NIMROD simulations of Innovative Confinement Concepts

Charlson C. Kim

PSI Center

U. Washington

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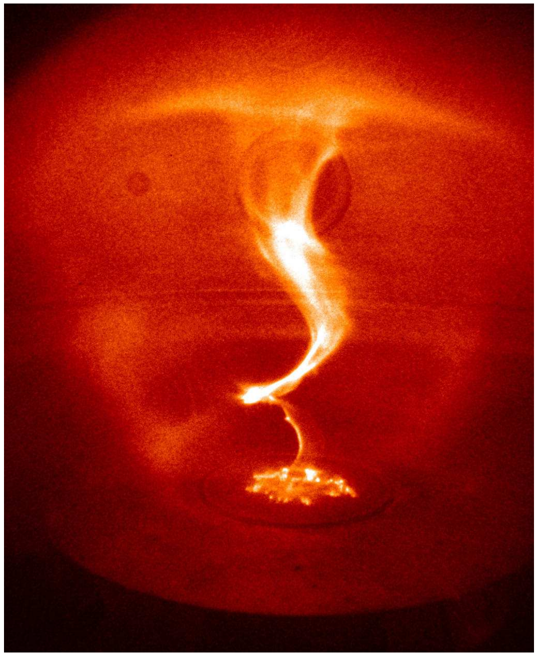
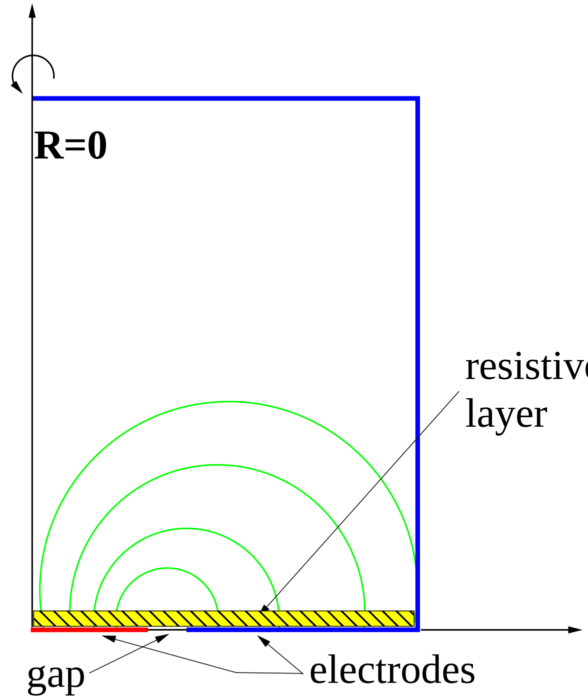
Outline

- Bellan Box simulations
- LDX simulations
- Lorentz Particles
- FRC simulations (from R. Milroy)

Coplanar Flux Injection Simulation[a]

- model P. Bellan's coplanar gun/"spheromak formation"





- cylindrical vessel with small flux gap of a few centimeters
- vacuum field is dipole-like $\sim 1mWb$
  - flux gap located at top of the arc
- peak current is $40 - 100kA$ ramped over $1 - 10\mu s$

[a]image from `http://ve4xm.caltech.edu/Bellan_plasma_page/`

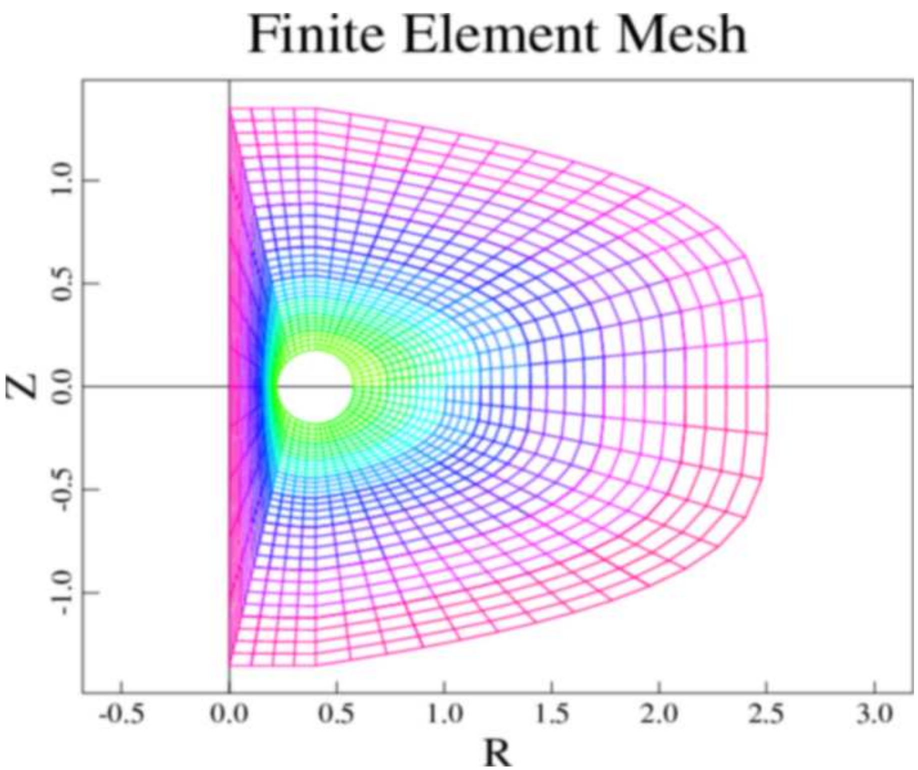
- thin highly resistive layer across bottom 10^5 larger than background resistivity
- thin highly viscous layer across bottom 10^5 larger than background
- this forces all $\mathbf{E}$ in the layer to $\eta\mathbf{J}$
  - improves issues with CFL and small `dt`
- low viscosity and resistivity yet no success in kinking!
- forming stable plasma fountain

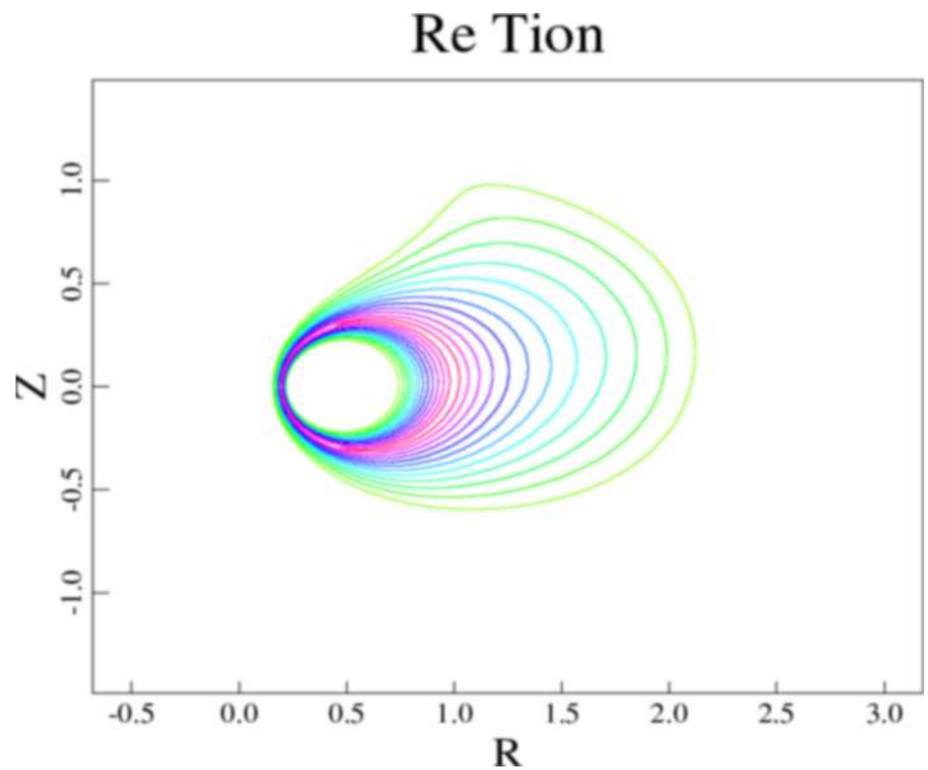
? flow keeps plasma from pinching?

? Hall physics?

LDX simulations

- levitated superconducting cryo-donut generates dipole field

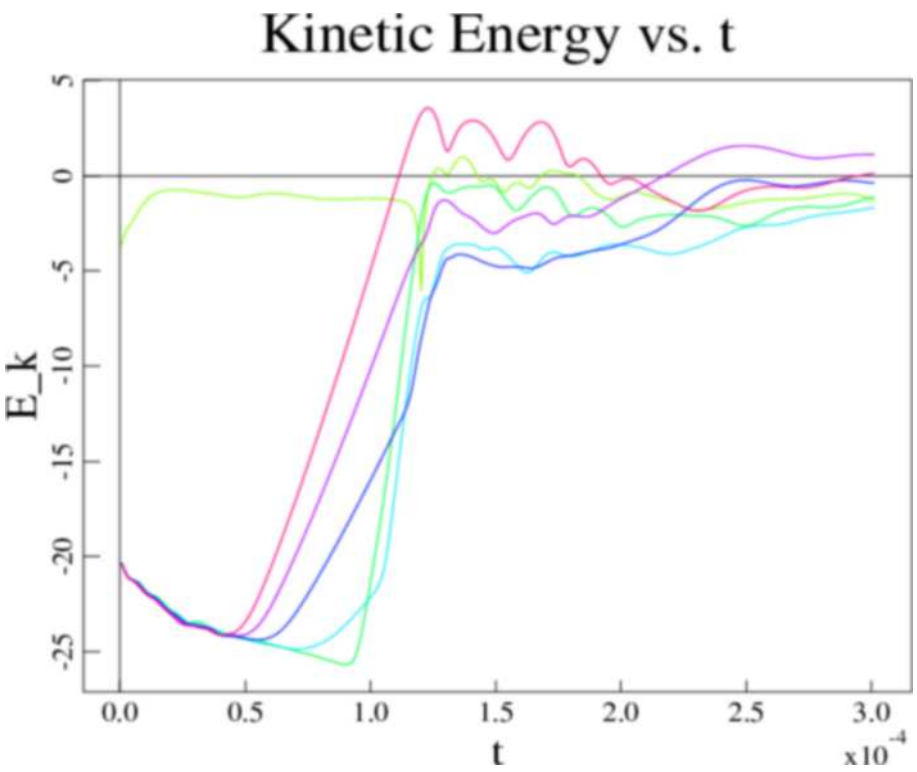


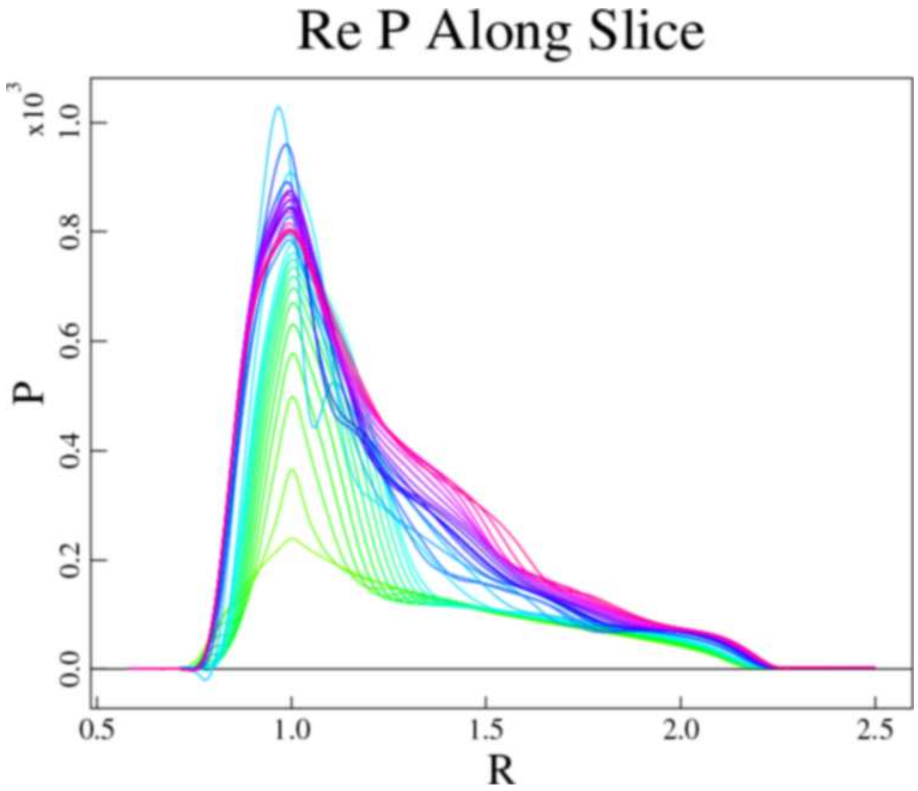


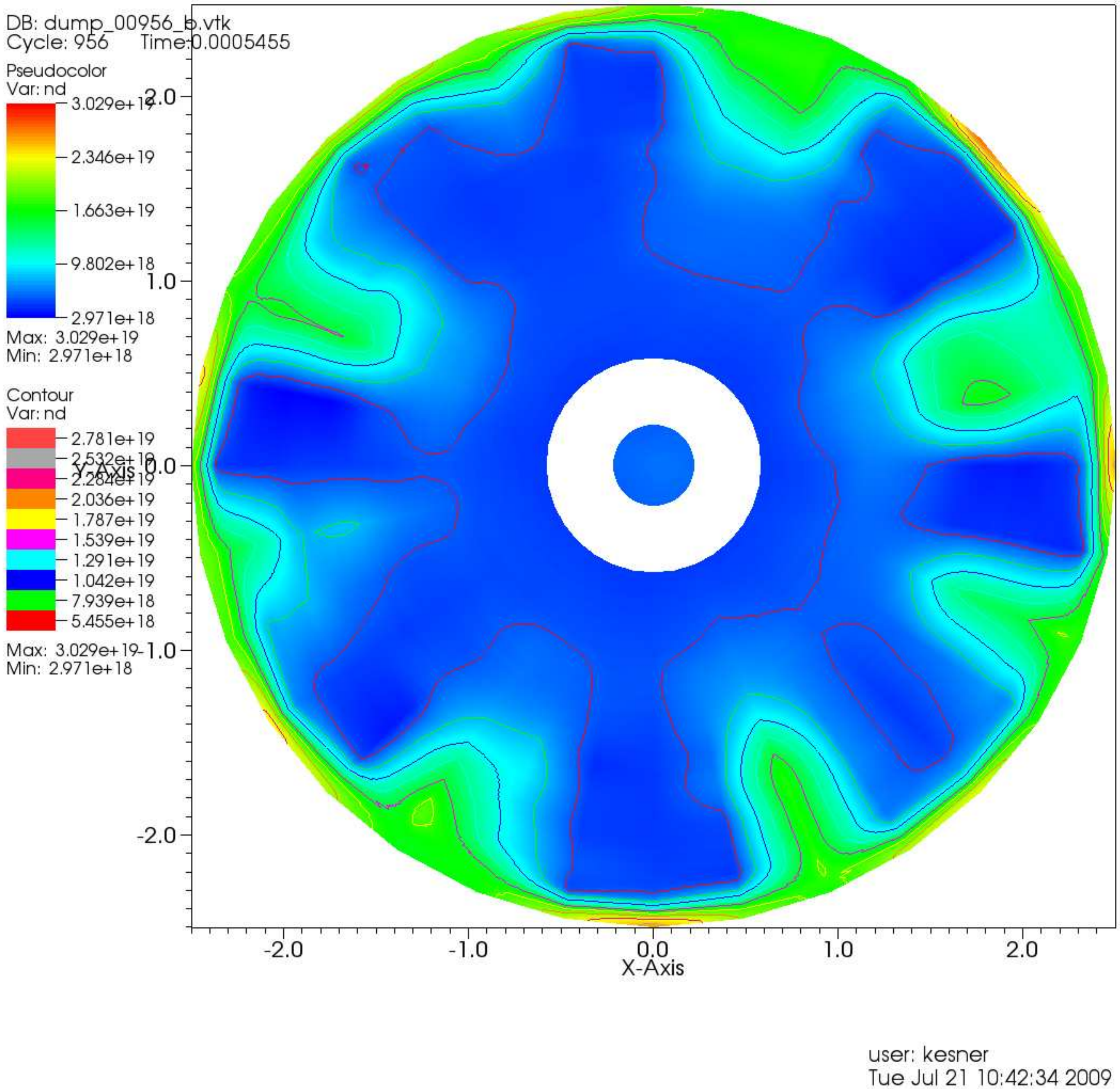
- divertor coil on top
- add heat source to "grow" axisymmetric equilibrium

Interchange Saturation

- use reset to add modes
- interchange unstable



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1.042e+19
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5.455e+18
Max: 3.029e+19
Min: 2.971e+18
Y-Axis
X-Axis
user: kesner
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δf Lorentz Particles

- Lorentz equation of motion

$$\dot{\mathbf{x}} = \mathbf{v}$$
$$\dot{\mathbf{v}} = \frac{q}{m}(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

- for Lorentz equations use[a]

$$f_{eq} = f_0(\mathbf{x}, v^2) + \frac{1}{\omega_c}(\mathbf{v} \cdot \mathbf{b} \times \nabla f_0)$$

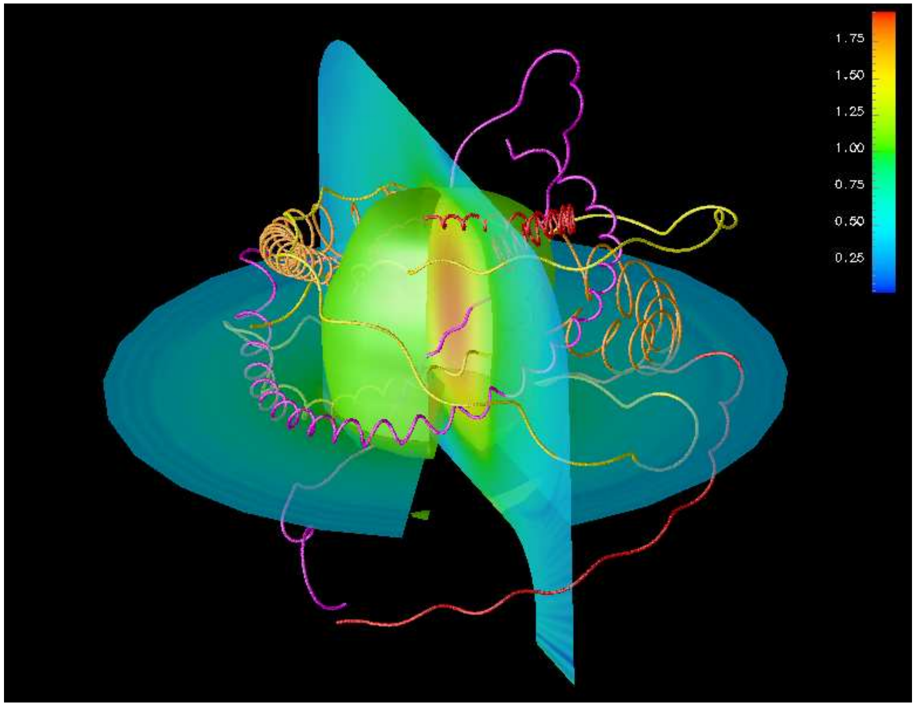
- weight equation is

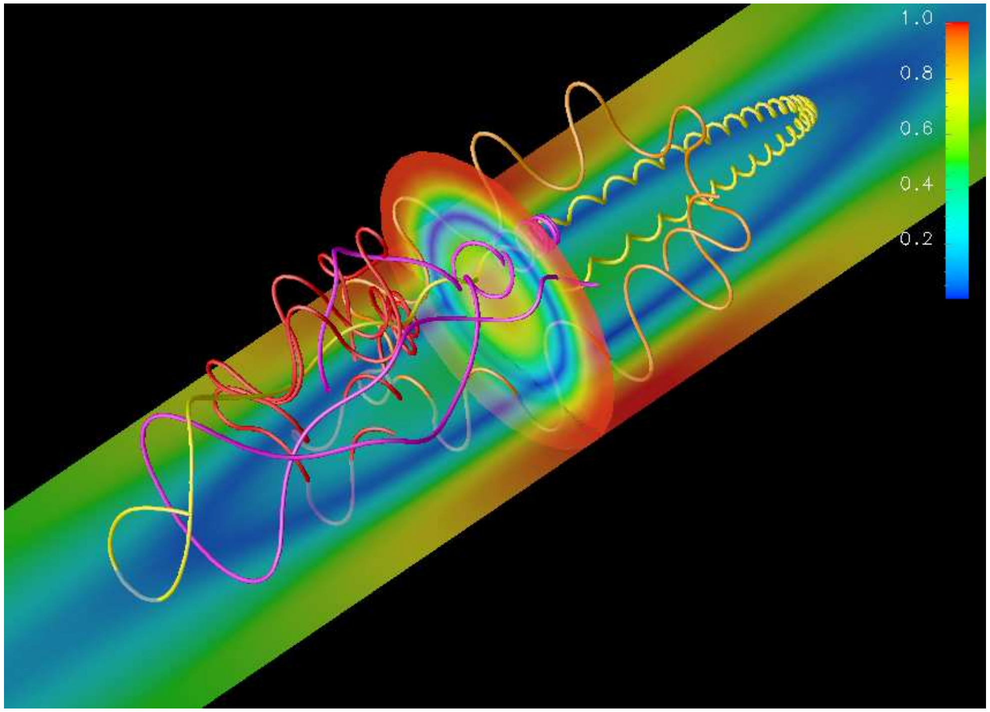
$$\dot{\delta f} = -\frac{\delta\mathbf{E} + \mathbf{v} \times \delta\mathbf{B}}{B} \cdot \mathbf{b} \times \nabla f_0 - \frac{2q}{m}\delta\mathbf{E} \cdot \mathbf{v}\frac{\partial f_0}{\partial v^2}$$

[a] M. N. Rosenbluth and N. Rostoker "Theoretical Structure of Plasma Equations", Physics of Fluids **2** 23 (1959)

Ion Orbits Nontrivial in ICC Devices

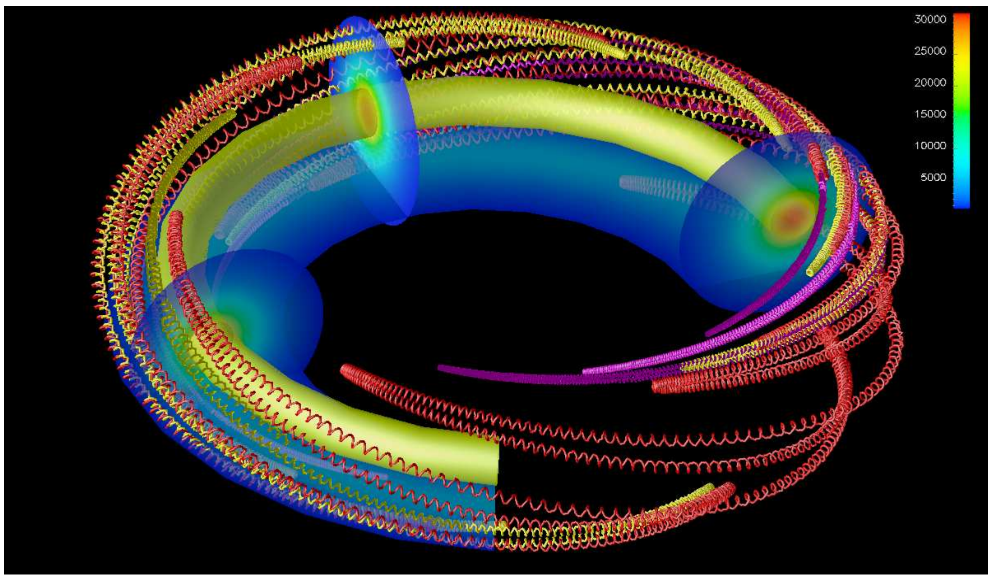
- nontrivial orbits in ICCs

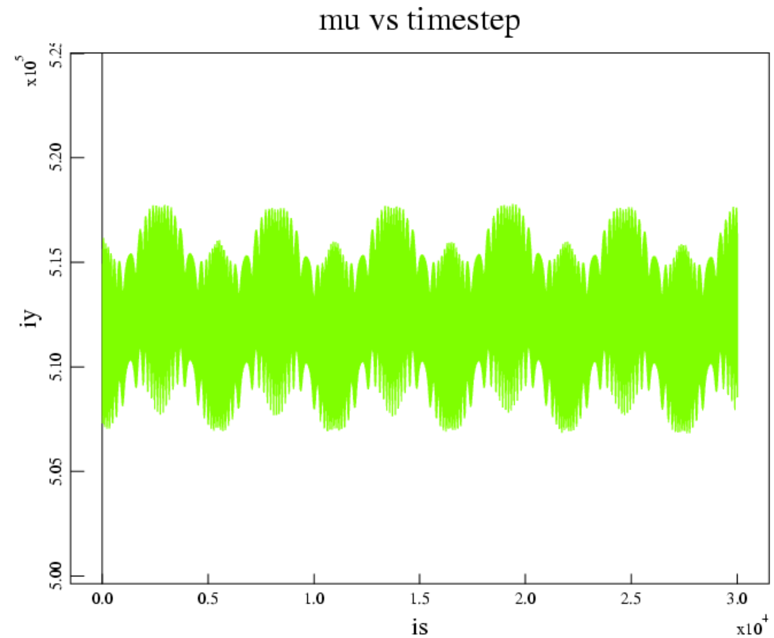




Full Ion Orbits in Tokamak

- full orbits has marginal consequences for overall trajectory in tokamaks



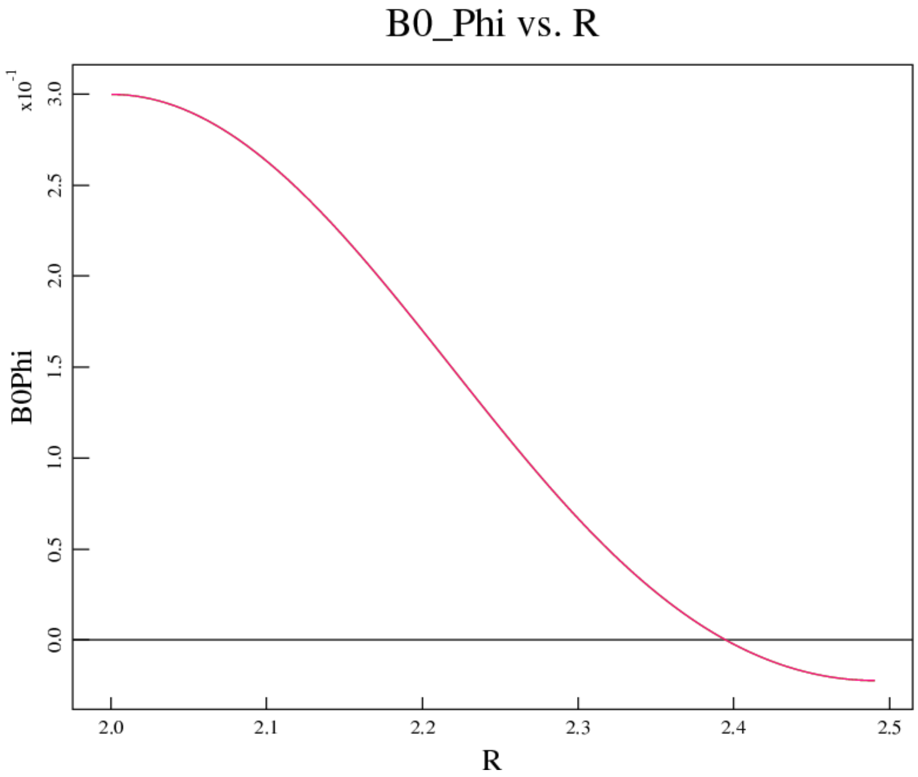


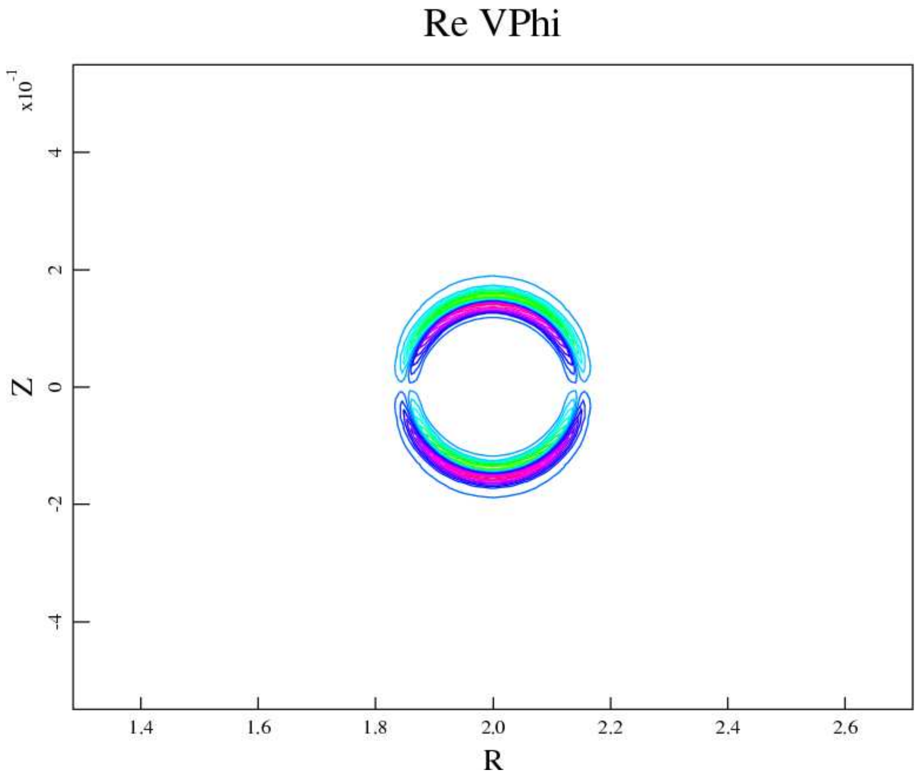
Linear Simulations of Tearing Modes in a RFP

- alpha model equilibrium $\nabla \times \mathbf{B} = \mu \mathbf{B} \quad \mu = 2\Theta \left[1 - \left(\frac{r}{a}\right)^{\alpha_0}\right]$
- parameters for straight cylinder

  $a = .5\text{m},\ B_0 = .3\text{T},\ \Theta = 1.75,\ \alpha_0 = 3,$

  $S = 1.e4,\ ka = 2,\ \gamma\tau_A = 1.3e-3$





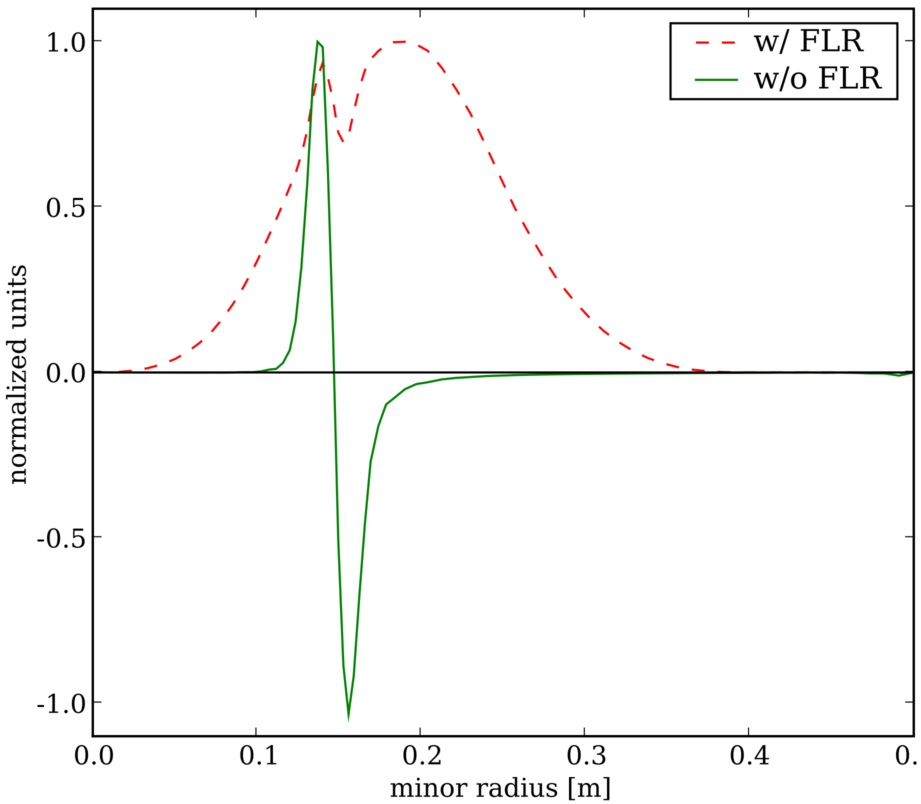
FLR Stabilization of RFP Tearing Mode

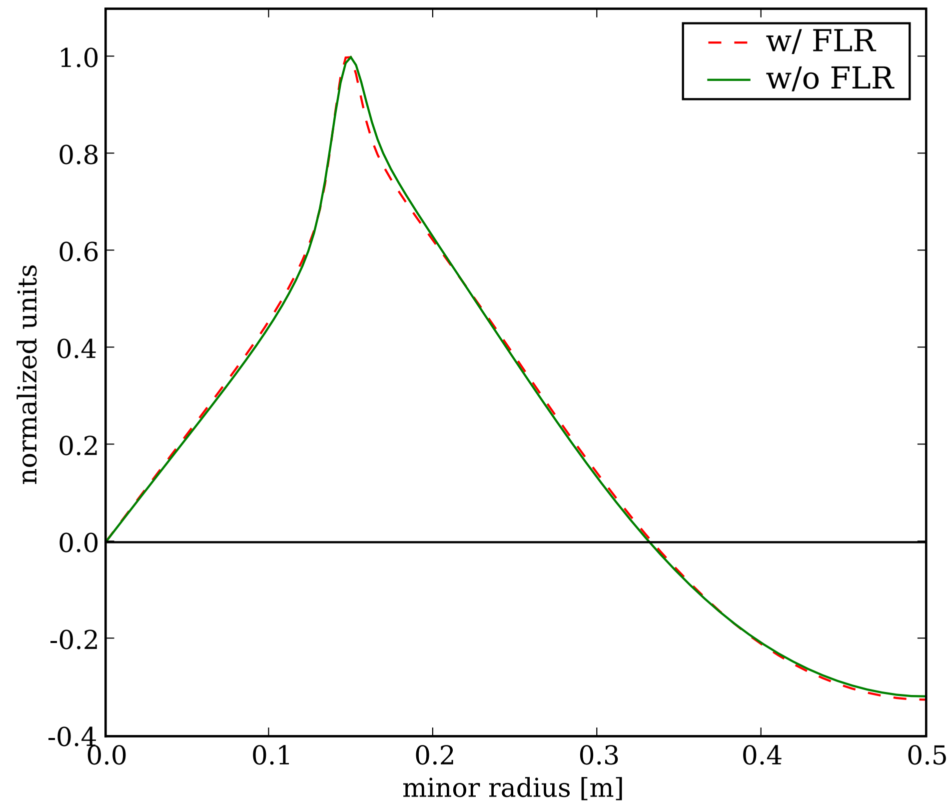
- stabilization with increasing $\mathbf{v}_\perp$

v_0(m/s)	L/a	$\gamma\tau_A$
base case	-	1.3×10^{-3}
1.0×10^6	.14	1.0×10^{-3}
1.5×10^6	.21	5.4×10^{-4}
2.0×10^6	.28	1.5×10^{-4}
2.5×10^6	.35	5.1×10^{-5}

- stabilization at $L/a \simeq 1/3$, where L is the Larmor diameter

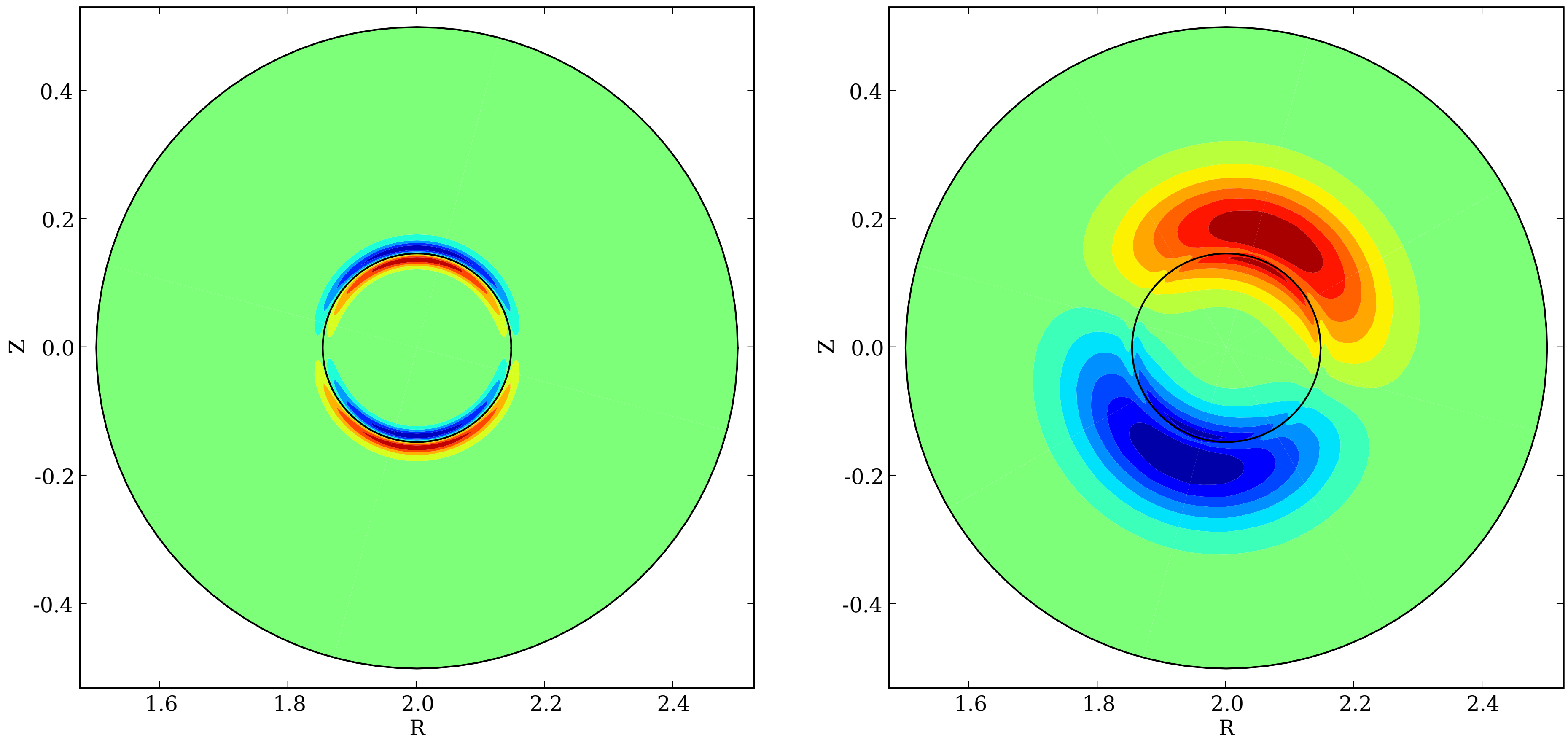
FLR Broadens Tangential Velocity Eigenmode Structure





- tangential velocity eigenmode substantially altered (left)
- magnetic eigenmode unaltered (right)

Comparison of V_ϕ Eigenmode



- inner circle shows resonance surface