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Current carrying filaments in the L-mode, H-mode and ELMs in RFX-mod tokamak operation

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The RFX-mod experiment is a fusion device born to operate as Reversed Field Pinch (RFP), with a major radius R= 2 m and minor radius a = 0.459 m, equipped with a first wall fully covered by graphite tiles. Its high versatility allowed operating also as an ohmic Tokamak, with a toroidal field up to 0.55T, extending the parameter range explored by other devices, for example in the very low q (a) <2 region, and in particular allowing comparative studies between tokamak and reversed field pinch in the same device [1]. RFX-mod is equipped with a set of 192 actively controlled saddle coils arranged in 48 poloidal arrays each of them consisting of 4 coils, fully covering the vessel torus. This system represents the state of the art of MHD mode feedback control [2]. In particular, it allows a noticeable flexibility, so that the magnetic boundary can be effectively controlled and modulated by applying resonant or non-resonant magnetic perturbations (MP) both in RFP and in tokamak configurations [3,4]. In the fusion community the application of MPs is widely studied as a promising tool in particular to limit the impact of plasma filaments and ELMs, in particular on plasma facing components [5]. An important issue is envisaged in the exploitation of the active control system for ELM mitigation studies in the RFX-mod2 the upgrade of the RFX-mod experiment [6,7]. Within this framework the aim of this contribution is providing the most recent achievements concerning the investigation of current carrying filament detected in the edge-SOL region of RFX-mod comparing L-mode and H-mode regime filament features and dynamics. A special attention is also devoted to the study of the filaments observed within the ELMy bursts contributing to disentangle their fine electrostatic and magnetic structure.
Filament properties in L and H-mode regimes in the RFX-mod operating as a tokamak. The dynamics of turbulent filaments in L-mode and ELM-free H-mode was studied in the RFX-mod device operating as a tokamak [8,9], where the H-mode was achieved by applying edge electrode biasing on Upper Single Null discharges [10].

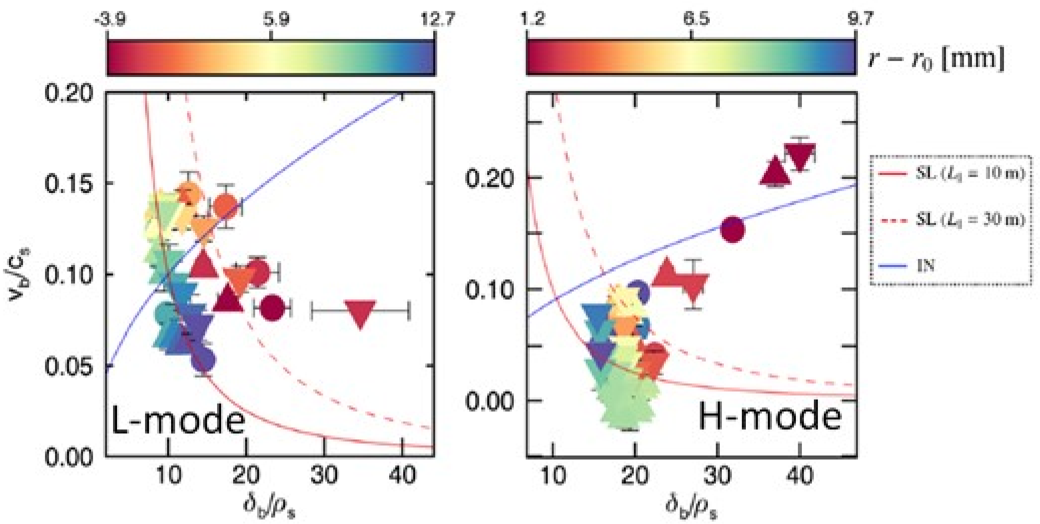

Figure 1: Filament normalized velocity vs normalized size in L-mode and H-mode. The symbol shape represents different shots. The red lines stands for the SL velocity scale at magnetic connection length L||= 10 m (full line) and L|| = 30 m (dashed line), the blue curve represents the inertial scale (IN). The colorbar refers the position of detected filaments with respect to the separatrix position.

Through advanced statistical techniques, filaments were detected and tracked from the edge to the Scrape-Off Layer (SOL) in a two-dimension floating potential map associated with extreme events of a fixed ion saturation current signal in the SOL. While in L-mode filaments travel almost freely, during the ELM-free H-mode phase their motion is restricted to the near SOL. In this region, the background shear decorrelation time becomes shorter than the filament convective time, favoring its suppression. However, the experimental observation of a nearly 'trapped' monopole potential points out the possible role of the vortex selection mechanism. The H-mode sparse filamentary transport in the far SOL was further confirmed from the measurements of a poloidally symmetric electrostatic sensors array on the wall: while in L-mode a clear loss channel at outboard mid-plane is observed, in ELM-free H-mode, it is virtually stopped. Lastly, it was observed that filaments in L-mode better scale according to the sheath limited (SL) regime [11], where parallel dissipation towards the wall governs the potential depletion (fig.1). The filament associated parallel current density, experimentally estimated from a 2D set of 3-axial coils installed in the probe head, is in qualitative agreement with this picture. In addition, the strong variation of the parallel connection length along the radial direction due to the plasma-wall proximity leads to a bifurcation, with filaments in the near SOL scaling differently from those further out (fig.1). On the other hand, H-mode regime filaments exhibit a better match with the inertial regime (IN), where parallel dissipation becomes less important. Such a result is consistent with the corresponding measured parallel current density.

Current carrying Edge Localized Modes fine structure in the Scrape-Off Layer of tokamak discharges. Similar statistical techniques [8 8] were applied for the study of electromagnetic features of ELM events detected during the occurrence of H-mode regime, biasing induced, in RFX-mod. In particular detailed electrostatic and magnetic features analysis revealed a complex fragmented and radially extended filamentary structure within a single ELM. Strong peaks in parallel current density Jtor are observed to characterize the ELM bunch. Analogous features were observed in COMPASS [12] and RFX-mod ELM structures. Indications of ELM fragments of moving towards far SOL is always observed.

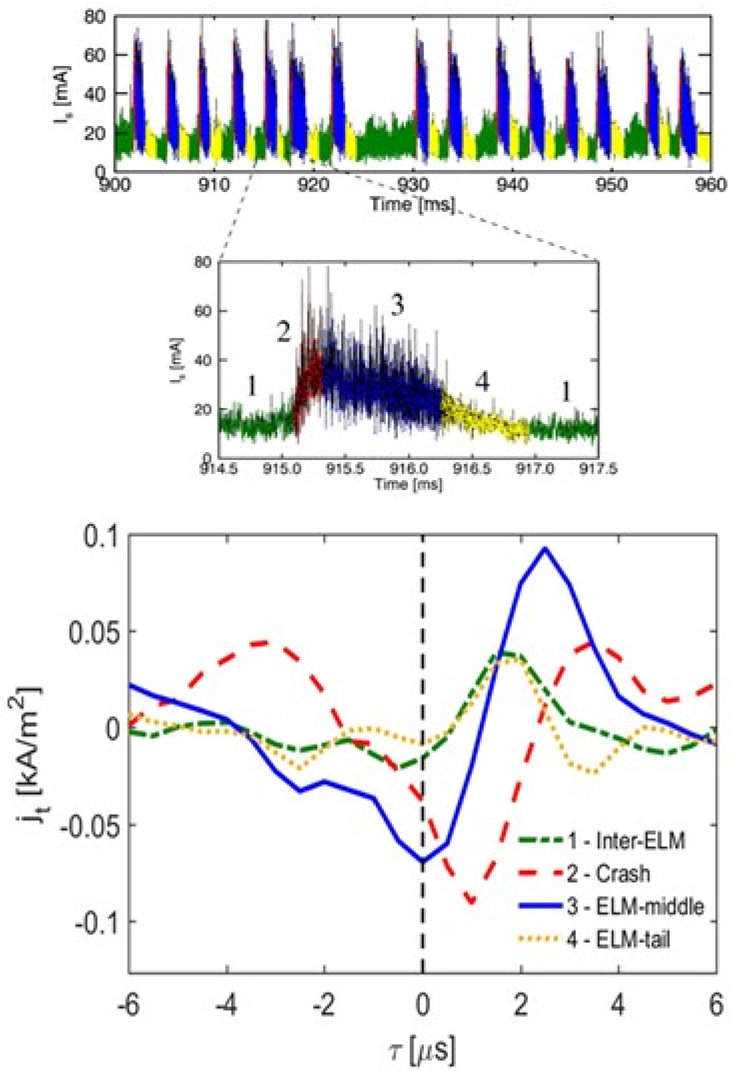

Figure 2: Average filamentary parallel current density measured at different phases within the ELM bunch burst. The bunch is identified by local ion saturation current, Is, top panels.

The time evolution of near-SOL radial profiles allowed the reconstruction of a sequence consistent with the cyclical establishment of strong edge gradients followed by the ejection of clusters of filamentary fragments (ELMs) with electromagnetic features (Fig. 2) [8,13]. This behavior is confirmed by the 2D local potential map reconstruction. Within the ELM burst cycle the ejection phases were identified with the "crash"and "middle-phase"within the ELM bunch, where radial propagation of current carrying filaments recovers transiently the L-mode filament dynamics.

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