Abstract Submitted
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Sorting Category: 5.1.1.2 (Experimental)

Calibration of a Three Path Thomson System at DIII-D[1] B.D. BRAY, C.L. HSIEH, T.N. CARLSTROM, General Atomics — The DIII–D Thomson system measures electron density and temperature with eight pulsed ND:YAG lasers along three paths through the plasma. Two vertical paths provide measurements in the lower divertor and core of the plasma and a third horizontal laser path was installed in 1999 to extend the measurements to the center of the plasma. The components of the new system must be carefully calibrated so the measurements can be combined into a single profile. A monochromator calibration and opto-electronic calibration measure the absolute sensitivity of the detector system dc and pulsed response, respectively. A Rayleigh scattering calibration and transmission calibrations measure the sensitivity of the system to scattered light. The calibrations are checked by a comparison of overlapping channels in the core system and between the core and horizontal systems. The contributions of the background and scattered light to the systematic and statistical uncertainties of the measurement must be understood to make these channel to channel comparisons.

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☐ Prefer Oral Session
☒ Prefer Poster Session

B.D. Bray
bray@gav.gat.com
General Atomics

Special instructions: DIII-D Poster Session 2, immediately following DM Thomas

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Introduction

The Thomson system measures electron temperature (Te) and density (ne) profiles at DIII-D

44 viewing locations on three laser paths measure profiles in the core and divertor regions of the plasma

A horizontal path was added in 1999 to extend the core measurements toward the center of the plasma.

Extensive effort is necessary to produce the small (10%) normalization variation in the core ne measurement

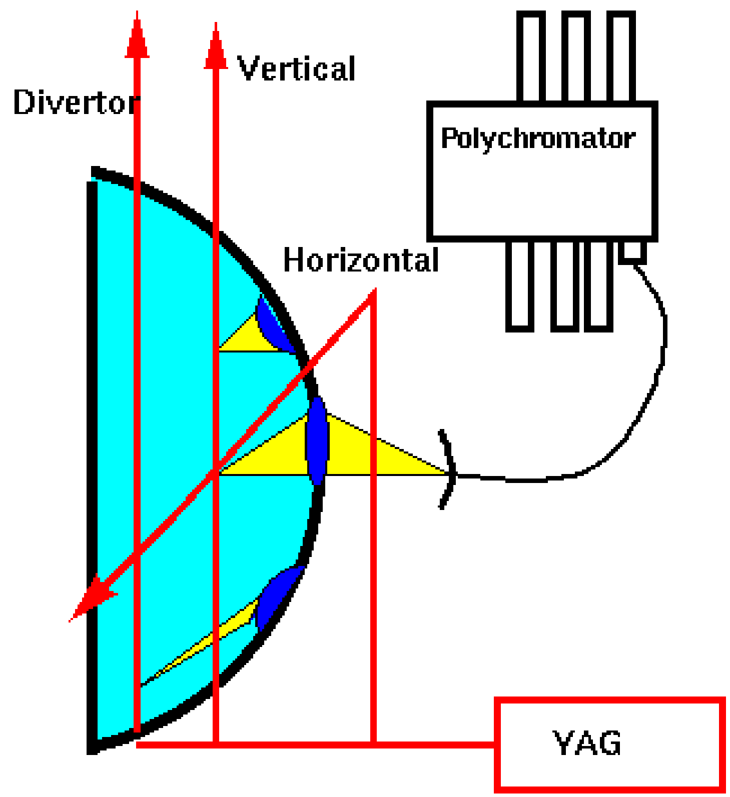
Currently, the calibration and alignment systems are being upgraded to further limit the effect of systematic errors on the profiles with reduced effort

Thomson Scattering Measured with 8 Pulsed YAG Lasers

4 Vertical, 3 horizontal and 1 Divertor lasers fire at 20 Hz.

The vertical and horizontal lasers are spaced 150 μs apart

Light from the vessel is focussed on an array of viewing fibers. Background and signal levels for each viewing location are measured with a 6 wavelength channel polychromator



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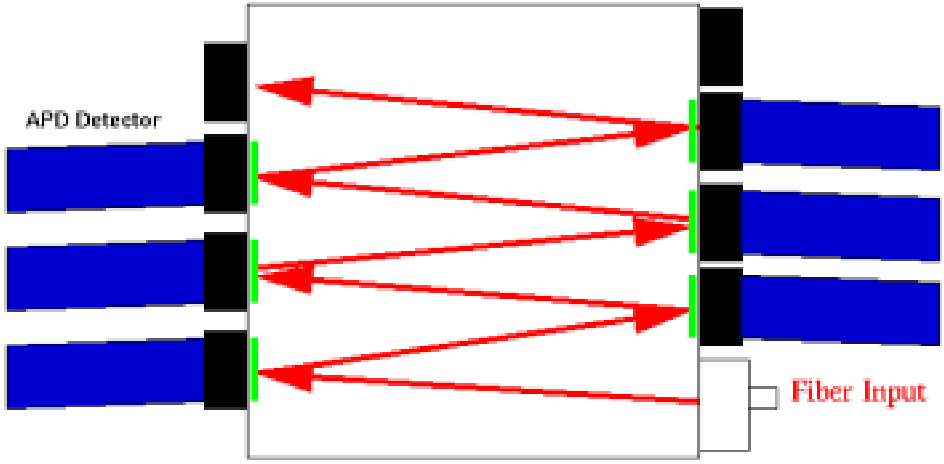
Polychromators have a Large Temperature and Density Range

Each polychromator contains 6 band pass filters and APDs



A filter at 1064nm is used to calibrate the detector with Rayleigh scattered light, the other channels measure the Thomson scattered light from the plasma

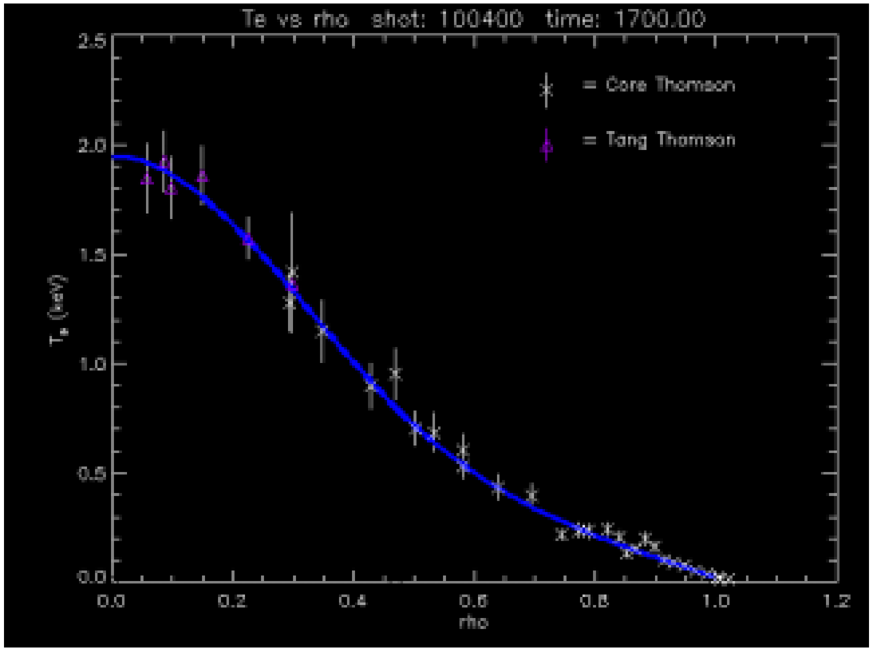
Short wavelength filters are sensitive to high Te and long wavelength to low Te

Thomson Viewing Locations

The three laser paths measure n_e and T_e in the divertor, and core regions.

The data is combined to give profiles throughout the plasma.

Because different lasers are used to measure the points along the different paths, the systematic errors between lasers as well as point to point become significant in the fits.

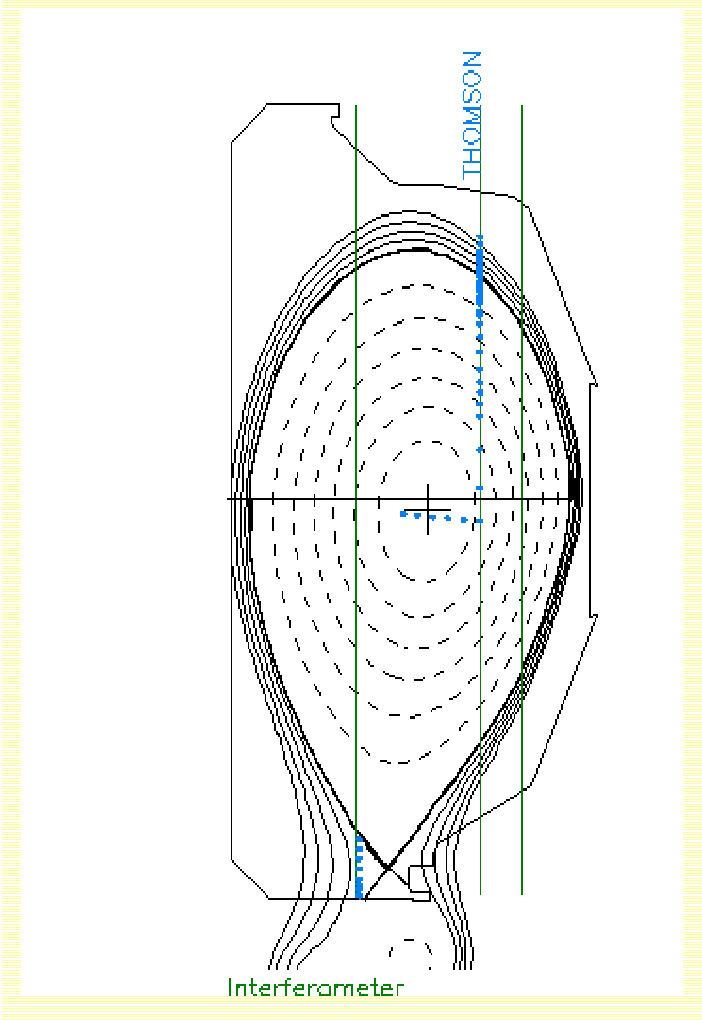


Thomson Density Is Cross Calibrated with CO_2 Interferometer

CO_2 interferometer line integrals are compared with the core Thomson data. Typically the difference in the normalization factor is less than 10%

The new horizontal points near the center of the plasma are not as well constrained by the CO_2 line integrals as the vertical core measurements

Divertor profiles cannot be normalized to other diagnostics so the stability of the calibration cannot be crosschecked



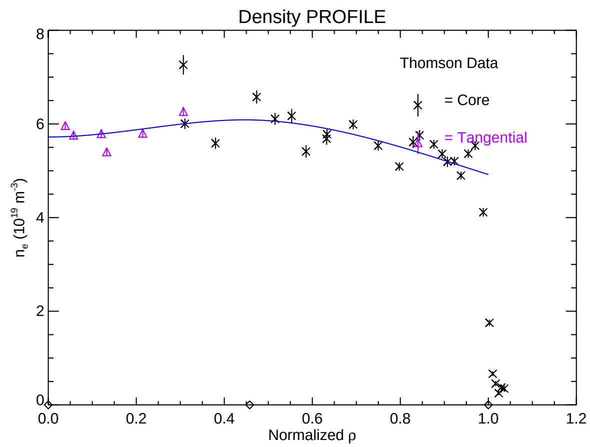
Model Dependence of Thomson Density Profiles

Density profiles are normalized to the CO_2 interferometer.

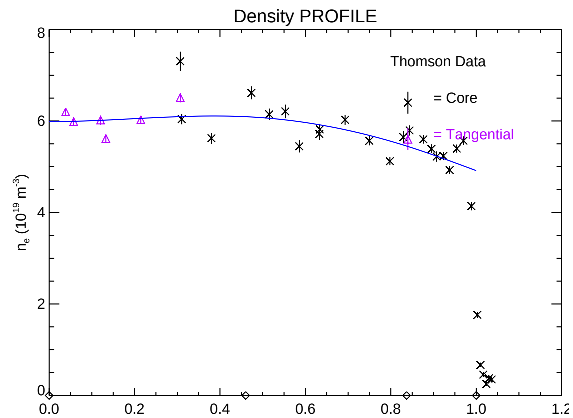
Changes in the model can change the relative CO_2 normalization and shift the central density of the Thomson profiles 10% due to the model dependence

Better calibrations and alignment can reduce point to point and laser to laser variations, which influence these fits

Model 1



Model 2



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Detailed Calibrations Required for Good Measurements

The Thomson system's careful calibration results in good consistency with the CO_2 measurements.

Every aspect from the laser energy entering the vessel, through the window and fiber attenuation, to the relative gain of the digitizer channels is calibrated. The alignment of the lasers is carefully monitored in relation to the viewing locations of each channel to assure the quality of the data.

The density measurements are especially sensitive to any calibration uncertainties since the density is proportional to the total observed signal. The temperature is determined by the relative distribution of the signal in the polychromator

Three Primary Calibrations Needed

The **Opto-electronic** calibration measures the ratio of the pulsed response to a laser pulse and the DC response of the detectors.

The DC **Spectral** Calibration measures the spectral response of the polychromator channels and is combined with the opto-electronic calibration to give the pulsed spectral response.

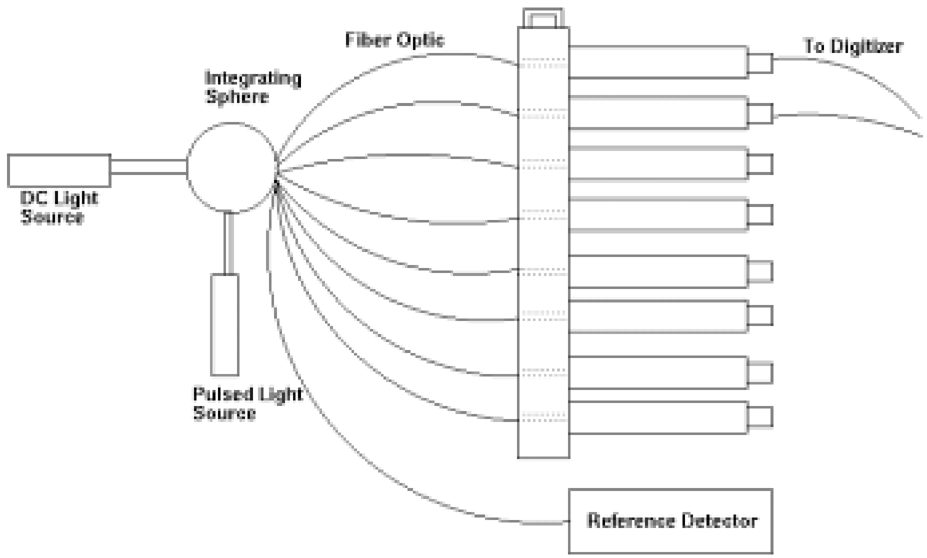
The Temperature is determined by the ratio of signals on the polychromator channel with these calibrations

The **Rayleigh** Calibration measures the acceptance and response of the YAG detector with Rayleigh scattered light from Ar gas.

The density is determined by scaling the Thomson cross section to the Rayleigh cross section, the observed Rayleigh sensitivity, and the polychromator spectral calibration

Opto-electronic Calibration

Two 1060 nm LEDs are used to measure the ratio of pulsed gain for a pulse which mimics the laser pulse shape and DC gain



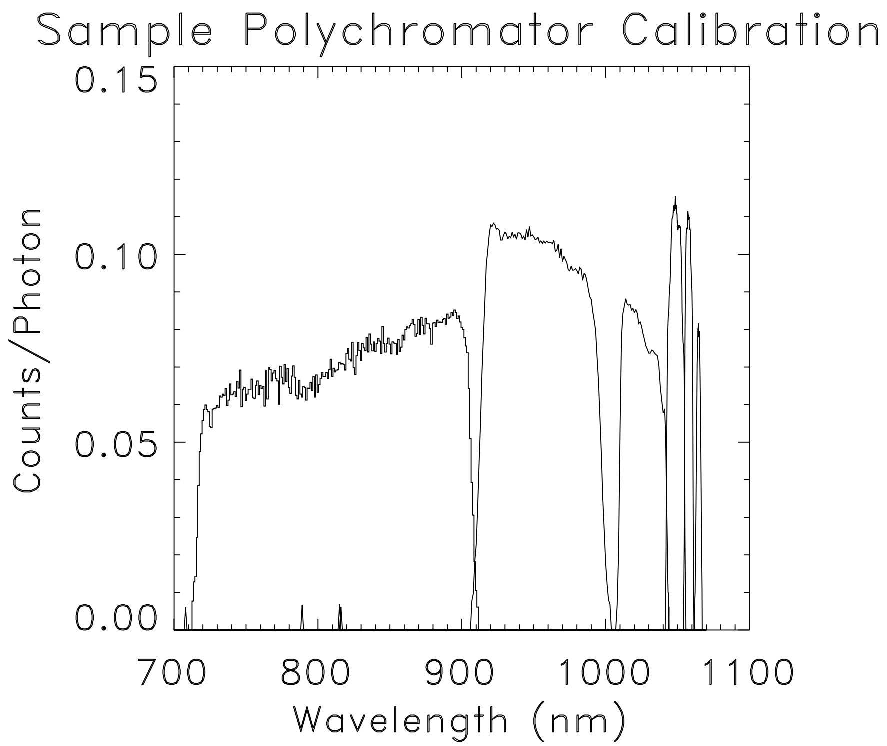
All detectors for a single polychromator are measured simultaneously to control systematic effects from the measurement of the absolute light level

An additional correction is added for the relative gate characteristics of the digitizer channels

Monochromator Used for Spectral Calibration

Absolute DC response vs wavelength is combined with the pulsed to DC ratio to give the pulsed response of each detector.

Systematic errors due to the wavelength calibration of the monochromator at the YAG line must be carefully controlled to accurately measure the narrow Rayleigh filter.



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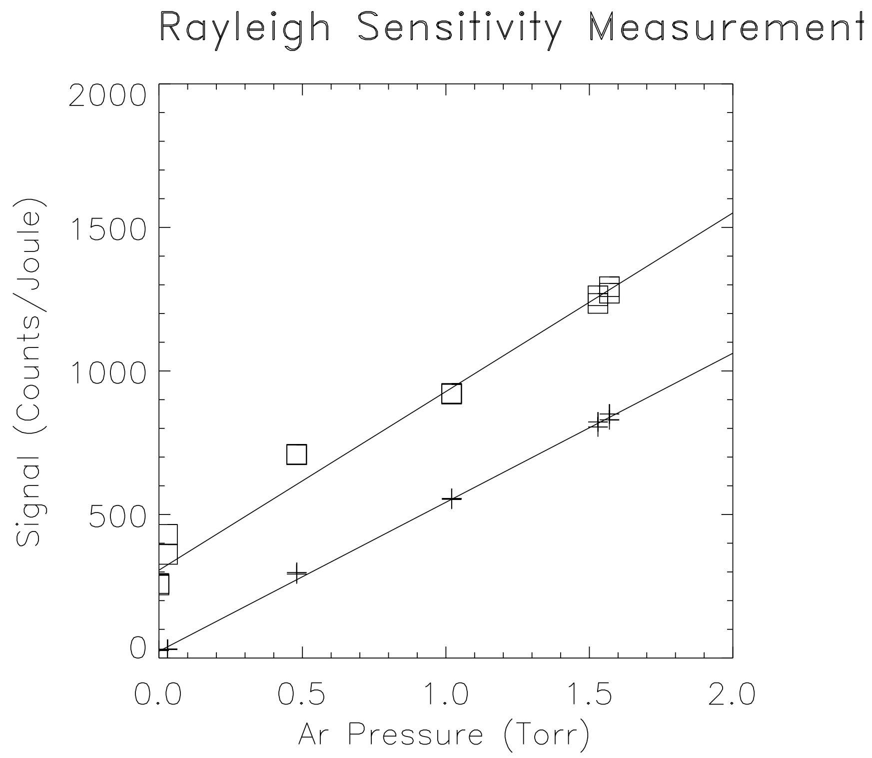
Rayleigh Scattering Used For Density Calibration

Rayleigh scattering from Ar gas measures the sensitivity of the polychromator to scattered YAG light. Measurements between operation periods monitor any degradation in the collection optics.

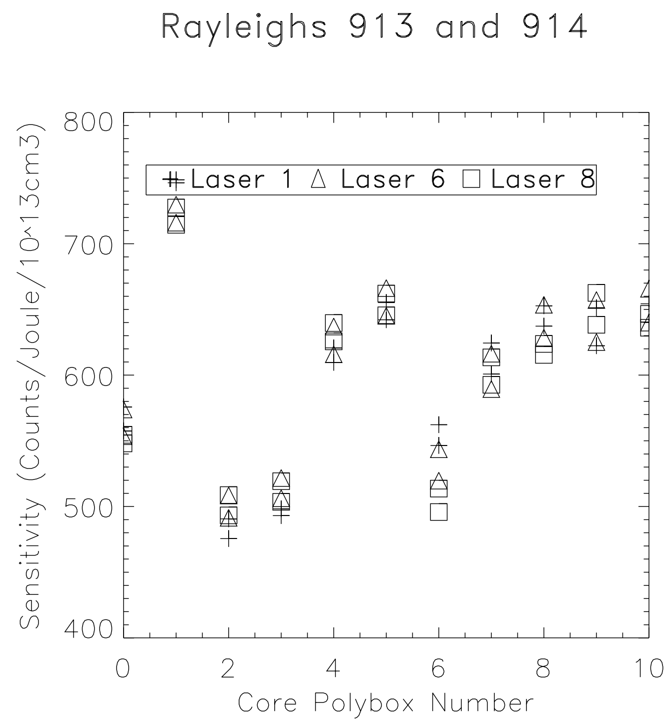
The stray light (light reflected from the laser exit tube rather than the gas) must be carefully controlled during the Rayleigh measurement



Careful Alignment Is Needed for Consistent Rayleigh Measurements

Approximately 5% systematic error in the core density due to low stray light and reproducible alignment

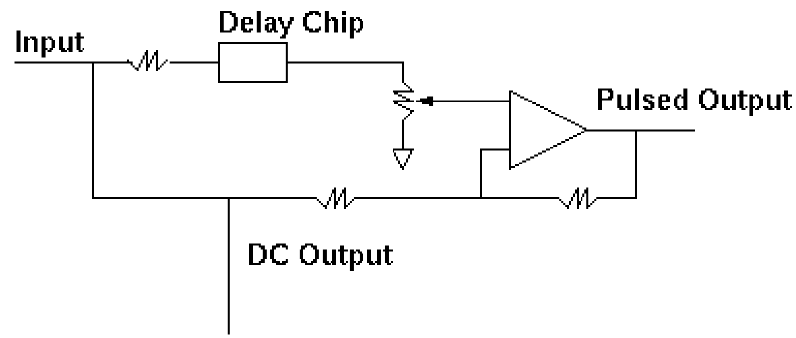
Tangential and Divertor channels have larger errors due to high stray light levels.

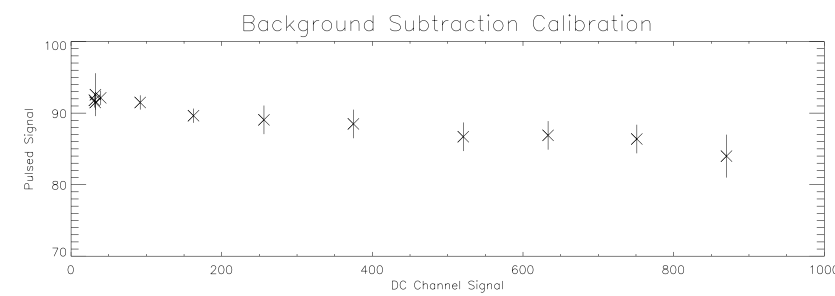


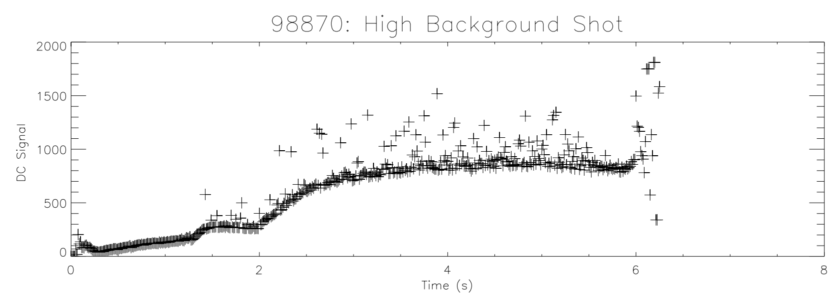
Background Light Corrections Needed For Some Shots

A differential amplifier subtracts most of the background light from the pulsed channel but an additional calibration is needed to correct the pulsed signal at high background levels.

Corrections can be up to 3% of the total signal level for high background data







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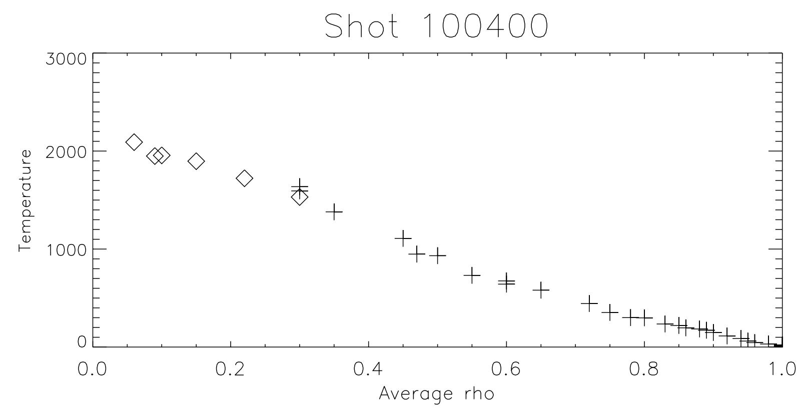
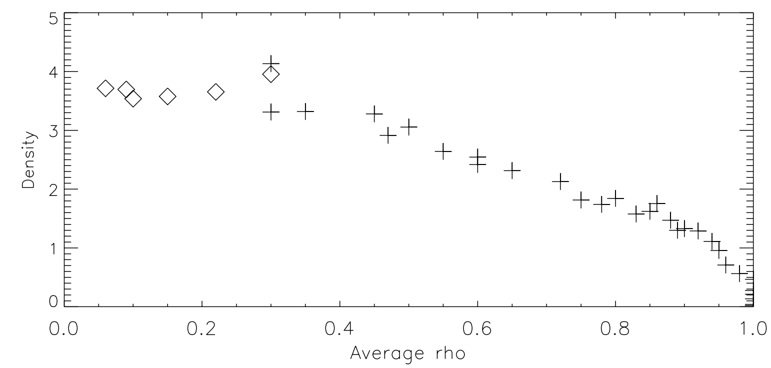
Calibration Corrections Improve Thomson Profiles

Corrections for the digitizer gain and background correction produce more self-consistent density and temperature profiles for the core system.





Alignment Modifications Will Improve Future Measurements

Alignment Feedback

A new beam monitor and feedback system is being installed for 2000 operations. The ND:YAG lasers will be automatically aligned shortly before the shot by making them co-linear with the HeNe guidance laser beams.

Alignment Targets

Internal alignment targets are currently used to align core and horizontal system. An additional alignment target will be added for the divertor system to improve alignment.

Additional Modifications Will Improve Measurements

Divertor Exit Baffles

Redesign and extend the divertor baffles to lower stray light levels. The divertor Rayleigh measurement is currently problematic due to extremely high stray light levels.

In-situ Opto-electronic gain monitors

Reduce problems with the digitizers and monitor gain during operations

Gain resistors

Changing the gain resistor in the APD electronics will lower the background gain relative to the pulsed gain and improve the dynamic range of the system and lower sensitivity to changes in the background light level

Summary

Current Thomson measurements ~10% density point to point systematic error + 10% path normalization for the core. Our goal is to reduce this to a 5% point to point and 5% path normalization and achieve similar confidence in the divertor density measurements.

Improved calibrations have produced a better understanding of the dominant systematic effects in the Thomson system and suggested several improvements.

Hardware installation is being completed for the feedback system and divertor baffles. This should produce further improvements in the systematic uncertainties in the density measurement by improving the alignment and reducing the stray light.