Experimental Safety Assessment Document (ESAD)

for the Base Equipment in Hall D

May 17, 2022

Updates and Revisions

March, 2022

- page 1: Repository and header: Copied files from *svn* to *git*. Updates should henceforth be taken from the new repository.
- page 36: Added Muon Wire Chamber for CPP experiment.
- page 15: Modify text to reflect the muon detector followed by vacuum beam pipe.

August, 2021

- Added an appendix for the testing setups at the PS

July, 2021

- Tim Fitzgerald replaces Todd Kujawa
- Update text on 5 Gauss and 600 Gauss boundaries.

February, 2021

- Edith Nissen replaces Todd Satogata

April, 2020

- page 11: in section 2.9 "Bert Manzlak" replaced by "Paul Collins" as LCO and contact information added.
- page 14: in section 3.5.1 "high voltage up to 3.5kV DC" changed to "high voltage up to 5kV DC".
- page 15: in section 3.4.3 "carstens" replaced by "stevensm", as e-mail of the Hall Work Coordinator.

- page 22: in "Magnetic Field" hazard subsection: a sentence about the physical barricade around the 600 Gauss area is added.

November, 2019

- replace "Mark Stevens" with "HallD Work Coordinator"
- remove Test-stand setups, is covered by OSPs and Task-List

January, 2019

- page 13: Mark Stevens replaces Tom Carstens.
- page 32: Minor editing of the DIRC description.
- page 37: In subsection 4.3, text is added, explaining possible installation of two lead sheets for trigger test.
- page 38: Subsection "4.4 FCAL insert prototype detector" removed as the detector no longer exists.

August, 2018

- Mark Stevens replaces Tom Carstens.
- Remove Test Compton Calorimeter based on lead glass.
- Add main Compton Calorimeter based on PbWO.
- Modify the CompCal section: remove F1 TDCs, update mitigation section, add V. Berdnikov to contact persons.

June, 2018

- Add DIRC to the detectors.

March, 2018

- Update first chapter with latest names and phone numbers.

Feb, 2018

- Add new prototype Calorimeter detector.

September, 2017

- Put revisions in inverse chronological order.

- Add new Chapter 4: Test Installations. Move old Sections 3.19 to 3.21 into new chapter.
- Add new Section 4.4: Prototype Muon Chamber.
- Fix incorrect phone numbers. Remove Mike Staib from CDC; add Mark Dalton to BCAL; replace Nathan Sparks with Alexandre Deur on TPOL.
- Fix typo in bibliography.

January, 2017

- Add new TRD prototype detector.
- Add a GEM prototype detector.
- Add FCAL insert prototype detector.

September, 2016

- Added Section 3.20 Compton Calorimeter.
- Remove Section 3.12 Forward Drift Chamber Spare Package.
- Fix Tom Carstens phone number.
- New fire protection manager Ed Douberly.
- Gas is vented in the hall.
- Fall protection for work on ladders not platform.
- Tim Whitlatch replaces George Biallas for Solenoid.
- Hearing protection in tagger hall when tagger under vacuum.

January, 2016

- page 21: Replaced Qiang with Zihlmann; Added Section 3.18 Triplet Polarimeter; Added Section 3.19 Total Absorption Counter

November, 2015

- Added Section 3.12 Forward Drift Chamber Spare Package

January, 2015

- page 12: 2 phone numbers; Cryo-target is now included

Contents

Chapter 1

Introduction

The ESAD document describes identified hazards of an experiment and the measures taken to eliminate, control, or mitigate them. This document is part of the CEBAF experiment review process as defined in Chapter 3120 of the Jefferson Lab EHS&Q manual, and will start by describing general types of hazards that might be present in any of the JLab experimental halls. This document then addresses the hazards associated with sub-systems of the base equipment of the experimental hall and their mitigation. Responsible personnel for each item is also noted. In case of life threatening emergencies call 911 and then notify the guard house at 5822 so that the guards can help the responders. This document does not attempt to describe the function or operation of the various sub-systems. Such information can be found in the experimental hall specific Operating Manuals.

Chapter 2

General Hazards

2.1 Radiation

CEBAF's high intensity and high energy electron beam is a potentially lethal direct radiation source. It can also create radioactive materials that are hazardous even after the beam has been turned off. There are many redundant measures aimed at preventing accidental exposure of personnel to the beam or exposure to beam-associated radiation sources that are in place at JLab. The training and mitigation procedures are handled through the JLab Radiation Control Department (RadCon). The radiation safety department at JLab can be contacted as follows: For routine support and surveys, or for emergencies after-hours, call the RadCon cell phone at 876-1743. For escalation of effort, or for emergencies, the RadCon manager (Keith Welch) can be reached as follows: Office: 269-7212, Cell: 876-5342.

Radiation damage to materials and electronics is mainly determined by the neutron dose (photon dose typically causes parity errors and it is easier to shield against). Commercial-off-the-shelf (COTS) electronics is typically robust up to neutron doses of about $10^{13} n/cm^2$. If the experimental equipment dose as calculated in the RSAD is beyond this damage threshold, the experiment needs to add an appendix on "Evaluation of potential radiation damage" in the experiment specific ESAD. There, the radiation damage dose, potential impact to equipment located in areas above this damage threshold as well as mitigating measures taken should be described.

2.2 Fire

The experimental halls contain numerous combustible materials and flammable gases. In addition, they contain potential ignition sources, such as electrical wiring and equipment. General fire hazards and procedures for dealing with these are covered by JLab emergency management procedures. The JLab Fire Marshall (Tim Minga) can be contacted at 269-7310 or cell 371-1687.

2.3 Electrical Systems

Hazards associated with electrical systems are the most common risk in the experimental halls. Almost every sub-system requires AC and/or DC power. Due to the high current and/or high voltage requirements of many of these sub-systems they and their power supplies are potentially lethal electrical sources. In the case of superconducting magnets the stored energy is so large that an uncontrolled electrical discharge can be lethal for a period of time even after the actual power source has been turned off. Anyone working on electrical power in the experimental Halls must comply with Chapter 6200 of the Jefferson Lab EHS&Q manual and must obtain approval of one of the responsible personnel. The JLab electrical safety point-of-contact (Tim Fitzgerald) can be reached at 269-7052.

2.4 Mechanical Systems

There exist a variety of mechanical hazards in all experimental halls at JLab. Numerous electro-mechanical sub-systems are massive enough to produce potential fall and/or crush hazards. In addition, heavy objects are routinely moved around within the experimental halls during reconfigurations for specific experiments.

Use of ladders and scaffold must comply with Chapter 6231 of the Jefferson Lab EHS&Q manual. Use of cranes, hoists, lifts, etc. must comply with Chapter 6141 of the Jefferson Lab EHS&Q manual. Use of personal protective equipment to mitigate mechanical hazards, such as hard hats, safety harnesses, and safety shoes are mandatory when deemed necessary. The JLab technical point-of-contact (Mark Loewus) can be contacted at 269-7847.

2.5 Strong Magnetic Fields

Powerful magnets exist in all JLab experimental halls. Metal objects being attracted by the magnet fringe field, and becoming airborne, possibly injuring body parts or striking fragile components resulting in a cascading hazard condition. Cardiac pacemakers or other electronic medical devices may no longer function properly in the presence of magnetic fields, and metallic medical implants (non-electronic) may be adversely affected by magnetic fields. Loss of information from magnetic data storage driver such as tapes, disks, credit cards may also occur. Contact Jennifer Williams at 269-7882, in case of questions or concerns.

2.6 Cryogenic Fluids and Oxygen Deficiency Hazard

Cryogenic fluids and gasses are commonly used in the experimental halls at JLab. When released in an uncontrolled manner these can result in explosion, fire, cryogenic burns and the displacement of air resulting in an oxygen deficiency hazard, ODH, condition. The hazard level and associated mitigation are dependent on the sub-subsystem and cryogenic fluid. However, they are mostly associated with cryogenic superconducting magnets and cryogenic target systems. Flammable cryogenic gases used in the experimental halls include hydrogen and deuterium which are colorless, odorless gases and hence not easily detected by human senses. Hydrogen air mixtures are flammable over a large range of relative concentrations: from 4% to 75% H2 by volume. Non-flammable cryogenic gasses typically used include He and nitrogen. Contact Jennifer Williams at 269-7882 or Jonathan Creel at 269-5925 in case of questions or concerns.

2.7 Vacuum and Pressure Vessels

Vacuum and/or pressure vessels are commonly used in the experimental halls. Many of these have thin Aluminum or kevlar/mylar windows that are close to the entrance and/or exit of the vessels or beam pipes. These windows burst if punctured accidentally or can fail if significant over pressure were to exist. Injury is possible if a failure were to occur near an individual. All work on vacuum windows in the experimental halls must occur under the supervision of appropriately trained JLab personnel. Specifically, the scattering chamber and beam line exit windows must always be leak checked before service. Contact Will Oren 269-7344 for vacuum and pressure vessels issues.

2.8 Hazardous Materials

Hazardous materials in the form of solids, liquids, and gases that may harm people or property exist in the JLab experimental halls. The most common of these materials include lead, beryllium compounds, and various toxic and corrosive chemicals. Material Safety Data Sheets (MSDS) for hazardous materials in use in the Hall is available from the Hall safety warden. These are being replaced by the new standard Safety Data Sheets (SDS) as they become available in compliance with the new OSHA standards. Handling of these materials must follow the guidelines of the EH&S manual. Machining of lead or beryllium, that are highly toxic in powdered form, requires prior approval of the EH&S staff. Lead Worker training is required in order to handle lead in the Hall. In case of questions or concerns, the JLab hazardous materials specialist (Jennifer Williams) can be contacted at 269-7882.

2.9 Lasers

High power lasers are often used in the experimental areas for various purposes. Improperly used lasers are potentially dangerous. Exposure to laser beams at sufficient power levels may cause thermal and photochemical injury to the eye including retina burn and blindness. Skin exposure to laser beams may induce pigmentation, accelerated aging, or severe skin burn. Laser beams may also ignite combustible materials creating a fire hazard. At JLab, lasers with power higher than 5 mW (Class 3B) can only be operated in a controlled environment with proper eye protection and engineering controls designed and approved for the specific laser system. Each specific laser systems shall be operated under the supervision of a Laser System Supervisor (LSS) following the Laser Operating Safety Procedure (LOSP) for that system approved by the Laboratory Laser Safety Officer (LSO).

Chapter 3

Hall D Specific Equipment

3.1 Overview

The following Hall D subsystems are considered part of the Experimental End-station Base Equipment [1]. Many of these subsystems impose similar hazards, such as those induced by magnets and magnet power supplies, high voltage systems and cryogenic systems. Note that a specific system may have several hazards. For each major system, the hazards, mitigation, and responsible personnel are noted. The material in this chapter is only intended to familiarize people with the hazards and responsible personnel for these systems. It in no way should be taken as sufficient information to use or operate this equipment.

3.2 Checking Inputs to Machine Fast Shutdown System

In order to ensure that identified hall equipment is tied into the machine fast shutdown (FSD) system, the list of FSD inputs must be specified as part of the Hall D Checklist prior to closing the hall. Verification that the system is operational is documented via completion of the checklist.

3.3 Beamline

The control and measurement equipment along the Hall D beamline consists of various elements necessary to transport beam with the required specifications onto the reaction target and the dump and to simultaneously measure the properties of the beam relevant to the successful implementation of the physics program in Hall D. The accelerator division has the primary responsibility of delivering the electron beam to the electron dump in the tagger hall. The tagger magnet separates the electron beam from the photon beam for use in experiments in Hall D. In order to ensure safe and reliable operation, all work on the beamline must be coordinated with both Physics Division and Accelerator Division.

3.3.1 Photon Beamline

The equipment along the photon beamline is the responsibility of Hall D. However, close coordination with the MCC and Accelerator Divisions is essential, as the steering of the photon beam is accomplished by adjusting the angles and parameters of the electron beam at the radiator.

3.3.2 Collimator Enclosure

The photon beam is highly collimated using limiting apertures that allow only about 15% of the beam to be transmitted to the experimental area. Therefore the radiation levels in the collimator enclosure may increase so that special radiological postings are required.

3.3.3 Hazards

Various hazards can be found along the electron and photon beamlines. These include radiation areas, vacuum windows, high voltage, magnetic fields, and remote operation of moving devices.

3.3.4 Mitigation

All magnets (dipoles, quadrupoles, sextupoles, beam correctors) and beam diagnostic devices (BPMs, scanners, Beam Loss Monitor, viewers) necessary for the transport of the electron beam are controlled by the Machine Control Center (MCC) through EPICS [2]. The detailed safety operational procedures for the Hall D beamline is essentially the same as the one for the CEBAF machine and beamline. Personnel who need to work near or around the beamline should keep in mind the potential hazards:

- Radiation Hot Spots - marked by an ARM or RadCon personnel,
- Vacuum in the beam line tubes and other vessels,
- Thin windowed vacuum enclosures (e.g. the tagging and pair spectrometers),

- Electric power hazards in vicinity of the magnets and photon beam monitors,
- Magnetic field hazards in vicinity of the magnets, and
- Conventional hazards (fall hazard, crane hazard, moving equipment under remote control, etc.).

These hazards are noted by signs and the most hazardous areas along the beamline are roped off to restrict access when operational. Signs are posted by RadCon for any hot spots along the beamline and RadCon must be notified before work is done in a posted area. The terminals of some magnets are covered with plastic sheets for electric safety. Any access to these magnets requires the Lock and Tag procedure [3] and the appropriate training, including the equipment-specific one. Additional safety information is available in the following documents:

- EH&S Manual [3]
- PSS Description Document [4]
- Accelerator Operations Directive [5]

3.3.5 Responsible Personnel

Since the beamline requires both accelerator and physics personnel to maintain and operate and it is very important that both groups stay in contact that any work on the Hall D beamline is coordinated. The list of responsible personnel are given in Table 3.1.

Name	Dept.	Extension [1]	e-mail	Comment
Edith Nissen	CASA	7599	nissen	Liaison
Mike McCaughan	Accelerator	5572	michaelm	Operations Liaison
Alexandre Deur	Hall D	7526	deurpam	Detectors
Alexander Somov	Hall D	5553	somov	Detectors
HallD Work Coordinator	Hall D	876-3940		Tagging Magnet

Table 3.1: List of responsible personnel for the beamline.

[1] Phone prefixes are the following: Telephone numbers: 757-269-XXXX, Pager numbers: 757-584-XXXX.

3.4 Vacuum Systems

The Hall D vacuum system consists of three separate subsystems. The vacuum in the electron line to the tagger magnet is designed to maintain a pressure of 1×10^{-6} Torr. It is connected to the photon beamline through the vacuum chamber of the tagger magnet. The vacuum spaces can be isolated from one another via a valves on either side of the goniometer vacuum chamber and a valve downstream of the tagging spectrometer. Vacuum pumps are installed on the goniometer and tagger magnet vacuum chambers. The vacuum in the beam pipe that connects the tagger hall with the collimator hut is maintained at a pressure of about 1×10^{-5} Torr with a pump located at the downstream wall of the tagger hall. The beam pipe is closed off with a window at the entrance to the collimator enclosure. Following the active collimator, the vacuum extends through the pair spectrometer magnet to a window at the entrance to the target. The photon beam travels in air from the target to the downstream end of the forward calorimeter, and past the FMWPC muon chamber during the CPP experiment, where it enters an enlarged beam pipe that transports the beam to the downstream wall of Hall D.

3.4.1 Hazards

Hazards associated with the vacuum system are due to rapid decompression in case of a window failure. Loud noise can cause hearing loss.

3.4.2 Mitigation

To mitigate the hazard, all personnel in the vicinity of entrance and exit windows (tagging magnet, photon beam pipe entering the collimator hut and pair spectrometer) are required to wear ear protection when the system is under vacuum. Warning signs must be posted at the area. In addition, all vacuum vessels and piping are designed as pressure vessels.

3.4.3 Responsible Personnel

The authorized personnel is shown in Table 3.2.

Name	Dept.	Phone	e-mail	Comment
HallD Work Coordinator	Hall D	876-3940		Hall Work Coordinator

Table 3.2: List of responsible personnel for the beamline vacuum.

3.5 Detector Electronics

The electronics consists of multiple VXS, VME crates housing various readout modules such as fADC250, fADC125, F1TDCs, 16-ch discriminators, trigger modules and various other units; Wiener MPOD chassis housing a number of modules supply low voltage power and bias to frontend electronics installed on various detectors; CAEN chassis housing a number of modules supply high voltage to PMT-based detectors. Frontend custom electronics boards are installed on most detectors to handle the signal processing needs of each detector and for low noise readout.

Signal and power transmission is handled by a large number of copper cables interconnecting the various electronics modules and detector elements. A smaller number of optical cables are employed to transmit synchronization, time-keeping signals and various other communication services throughout the experimental hall.

3.5.1 Hazards

Hazards associated with the power demands of the crates and chassis pose risk of fire and personnel exposure to high voltages and high currents. The modules housed by the CAEN chassis, in particular, can supply high voltages up to 5kV DC. Some of the modules housed by the MPOD chassis, and used for biasing SiPMs, also pose a personnel hazard and can supply voltages up to 120V DC; other modules supply low voltages up to 30V DC but at low currents per channel of up to 5A DC. There is also a fire hazard associated with cabling throughout the experimental hall.

3.5.2 Mitigation

All the crates and chassis are commercially available and are powered from 208V AC. These meet stringent safety requirements set by various qualified agencies such UL and TUV. The high power supplies are not user serviceable in the experimental setting and have no exposed parts which could pose a safety hazard. Internal fans help manage thermal loads and several internal controls are implemented to provide limits on over current and over temperature excursions. Additionally, aluminum blank panels have been installed to limit access to the backplane on the rear of the chassis and on the front side where slots are unused. All the power distribution from high voltage, low voltage and bias supplies is power-limited for current and voltage and interlocked via the slow controls system.

All the cables are NEC UL rated CL2 or better and conform to the 2011 edition of the NEC NFPA70 code requirements for fire prevention and thus, limit flame propagation in case of fire. Additionally, all the cables are shielded and referenced to ground for added personnel and equipment safety.

3.5.3 Responsible Personnel

The individuals responsible for the operation of the detector electronics are shown in Table 3.3.

Name	Dept.	Extension [1]	e-mail	Comment
Fernando Barbosa	Hall D	7433	barbosa	Hall D Electronics Engineer

Table 3.3: List of responsible personnel for Hall D electronics.

3.6 Tagging Spectrometer

The tagging spectrometer resides in the tagger hall. It consists of the dipole magnet and two detector systems: the fixed array hodoscope and the microscope. The operation of the dipole is controlled by the accelerator to guide the full energy beam to the electron dump. For a 12 GeV-electron beam, the magnet is operated at the nominal current of 223 A. Any changes to its settings must be coordinated with the accelerator machine control center (MCC).

The fixed array is an array of scintillation counters covering the energy range of 3.048 to 11.78 GeV, excluding the coherent peak range. The scintillators are viewed using Hamamatsu R9800 pmts equipped with custom dividers that include an amplifier. The microscope covers the coherent peak range from 8.1 to 9.1 GeV using an array of square fibers. The fibers are viewed using Hamamatsu S10931-050P MPPCs. The MPPCs operate at a voltage less than 77 V.

3.6.1 Hazards

The hazards include those associated with the operation of a large magnet and vacuum chamber, as well as high voltage that powers the photomultipliers in the fixed array hodoscope. The relatively high radiation environment can also impact the detector operation. The hazards include the following:

- thin window/vacuum
- electrical power
- high voltage for fixed array (see Section 3.5)
- magnetic field
- radiation damage, especially to MPPCs in microscope

3.6.2 Mitigation

Electrical Power for Dipole

Changes to its settings to the magnet must be implemented by the accelerator machine control center (MCC) and consistent with the operation of the electron beam. Maintenance and servicing of the dipole can only be conducted by trained personnel. Additional information can be found in the Operational Safety Procedure to map the magnet [6] . During normal operation, the terminals of the magnet are covered by plastic sheets for safety.

Thin Window

Eye protection is required when working near the magnet when the system is under vacuum. A protective cover should be installed during maintenance periods to protect the thin window from puncture.

Magnetic Field

All required barricades, lights and signage shall be present when the system is activated, and these signs/barricades communicate the hazards present.

Radiation Environment

The radiation environment in the tagger area, which is created by the 5.5 pass electron beam delivered to beam dump, can affect the performance of electronics and detectors. To minimize its expose radiation, the readout electronics are located under the tagger magnet. The tagger microscope readout is also located near the floor away from the most intense radiation and surrounded with polyethylene pellets to minimize exposure to neutrons.

3.6.3 Responsible Personnel

The individuals responsible for the operation of the tagging spectrometer are shown in Table 3.4.

3.7 Pair Spectrometer

The pair spectrometer consists of a dipole magnet, vacuum chamber and a hodoscope consisting of high-granularity and low-granularity counters. The operation of the

Name	Dept.	Extension [1]	e-mail	Comment
Alexandre Deur	Hall D	7526	duerpam	Detectors
Alexander Somov	Hall D	5553	somov	Detectors
HallD Work Coordinator	Hall D	876-3940		Tagging Magnet & Vacuum

Table 3.4: List of responsible personnel for the tagging spectrometer.

dipole is controlled by Hall D. For the coherent photon peak at 9 GeV, the magnet is operated up to a current of 1300 A.

The low-granularity counters consist of scintillator counters viewed by Hamamatsu H7415 photomultiplier tubes. They operate at a typical voltage of 1300 V. The high-granularity hodoscope consists of thin scintillators, with light collected through wavelength-shifting fiber to Hamamatsu S10931-50P MPPCs. The operating bias for these sensors is 77 V The system is air cooled.

3.7.1 Hazards

The hazards include those associated with the operation of a large magnet and vacuum chamber, as well as high voltage that powers the photomultipliers in the low-granularity counters. The hazards include the following:

- thin window/vacuum
- electrical power
- high voltage for fixed array (see Section 3.5)
- magnetic field

3.7.2 Mitigation

Electrical Power for Dipole

The dipole current is set to match the energy of the photon beam and accomplished using the EPICS control GUI. Maintenance and servicing of the dipole can only be conducted by trained personnel. Additional information can be found in the OSP for mapping the magnet. During normal operation, the terminals of the magnet are covered by plastic sheets for safety.

Magnetic Field

All required barricades, lights and signage shall be present when the system is activated, and these signs/barricades communicate the hazards present.

Thin Window

Hearing protection is required when working near the magnet when the system is under vacuum. When not in use, the window is protected from puncture with a cover.

3.7.3 Responsible Personnel

The individuals responsible for the operation of the pair spectrometer are shown in Table 3.5.

Name	Dept.	Extension [1]	e-mail	Comment
Alexander Somov	Hall D	5553	somov	Detectors
HallD Work Coordinator	Hall D	876-3940		Pair Spectrometer Magnet

Table 3.5: List of responsible personnel for the pair spectrometer.

3.8 Solenoid

The superconducting solenoid provides the magnetic field for the tracking of charged particles and hosts several detector packages including the Barrel Calorimeter, Central Drift Chamber, Forward Drift Chamber, Start Counter and the target. The length of the solenoid is 4 m and the diameter of the bore is 1.85 m. The solenoid consists of four liquid helium cooled superconducting coil sets that generate a magnetic field up to 2.0 Tesla with a maximum current of 1350 A.

3.8.1 Hazards

The hazards of the superconducting solenoid include the following:

- Electrical hazard
- Cryogenic hazard
- Vacuum hazard

- Magnetic field
- Stored energy
- Fall hazard

3.8.2 Mitigation

Electrical Hazard

The power supply for the solenoid operates with input voltages of 120 VAC and 480 VAC and is interlocked to a current limit of 1350 A. Maintenance and servicing of the power supply can only be conducted by "Qualified Electrical Workers". Additional information can be found in the OSP for the Hall D Solenoid Magnet –Cryogenic Operations [7] . During normal operation, connections at the power supply are made inside the cabinet that has interlocked doors. Insulated cables carrying current to the magnet are routed with cable trays with all exposed leads and terminations covered by nonconductive (0.25" thick Lexan) or expanded metal enclosures.

During fast dump or quench, high voltage spikes may be induced on current leads and voltage taps. The leads from the voltage tap wires connect to the control system wiring through current limiting resistors to reduce any current-voltage combination to within the Class 1 Electrical Classification of the EHS&Q Manual.

Cryogenic Hazard

Nitrogen and helium are two types of cryogen used to keep the coils superconducting. The total volume of liquid helium in the solenoid is about 450 kg. Proper insulations are installed on all piping accessible to personnel. In the event of a quench or loss of insulating vacuum event, relief valves on the helium and nitrogen vent generated gas. The valves vent above or away from personnel to prevent possible exposure. In the very unlikely event that the helium vessel ruptures into its vacuum vessel during a pressure spike, the vacuum vessels relieve into the bore of the magnet through relief valves. Channels in the yoke route most of the helium to the space beneath the magnet, between the concrete mounts. Coil 2 is the exception, where deflectors around its chimney-mounted relief valves direct any helium away from personnel.

The bore and the area beneath the solenoid are posted as ODH 1 areas and the rest of Hall D remains ODH 0 up to 32′. Appropriate ODH signs are posted at all entrances to the hall and an oxygen monitoring system is installed in the hall and operational.

Vacuum Hazard

The purpose of the vacuum system is to provide 10^{-5} Torr or better thermal insulating vacuum to four superconducting coils and one cryogenic distribution box. After liquid helium is introduced into the coils, a Loss of Vacuum (LOV) event with a full air inrush through even a 2 inch diameter hole can lead to very high heat transfer to the helium vessel with the resulting phase change in the liquid helium and potential high pressure expulsion from the vessel. We mitigate the possibility of such LOV events to "Extremely Low" with several enhancements. Thin or vulnerable portions of the vacuum vessel are armored with metal shields. We also added vacuum breaks between coils and distribution box to confine the loss to only one of the five insulating volumes. We further designed the vacuum valve control to be fool proof and fail safe to prevent an LOV by mis-operation.

Magnetic Field

When powered up to 1350 A, the solenoid can generate up to 2.0 Tesla field in the bore and up to 600 Gauss in the zones that extend somewhat beyond the magnet bore. The 5 Gauss boundary restricting access by personnel with surgical implants and bioelectric devices, the 200 Gauss crane boundary, and the 600 Gauss whole body boundary were found and recorded during the commissioning of the solenoid.

Strong magnetic field will attract loose ferromagnetic objects, possibly injuring body parts or causing serious damage to the detectors inside the bore of the magnet. Prior to energizing the magnet, a sweep of cordoned area will be performed for any loose magnetic objects. **A physical barricade is built around the 600 Gauss area to prevent personnel from accidentally entering the area. All personnel who must enter the 600 Gauss area will be trained to remove ferromagnetic objects from themselves.**

To prevent personnel with surgical implants and bioelectric devices from entering the 5 Gauss boundary, lighted warning signs are placed at the doors of the hall when the Solenoid is energized as well as flashing red beacons and personnel barricades are installed at the actual 5 Gauss contour. This 5 Gauss line is the labyrint door (with LED sign). The 600 Gauss line is baricaded and signed and also painted on the floor near the solenoid bore on both ends.

Stored Energy

At 1350 A, the total energy stored in the magnet is about 23 Mega Joule. The energy is dumped into a dump resistor upon sudden loss of hall electrical power. The total time for current run-down is 20 minutes in this event. An animated LED-sign above the power supply indicates that current remains in the conductors during this period.

The ”Hall D Solenoid Power Supply OSP” indicates that the doors to the power supply shall not be opened while this “Current in Magnet - Do Not Open” sign is lit.

Fall Hazard

Passive fall protection including guardrails and toe boards, is installed throughout the solenoid platform. SAF307, Ladder Safety Training, is required for all personnel who work on the ladders.

3.8.3 Responsible Personnel

The individuals responsible for the operation of the solenoid are shown in Table 3.6.

Table 3.6: List of responsible personnel for the solenoid.

Name	Dept.	Extension[1]	e-mail	Comment
Tim Whitlatch	Hall-D	5087	whitey@jlab.org	Solenoid
Beni Zihlmann	Hall-D	5310	zihlmann@jlab.org	Solenoid/PXI
Jonathan Creel	CRYO	5925	creel@jlab.org	Cryogenics
HallD Work Coordinator	Hall-D	876-3940		Power Supply
Nick Sandoval	Hall-B/D	6506	sandoval@jlab.org	PLC

3.9 Cryogenic target

The standard Hall D experimental equipment package includes a cryogenic target consisting of either liquid hydrogen (LH2) or liquid deuterium (LD2) operating at temperatures near 20 K. In addition by installing a heat shield around the target cell, it can be operated also with liquid ^4He (LHe).

The target comprises a small kapton target cell and condensing system that are contained within a vacuum-insulated scattering chamber. The scattering chamber is rigidly attached to a rail-mounted cart for easy installation into the Hall D solenoid. Most of the equipment for operating the cryotarget is also mounted on the insertion cart, including the control electronics, a small gas handling panel, and the hydrogen storage tanks. The gas panel, vacuum pumps, and scattering chamber are connected to a dedicated vent line leading outside the hall. A small, water-cooled compressor for the target refrigerator is located beneath the target on the Hall D floor and connects to the target via flexible lines.

3.9.1 Hazards

The target contains a condensed cryogenic fluid and is considered a pressure vessel. Sudden warming of the target due to a vacuum breach could result in rapid expansion of the target fluid. The system is designed to safely vent the excess pressure unless the vent lines are blocked by frozen hydrogen and/or frozen contaminates in the gas. The downstream portion of the scattering chamber consists of 1 cm thick Rohacell foam. The scattering chamber utilizes a thin beam-exit window at the downstream end. Failure of the foam extension or thin window could produce a loud noise, and could result in a failure of the target integrity. The target utilizes flammable gases (hydrogen and/or deuterium) during operation. Failure of the system could release flammable gas into the hall. The hydrogen/deuterium target gases and the helium used in the target refrigerator are potential ODH risks, and failure of either system could reduce the oxygen levels in the hall.

3.9.2 Mitigation

- The target system has been designed and constructed in accordance to AMSE standards, most notably ASME B31.12.
- During operation the foam extension and thin window are surrounded by the Hall D start counter and is therefore difficult to access.
- A protective shield shall be placed around the foam extension and thin window whenever start counter is not in place and the system is under vacuum.
- Personnel working near the target shall wear hearing and eye protection whenever the foam extension and window are exposed and the system is under vacuum.
- The target system utilizes redundant, ASME-compliant reliefs to prevent overpressurization of the system in the event of a vacuum breach.
- The system reliefs (gas panel and scattering chamber) and vacuum pump exhausts shall be tied to a dedicated vent line leading outside the hall. This line shall at all times be purged by an inert gas.
- The area around the target installation shall at all times be monitored for the release of flammable gases by the Hall D VESDA system.
- In the event of a hydrogen leak inside the scattering chamber, all potential ignition sources within the scattering chamber will be automatically deenergized by a vacuum switch set at 10 torr.

- The quantity of flammable gas (H2 or D2) is less than 100 g and is therefore considered a Class 0 installation (<600 g) and the rules and regulations for this installation shall be followed, notably:
  - The area shall be posted "Danger Flammable Gases. No Ignition Sources."
  - Combustibles and ignition sources shall be minimized within 10 feet or three meters of target's gas handling equipment, and piping.
- No cold, cryogenic components are accessible by personnel.
- The target does not operate in a confined space, and the total quantity of hydrogen/deuterium/helium in the system is under 1000 standard liters. This presents a negligible oxygen deficiency risk in Hall D and therefore is a Class 0 ODH installation.
- Hydrogen/deuterium shall be loaded into the system by qualified personnel only, and those personnel shall follow approved operational gas-handling procedures to minimize potential contamination of the target gas.
- The target control software will include numerous alarm set points (temperature, pressure, vacuum, heater power, etc) to alert users to potential problems.
- Pressure and temperature interlocks shall automatically power off the target refrigerator to minimize the possibility of freezing the hydrogen gas or introducing contaminates in the gas at subatmospheric pressure.

3.9.3 Responsible Personnel

The individuals responsible for the operation of the gas system are shown in Table 3.7

Name	Dept.	Extension	e-mail	Comment
Chris Keith	Target Group	5878	ckeith	

Table 3.7: List of responsible personnel for the target.

3.10 Detector Gas Supply System

The detector gas system supply provide the operating gas, an argon CO_2 gas mixture, to the two tracking chambers, the FDC and CDC. The gas is saturated with isopropyl alcohol vapor to protect against detector aging. The Argon and CO_2 gases are held in high pressure gas bottles outside Hall-D and pressure regulators reduce the high pressure to 50 psi before getting into the gas shed where the appropriate mixing is achieved using mass flow controllers (MFC) from BROOKS. After mixing and vapor enriching with isopropyl alcohol the gas is guided into the hall and fed to the detectors controlled by MFC. The exhaust of the detectors is connected to a bubbler system and the gas is vented to the hall.

3.10.1 Hazards

There is a high pressure gas system from the gas supply bottle (3000 psi max) past the regulator (50 psi max) into the gas shed up to the MFC. At that point the pressure drops to below 14 psi and the system is not a high pressure system anymore. The two gas types argon and CO_2 are mixed into a tank from which the gas is extracted and passing though an alcohol bubbler system inside a refrigerated area. The following hazards are identified:

- High pressure gas supply
- Low pressure mixing tank
- Flammable alcohol

3.10.2 Mitigation

A restricting orifice is installed outside the gas shed in the gas supply line to limit the amount of gas flow in the worst case scenario of a ruptured line in the gas shed. This restricting of flow will keep the gas shed an OHD class 0 room at any time.
The gas system is considered NOT a high pressure system after the MFC. The MFC themselves restrict the gas flow and are normally closed (closed at no power). In addition a mechanical relive valve, set at 14 psi is installed at the mixing tank to prevent any possible over pressure.
The alcohol resides inside a refrigerator to minimize evaporation and all electric circuitry has been removed from inside the refrigerator.

3.10.3 Responsible Personnel

The individuals responsible for the operation of the gas system are shown in Table 3.8

Name	Dept.	Extension [1]	e-mail	Comment
Nick Sandoval	Hall B/D	6506	sandoval	PLC
Beni Zihlmann	Hall D	5310	zihlmann	Contact

Table 3.8: List of responsible personnel for the detector gas system.

3.11 Forward Drift Chamber

The Forward Drift Chamber (FDC) is a 12,672 channel system consisting of four packages, each having six chambers (cells). Each chamber has a wire plane sandwiched between two cathodes consisting of readout strips. The chambers within a package have independent gas volumes, but are separated with a flexible mylar membrane. Positive (up to 2300V) and negative (up to 500V) HV is applied on the sense and field wires respectively with currents not exceeding 10 μA per HV channel. The detector (including cables) emits a total power of about 1500 Watt, of which about 900 Watt inside the magnet, due to the LV applied on the detector pre-amplifiers; a cooling system using Fluorinert is used to keep the temperature on the pre-amplifiers below 50^0 C.

3.11.1 Hazards

The hazards associated with the HV and LV are discussed Section 3.5. Damage to the detector can occur if the pressure in the chambers is more than 200 Pa above the atmospheric or if it is below the atmospheric pressure. Damage to the detector can occur if the pressure difference between the chambers within a package exceeds 30 Pa. In addition, damage to the equipment can occur if the cooling system fails while the pre-amplifiers are powered.

3.11.2 Mitigation

The gas control system is designed in a way to warn and prevent over/under-pressure in the chambers. The internal pressure in the chambers is constantly monitored to prevent high pressure differences between chambers within a package.

A hardware interlock turns off the pre-amplifier supply in case the cooling system fails.

3.11.3 Responsible Personnel

The individuals responsible for the operation of the FDC are shown in Table 3.9

Name	Dept.	Extension [1]	e-mail	Comment
Lubomir Pentchev	Hall D	5470	pentchev	Contact
Nick Sandoval	Hall B/D	6506	sandoval	PLC
Beni Zihlmann	Hall D	5310	zihlmann	Contact

Table 3.9: List of responsible personnel for the Forward Drift Chamber (FDC) system.

3.12 Central Drift Chamber

The Central Drift Chamber (CDC) is a straw tube chamber with 3522 straws 150 cm in length. The downstream end gas plenum has a thin aluminized Mylar window of 2 mil thickness. The anode wires are from made of 20 μm thick gold plated tungsten. The nominal high voltage (HV) applied to the wires is about 2100V. The detector is in the magnet bore but all the electronics is accessible from upstream. A low voltage (LV) system powers the 149 pre-amplifier cards each consuming about 1.5 Watt.

3.12.1 Hazards

The hazards associated with the HV and LV are discussed in Section 3.5. Damage to the detector may occur if the gas pressure inside exceeds $\sim$200 pascal at the downstream gas plenum. Damage to the electronics can occur if the cooling system fails while the pre-amplifiers are powered.

3.12.2 Mitigation

The gas control system is designed to prevent over-pressure at the downstream gas plenum by hardware. The internal pressure in the downstream gas plenum as well as the input and output pressure of the detector is constantly monitored and connected to the epics alarm system.

Temperature sensors are installed in the vicinity of the pre-amplifier cards to monitor the temperature and are connected to the epics alarm system.

3.12.3 Responsible Personnel

The individuals responsible for the operation of the CDC are shown in Table 3.10

Name	Dept.	Extension [1]	e-mail	Comment
Beni Zihlmann	Hall D	5310	zihlmann	Contact
Nick Sandoval	Hall B/D	6506	sandoval	PLC

Table 3.10: List of responsible personnel for the Central Drift Chamber (CDC) system.

3.13 Barrel Calorimeter

The barrel calorimeter (BCAL) is a lead-scintillating fiber matrix readout with 3840 S12045 Hamamatsu multi-pixel photon counters (MPPCs). The MPPC light sensors operate a bias voltage less than 76 V. Liquid coolant is circulated through the readout assemblies to set and maintain the temperature of the sensors at their operating temperature between 5 and 25°C.

3.13.1 Hazards

For electronic hazards, see Section 3.5. Damage to the equipment can occur if the temperature in the readout assemblies exceeds prescribed limits. If the system reaches low temperatures, condensation can form in the electronics of the readout assemblies. If the chiller fails and the power is on, temperatures will rise uncontrolled and also damage electronics.

3.13.2 Mitigation

An interlock system, based on PLCs, checks the temperature and humidity in the readout assemblies and coolant flow through the system. It shuts off the power to the MPPC electronics and the chiller in case limits are exceeded. Alarms are issued prior to activating the interlock.

3.13.3 Responsible Personnel

The individuals responsible for the operation of the BCAL are shown in Table 3.11.

Name	Dept.	Extension [1]	e-mail	Comment
Mark Dalton	Hall D	6931	dalton	JLab Contact

Table 3.11: List of responsible personnel for the BCAL system.

3.14 Forward Calorimeter

The forward calorimeter (FCAL) is a circular array of 2800 lead-glass blocks, each viewed by FEU 84-3 photomultiplier tubes. The high voltage to operate the photomultiplier tubes is generated internally to the base assembly using a Cockcroft-Walton voltage divider assembly. External supplies deliver 24 V to power the bases.

3.14.1 Hazards

For electronic hazards, see Section 3.5. The photomultiplier tubes are operated inside a dark room attached to the back of the lead-glass array, which allows trained personnel to operate the system when the bases are powered. Damage to the equipment can result if the photomultiplier tubes are exposed to room light.

3.14.2 Mitigation

The power to the photomultiplier tubes is interlocked using sensors that verify that the room is dark and closed. Access to the dark room is administratively controlled to trained personnel and crash buttons are installed if an experimenter need to exit quickly. Procedures for use of the dark room and a description of required training are detailed in D00000-01-06-P006.

3.14.3 Responsible Personnel

The individuals responsible for the operation of the FCAL are shown in Table 3.12.

Name	Dept.	Extension [1]	e-mail	Comment
Matt Shepherd	Indiana U.	812-856-5808	shepherd	Collaboration
Mark Dalton	Hall D	6931	dalton	JLab Contact

Table 3.12: List of responsible personnel for the FCAL system.

3.15 Time-of-Flight System

The time-of-flight (TOF) system is an array of plastic scintillator viewed by 2"-diameter Hamamatsu H10534MOD photomultiplier tubes. The photomultiplier tubes are powered using commercial CAEN A1535SN negative high voltage, where the typical operating voltage is 1750 V.

3.15.1 Hazards

The personnel hazard with these devices is the high voltage. This same hazard can damage the equipment if the voltage is left on when a tube is exposed to room lighting. For electronic hazards, see Section 3.5.

3.15.2 Responsible Personnel

The individuals responsible for the operation of the TOF system are shown in Table 3.13.

Name	Dept.	Extension [1]	e-mail	Comment
Paul Eugenio	FSU	850-325-0314	eugenio	Collaboration
Beni Zihlmann	Hall D	5310	zihlmann	JLab Contact

Table 3.13: List of responsible personnel for the time-of-flight (TOF) system.

3.16 Start Counter

The start counter consists of 30 scintillators surrounding the target, which are read out with Hamamatsu S10931-50P MPPCs. The operating bias for these sensors is less than 77 V. The system is air cooled.

3.16.1 Hazards

For electronic hazards, see Section 3.5.

3.16.2 Responsible Personnel

The individuals responsible for the operation of the start counters are shown in Table 3.14.

Name	Dept.	Extension [1]	e-mail	Comment
Werner Boeglin	FIU	305-348-1711	boeglinw	Collaboration
Beni Zihlmann	Hall D	5310	zihlmann	JLab Contact

Table 3.14: List of responsible personnel for the start counter system.

3.17 Triplet Polarimeter

The triplet polarimeter is a vacuum-housed silicon detector placed downstream of the active collimator and just upstream of the pair spectrometer, in the collimator cave. The detector is in a vacuum chamber that is part of the beamline. Signals from the silicon detector are sent through a vacuum feed-through to preamplifiers located next to the detector; those preamplified signals are then sent to fADC250s for readout. The operating HV for the detector is 200 V and the LV is ±12 V. There is a small fan that cools the preamp box, but this plays only a small role due to the ambient cooling that exists in the collimator cave. Within the vacuum chamber there is a converter tray that holds up to three converters; the converters are made of beryllium.

3.17.1 Hazards

For electronic hazards, see Section 3.5. The thin windows on the vacuum beamline in the collimator cave may cause a loud noise if window failure occurs, which may be hazardous to hearing. Beryllium is a hazardous material, and can cause various health issues if inhaled.

3.17.2 Mitigation

- To protect hearing in the event of a failure of thin windows in the beamline, ear protection should be worn at all times when working in the collimator cave (see Secs. 3.3, 3.4)
- Since the vacuum surrounding the polarimeter is part of the photon beamline, handling of the vacuum during beamtime should be done by the engineering group, led by the HallD Work Coordinator.
- A warning sign attached to the vacuum chamber warns that the chamber contains beryllium. When not in use, the beryllium foils are stored in a locked keybox at the upstream end of the collimator cave. Contact HallD Work Coordinator on how to access the foils.
- Only personnel who have received beryllium training may access and handle the beryllium foils.

3.17.3 Responsible Personnel

The individuals responsible for the operation of the polarimeter are shown in Table 3.15.

Name	Dept.	Extension [1]	e-mail	Comment
Alexandre Deur	JLab	7526	deurpam	JLab contact
Michael Dugger	ASU	602-832-3907	dugger@jlab.org	
Barry Ritchie	ASU	480-965-4707	Barry.Ritchie@asu.edu	
HallD Work Coordinator	JLab	876-3940		for beamline vacuum

Table 3.15: List of responsible personnel for the polarimeter system.

3.18 Total Absorption Counter

The total absorption counter (TAC) is a $20 \times 20 \times 40$ cm^2 block of SF-5 lead-glass located at the end of the Hall D beamline. During the regular production runs TAC is retracted from the beam to prevent a rapid radiation damage due to large photon flux. The TAC is inserted into the beamline using a horizontal translation stage only during the special calibration runs to determine the absolute normalization of the Hall D pair spectrometer detector. During these runs the electron beam current will be ≤ 10 nA and the thin 2×10^{-5} radiation-length radiator will be used. The TAC uses a single 5" Hamamatsu PMT as the photo-detector. These tubes are powered using commercial CAEN A1535SN negative high voltage, where the typical operating voltage is 2100 V.

3.18.1 Hazards

The personnel hazard with these devices is the high voltage. This same hazard can damage the equipment if the voltage is left on when a tube is exposed to room lighting. The TAC will suffer radiation damage if it is inserted into the photon beamline when running with a beam current ≥ 20 nA or with a radiator thicker than 2×10^{-5}. For electronic hazards, see Section 3.5.

3.18.2 Mitigation

In order to prevent excessive radiation damage to TAC, the motorized stage will be interlocked in EPICS with the electron beam current, the type of the radiator inserted into the beamline, scaler rates and high voltage of TAC. If a wrong configuration is detected, the slow controls software will automatically retract TAC from the beam.

3.18.3 Responsible Personnel

The individuals responsible for the operation of the TAC system are shown in Table 3.16.

Name	Dept.	Extension [1]	e-mail	Comment
Hovanes Egiyan	Hall D	5356	hovanes	JLab Contact
HallD Work Coordinator	Hall D	876-3940		translation stage

Table 3.16: List of responsible personnel for the total absorption counter (TAC) system.

3.19 DIRC

The DIRC is a plane of 4 independent boxes each containing 12 fused silica radiator bars with a size of 4.9 m x 35 mm x 17.25 mm, which are housed in an honeycomb shell with a thin aluminum skin. Each pair of bar boxes is optically coupled to a water-filled expansion volume, known as the Optical Box (OB). The Cherenkov photons from the radiators propagate through the water-filled OB and are detected by an array of Hamamatsu H12700 multi-anode photomultiplier tubes in each OB. The photomultiplier tubes are separated from the water by a fused silica window and are powered using commercial CAEN A1535SN negative high voltage modules, with a typical operating voltage of about 1000 V.

3.19.1 Hazards

For electronic hazards, see Section 3.5. The photomultiplier tubes are operated inside a dark box attached to the optical box, which allows for maintenance of the system while the bases are powered off. Damage to the equipment can result if the photomultiplier tubes are exposed to room light.

3.19.2 Mitigation

The power to the photomultiplier tubes is interlocked using proximity sensors that verify that the dark box is closed.

3.19.3 Responsible Personnel

The individuals responsible for the operation of the DIRC are shown in Table 3.17.

Name	Dept.	Extension [1]	e-mail	Comment
Wenliang Li	William&Mary		billlee@jlab.org	
Justin Stevens	William&Mary		jrsteven@jlab.org	
Tim Whitlatch	Jlab	5087	whitey@jlab.org	mechanical
Fernando Barbosa	Jlab	7433	barbosa@jlab.org	electronics

Table 3.17: List of responsible personnel for the DIRC.

3.20 Compton Calorimeter

The Compton calorimeter (CompCal) is a calorimeter made up by a matrix of 12 by 12 PbW04 crystals with a 4.1 cm by 4.1 cm hole for the beam. The dimension of each crystal is 2.05 cm by 2.05 cm by 20 cm. Hamamatsu R4125 PMTs are coupled directly to the crystals protected with a 50 μm mu-metal shield. The crystals are enclosed in a light tight box that has the capability to cool the crystals down to an operating temperature of about 15° C. The same type of chiller used for the BCAL is used in this application. The dew point is kept sufficiently low by flushing the detector box with dry nitrogen similar to the BCAL. The detector signals are digitized using flash ADCs (fADC250). The required HV is supplied by standard CAEN HV main frames used throughout the GlueX detector. The whole detector assembly is mounted on an xy-stage capable of moving the detector ± 15 cm in both dimensions to position each crystal onto the beam. The horizontal stage has an extended range to move the detector fully out of the beam into a parking position.

3.20.1 Hazards

The personnel hazard with these device is the high voltage. This same hazard can damage the equipment if the voltage is left on when a tube is exposed to room lighting. For electronic hazards, see Section 3.5. High humidity can cause condensation on the cool parts of the detector and damage the voltage divider and PMT. The xy-motion stage can move the calorimeter through the beam. The CompCal will suffer radiation damage if it is inserted into the photon beamline when running with a beam current ≥ 20 nA or with a radiator thicker than 2×10^{-5}.

3.20.2 Mitigation

The HV power supply is from CAEN with SHV connections that meet current safety standards in the HALL. The currents on the power supply are limited by software and hardware limits. These will automatically shutdown the HV in case of accidental exposure of the detector to ambient light. The dew point is kept low using dry nitrogen and the temperature of the detector is monitored using 6 RTDs one humidity sensor and one environment sensor using the standard Hall PLC system and alarm handler. The calorimeter motion stage has limit switches that prevent the calorimeter from being accidentally moved though the beam. Similar to the TAC, in order to prevent excessive radiation damage to the calorimeter during calibration runs, the motorized stage will be interlocked in EPICS with the electron beam current, and the type of the radiator inserted.

3.20.3 Responsible Personnel

The individuals responsible for the operation of the CompCal system are shown in Table 3.18.

Name	Dept.	Extension [1]	e-mail	Comment
Alexander Somov	Hall D	383-3446, 5553	somov	Detector
Vladimir Berdnikov	Hall D/C	6928	berdnik	Detector
HallD Work Coordinator	Hall D	876-3940		translation stage
Hovanes Egiyan	Hall D	5356	hovanes	motor control

Table 3.18: List of responsible personnel for the Compton Calorimeter (CompCal) system.

3.21 FMWPC

The FMWPC (forward multi wire proportional chamber) is the main detector system for muon identification in the charged pion polarizability (CPP) experiment located behind the FCAL on the downstream platform. There are six individual chambers sandwiched between heavy iron absorbers to help separate pions from muons. Each chamber has 144 sense wires separated by 1.016 cm. The sense wires gold plated tungsten with a diameter of 20 μm while the field wires are 50.8 μm thick made from copper-beryllium(1.5%) alloy. The central area of about 18cm diameter where the photon beam passes through has carbon tubes around the wires to render the area insensitive to particles. This area has also reduced material to minimize the material seen by the photon beam.

Each wire chamber is operated with a argon-CO2 gas mixture (90%/10%) delivered from the gas shed upstairs. The gas source is bottles located outside the gas shed similar to the gas storage for the FDC and CDC chambers. Each chamber will be flushed with this gas at about 300 sccm to ensure stable operation. This will amount to a total flow of about 1.8 l/m with the exhaust into HallD. This flow is comparable to the 2 l/m exhaust from the CDC at is maximum operating flow.

The HV applied to the wires is around +1765V provided by the same type of CAEN HV modules and main frame as is used for the FDC and CDC. Similarly the LV system that provides ±5 V is also the same type (Wiener) as is used for the FDC and CDC.

The pre-amplified detector signals are low voltage differential and will be digitized by the same type of flash ADCs as is used for the CDC and FDC with the same type of VXS crates used throughout HallD.

On the downstream end of the FMWPC four scintillator paddles are mounted two on either side of the beam line each with an active area of 120 cm long and 20 cm wide. They are oriented in a vertical position and are used determined the wire chamber efficiency while in operation. The scintillators have PMTs on both ends similar to the TOF detector and are also operated with HV based on the same type of equipment used for the TOF and the DIRC detectors.

3.21.1 Hazards

During installation, the cabling of the FMWPCs require special care, especially for the chambers that have vertical wires. For the vertical FMWPCs, the connectors are on top and are not easily accessible. They can be accessed using the chair lift, which can only be operated by trained personnel. The cabling will be installed by Nick Sandoval and Chris Stanislav in coordination with Hall Work Coordinator. Any service of the cables or connectors must be completed with similarly trained personnel in close collaboration with the Hall Work Coordinator.

The hazards associated with the HV and LV are discussed in Section 3.5. Since the chambers have very strong entrance and exit planes (honey-comb reinforced aluminum plates) no structural deformation is expected during operation.

3.21.2 Mitigation

Installation and connections of the cables for the vertical FMWPCs will be conducted by personnel trained on the use of the chair lift and familiar with the cabling plan. Shift personnel are not allowed to perform this task.

The gas supply to each chamber is controlled by mechanical rota-meters that limit the maximum flow to 500 sccm. They are equipped with a limiting orifice and a mechanical needle valve. The pre-amplifier electronics is shielded with an aluminum frame grounded to the common HallD grounding system. The shield itself is in direct contact with the HallD air that is cooled by the HallD air conditioning system providing sufficient cooling for the pre-amplifier electronics.

3.21.3 Responsible Personnel

Name	Dept.	Extension [1]	e-mail	Comment
Rory Miskimen			miskimen@physics.umass.edu	Detector
Elton Smith	Hall D	7625	smith@jlab.org	Detector
Beni Zihlmann	Hall D	5310	zihlmann@jlab.org	Detector

Table 3.19: List of responsible personnel for the FMWPC system.

Chapter 4

Appendix: Test Installations

The Pair Spectrometer produces electron and positron beams that are used to test parasitically different detector prototypes. The most permanent testing setups are listed in this appendix, while for the rest, individual OSPs are required.

4.1 Transition Radiation Detectors (TRD)

Several Transition Radiation Detector prototypes are being tested. They are all very similar mechanically and electrically and differ by the type of their amplification stage and readout configuration.

The TRD prototypes have outer dimensions of about 50×50 cm^2 including electronics. The front face of the detector is occupied by radiators made from fleece (lint), foam, or stack of thin foils. The detector itself has an entrance window for the gas volume, then a cathode at a negative potential of up to 6500 Volts followed by a drift volume of 2 cm depth filled with either Ar/CO2 or Xe/CO2 gas mixtures. The drift volume is followed by a micro-pattern amplification stage (GEM or Micromegas), which is different for the different prototypes and can be at a maximum negative potential of 3500 Volts. The signals are readout from a strip plane which is set at ground. Up to 480 channels are read out using the same pre-amplifiers as the FDC and CDC (see 3.11) and digitized with the standard HallD flashADC-125 (see 3.5). The data acquisition (DAQ) system is organized in an additional VXS crate using standard JLab modules, located in one of the drift chamber racks. The TRD DAQ system is independent from the main GlueX DAQ and requires only a trigger signal from the pair spectrometer detector.

4.1.1 Hazards

The detector cathodes require negative HV of up to 6.5 kV. The detectors also require low voltage (LV) for the operation of the pre-amplifier cards. The operating gas is Ar/CO2 or Xe/CO2.

4.1.2 Mitigation

The HV power comes from standard CAEN NIM modules. The HV cable used for the cathode is rated at 8kV. All the other HV cables are 5kV-rated. The LV is supplied by the standard HallD MPOD modules and cables (see 3.5). The gases used are non-flammable and non-toxic. The gas supply system is located in the gas shed (with all the required safety measures) and only low-pressure (< 1psi), low-flow (< 200ccpm)lines run to the detectors, see also 3.10.

4.1.3 Responsible Personnel

The individuals responsible for the operation of the TRD system are shown in Table 4.1.

Name	Dept.	Extension [1]	e-mail	Comment
Lubomir Pentchev	Hall D	5470	pentchev	Contact
Sergey Furletov	Hall D	5332	furletov	Contact

Table 4.1: List of responsible personnel for the transition radiation detector (TRD) system.

4.2 GEM detectors

Several GEM detectors are being tested that differ by their amplification stage and readout pattern, otherwise almost identical mechanically and electrically.

These detectors use gas electron multiplier (GEM) for signal amplification. The external dimensions of a GEM detector is 20 cm in width 20 cm height and 3 cm in thickness. The maximum HV is about 4.5 kV negative. The detector uses Ar/CO2 gas mixture. One GEM detector has 288 digitization channels read out via SRS (scalable readout electronics) system, a CERN-standard system that is used also in the other halls.

4.2.1 Hazards

The detectors require negative HV of up to 4.5 kV. The operating gas is Ar/CO2.

4.2.2 Mitigation

The HV system is a standard commercial product from CAEN with SHV connections that is in standard use throughout the lab. 5kV-rated cables are used. The gases used are non-flammable and non-toxic. The gas supply is located in the gas shed, that includes a high-pressure bottle, a regulator with a relief valve and a rotameter. Only low-pressure lines with limited flow run to the detectors, see also 3.10.

4.2.3 Responsible Personnel

The individuals responsible for the operation of the GEM system are shown in Table 4.2.

Name	Dept.	Extension [1]	e-mail	Comment
Lubomir Pentchev	Hall D	5470	pentchev	Contact
Kondo Gnanvo	UVA	7243	kagnanvo	Contact

Table 4.2: List of responsible personnel for the GEM detector system.

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