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The Reversed Field Pinch Physics: the Low Field Alternative to Fusion

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The Reversed Field Pinch (RFP) is a low magnetic field configuration for the confinement of thermonuclear plasmas. It exploits the pinch effect due to a current flowing in a plasma embedded in the toroidal magnetic field, which is one order of magnitude smaller than in a tokamak. It thus represents a non-disruptive, ohmically heated approach to magnetic fusion, based on self-organization and technological simplicity.

This talk presents recent advancements on the RFP physics, and the perspectives of the configuration as a viable alternative to magnetic fusion. The RFP community, though rather small, is present across the world, including in Asia the RELAX device in Japan and the newly built KTX in PRC, RFX-mod in Italy, MST in the USA and EXTRAP T2-R in Sweden.

For a long period the RFP has been disregarded for its low confinement properties, associated to the presence of magnetic chaos and turbulence due to the growth and saturation of various MHD instabilities. This paradigm has changed in the last years, also thanks to the introduction in some devices of powerful control systems, able to stabilize or reduce MHD modes. Two main improved confinement regimes have been discovered and routinely produced in the experiments. At high Lundquist number values, obtained at high plasma current, a new robust operational regime is found, as predicted by MHD modeling, associated to the spontaneous occurrence of a new self-organized helical equilibrium with a single helical axis, reduced magnetic fluctuations and strong transport barriers. Improved confinement regimes have been also actively stimulated by inductive profile control to minimize MHD activity.

The steep electron temperature and density gradients in these improved plasmas are prone to the destabilization of small-scale instabilities, in the form of microtearing and trapped electron modes, exhibiting experimental spectral properties in good agreement with gyrokinetic calculations. The possible presence of long wavelength MHD pressure-driven tearing modes is, however, one of the remaining issues of the high β regimes.

A positive isotope effect has been found in helical RFP plasmas, as well as the natural tendency of strong outward impurity convection.

The very interesting property of classical high energy particle confinement is exhibited by the RFP equilibrium and a non-maxwellian high energy tail is measured within the ion velocity distribution function. The latter is further enhanced during the spontaneous reconnection processes cyclically occurring in the plasma, which are known to induce particle acceleration and heating. The observation of a variety of Alfvén eigenmodes can be considered as the indirect evidence of such fast ion population, whose effects and dynamics have been studied also thanks to neutral beam injections. Main consequence of this suprathermal ion component is the observed enhanced neutron production from DD fusion reactions.

The improved confinement with current, the spontaneous tendency to develop high ion tails, the engineering simplicity, the resilience to impurity penetration, the immunity to disruptions make altogether the RFP an appealing field of investigation for viable developments of fusion related research.