Guidelines proposal for Chapter 4 of the DTT Research Plan
Transport physics and modelling tools for plasma scenarios

[DTT main missions (from EG1):

- Validation of optimum power exhaust strategy for DEMO and related plasma scenarios, with full core-edge integration at high performance
- Support to the various phases of ITER exploitation **]**

DTT characteristics relevant for transport studies:

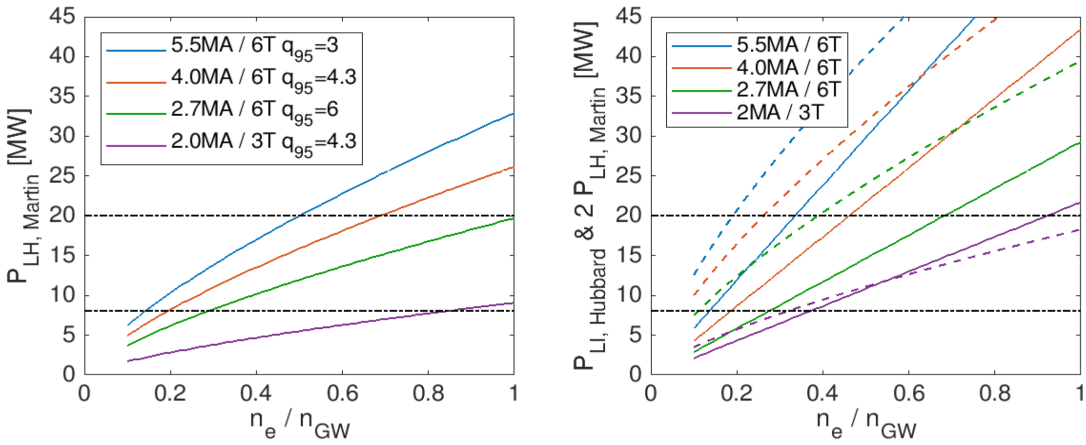
- High field, high current, high heating power, dominant electron heating, flexibility in heating at both full field / full current and half field / half current
- ECRH density cut-off at Greenwald density limit, edge opacity to neutral penetration
- high density and low collisionality
- Full W walls (ITER and DEMO)
- Small L-mode window at half field, broader L-mode window at full field
- Operation with both favourable and unfavourable grad B configuration for H-mode access
- Limitations: limited auxiliary ion heating, limited length of flat top at max current and max density (close to the Greenwald limit), modest current drive at full field and full current

DTT main missions (from a confinement and transport standpoint):

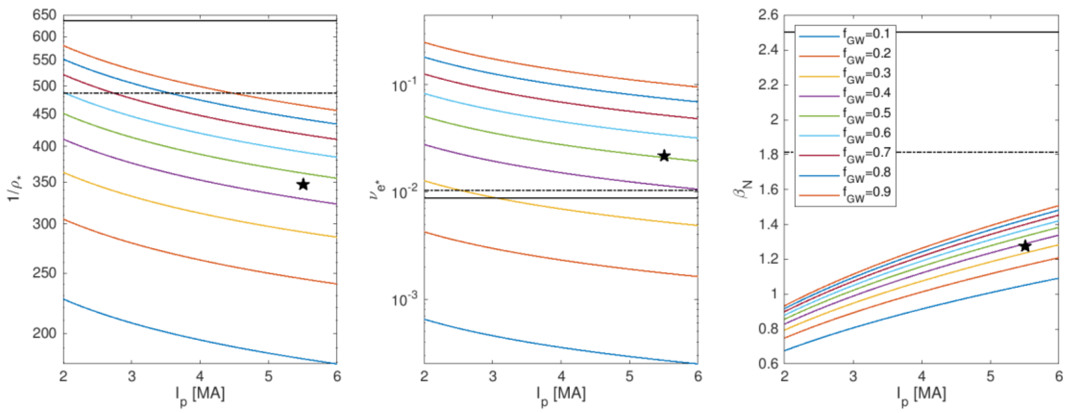
- Compatibility of power exhaust strategies with existence of confinement regimes (particular relevance to be given to stationary ELM-free and small ELM regimes with high confinement)
- ELM-free (seeded no ELM regimes (XPR / CRD), EDA , small ELMs (QCE = type II ELMs), I-mode, WPQH)
- Otherwise, ELM control techniques?
- Possibility to reach detachment in each of these regimes
- Role of radiation from impurity seeding on accessibility and performance of the regimes
- Control of profiles of impurity densities and radiated power density
- Access to high confinement regimes (in particular H-mode) with dominant electron heating, high radiation fractions and limited edge neutral penetration
- Confinement (core and pedestal) properties over the large variations of parameters allowed by DTT design (field, current, power and density, comparison of low and high field
- Plasma rotation (intrinsic and with external torque)

DTT operational windows in engineering and dimensionless parameters at half field and full field

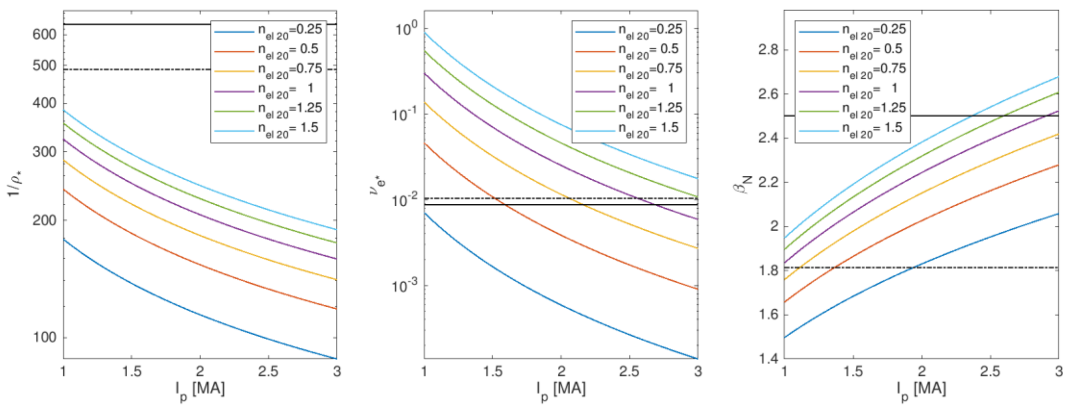
- L- , H-mode operational windows according to scaling laws at different current and fields as well as I-mode operational windows (here the complete Martin's scaling is considered, to keep in mind 25% observed reduction in W wall.



- **Achievable dimensionless parameters in L-mode and H-mode making use of confinement scaling laws**. Here below an example with 40 MW of auxiliary heating at 5.8T, dimensionless parameters are plotted as a function of the plasma current for different values of the electron density (dashed horizontal line is the ITER baseline reference, solid line is a DEMO-like reference) (computed with H20IL = 0.85, consistent with ASTRA/TGLF-SAT2 result).

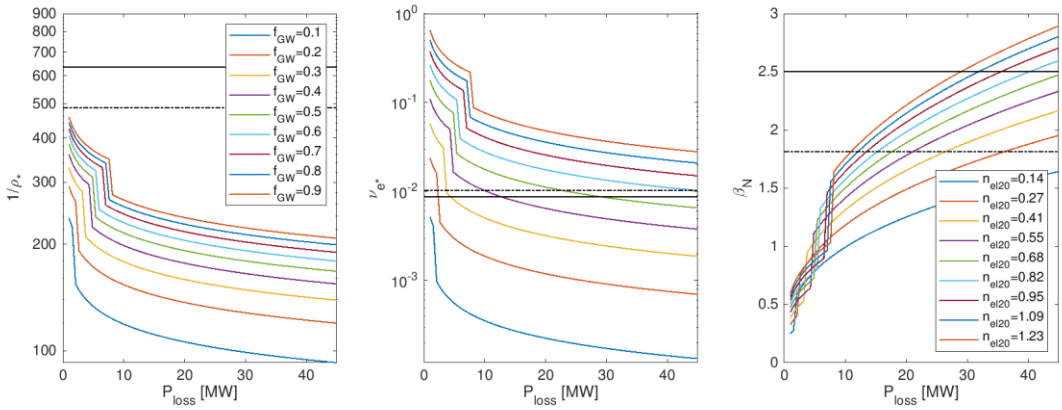


Other example is at 2.9T and 2.7 MA as a function of the auxiliary heating power for different electron densities



The L-H transition power is consistently computed using the Martin's scaling times 0.75, which includes the observed reduction in W wall. In particular, one can observe the possibility of exploring high β scenarios at half field and high heating power, in the density and collisionality range expected for DEMO (absolutely unique feature with W-walls (add Nicola's point if/when available).

Interesting case is provided by the idea of pushing towards hybrid operation with full power at 2.0 MA and 2.9T, q95 ~ 4.6. Assuming H=1.2, DEMO relevant beta_N is reached at DEMO collisionality and DEMO density (and still at the "reasonable" Greenwald fraction around 0.6). With a W wall environment, this promises unique and unprecedented capabilities.



DTT research on confinement & transport organized in 4 blocks
(feasibility in terms of scenarios from A to E is marked)

1. **General confinement properties**
   - OH and L-mode properties of confinement (including positive and negative δ, scaling of confinement / transport vs Ip, BT, ne in electron heated conditions, ρ* scaling, isotope studies) (A – E)
   - Properties of H-mode confinement (note DTT should be able to access H-mode with ECRH(+ICRH) only) (BT vs q_{95}, and BT vs R (low vs high field), opaque edge and fueling, isotope studies) (B – E)
   - Negative vs positive triangularity (in principle also possible from relatively early phase). Requires ion heating for complete investigations (A – E)

2. **Of general relevance for core – edge integration**
   - Regimes with no ELMs or small ELMs, XPR-CRD, EDA, QCE, WQH, I-mode, negative δ
   - Impurity seeded detached scenarios at (or approaching) ITER- and DEMO-relevant values of ν*, ρ* and β with ITER- and DEMO-like plasma shape (C – E)
   - Effects of Greenwald fractions on edge and core transport (C – E)
   - Plasmas with high density but low collisionality ((C)D - E)
   - Impurity control (B – E)
   - Study of Hybrid and Advanced Tokamak scenarios and of their compatibility with power exhaust solutions. Unclear the possibility of developing central magnetic flux pumping (no clear theory-based ordering parameter of experimental results so far) (C – E)
   - Comparison high/low BT (C – E)

3. **Specifically on L-H transition and H-mode pedestal (B – E)**
   - L-H transition physics, impact of divertor configurations and exhaust requirements (impact of impurity seeding and of separatrix density, opaque edge, isotope studies) as well as impact on pedestal performance in H-mode
   - Pedestal physics beyond MHD peeling-ballooning, role of resistive MHD in limiting pedestal top pressure (collisionality, high density decorrelation)
   - Physics of fuelling by gas puff and pellet injection (impact on L-H transition, pedestal and confinement)
   - High density and low collisionality
   - Effects of shaping (from high positive δ~0.5 to negative δ)

4. **More specific on (core) transport (A – E)**
   - Transport in plasmas with dominant electron heating and low torque
   - Confirm & further assess ITG / TEM / ETG (high density) paradigm (n/n_{GW} vs ν)
   - Ion stiffness mitigation strategies
   - Density peaking at negligible core NBI particle sources
   - Impurity transport
   - Properties of intrinsic rotation / residual stress (profile shearing, ρ* scaling, ...) in L- & H-mode
   - Turbulence diagnostics, model validation

Integrated and theory modelling tools:
- METIS (full discharge scenarios modelling)
- JINTRAC (HFPS) : JETTO+SANCO coupled to EDGE2D/ EIRENE
- Edge codes ⟹ interaction with EG 2
- ASTRA (includes STRAHL) and IMEP
- TGLF and QuaLiKiz (+ NN versions)
- Heating modules ECRH / ICRH : GRAY, TORBEAM, PION (TORIC) ...
- NBI: PENCIL, RABBIT, NUBEAM, ASCOT, ORBIT … ⟹ interaction with EG 4
- Gyrokinetic codes (GENE, GKW) ⟹ interaction with Theory EG 5
- ...

Diagnostics (?)
- Short description diagnostic requirements (on three levels, indispensable diagnostics for operation, diagnostics required for transport studies (core / edge), + additional wish list)