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Validation of reduced transport models for integrated modeling of ASDEX Upgrade L-mode discharges in the European Transport Simulator

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Background & mission

WHAT? **Validation of reduced transport models** for full-radius predictive simulations of **ASDEX Upgrade** (AUG) **L-mode plasmas** with the **integrated modeling** framework the European Transport Simulator (ETS) [1].

WHY? Predictions of future tokamak experiments (eg. ITER) require accurate and efficient models of turbulent transport. For full discharges, including ramp-up, we must be able to model **L-mode** plasmas. With integrated modeling, multiple physics models can be combined to perform simulations of kinetic profiles in tokamak plasmas—but do existing **reduced turbulent transport models** perform well enough?

Strategy

(1) Use data from a single time point in experiment as initial- and boundary conditions in ETS; evolve flat-top kinetic profiles self-consistently to steady state, with three different transport models: Bohm-gyroBohm (BgB) [2], extended drift wave model (EDWM) [3] and the Trapped Gyro-Landau-fluid model (TGLF-SAT2) [4].

(2) Compare modeled profiles and thermal energy to experimental data.

(3) Run TGLF-SAT2 standalone on ETS input as well as steady state profiles to enable comparison to GENE linear simulations (see poster by M.M. Skyllas for GENE results).

(4) Identify any gaps (physics and/or numerics based) that must be addressed for successful profile predictions.

AUG experimental info and data treatment

Two AUG L-mode discharges were modeled with ETS: AUG#35221 (H) and AUG#35475 (D) (modeled with ASTRA+TGLF-SAT2 in Ref. [6]). Common features of AUG#35221 and AUG#35475:

- Similar engineering parameters: $B_T \sim 2.45$ T, $I_p = 0.83$ MA, $\langle n_e \rangle_{\text{line}} \sim 2 \cdot 10^{19}\text{m}^{-3}$.
- Three consecutive heating mixes applied during flat-top: 100% NBI, mixed (50% NBI+ 50% EC) and 100% EC. Total heating $\sim$ 1.3 MW for all heating phases.
- Experimental data obtained via TRVIEW [5].

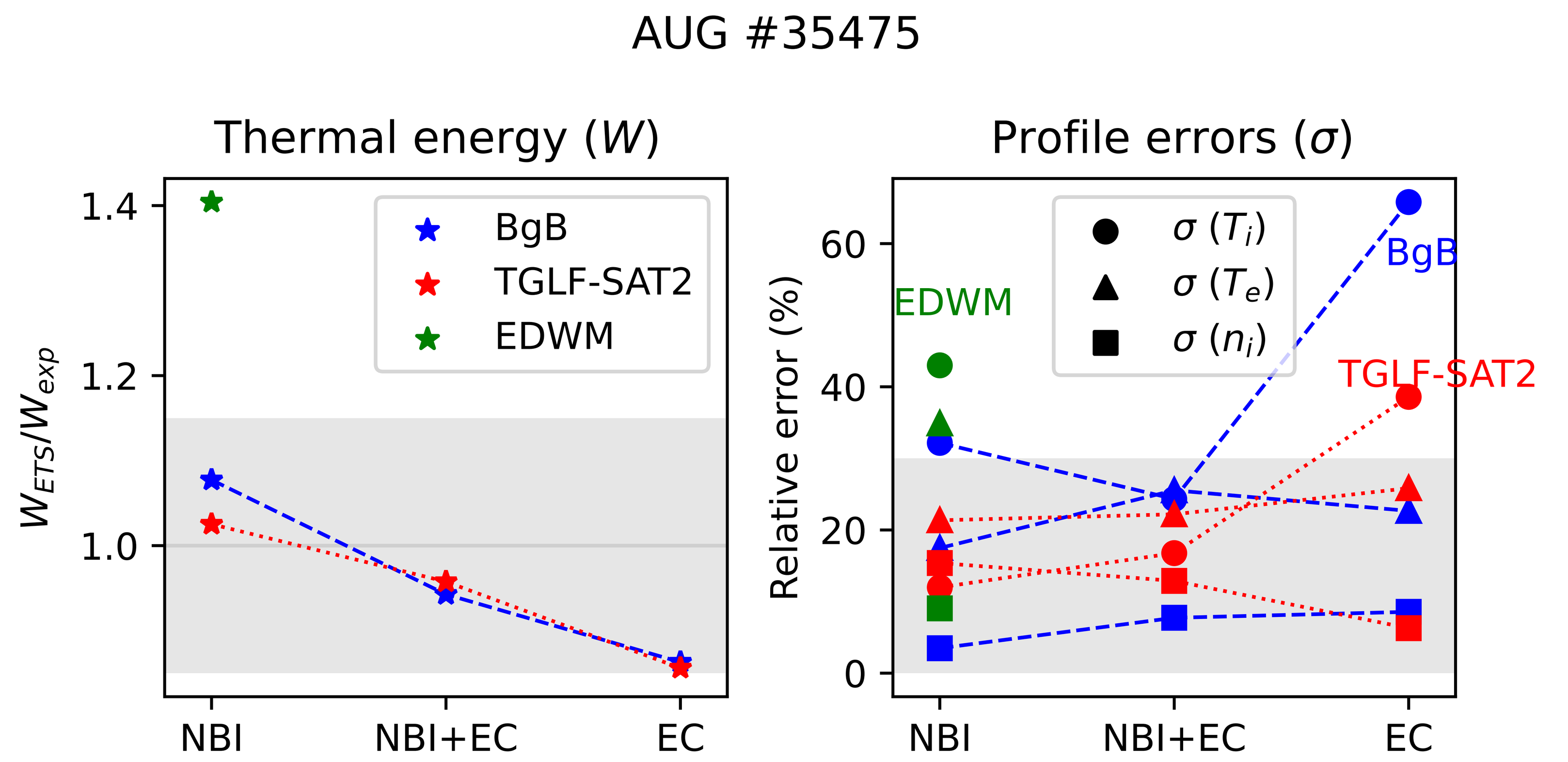
This poster shows only **predicted and experimental profiles** for one of **the most challenging** cases to model: the **EC heated phase** ($t = 5.46$ s) in **AUG#35475 (D)**. See conference paper for other heating phases and AUG#35221 (H).

Results AUG#35475: ETS predictions vs. experimental data

Ion density n_i and temperatures T_e and T_i were self-consistently modeled with ETS for $0 < \rho_{\text{tor}}^{\text{norm}} < 1$. Each discharge and heating mix was modeled with the three transport models EDWM, BgB and TGLF-SAT2. Errors $\sigma(d)$ for profiles $d = T_i$, T_e, n_i are estimated as the difference between experimental and predicted d at point ρ_i (as in Ref.[7]):

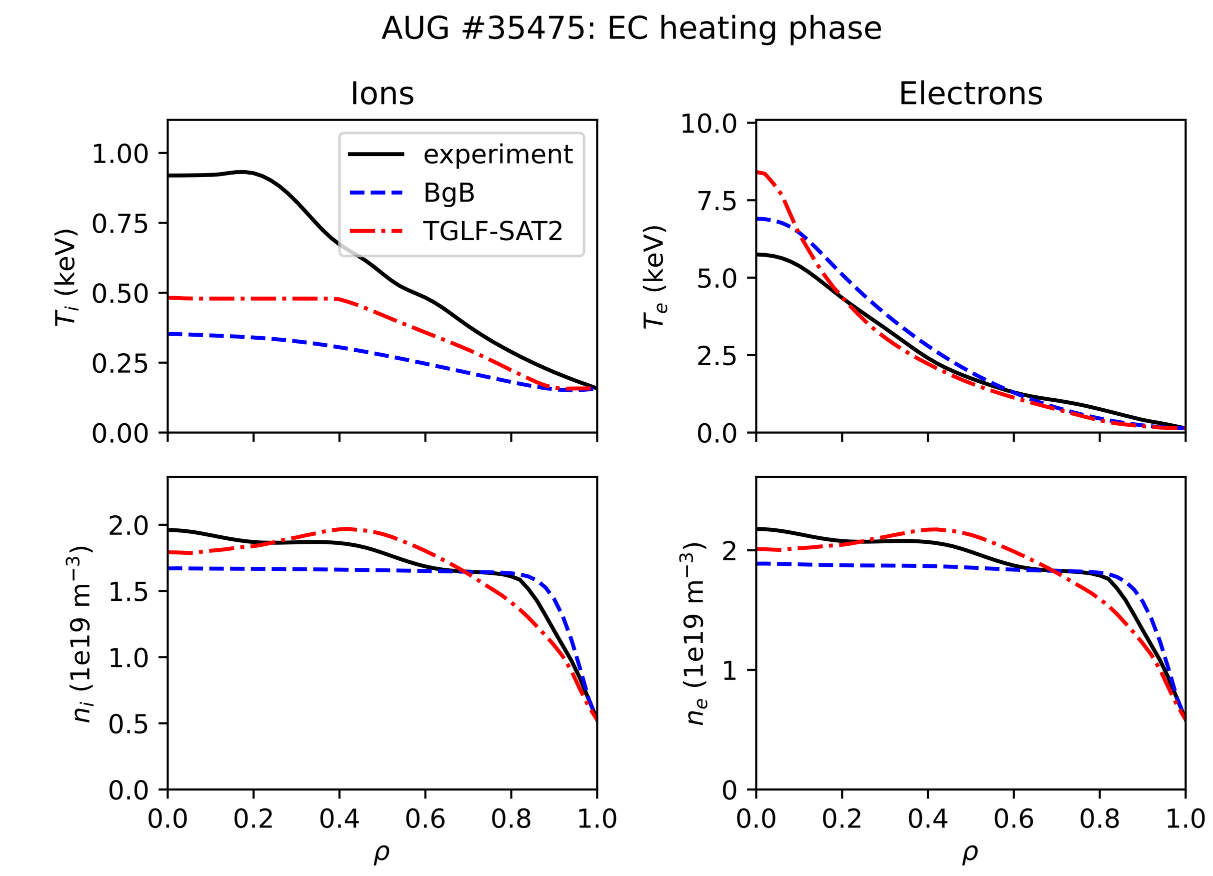
$$\sigma(d) = \sum_i^N \frac{2}{N} \left| \frac{d_{\text{exp},\rho_i} - d_{\text{ETS},\rho_i}}{d_{\text{exp},\rho_i} + d_{\text{ETS},\rho_i}} \right|$$

EDWM overpredicts thermal energy (W), while BgB and TGLF-SAT2 W predictions are within $\pm 15\%$ of experimental thermal energy. Accuracy of transport models go down for EC heating phase, when $T_e/T_i \gg 1$ at plasma core.



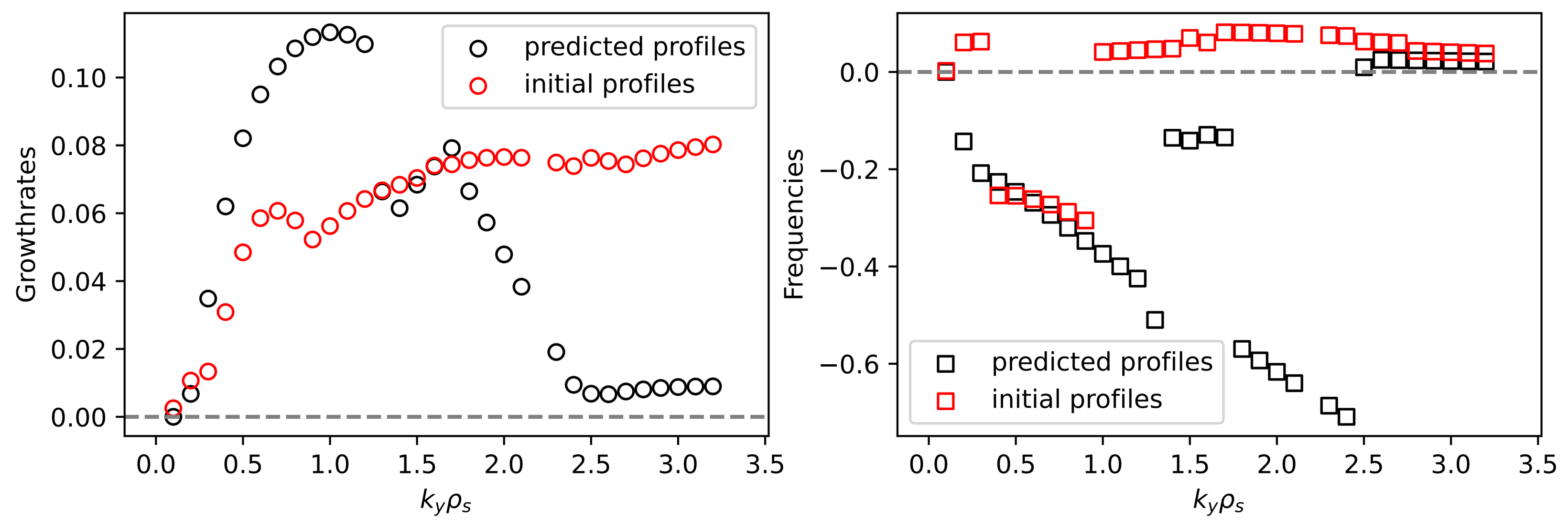
Results AUG#35475: ETS predicted profiles, EC heating

- EC modeled with Torbeam
- Neoclassical transport: NCLASS
- n_e from quasi-neutrality
- Fueling scheme: Gaussian ion source at $\rho = 1$, scaled to reach target $\langle n_e \rangle_{\text{vol}}$, width tuned to BgB simulation (#35475 NBI phase)



Results AUG#35475: TGLF-SAT2 k_y scans, EC heating, $\rho = 0.3$

Standalone TGLF-SAT2 k_y scans were performed on ETS predicted and initial (experimental) profiles respectively, at three different ρ points per heating mix. At $\rho = 0.3$ with EC heating, TGLF-SAT2 predicts the most unstable mode is in the electron direction ($\omega < 0$) for the ETS predicted profiles (black), and $\omega < 0$ (electron direction) for $0.3 < k_y\rho_s < 1$, and $\omega > 0$ (ion direction) for $k_y\rho_s > 1$ for the initial profiles (red).



Conclusions

For the two L-mode discharges AUG#35475 (D) and AUG#35221 (H):

- BgB and TGLF-SAT2 predcitions of thermal energy (W) are within $\pm 15\%$ of experimental W.
- Edge density gradients not well captured by TGLF-SAT2.
- TGLF-SAT2 overpredicts T_i in core with NBI heating; BgB and TGLF-SAT2 overpredict T_e in core with EC heating.
- T_i in the core underpredicted when $T_e/T_i \gg 1 \Rightarrow$ further investigation required for predictive modeling in ETS of plasmas where electron heating dominates.
- EDWM does not capture electron scale turbulence, yielding unrealistic predictions for EC heated plasmas.
- TGLF-SAT2 standalone k_y scans indicate ETS+TGLF-SAT2 predicted steady state profiles give transport mechanisms that differ from those predicted by GENE from the experimental profiles (see poster by M.M. Skyllas).

Outlook

- Further investigation of underprediction of T_i and overprediction of T_e when $T_e/T_i \gg 1$; due to too low collisionality (Z_{eff} too low?), sawteeth, rotational effects?
- Extend simulations: impurities, time evolution of kinetic profiles (ramp-up), neutral fueling, more discharges, additional machines.
- Investigate discrepancies between GENE and TGLF-SAT2 standalone results; sensitivity scans etc.
- Add analytic ETG model to EDWM to improve performance—EDWM does currently not capture electron scale turbulence.

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