# Computations for the DOE Milestone on Edge Localized Modes

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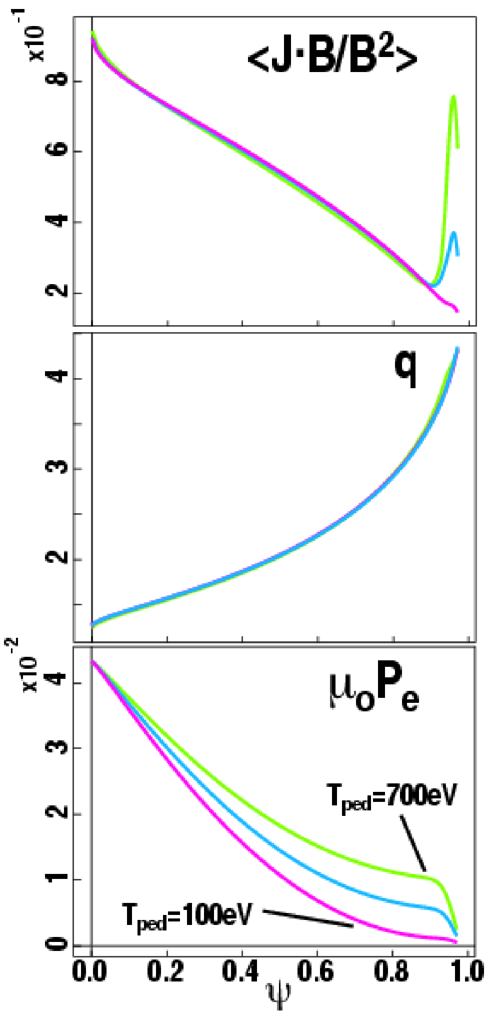
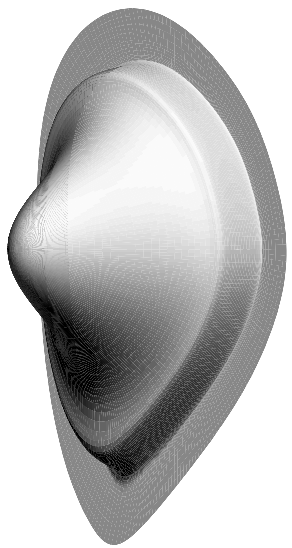
# Milestone Statement

*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.*

# Nonlinear Computations

- Our first nonlinear simulations used an idealized equilibrium that was ballooning dominant (low shear).
- We generated a sequence of equilibria based on fits to DIII-D shot 86166.
- Edge profiles were massaged to achieve varying degrees of kink vs. pressure drive without extreme deviation from measured data.
- The $T_{ped}$=700 eV edge case has been used for nl. calcs.



Simulation domain extends beyond the separatrix, as indicated in this plot of $P_{eq}$.

- **The sharp change to flat pressure is problematic for our nonlinear computations.**

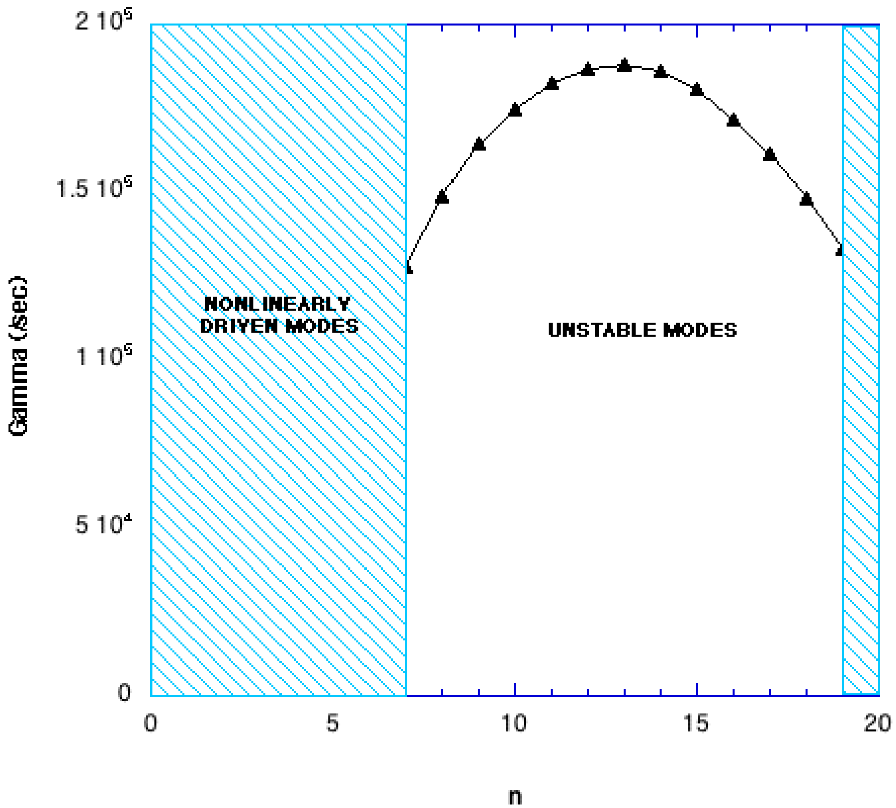
# A recent series of nonlinear simulations emphasized robustness to obtain 'late nonlinear' evolution.

- Toroidal resolution is the milestone-required $0 \leq n \leq 21$.
- All evolve number density, and $n_{eq}+n_0(t)$, i.e. $\langle n \rangle$, is used in coefficients for all but the earliest attempts.
- Resistivity is $\langle T \rangle$-dependent.
- Anisotropic thermal conduction is used with <u>fixed</u> diffusivities:

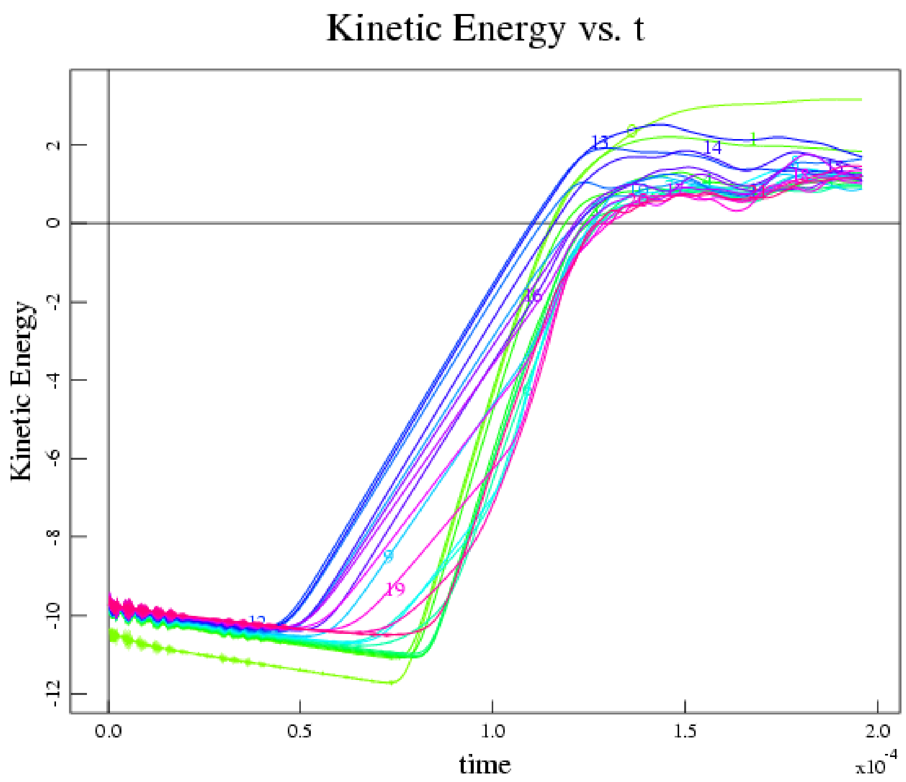
$$\left(\chi_{\|}, \chi_{\perp}\right) = \left(1, 10^5\right) \text{and} \left(25, 2.5\times 10^6\right) \text{in m}^2/\text{s}$$

- The 'vacuum' pressure has a constant offset to raise the edge plasma above $T=0$.
- A variety of poloidal meshes (number of elements, basis functions, packing) have been applied. The most accurate and robust is a moderately packed 40×72 mesh of biquartics.

With the chosen parameters, the linear growth-rate spectrum is peaked around *n*=10, and the nonlinear evolution does not suffer a “UV catastrophe.”

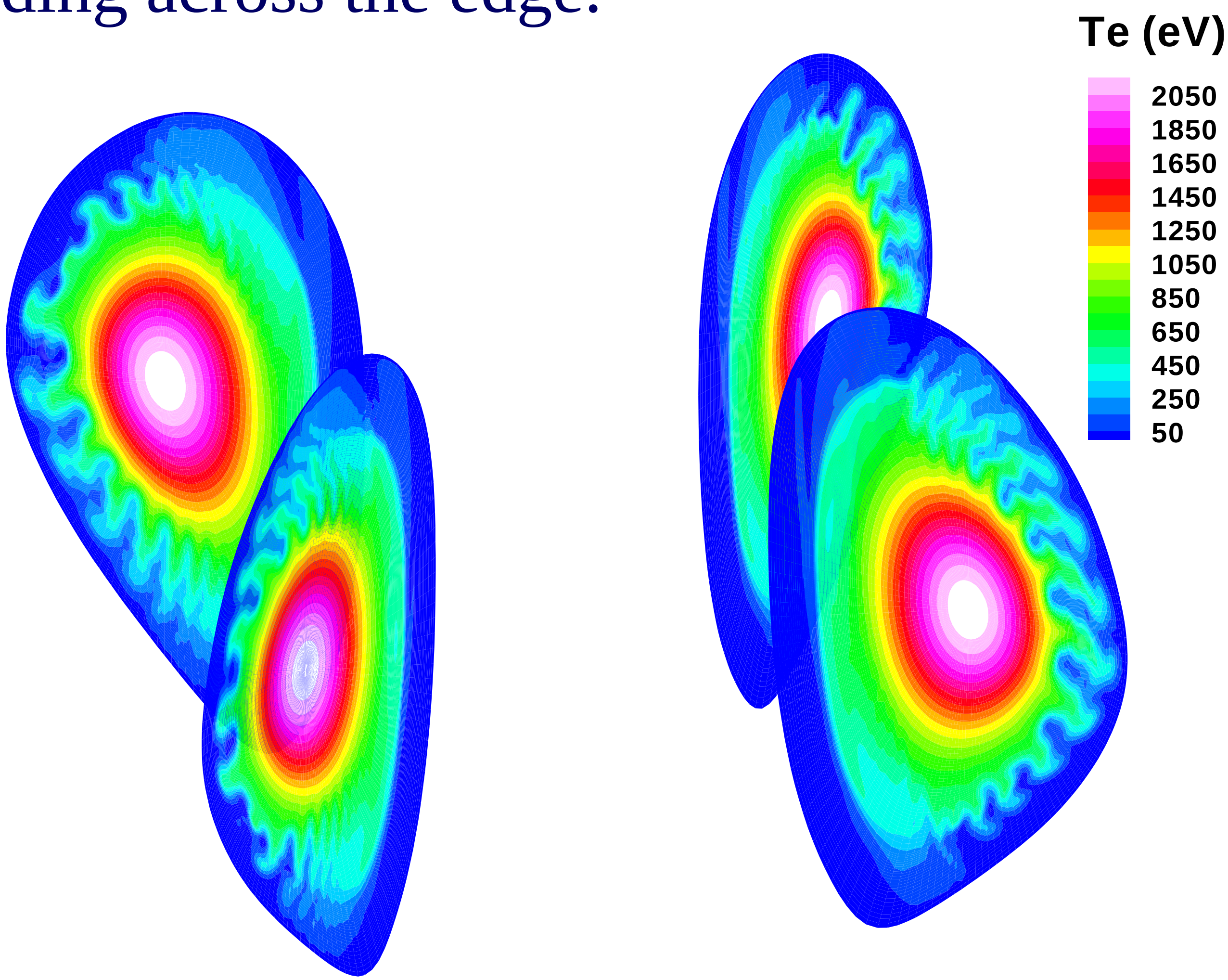



Linear Spectrum



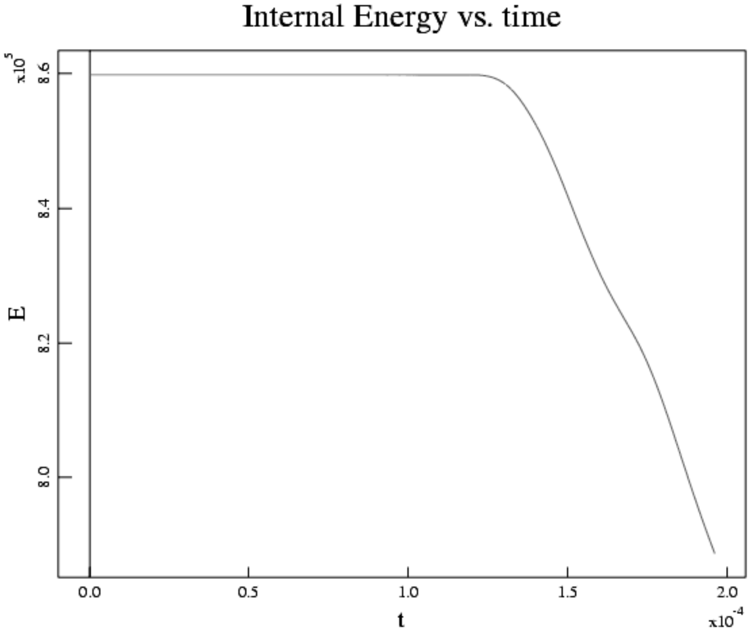

Nonlinear Fluctuation-energy Evolution

# The nonlinear evolution shows ribbon-like structures extending across the edge.

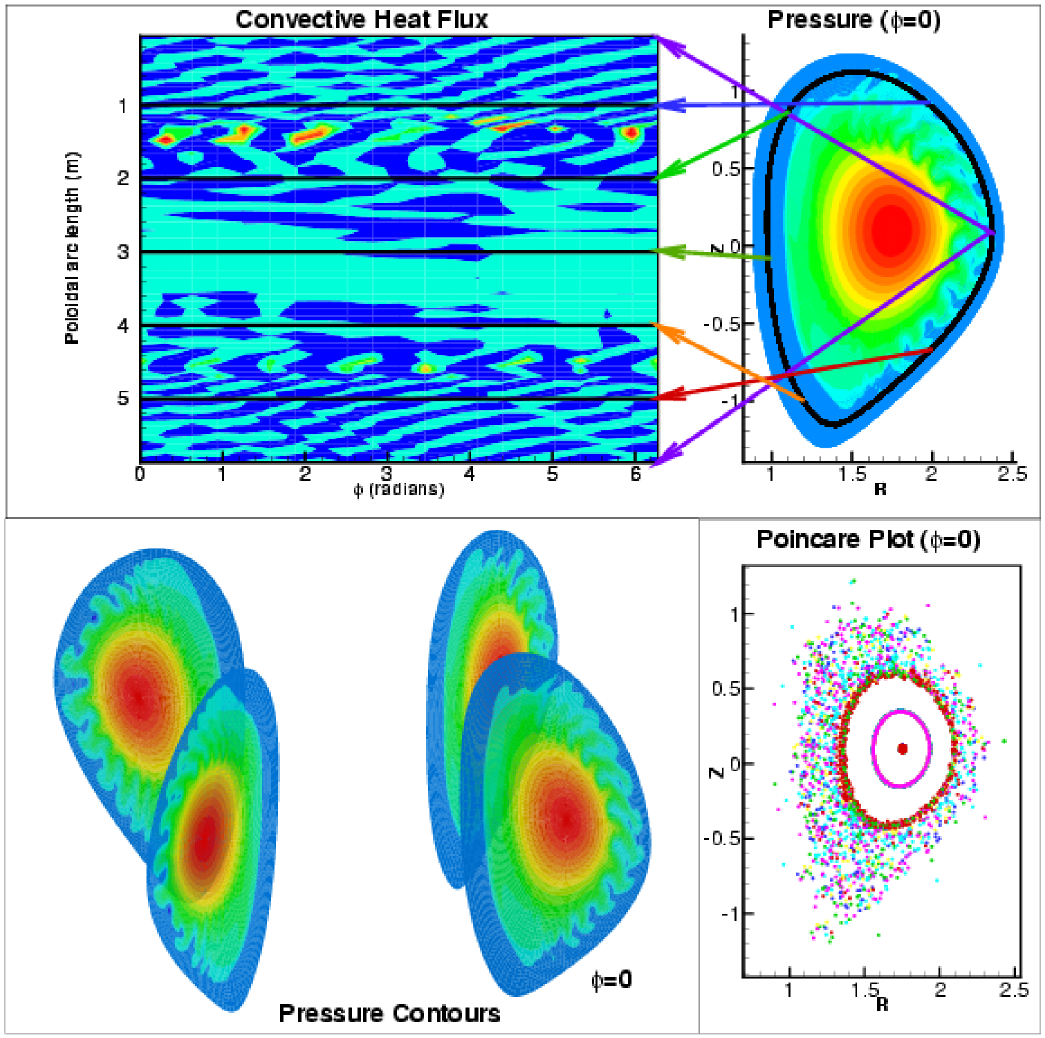



• In this case, the pressure perturbations impact the entire pedestal region.

Thermal energy is lost to the wall, and we have evaluated where it is deposited.




A significant fraction of internal energy is lost in 10s of microseconds.




Composite plot at $t$=0.14 ms.

# Conclusions

- Equilibrium-field profiles need to be accurate across the separatrix. Or, we will have to let the nonlinear time-dependent codes relax the profiles.

- Do we also need transport information with the MHD equilibrium?

- Our initial nonlinear computations show mode coupling that excites low-*n* fluctuations.

- The computations also demonstrate the feasibility of simulations with coupled edge/core activity. Possible coupling to RWM is of interest.