

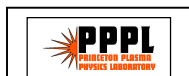


Ion and Electron Temperature Measurements with X-ray Spectroscopy

M. Bitter, K. W. Hill, L. Roquemore
Princeton Plasma Physics Laboratory

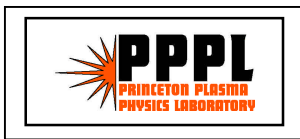
P. Beiersdorfer
Lawrence Livermore National Laboratory

NSTX Results Review, September 19-20, 2001



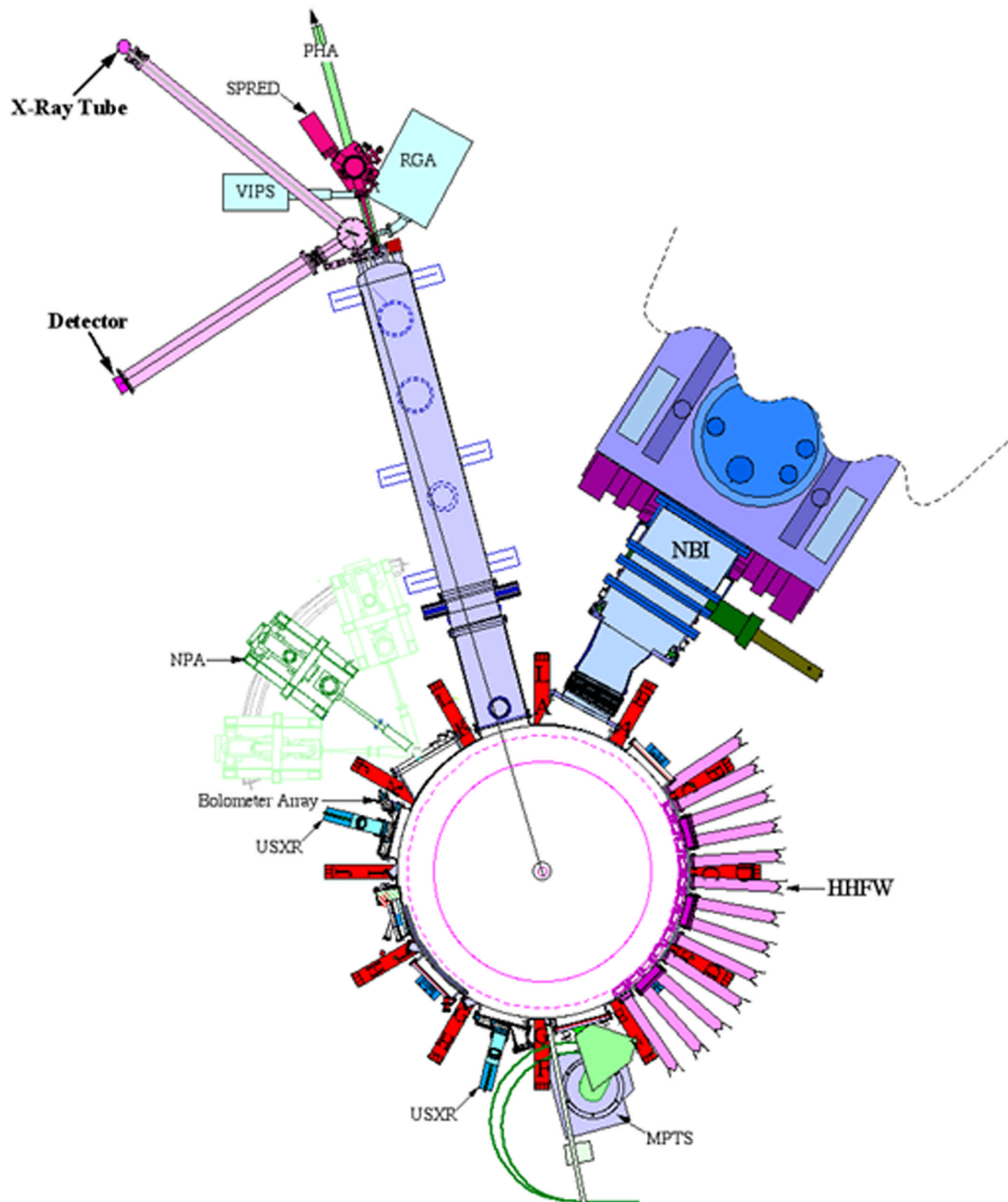
Instrumental Characteristics

- Ti(0) and Te(0) have been measured independently from the *Dielectronic Satellite Spectrum* of helium-like argon, ArXVII, in the narrow wavelength range from 3.9494 to 3.9944 Å, with a time resolution is 10 ms.
- The amount of argon needed is minimal. Argon is injected at –500 ms for 10 ms from a 67 cc large volume causing a pressure blip of 1×10^{-7} Torr on the fast ion gauge.
- By installation of a 2D detector, the instrument can be upgraded to an imaging X-ray crystal spectrometer, which will provide profiles of Ti(R) and Te(R) from an 80 cm high cross-section of the plasma with a spatial resolution of 1 cm and time resolution of 10 ms.



NSTX Spherical Crystal Spectrometer

(with calibration mechanism shown)



Ti Measurements

- Ti-measurements from the Doppler width of the $1s2p - 1s^2$ resonance line and the $1s2s - 1s^2$ forbidden line are the main diagnostic application.
- They are especially important as a non-perturbing Ti diagnostic in the absence of neutral beams - for instance, in plasmas with RF (HHFW) heating.
- In contrast to CHERS, which depends on the injection of a 20 ms long neutral beam blip and which provides a $Ti(R)$ at only one instant in time, the XCS provides the entire time history of Ti.
- CHERS may therefore miss important dynamic developments in the plasma as demonstrated by the data from shot 105830.
- **A neutral beam blip also perturbs the plasma.**

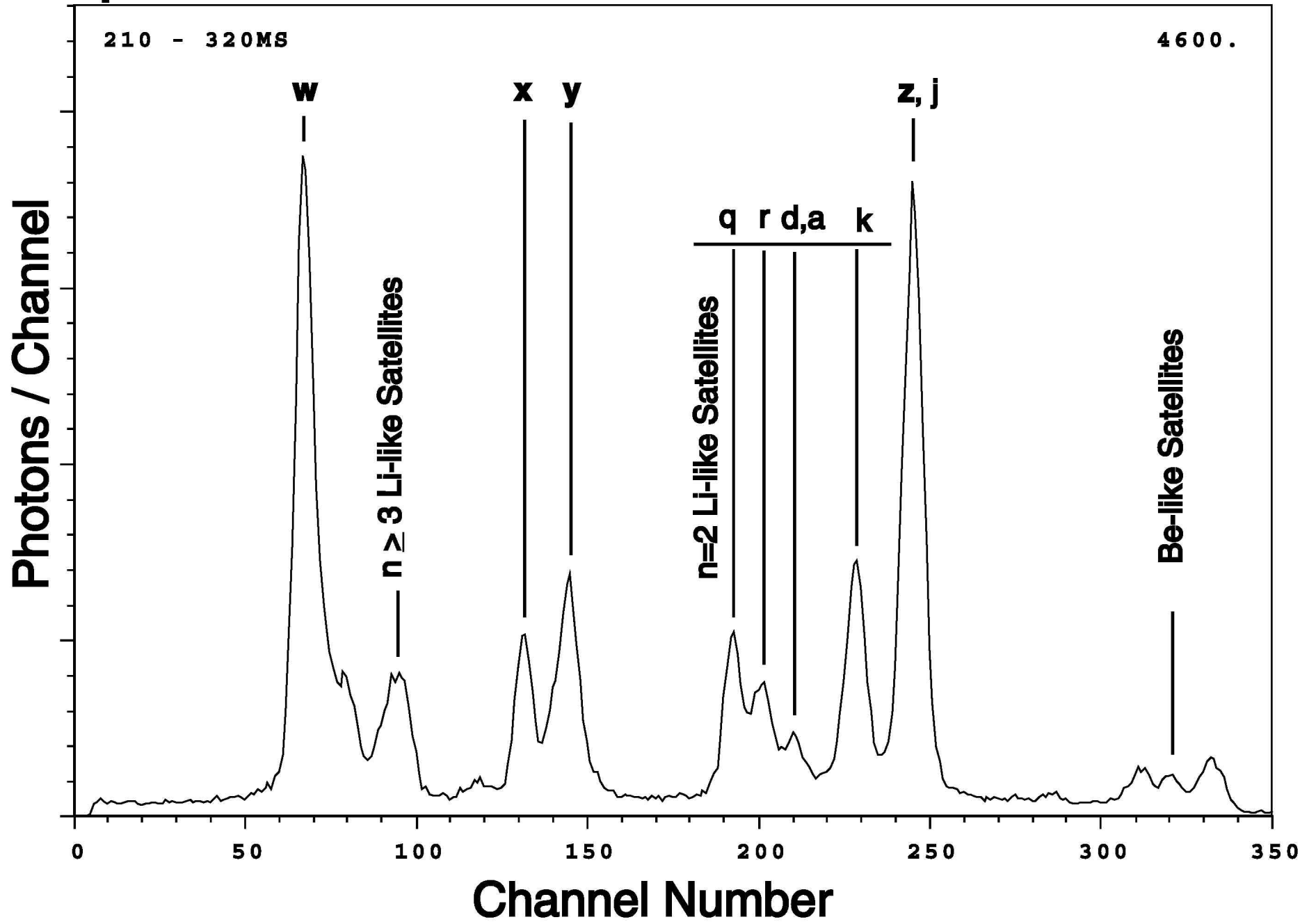
Te Measurements

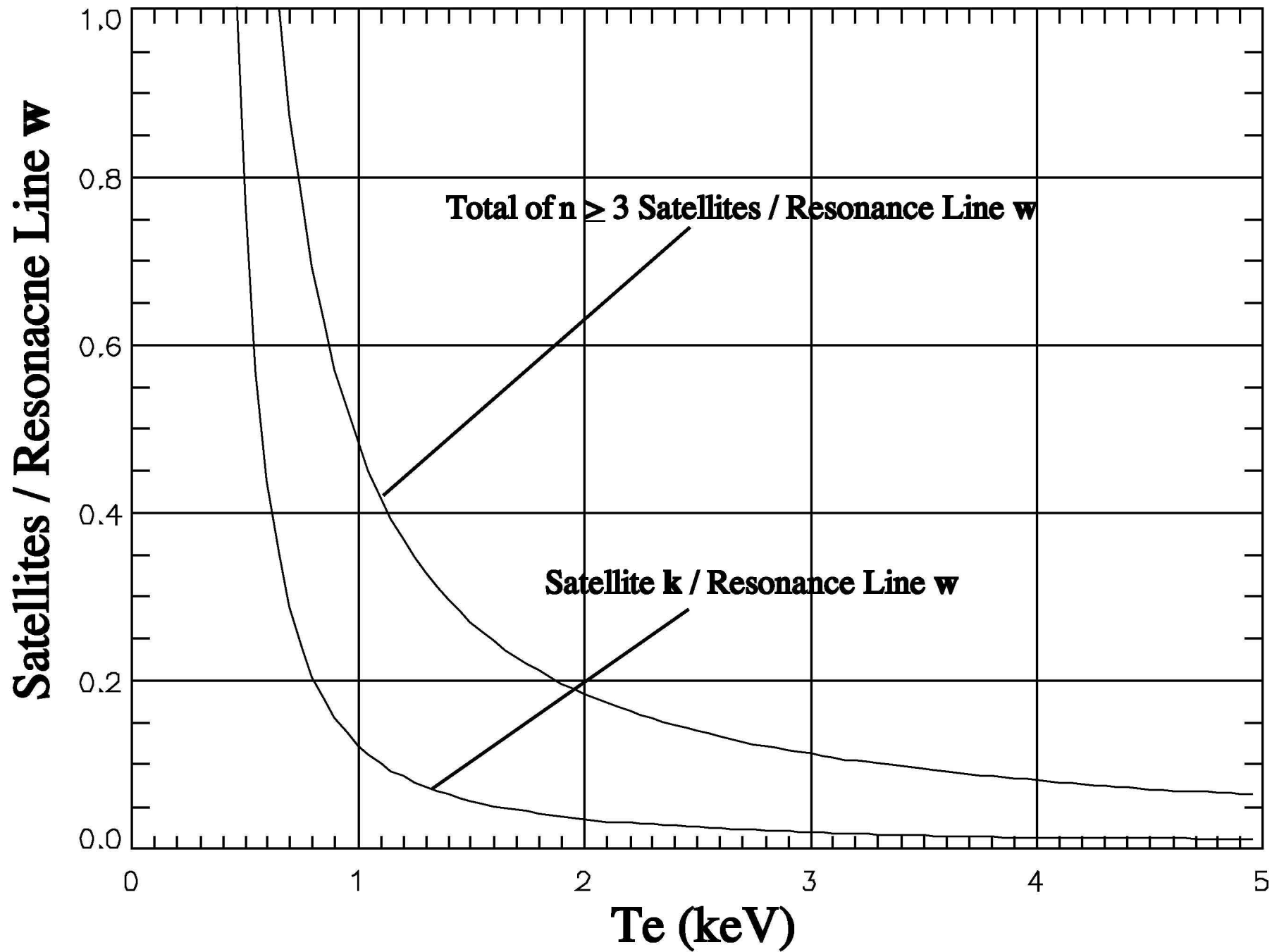
- The intensity ratios of the dielectronic satellites $1s2pnl - 1s^2nl$ with $n = 1,2,3\dots$ to the resonance line w are a sensitive Te-diagnostic for $0.5 < Te < 3$ keV.
- Te-results from the X-ray Crystal Spectrometer (XCS) are in good agreement with Thomson scattering for $Te > 1$ keV.
- However, for $Te < 1$ keV, there is a systematic difference of 40% between the XCS and Thomson scattering: $Te\text{-XCS} = 700$ eV and $Te\text{-Thomson} = 500$ eV.
- A detailed comparison with atomic theory and experimental results from EBIT will be presented for XCS data from shots 105885 – 105890.

Measurements of the argon ion charge state distribution

- **are another important diagnostic application of the XCS data for ion transport studies. But they will not be discussed in this talk.**

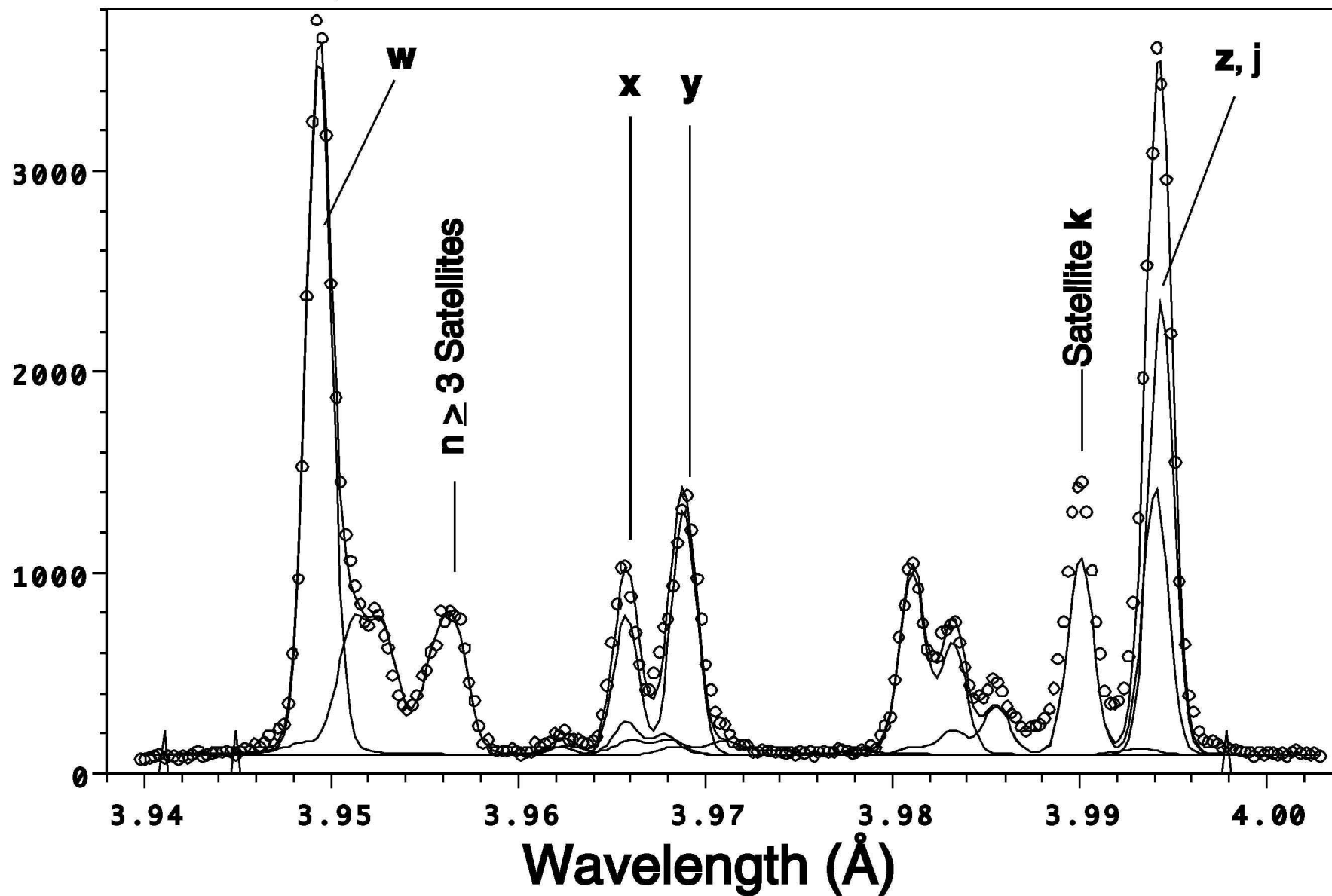
Spectrum of ArXV - ArXVII from shots: 105885 - 105 890





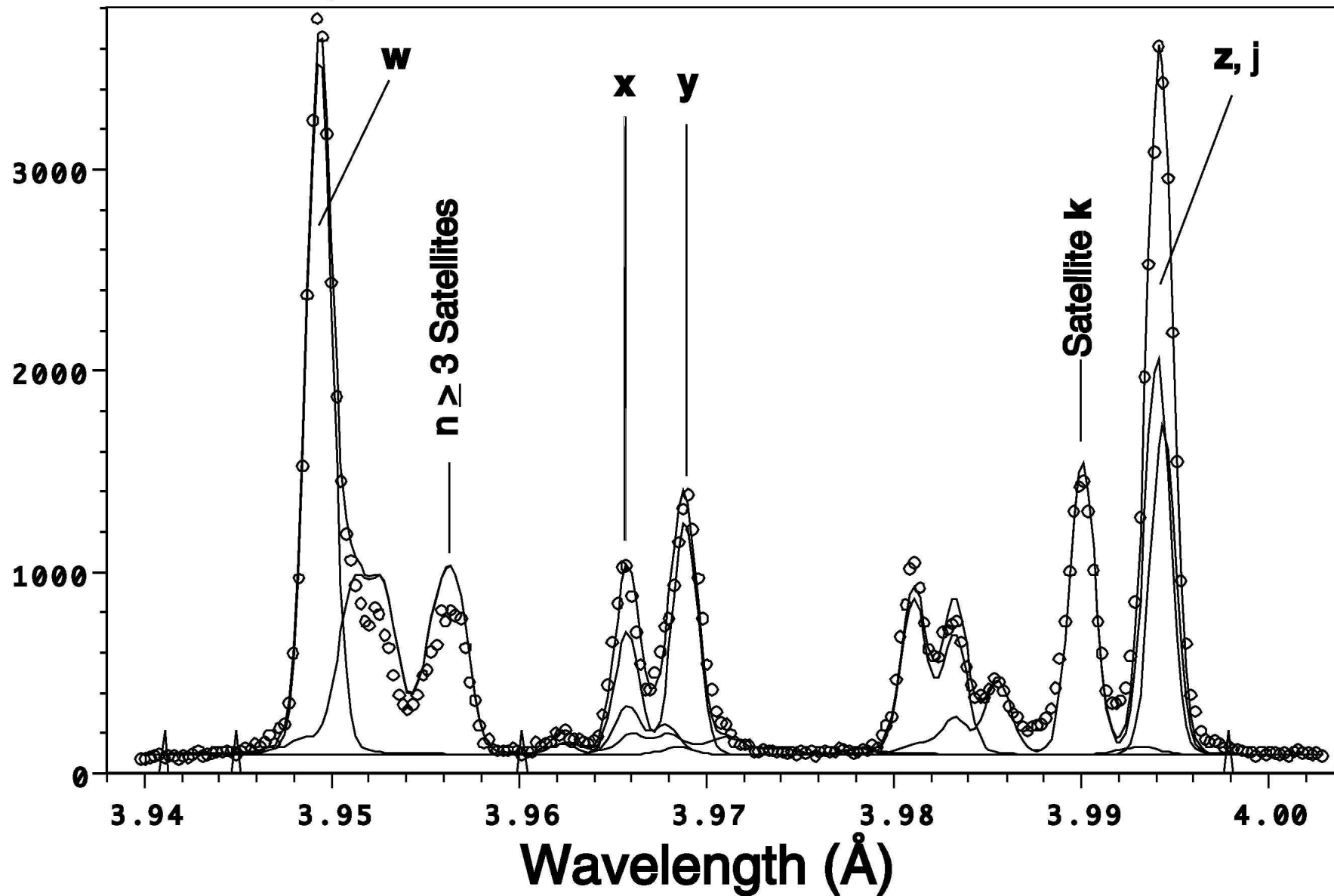
Te from least squares fit to $n \geq 3$ Satellites (*Theory Vainshtein*)

Te = 0.72 keV ; Ti = 0.43 keV



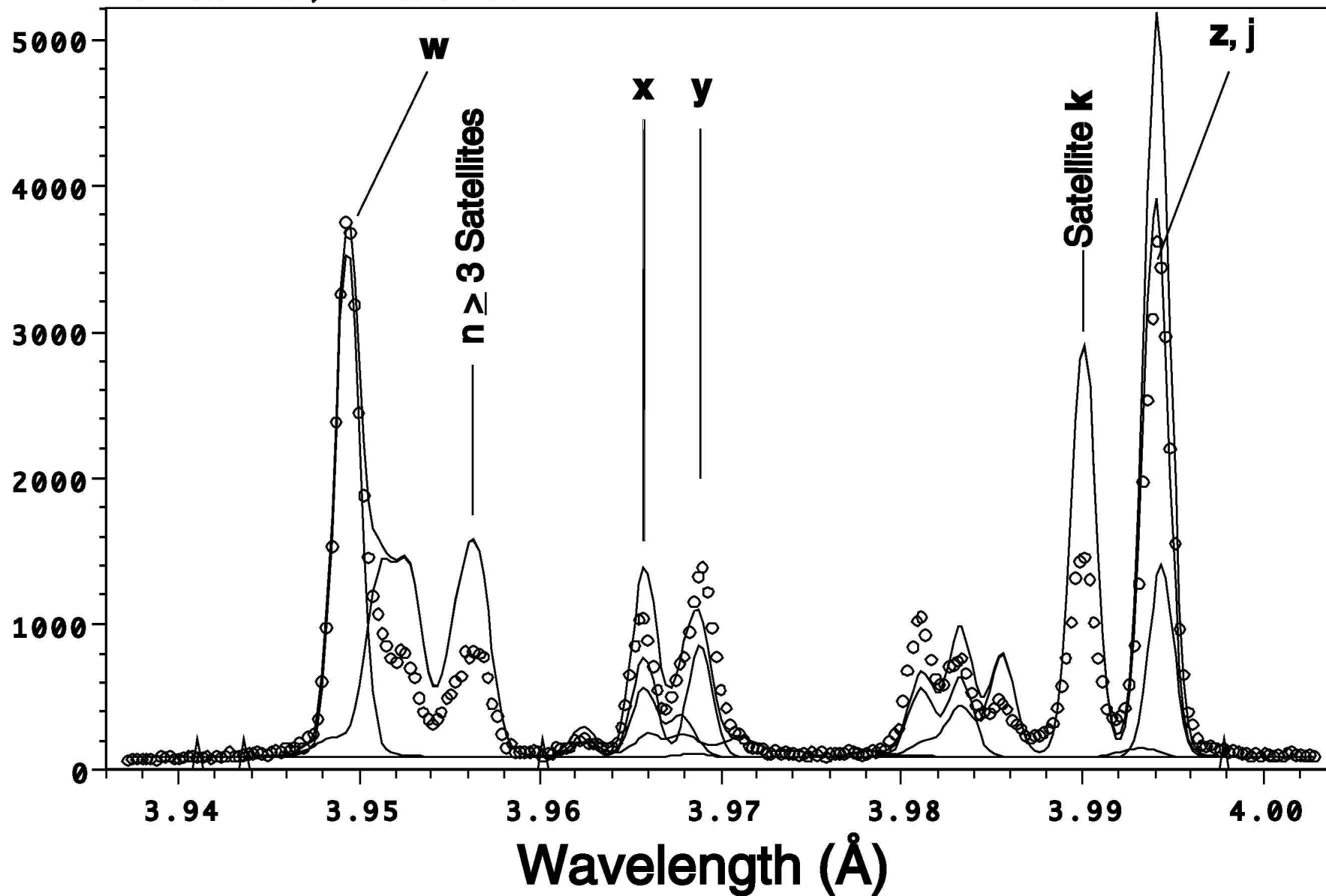
Te from least squares fit to $n = 2$ Satellites (*Theory Vainshtein*)

Te = 0.62 keV ; Ti = 0.43 keV

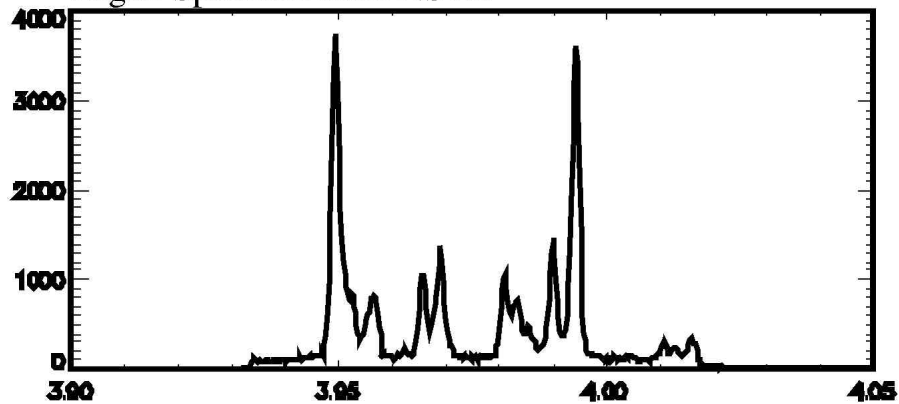


Te = 0.5 keV (fixed) ; XA =YA =ZA =1 (fixed) (Theory Vainshtein)

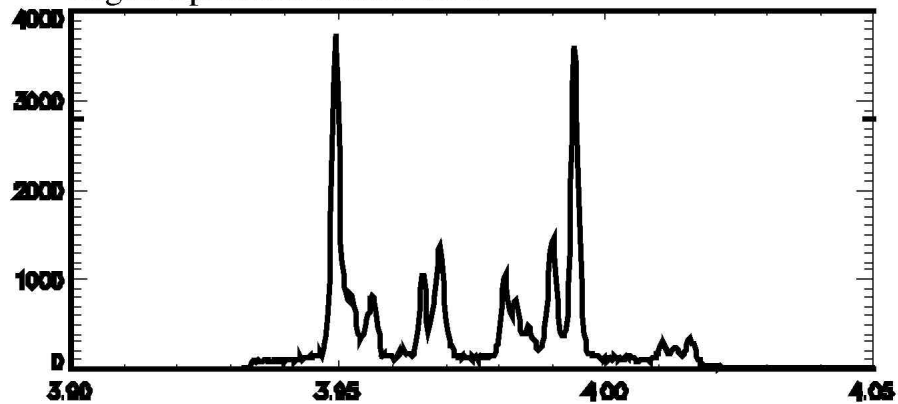
Te = 0.5 keV ; Ti = 0.43 keV



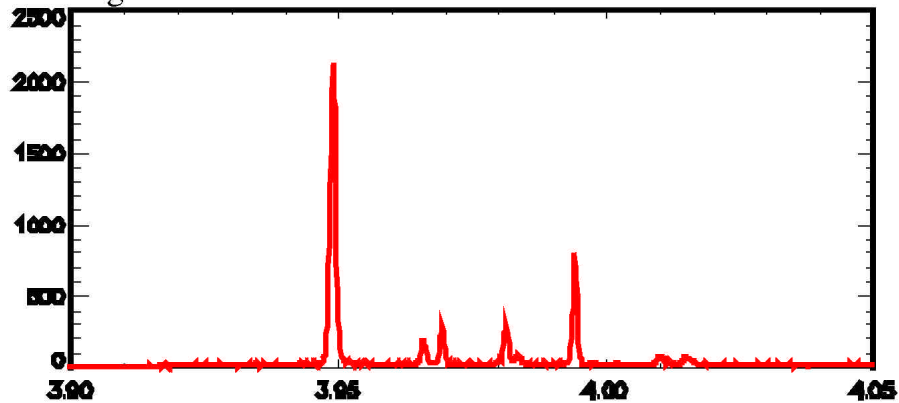
Argon Spectrum from NSTX



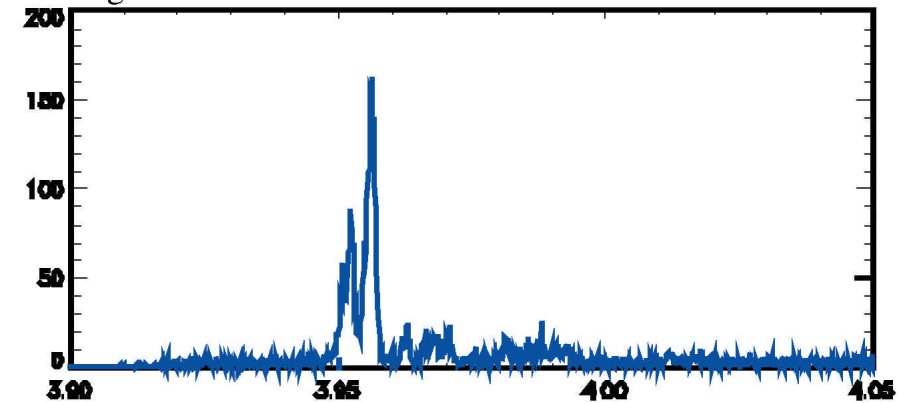
Argon Spectrum from NSTX



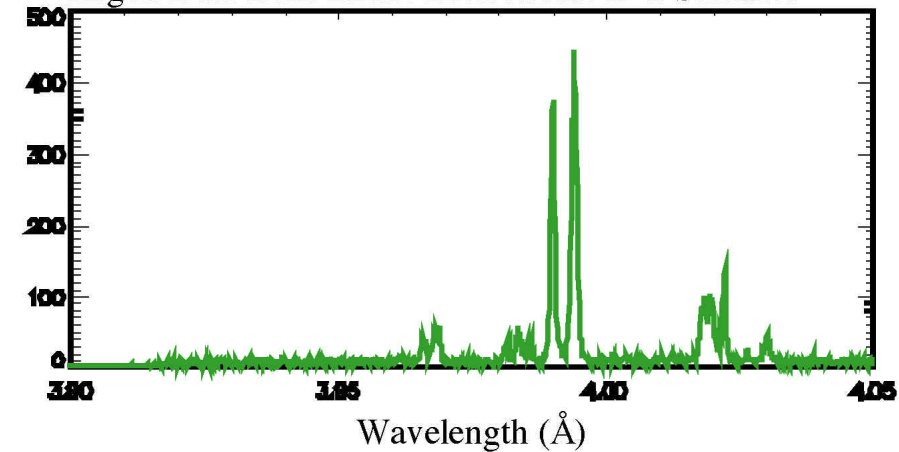
Argon Data from EBIT: Direct Excitation



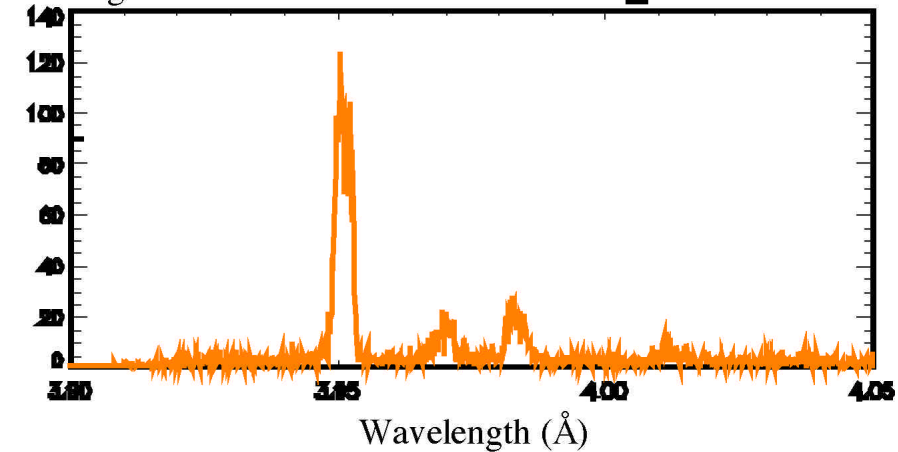
Argon Data from EBIT: Dielectronic n=3 Satellites

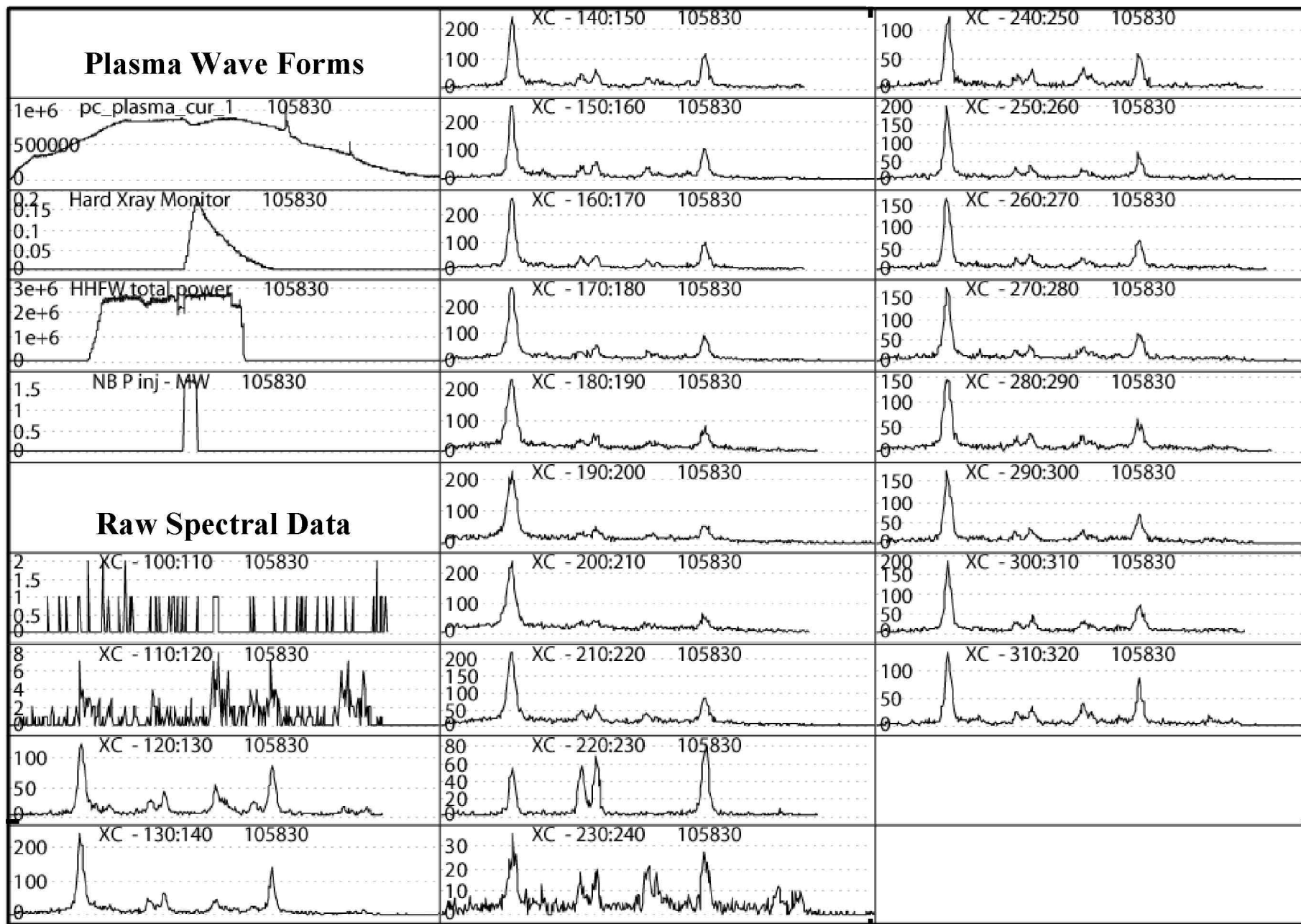


Argon Data from EBIT: Dielectronic n=2 Satellites



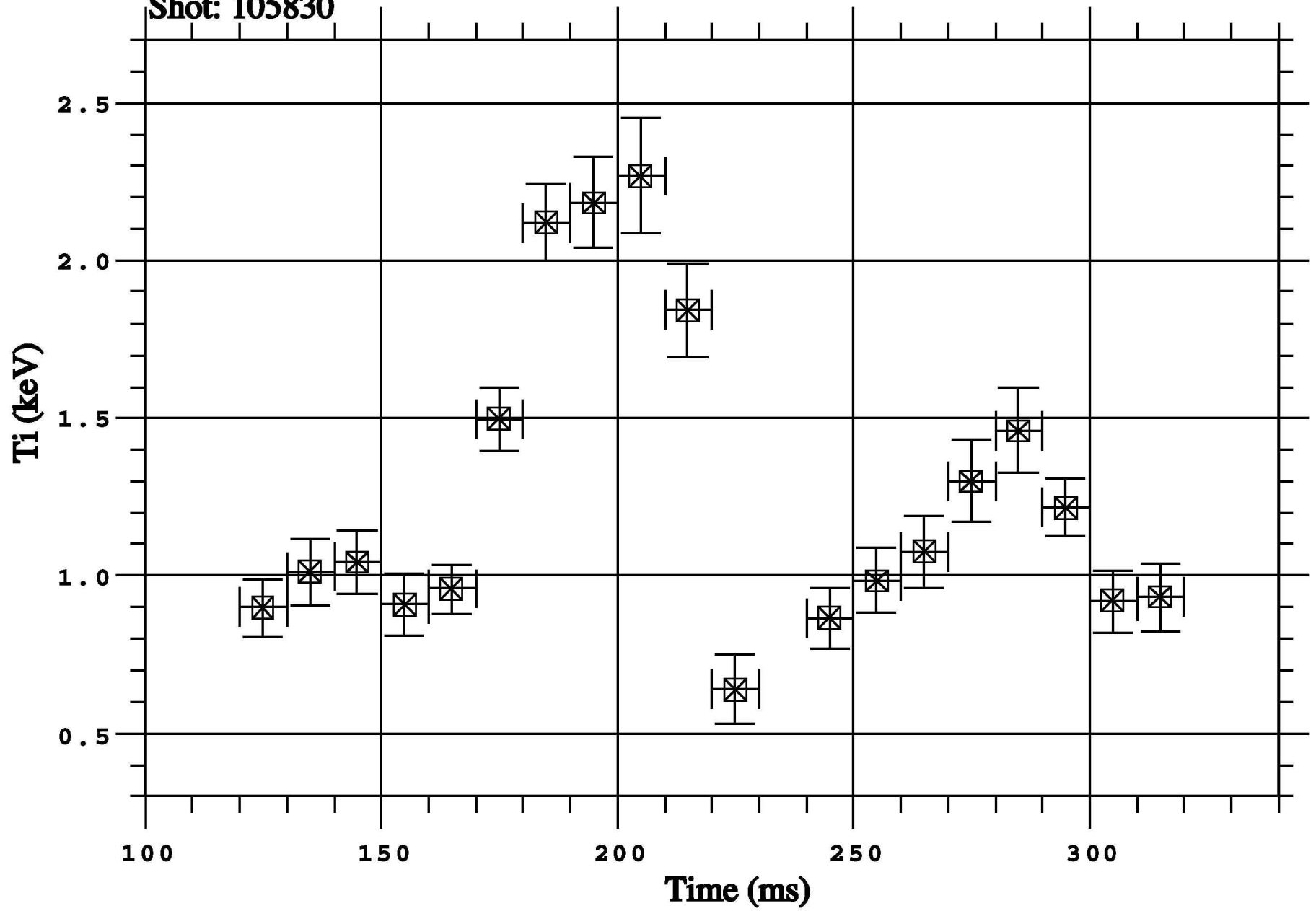
Argon Data from EBIT: Dielectronic n \geq 4 Satellites





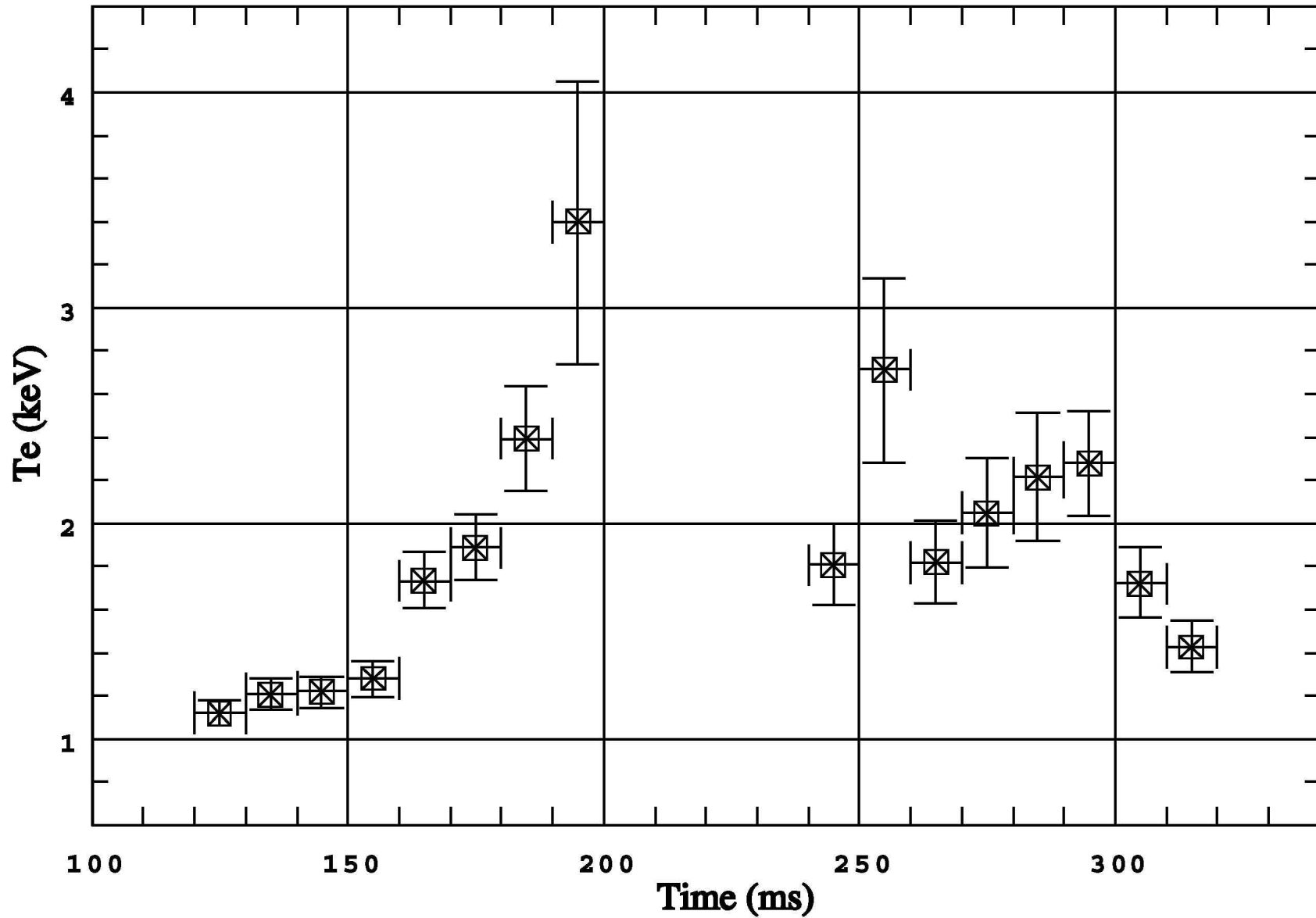
Ion Temperature from Line w

Shot: 105830



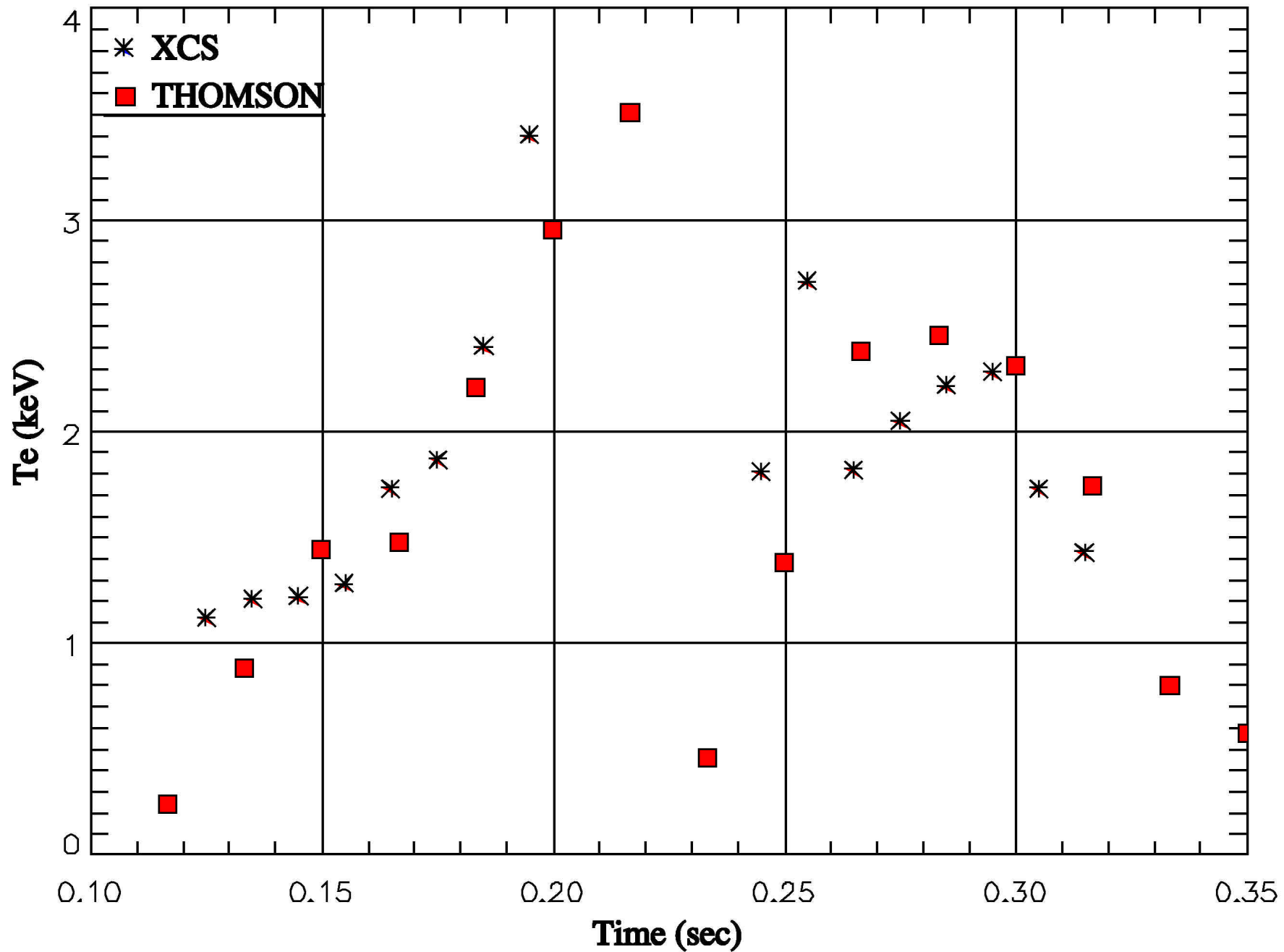
Electron Temperature from $n \geq 3$ Satellites

Shot: 105830



Electron Temperature from XCS and Thomson

Shot: 105830



Summary

- Ti(0) and Te(0) were measured with a time resolution of 10 ms.
- Count rate and spectral resolution are presently compromised by the use of an old 1D detector from the former TFTR spectrometers, which leads to an instrumental ΔE correction of 600 eV.
- With a new 2D detector, both the count rate and spectral resolution will be improved by a factor of 2, and the instrumental ΔE correction will be improved by a factor of 4 to $\Delta E=150$ eV.
- The new 2D detector will also make it possible to obtain profiles of Ti(R) and Te(R) with a spatial resolution of a few cm and a time resolution of 10 ms.
- These profiles will be the first measured perpendicular to the horizontal mid plane of NSTX.
- This new imaging X-ray crystal spectrometer will significantly advance the X-ray spectroscopy of tokamak plasmas.