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The Science Program of the TCV Tokamak: Exploring Fusion Reactor and Power Plant Concepts

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TCV is acquiring a new 1 MW neutral beam and 2 MW additional third-harmonic ECRH to expand its operational range. Its existing shaping and ECRH launching versatility was amply exploited in an eclectic 2013 campaign. A new high-confinement mode (IN-mode) was found with an edge barrier in density but not in temperature. Density limits close to the Greenwald value were reached –at reduced confinement - by sawtooth regularization with ECRH. The edge gradients were found to be regime-dependent and to govern the scaling of confinement with current. A new theory predicting a toroidal rotation component at the plasma edge, driven by inhomogeneous transport and geodesic curvature, was tested with promising results. The L-H threshold power was measured to be 15-20% higher in both H and He than D, to increase with the length of the outer separatrix, and to be independent of the current ramp rate. Core turbulence was found to decrease from positive to negative edge triangularity deep into the core, consistent with global confinement increase. The geodesic-acoustic mode was studied with multiple diagnostics, and its axisymmetry was confirmed by a full toroidal mapping of its magnetic component. The heat flux profile decay length and heat load profile on the wall were documented as functions of plasma shape in limited plasmas. In the snowflake (SF) divertor configuration we have documented the heat flux profiles on all four strike points. SF simulations with the 3D EMC3-Eirene code, including the physics of the secondary separatrix, underestimate the flux to the secondary strike points, possibly resulting from steady-state ExB drifts. With neon injection, radiation in a SF was 15% higher than in a conventional divertor. The novel triple-X and X-divertor configurations were achieved transiently in TCV. A new sub-ms real-time equilibrium reconstruction code was used in ECRH control of NTMs and in a prototype shape controller. The detection of visible light from the plasma boundary was also successfully used in a position-control algorithm. A new bang-bang controller improved stability against vertical displacements. The RAPTOR real-time transport simulator was applied to current density profile control experiments with ECCD. Shot-by-shot internal inductance optimization was demonstrated by iterative learning control of the current reference trace.

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