University of Strathclyde
Glasgow

# State of CX analysis tools

Martin O'Mullane
Department of Physics
University of Strathclyde

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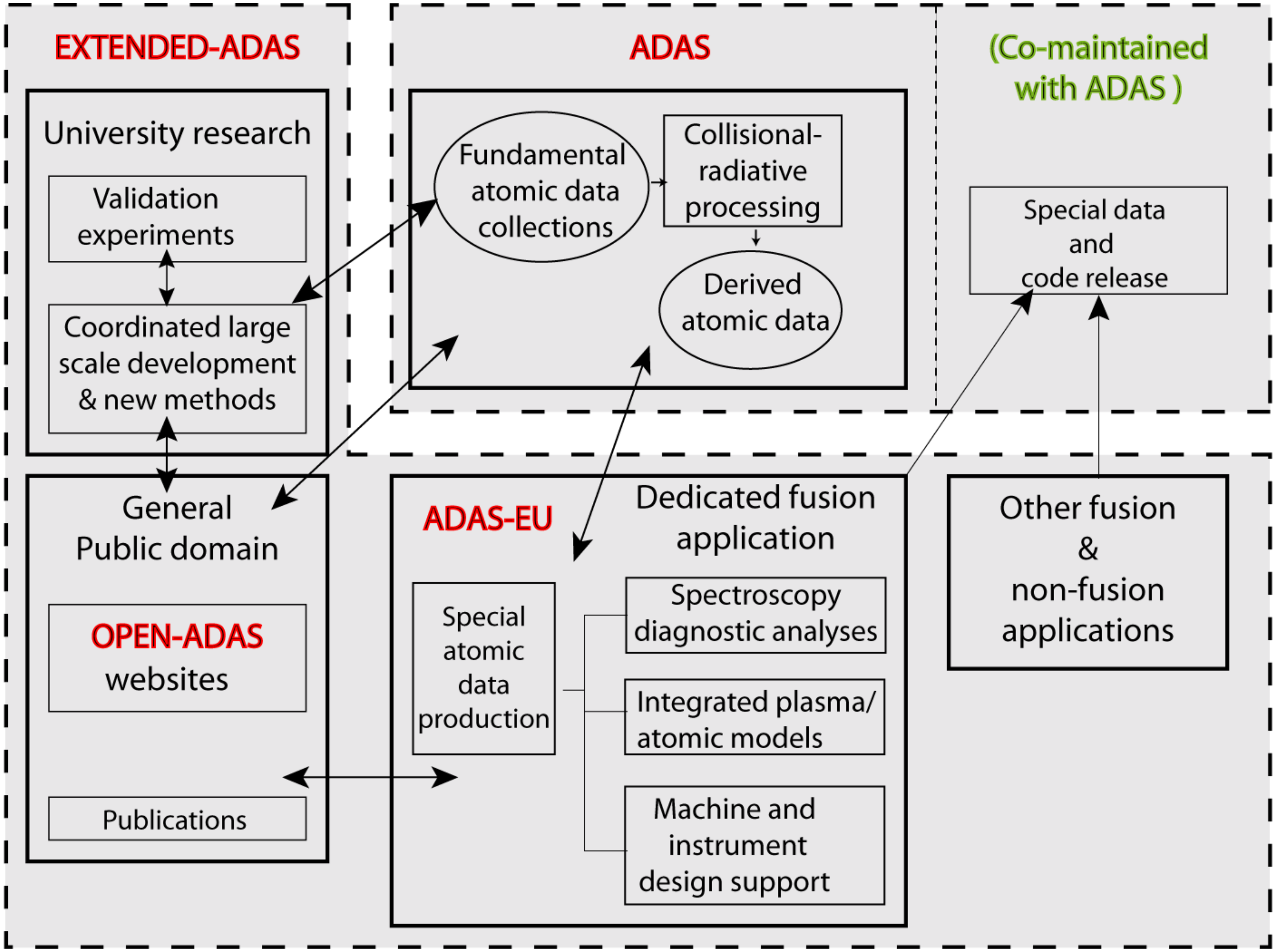
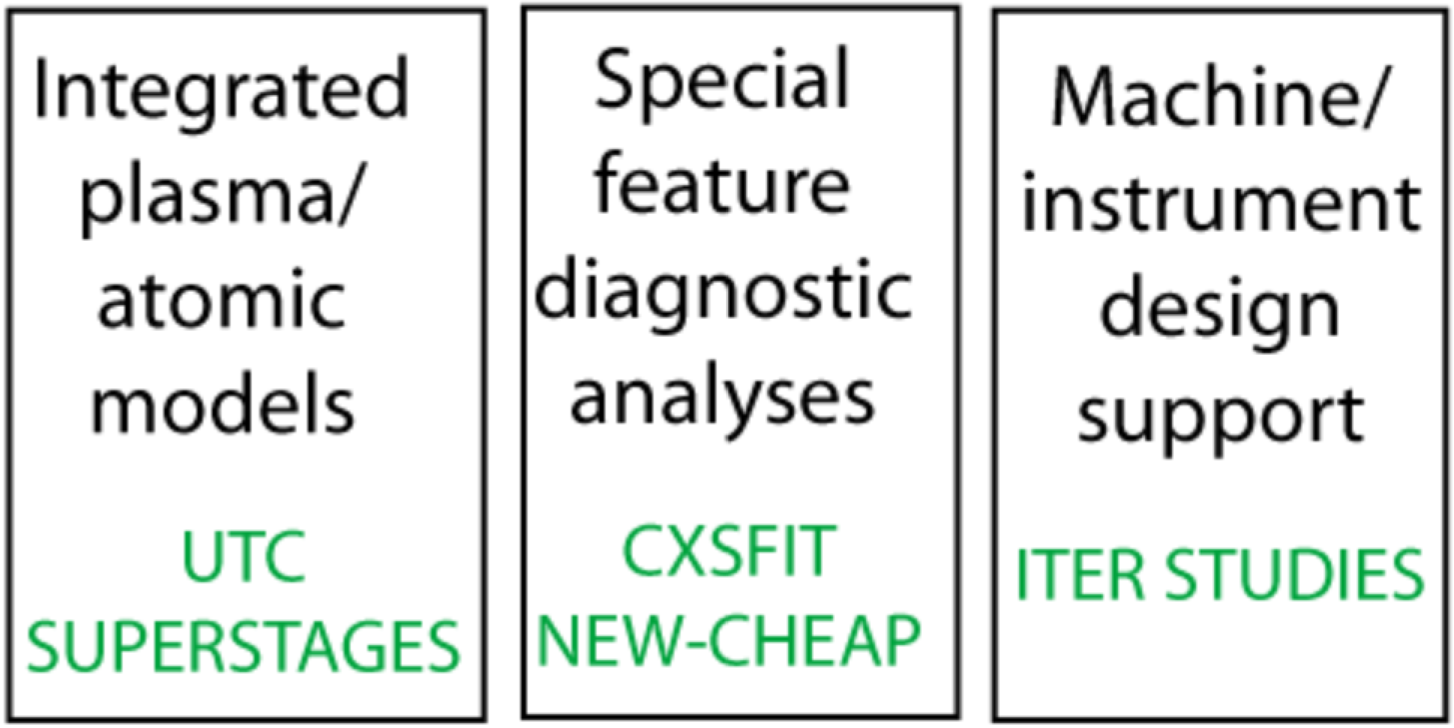
# The ADAS family and relationships


EXTENDED-ADAS
University research
Validation experiments
Coordinated large scale development & new methods
General Public domain
OPEN-ADAS websites
Publications
ADAS
Fundamental atomic data collections
Collisional-radiative processing
Derived atomic data
(Co-maintained with ADAS )
Special data and code release
ADAS-EU
Dedicated fusion application
Special atomic data production
Spectroscopy diagnostic analyses
Integrated plasma/ atomic models
Machine and instrument design support
Other fusion & non-fusion applications

# Codes co-developed with ADAS

Although ADAS data is used in many codes — SOLPS, EDGE2D, TRANSP, STRAHL, ITM — a number of plasma analysis codes have been developed by ADAS personnel and are co-maintained with ADAS.



Integrated plasma/ atomic models

UTC
SUPERSTAGES

Special feature diagnostic analyses

CXSFIT
NEW-CHEAP

Machine/ instrument design support

ITER STUDIES

# CXSFIT — Charge Exchange Fitting

Developed by:

- Allan Whiteford (ADAS)
- M G von Hellermann, Thijs Versloot (FOM/Jülich)
- K-D Zastrow, T M Biewer,$^\star$ C Giroud and A G Meigs (CCFE/JET)
- L D Horton (EFDA)
- C F Maggi, J Schirmer, T Pütterich, R McDermott (IPP-Garching)

$\star$ Permanent institution: ORNL

Documentation:

- http://www.adas.ac.uk/notes.php or
- http://edoc.mpg.de/371982

# Background

Fitting charge exchange spectra has always been a complicated process:

- on the fly wavelength calibration (based on Be line position),
- the passive signals means a one Gaussian fit is usually not possible,
- other lines make it difficult to fit the background,
- using carbon temperatures to aid in the fitting of helium spectra,
- coupling line positions together based on known wavelengths,
- now we have tungsten contaminating the spectra,
- and many many more.

von Hellermann and co-workers developed advanced techniques to solve all of these issues at JET — resulted in a computer code called KS4FIT.

# KS4FIT

Practical implementation of charge exchange fitting at JET was called KS4FIT:

- originally written for the IBM but ported to Linux,
- reads spectra (JPFs) and writes results (PPFs),
- had a TSO/ISPF-style interface,
- now replaced by CXSFIT.

However, KS4FIT exists outside of JET where it is a different thing:

- same core fitting algorithm,
- input and output are completely different,
- packaged along with InSPECtor (JAVA fitting code).

It's the latter version of KS4FIT (the pure fitting engine) which CXSFIT uses.

# CXSFIT

CXSFIT is a joint development between ADAS, FOM, Garching, Jülich and UKAEA to provide a universal interface to KS4FIT.

Graphical user interface written in IDL.

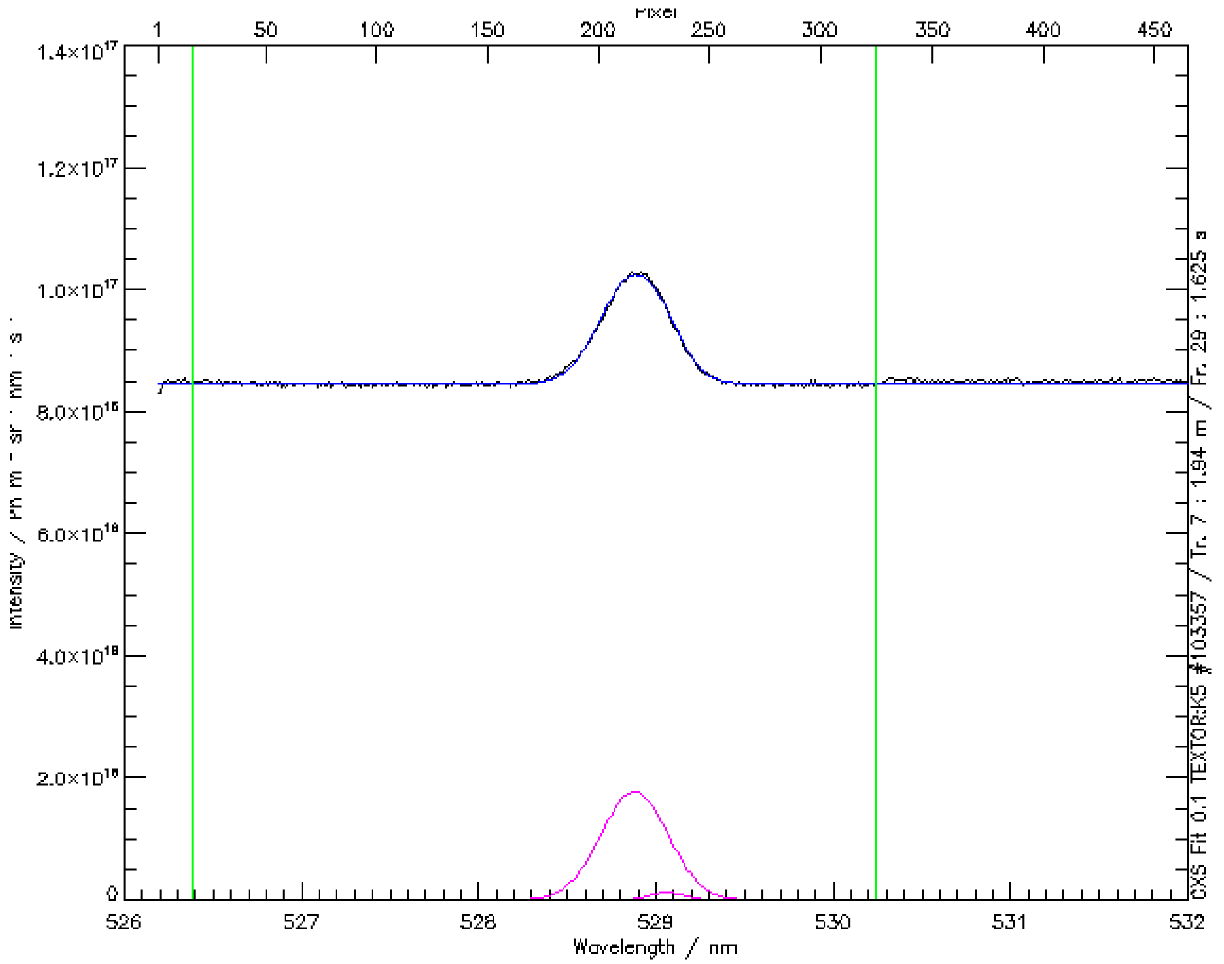
Contains all of the features present in KS4FIT.

Provides visualisation of each fit and of the overall results.

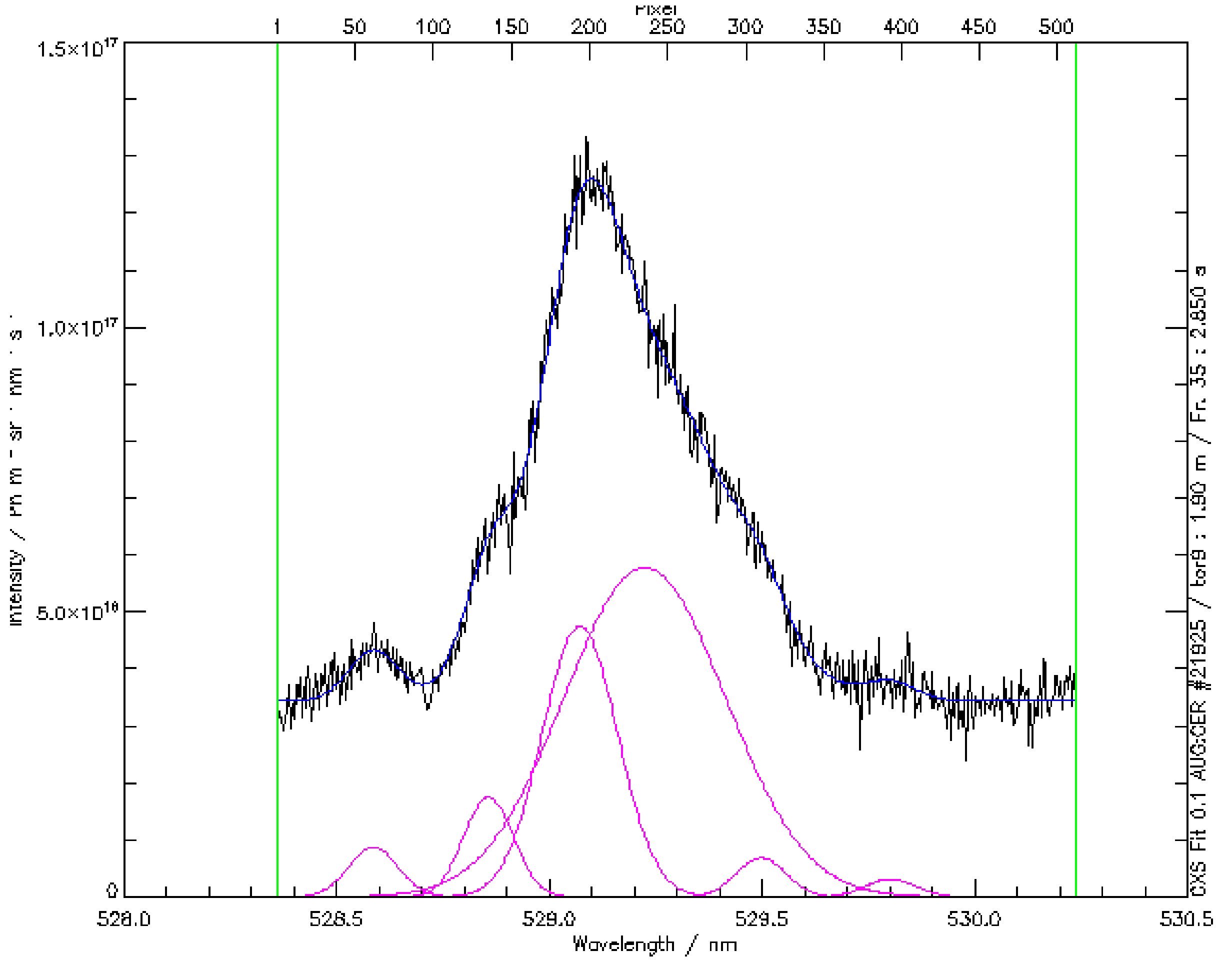
Almost all of the code is machine independent:

- Machine specific reading/writing routines need to supplied.
- Now have identical code running on AUG, JET, TEXTOR and Tore Supra!

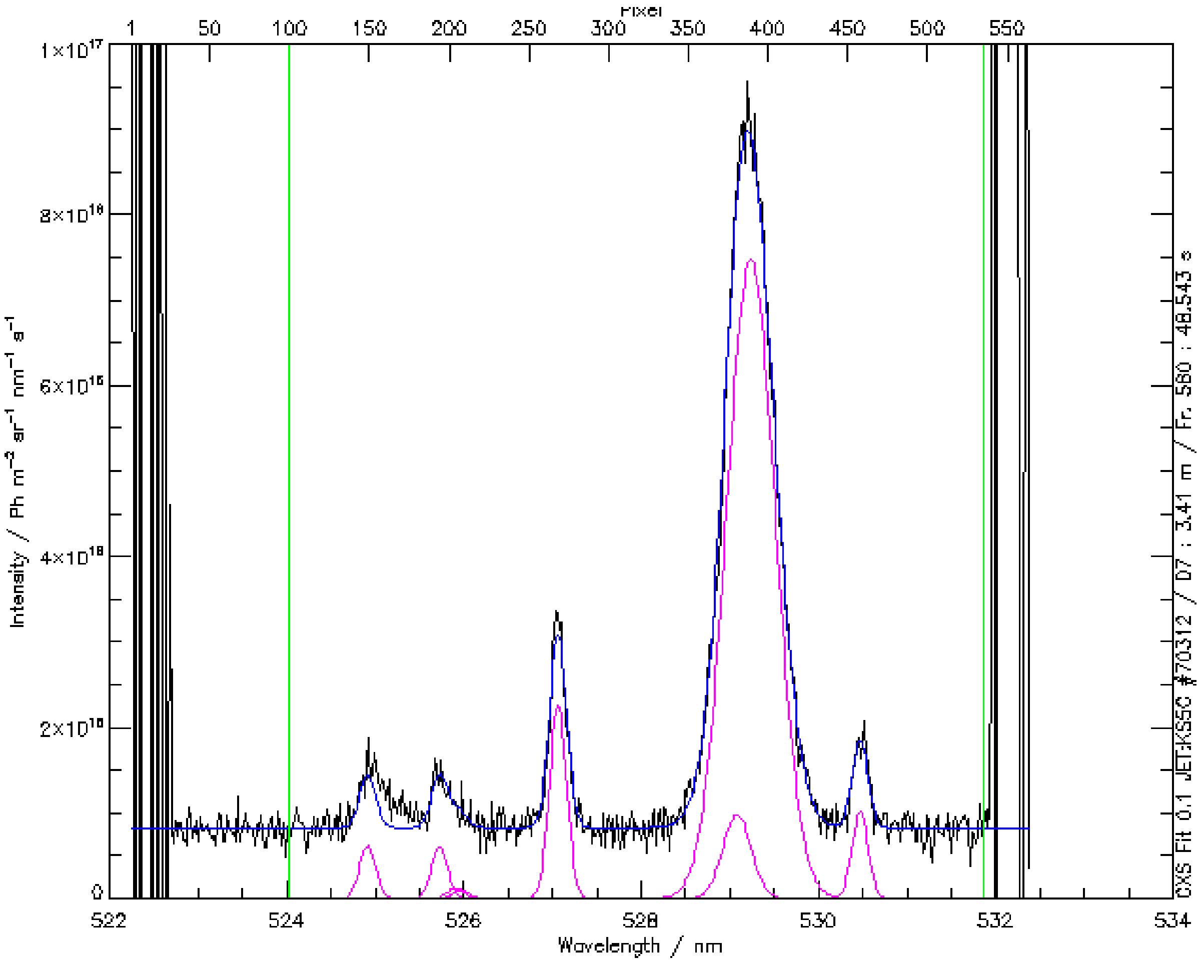
# Example spectra — TEXTOR



# Example spectra — AUG



# Example spectra — JET



# Current usage and deployment

Used exclusively on all JET core spectroscopy systems (KS5A-E),

- Reads from JPFs and takes geometry etc. from central location.
- Writes directly to PPFs.

Used at AUG on CER and CHR core systems plus CHZ edge system,

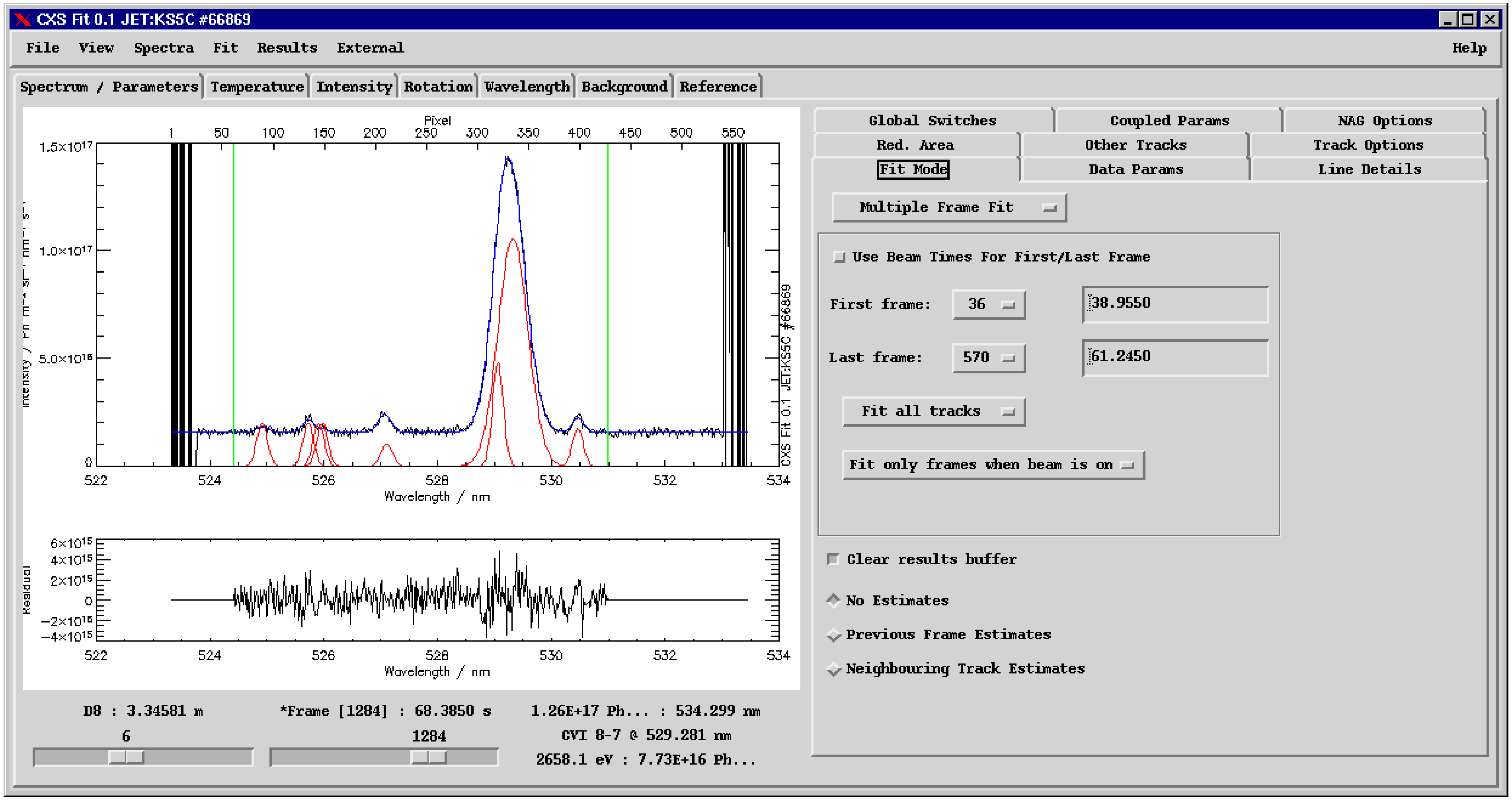
- Reads level-0 shotfiles (spectra) and geometry etc. from central location.
- Writes directly to level-1 shotfiles compatible with cview.

Replaced InSPECtor at TEXTOR on all Kameras (1-6).

- Reads directly from TWU (both spectra and all other information).
- Writes directly to TEXTOR TPD system.

In routine use on Tore Supra at CEA Cadarache.

# The Graphical Interface



Multiple Frame Fit

□ Use Beam Times For First/Last Frame

First frame: 36 38.9550

Last frame: 570 61.2450

Fit all tracks

Fit only frames when beam is on

□ Clear results buffer

◆ No Estimates

◇ Previous Frame Estimates

◇ Neighbouring Track Estimates

D8 : 3.34581 m

6

*Frame [1284] : 68.3850 s

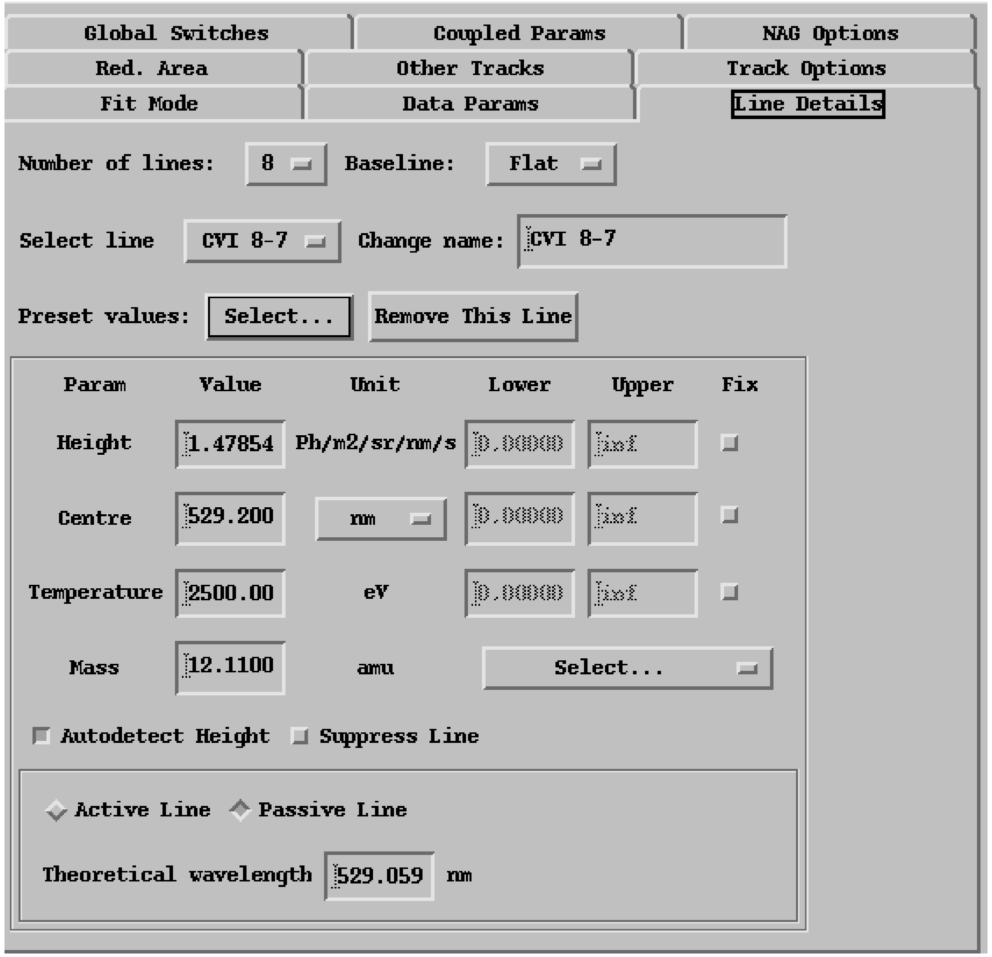
1284

1.26E+17 Ph... : 534.299 nm

CVI 8-7 @ 529.281 nm

2658.1 eV : 7.73E+16 Ph...

# Feature Highlights: In-built line database



Number of lines: 8 Baseline: Flat

Select line CVI 8-7 Change name: CVI 8-7

Preset values: Select...

| Param | Value | Unit | Lower | Upper | Fix |
|---|---|---|---|---|---|
| Height | 1.47854 | Ph/m2/sr/nm/s | 0.00000 | inf | □ |
| Centre | 529.200 | nm | 0.00000 | inf | □ |
| Temperature | 2500.00 | eV | 0.00000 | inf | □ |
| Mass | 12.1100 | amu | Select... | | |

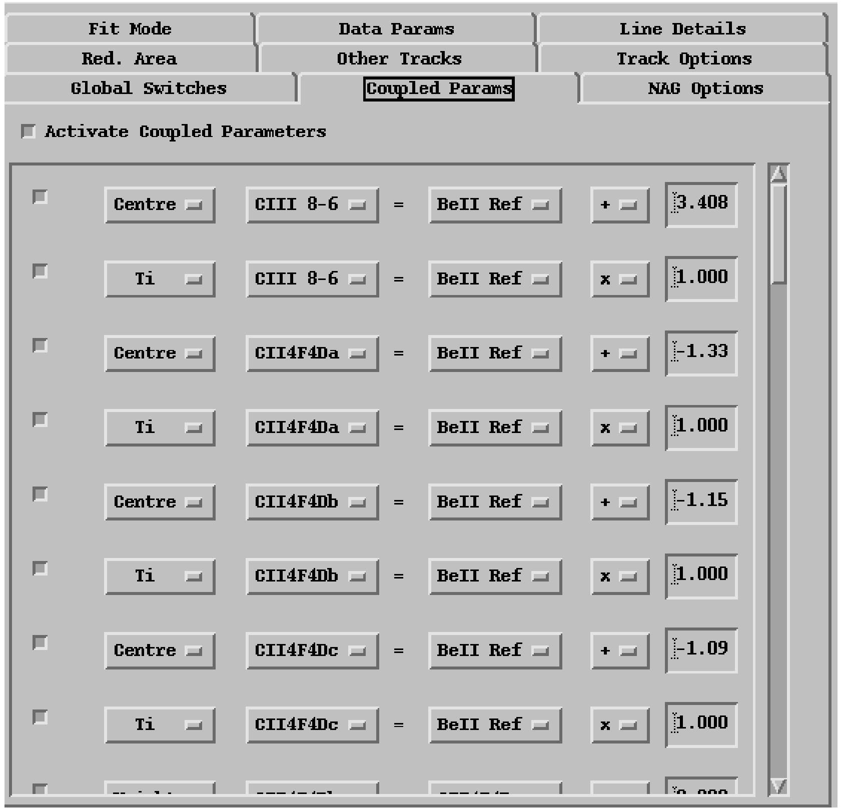
□ Autodetect Height □ Suppress Line

◇ Active Line ◇ Passive Line

Theoretical wavelength 529.059 nm

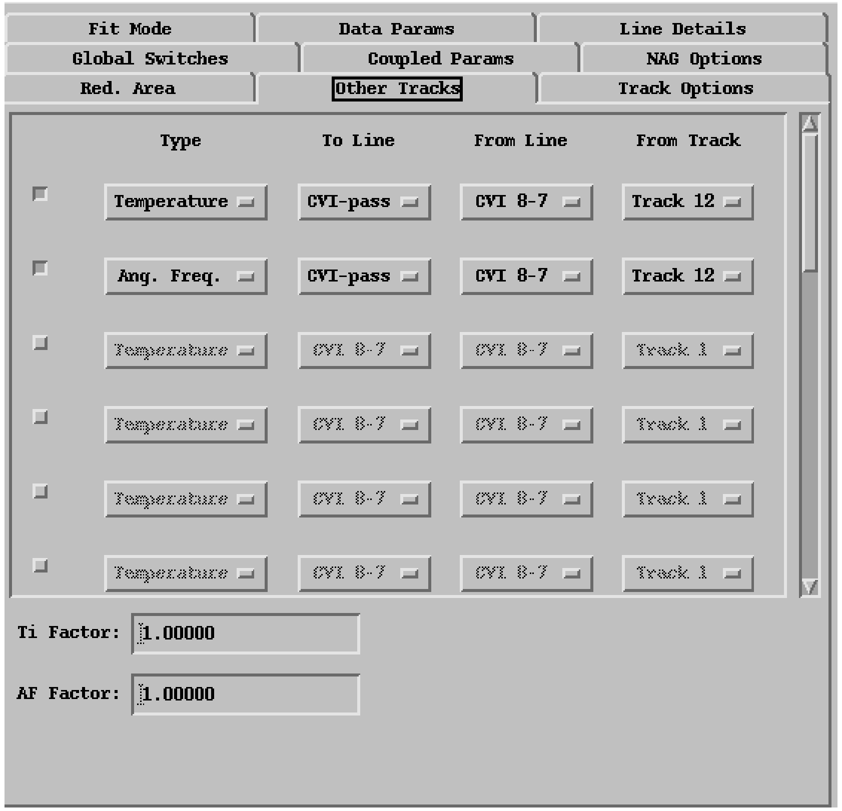
- Very high quality observed wavelengths included in program.
- Gives best quality rotations and on-the-fly calibration.
- If wanted, can be selected automatically based on line position.
- Can be overridden by the user if necessary.

# Feature Highlights: Complex coupling



□ Activate Coupled Parameters

| | | | | | | |
|---|---|---|---|---|---|---|
| □ | Centre | CIII 8-6 | = | BeII Ref | + | 3.408 |
| □ | Ti | CIII 8-6 | = | BeII Ref | x | 1.000 |
| □ | Centre | CII4F4Da | = | BeII Ref | + | -1.33 |
| □ | Ti | CII4F4Da | = | BeII Ref | x | 1.000 |
| □ | Centre | CII4F4Db | = | BeII Ref | + | -1.15 |
| □ | Ti | CII4F4Db | = | BeII Ref | x | 1.000 |
| □ | Centre | CII4F4Dc | = | BeII Ref | + | -1.09 |
| □ | Ti | CII4F4Dc | = | BeII Ref | x | 1.000 |



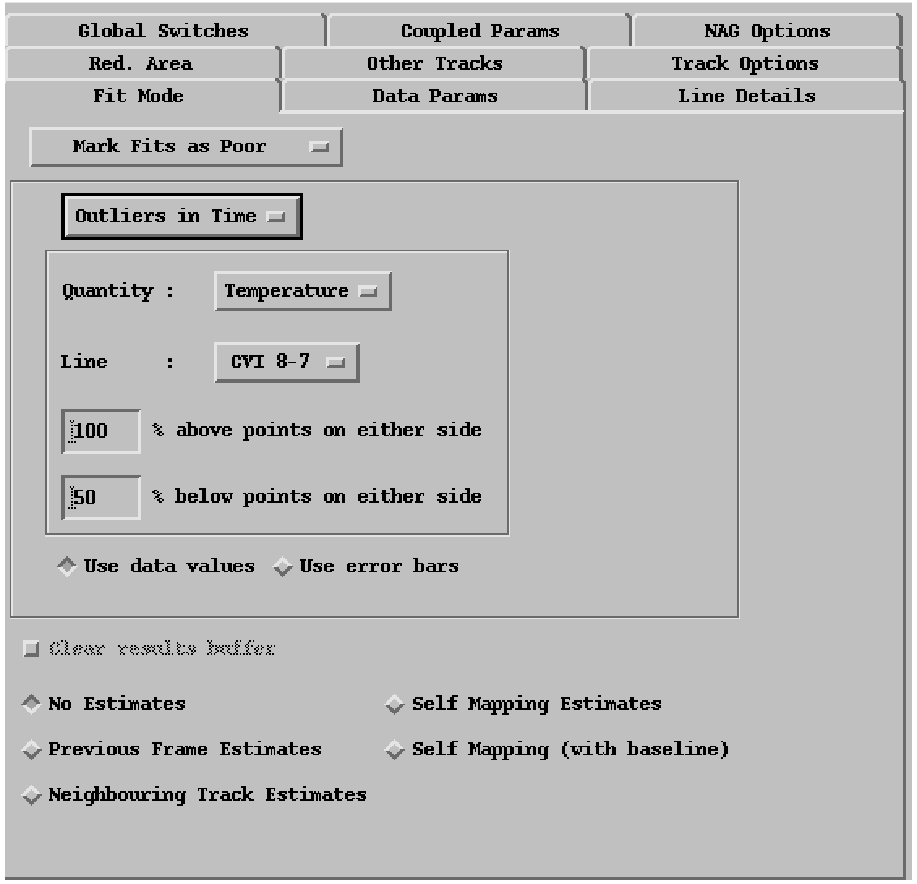
| | Type | To Line | From Line | From Track |
|---|---|---|---|---|
| □ | Temperature | CVI-pass | CVI 8-7 | Track 12 |
| □ | Ang. Freq. | CVI-pass | CVI 8-7 | Track 12 |
| □ | Temperature | CVI 8-7 | CVI 8-7 | Track 1 |
| □ | Temperature | CVI 8-7 | CVI 8-7 | Track 1 |
| □ | Temperature | CVI 8-7 | CVI 8-7 | Track 1 |
| □ | Temperature | CVI 8-7 | CVI 8-7 | Track 1 |

Ti Factor: 1.00000

AF Factor: 1.00000

Can couple inside a spectrum or across tracks.

# Highlights: detecting poor data



Quantity : Temperature

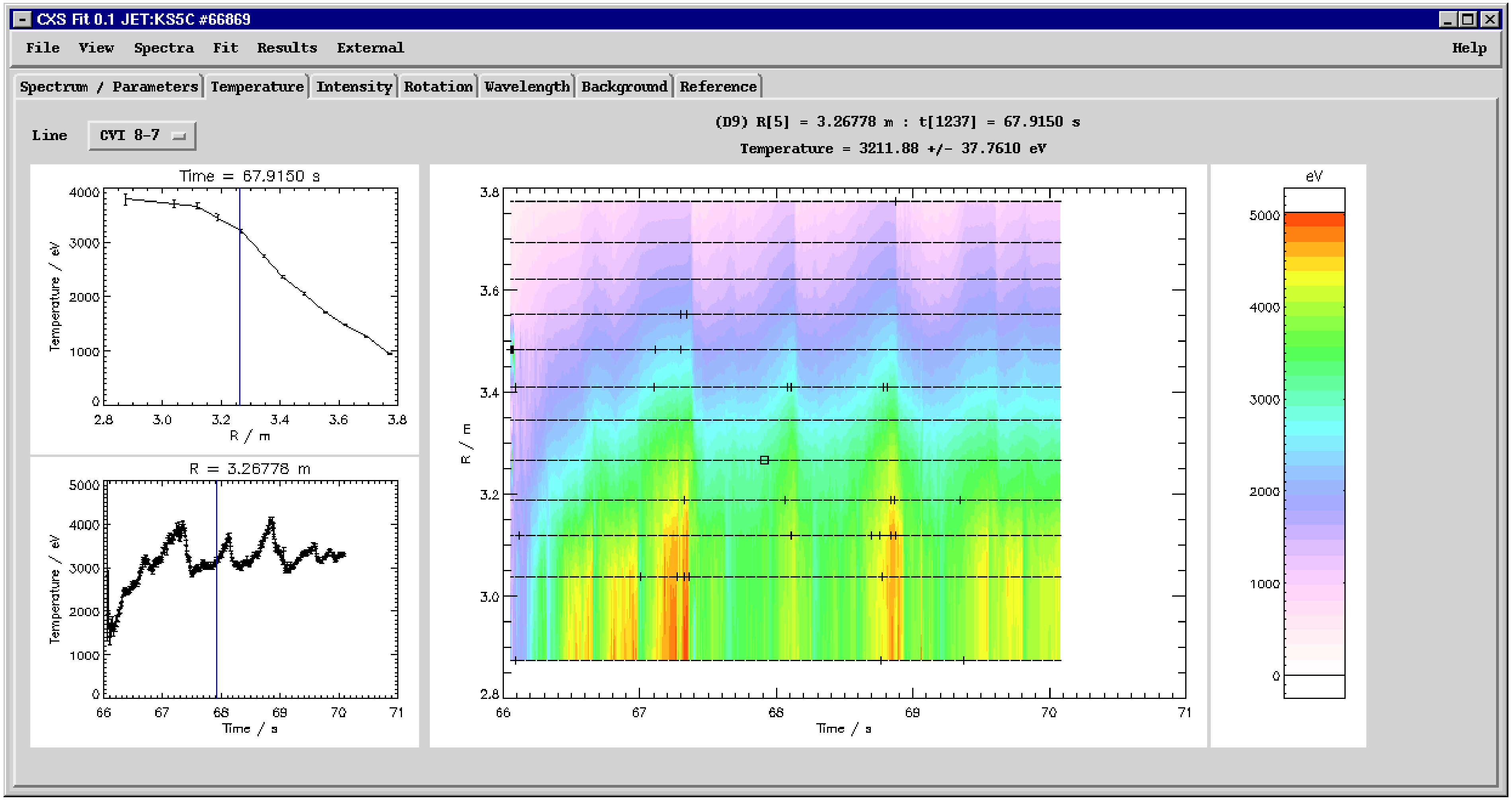
Line : CVI 8-7

100 % above points on either side

50 % below points on either side

- Can do analysis of fit results to check quality/sanity
- Outliers in time or non-physical $T_{\mathrm{i}}$ profiles
- Necessary on systems with high temporal resolution.
- Can be used as part of a more complex analysis.

# Preview of results



(D9) R[5] = 3.26778 m : t[1237] = 67.9150 s

Temperature = 3211.88 +/- 37.7610 eV

# Repairing spectra

Even with all the options available, usually a few of the fits don’t converge.

Marked with crosses (poor fits) or stars (failed fits) in the output preview.

Options exist to refit the failed or poor frames with new fit options:

- ‘standard’ current procedure at JET is to use the previous frame estimates,
- sometimes necessary to do individual fits by hand,
- conceivable that different temporal regions may need different setup entirely.

However, this means that to reproduce results or use the same recipe on a different shot there are multiple parameter settings which need to be used.

# Fit History

CXSFIT stores the fit history, i.e.:

- The list of steps used to produce the current fit in terms of what the fit options were set to each time a fit was initiated.

Fit histories can be saved as default recipes (also written to default output).

Very simple history might be:

1. fit all frames with beam on for all times,
2. fit any failed frames using previous frame estimates,
3. fit any remaining failures using neighbouring tracks option.

Allows the user to load in a spectrum, load a recipe and then “replay” the history. Standard recipes can be developed for particular instruments.

# The command line

CXSFIT can be controlled from the command line for convenience or for batch processing, examples are:

Load a spectrum at startup:

```
– cxsfit cer:17148
```

Do batch processing using the same recipe:

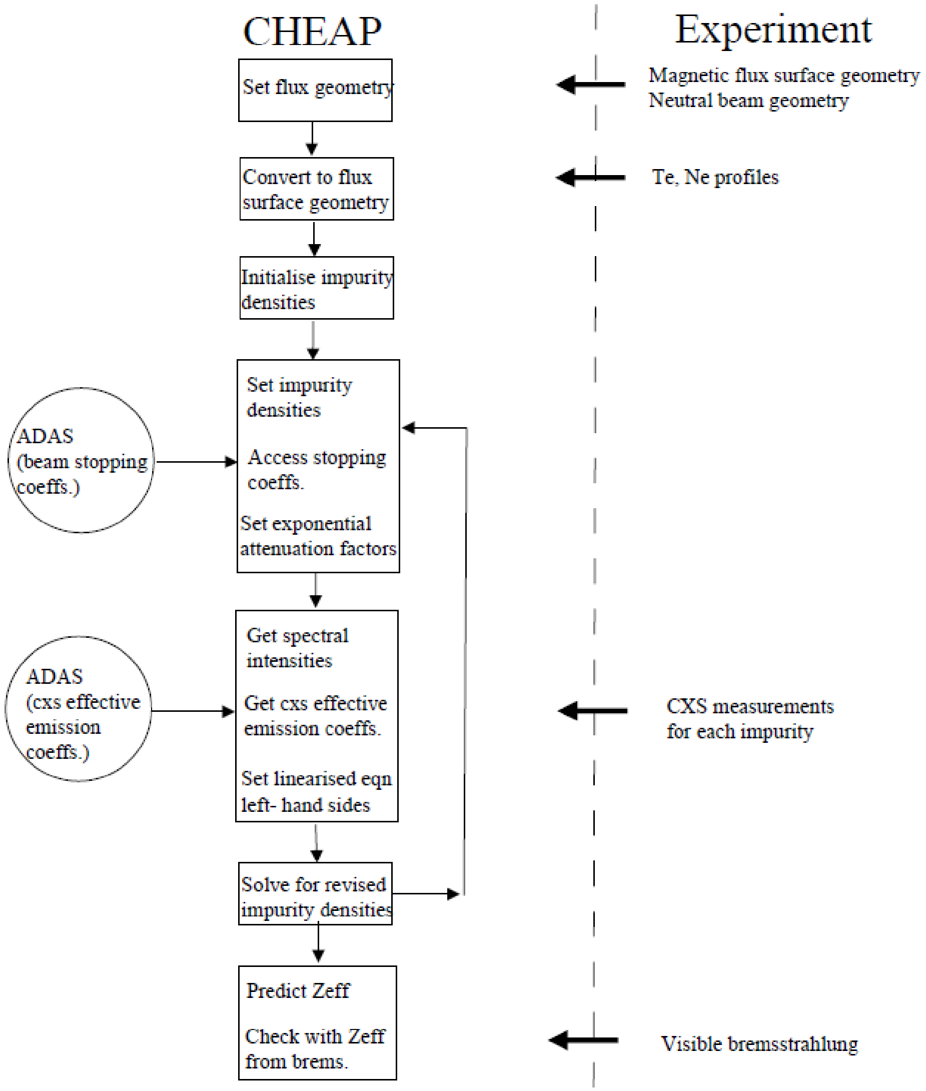
```
– cxsfit ks5c:66869 ks5c_carbon8-7.fit replay save ks5c_66869.cxf quit
– cxsfit ks5c:66870 ks5c_carbon8-7.fit replay save ks5c_66870.cxf quit
– cxsfit ks5c:66871 ks5c_carbon8-7.fit replay save ks5c_66871.cxf quit
```

Reload a previously saved setup:

```
– cxsfit k5_103357.cxf
```

# CHEAP — Charge Exchange Analysis Package

Convert analysed CX spectra into impurity concentration profiles.



CHEAP
Experiment
Set flux geometry
Magnetic flux surface geometry
Neutral beam geometry
Convert to flux surface geometry
Te, Ne profiles
Initialise impurity densities
ADAS (beam stopping coeffs.)
Set impurity densities
Access stopping coeffs.
Set exponential attenuation factors
ADAS (cxs effective emission coeffs.)
Get spectral intensities
Get cxs effective emission coeffs.
Set linearised eqn left- hand sides
CXS measurements for each impurity
Solve for revised impurity densities
Predict Zeff
Check with Zeff from brems.
Visible bremsstrahlung

# CHEAP — present and future

- Developed at JET on IBM but tied to JETisms.
- Developed by M von Hellermann, R Koeing, K-D Zastrow and team.
- Ambition for NEW-CHEAP to match universal nature of CXSFIT.
- Prototype IDL version exists at IPP Garching.
- .... but is a little slow and has not displaced current JET implementation.
- We need new people to help develop the code.

- To learn how to use CXSFIT visit us at either:
  JET, AUG, TEXTOR or Tore Supra.
- Volunteer to work on making a universal NEW-CHEAP.