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Approximation of Space Charge Effect in the Presence of Longitudinal Magnetic Fields



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Verification with Astra

A fast approximation algorithm based on the infinitely long uniform beam model have been developed. By focusing solely on the motion of the outermost particle, it achieves a good fit with Astra. This validation and its efficiency provide opportunities for additional calculations







Method

- $-\ddot{x} = A_1 x A_2 \dot{y}; \ \ddot{y} = A_1 y + A_2 \dot{x}$
- $-A_1 = qI/\gamma^3 m_0 2\pi\varepsilon_0 \beta cR_0^2; A_2 = qB/\gamma m_0$
- 4th order Runge-Kutta Comparison
- Relative errors: below 3%
- Time: several minutes to < 1s

Approximation results

Features

- Expansion
 - Mitigated by the longitudinal B
 - R no longer increases monotonically
- Oscillation
- With distance period 2*D* and amplitude R_m - $B \uparrow \Rightarrow D \downarrow \& R_m \downarrow$

When an external longitudinal magnetic field is introduced, the expansion of the beam under the influence of space charge is mitigated through beam rotation. Additionally, the beam's radius exhibits periodic oscillations as the transport distance increases. By employing a fast approximation algorithm, we are able to accurately fit the oscillation parameters using polynomials of the reciprocal of the magnetic field. These results provide valuable insights for controlling

 $-B \rightarrow +\infty \Rightarrow R_m \rightarrow R_0$

Parameters	Reference Beam	Test Beam
Gamma	20.57	20
Kinetic energy	10 MeV	9.71 MeV
Initial radius	2.0 mm	5.0 mm
Initial length	50 mm	50 mm
Equivalent current	2.997 A	5.993 A
Transport distance	50 m	50 m
Charge	-0.5 nC	-1.0 nC

the phase space of the beam.



[1] J. Amundson, P. Spentzouris, J. Qiang, et al., Synergia: An accelerator modeling tool with 3-D space charge, J. Com-put. Phys. 211, 229 (2006). doi: 10.1016/j.jcp.2005.05.024
[2] K. Schindl, in Joint US-CERN-Japan-Russia Particle Ac-celerator School on Beam Measurement, ed. by S.I. Kuro-kawa (Montreux, Switzerland, 1998), pp. 127-151. doi: 10.1142/9789812818003_0004

[3] https://www.desy.de/~mpyflo/