Radiological Safety Analysis Document for Heavy Photon Search experiment engineering run

This Radiological Safety Analysis Document (RSAD) will identify the general conditions associated with running the Heavy Photon Search experiment in Hall B, and controls with regard to production, movement, or import of radioactive materials. [1]

1 Description

The engineering run of Heavy Photon Search (HPS) experiment, E12-11-006, will take place from October 2014 to June 2015 in the experimental Hall-B. The HPS run will use a detector located in the downstream alcove of Hall-B. The setup is based on a three magnet chicane where the first and the last dipoles serve as bending magnets, while the middle one, 18D36 dipole, will be used as a spectrometer magnet. The beam will be transported through the hall to the HPS target using the standard 3 inch vacuum beam pipe. There are no other targets or vacuum windows along the beam before and after the HPS target. The target and the tracking detector are located in the vacuum. A set of vacuum chambers will allow passage of beam to the dump in the vacuum. The vacuum beam line and the chicane magnets are configured in such a way that the beam will have clear passage to the Hall B electron beam dump whether or not the chicane magnets are energized.. Chicane magnet power supplies are interlocked with beam delivery system (FSD). Beam delivery will be terminated in the event of a magnet power supply trip.

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For production data taking HPS will use a 4 μm thick (0.125% r.l.) tungsten target located at the beginning of the analyzing magnet and up to 400 nA electron beams at energies 1.1 GeV and 2.2 GeV. There will be other target foils mounted on the target ladder, 500 μm carbon (0.3% r.l.), 700 μm CH_2 (0.25% r.l.), and 8 μm tungsten (0.25% r.l.) for calibration purposes. The maximum luminosity during the run will be $< 10^{34}$ sec^{-1} cm^{-2} per nucleon. During running with beam currents above 50 nA, Hall B beam stopper (a 30 cm long cooled copper absorber) will be positioned before the Faraday Cup, to prevent overheating. The bremsstrahlung photons produced in the target will have 30 mrad angle relative to the electron beam and will be directed to a photon beam dump mounted behind the first shielding wall between the Hall-B downstream alcove and the tunnel. The photon dump will be the same as during the CLAS TPE experiment, although the HPS photon beam intensity will be 100 times smaller.

The HPS detectors will be located in close proximity of the electron beam plane. Detail GEANT simulations have been carried out to asses possible radiation effects to the detectors and electronics (see for example effect of the neutron radiation on electronics described in Appendix).

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 Departement.

Adherence to this RSAD is vital.

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

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.

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 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 Beam line 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 beam line components, or previously used shielding or collimators. The RCD 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. Remote movement of target configurations shall be permitted, providing the method of

movement has been reviewed and approved by the Radiation Control Department.

No work is to be performed on beam line 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

None.

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 outside the scope of this RSAD without formal Radiation Control Department review. Alteration of these components (including the exit beam line 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 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 funds 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

8 Appendix: Radiation damage to the HPS electronics

While most of the HPS electronics are located away from the beam line, the front-end electronics boards (FE boards) are inside the vacuum chamber of the PS magnet at 20 cm from the HPS target. There are ten FE boards and each FE board has one Xilinx Artix 100T FPGA and 25 voltage regulator MOSFETs, which are potentially vulnerable to radiations, especially neutrons. While the radiation damage from Total Ionizing Dose (TID) and Non Ionizing Energy Loss (NIEL) are negligible, Single Event Upset (SEU) may cause data corruption in FPGA and Single Event Gate Rupture (SEGR) may permanently damage MOSFET.

BaBar detector at SLAC had 47 FPGAs near the interaction point and observed many SEUs. Based on the BaBar experience and taking the geometry difference into consideration, we estimate 1 SEU/day at the neutron flux of 8000 neutrons/cm^2/sec.

Since all the MOSFETs are operated at less than 5 V gate voltage, SEGR is verly unlikely to take place.

8.1 Neutron production calculation

Neutron production calculations were made using the particle interaction simulation code FLUKA and Geant4. Following neutron production sources have been studied,

1. SVT Protection Collimator (1 cm Tungsten) 3 m upstream of the HPS target
2. HPS Target (4 μm Tungsten)
3. PS Magnet Coil/Body at the beam's right
4. ECal vacuum chamber and downstream beam pipe
5. Beam dump

Among these sources, the HPS target is by far the dominant neutron source for the FE boards and the neutron production rate is 2×10^{-6} neutrons per 2.2 GeV e-. The neutron flux at the FE boards is estimated to be 700

neutrons/cm^2/sec at the beam current of 200 nA. This neutron flux is at least a factor of ten lower than the neutron flux expected to cause 1 SEU/day.

8.2 Radiation damage to the standard electronics components in the Hall

The experiment is not expected to produce significant levels of neutron radiation that may cause damage to the Hall electronics located on the Forward Carriage or on the Space Frame. The beam energies and the integrated luminosity of the experiment are in the same range as for the CLAS nuclear target experiments. Furthermore, the target and the detector are located in the downstream alcove. Any radiation produced on the target or in any parts of the detector will be confined to the alcove or downstream tunnel (towards beam dump).