Ongoing GENE-Tango simulations of ITER baseline scenario

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with

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Overview

- GENE-Tango coupling
- Description plasma scenario: ITER 15MA post-SW crash
- GENE-Tango EM simulation
- GENE-Tango ES simulation
- Comparison with reduced models
- Conclusions

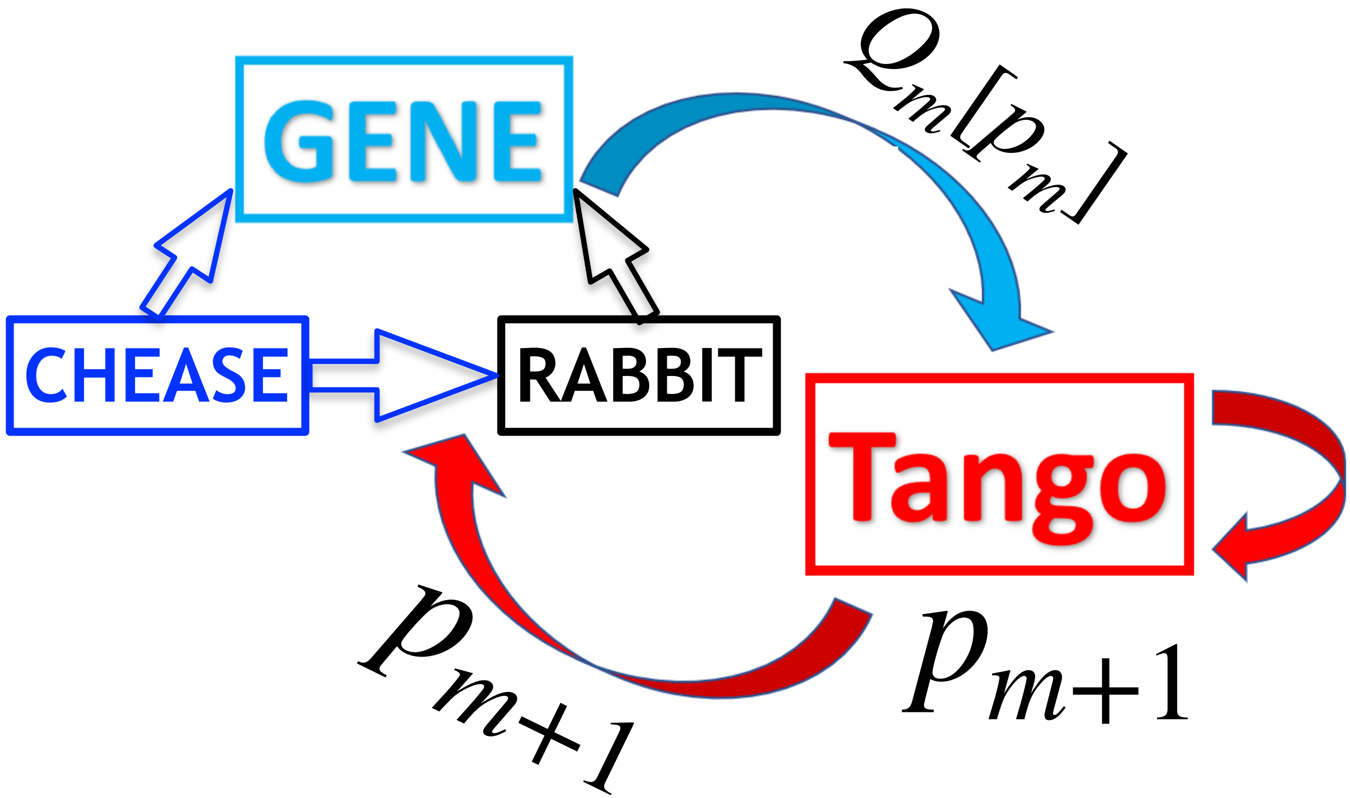
GENE-Tango coupling

GENE-Tango coupling

(i) GENE evaluates turbulence levels for given pressure profile

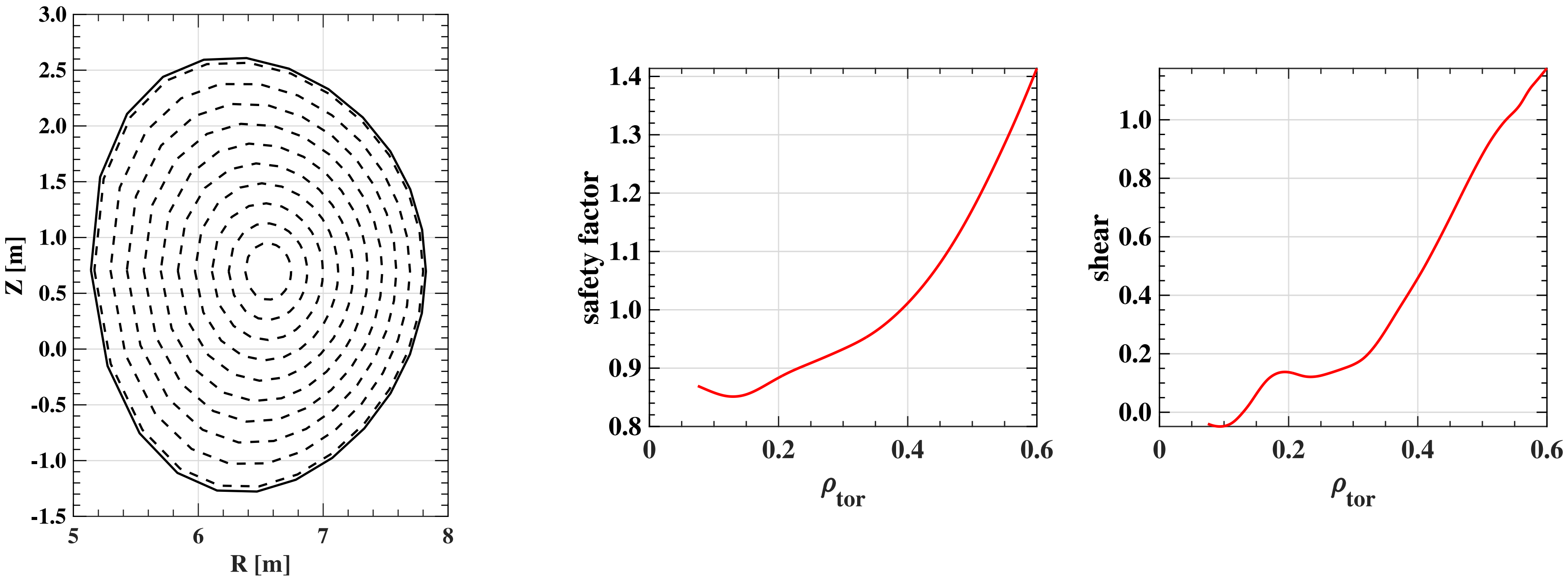
(ii) Tango evaluates new plasma profiles consistent with given turbulence levels and experimental sources.

(iii) New profiles transferred back to GENE and the process is repeated.



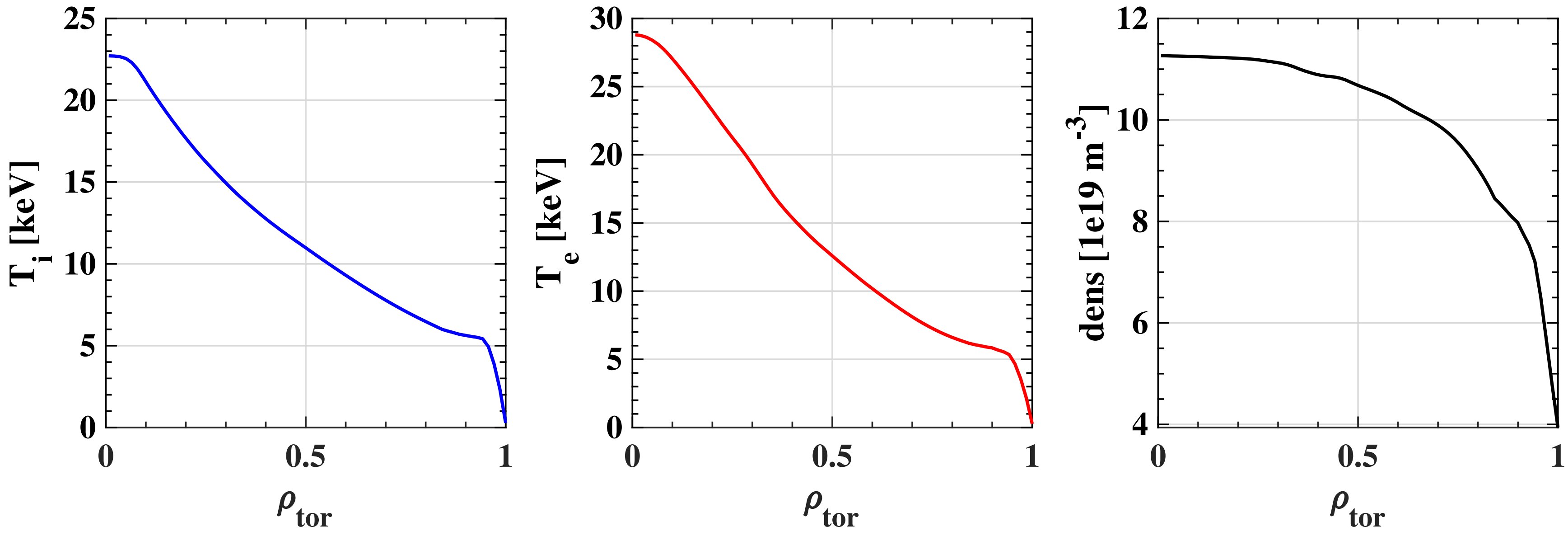
Plasma scenarios: i) post-SW crash; ii) pre-SW crash

- GENE-Tango simulations at ITER for baseline $Q = 10$, $I_p = 15MA$ are currently on-going.
- Plasma profiles initialized to the ones computed by QualiKiz-JETTO.
- Simulations: (i) without alpha particles in GENE EM, (ii) without alpha particles in GENE ES, (iii) with alpha particles in GENE.



Initial setup

- We start the GENE-Tango simulations using the QLK-JETTO profiles.
- NBI, ECRH, Ohmic heating are taken from QLK-JETTO and kept fixed.
- Alpha heating, Prad (Bremsstrahlung, line radiation, syncrotron radiation) and energy exchange are computed in GENE-Tango at each interation.
- Particle source is fixed to the one of QLK-JETTO (NBI+Pellett).
- Geometry evolved with CHEASE and vtor kept fixed.



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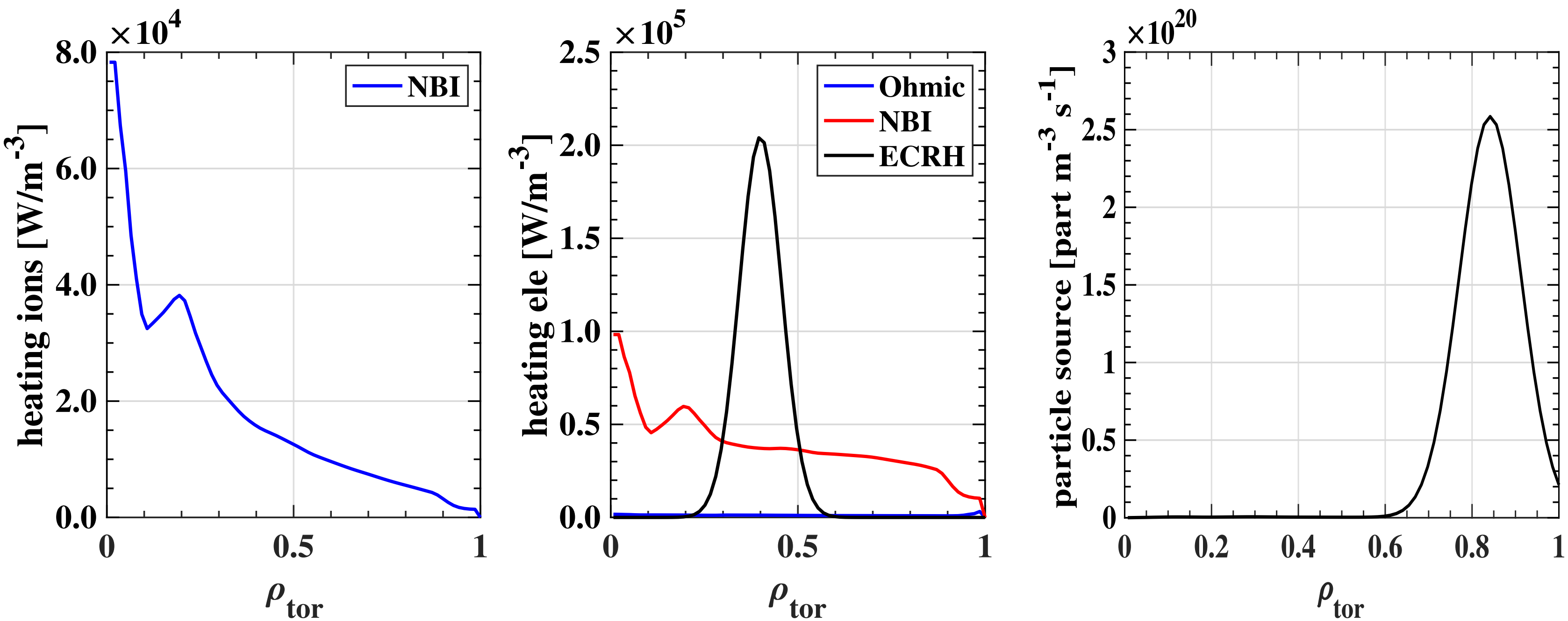
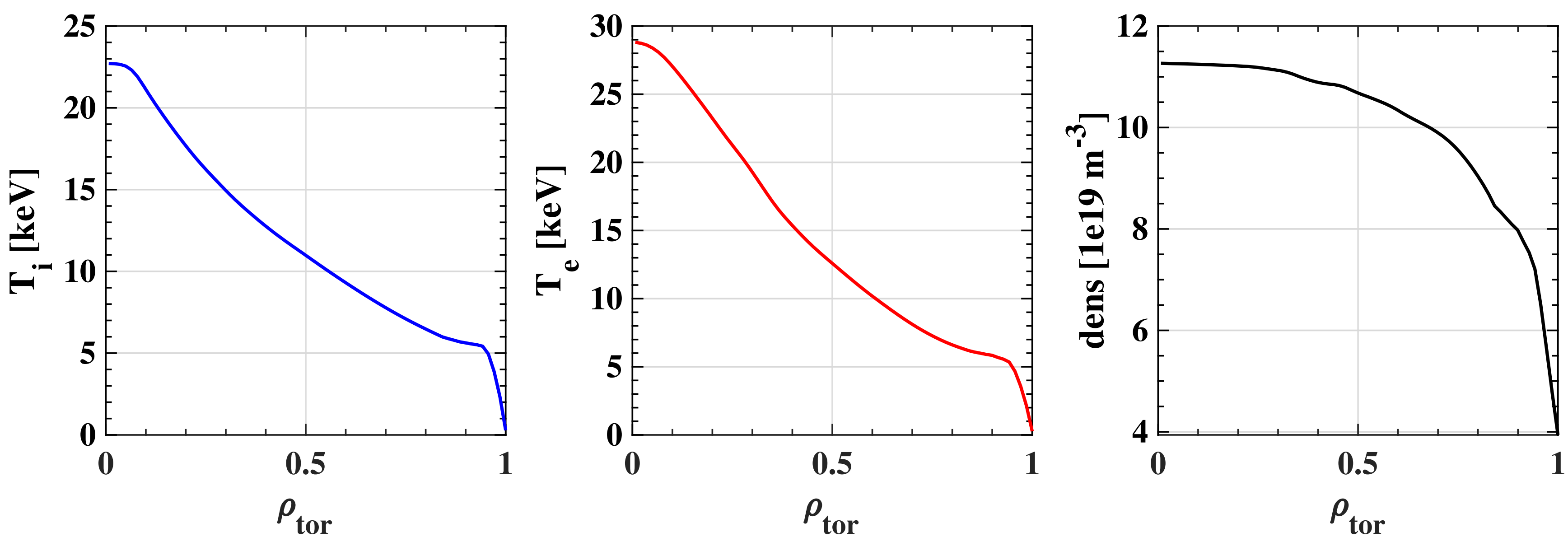


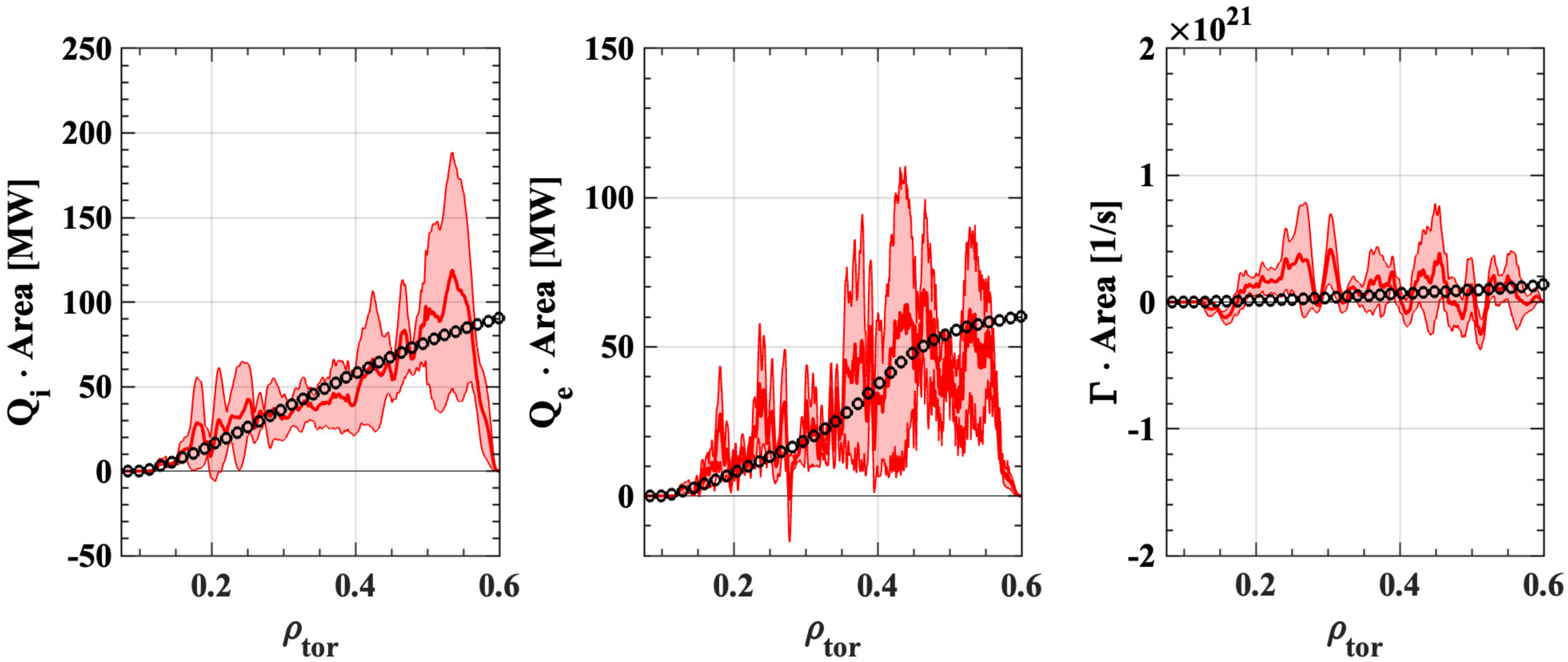
Numerical setup

- GENE resolutions in (nx, ny, nz, nv, nmu) = (1024, 96, 48, 48, 32).
- Spectra covered goes from n = 5 to n = 475, ky rho (x = 0.34) = 0.02 to 2 (ITG + TEM).
- Toroidal rotation included, collisions, electromagnetic effects, realistic geometry, realistic electron-ion mass ratio.
- Radial domain rho = [0.075 to 0.6].



GENE-Tango without alphas EM

- GENE-Tango EM simulation at ITER for baseline $Q = 10, I_p = 15MA$ is close to converge.
- Plasma profiles initialized to the ones computed by QualiKiz-JETTO.
- Turbulent fluxes computed by GENE match the integral of the sources.



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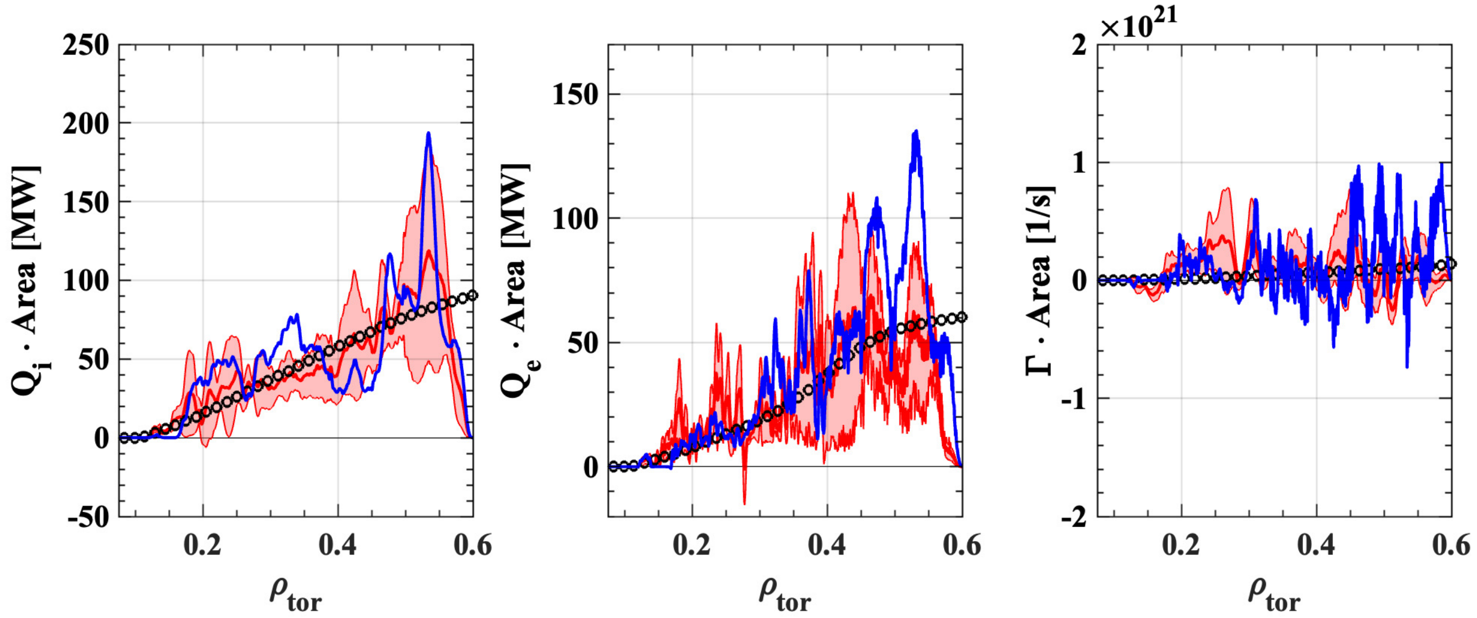
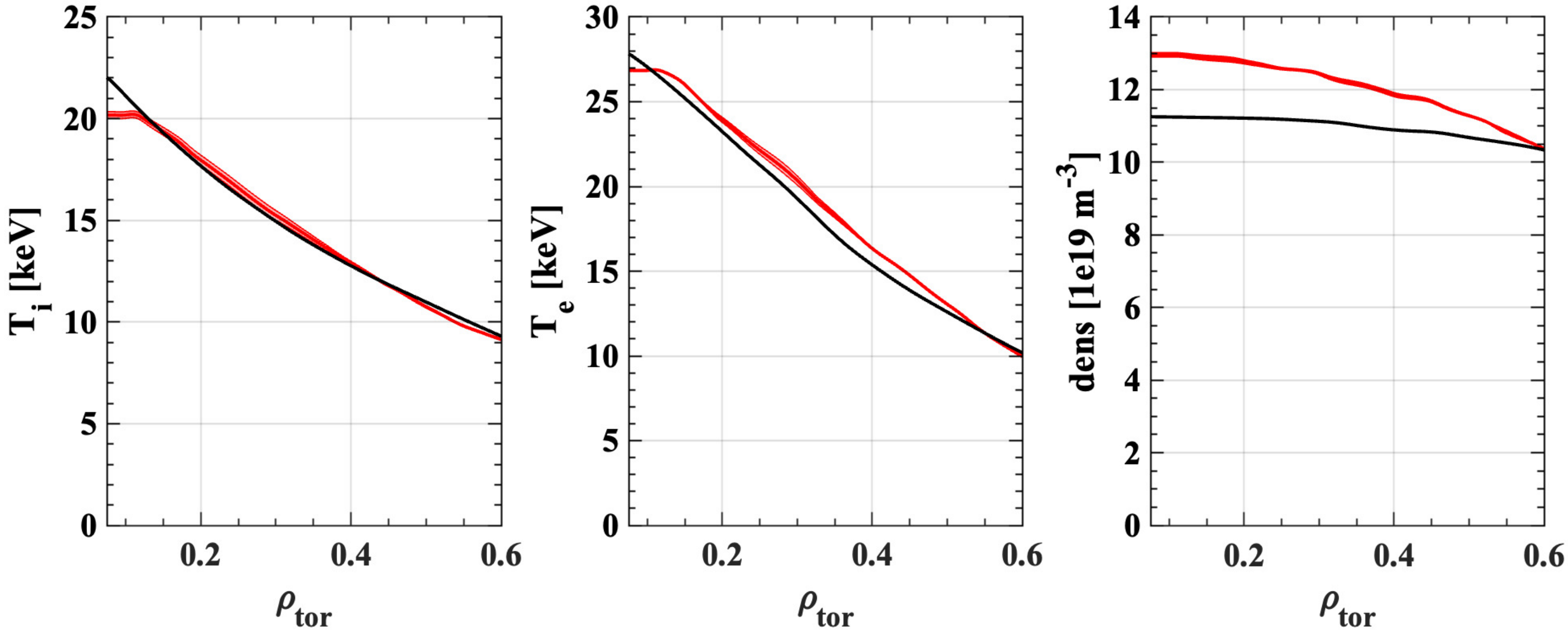


- Taking the last plasma profiles computed by GENE-Tango and running a stand-alone GENE simulation we obtain fluxes consistent with the power balance.

GENE-Tango without alphas EM

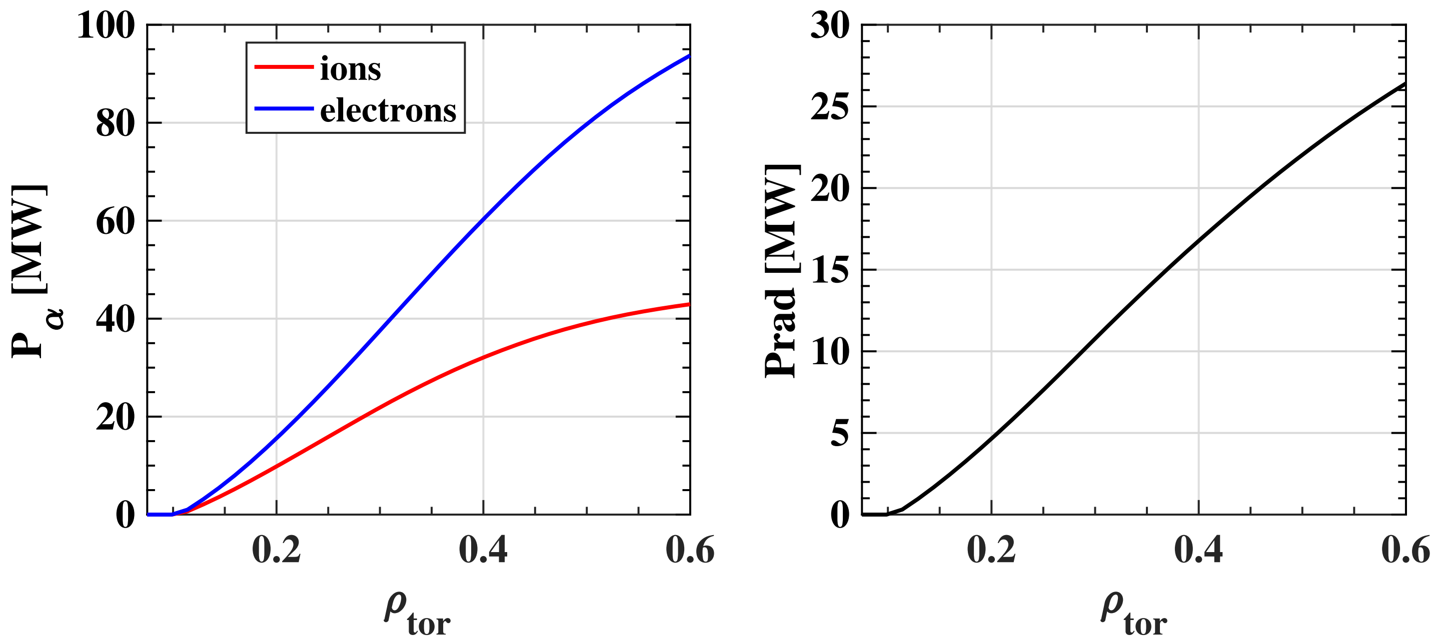
- GENE-Tango profiles are not changing significantly over the last five iterations.
- Due to an inward particle flux in rho = [0.4 - 0.6] we observe a density peaking.



- Similar profiles compared to QLK-JETTO (black), except for the plasma density, where GENE-Tango predicts more peaked profiles.

GENE-Tango without alphas EM

- According to GENE-Tango, total fusion power is ≈ 130MW with radiation of ≈ 25MW



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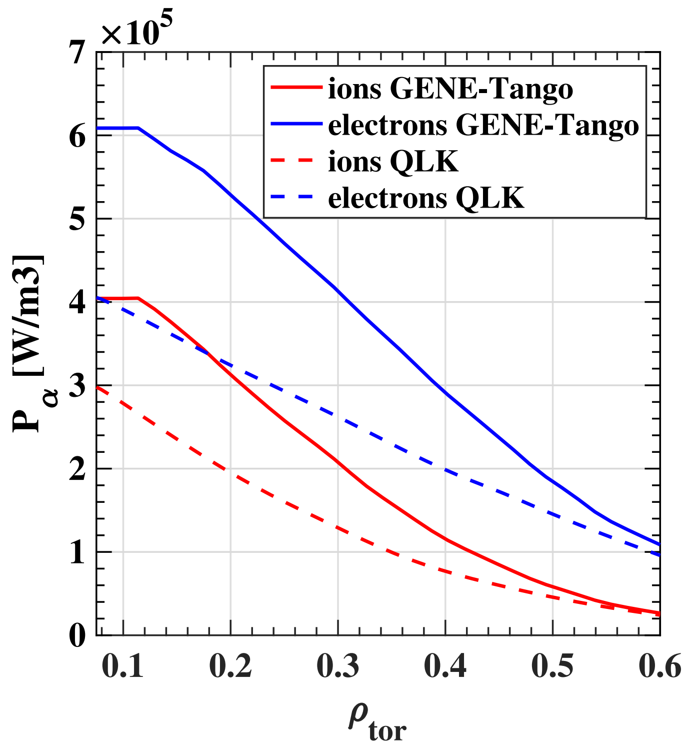
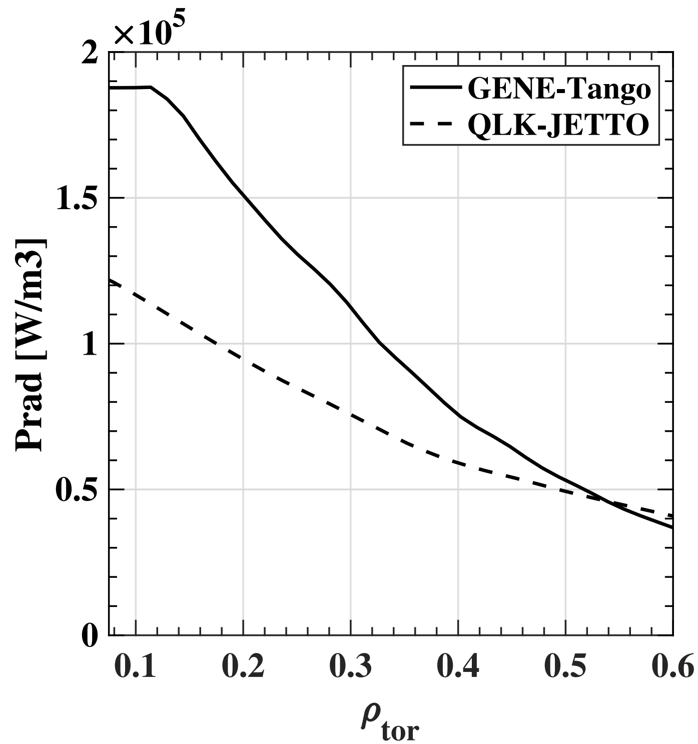
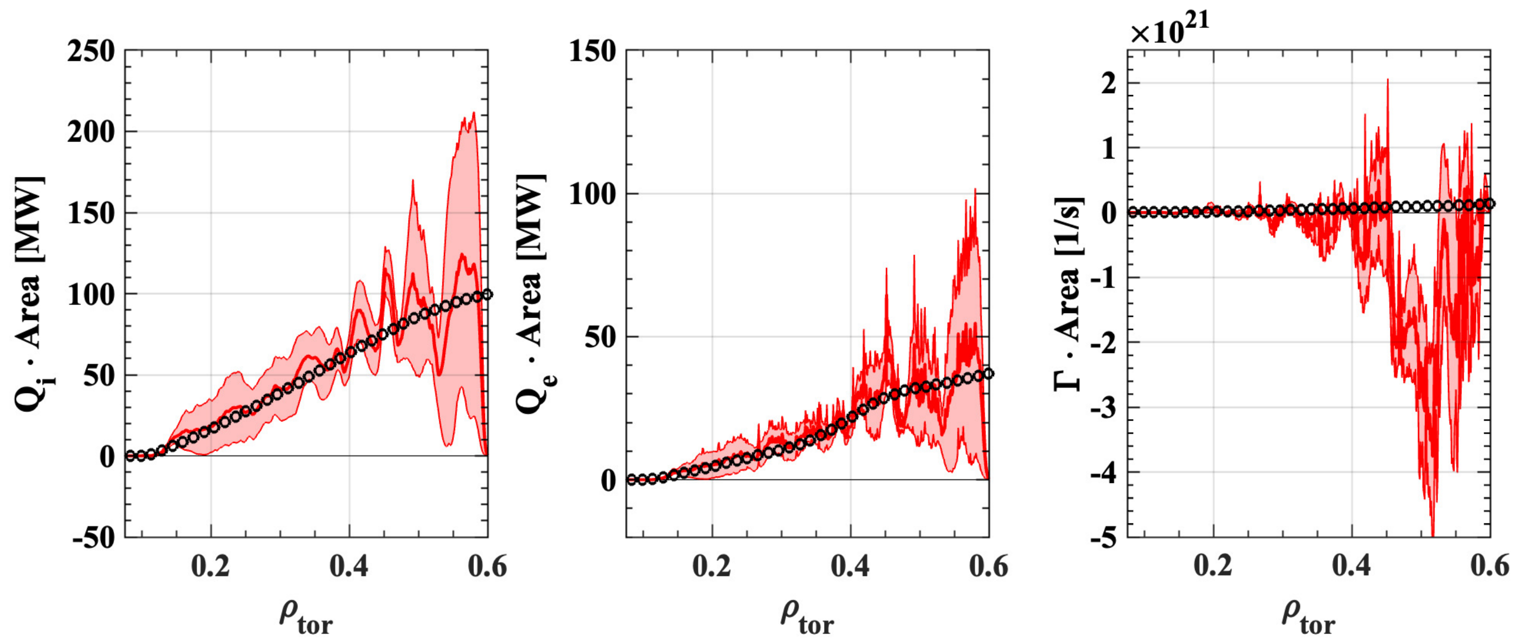




- QLK-JETTO predicts a lower fusion output and reduced radiation compared to GENE-Tango, primarily due to differences in the plasma density

GENE-Tango without alphas ES

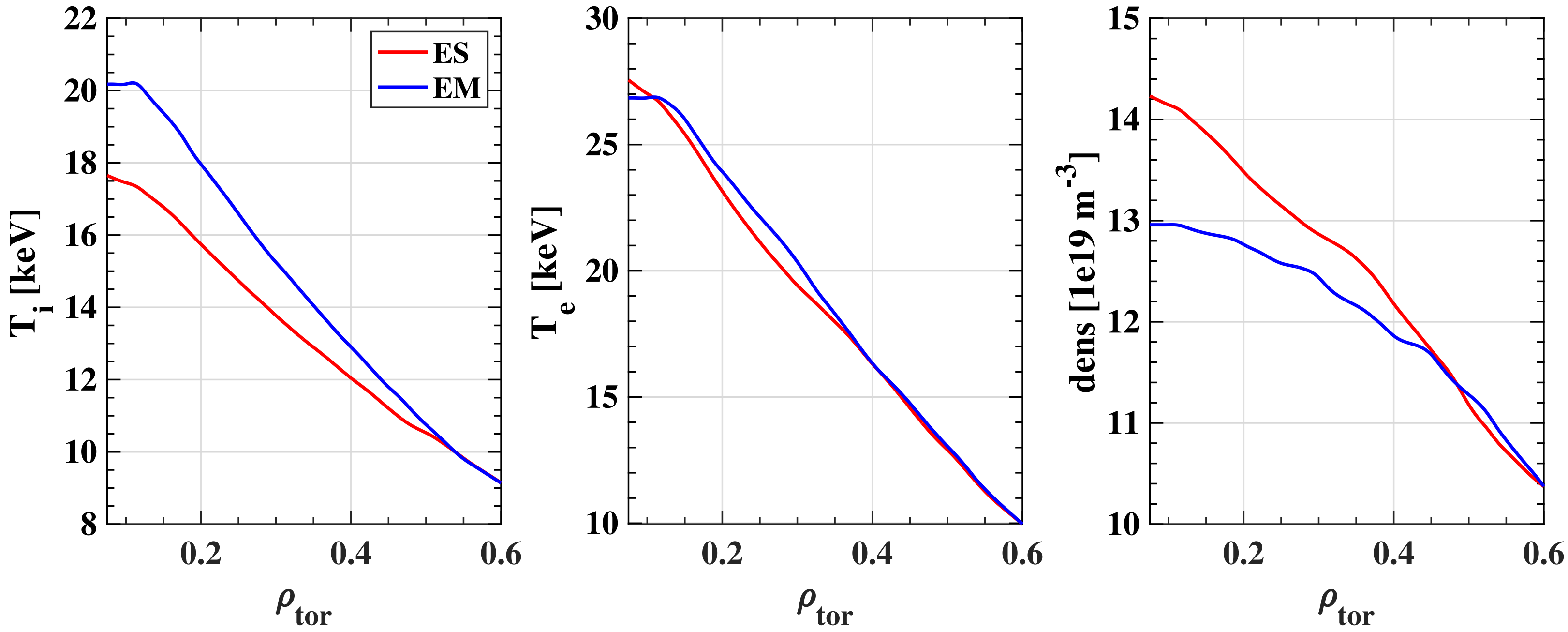
- GENE-Tango ES simulations at ITER for baseline $Q = 10$, $I_p = 15MA$ are currently on-going.
- Ion and electron heat fluxes match well the injected power.
- Density still needs to evolve to account for the inward flux at rho = [0.4 - 0.6]



- More iterations are on-going.

Comparison of GENE-Tango EM and ES profiles

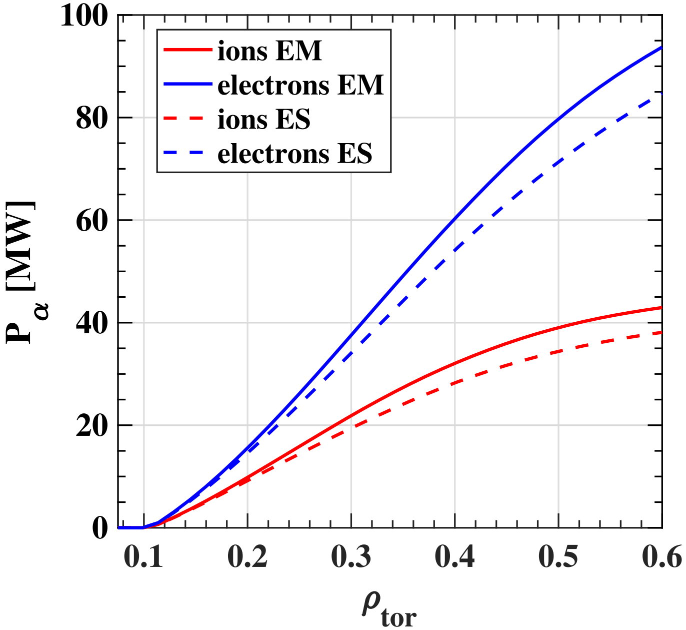
- Ion temperature profile is more peaked in the EM GENE-Tango simulations likely due to β-stabilization of ITG turbulence.
- However, EM fluctuations leads to an increase in the outward particle flux, that reduces the density peaking.

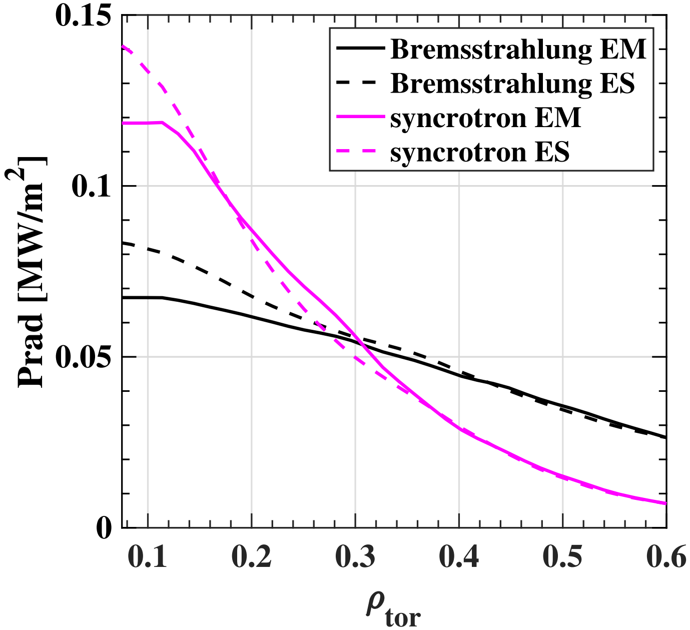


- Electron temperature profile is not strongly affected by the inclusion of EM effects.

Comparison of GENE-Tango EM and ES profiles

- Due to the higher Ti in the electromagnetic simulations, the resulting Pfus is slightly larger compared to the electrostatic run (still not fully converged).
- The radiation is higher in the electrostatic simulations because of the more peaked density profile





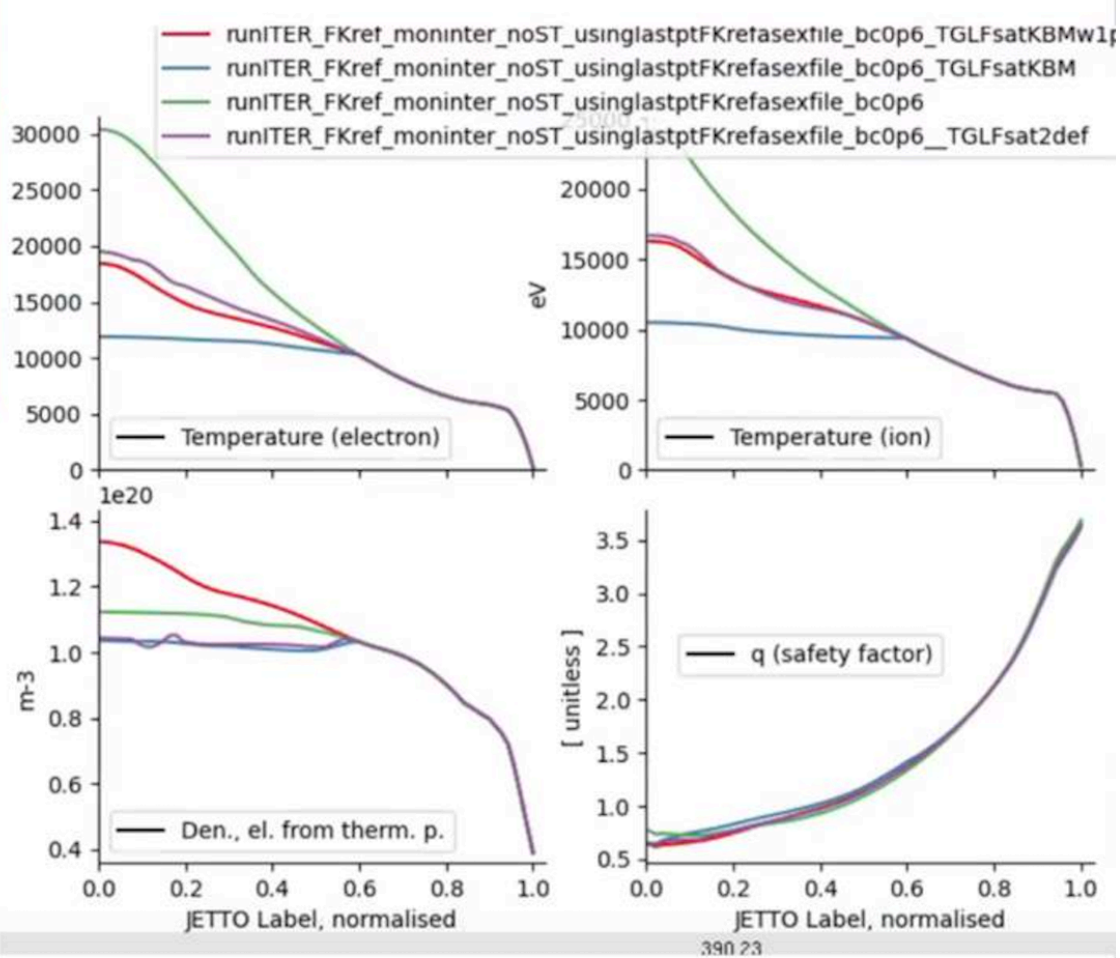
Comparison with reduced turbulence models

	TGLFsat2 default	TGLFsat2 'KBM'	TGLFsat2 no spurious no KBM
Min ky	0.05	0.1	0.1
filter	2	-1.5	-1.5
width	1.65	3	1.65
Alpha_zf	1	-1	-1

QuaLiKiz

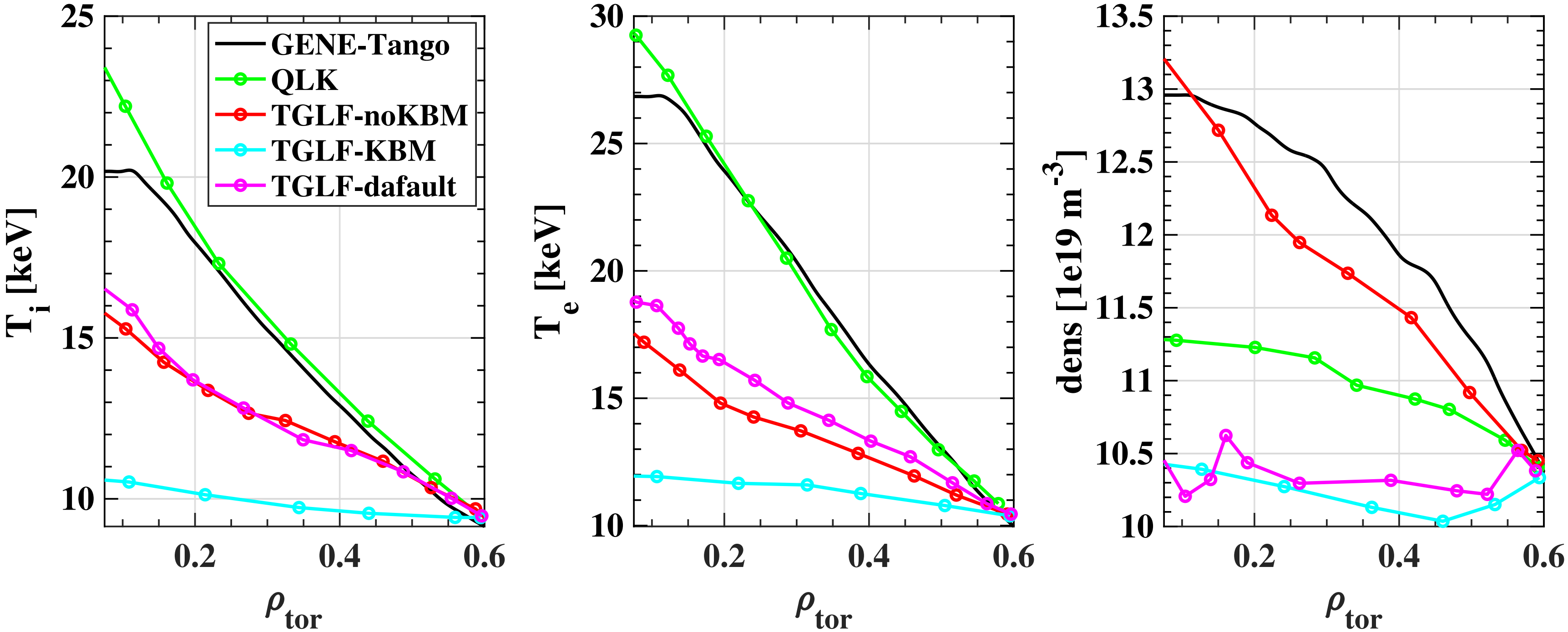
BC=0.6

Are 'TGLF KBM' realistic or overestimated?
Need stand alone TGLF vs GENE/GKW
+ GENE-Tango comparaison



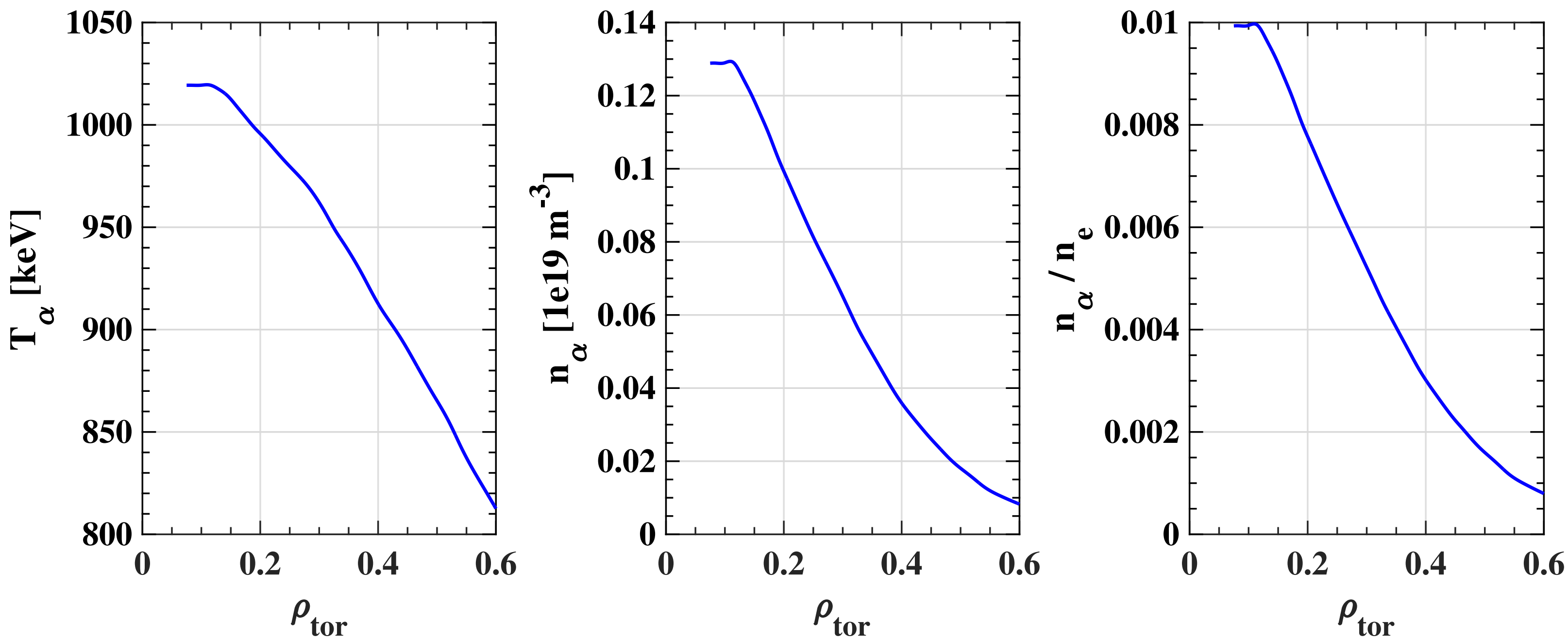
Comparison with reduced turbulence models

- QLK-JETTO shows a good agreement with the EM GENE-Tango temperature profiles, but it underestimates the density peaking, leading to a lower fusion output.
- TGLF-JETTO consistently underpredicts both the ion temperatures and plasma density, regardless of the specific settings applied.



Alpha density

- GENE-Tango simulations including alpha particles in GENE will start soon.
- Tango will self-consistently compute the alpha particle density and temperature for each updated thermal profile, adjusting these values at every iteration



- The initial profiles, obtained from the EM GENE-Tango simulation neglecting alpha particles in GENE, are shown above.

On-going analyses and future plans

- Convergence tests are ongoing using the final profiles from the EM GENE-Tango simulations, with parameters set to (nx, ny, nz, nv, nmu) = (2048, 96, 48, 48, 32).

- Linear stability analyses, both FT and global, is on-going for the final EM GENE-Tango profiles.

- Nonlinear FT simulations is on-going at various radial locations using the final profiles for both ES and EM cases.

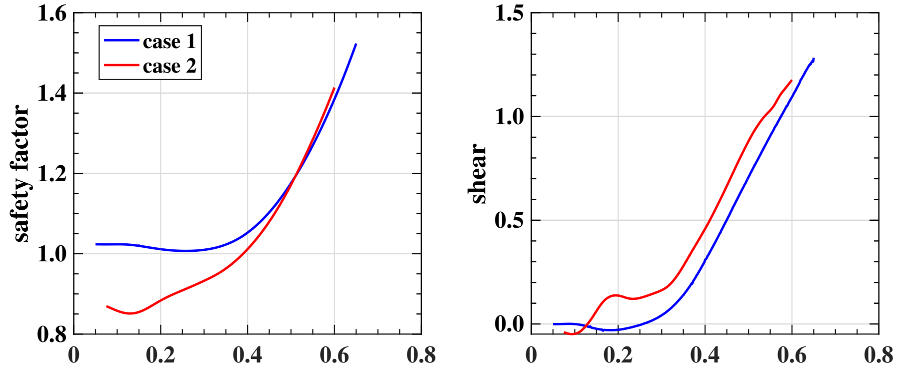
- Multi-scale FT simulations at rho = 0.3 and rho = 0.5 are on-going to assess the role of ETG turbulence in the ITER baseline scenario using the final EM GENE-Tango profiles.

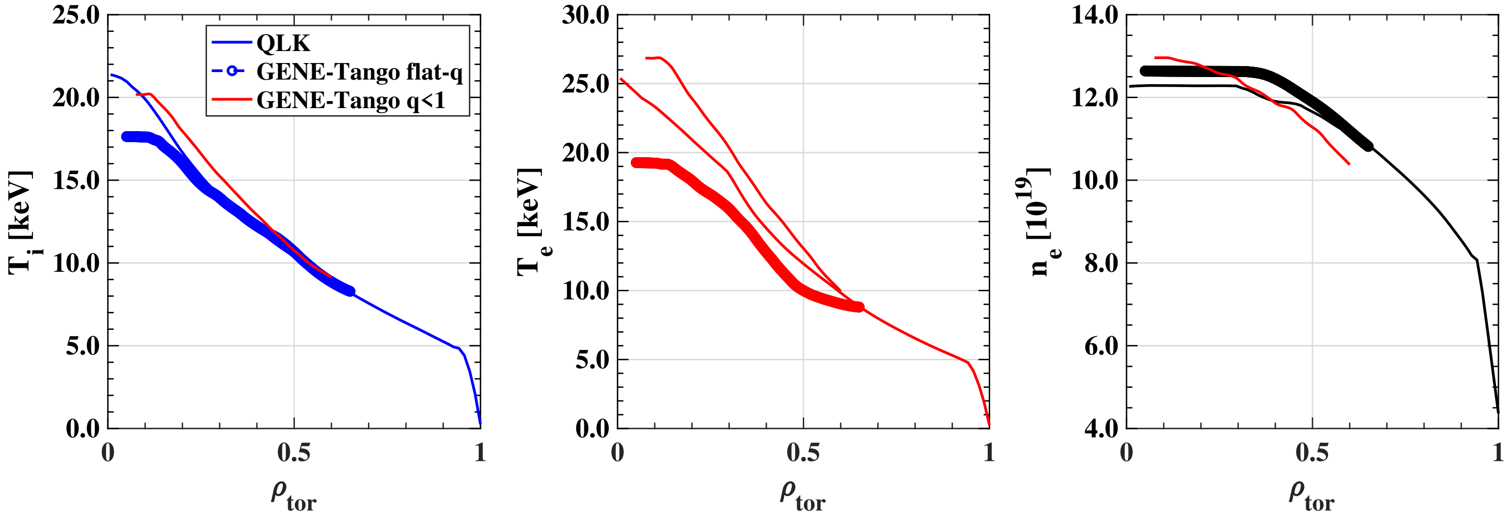
- Benchmarking against other FT and global codes is crucial due to the challenging nature of these simulations.

- Revisit the flat q-profile case, this time using higher radial resolution.

- Perform parameter scans over the boundary values of Ti, Te and density at rho = 0.6, and evaluate the impact on the fusion output.

On-going analyses and future plans





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- Perform parameter scans over the boundary values of Ti, Te and density at rho = 0.6, and evaluate the impact on the fusion output.

Points for discussions

- What is the best wat for running GENE-Tango including alpha particles?
  - Evolve the thermal ion density profile.
  - How should the helium ash be handled in Tango? Currently, I am using a fixed helium ash profile based on the one obtained from the reference QLK-JETTO simulation.
  - Helium ash can be included in GENE at a later stage, once the simulation with alpha particles has converged, to investigate helium ash accumulation.
- Run stability analyses of alpha particle-driven modes and the SAW continuum using FAR3D, LIGKA, ORB5, or GENE?
- If modes are identified, we can perform nonlinear simulations with FAR3D and subsequently incorporate the modified alpha particle profiles into GENE-Tango.
- …