Experiment Safety Assessment Document for the E01-011 experiment (HKS)

May 20, 2005

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1 Introduction and Scope of this document

Hall C experiments E01-001 (HKS) and E02-017 (LIFETIME) will employ a new hypernuclear spectroscopy system which is not part of the standard Hall C equipment. The new equipment items are:

1. a beam correction magnet
2. a solid target system
3. a dipole magnet (Splitter)
4. a split-pole magnet (ENGE) and associated detector package
5. a kaon spectrometer (HKS) consisting of 3 magnets, QQD, and associated detector package
6. power supply for HKS dipole
7. a fission chamber.
8. a modified beam dump line

The locations of the two new spectrometers, ENGE and HKS in Hall C, are shown in Fig.1. Both experiments will share the above equipment, except for the fission chamber which will be used by the LIFETIME experiment only. However, this chamber will already be operational and located in an off-beam location for the duration of the HKS experiment.

This document does not replace, but supplement the standard ”ESAD for the Hall C Base Equipment”. Where appropriate, references will be made to the Hall C ESAD. Therefore, Collaborators are required to be familiar with both documents. Further, 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 new equipment only and explain the mitigation of such hazards.

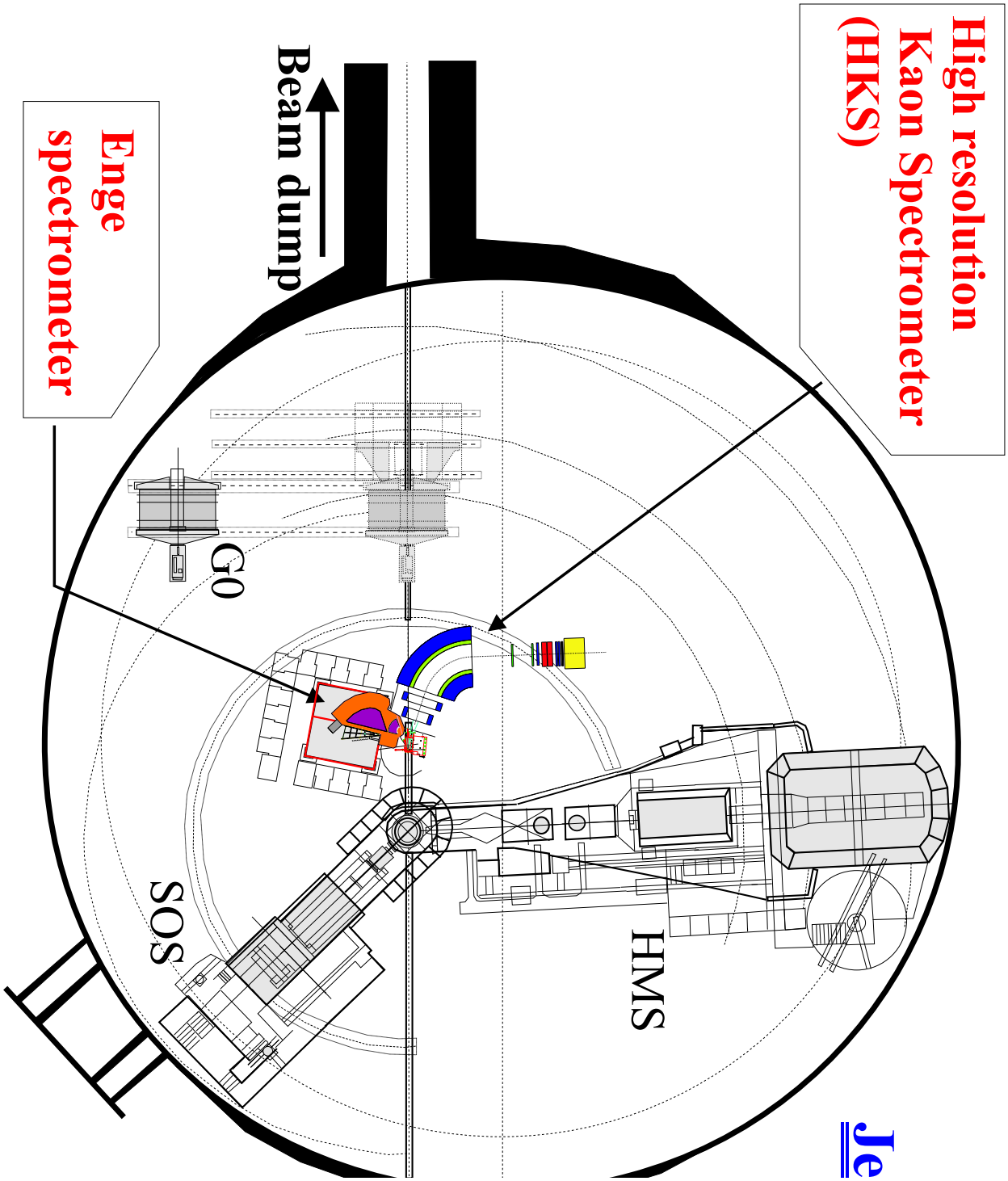

Figure 1: Expected Hall C setup of the HKS and Enge spectrometer. The installation can be compatible with the HMS, SOS and G0 setup.

2 “Standard” Hall C base equipment

The “Standard” Hall C base equipment berifely mentioned in this sedction 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.

2.1 Standard Hall C Beam Line

The beam line is the standard one used for all the previously completed experiments with $\sim$2 GeV beam energy in Hall C, including already existing beam line equipment and beam diagnostic elements, such as BPMs, BCMs, superharps, SLI, fast energy and position locks, and fast raster system. The only exception is a new addition of a small correction dipole magnet to be located a few meters upstream of the HKS target. It is needed to compensate and redirect the beam trajectory deflected by the fringe field of the Splitter magnet, and brings the beam position back to the center and also correct the incoming beam angle offset at the experimental target. New beam loss monitors and interlocks will be installed for safety with this new addition.

2.2 Gas system for drift chambers

The experiments will use gas mixture (argon-ethane 50/50) and the existing handling system that are commonly used for SOS and HMS gas chambers. New gas connections will be installed from the gas handling system to both of the drift chambers of the HKS and Enge spectrometers.

3 Hazardous and Toxic Materials

3.1 Lead Shielding

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 Patty Hunt at 7039.

3.2 Amino-G-Salt (Water Čerenkov)

The HKS water Čerenkov counters contain Amino-G-Salt, a fluorescing substance, as wave-length shifter. The Amino-G-Salt is directly dissolved in the water radiator. Amino-G-salt (7-amino-1,3-naphtalenedisulfonic acid monopotassium salt hydrate) is corrosive and may cause burns in case of contact with skin, eyes, and mucous membranes. For details see MSDS # 20971 (attached in Appendix and posted in the detector area).

Hazard mitigation

- The animo-g-salt solution is prepared at the R&D chemical room under the supervision of chemical hygiene personnel. Only dilute solutions will be present in the hall.
- A dedicated TOSP decribes the fillling and emptying as well as cleanup procedures after a spill. Only personnel listed on this TOSP are authorized to handle the dilute solutions.
- Any spill should be reported to expert personnel who will initiate proper cleanup procedures.
- In case of a spill, the HV to the water Čerenkov detector should be turned off and the coresponding HV frame on the second florr of the counting house should be disabled by unplugging the power cord.
- Protective equipment safety glasses, gloves, and spill absorbers will be stored in the detector hut at a location off the floor and away from the detector stack.
- An eye shower will be placed in the detector hut.

4 Magnets and Magnet Power Supplies

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 beacon must be on when the magnets are energized.

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

4.1 Hazards of static magnetic fields

Collaborators will have access to the vicinity of the following magnets:

- ENGE split pole
- HKS dipole
- Splitter magnet
- Beam corrector (BW) upstream of splitter

In addition there will be two beam magnets (BZ & DZ) downstream from the splitter used to steer the beam back to the beam dump tunnel. These two magnets are mounted on posts and not accessible by collaborators.

4.1.1 Splitter magnet (C dipole)

A C-type dipole magnet (Splitter, 6.3 tons, 6” gap) will be used to separate the scattered electrons and the positively charged kaons and other hadrons at forward direction. The operational magnetic field at the center is 1.546 T. 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 de-energized 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.

4.1.2 Split-Pole magnet (Enge) and its supporting platform

A split-pole magnet (Enge, 55 tons, B=1.45 T) is used to detect and momentum-analyze the low energy scattered electrons (Fig.**??**). The field behind the yoke in the vicinity of the detectors has been measured. At a distance of 1 ft from the iron yoke the field is 15 gauss and 3 gauss at an excitation of 1.9 T and 1.5 T, respectively. The experimental conditions require an excitation to 1.45 T.

Hazard mitigation

- Fringe field values will be confirmed, once the magnet can be energized.
- 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.

4.1.3 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 will exceed 5 Gauss but will be significantly less than 600 Gauss. So far the magnet could not be fully energized at Jefferson Lab. Extrapolations from partial excitation predict a field of less than 10 - 15 G. Once the magnet can be fully energized, experimental reasons will require a

careful mapping of the fringe field in the accesible areas of the HKS detector hut. However, these areas are approx. 6 ft away from the iron yoke and also separated by a thick iron wall.

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.

4.1.4 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.

4.2 Electrical hazards from magnet power supplies and current leads

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

The ENGE, HKS Q1 & Q2, Splitter, and BZ & DZ 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. Associated hazards are similar to those from operating the existing conventional 300 kW magnet power supplies in Hall C used for HMS and SOS. Therefore, the same safety procedure will be followed as described in the "ESAD for the Hall C Base Equipment", **Chapter 2.6 "Magnets and Magnet Power Supplies"**. 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 or grounded shields in such a manner as to make it impossible for personnel to accidentally touch those leads with their bodies or with a tool.
- Warning signs will be placed on the shields.

Table 1: The existing / newly installed Power Supplies for E01-011

	Voltage	Current	For HKS	Previous
1.	160V	1000A	Q1	SOS Q
2.	250V	1000A	Q2	SOS D1
3.	160V	1000A	DZ	SOS D2
4.	150V	1500A	Enge	Moller
5.	150V	1000A	Splitter	HNSS-SPL
6.	252V	1254A	D	New

- 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.

4.3 Vacuum Hazard

The greatest safety concern for the vacuum vessels are the kevlar/mylar windows at the exits of the ENGE 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 windows to two. Apart from this system, there are no additional vacuum or pressure vessels, i.e. all new detectors operate at atmospheric pressure.

4.3.1 Vacuum System

4.3.2 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 3 month. Even taking into account the installation time, the window will be in use for less than 1 year.

4.3.3 ENGE Vacuum System

Direct access to a large fraction of the ENGE exit window is blocked by the honeycomb drift chamber and the scintillator hodoscopes. Access to the regions not blocked by detectors is partly blocked by cable trays and shielding walls. As these regions are also outside of the usefull acceptance, they will be permanently covered with a plastic shield to prevent accidental damage to the windows.

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 3 month. Even taking into account the installation time, the window will be in use for less than 1 year.

5 New detectors

The detectors in the ENGE 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 standard Hall C ESAD, **with the exception of the Water Čerenkov. This detector is filled with a solution containing a corrosive salt. Hazards and procedures are outlined in Sec. 3.2.**

5.1 Fission fragment detector and target chamber

This is an additional chamber that will be installed in front of the HKS target chamber only for 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.

6 Electrical Systems

All newly installed detector systems and their associated electronics are similar to the existing equipment. Thus, the standard safety procedures should be followed as outlined in “ESAD for the Hall C Base Equipment”, Chapter 2.4 “Electrical System”.

Hazard mitigation

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

6.1 Hazards from HV power supplies

The experiment utilizes the G0 high voltage frames on the second floor of the counting house (CAEN SYS403). These supplies provide up to 3 mA at 3000 V. The operation of these supplies and the associated hazards are identical to those outlined in the standard Hall C ESAD.

Hazard mitigation

- Cable and SHV connectors are shielded.
- Turn off the main HV supply when attaching/removing HV cables.

New electronics will be installed in the Hall C as well as in the counting house electronics room as other major installation experiments use third non-standard arm.

6.2 Electronics for E01-011 and E02-017

In addition to the standard electronics in Hall C such as chamber and PMT HV power supply, the E01-011 and E02-017 experiments require extra VME, NIM, CAMAC modules, their crates, high voltage power supplies, low voltage power supplies to be installed for operation of detectors, data collections, and event trigger formations.

The modules will be installed in downstairs of HKS and ENGE platforms as well as in the counting house electronics room.

7 Radiation Safety and Personnel Safety Sytem

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 Hall C ESAD and Radiation Work Permit apply.

Contrary to the HMS and SOS huts, equipment in the ENGE 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.

7.0.1 Beam dump line

The electron beam and forward bremsstrahlung photons will be guided to the standard Hall C dump thorough a new dump line system. The primary electron beam will be deflected by the Splitter magnet and the straight forward bremsstrahlung photons. The electron beam will be bent back to merge with the bremsstrahlung photons behind the HKS-D magnet and aimed straight toward the Hall C dump. For this purpose, two additional bending magnets (BZ and DZ) will be installed on the new post-beam line to re-orient and merge the electron beam. Additional small corrector magnets and beam viewers will 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.

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.

8 ODH Hazards

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. The detector hut is completely open to the back.Therefore, no additional ODH hazard should exist.

9 References

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