M3D-C1 Updates and Plans

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GENERAL ATOMICS

Resistive Wall

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- **3 regions:**
  - Plasma (MHD)
  - RW ($\mathbf{E} = \eta_W \mathbf{J}$)
  - Vacuum ($\mathbf{J} = 0$)

- **BCs on $\mathbf{v}$, p, n set at inner wall; BCs on $\mathbf{B}$ set at outer wall**

- **Potential advantages:**
  - More scalable than using RW BCs
  - Can treat non-thin walls

- **Disadvantages:**
 - Bigger matrices
  - Need to include PF coils inside domain
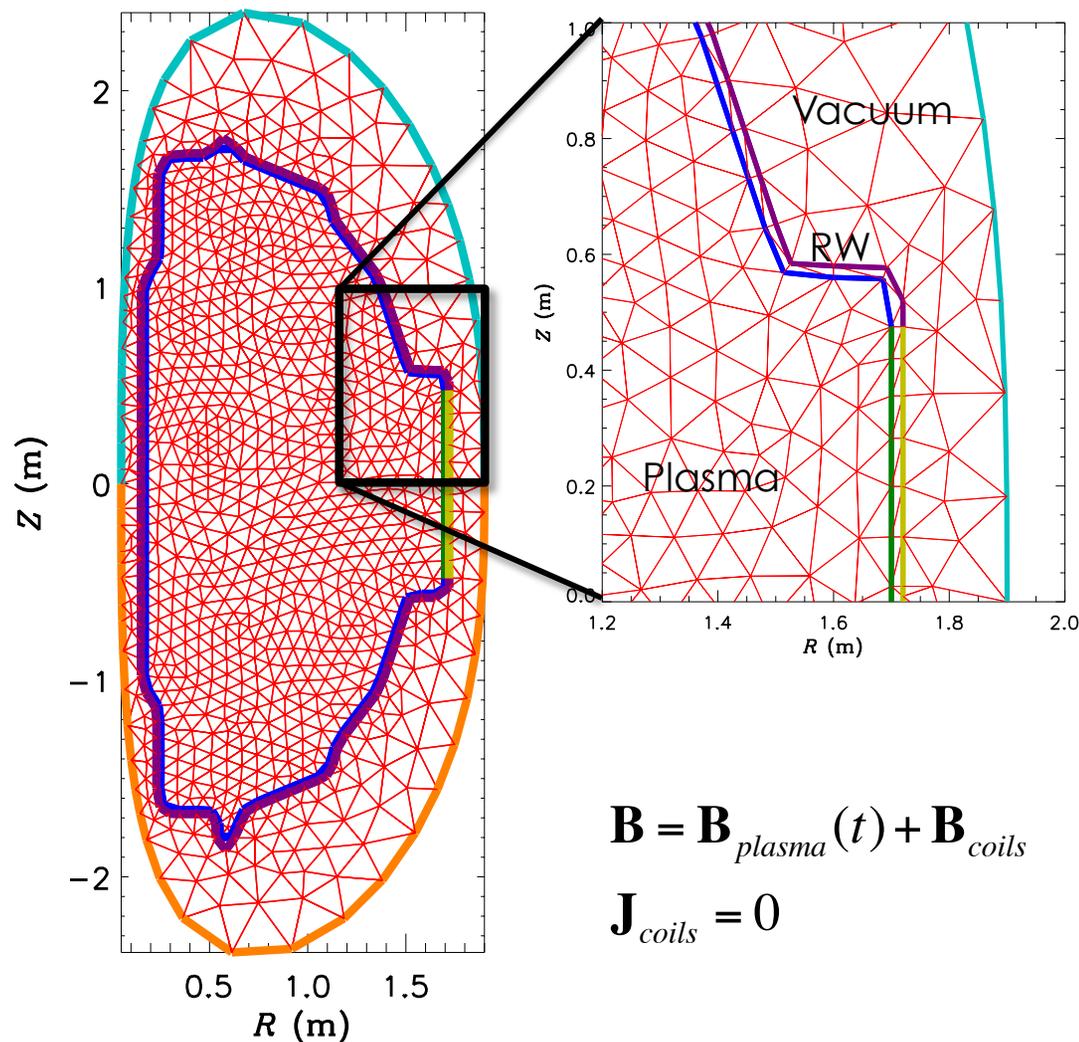
$$\mathbf{B} = \mathbf{B}_{plasma}(t) + \mathbf{B}_{coils}$$

$$\mathbf{J}_{coils} = 0$$

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Initial Calculations Show Eddy Currents in the RW
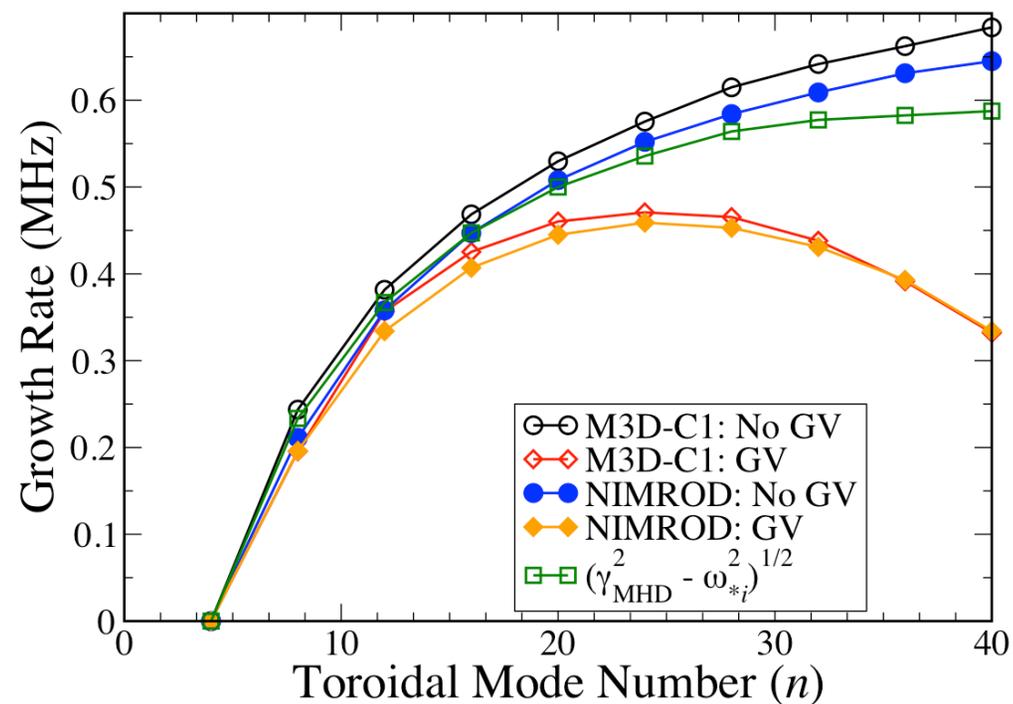
- **Highly resistive test shows plasma current decaying and drifting outward**

  - $\eta_{plasma} \sim 10^{-3}$
  - $\eta_{SOL} \sim 3 \times 10^{-2}$
  - $\eta_W = 10^{-3}$

- **Strong eddy currents form in wall to oppose decay / drift**

- **Next step: model VDE**

J_{φ}

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ELM Benchmark
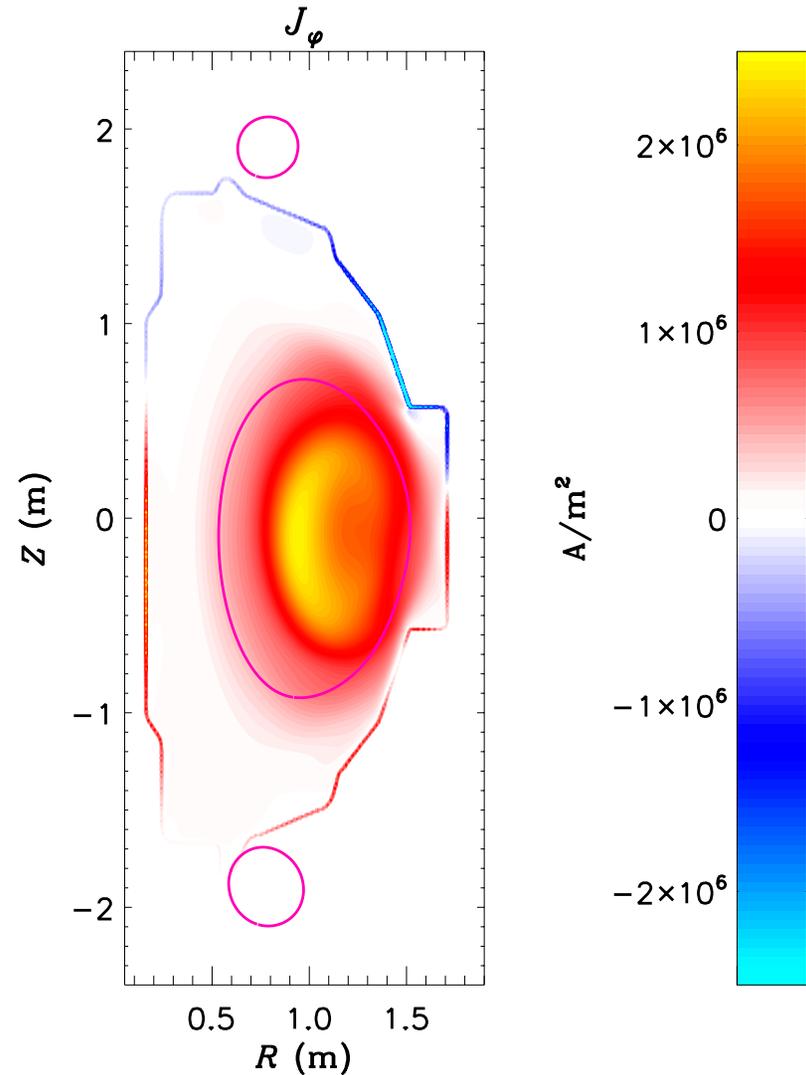
- **Calculation used CBM18 case**
  - Circular cross section, wide pedestal,
  - Same case used by BOUT++ and earlier NIMROD/M3D-C1 benchmarks

- **Good agreement between M3D-C1 and NIMROD**

- **Stabilization seems much greater than $\omega_{*i}/2$ approximation in this case**

Legend:
- M3D-C1: No GV
- M3D-C1: GV
- NIMROD: No GV
- NIMROD: GV
- $(\gamma_{MHD}^2 - \omega_{*i}^2)^{1/2}$

X-axis: Toroidal Mode Number (n)
Y-axis: Growth Rate (MHz)

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Nonlinear 2-Fluid Peeling-Ballooning Calculations Have Been Carried Out With M3D-C1

- **CBM18 case successfully carried through early-nonlinear stage of evolution**
  - Full (eight-field) two-fluid model
  - Spitzer resistivity ($S \sim 1.5 \times 10^9$), no hyper-resistivity
  - "Realistic" anomalous perpendicular transport coefficients ($\sim$few m^2/s)
  - Isotropic thermal diffusivity

- **Limitation appears to be pressure remaining positive**
  - Pressure equation is first to fail; previous solve < 60 GMRES iterations

- **Ready for benchmark!**

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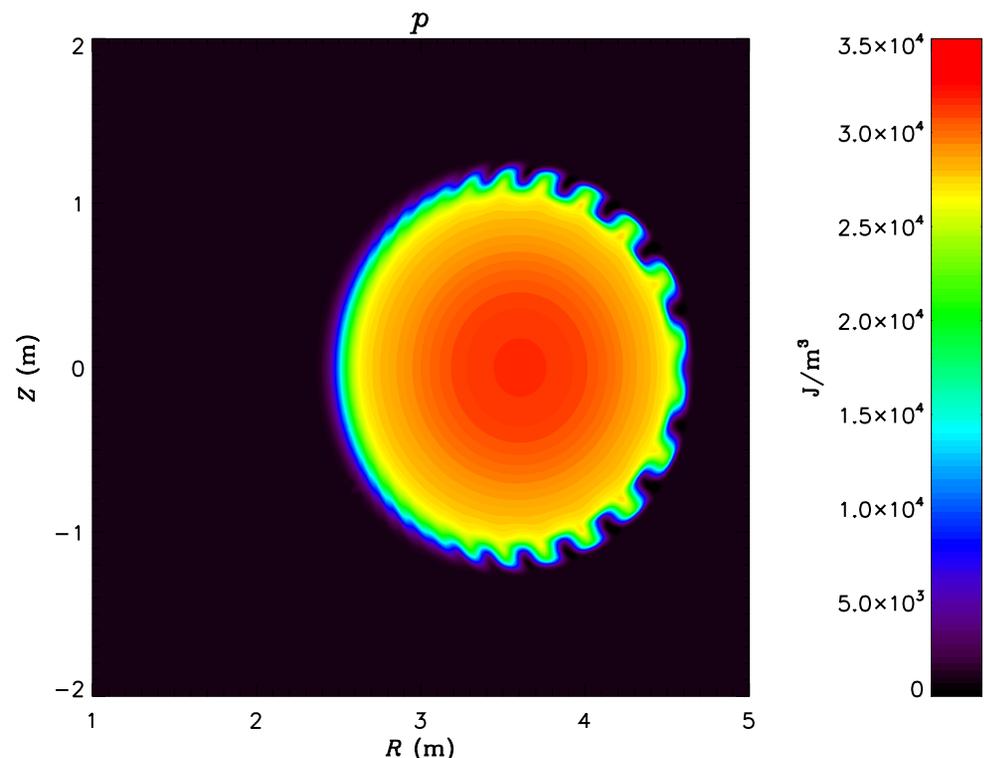
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3D Response Modeling

M3D-C1 Used For ITER ELM Control Coil Modeling

- **ELM suppression metrics were evaluated using a set of 162 DIII-D discharges**
  - Island Overlap Width (IOW)
  - "Local Chirikov" Parameter (σ_{ped}): extent of island overlap at pedestal top

- **Local Chirikov Parameter correlates well with ELM suppression**

Metric	Threshold	Accuracy
Vacuum IOW	12.7%	63%
Plasma IOW	6.4%	70%
Vacuum σ_{ped}	1.55	89%
Plasma σ_{ped}	0.90	73%

- **Including plasma response does not always improve correlation!**
  - Plasma response calculation is more sensitive to equilibrium
  - Plasma response conflates cause and effect

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M3D-C1 Used For ITER ELM Control Coil Modeling

- **Both linear and nonlinear response was calculated for several ITER scenarios**
  - 3 of 4 metric thresholds were achievable for all scenarios within specs of ITER control coils

- **EMC3-EIRENE calculations showed broader heat flux deposition from M3D-C1 fields than "heuristically screened" fields**
  - M3D-C1 shows weaker screening than cylindrical model
  - "Kinking" response enhances stochasticity

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Future Plans

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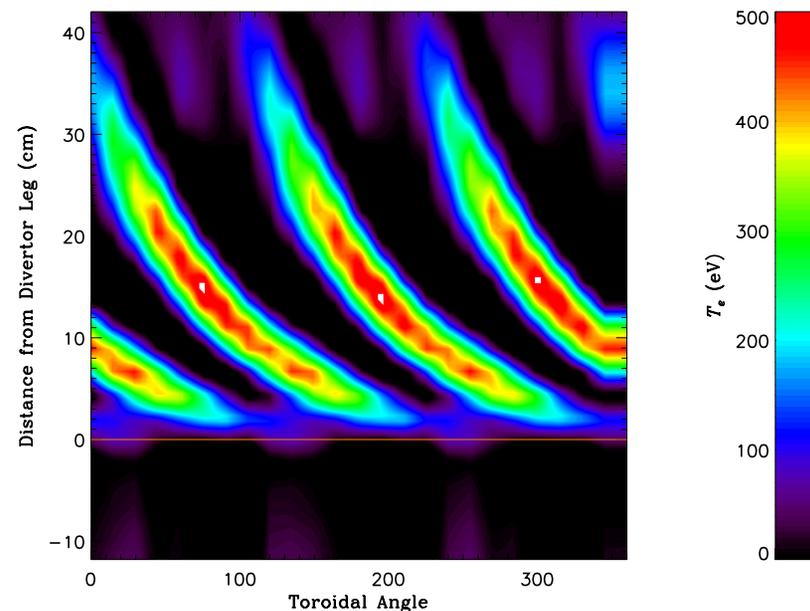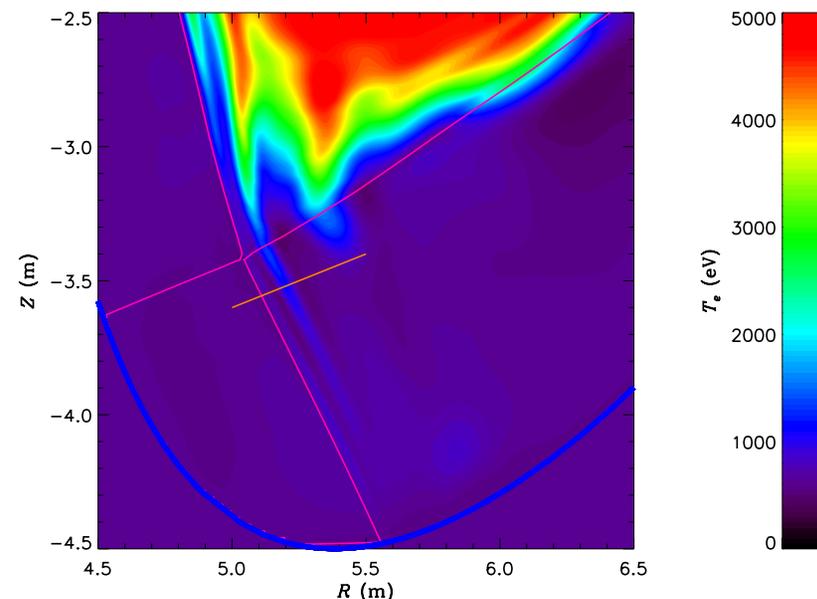
(Near) Future Plans

- **VDE with resistive wall**

- **3D perturbed equilibrium reconstruction**
  - Use measured magnetic field as boundary condition for linear response calculation

- **NIMROD / M3D-C1 Benchmarking**
  - 3D Response (126006? Linear? Nonlinear?)
  - Nonlinear ELM
  - Tearing mode w/ sheared rotation? (ITPA-MHD JA1)