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Change of paradigm for the reversed field pinch and its impact on fusion science

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The reversed field pinch (RFP) community is submitting to Nuclear Fusion a review paper providing the state of the art of this configuration and describing its impact on fusion science [1]. It shows that in the last three decades, a change of paradigm occurred for the RFP [2]. Indeed, since 1990, MHD simulations displayed a bifurcation from a chaotic state to a helical and almost regular one [3]. Experimentally, this bifurcation was found in 2000 to occur when current increases [4]. Increasing further the current, a second bifurcation occurs, leading to the formation of an internal transport barrier [5,6]. RFP physics had a clear impact on fusion science. For instance, explaining the hybrid mode of operation of the tokamak, operating the DIII-D tokamak with an edge safety factor q95<2, and demonstrating simultaneous active suppression of multiple resistive wall modes by active coils.

This poster reviews the salient features of the research on the Reversed Field Pinch (RFP) in the last three decades and its impact on fusion science [1,2]. It shows that in this period a change of paradigm occurred for the RFP, first conceptually, and then consequently experimentally. Taylor relaxation theory for the RFP emerged at the time where no MHD simulation was possible and where the RFP was crowded with magnetic chaos and poor confinement. However, since 1990 MHD simulations refuted this theory by displaying a bifurcation from a chaotic state to a helical and almost regular one [3]. Experimentally, this bifurcation was found to occur when current is increased [4]. Increasing further the current, a second bifurcation predicted theoretically [5] occurs, leading to the formation of an internal transport barrier [6].

This was an incentive for the project leading to the KTX machine in Hefei, a large RFP in operation since 2015, and motivated the present upgrade of the RFX-mod device, the largest present RFP (major radius R=2m and minor radius a=0.459 m, Padua, Italy) to remove most of the limitations due to its present sub-optimal magnetic front-end. RFP physics had a clear impact on fusion science. For instance, its dynamo theory [7] was used to explain the hybrid mode of operation of the tokamak [8], and to operate the DIII-D tokamak with an edge safety factor q95<2 through active control [9]. This type of dynamo is also present in a flux rope configuration susceptible to the kink instability [10]. RFP feedback control techniques enabled the simultaneous suppression of multiple resistive wall modes by active coils [11].

These important results were obtained by a small community. They motivated the present upgrade of RFX-mod. The upgraded machine will enable checking the quality of confinement at high current, and deciding whether the road to fusion opens for the RFP.

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