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PhD PROPOSAL 2017

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Title : Dynamics of the sawtooth crash: implication for energy, impurity and fast ion fluxes

Topic description: Tokamaks are affected by regular periodic reorganizations of the core plasma. A complete sawtooth can be subdivided in two phases: a slow rise (typ. tens milliseconds) of the core temperature and density followed by an abrupt crash (typ. 100 microseconds) that flattens temperature and density profiles. During the quiescent phase, energy and particles are confined in the core and impurity penetration is slow. During the crash, magnetic field lines are broken and reconnected yielding to particle and impurity influx and outflow. Sawteeth are of renewed interest in present tungsten devices because the periodic impurity core flushing helps to limit tungsten accumulation in the plasma core. In ITER this beneficial effect could be mitigated by induced expulsion of fast alpha particles.

The aim of this thesis is to investigate the dynamic of the sawtooth crash and its effect on particle, energy and fast ion fluxes. Although progresses have been recently made on the quiescent sawtooth phase, the exact processes behind sawtooth crashes remain unclear. Even the field line reconnection is not fully understood; full magnetic reconnection is predicted by some models whereas alternative theories require only an incomplete reconnection. Sawtooth reconnection bears similarities with reconnection phenomena that occur in astrophysics such as in solar atmosphere or magnetic planetary tail.

A major difficulty for sawtooth crashes is the limitation of diagnostic capabilities to follow the fast crash dynamic (typ. 100 μs). On WEST, ultrafast reflectometry and Electron Cyclotron Emission Imaging (ECEI) will provide for the first time simultaneous 2D images of density and temperature profiles with a time resolution of few microseconds. Previous results have shown that particle and energy dynamics are different: density is governed by the reconnection flows whereas temperature evolution is dominated by field line reconnection. Recently, it was also shown that value of the core current profile could be recovered from high frequency MHD modes which are triggered by sawtooth crash. These new diagnostics should allow a better radial localization of these modes.

In support of the experimental results, XTOR simulation will be performed. XTOR code is being developed at the Centre de Physique Théorique at Ecole Polytechnique. It can simulate the MagnetoHydroDynamic (MHD) instabilities responsible for sawtooth activity in nonlinear regime. For energetic particles, a “hybrid” version will be used, which computes the evolution of energetic ions coupled to MHD equations.

This thesis is based on the joint pillars of experimental observations and numerical simulations. XTOR simulations will first be compared to existing results on Tore Supra and KSTAR, the Korean tokamak. On KSTAR, a unique system of 3 ECE imaging diagnostics allows an almost 3D reconstruction of temperature map inside the core. ECEI operation in WEST is planned for 2018. 2D images of density and temperature profiles will then be simultaneously observed to better understand the dynamic of the

field lines and flows during the reconnection.

This study will be led in collaboration with the Centre de Physique Théorique at the Ecole Polytechnique. The student will also collaborate with the ECE imaging Korean team which is developing the ECEI diagnostic for WEST.