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ADAS beam population model – a sensitivity study

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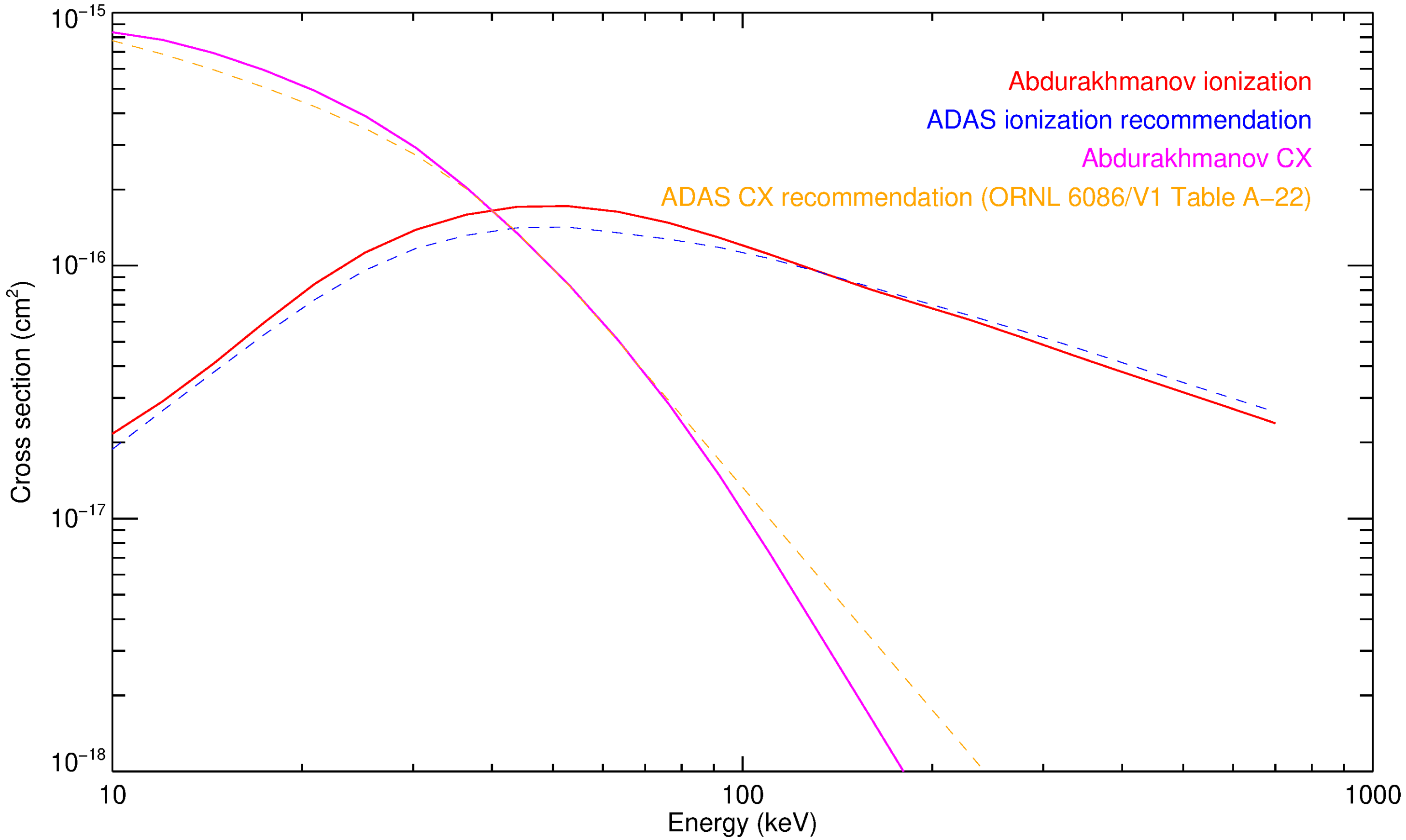
Dominant atomic process

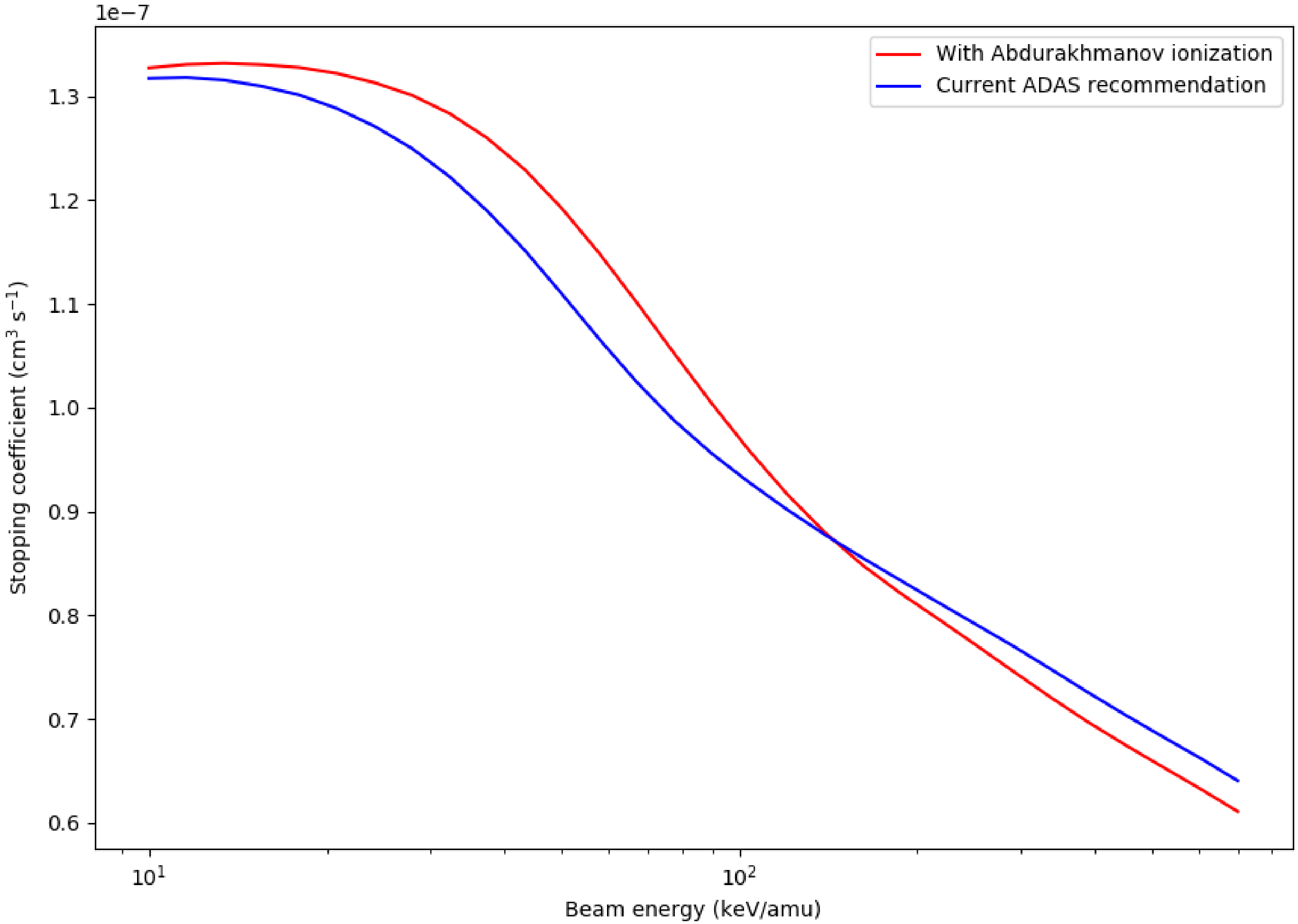
- Beam stopping is an effective ionisation rate.
- The primary $H^0 + H^+ \rightarrow H^+ + H^+ + e^-$ controls the overall value.
- New work since the Janev compilation of 1993.
- suggest an increase of ~10% at peak of cross section.



I B Abdurakhmanov et al, J Phys B, **49** (2016) 03LT01

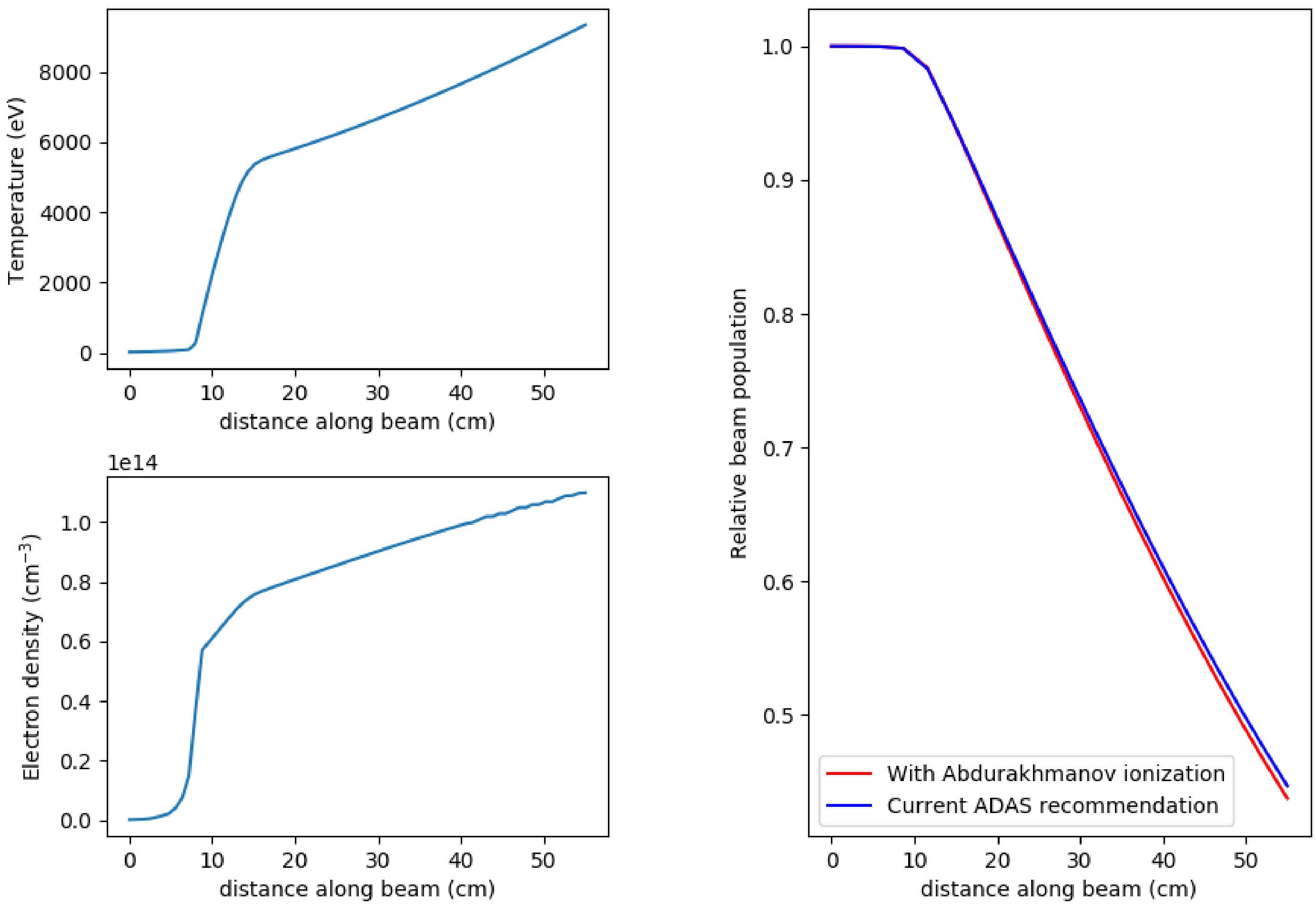
Difference in stopping coefficient

- Only alter the primary $H^0 + H^+ \rightarrow H^+ + H^+ + e^-$ cross section.
- Te = Tion = 2keV. Electron and ion density of 6×10^{13} cm^{-3}.



Difference in stopping coefficient

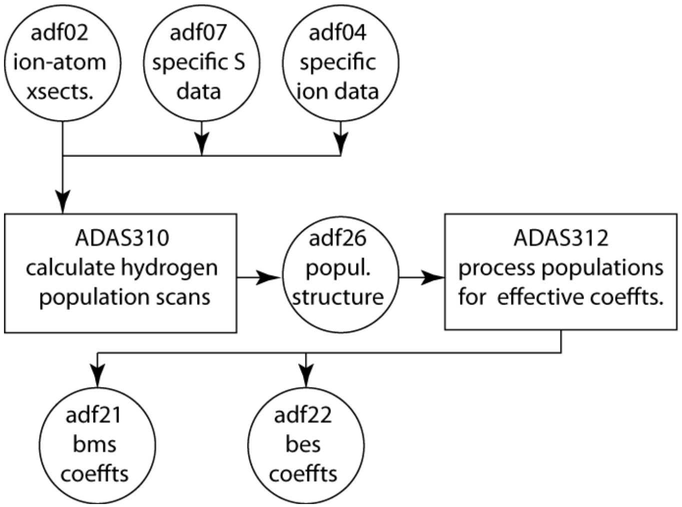
- Only alter the primary $H^0 + H^+ \rightarrow H^+ + H^+ + e^-$ cross section.
- Simple pencil attenuation calculation – just to explore the atomic physics.
- ITER test case with beam energy of 100keV/amu, Te = Tion and Ne=Nion.

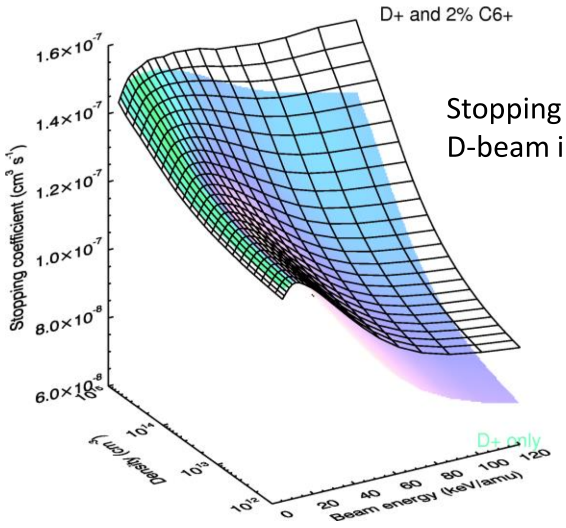


ADAS beam model

The ADAS beam model is a bundle-n collisional-radiative calculation:

- n~100 included with assessed/recommended data for n=1-5 levels.
- Impact parameter formulasims for electron and ion excitation and ionisation (Lodge, Percival-Richard, Van Regemorter, Burgess, Vainstein) are used when other data are not available.
- H Anderson et al, PPCF, **42** (2000) p781 (doi:[10.1088/0741-3335/42/7/304]) or adas310 [manual].





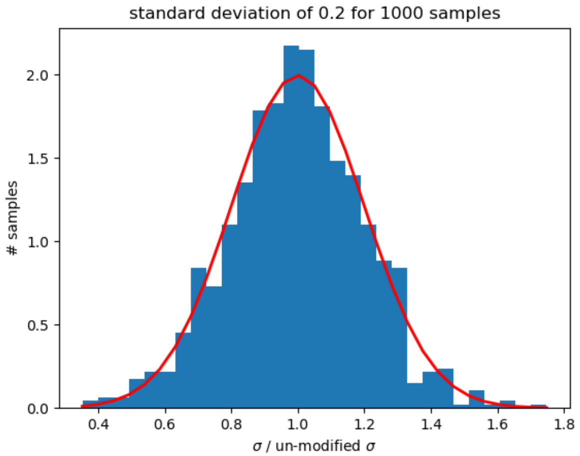
Stopping coefficient for D-beam in $2x10^3$ plasma.

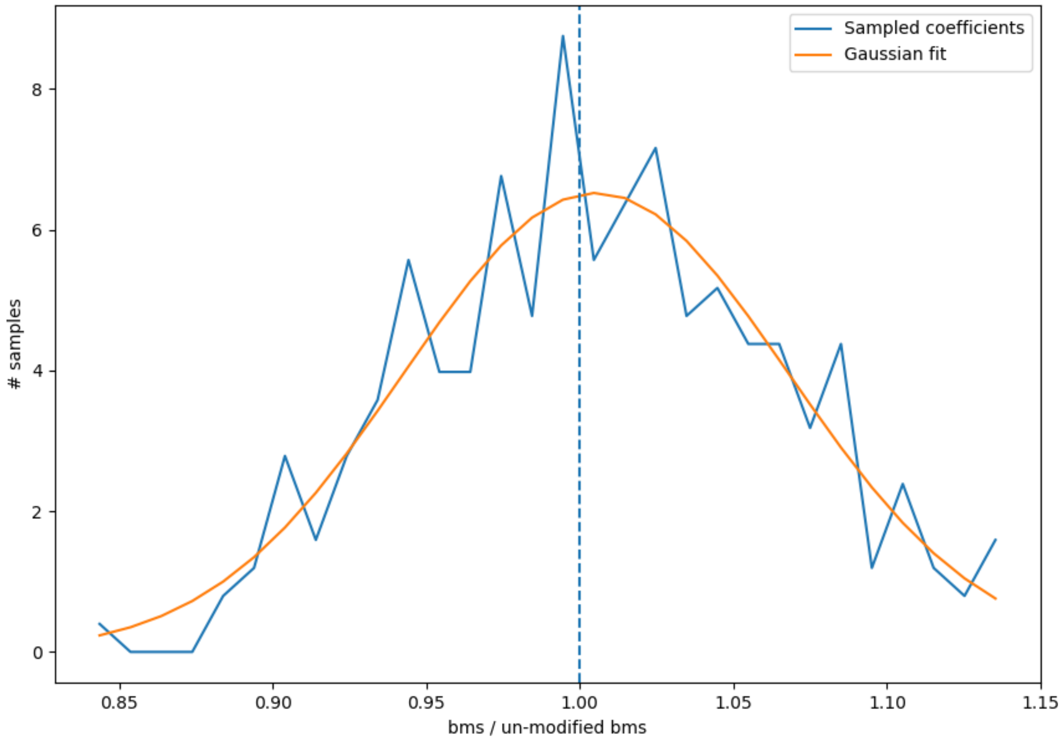
- Develop a new ADAS code (adas316) combining the role adas310 and adas312.
- adas316 is instrumented to modify any, or all, n-n’ rates or ionization from any n.

Propagation of uncertainty

The ADAS beam model is a bundle-n collisional-radiative calculation:

- CR model driven by atomic cross sections; excitation, de-excitation and ionization
- Plasma ion and electron populations are the drivers.
- Beam stopping and emission are parameterized by beam energy and Te, Tion, Ne and Nion.
- Assume a normal distribution for each atomic process and see if we recover sufficiently normal bms and bme coefficients.





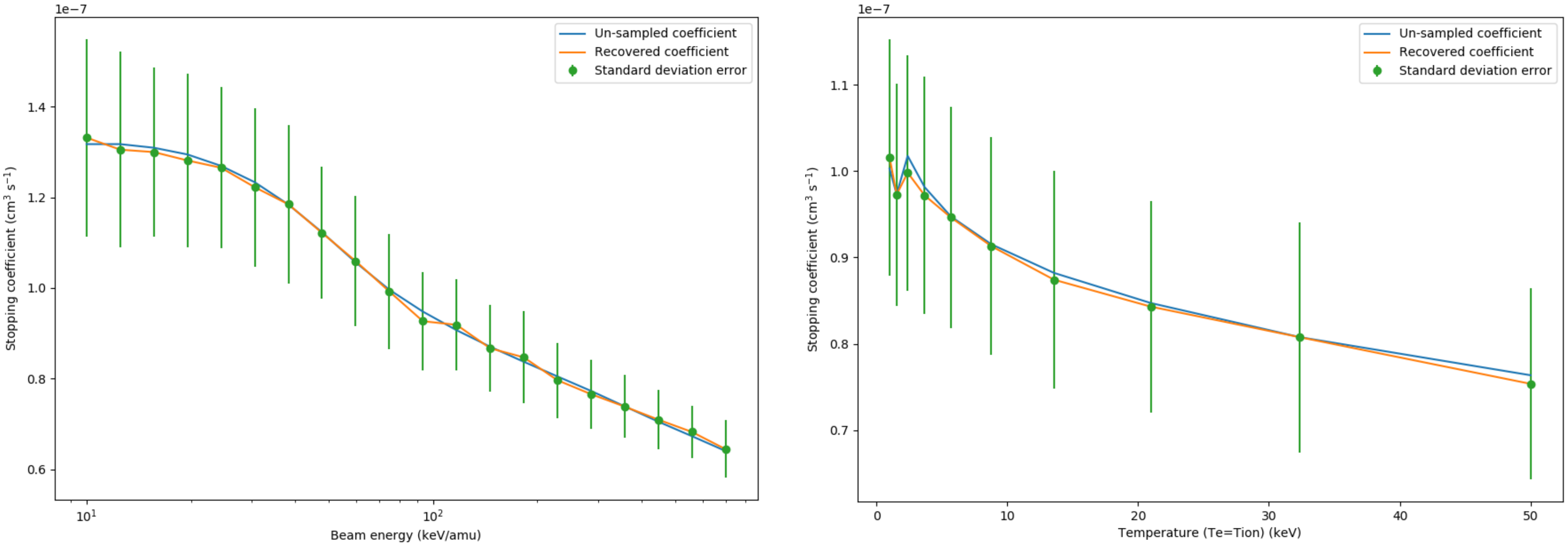
- Apply sd=0.2 for ion impact ionization
- sd=0.1 for e-impact ionization
- 250 samples for each

Result: bms/un-modified bms mean is 1.0055 with sd=0.0619

Propagation of uncertainty – as an error bar

Sample uncertainties in H^0-impact and e-impact ionization

- Apply sd=0.2 for ion impact ionization
- sd=0.1 for e-impact ionization



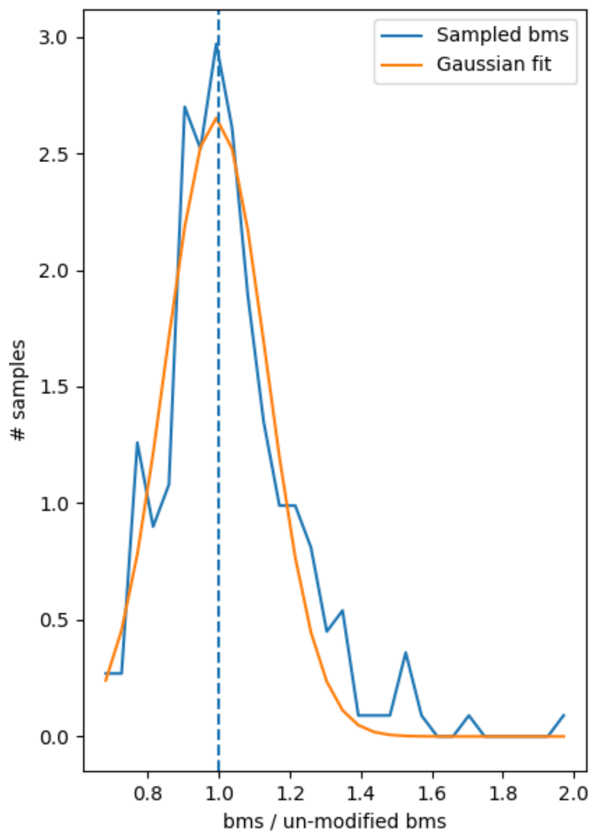
- How close the stopping coefficient matches the value recovered by fitting the spread from the sampled atomic cross sections depends on the number of samples.
- For bms vs. energy 250 was sufficient but Te(=Tion) required 450 samples.
- The error bar is the standard deviation from the Gaussian (normal) fit.
- Error bar decreases for increasing energy but remains similar over Te.

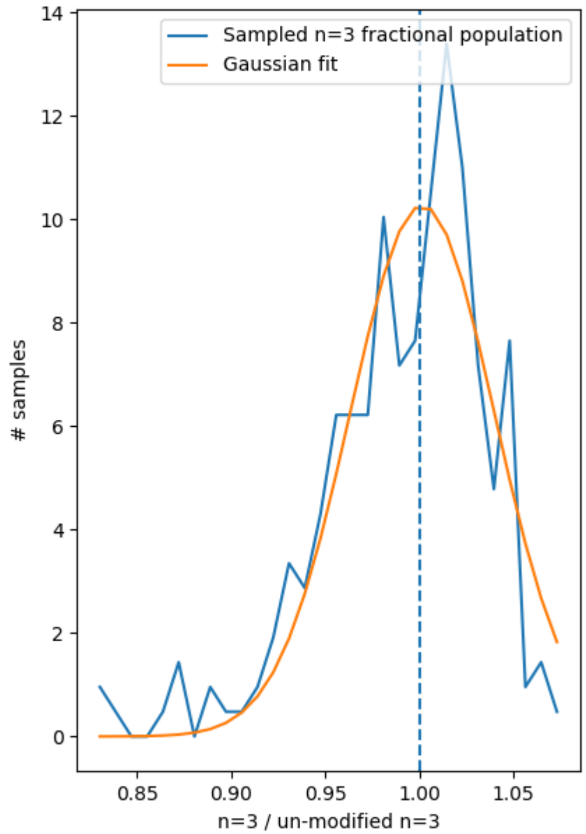
Propagation of uncertainty – multiple simultaneous processes

Sample uncertainties in ionization and H^0-impact excitation

- Apply sd=0.2 for ion impact ionization
- sd=0.1 for e-impact ionization
- sd=0.2 for ion impact excitation for n=2->1, n=3,4,5 -> 1 and n=3,4,5 -> 2
- 250 samples for each

- bms mean,sd : 0.992, 0.142
- n=3 mean,sd: 1.002, 0.038





Slight skew on fits – possible indication of correlation?

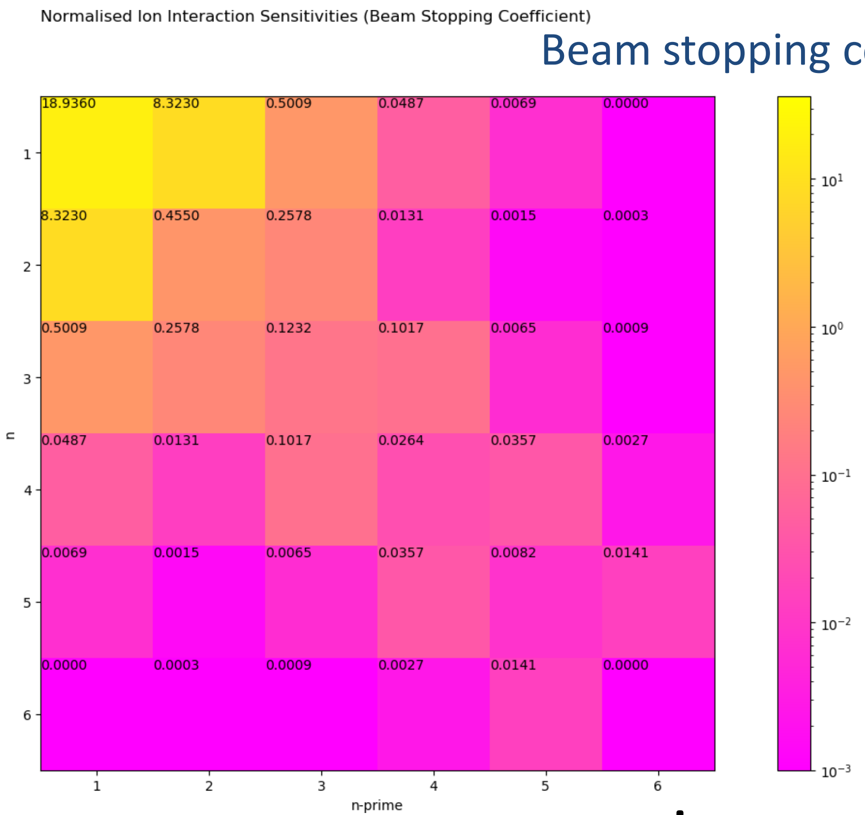
Ranking the contribution of atomic processes

The ADAS beam model is a bundle-n collisional-radiative calculation:

- The influence of each atomic process can be ranked.
- Not each processes has the same influence on beam stopping and on beam emission (n=3 population).

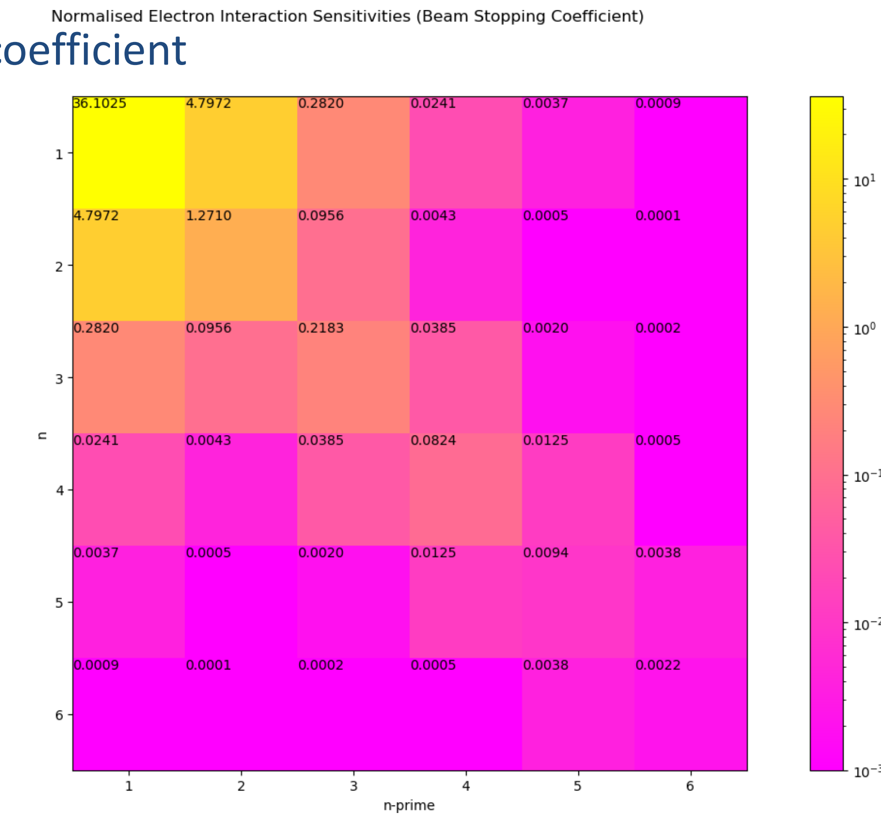
Beam stopping coefficient

n



n’

Ion impact processes



Electron impact processes

Ranking the contribution of atomic processes

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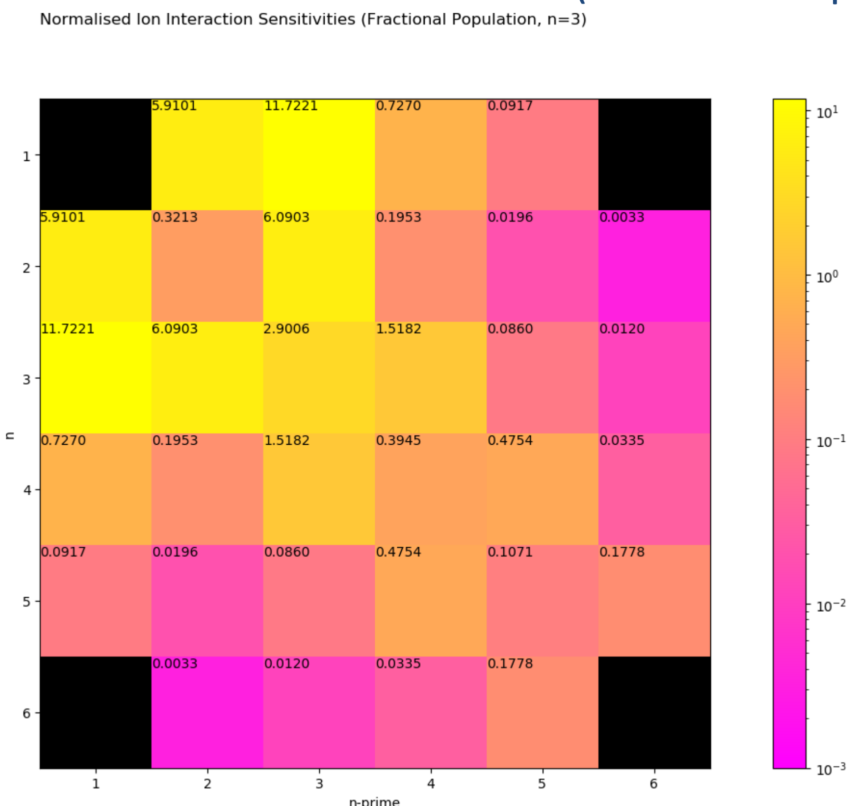
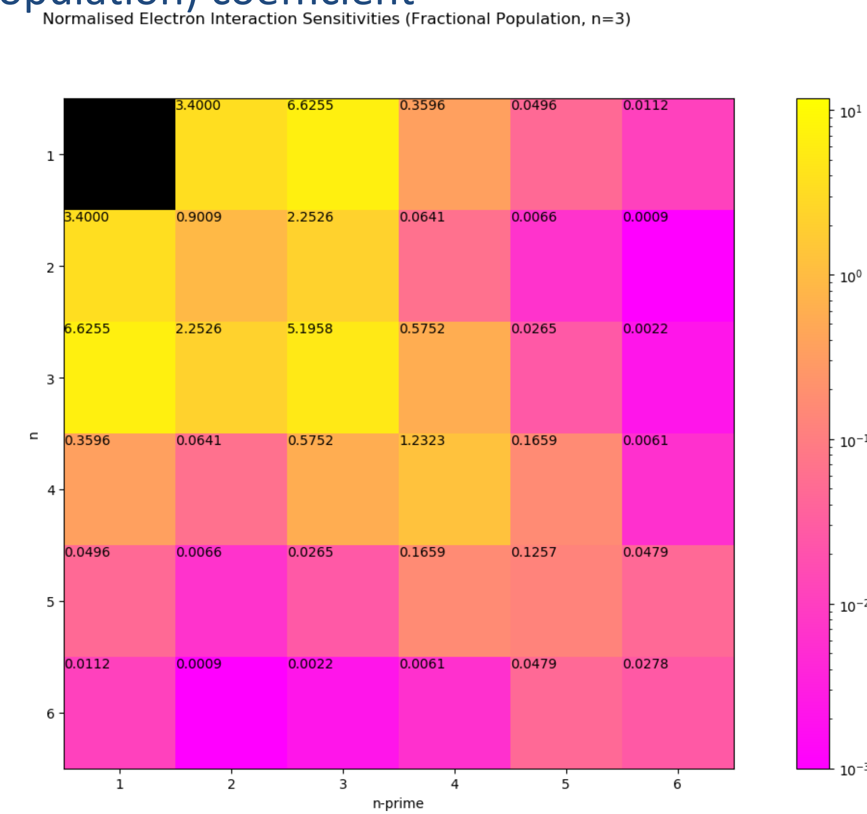
Beam emission (n=3 relative population) coefficient

n



n’

Ion impact processes



Electron impact processes

Goals and next steps

- The workshop came a little early for our investigations.
- A goal for ADAS is to provide an error surface over the parameters of the bms (adf21) and bme (adf22) files.
- Assigning an error to each atomic process is fraught with subjective opinion.
- Correlation effects are ignored for now but any skew in the recovered distributions may be small enough to be neglected.

- How to use the uncertainty estimations is also uncertain – compare using an adf21 + error approach to a sampling population model at each point in the beam attenuation calculation.

- Run simple/toy ADAS beam attenuation model for workshop cases with central ADAS adf21 and with the new ionization data of Abdurakhmanov.
- 'Benchmark' the simple ADAS beam attenuation model against the more sophisticated CHEAP algorithm to assess whether it can be used to give a physics insight to beam attenuation behaviour.
- Prepare a list of atomic processes, ranked by importance for bms and bme, to focus future discussions on how to assign uncertainty estimates to the fundamental atomic cross sections.