Person: Poudel, Jiwan (jpoudel@jlab.org)
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Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Review and Approval Form # 150850
(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for Instructions)

Type:	***OSP*** Click for OSP/TOSP Procedure Form Click for LOSP Procedure Form Click for LOTO-COMPLEX Information Click for LOTO-GROUP Information
Serial Number:	***ENP-23-150850-OSP***
Issue Date:	***3/20/2023***
Expiration Date:	***3/20/2026***
Title:	***Hadron Calorimeter (HCal) for SBS experiments***
Location: (where work is being performed) Building Floor Plans	***101 - Experimental Hall A - A103***
Location Detail: (specifics about where in the selected location(s) the work is being performed)	***Hall A, beam-right, downstream of SBS spectrometer. Multiple positions for different kinematic points, and depending on beam energies actually available.***
Risk Classification: (See ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment)	Without mitigation measures (3 or 4): ***3*** With mitigation measures in place (N, 1, or 2): ***1***
Reason:	This document is written to mitigate hazard issues that are : ***Determined to have an unmitigated Risk code of 3 or 4***
Owning Organization:	***PHALLA***
Document Owner(s):	***Poudel, Jiwan (jpoudel@jlab.org)*** Primary ***Wojtsekhowski, Bogdan (bogdanw@jlab.org)*** ***Jones, Mark (jones@jlab.org)***

Supplemental Technical Validations

50V or Greater: De-energized Work (Bonnie Rodriguez, Phillip Stanley)
Mode 1: Class 1, 2, and 3 Electrical Equipment (Bonnie Rodriguez, Phillip Stanley)
Mode 2: Class 2 and 3 Equipment (Bonnie Rodriguez, Phillip Stanley)
Aerial Work Platforms (Scissor/Aerial Lifts, Boom Trucks) (Joe Thomas, Tom Renzo)
Portable Hand Tools (Bill Rainey, Chad Bailey)
Four Feet or More Above the Ground (other than ladder or scaffold). (Bill Rainey, Chad Bailey)
Ladders (Bill Rainey, Chad Bailey)
ESH&Q Liasion (Bert Manzlak)

Document History

Revision	Reason for revision or update	Serial number of superseded document
6	***Change of Document owner and Lead worker for HCAL, as previous personnel are not available now.***	***ENP-21-119584-OSP***

Lessons Learned	Lessons Learned relating to the hazard issues noted above have been reviewed.
Comments for reviewers/approvers:	***Needed revision because of the change in Lead worker and document owner for HCAL***

Attachments

Procedure: ***OSP_HCAL.pdf***

THA: ***THA_HCAL.pdf***

Additional Files: ***Operations_manual_HCAL.pdf***

Review Signatures

Subject Matter Expert : Electricity->50V or Greater: De-energized Work	**Signed** on 3/16/2023 4:25:05 PM by Phillip Stanley (pstanley@jlab.org)
Subject Matter Expert : Electricity->Mode 1: Class 1-> 2-> and 3 Electrical Equipment	**Signed** on 3/16/2023 4:25:10 PM by Phillip Stanley (pstanley@jlab.org)
Subject Matter Expert : Electricity->Mode 2: Class 2 and 3 Equipment	**Signed** on 3/16/2023 4:25:11 PM by Phillip Stanley (pstanley@jlab.org)
Subject Matter Expert : Material Handling Equipment->Aerial Work Platforms (Scissor/Aerial Lifts-> Boom Trucks)	**Signed** on 3/16/2023 7:34:54 AM by Joe Thomas (thomasb@jlab.org)
Subject Matter Expert : Portable Hand Tools	**Signed** on 3/16/2023 11:48:11 AM by Chad Bailey (cbailey@jlab.org)
Subject Matter Expert : Working at Elevations->Four Feet or More Above the Ground (other than ladder or scaffold).	**Signed** on 3/16/2023 11:48:12 AM by Chad Bailey (cbailey@jlab.org)
Subject Matter Expert : Working at Elevations->Ladders	**Signed** on 3/16/2023 11:48:13 AM by Chad Bailey (cbailey@jlab.org)

Approval Signatures

Division Safety Officer : PHALLA	**Signed** on 3/16/2023 4:26:23 PM by Ed Folts (folts@jlab.org)
ESH&Q Division Liasion : PHALLA	**Signed** on 3/20/2023 4:17:47 PM by Bill Rainey (wrainey@jlab.org)
Org Manager : PHALLA	**Signed** on 3/16/2023 4:39:19 PM by Mark Jones (jones@jlab.org)

Click here when you have read and understand this document

'306','214','218','106'1.CS.003 Jones, Mark SURA/CEBAF PHALLA 03/21/2023 Poudel, Jiwan SURA/CEBAF-TERM PHALLA 03/21/2023 Seeds, Sebastian USER - GRADUATE PADMIN 03/21/2023 Wojtsekhowski, Bogdan SURA/CEBAF PHALLA 03/21/2023

Skill
Understanding of procedure ENP-23-150850-OSP (OSP-150850)

Course
ENP-23-150850-OSP Qualification

Class
Online/Web/Intranet

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Form

(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for instructions.)

Click For Word Doc

Title:	Hadron Calorimeter (HCal) for SBS experiments		
Location:	Hall A	**Type:**	X OSP ☐TOSP
Risk Classification (per Task Hazard Analysis attached) (See *ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment*.)		**Highest Risk Code Before Mitigation**	3
		Highest Risk Code after Mitigation (N, 1, or 2):	1
Owning Organization:	***PHALLA***	**Date:**	03/14/2023
Document Owner(s):	Jiwan Poudel		

DEFINE THE SCOPE OF WORK

1. Purpose of the Procedure – Describe in detail the reason for the procedure (what is being done and why).

Use of HCal calorimeter for SBS experiments; movement of calorimeter; Installation/removal of the calorimeter

The Hall A Hadron Calorimeter, HCAL-J, will be mounted downstream of the SBS spectrometer magnet and used to detect hadrons (principally protons and neutrons.). It is constructed from 288 individual detector modules assembled into an array 12 modules wide by 24 modules high (180 cm wide x 360 cm high). The total weight of the HCAL-J detector is approximately 40 tons, but the modules are mounted into 4 sub-assemblies, mounted atop a support, so that the individual sub-assemblies can be positioned with a 20-ton capacity crane. The front-end electronics racks and two platforms allowing access to the PMTs are mounted in a gantry behind the HCal detector (see figure 1).

Originally, it was intended that the Hall A crane would move the calorimeter by unstacking and re-stacking these sub-assemblies and moving the support structure and gantry. To achieve faster movement, the system was re-designed to allow movement of the entire calorimeter and gantry on Hillman rollers. This motion is described in a separate OSP for HCal motion. With the failure of the Hall A crane, this method of moving the HCal has become the only practical solution.

The individual modules are each constructed from two rows of alternating iron energy absorbers (to cause hadronic showers) and plastic scintillators. A single sheet of wavelength shifter runs the length of the modules between the two rows. The wavelength shifter directs light, through a light-guide, to a 2 inch diameter PMT mounted on the back of the module. The HCAL-J array has 288 modules, thus 288 PMT signals. The array is instrumented using existing XP2262H and XP2282/B PMTs.

The high voltage to the 288 PMTs will be provided through standard HV cables and utilizes SHV connectors. They are rated at 5,000 volts and 4 amps. The power supplies' maximum output is significantly below these ratings, and we plan to run at voltages below 2500 volts on the 2282 PMTs and 2000 volts on the 2262 PMTs, unless specifically authorized by Scott Barcus or Brian Quinn, and less than15 mA per channel. The plastic PMT housing on the 2262 and 2282B PMTs prevents accidental contact with the HV divider chain in the base.

The signals are less than 5 volts and will be output on BNC coax connectors. The SHV connectors are designed to prevent any accidental connections between SHV and BNC connectors. Signals go to front-end electronics on upper-level of gantry. These are NIM and VME electronics. Signals from those modules go, via 100 m coax BNC cables, to standard electronics in the shielded electronics hut.

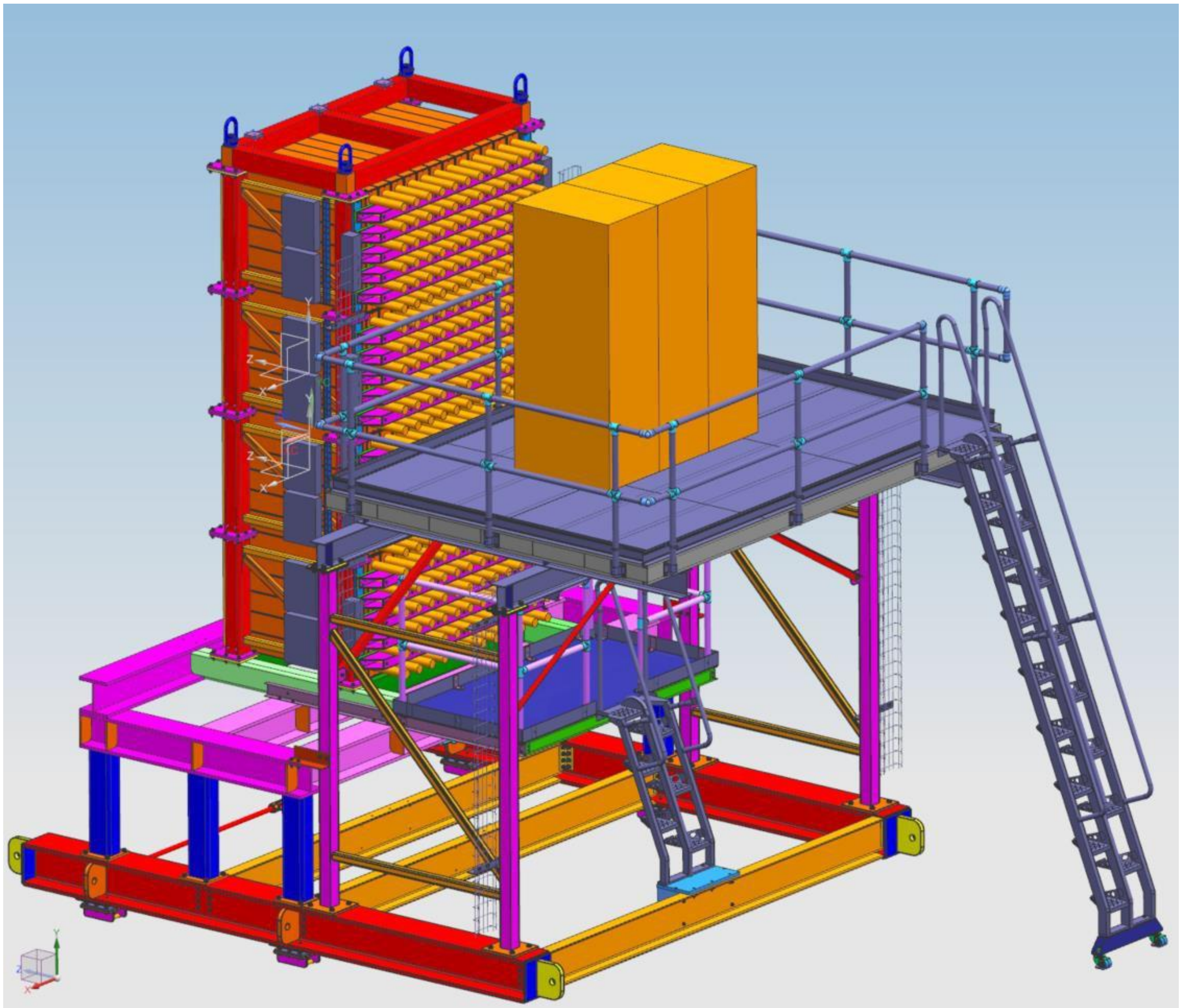

Figure 1. View of HCal and gantry after installation of lower access platform and attached access ladders. The cable trays are not shown, nor are three cable-access through-holes in the upper platform.

HCAL-J also includes an LED/fiber-optic pulser system to facilitate signal checkout and stability monitoring. The TTL logic of the Pulser Power Distribution Boxes (PPD boxes) requires 5V power. The 160 V power to the LED boards enters the PPD boxes through a 12 kΩ resistor which limits the maximum current to below the DC let-go threshold. The pulser system will use blue LEDS distributed via fiber optics. This avoids the safety issues associated with systems which use a UV-laser system to excite scintillators.

To prevent degradation of the PMTs due to helium contamination in the Hall A atmosphere, the bases will be supplied with a small positive pressure of clean air.

For transport of HCal in and out of the Hall, it will be necessary to coil the front-end cables of each subassembly on the sides of the subassembly. Securing and removing these cable coils will require the use of lifts. The job should be possible using a scissor lift with personnel remaining withing the platform and the hand-rails remaining in place. If use of a boom-supported lift is necessary for this or any other access to HCal, the work will only be done by personnel with fall-protection training and wearing properly secured fall-protection harnesses Hoists will only be operated by properly trained members of the Hall A technical staff, or equivalent, authorized by Jesse Butler

Servicing/replacement of individual PMTs may require use of a two-step ladder on the platforms. The ladder would be kept 4 ft. away from the edges of the platform and would only be used between the platform and HCal.

(For details, please see the details in attached operation manual of HCAL)

2. Scope – include all operations, people, and/or areas that the procedure will affect.

Hall A experiments using Super Bigbite Spectrometer(SBS); Hall A installation/removal of SBS experiments.

3. Description of the Facility – include building, floor plans and layout of the experiment or operation.

Hall A, beam-right, downstream of SBS spectrometer. Multiple positions for different kinematic points, and depending on beam energies actually available.

ANALYZE THE HAZARDS and IMPLEMENT CONTROLS

4. Hazards identified on written Task Hazard Analysis

Electric shock (hazard, after mitigation): 1
Ladders (hazard, after mitigation): 1
Hand tools (hazard, after mitigation): 1
Fire (hazard, after mitigation): 1

5. Authority and Responsibility:

5.1 Who has authority to implement/terminate

Hall A/C Leader, Hall A Work Coordinator, HCAL authorized personnel

5.2 Who is responsible for key tasks

Jiwan Poudel, Sebastian Seeds , Bogdan Wojtsekhowski, Jessie Butler

5.3 Who analyzes the special or unusual hazards including elevated work, chemicals, gases, fire or sparks (See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

Work Coordinator or designee

6. Personal and Environmental Hazard Controls Including:

6.1 Shielding

N/A

6.2 Barriers (magnetic, hearing, elevated or crane work, etc.)

N/A

6.3 Interlocks

N/A

6.4 Monitoring systems

N/A

6.5 Ventilation

N/A

6.6 Other (Electrical, ODH, Trip, Ladder) (Attach related Temporary Work Permits or Safety Reviews as appropriate.)

Use of current-limited high voltage supply at 2.5 kV. Use of shielded HV cables and connectors. Require HV off for all work, and HV cable disconnected for access to pulser-power distribution boxes.

7. List of Safety Equipment:

7.1 List of Safety Equipment:

SAF 202/SAF 202B for use of manlifts

7.2 Special Tools:

N/A

8. Associated Administrative Controls

Setup, removal, or changes to the HCal setup may be coordinated through Scott Barcus, Brian Quinn, members of the Work Coordinator's staff, members of Hall A/C staff, and others designated by Scott Barcus or Brian Quinn.

9. Training

9.1 What are the Training Requirements (See List of Training Skills)

ODH training, Rad-worker I. Ladder safety training if requiring access by ladder. Equipment-specific training. Jlab QEW training a the minimum of ESC001 (Basic Electrical Safety), Electrical Work Site Safety (ESC003), ESC007 (LOTO) and ESC008 (Electrical Safety Practical)

DEVELOP THE PROCEDURE

10. Operating Guidelines

See Operations manual for HCal.
https://hallaweb.jlab.org/wiki/index.php/SuperBigBite#HCAL_calorimeter
and pages within. Do not modify the system unless authorized
By Scott Barcus or Brian Quinn and with training as noted above.

11. Notification of Affected Personnel (who, how, and when include building manager, safety warden, and area coordinator)

Contact Hall Work Coordinate prior to start of work, daily.

12. List the Steps Required to Execute the Procedure: from start to finish.

1. HCal installation prior to start of experiments.
2. If necessary, connect HV unit to the PMTs.
3. If needed, connect the electronics, data acquisition to the PMTs..

For detailed operation of detector, refer to HCal manual.

13. Back Out Procedure(s) i.e. steps necessary to restore the equipment/area to a safe level.

1. Turn off high voltage
2. Reassess the job before turning power back on.

14. Special environmental control requirements:

14.1 List materials, chemicals, gasses that could impact the environment (ensure these are considered when choosing Subject Mater Experts) and explore EMP-04 Project/Activity/Experiment Environmental Review below

N/A

14.2 Environmental impacts (See EMP-04 Project/Activity/Experiment Environmental Review)

N/A

14.3 Abatement steps (secondary containment or special packaging requirements)

N/A

15. Unusual/Emergency Procedures (e.g., loss of power, spills, injury, fire, etc.)

In the event of injury, or an immediate emergency exists, call **911** and also notify:

- Guards (**x5822**)
- Occupational Medicine (**x7539**)
- Crew Chief (**x7045**) (if inside the fence)

In case of an injury follow standard JLAB procedures. Initial response cards are located with each phone for appropriate emergency phone numbers. Additional information can be found at https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-24400/*.pdf.

16. Instrument Calibration Requirements (e.g., safety system/device recertification, RF probe calibration)

N/A

17. Inspection Schedules

N/A

18. References/Associated/Relevant Documentation

Operations manual of HCal

19. List of Records Generated (Include Location / Review and Approved procedure)

Submit Procedure for Review and Approval (See ES&H Manual Chapter 3310 Appendix T1 OSP & TOSP Instructions – Section 4.2 Submit Draft Procedure for Initial Review):

- Convert this document to .pdf
- Open electronic cover sheet: https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-24048/3310T1Form.doc
- Complete the form
- Upload the pdf document and associated Task Hazard Analysis (also in .pdf format)

Distribution: Copies to Affected Area, Authors, Division Safety Officer
Expiration: Forward to ES&H Document Control

Form Revision Summary

Revision 1.7 – 02/25/2021 – Corrected link to Word doc; updated 'ESH&Q' to "ES&H'; other minor edits. No approval required.

Revision 1.6 – 06/23/2020 – Update section 15 to reflect guard number, what to do in an emergency, crew chief numbers, etc. approved by H. Fanning

Revision 1.5 – 04/11/18 – Training section moved from section 5 Authority and Responsibility to section 9 Training
Revision 1.4 – 06/20/16 – Repositioned "Scope of Work" to clarify processes
Qualifying Periodic Review – 02/19/14 – No substantive changes required
Revision 1.3 – 11/27/13 – Added "Owning Organization" to more accurately reflect laboratory operations.
Revision 1.2 – 09/15/12 – Update form to conform to electronic review.
Revision 1.1 – 04/03/12 – Risk Code 0 switched to N to be consistent with 3210 T3 Risk Code Assignment.
Revision 1.0 – 12/01/11 – Added reasoning for OSP to aid in appropriate review determination.
Revision 0.0 – 10/05/09 – Updated to reflect current laboratory operations

ISSUING AUTHORITY	FORM TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ES&H Division	Harry Fanning	04/11/18	02/25/24	1.6

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Task Hazard Analysis (THA) Worksheet

(See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

Author:	Jiwan Poudel	**Date:**	03/14/2023	**Task #:** If applicable	

Complete all information. Use as many sheets as necessary

Task Title:	Hadron Calorimeter (HCAL) for SBS experiments			**Task Location:**	Hall A
Division:	Physics	**Department:**	Hall A	**Frequency of use:**	Used in experiments over next few years.
Lead Worker:	Jiwan Poudel				
Mitigation already in place: Standard Protecting Measures Work Control Documents	Use of shielded HV cables and connectors, and shielded LV cables and connectors, JLab standard 12 gauge extension cords, and fixed ladder in HCAL platform				

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
1	Electrical shock from high voltage supplying PMTs	M	M	3	Use of current-limited high voltage supply to PMTs (below 1.5mA and 2.5kV). Use of standard SHV connectors and shielded HV cables. PMT bases are insulating plastic.	HV cables are already connected to the PMTs and Power supply, and those cables are only connected/disconnected, when power supply is OFF. Equipment-specific training. Jlab QEW training a the minimum of ESC001 (Basic Electrical Safety), Electrical Work Site Safety (ESC003), ESC007 (LOTO) and ESC008 (Electrical Safety Practical)	1

Task Hazard Analysis (THA) Worksheet

(See ES&H Manual Chapter 3210 Appendix T1
Work Planning, Control, and Authorization Procedure)

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
2	Electrical shock from 160 V supply to LED pulsers	M	M	3	Use of standard SHV connectors and shielded HV cable. Pulser power boxes are large BUD boxes with transparent covers so their status LEDs can be read without opening box. Pulser power enters box through 12 kΩ resistor, limiting current to less than 13.5 mA, well below the D.C. let-go threshold of ~60 mA.	High voltage cables are only connected or disconnected to/from the detectors, power supplies, and patch panels when power supply is not energized. For any access inside the pulser power distribution box or pulser box, the voltage will be turned off, then the SHV cable must be disconnected. Equipment-specific training. Jlab QEW training a the minimum of ESC001 (Basic Electrical Safety), Electrical Work Site Safety (ESC003), ESC007 (LOTO) and ESC008 (Electrical Safety Practical)	1
3	Use of ladder for access to work platforms	M	M	3	Use of ladder training and having an observer/assistant.	SAF307 Ladder Safety	1
4	Portable hand tools	L	M	2	Tools, such as power drills, may be used for minor work. Anyone using portable hand tools must make themselves familiar with ES&H manual chapter 6120 prior to their use	EH&S manual chapter 6120	1
5	Fire	H	L	3	Signal and HV cables to/from the PMTs are standard JLab cables except multi-conductor HV cable used between 'breakout boxes' in the electronics hut and HCal support structure	https://www.jlab.org/esh/electricalsafety/code-standards	1

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
6	Covid-19 contamination (if at an elevated MEDCON level)	M	M	3	Face covering required. Maintain social distancing of 6' or use appropriate PPE if 6'distancing cannot be maintained.	OSP ESH-20-106466-OSP. \ Follow required guidelines	1
7	Securing and removing cable coils will require the use of lifts. When possible, this will be done using a scissor lift. Use of a boom-supported lift is necessary for this or any other access to HCal,	H	L	3	Scissor lift must have hand rails installed, personnel must stay within confines of platrorm. If boom-supported lift is required, the work will only be done by personnel with fall-protection training and wearing properly secured fall-protection harnesses. Lifts will only be operated by properly trained Hall A technical staff, or equivalents, authorized by Jesse Buttler.	SAF202 and SAF202B	1

Highest Risk Code before Mitigation:	3	**Highest Risk Code after Mitigation:**	1

When completed, if the analysis indicates that the Risk Code before mitigation for any steps is "medium" or higher (RC≥3), then a formal Work Control Document (WCD) is developed for the task. Attach this completed Task Hazard Analysis Worksheet. Have the package reviewed and approved prior to beginning work. (See ES&H Manual Chapter 3310 Operational Safety Procedure Program.)

Form Revision Summary

Revision 0.2 – 07/26/21 – Periodic Review; updated header and footer
Periodic Review – 08/29/18 – No changes per TPOC
Periodic Review – 08/13/15 – No changes per TPOC
Revision 0.1 – 06/19/12 - Triennial Review. Update to format.
Revision 0.0 – 10/05/09 – Written to document current laboratory operational procedure.

ISSUING AUTHORITY	TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ES&H Division	Harry Fanning	08/29/18	07/26/24	0.2

Operations Manual of Hadron Calorimeter (HCAL)

Jiwan Poudel

1 Introduction

The Hadron Calorimeter (HCAL) is a sampling calorimeter designed to measure the energy of several GeV protons and neutrons. It is used for measuring hadron energy and triggering purposes in the upcoming Super BigBite Spectrometer (SBS) program to study nucleon form factors. The SBS nucleon form factor experiments explore higher Q2 regions and also reduce uncertainty of form factors in lower region. The GMn experiment measures the magnetic form factor of the neutron by measuring quasielastic electron scattering cross section ratios d(e,e'n)p/d(e,e'p)n off liquid deuterium. The GEn experiment measures the GEn/GMn ratio using the double polarization technique to measure the asymmetry of electron scattering off of polarized Helium-3. The GEp experiment measures the ratio GEp/GMp at high Q2 using the polarization transfer method to scatter electrons from a liquid hydrogen target. In all these SBS collaboration, HCAL is a crucial detector system in the nucleon arm of the experimental Hall A as shown in figure 1.

Figure 1: HCAL detector system inside the hall A for SBS-collaboration

2 Experimental Setup

HCal is constructed from 288 individual detector modules assembled into an array of 12 modules wide by 24 modules high (180 cm wide x 360 cm high) as shown in Figure 2. These modules are spread across four craneable subassemblies, and the detector weighs approximately 40 tons in total. Each module is made up of 40 layers of 1 cm thick scintillator (PPO only, 2,5-Diphenyloxazole) alternating with 40 layers of 1.5 cm thick iron absorbers, and each module measures 15×15 cm^2 with a length of 1 m. The hadrons strike the iron causing them to shower, and the scintillators produce photons from these shower particles. In the center of the iron and scintillators is a BC-484 wavelength shifter (decay time 3 ns) which improves light collection efficiency and uniformity. The photons in the wavelength shifter are transported to photomultiplier tubes (PMTs) on one end of the modules via custom built light guides as shown in Figure 3.

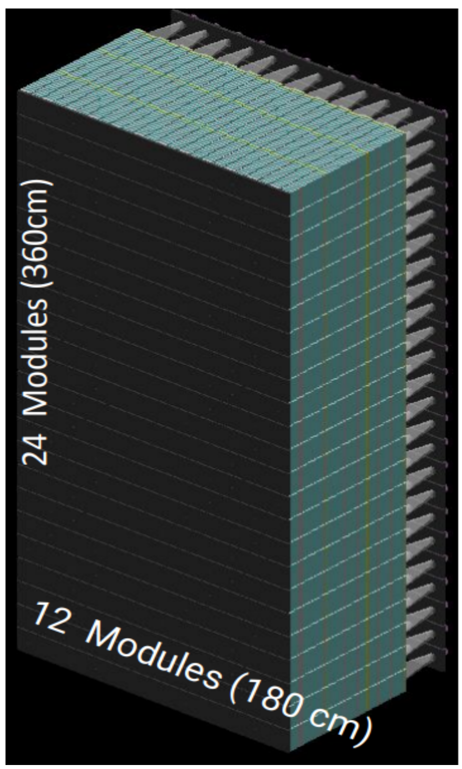

Figure 2: HCAL assembly with 24 rows and 12 columns

The wavelength shifter directs light to a 2 inch diameter PMT mounted on the back of the module. The completed HCAL array will have 288 PMTs (instrumented using existing 192 Photonis XP2262 and 96 Photonis XP2282 PMTs). A row of alternating iron absorbers/scintillators can be seen looking through the wavelength shifter as detailed in Figure 3.

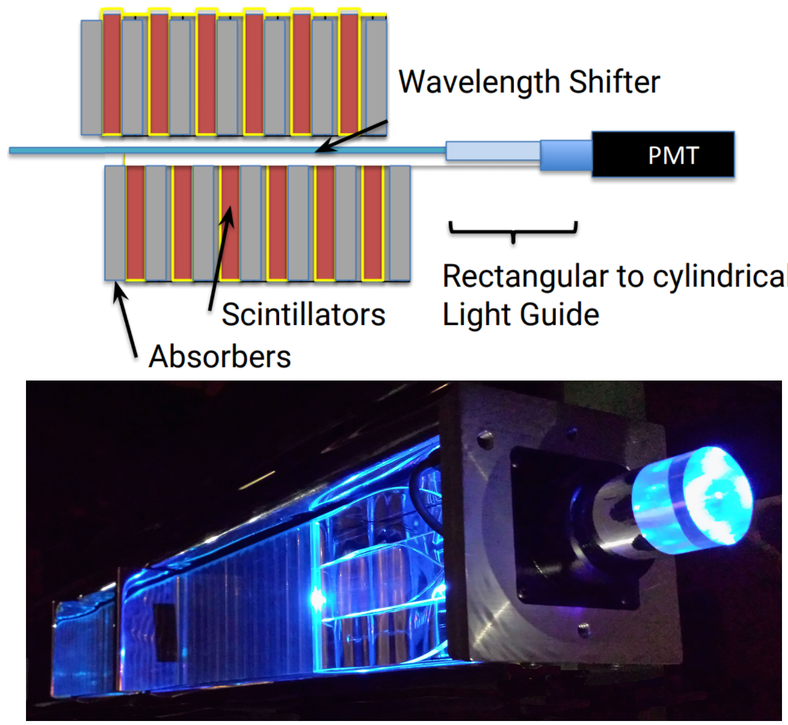

Figure 3: Interior of the HCAL modules in the SBS-experimental programs. Top picture illustrates the interior which consists of two rows of the alternating iron and scintillator, with a wavelength shifter in between. Bottom picture shows the interior of a lid module removing PMT housing and one row of aborbing irons+scintillors

To prevent the degradation of PMTs performances because of the helium contamination (helimum poisoning) in the Hall, there are spigots at the back of each PMT housing to flow clean air. Dry nitrogen could be supplied to the distribution manifold located in each sub-assembly, if the helium concentration is increased in the hall to prevent PMTs from degradation.

The cabling scheme is designed in such a way that all channels can be accessed at numerous points between the detector PMTs and the back-end DAQ electronics. The HCAL cable system can be broken into three groups based on whether the physics signals flow to the fADC250s, the F1TDCs, or the UVA-120 summing modules. Figures 4 and 5 describes how the signal from the HCAL detector flows through the front-end and back-end side electronics on each of these three paths before being recorded by the DAQ modules. Signals from PMTs are few mVs, which are passed to 10x amplifier first, output of which are sent to fADCs, f1TDCs and summing modules. So, front-end consists of NIM crate and NIM electronics to process signals before it vanishes while reaching to the DAQ bunker. Signals from front-end goes via 100 m of coax BNC cables to the back-end located at the shielded DAQ bunker.

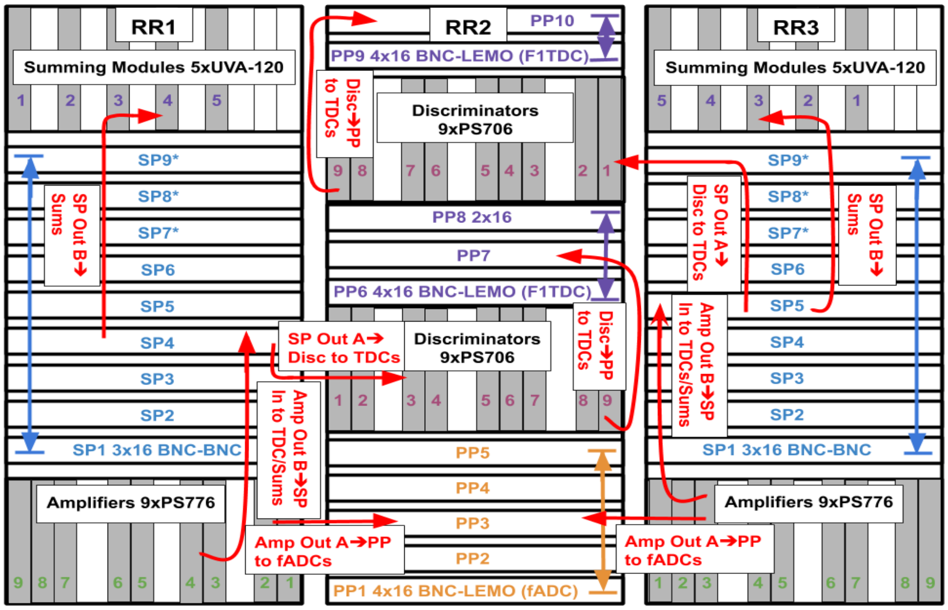

Figure 4: Front-end Electronics in the upper platform of HCAL and signal mapping. Six NIM crates consisisting of different NIM modules are present in this region. (RR represents to Rack, SP to Split Panel and PP to Patch Panel).

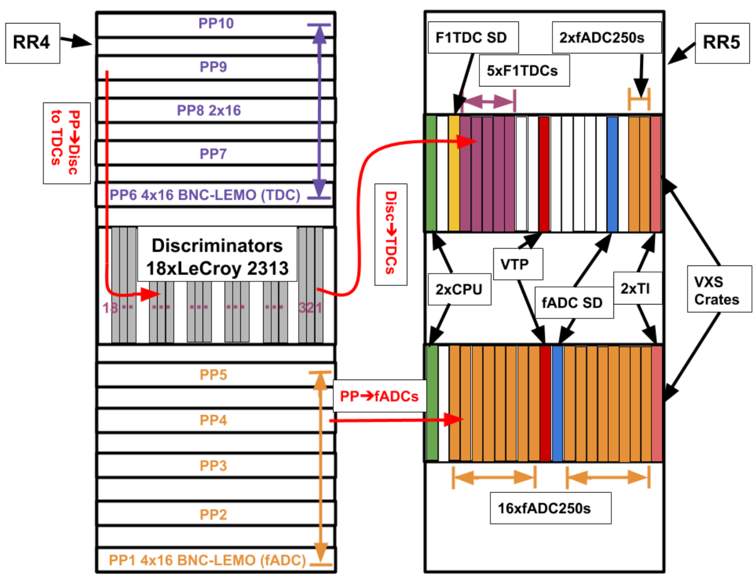

Figure 5: Back-end Electronics in the DAQ bunker and signal mapping. Two VXS crates, one VME crate and one NIM crate are present in this region.

In addition to 288 modules/PMTs of hcal, there are 4 more PMTs attached to both ends of two long scinntillator paddles which are used in the HCAL system to set-up an external cosmic triggering. One of the paddle is placed on top and another at the bottom of the HCAL blocks. Extra LECROY module is added to the HCAL power supply system, to supply the hight voltage to these PMTs. The signal output of these four PMTs are ORed to get trigger for the hcal while operating in external cosmic trigger mode. This trigger set-up is in addition to the self triggering set-up using summing modules, so that we could choose one of them during the cosmic run.

HCAL also includes an LED/ fiber optic pulser system to facilitate signal checkout and stability monitoring. The TTL logic of the Pulser Power Distribution Boxes (PPD boxes) requires 5V power. The 160 V power to the LED boards enters the PPD boxes through a 12 kohms resistor which limits the maximum current to below the DC let-go threshold. The pulser system will use blue LEDS distributed via fiber optics. This avoids the safety issues associated with systems which use a UV-laser system to excite scintillators.

3 Operations Procedure

- Make sure all the cables are connected properly in both Front-end and back-end units, starting from the signal output of PMT in each module
- Make sure that all the HV cables are connected to the PMTs of each module, the other end of which is connected the Lecroy HV supply in DAQ bunker
- Turn On all the NIM crates in the Front-end which hosts amplifiers, discriminators and summing modules (Figure 4 above)
- Load the pre-saved operating voltages of the PMTs in the HV control GUIs (Figure 6 below)
- Enable all channels and turn On high voltages of all PMTs
- Set the Digital to Analog (DAC) threshold appropriately using DAC gui (∼25 mv would be okay for the test)
- Make sure that counter in DAQ bunker (or DAQ scalar rate) shows HCAL triggers (∼400 for cosmics with 25 mV threshold)
- Make sure that HCAL back-end crates (ROC16 and ROC17) are On and running in the DAQ bunker (Figure 5 above)
- Now, HCAL system is ready to accumulate data. Collect data running CODA in the Hall A DAQ VNC with appropriate pre-scaling.

Note: While taking cosmic run with top/bottom paddles, turn ON HV on those paddles also.

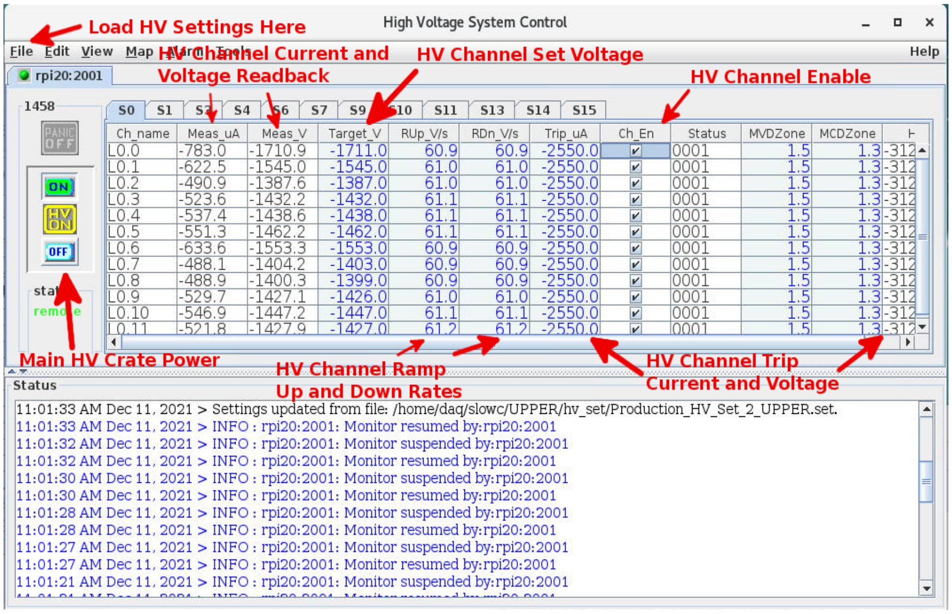

Figure 6: HCAL high voltage GUI and adequated labels

4 Potential Hazards

- Electrical safety: Power rating should be checked to prevent electric shock. Jlab standard extension cable should be checked to prevent further issues of heating/firing.
- High Voltage: HCAL requires up to 2.5 kV and 1.5 mA per channel to perform effectively, which could be hazardous in case of a short-circuit.
- Height: HCAL assembly is 3.6 m tall, in which each PMTs could not be reached from the ground level.
- Helium poisoning of PMTs: The PMTs are susceptible to degradation when exposed to the raised helium concentration levels.

5 Hazard Mitigation and Safety

- JLab standard 12 gauge extension cable should be used
- HV should not exceed 2.5 kV per channel in the PMTs
- Sophisticated HV supply system with auto cut-off to all HV
- Proper choice of HV cables, and SHV connectors

- Two fixed ladders in the HCAL frame, making it easy to access all layers of PMTs.
- Monitoring of Helium concentration in the hall periodically, and supply of dry nitrogen to the distribution manifold located on each sub-assembly if required.

Jefferson Lab EH&S should be followed properly, and all the personnels working in the HCAL system must have appropriate trainings.

6 Authorised Persons

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Scan the following QR code and complete the training registration in order to testify that you have read, understand, and agree to abide by the procedure specified in the above referenced work control document: