Max-Planck-Institut für Plasmaphysik

Integrated modelling of plasma confinement and L-mode turbulence in GK simulations

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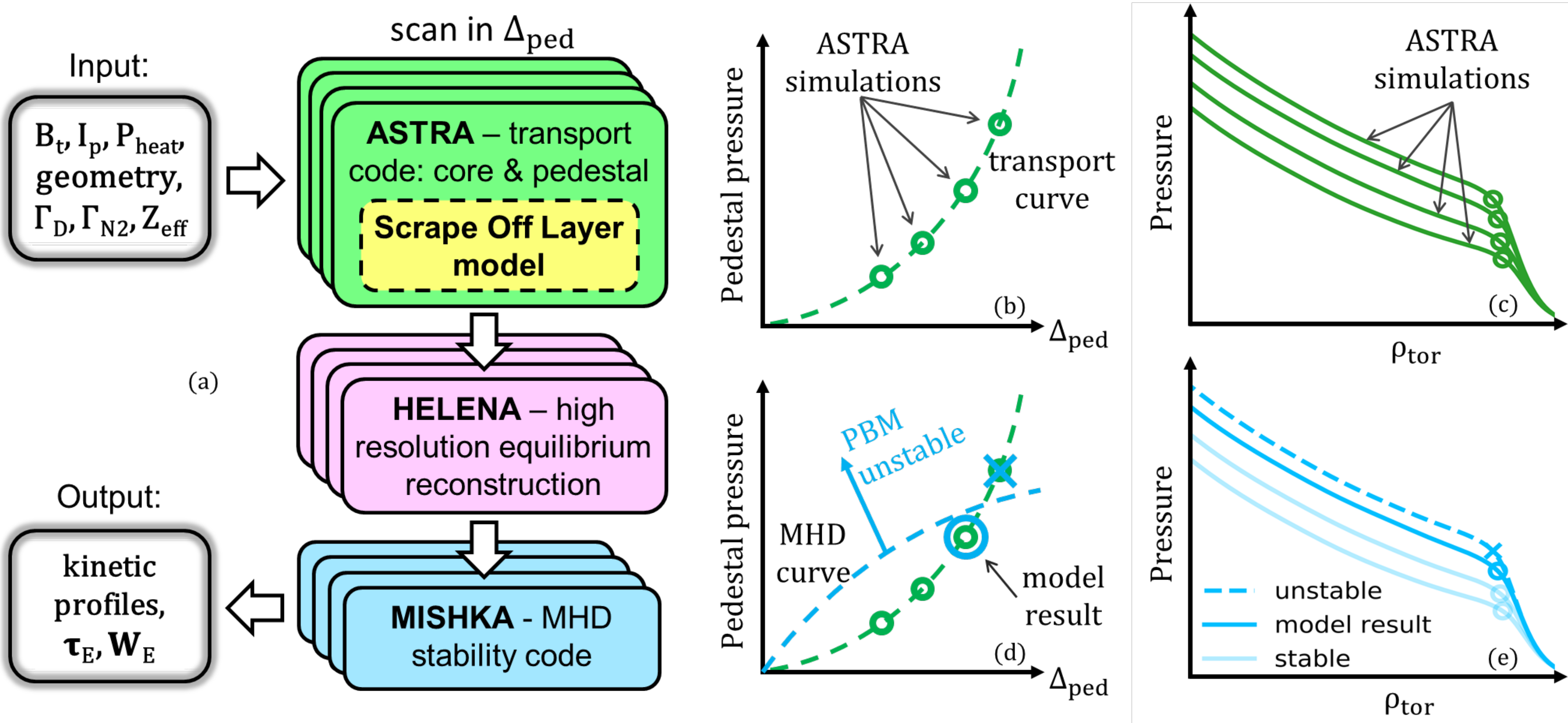
This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

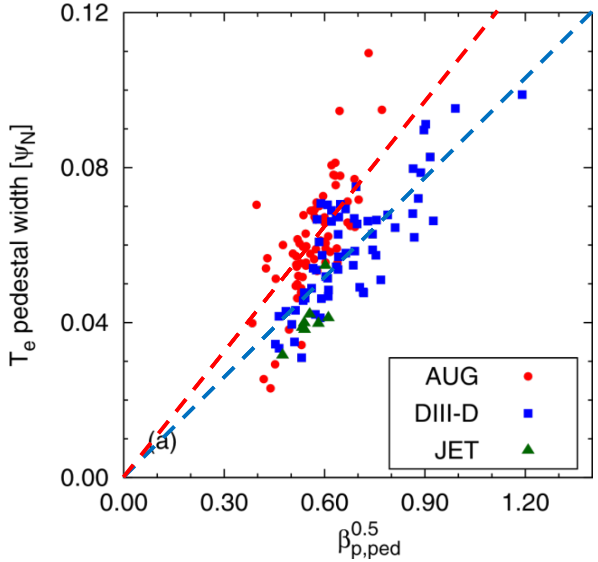
Integrated Model based on Engineering Parameters (IMEP)



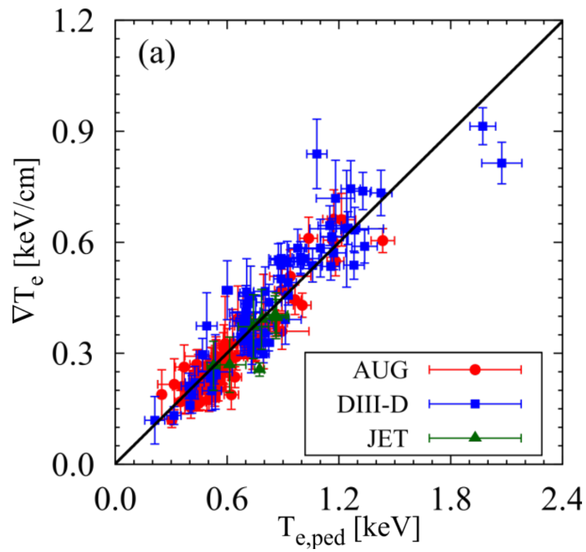
[T. Luda *et al* 2020 *NF*]
[T. Luda *et al* 2021 *NF* (to be submitted)]

Pedestal transport model

- The EPED pedestal model: [P. B. Snyder *et al* 2009 *PoP*]
  - assumes: $\Delta\Psi_N \sim (0.076, 0.11)\beta_{p,ped}^{0.5}$
  - requires $n_{e,top}$ as input
  - assumes $T_{e,top} = T_{i,top}$



- AUG, DIII-D, and JET pedestals exhibit one common feature: $< \nabla \mathbf{T_e} > / \mathbf{T_{e,top}} \approx \mathbf{constant}$
  [P.A. Schneider *et al* 2013 *NF*]

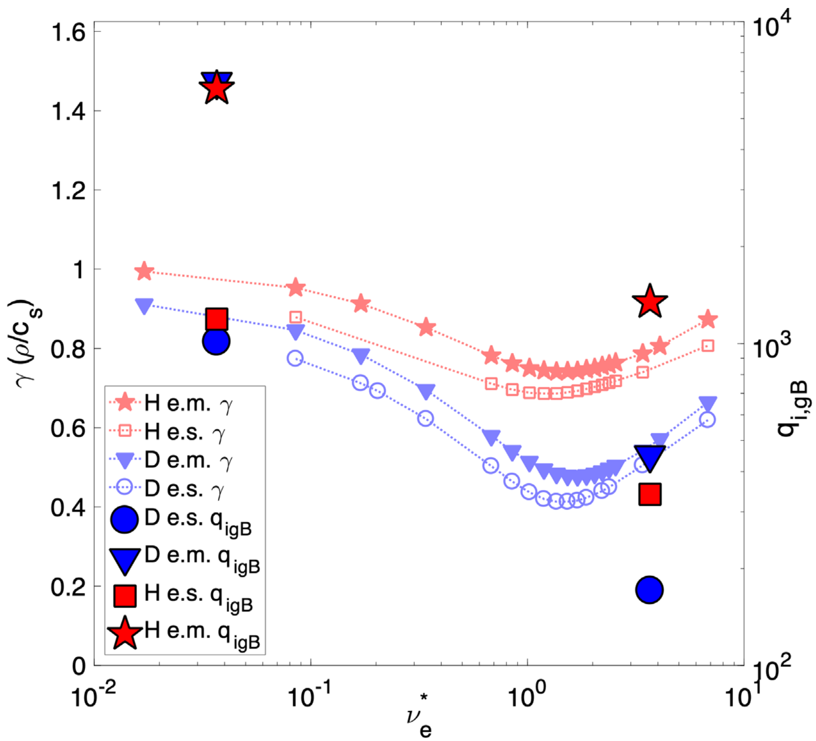


- We **implemented in our model** the condition $\frac{<\nabla \mathbf{T_e}>}{\mathbf{T_{e,top}}} = -0.5\ [1/\mathrm{cm}]$

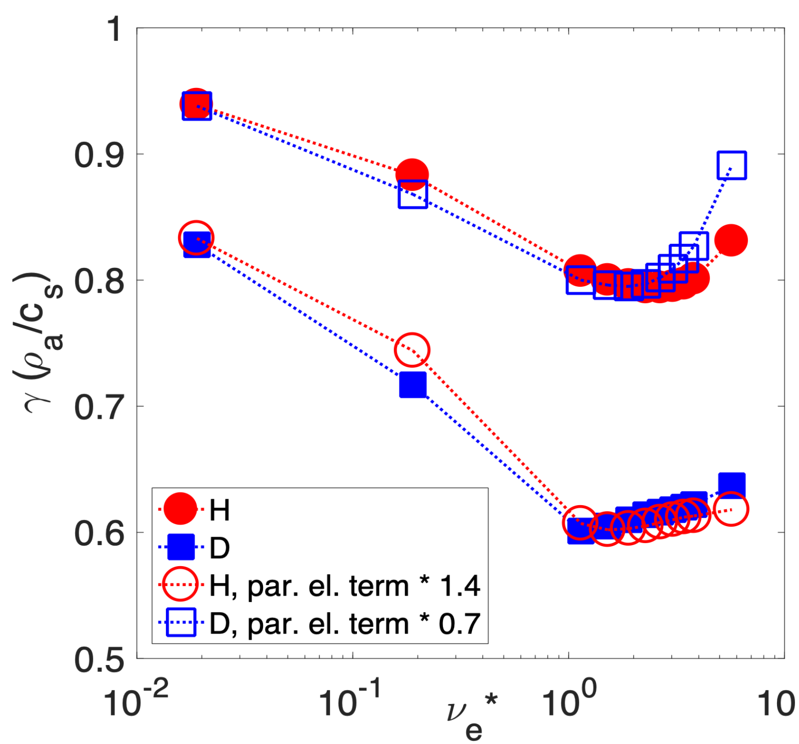
L-mode edge turbulence and isotope

->Strong effect of collisions and isotope mass on L-mode edge turbulence
->Strong e.m. effects on L-mode edge turbulence
->Strong role of parallel electron dynamics for L-mode edge turbulence

role of collisionality and isotope



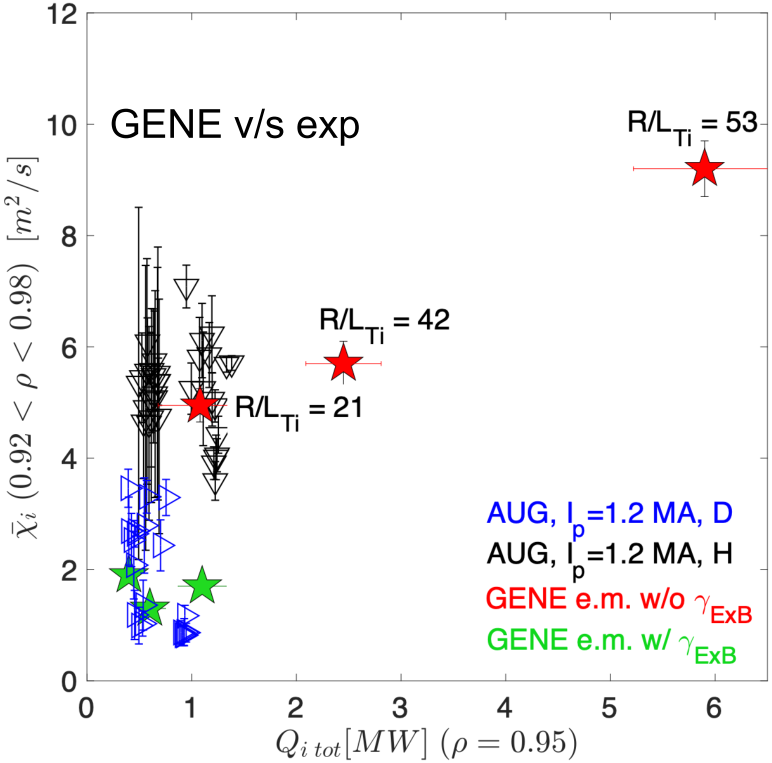
role of parallel el. dynamics



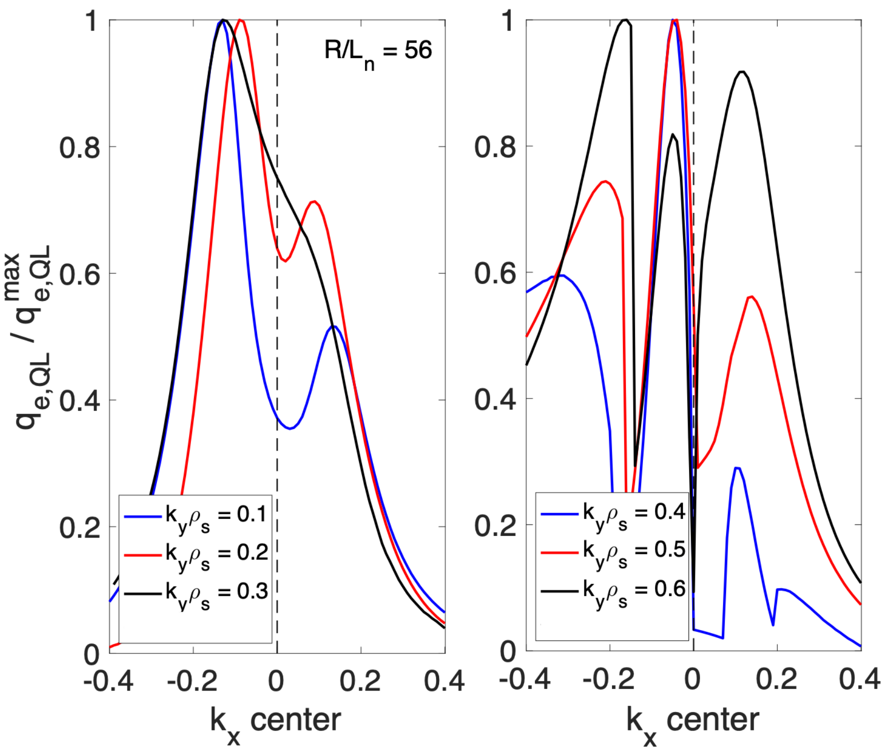
see: N. Bonanomi et al 2019 Nucl. Fusion 59 126025

L-mode edge turbulence and isotope II

-->Important role of R/L_{Ti} and ExB shear for L-mode edge turbulence (role of different normalized gradients studied). Quantitative agreement with exp.
--> Important role of finite-k_x instabilities observed in GENE local simulations



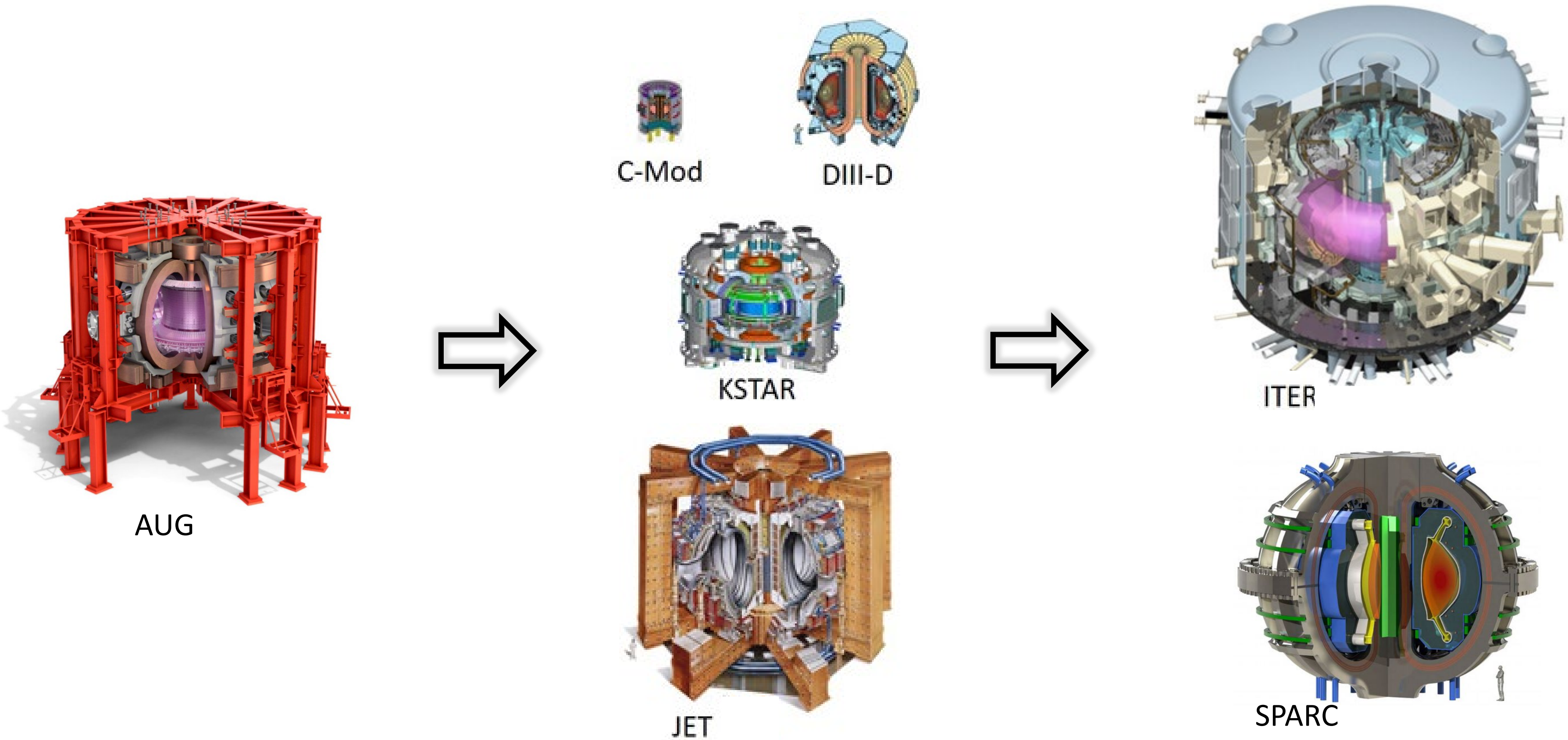
Finite k_x instabilities and QL transport



see: N. Bonanomi et al 2021 APS invited, accepted PoP

Outlook

- Applicability to **other tokamaks** and theoretical foundation of pedestal transport model to be investigated



Outlook

- Applicability to **other tokamaks** and theoretical foundation of pedestal transport model to be investigated

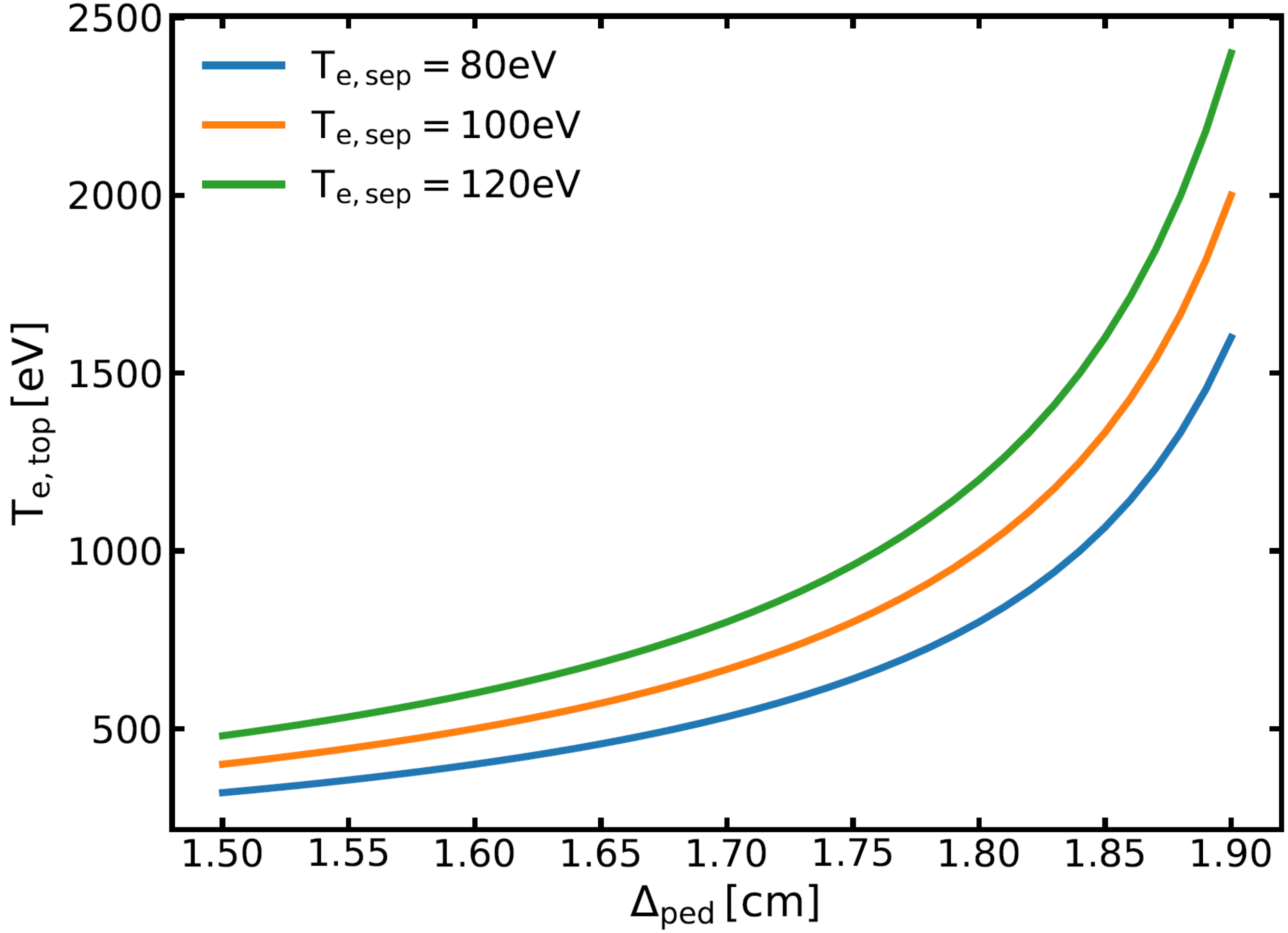
- Pedestal transport model to be modified / extended with additional theoretical and experimental results
(pragmatic approach compatible with transport modelling)

- Model open and ready to be informed with the results of GK simulations

- Edge turbulence properties in L-mode edge approaching L-H transition under investigation with GENE simulations (Bonanomi NF 19, PoP 21).

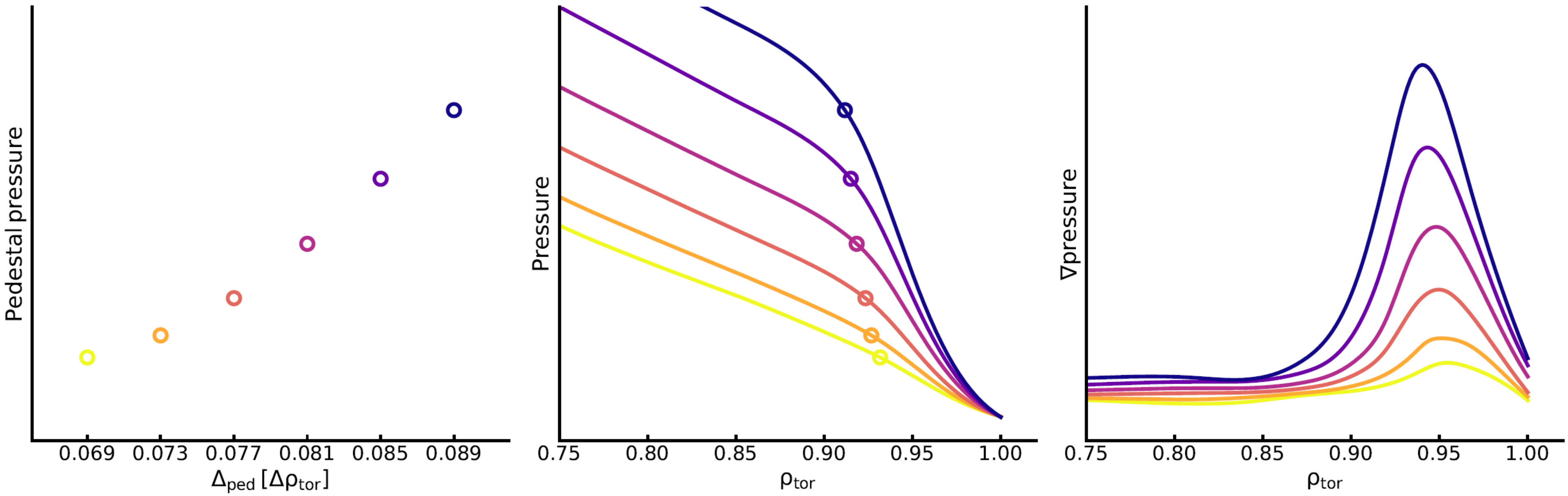
Backup slides

$$T_{e,top} = \frac{T_{e,sep}}{(1 - 0.5\,\Delta_{ped})}$$



Backup slides

- For every Δ_{ped} of the scan, ASTRA changes $\boldsymbol{\chi}_{\mathbf{e,ped}}$ until $\frac{<\nabla T_e>}{T_{e,top}} = -0.5$ is satisfied
- The obtained $\chi_{\text{e,ped}}$ is used to evaluate $\chi_{\text{i,ped}}$: $\boldsymbol{\chi}_{\mathbf{i,ped}} = \boldsymbol{\chi}_{\mathbf{e,ped}} + \boldsymbol{\chi}_{\mathbf{i,NEO}}$
- Modelling of the electron density: $\mathbf{D}_{\mathbf{n,ped}} = \mathbf{c}_{\mathbf{D}/\boldsymbol{\chi}}\boldsymbol{\chi}_{\mathbf{e,ped}} + \mathbf{D}_{\mathbf{n,NEO}}$
- $c_{D/\chi} = 0.06$ and $C_{\text{n,ped}} = -0.05$ [m/s] obtained with an **optimization** procedure trying to match different experimental pedestal density profiles



Backup slides

This modeling workflow is tested by simulating **50** H-mode stationary phases from ASDEX Upgrade discharges covering wide variations in:

B_t = 1.5 - 2.8 [T] **I_p** = 0.6 – 1.2 [MA]

P_{net} = 2 – 14 [MW] **q_{95}** = 3 - 8

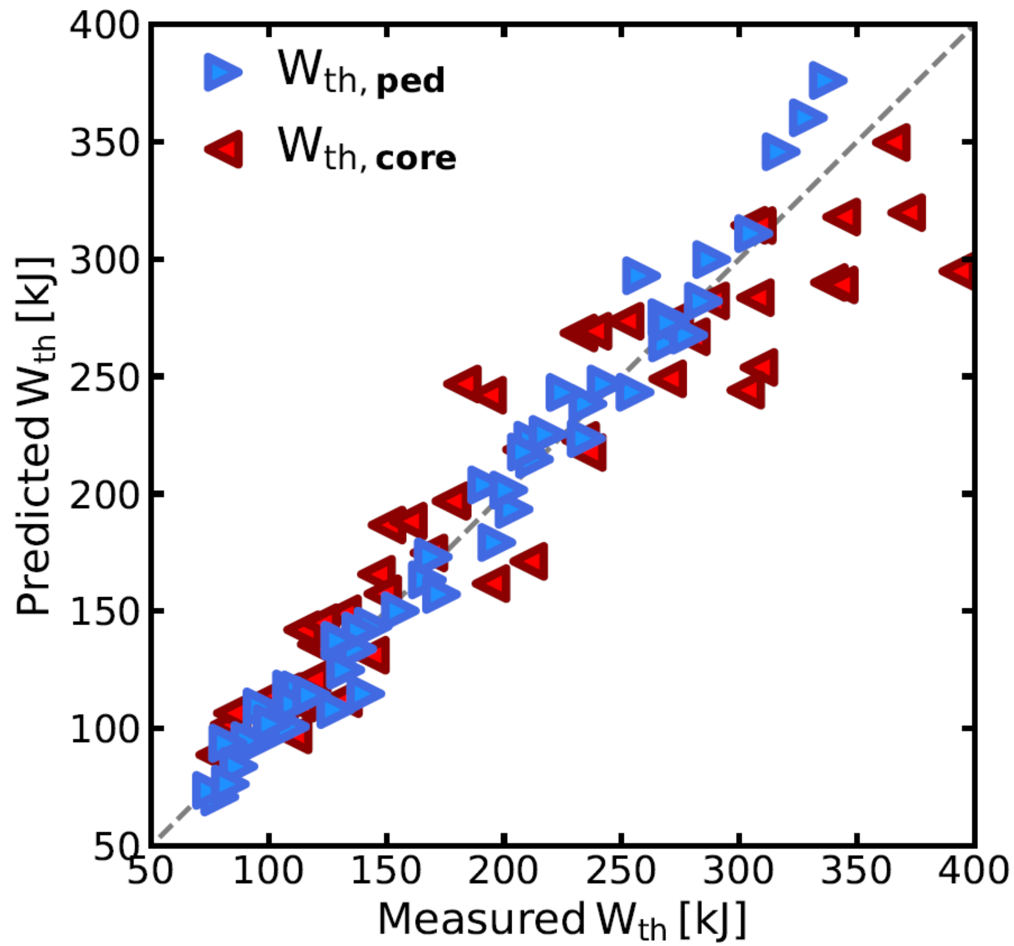
Γ_D = 0 – 8 x 10^{22} [e/s]

δ = 0.19 – 0.42

V_{NBI} = 42 - 92 [kV]

This approach can accurately predict the **pedestal energy**, and can describe the effect of the different parameters on pedestal confinement for this database

The **core energy** can be overpredicted by TGLF due to low stiffness, or underpredicted due to too low stabilization mechanisms (fast ions, β effects)



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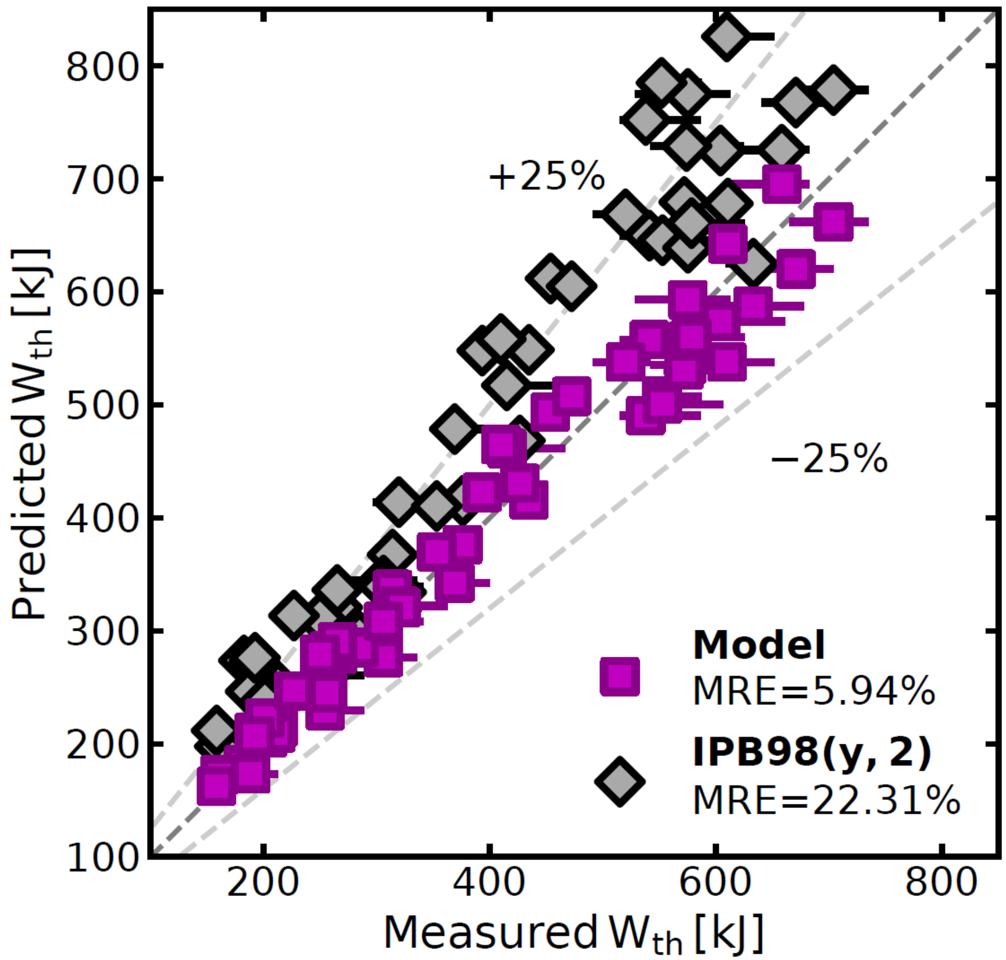
The model:

- ✓ is **more accurate** with respect to the IPB98(y,2) scaling law
- ✓ can accurately **capture the effect** of the different operational parameters

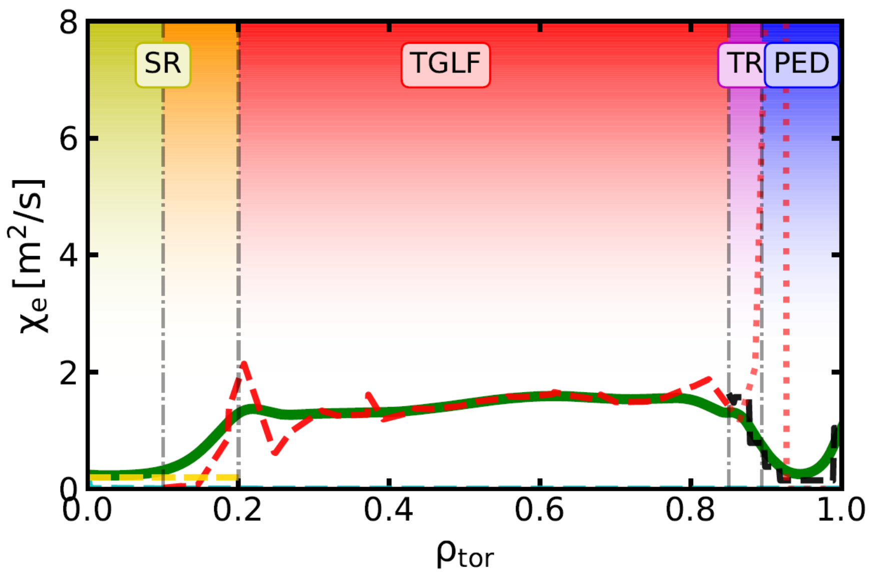


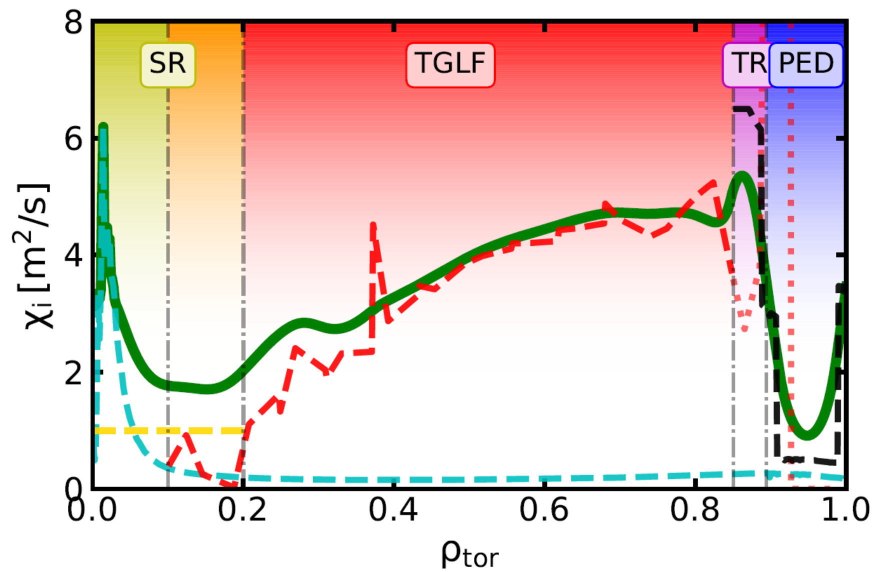
Backup slides

Example of the heat diffusivities for electrons and ions for a given Δ_{ped}:

- - - Before smoothing

—— After smoothing





TGLF, **NCLASS**, **sawtooth transport**,

diffusivities in the **pedestal** and **transition** regions

$$\chi_{tr} = c_1 + c_2\chi_{ped}$$