Onset of the thermonuclear instability and Oscillatory States near Ignition

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Ignition, that is the condition when the nuclear plasma heating equals the rate of plasma energy loss, can be achieved in high magnetic field experiments such as Ignitor at relatively low peak temperatures [1]. At this stage of the plasma heating cycle the thermonuclear instability can develop. The aim of analysis that is presented is to identify the conditions under which the instability can be prevented from producing an excessive temperature excursion and where an oscillatory state, corresponding to values of the fusion criticality parameter $\mathrm{P}_{\alpha}/\mathrm{P}_{\mathrm{loss}}$ slightly lower than unity, can be achieved (under quasi steady state conditions characterized by $\mathrm{P}_{\mathrm{fusion}}/\mathrm{P}_{\mathrm{input}} > 10$). The considered plasma thermal diffusivity and degree of plasma purity are consistent with those obtained by high magnetic field experiments (most recently by the FTU machine), in which high densities with peaked profiles have been produced by repeated pellet injections, as planned for Ignitor. In fact oscillatory states have been produced rather easily by our numerical simulations, carried out by the 1-1/2D JETTO transport code, in subignited regimes where proper combinations between the tritium to deuterium ratio and additional ICRH pulses are used to maintain these quasi-stationary states.

Moreover a set of representative nonlinear equations designed to describe an oscillatory state near ignition has been formulated. This produces a relatively rapid sequence of temperature rises, due to nuclear heating, and crashes due to an instability driven by the plasma pressure gradient in the central region of the plasma column. The pressure profile from which this sequence starts is the "canonical" profile that has been identified [2] as being reached at ignition under a variety of conditions for high density plasmas (i.e. peak densities around $10^{21}\, m^{-3}$)

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[1] B. Coppi, A. Airoldi, F. Bombarda et al, *Nuclear Fusion* **41**, 1253 (2001).
[2] A. Airoldi and G. Cenacchi, *Nuclear Fusion* **41**, 687 (2001)