We have discovered a possible "natural fueling" mechanism in tokamak fusion reactors using large scale gyrokinetic turbulence simulation. In the presence of a heat flux dominated tokamak plasma, cold ions naturally pinch radially inward. If cold DT fuel is introduced near the edge using shallow pellet injection, the cold fuel will pinch inward, at the expense of hot Helium ash going radially outward. By adjusting the cold DT fuel concentration, the core DT density profiles can be maintained. We have also shown that cold source ions from edge recycling of cold neutrals are pinched radially inward. This mechanism may be important for fully understanding the edge pedestal buildup after an ELM crash. These results were highlighted in an Invited Talk, by W. Wan at the 2010 American Physical Society Division of Plasma Physics meeting and are discussed in two publications (listed below).

Work specific to DE-FC02-08ER54960 includes benchmarking the gyrokinetic turbulence codes in the electromagnetic regime. This includes cyclone base case parameters with a increasing plasma beta. The code comparisons include GEM, GYRO and GENE. There is good linear agreement between the codes using the Cyclone base case, but including electromagnetics and scanning the plasma beta. All the codes have difficulty achieving nonlinear saturation as the kinetic ballooning limit is approached. GEM does not saturate well when beta gets above about 1/2 of the ideal ballooning limit. We find that the lack of saturation is due to the long wavelength $k_y$ modes being nonlinearly pumped to high levels. If the fundamental $k_y$ mode is zeroed out, higher values of beta nonlinearly saturate well.
Additionally, there have been studies to better understand CTEM nonlinear saturation and the importance of zonal flows. This is in collaboration with D. Ernst, MIT. This collaborative work with Ernst is specific to cooperative agreement DE-FC02-08ER54960. We have continued our investigation of trapped electron mode (TEM) turbulence following [Lang 07]. More recently, we have focused on the nonlinear saturation of TEM turbulence. An important feature of TEM is that in many parameter regimes, the zonal flow is unimportant [Dannert 05, Lang 07]. We find that when zonal flows are unimportant, zonal density is the dominant saturation mechanism [Lang 08]. We developed a simple theory that agrees with the simulation and predicts zonal density generation and feedback stabilization of the most unstable mode even in the absence of zonal flow. This work was published in Ref. [Lang 08], and is the subject of Jianying Lang's Ph. D. Thesis. Comparisons between GEM and GS2 and the role of zonal flow where the topic of D. Ernst, et al. 2008 IAEA paper [Ernst 08] and of Darin Ernst's APS-DPP invited talk and a related collaborative paper was published in Physics of Plasmas[Ernst09].

In collaboration with G. Rewoldt, PPPL we are using GEM to simulate NSTX discharges. This work was presented at the past two American Physical Society - Division of Plasma Physics meetings. Previous results by Rewoldt directly comparing GEM simulation of equilibrium data from DIII-D shot 128527 at t=3.45 seconds have been published in Ref. [Chen 08]. We have also done verification and validation on DIII-D in collaboration with C. Holland and T. Rhodes and this work has been published in the journal Nuclear Fusion (see publications below). Good agreement with GYRO and DIII-D flux levels where reported in the core region.

**Related References**


**Recent Publications and APS Invited Talks**


*Linear gyrokinetic simulation of high-n toroidal Alfvén eigenmodes in a burning plasma*, Yang Chen, Scott E. Parker, J. Lang, and G.-Y. Fu, Phys. Plasmas 17, 102504 (2010).

*The pinch of cold ions from recycling in the tokamak edge pedestal,* Weigang Wan, Scott E. Parker, Yang Chen, Gunyoung Park, Choong-Seock Chang and Daren Stotler, Phys. Plasmas 18, 056116 (2011).

*Fluid electrons with kinetic closure for long wavelength energetic particles driven, modes,* Y. Chen and S.E. Parker, Phys. Plasmas 18, 055703 (2011)