Small-ELM H-modes in strongly shaped MAST Upgrade tokamak plasma

K. Imada[1,2], S. Saarelma[3], D. Dunai[4], T. Rhodes[1,3], V. Hall-Chen[3], T.H. Osborne[1], S. Blackmore[3], X. Chen[1], D. Dickinson[2], M. Knolker[1], J. Parisi[5], P.B. Snyder[6], H.R. Wilson[7] and the MAST Upgrade Team[3]

[1] *General Atomics, San Diego, CA 92186-5608, USA*

[2] *York Plasma Institute, School of Physics, Engineering and Technology, University of York, Heslington, York YO10 5DD, U.K.*

[3] *UKAEA, Culham Campus, Abingdon, Oxfordshire, OX14 3DB, UK*

[4] *Plasma Physics Department, HUN-REN Centre for Energy Research, Budapest, Hungary*

[5] *Princeton Plasma Physics Laboratory, NJ, USA*

[6] *Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*

[7] *UK Industrial Fusion Solutions Ltd., West Burton Power Station, Retford, DN22 9BL, UK*

Future pilot tokamak power plants will likely maintain fusion-relevant conditions in high-confinement modes (H-modes), characterised by the formation of a "pedestal". However, the resulting steep radial pressure gradient often triggers edge localised modes (ELMs), the largest types of which (Type-I) can degrade core confinement and cause serious damages to vessel walls. Future tokamaks must therefore operate in Type-I ELM-free regimes, whilst maintaining the high core confinement of standard H-modes.

One such example is the quasi-continuous exhaust (QCE) regime, in which the pedestal height is still comparable to Type-I ELMy regimes, but with increased radial transport across the pedestal suppressing the ELMs. Observations on ASDEX Upgrade[1] indicate that QCE regimes can be triggered in strongly shaped plasmas with high elongation and triangularity, compared to the Type-I ELMy counterpart.

In recent experiments at MAST-U spherical tokamak, a number of discharges exhibited long Type-I ELM-free periods [2] with high triangularity and squareness, and elevated Dα emission level. MHD stability analysis using the ELITE code shows the pedestals are very close to the ideal ballooning limit, even though Type-I ELMs are not triggered. Doppler Back-Scattering system and Beam Emission Spectroscopy data show increased density fluctuation amplitudes in the pedestal region, with the modulation consistent with high-frequency Type-II ELMs. All the evidence points to these "Type-I ELM-free" periods corresponding to the QCE regime, which is the first such identification on MAST-U. If QCE regimes in spherical tokamaks are found to be scalable to reactor-relevant conditions, then our results will have significant impact on the scenario design of pilot power plants, such as STEP.

[1] M. Dunne et al, Nucl. Fusion **64** 124003 (2024)

[2] K. Imada et al, Plasma Phys. Control. Fusion **66** 125011 (2024)