Off-axis NBI-driven energetic particle modes at ASDEX Upgrade

Ph. Lauber\textsuperscript{1}, B. Geiger\textsuperscript{1}, M. Maraschek\textsuperscript{1}, L. Horvath\textsuperscript{2}, C. Di Troia\textsuperscript{6}, G. Papp\textsuperscript{1}, M. Dunne\textsuperscript{1}, A. Biancalani\textsuperscript{1}, M. Schneller\textsuperscript{1}, X. Wang\textsuperscript{1}, I. Classen\textsuperscript{4}, V. Igochine\textsuperscript{1}, A. Mlynek\textsuperscript{1}, M. García-Muñoz\textsuperscript{1,5}, V. Nikolaeva\textsuperscript{1,1}, L. Guimarais\textsuperscript{3}, NLED Enabling Research Team, and the ASDEX Upgrade Team

\textsuperscript{1}Max-Planck-Institut für Plasmaphysik, Garching, Germany
email: pwl@ipp.mpg.de

\textsuperscript{2}Institute of Nuclear Techniques, BME, Budapest, Hungary

\textsuperscript{3}Associação EURATOM/IST, Instituto de Plasmas e Fusão Nuclear, Instituto Superior Tecnico, Universidade Técnica, 1049-001 Lisboa, Portugal

\textsuperscript{4}FOM Institute Differ - Dutch Institute for Fundamental Energy Research, Association EURATOM-FOM, 3430 BE Nieuwegein, The Netherlands

\textsuperscript{5}Department of Physics, University of Seville, Seville, Spain

\textsuperscript{6}ENEA, Frascati, Italy

The off-axis injection of neutral beam ions (2.5 MW) during the current ramp-up phase in ASDEX Upgrade gives rise to strongly non-linear energetic particle bursts emerging from the TAE gap. The modes seem to be similar to observations on JT-60U [Shinohara, 2002-2004] or on spherical tokamaks with the important difference that at ASDEX Upgrade the ratio of the velocity of injected beam ions compared to the Alfven velocity is far below 1 ($v_{NBI}/v_A \sim 0.4$). The fast ion $\beta$ in these discharges is transiently comparable or even larger than the thermal $\beta$ allowing one to explore a unique parameter space relevant for the stability of burning plasmas. Additionally, a clear correlation of these bursts and energetic particle driven geodesic acoustic modes (EGAMs) is observed, indicating a velocity space coupling of both modes.

Based on various diagnostics measurements and beam deposition calculations for the energetic particle distribution function, a kinetic stability analysis will be shown, investigating the drive mechanism of the EGAMs and the TAE bursts. The non-linear features of the modes will be discussed. More generally, these results will allow us to understand in a detailed way the transition from weakly-driven Alfven modes to strongly-driven energetic particle modes and the interaction mechanisms of AEs with zonal modes, both experimentally and theoretically/numerically.

Figure 1: Spectrogram of the magnetic pick-up coil signal in the presence of off-axis (co-direction) NBI drive (#31213).

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.