CIP 2026

Core-edge integrated predictions of DTT scenarios from early phases to full power operations

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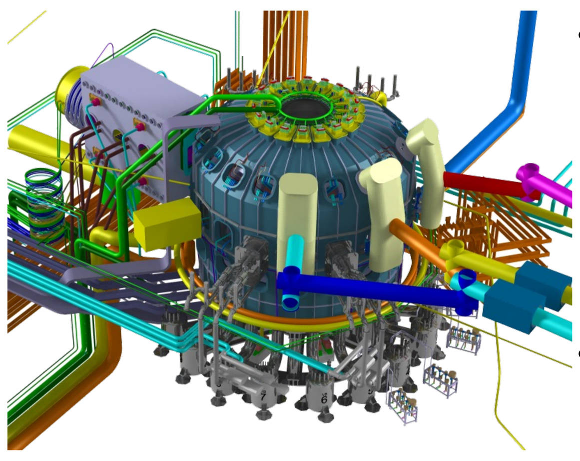
The DTT tokamak

- The Divertor Tokamak Test (DTT) facility is currently under construction in Frascati (Italy).
- Its main objective is to develop credible solutions for heat and particle exhaust, in a core-edge integrated approach, to assess the compatibility of exhaust solutions with reactor relevant core performance.

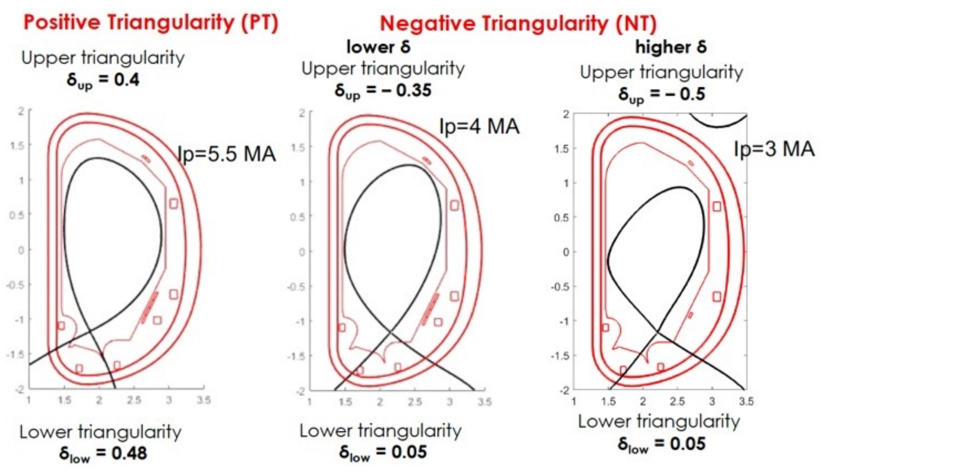
TABLE 1: DTT MAIN DESIGN PARAMETERS	
major radius R (m)	2.19
minor radius a (m)	0.70
Volume (m^3)	35
Gas	Deuterium
Plasma current (MA)	5.5
Vacuum $B_{toroidal}$ at R=2.19 m	5.85
Electron density $\overline{n_e}$ (10^{20} m^3)	1.5
Auxiliary power P_{tot} (MW)	45
P_{ECRH} (MW)	29
P_{ICRH} (MW)	6
P_{NBI} (MW)	10



- DTT will also contribute to study topics such as transport, MHD, energetic particle physics, heating and current drive.
- A complete Research Plan has been issued in May 2024.

Integrated modelling of DTT scenarios

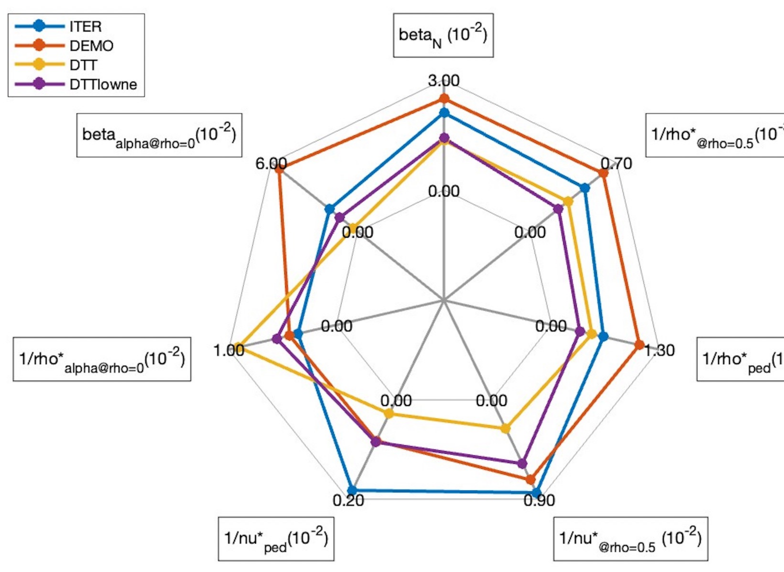
- Integrated modelling of DTT scenarios has been key for the design optimization: finalization of machine size, choice of heating mix and fuelling, nuclear shield assessment, choice of Central Solenoid, diagnostic design. It has also been the starting point for the elaboration of the DTT Research Plan.
- Simulations have been performed using the ASTRA or JINTRAC transport frameworks using: TGLF SAT2 for core turbulent transport, NCLASS or FACIT for neoclassical transport, GRAY for ECH, PION for ICH, PENCIL or RABBIT for NBI, EUROped for pedestal. Electromagnetic equilibria have been developed using CREATE-NL+ and CREATE-L codes.
- Predicted quantities: T_e, T_i, n_e, n_{Ar}, n_W, J. Boundary conditions were taken from edge/scrape-off layer simulations. Rotation is modest and has little effect on transport. Equilibrium evolved self-consistently.
- Steady-state simulations have been made for the steady-state flat-top and dynamic simulations for current ramp-up and ramp-down
- The geometric configurations used are SN PT and NT. XD in progress.



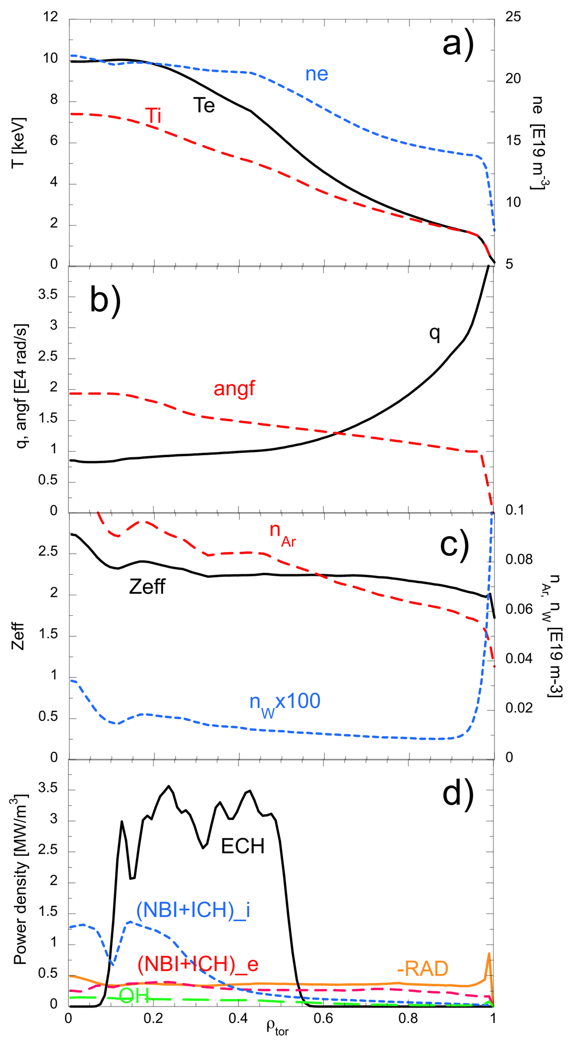
Scenario	I_p (MA)	B_T (T)	divertor	Power installed (MW)		
				EC	IC	NBI
Phase 1 ~ 5 years						
A	2	3	SN/XD	8	0	0
A NT	1.5	3	NT	8	0	0
B	2	3	SN/XD	16	4.75	0
B NT	1.5	3	NT	16	4.75	0
C	4	6	SN/XD	16	4.75	0
C NT	3	6	NT	16	4.75	0
Phase 2 ~ 5 years						
D	5.5	6	SN	16	4.75	10
D XD	4.5	6	XD	16	4.75	10
D NT	4	6	NT	16	4.75	10
D at low B_T	2.75	3	SN	16	4.75	10
Phase 3 > 10 years						
E	5.5	6	SN	32	9.5	10
E XD	4.5	6	XD	32	9.5	10
E NT	4	6	NT	32	9.5	10
E at low B_T	2.75	3	SN	32	9.5	10

Full Power Scenario

Comparing DTT dimensionless parameters with ITER and DEMO

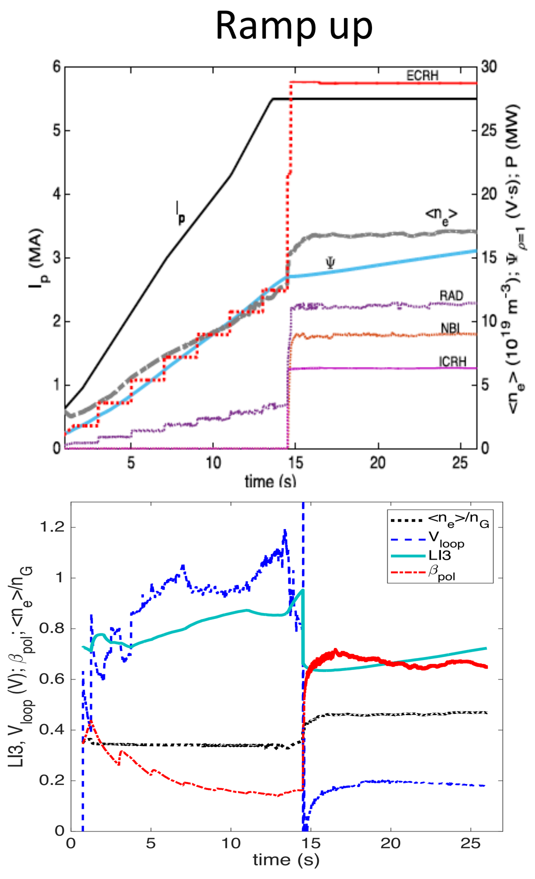


Flat-top



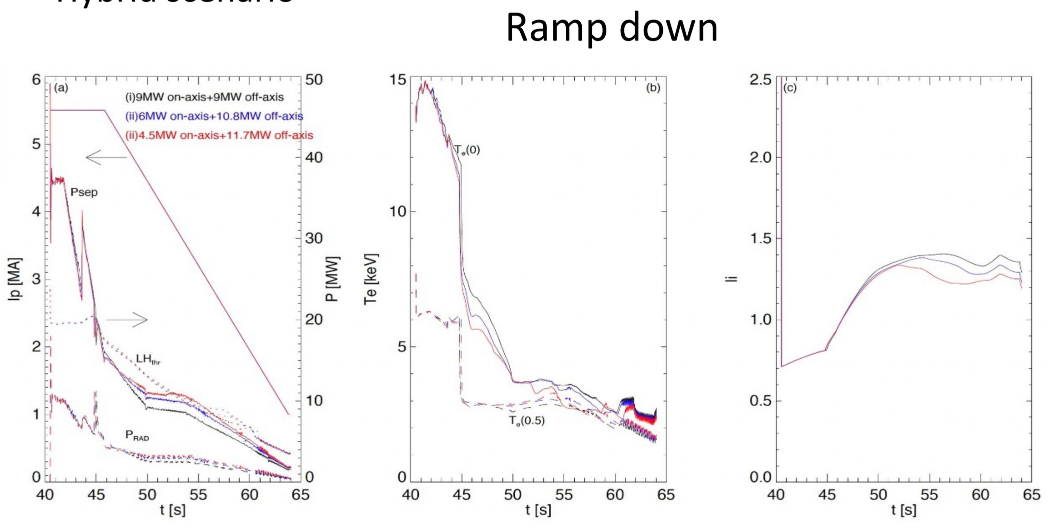
- Off-axis ECH is used in ramp-up and ramp-down to control l_i and limit CS flux consumption→ flat-top~ 30-40 sec

Ramp up



- In flat-top ECH is kept broad to avoid TEM dominant behaviour and density drop
- W is not accumulating
- Large sawteeth are an open issue → develop an Hybrid scenario

Ramp down

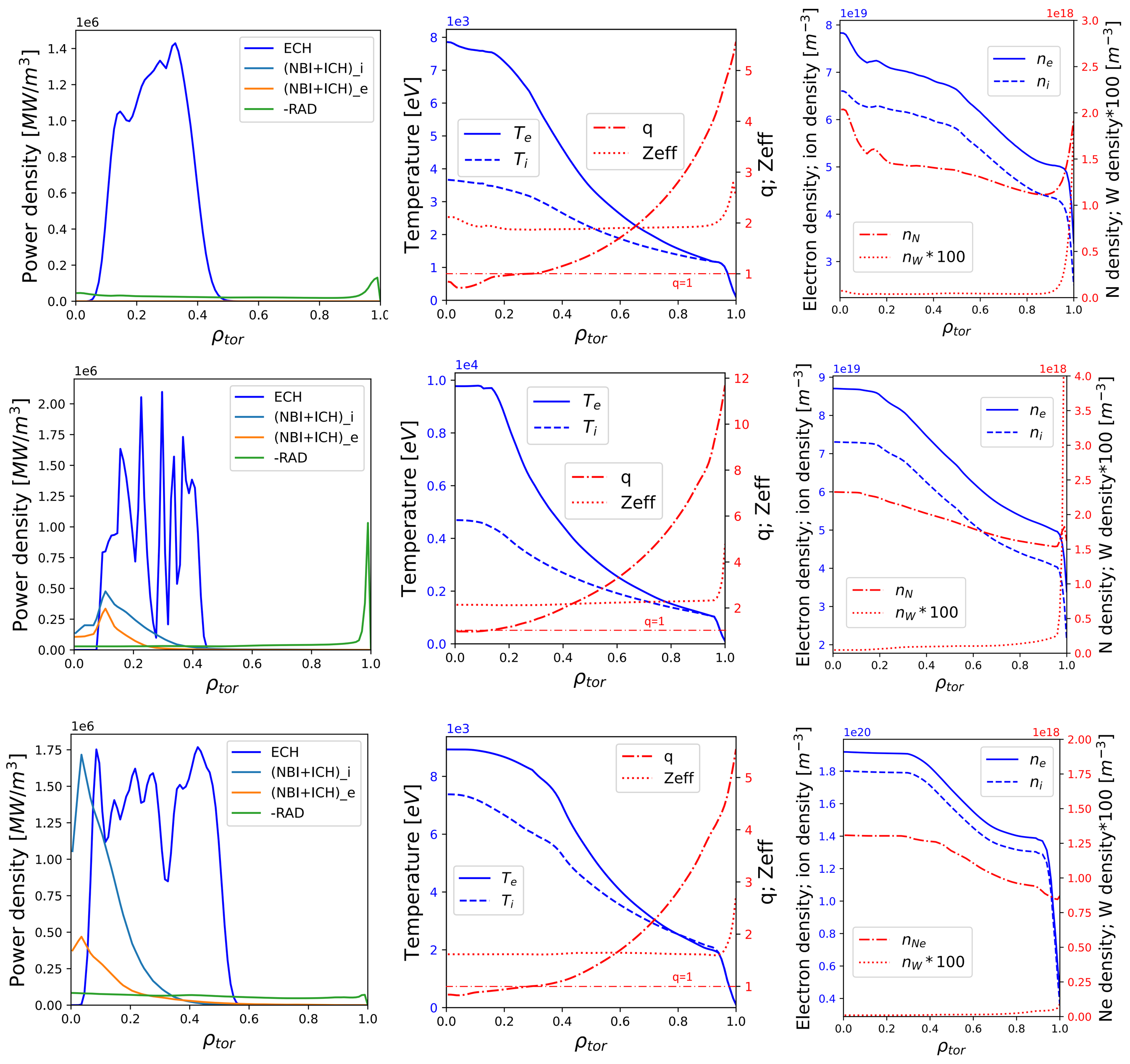


Early Operation Scenarios

Scenario A
I_p =2MA
B_t=3T
7.2 MW of ECRH

Scenario A*
I_p =2MA
B_t=6T
7.2 MW of ECRH
1.5 MW of ICRH

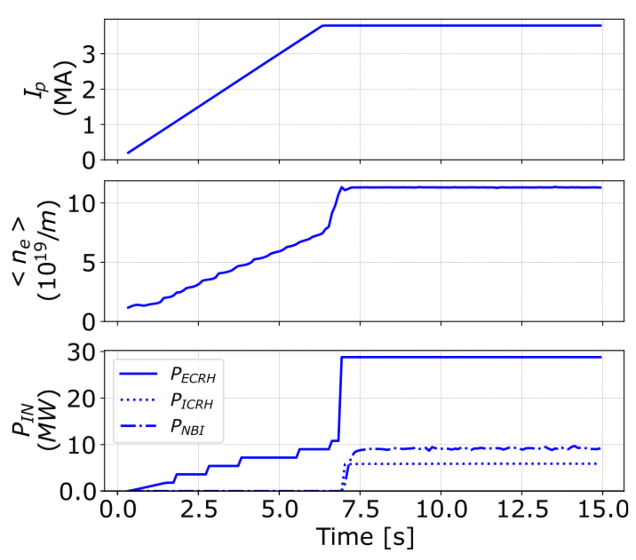
Scenario C
I_p =4MA
B_t=6T
16 MW of ECRH
4.75 MW of ICRH



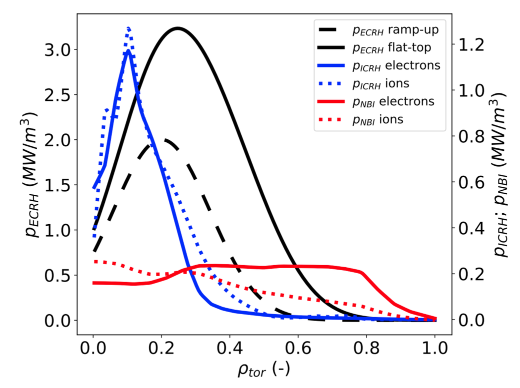
- Scenario A, A* and C at flat-top have been simulated with JINTRAC but taking impurity profiles from ASTRA in self-consistent iterations. All are in H-mode. A continuous sawtooth model has been applied.
- All simulations are stored in IMAS framework in a database provisonally located on the ITER cluster.

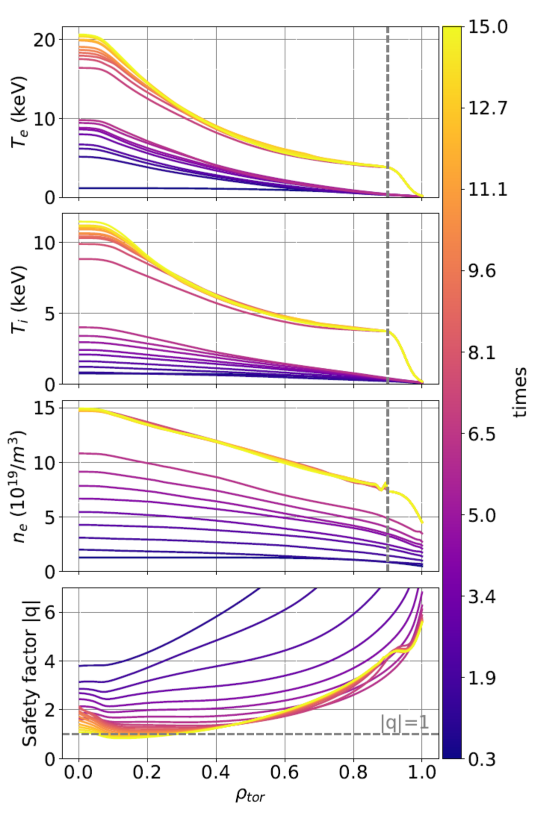
Hybrid Scenario

- In DTT, the q-profile tailoring is possible by acting on the resistivity rather than actively injecting current → **Early heating as soon as possible!**
- Early X-point formation (1.5s) is needed to anticipate the heated phase.
- The overshoot is unfeasible, and the ECCD at high density does not strongly modify the q-profile.



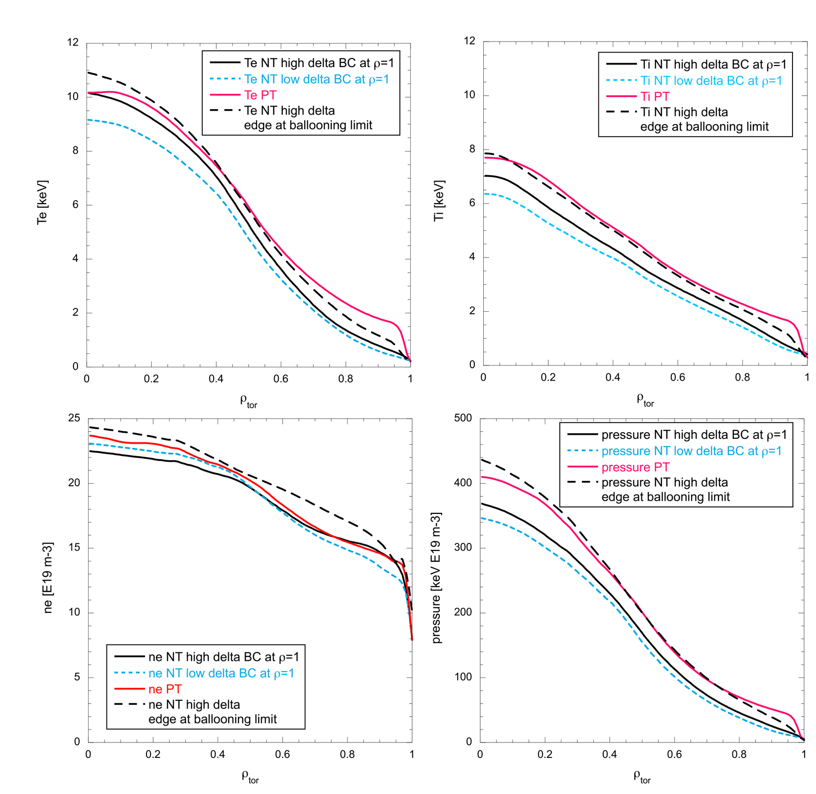
- **q(0) ~ 1 ; q_{95} ~ 4; li ~ 0.75**
- **f_{BS} ~ 0.45 ; β_N ~ 1.5 ; $H_{98}(y,2)$ ~ 1.0**
- **Broad q~1 maintained for ~ 8 s**

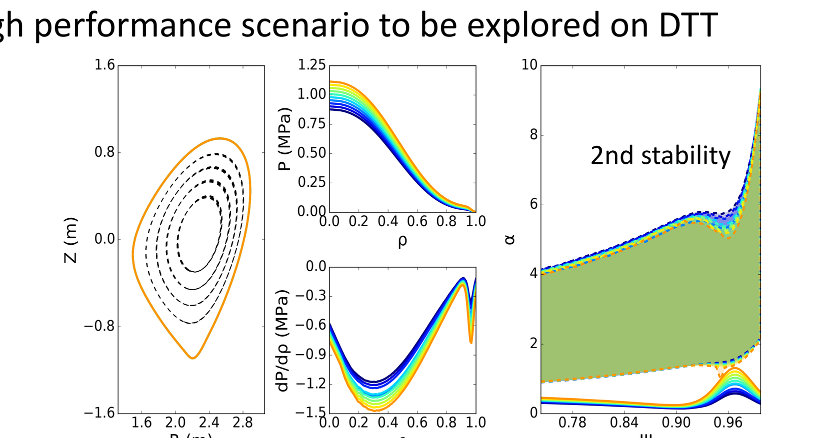




Negative Triangularity Scenario

- Two NT shapes designed, with lower and higher |δ|. Both prevent access to 2nd stability and H-mode.
- Modelling up to separatrix: pedestal loss not recovered but central pressure only ~ 10 % lower than PT H-mode and without ELMs → Valuable ELM-free high performance scenario to be explored on DTT





- Experiments on TCV ad AUG with similar shapes as DTT show an improved NT edge which TGLF is not able to capture
- An upper limit for the DTT prediction is therefore to set the edge gradient close to the ideal ballooning limit and BC at ρ_{tor}=0.94
- In this case, the NT high delta simulation recovers and even exceeds the central pressure of the PT H-mode case

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