Gyrokinetic Calculations with the GEM code

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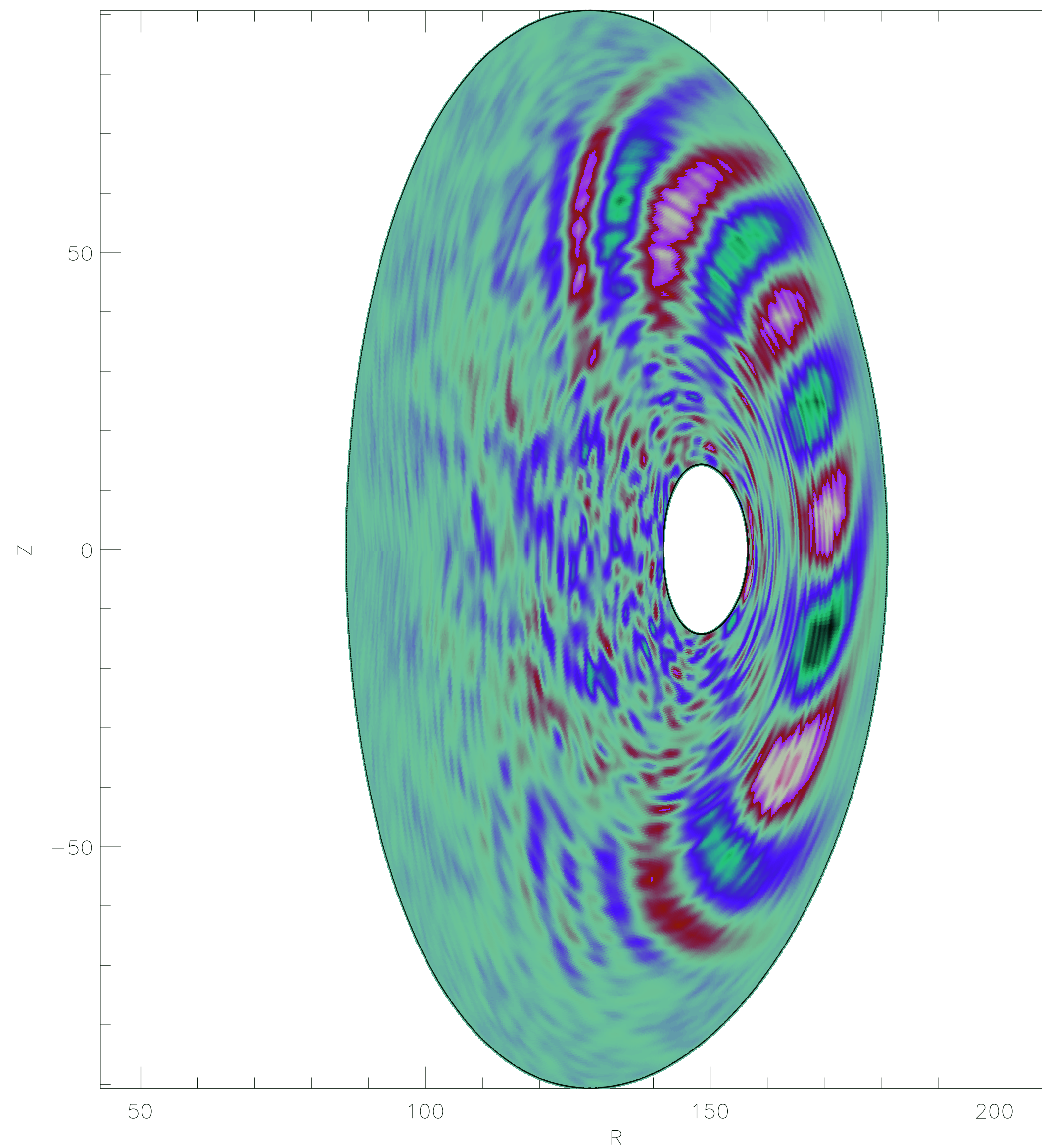
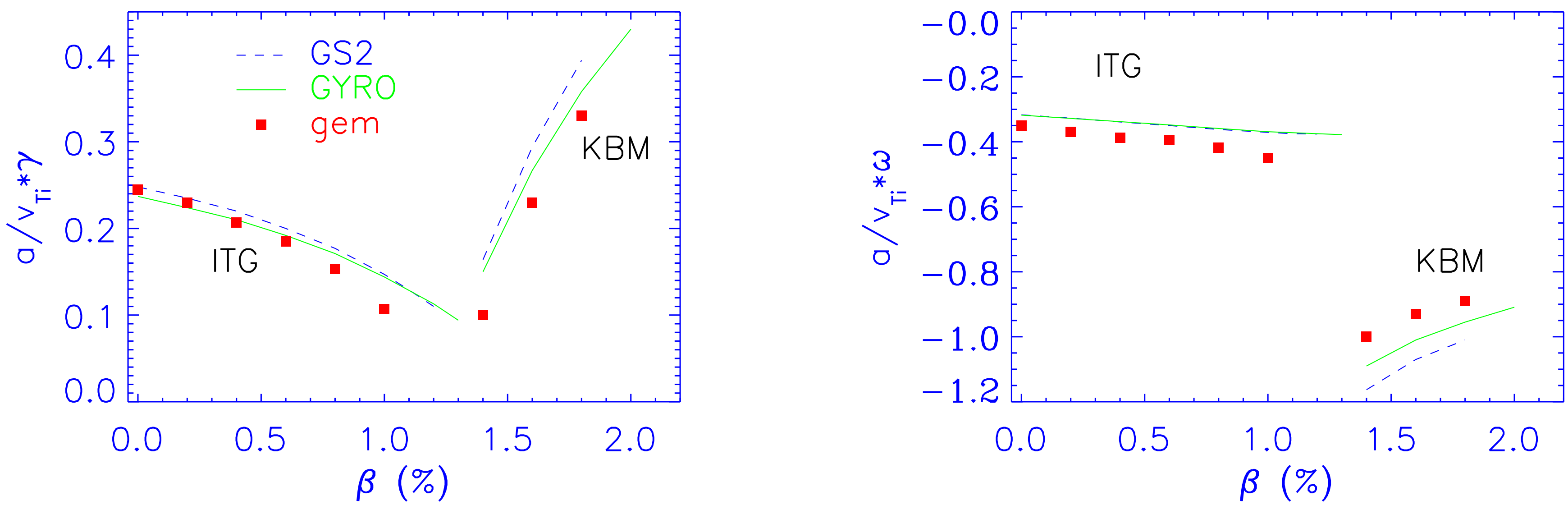
The GEM Code

- $p_\parallel$ formulation, the split-weight scheme, high-β Ampere algorithm
- Use field-line-following coordinates
  - Cover $0 \leq \theta \leq 2\pi$
  - Radially global
  - Arbitrary size toroidal section
- Passing and trapped electrons
- Collisions
- Magnetic perturbations
- Nonlinear Landau damping effect
- Arbitrary shape tokamak equilibrium and equilibrium flow



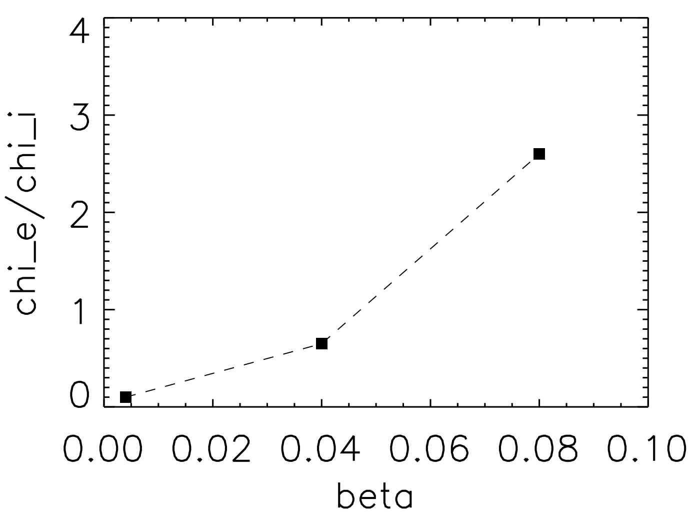
Linear Benchmark with Continuum Codes Shows Good Agreement

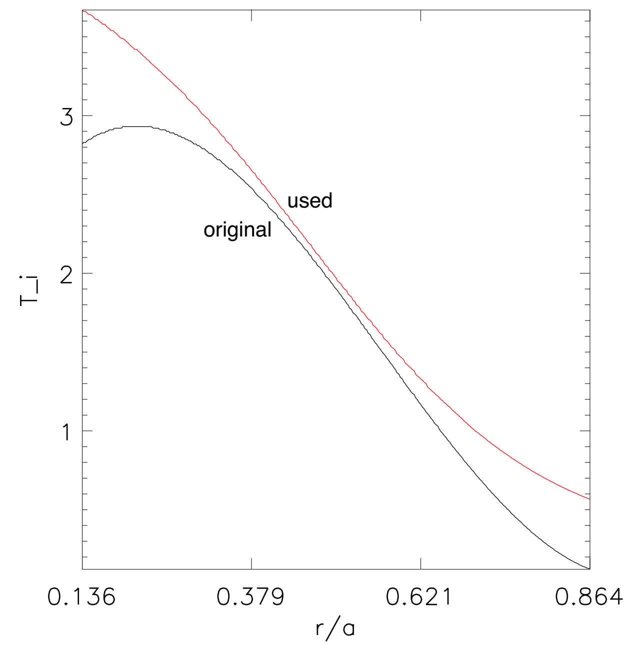


- $k_y\rho_i = 0.3$. Deuterium plasma with $R_0/L_T = 9$, $\eta_i = 3$, $q = 2$, $\hat{s} = rq'/q = 1$, with trapped electrons, flux tube

Chen and Parker, JCP 189, 463 (2003)
Candy and Waltz, JCP 186(2), 545 (2003)
Dorland, 18th IAEA (2000)

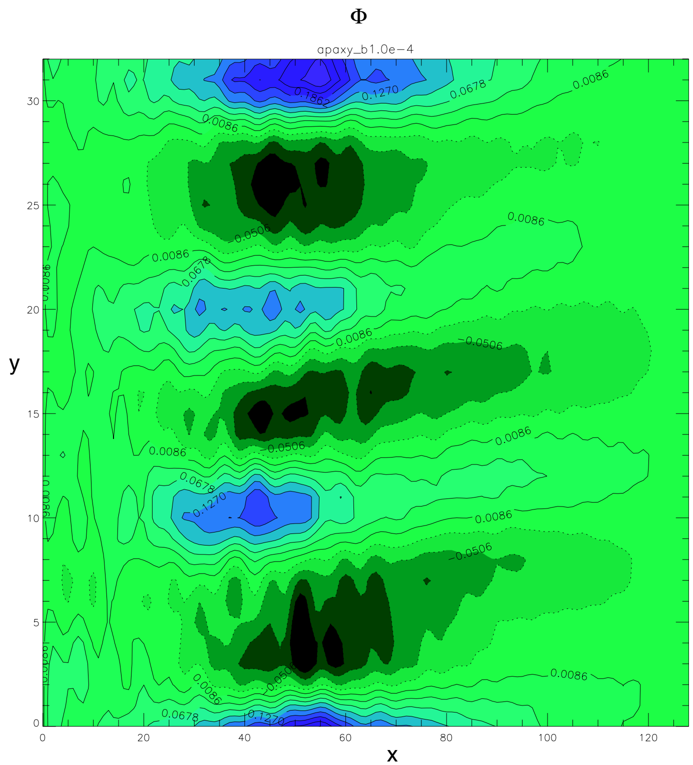
Linear $\chi_e \gg \chi_i$ as β increases

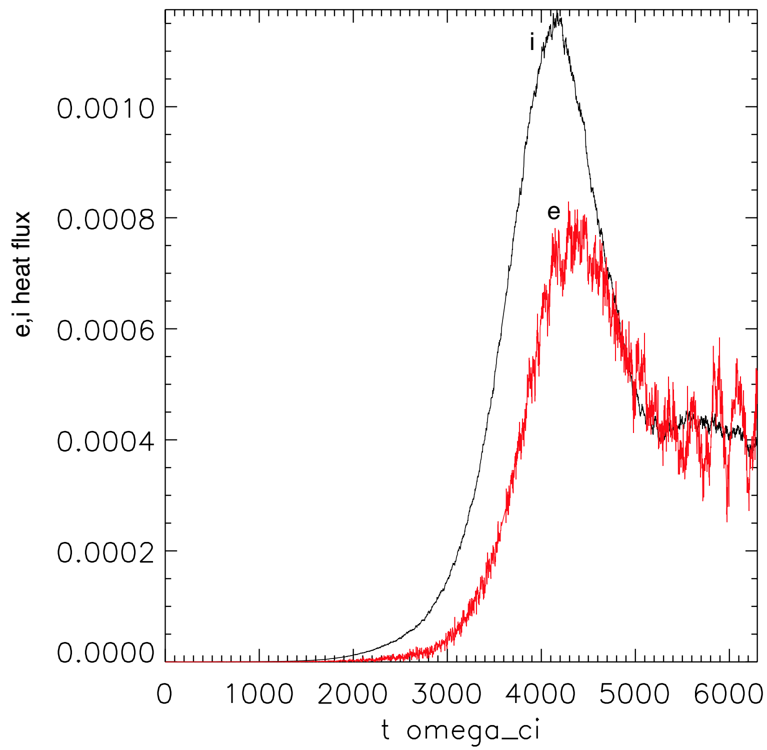




- $T_i = T_e$ modified to have mode centered in the simulation domain. $\frac{dn}{dr} = 0$
- Linear simulation for $n = 8$. No collisions.
- Cyclone Base Case (DIII-D H-Mode) typically yields $\chi_e \sim \frac{1}{4}\chi_i$ from ion scale turbulent transport

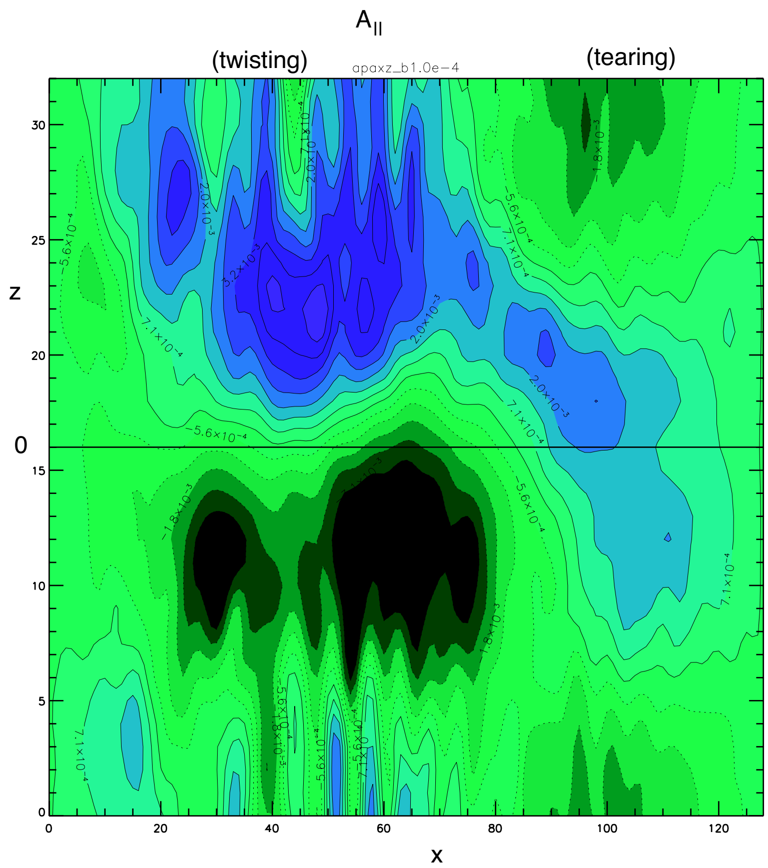
Zonal Flow not Dominant at Saturation





- $\beta = 5\%$, Simulation domain $(0.35a, 0.65a)$
- One ion species with $m_i = 2$
- $\omega_{\rm ci}\triangle t = 0.2$, $m_p/m_e = 1837$.
- $4M$ particles per species.

Tearing Parity Modes?



- T and q profile from Redi and Kaye et al. EPS-004, with dn/dr=0
- GS2 simulation indicates unstable micro-tearing modes.
- Since $a/\rho_i \sim 50$, strong radial coupling can occur for ion scale modes with $0.1 < k_\theta \rho_i < 1$.

Code Extensions and NSTX Applications

- Results shown here for NSTX were for a very rough representation of NSTX, with constant ellipticity ϵ, triangularity δ, and dR_0/dr.
- Interfacing of GEM with TRANSP data on TRANSP grid now under way, to use TRANSP density and temperature profiles for four species (electrons, main ions, impurity ions, and hot beam ions)
- GEM uses Miller MHD equilibrium, requiring radial profiles for ϵ, δ, q, and R_0.
- Will take parallel current profile and total pressure profile and boundary shape from TRANSP run, and then compute high-resolution global MHD equilibrium with JSOLVER
- Then will extract radial profiles of ϵ, δ, q, and R_0 from JSOLVER results for use in GEM's Miller MHD equilibrium.
- Can then use GEM with experimentally-realistic data from any TRANSP run, including geometric variation
- Limitation: GEM now includes Φ and $A_\parallel$, but not $A_\perp$ ($\delta B_\parallel$)
- GEM has capabilities now (non-circular cross section and $A_\parallel$) that will not be combined in a single version of the GTC code for some period yet; this makes GEM mode immediately usable for NSTX applications