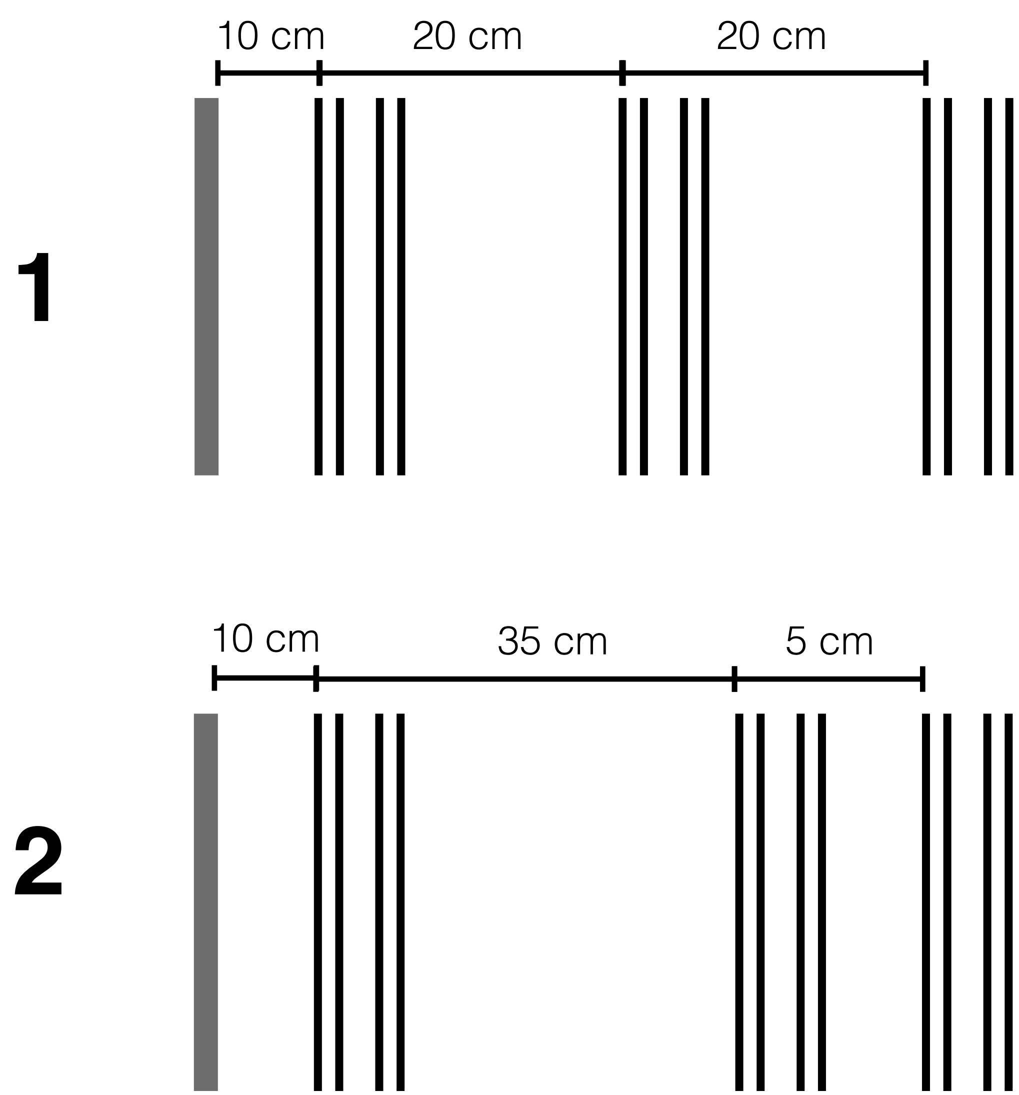
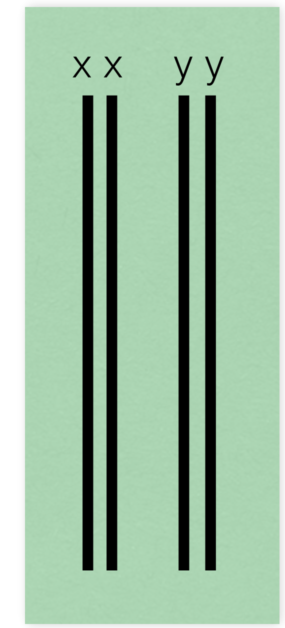
Preliminary studies about CBC (CMS) for MUonE:

- tracking resolution
- possible distances optimization
- impact on correlation curve

A. Principe - 9/10/2018

CBC: material budget





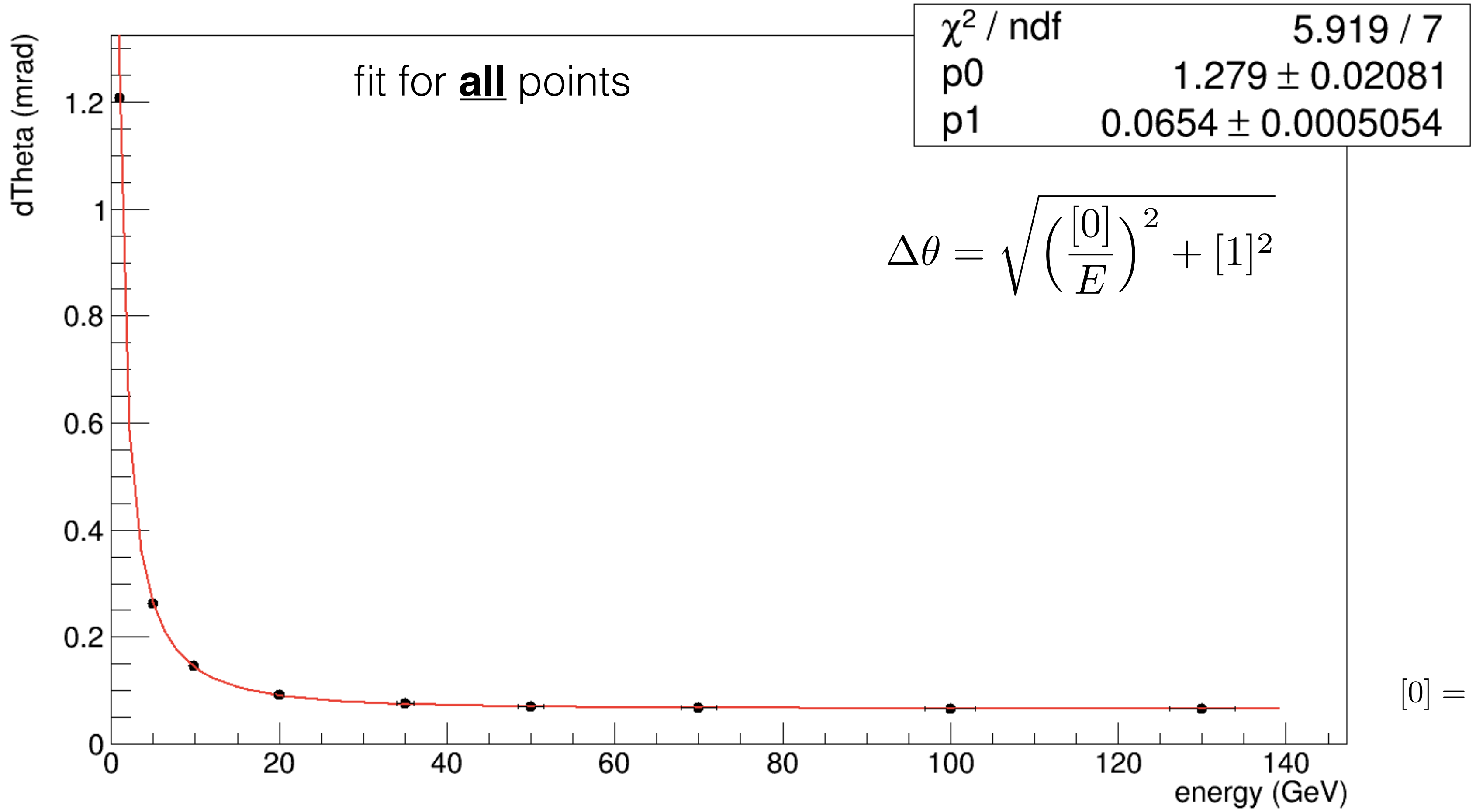
module thickness = 4*300 um = 1.2 mm
single readout pitch: 90 um (binary)
intrinsic layer resolution: 90/sqrt(12)
doublet point resolution: ~90/sqrt(24)
dx = 2 mm
dy = 2 mm
dxy = 1 cm
range CBC dx/dy doublet = [1.6, 4] mm

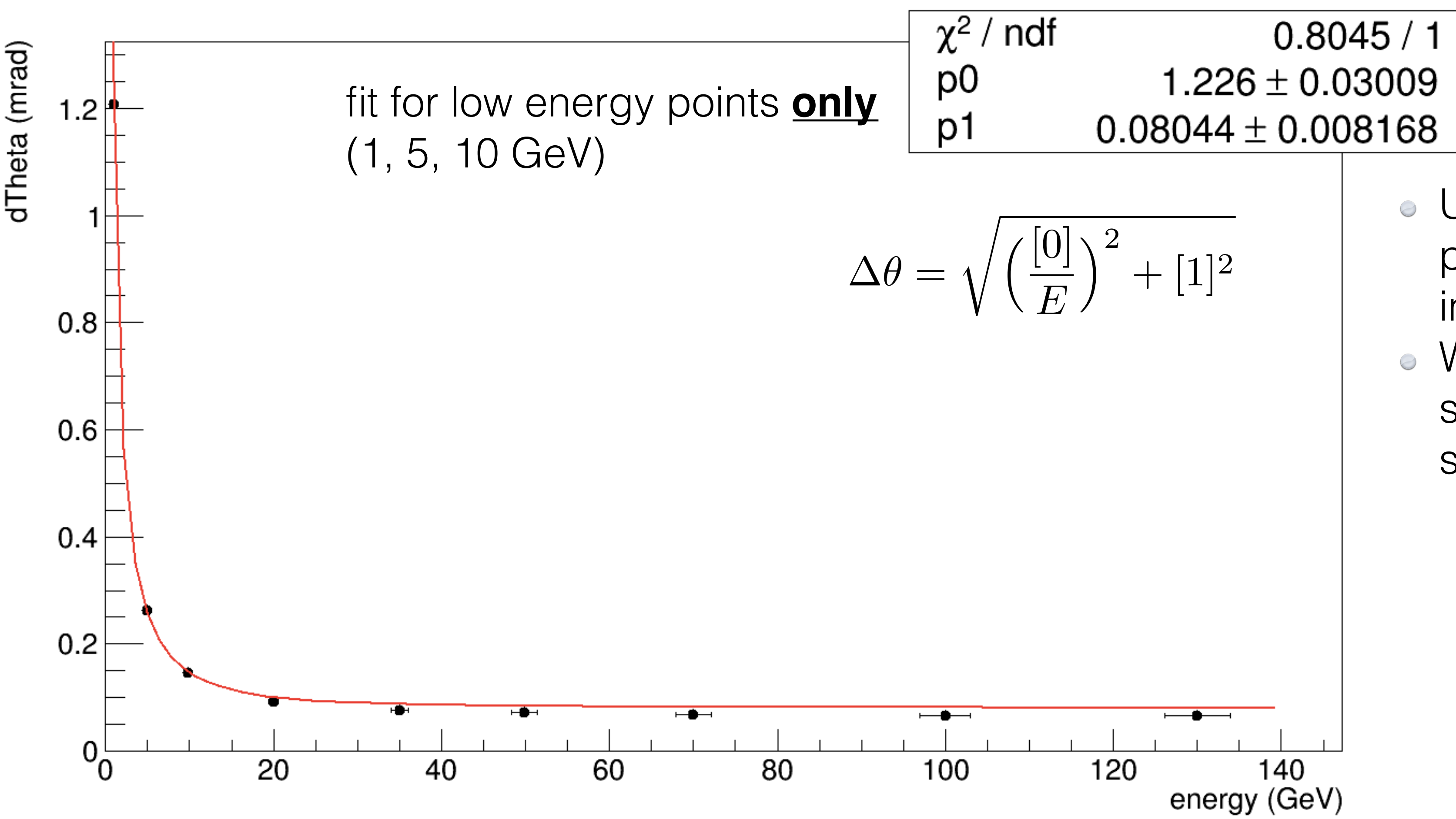
Possible improvements / optimization:
- relative layer distances: setup2 better for low energies;
- module arm: L > 50 cm?
- eliminate doublets?

Interaction probability
(cross section LO, Ebeam=150 GeV, E>1 GeV, 245 ub)
- 1 cm **Be**: **~1.21e-4**
- 1.2 mm*3 **Si**: ~0.40*1.21e-4 = **0.49e-4**

- (Z/W)Be = 0.444, (Z/W)Si = 0.499, d_Si/d_Be = 0.36
- X0_Be = 35.28 cm, X0_Si = 9.37 cm.

Tracking resolution CBC setup1 (20cm/20cm) vs energy





$$[0] = 13.6\sqrt{\frac{nd}{X_0}}\left(1 + 0.038\log\frac{nd}{X_0}\right)$$

$$[1] = \sqrt{2}\frac{\delta x}{L_{mod}}$$

$$[0] = 13.6\sqrt{\frac{3.6\cdot 0.03}{9.37}}\left(1 + 0.038\log\frac{3.6\cdot 0.03}{9.37}\right) \approx 1.21\ \mathrm{mrad}\cdot\mathrm{GeV}$$

$$[1] = \sqrt{2}\frac{p/\sqrt{24}}{40.2\ \mathrm{cm}} \approx 0.065\ \mathrm{mrad}$$

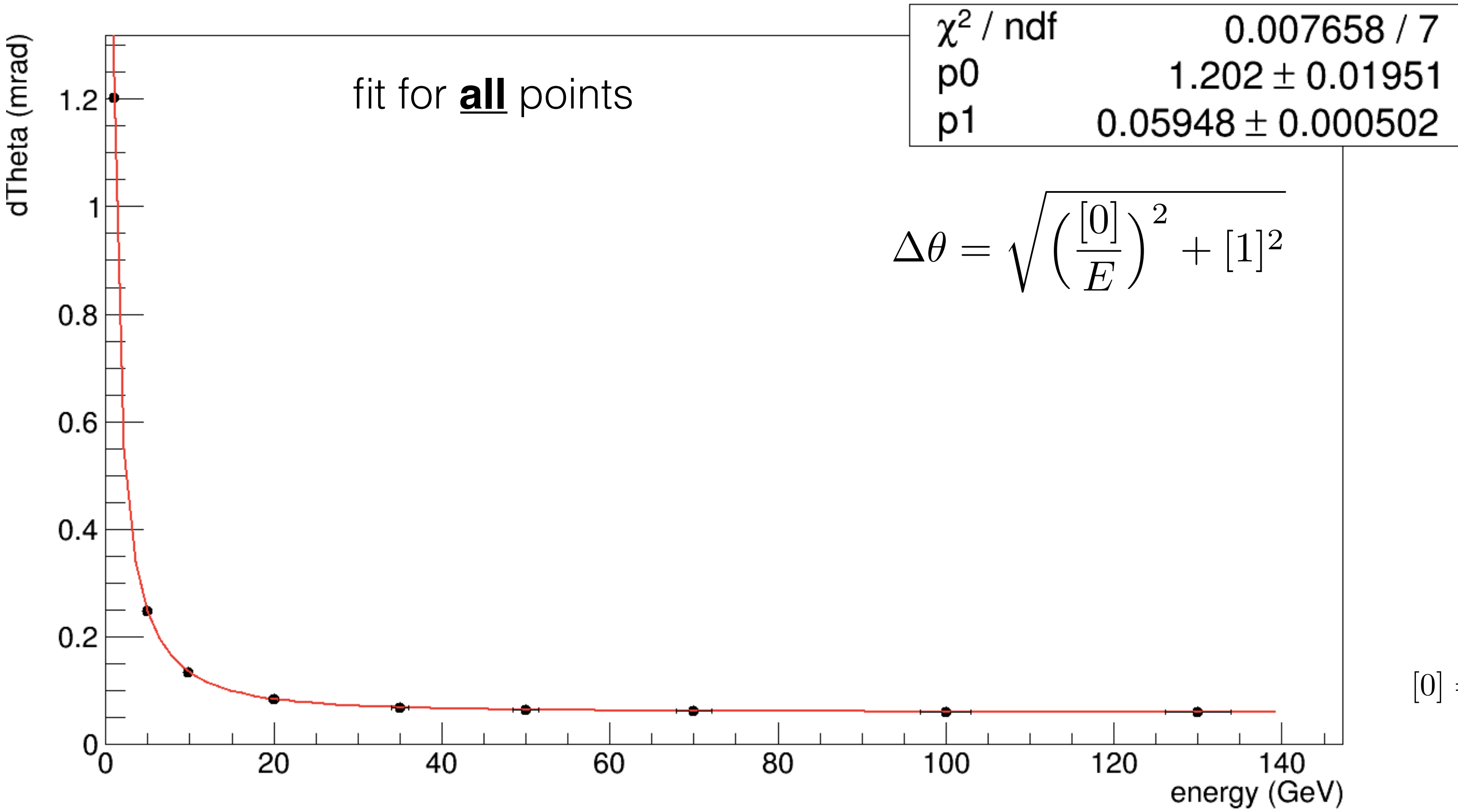
- Using all points, fit looks quite good: in particular asintotic term is in agreement with intrinsic resolution of CBC doublets.
- With low energy points only, asintotic term is slightly larger than expected one from p/sqrt(24):

$$[1] = \sqrt{2}\frac{23\ \mu\mathrm{m}}{40.2\ \mathrm{cm}} \approx 0.081\ \mathrm{mrad}$$

or

$$[1] = \sqrt{2}\frac{p/\sqrt{24}}{32\ \mathrm{cm}} \approx 0.081\ \mathrm{mrad}$$

Tracking resolution CBC setup2 (35cm/5cm) vs energy

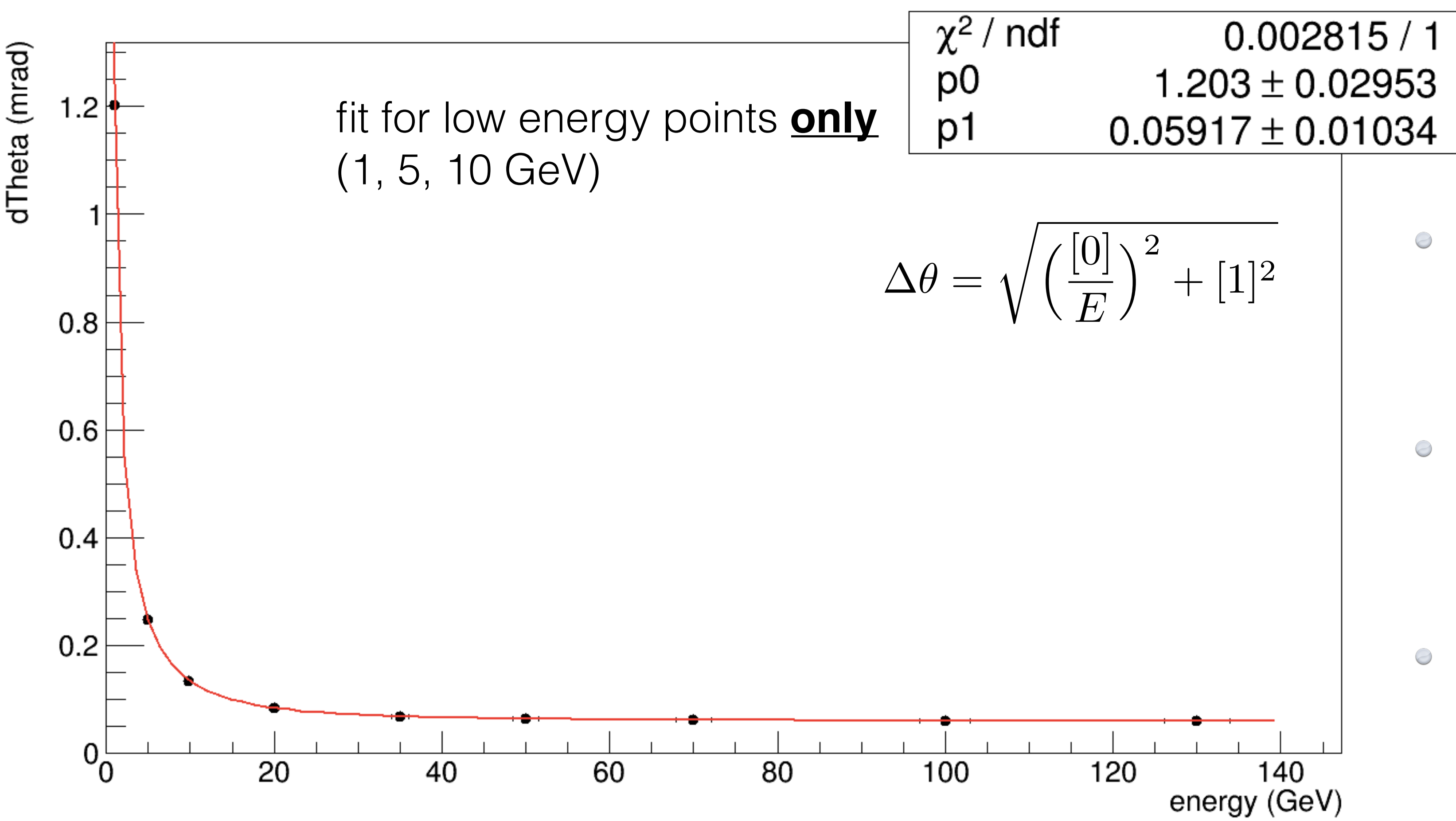


$$[0] = 13.6\sqrt{\frac{nd}{X_0}}\left(1 + 0.038\log\frac{nd}{X_0}\right)$$

$$[1] = \sqrt{2}\frac{\delta x}{L_{mod}}$$

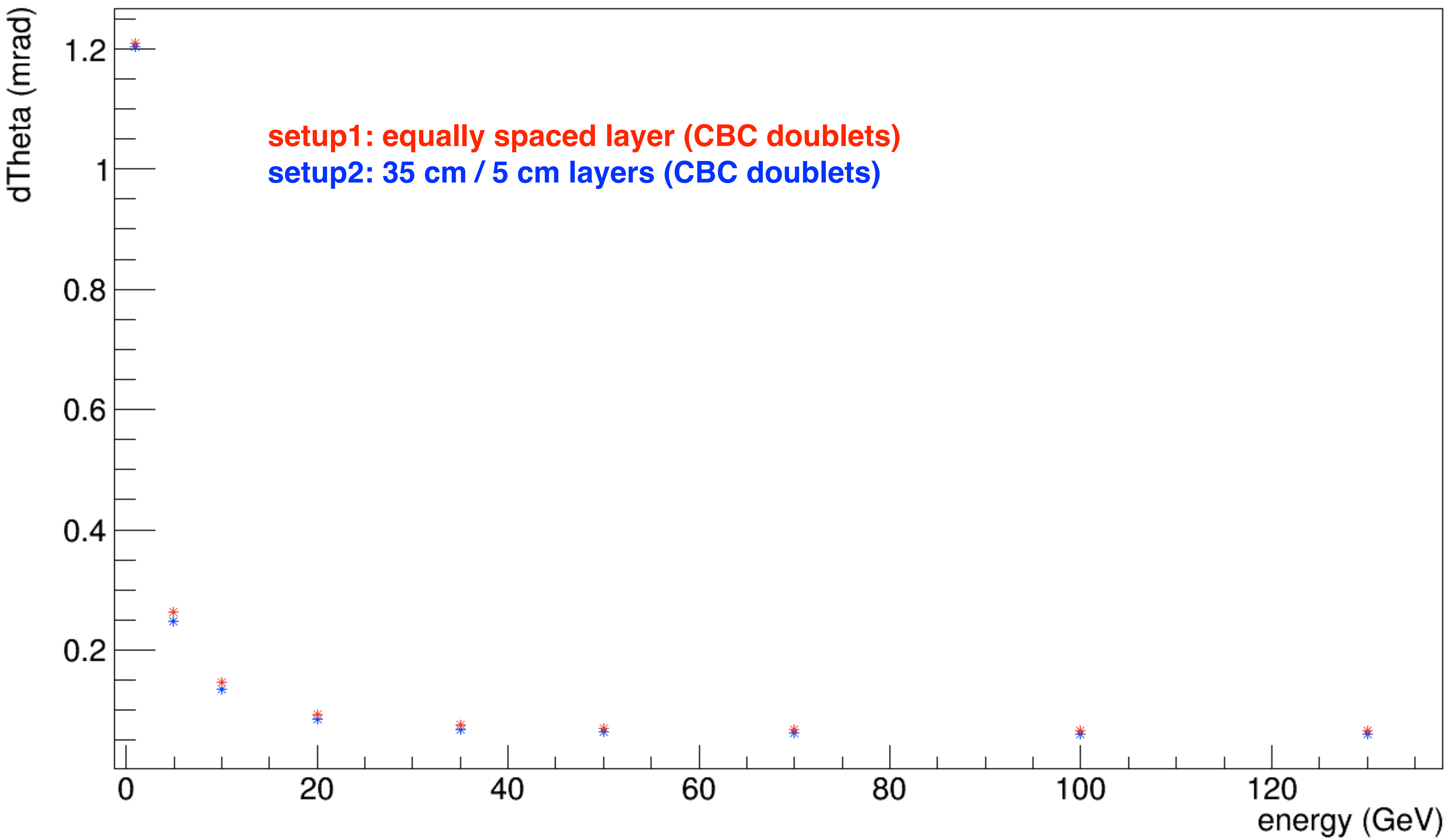
$$[0] = 13.6\sqrt{\frac{3.6\cdot 0.03}{9.37}}\left(1 + 0.038\log\frac{3.6\cdot 0.03}{9.37}\right) \approx 1.21\ \mathrm{mrad}\cdot\mathrm{GeV}$$

$$[1] = \sqrt{2}\frac{p/\sqrt{24}}{40.2\ \mathrm{cm}} \approx 0.065\ \mathrm{mrad}$$



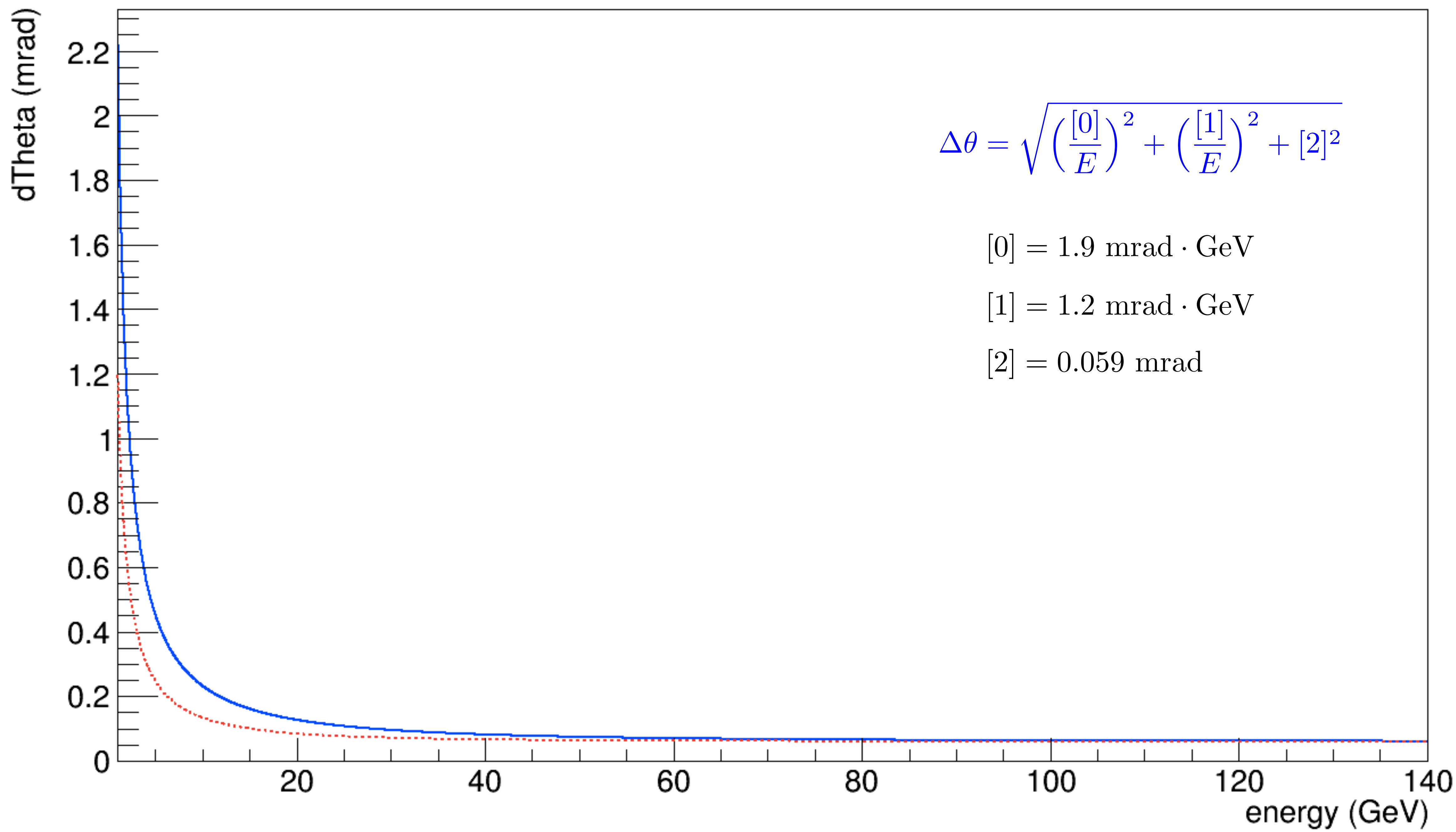
- Optimizing the distances, both fit are compatible and resolution term is lower than expected.
- Tracking fit of low energy particles uses only about two station (of three), because of multiple scattering: so for these the formula [1] contains an effective $L_{eff} < L_{mod}$
- With this simple optimization $\boldsymbol{L_{eff} \sim L_{mod}}$ for all energies.

Tracking resolution comparison setup1/setup2

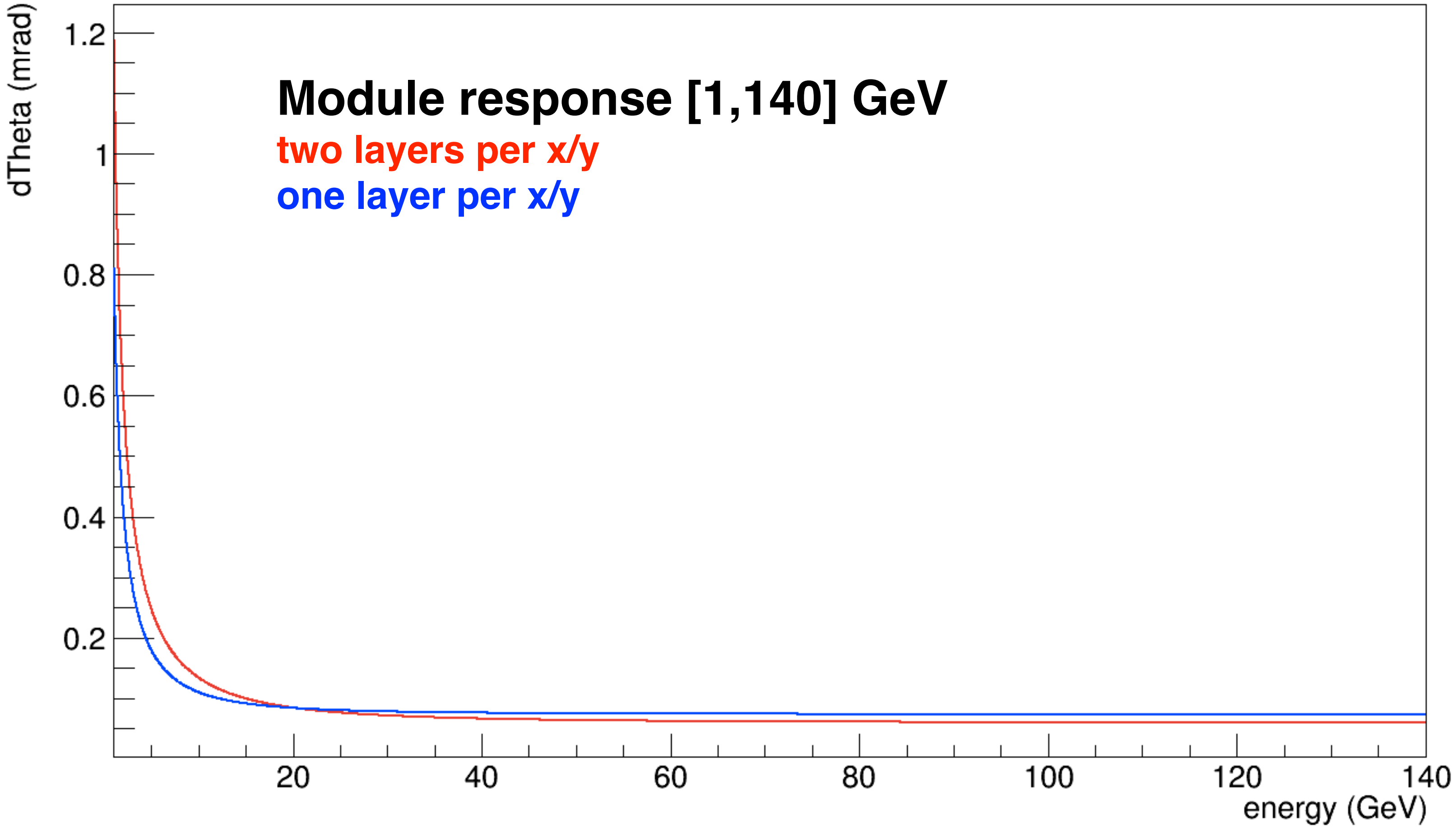


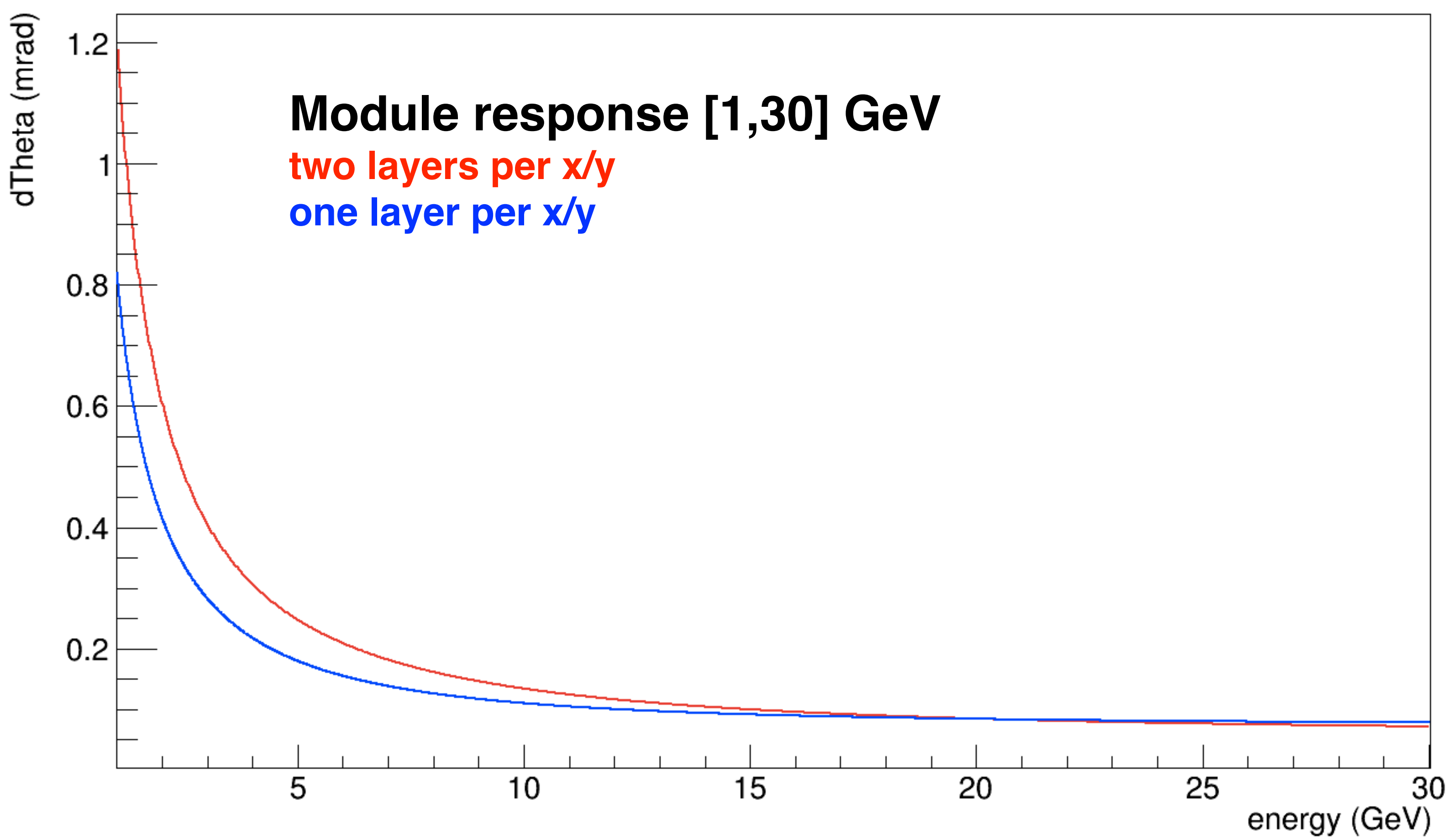
- Anyhow the effect of this optimization appears not too evident: mcs dominates at low energies on the intrinsic resolution.

Convolution target x apparatus module



- An attempt to convolve target and apparatus effects, in a gaussian approximation.
- ~1.9 mrad is the mcs sigma of 1 GeV particle on 1 mm of Be.
- This can be useful for a convolution studies with cross section to take in account experimental smearings within the fitting procedure: to extract the running of alpha in a condition closer to the real one.





Resolution function:
doublet CBC / modified CBC

$$\Delta\theta = \sqrt{\left(\frac{[0]}{E}\right)^2 + [1]^2}$$

$[0] = 1.2 \text{ mrad} \cdot \text{GeV}$

$[1] = 0.059 \text{ mrad}$

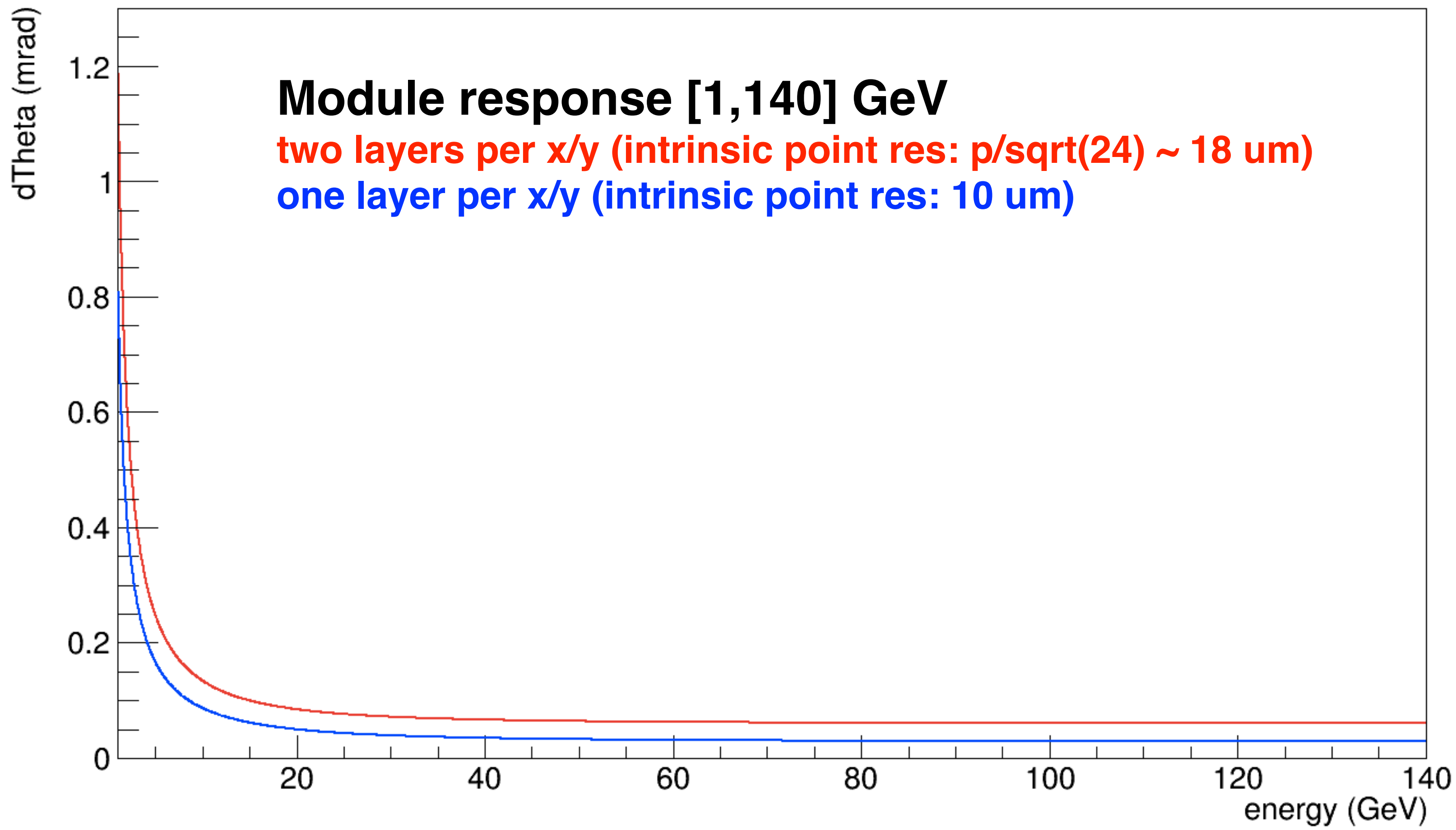
$[0] = 0.82 \text{ mrad} \cdot \text{GeV}$

$[1] = \cancel{0.074} \text{ mrad}$ (L = 50 cm)

$[1] = 0.091 \text{ mrad}$ (L = 40 cm)

- **Doublet** resolution: 90/sqrt(24) ~ 18 μm
- **Single layer** resolution: 90/sqrt(12) ~ 26 μm

- CBC with single layer only per view is better for low energy (low mcs), but slightly worse for E > 30-40 GeV.
- Anyway ~sqrt(2) difference for E < 5 GeV.



Resolution function: doublet CBC / TOP solution

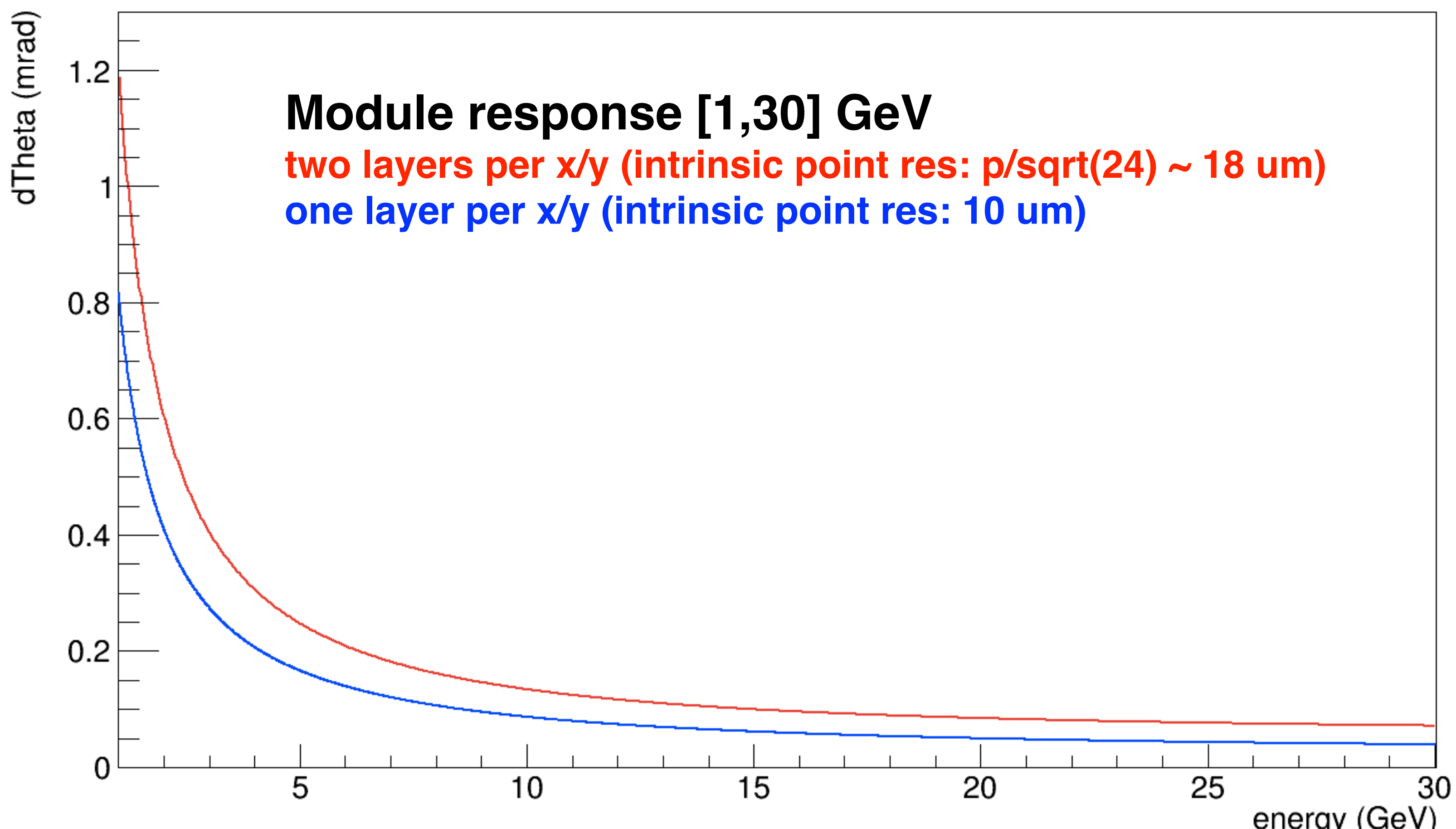
$$\Delta\theta = \sqrt{\left(\frac{[0]}{E}\right)^2 + [1]^2}$$

$[0] = 1.2\ \mathrm{mrad} \cdot \mathrm{GeV}$

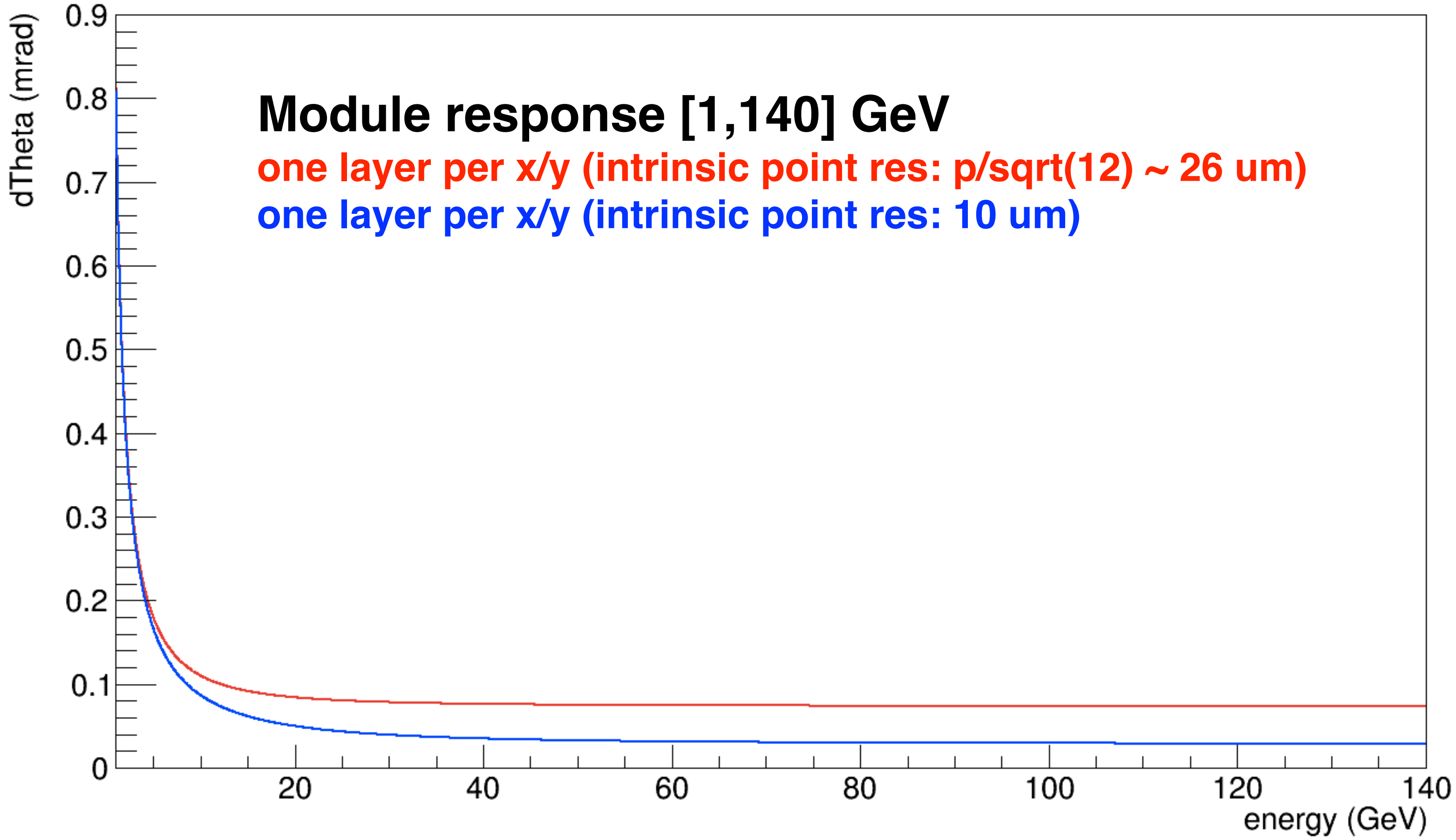
$[1] = 0.059\ \mathrm{mrad}$

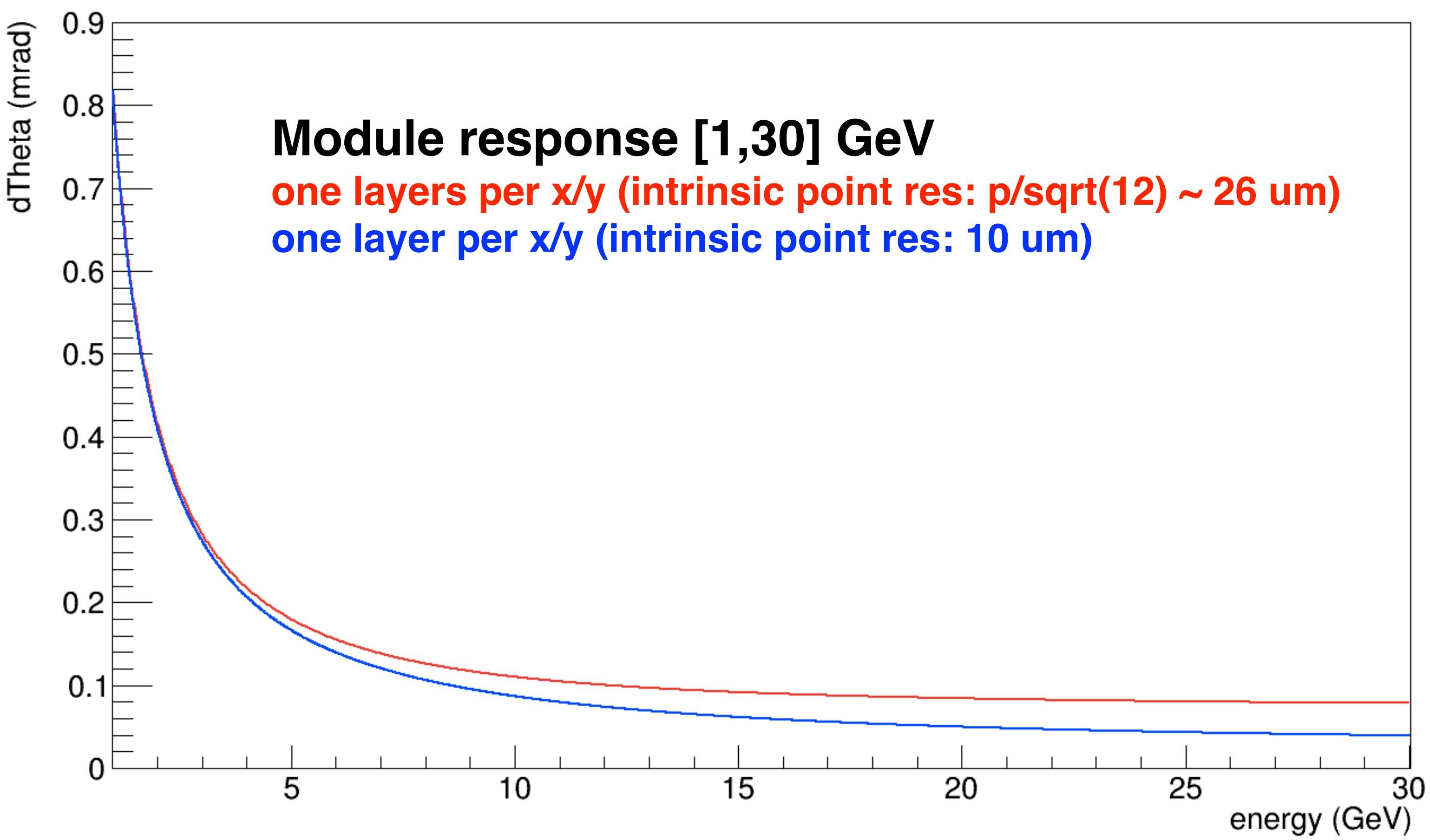
$[0] = 0.82\ \mathrm{mrad} \cdot \mathrm{GeV}$

$[1] = 0.028\ \mathrm{mrad}$



- Doublets offer double material budget (low energy effect, E < 10-20 GeV) and have a double intrinsic res (for E > 20-30 GeV).
- A factor sqrt(2) for E < 10-20 GeV instead of a linear scaling in asintotic term (intrinsic).





Resolution function: modified CBC / best solution

$$\Delta\theta = \sqrt{\left(\frac{[0]}{E}\right)^2 + [1]^2}$$

$[0] = 0.82\ \mathrm{mrad} \cdot \mathrm{GeV}$

$[1] = 0.0\cancel{74}\ \mathrm{mrad}$ (L = 50 cm)

$[1] = 0.091\ \mathrm{mrad}$ (L = 40 cm)

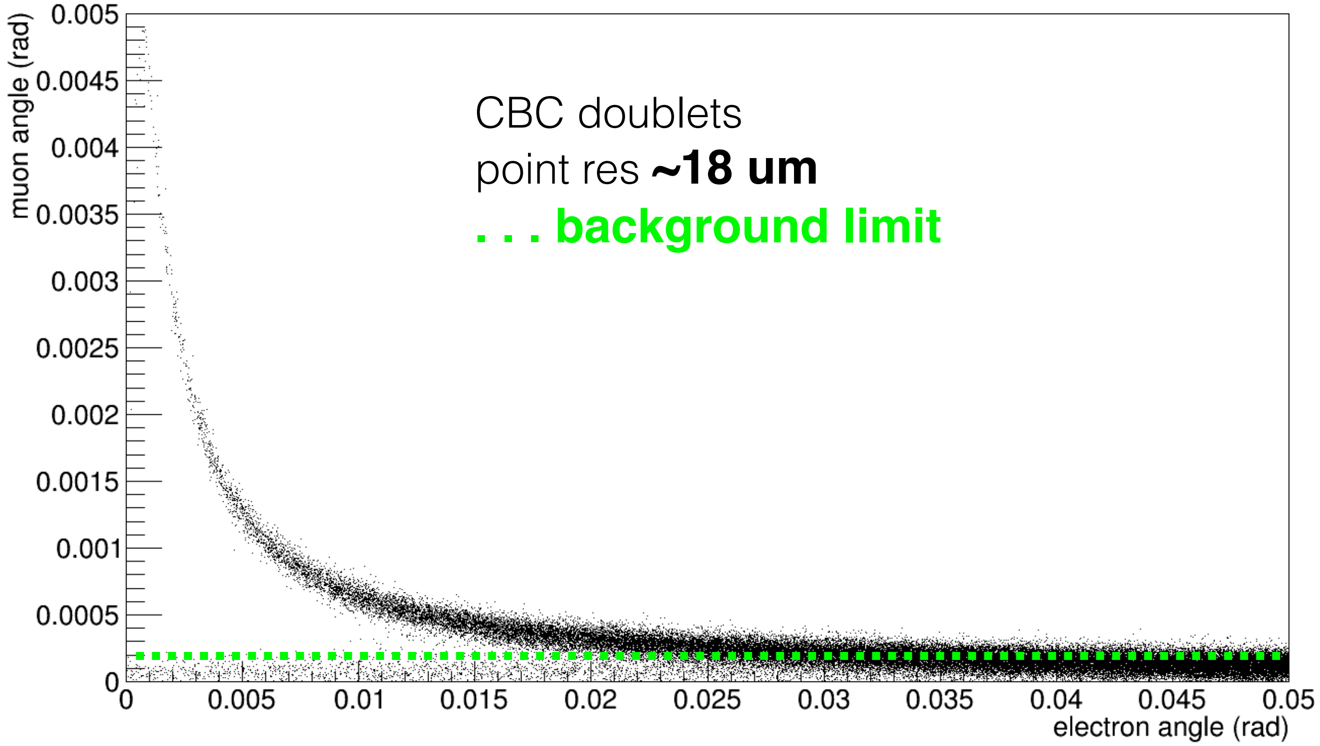
$[0] = 0.82\ \mathrm{mrad} \cdot \mathrm{GeV}$

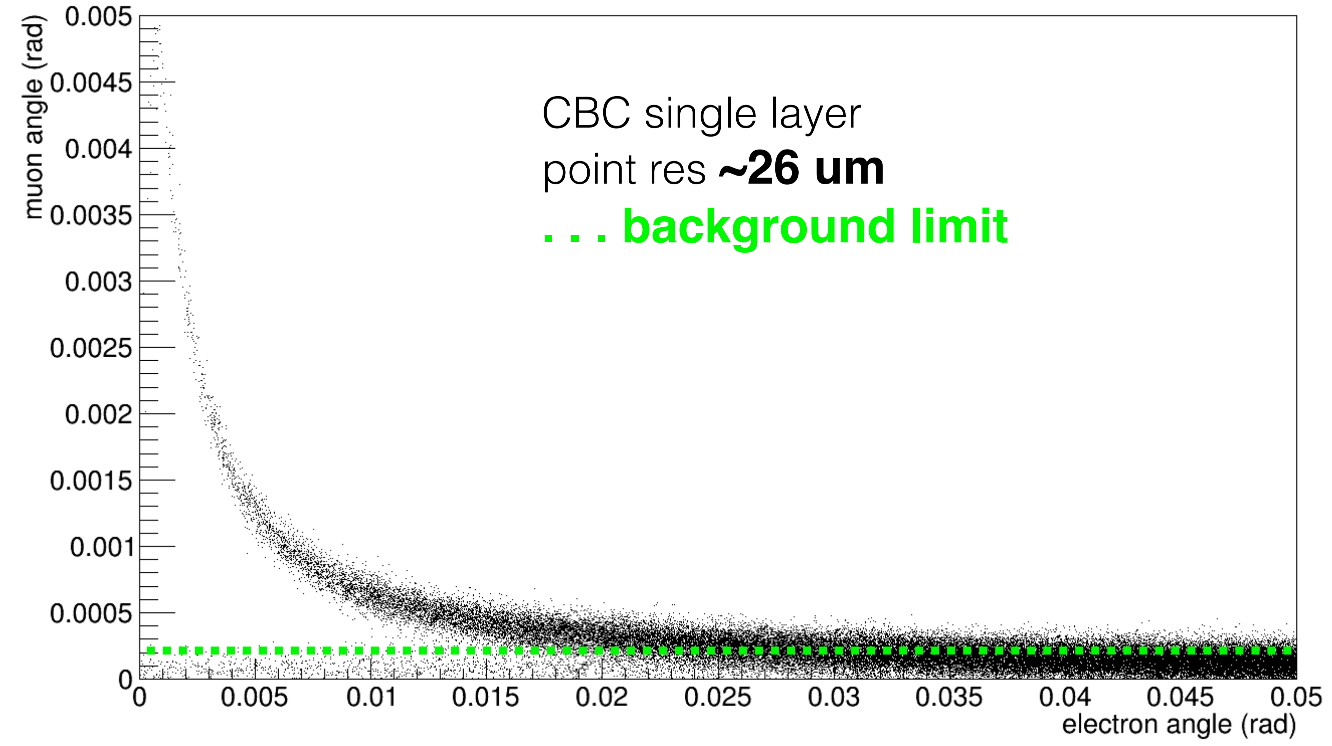
$[1] = 0.028\ \mathrm{mrad}$

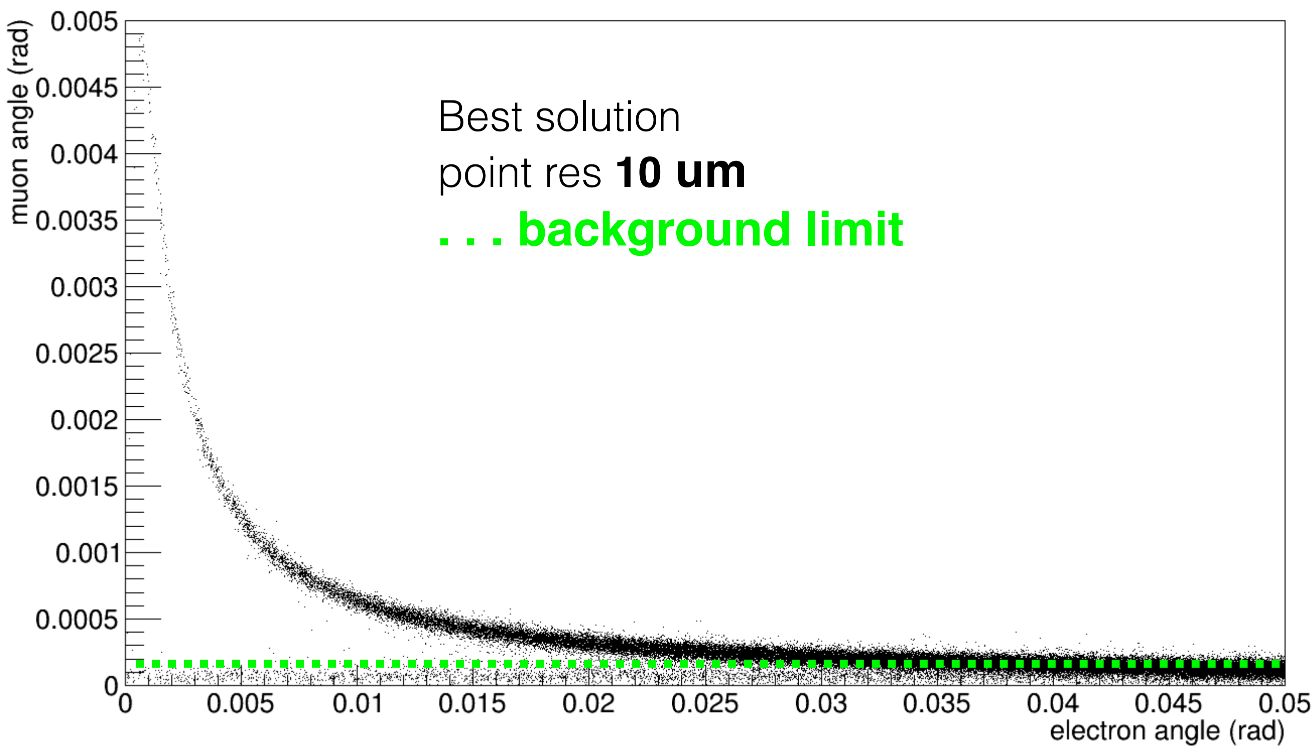
- CBC with single layer only per view looks like the best solution at low energy (less material budget), but it's worse for E > 10 GeV because of different intrinsic resolution.

Comparisons: correlation plot θ_μ θ_e

160 GeV on 1 mm Be, 3% beam energy spread







- CBC doublets: background intersects signal at about 25-30 mrad.
- Modified CBC: at about 20 mrad.
- Top solution: ~30-35 mrad.

- From this point of view, p/sqrt(24) = 18 um (best CBC res) looks like at limit.
- Changing the chip to eliminate a layer per view does not seem to be appropriate, because the single layer resolution is too low.

Remarks

- Very preliminary studies on CBC tracking performance.
- Possible improvements and optimization, but it seems from the point of view of tracking we are “close” to the best solution (10 um, one layer per view): how close it will have to be understood with the workflow and the determination of performance on the final precision of running.
- Pay attention to the correlation plot and signal / background discrimination: the resolution of CBC doublets appears at the limit anyway.
- Moreover, the effect of the material budget activity introduced by the doublets will have to be studied: it does not seem to make sense to remove a layer, given the poor point resolution of a single layer.