The Effect of Uncertainties in the Ionisation Cross Sections in NBI Transport Simulations

Michael Kraus, Sebastian Schwarzhuber, Joerg Stober, Giovanni Tardini

Max-Planck-Institute for Plasma Physics, Garching, Germany

Introduction

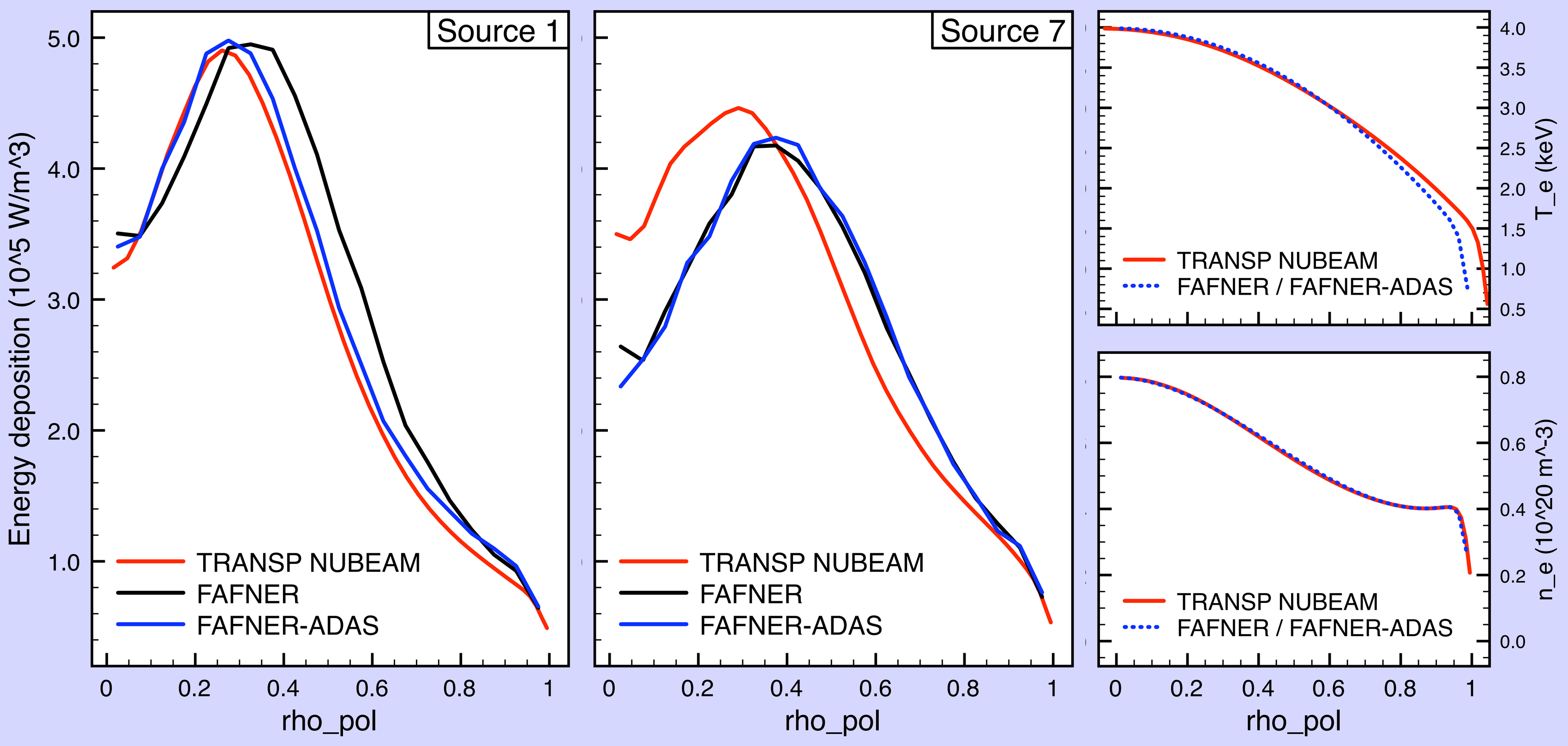
At IPP two NBI transport simulation codes, FAFNER (IPP) and NUBEAM (PPPL), are used to calculate NBI heating profiles for experiments at ASDEX Upgrade as well as for analysis of experiments. Occasionally, both codes give quite different results, especially for plasmas with high densities. The reason is believed to be the used ionisation cross sections.

Calculation of accurate NBI heating profiles is important for a number of experimental studies in fusion science, for example current drive or plasma scaling in terms of dimensionless parameters. After aligning the results of FAFNER and NUBEAM, further simulations in these fields will be carried out.

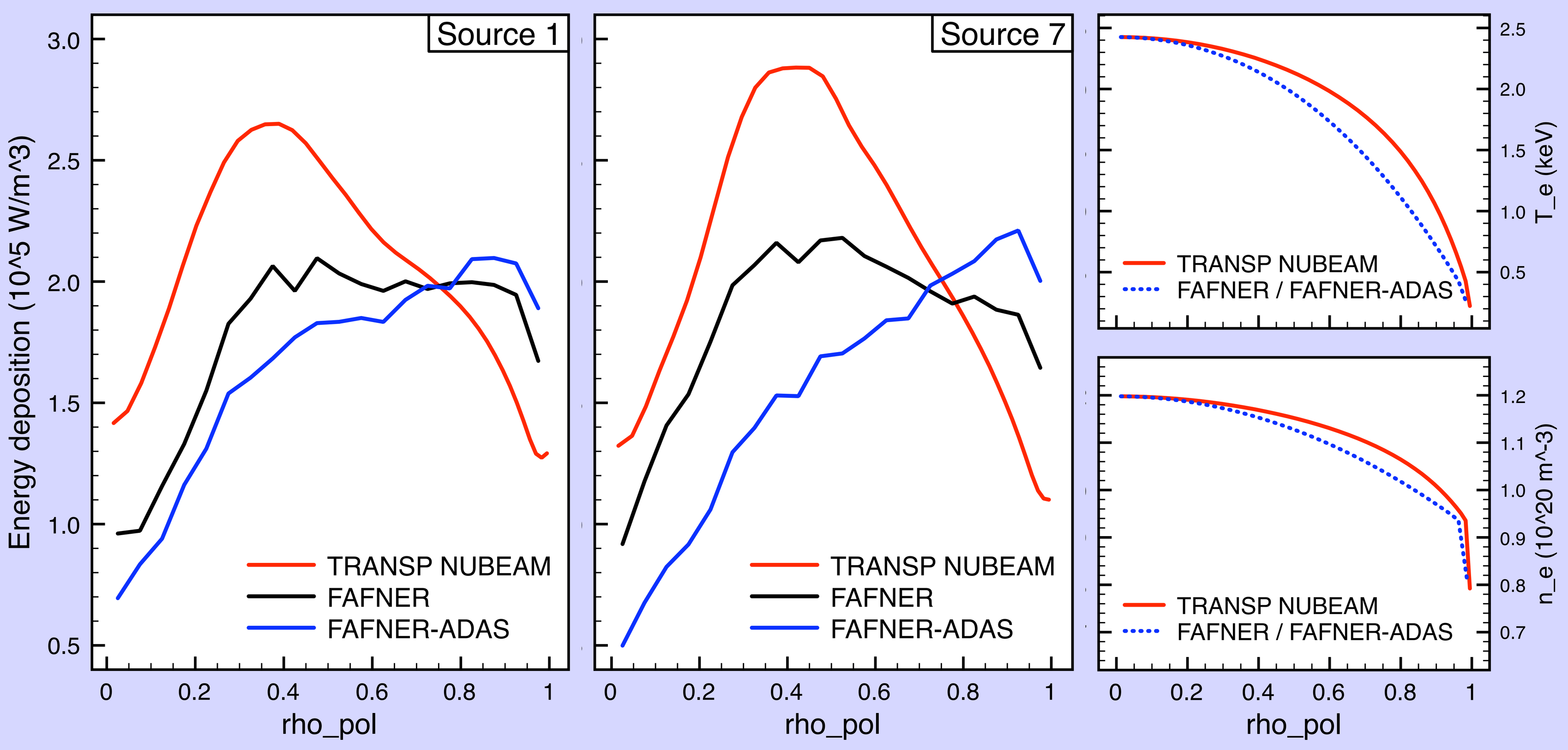
Comparison of FAFNER and NUBEAM

FAFNER and NUBEAM are Monte Carlo packages for NBI physics. Both take into account multiple beam lines, beam geometry, as well as beam composition by isotope and energy. The main difference is, that FAFNER is stationary, whereas NUBEAM is time dependent.

Asdex Upgrade Shot #17870 (lower density, Z_{eff} = 1)



Asdex Upgrade Shot #17847 (higher density, Z_{eff} = 1)



- Plasma and neutrals were deuterium in both cases
- Direction of source 1: perpendicular to the torus
- Direction of source 7: tangential injection

Comparison of FAFNER and NUBEAM for plasmas with moderately high densities yield substantially different results.

As the temperature and density profiles show very good agreement, internal differences like the used mapping can be ruled out as a major cause for this different results. However the energy deposition profiles show a severe deviation at higher densities, which hints to a problem in or prior to the ion slowing down calculations.

Doing simulations for a plasma with constant density and temperature throughout the plasma, the shine through and mean free path of the injected neutrals were found to differ up to 20%, which points to a problem prior to the slowing down process, and so in the ionisation cross sections.

Ionisation cross sections

The used cross sections from the different atomic data collections [1,2] are usually described by a polynomial or another analytic expression fitted to experimental data. The uncertainty of those fits is up to 50%; for Hydrogen it's between 10% and 20%.

ADAS [3] is based on newer, more accurate cross section measurements and uses cubic spline interpolation between experimental values. In particular ADAS includes excited neutral states, which becomes important at high densities.

Implementing cross sections from ADAS into FAFNER increased the difference in the results of both codes. This finding supported our assumption that one of the main reasons for the differences are the cross sections used in NUBEAM and FAFNER.

For further verification, the NUBEAM cross sections will be implemented into FAFNER, to see if afterwards the results of both codes are better aligned. If so, the new cross sections may be implemented into NUBEAM and further comparison of both codes will be carried out.

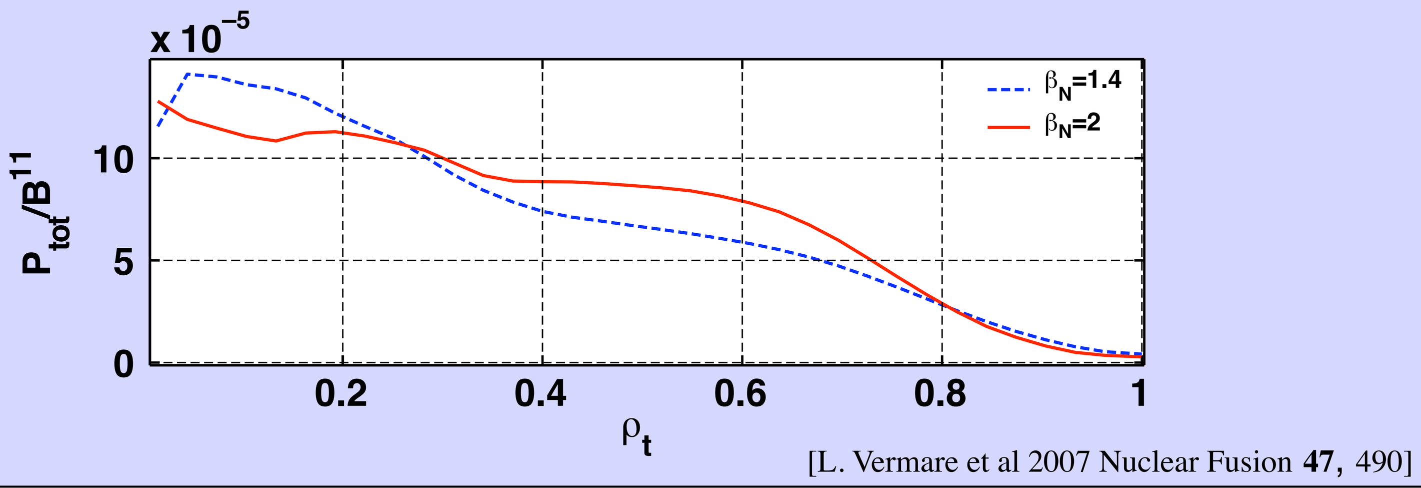
Origin of the used cross sections:
(1) NUBEAM: Barnett, *"Atomic Data for Fusion"* (ORNL *"Red Books"*), 1990, implemented in the NTCC PREACT module
(2) FAFNER: Freeman & Jones, *"Atomic Collision Processes in Plasma Physics Experiments"*, 1974
(3) FAFNER-ADAS: *ADAS v2.12, http://www.adas.ac.uk/*, 2007

Dimensionless parameters and plasma scaling

Dimensionless plasma parameters like β, ρ^*, ν^*, q, ϵ, δ, κ, T_i/T_e are useful to describe the scaling of plasma energy transport from present day devices to larger experiments, like ITER.

On ASDEX Upgrade experiments were done on the β dependency of confinement and heat transport. β was modified in a certain range, whereas all other dimensionless parameters were set constant.

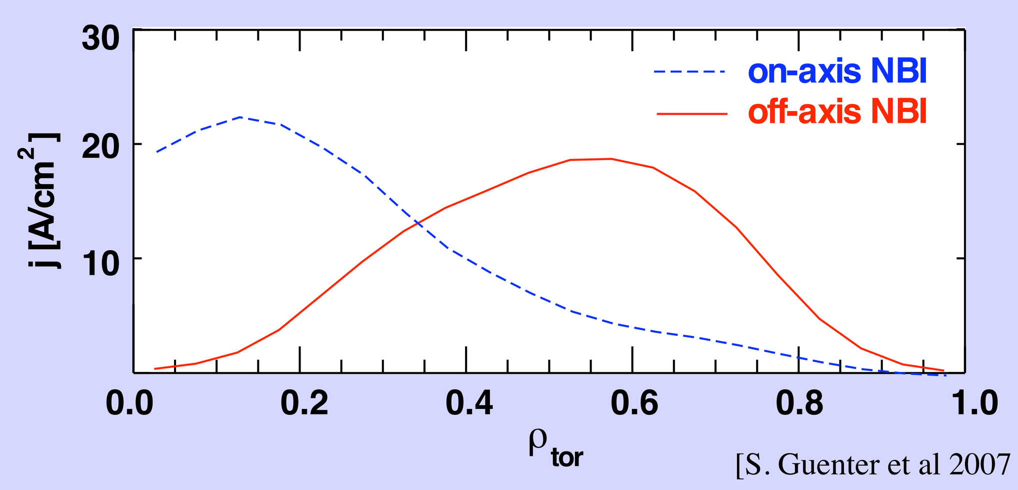
For these experiments it's very important to have equal heating profiles for all plasma setups, what requires careful calculations prior to the experiments, to assure the resulting energy deposition profiles from NBI heating have the necessary shape.



[L. Vermare et al 2007 Nuclear Fusion **47**, 490]

NBI driven plasma current

NBI is one possibility for inductionless plasma current drive in a tokamak. Experiments on ASDEX Upgrade at sufficiently low total heating power show a very good correspondence between the measured current profiles and simulations for on- and off-axis NBI heating like the one shown in the figure below. Beyond a certain heating power a major deviation between calculated and observed current profiles occurs. Because this topic is very important, the ionisation cross sections have to be ruled out as a potential fault.



[S. Guenter et al 2007 Nuclear Fusion **47**, 920]