Contribution ID: **703** Type: **Overview**

Overview of recent progress in understanding NSTX and NSTX-U plasmas & Overview of new MAST physics in anticipation of first results from MAST Upgrade

Tuesday 23 October 2018 18:20 (15 minutes)

A. The mission of the spherical tokamak NSTX-U is to explore the physics that drives core and pedestal transport and stability at high-β and low collisionality, as part of the development of the ST concept towards a compact, low-cost ST-based Pilot Plant. NSTX-U will operate at up to 2 MA and 1 T with up to 10 MW of Neutral Beam Injection (NBI) power for 5 seconds with up to 4 MW of High Harmonic Fast Wave (HHFW) power. In this parameter space, electromagnetic instabilities are expected to dominate transport. Furthermore, beam-heated NSTX-U plasmas will be able to explore the energetic particle (EP) phase space that is relevant for both α-heated conventional and low aspect ratio burning plasmas. A further objective is to develop the physics understanding and control tools to ramp-up and sustain high performance plasmas in a fully-noninductive fashion for pulse lengths up to 5 s. NSTX-U began research operations in 2016, producing 10 weeks of commissioning and scientific results. However, a number of technical issues, including the failure of a key divertor magnetic field coil, resulted in the suspension of operations and initiation of Recovery activities. During the Recovery outage, there has been considerable work in the area of analysis, theory and modeling with a goal of understanding the underlying physics to develop predictive models that can be used for high-confidence projections for both ST and higher aspect ratio regimes. The studies have addressed issues in thermal plasma transport, indicating the importance of non-local and multi-scale effects, EP-driven instabilities at ion-cyclotron frequencies and below, studying the wave-particle interactions and development of descriptive predictive models, and heat flux width modeling and the role of turbulence broadening. NSTX-U is expected to resume operations during CY2020.

This work was supported by US Department of Energy Contract No. DE-AC02-09CH11466

B. MAST Upgrade will operate in 2018 with unique capabilities to explore plasma exhaust and alternative divertor configurations to address this key issue for DEMO. Modelling of the interaction between filaments with BOUT++ indicates filaments separated by more than 5x their width move independently, and their velocity is slightly perturbed by if their separation is 1 width, suggesting radial density profiles can be modelled as the superposition of filaments. Secondary filaments on MAST are found up to 1ms after type-I ELMs that correlate with plasma interaction with surfaces near the X-point. A quiescent region devoid of filaments near the X-point has been routinely observed, extending from the separatrix to a normalised flux of 1.02. Counter-streaming flows of doubly ionised carbon along field lines, generated by localised gas puffing, have been observed and reproduced in EMC3-EIRENE simulations. MAST-U will be an excellent facility for understanding detachment onset and control in closed divertors. SOLPS modelling predicts the upstream density needed to reach detachment will be over 2x lower in the Super-X configuration compared with the conventional divertor due to increased total magnetic flux expansion. Analytic modelling predicts detachment control in a Super-X is more amenable to external control. Detailed measurements of transport through the edge have been made in MAST L-mode plasmas to characterise a Geodesic Acoustic Mode 2cm from the separatrix. Interpretation of plasma potential profile measurements using ball-pen probes have been improved through kinetic modelling, showing that electrons polarise the material around the probe, leading to ExB drifts of ions to the probe.
Measurements of the effects of sawteeth on fast ion confinement on MAST indicate that passing and trapped particles are equally redistributed by the sawtooth crash. There is no apparent energy threshold for redistribution, indicating redistribution due to a mechanism resonant with the m=1 perturbation. Gyrokinetic simulations of ETG turbulence in MAST are in close agreement with the measured collisionality dependence of the energy confinement time. Beam emission spectroscopy measurements show that flow shear leads to eddy tilting in up-down symmetric plasmas and skewed density fluctuations. First results from MAST Upgrade operations will be presented.

Country or International Organization

United States of America

Paper Number

OV/5-5Ra

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Session Classification: OV/5 Overview Magnetic Fusion

Track Classification: OV - Overviews