RSAD for 2019 Isotope Run in the LERF

This Radiological Safety Analysis Document (RSAD) identifies the general conditions associated with running the isotope production R&D irradiations in the LERF vault, and the radiological controls associated with the production, movement and handling of the radioactive materials.

I. Description

The Isotope Program at JLab partially addresses the national need for research radioisotopes, especially ^{67}Cu, by investigating photo-production using photo-nuclear reactions induced by bremsstrahlung photons from a high-power electron linac. For a complete description of the program, see:
https://jeffersonlab.sharepoint.com/:w:/r/sites/IsotopeProductionDocuments/Shared%20Documents/Supporting%20documents/Isotope_Production_at_Jefferson_Lab_Proposal.docx?d=wc42618b653a64299a4dd955aaaab7f72&csf=1&e=Tz3qvx

For the R&D program, beam conditions will consist of CW beam up to 40 MeV with up to 5 kW of beam power. The irradiation plan calls for a run at 1kW beam power to confirm the radiation shielding configuration and hardware performance before increasing beam power to 5kW. This RSAD covers the irradiation planned for 2019, which is all at 1 kW.

The gallium target will be contained in a boron nitride "crucible" which will be removed from the irradiation area using long-handled tongs and placed in a lead pig. The pig will then be placed in a "Type A" shipping container and sent to VCU, where radiochemical separation of the ^{67}Cu from the target will be conducted.

Targets will consist of approximately 60 g of gallium, constrained geometrically to a narrow cylinder about 10 cm in length. A tungsten radiator of approximately 1 mm thickness is positioned immediately upstream of the crucible. To mitigate conditions created by the irradiation, a shielded "hutch" has been designed to contain the target and radiator. The hutch allows for relatively easy access to retrieve the irradiated target, while maintaining distance and shielding between workers and the radiator when removing the target.

Individual irradiations are planned to run for approximately 24-36 hours. A cooldown period of 8-24 hours post-irradiation will allow unwanted radionuclides to decay significantly, with reduction in the related radiation dose rates. Special procedures approved by RadCon will be used to extract the target and place it in a shielded pig. It will then be prepared for shipment.

II. Summary and conclusions

The isotope production R&D experiment is not expected to produce significant levels of radiation at site boundary or in occupied areas of the LERF building. Radiation levels will be continually recorded and periodically checked by the Radiation Control Department to ensure

that exposure levels in occupied areas do not exceed limits for the posting levels. Radiation hazards associated with activation of the targets and surrounding hardware require special consideration. Activation levels in the target assembly will cause significant dose rates in the

local area when the target is unshielded. Radiation Areas and High Radiation Areas are expected in the vicinity of the target and shield. There should be no regular need to access the target area during the experiment. As specified in Sections IV, VI, and VII, access to the target assembly, removal of targets or related hardware, transfer of radioactive material, or modifications to the the target-related hardware must be reviewed and approved by the Radiation Control Department (RCD). Adherence to this RSAD is vital.

III. Calculations of radiation dose at site boundary

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 experimental conditions. This budget may be specified in terms of dose accumulation (in 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, and the Director of Jefferson Lab.

Given the location of the LERF facility and its shielding configuration, the contribution to site boundary dose from routine operations of the LERF accelerator are negligible. Monte Carlo simulations were conducted to develop design specifications for the isotope target shielding that ensures conditions outside the primary vault shield do not exceed thresholds for posting radiological conditions beyond those routinely encountered from operating in energy-recovery mode. This ensures the radiation "footprint" of the facility does not impact surrounding areas.

The adequacy of the shielding will be verified during the run period by using the active monitors in the LERF to track conditions continually. These measurements will be supplemented by radiation surveys during the irradiation runs. If there is any indication that the experiment may cause personnel or environmental dose to approach Jefferson Lab dose Alert levels, the Radiation Control Department will require a meeting with the experimenters and the Head of Accelerator Operations to determine if the experimental conditions are accurate, and to assess what actions may reduce the dose rates.

IV. 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.

A. From beam in the vault

When the LERF vault 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 vault 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 vault to check for personnel.

After the sweep, another announcement will be made, indicating a change to Power Permit, followed by Beam Permit. The Run-Safe boxes will indicate "OPERATIONAL" and "UNSAFE". IF YOU ARE IN THE VAULT AT ANY TIME THAT THE RUN-SAFE BOXES INDICATE "UNSAFE", IMMEDIATELY PRESS THE "PUSH TO SAFE" BUTTON ON THE BOX.

Controlled Area Radiation Monitors (CARMs) are located in strategic areas in occupied spaces around the LERF to ensure that unsafe conditions do not occur in these areas. This experiment is unlikely to produce increased radiation outside the vault in areas not normally controlled for radiological purposes. The Radiation Control Department (RCD) will monitor the CARMs and make surveys as necessary to assess the impact of the experiment on radiation levels around the LERF.

Simulations using the FLUKA MC code indicated that the shielding around the target and the collimator is sufficient to limit the dose rates in the occupied space outside the vault below the threshold for a Radiologically Controlled Area (RCA). The highest calculated dose rate above the floor in the RF gallery is estimated to be about 0.02 mrem/h at 5kW with 40 MeV beam.

NOTE: The experimenters shall ensure that RadCon personnel are present upon initial delivery of production beam to the target in order to conduct confirmatory surveys outside the vault.

B. From activation of target and beamline components and other materials

1. **Given the conditions for this experiment, it is possible that a Radiation Area will exist outside the shielded target hutch following irradiation, depending on how much decay time is allowed prior access.** Conditions will be assessed by RadCon prior to allowing direct access to the target assembly. No access to the target should occur sooner than 8 hours after irradiation for 1 kW runs and 24 hours for 5 kW runs. An RWP will be developed to authorize and manage work in the vicinity of the bunker.
2. **The target assembly is expected to be significantly activated. Whole body dose rate in the vicinity of the unshielded target assembly, following decay, is expected to approach 500 mrem/h for the 1 kW runs.** All work on or around the target area will require a job-specific RWP at minimum, and may require review by the Jefferson Lab Radiation Review Panel.

   Localized radioactive contamination is expected on the target and related components. Appropriate surveys will be performed to determine the extent of contamination, and RWPs will reflect appropriate controls based on the levels. **All posted guidance for contamination control must be observed.**

3. **This experiment may produce low levels of airborne radioactivity which may impact environmental effluent standards and produce localized or generalized buildup of surface contamination in the vault.** Airborne radioactivity concentration in the vault will be measured continuously. **If airborne radioactivity concentration as monitored by the AMS-4 air monitor in the vault exceeds 1.0E-6 µCi/cc**, RCD will require a

   meeting with the experimenters to determine what actions may be needed to reduce the airborne radioactivity effluent levels and control/minimize contamination inside the vault.

4. **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 by the Radiation Control Department.

   NOTE: Work planning for all radiological work shall be coordinated through LERF Work Coordinator (Jim Coleman).

C. Other sources

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 nonexempt), previously used targets or radioactive beamline components, previously used shielding or collimators, or He-3 containers. The RCD inventories and tracks all radioactive materials onsite. The Radiation Control Department may survey the experimental setup before experiments begin as a baseline for future measurements if significant residual activity levels are present.

Tanks or cylinders of He-3 containing more than 10 mCi of tritium (H-3) shall not be stored or used in an experimental area without the express, written permission of the RCD manager. Any containers of He-3 brought on site shall be assessed for the tritium content before use. Additionally, He-3 containers should not be stored in the experimental hall when not in use.

V. Incremental shielding or other measures to be taken to reduce radiation hazards

A purpose-built shield for the target irradiation has been designed and approved for this experiment. See https://misportal.jlab.org/doc_validation/processes/27 for details. Additional shielding may be needed to ensure doses are ALARA when the target is extracted from the irradiation position. If local working area radiation levels are above 250 mrem/h, portable shielding should be employed to reduce anticipated doses and the JRRP should be informed of activities being conducted to reduce dose.

The RCD Manager will notify the Primary Investigator and Accelerator Division Safety Officer of any identified trends, which might impact access to the vault or create conditions requiring broad changes to radiological working standards (i.e. General Access RWP revision). The RCD Manager will recommend engineered or other controls considered necessary to prevent significant degradation of the radiological conditions in the vault.

VI. Operations procedures

A. 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 governing access to all accelerator enclosures must be read and followed by all participants in the experiment. This RWP can be read and electronically signed online at: https://misportal.jlab.org/railsForms/rad_work_permits/79633/briefing

B. Any individual with a need to handle radioactive material at Jefferson Lab shall first complete Radiation Worker (RW-I) training.

C. 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. The beam current/power and other beam parameter restrictions shall be documented in the Operational Restrictions list at
http://opweb.acc.jlab.org/internal/ops/ops_webpage/restrictions/ops_restrictions.html

D. No beamline component in the target beamline may be altered outside the scope of this RSAD without formal Radiation Control Department review. Alteration of these components may result in increased radiation production in the vault and in occupied spaces outside the vault.

E. Any requested changes outside of the approved experimental parameters submitted (i.e., current, energy, target material, target thickness, run time) for this experiment shall require a formal review by the Radiation Control Department, and a new revision to the RSAD.

F. Standard procedures

Radiation Work Permits (RWPs) are the standard work authorization documents used to control radiological work. RCD will require RWPs based on established trigger levels.

Standard RSAD controls apply: RCD shall be contacted for any of the following activities:

1. Entry to Radiation Areas or High Radiation Areas
2. Movement of shielding or collimators
3. Any work on beamline components associated with the target
4. Maintenance of known or potentially contaminated systems
5. Any destructive modifications to activated components (drilling cutting, welding, etc.)

All posted guidance and instructions for contamination controls, shielding configuration, and access to radiological areas must be adhered to.

NOTE: Work planning for all radiological work shall be coordinated through the LERF work coordinator (J. Coleman) using the appropriate Work List (e.g. ATLis) planning tool.

VII. Decommissioning and decontamination of radioactive components

Experimental equipment used during this experiment shall be stored and moved in a manner approved by RCD. After sufficient decay of the radioactive target, beamline and shielding configurations, appropriate storage and disposition arrangements shall be made. All transportation shall be done in accordance with United States Department of Transportation Regulations (Title 49, Code of Federal Regulations) or International Civil Aviation Organization

(ICAO) regulations. In the event that special disposal arrangements are needed due to production of Mixed Low Level Waste or other unusual waste forms, the experimenters shall arrange for appropriate transfer of funds for disposal of the material. Jefferson Lab cannot indefinitely store radioactive targets and experimental equipment.

The Radiation Control Department may be reached at any time through the Accelerator Crew Chief (269-7045) or directly by calling the RadCon Cell Phone (876-1743). On Weekends, Swing Shift, and Owl Shift, requests for RadCon support should be made through the Crew Chief. This will ensure that there is prompt response with no duplication of effort.

Approvals:

Radiation Control Department Head

9/24/19
Date