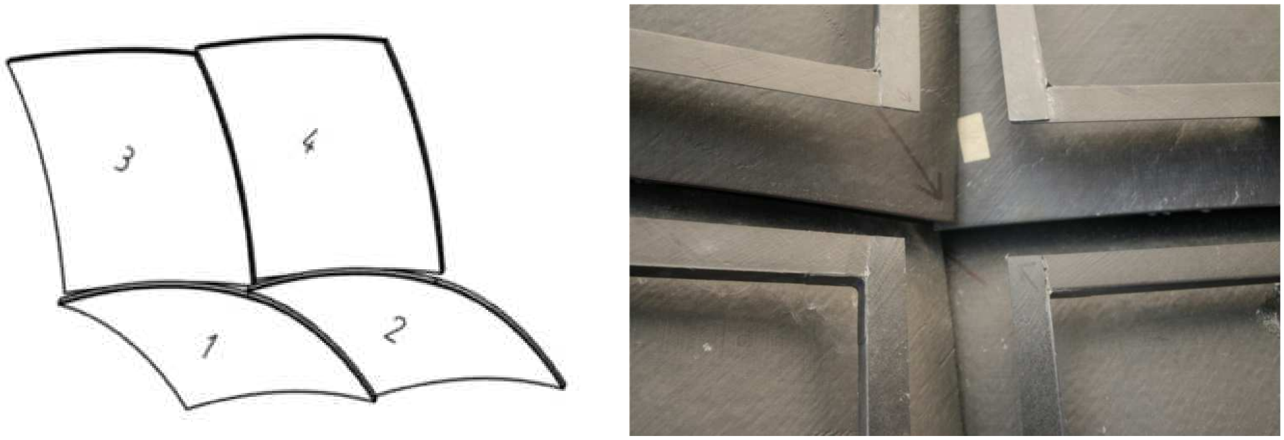

Figure 4: Left: Schematic drawing of mirror orientations (item 3) for the SHMS Heavy Gas Čerenkov detector (viewed from upper front).
Right: Close-up view of the backside of the SOS Gas Čerenkov detector, showing the mirror backing and rectangular stiffening brackets, both made of carbon fiber epoxy. The four spherical mirrors are interleaved without support in the center of the detector in a manner similar to that planned for the SHMS Heavy Gas Čerenkov. This serves as the reference design for the mirror backing (item 4), although the mirrors needed for the SHMS will be about a factor of two larger in both dimensions and substantially more massive.

the design which provides the best combination of mirror rigidity and ease of fabrication. One of the spare mirrors is intended to be used for prototyping. The UofR machine shop estimates one man-week of design time and one man-week of construction time for this task. Including PST+GST on the materials brings the total to $5,539 (item 4).

Mirror Mounts: Since the mirror mount assemblies are located immediately outside the beam envelope (Fig. 5), they do not have any areal density restrictions. Our intention is to specify eight points along the inner circumference of the cylindrical vessel where the vendor will weld small mounting brackets. A machined aluminum assembly supporting the weight of the mirrors will be bolted to these mount points. The mirror positions and angles need to be adjustable for optical alignment purposes. Since the SHMS experimental program requires the Heavy Gas Čerenkov detector to be replaced with a proton polarimeter during G_E^p/G_M^p proton form factor measurements, the mirror mounts also need to maintain accurate mirror positioning and alignment during craning operations. The machine shop cost estimate includes design time for the mirror mount assembly as well as all construction costs. Including PST+GST on the materials brings the total to $7,033 (item 5).

Aluminization: We expect to have these mirrors aluminized at the CERN Detector Laboratory. CERN has aluminized all of the mirrors used in Čerenkov detectors used at JLab, and the necessary personal connections are in place to ensure this arrangement continues. As the 55×60 cm^2 mirrors are relatively large, they do not fit in normal-sized vacuum deposition chambers, greatly limiting the number of available vendors. The CERN vacuum deposition chamber has been confirmed to be able to accommodate our blanks. Furthermore, the CERN laboratory will include UV reflectivity measurements (to 200 nm) to ensure good quality control, while most vendors are unable to measure the reflectivity much below 300 nm. The cost to do this work is 10,000 Swiss Francs for four mirrors plus one spare. Conversion to Canadian dollars gives a value of $10,200 (item 6). This is

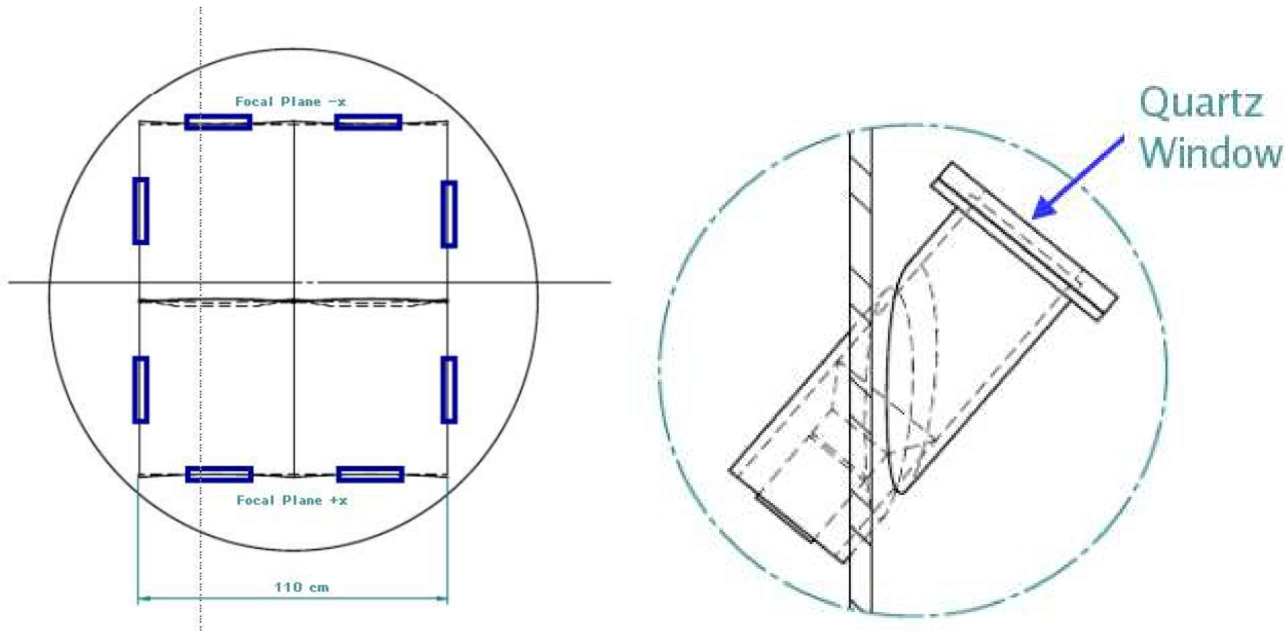

Figure 5: Left: Schematic drawing of the mirror mounting assembly attachment positions immediately outside of the beam envelope (item 5).
Right: Schematic view of a PMT in its tubular side port, viewing the radiator gas through a quartz window (item 9). The port is wider than strictly necessary to hold the PMT and mu-shield, to allow a lateral optical alignment adjustment. A mounting assembly (item 10) will be needed to maintain the alignment of the PMT and provide electrical isolation of the mu-shield from the side port.

admittedly expensive, but this lab has a proven track record of providing excellent and uniform mirror reflectivity for Čerenkov applications.

3.3 Photomultiplier Tubes, Windows and Mounts (Items 7-10)

This detector requires four 5” photomultiplier tubes (PMTs) with high gain and good UV sensitivity. Since the C_4F_8O radiator gas strongly absorbs UV wavelengths below 165 nm, it is sufficient to use PMTs with UV-grade glass windows rather than quartz windows. PMTs with UV-grade glass windows are considerably cheaper, less fragile, and have good spectral sensitivity to 175 nm. To avoid mechanical stress on the PMTs due to the varied pressures that the detector is intended to operate at (see proposal section), the PMTs will be mounted outside the pressure vessel, viewing the enclosure through UV-grade viewports, as already discussed. For this reason, it is also desirable for the PMT to have a flat face, for mounting against the viewports.

The Photonis XP4508B would have been the perfect PMT for this application. After their recent departure from the PMT market, the two remaining suppliers are Hamamatsu and ElectronTubes. Quotations from both vendors are attached.

Hamamatsu: The only high-gain 5” PMT that Hamamatsu makes with a UV-grade glass window is the R1584. Unfortunately, this PMT has a curved spherical face, and so a spherical-to-flat adapter is required (Fig. 6). The version of the R1584 with a flat face, the R1250, is unfortunately only available with a regular glass window, which absorbs UV wavelengths shorter than 300 nm. The quotation from Hamamatsu includes the R1584 plus magnetic shield and base assembly. U.S.$321 is saved per PMT by purchasing these items together, rather than separately. Hardin Optical is willing to make the necessary spherical adapter in small quantities, and their quotation is also attached.

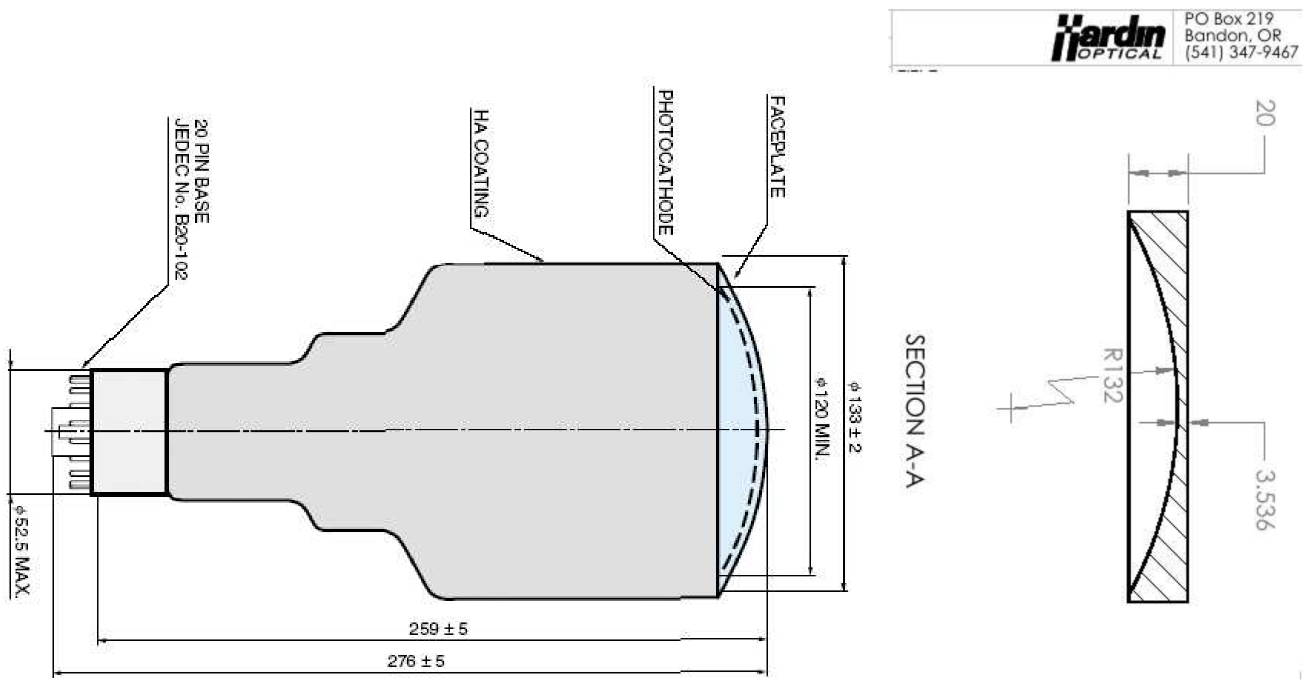

Figure 6: Left: Hamamatsu R1584 5” PMT.
Right: Convex adapter (item 8) to mate PMT (item 7) to quartz window (item 9).

ElectronTubes: The ElectronTubes 9823B is a high-gain flat-face 5” PMT with performance characteristics similar to the Hamamatsu R1250. In this case, the Hardin Optical spherical adapter would not be required. Jefferson Lab Hall B has already placed a large order for the quartz glass version of this PMT (9823QB), which is sensitive down to 160 nm, so they are not willing to consider any orders for the UV-glass version at this time. For this reason, the ElectronTubes quotation is U.S.$1776 higher per PMT than the Hamamatsu + convex adapter quotations.

Therefore, the budget summary includes the Hamamatsu R1584 PMT, magnetic shield and base, as well as the Hardin convex adapter. A total of five Hamamatsu PMTs and bases are requested. JLab colleagues have had difficulty getting PMTs with good noise levels and have recommended the purchase of at least one extra so we can select those with the best performance. In addition, this will provide a spare in case of breakage or malfunction. Hardin Optical is also willing to provide the flat Spectrosil UV-grade viewports (item 9), at a cost of $U.S.1,125 each (plus taxes and shipping).

PMT Mounting Assemblies: As shown in Fig 5, each PMT is housed in a tubular side port which is wider than strictly necessary to hold the PMT and mu-shield, in order to provide up to 1 cm lateral optical adjustment. We plan to construct nylon sleeves which to maintain the PMT optical alignment and isolate electrically the magnetic shield from the tubular side mount. Including one prototype, we expect $400 materials cost per enclosure, and a total of 60 hrs design time and 40 hrs machine shop time. Including PST+GST on the materials brings the total to $5,633 (item 10).

3.4 Miscellaneous Items

We plan to do a complete vacuum test and optical alignment of all elements of the detector before disassembling and shipping to Jefferson Lab. Completing the remaining detector design items, participating in the design prototype discussions, contributing to the various planned tests, and writing the results up as formal reports, are all excellent student projects (at both B.Sc. and M.Sc. level). Installation of the detector at JLab and commissioning of the SHMS will provide excellent graduate student and PDF training ground. All HQP training and travel expenses in support of this project will be borne by Discovery Grants held separately by the applicants. The remaining miscellaneous items listed below are for minor hardware items needed for these tests, and for shipping.

Optical tests: We have already mentioned that a series of spot-size and Ronchi tests are planned to check the mirrors for optical distortions and select the best ones for shipment to CERN. The mirror optical alignment can be checked by mounting a small laser at the intended PMT cathode position and comparing the reflected spot location with our optical calculations. Going the other way, one can mount a grid of LEDs some distance from the mirrors and check the reflected light positions at the PMT face. Two different optical alignment jigs are needed for these tests. We have allocated \$500 for the purchase of small lasers, LEDs, batteries, DC power supplies and mechanical assemblies (item 16).

Vacuum tests: Thanks to the cryogenic target work that Dr. Mathie did in Regina for the TRIUMF CHAOS experiment in the 1990's, the UofR has a good selection of on-site vacuum equipment. However, because the cylindrical vessel volume is nearly 3 m^3, larger KF40 size vacuum fittings and valves need to be purchased to achieve an adequate pumping speed with the existing KF25 size vacuum system. We have identified the items listed in the attached quotation by Kurt J. Lesker Company as the minimum set of components absolutely required for this task. Adding PST+GST to these items brings the total to \$2,239 (item 17).

Shipping: Construction of a sturdy wooden crate to safely ship the vessel to Jefferson Lab has been estimated by the UofR carpentry shop to be \$700. Cost to ship a 1400 lb. (635 kg) crate from Richmond, BC (EBCO) to Regina has been estimated by T. Doyle Transport to be \$2,500, plus GST. Cost to ship this same item from Regina to Newport News, Virginia (JLab) has been estimated to be \$4,850, including brokerage charges. Since the vendor quotations for PMTs, mirrors, etc. do not include any provision for shipping costs to Regina, an extra \$1,000 is added to cover this expense. The total shipping costs for the vessel are estimated at \$8,517.

Construction of a wooden crate with rigid insulation to safely ship the mirrors to/from CERN via air freight has been estimated by the UofR carpentry shop to be \$500. Air freight of the mirrors from Regina to Geneva has been estimated by T. Doyle Transport to be \$3,500 and the shipment from Geneva to Newport News, Virginia to be \$2,900 (both including brokerage costs and air fuel surcharges).

The total shipping costs are estimated at \$15,417 (item 19).

3.5 Parts and Equipment provided from Other Sources

Items which are necessary for the operation of the Heavy Gas Čerenkov detector, but are not requested here, include:

- The OctaFluoroTetraHydrofuran radiator gas, C_4F_8O (item 11). This gas is used in the semiconductor industry and is widely available from many commercial suppliers. Jefferson

Lab is expected to provide this gas as an operational expense of Hall C. Estimated cost per 1 atm fill: U.S.$700.

- Design, assembly and installation of the gas handling system (item 12). Since good $\pi:K$ separation requires the reduction of the gas pressure at high momenta, the detector is expected to undergo frequent gas pressure changes. Infrequent pressure decrease can be achieved either by venting or pumping the inert C_4F_8O to atmosphere. The gas system, to include all plumbing, gas metering and purification hardware, is the responsibility of Jefferson Lab. Estimated cost: U.S.$10,000.

- HV, Readout Electronics, and necessary cables (items 13-15). Since this detector has only four PMTs to be read out every event, it is much more efficient for this item to be provided by Jefferson Lab, as part of the SHMS focal plane detectors readout system, than to be requested as a separate item here. Estimated cost: U.S.$7,500.

- Support stand (item 18). As already mentioned, the SHMS detector support stand has been funded by the NSF. We are expected to provide several mount points welded to the outside of the cylindrical vessel. Jefferson Lab will design and provide the brackets and other hardware needed to secure Heavy Gas Čerenkov in its proper alignment in the support stand relative to the other detectors. All other costs associated with the rigging, alignment and mounting of the detector are expected to be borne by Jefferson Lab. Estimated incremental cost to mount this detector: U.S.$10,000.

Please see the attached letter of support from Jefferson Lab regarding these items.

4 Statement on Research Time hours/month

We consider this RTI application to be an integral part of the Hall C SHMS+HMS experimental program. Therefore, for consistency, this RTI application reflects the number of research hours per month each applicant expects to make use of the equipment/resource after it is in place in Hall C and is contributing to the initial Hall C experimental program. It does not reflect the current division of the applicant's research hours.

Ross Machine Shop

Where Quality Counts

40 Kress Street
Regina, Sask. S4N 5Y3
Bus: (306) 721-6680
Fax: (306) 721-8590
Email: rossmachine@sasktel.net

QUOTATION

Date:	Oct 22/09
Estimated Delivery Date upon Receipt of Order:	12 weeks ARO
F.O.B.	Ross Machine

To: **University of Regina**

Attention: **Garth Huber**

Fax: **585-5659** Telephone: **585-4240**

E-Mail: **huberg@uregina.ca**

Cust. Ref.: Ross Quote: **3703**

We thank you for the opportunity of submitting the following prices and specifications

Quantity	*Description*	*Unit $*	*Total $*
1 ea	Vessel fabrication and machining as per supplied drawings	*$53,384.00*	$53,384.00
	-included above is LPI testing welds and vacuum testing vessel		
	-All bolt holes as per your email		
	-Bolts		
	-Oring		
	-3 Aluminum windows 7075 T-6		
	NOTE: This is a budgetary price.		

Sub-Total	**$53,384.00**
G.S.T.	*Extra*
P.S.T.	*Extra*
TOTAL	

This quote is valid for **15 days**

Per: **Kevin Lorenz**

General Conditions: Materials subject to price and availability at time of order.
Delivery date based upon lead time at time of quotation and is subject to change at time of order.
Terms of Payment: Net 30 days on date of invoice (upon approved credit).
Taxes: EXTRA where applicable.

EBCO QUOTATION FOR PRESSURE VESSEL

From: Dan Baum <dan_baum@ebco.com>
Sent: Friday, October 16, 2009 1:55 PM
To: Garth Huber <huberg@uregina.ca>
Subject: RE: Estimate on a vessel fabrication

Hi Garth,

Our best estimate based on the current information is a total of approximately $56,000 FOB Ebco, not including taxes, and not including the supply of all the bolts.

The breakdown is as follows:

$27,000 for the basic can with the two flanges welded on and the machining of the flanges after welding. Also includes the 4 nozzles, with the nozzle flanges machined before the nozzles are welded into the can. Price also includes the supply of the two large window clamp rings and the 4 small nozzle window clamp rings.

$2,500 for leak checking. To do a leak check we would have to make blank off plates (with some kind of seal) to cover all the openings, then we could pump the air out and do the leak check with our helium leak detector. A less expensive option would be to simply check all of the welds for cracks using the dye penetration method. That would only only cost about $500 to do. This method does not check for leaks directly, but if no cracks can be found there shouldn't be any major leaks. The choice of the most appropriate method depends on how much vacuum you are trying to be pull, and how sure you want to be that there are no leaks.

$1,000 for brackets where mirror mounts can be attached.

$1,500 for brackets where main vessel can be mounted.

$17,000 for additional machining, drilling holes for bolts in flanges and cover plates, O-ring grooves, machining nozzle details.

$7,000 for three 1mm thick 7075 aluminum alloy sheets complete with holes, to match flanges.

Please note that this is still a very rough estimate, and it will need to be reviewed after the design is complete and we see all of the drawings.

Best regards,
Dan Baum, PMP
Manager of Sales & Marketing, LMF Division
Ebco Industries Ltd.
Direct phone 604-276-1491

EUROPTEC QUOTATION FOR GLASS MIRROR BLANKS

From: Schmeling John <John.Schmeling@europtec.com>
To: 'huberg@uregina.ca' <huberg@uregina.ca>
Date: Tue, 1 Sep 2009 20:46:12 +0200
Subject: FW: glass for radiation detector

Hi Garth,

Based on our conversation yesterday, I checked into a few things and here is what I found out:

1.) Molds: We do not have any molds on-hand that would meet your requirements. A new mold to do this low volume requirements would be approximately $3000 - $3500.
2.) Budget Price:
5 Pieces - $500/unit
10 Pieces - $350/unit
Freight: Ex-Works - Clarksburg, WV
Payment Terms: TBD

* As we discussed, we have a $2500 minimum order amount per item for our bending operation.
* We are currently running our bending operation every other month based on the orders we have in-house. Therefore the lead-time would be 6 - 8 weeks.
* EuropTec will not be responsible for any mirror coating services.

Finished Size: 60cm x 55cm (23.622" x 21.654")
Thickness: 3mm
Shape: Rectangular, spherical bend
Radius of Curvature: Approximately 45.25" ± 1-2" (115cm)
Specification: Per attached document

Please let me know if you have any questions.

Thanks,

John Schmeling
EuropTec USA, Inc.
423 Tuna Street
Clarksburg, WV 26301
Direct: (952) 892-3780
Fax: (952) 892-3305
Cell: (507) 838-7311
Skype: john.schmeling
e-mail: john.schmeling@europtec.com
website: www.europtec.com

From: Schmeling John <John.Schmeling@europtec.com>
To: 'Garth Huber' <huberg@uregina.ca>
Date: Tue, 1 Sep 2009 22:09:13 +0200
Subject: RE: FW: glass for radiation detector

Hi Garth,

The parabolic mirror blanks is an option we could do and explore together. From what I understand it really comes down to your required tolerances and surface quality requirements. If your tolerances are not extremely tight, it can probably be done for a similar price.

Thanks,
John

-----Original Message-----
From: Garth Huber [mailto:huberg@uregina.ca]
Sent: Tuesday, September 01, 2009 2:05 PM
To: Schmeling John
Subject: Re: FW: glass for radiation detector

Dear John:

Thank you very much for the quotation. I am still doing the final optics studies of the detector and so it is very helpful to know that you can meet my needs. I am not surprised that you would have to make a new mold for me. In this case, is there any possibility of making a parabolic mold instead of a spherical one?

Thanks,
Garth Huber

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

GENEVE, SUISSE
GENEVA, SWITZERLAND

Mail address: CERN
PH Department
Detector Technologies Group
CH-1211 GENEVE 23
Switzerland

Téléfax/fax : +41 (22) 767 8915
Téléphone/Telephone : +41 (22) 767 8909
E-mail : Christian.Joram@cern.ch

Garth Huber
University of Regina
Regina, SK S4S-0A2 Canada

Geneva, October 19, 2009

Quotation

Application of Reflective Coatings on 5 Mirror Substrates

Approximate mirror dimensions: 60 cm x 55 cm. Spherical shape. Reflectivity to be optimized for Cherenkov applications.

Work performed by CERN:

- Optimization of coating parameters
- Process verification on sample mirros
- Production coatings after acceptation of sample quality by client
- Whitness samples for every coating
- Reflectivity measurements (200-600 nm) for every mirror

Cost per mirror: CHF 2,000.-
Total Cost: CHF 10,000.-

The cost does not include transport and packaging. The work is carried out on a best effort basis. No responsibility is assumed for acciditental breakage of mirror substrates or delays in the production due to internal priority changes.

C. Joram

Group Leader

UNIVERSITY OF REGINA
FACULTY OF SCIENCE MACHINE SHOP

1. Integrated carbon fiber backing and stiffening brackets for four concave mirrors measuring 22 inches x 24 inches.

Materials:

1 " x 2" x .050" wall rectangular carbon fiber tube	1440.00
5.7 oz carbon fiber fabric plain weave	360.00
System 2000 Epoxy Kit	135.00
Poly bag film	36.00
Release Film	108.00
Carbon fiber tape	55.00
Shop Supplies	200.00
	======
Materials Total (shipping, duty and brokerage extra)	2334.00 USD

Design time for brackets and to test fabrication technique (estimated)
40 hrs. x $35/hr = 1400.00 CAD
Labour to apply carbon fiber materials to mirrors (estimated)
40 hrs. x $35/hr = 1400.00 CAD

2. Mounting fixtures to secure four concave mirrors after carbon fiber is applied into supplied cylindrical pressure vessel. The mirror mounting angles will be adjustable in 3 axes to provide necessary optical alignment.

Materials: Aluminum and fasteners		2000.00 CAD
Design time (estimated)	80 hrs. x $35/hr =	2800.00
Machine shop Labour (estimated)	60 hrs. x $35/hr =	2100.00
		=======
Total		6900.00

3. Mounting assemblies to secure PMT, mu-shield and base in tubular nozzle of supplied cylindrical pressure vessel. The assembly will provide electrical isolation of grounded mu-shield and allow transverse adjustability of PMT for optical alignment. Estimate is for one prototype and four assemblies.

Materials: Nylon, aluminum and fasteners		2000.00 CAD
Design time (estimated)	60 hrs. x $35/hr =	2100.00
Labour	40 hrs. x $35/hr =	1400.00
		=======
Total		5500.00

D. Kolybaba
October 6, 2009

Hamamatsu Corporation

360 Foothill Road
PO Box 6910
Bridgewater, NJ 08807-0910
Phone: 908-231-0960
Fax: 908-231-0405
Email: order@hamamatsu.com
908-231-0960

Date	8/5/2009
Quote #	7587
Valid Until	9/4/2009
Sales Engineer	WestCanadaSalesRegion Team
Terms	Upon Credit Approval
Ship Via	Best Method
FOB	Middlesex, NJ

Address
3737 Wascana Parkway
Regina SK S4S 0A2
Canada

Product Number	Description	Quantity	Qty Range	Unit Price	Lead Time
R1584	PHOTOMULTIPLIER TUBE	4	1-5	3,331.00	
E7693	SOCKET ASSEMBLY	4	1-5	577.00	
E989-26	MAGNETIC SHIELD	4	1-5	407.00	
H6528	PHOTOMULTIPLIER TUBE ASSEMBLY: R1584	4	1-5	3,994.00	

The prices and terms on this quotation are not subject to verbal changes or other agreements unless approved in writing by the Main Office of the Seller. All quotations and agreements are contingent upon strikes, accidents, fires, availability of materials, and all other causes beyond our control. Prices are based on costs and conditions existing on date of quotation and are subject to change by the seller before final acceptance. Typographical and stenographic errors subject to correction. Purchaser agrees to accept either overage or shortage not in excess of ten percent to be charged for pro-rata. Purchaser assumes liability for patent and copyright infringement when goods are made to Purchaser's specifications. When quotation specifies material to be furnished by the purchaser, sample allowance must be made for reasonable spoilage and material must be of suitable quality to facilitate efficient production. Conditions not specifically stated herein shall be governed by established trade customs. Terms inconsistent with those stated herein which may appear on Purchaser's formal order will not be binding on the Seller. An additional packaging and handling fee will be assessed and added at time of shipping. Minimum purchase requirements apply to certain products.

Hardin Optical Company
PO Box 219
87679 Kehl Road
Bandon, OR 97411

Ph: (541) 347-9467
Fax: (541) 347-2611

Quote

Number: 2273 Date: 19-Aug-09

To	Quote To
University of Regina Regina, SK S4S-0A2 CANADA	Dr Garth Huber University of Regina Regina, SK S4S-0A2 CANADA
Ph: 1-306-585-4240 Fax: 1-306-585-5659	Ph: 1-306-585-4240 Fax: 1-306-585-5659

Terms	Ship Via	Salesperson
Net 30 Days	UPS Blue	BOBS

Quantity	Description	Unit Price	Amount
	Reference: E-mail 081409 This quote is valid for 30 days. Delivery of item(s) is F.O.B. Hardin Optical Company, Bandon, Oregon. Credit issued with prior approval from Hardin Optical Company. Shipping costs are not included in the quoted price. Hardin Optical Company is an SBA certified small, HUBZone business.		
4 ea	Line: 001 Part: PMT ADAPTER Rev: Material: Corning 7980	$1,100.00	
4 ea	Line: 002 Part: PMT WINDOW Rev: Material: Corning 7980	$1,200.00	
4 ea	Line: 003 Part: PMT ADAPTER Rev: Material: Spectrosil	$1,010.00	
4 ea	Line: 004 Part: PMT WINDOW Rev: Material: Spectrosil	$1,125.00	
	This is a ROM quote. Pricing and delivery are subject to change Item #001,#003 PMT Adapter Material: Noted in description Diameter 133mm +/-0.15mm Edge thicknes 20mm +/-0.2mm Center thickness 3.5mm +/-0.2mm R1 Radius: 132 mm +0.0 / -0.5mm 1-2 fringe IRR spherical @ 633nm R2 Plano: flatness 5-8 fringes, 1-2 fringe IRR @633nm Surface quality 60-40 Flat bevel 2.5mm max width Safety bevel 0.5mm Max		

Hardin Optical Company
PO Box 219
87679 Kehl Road
Bandon, OR 97411

Ph: (541) 347-9467
Fax: (541) 347-2611

Quote

Number: 2273 Date: 19-Aug-09

To

University of Regina
Regina, SK S4S-0A2
CANADA

Ph: 1-306-585-4240 Fax: 1-306-585-5659

Quote To

Dr Garth Huber
University of Regina
Regina, SK S4S-0A2
CANADA

Ph: 1-306-585-4240 Fax: 1-306-585-5659

Terms	Ship Via	Salesperson
Net 30 Days	UPS Blue	BOBS

Quantity	Description	Unit Price	Amount
	--- Item #002,#004,Window Material: Noted in description Diameter 180mm +/-0.15mm Thickness 10mm +/-0.15mm Surface flatness 5-8 fringes, 1-2 fringe IRR @633nm Surface quality 60-40 Safety bevel 0.5mm max ____ Delivery 16 -18 weeks ARO Per the glass manufacturer the delivery and price is subject to change do to the type of material . Thank you for the opportunity to submit this quotation.		

Quotation

Quotation No:	10085
Enquiry ID:	
Your Ref:	
To:	**Garth Huber**
	University of Regina

Electron Tubes
100 Forge Way
Unit F
Rockaway
New Jersey
07866
Tel: 1-800 521 8382
Fax:1-973 586 9771
paul@electrontubes.com

19-Aug-2009

e-mail	huberg@uregina.ca

All Prices in US Dollars.

Ref	Part No	Description	Unit Price	Qty	Total Price	Delivery
1	9823QB	5" fast photomultiplier with quartz window	$6,500.00	4	$26,000.00	12 weeks
2	C638	voltage divider with socket	$130.00	4	$520.00	8 weeks
3	MS130A	magnetic shield	$150.00	4	$600.00	8 weeks
			TOTAL		$27,120.00	

Quoted by: Paul Davison, Sales Manager

All quotations are subject to our standard terms and conditions, unless otherwise stated.

Please state Quotation No. on Order.
Payment terms: Net 30 Days, FOB Destination

Kurt J. Lesker Company

Buy Online or Call 800.245.1656

Shopping Cart

Check Out

ABOUT SSL CERTIFICATES

QTY	Part No.	*Quick Order*
		Add to Cart

	Part Number	Description	Unit Price	Quantity	Subtotal	Availability
Delete Item	**KJL-5311**	Thermocouple Gauge Tube, 1/8" NPT	Can $74.25	1 Update QTY	Can $74.25	In Stock
Delete Item	**SL0150MVQF**	Stainless Steel Inline Valve	Can $445.50	2 Update QTY	Can $891.00	In Stock
Delete Item	**QF40-150-SRV**	KF (QF) Centering Rings (Stainless Steel)	Can $16.20	5 Update QTY	Can $81.00	In Stock
Delete Item	**QF25-100-CHA**	KF (QF) Lever Clamps (Aluminum)	Can $51.64	1 Update QTY	Can $51.64	KJLC will contact you
Delete Item	**QF40-150-X**	4-Way KF (QF) Crosses	Can $201.15	1 Update QTY	Can $201.15	In Stock
Delete Item	**QF40XFNPT2**	KF (QF) Flange to Female NPT Fitting Adapter	Can $37.80	1 Update QTY	Can $37.80	In Stock
Delete Item	**QF40-150-CHA**	KF (QF) Lever Clamps (Aluminum)	Can $55.82	5 Update QTY	Can $279.11	In Stock
Delete Item	**QF40X8SWG**	KF (QF) Flange to Swagelok Fitting Adapter	Can $108.00	1 Update QTY	Can $108.00	In Stock
Delete Item	**QF25X8SWG**	KF (QF) Flange to Swagelok Fitting Adapter	Can $101.25	1 Update QTY	Can $101.25	In Stock
Delete Item	**QF40-150-FT**	KF (QF) Flange to Baseplate Port Adapter	Can $263.25	1 Update QTY	Can $263.25	In Stock
Delete Item	**QF25-100-SRV**	KF (QF) Centering Rings (Stainless Steel)	Can $10.80	1 Update QTY	Can $10.80	In Stock
Total: Can$2,099.25						

Prices are F.O.B. Toronto, Ontario (GST and PST will be added as applicable)
Availability reflections are for USA (other locations on in stock items 2-3 days)
Orders must be received by 4:00 pm Eastern Time (USA) to be processed same day

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ISO Certified: 9001-2008

T.DOYLE TRANSPORT SHIPPING QUOTATION

From: "Mike Gizen" <mike@doyletransport.com>
To: "'Garth Huber'" <huberg@uregina.ca>
Subject: RE: Shipping quotation request
Date: Mon, 19 Oct 2009 08:07:11

Hello Garth

I have some rates for the larger shipment.

From Richmond, BC to Regina, SK will be 2500.00. This will include all charges except GST, which is extra.

From Regina, SK to Newport News, VA 4850 This will include all charges

For the second shipment the rate will be:

Regina, SK to Geneve : 3500.00 This will include all charges no GST on international shipments

Geneve to Newport News, VA: 2900.00 This will include all charges no GST on international shipments

I am still waiting on some options on the second shipment. This price may be reduced depending on what I can find

If you have any questions please contact me any time

Thanks
Mike Gizen
Traffic Coordinator
306-781-8198

> -----Original Message-----
> From: Garth Huber [mailto:huberg@uregina.ca]
> Sent: Thursday, October 08, 2009 12:20 PM
> To: mike@doyletransport.com
> Subject: Re: Shipping quotation request
>
> Dear Mike:
>
> We are in the detailed planning process for an upcoming project, and I
> need a price estimate for shipping the following items:
>
> 1) Large crate of dimension approximately 2m X 2m X 1.5m weighing
> approximately 1400 lb. The crate would contain an aluminum pressure
> vessel used for scientific work. [The vessel would be depressurized at
> the time of shipping.]
> The shipment does not need to get to its destination quickly, but it
> does need to get there safely. The value of the vessel is approximately
> C$50,000.
>
> a) I need a price estimate to ship this crate from the University of
> Regina, Regina, SK S4S-0A2 to
>   Jefferson Laboratory
>   12000 Jefferson Ave.
>   Newport News, VA 23606

```
>
> b) We are looking at the possibility of having this vessel made in
> Vancouver. In this case, I need a second price estimate to ship this
> item from:
>    EBCO INDUSTRIES LTD.
>    7851 Alderbridge Way
>    Richmond, B.C. V6X 2A4
> to the University of Regina.
>
> 2) Wooden crate containing fragile glass mirrors, insured at a value of
> $30,000.  The crate dimension is approximately 0.9m X 0.8m X 1.0m and
> weighing approximately 100 lb.  The crate would need to be shipped
> insured air freight.
>
> a) I need a price estimate to ship this crate from the University of
> Regina to:
>    CERN
>    Site de Meyrin
>    CH-1211 GENEVE 23
>    SWITZERLAND
>
> b) I need a price estimate to ship this crate from CERN to Jefferson Lab.
>
> Please let me know what my best options would be for these shipments and
> pricing.  I can be reached at 585-4240 if you have any questions.
>
> Garth Huber
> --
> Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2,
Canada.
> tel: 1-306-585-4240. fax: 1-306-585-5659.
```

2 Relationship to Existing NSERC Support

2.1 Applicant

The applicant, G.M. Huber, has a $38,000/yr Individual Discovery Grant which expires in March, 2011, and is a co-applicant on a $140,000/yr Project Grant which expires in March, 2012. In 2008, Jefferson Lab received final construction approval (CD-3) for its upgrade to 12 GeV operation. Until the completion of this upgrade, Huber's research efforts are divided between preparations for the "12 GeV Upgrade", the analysis and publication of data from "6 GeV" experiments (both supported by the Individual Grant), and the interim program at Mainz (supported by the Project Grant). Huber's experimental program is expected to be based exclusively at JLab after the completion of the ugprade.

This RTI grant application makes no request for student support or travel needed for the construction and commissioning of the detector, as these expenditures will come from Huber's Individual Discovery Grant.

2.2 Co-Applicants

With the exception of Hornidge, all of the co-applicants have research programs at Jefferson Lab which are supported by NSERC Project Grants or Individual Discovery Grants. All of these funds are fully committed for their respective Jefferson Lab programs and there is no overlap in expenditure between those grants and the funds requested here.

Scientific Motivation: Much progress has been made toward unraveling the structure of the nucleon. It is well known that inclusive electron scattering at high momentum and energy transfer is governed by elementary interactions with quarks and gluons. But our understanding is fragmented, particularly in the confinement region of QCD. One obstacle to our improved comprehension is that exclusive and semi-inclusive deep inelastic scattering studies at large Q^2 are difficult because they require continuous, high luminosity electron beams, and detectors with good particle identification and reproducible systematics. The Jefferson Lab (JLab) upgrade is intended to address these issues, with a doubling of the maximum electron beam energy to 12 GeV, and the construction of new experimental apparatus.

Hall C will provide the only magnetic spectrometer, the Super High Momentum Spectrometer (SHMS), able to detect charged particles with momenta approaching that of the highest electron beam. Together with its companion, the HMS, this will make Hall C the only facility in the world capable of studying (deep) exclusive reactions up to $Q^2 \approx 15$ GeV^2, with appropriate high luminosity. By extension, only Hall C will be able to exploit fully semi-exclusive reactions in the critical region where the electroproduced hadron carries almost all of the energy transfer. The SHMS is designed to achieve angles down to 5.5^o, and operate at a luminosity of 10^{39}/s/cm^2. The existing HMS complements the SHMS well, with an angular range down to 10.5^o, and a maximum momentum of 7.3 GeV/c. Both spectrometers will be rigidly connected to a central pivot, permitting rapid and reproducible rotation characteristics which simplify accurate measurements, including Rosenbluth L/T separations. The SHMS momentum and target acceptances are designed to be both large and nearly uniform, allowing for both fast and accurate data collection. The SHMS+HMS spectrometers, in combination with the large luminosity, will enable the measurement of the smallest cross sections and greatly facilitate studies in the transition from hadronic to quark-gluon degrees of freedom.

Three experiments forming a key component of the initial SHMS+HMS scientific program have Canadian leadership and are provisionally approved for 270 days of beam (assuming 50% data taking efficiency):

E12-06-101: Measurement of the Charged Pion Form Factor to High Q^2, Spokespersons: D. Gaskell, G. Huber. An important issue in our understanding of the strong interaction is the transition from 'strong QCD' at long distance scales to perturbative QCD at short distance scales. The pion is one of the simplest QCD systems available for study, and its electric form factor is one of the best ways to probe this transition experimentally. The measurements will greatly extend our knowledge of this observable.

E12-07-105: Scaling Study of the L-T Separated Pion Electroproduction Cross Section at 11 GeV, Spokespersons: T. Horn, G. Huber. The extraction of Generalized Parton Distributions (GPD) from hard exclusive reactions relies on the factorization of the amplitude into hard and soft processes. If factorization holds, the longitudinal cross section should be dominant and the separated cross sections scale according to the $1/Q^n$ predictions of pQCD. The measurements will determine if GPDs can be determined from meson electroproduction.

E12-09-011: Studies of the L-T Separated Kaon Electroproduction Cross Section from 5-11 GeV, Spokespersons: T. Horn, G. Huber, P. Markowitz. A direct comparison of the scaling properties of L/T separated $p(e,e'K^+)\Lambda,\Sigma^0$ and $p(e,e'\pi^+)n$ cross sections will further investigate the transition from hadronic to partonic degrees of freedom in exclusive processes. Measurements of the longitudinal cross section at low $-t$ will determine whether the K^+ electric form factor can be inferred from these data.

Heavy Gas Čerenkov Operating Principle and Design: These experiments all require good $\pi^{\pm}$ identification. Above ~ 3 GeV/c, hadron species cannot be reliably distinguished by time of flight over the 2.2 m baseline planned for the SHMS detector stack, and so information from Čerenkov detectors becomes increasingly relevant. To provide good $\pi^{\pm}/K^{\pm}$ separation over the SHMS momentum range, we propose to construct a threshold Čerenkov detector using the heavy gas C_4F_8O as a radiator. This gas has characteristics similar to C_4F_{10}, with $n = 1.00137$ at standard temperature and pressure, but it is more easily available commercially, and at a small fraction of the cost.

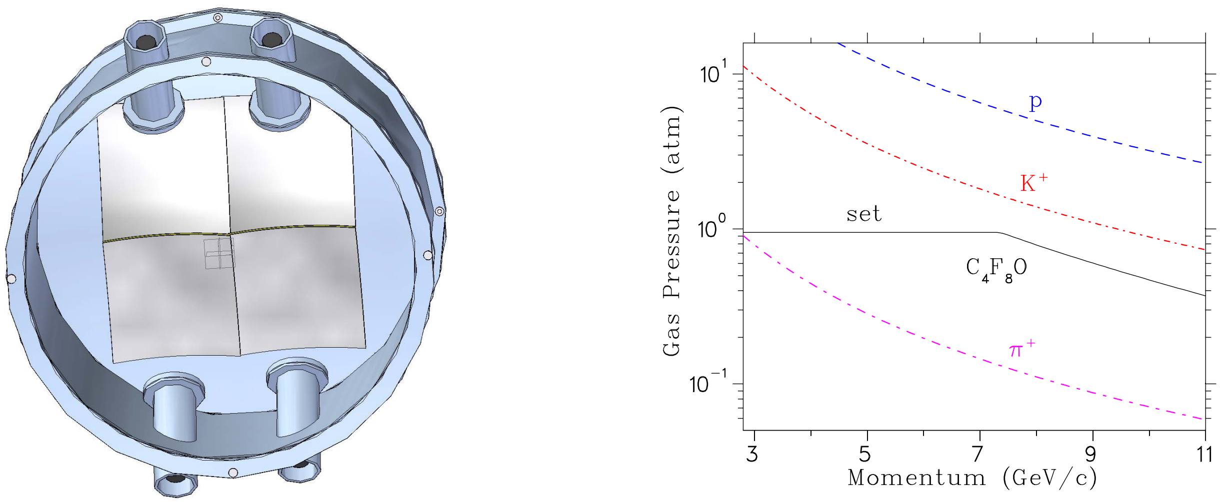

Figure 1: Left: The detector, with the entrance window removed to show the mirrors inside. Right: Threshold C_4F_8O pressure required for Čerenkov light generation from the particles indicated. The solid curve indicates the operating pressure planned for the detector.

A plan view of the Heavy Gas Čerenkov detector is shown in the left panel of Fig. 1. The enclosure is an aluminum alloy cylindrical vessel (1.85 m outer diameter and 1.3 m length). The PMTs are located in side ports, viewing through 1 cm thick UV-grade windows, which allows for better isolation of the pressurized cavity. Four mirrors and photomultipliers are required to cover the SHMS focal plane envelope. The 55 cm$\times$60 cm mirrors are thin glass, structurally reinforced with carbon fiber epoxy, and mounted to the vessel outside of the beam envelope. In the right panel, the solid curve indicates the threshold gas pressure for different particle species versus momentum. We plan to use 0.95 atm pressure up to 7.3 GeV/c, and sub-atmospheric pressure (down to 0.35 atm) at higher momenta. The gap between the 'set' and 'K^+' curves above 7.3 GeV/c takes into account the momentum acceptance of the SHMS and an error allowance in setting the gas pressure. To simplify the gas purification, it is intended to pump the detector to vacuum and then introduce the heavy gas. From a Geant4 simulation of the optics, and an estimate of background due to subthreshold particles generating knock-on electrons, we expect a $\pi^{\pm}$ detection efficiency $> 99\%$, and $\pi^{\pm}/K^{\pm}$ separation of 1000:1, dropping to 200:1 at the highest momenta.

Training of HQP: This is an ideal student training project. NSERC USRA student Paul Selles worked in 2009 on the detector design and optics simulations. Upcoming student projects will include optical quality tests of the parabolic mirrors (iris tests and coarse Ronchi grid tests), cosmic ray testing of the detector, and further simulations. Installation of the detector at JLab and commissioning of the SHMS will provide excellent graduate student and PDF training ground.

Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

October 15, 2009

Letter in Support of the Research Tools and Instruments
Grant Application of Dr. Garth Huber

I are writing to confirm that Jefferson Lab is aware of and fully supportive of Dr. Huber's NSERC grant application for the SHMS Heavy Gas Cerenkov detector. This detector is an essential part of the SHMS focal plane instrumentation and is vital for pion/Kaon separation if the planned suite of experiments are to meet their scientific goals.

Along with the rest of the planned SHMS focal plane instrumentation, Dr. Huber's proposed detector design has undergone several Jefferson Lab reviews, the most recent one being on August 5, 2009. This review concluded that "the SHMS focal plane detectors, as designed, all rely on tried and true technologies and were demonstrated to meet or exceed all the performance expectations for the envisioned Physics program."

This is to confirm that Jefferson Lab will arrange for, and provide the funds for the purchase or construction of the items necessary to integrate fully the Heavy Gas Cerenkov detector into the SHMS focal plane instrumentation. This includes:

- C_4F_8O radiator gas and gas handling system.
- HV, Readout Electronics, and Cables.
- Brackets and other hardware needed to secure the Heavy Gas Cerenkov detector in the SHMS detector stand, as well as any costs associated with the rigging, aligning and mounting of the detector.

Sincerely,

Dr. Howard Fenker
Assistant Project Manager for the
Hall-C 12 GeV Upgrade