# Plasma Energetic Particle Simulation Center (PEPSC)

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on behalf of PEPSC team

PSACI PAC Meeting, June 5th, 2008, Princeton, NJ

# Outline

- Introduction
- Research Plan
- Project status
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# Introduction

- PEPSC is a collaborative advanced simulation center for energetic particle physics.
- It is funded by OFES's base program. The funding directly supports about 1FTE of senior staff and 2 postdocs. The funding period is from March 2008 to March 2011.

PEPSC team:

- PPPL: Guoyong Fu, Stephane Ethier, Nikolai N. Gorelenkov, Ravi Samtaney ;
- IFS: Herbert L. Berk, Boris N. Breizman, James W. Van Dam;
- Univ. Colorado: Yang Chen,Scott E. Parker;
- ORNL: Scott A. Klasky

# Goal of PEPSC

- Predictive simulations of energetic particle-driven instabilities and transport in burning plasmas

- Predictive simulations → code Verification/Validation;
- EP instabilities → Gyrokinetic/MHD hybrid model;
- Transport → long time nonlinear simulations;
- Burning plasmas → massively parallel computation to resolve multiple high-n modes

# PEPSC Plan

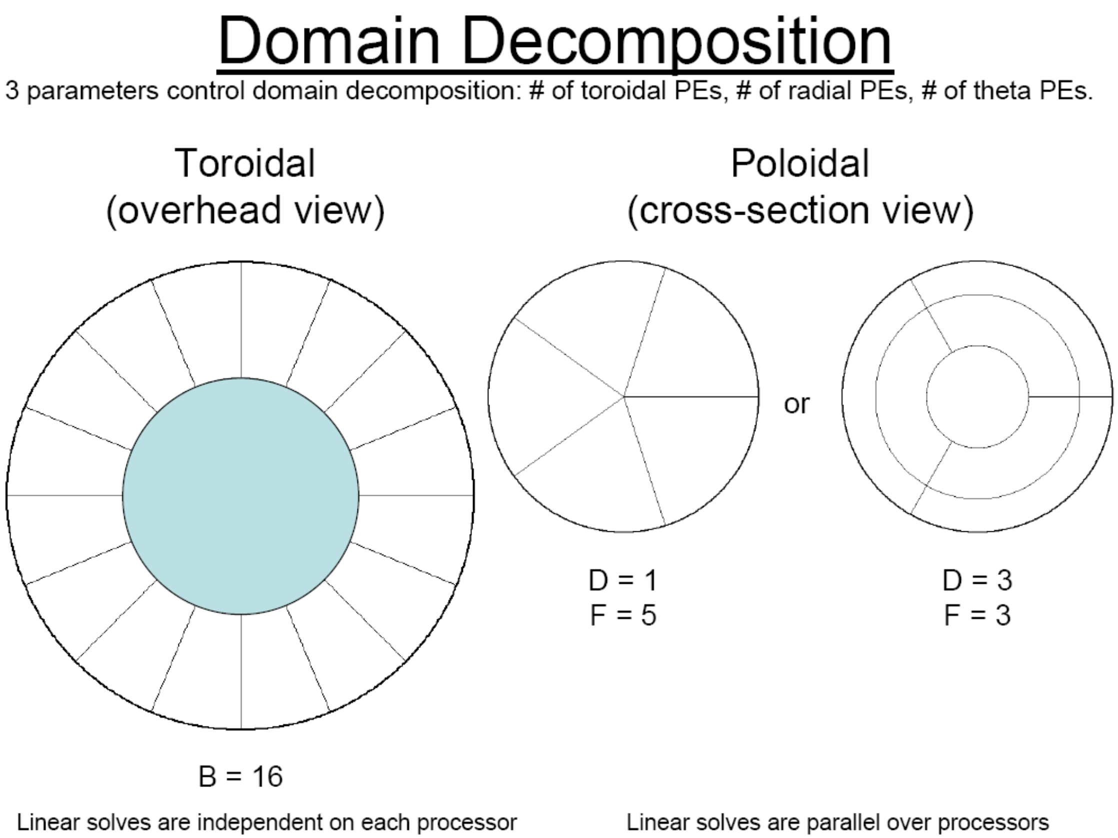
- **Upgrade M3D-K code**: extension to 3D domain decomposition for particles; add source and sink.
- **Build a new gyrokinetic/MHD hybrid code GKM** (start from M3D-K) that uses gyrokinetic closure to include kinetic effects of thermal ions as well as energetic particles.
- **Implement advanced numerical methods**: nonlinear implicit method, high-order finite elements, and workflow method. Also, optimize code speed.
- **Explore reduced models** for comparison with GKM.
- **Apply codes to experiments** for code validation and physics understanding.
- **Apply GKM to ITER** for simulations of alpha particle-driven high-n TAEs.

# Research Plan (2008-2009)

- Extend particle domain decomposition to 3D (scale to >1000 processors);
- Add source/sink (with CU);
- Formulate nonlinear GKM model (with IFS);
- Build GKM0 (initial GKM version);
- M3D-K simulations of beam-driven Alfven modes in NSTX.

# Extend particle domain decomposition to 3D

We have currently 2D domain decomposition(poloidal and toroidal). We plan to add domain decomposition in radial direction in order to use more than 100s of processors.



# Add source/sink

- Need source and sink for long time simulations;
- Source (NBI injection, alpha particle birth);
- Sink ( collisional slowing down,  particle loss to the wall)

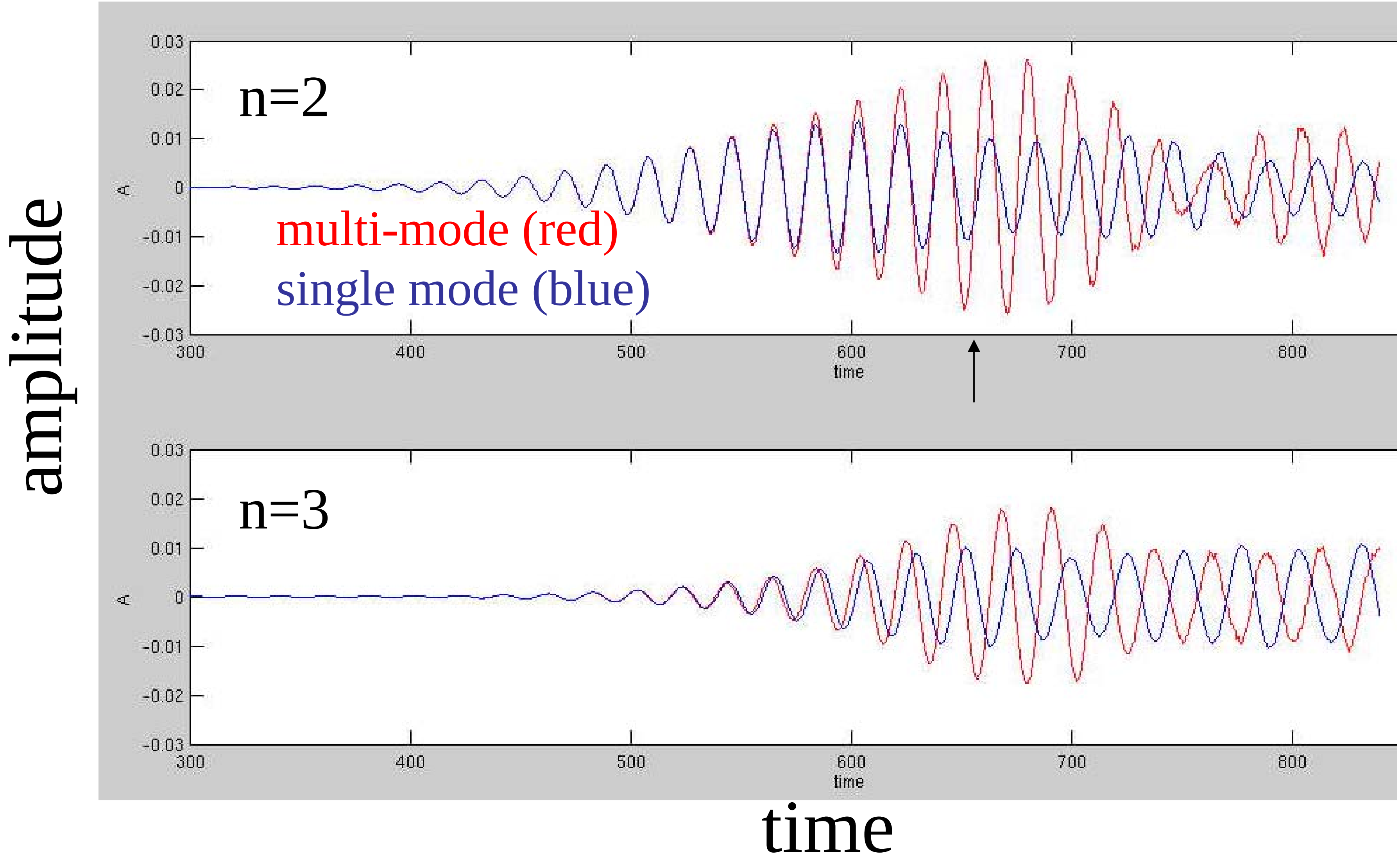
# Formulate nonlinear GKM model

- Formulate nonlinear GKM mode based on gyrokinetic equation;
- Use hybrid model to recover exactly the MHD dynamics;
- Treat kinetic effects of both thermal species and energetic particles on equal footing;
- Kinetic effects are treated using PIC method (kinetic closure rather than fluid closure).

# M3D-K simulations of beam-driven Alfven modes in NSTX.

- Continue M3D-K simulations of beam-driven Alfven modes in NSTX plasmas;
- Emphasize multiple mode dynamics;
- Test source/sink with collisions;

# Multi-mode simulations show strong mode-mode interaction.



# Project Status

- The center formally began operation with a one-day kickoff meeting on March 29th, 2008 in Boulder, Colorado.

- A center website has been setup.

(http://w3.pppl.gov/theory/PEPSCHome.html).

- An initial model for the gyrokinetic/MHD code GKM has been formulated.The model can describe various Alfven eigendmodes (TAE, RSAE, BAAE etc), kinetic Alfven waves, sound waves, and Geodesic Acoustic Modes for general tokamak equilibrium.

- The first version of GKM has been constructed and has been used successfully in simulating TAE and RSAE.

# PEPSC Kickoff Meeting

March 29, 2008
Boulder Creek Board Room
Millennium Harvest House Hotel
Boulder, Colorado
(Jim Van Dam, Chair)

| | | |
|---|---|---|
| 8:00 | G. Fu | Project Overview and PPPL Plan |
| 8:40 | H. Berk | IFS Plan |
| 9:00 | Y. Chen | Colorado Plan |
| 9:20 | S. Klasky | ORNL Plan (Incite/Workflow) |
| 9:40 | Coffee Break | |
| 10:00 | G. Fu | GKM Version Zero and Beyond |
| 10:30 | Y. Chen | Source and Sink for GKM |
| 11:00 | N. Gorelenkov | Code Verification/Validation |
| 11:30 | R. Samtaney | JFNK Method for GKM |
| 12:00 | Lunch | |
| 14:00 | ALL | Informal Discussions |
| 18:00 | adjourn | |

# http://w3.pppl.gov/theory/PEPSCHome.html

## Plasma Energetic Particle Simulation Center (PEPSC)

**PEPSC Home**

Overview

People

**Presentations**

Team Meetings

Welcome to the homepage of this DOE-sponsored advanced simulation project, a collaboration research effort by investigators from Princeton Plasma Physics Laboratory, Institute for Fusion Studies, Univesity of Colorado, and Oak Ridge National Laboratory.

PPPL PRINCETON PLASMA PHYSICS LABORATORY

UNIVERSITY OF COLORADO 1876

ORNL

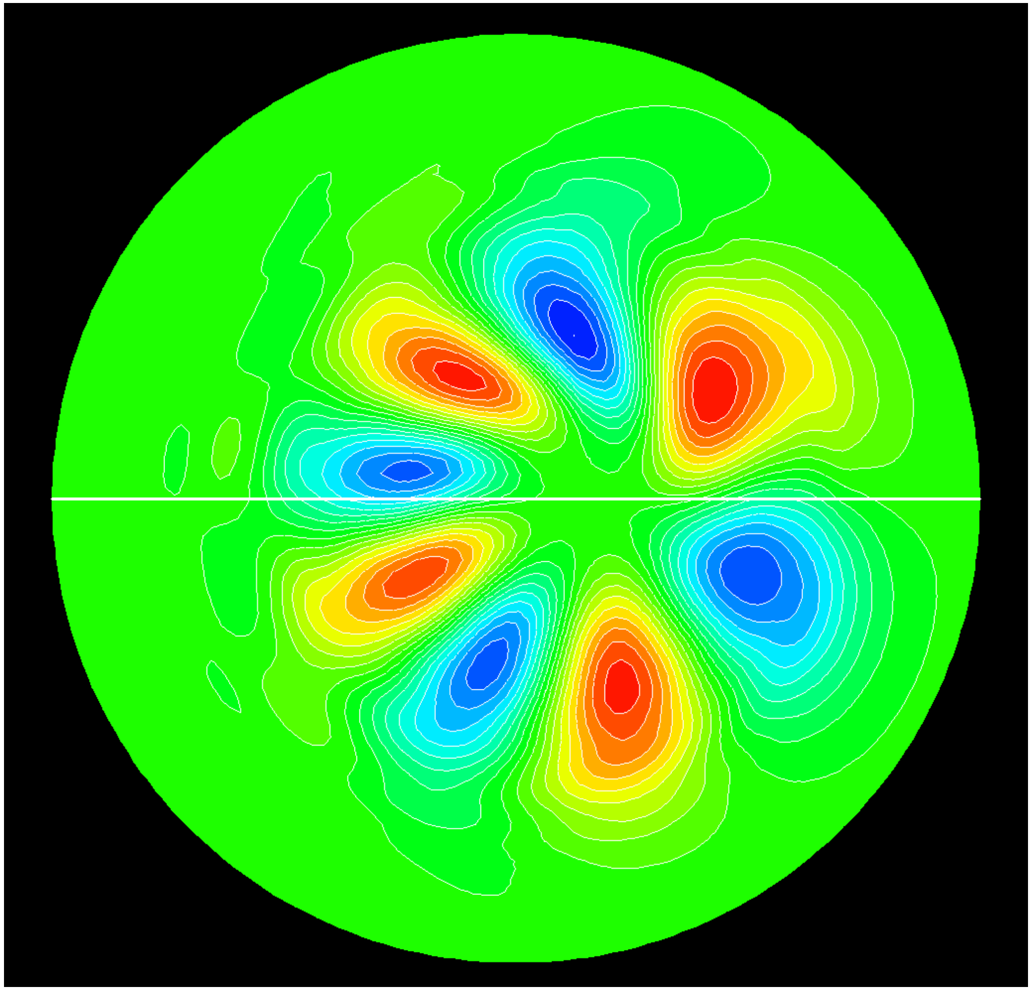
INSTITUTE OF FUSION STUDIES AT THE UNIVERSITY OF TEXAS AT AUSTIN

# Gyrokinetic/MHD model for GKM

$$-\frac{d}{dt}\nabla\cdot\left(\frac{1}{V_A^2}\nabla_\perp\Phi\right)+\boldsymbol{B}\cdot\nabla\frac{\boldsymbol{B}\cdot(\nabla\times\nabla\times\boldsymbol{A})}{\boldsymbol{B}^2}+(\nabla A_{\|}\times\boldsymbol{b})\cdot\nabla\left(\frac{J_{\|0}}{B}\right)$$

$$=\frac{1}{V_A^2}\left(\frac{3\mathbf{v}_t^2}{4\Omega^2}\right)\nabla_\perp^4\frac{d\Phi}{dt}+\boldsymbol{b}\times\sum_j\nabla\left(\frac{env_t^2}{2B\Omega^2}\right)_j\cdot\nabla\nabla_\perp^2\Phi-\sum_j\int(e\mathbf{v}_d\cdot\nabla f)_j d^3v$$

# n=2 RSAE from GKM0



# Summary

- PEPSC goal is predictive simulations of energetic particle-driven instabilities and transport in burning plasmas.
- The main task is building, V&V and application of a new gyrokinetic/MHD code GKM.
- The project began in March 2008 and we are on the way to simulate alpha particle-driven instabilities in burning plasmas (ITER!).