7.0 Thesis summary and discussion

The work in this thesis involved modelling, measuring and predicting the attenuation and emission associated with fast neutral diagnostic beams. There were two main beam species which were of interest. We were first concerned with modelling and measuring the attenuation and emission associated with fast a neutral deuterium beam. Secondly we were involved with developing a collisional-radiative model to predict the attenuation and emission from a fast neutral helium beam.

Focusing on the work regarding a neutral deuterium beam. Using an existing collisional-radiative model from the ADAS system, ADAS310. We calculated and investigated the parameter dependencies of effective beam stopping and Balmer-alpha emission coefficients. We also developed an interactive program to allow one to visually inspect and archive the derived data obtained from ADAS310. This program is now part of the ADAS package and is known as ADAS312. We investigated the accuracy of the linear interpolation and combination method which is employed to archive and facilitate the rapid assembly of composite coefficients.

The effective stopping coefficients were used to model the attenuation of the neutral deuterium beams at JET Joint Undertaking, while the effective emission coefficients were employed to recover the neutral deuterium beam density using Balmer-alpha beam emission spectroscopy. After refinements in the analysis of the beam emission spectrum, consistency in the charge exchange analysis and the use of improved fundamental atomic data which enters as input into ADAS310. We found that that the measured beam densities agree to within 27 % of the values obtained from the numerical attenuation calculation for single beam bank pulses, while for double beam bank pulses the measured neutral beam densities agree to within 20 %.

Nevertheless more work is required to establish beam emission spectroscopy as a truly reliable diagnostic in the sense that it can replace the numerical attenuation calculation. The most immediate difficulty involves analysing vast numbers of spectra accurately and efficiently. Even though we have demonstrated that the spectral fitting of only the $+\pi3$ and $+\pi4$ components is sufficient to recover the beam density, it is more accurate to consider the analysis of all of the Stark components. The analysis of the beam emission spectrum should really be done on an interactive basis where more consideration is given to the residuals obtained from the synthetic and measured spectrum. A possible long term goal would be to build up a database of analysed spectra which could then be used as a training set for a neural network. The neural network could then be used to analyse the bulk of the spectra.

If we now consider the work concerning a fast neutral helium beam. We have developed a collisional-radiative model to predict the attenuation and emission associated with a fast neutral helium beam. This program is an off line FORTRAN code and is intended to be placed into the ADAS package as ADAS311 in the near future. ADAS311 is a spin resolved model which calculates the equilibrium populations of each of the angular sub-states up to an arbitrary principal quantum shell, above which the population of each principal quantum shell is then calculated. The model also calculates collisional-radiative cross coupling and recombination coefficients. We have also developed a computational tool, analogous to ADAS312, which is employed to allow one to inspect and archive the derived atomic data obtained from ADAS311. This program is also intended for use within the ADAS package as ADAS313.

Using ADAS311 and ADAS313 we have studied the quasi-static excited population structure of the beam atoms. We also considered the influence of the non-equilibrium metastables on the population of the levels contained within the n=4 shell. The parameter dependencies of the collisional-radiative coupling coefficients were also explored and later used to model the evolution of the metastable populations. For a beam where the initial metastable content is zero, we have shown that the metastable levels are populated on entry to the plasma and are then strongly attenuated as the beam continues. Modifying the initial metastable content of the beam does enhance their survival, however spectroscopic observations are now required to investigate whether the metastable populations are suffice to enable preferential charge exchange from the ground state and the metastable levels to occur.

Spectroscopic observations with a neutral helium beam would also allow us to experimentally validate and improve upon our model. In the case of a fast helium beam (> 50 keV amu^{-1}), since the fundamental ion-atom collision data is more accurately known in this region, it is expected that there would be good agreement between theory and experiment. This however is not the case for a low energy beam (E < 10 keV amu^{-1}), the fundamental data in this region has a greater uncertainty and so discrepancies between theory and experiment are to be expected. Also the influence of the Lorentz electric field has not been taken in account in our model and it is in this region where its influence is most significant.