ES&H DIVISION
RADIATION CONTROL DEPARTMENT

Radiological Safety Analysis Document

CLAS12

Hall B Run Group M

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Thomas
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Hall B Run Group M

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Contents

This Radiological Safety Analysis Document (RSAD) identifies the general conditions associated with the CLAS12 (Run Group M [RG-M]) 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-M will take place from the fall of 2021 through winter 2022 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 used in its standard detector and shielding configuration with the Forward tagger off and the Large Moller cone installed. The RG-M run will use up to 6.6 GeV (up to 3 passes) electron beam, with currents up to 300 nA. This run will use several targets varying from cryogenic liquid targets to heavy, 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 RG-M is the Saclay cryo target, a system that has been used in Hall B throughout the 6 and 12 GeV eras. CLAS12 RG-M will use the following liquid targets in the Saclay cryo target system (H_2, D_2, ^{4}He, Ar) as well as the solid targets (^{120}Sn, C). This target system will be able to support all the targets of interest, except for ^{40,48}Ca which will require encapsulation and will need to be mounted separately. The targets are 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 cells, and at the exit of the scattering chamber.

The details of all components, such as windows and cells, are shown on the beam line drawing, including thicknesses and locations. The beam line drawings can be found at Hall B beam line.

Table 1. Target configurations that will be used in RG-M

Energy (GeV)	**Target**	**Thickness** (cm)	**Density** (g cm^{-3})	**Areal Density** (mg cm^{-2})	**T/X_o** [1] (%)	**Beam Current** (nA)	Luminosity [2] (10^{35} s^{-2} cm^{-2})
6.6	LH	5	0.071	355	0.6	80	1
	LD2	5	0.164	820	0.7	70	2
	LHe	5	0.125	625	0.7	90	2
	LAr (+ C)	0.5 (0.2)	1.396	698 (440)	3.6 (1.0)	80 (130)	2
			(2.20)				
	C [3]	0.2	2.20	440	1.0	130	2
	^{120}Sn [3]	0.03	7.31	205	2.3	277	2
	^{40,48}Ca	0.13	1.55	200	1.2	280	2
	empty	–	–	–	–	525	–
4.4	LH	5	0.071	355	0.6	108	1.5
	LAr (+ C)	0.5 (0.2)	1.396	698 (440)	3.6 (1.0)	110 (175)	3
			(2.20)				
	empty	–	–	–	–	450	–
2.2	LH	5	0.071	355	0.6	5	0.06
	LAr (+ C)	0.5 (0.2)	1.396	698 (440)	3.6 (1.0)	5 (8)	0.13
			(2.20)				
	Empty	–	–	–	–	380	–

[1] thickness (T) per radiation length (X_o)
[2] per nucleon
[3] 4-foil target cell
Note: where liquid targets are denoted by "L" and solid targets are simply listed as the chemical composition

The targets will be set up in several configurations which are detailed in Table 1. One will be a 5 cm long liquid cell for Hydrogen, Deuterium, and ^{4}He. Another will be a 0.5 cm liquid cell for Ar in combination with a solid C target which can be moved in and out of the beam line. The remaining solid targets are composed of a solid disk of Calcium- 40 and -48, and two multi-foil targets which are composed of 4 foils in total. These multi-foil targets are made of Carbon and isotopically pure ^{120}Sn.

The liquid targets are centered in the solenoid magnet around the beam axis z=0 cm, with lateral

extent of 2.5 cm. The LAr + C target is centered such that the LAr cell is at -2.5 cm and the Carbon foil is at 2.5 cm. The Calcium targets are centered at 0 cm. The multi-foil targets (4-foils) of Carbon and Tin are spaced at intervals of -1.875, -0.625, 0.625, and 1.875 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 easier experimental comparison.

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 IV (B) and VII, 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 HPS RG-M 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).