Measurement of electrons from beauty-hadron decays in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE

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Inha University

koALICE workshop — 4-7 Jan 2022

Annual report in 2021

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE

CERN

CERN-EP-2019-119
9 May 2019

Measurement of electrons from beauty-hadron decays in pp and Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV

ALICE Collaboration*

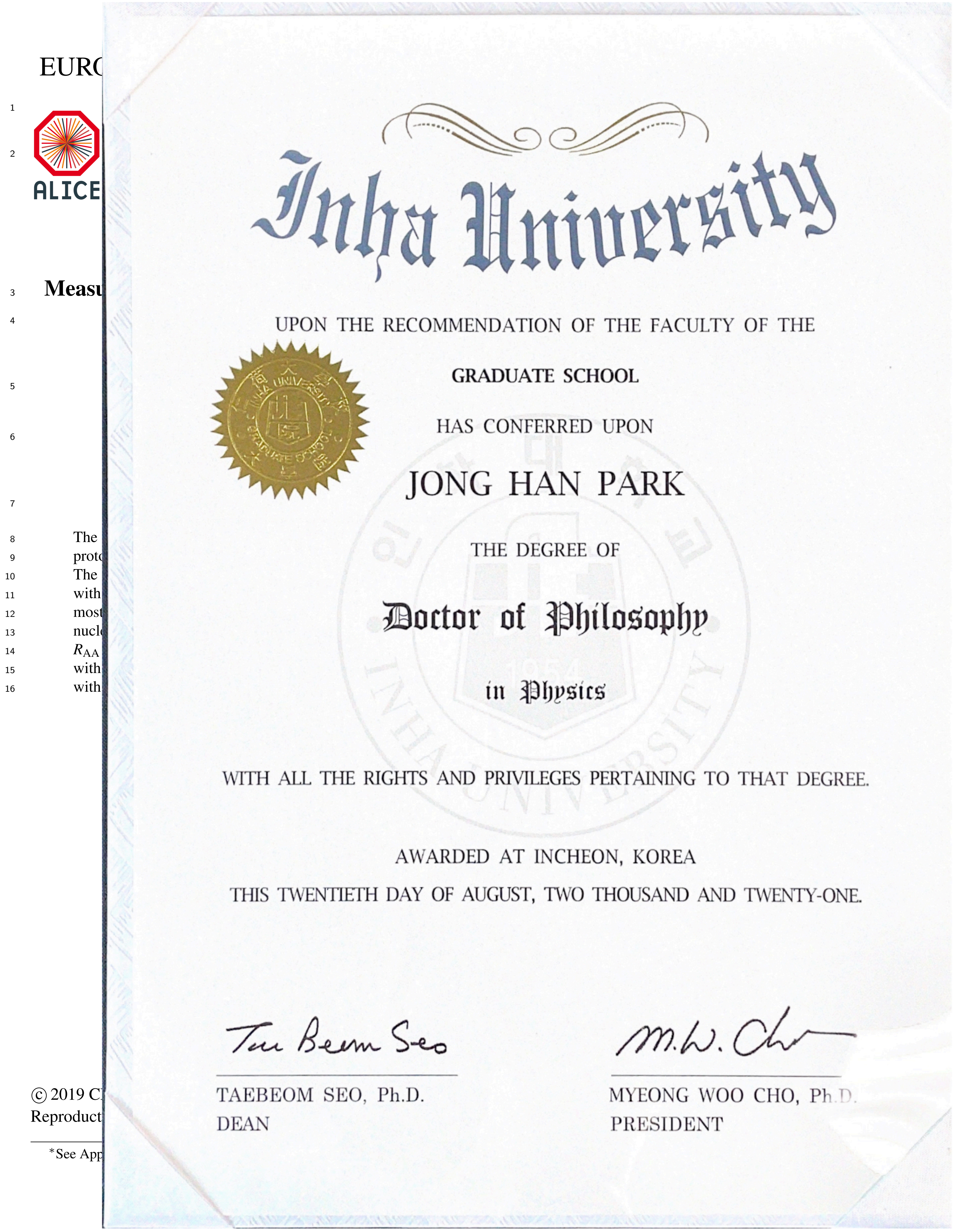
Abstract

The production of electrons from beauty-hadron decays was measured at mid rapidity in proton-proton (pp) and central Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV using the ALICE detector at the LHC. The yield measured in pp in the transverse momentum interval $2 < p_{\rm T} < 8$ GeV/c was compared with models based on perturbative quantum chromodynamics calculations. The yield in the 10% most central Pb-Pb collisions, measured in the interval $2 < p_{\rm T} < 26$ GeV/c, was used to compute the nuclear modification factor $R_{\rm AA}$, extrapolating the pp reference $p_{\rm T}$ above 8 GeV/c. The measured $R_{\rm AA}$ is compatible with a constant value of about 0.4 for $p_{\rm T} > 4$ GeV/c. The results are consistent with several theoretical models based on different implementations of the interaction of heavy quarks with a quark–gluon plasma.

*See Appendix A for the list of collaboration members

- Paper preparation for b→e in Pb—Pb at 5.02 TeV
  - ➡ Target journal : Physical Review C (IRC round 2)
  - ➡ Plan to submit on arXiv before QM 2022

Annual report in 2021



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Annual report in 2021

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE-ANA-2018-0000
December 27, 2021

Measurement of electrons from beauty-hadron decays in pp collisions at $\sqrt{s}$ = 13 TeV using TPC+TOF

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Abstract

The p_{T}-differential cross section of electrons from semi-leptonic decays of beauty-hadrons has been measured at mid-rapidity ($|y| < 0.8$) in the transverse momentum range $2 < p_{\mathrm{T}} < 8$ GeV/c in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE at the LHC. Electron identification is done with the Time Projection Chamber (TPC) and the Time-Of-Flight (TOF) detectors of the ALICE apparatus. A separation of beauty-hadron decay electrons from background ones can be achieved by track impact parameters. The detailed analysis procedure will be discussed in this note.

- Paper preparation for b→e in Pb—Pb at 5.02 TeV
  - ➡ Target journal : Physical Review C (IRC round 2)
  - ➡ Plan to submit on arXiv before QM 2022
- Graduate in Aug
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- Take over b→e analysis in pp at 13 TeV
  - ➡ Today's main talk

Heavy-flavor production in pp collisions

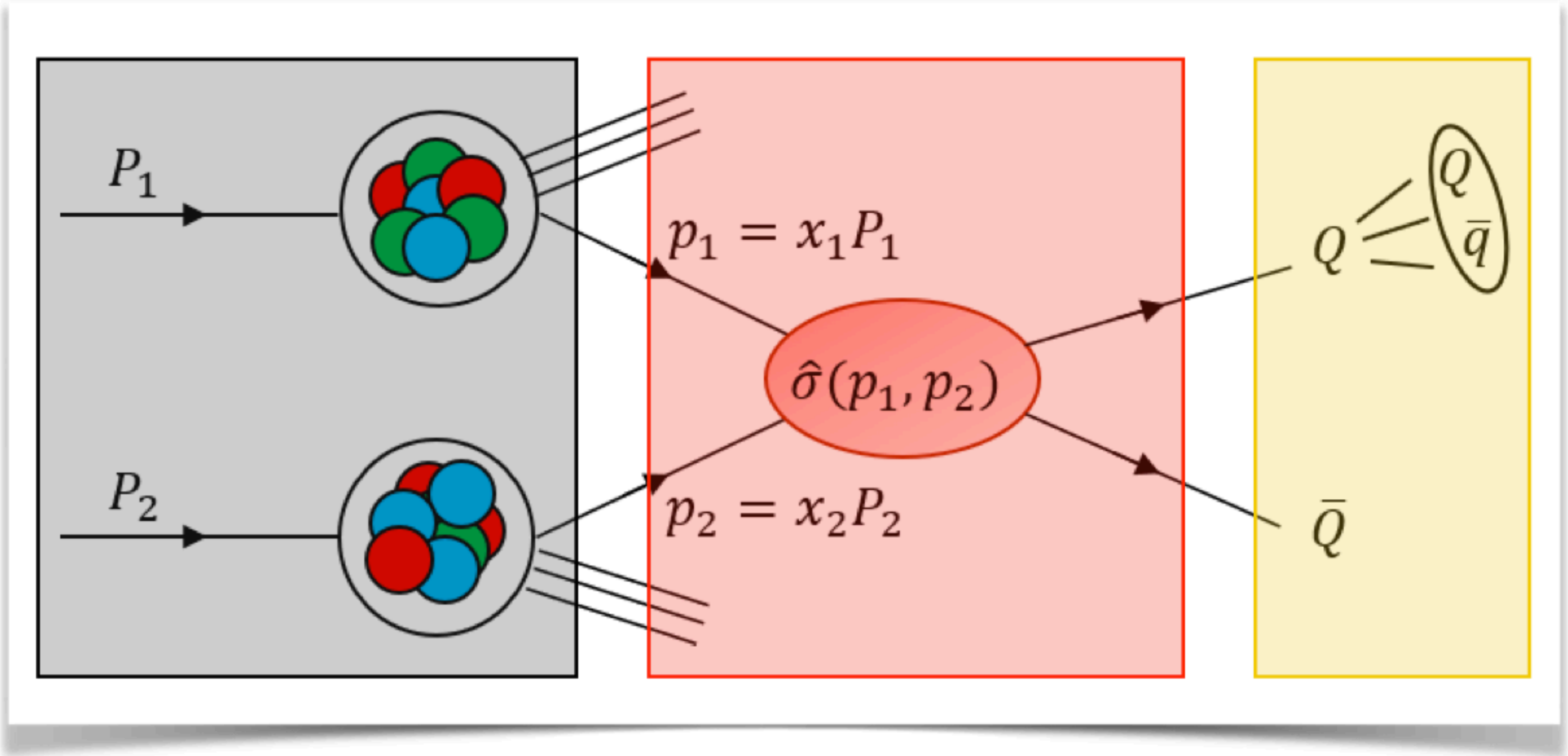
- Heavy quarks produced in initial hard scattering processes
- HF hadron production measurements → test of pQCD calculations

$$\sigma^{\text{hard}}_{AB\to h} = \text{PDF}(x_a, Q^2)\text{PDF}(x_b, Q^2) \otimes \sigma^{\text{hard}}_{ab\to c}(x_a, x_b, Q^2) \otimes D_{c\to h}(z = p_h/p_c, Q^2)$$

Parton distribution function (PDFs)

Hard scattering cross section (pQCD)

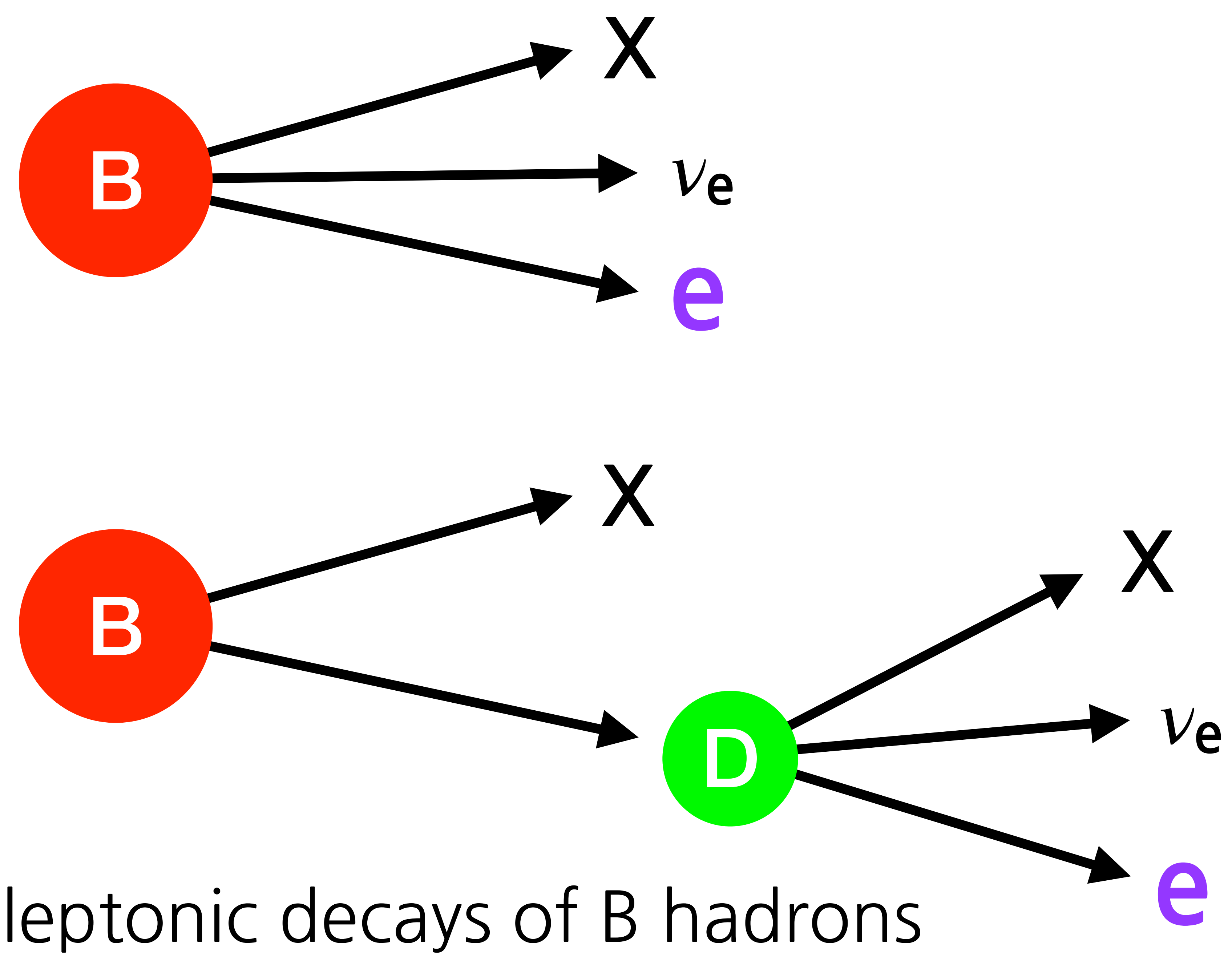
Fragmentation function (hadronization)



- Description in pp collisions based on factorization theorem → fragmentation functions assumed universal and constrained from e^+e^-/ep measurements

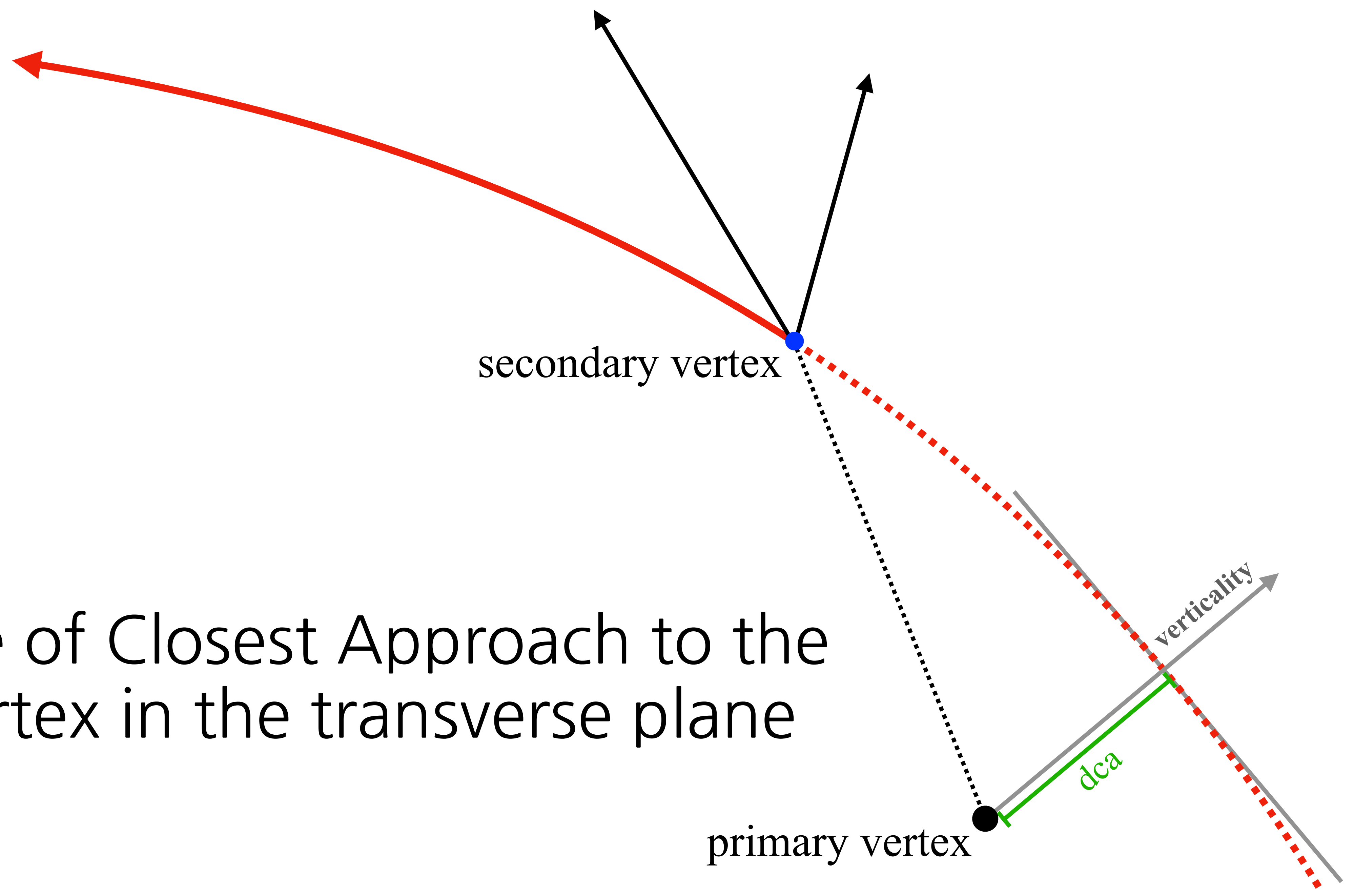
Electrons from beauty-hadron decays

- Substantial branching ratio of semi-leptonic decays of beauty hadrons (~10%)
- Sizable decay length ($c\tau \approx 450$—$500\,\mu$m) of beauty hadrons
  - ➡ Move far from the primary vertex than background hadrons → large DCA
- Exploit the track impact parameter (IP) distributions



semi-leptonic decays of B hadrons

IP : Distance of Closest Approach to the primary vertex in the transverse plane



Signal extraction

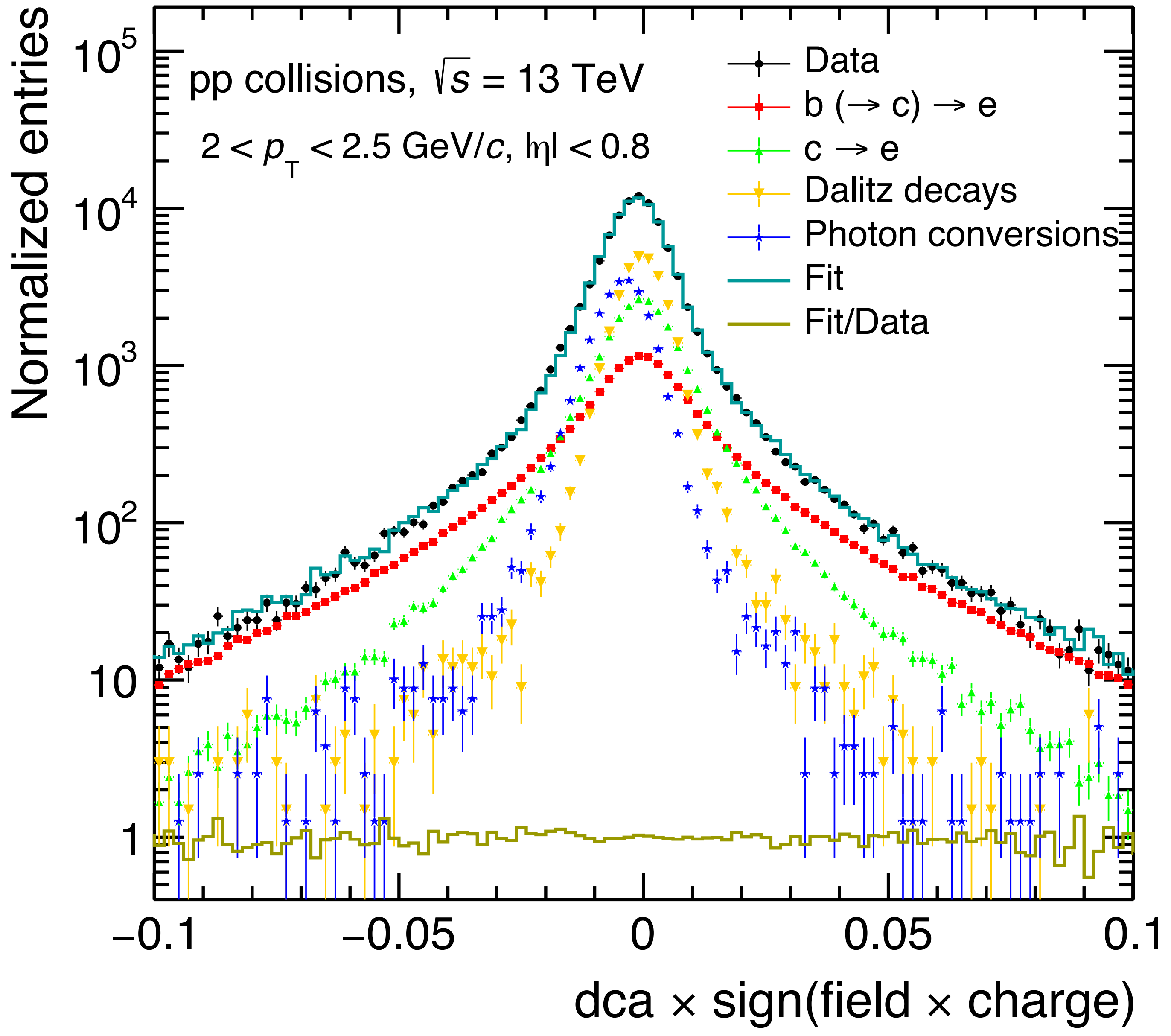
- Template fit method based on maximum likelihood approach

$$\log L = \sum_{\text{bin}} \text{data(bin)} \cdot \log \text{fit(bin)} - \text{fit(bin)} + \sum_{\text{bin}} \sum_{\text{source}} N_{\text{source}}(\text{bin}) \cdot \log A_{\text{source}}(\text{bin}) - A_{\text{source}}(\text{bin})$$

Likelihood for weighted sum of expectation values to correspond to data

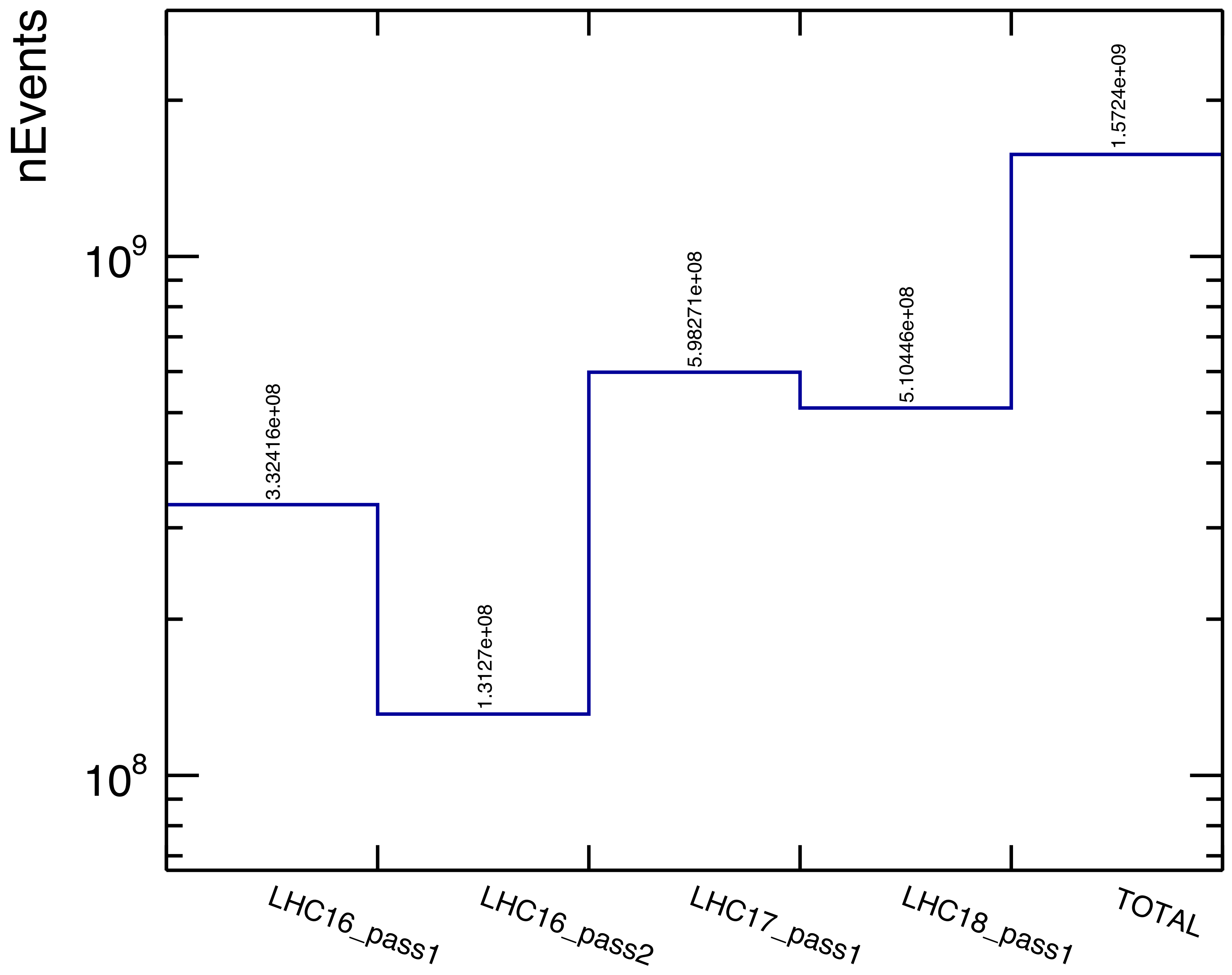
Likelihood for expectation values to correspond to MC templates

- Stochastic extraction using the impact parameter fit
- Importance of MC templates to have realistic behavior based on data and model predictions



Dataset and analysis strategy

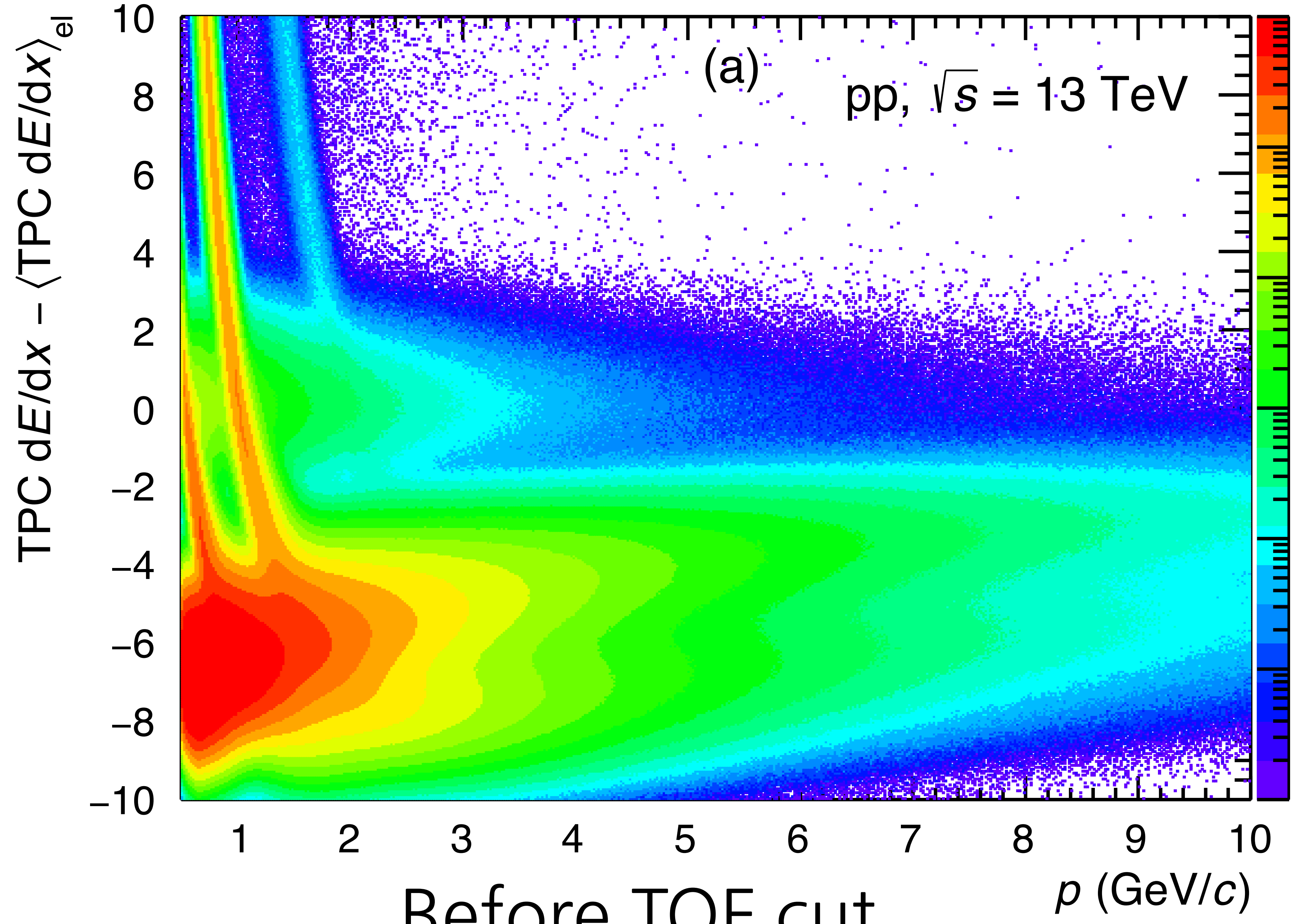
- pp collisions at 13 TeV collected during 2016—2018
  - ➡ Nr. of events : ~1.6×10^9 events



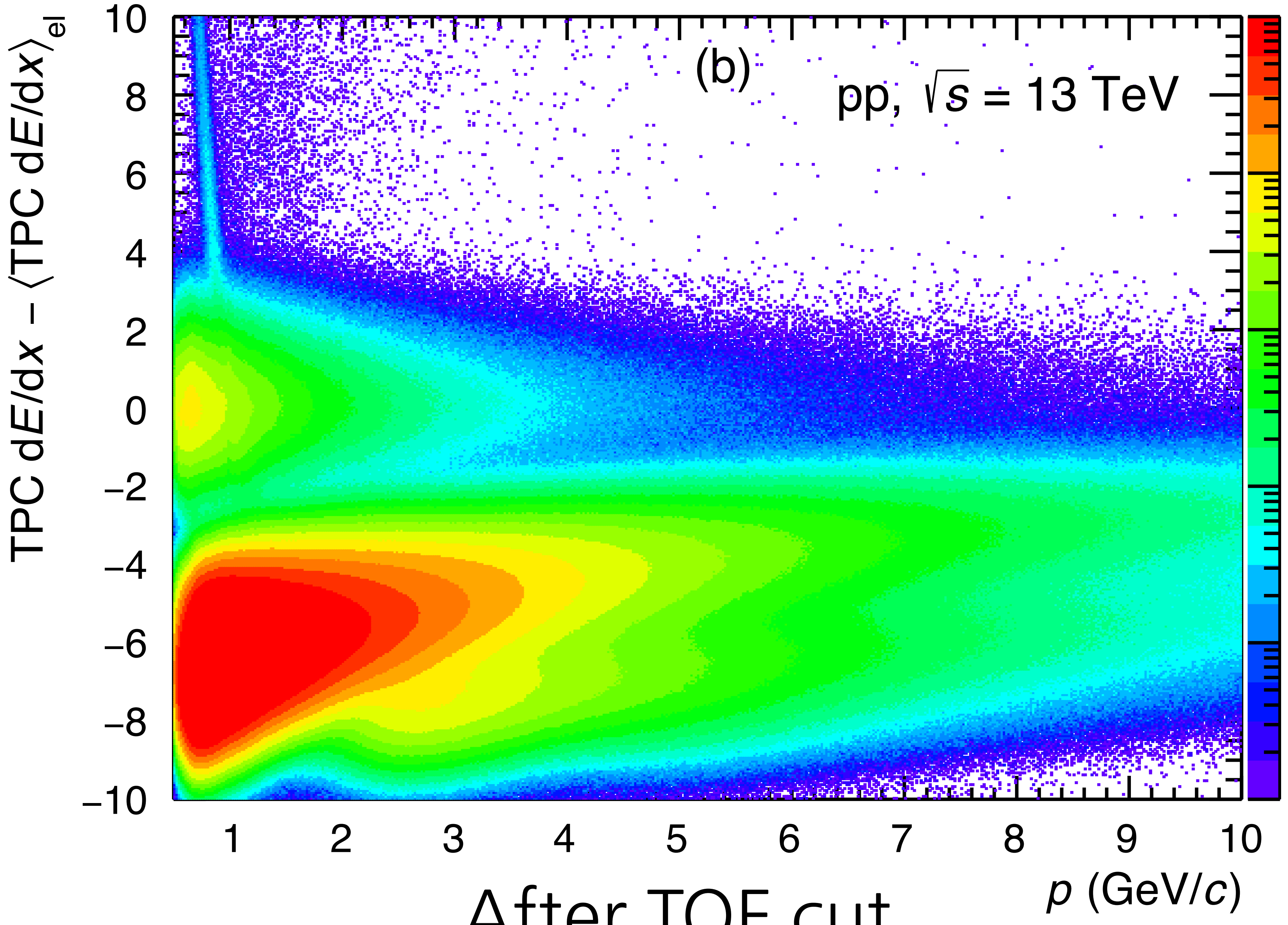
- Analysis strategy
  - ➡ Select good quality events
  - ➡ Select tracks fulfilling high purity electron conditions
  - ➡ Electron identification using TPC+TOF
  - ➡ MC template corrections
  - ➡ Fit the impact parameter distribution in data using templates
  - ➡ Correction for acceptance and track selection criteria

Electron identification

- 3σ selection of TOF eID hypothesis
  - ➡ Most hadron contamination removed
  - ➡ Electron band has almost no change in TPC nσ vs. p distribution
- Reduce the remaining contamination by an asymmetric TPC nσ cut : $-1 < n\sigma_{TPC} < +3$



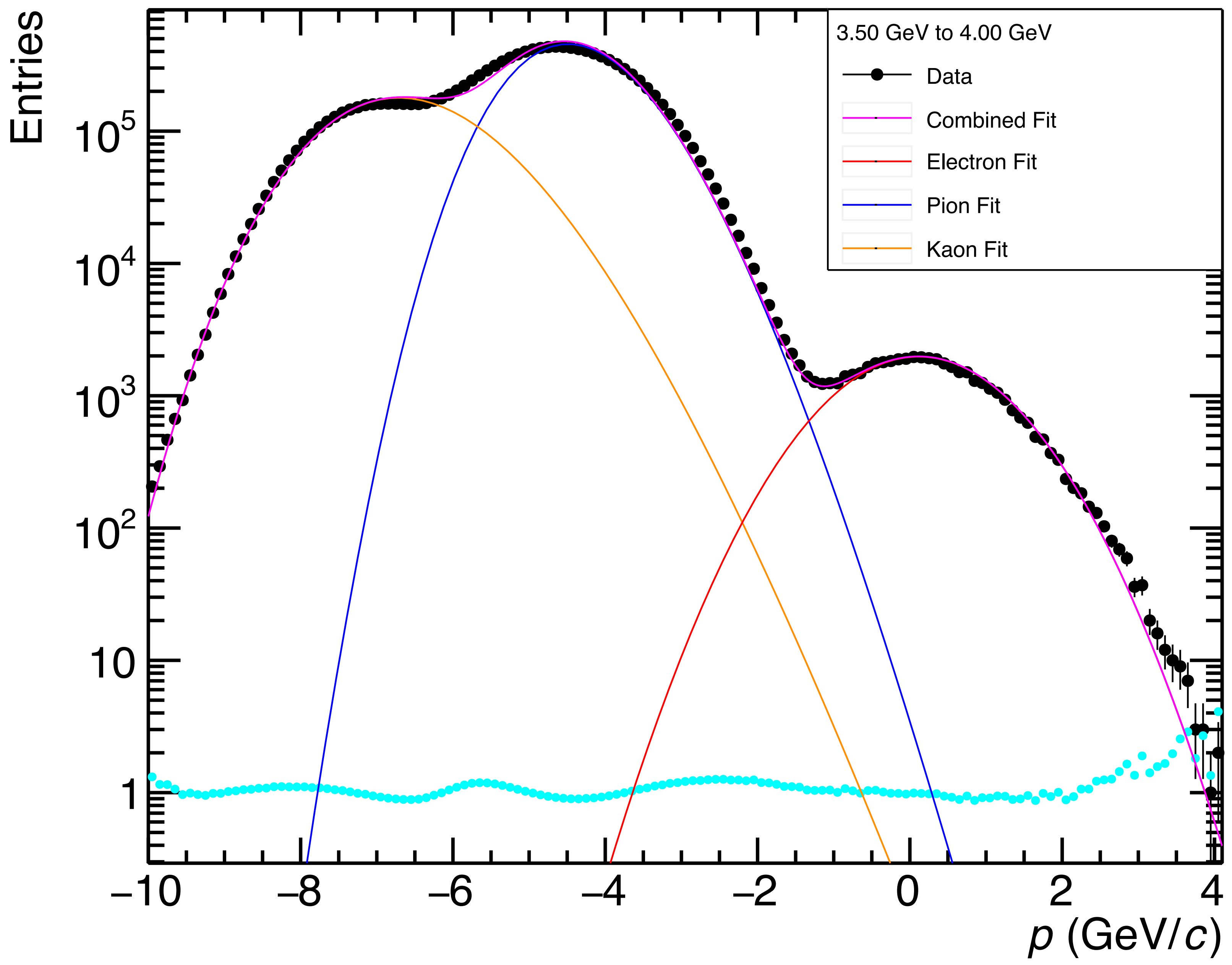
Before TOF cut



After TOF cut

Estimation of TPC eID efficiency and hadron contamination

- Fit the projection of TPC nσ vs. p on the nσ axis
  - Kaon/Pion described by Landau × Exponential
  - Electrons described by Gaussian (default) and Landau × Exponential (systematics)

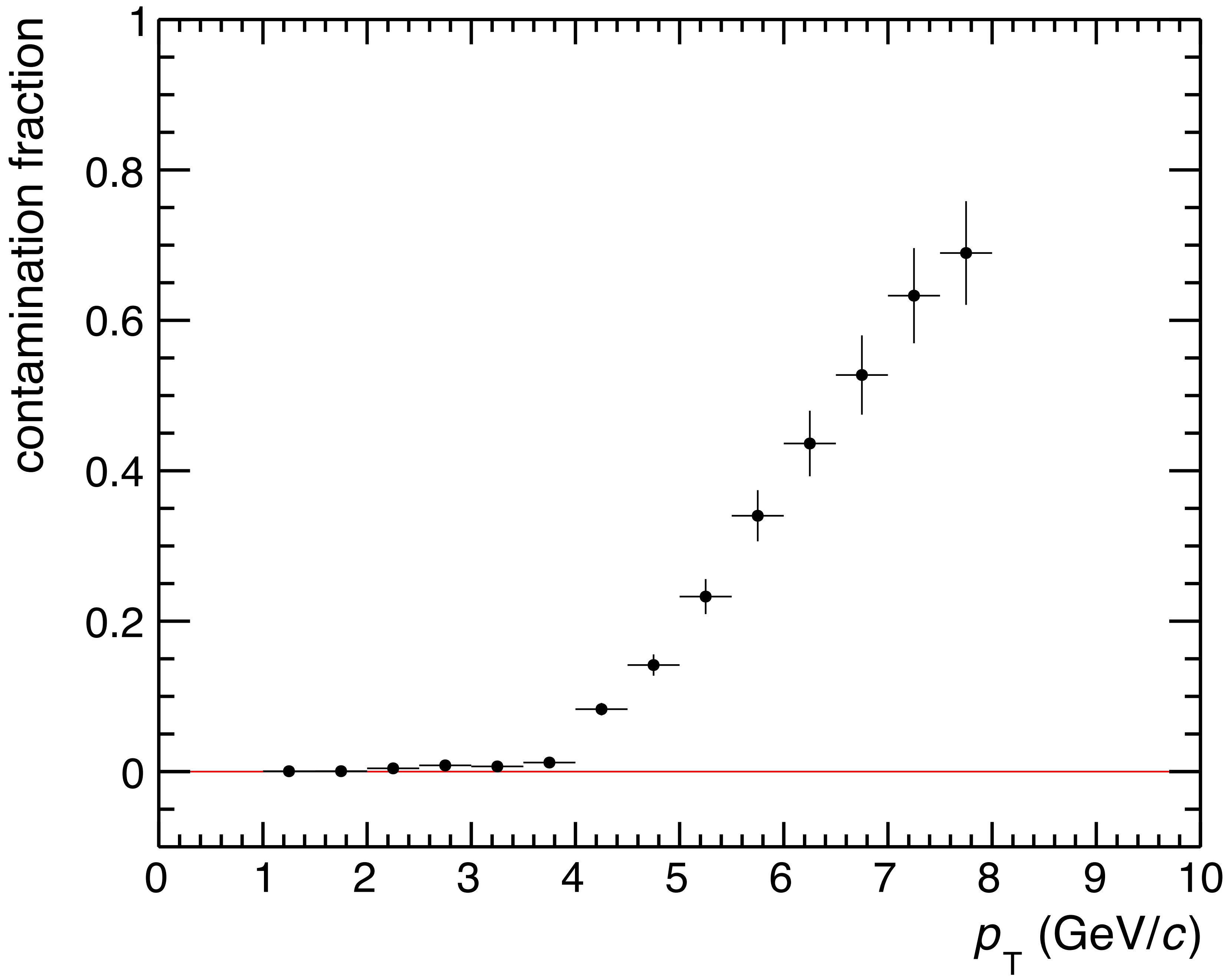


Efficiency

- Gaussian : ~87%
- Landau × Exp. : ~89%

Hadron contamination

- Hadrons for $p_T > 4$ GeV/c

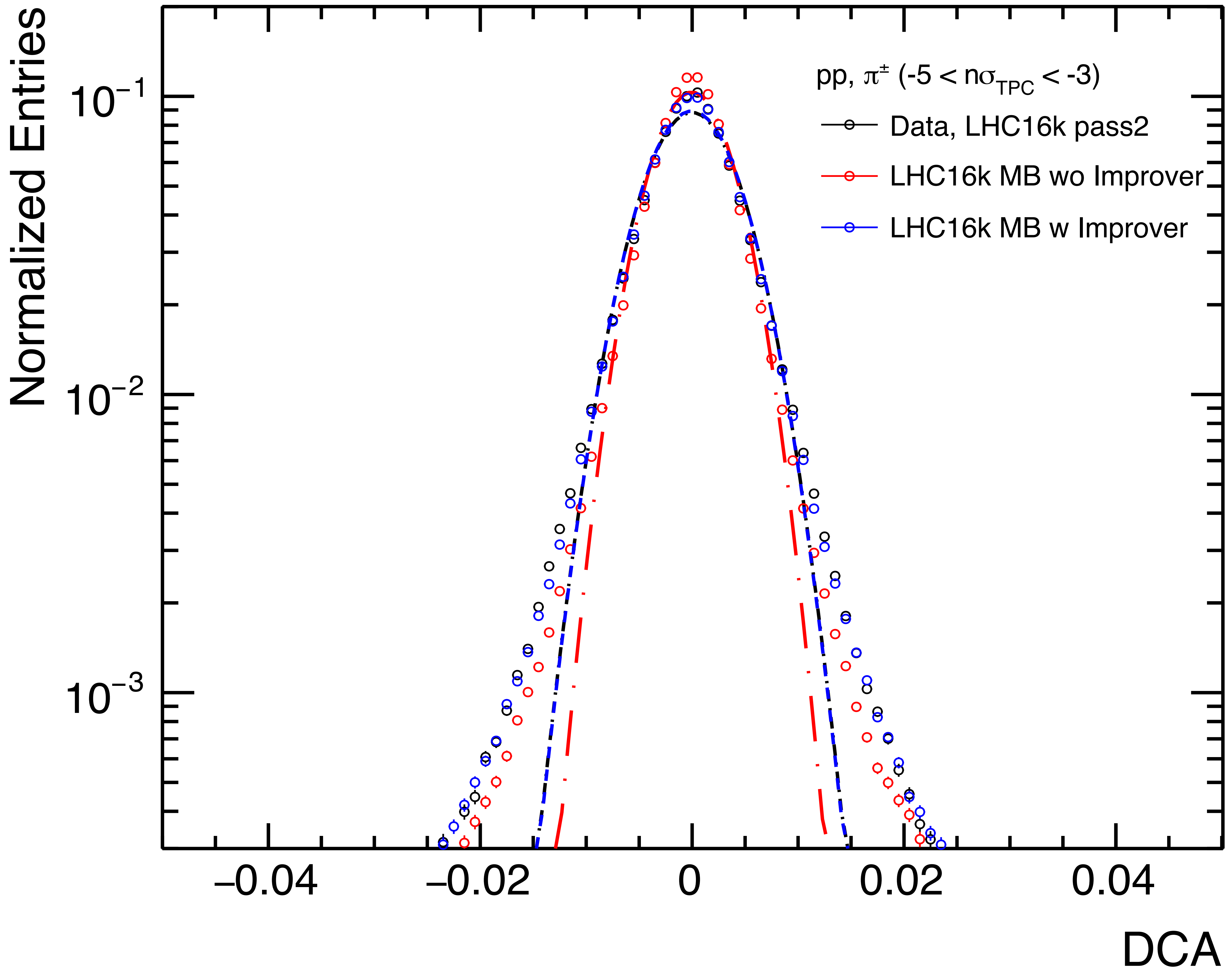


$$Efficiency(\epsilon) = \frac{Electrons\ in\ -1 < n\sigma_{TPC} < 3}{Total\ number\ of\ electrons\ in\ curve}$$

$$Contamination = \frac{Int.\ of\ hadron\ function\ in\ -1 < n\sigma_{TPC} < 3}{Int.\ of\ total\ function\ in\ -1 < n\sigma_{TPC} < 3}$$

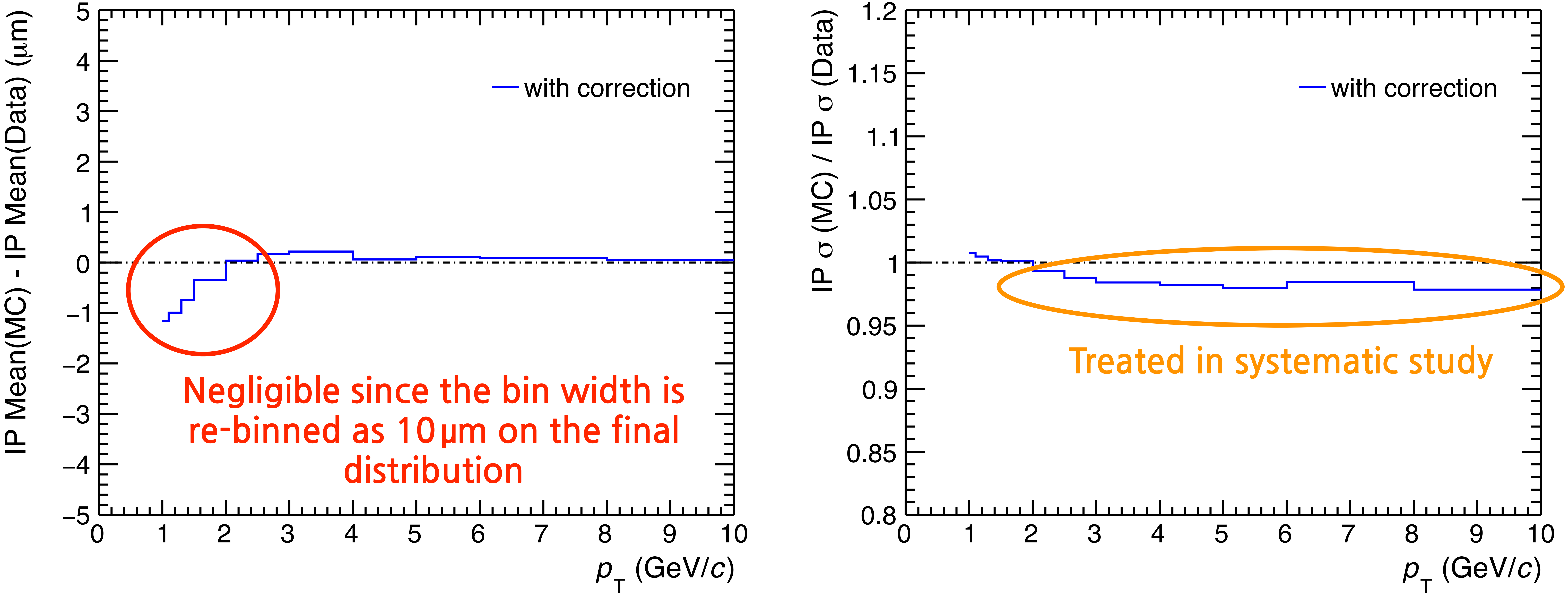
MC template correction : IP mean and resolution

- Observe the track impact parameter differences between data and simulation
- Track impact parameter correction with AliAnalysisTaskSEImproveITSCVMFS
- Assurance check with charged pions
  - ➡ Select charged pions with $-5 < n\sigma_{TPC} < -3$
- Impact parameter mean and resolution extracted by a gaussian fit



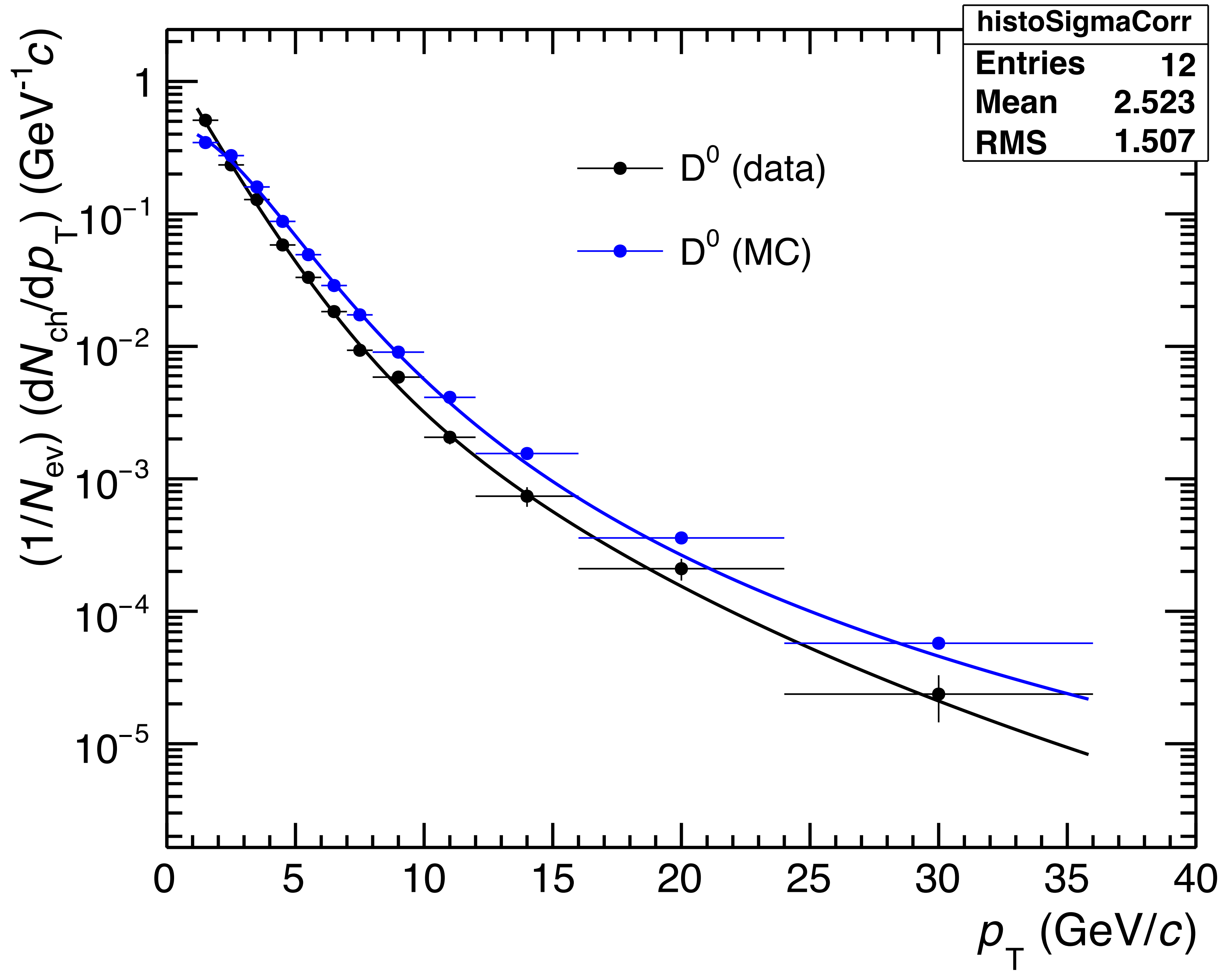
MC template correction : IP mean and resolution

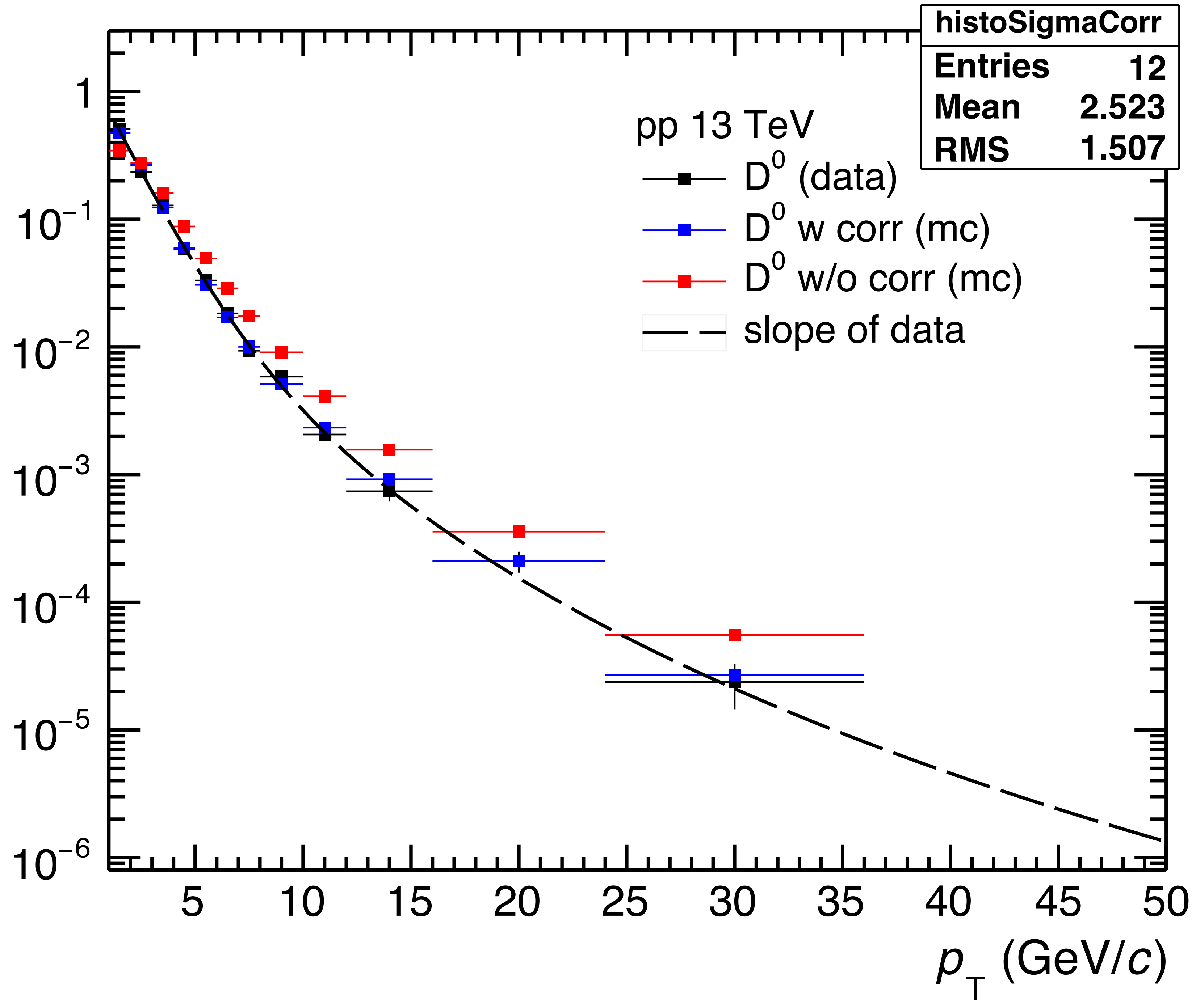
- Deviation still exists on both mean and resolution after correction
  - ➡ Maximum of 1 μm on the mean and 2 % on the resolution



MC template correction : HF hadron spectra

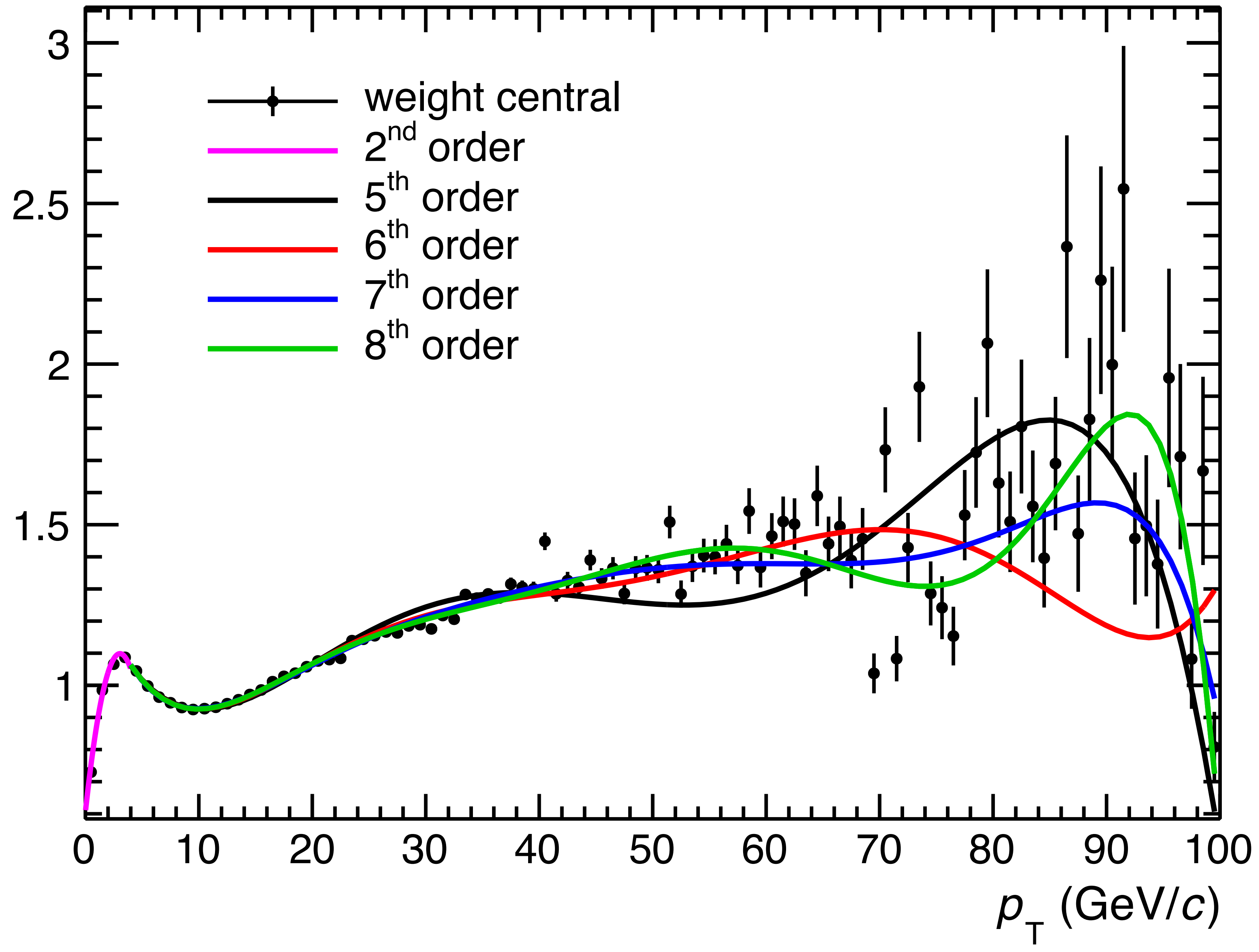
- Track impact parameter depends on p_T distribution of mother particle
- D^0 spectrum in MC slightly differs from the measured D^0 spectrum
- Interpolate both spectra and the ratio function is used as weight (data fit/MC fit)
  - ➡ Described by Tsallis function





MC template correction : HF hadron spectra

- Not possible to use the same approach as charm case
  - ➡ b→e spectrum provides information of B hadron spectrum
  - ➡ The information is not available prior to the b→e measurement
- Model prediction, FONLL is adopted as a reference of B hadron spectrum
- B hadron p_T weight : interpolation of B hadron p_T in MC over FONLL
  - ➡ 2nd order polynomial for $p_T < 3.5$ GeV/c
  - ➡ 6th order polynomial for $p_T > 3.5$ GeV/c
- Not accept B hadrons having $p_T > 70$ GeV/c
  - ➡ No matter due to very small contribution



MC template correction : Charm hadron yield

- Various charm hadrons have relatively different decay length
  - ➡ All B hadrons have almost similar decay length

Species	D^0	D^+	D_s	Λ_c
Decay length ($c\tau$)	122.9 μm	311.8 μm	151.2 μm	60.7 μm

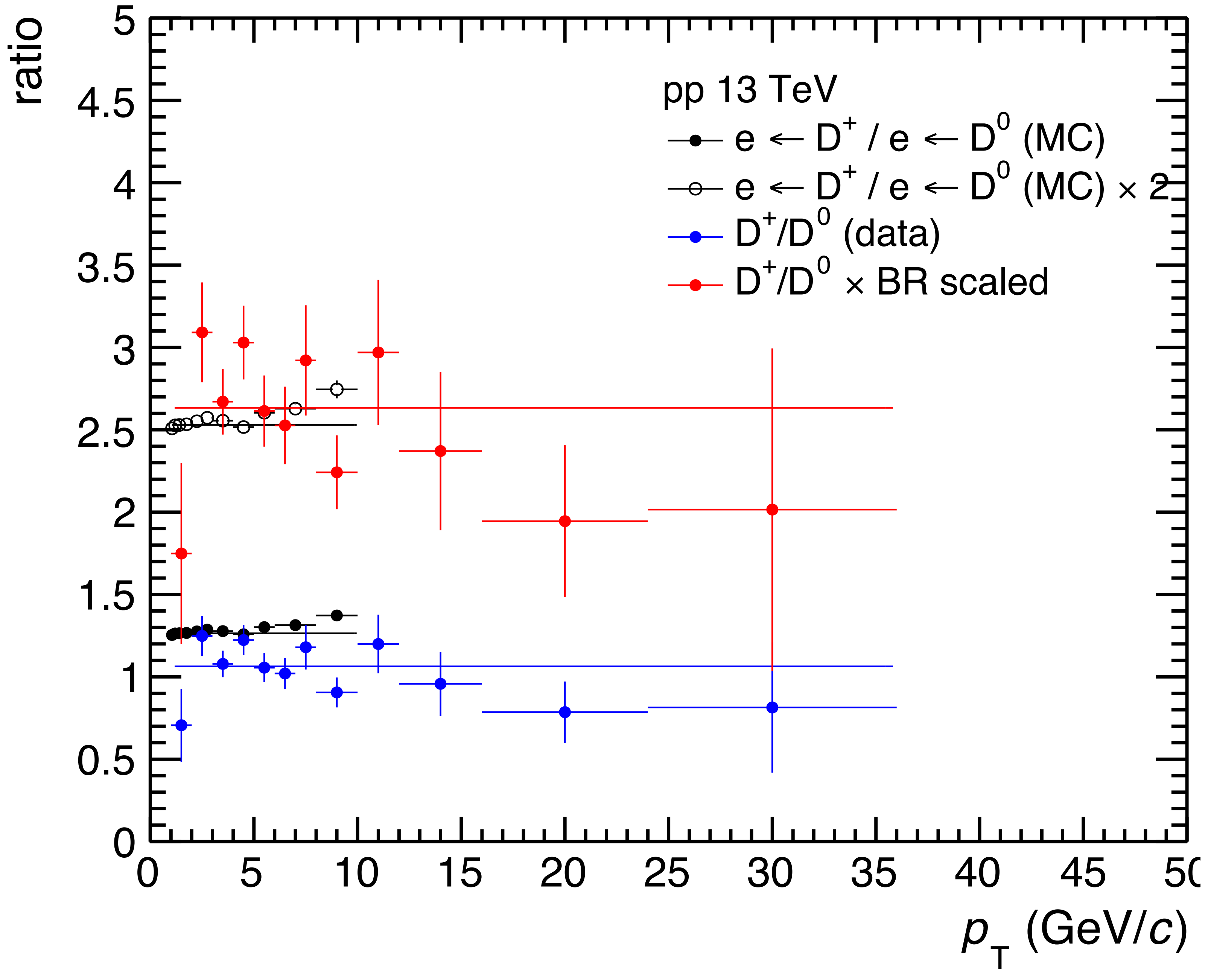
- Total charm template is the sum of various charm hadron templates

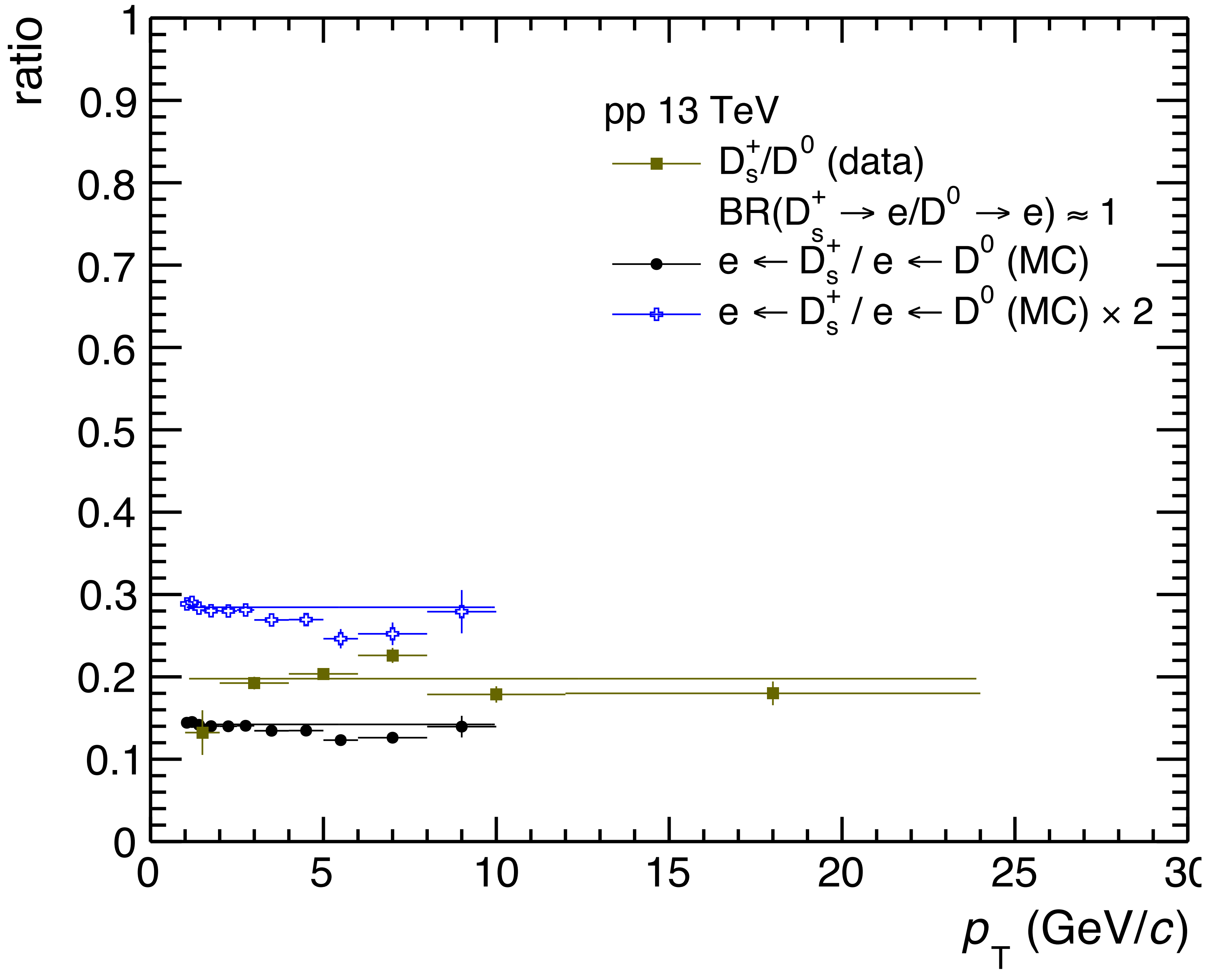
$$DCA_{\text{charm}} = DCA_{D^0} + DCA_{D^+} + DCA_{D_s} + DCA_{\Lambda_c}$$

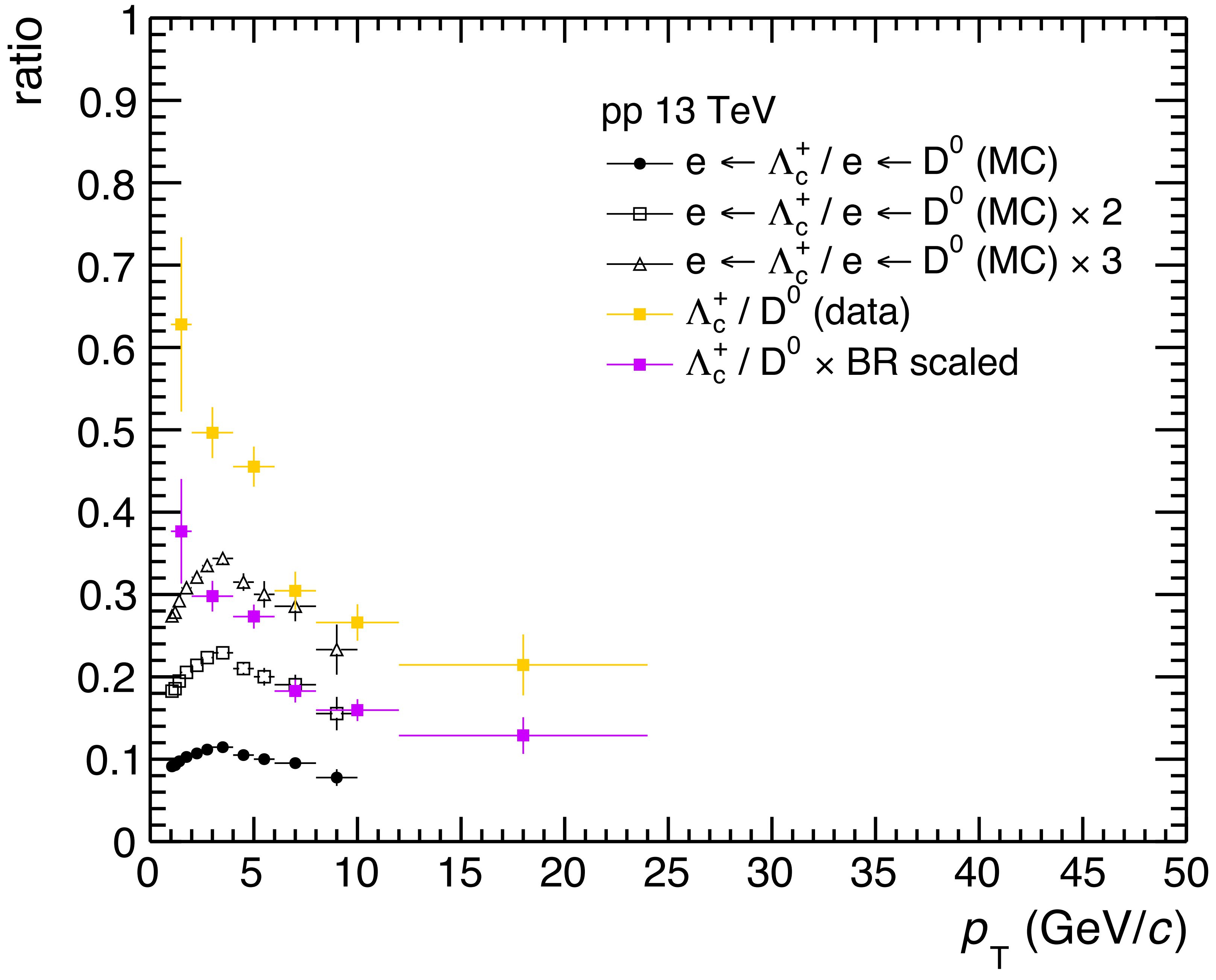
Ex) If the simulation underestimates the Λ_c,
total charm template is wider than real charm DCA distribution

MC template correction : Charm hadron yield

- ALICE measured charm hadron fraction w.r.t D^0 mesons
- Simulation underestimates D^+, D_s, and Λ_c
  - ➡ Consider a branching ratio in the comparison between data and simulation
- Scale the D^+, D_s, and Λ_c templates based on the measurements







b→e production cross section in pp collisions at 13 TeV

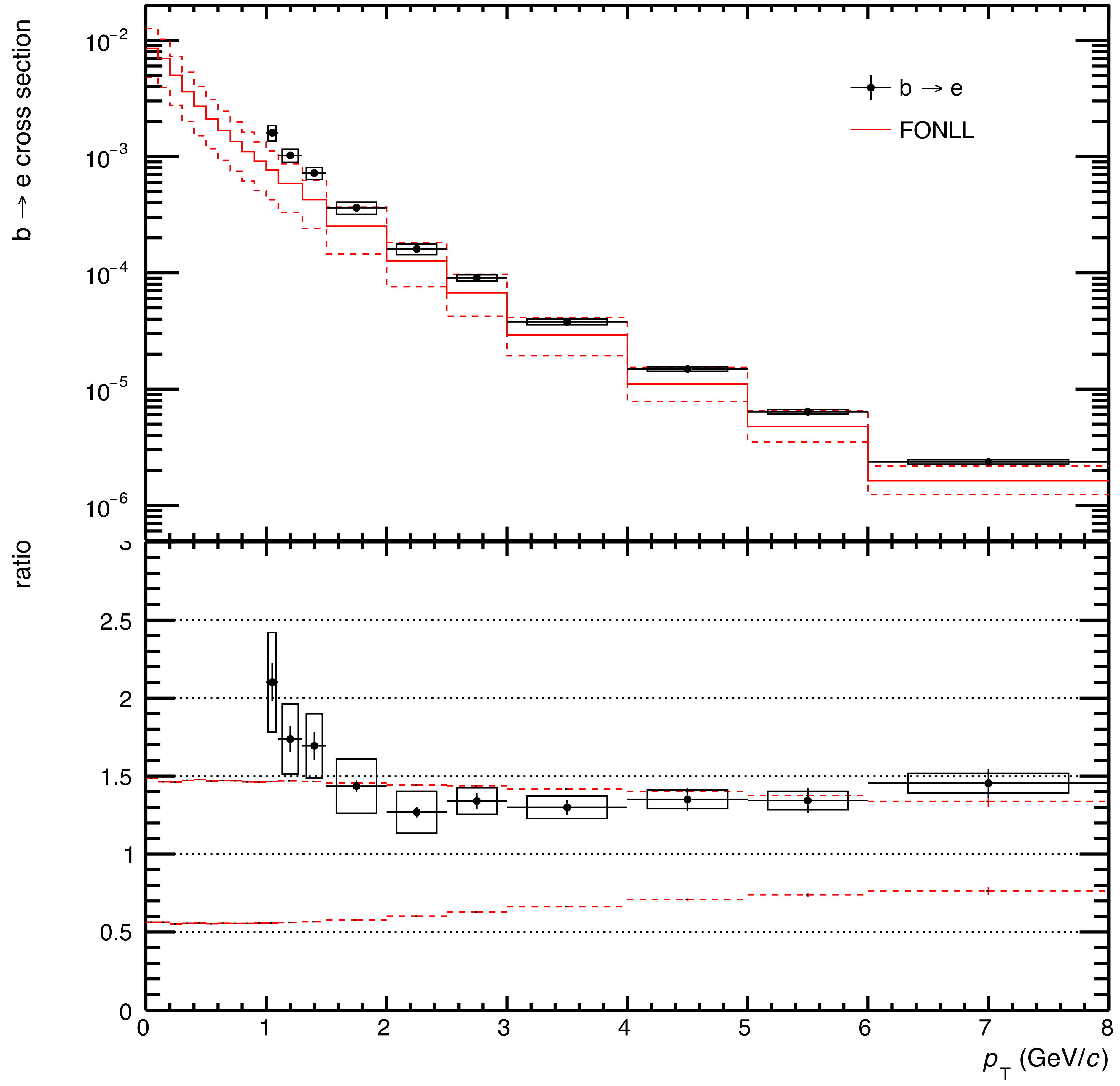
- b→e production cross section
- Compared with FONLL prediction
  - ➡ Lying on the upper edge of the prediction
  - ➡ Comparable within uncertainty for p_T > 1.5 GeV/c

Statistical uncertainty estimated by Toy model approach

Systematic uncertainty

- ➡ Maximum of 15% at lowest p_T interval
- ➡ Minimum of 4% at highest p_T interval

- Large deviation at very low p_T as a former analysis



Summary and Outlook

- Finalize b→e paper (Pb—Pb collisions at 5.02 TeV) before QM
- b→e analysis in pp collisions at 13 TeV
  - ➡ Remaining systematics : IP resolution correction
  - ➡ Preparation for preliminary in Feb
  - ➡ Poster presentation at QM2022 by Vivek (b→e high p_T analyzer)
- ITS3 beam test in Jun 2022
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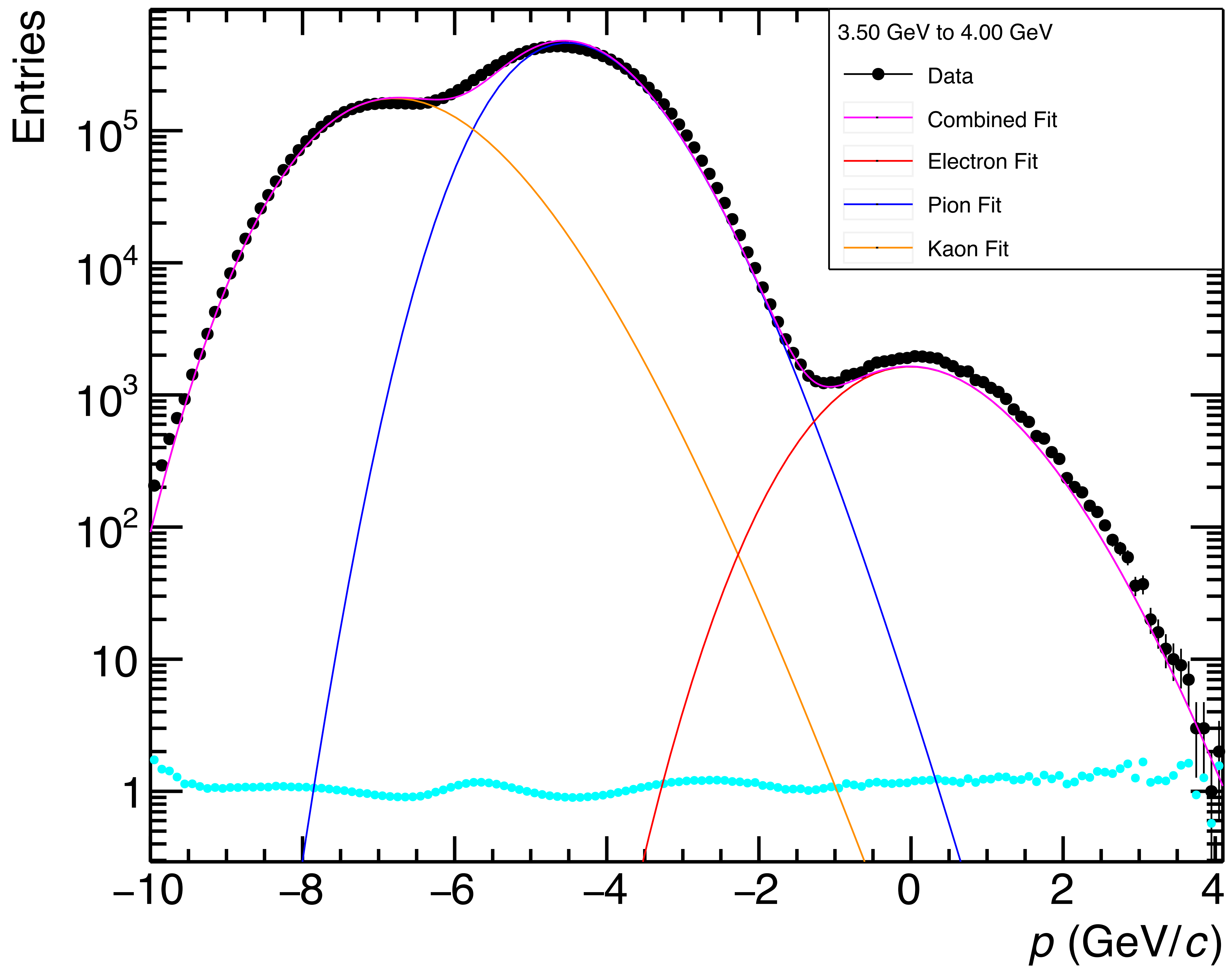
Thank you for your attention

진지… 궁서…

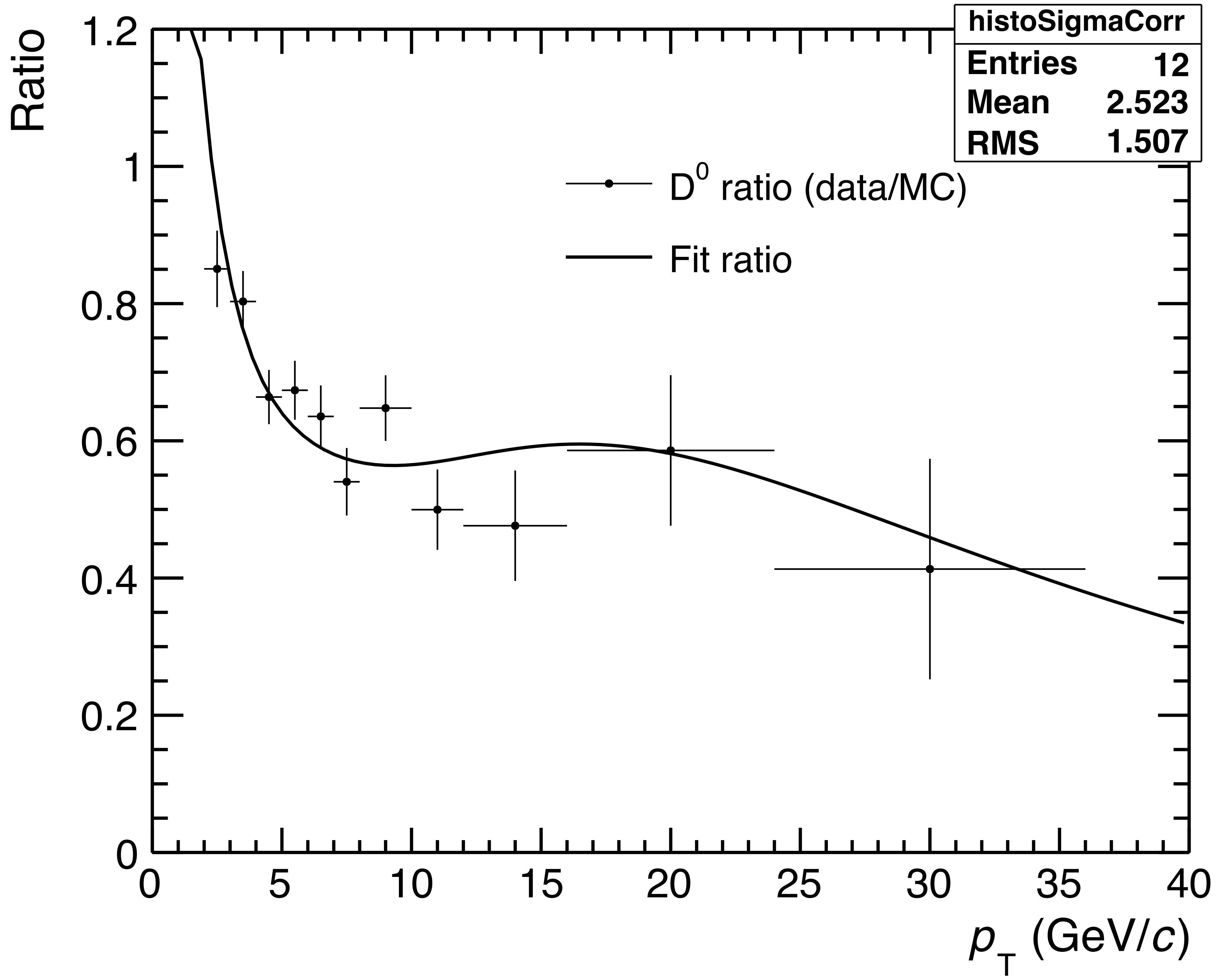
새해 복 많이 받으세요

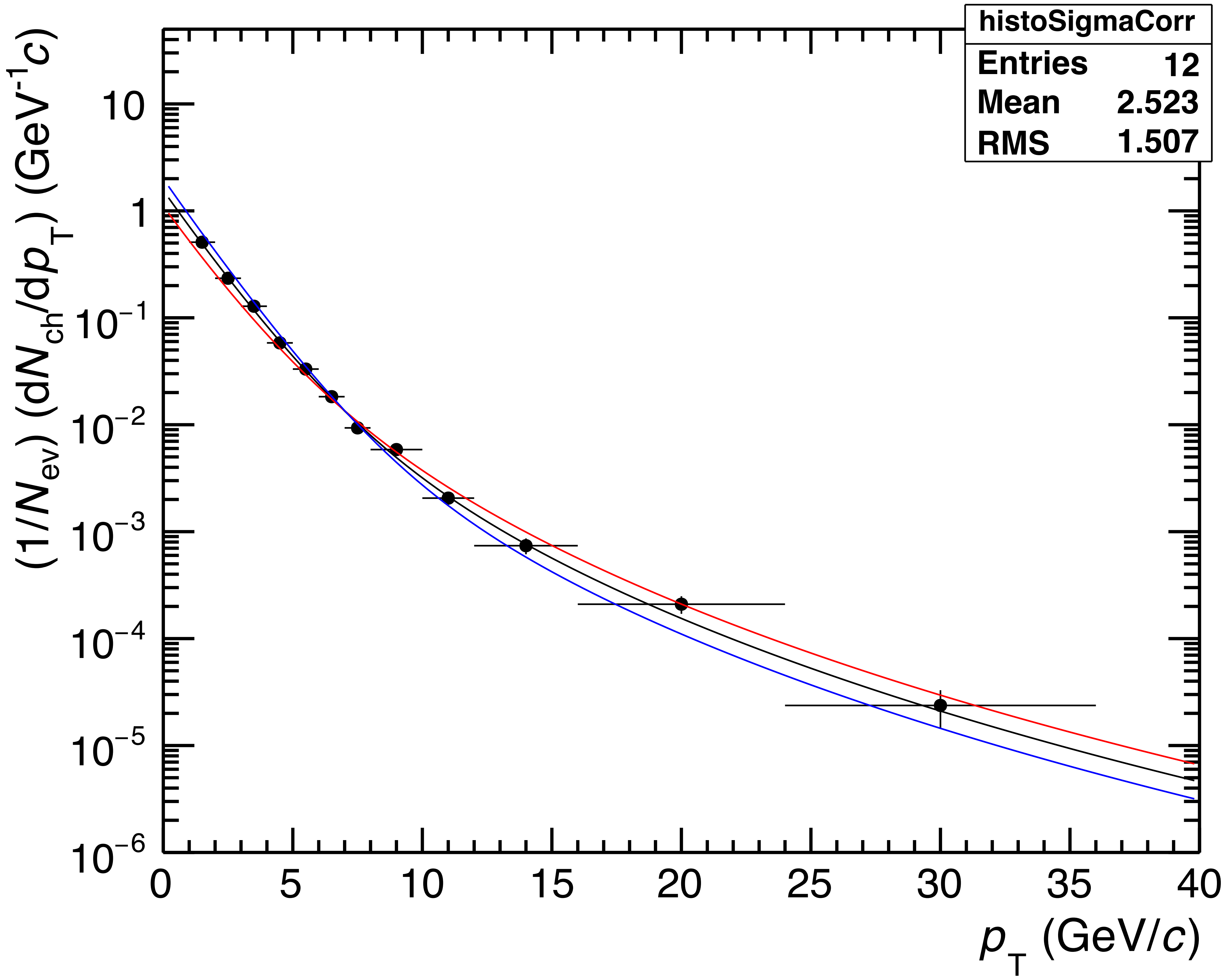
BACKUP

- TPC nσ fit - electron peak described by Landau × Exponential



- D meson weight and variation for D^0 spectrum





- B hadron spectrum before and after weight
- Variation of B hadron weight for systematics