RSAD for 2019-2020 Experimental Run in Hall A
(E12-11-101 and E12-12-004: PREX-II and CREX)
(revision 1)

This Radiological Safety Analysis Document (RSAD) identifies the radiation budget for the experiment, the verification process for the radiation budget, and controls with regard to production, movement, or import of radioactive materials.

I. Description

Experiment E12-11-101 (PREX-II: Precision Parity-Violating Measurement of the Neutron Skin of Lead) and E12-12-004 (CREX: Parity-Violating Measurement of the Weak Charge Distribution of $^{48}$Ca to 0.02 fm Accuracy), will be run back-to-back in Hall A in 2019 and 2020. PREX-II plans to run from June 17, 2019 until August 18, 2019. CREX runs in two periods: from Nov 1, 2019 until Dec 19, 2019, and from Feb 15, 2020 until March 25, 2020. The current for PREX-II will normally be 70 microamps for 25 PAC days, and some lower current running on other targets. For CREX we assume 150 µA for the estimates for 35 PAC days as requested (the final current will depend on the accelerator capabilities). The beam energy is 0.950 GeV for PREX-II and 2.2 GeV for CREX. The other targets will see mostly much lower currents for calibration and checkout purposes. A description of the experiment may be found in the proposals at: http://hallaweb.jlab.org/parity/prex/pbupII.pdf and http://hallaweb.jlab.org/parity/prex/c-rex2013_v7.pdf.

To mitigate the impact of radiation on the hall and at the site boundary, the experiments will deploy a water-cooled copper-tungsten collimator downstream of the target, as well as supplemental shielding surrounding this collimator and around and above the target. The collimator is designed to absorb as much power as possible from the target (~2.5 kilowatts at scattering angles exceeding 0.78°) which would not otherwise transport to the beam dump. The strategy is described in some detail in the Design Document http://hallaweb.jlab.org/parity/prex/PrexCrexDesign.pdf

II. Summary and conclusions

The boundary dose accumulation in 2019 due to the PREX, and the beginning of the CREX runs in Hall A is estimated to be approximately 4.4 mrem, i.e. 44% of the annual design goal, and the contribution from the second half of CREX in 2020 to be approximately 2.1 mrem, i.e. 21% of the annual design goal in 2020. Radiation levels will be continually recorded and periodically checked by the Radiation Control Department to ensure that the site boundary goal is not exceeded. Radiation hazards associated with activation of the targets and the beam line hardware require special consideration. The experiment will likely cause Radiation Areas and High Radiation Areas in the Hall. There will be no regular need to access the target platform during the experiment. As specified in Sections IV, VI, and VII, the manipulation and/or handling of targets or beam line hardware (potential radioactive material), the transfer of radioactive material, or modifications to the beam line downstream from the target assembly 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.

The radiation budget for the Summer/Fall of 2019 Run in Hall A is approximately 4.4 mrem, or 44% of Jefferson Lab's annual design goal. The contribution from the second half of the CREX experiment in the Spring of 2020 is approximately 2.1 mrem, or 21% of the annual design goal in 2020. The attached Radiation Budget Form illustrates the calculations, which are the result of joint effort between the Radiation Physics Group in RCD and the Collaboration. Detailed Monte Carlo simulations were not possible for this complicated experimental setup. The first simplified model calculations were performed using the standard tools by Rad. Physics, and then the Collaboration used Geant4 code for further optimization of the shielding around the target. The optimized shielding design allowed to approximately half the expected boundary doses (see the Section 2.8.1 in the Design Document). The new Radiation Budget Form reflects these changes. The dose accumulation is split between the calendar years such that the 2019 contribution comes from PREX and a half of CREX, and the remaining half of CREX contributes to the 2020 Rad. Budget.

The Hall’s contribution to the boundary dose will be verified during the run period by using the active monitors at the Jefferson Lab site boundary to keep up with the dose for the individual setups. 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 site boundary. If the site boundary dose approaches or exceeds 10 mrem during any calendar year, the experimental program will not proceed until a resolution is reached and approved by the Lab Director.

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 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 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 PRESS THE "PUSH TO SAFE" 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. This experiment may create regions of increased radiation outside the hall 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 hall.

NOTE: Calculated dose rates for this experiment are significantly higher than the design average dose rate goal. Any indication that the levels may exceed 5 mrem/h dose rate in an occupied area will require immediate mitigation, with continued operations contingent on a formal review of conditions and operational parameters, and final approval of operations exceeding this threshold by the Jefferson Lab RadCon Manager, in consult with Physics and Accelerator Division Safety Officers.
B. From activation of target and beamline components and other materials in the hall

Extensive simulations of the experimental setup by the Collaboration, using the FLUKA MC code indicated that the shielding around the target and the collimator is sufficient to limit the dose rates from the activation at the High Radiation Area level, but below the level of 1 rem/h one hour after a beam interruption (see the documents at https://prex.jlab.org/DocDB/0001/000175/001/FLUKA_PREX_FullCollimShieldingDesign.pdf and https://prex.jlab.org/DocDB/0002/000218/001/BoratedConcreteComparison.pdf). It is not expected that extraordinary high radiation conditions will be present in the Hall during and after the run. However, the customary radiation protection measures must be taken.

1. **Given the conditions for this run period, it is expected that a High Radiation Area will develop near the target, downstream septum area, and at the interface between the hall and the beam dump tunnel; whole body dose rates in these areas could exceed 1 rem/hr.** Suitable barriers are to be staged in the Hall for use around these locations in the event this condition occurs, in order to comply with regulatory requirements for physical access controls.

2. **The target chamber area and downstream beamline are expected to become significantly activated.** No work on this portion of the beamline is to be conducted without RCD review. For ALARA purposes, no access to the target should be expected during first 2-3 days after operations. If access to the target is needed, it is possible that the work will need formal approval by the Jefferson Lab Radiation Review Panel. All work on or around the target area will require a job-specific RWP at minimum.

   NOTE: Work planning for all radiological work shall be coordinated through the hall Work Coordinator (Jessie Butler).

3. **The area around the beam dump/hall interface will become a radiation area and may become a high radiation area.** The area around the Moller polarimeter targets may also become a Radiation Area. Always confer with RCD prior to entry to any posted Radiation or High Radiation Area.

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.

5. **This experiment is expected to produce low levels of airborne radioactivity which may impact environmental effluent standards and produce localized or generalized buildup of surface contamination in the hall.** Airborne radioactivity concentration in the hall is measured continuously. If airborne radioactivity concentration as monitored by the AMS-4 air monitor in the experimental hall exceeds an average of 1.0E-5 μCi/cc (rev.1) for a period of greater than 5 consecutive days, 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 be needed to reduce the airborne radioactivity effluent levels and control/minimize contamination inside the hall.

6. **Low levels of surface contamination are expected on and around the target chamber and downstream beamline.** The RCD will monitor for the presence of this hazard as appropriate, and will require administrative controls and/or PPE commensurate with the conditions. All posted guidance for contamination control must be observed. Refer to the General Access RWP for details regarding controls for potentially affected systems.

7. **(rev.1) Under high-current running conditions, deposition of short-lived air activation products may occur in general areas of the hall.** RCD will periodically monitor for this condition. In the event that such conditions are detected, the RCD, in consultation with Physics Division, will institute an appropriate access delay protocol to allow time for these radionuclides to decay prior to entry to the hall.

8. **The collimator cooling water system will become internally contaminated and may develop significant radiation levels in vicinity of water reservoir, especially shortly after beam operations.** All
maintenance on the cooling water system requires RCD concurrence and breaching the system will require an RWP.

9. **Some sections of beamline may contain indium gaskets/seals.** These components should always be considered potentially contaminated. Always consult with RCD prior to disassembling any beamline components incorporating indium seals.

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 hall 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**

Additional shielding is planned for this experiment and will be deployed as designed. It is up to Physics Division management to consider the potential dose from this experiment and its impact on the annual dose budget.

The RCD Manager will notify the Hall Leader and Physics Division Safety Officer of any identified trends, which might impact access to the hall 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 hall.

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 the Halls and the accelerator enclosure 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-1) 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 target 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.
E. Any requested changes outside of the experimental parameters submitted for the calculation of the radiation budget (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 (RWP) 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. Breaching the target chamber physical envelope
4. Any work on beamline components downstream of the target
5. Maintenance of known or potentially contaminated systems
6. 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 hall work coordinator (J. Butler) using the ATLiS work planning tool.

VII. Decommissioning and decontamination of radioactive components

Experimenter 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 returned 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 Civil Aviation Organization (ICAO) 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 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.

Approval

[Signature]
Radiation Control Department Manager

7/19/2019
Date
## RADIATION BUDGET FORM

### Hall: A

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% of allowed dose for the total time: 348.07
% of allowed dose for the run time only: 348.07

*If > 200%, discuss result with Physics Research EH&S officer*

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Attachment A

*date form issued: April 12, 2019 authors: P Degtiarenko*