Dual-RICH simulations (Update)

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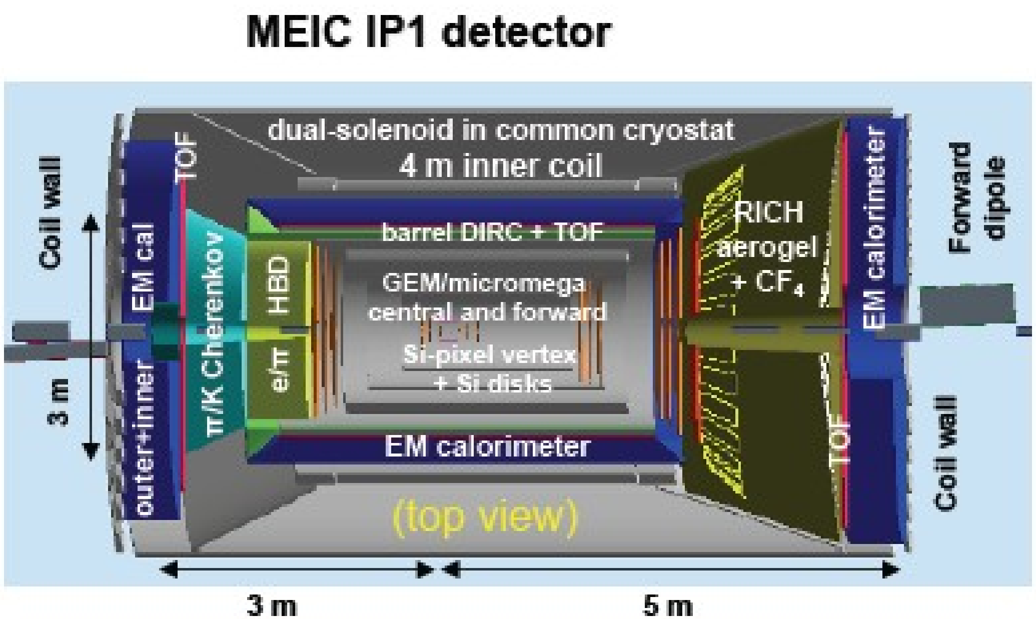
for the EIC PID meeting
9-28-2015

MEIC detector concept for EIC

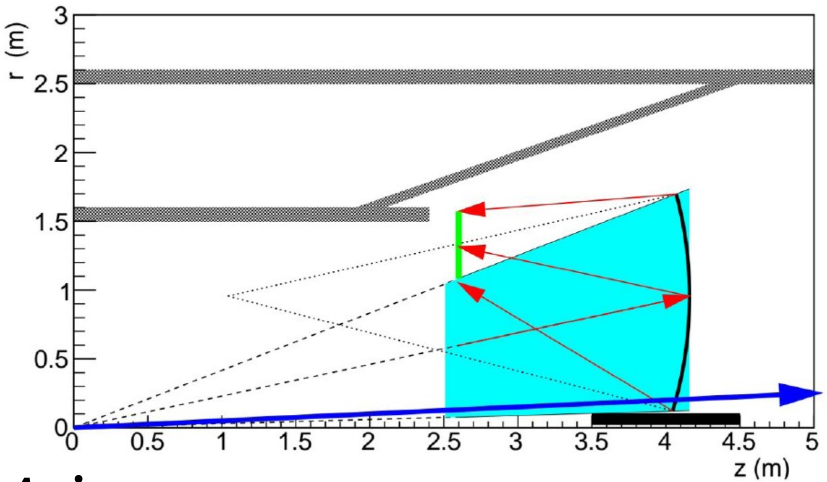


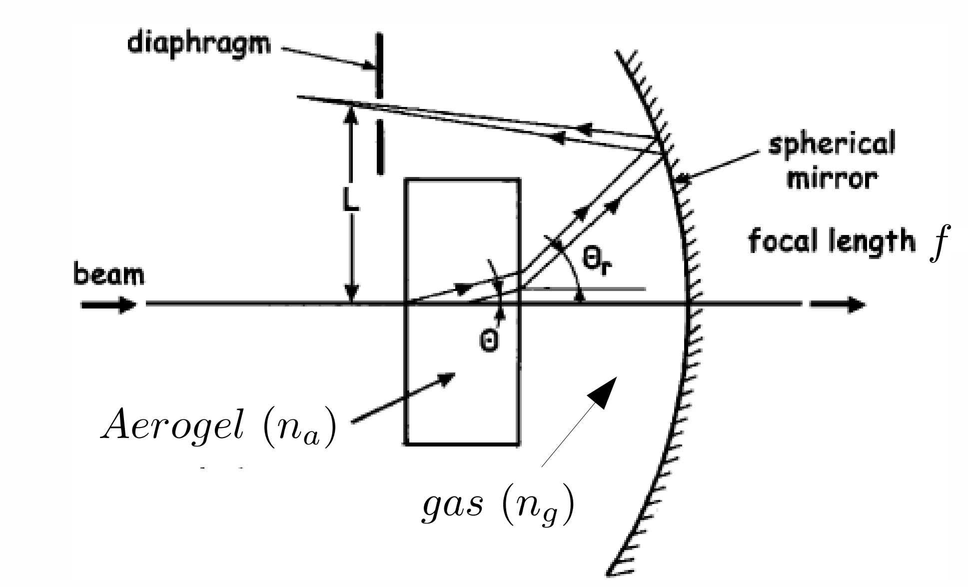
Dual-radiator RICH:
- Proximity configuration: excluded, can not garantee momentum coverage up to 50 GeV
- Outward-reflecting mirror configuration: under study

MEIC π/K/p ID up to 50 GeV

- TOF in both endcaps and barrel
- DIRC in barrel (compact "camera")
- Dual-radiator RICH in hadron endcap
- Modular aerogel RICH in electron endcap

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

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

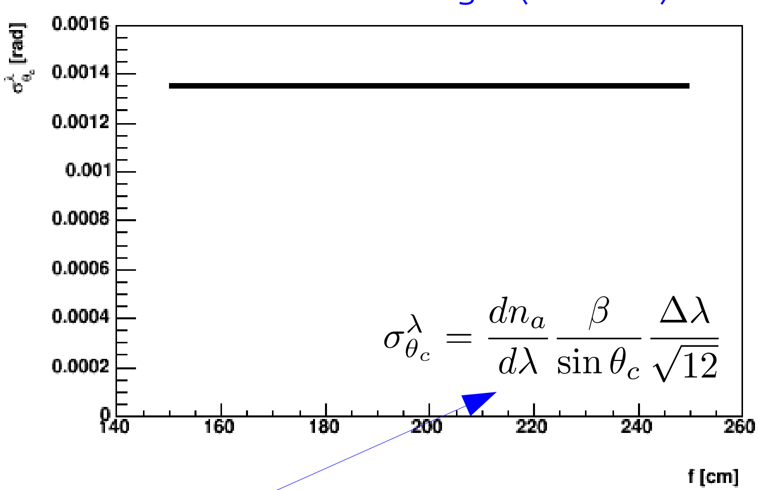
Gas

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

Mirror focusing – chromatic error

Geometry independent error: does not depend on the focal length

Photons from Aerogel (n = 1.02)



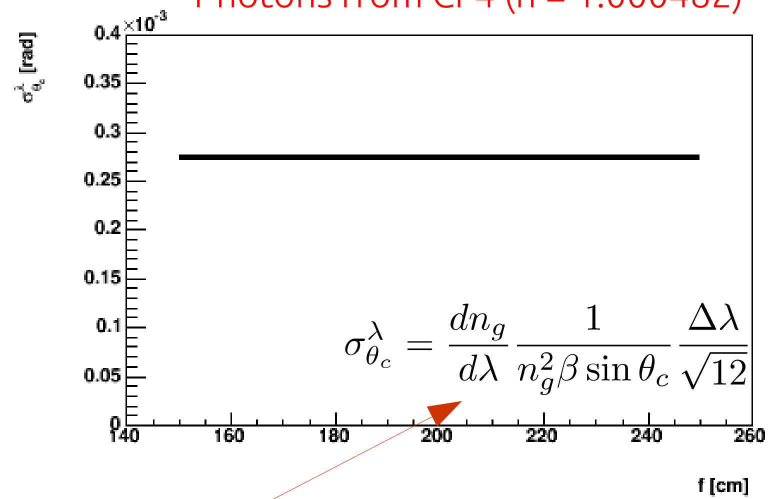
$$\sigma^{\lambda}_{\theta_c} = \frac{dn_a}{d\lambda}\frac{\beta}{\sin\theta_c}\frac{\Delta\lambda}{\sqrt{12}}$$

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

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

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

Photons from CF4 (n = 1.000482)



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

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

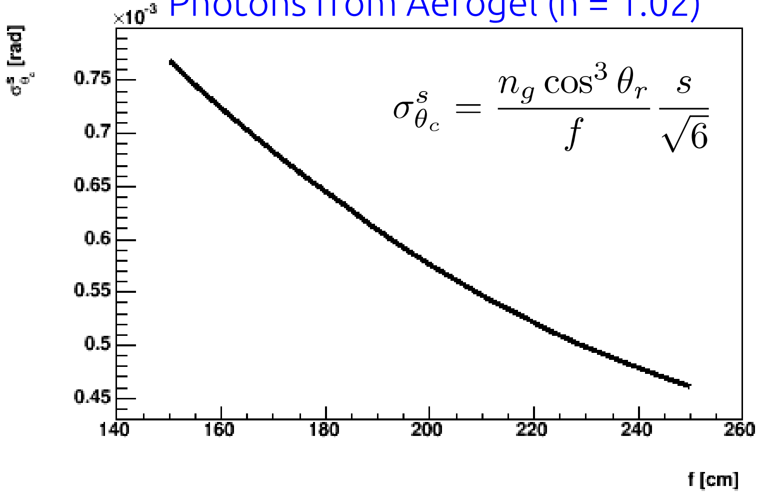
$$<\lambda>= 400\ nm \quad <p>= 40\ GeV$$

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

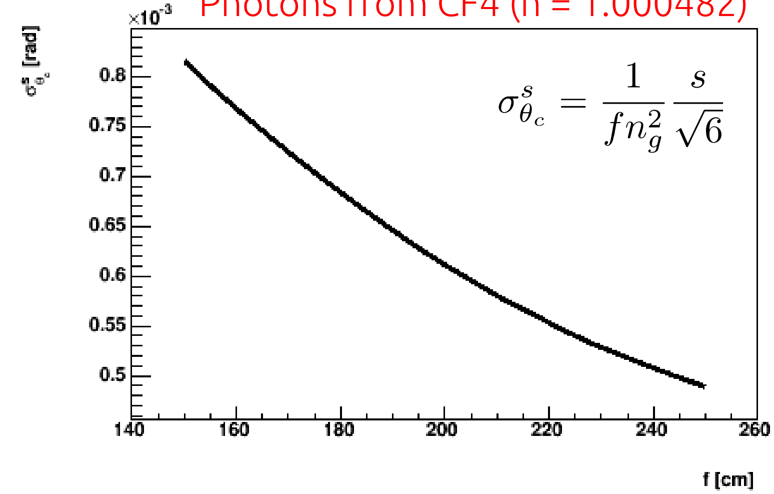
Mirror focusing – pixel error

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

Photons from Aerogel (n = 1.02)



Photons from CF4 (n = 1.000482)



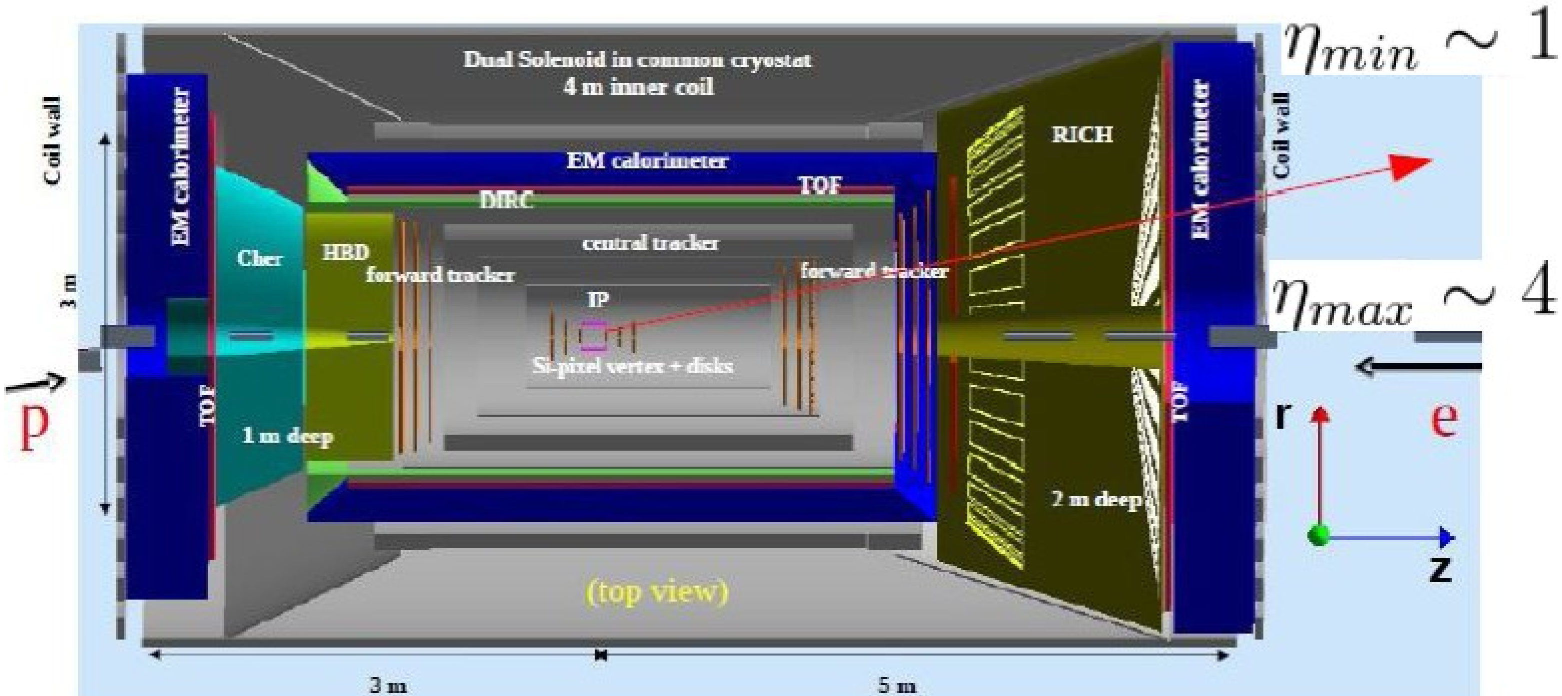
- In a spherical mirror configuration, the error due to the magnetic bending has to be added to the chromatic and pixel size errors
- Others errors that have to be added are:

  - $\sigma_{emission}$ (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)

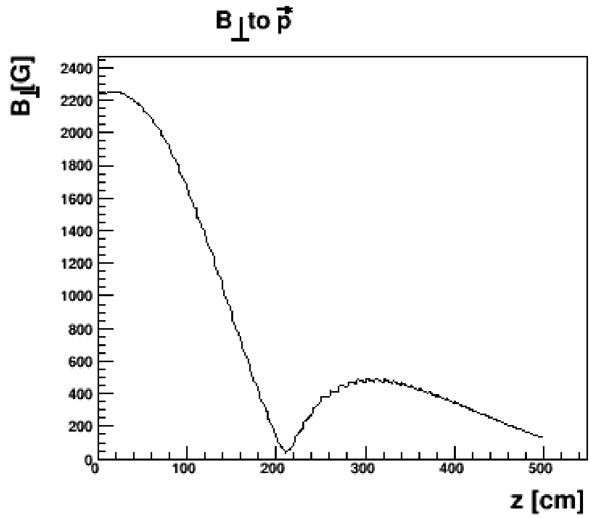
Field effect – distortion for RICH

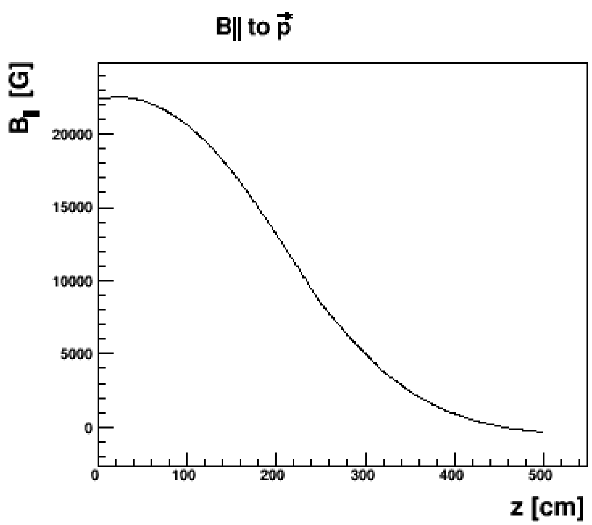


- RICH is in magnetic field
- Effect estimated using a new field mesh (map version 3) of 5 cm step in (z,r), a mesh of 1 cm step in (z,r) has been obtained interpolating the original map v3 (map v3 by Paul Brindza)
- The bending of the trajectory has been evaluated using a semi-analytical method (the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

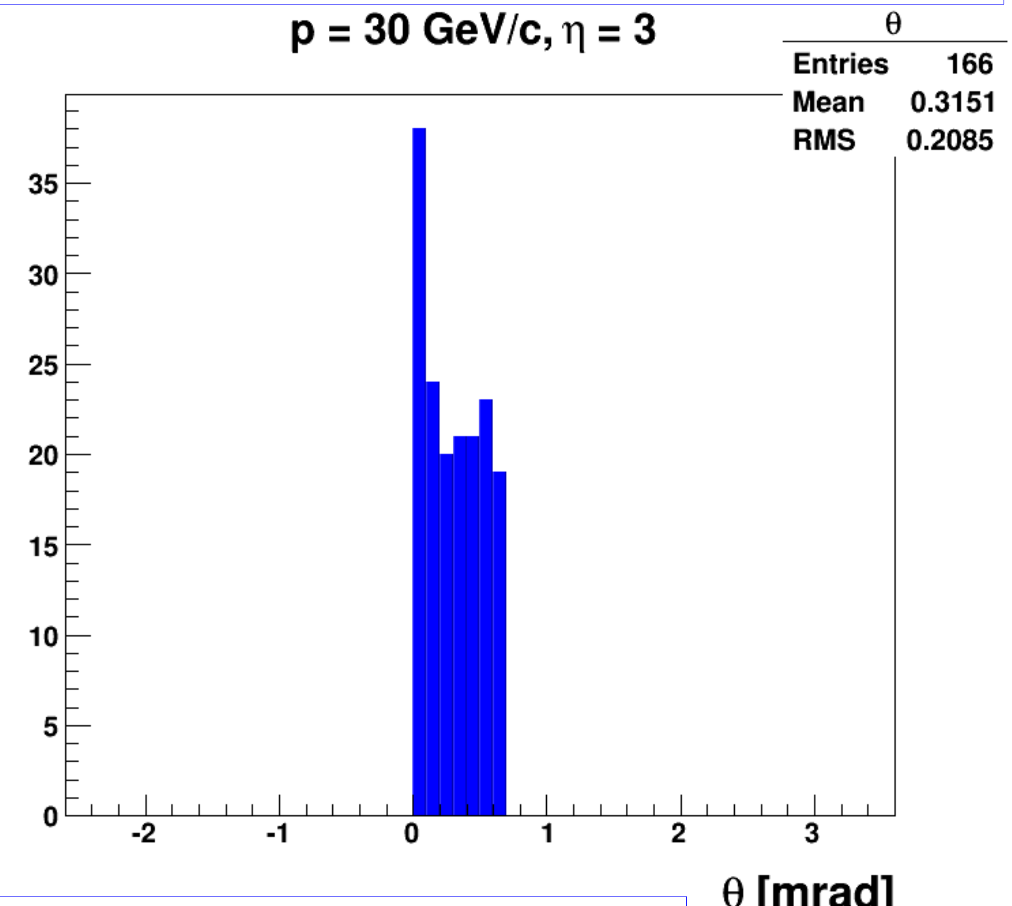
Field effect – distortion for RICH

Field components along the track for η = 3





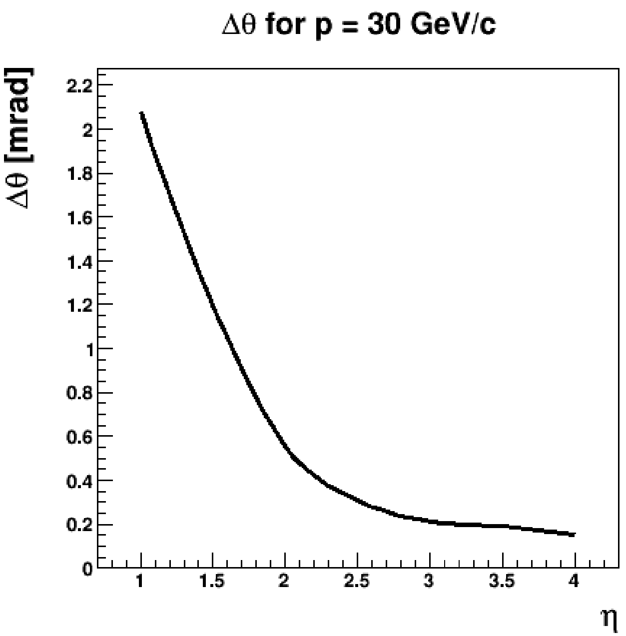
θ is the bending angle of the tangent versor along the track in z = [220,385] cm (RICH position)

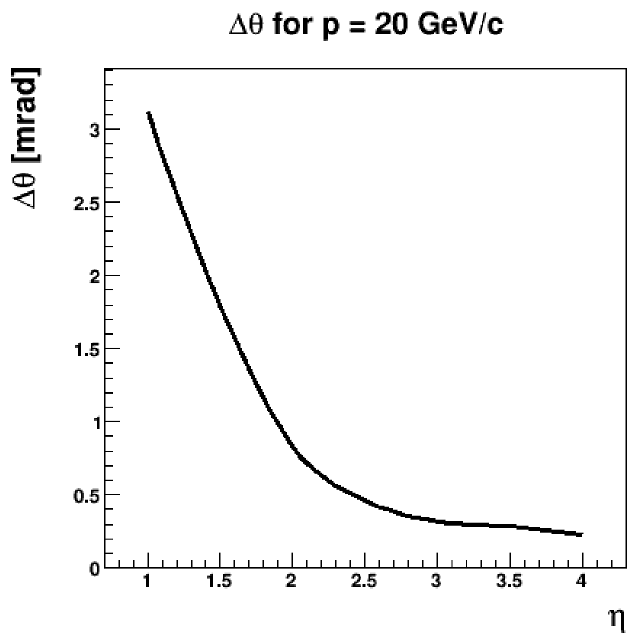


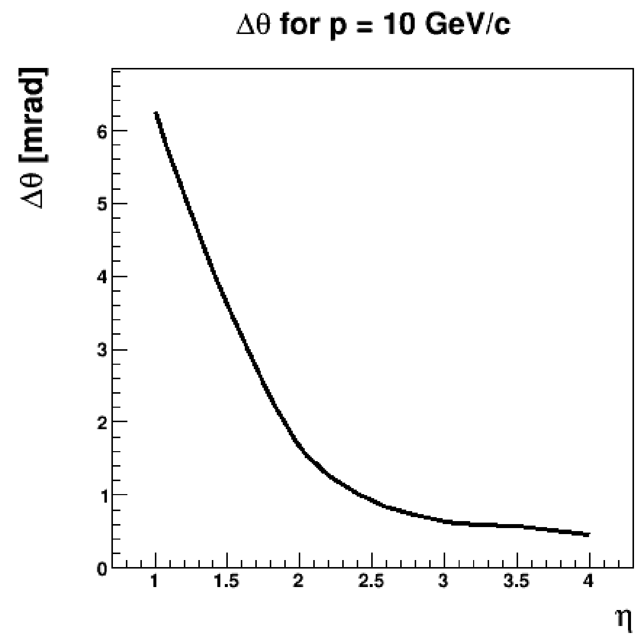
RMS = Δθ --> error on the Cherencov angle due to the bending of the track

Field effect – distortion for RICH

Δθ vs η for three different momenta of the particle



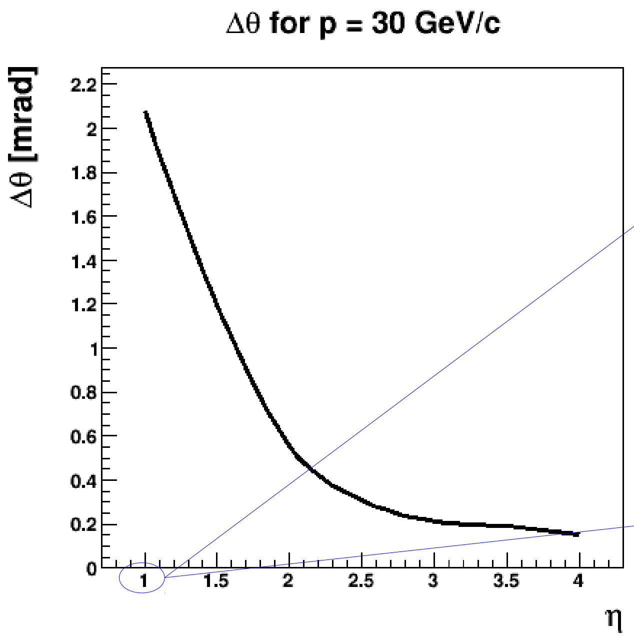


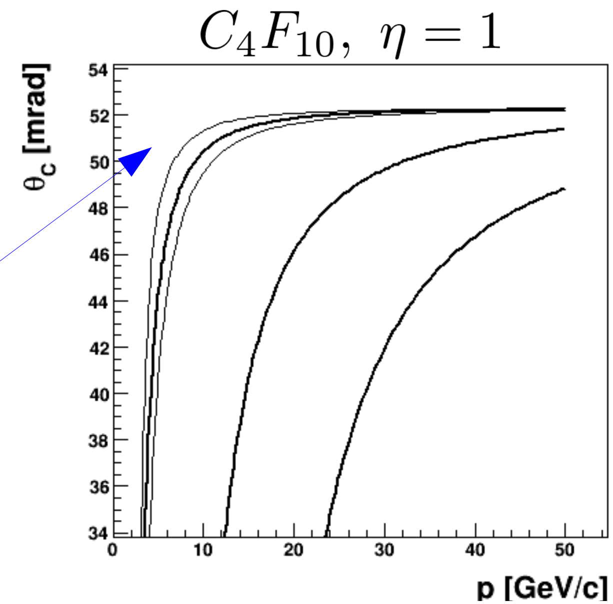


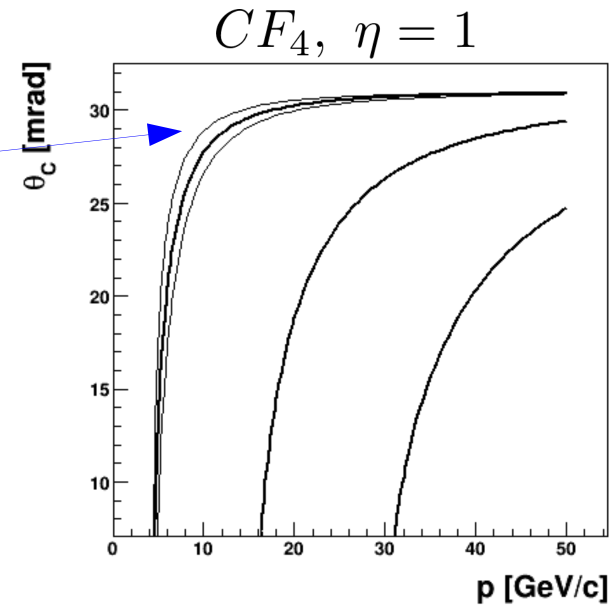
Field effect – radius+- 1 σ   effect

RICH ring error

$$\delta R = \Delta\theta/\sqrt{2N_\gamma}\cdot(10\ GeV/c)/p$$





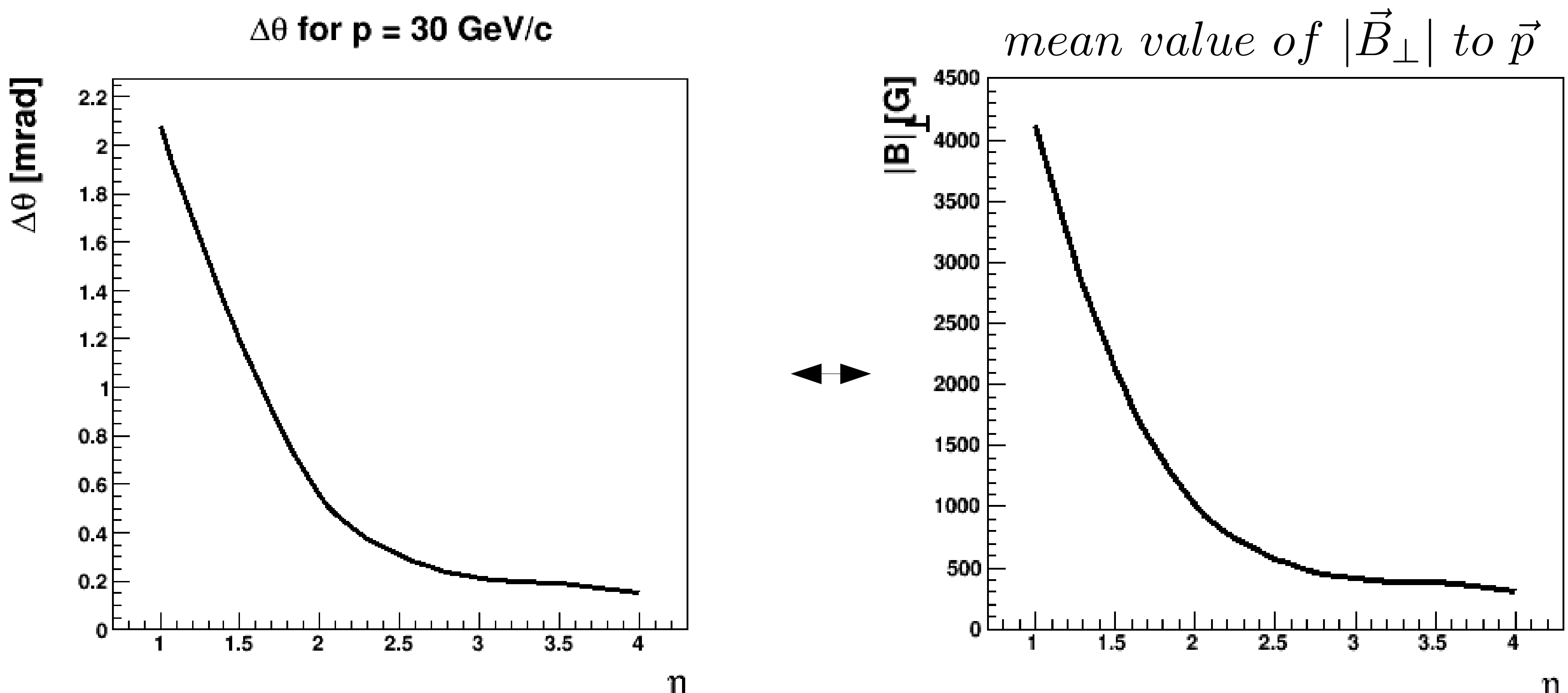


Mean number of p.e. used in the formula:

$$C_4F_{10} \to N_\gamma \sim 25$$

$$CF_4 \to N_\gamma \sim 15$$

Field design – important parammter

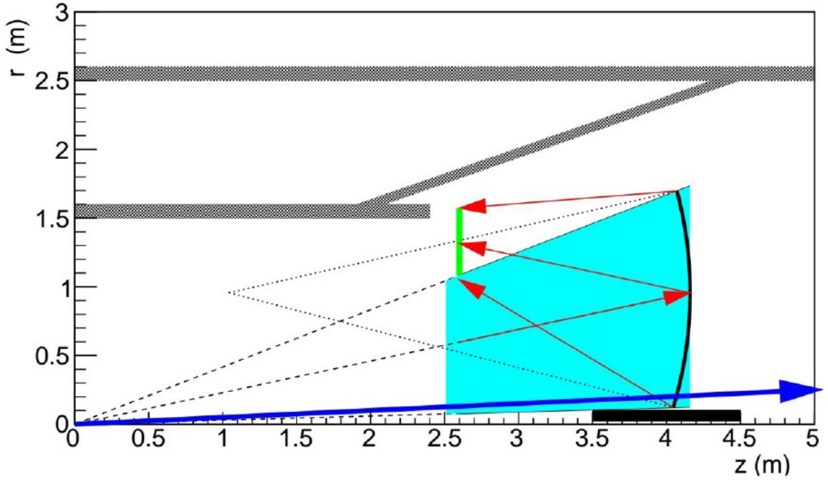


- The mean value of the component of B perpendicular to the track at a given angle is strictly proportional the the bending error on the Cherenkov angle.
- Two ways to reduce this error:

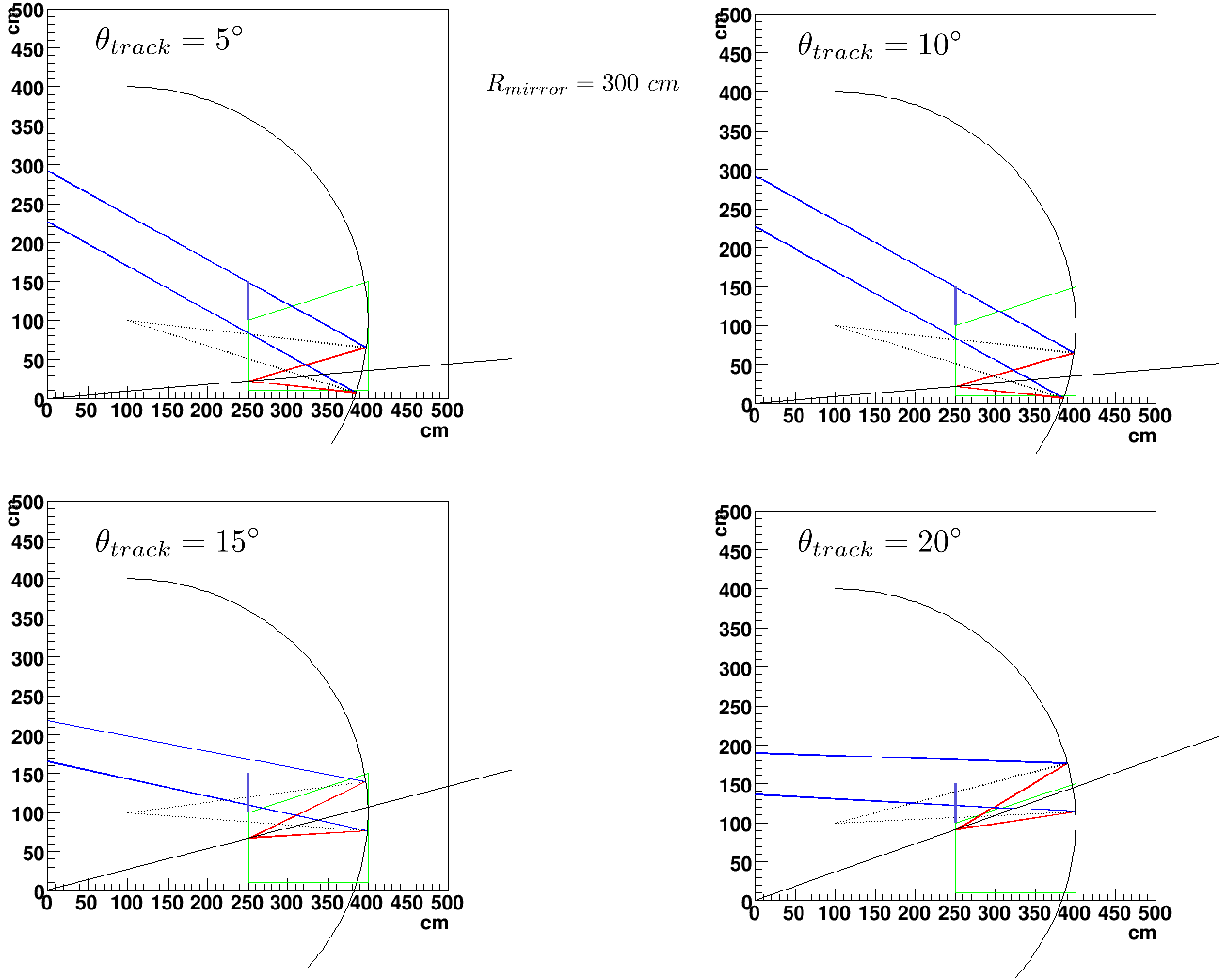
  - reduce the magnitude of the field

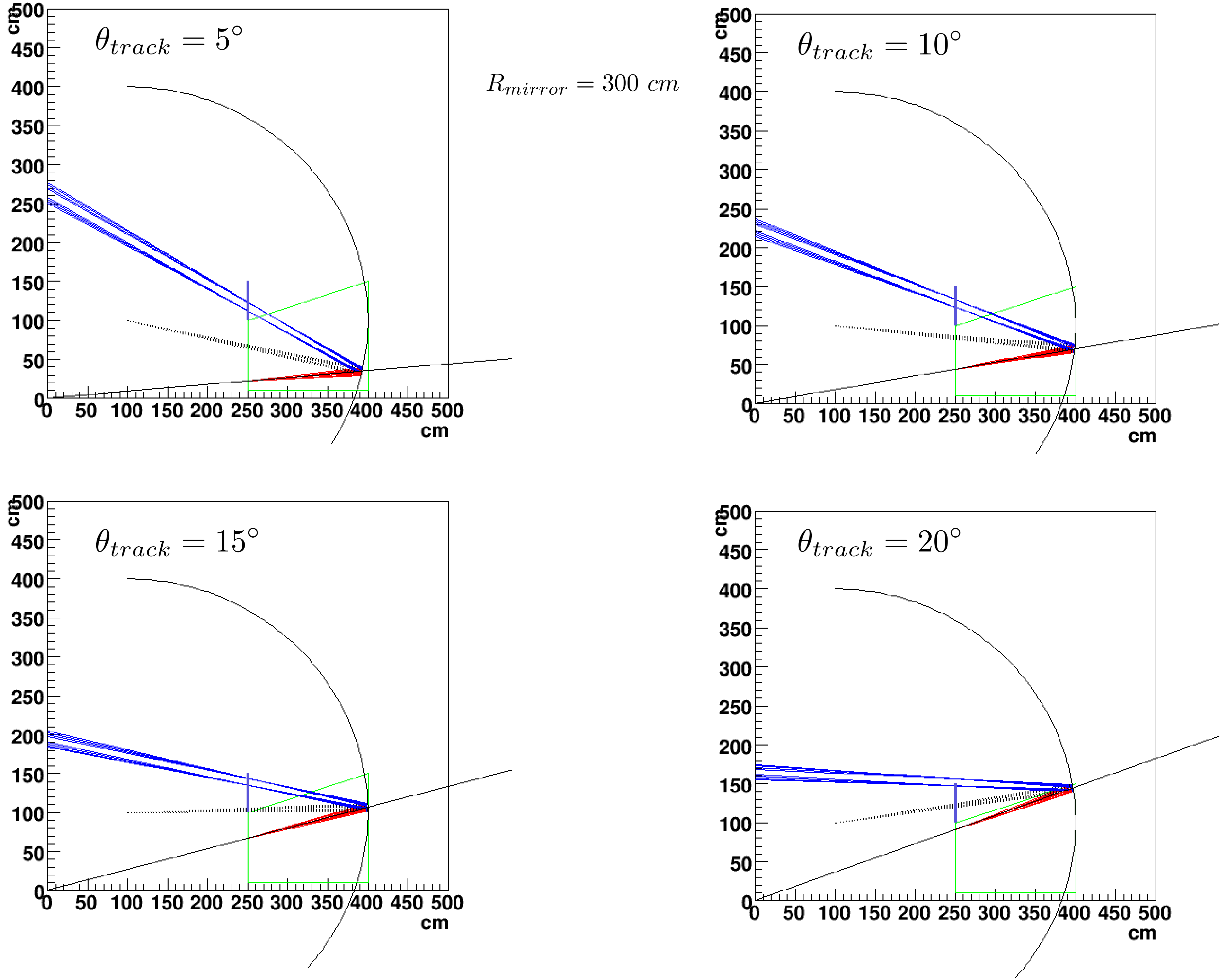
  - do the field as parallel/antiparallel as possible to the track in the RICH region

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


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


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

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
- To minimize the field impact in the RICH region, the component of the field perpendicular to the track should be minimized
- Next step: use the ray tracer to study useful configurations:
  - Parameters and number of mirrors
  - Position of the photon-detector/focal plane
- In our case one has to add also the error due to the track bending to the usual total error for a mirror configuration

$$\sigma_{\theta_c}^{1\ p.e.} = \sqrt{\sigma^2_{chromatic} + \sigma^2_{pixel} + \sigma^2_{aberration} + \sigma^2_{track} + \sigma^2_{magnetic}}$$

- The *aberration* and *track* has to be evaluated, when good configuration for the mirror(s) will be fixed