12 GeV Upgrade Project

DESIGN SOLUTIONS DOCUMENT

Upgrade Hall C

Version 1.2

August 6, 2010

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APPROVALS

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REVISION LOG

Version No.	Description of the Changes Made	Revision Date
1.0	Original	May 2007
1.1	Updated Hall C CAM to H. Fenker. Updated Hall C Leader (Acting) to S. Wood on approval page.	May 2008
1.2	Added acronyms. Clarified magnet, shielding, cryogenics, and beamline details. Minor edits. Updated Physics APM to Glenn Young on approval page Updated Hall C Leader title on approval page.	August 2010

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ACRONYMS

AC	Alternating current
ADC	Analog-to-Digital Converter
ALARA	As low as reasonably achievable
ASME	American Society of Mechanical Engineers
CHL	Central Helium Liquefier
CODA	CEBAF Online Data Acquisition
CW	Continuous Wave
DAQ	Data Acquisition
DC	Direct Current
DI	Deionized
DOE	Department of Energy
DSD	Design Solution Document
EH&S	Environment, Health and Safety
FPC	Fundamental Power Coupler
FPP	Focal Plane Polarimeter
ft	Feet
G0	G-Zero Experiment
GPM	gallons per minute
HB	Horizontal Bend Magnet
HEPA	High-efficiency particulate air
HMS	High Momentum Spectrometer
HOM	Higher-Order Mode
Hz	Hertz
I&C	Instrumentation and Controls
ID	Internal diameter
JLab	Thomas Jefferson National Accelerator Facility
kV	kilovolt
kW	kilowatt
LCC	Life-cycle cost
LCW	Low Conductivity Water
Linac	Linear accelerator
LLRF	Low level radio frequency
LVDT	Linear Variable Differential Transformer
MHz	Megahertz
NFPA	National Fire Protection Association
ODH	Oxygen Deficiency Hazard
PID	Proportional Integral Derivative
PMT	Photo Multiplier Tube
PPS	Personnel Protection System
R&D	Research and Development
rf/RF	Radio frequency
SHMS	Super-High Momentum Spectrometer
SOS	Short Orbit Spectrometer
SRD	System requirements document
SRF	Superconducting Radio Frequency
TDC	Time-to-Digital Converter
WBS	Work Breakdown Structure

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1 System Description

The 12 GeV Upgrade Project scope is divided into three major systems: 1) Accelerator System, 2) Physics System, and 3) Civil Construction System. The Physics System is further divided into four systems: 1) Hall A Upgrade, 2) Hall B Upgrade, 3) Hall C Upgrade, and 4) Hall D.

The Physics System equipment planned for the Upgrade project takes full advantage of apparatus developed for the present program. In Hall C a new, high-momentum magnetic spectrometer (the SHMS, Super-High-Momentum Spectrometer) will be constructed. The SHMS will be powerful enough to analyze charged particles with momenta approaching that of the highest energy beam. Together with its companion, the existing High Momentum Spectrometer (HMS), this will make Hall C the only facility in the world capable of studying (deep) exclusive reactions up to the highest momentum transfers, $Q^2 \sim 18\ (GeV/c)^2$, with appropriate high luminosity. By extension, only Hall C will be able to fully exploit semi-exclusive reactions in the critical region where the electro-produced hadron carries almost all of the transferred energy.

Charged particles with such high momenta are boosted by relativistic kinematics into the forward detection hemisphere. Therefore, the SHMS is designed to achieve angles down to 5.5°, and up to 40°. The SHMS will cover a solid angle of over 4 msr, and boasts a large momentum and target acceptance. The existing HMS complements SHMS well, with a solid angle of up to 10 msr, an angular range between 10.5° and 90°, and a maximum momentum of 7.3 GeV/c.

2 Upgrade Hall C System Requirements

The Hall C System shall meet the following requirements:
Provide, as companion to the existing HMS magnetic spectrometer, a new spectrometer that permits rapid, remote angle changes and reproducible rotation characteristics, with as main properties:

Central Momentum Range	2 - 11 GeV/c
Angle Range	5.5 - 40 degrees
Solid Angle	> 4.0 msr
Momentum Resolution	< 0.2%

- Capability to handle 11 GeV polarized electron beams, with beam currents up to 90 μA, and
- Provide protection from magnetic, cryogenic and fall hazards to workers and the public.

3 Technical Approach to meet the Upgrade Hall C System requirements

The envisioned physics program in Hall C is based upon a pair of high-momentum magnetic spectrometer systems. A new Super-High Momentum Spectrometer (SHMS) will act as a companion to the existing High-Momentum Spectrometer (HMS) so that, taken together, the system will provide full momentum range single-arm capabilities as well as double-arm coverage over the entire kinematic region of interest to the proposed experiments. The new SHMS must have acceptance for very forward-going particles, down to scattering angles as low as 4.5° (with a central spectrometer-axis at 5.5°), and analyzing power for a particle momentum approaching that of the incoming beam (11 GeV/c). It must provide excellent particle identification even at these high energies. It must be capable of rapid, accurate changes to the kinematic settings with well understood acceptances allowing experiments to efficiently cover broad regions of phase space, enabling, for example, precision Rosenbluth or "L/T" separations. The basic design must be flexible enough such that specialized detector elements, such as polarimetry or additional particle identification systems, can be incorporated to satisfy the needs of particular experiments. Lastly, it must possess a sufficiently efficient, highly time-resolved trigger system and a target and data-acquisition system suitable for running at high luminosity.

3.1 SHMS

The HMS-SHMS spectrometer pair will be rigidly connected to a central pivot which permits both rapid, remote angle changes and reproducible rotation characteristics which simplify accurate measurements. From its inception, the SHMS momentum and target acceptances have been designed to be very flat, with performance similar to that of the HMS. This also simplifies making accurate measurements. These capabilities will facilitate experiments which rely on a large number of angle and momentum settings, such as L–T separations, for which accurate pointing as well as flat momentum and target acceptances are essential.
The SHMS is an 11 GeV/c superconducting spectrometer. The magnet system consists of a cold-iron small horizontal-bend dipole, one cold iron quadrupole magnet, similar in design to the HMS Q1, two identical warm-bore quadrupole magnets, and a warm-bore dipole magnet that is 5 m long. The cryogenics are proven systems using standard JLab components. The control systems and magnet power supplies are proven commercial systems. The shield house is a composite of concrete, boron carbide, steel and lead. The magnets and the shield house are supported by a welded steel structure with steel drive wheels.

3.1.1 Superconducting Magnets

HB Magnet: The SHMS design requires an initial Horizontal Bend of 3 degrees to reach the 5.5 degree scattering angle when the HMS is at its minimum angle of 12 degrees. To serve this requirement we have designed a small 60 cm long effective length 3 Tesla Horizontal Bend (HB) Dipole magnet. This compact cold iron yoke superconducting "C type" magnet uses a relatively high current density SC coil to achieve this field in a compact package that permits the small scattering angle without leaking substantial field into the path of the outgoing electron beam. This magnet though small shares many common systems with the larger magnets of SHMS for overall efficiency and commonality of design.

Q1 Magnet: The SHMS spectrometer requires a special design for its first quadrupole magnet (Q1), with the requirement to reach the scattering angle of 5.5 degrees implying a slim magnet. To achieve sufficient acceptance it yet requires a gradient of close to 9 T/m and 40-cm aperture. These requirements are close to what the existing HMS Q1 magnet has already achieved. The large cold-iron HMS Q1 magnet was designed by Oxford Instruments with considerable margin in operating current, such that the required gradients for HMS could be reached given some uncertainty in the yoke packing factor and the performance of the then new design. The cold iron quads worked as designed and the margins, also in current leads, superconductor critical current, and force containment, were never called into service. Dedicated R&D tasks were started to confirm that these margins can be effectively used for the SHMS Q1 design.

Q2/3 Magnets: The pair of 60 cm warm bore cosine two theta style superconducting quadrupoles provides the focusing for the SHMS and the transmission of a relatively large solid angle. These magnets operate at 5000 Amps and use a common SC cable with all five magnets and a common composite conductor with the large SC Dipole. The other quadrupole magnet systems such as cryo interface, DC power and controls are also common design systems. These cosine-two-theta quads produce 13 Tesla per meter gradients and are each near 2 meters overall length.

Large Dipole Magnet: The momentum analysis for SHMS comes from the 3.9 Tesla 4.1 meter long (2.9 meter effective-field length) superconducting dipole magnet. This magnet has a 60 cm warm bore, 11.2 Tesla-meters of bend strength and is a cosine theta type design. The dipole and the pair of cosine two theta quads all have warm external return yoke iron. The superconductor for the dipole is identical to that used in the cosine two theta quads and is a completely cryo-stable design. This means that the magnets CANNOT quench if they are kept full of liquid Helium. The Dipole magnet uses the common design DC power supply, cryogenic interface and PLC based control system.

Magnet DC Power and Energy Dump Systems

The DC power system for the SHMS magnets will consist of five independent power supplies. These supplies will be 12-pulse SCR supplies with a final stage transistor regulator providing stability of 10 ppm. They will be low-voltage high-current commercial units readily available from several suppliers. A nominal DC current of 5000 A at 10 V is a reasonable choice for all the SHMS magnets, thus the DC power supplies can be a common design using similar construction and components. These five DC supplies will have an integral automatic polarity reversal switch, an internal fast energy dump and dump switch, integral quench detection electronics hard wired into the DC supply and NMR field stabilization. These DC supplies will be able to provide full current ramp up or down in ~ 30 minutes for the SHMS. The energy dump systems will consist of a 10 V ramp-down, a slow dump and a fast dump resistor. The fast dump voltages are chosen to maintain a reasonable final coil temperature near 80 K and will be 200 Volts maximum depending on the final inductance. The large cold mass and moderate current densities ensure that there is sufficient cold material within each magnet to absorb a large fraction of the stored energy at a low final temperature during a quench discharge.

3.1.1.2 Magnet Control System

The SHMS magnets will each have a control system that is self contained and able to be operated remotely via a proprietary Allen Bradely interface. This control system is near identical to that recently installed on the HMS spectrometer to replace the ageing legacy systems. The magnets' internal controls will take care of interlocks, operating valves by PID, and converting information from the magnet into engineering units. The Human Machine Interface software system will allow operation from remote screens, archival data logging and graphic display. System maintenance and troubleshooting is readily facilitated by "expert screens" that are password protected. A dual processor PLC designed for critical fail safe process control will be used. Such PLCs can switch the process control from primary to secondary in under 50 ms or one PLC cycle in the event that the primary processor fails. They can also be switched manually or by software for routine maintenance. The use of dual processor PLCs virtually eliminates system shutdowns due to PLC failure. The PLC will use a combination of commercial electronics and PLC I/O modules for signal acquisition. Liquid level control and cryogenic thermometry is straightforward to provide using commercially available units. Readouts of magnet voltages, pressures, strain gauges and valve position LVDTs will be performed by standard PLC plug–ins.

3.1.2 Support Structure and Carriage

The SHMS support structure will be a welded steel frame riding on steel wheels and a center bearing. The structure will be built from prefabricated sections that must be welded together in the Hall. The steel structure will have a main beam section that will carry the entire spectrometer. The entire beam and spectrometer will ride on large hinged steel wheel bogies and floor mounted rails to allow precise scattering angle changes. This system is similar to that used in the HMS and SOS spectrometers. The steel fabrications will be hollow welded structures similar to ship hull sections. As such they will have internal access to permit complete welding of all seams and joints. The wheel sections will be driven by motors and reducers with variable frequency drives. The wheels are planned to be conical sections that are machined at the proper angle to control the radius of rotation. The use of the successful "Bertozzi" hinges on the wheel assemblies to eliminate the large radial forces that arise from even small misalignments is incorporated in the design.

3.1.2.1 Spectrometer Motion System

The SHMS spectrometer has a required range of motion from 5.5 degrees to 40 degrees. Proximity detectors will ensure that the system always moves in a safe angular range and that obstacles are avoided. Positioning accuracy consists of three components: angular measurement, pointing control, and distance from pivot. The scattering angle positioning tolerance will be 0.01 degrees, the pointing tolerance will be $\pm$ 0.5 mm, and the distance off the pivot will be constant to within $\pm$ 1 mm. While it may be possible to measure these quantities more accurately, these are the spectrometer setting tolerances. Note that this is similar to what has been obtained with the HMS. The scattering angle will be measured by a shaft encoder that can detect an angle change of 0.003 degrees. A scale etched into the floor at the radius of the rear drive wheels and viewed by a video camera with a graticule lens will confirm the scattering angle setting. Pointing and distance from pivot will be controlled by a large central crossed roller bearing. The accuracy of such bearings is a few thousandths of an inch. The motion of the SHMS spectrometer will be coordinated by a stand-alone PLC that integrates the drive wheel motion, angle read-back, proximity sensors, and obstacle detection. The rotation motion will be limited to a preprogrammed range set in EPROM in the PLC and by the proximity detection. This design is similar to the HMS rotation control system. A view of the pivot showing simultaneous connection of the SHMS and the HMS, is provided in Figure 1.

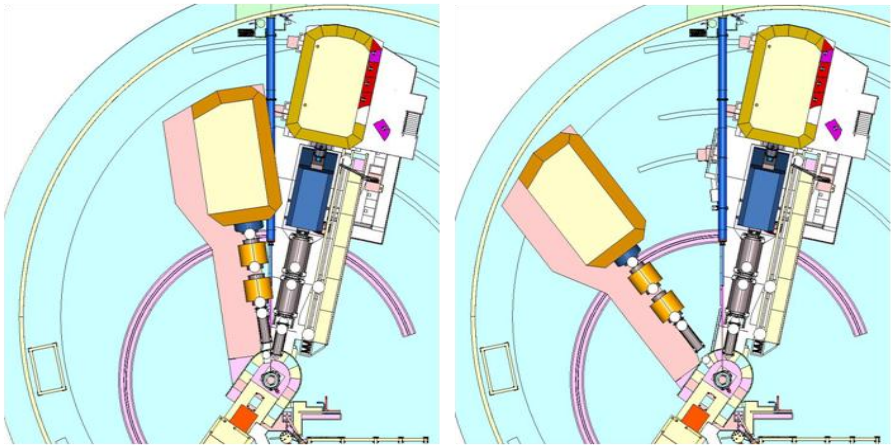

Figure 1. The SHMS-HMS spectrometer pair in two configurations: the SHMS at 5.5° (left) and the SHMS at 40° (right). In both cases the HMS is at 12°.

3.1.3 Shield House

The SHMS spectrometer shield house will be a reinforced cast concrete structure that is built on the steel carriage. The concrete thickness will be 100 cm on the side towards the pivot, 75 cm on the beam side, 70 cm in the floor, and 63.5 cm on the remaining walls. . The concrete is formed and poured in place. Access for equipment installation/removal will be via removal of several concrete roof beams. The interior surfaces of the concrete walls will be covered with the equivalent of up to 5 cm of pure boron (as either a boron-carbide-loaded concrete layer, or as commercially available boronated plastic) to capture thermalized neutrons and up to 5 cm of lead shielding. The lead will be covered and constrained by a system of aluminum plates and C channels. The interior of the shield house will be split into a detector room and an electronics hut, with the two areas isolated by a 100 cm thick concrete wall equipped with a personnel door. Personnel access from outside will be provided by a hinged door which enters the electronics hut. There will be a limited amount of space inside the shield house to allow a corridor access on both sides of the detector stack.

3.1.4 Cryogenics

The SHMS magnets will be designed with a cryogenic interface similar to the existing HMS magnets. Internally the magnets will have thermal siphon circulation from helium and nitrogen reservoirs. The reservoirs will contain dual relief devices: an ASME coded mechanical relief and a rupture disc set at a 25% higher pressure. Exhaust lines for relief which are separate from the cool-down lines will be used so that there will be no chance of a contamination blockage in these pressure relief paths. Temperature sensors, liquid level sensors, and voltage taps will be within the reservoirs. The magnets will have liquid level control and valves to permit independent warm up or cool down using a local heat exchanger. The cryogenic supply will use the existing Hall C G0 cryogenics distribution can relocated near the pivot. The SHMS cryogenic system will use a new cryogenic distribution box mounted on the front of the SHMS and a flexible transfer line similar to that constructed for the G0 experiment. The magnets will be connected by JLAB standard U-tubes similar to those used on HMS magnets. A set of gas manifolds installed on the SHMS will collect and return cryogenic gases to the existing Hall C cryogenics system. A stand and a platform are required for support of equipment and for personnel access. The system is completed by automated cool-down valves and actuators identical to those used on HMS.

3.1.5 Vacuum

The SHMS spectrometer will have three vacuum systems dedicated to the operation of the large superconducting magnets, the SHMS spectrometer vacuum, and the Cherenkov detector. The SHMS cryogenic system is presumed to be made leak tight and will be self cryo-pumped so a dedicated vacuum system is not included in the design. In the case of the large super conducting magnets, a vacuum system tailored to leak testing, commissioning and biannual vacuum servicing will be included as a dedicated system. The spectrometer and Cherenkov vacuum systems will be dedicated to those devices and will be permanently installed on the SHMS. The pumping system for the large super conducting magnets will consist of a turbo pump backed by a direct drive roughing pump. This magnet vacuum system will be stored off-line and only used during initial commissioning and the very infrequent magnet warm-ups where vacuum servicing (if necessary) becomes possible. The SHMS will have thin aluminum entrance and exit windows. The windows will be hydro-formed spherical shapes similar to those in use on the HMS. The slit chambers, that house the two so-called "sieve slit" and the large octagonal aperture-defining collimators, are also part of the vacuum system. This remotely controllable slit system is essentially a copy of existing HMS and SOS systems.

3.2 Detector Systems

The basic SHMS tracking and trigger includes two tracking wire chambers near the focal plane, and two x and y hodoscopes defining the trigger, S1x, S1y, S2x, and S2y. The S1x, S1y, and S2x planes consist of scintillator detectors, whereas the S2y plane will be a quartz Cherenkov detector to achieve high confidence selection of charged particles. A C4F10 Cherenkov detector and a lead-glass calorimeter will complete the "standard" SHMS detector stack. A Nobel-gas Cherenkov detector, interchangeable with the last 3 meters of the spectrometer vacuum system, is used for dedicated experiments.

3.2.1 Wire Chambers

The SHMS tracking system will provide the only measurement of particle momentum and production angle in the spectrometer. Given an adequate description of the magnetic optics, the momentum and production angles are determined by measuring enough of the track to generate a track vector at the reference plane, then projecting it back to the target.

Although multiple scattering is reduced at higher momentum, it is still a significant effect limiting momentum and angular resolution, even at 11 GeV/c. We have considered several alternatives to wire chambers for tracking in the SHMS, but conclude that gas drift chambers remain the best choice to simultaneously provide the necessary position resolution while keeping the detector mass low. The particular design we have chosen is based upon the successful SOS drift chambers, with only minor modifications suggested by the different SHMS optical parameters and lessons learned from the original design. These chambers provide better than 180-μm single-plane resolution and operate at rates of at least 1 MHz per wire, while placing only about 0.002 radiation lengths of material in the path of particles for a stack of six sense planes. These chambers are constructed using the "open plane" technique, in which individual wire and cathode (foil) planes are fabricated on a work bench, then stacked up on a rigid frame to make the chamber assembly. This method of construction is relatively simple and robust, lending itself nicely to fabrication in a modest workspace. Lastly, we plan to use commercially available readout electronics of the same design as presently in use in the SOS, the HMS, and other wire chambers at JLab.

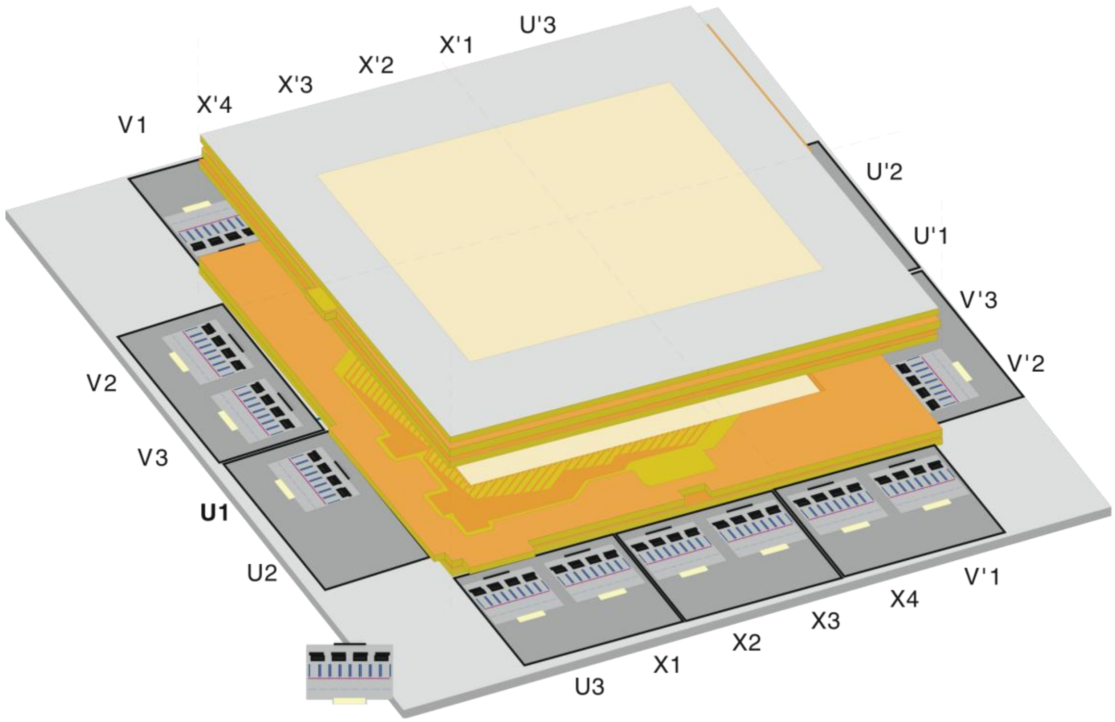

Figure 2. Block diagram of the SHMS Wire Chamber Assembly. The chamber is built by stacking individual wire and foil planes, each fabricated separately using precision tooling.

3.2.2 Basic Trigger System: Plastic Scintillator and Quartz Cherenkov Detectors

Folding in our experience with the Hall C scintillating hodoscopes, we arrive at the following specifications for the SHMS hodoscopes:

- Trigger: because it is the heart of the SHMS trigger, the hodoscope must have $\geq$99.9% trigger efficiency for minimum ionizing particles. To help ensure high efficiency, the pulse height variation across an element should be less than 10%. There must also be sufficient redundancy such that an $S_1 \cdot S_2$ coincidence is robust with respect to the inefficiency (or even loss) of a few channels. The detector should also be insensitive to background.
- Rejection of accidentals: the mean-time resolution of the SHMS focal plane must be at least 100 ps (rms). This will easily permit a coincidence time resolution of 200 ps (rms) so that a $\pm$ 1-ns cut (single beam bucket) on coincidence time would remove only the tails of the good event distribution beyond 5σ .
- Wire chamber tracking efficiency: the segmentation of the hodoscope X and Y elements has to be sufficiently fine to define a beam of particles which pass through the active region of the wire chambers.
- The hodoscope should have minimal adverse impact on downstream detectors.

The solution which meets all of the above specifications is two pairs of X-Y hodoscopes, similar to those currently installed in the HMS and SOS. The two arrays would be separated by roughly 2 m, with S1 following the Wire Chambers and S2 just before the Calorimeter. The new features which we would like to emphasize are that

1. S1x, S1Y, and S2X will be made of "thin" (*e.g.* 5 mm), scintillator elements with long attenuation length BC408,
2. S2Y will consist of a relatively "thick" (*e.g.* 2cm-3cm) quartz Cherenkov radiator elements, and
3. Standard 12-stage PMTs like the XP2262B or ET-9814B will be employed, operated at low anode currents for extended lifetime.

Since the existing Hall C hodoscopes are made of scintillator, the most dramatic change listed above is the use of a quartz Cherenkov for the S2Y array. Simulations show it is reasonable to expect a few hundred photoelectrons for a 1-meter length quartz radiator with a moderately good surface reflectivity. A quartz Cherenkov detector operated at a threshold of 100 photoelectrons could be essentially 100% efficient and blind to low-energy backgrounds, resulting in a much cleaner trigger. This capability is critical for the clean detection (and accurate tracking efficiency determination) of protons in extremely low cross section measurements at a CW facility.

3.2.3 Noble-Gas Cherenkov Detector

This Cherenkov detector is used for dedicated experiments only. The Noble-gas Cherenkov tank will replace the final 3 m of the spectrometer vacuum system as it enters the SHMS detector hut. The diameter needs to be only about 60 cm at the upstream end, and cover 75×100 cm^2 at the downstream end. A vacuum window with the same scattering properties as the standard one would be installed upstream of the Cherenkov counter. The Cherenkov windows and mirrors and their supports will be made lightweight so as to keep multiple scattering at a minimum. Even then, the detector would only be compatible at the high end of the SHMS momentum range.

3.2.4 Heavy-Gas Cherenkov Detector

The enclosure of the heavy-gas (C_4F_{10}) Cherenkov is a cylinder of nonmagnetic stainless steel, with the PMTs located outside, viewing through a 1-cm thick UV-grade fused silica window. This allows for better isolation of the pressurized cavity, and allows one to maintain proper PMT-mirror optical alignment should the PMT require servicing. Four mirrors and PMTs are required to cover the SHMS beam envelope. For PMTs we have selected the 5” Hamamatsu R1584 with spherical faceplate adaptor, similar to the PMT currently used in Hall B, except with an adapter of fused silica, which allows for flush mating with the quartz window. A custom-design voltage divider with boosted voltage between the photocathode and the first dynode will be used to provide optimum focusing of the photoelectrons, and so minimize losses within the dynode chain. To minimize aberrations, the mirrors should be thin glass, which can be structurally reinforced outside of the beam envelope. Protected aluminum mirror coatings with $>90\%$ reflectivity down to 200 nm are commercially available. We will use $0.020''$ titanium for the particle entrance and exit windows, the same material as used on the larger-volume G0 spectrometer.

3.2.5 Electromagnetic Calorimeter

The electromagnetic calorimeter is used for coarse energy determination of electrons ($\sim5\%/\sqrt{E}$) and pion/electron separation of order 100:1. Since this is not too demanding, the baseline design of the calorimeter for the SHMS spectrometer in Hall C assumes the use of existing lead glass blocks. Two specific sizes are considered: ($10x10x70cm^3$) and ($9x9x50cm^3$). The former is what is used in the HMS and SOS spectrometers, while the latter, previously used by the HERMES experiment at DESY, have been transferred to JLab. Several configurations were studied to optimize the energy resolution, the shower containment, and the particle identification efficiency. Versions with the longer blocks transversely arranged, and the shorter blocks longitudinally arranged, both fulfilled our requirements. The addition of a layer of transversely oriented lead glass blocks to the longitudinal arrangement, acting as a pre-shower detector, improves the pion rejection by a factor of five. This final configuration requires 28 of the longer (70 cm) detectors and 224 of the shorter (50 cm) detectors.

3.2.6 Focal Plane Polarimeter

The focal plane polarimeter (FPP), constructed for operation in the HMS, will have to be moved to the SHMS for dedicated experiments. The FPP is in effect two polarimeters in series, with a CH_2 analyzer followed by drift chambers and then an additional CH_2 analyzer followed by drift chambers. The SHMS detector system is fully compatible with installation of the HMS FPP system, assuming removal of the 2nd Cherenkov detector, and any installed dedicated particle identification in the available free space. Although this FPP already exists and is not part of the 12 GeV Upgrade, it does affect design considerations.

3.3 Trigger, Electronics and Computing

Trigger: The focal plane trigger electronics used for the HMS and SOS has been designed to be flexible, fast and efficient at detecting particles. These triggers consist of requiring hits in a majority of the hodoscope planes combined with options to require or veto on signals from the various particle-ID capable detectors in the focal plane hut. The SHMS trigger electronics will be similar to the HMS and SOS logic but there will be opportunities for increased sophistication in the trigger.

DAQ Electronics: The JLab Physics Electronics Group has developed a 64/32 channel TDC based on the F1 chip. These have been used in earlier Hall C experiments, such as the HKS experiment in 2005, for wire chamber readout (with the same type of wire chambers we plan to use in SHMS). When used in the 32 channel mode, this TDC will have a least count of 60 ps, yielding sufficient time resolution for any PMT-based detector. We further plan to use standard ADCs, which operate by integrating the current on an input while a gate is present, which are sufficient for the SHMS-detector operation.

Data Acquisition and On-line Software: The philosophy of the data-acquisition system for Hall C with the SHMS is that the DAQ should not be the limiting factor in the event rates that can be handled. Experience in Hall C has shown that factors other than DAQ, such as accidentals rates or singles rates on individual detectors, generally limit overall trigger rates to less than 10K events/s. With the front end TDC and ADC electronics, a DAQ system can be constructed that can handle event rates of up to 10K/s with minimal dead time. Future improvements in the speed and cost of networking, CPUs, and disk drives will only help to simplify the design of the DAQ system. Data acquisition will continue to be managed by the Jefferson-Lab developed CEBAF Online Data Acquisition package (CODA). We only assumed a modest online computing farm, compatible with the experience of a decade of large-installation experiments in Hall C.

3.4 Beam Line: Raster Systems, Polarimetry, and Polarized Target Chicane

The majority of the beamline upgrades required for Hall C operation at 11 GeV will already have been accomplished during the installation of a Hall C Compton Polarimeter (planned for 2009). The Compton Polarimeter will require significant reconfiguration of the Hall C beamline. Required beamline upgrades include, in principle, modifications to the Hall C fast and slow raster systems, as well as the polarized target magnet chicane and Hall C Møller and Compton Polarimeters. The fast and slow raster improvements will, however, make use of existing spares to increase the bending power at higher energy, and are thus beyond the 12 GeV scope. The polarized target chicane simply requires the replacement of a single (existing) dipole, while the Møller polarimeter will require an additional large quadrupole magnet, also already existing, and modifications to its collimator system. In the latter case, only modest vacuum channel changes, and cabling to an additional power supply, are required. It should be noted that the Compton Polarimeter built for the Q_{weak} experiment has not been designed with 11 GeV operation in mind, so significant improvement will be necessary once it has been installed: the vertical displacement of the beam line chicane and the associated vacuum chambers need modification.

3.4.1 Energy Measurement System

The Hall C arc beam transport line has been used as a magnetic spectrometer to measure the beam energy between 0.5 GeV and 5.8 GeV. In order for the arc dipoles to transport 11 GeV beam they must be converted from “C” to “H” style dipoles (included in Accelerator Beam Transport) to reduce the amount of saturation at high energies. A remap, reinstallation, and resurvey will be required prior to restoration of absolute energy measurements with 0.1% errors.

3.4.2 Scattering Chamber

Due to fortunate circumstances, Hall C already owns a scattering chamber compatible with SHMS operation, as a new scattering chamber had to be designed and constructed for an experiment to run in 2007/8. Hence, no modifications to the target systems are required. Modifications are required to the SHMS exit windows (and associated window test chamber), and scattering chamber vacuum systems.

3.4.3 Beam Dump Line

A dedicated beam dump line needs to be designed compatible with small-angle operation of both the SHMS (down to 5.5^o) and the HMS (down to 10.5^o).

3.5 General Infrastructure

Existing Hall C infrastructure which can be applied to the upgrade includes AC power, Low Conductivity Water (LCW), high voltage and signal cables with their associated patch panels. There are 550 signal cables and 600 high voltage cables, all of which go to the counting house. Approximately half of these will be available for the SHMS. An additional cable tray exists which will also provide space for future upgrades. Hall C will provide approximately 100 amperes of "clean" power for powering the SHMS detectors and 250 Amperes of "dirty" power available in Hall C for powering potentially noisy motors, turbopumps, etc. The SHMS power supplies will require approximately 50 gallons per minute (GPM) of LCW which can easily be supplied using existing Hall C LCW. 2.0 MVA of power was installed for earlier Hall C's large installation experiments; this power can be used for the SHMS.

No upgrade to existing AC power, LCW, cables, or patch panels is required for the SHMS. Note that cryogenics for the superconducting magnets of the SHMS will be fed off the existing G0 cryogenic can relocated near the Hall-C pivot.