TSVV2 Annual Meeting, Lausanne

ASTRA-TGLF modelling of high delta NT shapes in DTT

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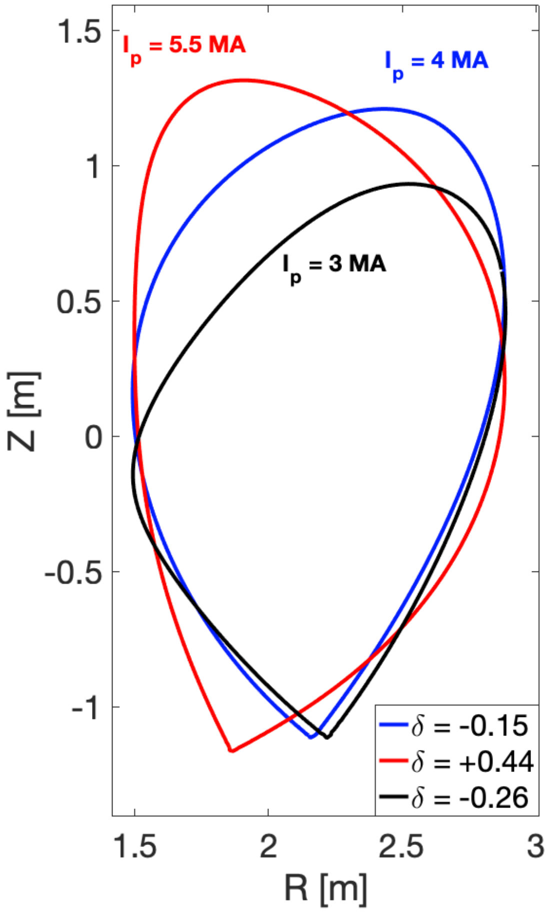
Introduction – NT plasmas in DTT



NT and PT configurations

	I_p [MA]	B_T [T]	δ_{up}	δ_{low}	δ_{avg}	κ	q_{95}
PT	5.5	5.85	0.41	0.47	0.44	1.79	3.89
NT LD	4.0	5.85	-0.35	0.05	-0.15	1.67	3.80
NT HD	3.0	5.85	-0.48	-0.04	-0.26	1.47	3.27

- NT and PT scenarios will have the same input power (~45 MW)
- Same B_T, different plasma current I_P to have similar q_{95}

Two NT configurations:

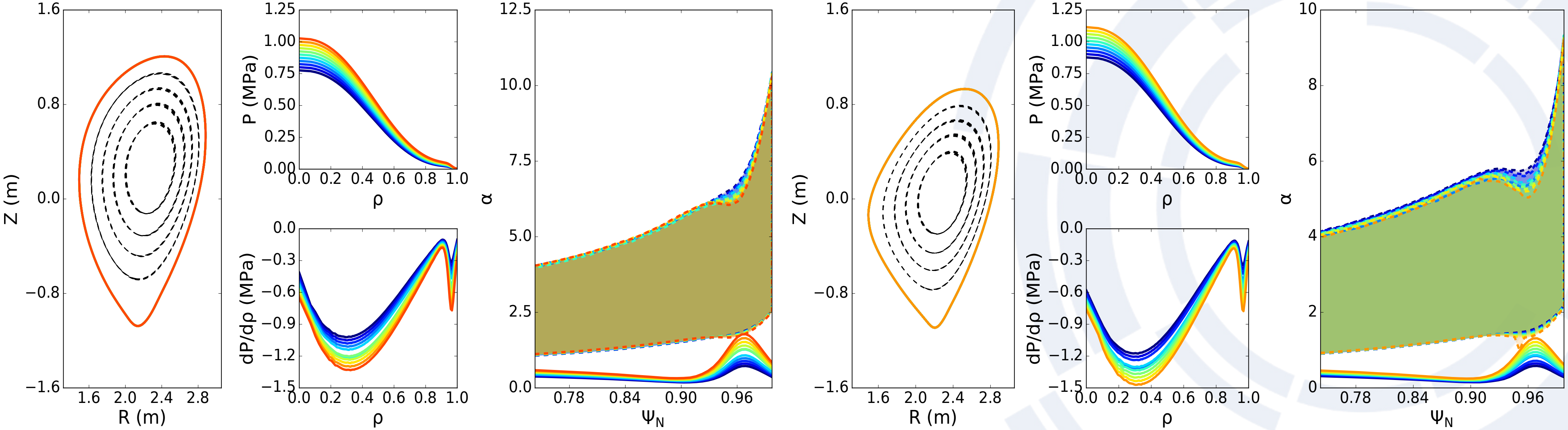
i. Low-Delta (LD), with a moderate triangularity value (A.Mariani et al., Nuclear Fusion 64 (2024) 046018

ii. High-Delta (HD), a newly designed shape with **improved** $\boldsymbol{\delta_{top}}$, but reduced overall volume and elongation

Introduction - Pedestal stability

Results from BALOO simulations:

- The ideal (infinite-*n*) ballooning modes limit the edge pressure gradient in DTT NT plasmas
- Both NT shapes are strong enough to **prevent robust H-mode access** ⟶ **L-mode**



Normalised pressure gradients vs. ballooning instability limits evaluated for a set of possible NT low-δ and high-δ pressure profiles in DTT. Courtesy of O.A. Nelson.

The limit gradient can be used in ASTRA simulations as upper limit for the scenario performance

Introduction - edge modelling

Results from SOLEDGE2D-EIRENE simulations in order to assess boundary conditions:

- PT: transport profiles such as to reproduce the Eich's scaling for the power fall-off length λ_q
- NT: no well validated scaling, transport levels derived from TCV experiments

	n_e [10^{19} m^{-3}]	T_i [keV]	T_e [keV]	T_i/T_e
PT	7.92	0.293	0.200	1.47
NT LD	7.92	0.363	0.200	1.82
NT HD	7.92	0.415	0.230	1.80

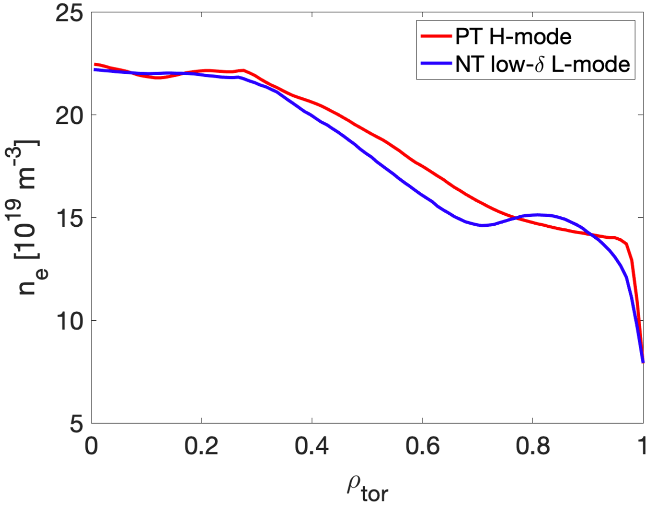
n_e, T_i, and T_e at the separatrix predicted using SOLEDGE2D-EIRENE. Courtesy of P. Innocente.

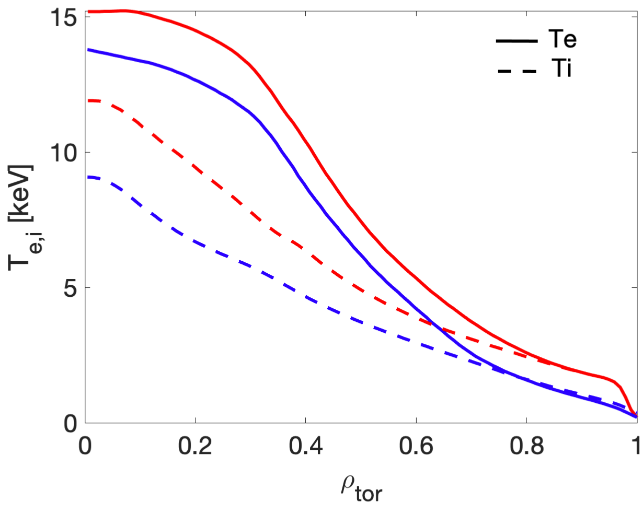
ASTRA/TGLF-SAT2 modelling setup (supported by JINTRAC/JETTO)

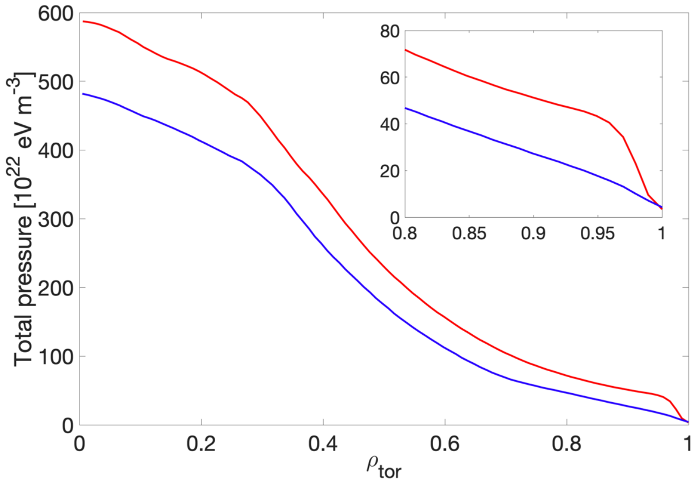
- Main species predicted up to the pedestal in H-mode and **throughout the whole radius in L-mode**
- **Impurity transport** (Ar and W) solved up to the separatrix in all cases, level chosen to have Prad requested by SOL
- NC transport of main particles is computed with **NCLASS**
- NC transport of impurities solved by **FACIT**
- Turbulent transport simulated using **TGLF-SAT2** for all species
- Flux surfaces at $\rho_{pol} < 1$ self-consistently computed using the equilibrium solver **FEQUIS**
- The heat sources are calculated by **JINTRAC/JETTO** simulations, and then kept fixed in ASTRA
- The plasma rotation is computed within **JINTRAC/JETTO** suite using a semi-empirical model

New: the flux surface geometry is now fully passed to TGLF using **Elite** (in past simulations TGLF used Miller approximation). Unlike Miller, **Elite preserves the up-down asymmetry of the flux surfaces**

Predictive transport studies – main results

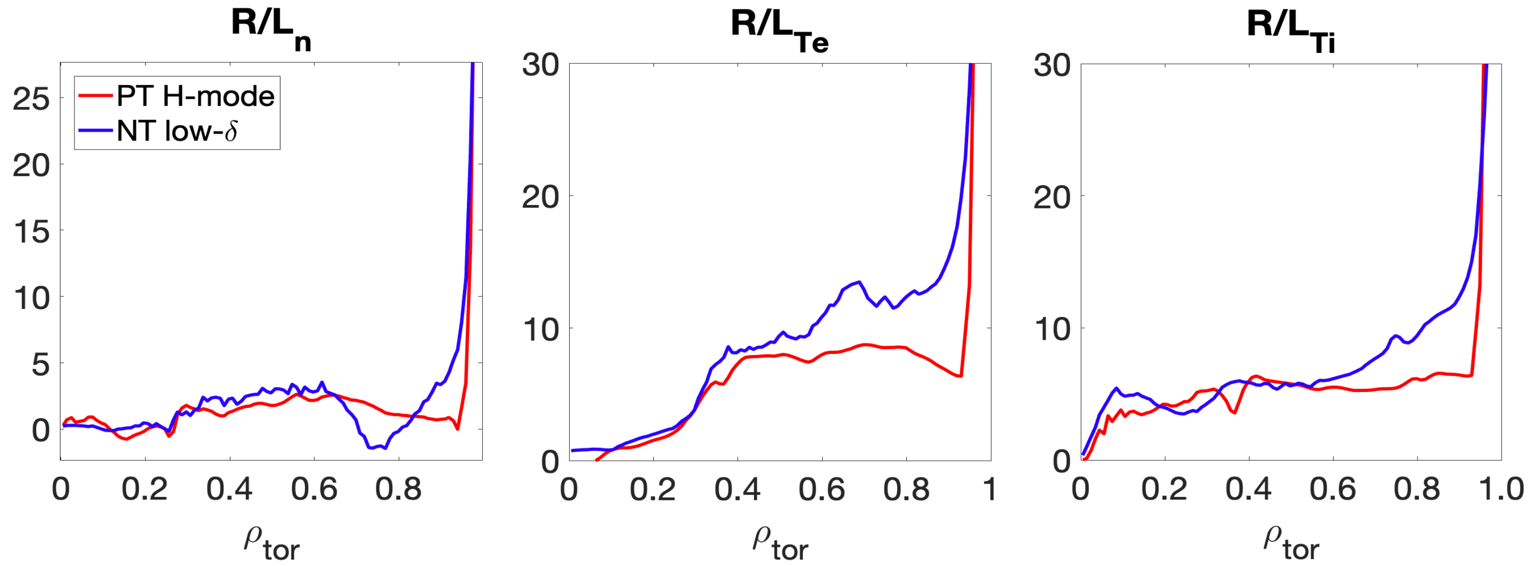






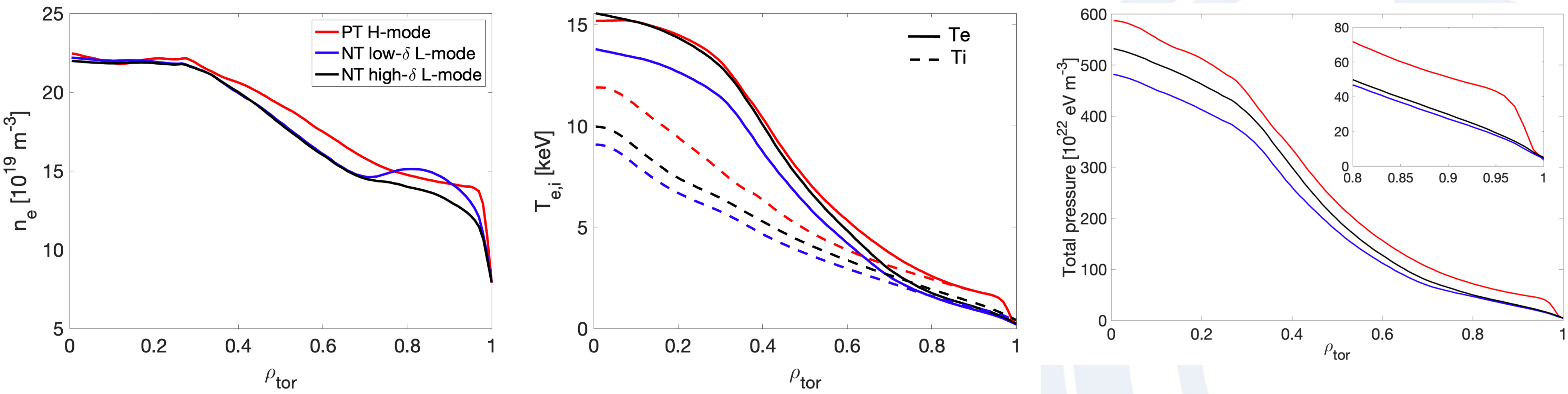
- for the **NT Low-Delta** case, total pressure 80% of the **PT** counterpart, scenario with good performance in absence of ELMs

Predictive transport studies – main results



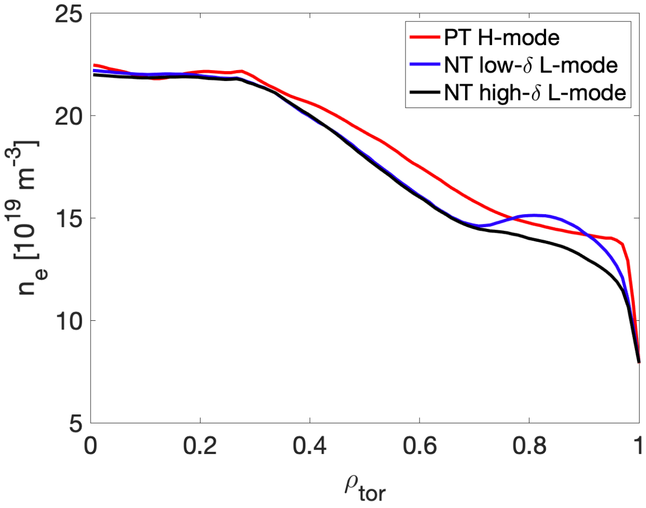
- for the **NT Low-Delta** case, total pressure 80% of the **PT** counterpart in absence of ELMs
- Higher $R/L_{Te,i}$ is due to geometry in addition to one being an L-mode (**NT LD**) and the other an H-mode (**PT**)

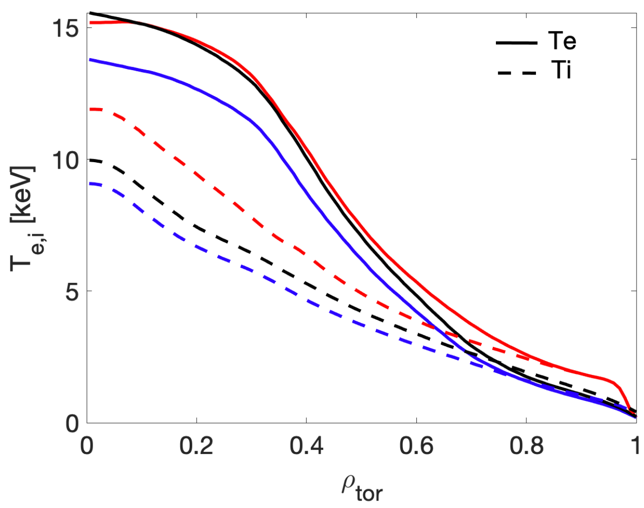
Predictive transport studies – main results

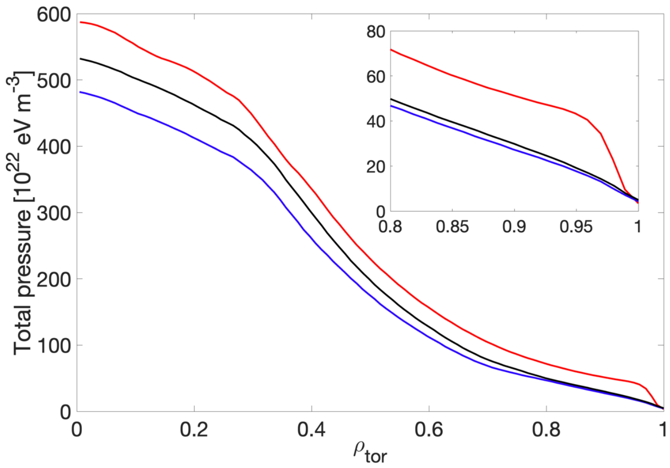


- for the **NT Low-Delta** case, total pressure 80% of the **PT** counterpart in absence of ELMs
- Higher $R/L_{Te,i}$ is due to geometry in addition to one being an L-mode (**NT LD**) and the other an H-mode (**PT**)
- **NT High-Delta** exhibits T_e that gets closer to the **PT** H-mode and matches its central profile
- Unlike T_e, no improvement in the ion temperature T_i is predicted

Predictive transport studies – main results







- More negative δ_{top} increases the confinement performance
- P_{tot} is higher for **NT HD** than **NT LD** throughout the radius
- $P_{tot} > 90\%$ of the **PT** value at R_0, without dangerous ELMs

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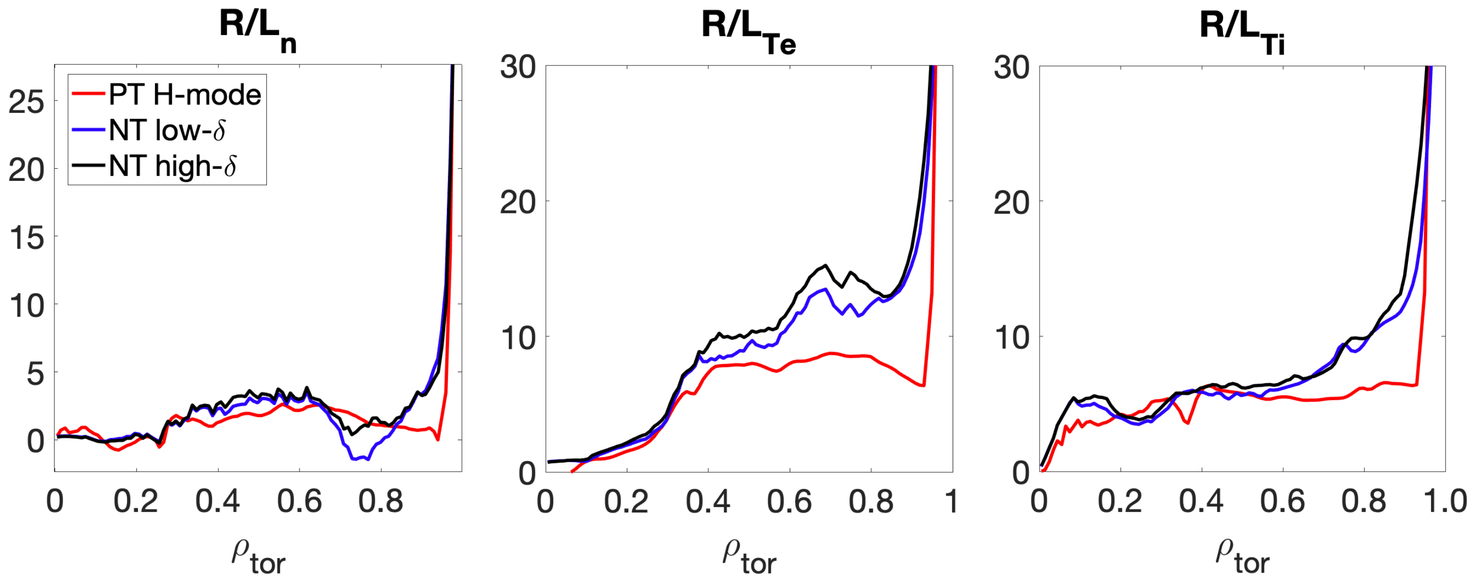

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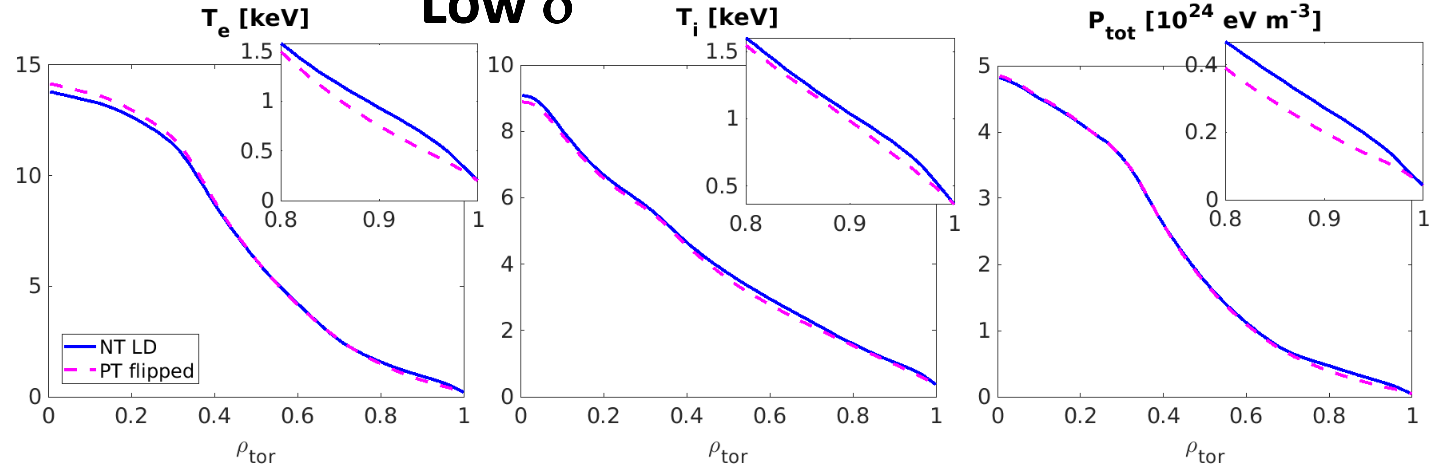
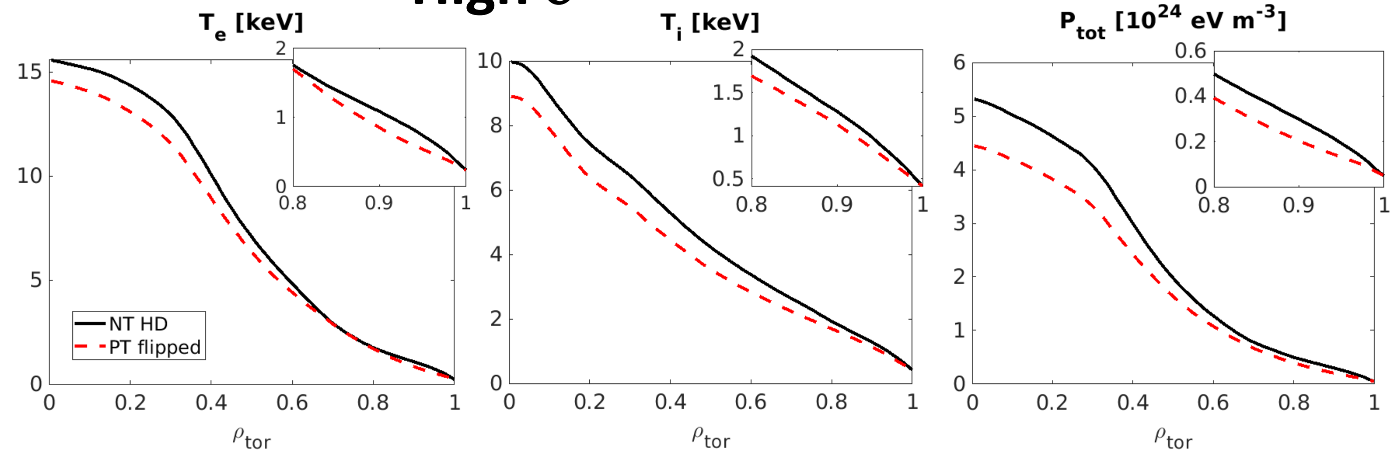
Predictive transport studies – flipping the LCFS

Low δ



High δ



Numerical experiment to discern the pure δ effect:

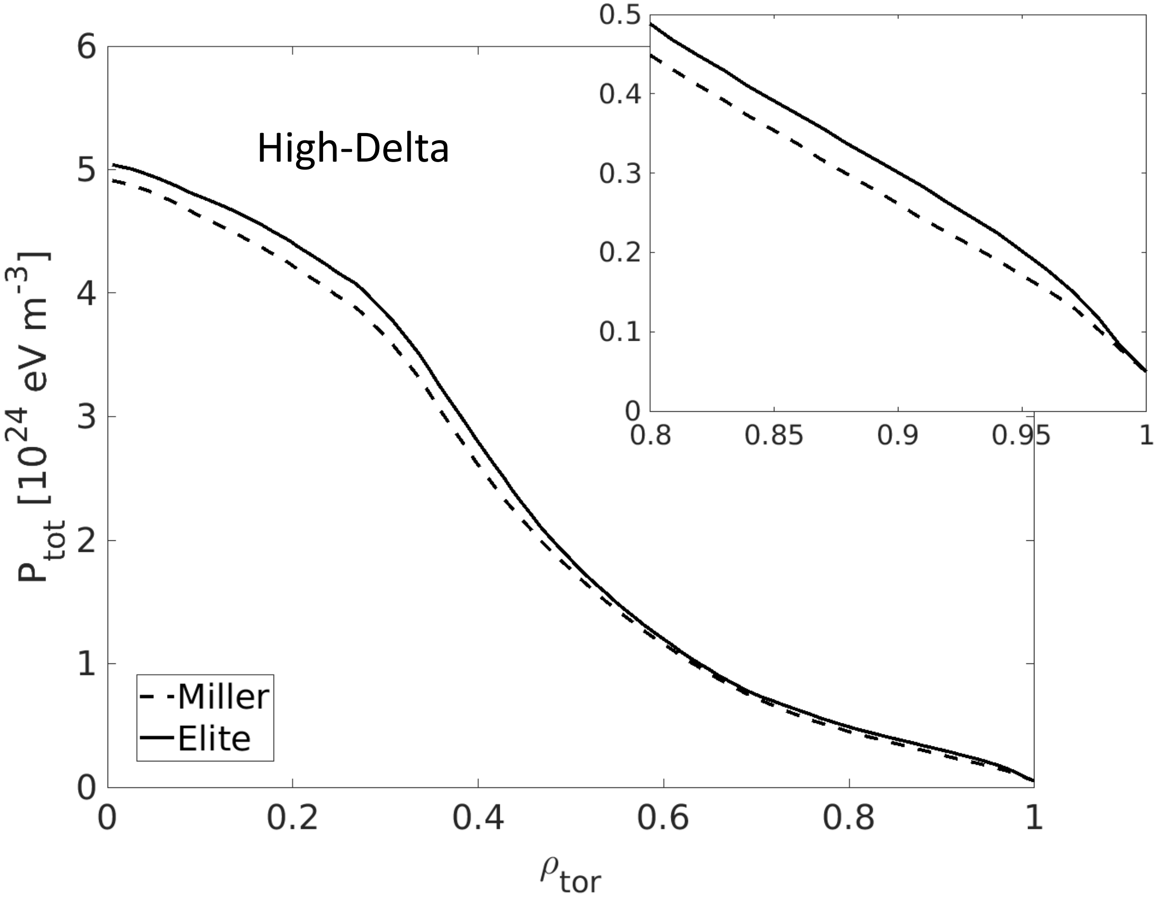
- LCFS simmetrically flipped
- BC unchanged
- Same heating and impurities

An improved confinement is observed at the edge in NT, as the proto-pedestal is never predicted for PT flipped.

The beneficial effect is much large in HD and particularly clear outside 0.9.

Predictive transport studies – Elite vs. Miller High-Delta

- A comparison between **Elite** and **Miller** equilibrium reconstruction has been performed
- As expected, the use of **Miller** partially mitigates the triangularity effect, as the up-down asymmetrical shapes are **badly reconstructed**
- TGLF coupled with Elite **better highlights** the good properties of $\delta < 0$ at the edge

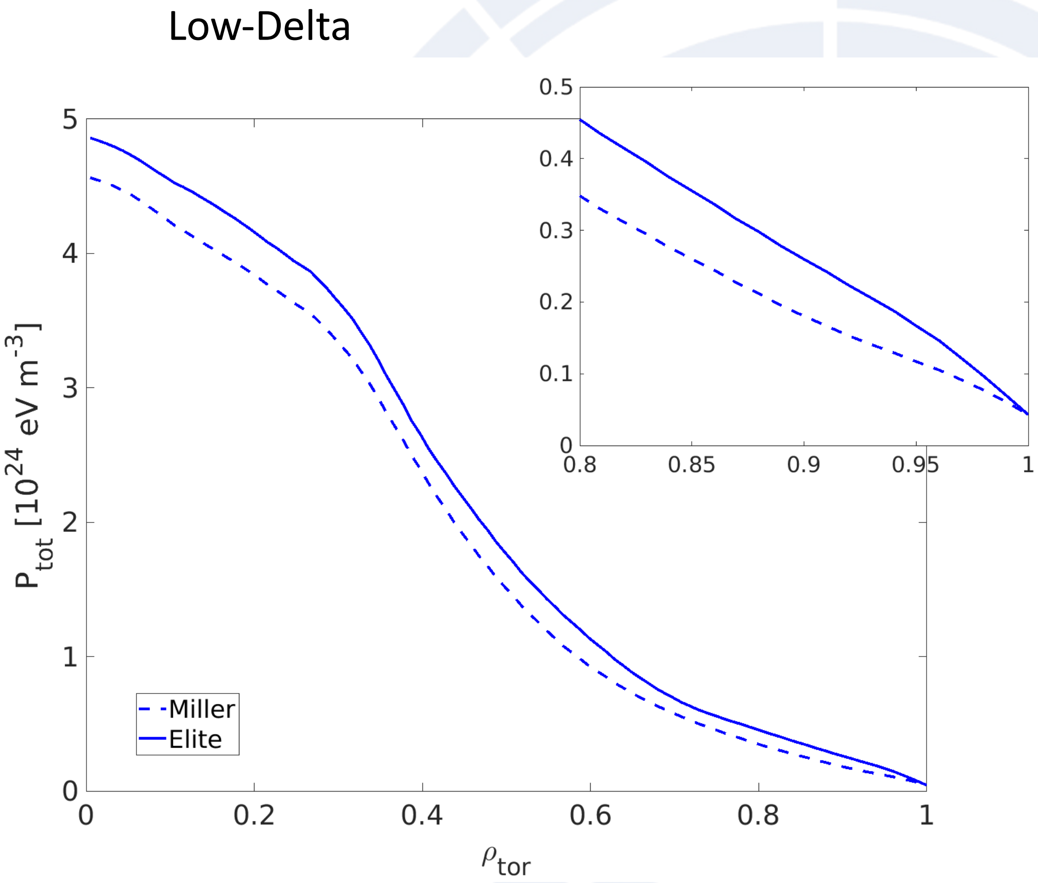


Predictive transport studies – Elite vs. Miller Low-Delta

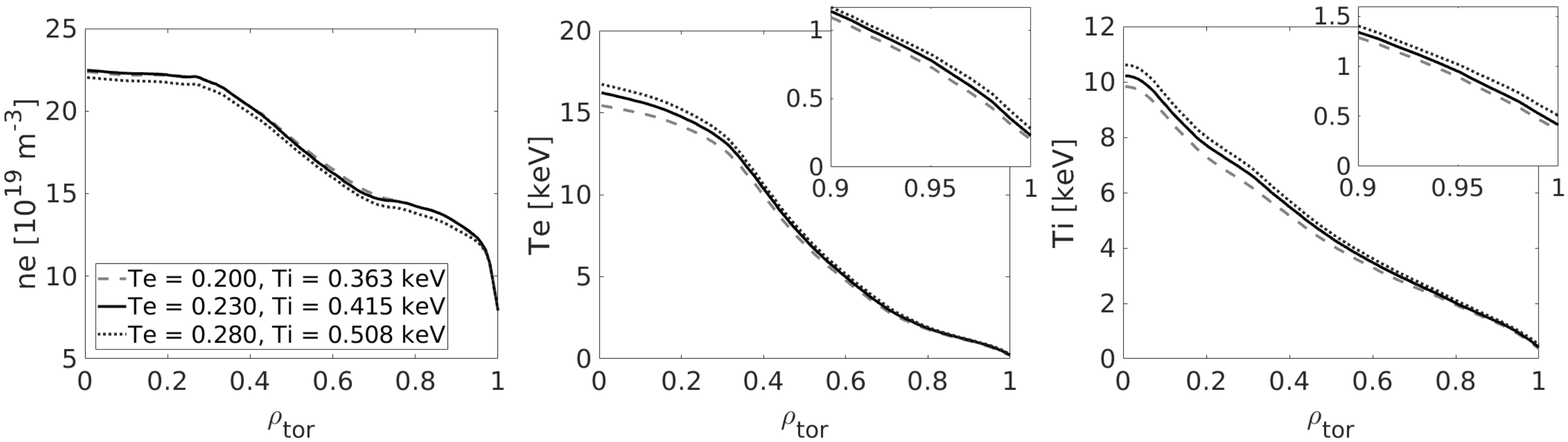
- **NT HD** higher up-down asymmetry than **NT LD**, but Elite vs. Miller is more evident in **LD**

- δ_{top} from -0.48 to -0.29 in **NT HD**, still a strong triangularity value

- δ_{top} drops below -0.19 in **NT LD**. This value might be too low to build the proto pedestal.



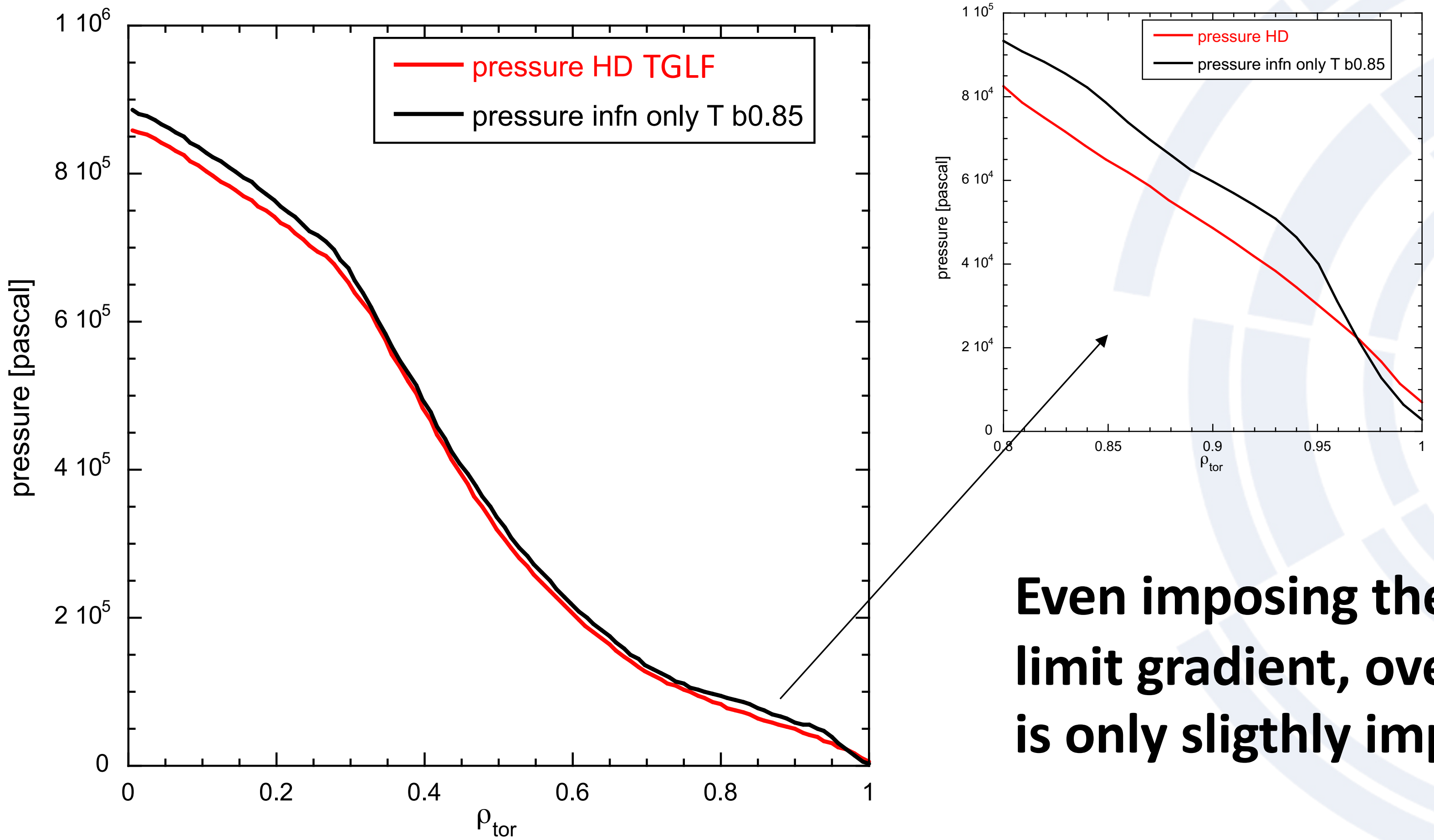
Predictive transport studies – scan on $T_{i,sep}$



- A possible beneficial effect of $\delta < 0$ may come from the SOL and thus affect the ASTRA boundary conditions
- The impact of BCs is investigated by adjusting $T_{i,e}$ at the LCFS in ASTRA, while maintaining the same ratio ${}^{T_i}/_{T_e}$

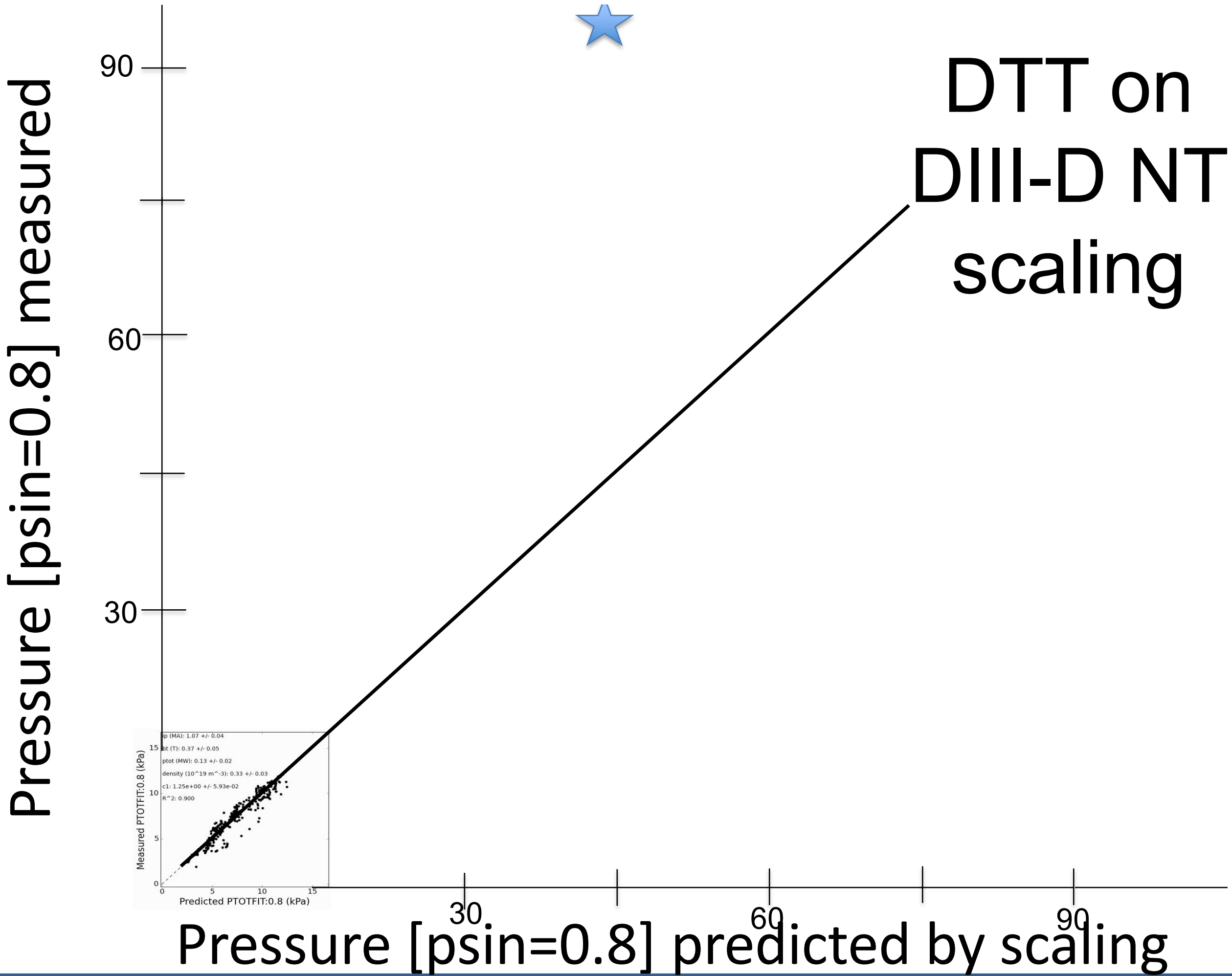
The simulations predict that the temperature BCs have **minimal impact** on central performance, with kinetic profiles being affected by a **maximum of 8%** at R_0

Imposing edge profiles close to ideal ballooning limit



Even imposing the ideal ballooning limit gradient, overall performance is only sligthly improved

DIII-scaling and DTT



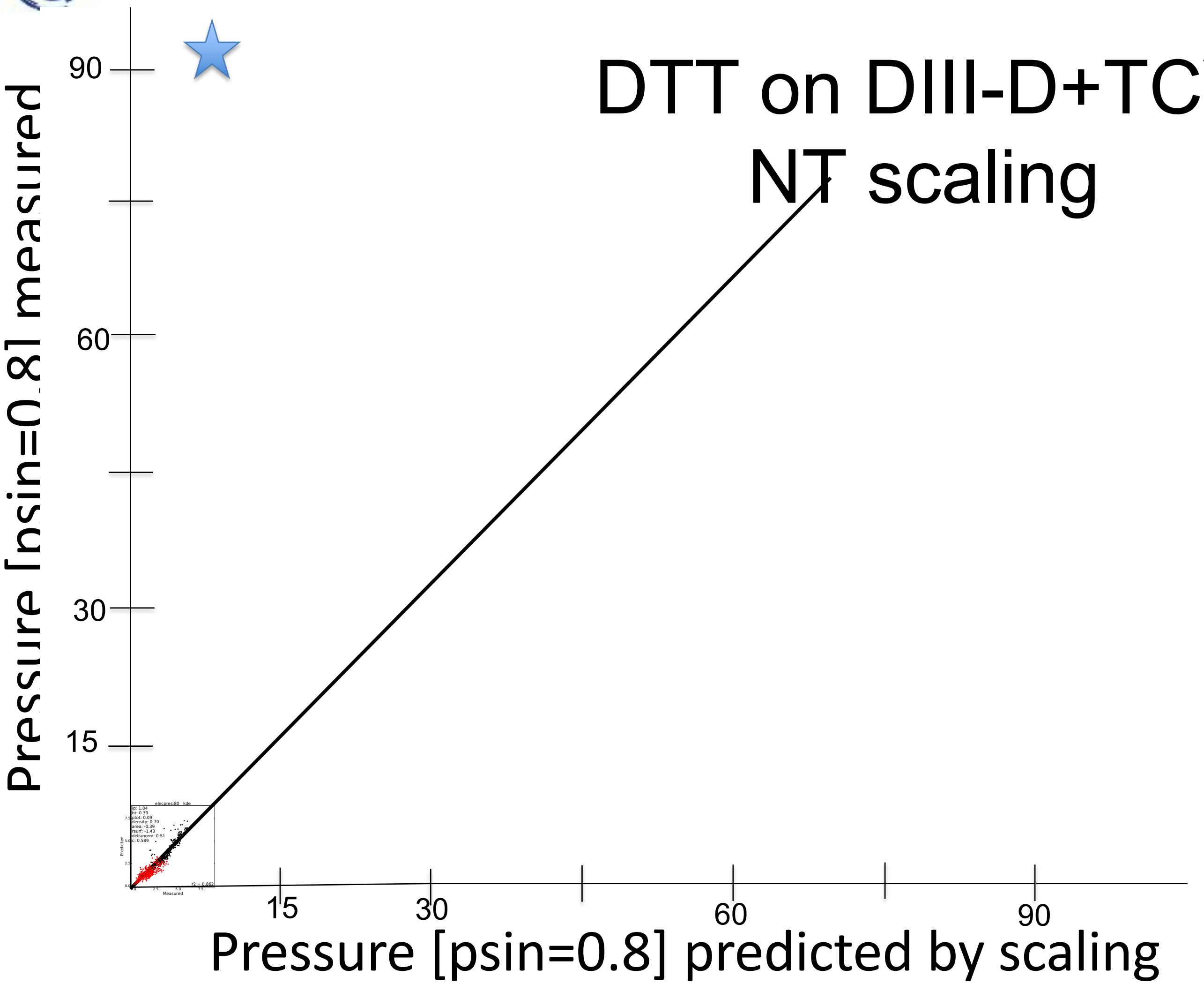
pressure at psin=0.8 [kPa] = 1.25 *Ip[MA]^1.07*BT[T]^0.37 *ptot[MW]^0.13*ne_lin[E19m-3]^0.33

- DTT very far from domain explored by DIII-D
- TGLF predictions are in fact much more optmistic than scaling

CONCLUSIONS

- New ASTRA-TGLF simulations made for higher δ NT scenario in DTT
- Using full geometry in TGLF gives more improvement due to NT than using Miller
- Effect of NT clearly seen in the edge region
- Higher δ shape leads to higher edge gradients but global performance is similar due to reduction in volume and current
- A marked insensitivity of the kinetic profiles to the boundary conditions at separatrix is observed with TGLF, at variance with simplistic expectations. Even using edge profiles close to ideal ballooning limit does not lead to significant improvement.
- We plan to do GK simulations in the edge region where TGLF sees the profile enhancement
- TGLF predictions for DTT are much more optimistic than DIII-D scaling

DIII+TCV scaling and DTT



re at psin=0.8 [kPa] =
p[MA]^1.04*BT[T]^0.39*ptot[MW]^0.09*
E19m-3]^0.7*area^-0.39*rsurf^-1.43*
rm^0.51

Even more off with respect to TGLF simulations

Predictive transport studies – Elite vs. Miller High-Delta