Impact of stochastic magnetic fields on edge localised modes in TEXTOR

B. Unterberg [1], C. Busch [1], M. de Bock [2], P.Dumortier [3], K.H. Finken [1], St. Jachmich [3], R. Jaspers [2], M. Jakubowski [1], D. Kalupin [1], H.R. Koslowski [1], A. Krämer-Flecken [1], M. Lehnen [1], Y. Liang [1], K. Löwenbrück [1], H. van der Meiden [2], O. Schmitz [1], G. Sergienko [1], S. Soldatov [4], M. Tokar [1], G. van Wassenhove [3], S. Varshney [2], Y. Xu [3], O. Zimmermann [1]

and the TEXTOR team [1,2,3]

1) Institut für Plasmaphysik, Forschungszentrum Jülich, Ass. EURATOM- FZ Jülich, D-52425 Jülich, Germany*

2) FOM Instituut voor Plasmafysica Rijnhuizen, Ass. "FOM- EURATOM", NL-3430 BE, Nieuwegein, The Netherlands*

3) Laboratoratoire de Physique des Plamas – Laboratorium voor Plasmafysica, Ass. "EURATOM-Belgian State", ERM- KMS, B- 1000 Brussels, Belgium*

4) Nuclear Fusion Institute, Russian Research Centre "Kurchatov Institute", Kurchatov Square 1, 123182 Moscow, Russia

**** Partner in the Trilateral Euregio Cluster***

Outline

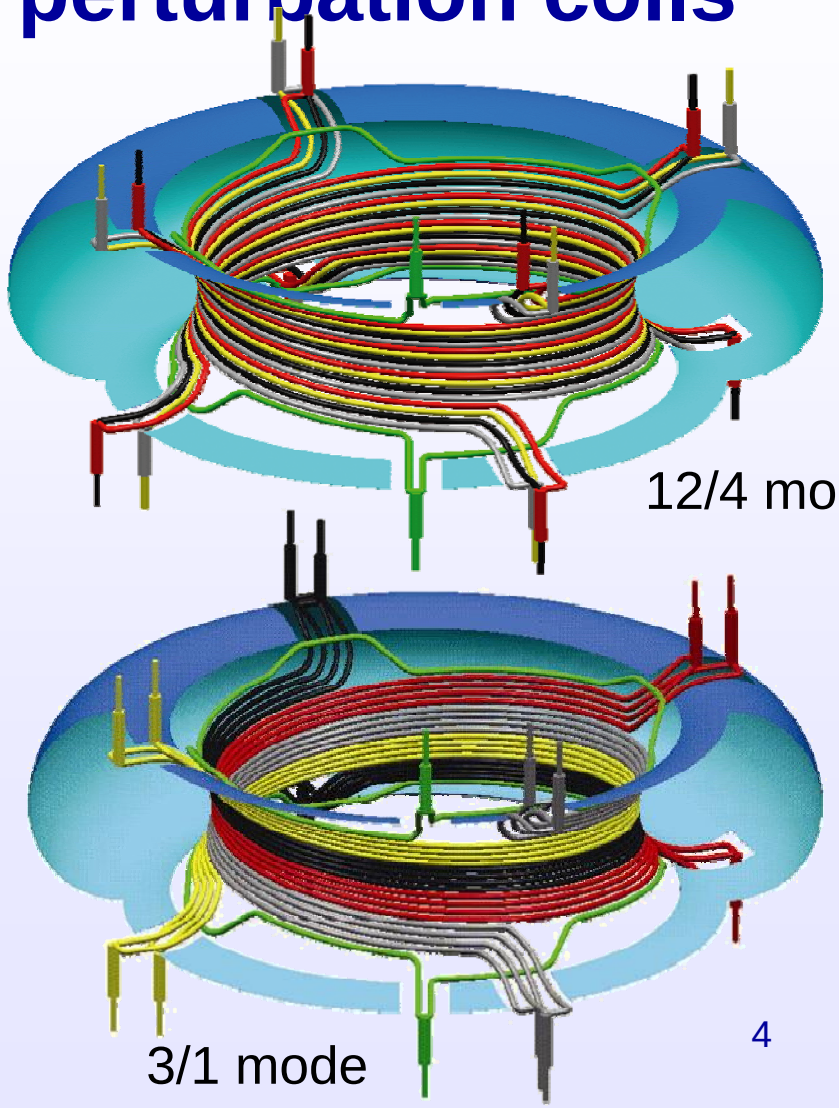
- Introduction: Issues for ELM mitigation by resonant magnetic perturbations
- The Dynamic Ergodic Divertor (DED) – a flexible tool to control the magnetic field structure at the edge
- Limiter H-mode scenario in TEXTOR
- Impact of DED on plasma edge characteristics in limiter H-mode discharges
- Concluding remarks, open issues and challenges

Issues for ELM mitigation by resonant magnetic perturbations

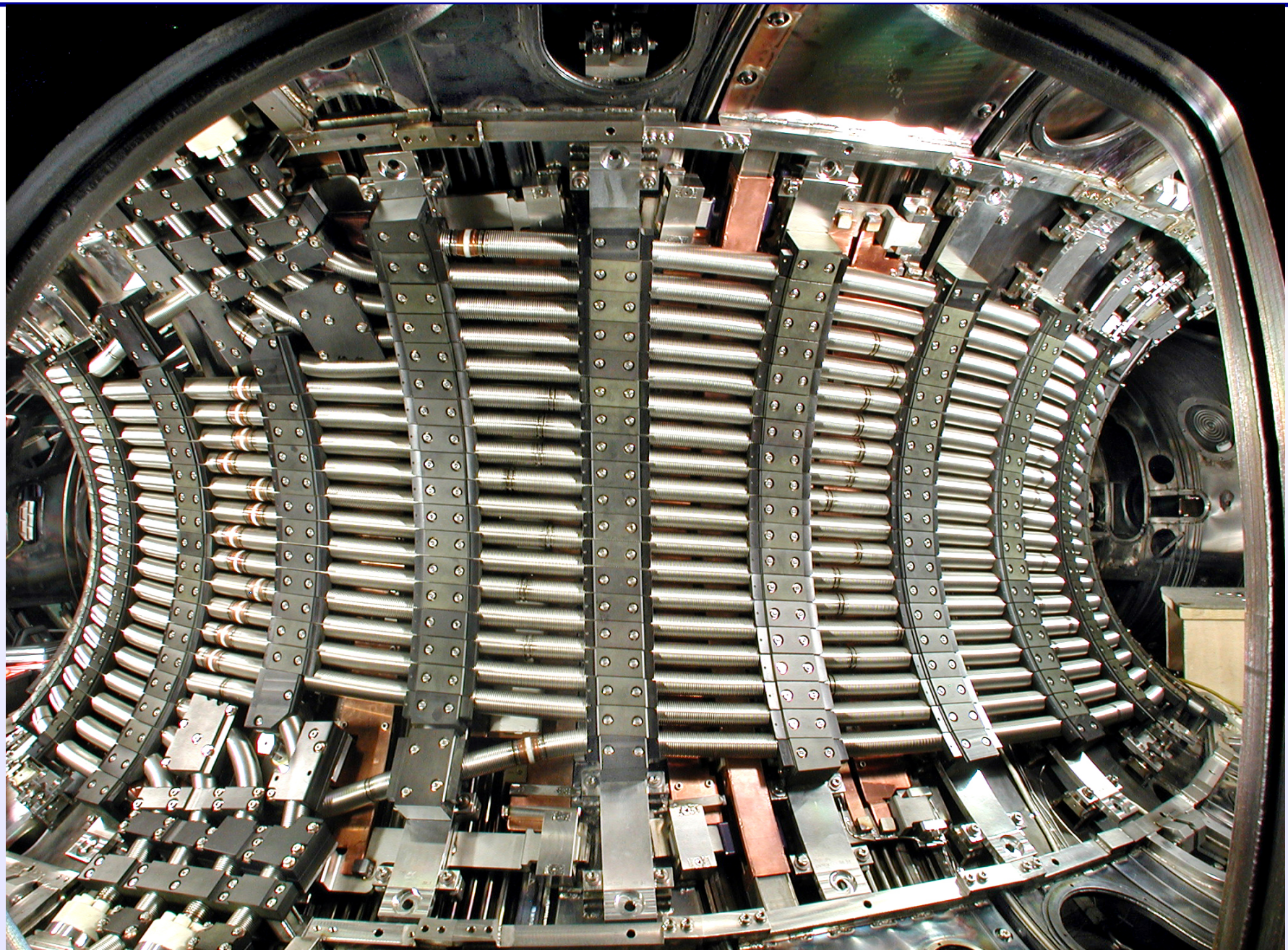
- Proof of principle successfully demonstrated in DIII-D, complementary experiments in other devices needed to broaden data base
  - extrapolation to future devices
  - benchmark for theory and modelling
- Impact of perturbation spectrum on edge pedestal and global plasma performance (mode excitation) particularly important as options for future installations (as ITER) rather restricted by technical constraints

The Dynamic Ergodic Divertor – a flexible set-up of perturbation coils

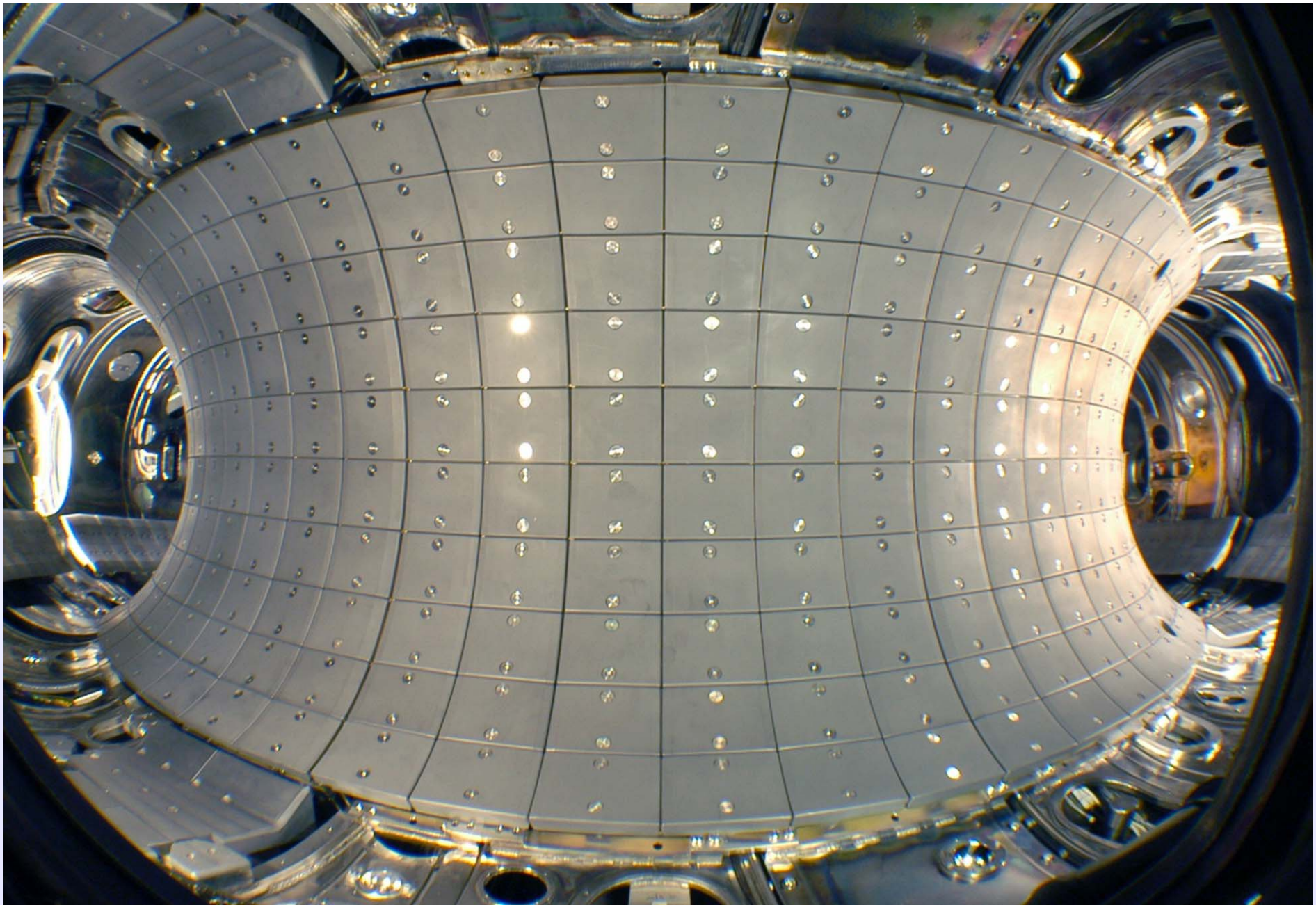
- 16 (+ 2 compensation) coils mounted at the HFS
- Helical pitch aligned to field lines on q=3 surface
- Perturbation current up to 15 kA per coil
- DC, AC at 50 Hz, 1-10 kHz, slow strike point sweeps
- Base modes: 12/4, 6/2 and 3/1



Impact of stochastic magnetic fields on edge localised modes in TEXTOR

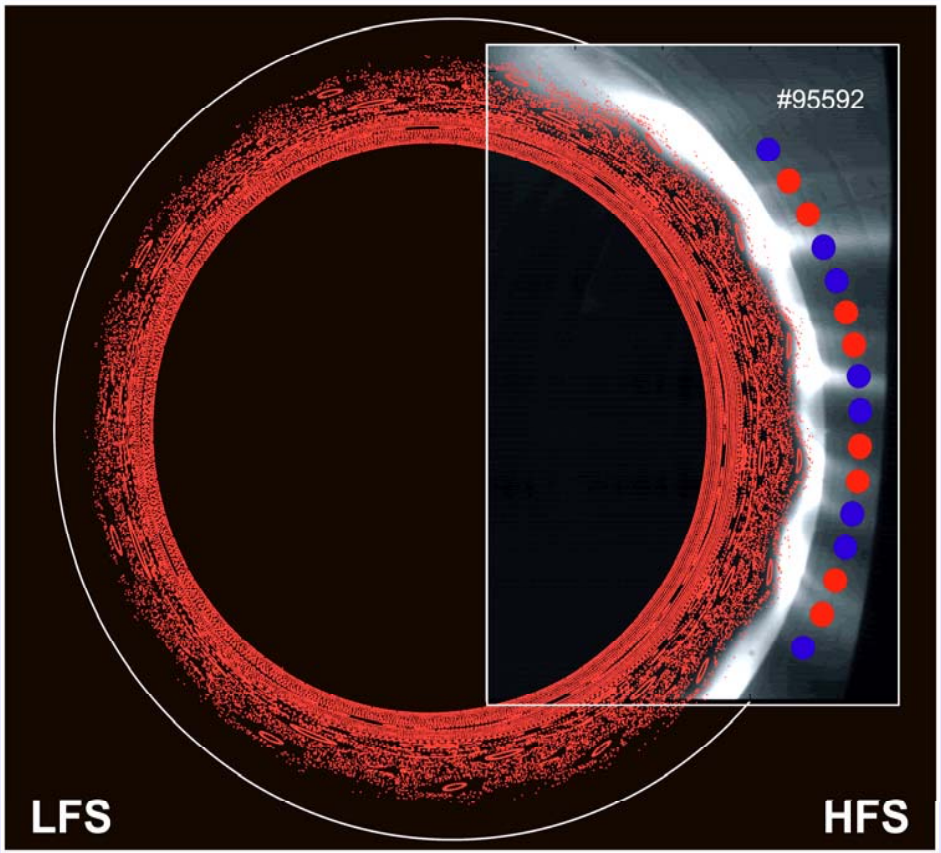


Impact of stochastic magnetic fields on edge localised modes in TEXTOR

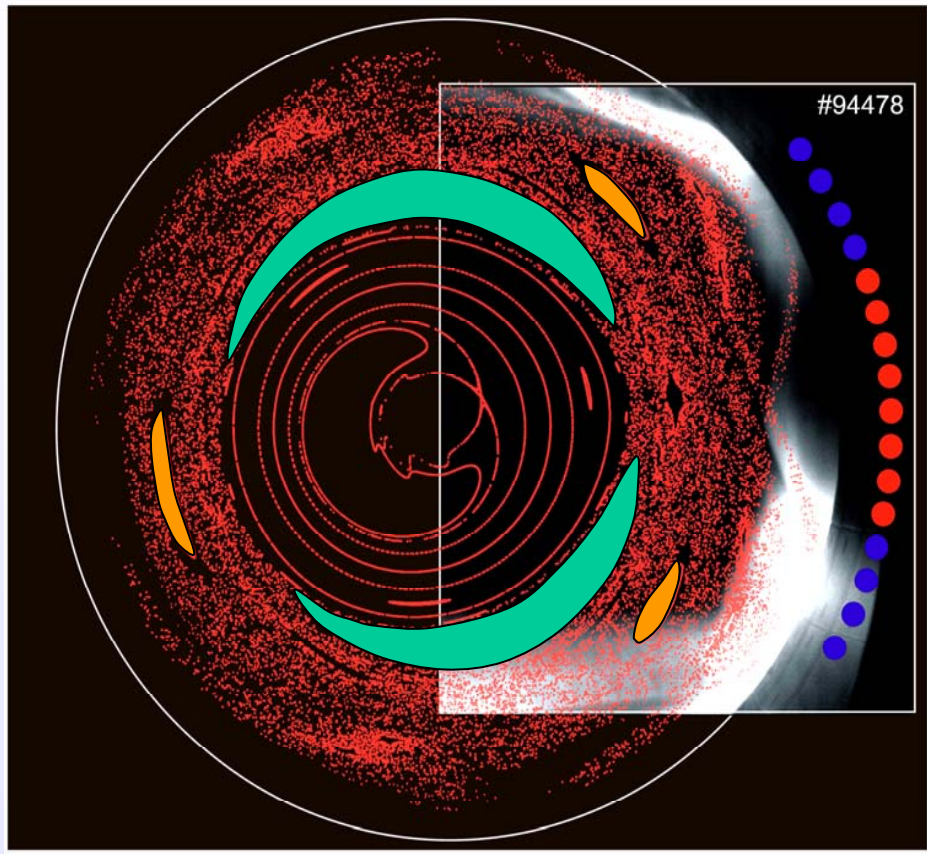


Magnetic topology and plasma response as seen in CIII emission

m/n = 12/ 4 configuration



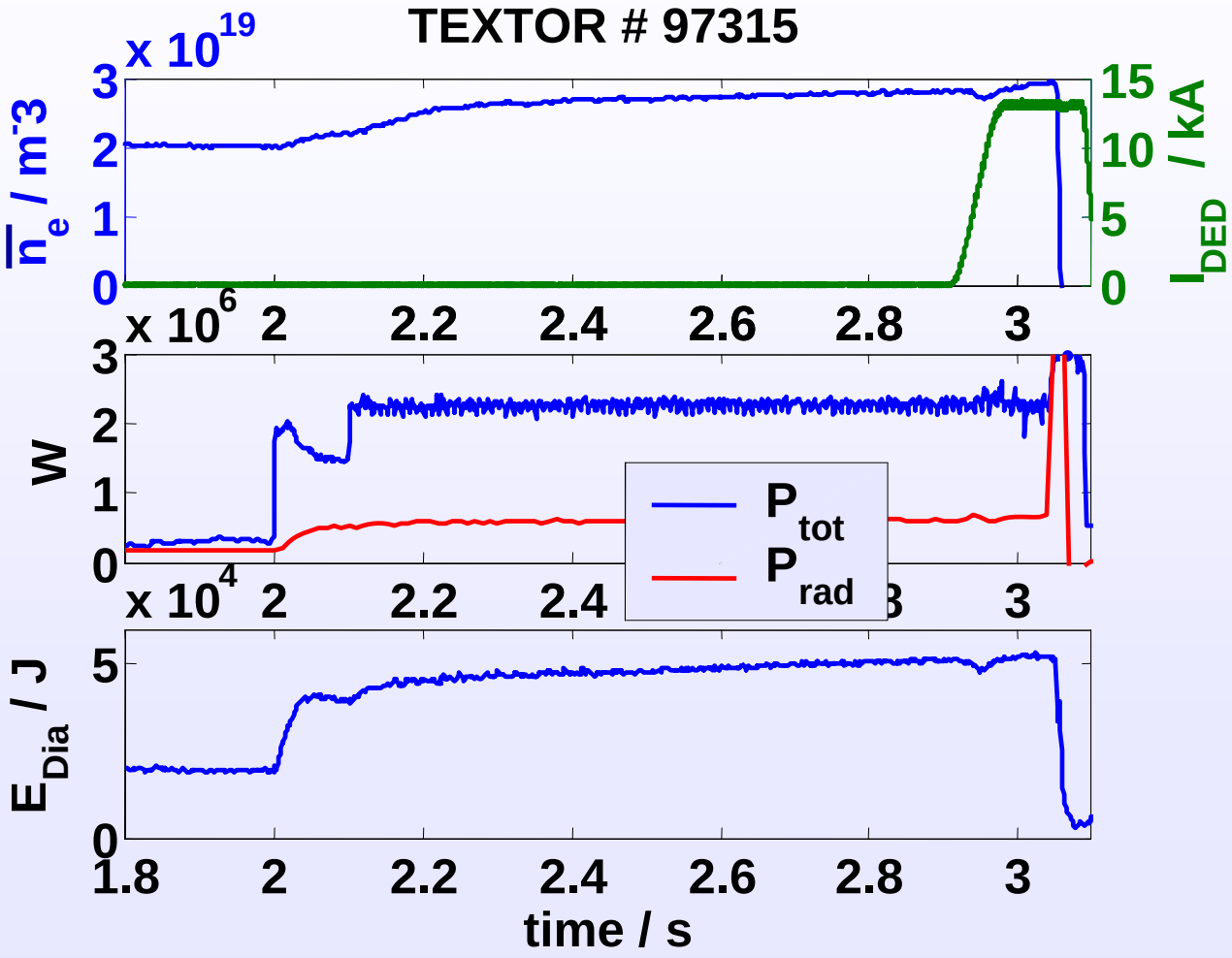
m/n = 3/1 configuration

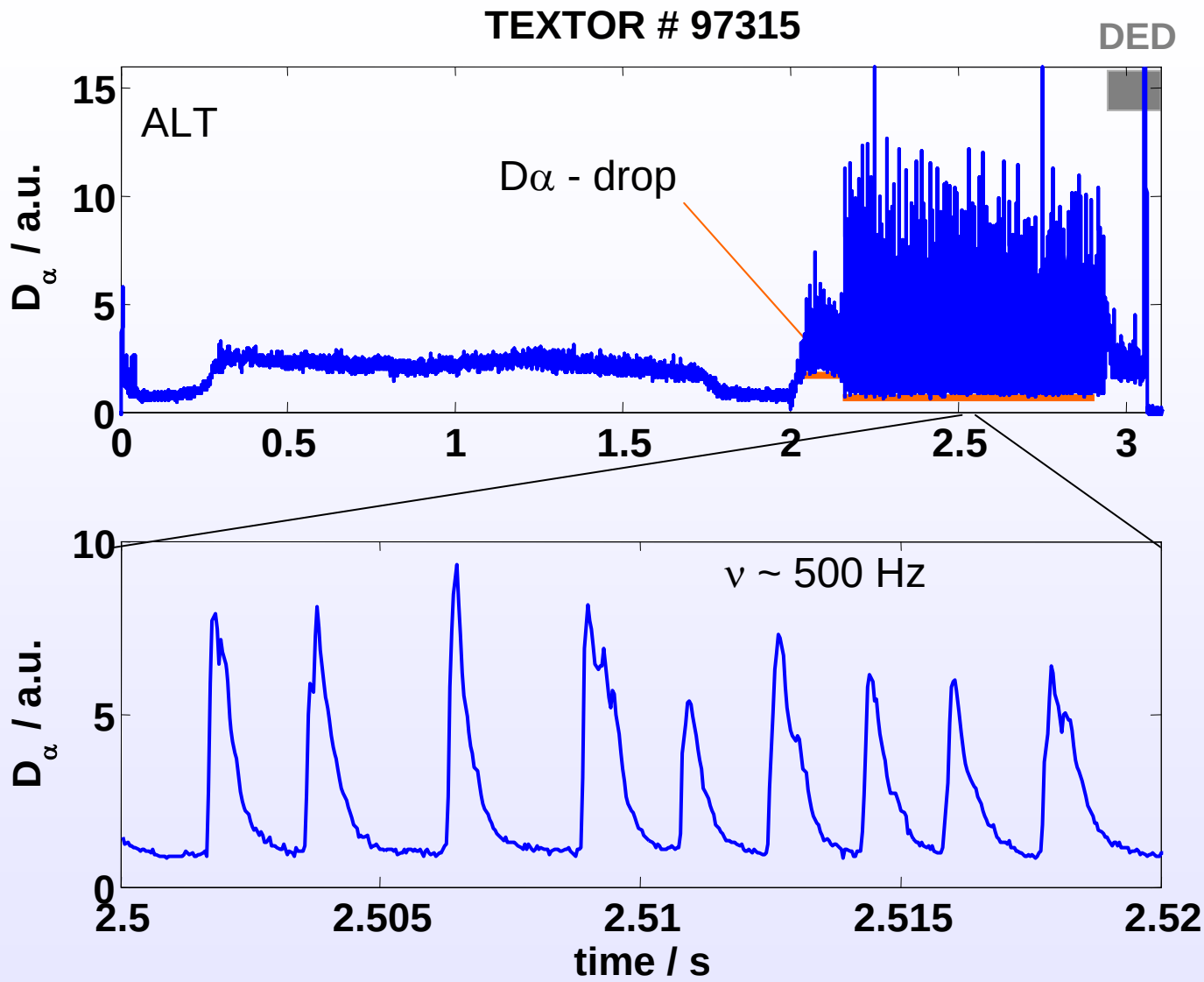


Limiter H-mode scenario in TEXTOR

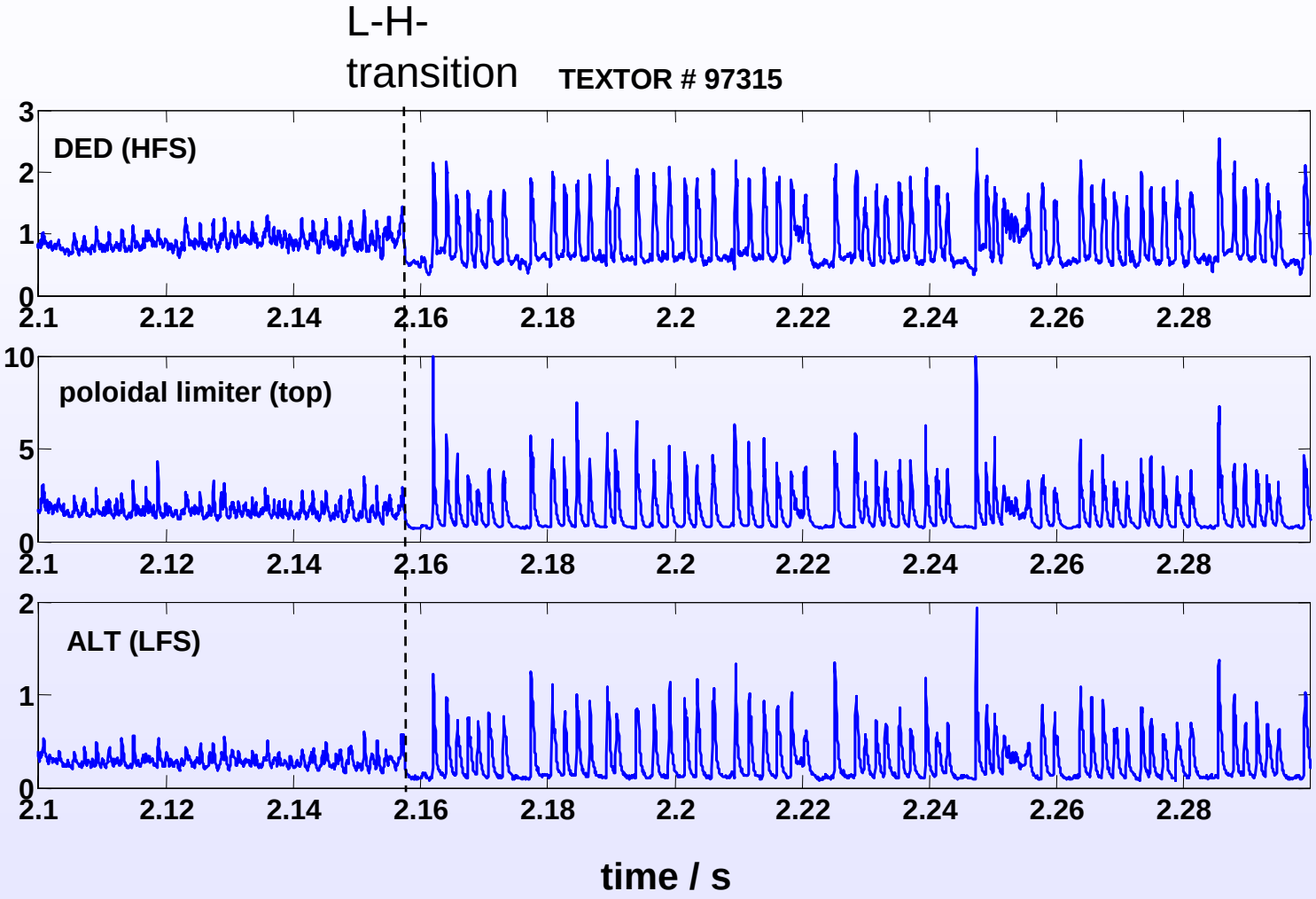
- Recipe for access to H-mode scenario in the limiter tokamak TEXTOR
  - low magnetic field (B_T <= 1.4 T), q_a slightly above 3
  - high heating power (P_{SOL} > 1.5 MW, 2x power threshold prescribed by scaling for divertor machines)
  - plasma shifted towards high field side -> substantial restrictions for edge diagnostics
- Overall characteristics of scenario
  - reduction of recycling flux all around the machine, corresponding improvement of particle confinement
  - global effects on energy confinement small (~15% at best)
  - evidence for increased pressure gradient at the edge (mainly in density)
  - substantial spin up of poloidal rotation at the edge, toroidal rotation almost unchanged
  - ELM- like particle and heat flux bursts to PFCs and corresponding relaxations of edge barrier

Basic scenario: Ip= 240 kA/ Bt= 1.2 T, plasma shifted to HFS (R=1.68m / a=0.4m)

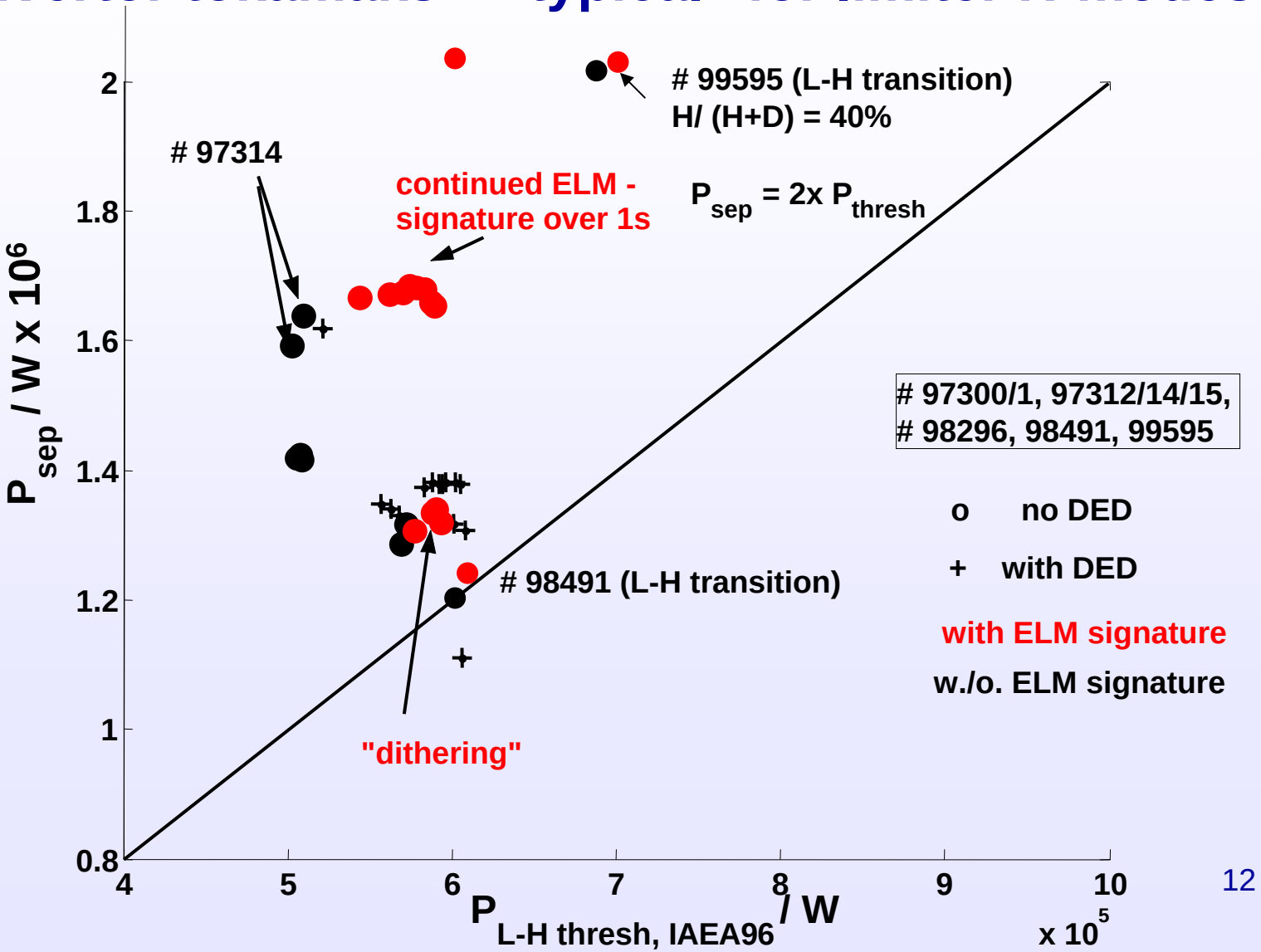



TEXTOR # 97315
DED
ALT
Dα - drop
D_α / a.u.
15
10
5
0
0
0.5
1
1.5
2
2.5
3
ν ~ 500 Hz
10
5
0
2.5
2.505
2.51
2.515
2.52
time / s

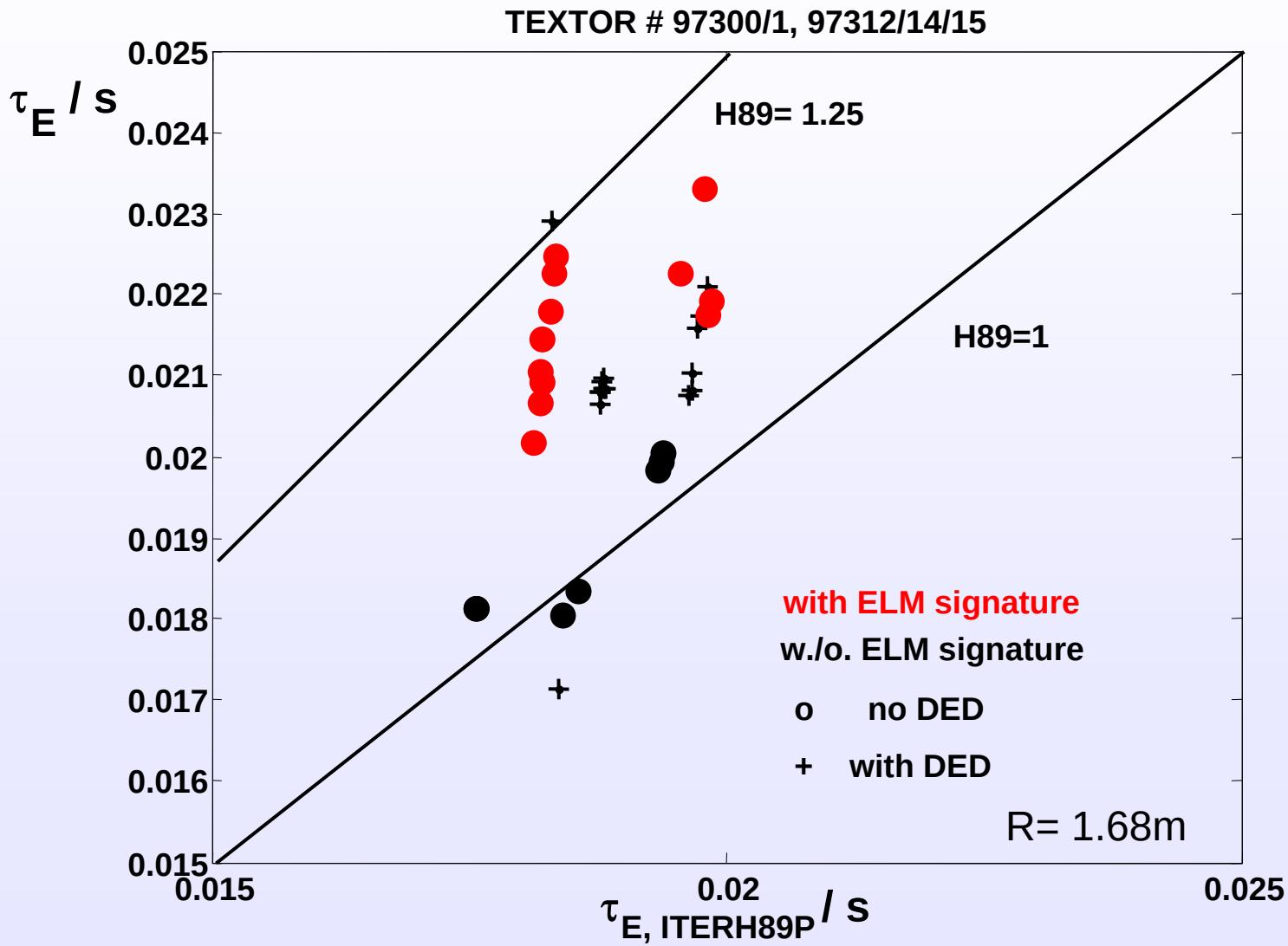
Dα drop seen all around the machine



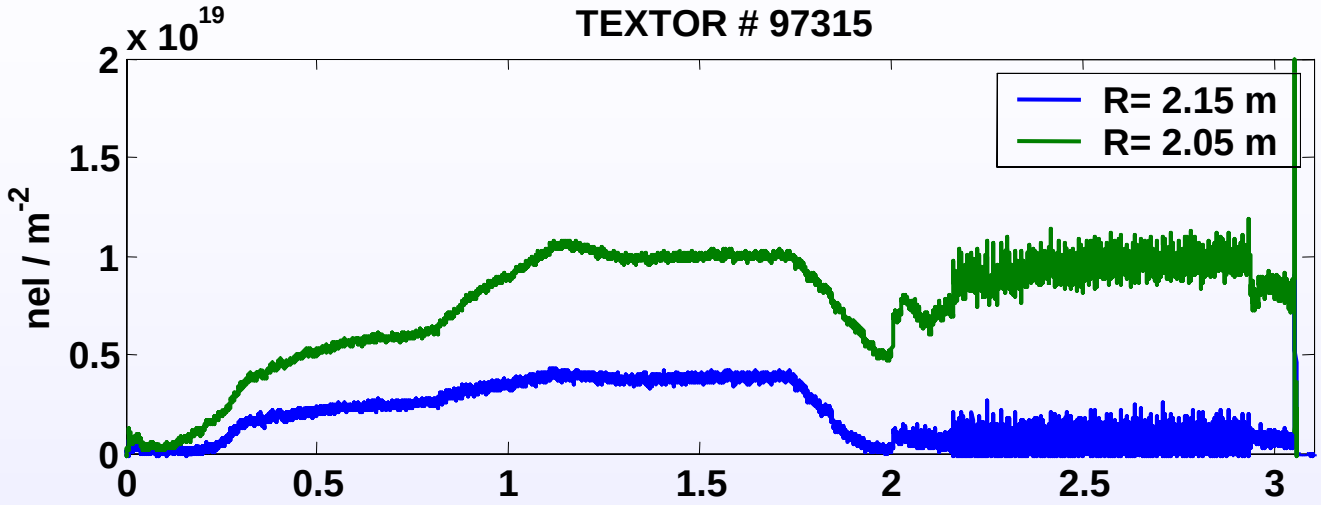
Power threshold about twice the L-H threshold in divertor tokamaks – "typical" for limiter H-modes

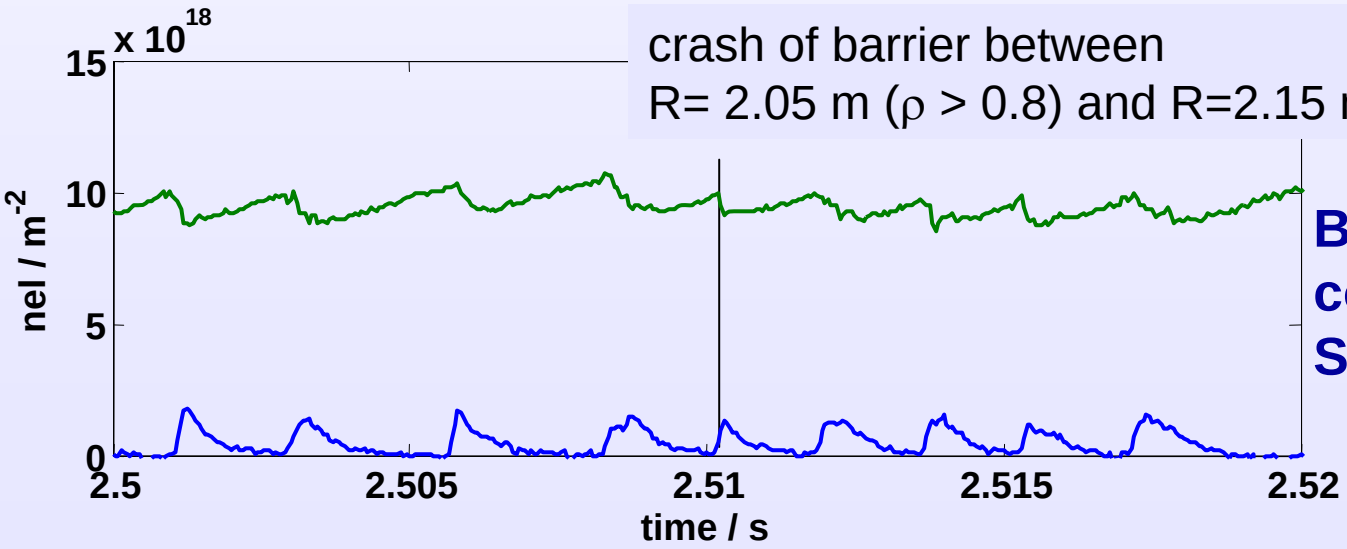


Improvement of energy confinement modest



Outermost interferometer channels @LFS indicate barrier - relaxation events

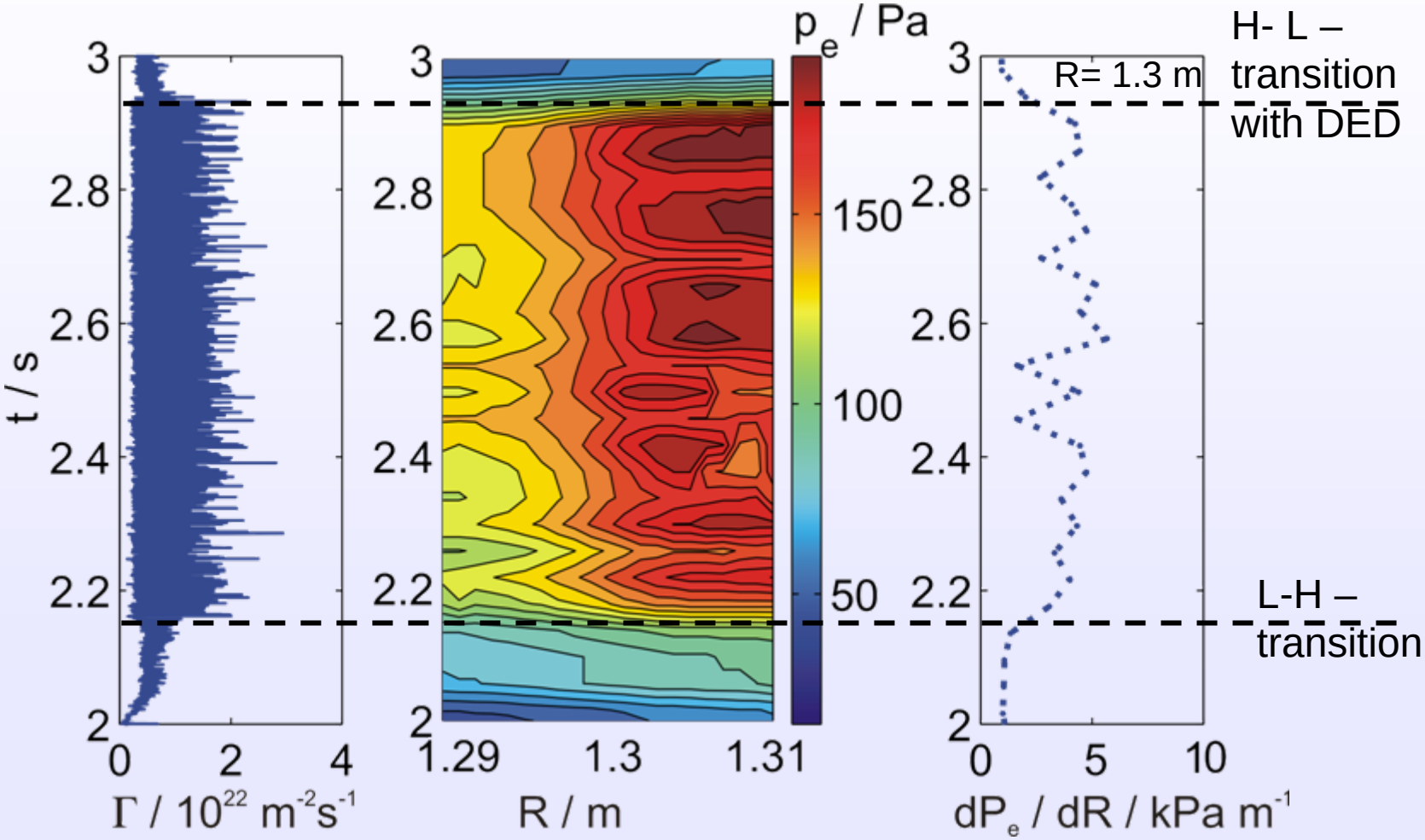




crash of barrier between
R= 2.05 m ($\rho > 0.8$) and R=2.15 m ($\rho > 1$)

Barrier position confirmed by SXR cameras

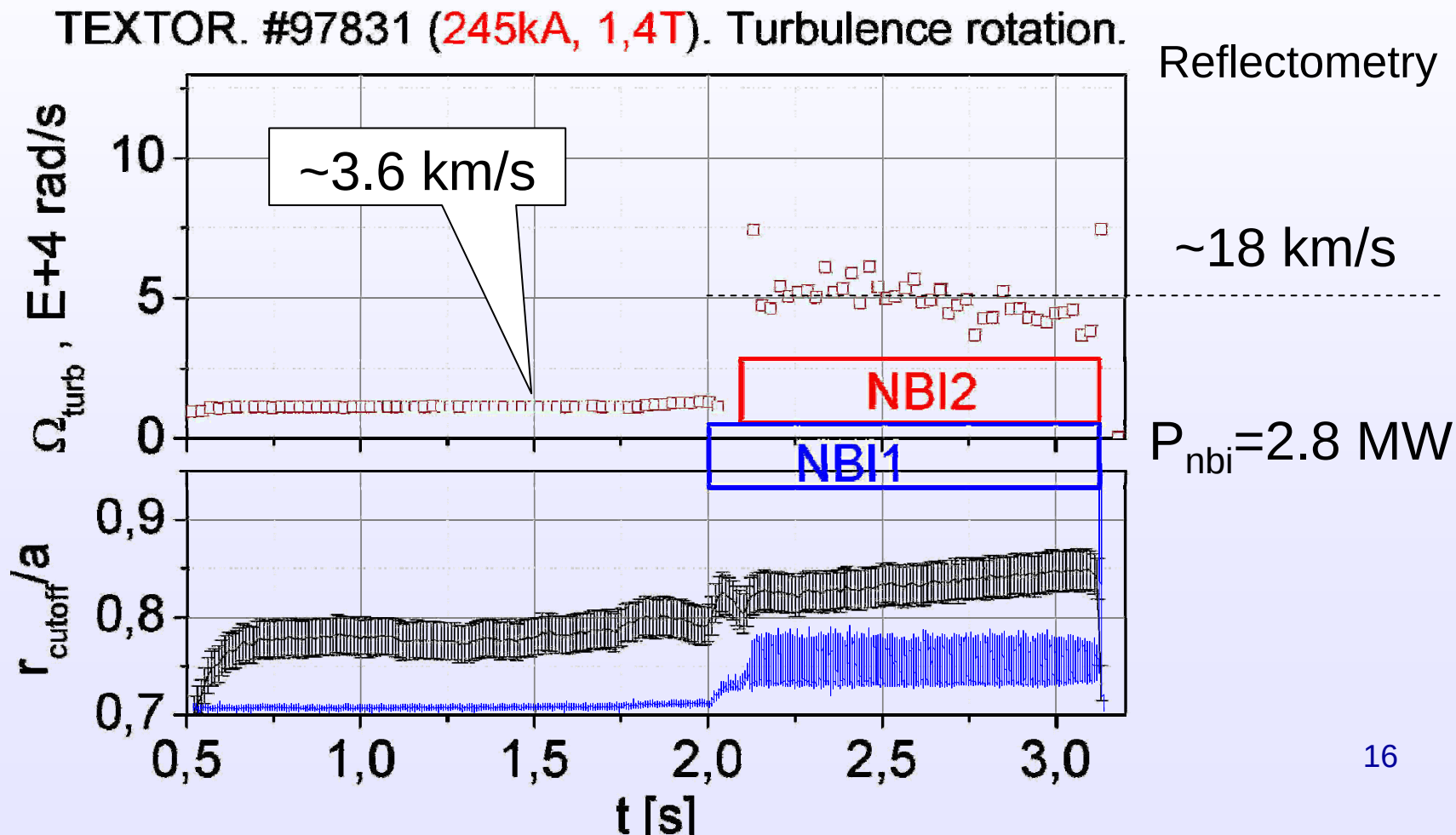
Evolution of edge pressure HFS
TEXTOR # 97315 (thermal He beam*)



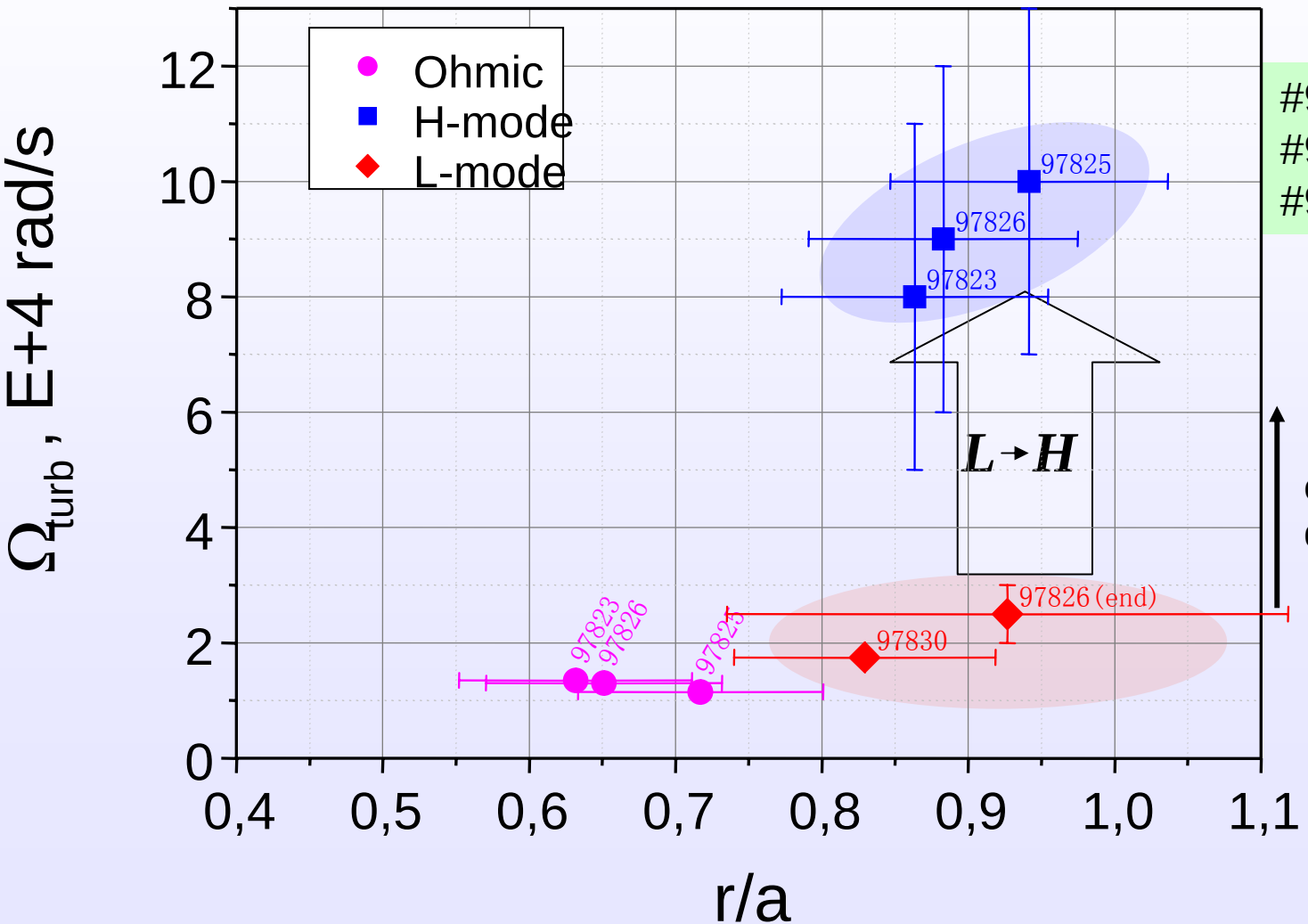
*extension of CR model by courtesy of M. Brix

Substantial spin up of perpendicular turbulence rotation in electron diamagnetic drift direction

(indicating more negative E_r)



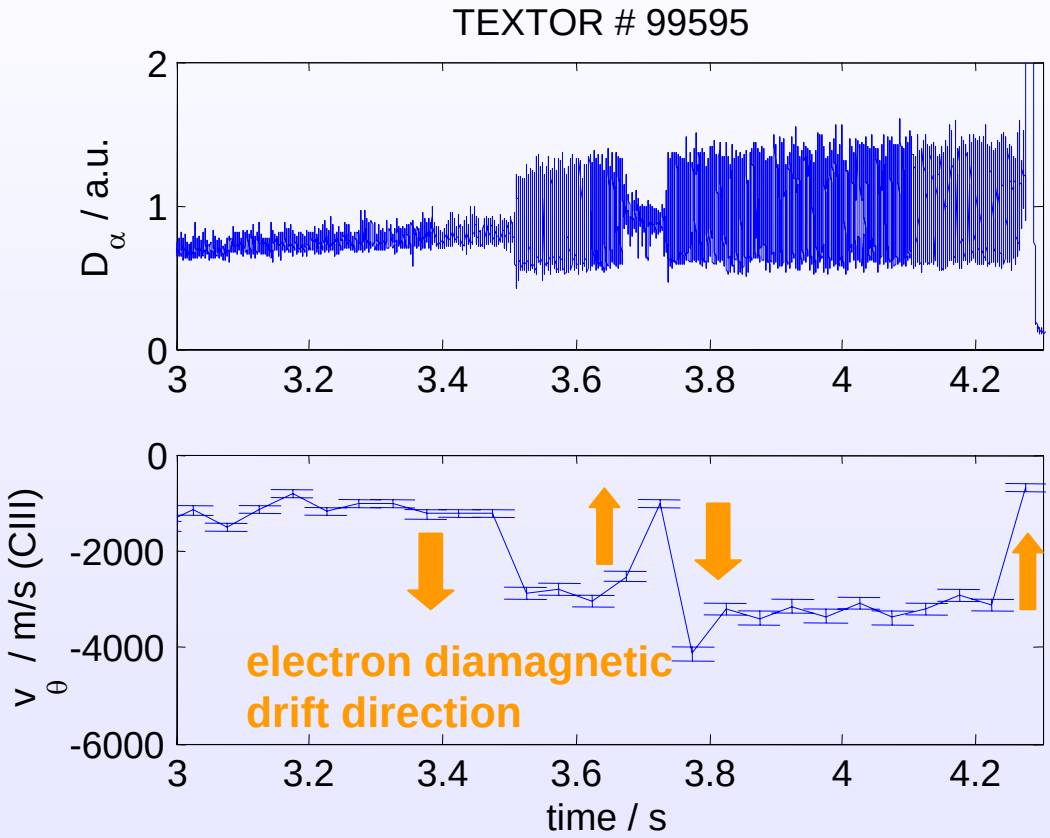
Radial profile of perpendicular turbulence rotation



#97823 – f_0=36 GHz
#97826 – f_0=33 GHz
#97825 – f_0=28 GHz

electron diamagnetic drift direction

Effect on poloidal rotation qualitatively confirmed by spectroscopic Doppler measurements on CIII

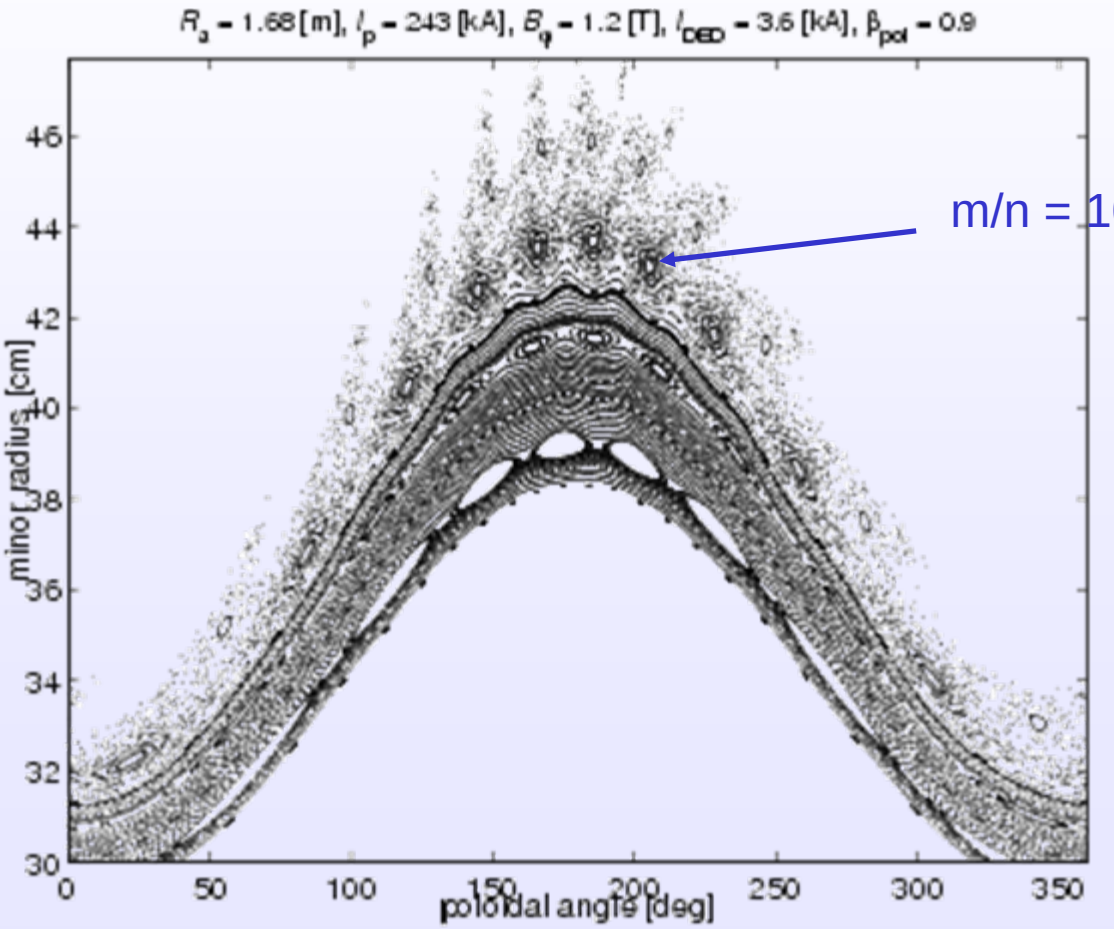


Application of the Dynamic Ergodic Divertor during limiter H-mode phases

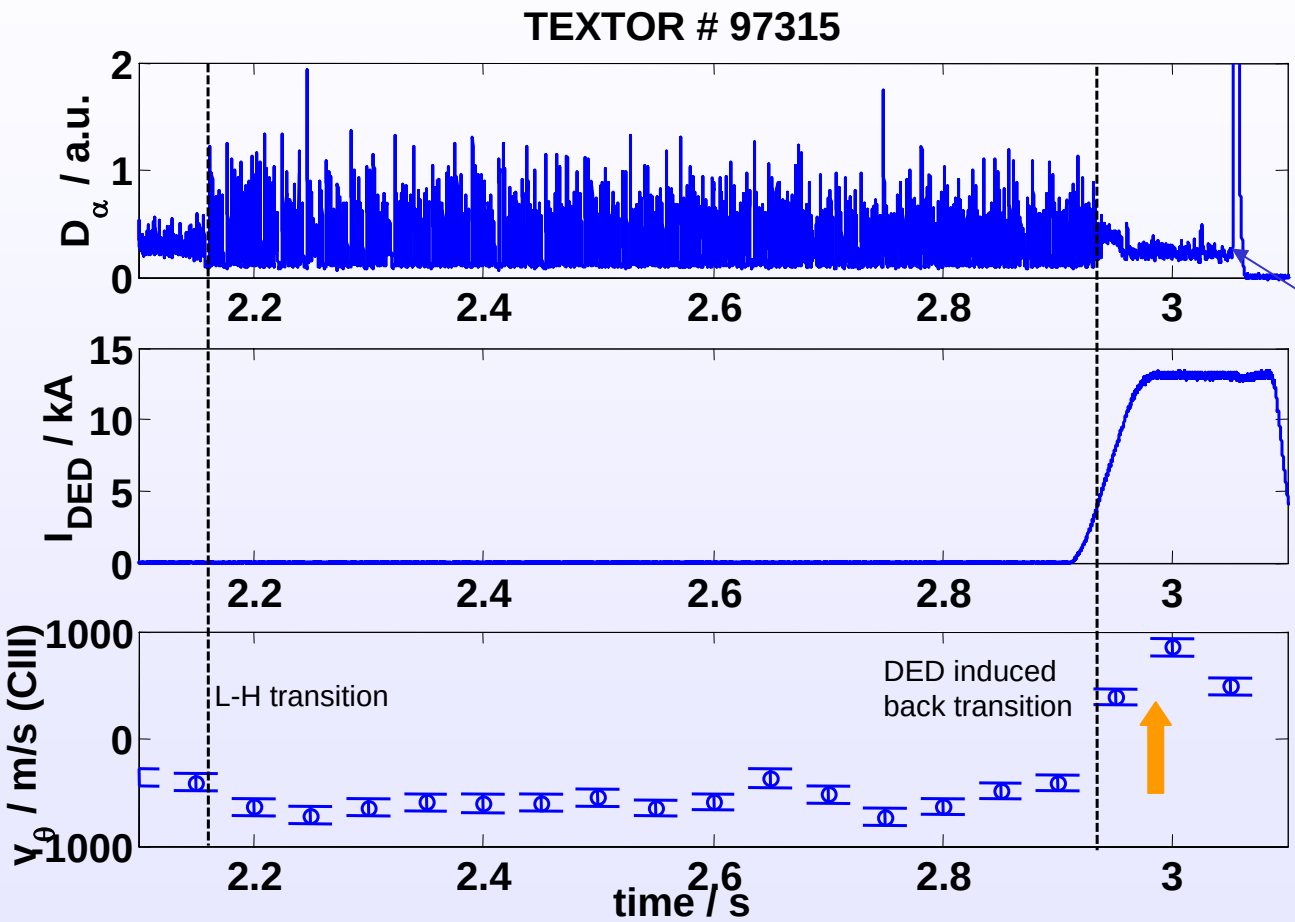
- Initial results, more systematic studies to come…
- Poloidal edge rotation is reverted:
  - Common observation with edge ergodisation, attributed to cross field current needed to compensate parallel electron losses, accompanied with formation of positive radial electric field
- Reduction of ELM-like D_α bursts with increasing perturbation current, finally complete suppression
- Pedestal diminishes accordingly.
- Limiter H-mode finally terminates.
- 3/1 configuration: disruption at low perturbation current (fast mode onset) because of low q_a operation
- **No operational window found so far where ELMs are "mitigated" completely with an unchanged pedestal.**

Example 1, 12/4 configuration, DED DC

Poincaré plot for I_{DED} =3.6 kA – ELMs disappear

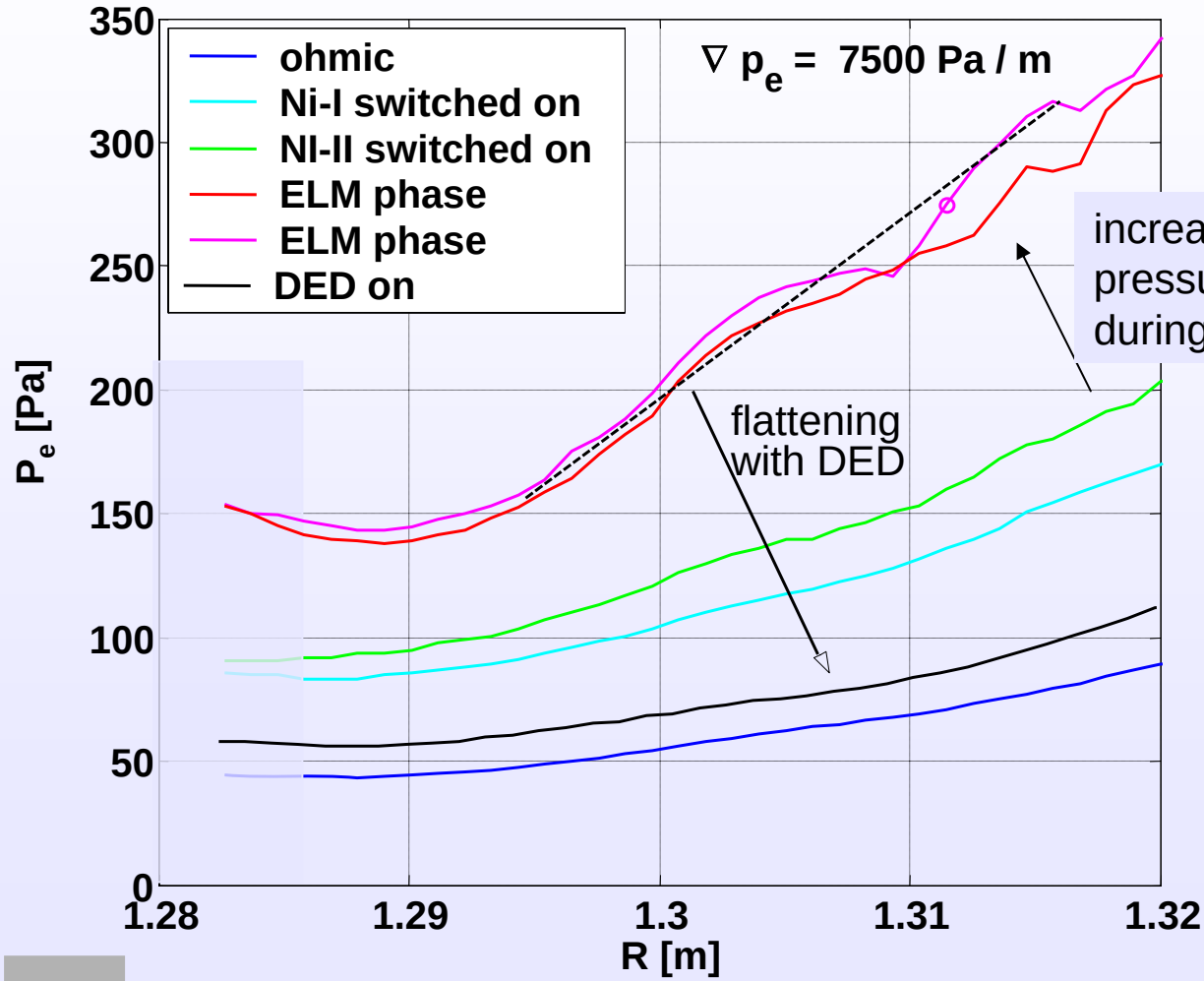


Example 1, 12/4 configuration, DED DC



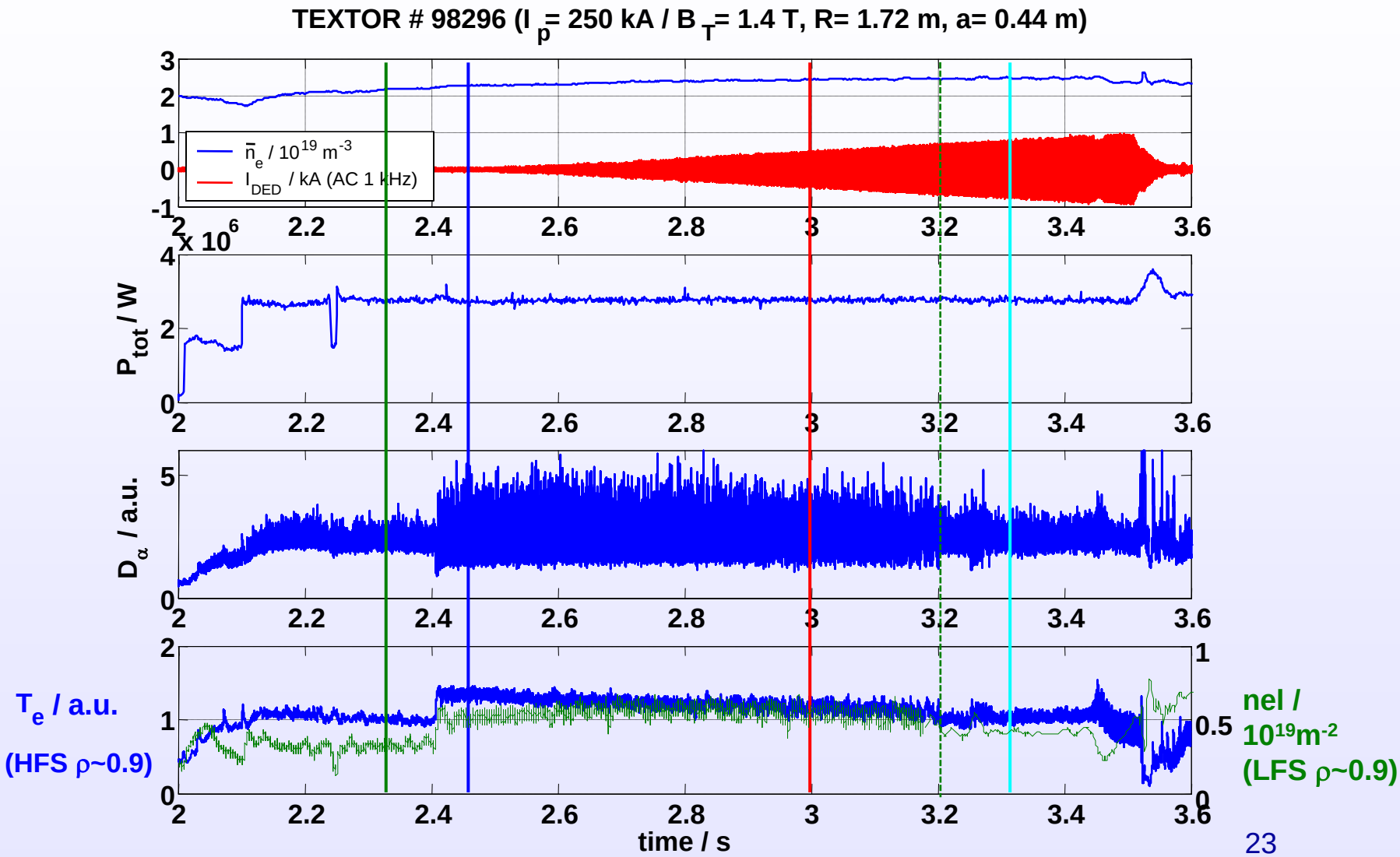
coupling of 3/1 and 2/1 tearing mode

Electron pressure profiles measured by inner He- beam

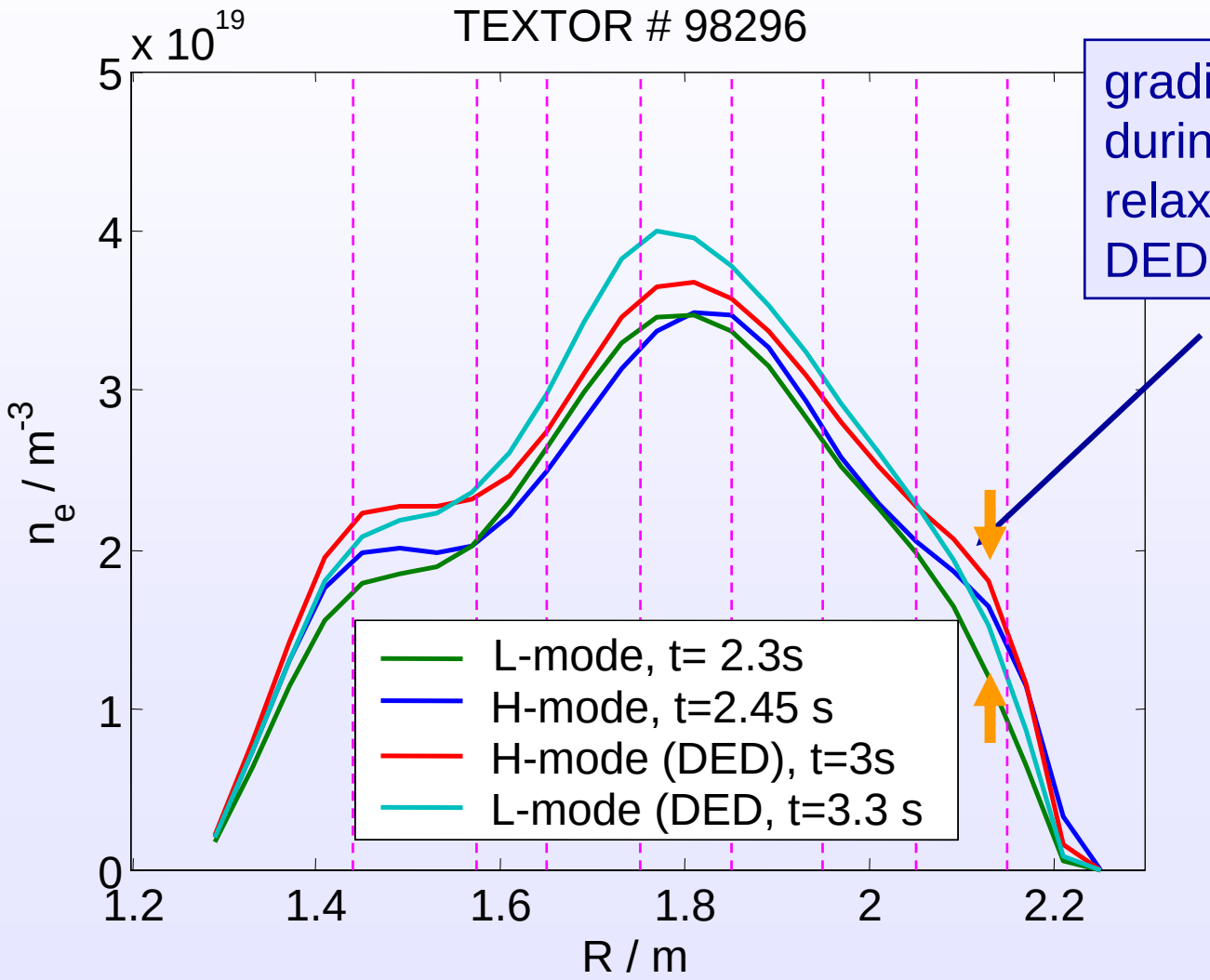


DED target plate

Example 2: DED 3/1 configuration, 1 kHz AC



Density evolution
L -> H-mode -> DED phase



gradient enhanced during H-mode, relaxed back with DED

Concluding remarks and open issues

- Limiter H-mode scenario developed in TEXTOR
  - high power threshold, high frequency ELM bursts, edge pedestal mainly in density, substantial spin up of perpendicular / poloidal rotation indicating Er well
- Initial experiments show strong influence of magnetic perturbations induced by DED:
  - reversal of poloidal rotation at the edge, relaxation of edge gradients, narrow operational margin in 3/1 configuration because of low mode threshold
  - no operational window for suppression of ELMs with unchanged pedestal
- More detailed information on pedestal quantities needed.
- More systematic studies on MHD characteristics yet to come.
- New experiments in 6/2 configuration of DED are planned.
- With more data from TEXTOR available, comparisons to results from other devices (DIII-D) with respect to the basic mechanisms of ELM mitigation by magnetic perturbations can start.