ELM control

Effect of external magnetic perturbations on edge profiles

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DIII-D experimental RMP ELM stabilization

- Applied resonant external magnetic perturbations
  - Evans et al., Phys. Plas 13, 056121 (2006)
  - m/n = 11/3, 12/3, 13/3
  - dB/B ~ 0.0003

- High collisionality: $\nu_{*e} \sim 1$
  - Particle transport >> thermal transport
  - Small high frequency ELMs

- Low collisionality: $\nu_{*e} \sim 0.1$
  - Particle transport >> thermal transport
  - No MHD activity

CPES SCIDAC project

Simulate ELM cycle

Neoclassical pedestal formation and bootstrap current

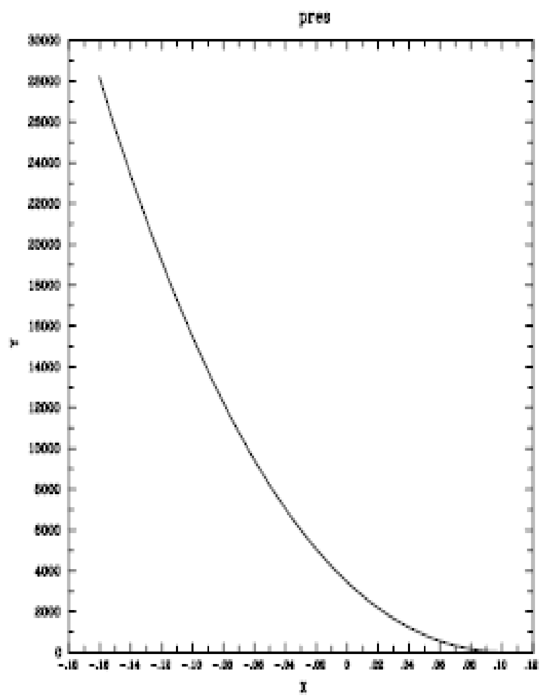
- **XGC neoclassical kinetic code**
  - **Reasonable agreement with experiment**
  - **Guiding center ion orbits**
  - **Neutral model**
  - **Gyrokinetic version under development**

ELM crash

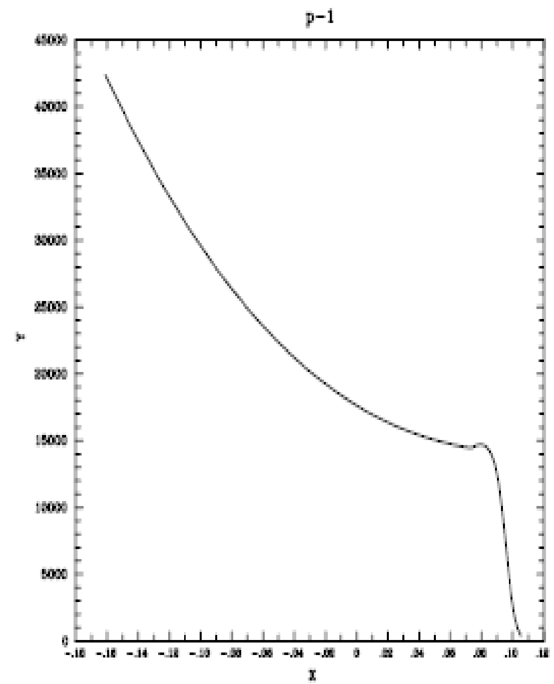
- **M3D extended MHD code**
  - **Calculate equilibrium using XGC profiles**
  - **Check linear stability**
  - **Nonlinear simulation of unstable equilibria**

Profile merging between G096333 and XGC0

G096333 pressure
No pedestal structure

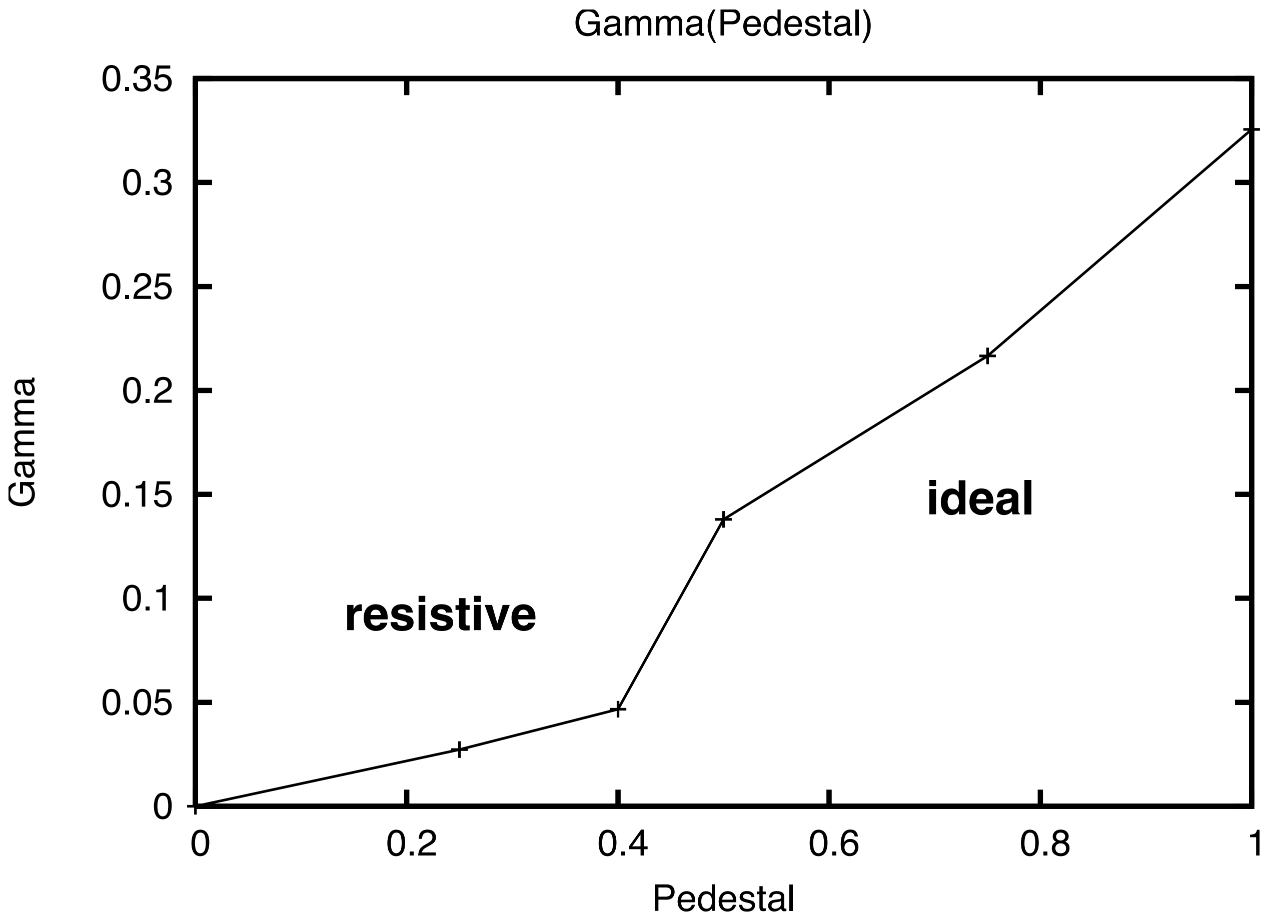


XGC0 pressure added
pedestal structure formed



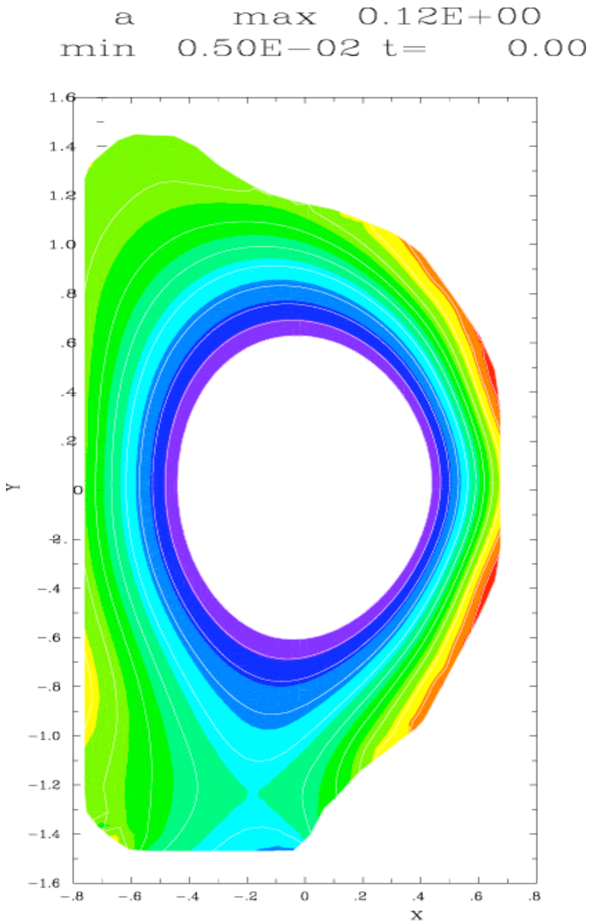
XGC initialized with EFIT equilibrium with no pedestal and bootstrap
Calculates new pedestal and bootstrap profiles
M3D initialized with original EFIT equilibrium and new profiles
Calculates new equilibrium and eqdsk file

Growth rate of n = 9 mode varying pedestal fraction

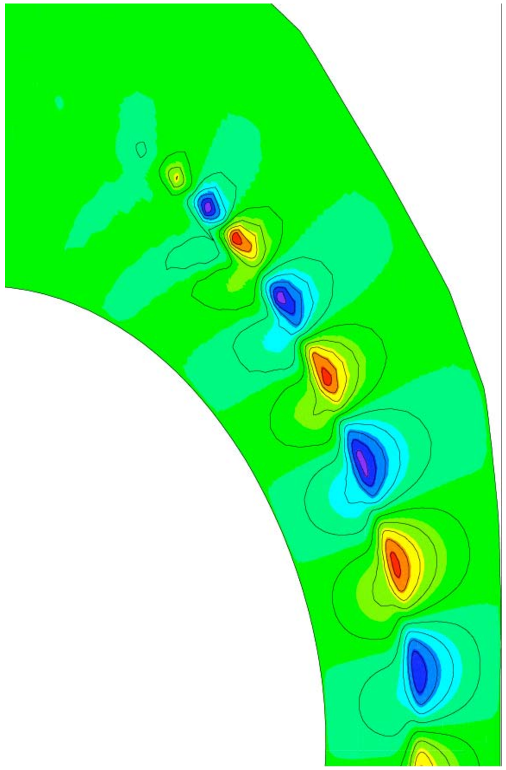


Fraction of XGC pedestal is varied from 0 to 1 in M3D
Calculate linear stability, resistive MHD model
$S = 10^6$ at top of pedestal, $S = 10^2$ at bottom of pedestal

M3D equilibrium and linear simulation full pedestal, ideal MHD mode

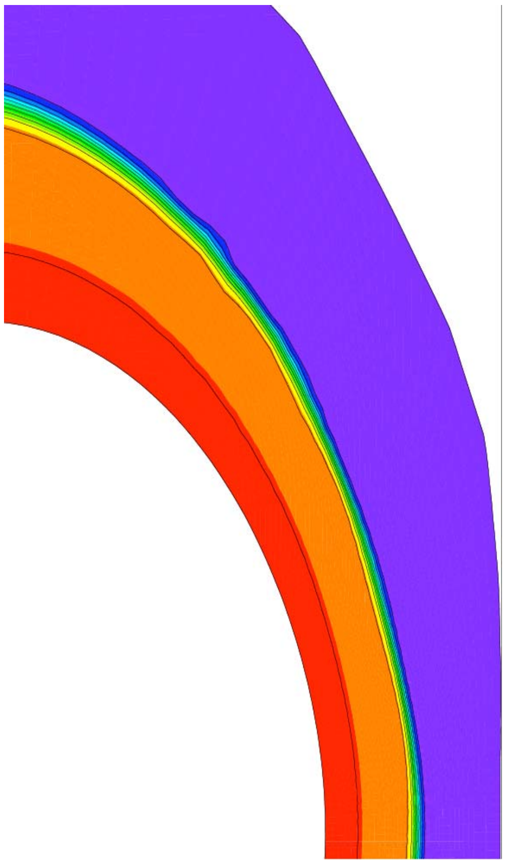


Reconstructed equilibrium poloidal magnetic flux

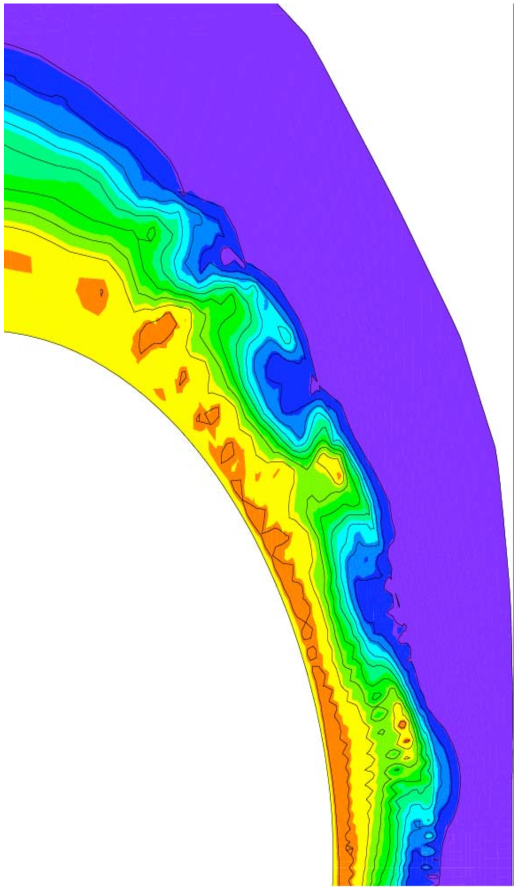


Linearly perturbed poloidal magnetic flux, n = 9

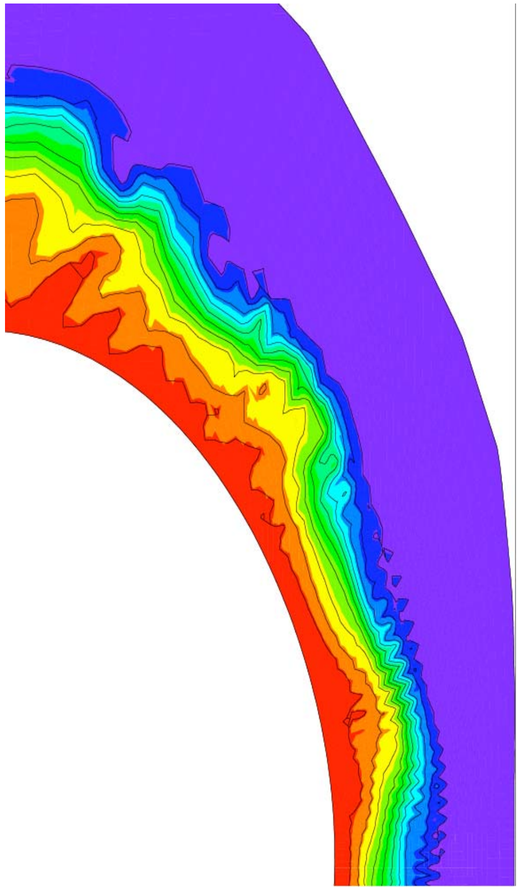
M3D nonlinear ELM: pressure evolution



T=18
Initial pressure
With pedestal

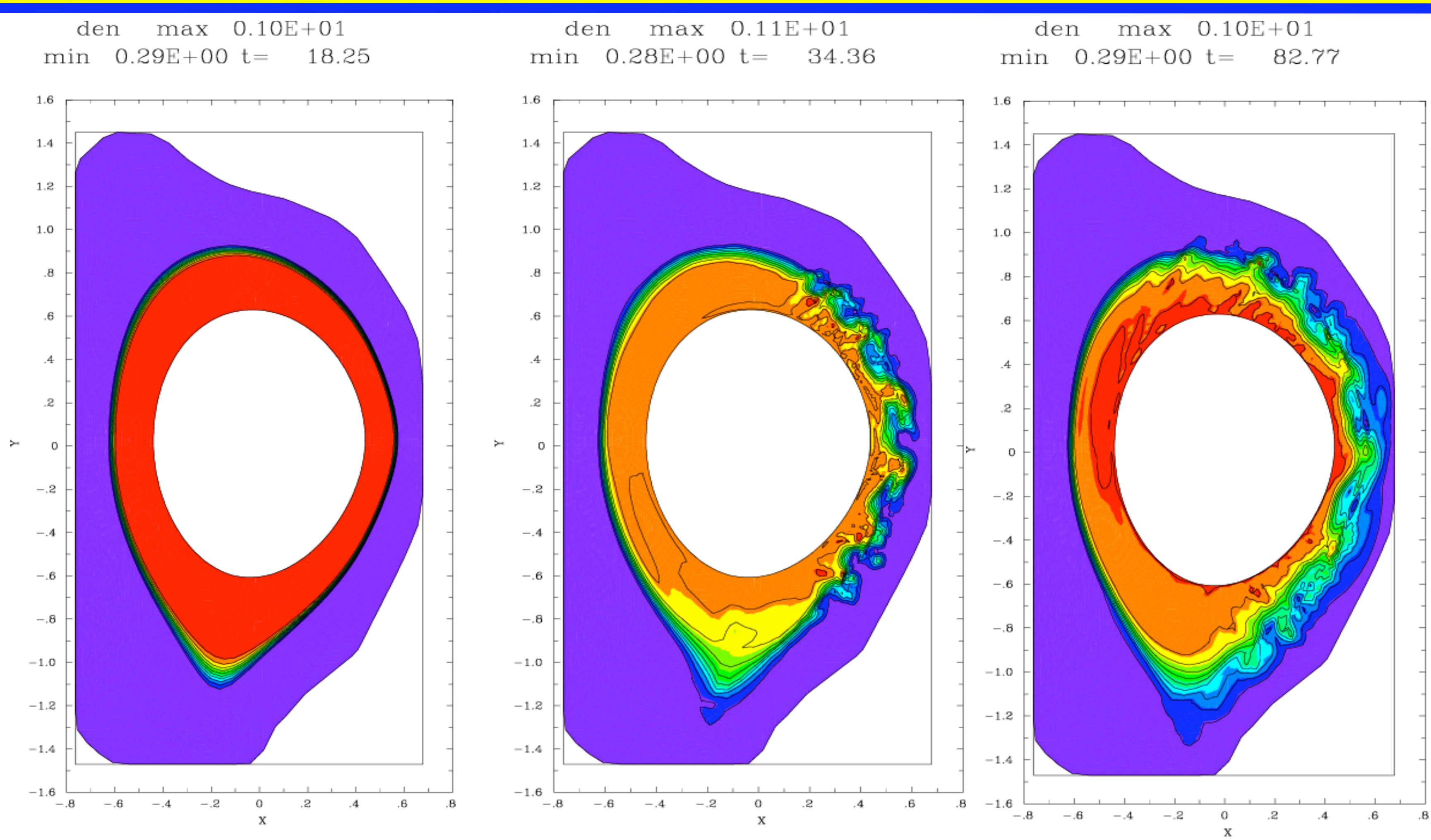


T=34
ELM near
its maximum amplitude
Blob like structures seen



T=83
Pressure relaxing

Ideal ELM density evolution



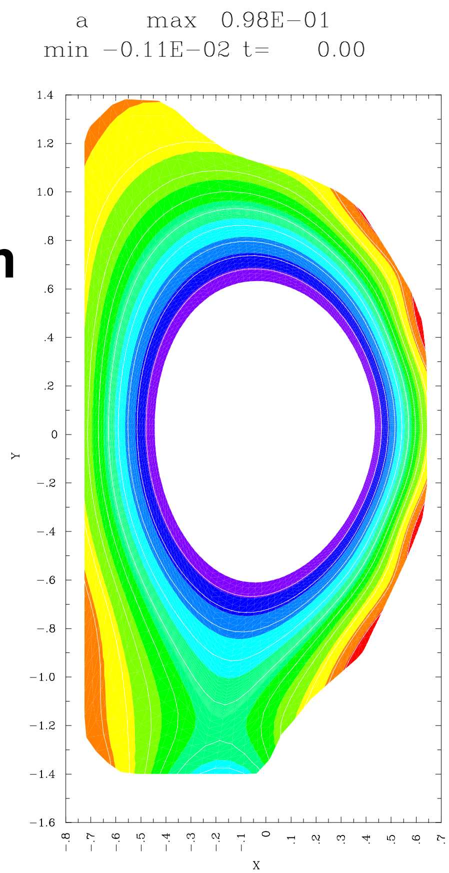
T=18 T=34 T=83

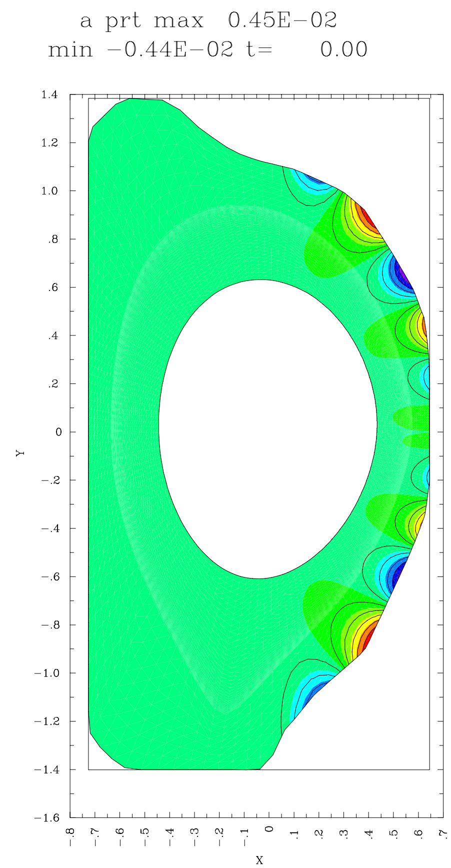
Density perturbation and its radial extent is significantly larger than those of temperature and pressure perturbations for the same calculation

Effect of large parallel thermal conduction – Temperature equilibrates to wall

Add dB to ideal stable case (0.4 pedestal)

Equilibrium Poloidal flux

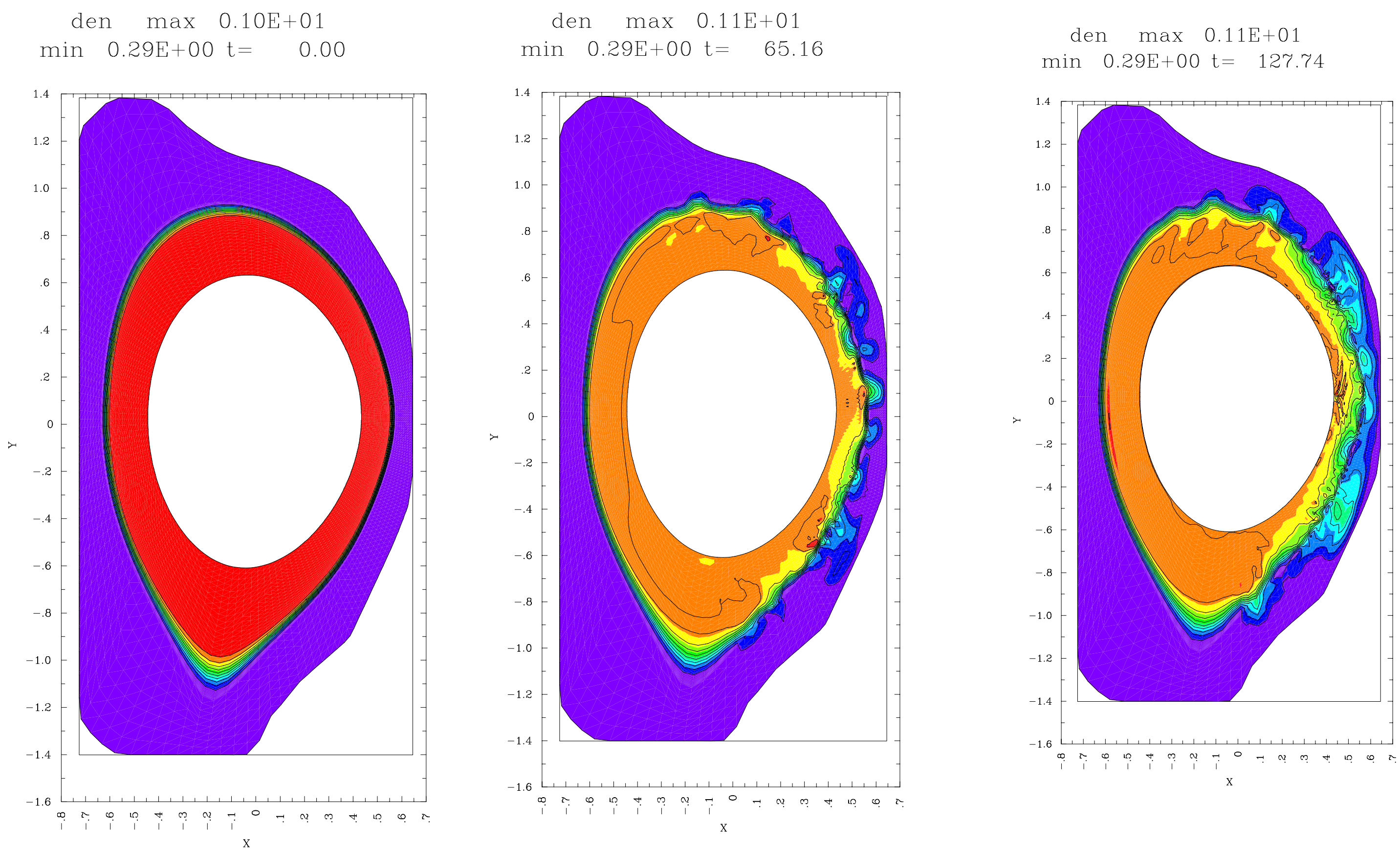




Perturbed Poloidal flux

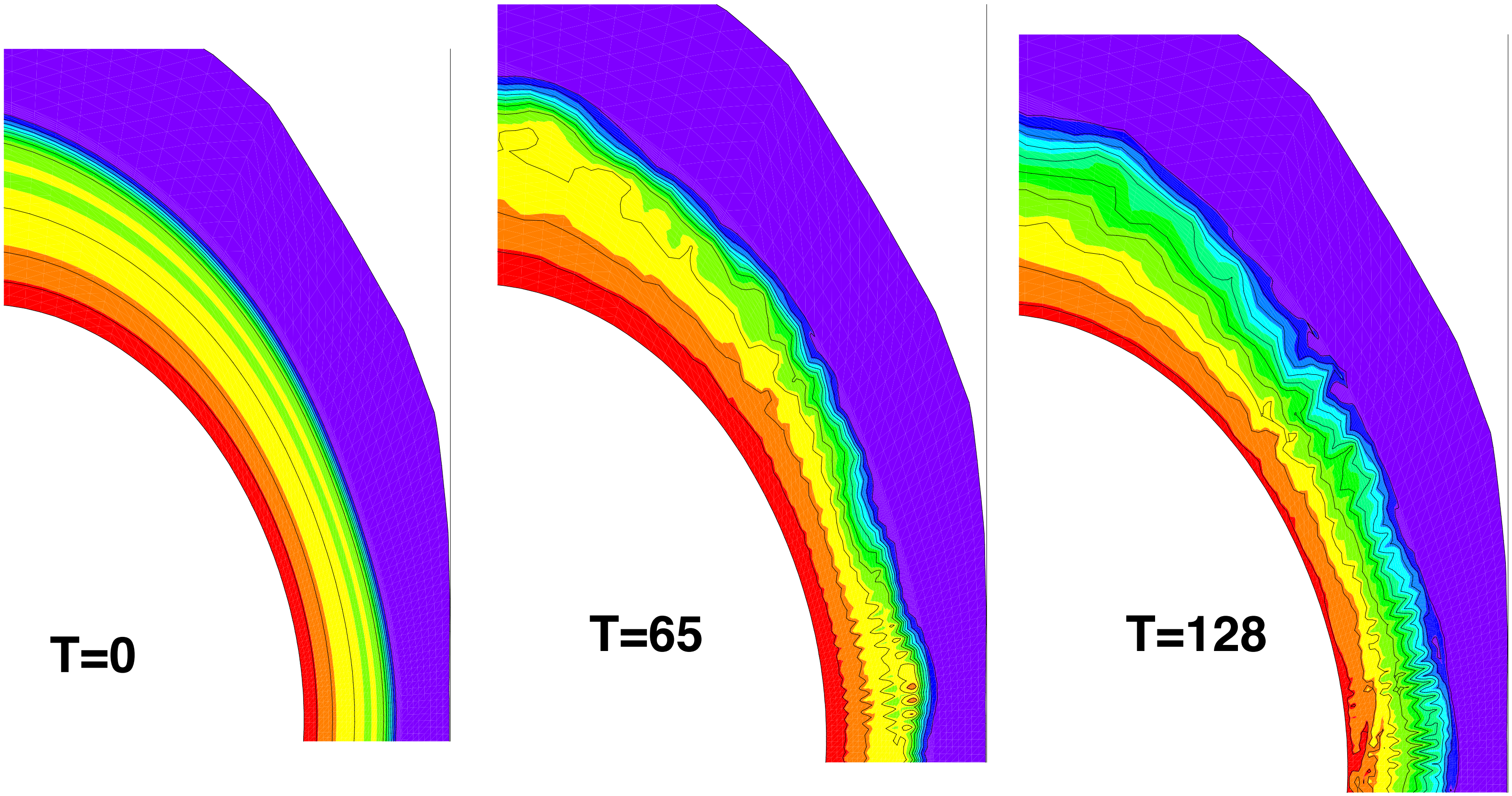
Add m/n = 11/3,12/3,13/3 magnetic field perturbations
<dB/B> = 0.0004, similar to DIII-D coils
Resistively unstable

Ideal stable density evolution



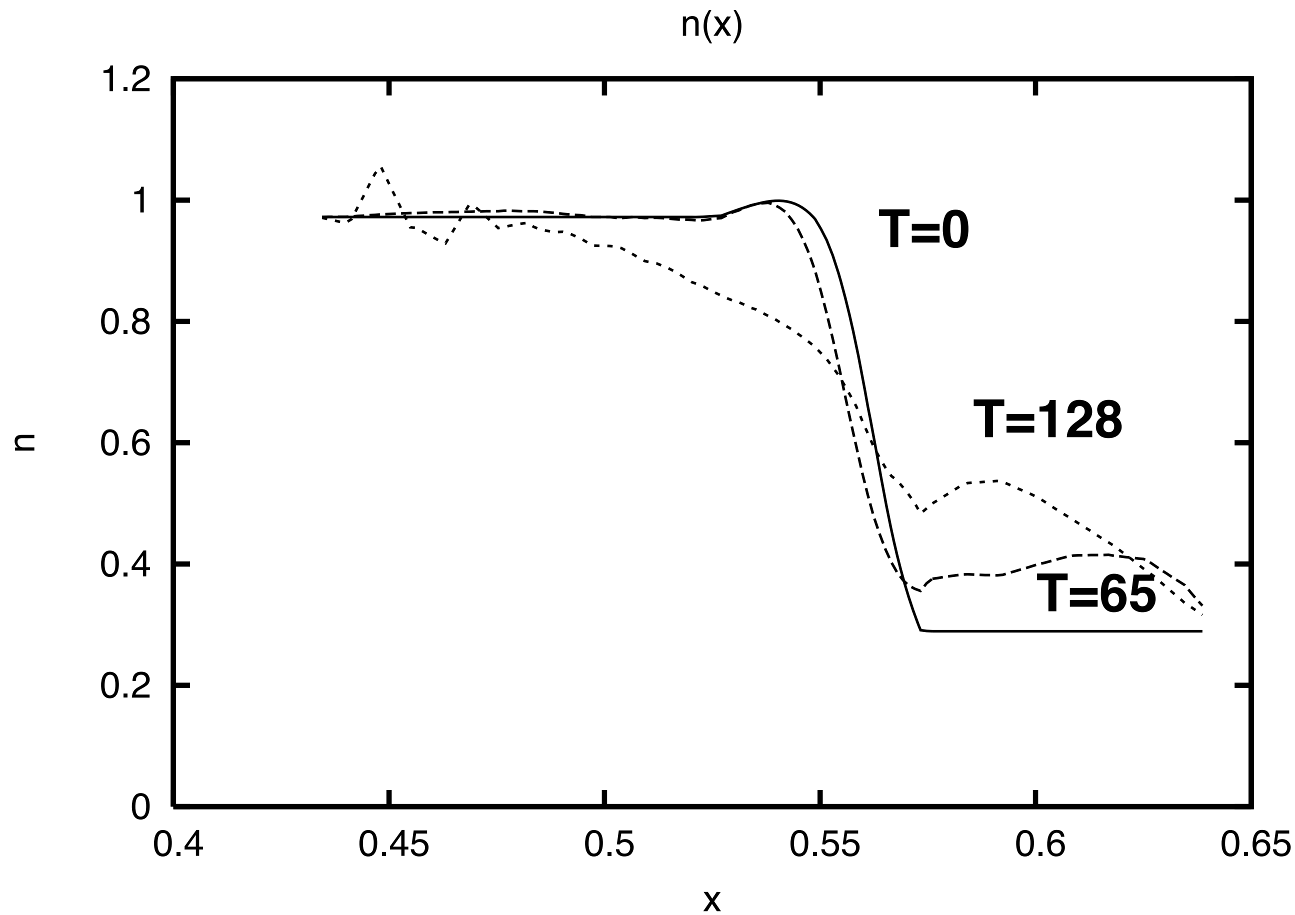
Low amplitude density perturbations compared to ideal case

Ideal stable pressure evolution



Pressure and temperature perturbations are small compared to Density perturbations and to ideal case pressure perturbations
Effect of parallel thermal conduction

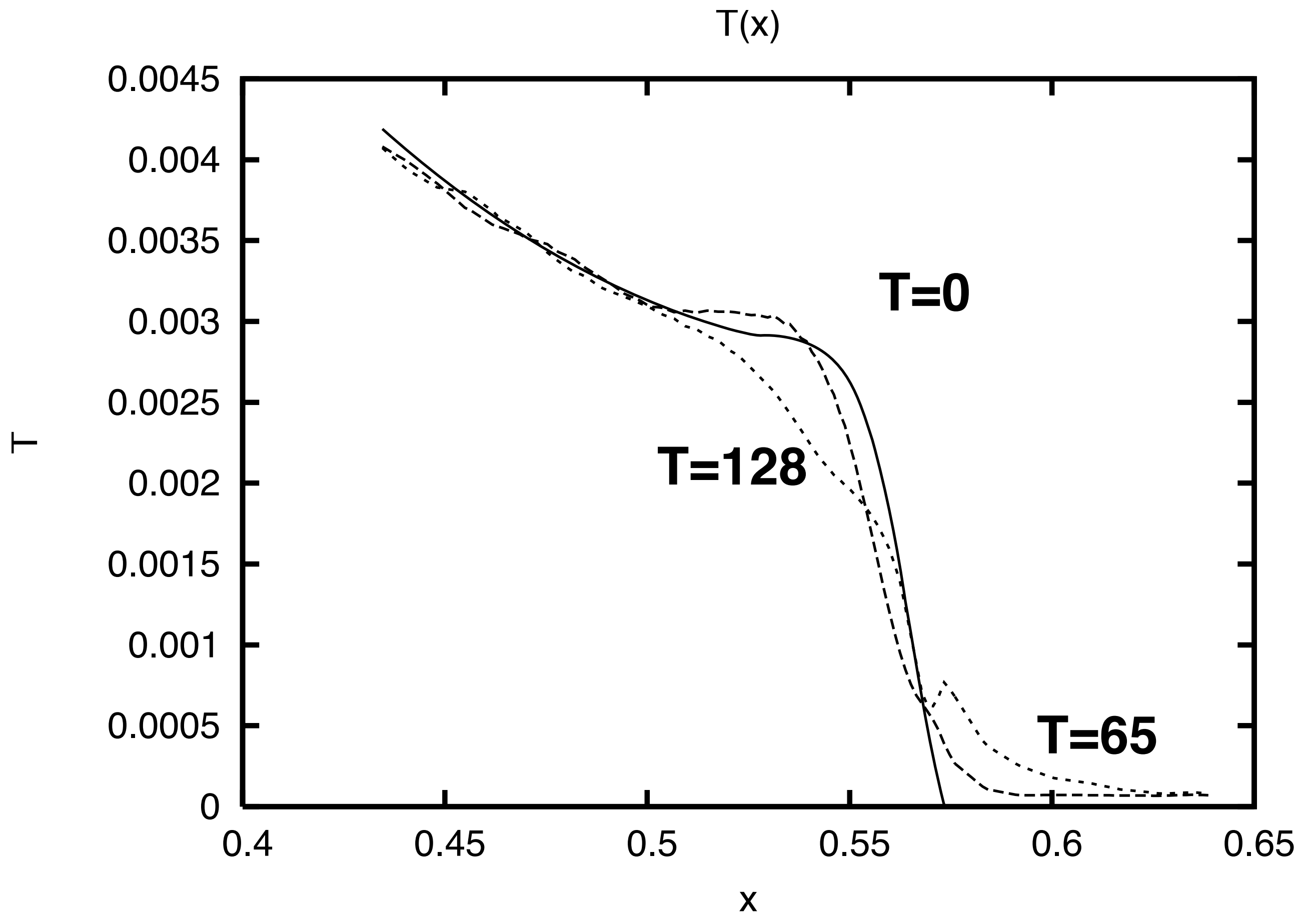
Density Profiles



Significant Density outside initial separatrix

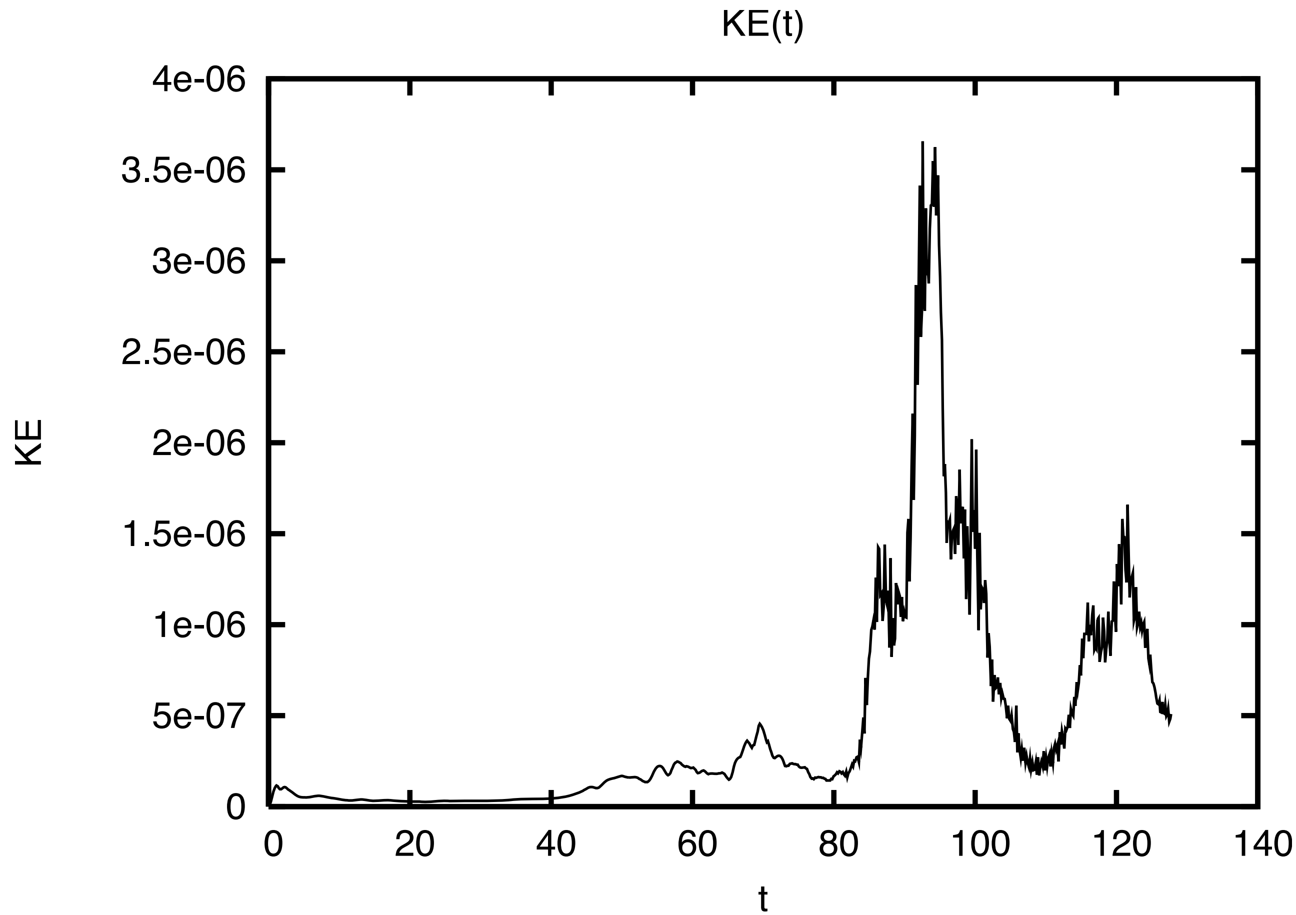
t=128 is after ELM

Temperature profiles



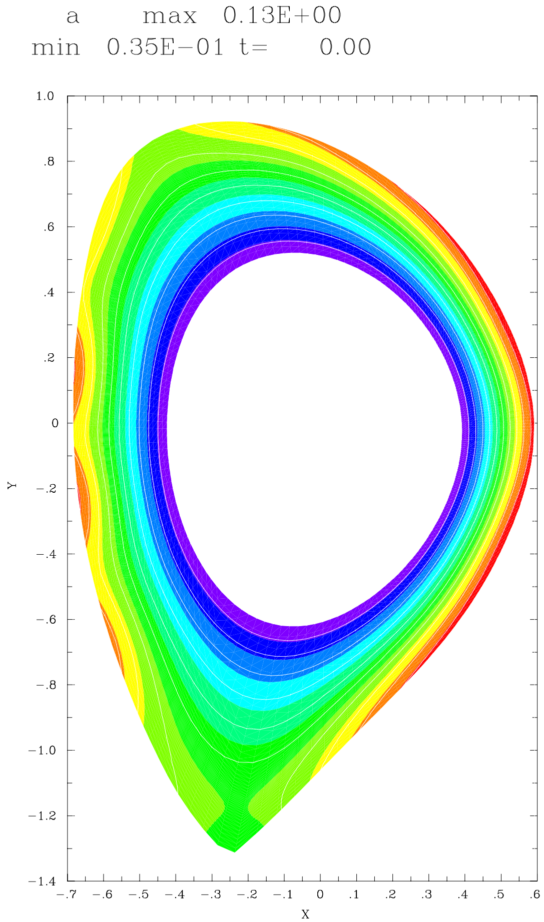
Temperature stays close to initial profile
Small perturbations outside initial separatrix
Parallel thermal conduction effect

KE Time history

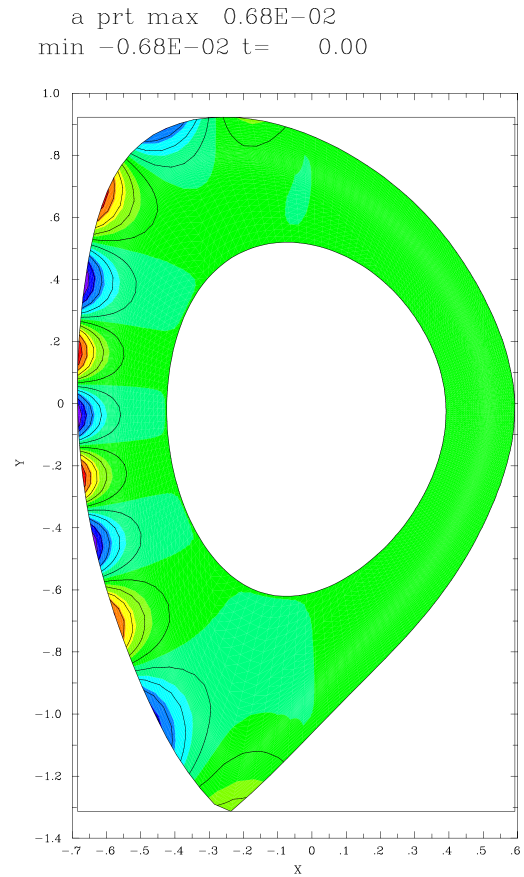


Small ELMs associated with KE bursts. Density is advected by magnetic perturbations before ELMs occur

Density transport does not require ELM
Inboard magnetic perturbation

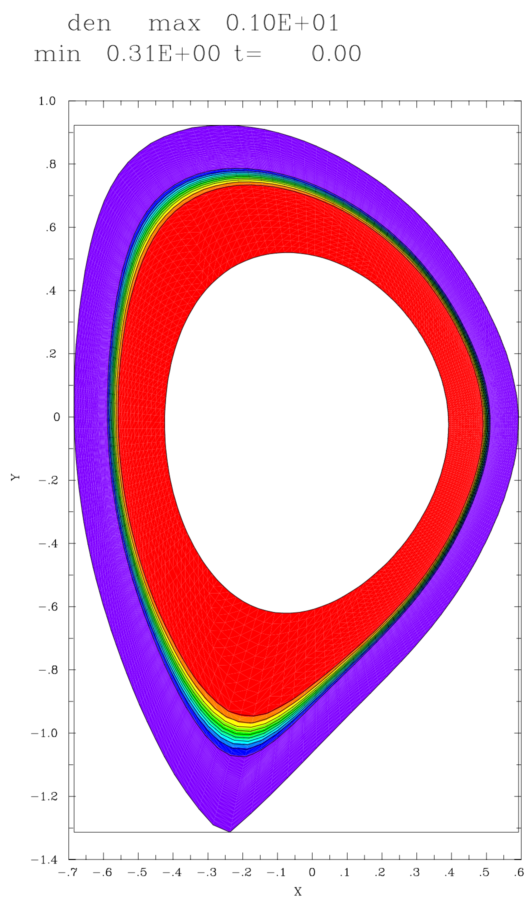


Poloidal magnetic flux

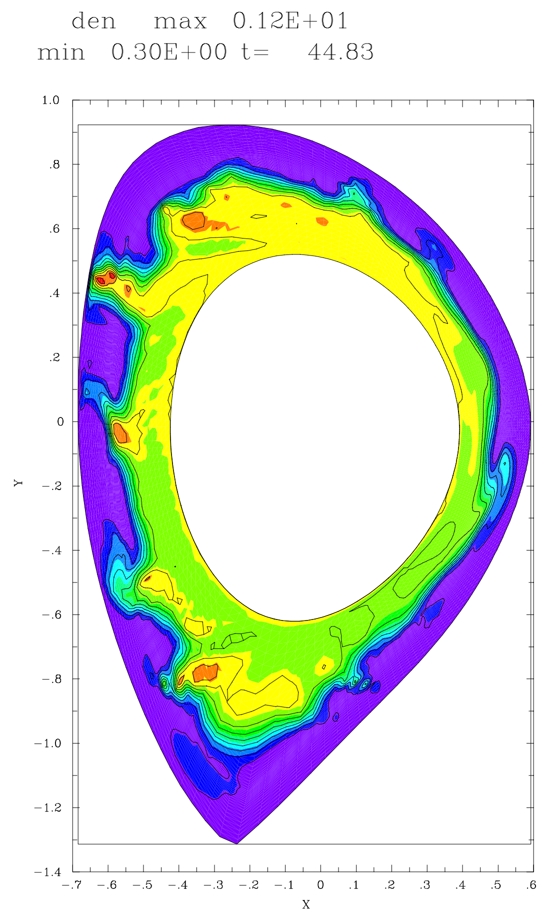


Perturbed poloidal magnetic flux
Magnetic perturbations on inboard side to avoid coupling to MHD modes

Density evolution with inboard dB



Initial density DIII-D
g113317



Density at t=44
Density perturbations follow
Magnetic perturbations

Collisionality effect

- **Simulations resemble high collisionality DIII-D**
  - **Particle transport >> heat transport**
  - **(density profile perturbations >> T or p profile pert.)**
  - **Small rapidly repeating ELMs**
- **Low collisionality: resistive modes are either stabilized by diamagnetic drift, or grow much more slowly**
  - **ELMs should not occur, although density will be advected by magnetic perturbations**
  - **Two fluid simulations in progress**

Pedestal growth

- **Pedestal was artificially set to a lower value than predicted by XGC code**
- **Add 3D magnetic perturbations to XGC0**
  - **Expect that pedestal height will be lower depending on dB/B**
  - **Expect a larger effect on electrons than ions**
    - **Electrons contribute to pedestal height as well as bootstrap current**
  - **In progress**

Summary / future

- **Simulated ELM suppression in DIII-D**
  - **Used similar magnetic perturbations to DIII-D**
  - **Artificially lowered pedestal height**
  - **Results so far are similar to high collisionality case**
    - **Density loss larger than temperature loss**
    - **Small amplitude MHD activity (small rapid ELMs)**
  - **Low collisionality case**
    - **Add 2 fluid drifts**
    - **Expect to stabilize resistive modes – ELM free**
    - **dB will still cause density advection**
- **Self consistent pedestal calculation**
  - **Add 3D dB/B to XGC**
  - **Expect lower pedestal to be ideal MHD stable**