Effect of Post-Thermal-Quench Shattered Pellet Injection on Runaway Electrons Generation in ITER

Lovepreet Singh*[1], Eric Nardon[2], Lorenzo Votta[3], Mathias Hoppe[3], and Oskar Vallhagen[4]

[1]CEA-IRFM, F-13108 Saint-Paul-les-Durance, France – CEA, IRFM, F-13108 Saint-Paul-Lez-Durance – France

[2]CEA-IRFM, F-13108 Saint-Paul-les-Durance, France – CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France – France

[3]Department of Electrical Engineering, Royal Institute of Technology, SE-11428 Stockholm, Sweden – Sweden

[4]Department of Physics, Chalmers University of Technology, SE-41296 Gothenburg, Sweden – Sweden

Abstract

In the study by Nardon et al. (2022), Nucl. Fusion 62, 026003, the mitigation of runaway electron (RE) seeds through interactions with Hydrogen shattered pellet injection (SPI) fragments during an ITER disruption was investigated. The proposed mechanism involves RE losing energy upon colliding with pellet fragments, with the energy loss governed by the stopping power of the fragment material. These fragments are injected into the plasma during the current quench (CQ), early enough in time when the RE population is small and the shards can effectively penetrate the plasma. If the rate of energy dissipation due to these interactions exceeds the acceleration of RE driven by the loop voltage, the formation of a large RE population could potentially be suppressed. The study demonstrated the feasibility of stopping RE with kinetic energies up to 10 MeV within a minor radius r of 1 m. However, the analysis was based on simplifying assumptions, including a constant loop voltage and a maximum RE kinetic energy of 10 MeV. In our work, we relax these assumptions by considering a spatially varying loop voltage and removing the upper bound on RE kinetic energy. Our results show that RE with energies up to 100 MeV can be stopped in the core region ($r< 0.5$ m). In the outer plasma region ($r> 0.5$ m), only RE with energies up to approximately 10 MeV are effectively stopped. However, this appears insufficient to significantly help avoid the formation of large RE beams. Another potential effect of SPI during the CQ phase is the increase in electron density caused by the vaporization of injected fragments due to interactions with the forming RE beam. We are currently investigating with DREAM whether this density increase can be harnessed to approach the Rosenbluth critical density, thereby strongly reducing the avalanche multiplication of RE. Nonetheless, recombination may pose a significant challenge to this approach, as indicated by Vallhagen et al. (2020), J. Plasma Phys. 86, 475860401.

*Speaker