ES&H DIVISION
RADIATION CONTROL DEPARTMENT

Radiological Safety Analysis Document

CLAS12

Hall B Run Group C

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This Radiological Safety Analysis Document (RSAD) identifies the general conditions associated with the CLAS12 (Run Group C [RG-C]) runin Hall B, as well as the controls associated with production, movement, or import of radioactive materials.

1 DESCRIPTION

The physics run of the CLAS12 RG-C will take place in summer 2022 through spring 2023 in experimental Hall B. The CLAS12 is a multipurpose detector system based on toroidal (forward detector) and solenoid (central detector) super-conducting magnets. The detector system includes Cherenkov Counters, Drift Chambers, Scintillation Counters, Silicon-strip detectors, Micro-mega gas detectors, and Calorimeters. For the RG-C, the CLAS12 polarized solid target will be used, adding a 1 K evaporation refrigerator and microwave system to CLAS12.

The CLAS12 polarized target will be located in the center of the 5 T solenoid magnet, and will consist of a 2 cm diameter Kel-F cell, with 0.05 mm foil aluminum windows, containing beads of solid NH_3 or ND_3 target material. This cell is held in a bath of liquid helium at near 1 K at the end of a 3 m long horizontal refrigerator, which allows the beam to pass through its center. Upon entering the refrigerator through an Al window, the beam will travel 3 m through a tube containing low pressure (<1 torr) helium gas, before passing through the aluminum window of the target bath. The beam then passes through 2 mm of super-fluid helium before entering and after exiting the 5 cm long target cell. Finally, the beam will exit the refrigerator through an aluminum bath window, aluminum inner vacuum window and aluminum outer vacuum window. The areal density of NH_3(+He) cell is 3(+0.3) g/cm^2. The areal density of the ND_3(+He) cell is 3.5(+0.3) g/cm^2. This corresponds to roughly 8% of radiation length.

In this run period beams of up to 11 GeV (5 pass) will be used. (The first week of running will be at 1 pass, 2.2 GeV). The typical luminosity during the run will be ~10^{35} cm^{-2}s^{-1}, the nominal design luminosity for CLAS12. Typical production beam currents will be up to 10 nA. The beam will be rastered over the target area with a spiral pattern. These production runs will take about 100 hours per week, for a total of 2800 hours.

For empty target runs (no NH_3 or ND_3 in the target cell) the beam current could be up to 100 nA, to reach the same luminosity. We expect to run about 2 hours per week on empty targets, for a total of about 70 hours spread over the entire 8 months.

We will also use (for calibration purposes) ancillary C, CH_2 and CD_2 targets, each with a thickness of 3 g/cm^2. The beam current on these targets will also be up to 10 nA. We expect to run about 4 shifts (32 hours) per week on these ancillary targets, for a total of 1000 hours.

To achieve a higher polarization of the ND_3 material, it will be irradiated by 50 nA beam current for 3-6 hours. This procedure will be repeated four times over the run period, for a total of 20 hours. During irradiation all CLAS12 detectors will be turned off.

During running with beam above 15 nA at 11 GeV (160 W), the Hall B beam stopper (a 30-cm long, water cooled-copper absorber) will be inserted before the Faraday Cup to prevent overheating. For the beam tuning and Møller runs, the beam will be directed into the beam dump in the Hall B Tagger dipole yoke. The beam current for these operations will be up to 10 nA. Møller runs will occur about once every 1 to 2 weeks for 1 to 2 hours each.

Target configurations that will be used in RG-C

Energy (GeV)	**Target**	**Beam Current** (nA)	**Beam Days**
2.2	NH_3. ND_3	10	6.9
	empty	100	0.1
11	C, CH_2, CD_2	10	1.3 per week
	empty	100	0.1 per week
	NH_3, ND_3	10	5.5 per week
	Moller	10 to tagger yoak dump	0.1 per week
	Polarization ND_3, NH_3	50	0.2 x 4 times per run period

2 SUMMARY and CONCLUSIONS

The experiment is not expected to produce significant levels of radiation at the site boundary. However, it will be periodically monitored by the Radiation Control Department to ensure that the site boundary goal is not exceeded. The main consideration is the manipulation and/or handling of target(s) or beam line hardware. As specified in Sections 4.2 and 7, the manipulation and/or handling of target(s) or beam line hardware (potential radioactive material), the transfer of radioactive material, or modifications to the beam line after the target assembly must be reviewed and approved by the Radiation Control Department.

Adherence to this RSAD is vital.

3 CALCULATIONS of RADIATION DEPOSITED in the EXPERIMENTAL HALL

The radiation budget for a given experiment is the amount of radiation that is expected at site boundary as a result of a given set of experiments. This budget may be specified in terms of mrem at 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 Radiation Control Department Head, the Director of Jefferson Lab, and the Department of Energy.

Calculations of the contribution to Jefferson Lab's annual radiation budget that would result from running under a broad variety of conditions typical of Hall B operations indicate that the contribution from this experiment will be negligible. With this expectation, we have not carried out calculations for the specific running conditions of this experimental group.

This expectation will be verified during the experiment by using the active monitors at the Jefferson Lab site boundary to keep up with the dose for the individual setups from Hall B and the other Halls. If it appears that the radiation budget will be exceeded, the Radiation Control Department (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 reduce the dose rates at site boundary. If the site boundary dose approaches or exceeds 10 mrem during any calendar year, the experimental program will stop until a resolution can be reached.

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 and the Experimenter's home institution policies.

The following controls shall be used to

- prevent unnecessary exposure of personnel;
- comply with Federal, State, and local regulations;
- adhere to TJNAF procedures; and,
- the Experimenter's home institution policies.

4.1 From 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 for personnel.

After the sweep, another announcement will be made, indicating a change to *Power Permit*, followed by *Beam Permit*. The lights will dim and 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 HIT THE 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.

4.2 From Activation of Target and Beam line Components

The Radiation Control Department shall be notified of all radioactive materials brought to Jefferson Lab. These materials include, but are not limited to

- radioactive check sources of any activity, exempt or non-exempt;
- previously used targets or radioactive beamline components; or,
- previously used shielding or collimators.

The RCD inventories and tracks all radioactive materials onsite. If radioactive materials are incorporated into an experimental setup, surveys may be conducted on the setup before experiments begin.

RadCon will coordinate movement of all used targets, collimators, and shields. RadCon staff will further assess the radiation exposure conditions and implement controls, as necessary, based on the radiological hazards.

There shall be no local movement of activated target configurations without direct supervision by the RCD. Remote movement of target configurations shall be permitted, providing the method of movement has been reviewed and approved by the RCM.

No work that could result in dispersal of radioactive material (e.g., drilling, cutting, or welding) is to be performed on beamline components. Such activities must be conducted only with specific permission and control of the Radiation Control Department.

5 INCREMENTAL SHIELDING or OTHER MEASURES to REDUCE RADIATION HAZARDS

None

6 OPERATIONS PROCEDURES

All experimenters must comply with experiment-specific administrative controls which begin with the measures outlined in the experiment's Conduct of Operations document. These controls may include radiological work permits (RWP), temporary operational safety procedures (TOSP), operational safety procedures (OSP), and/or any verbal instructions from RadCon. A General Access RWP (GARWP) that governs access to Hall B and the accelerator enclosure is in place and may be found in the Machine Control Center (MCC). All those who participate in the RG-C

experiment must be read and electronically sign the GARWP signifying that they understand and will abide by the permit. Any individual with a need to handle radioactive material at Jefferson Lab shall first complete Radiation Worker Level I (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 power restrictions on the target are well known. Exceeding these power restrictions may lead to excessive and unnecessary contamination, activation, and personnel exposure.

No scattering 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 from the Hall and a resultant increase in dose at the site boundary.

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 such target configurations, they shall be delivered to the experimenter's home institution for final disposition. All transportation shall be done in accordance with United States Department of Transportation (Title 49, Code of Federal Regulations) 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 funds transfers for disposal of the material. *TJNAF cannot store indefinitely any radioactive targets or experimental equipment.*

The Radiation Control Department may be reached at any time through the Accelerator Crew Chief (269-7050).