The Effects of an Electric Potential on Azimuthal Particle Velocity in an FRC

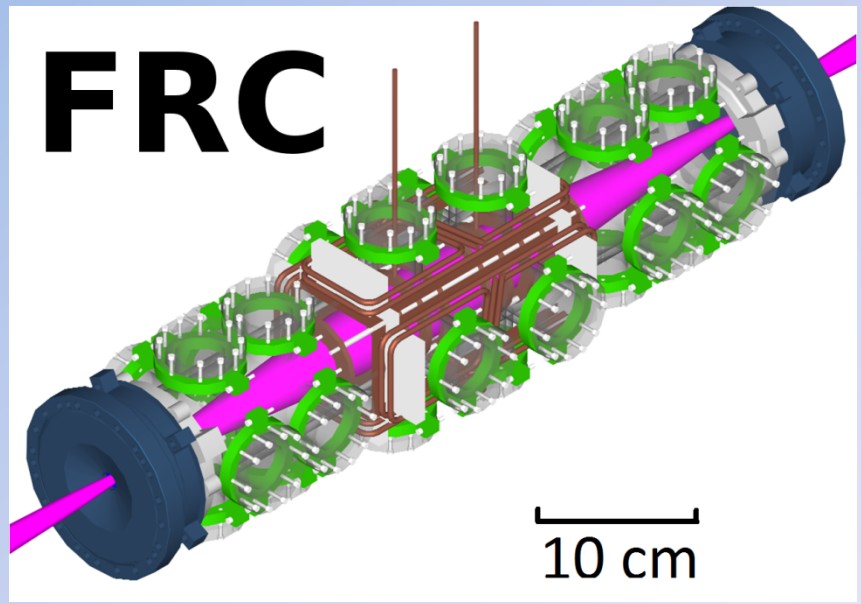
By Stephen Pollard

Thank you to PPPL and PPST

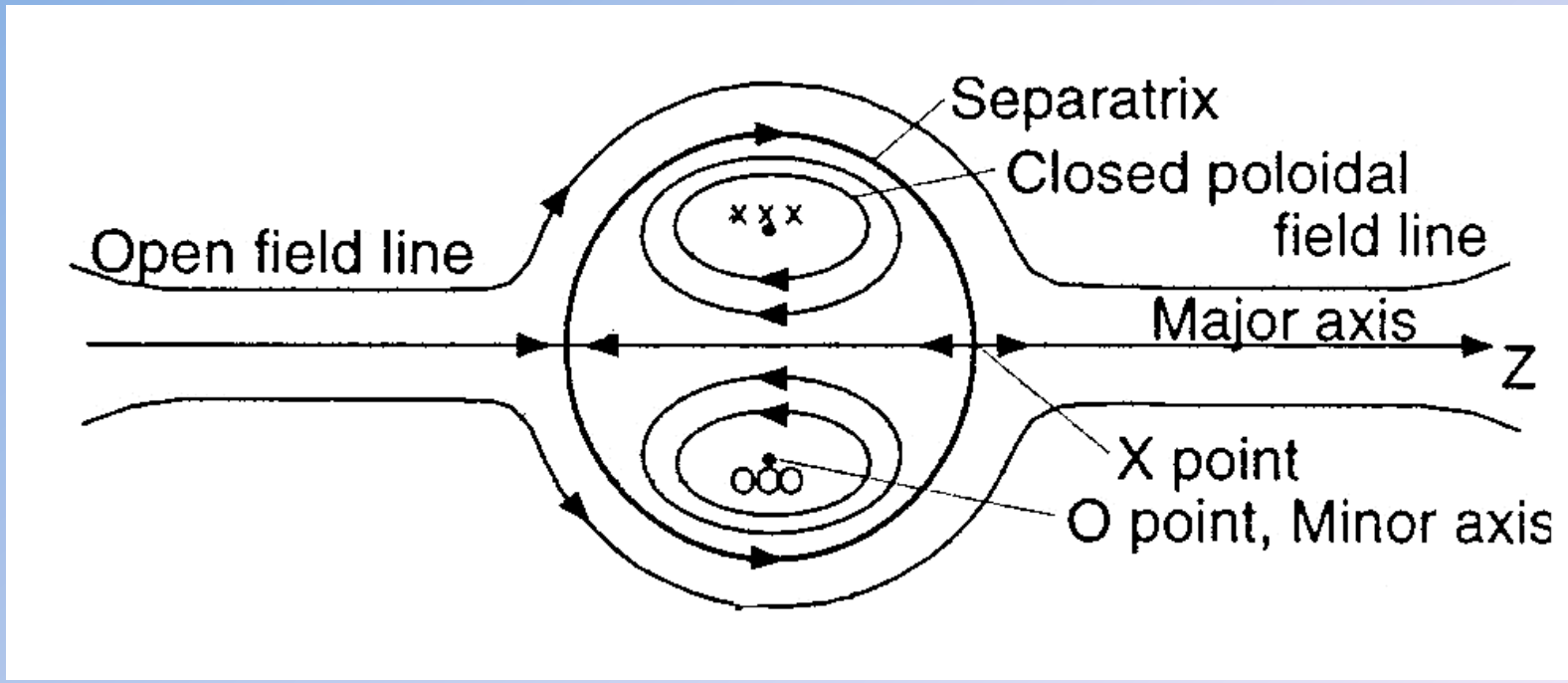
Field Reversed Configuration

Goal of Field Reversed Configuration at PPPL:

- Produce net power from fusion reactions in hot magnetized plasmas



Magnetic Field Lines in FRC



Major Questions: Plasma Current

What current profile best contributes to containment?

In what direction should the plasma flow?

How much total current is optimal?

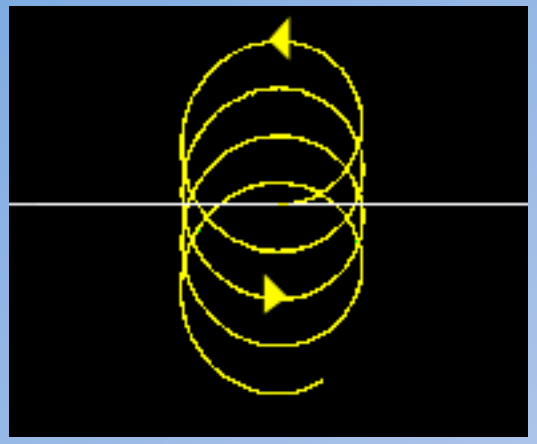
What I Did: Test particle simulations

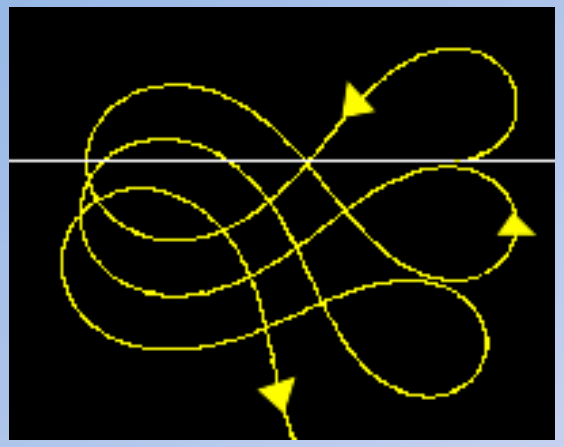
- What: Studied normalized average angular velocity versus multiple initial variables (r, Energy, E field, B Field, RMF strength)
- Why: This average influences magnitude and direction of the current in the plasma
- Methodology: Use individual particle orbits to gain understanding of optimal current profile

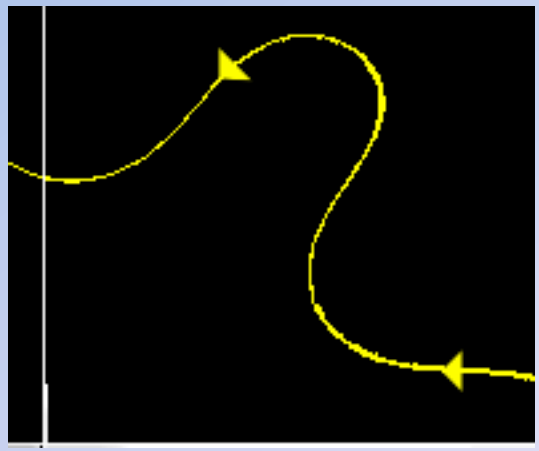
Test Particle Simulations

- Single particle simulation
  - Numerical calculation using Hamilton's equations of motion with prescribed fields
  - Trace particle around machine
  - Must assume collisionless Hamiltonian
- Not a fluid model
- Not a particle in cell model
  - Simulates multiple particles

Particle Orbits
No electric Field







Cyclotron Orbits

- Lowest energy
- Ions drift in -ϕ direction. Electrons in +ϕ

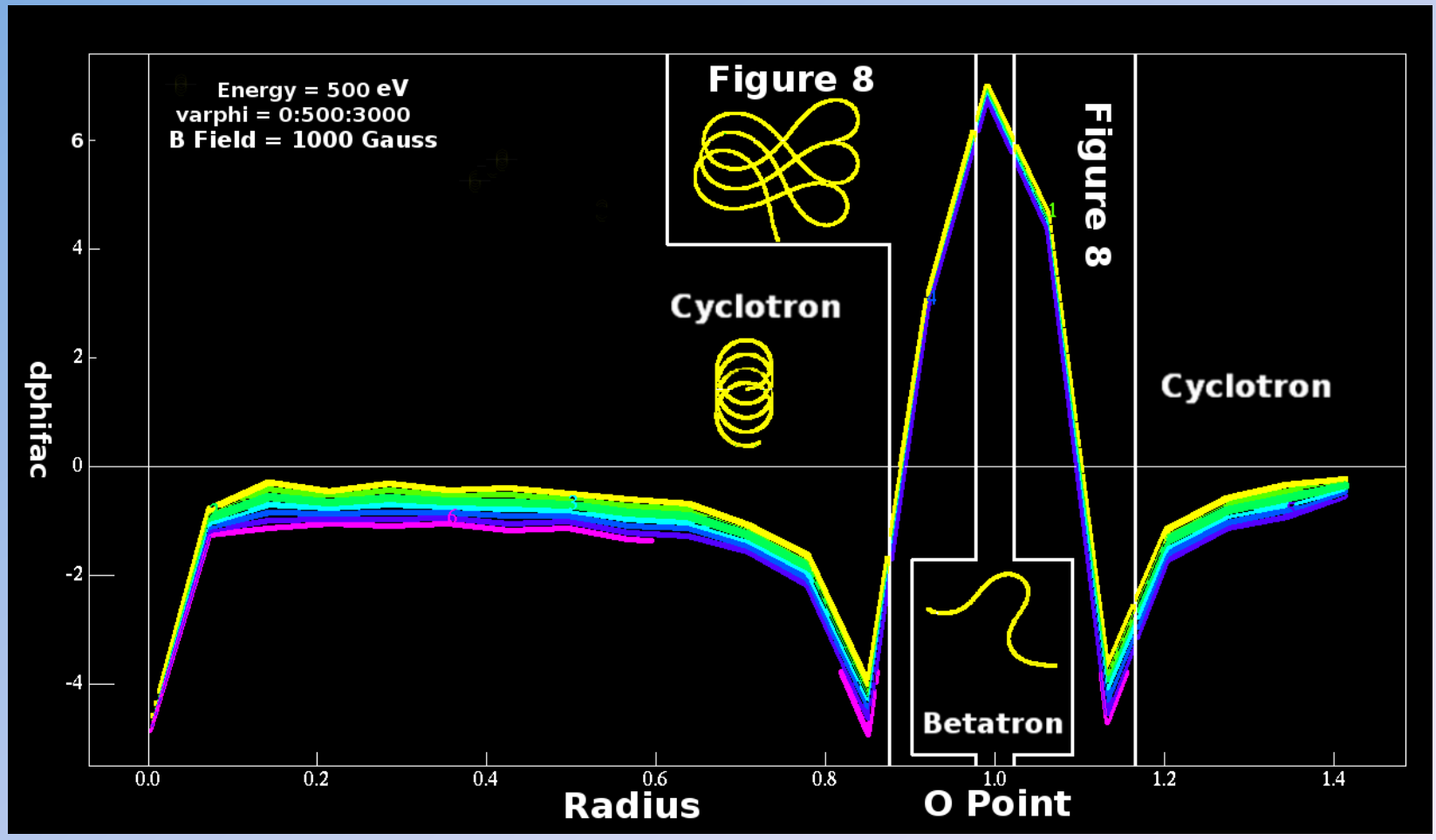
Figure Eight Orbits

- Medium energy
- Drift in either + ϕ or $-\phi$ direction

Betatron Orbits

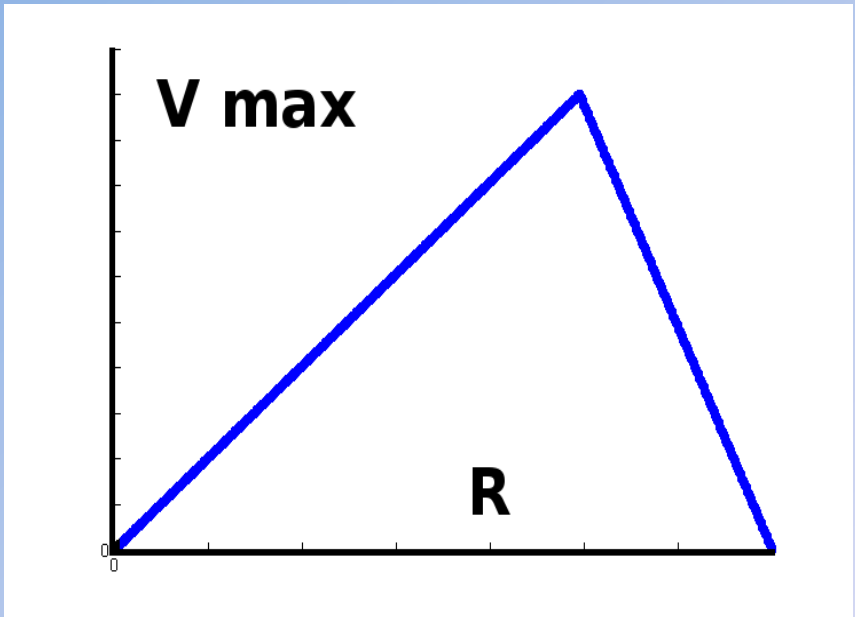
- Highest energy
- Ions drift in +ϕ direction. Electrons in -ϕ direction

Orbits

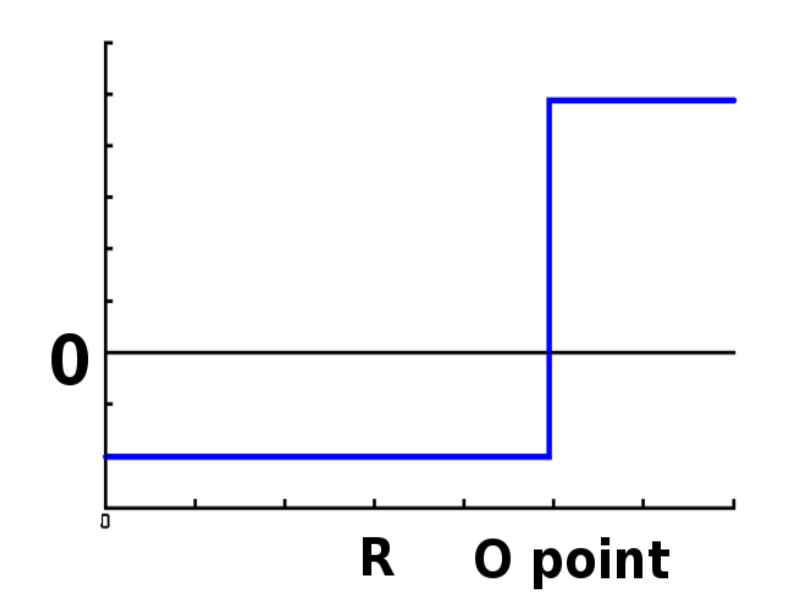

Energy = 500 eV
varphi = 0:500:3000
B Field = 1000 Gauss
Figure 8
Figure 8
Cyclotron
Cyclotron
Betatron
dphifac
6
4
2
0
-2
-4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Radius
O Point

Modeling a Positive Potential

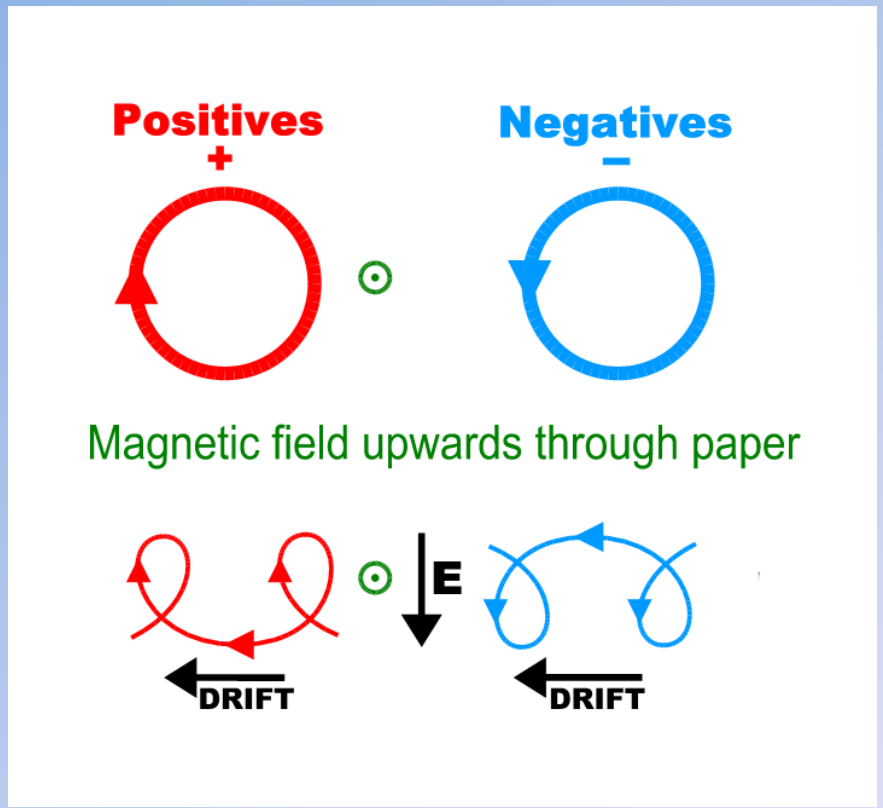
Potential vs. R



E field vs. R



E cross B Drift



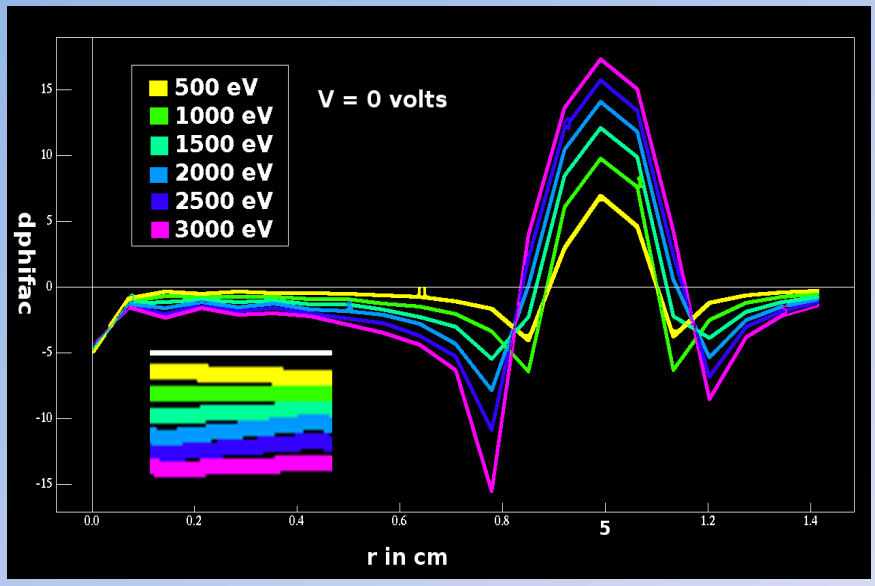
The net effect is a drift in the ExB direction

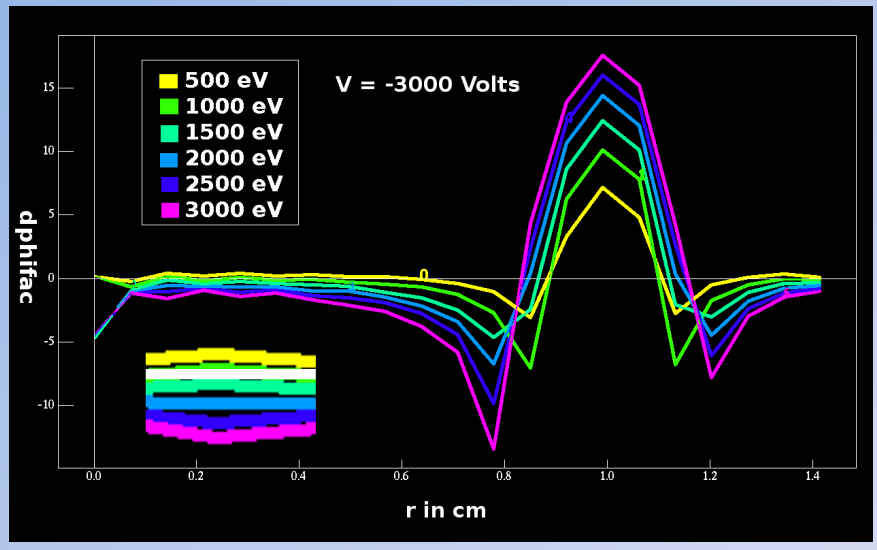
E cross B Drift: In Theory

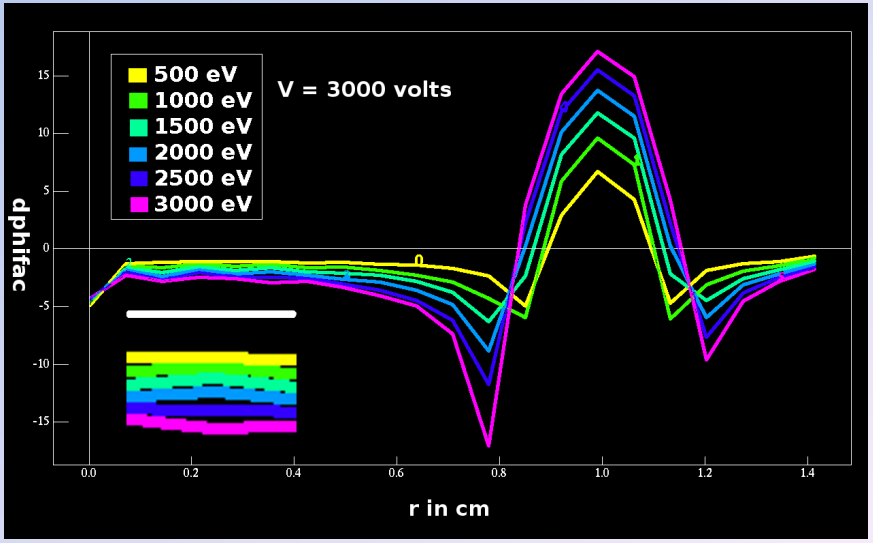
- In the positive potential model, electrons and ions drift in $+\phi$
- In the negative potential model, electrons and ions drift in $-\phi$
- Single particle theory predicts that dphifac of cyclotrons should increase linearly with the voltage

Electrons in a small RMF

Results: dphifac is more positive with higher voltage

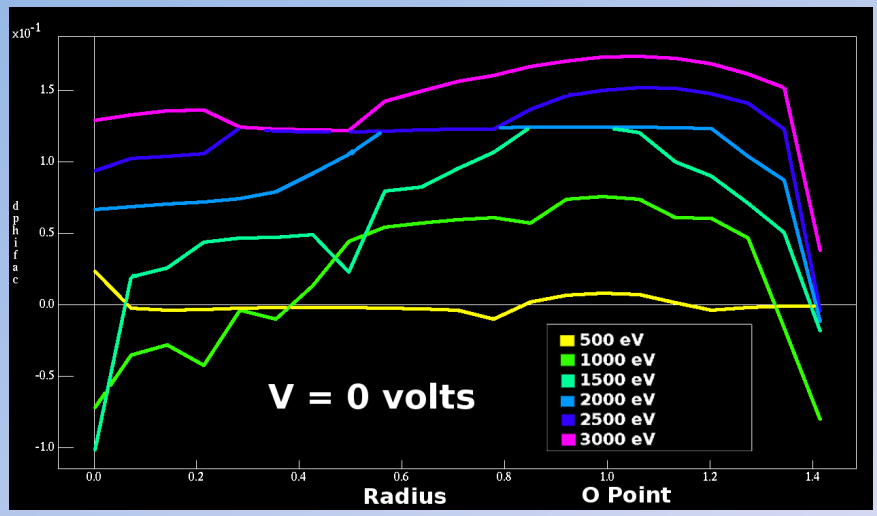


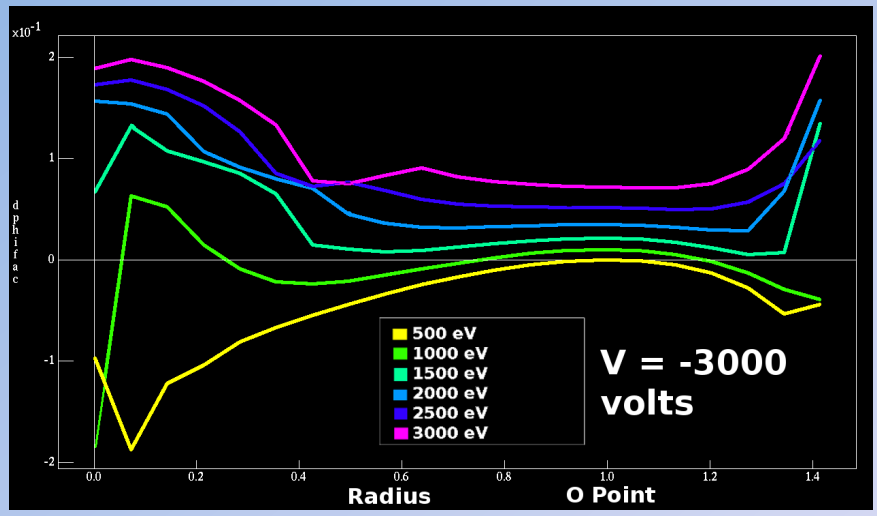


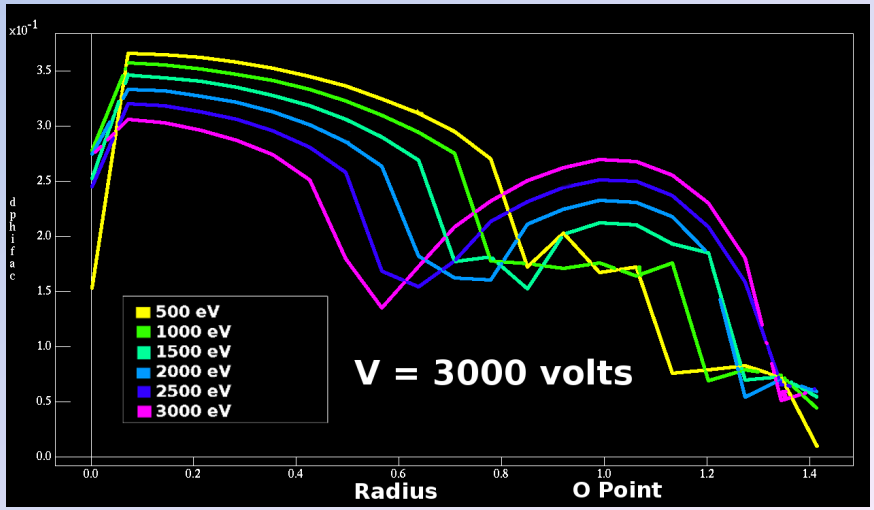


Ions in a small RMF

Results: dphifac is more positive with higher voltage
Up is positive phi direction







Conclusion

- Electric potential linearly affected electron cyclotron orbits
- Figure Eight and Betatron orbits were unchanged by E field
- An increasing E field decreases net current
- E cross B drift may reduce net current but more research is needed to show if the E field affects confinement or not