the rfx experiment

The Reversed Field Pinch (RFP) is an axisymmetric toroidal system in which the plasma is confined by a combination of a poloidal field produced by the plasma current I_{tor} flowing around the torus and a toroidal field, Btor, produced by currents flowing both in the plasma and in external coils.
Schematically the system is similar to a Tokamak and consists of a toroidal vessel, in which the plasma is formed, surrounded by a toroidal winding, that generates the initial Btor, and coupled to a coaxial transformer whose secondary is the plasma current I_{tor}.
The configuration derives its name from the fact that the toroidal magnetic field in the outer region is reversed with respect to its direction on the axis (fig. 1).

A typical profile of the magnetic field is shown in fig. 2a (solid line).
If the toroidal winding acts as a flux conserver, the field profile is automatically generated by raising the plasma current to a convenient level. In fact, while the current is raised, the plasma generates an additional toroidal flux in the inner part of the column and the coil reacts in order to keep the total flux constant: in the outer region the toroidal field is thereby reduced and even reversed, hence the name of the configuration. The reversal can be enhanced and controlled by the external circuits.
While in a classical conductor the toroidal field in a steady state would reach, by diffusion, a uniform radial distribution, in a RFP the plasma relaxation processes maintain the configuration by a mechanism called "dynamo effect" (by analogy to theories of the earth magnetic field generation).
The most significant difference between Tokamak and RFP magnetic field configurations is that in the Tokamak the toroidal field is much larger than the poloidal field, whereas in the RFP the toroidal and poloidal components are of the same order of magnitude and the toroidal field reverses in the plasma outer region.

Two parameters allow to identify a RFP configuration: the pinch parameter *Theta*= B_{pol} (a)/<B_{torave}>, and the reversal parameter F = B_{tor} (a)/<B_{torave}>, where B_{pol} (a) and B_{tor} (a) are the poloidal and toroidal field components at the wall and <B_{torave}> is the toroidal field averaged over the plasma cross-section. Taylor's theory states that, if the magnetic helicity and the toroidal flux are conserved, a plasma, with *Beta*= 0, spontaneously relaxes to a minimum energy force-free state described by the equation:
rot**B** = k**B**

where k is uniform and *k*a = 2 Theta. In cylindrical geometry, the solution of eq. (1) is given by Bessel functions (dotted lines in fig. 2a) and for *Theta*> 1.2 the toroidal field reverses at the wall.
However, it is found experimentally that RFP plasmas have finite Beta and the current density tends to vanish at the wall, i.e. *k* is not uniform (fig. 2b), so that the experimental profiles depart from the theoretical ones (solid lines in fig. 2a).
Fig. 3 shows where the preferred classes of parameters of Tokamak and RFP lie in the F - Theta diagram. The BFM (Bessel Function Model) curve corresponds to the theoretical Taylor's curve of force-free configurations, the other curves refer to a model which takes into account a non uniform *k* and a finite *Beta*. The Tokamak is at the left end of the diagram, with a large positive and almost uniform toroidal field and a comparatively small toroidal current (F ~ 1 and *Theta* small). The RFP configurations lie at the other extreme (F <0 and *Theta*> 1.2).
As shown in the same figure, these configurations are the result of the dynamical balance of the counteracting actions of resistive diffusion and relaxation processes. The first one tends to shrink the toroidal current distribution, whereas the second one, driven by MHD modes destabilized by the resistive diffusion, tends to restore the previous state. As a consequence, a RFP configuration is continuously regenerated through magnetic fluctuations.
The experiments carried out in the last two decades on RFP devices allowed to largely extend the knowledge of these phenomena; more recently, the two large RFP machines (MST in Madison, Wisconsin and RFX in Padova), while improving the overall picture thanks to the evolution of diagnostic instruments and of interpretation models, showed the possibility to actively influence plasma dynamics, so opening new operational windows and deepening the general understanding of magnetically confined plasma dynamics.