GYROkinetic Simulations of Transport in NSTX

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NSTX Results Review, 12-14 December 2005

Overview

ExB shear stabilization of low-k modes is expected in spherical tokamaks.

But application of linear ExB "quench rule" is of questionable validity:
"*We cannot be confident of these modifications and limitations on the quenching condition for general profiles at finite ρ^* without nonlinear simulations. These cannot be done with the fast flux tube codes and require three dimensional (3-D) full radius codes …*"
Waltz, et al., Phys. Plasmas 5 (1998) 1784.

Nonlinear turbulence simulations (GYRO) reported previously show:

1) Sheared flows play a very important stabilizing role, but
they do not completely stabilize the low-k turbulence.
The residual low-k turbulent transport is large.

2) Kinetic electron drive is more important than 'pure' ITG drive.

Important Issues for NSTX Simulations

A 'full radius' simulation is required to include profile effects.
Parameters vary significantly in a radial domain of 50 ρ_i .

Kinetic electron effects enhance ITG mode turbulence,
so a non-adiabatic electron model is needed.
Need to model electron collisions, which are stabilizing.
TEM effects are significant in most tokamak plasmas,
but they are more important than usual in these simulations.

It is necessary to include the background ExB sheared flows,
these are expected to be a major stabilizing factor.

NSTX is highly shaped, with very low aspect ratio.
Need realistic geometry, not high-aspect ratio s-α model.

β~10% is well below limit, begin with electrostatic simulations.
Electromagnetic effects are important in higher β NSTX plasmas.

Verification: convergence testing

Varied numerical grid, produced small changes in predicted power flows:
(standard settings in green, variation in red)

Number of toroidal modes: 8 □ 16
Number of trapped/passing pitch angles: 4 □ 8
Number of orbit segments (error $1/N^4$): 9 □ 6
Number of energies in modified Gauss-Laguerre integration: 8 □ 16

New convergence tests

Increase the radial resolution, reduce spacing: 3/4 □$_s$ □ 3/8 □$_s$
little change
Extend the radial domain: $0.5 < r/a < 0.8$ □ $0.3 < r/a < 0.8$
BIG CHANGE !

Summary and Further Work

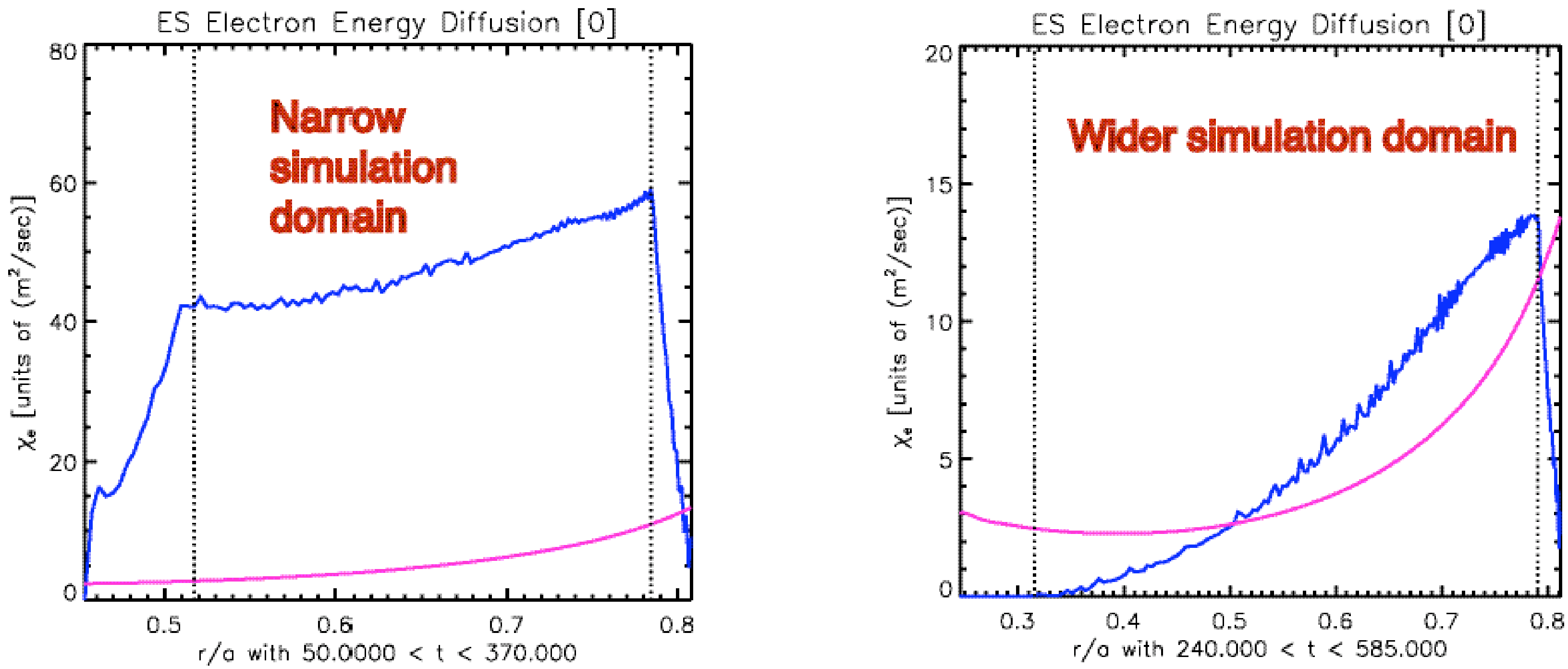
The radial extent of the domain has a big influence on the turbulence.
this has not been seen before in DIII-D simulations, I think.

Detailed understanding is needed.

Consultation with Waltz and Candy will occur in January.

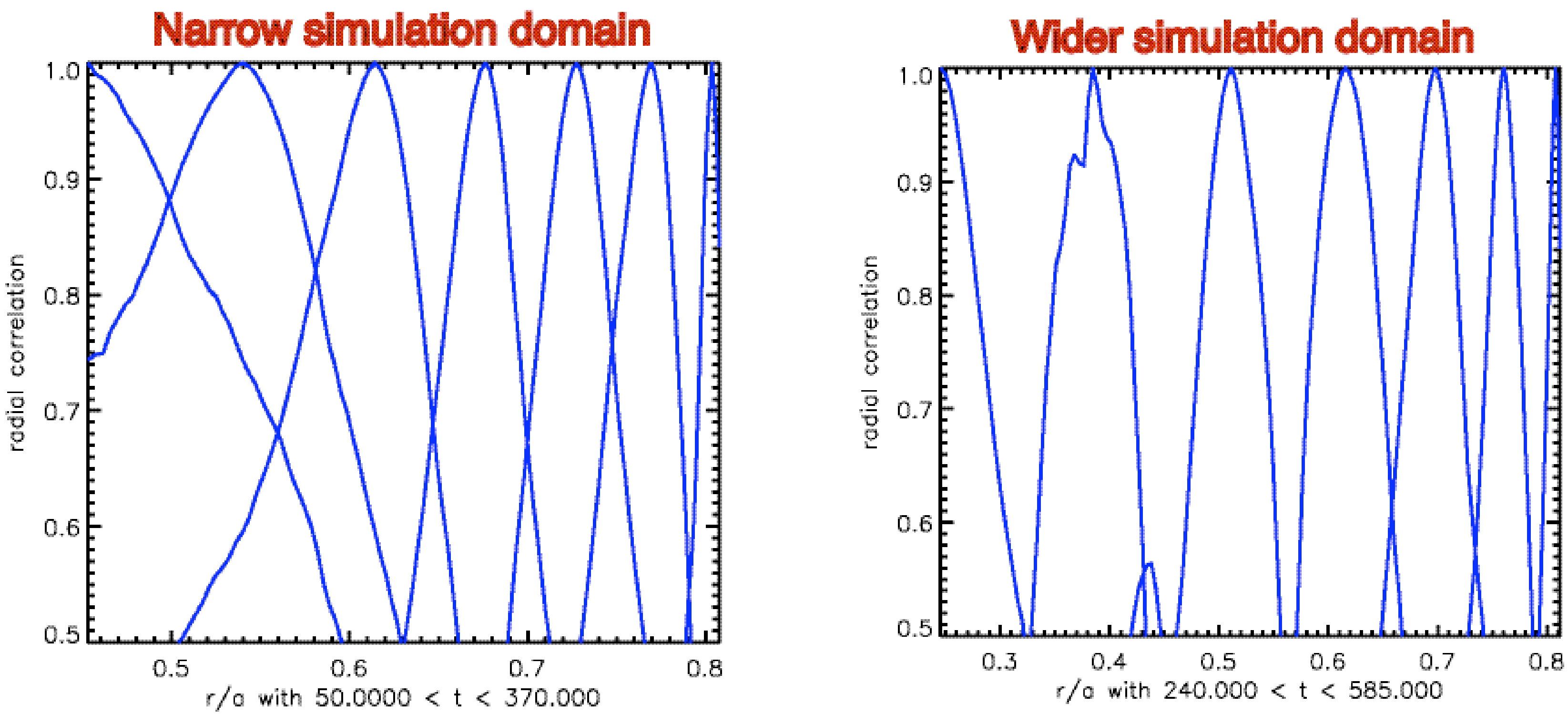
This new development is consistent with confinement in NSTX depending strongly on B_{tor}, or more directly, on ρ_i/a.

Turbulence Shrinking?



- Including the stable deep core reduces turbulence.
- Order of magnitude reduction near r~a/2.
- Even near the edge, fluxes are down by a factor of 1/4.
- Zonal flow level about the same; n>0 components smaller.
- Predicted ion flux is still much higher than in experiment.

Radial Correlation Lengths Reduced in Larger Simulation



- Radial correlation length reduced for r/a<0.6
- Correlation length unchanged near the edge.