Formation of the radial electric field profile in WEST tokamak

Laure Vermare, Guilhem Dif-Pradalier, Pascale Hennequin, James Paul Gunn, Xavier Garbet, Jean-Francois Artaud, Ozgur Gurcan, Clarisse Bourdelle, Frédéric Clairet, Nicolas Fedorczak, et al.

▶ **To cite this version:**

Laure Vermare, Guilhem Dif-Pradalier, Pascale Hennequin, James Paul Gunn, Xavier Garbet, et al.. Formation of the radial electric field profile in WEST tokamak. FEC 2020 - 28th IAEA fusion energy conference, May 2021, E-Conference, France. . cea-03520480

HAL Id: cea-03520480
https://cea.hal.science/cea-03520480

Submitted on 11 Jan 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

FORMATION OF THE RADIAL ELECTRIC FIELD PROFILE IN WEST THE TOKAMAK

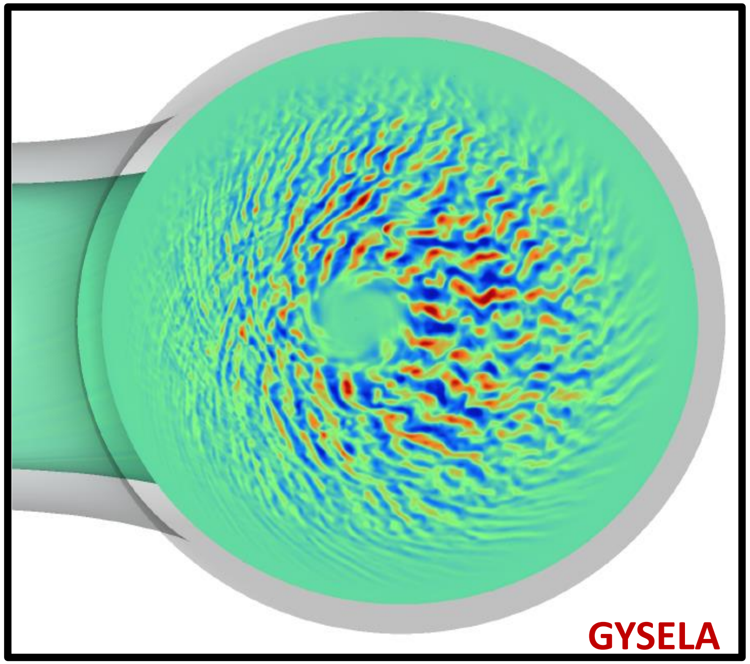
L. Vermare[1], P. Hennequin[1] , M. Peret[2], C. Honoré[1], C. Bourdelle[2], F. Clairet[2], R. Dumont[2], N. Fedorczak[2], M. Goniche[2], J. Gunn[2], P. Maget[2], J. Morales[2], R. Varennes[2] and the WEST team

[1] Laboratoire de Physique des Plasmas
Ecole Polytechnique, 91128 Palaiseau, France

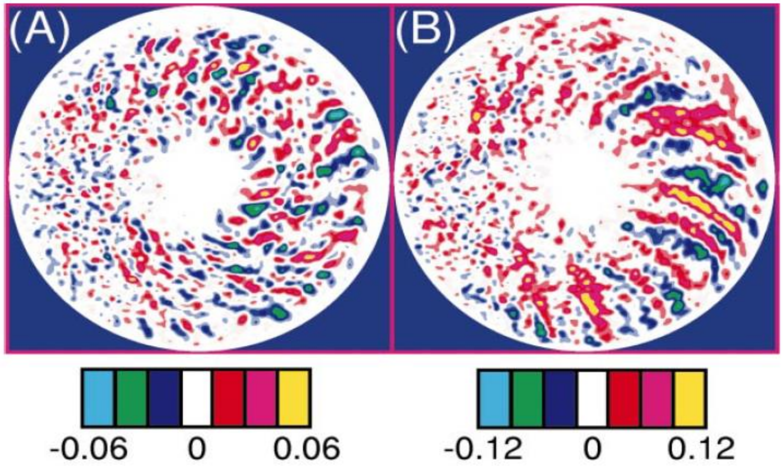
[2] IRFM, CEA, Cadarache, 13108 Saint Paul lez Durance

Context and motivations

Micro-turbulence generates **radial transport** of heat and particles
reducing fusion plasma performances



Tilting and decorrelation of turbulence by **sheared ExB velocity**
reduces turbulent transport



[Z. Lin, Science1998]

Shearing coming from mean flow (equilibrium flow) & ZF have the same impact on turbulence

Reduction of turbulence in transport barriers

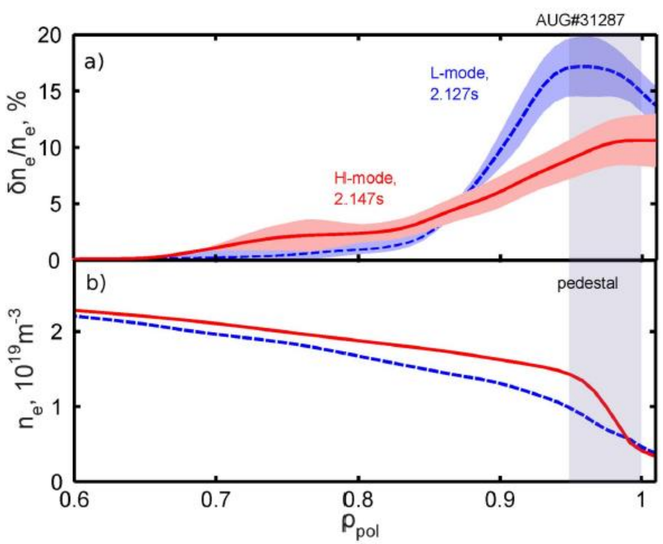
EXPERIMENTALLY => above a certain threshold in power crossing the separatrix

Edge barrier formation :
transition to a High confinement mode **(H mode)**

- → **core pressure x2**
- → **strong turbulence reduction at the core/edge interface**
- → **strong associated sheared flows**

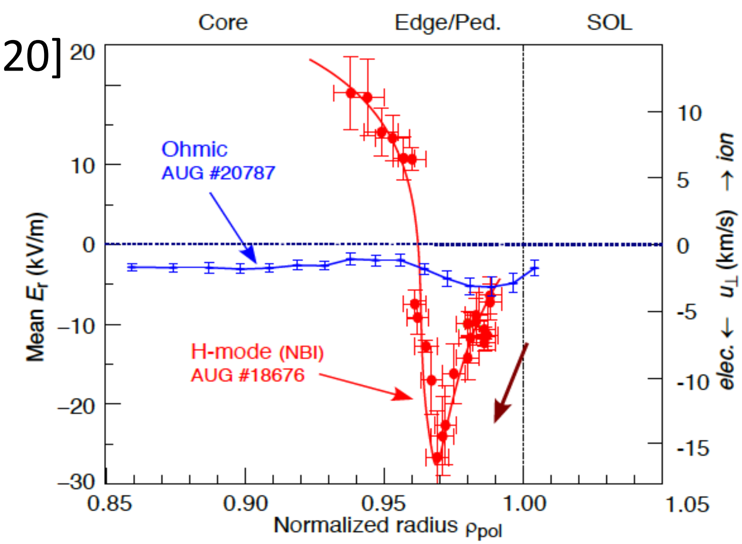
coming from pressure gradient and turbulence generated flows

Sensitive to the magnetic configuration
when B×∇B drift is directed toward the active X-point, P_{LH} is lower
= **favorable configuration**
[Ryter, NF2013]
and **correlated with $V_{E\times B}$ shear** (proxy min(V))
[Cavedon, NF2020]



[Medvedeva, PPCF2017]

[Cavedon, NF2020]



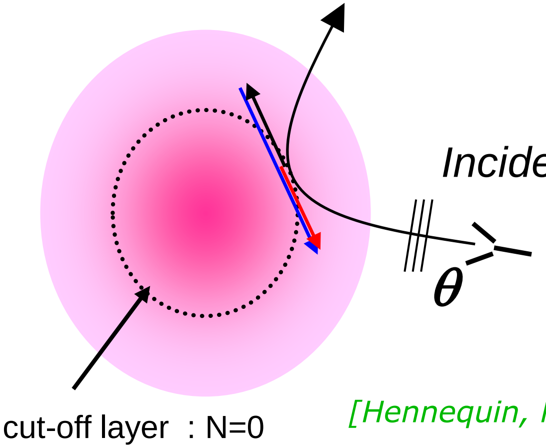
[Conway, EFTSOMP 2011]

-> Dynamics of the transition not completely understood
-> Sensitivities of the power threshold to the magnetic topology

Doppler Backscattering System

Detection of the back-scattering electric field Ed (t) :

$$E_d(t) \propto \int_V \tilde{n}(\vec{r},t)e^{-i\vec{k}.\vec{r}}d^3r \equiv \tilde{n}(\vec{k},t)$$

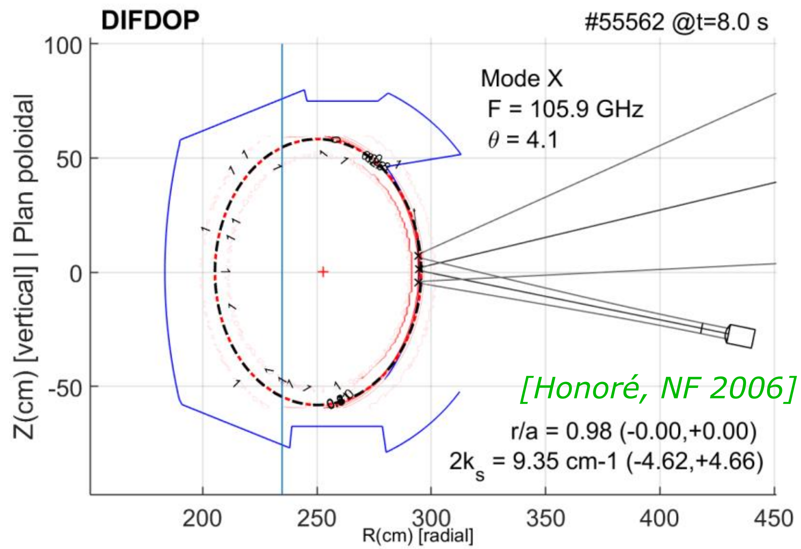


[Hennequin, NF 2006]

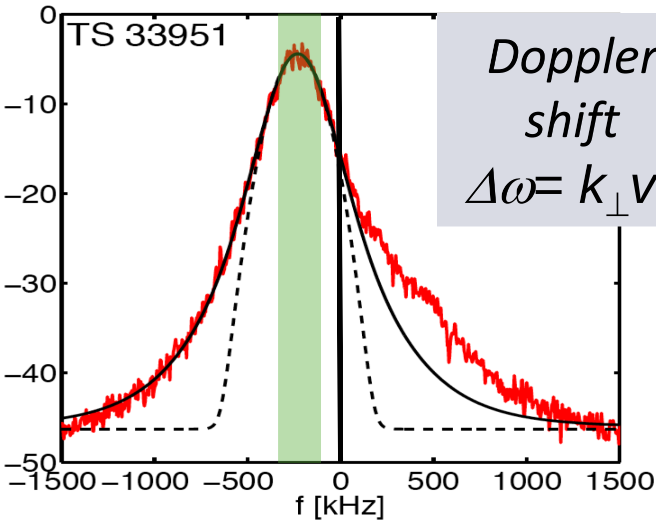
⇒Measurement of the speed of density fluctuations with :

- spatial localization
- spatial scale selectivity

Require beam tracing code to evaluate $k_\perp$ & ρ from density profile & equilibrium



[Honoré, NF 2006]



Doppler shift
$\Delta\omega = k_\perp v_\perp$

Perpendicular velocity in the laboratory frame:

$$V_\perp = \boxed{V_{E\times B}} + \langle \omega/k \rangle_{fluc}$$

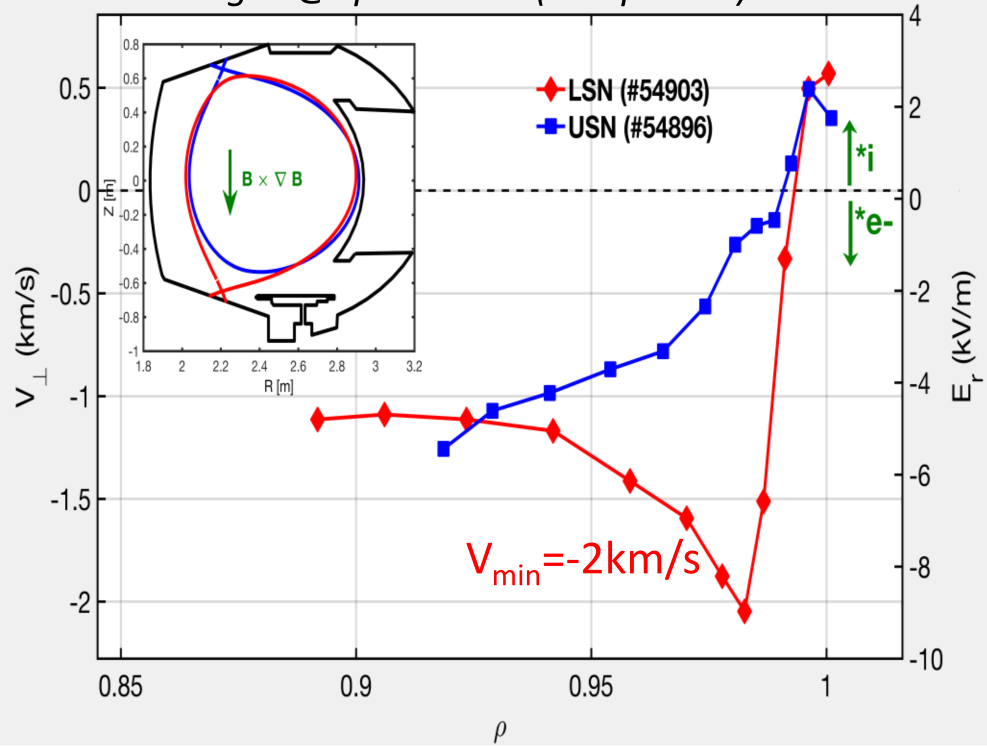
considering $V_{E\times B} >> \langle \omega/k \rangle_{fluc}$

-verified experimentally at this edge-

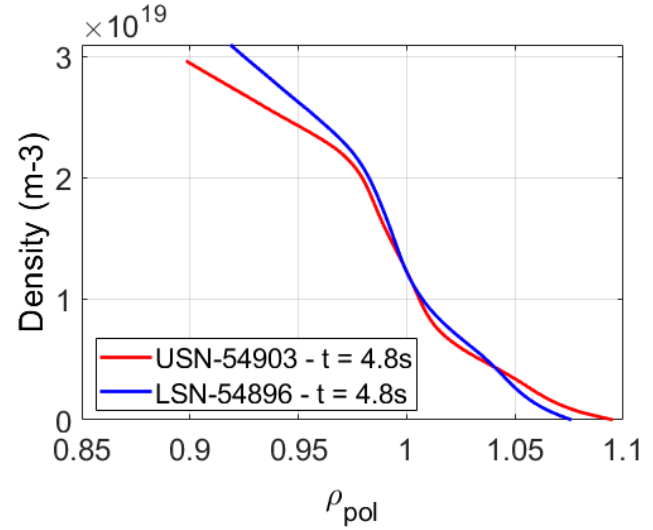
Radial shear of Er stronger in LSN configuration

In **low power** & **low plasma current** discharges, **no well in the Er profile in USN** while the profile exhibits a moderate but clear well just inside the separatrix in LSN

Ohmic discharges @ Ip = 400kA (i.e. q95 = 5)



while density profiles are similar

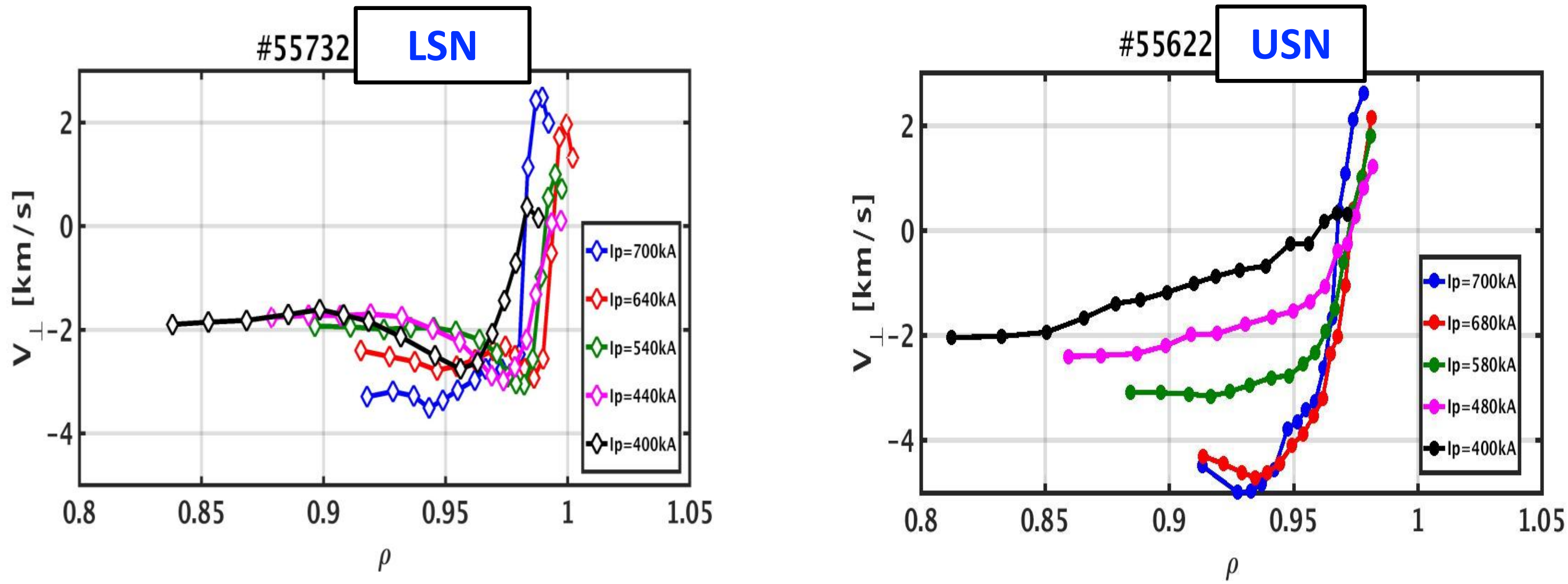


Similar observations on AUG *[Schirmer, NF 2006]*
on DIII-D *[Carlstrom, PPCF 2002]*
on MAST *[Meyer, JoP 2008]*
and same tendency changing contact points on Tore Supra *[Hennequin, EPS2010]*

This observation is **consistent** with the common belief that LSN (magnetic drift toward X point) is a **favourable configuration**

Impact of the plasmas current depends on the magnetic conf.

Experiments performed to study the impact of plasma current on both configurations



⇒ The velocity profile forms **a well when increasing the plasma current in USN**

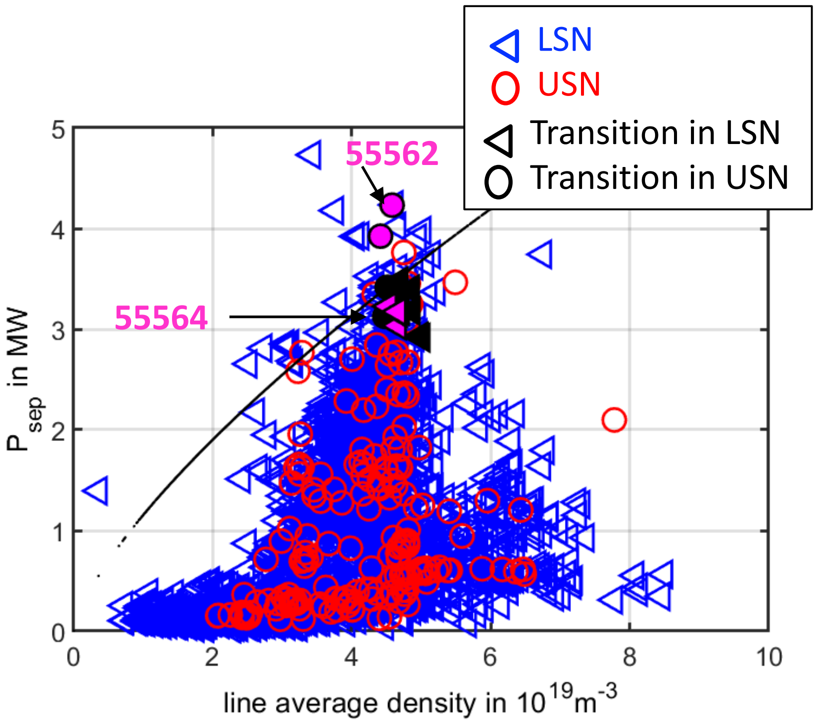
⇒ A weaker effect is observed in LSN

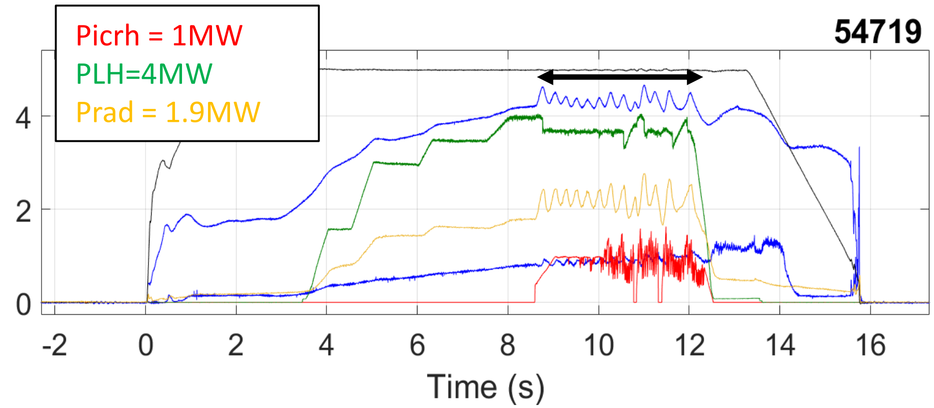
⇒ Leading to an **opposite situation** = **USN more "favorable" in WEST ?**

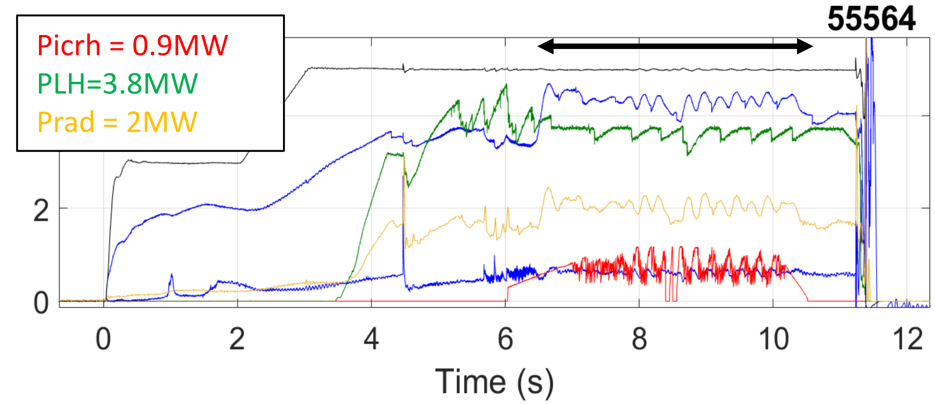
L-H transitions observed in WEST in LSN configuration

First **L-H transitions** have been obtained in WEST plasmas => no clear H-mode regime but several signs of the transition (energy increase, internal inductance decrease, edge steepening of density profile, flux on divertor target decrease, reduction of gas puff rate…)

Heat power crossing the separatrix close to the threshold with high level of radiation
=> oscillatory regimes



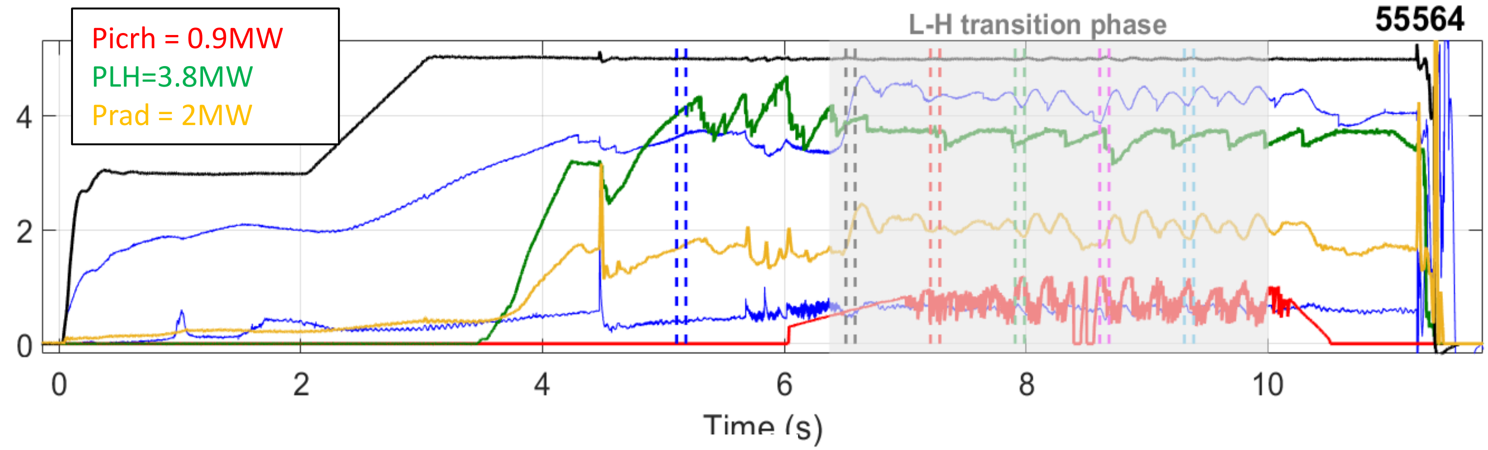




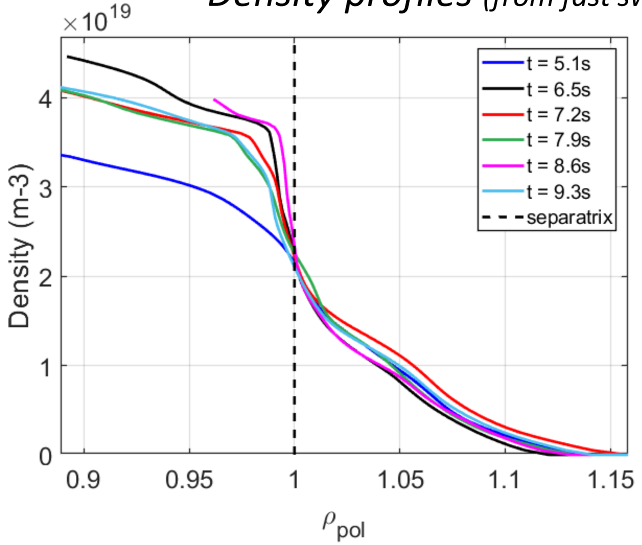
Transitions have been also observed in USN configuration
=> Similar simultaneous sign of transition but different behavior

Density pedestal & Er well formed consistantly

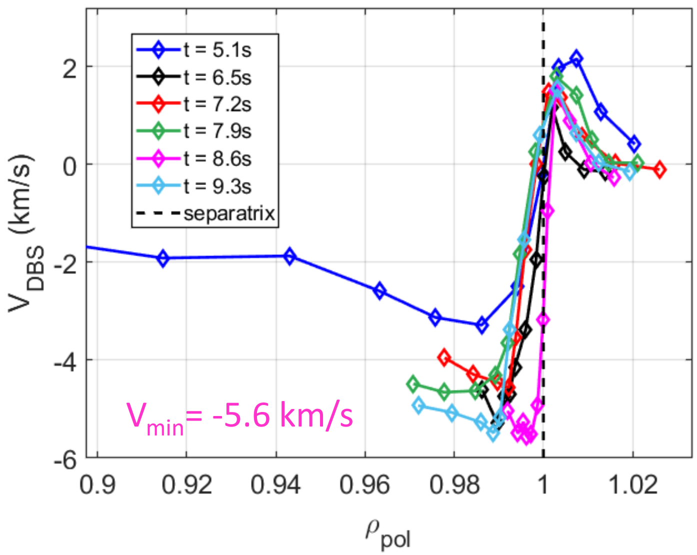
LSN



Density profiles *(from fast sweep reflectometry)*



Velocity profiles *(from DBS)*



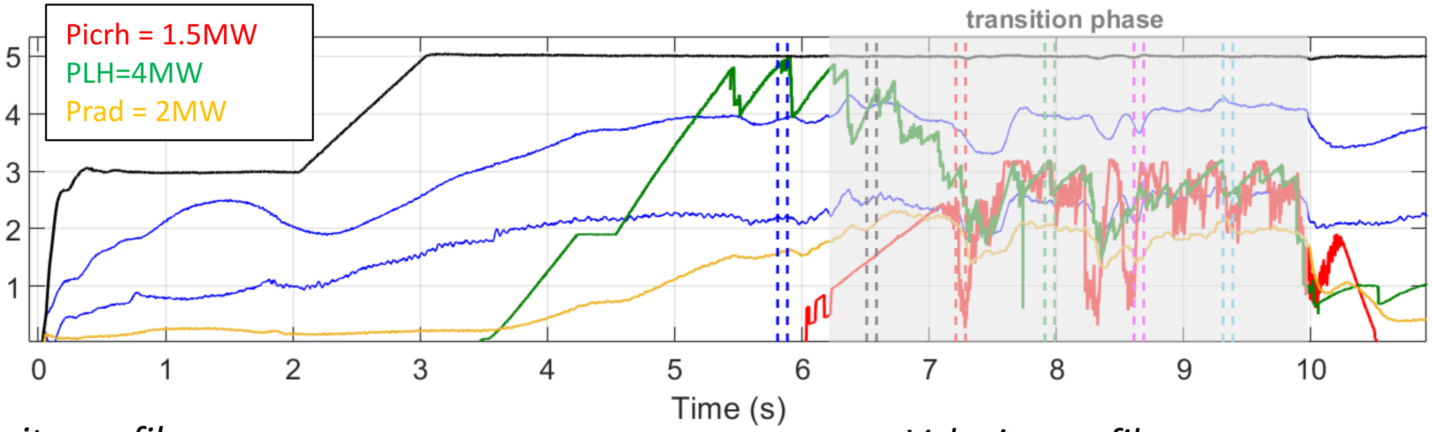
⇒ Establishment of a **density pedestal**

⇒ Formation of a **deeper well just inside the separatrix**

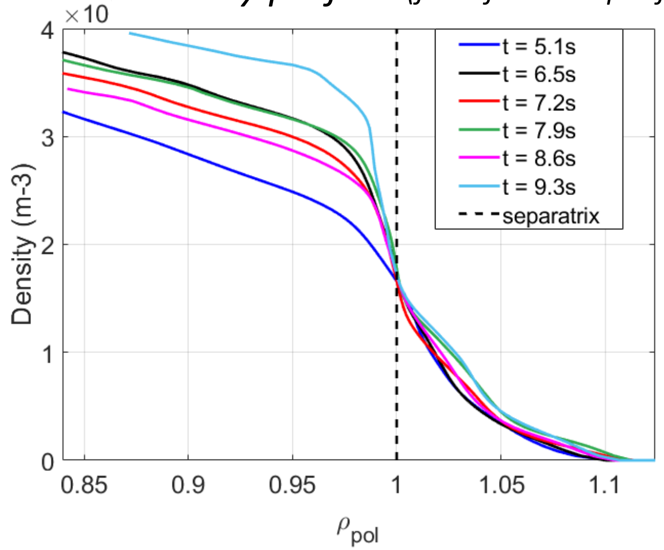
⇒ **Deepening** of the profile **consistent with neoclassical prediction (Er ∝∇P)**

Transitions also observed in USN

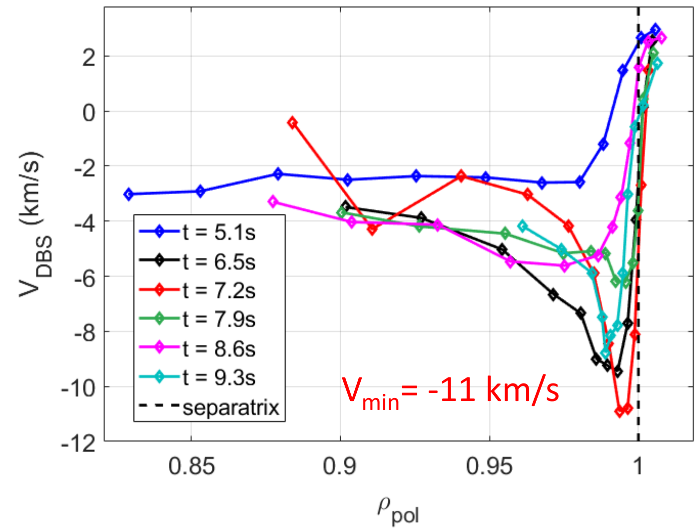
USN



Density profiles (from fast sweep reflectometry)



Velocity profiles (from DBS)



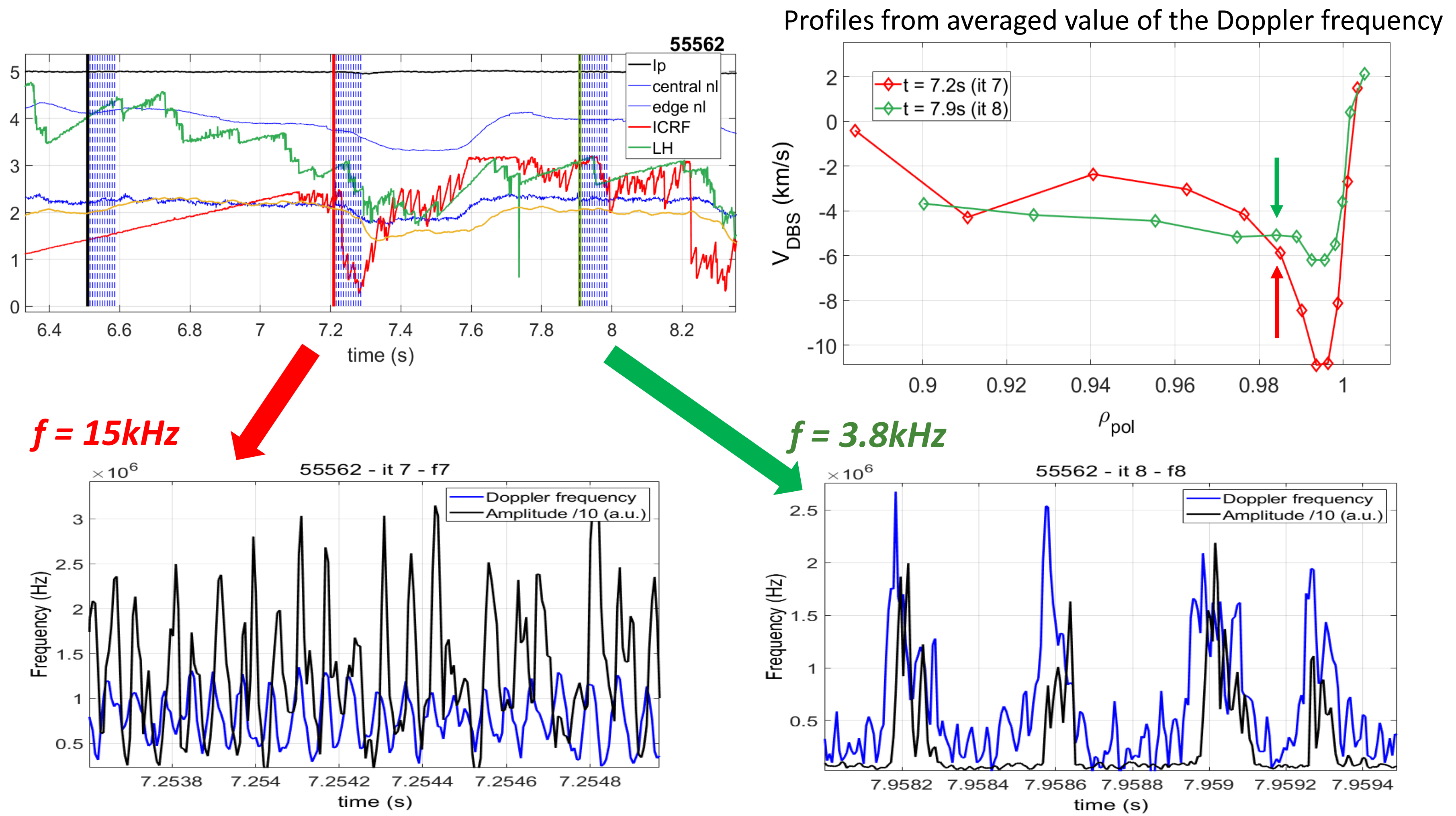
⇒ Increase of the density gradient at the edge

⇒ **Less clear density pedestal as compared to LSN**

⇒ **Deepest well observed in WEST** so far

⇒ Deepening of the profile **not completely consistent with neoclassical prediction** (Er $\propto \nabla P$) at least from the $\propto \nabla n/n$ contribution, role of $\propto \nabla T$?

Dynamics similar to I-phase observed in USN configuration



Dynamics changes from oscillatory to burst events similarly to the behavior observed during an I-phase [Conway, PRL2011] [Hennequin, private communication]

Summary

- **Low power & low current discharges** : **no Er well in the USN** configuration

- **Strong sensitivity of the Er well to the plasma current in USN**
  - Surprising since no dependence with Ip on the scaling law of power threshold [Martin, JFCS 2008]
  - On the other hand, safety factor enters into play through several mechanisms that generate Er (orbit losses, neoclassical viscous damping, turbulence drive…)
  - Investigation through reduced model based on edge turbulence [Peret, NF2021] and study of the competition between turbulence and magnetic ripple [Varennes]

- **At high power or high current**, the **velocity profile is more sheared in USN than in LSN** against the expectation considering favorable (i.e. LSN in WEST) versus unfavorable (USN in WEST) configuration

- **L-H transitions are observed in LSN** configuration, with **density pedestal formation concomitant with Er well formation** => **consistent with neoclassical picture**

- **Transitions also observed in USN**, with **a deeper Er well** and **less pronounced density pedestal & Er dynamics similar** to observation on ASDEX Upgrade during some **I-phases**

$\Rightarrow$ **Continue exploring both configurations and the higher density branch, as well as I-mode access**