Charge Exchange for Heavy Species

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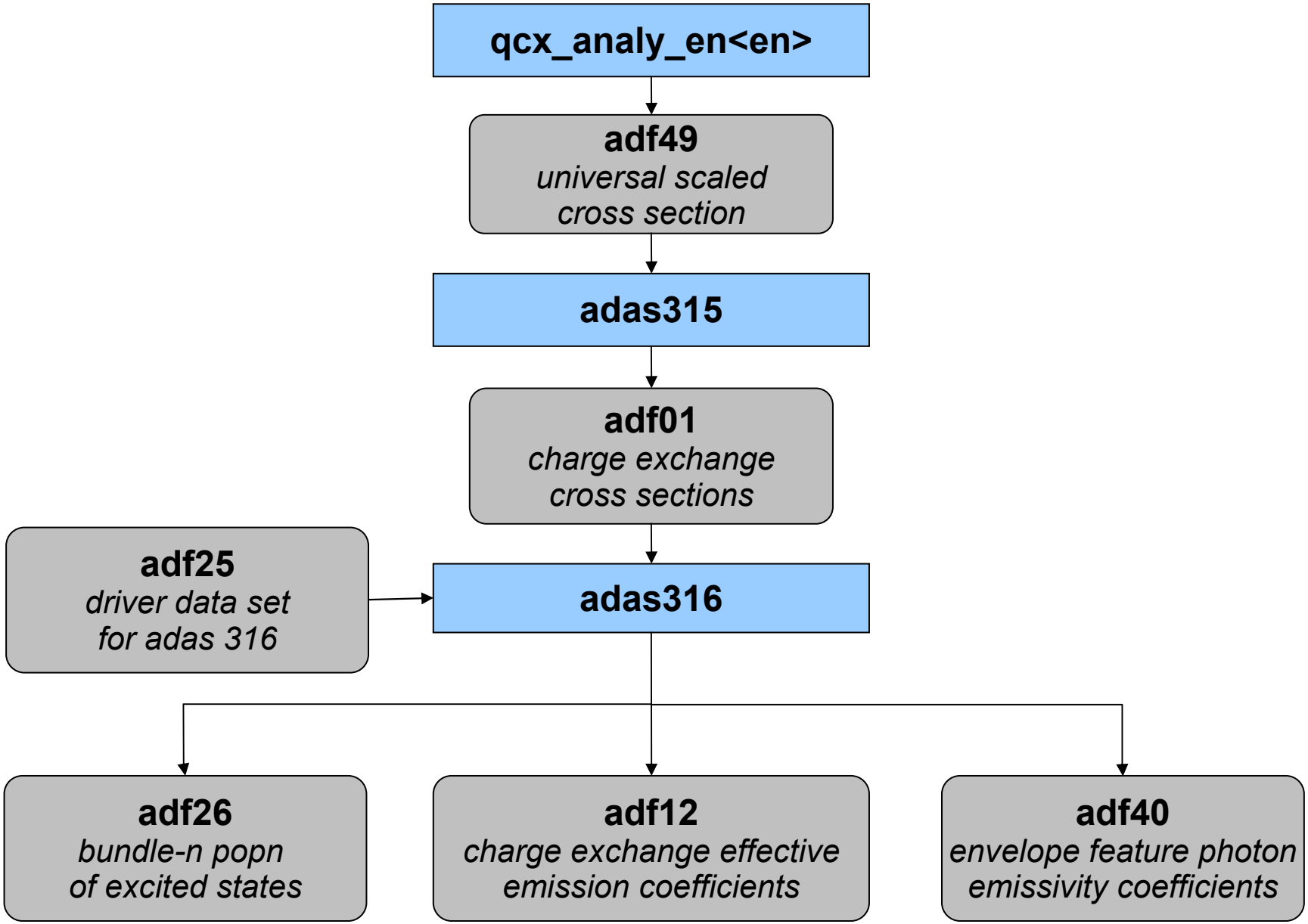
Motivation

- ITER plasmas will contain ~ 1E-6 concentration of tungsten.
- What would tungsten CX emission look like?
- Will it provide useful line features?
- Will it interfere with background measurements (e.g. Bremsstrahlung)
- Estimates of charge exchange emission from tungsten do not exist. This is largely due to the lack of cross section information for these elements.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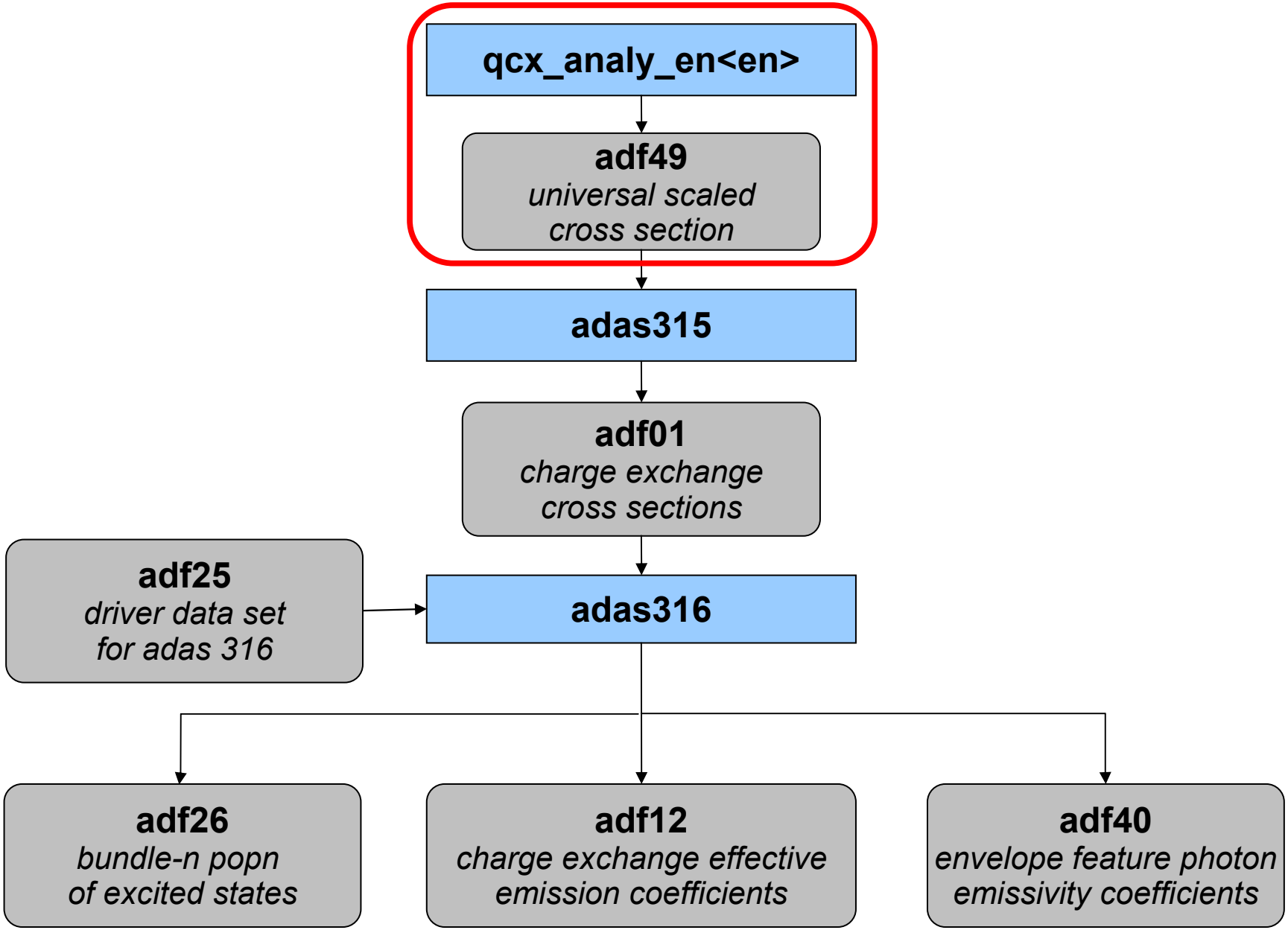
charge exchange effective
emission coefficients
adf40
envelope feature photon
emissivity coefficients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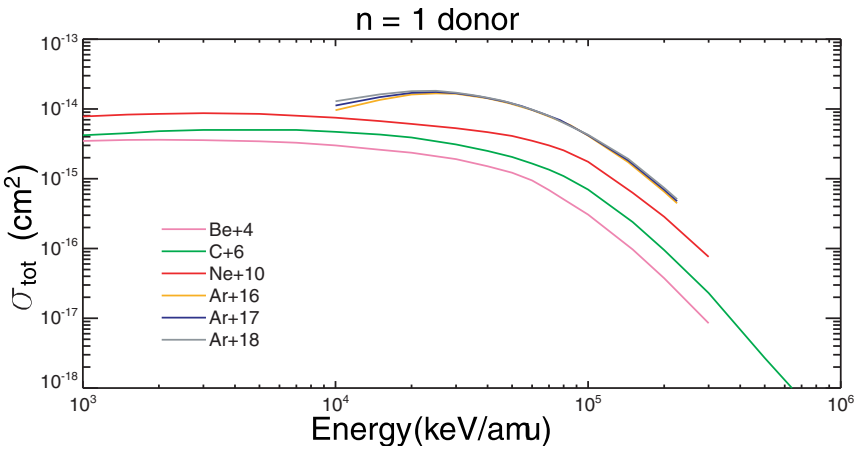
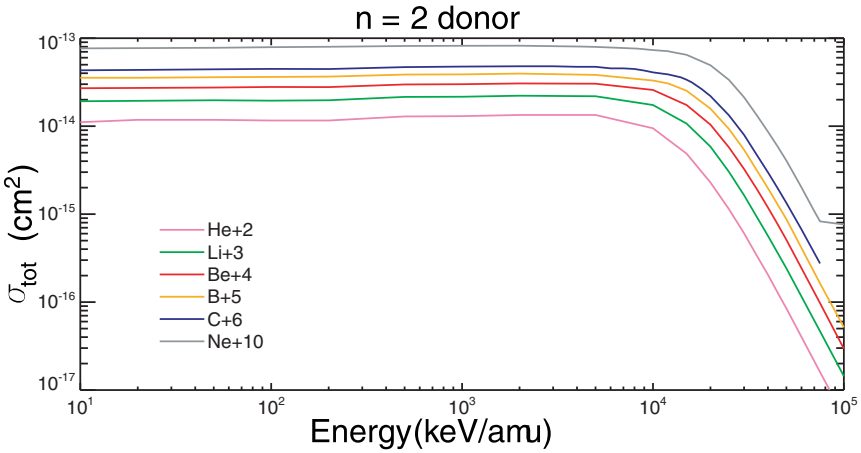
Scaled total CX cross section

n=1



n=2



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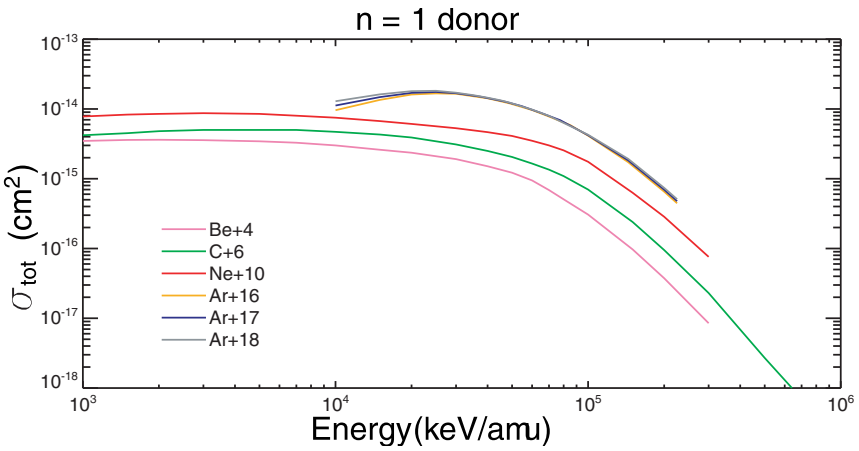

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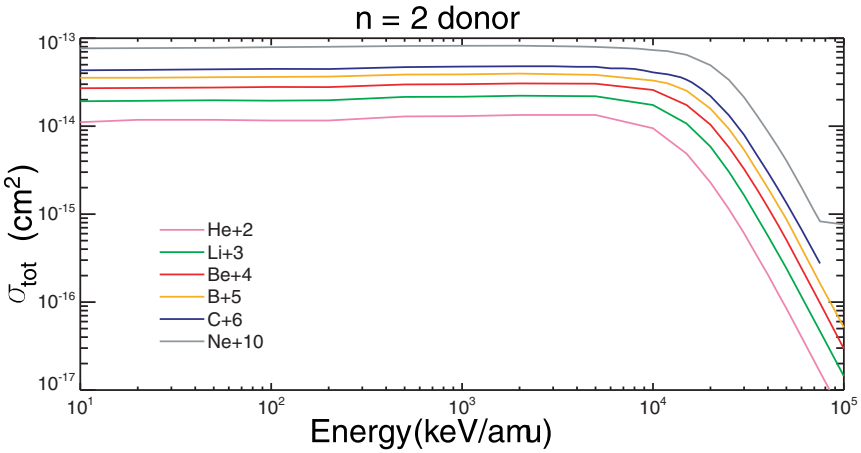

$$\overline{\sigma}_{tot} = \frac{\sigma_{tot}}{Z_1^{\alpha}} \qquad \overline{E} = \frac{E}{Z_1^{\beta}}$$

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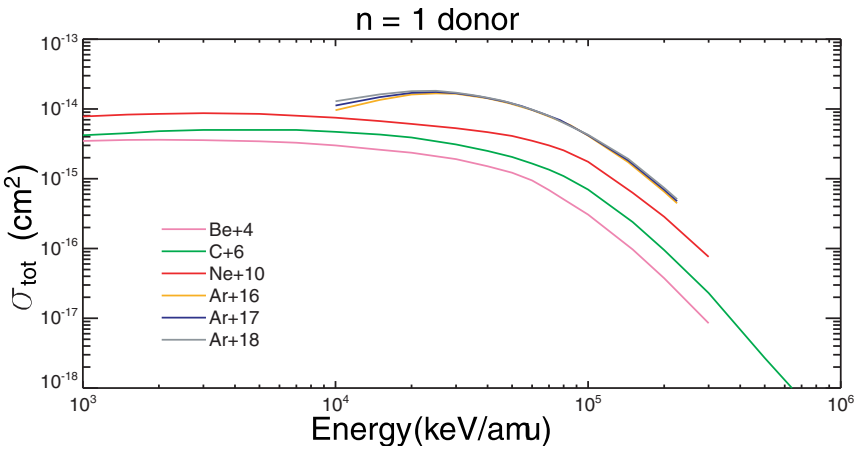

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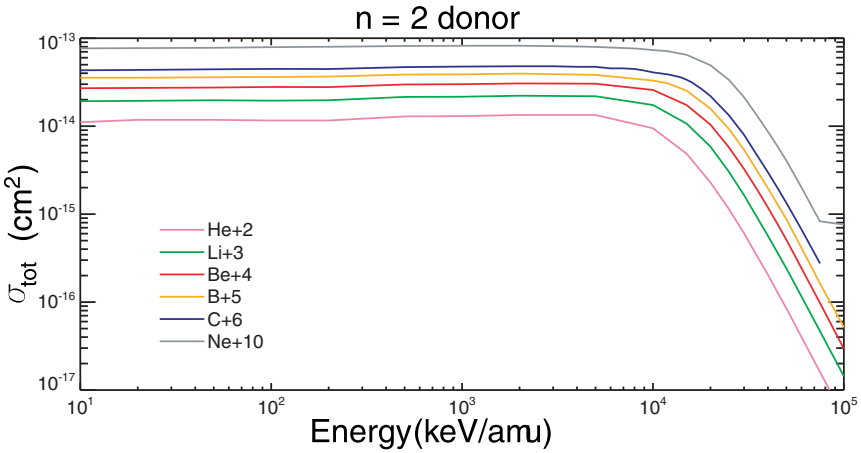

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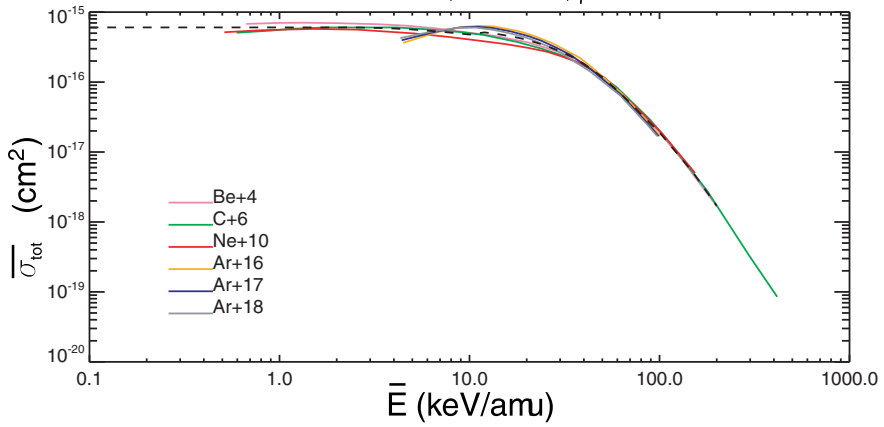
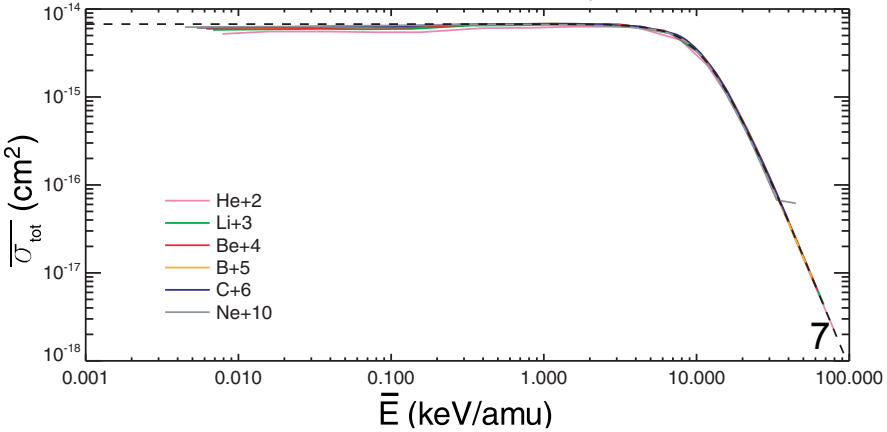
Scaled cross section, α=1.18, β = 0.29

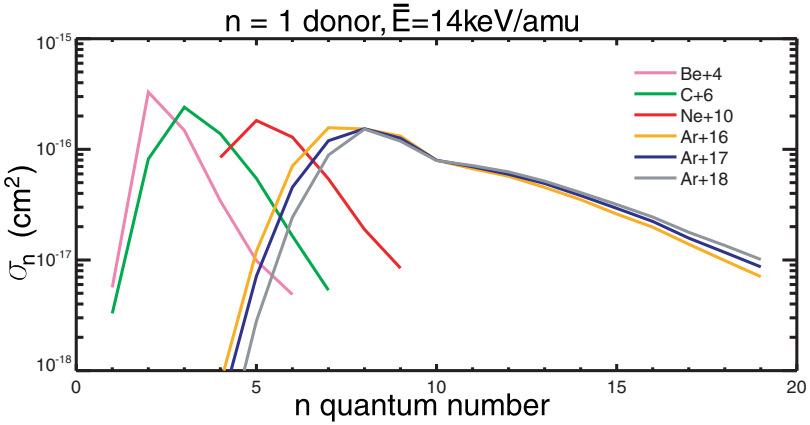


Scaled cross section, α = 1.13, β = 0.25



n resolved cross section

n=1



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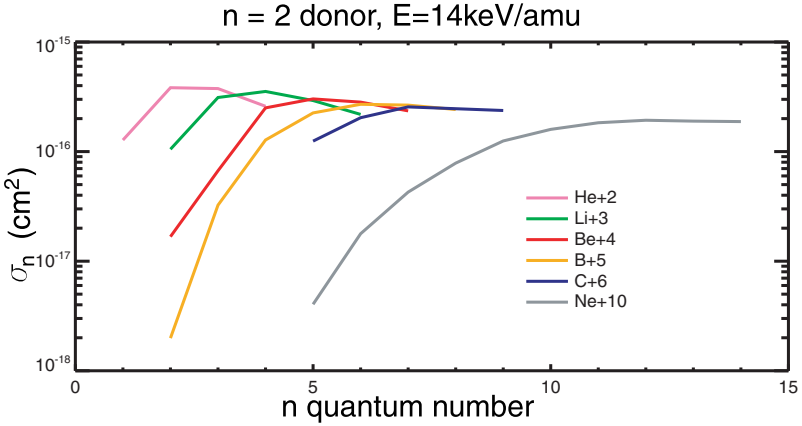

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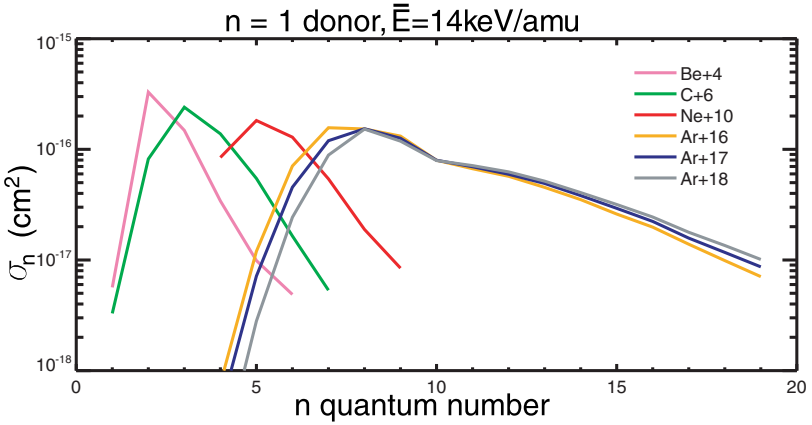

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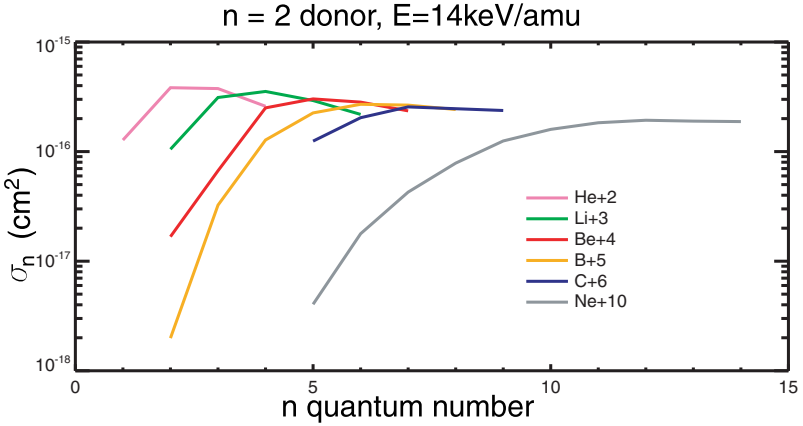

$$\overline{\sigma_n} = \frac{\sigma_n}{Z_1^{\delta(\bar{E})}} \qquad \bar{n} = \frac{n}{Z_1^{\gamma(\bar{E})}}$$

n resolved cross section

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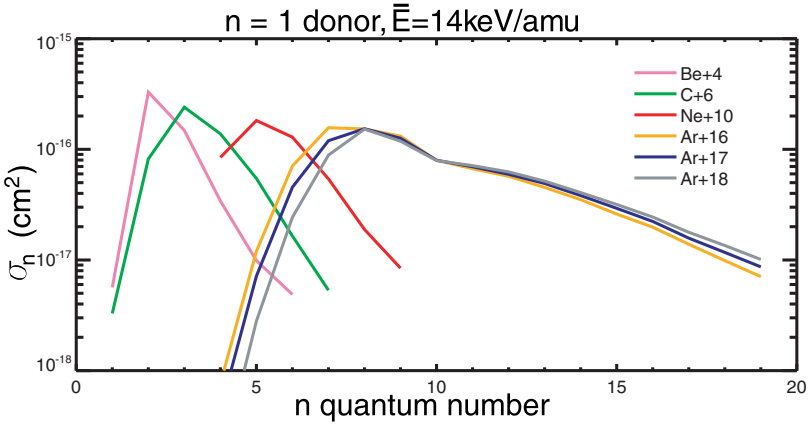

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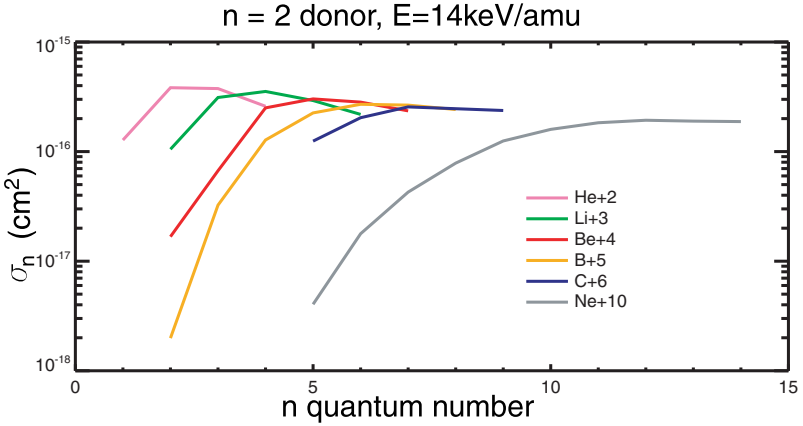

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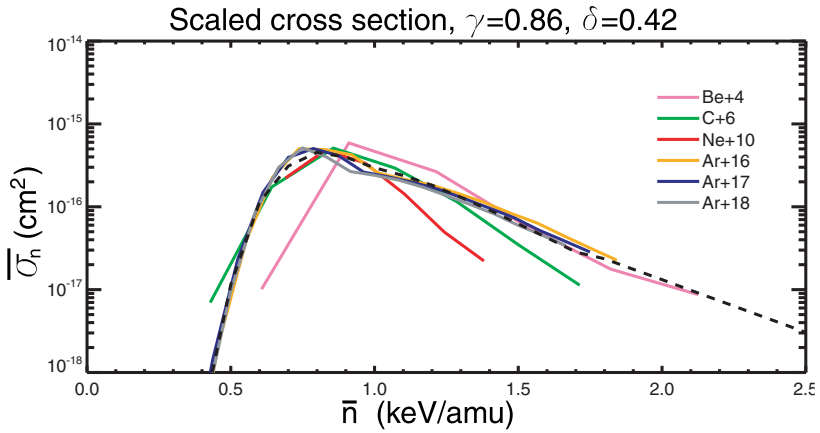
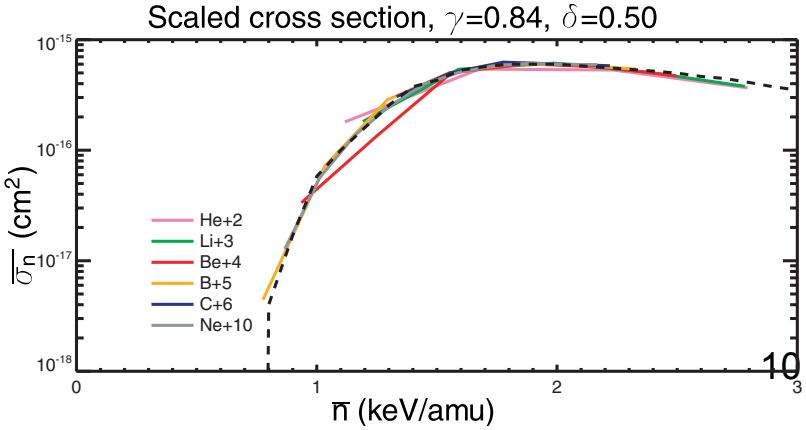
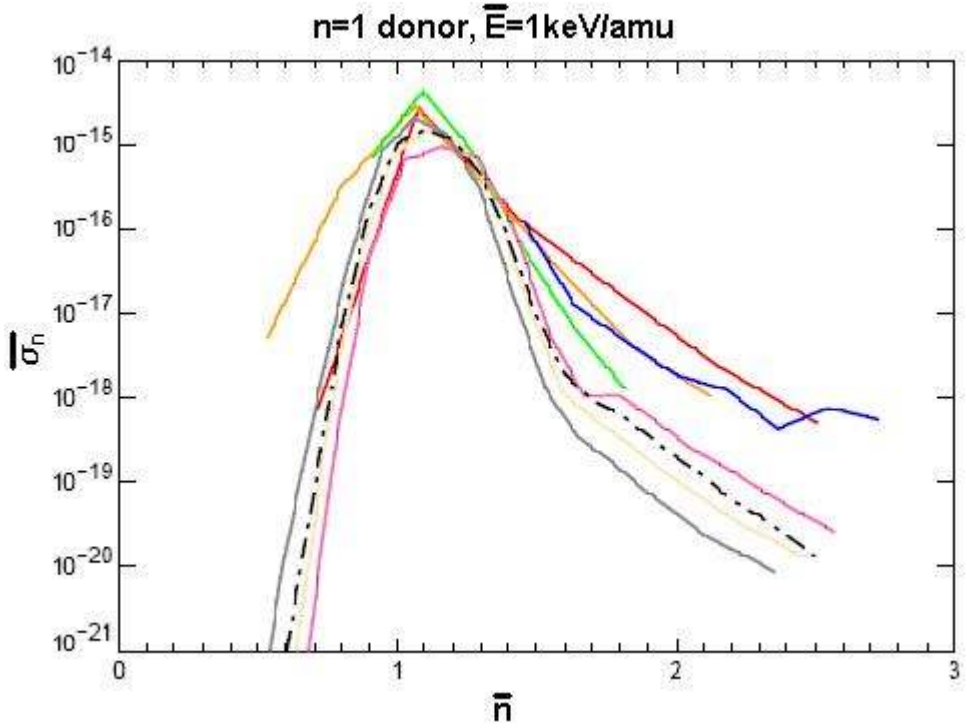




Some issues at low energies



$\bar{E}$=1keV/amu

This would be a 4keV/amu beam for tungsten.

So not really a worry…

$$\bar{\sigma}_{tot} = \frac{\sigma_{tot}}{Z_1^{\alpha}}$$

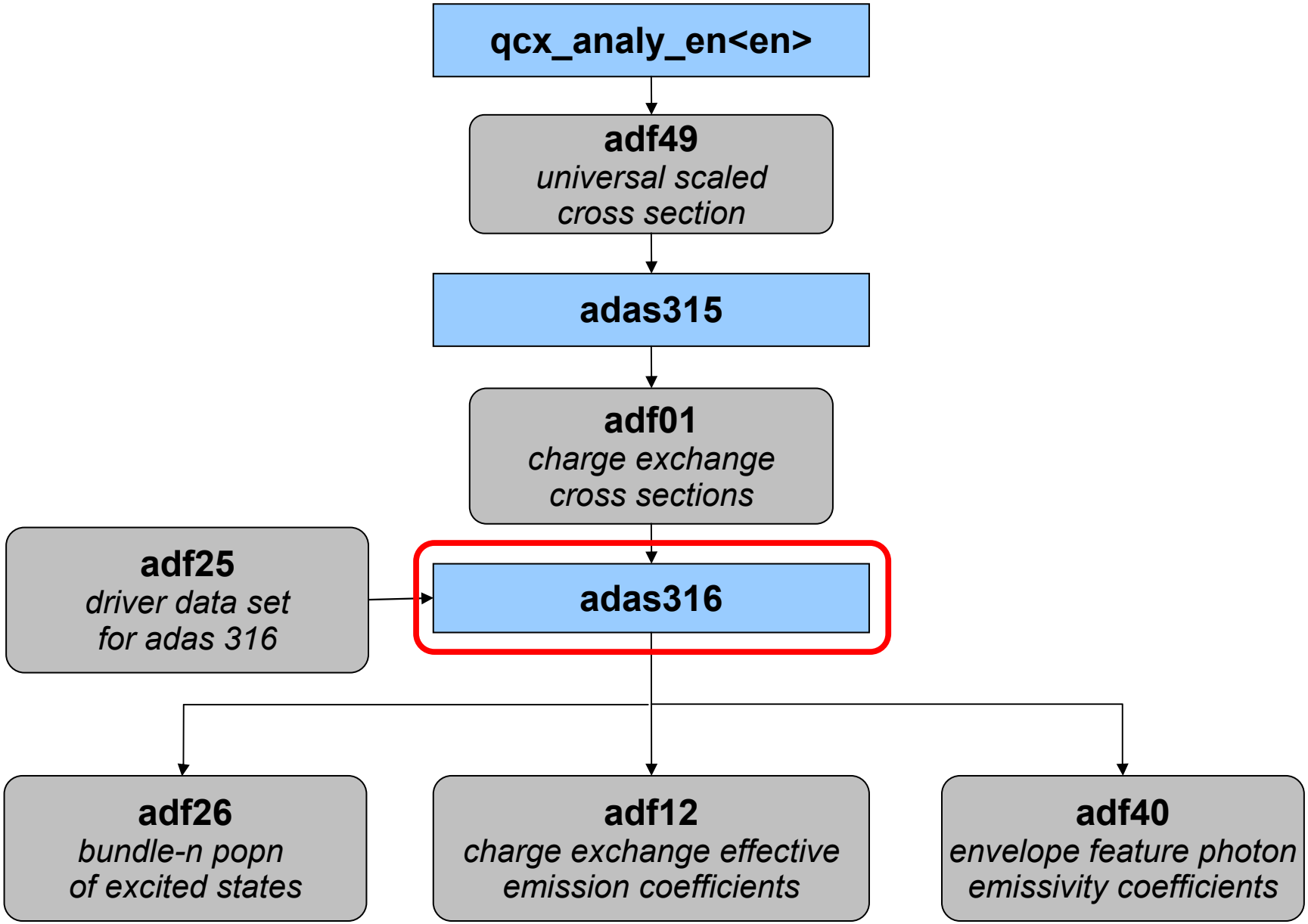
$$\bar{\sigma}_n = \frac{\sigma_n}{Z_1^{\delta(\bar{E})}} \qquad \bar{n} = \frac{n}{Z_1^{\gamma(\bar{E})}}$$

Health Warning / Acknowledgement

This is clearly not the ideal solution. Ideally we would have cross sections for heavier elements. But this is computationally difficult.

However in the absence of this data this forms the basis of a best guess of the CX emission from heavy species.

Routines used for generating universal cross sections have been designed to accept new data sets, so as further data becomes available coefficients can be refined.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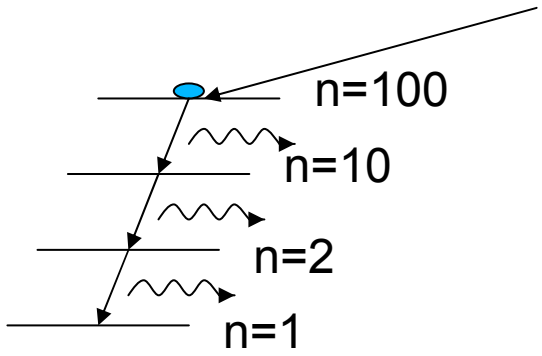
Bundle n model

(*charge exchange effective emission coefficients)*

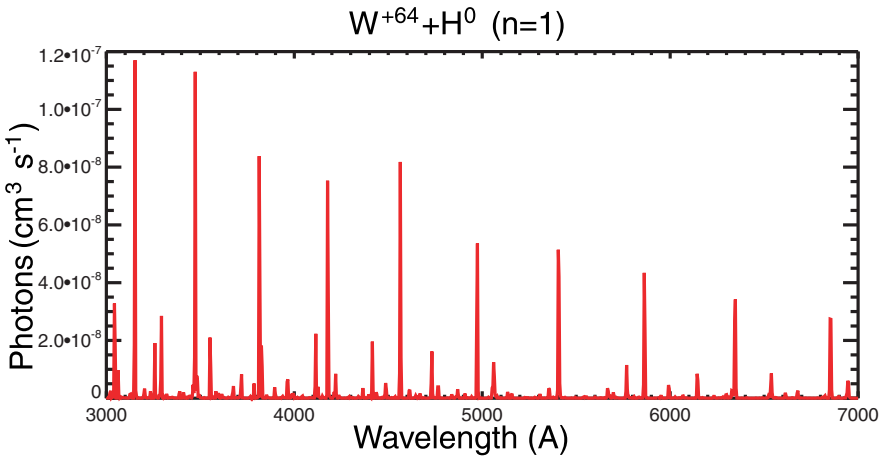
As part of ADAS 316, ADF12 files are produced giving the effective CX emission coefficients.

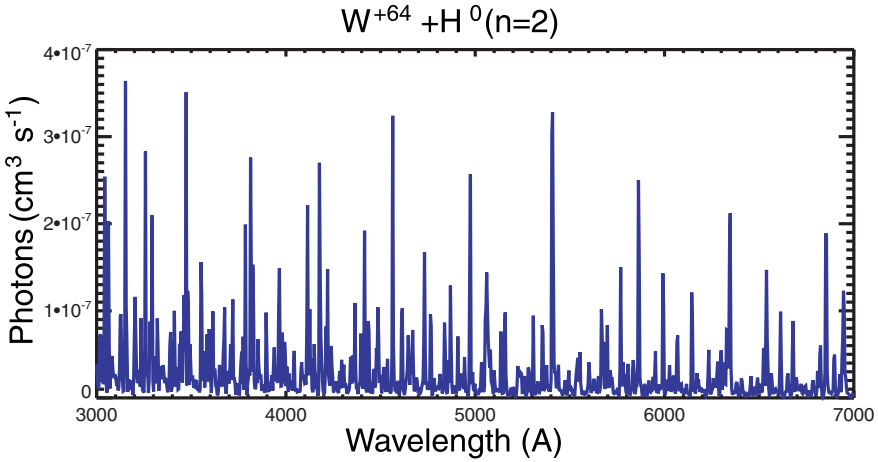
This model takes into account full cascades from capture into upper levels of the recombining ion and includes emission from these cascading electrons.



Akin to Photon Emissivity Coefficients used for line emission

Sample emission from 1 ion (W^{+64})





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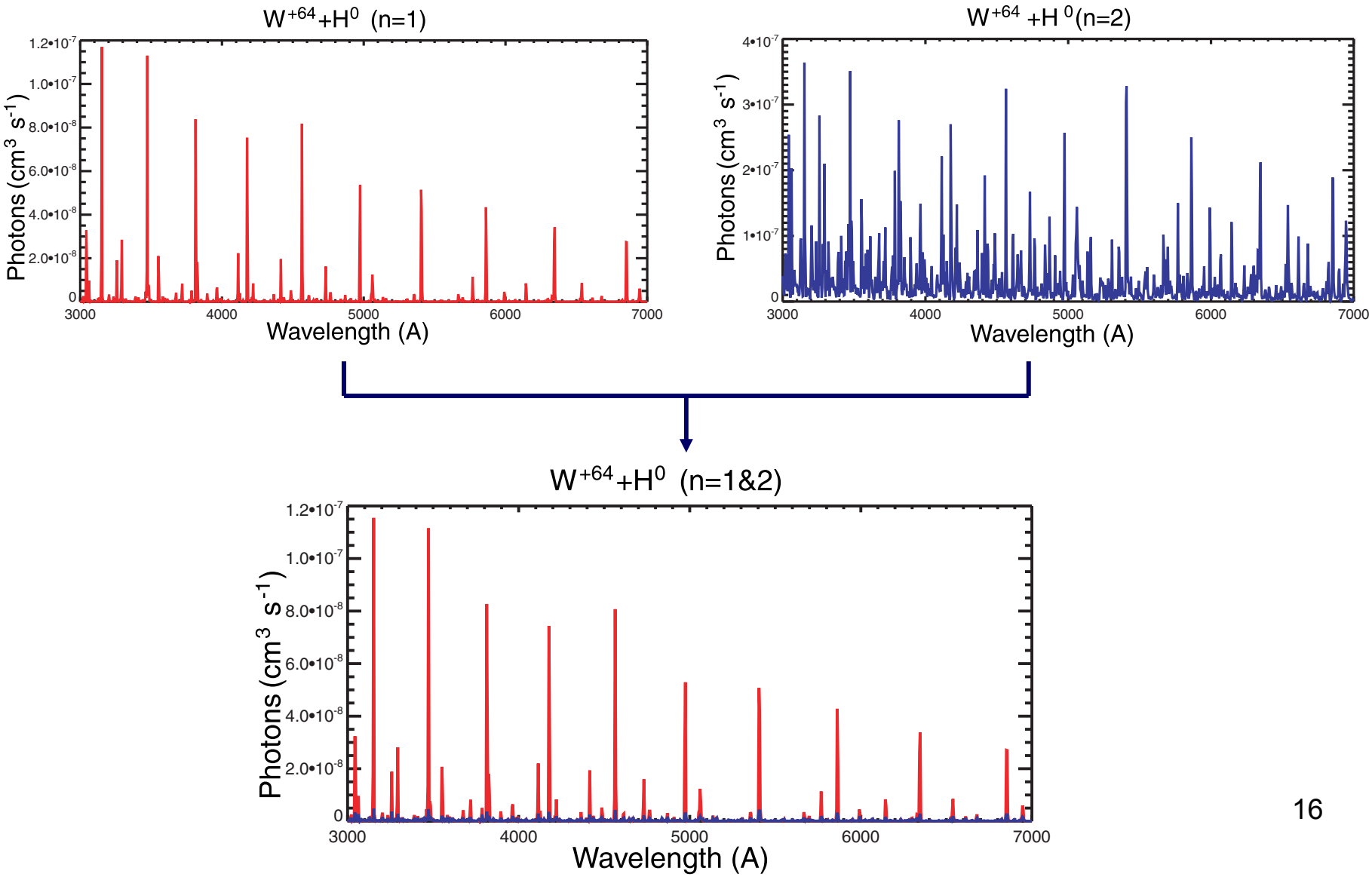
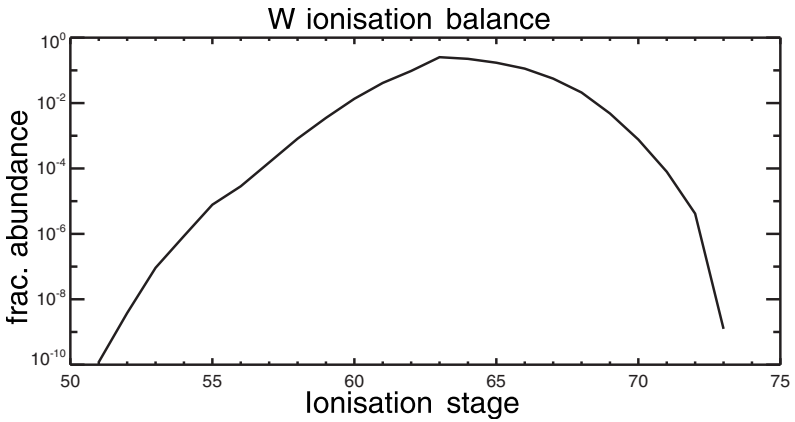
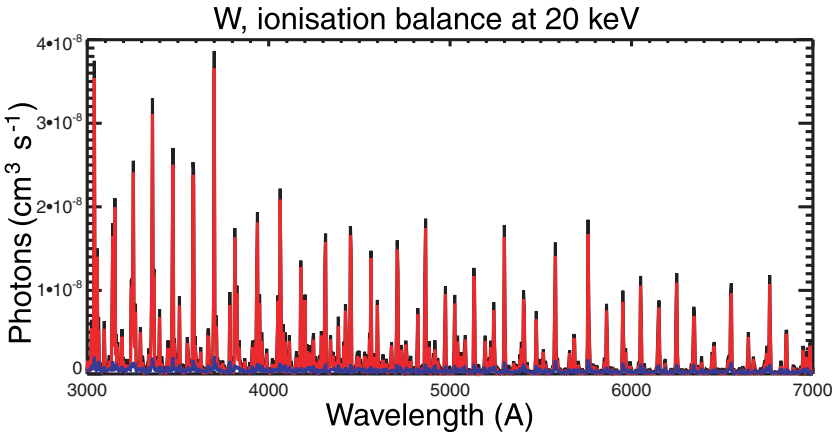


W emission from core





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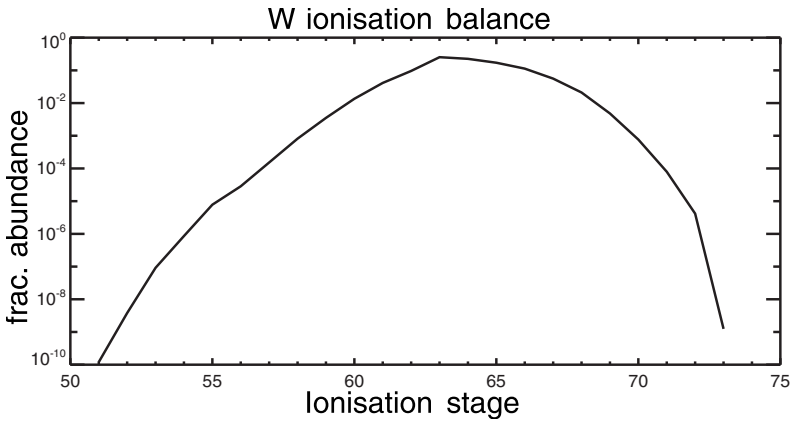
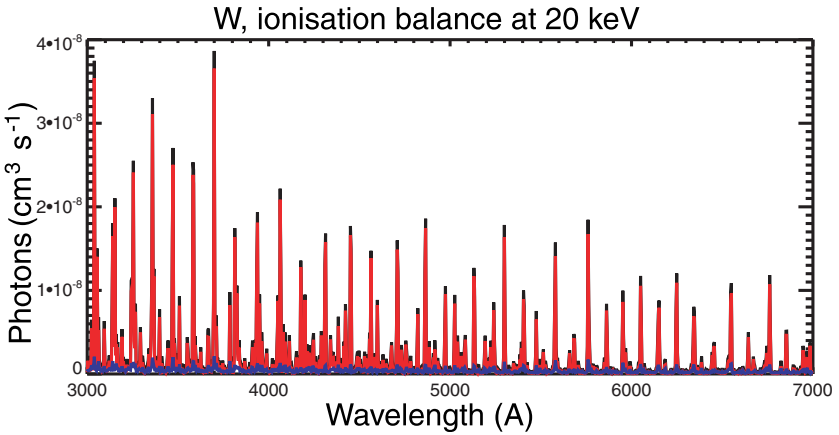
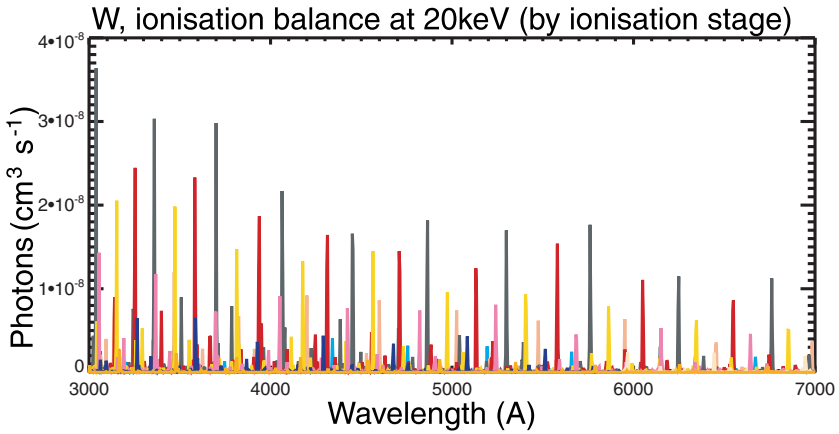
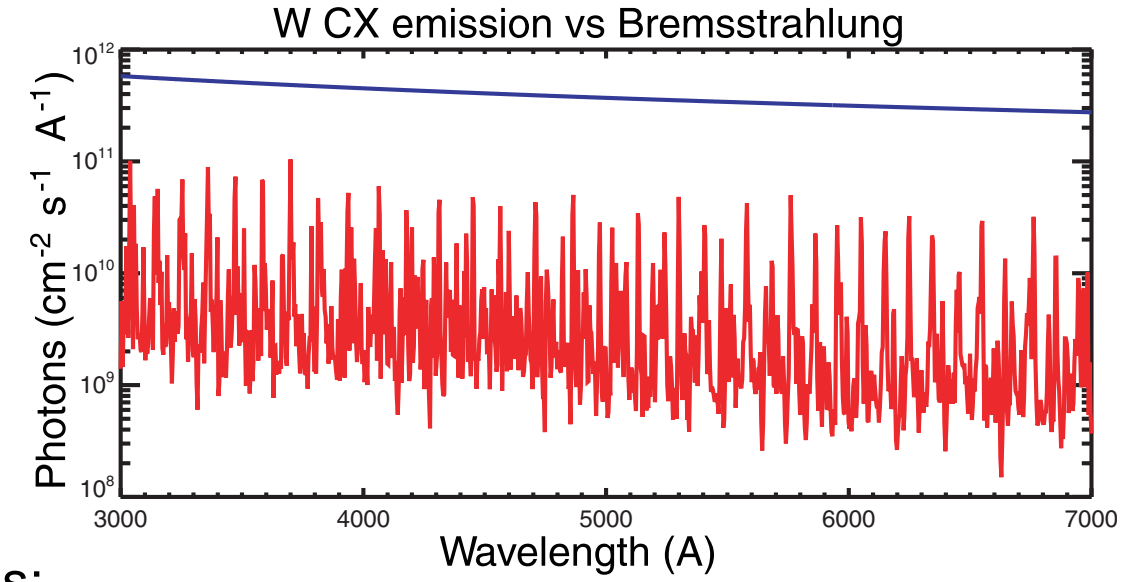






Simple ITER prediction



Assumptions:

- 50 keV/amu D beam (diagnostic NB), J_{NBI}=300A/m^2, I_{NBI}=60A
- Using ITER scenario 2 (T_e=20keV core, N_e=1x10^{14}cm^{-3})
- No transport – steady state ionisation balance
- Assume looking vertically down on the beam at the core.
- No beam attenuation effects taken into account.
- W concentration = 1x10^{-6} of N_H^+

Summary

- A method has been devised for extrapolating from currently available cross section data to produce CX cross sections for heavy species, via a universal scaled cross section.

- These methods are ready to accept any new cross section information that is produced to refine coefficients.

- ADAS machinery has been put in place for calculating CX spectra based upon this data in the bundle n model.

- Preliminary results show that CX emission from W in ITER is going to be ~1% of the Bremsstrahlung level

Further work

- Investigate extending model to l-resolved data.
- Use to predict spectra from moderately heavy species (Ni? Kr?) and test against experiment / better calculations.
- Add more cross sections.