Possible NSTX plasma transport issues associated with gyrokinetic simulations

W. X. Wang

PPPL

N-year plan of GTC simulations – short term

- Investigate turbulence transport properties of NSTX plasmas over a wide range of spectrum with focus on electron transport.
- Current activities focus on nonlinear ITG-TEM and ETG simulations of NSTX discharges, and comparison with experimental measurement of ion and electron transport, fluctuation spectrum, etc.
- Study neoclassical and turbulence-driven (both diffusive and convective) toroidal angular momentum transport.
- Impurity physics in both neoclassical and turbulent simualtions.
- Develop electromagnetic turbulence simulation for experiment.

N-year plan of GTC simulations – long term

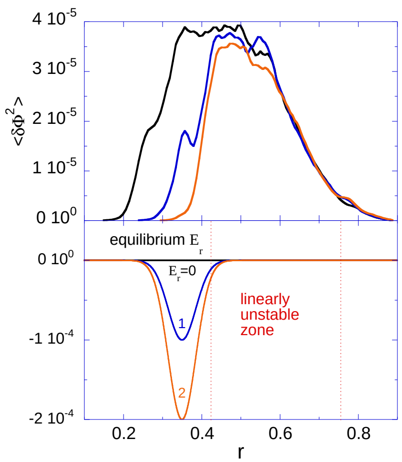
- Study interplay between neoclassical and turbulence dynamics.
- Apply nonlinear EM simulation to NSTX experiments, finite-β effects, micro-tearing etc.
- Investigate transport barrier dynamics; turbulence in driving-system.
- Application to energetic particle physics.
- Apply nonlinear simulation to ITER.

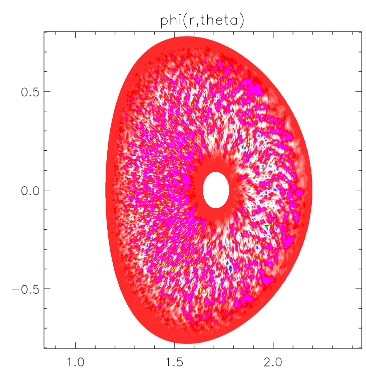
Outline of possible issues for validation

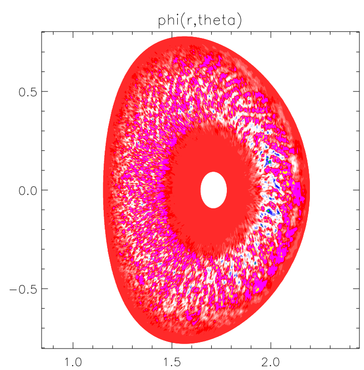
- Experimental test of turbulence spreading and control.
- Test the role of zonal flows.
- Is ITG relevant to NSTX transport?
- Energy and momentum coupling between main ions and impurities.
- Anisotropic property of NSTX plasmas and effects on transport.

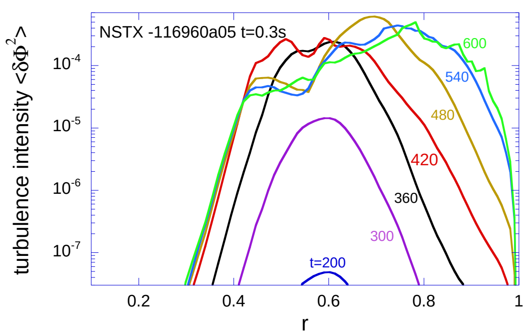
Experimental test of turbulence spreading and control

- Turbulence spreading is a rather generic phenomena, which may be responsible for transport nonlocality observed in experiment
- Simulations show that an experimentally relevant $\mathbf{E} \times \mathbf{B}$ shear layer can reduce, and sometimes even block, turbulence spreading
- Reversed magnetic shear is also shown to reduce the turbulence spreading
- Experimental test – can we control dynamics of $\mathbf{E} \times \mathbf{B}$ shear layer and variations of magneic shear?

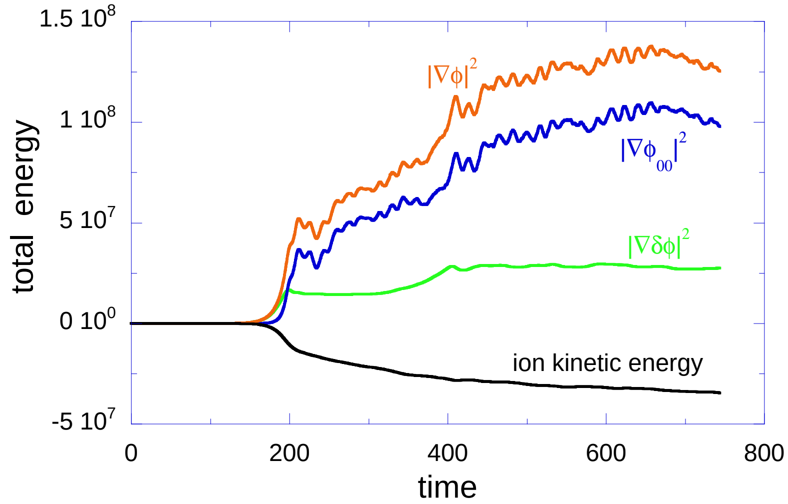








Test the role of Zonal flows

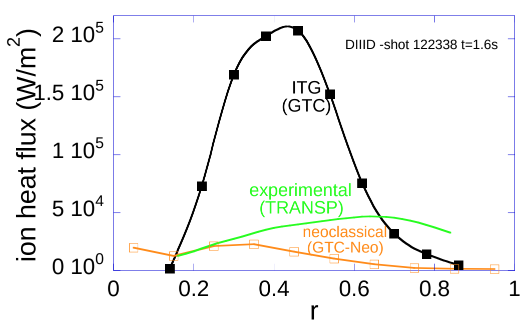


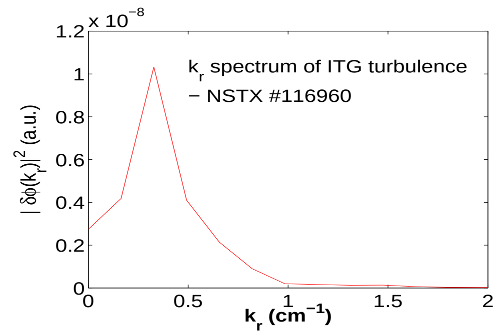
- Self-generated zonal flows regulate turbulence, and reduce transport through: i) shear flow decorrelation; ii) lowering fluctuation level.

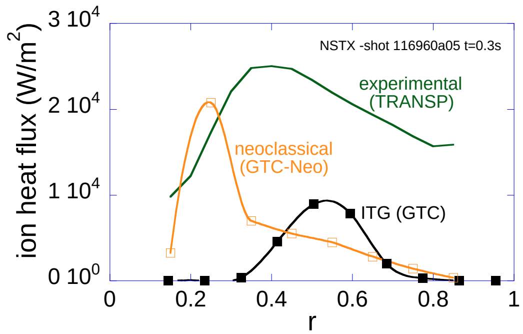
- Simulation shows that zonal flows contain energy remarkably higher than turbulence. Zonal flows extract a large amount of energy from turbulence components during their generation process. This, in part, appears to be a natural picture of turbulent transport reduction by zonal flows.

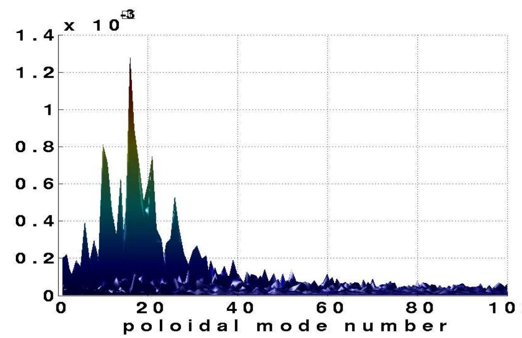
- Is it possible to test the role of zonal flow experimentally, for instance, by measuring zonal flow amplitude or energy?

Is ITG relevant to NSTX transport?









- Ion energy transport is often observed at neoclassical level
- Our simulations show ITG turbulence may have significant fluctuation amplitude, but drives insignificant (if not zero) ion energy transport in NSTX.
- low-k measurement can tell if ITG exists and drives any transport $\Longrightarrow$ to validate simulation

Energy and momentum coupling between main ions and impurities

- Many experimental measurements are made, relying on impurities.
- However, most of the energy and momentum in plasma are contained in the bulk ions.
- We pay attention to the coupling between bulk ions and impurities (through both neoclassical process and turbulent process).
- for example, toroidal momentum transport of species s

$$\frac{\partial U_s}{\partial t} + \frac{1}{\mathcal{V}'}\frac{\partial}{\partial r}(\mathcal{V}'\Pi_s) = T + \Gamma_s + R_s$$

U_s: angular momentum density

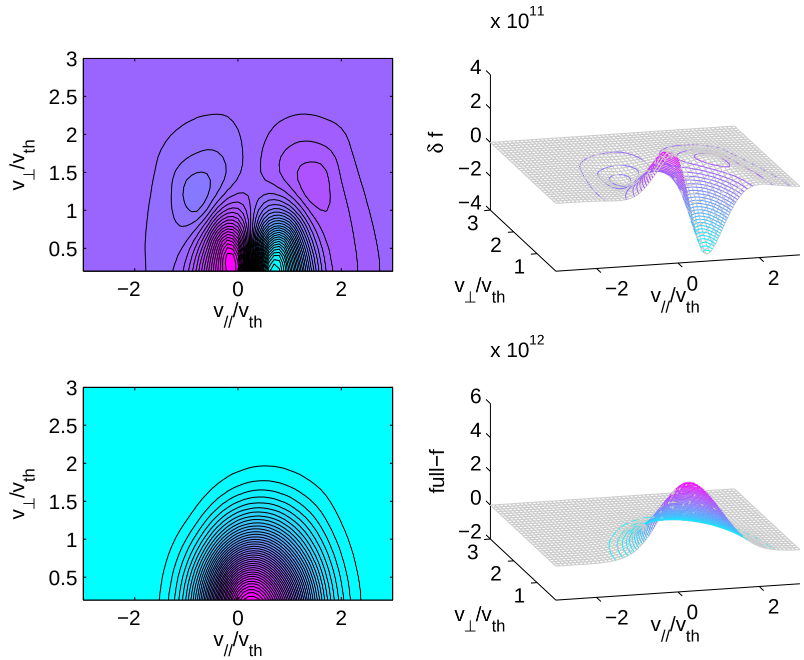
Π_s: angular momentum flux (including both diffusion and convective)

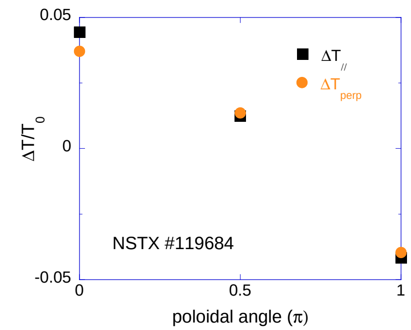
T: torque

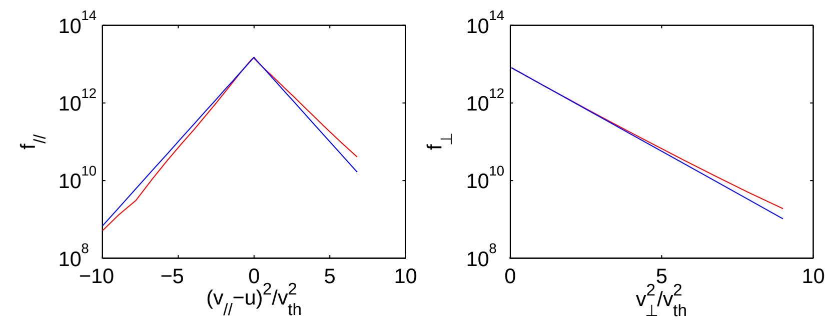
Γ_s: particle flux

R_s: momentum exchange between different species

Anisotropic property of NSTX plasmas and effects on transport







- Neoclassical simulation shows that plasma anisotropy is small.
- However, it is observed that there is considerable variation of T_i on magnetic surface ($\sim 10\%$ difference between outer and inner sides on mid-plane).
- Does it matter in experiment? what are the implications to transport and equilibrium (for example, relation to the role of rotation on equilibrium)?