Runaway Electron Avalanche and Confinement studies in MHD Simulations

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Confinement of runaways on NIMROD computed field lines is studied by following trace fast electrons

- Simulation is seeded with randomly located trace fast electron
- Initial velocities are suprathermal but not strongly relativistic
- Electrons are accelerated by the electric fields, slowed by collisions, and follow the field lines perfectly
- Model provides no information about seed terms or avalanche, purpose is only to study confinement
- Near term upgrades will incorporate drift orbit effects, and synchrotron radiation drag

$$\frac{\partial r}{\partial t} = v_{\parallel} | \hat{b}_r | \quad (1)$$

$$\frac{\partial z}{\partial t} = v_{\parallel} | \hat{b}_z | \quad (2)$$

$$\frac{\partial \phi}{\partial t} = v_{\parallel} | \hat{b}_{\phi} | / r \quad (3)$$

$$\frac{\partial v_{\parallel}}{\partial t} = -(eE/m + \nu_{ee} v_{\parallel}) / \gamma^3 \quad (4)$$

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Part 1: RE tracking as a post-processing tool

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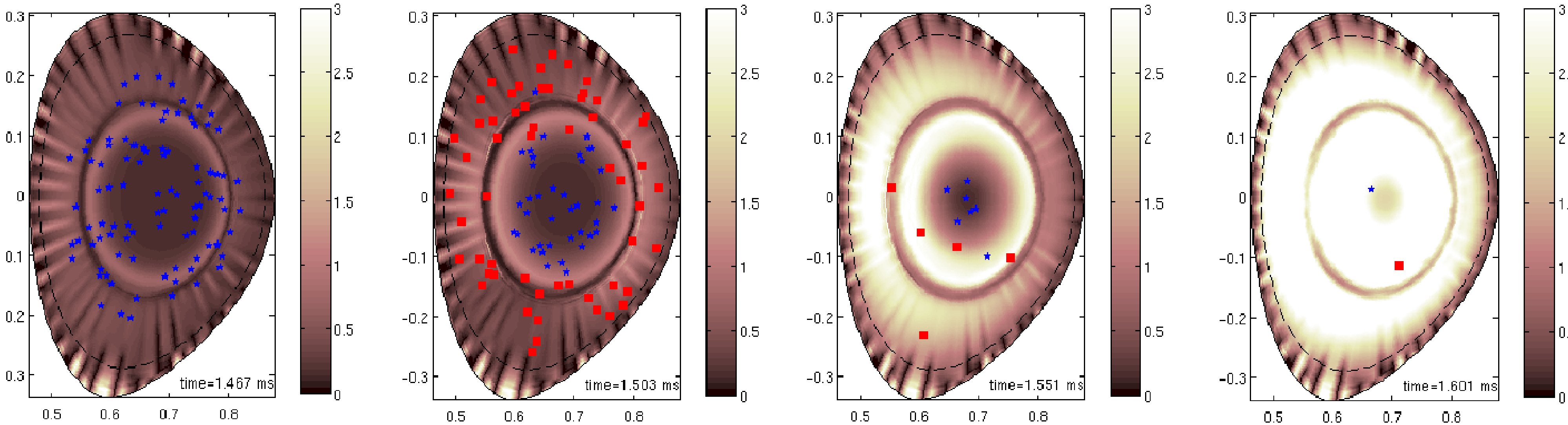
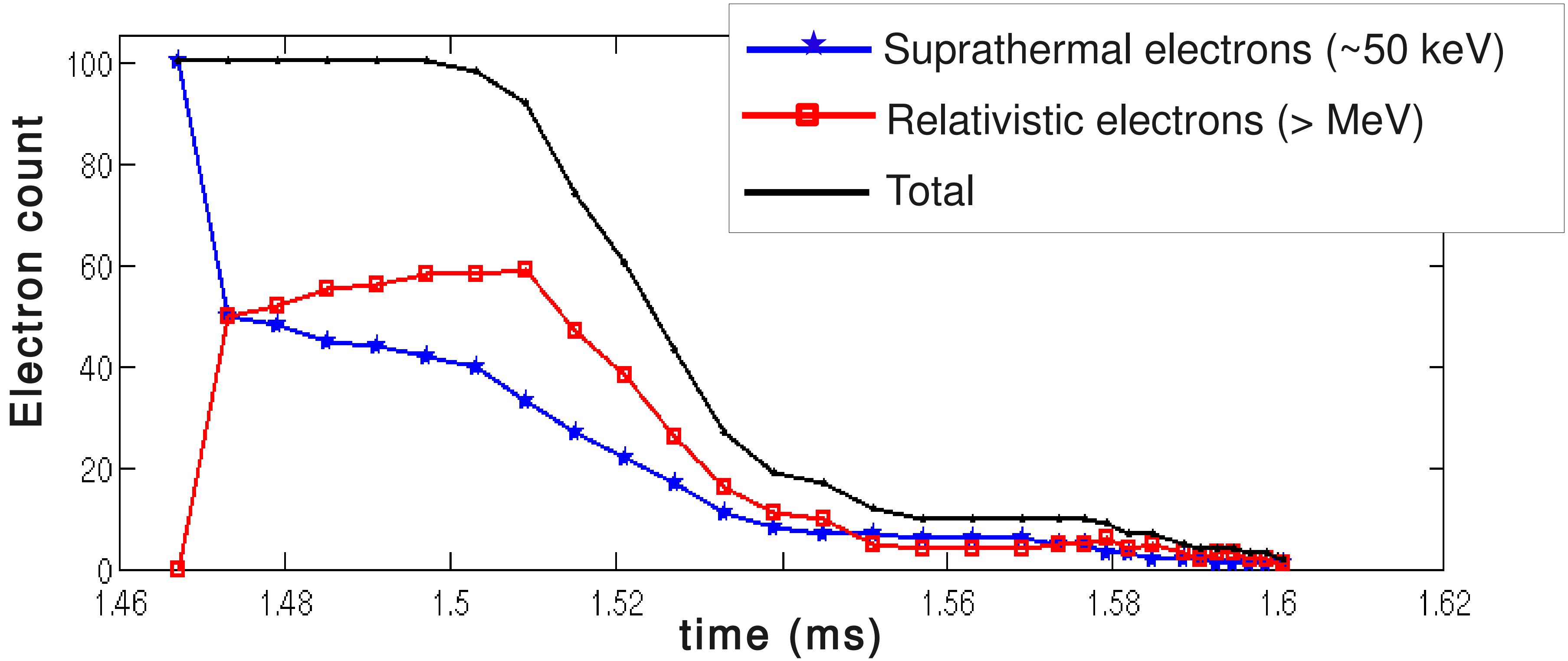
Relativistic electrons lie mainly in the colder edge region and are lost first when fields become stochastic



1.467 ms 1.503 ms 1.551 ms 1.601 ms

- Test electrons, sorted by energy, are shown at four times
- Background shows magnitude of the electric field, which rises sharply during the thermal quench
- Electrons that travel outside the dashed line are considered “escaped”

Seeded electrons are accelerated to relativistic energies, but lost during the thermal quench



- Total of 100 electrons are seeded with ~50 keV energy; electrons are sorted between those that are highly relativistic and those with remaining near 100 keV
- Fields are updated intermittently when integration is done in post-processing

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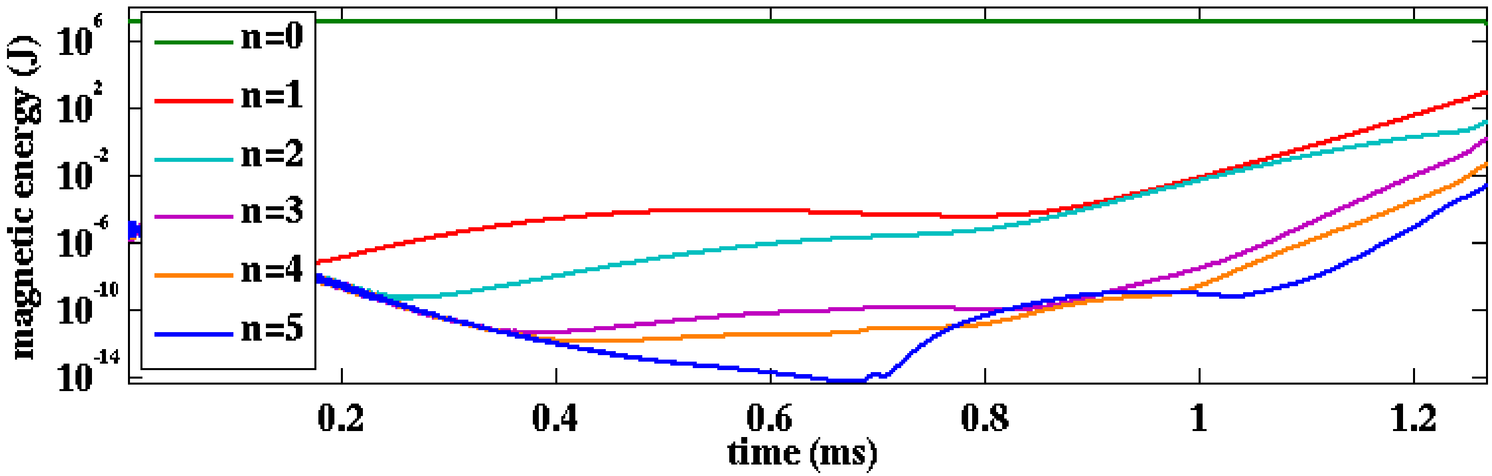
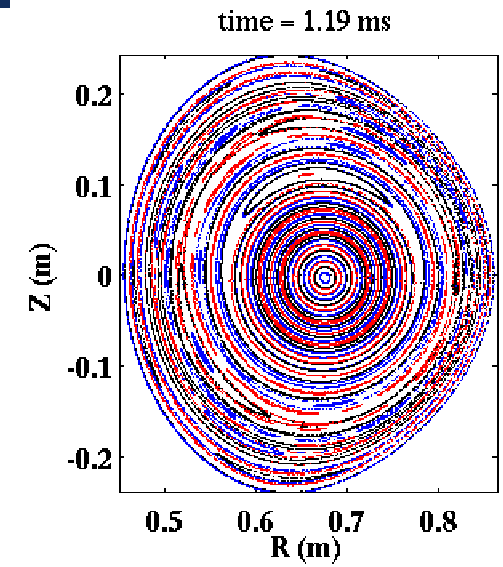
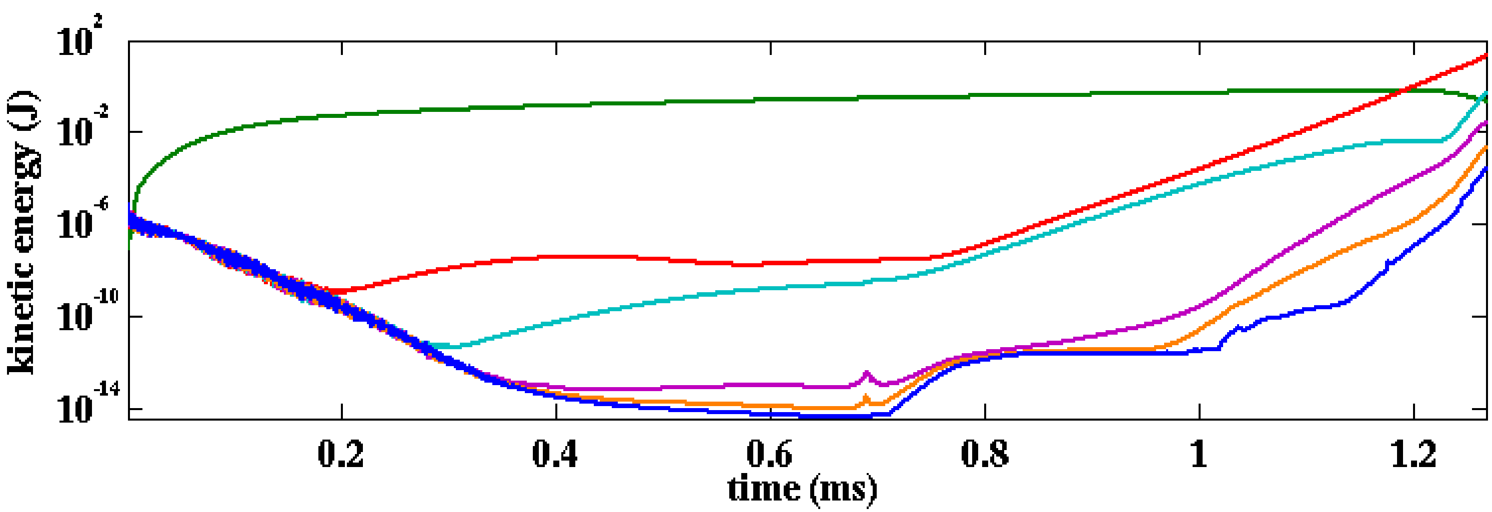
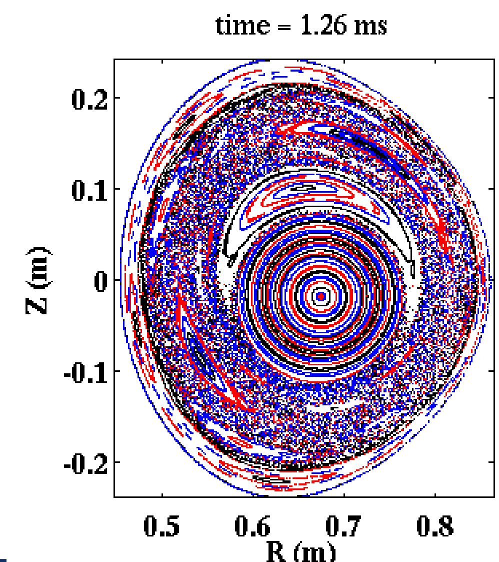
Part 2: NIMROD fast electron tracking during runtime

Simulation of pre-thermal quench phase completed with runtime fast electron tracking

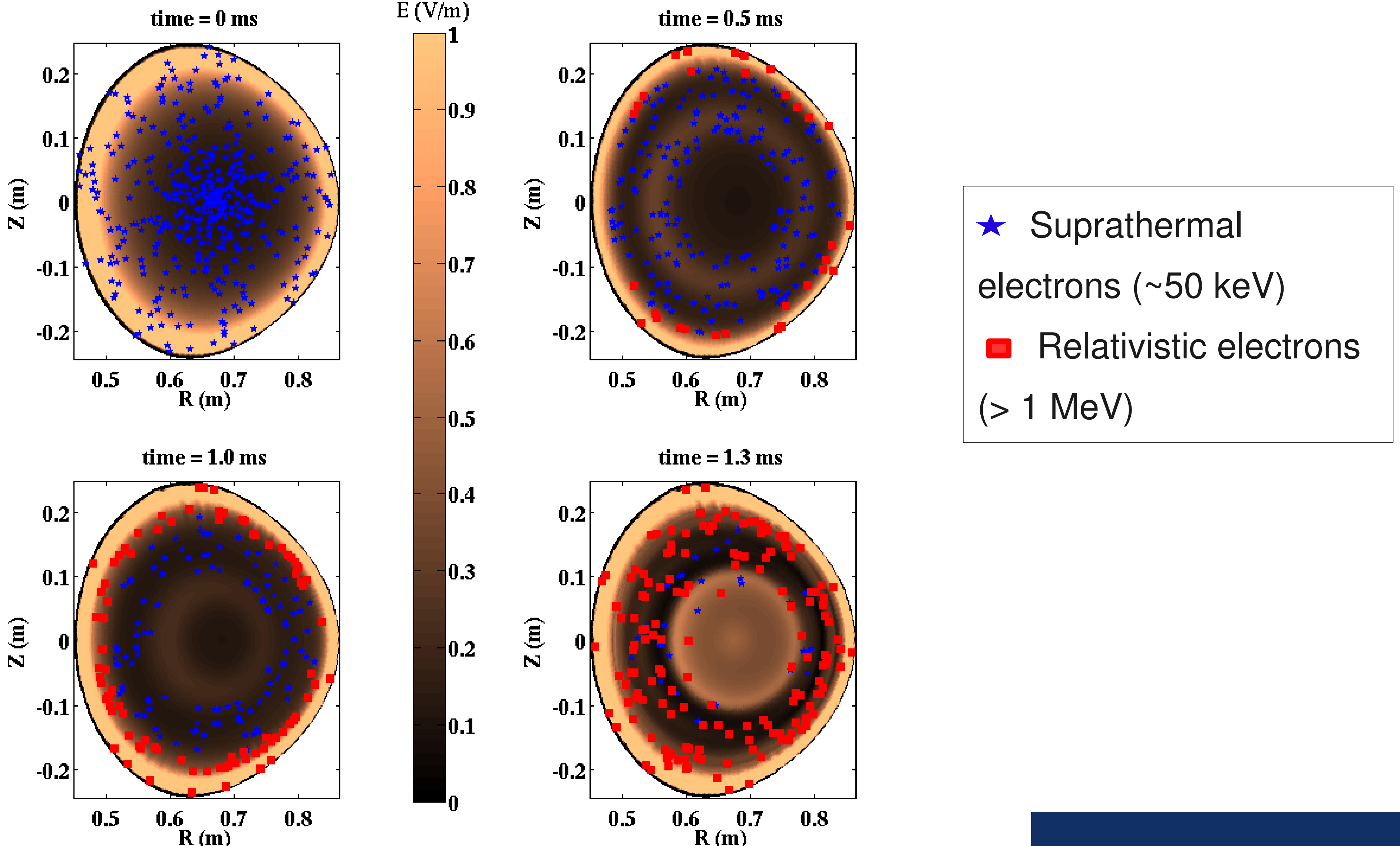




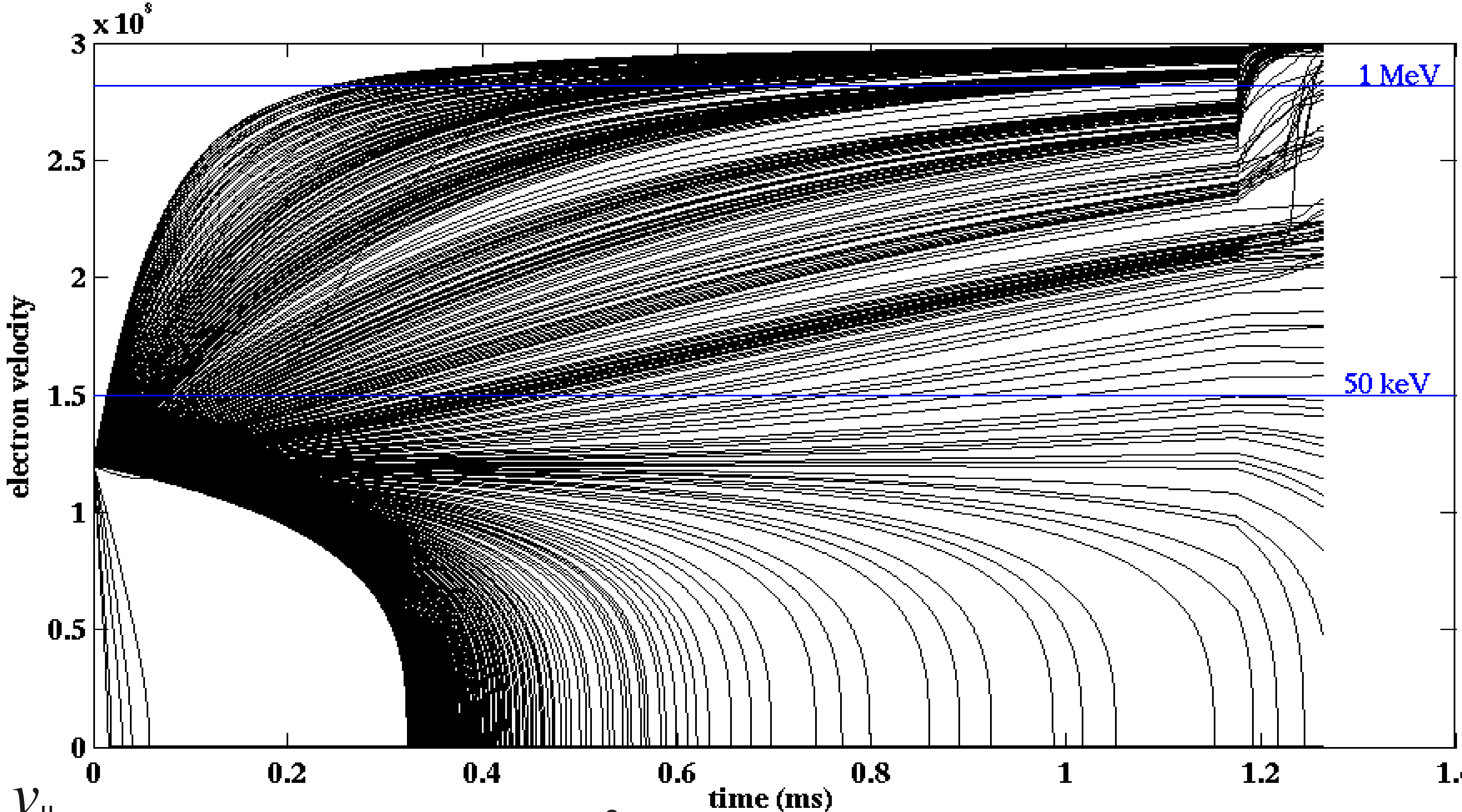




Suprathermal electrons at the edge accelerate to relativistic velocities



Collisional drag on electrons in the core exceed the electric field acceleration



$$\frac{\partial v_{\|}}{\partial t} = -(eE/m + \nu_{ee} v_{\|})/\gamma^3$$

$$\nu_{ee} = 7.7\times 10^{-6} n_e \lambda_{ee} \epsilon^{-3/2}$$

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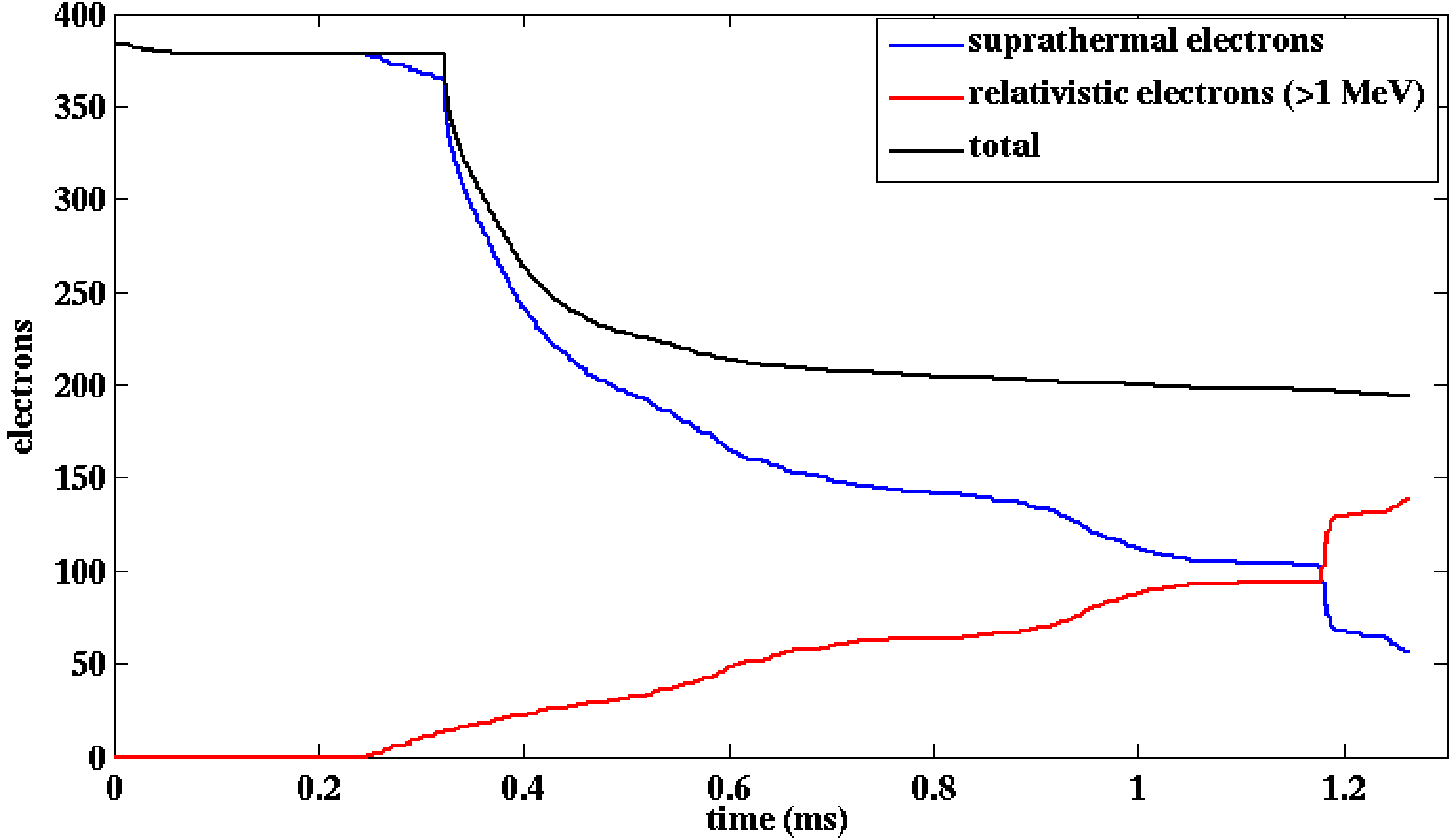
Overall all, many suprathermal electrons are lost to collisional slowing before thermal quench begins



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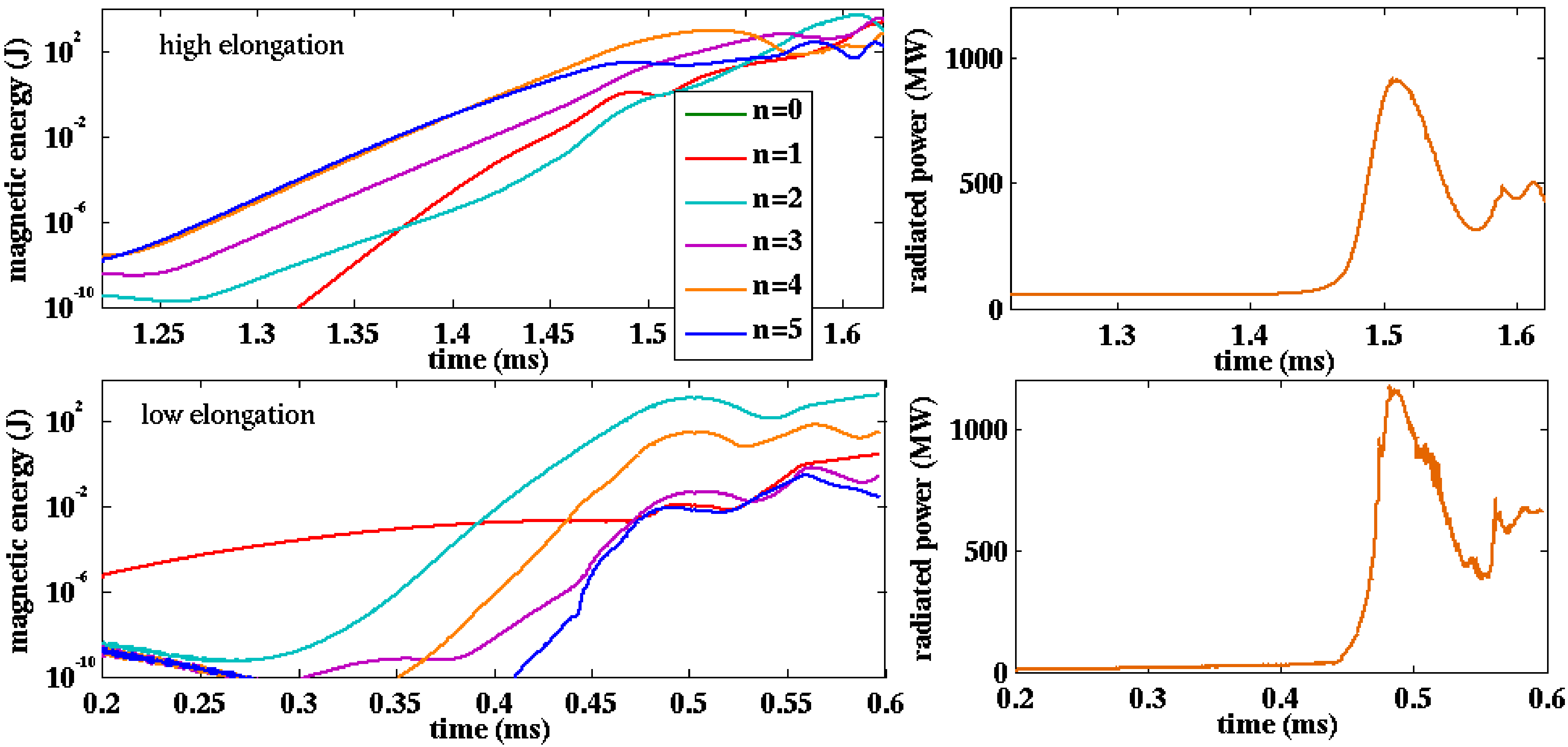
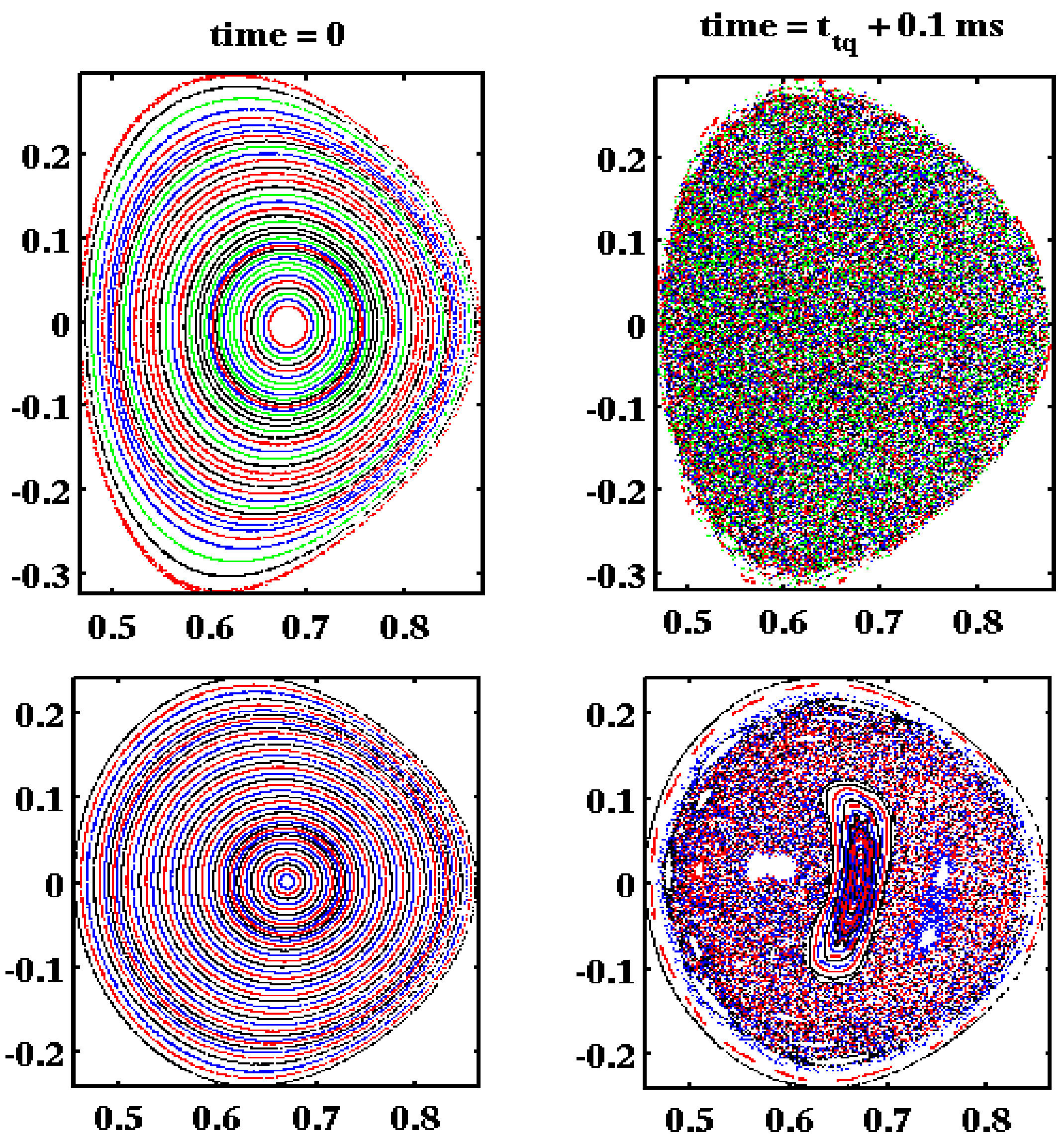
Part 3: Effects of elongation on post thermal quench confinement

Comparison of two similar C-Mod Ne gas jet cases with different elongation



Low elongation case retains good flux surfaces longer relative to thermal quench timing



- Immediately following the thermal quench (as defined here by the radiated power peak), the low elongation case has some good core flux surfaces
- May be related to greater separation of saturated mode energies

Summary and Future Work

• The trajectories of trace fast electrons can now being integrated in NIMROD. Initial analysis was done in post processing, and is now possible during runtime

• Preliminary fast electron confinement studies with NIMROD have found a sudden loss of confinement at the time of the thermal quench, as well as the thermalization of seed fast electrons in the period prior to the thermal quench

• Elongation may play a role in fast electron confinement during and after the thermal quench, and it's role is being investigated with NIMROD simulations

• Additions to the fast electron confinement model in NIMROD will include drift orbits effects and synchrotron radiation drag

• Studies of the runaway electron avalanche are planned using NIMROD output in conjunction with CQL3D

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