PREX/CREX 2nd Experimental Readiness Review

(PREX/CREX ERR)

Review held May 17, 2017

This document dated June 14, 2017

Committee Members:

1. Ed Folts (observer)
2. Arne Freyberger (beam)
3. Javier Gomez (observer)
4. Dave Mack (chair)
5. David Meekins (target)
6. Todd Kujawa (EHS&Q/electrical)
7. Bert Manzlak (EHS&Q)
8. Jack Segal (power supply)
9. Pavel Degtiarenko (radiation)
10. Mark Wiseman (septum)

Executive Summary

The PREX/CREX experiments pass this 2nd ERR. However, they should only be considered by the scheduling committee after our recommendations are closed, in particular after their detailed commissioning plans are approved by the Physics AD Deputy.

There are 11 charge items. They are presented one per page.

1. **What is the operational status of the equipment?**

Progress is adequate for this stage. A Figure of Merit (FOM) analysis including systematic errors led to a single target configuration, eliminated the concern over higher fields in the septum magnet, reduced the site boundary dose, all while yielding almost the same error bars. The collaboration should be congratulated. (Such a FOM analysis should become the gold standard for large experiments at JLab.) The collaboration has provided Hall A with required dimensions and tolerances. Durations were estimated for major activities and a draft schedule was presented.

What are the completion/commissioning schedule and tasks?

Listing only a few major items:

- The target can be built by Spring 2018 with some stress on the target group.
- The quadrupole fringe fields must be addressed in the short term at high priority.
- A single new coil is needed for the septum and is a relatively long lead item needed for procurement. Early availability of funds could help reduce the schedule risk associated with this item. No spare coils were mentioned but if needed they should be bought at the same time.

Listing some minor items:

- Use of the water/steel target for absolute angle determination assumes that relative z positions for the water/steel target and the production targets are known to a certain accuracy. That alignment and survey tolerance, which the collaboration quickly estimated offline, should be communicated to the target group.

Regarding commissioning schedule and tasks, see below.

2016 Recommendation: *The next ERR would seem to be the appropriate time for a detailed schedule and final task list. Completion plans and commissioning must be covered at the next review.*

More detail is needed on commissioning plans, and this cannot wait until the Final Readiness Review in its present form. <u>To be considered for scheduling, the collaboration must submit to the Physics AD Deputy, Patrizia Rossi, the following:</u>

- plan to alignment the electron beam with the (hole) target (possibly dropping the BeO target),
- plan to align the electron beam on the dump face,
- plan to commission the beam raster system,
- plan to quickly establish polarimetry with sub-1% uncertainty.

2. Is the 48Ca target geometry optimized for background suppression?

Yes. This item was in principle addressed at the last review. However, a new question arose as to whether evaporating/sputtering lead could contaminate the 48Ca target. Drawings of the target show that the both the lead and 48Ca targets are sufficiently re-entrant that zero bounce contamination is not possible. Contamination after a single bounce is unlikely since most of the lead will stick to the relatively cold scattering chamber wall, and because the area of the 48Ca target is a tiny fraction of internal area of the scattering chamber. Running CREX before PREX would alleviate any such potential concern of course.

This charge sub-item should be closed.

Are local shielding and machine protection systems required to minimize detector background in place?

Yes. This charge sub-item was addressed at the last review.

Have the proper measures been taken to protect the 48Ca target from oxidation?

See comments below.

2016 Recommendation: *In the event of long term vacuum loss, or if the scattering chamber needs to be brought up to atmospheric pressure, we recommend that the ^{48}Ca target be protected with inert gas. The collaboration also needs to think about how to remove and store the ^{48}Ca target at the end of the experiment.*

This will be incorporated into the target design. This 2016 Recommendation is closed.

We have no new recommendations on the 48Ca target. Charge item #2 should be closed.

3. Have the proper measures to protect the 208Pb target from melting been taken?

The proposed 208Pb target solution appears adequate for completing the measurement. The diamond layer and thermal coupling will be more robust, the raster frequency will be modified to reduce temperature spikes relative to PREX-I, and the ladder will incorporate many extra targets. The simulations and presentation shown were commendable.

This charge sub-item should be closed.

Have measures been taken and defined to prevent and monitor density fluctuations?

Yes. This charge sub-item was addressed at the last review.

2016 Recommendation:

- *It is desirable to consider and develop an engineered solution to capture melted lead.*

It was explained to us that the lead in a failing target is dispersed by evaporation/spattering so it is not possible to "capture melted lead". The target chamber used for this experiment will be custom built for this experiment and will contain any lead contamination.

This 2016 recommendation is closed.

- *There remains a general lack of understanding of the failure modes of the target. Because the thermal conductivity of diamond is negligible near 4K, a steady-state analysis could conceivably miss the possibility of damage/melting from a too-rapid beam ramp. At the next ERR, the results of a time-dependent analysis from 4K to equilibrium temperature should be presented assuming instant turn-on of the beam.*

Impressive simulations were carried out which first of all demonstrated this was not an issue. The simulations also revealed a way to reduce previously unrecognized fast temperature spikes of 10's of degrees by slightly increasing the difference in raster frequencies. This 2016 recommendation is closed.

We have no new recommendations on the 208Pb target. Charge item #3 should be closed.

4. The septum magnet will be operated at higher current density during CREx. Has the safe and efficient magnet operation at this current density been satisfactorily addressed by the collaboration?

Effectively, yes. With the new CREX kinematics, the septum will now be operated at less than 75% of the current used in g2p. Thus the septum operation is no longer particularly aggressive. However, see below for two new Recommendations relevant to "safe and efficient magnet operation".

Is the water-cooling system adequate for the high current?

Yes. An accounting of the LCW in Hall A has confirmed that there are sufficient GPM available to support the experiment. This has retired this concern. A measurement of the total GPM currently in the hall is planned for the near term which will benefit general hall operations. The details of the distribution matching for the experiment still need to be done and has been included in the E&D labor estimate.

2016 Recommendation: *A detailed LCW estimate should be presented for the entire experiment.*

This was done. This 2016 Recommendation should be closed.

Although the cooling water hoses are not particularly close to the region where the enamel on the inner coil shows discoloration from previous running, the committee noted during its discussions that a septum hose failure several weeks into the run could end the experiment. To reduce this likelihood, we have two new recommendations.

New Recommendations:

- Use relatively rad-hard water hoses for the septa and Q1's. Replacements may be needed for the Q1's after the experiment, so consider ordering two sets (or metal piping).
- Explore reversing the orientation of the septum magnet (upstream vs downstream) so that the hoses move to the downstream side. If there is a water leak and personnel have to access the hoses, this will put them significantly further from the highly activated collimator and target. (This was apparently not an option with the previous, larger superconducting HRS quadrupoles, but it may now be an option with the new resistive quadrupoles.)

5. Does the operation of the septum magnet produce any residual field along the beam line? If it does, has its effect on beam transport been evaluated and shielded properly?

Yes, but the effect of the septum is relatively small. The larger effect that was discovered was the quadrupole fringe fields which have the potential to defocus low energy electrons downstream of the target and increase dose levels by an order of magnitude. Hall A staff are exploring the use of an iron pipe to magnetically shield the beam in the cramped space between two quadrupoles.

We suggest two iron shunt pieces as another possibility for magnetic shielding, one above and one below the beamline, located between the quads.

We also suggest incorporating the quadrupole hoses and power lead shields into the above magnetic shielding study. It was noted that the actual space is even more cramped than the CAD model suggested.

2016 **Recommendations:** *The experimenters should*

- *include the effect of the HRS Q1 fringe fields on potential beam deflection, then*
- *check with Keith Welch that the magnified beam spot is safe for beam dump operation, or develop mitigation procedures.*

This was done. Deflection was small, but backgrounds increased dramatically due to the quadrupole fringe fields as discussed above. Mitigation is in progress.

New Recommendation:

Continue efforts to resolve the quadrupole fringe field issue. We are confident a solution will be found, but it must be given high priority since the lack of a solution would be fatal to the experiment. Radiological changes resulting from the mitigation should be assessed as well as the impacts on the installation/de-installation schedules.

6. Have the EHS&Q considerations been properly included in the design of the equipment?

Compliance to date has been satisfactory. This needs to continue, and there are OSP's to finalize, etc. Clean up of the HPDE is being considered in the support design of the shielding. Maintenance of items under the shielding should also be considered.

2016 Recommendation: *The next ERR should give particular attention to whether EHS&Q considerations have been properly included in the near final design of the equipment.*

The collaboration and Hall A staff have done this. This 2016 Recommendation is closed.

New Recommendation:

- The HDPE shielding is a large potential fuel load. This hazard should be mitigated by procuring flame-retardant HDPE or other means.

By its nature, charge #6 will remain open until the experiment runs.

7. Are the anticipated beam characteristics (parity quality, general stability..) expected to be within the required specification to perform these experiments?

Yes. A systematic approach for halo reduction was outlined. Other beam parameters and monitor resolutions are adequate. The collaboration will continue making parasitic measurements of beam properties with their parity daq.

2016 Recommendations:

- *The Parity Quality Beam team should continue to establish robust parity beam diagnostics in the Hall-A line. Aggressively request the use of beam studies time during beam operations.*
- *Prepare to study parity beam quality with CEBAF at near 2 GeV/pass during Fall 2016 and Spring 2017 beam operations.*

The collaboration has done testing significant testing when beam was available. Charge item #7 should be closed.

8. Are the radiation levels expected to be generated in the hall acceptable? I.e. has the impact of the radiation generated in the hall equipment and infrastructure been properly calculated and mitigated? This includes:
o The scattering chamber
o The beam-line downstream of the scattering chamber
o The instrumentations (electronics, ...)

This looks generally in good shape. RadCon will review the presented calculations and make recommendations.

2016 Recommendations:

- *Dose simulations for the HRS power supply platform should be checked against measurements during upcoming Hall A beam operations.*

  This was apparently not done. The question is important, but in hindsight the committee realizes that asking the collaboration to do both the dosimetry and the simulations was perhaps unreasonable. Dave Hamlette in the RadCon group may be able to assist with opti-chromic rods, for example. Javier Gomez in Hall A would be an appropriate contact person as there may be charges. This 2016 Recommendation remains open.

- *Based on the conceptual shielding design, the site boundary dose is approaching the limit even assuming no Hall C operation (primarily due to CREX running). To increase the confidence that the site boundary dose in a given calendar year will not be exceeded, and simplify multi-Hall scheduling, the collaboration should implement their idea of installing additional shielding over the ^{48}Ca target to reduce sky-shine.*

  This has now been incorporated into the base design. This 2016 Recommendation item is closed.

- *Another iteration of the radiation calculations will be needed when the engineering design of the targets and the interaction region is finalized.*

  The present impressive calculations were done for the conceptual design of the shielding. They may need to be repeated for the final engineering design depending on the magnitude of changes. This 2016 Recommendation remains open, and can be closed at the discretion of the Hall A group leader.

New Recommendation:

- The HDPE shielding configuration should take ALARA into consideration: e.g., rad-hard containers that speed up the de-installation of large amounts of HDPE in highly activated areas.

9. Are the responsibilities for carrying out each job identified, ….

The responsibilities looked in good shape. We suggest formalizing the relationship between the collaboration and the Source Group with a named collaborator to work with Riad Suleiman.

We'll leave this charge sub item open to gently motivate further refinements.

…. and are the manpower and other resources necessary to complete them on time in place?

We were presented a 4+10 week schedule for de-installation of the previous experiment, installation of PREX/CREX, and routine but essential maintenance on Hall A systems.

With existing Hall A manpower at 50% duty factor on this one project, we were told design and engineering could be completed by Fall 2018. This scenario implies that actual construction and installation would occur even later. Significant funding for equipment procurements, as well as additional design and engineering manpower, would be needed to be ready for a Fall 2018 run. Answering this funding and manpower question will be a factor in determining the earliest practical time slot for which the experiment can realistically be scheduled.

2016 Recommendations: *The experimenters should work with Hall A management to better quantify their design and engineering needs.*

The collaboration has done this. The design is essentially frozen, although some small matters will surely arise. This 2016 Recommendation is closed.

10. Has the equipment ownership, maintenance and control been defined during beam operations?

This appears to be in good shape. We'll leave this charge item open to gently motivate further refinements.

11. Are the specific documentation and procedures to operate safely and efficiently the equipment, in place and adequate?

Progress is adequate for this stage. Much of the documentation is in draft form. Completion of this documentation will be *critical* for the final readiness review. Because of the unusually high expected activation near the target area, procedures for accessing Hall A for reconfiguration, rebooting, or repair will have to be extremely well communicated to the collaboration and technical support staff.

This includes demonstrated readiness for full rate capability and expedient analysis of the data.

PREX/CREX are, for the most part, integrating mode experiments so high rates are not problematic. This is a 2nd generation PREX run so the analysis software and procedures already largely exist.

This sentence of charge item #11 should be closed.