Poster Presentation

Gyrokinetic particle simulations were used to study the effects of hydrogen isotopes on microturbulence. GTC, a well-known parallel code was used to run the simulations of ion temperature gradient (ITG) driven microturbulence for the three isotopes under the same conditions. In this study we focused on the ion thermal diffusivity, ITG growth rate, and spectral content. In our simulations we found that there was a need to increase the number of particles per cell and toroidal planes to achieve more conclusive results. The comparison between the ion thermal diffusivity of the three species gave favorable results, as did the growth rate study. The values found for tritium were lower in both studies, which would imply less turbulence in that plasma. Spectral analysis of turbulence had similar results. ITG instability develops a broader spectrum in hydrogen while tritium's is much narrower. This shows that tritium plasma has a lesser amount of turbulence when compared to hydrogen. These results are favorable and they imply that future D-T experiments could gave great success.

Numerical Study of Isotope Effect in Tokamaks using GTC

G. Woodbury-Saudeau (University of Puerto Rico), advised by Drs S. Ethier and W.W. Lee (PPPL)

BACKGROUND

- Hydrogen atoms come in 3 isotopes: hydrogen (1 proton), deuterium (1 proton, 1 neutron), and tritium (1 proton, 2 neutrons)
- Very few tokamak experiments have used tritium fuel.
- Yet, an electricity-producing tokamak fusion reactor will use a mix of tritium and deuterium as its fuel since that fusion reaction has the lowest energy barrier.
- Since all of the current experiments use either hydrogen or deuterium plasmas and observe differences between the two, how will tritium behave? Will it lead to better or worse confinement?

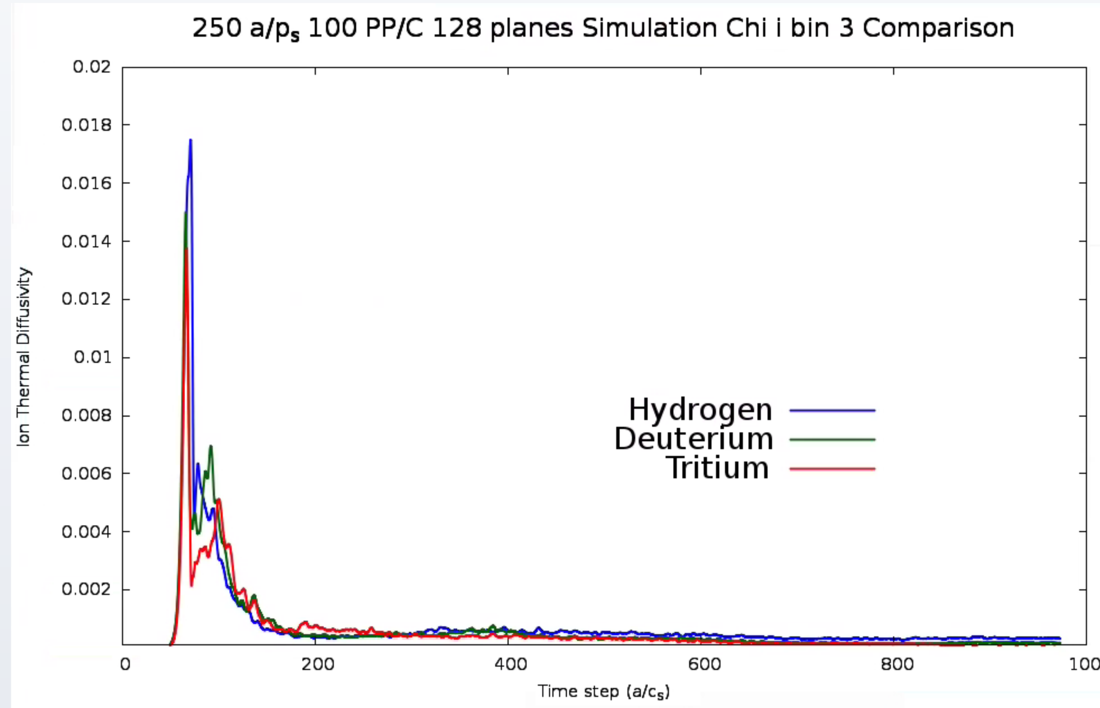
OBJECTIVES

- Use gyrokinetic particle simulations to study the effects of hydrogen isotopes on microturbulence, which is believed to be the most important phenomenon in determining energy and particle confinement.
- We use the well-known GTC parallel code [1] to run simulations of ion temperature gradient (ITG) driven microsturbulence for the 3 isotopes under the same conditions.
- Assess the effects of isotopes on ITG growth rate, heat diffusivity, and spectral content.

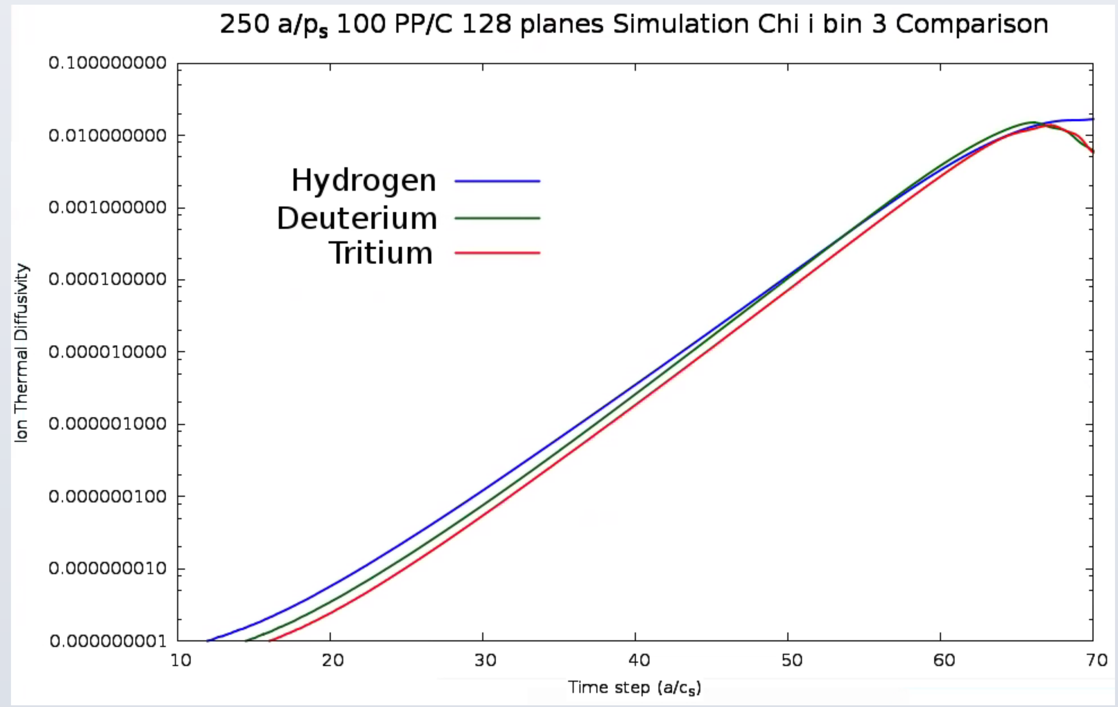
SIMULATION PARAMETERS

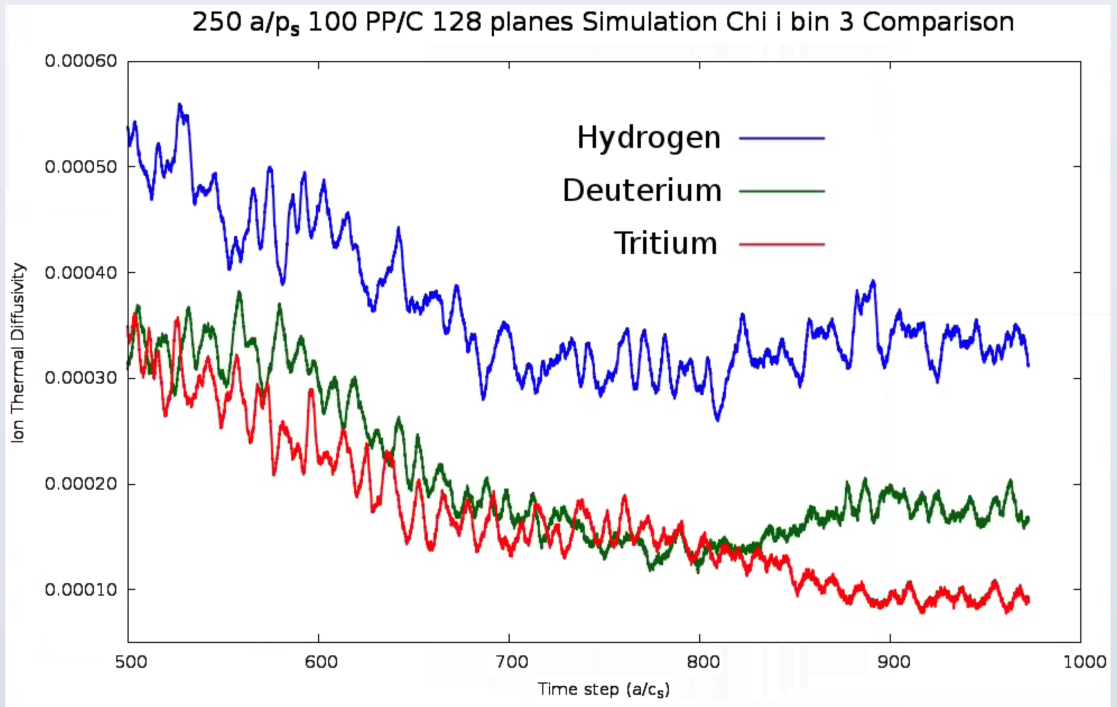
- Full 3D simulation of circular cross-section tokamak (similar to PPPL's old TFTR).
- Major radius of R_0 = 186.4 cm
- Minor radius a = 0.358 R_0 = 66.73 cm
- Magnetic field on axis B_0 = 19100 Gauss
- Background ion temperature T_i = 2.5 keV
- Flat top temperature gradient profile
- Large-aspect ratio analytical magnetic equilibrium ($B = B_0/(1 + (r/R_0)\cos(\theta))$)
- Run all simulations 3 times, each with a different isotope. The only change is the ion mass.

SIMULATION RESULTS



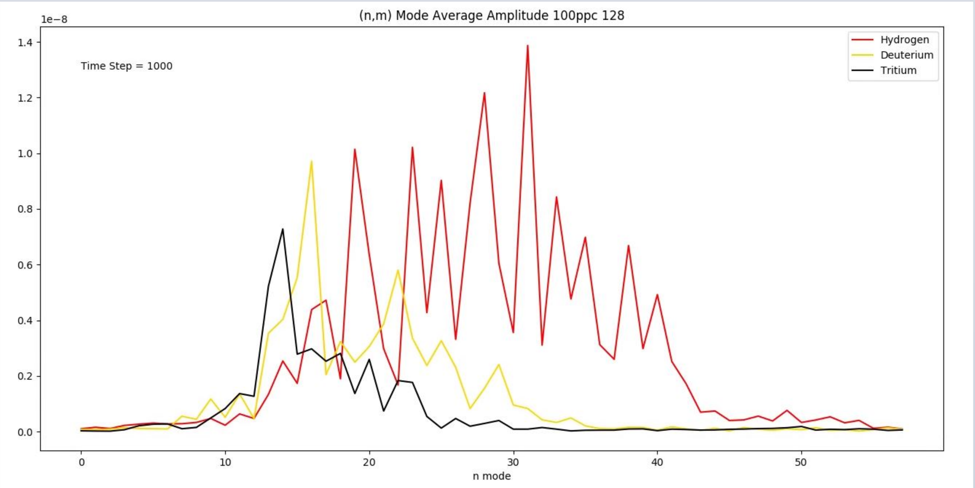
- Full time-dependent simulations of ITG turbulence for the 3 isotopes using the exact same parameters.
- 2 billion particles, 128 poloidal planes, 151,000 grid points per plane.
- Fully self-consistent turbulence calculation.
- Start with very low-level perturbation
- Simulation goes through exponential growth of turbulence (ITG instability) during "linear" phase, followed by non-linear saturation of turbulence (peak of diffusivity) due to a secondary instability, which manifests itself as a zonal flow. The heat flux drops and fluctuates until system reaches a statistical steady state.



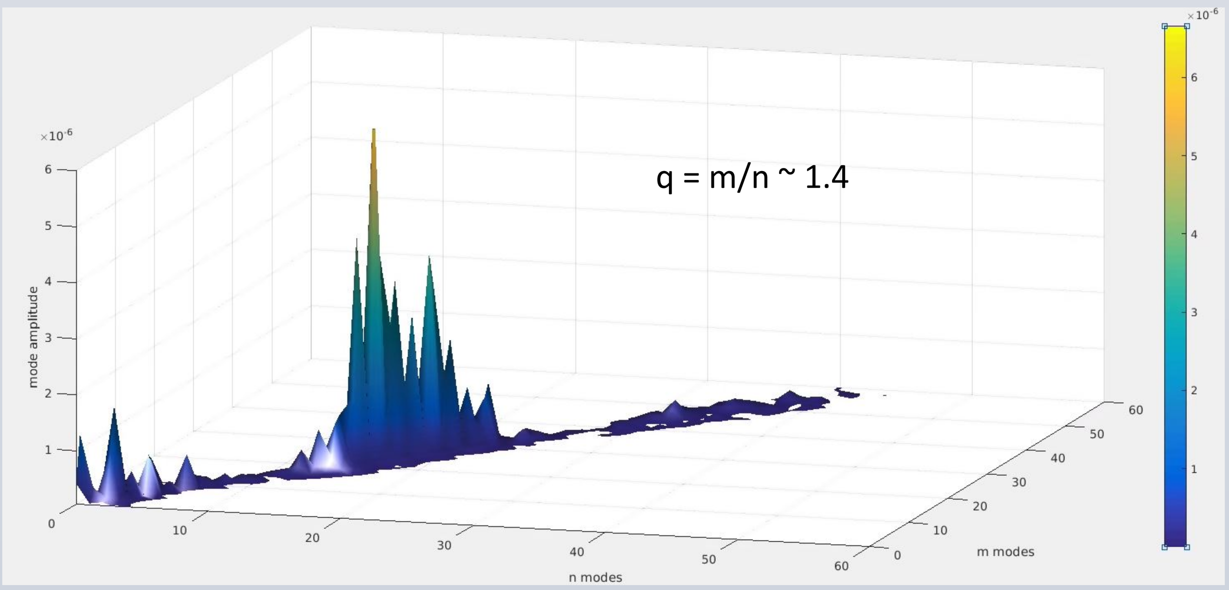


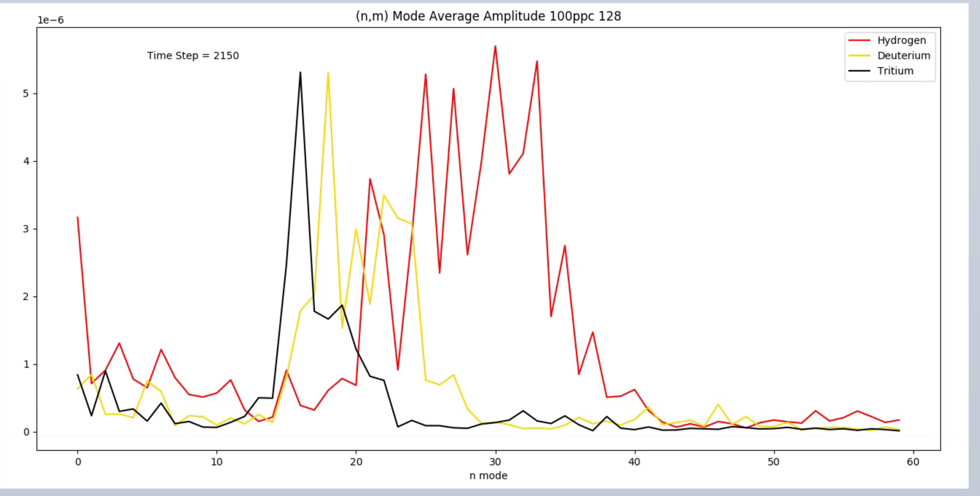
Final steady-state heat diffusivity of tritium plasma is lower than deuterium, which is in turn lower than hydrogen.

SPECTRAL ANALYSIS OF TURBULENCE

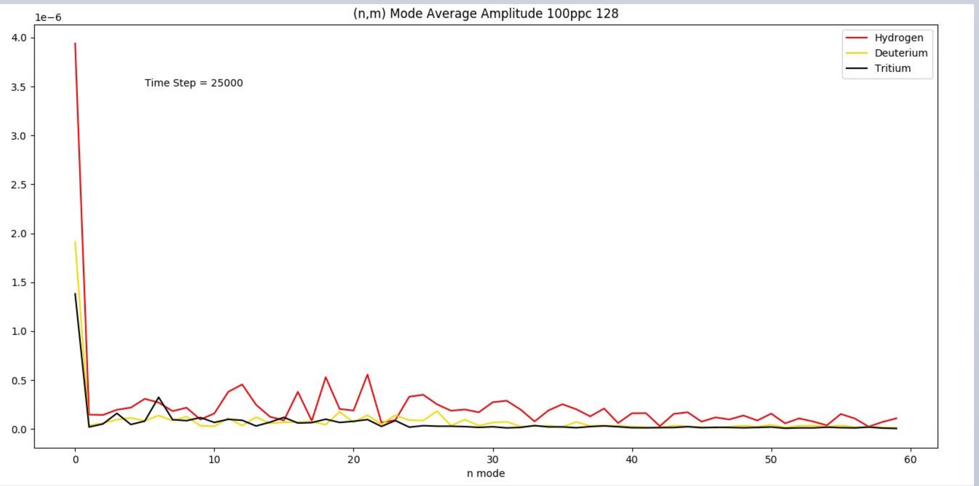


Early linear stage: ITG instability develops
Hydrogen plasma has broad spectrum while Tritium is much narrower





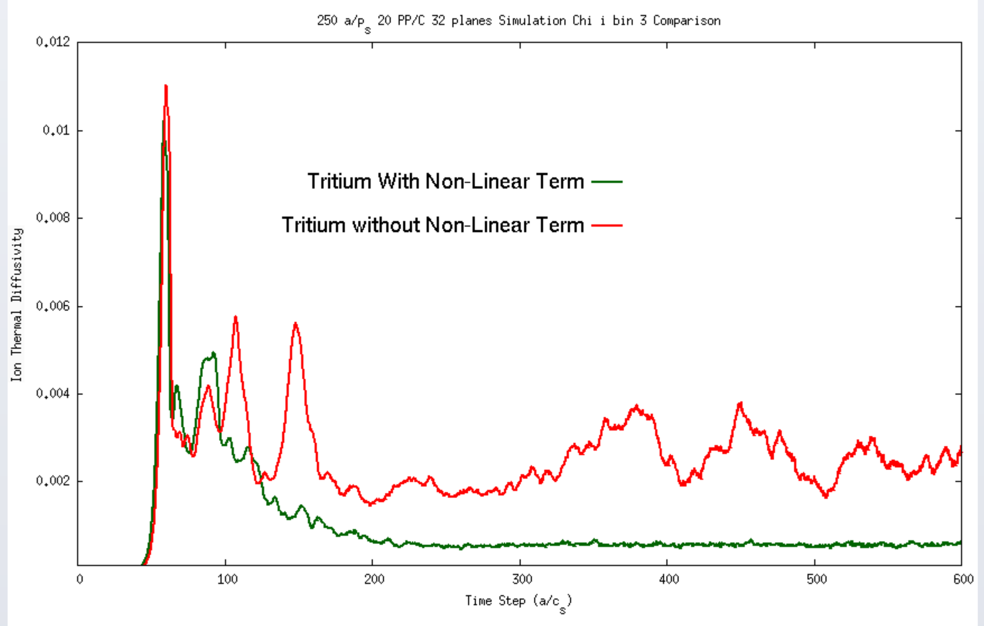
Non-linear stage near saturation. Zonal flow develops and turbulence starts to cascades toward longer wavelengths



Late stage turbulence. Largest modes at low "n,m" and rest of turbulence energy spread over very broad spectrum

CONVERGENCE STUDY

- Convergence study of the number of particles per cell (20, 40, 60, 80, 100) and number of poloidal planes (32, 64, 128) was carried out
  - 128 planes and 100 particles per cell give the best, converged results
- Tests were also done with and without including the velocity space nonlinearity term. This term turns out to be very important for energy conservation and stability of the simulation.



CONCLUSIONS

- **Heat diffusivity of Tritium is lower than deuterium, which is in turn lower than hydrogen = favorable scaling for deuterium-tritium experiments!! Good for ITER and future commercial reactors.**
- **Spectral analysis shows overall broader spectrum for hydrogen than deuterium and tritium = higher turbulence in hydrogen plasmas**
- **Seems to confirm previous study on a simpler system [2].**

REFERENCES

[1] Z. Lin, S. Ethier, T. S. Hahm, and W. M. Tang, *Phys. Rev. Lett.* **88**, 195004-1 (2002).
[2] W.W. Lee and R.A. Santoro, *Phys. Plasmas* 4, p. 169 (1997).

ACKNOWLEDGMENTS

This work was made possible by funding from the Department of Energy for the Summer Undergraduate Laboratory Internship (SULI) program.

CONTACT

- Gabriel S. Woodbury-Saudeau: gabriel.woodbury@upr.edu
- Stephane Ethier: ethier@pppl.gov