Edge parallel current drive in Tokamaks as a tool to stabilize plasma boundary

Vladimir Svidzinski, FAR-TECH, Inc.

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FAR-TECH, Inc., 3550 General Atomics Court, MS 15-148, San Diego, CA 92121
Tel: (858) 455-6655, Fax (858) 450-9741   www.far-tech.com

Experimental motivation

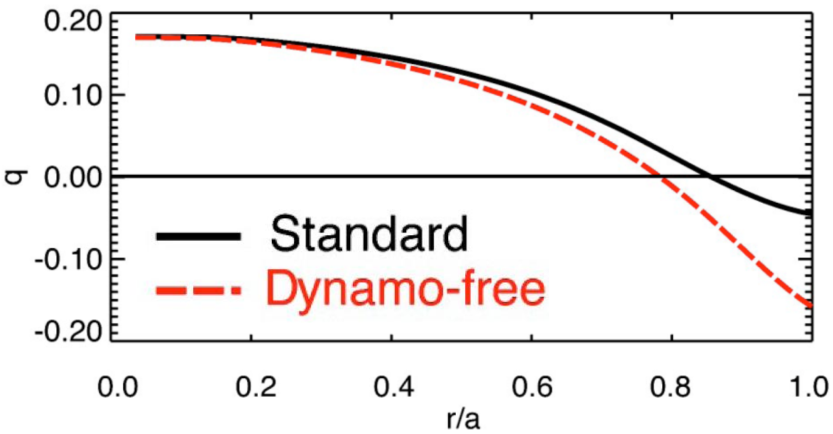
Pulsed parallel current drive in Madison Symmetric Torus RFP

- Strong parallel current is driven at the plasma edge region.

- During the drive plasma fluctuations are suppressed everywhere including at the plasma edge resulting in a ten-fold confinement improvement.

- In this regime **plasma boundary is stable** in spite of a relatively strong edge pressure gradient, high plasma beta and a strong unfavorable curvature of equilibrium magnetic field at the edge in RFP.

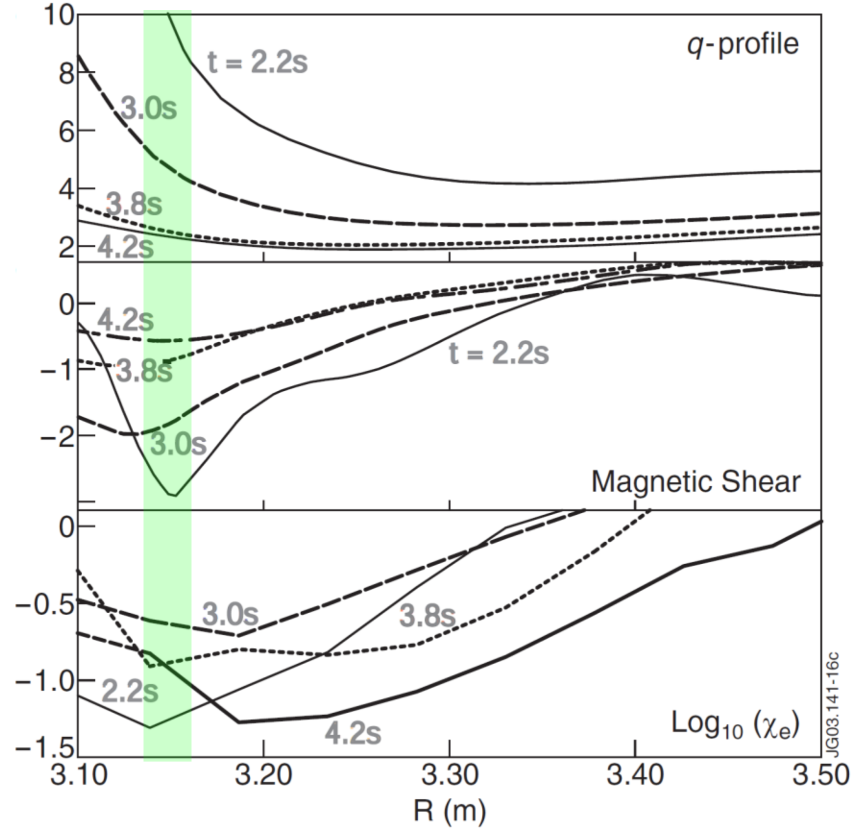
- **q'<0** and **magnetic shear is strong** at the edge



Formation of internal transport barrier in discharges with reversed magnetic shear on JET

- Strong of-axis current was driven by Lover Hybrid Current Drive to form a reversed q-profile with a **large negative shear q’<0** in the plasma core.

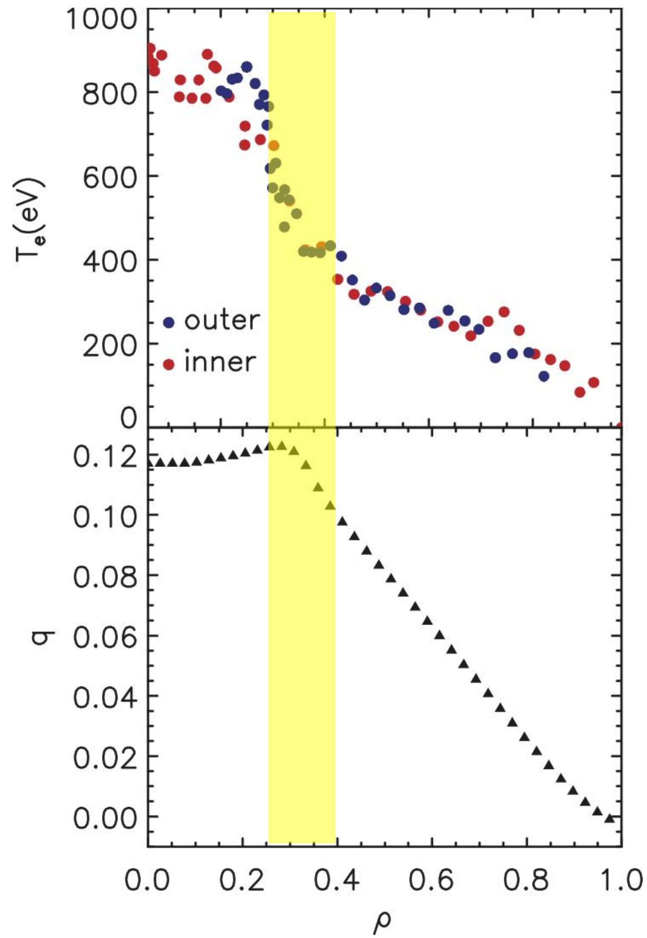
- ITBs were formed at location of a **strong negative magnetic shear** - location of the driven current (Baranov et al Plasma Phys. Control. Fusion 2004).



Formation of electron internal transport barriers in helical equilibrium in RFX-mod RFP

- Helical states are characterized by a reversed shear *q* profile.

- eITBs are formed near location with **large q'<0** ?



M. Gobbin APS DPP 2010.

- Plasma instabilities are suppressed in the region of strong negative shear.

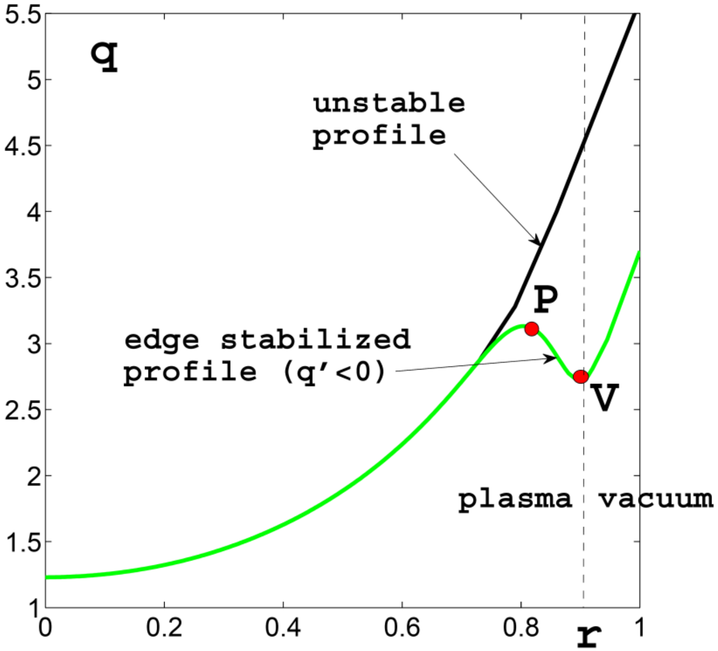
- We propose to create a strong negative magnetic shear at the plasma edge in tokamak by driving strong edge parallel current either inductively or noninductively.

- By analogy with the JET results we propose to move the ITB to the plasma edge and place it on top of the pedestal in the H-mode discharge to further enhance and stabilize the latter.

Simplified theoretical arguments

- In RFP the edge pulsed parallel current stabilizes edge pressure gradient driven modes due to the strong negative shear created by this current and due to the proximity of conducting wall to the plasma edge. (V. Svidzinski et. al., Nuclear Fusion 2010).

- Strong negative magnetic shear created by the driven current and the proximity of conducting wall may stabilize the plasma edge in Tokamak.



P - location of maximum driven edge current

V - location of plasma-vacuum boundary

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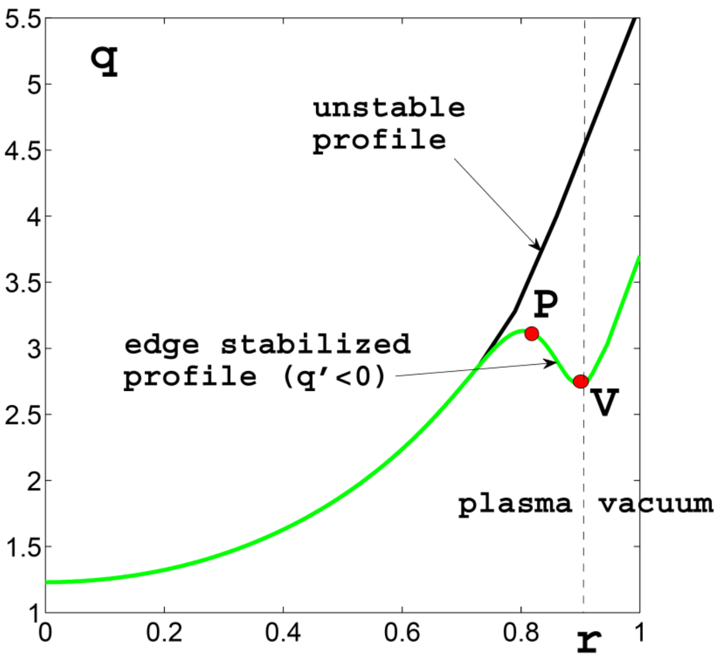

Instability drive: $\delta W_S \sim |q_P - q_V|$

Stabilizing factors:

for pressure driven modes: $\delta W_V \sim \dfrac{1}{d}(q_P - q_V)^2$

for current driven modes: $\delta W_F \sim (q_P - q_V)^2$

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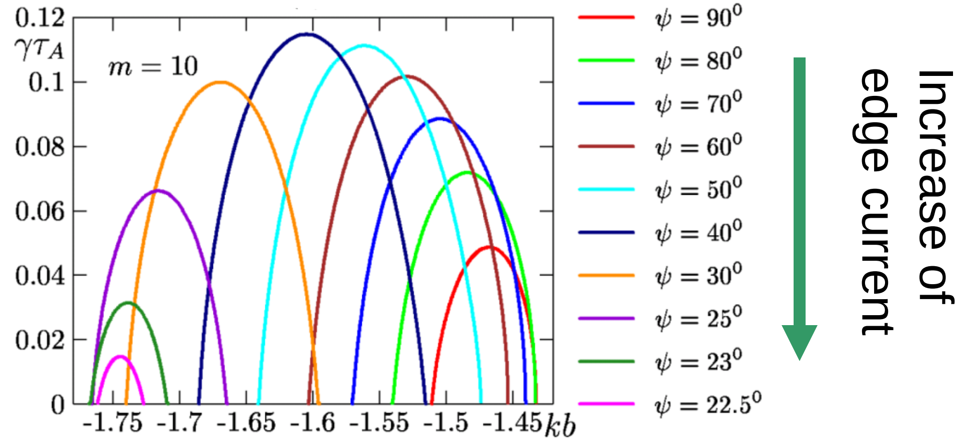
- In this regime strong edge currents are stabilizing while weak currents are destabilizing

Stabilization of edge modes in tokamak-like cylindrical equilibrium by the driven edge parallel current (V. Svidzinski et. al., Nuclear Fusion 2010).



- Density of the driven edge current is comparable to the one in plasma core

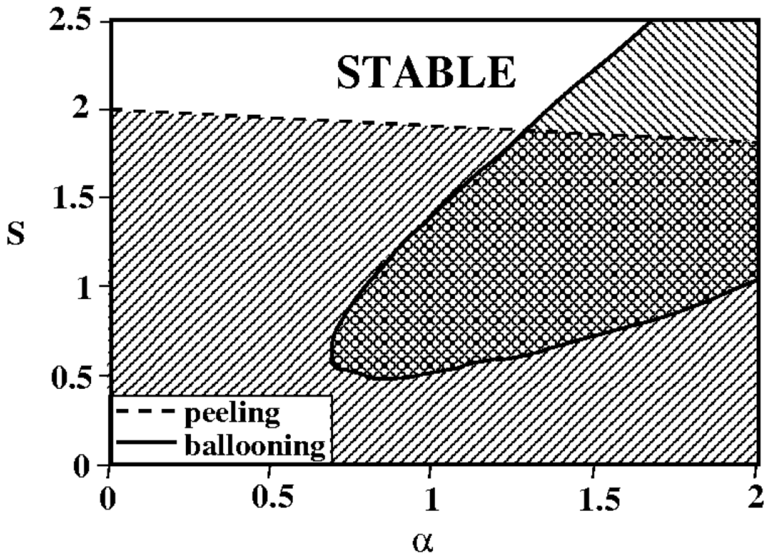
- In infinite n limit (Connor et. al. Phys. Plasmas 1998):

$$\sqrt{1-4D_M} > 1 + \frac{2}{2\pi q'} \oint \frac{J_{\|} B}{R^2 B_p^3} dl,$$

q'<0 is stabilizing

- Detailed analysis of the proposed plasma edge stabilization method in toroidal equilibrium is required to make definite conclusions about its practicality and to justify its experimental validation.

$$s = \frac{r}{q}\frac{dq}{dr}, \quad \alpha = -\frac{2\mu_0 R q^2}{B^2}\frac{dp}{dr}$$



- Study region with s<0

- Development of parallel stability code suitable for this analysis is under way at FAR-TECH