Shattered Pellet Injection experiments at ASDEX-Upgrade for design optimisation of the ITER Disruption Mitigation System

S. Jachmich¹, M. Lehnen¹, G. Papp², U. Kruezi¹, M. Bernert², A. Bock², J. Cerovsky³,

M. Dibon², O. Ficker³, D. Fiorucci⁴, P. Heinrich², G. Kocsis⁵, B. Kurzan², P. de Marné²,

T. Peherstorfer⁶, U. Sheikh⁷, T. Eich², J. Hobirk² and the ASDEX Upgrade Team^{*}

- ¹ ITER Organization, Route de Vinon, CS 90 046, 13067 Saint Paul Lez Durance, France
- ² Max-Plank-Institut für Plasma Physik, D-85748, Garching, Germany
- ³ Institute of Plasma Physics of the CAS, Prague, Czech Republic
- ⁴ ENEA research center Frascati, Via Enrico Fermi 45, 00044 Rome, Italy
- ⁵ Centre for Energy Research, Budapest, Hungary
- ⁶ Vienna University of Technology, Vienna, Austria
- ⁷ EPFL, Swiss Plasma Center (SPC), CH 1015 Lausanne, Switzerland

* see author list of U. Stroth et al. Nucl Fus 62, 042006, 2022

ITER is planning to install a disruption mitigation system (DMS), which is essential to protect the machine against detrimental effects resulting from disruptions. To fulfil this task, the DMS will consist of several shattered pellet injectors (SPI) to deliver neon (Ne) and a large quantity of protium in the form of fragments to the plasma. The fragment size and velocity distribution and spatial spread of the plume are governed by the chosen shattering unit geometry and the velocity of the impacting pellet. The specifications for the DMS shattering unit are determined in a concerted effort through modelling to predict the optimum fragment injections for ITER, design testing in dedicated laboratories and experiments on existing tokamaks. In order to study the effects of different fragment plume characteristics on the material assimilation efficiency, a triple barrel SPI equipped with three different shattering units, together with new bolometric systems and fast cameras observing the injection were installed on ASDEX-Upgrade (AUG) as part of the ITER DMS Task Force activities. The angles of two of the shattering units were chosen such that similar fragment size distributions can be achieved while having different parallel velocity components, with the third unit being designed to produce a less collimated fragment plume. The shattering units were characterised in laboratory experiments prior the installation of the injector at the torus. The amount of injected material can be tailored by varying the pellet lengths and diameters. With these features, the AUG-SPI offers the unique possibility to compare the impact of different shattering unit designs on disruption mitigation processes.

The AUG SPI experiments have mainly focused on pre-thermal quench (TQ) ablation studies with single injections of deuterium (D) pellets for runaway electron avoidance and Ne-D mixtures for TQ mitigation into plasmas over a range of different thermal energies, but without pre-existing instabilities. Injections of D pellets shattered into small fragments resulted in longer pre-TQ durations but with lower edge density rise compared to injections with large fragments. The core assimilation appears to be better for larger and slower fragments, due to their deeper penetration as observed by fast cameras. The material assimilation seems to further benefit from adding Ne in fractions of ~0.17% as indicated by highest edge density rise measured with interferometry. This is in line with results from modelling cases performed for ITER suggesting a reduction of plasmoid drifts, which would otherwise impede deep material deposition: small quantities of Ne improves the penetration by reducing the local plasma temperature. The long pre-TQ phases induced by mainly D SPI producing small fragments allowed the application of staggered injection schemes aiming at a higher density rise and accompanying energy loss prior the TQ to reduce the amount of Ne needed for the final TQ-mitigation.

In this contribution, the results from these AUG SPI experiments will be presented and the conclusions drawn from them for the design the ITER DMS shattering unit will be summarised.