Particle Trajectory in a Wien Filter

Phyllis Whittlesey

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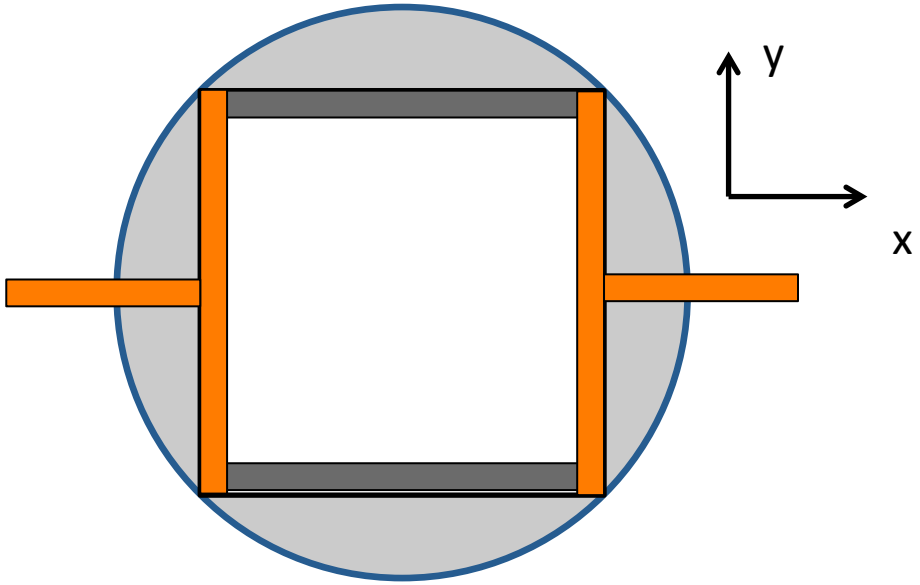
Outline

- Background
  - What is a Wien filter
  - Used in?
  - Description of SPC - parameters
  - Description of test
- Numerical Methods – breakdown of code
  - Definition of boundaries
  - Solution of V
  - Solving for E
  - Nearest neighbor interp in 2D & RK
- Results
  - Parts that are right
    - Show V for 2 scenarios
    - Show different mass
    - Show different velocity
  - Problems
  - Possible Solutions

What is a Wien Filter?

- AKA Mass / Velocity Filter
- Principle based on Lorentz Force



$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

$$-\vec{E} = \vec{v} \times \vec{B}$$

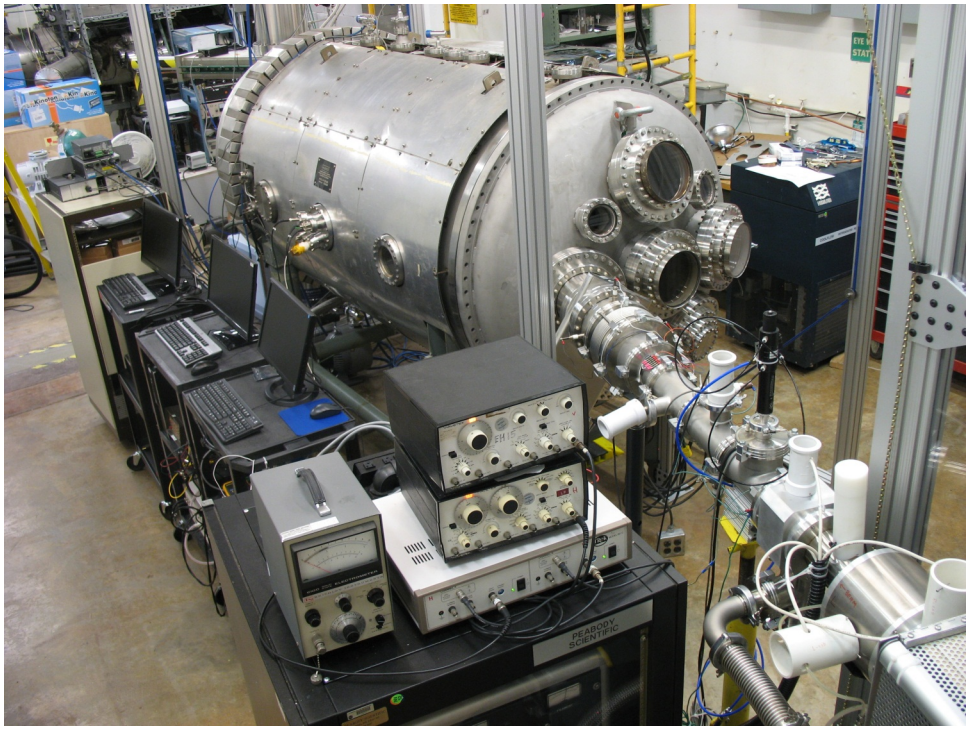
$$\frac{1}{2}\frac{E^2}{B^2}\frac{1}{T} = m$$

$$\frac{\partial U}{\partial z} = -q(E_z - v_x B_y)$$

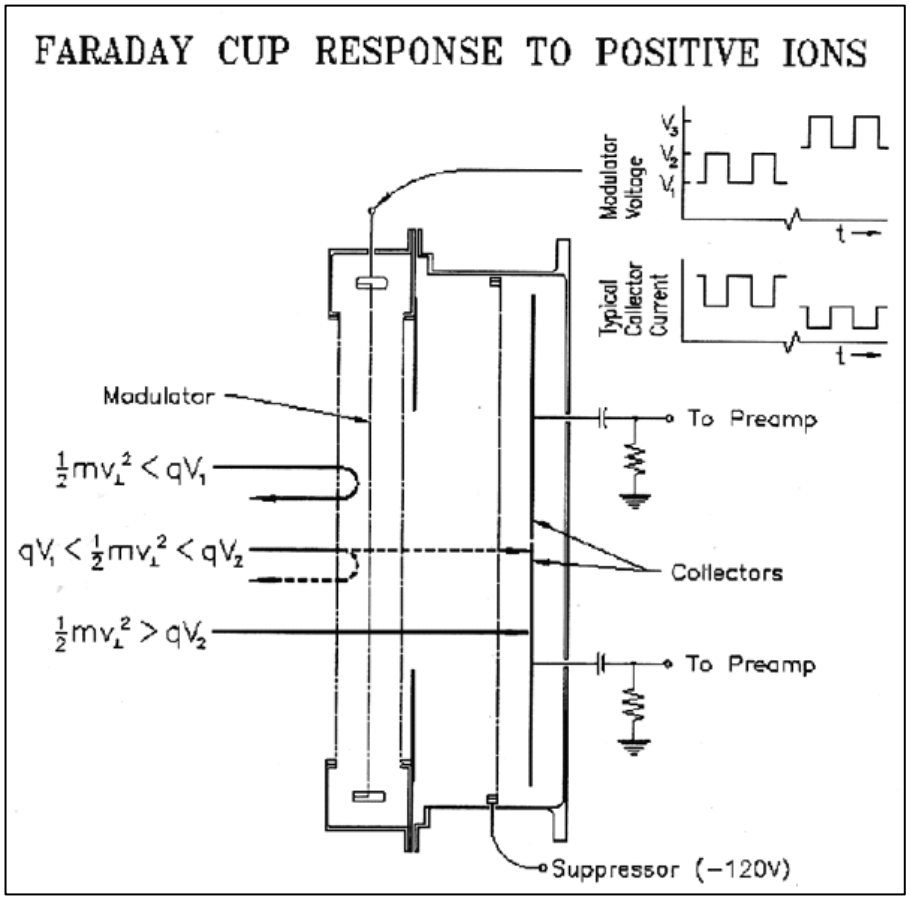
$$\frac{\partial U}{\partial x} = -q(E_x - v_z B_y)$$

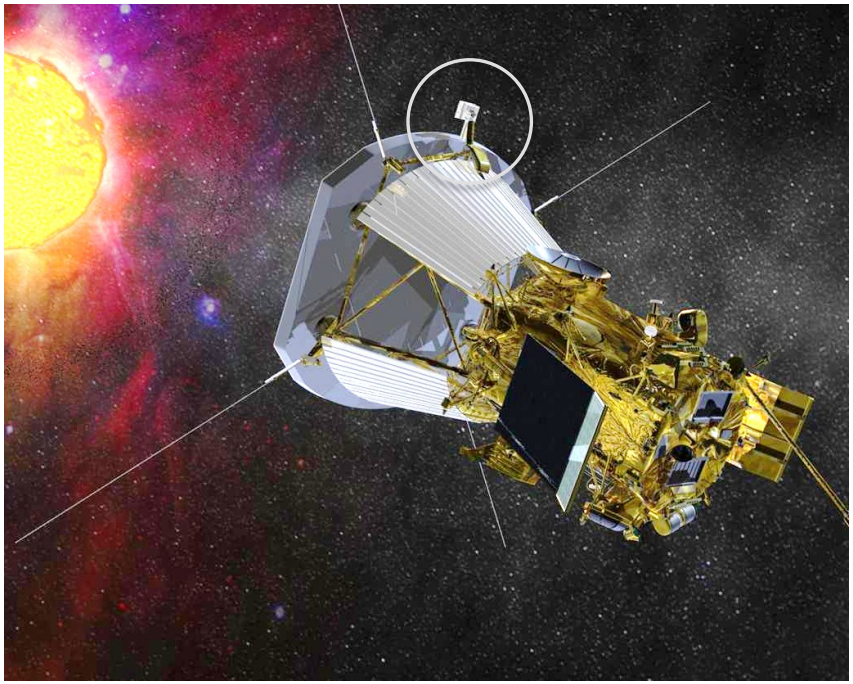
What is a Wien Filter?

- Used in ion beam systems
- Species generated are of same energy
- Mass selector



SPC – Solar Probe Plus





Wien Filter Model

- Define parameters & boundaries for B & E
  - B Uniform, E solved from V
- Parts taken from sor_poisson2.cc
- Grid size driven by source dimensions
- Takes between 2000 & 7000 iterations

$$\nabla^2 V = 0$$

$$M = 1001$$

$$N = 101$$

$$V0 = 100 - 100000$$

Wien Filter Model

- Solve for E from V
- Fourth order central five point stencil
- Yields results in x & z

$$V = -\nabla\vec{E}$$

$$f'(x) = \frac{1}{12\Delta}(f_{i-2} - 8f_{i-1} + 8f_{i+1} - f_{i+2})$$

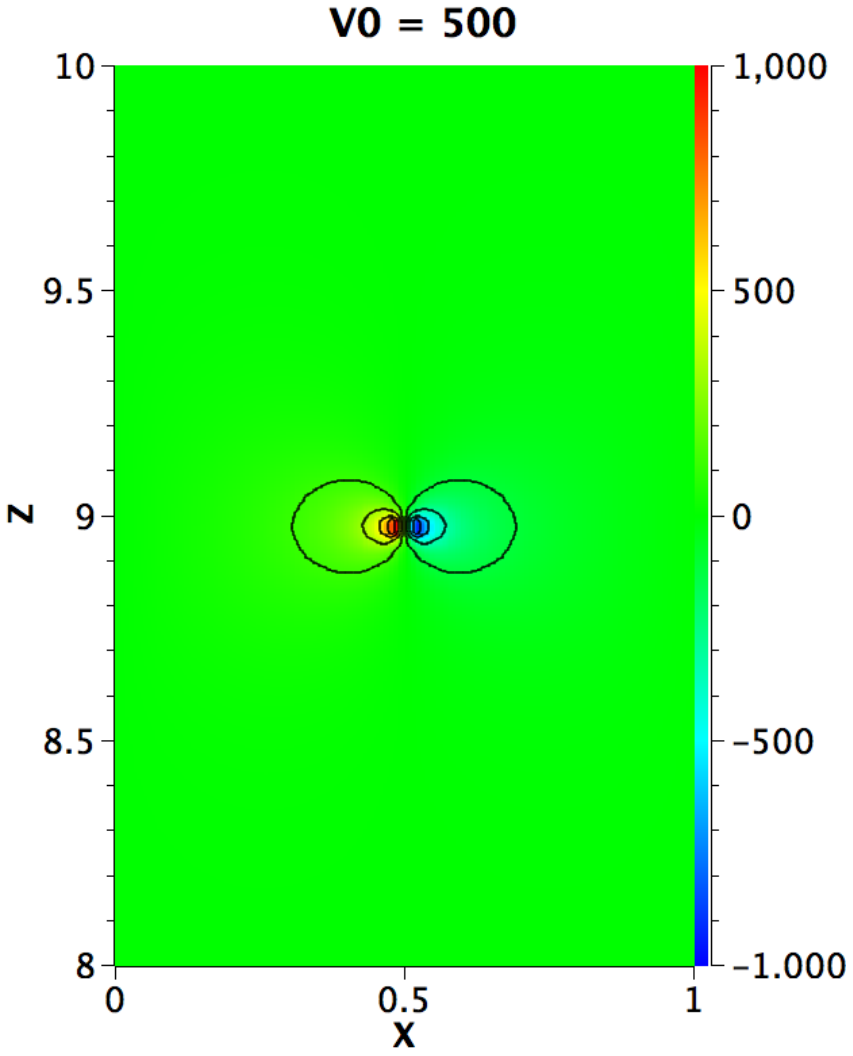
Wien Filter Model

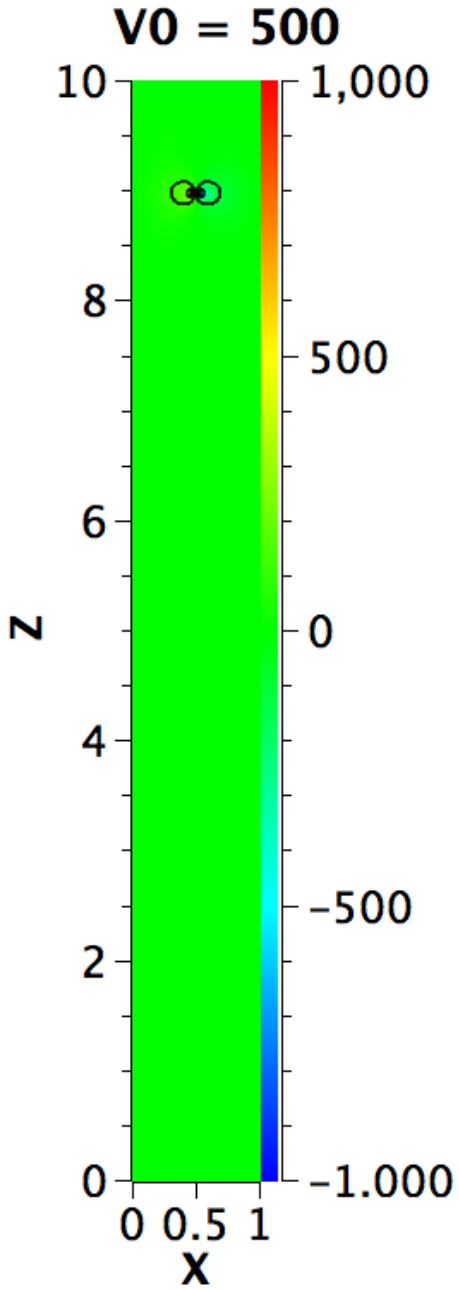
- Particle trajectory
  - RK4 method used
  - E inputs handled using “nearest neighbor” approximation

$$\frac{\partial U}{\partial z} = -q(E_z - v_x B_y)$$

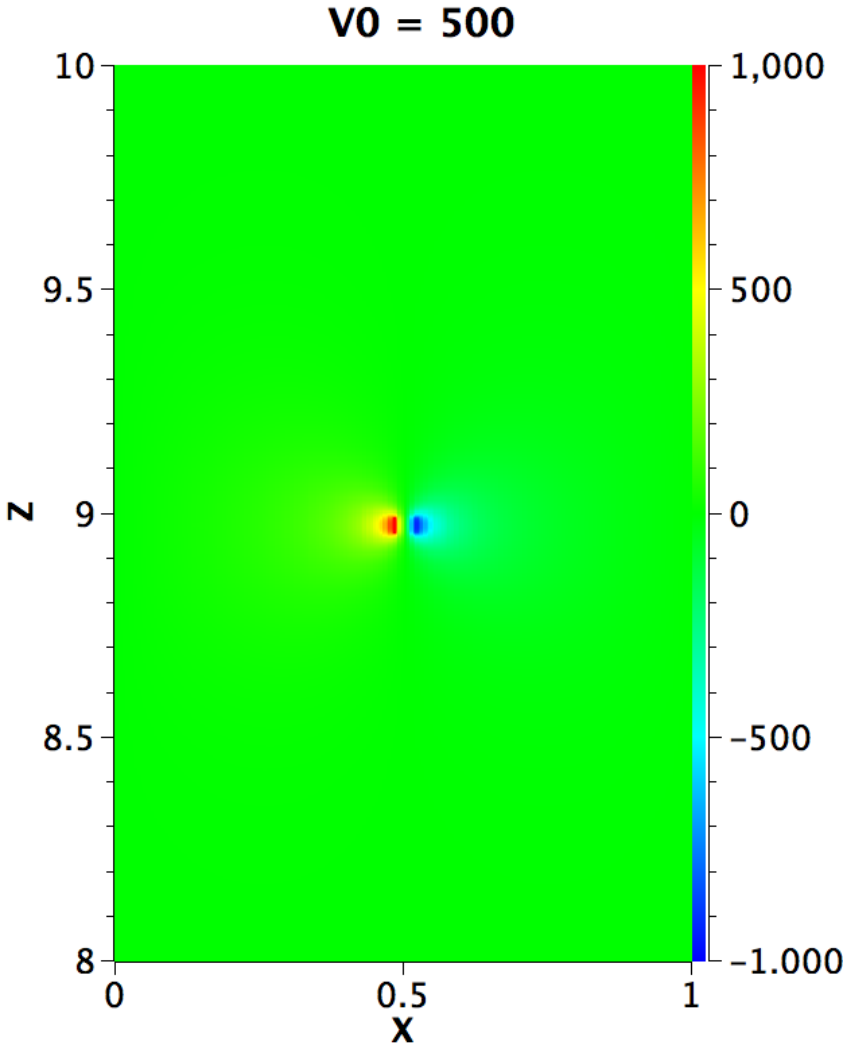
$$\frac{\partial U}{\partial x} = -q(E_x - v_z B_y)$$

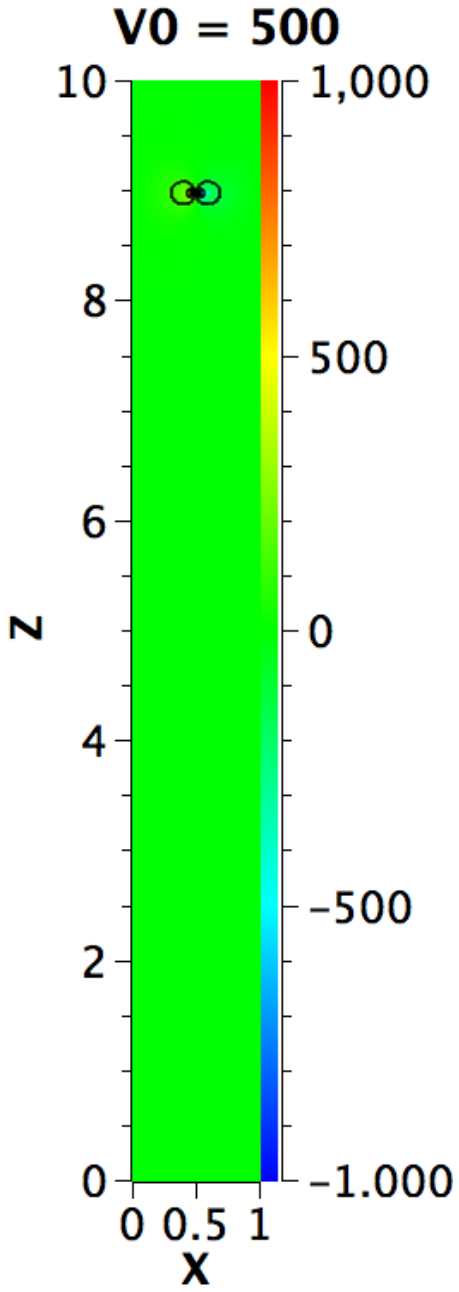
Results - V


V0 = 500
10
9.5
9
8.5
8
z
0
0.5
1
x
1,000
500
0
-500
-1.000

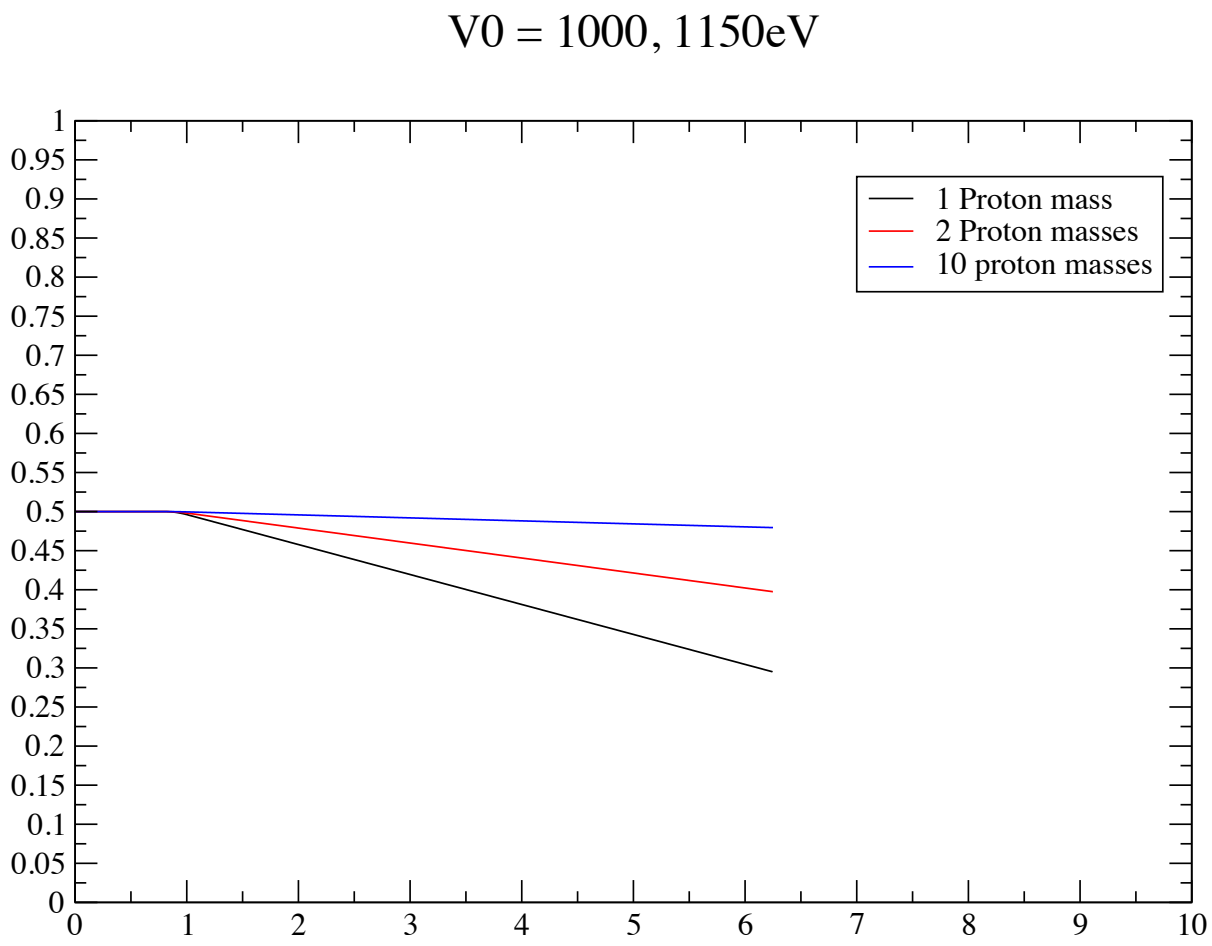

V0 = 500
10
8
6
4
2
0
z
0 0.5 1
x
1,000
500
0
-500
-1.000

Results - V

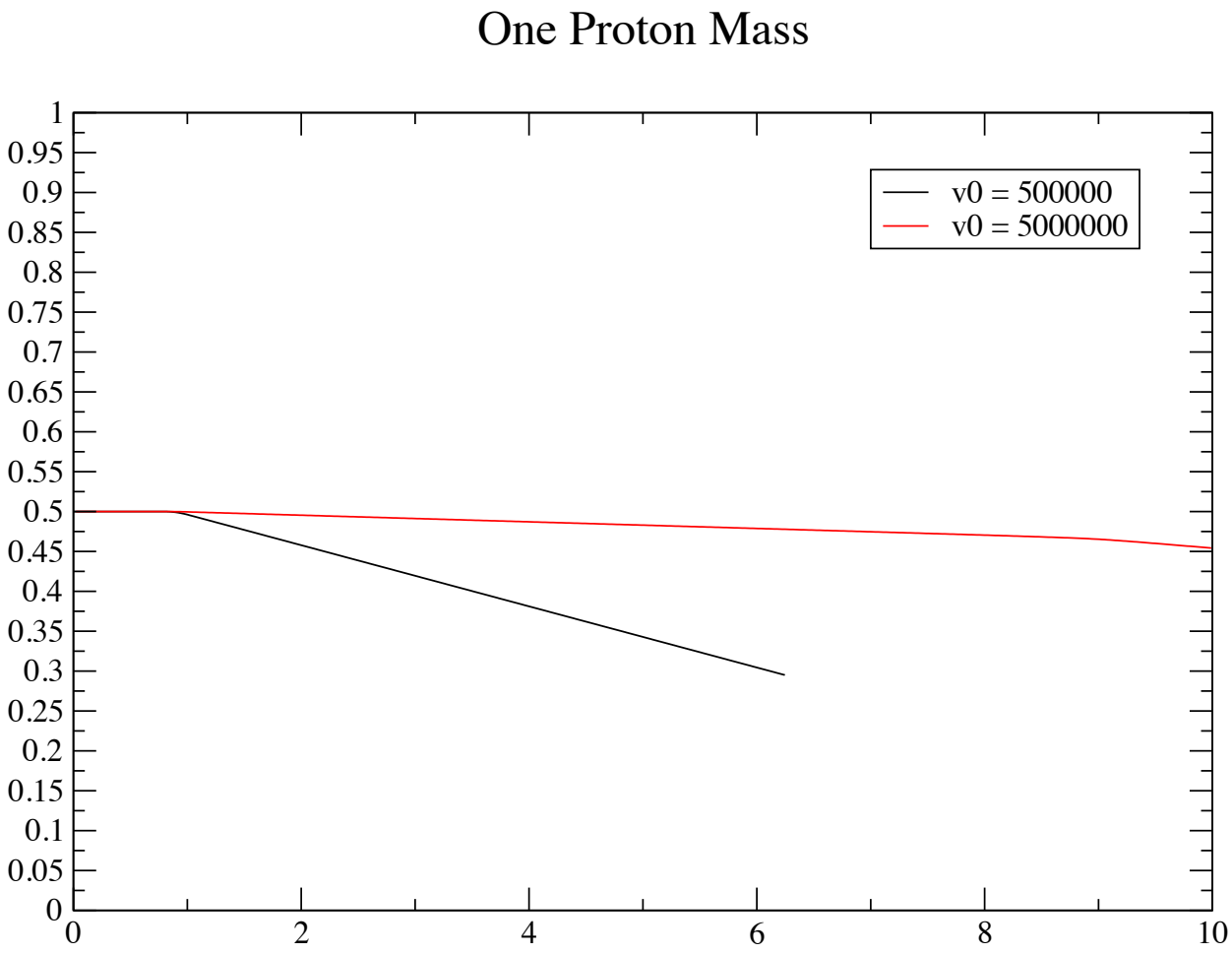

V0 = 500
10
9.5
9
8.5
8
z
0
0.5
1
x
1,000
500
0
-500
-1.000


V0 = 500
10
8
6
4
2
0
z
0
0.5
1
x
1,000
500
0
-500
-1.000

Results – Mass



Results – Velocity



Problems

- Electric field doesn't seem to be working properly within RK4 section
  - No ion trajectories for x > 0.5m
- Edge of field behavior
  - Ions shouldn't experience force near edge of field
  - Could be result of beam pipe structure narrow exit aperture

Future Work

- Resolve E field problem
- Develop a better B field model & implement
- Look at developing 3D model for filter