ES&H DIVISION
RADIATION CONTROL DEPARTMENT

radiological safety analysis document

CLAS12

Hall B Run Group E

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Thomas Jefferson National Accelerator Facility

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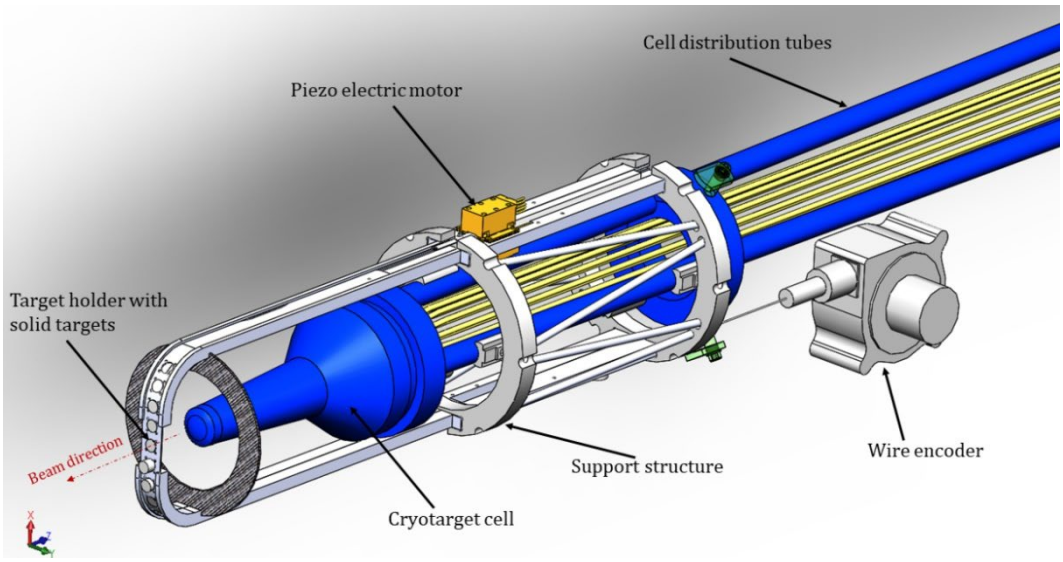
Contents

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

1 DESCRIPTION

The Physics Division run of the CLAS12 RG-E will take place during the spring of 2024 in Experimental Hall B. CLAS12 is a multipurpose detector system based on toroidal (forward detector) and solenoid (central detector) superconducting magnets. The detector system includes Cherenkov Counters, Drift Chambers, Scintillator Counters, Silicon-Strip detectors, Micro-Mega gas detectors, and Calorimeters. During this period, CLAS12 will be used in its standard detector and shielding configuration with the Forward Tagger (FT) OFF and the large Moller cone installed. The RG-E run will use up to 11 GeV, or the maximum energy possible, at 5 passes polarized electron beam, with currents up to 200 nA during the luminosity scans. Several targets varying from cryogenic liquid targets to heavy, solid targets will be used. The entire target system (the Double-Target was built in CCTVal/UTFSM, Chile) will be located inside the vacuum scattering chamber, installed within the central detector, in the center of the 5 T solenoid magnet. The RG-E Double-Target system utilizes a combination of the JLab/CLAS12 cryotarget and various solid material targets, which can be interchanged and used for other run periods. A piezo-motor, which is needed to move the volume because it is in a strong magnetic field, is used for this purpose. The solid targets are affixed to a specialized flexible band (refer to the figure below). The cryotarget consists of a 2 cm target cell that will contain liquid deuterium (LD_2) or liquid hydrogen (LH_2). The interchangeable solid targets, having an area of 5.25 mm^2, are affixed to a flexible band and are made of five materials: ^{208}Pb,^{120}Sn, ^{63}Cu, ^{27}Al, and ^{12}C.

The entire Double-Target system has the capability of aligning the solid targets with the cryotarget in front of the beam with a spatial precision of 0.04 mm.



Target system for RG-E

The solid target band system is enclosed within a vacuum vessel, co-located with the cryogenic system. Surrounding the target system area is a scattering chamber constructed from 1.2 mm thick carbon fiber. Aluminum windows are utilized at the liquid cell's entrance and exit, as well as at the scattering chamber's exit. Comprehensive details of all components, including windows and cells, along with their thicknesses and locations, are outlined in the beamline drawing located in the Beamline Manual.

The Double-Target will be arranged in different configurations, as delineated in the table below. The beam current values inside the table represent the maximum possible currents that will be used. During the production run, however, the expected beam current will be 70 nA for all configurations that will have a full liquid target cell. Simultaneously, the liquid target (full or empty) *and* one solid target will be exposed to the beam. The downstream endcap of the liquid target is positioned within the solenoid magnet at the beam axis, specifically at z = -2 cm (where z = 0 cm is the solenoid magnet center). Meanwhile, the solid target is situated at z = 2 cm.

The beam current settings specified in the table are expected during the RG-E period and will be aiming for up to 2.5 times the CLAS12 nominal luminosity of 10^{35} cm^{-2} s^{-1}.

Periodic luminosity scans will be conducted for detector efficiency studies, during which the beam current may be increased up to 200 nA.

CLAS12 RG-E liquid and solid target configurations

Energy	Target	Target Thickness* (cm)	Target Density* (g cm^{-3})	Target Areal Density* (mg cm^{-2})	T/X_o* (%)	Beam Current (nA)	Per-nucleon Luminosity (10^{35} cm^{-2} s^{-1})
	liquid/solid						
11 GeV (or maximum possible)	LD2 / 12C	2 / 0.148	0.16 / 2.26	328 / 334	0.26 / 0.77	100	2.48
	LD2 / 27Al	2 / 0.120	0.16 / 2.70	328 / 324	0.26 / 1.35	100	2.45
	LD2 / 63Cu	2 / 0.036	0.16 / 8.96	328 / 323	0.26 / 2.51	90	2.19
	LD2 / 120Sn	2 / 0.030	0.16 / 7.31	328 / 219	0.26 / 2.49	90	1.84
	LD2 / 208Pb	2 / 0.014	0.16 / 11.35	328 / 159	0.26 / 2.49	90	1.64
	LH2 / 208Pb	2 / 0.014	0.071 / 11.35	142 / 159	0.22 / 2.49	90	1.02
	Empty / 208Pb	2 / 0.014	0.0 / 11.35	0.0 / 159	0.0 / 2.49	165	0.99

2 SUMMARY and CONCLUSIONS

This 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 the site boundary as a result of a given set of experiments. This budget may be specified in terms of mrem at the site boundary or as a percentage of the Jefferson Lab design goal (10 mrem per year) for dose to the public. The 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 Manager, the TJNAF Director, 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 site boundary to keep up with the dose for the individual setups from Hall B and the other Experimental Halls. If it appears that the radiation budget will be exceeded, the Radiation Control Department (RCD, or RadCon) 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 site boundary dose rates. 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 TJNAF and the experimenter's home institution policies.

4.1 Beam in the Hall

When the Hall status is *Beam Permit*, there are potentially lethal conditions present. As such, 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 Activation of Target and Beamline Components

The RCD 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.

All radioactive materials onsite are inventoried and tracked by RadCon staff. If radioactive materials are incorporated into an experimental setup, surveys may be conducted on the setup before experiments begin.

Movement of all used targets, collimators, and shields is coordinated by RadCon, who 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 coordination with RadCon. Remote movement of target configurations shall be permitted, providing the method of movement has been reviewed and approved by the RCD.

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 RCD.

5 INCREMENTAL SHIELDING or OTHER MEASURES to REDUCE RADIATION HAZARDS

n/a

6 OPERATIONS PROCEDURES

All experimenters must comply with experiment-specific administrative controls which begin with the measures outlined in the experiments 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. The General Access RWP (GARWP) governing 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-E 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 review by the Radiation Control Department. 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 conducted in accordance

with United States Department of Transportation (49 CFR Transportation) 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 to TJNAF 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).