Atomic Model for Fast Atoms in Fusion Plasmas

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Nowadays, one cannot imagine the diagnostic of magnetic fusion without active beam spectroscopy: measurements of plasma temperature and rotation, density of impurity species, magnetic field or fast ions profiles are probably the most representative examples of experimental data obtained using the injection of high energetic neutral particles with an energy of 10…100 keV into the plasma. The atomic data plays an essential role in deriving practically all experimental quantities, especially those connected with the spectral line intensities.

In this work the impact of electro-magnetic fields on the atomic data needed for the interpretation of the emission of neutral hydrogen or deuterium beams will be discussed in detail. Indeed, the ions in fusion plasmas are confined by strong magnetic field **B** on the order of 1...5 T and in addition to magnetic field the bound electron experiences a translational electric field $\boldsymbol{F}=\mathbf{v}\times\mathbf{B}$ in the rest frame of the atom, where **v** is the beam velocity. The impact of electromagnetic field dominates by an order of magnitude the fine-structure separation so that the collisional-radiative atomic models must be formulated in terms of new *eigenstates* for these atoms. We present the results using a *statistical, i.e.* the populations of magnetic levels are proportional to their statistical weights, and a *non-statistical* atomic model. The very good agreement between the different statistical models was obtained in the last decade; however the measurements of Hα line emission [1] in fusion devices (JET, ALCATOR-C, ASDEX, etc.) show clear non-statistical features. In order to resolve the deviations between the measurements and the theoretical description the new atomic model must be formulated within the new *eigenstates* (parabolic states for linear Stark effect) of the atom. We describe in details the calculation of excitation cross-sections within the parabolic states or, alternatively, using the density matrix approach in the basis of the spherical wave-functions and show the role of orientation between the direction of electric field and beam direction. The calculated line ratios within the Hα line multiplet are found in very good agreement with the experimental data from JET and ALCATOR-C [2]. Finally, the non-statistical features combined with the Zeeman effect lead to a variation of the derived pitch angle of the magnetic field in the order of 2-3° [3] relative to the pure statistical calculations.

[1] Delabie E. et al, Plasma Phys Contr. Fusion. **52** (2010) 125008

[2] Marchuk O. et al, J Phys. B.: At. Mol. and Opt. Phys. **43** (2010) 011002

[3] Reimer R et al, Plasma Phys. Contr. Fusion. (2015) (submitted)