A Multiple Scattering model for the MuonE experiment

Riccardo Nunzio Pilato

We defined a model to determine the MS effects on the spatial angle θ_R, starting from the distributions of $\delta\theta$ and α:

$$\delta\theta_X = \delta\theta_{\mu X} + \delta\theta_{eX}$$

$$(\delta\theta_X, \delta\theta_Y) \rightarrow (\delta\theta, \alpha) \qquad \delta\theta_X = \delta\theta \cos\alpha \qquad \delta\theta_Y = \delta\theta \sin\alpha$$

Assuming a rotational simmetry...

- α has a uniform distribution
- $\delta\theta$ is distributed according to

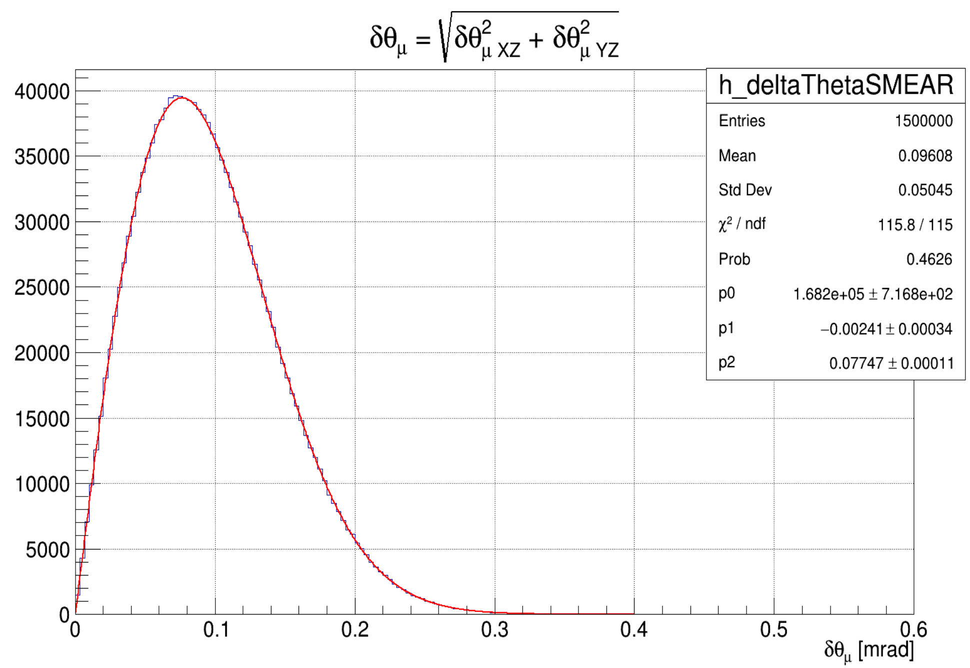
$$p(\delta\theta) \propto \delta\theta f(\delta\theta_X)|_{\delta\theta_X = \delta\theta}$$

For the muons:

Generation of muons with
E = 150 GeV ± 3% along the the z axis,
passing through the upstream detector

$$f_\mu(\delta\theta_\mu) \propto \delta\theta_\mu \frac{1}{\sqrt{2\pi}\sigma_\mu} e^{-\frac{(\delta\theta_\mu - \mu_\mu)^2}{2\sigma_\mu^2}}$$

Intrinsic resolution of the tracker
is the most relevant effect



For the electrons:

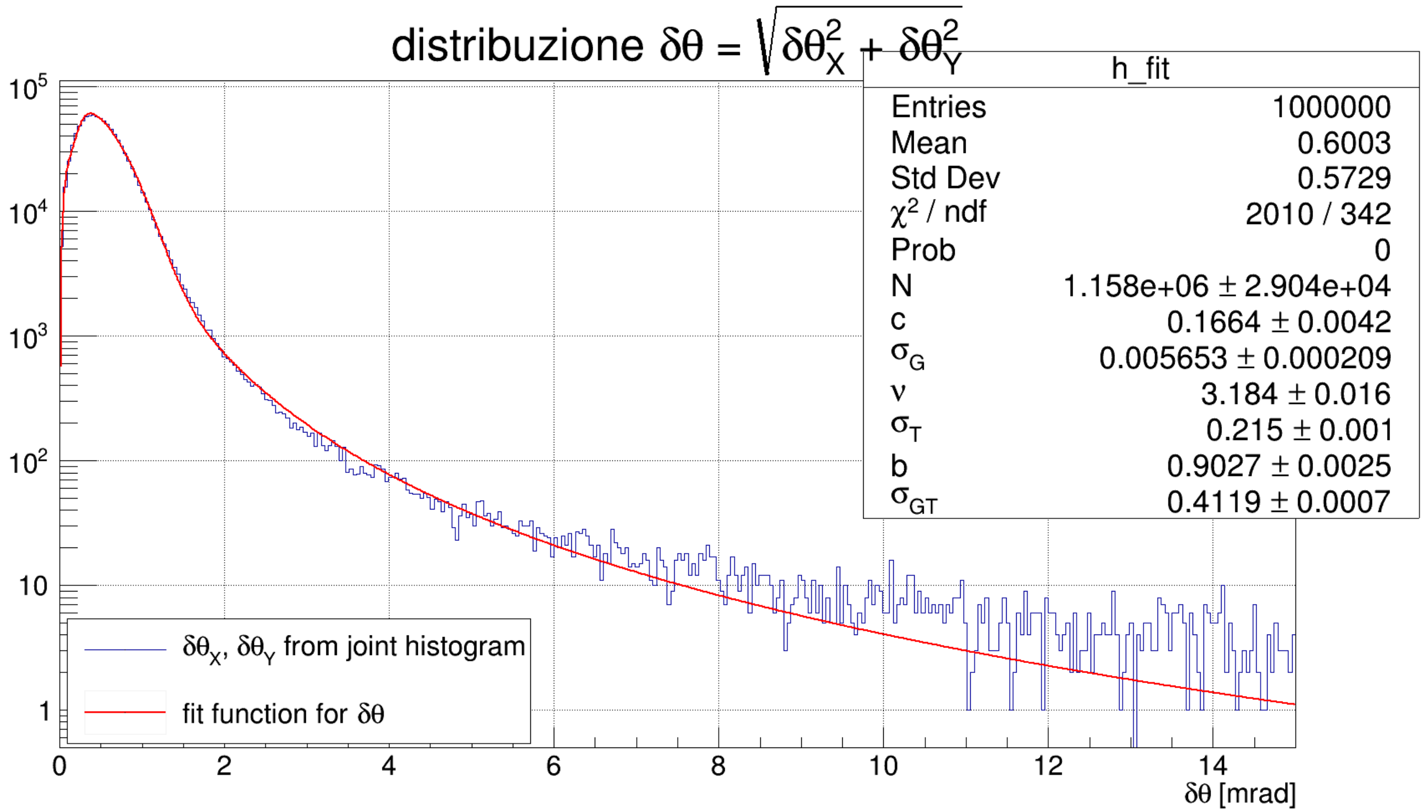
St = student distribution

$$f_e(\delta\theta_e;\ \vec{p}) = N\delta\theta_e\{c\,[St(\delta\theta_e,\nu,\sigma_T) - Gaus(\delta\theta_e,\sigma_G)] + b\,Gaus(\delta\theta_e,\sigma_G) + (1-b)Gaus(\delta\theta_e,\sigma_{GT})\}$$

Fit the distribution $\delta\theta_e$ can be difficult, so it is better to determine the parameters of the pdf using the convolution

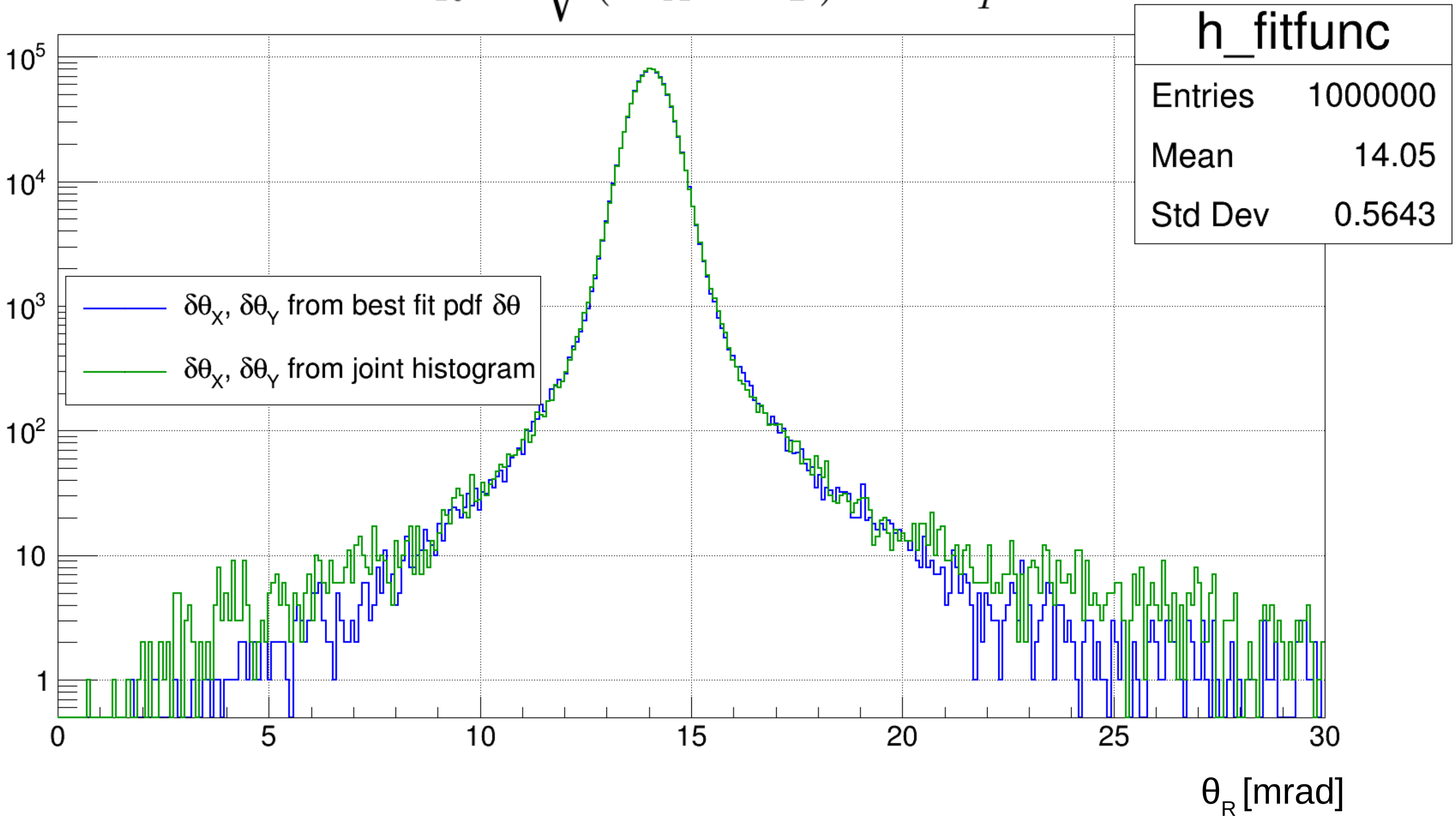
$$p(\delta\theta;\ \vec{p}) = \int_0^{\delta\theta} f_\mu(\delta\theta_\mu) f_e(\delta\theta - \delta\theta_\mu;\ \vec{p})\ d\delta\theta_\mu$$

Generation of electrons at fixed energy/angle in the center of Be target, passing through the downstream detector



Even if the fit is not precise, because of the high correlation between the parameters, in this way the distribution of θ_R is well reproduced

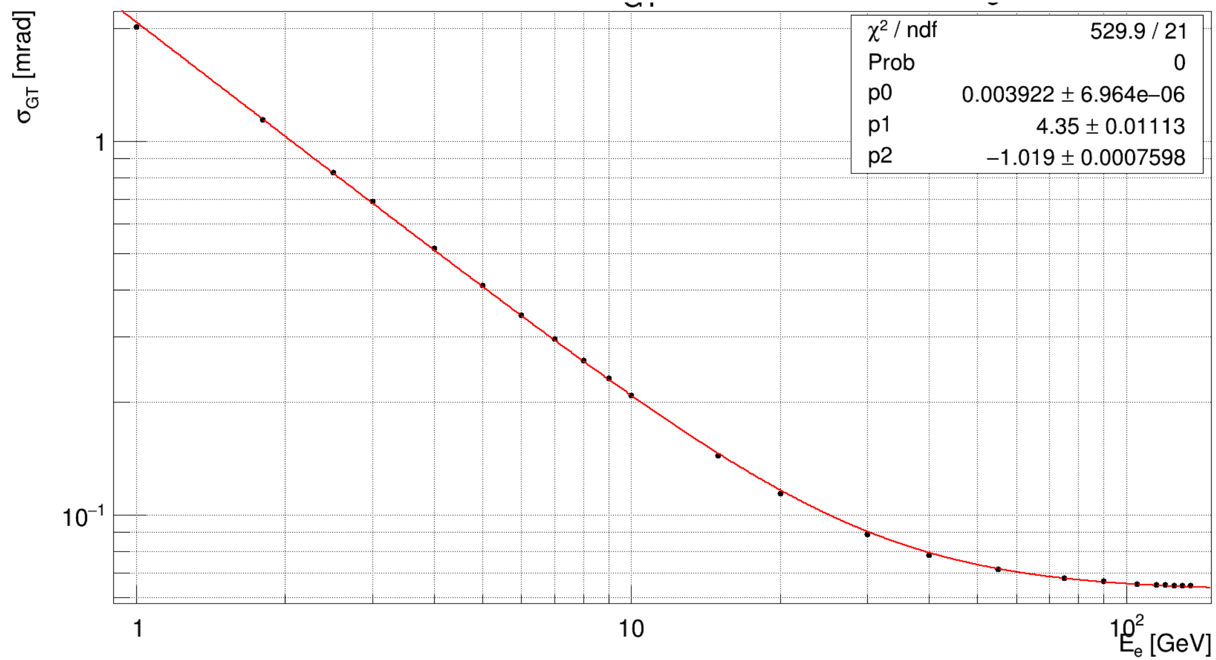
$$\theta_R = \sqrt{(\delta\theta_X + \theta_T)^2 + \delta\theta_Y^2}$$



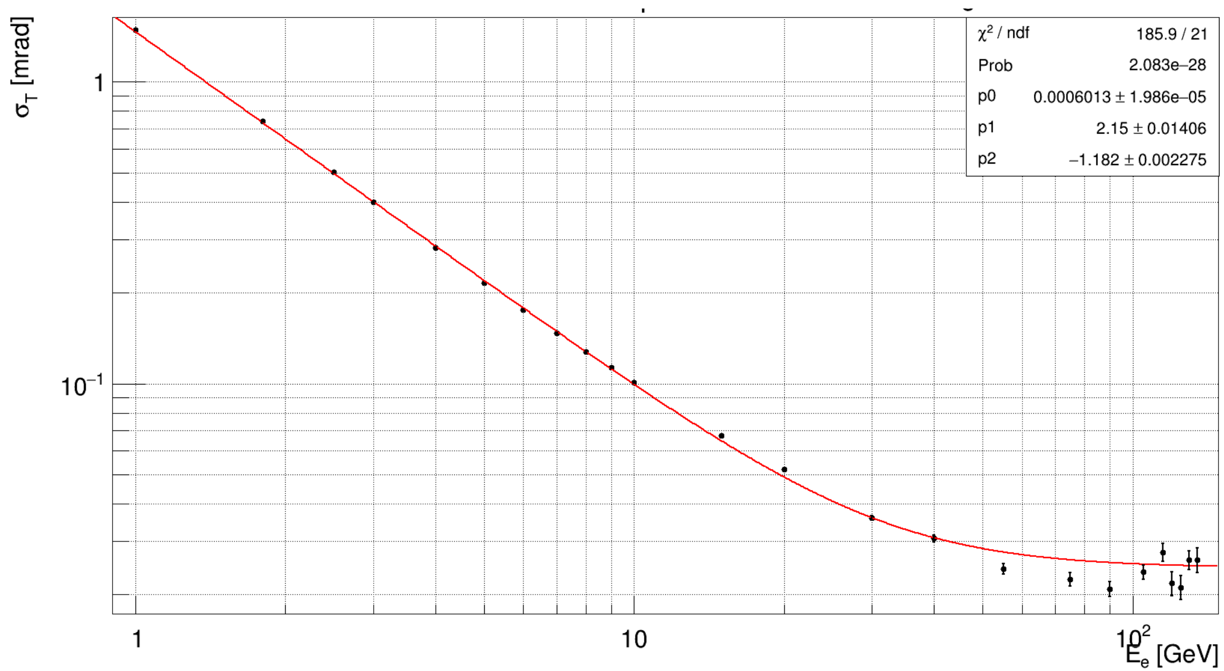
In order to obtain a complete parameterization of MS effects, it is necessary determine how the parameters that define the shape of $f_e(\delta\theta)$ evolve with electron’s energy.

Since the fit procedure is not very precise at the moment, only some parameters show a well defined behaviour

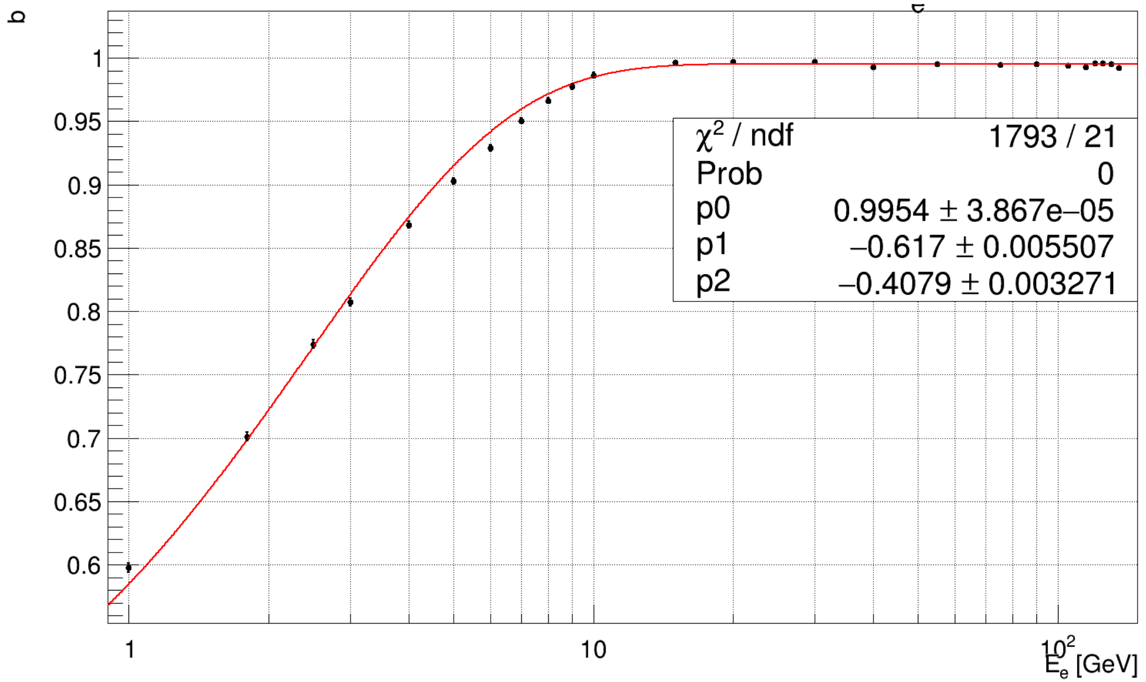
$$\sigma_{GT}(E_e) = \sqrt{p_0 + p_1 E_e^{2\cdot p_2}}$$



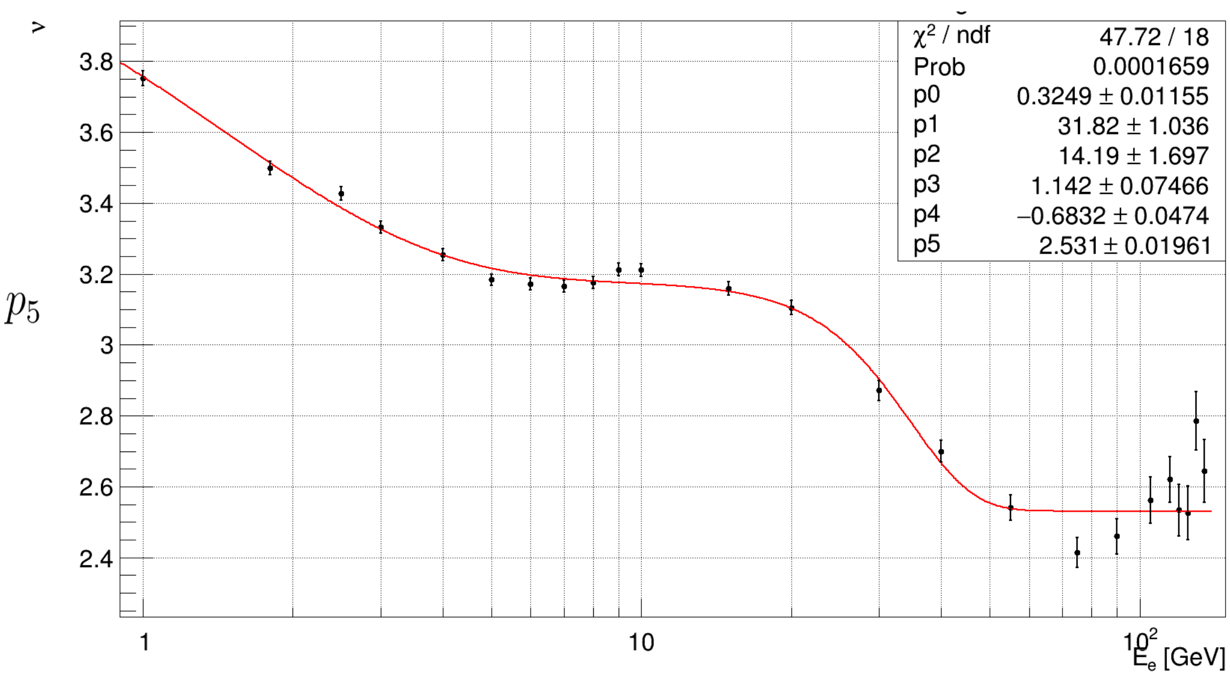
$$\sigma_{T}(E_e) = \sqrt{p_0 + p_1 E_e^{2\cdot p_2}}$$



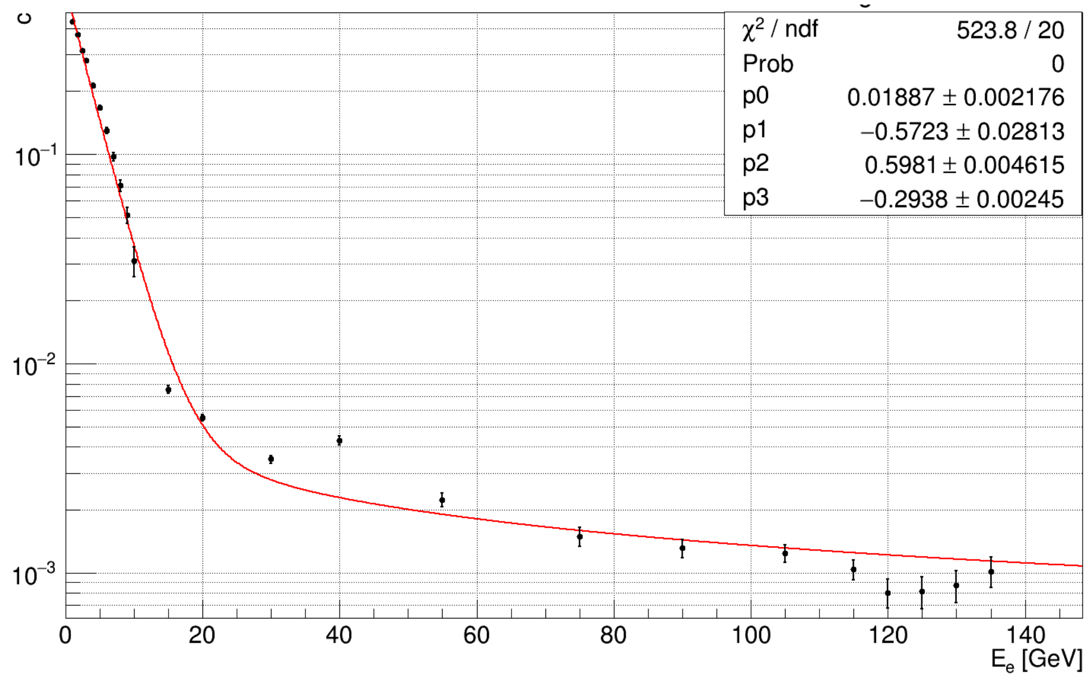
$$b(E_e) = p_0 + p_1 \; e^{p_2 \cdot E_e}$$



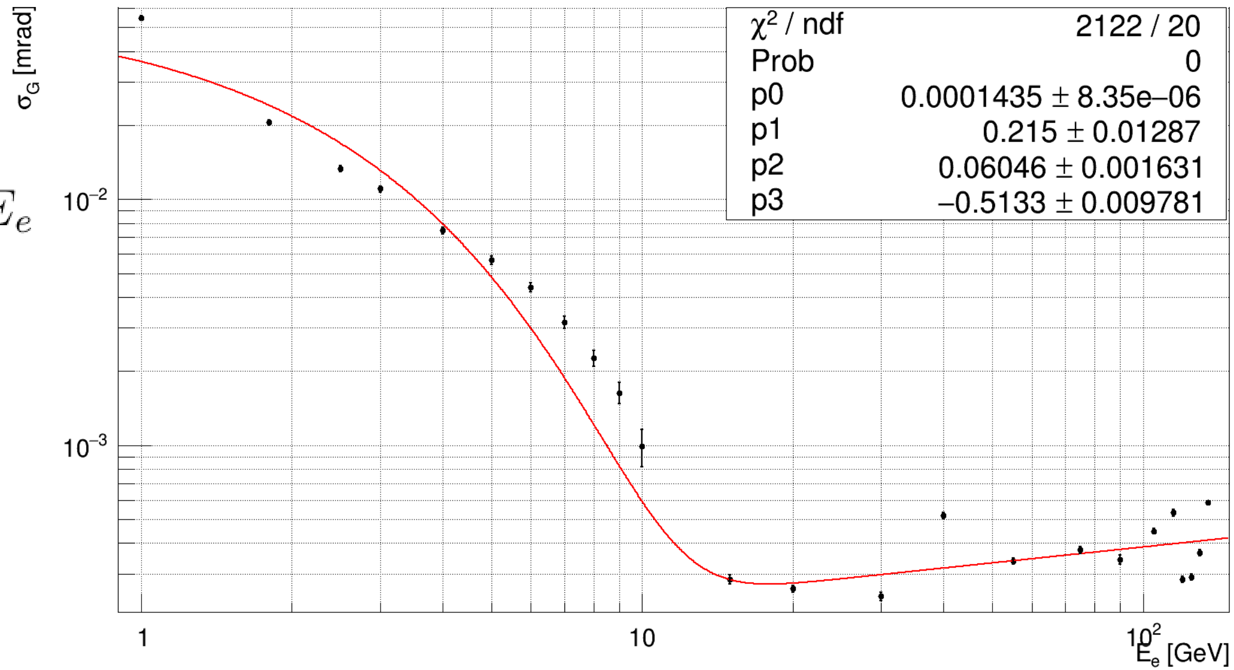
$$\nu(E_e) = p_0 \; erfc\left(\frac{E_e - p_1}{p_2}\right) + p_3 e^{p_4 \cdot E_e} + p_5$$



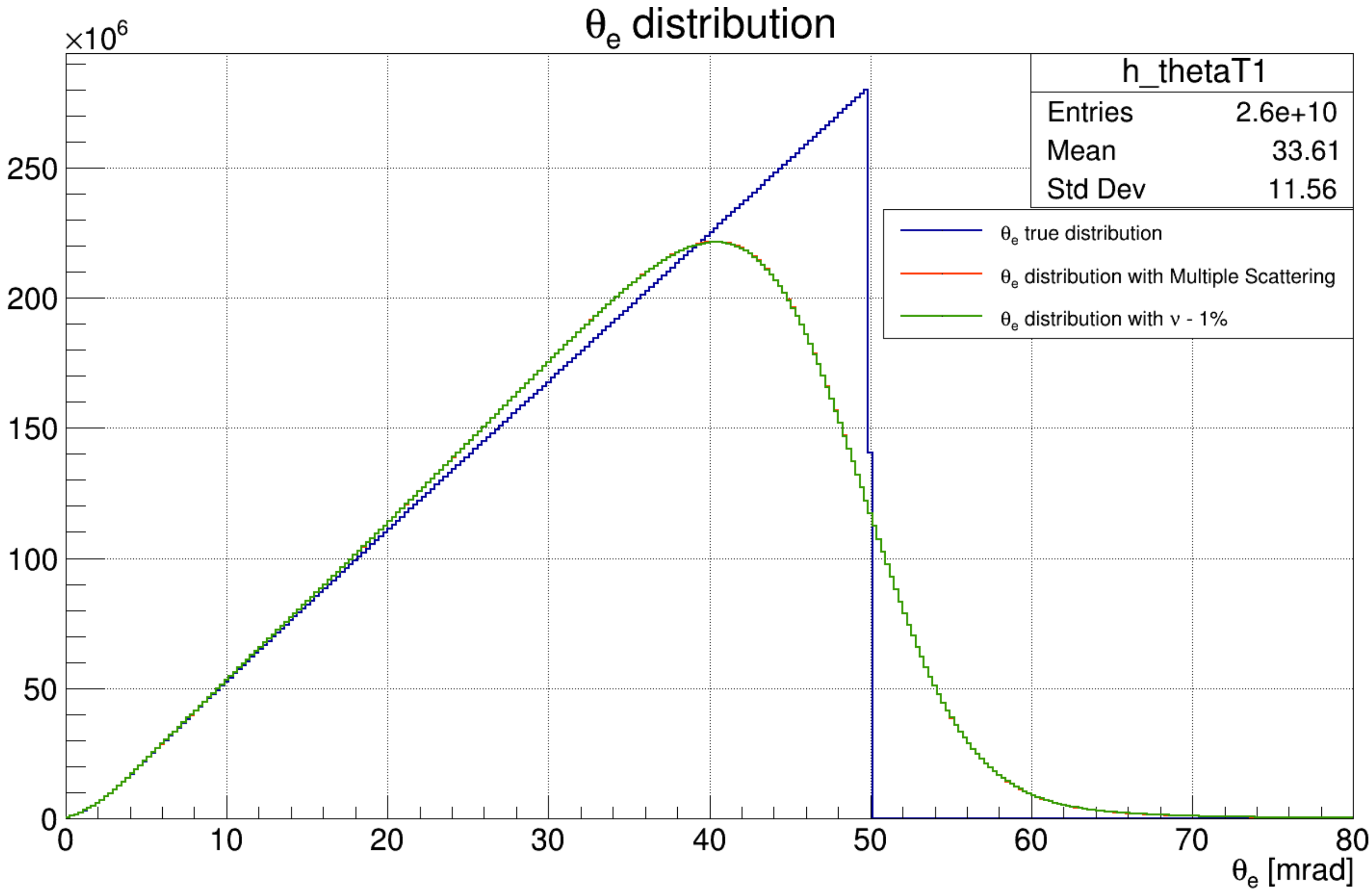
$$c(E_e) = p_0 E^{p_1} + p_1\ e^{p_2 \cdot E_e}$$

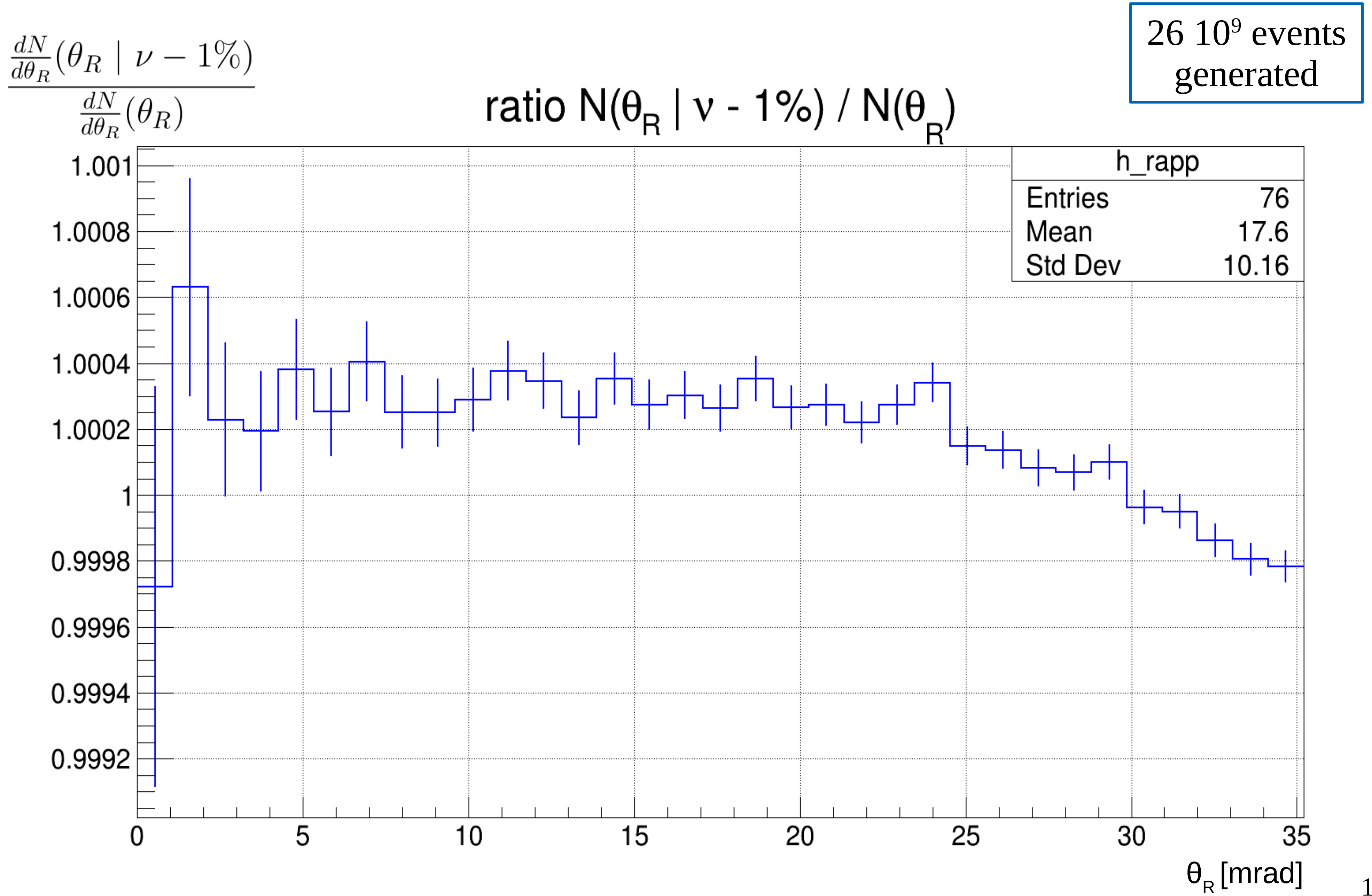


$$\sigma_G(E_e) = p_0 E^{p_1} + p_1\ e^{p_2 \cdot E_e}$$



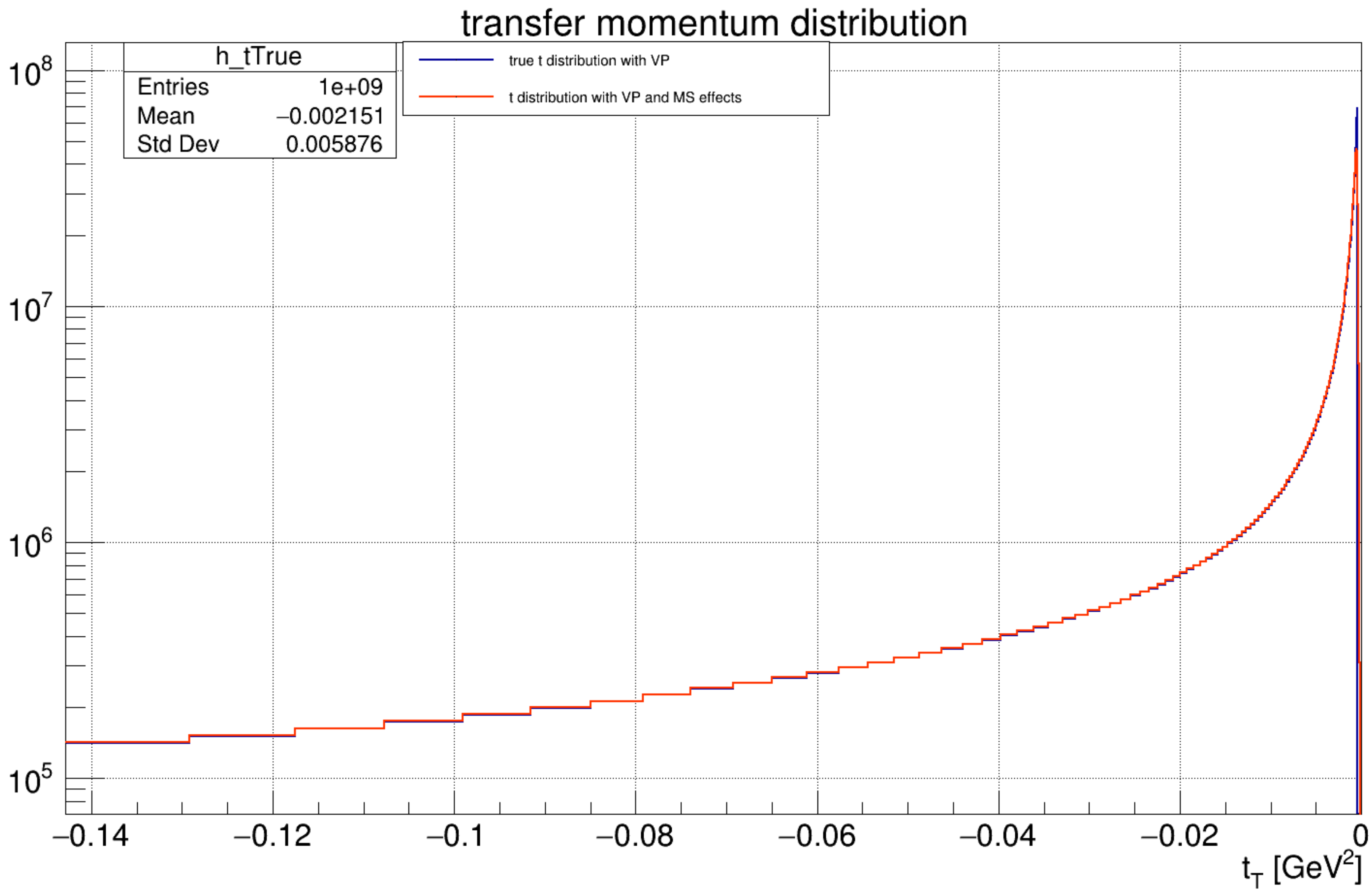
Once defined the parameterization of $f_e(\delta\theta)$, we tried to build the distribution of the spatial angle θ_R and study the effect of increase of the tails





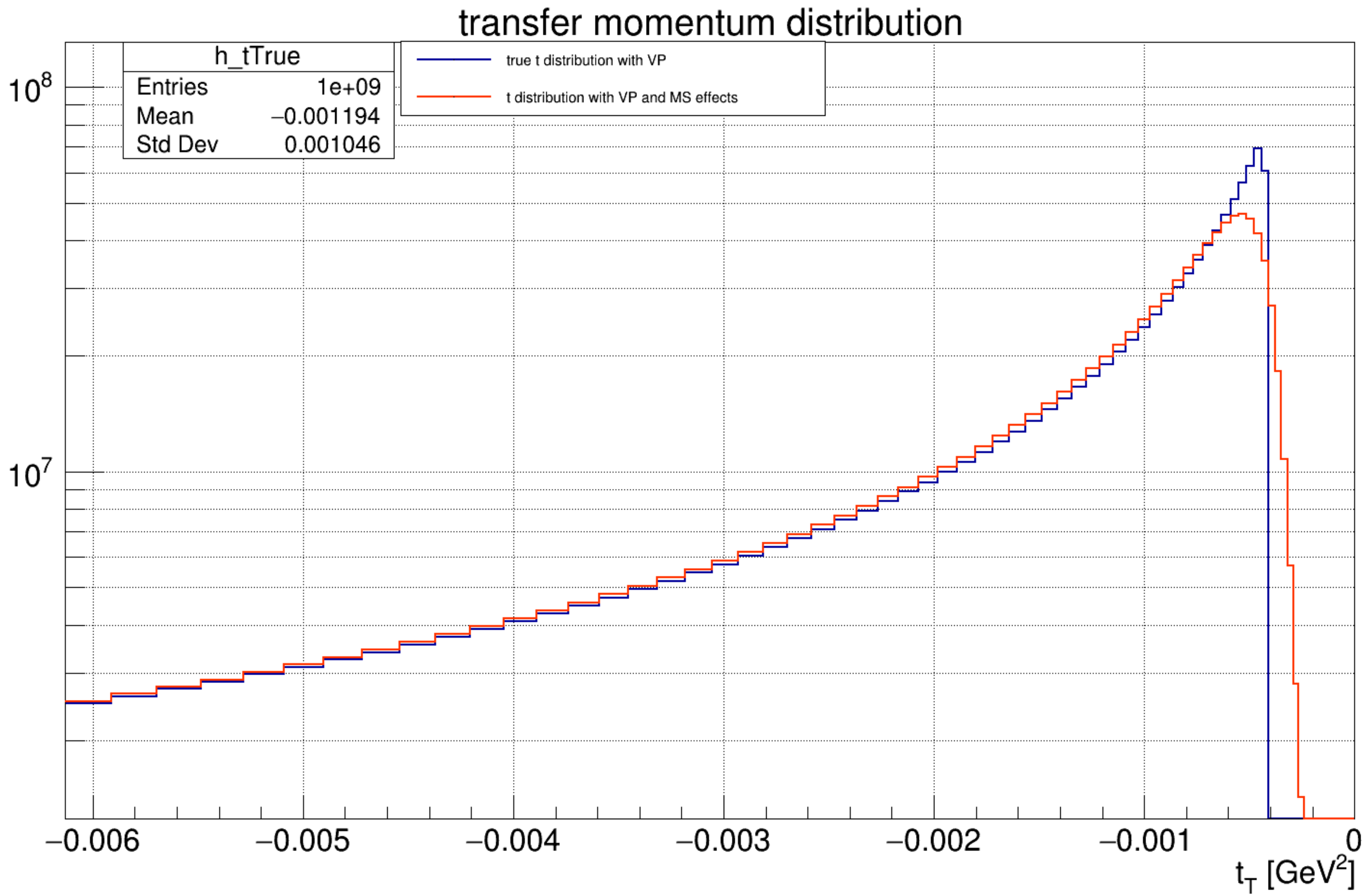
$\frac{\frac{dN}{d\theta_R}(\theta_R \mid \nu - 1\%)}{\frac{dN}{d\theta_R}(\theta_R)}$
ratio N(θ_R | ν - 1%) / N(θ_R)
26 10^9 events generated
h_rapp
Entries 76
Mean 17.6
Std Dev 10.16
1.001
1.0008
1.0006
1.0004
1.0002
1
0.9998
0.9996
0.9994
0.9992
0
5
10
15
20
25
30
35
θ_R [mrad]

At the moment we moved from θ_e to the transfer momentum t, in order to study MS effects on the t distribution and define a procedure to extract $\Delta\alpha_{had}$



150 bins evenly spaced in x

At the moment we moved from θ_e to the transfer momentum t, in order to study MS effects on the t distribution and define a procedure to extract $\Delta\alpha_{had}$



Conclusions

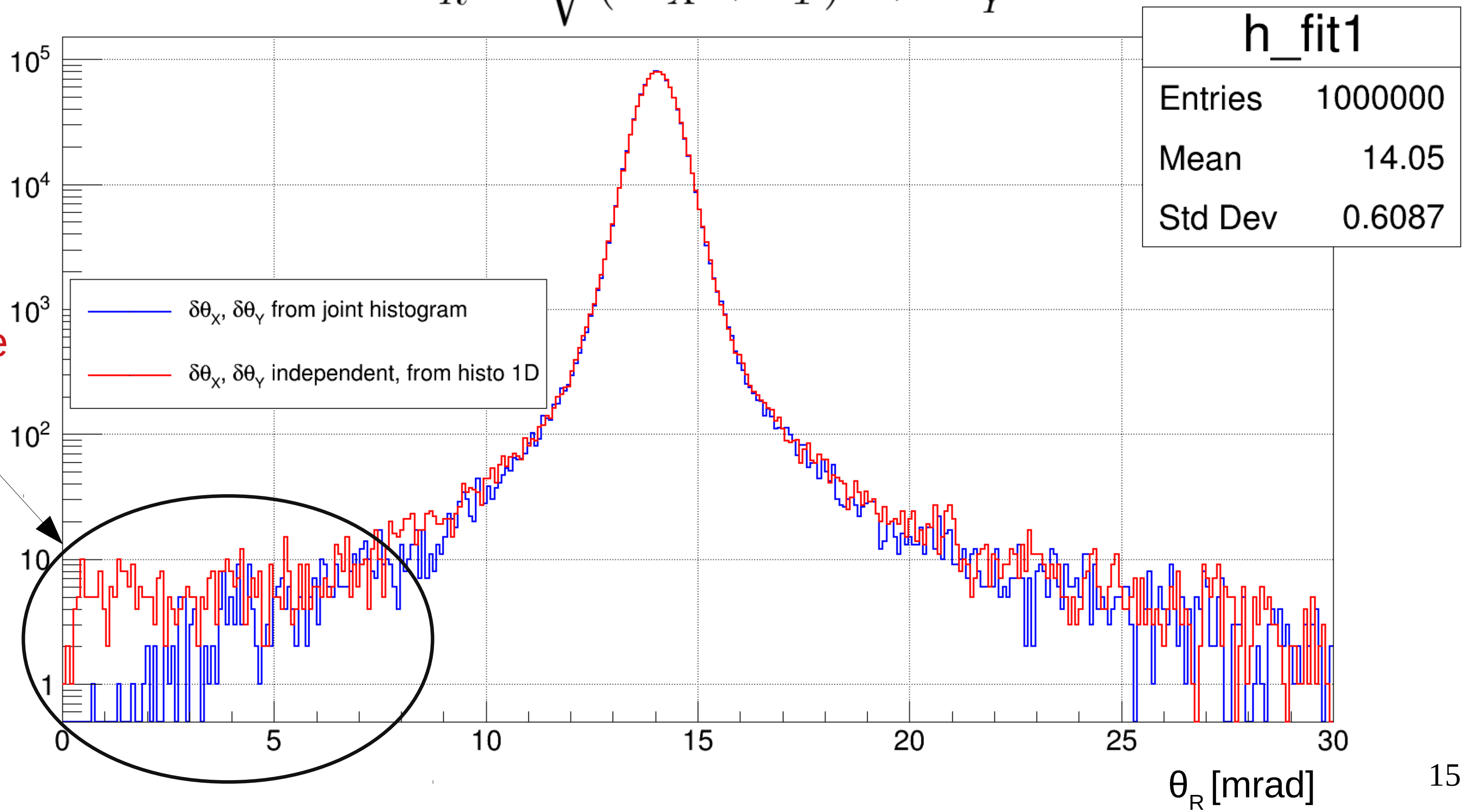
- The work done on the Multiple Scattering shows that the approximation of independency between $\delta\theta_X$ and $\delta\theta_Y$ is not sufficient to determine properly the distribution of θ_R, because of a different behaviour in the signal region ($\theta_R \sim 0$ rad).
- A 1% flat systematic error on the knowledge of the tails has an effect of few 10^{-4} in the signal region, but this result at the moment is limited by statistics.
- Further studies are ongoing to determine what is the effect of a miscalibration on the MS parameterization on the final a_μ^{HLO} measurement.

BACKUP

Moreover, the eccess of events at $\theta_R \sim 0$ found considering as independent the two projections $\delta\theta_X$ and $\delta\theta_Y$ disappears considering the $\delta\theta$ distribution

$$\theta_R = \sqrt{(\delta\theta_X + \theta_T)^2 + \delta\theta_Y^2}$$

Assuming independency brings to overestimate the effect of the tails



Assuming $\delta\theta_Y = 0$, $\theta_R = \delta\theta_X + \theta_T$

What happens in this case to the distribution of θ_R, if I increase the effect of the tails by 1%?