



General Particle Tracer (GPT) Simulations of Proposed Stern- Gerlach Experiment Layout

A. Hofler

March 29, 2017

Summary of Elegant Model

- Beam characteristics

- $p_{\text{central}} = 1.732 m_e c \Rightarrow E_k = 507.7 \text{ keV}$
- $Q = 0.65 \text{ nC} \Rightarrow 325 \text{ mA}$ at 499 MHz
- $\sigma_{x,y} = 7 \text{ mm}$
- $\sigma_t = 1.16 \text{ ps}$
- $\epsilon_{n(x,y)} = 1 \text{ mm mrad}$

| Beam line element | Length (cm) | Setting | Center location (m) |
|------------------------------------|-------------|---|---------------------|
| Solenoid | 5 | 0.0293 T | 0.1860 |
| Permanent Magnet Quadrupole (PMQ)* | 0.6* | $K1 = -133333 \text{ 1/m}^2 \Rightarrow -400 \text{ T/m}^*$ | 1.0029 |
| Solenoid | 5 | 0.0293 T | 1.8198 |
| Solenoid | 5 | 0.0293 T | 2.1918 |
| PMQ | 0.6* | $K1 = 133333 \text{ 1/m}^2 \Rightarrow 400 \text{ T/m}^*$ | 3.0087 |
| Solenoid | 5 | 0.0293 T | 3.8256 |

*R. K. Li and P. Musumeci, Phys. Rev. Applied **2** 024003 (2014)

Summary of GPT Model

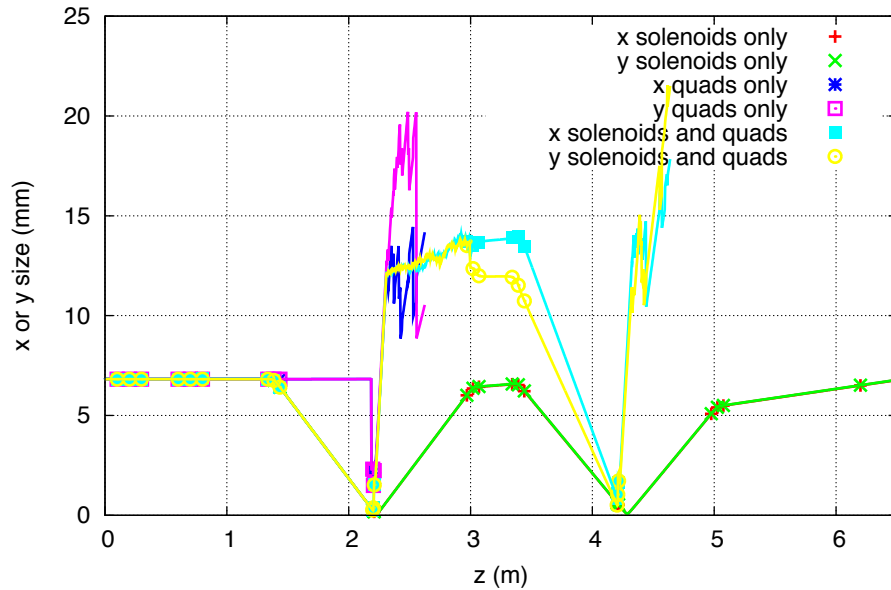
- Analytical magnet models
 - Solenoid does not remove particles (setpoint in nI (A turns/m))
 - Quadrupole has fringe fields and removes particles
- Matching quads arbitrarily placed and unused
- Beampipe aperture 5.4 cm
- Beam characteristics
 - $E_k=507.7$ keV
 - $Q=0.34$ pC \Rightarrow 170 μ A at 499 MHz
 - $\sigma_{x,y}=6.45-6.83$ mm
 - $\sigma_t=1.16$ ps
 - $\epsilon_{n(x,y)}=1$ mm mrad
- 5000 macro-particles

| Beam line element | Length (cm) | Aperture (cm) | Attempted Setting | Center location (m) |
|-------------------|-------------|---------------|---|---------------------|
| Quadrupole | 10 | 5.4 | 0 | 0.2 |
| Quadrupole | 10 | 5.4 | 0 | 0.7 |
| Solenoid | 5 | 5.4 | 0.0293 T \Rightarrow 34363 A turns/m | 1.3860 |
| PMQ | 0.6* | 0.3* | -400 T/m* | 2.2029 |
| Solenoid | 5 | 5.4 | 0.0293 T \Rightarrow 34363 A turns/m | 3.0198 |
| Solenoid | 5 | 5.4 | 0.0293 T \Rightarrow 34363 A | 3.3918 |
| PMQ | 0.6* | 0.3* | 400 T/m* | 4.2087 |
| Solenoid | 5 | 5.4 | 0.0293 T \Rightarrow 34363 A turns/m | 5.0256 |

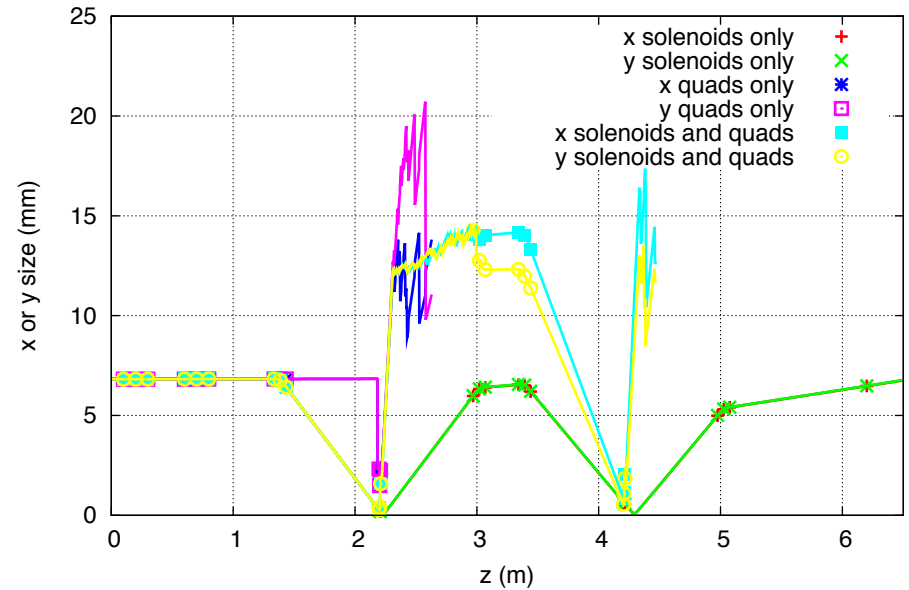
*R. K. Li and P. Musumeci, Phys. Rev. Applied **2** 024003 (2014)

Default Solenoid and Quad Settings

Transverse Beam Size: No SC initial size 6.83 mm
Default Solenoid and Quad Settings



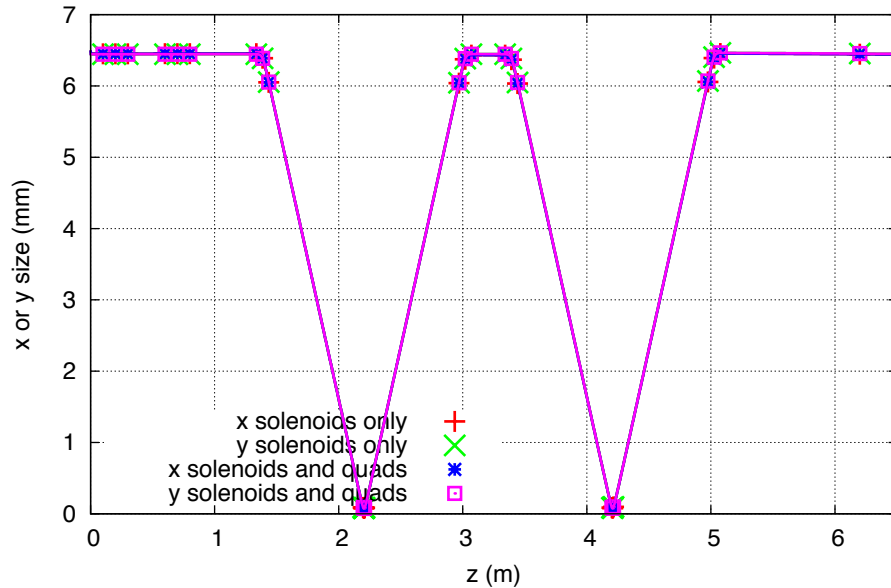
Transverse Beam Size: SC initial size 6.83 mm
Default Solenoid and Quad Settings



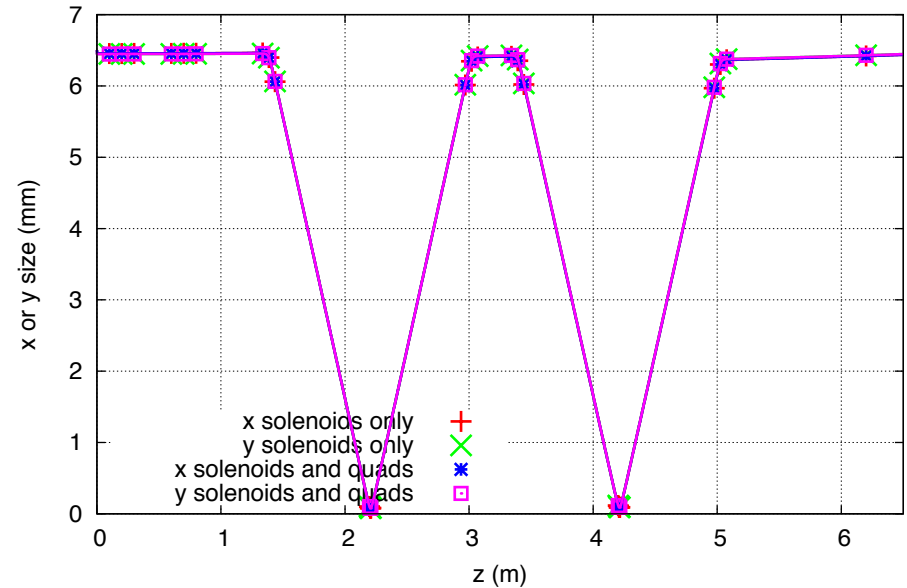
With space charge off, solenoids at default settings, and quads off, adjusted beam size to achieve 100% particle transmission. 7 mm \Rightarrow 6.83 mm

Modified Solenoid and Quad Settings

Transverse Beam Size: No SC initial size 6.45 mm
Modified Solenoid and Quad Settings

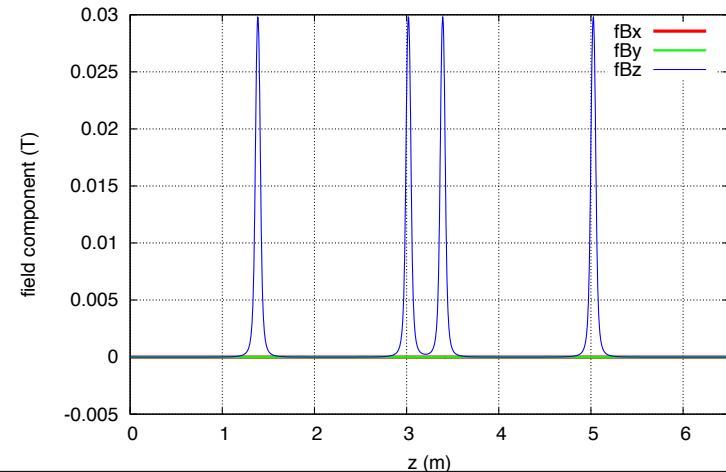


Transverse Beam Size: SC initial size 6.46 mm
Modified Solenoid and Quad Settings



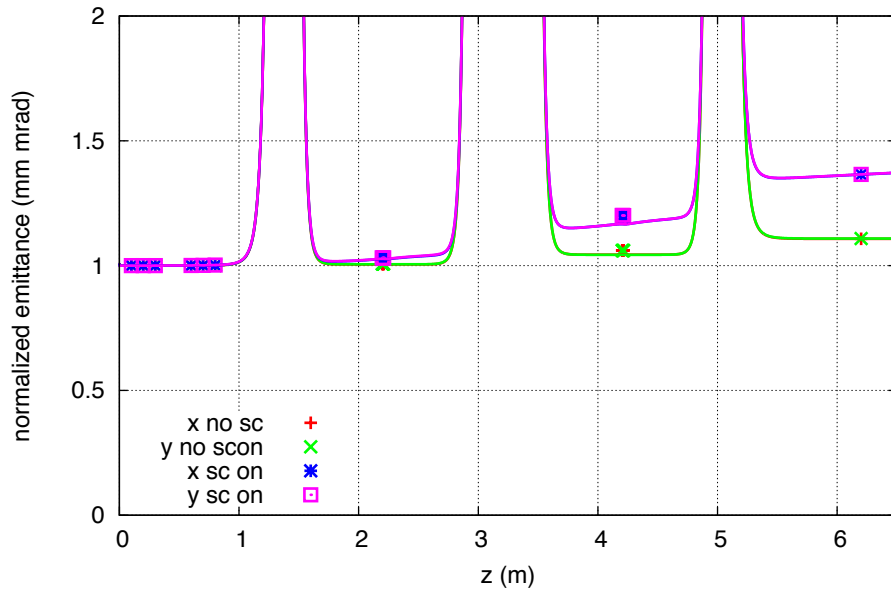
- 1) With space charge off and quads off, adjusted solenoid to focus beam at center of quadrupole. 34363 A turns/m \Rightarrow 34884 A turns/m (~ 1.015 times default)
- 2) With space charge off and quadrupoles off, adjusted beam size to achieve 100% transmission. 6.83 mm \Rightarrow 6.45 mm
- 3) With space charge off and solenoids on, adjusted quadrupole setting for 100% transmission. 400 T/m \Rightarrow 0.002 T/m ($\sim 5 \times 10^{-6}$ times default)
- 4) With space charge on, adjusted beam size for 100% transmission. 6.83 mm \Rightarrow 6.46 mm

B field components: No SC initial 6.45 mm
Modified Solenoid and Quad Settings

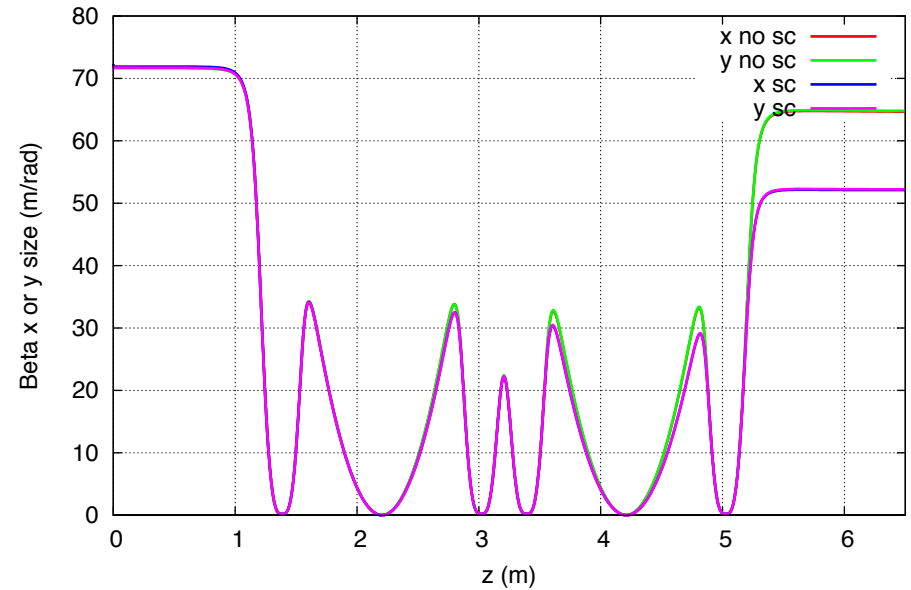


Modified Solenoid and Quad Settings

Normalized Emittance: No SC initial 6.45 mm SC initial size 6.46 mm
Modified Solenoid and Quad Settings



Betas: No SC initial 6.45 mm SC initial size 6.46 mm
Modified Solenoid and Quad Settings



Theoretical Optimal Performance for CEBAF Injector

- For comparison purposes
- Optimization for full injector running
- Beam characteristics just upstream of the entrance to the 500 keV spectrometer
 - $E_k = 487$ keV
 - $0.7 < \sigma_{E_k} < 1.5$ keV
 - $0.002 < Q < 0.34$ pC $\Rightarrow 1 < I < 170$ μ A at 499 MHz
 - $0.1 \leq \sigma_{x,y} \leq 0.7$ mm
 - $1.3 < \sigma_t < 6.5$ ps
 - $0.06 \leq \epsilon_{n(x,y)} \leq 0.2$ mm mrad