Studies with GTC-Neo,

including: Recent Applications of GTC-Neo for:

(1) Studies of Toroidal Angular Momentum and Ion Heat Transport, and

(2) Implications for CHERS Temperature Measurements

G. Rewoldt, W.X. Wang, M. Bell, S. Kaye,

W. Solomon, R. Nazikian, and W.M. Tang

Princeton Plasma Physics Lab

INTRODUCTION

• GTC-Neo is a global δf gyrokinetic particle-in-cell code, including finite-orbit-width (banana width) effects, which make the transport nonlocal. It implements a collision operator that conserves particle number, momentum, and energy.

- W.X. Wang, G. Rewoldt, W.M. Tang, F.L. Hinton, J. Manickam, L.E. Zakharov, R.B. White, and S. Kaye, Phys. Plasmas **13**, 082501 (2006)

- W.X. Wang, W.M. Tang, F.L. Hinton, L.E. Zakharov, R.B. White, and J. Manickam, Comp. Phys. Commun. **164**, 178 (2004)

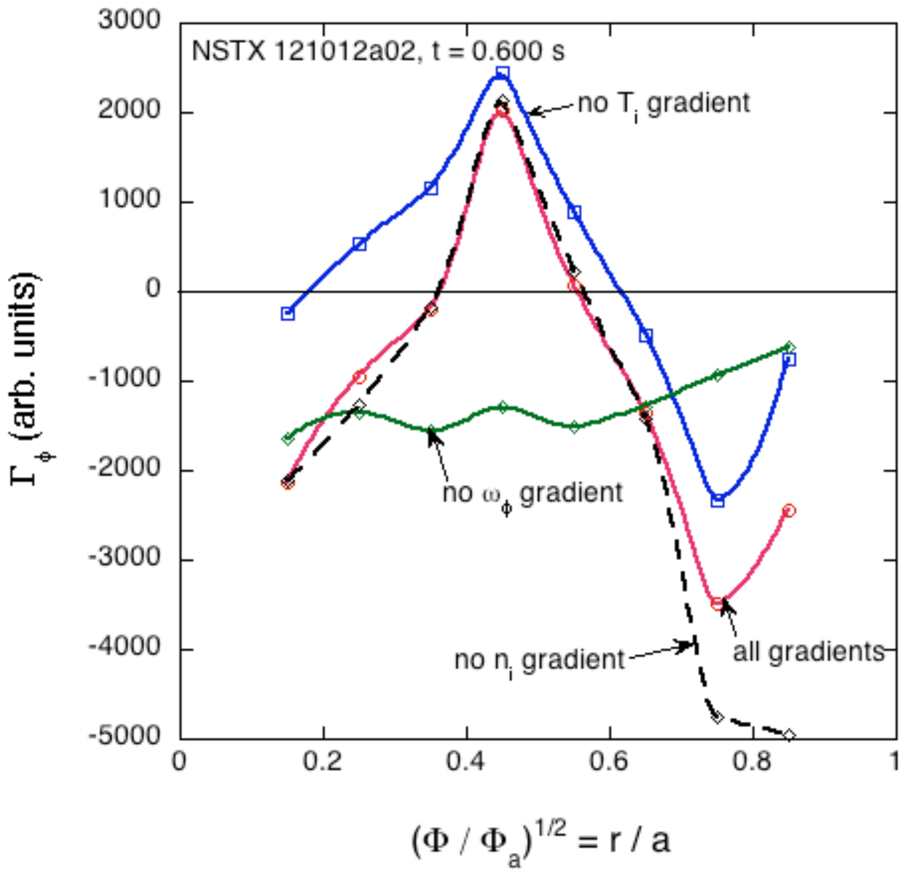
• GTC-Neo can calculate neoclassical particle, momentum, and energy fluxes, along with E_r, E_θ, j_b, etc., and can be run with both ion and electron dynamics operative

• GTC-Neo is interfaced with the TRANSP code to obtain input experimental density, temperature, and toroidal rotation frequency profiles, and with the JSOLVER and ESC global MHD equilibrium codes for the geometry information.

INTRODUCTION-2

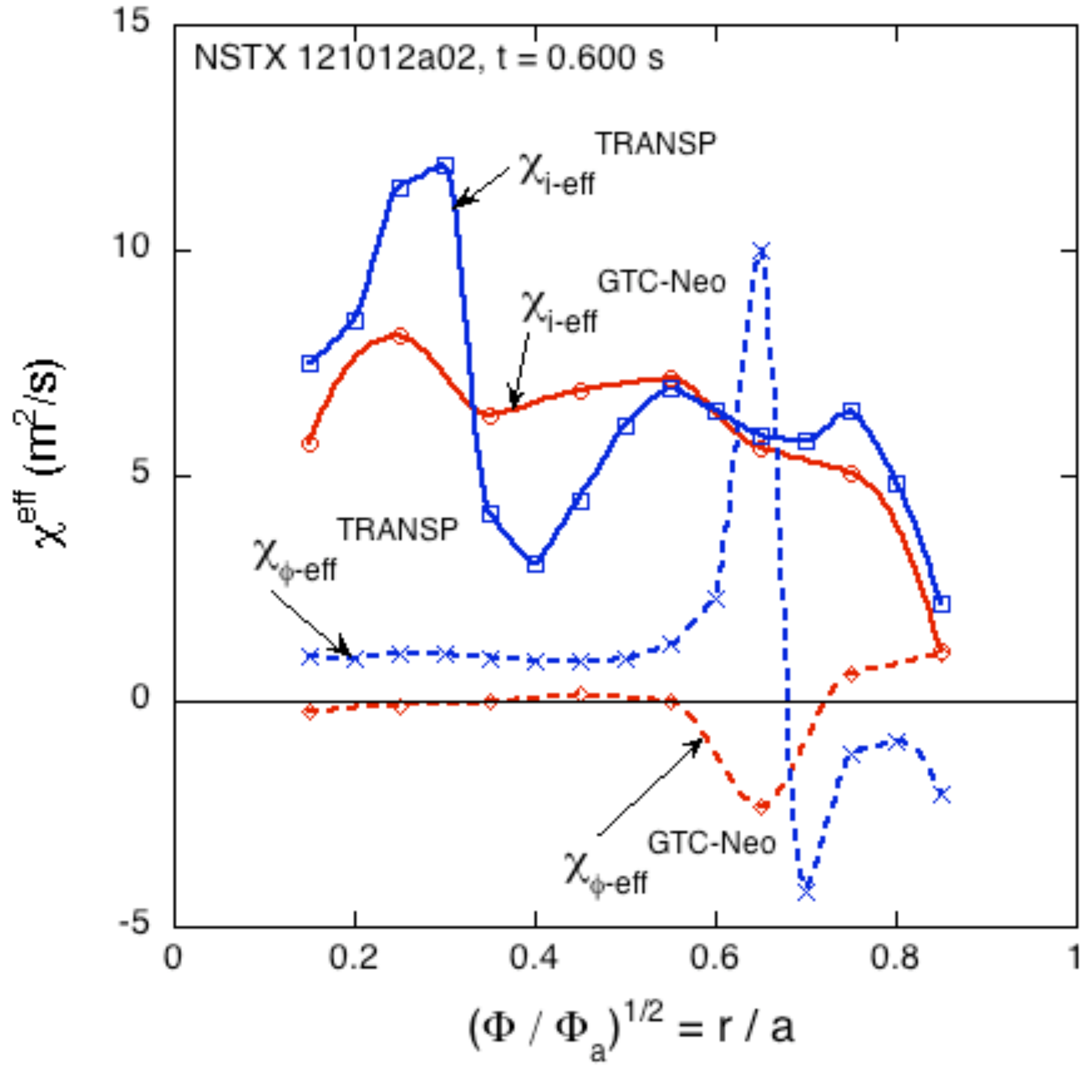
• At present, the GTC-Neo calculation includes only a single ion species (deuterium). It is planned to extend GTC-Neo to (1) nonlocal (canonical) Maxwellian ($\Rightarrow$ big help with “noise”), and (2) multiple ion species, in the near future.

(1) Radial Flux of Toroidal Angular Momentum: Sensitivity to Spatial Gradients



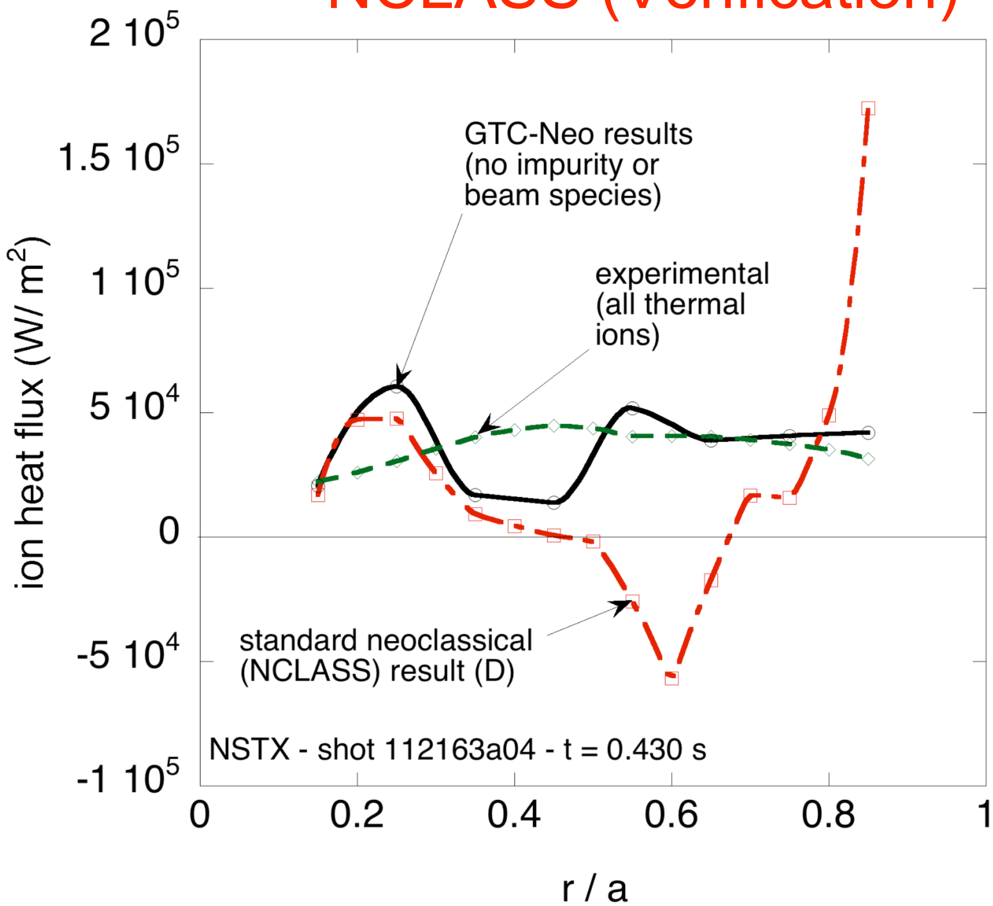
- Here Γ_ϕ, the radial flux of toroidal angular momentum, is shown for an NSTX case (in internal code units) versus r/a (the square root of the normalized toroidal flux)
- We compare results of a GTC-Neo run (with all gradients turned on) with results from three runs, each with one gradient turned off (rotation frequency $\omega_\phi = v_\phi / R$ gradient, ion temperature T_i gradient, and ion density $n_i = n_e$ gradient)
- The n_i gradient contribution is small, (except near the outer boundary where the density gradient becomes large)
- The T_i gradient contribution is moderate and is always inward (pinch!)
- **The ω_ϕ gradient contribution is largest, and has different signs at different radii**
- Thus the Γ_ϕ "diagonal term" from the rotation frequency gradient is larger than the "off-diagonal terms" in the "transport matrix" (though the system in fact is not quite linear)

χ_ϕ^{eff} versus χ_i^{eff} for NSTX case



- Here we show $\chi_\phi^{eff} = \Gamma_\phi / [R^2 n_i m_i (d\omega_\phi/dr)]$ (in m^2 / s) versus r/a for the same NSTX case, along with $\chi_i^{eff} = Q_i / [n_i (dT_i/dr)]$, both from GTC-Neo (neoclassical) and from TRANSP (experimental)
- For this NSTX case, ion energy transport is comparable to neoclassical (so anomalous ion energy transport is small), yet angular momentum transport is much larger than neoclassical (so **anomalous angular momentum transport is dominant**)!
- However, both χ_i^{eff}'s are several times larger than both χ_ϕ^{eff}'s! (role of electrons ?)
- Comparable results for seven other NSTX cases

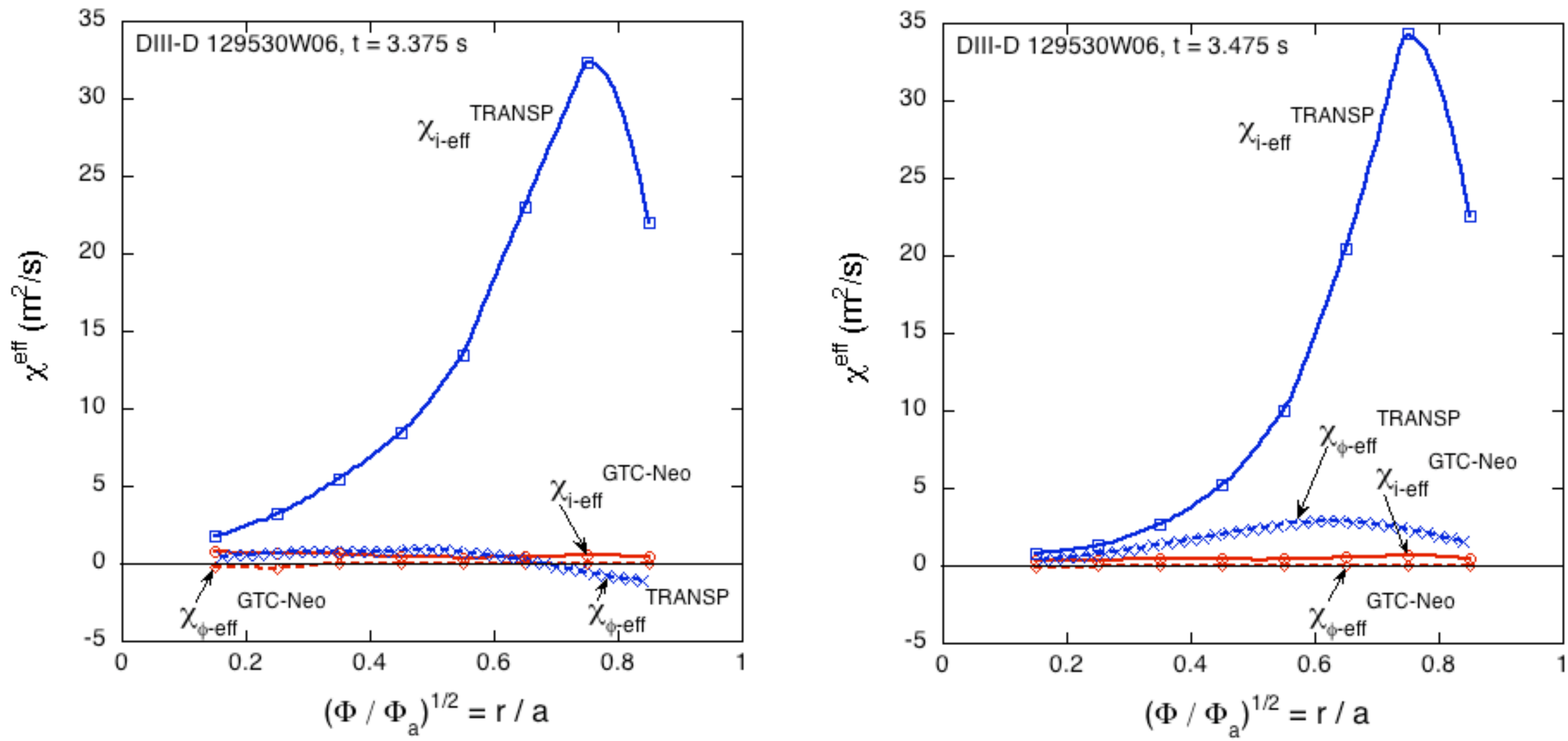
Comparison to Experiment (Validation) and to NCLASS (Verification)



- Nonlocal (due to finite ion orbit effects) GTC-Neo results always “smoother” than local NCLASS results

- GTC-Neo results usually closer to experimental (TRANSP) results

χ_ϕ^{eff} versus χ_i^{eff} for DIII-D cases



- For these two DIII-D cases, ion energy transport is strongly anomalous, as is also the angular momentum transport (though much smaller)

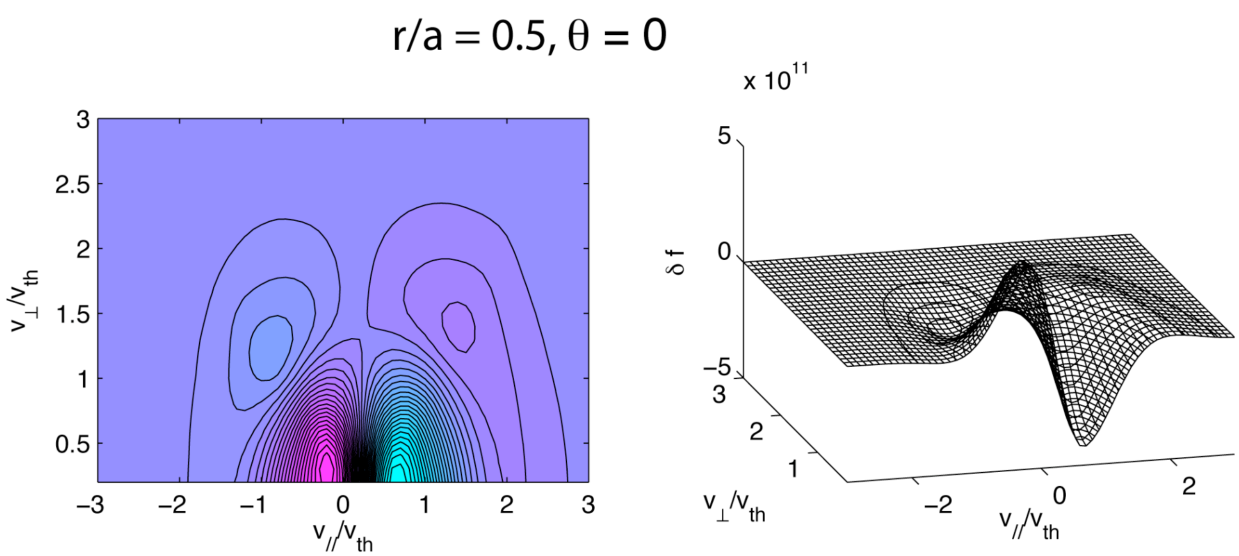
(2) Nonlocal Neoclassical Calculation of Anisotropic Properties in NSTX, (with Implications for CHERS T_i Measurements)

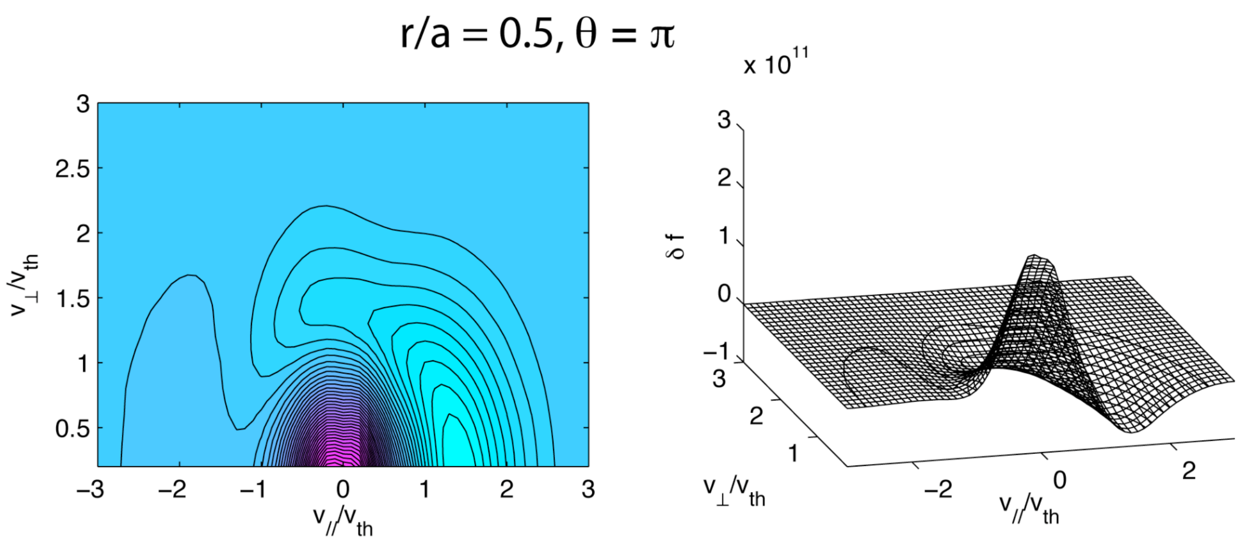
• GTC-Neo is a δf particle-in-cell code, with finite-orbit-width (banana width) effects, which make the transport nonlocal. We are now extending it to examine temperature perturbations $\delta T_\perp$ and $\delta T_{||}$ coming from δf (see following pages for preliminary NSTX results), and to examine δf itself at various locations.

• These results can significantly impact the interpretations for the CHERS diagnostic for measurements of T_i, which presently assumes a standard local Maxwellian distribution.

• Modifications from the δf calculated by GTC-Neo here are shown to produce significant changes to the T_i results from the old (local Maxwellian only) model.

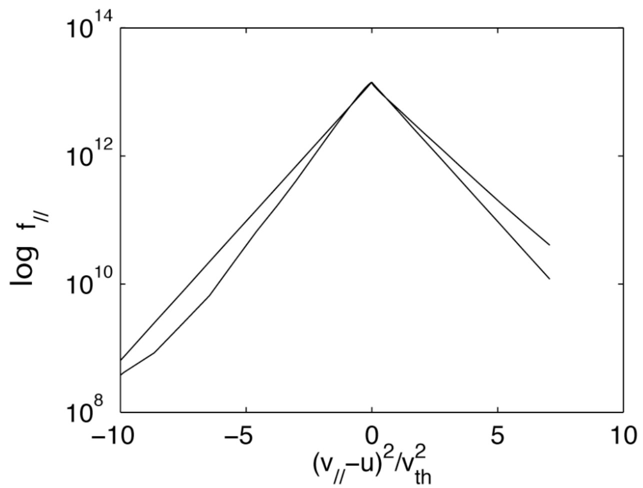
GTC-Neo Preliminary results for NSTX 121314a01, t = 0.325 s

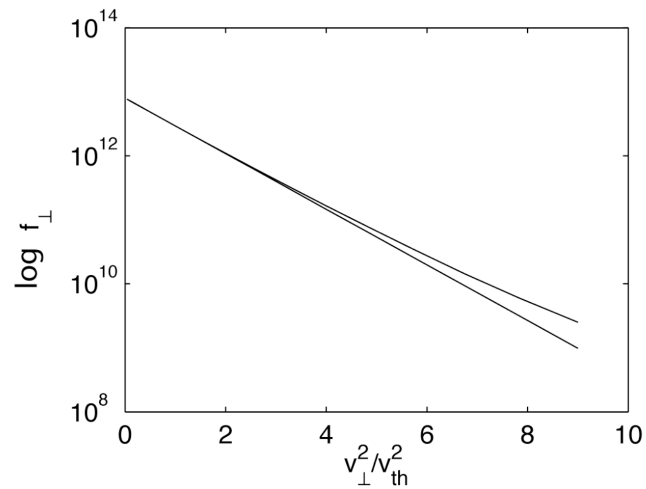


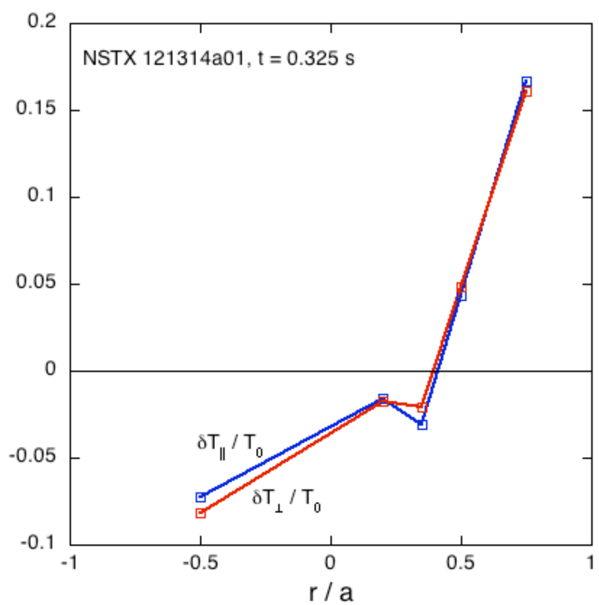


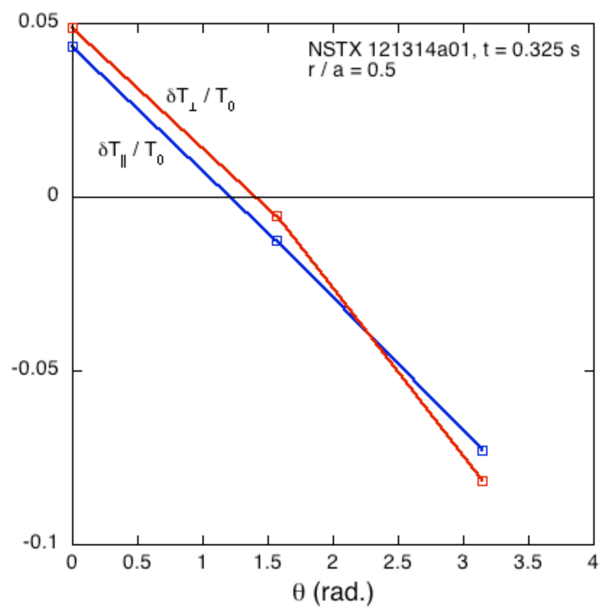
- Contour plots and perspective plots of δf on outboard midplane and inboard midplane
- **Strong differences in δf at two locations** ($\Rightarrow$ implications for interpretation of CHERS T_i measurements)

GTC-Neo Preliminary results for NSTX 121314a01, t = 0.325 s









- In $v_{||}$ and $v_{\perp}$ distributions, log plots should be straight lines for Maxwellians. Some **departure from Maxwellians**
- $\delta T_{||}$ and $\delta T_{\perp}$ not very different
- Corresponding $\delta T_{||}$ and $\delta T_{\perp}$ have strong r and θ variation, which increases proportional to banana width. Variation may be big enough to measure with PCHERS.

CONCLUSIONS

Part 1:

• GTC-Neo has obtained its first results for Γ_ϕ and χ_ϕ^{eff} for NSTX and DIII-D cases. The neoclassical radial transport of **toroidal angular momentum** is seen to be **mainly anomalous**, whether the ion energy transport is mainly anomalous or mainly neoclassical!

Part 2:

• The δf calculated by GTC-Neo is seen to vary strongly with location, in preliminary calculations for NSTX cases. The corresponding $\delta T_{||}$ and $\delta T_\perp$ vary strongly with radius and poloidal angle. However, $\delta T_{||}$ and $\delta T_\perp$ are quite similar (isotropy). **The results show some departure from a Maxwellian, that could be significant in proper interpretation of CHERS measurements of ion temperature.**