中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

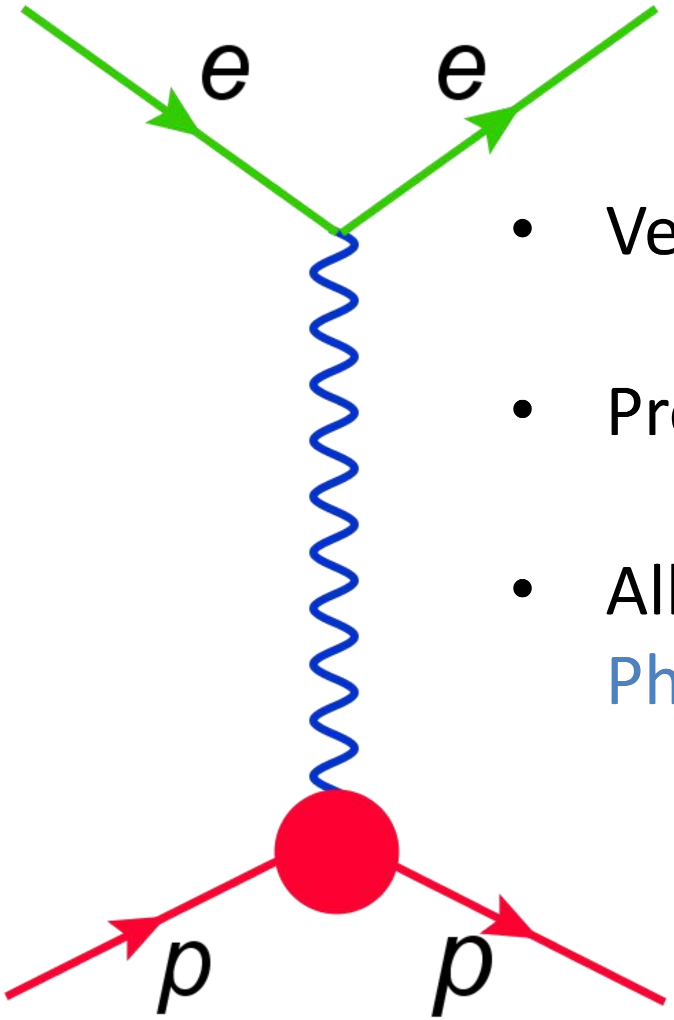
Torodial Magnet Design for The Proton Polarimetry at EicC

Boxing Gou（勾伯兴）
gouboxing@impcas.ac.cn

EicC Bi-weekly Meeting

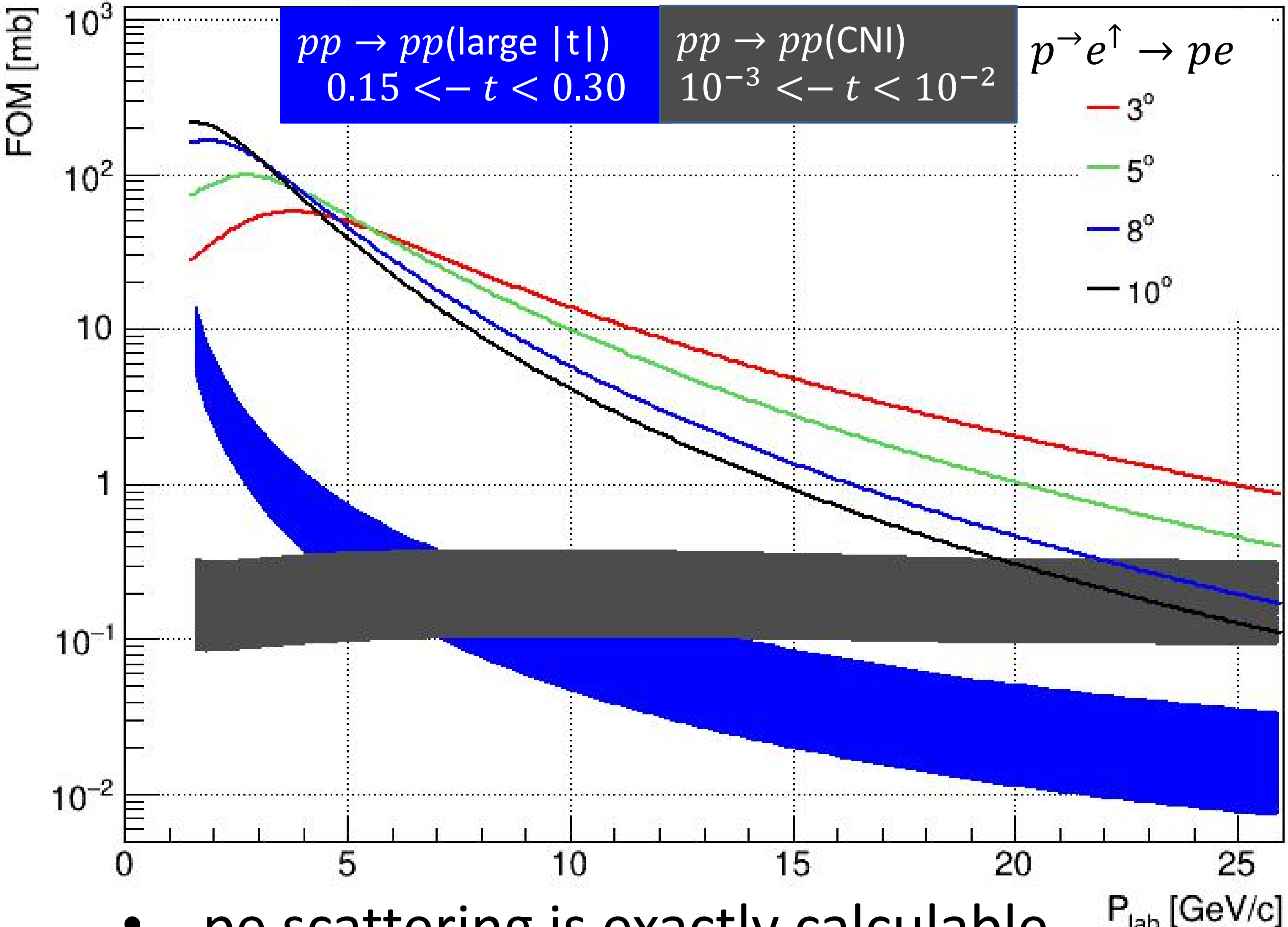
February 16, 2022

pe→pe



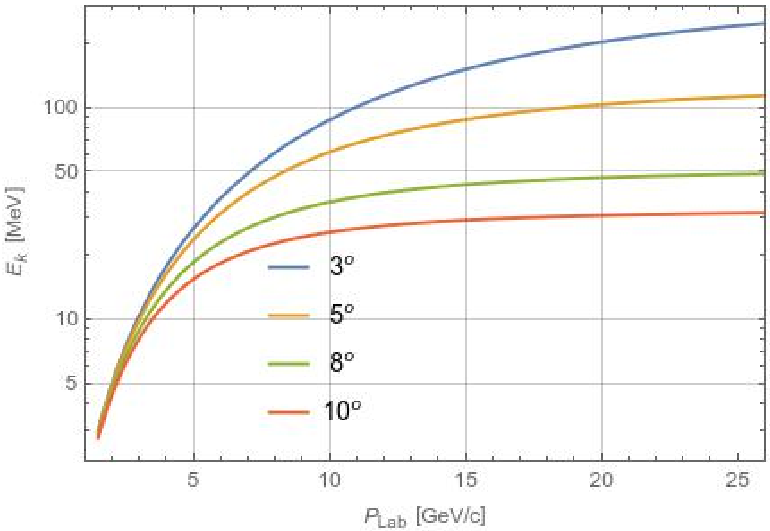
- Very small Q^2 in inverse kinematics
- Proton form factor well measured
- All observables are exactly calculable
  Phys. Rev. C **84**, 015212(2011)

Reference Reactions for Proton Polarimetry



- pe scattering is exactly calculable
- be able to measure longitudianl polarization

Concept for Electron Detection

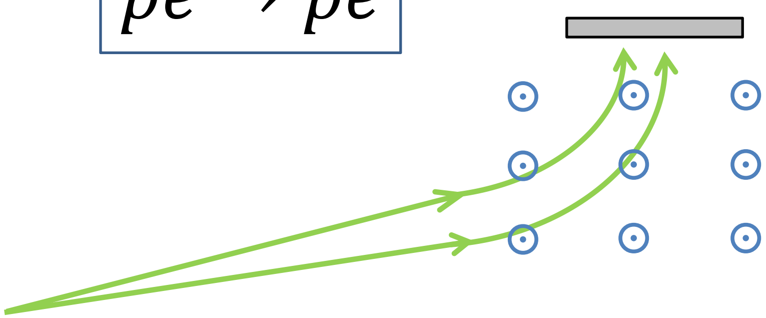


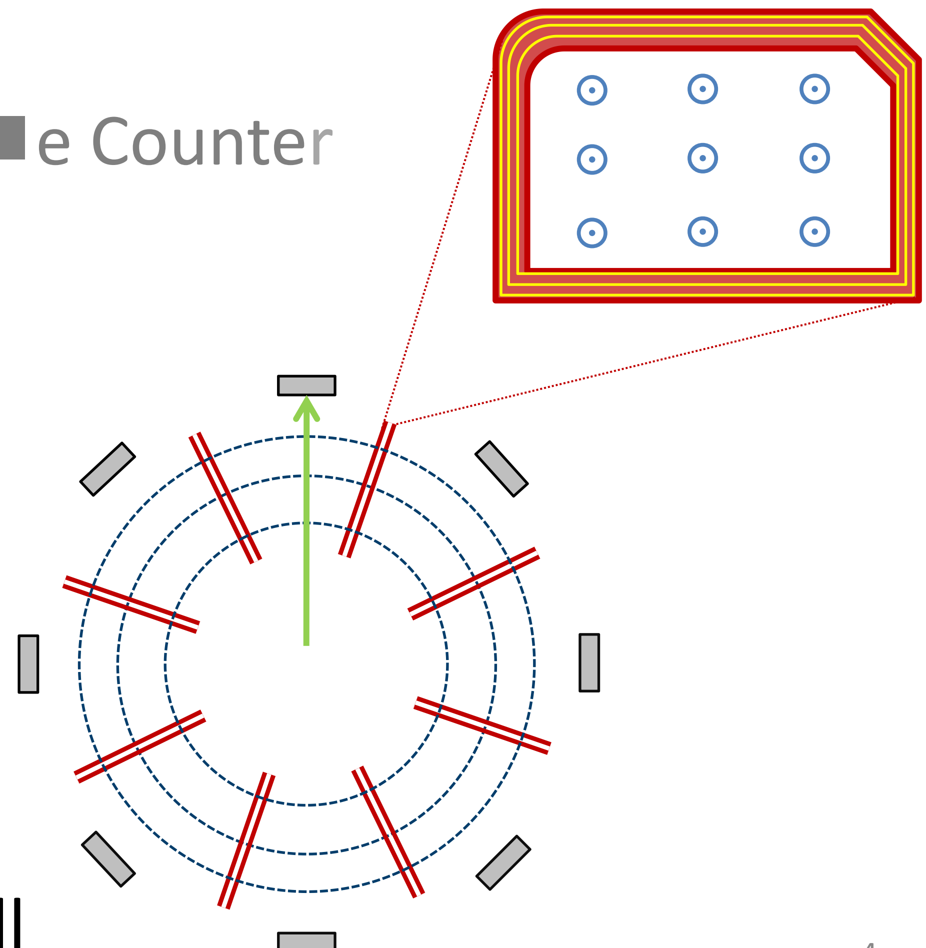
■ Electric coil

■ Toridal magnet

■ e Counter

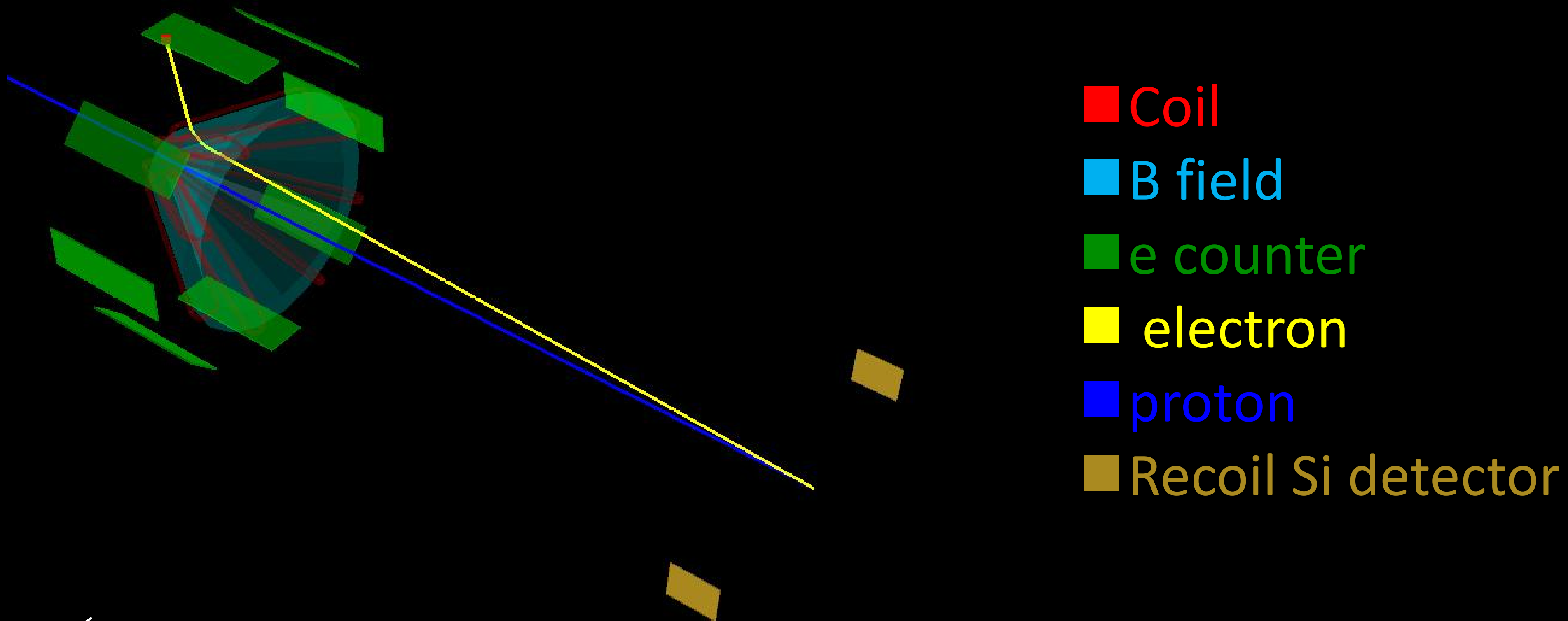
$$pe \to pe$$





Might be applicable to D and 3He beam polarimetry as well

MC Simulation -- Electron Detector



- ✓ MC simulation package ready
- ➢ Many parameters to optimize
  - Field: geometry, position, strength
  - eCounter: geometry, position, material
  - …

Magnet Design -- Particle Motion in B Field

- B field in toroidal magnet follows power distribution
- Charged particles experience Lorentz force in B field

$$\vec{F} = m\frac{d\vec{v}}{dt} = -e\,\vec{v}\times\vec{B}(R) \quad (1)$$

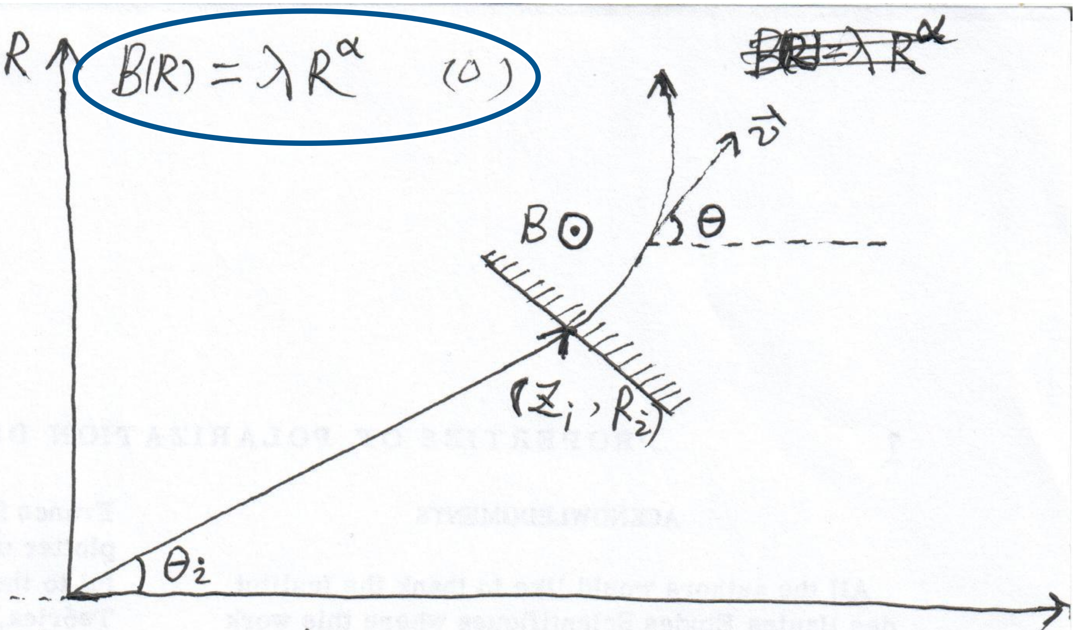
$$B(R) = \lambda R^{\alpha} \quad (0)$$

$$v_R = v\sin\theta \quad (2)$$

$$v_z = v\cos\theta \quad (3)$$

$$\frac{dv_R}{dt} = \frac{e}{m}B(R)\,v_z \quad (4)$$

$$\frac{dv_z}{dt} = -\frac{e}{m}B(R)\,v_R \quad (5)$$



• Substitute (2) and (3) into (5), one obtains

$$d(v\,\overset{\cos\theta}{\cancel{\sin\theta}}) = -\frac{e}{m}B(R)\,v_R\,dt \implies \frac{d(\overset{\cos\theta}{\cancel{\sin\theta}})}{d\theta}\cdot d\theta = -\frac{e}{mv}B(R)\,dR \implies$$

$$\implies \overset{-\sin\theta}{\cancel{-\cos\theta}}\,d\theta = -\frac{e}{mv}B(R)\,dR \quad (6)$$

Magnet Design -- Particle Motion in B Field

The solution

Z and R are functions of θ

$\alpha = -1$

$$R = R_i\, e^{\left[\frac{mv}{e\lambda \frac{1}{R_i} R_i}\left(\cos\theta_i - \cos\theta\right)\right]} = R_i\, e^{\left[\frac{\rho_i}{R_i}\left(\cos\theta_i - \cos\theta\right)\right]}$$

$$Z = Z_i + \rho_i \int_{\theta_i}^{\theta} e^{\left[\frac{\rho_i}{R_i}\left(\cos\theta_i - \cos\theta\right)\right]} \cos\theta \cdot d\theta$$

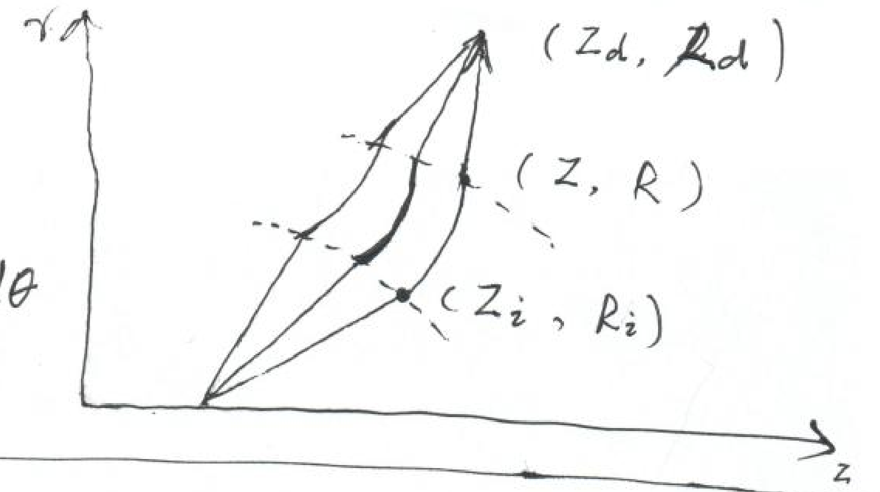
$\alpha \neq -1$

$$R = R_i \left\{1 + \frac{\rho_i}{R_i}(\alpha+1)\left[\cos\theta_i - \cos\theta\right]\right\}^{(\alpha+1)^{-1}}$$

$$Z = Z_i + \rho_i \int_{\theta_i}^{\theta} \frac{\cos\theta}{\left\{1 + \frac{\rho_i}{R_i}(\alpha+1)\left[\cos\theta_i - \cos\theta\right]\right\}^{\frac{\alpha}{\alpha+1}}}\, d\theta$$

Magnet Design -- Find The Focal Point

$$
\begin{cases}
R = R_i \, e^{\left[\frac{\rho_i}{R_i}(\cos\theta_i - \cos\theta)\right]} \\[2ex]
Z = Z_i + \rho_i \displaystyle\int_{\theta_i}^{\theta} e^{\left[\frac{\rho_i}{R_i}(\cos\theta_i - \cos\theta)\right]} \cos\theta \, d\theta
\end{cases}
$$



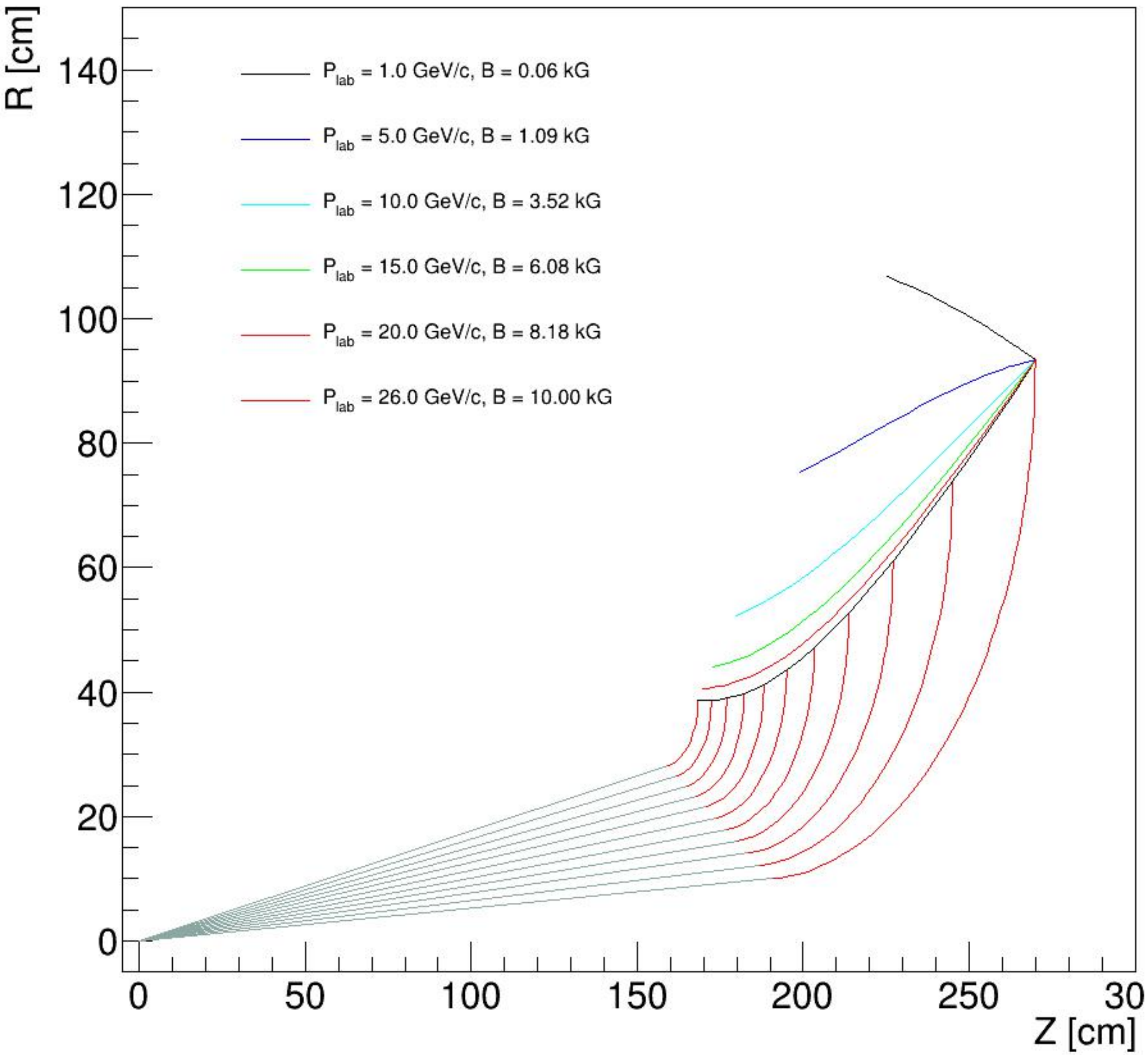
$$\frac{R_d - R}{Z_d - Z} = \tan\theta$$

$$\frac{R_d - R_i \, e^{\frac{\rho_i}{R_i}(\cos\theta_i - \cos\theta)}}{Z_d - Z_i - \rho_i \displaystyle\int_{\theta_i}^{\theta} e^{\frac{\rho_i}{R_i}(\cos\theta_i - \cos\theta)} \cos\theta \, d\theta} = \tan\theta$$

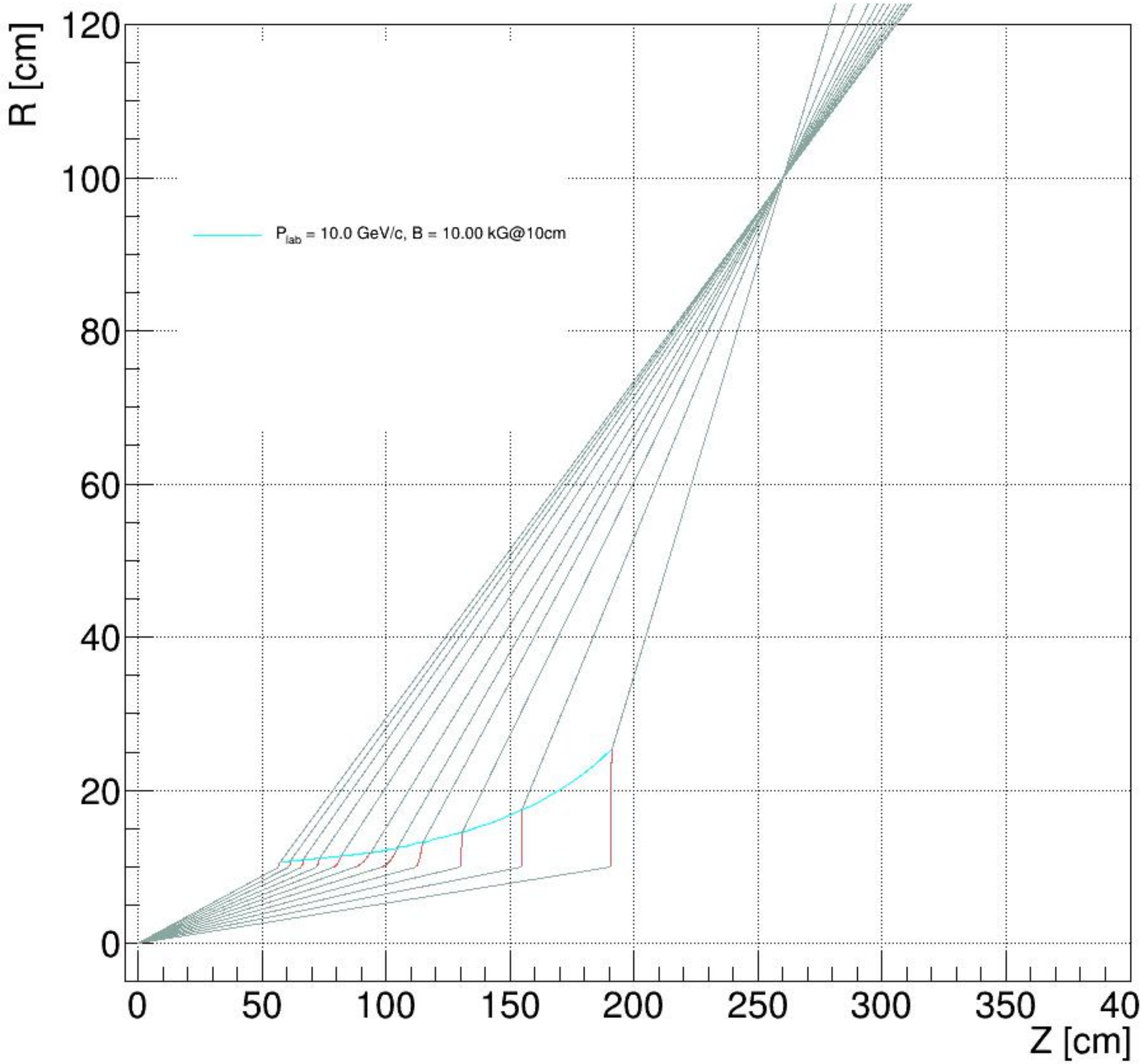
- θ determined numerically
- Exit boundary calculated from θ

Magnet Design -- Crosscheck

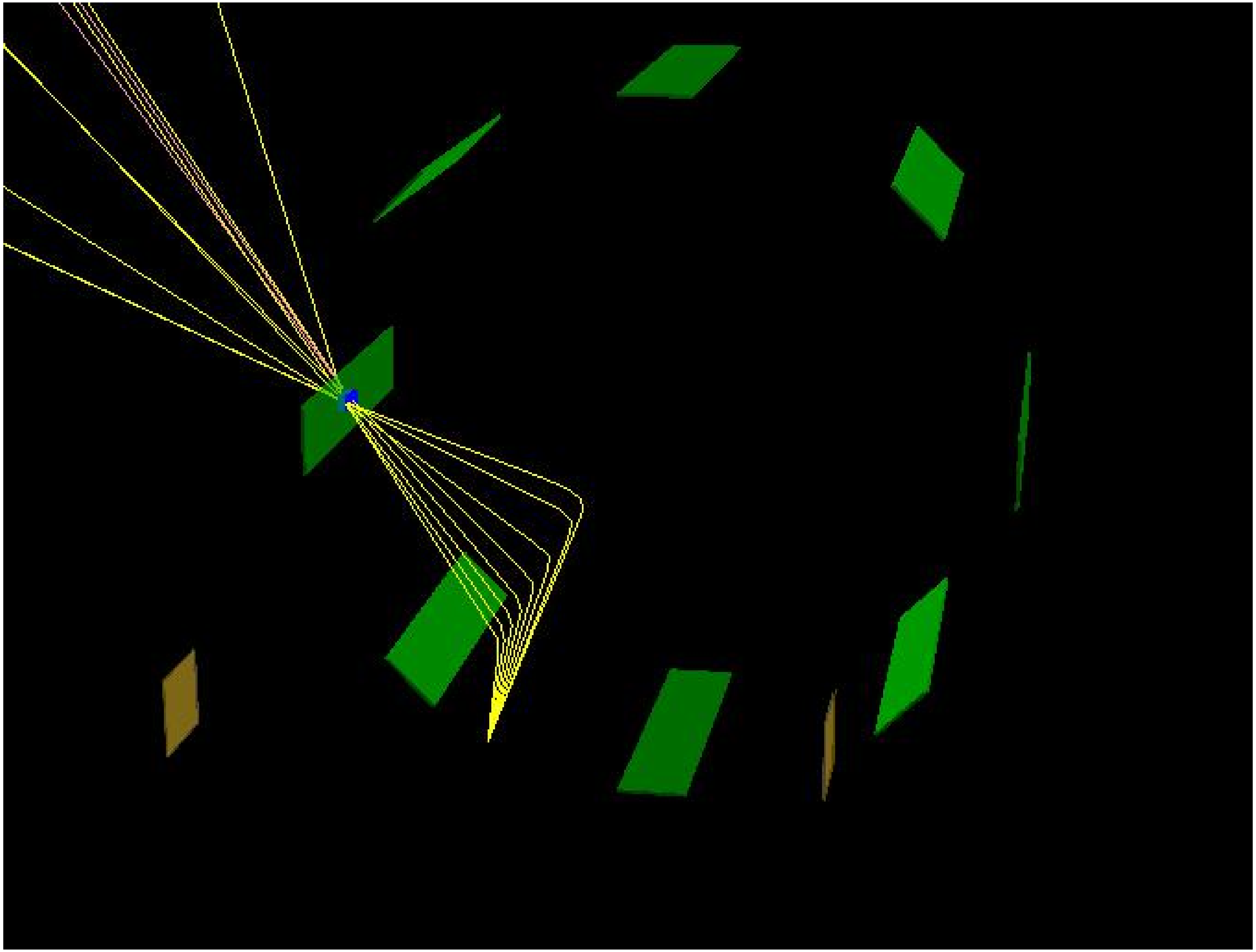
Same result as obtained in geometrical method for uniform field :)



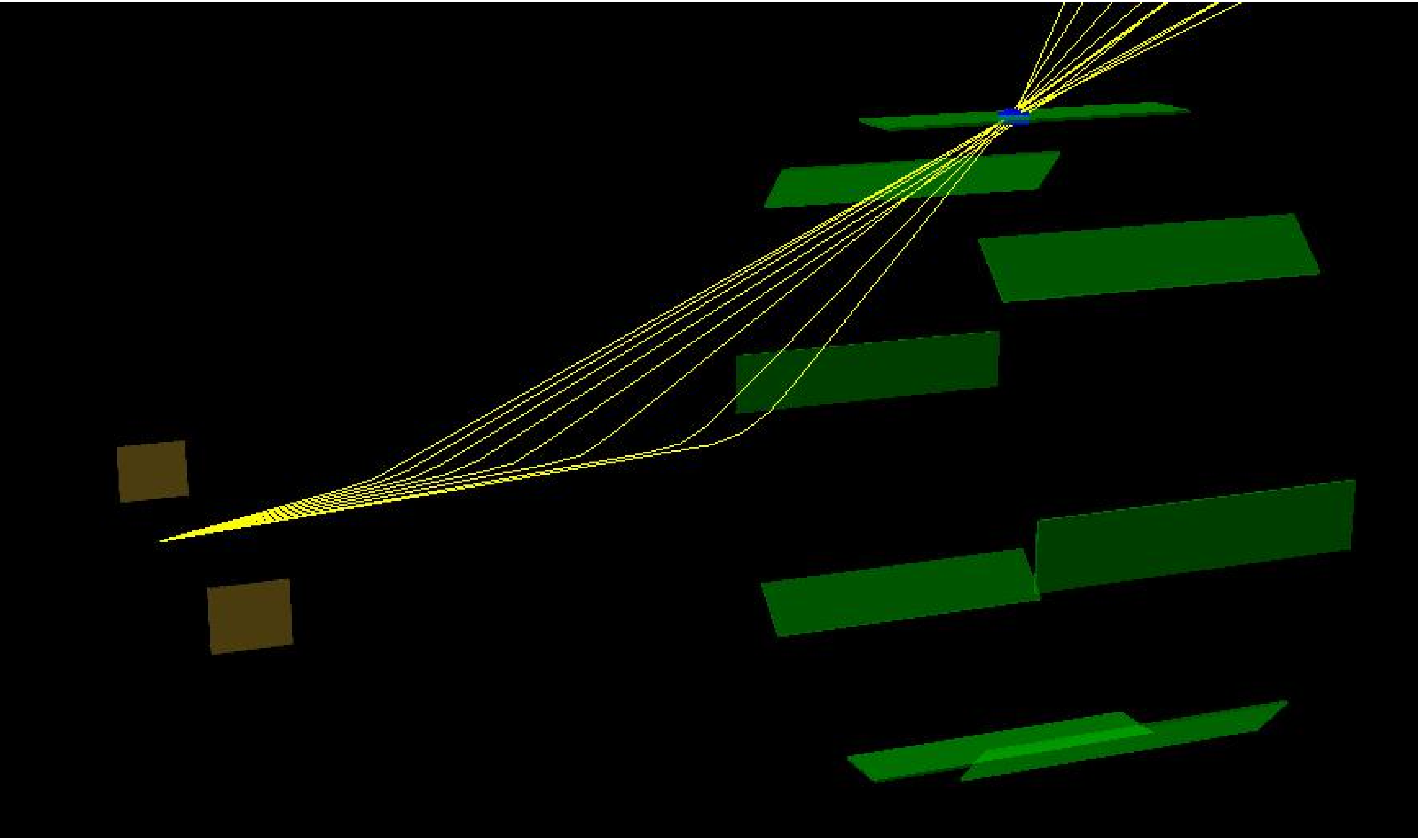
Magnet Design -- A Solution at 10 GeV/c



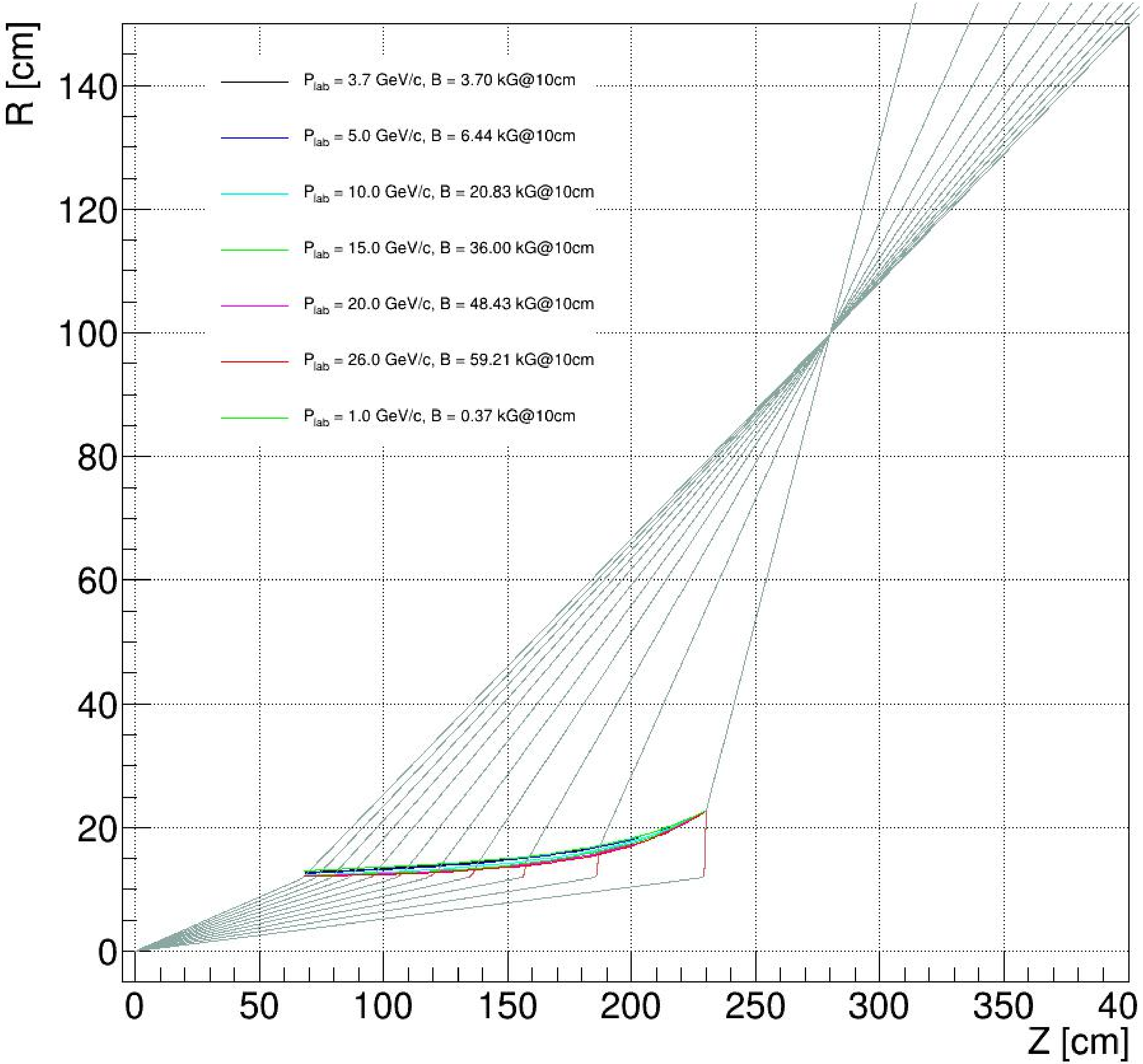
Magnet Design -- B Field Implemented in Sim Code



Magnet Design -- B Field Implemented in Sim Code

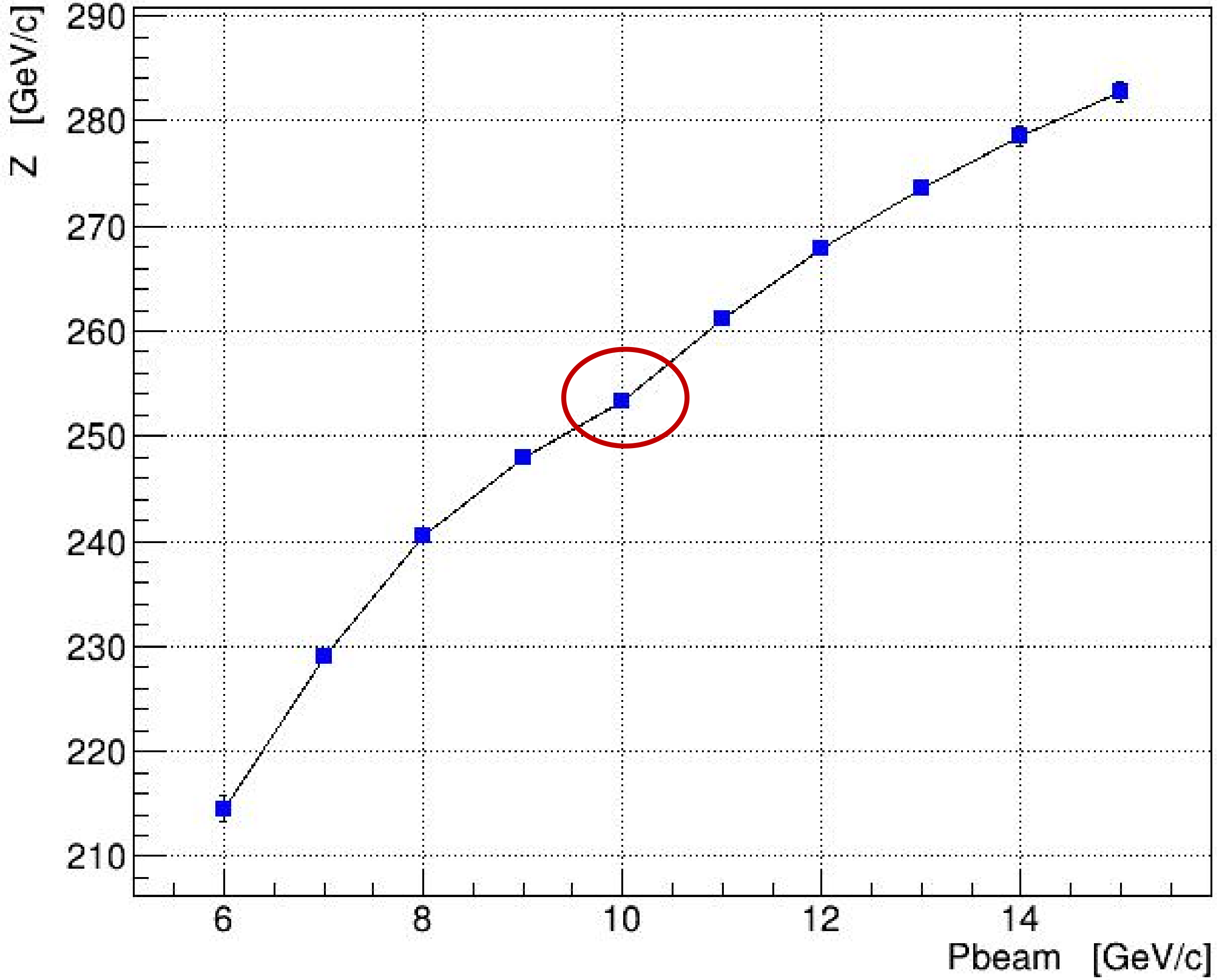


Magnet Design -- Beam Energy Dependence



Magnet Design -- Beam Energy Dependence

coil optimzed at 10 GeV/c



To-do

- ☐ Optimize geometry
  - coil
  - focal position
  - detector

- ☐ Magnetic field emulation
  - with COMSOL
  - in progress

- ☐ Background study
  - pythia generator ready

Thank you