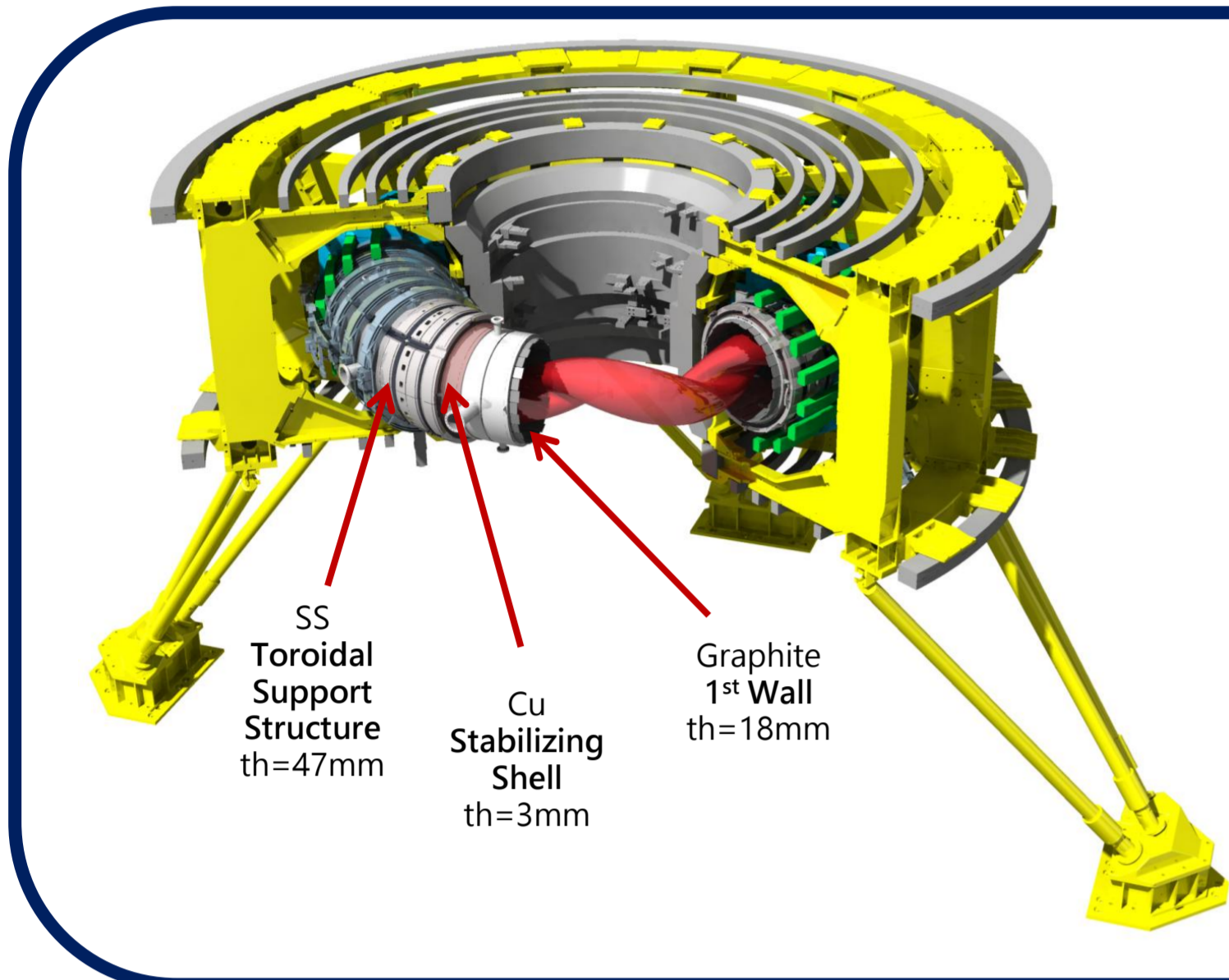


Magnetic fluctuations in fusion relevant plasmas in the RFX-mod device

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From RFX-mod to RFX-mod2: The true potential of RFP Plasmas



RFX-mod2: expected to start its first experimental phase in 2027

Major Radius	0.2 m
Minor Radius	0.46 m
Plasma Current	2 MA
Toroidal Magnetic Field	0.7 T
Ohmic heating only	60 MW
Plasma electron Temperature	> 1.5 keV
Pulse Durations	1 s

GOALS

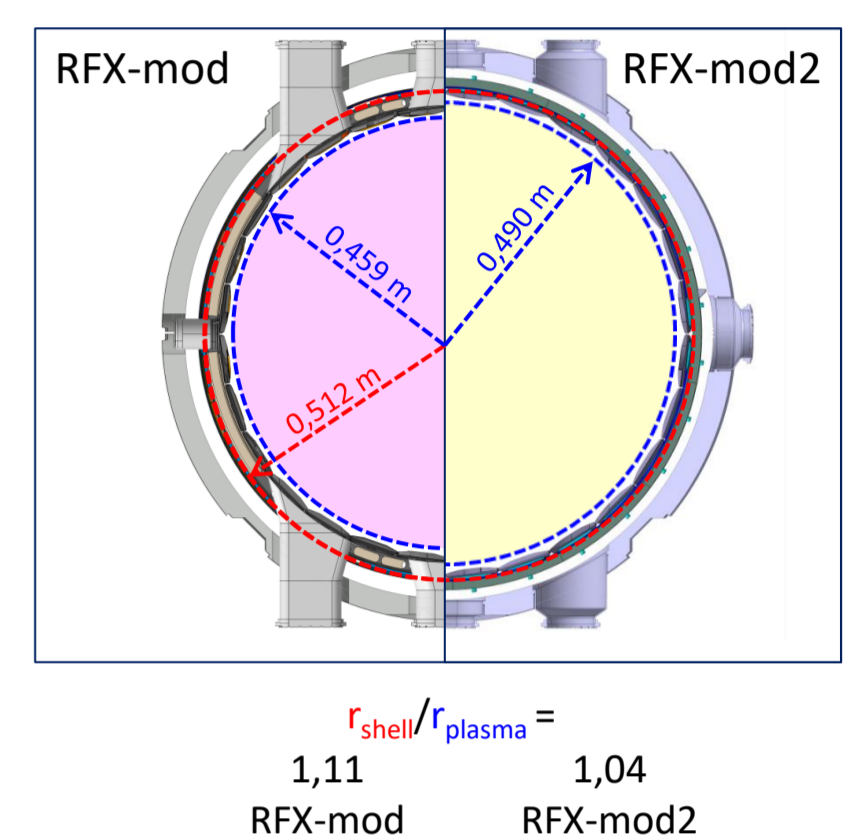
- Explore the potential of the **Reversed Field Pinch (RFP)** configuration
- Understand key science and technology problems in the **roadmap to ITER**

TOOLS

- Largest RFP** device in the world
- Multiple configurations: 200kA Tokamak / **Ultra low-q**
- Advanced **MHD feedback control** system
- RFP advanced helical states featuring 3D properties that can be studied through **stellarator tools**

RFX-mod2: an upgrade of the Reverse Field eXperiment (RFX-mod)

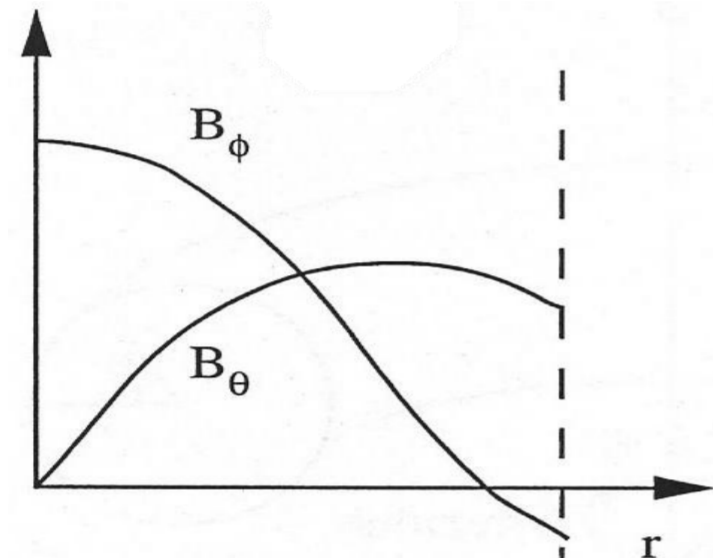
- Reduced **shell/plasma proximity** (removed vacuum vessel)
- Higher **Plasma Currents** (RFX-mod: 0.6 MA)
- Increased **speed and resolution** for improved diagnostics and control systems



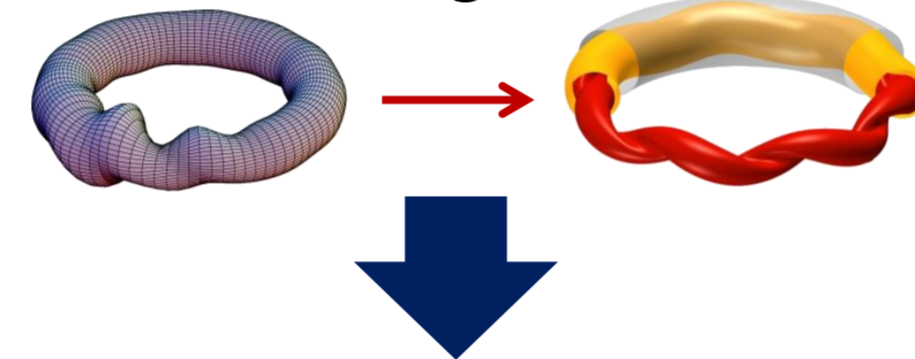
Wide versatility to explore magnetic configurations

Reversed Field Pinch

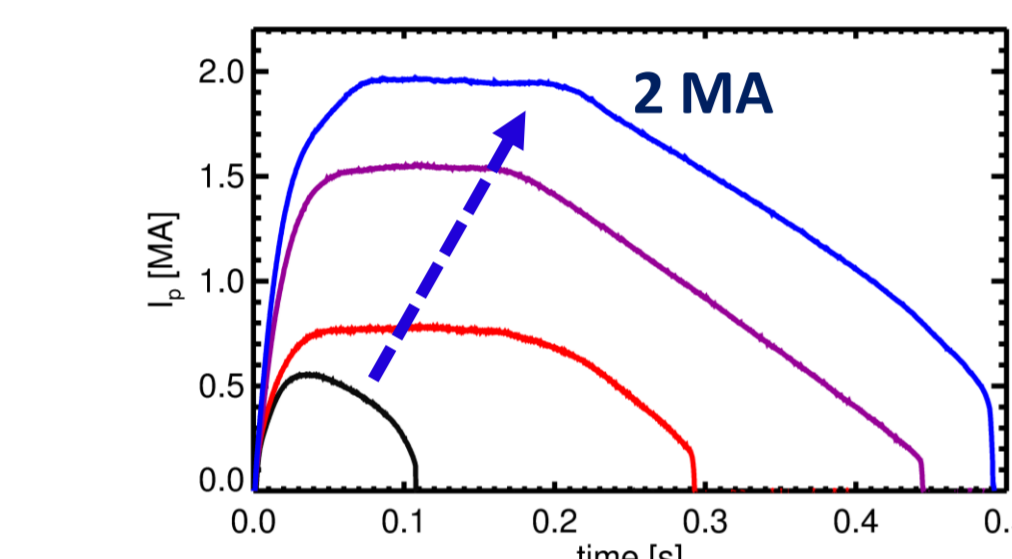
Self-organized helical plasma to improve confinement properties, achieved through the reversal of the toroidal field near the plasma edge



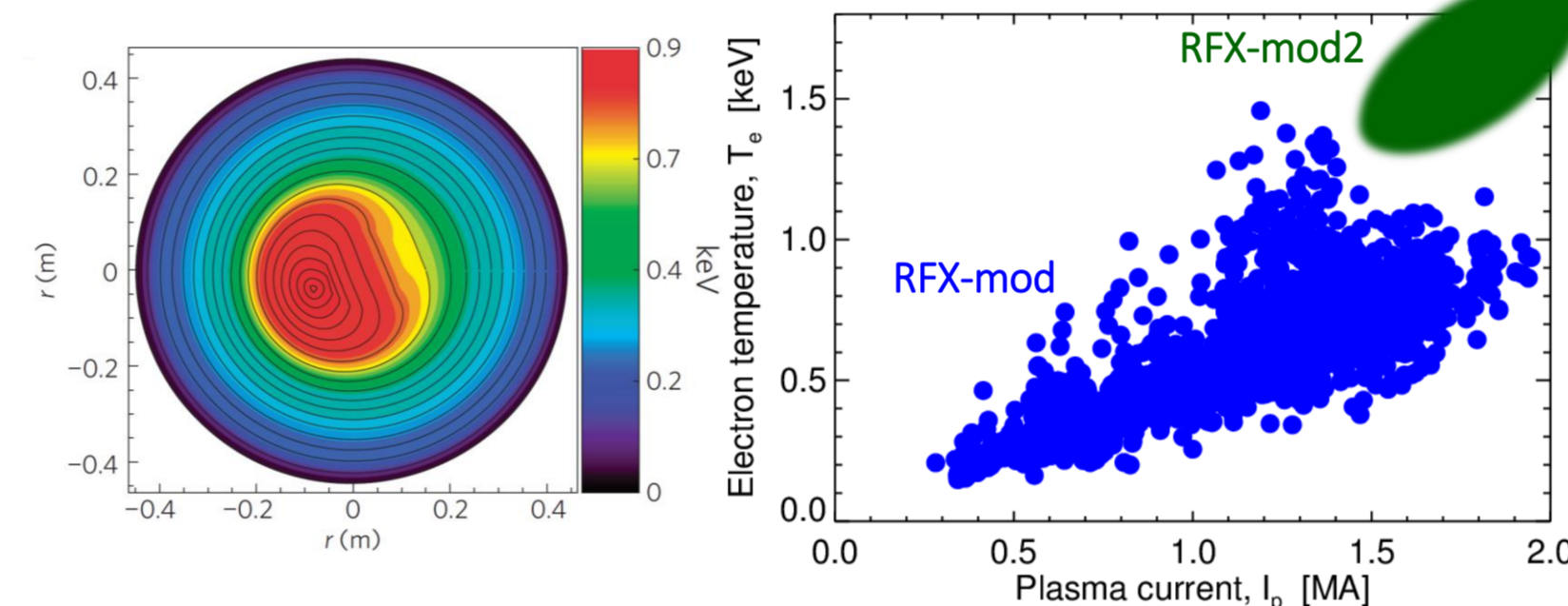
Quasi-Single-Helicity (QSH) operation + Reduced Magnetic Chaos



Improved confinement and performance



Use of advanced MHD-control techniques to achieve higher poloidal currents



Tokamak

Large **Plasma Shape** flexibility

- Single / double null
- Positive / negative triangularity

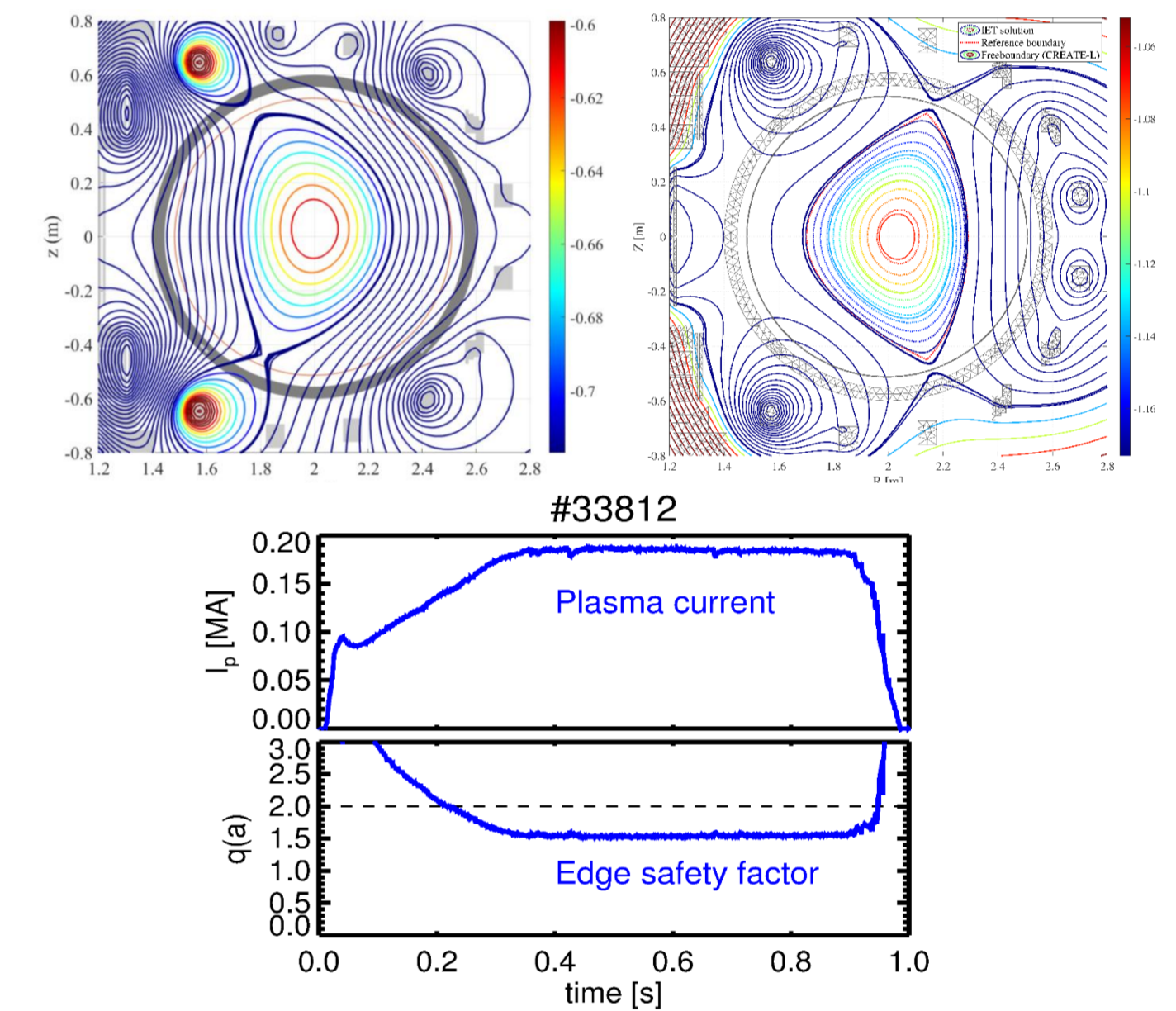
Plasma Current ≤ 0.2 MA

Robust $q(a) < 2$ operation

H-mode achievement (polarized electrode)

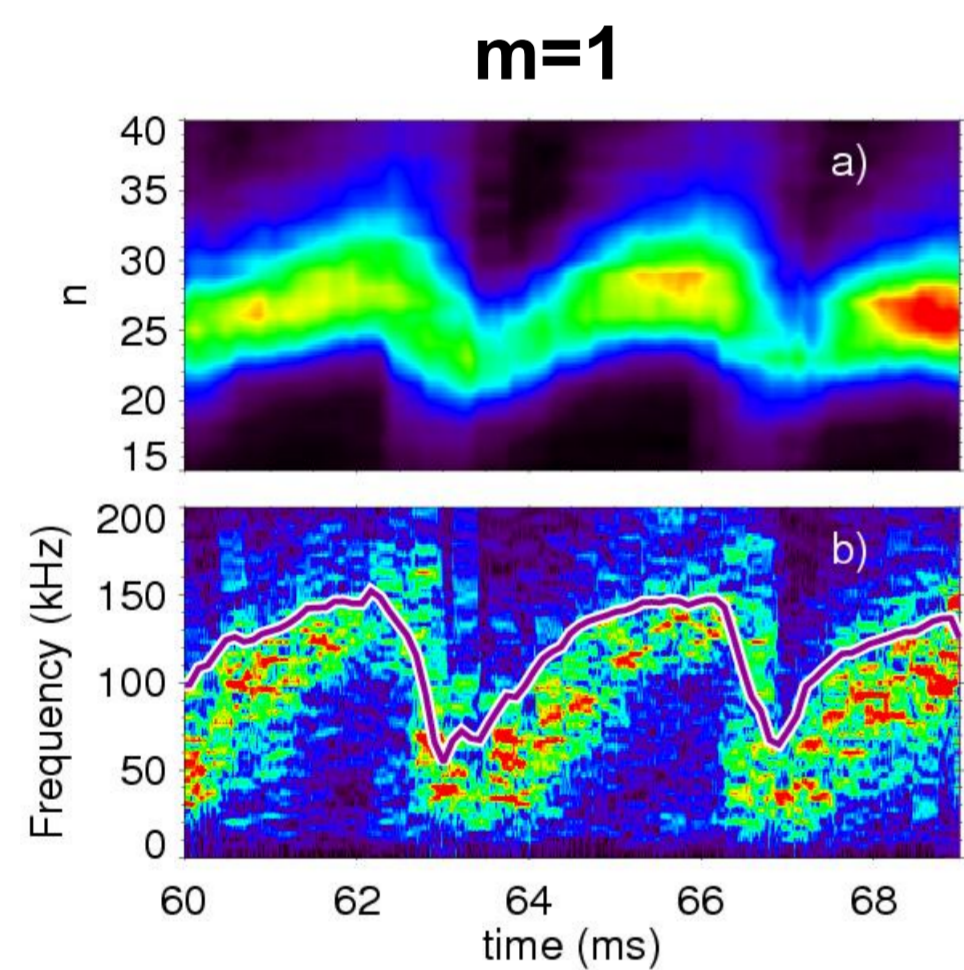
Studies of effect of magnetic perturbations on instability control and disruption avoidance

Sawtooth Control ($n=1$ applications)



High-frequency instabilities in RFP plasmas

Edge resonant modes



Driven mainly by relaxation of pressure gradients

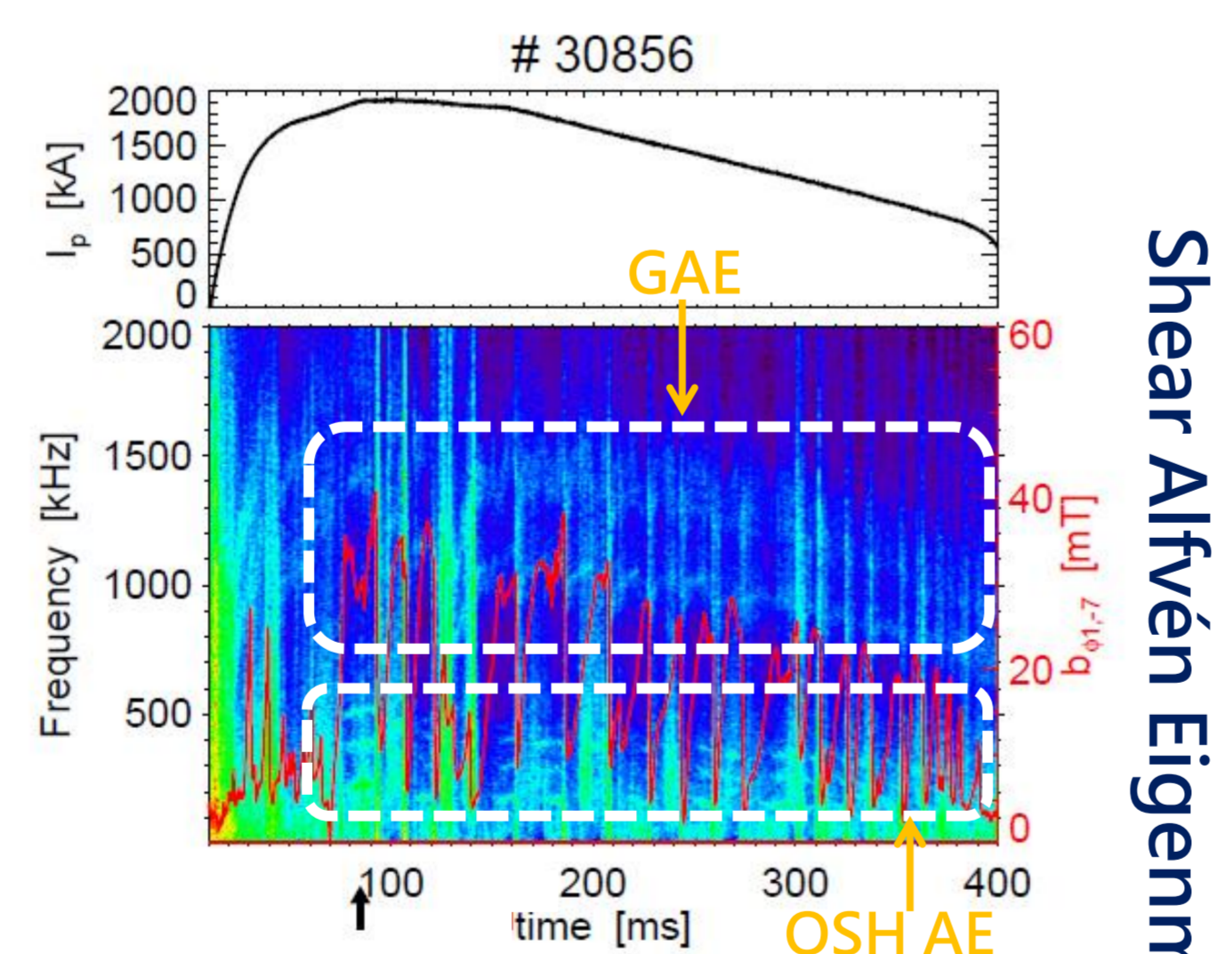
Localized at the plasma edge characterized by (relatively) high frequencies and high toroidal mode number ($n > 20$)

Strong correlation between the resonant modes and frequency evolution to $q(a)$ (fast response)

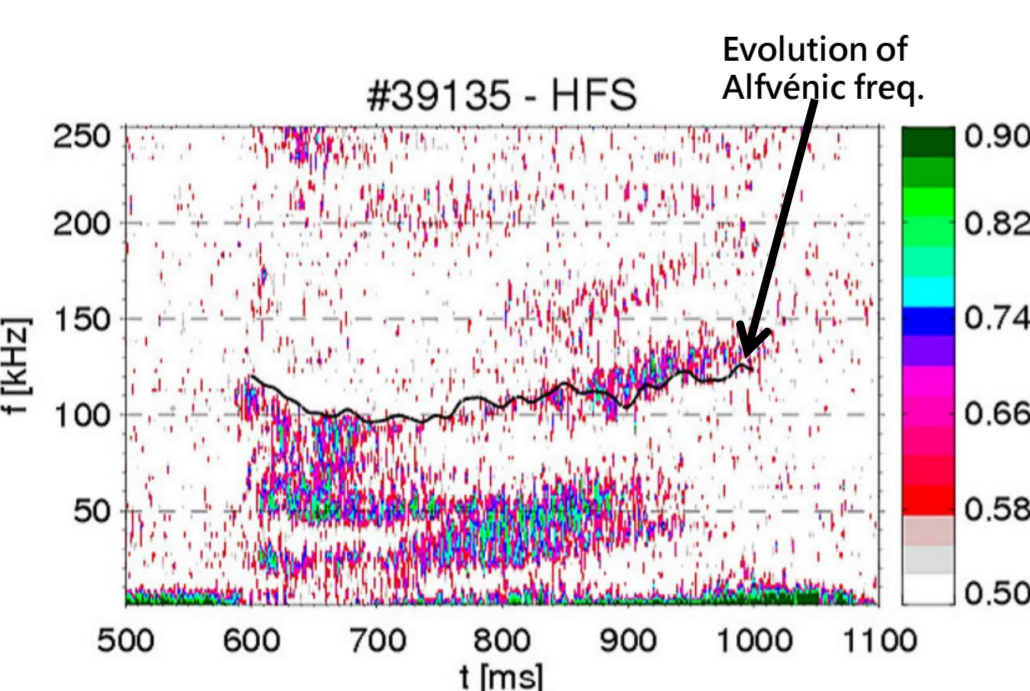
Coherent HF fluctuations, described by the Alfvén group velocity, linked to magnetic reconnection

$$v_A \equiv \frac{B}{\sqrt{\mu_0 \rho}}$$

- Global Alfvén Eigenmodes (GAE)** [600 – 1200 kHz] present during the whole discharge
- AE during QSH states** [100 – 600 kHz], found at high I_p , discontinuous in time, arise only when plasma spontaneously organizes in a helical equilibrium



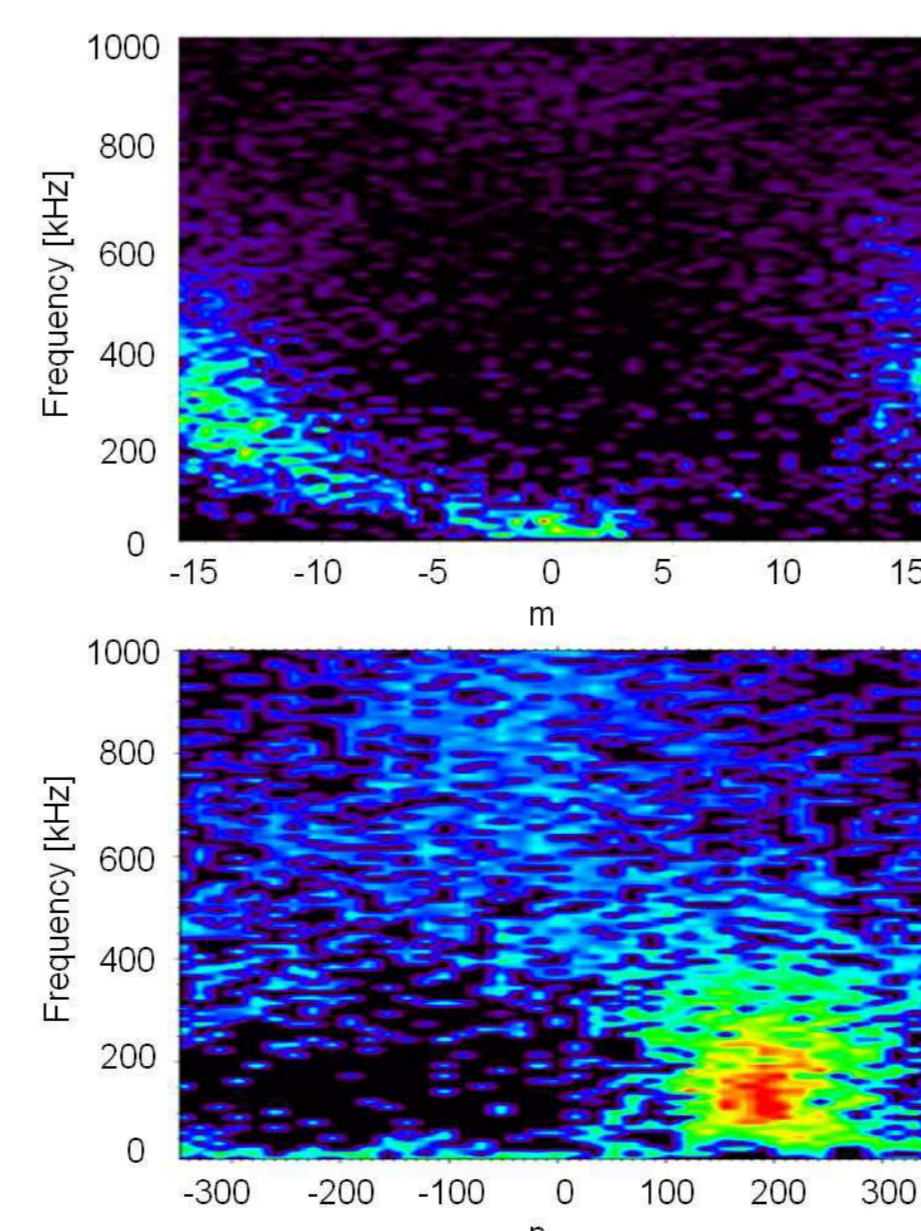
Shear Alfvén Eigenmodes



Microtearing modes

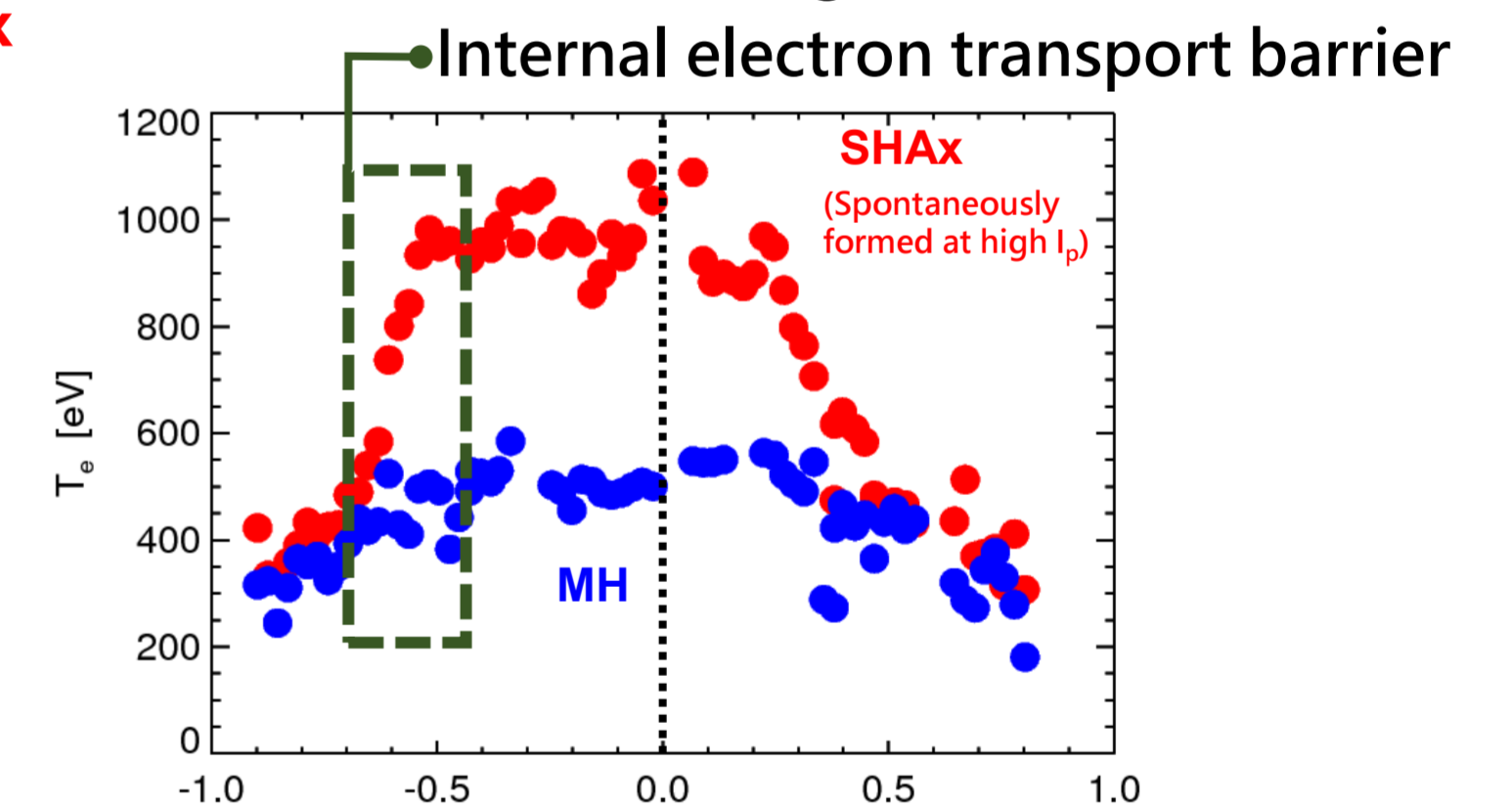
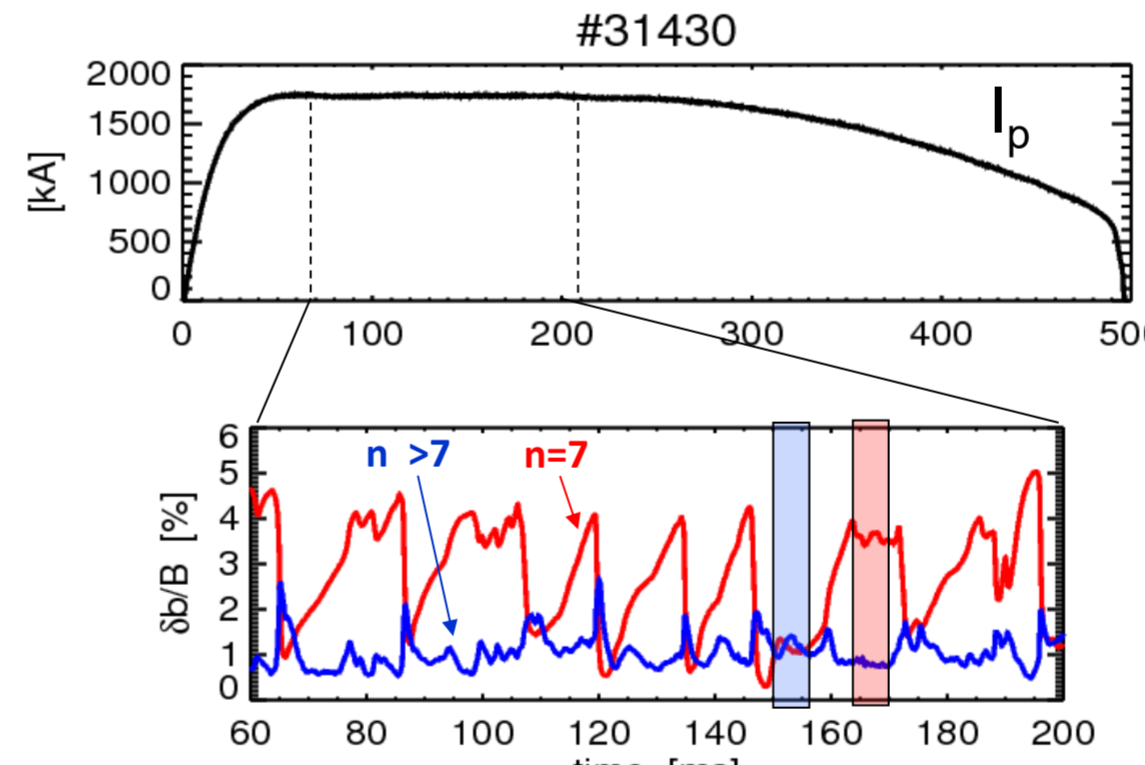
Microinstabilities ($\lambda \sim R_L$) characterized by high m and very high n , typically driven by ∇T_e

- Particularly favorable in RFP plasmas (high β and collisionality)
- Significant presence for long-lasting QSH states



OPCD: Current Control for Improved Performance

Multiple Helicity MH \rightarrow Single Helical Axis SHAx = Reduced magnetic chaos

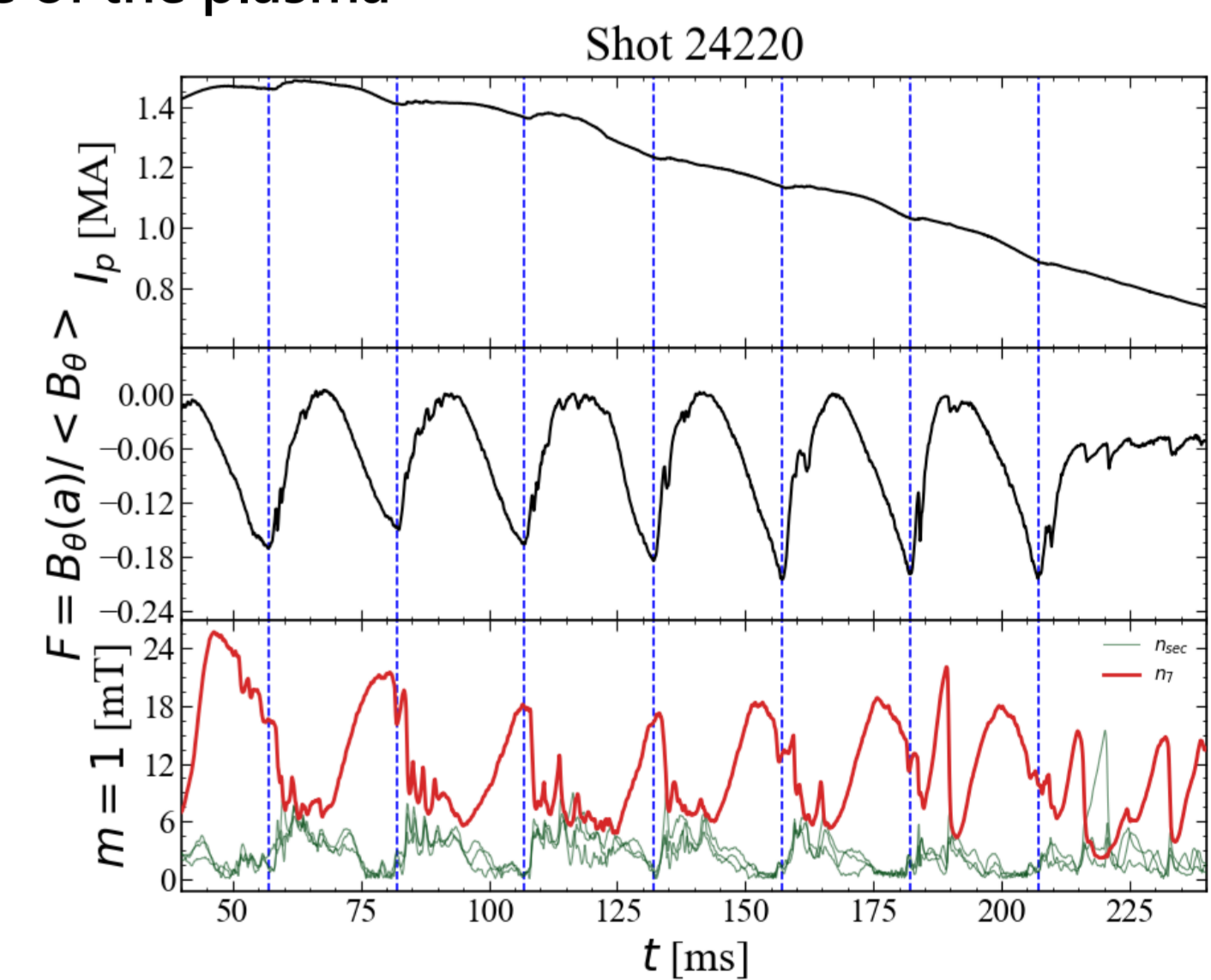


(Quasi) Single Helicity as the preferred topology for optimal performance in an RFP plasma

The **Oscillating Poloidal Current Drive (OPCD)** aims to consistently stimulate the QSH state through an alternating poloidal current in the edge of the plasma

- Average additional net input power observed to be negligible
- Minimum of the Reversal Field Parameter F possibly correlated to increase of dominant mode + decrease of secondary modes (QSH)
- Larger faculty to dynamically control the equilibrium and regulate reconnective events through OPCD
- OPCD expected to be correlated with higher global confinement time

RFX-mod data is being used to evaluate OPCD's feasibility for operation at RFX-mod2



Conclusions

The future RFX-mod2 experiment represents a renewed and unique experimental platform for the study of different magnetic configurations with particular focus on the RFP plasmas. The uniqueness of this configuration, along with the experiment's upgrades, will grant a distinctive opportunity to understand and apply modern and sophisticated experimental techniques to further optimize the confinement properties of fusion plasmas. Studies regarding magnetic instabilities and current drive will result fundamental to optimize operations at RFX-mod2

References

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