Person: Michaels, Robert (rom@jlab.org) Org: PHALLA	Status: PROCESSED Saved: 5/23/2019 10:33:45 AM Submitted: 5/23/2019 10:33:45 AM

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Review and Approval Form # 84028
(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for Instructions)

Type:	***OSP*** Click for OSP/TOSP Procedure Form Click for LOSP Procedure Form
Serial Number:	***ENP-19-84028-OSP***
Issue Date:	***5/28/2019***
Expiration Date:	***7/28/2020***
Title:	***Shielding and Collimation for PREX and CREX***
Location: (where work is being performed) Building Floor Plans	***101 - Experimental Hall A - A100*** — Location Detail: (specifics about where in the selected location(s) the work is being performed): ***Pivot Region***
Risk Classification: (See ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment)	Without mitigation measures (3 or 4): ***1*** With mitigation measures in place (N, 1, or 2): ***1***
Reason:	This document is written to mitigate hazard issues that are : ***New/previously unrecognized Hazard Issue***
Owning Organization:	***PHALLA***
Document Owner(s):	***Michaels, Robert (rom@jlab.org)*** Primary ***Gal, Ciprian (ciprian@jlab.org)***

Supplemental Technical Validations

Other Hazards:
Radiation and Contamination (David Hamlette)

Document History

Revision	Reason for revision or update	Serial number of superseded document
1	***Use the "Procedures" form***	

Lessons Learned	Lessons Learned relating to the hazard issues noted above have been reviewed.
Comments for reviewers/approvers:	***The THA is improved on May 23 thanks to Ed Folts and Dave Hamlette. I tried to save this as a revision 2 but when after saving it the document history reverted to revision 1. Anyway, a new THA.***

Attachments

Procedure: ***OSP_Form_RadiationCollim.pdf***

THA: ***THA_Rad.pdf***
Additional Files: ***PREX_CREX_RadiationShielding_OSPsupportDoc.pdf***

Review Signatures	
Additional Authorization : Associate Director - ESH&Q	**Signed** on 5/23/2019 5:08:57 PM by Bob May (may@jlab.org)
Person : May, Bob (may) **Reasoning:** Alternate Physics ES&H Liaison	**Signed** on 5/24/2019 8:29:15 AM by Bob May (may@jlab.org)
Person : Subject Matter Expert : Radiation and Contamination	**Signed** on 5/23/2019 1:17:33 PM by David Hamlette (hamlette@jlab.org)

Approval Signatures	
Division Safety Officer : PHALLA	**Signed** on 5/24/2019 8:29:58 AM by Ed Folts (folts@jlab.org)
Org Manager : PHALLA	**Signed** on 5/28/2019 2:24:07 PM by Patrizia Rossi (rossi@jlab.org)
Safety Warden : Experimental Hall A - A100	**Signed** on 5/28/2019 7:49:20 AM by Jessie Butler (jbutler@jlab.org)

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Form

(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for instructions.)

Click For Word Doc

Title:	Shielding and Collimation for PREX/CREX		
Location:	Hall A	**Type:**	☒ **OSP** ☐ **TOSP**
Risk Classification (per Task Hazard Analysis attached) (See *ESH&Q Manual Chapter 3210 Appendix T3 Risk Code Assignment*.)		**Highest Risk Code Before Mitigation**	1
		Highest Risk Code after Mitigation (N, 1, or 2):	1
Owning Organization:	Hall A, Jefferson Lab	**Date:**	May 1, 2019
Document Owner(s):	Robert Michaels		

DEFINE THE SCOPE OF WORK

1. Purpose of the Procedure – Describe in detail the reason for the procedure (what is being done and why).

Mitigate the radiation hazard in Hall A during PREX and CREX. The hazard is produced by the electron beam hitting a thick target.

2. Scope – include all operations, people, and/or areas that the procedure will affect.

Deploy passive shielding and collimation in Hall A in the pivot region around the target and septum, as well as along the beamline near the beam dump. Also there is a collimator at the entrance to Q1 and sieve slits. Jessie Butler and his crew are constructing this. The system was designed by the Hall A engineering team in consultation with the experimentalists. Access to the region will be restricted (see 6.2).

3. Description of the Facility – include building, floor plans and layout of the experiment or operation.

See also the supplement for more details. New, specialized components are being deployed in Hall A : radiation-hard vacuum seals, a beamline collimator to absorb power that would otherwise hit downstream beamline elements, concrete and plastic (neutron) shielding around the aforementioned collimator and near the target and beam dump, and sieve slits and a collimator at the entrance to the Q1 magnet on the HRS. The Q1 collimator defines the acceptance of the HRS, and the sieve slits are plates with holes used in the standard way to calibrate the transport tensor for particles passing through the HRS.

ANALYZE THE HAZARDS and IMPLEMENT CONTROLS

4. Hazards identified on written Task Hazard Analysis

Radiation is the hazard. The design was supported by extensive Geant 4 simulations under the guidance of the Radiation Controls Groups, and has passed the scrutiny of the ERR process. A Task Hazard Analysis sheet was written and is attached. An RSAD has been separately produced.

5. Authority and Responsibility:

5.1 Who has authority to implement/terminate

Jessie Butler

5.2 Who is responsible for key tasks

Jessie Butler

5.3 Who analyzes the special or unusual hazards including elevated work, chemicals, gases, fire or sparks (See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

The Radiation Control Group in concert with Jessie Butler.

6. Personal and Environmental Hazard Controls Including:

6.1 Shielding

Concrete Shielding and Neutron Shielding. For details see the attached supplement

6.2 Barriers (magnetic, hearing, elevated or crane work, etc.)

A fence enclosure of 20 foot radius will be installed around the target region. This will create a barrier around the pivot and entrance will be controlled by RADCON. This is an radiation ALARA requirement due to the radiation in this region. The fence also serves as a safety barrier for electrical and magnetic safety, which is the subject of a separate OSP on the Septum Magnet. (This is the same fence used in the past two years by the Tritium family of experiments and by the APEX experiments.)

6.3 Interlocks

None

6.4 Monitoring systems

The temperature at various points will be monitored. If the water flow to the beam collimator is interrupted, the beam should be shut off to avoid over-heating on this collimator. See 15. and see the attached supplement for details about this collimator.

6.5 Ventilation

Nothing additional

6.6 Other (Electrical, ODH, Trip, Ladder) (Attach related Temporary Work Permits or Safety Reviews as appropriate.)

None

7. List of Safety Equipment:

7.1 List of Safety Equipment:

none

7.2 Special Tools:

none

8. Associated Administrative Controls

RADCON approval for entrance to the region near the target. An RSAD has been developed.

9. Training

9.1 What are the Training Requirements (See List of Training Skills)

No extra training, just the normal training for working in Hall A.

DEVELOP THE PROCEDURE

10. Operating Guidelines

The only items that needs to be “operated” during the experiment are the sieve slit and water flow to the beam collimator. The sieve slits will be moved in and out of the beam using ropes that extend outside the 20 foot fence. This will occur about 20 times during the two years of running. All the other components described in this OSP are "passive". They are set up by Jessie Butlers team and then left alone. After the experiments, RADCON will need to be involved with checking that it is safe to take down the apparatus.

11. Notification of Affected Personnel (who, how, and when include building manager, safety warden, and area coordinator)

Jessie Butler and his team.

12. List the Steps Required to Execute the Procedure: from start to finish.

Build the shielding and collimation according to the drawings provided by engineering.

13. Back Out Procedure(s) i.e. steps necessary to restore the equipment/area to a safe level.

RADCON should conduct surveys and check if it is safe to take down the equipment after the experiment.

14. Special environmental control requirements:

14.1 List materials, chemicals, gasses that could impact the environment (ensure these are considered when choosing Subject Mater Experts) and explore EMP-04 Project/Activity/Experiment Environmental Review below

none

14.2 Environmental impacts (See EMP-04 Project/Activity/Experiment Environmental Review)

none

14.3 Abatement steps (secondary containment or special packaging requirements)

none

15. Unusual/Emergency Procedures (e.g., loss of power, spills, fire, etc.)

If there is loss of water cooling to the main beam collimator, the beam should be shut off; however, this does not need to be an FSD since the timescale would be minutes to heat up and an over-heating incident should not damage anything. We will monitor temperatures in EPICS and have an alarm, and the shift crew should turn off the beam and consult with experts.

16. Instrument Calibration Requirements (e.g., safety system/device recertification, RF probe calibration)

none

17. Inspection Schedules

none

18. References/Associated/Relevant Documentation

See the attached supplement

19. List of Records Generated (Include Location / Review and Approved procedure)

The approval of this system was part of the ERR process. An RSAD has been developed.

Submit Procedure for Review and Approval (See ES&H Manual Chapter 3310 Appendix T1 OSP & TOSP Instructions – Section 4.2 Submit Draft Procedure for Initial Review):

- Convert this document to .pdf
- Open electronic cover sheet:

https://mis.jlab.org/mis/apps/mis_forms/operational_safety_procedure_form.cfm

- Complete the form
- Upload the pdf document and associated Task Hazard Analysis (also in .pdf format)

Distribution: Copies to Affected Area, Authors, Division Safety Officer
Expiration: Forward to ESH&Q Document Control

Form Revision Summary

Revision 1.5 – 04/11/18 – Training section moved from section 5 Authority and Responsibility to section 9 Training
Revision 1.4 – 06/20/16 – Repositioned "Scope of Work" to clarify processes
Qualifying Periodic Review – 02/19/14 – No substantive changes required
Revision 1.3 – 11/27/13 – Added "Owning Organization" to more accurately reflect laboratory operations.
Revision 1.2 – 09/15/12 – Update form to conform to electronic review.
Revision 1.1 – 04/03/12 – Risk Code 0 switched to N to be consistent with 3210 T3 Risk Code Assignment.
Revision 1.0 – 12/01/11 – Added reasoning for OSP to aid in appropriate review determination.
Revision 0.0 – 10/05/09 – Updated to reflect current laboratory operations

ISSUING AUTHORITY	FORM TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ESH&Q Division	Harry Fanning	04/11/18	04/11/21	1.5

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Task Hazard Analysis (THA) Worksheet

(See ES&H Manual Chapter 3210 Appendix T1
Work Planning, Control, and Authorization Procedure)

Click For Word

Author:	**Robert Michaels**	**Date:**	4/2/2019	**Task #:** If applicable	

Complete all information. Use as many sheets as necessary

Task Title:	Use of **Shielding and Collimation for PREX and CREX**			**Task Location:**	Hall A
Division:	Physics	**Department:**	Hall A	**Frequency of use:**	6/15/2019 through 4/15/2020
Lead Worker:	**Jessie Butler, Robert Michaels, Ciprian Gal, Kent Paschke**				
Mitigation already in place: Standard Protecting Measures Work Control Documents					

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation

Task Hazard Analysis (THA) Worksheet

(See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
	Radiation damage to Hall Equipment	H	H	4	A water cooled collimator has been installed downstream of the target Radiation shielding around collimator Radiation shielding above target chamber Radiation shielding in front of, inside of and downstream of septum magnet. Radiation shielding around the beam line. Though not mentioned in this OSP the radiation shielding at the Beam Dump has been augmented	Rad I and Rad II training Standard RWP Target area to be monitored by RCG and posted appropriately and work specific RWP issued as required 20 ft. boundary fence to be installed around Hall A pivot to be controlled by RCG as required	2

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
	Radiation to the environment	H	M	4	Radiation shielding around collimator Radiation shielding above target chamber Radiation shielding in front of, inside of and downstream of septum magnet. Radiation shielding around the beam line. Radiation shielding augmented at the Beam Dump Standard RCG radiation monitoring system used to verify site and Hall A radiation levels	Rad I and Rad II training Standard RWP Target area to be monitored by RCG and posted appropriately and work specific RWP issued as required 20 ft. boundary fence to be installed around Hall A pivot to be controlled by RCG as required	1

Sequence of Task Steps	**Task Steps/Potential Hazards**	**Consequence Level**	**Probability Level**	**Risk Code (before mitigation)**	**Proposed Mitigation (Required for Risk Code >2)**	**Safety Procedures/ Practices/Controls/Training**	**Risk Code (after mitigation**
	Radiation to personnel	H	H	4	Radiation shielding around collimator Radiation shielding above target chamber Radiation shielding in front of, inside of and downstream of septum magnet. Radiation shielding around the beam line. Radiation shielding augmented at the Beam Dump Target area to be monitored by RCG and posted appropriately and work specific RWP issued as required	Rad I and Rad II training Standard RWP Target area to be monitored by RCG and posted appropriately and work specific RWP issued as required 20 ft. boundary fence to be installed around Hall A pivot to be controlled by RCG as required	1

Highest Risk Code before Mitigation:		**Highest Risk Code after Mitigation:**	

When completed, if the analysis indicates that the Risk Code before mitigation for any steps is “medium” or higher (RC≥3), then a formal Work Control Document (WCD) is developed for the task. Attach this completed Task Hazard Analysis Worksheet. Have the package reviewed and approved prior to beginning work. (See ES&H Manual Chapter 3310 Operational Safety Procedure Program.)

Form Revision Summary

Periodic Review – 08/29/18 – No changes per TPOC
Periodic Review – 08/13/15 – No changes per TPOC
Revision 0.1 – 06/19/12 - Triennial Review. Update to format.
Revision 0.0 – 10/05/09 – Written to document current laboratory operational procedure.

ISSUING AUTHORITY	TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ESH&Q Division	Harry Fanning	08/29/18	08/29/21	0.1

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Shielding and Collimation for PREX/CREX

Supplement to the OSP with the same name

This document describes the passive shielding and collimation installed for the PREX/CREX experiments. With the exception of the sieve slits, this equipment does not require any operation or supervision from the shift crew.

The PREX-II and CREX experiments will run from June 15, 2019 until March 27, 2020 with some downtime in between. These experiments will produce a high electromagnetic and neutron radiation in the hall compared to typical running conditions of previous experiments in Hall A, without mitigation. The purpose of the beamline shielding and collimation is to reduce the hazards caused by radiation. Components near to the target or downstream of the target may receive high radiation dose levels. There are two important general considerations which help to reduce the radiation levels in the hall. The first is the attempt to transport as much beam power as possible into to the beam dump, but to control radiation production by stopping as much as the un-transportable power as possible into a single, well defined collimator location. Radiation shielding around this beam collimator is then used to mitigate the radiation production from that region.

The pivot region consists of the scattering chamber, collimator assembly, and septum. There is a continuous vacuum connection, without windows, through the scattering chamber, the septum and HRS magnets. Elements of the pivot region can be seen in Figures 1-3.

The experimental acceptance is defined by a collimator in the entrance the first quadrupole of the HRS.

Specialized Components of the Pivot Region

- **Vacuum System and Seals:** Near the target region there will be significant radiation damage during running and significant radiological activation. At small angles downstream of the target, all vacuum seals are metal. Possible radiation damage of all control or monitoring hardware (motors, pumps, sensors, etc.) on the target chamber or collimator box has been taken into account in the design of the area.
- **Beamline collimator:** To prevent excess electromagnetic radiation to be distributed around the experimental hall, a beamline collimator is used in front of the septum to catch scattering larger than $\sim 0.78\,\text{deg}$. This collimator absorbs about 2.5 kW of beam power during the PREX production running. The collimator is housed inside a collimator box (see Sec. B).
- **Q1 collimators:** The acceptance-defining collimators are placed after the septum and before the Q1 magnets. They are further described in Section G.
- **Neutron shielding:** Shielding is required to reduce the high rate of moderate energy neutrons emitted from the beam collimator. This shielding uses high-density polyethylene and concrete, described in Section H.
- **Skyshine shielding:** Heavy nuclear shielding is required over the collimator and over the target to reduce the site boundary dose caused by skyshine neutrons. These components are described in Section H 1.
- **Sieve Slits** are to be remotely insertable so that optics calibration data can be taken throughout the run as needed without needing to enter the radiologically activated region near the pivot. The sieve slits are located in the collimator box.
- **Target Chamber:** A separate OSP on the target chamber will be available.
- **Septum Magnet:** A separate OSP on the septum magnet will be available.

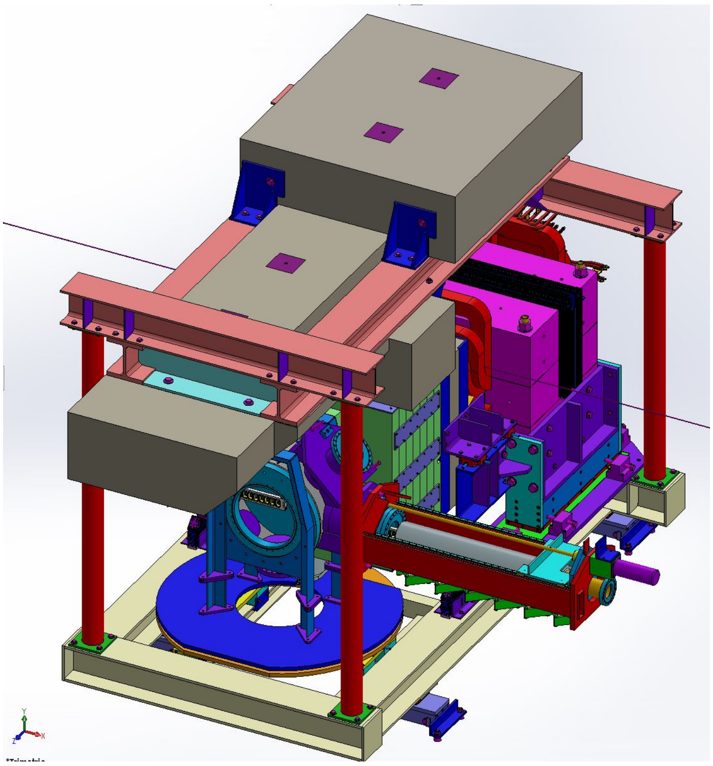


FIG. 1: Perspective view of the pivot region with shielding.

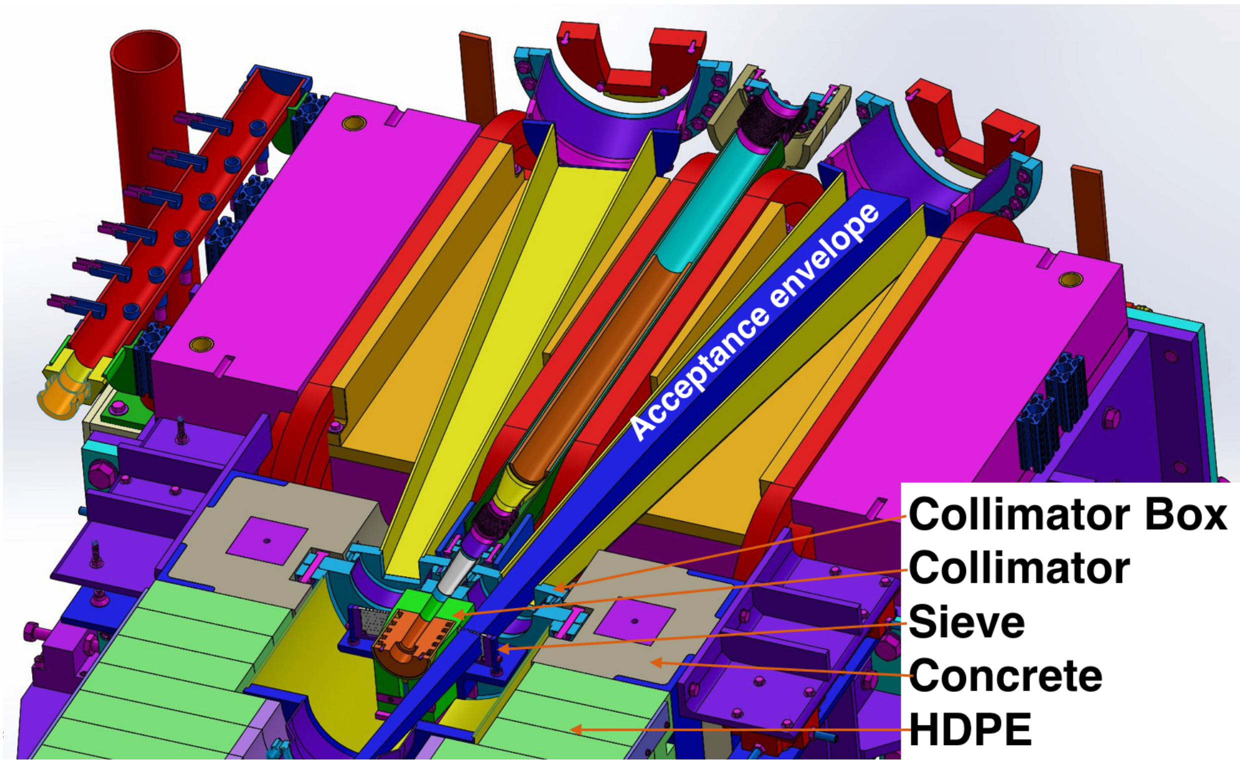


FIG. 2: Perspective view of the pivot region with shielding.

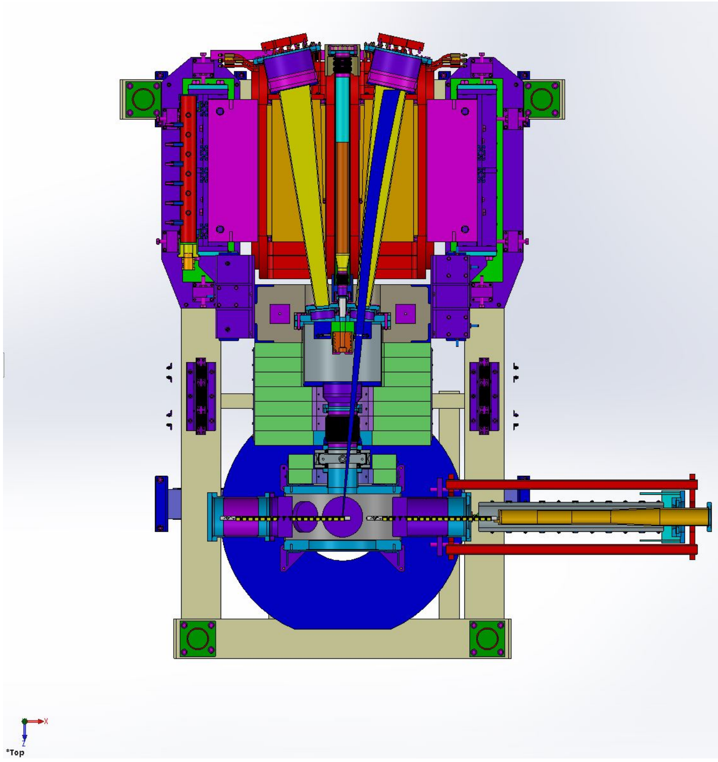


FIG. 3: Top view of horizontal midplane cut through the pivot region.

A. Vacuum System and Seals

The scattering chamber is made of aluminum. All beamline seals are metal seals. The downstream gate valve and exit beampipe is stainless steel to avoid elastomer seals which can be damaged by the radiation. An estimate of the integrated radiation dose during the experiment suggests that the integrated dose may be over the nominal damage threshold for most polymers.

B. Collimator Box

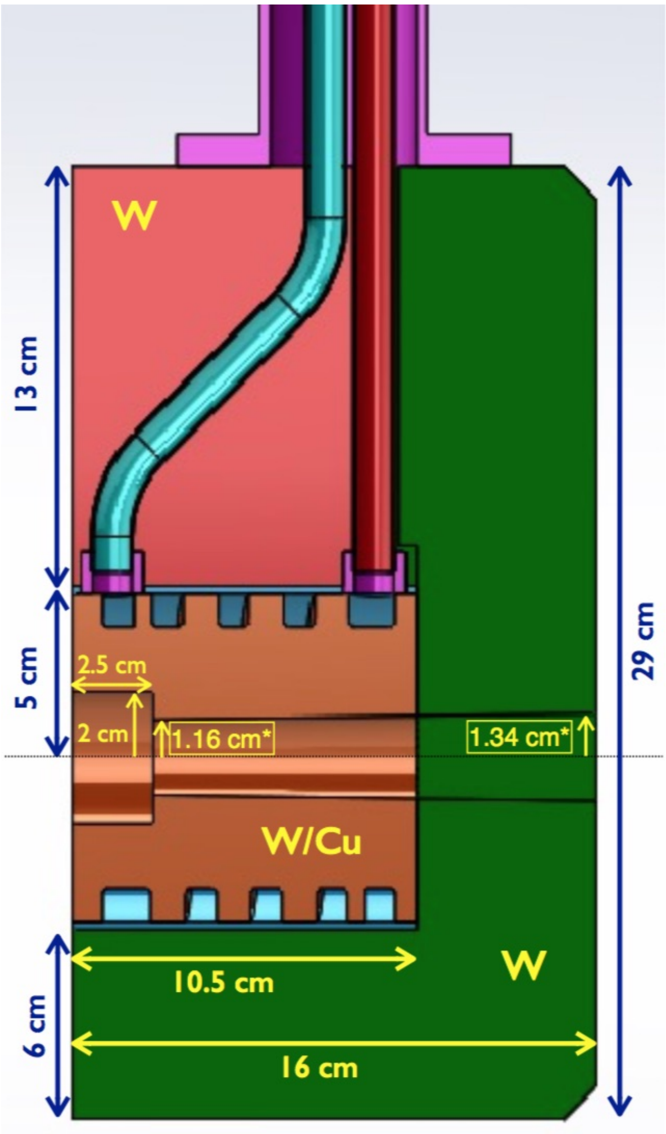
The collimator box connects the scattering chamber to three separate vacuum volumes on the downstream side: the beam pipe running through the septum magnet and the left and right spectrometer vacuum boxes that penetrate the septum bore. The box houses the beam collimator and sieve slits for optics calibration.

This box is made of aluminum. Only metals seals were used on this vacuum enclosure. The spectrometer vacuum boxes attach directly to the downstream face of the collimator box, while the beampipe attaches to a flange on a extension pipe.

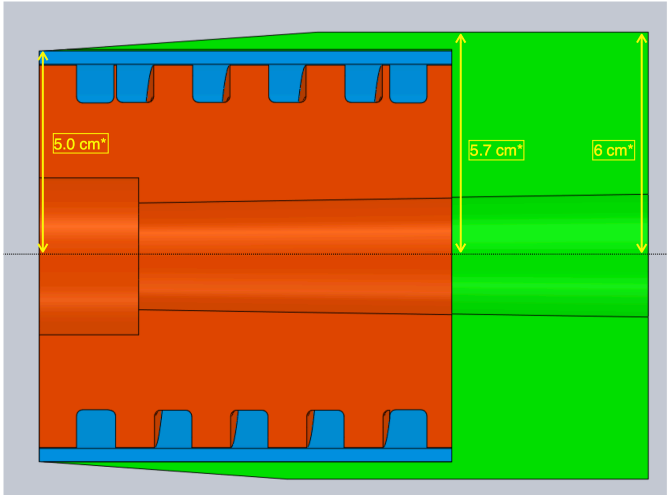
C. Beam Collimator

The beam collimator assembly consists of two pieces: a 70% W / 30% Cu alloy collimator, cut to allow cooling water flow and brazed inside a copper jacket. (This component is based on the design of the Qweak tungsten collimator.) This inner collimator is housed in a larger jacket made of sintered tungsten. The inner collimator has a total radius of 5 cm, and length of 10.5 cm. The water channel is about 5 mm in the radial dimension, spiraling around the collimator and attached to water lines on the top of the collimator at each end. Dimensions are labeled in the illustrations in Fig. 4a and 4b.

The inner bore of the beam collimator has a radius tolerance of 0.2 mm. The width of the collimator is designed to subtend an angle of $3.45° \pm 0.1°$ to each side of the beam. It is specified with a tolerance of 0.5 mm on construction



(a) Side view of the beam collimator.



(b) Top view of the beam collimator.

and 1 mm on alignment, so that it does not interfere with acceptance. The 1 mm alignment tolerance is also sufficient to not significantly increase the deposited beam power.

The tungsten jacket is 12 cm wide at the downstream side. It does not extend all the way to the front of the inner collimator on the sides. It extends 13 cm above and 6 cm below the inner collimator for a total height of 29 cm. It is about 16 cm in length. The front face of the jacket is flush with the front of the inner collimator.

There is a 2 cm radius, 2.5 cm long cylinder removed from the front of the inner collimator. This puts the peak beam power deposition inside the tungsten collimator, rather than close to the front face.

The beam bore through this collimator matches a conical opening angle of 0.78° from the PREX production target. On the back end of the tungsten jacket, this corresponds to a radius of 1.34 cm. At the narrowest point, 2.5 cm downstream of the collimator front face, the beam bore has a radius of 1.16 cm.

The collimator is positioned with the front face 22 cm upstream of the pivot, or 88 cm downstream of the PREX/CREX production target.

The collimator is water cooled, with a maximum total power for production running expected to be about 2.5 kW (Table I). The water lines are run upward through the collimator jacket. It is assumed that this needs a closed cooling circuit due to tritium production in the cooling water.

The collimator is be held by a vertical support, and rest on floor of the collimator box. It should have some alignment pinning, to support the 1 mm alignment tolerance.

After operation, this collimator is to be lifted up into the collimator housing, which contains shielding that will

	PREX	CREX
Current	70 μA	150 μA
Power/μA	36.2 W/μA	5.96 W/μA
Total power	2536 W	893 W

TABLE I: Power deposited in beamline collimator, for PREX and CREX at 5.13 deg scattering angle, 0.95 GeV and 2.2 GeV beam energies, respectively.

limit the radiation dose from the activated collimator materials.

D. Sieve Slit Collimators

The sieve slits are the same dimensions as those used during PREX-I. Motion feed-through that can be remotely actuated will position the sieve optics collimator between a "beam out" position, in which they swing free of the spectrometer acceptance, and a precisely determined "beam in" position, where they do entirely cover the spectrometer acceptance.

The remote actuation is necessary so that these can be used even after significant activation has started at the pivot. These will be manual actuators connected to a long tether. To move the sieve from one position to another, the shift crew must take access and pull on the tether on the correct side of the beam. The tethers will be outside the fenced area around the pivot. There will be labels at the tether and clear instructions posted on how to manipulate them. The instructions will also be easy to find in the "how to" documentation of the experiment.

E. Spectrometer Vacuum Boxes

A vacuum box in the acceptance bore of each side of the septum connects from the collimator box to the HRS vacuum pipe. This vessel is made of 1/4" non-magnetic stainless steel. The cross-sectional vertical and horizontal dimensions of this box allows acceptance of the signal tracks.

F. Septum Beam Pipe

The existing septum beampipe has been used. It is made with magnetic steel, and integrated with a steel rectangular box surrounding it to assist with magnetic shielding. The ID is 3.25", and the septum requires robust vacuum connections and magnetic shielding. Tolerances set by mechanical considerations, not physics.

Additional magnetic shielding is used to cover between the collimator box and the septum beampipe, as shown in Fig. 5. The shield is magnetic steel, and have 1/2" thick vertical walls. A similar shield is also used for the downstream end of the septum beampipe.

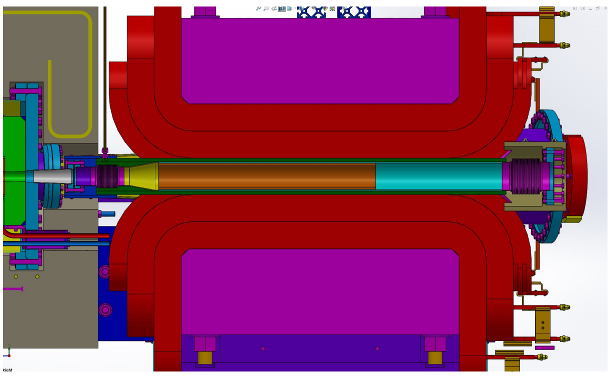


FIG. 5: Septum beam pipe with insert (orange) and additional magnetic shielding boxes around upstream and downstream bellows.

G. Q1 Collimator

A collimator is deployed in the aperture to each Q1. This collimator is designed to be the most strict cut on rays into the spectrometer, so it will define the spectrometer acceptance. This collimator is similar to what was used in the first run, shown in blue in Fig. 6. The location of the collimator will define the scattering angle for the experiment. The collimators are 4 cm thick lead.

This collimator has a specified acceptance shape. Symmetry between the two HRS is important; both left/right and up/down symmetry should be preserved.

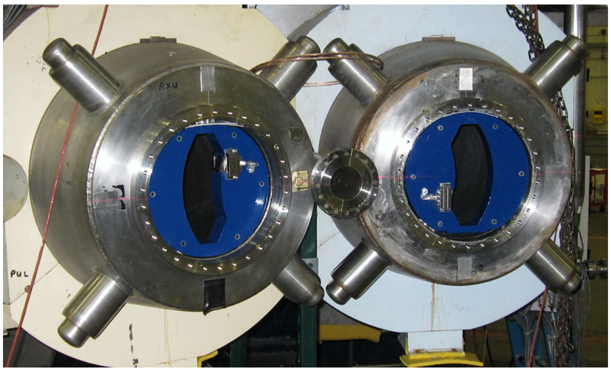


FIG. 6: Q1 acceptance collimators installed for PREX-I.

H. Radiation Shielding

In addition to this OSP, the reader may consult the Radiation Safety Assessment Document (RSAD).

High-density polyethylene (HDPE) is placed around the collimator in order to attenuate the moderate energy neutrons which drive much of the radiation damage to electronics in the experimental hall.

1. Skyshine Shield

Concrete blocks are used over the collimator region to attenuate high-energy neutrons ($E_{neutron} > 30$ MeV) which drive the site-boundary dose rate.

The target block is positioned 50 cm above the beamline, ranges from 1.2 m upstream of the target to 70 cm downstream, and has a full width of 125 cm. To allow space for the optics target mover in the scattering chamber, a wedge is cut off of the beam right side of this block, starting at the upstream edge and continuing to about 20 cm downstream of the target. The mass of this concrete block is about 1,800 kg.

The collimator block in the reference design is positioned higher, about 1 meter above the beamline, in order to avoid possible mechanical interferences with the collimator housing or septum magnet. The upstream end of this block matches the downstream end of the target block. It is 140 cm long along the beamline, and 125 cm wide. The mass of this block is about 1,700 kg. Together, the two blocks attenuate about 55% of the power in high energy neutrons that would reach the hall roof in the CREX configuration, and about 40% of the power in high-energy neutrons in the PREX configuration.

The placement of these skyshine shields are shown in Fig. 7 and Fig. 1.

I. Collimator Neutron Shielding

The HDPE shielding around the collimator region is shown in Figures 2, 3, and 7. It is constructed out of several layers but with different cutouts so that it closely follows the shape of the beamline elements between the target chamber and the collimator box. At about the mid-point of the collimator until the back of the collimator we place a custom designed concrete block that again has an apperture that allows for the different shapes of the flanges and collimator box.

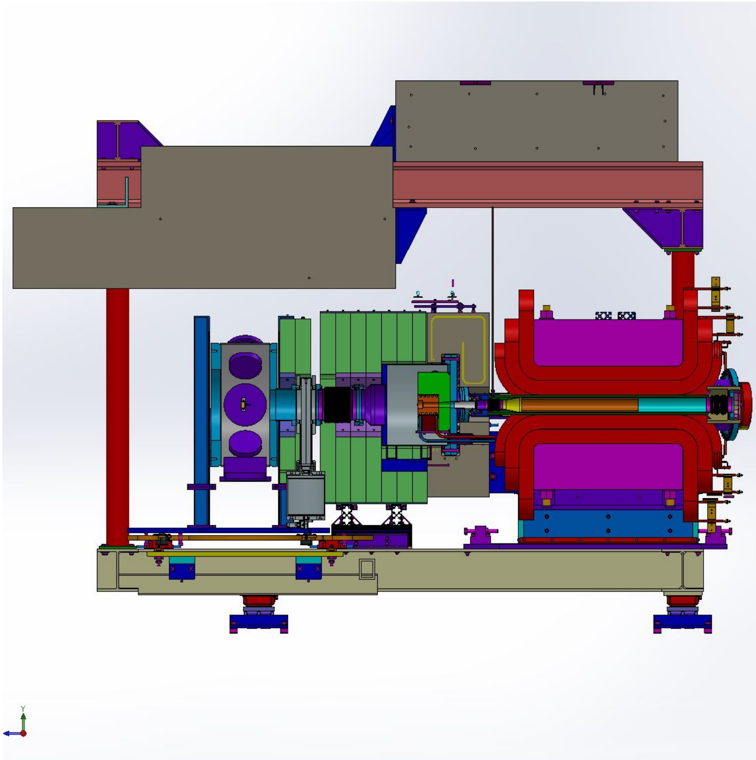


FIG. 7: Side view of pivot region, with vertical midplane cut, showing location of the sky-shine shield relative to the scattering chamber and collimator.

By signing this page, you testify that you have read, understand, and agree to abide by the procedure specified in the above referenced work control document:

Serial Number: ENP-19-84028-OSP

Title: Shielding and Collimation for PREX and CREX

Name	**Signature**	**Date**