Progress on the Computational Modeling of ELMs with NIMROD and the '05 Theory Milestone

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DOE Milestone for 05' on ELM Simulation Has Been Met

1st Q (end of December 04)
Quantify the scaling of unstable modes with resistivity and thermal conduction, and compare to linear codes

2nd Q (end of March 05)
Do simulations using accurate experimental profiles, and extend models to include ion stress tensor effects

3rd Q (end of June 05)
Further extend the studies to include variation of the electron pressure along field line, and look for appropriate equilibrium for test cases

4th Q and FINAL (end of September 05)
Perform parametric studies to better understand the edge physics regimes of laboratory experiments. Simulate at increased resolution (up to 20 toroidal modes), with density evolution, late into the nonlinear phase and compare results from different types of edge modes. Simulate a single case including a study of heat deposition on nearby material walls.

Several physics issues were addressed in the linear studies

NIMROD agrees with ELITE and GATO Linear Mode Structure for ideal ELM cases, and growth rate for ballooning dominant cases

Ideal Growth Rates Bracketed by NIMROD Depending on Edge Dissipation

Discrepancy in growth rate spectrum for some cases

Preliminary application of parallel kinetic heat flux closure shows peaking along linear eigenfunction, consistent with Braginskii

Preliminary inclusion of Hall physics causes change in linear eigenfunctions and adds rotation, but has little effect on growth rates.

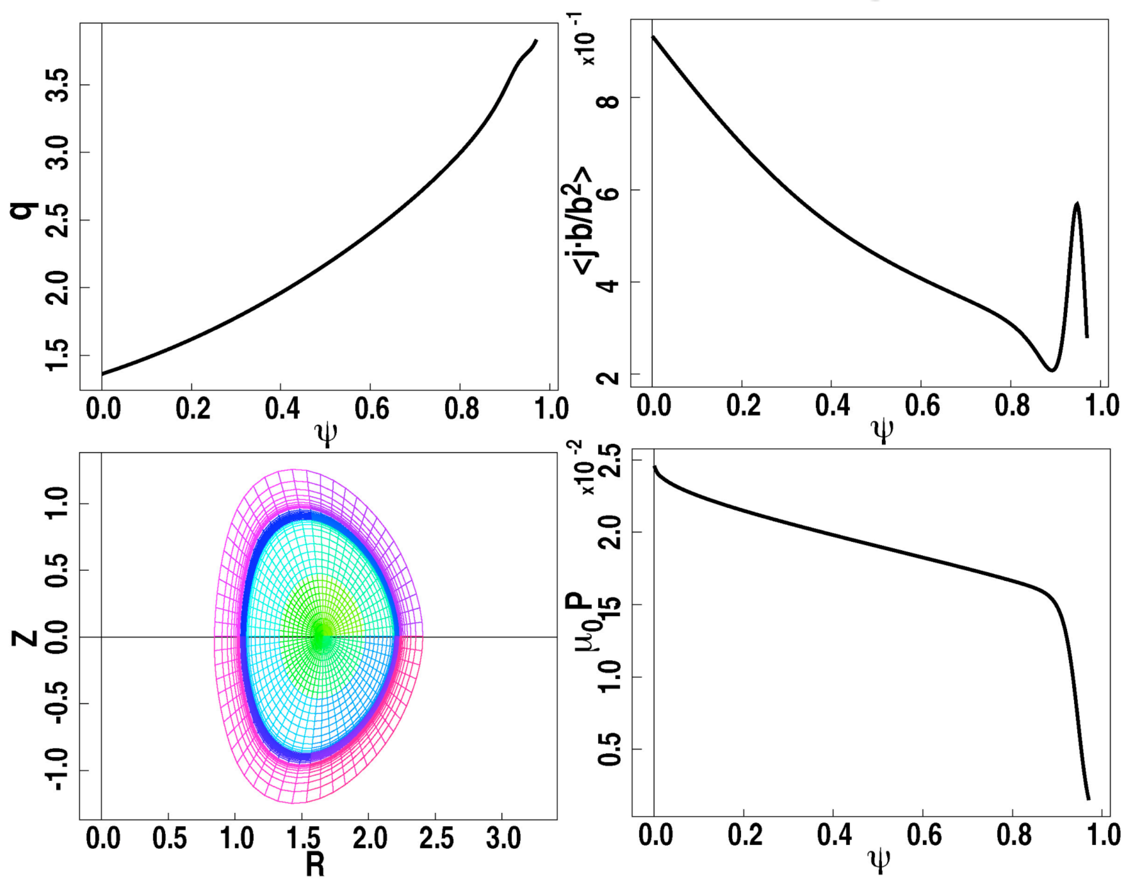
Initially, A Limited, Edge Pedestal Equilibrium Specified for Study

$$T(\psi) = T_0(1 - T'\psi)(1 + 0.5(tanh(\alpha(\psi_{ped} - \psi)) - 1)$$

$q(\psi)$ set to moderate shear case from experiment

$$T_0 = 5keV$$
$$T' = 0.9$$
$$\alpha = 30$$
$$\psi_{ped} = 0.95$$

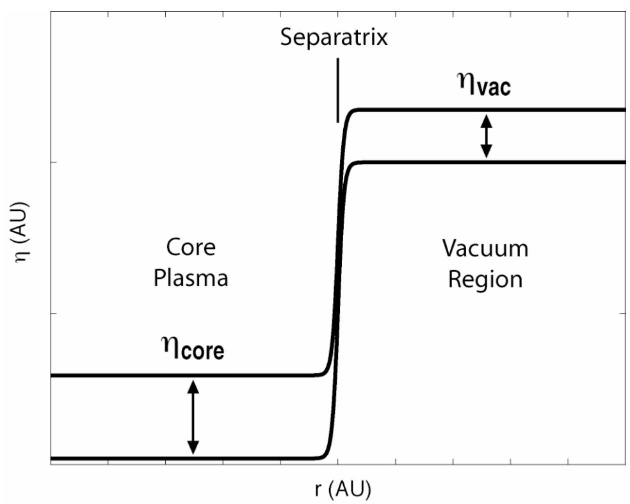
- **DIII-D geometry with T and q profiles specified**
- **Teq/Corsica code used to find FF' profile and vacuum flux for solution to Grad-Shafranov equilibrium**
- **Flat Core Profiles**
    - **Stable in Core**
    - **Unstable at Edge**
- **Moderate Edge q**

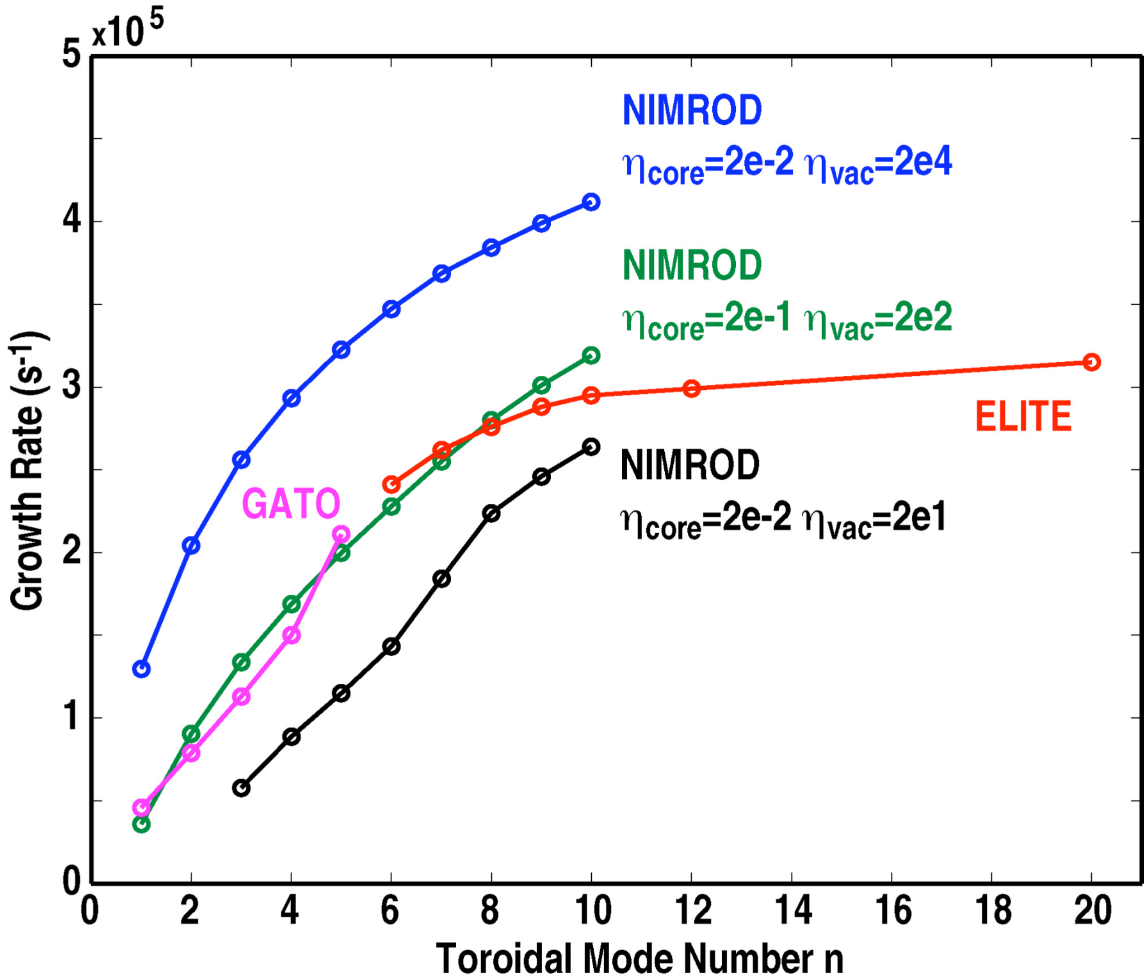


Ideal Growth Rates Bracketed by NIMROD Depending on Dissipation

Viscosity and Resistivity have opposite effects.

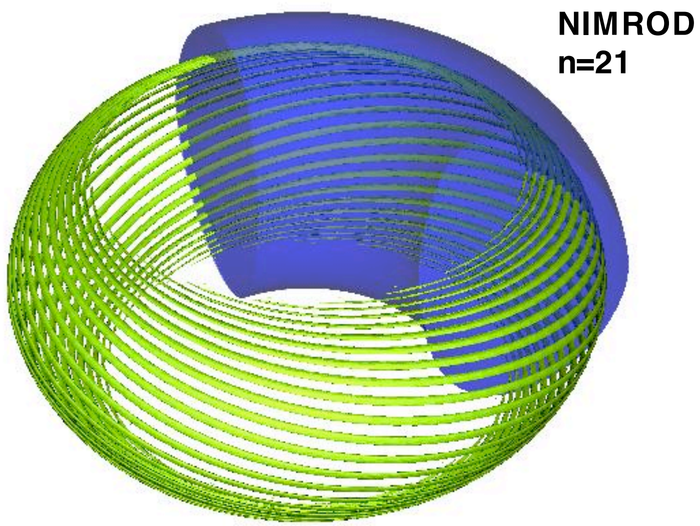
High resistivity in vacuum and adiabatic convergence in both resistivity and viscosity necessary to approach ideal results.

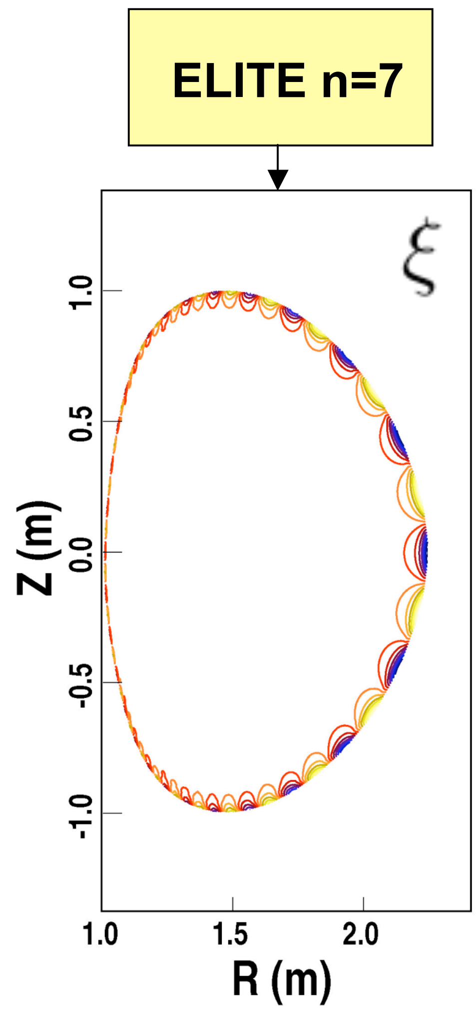


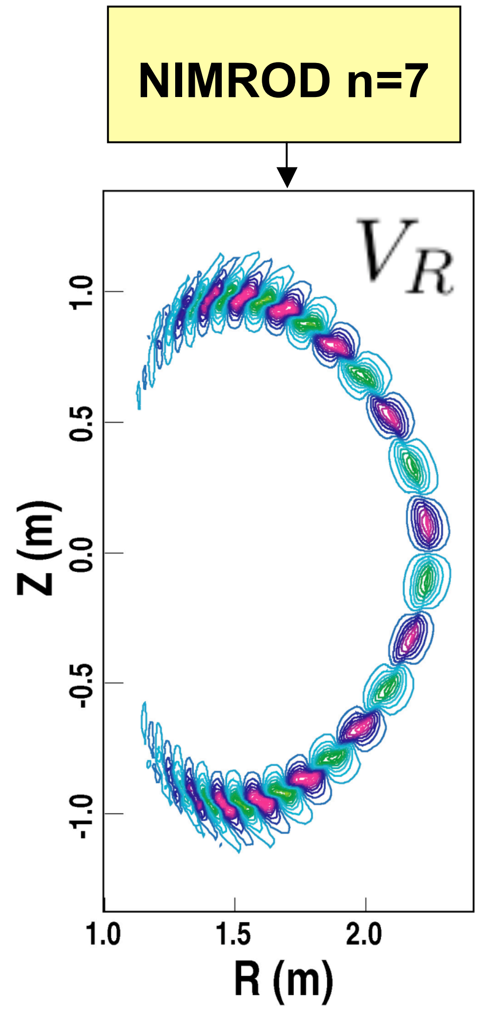


NIMROD Agrees with ELITE Linear Mode Structure

Poloidal and radial distribution of the mode is in good agreement

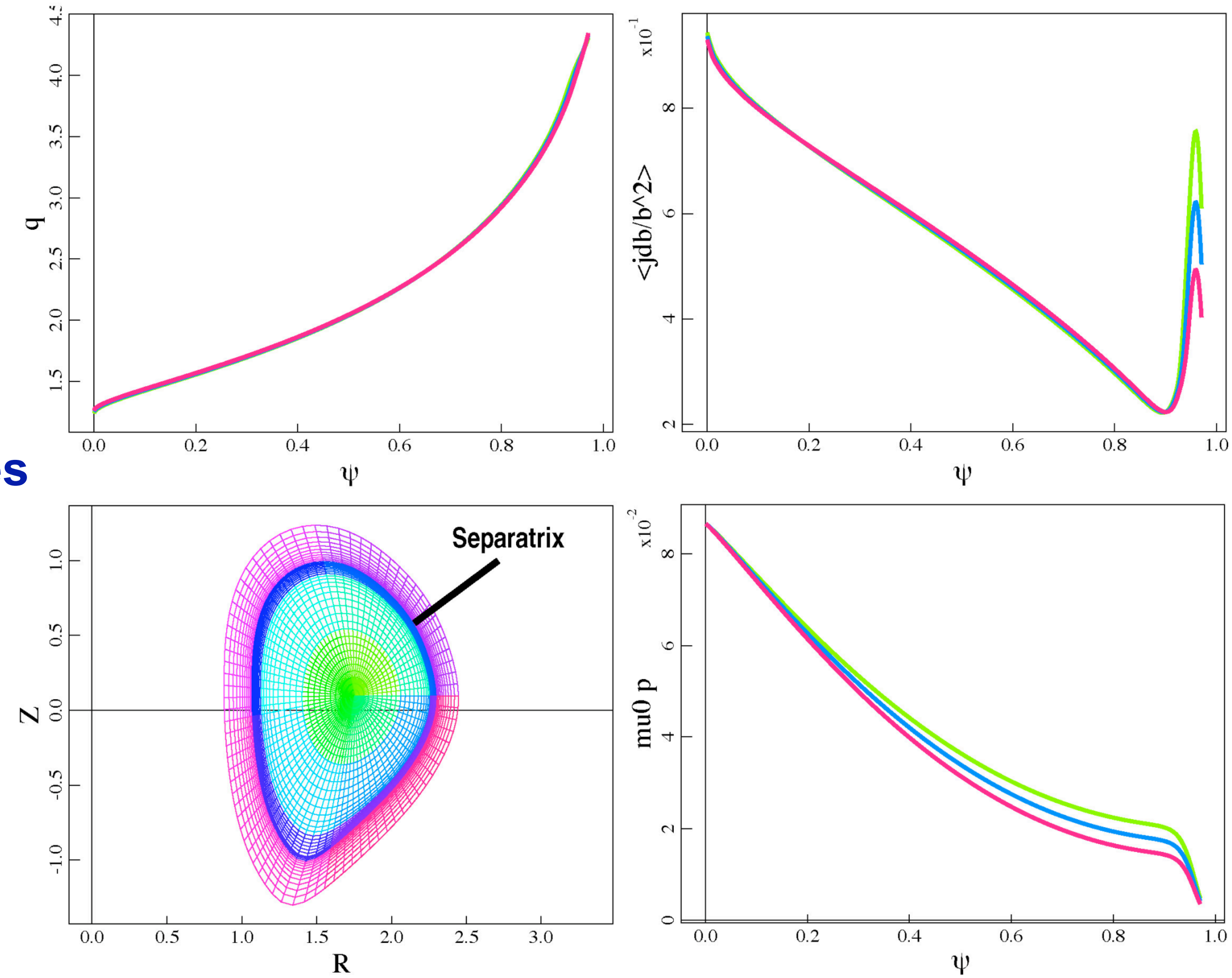






A Realistic DIII-D Diverted H-mode Equilibrium Specified for Further Studies

- Diverted Case
- Pedestal Edge
- High Edge Current
- Realistic Core Profiles
    - Stable in Core?
    - Unstable at Edge

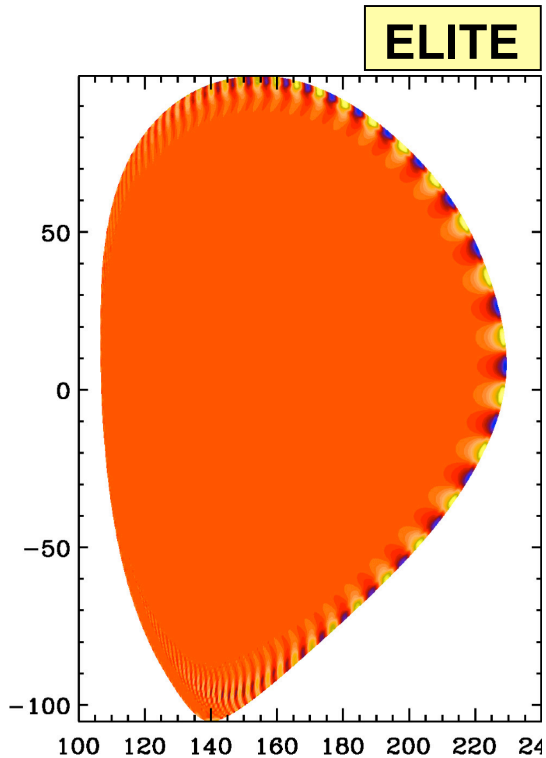


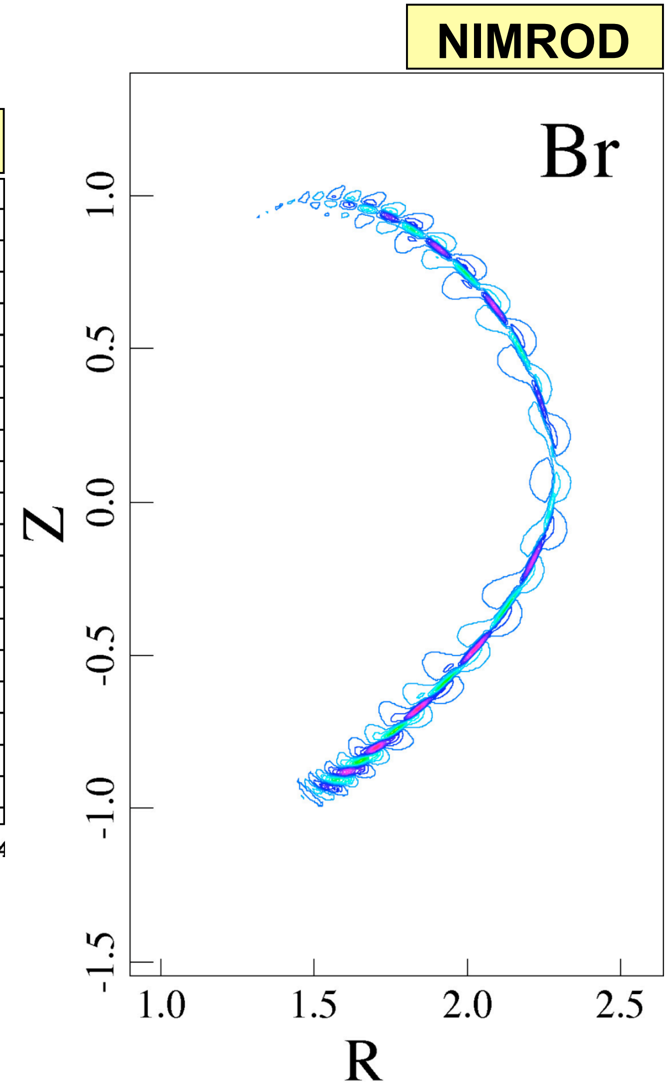
The edge of the equilibrium is found to be linear ideal unstable

The eigenfunctions from NIMROD and ELITE of the edge localized mode agree qualitatively.

Growth rate of n=20 is approximately 2.5×10^5 s^{-1}

DCON also finds low n to be unstable at edge.

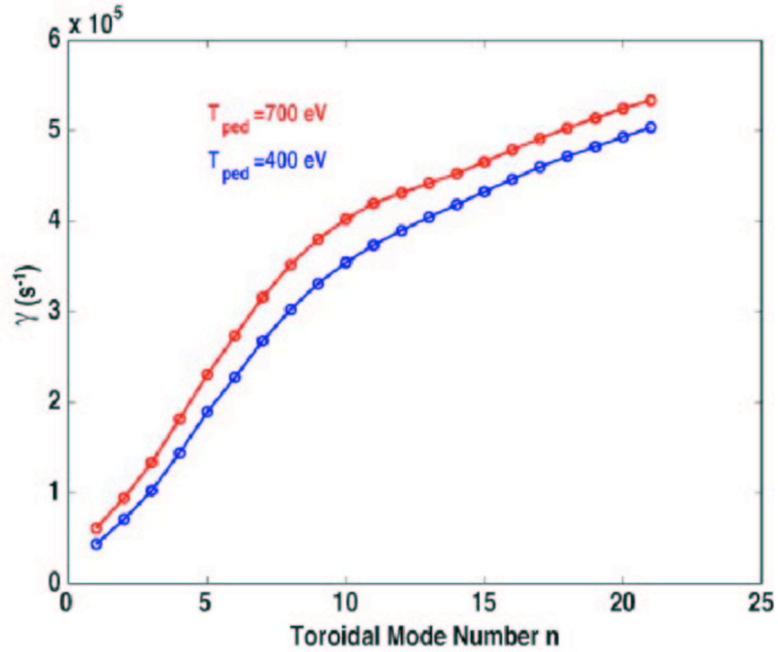




Growth rate spectrum increasing monotonically with n in NIMROD

Little change in growth rates with large change in temperature, with same density profile.

Lower temperature cases have internal mode unstable.



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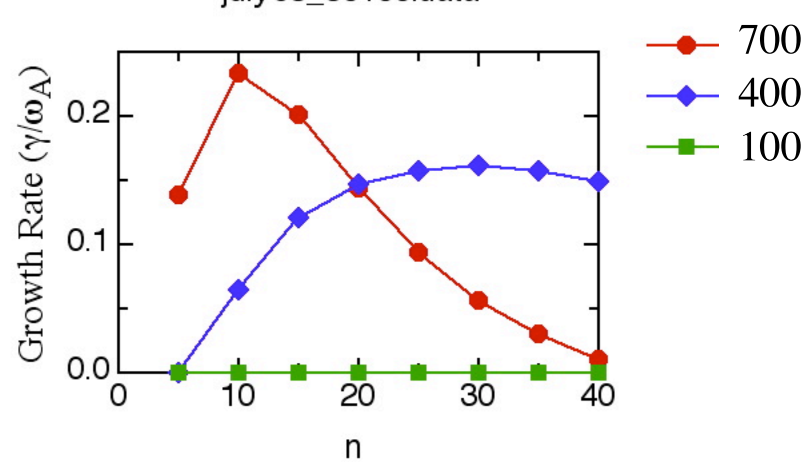
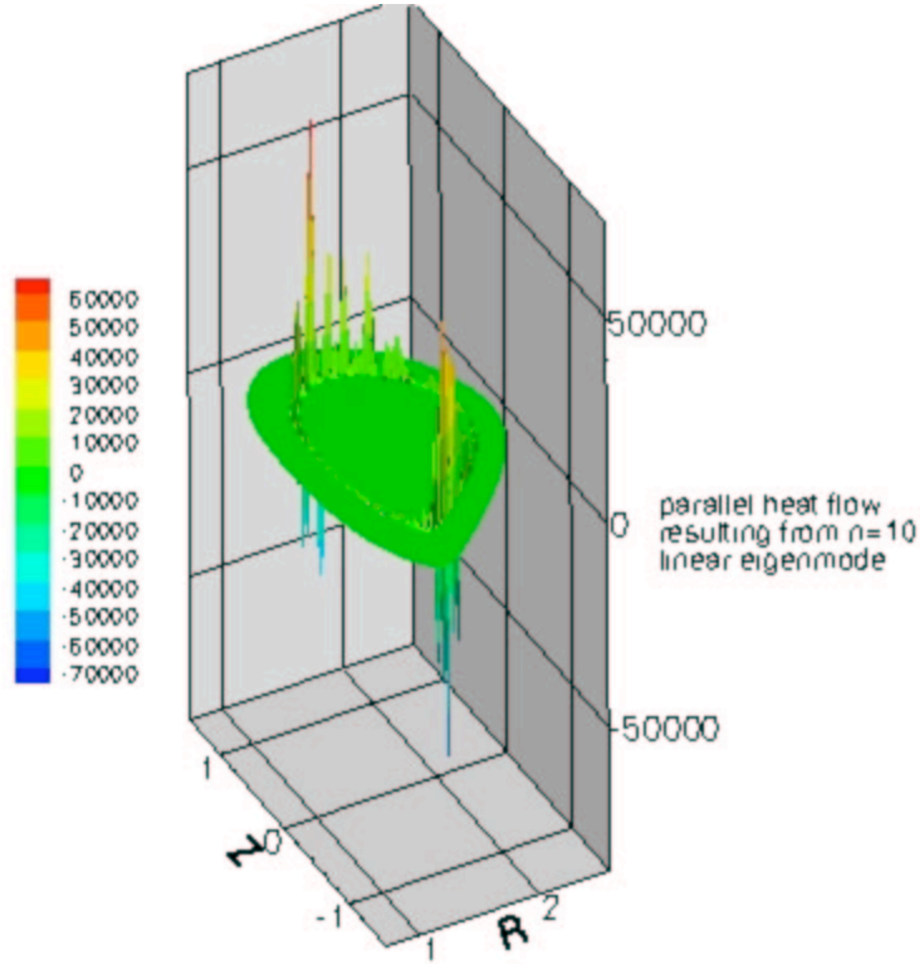
For comparison, the ELITE result is quite different

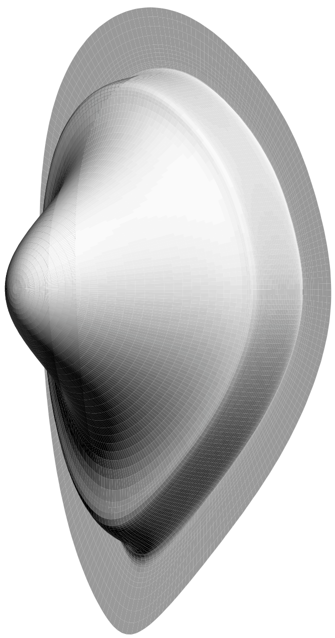


Parallel heat flow closure shows peaking along linear eigenfunction

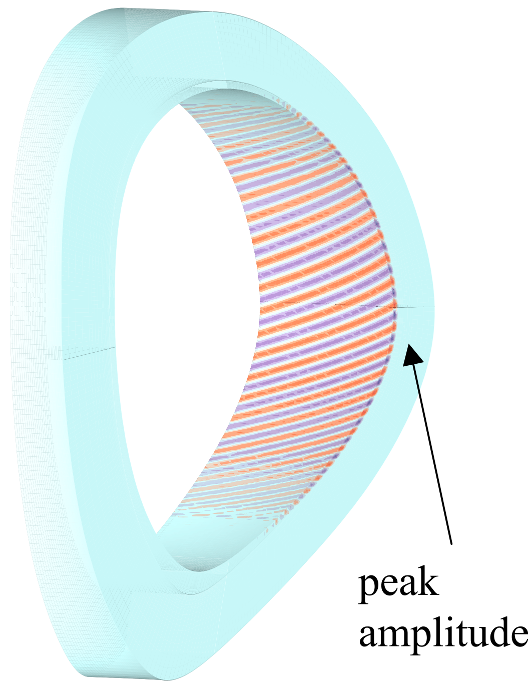
Parallel heat flow resulting from the n = 10 mode obtained with a non-local, parallel kinetic closure calculation. Note the concentration near the edge. The result is consistent with the use of in the Braginskii closure used in the NIMROD calculations.



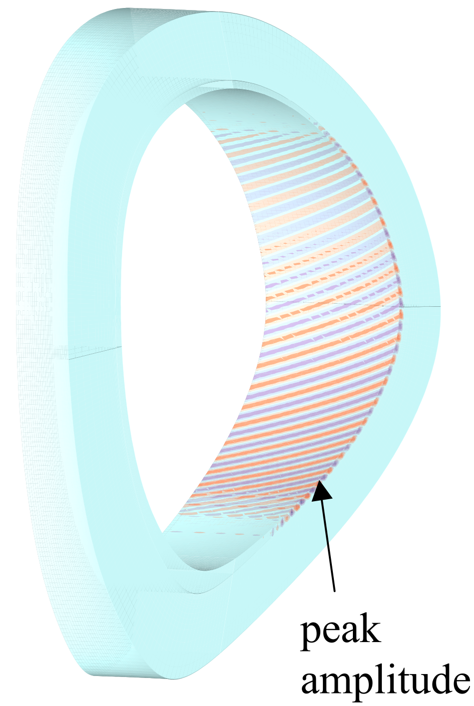
Preliminary application two-fluid effort to a linear study of ELMs in DIII-D equilibria.



Equilibrium Pressure



MHD perturbed pressure



Two-fluid perturbed pressure

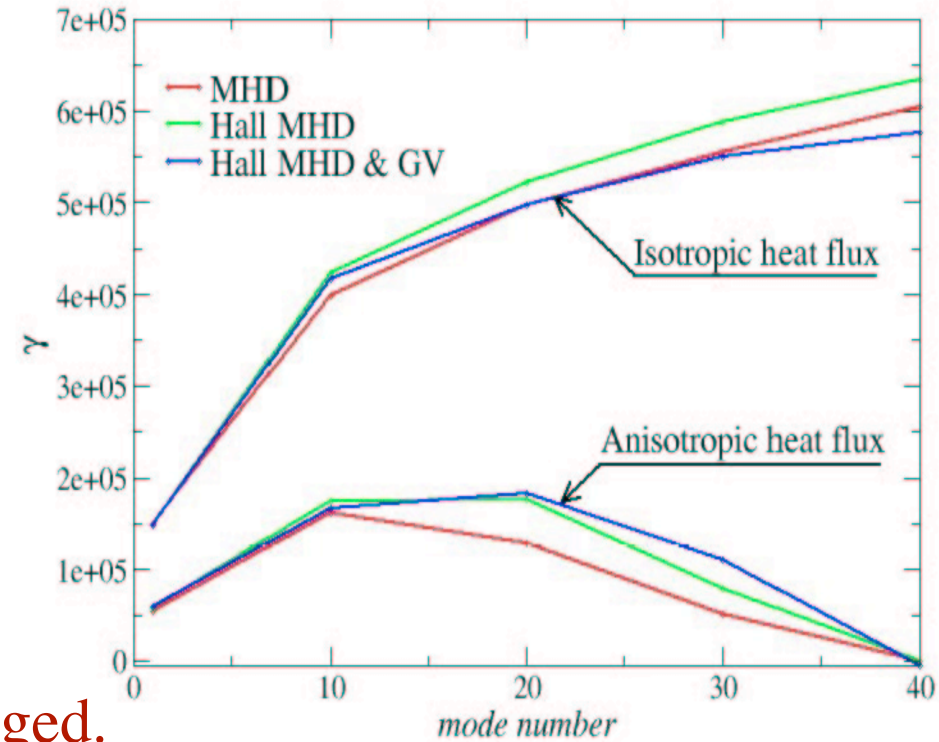
• The two-fluid model (including Hall and gyroviscous effects) shifts this n=40 mode downward and induces rotation.

• $\gamma\tau_A$=0.62 (MHD); $\gamma\tau_A$=0.53 and $\Omega\tau_A$=0.44 (HMHD+GV).

• **Important caveat: the self-consistent equilibrium flows are not included.**

Preliminary XMHD results show little effect, in contradiction to expectation

Linear growth rate as a function of toroidal mode number for the case of 400 eV pedestal temperature, $S = 3.7\times10^7$, $Pm = 10^{-3}$, showed little effect from gyroviscosity and Hall physics.



Anisotropy may not be converged.

Linear computation for the Tped = 700 eV equilibrium without anisotropic thermal conduction finds only a 13% reduction in growth rate when Hall and gyroviscous effects are included at n=40.

Summary

•The 05 milestone has been met.

•Accurate linear ideal spectrum for equilibria must be achieved for the correct linear stability characteristics, which will strongly affect nonlinear evolution.

•The effects of resistivity and viscosity on edge localized modes are moderate but important, and must be understood. Linear resistive stability of equilibria can differ significantly from linear ideal stability, despite a dominantly ideal mode.

•With two fluid treatment, the differences are expected to be extreme, however preliminary inclusion of Hall terms showed little effect on growth rates.

•Carl Sovinec now review the nonlinear results…