Guidelines proposal for Chapter 2 of the DTT Research Plan
Plasma scenarios

1. Introduction

This chapter provides

1) a recall of heating phases
2) a general overview of achievable plasma scenarios in the different heating phases
3) examples of flat-top profiles obtained by JINTRAC/ASTRA integrated modelling with first-principle transport models
4) basic guidelines on pulse design (Ip ramp-up, flat-top, Ip ramp-down) and flux consumption optimization. Use of METIS to explore complete scenario time evolution.
5) examples of full pulse simulations obtained with ASTRA integrated modelling with first-principle transport models
6) discussion on alternative scenarios to baseline
7) discussion on negative triangularity

2. DTT heating phases

Recalls DTT phases with their heating capabilities (A, B, C, D, E)

scenario	q95	I	BT	divertor	EC (installed)	IC (installed)	NBI (installed
A	**5 (SN)**	**2**	**3**	**SN/XD**	**8**	**0**	
A NT	5	1.5	3	NT	8	0	
B	**5 (SN)**	**2**	**3**	**SN/XD**	**16**	**4**	
B NT	5	1.5	3	NT	16	4	
C	**5 (SN)**	**4**	**6**	**SN/XD**	**16**	**4**	
C NT	5	2.9	6	NT	16	4	
D	**3**	**5.5**	**6**	**SN**	**16**	**4**	**5-10**
D XD	TBD	4.5	6	XD	16	4	5-10
D NT	3	4	6	NT	16	4	5-10
D low	5	2	3	SN	16	4	5-10
E	**3**	**5.5**	**6**	**SN**	**32**	**8**	**10**
E XD	TBD	4.5	6	XD	32	8	10
E NT	3	4	6	NT	32	8	10
E low	5	2	3	SN	32	8	10

Phase 1
2028-2032 (scenarios A to C)

Phase 2
2032-2036 (scenarios C NT to D XD/D NT)

Phase 3
2036-2040 (scenarios D low to E low)

3. Scenarios that can be accessed by DTT in the different heating phases

3.1 Phase A: 8 MW ECH 2028-2030

Power	BT/Ip	Achievable scenario
	3/2	H-mode baseline SN , XD ($\beta_N = 1.1$)
8 MW ECH	3/1.5	NT L-mode
	3/2	Hybrid? ($\beta_N = 1.1$) (H=1)

A

3.2 Phases B and C: 20 MW ECH+ICH 2030-2032

Power	BT/Ip	Achievable scenario
	3/2	H-mode baseline SN , XD ($\beta_N = 1.6$)
16 MW ECH +4 MW ICH	3/1.5	NT L-mode
	3/1.5	Hybrid ($\beta_N = 1.4$) (H=1)
	3/1.5	High β AT scenario
	6/4	H-mode baseline SN , XD ($\beta_N = 1.0$)
16 MW ECH +4 MW ICH	6/3	NT L-mode
	6/4	Hybrid
	6/4	I-mode
	6/4	EDA, QCE, QH, WPQH

B

C

3.3 Phase D: 30 MW ECH+ICH+NBI 2032-2036

Power	BT/Ip	Achievable scenario
	6/5.5-4.5	H-mode baseline SN , XD ($\beta_N = 1.3–1.2$)

D

16 MW ECH +4 MW ICH + 10 MW NBI	6/4.	NT L-mode
	6/4.5	Hybrid
	6/5.5	I-mode (but NBI counter-current)→ use reverse BT/Ip and LSN no NBI
	6/5.5	EDA, QCE, QH, WPQH
	3/2	H-mode baseline SN , XD ($\beta_N = 1.8$)
16 MW ECH +4 MW ICH + 10 MW NBI	3/1.5	NT L-mode
	3/2	Hybrid
	3/1.5	High β AT scenario ($\beta_N = 1.6$)

D
Low BT

3.4 Phase E: 45 MW ECH+ICH+NBI 2036-2040

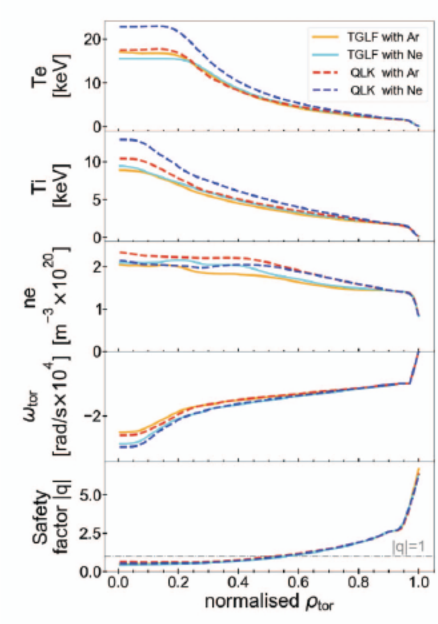
Power	BT/Ip	Achievable scenario
	6/5.5-4.5	H-mode baseline SN , XD ($\beta_N = 1.5–1.35$)
32 MW ECH +8 MW ICH + 10 MW NBI	6/4.5	NT L-mode
	6/4.5	Hybrid
	6/5.5	I-mode (but NBI counter-current)
	6/5.5	EDA, QCE, QH, WPQH
	3/2	H-mode baseline SN , XD ($\beta_N = 1.8$)
16 MW ECH +4 MW ICH + 10 MW NBI	3/1.5	NT L-mode
	3/2	Hybrid ($\beta_N = 1.8$)
	3/1.5	High β AT scenario ($\beta_N = 1.6$, H=1)

E

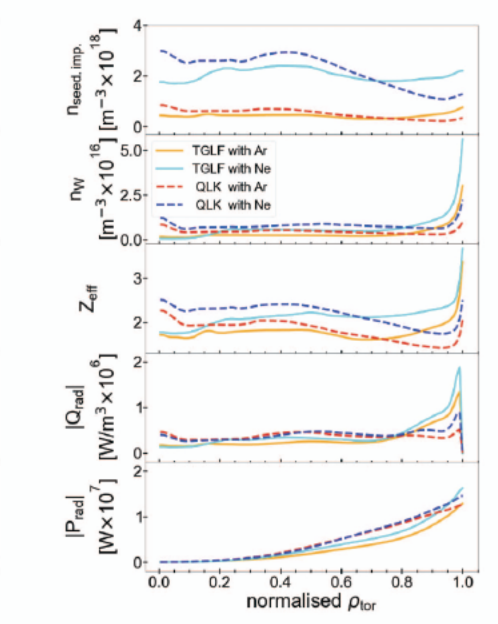
E
Low BT

4. Flat-top profiles obtained by JINTRAC/ASTRA integrated modelling with first-principle transport models

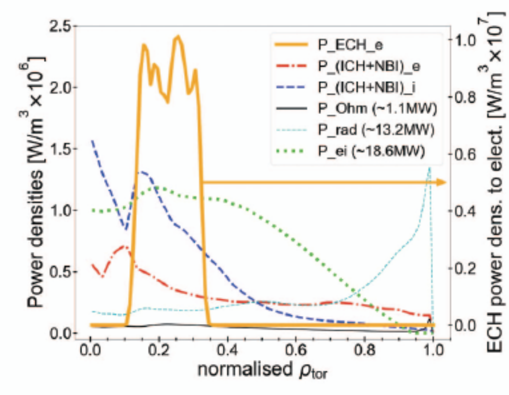
4.1 Scenario E SN baseline



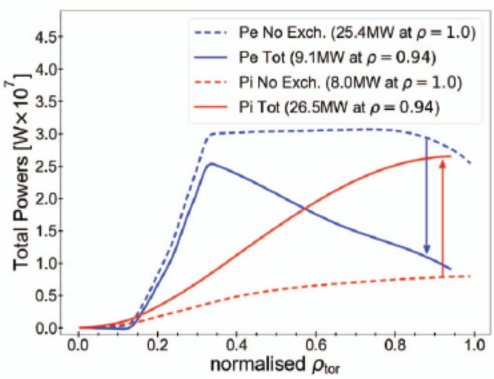
(a)



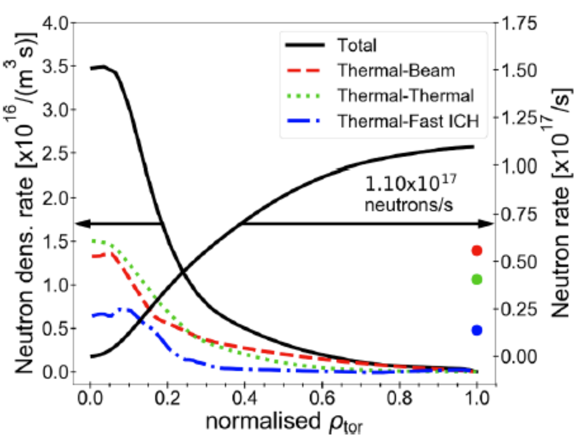
(b)

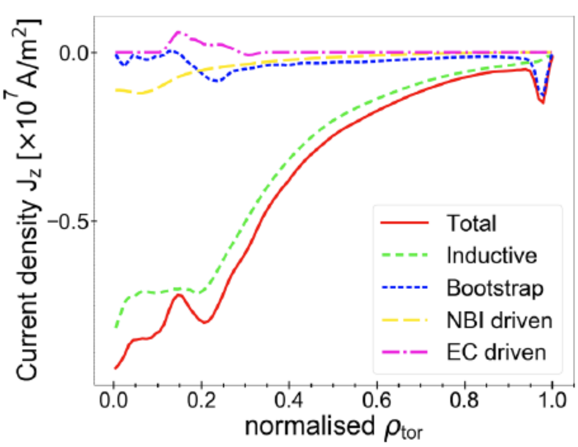


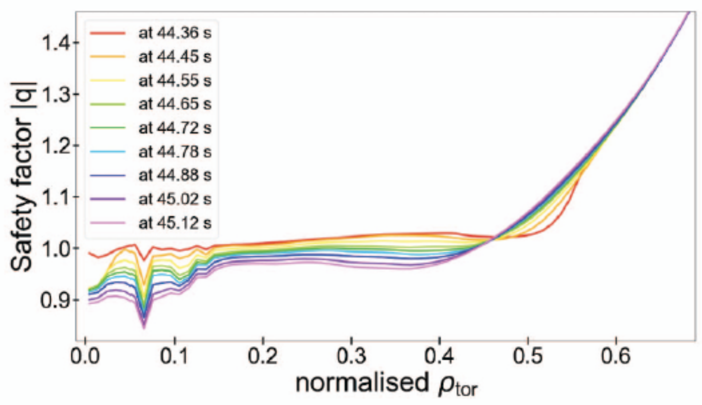
(a) Power densities.



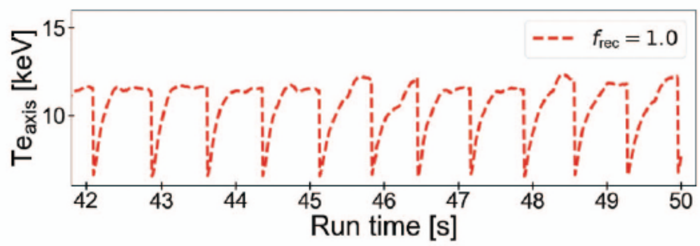
(b) Volume integrated powers.







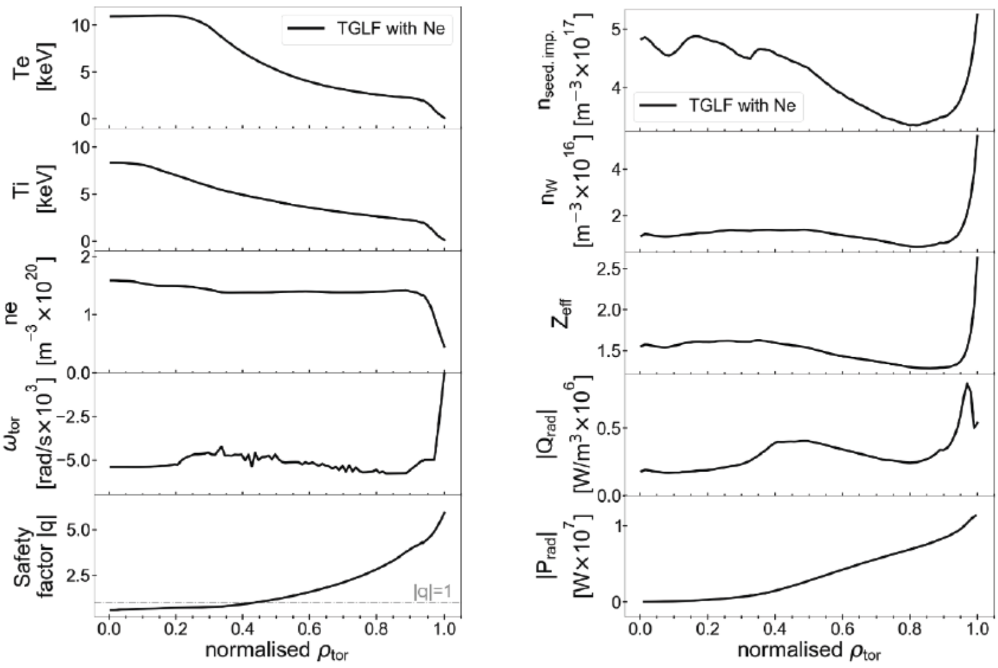
(a) Relaxation of the $|q|$ profile.



(b) Time evolution of T_{e_0}.

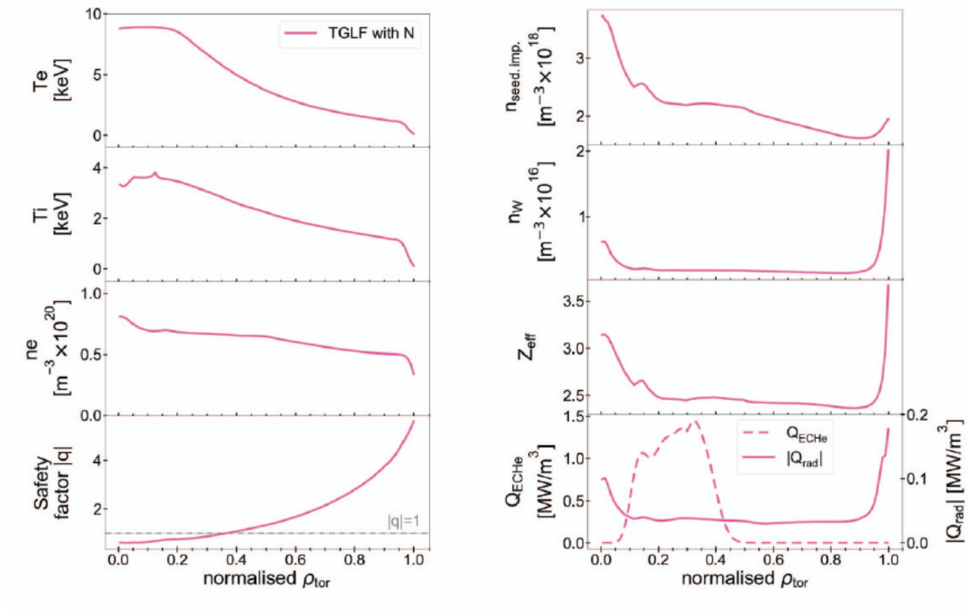
Figure 9. Time evolution (a) of the $|q|$ profile after a sawtooth crash and (b) of the electron temperature at the plasma centre T_{e_0}, using a complete reconnection model (i.e. with $f_{rec} = 1.0$).

4.3 Scenario C SN baseline



(a) (b)

4.2 Scenario A SN baseline



(a) (b)

5. Designing the full time evolution of a DTT scenario

Discuss using METIS various critical elements of building a scenario, up to a complete time dependent METIS simulation

5.1 Break-down

D.Ricci_M.Mattei flux consumption ~ 1.5 Vs

5.2 Ip ramp-up

Discuss Ip rate minimum 400 kA/s, need of impurities from which time, role of density and power to save flux, when L-H transition is acceptable flux consumption ~ 13.5 Vs

5.3 Flat-top

Discuss minimum duration for physics results flux consumption ~ 4.5 Vs

5.4 Ip ramp-down

Ip rate 250 kA/s,discuss problem of li increase and impurity radiative collapse, need of slow decrease of ECH heating, keep 10 MW ECH off-axis flux consumption not an issue since the inductive part is recharging the CS

6. ASTRA simulations of DTT E and A SN scenarios using IMEP and TGLF

6.1 Scenario E SN baseline

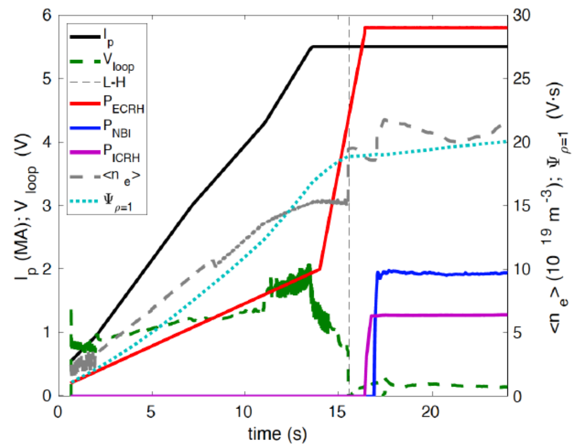
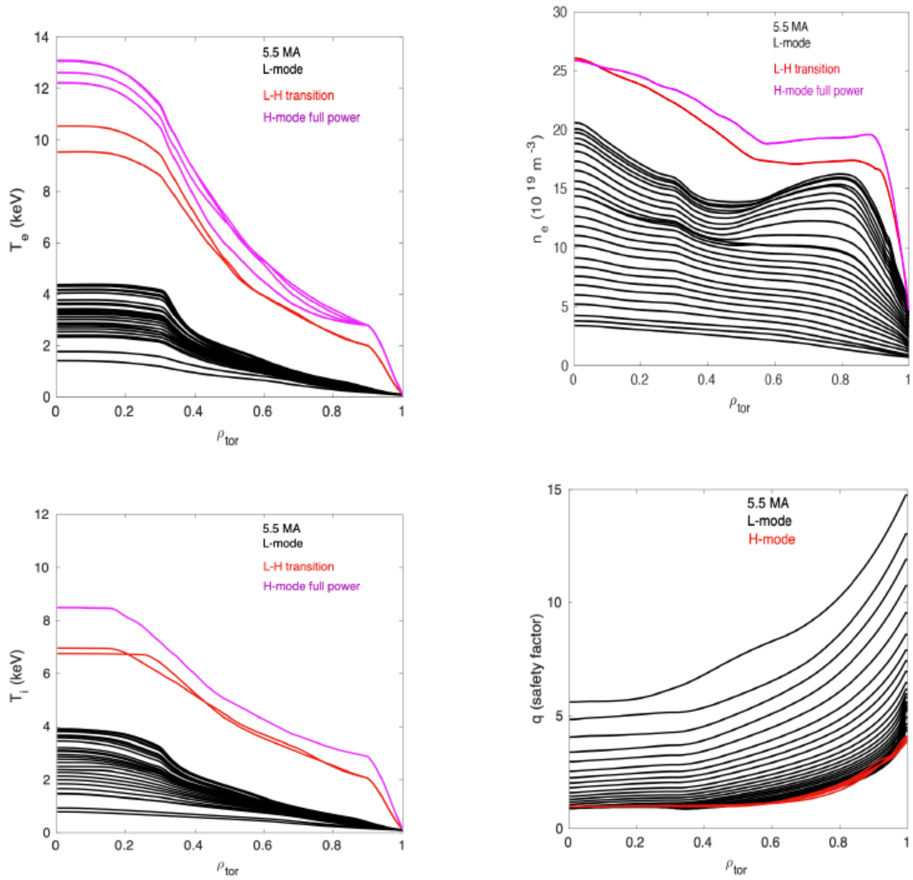


Fig.5: Time evolution of the main plasma parameters and heating sources for the case with 5.5 MA, with impurities, L-H transition based on Martin scaling.



From N.Bonanomi et al., to be submitted

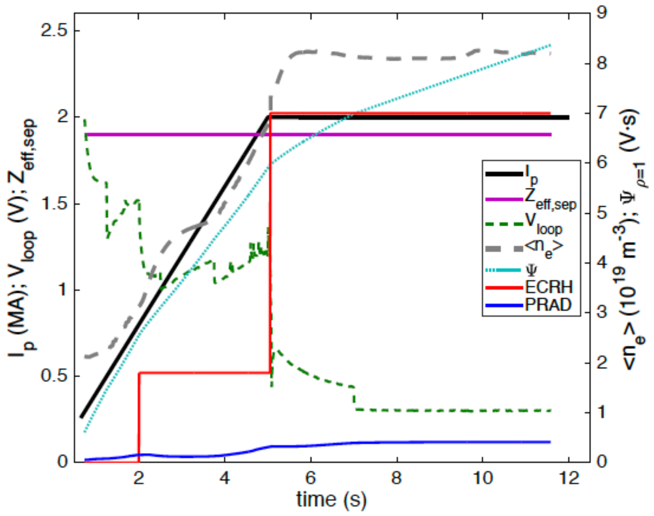
Comparison DTT-ITER-DEMO

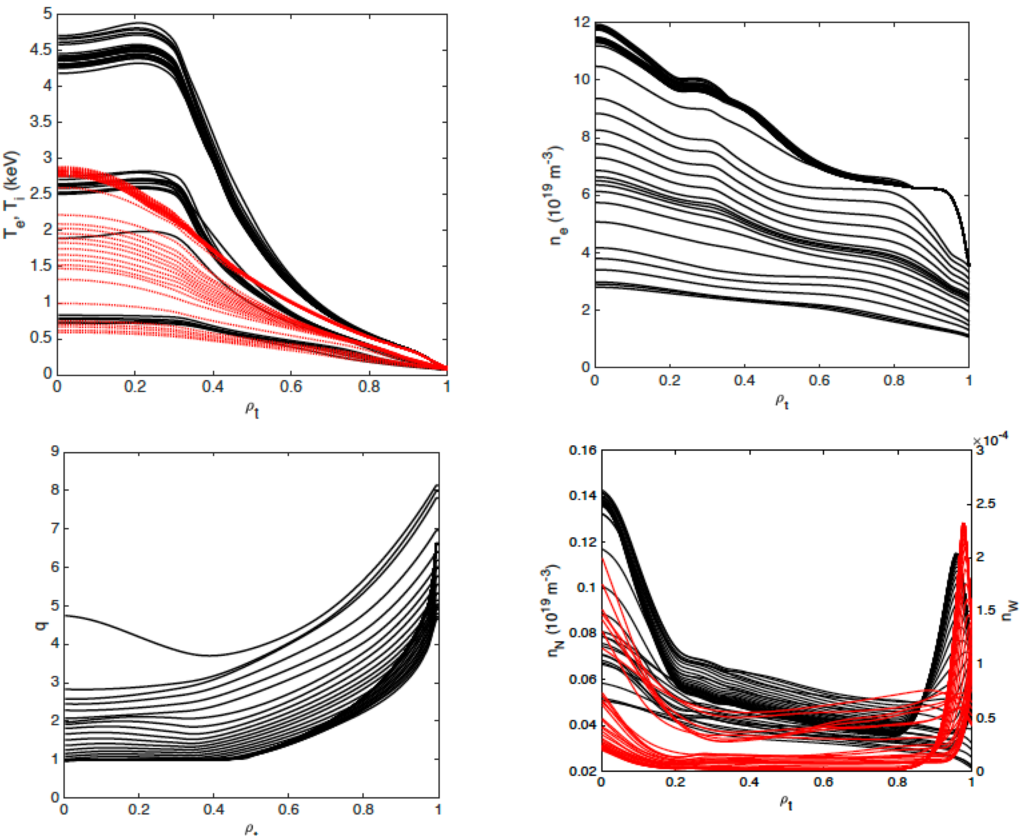
	DTT 5.5 MA 0.55 nGW at flat top	ITER	EU DEMO 2018
R [m] / a [m]	2.19/0.7 = 3.1	6.2/2.0 = 3.1	9.07/2.93= 3.1
Ipl [MA] / Btor[T]	5.5/5.85	15/5.3	17.75/5.86
Psep/R [MW/m]	15	14	18.9
Ptot [MW]	45	150	450
Pulse length [s]	<95	400	7200
β_N [%]	2.1	2.1	2.5
τ_E [s] P=Psep	0.45	2.9	6.9
ρ^* at ρ_{tor}=0.5 [10^{-3}]	4.1	2.0	1.5
ν^* at ρ_{tor}=0.5 [10^{-2}]	0.75	0.3	0.3
ρ^*_{ped} [10^{-3}]	2.5	1.4	0.8
ν^*_{ped} [10^{-2}]	8	2.2	8
q_{95}	3.15	3.2	3.89
n_{GW} [10^{20} m-3]	3.6	1.2	0.66

Table 3: Comparison of main plasma parameters for reference baseline full power scenarios in DTT (flat-top of Fig.5-6, n_e/n_{GW}~0.6), ITER and DEMO. Definitions ν_e*=6.921 10^{-18} (q R n_e Z_{eff} lnΛ_e) /(T_e^2 $\varepsilon^{3/2}$) with lnΛ_e =31.3-ln($\sqrt{n_e}/T_e$) and with ε= (a/R) $\sqrt{(1+k^2)/2}$ where a and R are the minor and major radii of the machine, k the elongation at the separatrix, while local values of q, Z_{eff}, n_e, and T_e are used. $\rho^*=\sqrt{2T_i m_i}/$ (e a B_{tor}) with T_i in [J] and m_i in [kg].

6.2 Scenario A SN baseline

Simulations to be improved





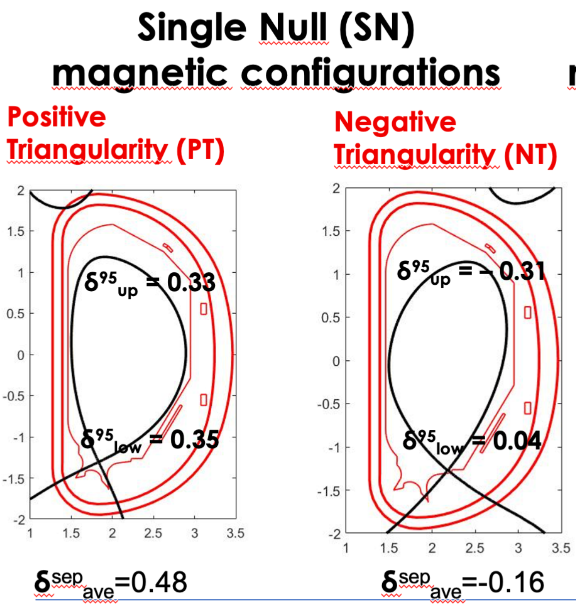
From N.Bonanomi et al., to be submitted

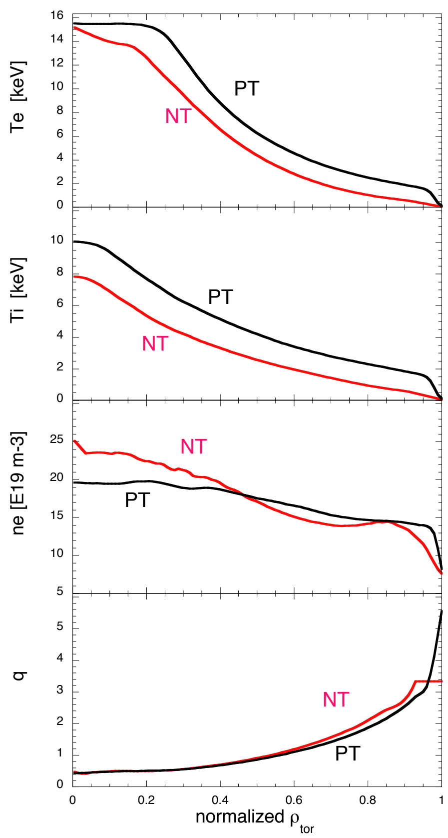
7. **Alternative scenarios to ELMy H-mode baseline**

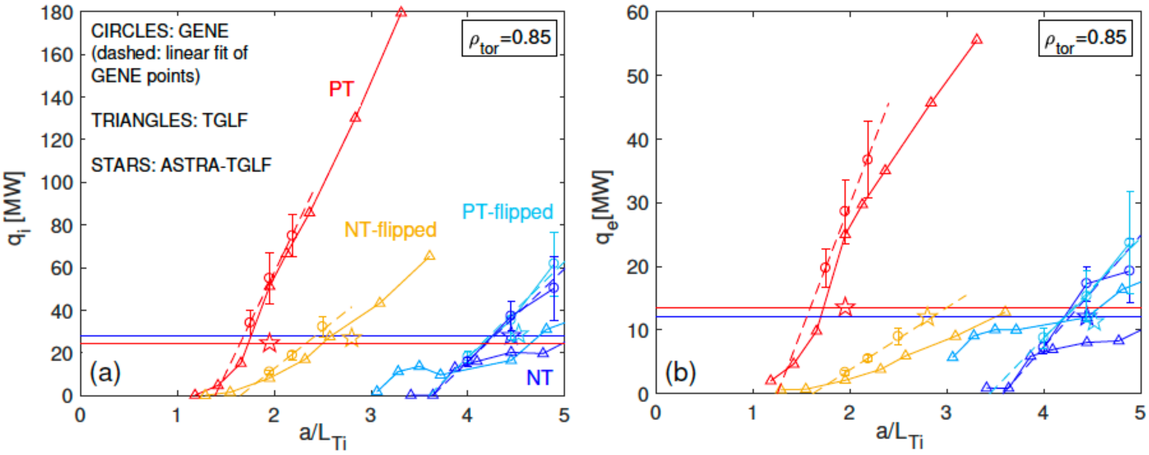
7.1 Small ELM scenarios

7.2 Advanced scenarios

8. **Discussion on negative triangularity scenarios**







TGLF Sat2 validation against NL GENE [Mariani, to be submitted]