Dual-RICH simulations (Update on magnetic field effect)

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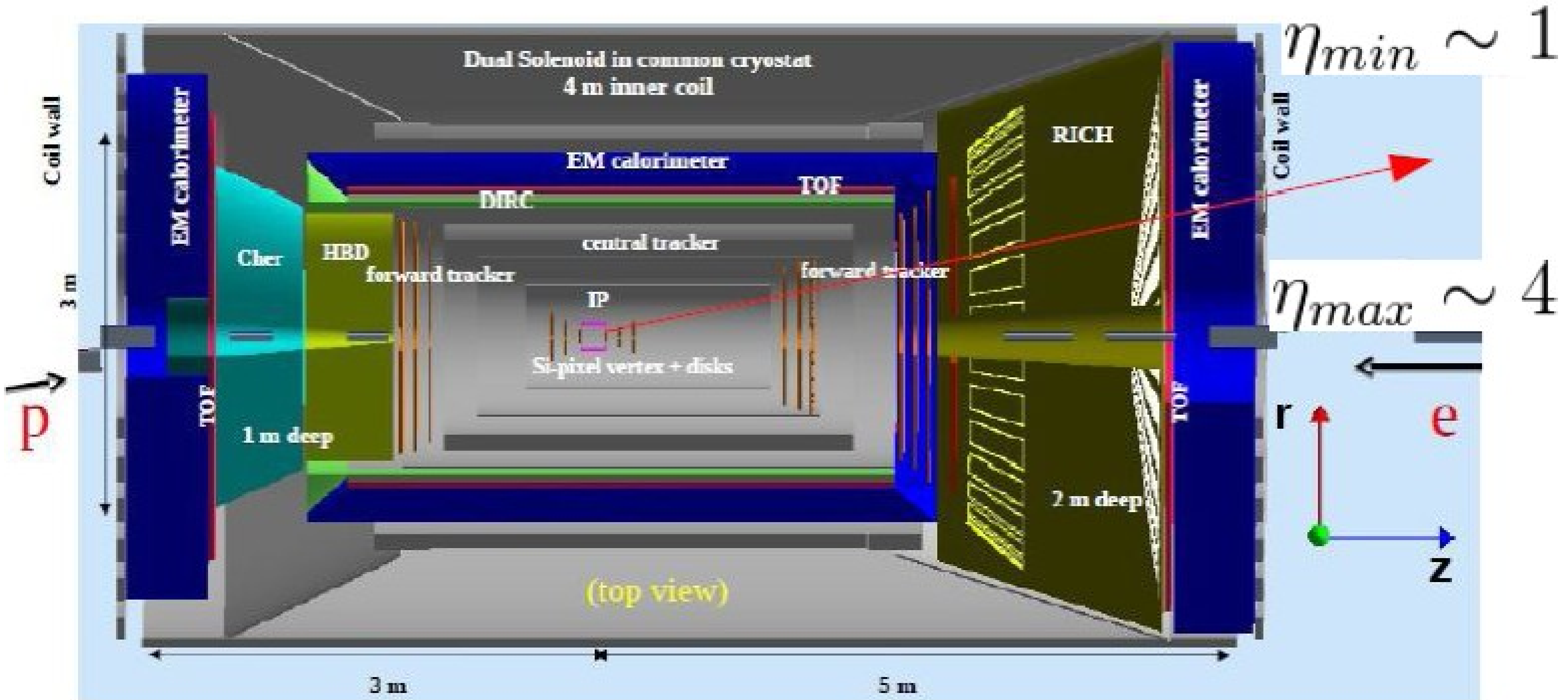
for the EICPID RICH meeting
10-5-2015

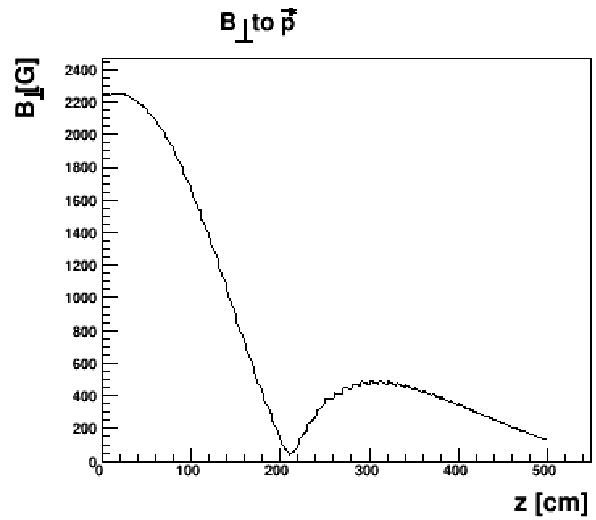
Field effect – distortion for RICH

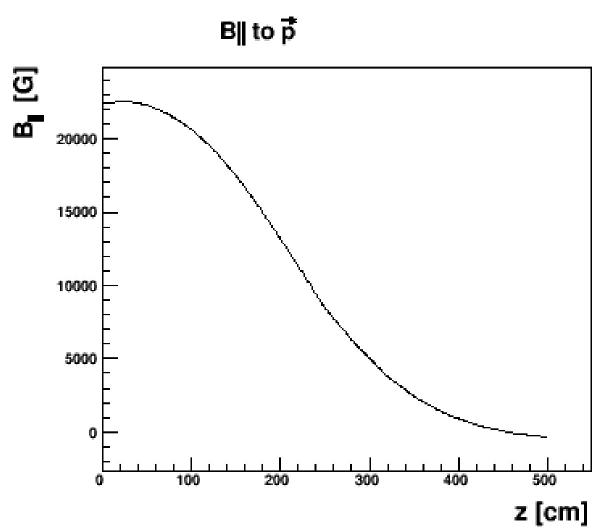


- RICH is in magnetic field
- Effect estimated using a new field mesh (map version 3) of 5 cm step in (z,r), a mesh of 1 cm step in (z,r) has been obtained interpolating the original map v3 (map v3 by Paul Brindza)
- The bending of the trajectory has been evaluated using a semi-analytical method (the same used in the past talk)

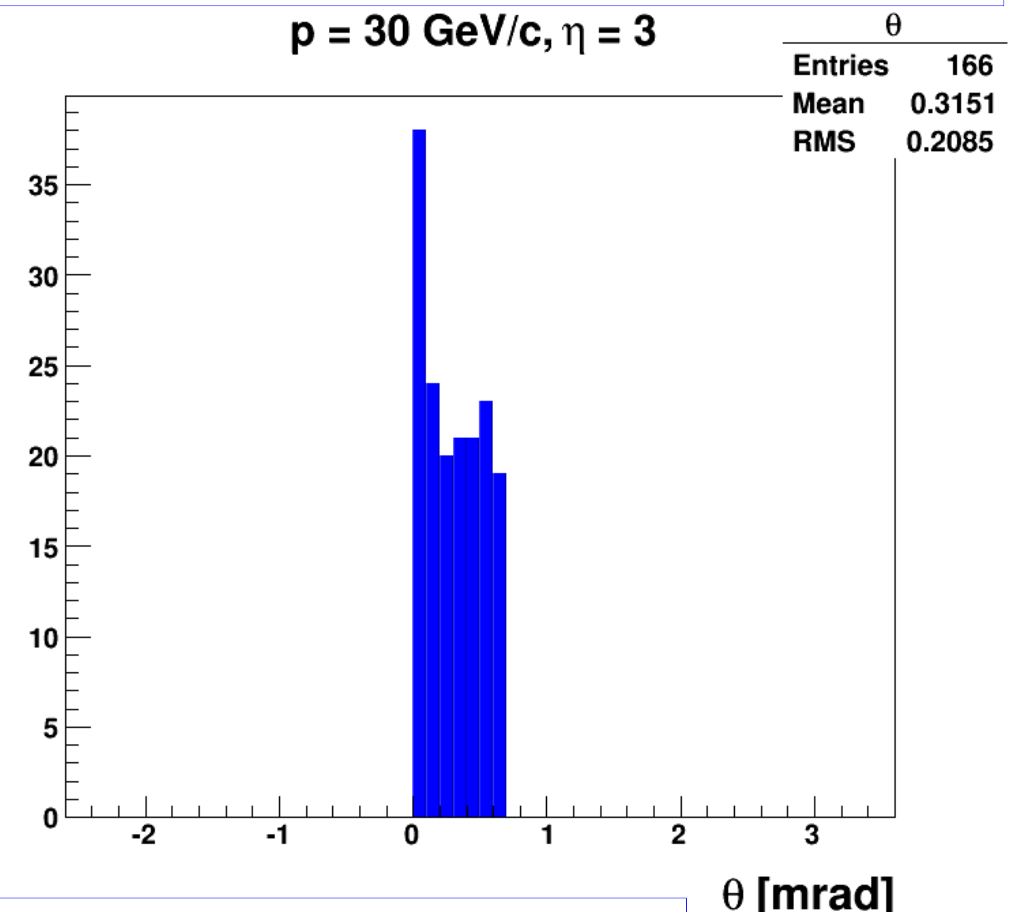
Field effect – distortion for RICH

Field components along the track for $\eta = 3$





θ is the bending angle of the tangent versor along the track in z = [220,385] cm (RICH position)

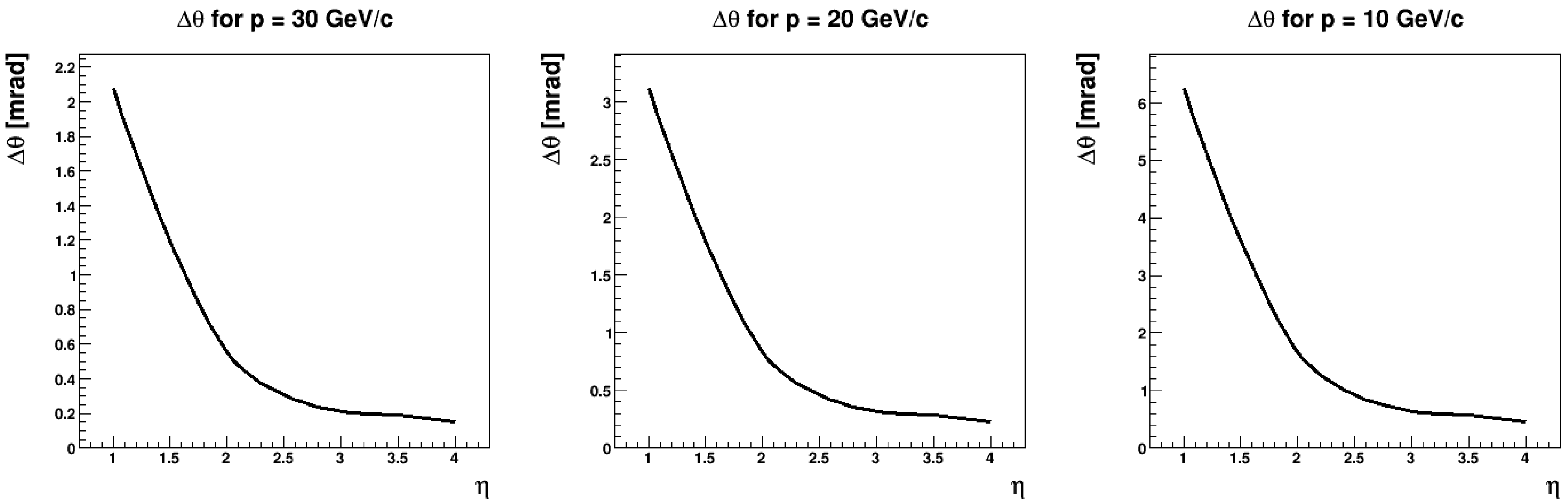


RMS = $\Delta\theta$ --> error on the Cherencov angle due to the bending of the track

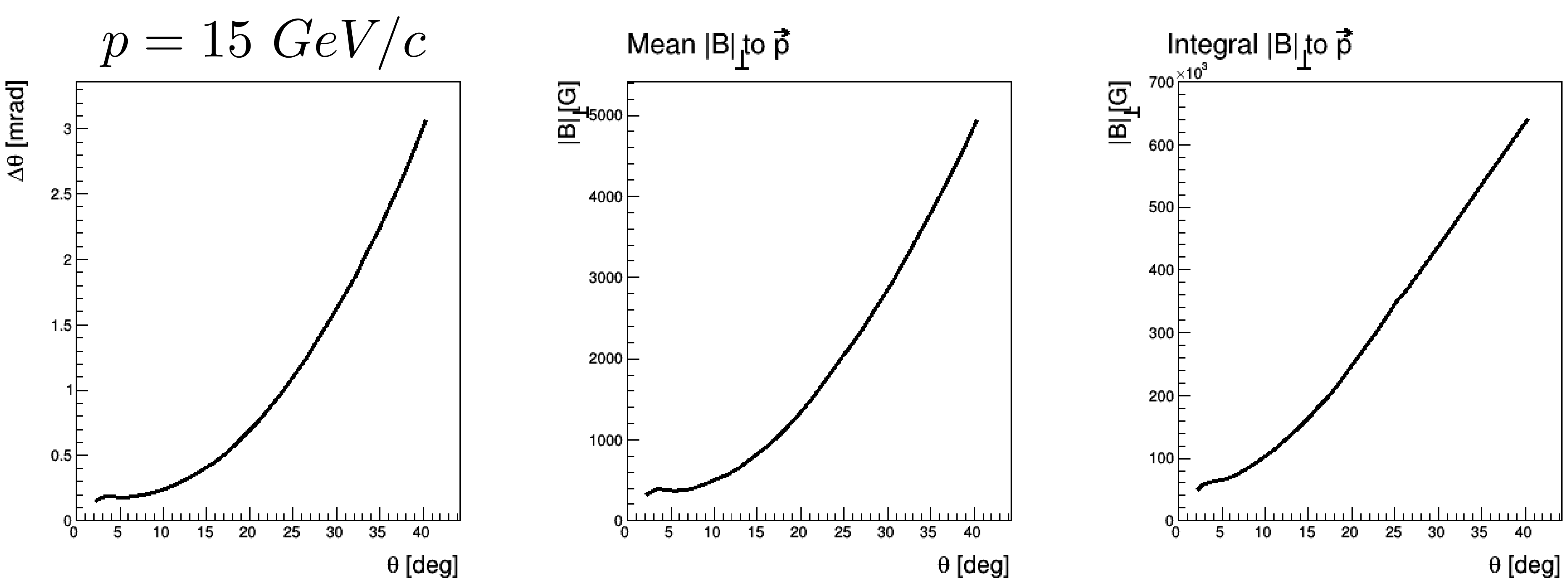
Field effect – distortion for RICH

Δθ vs η for three different momenta of the particle

Single p.e error un the Cherencov angle due to the field distortion



Error vs transverse field

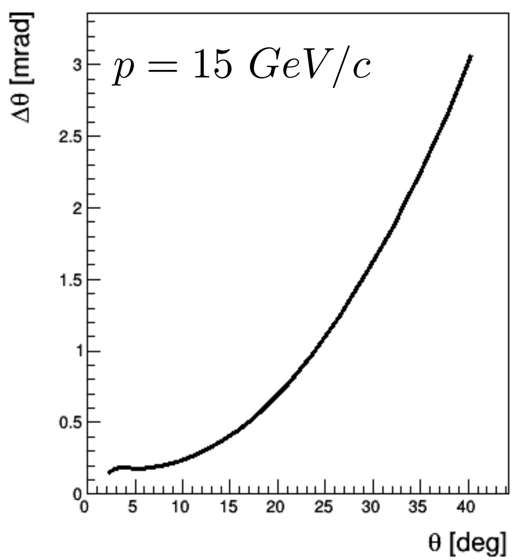


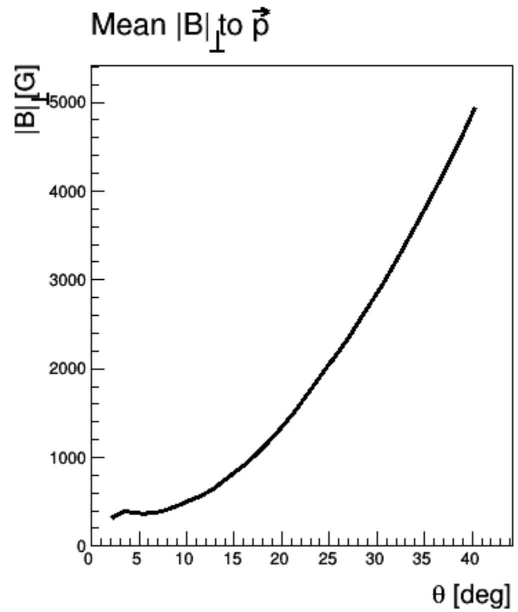
This effect is important for the photons coming from the gas.

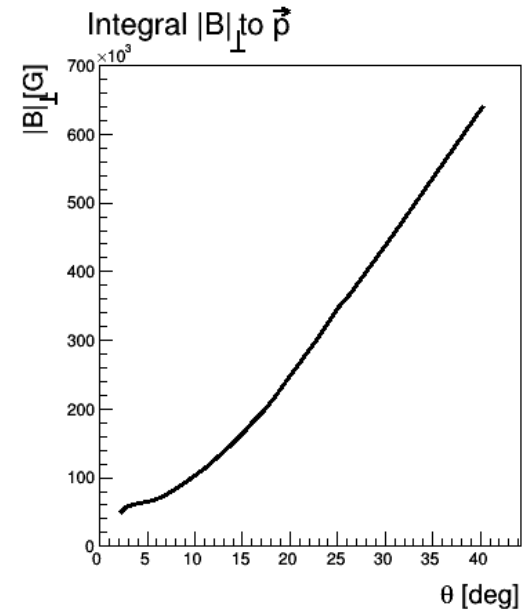
For CF_4 gas the typical 1 p.e. error contributions on the Cherenkov angle is order 0.5 – 0.3 mrad (see backup slides).

Error for different RICH regions

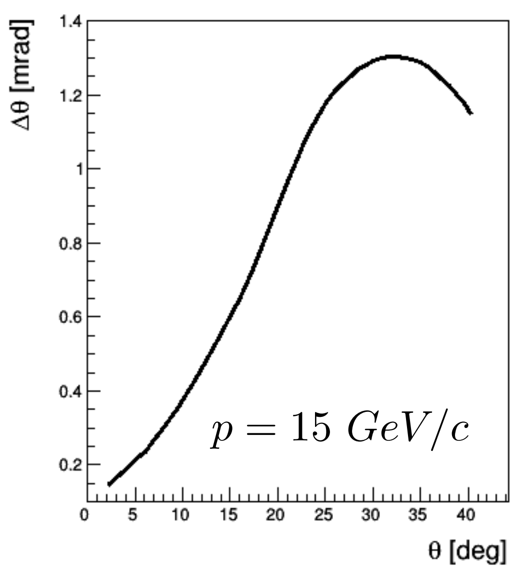
$RICH\ [220, 300]\ cm$

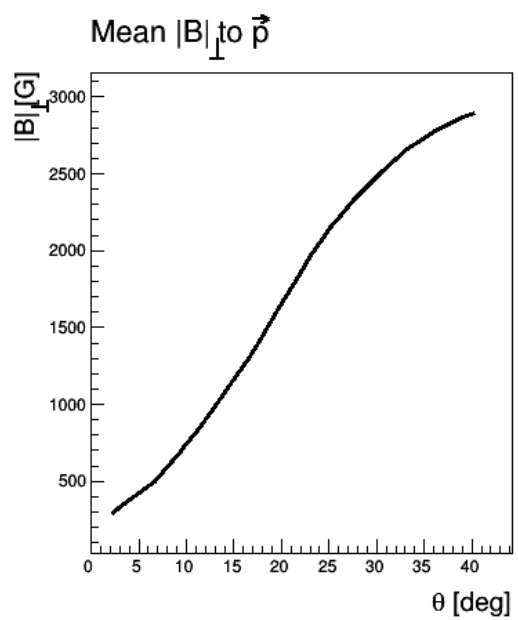


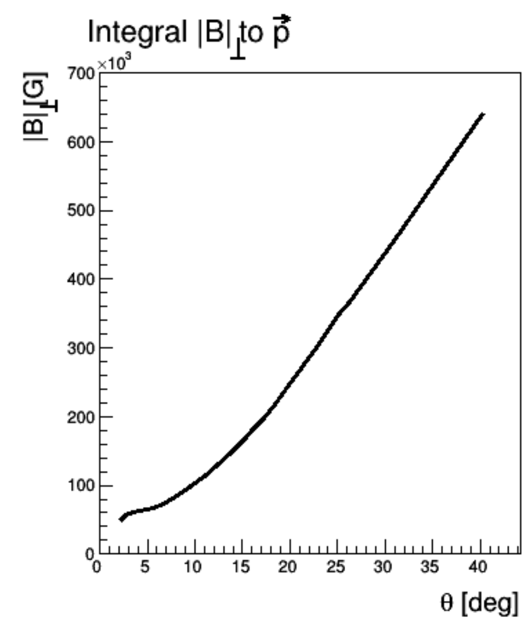




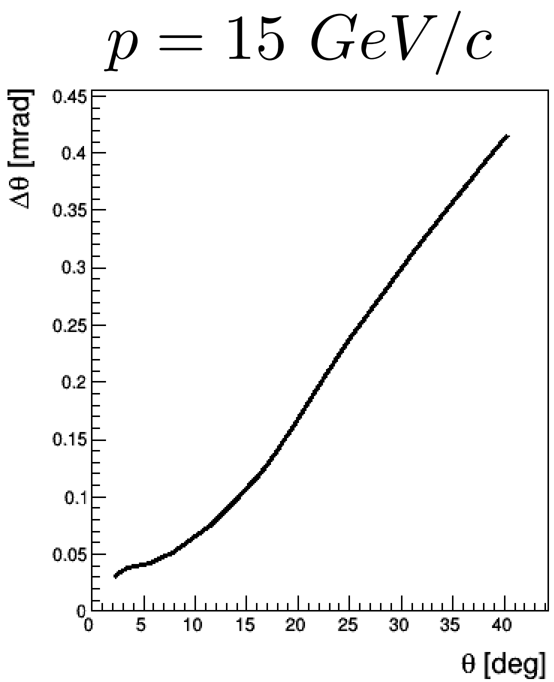
$RICH\ [300, 385]\ cm$

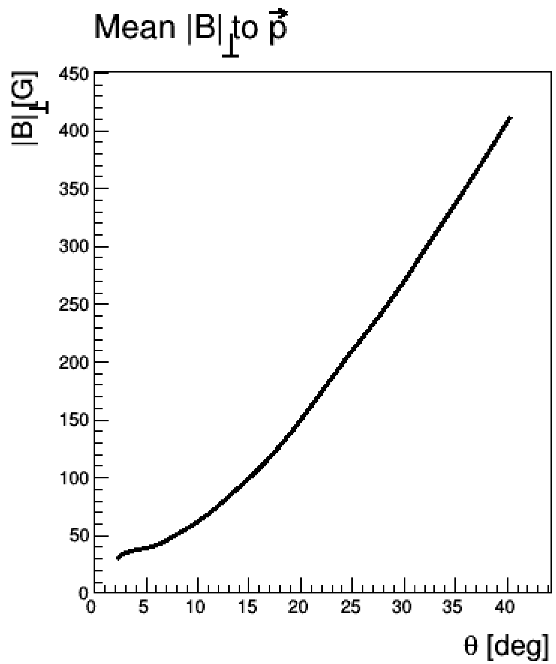


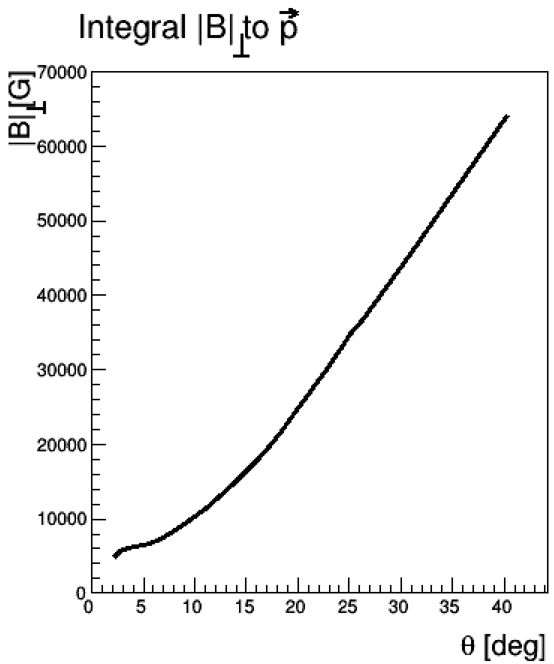




Field design – important parameter





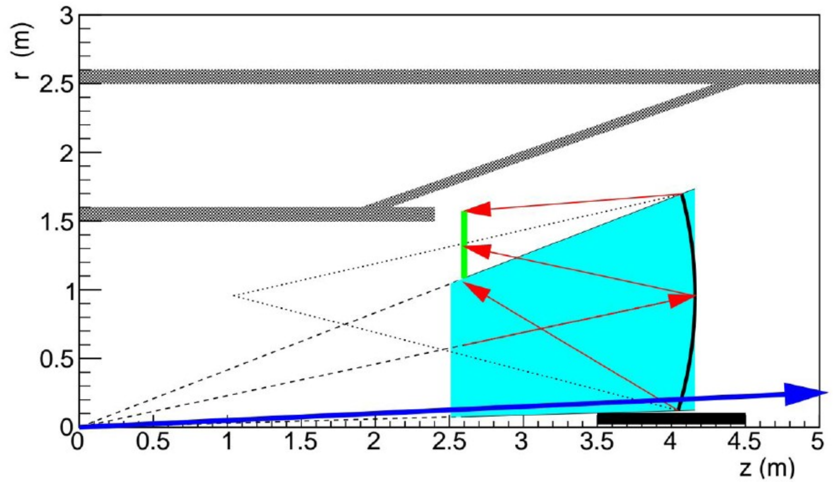


- The mean value of the component of B perpendicular to the track at a given angle is strictly proportional the the bending error on the Cherenkov angle.
- Two ways to reduce this error:

  - reduce the magnitude of the field

  - chenge the field geometry (field parallel/antiparallel to the track momentum)

Towards a realistic mirror configuration



- A 2D optical ray tracing software has been developed (based on C++)
- The reflection of the Cherenkov photons can be simulated for different radiators and different mirror configurations
- The photon-detector position can be studied in relation to the focal plane

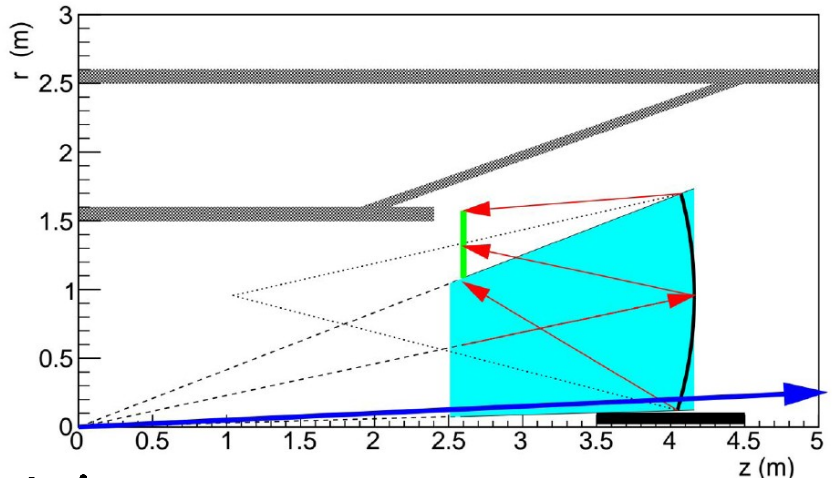
Comments and next developments

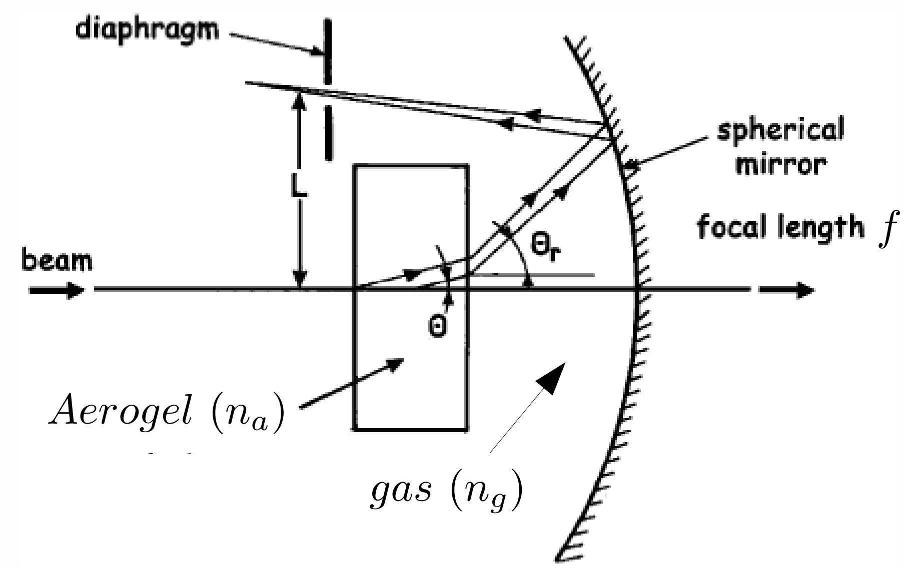
- With field map version 3, the error on the Cherencov ring has a small but not negligible impact on the Cherencov angle
- We have a tool to try different field map
- Next step: use the ray tracer to study useful configurations:

  - Parameters and number of mirrors (two spherical mirrors configuration under study)

  - Position of the photon-detector/focal plane

Focusing configuration – mirror (ideal)





Main error contributions:

- Chromatic
  - emission **λ** uncertainty
- Pixel-size uncertainty
  - pixel detector granularity
- Scattering of light
  - **λ** in the range [300,500] nm, UV light filtered

Chromatic error (1 p.e.): *Pixel error (1 p.e.):*

Aerogel

$$\sigma^{\lambda}_{\theta_c} = \frac{dn_a}{d\lambda}\frac{\beta}{\sin\theta_c}\frac{\Delta\lambda}{\sqrt{12}} \qquad \sigma^{s}_{\theta_c} = \frac{n_g\cos^3\theta_r}{f}\frac{s}{\sqrt{6}}$$

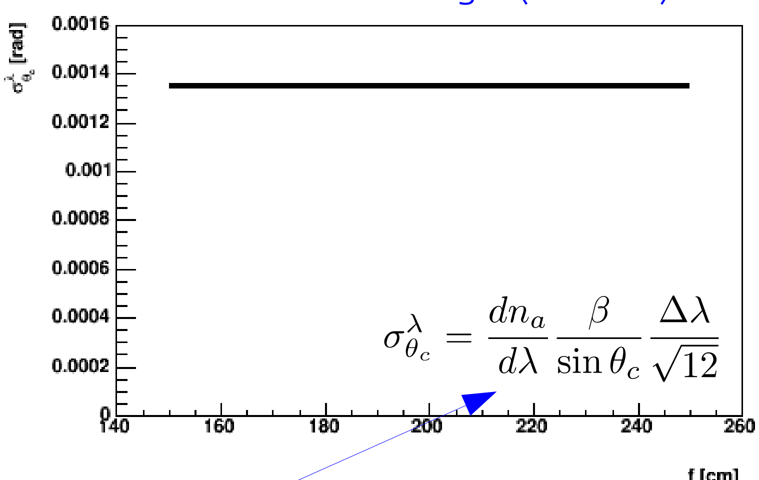
Gas

$$\sigma^{\lambda}_{\theta_c} = \frac{dn_g}{d\lambda}\frac{1}{n_g^2\beta\sin\theta_c}\frac{\Delta\lambda}{\sqrt{12}} \qquad \sigma^{s}_{\theta_c} = \frac{1}{fn_g^2}\frac{s}{\sqrt{6}}$$

Mirror focusing – chromatic error

Geometry independent error: does not depend on the focal length

Photons from Aerogel (n = 1.02)



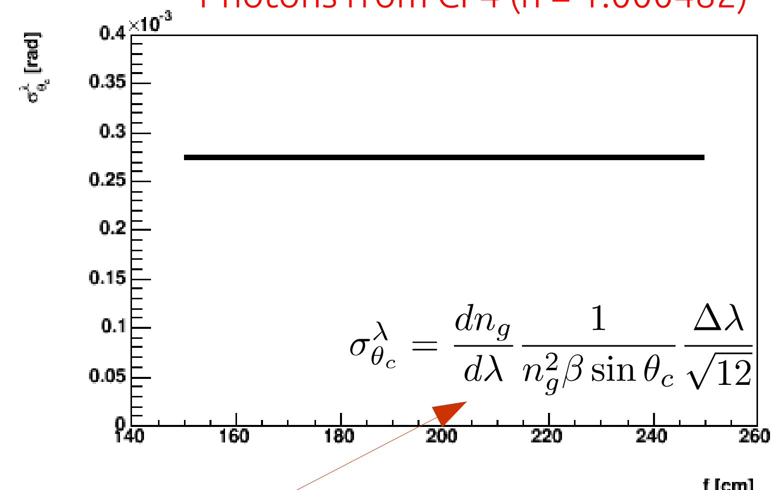
$$\sigma^{\lambda}_{\theta_c} = \frac{dn_a}{d\lambda}\frac{\beta}{\sin\theta_c}\frac{\Delta\lambda}{\sqrt{12}}$$

$$n_a^2(\lambda) = 1 + \frac{0.096\lambda^2}{\lambda^2 - 84^2}$$

$$<\lambda>= 400\ nm \quad <p>= 5\ GeV$$

M. Contalbrigo talk at RICH 2013 (http://rich2013.kek.jp/program.html)

Photons from CF4 (n = 1.000482)



$$\sigma^{\lambda}_{\theta_c} = \frac{dn_g}{d\lambda}\frac{1}{n_g^2\beta\sin\theta_c}\frac{\Delta\lambda}{\sqrt{12}}$$

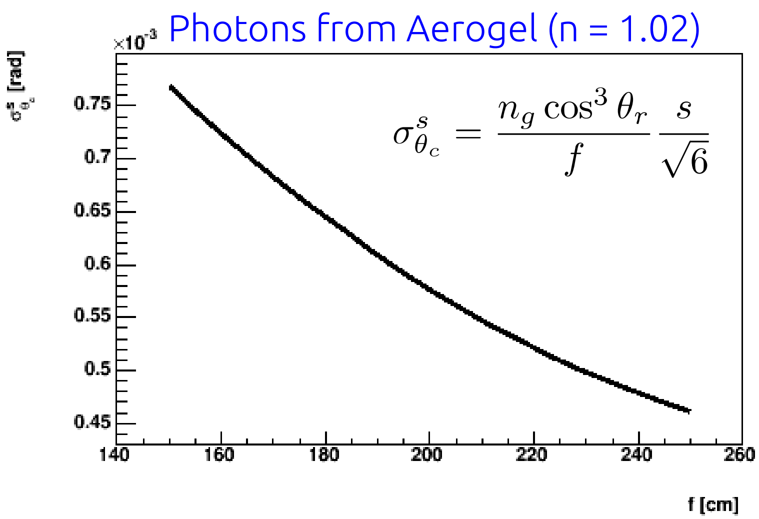
$$(n_g(\lambda) - 1)\times 10^{-6} = \frac{0.12489}{61.8^{-2} - \lambda^{-2}}$$

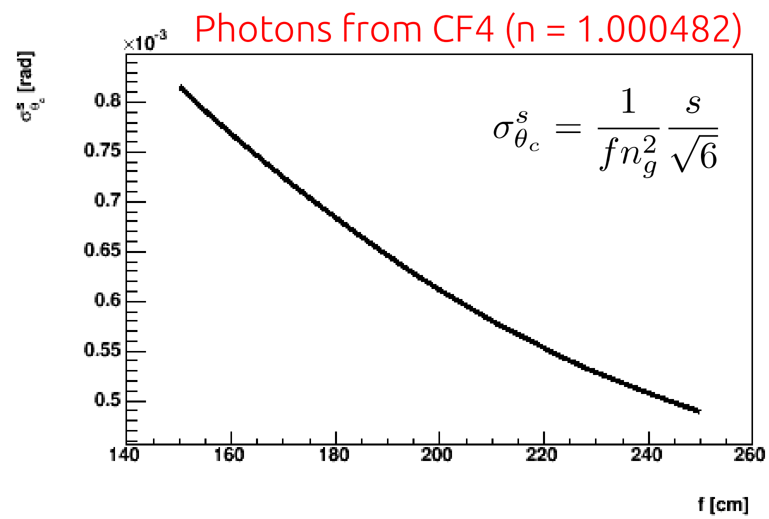
$$<\lambda>= 400\ nm \quad <p>= 40\ GeV$$

Alves Jr, A. Augusto, et al. "The LHCb detector at the LHC." Journal of instrumentation 3.08 (2008): S08005.

Mirror focusing – pixel error

$$pixel\ size:\ \ s = 3\ mm$$



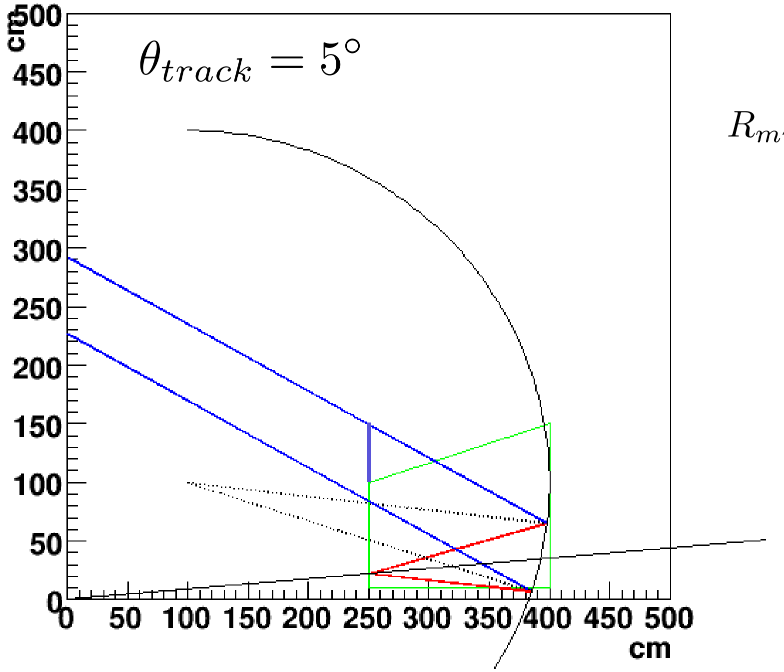


- In a spherical mirror configuration, the error due to the magnetic bending has to be added to the chromatic and pixel size errors
- Others errors that have to be added are:

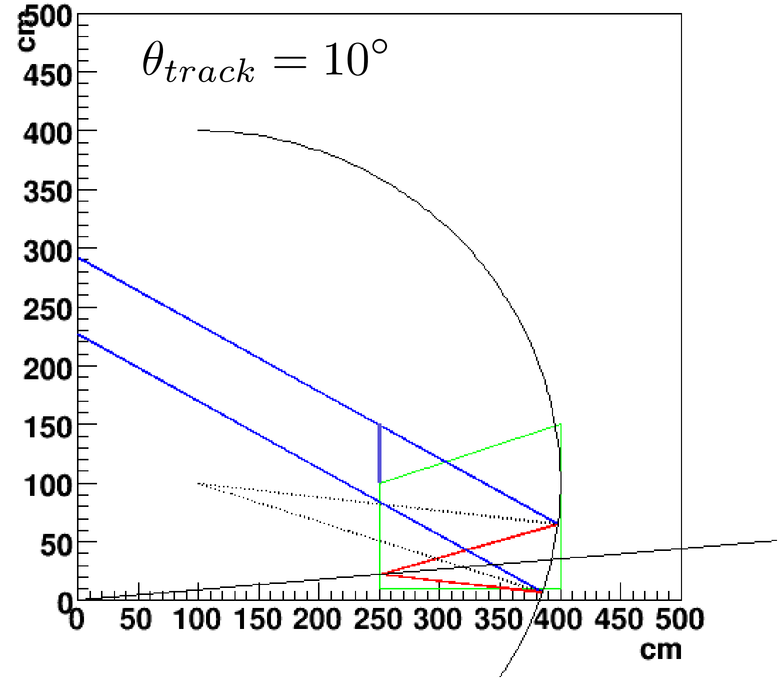
  - $\sigma_{emission}$ (if the mirror is tilted/aberrations) → geometry dependent

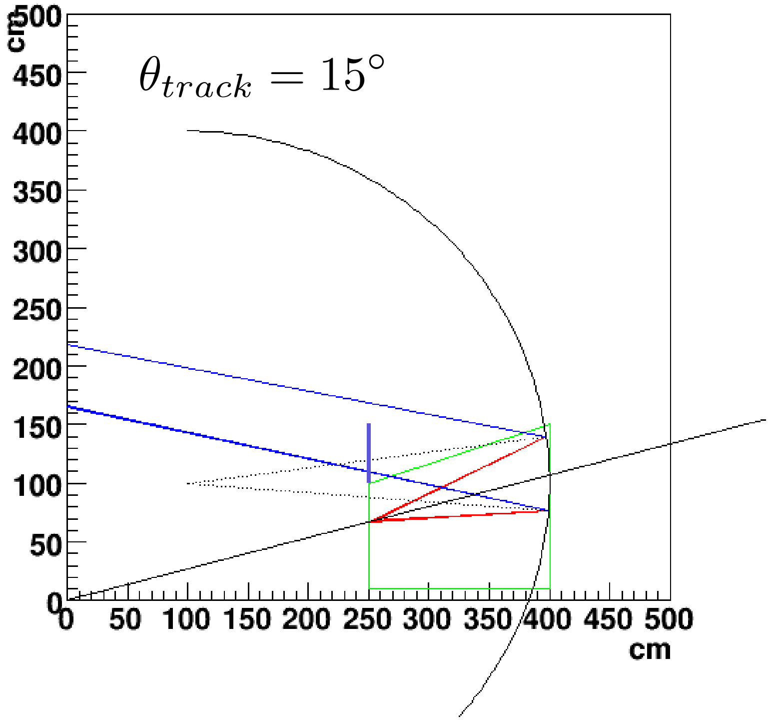
  - σ_{track} (due to the error on the track)

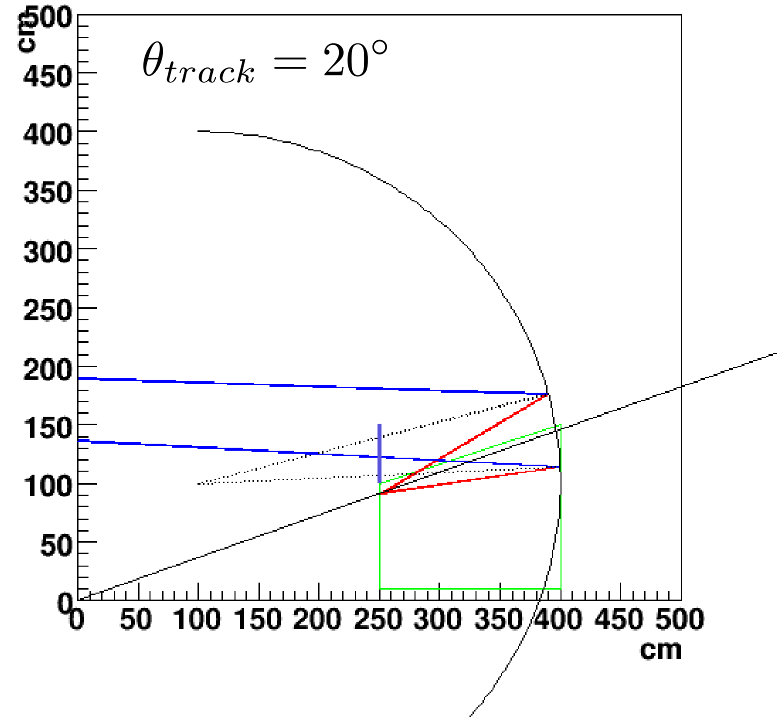
  - $\sigma_{magnetic}$ (due to the bending of the track)

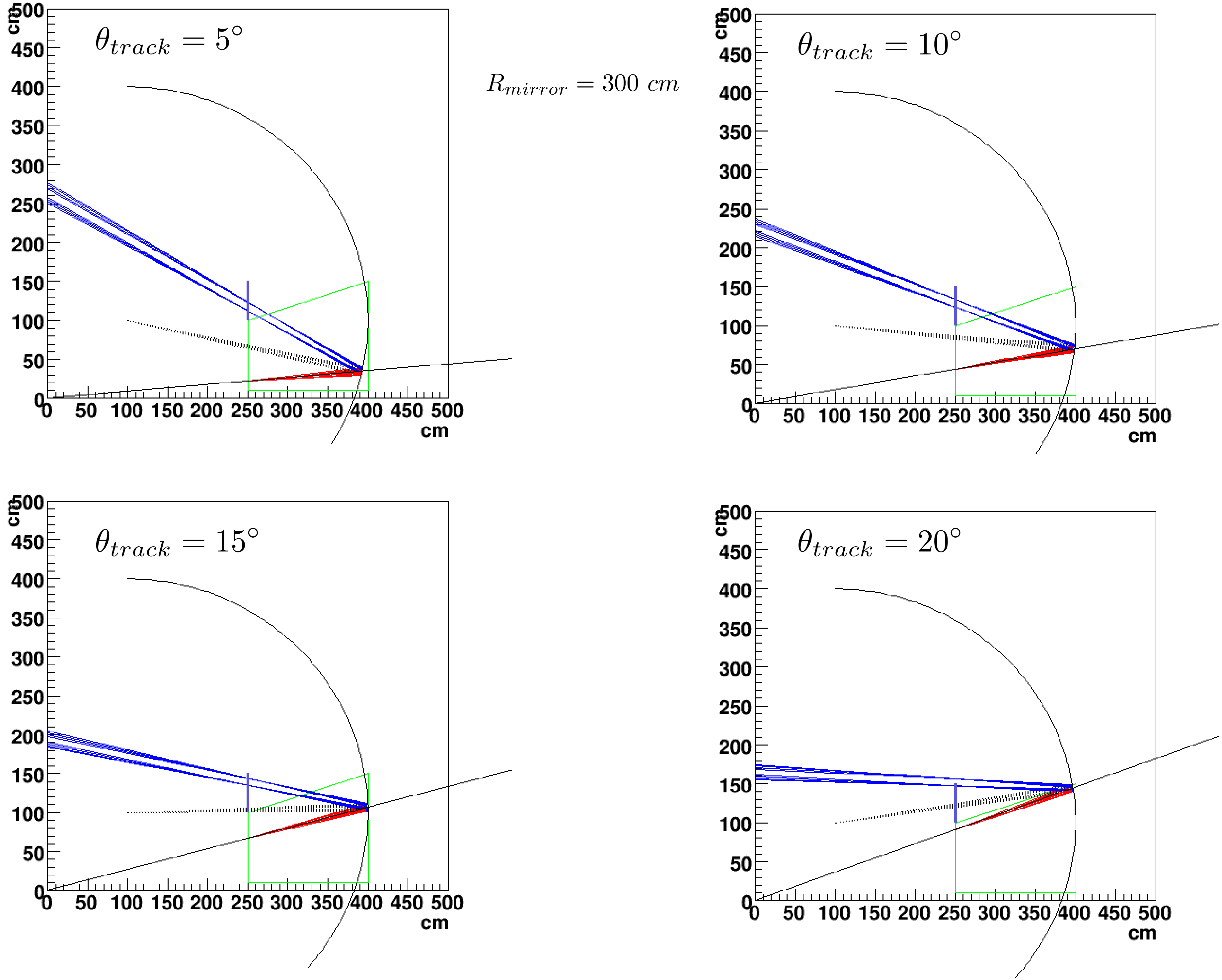


$R_{mirror} = 300\ cm$








$\theta_{track} = 5°$
$R_{mirror} = 300\ cm$
$\theta_{track} = 10°$
$\theta_{track} = 15°$
$\theta_{track} = 20°$
cm
0 50 100 150 200 250 300 350 400 450 500
cm