Experiment Safety Assessment Document for SANE (E07–003)

October 31, 2008

Contents

1 Introduction and Scope

Jefferson Lab has mounted an experimental proposal (E07-003) to measure the spin structure functions g_1 and g_2 of the proton. The experiment requires equipment which is not part of the set of standard equipment in Hall C. These are a polarized target, a large electron detector ('Beta'), and a chicane of two electromagnets.

This document deals with each of these systems separately and evaluates the hazards associated with each system. It further identifies what measures have been implemented in order to mitigate the hazards that have been identified.

2 Polarized Target

Polarized targets have been used in nuclear and high energy scattering experiments for many years. The ability to align the spin of nuclei has been developed for experimental studies of the spin properties of matter. A variety of techniques have been developed, and polarized target technology continues to be an active field of research, with technical improvements occurring which allow for better and different experimental measurements.

This project follows well-established practices that have been utilized in several polarized target experiments at JLab since 1998. The UVa group and the JLab Target Group are responsible for the polarized target. The polarized target has successfully and safely used in three experiments (E143, E155 and E155x) at SLAC.

2.1 Target Components

The target at Jefferson Lab consists of several technical components:

- a superconducting solenoid operating at 5 Tesla at 4 K and power supply
- a helium refrigerator operating at 1 K
- an RF System to provide 140 GHz microwaves to dynamically polarize the material
- several small containers of solid ammonia (NH_3 and ND_3), the material which is polarized
- a vacuum pump and piping system to reduce the pressure in the refrigerator which cools by evaporation of helium
- a vacuum chamber to hold the refrigeration system, target material and the solenoid plus its cryostat.

In addition to the target, equipment to operate and maintain the target are installed in Hall C. These items consists of:

- electrical and mechanical utilities
- cryogenic utilities
- control panels and cables to permit operation of the target from the outside of Hall C
- monitoring equipment to allow measurement of target polarization
- beam pipe, beam transport and beam-safety equipment related to the target.

2.2 Target Location

The polarized target is located entirely within the Jefferson Lab Hall C building. It is located on the beam line which passes through the building, approximately in the center of the floor. Control cables and cryogenic plumbing have been extended to the outside of the wall, so that operation of the target can be accomplished while beam is passing through the Hall. Liquid nitrogen and helium are available for the cryogenic cooling.

The polarized target is located on the pivot in Hall C. For the purpose of this document, the target "lower platform" is taken to be the area above the pivot and below the target "upper platform". See Figure 1. This is the area where the thin vacuum windows in the dewar outer vacuum vessel are located. The HMS deck refers to the portion of the HMS located just beyond the pivot from which access to the pivot may be gained.

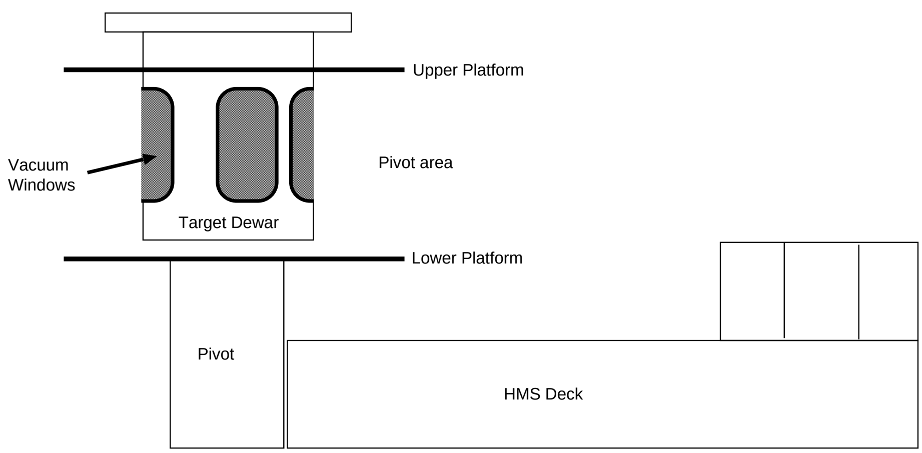

Figure 1: Layout of Polarized target in Hall C

2.2.1 Hazards

The target lower platform is more than 10 feet above the floor of the end station. If a person were to fall from the target lower platform to the floor of the endstation a serious or even a fatal injury could result.

2.2.2 Hazard Mitigation

Access to the target lower platform requires that the removable handrails are in place or that the worker use the fall protection harnesses that are available in the hall. Signs are posted at the access points to the lower platform stating these requirements.

2.3 Outer Vacuum Chamber

The outer vacuum can, OVC, for the polarized target is an aluminum vessel with an inner diameter of 91.2 cm, which was manufactured for JLAB by Ability Engineering. The can has five thin vacuum windows to allow for the detection of particles as well as passage of the primary electron beam. These windows are located at various angles around the radius of the can and have a height of 38 cm, with a thickness of 20 mils. The windows range in width from 25.4 cm to 47.7 cm.

2.3.1 Hazards

There exists an implosion hazard at the scattering chamber. If the scattering chamber windows were to be ruptured the pressure differential may cause an implosion. It is possible that those near the scattering chamber when an implosion occurs may suffer hearing damage.

2.3.2 Hazard Mitigation

All personnel working on the lower platform deck must have hearing protection. Signage is posted stating this requirement.

To prevent accidental rupture of the vacuum windows, plastic ($\frac{1}{4}''$ polycarbonate) protection shall be in place on the windows of the vacuum chamber that face areas were work on the lower platform may take place, when the target contains liquid He. The window facing the HMS may remain uncovered. The window on the SOS side, which is in closest proximity to the forward tracker will also not require a polycarbonate shield, since the forward tracker will provide the necessary protection.

2.4 Magnet Field

The 5 T magnetic field is produced by a set of precision superconducting, iron-free quasi-Helmholz coils which have substantial fringe fields. Further the vacuum chamber has thin windows that must be protected. The strong fringe field is capable of forcefully pulling objects to the magnet – the thin windows are thus doubly vulnerable.

2.4.1 Hazards

Certain precautions must be taken to ensure that hazards will not exist due to the effect of a magnetic field on magnetic materials or on surgical implants. Typical of such effects are the following:

- Large attractive forces may be exerted on equipment brought near to the magnet. The force may become large enough to move the equipment uncontrollably towards the magnet. Small pieces of equipment may therefore become projectiles, large equipment (e.g. gas bottles, power supplies) could cause bodies or limbs to become trapped between the equipment and the magnet. Either type of object may cause injury or death. The closer to the magnet, the larger the force. The larger the equipment mass, the larger the force.

- The operation of medical electronic implants, such as cardiac pacemakers, may be affected either by static or changing magnetic fields. Pacemakers may malfunction if exposed to fields above 5 gauss.

- Other medical implants, such as aneurysm clips, surgical clips or prostheses, may contain ferromagnetic materials and therefore would be subject to strong forces near to the magnet. This could result in injury or death. Additionally, in the vicinity of rapidly changing fields (e.g. pulsed gradient fields), eddy currents may be induced in the implant resulting in heat generation.

- The operation of equipment may be directly affected by the presence of large magnetic fields. Items such as watches, tape recorders and cameras may be magnetized and irreparably damaged if exposed to fields above 10 gauss. Information encoded magnetically on credit cards and magnetic tape including computer floppy discs, may be irreversibly corrupted. Electrical transformers may become magnetically saturated in fields above 50 gauss. The safety characteristics of equipment may also be affected.

- Loss of Magnet operation while beam is being delivered to the hall, and the target is polarized transversely would result in significant misteering of the electron beam.

2.4.2 Hazard Mitigation

To prevent the situations discussed above several actions have been taken. The magnet site has been reviewed and equipment that would be adversely effected by the high field has been removed.

Before the magnet is energized a sweep of the immediate area is required. The purpose of this sweep is to eliminate any loose metal objects that might be moved by the magnetic field.

The area around the magnet has been posted with signs that indicate the presence of the field and warn wearers of medical implants of the potential hazard.

A Hall probe will been installed near the magnet which is interlocked to the beam FSD, so that the beam will be shut down if the target magnet crashes when the chicane was energized during transverse field running. The probe has a digital display that gives additional visual indication of the state of the field.

3 Analysis of Special Hazard

In a previous accident, the sudden, catastrophic loss of insulating vacuum in the Hall C polarized target resulted in rupture of the magnet helium dewar. As a result, super-insulation was dispersed over distances of tens of feet, though no structural damage to the liquid nitrogen shield or the outer vacuum vessel occurred and no heavy projectiles were created. Also, the individual in the pivot area at the time did not suffer any injuries. The accident occurred after approximately three months of polarized target operation.

Loss of the insulating vacuum can occur rapidly if one of the thin vacuum windows is pierced. These vacuum windows are particularly vulnerable when the magnet is energized because the field of the target magnet is strong enough to pull relatively heavy metal objects (wrenches, survey tripods, etc.) from the hands of a person standing four or five feet away and project such objects through the windows – the thin windows are thus doubly vulnerable.

The following details the design changes intended to minimize the consequences of a sudden loss of insulating vacuum (IV) and other hazard mitigating measures and procedures.

3.1 Modifications to the magnet dewar

An analysis[1] of the pressure relief path for magnet dewar indicated that modifications to the existing risers and relief piping would significantly decrease the differential pressure across the dewar in the event of a combined IV loss and magnet quench. The calculations indicate that, with these modifications, a combined IV loss and magnet quench would not result in the rupture of the magnet can. These modifications have been made to the magnet dewar. The laboratory now considers the hazards associated with the operation of the magnet dewar to be significantly mitigated. These modifications **do not in any way** obviate the measures described below.

[1] Memo by Mike Seely to Dennis Skopik, December 6, 2000.

3.2 Hazard Mitigation

This section specifically takes into consideration the lessons learned from the accident of October 7, 1998, and describes the implemented controls. The mitigating measures fall roughly into three categories, which are not mutually exclusive: engineering measures (includes warning devices and signs), hall access control, and educational measures. The engineering measures and hall access controls are discussed in sub-sections below. The education measures (hazard awareness) are discussed separately, in section 7 at the end of this document.

3.2.1 Engineering Measures

Before the magnet can be energized, the following must be in place,

1. Plastic ($\frac{1}{4}''$ polycarbonate) protection shall be in place on the windows of the vacuum chamber when the target contains liquid He. The window on the SOS side, which is in closest proximity to the forward tracker, will not require a polycarbonate shield, since the forward tracker will provide the necessary protection. The window facing the HMS may remain uncovered.

   Polycarbonate shields may become become activated and may be a source of radioactive contamination. Notify RadCon before handling these shields.

2. To ensure that entry to the hazard areas is limited, both the upper and lower platforms will have single points of access. Access routes to upper platform are constrained to be only the stairs from the instrumentation platform. There will be a chain across the stairs that must be in place anytime the upper platform is not occupied. Signage will be hung from the chain. There will be no access to the upper platform from the SOS, and access to the lower platform will be restricted to occur only from the floor of Hall C, where a ladder will be placed, when needed, and then chained and locked to a fixed point, away from the SOS pivot extension adjacent to the Cherenkov stand, on the SOS frame. The key to this ladder lock will be with the Run Corrdinator, given to them by the Hall C Work Coordinator. This ladder is to be unlocked **only** after the magnet is powered off and the positive lead is locked and tagged in compliance with the Lab's policy. Red warning lights indicating the presence of a magnetic field will be clearly visible from all access points to the upper and lower platforms (See Figure 2).

3. The 5 gauss contour must be delimited by a sturdy, construction–type plastic fence or barrier tape. The area delimited must include the floor of the hall below the Beta detector, and the lower target platform. The upper platform, while within the 5 gauss contour of the target magnet, is not delimited by a barrier. Access to the upper platform is allowed during Controlled Access.

4. Signs restricting access to the interior of the 5 gauss contour must be posted and they must include the following wording:

Special Hazard
For Access Contact Run Coordinator at 876-1791

These signs must be posted at 10 foot intervals along the perimeter of the 5 gauss contour.

5. On the outer gate to Hall C a sign will be posted which reads

During Controlled Access
Contact Run Coordinator
Phone 876-1791 or 881-1420

There will also be a sign saying that persons with medical implants, such as pacemakers, are not allowed in the Hall.

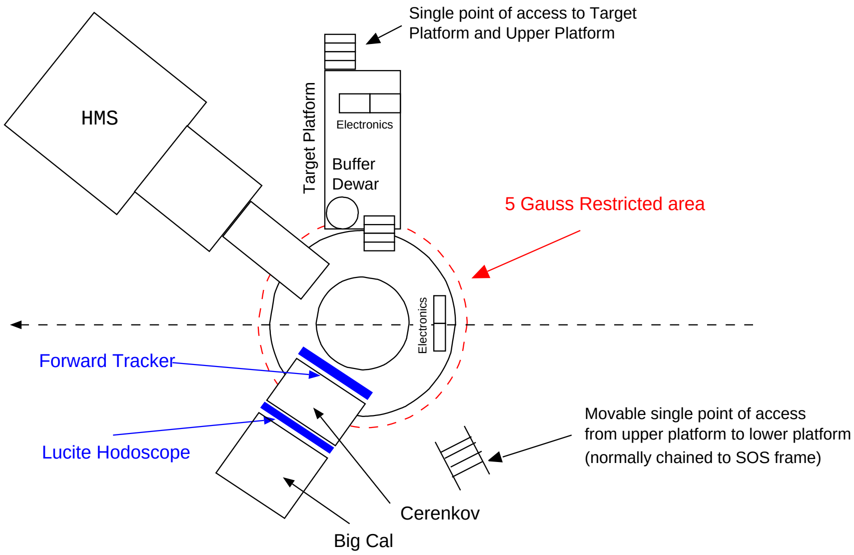

Figure 2: Approximate Restricted Area around Hall C pivot. Overhead view.

3.2.2 Hall Access Control

The reader should first refer to section A.1 of the COO with regard to the badge reader system in Hall C.

Ensuring that everyone who enters the hall is aware of the conditions and that those conditions are suitable for the needs of those entering is crucial. There are special added restrictions for work on the lower platform which apply regardless of the hall status.

Lower Platform Access

- All work on the lower platform is excluded while the magnet is on.

- When the magnet is not energized, only work approved by the Run Coordinator may proceed on the lower platform. In addition to approval, the following conditions must be met before work on the lower platform takes place: hearing and fall protection guidelines must be followed and a radiation survey must be performed after the target magnet is de-energized.

During normal running of the experiment (non-maintenance days), entries to the hall will normally be made while the hall status is Controlled Access. Maintenance days are ideal opportunities for target calibration studies, hence the normal state of the hall on maintenance days will be Controlled Access and a Target Operator will be on shift.

Controlled Access

Controlled Access entries will be controlled by the Badge Reader Physical Access Control system (see section A.1 of the Hall C COO).

- Those who have read the COO and ESAD may go to the hall to perform routine work anywhere that other restrictions do not apply. Examples of areas with additional restrictions are posted radiological hazards, the lower platform and the upper platform.

- Only individuals who are trained Target Experts or ARM's shall go to the upper platform. Other experimenters shall be accompanied by a Target Expert.

- Outside Workers must first contact the Hall C Work Coordinator who in turn will consult the Run Coordinator. If the proposed activity is deemed necessary and prudent, the Run Coordinator will provide authorization for hall access. All outside workers must check in at the Hall C counting house immediately before entering the hall. If the Run Coordinator feels it necessary, he/she will appoint a knowledgeable experimenter to escort the Outside Worker into the hall.

  In summary, **access authorization to Hall C for Outside Workers must be approved by the Run Coordinator.**

- The Run Coordinator has the right to deny access until the experiment is in a condition that allows the proposed work to proceed safely.

Transition to *Restricted Access*

It is inevitable that some activities will require that the state of the hall be changed to Restricted Access. By its nature, Restricted Access makes access to the hall much harder to control and extra precautions must be taken before going to this state. Even in Restricted Access, work on the lower platform is still regulated by signs on the 5 Gauss barrier that indicate the necessity to contact the Run Coordinator for entry. In addition, **The Hall C Safety Warden or**

his designee shall be present at all times while the magnet is cold and the hall is in Restricted Access.

Very strict rules govern the transition to Restricted Access. These rules, enumerated below, will be posted in the Hall C counting house and a written checklist will be provided for use by the Run Coordinator.

- The Run Coordinator is the only person who can request the transition to Restricted Access.
- He/she must arrange that the target field is de-energized and arrange that the serial line that allows remote communication with the target magnet power supply is removed from the supply. The Target Coordinator or his/her designee will disconnect the serial line.
- He/she must also arrange for the positive magnetic lead to be removed from the supply. The Target Coordinator or his/her designee will lock the lead connector in compliance with Jefferson Lab's lock and tag policy. A sign will be hung on the supply noting that it is forbidden to energize the target magnet while the hall is in Restricted Access.
- He/she must arrange that all vacuum window shields are in place (The only window cover that should need to be installed is that covering the window on the Beta side). The Hall C Work Coordinator or his/her designee is charged with the actual installation of the window cover. This individual shall wear hearing protection and a face shield while performing this operation.
- He/she must arrange for the Hall C Safety Warden or his designee to stay in the hall to supervise the activity that necessitated the change. The state of the hall shall revert to Controlled Access (or the Mag Locks will be Energized) when work allows or at the end of the working day.

The time order is: Run Coordinator decides that the hall state must change to Restricted Access. He/she requests that the Target Coordinator or his/her designee to ramp the target field down. The Target Coordinator or his/her designee must also disconnect the serial line to the magnet supply. The Run Coordinator also arranges for the positive magnetic lead to be removed from the supply and the lead connector then locked by the Target Coordinator or his/her designee in accordance with the lab's policy. Once the field is down, the Hall C Work Coordinator and an ARM can enter and install the vacuum window cover over the window on the Beta side. Then, a complete radiological survey can take place and the state of the hall can be altered. Finally, the Hall C Safety Warden (or his designee) must remain in the hall while it is in Restricted Access.

3.3 Magnet Power Supply

The power supply for the superconducting magnet is a low voltage device. It has a driving voltage of less than 10V and provides a maximum of 120 amps.

During normal operation it poses no special hazards. However during a quench of the magnet high voltages may be produced at the leads at the magnet. An insulating cover shall be placed over the connection of the current leads at the magnet.

3.4 Fire and Explosion Hazards

Water must not be used on electrical equipment and when sprayed on cryogenic liquids will rapidly freeze. The magnet ventilation may become blocked by ice with subsequent risk of explosion and the release of cryogens from the system. The surface temperature of containers for liquid nitrogen and helium, if not vacuum insulated, may be sufficiently low to condense oxygen or oxygen enriched air. This liquid in contact with flammable substances can become explosive. Local emergency services must be informed of the presence of a magnet operating in their area as this may affect their procedures in dealing with fires or other accidents.

3.5 Microwave Source and Power Supply

3.5.1 Hazards

Serious hazards exist in the operation of microwave tubes

1. High Voltage – Most microwave sources operate at voltages high enough to kill through electrical shock.

2. RF radiation – Exposure to RF radiation can cause serious bodily injury resulting in blindness or death. Cardiac pacemakers may be affected.

3. Hot coolant and/or steam - For liquid cooled collectors, the electron collector and water used to cool it reach scalding temperatures. Touching or rupture of the cooling system can cause serious burns.

3.5.2 Hazard Mitigation

1. High Voltage – The high voltage supply circuit has a protective interlock system which prevents accidental contact with high voltage. The interface box between the EIO and the power supply is sealed and has an interlock system such that if opened the high voltage is tripped off.

2. RF radiation – The "extended interaction oscillator", – the EIO tube, has a nominal operating point at 140 GHz. This frequency range is far beyond the current region of microwave hazards defined by existing standards. In this frequency range local heating effects are assumed to be the only hazard encountered.

   We have attempted to quantify possible leakage of microwave power from the waveguide system in order to minimize loss from the guides as well as to prevent burn injuries. We have been unsuccessful inasmuch as the frequency response of the equipment available to us was incapable of detecting any radiation in the frequency band of interest.

3. Hot coolant – This EIO operates at a temperature less than $40^\circ\, C$ and there is a hardware interlock which trips off the power supply if the temperature exceeds $40^\circ\, C$.

3.6 Additional Documents

Additional documents (for experimenters) associated with the Polarized Target are

1. The SANE Polarized Target Operation,

2. The SANE Polarized Target Microwave Power Supply Operation,

3. The SANE Polarized Target Anneal of Ammonia Target Material.

These documents can be found in the Hall C Counting House and constitute the *Polarized Target Handbook 2008.*

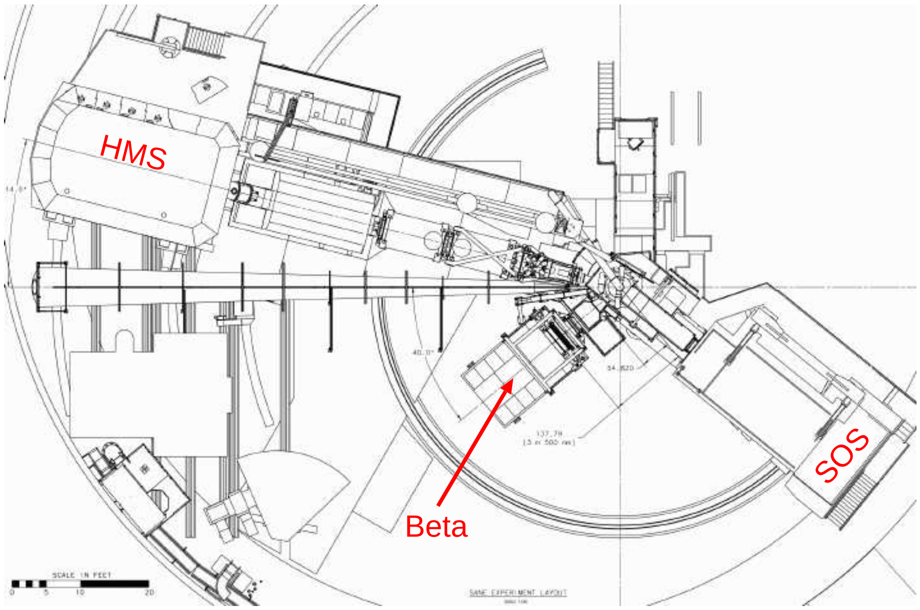

Figure 3: Location of the Beta Detector with respect to the spectrometers.

4 Beta Detector

The Beta Detector consists of four components: The BigCal calorimeter, the Gas Cherenkov, a lucite hodoscope and a forward tracker. Each of these subsystems are discussed in detail in the following sections. We note that hazards involving electrical systems and fire related to these devices are of the same nature and will be mitigated in the same manner as described in the base Hall C ESAD[2].

4.1 Large calorimeter (BigCal)

BigCal is installed on the SOS side on the beamline as shown in Fig. 3. The calorimeter consist of 1744 lead glass blocks which are enclosed in a black light-tight box (BigCal light box). The blocks come from different sources so there are 720 " RCS" blocks with dimensions of 4x4x40cm and 1024 "Protvino" blocks with dimensions of 3.8x3.8x45cm. The physical size of BigCal is about 120cm (width) by 240cm (height).

BigCal is placed on a platform which raises the middle of the calorimeter to beam height. The platform is about nine feet high and is accessed from the rear by a platform ladder. There is railing at all areas of the platform, so that one can access the platform without fall protection. Also on the platform are

[2]http://hallcweb.jlab.org/document/esad_base

six electronic racks which house signal cable patch panels and NIM crates which are used to amplify the signal, sum groups of eight signals and form the trigger.

4.1.1 Hazard

Since the detector is mounted on an elevated platform, individuals working on the platform face the potential hazard of falling off.

4.1.2 Hazard Mitigation

Rails will be installed on all stairways and open platforms to help prevent accidental falls. Another potential falling hazard has been avoided by routing all cables along the sides at the bottom of the detector package, eliminating any need to climb on top of it.

4.2 Gas Cherenkov Detector

The gas Cherenkov shown in Fig. 4 is installed on its own platform which is pushed close to the SOS platform. (See also Fig. 2.) The height of the platform is about 9 feet and allows for easy access to the side panel and photomultiplier tubes. The volume of the detector is filled with dry Nitrogen gas either from compressed gas cylinders or from a liquid Nitrogen dewar. The gas system controller will be mounted in the SOS electronics racks at the rear of the spectrometer. The Cherenkov "tank" pressure is maintained slightly above atmospheric pressure. Due to the extremely small differential pressure, there is no overpressure hazards to persons working around the tank. However, there are safety valves in place should this unlikely overpressure occur.

After performing maintenance work inside the tank and thus exposing it to room environment, the volume must be flushed with dry nitrogen. This can be done two ways, automatically or manually. On the controller panel there is an auto/manual switch. The automatic switch allows the microprocessor based controller to take over. Ideally, there are two modes for the automatic operation, flushing and Maintain, which must be written to the driver from the controlling computer. This computer is connected via RS-232. In the flush mode, the vent valve is fixed open and the fill valve opens while the pressure is under a set limit. The electro-mechanically controlled solenoid vent valve is mounted at the base of the tank and would be used as the primary relief during an over pressure condition in the tank.

Furthermore, based on trials at Temple University, the average delivery flow rate of Nitrogen while maintaining a differential pressure of 10 torr is less than 1 Standard Cubic Foot per Hour (SCFH). For an ideal hermetic and perfectly sealed tank this rate would be zero, and therefore this rate is also referred to as a *leak rate*. This is the rate that gas will enter the Cherenkov Tank when the manometer calls for more gas and automatically opens the fill solenoid valve to maintain set point pressure.

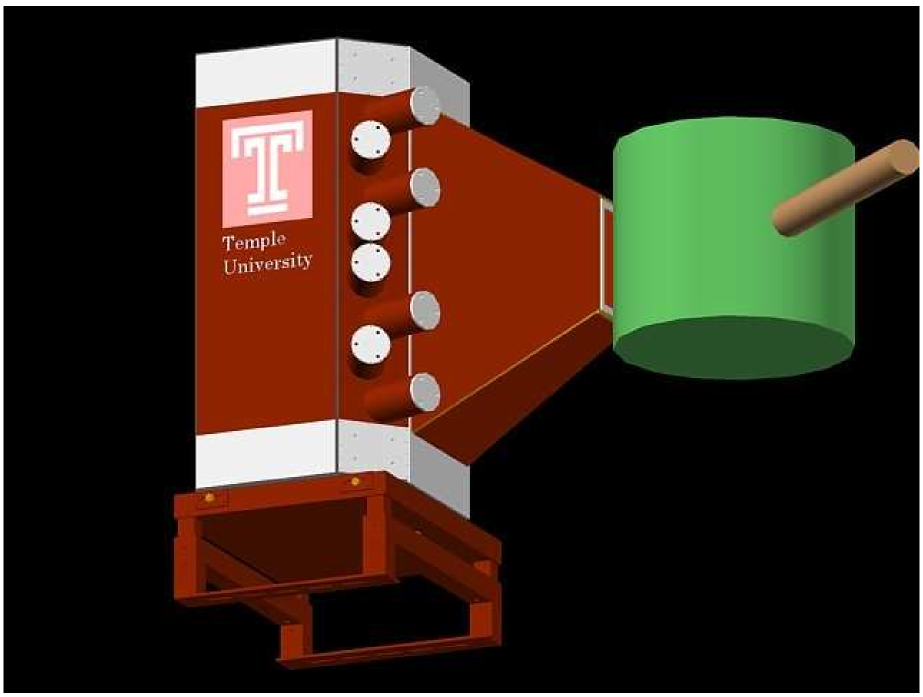

Figure 4: CAD drawing of the gas Cherenkov installed on its stand.

4.2.1 Hazard

The Cherenkov is located in close proximity to the polarized target. Anyone servicing the Cherenkov must be aware of the associated hazards discussed in section 2.

Since the detector is mounted on an elevated platform, individuals working on the platform face the potential hazard of falling off.

When programming the controller, one must take care in choosing an operating pressure setting. Due to atmospheric fluctuations, the differential pressure varies slowly and thus problems can occur long after programming. The suggested setting is **775 torr**. In case of depressurization due to overpressure the likely location of failure is the front or back windows because of their small thickness. Due to the low pressures of the tank there should be no issue of safety for those working around the tank, except for the possibility of extreme over pressure, in which case the valves described below will take effect. Furthermore, the solenoid valves are powered by **standard 110VAC** so care must be taken when connecting, disconnecting, and working with these valves.

4.2.2 Hazard Mitagation

While working on Cherenkov on this platform, eye and hearing protection must be worn as discussed in section 2.

To allow work to be completed without the need for fall protection, the yellow side rails must be installed around the entire perimeter of the platform before starting work.

Access to the Cerenkov platform will be done by a step ladder. The step ladder is stored in the truck ramp. When access is needed the step ladder is brought from the truck ramp. Then it is opened and tied off to the Cerenkov platform. While on the platform earplugs and safety glasses will be worn and Non-magnetic tools will be used. The hand rail will have to be removed to access the platform. After working on the platform, then the handrail is placed back in place and the ladder is returned to the truck ramp.

Two Circle Seal 500 series pop-off valves are installed on the tank, one near the top, one near the bottom. Set at 0.5 to 1 psig cracking pressure according to manufacturers charts each will allow .08 SCFM (x 60 minutes will give a gas relief capability 4.8 SCFH. Total 2 x 4.8 = 9.6 SCFH). One alone should have plenty of capability to keep the tank from over pressurizing. These valves of course do not depend on any external connections and reseal when the overpressure condition is relieved.

4.3 The Lucite Cherenkov Hodoscope

The Lucite Cherenkov hodoscope is located in front of the BigCal, at 240 cm from the target. The distance between Lucite and BigCal is 80 cm. The purpose of the hodoscope is (1) to detect charged particles above the threshold (primarily electrons and pions) with high efficiency; (2) to assist in providing a high level

Figure 5: Front view of the Lucite Hodoscope. The last bar is missing.

of $\pi^{\pm}$ rejection (1000:1) for the case of electron trigger; (3) to provide useful position resolution at a reasonable cost. The front view of the hodoscope is presented in Fig. /refFIG1. The hodoscope consists of a plane of 28 bars in horizontal direction. The width of each bar is 6 cm and the length is 97 cm. The ends of the bars are cut at 45° with respect to the surface. The 45° cut provides transmission of the Cherenkov light into the light guide and then to PMT, at the level of about 100%. The amount of reflected light is negligible. The bars are curved with a radius of curvature equal to the distance from the target: 240 cm. The curvature provides (90 ± 1) impact angle for the particles emerging from the target. The light guide has a length of 10 cm. One end matches the 45° cut of the bar, and the other end is round, with the diameter of 50 mm.

4.3.1 Hazard

The main source of hazard is the high voltage, which may be as high as 2300 V, applied on 56 PMTs, 28 at each side of the hodoscope. In order to prevent high voltage leak to the frame, each PMT is wrapped in a wide 300 m black insulation tape.

4.3.2 Hazard Mitigation

The high voltage cables and the SHV connectors for the hodoscope PMTs are shielded and properly routed in cable trays holding rest of the high voltage cables for the BigCal detector. The main HV crate is turned off when attaching/removing HV cables.

4.4 Forward Tracker

The Forward Tracking Hodoscope is the first element of the BETA detector package. It consists of one horizontal (X) and three vertical (Y) planes made of BC-408 plastic scintillators together with wavelength shifting fibers. The main purpose of this X-Y hodoscope detector is to provide redundant and efficient electron detection with limited tracking to suppress background. The detector will provide improved target position resolution (to better than 0.5 cm) in addition to its ability to reject non-target related backgrounds. An additional goal for the hodoscope is the partial ability to determine the sign of low momentum charged particles to discriminate positrons from electrons.

The dimensions of the X counters are $3 \times 3 \times 400$ mm^3 and those of the Y are $3 \times 3 \times 220$ mm^3. All four planes are packaged between two G10 frames. The overall size of the detector is $28 \times 52 \times 6$ cm^3 and it is mounted on an Aluminum frame just outside of the polarized target outside vacuum chamber at a distance of $\sim$50 cm from the target center. The frame is self-supporting and rests on the SOS platform directly in front of the gas Cherenkov detector.

The light output of the scintillators are transmitted by 2.5 m long wavelength shifting fibers which are directly attached to the scintillators. The fibers are connected to ten 64-channel multianode PMTs which are housed in a soft-iron box placed on the SOS platform on the left side of the beamline. The PMT signals are carried by $20'$ long signal cables which are connected to the tracker electronic modules in a CAMAC crate which is placed directly below the SOS platform close to the Hall C floor level.

4.4.1 Hazards

The forward tracker is placed in a region where the fringe field from the polarized target magnet is $\sim$5 kgauss. The hazards associated with strong fringe fields have already been delineated in the polarized target section of this document.

The supply voltage of the tracker PMTs range from 800-950 volts. These are provided by LeCroy high voltage crates located on the BigCal electronic platform in Hall C.

4.4.2 Hazard Mitigation

In addition to the precautionary measures taken to mitigate the polarized target magnetic field hazards, the area near the forward tracker has been posted with signs that indicate the presence of strong fringe fields and warn wearers of medical implants of the potential hazards.

The high voltage cables and the SHV connectors for the tracker PMTs are shielded and properly routed in cable trays holding rest of the high voltage cables for the BigCal detector. The main HV crate is turned off when attaching/removing HV cables.

Hazards involving electrical systems and fire related to these devices are of the same nature and will be mitigated in the same manner as described in the base Hall C ESAD[3].

5 Chicane

In order to accommodate the deflection caused by the large 5.1 Tesla holding field of the polarized target's Helmholtz coils magnet, additional magnets have been added to the Hall C beam line. These magnets, together with the target magnet, comprise a vertical chicane.

The magnets are standard accelerator dipoles. The first is a BE mounted at the end of the tunnel alcove. The second magnet, designated BZ1, precedes the taget in the beam line. BZ1 is mounted on a large jack stand that allows for its vertical position to be adjusted. The jack is motor powered and the controls are locked out during normal operations to prevent accidental damage to vacuum components. Adjustments are done at the request of the Run Coordinator by the accelerator survey group, in conjunction with accelerator division mechanical technicians.

The upstream (w.r.t the scattering chamber) beam line exit window is purchased commercially from Brush-Wellman. The upstream exit window is a 0.015 inch thick, 2 inch diameter Be plate mounted in a 4.5 inch diameter stainless steel CF flange.

To reduce background from bremsstrahlung in the target, the downstream line is a metallic beam pipe followed by a large helium bag.The pipe is at the same pressure as the bag.

5.1 Hazards and Hazard Mitigation

The dipoles are powered by three DANFYSIK supplies which are located behind the green shield wall near the SOS supplies. These power supplies are high current devices and are thus potentially lethal. The supply properties are summarized below.

Magnet Name	I_{max} (Amps)	V (Volts)
BE	320	40
BZ	500	40

The lead connections to all magnets have guards placed over them. In addition, there are red lights at the magnets which indicate that the supplies are DC enabled. MCC controls the magnets power supplies.

[3] http://hallcweb.jlab.org/document/esad_base

The supplies are not directly interlocked into the Fast Shutdown System (FSD). Protection against failure is provided by a number of measures. First, the total beam current into Hall C is limited by a BCM in the alcove (formerly BCM3). The limit is about 1.5 μA CW. As a final precaution, a Hall effect probe monitors the fringe field of the target magnet and the output of this probe is tied to the FSD.

The magnets in the chicane are cooled by the Low Conductivity Water (LCW) system. This is a high pressure system, $P = 125$ psi, and an unconfined stream of water at this pressure could cause injury. The LCW water system uses water hoses rated for 300 psi and they have been tested.

6 Personnel Allowed to Operate E07-003 Equipment

This section will state all responsible personnel associated with one of the three subsystems, additional to the Hall C base equipment, used in the E07-003 experiment. These three additional subsystems are the polarized target, the Beta detector, and the beam line chicane. The general procedure to add to this list of responsible personnel is by authorization of the person(s) in charge of a subsystem **and** the Hall C Leader.

6.1 Polarized Target

The Polarized Target consists of several technical components, a 5T superconducting solenoid, a 1K helium refrigerator, a 140 GHz RF system, vacuum chamber and associated pumps, and small containers of polarizable solid ammonia. The responsible personnel for this complex system are (between parentheses the pager numbers)

Donald Crabb x5555 [UVa]

Donal Day x6233 [UVa]

Oscar Rondon x6233 [UVa]

Chris Keith x5878 (584-5878) [JLab Polarized Target Group]

Dave Meekins x5434 (584-5434) [JLab Polarized Target Group]

Mikell Seely x5036 (584-5036) [JLab Polarized Target Group]

Jonathan Mulholland x5503 (584-5503) [UVa]

James Maxwell x5474 (584-5474) [UVa]

Silviu Covrig x6410 [Jlab]

Narbe Kalantarians x7697 (584-0119) [Uva]

6.2 Beta Detector

Responsible personnel for the E07-003 Beta Detector are (between parentheses the pager numbers)

Mark Jones x7733 [JLab Staff Scientist]

Oscar Rondon x6233 [UVa]

Z.E. Meziani x5947 [Temple]

Seonho Choi x5601 [Seoul]

Donal Day x6233 [UVa]

Bill Vulcan x6271 (584-6271) [JLab Electrical Engineer]

Steve Wood x7367 (584-7367) [JLab Staff Scientist]

Hovhannes Baghdasaryan x7735 (584-5495) [UVa]

Mahbub Khandaker x7329 [Norfolk]

Cornel Butuceanu x6933 [Regina]

Peter Bosted x5851 (584-5985) [Physics Liaison]

Abdellah Ahmidouch x7353 [NCAT]

Sam Danagoulian x7353 [NCAT]

Hoyoung Kang x5038 [Seoul]

Brad Sawatzky x5457 [Temple]

Whitney Armstrong x5457 [Temple]

6.3 Beam Line Chicane

The beam line chicane for E07-003 is a shared responsibility for the JLab Accelerator Division, who is in charge of setting up the beam line for beam transport, and JLab Physics Division Hall Staff, especially for the beam transport after the Polarized Target. Note that any configuration change can affect the site boundary dose and the production of airborne radioactivity, and as such is the responsibility of the JLab Radiation Control group. Any change in the beam line configuration will have to be discussed with responsible personnel of these three groups.

Hari Areti x7187 (584-7187) [Accelerator Liaison]

Peter Bosted x5851 (584-5985) [Physics Liaison]

Vashek Vylet x7551 (584-7551) [Head JLab RadCon Group]

The Run Coordinator (cellular 876-1791) should be informed of any planned configuration change.

7 Educational Measures

This document contains information needed to operate the hall in a safe manner. The challenge is to disseminate the information contained in this document effectively to all the groups who are potentially effected by the rules of conduct delineated here and in the "Conduct of Operations". To this end the following steps will be taken.

- All Shift personnel are required to read and sign this document, the COO, as well as the Hall C base equipment ESAD and send verifying email to PDL Peter Bosted (bosted@jlab.org) and Oscar Rondon (or@virginia.edu).
- For ARMs, a special document, "General Guidance for Surveys in Hall C during the SANE experiment" will be prepared and available at the "Information for Arm Monitors" webpage (http://www.jlab.org/accel/RadCon/ARMS.html).