# SLAC's polarized electron source laser system for the E -158 parity violation experiment

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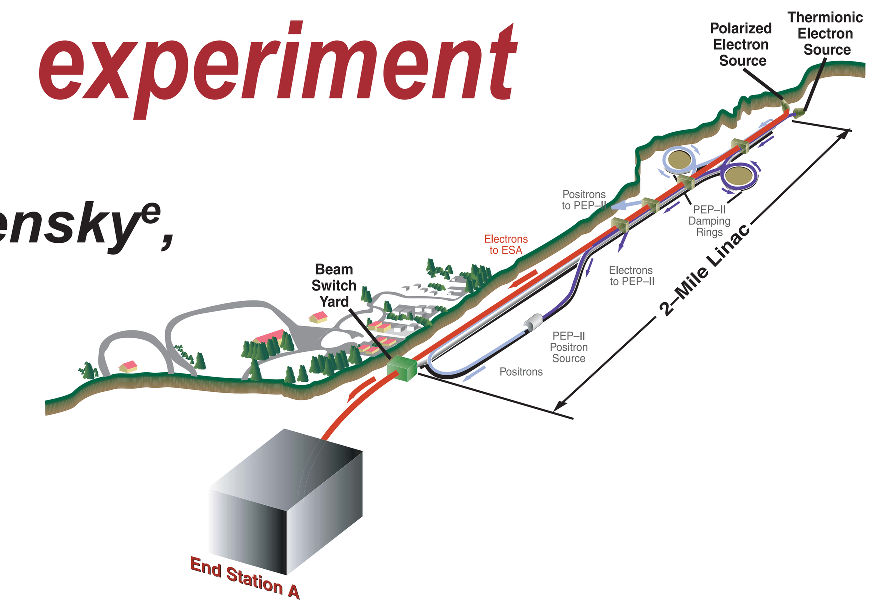
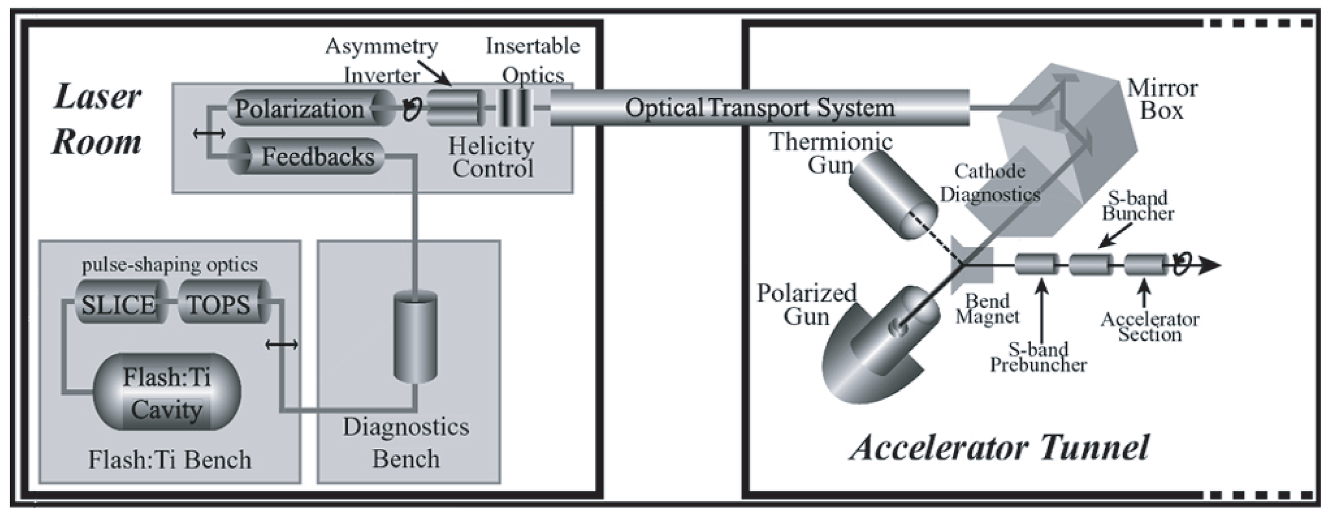


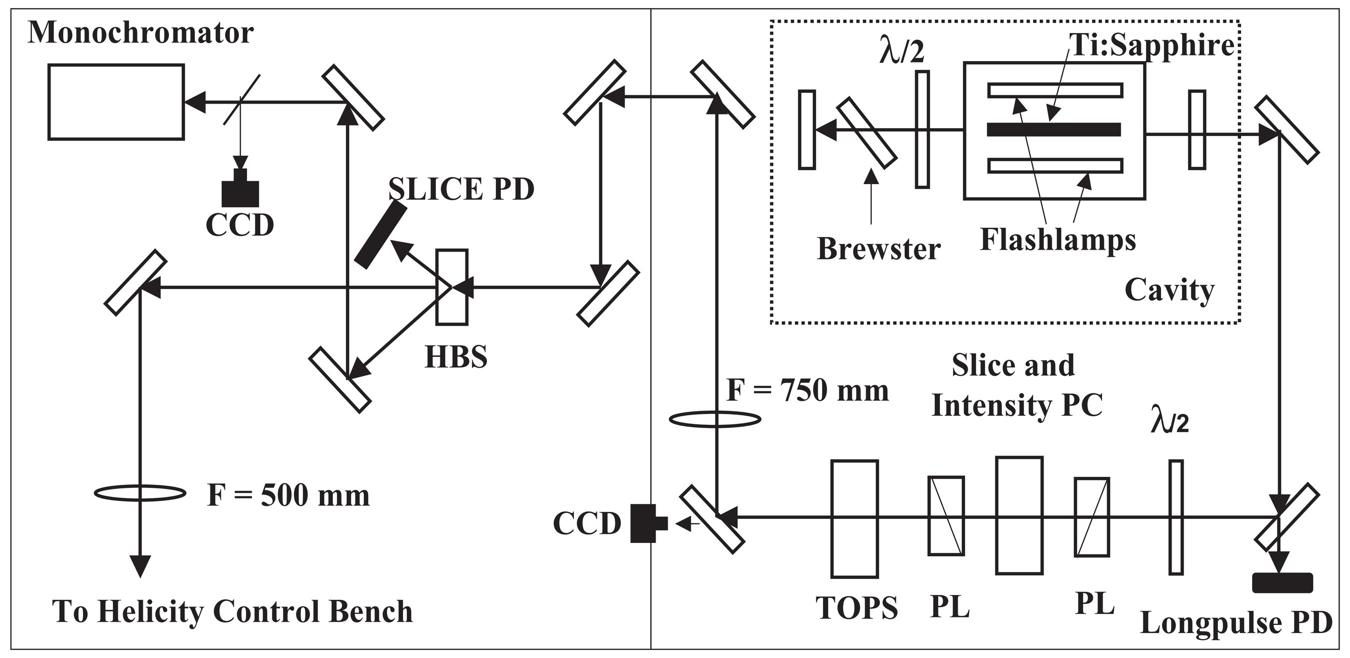

## ABSTRACT

Experiment E158 at SLAC will make the first measurement of parity violation in Møller scattering. The left-right cross-section asymmetry in the elastic scattering of a 45-GeV polarized electron beam with unpolarized electrons in a liquid hydrogen target will be measured to an accuracy of better than $10^{-8}$, with the expected Standard Model asymmetry being approximately $10^{-7}$. An intense circularly polarized laser beam for the photocathode electron source is required with the ability to quickly switch between left and right polarization states with minimal left-right asymmetries in the parameters of the electron beam. This laser beam is produced by a unique SLAC-designed, flashlamp-pumped, Ti:Sapphire laser. We present this laser system design and initial results from the recent commissioning run.

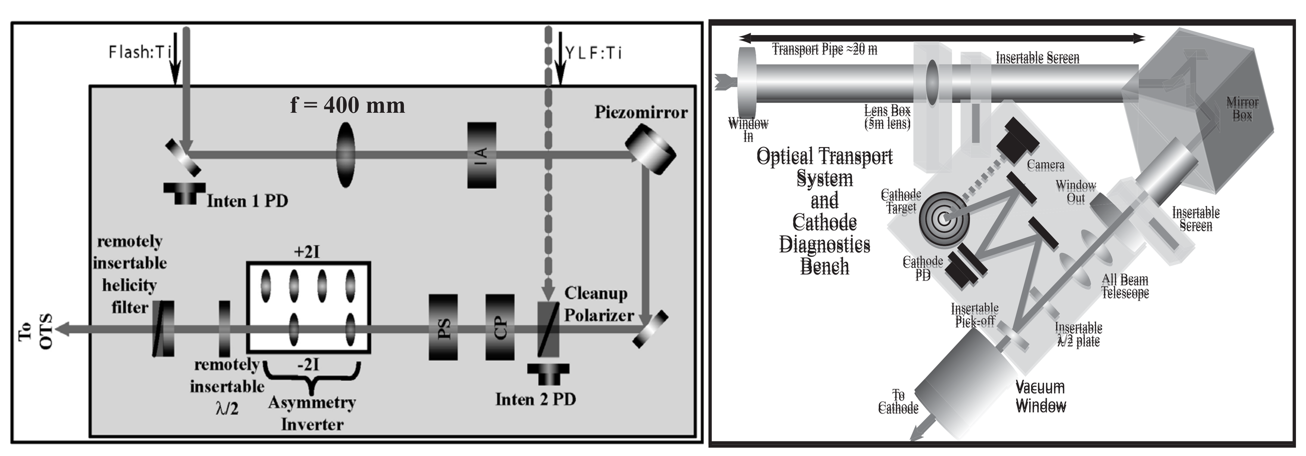
## General System Layout




## Flash:Ti and Diagnostics Bench




## Helicity Control Bench, Optical Transport System and Gun Bench



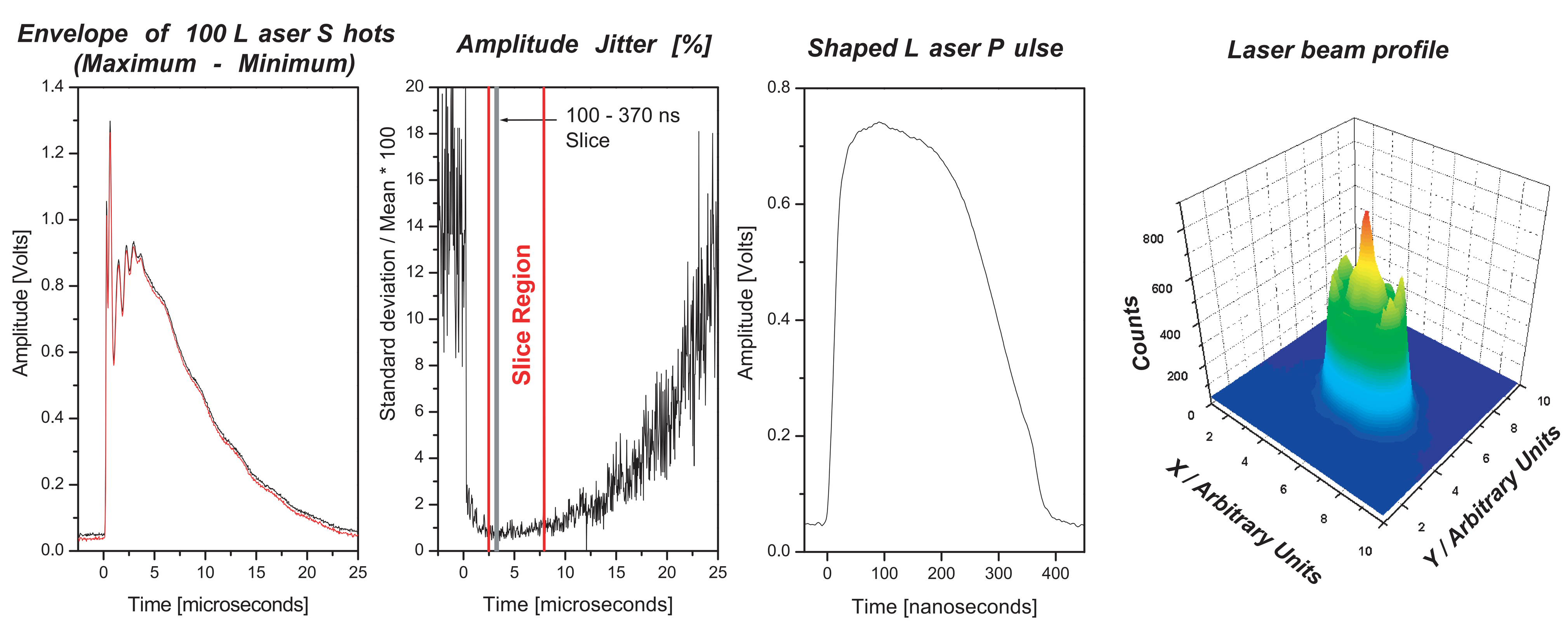

### Flashlamp pumped Ti:Sapphire laser cavity

| | |
|---|---|
| End mirror | 5 meter concave high reflector |
| Output coupler | 5 meter concave partial reflector (90%) |
| Cavity length | 1 meter |
| Lasing medium | Ti:Sapphire (0.1 % doping level); 6" x 4 mm |
| Wavelength selection | Quartz halfwave plate at Brewster angle |
| Rod orientation compensator | Halfwave plate |
| Pump scheme | flashlamp pumped in dual elliptical rhodium coated reflector |

### Flashlamp pumped Ti:Sapphire laser parameters for E-158

| | |
|---|---|
| Wavelength range | 805 nm (tunable +/- 50 nm) |
| Repetition rate | 120 Hz |
| Pulse length | 370 ns |
| Pulse energy | 600 µJ |
| Energy jitter | < 1 % rms |
| Position jitter at photocathode | 70 mm (for 1 cm $1/e^2$ diameter) |
| Circular polarization | 99.8 % |

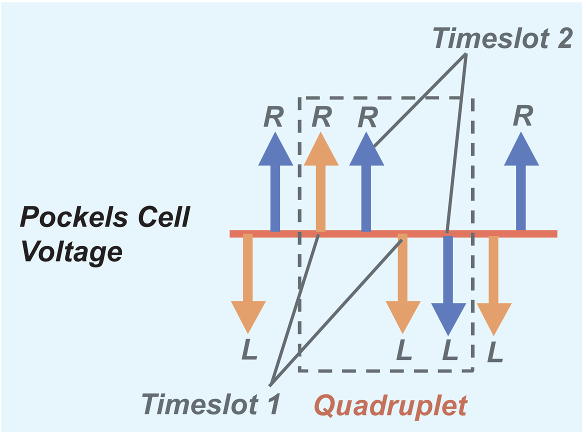
## Ti:Sapphire laser performance



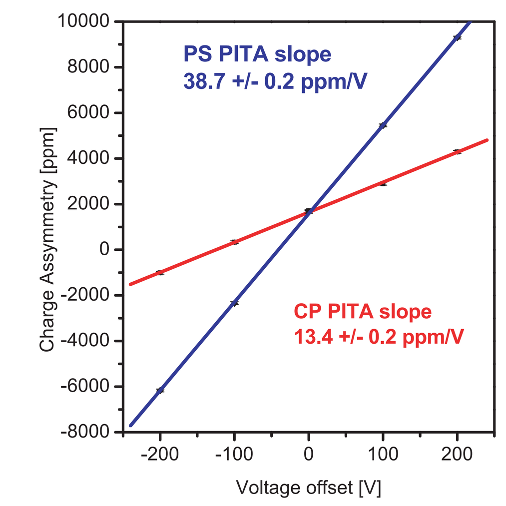

## Optical Pulse Shaping

A polarizer pair and a Pockels cell are used to 'slice' out a 370ns pulse from the ~ 20 µs long Flash:Ti laser pulse. Slicing occurs at the amplitude jitter minimum region. The 'Slice' pockels cell is also used for intensity control. A second Pockels cell ('TOPS') with fast electronics and polarizer allows for shaping of the pulse profile. A trapezoidal pulse shape is needed to achieve a flat energy profile in the electron beam due to beam loading effects.

## Helicity Control




A pair of Pockels cells (CP and PS with 45° relative orientation of their fast axes) can generate arbitrary elliptical polarization and are used to generate circularly polarized light of either helicity at the photocathode. The "Asymmetry Inverter" inverts the spatial profile and angle of the laser beam leaving the polarization optics, providing a means of cancelling helicity-correlated systematics introduced by the CP and PS cells. The insertable half-wave plate reverses the sign of the laser beam's helicity, providing another means of systematics cancellation. The "Intensity Asymmetry" (IA) Pockels cell can be pulsed differently for left and right helicity pulses. It is used for a feedback on the helicity-correlated intensity asymmetry. The "Piezomirror" is mounted on 3 piezoelectric stacks such that its angle can be adjusted differently for left and right helicity pulses. This mirror is used for the helicity-correlated position feedback. The helicity sequence is chosen with a pseudo-random sequence. Two consecutive pulses are chosen randomly and then the following two pulses are chosen to be their complements. This eliminates any jitter due to slow drifts or to beam differences for the two 60Hz timeslots when running at 120Hz.




E158 uses a strained-lattice GaAs photo - cathode. The quantum efficiency depends on the orientation of linear polarization of the incident light. Significant charge asymmetries result from the cathode's analyzing power coupled with small asymmetries in linear polarization for the 'left' and 'right' laser beams. The linear polarization can be adjusted by small changes to the CP or PS offset voltages. Optimizing these voltages for best laser circular polarization typically yields 1000ppm charge asymmetries. The CP and PS voltages are tuned to reduce this asymmetry to less than 100ppm. The Intensity Asymmetry feedback with the IA cell is then used to further reduce the asymmetry to << than 1ppm.

## Goals and Achievements for Helicity Control

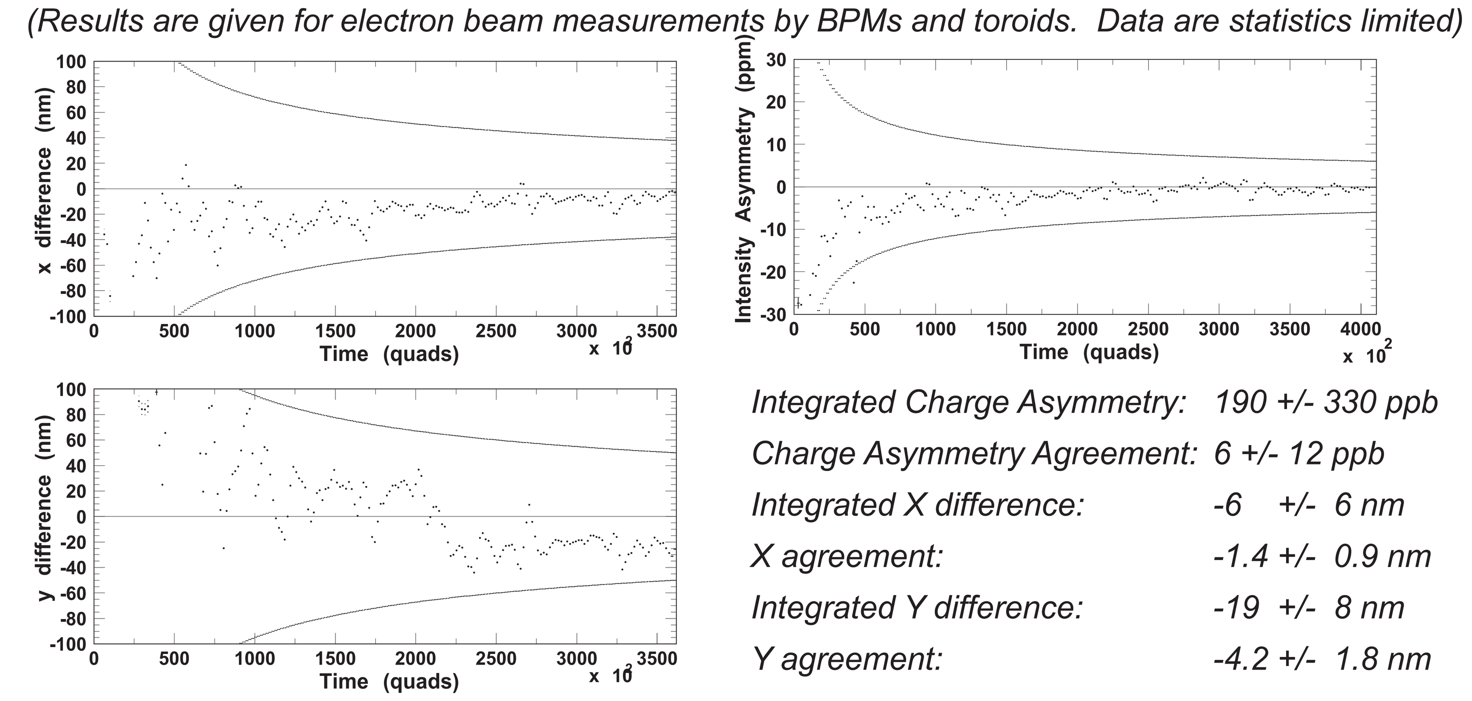
Nonzero helicity-correlated beam parameters can contribute a false asymmetry to the Møller scattering measurement. Data are divided into N feedback "miniruns." Feedback provides better-than-statistical scaling. Results are currently limited by statistics acquired. "Intensity asymmetry agreement" and "position difference agreement" refer to agreement in measurement by neighboring diagnostic devices. Error bars for the intensity asymmetry and position difference results are shown separately for 1/N and $1/\sqrt{N}$ scaling.

| | Achieved in T-437 | | E-158 Goal |
|---|---|---|---|
| Intensity Asymmetry | 0.2 +/- 5.7 ppm | $(1/\sqrt{N})$ | 200 ppb |
| | 190 +/- 330 ppb | (1/N) | |
| Intensity Asymmetry Agreement | 6 +/- 12 ppb | | 1 ppb |
| Position Difference | x: -6 +/- 37 nm | $(1/\sqrt{N})$ | 10 nm |
| | y: -19 +/- 49 nm | | |
| | x: -6 +/- 5 nm | (1/N) | |
| | y: -19 +/- 6 nm | | |
| Position Difference Agreement | x: -1.4 +/- 0.9 nm | | 1 nm |
| | y: -4.2 +/- 1.8 nm | | |

## Performance of Helicity Feedbacks

Integrated helicity-correlated intensity asymmetry and position difference feed-back results for ~8hrs of data. Smooth curves represent expected error bars for $1/\sqrt{N}$ scaling. Feedbacks compensate for statistical noise, causing integrated asymmetry to converge to zero faster than with statistical scaling alone.

(Results are given for electron beam measurements by BPMs and toroids. Data are statistics limited)




| | |
|---|---|
| Integrated Charge Asymmetry: | 190 +/- 330 ppb |
| Charge Asymmetry Agreement: | 6 +/- 12 ppb |
| Integrated X difference: | -6 +/- 6 nm |
| X agreement: | -1.4 +/- 0.9 nm |
| Integrated Y difference: | -19 +/- 8 nm |
| Y agreement: | -4.2 +/- 1.8 nm |