Systematic Investigation of Electron Transport in NSTX

E. Mazzucato, D. R. Smith, and K. L. Wong

I. Current Status

Much progress was made in the past 15 years on energy transport in tokamaks through the ion channel via ITG turbulence. However, transport through the electron channel in hot tokamak plasmas remains a mystery. In spherical tokamaks, ITG turbulence should be stabilized by the intrinsic flow shear. The observed values of χ_i in STs are typically at the neoclassical level, and electron thermal transport becomes the dominant heat loss mechanism in present ST experiments like NSTX and MAST. This makes electron transport the important transport issue in STs. We believe that knowledge in this area is vital towards understanding transport in the burning plasma regime, and electron transport has been an active research area in the NSTX program for the past few years. Some recent results are listed in the following:

(1). Density fluctuations with ETG characteristics were observed recently by collective scattering of 1 mm waves when the electron temperature gradient exceeds the instability threshold[1].

(2). Fluctuations amplitudes decrease when the ExB flow shear rate exceeds the ETG linear growth rate[2, 3] in H-mode discharges. However, the correlation between fluctuation amplitudes and electron energy transport is unclear.

(3). Microtearing modes can quantitatively explain χ_e at $r > a/2$ in some beam heated H-mode discharges[4]. This instability is driven by electron collision. Calculation with the GS2 code indicates that the instability growth rate decreases with electron collision frequency which is consistent with the observed density dependence of electron energy confinement time. It is theoretically possible to eliminate this instability by heating electrons at low density[5], but this was never confirmed experimentally.

(4). In high power beam-heated discharges, T_e profile is very flat in the plasma core ($r < a/2$) and microtearing modes are stable there. The high χ_e in this region can be explained by global Alfvén eigenmodes(GAE) excited by super-Alfvénic beam ions, and the trapped electron orbits can become stochastic[6].

II. Research Tools

Besides the conventional tokamak diagnostics, NSTX has unique capabilities specially designed for electron transport studies.

(1). A unique toroidal high-k scattering system is fully operational on NSTX to study very short wavelength ($k\rho_e < 0.6$) plasma turbulence. Its spatial resolution is typically three times better than the conventional scattering geometry. Interferometry data from this apparatus can measure density fluctuations at longer wavelengths.

(2). A new BES system will be installed on NSTX to investigate ITG/TEM turbulence. It should be capable of detecting density fluctuations associated with microtearing modes as well.

(3). A new PHA system is being installed to measure the evolution of the energy spectrum of the X-ray bremsstrahlung radiation. This is related to the electron distribution function from which electron transport properties may be inferred.

(4). A three-color 46 channel soft X-ray imaging system is available to measure electron temperature fluctuations below 300 kHz[7]. We plan to use it to search for microtearing modes[8].

(5). 6 MW of ICRF fast wave power is available for electron heating. Central electron temperature up to 6 keV has been achieved. This is a powerful tool to vary T_e over a wide range and study the corresponding changes in χ_e as well as the turbulence characteristics.

(6). Advanced gyrokinetic simulation codes like GTC, GS2, Gyro, GEM and the transport code TRANSP are readily available for data analysis.

III. Proposed Research Thrust

We have observed high-k turbulence with ETG characteristics, however, their impact on electron transport is unclear. ITG and TEM modes are predicted to be stabilized by the intrinsic plasma flow shear, and the upcoming BES diagnostic will seek direct experimental evidence of ITG/TEM suppression. Although microtearing modes are calculated to be unstable in H-mode plasmas and they should saturate at high levels to cause stochastic magnetic fields due to overlapping magnetic islands, these unstable modes were never positively identified in NSTX due to lack of suitable diagnostic. With the new tools described in section II, we can fill in these gaps and obtain a coherent picture of turbulent transport in ST's. We plan to carry out a systematic sequence of experiments to **simultaneously** measure fluctuations associated with ETG, ITG, TEM and microtearing instabilities and determine their effects on electron energy transport under various conditions. We shall make a serious attempt to eliminate microtearing instabilities by heating electrons at reduced plasma density. If successful, this would improve the electron energy confinement as well as the overall energy confinement in NSTX, and allow us to identify/attack new critical issues for ST's when they arise.

References

1. E. Mazzucato et al., PRL **101,** 075001 (2008).
2. D. R. Smith et al., submitted to PRL (2009).
3. D. R. Smith et al., Bull. Am. Phys. Soc**. 53,** No.14, 323 (2008)
4. K. L. Wong et al., PRL **99,** 135003 (2007).
5. K. L. Wong et al., PoP **15,** 056108 (2008).
6. D. Stutman et al., accepted for publication in PRL.
7. D. Stutman et al., RSI **74,** 1982 (2003).
8. K. L. Wong et al., Bull. Am. Phys. Soc**. 53,** No.14, 193 (2008).