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Nonlinear Gyrokinetic Simulations of Electron Turbulence in NSTX

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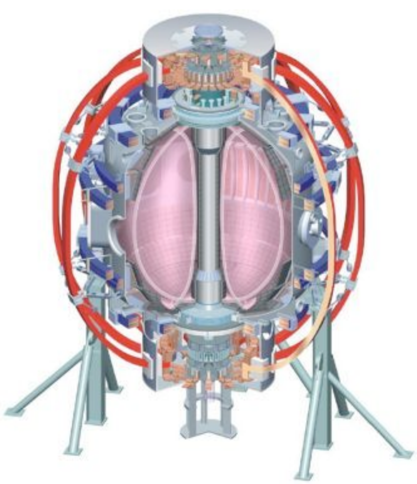

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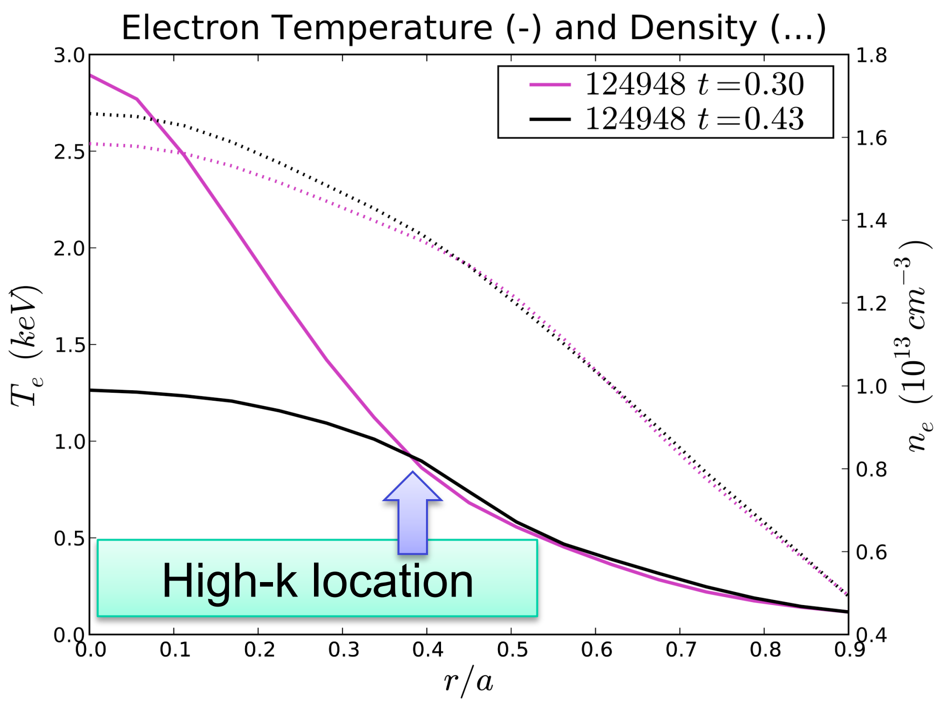
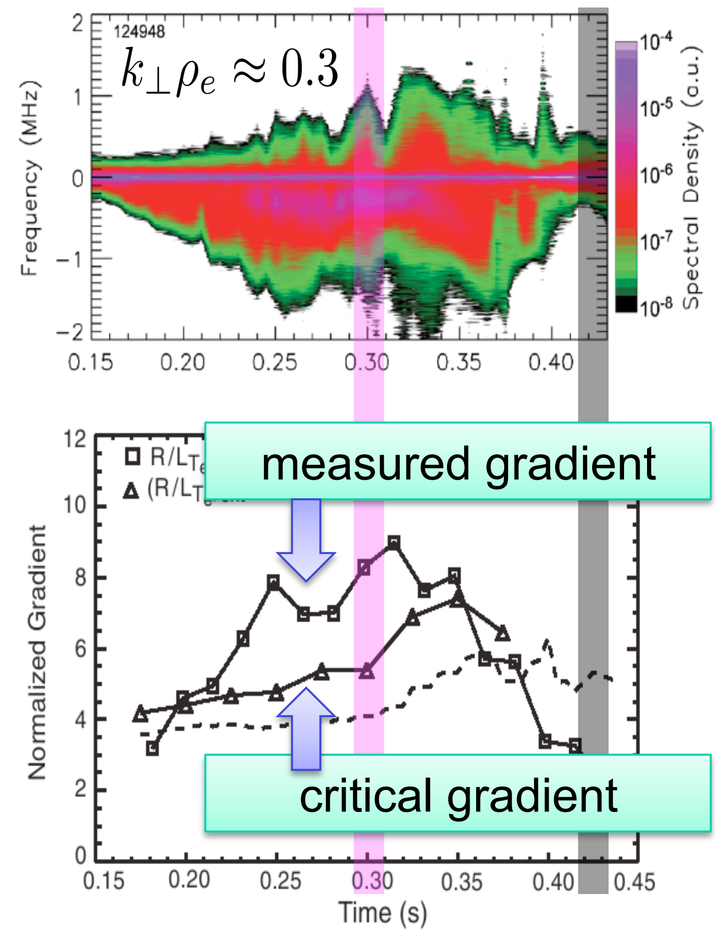
Summary

- Experimental evidence of Electron Turbulence in NSTX.
- Simulating NSTX electron turbulence is challenging.
- Global simulations show ETG-driven turbulence.
  - **ExB** shearing has little effect.
  - Collisions have little effect.
  - Magnetic perturbations have small effect.
- Reversed magnetic shear appears to control turbulence.
- Transport predictions indicate long wavelength turbulence may be important.

Electron-scale fluctuations in NSTX appear when linearly unstable to ETG



$$\left(\frac{a}{L_{T_e}}\right)_{crit} (t = 0.3\ s) \approx 3.3$$



Mazzucato et al PRL (2008)

Some physical parameters for NSTX 124948 @ 300 ms

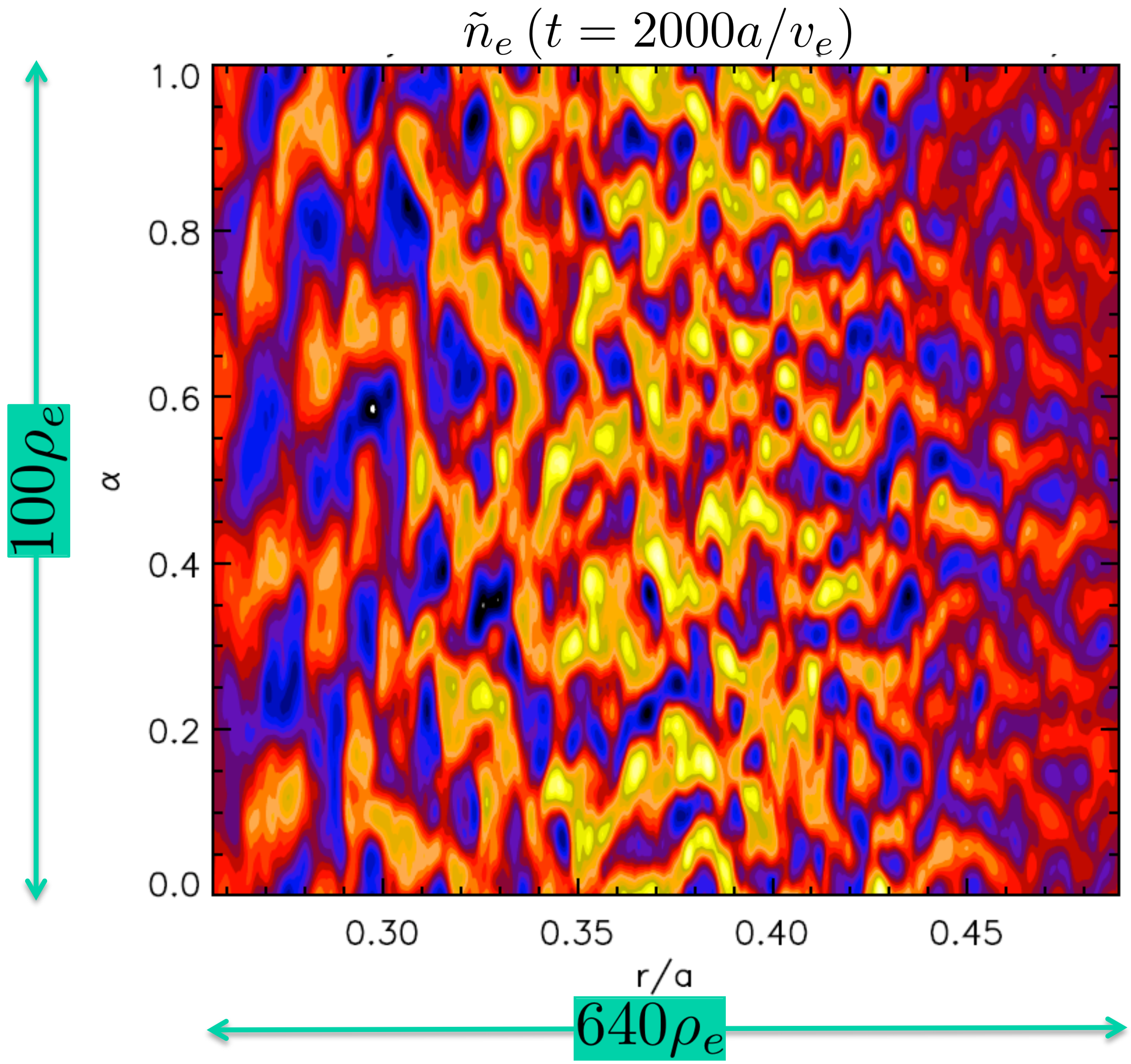
r_0/a	0.373
R_0/a	1.502
κ	1.859
δ	0.129
q	3.113
$\hat{s}$	-0.127
ρ_*	0.007
n_i/n_e	1.0
T_i/T_e	0.833

Z_{eff}	2.50
$\gamma_E(a/c_s)$	-5.6×10^{-3}
λ_D/a	9.4×10^{-5}
$\nu_{ei}(a/c_s)$	0.087
$\nu_{ii}(a/c_s)$	0
a/L_n	0.628
a/L_{T_i}	1.302
a/L_{T_e}	4.71
$\beta_{e,unit}$	6.1×10^{-3}

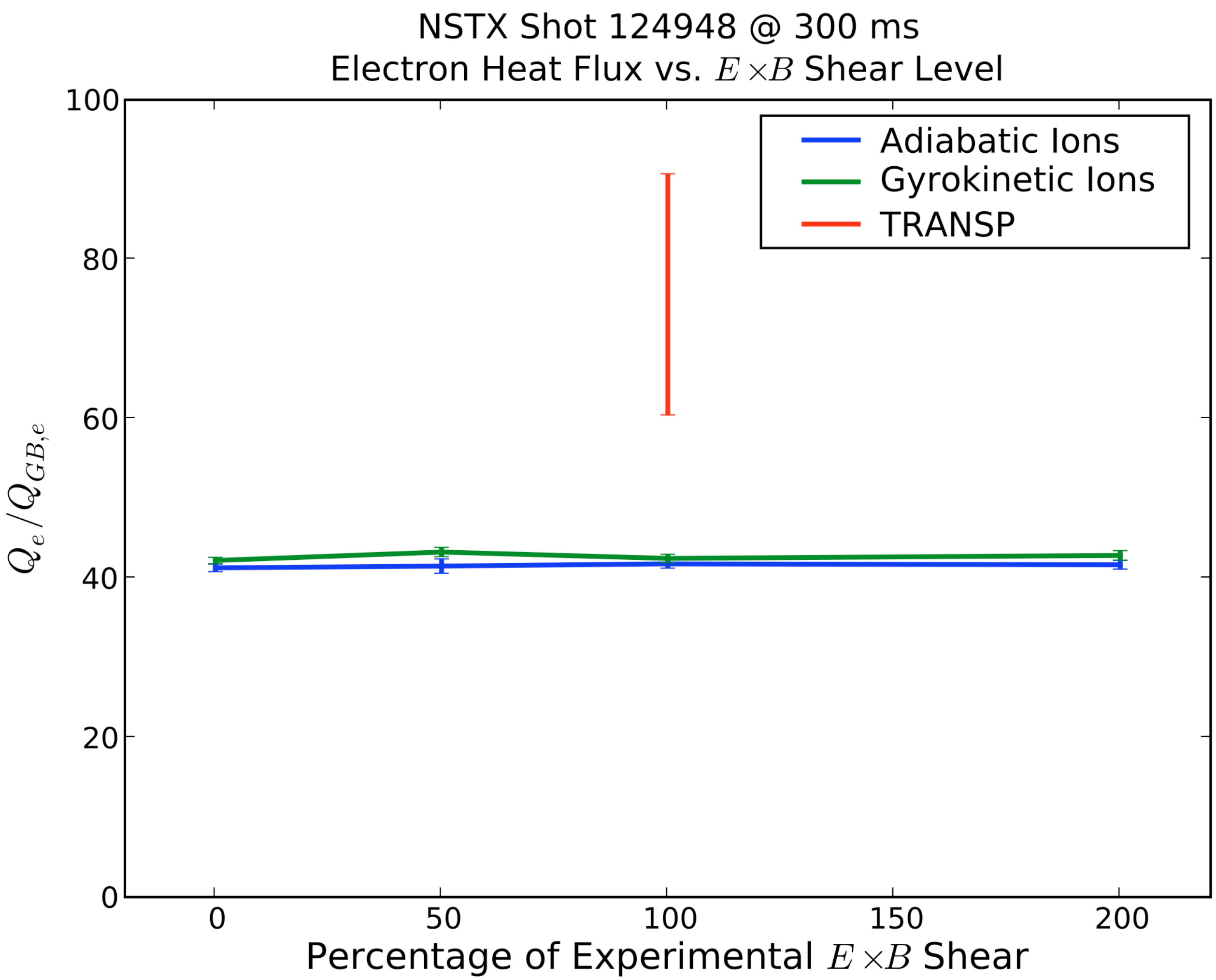
NSTX ETG simulations are tough.

- TGYRO/GYRO/NEO/TGLF pull data from TRANSP
  - Radial variation in profiles
- Higher resolution necessary for convergence
  - Resolve electron gyroradius
  - Increase velocity space, poloidal resolutions from standard
  - Small time step to get electron dynamics
  - Reduced mass ratio
- Gyrokinetic electrons; gyrokinetic (or adiabatic) ions
- Electrostatic or Electromagnetic
  - (no parallel magnetic compressions yet)
- 52 million distribution points
- 60,000 – 150,000 CPU hours each at ORNL's Jaguar

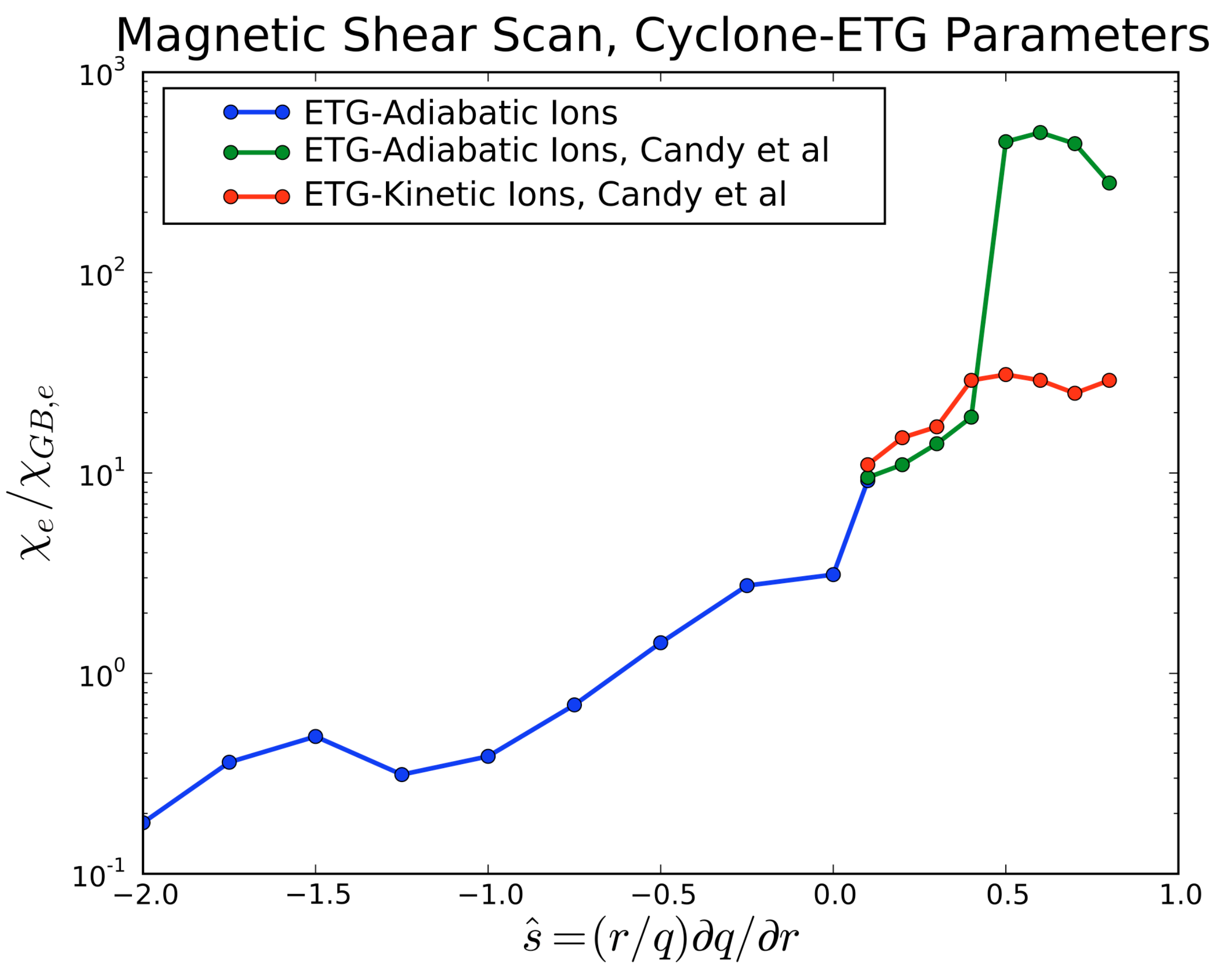
Global simulations show ETG turbulence.



Good agreement with models at experimental ExB shear level

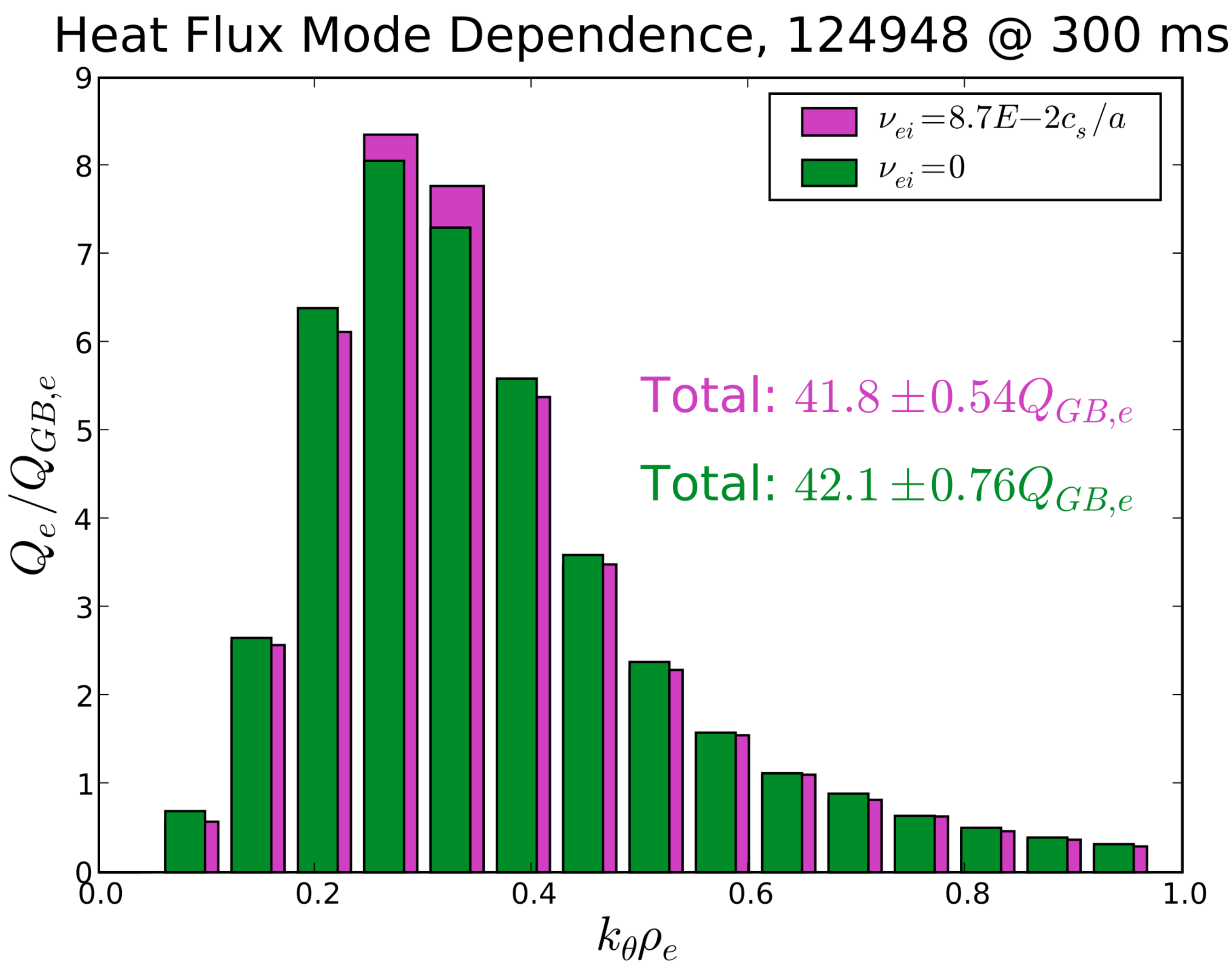


Reversed magnetic shear reduces ETG turbulence and adiabatic ion model inaccuracies.

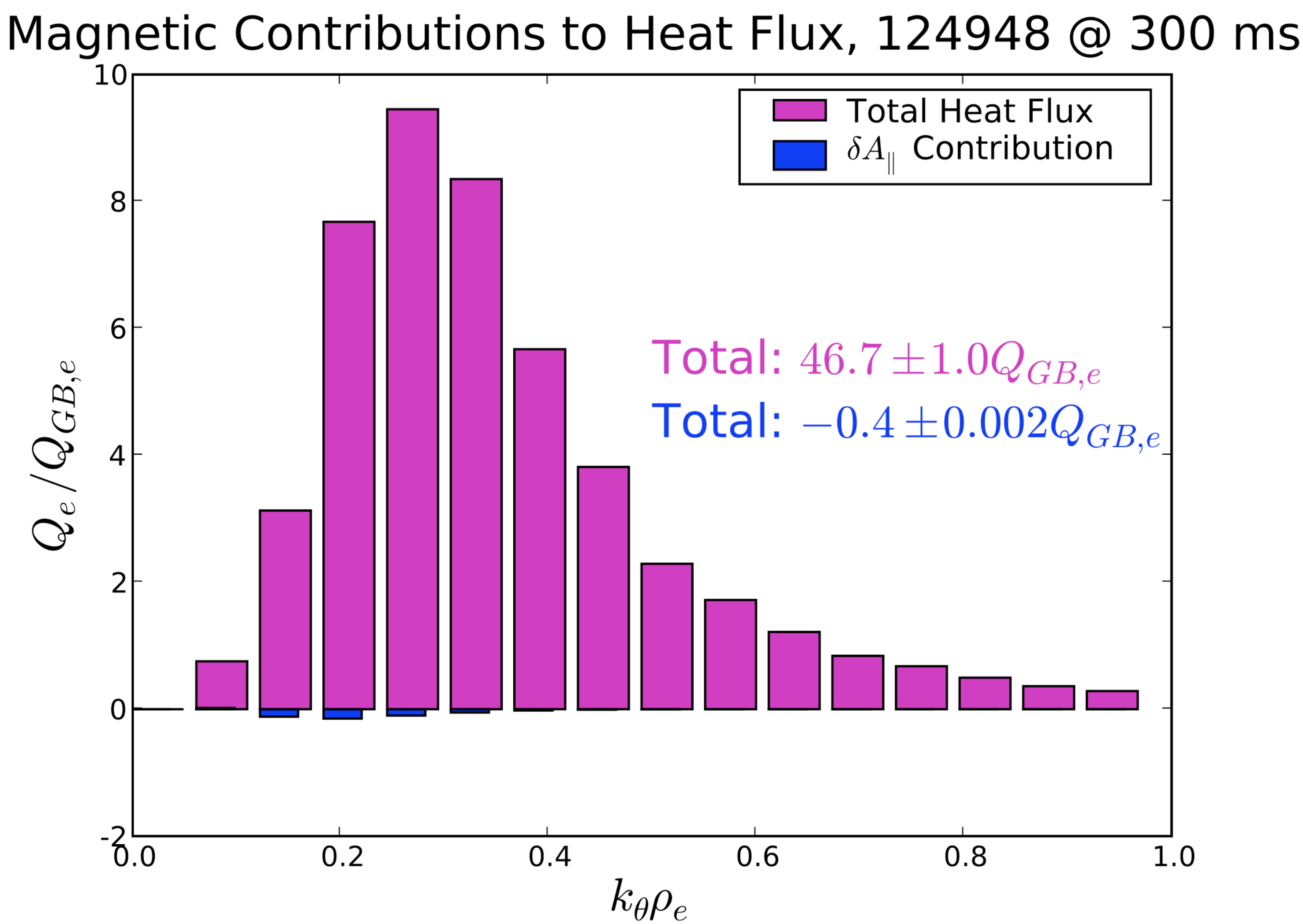


Candy et al PPCF (2007)

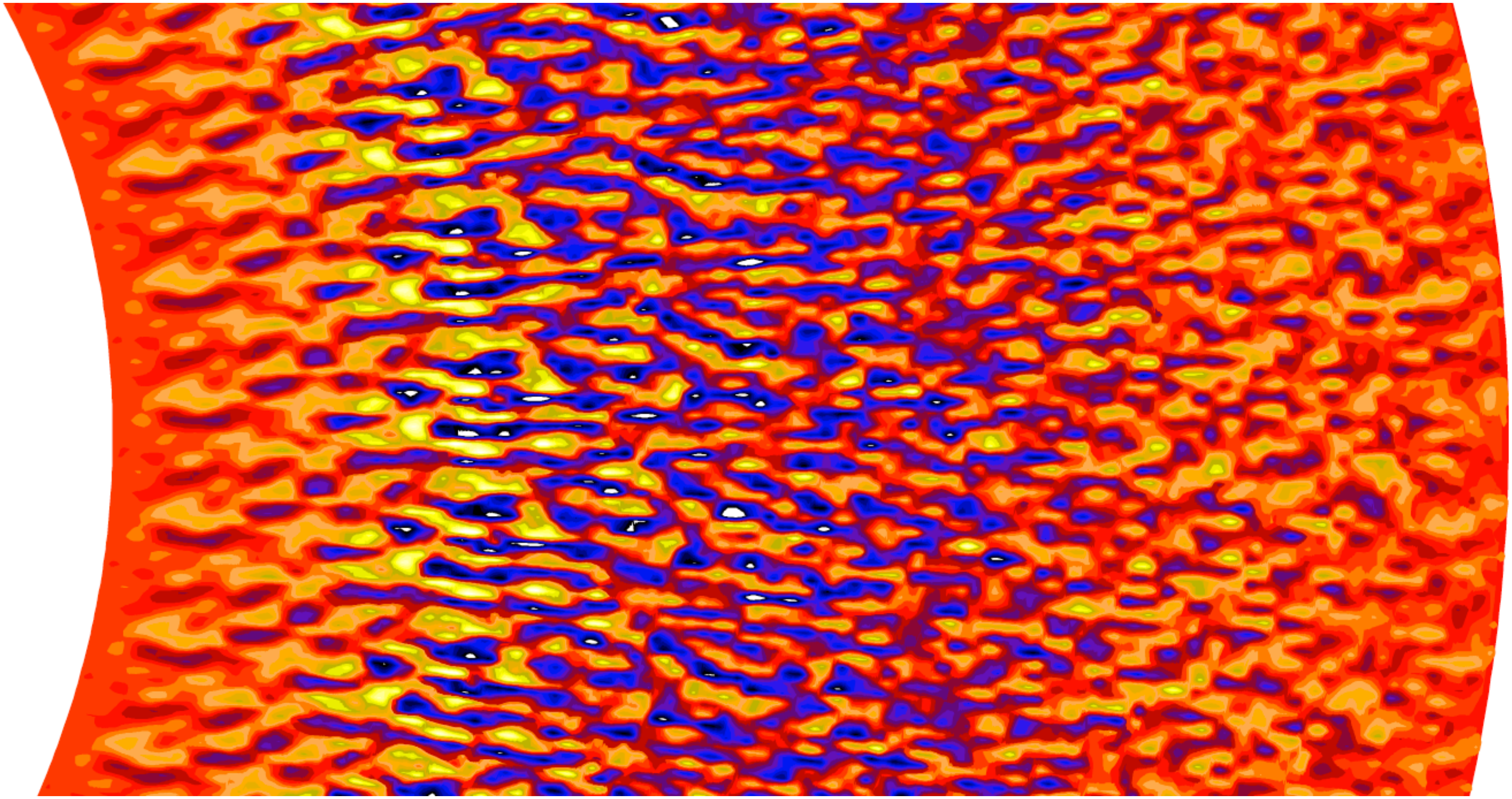
Removing electron-ion collisions has little effect on heat transport.



Adding magnetic fluctuations has slight effect at longer wavelengths.

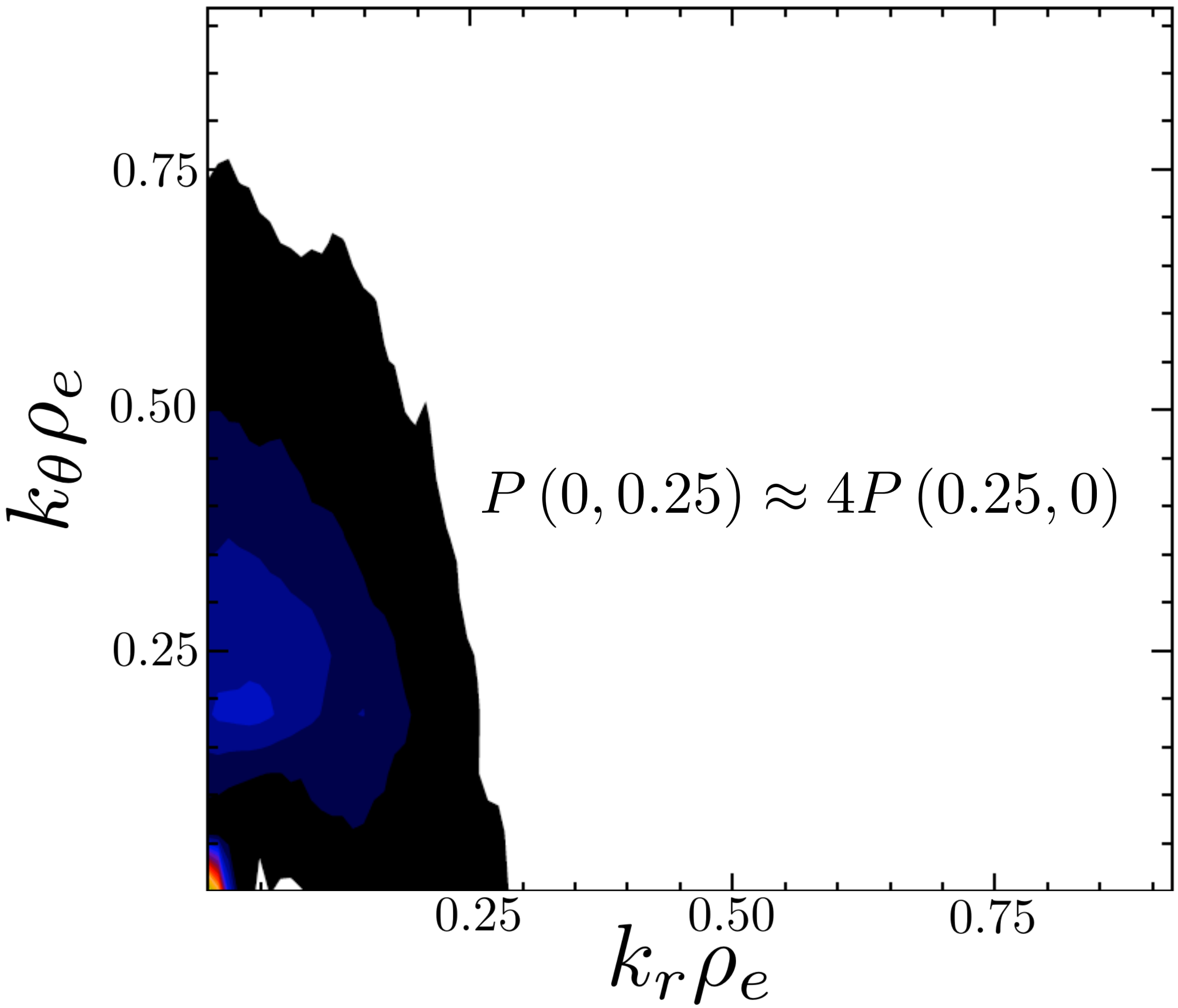


Poloidal cross-section shows elongated streamers.

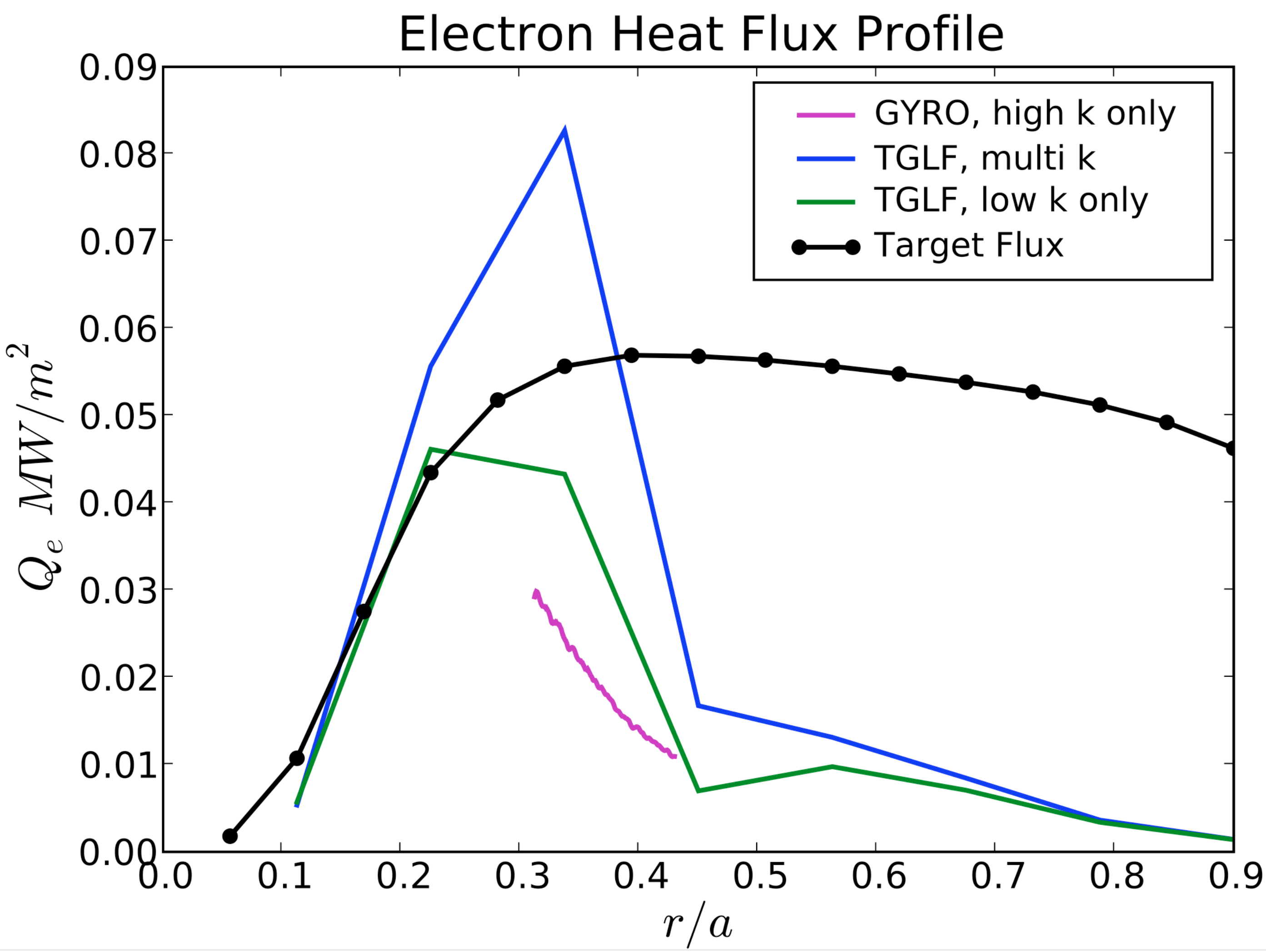


Radial direction

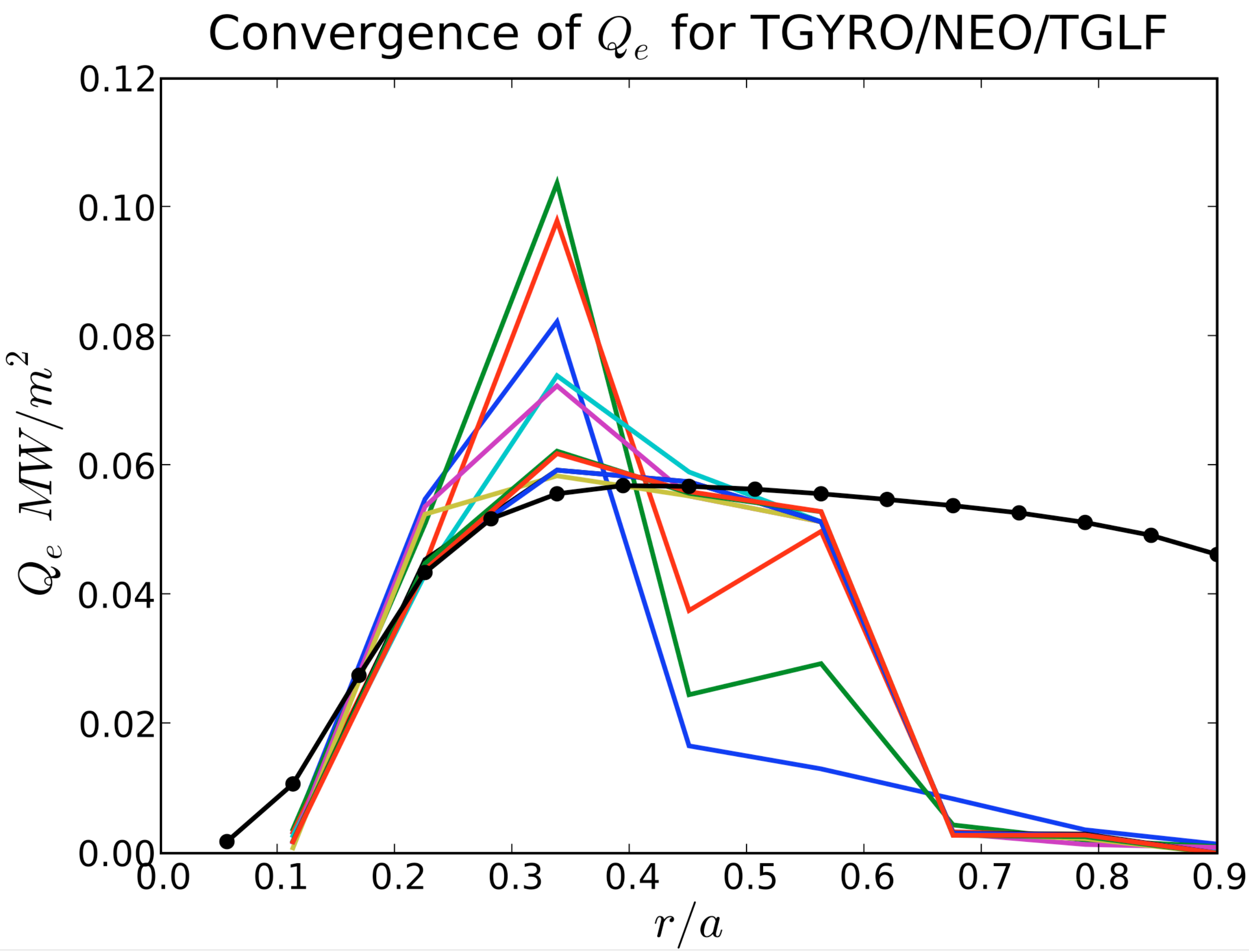
Anisotropic electrostatic potential power spectrum may have implications for experimental comparison.



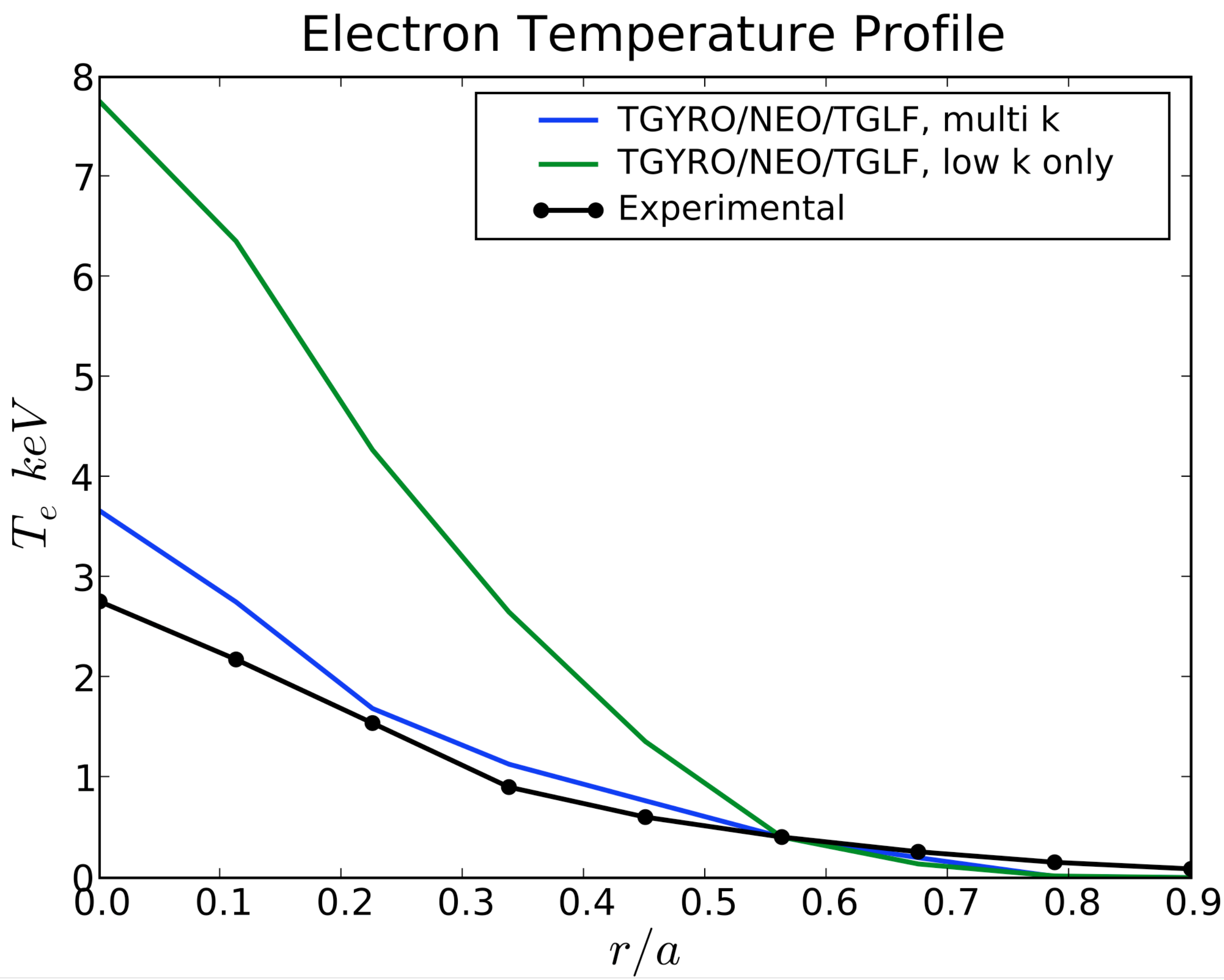
Great radial variation in heat flux predicted by GYRO and TGLF.



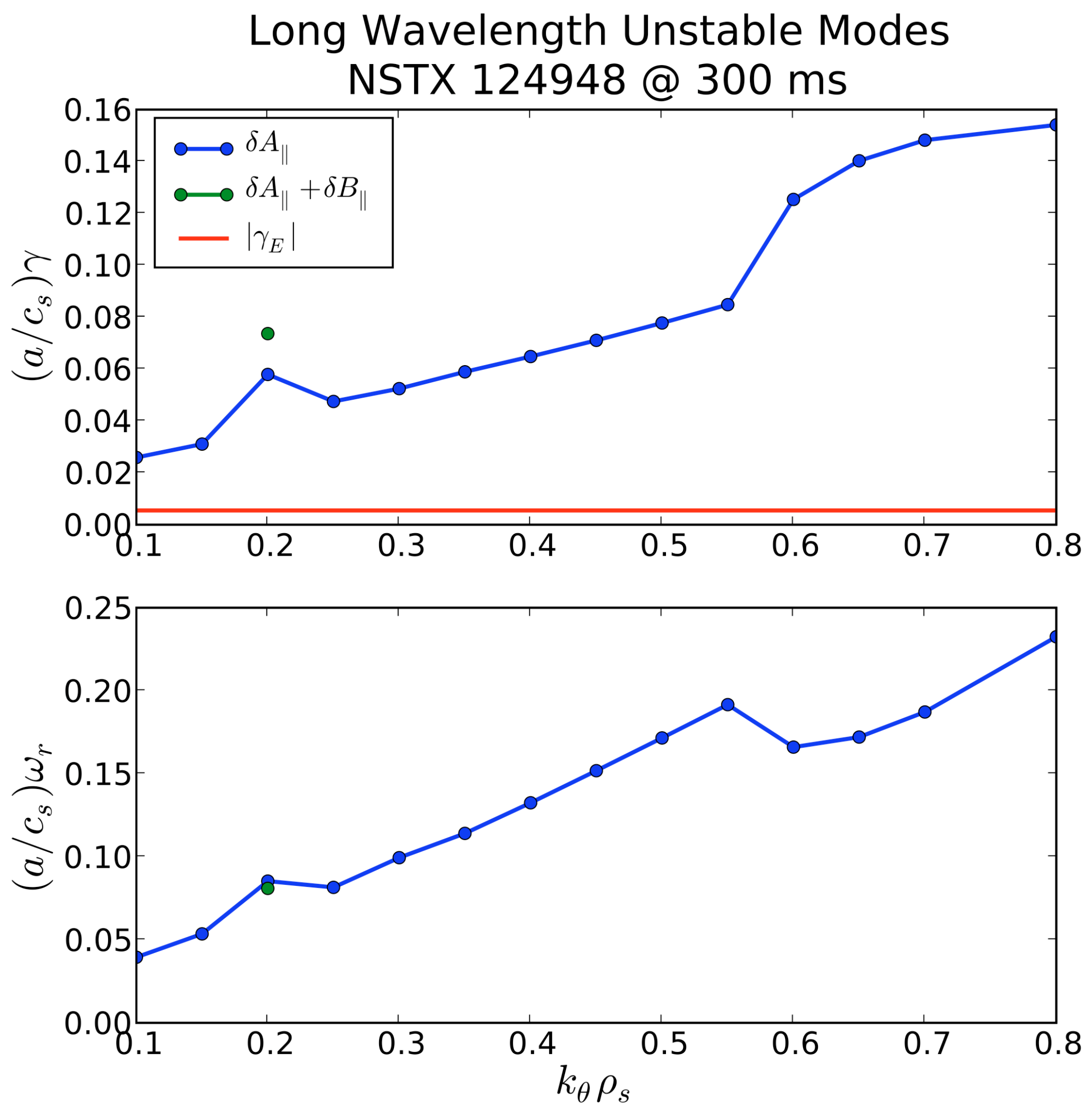
TGYRO-TGLF (with high k) converges to flat heat flux profile in plasma core.



Transport simulations with high-k give more accurate prediction of electron temperature gradient profile.



ExB shear may be too low to suppress long wavelength modes.



Key Points

- Nonlinear simulations of NSTX show ETG-driven turbulence.
  - Under-predict heat flux by factor of two with experimental gradients.
- Neither collisionality nor ExB shear affect the high-k electron energy flux.
- Reversed magnetic shear is important.
  - Model saturation and overall transport levels
- Long wavelength turbulence may contribute to electron energy flux.
  - Transport simulations with long and short wavelengths better predict electron temperature profile.
  - ExB shearing rate is lower than long wavelengths' growth rates.

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ETG may not be the only player.

Puzzles and Pathways

- How sensitive are simulations to the model?
  - Mass ratio, ion dynamics, compressional magnetic perturbations
- How sensitive are simulations to experimental uncertainty?
  - Temperature, density, impurity concentration
- What is the role of long wavelength turbulence?
  - Can it account for balance of electron heat flux?
  - Does it alter the properties of the ETG turbulence?

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We need to simulate steady-state shots diagnosed at multiple wavelengths.