ELM Simulations with M3D

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4-25-6

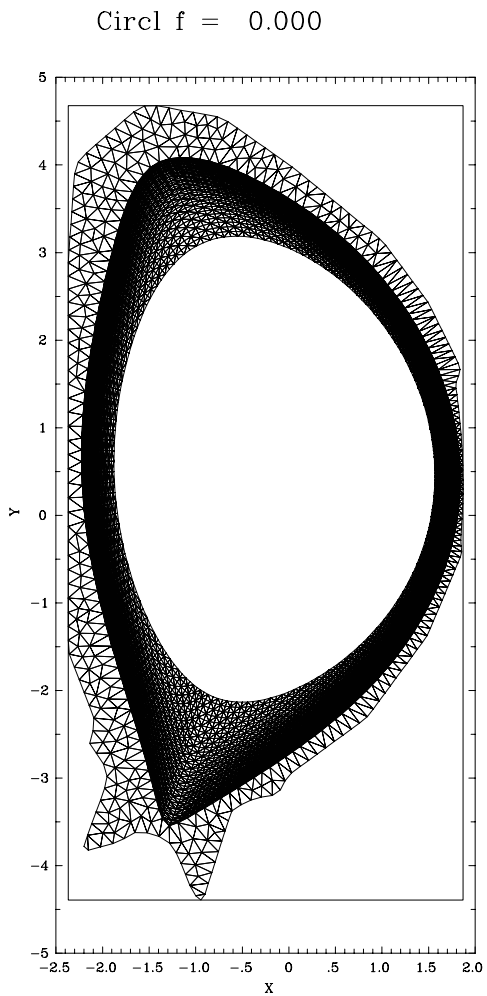
Outline

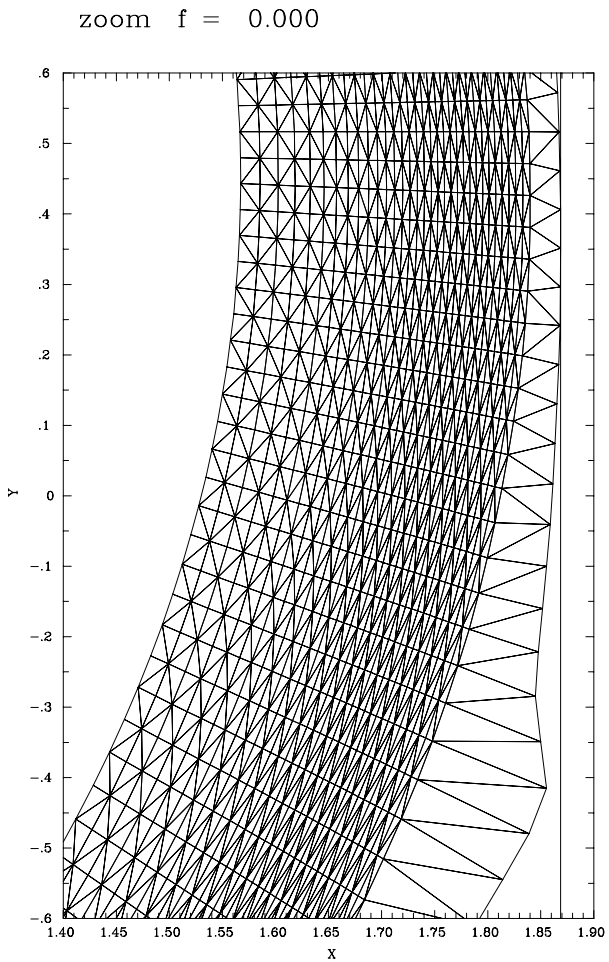
- ITER / DIII-D nonlinear ELM simulations
  - Mesh milestone: ITER: outflow to divertor
  - DIII-D: ELM saturation, little outflow
- density gradient milestone
  - Little effect on linear ideal modes
  - Accurate numerical equilibrium
  - peeling
- XGC coupling
  - mesh
- Future plans

M3D

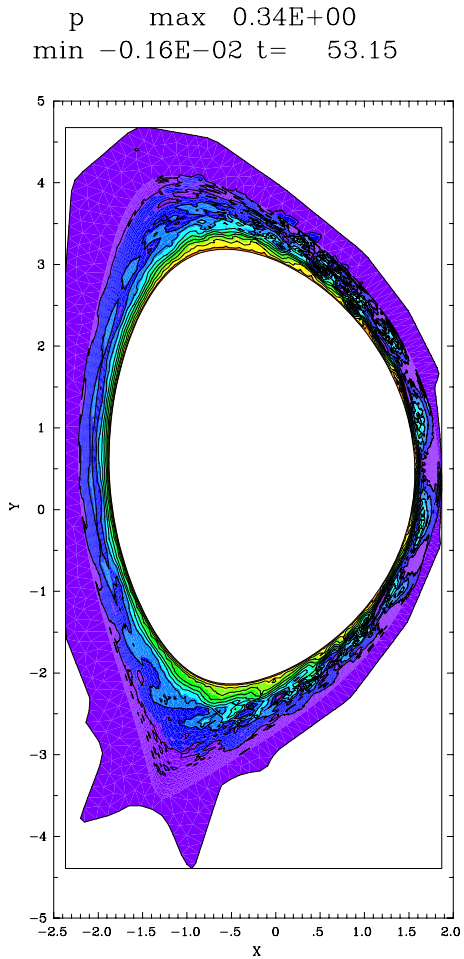
- **Extended MHD**
  - Resistive MHD
  - 2 fluid
  - hybrid
  - Neoclassical model
  - Coupling to neoclassical kinetic code XGC
- **Algorithmics**
  - Partially implicit
  - Parallel (mpi and omp implementations)
  - Unstructured poloidal mesh – includes magnetic separatrix
  - 1^{st} – 3^{rd} order FEL
  - SEL
  - Toroidal pseudospectral or FD
- **Vacuum modeled as 3D resistivity**
  - varies as $T^{-3/2}$
  - $S = 10^6$ at core boundary
  - $S = 10^2$ to simulate vacuum as cold plasma

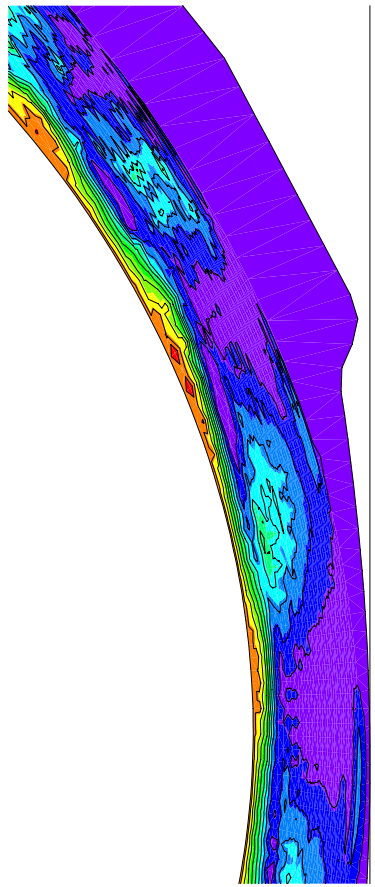
ITER mesh


Circl f = 0.000
5
4
3
2
1
0
−1
−2
−3
−4
−5
Y
−2.5 −2.0 −1.5 −1.0 −.5 0 .5 1.0 1.5 2.0
X

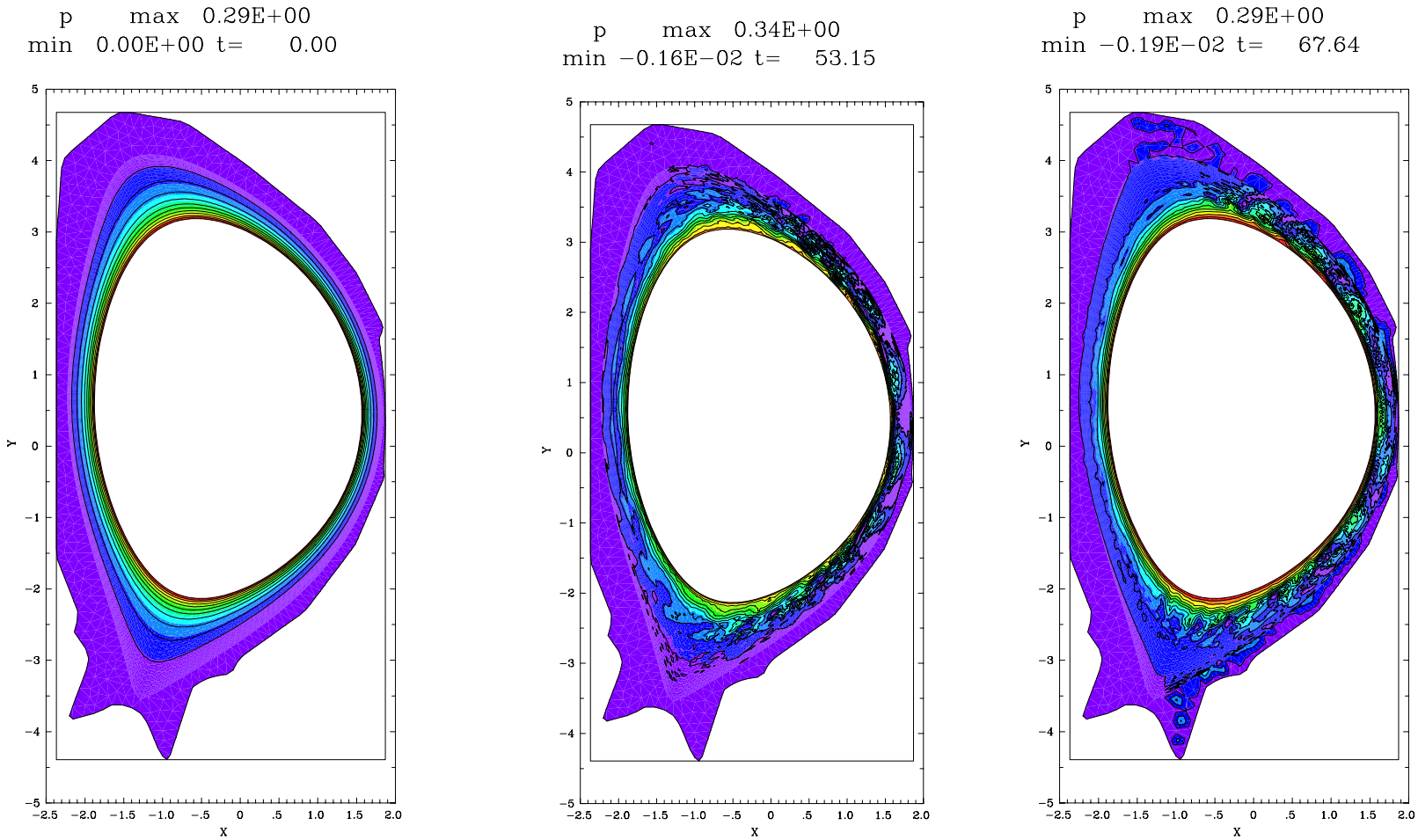

zoom f = 0.000
.6
.5
.4
.3
.2
.1
0
−.1
−.2
−.3
−.4
−.5
−.6
Y
1.40 1.45 1.50 1.55 1.60 1.65 1.70 1.75 1.80 1.85 1.90
X

ITER nonlinear ELM

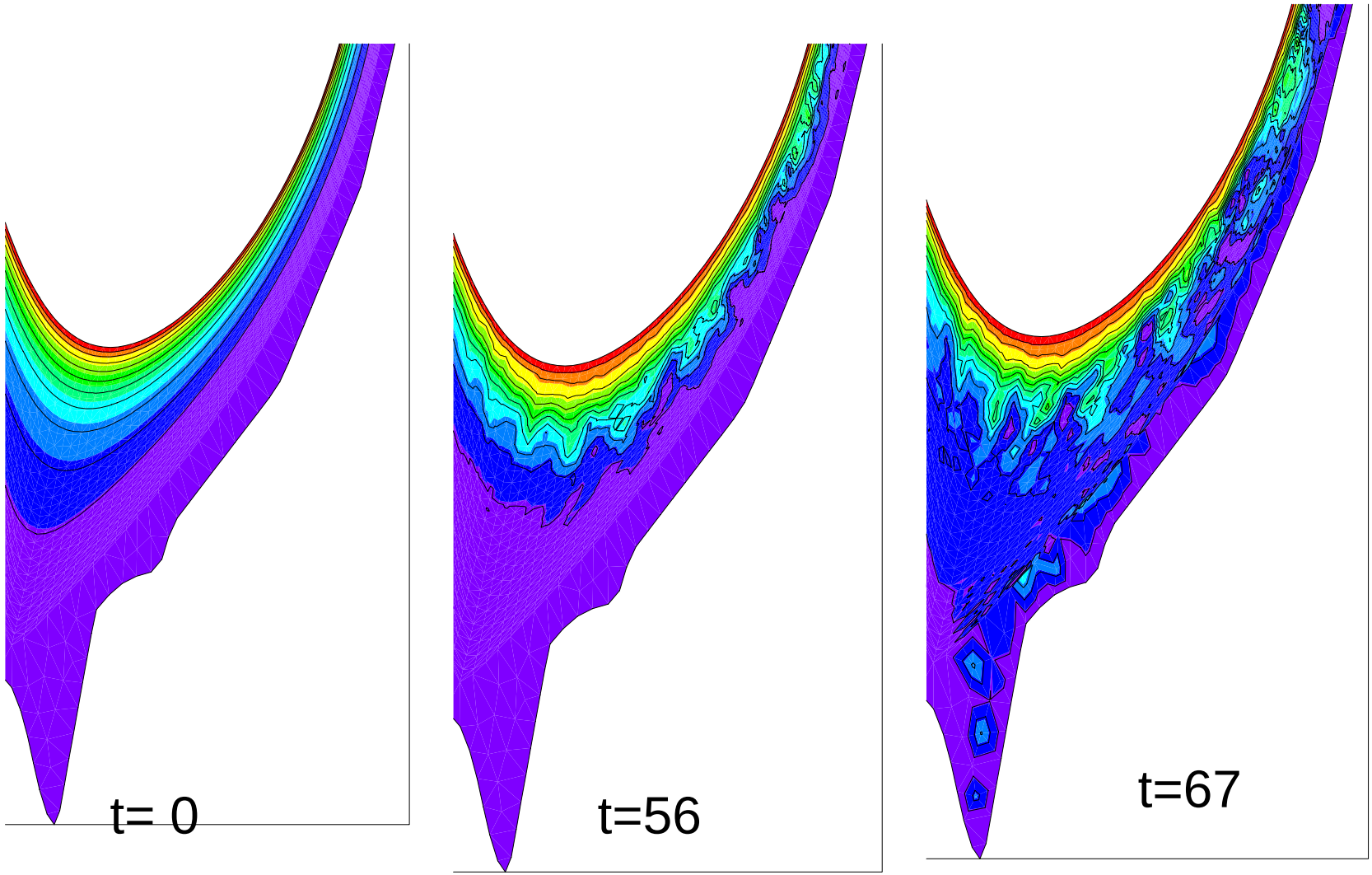




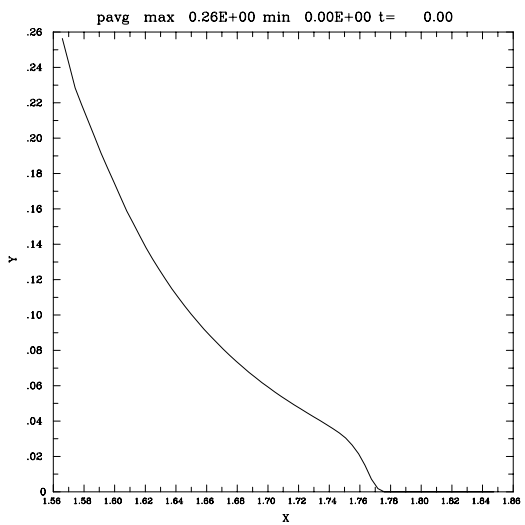
ITER ELM: pressure time evolution

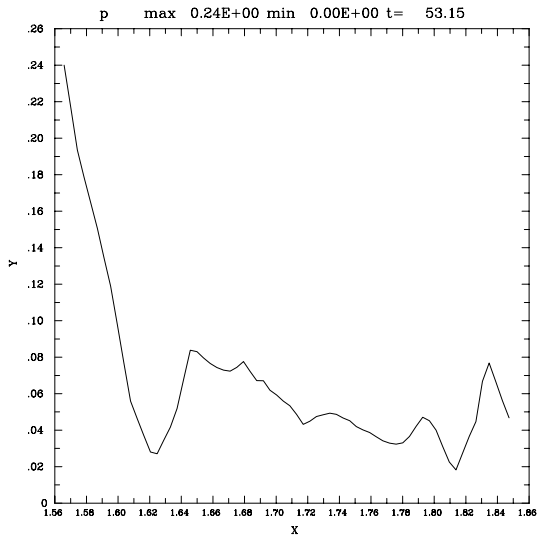


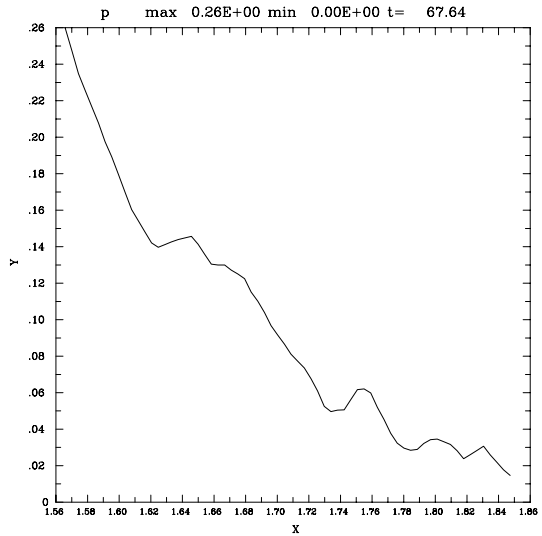
ELM pressure: initial, mode growth, outflow



ITER – pressure profiles initial, ELM crash, relaxation

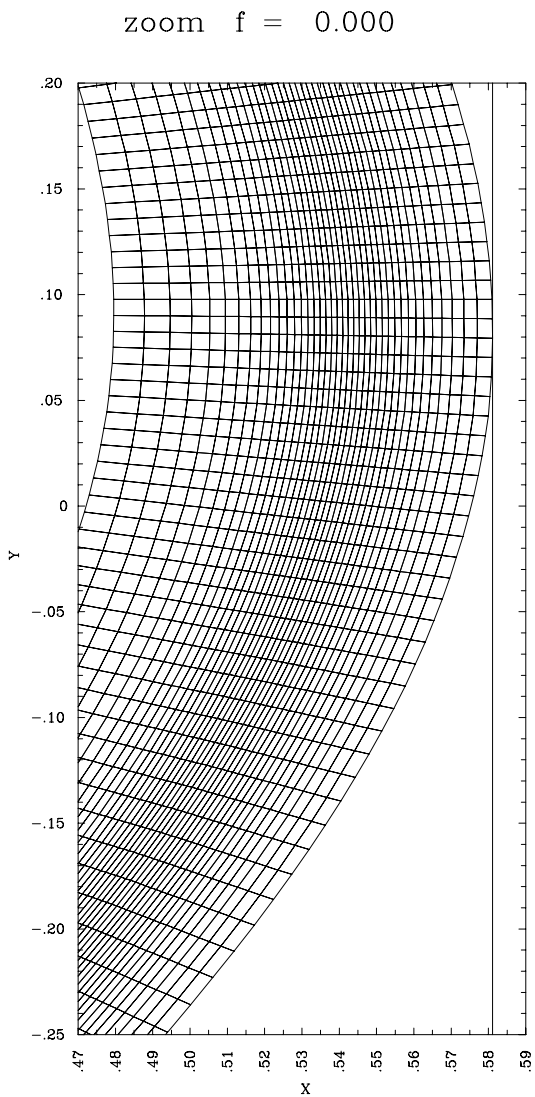




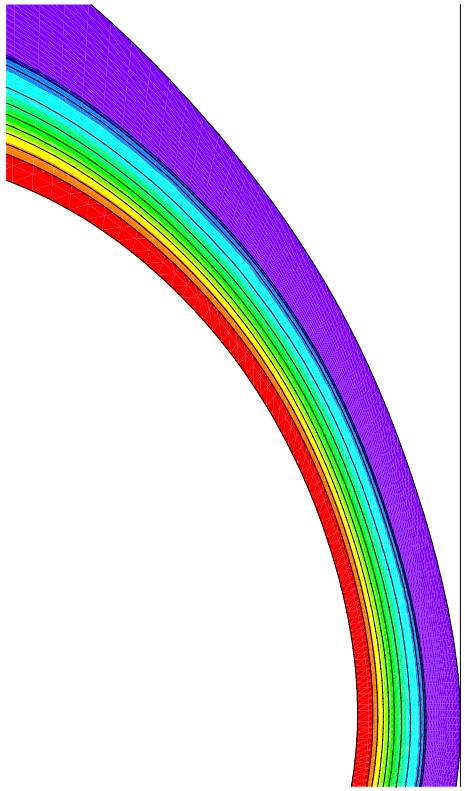


Mesh for DIII-D

- **Radial mesh packing to resolve gradients at the separatrix**
- **Angular packing to resolve ballooning modes**
- **Example**
  - **35x200**
  - **n = 0, 5, 10, … 25**

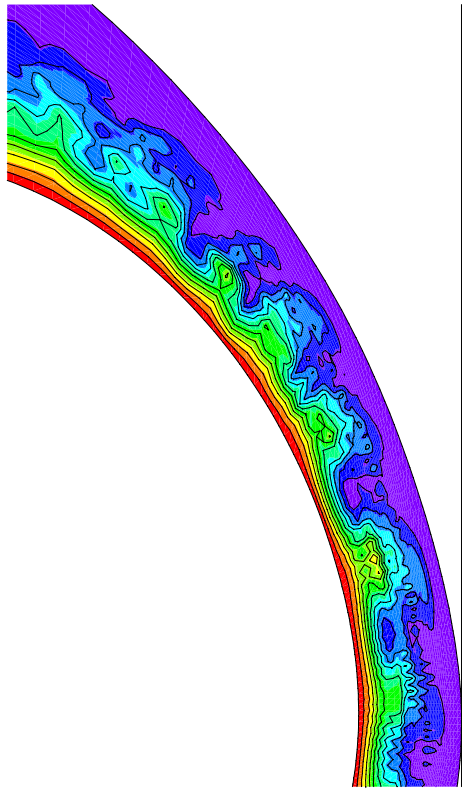


g086166 DIIID ELM



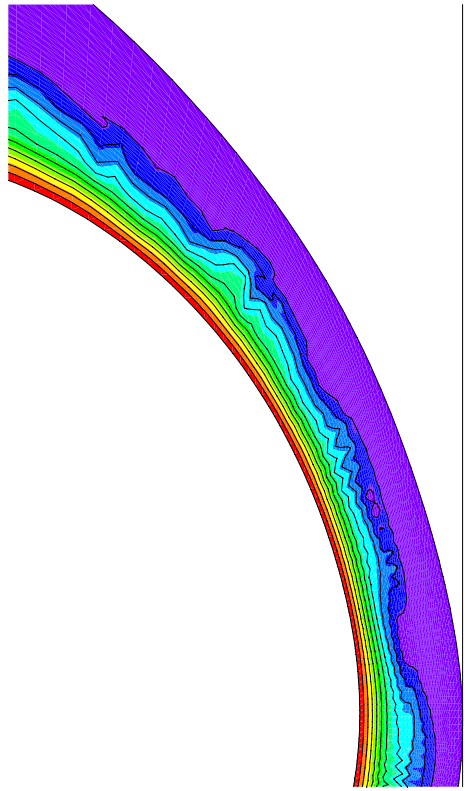
t = 27

Initial p



t = 67

ELM

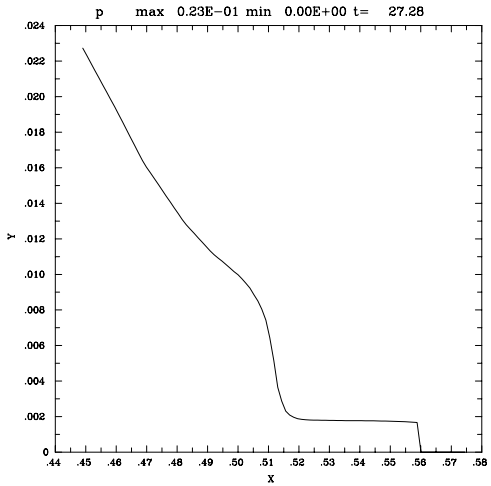


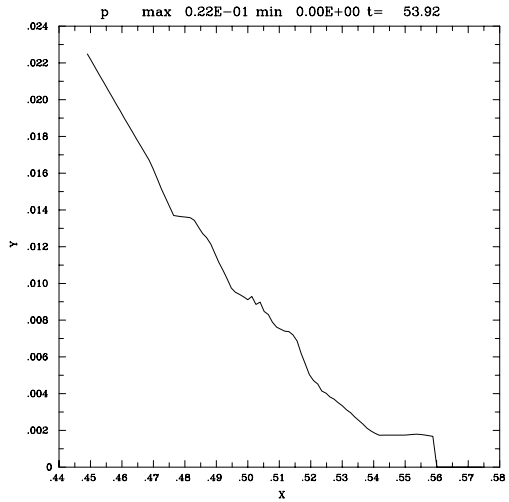
t = 106

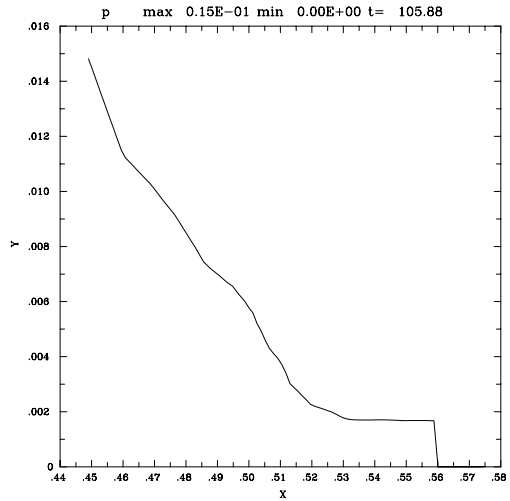
relaxation

Time development: p(R) profiles:

pressure pedestal expands across separatrix, then relaxes and moves inwards







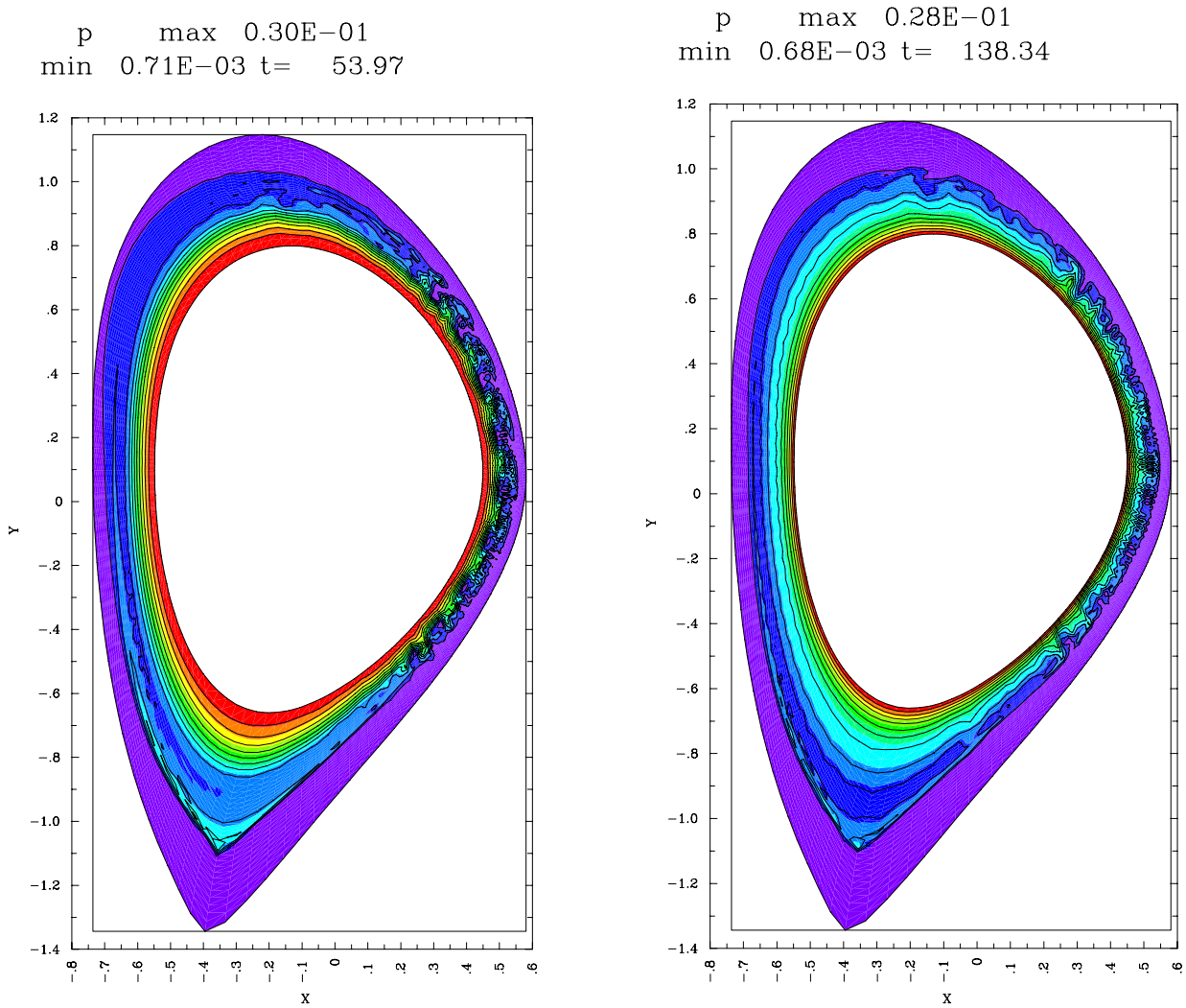
t = 27

t = 67

t = 106

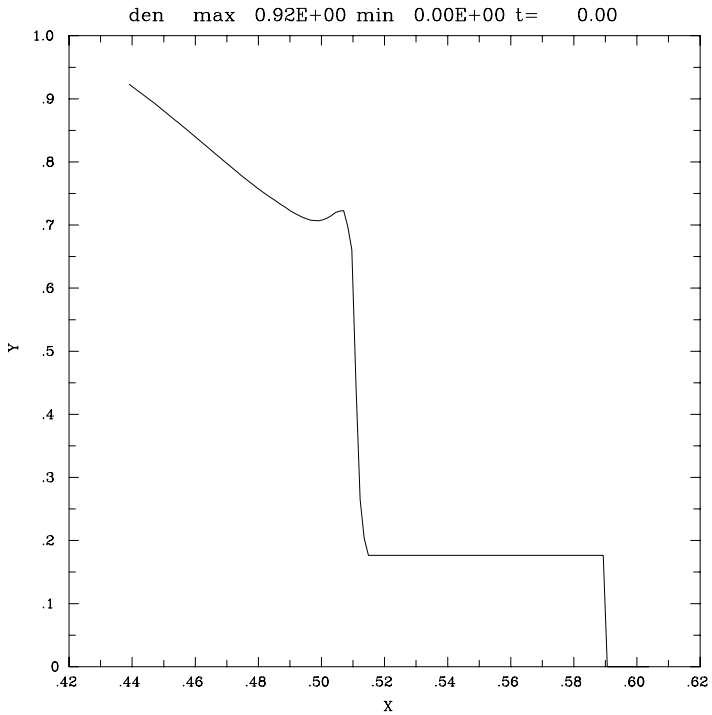
Drop off to the right of the plots is an artifact

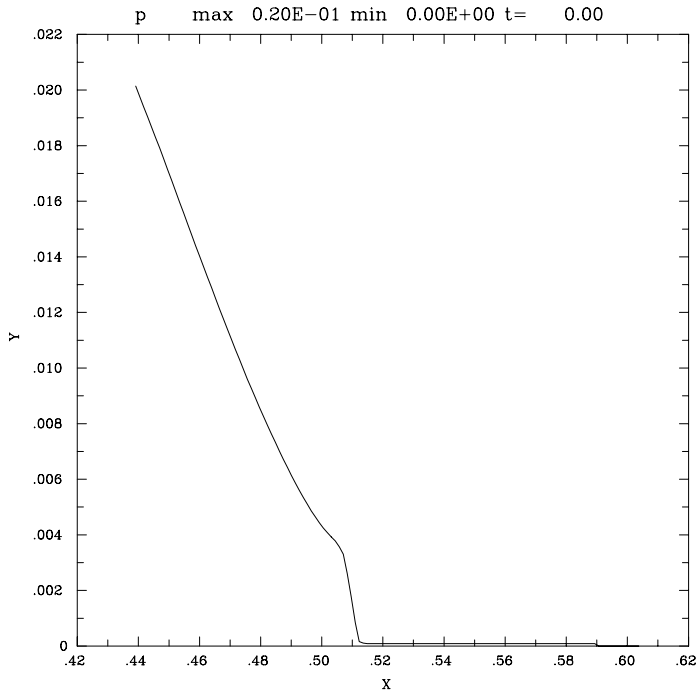
Little outflow to divertor



May be effect of boundary

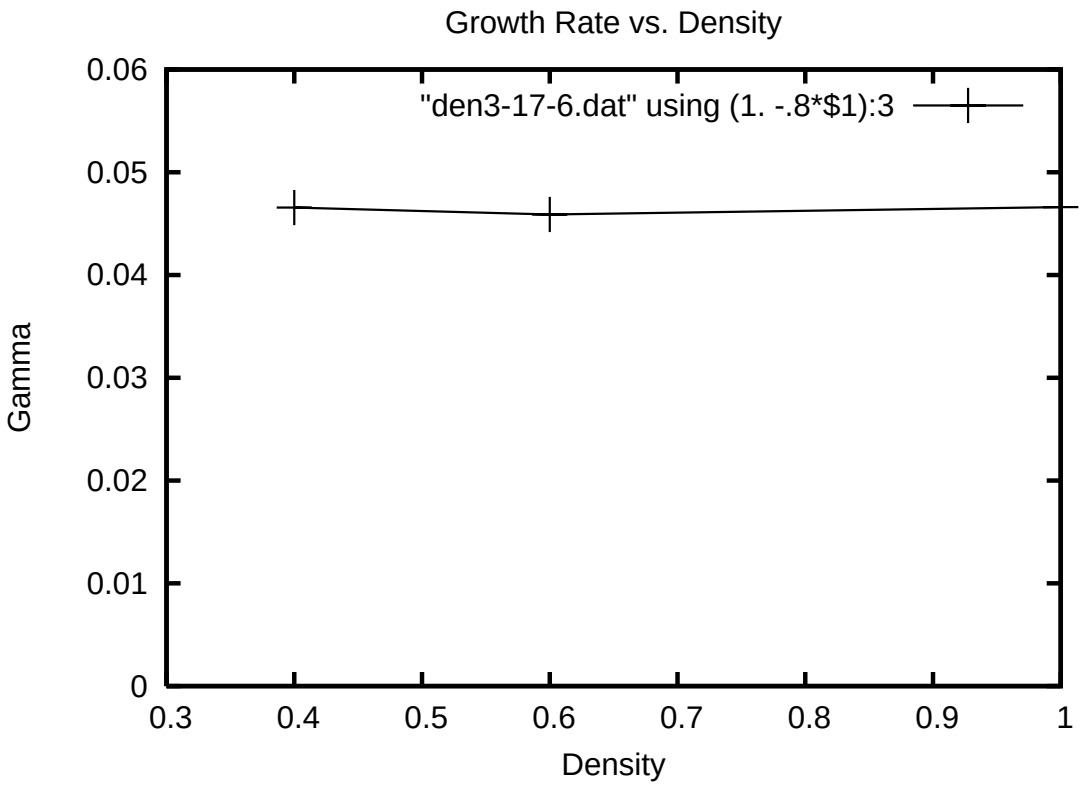
Density milestone: Density and temperature profiles





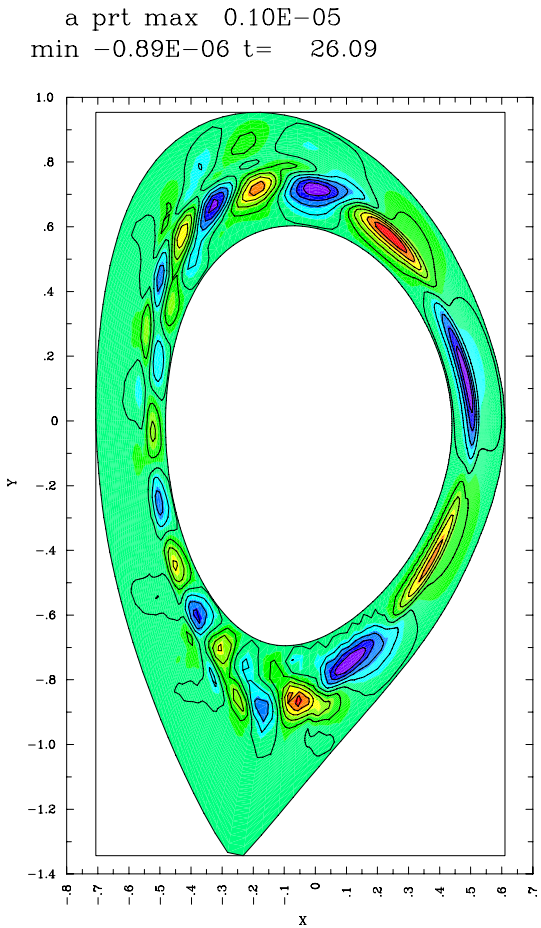
Added a floor value of edge density

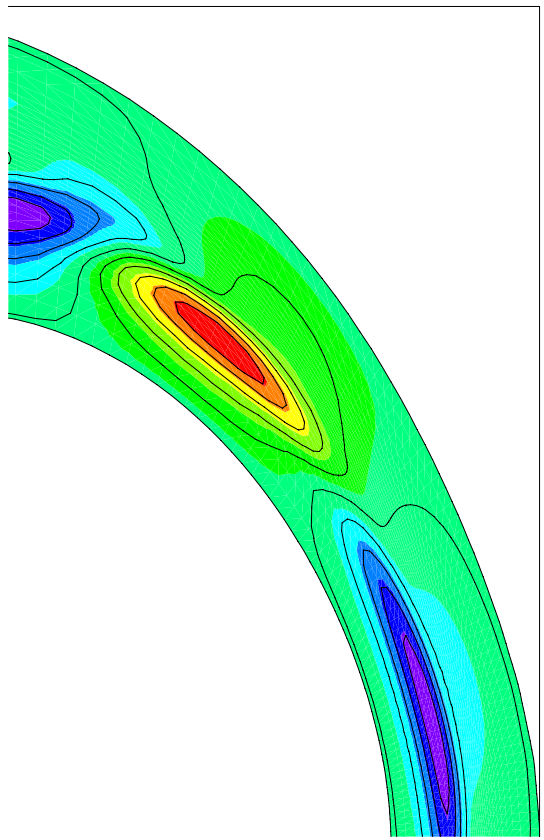
weak dependence of growth rate on relative edge density



In these runs, density was evolved. Numerical mode at low edge Density caused by lack of sufficiently accurate numerical equilibrium. Not evolving density seems to fix problem. Nonlinear: may need upwind numerical scheme.

Low n (3) peeling(?) in g113317

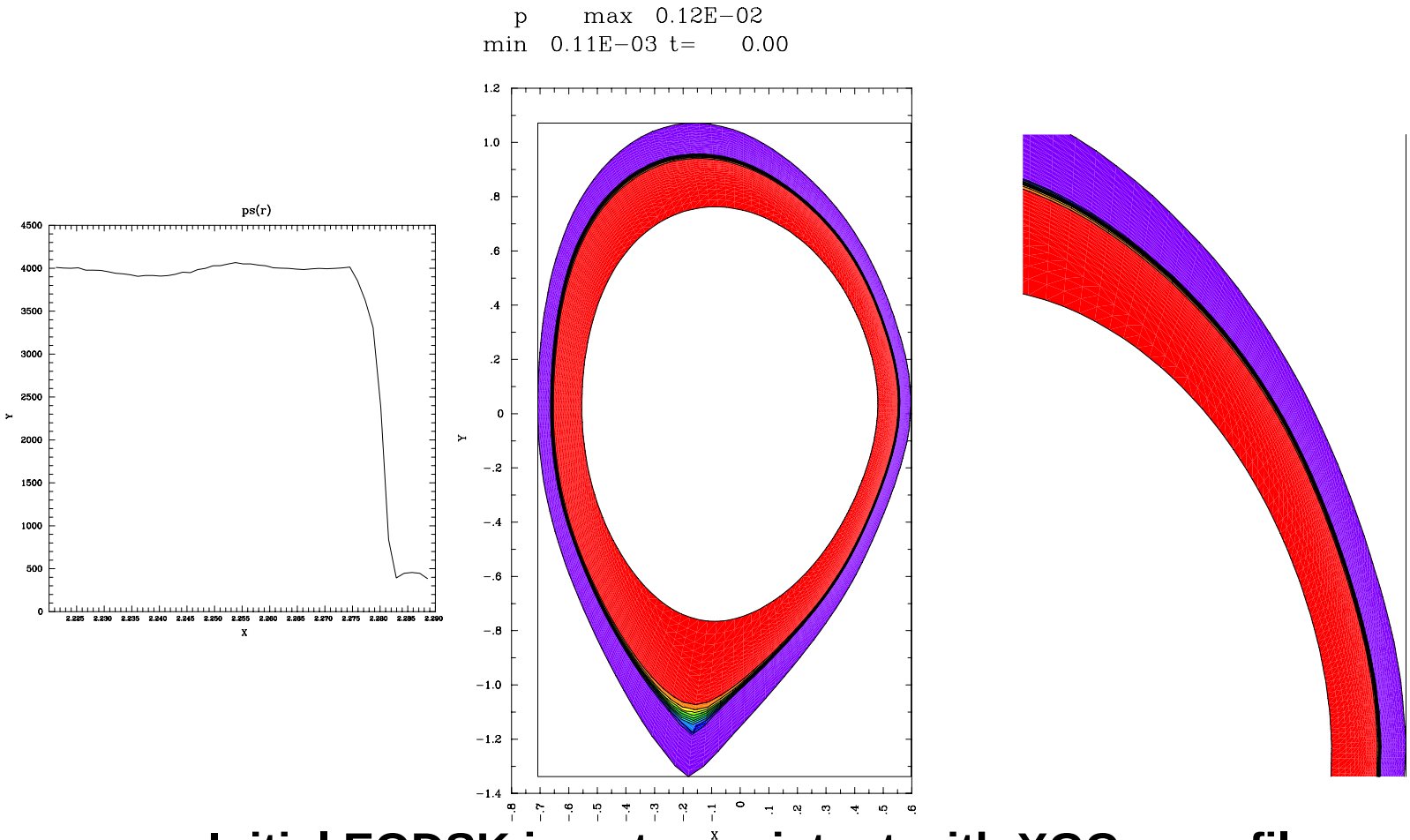




Pedestal model

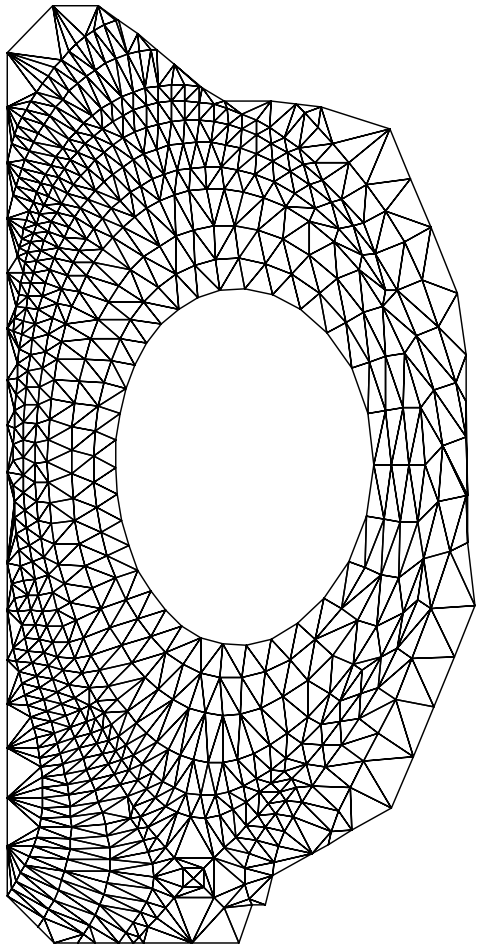
- **ELM instability**
  - Edge kinks: driven by bootstrap current
  - Ballooning modes: driven by pedestal pressure gradient
- **Previous simulations used EFIT equilibrium**
  - Bootstrap current model might not be valid at edge
- **XGC – neoclassical kinetic code**
  - In reasonable agreement with experiments
  - Calculates pedestal buildup
  - Calculates bootstrap current
- **M3D / XGC**
  - Profiles of p, n, … given to M3D code
  - If unstable, calculate ELM crash

Initial XGC pressure profile



- **Initial EQDSK is not consistent with XGC p profile**
  plan to couple XGC to EFIT
  need bootstrap current from XGC (or model)

XGC field line following mesh



Low resolution for clarity
Will try with M3D

future plans

- ITER / DIII-D nonlinear ELM simulations
  - Add more of scrape off region to DIII-D simulations
  - Better computational mesh
- Density evolution
  - Upwinding for nonlinear simulations
- Pedestal model
  - Improve coupling with XGC code
  - Include bootstrap current