Summary of Beam Parameters for PREX

This note provides a brief summary of important beam parameter requirements for the PREX experiment. Included is a summary table and a list of special considerations.

1 Beam Requirements Summary

PREX Beam Summary				
Beam Property	Nominal Value	Maximum Run-averaged Helicity-correlation[1]	HC One-day ("slug") Average	Maximum Jitter at 30 Hz
Average Current $\langle Q \rangle$	50-100 μA[1]	50 ppb	250 ppb	400 ppm
Energy	1.05 GeV	$\langle \frac{\Delta E}{E} \rangle \leq 1$ ppb	5 ppb	5 ppm
Energy spread σ_E/E	$10^{-}3$	-	-	-
Position x at target	0	<1 nm	5 nm	6 μm
Angle $y\prime$ at target	0	0.2 nrad	1 nrad	2 μrad
Position y at target	0	2 nm	<10 nm	12 μm
Angle $y\prime$ at target	0	0.5 nrad	3 nrad	3 μrad
Spot Size [2] at target	$>$ 150 μm x 150 μm (r.m.s., unrastered) $>$ 4mm x 4mm (box, rastered)	$\delta\sigma/\sigma < 10^{-4}$	10^{-3}	-

[1]The helicity-correlated spot size variations cannot be measured well. An upper bound must be established from an understanding of the source configuration and cancellations. Specifications here assume spin flipper cancellation.

[2]Position difference values here are quoted using the "qweak" convention of half-position difference, *i.e.* $(x_R - x_L)/2$. This matches the analysis code used in Hall A for the 2019 experimental runs.

- **Nominal Value:** This is the usual desired central value of the beam property.
- **Maximum Run-averaged Helicity-correlation:** This refers to the maximum value of the helicity-correlated (HC) difference (or asymmetry) that can be tolerated after averaging over the entire 600 hour run.
- **One-day "slug" Average:** Due to statistical noise, it is not possible to tell in a short measurement whether a systematic offset exists which will make it impossible to reach the run-averaged HC goal. Averaging beam parameters over approximately one day provides a convenient benchmark for convergence to the run-averaged HC goals, with enough statistical precision to perceive systematic offsets. These one-day average specifications are made with the assumption that the averages are statistically distributed, with no measurable offset. If the one-day averages are not distributed around a negligible systematic offset, corrective action will be necessary in order to assure convergence to the run-averaged goals.
- **Maximum Jitter at 30 Hz:** Previous parity-violation measurements at Jefferson Lab have operated by integrating the signal for a given beam property over a 33 msec time period, and forming differences between two successive 33 msec periods. The standard deviation of the distribution for those differences is what we refer to as "30 Hz jitter." For helicity reversal frequencies faster this 30 Hz nominal frequency, PREX will require "root-N" scaling of the jitter quoted here.

2 Special Considerations

1. **Helicity Reversal Frequency** Studies have demonstrated irreducible noise contributions at the level of 50 ppm at the 30 Hz reversal frequency. This noise would significantly impact the statistical precision of the PREX experiment. More importantly, a significant component of non-statistical noise increases susceptibility to higher-order effects which can lead to false asymmetries. For this reason, PREX requests the option of helicity reversal frequencies at 240 Hz, 120 Hz, and 30 Hz (the present default). The reversal frequencies faster than 30 Hz will require the adoption of a multiplet spin pattern to cancel 60 Hz line noise.
2. **Polarization Orientation** PREX is highly sensitive to components of transverse polarization. The experiment requires that both vertical and horizontal transverse polarization components to be below 2%. In addition, it is desired to use the Mott polarimeter to zero the vertical polarization component to within 2%.
3. **Priority in source configuration:** Like other parity-violation experiments, PREX will require priority in the source configuration (centering on the Pockels cell, etc.). In order to tune the source to minimize HC beam systematics, it will also be necessary to control setpoints for common devices such as the Insertable

Halfwave Plate, Rotating Waveplate, and Pockel cell voltages. (Changes to these setpoints can be made without significant impact on most experiments, for example, with negligible effect on beam polarization.) Other requirements for the source configuration may be negotiated with the Electron Gun Group.

4. **Time for source configuration:** Dedicated time for configuration of the laser optics of the source will be required. This does not require the use of the electron beam, but it is necessary that the process will conclude with a stable configuration optimized for helicity-correlated asymmetry control. Other significant changes to the laser optics made after this procedure will require additional configuration time on the laser table.

   Additional dedicated study time using the Hall A electron beam only will be required. Only beam in the injector is required. It is anticipated that 4-6 shifts total may be required, spread over a few days. Some portion of these studies will need to be repeated if there are any major changes to the polarized source.

5. **Control of other source lasers** Previous experience has suggested that significant helicity-correlated beam asymmetries can be generated in an otherwise well-configured "parity-quality" beam, when operated simulateously with another hall with large helicity-correlated asymmetries. PREX will require feedback mechanisms to control the helicity-correlated charge asymmetry of the Hall B laser (measured before the slit) and the Hall C laser (when operational).

6. **Electron Beam Transmission:** Significant clipping of the electron beam between the photocathode and the target can create excessive charge jitter or helicity correlated systematics on the beam. In particular, such clipping can create a helicity-correlated intensity asymmetry from helicity-correlated position differences. This can confuse diagnostics of the source and cause misguided corrections, using source optics, of problems created in beam transport. It is thought that clipping can also create higher moments of helicity-correlated asymmetries, such as spot-size asymmetries, and conditions with poor injector transmission have been seen to lead to high background rates in the Compton. To avoid such problems, PREX requires very clean electron transmission from source to target with minimal beam interception. Generally changes in mean value of the charge asymmetry should be kept to less than 10 ppm, and the width change less than 30 ppm, through the injector and into the hall.

7. **Helicity-Correlated Beam Spot Size:** No direct method exists to measure helicity-correlated differences in the beam spot size. While our understanding of the polarized source suggests that effects will be 10^{-4} or less, the sensitivity to this is high, and a credible result will require a convincing demonstration of a null effect. Spin rotation in the injector provides a method for a convincing "helicity flip" which does not interfere with the beam profile or mechanisms which might lead to a spot size asymmetry. Using such a spin rotator with a frequency between two days and one week will be a necessity for the PREX experiment. The new double-Wien system planned for installation in the injector will be used to provide this helicity flip.

8. **Beamtune and halo acceptable for Compton polarimeter:** In order to meet the precision goals of the experiment, it will be necessary to have reliable data from the Compton polarimeter continuously during production. It is therefore necessary that the beam be suitable for the use of the Compton polarimeter.

   A commonly-used criteria for operation of the Compton is a counting rate of 100 Hz/μA in the Compton photon detector, with the Compton laser off. The halo restriction is such that the Compton detector is the only instrument available at CEBAF which is suitable for monitoring this parameter at this level. This specification matches the requirement for use of the Compton system for most of the operational lifetime of the system, including the HAPPEX-II and HAPPEX-III experiments. It is expected that PREX experimenters will be closely collaborating with accelerator personnel to optimize the Compton photon background counting rates.

9. **Fast Feedback:** The fast feedback system for position and energy lock will be needed for the PREX run.

10. **Beam Modulation:** Air core steering coils in the Hall A beamline and the energy vernier in SL20 will be used to modulate beam position, angle, and energy in order to measure sensitivity to those parameters. It will be necessary to "pause" position lock and energy lock during these modulation periods.

11. **Phase Advance:** The successful use of the beam modulation system requires a significant phase advance between the modulation magnets and between the monitors used to characterize the beam motion, so that independent motions spanning the beam phase space can be observed. This has frequently proved challenging in Hall A. For well matched optics in the Hall beam line, it should be possible to design optics with sufficient phase advance. PREX experimenters will coordinate with accelerator on balancing these requirements with the other competing requirements on the Hall A beamline optics.

12. **Random Beam Jitter at Target** It is possible that the random beam jitter on target will become an important source of statistical noise in the PREX measurement. This leads to the requirement expressed in the table as "maximum 30 Hz jitter". This requirement is most strict in the horizontal position. The PREX design optics in the Hall should seek to minimize position jitter at the target without excessively increasing the angular jitter. Operational experience suggests that these specifications are achievable.

13. **Match to Design Beam Optics** It will be necessary with have the accelerator optics "well matched" during the PREX experiment. In particular, the helicity-correlated beam asymmetries are exacerbated if beam optics do not match design throughout the injector and linacs. If the beam is not matched through the BSY and into the hall, then beam spot sizes and beta-function phases are not well described by the optics model, and the various constraints on the beam line optics are more difficult to meet. It is therefore expected that matching must be done from the injector through delivery into Hall A early in the PREX commissioning period.

14. **Commissioning of New HRS Septum Magnets** New septum magnets will be added to the High Resolution Spectrometers for the PREX run. Although large effects are not expected, fringe fields from these new spectrometer magnets may affect the primary beam after target interaction. Safe beam operation with the magnets will need to be established during the commissioning period.

15. **Radiation levels** It is worth noting that the PREX target is a 10% radiator, and at high current and low energy the radiation load in the Hall will be signficant. System owners should be aware to prepare for possible radiation damage issues, and machine protection systems will need to be set to allow high luminosity operation without circumventing their function.

16. **Wien Flips** It is envisioned to change the state of the Wien spin rotator 3-5 times over the course of the experiment. This is an essential component to controlling possible false asymmetries due to beam conditions.

17. **Transverse Vertical Polarization** Residual false asymmetry from trasverse beam polarization is an important possible systematic for PREX. It will be necessary to configure for several shifts of running with a vertical beam polarization.

Change Log

Erroneous values for the intensity asymmetry (old HAPPEX values) were corrected.