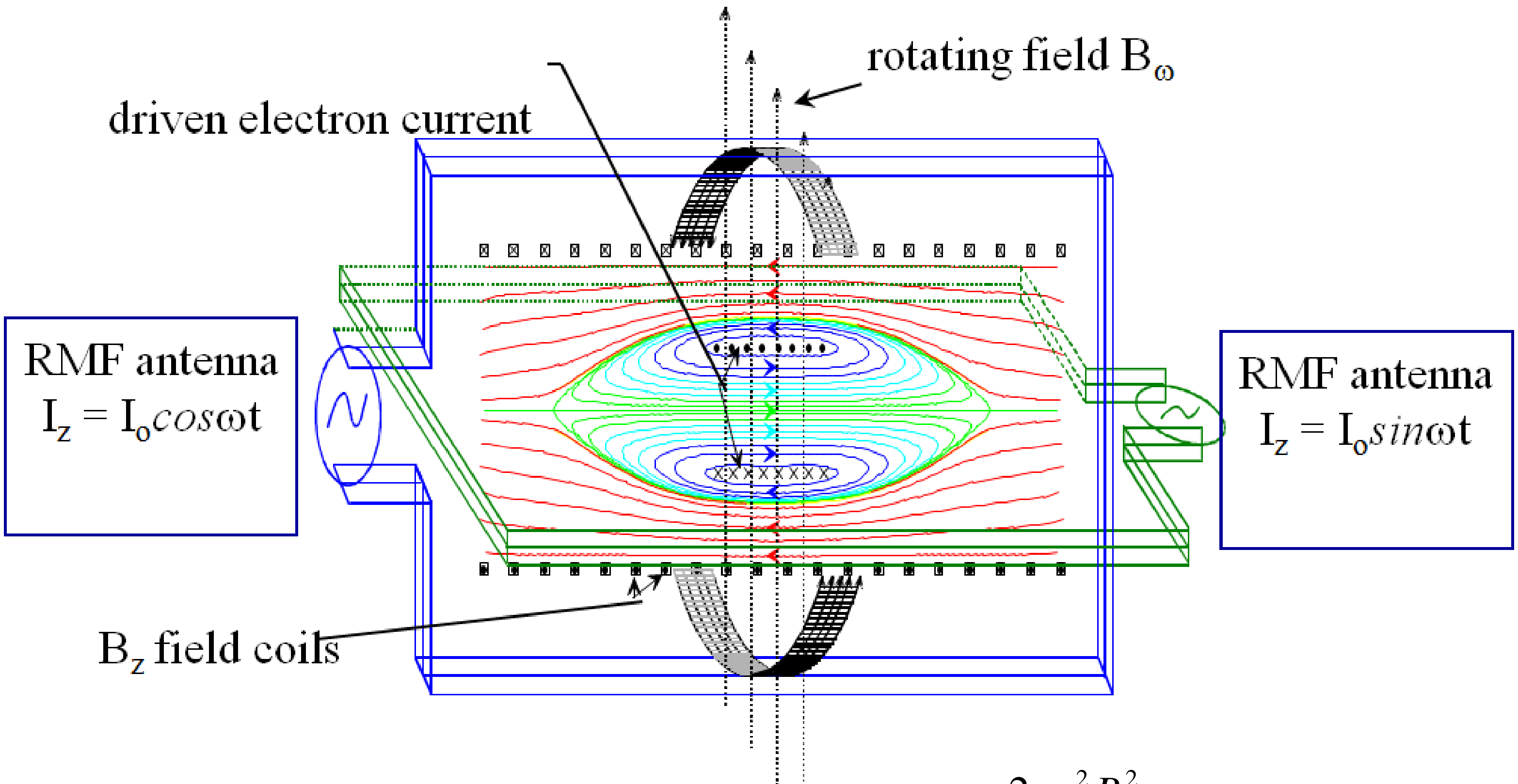
Rotating Magnetic Field Current Drive



$$\frac{d\phi_p}{dt} = 2\pi R E_\theta(R) = \frac{4}{\langle n_e \rangle e r_s^2}\left(\mathbf{T}'_{\mathrm{rmf}} - \mathbf{T}'_\eta\right)$$

$$\mathbf{T}'_{\mathrm{rmf}} = \frac{2\pi r_s^2 B_\omega^2}{\mu_o} f(\zeta)$$

$$\mathbf{T}'_\eta = 1.16\pi r_s^2 e n_m \left(\frac{B_e}{\mu_o}\right)\langle \eta_\perp \rangle$$

RMF Current Drive Calculations

- Study RMF current drive to form and sustain FRCs.
- Boundary conditions to represent finite length antennas have been implemented.
- Calculations have been performed with *even-parity* antennas forming an FRC from a uniform background plasma and magnetic field.
- These calculations only possible after pre-conditioner improvements made last summer.
  - Require finite electron mass ($m_e \sim m_i/100$), and large viscosities.
- Preliminary calculations are nonlinear: Employ n=0 and n=1 only.
- The Hall term is a zero'th order effect here.

RMF Boundary Conditions

- Apply RMF boundary condition:
  - Specify n=1 component of E_{tang} and B_{norm}
  - Express tangential component of a vector potential

$$\mathbf{A} = \left(A_z(z,t)\hat{z} + A_\phi(z,t)\hat{\phi}\right)e^{-i\omega t}\ e^{in\phi}$$

  - Assume that $\nabla \cdot \mathbf{A} \sim 0$ on the boundary (neglecting A_r) so A_θ can be expressed in terms of A_z:

$$A_\theta(z,t) = \alpha \frac{ir}{n}\frac{\partial A_z}{\partial z}$$

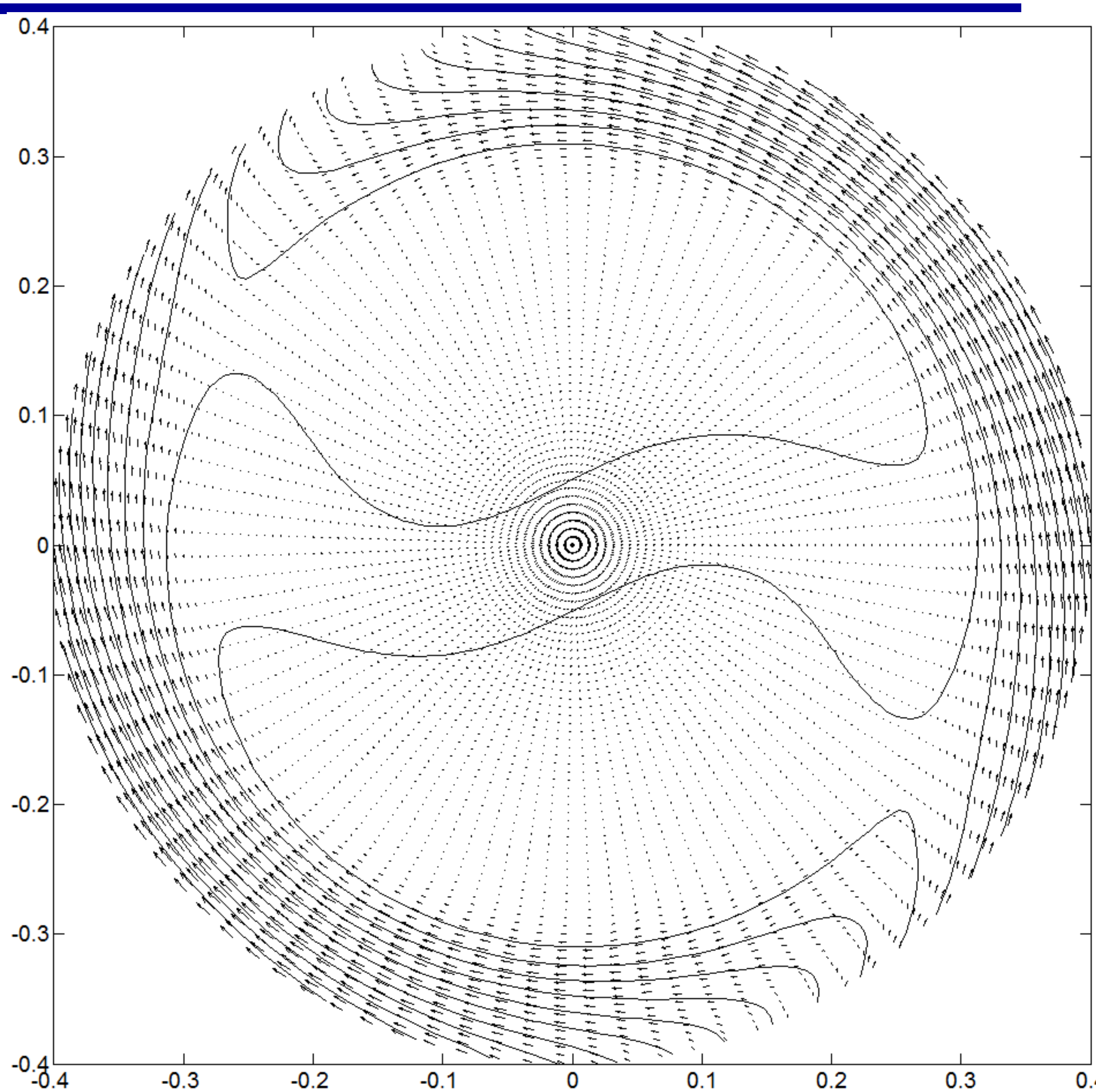
  - Express **E** and **B** in terms of **A**: $\mathbf{E} = -\frac{\partial \mathbf{A}}{\partial t}$

$$E_z(z,t) = \left(i\omega A_z - \frac{\partial}{\partial t}A_z\right) \quad E_\theta(z,t) = \left(i\omega A_\theta - \frac{\partial}{\partial t}A_\theta\right) \quad E_\theta(z,t) = -\alpha\frac{r}{n}\left(\omega\frac{\partial A_z}{\partial z} + i\frac{\partial}{\partial t}\frac{\partial A_z}{\partial z}\right)$$

$$B_r = \frac{1}{r}\frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z} \qquad B_r = \frac{in}{r}A_z - \alpha\frac{ir}{n}\frac{\partial^2 A_z}{\partial z^2}$$

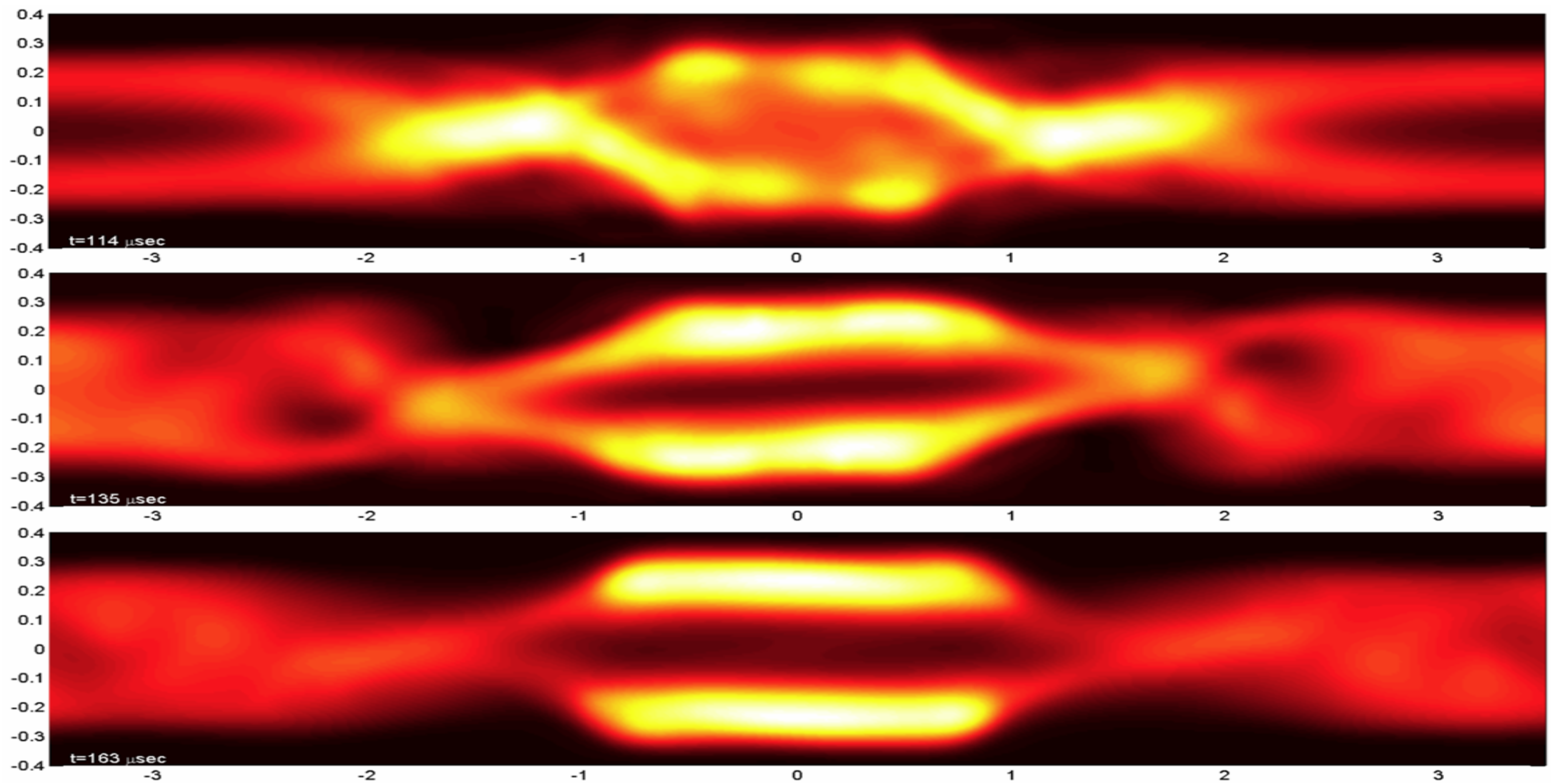
The n=1 RMF penetrates, rotating clockwise

- As n=1 RMF field penetrates, electrons begin to rotate synchronously it.



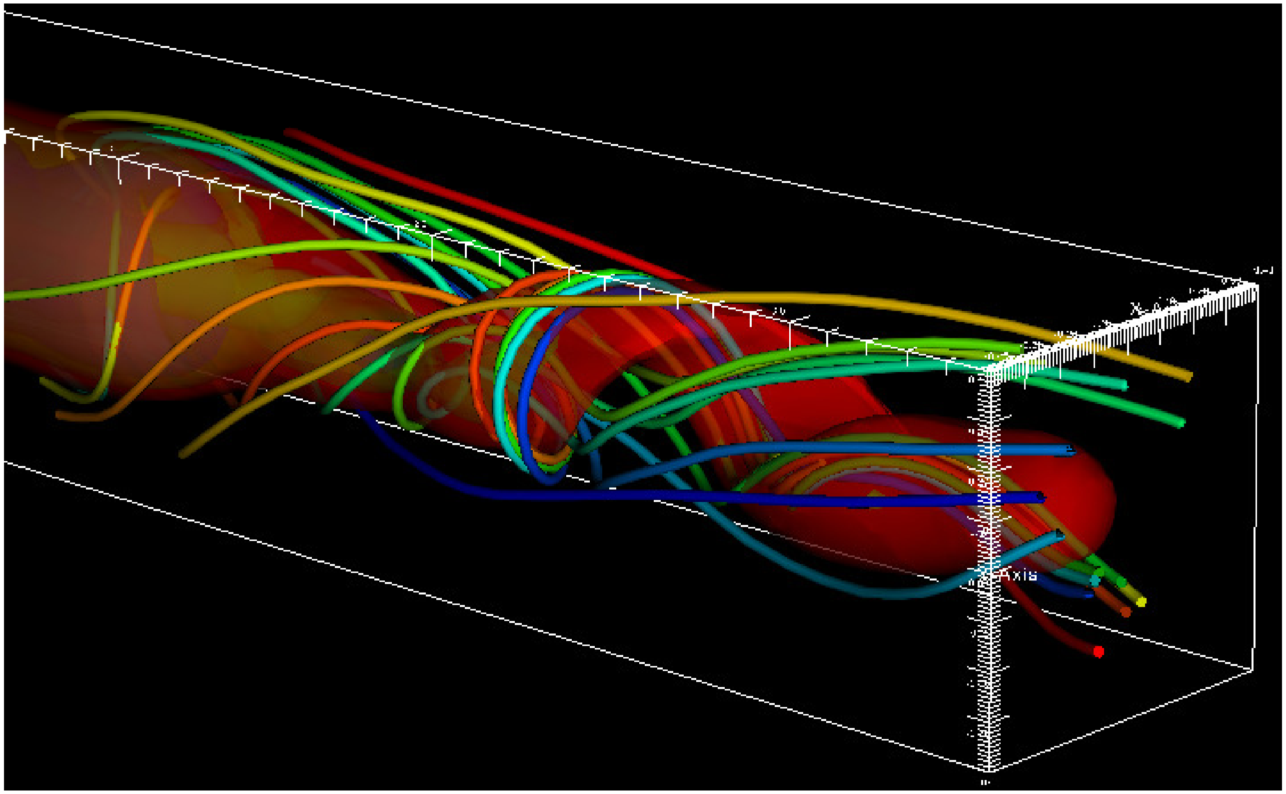
Pressure Contours as FRC Forms

- Initial plasma has strong tilt, but distortion decreases in time.



End-Shorting Boundary Conditions

- When end-shorting boundary conditions ($E_{tang}=0$) are applied at axial ends, a strong toroidal field develops near the FRC ends that can drive a kink instability on the open field-line plasma.
  - A probe is being developed for TCSU to investigate experimentally.



Summary

- Successes
  - Initial calculations of FRC formation employing RMF have been performed, and we are starting to learn new physics.
- Difficulties:
  - Difficulty running with anisotropic transport due to field null and *chaotic* fields. Would like anisotropic electron thermal conduction.
  - Require unrealistic viscosity and electron mass at this time. May be able to trade off higher resistivity for lower viscosity?
  - Still can experience high (> 100) iteration counts.
- Plans
  - Run with more toroidal modes.
  - Physics and numerical parameter scans.
  - Need charge exchange to prevent ion spin-up if viscosity is reduced.