EUROfusion

Non-linear MHD simulation of benign RE beam termination in JET

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IPP

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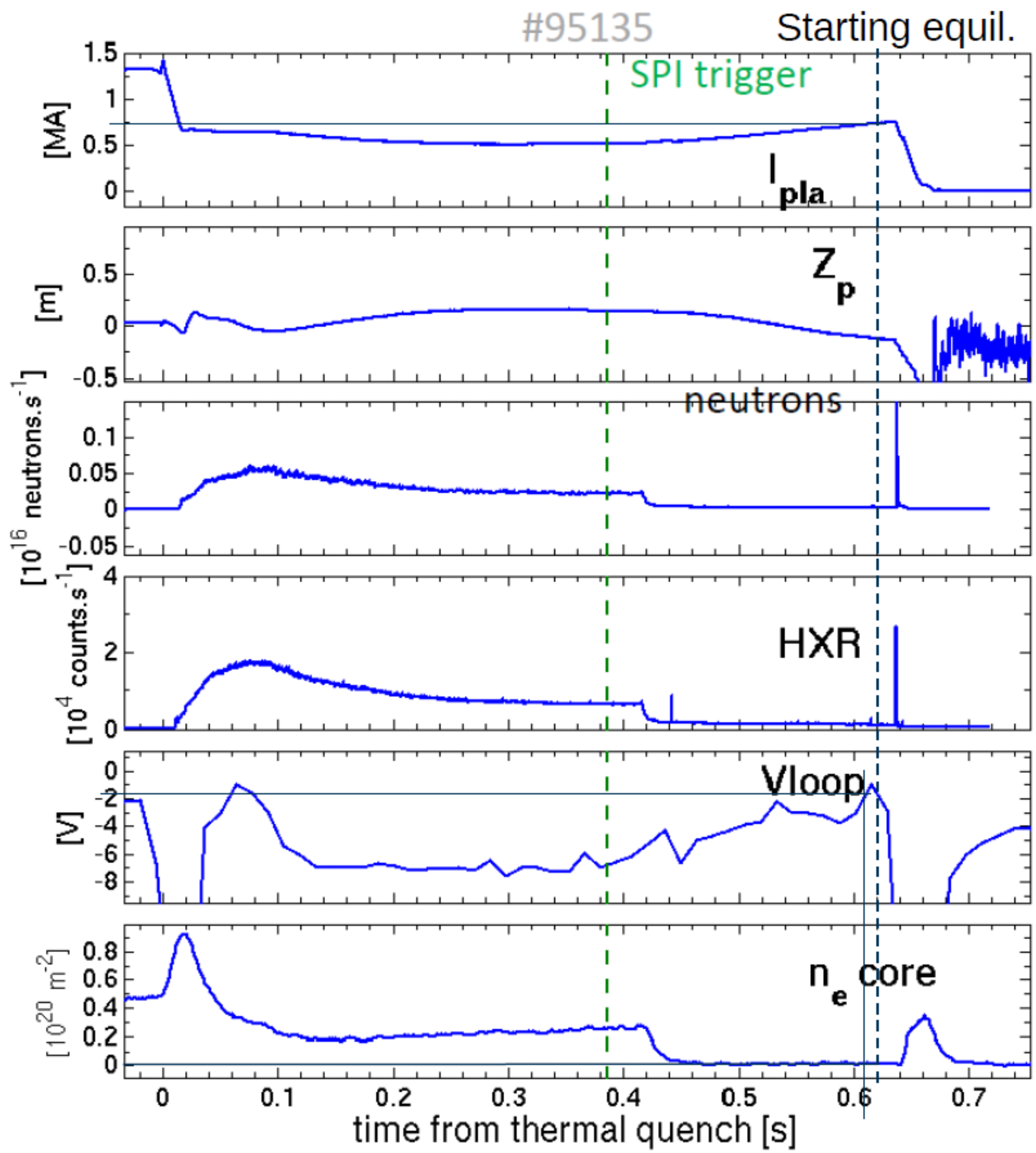
JET experiment with D_2 second injection[#]

- Disruption triggered by Argon SPI leading to an RE beam
- During the RE plateau phase, D2 is injected (2nd SPI)
- After about 240ms, fast loss of REs occur
- The discharge then terminates in a few tens of milliseconds, w/o any localized FW damage

Aim: Understand the MHD behaviour leading to the RE losses via non-linear simulations using JOREK[*]



Reux et al., Manuscript in preparation

* Huijsmans et al., NF 47, 659 (2007)
Czarny et al., JCP 227, 7423 (2008)
Hoelzl et. al. JPCS 401, 012010 (2012)
www.jorek.eu

Constraints on the equilibrium

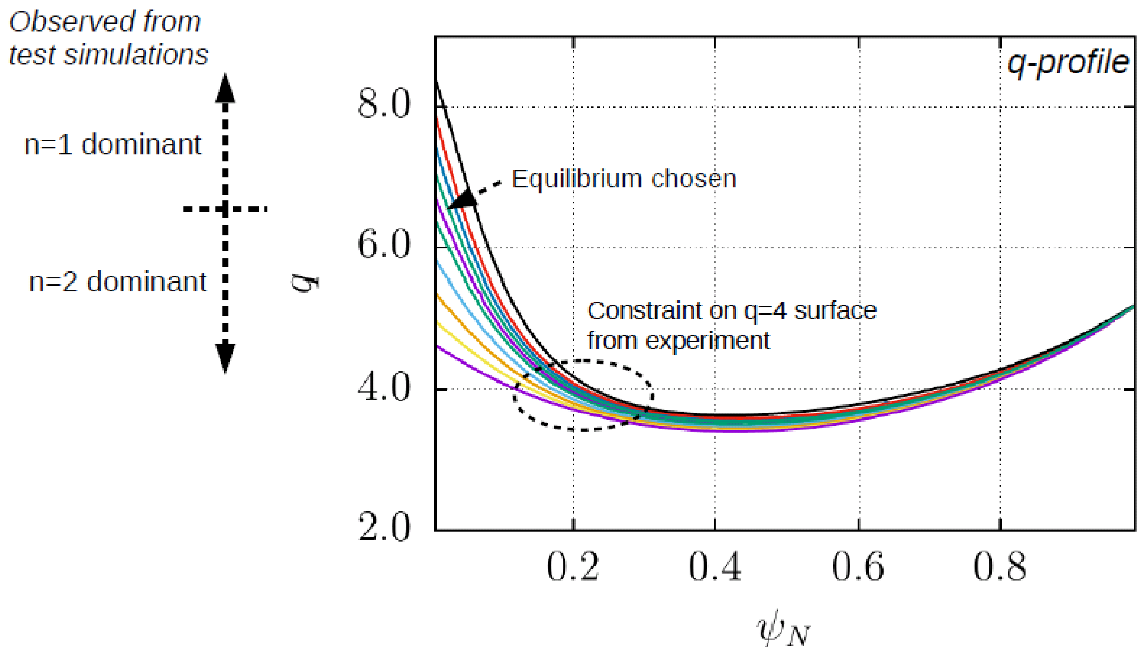
- Synchrotron (infrared) image reconstructions confirm a hollow current profile
- Experimental data indicate that

  \- before the crash, m=4 surface lies in the region of about *0.15m < r < 0.35m*

  - n=1 is the dominant toroidal mode

- Test simulations with JOREK indicate a transition from n=2 to n=1 dominance beyond a threshold central safety factor

Used to fix the lower bound of the central safety factor



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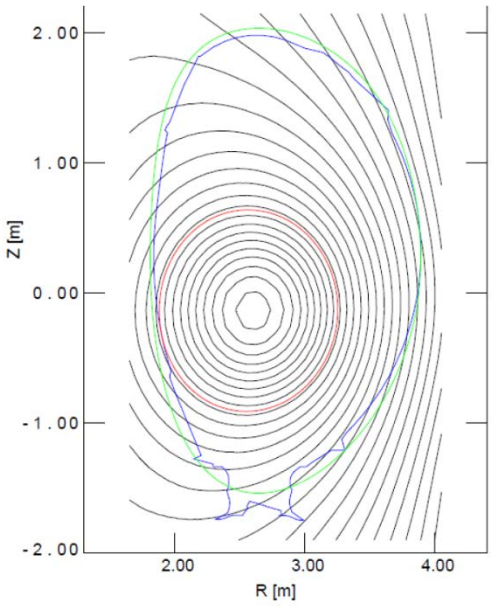
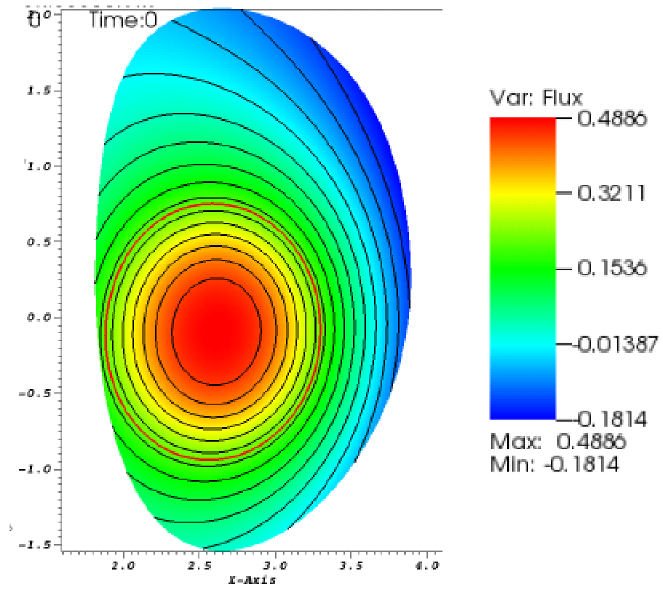
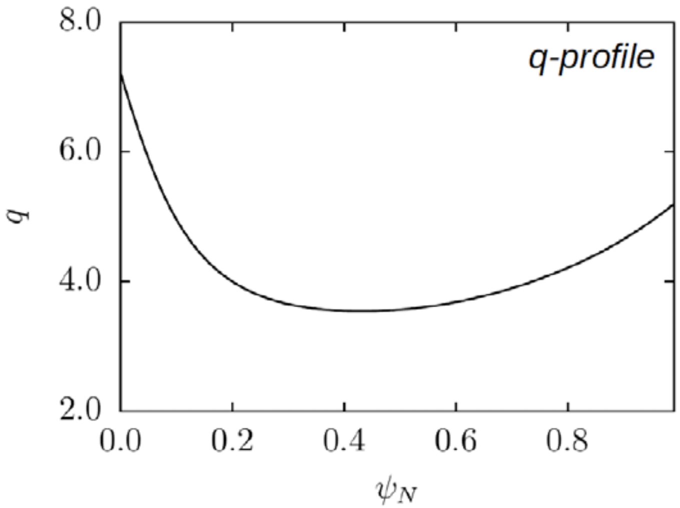
Equilibrium







Ip	-0.747MA
q_{max}	5.2
a	~ 0.7m

JOREK domain and model

- Domain covers the whole volume until the PFCs
- No impurities and neutrals
- RE-fluid*, no sources
- RE transport represented via anisotropic diffusion with, Dr,par / Dr,perp = 1×10^{11}
- Spitzer resistivity at 10eV (spatially uniform)
- Constant-in-time internal energy of the background cold plasma

Poloidal flux:
$$\frac{1}{R^2}\frac{\partial \psi}{\partial t} = -\frac{\eta}{R}\left(J_\phi - J_{r,\phi}\right) - \frac{1}{R}\left[u, \psi\right] - \frac{F_0}{R^2}\frac{\partial u}{\partial \phi} +$$

Plasma momentum:
$$\frac{\partial\left(\rho \boldsymbol{v}\right)}{\partial t} = -\nabla \cdot \left(\rho \boldsymbol{v}\boldsymbol{v}\right) + \boldsymbol{J} \times \boldsymbol{B} - \nabla_\perp p_{\mathrm{th}}$$

Generalized Ohm's law:
$$\boldsymbol{E} = \eta\left(\boldsymbol{J} - \boldsymbol{J_r}\right) + ...$$

RE density:
$$\frac{\partial n_r}{\partial t} = -\theta \nabla \cdot \left(v_{r,||}\hat{\boldsymbol{b}} n_r\right) + (1-\theta)\left[\nabla_{||} \cdot \left(D_{r,||}\nabla_{||} n_r\right) + \nabla_\perp \cdot \left(D_{r,\perp}\nabla_\perp n_r\right)\right]$$

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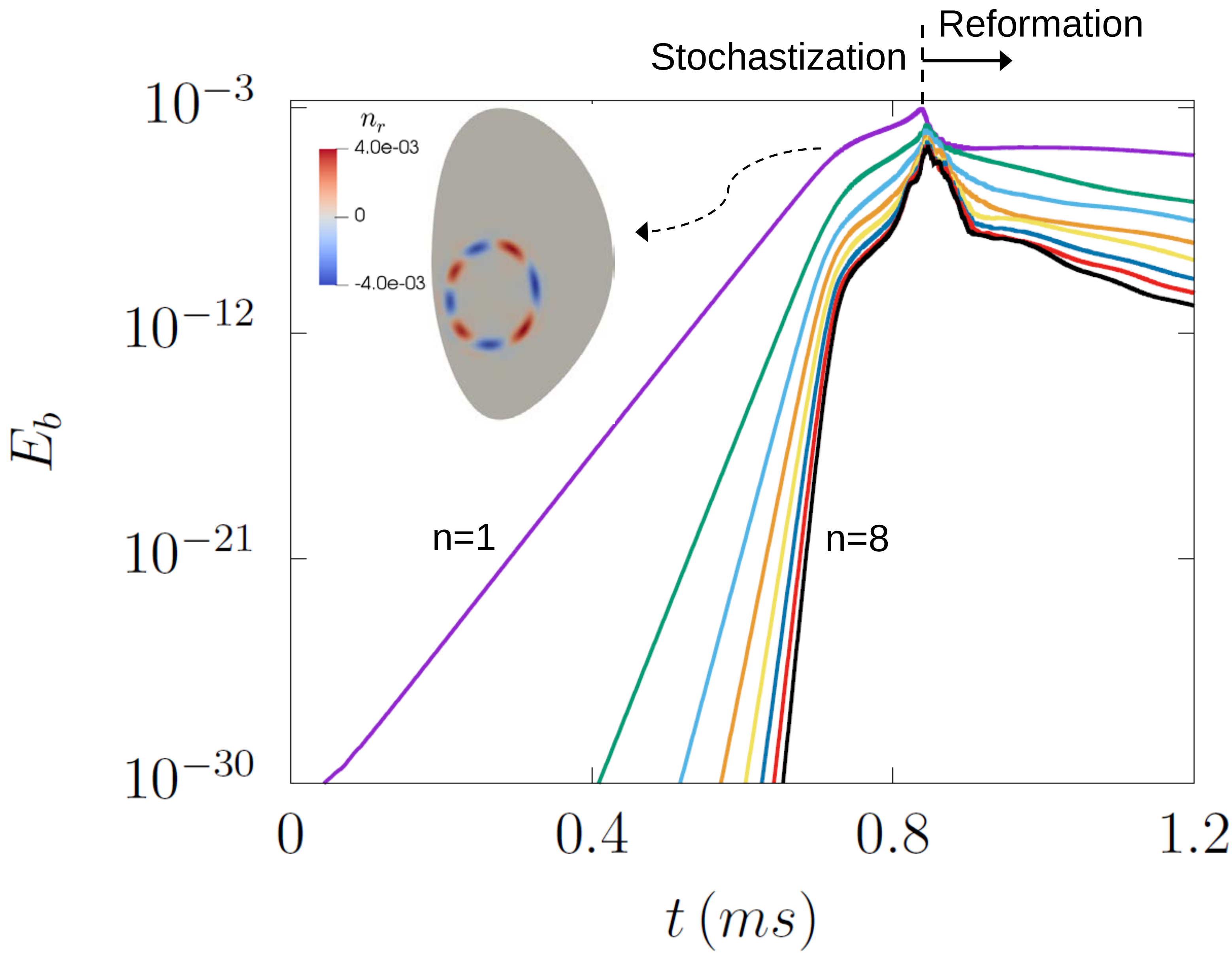
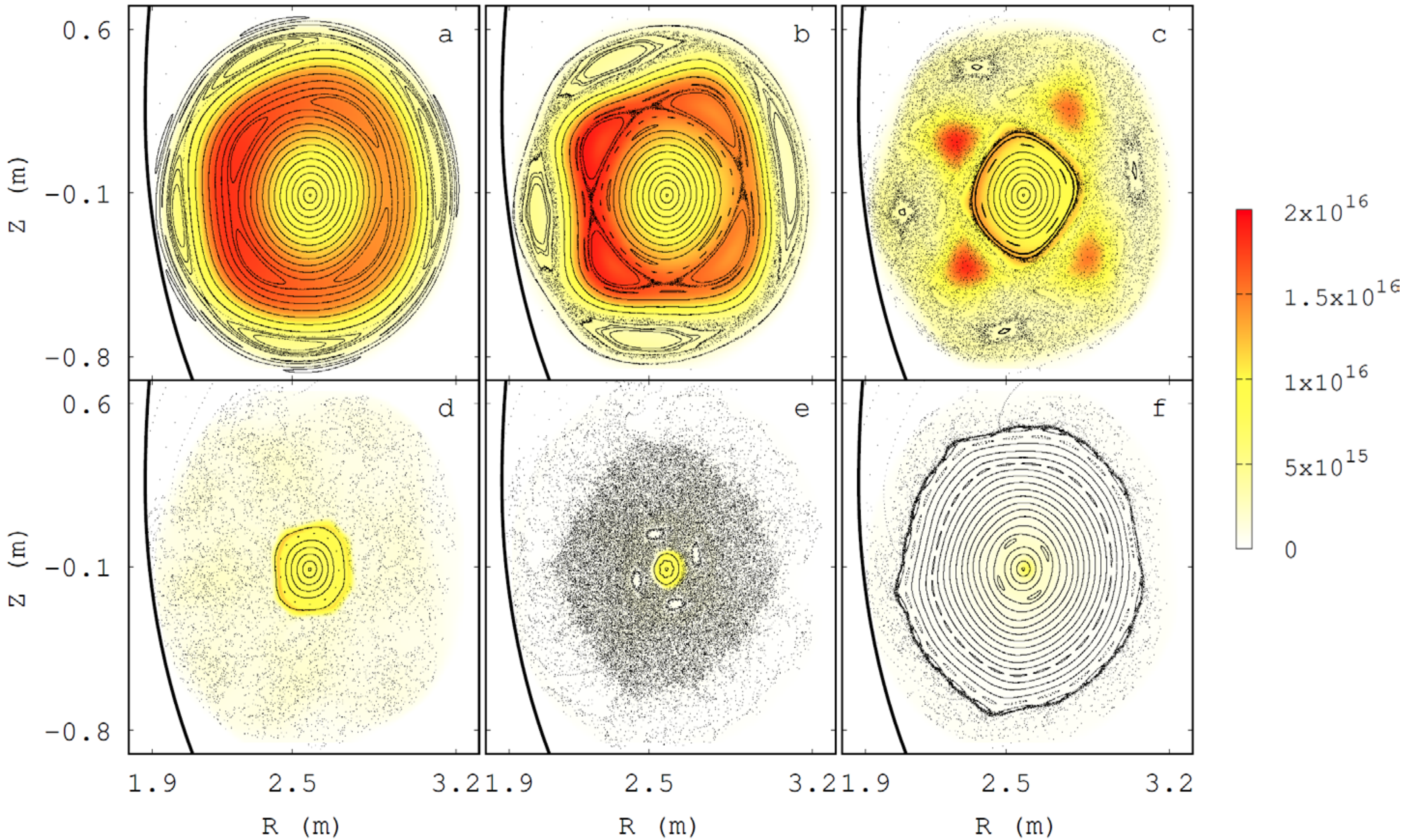
** Bandaru et al., Phys Rev. E 99, 063317 (2019)*

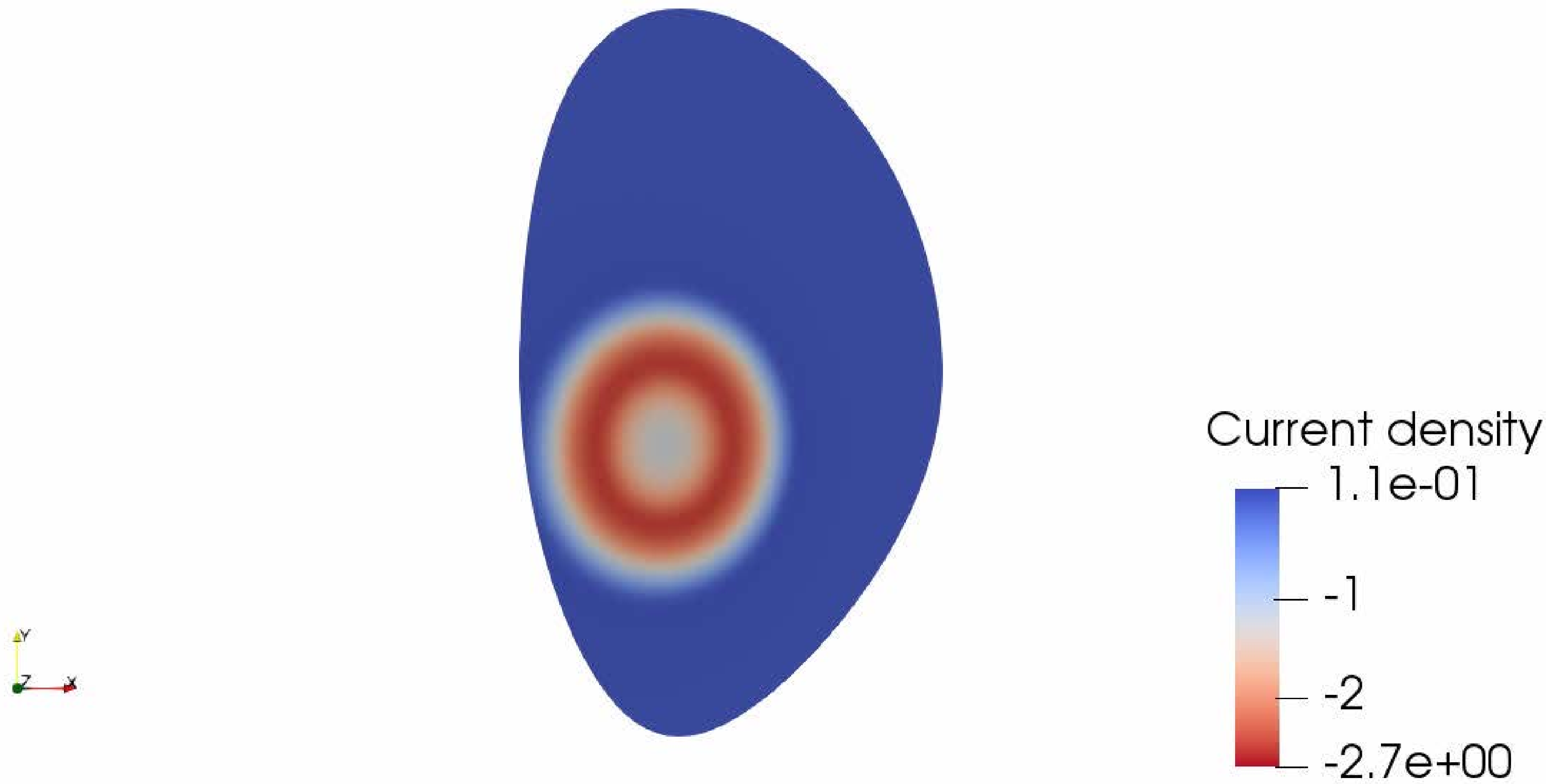
Energy of the poloidal magnetic field (modes n=1 to n=8)



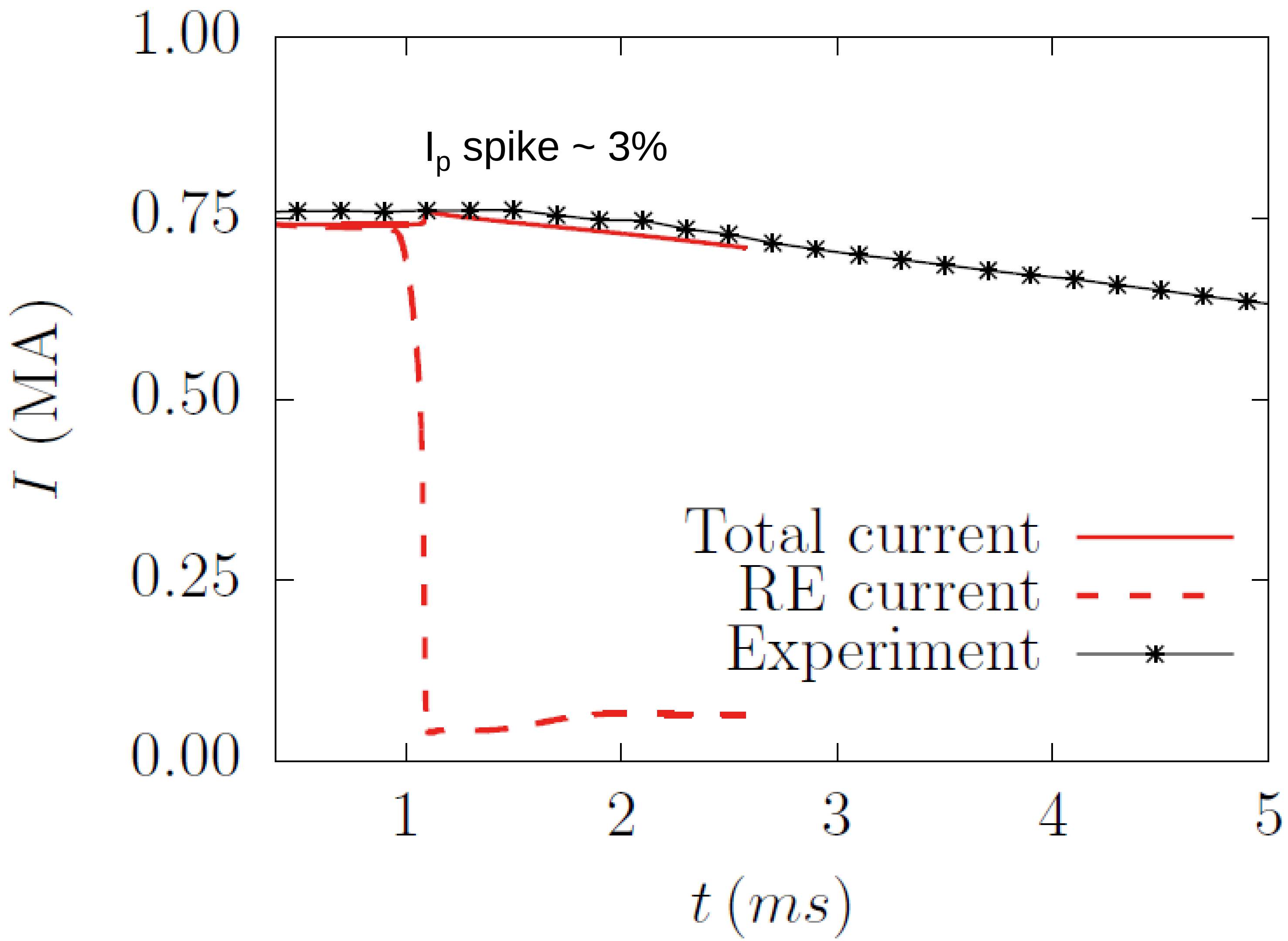
Stochastization and fast RE losses



Current flattening due to fast magnetic reconnection



RE loss and current spike



Summary

Simulations show very good agreement with experiments w.r.t.

- Fast timescale of MHD growth and crash
- (m,n) = (4,1) dominance and its observation just before the crash
- Shrinking of the core leading to near-complete stochastization and loss of REs

Outlook

- Model extension to incorporate partial screening effects of impurities
- Predictions catering to ITER disruption scenarios