

ES&H DIVISION
RADIATION CONTROL DEPARTMENT

radiological safety analysis document

CLAS12

Hall B Run Group D

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This Radiological Safety Analysis Document (RSAD) identifies the general conditions associated with the CLAS12 Run Group D (RGD) experiments to be run in Hall B; and, the controls associated with production, movement, or import of radioactive materials.

1 DESCRIPTION

The Physics Division, CLAS12 RGD run will take place during the summer of 2023 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 run period, CLAS12 will be in its standard detector and shielding configuration with the forward tagger (FT) **off and** the large Moller cone installed. The RGD run will use up to 11 GeV or the maximum energy possible (up to 5 passes) polarized electron beam, with currents up to 200 nA during the luminosity scans. This run will use several targets varying from cryogenic liquid to solid targets. Targets will be located inside the vacuum scattering chamber installed within the central detector in the center of the 5 T solenoid magnet.

The target system employed for RGD is the new cryo target which is currently under construction at Jefferson Lab. The cryo target will be used for the first time in the Hall B RGD run, and the so-called flag assembly (built by Hall B engineers), for solid targets. CLAS12 RGD will use the following liquid targets in the cryo target system (H_2 and D_2), as well as three types of solid foils (^{118}Sn , ^{63}Cu , ^{12}C) in the flag assembly (refer to the following table).

Target configurations for the CLAS12 RGD run periods

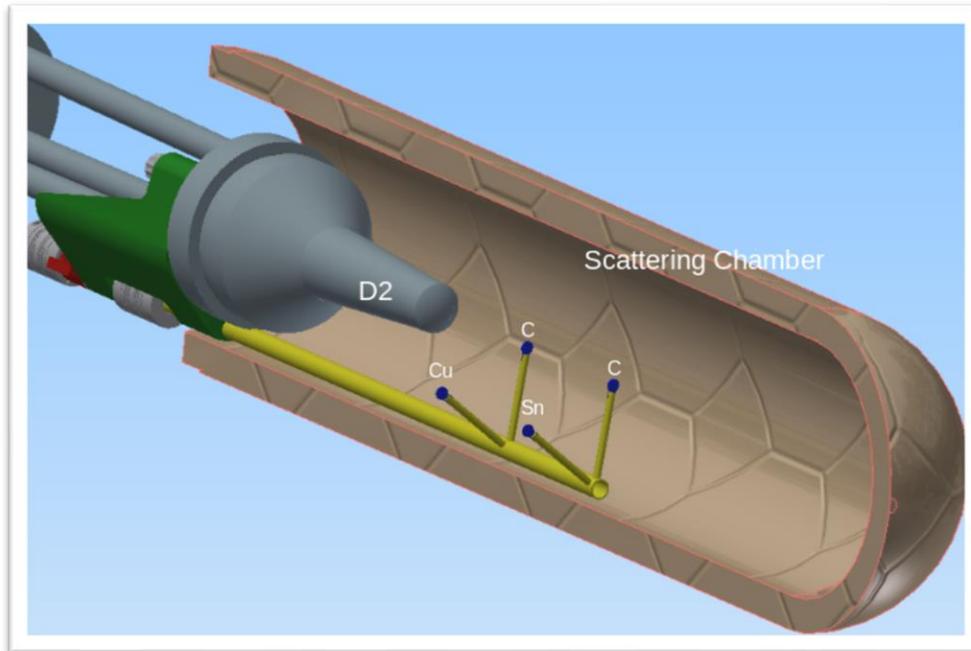
Energy	Target*	Thickness (2 foils)	Density	Areal Density (T)	T/X_0	Beam Current	Per-nucleon Luminosity
(GeV)		(cm)	(g cm ⁻³)	(mg cm ⁻²)	(%)	(nA)	(10 ³⁵ cm ⁻² s ⁻¹)
11 (or maximum possible)	LH ₂	5	0.071	355	0.56	100	1.3
	LD ₂	5	0.164	820	0.65	50**	1.5
	¹² C	0.2 (0.4)	2.20	440	1.03 (2.06)	50	1.7
	⁶³ Cu / ¹¹⁸ Sn	0.009 / 0.018	8.96 / 7.31	80.64 / 131.6	0.63 / 1.49	150	1.2
	Empty	–	–	–	–	165 ²	1

* liquid targets are denoted by L and solid targets are shown with their chemical composition

** approval to increase routine operations to 60 nA was granted 10/25/23

Note, revision 1: During luminosity scans, it was determined that optimum beam current for operation on the LD₂ target was 60 nA. There is no significant radiological impact due to this increase. The increase was granted via email on 10/25/23, and is incorporated by revision to this RSAD.

This target system will be able to support all the targets of interest. The flag assembly is housed in a vacuum vessel along with the cryogenic system. A scattering chamber is installed around the target cell area. This is made from Rohacell foam with a wall thickness of 6.5 mm. Aluminum windows are used at the entrance and exit of the liquid cell, and at the exit of the scattering chamber (refer to the following figure).



flag design showing foils (5 cm apart) mounted on the same shaft (bottom yellow rod) with 60-degree opening between their holding needles (yellow upward rods) that rotate together via a stepper motor

Component details, such as windows and cells, are shown on the beamline drawing, including thicknesses and locations. The beamline drawings can be found at the Hall B beamline.

Targets will be set up in configurations that are detailed in the Table above. One configuration or setup will be a 5 cm-long liquid (L) cell for hydrogen and deuterium. The remaining solid targets are composed of two-foil targets mounted in the flag assembly. These two-foil targets are made of either carbon or isotopically pure ^{63}Cu and ^{118}Sn .

The liquid targets are centered in the solenoid magnet at the beam axis $z = -5$ cm, assuming $z = 0$ cm is the solenoid/CLAS12 center, with lateral extent of 2.5 cm. The flag two-foil assembly of carbon (2 foils), or copper plus tin are spaced at intervals of -7.5 cm and -2.5 cm in the z -axis. This is done as a way to approximate the acceptance of the liquid target 5 cm lateral extent in the solid targets for compatible experimental comparison.

The beam current setting listed in the Table is anticipated for the RGD run-periods having up to 1.7 times the CLAS12 nominal luminosity of $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$. However, we will, from time-to-time perform, luminosity

scans for detector efficiency studies in which the beam current will be increased up to 200 nA for LD2, LH2, and simultaneously mounted ^{63}Cu and ^{118}Sn foils configuration, and up to 100 nA for the two carbon foils setup.

2 SUMMARY and CONCLUSIONS

This run period is not expected to produce significant levels of radiation at the site boundary. However, radiation levels will be monitored periodically by the Radiation Control Department (RCD) 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 below, 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 TJNAF design goal for dose to the public, which is 10 mrem per year. The 10 mrem/y 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 TJNAFs annual radiation budget that would result from running under a broad variety of conditions typical of Hall B operations, indicates that the contribution from these experiments 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, RadCon will call for 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 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 unnecessary exposure of personnel;
- comply with federal, state, and local regulations;
- adhere to TJNAF procedures; and,

- the Experimenter's home institution policies.

4.1 Beam in the Hall

When the Hall status is *Beam Permit*, potentially lethal conditions are present. 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 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 beam line 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 staff will coordinate movement of all used targets, collimators, and shields. They 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 RCD.

No work (e.g., drilling, cutting, or welding) that could result in dispersal of radioactive material is to be performed on beam line components. Such activities must be conducted only with specific permission and control by 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 at https://misportal.jlab.org/railsForms/rad_work_permits/144648/briefing. All those who participate in the RGD experiments must 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 successfully 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 and approval. Alteration of these components (including the exit beam line 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 experiments. 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 (757-269-7050).