PREX-II/CREX Response to ERR

1 Charge Item 1 - Status

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

1.1 *plan to alignment the electron beam with the (hole) target (possibly dropping the BeO target)*

After beam is established to the dump, after any beam down time, we will enforce the standard practice to first establish the alignment to the carbon hole target. The procedure is to insert this target and look at the rate distribution as a function of raster position running the HRS counting-mode DAQ and using the standard "spot++" program. The hole should be centered in the beam profile. Once the hole and normal rates in the HRS are established, we can turn off the raster and confirm a negligible trigger rate as the beam should be passing cleanly through the hole. Once the beam position is established at the beginning of the experiment, the BPM values at the last two BPMs can be recorded and will become a good reference since they normally would not change for the the experiment.

As summarized in the design document, there is no BeO target intended for this experiment, as radiation damage would likely render a viewer camera unusable early in the run. Instead, a carbon target with a hole will be used to align the beam.

1.2 *plan to align the electron beam on the dump face*

Fringe fields from the septum and the new Q1 magnets will be quadrupole in nature and no major deflections are anticipated for our proposed configuration. For modest offsets from the magnetic axis, the beam will not be deflected off of the dump face.

First, the beam will be delivered to Hall A following a standard procedure as outlined, for example, in the document MCC-PR-04-001 with the HRS Q1s and septum off. The beam should be centered on the dump using the combination of viewers, BPMs, knowledge of the orbit, and the ion chambers. Once delivered, we will then verify that the beam is not deflected by the HRS Q1s or the septum. With tune beam, we will start with HRS Q1s and septum at zero current, and beam centered on dump. Then the current in the septum will be slowly raised to verify the beam is not deflected from the dump. When septum set point is reached, bring up each Q1 current individually to verify it also has no appreciable effect on the beam position.

After we have established zero steering, the beam current will be slowly brought to operating current with no target in place while observing the ion chambers and radiation monitors. After that, the alignment procedure in Sec. 1.1 with the carbon hole target should be followed to center the beam. Then the experiment's main target in place (Lead for PREX, Calcium for CREX), will be put in place, and the raster commissioning will be performed, Sec. 1.3. Once the raster is established, the beam current will be slowly brought to operating conditions while observing the ion chambers and radiation monitors.

1.3 *plan to commission the beam raster system*

The procedure to set up the raster is explained in the document MCC-PR-04-003. The setup of the beam in Hall A is standard and the procedure to establish rastered beam on a lead target was developed during PREX-I.

The beam raster frequencies will be adjusted to make X and Y about 2% different since this was shown to reduce temperature spikes because it spreads the beam more uniformly on the target. This is possible without any changes to the circuit, but it will be verified before the run. In addition, the raster sweep is synchronized to the helicity period by using a 10 MHz master signal from the polarized injector to the raster driver; this suppresses the noise from nonuniformities in thickness within target. This was implemented in PREX-I and the new driver has become standard equipment.

After any beam down time alignment to the Carbon hole target will be reestablished, as specified in Sec. 1.1. The raster size is checked with the well-established Hall A "spot++" procedure. It can be corroborated with HARP scans at low current, which we perform periodically during the experiment as a cross check. Also at the start of the experiment we'll do standard calibrations and checkout of the BPMs, BCMs, and HARPs.

Since each lead target could have a slightly different alignment, and there is a possibility of target movement, the alignment of the lead (or calcium) target will always be checked when moved to this position using a similar procedure followed in PREX-I. First we establish 5 nA on a thin carbon target by observing the rates and adjusting the beam current using the laser attenuator and slits. Then we put in the lead target and run our DAQ in counting mode, observing the raster current distribution; since the triggers come from particles scattered in the target, and since the raster current is uniform, the observed distribution provides a profile of the target thickness and scattering cross section. On each new target we will test a larger raster and move the beam a few millimeters in each direction to ensure that we can identify the frame and establish that we are at least 2 mm away from it during normal running conditions.

1.4 *plan to quickly establish polarimetry with sub-1% uncertainty.*

The polarimetry uncertainty goal for PREX-2 is 1.1%, and the goal proposed for CREX was 0.8%. The collaboration experience with both Møller and Compton techniques have led to significant improvements in both techniques.

Møller Polarimetry For the Møller polarimeter, the leading source of uncertainty was knowledge of the target foil polarization, which appeared to be incompletely saturated, followed closely by the Levchuk correction. The new Møller polarimeter design should help control these sources of uncertainty.

The previous target ladder could not be aligned precisely to the field, and in fact the targets may have warped in the high field. The possible misalignment of the target foils would create incomplete saturation with the transverse field. The new Møller target system can be aligned more precisely with the field, and it will be assembled in the test lab for testing. A Kerr effect measurement of the relative magnetization is being developed to assist in the saturation studies. This technique could potentially allow for the determination of the optimum target position in a lab setting, saving beam commissioning time.

The simulation of the Møller spectrometer is also being improved, to better control acceptance and Levchuk correction uncertainties at high fields. The improved design, along with the testing and simulation to be done over the next year, will provide an easier path to 1% or better for PREX-II and CREX.

The commissioning plan seeks to first establish the alignment of the Møller target field with the beam direction, which is necessary for a precise understanding of the acceptance. Several shifts will be required for tuning up the spectrometer and detectors. A systematic study will verify the target saturation.

Møller commissioning plans

1. One 8 hour shift for magnet alignment data. Ramp magnet to 4 T in both directions and observe motion of beam on downstream targets.
2. One to two days to analyze beam optics data and determine misalignment values. This can happen while other commissioning tasks continue.
3. Less than one 8 hour shift in the hall with beam off to realign magnet. This can happen in concert with other in hall activities. Not necessary to dedicate beam off time for this.
4. One or two 8 hour shifts to verify magnet alignment and perform other commissioning tasks including checking tune of quadrupoles, tuning detector HV levels and ADC thresholds, verifying target motion system works as expected.
5. One 8 hour shift dedicated to the verifying target saturation. This involves scanning the B-field and rotating the target.

Compton Polarimetry PREX-I also pioneered the low energy, high precision Compton polarimetry. The green cavity which was necessary for low energies was ready and installed only just before the PREX run. The technique of integration of the photon detector was also new, having been used for the first time in the immediately preceding runs of HAPPEX-III and PVDIS. The use of photon integration was made more challenging by large background of neutrons from the production target.

The dominant uncertainty was the knowledge of the laser polarization inside the cavity. A technique developed during QWeak now allows for 0.2% precision on laser polarization inside the cavity. This technique has been applied to the Hall A system, so the laser polarization uncertainty will be negligible. This will be studied well before the run because a significant amount of work does not require beam.

Improved shielding in the target region will reduce neutron background at the Compton by about an order of magnitude. In addition, techniques developed during HAPPEX-III and PREX-I to measure the PMT characteristics have been used to optimize PMT bases for use during PREX-II and CREX.

Compton Commissioning Plans (≈ two 8 hour shifts)

- Establish beam in chicane, establish slow lock.
- Measure beam-off rate in photon detector. Verify background rate within limits.
- Perform vertical scan to establish beam intersection
- Verify laser-on and laser-off signal levels are in expected operation range of PMT
- Collect data. Perform systematic studies with PMT linearity measurements, PMT parameters, laser power, beam current, photon attenuator thickness. Accumulate counting spectrum to verify spectrum and detector response simulation.

2 Open Recommendations

2.1 Charge Item 4 - Septum Magnet

Recommendation: *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).*

The Hall A work coordinator has already contacted vendors in order to obtain quotes and solutions for metal water hoses with a rad-hard ceramic fitting to connect to the Q1s. A plan is in place to have these installed at the latest in summer of 2018.

Recommendation: *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.)*

We have contacted Alan Gavalya and he has already confirmed that there is enough space to reverse the septum direction. We have run radiation studies and have found a significant decrease in the radiation to the water hoses in this configuration.

2.2 Charge Item 5 - Residual Fields

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.*

Since the review, the collaboration has evaluated the realistic fringe field for the septum plus two Q1 quads in a TOSCA model. A solution to effectively eliminate the fringe field along the beamline in the region of the Q1 magnets has been developed and is being investigated to ensure beam transport to the dump is unaffected and that there is no appreciable increase in radiation dose to the hall.

2.3 Charge Item 6 - ESH&Q

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.*

We are in contact with the designers and have taken steps to minimize the fire risk associated with the HDPE and any final design will be evaluated by the safety group. We will investigate the procurement of flame-retardant HDPE.

2.4 Charge Item 8 - Radiation

Recommendation: *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.*

We have contacted the RadCon group (Pavel Degtiarenko and George Kharashvili) related to this item after our 2016 ERR. We have continued our discussion related to benchmarking simulations and dose rate simulations since then. Several comparisons have been made between different simulation packages showing reasonable consistency. Furthermore, Maduka Kaluarachchi (from the APEX collaboration) has been working with RadCon to establish an absolute calibration for the radiation monitors in and around the hall. It is expected that RadCon will make measurements of the dose rates around the hall in the upcoming runs.

Recommendation:*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.*

The collaboration continues to run radiation simulations throughout the design process to ensure changes do not produce significant increases to the hall electronics. A final radiation calculation will be available at the ERR before running the experiment.

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.*

ALARA considerations are being taken into account in the design process for the shielding. We will continue to keep this recommendation in mind as designs mature.

2.5 Charge Item 10 - Equipment Responsibility

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

The collaboration continues to be motivated to ensure all subsystems have proper responsibilities, procedures, maintenance, and control defined as we prepare for beam. We will continue our development of run plan details and assignment of tasks to specific individuals.