ES&H DIVISION
RADIATION CONTROL DEPARTMENT
Radiological Safety Analysis Document

Hall B Run Group F
(BONuS12, E12-06-113)

March 2020

RCD-RSAD-02.2020-HB #1
rev1

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

Thomas
Jefferson
National
Accelerator
Facility

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Hall B Run Group F

(BONuS12, E12-06-113)

rev1

Approval & Document Owner	Keith Welch, Manager Radiation Control Department	3/11/2020 Date

This Radiological Safety Analysis Document (RSAD) will identify the general conditions associated with the BONuS12 run (CLAS12 Run Group F) using a newly built RTPC and high pressure gas target together with the standard CLAS12 detector in Hall B and the controls associated with regard to production, movement, or import of radioactive materials.[1]

1 DESCRIPTION

The BONuS12 experiment is scheduled to collect data from February to May 2020 in Experimental Hall B using a newly built Radial Time Projection Chamber (RTPC), high-pressure gas target and the CLAS12 detector. CLAS12 is a multi-purpose detector system based on a toroidal (forward detector) and a solenoid (central detector) magnet. The detector system includes Cherenkov Counters, Drift Chambers, Scintillator Counters, Silicon-strip detectors, Micro-mega gas detectors, and Calorimeters. The RTPC is a small cylindrical GEM detector of 50 cm length and about 8 cm radius surrounding the target. The RTPC will be tuned to detect only low momentum protons. The target for BONuS12 will be a tiny volume of up to 6.0 atm (absolute pressure = 73.5 psig) deuterium, hydrogen, and helium gas at room temperature, located at the center of the solenoid, which is also the center of the Hall. The target is a 50 cm-long aluminum coated polyimide tube with a wall thickness of 50 μm and inner diameter of 6 mm. The target entrance and exit beam windows are made out of 15 μm-thick aluminum foil.
A third 15 μm thick aluminum foil closes the downstream end of the helium bag, located inside the Moller shield. Beams of various energies, from 2.1 up to 10.4 GeV, and maximum beam currents up to 450 nA will be used for the experiment.

The whole experiment includes two parts:

- first is a calibration run using 2.1 GeV beam energy, which includes two hours of empty target – one day on hydrogen target and one day on deuterium target, with beam current limited to 50 nA
- second is a run with up to 450 nA beam at 10.4 GeV, which includes 35 days of deuterium target and four days of hydrogen target (both at 6 atm absolute pressure), plus one day of calibration runs (One run with an empty [1 atm hydrogen] target will be taken at up to 450 nA.)

The peak nucleon luminosity of BONuS12 (not including the end window of the beamline) is $7.7 \times 10^{34}/cm^2/s$, which is only 77% of the designed CLAS12 luminosity.

In order to calibrate the drift velocity of the drift gas used by the RTPC, a drift chamber (18 cm x 12 cm x 10 cm box shape) will be used to measure the drift velocity. This device is not placed in the beamline, but on the gas panel in the Hall using two standard (2 μCi each), well shielded, ^{90}Sr radiation sources. Before being placed in the Hall, the device was reviewed and approved by the Radiation Control Department (RCD or RadCon).

2 SUMMARY and CONCLUSIONS

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

3 CALCULATIONS of RADIATION DOSE

The radiation budget is the amount of radiation that is expected at the site boundary as a result of a given experiment. 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), the Director of TJNAF, and the Department of Energy (DOE).

Calculations of radiation in the Hall have been carried out using FLUKA. To simplify the task, 41 days of maximum luminosity has been used in this calculation. In the FLUKA program, the RTPC holder, beam pipes and their end windows, the RTPC, and the CLAS12 solenoid have been included. Here are the FLUKA simulation results.

- Prompt dose rate: low everywhere in the Hall outside the beam pipe. The hot area, below 10 rem/h, is downstream of the target.
- Accumulated damage: after 41 days of 200 nA and 11 GeV beam, the accumulated 1-MeV-neutron equivalent damage to silicon is less than 10^{11} neutrons/cm^2 outside the beam pipe. (The limit that a silicon product starts to show damage is about several 10^{13} neutrons/cm^2.)
- Activation: after 41 days of running, the activated dose rate at 30 minutes post beam shut down is about 0.03 mrem/h at the target center. This is less than 0.001 mrem/h at 1 m away from the beam pipe.

These calculated results will be verified during the experiment. Site boundary radiation will also be verified 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 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 the site boundary. If the site boundary dose approaches or exceeds 10 mrem during any calendar year, the experimental program will cease 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, as well as with Jefferson Lab requirements; and, comply with 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; 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 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

All radioactive materials brought to Jefferson Lab shall be identified and notification made to the Radiation Control Department. 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 and will survey all experimental setups (before experiments begin) as a baseline for future measurements.

All movement of used targets, collimators, and shields will be coordinated by RadCon who will further assess the radiation exposure conditions and will implement controls, as necessary, based on the radiological hazards.

There shall be no local movement of activated target configurations without direct supervision of RadCon. There is no movement or change of target configurations in this experiment, except if the RTPC or the experimental target cell should fail and need to be replaced, or after the end of the experiment.

No work (e.g., drilling, cutting or welding) is to be performed on beamline components as this could result in dispersal of radioactive material. 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

After 41 days of beam time, the accumulated 1-MeV-neutron equivalent damage outside the beam pipe is below 10^{11} neutrons/cm^2, which requires no extra shielding anywhere 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 include, but are not limited to, Radiological Work Permits (RWP), Temporary Operational Safety Procedures (TOSP), Operational Safety Procedures (OSP), or any verbal instructions from RadCon. A General Access RWP (which may be found in the Machine Control Center [MCC]) is in place governing access to Hall B and the accelerator enclosure. *This RWP must be read and signed by all participants in the experiment.* Any individual with a need to handle radioactive material shall first complete Radiation Worker Level I (RW-I) training.

There shall be adequate communication between the experimenter(s) and 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 site boundary dose.

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 delivered to the experimenter's home institution for final disposition. All transportation shall be conducted in accordance with United States Department of Transportation Regulations (Title 49, Code of Federal Regulations) or International Air Transport Association regulations. In the event that the experimenter's home institution cannot accept the radioactive material due to licensing requirements, the experimenter(s) shall arrange for appropriate fund transfers for disposal of the material. Jefferson Lab cannot store any radioactive targets or experimental equipment indefinitely.

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