EUROfusion

Negative triangularity edge modelling with SOLEDGE2D / SOLEDGE3X-EIRENE on TCV

P.Muscente[1,2], P.Innocente[2], L. Aucone[3,5], A. Balestri[3,4], J.Ball[4], T. Bolzonella[2], G.Ciraolo[10], H.Bufferand[10], M.Dunne[7], M.Faitsch[7], S.Gorno[4], T. Happel[7], P. Mantica[5], A. Mariani[5], O. Sauter[4], M. Vallar[4], E.Viezzer[6], TCV team[8] and ASDEX Upgrade team[9]

paola.muscente@igi.cnr.it

[1]Centro di Ateneo "Centro Richerca e Fusione", Padova University, Italy; [2]Consorzio RFX (CNR, ENEA, INFN, Università di Padova, Acciaierie Venete SpA), Padova, Italy; [3]Dipartimento di Fisica 'G. Occhialini', Università di Milano-Bicocca, Milan, Italy; [4]École Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), 1015 Lausanne, Switzerland; [5]Istituto per la Scienza e la Tecnologia dei Plasmi, CNR, 20125 Milan, Italy; [6]University of Seville, Seville, Spain; [7]Max–Planck-Institut für Plasmaphysik, Boltzmannstraße 2, D-85748 Garching, Germany; [8]See the author list of H. Reimerdes et al 2022 Nucl. Fusion 62 042018, ; [9]See author list of U. Stroth et al. 2022 Nucl. Fusion 62 042006, [10]CEA, IRFM, 13108 St Paul-Lez-Durance, France

Università degli Studi di Padova
CONSORZIO RFX Ricerca Formazione Innovazione
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Aims of the study

Study **the edge transport** of **Negative Triangularity** and whether and how this D-shape could be a good alternative with respect to the Positive Triangularity H-mode from the **power exhaust point of view**

↓

interpretive and **predictive** tools to understand the properties of NT in heat, particles and momentum **transport in the SOL**

<u>Studies</u>

- Study how power and particle exhaust differ between **diverted L-mode** pulses with different triangularity

- Compare the edge transport in **NT configuration** with respect to the one in the **PT configuration in H-mode** (WPTE RT07 2022 + RT22-02 2023)

Outline

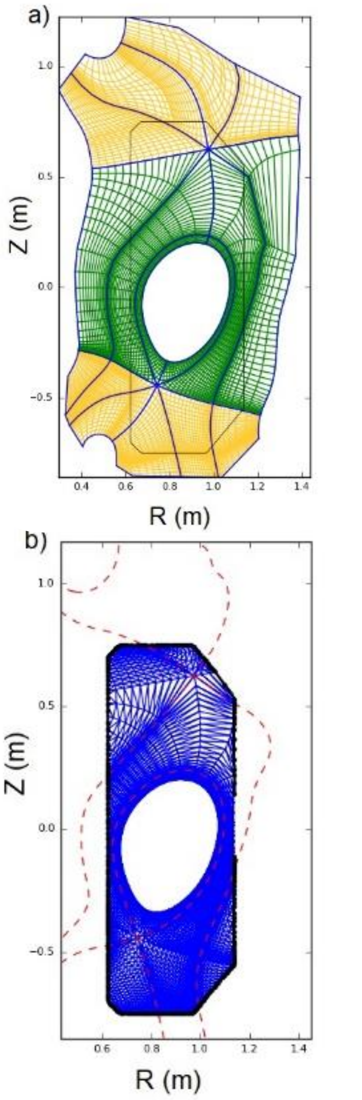
- Tools description
- Results of diverted L-mode pulses with different triangularity
- NT L-mode VS PT H-mode
    - Studies on TCV with DTT-like high power scenario
    - Comparison with previous results
- SOLEDGE3X first application
- Conclusions
- Future studies

Tools description

<u>SOLEDGE2D-EIRENE</u>*
- fluid transport code which solves reduced Braginskii equations for multi-species
- able to simulate tokamak edge plasma in 2D including the realistic wall geometry
- coupled with Monte-Carlo kinetic EIRENE code for neutrals
- requires empirical input parameters (e.g. P_{SOL}, cross-field diffusivities)

<u>How we used it in the studies here presented</u>
- No drifts
- No spatial magnetic field dependences are included in transport values
- No impurity → pure deuterium
- Heat trasport equal for electrons and ions

<u>SOLEDGE3X-EIRENE</u>**
- combination of SOLEDGE2D-EIRENE and the turbulence code TOKAM3X
- 3D first principle turbulence modelling

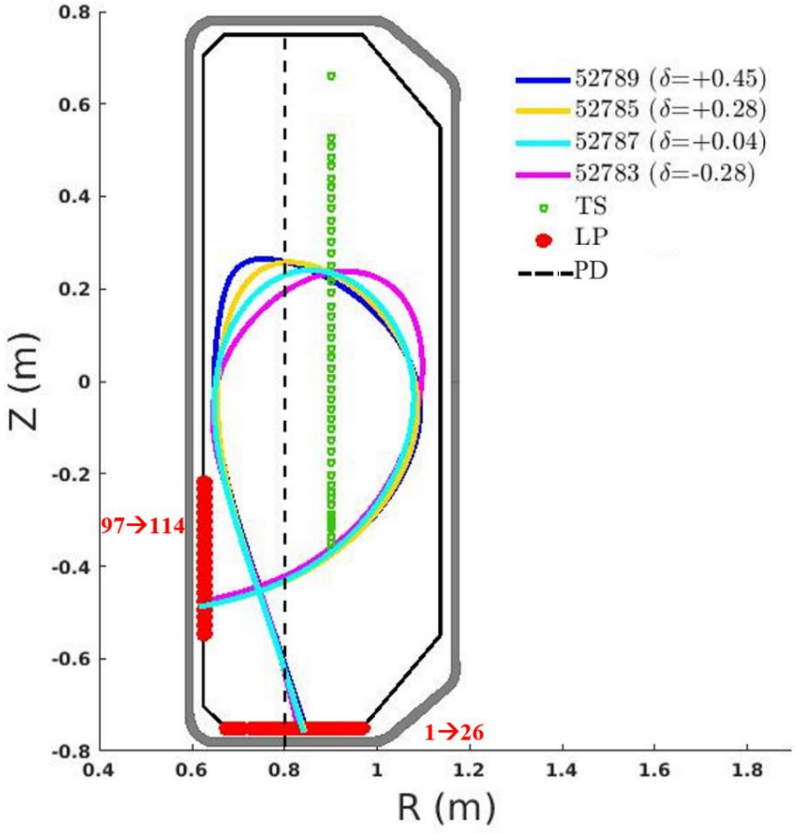


a) SOLEDGE2D quadrangles fluid mesh
b) b) EIRENE triangles mes;

*H. Bufferand et al., 2013, J. Nucl. Mater. 438 S445-S448
**H. Bufferand et al., 2015, Nucl. Fusion 55 053025

Diverted L-mode pulses with different δ_{up}

Equilibria of the TCV pulses



Investigate particle, heat diffusion and heat flux decay length (λ_q) behavior: NT L-mode VS PT L-mode

<u>Tool</u>

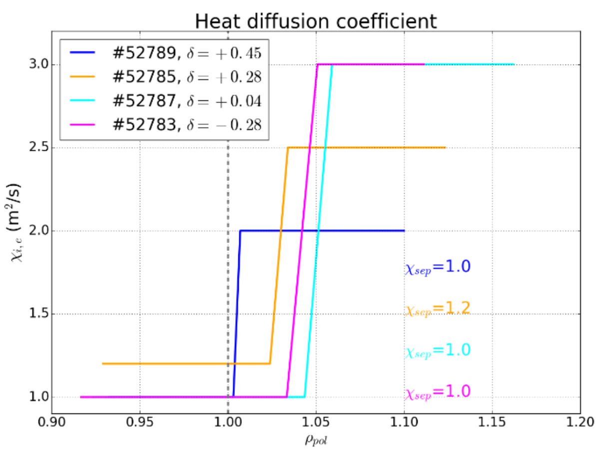
Transport with SOLEDGE2D-EIRENE

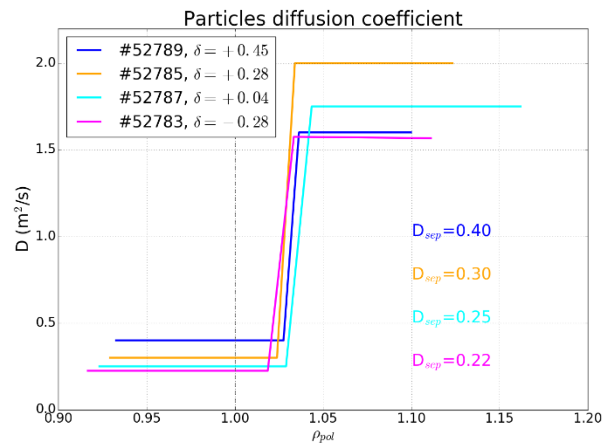
<u>Experimental dataset</u>

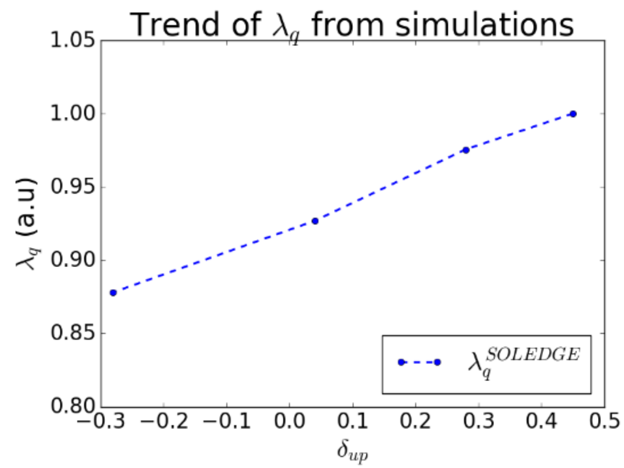
→ upper triangularity scan performed in TCV*
→ ohmically heated
→ L-mode
→ deuterium plasmas
→ high recycling regime

*M Faitsch et al., 2018 Plasma Phys. Control. Fusion 60 045010

Results







The study allowed to characterize the edge transport in NT discharges, showing that the **triangularity affects not only the core but also the edge transport**

In particular, focusing inside and at the separatrix :

→ Particle transport has a monotonic behaviour, decreasing going towards NT, while heat transport does not show any particular trend

→ λ_q on the outer mid plane increases monotonically with δ_{up} (consistent with IRT analysis*, GBS study** and SOLPS simulations***)

Additional studies fixing transport profiles shows that **triangularity affects more the particles or the heat diffusion in the whole near-SOL**

*M Faitsch et al., 2018 Plasma Phys. Control. Fusion 60 045010
**K Lim et al., 2023 Plasma Phys. Control. Fusion 65 085006
***E.Tonello, 2023 EPS Poster

NT L-mode VS PT H-mode: DTT-like

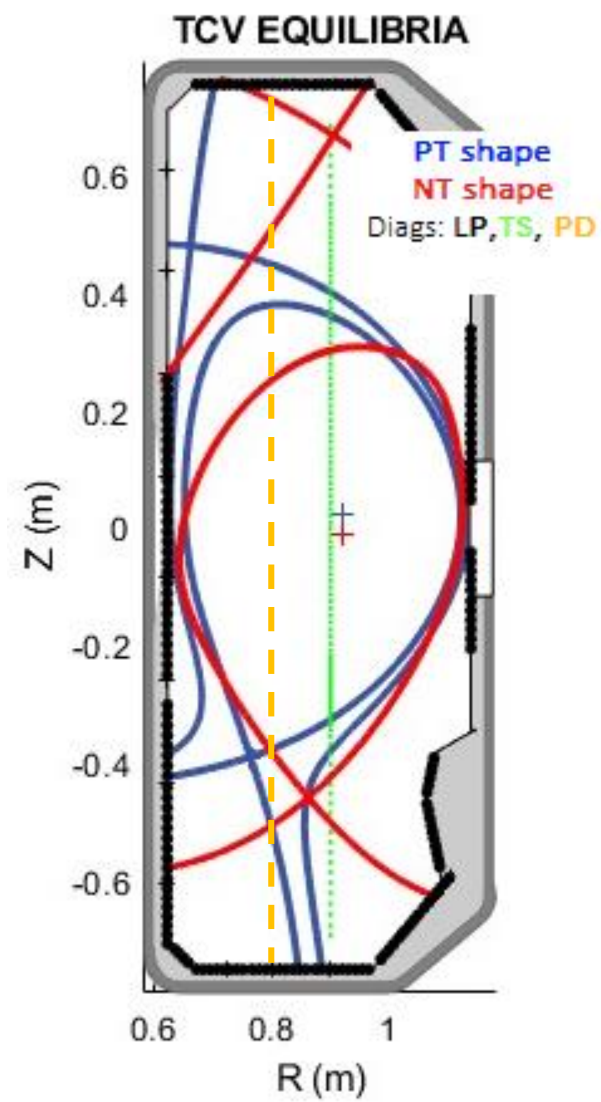
Pulses
PT#76702 VS NT#76735

Similar features
- Magnetic divertor configuration: SN
- $B_T \simeq 1.4$ T for TCV
- $I_{plasma} \simeq 200$ kA for TCV

DTT Triangularity
PT → $\delta_{top} \simeq +0.35$; $\delta_{bottom} \simeq +0.45$
NT → $\delta_{top} \simeq -0.35$; $\delta_{bottom} \simeq +0.07$

Input power (NBI only)
PT → 1300kw
NT →490kW

Tool
SOLEDGE2D-EIRENE



*H. Bufferand et al., 2013, J. Nucl. Mater. 438 S445-S448

NT L-mode VS PT H-mode: DTT-like

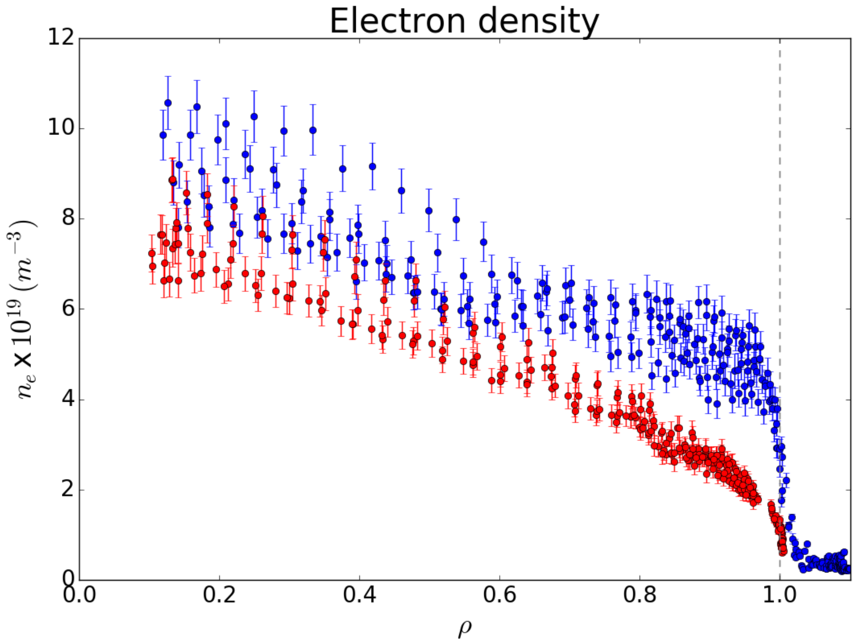
Why this couple of pulses?

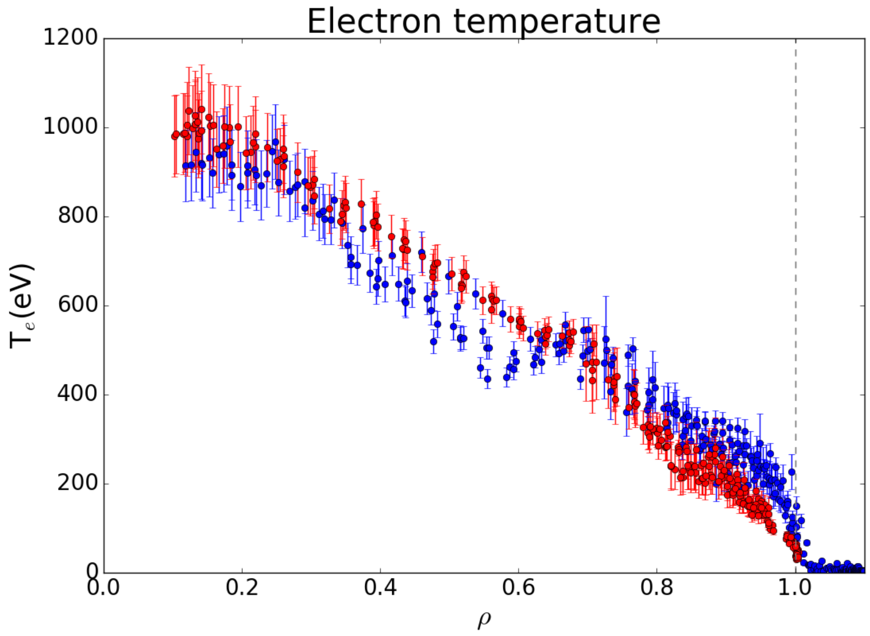
Figure below shows that the **NT L-mode recovers** the n_e and T_e of the PT H-mode **in the core** despite its L-mode condition and lower input power.

OMP profiles (TS data)

PT H-mode: 1300 KW

NT L-mode: 490kW



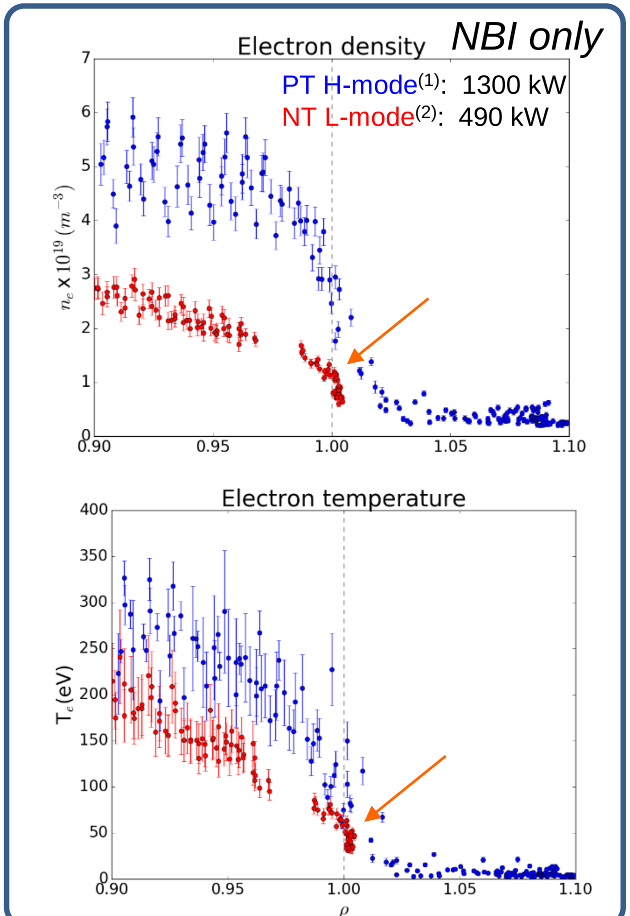


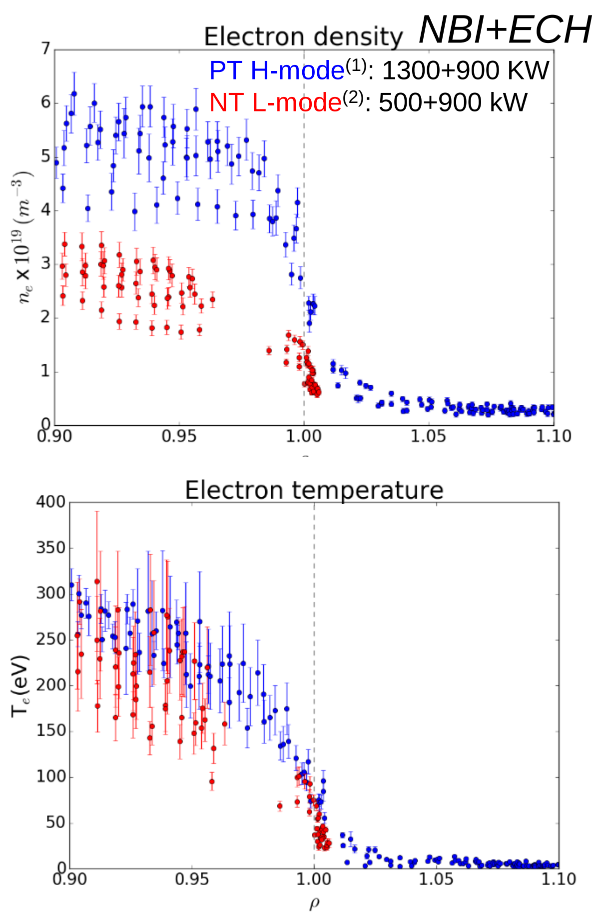
NT L-mode VS PT H-mode: DTT-like

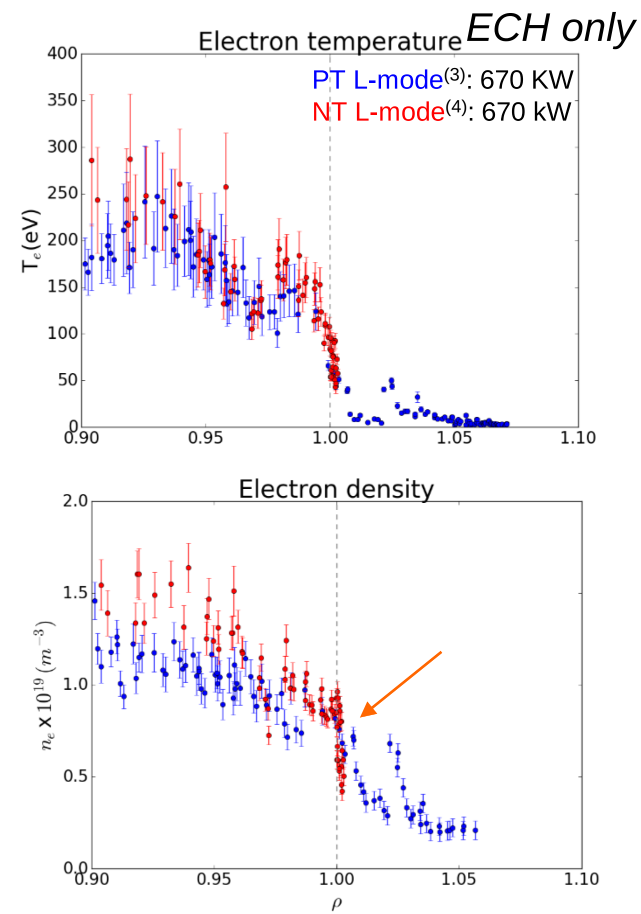
Experimental edge analysis - outer midplane

NT L-mode has a **little barrier** around the **separatrix**, in both density and temperature (agree with DIII-D* and turbulence study**)

→ Could this small barrier have a role in the good confinement which is achievable with the negative D-shape?







(1)TPN 76702; (2)TPN 76735; (3)TPN 76742; (4)TPN 76740

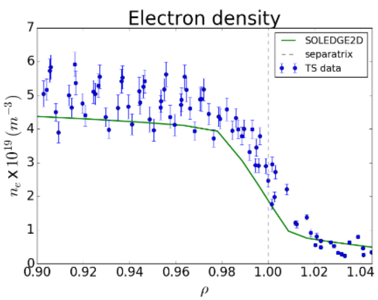
* Nelson A. O., et al. *arXiv preprint arXiv:2305.13458*, 2023
** K Lim et al., 2023 Plasma Phys. Control. Fusion 65 085006

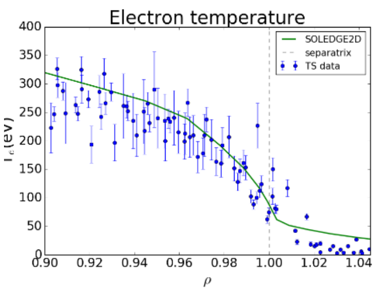
NT L-mode VS PT H-mode: DTT-like

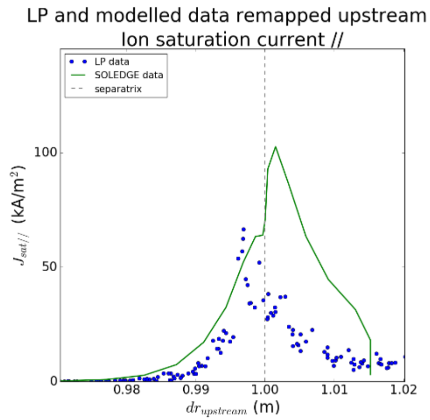
Matching experimental and modelled data TCV pulses - NBI only: PT H-mode vs NT L-mode

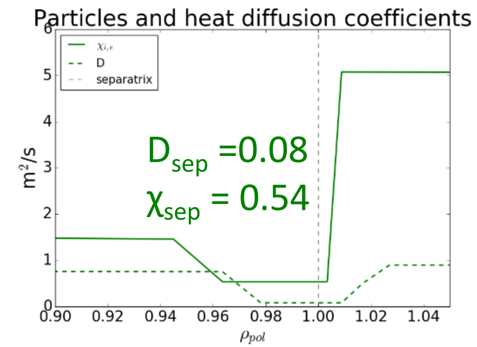
SOLEDGE2D-EIRENE particles and energy diffusion profiles optimised to match experimental measurements, TS in *fig.8a/b* and *fig.9a/b*, and LP in *fig.8c* and *Fig.9c*.

PT H-mode (1)

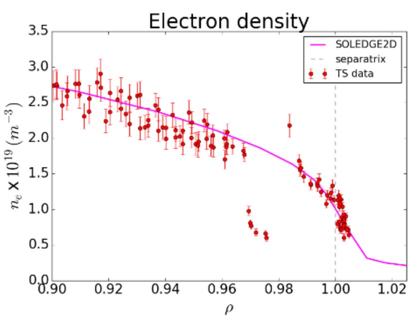


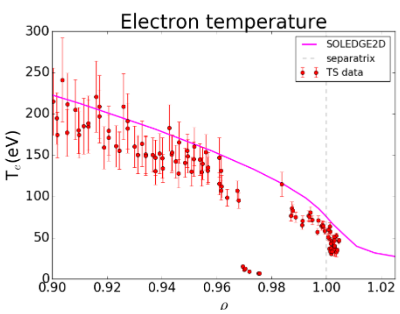


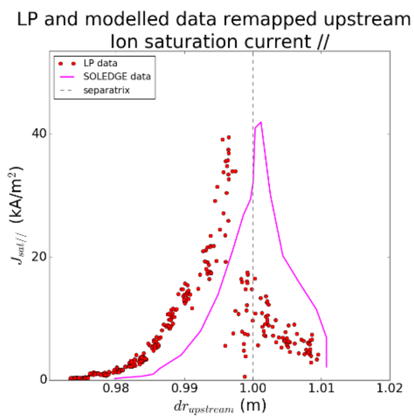


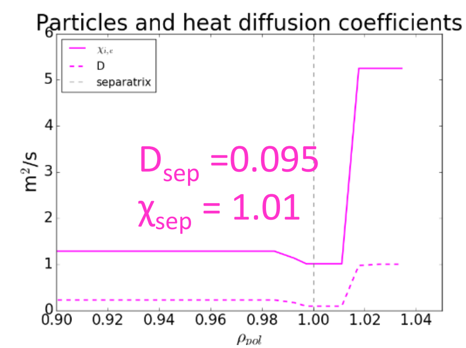


NT L-mode (2)









(1)TPN 76702; (2)TPN 76735

**LP preliminary interELMs data

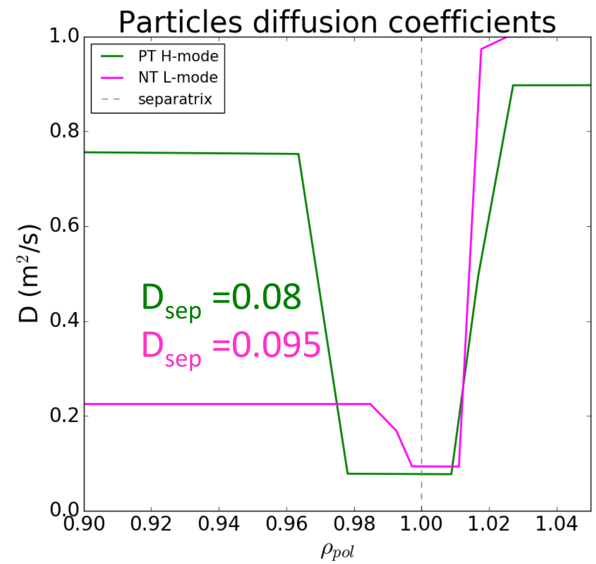
NT L-mode VS PT H-mode: DTT-like

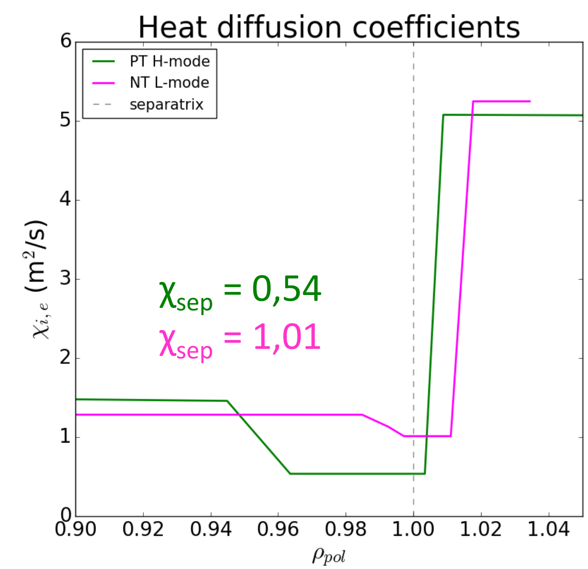
Transport comparison

- Transport studies confirm the **presence of a little barrier for NT**
- Diffusion values in agreement with previous studies*
- **NT transport** around the separatrix and in the near SOL is **more** wrt PT H-mode →heat transport is **twice**!

↓

good for the power exhaust!





*P.Muscente et al., 2023,Nucl. Mater. And Energy, 34 101386

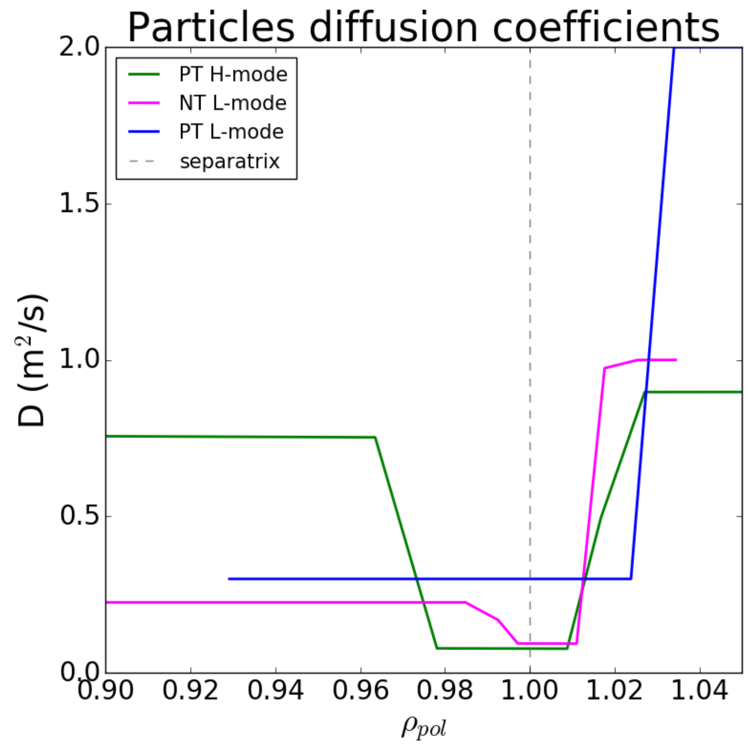
NT VS PT perpendicular transport

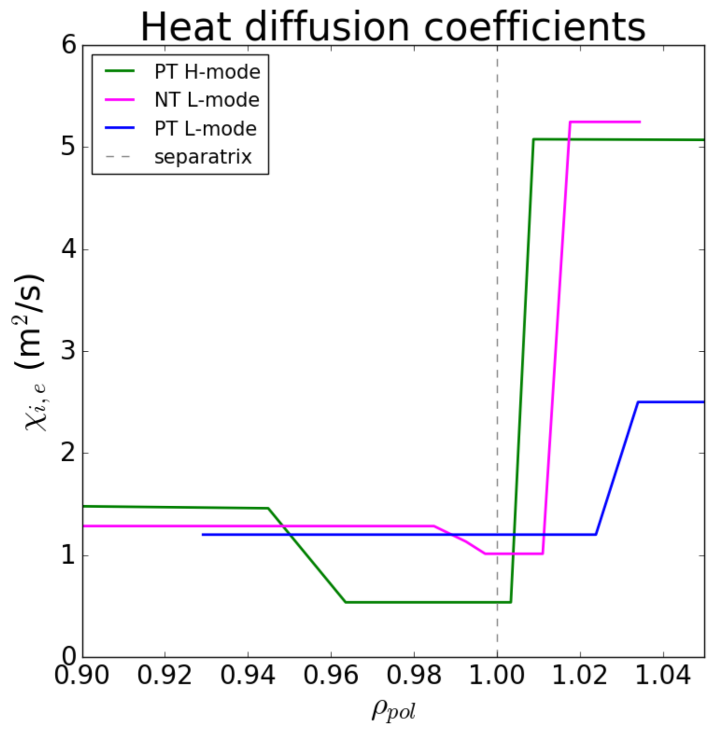
PT L-mode VS NT L-mode + PT H-mode VS NT L-mode

- **NT perpendicular transport** is **between PT L-mode and PT H-mode**

  →Power exhaust performance in between the two

- **NT has better power exhaust performance wrt PT H-mode with the same core performance!**





TPN 76702 TPN 76735 TPN 52785

SOLEDGE3X preliminary application

Improve power exhaust studies with a global approach to edge plasma modelling, including a 3D self-consistent description of the turbulence

SOLEDGE3X

All the features of SOLEDGE2D

+

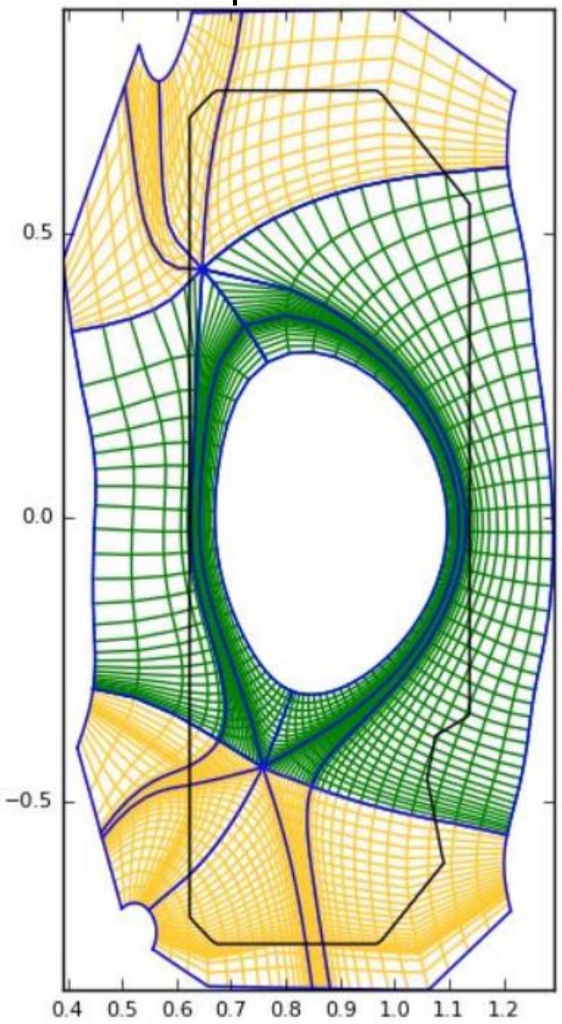
can manage turbulence

self-consistent

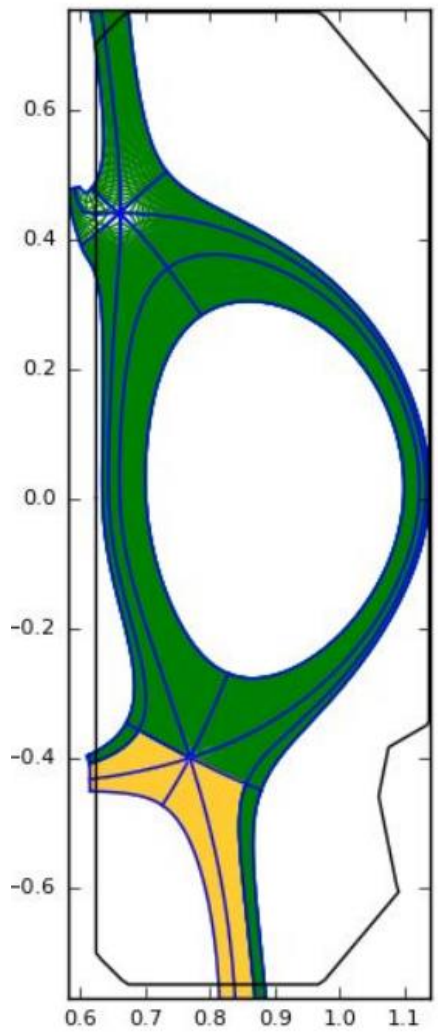
implemented in fluid neutral model: Charge Exchange and Elastic Collision

SOLEDGE3X preliminar application

Trasport mesh



Turbulence mesh



Pulse #73388 - PT L-mode

Definition of the mesh for turbulence

~ 1 mm in poloidal direction

Computational time to create the mesh:

IRFM matlab version ~ 24h

Our python version ~ 2h

In our python version was necessary to implement some new features for the good run of the code

Work flow

- reduced mesh to reduce the computational time
- Start with transport version until a good particle and energy balance is reached
- Activate 3D turbulence mode

Conclusions

Studies on diverted L-mode pulses with different triangularity shows

- Particle transport decrease towards NT (Focusing inside and at the separatrix)
- heat transport does show any particular trend
- triangularity affects more the particles of the heat diffusion in the whole near-SOL
- λq increases monotonically with δ_{up} (consistent with IRT analysis*, GBS study** and SOLPS simulations***)

NT L-mode VS PT H-mode

- presence of a little barrier for NT****
- Diffusion values found are in agreement with our previous studies
- **NT perpendicular transport** around the separatrix and in the near SOL is **bigger** that of PT H-mode

↓

Good for the power exhaust + good core confinement!

*M Faitsch et al., 2018 Plasma Phys. Control. Fusion 60 045010
**K Lim et al., 2023 Plasma Phys. Control. Fusion 65 085006
***E.Tonello, 2023 EPS Poster
****Nelson A. O. et al., *arXiv preprint arXiv:2305.13458*, 2023.

Future studies

- Simulation on other couples of pulses to study λ_q features and check NT features found
- Study on AUG pulses
- Use flux input parameters from core simulations to
  → Be able to divided in ions and electron dynamics
  → Match transport parameter with core simulations
- Turbulence simulation with SOLEDGE3X
- Comparison between transport and turbulence simulations

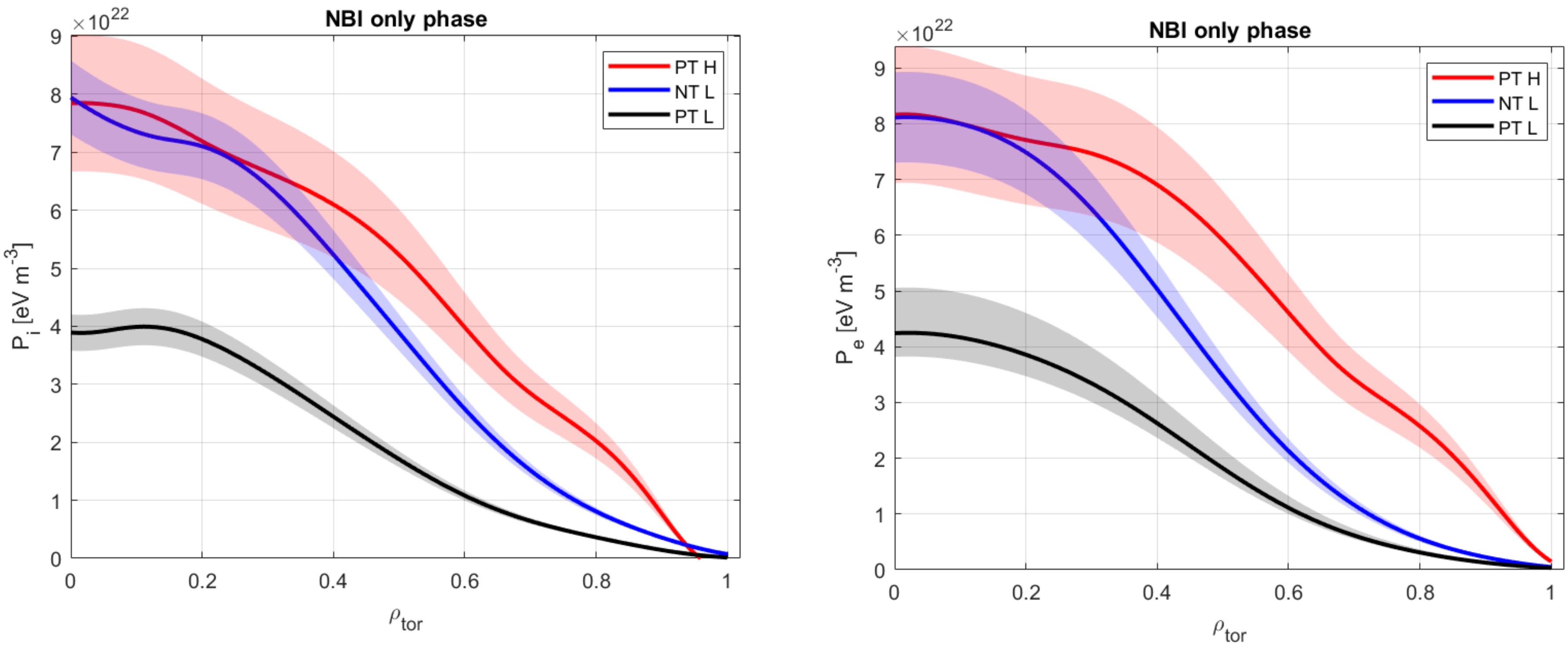
Thanks for your attention!

Backup slides

NT L-mode VS PT H-mode: parameters

	SHOT	76702 PT H-mode	76735 NT L-mode
	Time (s)	1,05 s	0,9s
Comparison Parameters	I_p	-200 kA	-175
	Volume / area	$1{,}41m^3/0{,}26m^2$	$1{,}42m^3/0{,}25m^2$
	q0/q95	1,4/4,5	0,9/4,43
	β_{pol}	1,1	0,89
	δ_{top} / δ_{bottom}	+0,4 / +0,5	-0,28/+0,09
	B_T (at R=0,88m)	-1,42 T	-1,42 T
	T_e max (TS)	1 keV	1 keV
	$<n_e>$ (FIR)	$6{,}2 \times 10^{19}$ m^{-3}	
Powers	P_{NBI} (with loss due to the duct)	1080 kW	422 kW
	$P_{gyro(ECH)}$	0	0
	P_{OHM}	150 kW	130kW
	$P_{rad,tot}$	600 kW	275 kW
	P_{ELMs}	2 kW	0
	P_{input} (without impurity) = $P_{NBI}+P_{OHM}+P_{ICRH}-P_{rad,tot}-P_{ELMs}$	**628 kW**	**277 kW**
Gas	Valve 1	D_2 0 atom/s (10 mbar/s = 10 x e^{20} molecules/s)	0
	Valve 2	0	0
	Valve 3	0	0
BC density	NBI electrons/s - Density_BC (flux)	**2,77 x e^{20}**	**1,55 x e^{20}**

NT L-mode VS PT H-mode: pressure



*See P.Mantica et al., TSVV-02 presentation on Monday