

12 GeV Parity Beam Parameters Table

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This note provides a summary of standard beam parameters for beam delivery to parity violation (PV) experiments. Included is a summary table and a list of special considerations.

Nominal Beam Properties

| Beam Property | Nominal Value and Range | Helicity Correlated 8-hour Average | Maximum Jitter at 30 Hz |
|----------------------------|--|--|---|
| Current | 5 – 100 μ A, 900 kW total max | <5 ppm | 2000 ppm |
| Energy | 1.0 – 10.6 GeV (2018-2020) 1.0 – 11.0 GeV (2021+) | $\left(\frac{\Delta E}{E}\right) < 15\text{ppb}$ (50 nm@ 35 mm/%) | 35 μ m (x-position in center of hall ARC) |
| Energy Spread σ_E/E | $<10^{-3}$ | - | - |
| Position x at target | 0 | <25 nm | 15 μ m |
| Angle x' at target | 0 | <10 nrad | 5 μ rad |
| Position y at target | 0 | <25 nm | 15 μ m |
| Angle y' at target | 0 | <10 nrad | 5 μ rad |
| Spot Size at target | 100 – 500 μ m ($\sigma_{x,y}$ unrastered) 5 mm x 5 mm (rastered) | $\left(\frac{\delta\sigma}{\sigma}\right) < 10^{-3}$ | - |
| Polarization | $P_L > 85\%$ ($P_V, P_H < 1\%$) | - | - |
| Beam Halo | $<10^{-4}$ integrated (> 2 mm from edge of rastered beam) | - | - |

Notes

1. **Nominal Value and Range:** This is the desired central value of the beam property.
2. **Helicity Correlated 8-hour Average:** This refers to the maximum value of the helicity-correlated difference (or asymmetry) that can be achieved after averaging over 8-hour run. These 8-hour averages are specified with the assumption that the averages are statistically distributed, with an active charge feedback, and with no measurable offset. If the 8-hour averages are not distributed around a negligible systematic offset, corrective action will be necessary.
3. **Maximum Jitter at 30 Hz:** PV measurements are 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 than this 30 Hz nominal frequency, experiments should expect “root-N” scaling of the jitter quoted here.

4. **Spot Size at Target:** The helicity-correlated spot size variations can only be measured on the laser table by experimentalists. An upper bound can be established from an understanding of the source configuration and cancellations.

Special Considerations

1. **Helicity Reversal Frequency:** The helicity board is programmed to provide 1-2000 Hz helicity reversal with wide range of T_Settle and T_Stable selections. The electro-optical properties of the KD*P Pockels Cell limit higher frequencies.
2. **Polarization Orientation:** PV experiments are highly sensitive to components of transverse polarization and require maximum longitudinal polarization. Beam with both vertical and horizontal transverse polarization components below 1% can be delivered. This will require small tweaks to the injector launch angle during the course of the experiment based on measurements of transverse-polarization asymmetries in the experimental hall. In addition, the Mott polarimeter will be used to zero the vertical polarization component to within 1%.
3. **Priority in source configuration:** PV experiments have priority in the source configuration (centering on the Pockels Cell ...). In order to tune the source to minimize helicity correlated beam systematics, it will also be necessary to control setpoints for common devices such as the Insertable Halfwave Plate, Rotating Waveplate, and Pockels 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 allocated before the start of PV experiments.
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 simultaneously with another hall with large helicity-correlated asymmetries. PV experiments have access to existing feedback mechanisms to control the helicity-correlated charge asymmetry of the other three halls.
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 or even a varying intensity asymmetry across the beam with very large asymmetries in the halo part of it. 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, PV experiments should have clean electron transmission from source to target.
7. **Helicity Correlated Beam Halo:** Of concern is halo with helicity correlated asymmetries that are vastly different than those of the main beam. When interacting with beamline pipe and components, helicity correlated backgrounds are generated that are very hard to measure and

correct for. Clean electron transmission from source to target may minimize this problem. Since the root cause is unknown, it may not.

8. **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 the double-Wien spin rotator with a frequency between two days and one week is foreseen for the PV experiments.
9. **Beam tune and halo acceptable for Compton polarimeter:** it may be required to have reliable data from the Compton polarimeter continuously during PV experiments. 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 the counting rate in the Compton photon and electron detectors, with the Compton laser off. The accelerator will work with the experimentalists to have an operational Compton polarimeter. At least four hours will be required to match the beam optics exiting the arc to that at the center of the Compton chicane.
10. **Fast Feedback:** The fast feedback system for position and energy lock will be operational (if it is needed to remove 60/120/180 Hz components in position or energy).
11. **Beam Modulation:** Air core steering coils in the experimental hall beamline and the energy vernier in SL20 are used to modulate beam position, angle, and energy in order to measure sensitivity to those parameters. PV experiments shall have the option to “pause” fast position lock and energy lock during these modulation periods. 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.
12. **Match to Design Beam Optics:** The accelerator optics should be well matched to design during PV experiments. Beam size as defined by $\text{Sqrt}(\text{emittance} \cdot \text{beta})$ shall be within a factor of four of design throughout the machine and preferably less than three at fifth pass extraction.
13. **Tracking Run Beam Intensity:** 100 pA to 10 nA is available for special low current runs. This beam will meet the standard beam requirements but not the parity-quality requirements.