Experiment Safety Assessment Document for the E05-115 experiment (HES/HKS)

August 19, 2009

Contents

1 Introduction and Scope of this document

This Experiment Safety Assessment Document follows the outline for this document as given in Section 3120-C of the Jefferson Lab EH&S Manual, and describes specic hazards existing with the HES/HKS Experiment Equipment in Hall C, and the specic measures installed for hazard mitigation. Furthermore, responsible personnel are listed. This document does not attempt to describe the function or operation of the various subsystems. Such information can be found in various standard references on particle and nuclear physics instrumentation and in the Hall C Operating Manual as well as the HES/HKS Wiki. Some specific subcomponents, e.g. beam line instrumentation, and their regular operation procedures are described in more detail in the Hall C Howtos and References, accessible from the Hall C web page (http://www.jlab.org/Hall-C/), or, in some case, in the older Hall C Operating Manual.

The HES/HKS experiment uses almost none of the standard Hall C equipment. Therefore, the *Experiment Safety Assessment Document for the Hall C Base Equipment* and the experiment specific document have been merged into this document. Only sections relevant to the current experiment have been incorporated from the Base Equipment document. In the unlikely and unplanned event that any of the base equipment (e.g. SOS or HMS) needs to be operated, responsible personnel need to refer to the Base Equipment document.

2 Description of Experimental Equipment

Hall C experiments E05-115 (HKS) and E02-017 (LIFETIME) will employ a new hypernuclear spectroscopy system which is not part of the standard Hall C equipment. The new and few existing equipment items are:

1. a modified beam line (pre-chicane) consisting of three magnets and two beam line girders that hold instrumentation
2. a solid target system
3. a dipole magnet (Splitter)
4. an electron spectrometer (HES) consisting of three magnets, QQD, and associated detector package
5. a kaon spectrometer (HKS) consisting of 3 magnets, QQD, and associated detector package
6. power supplies for HKS & HES dipoles
7. a local photon beam dump
8. a fission chamber.
9. Hall C Counting house, including CH electronics and upstairs auxiliary electronics room.

The locations of the two new spectrometers, HES and HKS in Hall C, are shown in Fig.1. The LIFETIME experiment will parasitically use the bremsstahlung photon beam; it will be installed in front of the photon beam dump.

Again, this document does not describe the function or operation of the various components. That information can be found in the various ”Operations Manuals” and ”How-To” documents. The following will identify the hazards associated with the equipment only and explain the mitigation of such hazards.

3 General Issues

The EH&S manual can be found on the web at `http://www.jlab.org/ehs/ehsmanual/index.html`. The principal contacts for the JLab EH&S group are

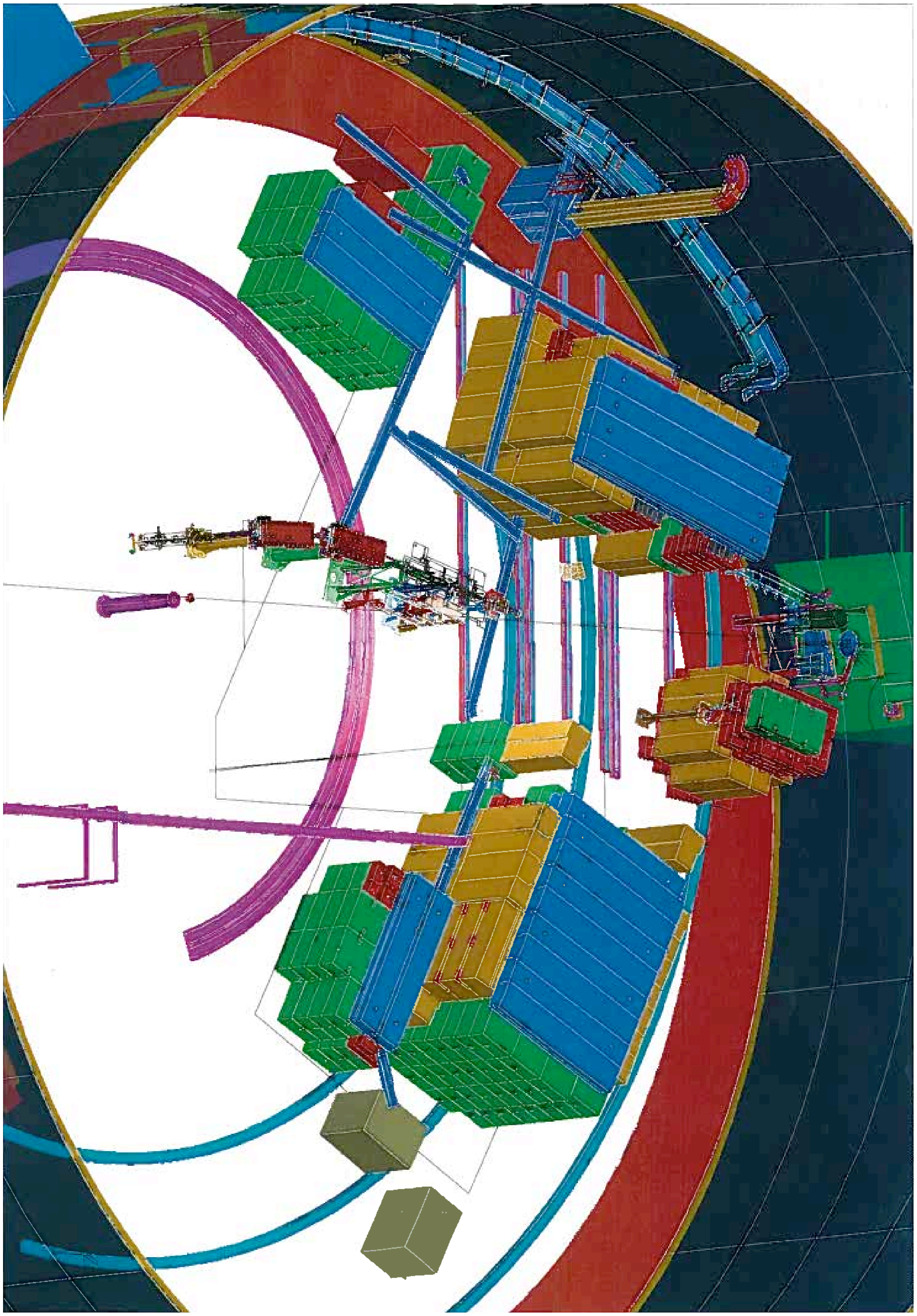

Figure 1: Expected Hall C setup of the HKS and HES spectrometers.

- Bert Manzlak - x7556 (Physics EH&S)
- Charles Hightower - x7608 (Physics EH&S)

The “Standard” Hall C base equipment briefly mentioned in this section will be utilized in the E01-011 (HKS) and E02-017 (LIFETIME) experiments. The safety procedures for the standard items listed below can be found in the general Hall C ESAD attached to this experiment specific ESAD.

4 Flammable Gas Systems

Hall C uses several flammable gas systems. Most notable are the hydrogen and deuterium flammable gas systems associated to the cryogenic targets. These systems will not be used in this experiment.

Furthermore, the Gas Handling System (GHS) providing gas for the HES and HKS drift chambers uses a 50:50 mixture (by volume) of argon and ethane gas. New gas connections will be installed from the gas handling system to both of the drift chambers of the HKS and Enge spectrometers. The gas is mixed in a specially-built GHS which passes the mixed gas through an alcohol (isopropanol) bubbler before passing it to the chambers. The gas flow is approximately 300 SCCM. Ethane is a flammable gas and should be treated accordingly. Argon is supplied in an A-cylinder under high pressure $P \approx 2000$ PSI. This confined high pressure gas represents a tremendous amount of stored energy. Care should be taken when handling these high-pressure bottles.

5 Electrical Systems

Hazards associated with electrical systems are the most common in the Hall C environment. Almost every subsystem requires AC and/or DC power. Due to the high current and/or high voltage requirements of many of these subsystems the power supplies are potentially lethal.

5.1 AC Power

Aside from the resetting of circuit breakers you should not attempt to solve any problems associated with AC power distribution without consulting responsible personnel.

Note that eye protection and non-flammable long sleeved clothing (leather gloves are optional) must be worn to even operate a 110 V breaker. Appropriate PPE will be available in the Hall close to the SOS power supplies as well as in the counting house.

Anyone working on AC power in Hall C must be familiar with the EH&S manual and must contact one of the responsible personnel.

- Bill Vulcan - x6271
- Joe Beaufait - x7131

5.2 Remote Control Systems

The remote control systems to operate the target and the HES and HKS collimator boxes are all located at the back side of the SOS power supplies (close to the entrance door to Hall C). Regular operation occurs through RS232 (or RS485) communication with the respective stepper-motors or BDS5 motors/actuators. Brake cables are added to prevent vertical ladders from falling in case of a power loss. All systems are equipped with emergency buttons.

Hazard Mitigation All non-routine maintenance shall be performed in strict accordance with the Jefferson Lab EH&S Manual, and in particular, with the chapters on Lockout, Tagout, and Electrical Safety.

5.3 High Voltage

The HES/HKS detectors in general require High Voltage, up to 3000 Volts, drawing currents up to a maximum of 3 mA. These voltages are provided by the CAEN SY403 high voltage supplies on the second floor of the counting house, which can deliver up to 3000 Volts at up to 3 mA current per channel. The following detector systems require this kind of voltages:

- HES and HKS Drift Chambers (about 2700 V)

- HES and HKS Scintillator Hodoscopes (about 2000 V)
- HKS aerogel Cherenkov detectors (about 2000 V)
- HKS water Cherenkov detectors (about 2000 V)
- HKS Lucite Cherenkov detectors (about 3000 V)
- Beam Loss Monitors in the Hall C Beam Line (about 1200 V)

Note that in addition the cold cathode gauges which are used to measure the pressure in the spectrometers and/or beam line utilize high voltage!

Hazards These High Voltages represent a potential hazard to personnel as well as a potential source of ignition.

Hazard Mitigation Cable and SHV connectors are shielded and meet existing EH&S standards. Common guidelines for safe operation have been established and are outlined in the Hall C Operating Manual. The operating policy is to turn off the CAEN High Voltages before work occurs around the detector that does not absolutely require the HV. DO NOT attach/remove HV cables when voltages are present on the channels (a red LED above each channel indicates the presence of a voltage). Turn off the main HV supply when attaching/removing HV cables. Several safety measures are taken to prevent the voltage divider bases from becoming sources of ignition:

- Current limiting and trip on overcurrent at the CAEN HV supply.
- The base PC boards are are enclosed in a metal housing (note that at only 9 Watts of power per channel is available).

5.4 Data Acquisition Electronics

Dedicated electronics, NIM, CAMAC, VME, and Fastbus is located in the Hall C Counting House, as well as underneath the two detector platforms and in dedicated electronics bunkers in the Hall. Most of the electronics require DC power. These DC voltages are provided by the power supplies of the crates in which the modules sit. There are several powered NIM crates, each with a power supply that requires 115 VAC input and provides approximately 200 Watts of power on +/- 6, 12, and 24 VDC output lines. There are 3 CAMAC crates which also require 115 VAC input, and provide a maximum of 400-500 Watts. There are also 3 VME crates, whose power supplies provide approximately 500 W. These all run off of clean power, which is provided from power strips installed in the racks, and use standard power cords. There are also 4 Fastbus crates which require 208 VAC input, and can provide a maximum power output of roughly 4000 W. While the NIM, CAMAC, and VME crates contain their own power supplies and are therfore fairly well protected, the Fastbus power supply is separate from the crate and does not provide intrinsic protection for the power leads and connections. Extra precautions must be taken to use these crates safely. There will be shields installed over the back of the fastbus power supplies to prevent contact with the power leads.

6 Fire Hazards

Fire Hazards are associated with the previously mentioned Electrical Hazards due to the power useage of the electronics. Furthermore, there are Fire Hazards associated with the use of flammable gases and/or materials. Flammable gases are discussed separately (Section 2.3 and 2.13). All hodoscope materials are in principle flammable. While encased in aluminum foil, if exposed to a direct flame these plastic materials would eventually melt. The elements would lose structural integrity, sag or fall to the floor, and the melted elements would likely be exposed to air and burn. The largest quantity of flammable material in Hall C is the insulation on the many power and signal cables. The hazard is minimized by using insulation that meets the required flammability codes and installing it in an approved manner. Still, workers must be aware of the presence of this large volume of fuel.

Hazard Mitigation

The spectrometers (and Hall C in general) are protected by a VESDA smoke detection system. The head sensitivity of the VESDA is 0.15 to 0.003 %, which means the system is sensitive to a few molecules per liter of air.

The HES and HKS magnet coils are protected from overheating (and hence fire) by a set of Klyxons (temperature-sensitive switches) which are interlocked to the power supplies. Both detector huts have gas monitors which are sensitive to Ethane gas leaks. Similar sensors are installed in the gas shed and inside the junction box where the gas lines first enter the hall. If a leak is detected, an alarm will go off in the Hall C Counting House and the main valves for ethane and argon supply in the gas mixing shed will be closed.

- Exits routes from the detector platforms should meet the emergency exit requirements and emergency exit signs and paths are posted.

- Familiarization with the above exit routes should be included in the experimental specific safety training requirement for all experimentalists who will participate in these experiments (Hall C walk through).

7 Magnets and Magnet Power Supplies

The experiment utilizes a large number of electromagnets, all resistive. Both the HES and HKS are QQD spectrometers with normal conducting coils. In addition, there will be a number of magnets along the beam line, notably the Splitter magnet, which is also part of the spectrometer system.

The magnets in the experimental areas are typically energized by remote control. During major down times the magnets are powered down for personal safety reasons as well as to reduce electrical power consumption. During short interruptions of beam delivery, with hall personnel entering the hall in the controlled access mode, the magnets are typically left energized. The main reason is that the time constants of large size magnets are long (of the order of hours), and frequent ramping or cycling will lead to inefficient operation. The principal hazards associated with the magnets are:

Electrical All the spectrometer magnets, and some of the beam line magnets, are high current devices ($I_{max} \approx 1100$ Amps). The power supplies that provide this current are potentially lethal. The most exposed and hence most dangerous places are inside the supplies themselves and at the magnet power leads.

Magnetic The spectrometer magnets produce large fields ($B_{central} \approx 10$ kG). The magnets all have return yokes and thus the external fields (near the magnets) are not nearly as large as the central fields but they may still be significant (up to about 1 kG). The raster magnets do not have a return yoke and may have external fields of a few hundred Gauss. Personnel working in the proximity of energized magnets are exposed to the following magnetic hazards which are all mitigated:

- danger of metal tools coming into contact with current leads, shorting out the leads, depositing a large amount of power in the tool, vaporizing the metal, and creating an arc.
- danger of metal objects being attracted by the magnet fringe field, and becoming airborne, possibly pinching body parts.
- danger of cardiac pacemakers or other electronic medical devices no longer functioning properly in the presence of magnetic fields.
- danger of metallic medical implants (non-electronic) being adversely affected by magnetic fields.
- lose of information from magnetic data storage devices such as tapes, disks, credit cards.

LCW The magnet coils and the magnet power supplies for both spectrometers as well as the beam line chicane magnets are all cooled by the Low Conductivity Water, LCW, system. This is a high pressure system, P = 240 PSI, and an unconfined stream of water at this pressure could cause injury.

Fire There also exists a potential fire problem associated with the high current power supplies. A short in one of the coils, or insufficient water cooling may lead to a fire in the power lines or the coils.

7.1 Hazard Mitigation

Two different modes of operation need to be distinguished: (1) *routine operation* involving work in the vicinity of the magnets, but *not* in close proximity to the electrical connections, and *not* involving any work that could result in purposely getting into contact with the coils or the leads, and (2) *non-routine operation* involving work on or near the exposed current conductors or connections (typically requiring removal of the shield) or any work that could result in contact, intentional or otherwise, with the coils or the leads.

Routine Operation The following measures shall be taken by the cognizant hall engineer (or his designee) to mitigate the hazards during routine operation:

- The current carrying conductors must be protected against accidental contact or mechanical impact by appropriate measures (e.g. run cables in grounded metal conduits or cable trays).
- All exposed current leads and terminations are covered by non-conductive rubberized tape in such a manner as to make it impossible for personnel to accidentally touch exposed leads with either their body or with a tool.
- Whenever a magnet is energized, a flashing light on the magnet or on the magnet support structure must be activated to notify and warn personnel of the associated electrical and magnetic field hazards.
- Administrative measures shall be implemented, as appropriate for the situation, to reduce the danger of metal objects being attracted by the magnet fringe field and becoming airborne. (Note that for most magnets strong magnetic elds are only encountered within non-accessible areas inside the magnet.) Areas where these measures are in effect shall be clearly marked.
- To reduce the danger of magnetic fields to people using pacemakers or other medical

implants, warning signs shall be prominently displayed at the entrance to each hall. The sign shall read:

DANGER
SAFETY HAZARDS MAY EXIST FROM
THE MECHANICAL FORCES EXERTED
BY THE MAGNETIC FIELDS UPON
MEDICAL IMPLANTS
NO PACEMAKERS

Electrical Work Restrictions are established according to hazard class and mode of work.

The *mode* of work is determined by the nature of the work:

1. deenergized

2. energized with reduced safety and restricted manipulative operations

3. energized with manipulative operations

The *hazard class* is determined by the type work (electrical or electronic) and the combination of voltage and current.

- Anyone working on the HES, HKS, or Splitter power supplies must comply with the Standard Operating Procedure (S.O.P.). They must be trained and qualified and obey the new arc flash and shock hazard procedure.

- All maintenance shall be performed in strict accordance with the Jefferson Lab EH&S Manual, (6220 and 6230) and with Lock Tag and Try (LTT). The following references should be consulted before power supply maintenance or operations are attempted: 1) the operating procedure provided by the manufacturer 2) the simplied magnet power supply maintenance procedure.

- Removal of any protective shield or cover for an electrical conductor shall be performed using administrative lockout procedures. The lockout shall be performed by the cognizant hall engineer (or his designee). The administrative lock shall not be removed until the protective shield or cover has been fully reinstalled.

Power-on Maintenance There will be no mode 3 (hot work) on any power supply in Hall C. Mode 3 work is defined as manipulative operations that are conducted with equipment fully energized and with some or all normal protective barriers removed.

Conclusion The practice of keeping electromagnets energized in the experimental areas during short accesses provides substantial benefits to the quality and effectiveness of the physics program. The resulting hazards have been mitigated by a combination of protective shields, personnel training, warning lights and signs, and administrative procedures.

LCW Hazard Mitigation The LCW water system for the spectrometer and beam line chicane magnets have been plumbed using hoses rated for 300 PSI. The power supply cooling water hoses have a similar safety margin. In case of problems with LCW contact one of the responsible personnel listed in Section 15.

The hazards associated with the operation of the new magnets are no different than those listed in the standard Hall C ESAD in section 2.6. As outlined in section 6440 of the EH&S manual "All work areas where the magnetic field exceeds 0.5 mT (5 G) will be posted" and in addition "At access points to work areas where the whole body magnetic field exceeds 60 mT (600 G): The hazard area shall be clearly delineated (i.e. Taped off)." A red light must be on when the magnets are energized.

All magnets are normal conducting and therefore don't constitute any additional cryogenic or ODH hazards.

7.2 Hazards of static magnetic fields

Collaborators will have access to the vicinity of the following magnets while potentially energized:

- HES dipole
- HKS dipole
- Splitter magnet
- Beam corrector (DW) upstream of splitter
- First beam chicane magnet at beam entrance to hall.

In addition there will be two beam magnets upstream from the splitter. These two magnets are mounted on posts and not accessible by collaborators. Also, the quadrupole magnets of both spectrometers are not accessible w/out ladders.

7.2.1 Splitter magnet

A large dipole magnet will be used to separate the scattered electrons and the positively charged kaons and other hadrons at forward direction. The fringe field close to the magnet and especially close to the target and slit assemblies may exceed 60 mT (600 Gauss). Routine operation and access will not require access to this area. Only work on the target, collimators and BW magnet require access to the area.

Hazard mitigation

- Hazard warning signs will be posted at all acceess routes.
- Areas where the field may exceed 600 G shall be roped off and posted accordingly.
- Because of the potential projectile hazard, the magnet shall be deenergized before working on the target or collimator assemblies.
- A sweep must be conducted to remove ferromagnetic objects from the field area before energizing the magnet.
- Hazard warning signs must be posted to indicate the ferromagnetic tool hazard in addition to the bioelectronic device hazard.
- The splitter magnet is considered part of the beam line and as such will be controlled by the accelerator. Therefore, any need to turn this magnet off needs to be communicated to and coordinated with MCC.

7.2.2 High-resolution Electron Spectrometer (HES)

The new high-resolution electron spectrometer consists of two quadrupoles and one dipole. The operational field of the dipole is $\approx$ 1.2 T and the fringe field behind the dipole on the detector platform will exceed 5 Gauss but will be significantly less than 600 Gauss.

Hazard mitigation

- As a precautionary measure, a sweep must be conducted to remove ferromagnetic objects from the field area before energizing the magnet.
- Hazard warning signs must be posted to indicate the ferromagnetic tool hazard in addition to the bioelectronic device hazard.
- During prolonged access periods (resticted access) the magnet should be denergized.

7.2.3 High-resolution Kaon spectrometer (HKS)

The new high-resolution kaon spectrometer consists of two quadrupoles (Q1, 8.2 tons, 6.6 T/m, r_{bore}=12cm; Q2, 10.5 tons, 4.19 T/m, r_{bore} =14.5cm) and one dipole (D, 210 tons, gap

20cm). The operational field of the dipole is 1.5 T and the fringe field behind the dipole exceeds 5 Gauss but will be significantly less than 600 Gauss.

Hazard mitigation

- Conventional magnet operation procedures as outlined in section 2.6 of the "ESAD for the Hall C Base Equipment" apply.
- As the magnetic field may exceed 0.5 mT (5 G) both levels of the detector hut hazard warning signs will be posted at all access routes.
- During prolonged access times (restricted access) the magnet should be deenergized whenever possible.

7.2.4 New corrector magnet (dipole)

A new corrector magnet will be installed a few meters upstream of the HKS target. This magnet will be part of the beam line and as such be controlled by the accelerator. Hazards should be comparable to any other beam line magnet.

7.3 Electrical hazards from magnet power supplies and current leads

All spectrometer magnets are high current devices. The most exposed and hence most dangerous places are inside the supplies and at the magnet power leads.

The HES Q1 & Q2, HKS Q1 & Q2, Splitter, and beam line chicane magnets will be powered by existing supplies from the standard equipment. A new power supply for the HKS dipole (252 V/1254 A) has been installed behind the HKS detector hut. A similar power supply for the HES dipole is located at the same area. Associated hazards are similar to those from operating the existing conventional 300 kW magnet power supplies in Hall C used for HMS and SOS. Typical magnet currents and voltages are listed in Table 1.

Hazard mitigation

- All exposed and accessible current leads and terminations shall be covered by non-conducting rubberized tape in such a manner as to make it impossible for personnel to accidentally touch those leads with their bodies or with a tool.
- When a magnet is energized, flashing lights on the magnets ot magnet support structure will warn personnel of the associated electrical (and magnetic field) hazard.
- Doors to the inside of the power supplies are locked during routine operation and have safety interlocks.

Table 1: The existing / newly installed Power Supplies for E05-115

	Voltage	Current	HKS use	Source
1.	160 V	1000 A	DZ	Inver-power D2
2.	150 V	1000 A	FZ	Danfysik
3.	160 V	1000 A	HKS Q1	Inver-power Q1
4.	70 V	520 A	HKS Q2	Danfysik
5.	252 V	1254 A	HKS D	Mitsubishi
6.	240 V	110 A	Splitter	Danfysik
7.	210 V	1100 A	HES Q1	Big Bite
8.	160 V	1500 A	HES Q2	Moeller
9.	220 V	1100 A	HES D	from Japan

8 Cryogenic and Oxygen Deficiency Hazards

The experiment will not use any cryogenic fluids.

A room temperature helium bag will be installed between HDC1 and HDC2 in the HKS. It is operated at 1 atm. The total volume of the bag is $50'' \times 34'' \times 14''$, less than 400 liters. Therefore, no additional ODH hazard should exist.

Right now, there are no plans to energize the HMS or Møller magnets. In fact, they are not needed for this experiment. Thus, in case of any unplanned operation of these devices refer to the Hall C Base Equipment ESAD.

However, cryogens – liquid nitrogen and helium – might/will be flowing to these magnets.

Hazards Contact with cryogenic fluids presents the possibility of severe burns (frostbite). The release and subsequent expansion of cryogenic fluids presents the possibility of an oxygen deciency hazard. Rapid expansion of a cryogenic fluid in a confined space presents an explosion hazard. Cryogenics in Hall C are present in the superconducting HMS magnets and the Møller superconducting solenoid. In the case of the superconducting HMS magnets and the cryogenic targets the ODH hazard is minimal, apart from the area above the Hall C crane. The Møller solenoid contains $<$2000 STP liters of target fluid. However, this solenoid is located in the alcove thus enhancing a possible ODH hazard. Apart from cryogenic fluids, the gas in the HMS and SOS gas Cerenkovs pose also a potential oxygen deciency hazard for access inside these detectors.

Hazard Mitigation Normally accessible areas of Hall C are listed as an Oxygen Deciency Hazard area of Class 0. No unescorted access is allowed without an up-to-date JLab ODH training. All volumes in the cryogenic systems which can be isolated by valves or any other means are equipped with pressure relief valves to prevent explosion hazards. All issues concerning the safe operation of both the HMS cryogenic magnet system and the Hall C cryotarget systems were reviewed by outside panels. No one may enter the Cerenkov tanks while there is radiator gas inside these tanks. The tanks should be pumped out and filled with air before access to the interior of these tanks is permitted. Possible leaks do not impose an additional hazard, e.g the total enclosed volume of the SOS Gas Cerenkov is 30 cubic feet, while the air conditioning unit in the hut replaces the air at a rate of 1100 cfm. The responsible personnel for access to an ODH-area are the principal contacts for the JLab EH&S group:

Bert Manzlak - x7556 (Physics EH&S)

Charles Hightower - x7608 (Physics EH&S)

9 Radiation Safety and Personnel Safety Sytem

CEBAFs high intensity, high energy electron beam is a potentially lethal radiation source and hence many redundant measures aimed at preventing accidental exposure of personnel to the beam or exposure to beam-associated radiation sources are in place. When the hall is in an accessible state, all beamline or target chamber equipment requiring machining or disassembly, and all components which need to be removed from the Hall, must be surveyed by an ARM or a member of the Radiation Control Department (RadCon). Only RadCon can approve unrestricted release of items from the hall (ARMs surveys may allow relocation, under the ARMs direction, but not release).

The radiation safety group 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 (Vashek Vylet) can be reached as follows[1]:

  Office: 269-7551

  Cell: 218-2733

  Pager: 584-7551

  Home: 772-6098

Two additional RUN/SAFE boxes have been installed on the upper (detector) levels of the spectrometer huts. Personnel working at the detectors should be aware of the location of these RUN/SAFE boxes. New procedures for sweeping the hall prior to beam delivery have been established. These procedures include the two spectrometer huts. Otherwise, established procedures as outlined in the general Radiation Work Permit apply.

Equipment in the HES and HKS spectrometer huts is subject to radiological survey prior to being removed from the Hall, if it has been at any time in the hall during beam-on conditions.

9.0.1 Beam dump line

The electron beam will be guided to the standard Hall C dump while the bremsstrahlung photons will be collected on a newly installed local photon beam dump. The electron beam will be pre-bent by a beam line chicane in front of the target. For this purpose, three additional bending magnets will be installed. Additional small corrector magnets and beam viewers will

[1] This information is current as of 11 Aug. 2009

be installed at various key positions for the safe beam transportation and monitoring. Beam loss monitors and interlocks will be also installed along the dump line at key positions. All this equipment will be controlled by the accelerator. It should not constitute any new hazards in addition to those already associated with the standard beam line components.

The local photon dump as well as the Splitter chamber and the HES Q1 yoke are likely to become high radiation areas after beam operation. Except for the target area, which will be covered in Sec. 14, these areas are not easily accessible without ladders and shall be posted accordingly. Any work in these areas most likely will require coordination with RadCon.

Hall probe readings from the splitter magnet, the two beam line magnets downstream from the splitter and the HKS dipole magnet will be continuously read. Tight thresholds will be set around the nominal readings (established during beam tuning). Crossing this thresholds with generate an FSD.

10 Vacuum and Pressure Hazards

The greatest safety concern for the vacuum vessels are the kevlar/mylar windows at the exits of the HES and HKS spectrometers. In contrast to the standard HMS/SOS setup, beam line, target/splitter chamber, spectrometer vacuum vessels, and exit beam line are all directly coupled. This reduces the number of critical windows to two. Apart from this system and the water cell target, which will be covered in Sec. 14, there are no additional vacuum or pressure vessels, i.e. all new detectors operate at atmospheric pressure. Note though that the hazards associated with the Møller vacuum system still exist.

All work on vacuum windows in Hall C must occur under the supervision of appropriately trained Jlab personnel.

10.1 Møller Vacuum System

The space between the Møller target and the two-arm detectors is evacuated to minimize multiple scattering. At the target the vacuum furthermore isolates the cold coil vessel from room temperature. These volumes represent an implosion hazard. This is especially true at the exit of the two arms in front of the Moller detectors where thin vacuum windows are mounted. The diameter of the exit windows is 20 cm. Experience from HMS window testing is used and applied to the Aluminum windows. Despite this, it is recommended to wear ear protection plugs, which are available at the entrances to the alcove. If working within 3ft. of the vacuum windows the wearing of ear protection plugs is mandatory.

10.2 HKS Vacuum System

The HKS exit window is the largest window used in the HKS and LIFETIME experiments. This window is located in the HKS detector hut, right infront of the first drift chamber, HDC1. The window is made from 216-μm Kevlar sheet sandwiched by 63.5-μm mylar sheets. Catastrophic window failure could generate a significant shock wave. This has the potential to cause hearing damage to anyone in close proximity to the window.

Hazard mitigation

- The window had been tested and determined to fail at at differential pressure of 4 atm. It will be operated at a differential pressure of 1 atm (atmospheric pressure outside to vacuum inside the magnet chamber).
- Direct access to the HKS exit window is blocked by the first drift chamber.
- When working closer than 3 feet to the window, i.e. working at the first drift chamber,

hearing protection should be worn. Hearing protection will be stored on the detector frame and warning signs posted.

- These type of windows should be replaced after roughly 1 year of operation. The experiment is scheduled to run for 2 months. Even taking into account the installation time, the window will be in use for less than 1 year.

10.3 HES Vacuum System

Direct access to a large fraction of the HES exit window is blocked by the honeycomb drift chamber and the scintillator hodoscopes.
Hazard mitigation

- When working closer than 3 feet to the window, i.e. working at the detectors, hearing protection should be worn.
- Hearing protection will be stored on the detector frame and warning signs posted.
- These type of windows should be replaced after roughly 1 year of operation. The experiment is scheduled to run for 2 months. Even taking into account the installation time, the window will be in use for less than 1 year.

10.4 Evacuated Beam Dump Line

The Hall C beam dump line has been changed to an evacuated beam line. In the evacuated beam dump line conguration there will be no Be window separating the scattering chamber vacuum from this beam dump line. The end window of the beam dump line will be an Al window, with inner diameter 3.75 inches consisting of 30 mil Be. Calculations have shown the Be window to reach a peak temperature of 270 F, even when the unlikely scenario occurs of an unrastered, 180 μA beam current hitting the window with no target in place. Such a scenario is unlikely, as we will have much lower beam currents. Expected currents are up to 50 μA. A Be beam diffuser resides at the entrance of the beam dump alcove, to enlarge the beam spot a the beam dump.
Hazard Mitigation An administrative current limit is imposed on beam delivery conditions, as given in the accelerator operational restrictions (see http://opweb.acc.jlab.org/internal/ops/ops webpage/restrictions/ops restrictions.php).

10.5 Working Near Vacuum Windows

Before entering the detector huts and working close to the windows, all personnel should check the spectrometer and/or scattering chamber vacuum gauges. Gauges, as well as the turbo pump controllers are located on the first floor in each spectrometer hut. Both spectrometer vacuum chambers and the scattering chamber inside the splitter magnet are vacuum coupled. Therefore, a low pressure reading on any of the gauges indicates that the entire system is under vacuum and that thus a hazard exists in close proximity to the exit windows.

If the spectrometers and/or scattering chamber are under vacuum:

- Before entering the detector hut, put on hearing protection. It is recommended that nobody should be closer than 3 feet from the windows without ear protection and that only those personnel who need to approach the windows be in their immediate vicinity.
- If you observe any of the following problems, vacate the area and contact one of the responsible personnel:
  - Visual defects, particularly wrinkles, discoloration, or uneven fiber stress.
  - Date of removal on tag near spectrometer window indicates a date near or after current date.
  - The pre-traced ring drawn onto the window perimeter has moved away from the perimeter.
- Never touch the vacuum windows, neither with your hands nor with tools.
- Use careful judgement if it is necessary to work near the vacuum windows. Do not place objects so that they may fall on the windows, etc.
- Do not work near the windows any longer than is absolutely necessary.

11 Conventional Hazards

11.1 Crane and Mechanical Equipment Operation

Hard hat use is required in Hall C whenever mechanized equipment is in use in the hall (Cranes, JLG lifts, man lifts, fork lifts), or when the entrances to the hall are marked with hard hat required signs. Hard hats are not required when fully within the beamline tunnel, the Spectrometer detector bunkers (HES & HKS) or the electronics bunkers. The Hall work coordinator may also grant exceptions for specific work with sensitive quipment when there is no overhead work above the work area.

11.2 HMS and SOS Carriage

The carriages are the support structures of the spectrometers. First and foremost as it is a multileveled structure it is important to keep in mind that people may be working above you. This means that the wearing of hard hats in Hall C is strongly advised. Taller individuals should be mindful when using the flight of steps leading towards the higher levels due to the limited head room at some points. Safety railings have been installed everywhere along the carriage perimeters. Be aware that some of these may be removed during the experimental data taking to enable spectrometer rotation and will need to be installed (or you need to wear a safety harness) before accessing these areas.

11.3 Hall C pivot area

The Hall C pivot area is to a large extent part of the SOS carriage, and as such, access to this pivot area requires also installment of the safety railings or the wearing of a safety harness. Experiment E05-115 will use a modified pivot area platform. The SOS Quad and Hall C target scattering chamber are removed. A new beam line girder will be installed on the platform. Access to the platform will be via a staircase on the upstream side of the SOS.

11.4 Fall Hazards

It cannot be overemphasized that one of the most significant hazards in Hall C is a simple fall. Even standard access routes such as stairs or ladders can lead to serious injury if proper care is not taken. The risk is multiplied if the individual is carrying a load of equipment such as oscilloscopes.**Equipment should never be carried up on ladders. Instead climb the ladder and then have someone hand you the equipment or use a line.**

Another fall hazard exists in the form of non-standard access routes. Generally speaking, these are to be avoided. An egregious example might be climbing a rickety chair to access a detector platform. However, use of a non-stndard access route such as a well-secured ladder may occassionally be necessary.

When access to areas is required that would allow a fall of 4 feet or more, use fall protection as mandated by the EHS manual.

11.5 Spectrometer Rotation

Except for the installation period, which requires moving the SOS, spectrometer rotation is not necessary and remote rotation of the spectrometers should be disabled. In the unlikely event that a spectrometer rotation would become necessary consult the Hall C ESAD.

11.6 Slit Systems

The HKS and HES slit ladders each consist of heavy densimet blocks, collimators and sieve slits. These can easily cause serious damage to body parts. Install a metal support under the slit ladder when you work with your hands under it. The remote control systems are equipped with a brake cable to prevent the slit ladders from sliding down in case of a power failure, but this must not be relied upon for personnel safety.

11.7 SOS Shield House Doors

No operation of the SOS doors is anticipated. In the unlikely event that a door operation is necessary, consult the Hall C ESAD.

12 Hazardous and Toxic Materials

12.1 Target Materials

Some of our target materials may pose a serious safety concern. At this moment the only two special target materials we own are ceramic Beryllium-Oxide (BeO) and Beryllium (Be). In solid form, BeO is completely safe under normal conditions of use. The product can be safely handled with bare hands. However, in powder form all Beryllia are toxic when airborne. Overexposure to airborne Beryllium particulates may cause a serious lung disease called Chronic Berylliosis. Beryllium has also been listed as a potential cancer hazard. Furthermore exposure to Beryllium may aggravate medical conditions related to airway systems (such as asthma, chronic bronchitis, etc.). Since beryllia are mainly dangerous in powdered form, do not machine, break, or scratch these products. Machining of the Beryllia can only be performed after consulting the EH&S staff. It is good practice to wash your hands after handling the ceramic BeO. If handling the pure Beryllium target wear gloves and an air filter mask. These target materials are stored in the yellow target storage cabinets, either in the back room of the counting house or in the black safe downstairs in the Hall C experimental area.

12.2 Lead Shielding

Note that the lead shielding blocks we use also form a potentially toxic material. Unwrapped or painted lead blocks may only be handled by certified lead workers who have undergone lead worker training. Gloves must be worn when handling uncovered blocks (this excludes blocks that are completely painted or wrapped in Heavy-Duty Aluminum Foil). Lead worker training is not required for the handling of lead bricks contained plastic bags. However, steel-toed shoes must always be worn when handling lead bricks of any type. Do not machine lead yourself, contact the EH&S personnel or the Jefferson Lab workshop to ask for the procedure to machine lead.

Lead bricks, lead sheet, and lead shot bags will be used to reinforce shielding of the detector huts. Most of this shielding should be in place prior to the start of the experiment, however, some modifications and/or installation of additional shielding might be required during data taking. Likely places where lead shielding could be found are around the beam line close to the spectrometer entrances and inside the detector huts close to the spectrometer exits.

Hazard Description

Lead poses a health hazard when ingested or inhaled. Further, falling lead shielding poses a significant crushing hazard, especially to unprotected feet.

Hazard Mitigation

Complete guidelines for the safe handling of lead are outlined in Section 6680 of the EH&S Manual.

- Complete Lead Worker Training (SAF 136) before working with lead. Call Jenniffer Williams at 7882 to schedule training.
- Do not handle lead unnecessarily. When you do handle it, wear appropriate personal protective equipment (PPE) such as disposable coveralls as well as protective gloves made of impermeable material like leather or rubber and respiratory protection.
- After working with or near lead, wash your hands and face before eating, drinking, or smoking.
- Do not take food, cigarettes, or other tobacco products into areas using lead, and don't eat, drink, or smoke where lead is handled or stored.
- Do not take part in a lead contact activity with an unprotected open wound. Consult with Jefferson Lab Medical Services if you have any questions.
- Use a HEPA (high-efficiency particulate air) vacuum or a wet method to reduce dust during cleanup of areas where lead dust may be present. Do not dry sweep or use compressed air.
- Wear safety shoes. For more information on requisitioning safety shoes at Jefferson Lab, call ext. 7238.

For further questions consult the EH&S manual and/or call Jennifer Williams in ES&H, ext 7882.

13 New detectors

The detectors in the HES and HKS spectrometer hut are of the same type as those used in the HMS/SOS configuration, i.e. scintillators, drift chambers, and Čerenkov detectors. Incontrast to the HMS/SOS configuration none of the new detectors is operated sub-atmospheric or above atmosphere. No additional hazards exit than those oulined in the previous sections.

13.1 Fission fragment detector and target chamber

This is an additional chamber that will be installed in front of the photon beam dump for the E02-017 experiment. The common chamber contains four sets of multi-wire proportional chambers, two above and two below the E02-017 target, in a common low pressure ($\sim$3 torrs) heptane gas. The vapor of heptane is extracted naturally due to low pressure from the heptane liquid in a small bottle outside of the chamber. The chamber has its own electronics inside the hall under the chamber as well as in the counting hall as an independent arm. Although the heptane liquid is flammable liquid, the amount used will be very small, less than 4 fl Oz (120 ml). The vapor is sealed within the fission fragment detector chamber. Pressure is extremely low and the amount is very small. The working vapor is replaced only once a week and liquid is handled only before installation and after the experiment. Thus it will not be identified as a hazard item.

The fission fragment detector and its scattering chamber will be directly exposed to the photon beam. Components likely will be activated after beam exposure. During the run, the detector will be enclosed inside the photon dump and therefore inaccessible. Any access to, work on, and decomissioning off the fission detector need to be coordinated with RadCon and Hall technical staff.

14 Target

(Note [2])

14.1 Overview

The target is located right at the upstream field boundary of the splitter magnet. It consists of a long support at which end there is room for a target holder and also a water cell target.

A stepper motor moves the target ladder with foils horizontally, into and out of the beam. Hard stops prevent motion of the ladder beyond the limit switches. Target motion should be interfaced with the FSD system.

14.2 Safety Issues

The safety issues concerning the target are (a) its proximity to the splitter magnet and the resulting strong magnetic field when the splitter is energized, and (b) activation of the target ladder, the targets itself, and the water used for cooling and the water cell target.

14.2.1 Magnetic Field Hazard

The magnetic field hazards and hazard mitigation have been outlined in Section 7.2.1, i.e. the magnet shall be de-energized before working on the target assembly and a sweep must be conducted to remove ferromagnetic objects from the field area before energizing the magnet.

14.2.2 Radiation Hazard

The water cooling system is a closed loop, using a portable welding-torch water cooler, located under the beam line just upstream of the target. The cooler is kept in a tray which is intended to provide secondary containment in case of a leak. The cooling system must not be breached or drained without concurrence from the RCG. Accidental breach or spill constitutes a radiation contamination hazard. A spill control kit, capable of containing a system leak or spill, is staged by the door to the hall. In the event of a spill notify the RCG.

The target ladder, the target holder, and the targets themselves are potentially contaminated after beam exposure. Therefore, any work that requires the removal of the target ladder from the vacuum chamber needs to be coordinated with the RCG and most likely will require Radworker II training.

After beam exposure, the area close to the target is likely to be a Radiation Area or High Radiation Area. This will impact also any work on components outside of the vacuum cham-

[2] Issues concerning the water cell target have been adopted from the Hall A Operation Manual, Chapter 13

ber, for example the stepper motor and drive. Observe any posted signs and coordinate work accordingly with the RCG.

14.2.3 Authorized Personnel

The responsible personnel are shown in the following table:

Name	Phone
Liguang Tang	6255
Nue Nakamura	5324
Tomo Maruta	5324
Dave Meekins	5434

14.2.4 Radiological hazards

Due to the relatively large beam currents required for experiment E05-115, the potential for radiological contamination of the target fluid and scattering chamber area exists. Therefore, all personnel entering the target area after beam has been impinging on the target must follow standard radiological control procedures. Prior to entry into the area the Radiation Control Group must be consulted. The system must only be accessed by authorized personnel

14.2.5 The water system

There are about 15 gallons of pure water in the circuit. The water tank, the tubes, the target and the cell containing the target fluid are made of stainless steel. Connections between individual parts of the system will be made with VCR Metal Gasket Fittings.

The water should not be released into the hall drains. Measurements at convenient intervals should be made by the radiation control group on samples to permit determinations of the radionuclide yields. In the case of water loss or the need to drain the water, the radiation control group has to be informed to permit precautionary measurements and controls. Appropriate sinage on the water system indicates this.

15 Responsible Personnel

General		
ODH	Bert Manzlak	7556
	Charles Hightower	7608
Radiation Safety	Oncall cell	876-1743
	Keith Welch	7212
AC Power	Bill Vulcan	6271
	Joe Beaufait	7131
LCW Operations	Joe Beaufait	7131
	Bill Vulcan	6271
	Walter Kellner	5512
Fire	Dave Kausch	7674
	Bert Manzlak	7556
	Charles Hightower	7608
Cryogenics	Oncall pager	6393
	Walter Kellner	5512
Mechanical	Oncall pager	6393
	Walter Kellner	5512

Beam Line		
Raster Systems	Mark Jones	7733
	William Gunning	5017
Superharp Systems	Mark Jones	7733
	Steve Wood	7367
Møller Polarimeter	Dave Gaskell	6092
Current Measuring Devices	Dave Mack	7442
Target	Tomo Maruta	5036
	Dave Meekins	5434
Pre-chicane	Crew Chief	

Detectors (Some best reached through the counting house at 6000)		
HES & HKS Scintillators	Tomo Maruta	5324
	Nue Nakamura	5324
HKS Drift Chambers	Liguang Tang	6255
	Lulin Yuan	6302
HES Honeycomb Drift Chamber	Tomo Maruta	5324
	Nue Nakamura	5324
HES 2nd Driftchamber	Liguang Tang	6255
	Lulin Yuan	6302
HKS Aerogel Cherenkov	Joerg Reinhold	6168
HKS Water Cherenkov	Tomo Maruta	5324
	Nue Nakamura	5324
HKS Lucite Cherenkov	Liguang Tang	6255
	Lulin Yuan	6302
High Voltage Supplies	Bill Vulcan	6271
	Joe Beaufait	7131
	Steve Wood	7367

Spectrometers - General		
Vacuum Windows	Walter Kellner	5512
	Andy Kenyon	7555
Vacuum System	Andy Kenyon	7555
	Walter Kellner	5512
Slit System	Bill Vulcan	6271
	Tomo Maruta	5324
Gas Mixing System	Brian Kross	7022
	Bill Vulcan	6271
Shield House	Walter Kellner	5512
	Andy Kenyon	7555
Magnets and Power Supplies	Bill Vulcan	6271
	Joe Beaufait	7131
	Steve Wood	7367

Counting House		
Electronics	Mark Jones	7733
	Steve Wood	7367
Data Acquisition	Steve Wood	7367
	Mark Jones	7733
	Dave Abbott	7190

16 References

- Experiment Safety Assessment Document (ESAD) for the Hall C Base Equipment
- Hall C Operating Manual
- HKS Operating Manual (Wiki)
- Final Documents for Tohoku Univ. Kaon Spectrometer (Mitsubishi Elec. Co.)