Anomalous transport and losses of energetic particles in burning fusion plasmas

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Energetic particles (EP) are ubiquitous in fusion plasmas and need to be well-confined in order to transfer their energy to thermal particles and thus achieve self-sustained fusion reactions. However, a fusion plasma is a complex system where micro- and macro-instabilities develop. These instabilities can dramatically reduce the EP confinement and therefore limit the performance of future fusion devices such as ITER. This is the reason why understanding and controlling EP transport in the presence of different instabilities is of prime importance on the route towards steady-state scenarios.

In the first part of this presentation, we give an overview of the theory, modelling and experimental observation of transport and losses of EP in the presence of electromagnetic instabilities. In the second part, we provide a deep insight into the impact of single-helicity modes, such as Energetic Geodesic Acoustic Modes (EGAMs) [1-3] or tearing modes [4-7], characterized by one poloidal (m) and one toroidal (n) mode numbers. Although such modes are not believed to produce chaotic transport, significant losses of EP have been observed, both experimentally and numerically. The purpose of this second part is to shed light on these observations and provide an explanation for the losses of EP in the presence of single-helicity modes, leading to the characterization of the transport as anomalous.

Such transport has been analysed and quantified using the recently developed *Toroidal Accelerated PArticle Simulator* (TAPAS) [8]. For this purpose, TAPAS has been parallelized and deployed on Graphical Processing Units (GPU), exhibiting an acceleration factor of 10 with respect to classical CPU partitions. The capabilities of TAPAS to integrate a large number of trajectories (>10^9) and produce an enormous amount of data are exploited to analyse the transport and losses of fusion-born alpha particles [8]. Finally, the efficiency of TAPAS allows us to build a large database of loss patterns of alpha particles and thereby unveil the fundamental physics of their transport and losses.

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