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Runaway Electron Studies and Plasma Restart from a RE Beam on TCV

Tokamak disruptions have the potential to create runaway electrons (RE) and if unmitigated, could cause severe localized damage. The physics of RE are not sufficiently understood and TCV has developed an extensive set of controls and diagnostics to contribute to this field of research. Successful mitigation of RE beams on TCV has been achieved through three techniques: 1) controlled ramp-down of the RE current to a few kA; 2) mitigation through high-Z gas injection; and 3) plasma restart within the confining poloidal field generated by the RE beam.

Full conversion of ohmic to RE current is achieved on TCV through massive gas injection (MGI) into a low density plasma[1]. Typically, limited plasmas with densities <1e19m-3 are used to produce pre-disruption electric fields ˜20-40x larger than the classic critical electric field. The resulting pre-disruption RE population acts as a seed during the MGI induced disruption and Figure 1 presents this nominal TCV scenario. RE beams of 200kA and durations in excess of 1s can be reliably produced. Databases scanning plasma parameters and RE creation are available for a range of densities, shapes (negative triangularity, elongations up to 1.5, diverted configurations), injection gas species (D2, He, Ne, Ar, Kr and Xe, Figure 2) and injection quantities. Diagnostic collaborations have provided additional new capabilities such as a multispectral imaging system to measure the pre-disruption RE seed and examined its properties through modelling with SOFT[2].

![Basic plasma parameters in reference RE discharge #52717. Left –plasma current and loop voltage, middle –line integrated electron density and hard x-ray signal from the PMTX diagnostic, right –electron density and temperature from Thomson Scattering at z=0.25m][fig1]

![Natural decay rate of beams with D2, He, Ne, Ar, Kr and Xe injection. From top to bottom –plasma current, hard x-ray signal measured with PMTX diagnostic, line integrated electron density and mid-plane neutral pressure.][fig2]

Plasma restart after formation of a RE beam has been demonstrated on TCV[3]. Massive D2 injection into a low density plasma resulted in RE beam formation with a background plasma temperature too low for Thomson Scattering (<6eV). The core plasma temperature was observed to increase back to the pre-disruption temperature in ˜100ms with the hard x-ray signal subsiding over ˜100-150ms, as shown in Figure 3. Experiments exploring flushing of heavier impurities with D2 injection have not been successful in restarting the plasma due to high radiation losses and increased resistivity of the background plasma. Auxiliary heating with neutral beam injection and radiofrequency waves was able to increase background plasma temperature but a complete plasma restart after D2 flushing has yet to be achieved. Modelling is underway using the relativistic kinetic Fokker-Planck code LUKE to investigate the physics involved.

![Plasma restart from a RE beam. From top to bottom –plasma current, line integrated electron density, highest measured electron temperature and HXR emission.][fig3]

[1] J. Decker, in preparation
[2] M. Hoppe, Submitted to NF: 103811
[3] U. Sheikh, in preparation

[fig1]https://www.dropbox.com/s/zaasamutb4pj1zx/scenario.jpg
[fig2]https://www.dropbox.com/s/emjfqf28n60agci/gas_scan.jpg
[fig3]https://www.dropbox.com/s/pf4rzh86h7xixif/restart.jpg

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