Research Pogram of Dr. Vianello

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3D Physics in present and future Fusion devices

3D effects are becoming extremely important in the fusion research. Also intrinsic two-dimensional configurations as Tokamaks are now fostering research in the application of the magnetic perturbation, which naturally breaks the symmetry of the configuration, in particular with the aim of controlling plasma instabilities such as the Edge Localized Mode. The possibility of controlling these instabilities is mandatory for the future devices. A bunch of work remains to be done to understand the consequences of 3D fields and magnetic perturbation in confined plasma. Planned research foresees the study of effects of 3D field in:

(a) Profiles: Detailed experimental characterization of edge and SOL modification caused by magnetic perturbations in fusion devices including tokamaks, reversed field pinches and stellarators (international collaborations are foreseen). Emphasis will be devoted to the determination of the reasons causing the density pump-out observed in varios experiments highlighting the enhanced transport channel and the role of high-k turbulence in determining this process. This require the analysis of the interaction between perturbed magnetic surfaces and plasma turbulence.

(b) Edge flow: Edge flow and edge radial electric field are found to be modified by magnetic perturbation. Helical radial electric field arises as a consequence of ambipolar response. Still lack of knowledge exists on the spatial relationship between applied perturbation and ambipolar response and the role of collisionality/viscosity or plasma density in determining the spatial phase relation between vector and scalar potential remains unknown.

(c) Core region: Proposed activity regards the role of 3D fields in controlling MHD modes as RWM or tearing instabilities or tailoring of sawtooth activity, and in the effect of 3D fields in the modification of core rotation of both plasma and MHD modes. Indeed these effects are mandatory in order to understand the possibility to modify flow profile by opportunely governing magnetic perturbation by exploring the role of Neoclassical Toroidal Viscosity and electromagnetic torque in the plasma. This research line may be exploited using data obtained both in Reversed Field Pinches and in Tokamaks

(d) Energetic particles: ITER and future devices will operate with a large population of fast particles, both as fusion reaction products, or because of high energy Neutral Beam Injection (ITER Neutral Beam Injector will operate with a maximum energy of 1 MeV). Thus research on Energetic Particle driven modes are mandatory in order to anticipate the challenges future magnetic devices. Research has to be pursued by means of theoretical and numerical models (turbulence spreading of energetic particles, energetic particle modes stability as examples) but also experimentally. For this porpoise experiments may be considered in small devices with fast ion sources (NBI or ICRH) or in general with detailed studies of the interaction between MHD modes and fast particles. Tools for controlling MHD modes or modification of profiles through non-axysimmetric magnetic field can be considered for perturbative studies of energetic particle redistribution.

As an ancillary subject a research activity on *Spontaneous and induced rotation* is proposed. A strong effort has been devoted by the fusion community to the comprehension of the spontaneous rotation, both toroidal and poloidal rotation, observed in fusion relevant plasmas. Understanding the physics underlying this topic is fundamental, as spontaneous rotation would help in the control of dangerous MHD instabilities in future devices. Various theories have been proposed including theories regarding the role of turbulence and residual stress or Up-down asymmetry. Furthermore little knowledge exists on the mechanism governing momentum transport from the core to the edge of toroidal plasmas. This task may be studied using perturbative approach such as biased limiter or divertor plates, pulsed NBI momentum transfer or varying edge magnetic ripple (which has been shown to produce effects on spontaneous rotation) or applying Resonant and non-resonanant magnetic perturbation. On this topic experimental effort should be devoted on studying flow generation around magnetic islands and difference arising from the application of resonant and non-resonant magnetic perturbation. Momentum transfer may be studied also using spontaneous effects such as Relaxation events in Reversed Field Pinches or sawtooth crashes exploring in this way the effect of electromagnetic torque on plasma rotation.

All the proposed activity share commonalities among all the major magnetic configuration but also with different scientific communities in particular with astrophysical plasmas: indeed interaction between magnetic islands and magnetic field with energetic particles, or modification of high-k turbulence by means of magnetic field are all topics with great resonances also in astrophysical science. Beneficial results can be obtained by strengthening collaborations within all these communities and additional benefits could result from the already established collaborations of the candidate also with solar physics groups.