Monte Carlo simulation of ICRF discharge initiation at $\omega_{pe} < \omega$ and investigation of model validity at higher densities

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The radio-frequency (RF) plasma production technique in the ion cyclotron range of frequency (ICRF) is studied for applications for wall conditioning (ICWC) in superconducting fusion machines ($T_e = 3 - 5\text{eV}, n_e < 10^{12}\text{cm}^{-3}$), for RF-assisted start-up in tokamaks and for target plasma production ($n_e = 10^{13}\text{cm}^{-3}$) in stellarators [1].

A code was developed to model the ICRF discharge initiation. The 1D Monte Carlo code RFdinity1D [2] traces electron motion along one toroidal magnetic field line, accelerated by the RF field in front of a one strap ICRF antenna. Possible electron collisions are weighted by a Monte Carlo procedure taking into account their energies and the related electron collision cross sections for three $e-H_2^+$ reactions types, ionisation, excitation and dissociation [3]. The code was updated to contain additionally $e-H_2^+$ recombination, Coulomb collisions between electrons and ions ($H^+$ and $H_2^+$), as well as an improved collision description in 3D velocity space.

We could thus study the electron multiplication rate as a function of RF discharge parameters (i) RF vacuum electric field strength, (ii) RF frequency and (iii) neutral pressure ($H_2$) at the condition $\omega_{pe} < \omega$, and the evolution of the electron velocity distribution functions. We also investigated the validity of the model at higher densities ($\omega_{pe} > \omega$), where two additional phenomena become important. Firstly, Coulomb collisions between electrons and ions become sufficiently frequent, they are taken into account using the binary collision model by Takizuka [4], and secondly, the excitation of plasma waves may modify the vacuum electric field distribution.

Plasma breakdown in the code is defined as the moment when a critical electron density $n_{ec}$ is reached, at which the Coulomb collisions frequency exceeds the $e-H_2$ ionisation frequency. Qualitative agreement is obtained between simulations and experimental breakdown times in the literature and experimental data of the ASDEX Upgrade and TEXTOR tokamak.