Edge Pedestal Studies in Improved H-mode in ASDEX Upgrade

A status report

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ASDEX Upgrade 2006

W coverage:
new – all LFS limiters
“everything except lower divertor”
(cf. W lower divertor experiment 1996)

20 MW NBI (8 sources)
2 “CD” sources tangential mid-radius HFS

8 MW ICRH (max. coupled 7.9 MW) 30-40 MHz
directional couplers to dump
reflected power (ELMs)
2 coupled antenna pairs

ECRH:

- 1.5 MW/2 s (2.1 MW/1 s) 140 GHz
- 1 MW/10 s 105/140 GHz,
  fast steerable mirrors (being commissioned)

Outline

Improved H-mode (aka: “Hybrid”-Scenario)

What is the origin of the observed confinement improvement ?

Snapshot of ongoing experimentation

$\Rightarrow$ expect more results at ITPA, EPS 2006, IAEA 2006

Improved H-Mode: Higher confinement with increased heating power

$H_{98(y,2)}$ $1 \rightarrow 1.3$

β_N $1.8 \rightarrow 2.8$
(2.6 with NTM)

P_{NBI} $5 \rightarrow 7.5$ MW

Mild density peaking

Type I ELMs
(type II possible
at high density)

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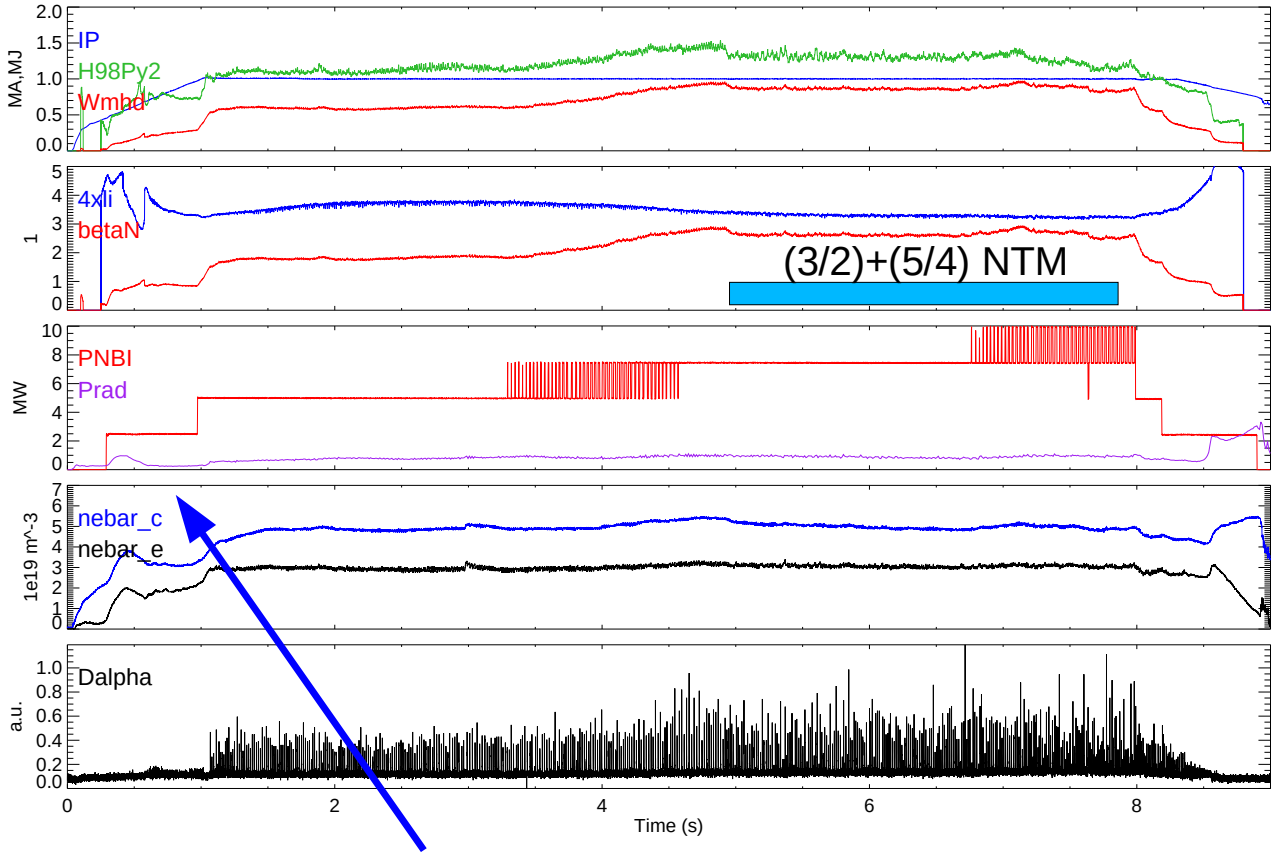
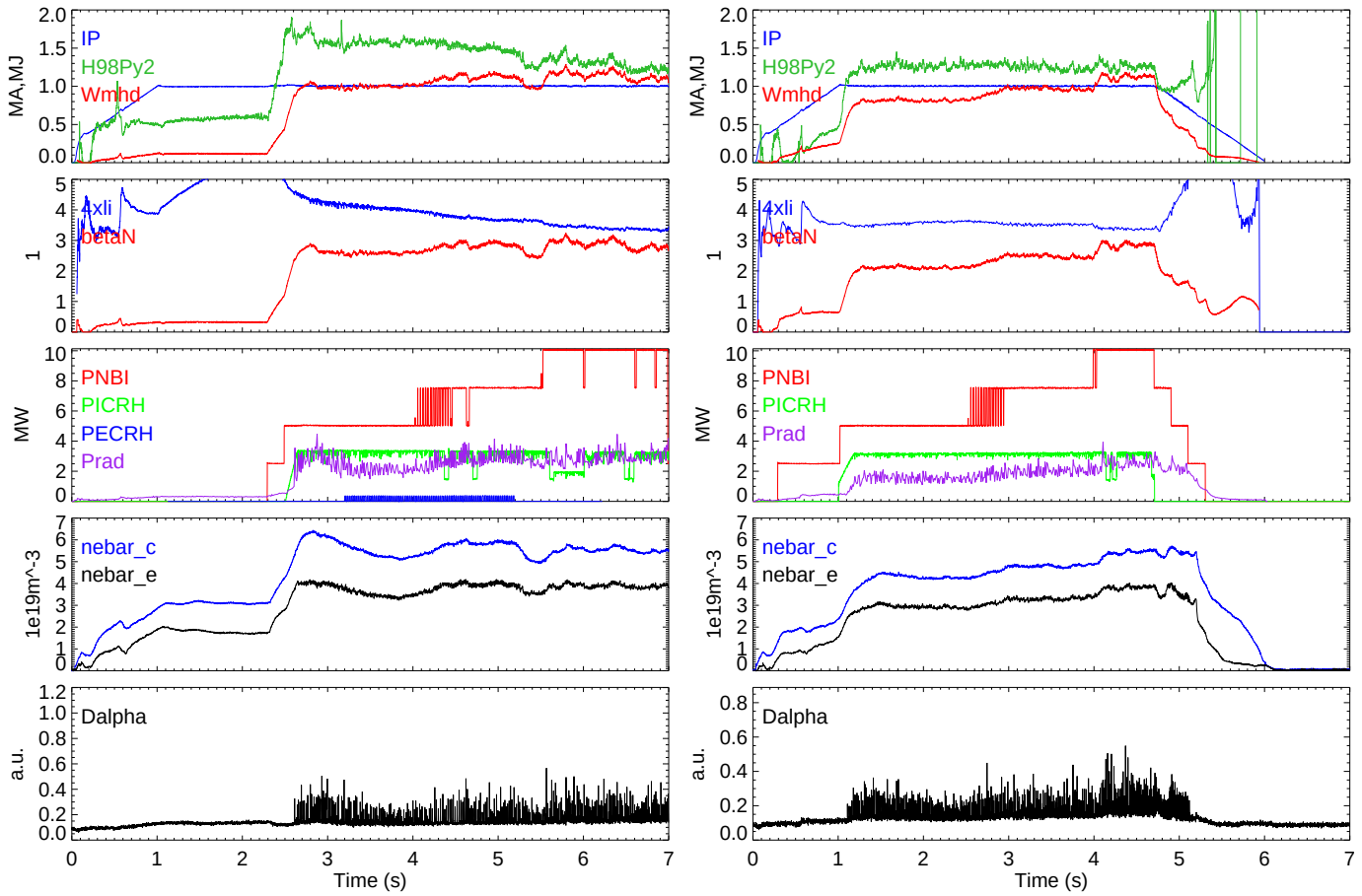


Early heating: flat central shear, $q(0) \gtrsim 1$, no/small sawteeth

Confinement improvements also possible with late heating

late heating (AUG #20438)

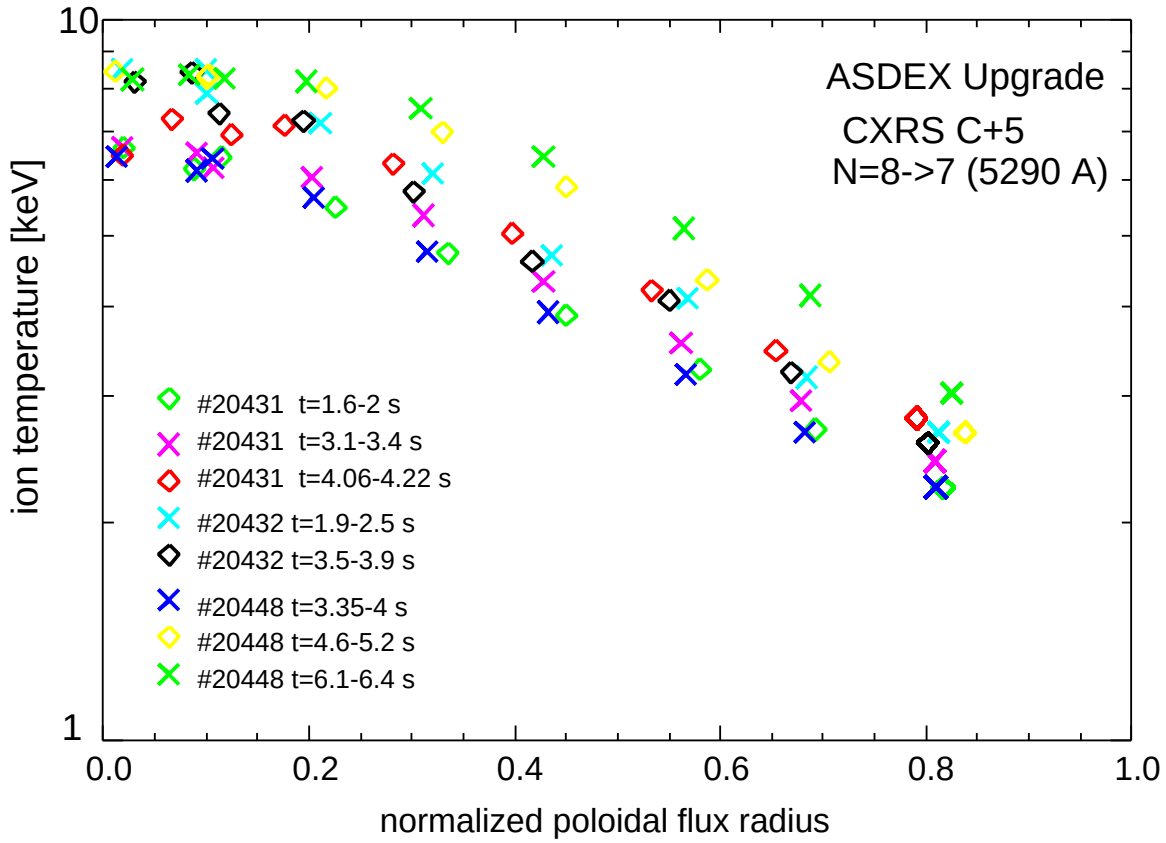
early heating (AUG #20433)



Reason for confinement improvement not yet clear – ongoing experimentation

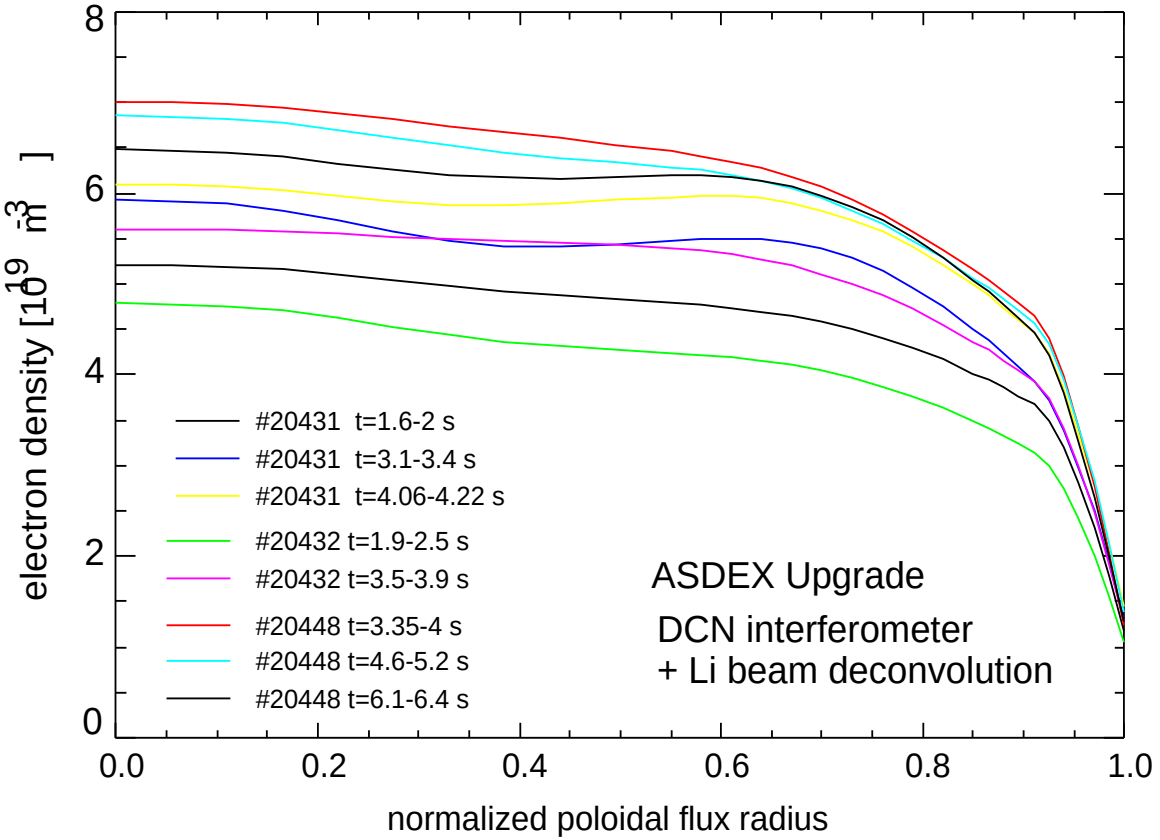
Heating power variation - Stiff temperature profiles: Edge/core relation

note
log scale!



Similar gradient length – no "ITB" transition

Confinement improvement does not require strongly peaked density profiles



Large core density gradients obtained (especially high δ, Sips PPCF **44** (2002) B69)
but found unfavourable for impurity transport (W !)

Central RF heating controls density and impurity peaking

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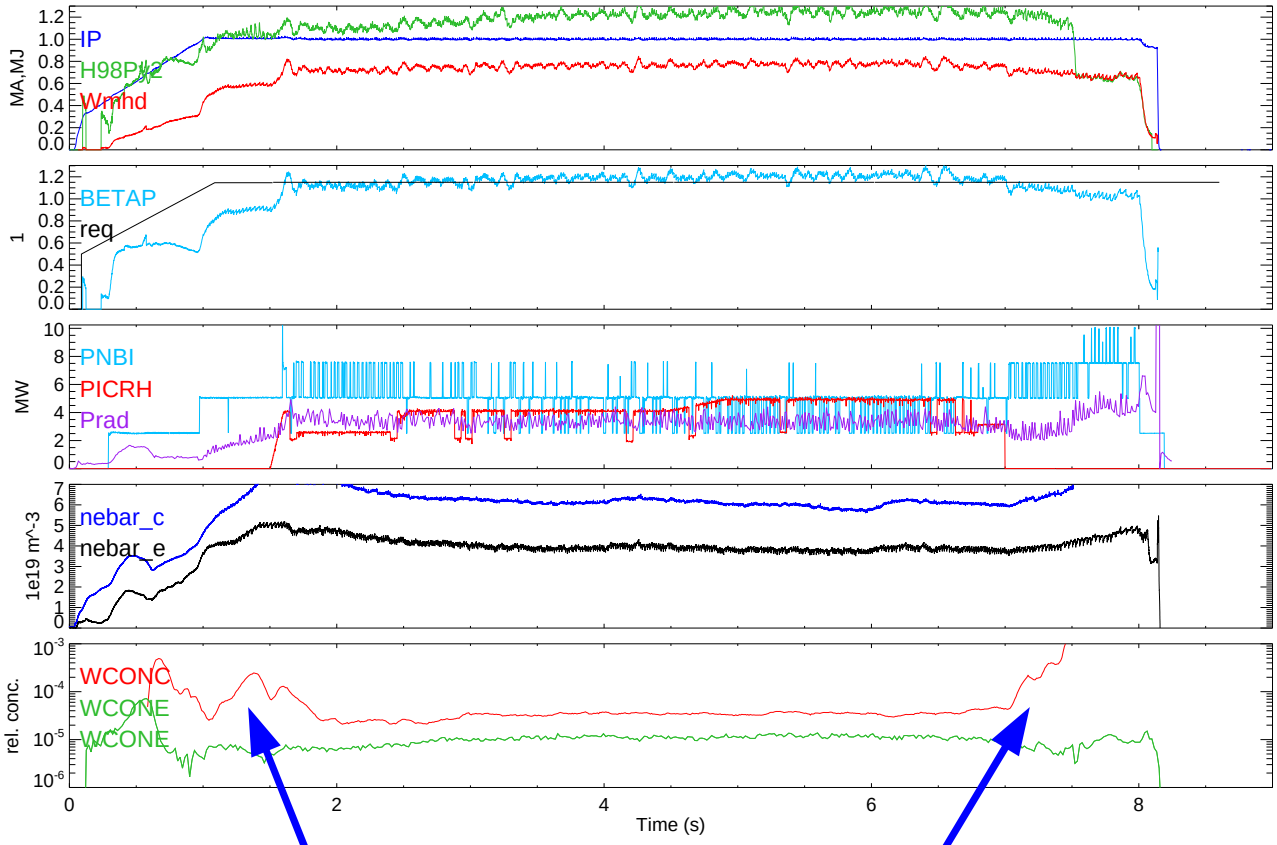
$\beta_p = 1$
feedback controlled (NBI)

Significant RF power
(centrally deposited)

Mild density peaking
maintained,
density “pump out”

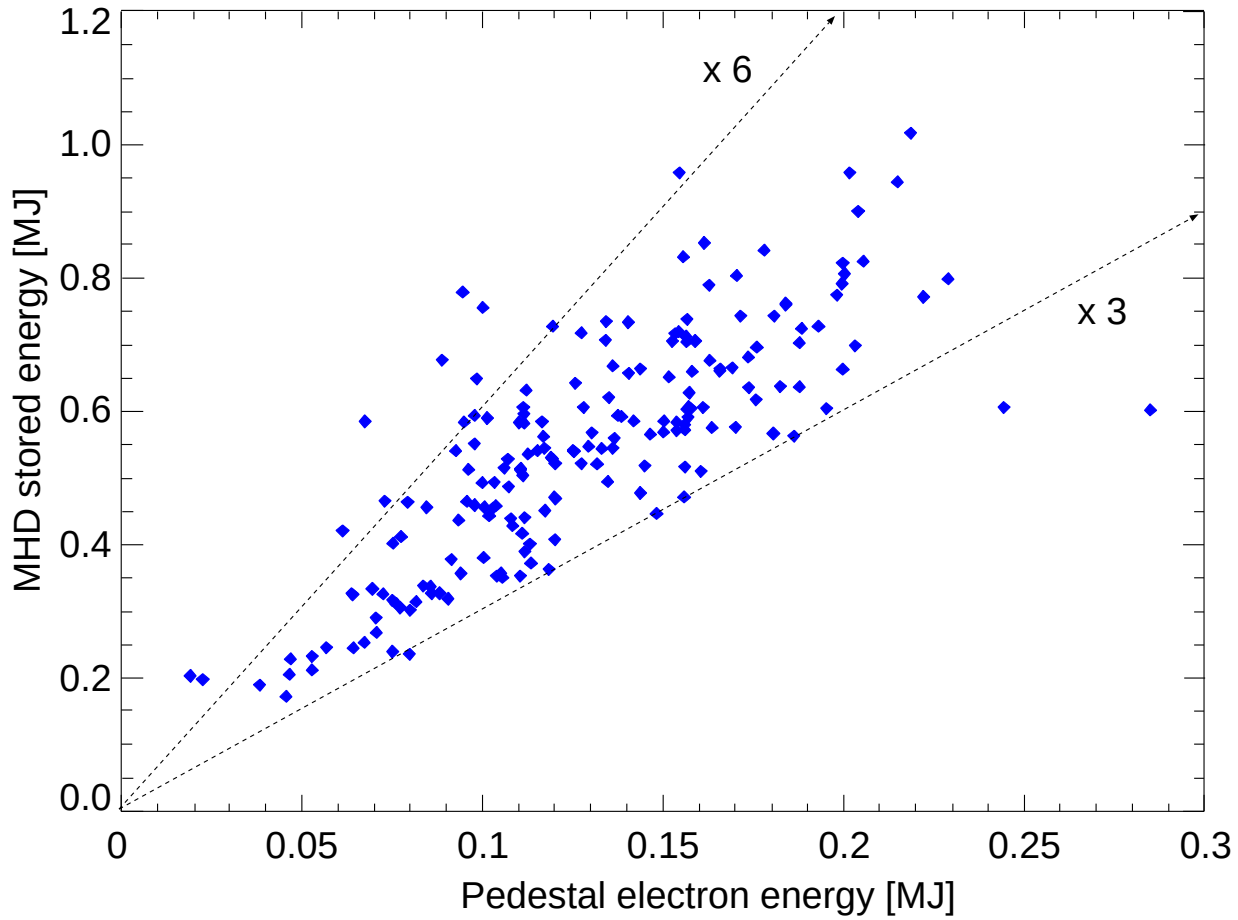
W accumulation
suppressed with ICRH



peaking of W concentration

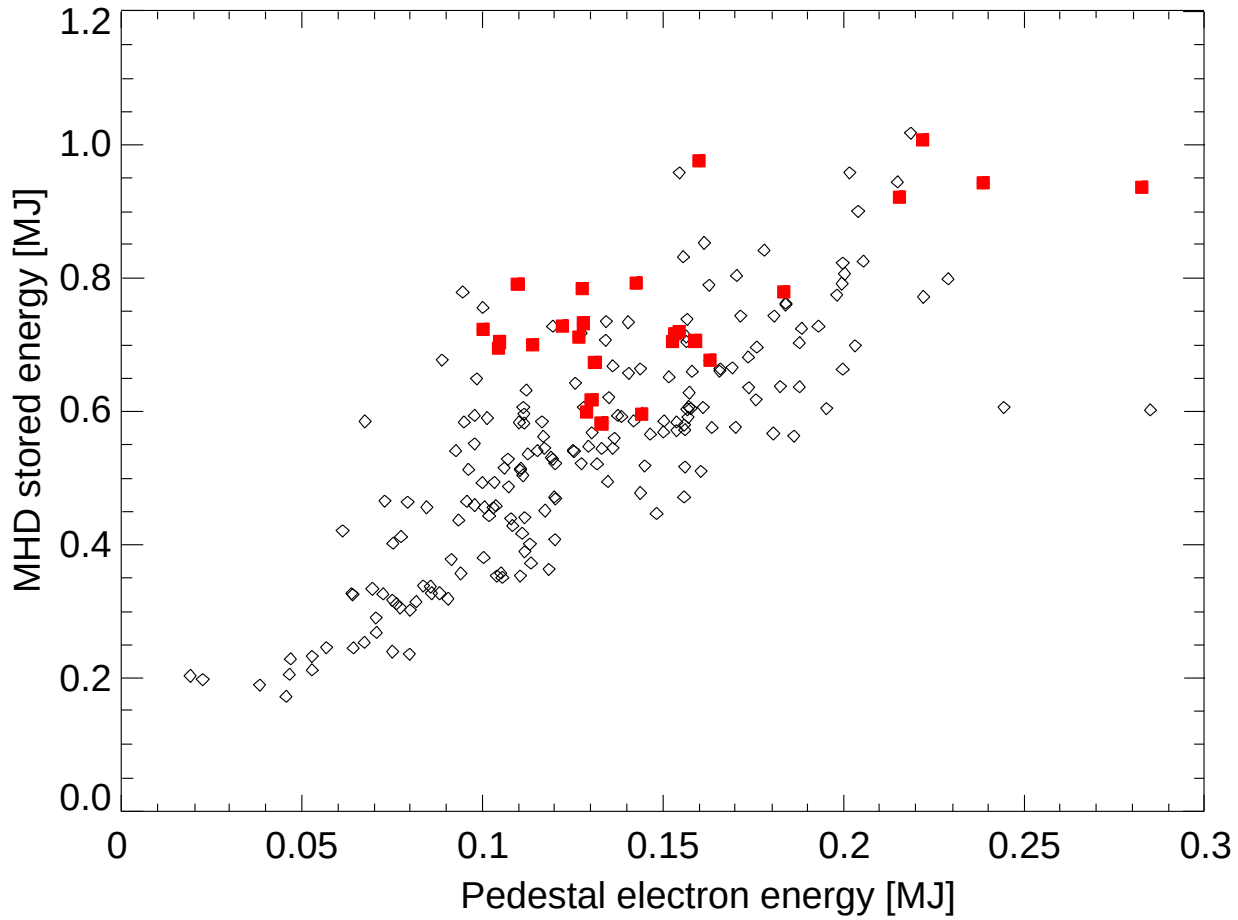
A Stäbler et al., NF **45** (2005) 617

Stored energy relates to pedestal energy (Standard H-mode)



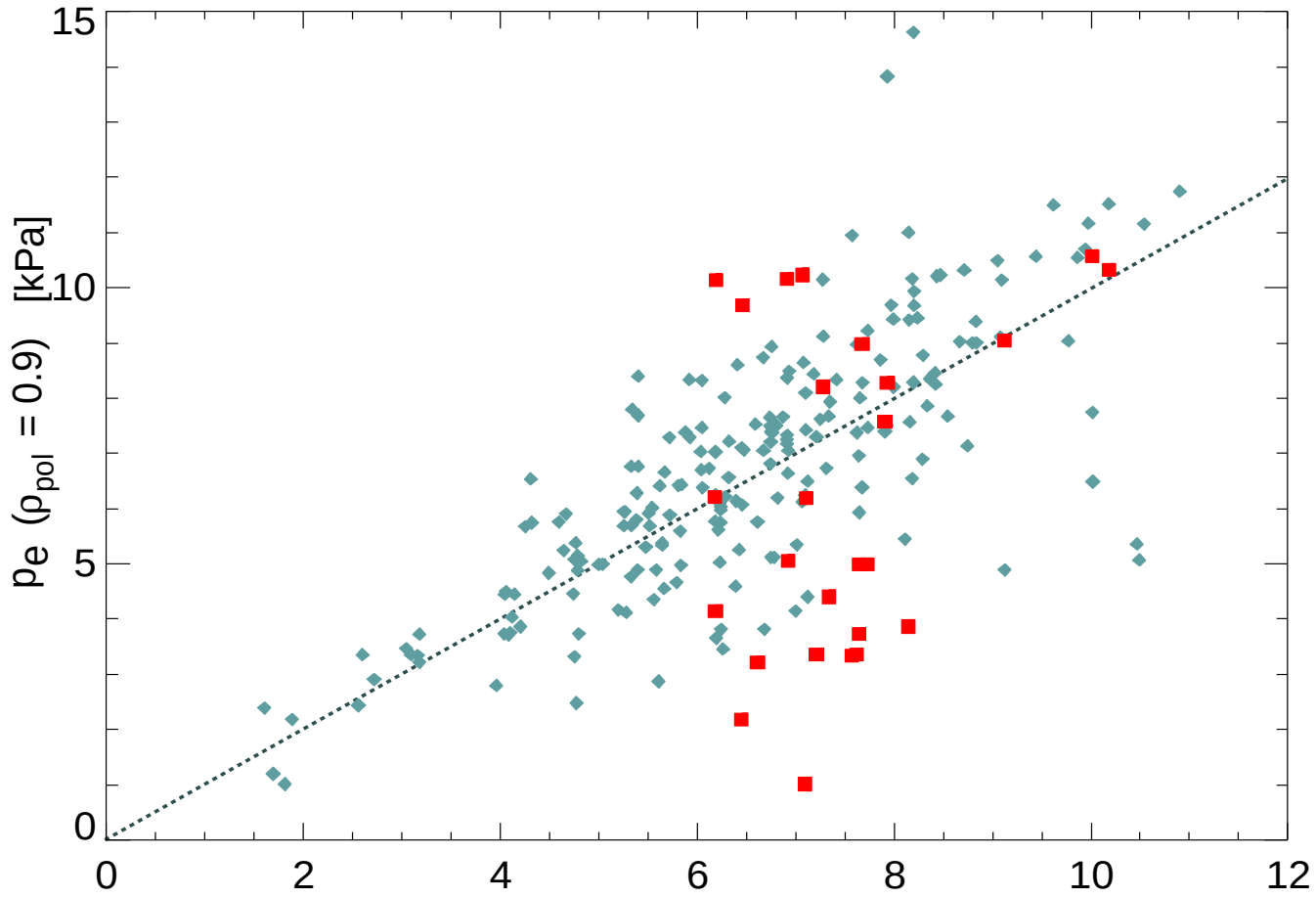
ASDEX Upgrade
Topical Database

Stored energy relates to pedestal energy (Standard *and* Improved H-mode)



ASDEX Upgrade
Topical Database

Improved H-mode edge pressure (ρ=0.9) does not follow "Standard" H-mode dependencies



$$4.23214 \quad I_p^{1.47\mp0.12} P_{tot}^{0.22\pm0.045} (\delta_u + 1)^{0.96\pm0.26} q_{95}^{0.046\pm0.13}$$

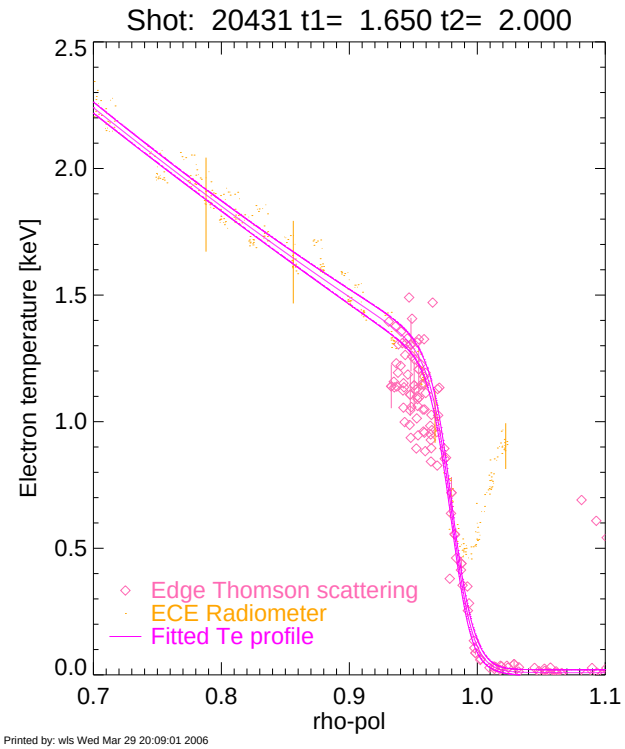
Suspect different power dependence

(little variation in other parameters)

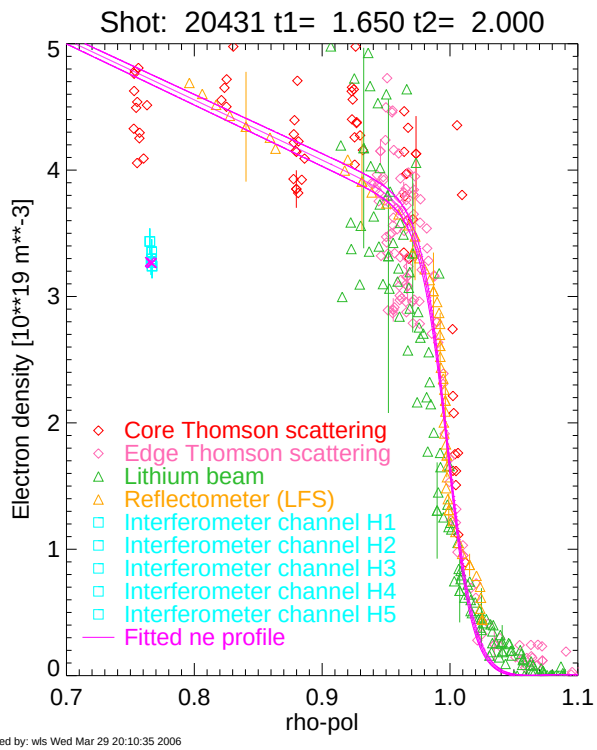
ASDEX Upgrade Topical Database

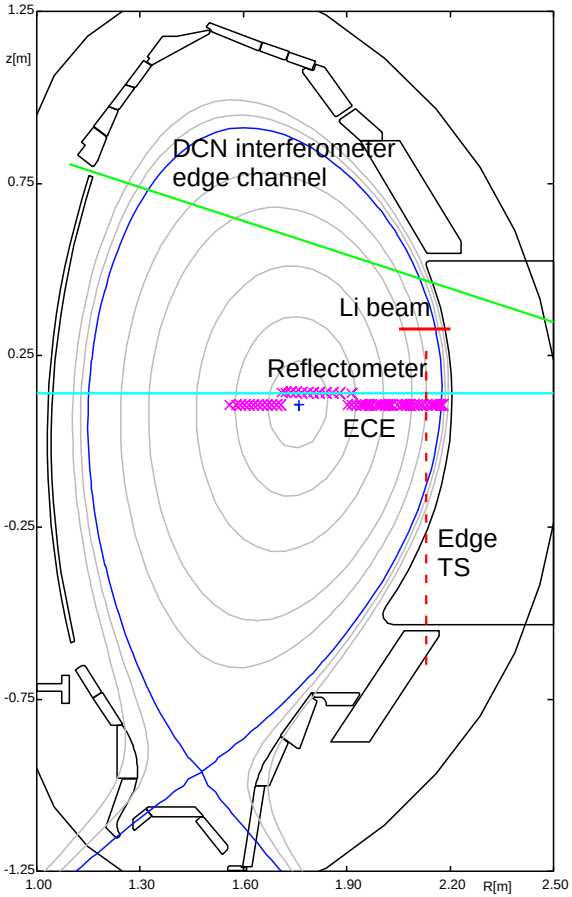
Edge pedestal measurements

Electron temperature:
ECE, Thomson scattering



Electron density:
Thomson scattering, Li-beam
Reflectometry (LFS, HFS),
DCN + CO2 interferometers

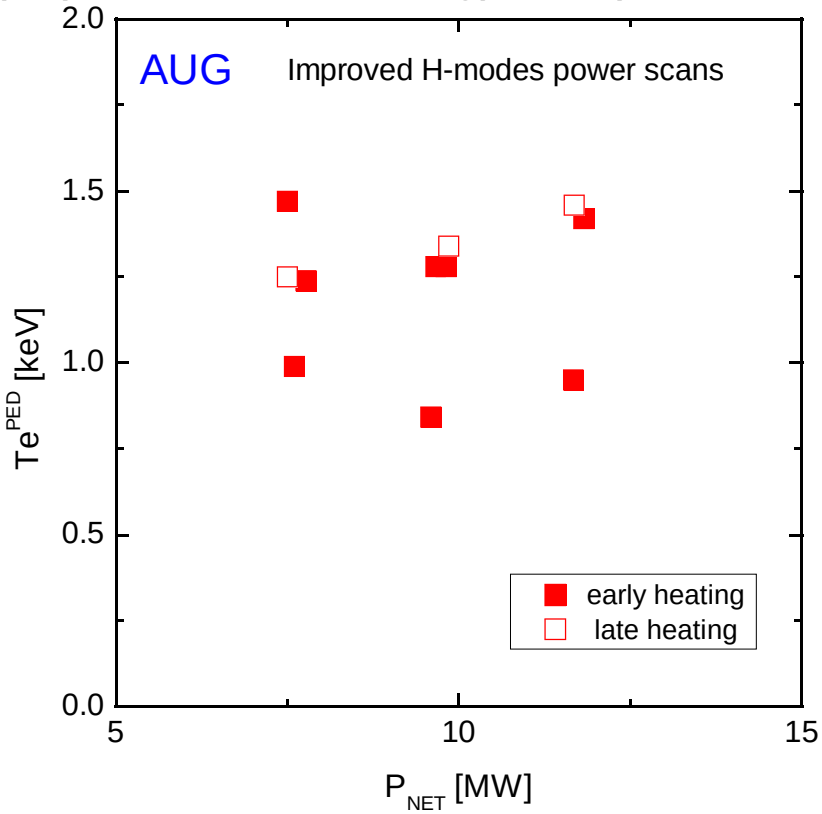




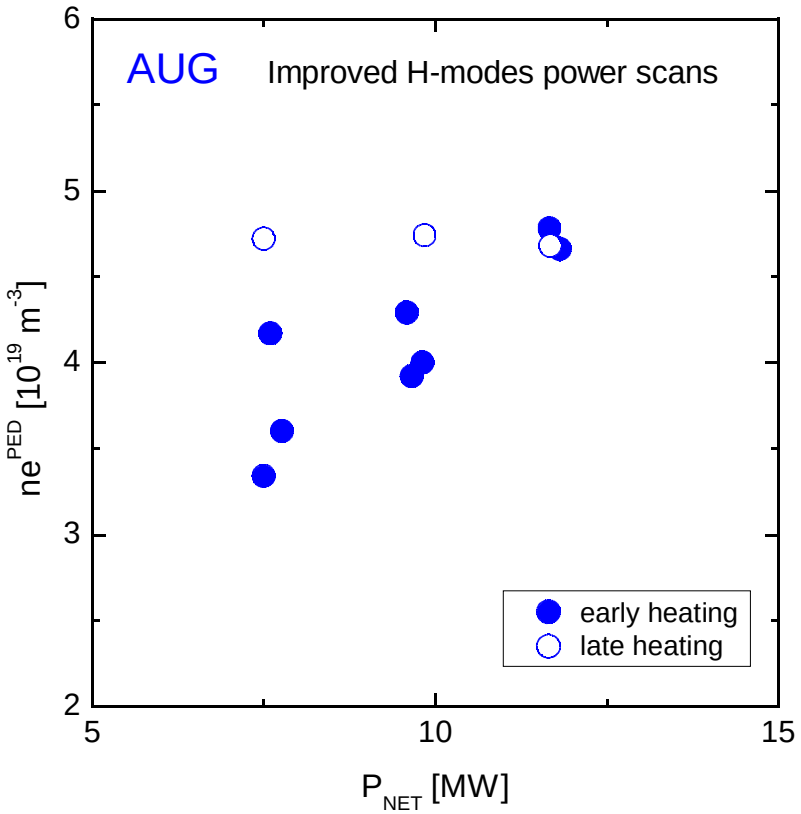
Modified tanh fit to extract pedestal parameters

Pedestal temperature and density increase with heating power

Pedestal temperature:
Weak dependence or increase
(esp. with late heating) with power



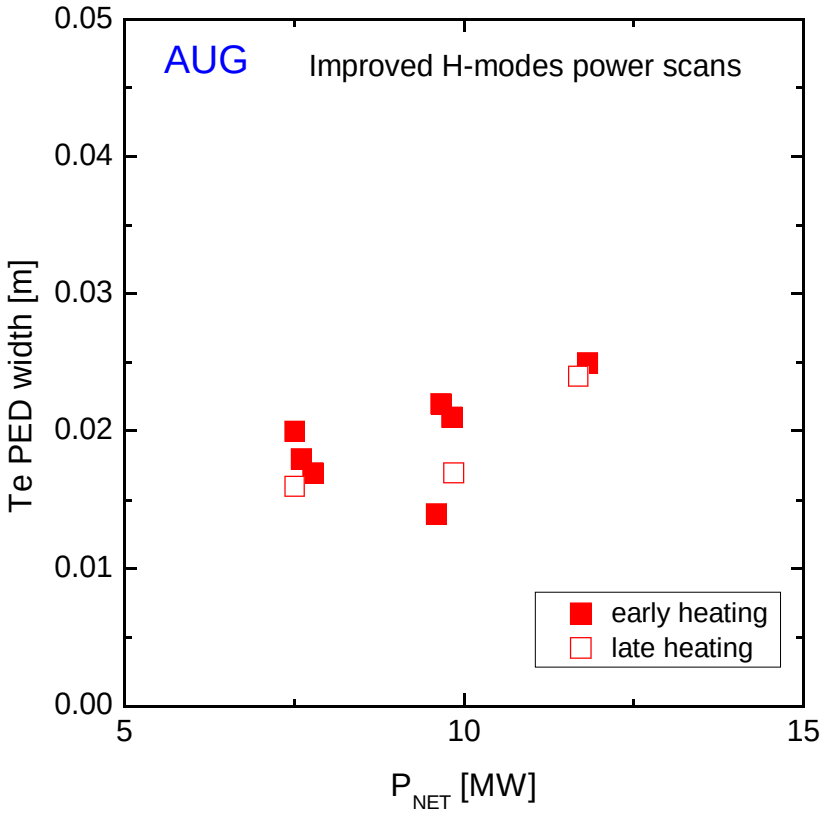
Pedestal density increases with power
in early heated case



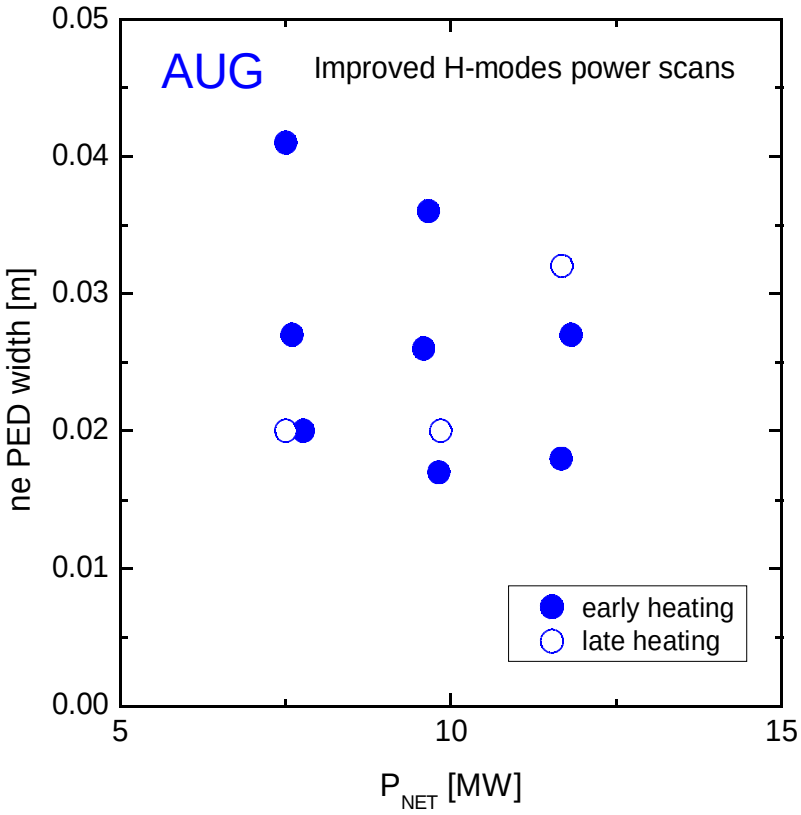
Pedestal pressure (energy) increases with heating power (C Maggi, EPS 2005)

Width of gradient region

Temperature: Width tends to increase with heating power



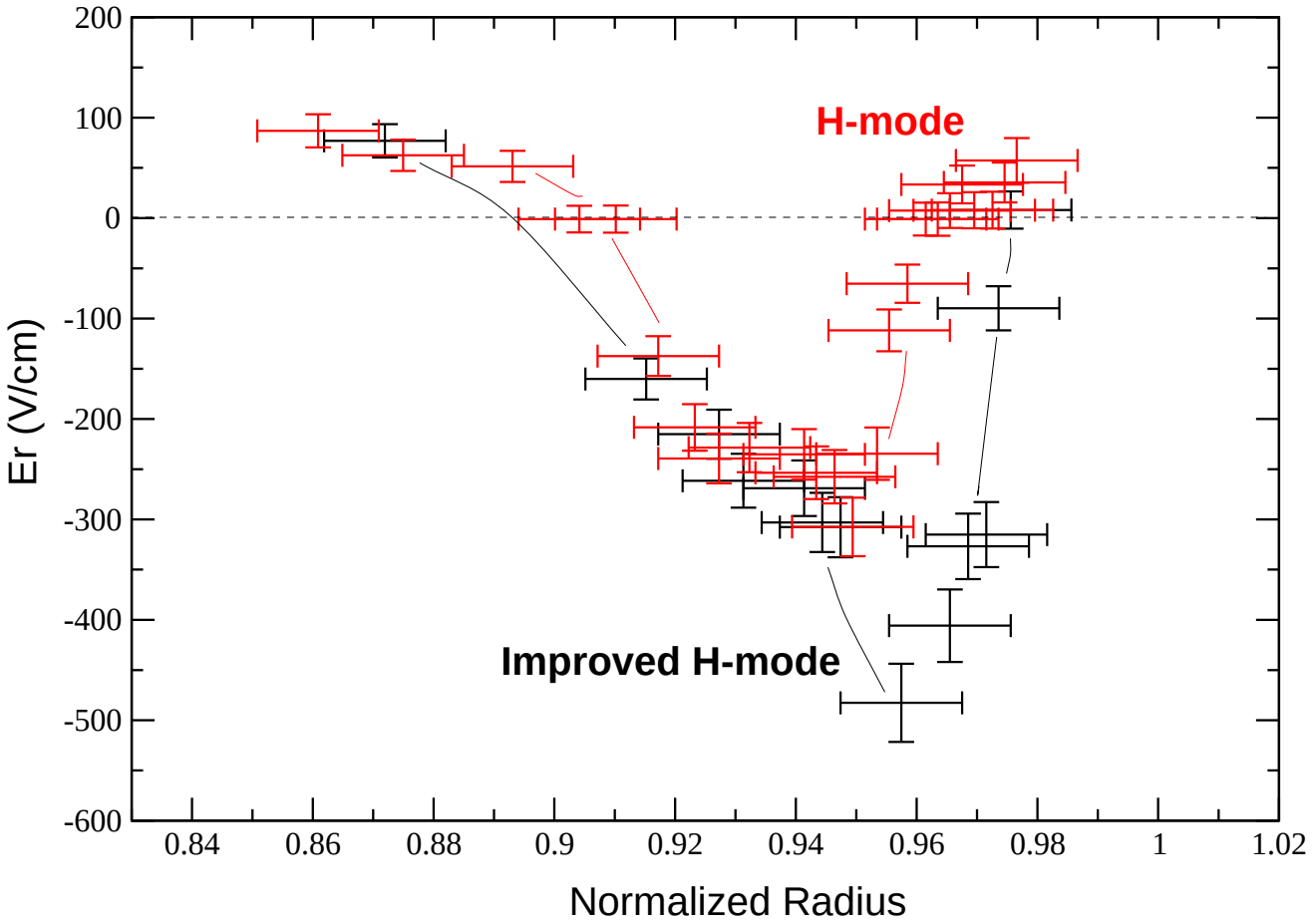
Density: Width scaling with heating power unclear



Pedestal radial electrical field correlates with confinement quality

Doppler reflectometry ($v_\perp \sim E_r/B$)

J Schirmer et al., subm. NF



Summary and Conclusions

"Stiff" (constant gradient length) core temperature profiles suggest that confinement improvement in Hybrid scenario is not due to transport barrier formation

Density peaking kept moderate or small, central heat flux used as "actuator"

Absence of sawteeth helps to avoid NTM (metastable operation) and extends accessible range of β_N but confinement improvement even if NTM present

Pedestal pressure (temperature and density) depends on heating power, stronger than in standard H-mode

Width of temperature gradient region increases with power,
density width scaling under analysis (L D Horton, EPS 2006)

Possible origin of enhanced edge stability might be an (observed) increase of the radial electrical field (ExB velocity) and its shear