RooFit : Fitting of the Δt Resolution Function

Vladimir Chekelian for discussion 19.12.2018

→ **Time dependent analyses:** *unbinned maximum likelihood fit to* $\Delta t = t_{Bsig} - t_{Btag}$

maximum $\boldsymbol{L} = \prod_i \boldsymbol{P}(\Delta \boldsymbol{ti}, physics\ \&event\ reco\ parameters)$, *where*

$$\boldsymbol{P}_{sig,\ bkg}(\Delta \boldsymbol{t}) = \int_{-\infty}^{+\infty} \boldsymbol{d}(\Delta \boldsymbol{t}')\ \wp_{\mathbf{sig,\ bkg}}(\Delta \boldsymbol{t}')\ \boldsymbol{R}_{\mathbf{sig,\ bkg}}(\Delta \boldsymbol{t} - \Delta \boldsymbol{t}')$$

→ **Fitting of the Resolution Function** $\boldsymbol{R}_{\mathbf{sig,\ bkg}}(\Delta \boldsymbol{t} - \Delta \boldsymbol{t}')$:

- *using RooFit package in Root and MC of B0 B0bar (Bsig → J/Psi K0s)*
- *make fits of* $\Delta \boldsymbol{t}$*-pulls corresponding to* $(\Delta \boldsymbol{t}_{rec} - \Delta \boldsymbol{t}_{true}) / \delta_{ev}(\Delta \boldsymbol{t})$ *(errors per event)*
- $\Delta \boldsymbol{t}$*-pull distribution is equivalent to* $\Delta \boldsymbol{t}$ *resolution function with transformation:*
  parameters ($\Delta \boldsymbol{t}$*-pull model*) → *parameter**$\delta_{ev}(\Delta \boldsymbol{t})$ ($\Delta \boldsymbol{t}$ *resolution function*)
  e.g. *Gauss(dtPull,* μ, σ*)* → *Gauss(dt,* $\mu * \delta_{ev}(\Delta \boldsymbol{t})$, $\sigma * \delta_{ev}(\Delta \boldsymbol{t})$*)*
- $\Delta \boldsymbol{t}$*-pulls are fitted by three gaussian functions:*

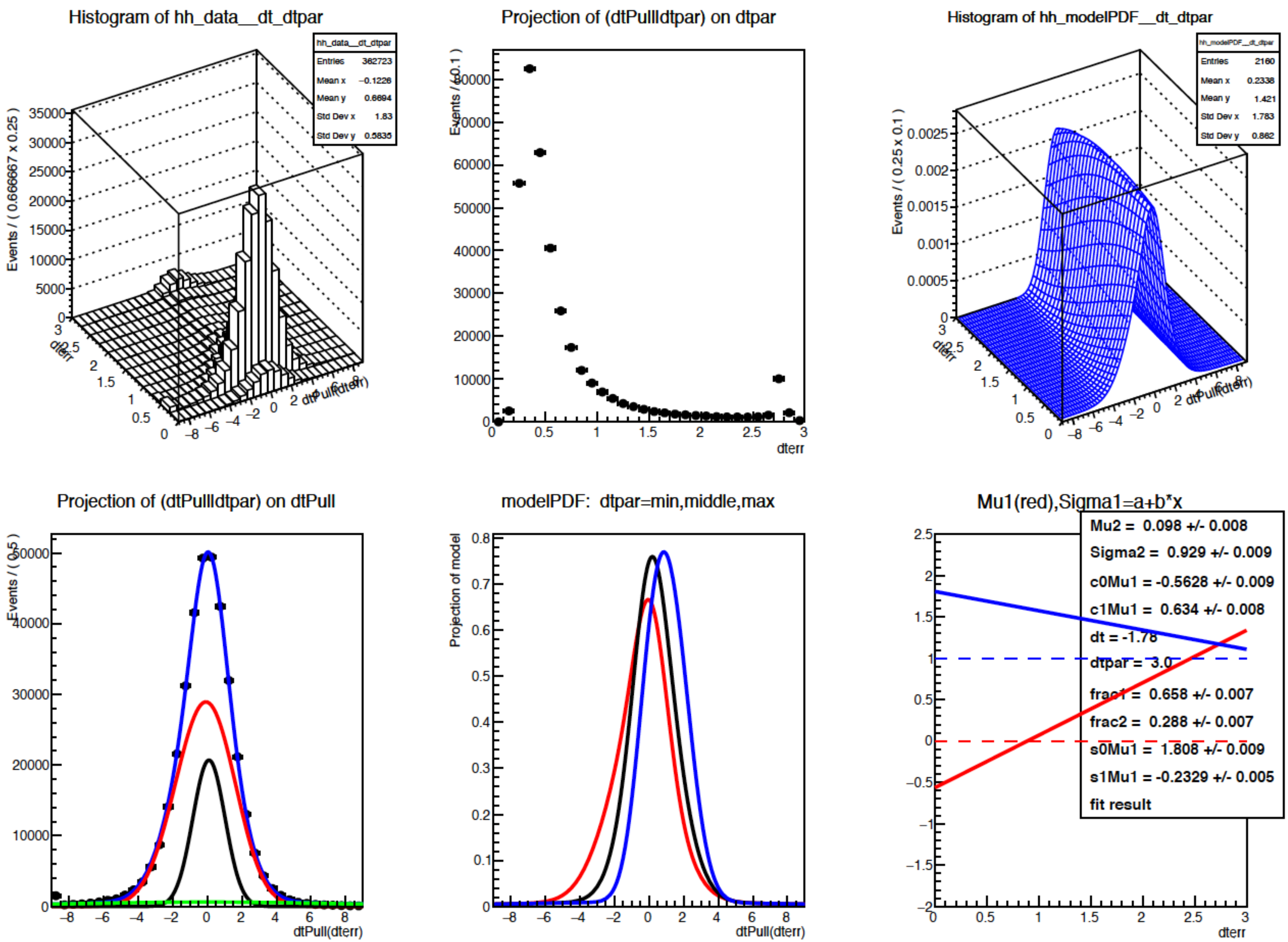
$$f_1 * G_1(dtPull, \mu_1, \sigma_1) + f_2 * G_2(dtPull, \mu_2, \sigma_2) + (1 - f_1 - f_2) * G_3(dtPull, \mu_3, \sigma_3)$$

G_1: $\mu_1 = c0 + c1 * evpar$, $\sigma_1 = s0 + s1 * evpar$, *where c0, c1, s0, s1 are free*
and $evpar = \delta_{ev}(\Delta \boldsymbol{t})$, $\Delta \boldsymbol{t}$*(true), Pvalue, zBtag(true,rec)*

G_2: μ_2, σ_2 *are two free parameters independent of* $\delta_{ev}(\Delta \boldsymbol{t})$

G_3: $\mu_3 = 0.$, $\sigma_3 = 8.$ *are fixed and fractions* f_1 *and* f_2 *are free*

RooFit : dependence of Δt−pull on Δt error



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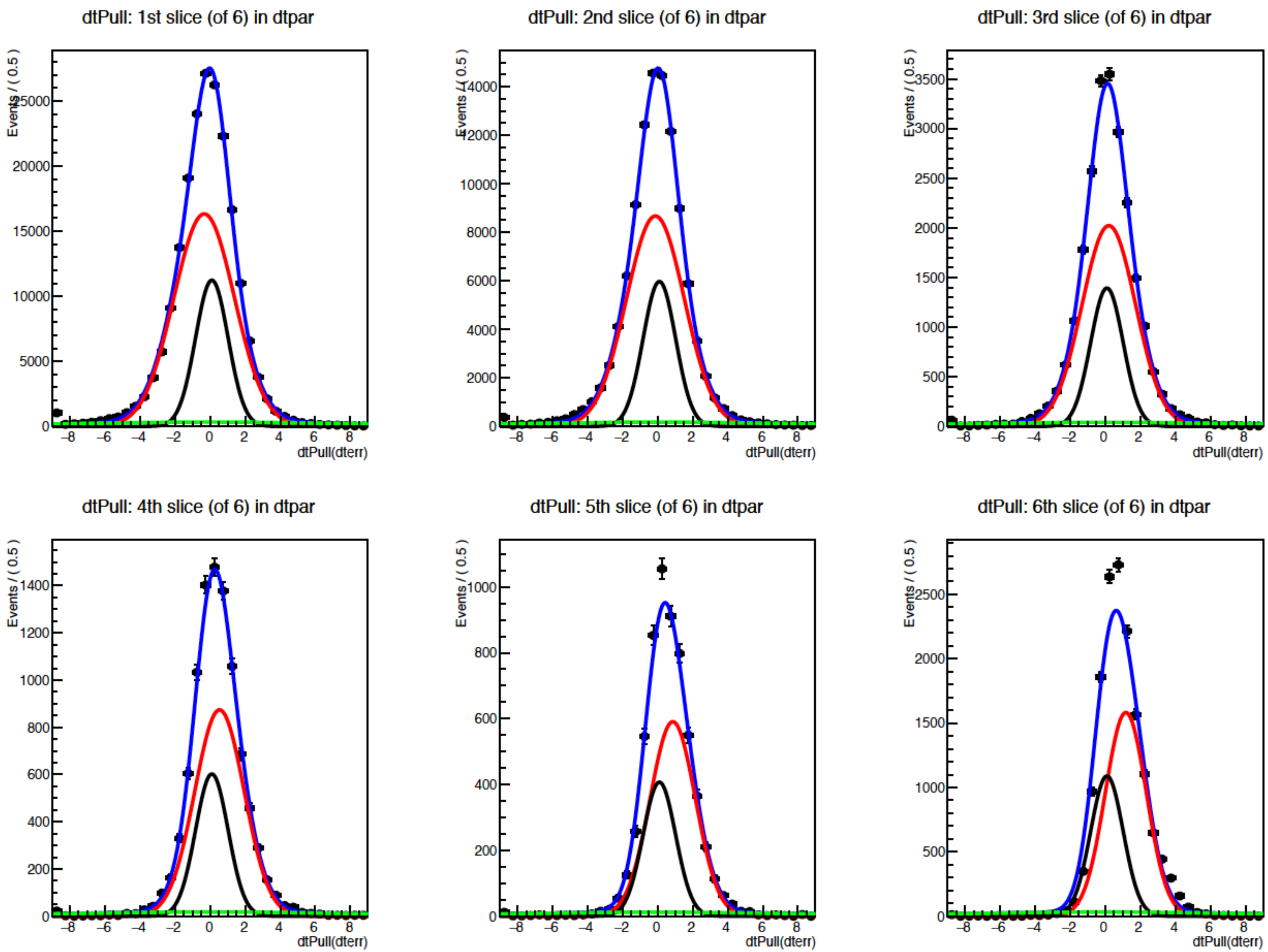
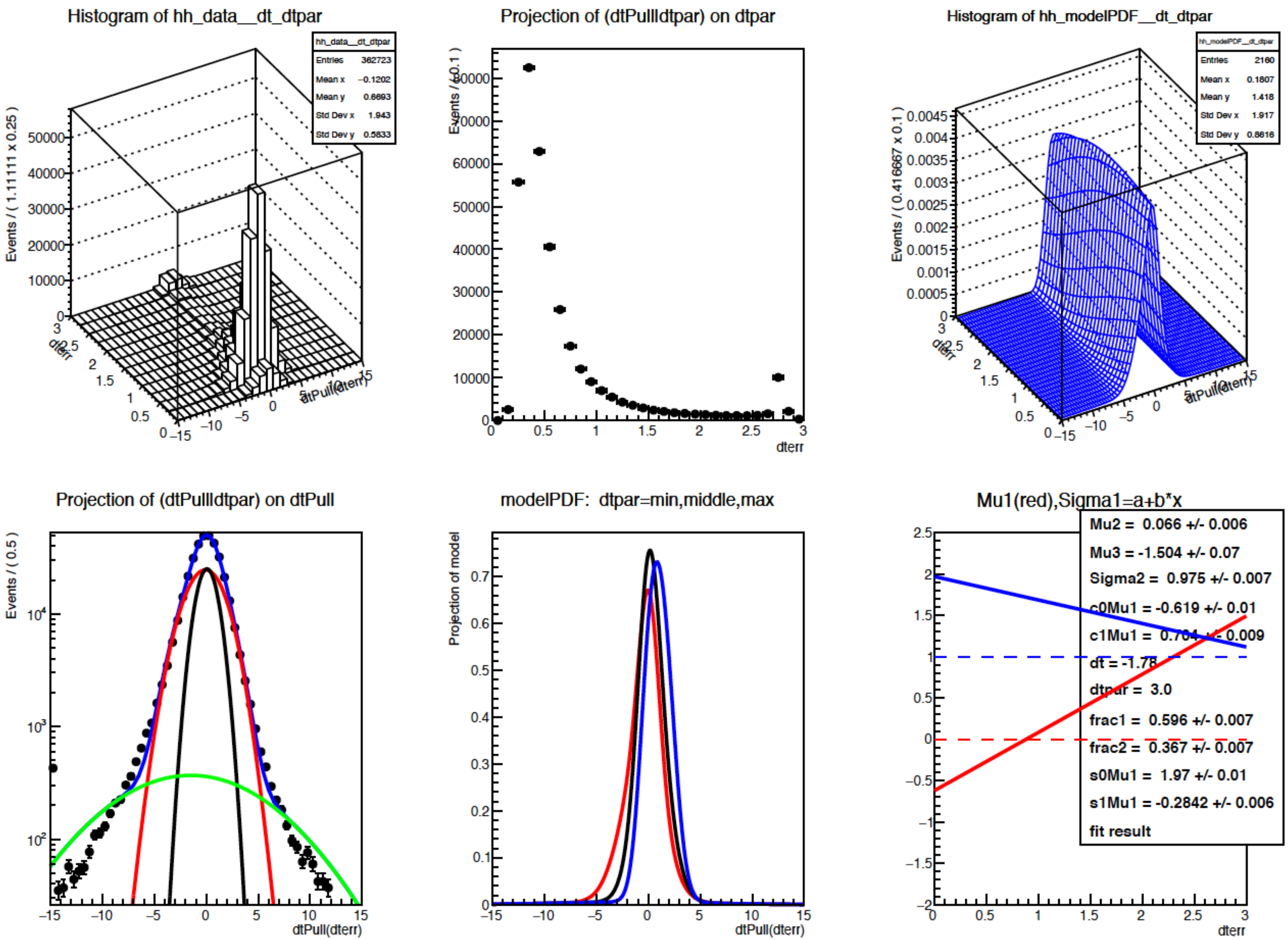


RooFit : dependence of Δt–pull on Δt err (log)



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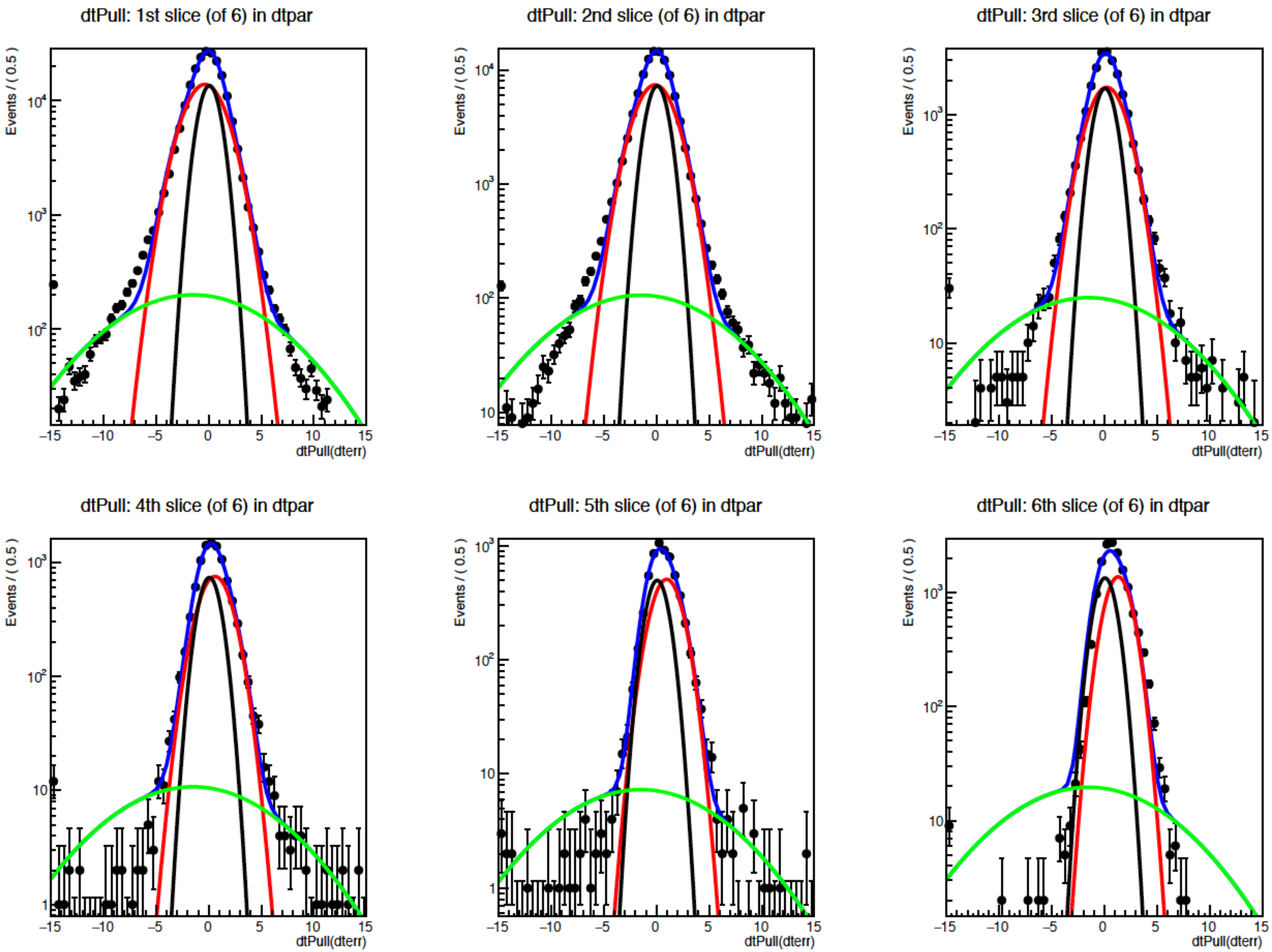
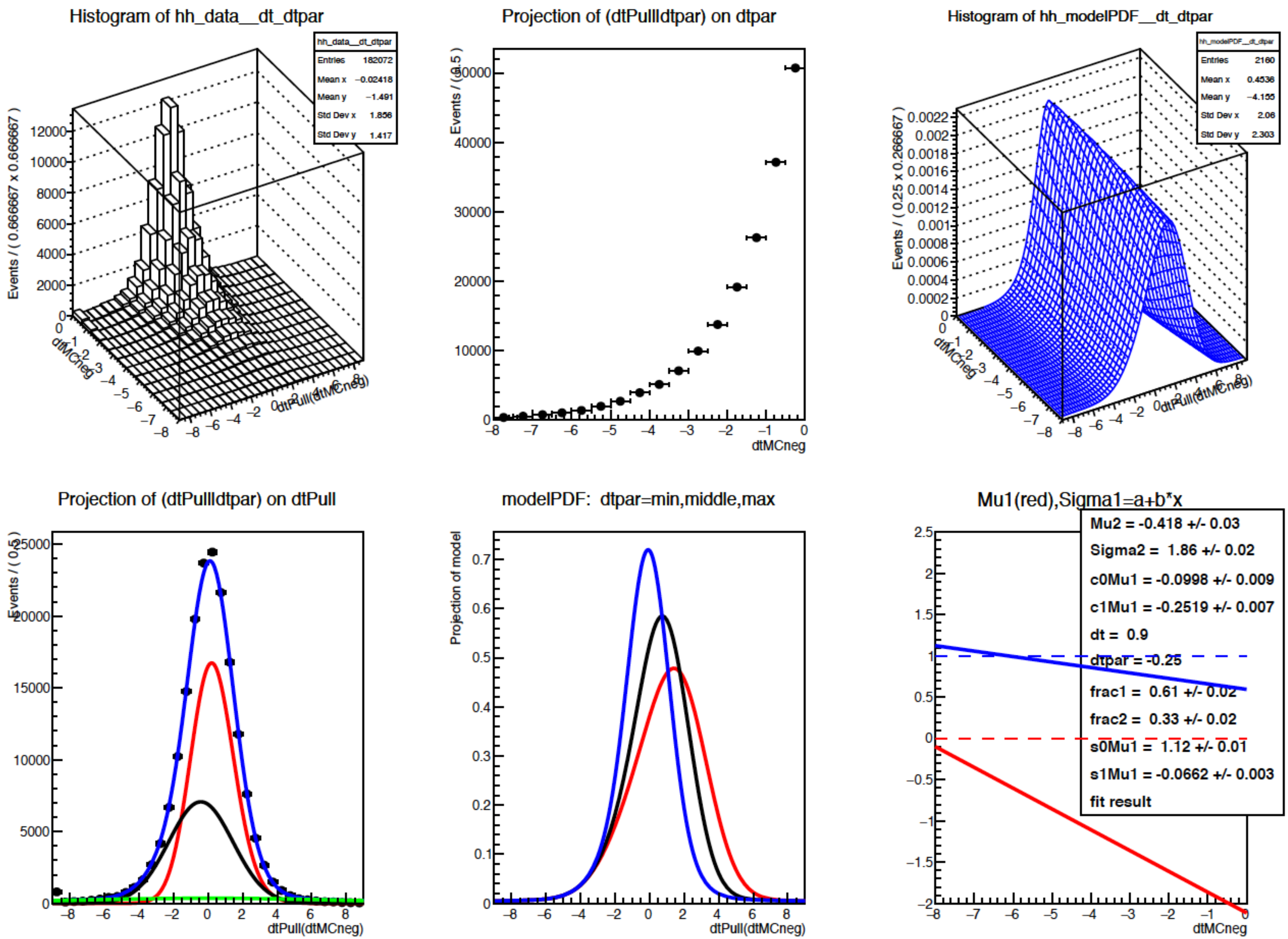


RooFit: dependence of Δt−pull on Δt−true(<0)



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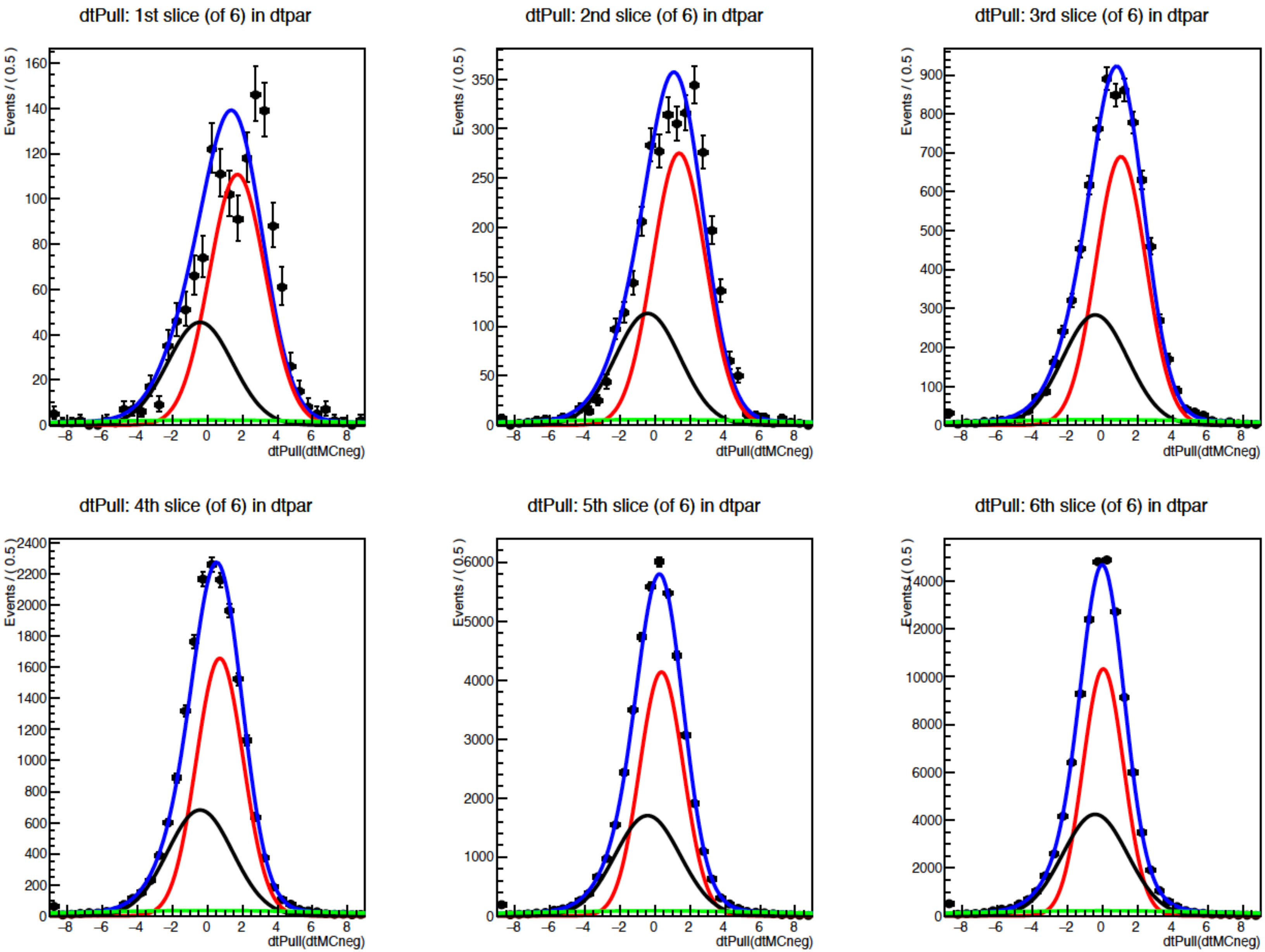

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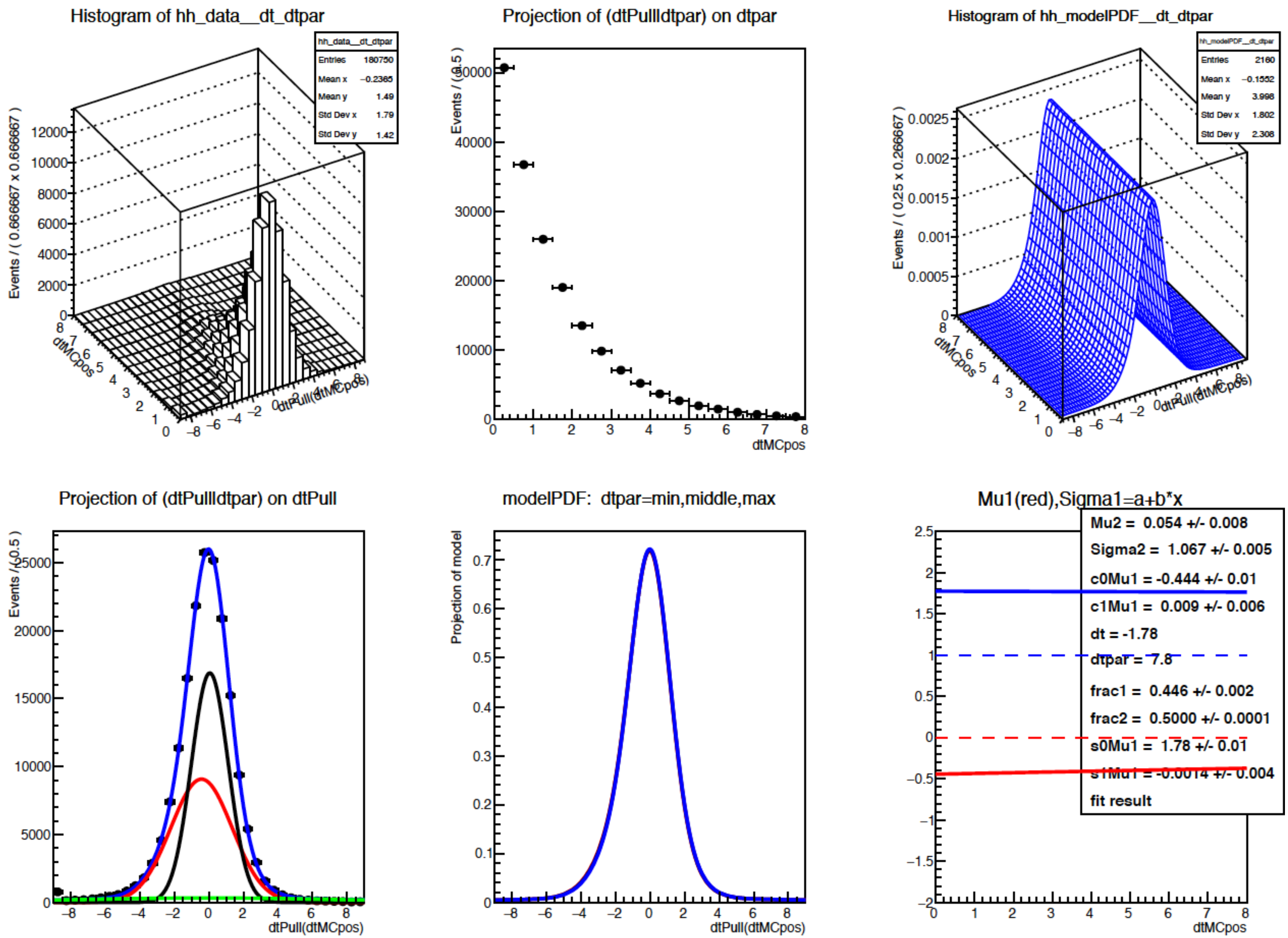

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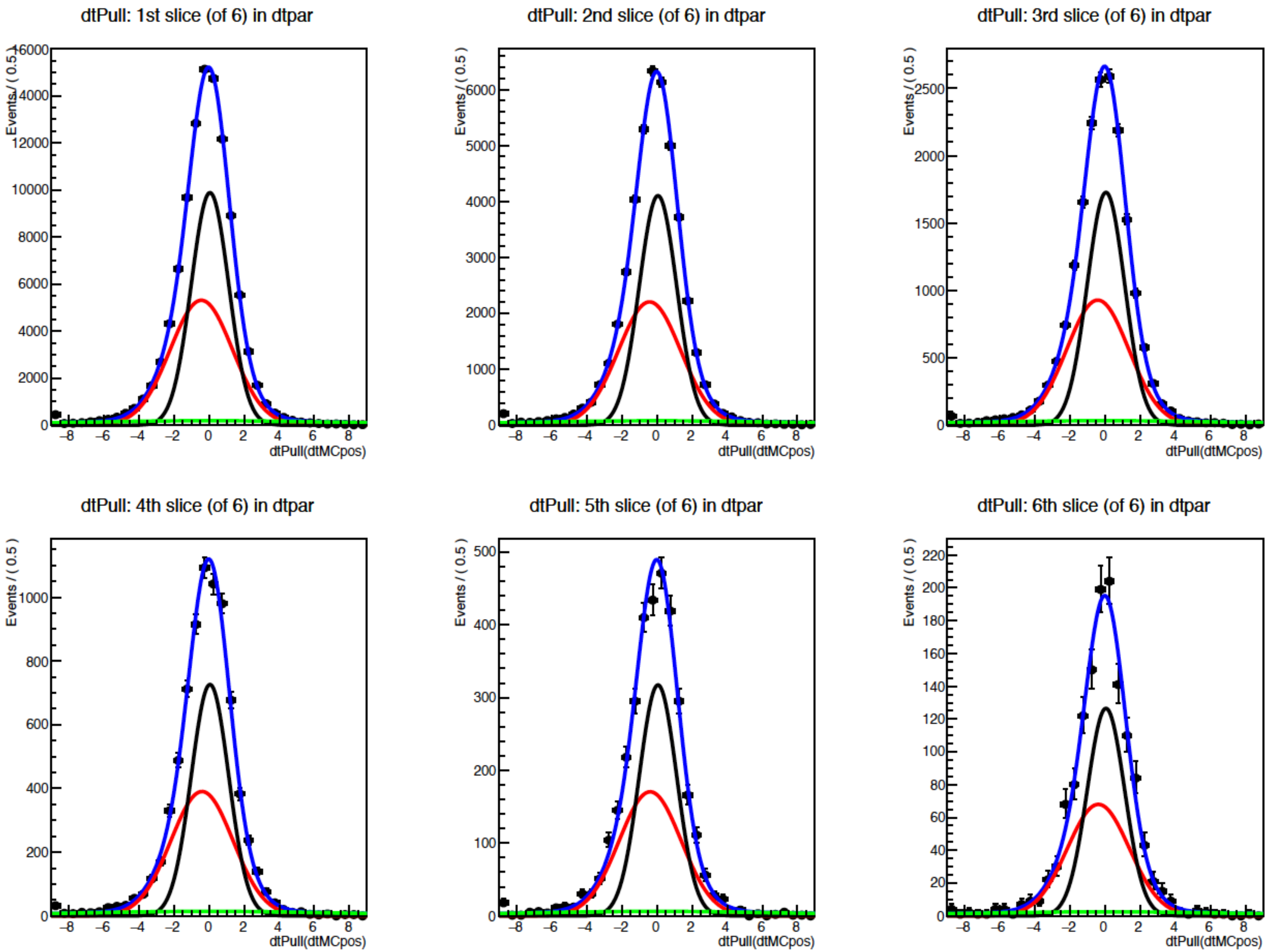
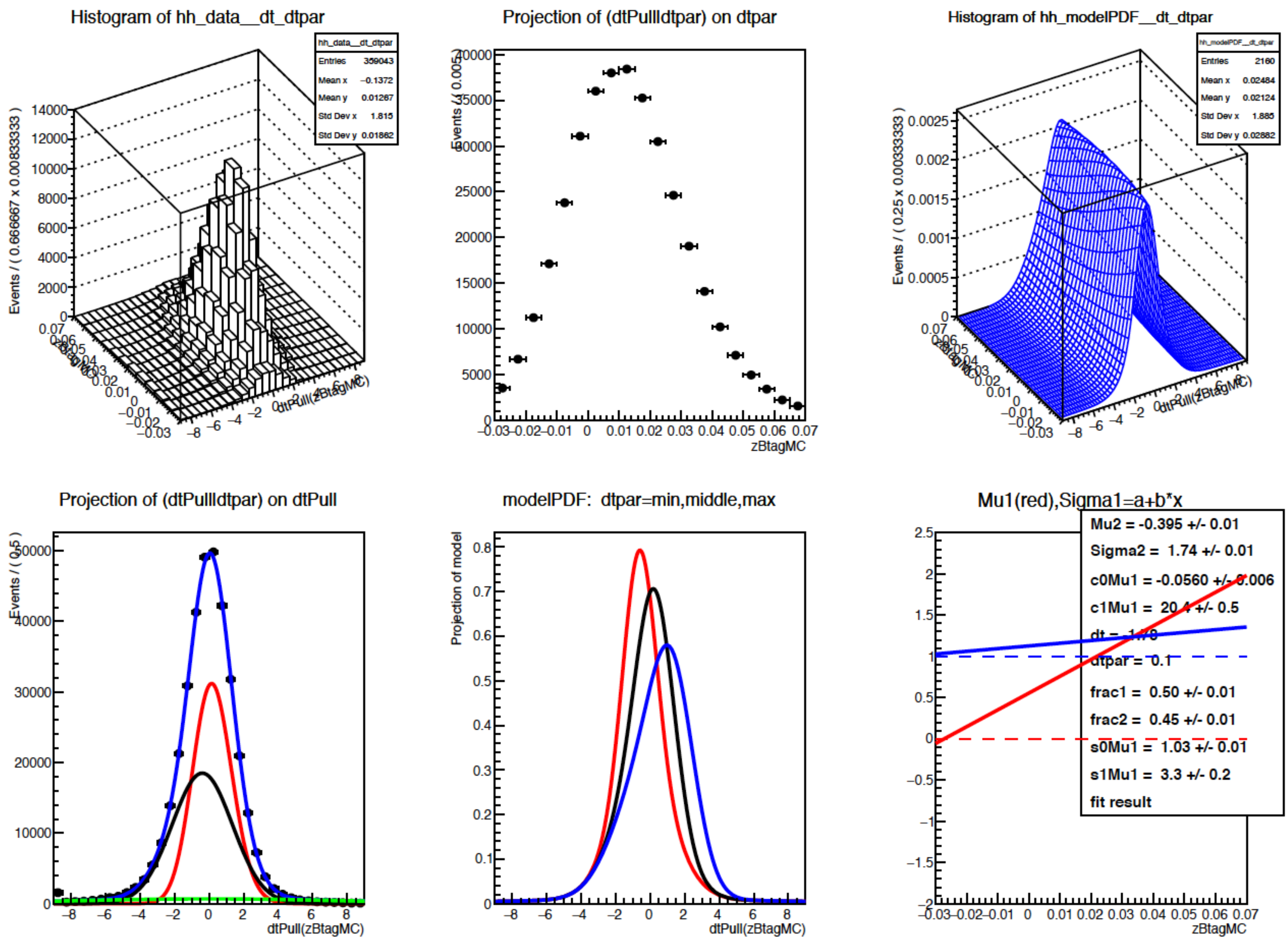


RooFit : dependence of Δt−pull on zBtag(true)



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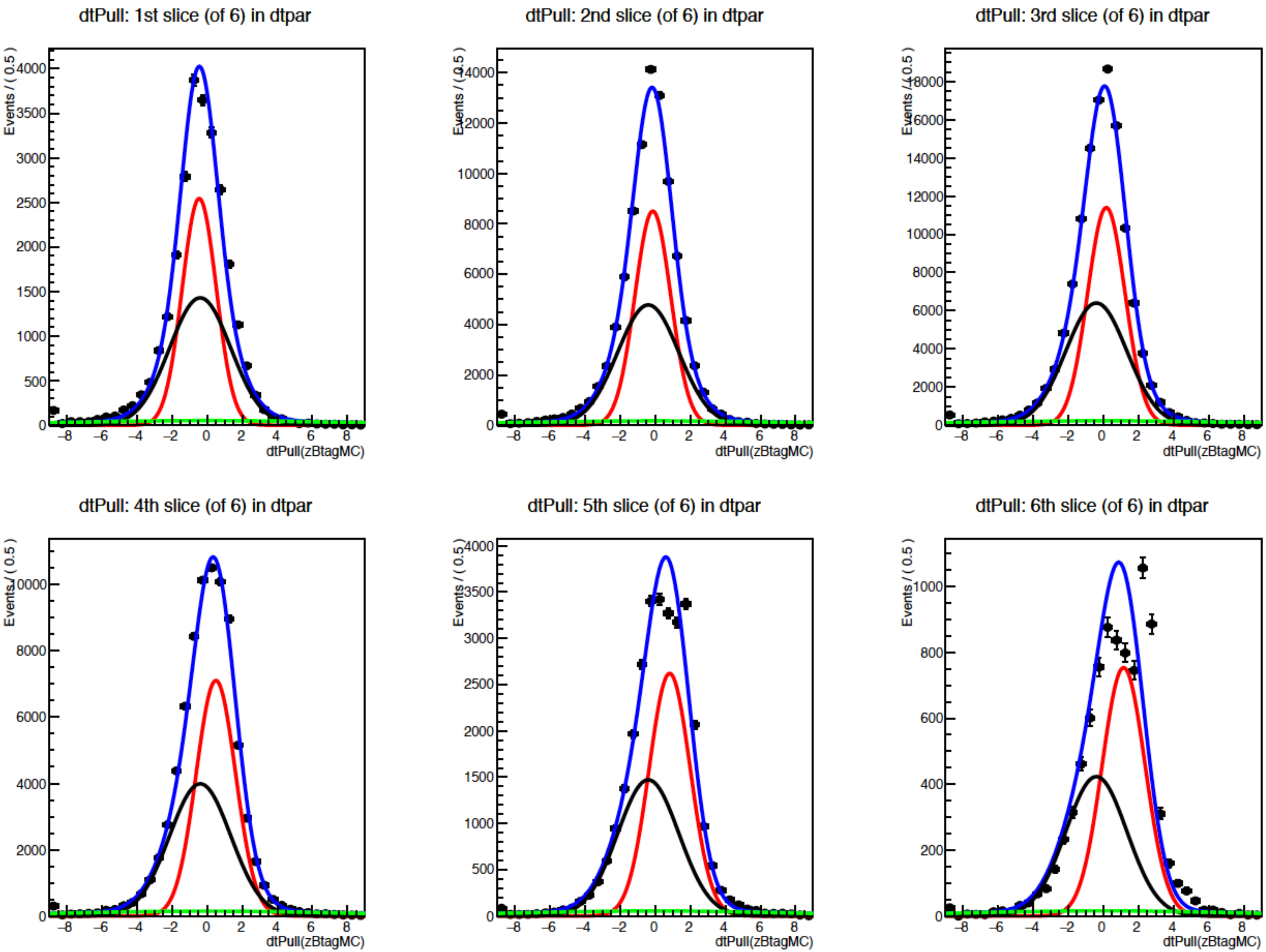
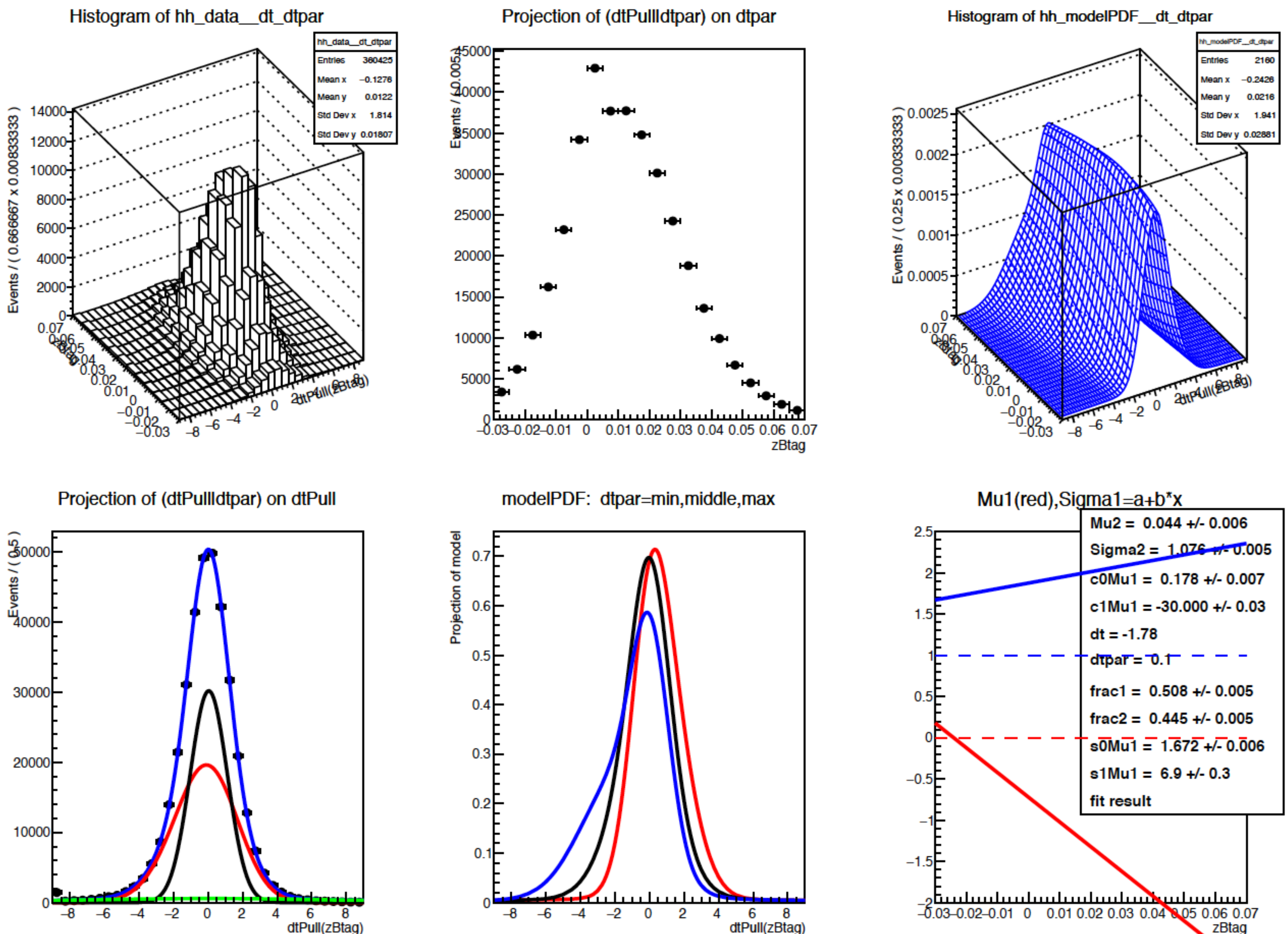
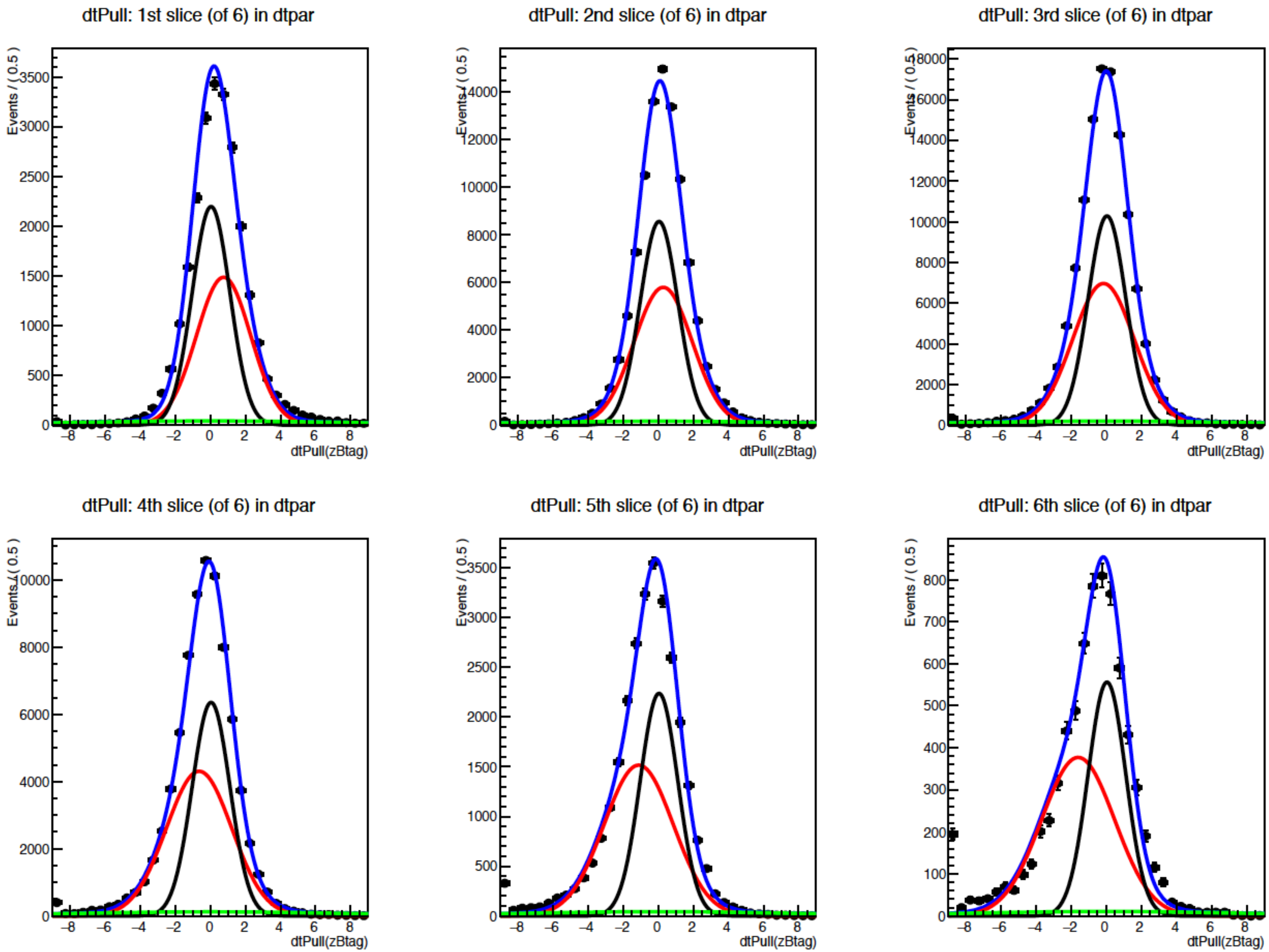


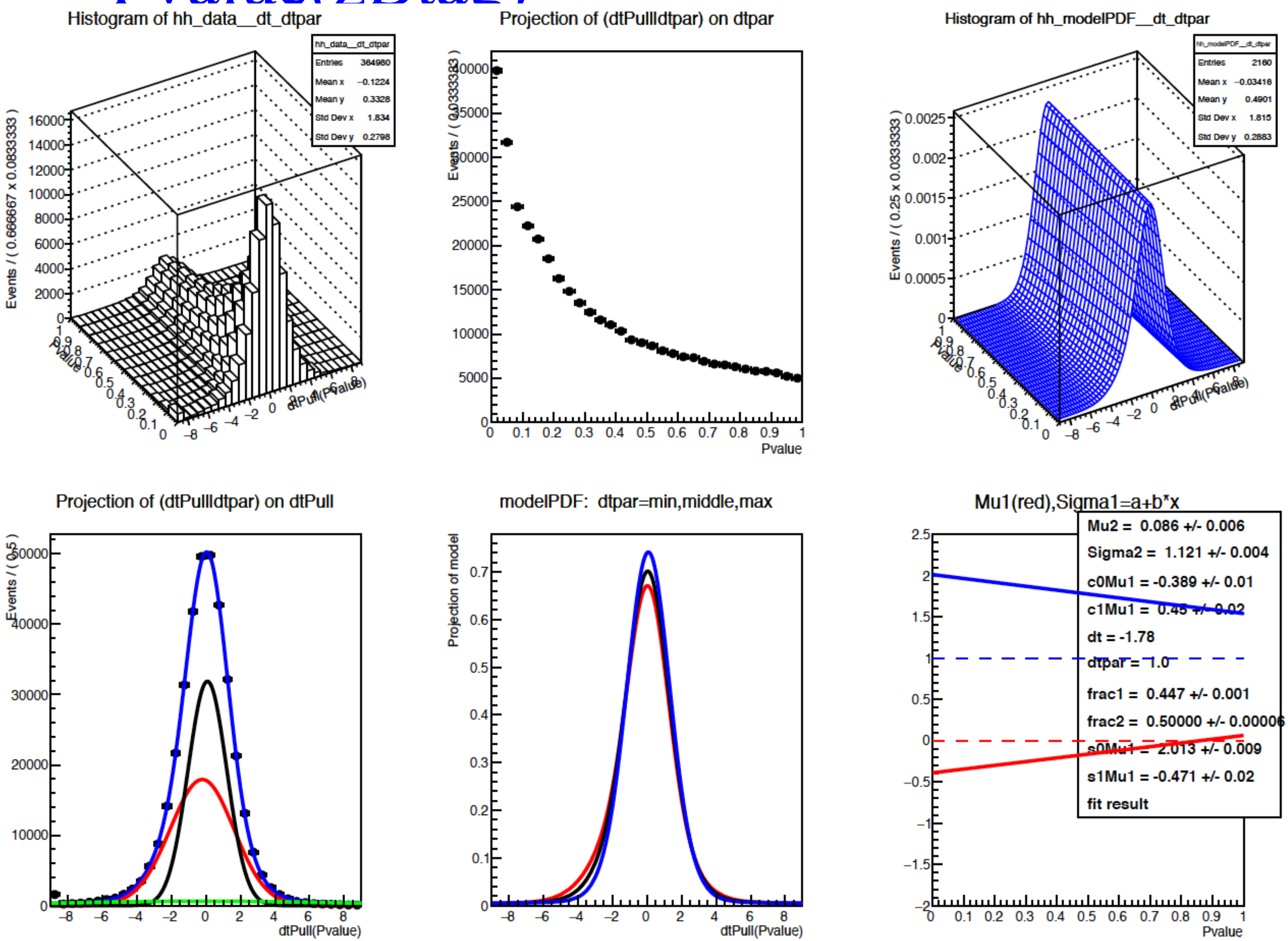
RooFit : dependence of Δt−pull on zBtag(rec)



RooFit : dependence of Δt–pull on zBtag(rec)



RooFit: dependence of Δt−pull on Pvalue(zBtag)



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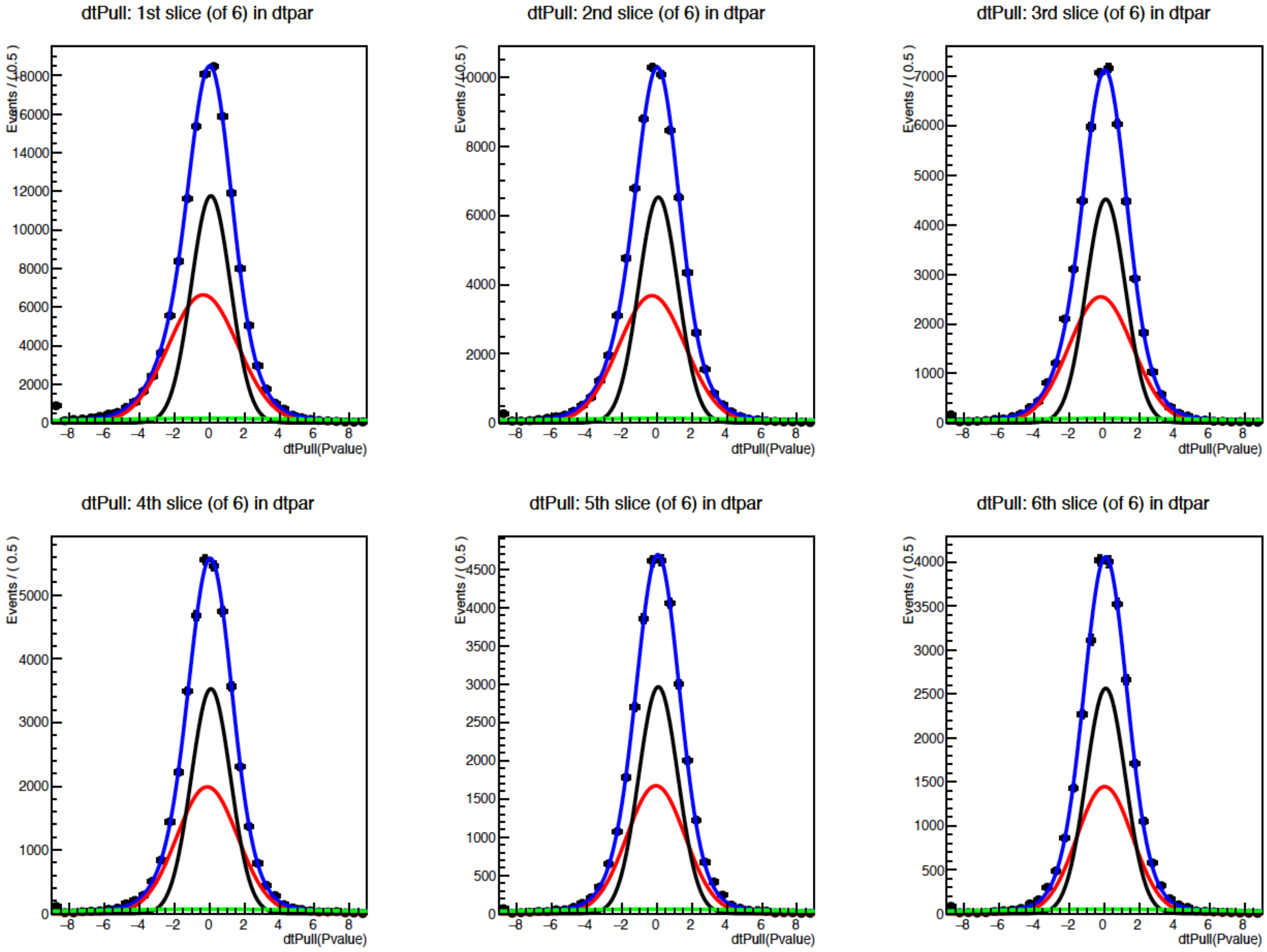


RooFit for Time Dependent Analyses

→ **Platform for the Time dependent analyses:**

RooFit package in Root

- is developed to make this kind of of analyses

- looks as a right choice for us

→ **All that can be done in RooFit:**

unbinned maximum likelihood fit to the observed Δt=t(Bsig)-t(Btag) distribution to define physics parameters of interest

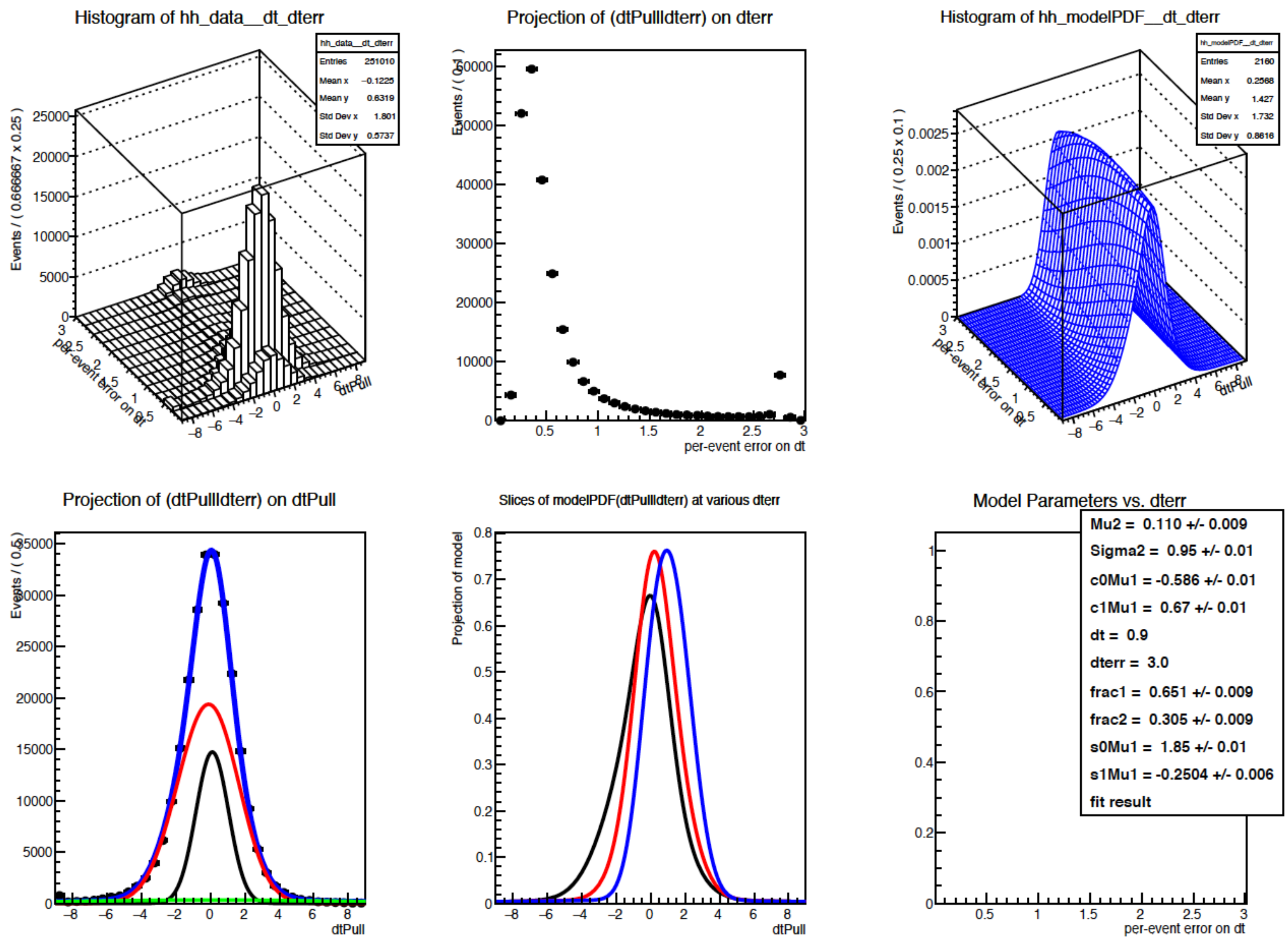
$$\text{maximum} \quad \boldsymbol{L} = \prod_i \boldsymbol{P}(\Delta \boldsymbol{t} \boldsymbol{i}\,, physics\ \&event\ reco\ parameters)$$

The event probability density function (PDF) is a convolutions of a true physics PDF and a resolution function $\boldsymbol{R}_{\mathbf{sig,\,bkg}}(\Delta \boldsymbol{t} - \Delta \boldsymbol{t}')$:

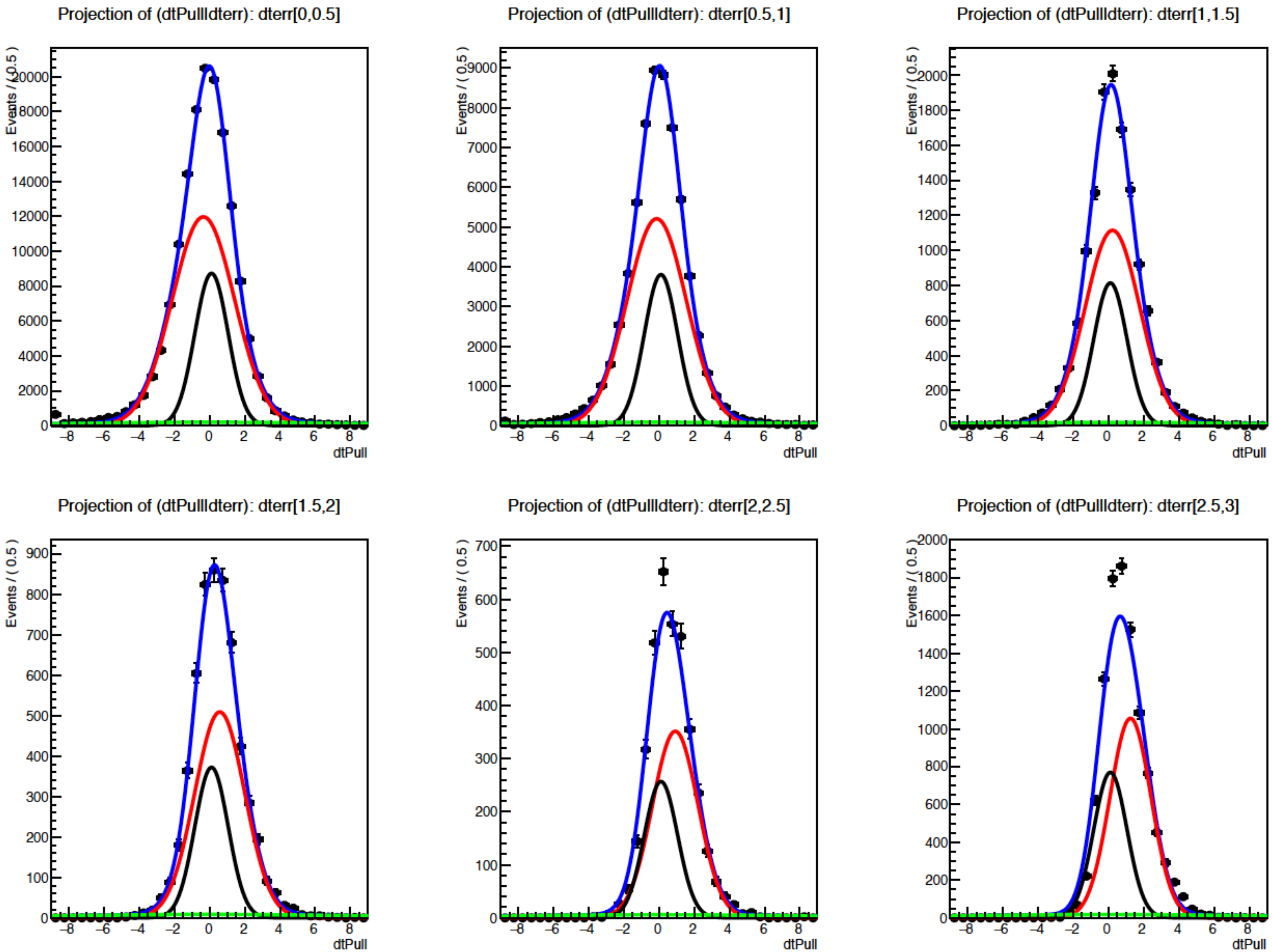
$$\boldsymbol{P}_{sig,\,bkg}(\Delta \boldsymbol{t}) = \int_{-\infty}^{+\infty} \boldsymbol{d}(\Delta \boldsymbol{t}') \;\; \wp_{\mathbf{sig,\,bkg}}(\Delta \boldsymbol{t}') \;\; \boldsymbol{R}_{\mathbf{sig,\,bkg}}(\Delta \boldsymbol{t} - \Delta \boldsymbol{t}')$$

Strictly speaking (as it has been assumed in Belle and BABAR), $\boldsymbol{R}_{\mathbf{sig,\,bkg}}(\Delta \boldsymbol{t} - \Delta \boldsymbol{t}')$ *should be fully factorized from* $\wp_{\mathbf{sig,\,bkg}}(\Delta \boldsymbol{t}')$ *and does not depend on true* $\Delta \boldsymbol{t}$*' or any other "true" variable.*

Δt-pulls with Δt error as a input parameter



Δt-pulls for slices in Δt errors from 0 to 3 ps



Δt Resolution Function

→ **Time dependent analyses:**

- *B meson lifetime*
- *mixing and B0B0bar oscillations*
- *time-dependent CP asymmetry*

→ **Method:**

unbinned maximum likelihood fit to the observed Δt=t(Bsig)-t(Btag) distribution to define physics parameters of interest

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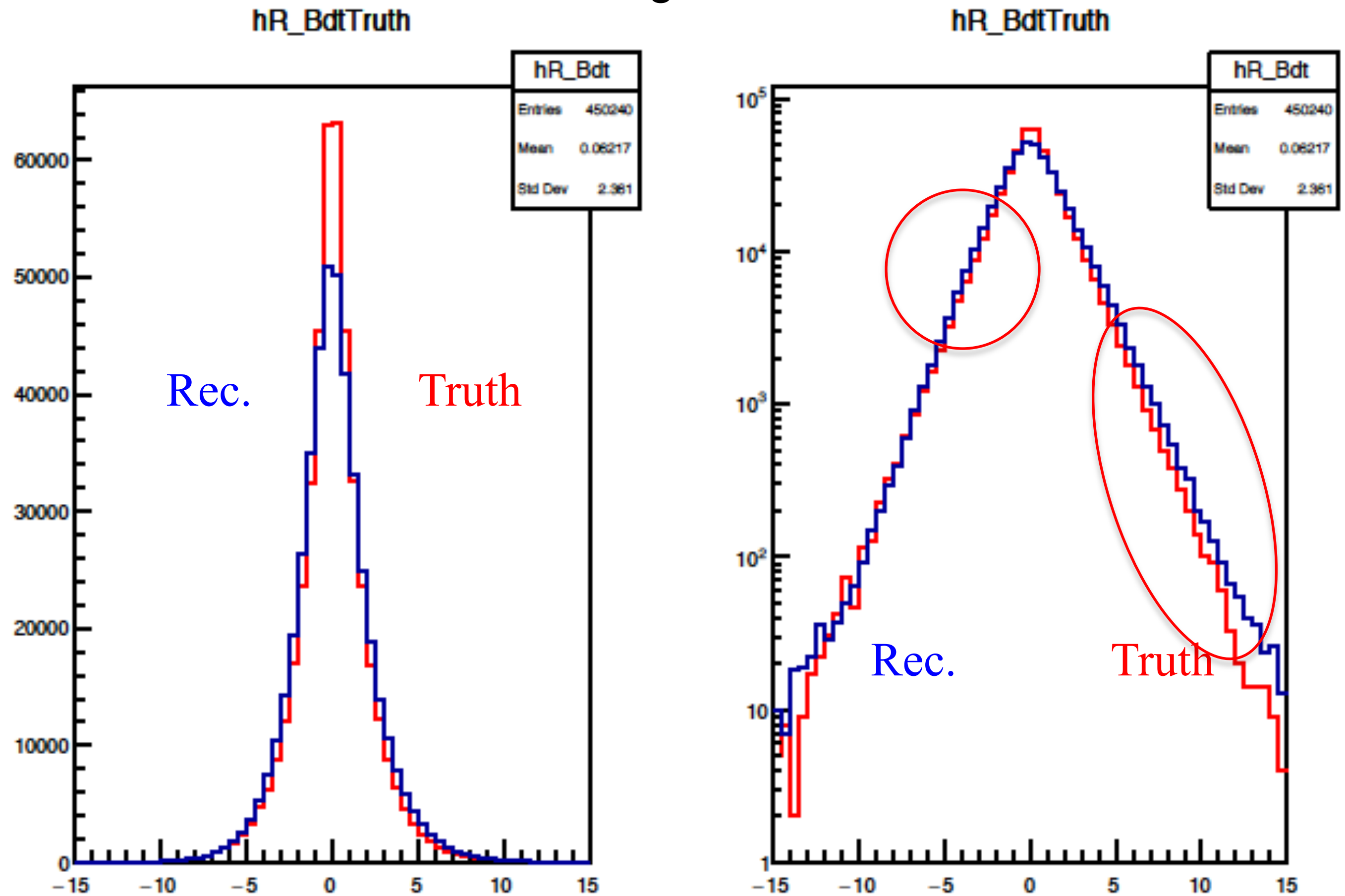
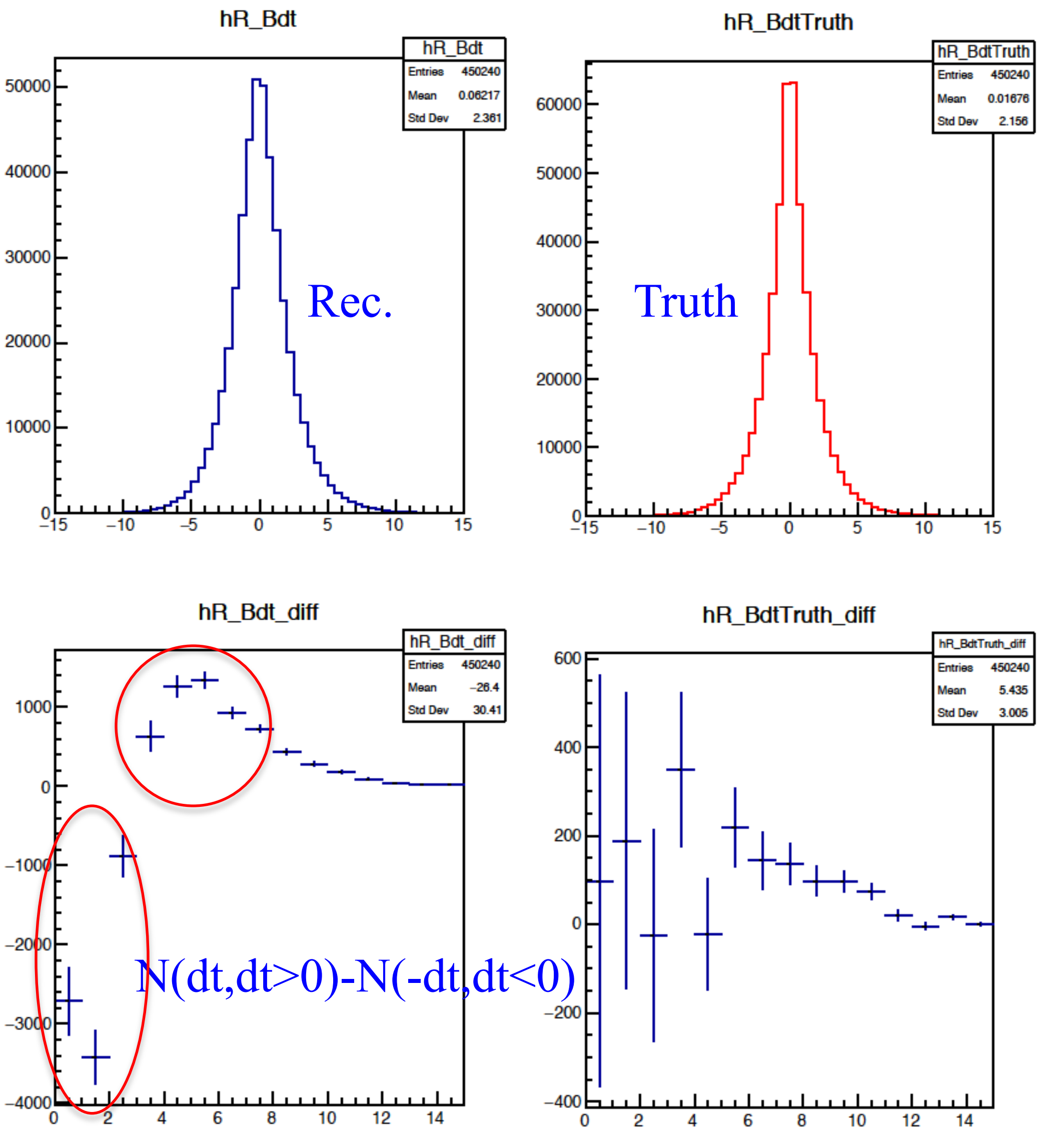
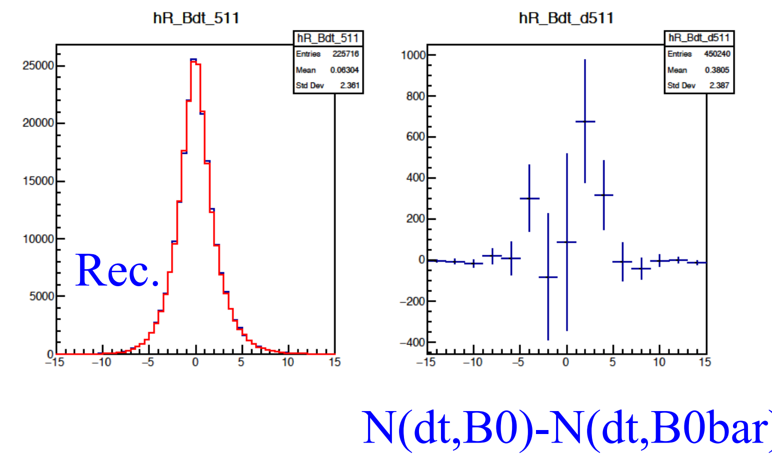
True and reconstructed Δt distributions

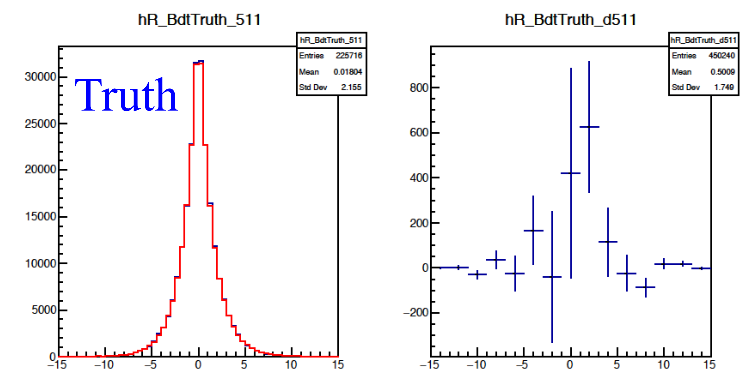
B0B0bar MC, Signal: B0→J/Psi K0S



Comparison of true and reconstructed Δt



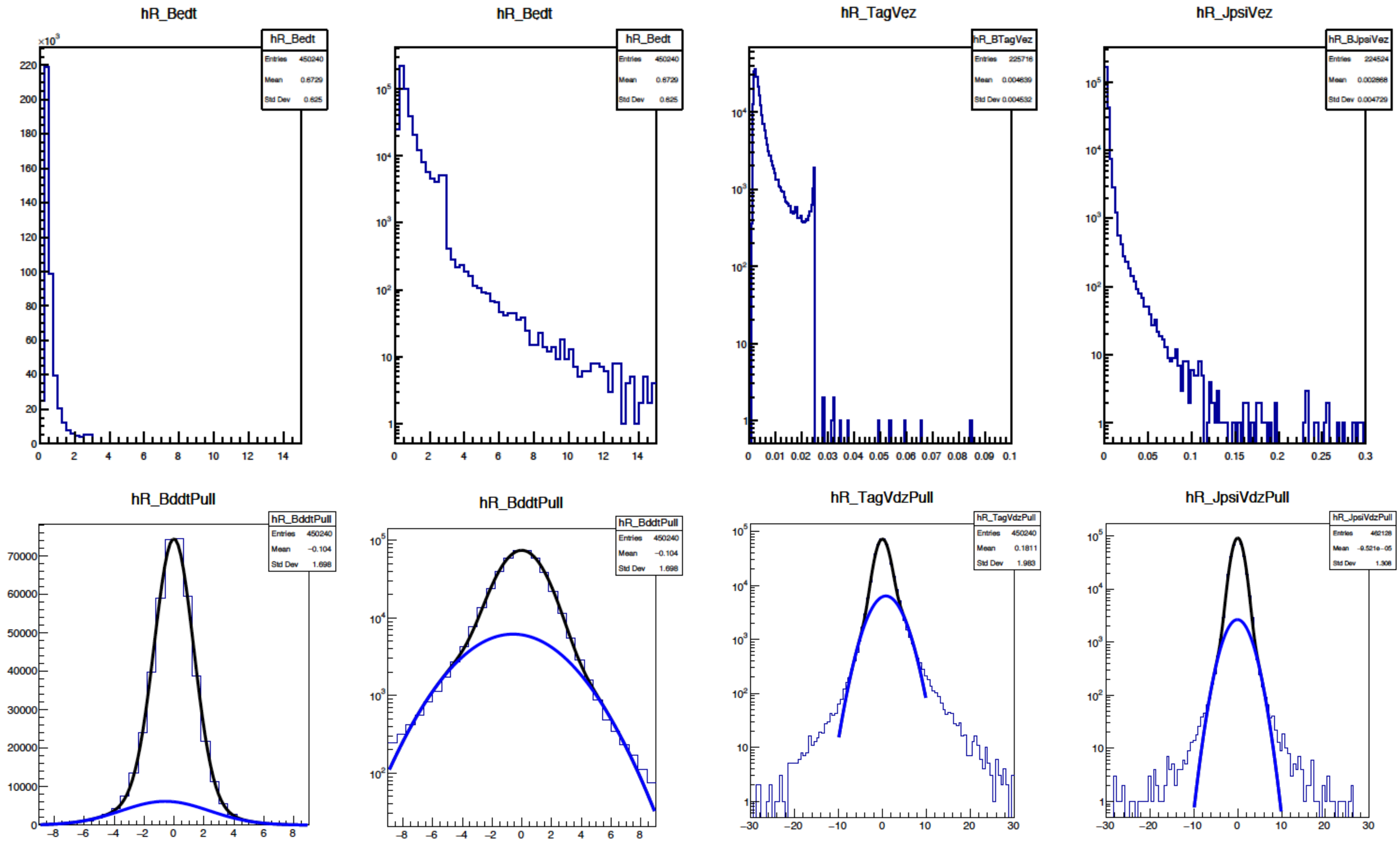




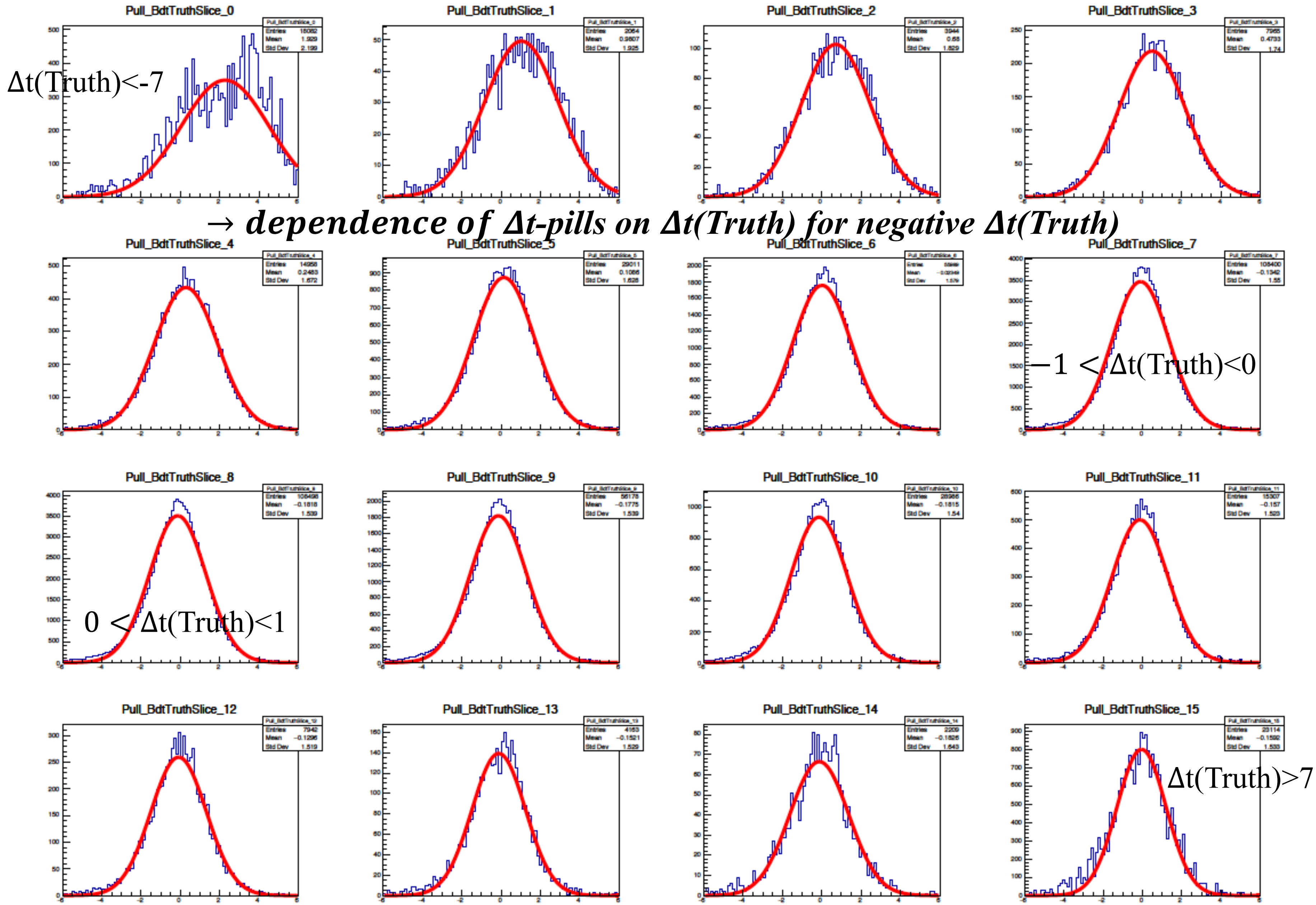
→ *strong differences in reco for positive and negative* Δt *(D-mesons, Beam spot)*

→ *CPV asymmetry is less sensitive but much smaller than* Δt *biases in reco*

Uncertainties and pulls: Δt, z(Btag), z(J/Psi)



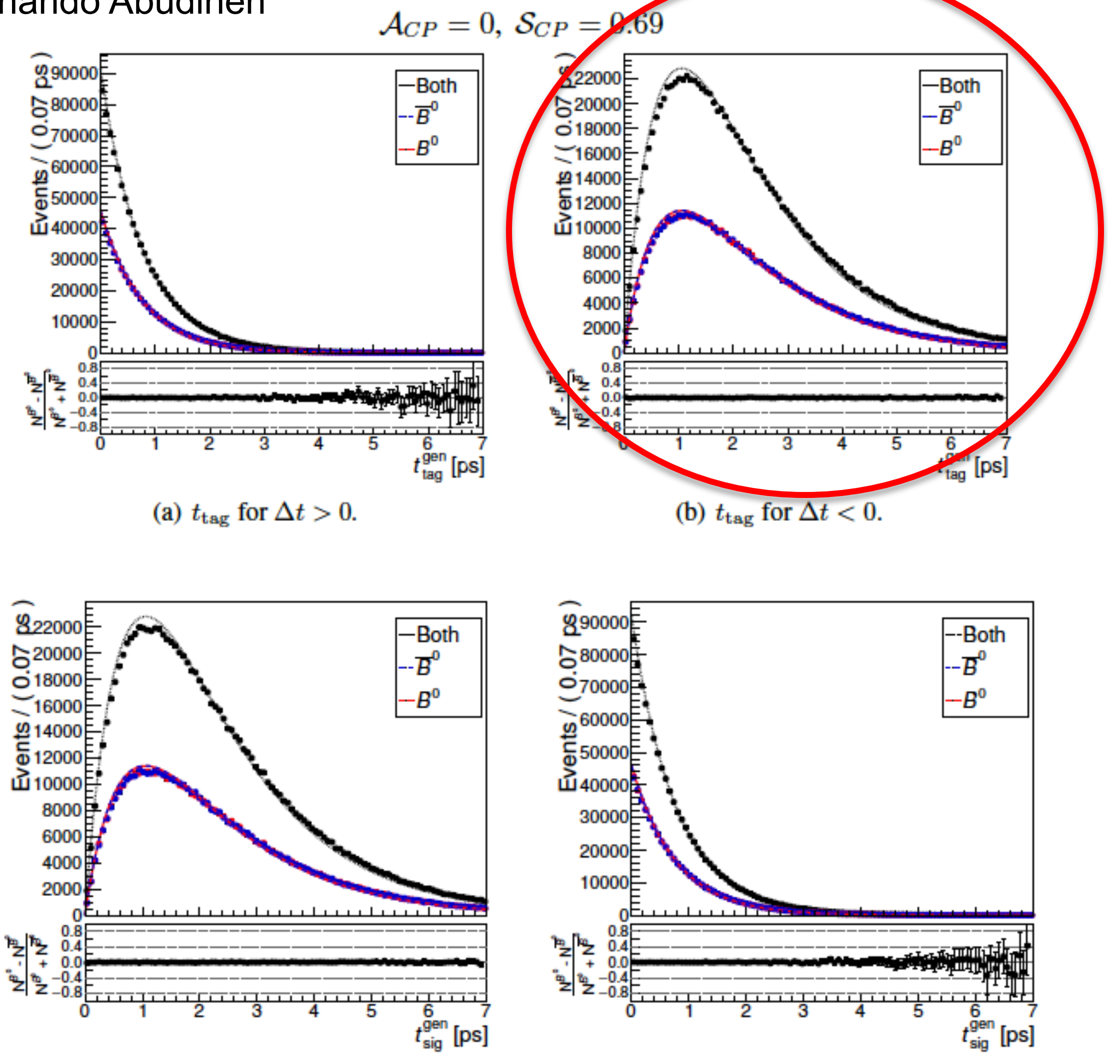
Δt-pulls for Δt(Truth)-slices from -8. to 8.



→ dependence of Δt-pills on Δt(Truth) for negative Δt(Truth)

Explanation of the dependence on Δt(Truth)

Phd Fernando Abudinen



(a) $t_{\rm tag}$ for $\Delta t > 0$.

(b) $t_{\rm tag}$ for $\Delta t < 0$.

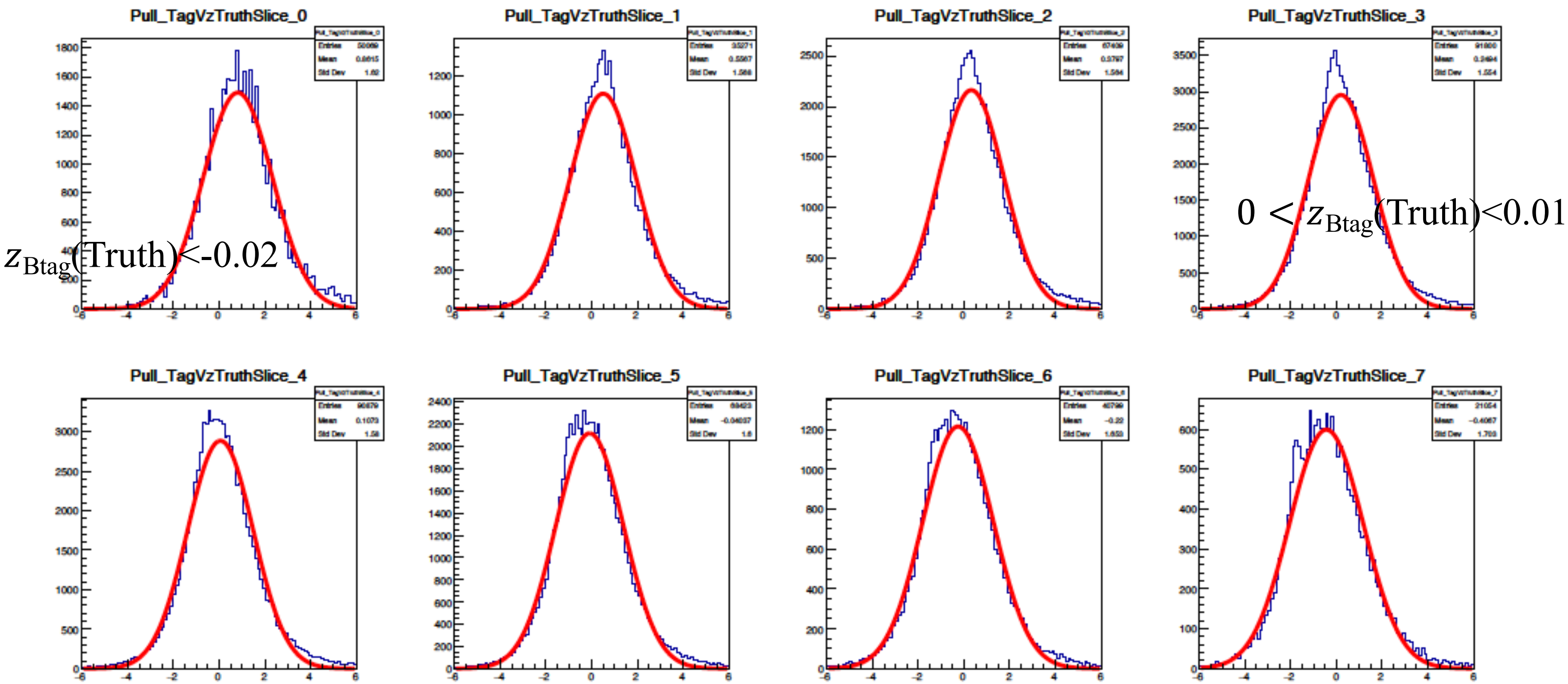
(c) $t_{\rm sig}$ for $\Delta t > 0$.

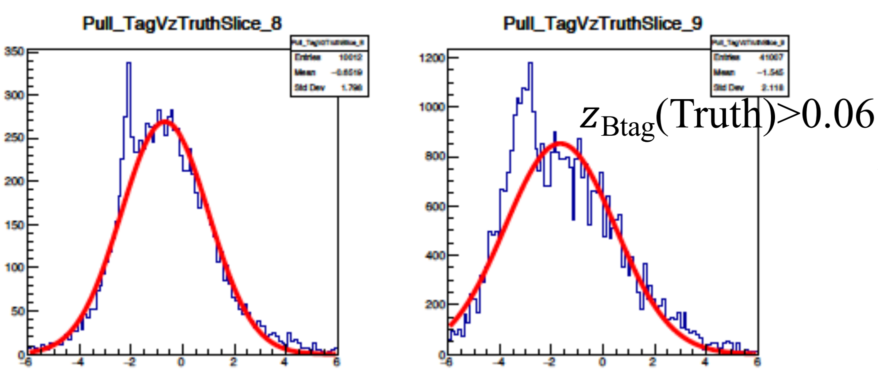
(d) $t_{\rm sig}$ for $\Delta t < 0$.

→ ***Possible explanation for Δt(Truth)-dependence of Δt-pulls for negative Δt(Truth):***

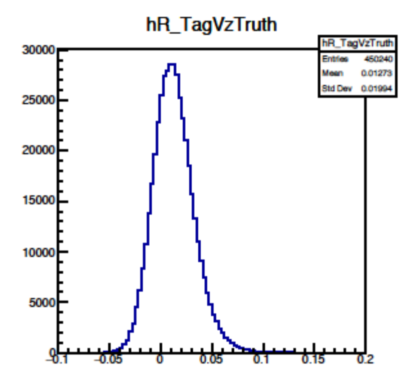
if t_{Btag} is positive and large the reconstructed Btag vertex position is biased towards the beam spot which is used as constraint in the vertex fit

z_{Btag}-pulls for slices in z_{Btag}(Truth)





→ ***Bias of z_{Btag}(reco) at large values of z_{Btag}(Truth)***



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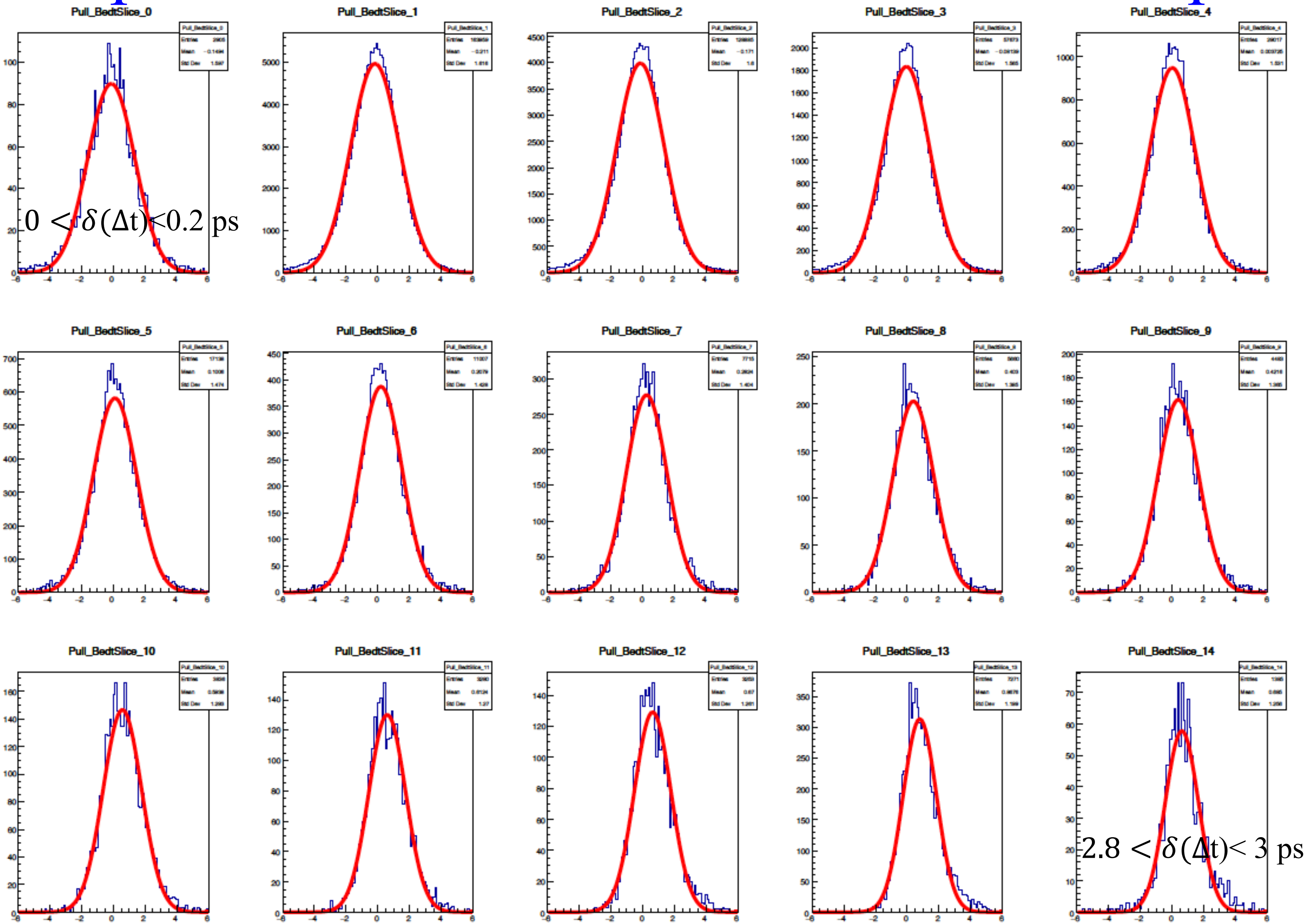
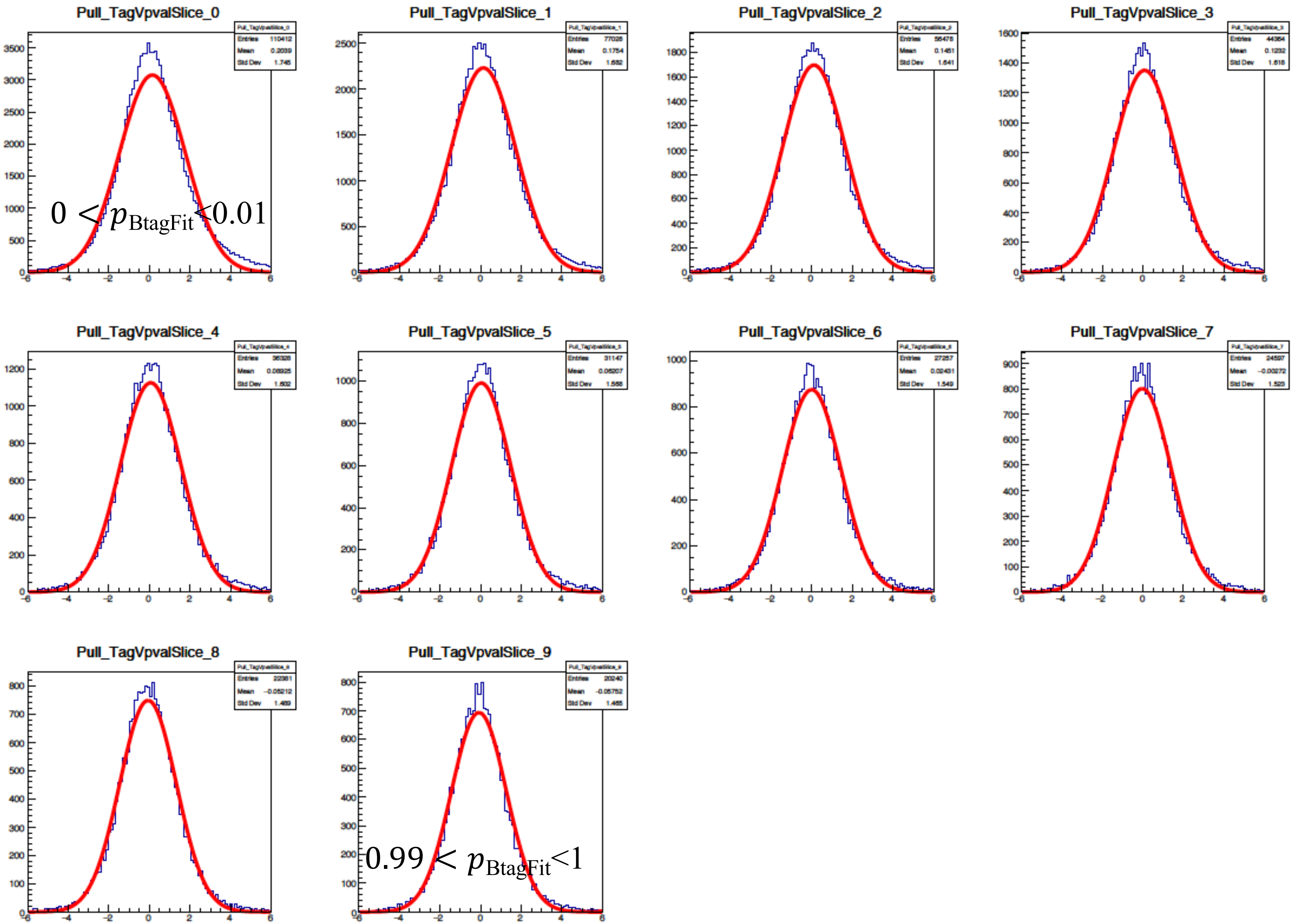


z_{Btag}-pulls for slices in p-value of Btag fit



Summary

Biases of the Δt distribution due to reconstruction are considerably stronger than the effect caused by CPV asymmetry (although measurement of CPV asymmetry is less sensitive to these biases).

Biases in the Δt distribution are due to decays of D-mesons and the beam spot constraint in the Btag vertex fit.

The Δt resolution function (Δt-pulls) depends on

- ***Δt(Truth); t_{Btag}(Truth)*** → ***strictly forbitten ! It is open what to do.***
- ***δ(Δt) – error of Δt***
- ***p-value of the Btag-fit.*** → *more fancy variables ("ξ^2", "t") are used in Belle but they are not (will not be ?) available in Belle2*