Nonlinear Gyrokinetic Simulations of the NSTX Spherical Torus*

J. L. Peterson,‡ G. W. Hammett, D. Mikkelsen, S. Kaye, E. Mazzucato, D. R. Smith, R. Bell, B. LeBlanc, *PPPL*, H. Yuh, *Nova Photonics, Princeton, NJ*
J. Candy, R. E. Waltz, E. A. Belli, G. M. Staebler, *General Atomics, San Diego, CA*

American Physical Society Division of Plasma Physics Meeting, Atlanta, Georgia, November 2009

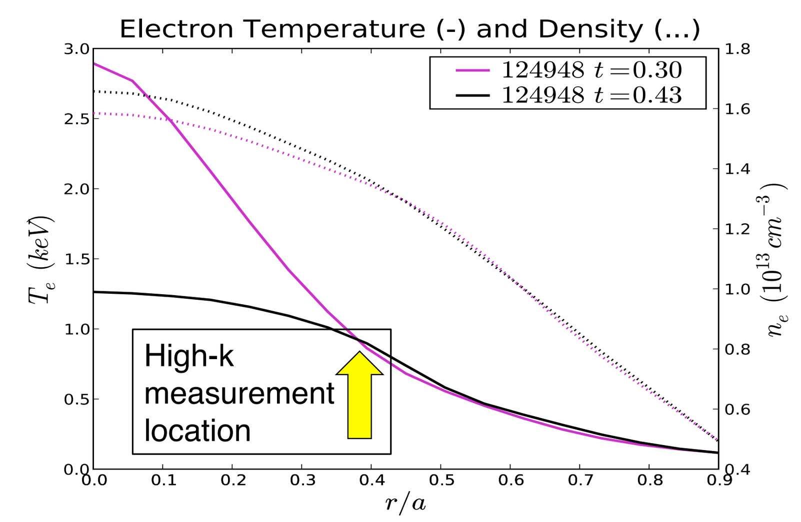
‡ jpeterso@pppl.gov

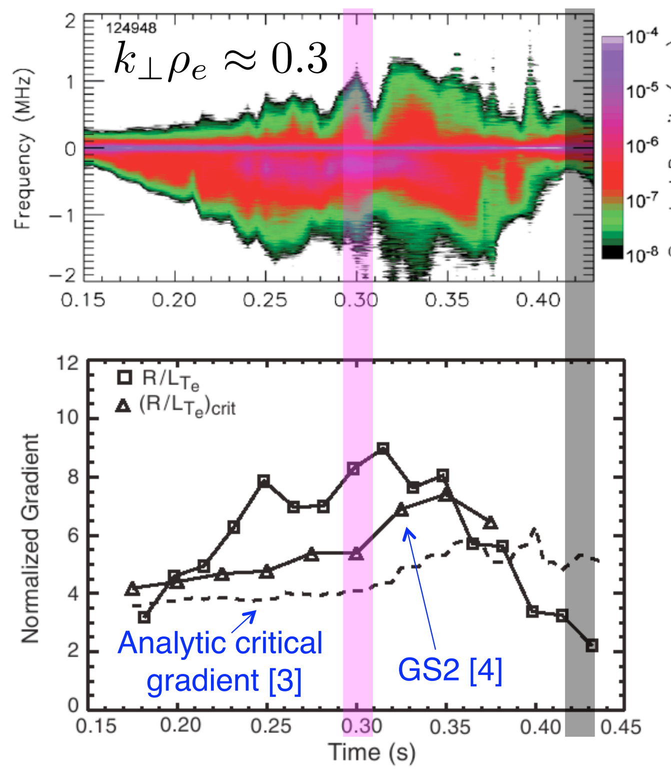
* Work supported by US DOE Contract No. DE-AC02-09-CH11466

Abstract

Recent progress in the numerical simulation of plasma turbulence has led to a greater understanding of the mechanisms behind anomalous heat and particle losses in tokamaks. However, the source of turbulent transport in machines with smaller aspect ratios, such as the National Spherical Torus Experiment (NSTX), remains elusive. Leading contenders for explaining transport in spherical tori include turbulence driven by the Electron Temperature Gradient (ETG) mode and microtearing modes. We present here nonlinear GYRO [1] simulations of microturbulence in a variety of NSTX discharges and make comparisons between numerically simulated and experimentally measured levels of electron-scale turbulence.

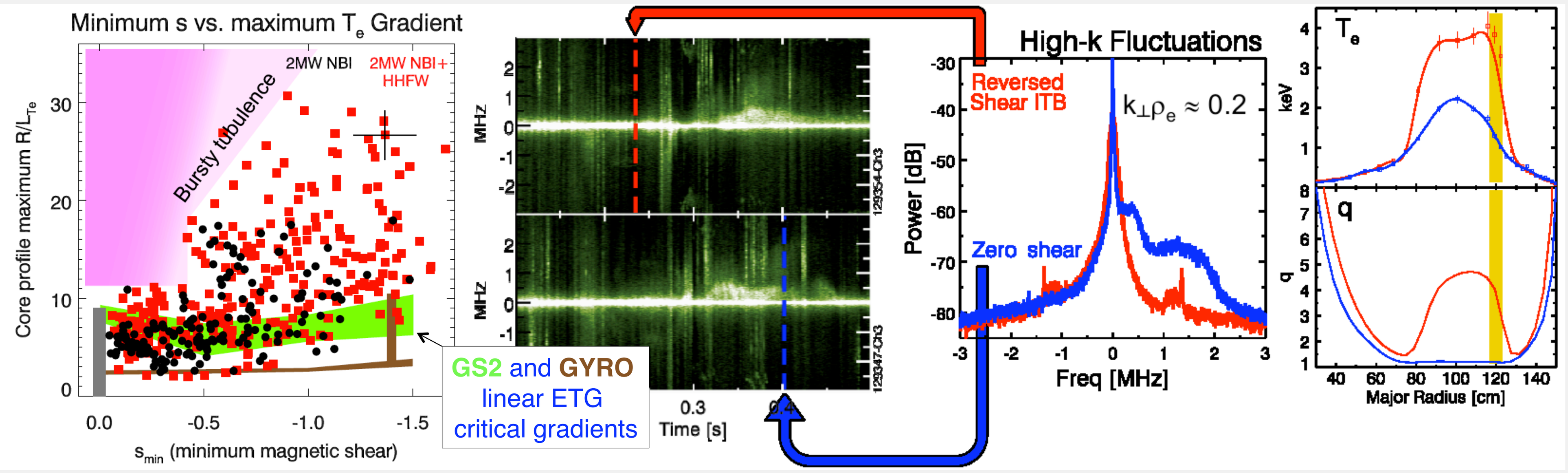
Electron-scale density fluctuations are measured in NSTX plasmas





NSTX Shot 124948 shows high levels of electron gyro-scale fluctuations during HHFW heating when the electron temperature gradient is above the GS2-calculated linear stability threshold for ETG turbulence. Fluctuations reduce after the RF pulse ends [2].

Reversed magnetic shear affects these fluctuations

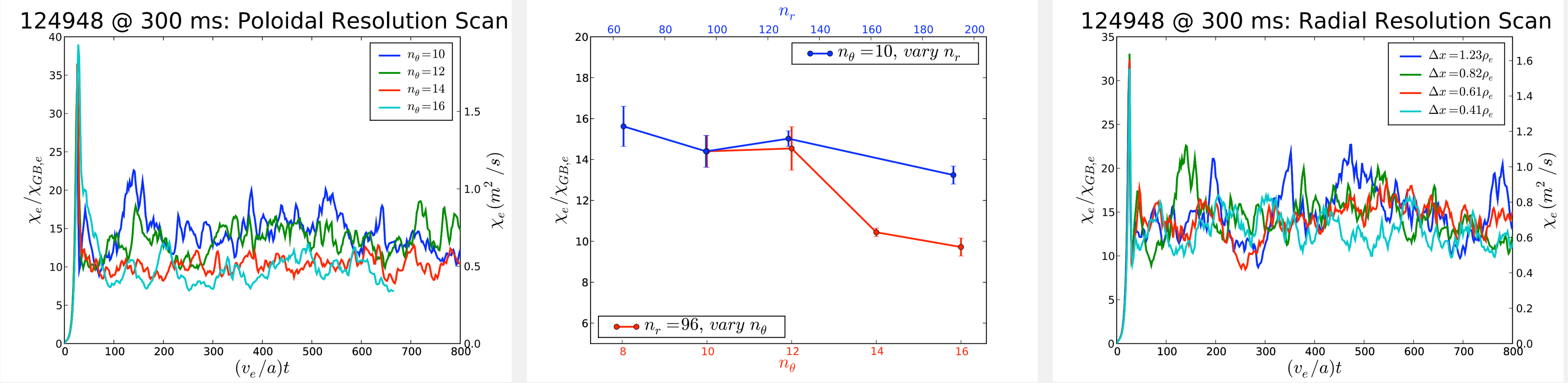


Shots **129347** and **129354** together show reduced high-k [2] activity, despite large electron temperature gradients, during reversed-shear discharges. Reversed magnetic shear could be linked to electron internal transport barriers. NSTX plasmas with strong reversed shear are found to have temperature gradients well above linear ETG critical thresholds [5].

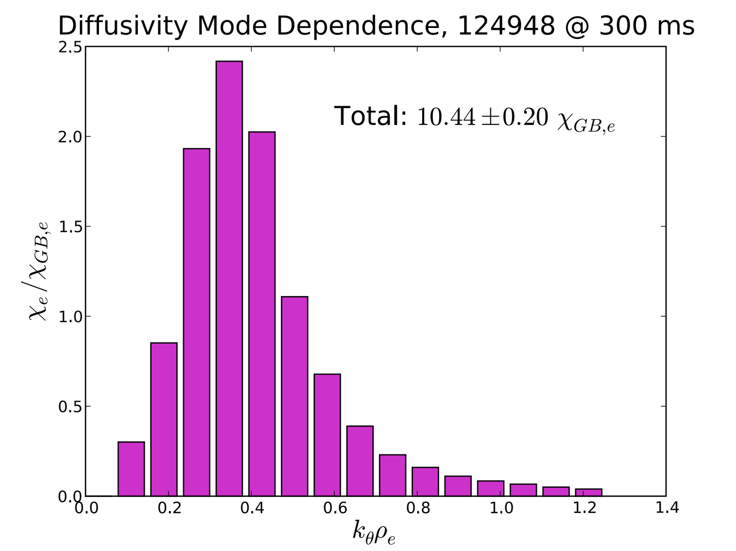
Electron Temperature Gradient Turbulence Simulations

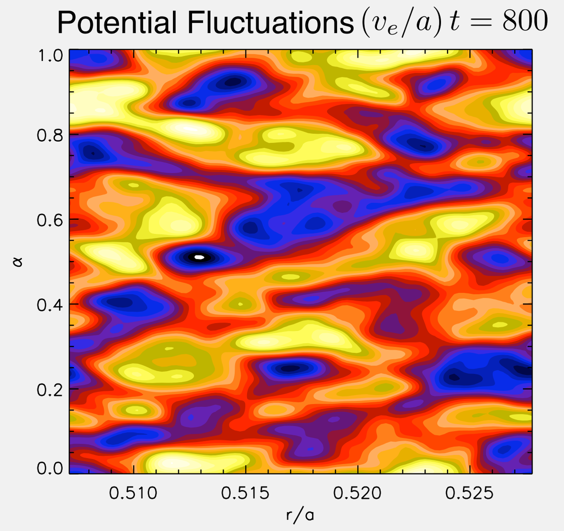
Simulation Parameters

NSTX Experimental Profiles	Electrostatic	Adiabatic Ion Approximation
Periodic Flux Tube	Electron-Ion Collisions	Shaped Analytic Geometry
128-Point Velocity Space Grid	~ 80 Electron Gyro-radii Square	~ 860 CPU Hours Each

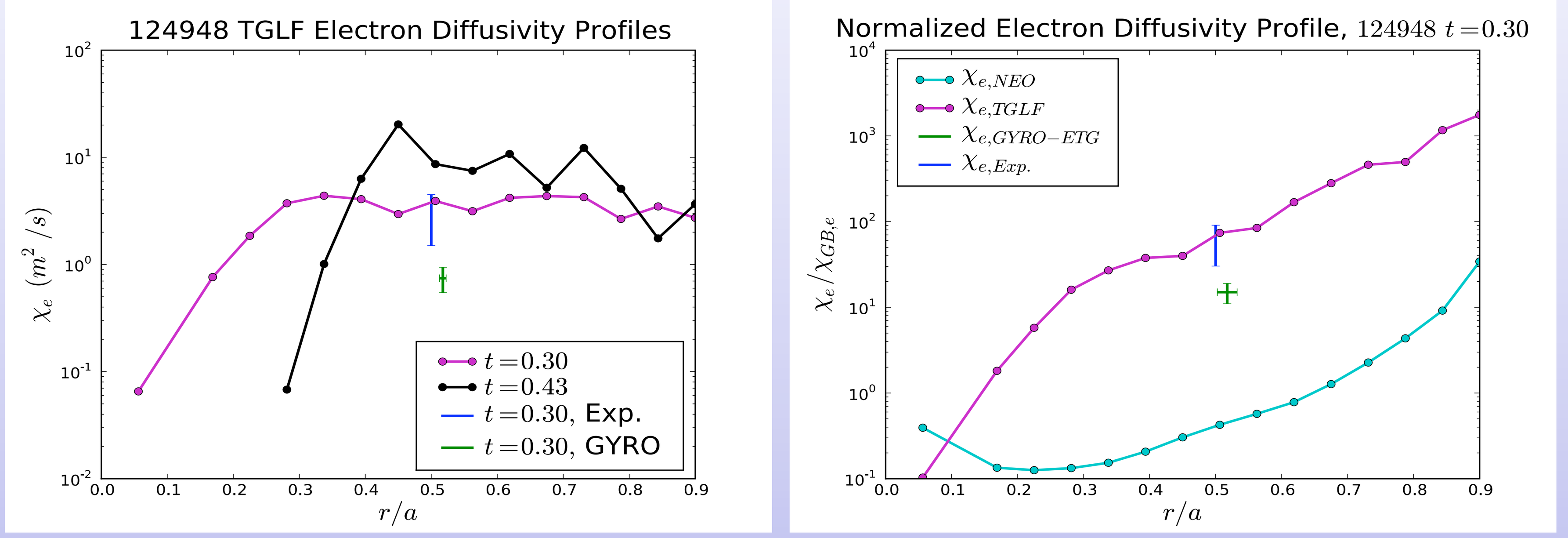


Above: Nonlinear simulations of NSTX using adiabatic ions show convergence in space and time. Radially, one needs to resolve the electron gyro-radius, while poloidally 14 points per passing particle are necessary, slightly more than required for non-NSTX plasmas [6]. Additionally needed convergence studies include longer time runs, velocity space and box size.



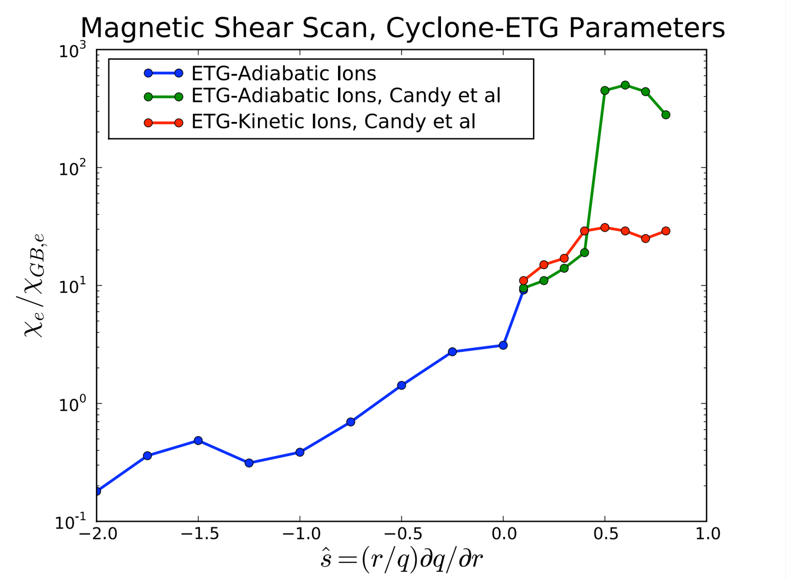


Left: Saturated turbulence shows potential fluctuations with electron-scale eddies and peak electron thermal transport in the ETG range during strong high-k activity.



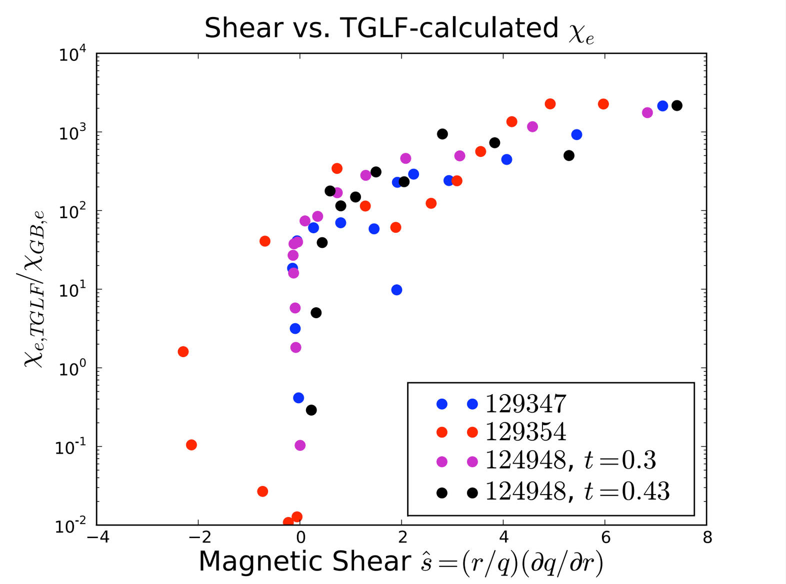
TGLF [7] and NEO [8] show that electron turbulent transport is well above neoclassical levels, and that when high-k activity is lowered, transport is less, but TGLF predictions must be benchmarked against NSTX data and more-detailed GYRO simulations.

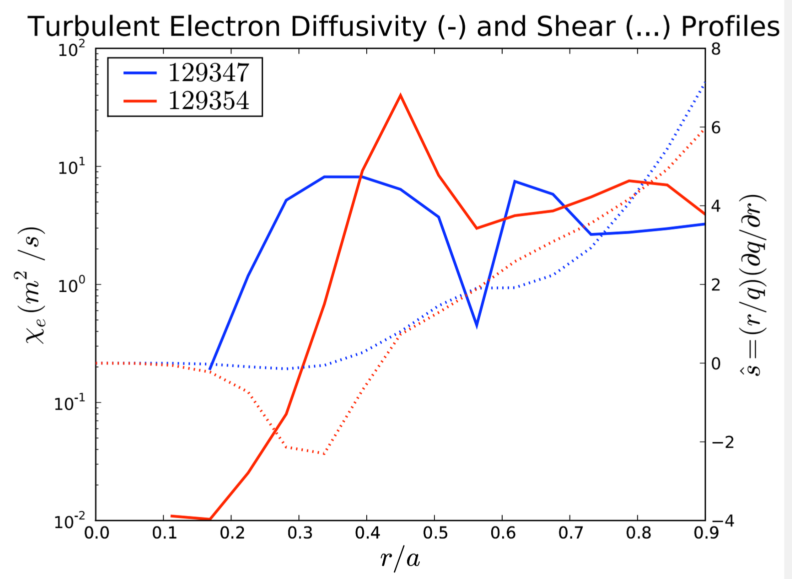
Reversed Magnetic Shear Lowers Transport Levels



Left: GYRO simulations using Cyclone ETG parameters [1, 9] show reduced electron transport when magnetic shear reverses. Also, lower values of shear help the adiabatic ion model saturate [1].

Below: TGLF simulations of reversed-shear discharges show a drop in NSTX electron thermal transport and support the electron-internal transport barrier observations [5].





Conclusions and Open Questions

- Nonlinear Simulations of NSTX turbulence demonstrate ETG-driven turbulence.
- TGLF shows increased electron thermal transport during high-k diagnostic activity.
- GYRO and TGLF predict decreased electron transport with reversed magnetic shear.
- Inside regions of reversed magnetic shear, predicted electron transport is low.

- What other factors are important for NSTX turbulence simulations?
- How well do TGLF and GYRO agree for NSTX?
- What are the steady-state predicted transport profiles for NSTX?
- What is the connection between high-k fluctuations and gyrokinetic turbulence?

References

[1] J. Candy, R. E. Waltz et al., J. Phys. Conf. Ser. **78**, 012008 (2007)
[2] E. Mazzucato et al., Phys. Rev. Letters **101**, 075001-4 (2008)
[3] F. Jenko et al., Phys. Plasmas **8**, 4096 (2001)
[4] W. Dorland et al., Phys. Rev. Letters **85**, 5579 (2000)
[5] H. Yuh et al., Phys. Plasmas **16**, 056120 (2009)
[6] J. Candy and R. E. Waltz, Phys. Plasmas **13**, 032310-11 (2006)
[7] G. M. Staebler et al., Phys. Plasmas **14**, 055909 (2007)
[8] E. A. Belli and J. Candy, Plasma Phys. Control. Fusion **51**, 075018 (2009)
[9] A. Dimits et al., Phys. Plasmas **7**, 969 (2000)