LH Transitions in TCV

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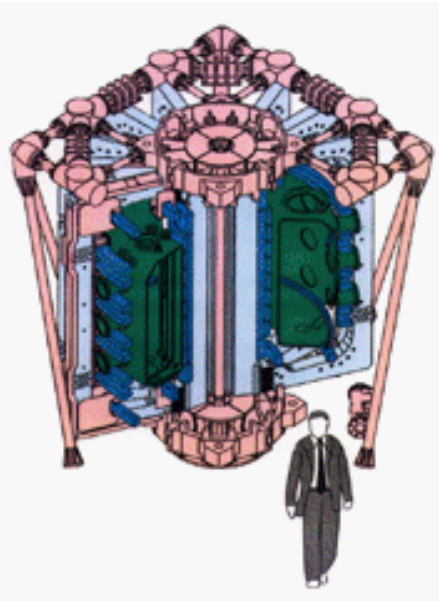
Outline:

- Operational domain of H-mode in TCV
- Overview of LH transition studies
- Future studies and possible collaborations

TCV

- R=0.88m, a=0.25m, Ip<1MA, Bt<1.5T
- 16 independent shaping coils, ECH/ECCD



LH transition - Operational Domain

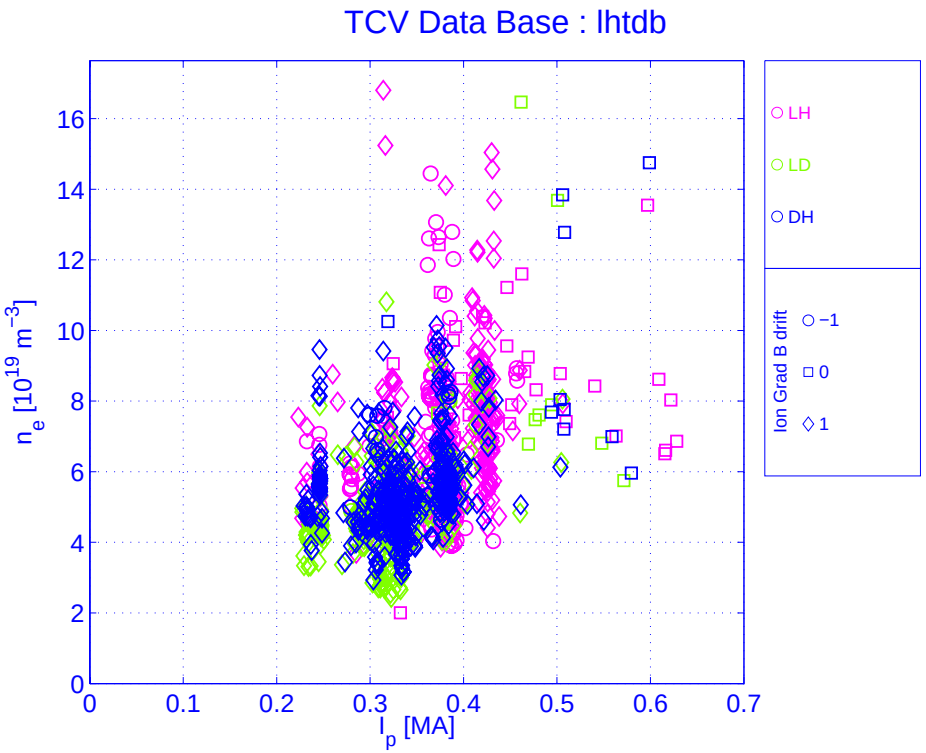
Ohmic H-mode

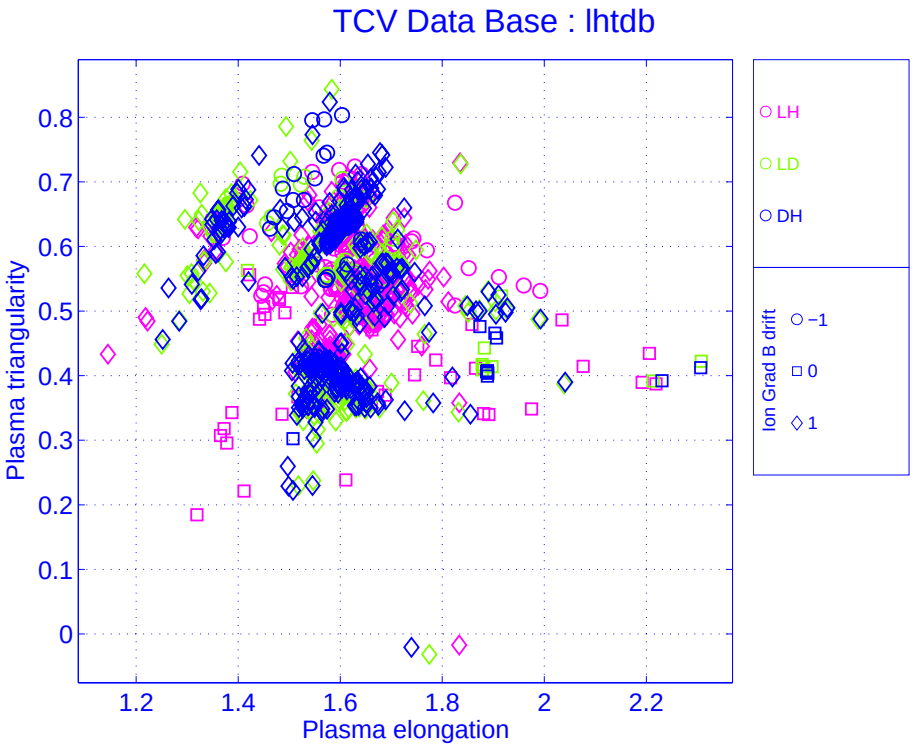
Regularly obtained in diverted (SN &DN) plasmas with:

- I_p>250kA
- n_e>3 10^{19} m^{-3}

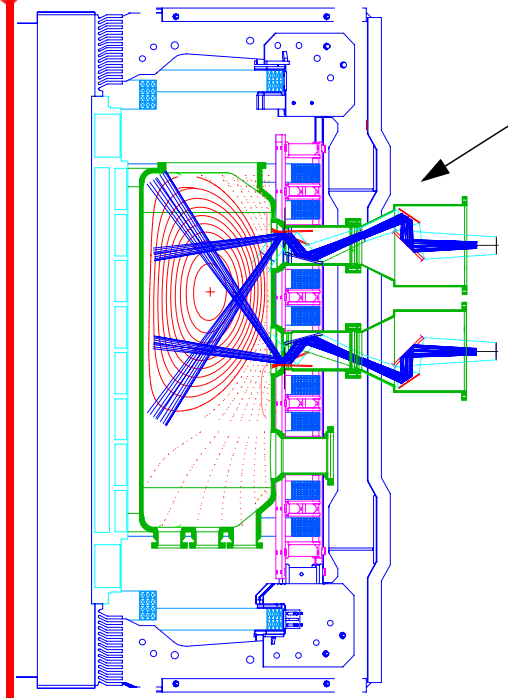
$1.2 < \kappa < 2.2$

$0.2 < \delta < 0.8$



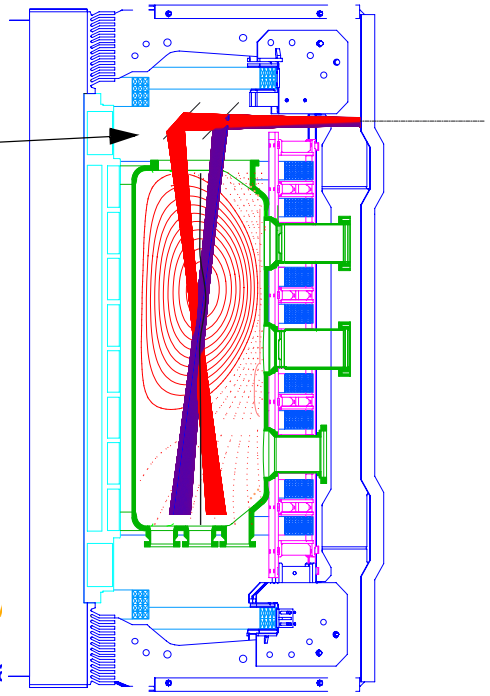


LH Transition - Operational Domain II



LH Transitions with ECH

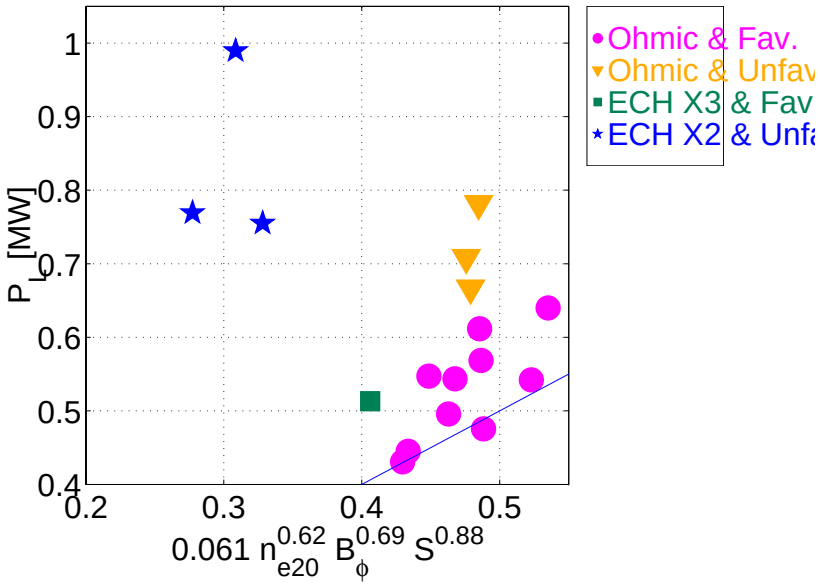
- X2: 82.4GHz - Lateral launch
- X3: 118GHz - Vertical launch



H mode / ECH X2 have disconnected plasma density ranges

Influence of ion gradB drift

Influence of low density plasma



Y.Martin et al, PPCF 2003, A351

LH Transition - Operational Domain III

Other important parameters:

- Gaps (inner gap & outer gap)
- X-point position (distance from the wall)
- Divertor configuration
- Scenario
- Sawteeth
- Conditioning

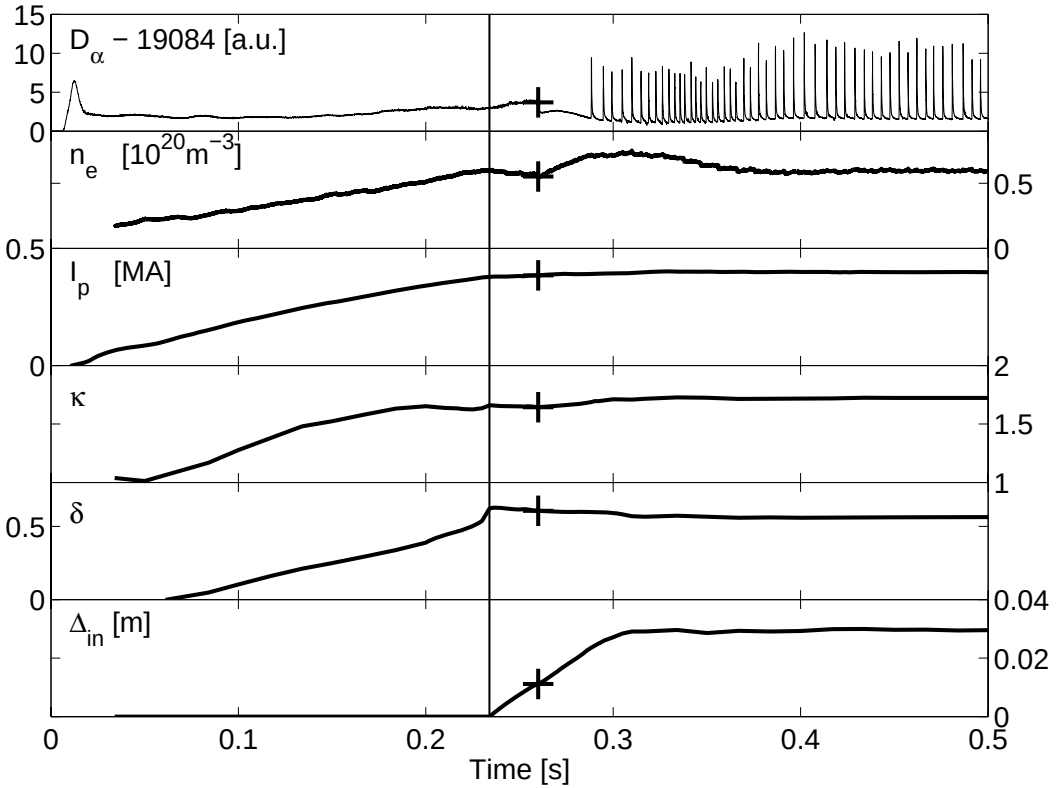
Influence of these parameters is established ...

... but the mechanisms remain unclear

LH transitions leading to stationary ELMy H-mode

Strategy:

- Since most transitions appear during divertor formation, prepare a stationary, limited plasma and then move to SN configuration
- Scans of I_p, n_e, κ, δ, B_t



Results:

- L-mode
- ELMy
- ELM free then ELMy
- ELM free

Operational domain of LH transitions leading to ELMy

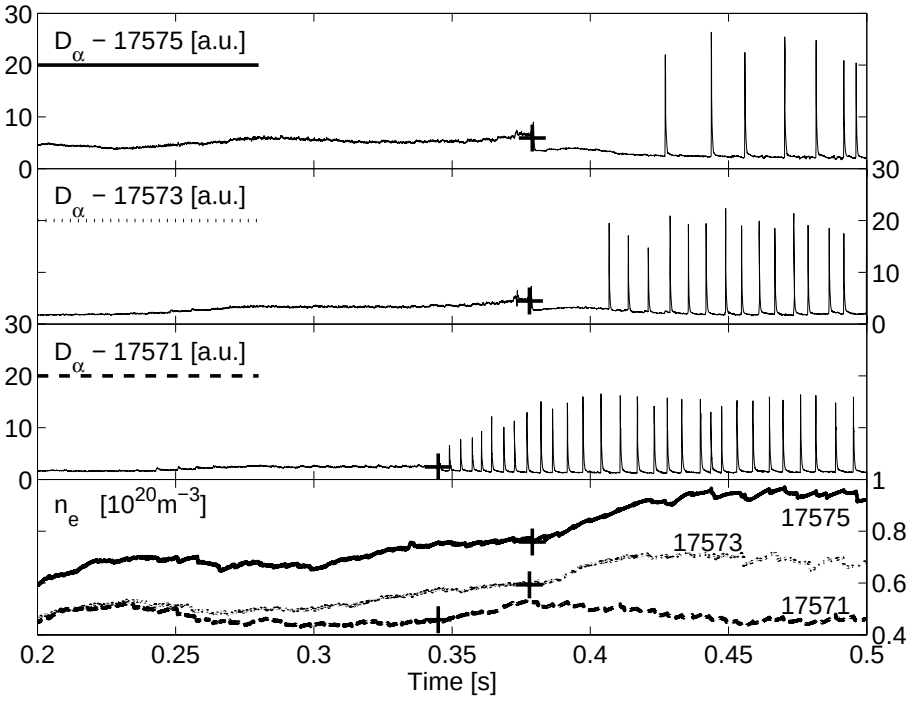
- I_p~410kA κ ~1.7
- n_e~6 10^{19} m^{-3} δ ~0.6

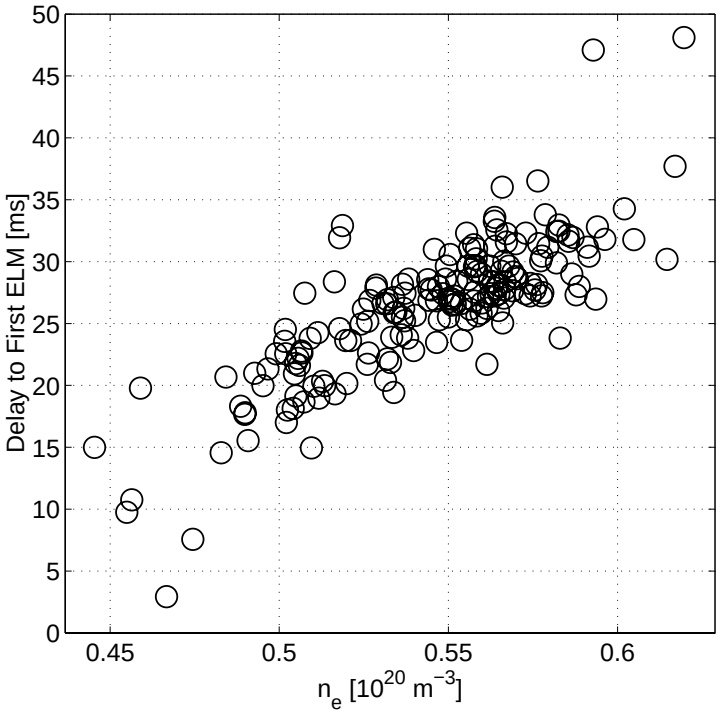
ELM free phase duration

Influence of the plasma density at the LH transition:

The duration of the ELM free phase increases with plasma density at the LH transition

Same result with plasma triangularity





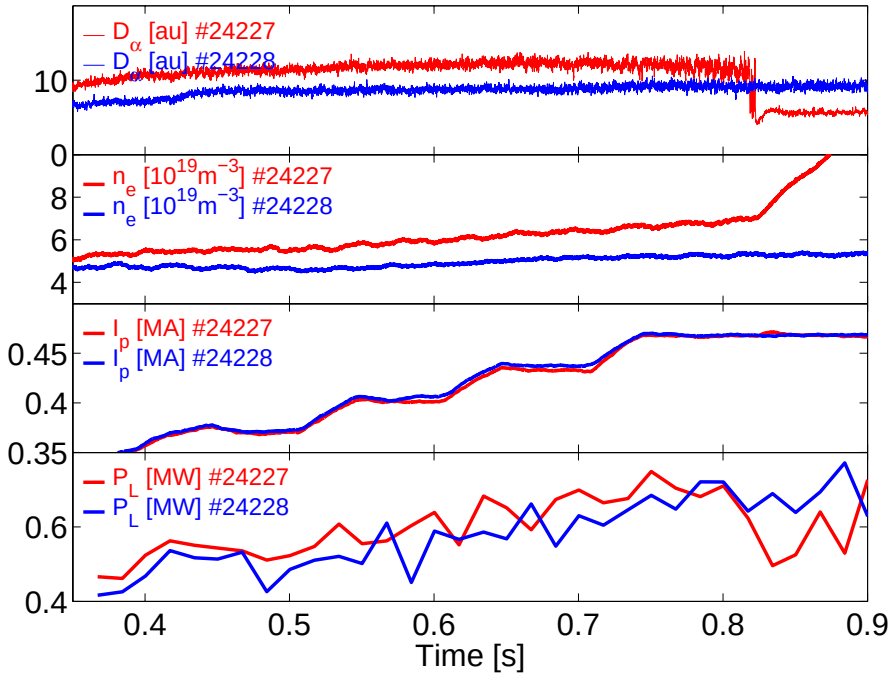
Scan of Ohmic Power

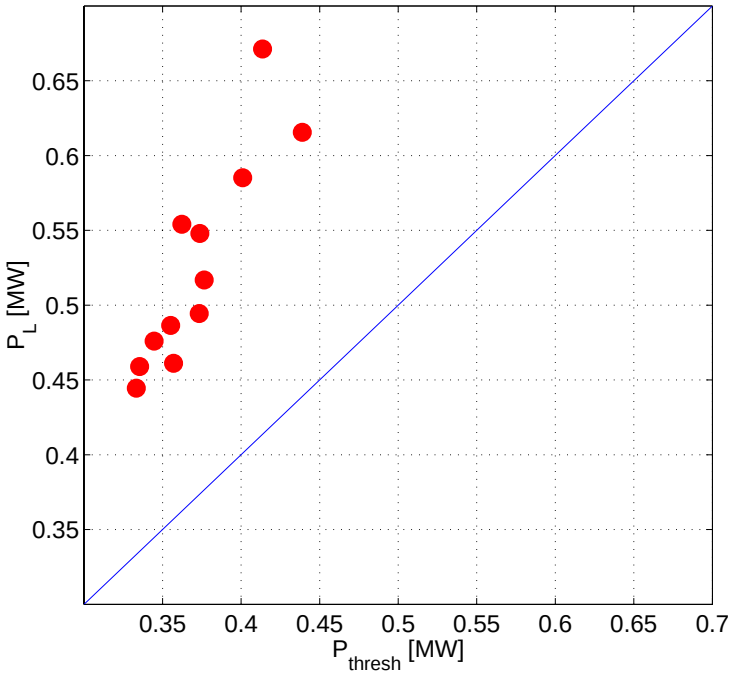
Experiment:

- Steps in Ip, different plasma densities, while in diverted configuration

Result:

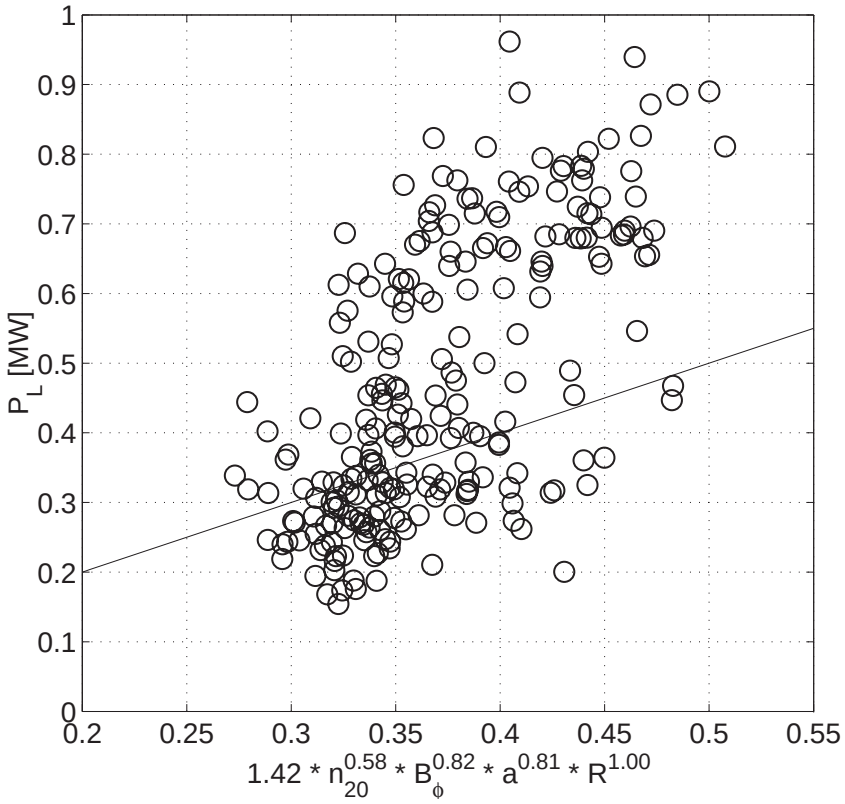
- Threshold power in general much higher than the scaling
- LH Transition occurred in the higher density case





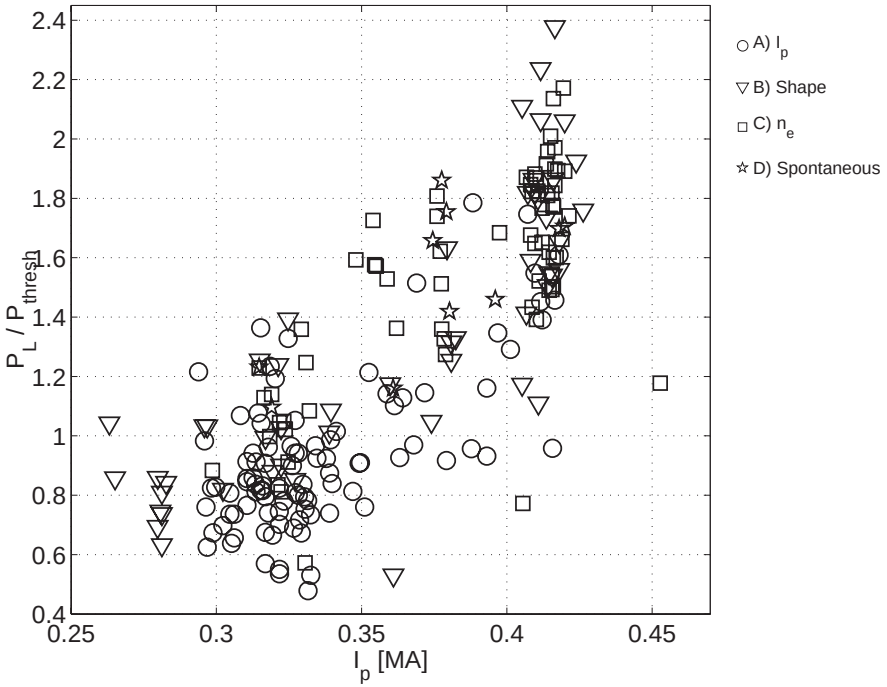
Effect of discharge scenario

In TCV ohmic plasmas, large variation of loss power, measured at the LH transition, for a given expected threshold power value



Different scenario analysed:

- Plasma current ramp/steps in SN
- Density ramp in SN
- Lim to SN
- Spontaneous LH transition



Threshold lower when LH transition obtained while moving from Lim to SN

Y.Martin, EPPWS, Cadarache, 3-5 April 2006

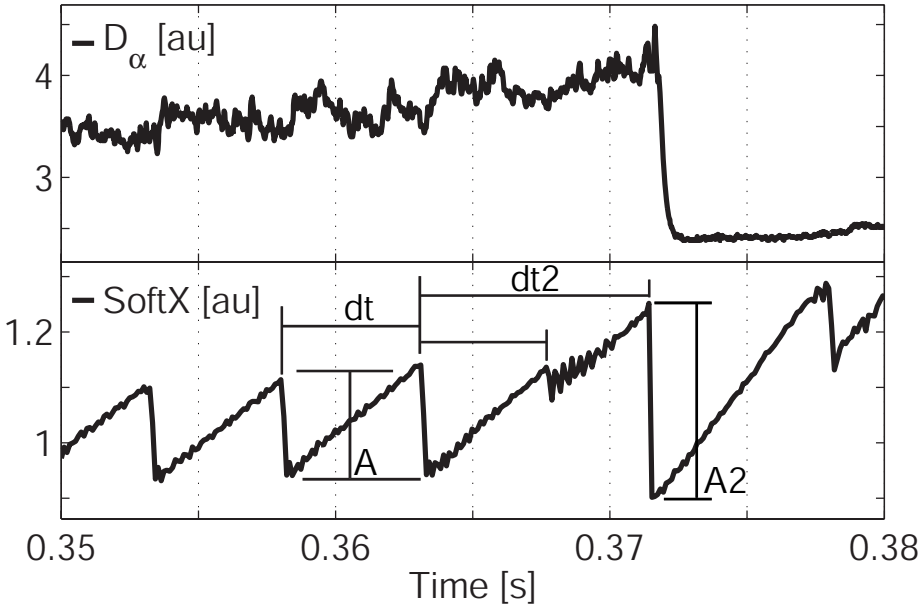
Y.Martin et al, PPCF 2002, A143

Effect of sawteeth

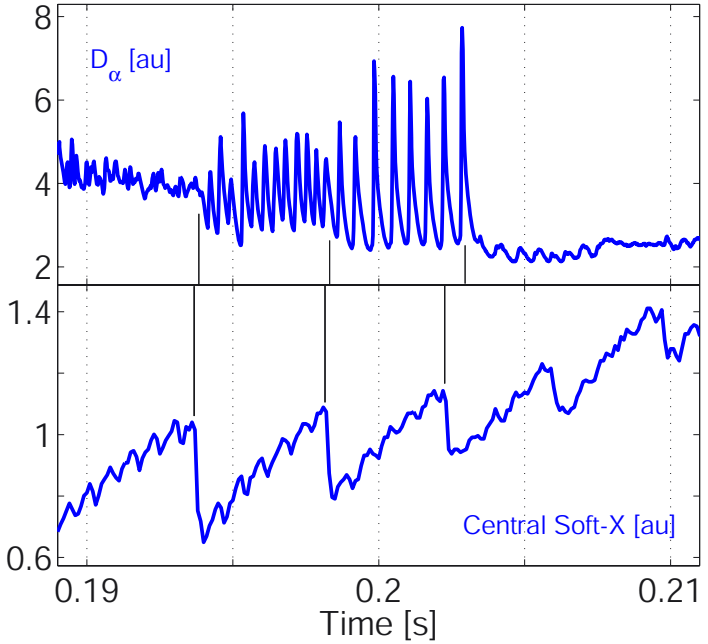
Analysis of most LH transitions to study the synchronisation between sawteeth and LH transitions

Examples of synchronised behaviour:

with double sawtooth



of dithering activity



Y.Martin et al, PPCF 2004, A77

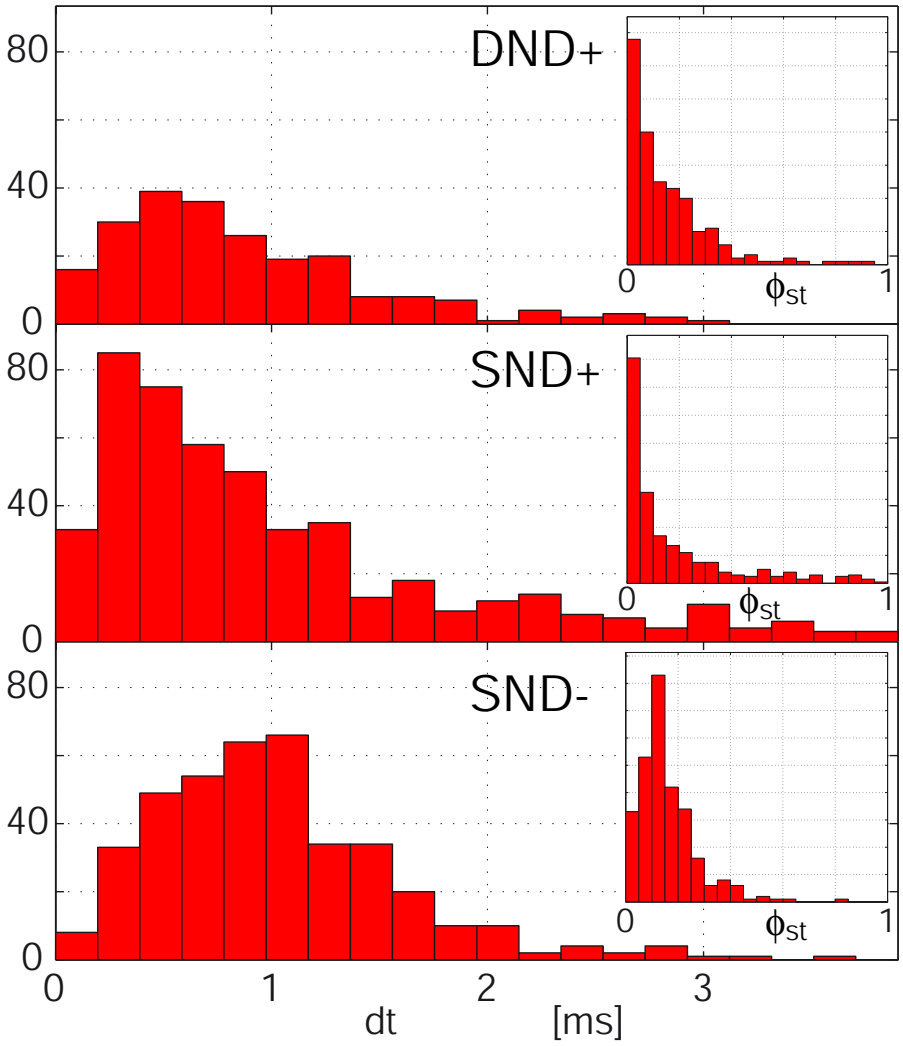
Effect of sawteeth II

Statistical analysis of the delay between sawtooth crash and LH transition

Representation of the delay and the phase of the LH transition in the sawtooth cycle

Good synchronisation in all plasma configuration

Delay is function of the ion gradB drift



Y.Martin et al, PPCF 2004, A77

Statistical Analysis - Discriminant analysis

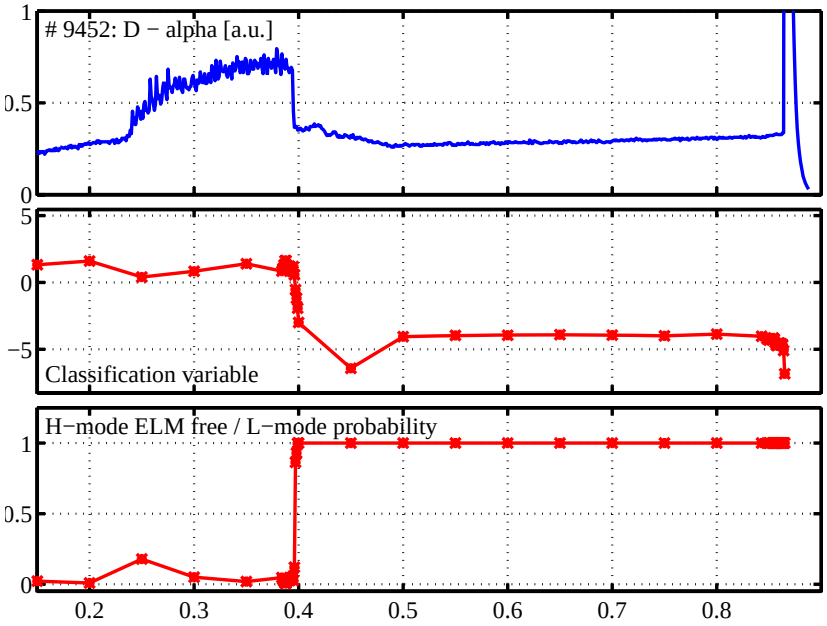
Mode L / Mode H

Parameters:

I_p, n_e, κ, δ, B_t

Clear discrimination

Good statistics



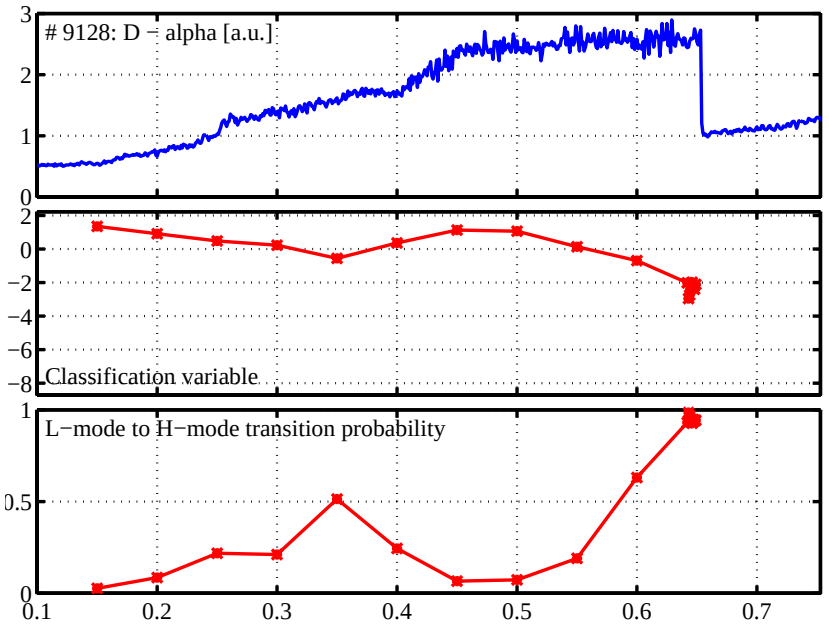
Mode L, before / at the LH transition

Parameters:

I_p, n_e, κ, δ, B_t, Δ_{in}, T_e, P_{ohm}, ϕ_{gas}

Light discrimination

Poor statistics



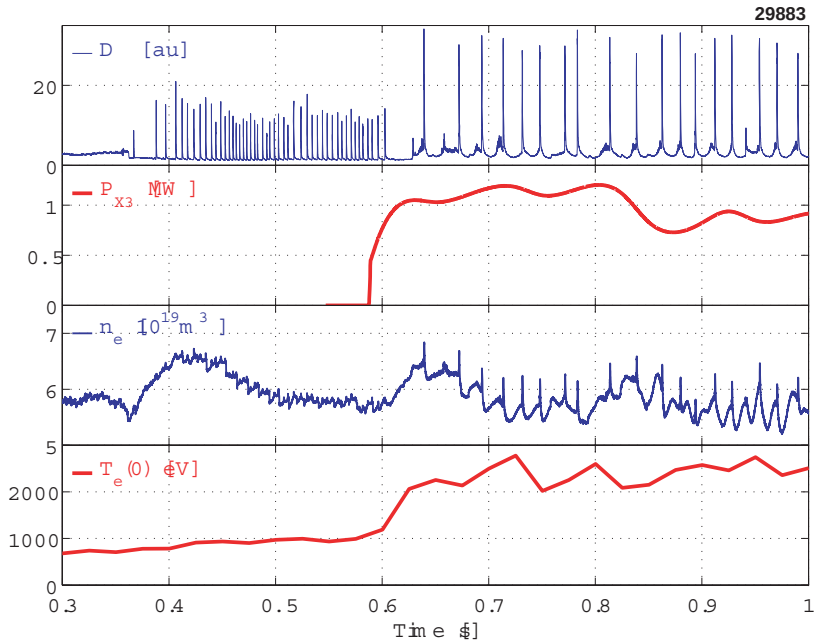
Y.Martin et al, PPCF 1998, 697

Future / Collaborations

Future plans

Little experimental programme

- LH transitions with ECH X3 for ensuring type I ELMs with ECH
- Back (HL) transition



Collaborations

- TCV provides a wide operational domain of ohmic LH transition
- TCV provides opportunities for model testing

Conclusions

LH transitions obtained in a wide plasma operational range with ohmic heating only and with additional ECH

Observations, quantifications:

- Threshold in plasma density and current
- Influence of plasma shape, magnetic field, ion gradB drift
- Influence of sawteeth, VV conditioning
- Influence of discharge evolution scenario

Could these dependencies be explained by existing models ?