4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

# Electron runaway in massive material injection scenarios in ASDEX Upgrade using state-of-the-art generation models

O. Linder[1], E. Fable[1], F. Jenko[1], G. Papp[1], G. Pautasso[1], the ASDEX Upgrade Team[†] and the EUROfusion MST1 Team[‡]

[1] Max Planck Institute for Plasma Physics, Germany, [†] See author list of H. Meyer et al., Nucl. Fusion **59**, 112014 (2019), [‡] See author list of B. Labit et al., Nucl. Fusion **59**, 086020 (2019)

E-mail (speaker): Oliver.Linder@ipp.mpg.de

The generation of runaway electrons (RE) during massive material injection (MMI) in both present-day and future fusion devices, such as ITER, is described adequately only under consideration of kinetic effects in the presence of partially ionized impurities [1][2]. The importance of these effects is demonstrated in first-of-a-kind integrated simulations of massive gas injection (MGI), background plasma evolution, and RE generation in artificially induced disruptions in ASDEX Upgrade (AUG) [3]. A solid understanding of the processes governing electron runaway is mandatory to ensure successful operation of ITER through design of an effective disruption mitigation system, since RE currents of several MA generated during a disruption can severely damage plasma facing components, thus jeopardizing the ITER mission. Experimental investigation of RE generation in present-day devices, e.g. at AUG [4][5], is therefore complemented by computational studies.

For the simulation of RE generation following MMI, a toolkit based on the coupled 1.5D transport codes *ASTRA-STRAHL* [6][7] has been developed [3]. The background plasma is evolved by *ASTRA*, evaluating the macroscopic transport equation $\partial_t Y = -\vec{\nabla}\boldsymbol{\Gamma}_Y + S_Y$. Similarly, the density of individual impurity charge states is evolved by *STRAHL*, considering rate coefficients for electron-impact ionization and recombination from *ADAS* [8]. In the process, impurity radiation is calculated for application as an energy sink term. The generation of REs can be described either by aforementioned state-of-the-art models [1][2] or by commonly used formulae [9][10]. The implementation of the latter in *ASTRA* has been verified successfully against calculations by the disruption code *GO* [11].

Modeling RE generation in AUG discharges of argon (Ar) MGI, the evolution of key plasma parameters (such as plasma current evolution, line integrated electron density, etc.) is calculated well in agreement with experimental observations. Importantly, experimental observations can be explained in this framework only through application of state-of-the-art models for electron runaway in the presence of partially ionized impurities [1][2]. Neglecting aforementioned kinetic effects by describing RE generation through commonly used formulae, simulations fail to capture experimental trends, such as e.g. onset of RE generation and magnitude of post-disruption RE current. Consequently, kinetic effects in the presence of partially ionized impurities are crucial to describe electron runaway during MMI.

In the simulations presented, injection of material into the confined plasma is well described by a 1D approach. Despite the complexity and 3D nature of MGI using individual gas valves, the approach chosen is found suitable as e.g. the line integrated electron density is reproduced. Here, neutral Ar is assumed to propagate from just outside the LCFS into the core plasma with thermal velocity $v_{\mathrm{th}} = \sqrt{T/m} = 246\ \mathrm{m/s}$ until being ionized. The transport of ionized material is governed by both neoclassical and MHD phenomena. As the bulk of the material injected reaches the $q = 2$ surface, an MHD $(m, n) = (2,1)$ mode and higher harmonics are excited, giving rise to additional transport [6]. To describe this effect, a 0D model of transport coefficients decaying exponentially with time is found suitable; the magnitude of which is determined from one AUG discharge [3]. The same coefficients can also be applied in simulations of other, similar AUG discharges. Still, further studies using a non-linear MHD framework will have to assess the applicability of the chosen transport coefficients.

Since the toolkit presented is found suitable for the study of electron runaway in MMI scenarios, the impact of varying impurity amounts, species and composition (in particular the impact of $D_2$ admixture [1]) on RE generation is to be explored further and compared to experimental observations (see e.g. [11]).

## References

[1] L. Hesslow et al., NF **59**, 084004 (2019)
[2] L. Hesslow et al., JPP **85**, 475850601 (2019)
[3] O. Linder et al., Submitted to NF (2020)
[4] G. Pautasso et al., PPCF **59**, 014046 (2020)
[5] G. Pautasso et al., Accepted by NF (2020)
[6] E. Fable et al., NF **56**, 026012 (2016)
[7] R. Dux et al., NF **39**, 1509 (1999)
[8] H.P. Summers. The ADAS User Manual (adas.ac.uk)
[9] J.W. Connor et al. NF **15**, 415 (1975)
[10] M.N. Rosenbluth et al. NF **37**, 1355 (1997)
[11] G. Papp et al., NF **53**, 123017 (2013)
[12] G. Papp et al., 46th EPS, I4.105 (2019)