EX/2

Development towards an ELM-free DEMO pedestal radiative cooling scenario in ASDEX Upgrade

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[1]see author list of *H. Meyer et al. 2019 Nucl. Fusion **59** 112014*
[2]see author list of *B. Labit et al. 2019 Nucl. Fusion **59** 086020*

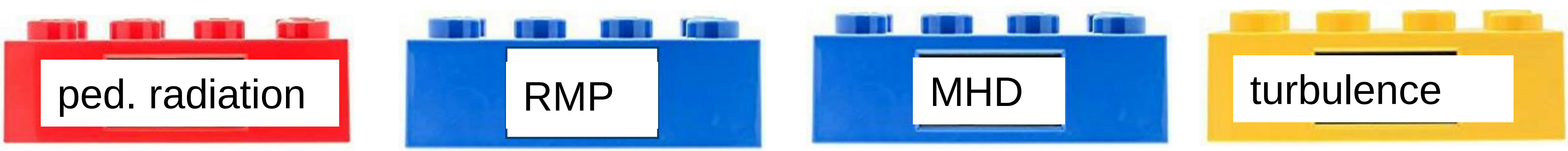
DEMO must operate in a no-ELM scenario

Toolbox for an integrated no-ELM scenario

EHO
Quasi-coherent mode

Outer core radiative cooling to reduce Psep

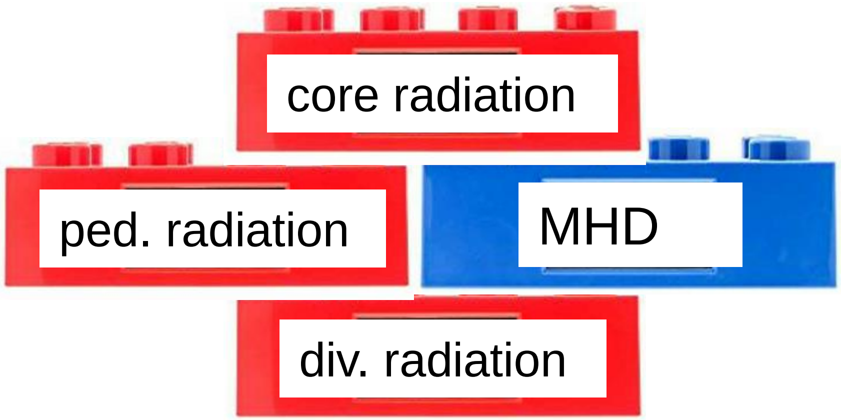
Mechanism for reduction of pedestal pressure (gradient, current, ..)



Divertor radiation to achieve detachment

‚X-point radiator‘
→ Fri, M. Bernert, EX-7

Radiation is a key element of the integrated no-ELM scenario



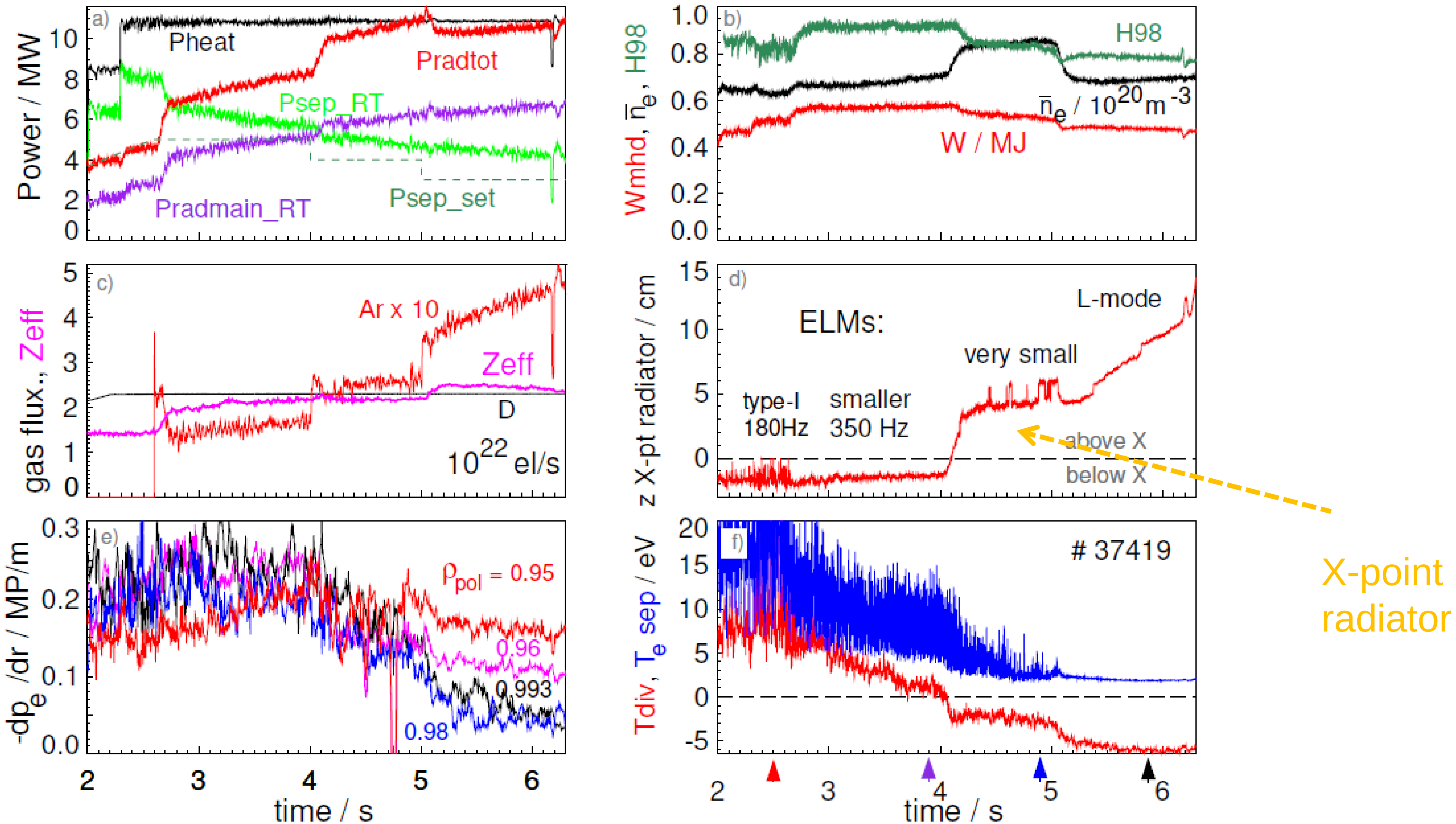
elements have to match together
different requirements will call for impurity mix

This talk will adress a few topics regarding integration of impurity seeding using as example the EDA H-mode

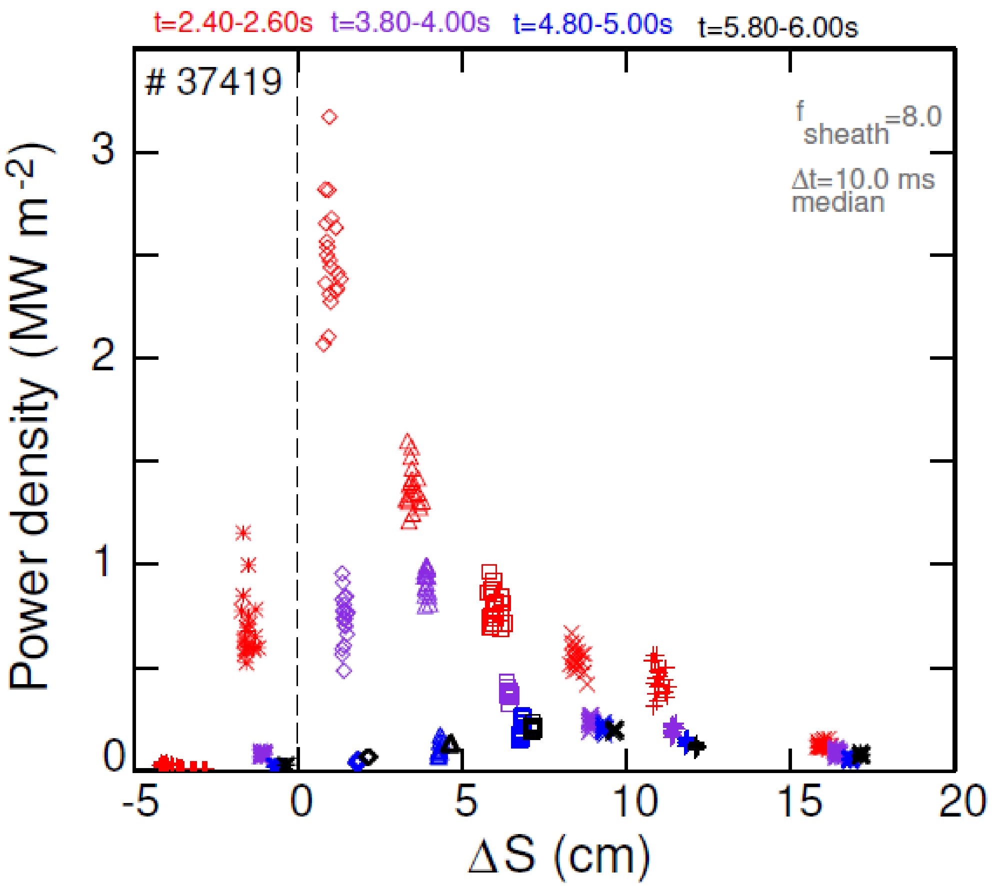
Outline

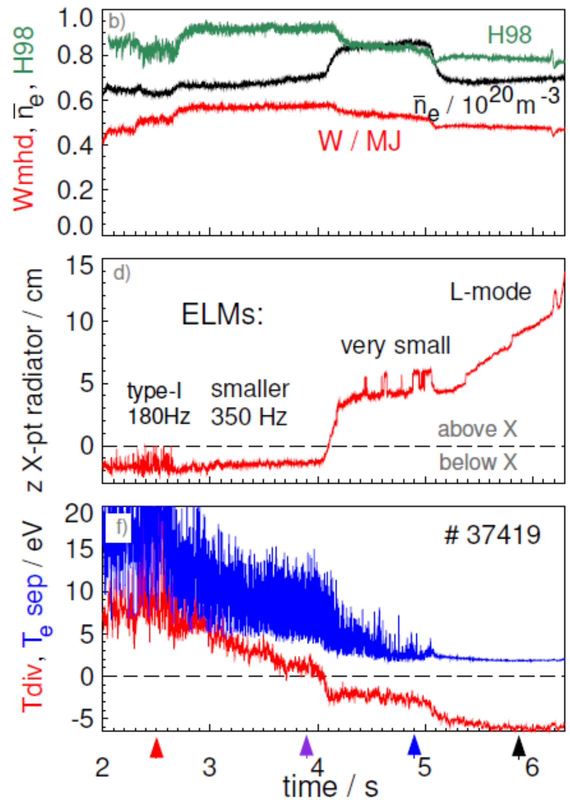
- Development of a typical AUG discharge with increasing Ar puff level
- Pedestal tailoring by argon seeding in the **EDA H-mode**
  - behaviour of the quasi-coherent mode (QCM) with seeding
- Integration with divertor radiation / detachment
- Conclusions and next steps

Standard H-mode response to rising Ar puff level

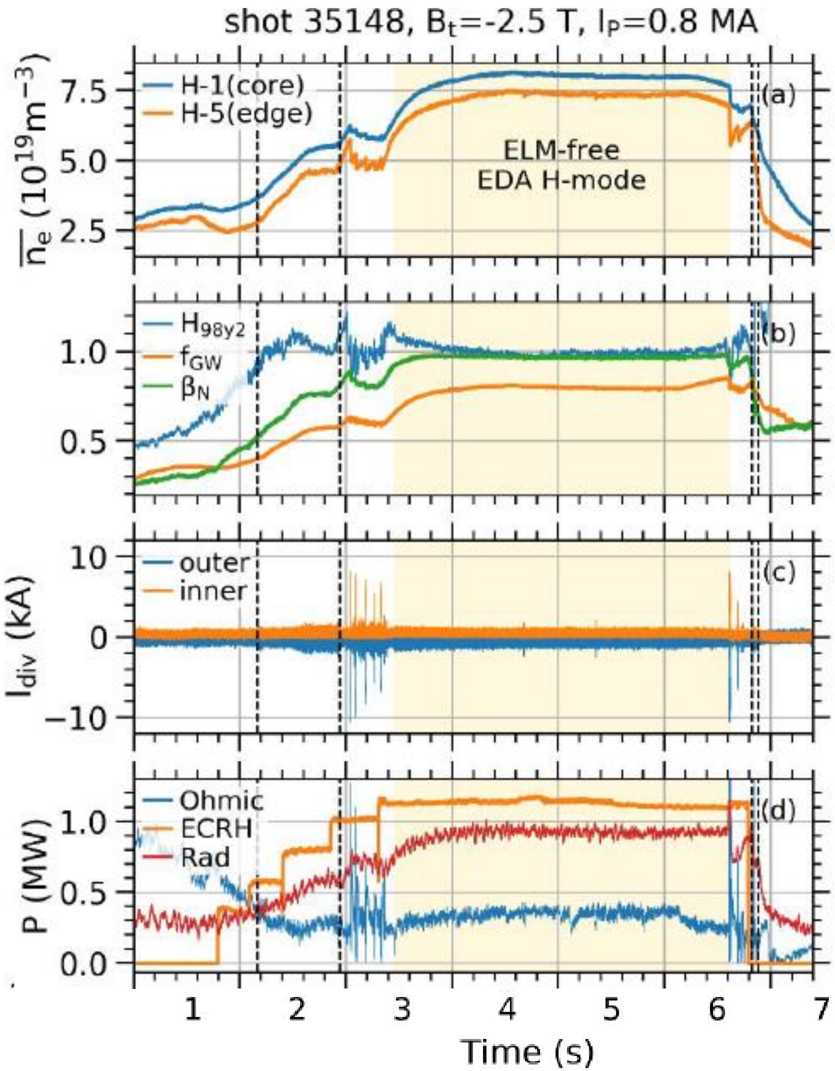


Standard H-mode response to rising Ar puff level



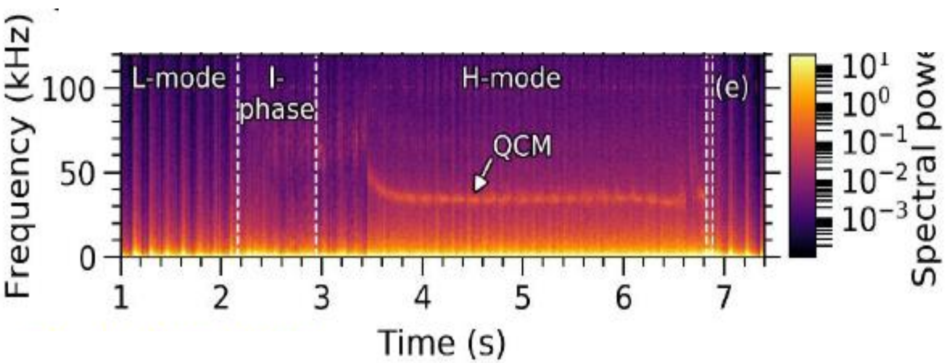


EDA H-mode in ASDEX Upgrade (high shaping)



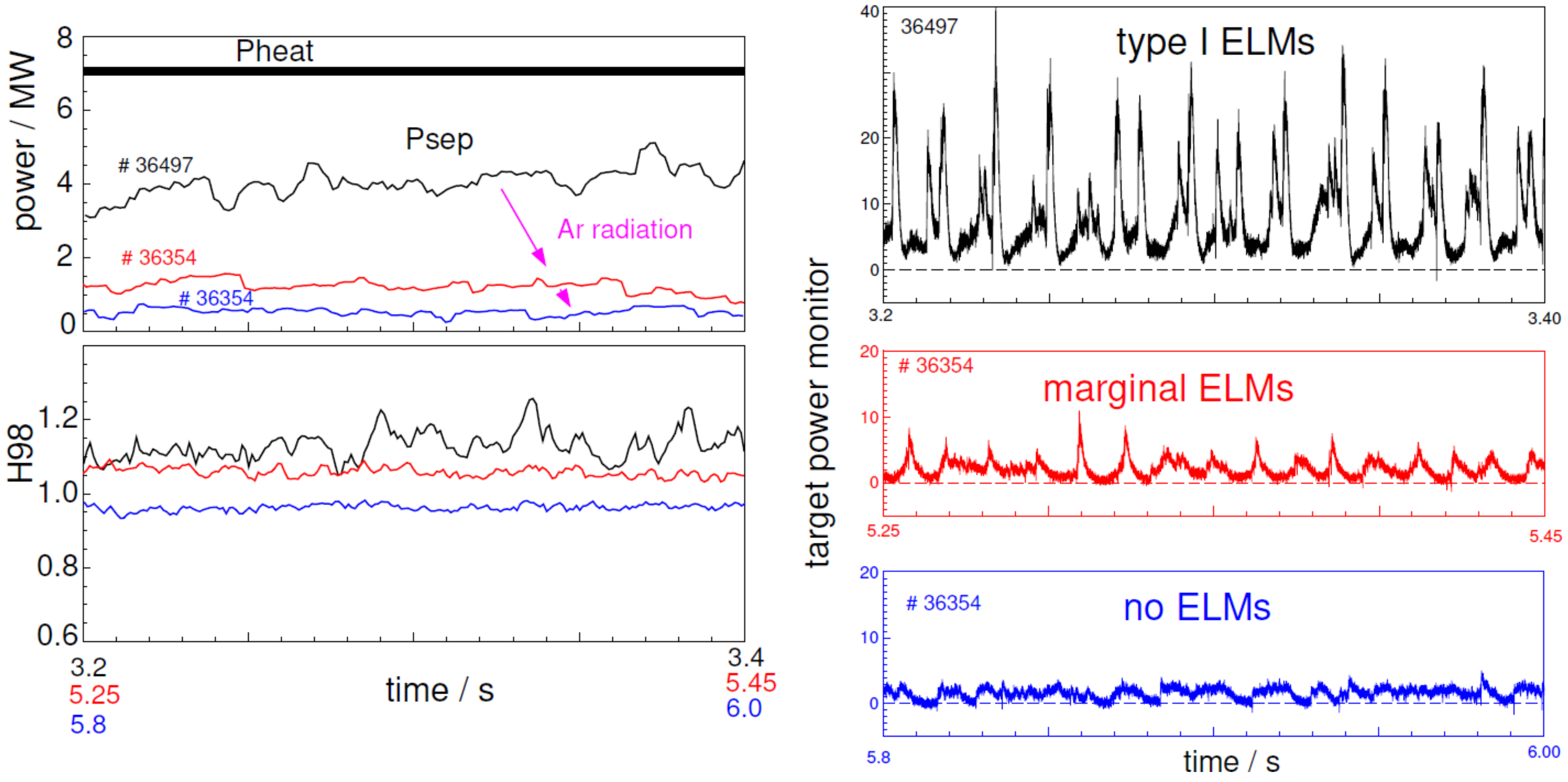
EDA H-mode obtained at AUG at relatively low ECRH power
- upper power threshold to type-I ELMs

→ to be combined with impurity radiation at or inside pedestal



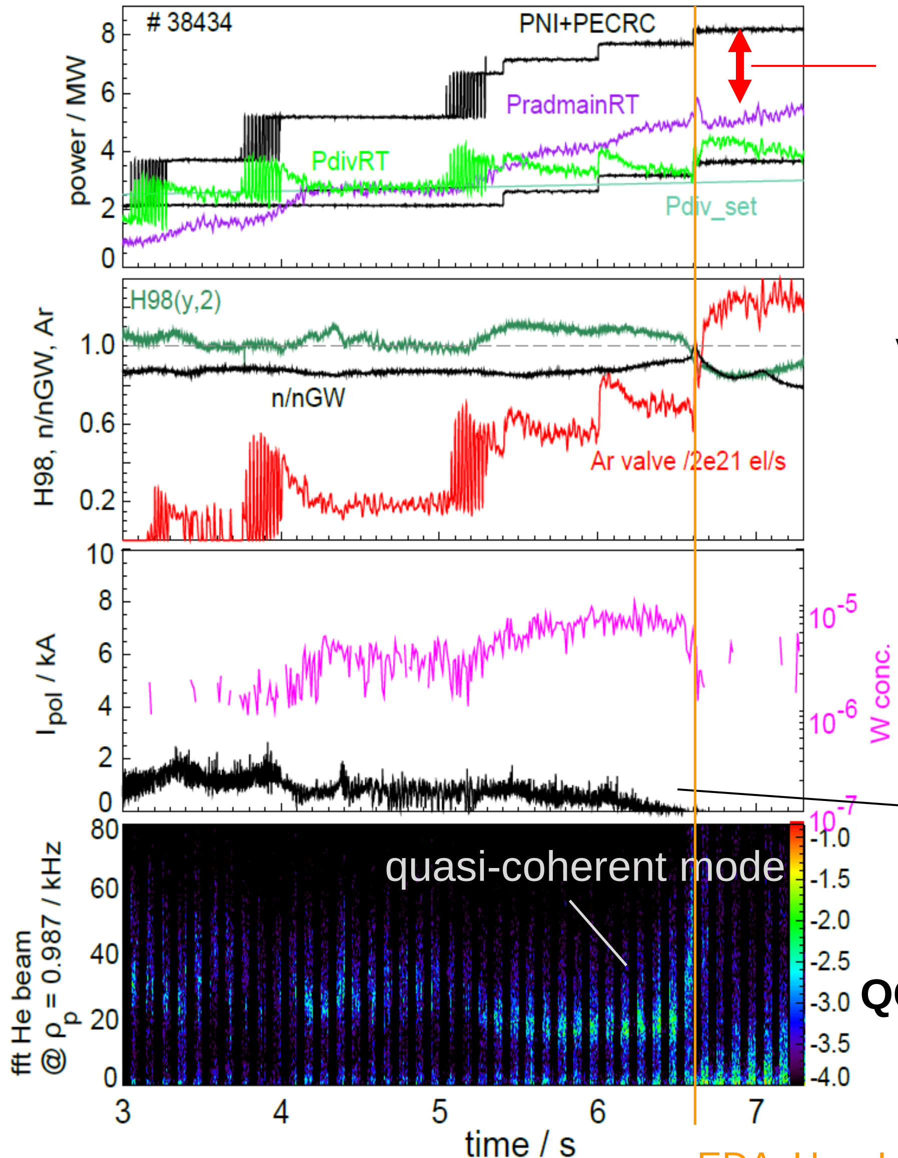
L. Gil et al., NF 2020
very similar to C-Mod EDA H-mode

Variation of P_{sep} by Ar seeding (EDA conditions)



complete ELM suppression at very low P_{sep}

EDA H-mode extended to high power by controlled Ar seeding



power to divertor controlled via Ar seeding

quite narrow power window in Psep for L- EDA - ELMy

very good performance: $H_{98}>1$, $n/n_{GW}=0.9$, , β_N = 2

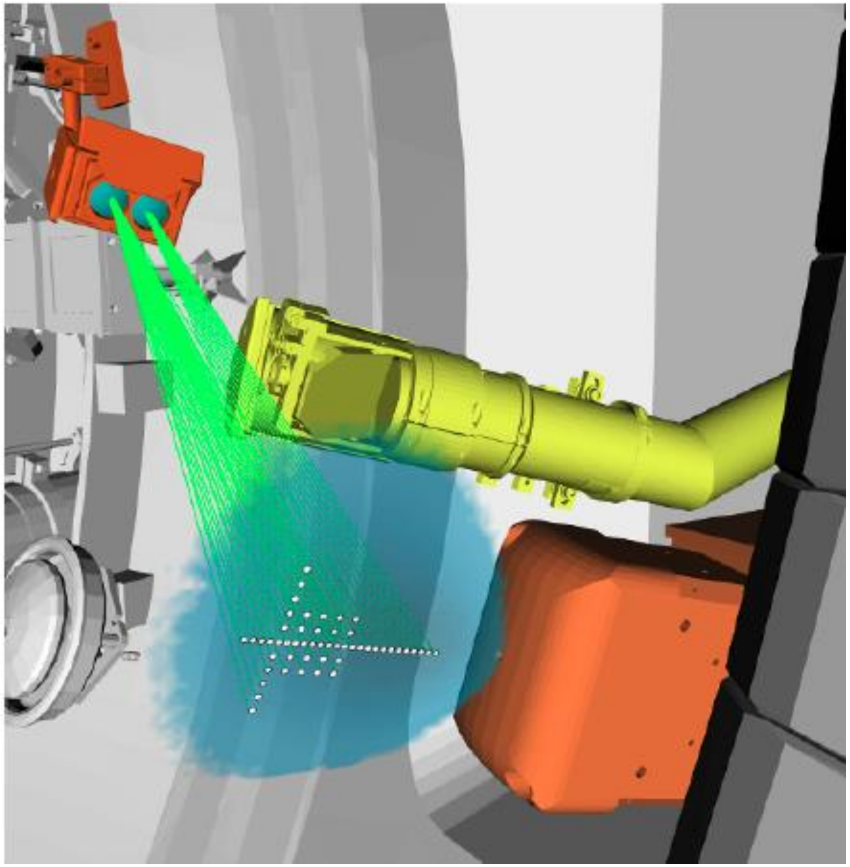
low tungsten concentration < 10^{-5}

completely ELM-free

QCM @ 20-30 kHz provides full ELM suppression

EDA H → L-mode

Quasi-coherent mode directly seen by He-beam diagnostic



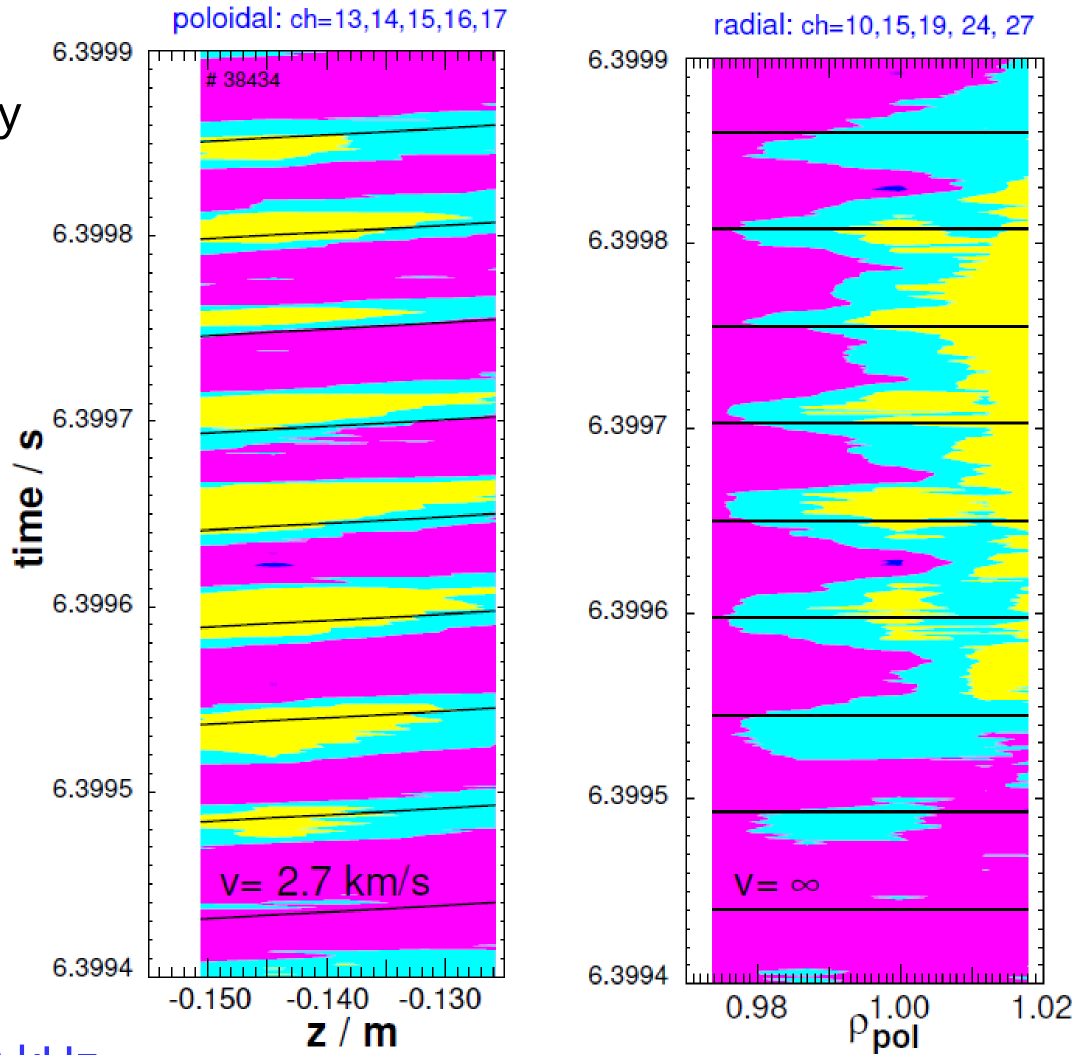
Helium-beam diagnostic visualises QCM

radial and poloidal l.o.s
tangent to flux surfaces

QCM rotates in electron-diagmagnetic direction (upward in omp)

He line 587 nm intensity

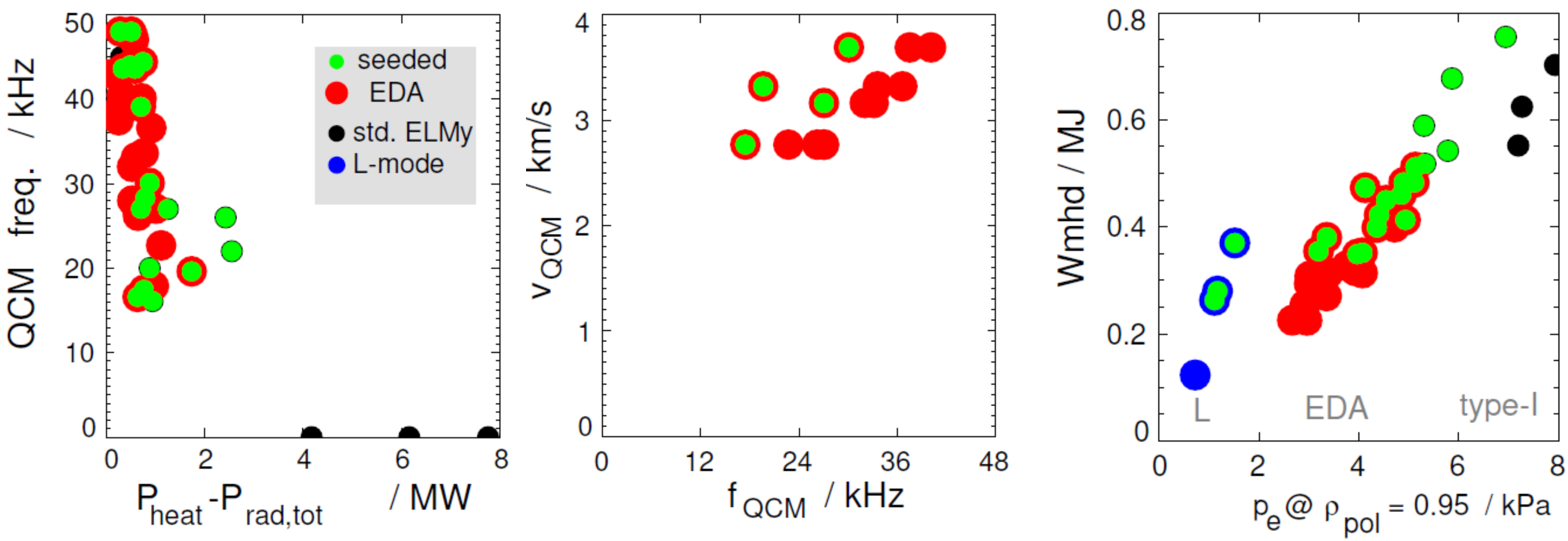
structures not
equally spaced
→ quasi-coherent



typical: v = 3 km/s, f= 30 kHz

$\rho_p \approx 0.99$

Database of seeded EDA discharges (I_p= 0.7 – 0.8 MA)



EDA H-modes only at low P_{sep}

QCM frequency decreases with P_{heat}-P_{rad}

v decreases with f

take 3 km/s at 30 kHz
assume $v_{hfs} < v_{lfs}$

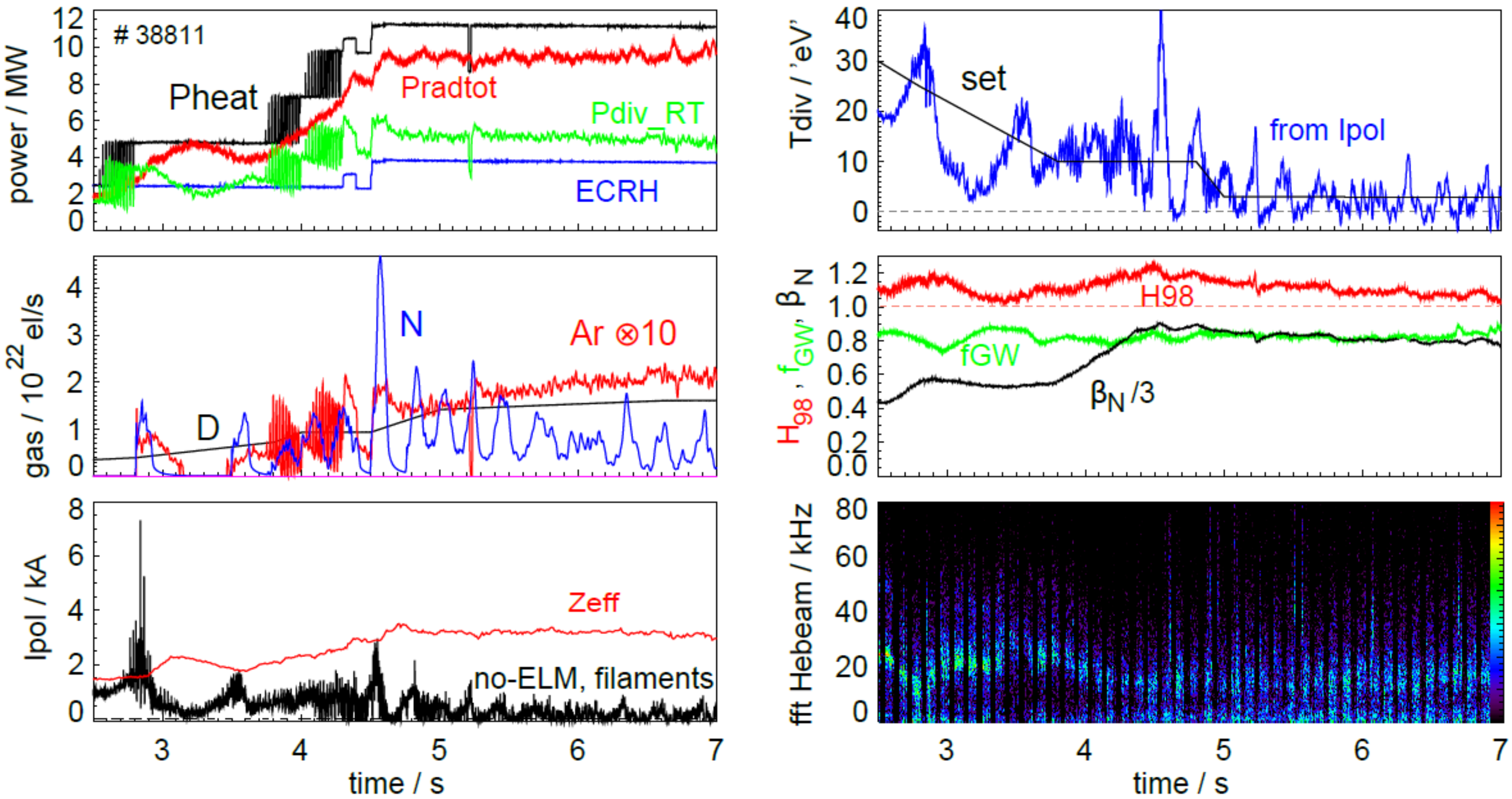
→ m ~ 100, n~ 20

Ar radiation reduces pedestal top pressure, retains stored energy

Scenario integration for partial divertor detachment

Double radiative feedback for high power, no-ELM, detachment

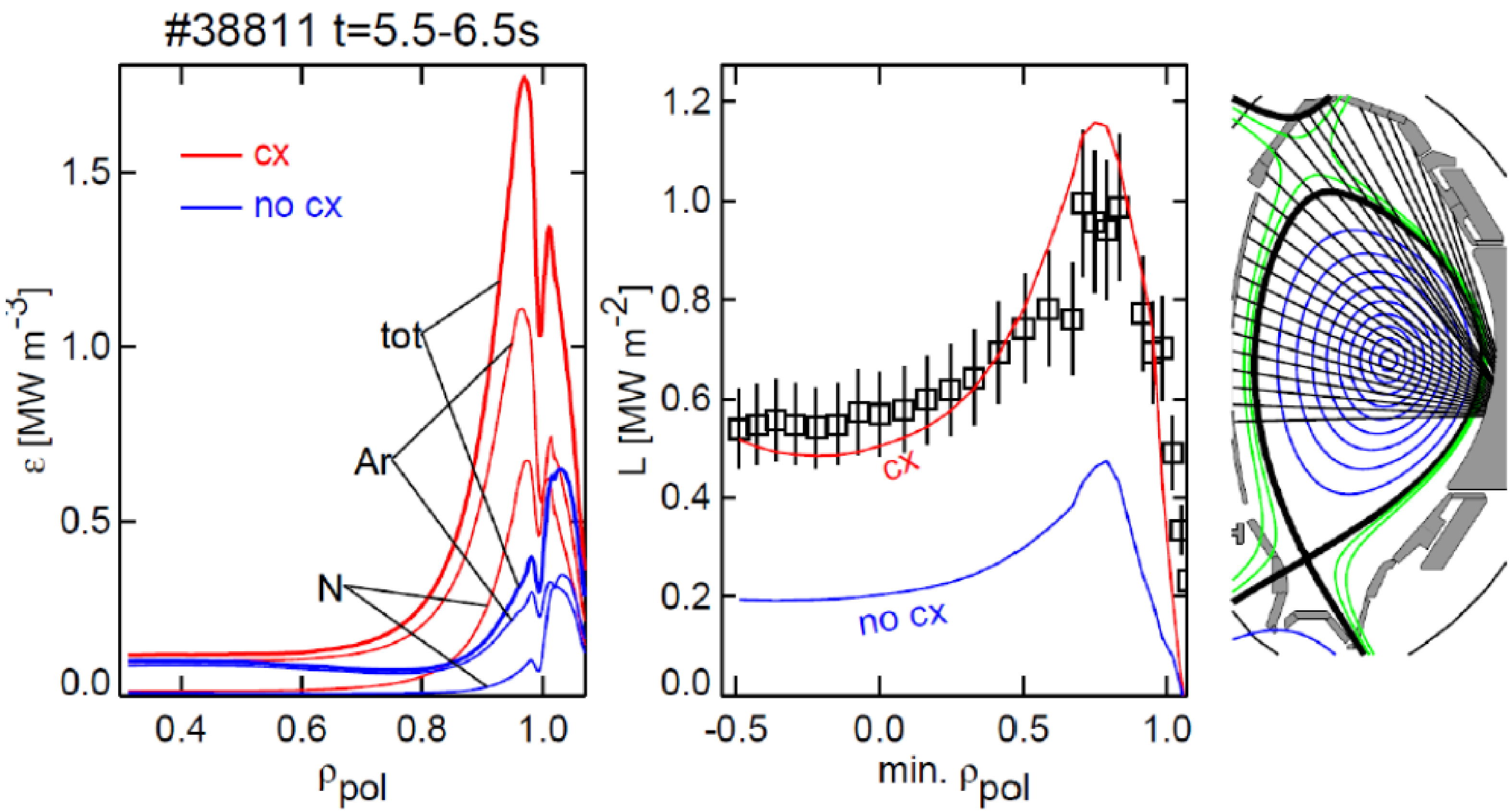
- Argon to maintain quasi-coherent mode and no-ELM state
- Nitrogen for divertor partial detachment



H_{98}= 1.05
β_N= 2.4
q_{95}= 5.8

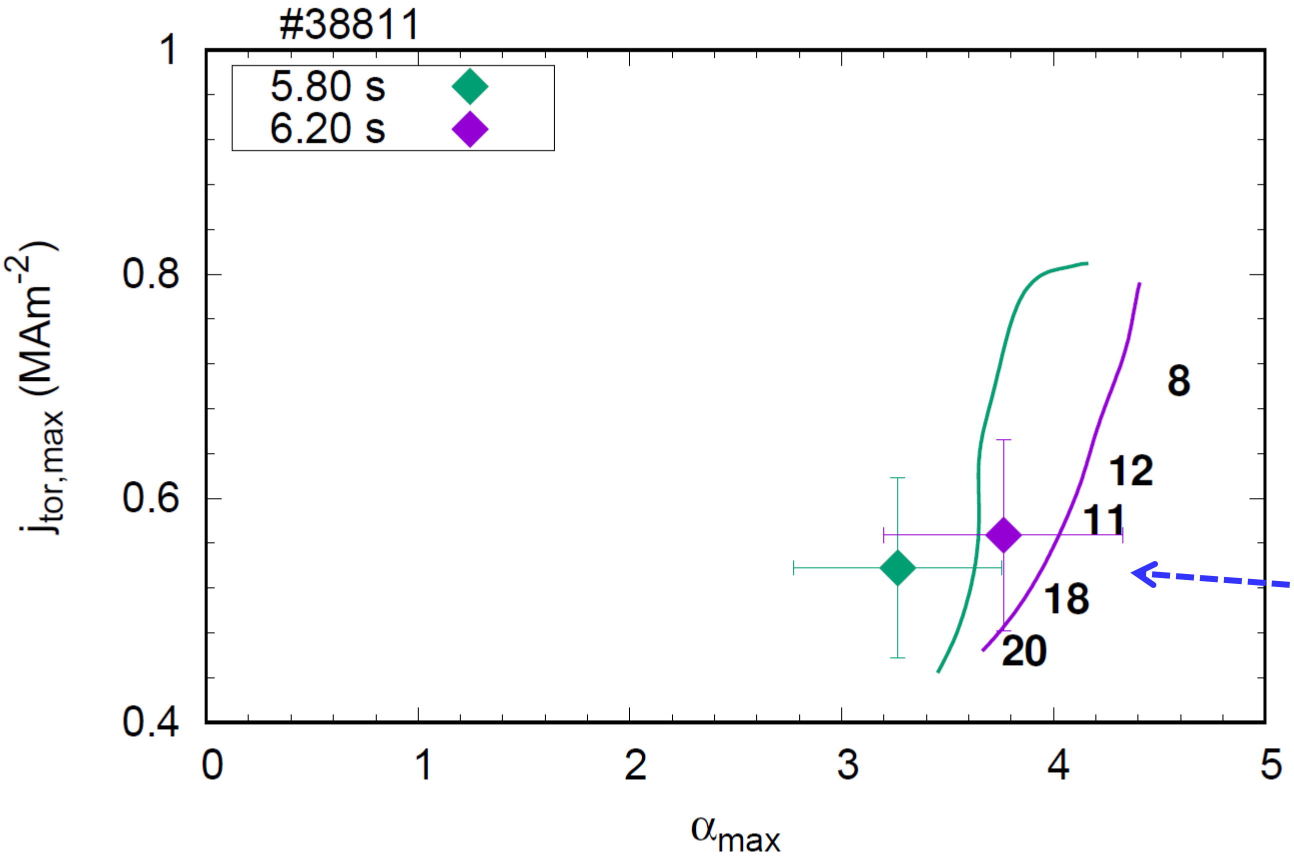
Combined Ar and N radiation in the pedestal

- effect of charge exchange ~ triples pedestal radiation
- $c_{Ar} \approx 0.3$ %, $c_N \approx 1$ % $\rightarrow$ more pedestal radiation per dilution from Ar



MHD stability analysis

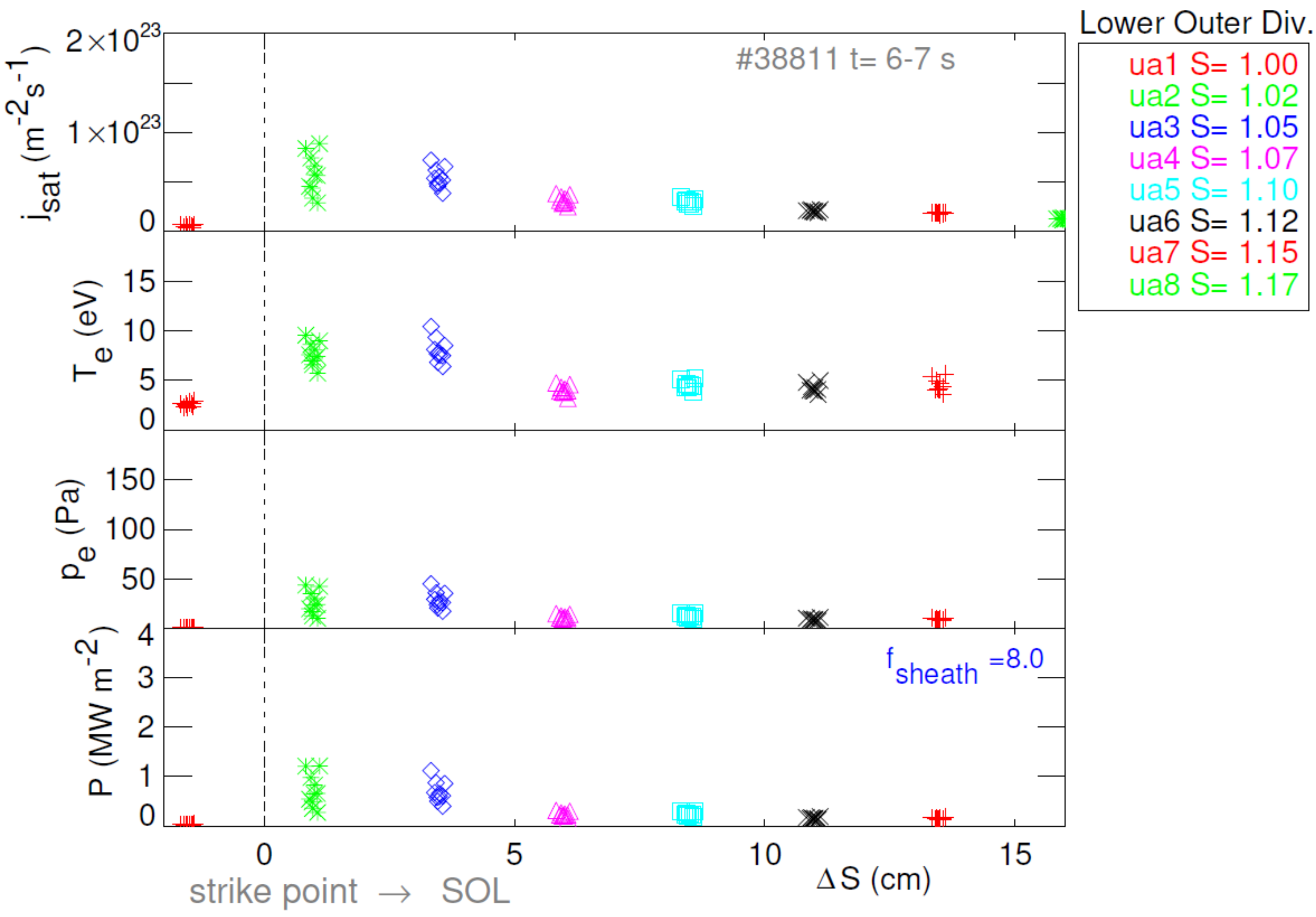
- EDA H-mode is stable close to ballooning limit



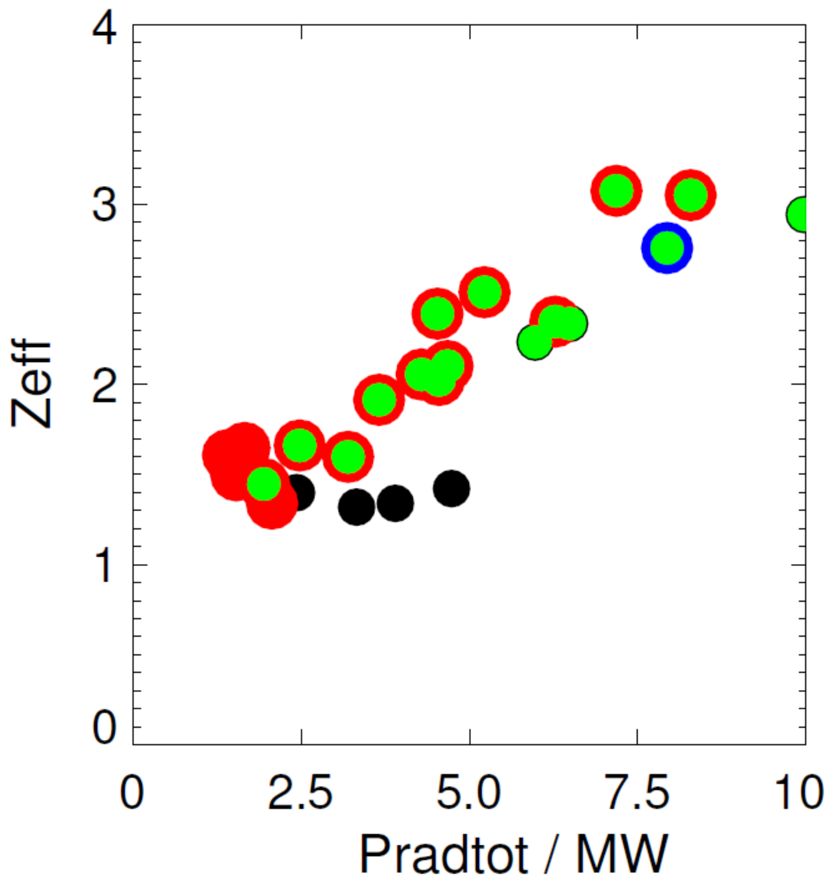
most unstable n from max. ∇p var.

Partial detachment with combined Ar+N achieved

- Langmuir probes along outer divertor target



Core fuel dilution must be restricted to minimum

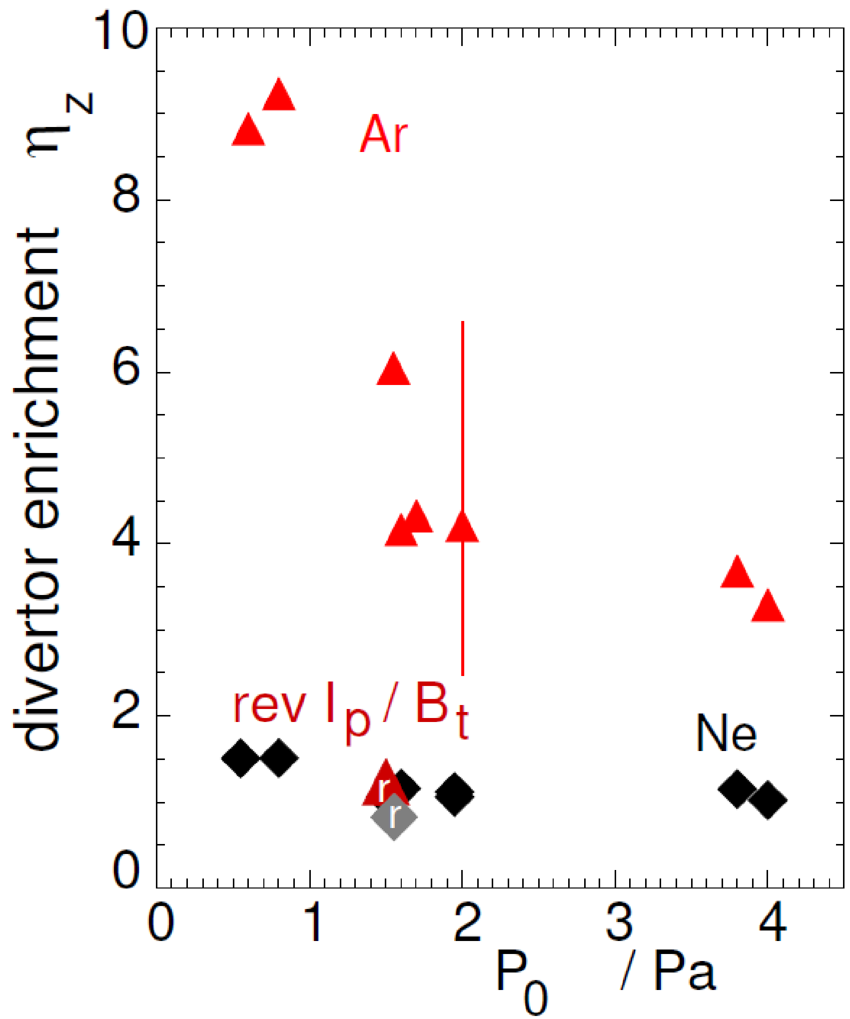


ΔZeff= 1.5 by Ar $\rightarrow$ $c_{Ar} \approx 0.5$ %

$\rightarrow$ 9 % dilution

Divertor enrichment is a key parameter for detachment efficiency

Enrichment: $\eta = \Gamma_{Z^0}/\Gamma_{D^0}$ (div) / n_z/n_e (core)



η is a measure for relative divertor radiation / core dilution

Argon performance much better compared to Neon

only for standard I_p/B_t direction

– modelling with full drifts required
– element for divertor optimization

Summary and next steps

Integration of a no-ELM scenario and divertor detachment
achieved on ASDEX Upgrade in EDA H-mode with Ar and N double feedback

Next:

- reduce safety factor q_{95} (X3 heating instead of X2 for tungsten control)
- extend to higher divertor neutral pressure to make Ar an efficient divertor radiator ($\rightarrow$ QCE scenario ?)
- alternative divertor configuration ?
- direct control of the quasi-coherent mode ?
- modelling for extrapolation (divertor, transport, MHD and stability)