ES&H DIVISION
RADIATION CONTROL DEPARTMENT

radiological safety analysis document

Hall C Summer 2023 – Spring 2024 Run

E12-13-010, E12-13-007, E12-22-006

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June 23, 2023

RCD-RSAD-06.23.2023-HC

Priority review level	1
Document classification	4
Next review due	n/a

Submit for approval	☐ yes	☑ no

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Hall C Summer 2023 – Spring 2024 Run

Measurement of Semi-Inclusive π◦ Production as Validation of Factorization
(E12-13-007)

Exclusive Deeply Virtual Compton and Neutral Pion Cross-Section Measurements in Hall C
(E12-13-010)

Deeply Virtual Compton Scattering off the neutron with the Neutral Particle Spectrometer in Hall C
(E12-22-006)

RCD-RSAD-06.23.2023-HC

Approval

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Hall C

Contents

This Radiological Safety Analysis Document (RSAD) identifies the radiation budget for the experiment, the verification process for the radiation budget, and controls with regard to production, movement, or import of radioactive materials.

1 DESCRIPTION

This RSAD covers the series of experiments scheduled for the summer 2023 – spring of 2024 in Hall C.

Three experiments will run during this period.

- **E12-13-010:** Exclusive Deeply Virtual Compton (DVCS) and Neutral Pion Cross-Section Measurements in Hall C
- **E12-13-007:** Measurement of Semi-inclusive pi0 production as Validation of Factorization
- **E12-22-006:** Deeply Virtual Compton Scattering off the neutron with the Neutral Particle Spectrometer in Hall C

They are aiming at accessing Generalized Parton Distributions of the proton and neutrons for the DVCS experiments and Transverse Momentum Dependent parton distributions for the SIDIS measurement which are both essential for the understanding of how quarks and gluons are spatially distributed inside nucleons.

The experiments will be using a new calorimeter system the Neutral Particle Spectrometer (NPS) with the Hall C HMS spectrometer to extensively probe the kinematic range accessible with a 11 GeV beam.

It is an improvement of the Hall A DVCS experiment setup using a sweeper magnet near the target, a high-resolution calorimeter the Hall C HMS, greatly enhancing the luminosity and range accessible for DVCS and pi0 production. The new calorimeter will be sitting on a platform attached to the SHMS allowing accurate angular positioning. All the new calorimeter electronics is located in the SHMS electronics hut.

Proposals and additional information about the NPS detector can be found at

https://wiki.jlab.org/cuawiki/index.php/NPS_Experiments and

https://wiki.jlab.org/cuawiki/index.php/Main_Page

2 SUMMARY and CONCLUSIONS

The boundary dose accumulation due to this run in Hall C is estimated to be approximately **3 mrem**, i.e., about **30%** of the annual design goal. Dose rates averaged over the run time are expected to be below the alert threshold of 200%, with the expectations that the dose rates both inside the Hall and at the boundary will be typical for the experiments in Hall C. The dose accumulation at the boundary will be split between the calendar years 2023 and 2024. Radiation levels will be continually recorded and periodically checked by the Radiation Control Department (RCD) to ensure that the site boundary goal is not exceeded. Radiation hazards associated with activation of the beam line hardware require special consideration. As specified in Sections 4, 6, and 7, the manipulation and/or handling of the target(s) or beam line hardware (potential radioactive material), the transfer of radioactive material, or modifications to the beam line downstream from the target assembly must be reviewed and approved by the Radiation Control Department.

Adherence to this RSAD is vital.

3 CALCULATIONS of RADIATION DOSE at the SITE BOUNDARY

The radiation budget for a given experiment is the amount of radiation that is expected at the site boundary as a result of a given set of experimental conditions. This budget may be specified in terms of mrem at the site boundary or as a percentage of the Jefferson Lab design goal for dose to the public, which is 10 mrem per year. The Jefferson Lab design goal is 10% of the DOE annual dose limit to the public, and cannot be exceeded without prior written consent from the RCD Manager (RCM) and the TJNAF Director.

The radiation budget for the run period from summer 2022 – spring 2023 run in Hall C is approximately **3.03 mrem**, or about **30%** of Jefferson Lab's annual design goal. The attached Radiation Budgets detail the calculations for all panned experiments in the period.

The Hall's contribution to the boundary dose will be verified during the run period by using the active monitors at the Jefferson Lab site boundary to keep up with the dose for the individual setups. If it appears that the radiation budget will be exceeded, the RCD will require a meeting with the Head of the Physics Division to determine if the experimental conditions are accurate, and to assess what actions may reduce the site boundary dose rates. If the site boundary dose approaches or exceeds 10 mrem during any calendar year, the experimental program will not proceed until a resolution is reached and approved by TJNAF's Director.

4 RADIATION HAZARDS

The following controls shall be used to prevent the unnecessary exposure of personnel and to comply with Federal, State, and local regulations, as well as with Jefferson Lab policies.

4.1 Beam in the Hall

When the Hall status is Beam Permit, there are potentially lethal conditions present. Therefore, prior to going to Beam Permit, several actions will occur. Announcements will be made over the intercom system notifying personnel of a change in status from Restricted Access (free access to the Hall is allowed, with appropriate dosimetry and training) to Sweep Mode. All magnetic locks on exit doors will be activated. Persons trained to sweep the area will enter by keyed access (Controlled Access) and search in all areas of the Hall to check for personnel.

After the sweep, another announcement will be made, indicating a change to Power Permit, followed by Beam Permit. The Run-Safe boxes will indicate "OPERATIONAL" and "UNSAFE".

> IF YOU ARE IN THE HALL AT ANY TIME THAT THE RUN-SAFE BOXES INDICATE "UNSAFE", IMMEDIATELY PRESS THE "PUSH TO SAFE" BUTTON ON THE BOX.

Controlled area radiation monitors (CARMs) are located in strategic areas around the Hall and the Counting House to ensure that unsafe conditions do not occur in occupiable areas. The Radiation Control Department will monitor the CARMs and make surveys as necessary to assess the impact of the experiment on radiation levels around the hall.

> **Note:** Any indication that the levels may exceed 5 mrem/h dose rate in an occupied area will require immediate mitigation, with continued operations contingent on a formal review of conditions and operational parameters, and final approval of operations exceeding this threshold by the Jefferson Lab RCM, in consult with Physics and Accelerator Division Safety Officers.

4.2 Activation of Target, Beamline Components and Other Materials in the Hall

It is not expected that extraordinarily high radiation conditions will be present in the Hall during and after the run. However, the customary radiation protection measures must be taken.

- **Given the conditions for this run period, it is expected that High Radiation Areas will develop near the target area and the narrow downstream beam line. A High Radiation Area may also occur at the beam dump/hall interface. Whole-body dose rates in these areas have the potential to exceed 1 rem/h. The establishment of physical access controls may be necessary to comply with regulatory requirements based on the radiation levels.** Always confer with RCD prior to entry to any posted Radiation or High Radiation Area.

- One issue of note for the RSAD is that rotation of the SHMS to small angles will require "spotters" in the hall to observe the rotation. In some cases, the spotter may need to be close to the downstream beamline to make sure there is no collision between the beamline and SHMS. **After some period of running, the beamline will likely be activated, so careful coordination with RadCon will be required, to develop and implement methods for ALARA radiation exposure mitigation**.

- **After the experiment commences, ALL work in the vicinity of the target chamber (within several meters up and downstream)** requires RCD review.

- This experiment is expected to produce low levels of airborne radioactivity, which may impact environmental effluent standards and produce localized or generalized buildup of surface contamination in the hall. Airborne radioactivity concentration in the hall is measured continuously. **If airborne radioactivity concentration as monitored by the AMS-4 air monitor in the experimental hall exceeds an average of 1.0E-6 µCi/cc for a period of greater than 5 consecutive days**, RCD will require a meeting with the experimenters and the Head of the Physics Division to determine if the experimental conditions are accurate, and to assess what actions may be needed to reduce the airborne radioactivity effluent levels and to control/minimize contamination inside the hall.

- **Low levels of surface contamination are expected on and around the target chamber and downstream beamline**. The RCD will monitor for the presence of this hazard as appropriate, and will require administrative controls and/or PPE commensurate with the conditions. **All posted guidance for contamination control must be observed.** Refer to the General Access RWP for details regarding controls for potentially affected systems.

- **Some sections of beamline may contain indium gaskets/seals**. These components should always be considered potentially contaminated. Always consult with RCD prior to disassembling any beamline components incorporating indium seals – regardless of radiation levels.

4.3 Other Sources

All radioactive materials brought to Jefferson Lab shall be identified to the Radiation Control Department. These materials include, but are not limited to radioactive check sources (of any activity, exempt or nonexempt), previously used targets or radioactive beamline components, previously used shielding or collimators, or He-3 containers. The RCD inventories and tracks all radioactive materials onsite. The RCD may survey the experimental setup before experiments begin as a baseline for future measurements if significant residual activity levels are present.

Tanks or cylinders of He-3 containing more than 10 mCi of tritium (H-3) shall not be stored or used in an experimental hall without the express written permission of the RCD manager. Any containers of He-3 brought on site shall be assessed for the tritium content before use. Additionally, He-3 containers should not be stored in the experimental hall when not in use.

5 INCREMENTAL SHIELDING or OTHER MEASURES to REDUCE RADIATION HAZARDS

The RCD Manager will notify the Operations Director, Hall Leader, and Accelerator and Physics Division Safety Officers of any identified trends which might impact access to the hall or create conditions requiring broad changes to radiological working standards (i.e. General Access RWP revision). The RCD Manager will recommend

engineered or other controls considered necessary to prevent significant degradation of the radiological conditions in the hall.

6 OPERATIONS PROCEDURES

- **All experimenters must comply with experiment-specific administrative controls**. These controls begin with the measures outlined in the experiment's Conduct of Operations Document, and also include, but are not limited to, Radiation Work Permits, Temporary Operational Safety Procedures, and Operational Safety Procedures, or any verbal instructions from the Radiation Control Department. A general access RWP governing access to the Halls and the accelerator enclosure must be read and followed by all participants in the experiment.

- Any individual with a need to handle radioactive material at Jefferson Lab shall first complete Radiation Worker (RW-I) training.

- **There shall be adequate communication between the experimenter(s) and the Accelerator Crew Chief and/or Program Deputy** to ensure that all beam restrictions are understood and not exceeded. Exceeding these power restrictions may lead to excessive and unnecessary contamination, activation, and personnel exposure. The beam current/power and other beam parameter restrictions shall be documented in the Operational Restrictions list at http://opweb.acc.jlab.org/internal/ops/ops_webpage/restrictions/ops_restrictions.html

- **No target chamber or downstream component may be altered** outside the scope of this RSAD without formal Radiation Control Department review. Alteration of these components (including the exit beamline itself) may result in increased radiation production in the Hall and a resultant increase in site boundary dose.

- **Any requested changes outside of the experimental parameters submitted for the calculation of the radiation budget (e.g., current, energy, target material, target thickness, run time)** for this experiment shall require a formal review by the Radiation Control Department, and a new revision to the RSAD.

- **Standard procedures**
  Radiological work permits (RWPs) are the standard work authorization documents used to control radiological work. RadCon will require RWPs based on established trigger levels.

  Standard RSAD controls apply; the RCD shall be contacted for any of the following activities.
  - Entry to Radiation Areas or High Radiation Areas
  - Movement of shielding or collimators
  - Breaching the target chamber physical envelope
  - Any work on beamline components downstream of the target
  - Maintenance of known or potentially contaminated systems
  - Any destructive modifications to activated components (drilling, cutting, welding, etc.)

All posted guidance and instructions for contamination controls, shielding configuration, and access to radiological areas must be adhered to.

Note: Work planning for all radiological work shall be coordinated through the hall work coordinator using the ATLis work planning tool.

7 DECOMMISSIONING and DECONTAMINATION of RADIOACTIVE COMPONENTS

Experimenters shall retain all targets and experimental equipment brought to Jefferson Lab for temporary use during the experiment. After sufficient decay of the radioactive target configurations, they shall be returned to the experimenter's home institution for final disposition. All transportation shall be done in accordance with United States Department of Transportation Regulations (Title 49, Code of Federal Regulations). In the event that

the experimenter's home institution cannot accept the radioactive material due to licensing requirements, the experimenter shall arrange for appropriate transfer of funds for disposal of the material. Jefferson Lab cannot indefinitely store radioactive targets and experimental equipment.

The Radiation Control Department may be reached at any time through the Accelerator Crew Chief (269-7045) or directly by calling the RadCon cell phone (876-1743). On weekends, swing and owl shifts, requests for RadCon support should be made through the Crew Chief. This will ensure prompt response with no duplication of effort.

8 RADIATION BUDGETS

Hall: C **RADIATION BUDGET FORM** *page:* 1 of 1

Exp. # E12-13-010 E12-13-007 **rev:** **run dates: 2023-2024** **name of liaison: A. Camsonne**

setup number			1	2	3	4	5	6	7	8	9	10	11	
beam	energy	GeV	11.0	11.0	11.0	6.6	6.6	8.8	8.8	8.8	11.0	6.6	8.8	*totals:*
	current	uA(CW)	28.0	50.0	11.0	28.0	11.0	28.0	5.0	50.0	40.0	40.0	40.0	
exp't target	element		H	H	H	H	H	H	H	H	Al	Al	Al	
	thickness	mg/cm2	710	710	710	710	710	710	710	710	536	536	536	
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Z		1	1	1	1	1	1	1	1	13	13	13	
	A		1	1	1	1	1	1	1	1	27	27	27	
cryo tgt window	element		Al	Al	Al	Al	Al	Al	Al	Al				
	thickness	mg/cm2	137	137	137	137	137	137	137	137				
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
	Z		13	13	13	13	13	13	13	13	0	0	0	
	A		27	27	27	27	27	27	27	27	0	0	0	
critical window	radius	cm	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	
	dist. to pivot	m	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.58	
scattering weighting factor			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
time	run time (100% eff.)	hours	624	168	24	144	24	144	24	24	96	24	24	1320
		days	26.0	7.0	1.0	6.0	1.0	6.0	1.0	1.0	4.0	1.0	1.0	55.0
	installation time	hours												0
		days	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
dose rate at the fence post (run time)	method 1	urem/hr	0.57	1.02	0.23	0.72	0.28	0.63	0.11	1.13	1.53	1.63	1.57	
	method 2	urem/hr												
	conservative	urem/hr	0.57	1.02	0.23	0.72	0.28	0.63	0.11	1.13	1.53	1.63	1.57	
dose per setup		urem	358	172	5	104	7	91	3	27	147	39	38	989.8
% of annual dose budget		%	3.6	1.7	0.1	1.0	0.1	0.9	0.0	0.3	1.5	0.4	0.4	9.898
% of allowed dose for the total time														65.69
% of allowed dose for the run time only														65.69

If > 200%, discuss result with Physics Research EH&S officer

date form issued: June 9, 2023 *authors:* P. Degtiarenko

Hall: C

RADIATION BUDGET FORM

Exp. # E12-22-006 **rev:** **run dates: 2023-2024** **name of liaison: A. Camsonne**

setup number			1	2	3	4	5	
beam	energy	GeV	11.0	11.0	8.8	8.8	6.6	*totals:*
	current	uA(CW)	28.0	50.0	28.0	50.0	28.0	
exp't target	element		D	D	D	D	D	
	thickness	mg/cm2	1620	1620	1620	1620	1620	
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	
	Z		1	1	1	1	1	
	A		2	2	2	2	2	
cryo tgt window	element		Al	Al	Al	Al	Al	
	thickness	mg/cm2	137	137	137	137	137	
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	
	Z		13	13	13	13	13	
	A		27	27	27	27	27	
critical window	radius	cm	2.06	2.06	2.06	2.06	2.06	
	dist. to pivot	m	2.58	2.58	2.58	2.58	2.58	
scattering weighting factor			0.50	0.50	0.50	0.50	0.50	
time	run time	hours	624	144	144	24	144	1080
	(100% eff.)	days	26.0	6.0	6.0	1.0	6.0	45.0
	installation time	hours						0
		days	0.0	0.0	0.0	0.0	0.0	0.0
dose rate at the fence post (run time)	method 1	urem/hr	1.68	2.99	1.69	3.03	1.70	
	method 2	urem/hr						
	conservative	urem/hr	1.68	2.99	1.69	3.03	1.70	
dose per setup		urem	1046	431	244	73	245	2039
% of annual dose budget		%	10.5	4.3	2.4	0.7	2.5	20.39
% of allowed dose for the total time								165.4
% of allowed dose for the run time only								165.4

If > 200%, discuss result with Physics Research EH&S officer

date form issued: June 9, 2023 *authors:* P. Degtiarenko