

Experimental test of Ar CXRS cross sections on ASDEX Upgrade

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- Ar is an important species for ITER as radiator for divertor cooling
- Ar is going to be important in present day C-free tokamaks (AUG, in the future also JET with metal walls)
- CXS lines have already been observed for Ar XVI and Ar XVIII in other tokamaks (e.g. DIII-D, JET), however discrepancies were found in trying to reconcile CX and SXR measurements for Ar.
- Main source of fundamental state selective CX data for Ar: standard CTMC (in use by the fusion community and available in ADAS)
- New CTMC calculations from UAM group (Errea, Illescas et al.) with improved initial distributions show pronounced discrepancies with standard CTMC, especially in energy range of AUG NB's.

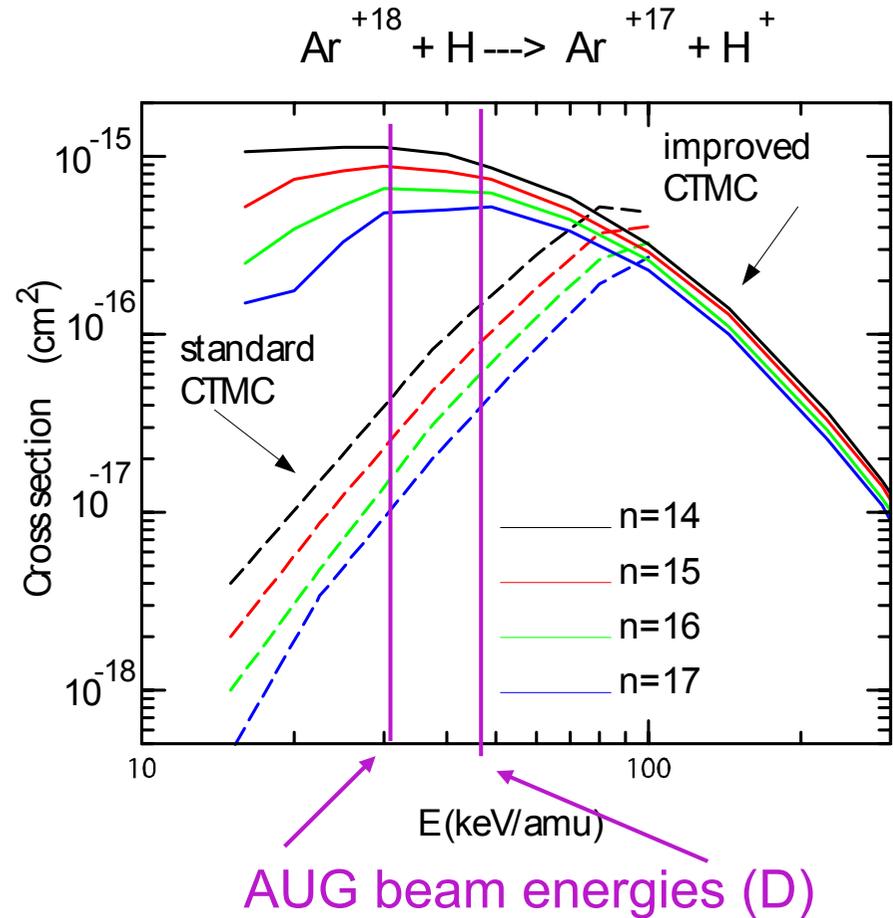
Aims of the experiment



Quantitative CXRS spectroscopy with Ar

Benchmark comparison of CX theory and observation by multi-line study of Ar XVIII, Ar XVII and Ar XVI

Recommendation of preferred CX cross sections for Ar and their incorporation in ADAS

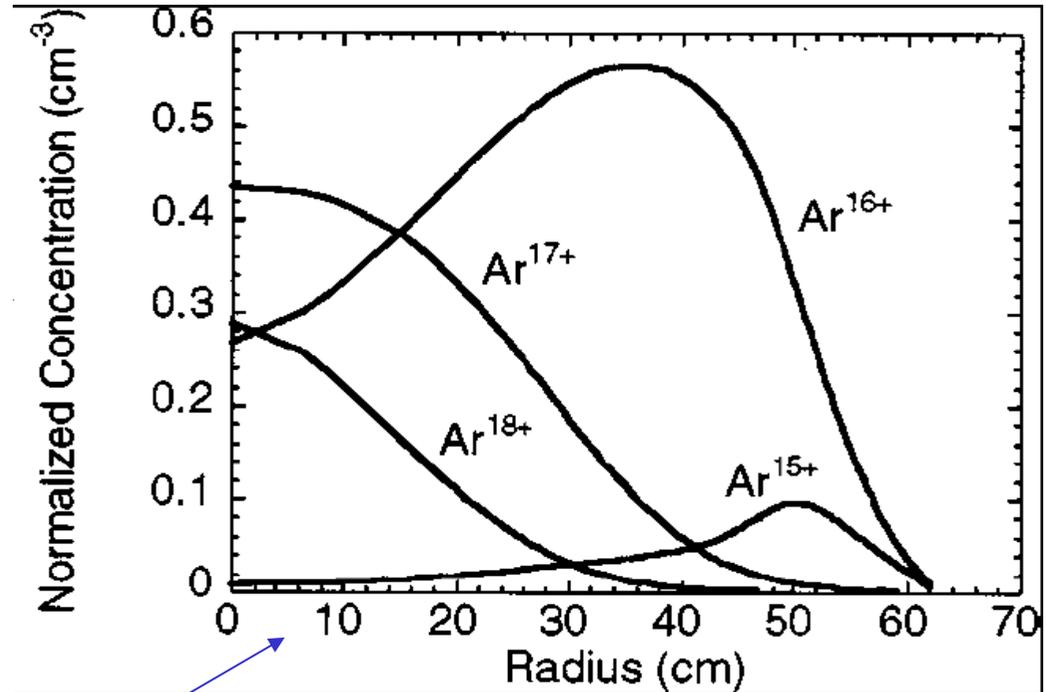


Experimental conditions



Ar is not completely ionized
in present day tokamaks:
several ionization stages
coexist << >>
observations depend on T_e
(& transport)

Simultaneous observations
of the various lines from
different charge states



Normalized Ar concentrations from STRAHL
for DIII-D ELMy H-mode

D.G. Whyte et al., Phys. Plas. **5** (1998) 3694

Summary of experimental conditions:

Discharge: (September 2007)

0.8 MA / -2.5 T, 3 beam sources

central ECRH to avoid impurity accumulation

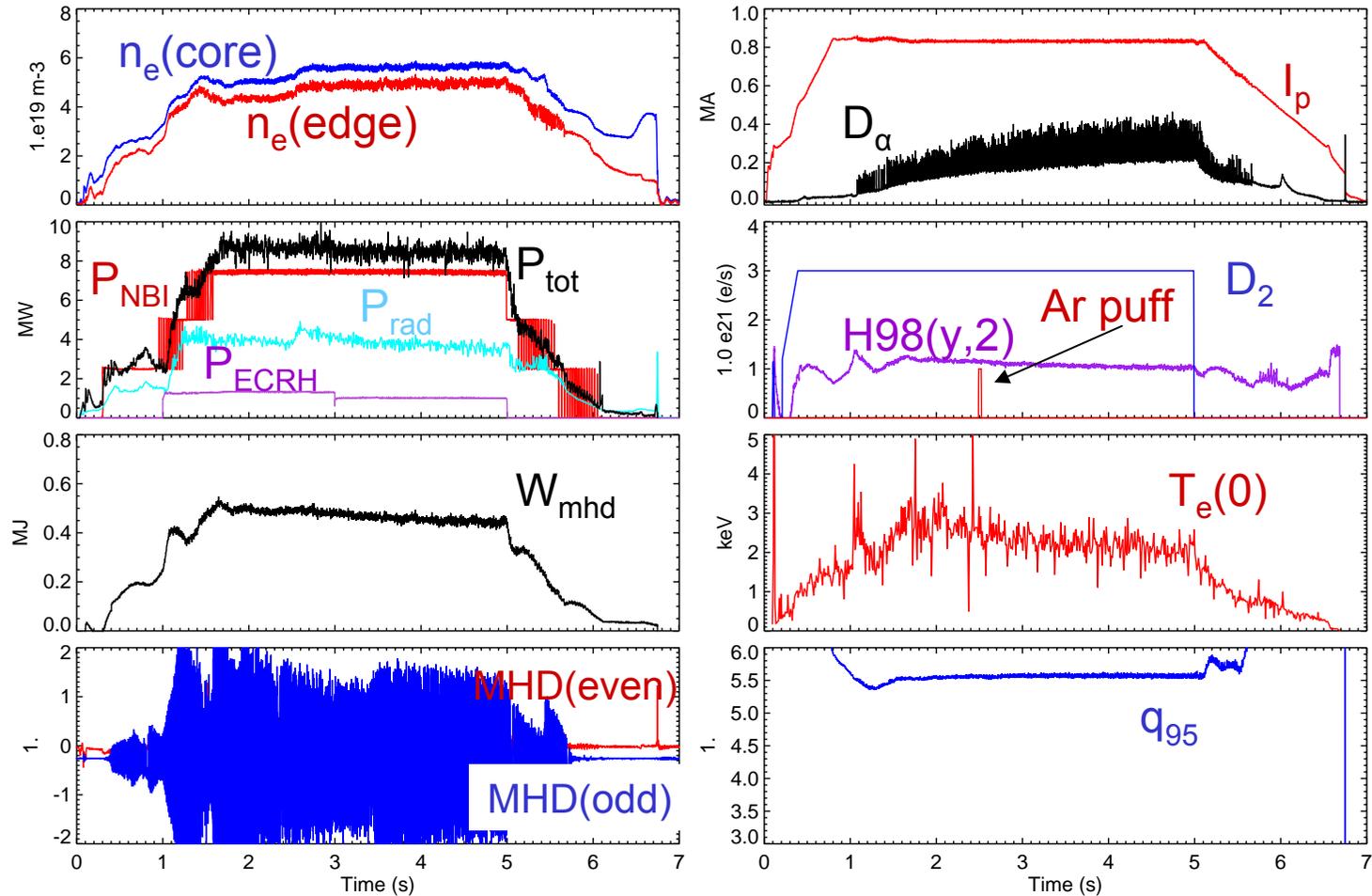
small diagnostic Ar puff

$Te(0) > 3$ keV necessary to measure Ar XVIII

The same shot needs to be repeated in order to measure the various transitions of Ar XVIII, XVII and XVI in the same plasma: working hypothesis = the same Ar density is measured in each discharge

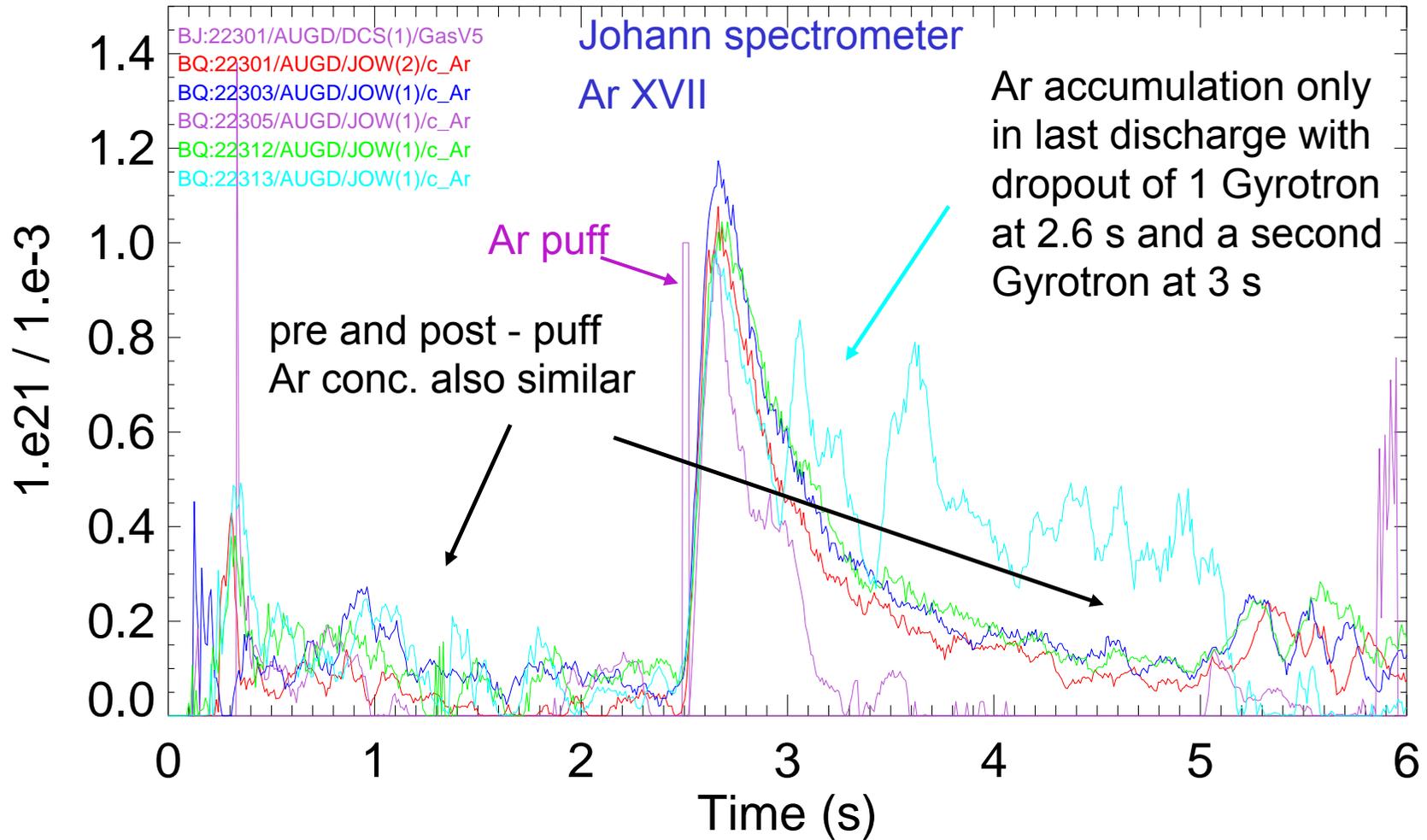
No evidence of impurity accumulation from SXR measurements (Ar XVII, Johann spectrometer)

Example of AUG discharge: #22301



cview (gdc) v3.45 - User: cfm - Mon Oct 8 15:29:20 2007 cfm/cview/StdSet/Ar_CXRS.cvs : 22301

Similar evolution of Ar conc. from shot to shot:



Measured transitions



| Transition | Ar XVIII (Å) | Ar XVII (Å) | Ar VI (Å) |
|------------|-----------------|----------------|--------------|
| 14-13 | * | * | 4365.23 |
| 15-14 | 4275.23 | 4793.17 | 5411.03 |
| 16-15 | 5223.87 | 5856.62 | 6611.65 |
| 17-16 | n.m. | * | * |

- Only 5 discharges were allowed for this experiment
- both core CXRS spectrometers used, focussed on NB sources with slightly different beam energies (60 and 93 kV)
- however this is taken into account in the density calculation and the discrepancy between the 2 CX data sets at a given energy > than variation of cross sections between 30 and 46 keV/amu

* outside wavelength range of AUG core CXRS spectrometers

n.m below detection limit of CER and outside λ range of CHR

The experiment was successful

7 new spectral regions were measured

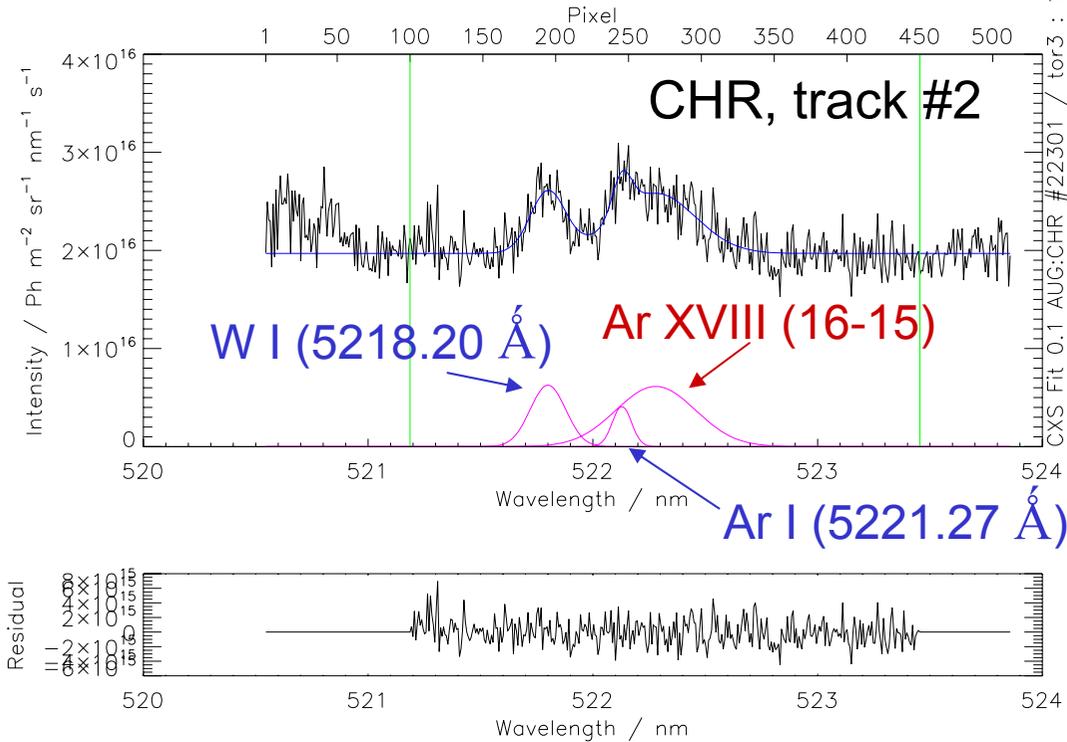
Fitting of the spectra is in progress: challenging!

First measurements of Ar XVII CX lines

Ar CX atomic data are in place and ready to be used (in ADAS format), **except for effective CX rate coefficients for n=2 beam donor (adf12)**

Analysis in progress ... : first consolidate fits of intensities, then run cheap code for Ar density calculations using the two atomic data sets, compare with Ar density from absolutely calib. SXR signals of Ar XVII

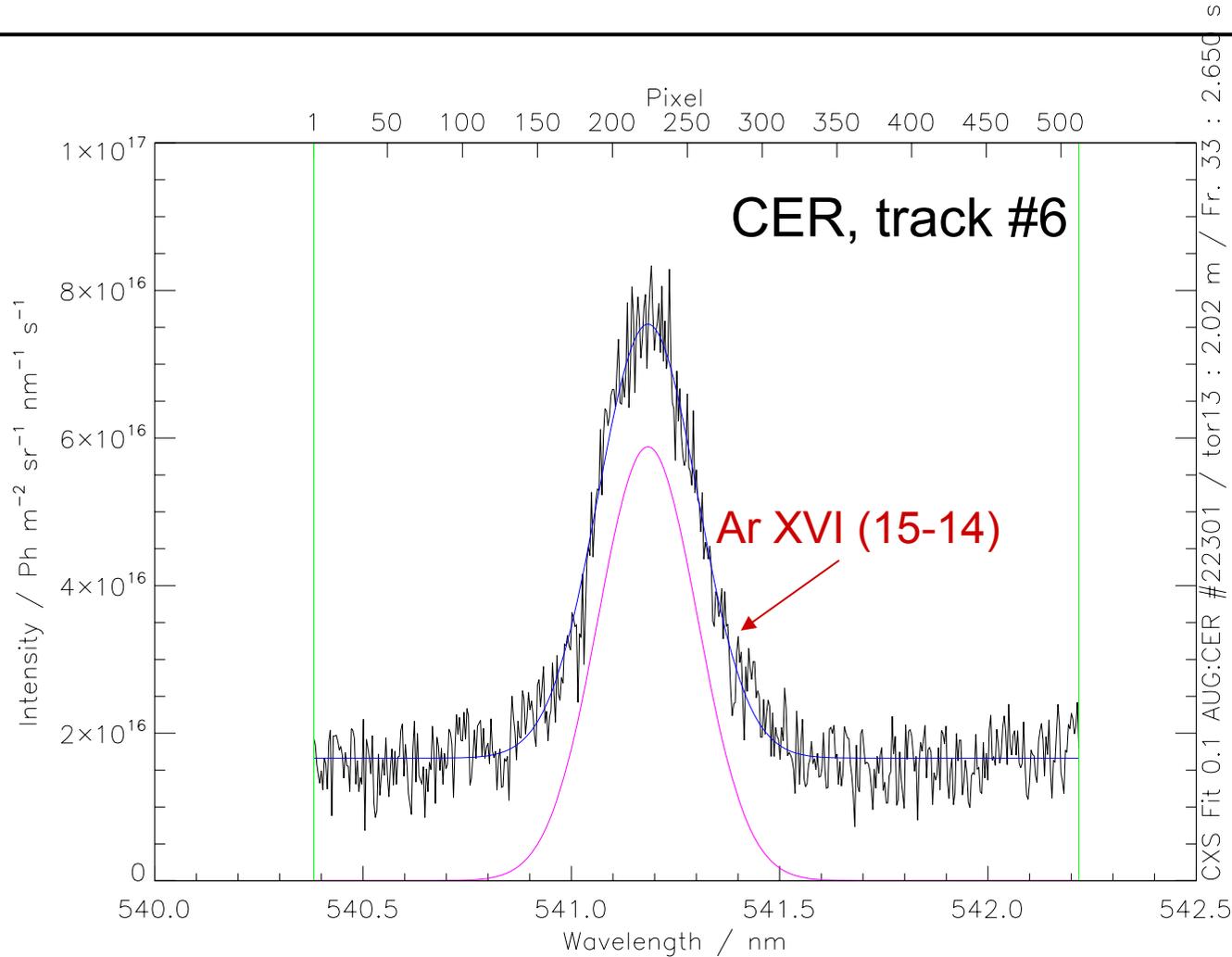
Example of spectra (preliminary fits!)



Ar XVIII (16 – 15)

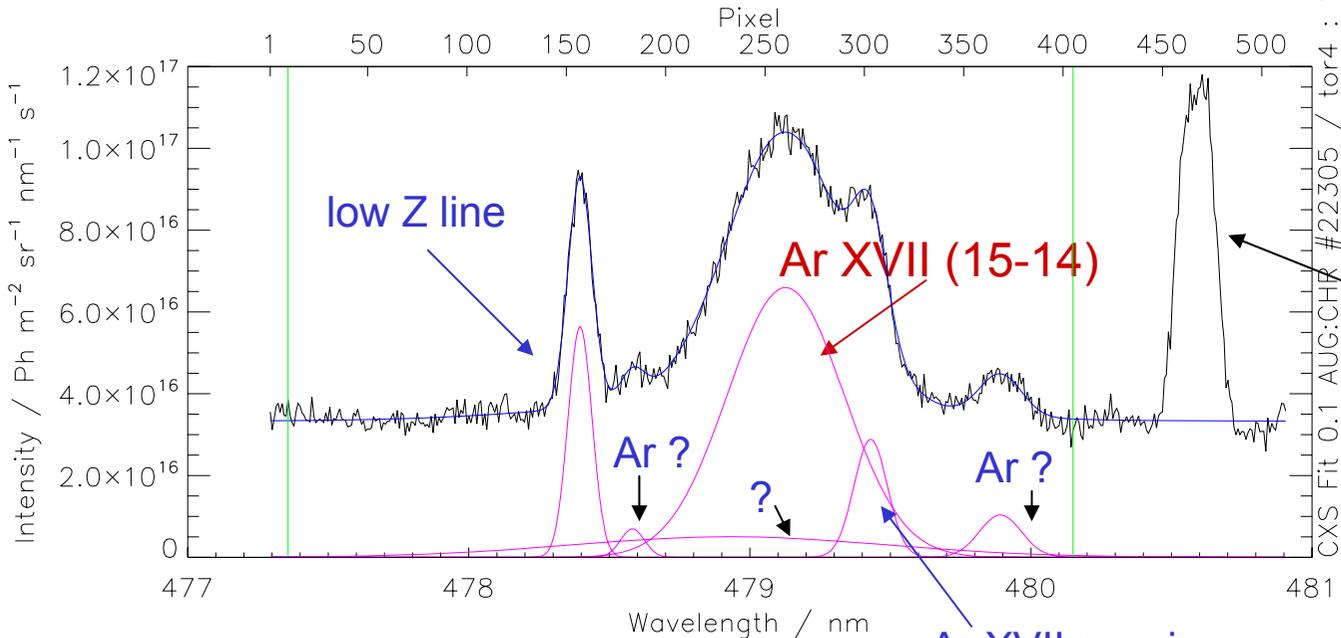
Fr. 34 : 2.750 s / tor3 : 1.77 m / CXS Fit 0.1 AUG:CHR #22301

Example of spectra (preliminary fits!)



Ar XVI (15 – 14)

Example of spectra (preliminary fits!)



Ar XVII (15 – 14)

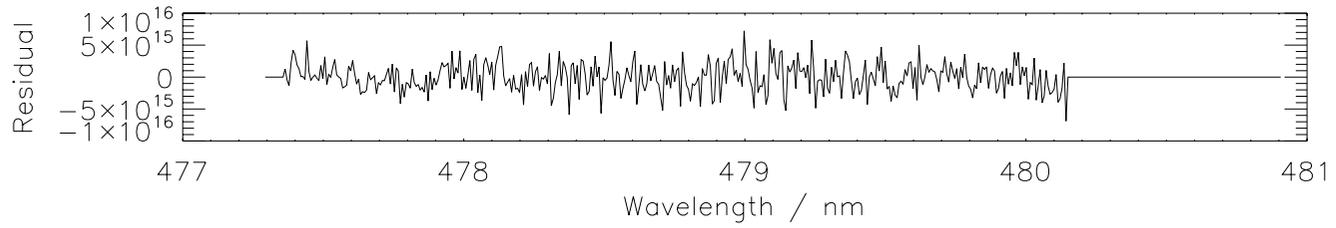
Ar II (4806.02 Å)

Not yet understood!

Ti too high compared to Ar XVIII and Ar XVI

Ti = 6477.7 eV

CHR, track #3, t=2.75 s

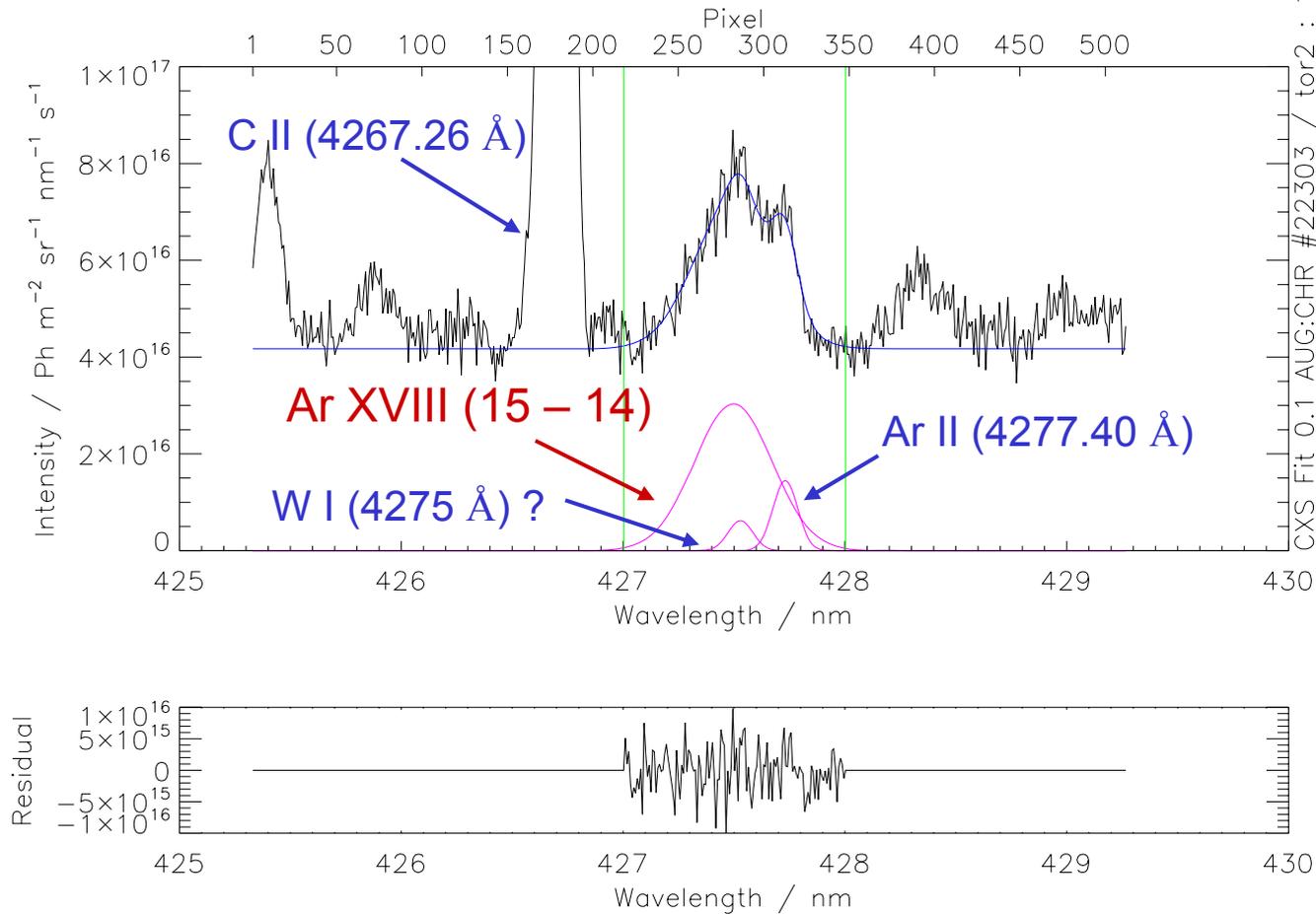


CXS Fit 0.1 AUG:CHR #22305 / tor4 : 1.81 m / Fr. 34 :

Example of spectra (preliminary fits!)



CXS Fit 0.1 AUG:CHR #22303 / tor2 : 1.73 m / Fr. 34 : 2



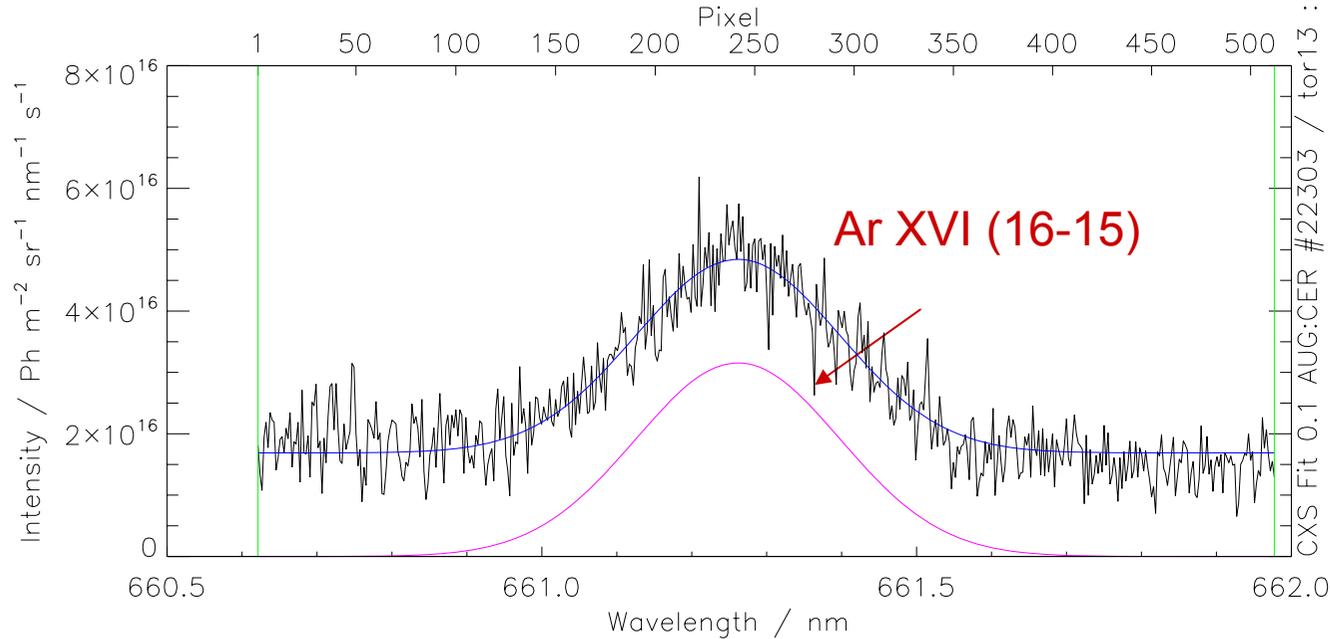
Ar XVIII (15 – 14)

CHR, track #1

Example of spectra (preliminary fits!)

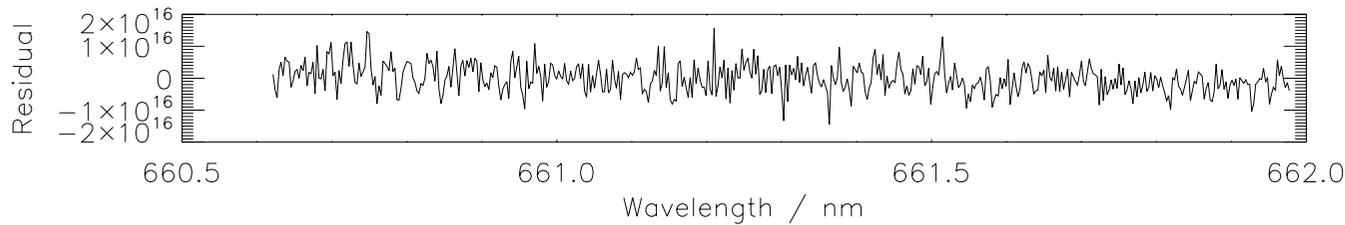


CXS Fit 0.1 AUG:CER #22303 / tor13 : 2.02 m / Fr. 34 :

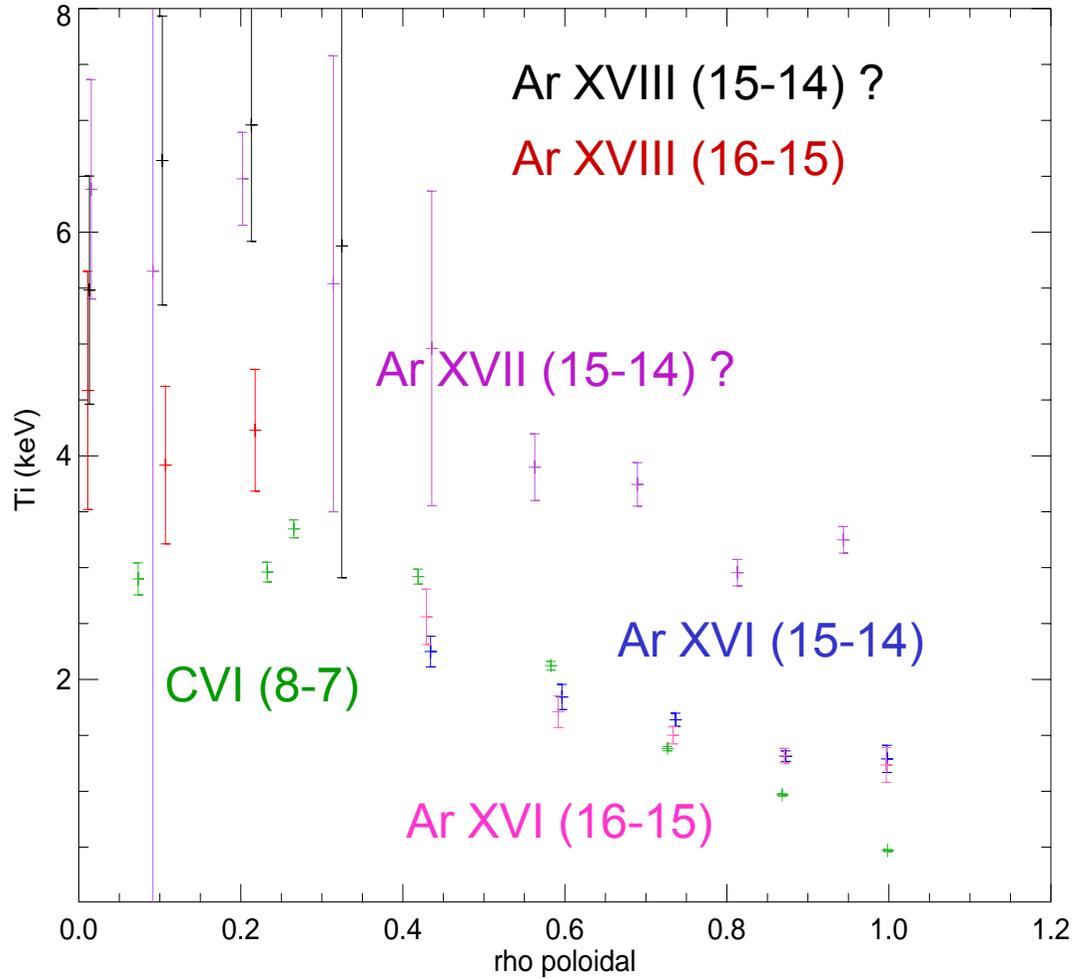


Ar XVI (16 – 15)

CER, track #6



Preliminary spectral analysis: Ti profile as check



cview-prof (gdc) v2.49 - User: cxrs - Wed Oct 10 16:23:19 2007 /afs/ipp/home/c/cxrs/cview/StdSet/Ar_CXRS_Ti.cvp : 0