Ion and Electron Temperature Measurements with X-ray Spectroscopy

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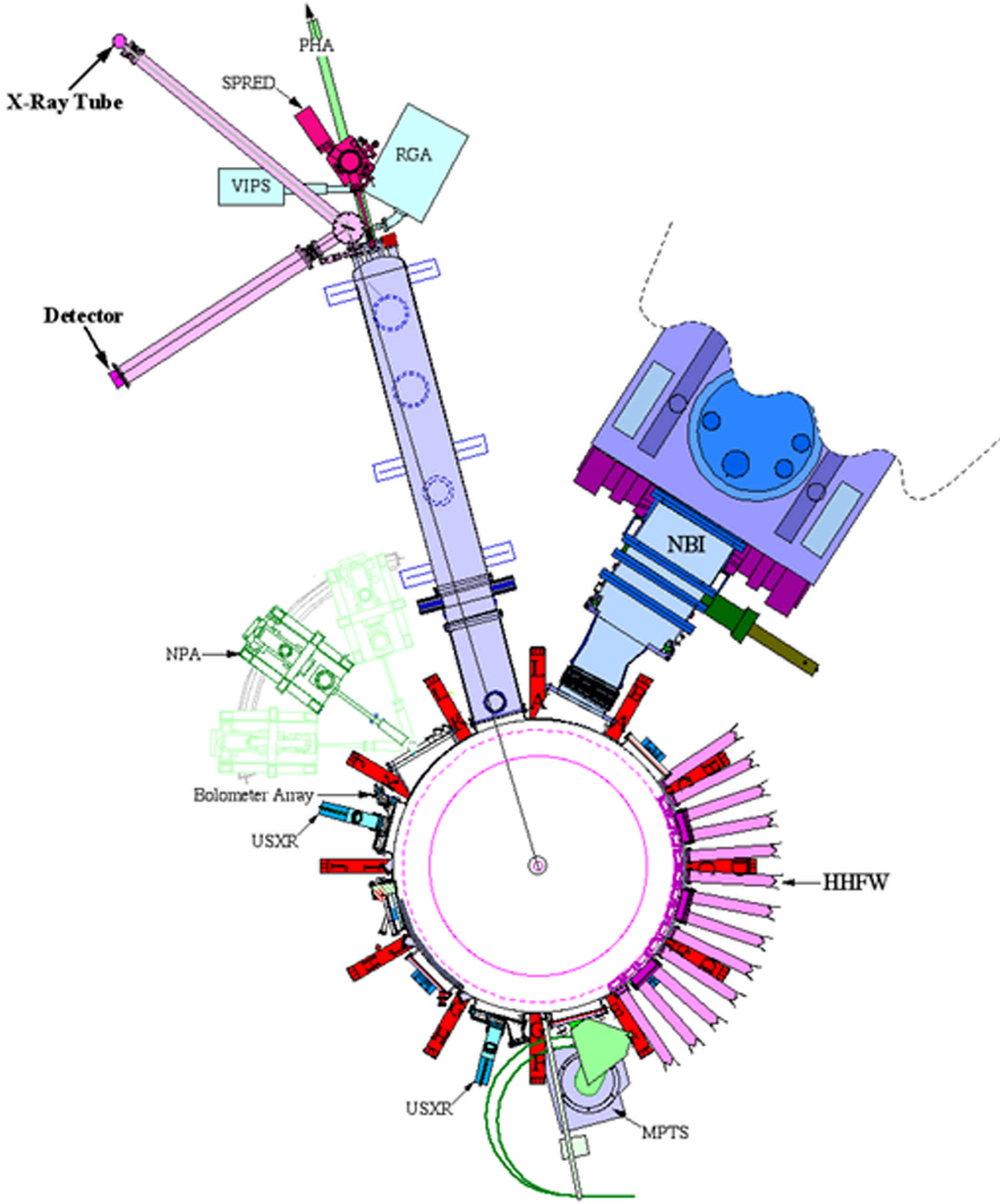
Instrumental Characteristics

- 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 A, 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… to the resonance line **w** are a sensitive Te-diagnostic for 0.5 < Te < 3 keV.

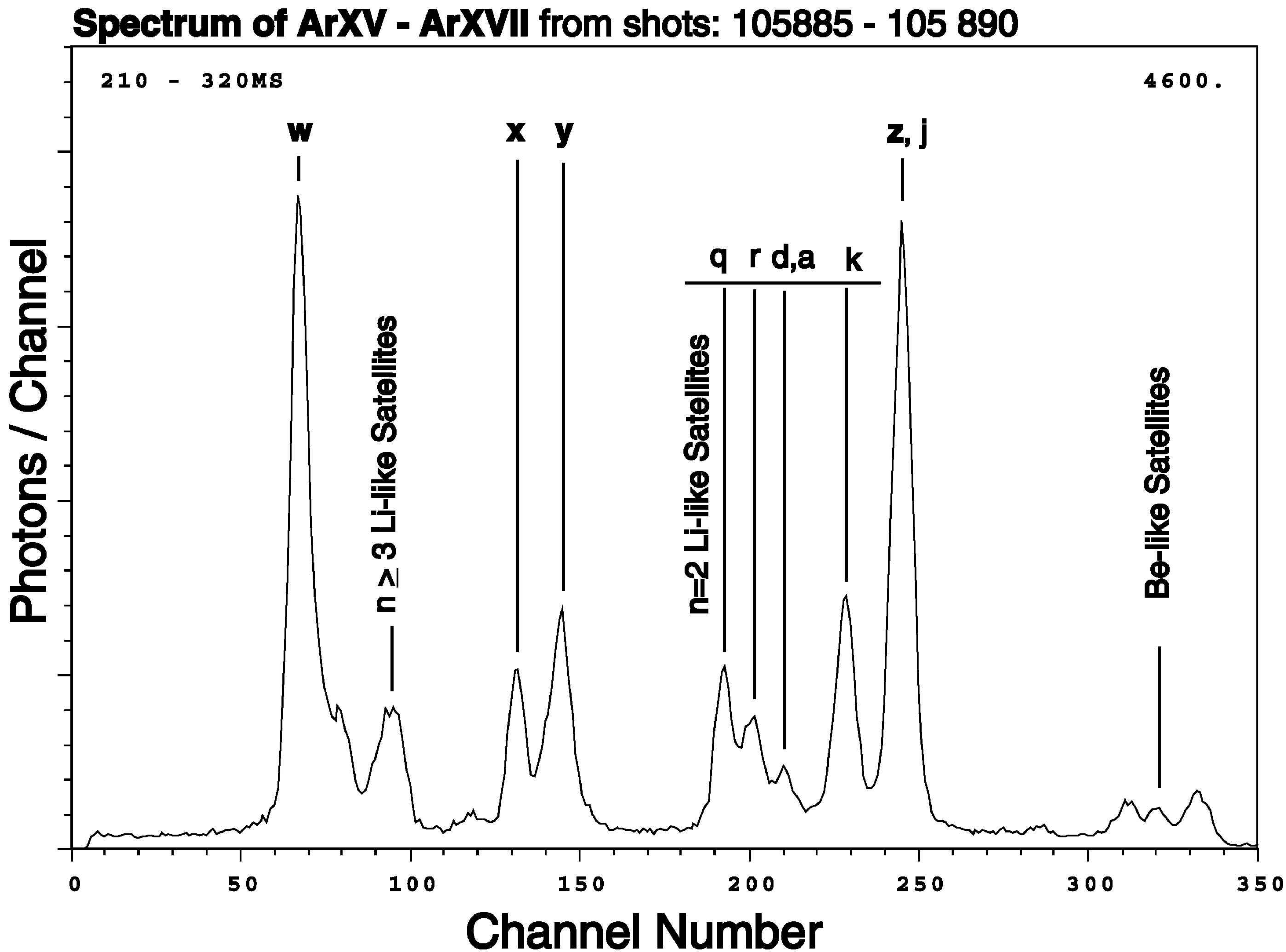
- Te-results from the X-ray Crystal Spectrometer (XCS) are in good agreement with Thomson scattering for Te > 1 keV.

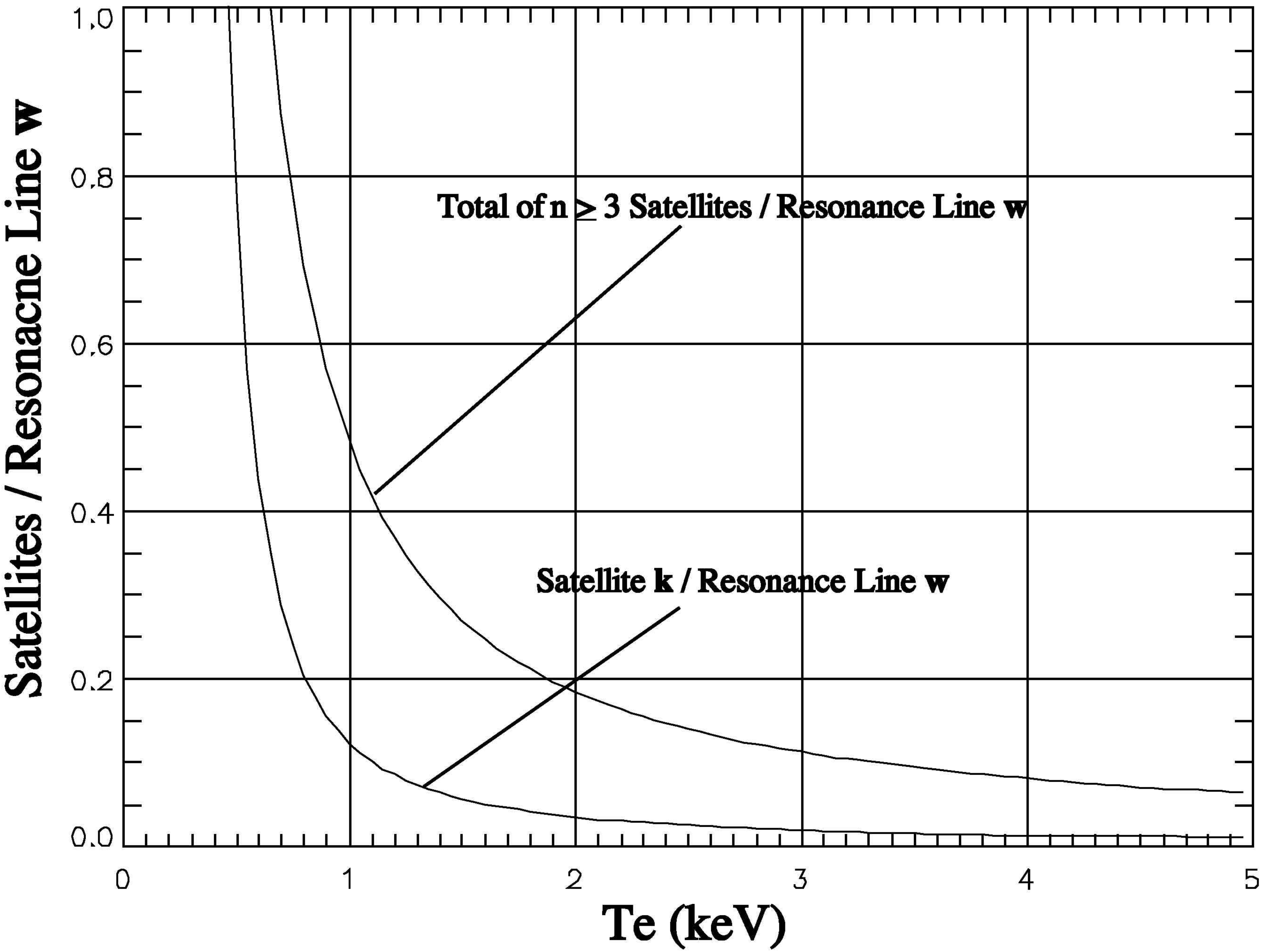
- However, for Te < 1 keV, there is a systematic difference of 40% between the XCS and Thomson scattering: Te-XCS = 700 eV and Te-Thomson= 500 eV.

- A detailed comparison with atomic theory and experimental results from EBIT will be presented for XCS data from shots 105885 – 105890.

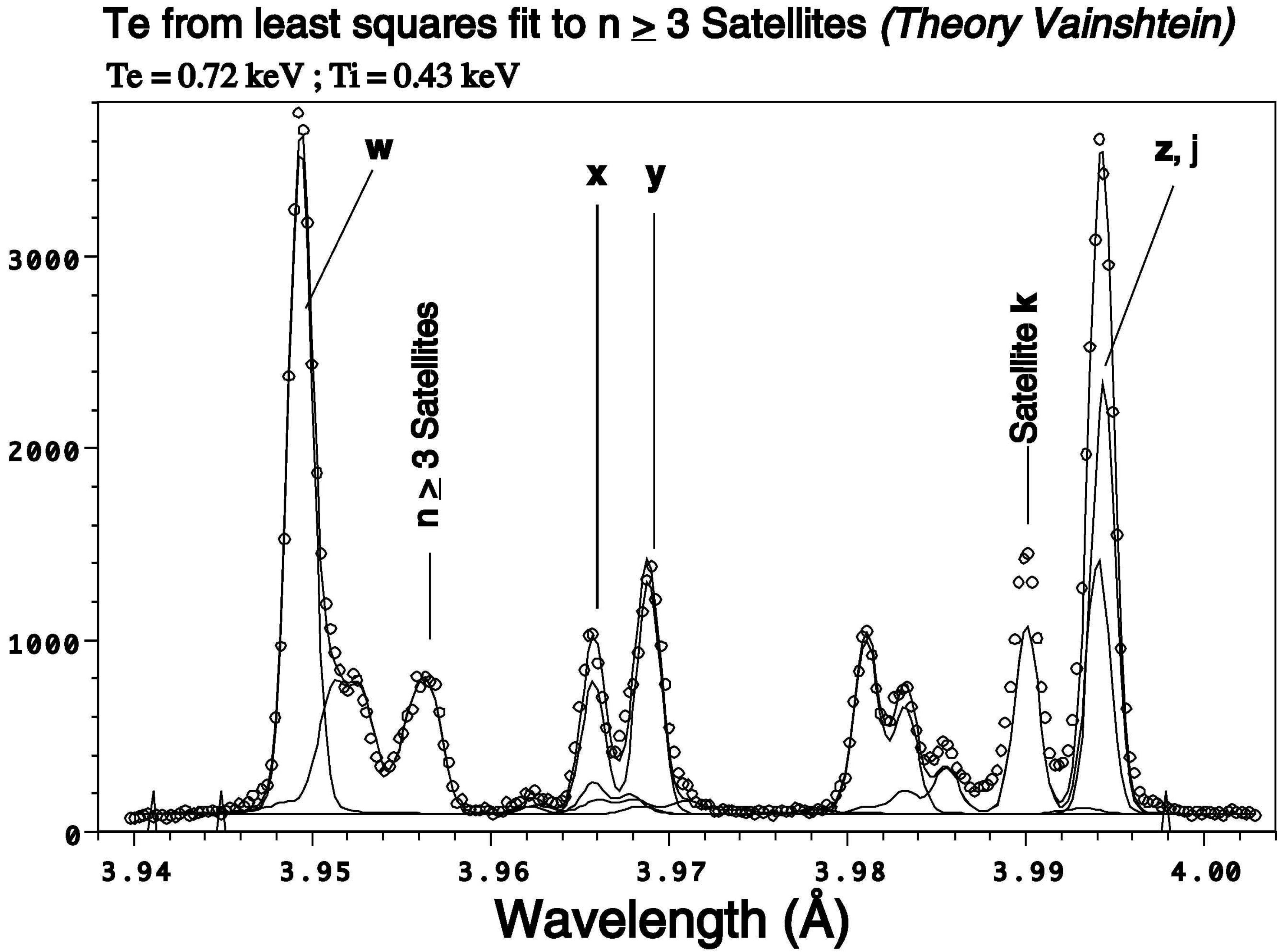
Measurements of the argon ion charge state distribution

- **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
210 - 320MS
4600.
w
x
y
z, j
q
r
d,a
k
n ≥ 3 Li-like Satellites
n=2 Li-like Satellites
Be-like Satellites
Photons / Channel
Channel Number
0
50
100
150
200
250
300
350



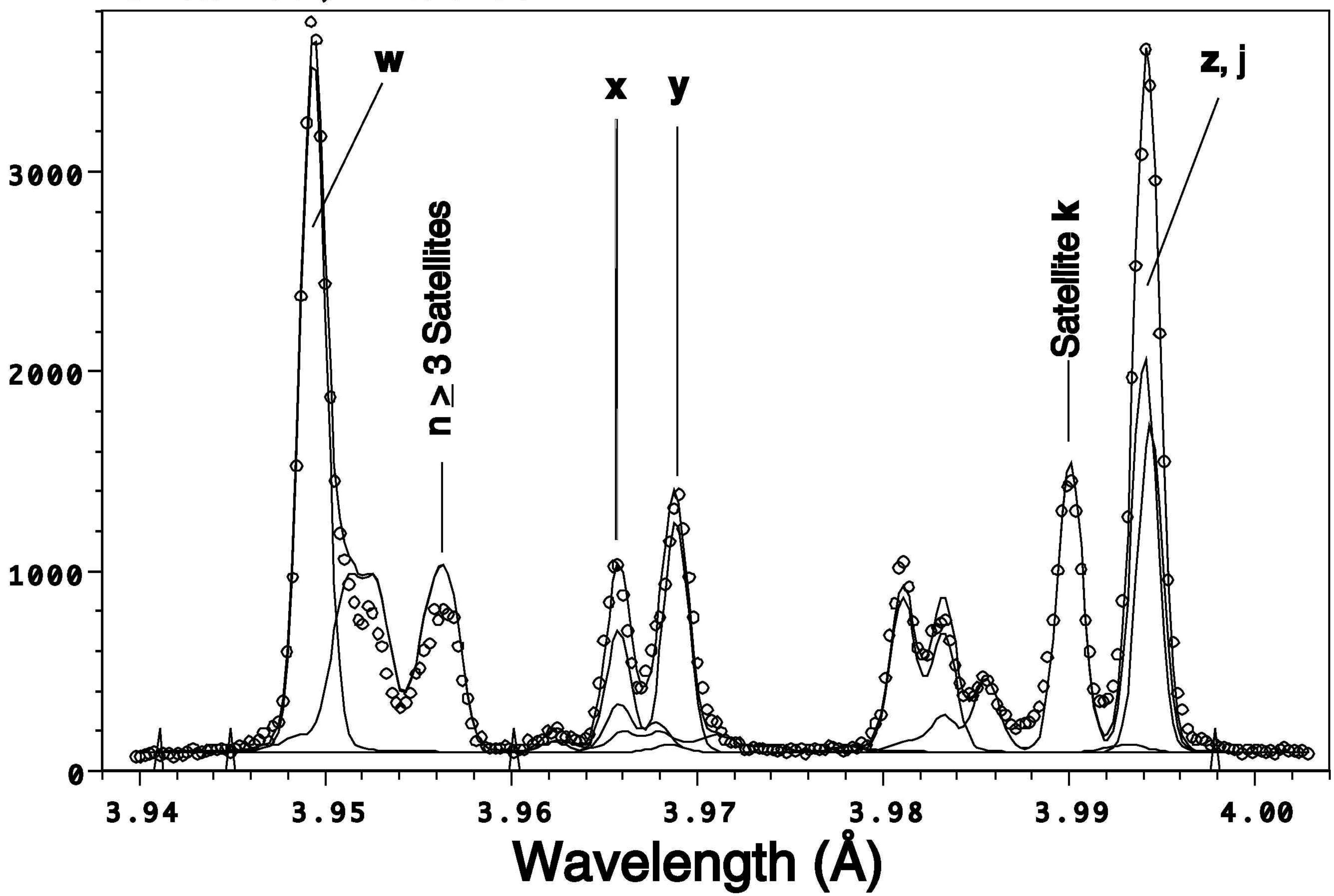
Satellites / Resonacne Line w
Te (keV)
Total of n ≥ 3 Satellites / Resonance Line w
Satellite k / Resonance Line w
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5

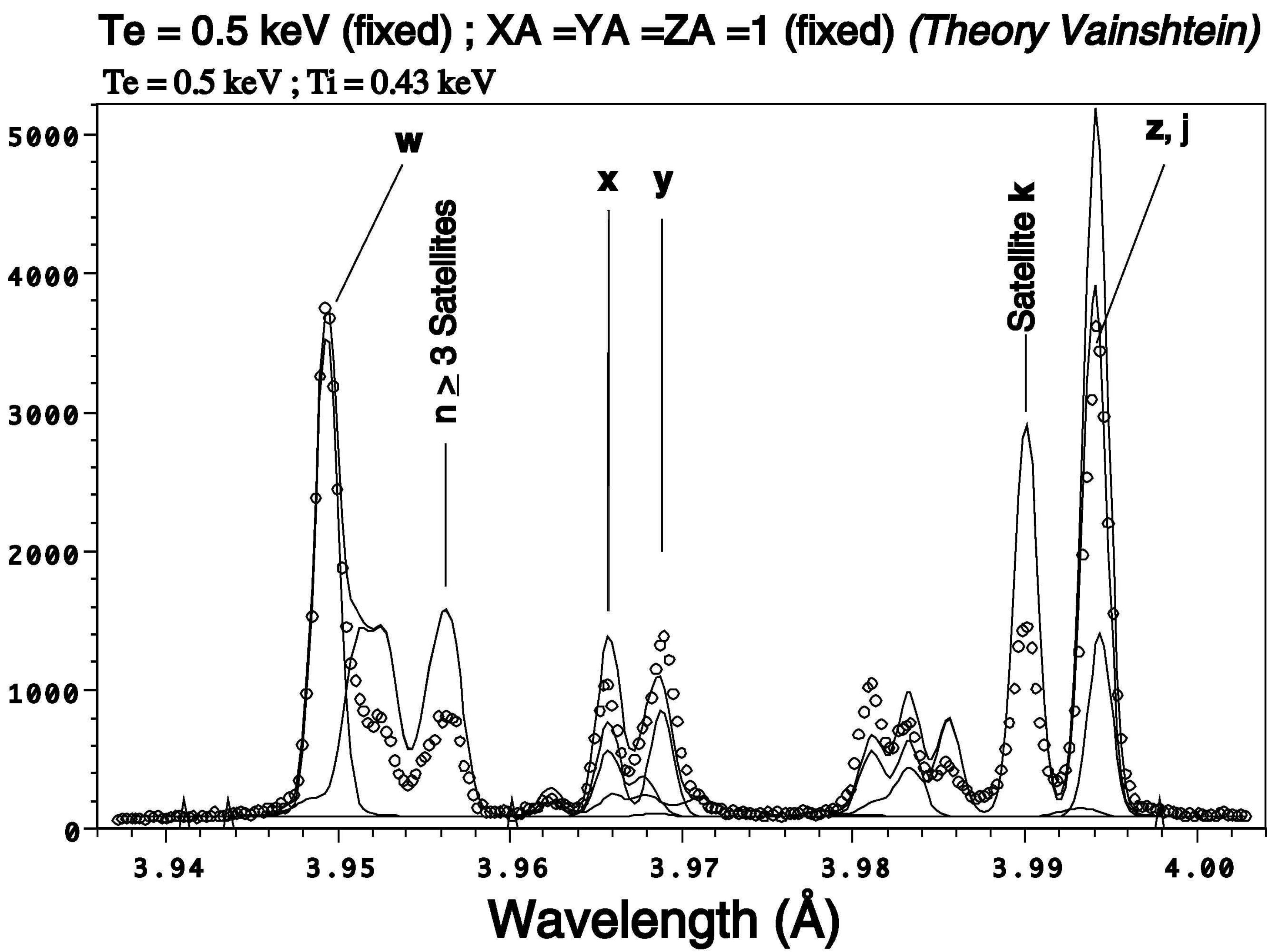


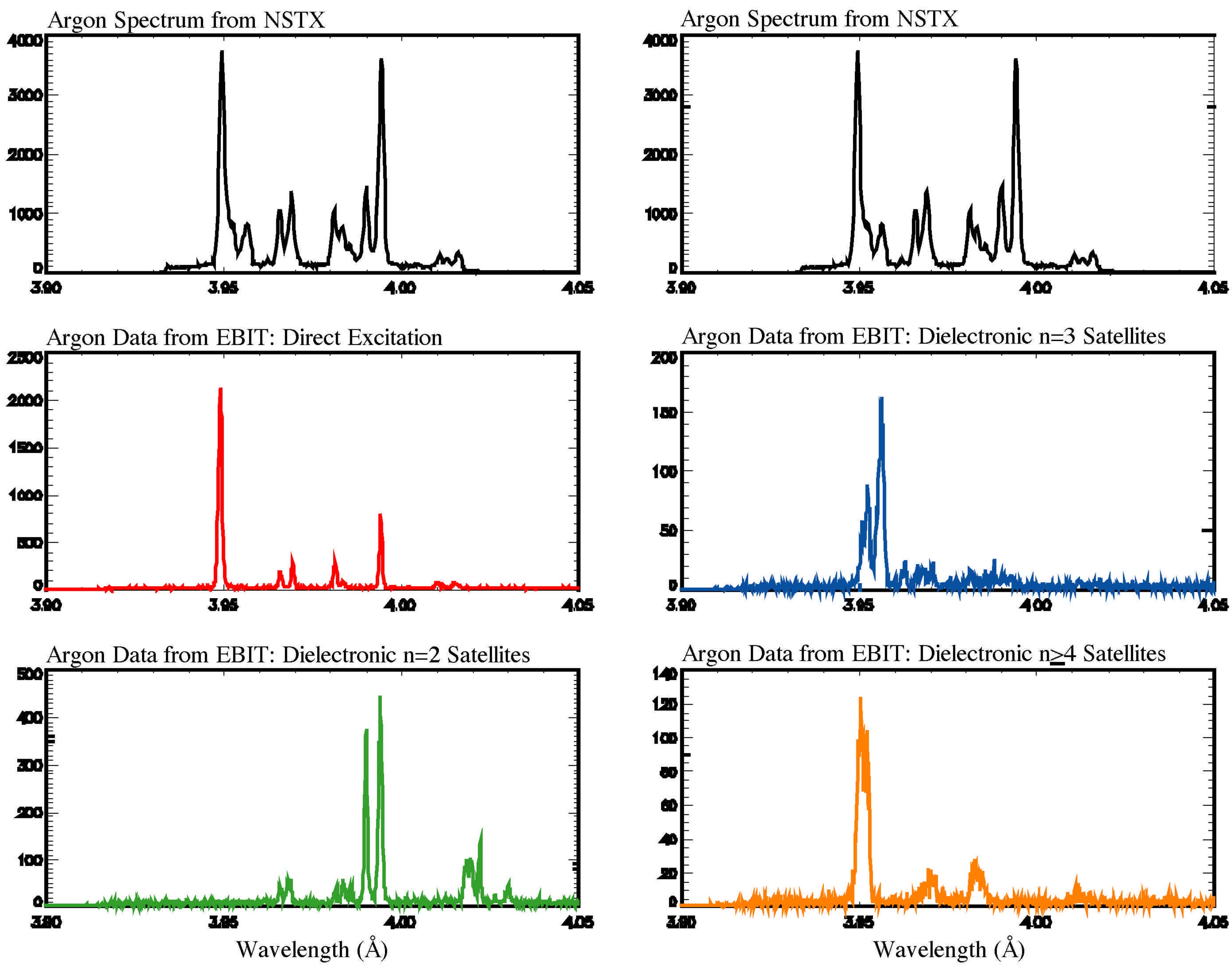
Te from least squares fit to n ≥ 3 Satellites (Theory Vainshtein)
Te = 0.72 keV ; Ti = 0.43 keV
w
x
y
z, j
n ≥ 3 Satellites
Satellite k
3000
2000
1000
0
3.94
3.95
3.96
3.97
3.98
3.99
4.00
Wavelength (Å)

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

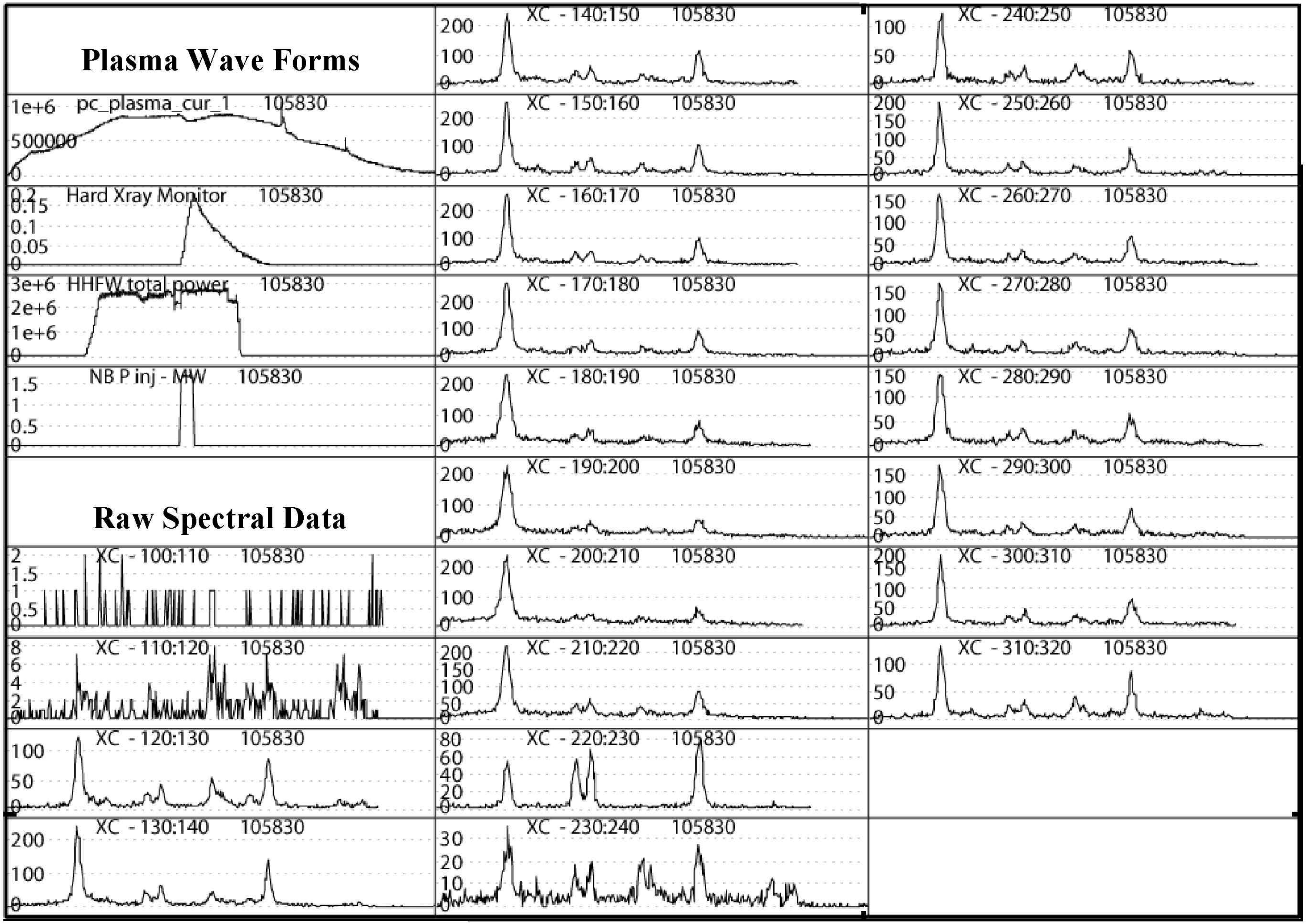
Te = 0.62 keV ; Ti = 0.43 keV

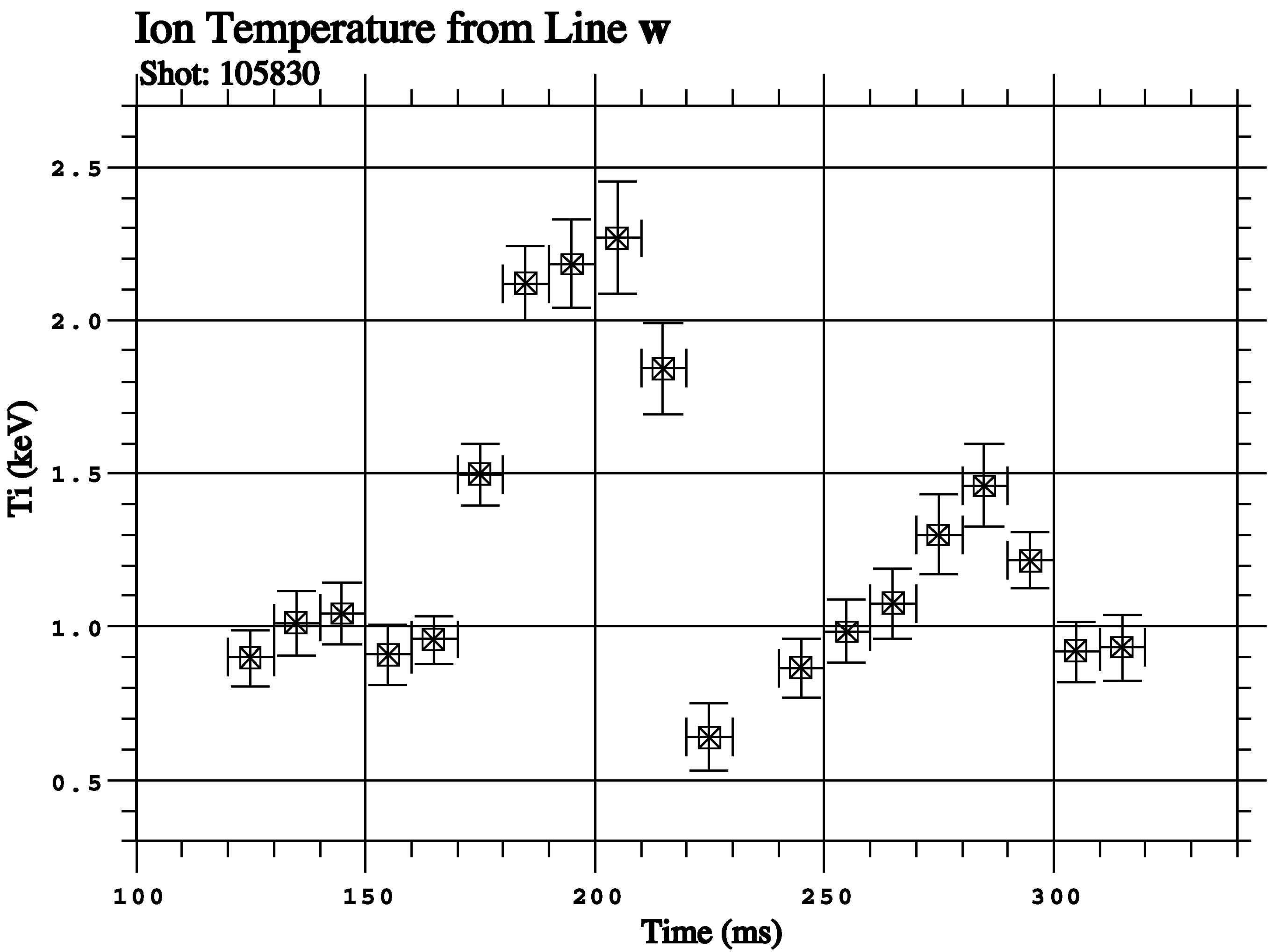


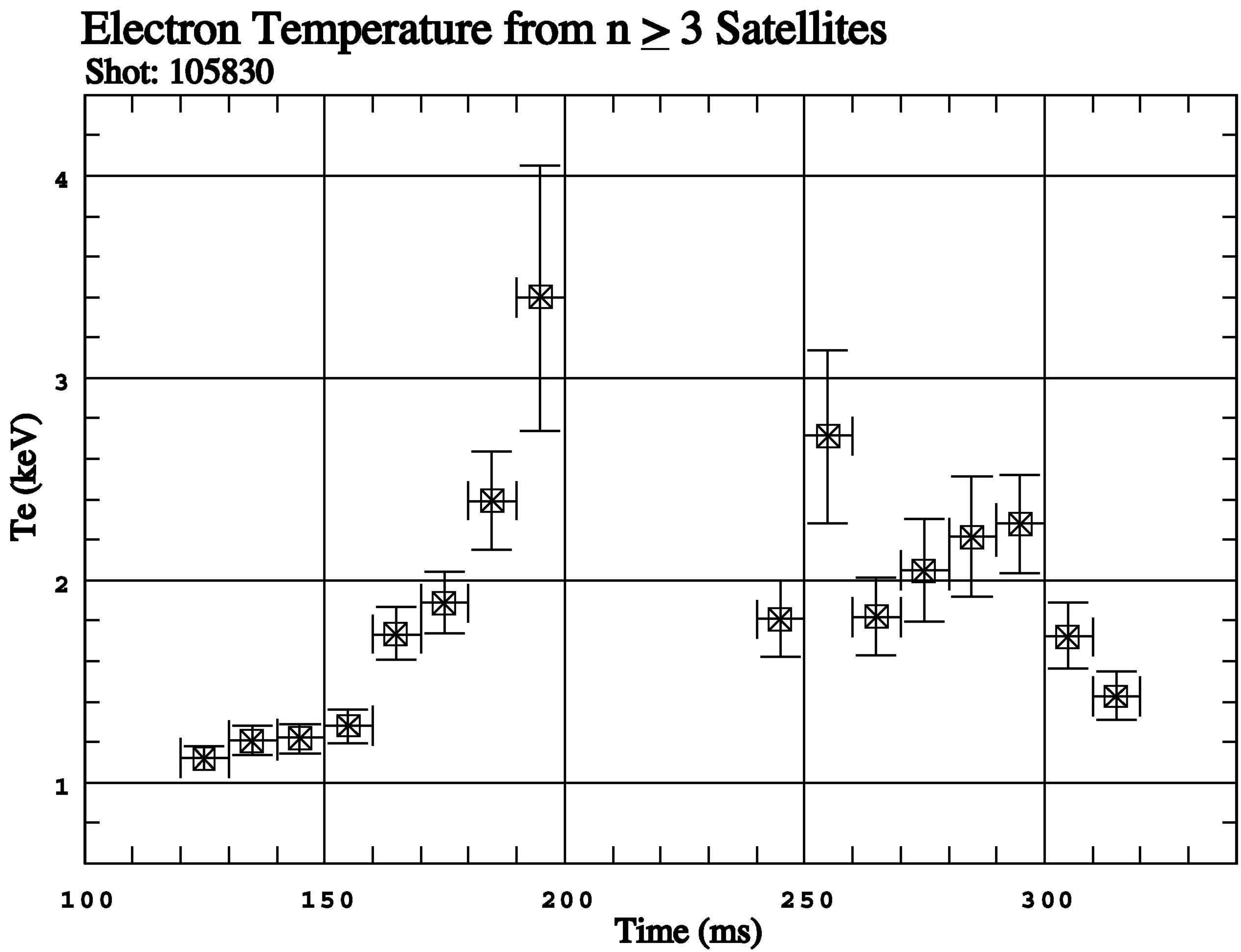

Te = 0.5 keV (fixed) ; XA =YA =ZA =1 (fixed) (Theory Vainshtein)
Te = 0.5 keV ; Ti = 0.43 keV
w
n ≥ 3 Satellites
x
y
Satellite k
z, j
5000
4000
3000
2000
1000
0
3.94
3.95
3.96
3.97
3.98
3.99
4.00
Wavelength (Å)

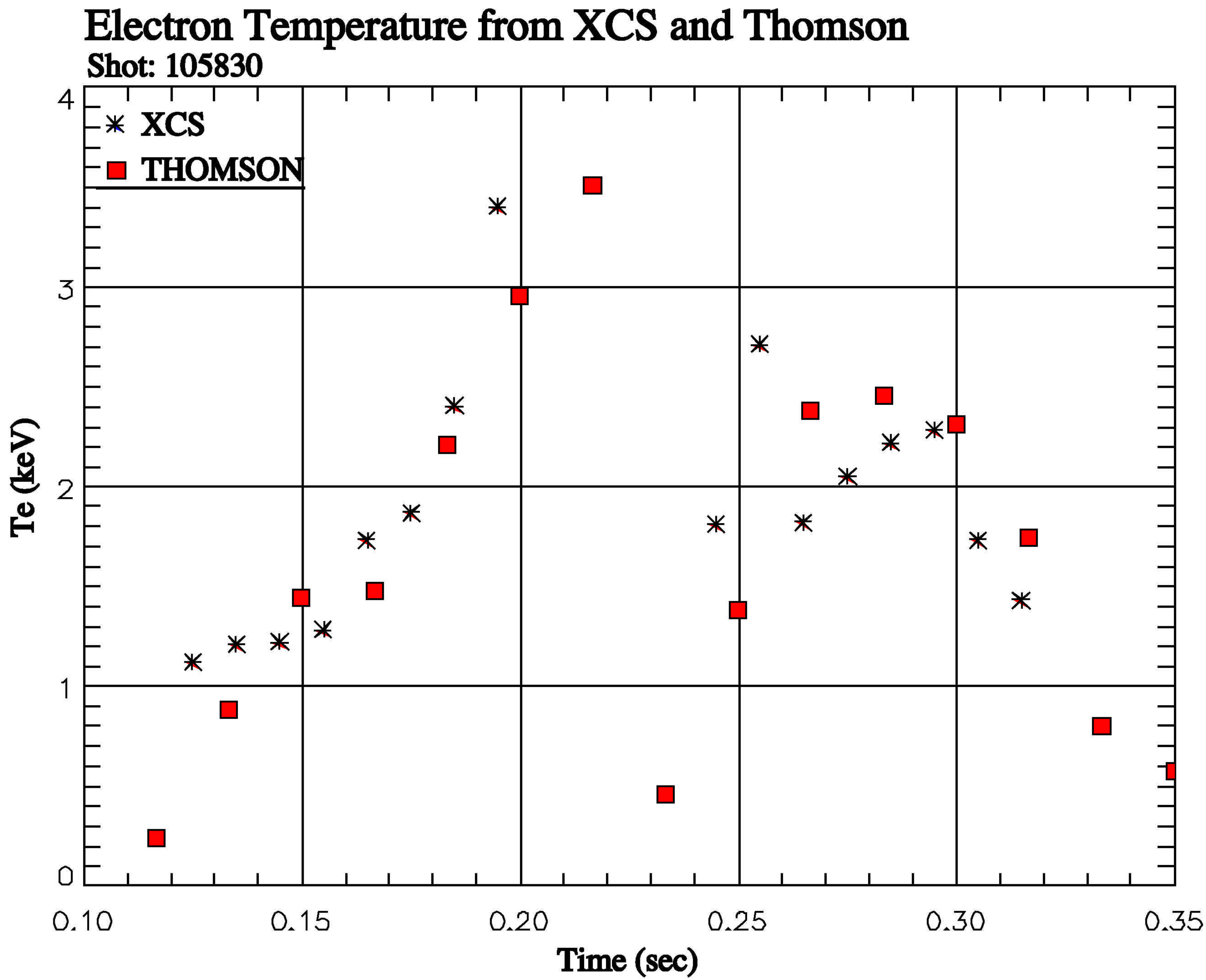


Argon Spectrum from NSTX
Argon Spectrum from NSTX
Argon Data from EBIT: Direct Excitation
Argon Data from EBIT: Dielectronic n=3 Satellites
Argon Data from EBIT: Dielectronic n=2 Satellites
Argon Data from EBIT: Dielectronic n≥4 Satellites
Wavelength (Å)
Wavelength (Å)


Plasma Wave Forms
pc_plasma_cur_1 105830
Hard Xray Monitor 105830
HHFW total power 105830
NB P inj - MW 105830
Raw Spectral Data
XC - 100:110 105830
XC - 110:120 105830
XC - 120:130 105830
XC - 130:140 105830
XC - 140:150 105830
XC - 150:160 105830
XC - 160:170 105830
XC - 170:180 105830
XC - 180:190 105830
XC - 190:200 105830
XC - 200:210 105830
XC - 210:220 105830
XC - 220:230 105830
XC - 230:240 105830
XC - 240:250 105830
XC - 250:260 105830
XC - 260:270 105830
XC - 270:280 105830
XC - 280:290 105830
XC - 290:300 105830
XC - 300:310 105830
XC - 310:320 105830


Ion Temperature from Line w
Shot: 105830
Ti (keV)
2.5
2.0
1.5
1.0
0.5
100
150
200
250
300
Time (ms)


Electron Temperature from n ≥ 3 Satellites
Shot: 105830
Te (keV)
4
3
2
1
100
150
200
250
300
Time (ms)



Electron Temperature from XCS and Thomson
Shot: 105830
XCS
THOMSON
Te (keV)
Time (sec)
0
1
2
3
4
0.10
0.15
0.20
0.25
0.30
0.35

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 ΔTi 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 ΔTi correction will be improved by a factor of 4 to ΔTi=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.