Particle Trajectory in a Wien Filter

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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

FARADAY CUP RESPONSE TO POSITIVE IONS

\[ \frac{1}{2} m v_1^2 < q V_1 \]

\[ q V_1 < \frac{1}{2} m v_2^2 < q V_2 \]

\[ \frac{1}{2} m v_2^2 > q V_2 \]

Suppressor (-120V)
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

\[ \nabla^2 V = 0 \]

\[ M = 1001 \]

\[ N = 101 \]

\[ V_0 = 100 - 100000 \]
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
Results – Mass

\[ V_0 = 1000, 1150\text{eV} \]
Results – Velocity

One Proton Mass

\[ v_0 = 500000 \]

\[ v_0 = 5000000 \]
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