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Measurements of the counting statistics of Image Plate TR for quantitative x-ray spectroscopy of high temperature plasmas

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Abstract

- X-ray films such as Kodak RAR-2492 and DEF are no longer being produced. Fuji TR Image Plate has been proposed as a suitable replacement detector medium for x-ray spectroscopy research and is in frequent use at NIF, Omega, and Z. For the purposes of quantitative spectroscopic measurements, knowledge of the detector system counting statistics is required to allow quantitative comparisons between theoretical x-ray spectra and experimental data. This article will discuss the experimental procedure and analysis of data for Fuji Image Plate TR as a detector medium. The resulting statistical fluctuations in photostimulated luminescence will be presented for a range of incident photon energies.

Outline

- Introduction
- Experiment
- Data Analysis
- Results
- Discussion

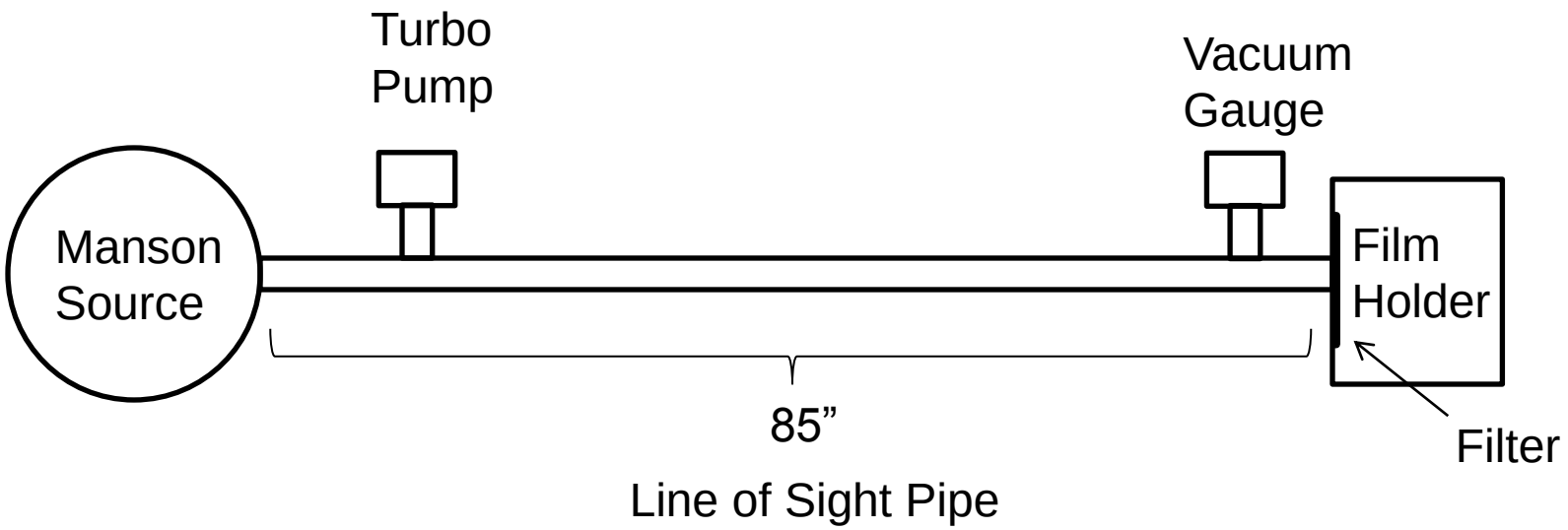
Introduction

- X-ray films are becoming extinct.
- Fuji TR Image Plate has been proposed as a suitable replacement detection medium for x-ray spectroscopy.
- Knowledge of detector system counting statistics is required to make quantitative comparisons between theory and experiment.

Experiment

- Using a Manson source detectors were exposed to known x-ray wavelengths – Al K-α (1.486 keV) & Mn K-α (5.898 keV)
- Image Plate and RAR 2492 were exposed together with a piece of IP set in front of the film covering about half of the 2492.
- Exposure times varied: 2.5, 5, 10, 20, 40, 160, and 180 minutes were used. IP PSL values were 0.7 to 23.6 PSL. Film intensity values were 2.18 to 43.53 $\gamma/\mu m^2$.
- Straight line of sight distance to film cassette was 85 inches.
- Filtering: 4 mils of Kapton at source + 12 μm Al at cassette
- 2492 was processed using Wyng-Lynch film processor and scanned on a Perkin-Elmer microdensitometer with a 22 μm scan box size.
- IP was scanned using a Fuji BAS5000 scanner.

Experimental Setup



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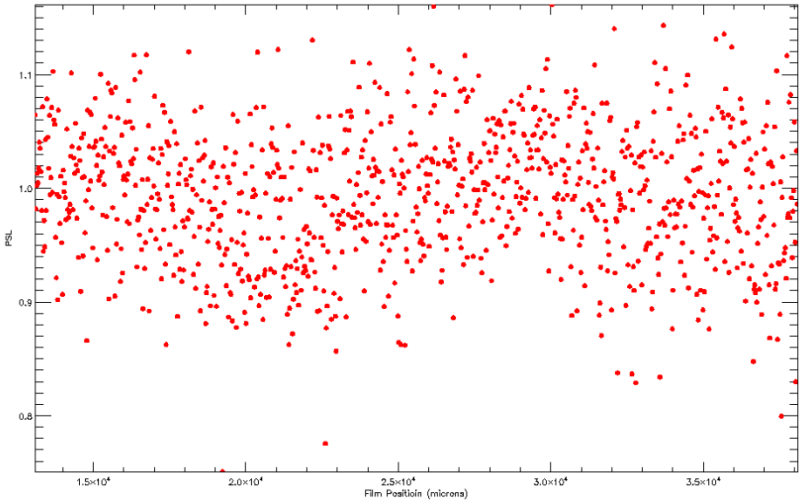
Data Analysis

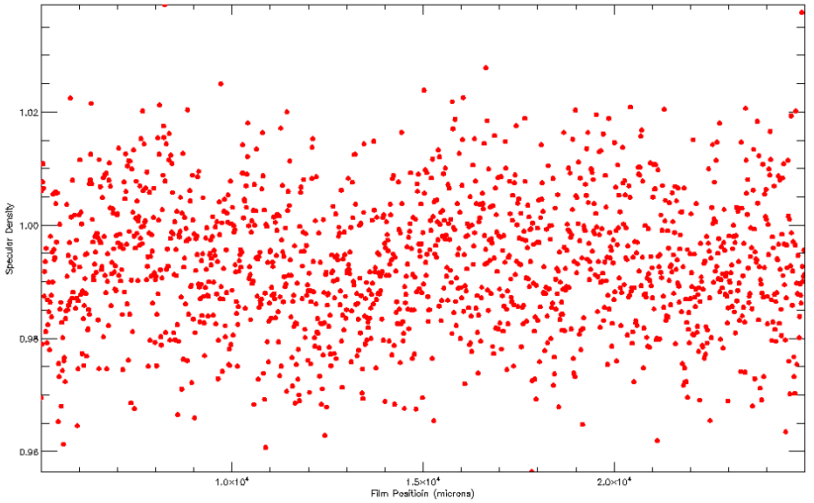
- Compare response of IP to film by verifying the data follows a Gaussian/Poisson distribution
  - Compute rescale factor[1,2] to convert intensity/PSL units into counts – RSF = $\langle E \rangle / \sigma_E^2$
- Compute scaling of Signal-to-Noise vs. Exposure
  - Plot $\log(\langle E \rangle / \sigma_E)$ vs. $\log(\langle E \rangle)$ and fit with Power law
  - Coefficient of fit should be ½ if data obey Poisson statistics
- Determine calibration for IP using 2492 as the standard
  - Plot PSL vs. γ/cm^2

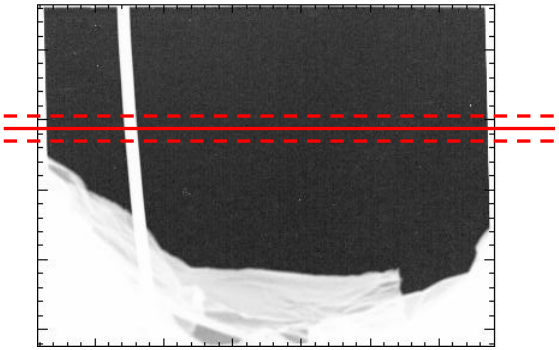
Sample Data

Image Plate – 1000 μm lineout

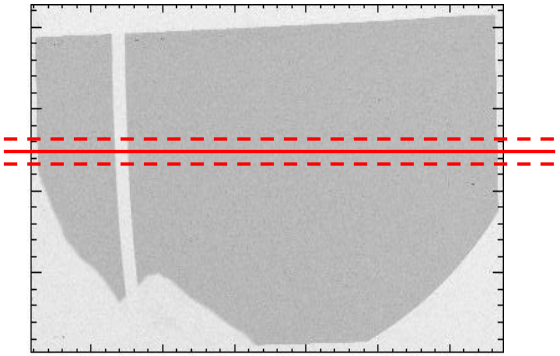


2492 – 1000 μm lineout





Lineout Location



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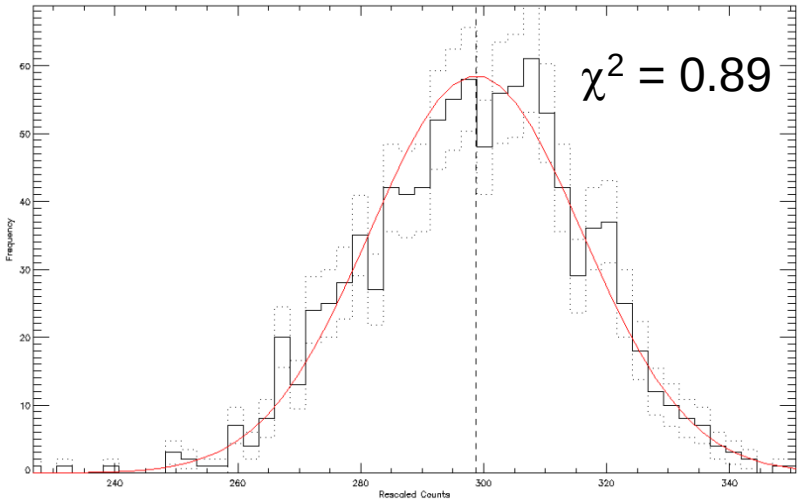
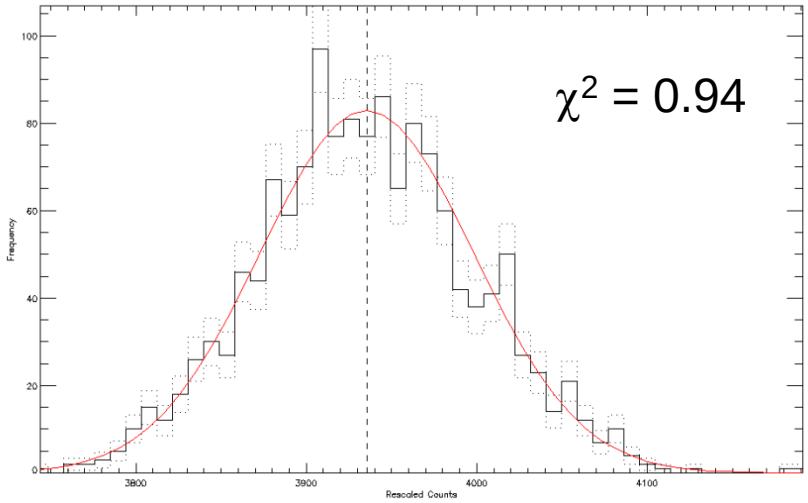
Gaussian Fit to Histogram using 50 bins 1000 μm lineout, Manganese Anode

IP Data – 40 min. Exposure



2492 Data – 40 min. Exposure



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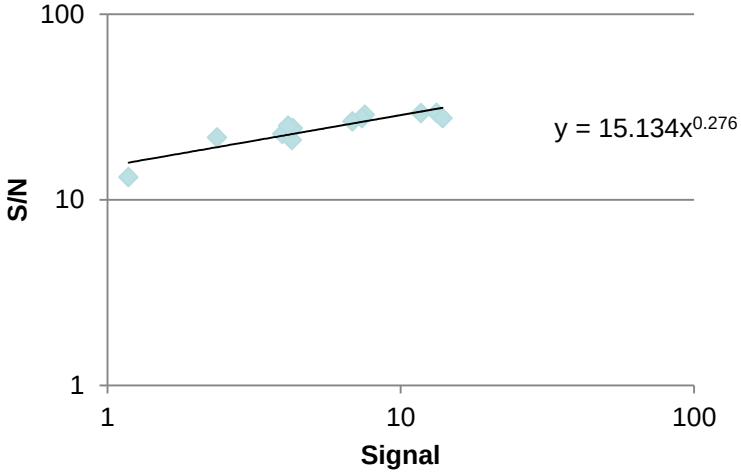
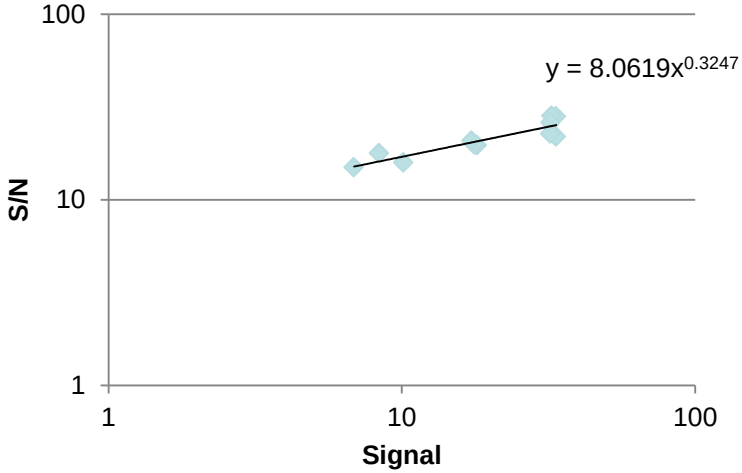
Does 2492 Data Obey Poisson Statistics?

100 μm lineout from Al K-α line
Energy = 1.486 keV



100 μm lineout from Mn K-α line
Energy = 5.898 keV



Not for this setup. In this case the film was set in the detector behind the IP. We hypothesize that the fluorescent decay of the IP caused additional exposure to the 2492 film, decreasing the slope from the expected $x^{0.5}$ behavior.

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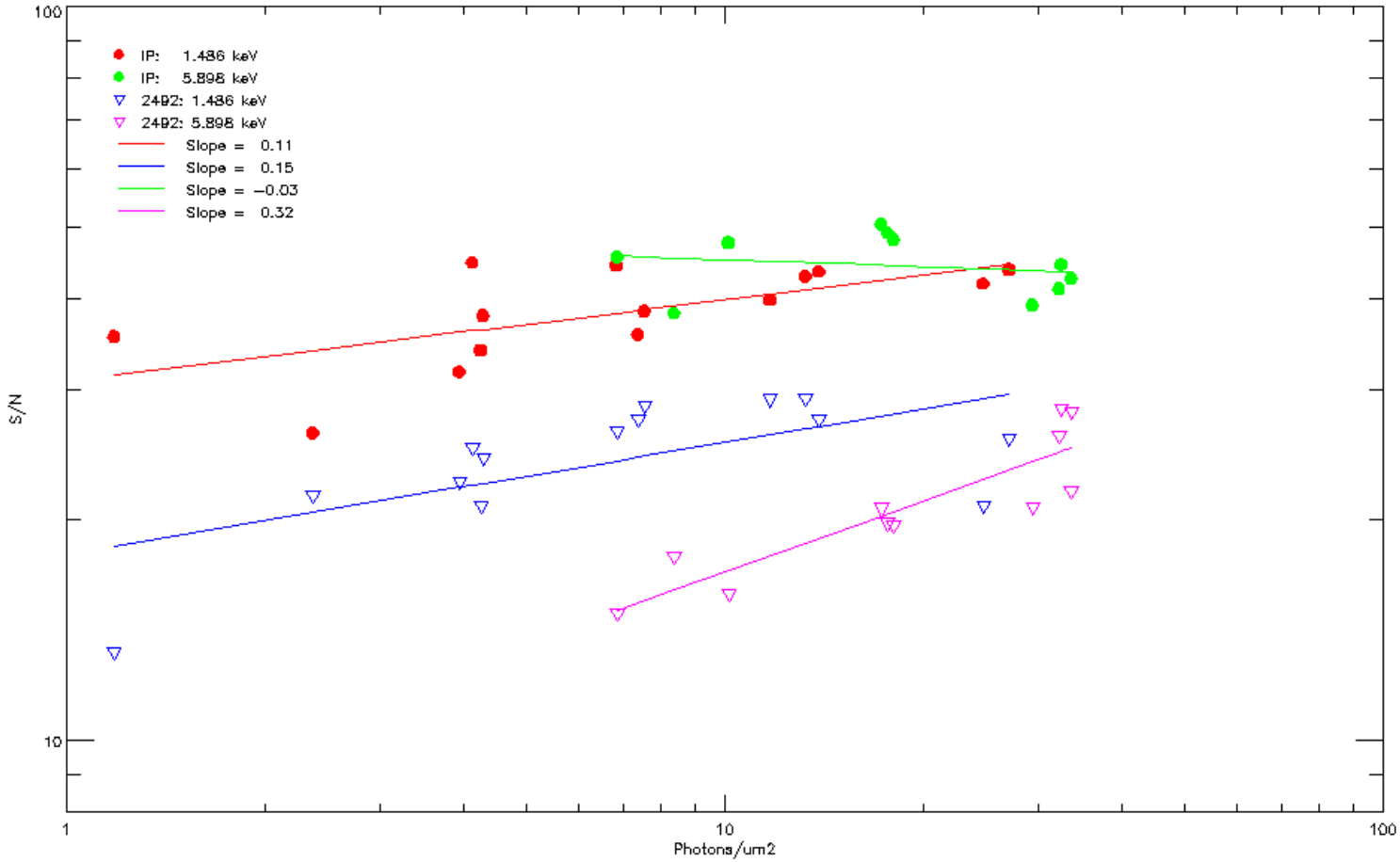
Signal-to-Noise for IP & 2492



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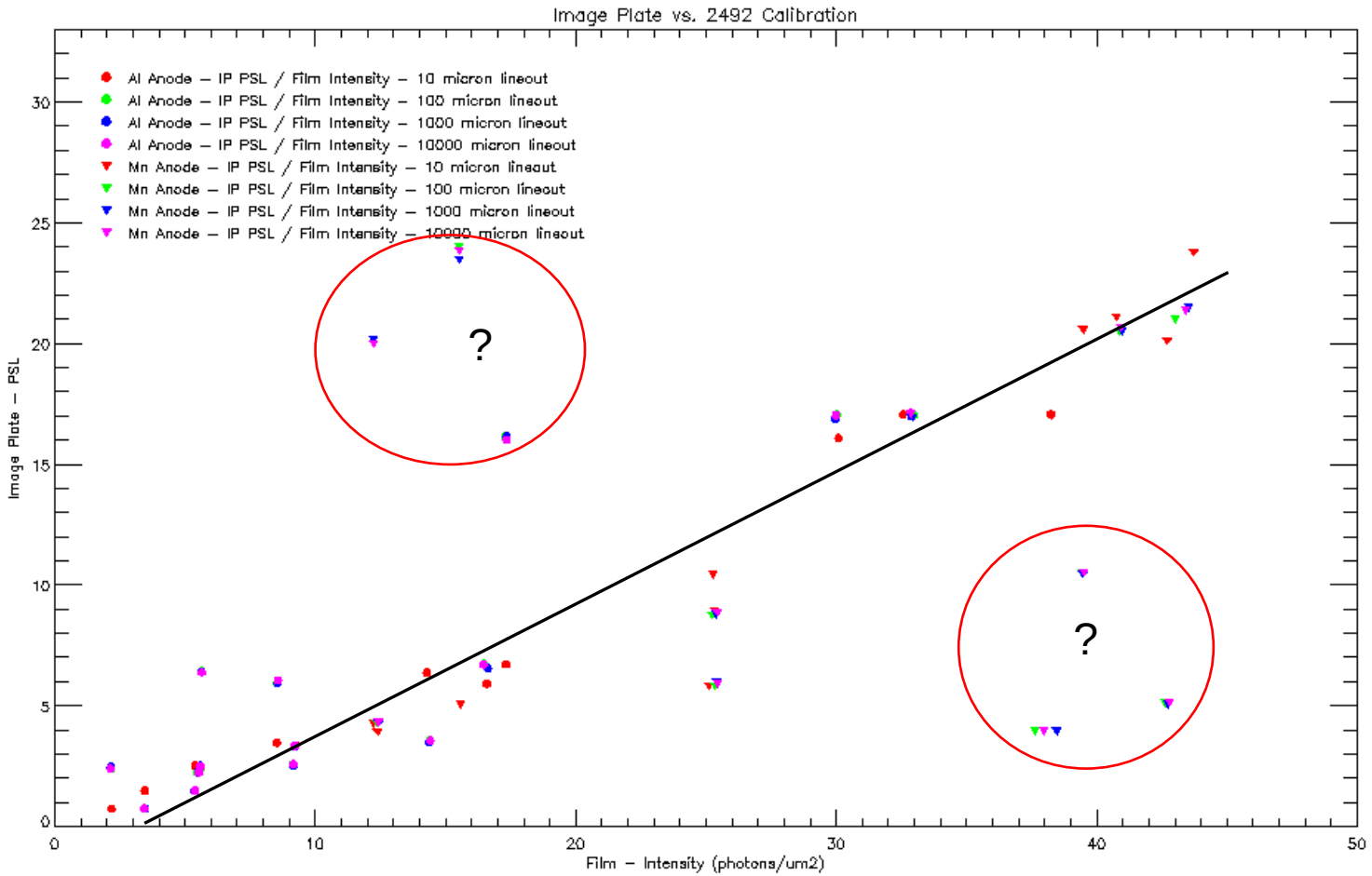
PSL vs. Intensity Calibration



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Discussion

- The S/N of measurements using IP does not increase with increasing PSL in a way that is consistent with Poisson statistics.
- The S/N of measurements using IP is better than 2492 film for the two incident photon energies where measurements were taken.
- All remaining stock of 2492 has been expired for several years. The increased fog level is of concern but there could be other unknown issues with expired film.
- MicroD scanners do show fluctuations in background levels from scan to scan, or even over a single scan. Careful attention needs to be paid to fog levels and fog subtraction.
- No appreciable gain in signal-to-noise is seen with higher exposure levels for Image Plate TR. Low level exposures may be beneficial.
- Image plate decays continuously once it has been exposed, with the most rapid decay occurring during the first 20 minutes after exposure stops. To determine a calibration for IP using 2492 as a standard this decay must be accounted for. In our experiment the fluorescent decay from the IP also exposed the 2492. Future experiments will be done using two identical line of sights to the source with IP in one and 2492 in the other.

References

1. G Dunham *et al*., Quantitative extraction of spectral line intensities and widths from x-ray spectra recorded with gated microchannel plate detectors *Review of Scientific Instruments* **78** 063106 (2007)
2. G Dunham *et al.,* Measurements of the counting statistics on RAR-2497 and DEF x-ray film *Review of Scientific Instruments* **75** 3687(2004)
3. I. J. Paterson *et al*., Image plate response for conditions relevant to laser-plasma interaction experiments *Measurement Science and Technology* **19** 095301 (2008)

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