

Updates on Identification of π , K , and p with ALICE TPC detector for LHC Run3 pp data

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ALICE

Introduction

- The motivation of studying proton-proton (pp) collisions:
 - to understand the physics of strongly interacting matter,
 - to explore the possibility of the de-confined state of matter in small systems,
 - generally, used as a reference to study heavy ion collisions (HIC).
- In this report,
 - Identification of pions, Kaons and protons using the TPC detector.
 - Multiplicity dependence of the p_T spectra will be explored.
 - Systematic uncertainties will be estimated.

Analysis details

ALICE Data: pp at $\sqrt{s} = 13.6$ TeV

- Period: [LHC24_pass1_MinBias](#)
- Run no.: 558801, 558783, 558757, 558752, 558750, 558744, 558726, 558685, 558676, 558656, 558633, 558627, 558615, 558606, 558604, 558602, 558551, 558535, 558482, 558449, 558437, 558433, 558422, 558410, 558409, 558406, 558390, 558387, 558383, 558369, 558354, 558330, 558329, 558327, 558291, 558288, 558284, 558275, 558273, 558247, 558244, 558221, 558217, 558215, 558182, 558179, 558155, 558153, 558150, 558126, 558124, 558122, 557926, 557913, 557897, 557876, 557862, 557749, 557744, 557726, 557723, 557717, 557691, 557681, 557659, 557613, 557547, 557531, 557509, 557482, 557481, 557444, 557425, 557415, 557374, 557350, 557339, 557336, 557321, 557299, 557291, 557271, 557251, 557233, 557226, 557149, 557138, 557119, 557118, 557112, 557104, 557074, 557026, 557021, 557019, 557012, 556997, 556981, 556979, 556958, 556954, 556939, 556923, 556913, 556909, 556907, 556889, 556872, 556834, 556816, 556767, 556741, 556734, 556716, 556680, 556664, 556662, 556641, 556640, 556639, 556562, 556542, 556517, 556497, 556491, 556485, 556482, 556461, 556454, 556437, 556412, 556372, 556370, 556284, 556269, 556248, 556237, 556218, 556210, 556182, 556164, 556160, 556152, 555976, 555967, 555965, 555960, 555958, 555933, 555917, 555900, 555883, 555881, 555860, 555853, 555850, 555801, 555798, 555790, 555789, 555763, 555761, 555759, 555742, 555740, 555723, 555722, 555707, 555705, 555695, 555693, 555676, 555651, 555649, 555612, 555596, 555591, 555575, 555546, 555543, 555540, 555504, 555482, 555478, 555476, 555451, 555443, 555435, 555431, 555411, 555408, 555401, 555398, 555374, 555370, 555345, 555344, 555308, 555270, 555267, 555259, 555254, 555232, 555226, 555208, 555202, 555187, 555172, 555166, 555160, 555156, 555152, 555150, 555124, 555122, 555121, 555073, 555071, 555047, 555023, 555022, 555020, 554998, 554973, 554970, 554968, 554920, 554898, 554880, 554873, 554837, 554835, 554808, 554791, 554774, 554772, 554768, 554752, 554736, 554732, 554728, 554714, 554703, 554701, 554633.

MC Data: pp at $\sqrt{s} = 13.6$ TeV

- Period: [LHC24f4d \(anchored to pass1\)](#)
- Run no.: same as [LHC24_pass1_MinBias](#)

3.4 Billion MC events

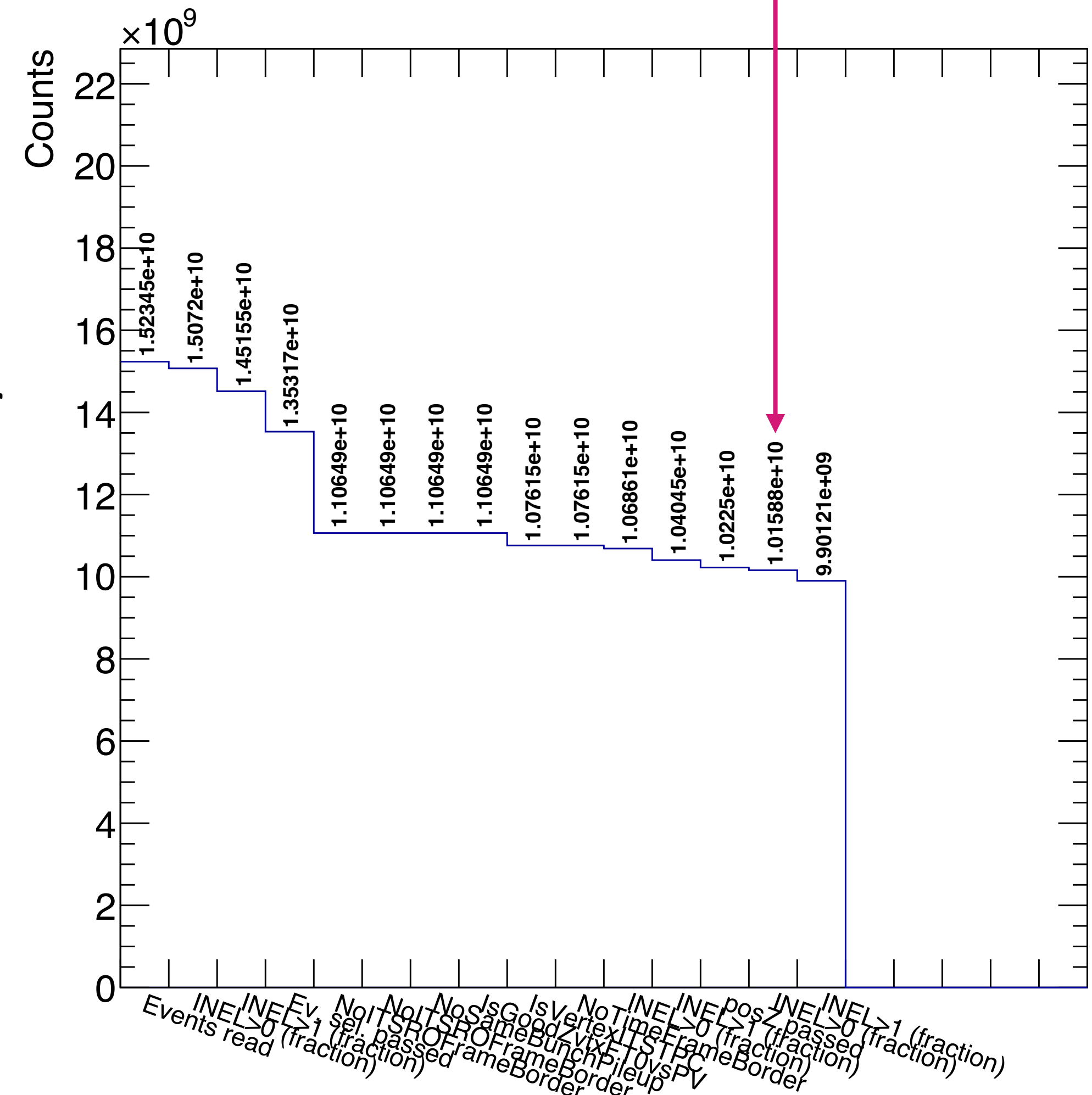
Event Selection:

- `bool sel8 = selection[kIsBBTOA] & selection[kIsBBTOC] + kNoTimeFrameBorder & kNoITSROFrameBorder`
- $|Z_{\text{vertex}}| < 10$ cm

Track Selection:

- Min TPC crossed Rows ≥ 70
- Min ratio of Crossed rows over findable clusters TPC ≥ 0.8
- Max χ^2 /TPC cluster ≤ 4
- Max χ^2 /ITS cluster ≤ 36
- TPC Refit & ITS Refit = True
- $DCA_Z \leq 0.1$ cm
- $|\eta| \leq 0.8$
- $|y| < 0.3$

~10 Billion INEL>0 events are selected



Analysis details

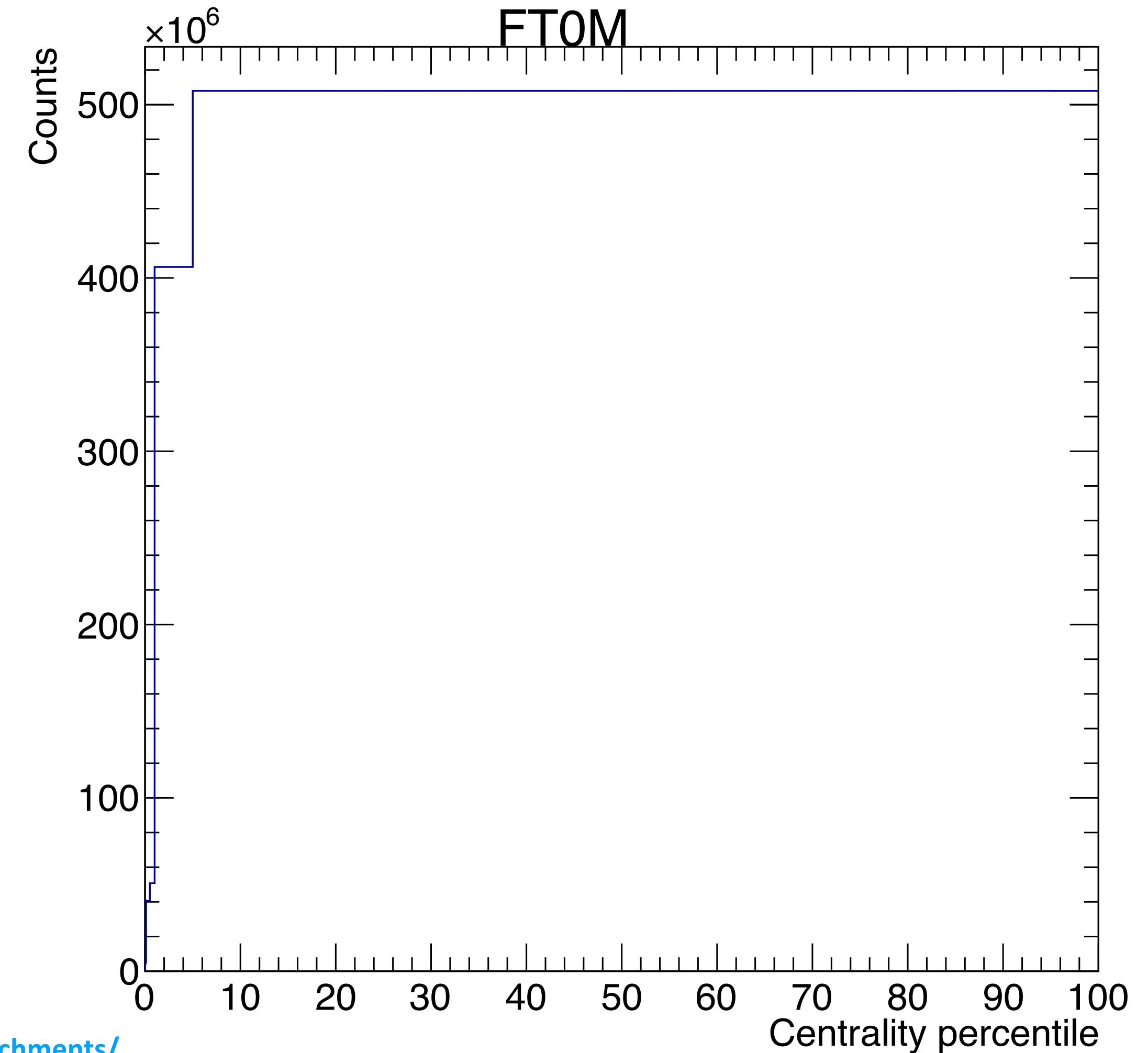
Multiplicity selection

- Multiplicity classes are selected based on the distribution of the summed signal amplitudes by FT0A and FT0C (the **FT0M** amplitude).

Multiplicity classes (in %) :

0-1, 1-5, 5-10, 10-15, 15-20,
20-30, 30-40, 40-50, 50-70,
70-100

Percentile (%)	$ \eta < 0.8$ $\langle dN_{ch}/d\eta \rangle$
	13.6 TeV
0-1	$20.07^{+0.42}_{-0.36}$
1-5	$17.28^{+0.27}_{-0.21}$
5-10	$14.88^{+0.24}_{-0.18}$
10-15	$13.19^{+0.21}_{-0.16}$
15-20	$11.88^{+0.19}_{-0.15}$
20-30	$10.30^{+0.19}_{-0.13}$
30-40	$8.62^{+0.16}_{-0.11}$
40-50	$7.24^{+0.13}_{-0.09}$
50-70	$5.58^{+0.10}_{-0.07}$
70-100	$3.52^{+0.07}_{-0.05}$
minimum bias	$7.12^{0.12}_{-0.09}$



[https://indico.cern.ch/event/1401276/contributions/5898065/attachments/2834477/4953080/Multiplicity_distributions_in_pp_collisions%20\(17\).pdf](https://indico.cern.ch/event/1401276/contributions/5898065/attachments/2834477/4953080/Multiplicity_distributions_in_pp_collisions%20(17).pdf)

Analysis details

Detector used : ALICE - Time Projection Chamber (TPC)

PID Technique : Unfolding of TPC NSigma signal

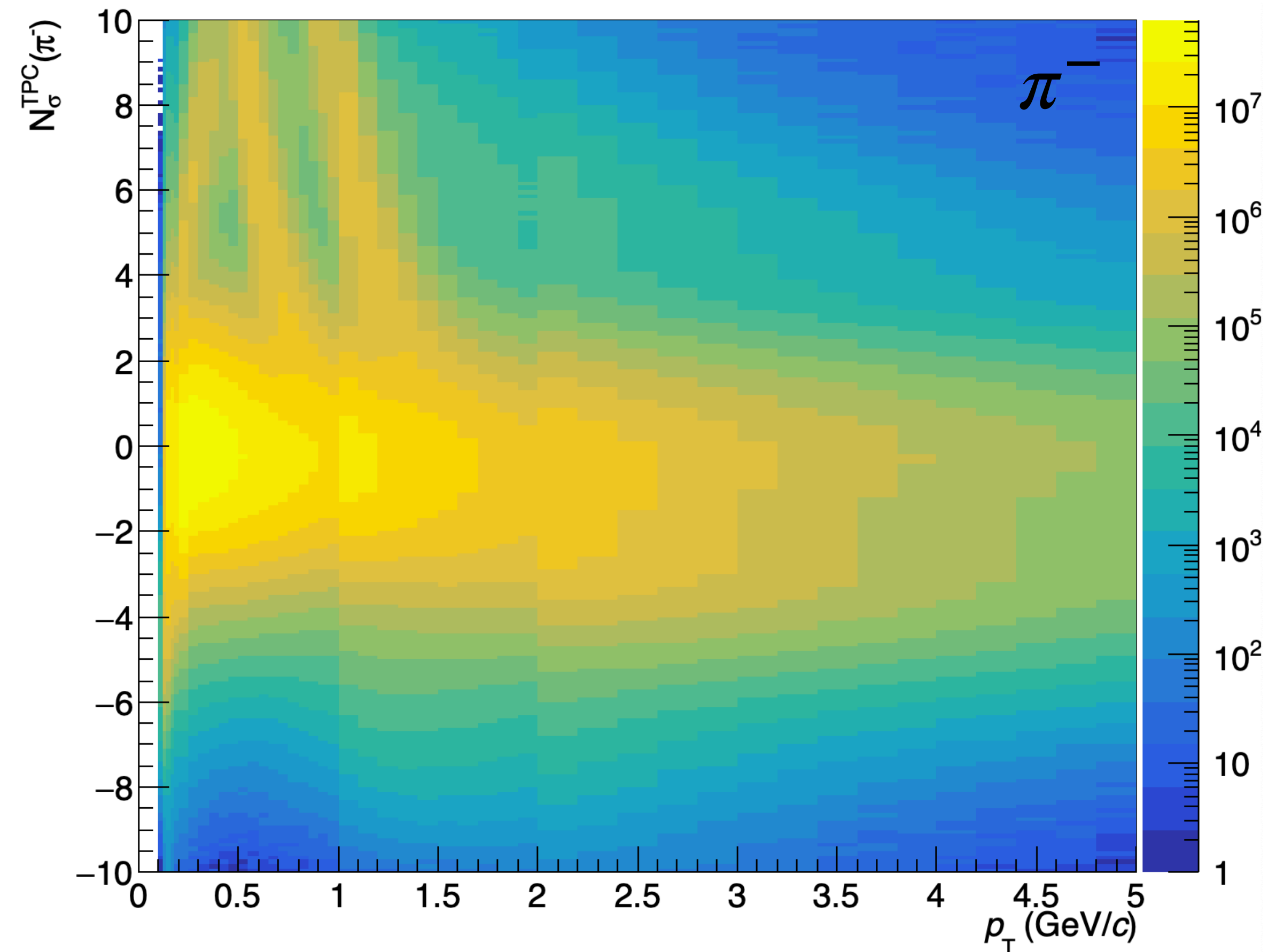
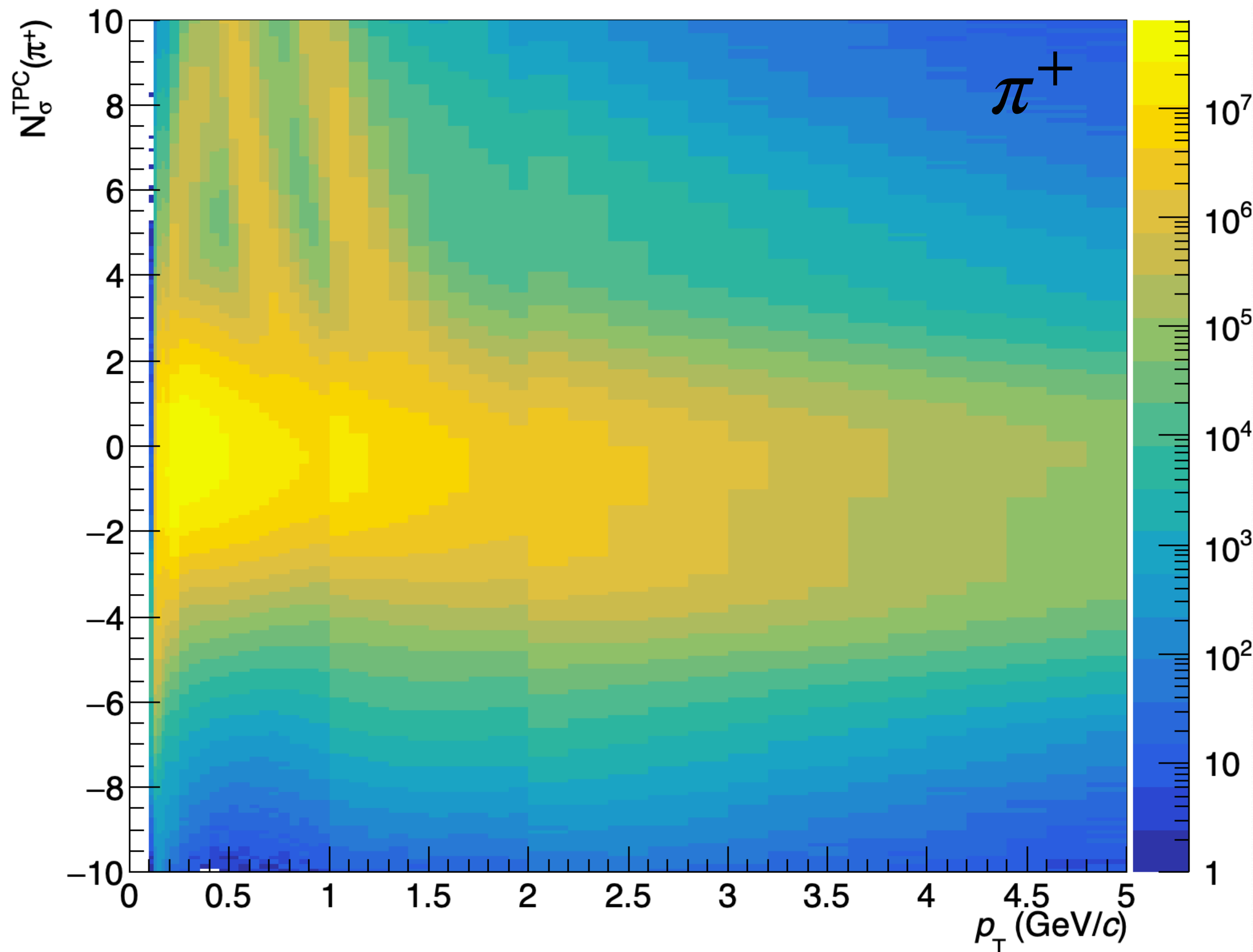
TPC PID p_T ranges:

- π^+, π^- : 0.2 - 0.6 (GeV/c)
- K^+, K^- : 0.3 - 0.6 (GeV/c)
- p, \bar{p} : 0.3 - 0.8 (GeV/c)

Results

NSigma Distribution of TPC signal

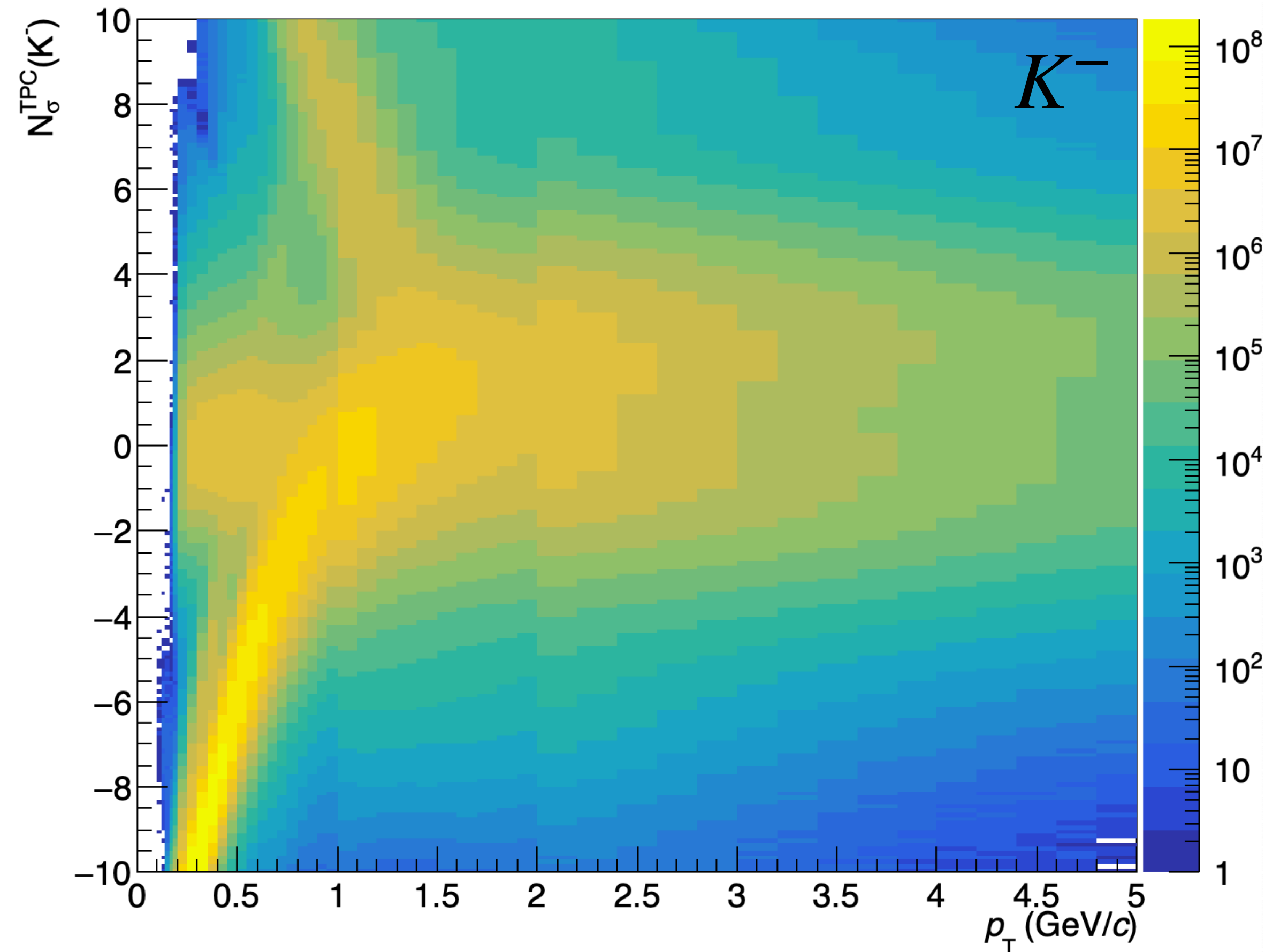
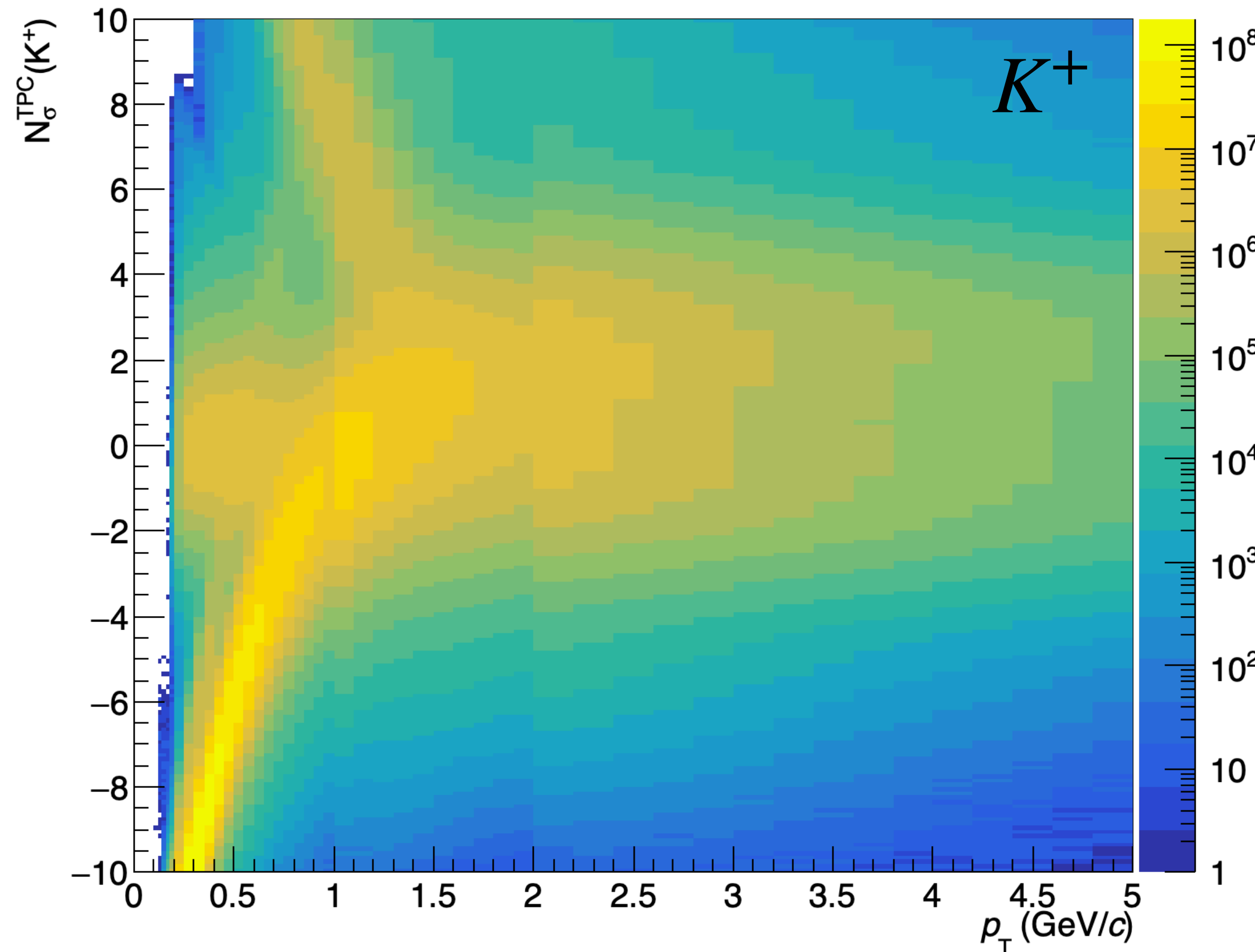
$$N_{\sigma}^{TPC} = \frac{dE/dx_{expected} - dE/dx_{measured}}{\sigma_{dE/dx_{measured}}}$$



Results

NSigma Distribution of TPC signal

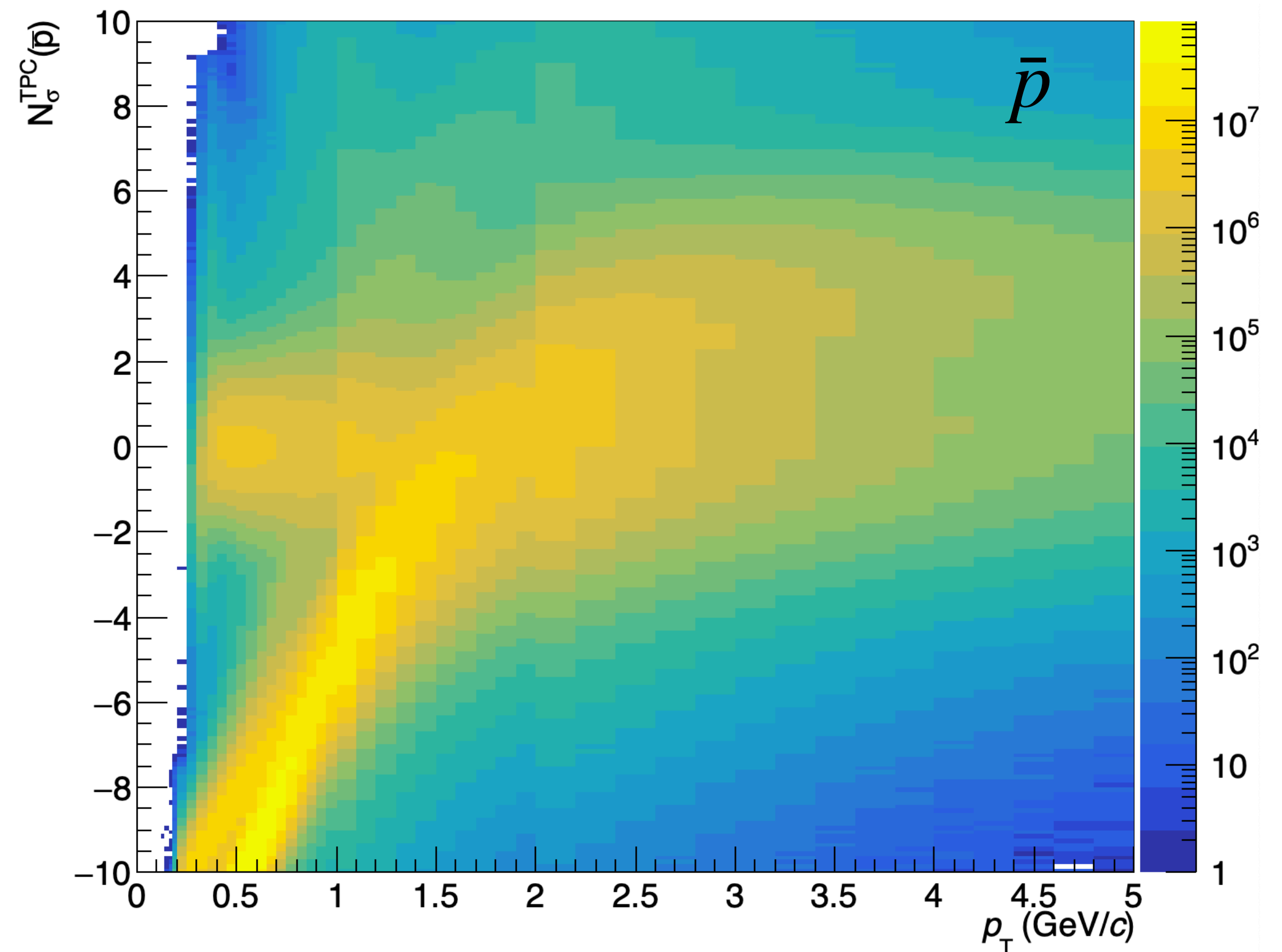
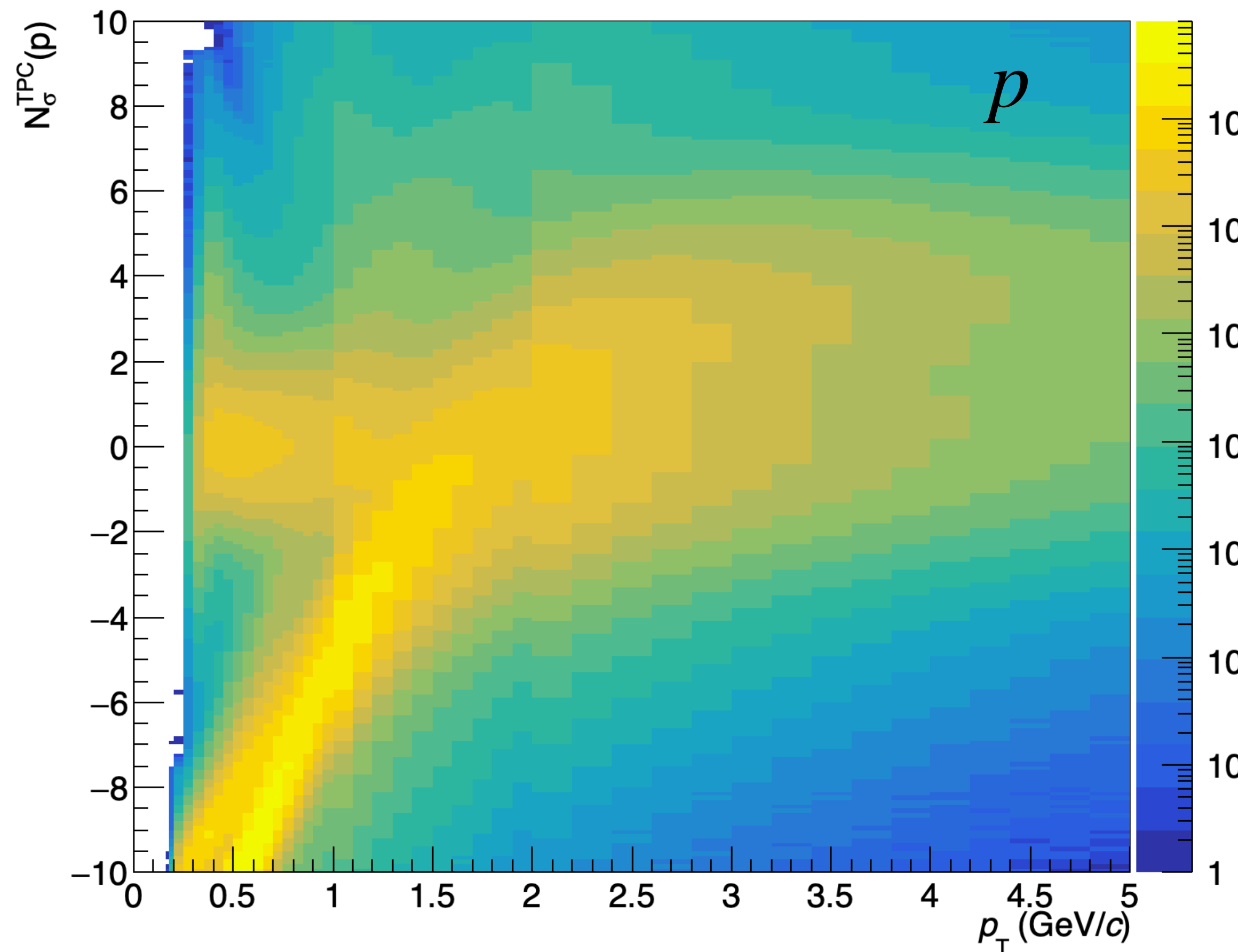
$$N_{\sigma}^{TPC} = \frac{dE/dx_{expected} - dE/dx_{measured}}{\sigma_{dE/dx_{measured}}}$$



Results

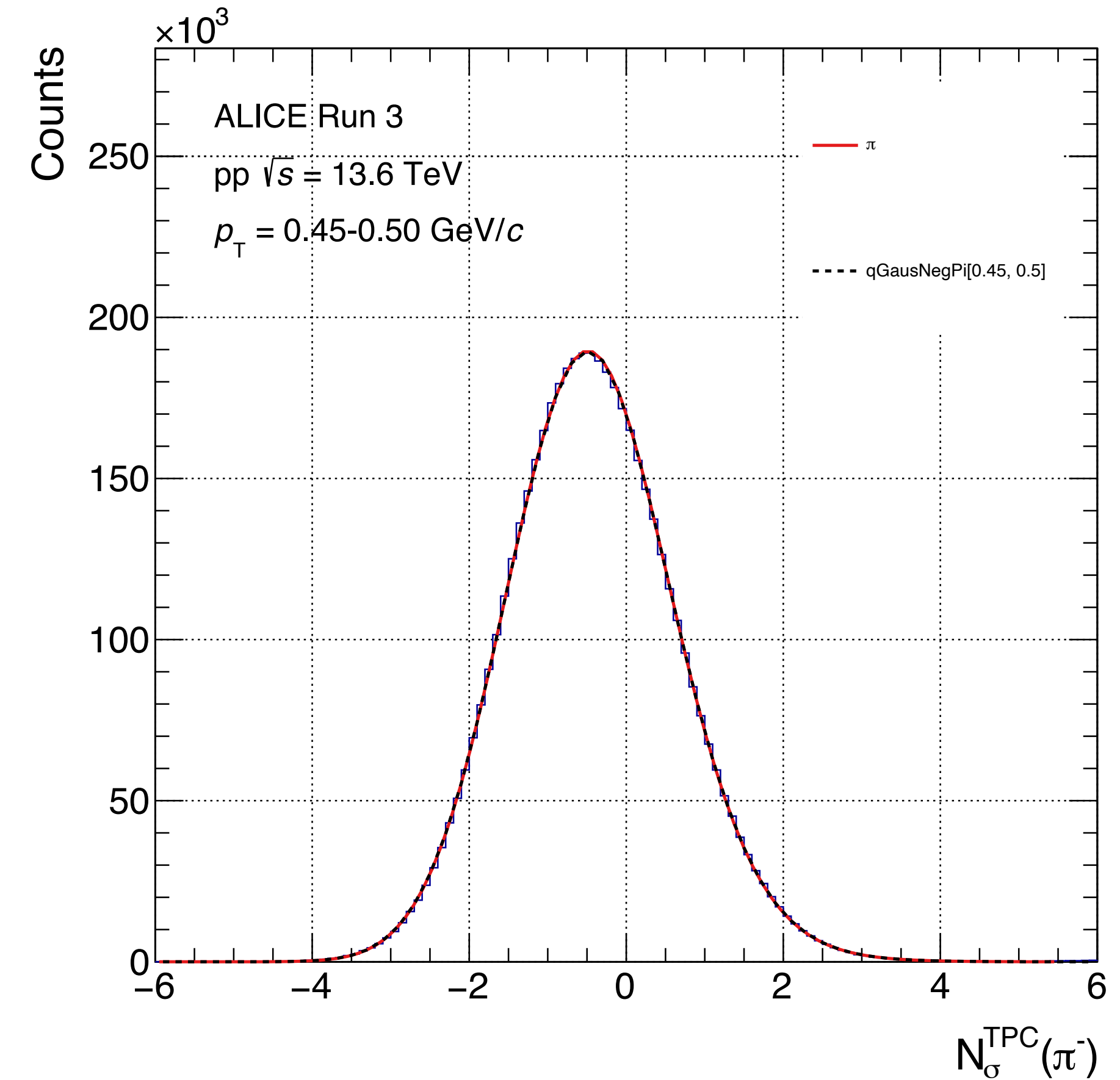
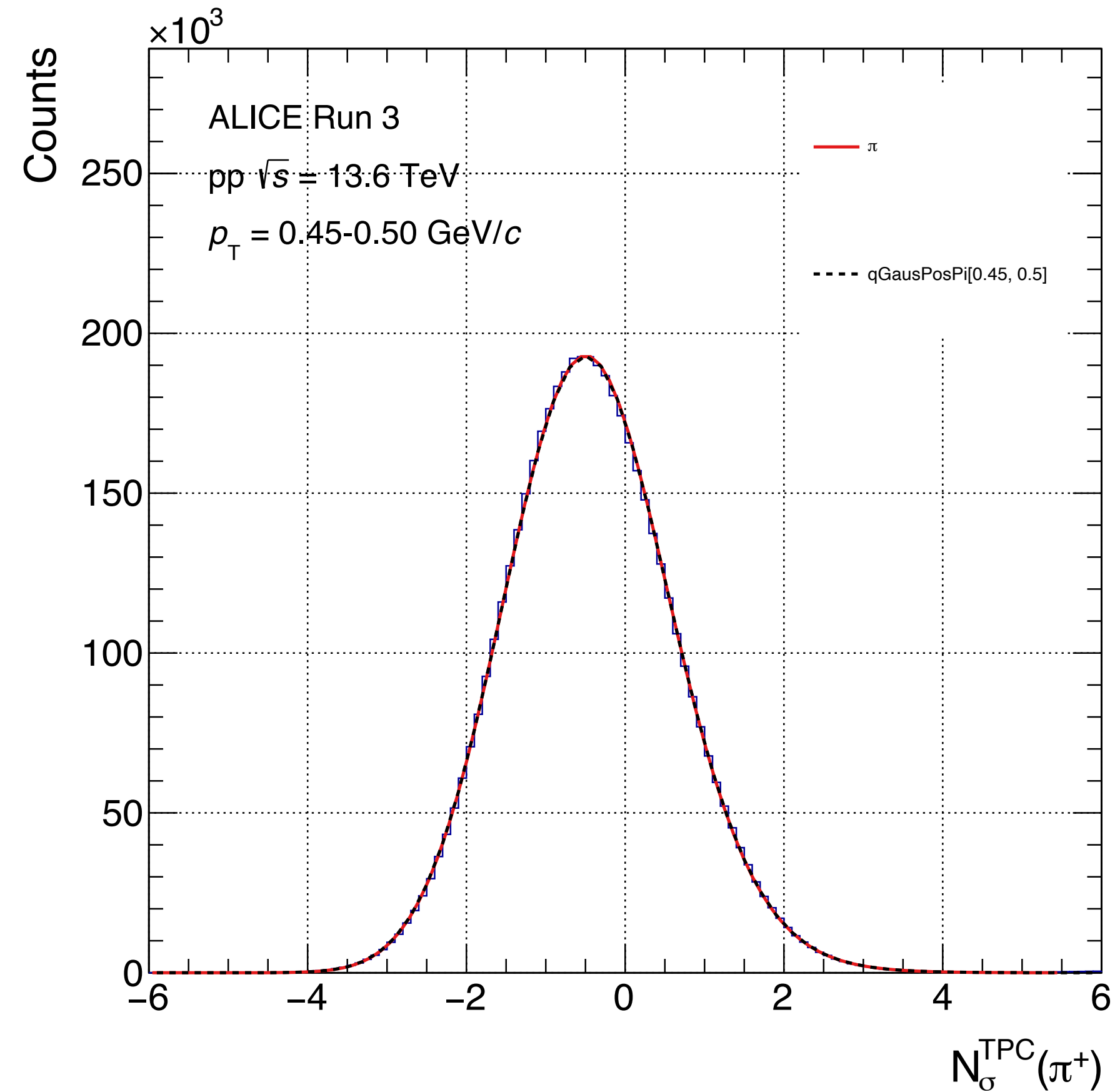
NSigma Distribution of TPC signal

$$N_{\sigma}^{TPC} = \frac{dE/dx_{expected} - dE/dx_{measured}}{\sigma_{dE/dx_{measured}}}$$



Results

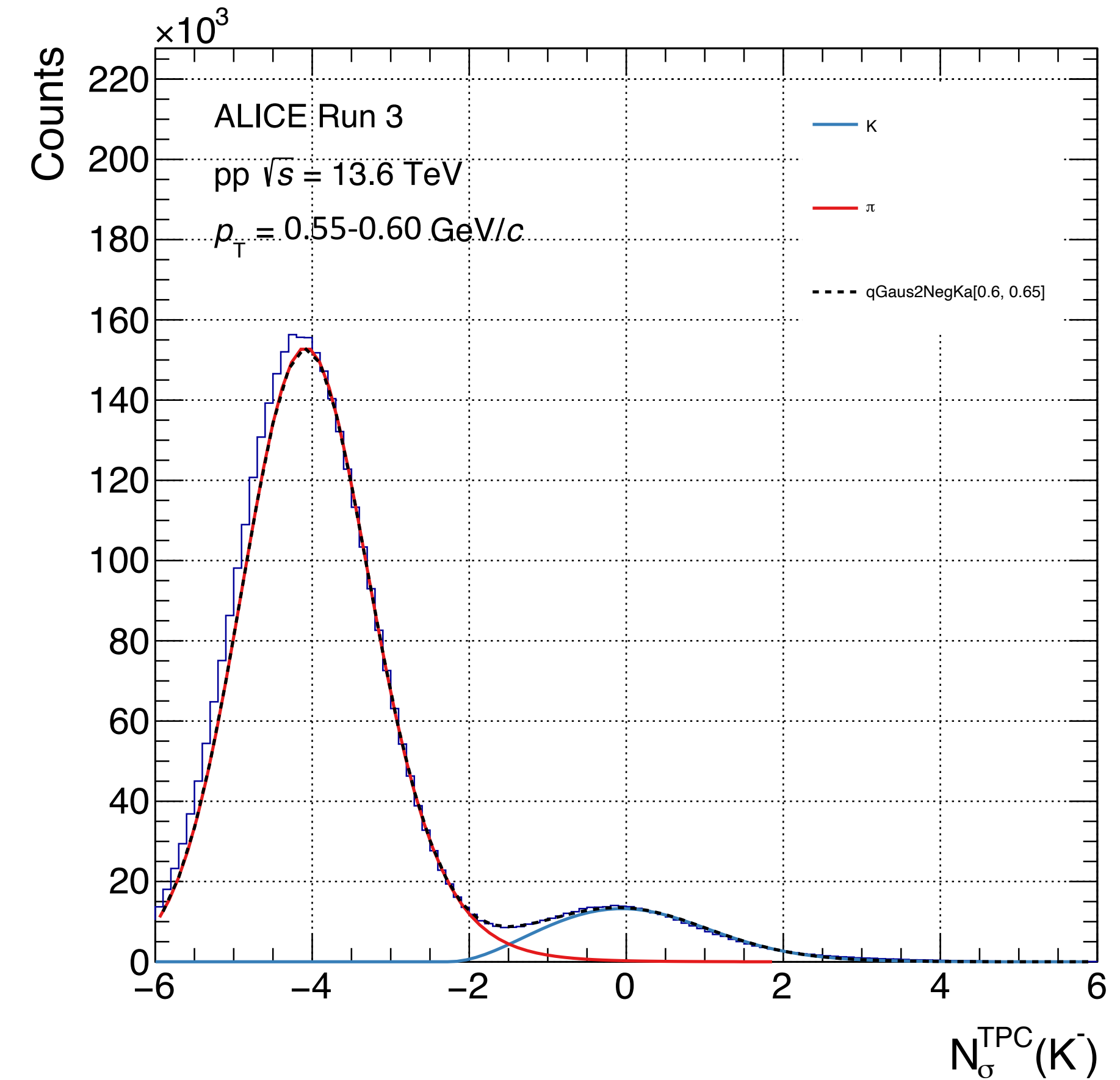
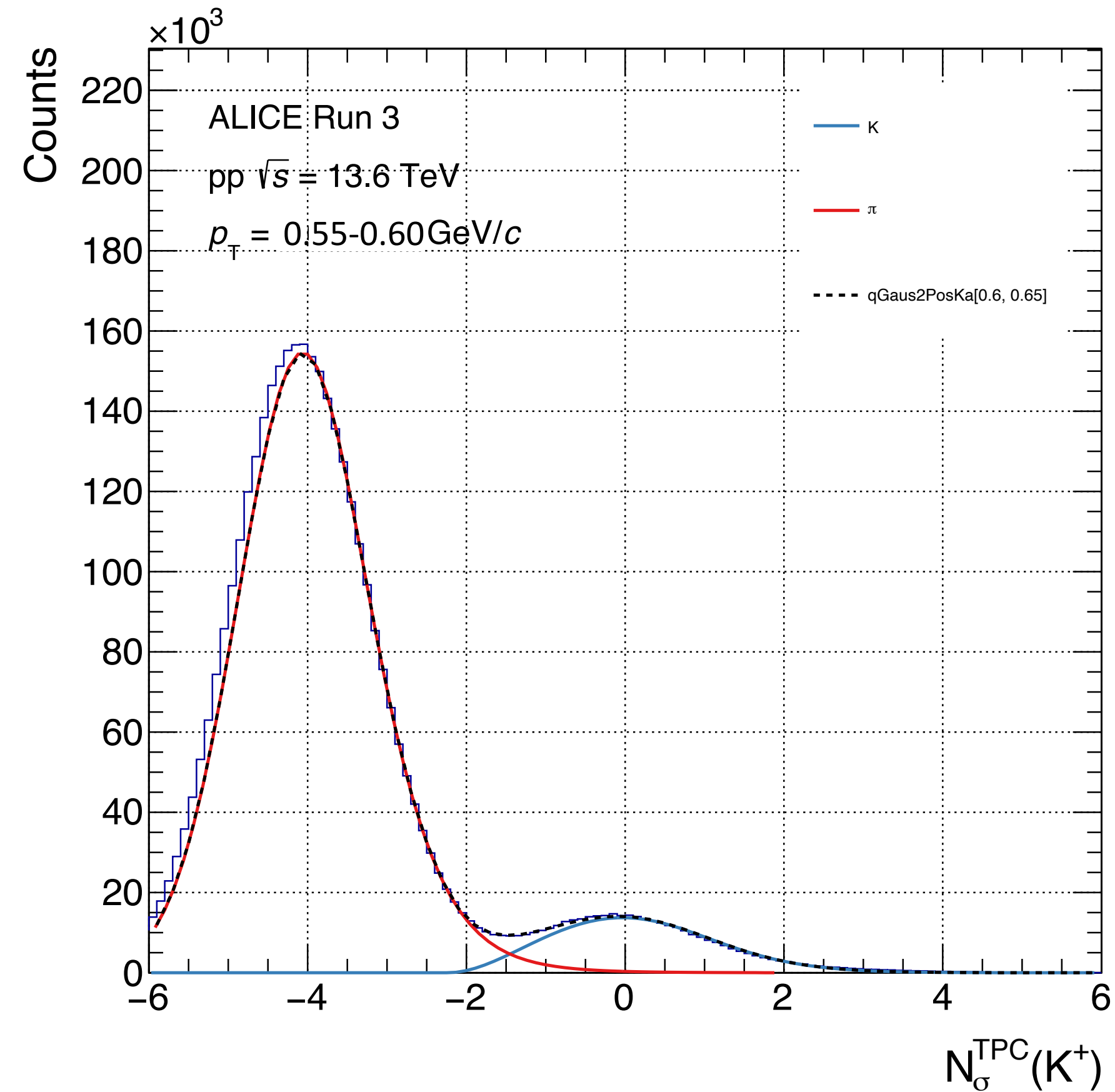
Fitting of TPC NSigma signal for π^+ , π^-



- The unfolded NSigma distribution is fitted with Gaussian+Exponential tail.
- Raw yield is extracted from the fitted template for each p_T bins.

Results

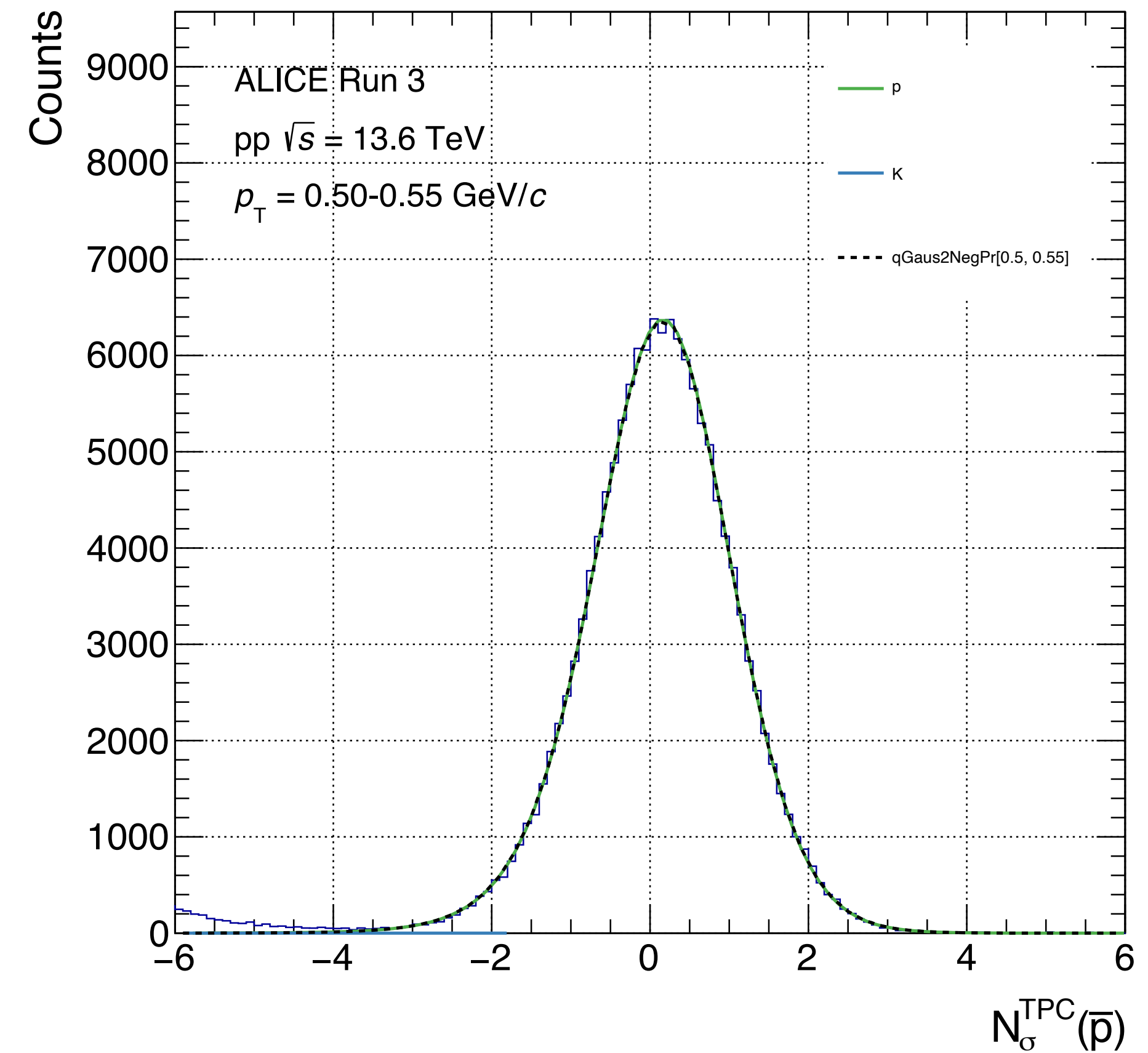
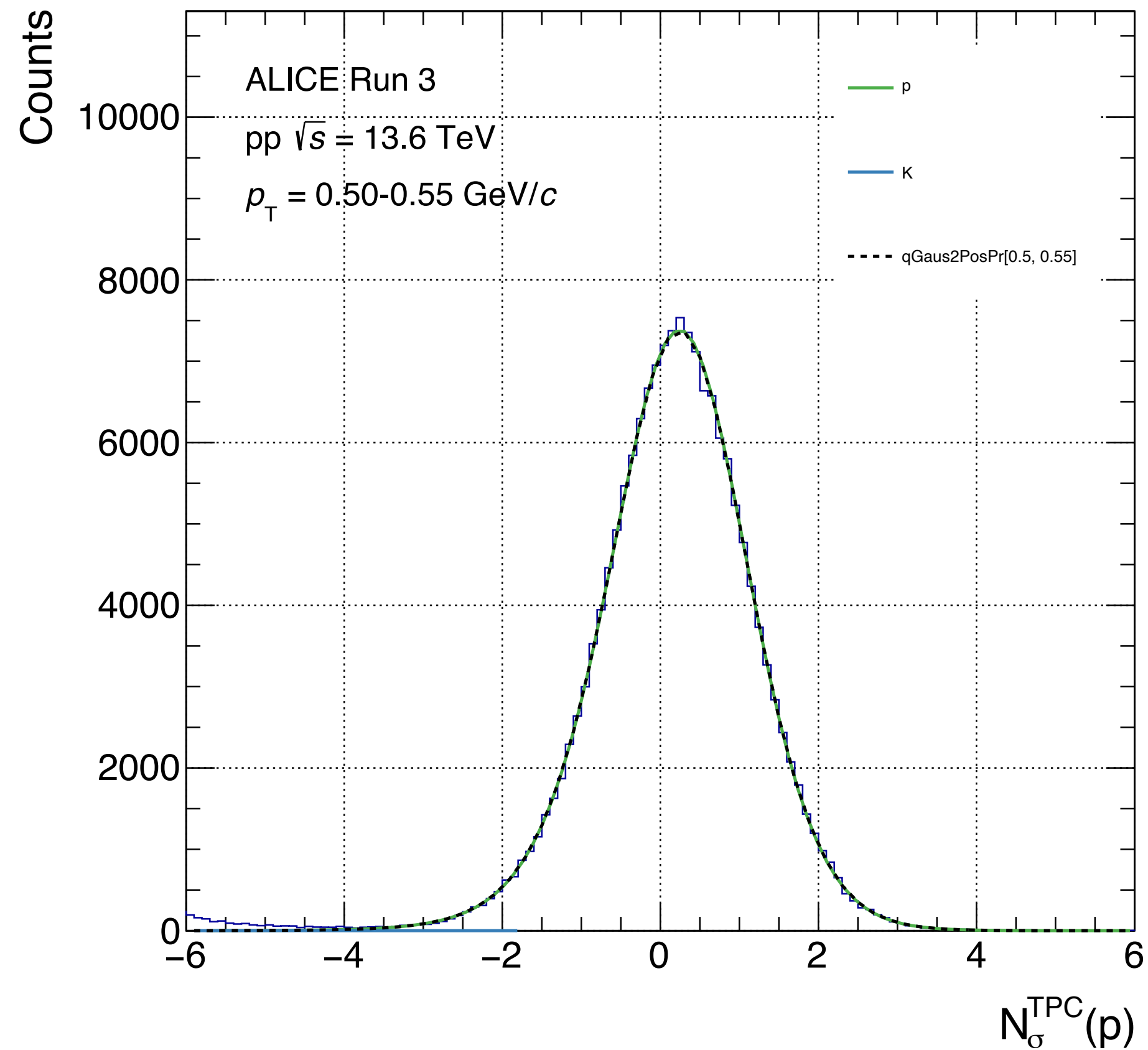
Fitting of TPC NSigma signal for K^+ , K^-



- The unfolded NSigma distribution is fitted with two-component Gaussian+Exponential tail.
- Raw yield is extracted from the fitted template for each p_T bins.

Results

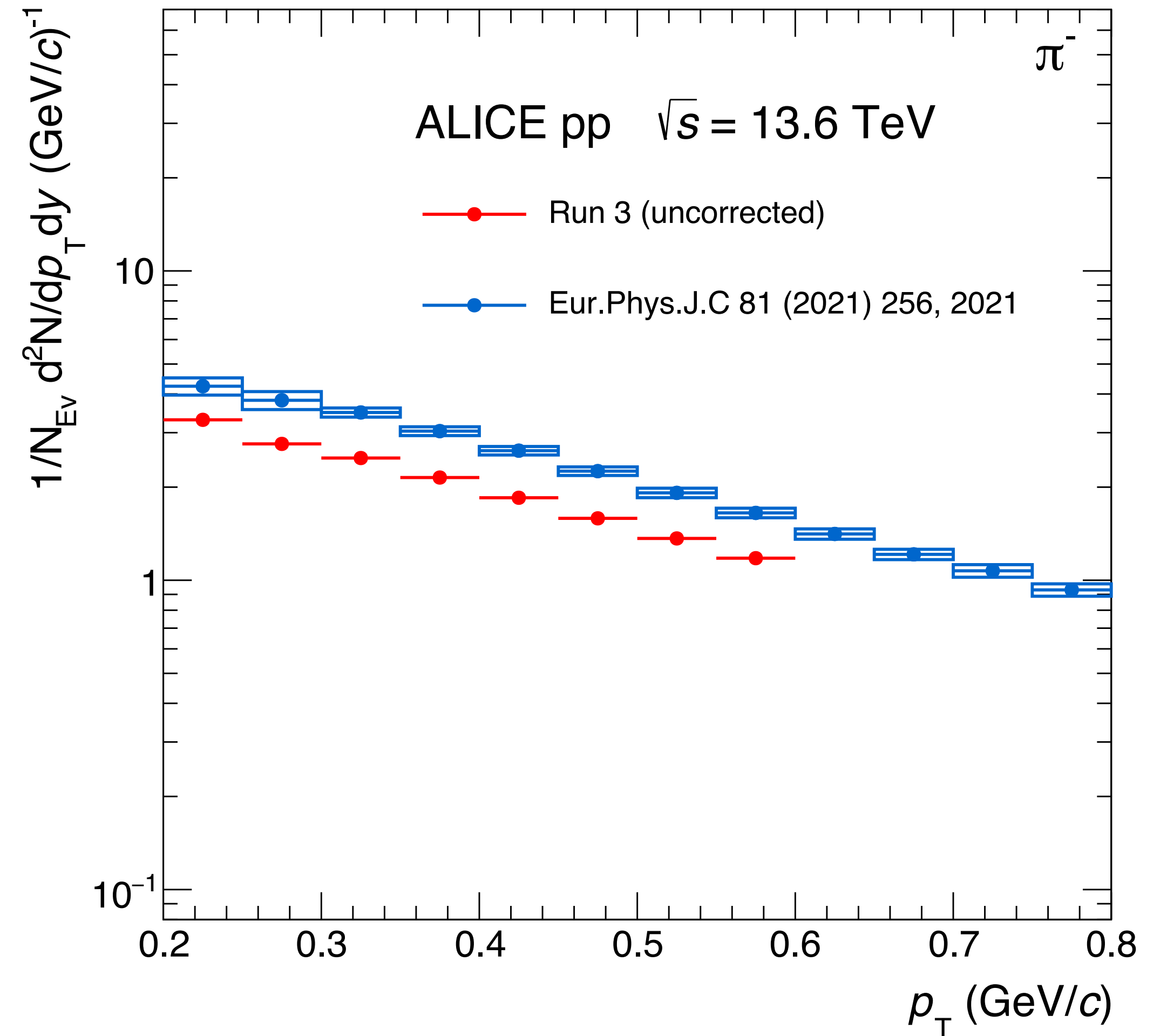
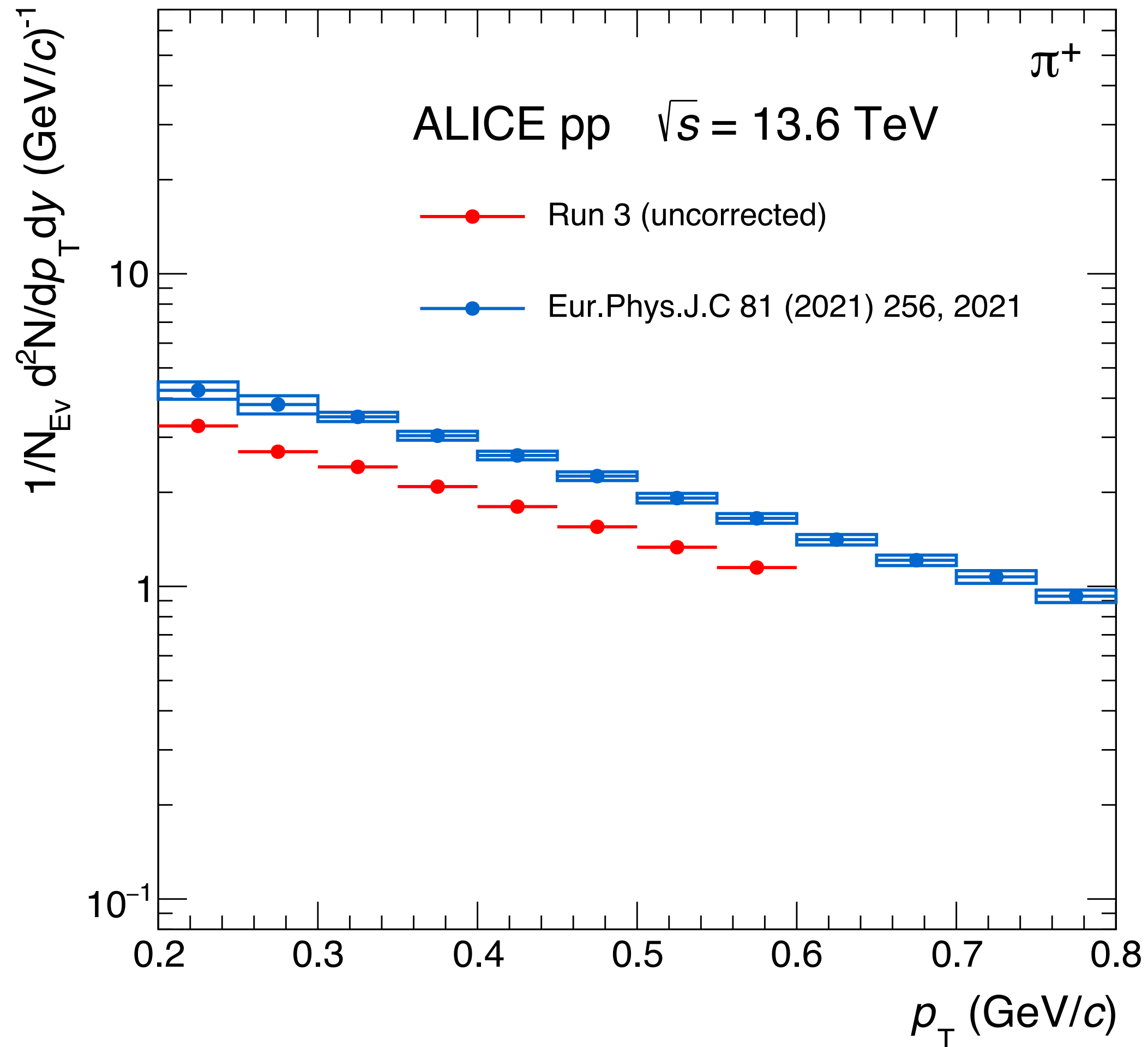
Fitting of TPC NSigma signal for p, \bar{p}



- The unfolded NSigma distribution is fitted with two-component Gaussian+Exponential tail.
- Raw yield is extracted from the fitted template for each p_T bins.

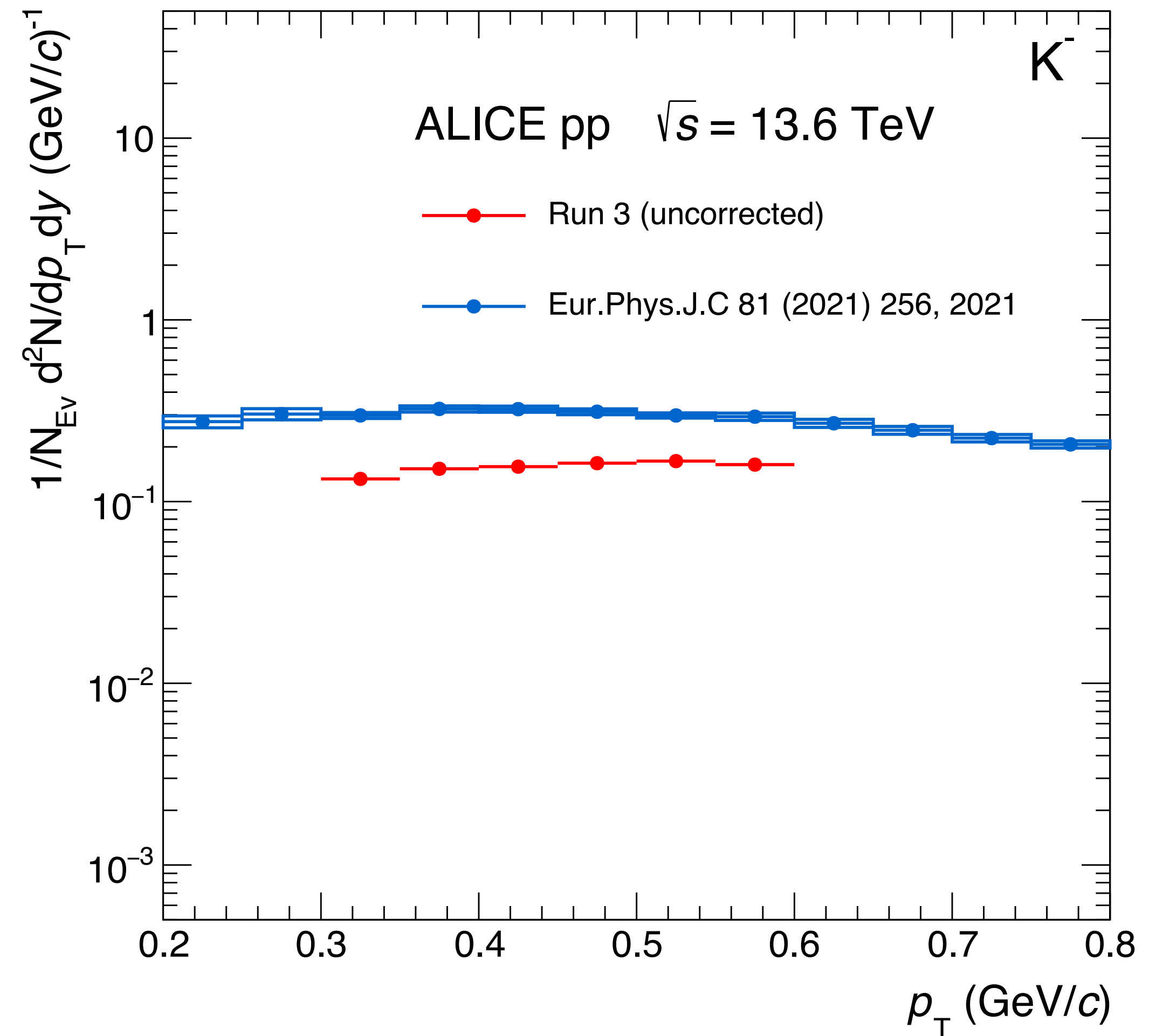
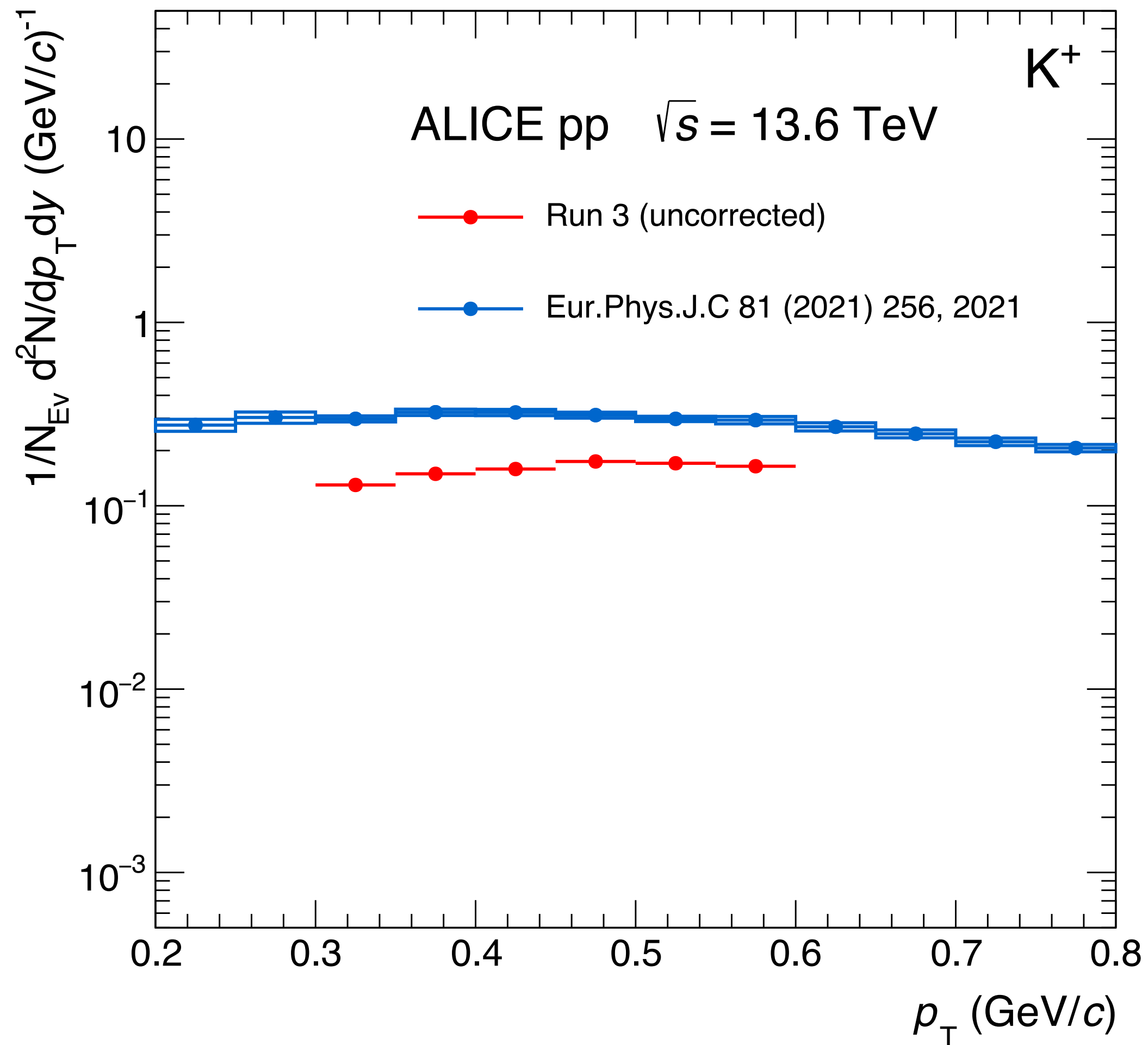
Results

Raw p_T spectra for π^+ , π^-



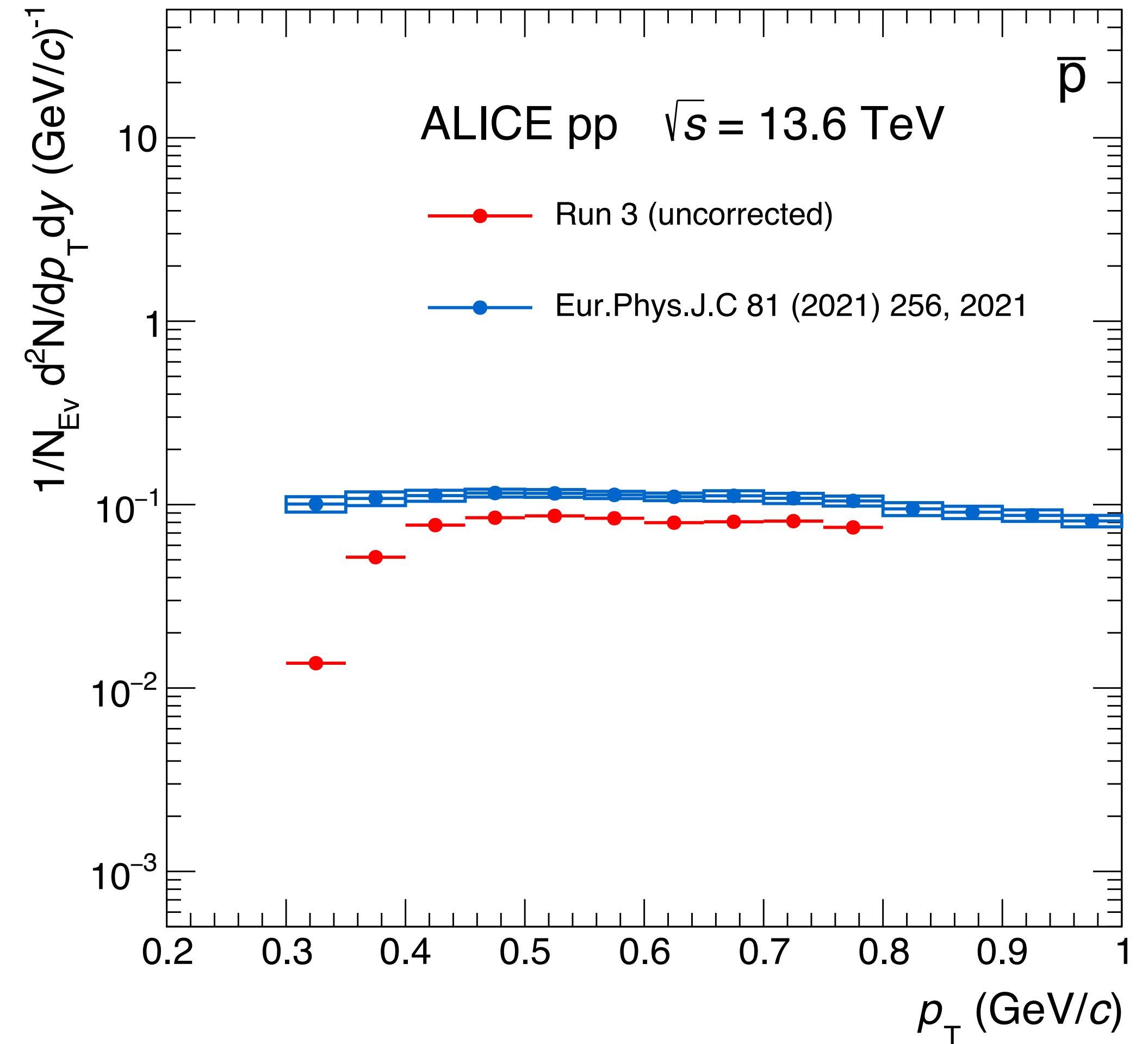
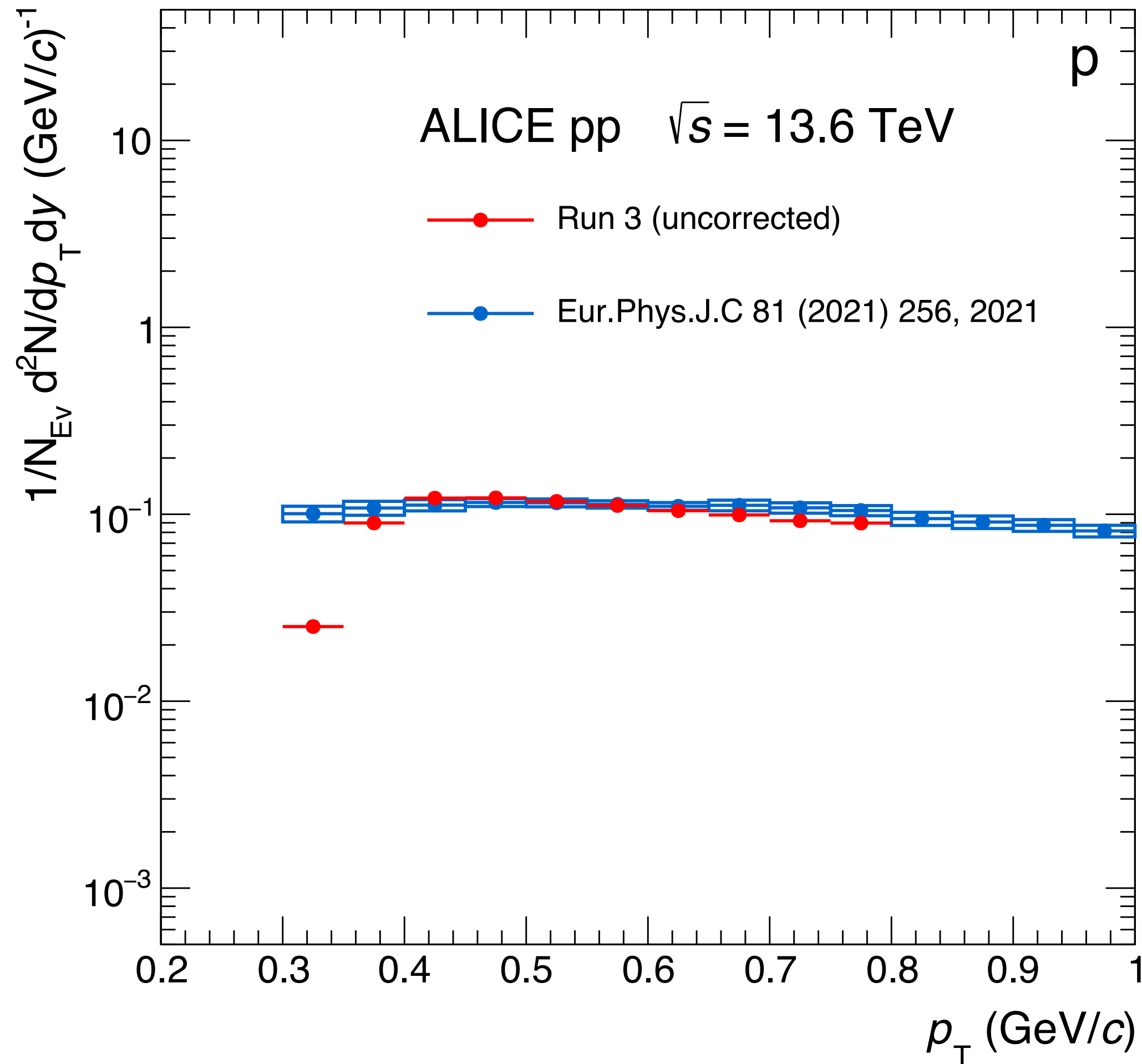
Results

Raw p_T spectra for K^+ , K^-



Results

Raw p_T spectra for p, \bar{p}



Tracking efficiency

- Accounts for the inability of the TPC detector to reconstruct all of the primary charged particles.
- Defined as the ratio of the number of reconstructed tracks and generated tracks using Monte Carlo truth information.

$$\epsilon_{tracking} = \frac{\text{reconstructed tracks (quality cuts + acceptance cuts)}}{\text{generated tracks (acceptance cuts)}}$$

Reconstructed Tracks

- Track quality cuts for TPC
- Only Primary charged particles are selected
- Pseudorapidity cut : $|\eta| \leq 0.8$
- Rapidity cut : $|y| < 0.3$
- PID based on MC truth with PDG code

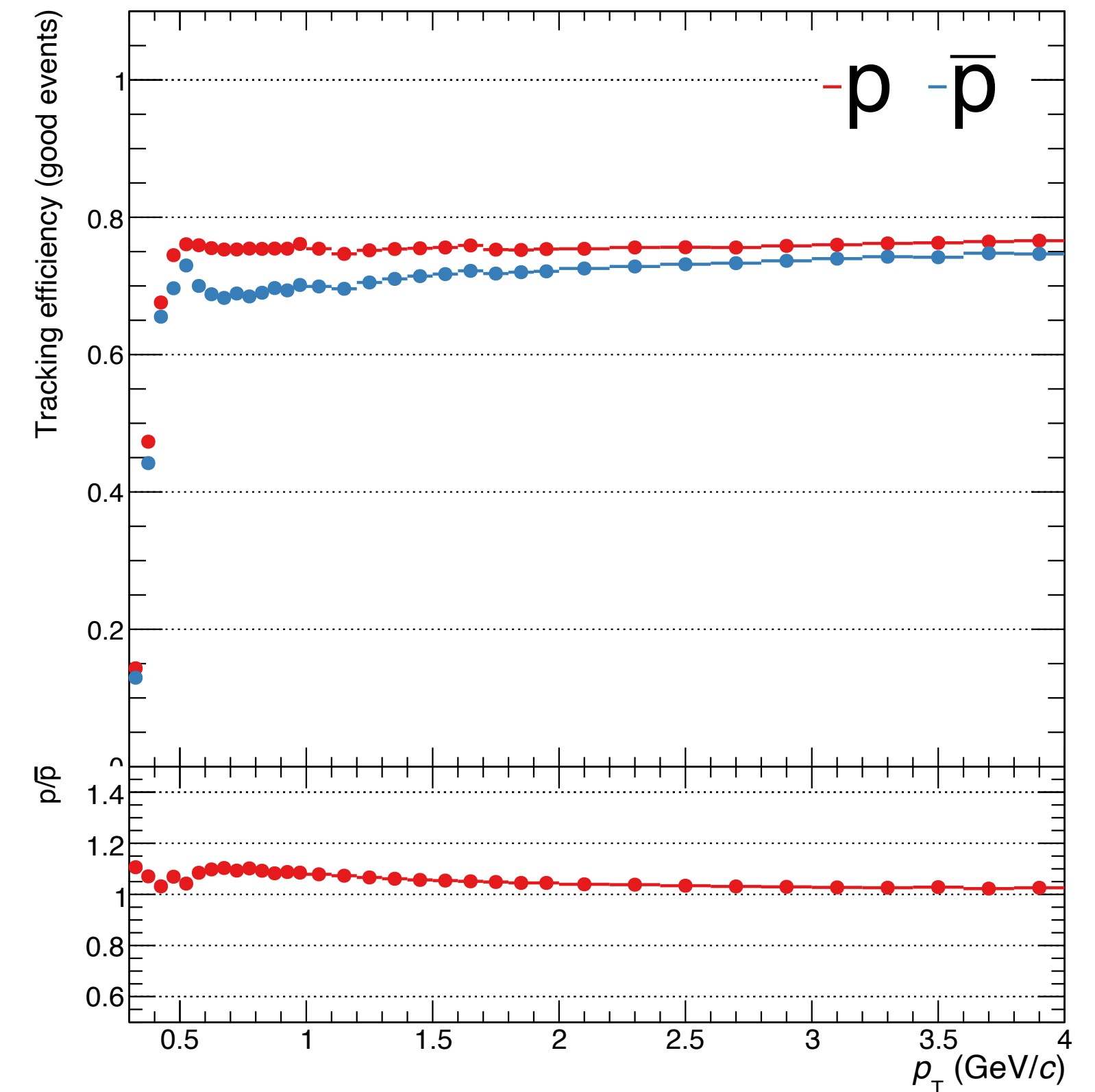
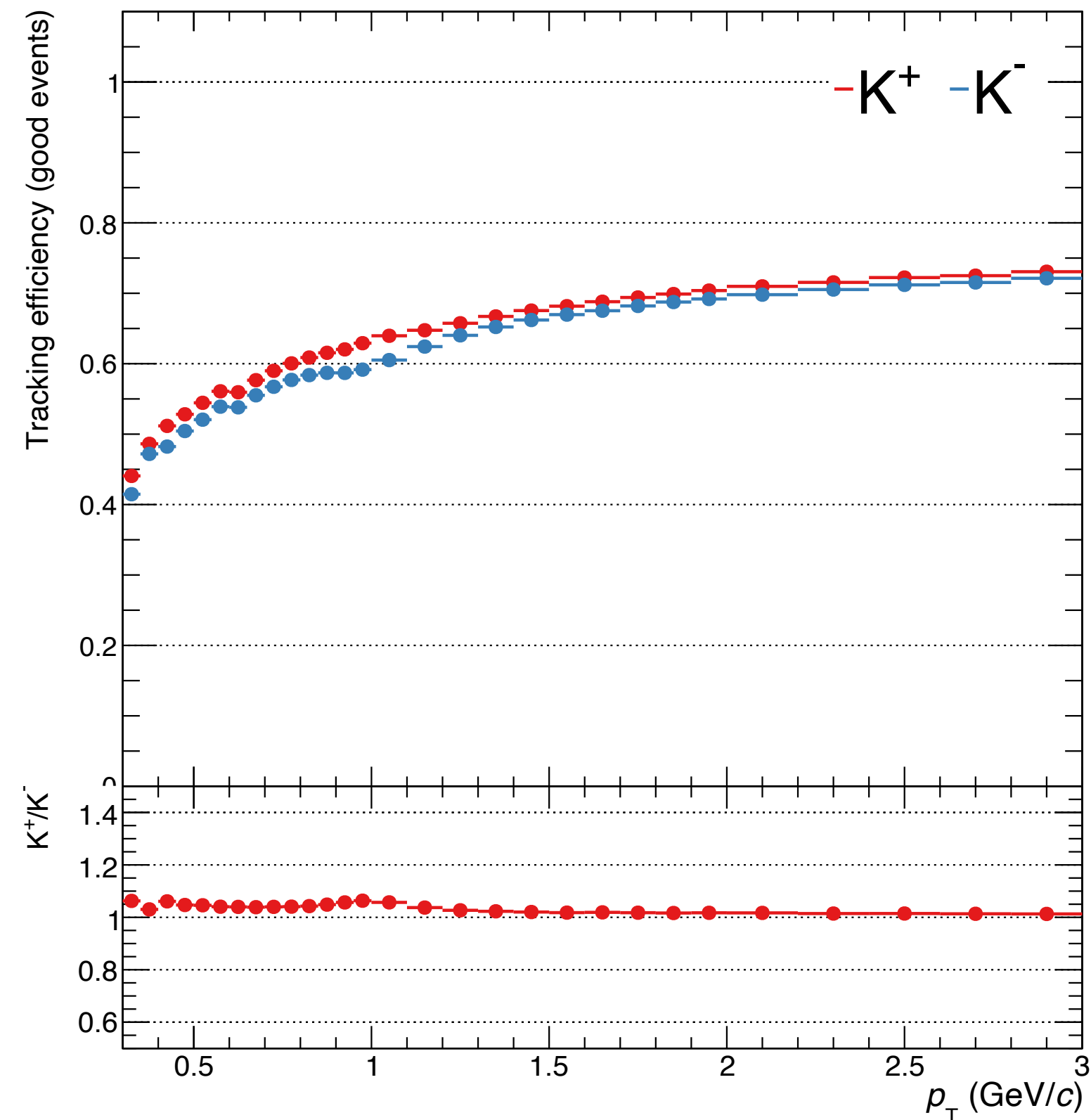
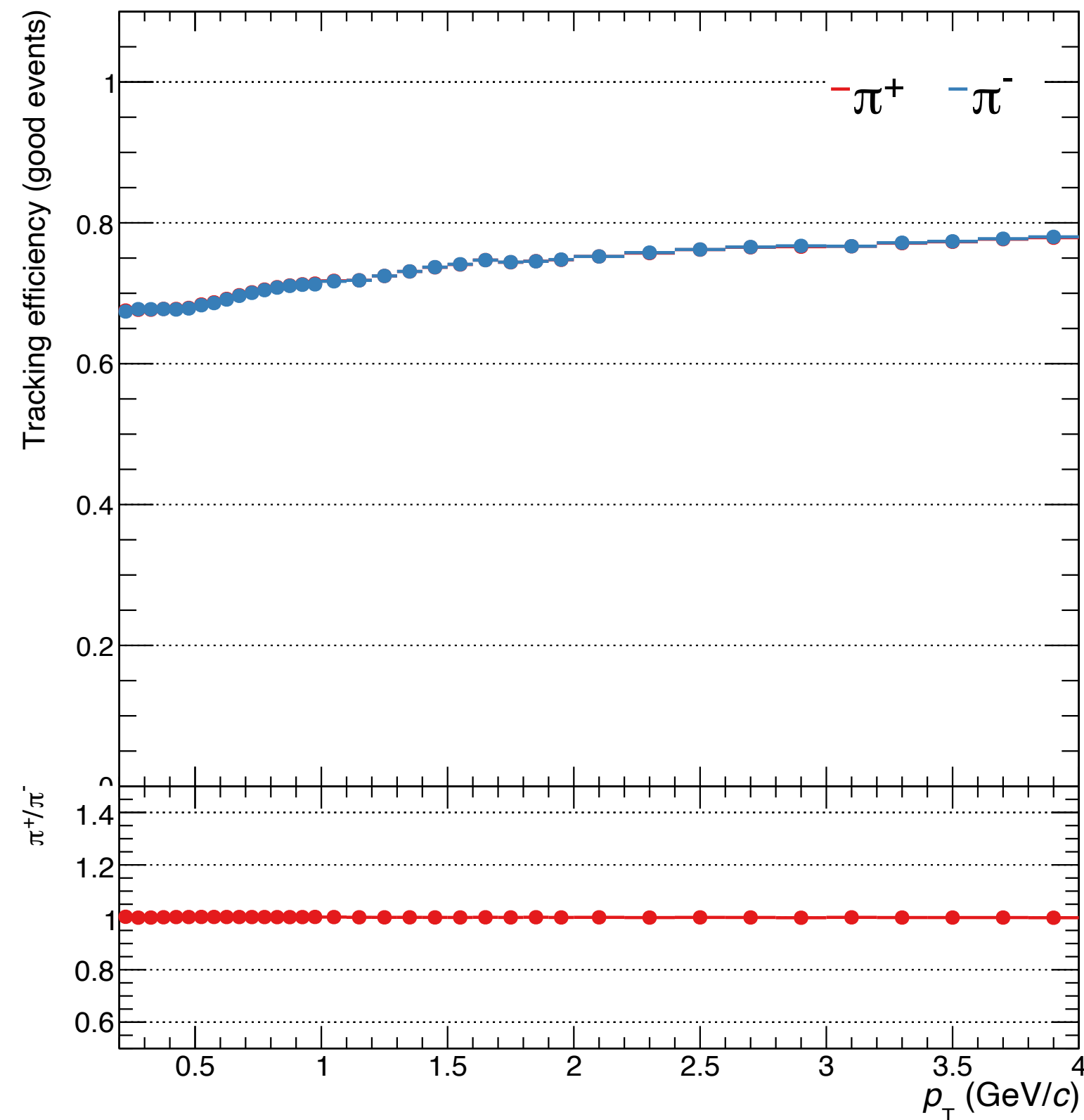
Generated Tracks

- Only Primary charged particles are selected
- Pseudorapidity cut : $|\eta| \leq 0.8$
- Rapidity cut : $|y| < 0.3$
- PID based on MC truth with PDG code

Results

Tracking efficiency

$$\epsilon_{tracking} = \frac{\text{reconstructed tracks (quality cuts + acceptance cuts)}}{\text{generated tracks (acceptance cuts)}}$$



Results

Estimation of primary fractions

Raw spectra = primary particles + secondary (weak decays + material knock out) particles

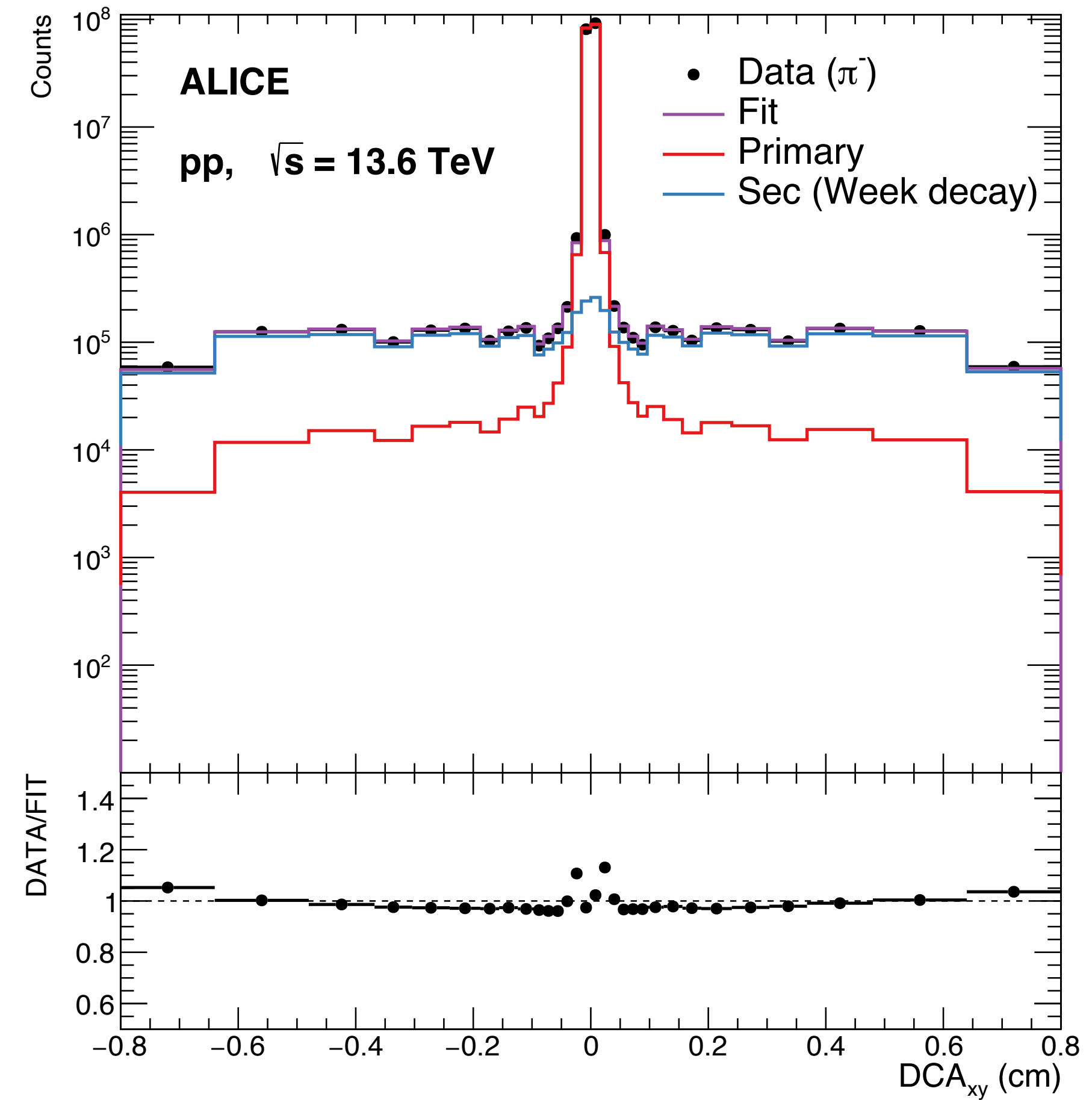
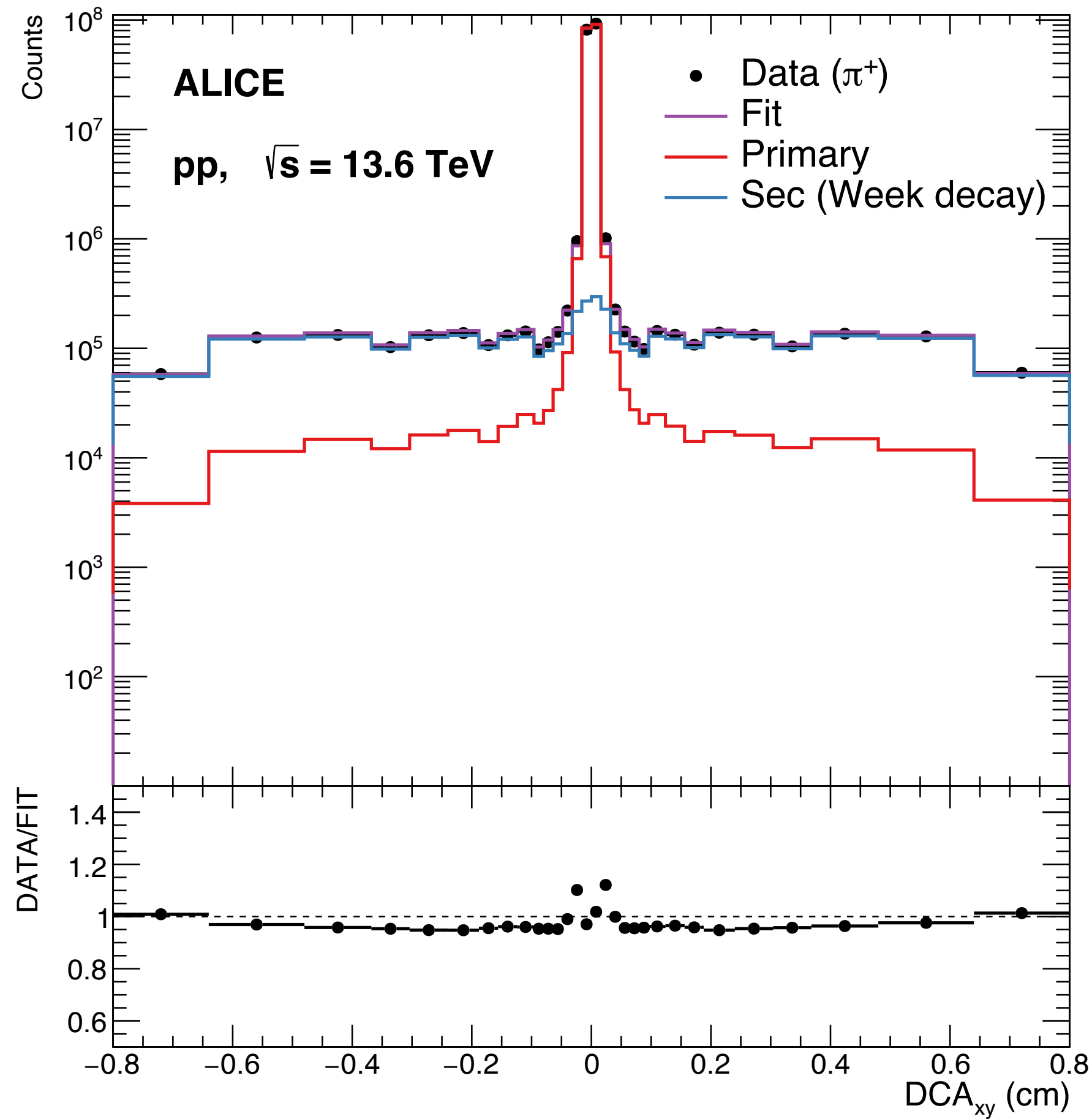
- For this, a selection based on the distance of closest approach of the track to the primary vertex in the x-y plane (DCA_{xy}) as a function of p_T is applied,

$$DCA_{xy} < 0.0105 + \frac{0.305}{p_T^{1.1}}$$

- Leftover contamination of secondary weak decays and material knock-out particles, that were not removed by the p_T dependent DCA_{xy} cut, has been taken into account by estimating the fraction of primary particles using the DCA_{xy} distribution of data and model based on MC truth information.
- The estimation of primary fractions is not necessary for Kaons.

Results

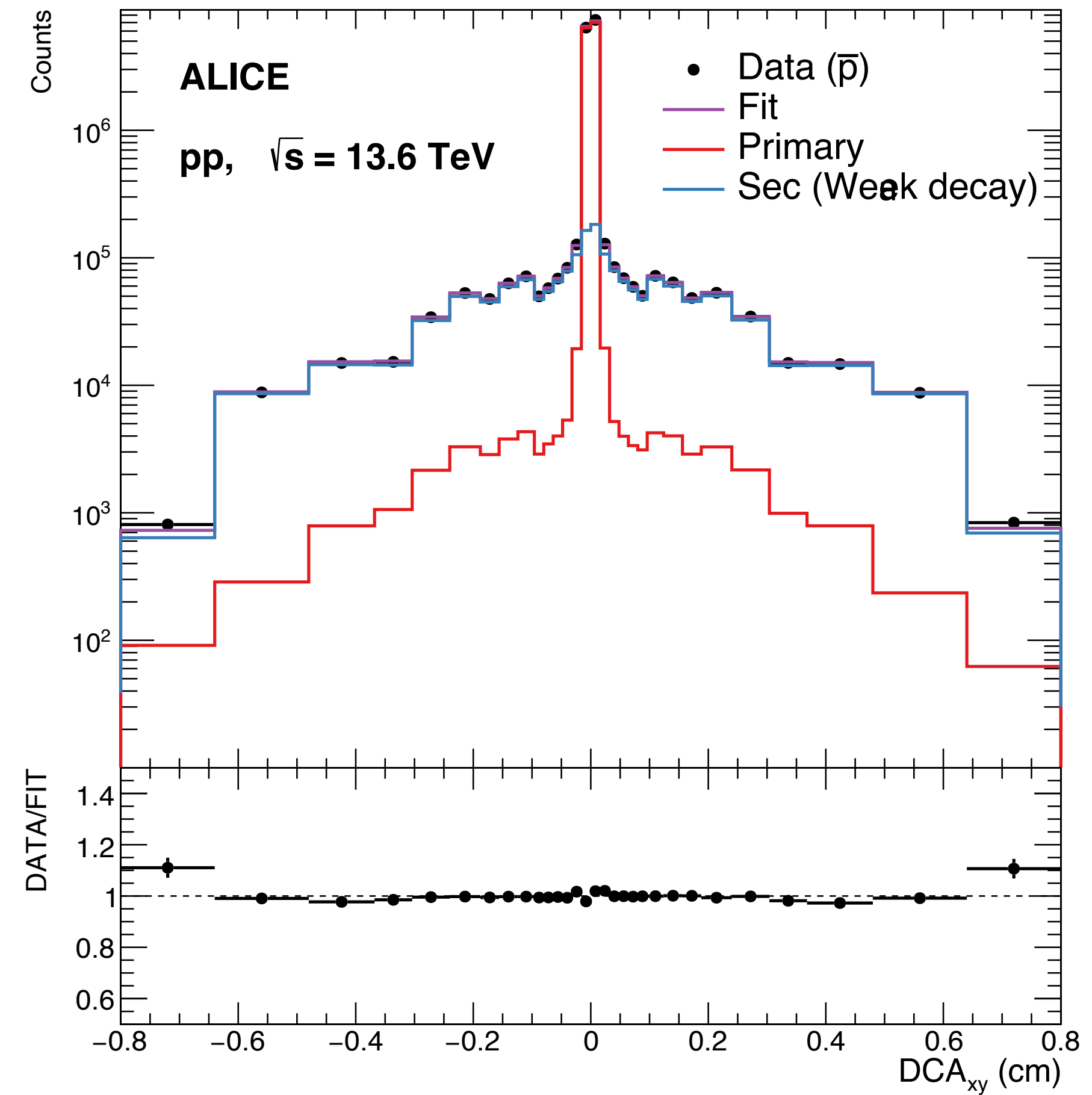
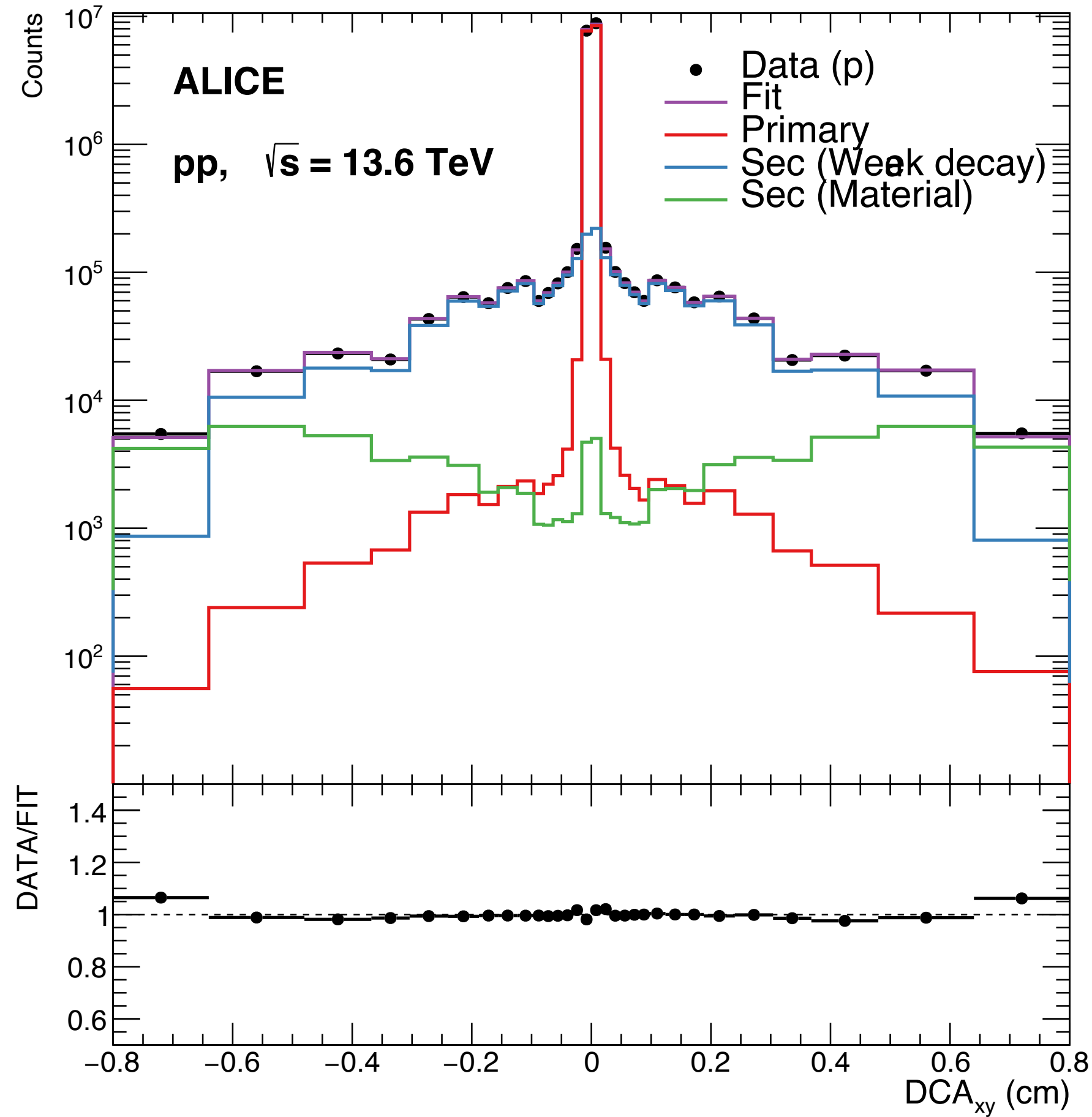
Estimation of Primary Fractions for π^+ , π^-



- Primary fraction is estimated using TFractionFitter (TFF)

Results

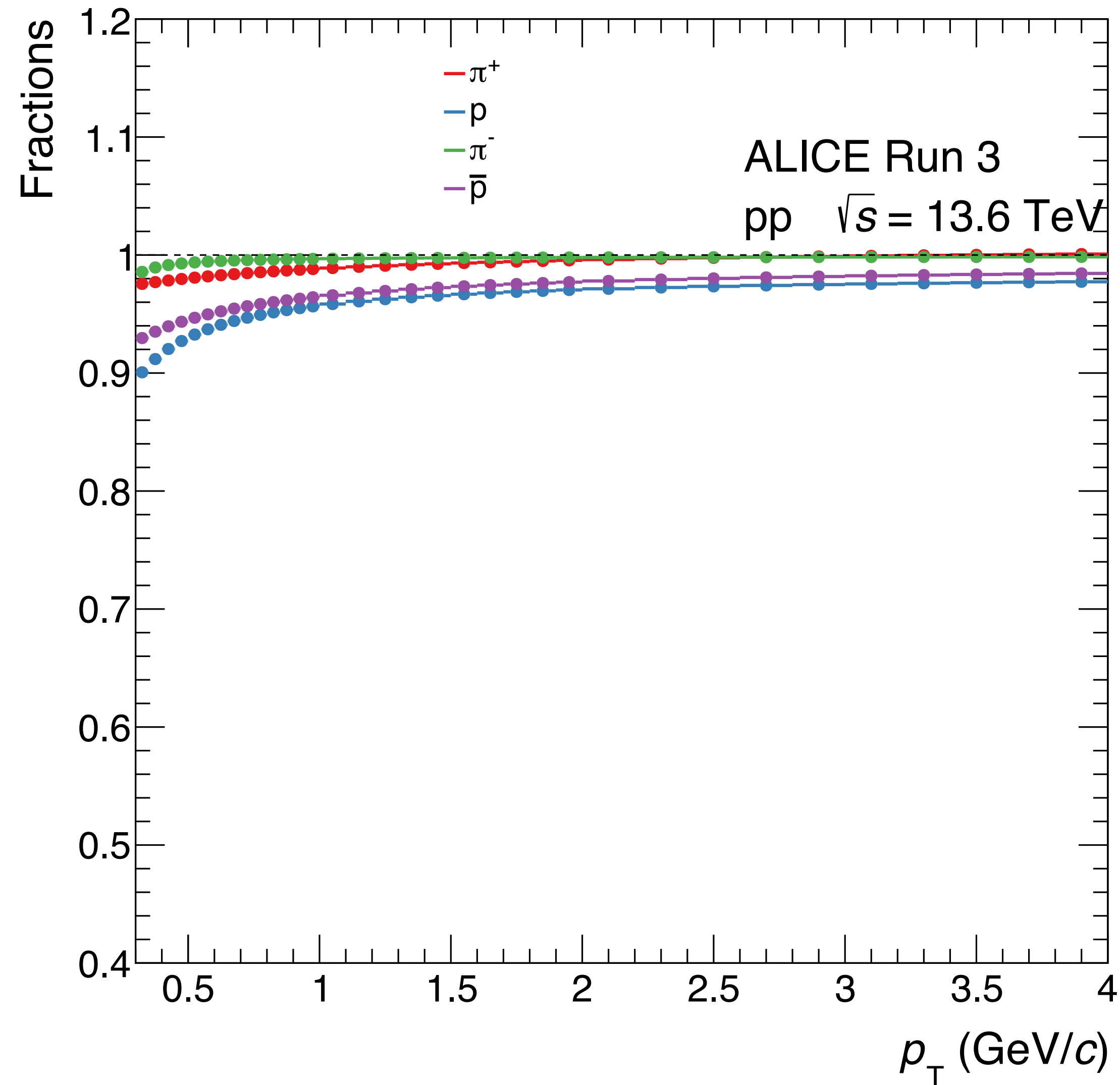
Estimation of Primary Fractions for p, \bar{p}



- Primary fraction is estimated using TFractionFitter (TFF)
- Contribution of secondary particles from material knock-out is prominent only for Protons

Results

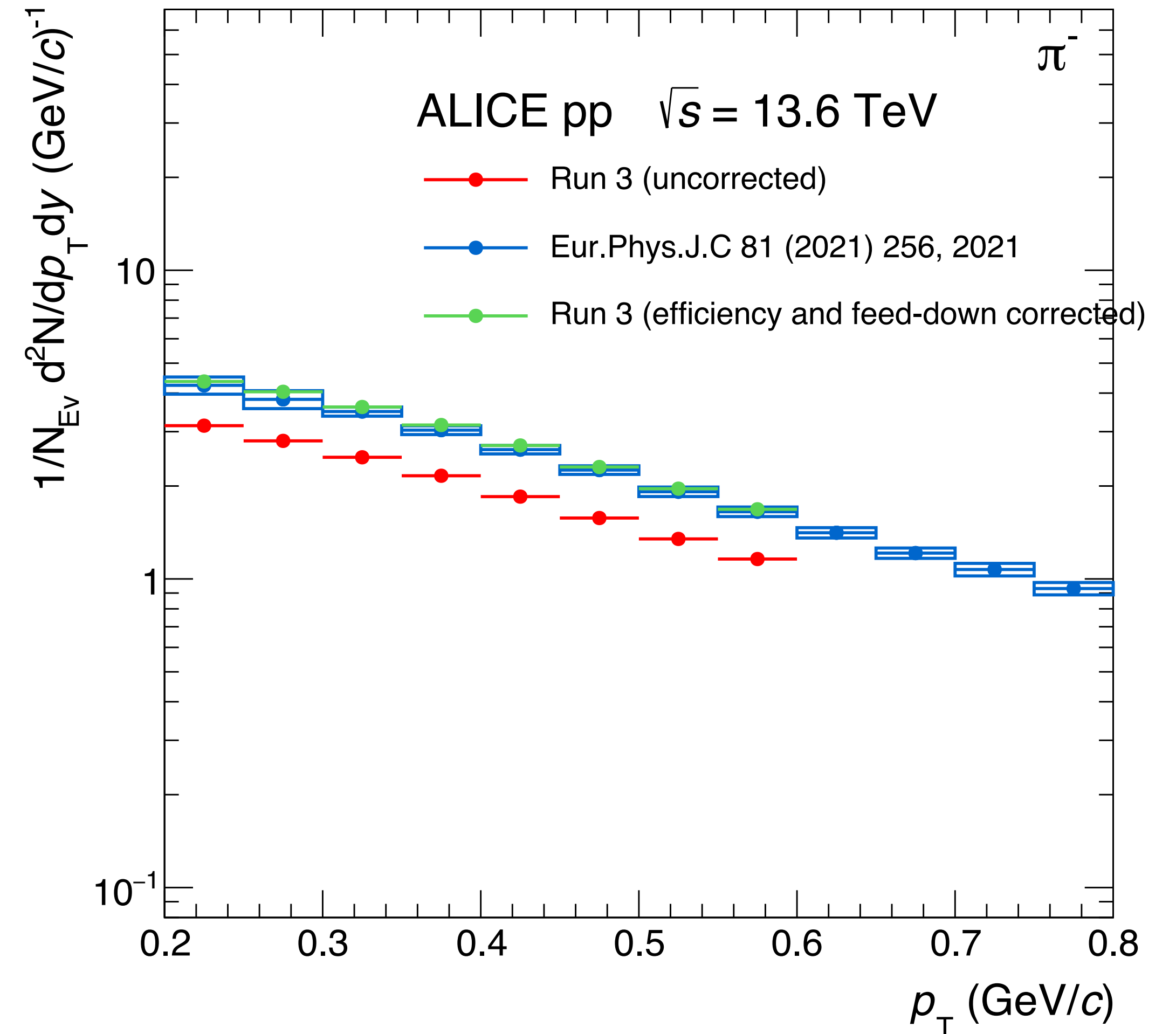
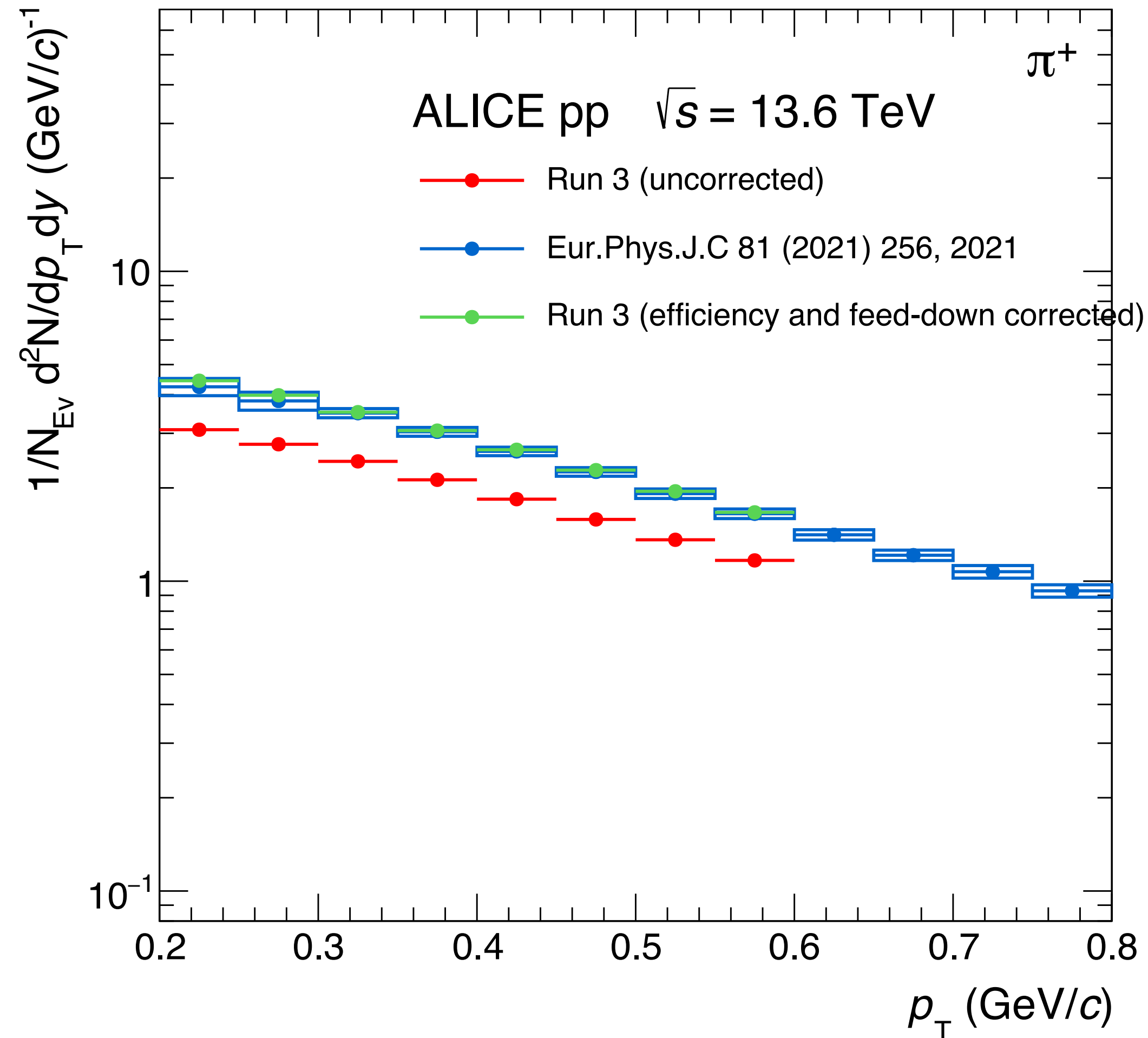
Primary fractions



Results

Corrected p_T spectra for π^+ , π^-

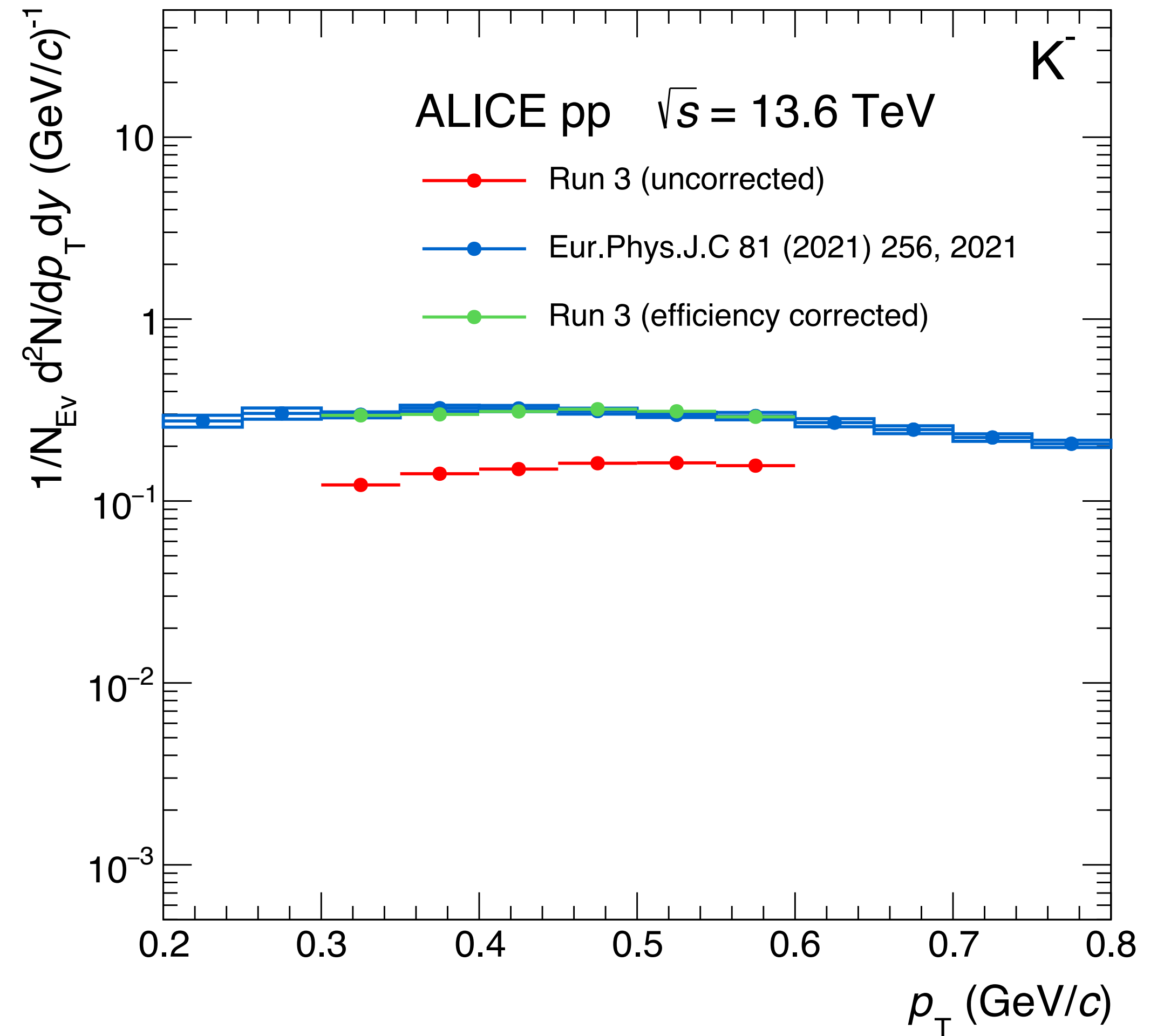
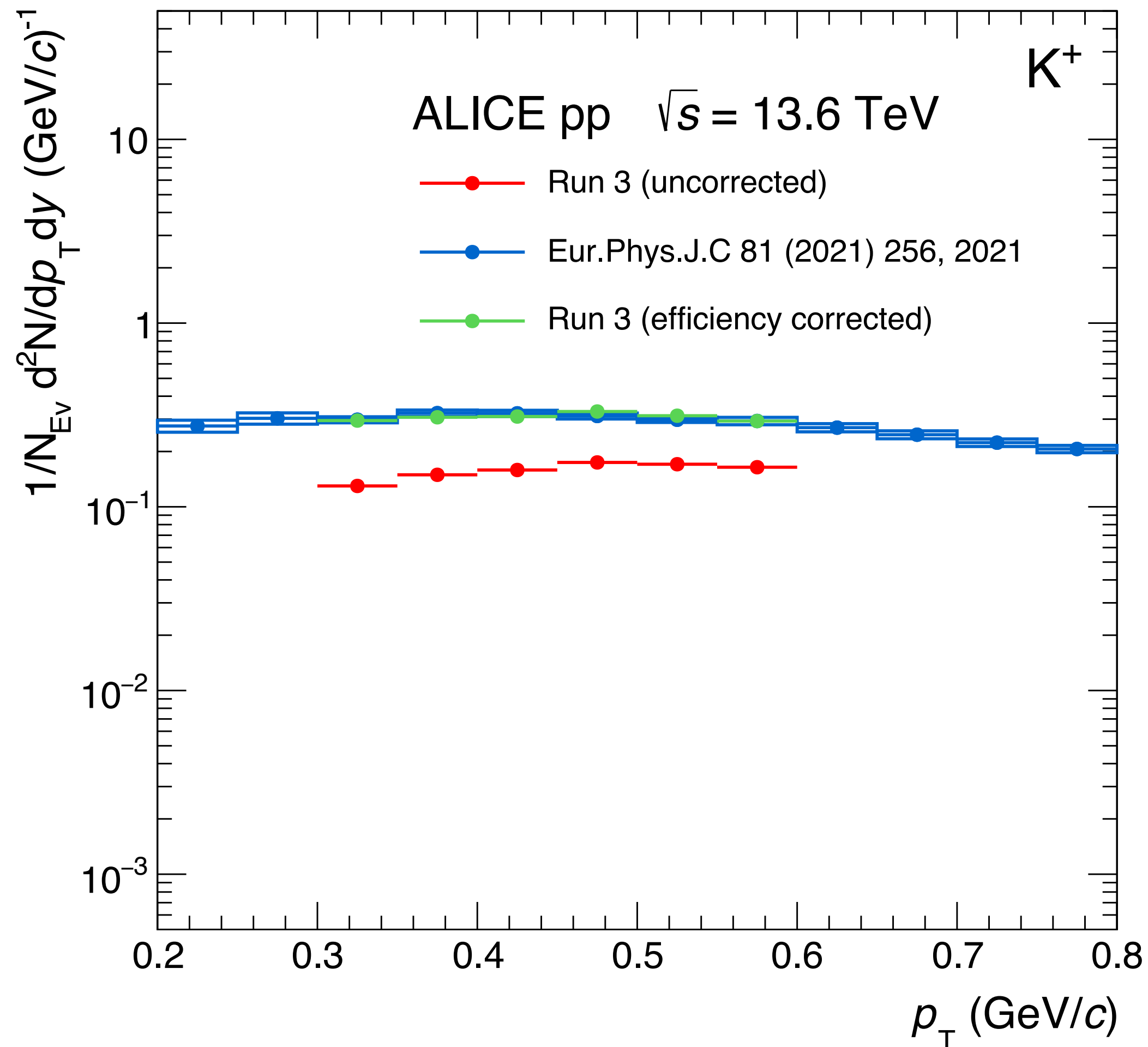
$$\frac{d^2N}{dp_T dy} = \frac{1}{N_{ev}} \times \frac{RawYield}{\epsilon_{tracking}} \times PrimaryFraction$$



Results

Corrected p_T spectra for K^+ , K^-

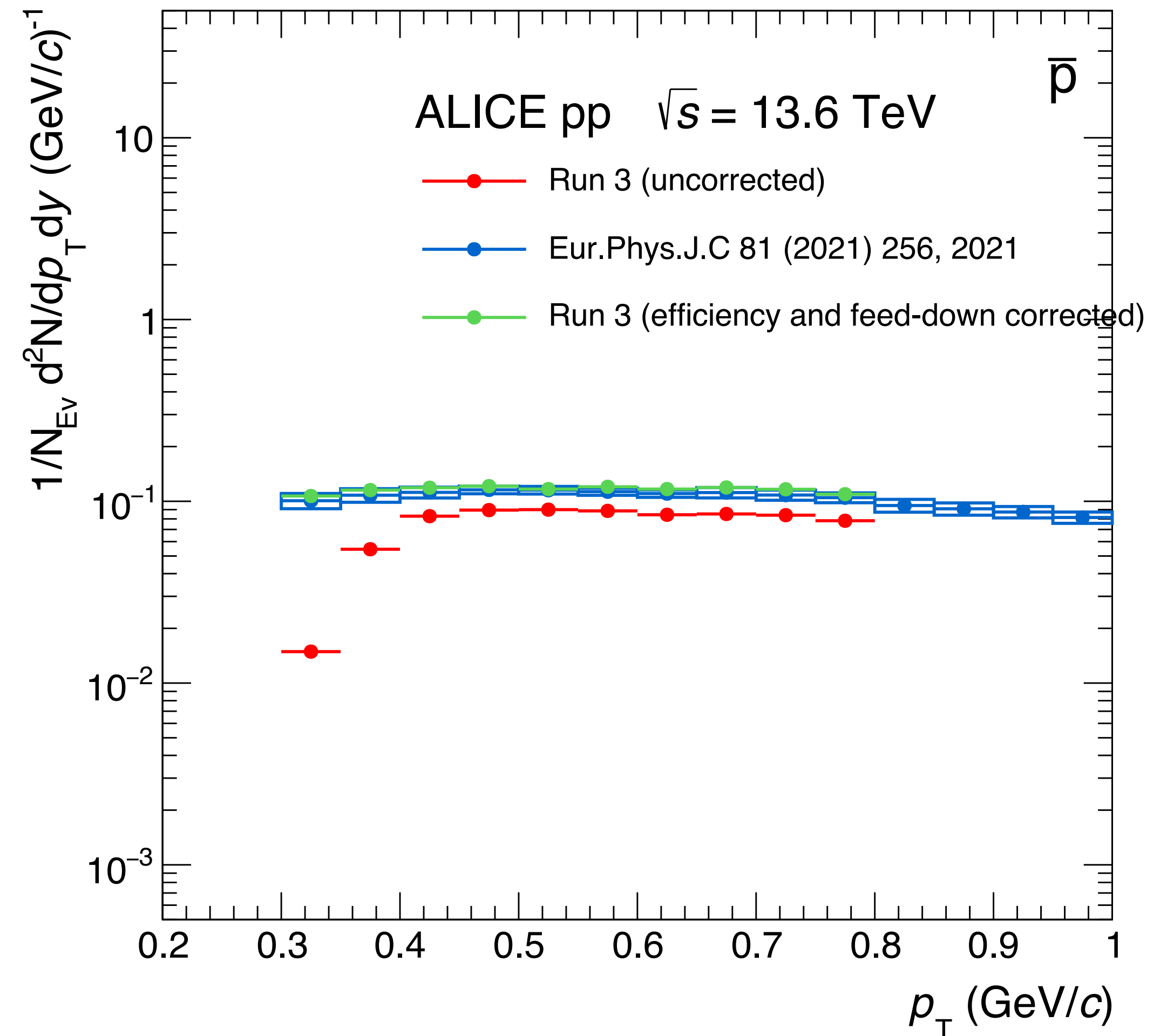
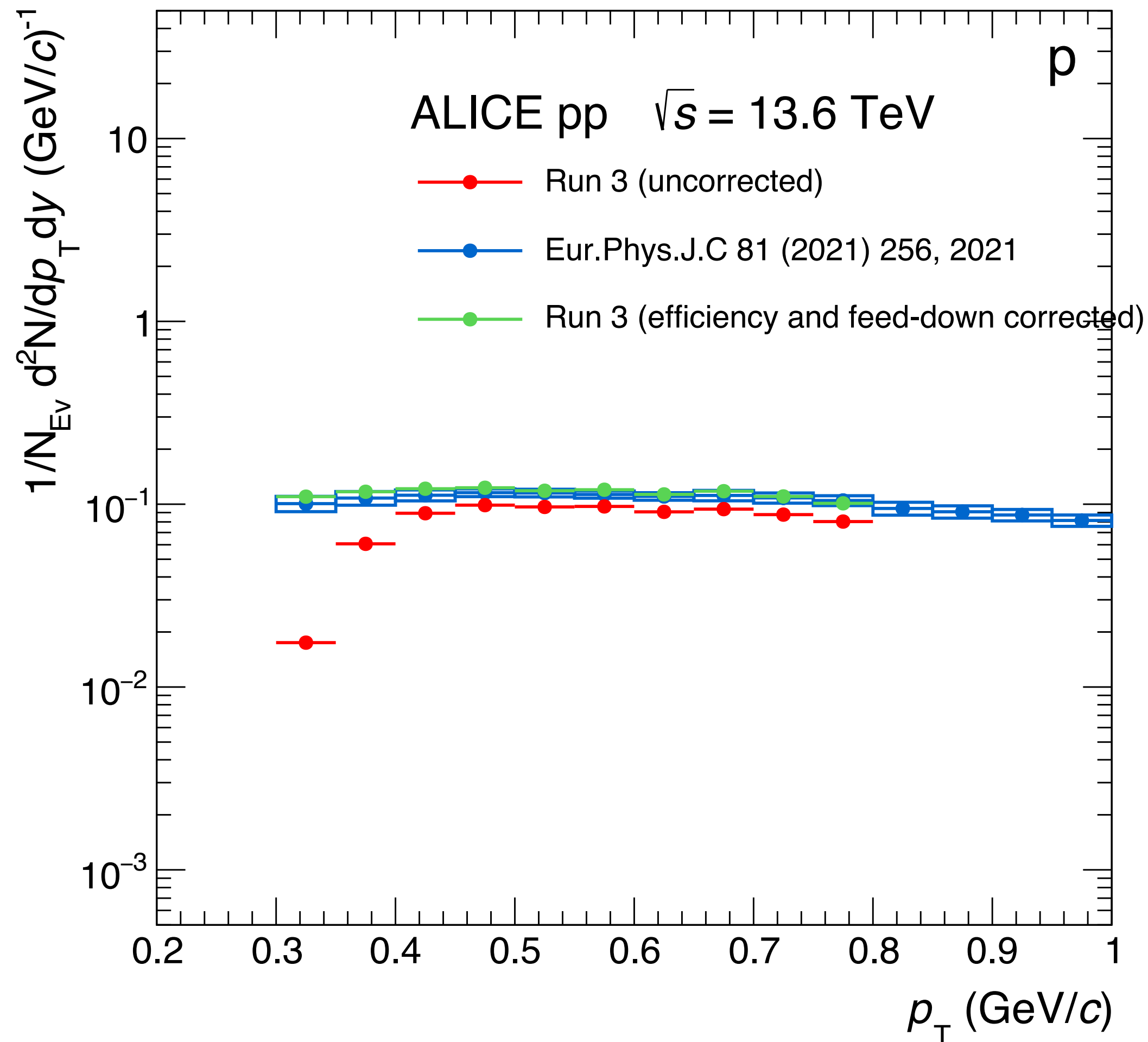
$$\frac{d^2N}{dp_T dy} = \frac{1}{N_{ev}} \times \frac{RawYield}{\epsilon_{tracking}}$$



Results

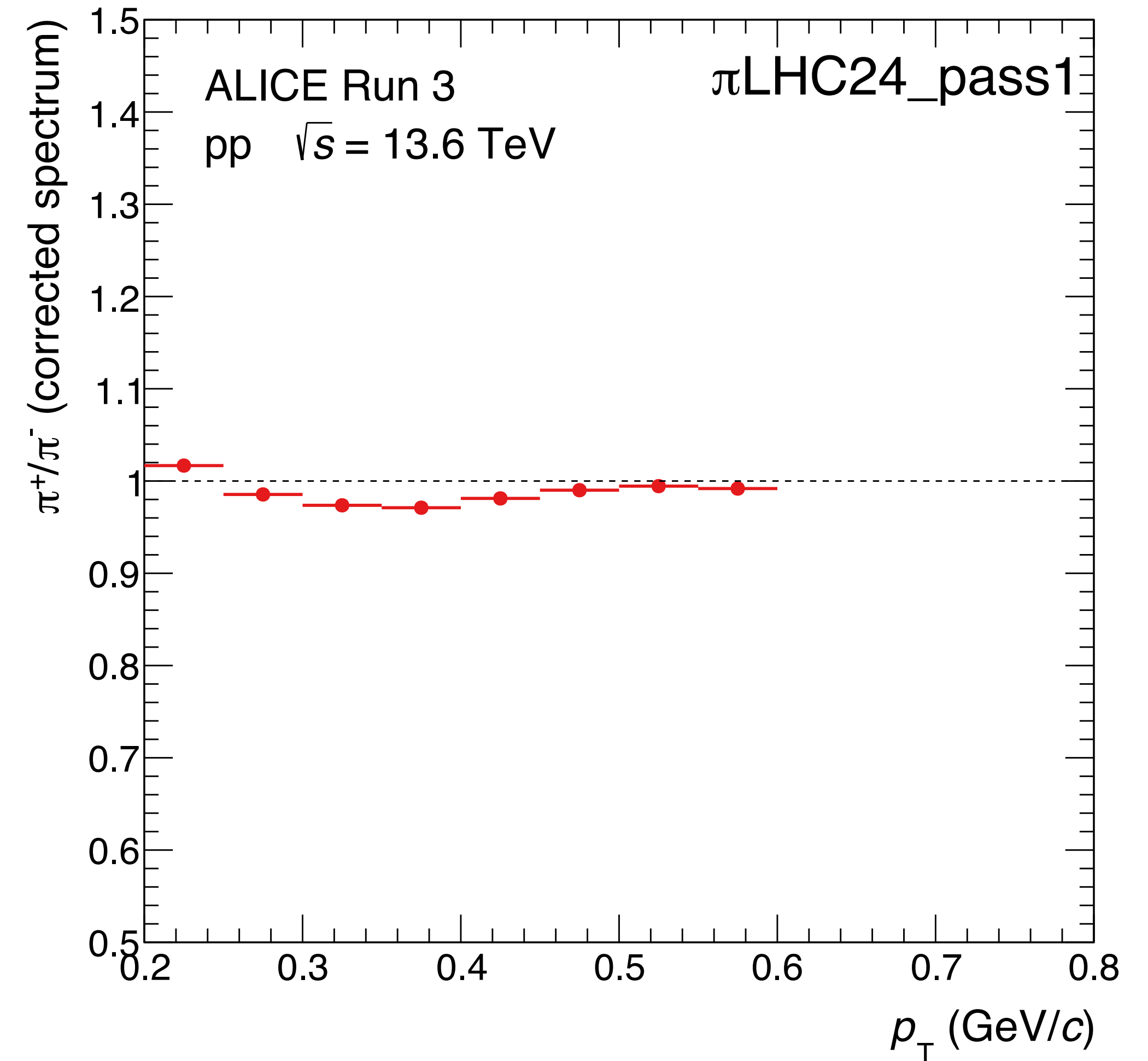
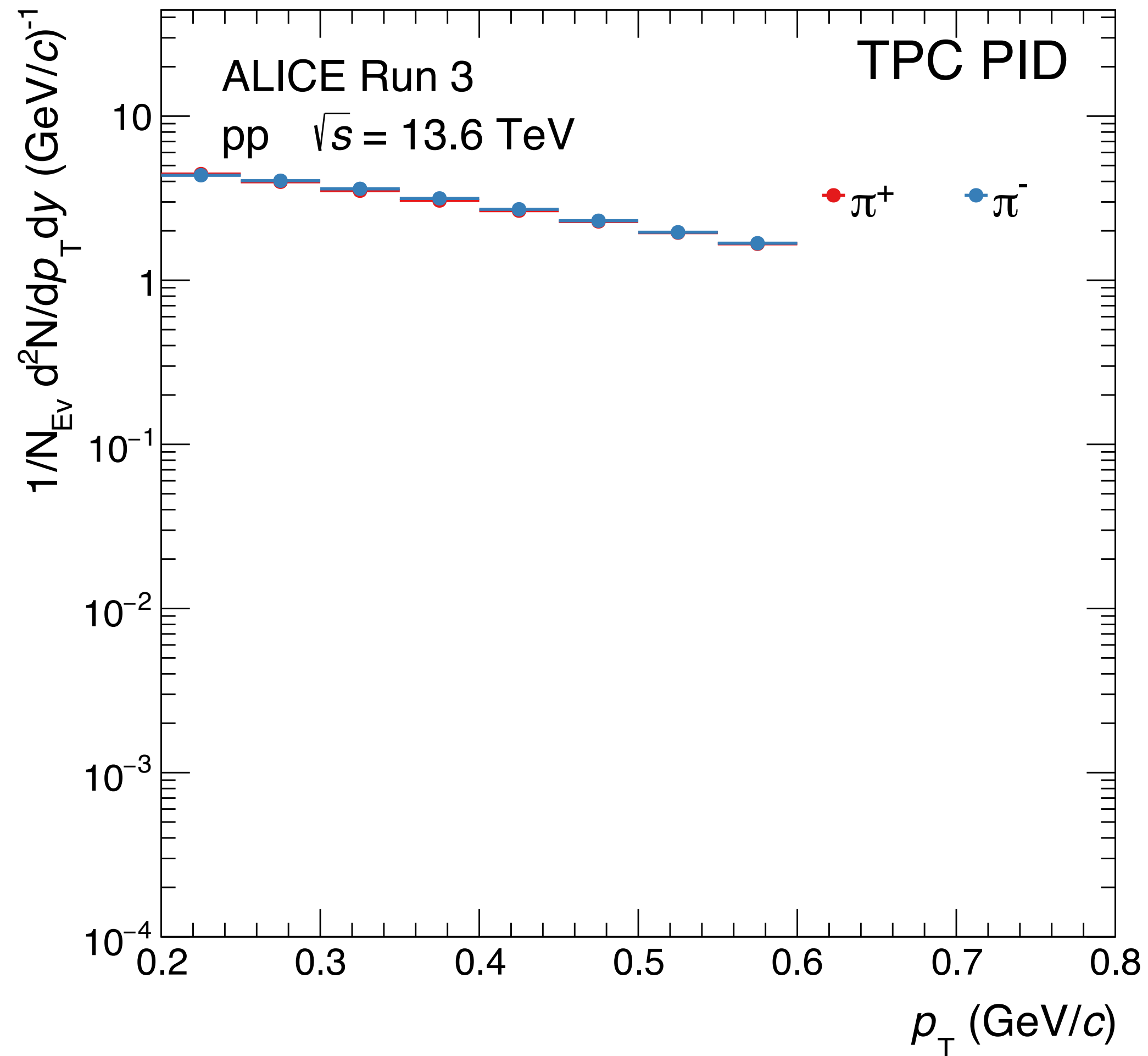
Corrected p_T spectra for p, \bar{p}

$$\frac{d^2N}{dp_T dy} = \frac{1}{N_{ev}} \times \frac{RawYield}{\epsilon_{tracking}} \times PrimaryFraction$$



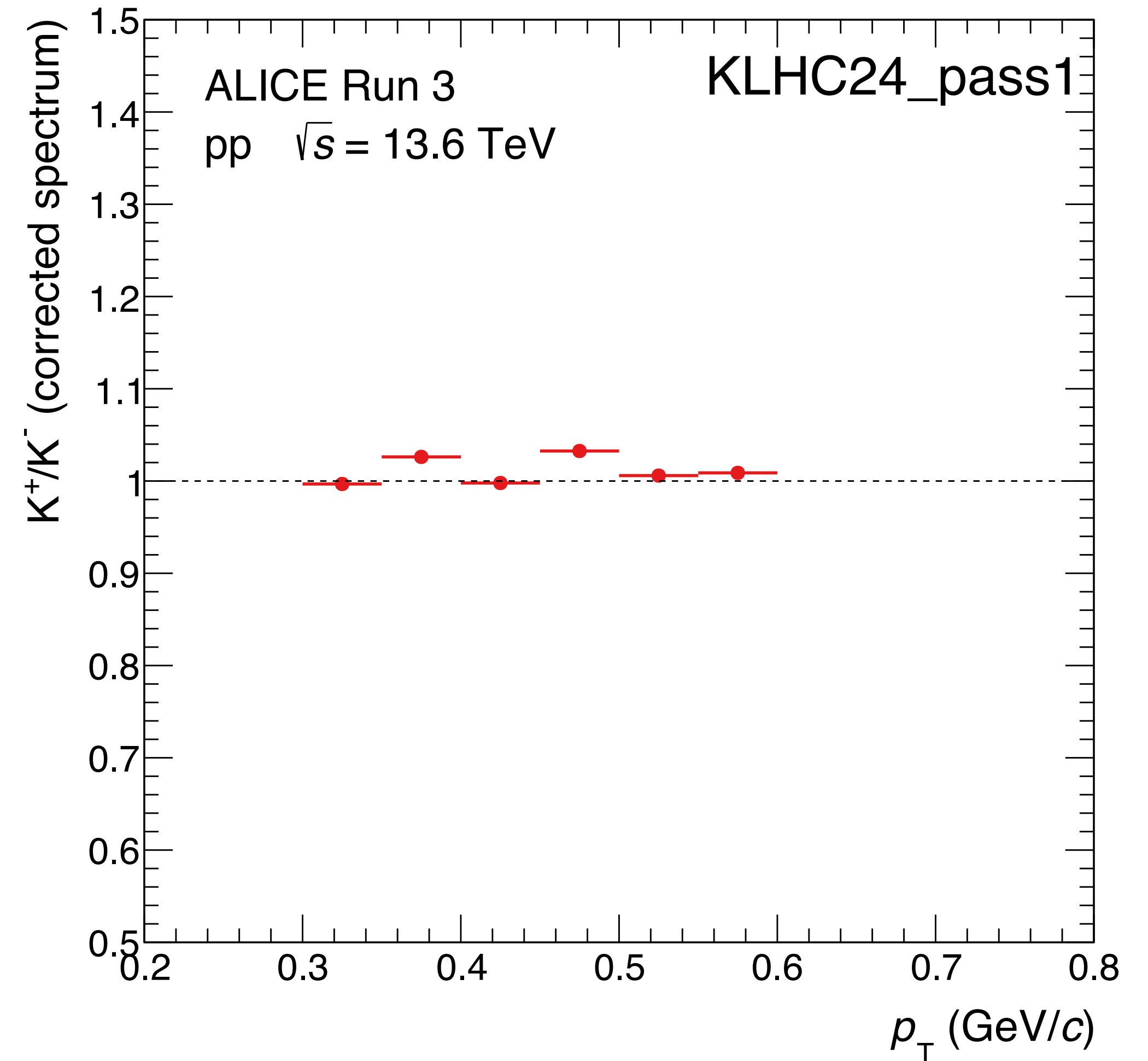
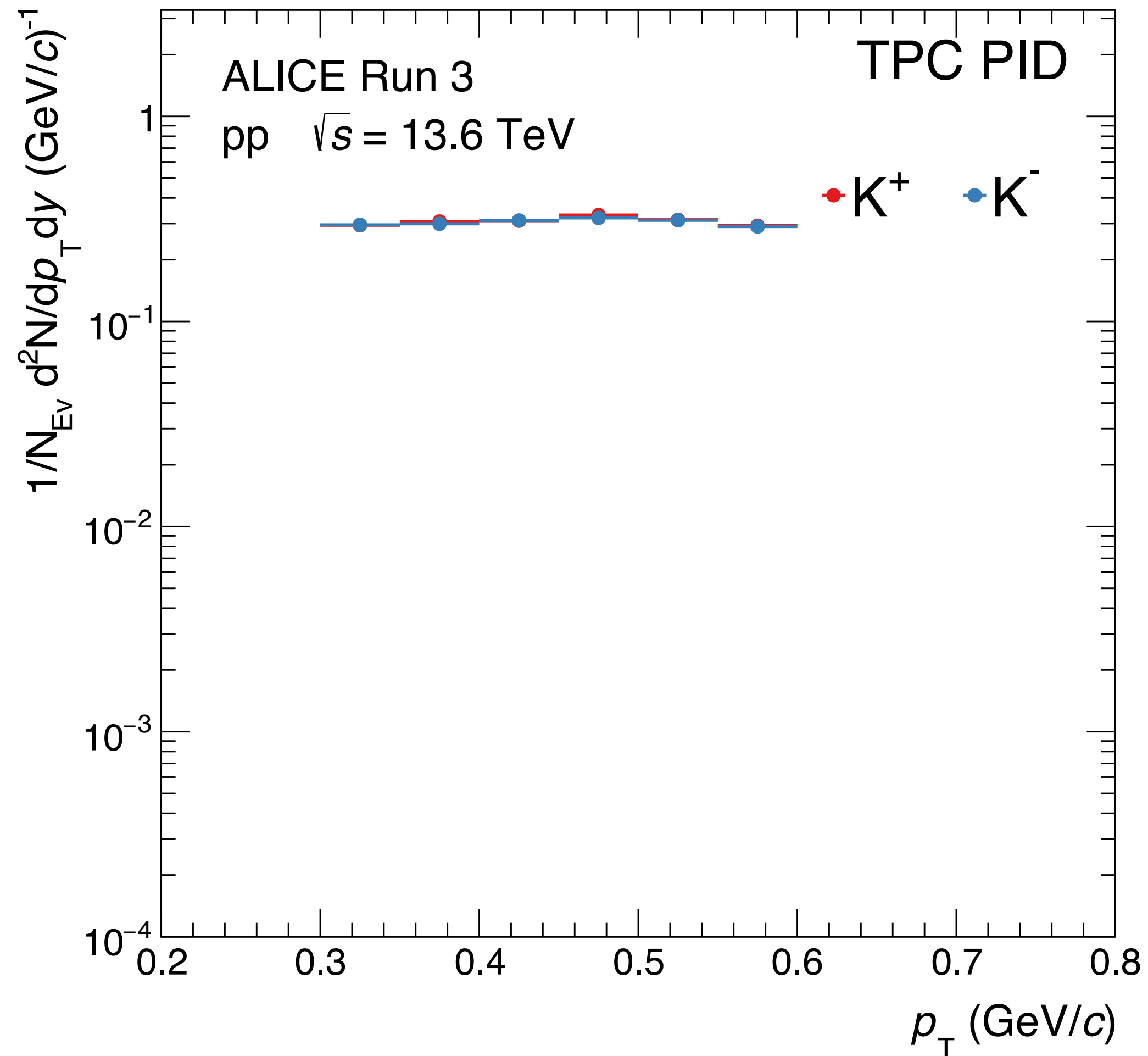
Results

Ratio between π^+ and π^-



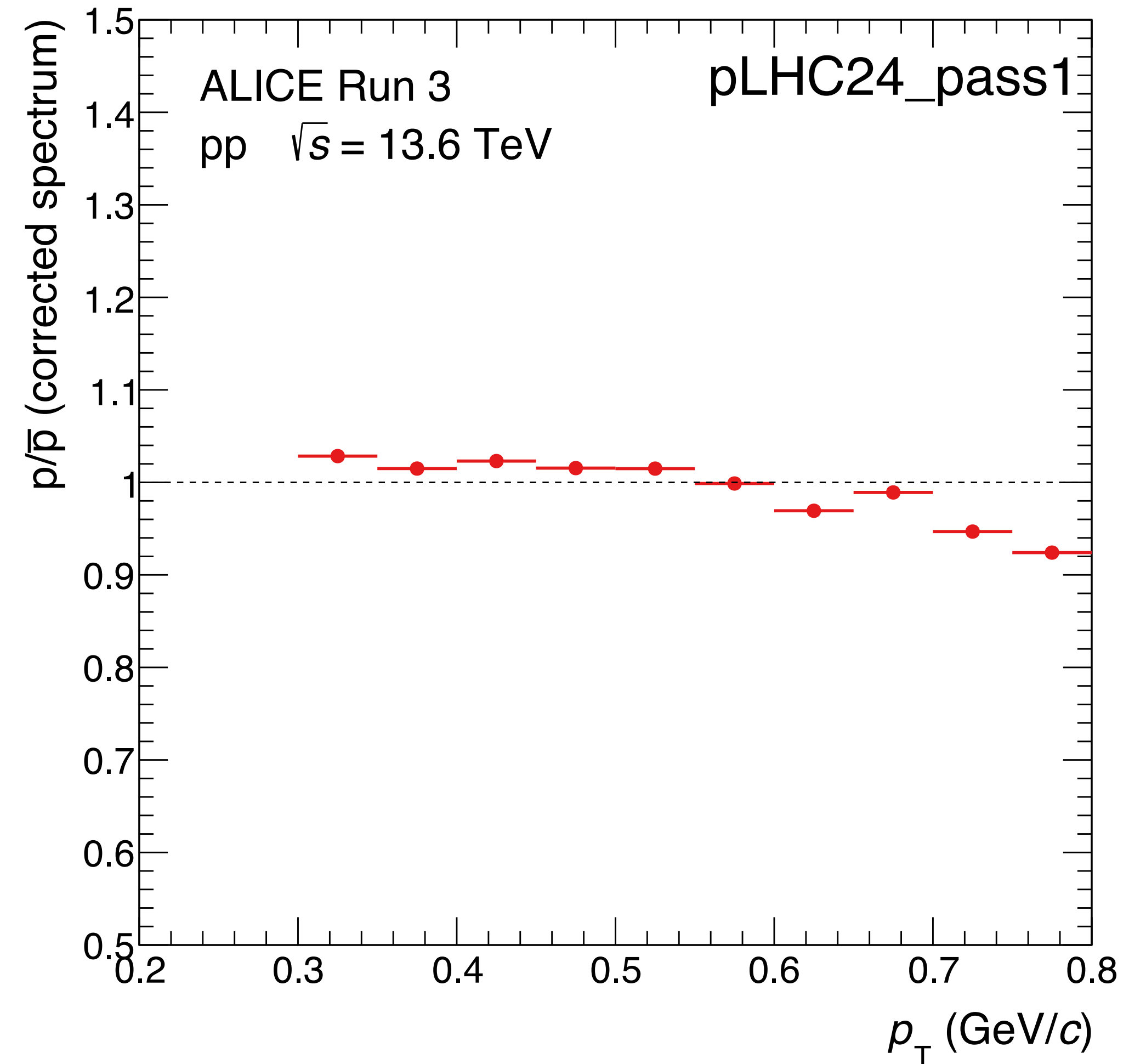
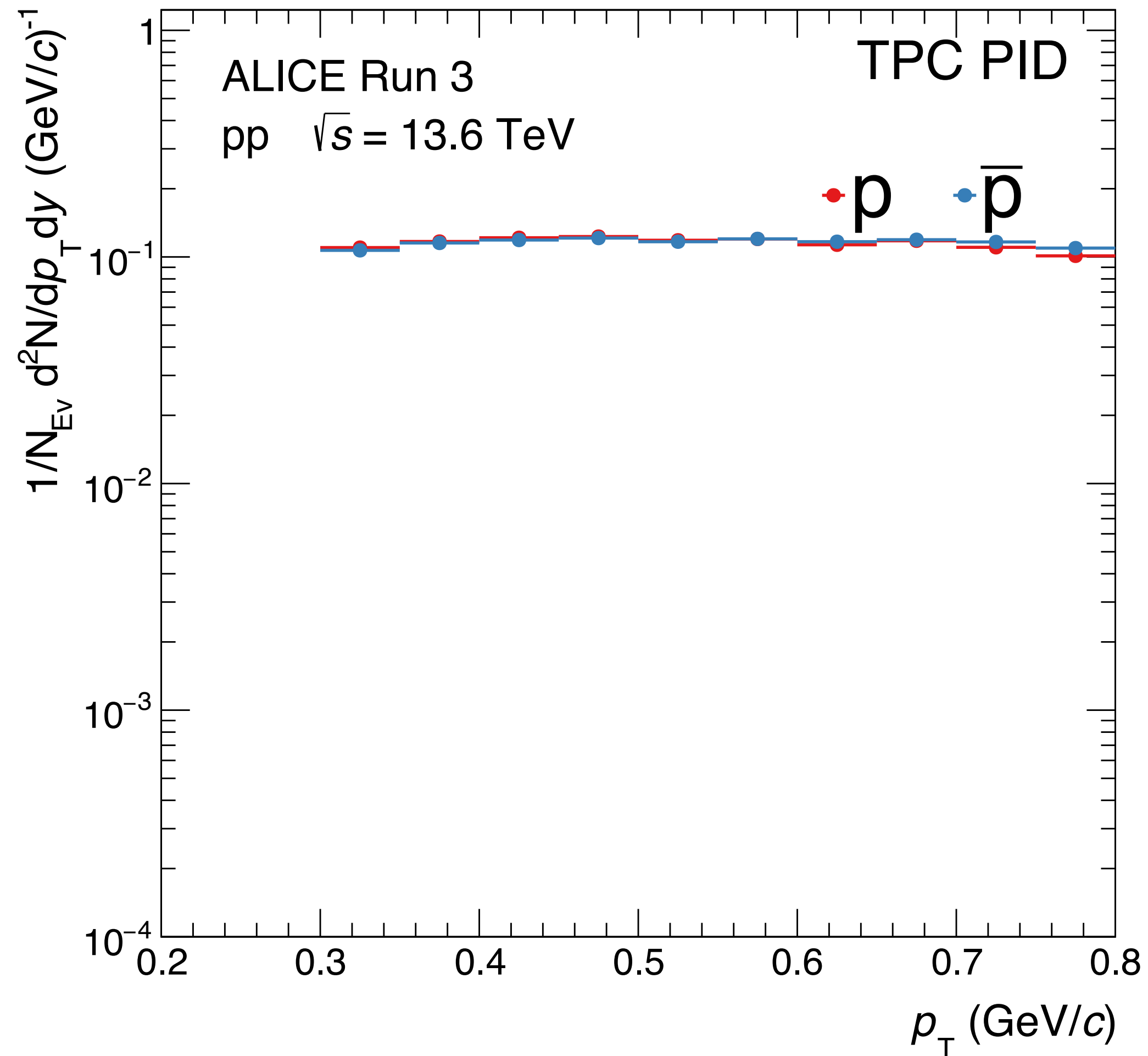
Results

Ratio between K^+ and K^-



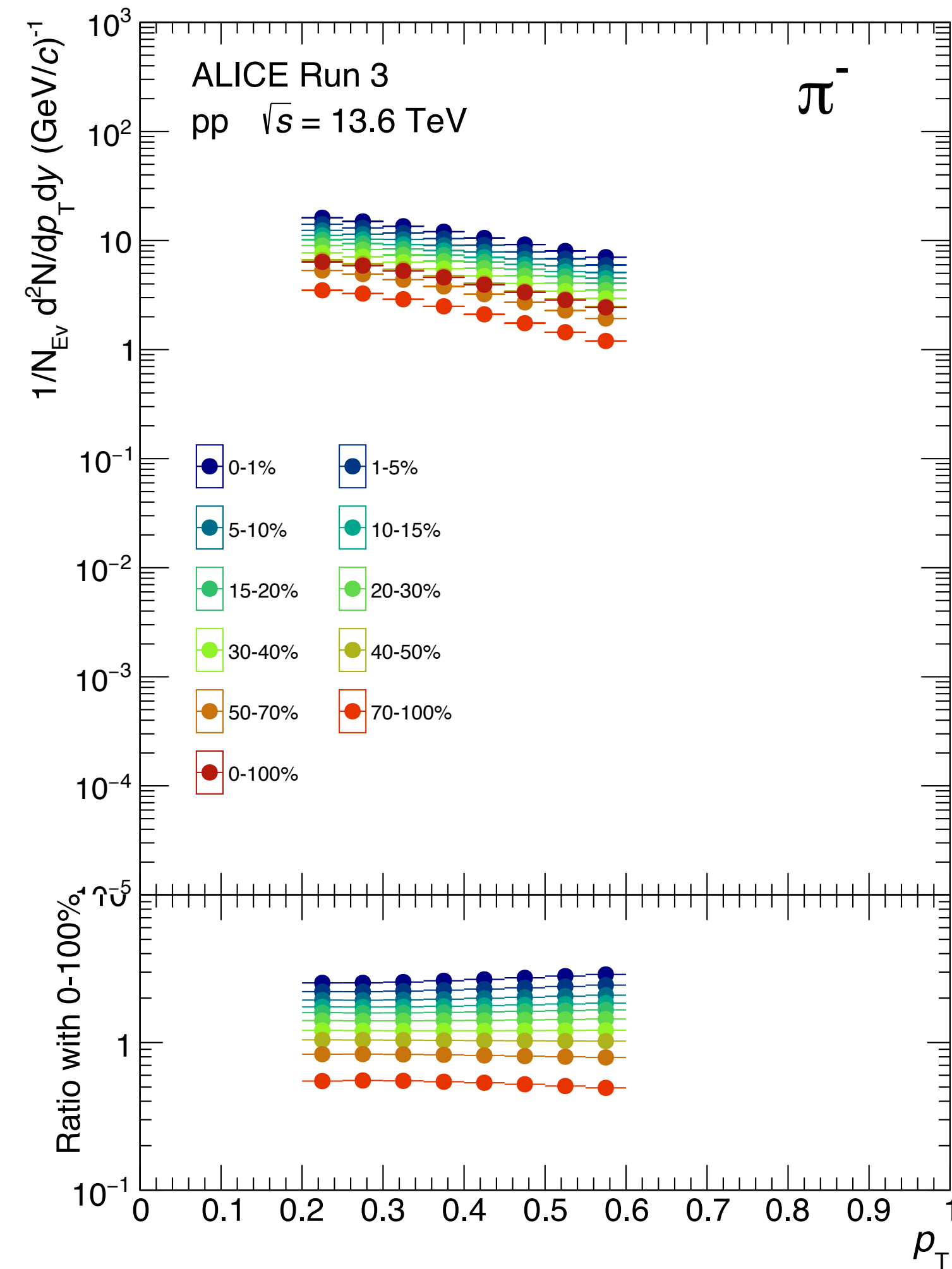
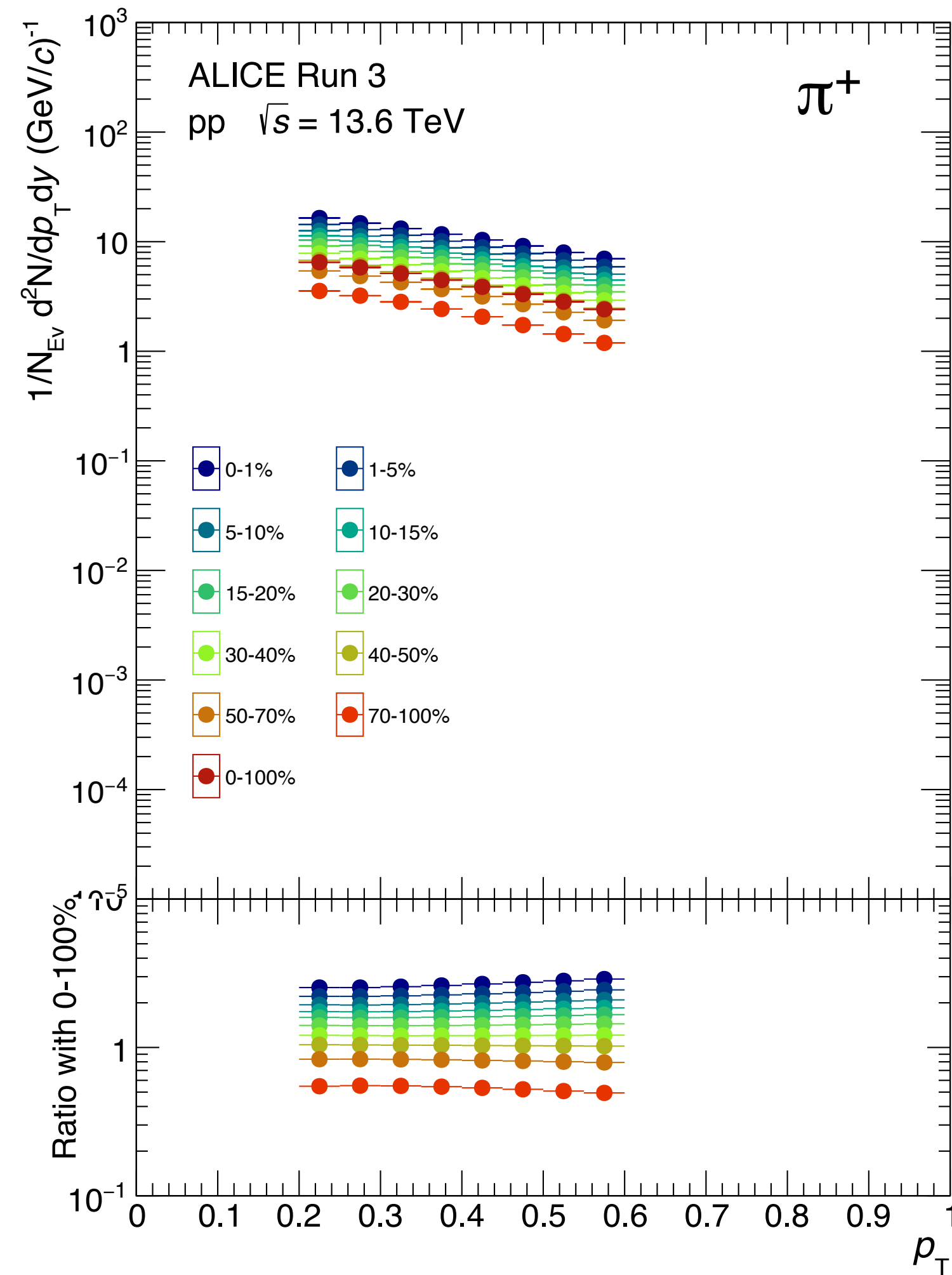
Results

Ratio between p and \bar{p}



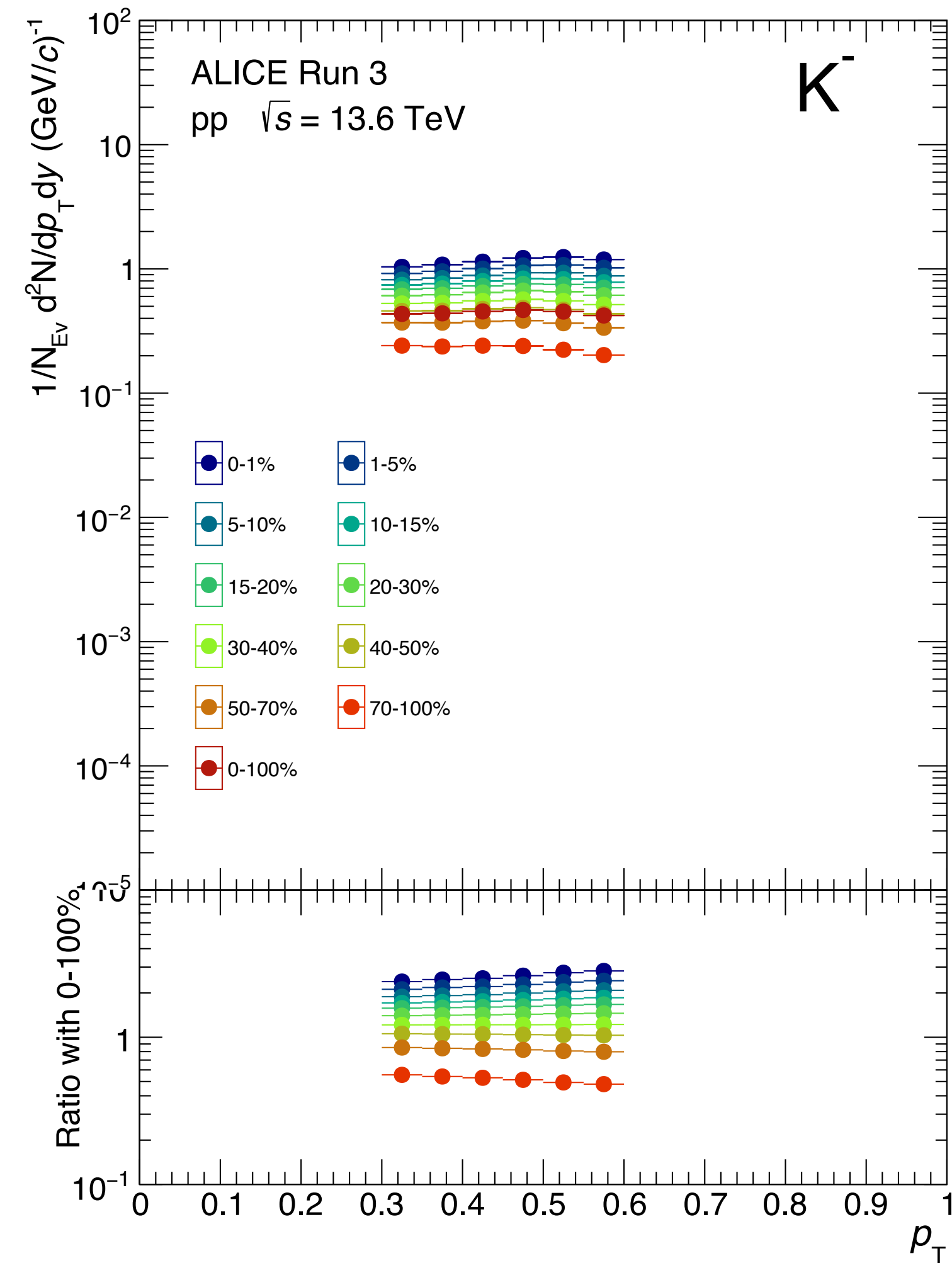
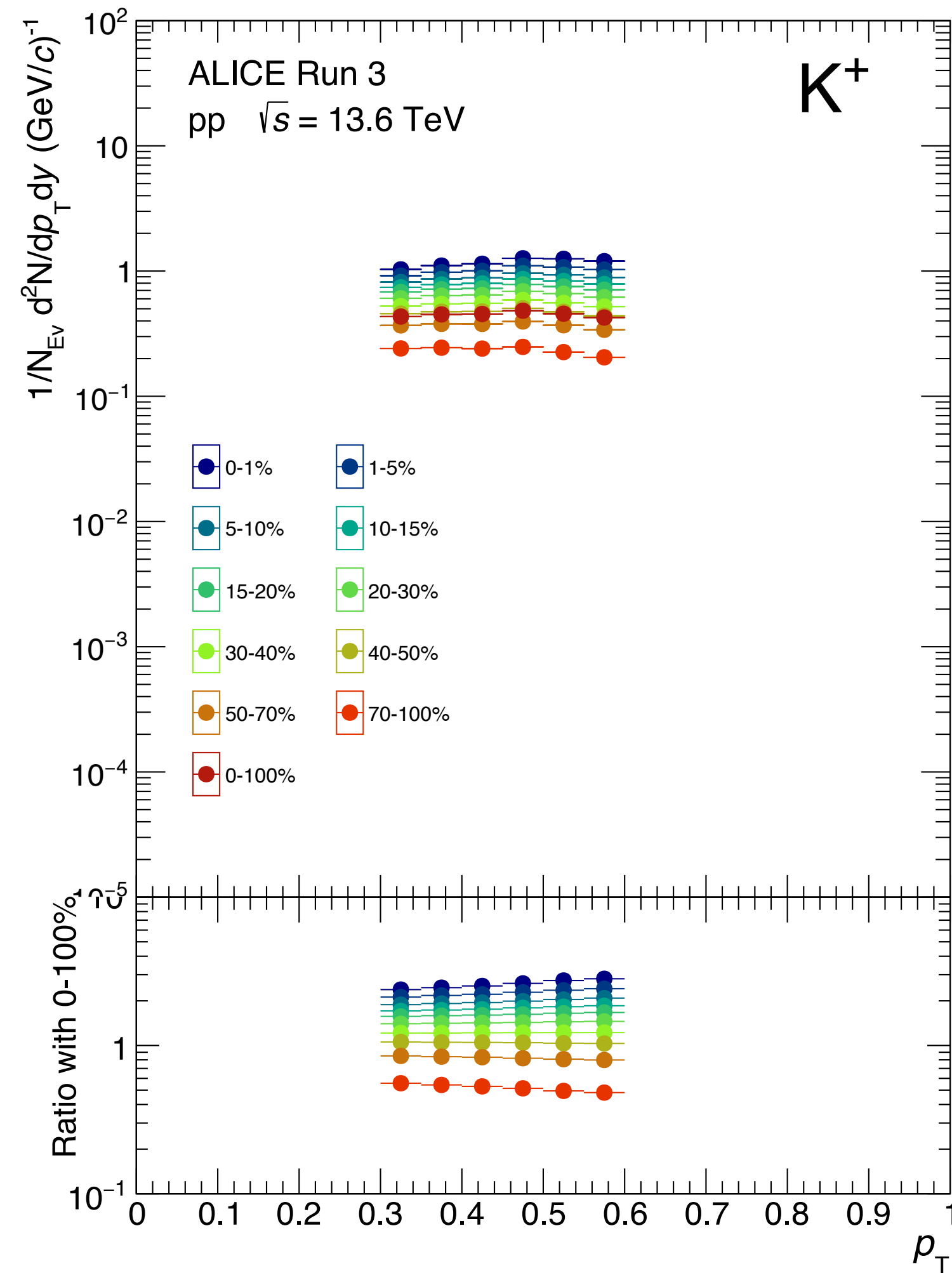
Results

Multiplicity dependent p_T spectra for π^+ , π^-



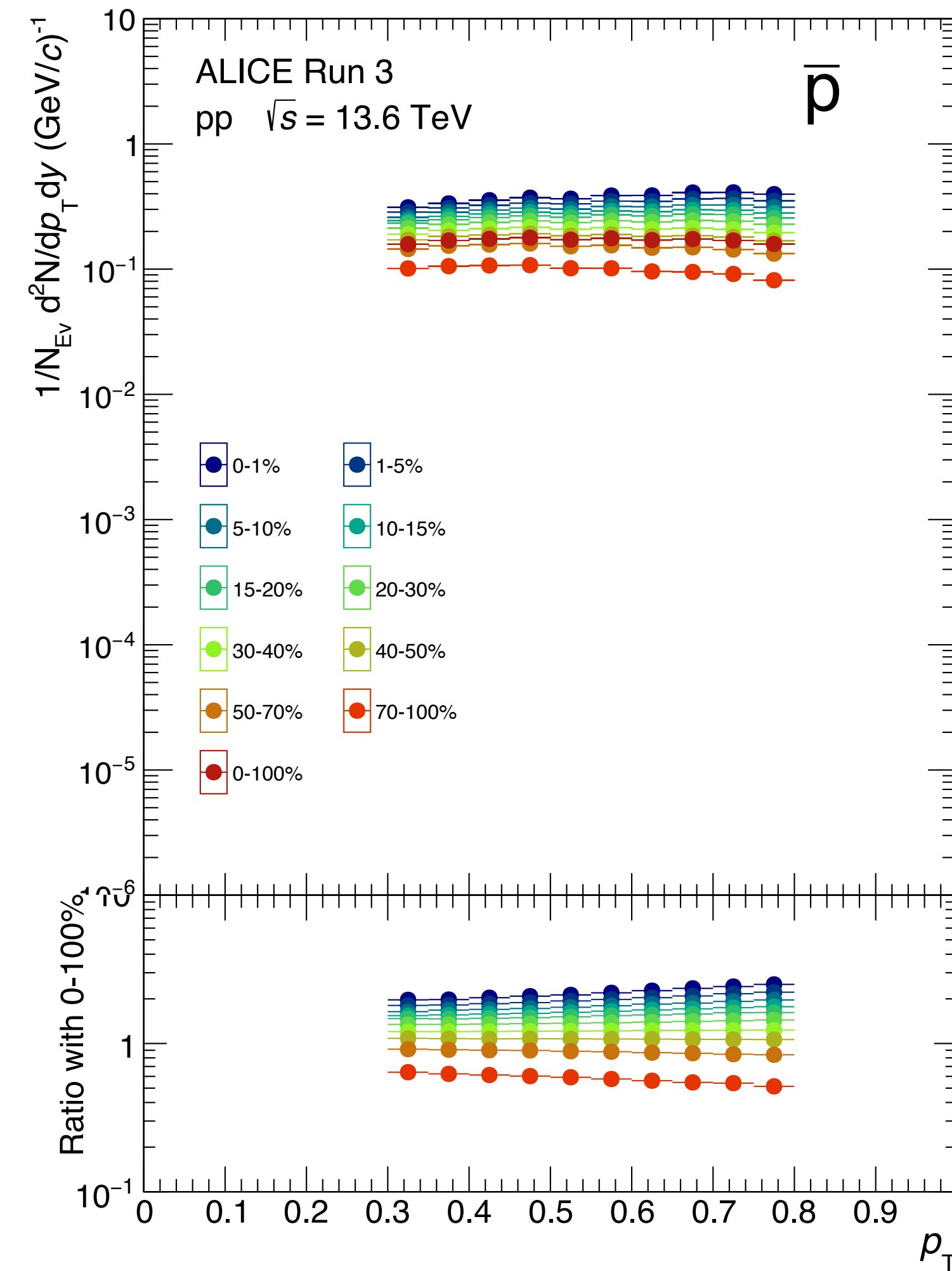
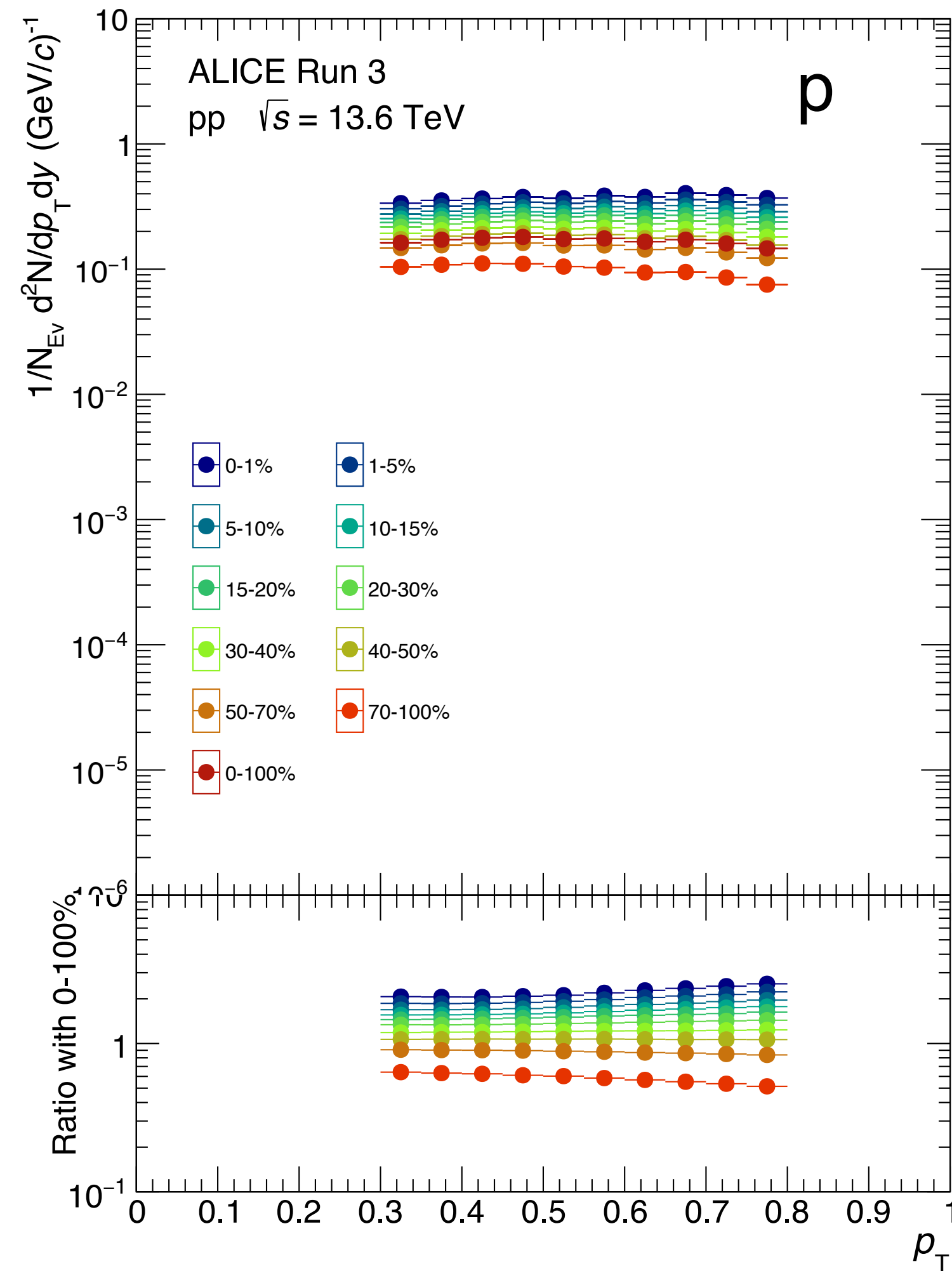
Results

Multiplicity dependent p_T spectra for K^+ , K^-



Results

Multiplicity dependent p_T spectra for p, \bar{p}



Results

Systematic Uncertainty

○ Track cut variation:

- maxChi2PerClusterITS: 30 & 40 (standard = 36)
- maxChi2PerClusterTPC: 3 & 5 (standard = 4)
- macDcaZ: 1 & 3 (standard = 2)
- minNCrossedRowsOverFindableClustersTPC: 0.75 & 0.85 (standard = 0.8)
- minNCrossRowsTPC: 60 & 80 (standard = 70)

○ PID Technique:

- Integral from the Template Fit
- Bin counting

○ Estimation of Secondaries:

- Standard calculation technique: TFractionFitter Variation: RooFit

○ Material Budget: (<https://its.cern.ch/jira/browse/O2-5700>)

- Standard: LHC24f3b Variation: LHC25a9_Plus10 and LHC25a9_Minus10

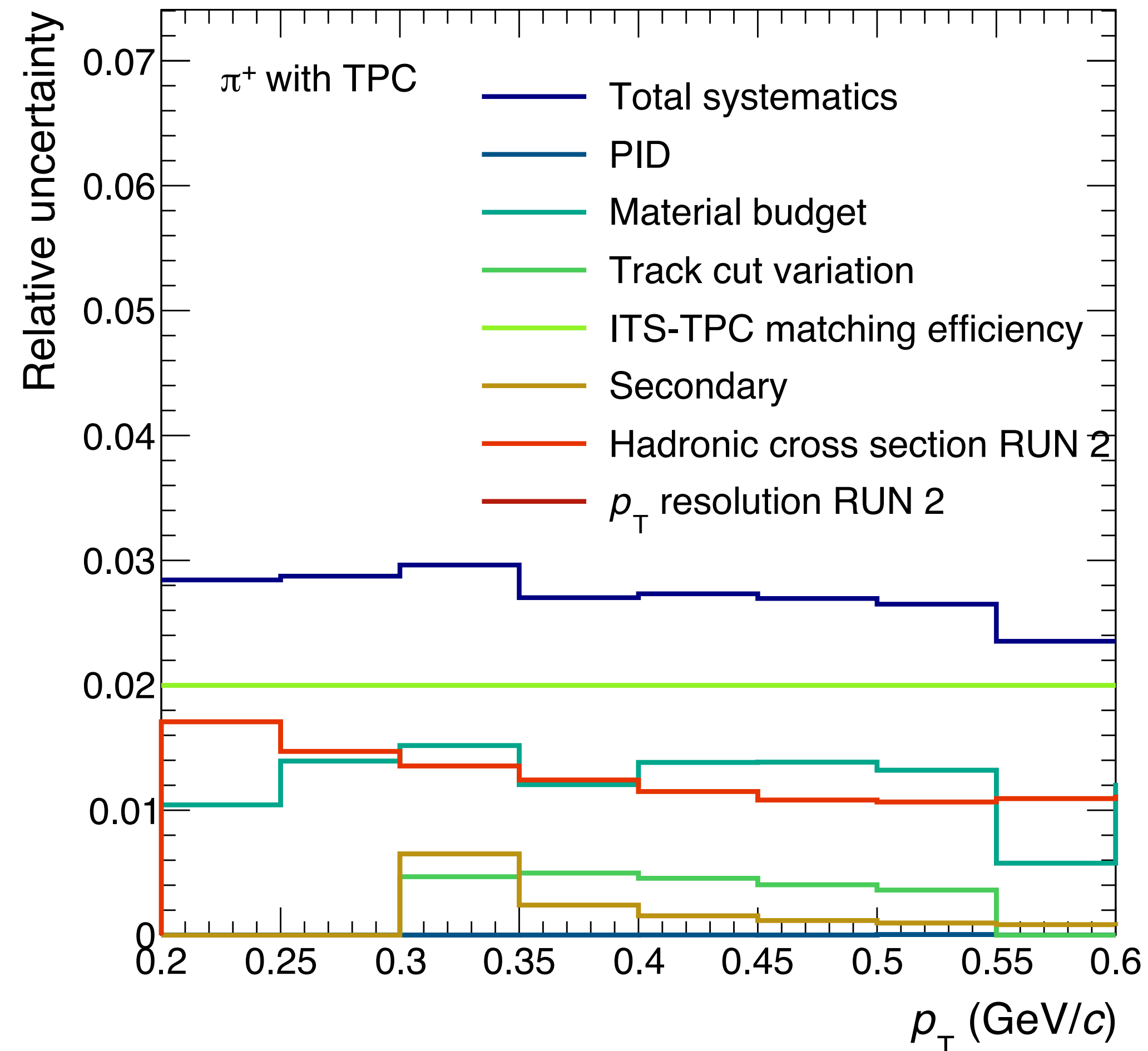
○ ITS-TPC Matching Efficiency

- Flat 2% for all p_T (taken from slide 13 of [HF analysis](#))

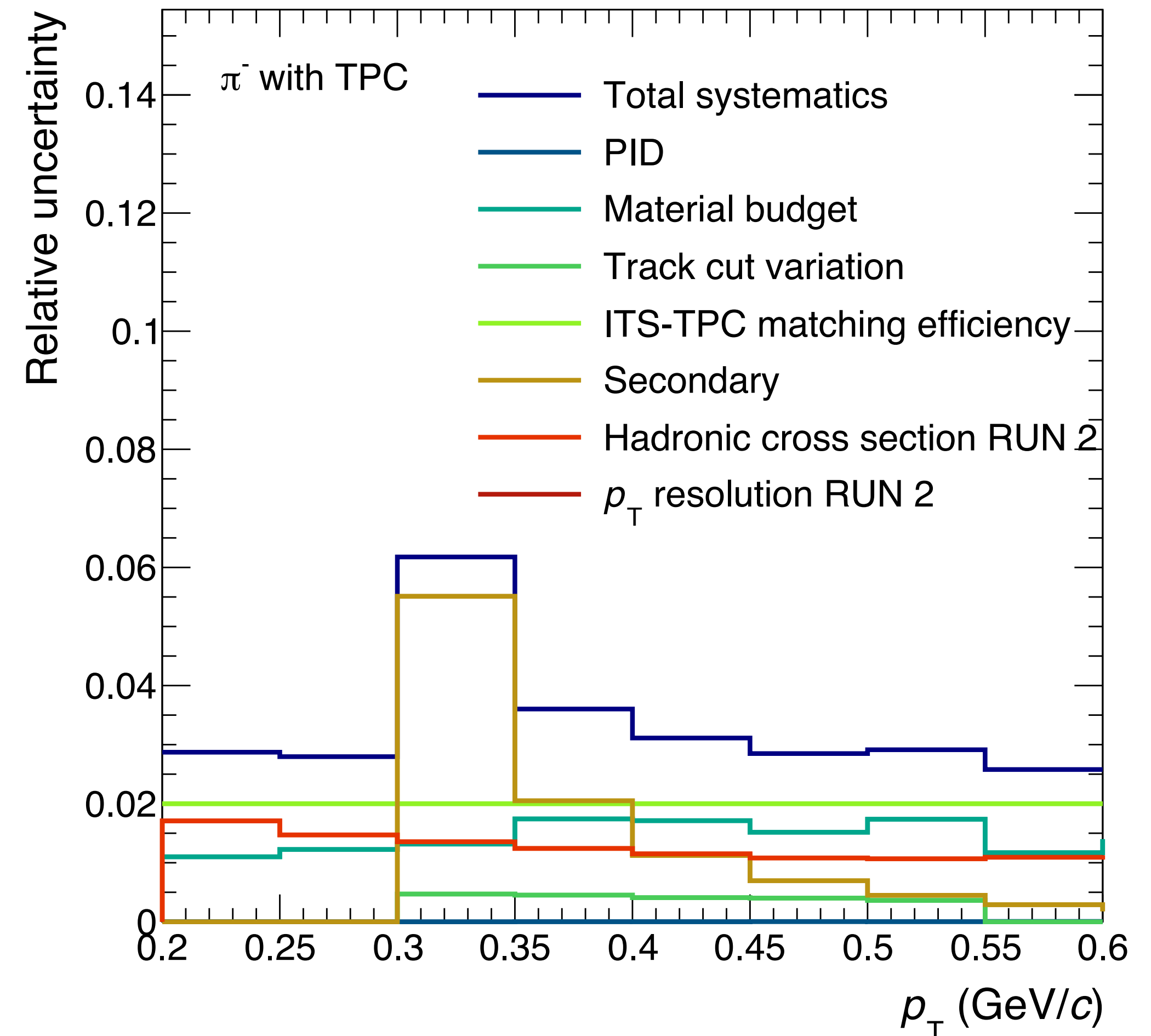
○ Hadronic Cross section: Taken from Run2

Results

Estimation of systematic uncertainty for π^+ , π^-



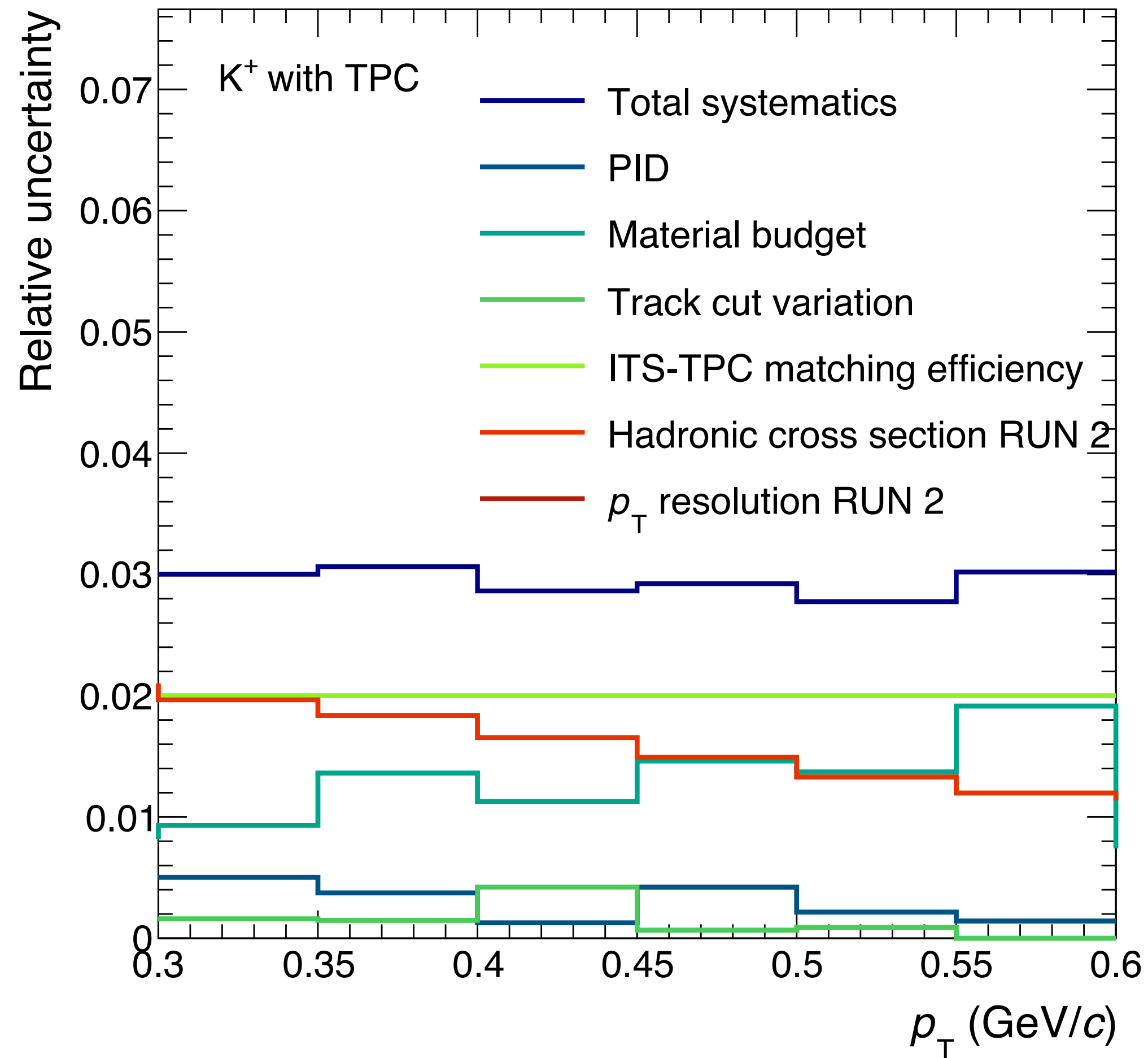
• Highest for ITS-TPC matching efficiency



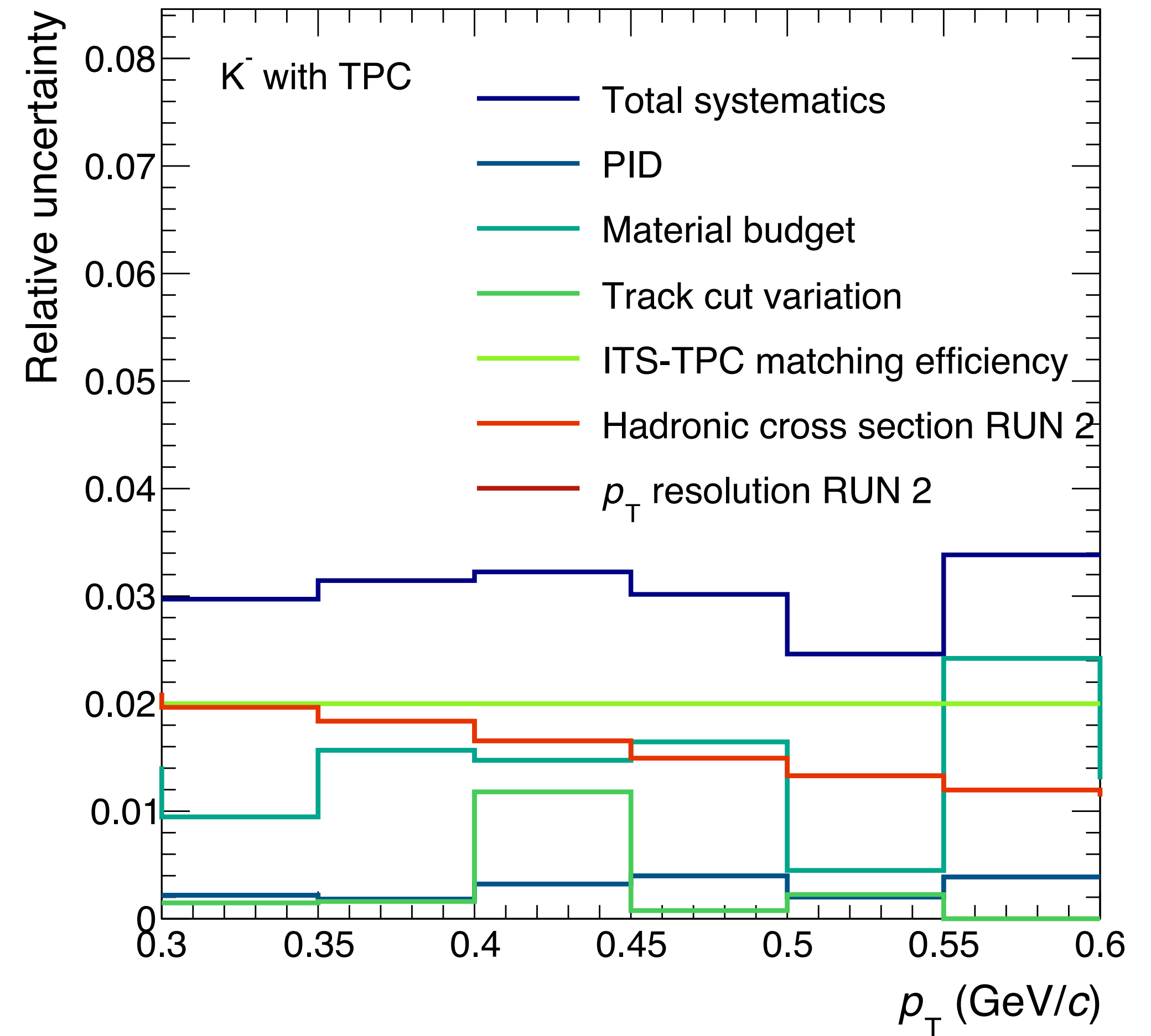
• Highest for secondary estimation

Results

Estimation of systematic uncertainty for K^+ , K^-



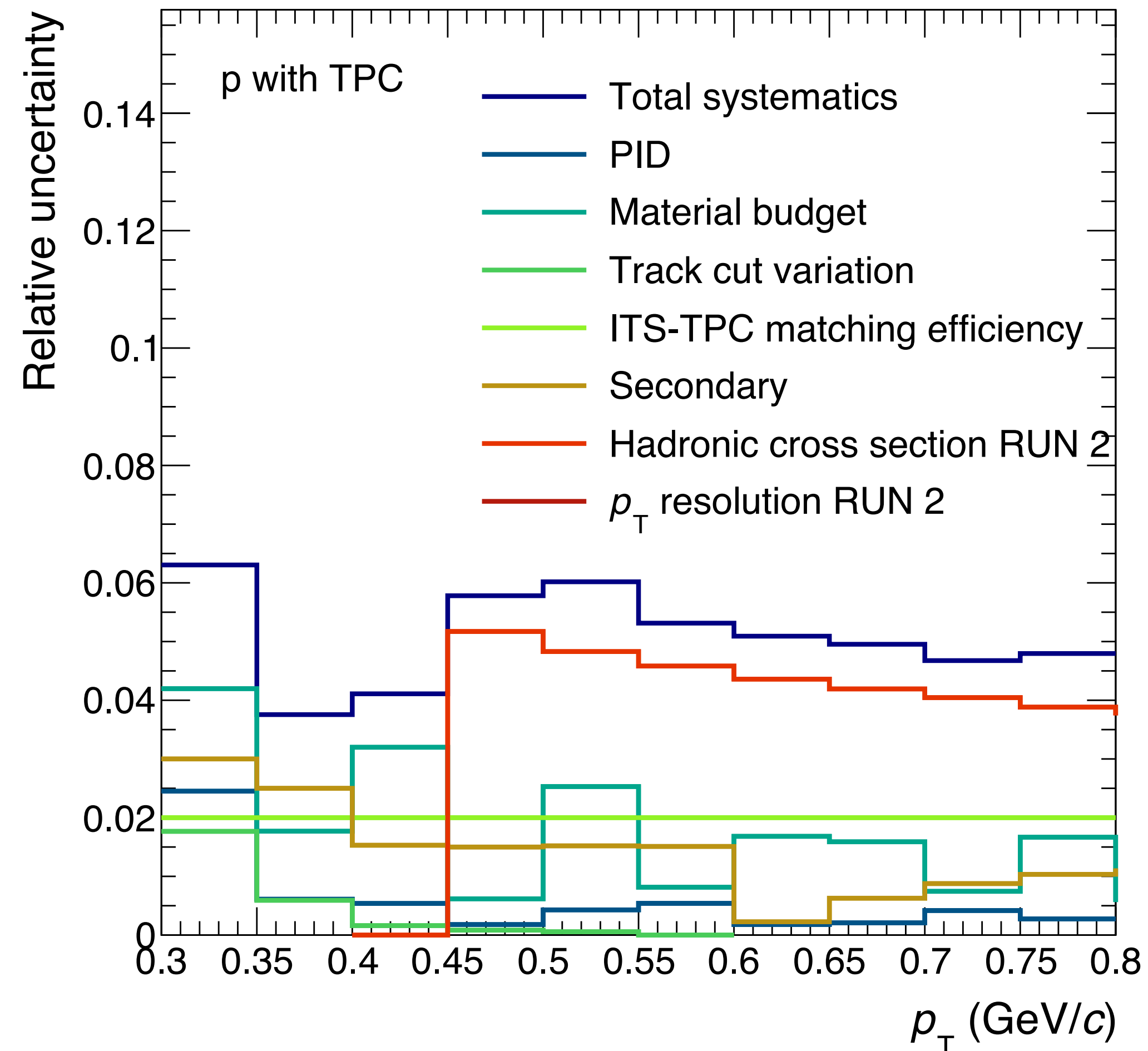
- Highest for ITS-TPC matching efficiency



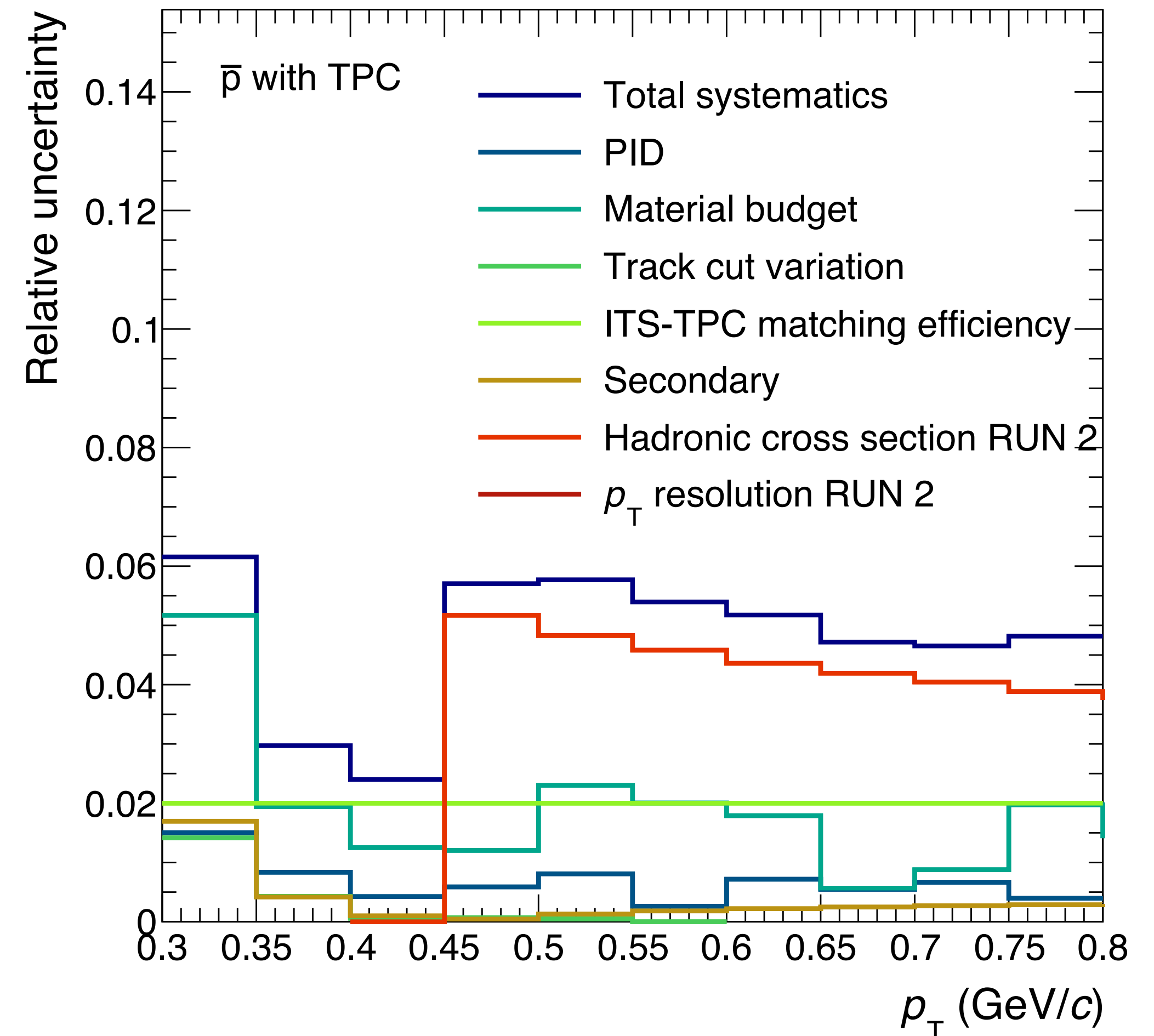
- Highest for material budget

Results

Estimation of systematic uncertainty for p, \bar{p}



- Highest for Hadronic cross-section (RUN2)



- Highest for Hadronic cross-section (RUN2) & material budget

Summary

- The raw p_T spectra of π , K and p were obtained from the unfolded NSigma distribution of TPC, using Gaussian+Exponential Template fit.
- Tracking efficiency and fraction of primary particles were also estimated.
- The corrected p_T spectra showed good agreement with that of Run2 pp results.
- The multiplicity dependance of the p_T spectra of π , K and p was also shown.
- The systematic uncertainties for the identified π , K and p were estimated.

Acknowledgement

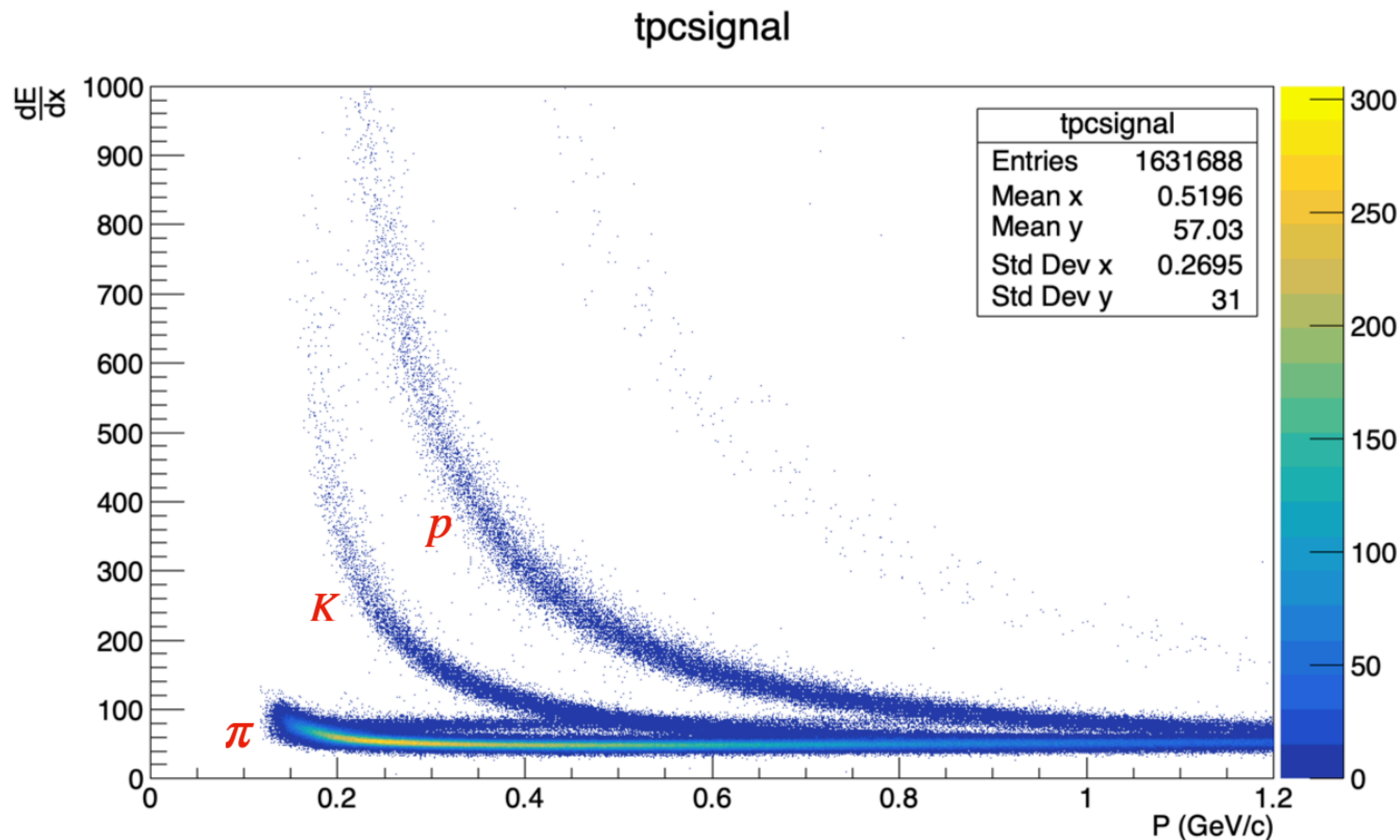
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Backup

PID using TPC dE/dx

Bethe-Bloch Formula for energy loss:
$$\left\langle \frac{dE}{dx} \right\rangle = \frac{4\pi N e^4 Z^2}{m_e c^2 \beta^2} \left(\ln \frac{2m_e c^2 \beta^2 \gamma^2}{I} - \beta^2 - \frac{\delta(\beta)}{2} \right)$$



N - no. density of electrons, e - elementary charge

m_e - rest mass of electron, Z - charge of the projectile

I - mean excitation energy of the atom

β - velocity of projectile, $\delta(\beta)$ - correction term

TPC NSigma is calculated as,

$$N_{\sigma}^{TPC} = \frac{dE/dx_{expected} - dE/dx_{measured}}{\sigma_{dE/dx_{measured}}}$$