Simulations of Microturbulence in JET and DIII-D plasmas

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and contributors to the EFDA-JET and DIII-D work programs

- We need to understand and control the microturbulence expected to cause anomalous transport in tokamak burning plasmas
- Our research compares nonlinear GS2 simulations of microturbulence fluxes with measurements in:

1. Two Advanced Tokamak plasmas
2. One DT ELMy plasma

- The simulated microturbulent fluxes are:

1. Suppressed within $\simeq$ half radius
2. Different for D and T
3. Impurity fluxes small in AT plasmas, inward in the DT ELMy plasma

Plasmas studied and questions asked

- JET and DIII-D AT plasmas with ITB's and high bootstrap fractions
  1. What causes accumulation of high Z impurities within ITB?
  2. Is large externally-driven flow shear (γ_{ExB}) required?
- JET DT ELMy plasma with record W_{DT}
  1. Is the transport of D and T similar?
  2. Do impurities accumulate?

Nonlinear microturbulence simulations with the GS2 code

Start with the Vlasov equation (Maxwell-Boltzmann equation) + collisions

Length scale and time scale ordering, gyro-averaging -> gyrokinetic equations

GS2 solves the gyrokinetic equations for evolution of $f(\vec{x}, v_{\parallel}, v_{\perp}, \text{species})$

Up to 0.94 billion meshpoints to resolve $f(\vec{x}, v_{\parallel}, v_{\perp}, \text{species})$

Miller equilibria for shaped flux surfaces, up to 6 species

Collisions modeled using an energy-dependent Lorentz collision operator

Electrostatic fluctuations (near future: include magnetic fluctuations & ExB shear)

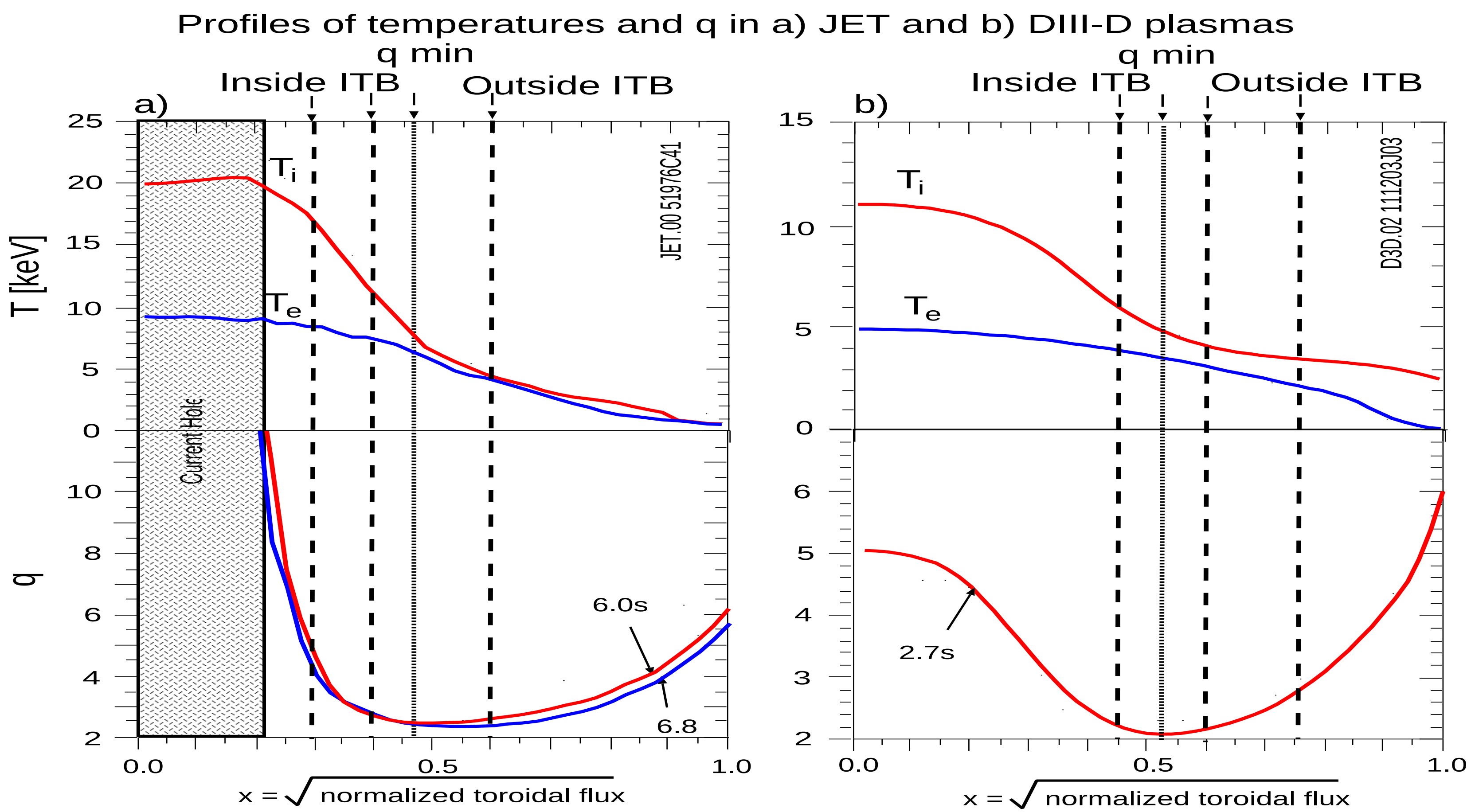
$k_{poloidal} \ \rho_{ion}$ from 0 up to 0.9 - 3.0

$n_{poloidal} = 24 - 48$

$n_{radial} = 24 - 125$

GS2 scales well up to 1024 processors on IBM SP

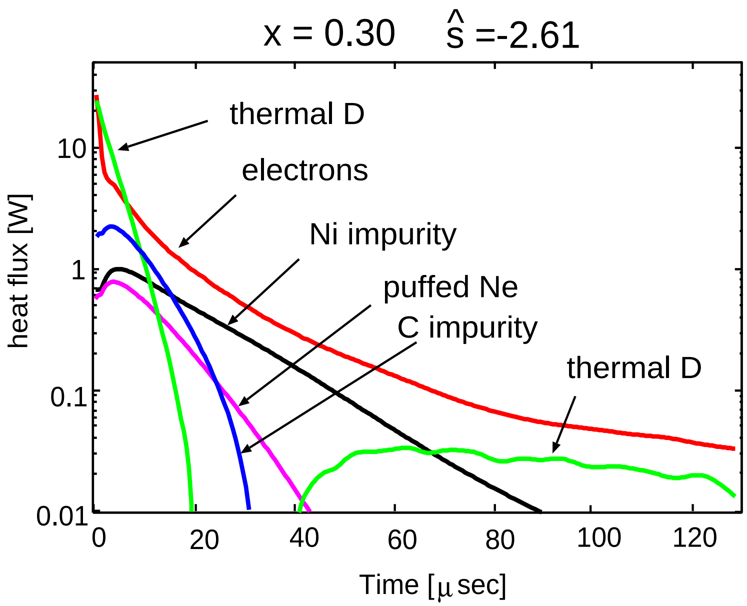
AT plasmas: ITB (defined by large R/L_{T_i}) ends near q_{min}

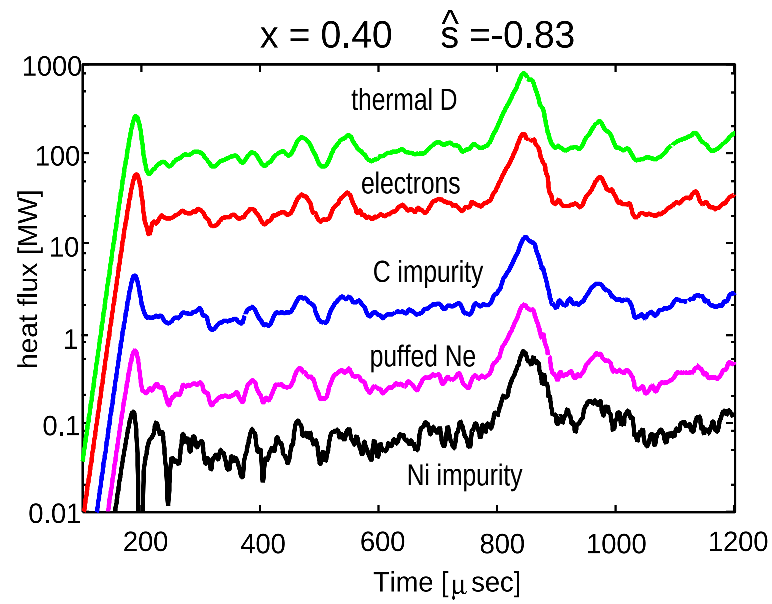


Microturbulence in JET AT plasma with current hole

Strong suppression for large negative $\hat{s}$

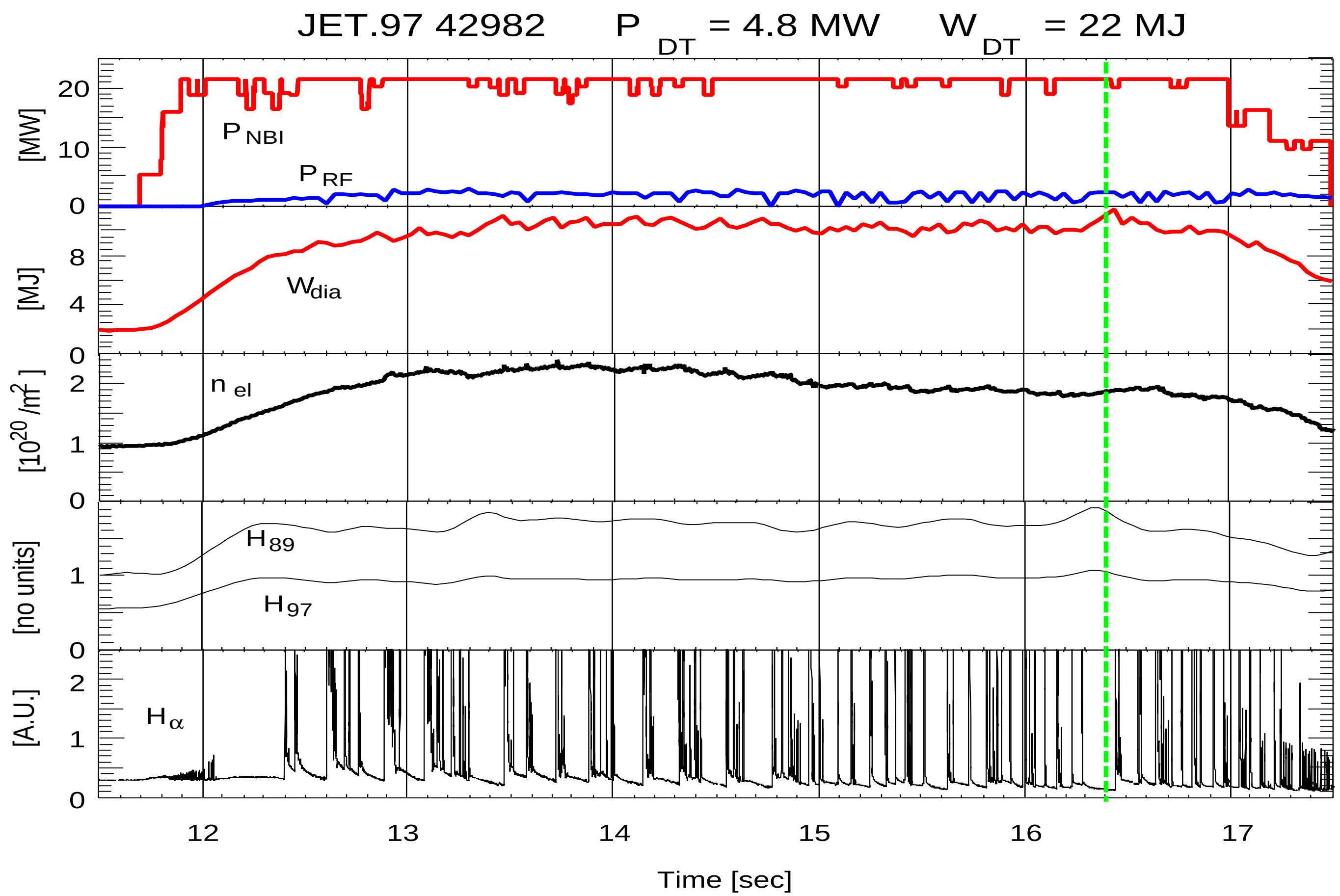
Microturbulence fluxes too large at weak and positive $\hat{s}$



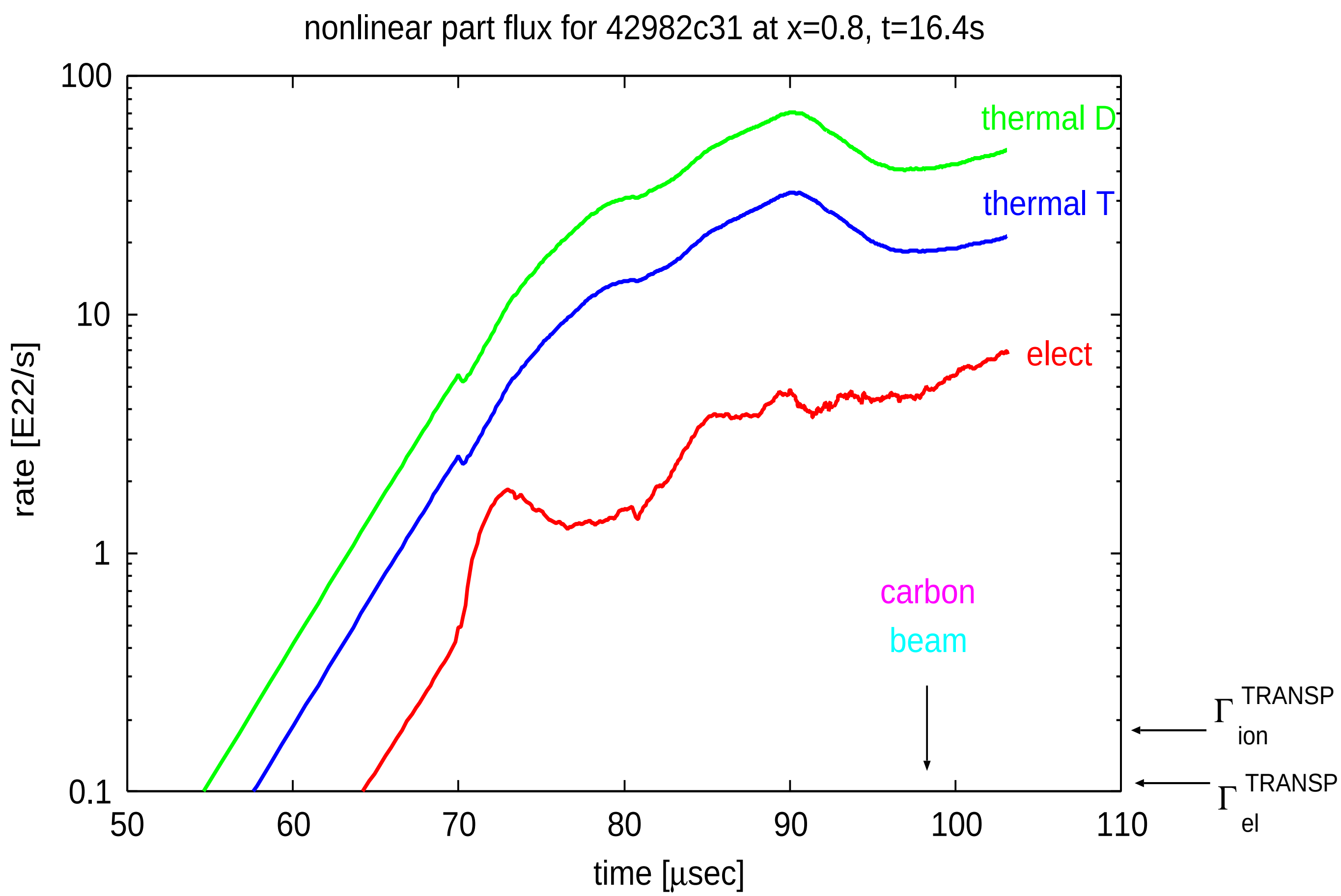


Similar results for particle fluxes and DIII-D AT plasmas

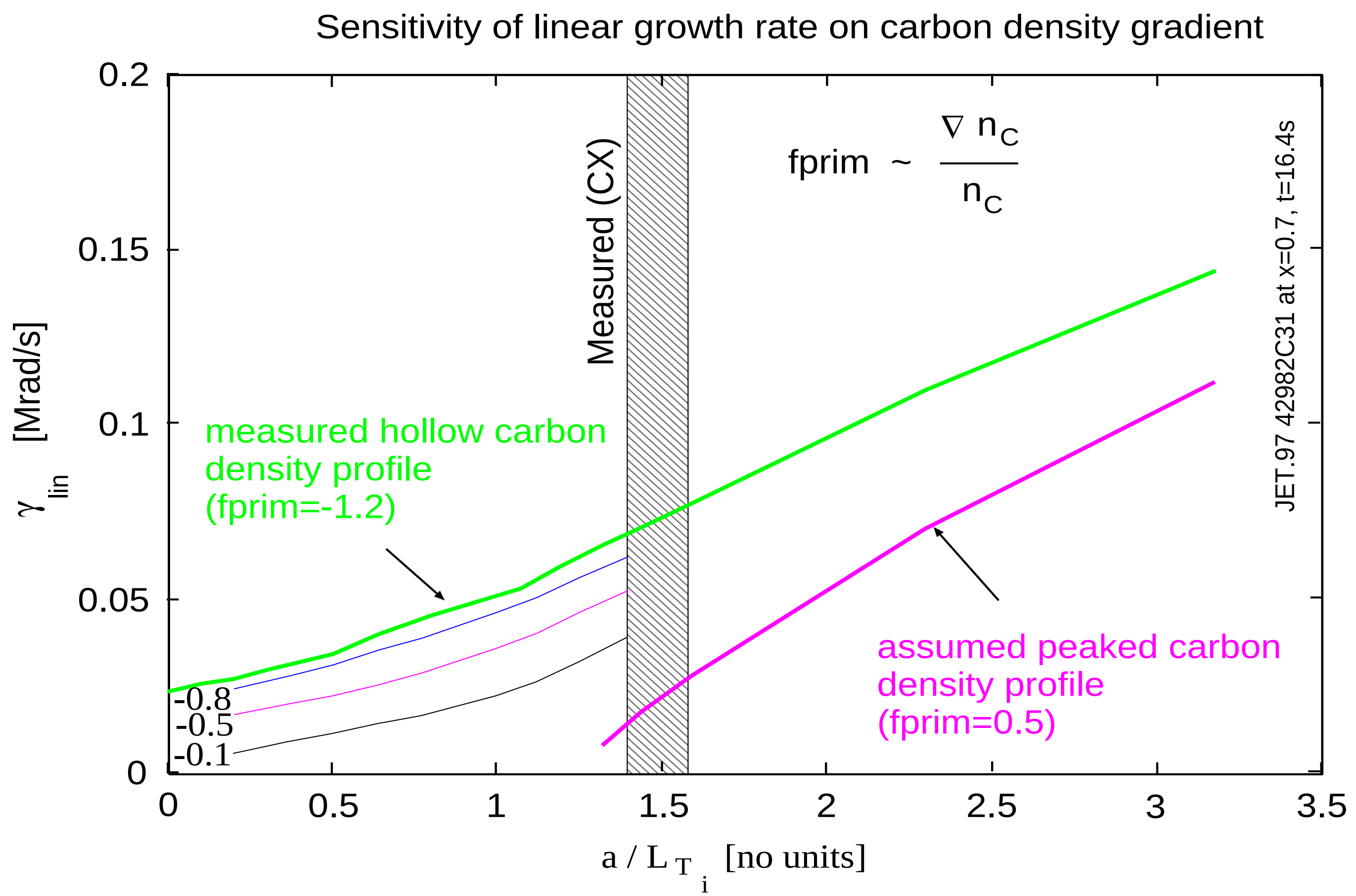
ELMy DT plasma from JET



Microturbulent particle fluxes in the JET DT ELMy plasma



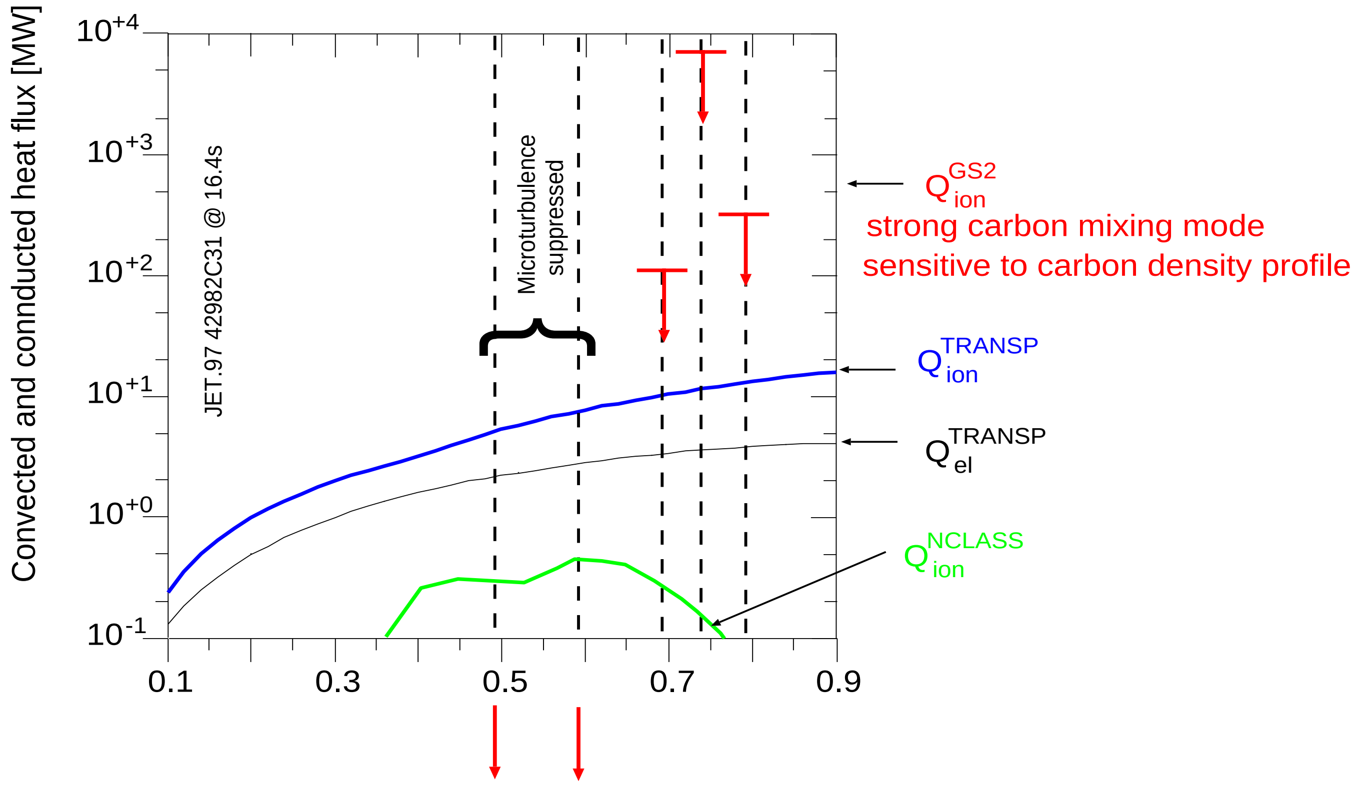
Linear growth rate reduced if impurity density less hollow



Profiles of heat fluxes in JET DT ELMy plasma

Neoclassical fluxes much lower than measured (as expected in moderate density JET ELMy)

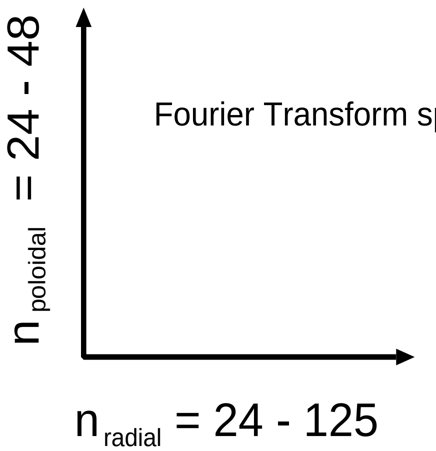
Microturbulent-driven heat fluxes either too high or too low

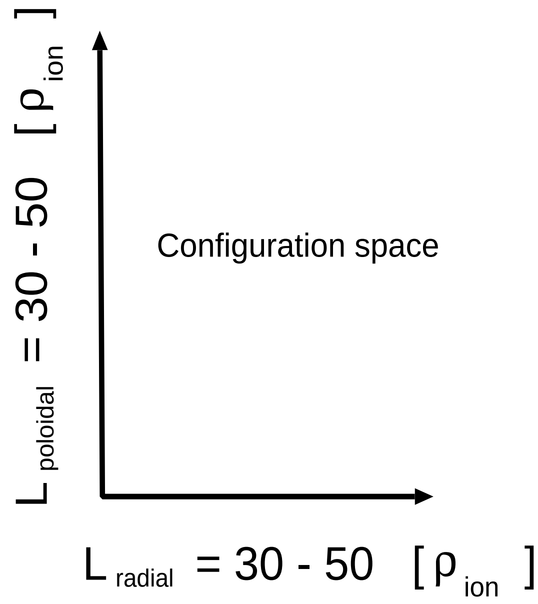


Results

- Hypersensitive dependence on impurity density profile
- Microturbulence in AT plasmas suppressed when $\hat{s}$ is sufficiently negative and $\alpha \propto |\nabla\beta|$ sufficiently large, even with large R/L_{T_i}
- Microturbulence suppressed in DT ELMy plasma within $\simeq$ half-radius, large and driven by impurity carbon mixing at larger radii
- Need to invoke externally-driven γ_{ExB} and/or EM β suppression further out
- Ignoring externally-driven γ_{ExB} and β stabilization, GS2 predicts heat and particle fluxes high by factors of 5-1000
- In AT plasmas impurity fluxes are outward, suggesting that impurity accumulation inside ITB's due to neoclassical, not microturbulence effects
- In ELMy plasmas impurity fluxes can be inward
- differing heat and particle fluxes for D and T
- Bursts of energy and particle fluxes in AT plasmas lasting 50-100 microsec

Movies of $\tilde{\phi}(x, y, \theta = 0; t)$ and 2-point correlations





Streamlines of v_{ExB} along contours of constant $\tilde{\phi}$

2-point correlation of $< \tilde{v}_{ExB}(\vec{x})\ \tilde{T}\ (\vec{x} + \vec{\Delta}) >$