



CONSORZIO RFX  
Ricerca Formazione Innovazione



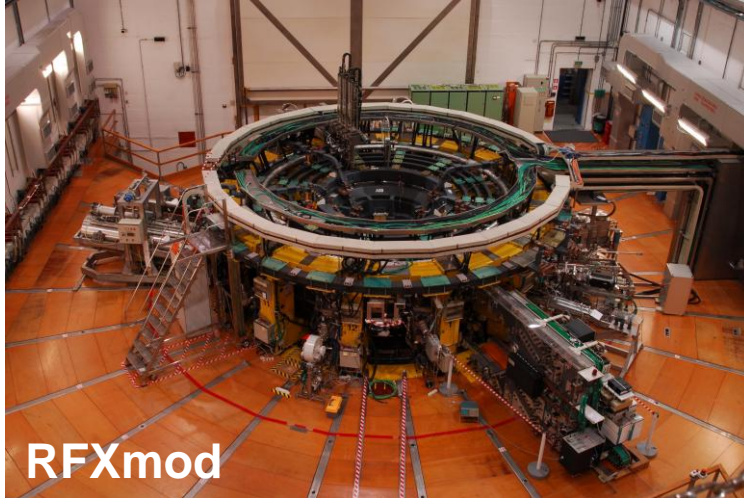
# Inductive Current Control to optimize magnetic confinement in RFP plasmas

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## Fusion Plasmas

Reversed Field Pinch (RFP) plasmas at RFXmod

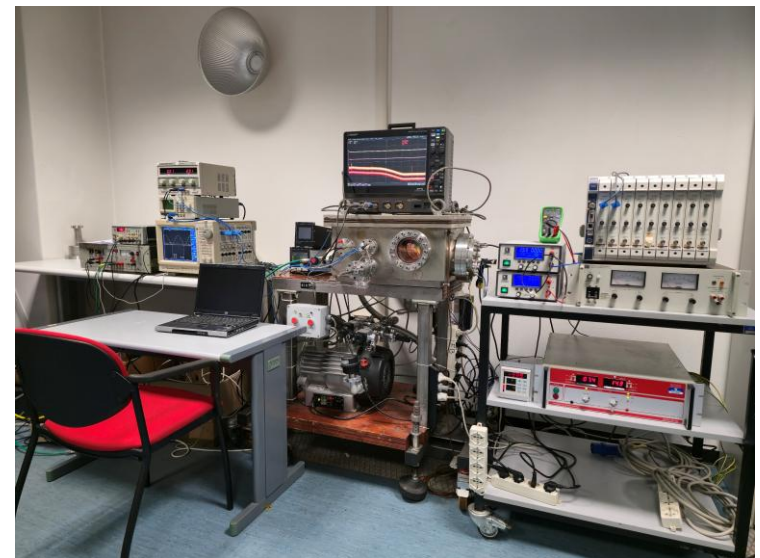
- High frequency magnetic instabilities
- Inductive Current Control
- Reconnection processes

## Laboratory Plasmas

Small-scale cold plasmas for emulation of the solar wind phenomena in controlled conditions

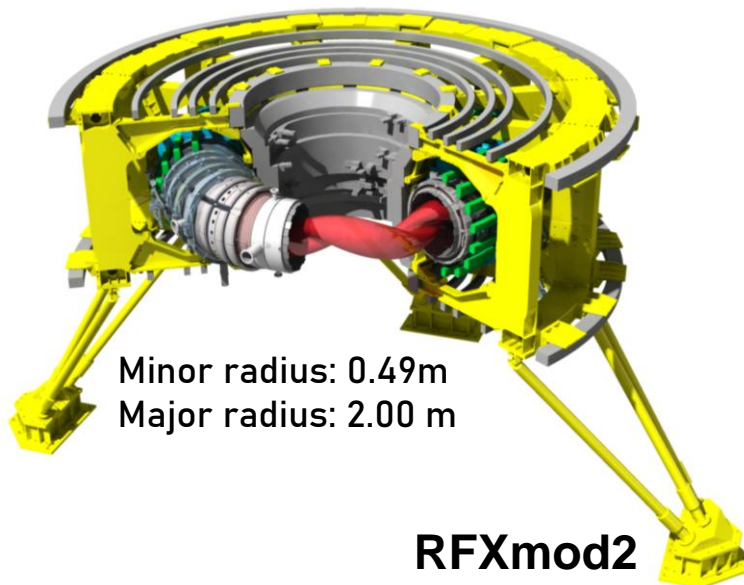
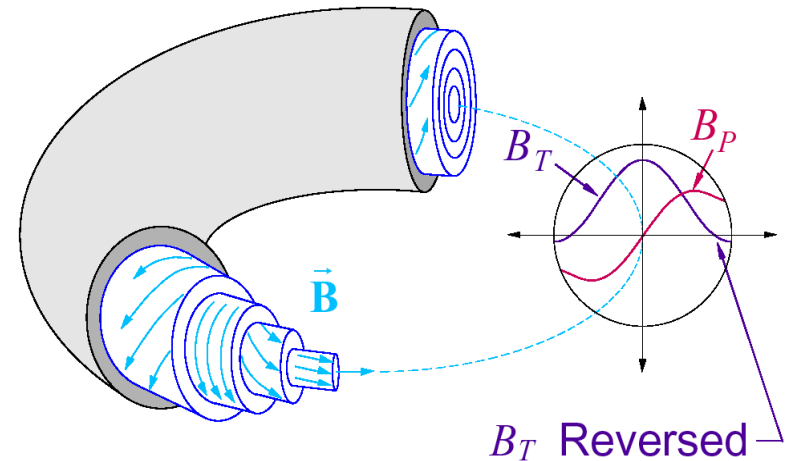
- Langmuir wave studies

(Tune in for next week's presentation!)



## Magnetic confinement done differently

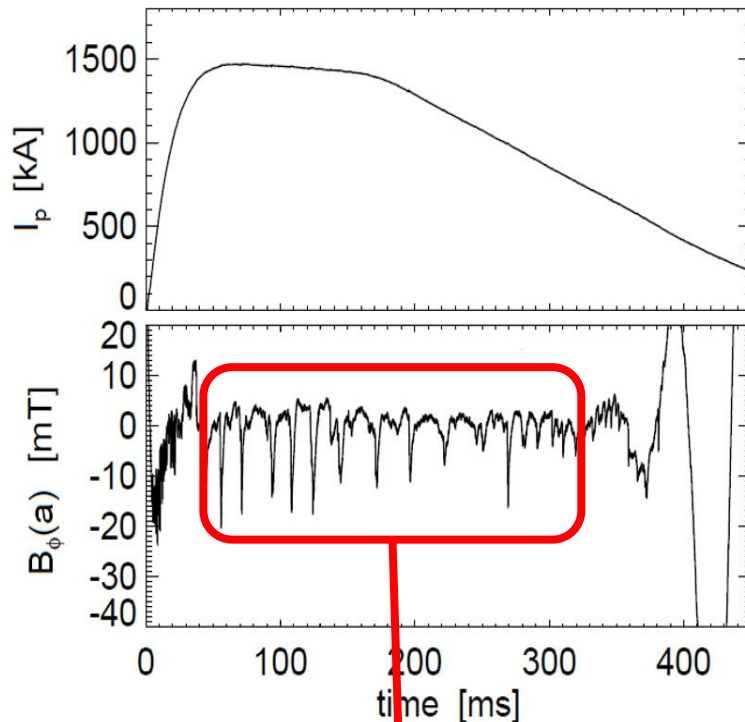
- Mainly characterized by the reversal of the  $B_T$  at the edge
- Plasma turbulence and magnetic fluctuations self-sustain the magnetic field  $\longrightarrow$  Dynamo effect



## Largest RFP device in the world!

- Starting operations in 2027 with improved diagnostics, control systems and general plasma performance
- Flexibility to operate in other configurations (Tokamak, ultra-low  $q$ )

## Relaxation to the minimum energy state with fixed global magnetic helicity



Large variations of the toroidal field at the edge

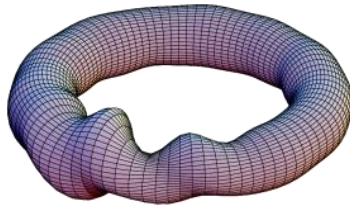
Magnetic reconnection as the process of **self-organization** of the magnetic topology

In RFP plasmas, reconnection events are **spontaneous**, and **almost cyclic**.

In some cases they result **detrimental** for the plasma performance since they destroy the ideal state of an RFP....

... which is?

## Multiple Helicity (MH)



The “base state” of an RFP  
Magnetic spectrum consisting of **Multiple Helicity Modes** (poloidal and toroidal) which results in a **chaotic** magnetic field

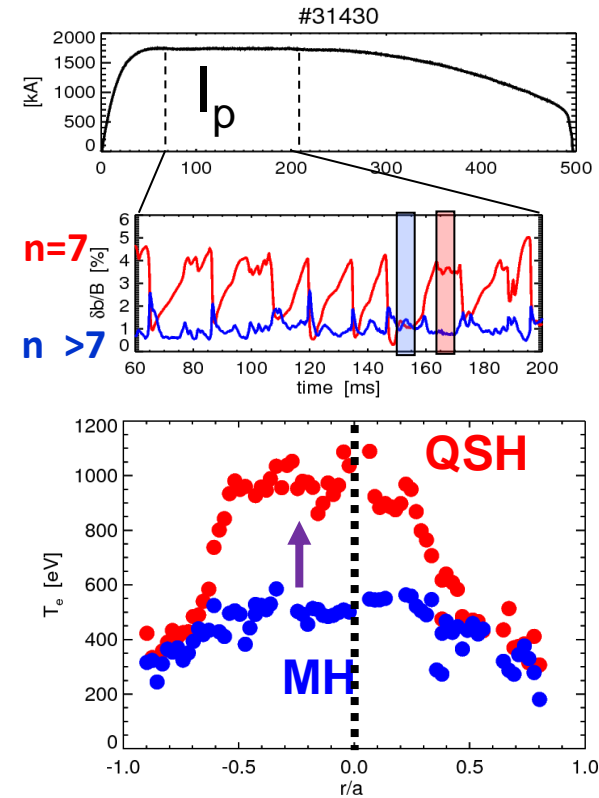
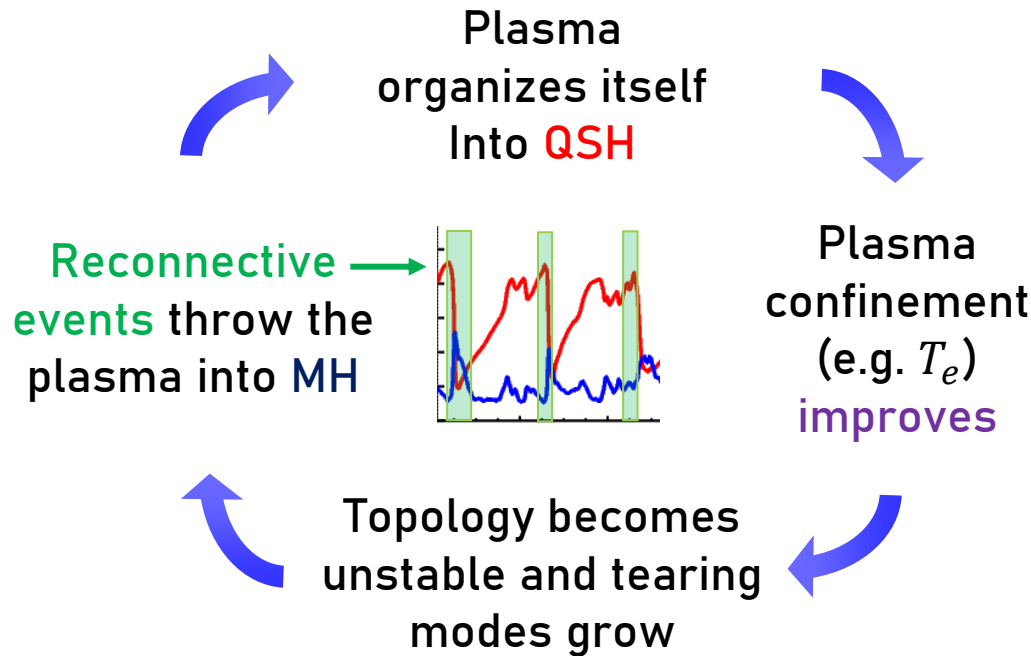
## Quasi-Single Helicity (QSH)



The self-organized optimal state  
A specific helical tearing mode becomes significantly **dominant**, which reduces the overall magnetic chaos. Typically, the topology is characterized by a **Single-Helical-Axis (SHAx)**

# Reconnection events governing QSH state

## The cyclic transition from MH to QSH



Is there something we can do about it?

**YES!**
  
 (we think)

# OPCD: A tool for reconnection control

## Forcing QSH into our plasmas

By actively inducing poloidal fields we are able to stabilize and promote (quasi) single helical structures.

Oscillating Poloidal  
Current Drive



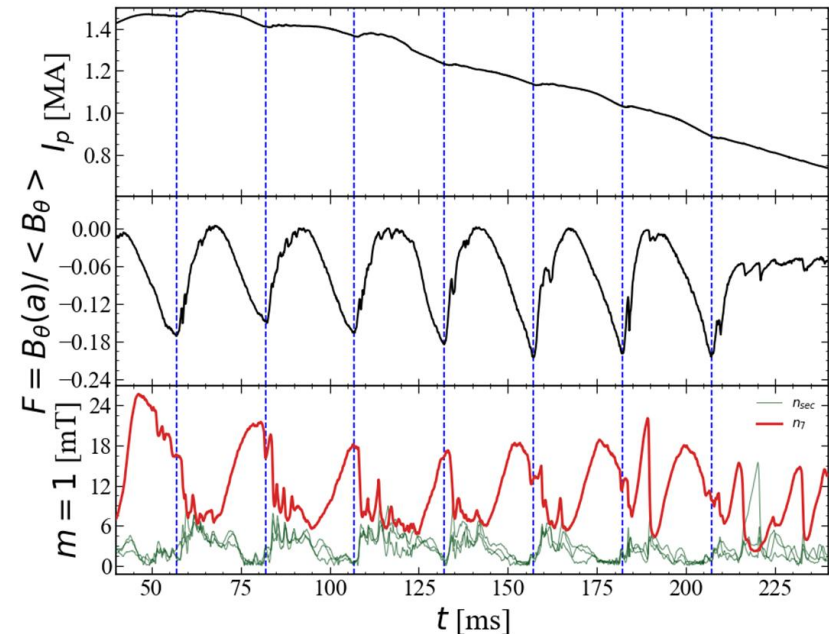
Through **controlled oscillations** in the induced poloidal field, this technique is able to entertain RFP's nonlinear magnetic relaxation cycle thus **regulating reconnection events**

Result: Strong (expected) correlation between OPCD intervention and **QSH stimulation**...

... but there might be a catch

## RFXmod data

Shot 24220



## Can OPCD unequivocally guarantee better confinement properties?

Probably not...

But we should be able to figure out when does the OPCD work, i.e. under which...

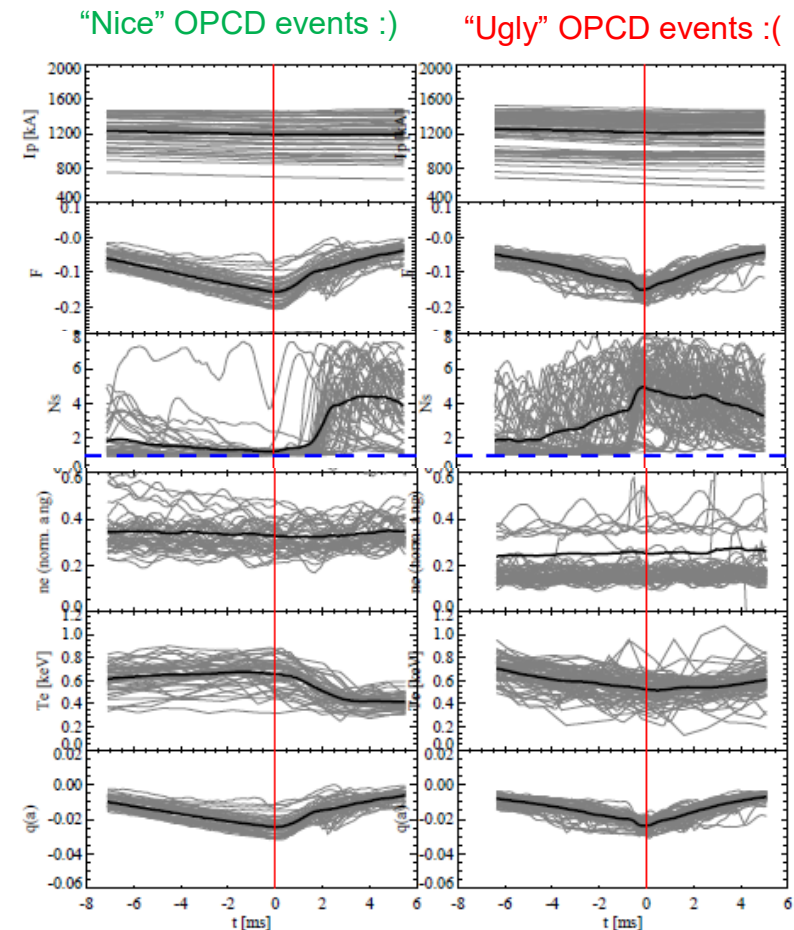
... tuning parameters

- Frequency of the oscillations
- Depth of  $F$

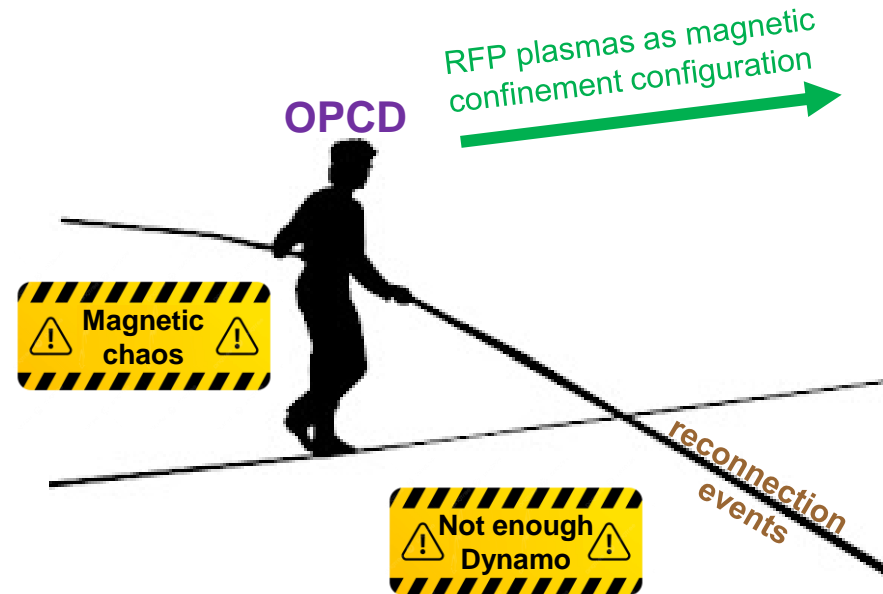
... conditions

- Regimes of temperature
- Regimes of density

And in particular, how OPCD relates to (other) reconnective events (crashes)



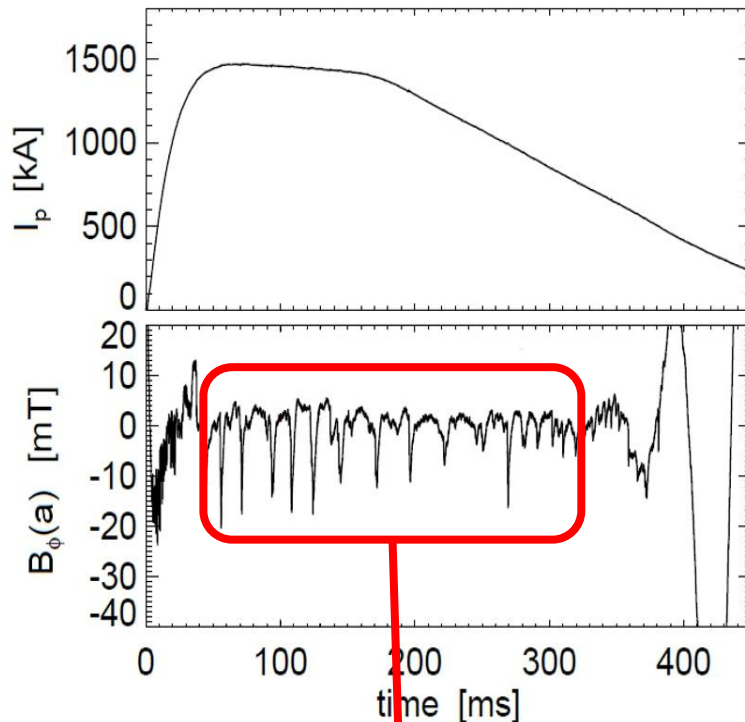
- RFP dynamics need magnetic fluctuations to sustain itself, but too many create transport losses
- OPCD intervenes as a modulation of the natural tendency of an RFP plasma to organize itself in order to optimize confinement
- Further investigations on this technique's optimization are being carried out on the verge of RFXmod2 starting operations in 2027





# Thank you!

## Relaxation to the minimum energy state with fixed global magnetic helicity



Large variation of the toroidal Field at the edge

Magnetic reconnection as the process of **self-organization** of the magnetic topology

In RFP plasmas, **reconnection events** are **spontaneous**, and almost **cyclic**. They associate with

- Impulsive **relaxations** of the magnetic profile
- Generation of **toroidal magnetic flux**
- **Ion heating** and **energy release**

In some cases they result **detrimental** for the plasma performance since they destroy the ideal state of an RFP....

... which is?