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Integrated modelling for tokamak plasma: physics and scenario optimisation

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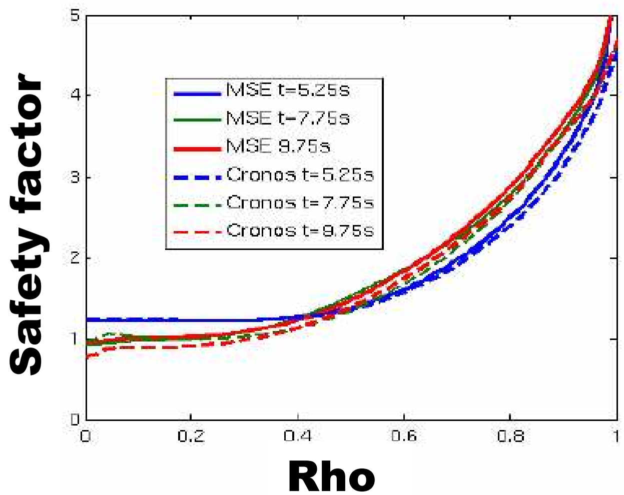
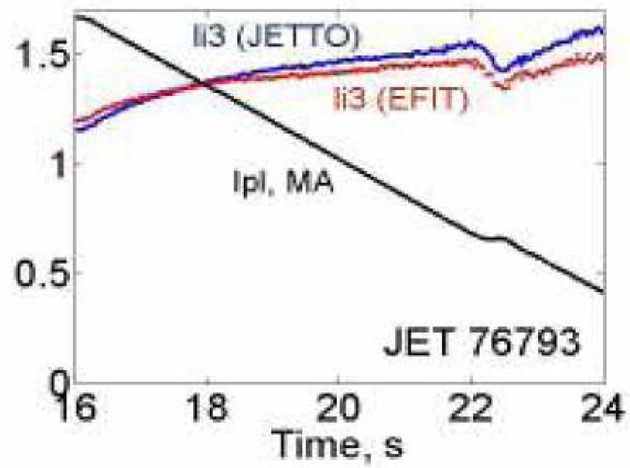
***See the Appendix of F. Romanelli et al., Proceedings of the 23rd IAEA Fusion Energy Conference 2010, Daejong, Korea**

Hybrid scenarios on JET and AUG: current diffusion





Current diffusion in HS: simulated and reconstructed (MSE/EFIT) q profile in JET discharge 75225 [3] (left); simulated (blue) and reconstructed (red) l_i during the current ramp down [5] (right).

JET:

- *main heating phase*: simulated (NCLASS) *q* profiles are consistent with EFIT (MSE, polarimetry, fast ion pressure) [3]

-*current ramp up and ramp down:*

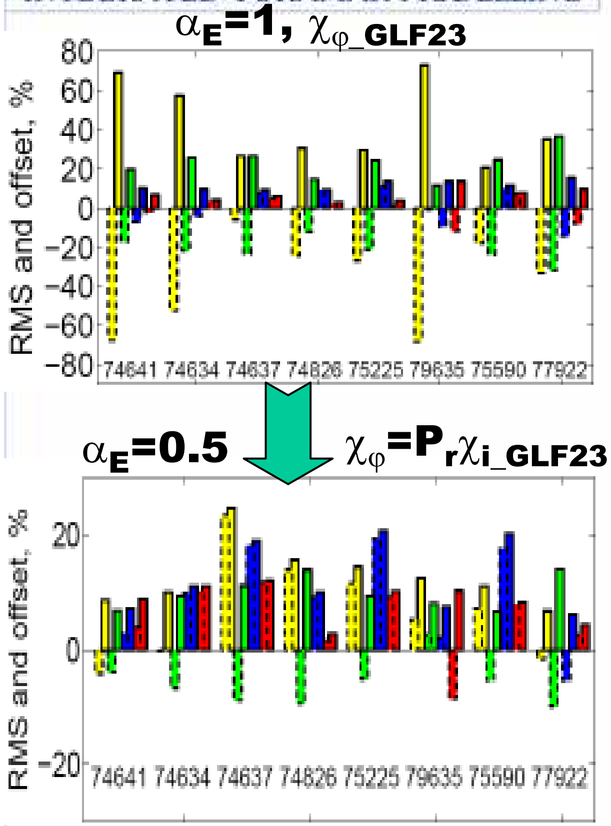
→ agreement for simulated and EFIT reconstructed l_i [4, 5]

→ 1st observed sawtooth crash during the *current ramp up* can be matched in modelling ($q_0 \approx$ 0.8-0.9) by adjusting the profile of Z_{eff} within its measured line averaged value

ASDEX-Upgrade:

- simulated $q_0 < 1$ (20995: 1/1 mode, then fishbones, q_0<1. 20993: 4/3, 3/2, 5/4 modes)

Hybrid scenarios on JET and AUG: core transport model validation (T_e, T_i, n_e, ω)



GLF23 model (main heating phase, JET& AUG):

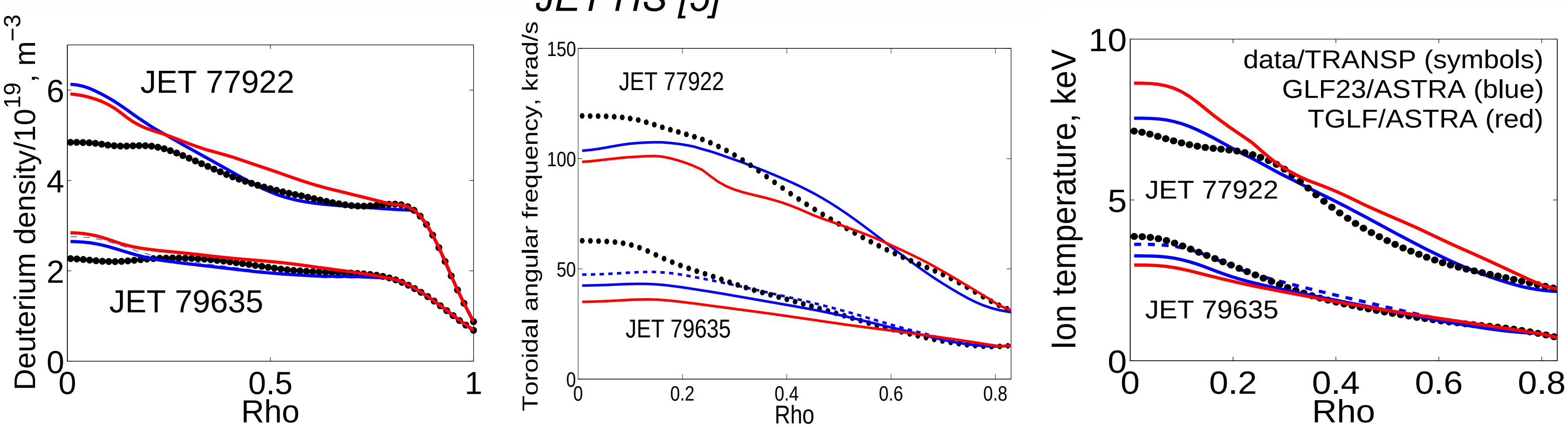
- effect of *s/q* shaping on the core confinement improvement [6]
- density in HS is over-predicted with the H-mode settings → weaker *ExB shear* effect in HS
- indication of momentum pinch in JET HS (P_r=0.2 - 0.5)

TGLF [7] (main heating phase, JET):

- T_i, n_D and ω prediction is close to GLF23
- over-estimated T_e

Bohm-gyroBohm:

- over-predicted density peaking with the H-mode settings for JET HS [8]
- accurate temperature prediction in JET and AUG HS [8]
- accurate T_e and n_e prediction during the current ramp down in JET HS [5]



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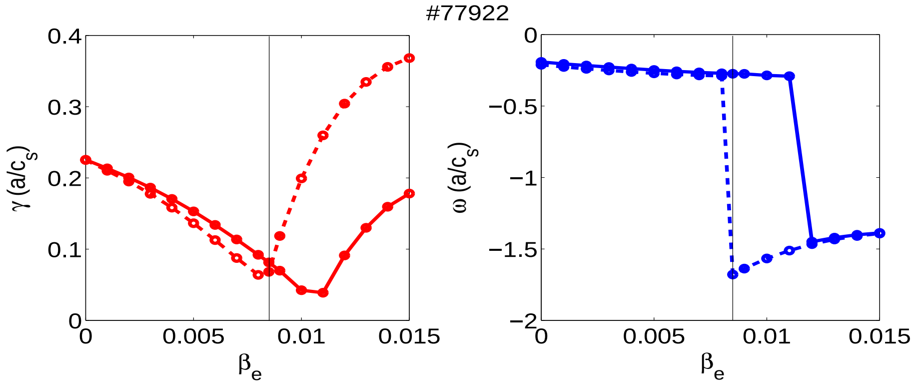
Hybrid scenarios on JET and AUG: core turbulence, pedestal, MHD

Micro-turbulence stability analysis (GYRO) for JET 77922 [9]:



- weak stabilising effect of the *ExB* shear on ITG turbulence

- strong *ExB* shear effect on the onset of KBM

- strong stabilising β_e effect

Growth rate (left) and frequency (right) simulated with (dashed) and w/o (solid) ExB shear. Experimental β_e value is shown by vertical line.

Particle confinement:

- first self-consistent TRANSP-EDGE2D simulations: Deuterium neutral influx through the separatrix, transport at the pedestal

- particle confinement time strongly exceeds the energy confinement time: $\tau_p \approx 0.4$ s, $\tau_E \approx 0.16$ s in #79635; $\tau_p \approx 0.54$ s, $\tau_E \approx 0.25$ s in #77922)

Pedestal transport, MHD stability and ELMs:

- Between ELMs D_D and χ_i are close to neoclassical, χ_e strongly exceeds the neoclassical transport

- Pedestal height in JET pulses is in a good agreement with the EPED model [10]

- 1st ELM after the current overshoot is triggered by the PB mode with *n*=10-14 in JET low δ HS

- Integrated modelling of type I ELMs: free bndry equilibrium (CREATE-NL), core-pedestal (JETTO) and SOL (EDGE2D)) → ELM mitigation by kicks in H-mode, prediction of observed density depletion, *Te*, thermal energy and *H*-factor with an increase of ELM frequency [11]

Conclusions

Improved confinement in existing HS:

- effect of *s/q* shaping at outer radii on the ITG driven transport [6]
- strong stabilising effect of β_e [9]
- weak effect of the *ExB* shear
-α_E=0.5 in GLF23 model is consistent with GK simulations when the destabilising effect of the parallel velocity shear is negligible

-indications of toroidal momentum pinch in JET HS

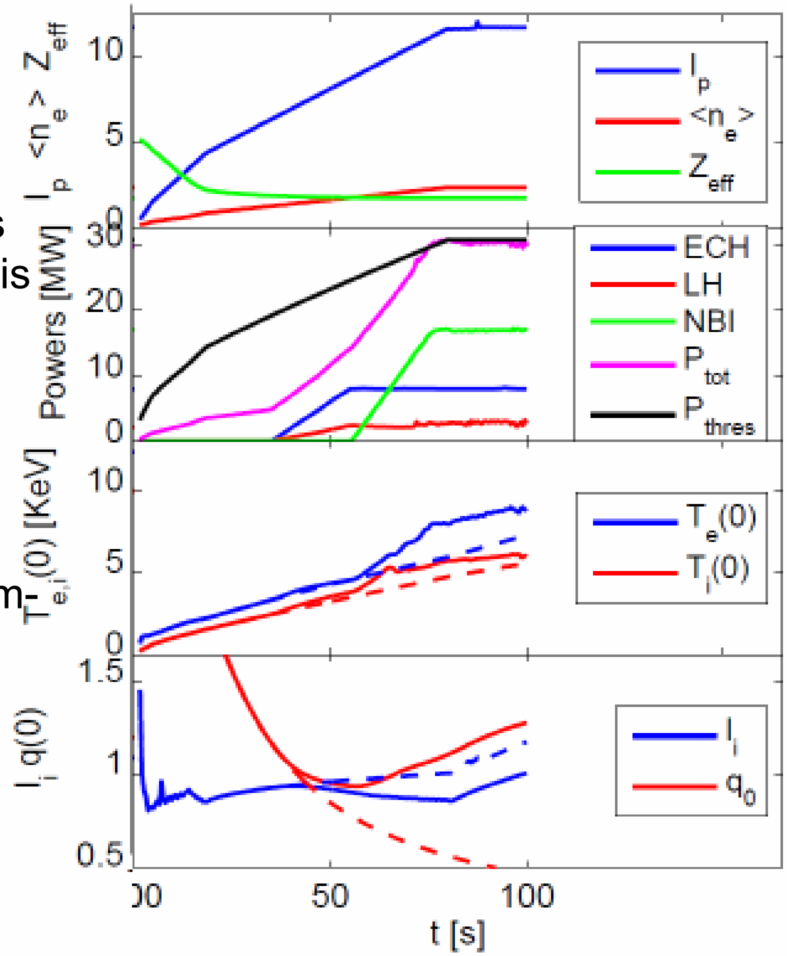
Validation of transport & stability models:

- reasonable temperature prediction with GLF23 and Bohm-gyroBohm models
- over-predicted density with the H-mode settings of the GLF23 and BgB → re-tuning of models [8]
-- pedestal height in JET HS in a good agreement with EPED model [10]

Application to ITER HS [16]:

- current ramp up [12]
- optimisation of heat mix [13]
- sensitivity to ECRH antenna [14]
- work in progress: impact of the density over-peaking, consistent core-EPED simulations, plasma control [15]

G.M.D.Hogeweij et al, submitted to Nucl. Fus.



Optimized current ramp up scenario (Bohm-gyroBohm model) in ITER (solid curves). Dashed curves show the evolution of temperatures, q_0 and l_i without any additional heating

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