Simulation of Relativistic Electrons Through a Magnetic Chicane

Matthias Fuchs
University of Nebraska-Lincoln, mfuchs@unl.edu

John Chrostek
University of Nebraska-Lincoln

Nathan W. Ray
University of Nebraska-Lincoln, nathan.ray@huskers.unl.edu

Jordan O'Neal
University of Nebraska-Lincoln

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The path length of the electrons is composed of two parts:
1. In the magnet, electrons move in a circular path with radius \( r \) based on their energy which is reflected by the \( \gamma \) term.
   \[ r = \frac{\gamma mc}{qB} \sqrt{\gamma^2 - 1} \]
   Taking into account the length of the magnet, \( l \), we obtain a path length of
   \[ s_m = r \cdot \arcsin \left( \frac{l}{r} \right) \]
2. Outside of the magnet, the paths lengths are determined by the angle the electrons make when leaving the magnet, \( \theta \), and the magnet separation \( d \).
   \[ s_d = \frac{d}{\cos(\theta)} \]
Combining the previous equations and accounting for the design of the chicane yields a total path length of
\[ s = 4s_m + 2s_d + d \]
Since \( s_m \) is significantly smaller than \( s_d \), and \( d \) is constant, we can ignore these terms when calculating the difference in path lengths.
\[ \Delta s = 2d \left( \frac{1}{\frac{1}{r_0^2} - \frac{1}{r_1^2}} \right) \]

**Results**
- **Input Parameters:**
  - \( \gamma = 2000 \) Lorentz factor of the base electron,
  - \( \delta = 5\% \) Energy difference,
  - \( B = 1T \) Magnetic field strength,
  - \( l = 2 \text{ cm} \) Magnet length,
  - \( d = 2 \text{ cm} \) Distance between the magnets.
- First, we used MATLAB to model a simple experiment involving 2 electrons. This was based on our theoretical calculations.
- Second, we used GPT to model a more complex experiment involving a beam of electrons.
- We examined the path length difference between the high and low energy electrons.
  - MATLAB: \( 0.108326 \mu m \)
  - GPT: \( 0.108297 \mu m \)
  - Difference: \( 0.03\% \)

**Implications and Future Research**
- We have been able to model electrons traversing a chicane.
- Due to the small difference between our two approaches, we believe our results are accurate.
- Our next step is to use the models we developed to find an optimal setup for compressing the electron bunch. This will allow us to create better quality X-rays.

**References for theoretical calculations:**