Radiological Safety Analysis Document for BONuS12 in Hall B

January 28, 2020

This Radiological Safety Analysis Document (RSAD) will iden- tify the general conditions associated with the BONuS12 run using a newly built RTPC the standard CLAS12 detector in Hall B and the controls associated with regard to production, movement, or import of radioactive materials.

1 Description

The BONuS12 experiment will take place in the winter of 2018 or the Spring of 2019 in experimental Hall B using a newly built Radial Time Projection Chamber(RTPC) 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 de- tector of 40 cm long and about 8 cm of 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 6 atm (absolute) deuterium or hydrogen gas at room temperature, located at the center of the solenoid, which is also the center of the hall. Beams of various energies, from 2.2 up to 10.5 GeV, and maximum beam currents up to 200 nA will be used for the experiment. The whole experiment includes two parts. The first part is calibration runs using 2.2 GeV beam, which includes two hours of empty target, one day on hydrogen and one day on deuterium target. The second part run with 200 nA beam at 10.5 GeV, which includes 35 days on deuterium target and four days on hydrogen target, plus one day of calibration runs using empty target. The peak nucleon luminosity of BONuS12 (not including the end window of the beamline) is $2 \times 10^{34}/cm^2/s$, which is only 20% of the designed CLAS12 luminosity. In order to calibrate the drift velocity of the drift-gas used by the RTPC, a drift chamber (20cm $\times$ 20cm $\times$ 15 cm box shape) will be used to measure the drift velocity. This device is not placed in the beamline, but somewhere in the hall using two standard (2 μCi) ^{90}Sr radiation sources. The ^{90}Sr radiation sources will be well shielded. Before placing this device into the hall, this device shall be reviewed and approved by the Radiation Control Department.

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 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 the Radiation Control Department. Adherence to this RSAD is vital.

3 Calculations of Radiation Deposited in the Experimental Hall (the Experiment Operations Envelope)

The radiation budget is the amount of radiation that is expected at the site boundary as a result of a given experiments. 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 Radiation Control Department Head, the Director of Jefferson Lab, and the Department of Energy.

Calculations of radiation in the hall has been carried out using FLUKA. To simplify the task, 42 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: prompt dose rate is low everywhere in the hall outside the beam pipe. The hot area is in the downstream of the target, which is below 10 rem/h.
- Accumulated damage: after 42 days of 200 nA and 10.5 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 42 days of running, the dose rate from activation at 30 minutes after the beam is shut down is about 0.03 mrem/h at the target center, less than 0.001 mrem/h at 1 m away from the beam pipe.

These calculated results will be verified during the experiment. The site boundary radiation has not been calculated, but it is expected to be negligible based on operational experience in Hall B. This will be verified by using 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 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 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 experimenters home institution policies.

4.1 From Beam in the Hall

When the Hall status is Beam Permit, there are potentially lethal con- ditions 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 From Activation of Target and Beamline Components

All radioactive materials brought to Jefferson Lab shall be identified 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 Radiation Control Department inventories and tracks all radioactive materials onsite. The Radiation Control Department will survey all experimental setups before experiments begin as a baseline for future measurements.

The Radiation Control Department will coordinate all movement of used targets, collimators, and shields. The Radiation Control Department will 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 by the Radiation Control Department. 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, and after the end of the experiment.

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

5 Incremental Shielding or Other Measures to be Taken to Reduce Radiation Hazards

After 42 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 also include, but are not limited to, Radiation Work Permits, Temporary Operational Safety Procedures, and Operational Safety Procedures, or any verbal instructions from the Radiation Control Department. A general access RWP is in place that governs access to Hall B and the accelerator enclosure, which may be found in the Machine Control Center (MCC); it must be read and signed by all participants in the experiment. Any individual with a need to handle radioactive material at Jefferson Lab shall first complete Radiation Worker (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 out- side 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 the 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 done 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 shall arrange for appropriate fund transfers for disposal of the material. Jefferson Lab 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).

Approvals:

Radiation Control Department Head Date