Experiment Safety Assessment Document (ESAD)
for
The Proton Charge Radius Experiment

April 26, 2016

Contents

Chapter 1

Introduction

This ESAD document describes identified hazards of the PRad 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. The document then addresses the hazards associated with all the experimental sub-systems of Experimental Hall B and PRad 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 to personnel by 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 protection manager Ed Douberly can be contacted at Office: 269-6638, Cell: (540)729-0095.

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 (Todd Kujawa) can be reached at 269-7006.

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 (Suresh Chandra) can be contacted at 269-7248.

2.5 Strong Magnetic Fields

Powerful magnets exist in all JLab experimental halls. Metal objects may be attracted by the magnet fringe field, and become 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. Metallic medical implants (non-electronic) may be adversely affected by magnetic fields. Loss of information from magnetic data storage devices such as tapes, disks, and 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

Not applicable for this experiment.

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 vessel 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 are 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 beryllia, 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

Not applicable for this experiment.

Chapter 3

Hall Specific Equipment

3.1 Overview

The following Hall B subsystems are considered part of the experimental endstation equipment for running the Proton Charge Radius (PRad) experiment engineering run. Many of these subsystems impose similar hazards, such as those induced by high voltage systems and vacuum systems. Note that a specific sub-system may have many unique hazards associated with it. For each major system, the hazards, mitigations, and responsible personnel are noted.

The material in this chapter is a subset of the material in the full Hall B operations manual and 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 Tie-in To Machine Fast Shutdown System

In order to make sure that hall equipment that should be tied into the machine fast shutdown (FSD) system has been properly checked, the hall work coordinator must be notified by e-mail prior to the end of each installation period by the system owner that the checks have been performed in conjunction with accelerator operations (i.e. checking that equipment's signals will in fact cause an FSD). These notifications will be noted in the work coordinator's final check-list as having been done. System owners are responsible for notifying the work coordinator that their system has an FSD tie-in so it can be added to the check-list.

3.3 Beamline

The control and measurement equipment along the Hall B beamline consists of various elements necessary to transport beam with required specifications onto the production target and the beam dump, and simultaneously measure the properties of the beam relevant to the successful implementation of the physics program in Hall B.

The beamline in the Hall provides the interface between the CEBAF accelerator and the experimental hall. All work on the beamline must be coordinated with both physics division and accelerator division in order to ensure safe and reliable transport of the electron beam to the dump.

3.3.1 Hazards

Along the beamline various hazards can be found. These include radiation areas, vacuum windows, high voltage, and magnetic fields.

3.3.2 Mitigations

All magnets (dipoles, quadruples, sextuples, beam correctors) and beam diagnostic devices (BPMs, scanners, beam loss monitors, viewers) necessary to transport and monitor the beam are controlled by Machine Control Center (MCC) through EPICS [1], except for specific elements which are addressed in the subsequent sections. The detailed safety operational procedures for the Hall B beamline should be 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 ARM of RadCon personnel,
- Vacuum in beamline tubes and other vessels,
- Thin windowed vacuum enclosures (e.g. the scattering chamber),
- Electric power hazards in the vicinity of magnets, and
- Conventional hazards (fall hazard, crane hazard, etc.).

These hazards are noted by signs and the most hazardous areas along the beamline are roped off to restrict access when operational (e.g. around the PRad target area). Signs are posted by RadCon for any hot spots. Survey of the beamline and around it will be performed before work is done on the beam line or around. The connection of leads to magnets have plastic covers for electrical safety. Any work around the magnets will require de-energizing the magnets. Energized magnets are noted by read flashing beacons. Any work on the magnets requires the ”Lock and Tag” procedures [2].
Additional safety information is available in the following documents:

– EH&S Manual [2];
– PSS Description Document [3]
– Accelerator Operations Directive [4];

3.3.3 Responsible Personnel

The beamline requires both accelerator and physics personnel to maintain and operate. It is very important that both groups stay in contact with each other to coordinate any work on the Hall B beamline. The authorized personnel is shown in table 3.1.

Name (first,last)	Dept.	Call [5]		e-mail	Comment
		Tel	Pager		
F.-X. Girod	Hall-B	6002		fxgirod@jlab.org	*1st Contact*
Stepan Stepanyan	Hall-B	7196		stepanya@jlab.org	*2nd Contact*
Michael Tiefenback	Accel.	7430	757-438-4523+	tiefen@jlab.org	*Contact to Hall-B*
Hari Areti	Accel.	7187	584-	areti@jlab.org	*Contact to Physics*

Table 3.1: Hall B beamline: authorized personnel.

3.4 Tagger Magnet and Power Supply

The tagger magnet is a large C magnet that is installed in the upstream alcove in Hall B. Its purpose is to deflect the full-energy electron beam through an angle of 30 degrees into the tagger beam dump, while deflecting lower-energy electrons into the detectors of the tagging system. The magnet is suspended from a steel support structure called the gantry. The tagger power supply is located on the floor in Hall B, next to the wall on the north side of the alcove. Power is supplied to the magnet by eight 535 mcm insulated copper cables, four supply and four return. The power cables run in grounded cable trays along the wall of the hall. The magnet is grounded by a bare 500 mcm copper cable that runs in the same cable trays. The ground cable is connected to the grounding plate in the hall floor, adjacent to the power supply. Additionally, the gantry steel is grounded directly to the magnet steel; ground does not rely on the support connections between the magnet and the gantry. Strain relief is provided for all cables. The power supply delivers up to 2400 A DC, at approximately 70 V. At full 2400 A excitation, the magnet can deflect a 6.1 GeV electron beam into the tagger beam dump. The power supply doors are interlocked. Additional interlocks are from a flow meter on the cooling water return for the magnet (not currently connected), and on a series of Klixon temperature gauges in contact with the magnet coils. The LCW system is used to cool both the power supply and the magnet. The power supply has an internal flow meter for its cooling water that is interlocked as well. Access to the high-field region is very restricted by the stainless steel vacuum extension to the magnet gap. Furthermore, the field is less than 100 Gauss at distances greater than 1 foot from the magnet, and less than 5 Gauss at distances greater than 10 feet from the magnet.

3.4.1 Hazards

The tagger magnets can present magnetic and electrical hazards when they are energized. The power supplies are potentially lethal electrical sources.

3.4.2 Mitigations

There are plastic covers on the connection panels for power leads on the magnets for electrical safety. Any work around the magnets will require de-energizing the magnets. Energized magnets are noted by red flashing beacons. Any work on the magnets requires a "Lock and Tag" procedure [2]. There will be beacons installed to notify when magnetic field is present. The magnet power supplies will be interlocked to the beam shutdown system (FSD). If any of power supplies will trip, beam delivery to Hall B will be interrupted.

3.4.3 Responsible Personnel

The tagger magnets will be maintained by the Hall B engineering group. The authorized personnel is shown in table 3.2.

Name (first,last)	Dept.	Call [5]		e-mail	Comment
		Tel	Pager		
Tech-on-Call	Hall-B				*1st Contact*
Doug Tilles	Hall-B	7566		tilles@jlab.org	*2nd Contact*

Table 3.2: Hall B beamline: authorized personnel.

3.5 PRad Target System

The Proton Charge Radius experiment in Hall B (PRad) utilizes a windowless, hydrogen gas jet target constructed by the Jefferson Lab Target Group. Room temperature hydrogen flows through a 25 K heat exchanger attached to a mechanical cryocooler, and accumulates in a 50 mm diameter, 40 mm long copper target cell located within a small (< 1 m^3) differentially pumped vacuum chamber. The target cell, which is suspended from the top of the vacuum chamber using a precision, 5-axis motion mechanism, has 25 μm thick kapton covers at both ends with 4 mm orifices for the electron beam. The covers are easily detachable, so different orifice sizes can be used to examine the effects of possible beam halo. The gas is pumped from the chamber using two large turbomolecular vacuum pumps with a combined pumping speed of 5700 l/s. The gas pressure within the cell is measured by a precision capacitance manometer and is expected to be approximately 0.6 torr during the PRad experiment, giving in an areal density of about 10^{18} H_2/cm^2. Two additional turbo pumps are attached to the upstream and downstream ends of the vacuum chamber to maintain a beamline vacuum less than 10^{-5} torr.

Hydrogen gas is metered into the target system using a precision, room-temperature mass flow controller, while gas pumped from the chamber is exhausted outside the experimental hall via the Hall B vent header. Mechanical interlocks are used to stop the flow of hydrogen gas in the event any of vacuum, pressure, or temperature failures. These interlocks ensure that the quantity of H_2 in the chamber is always less than 30 mg.

3.5.1 Hazards

The target utilizes hydrogen gas as the target material, while the cryocooler uses helium gas as a coolant. Therefore, a potential ODH risk is present. The total inventory of the H2 gas in the target system is about 1 liter, while the volume of helium gas necessary to operate the PTR is 81 liters[1]. The volume of Hall B is approximately 1.2 x 10^7 liters (437,500 ft^3). Release of the targets hydrogen/helium gases in this area would be completely negligible, decreasing the Hall B oxygen levels by less than 0.001%. Therefore, the gas jet target does not impact the ODH classification of this location. High-pressure cylinders of hydrogen, each containing approximately 8000 standard liters, will be used to supply gas to the target.

A few control electronics will be attached to an uninterruptable power supply (UPS), including the LS336 temperature controller and scattering chamber vacuum readout. This is primarily for monitoring reasons, because the system is designed to be intrinsically safe in the event of power outages. In all cases, the cryocooler simply turns off and the target slowly warms to room temperature. The (Normally Closed) valves that provides hydrogen gas to the target close, the upstream and downstream gate valves on the chamber close, and the turbo pumps spin down.

The volume of the vacuum chamber is approximately 0.26 m3, representing a stored energy of 26 kJ. This is less than the 100 kJ limit imposed by the Jefferson Lab EH&S manual for buckling analysis. It is also exempt from Code welding/brazing requirements. There are no thin windows on the chamber.

Two new components in the target system fall under the purview of pressure systems safety:
1) The gas handling panel in the experimental hall,
2) Chilled water lines between a pair of water chillers and the vacuum pumps and the cryocooler compressor.

The gas panel is constructed in accordance with ASME B31.3 (2012). It is supplied with gas from a standard H_2 cylinder, with regulator, located in the Hall B gas pad using existing pipes between the pad and the experimental hall. Relief valves located at the exit of the regulator ensure a maximum gas pressure of 30 psig in the gas handling system.

[1] Cryomech Inc., private communication

Chilled water is supplied to the turbo pumps and cryocooler compressor from a pair of NESLAB ThermoFlex 10000 chillers, each with a maximum outlet pressure of 60 psi. All fittings, lines and other components in the chilled water system are rated to a minimum working pressure of at least 90 psig. The chilled water system is now considered a low hazard system (stored energy less than 1000 ft-lbf) and is exempted from the pressure system program requirements now in effect. Nonetheless, it was constructed to and is in compliance with ASME B31.3 (2012) Cat D.

The PRad target utilizes hydrogen gas, which is flammable in air over a range of concentrations from 4% to 75%, by volume. The quantity of hydrogen gas inside the PRad target system (comprising the gas panel, internal piping and target cell, and target chamber) is about 1 standard liter, or 0.09 grams. Therefore the system may be classified as a Class 0 risk ($Q<0.6$kg). All potential ignition sources on the gas panel (pressure transducers and flow controllers) meet CLASS I DIV 1 GROUPS A, B, C, & D standards. All thermometers inside the chamber operate at very low voltage and currents. A 100 W heater is used to control the cryocooler temperature at about 25 K. It is automatically de-energized by the 1 torr pressure switch on the scattering chamber. Therefore the maximum quantity of H_2 that can be in contact with this potential ignition source is only 26 mg. The chamber will be evacuated of hydrogen and purged with an inert gas such as nitrogen or argon before it opened to air.

A standard cylinder of hydrogen (approx. 8200 standard liters) is used to provide a constant supply of H_2 gas to the target system. This cylinder is part of the standard Hall B liquid hydrogen target, is located in the Hall B gas pad, away from any ignition sources. It is capped when not in use and properly labeled Danger-Flammable Gas. The lines leading from the cylinder to the target installation have also been used for several years for the Hall B liquid hydrogen target. Any necessary extensions to these lines will be constructed in accordance to ASME 31.3 (2012).

All pump exhausts and relief lines from the target are attached to the same Hall B vent header that has been utilized for the Hall B liquid hydrogen target. A steady purge of inert nitrogen gas is used to prevent a flammable mixture in the vent. Any necessary piping between the PRad target installation and the vent header will be constructed in accordance to ASME 31.3 (2012). The vent header will be properly labeled Danger Flammable Gas. The Hall B flammable gas monitoring system will be in operation throughout the PRad experiment.

No cold portions of the PRad target are accessible by personnel. Due to the windowless nature of the target, no condensed cryogenic fluids can be accumulated within its volume, and the total quantity of vapor is only about 0.03 g.

Cernox thermometers monitor the temperature of the fluid at numerous locations, including the cryocooler cold head, the copper target cell, and the vapor inside the cell itself. The temperature of the cold head is regulated at about 25 K using a Lake Shore Model 336 temperature controller. Normally open contacts on the controller turn off the cryocooler before the temperature reaches the condensation point of H_2, about 22.3 K at 1 atm.

Frozen contaminates in the H2 gas could impede or stop the flow of gas to the target cell. However this does not represent a hazard, as no condensed fluids exist in the system. Nevertheless precautions are made to ensure the purity of the target gas for the PRad experiment. Detailed gas handling procedures will be utilized to ensure that no gases other than hydrogen (or helium, for purges) are present in the system. Only high purity hydrogen gas (research or scientific grade) will be used in the target, and this will be introduced into the cell through a purifier installed on the gas panel for further removal of water and oil.

3.5.2 Mitigations

The high pressure hydrogen cylinders will be located in the Hall B gas shed and connected to the target gas panel using existing lines in Hall B. The target is designed such that upon power failure the Cryocooler shuts off, gas valves close. The vacuum system of the target is designed to minimize volume and avoid any thin windows. A pressure switch on the chamber will automatically shut off hydrogen gas to the chamber at 1 torr. A check valve with Cv=0.66 is installed on the chamber to prevent overpressure, should the switch fail. All pressure systems of the target have been design and constructed in compliance with relevant ASME pressure system codes. Hazards will be mitigated by routine inspection, testing, and replacement of system components. The flammable gas hazard will be mitigated by flammable gas and hydrogen monitoring, use of non-sparking tools, minimization of ignition sources, compliance with ASME 31.12 for hydrogen piping, proper posting of Flammable Gas Area, inerting system prior to maintenance and repair, leak testing system before operating system, and following approved procedures during operation. Cryogenic system hazards will be mitigated by temperature and pressure alarms, temperature interlocks, minimization of target gas and volume, and Documented gas handling procedures.

The emergency and interlock response procedures are as follows:

- Flammabale gas alarm If the flammable gas alarm goes off, notify others, press the KILL switch on the target control panel, and evacuate the area.
- ODH alarm If the ODH alarm sounds, notify others, press the KILL switch on the target control panel, and evacuate the area.
- Low temeperature interlock The Lake Shore 336 temperature controller has normally open relays that will turn off the cryocooler if the temperature of the target gets too close to the condensation point of hydrogen. The system will slowly warm. This is not considered an emergency. Contact the Target Expert.
- Vacuum interlock A 1 torr vacuum switch will close electric valves HPA-1 and HPA-2 located on the target gas panel. This is not considered an emergency. Contact the Target Expert.

- Vent purge interlock A pressure switch is installed on the hydrogen vent line to ensure that it is adequately purged with an inert gas such as nitrogen. An alarm in the counting house will sound if this switch energizes. Check that the purge line is properly connected and that gas is flowing into the vent. If it is not, contact the Hall B work coordinator. If gas is flowing but the switch is still energized, contact the Target Expert.

The inspection and maintenance schedule is as follows:

- Every run
  Visually inspect all process piping.
  Leak check all process piping.
  Confirm operation of electronic monitoring and control hardware.
  Confirm all thermometer readouts (295 K at room temperature).
  Confirm operation of pressure switches PAH1.
  Confirm operation of check valve CV1.
  Zero pressure transducers PI1 and PI2 and calibrate against their corresponding pressure gauges.
  Inspect filter/purifier element FP1.
  Review and if necessary update the safety and operation manuals for the PRad target.
  Visually inspect vacuum pumps.
  Visually inspect the PTR, its compressor and Aeroquip connections.
  Visually inspect water-cooling piping for PTR compressor and turbo pumps.
  Confirm operation of flow switch for PTR compressor.
  Confirm PTR helium charge.

- Every year
  Have pressure gauges PI1 and PI2 calibrated by a vendor certified to JLab standards.

- Other
  Inspect/test all relief and check valves in the system every two years.
  Replace adsorber in PRT compressor after 20,000 hours of operation (consult PRT manual).

3.5.3 Responsible personnel

The target system will be maintained by the Hall B engineering group.

Name	Dept.	Phone	email	Comments
Target-on-call	Hall-B			1st contact
C. Keith	JLab Target Group		ckeith@jlab.org	2nd contact

Table 3.3: Personnel responsible for the target.

3.6 Vacuum Systems

The Hall B vacuum system consists of three segments, all interconnected. The beam transport line consisting of 1.5 to 2.5 inch beam pipes, the Hall B tagger magnet vacuum chamber, and for the PRad experiment a large ∼5m long vacuum chamber extending from the target to the PRad detector system. There is a 1.7m diameter 63 mil Al. window at one end of the vacuum chamber, just before the PRad detectors. The tagger vacuum chamber also has a large window, 8 inches over 30 ft Kevlar-Mylar composite window. The vacuum in the system is provided by a set of rough, turbo, and ion pumps and it is maintained at the level of better than 10^{-5} Torr.

3.6.1 Hazards

Hazards associated with the vacuum system are due to rapid decompression in case of a window failure. Loud noise can cause hearing loss. Also, there is a hazard related to the GEM chamber being sucked into the vacuum chamber in case of an accidental puncture of the vacuum window.

3.6.2 Mitigations

The PRad experiment is set up on level 1 of the Hall B Space Frame. This area will be roped off whenever the tank is under vacuum and warning signs limiting access will be posted Safety glasses and hearing protection will be required to enter level 1. A window cover has been fabricated from 1/8 thick aluminum to protect the window from damage due to something falling into the window. This cover will be attached to the window at all times except when the experiment is running. The protective window cover will be installed or removed only when there is no vacuum in the tank. This will remove the stored energy in the tank so people can work near the window. All operations near the window should be performed by authorized personnel only. The operations include but not limited to installation and removal of widow cover, connection of the beam pipe to the window. Any detector maintenance/repair work must be done only when there is no vacuume in the chamber and protective caver installed.

3.6.3 Responsible personnel

Name (first,last)	Dept.	Call [5]		e-mail	Comment
		Tel	Pager		
Tech-on-Call	Hall-B				*1st Contact*
Doug Tilles	Hall-B	7566		tilles@jlab.org	*2nd Contact*

Table 3.4: Hall B beamline: authorized personnel.

The vacuum system will be maintained by the Hall B engineering group. The authorized personnel is shown in table 3.4.

3.7 GEM Tracker

The Gas Electron Multiplier (GEM) tracker consists of a pair of large area 1.2 m$\times$ 0.6 m three layer ionization chambers. Both chambers will be powered by a single HV power supply. The signals will be read out via HDMI cables between the on-board pre-amplifier and digitizer boards and the SRS crate located next to the detector. A pre-mixed gas of 70% Argon and 30% CO_2 will be supplied continuously to the chamber.

3.7.1 Hazards

Hazards to personnel include the high voltage which biases the chamber, and the low current which powers the readout electronics.

3.7.2 Mitigations

Hazards to personnel are mitigated by turning off HV and LV power before disconnecting cables or working on the chambers and internal electronics.

3.7.3 Responsible personnel

Individuals responsible for the system are:

Name	Dept.	Phone	email	Comments
Kondo Gnanvo	UVa		nilanga@jlab.org	First contact
Nilanga Liyanage	UVa		kg6cq@virginia.edu	2nd Contact
Krishna Adhikari	MSU		adhikari@jlab.org	3rd Contact

Table 3.5: Personnel responsible for the GEM tracker.

3.8 Electromagnetic Calorimeter

The Electromagnetic Calorimeter (HYCAL)will be located approximately 7.4m (run configuration) or 8.7m (calibration configuration) upstream of the center of the CLAS12.

It consists of 1700 lead glass and lead tungstate detector modules, each with photomultiplier tubes with readout enclosed inside a temperature controlled enclosure. Each module is supplied with high voltage and is equipped with readout of dynode and anode signals. In addition, an LED based light monitoring system is used to deliver a pulse of light to each module via a fiber optic cable. The HYCAL will sit in two positions along the beamline. In the run configuration HYCAL will sit on a stationary cart, and in the calibration configuration it will be mounted on a transporter which will enable motion in the horizontal and vertical directions. The detector has overall dimensions of 1.5m 1.5m and will be centered on the beamline during production data taking. A 4cm 4cm hole at the center of the detector will allow the passage of the primary electron beam to the beam dump. Additionally, a Total Absorption Counter (TAC) will be placed approximately 1m downstream of the HYCAL (when it is in run position). These will be placed on a common cart which has the capability of moving them in and out of the beam with horizontal motion.

3.8.1 Hazards

Hazards associated with this device are electrical shock or damage to the PMTs if the enclosure is opened with the HV on. There is also hazard associated with coolant leak.

3.8.2 Mitigations

Whenever any work has to be done on the calorimeter, whether it will be opened or not, HV and LV must be turned off. Turn chiller off if enclosure will be opened for maintenance. Any large (more than couple of degrees in C) must be investigated to make sure that there are no leaks.

3.8.3 Responsible personnel

The authorized personnel is shown in table 3.6.

Name	Dept.	Phone	email	Comments
A. Gasparian	NC A&T		gasparan@jlab.org	1st contact
E. Pasyuk	Hall-B		pasyuk@jlab.org	2nd contact

Table 3.6: Personnel responsible for HYCAL.

3.9 CLAS12 Construction work

The main 12 GeV activity in Hall-B during the PRad run will be assembly of the CLAS12 Torus magnet. Beam running would occur during evenings, nights, and weekends or during other periods when it would not conflict with the regularly scheduled assembly of the CLAS12 Torus coils.

3.9.1 Hazards

There are no personal hazards associated with the running over evenings, nights, and weekends, and continue with torus assembly during the normal work hours. The only hazard is possible delays of start of the torus work after beam the delivery due to possible activation of beamline parts close to the torus assembly fixtures.

3.9.2 Mitigations

Every time Hall will switch from beam running to torus assembly, a fully survey of the hall will be conducted and Hall will be brought to "Restricted Access". Normally this will happen very early in the morning of work day (6am). If elevated radiation near torus assembly fixtures are found, work on torus must be delayed until conditions are acceptable.

However, we do not expect any excess radiation in the Hall or activation of any beam line components near the torus assembly area. The PRad target is located $\sim$ 10 meters upstream of the assembly area and it is a very thin gas flow target. Only tuned electron beam with less than 10 nA current, will be transported in vacuum through hall to the target. If beam conditions are not acceptable, which may result excess radiation, beam tune will be performed. Every time beam tune is required the Hall-B tagger magnet will be energized and beam will be dumped on the Hall-B tagger dump, shielded hole in the floor $\sim$ 15 meters upstream of the torus assembly area.

3.9.3 Responsible Personnel

Individuals responsible for the coordination of the torus assembly and PRad run:

Name	Dept.	Phone	email	Comments
PDL	Hall-B			1nd contact
E. Pasyuk	Hall-B		pasyuk@jlab.org	contact
D. Kashy	Hall-B		Kashy@jlab.org	contact

Table 3.7: Personnel responsible for coordination of the PRad run and the torus assembly.

Chapter 4

PRad Specific Addendum

4.1 Running Conditions

The PRad experiment will perform a high precision measurement of the proton charge radius. The energy of the electron beam will be 1.1 GeV and 2.2 GeV, the beam current for production running 10 nA. A photon radiator of thickness 10^5 radiation lengths will be used at currents of 0.1 nA. A very thin hydrogen gas flow target with a thickness of 10^{18} atoms/cc will be placed in the electron beam. These targets will be located approximately 15m upstream of CLAS12 center. The CLAS12 will not be used for this experiment. A multichannel calorimeter, the HYCAL, will be located approximately 7.4m (run configuration) or 8.7m (calibration configuration) upstream of the center of the CLAS12. It consists of 1700 lead glass and lead tungstate detector modules, each with photomultiplier tubes. Each module is supplied with high voltage and is equipped with readout of dynode and anode signals. In addition, an LED based light monitoring system is used to deliver a pulse of light to each module via a fiber optic cable. There will be a pair of GEM chambers for charged particle tracking on the upstream side of the HYCAL. The HYCAL will sit in two positions along the beamline. In the run configuration HYCAL will sit on a stationary cart, and in the calibration configuration it will be mounted on a transporter which will enable motion in the horizontal and vertical directions. The detector has overall dimensions of 1.5×1.5 m^2 and will be centered on the beamline during production data taking. A 4×4 cm^2 hole at the center of the detector will allow the passage of the primary electron beam to the beam dump.

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