Update on π, K and p production in High Multiplicity pp collisions at 13 TeV using TPC and TOF detectors

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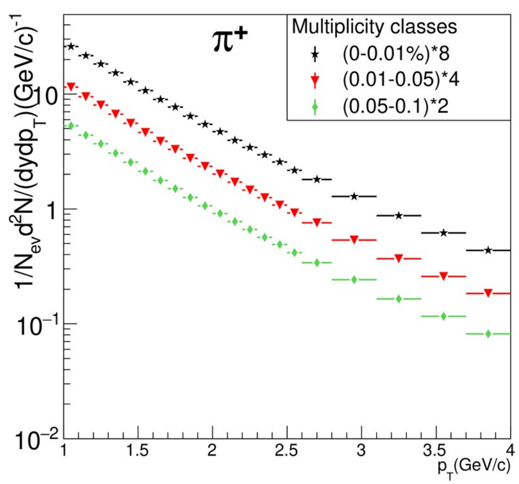
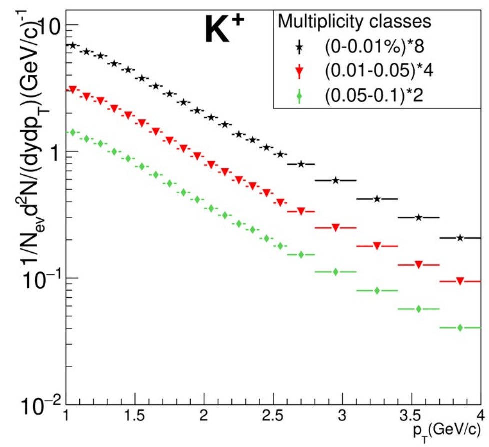
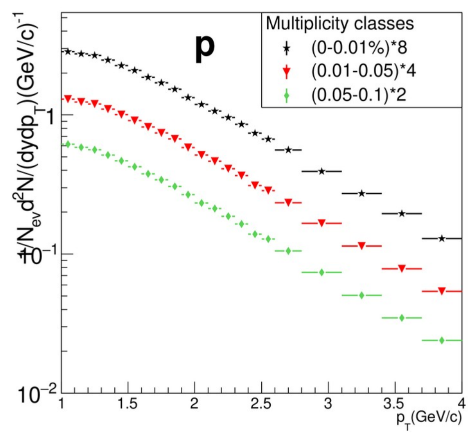
Work done and presented

- Obtained the TPC+TOF corrected spectra using the High Multiplicity (HM) trigger with fine bins of multiplicity 0-0.01%, 0.01-0.05%, 0.05-0.1% for pp collisions at 13 TeV.







Corrections applied:

- **Tracking efficiency**
- **Matching efficiency**
- **Feed-down correction**
- **Geant4 absorption correction**

New Update

- Obtained the corrected spectra for pions, kaons and protons using the TPC-TOF analysis.
- Combined spectra with other analysis i.e. ITSsa and kinks is obtained.
- Compare the spectra with published results.

Outline

- Motivation
- ALICE detector system
- Analysis details and Analysis crew
- Results & discussions
- Summary

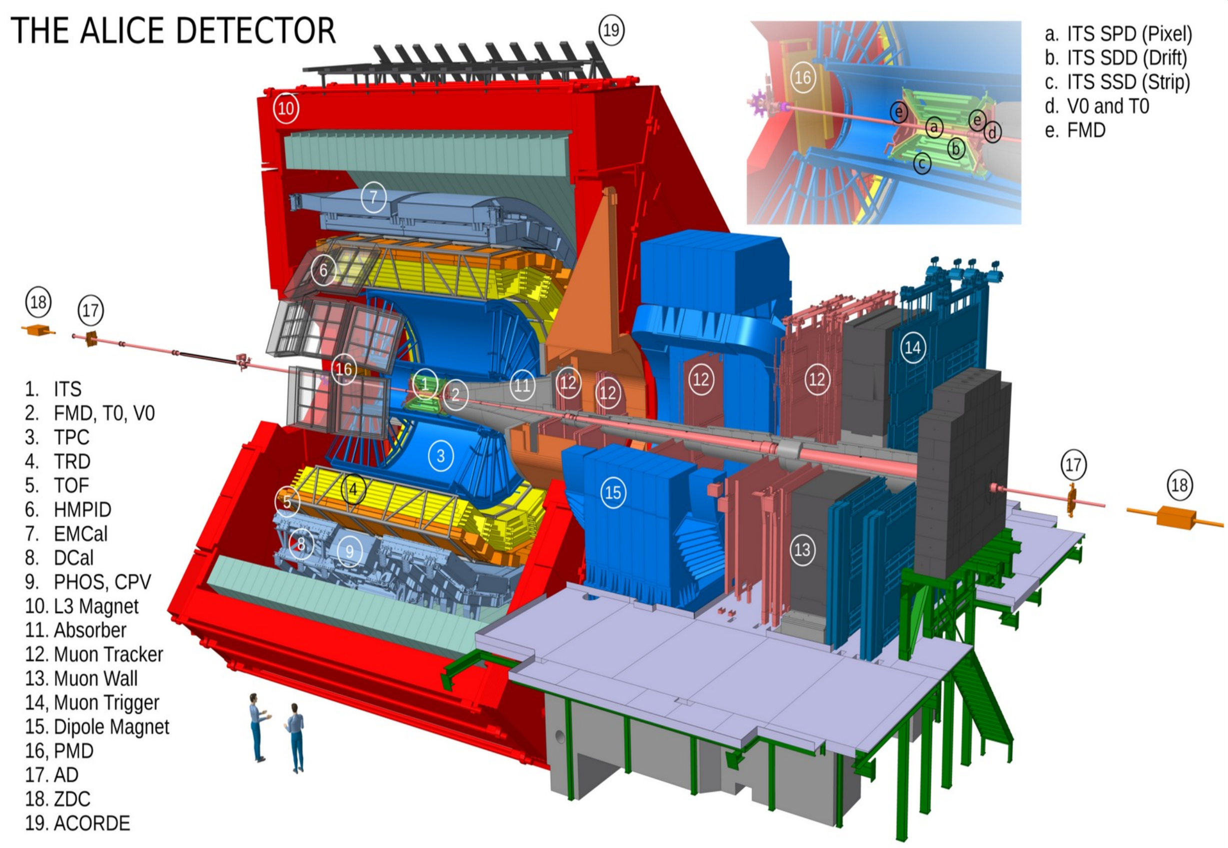
Motivation

- Study the thermodynamic property and explore the collective phenomena.
  - p_T – spectra of the identified hadrons carry the information of radial flow, chemical and kinetic freeze-out temperature.

- The particle ratio study helps to understand the hadron chemistry of the particle production.
  - Strangeness enhancement.

- Useful in comparison among the colliding systems.
  - High-multiplicity events are of particular interest because they exhibit behaviours reminiscent with Pb-Pb collisions.
  - Hints of collectivity in small systems (pp and pA).

ALICE Detector System



Inner Tracking System (ITS) |η| < 2.0 :

- ★ **Primary Vertex**
- ★ **Tracking**

Time Projection Chamber (TPC) |η| < 0.8 :

- ★ **Tracking**
- ★ **PID**

Time of Flight (TOF) |η| < 0.9 :

- ★ **PID**

Forward detector (V0):
V0A (2.8< η < 5.1) & V0C (-3.7< η <-1.7)

- ★ **Trigger, Centrality Estimator**

Multiplicity/Centrality event classes definition:

- ★ **V0M**

Analysis details

- Data Set : pp @ 13 TeV
- Period: LHC16l _pass2 (58 runs) (approx 8M events)

- MC Production : Pythia8
- Period: LHC20l7c (Geant 4), anchored to LHC16l_pass2

Event selection cuts:

- Physics selection: AliEventCuts:kHighMultV0
- Vertex Selection: $|V_Z| < 10$ cm.
- Multiplicity Estimator: V0M

- **Multiplicity bin (%):** 0-0.01(HM1), 0.01-0.05(HM2), 0.05-0.1(HM3)

Multiplicity Class	No. Of Events
HM1	0.78M
HM2	3.2M
HM3	4.01M

Track selection cuts:

- Hybrid Cut
  - FilterMask =816 (16(loose DCA) + 32 (Tight DCA) + 256 +512(Hybrids))
- Rapidity distribution Cut:
  - $|y|<0.5$
- TPC cluster cut
  - TPC has minimum 70 clusters

Analysis crew

- ITS stand alone
  - **Rajendra Nath Patra:** University of Jammu (IN)

- TPC+ TOF fits:
  - **Navneet Kumar, Lokesh Kumar:** Deapartment of Physics, Panjab University, Chandigarh (IN)

- Kink topology:
  - **Martha Spyropoulou-Stassinaki:** Department of Physics, National and Kapodistrian University of Athens (GR)

- Coordination:
  - **Nicolo Jacazio:** Universita e INFN, Bologna (IT)
  - **Ivan Ravasenga:** CERN, Geneva

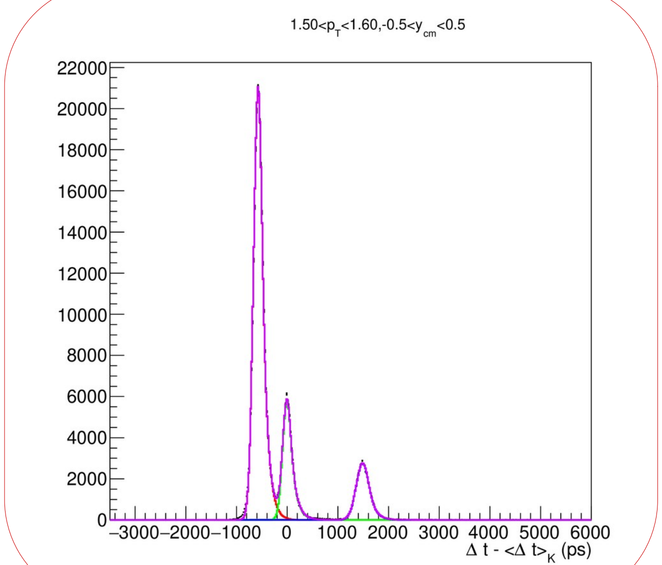
Analysis Region			
	p_T (GeV/c)		
	π	**K**	**p**
ITSsa	0.1-0.75	0.2-0.6	0.3-0.7
TPC-TOF	0.6-4.0	0.6-4.0	0.7-4.0
Kinks	0.25-0.75	0.25-0.95	--

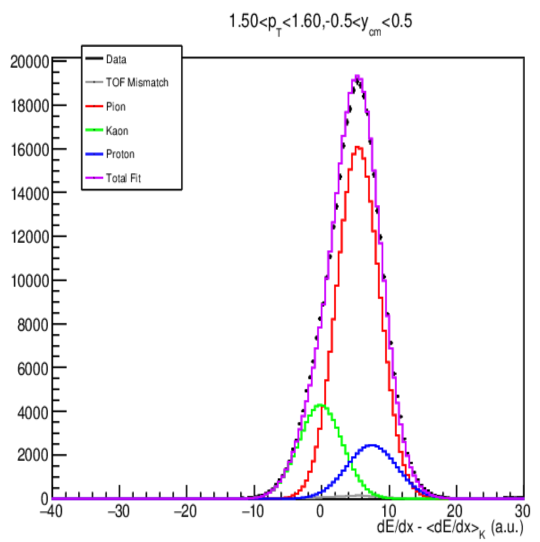
Particle Identifications (PIDs)

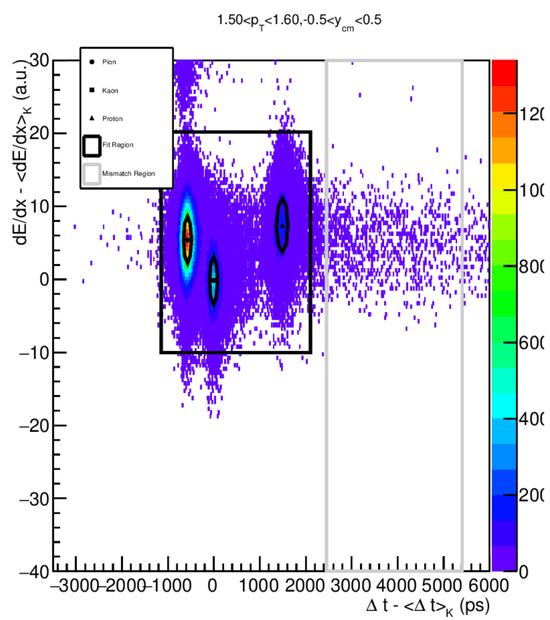
- For PIDs we use combination of both TPC and TOF detctors
- In this analysis we use two dimensions fit method
- For each particle ($\pi/\kappa/p$), the $T_i = t - \langle t \rangle_i$ and $X_i = \frac{dE}{dx} - \left\langle \frac{dE}{dX} \right\rangle_i$ distributions are obtained. $_{|V_z|<10cm}$
- A template is included in the fit for TOF mismatch.
- For Fitting we use a model where every peak in (TOF,TPC) is described as:

$$\frac{dN^2_{tot}}{dT_i dX_i} = \sum \frac{dN^2_j}{dT_i dX_i} + M_i$$

  - The best fitting parameters are found by maximizing the log likelihood of the model.

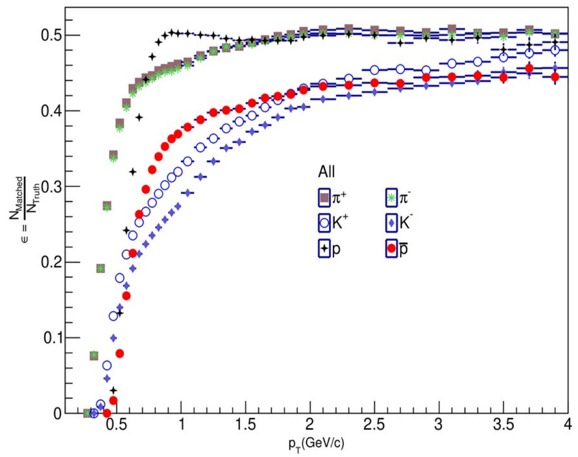




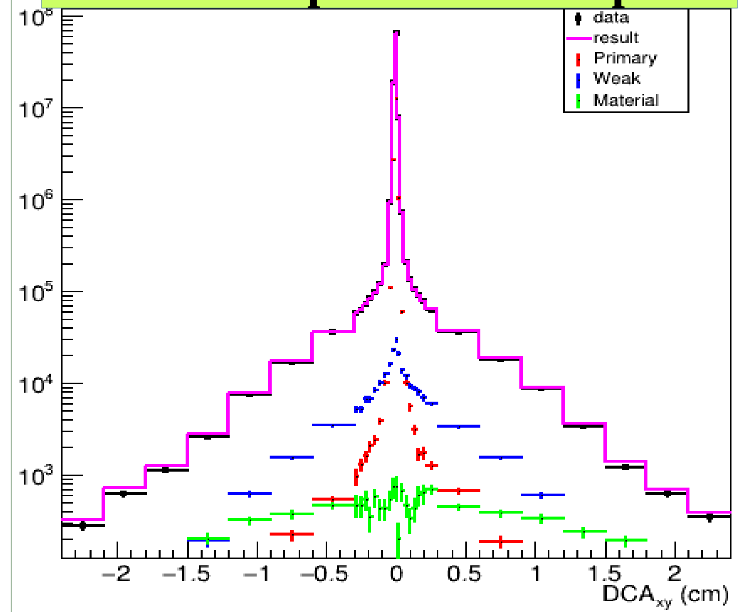


Correction factors

➢ Correction factors for the pions, kaons and protons (Total Efficiency corrections + absorption correction).



DCA Template Fit Example



Pions

- ★ Tracking efficiency
- ★ Matching efficiency
- ★ PID efficiency
- ★ Feed-down corrections

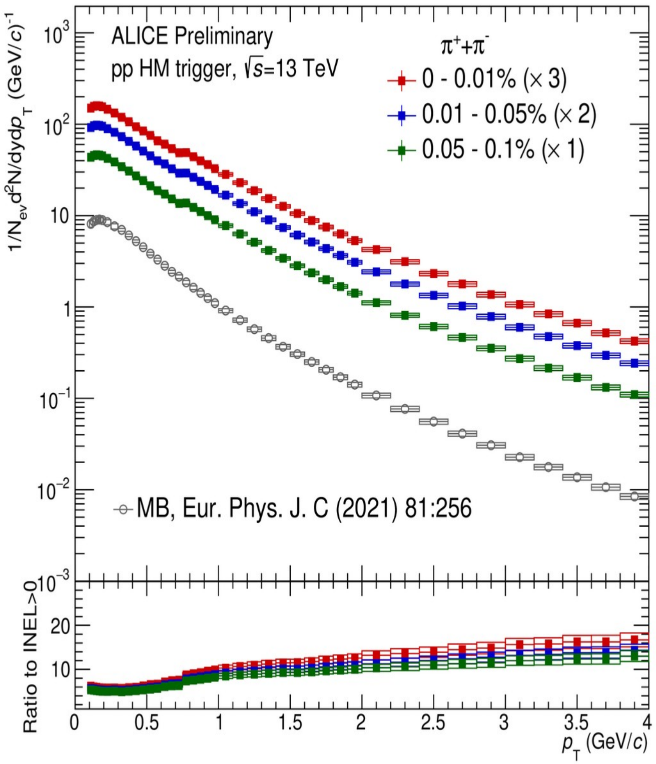
Kaons

- ★ Tracking efficiency
- ★ Matching efficiency
- ★ PID efficiency

Protons

- ★ Tracking efficiency
- ★ Matching efficiency
- ★ PID efficiency
- ★ Feed-down corrections
- ★ Geant4 absorption corrections

Light flavor spectra in HM pp events



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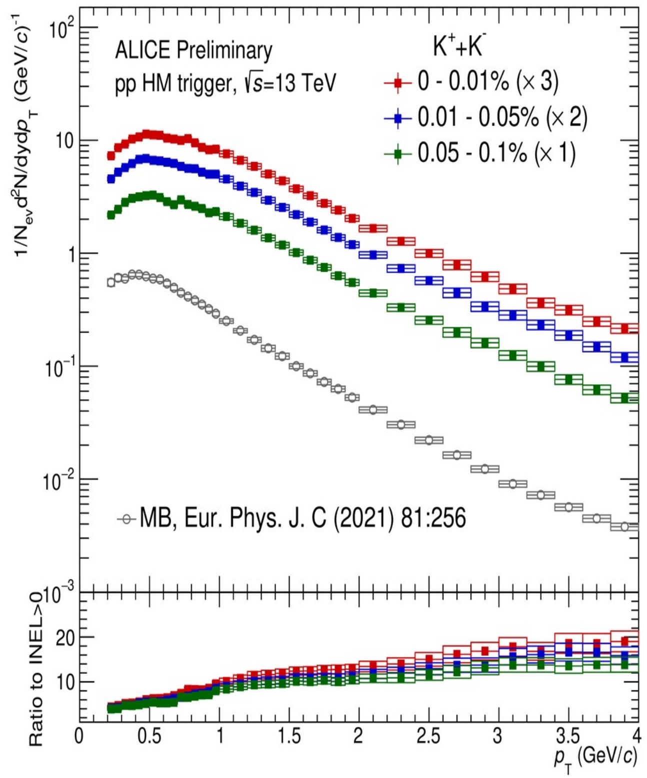

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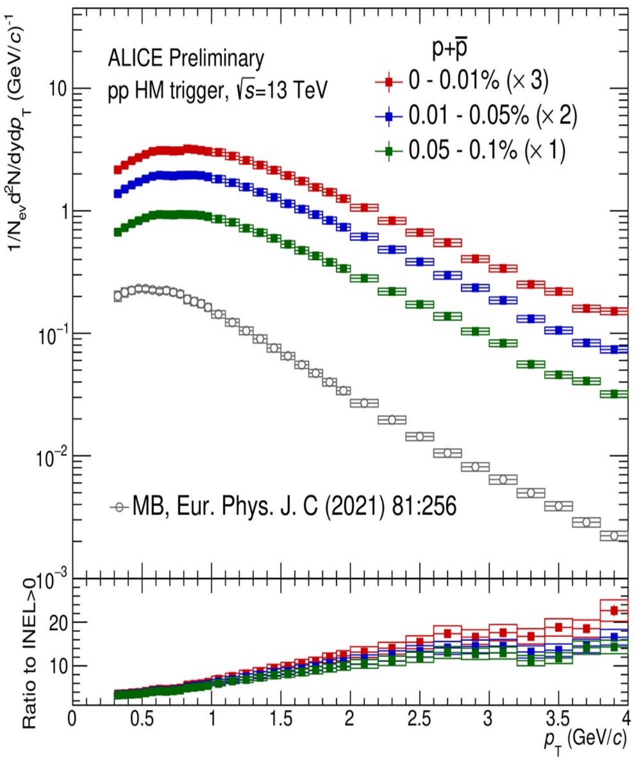

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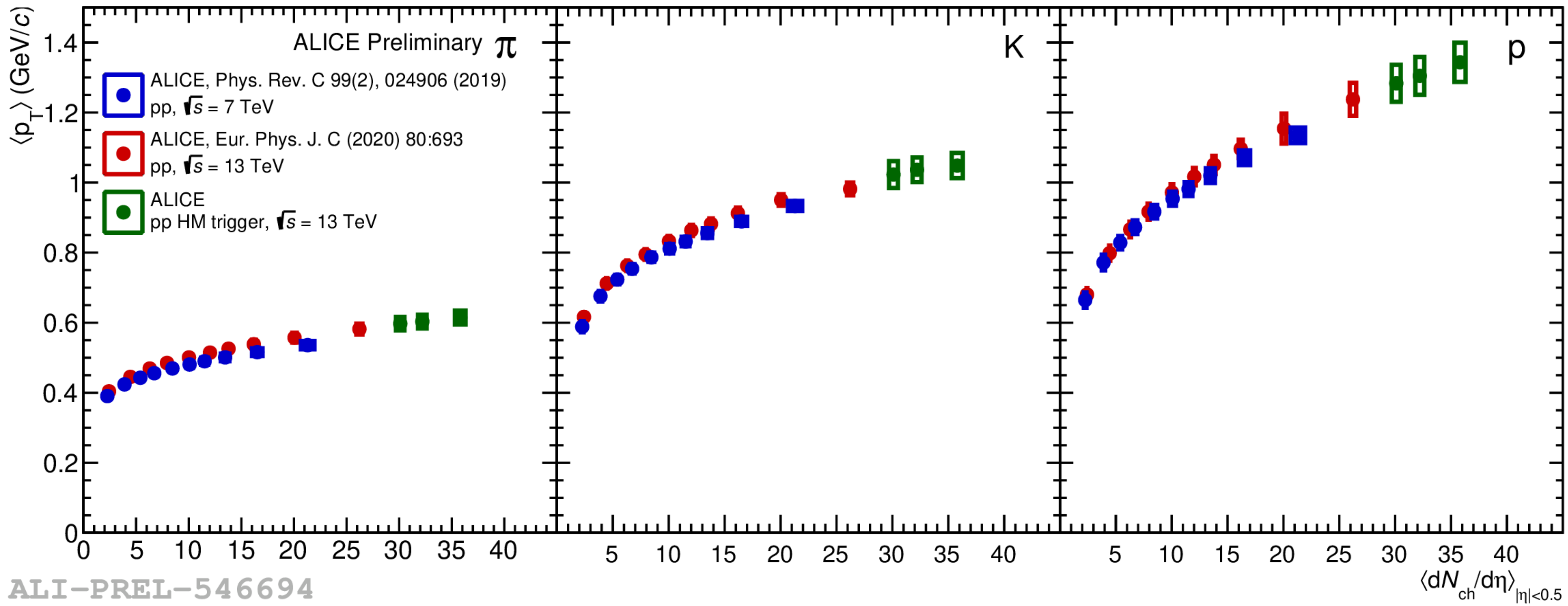
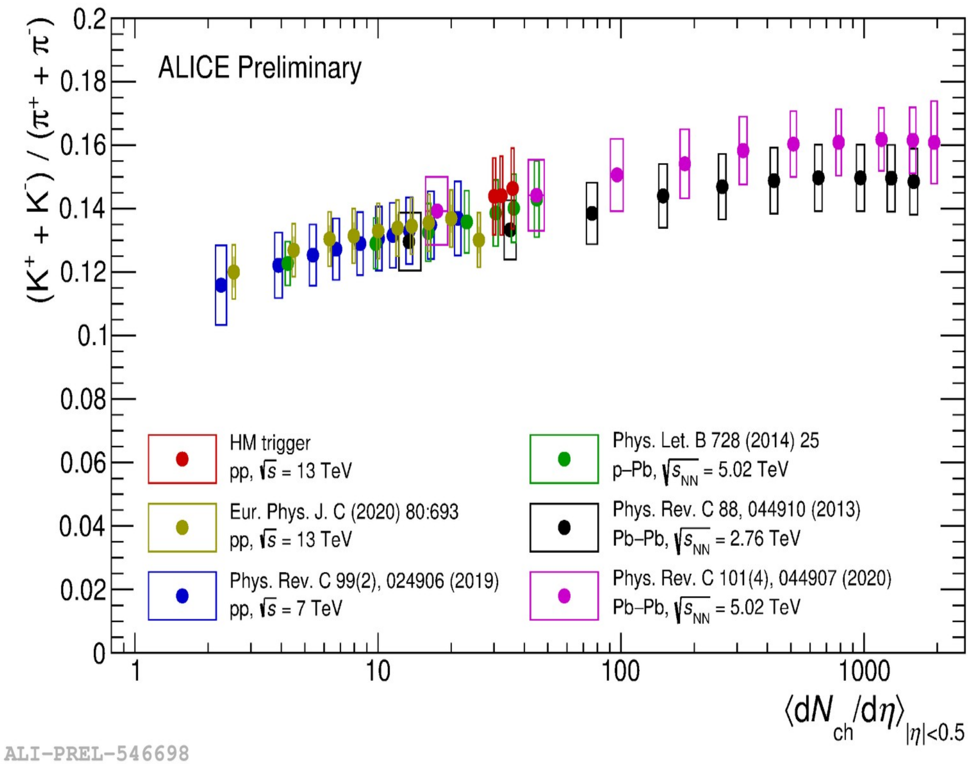
- p_T spectra of π, K, p for pp, 13 TeV HM classes. The ratio to MB spectra [EPJ C (2021) 81:256].
  – mass dependent hardening can be observed.

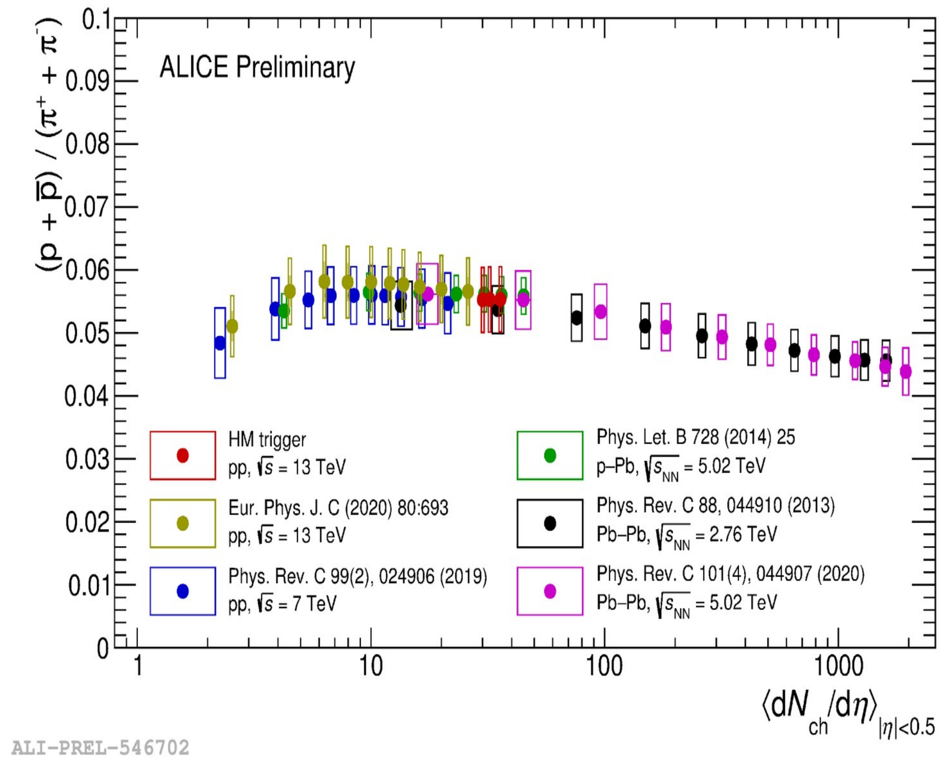
$\langle p_T \rangle$ measurement in pp collisions



- Multiplicity dependent p_T increases in pp system as found in Pb–Pb collisions,
- The increase is steeper with mass - supports the picture of the collective evolution (radial flow)

Ratio of particles (K/π and p/π)



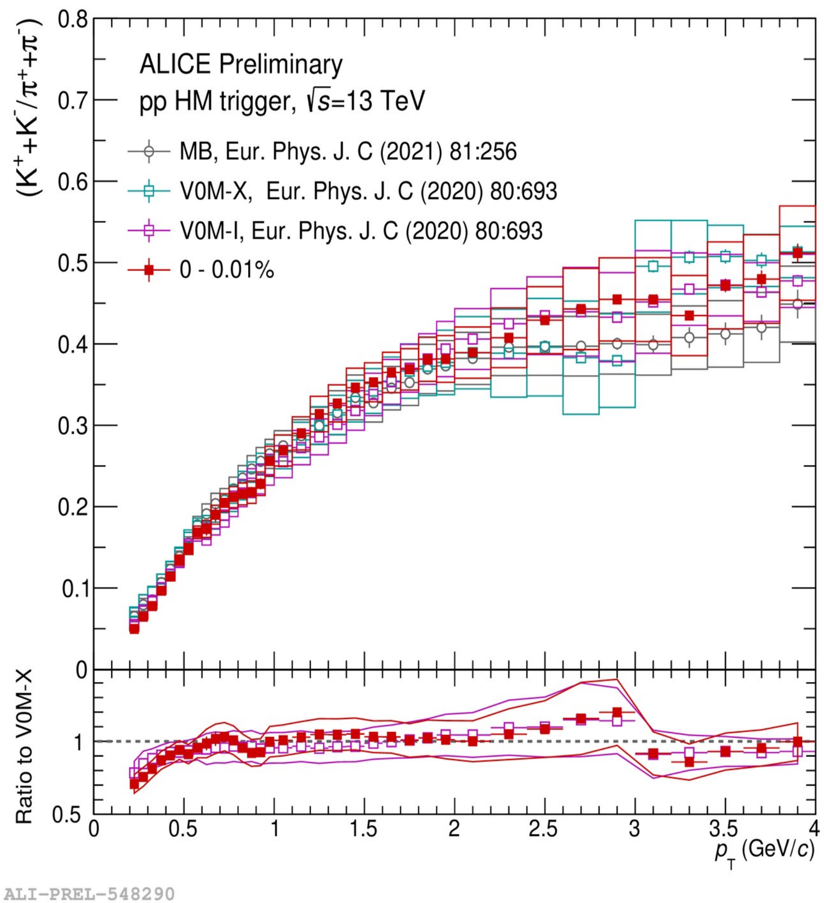


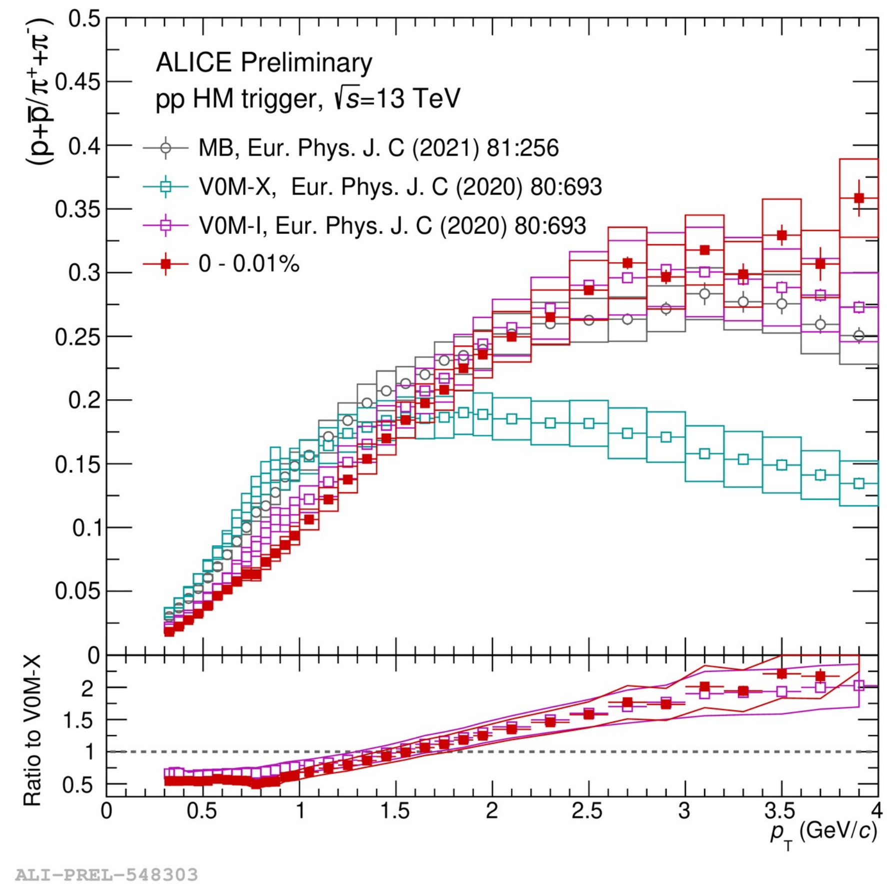
- Smooth transition of ratio of the particles from pp to Pb–Pb collisions.
- increasing trend of the K/π ratio -> Strangeness enhancement
- Decreasing trend in the p/π interpreted as antibaryon-baryon annihilation.

The HM results follow the smooth transition.

- K/π and p/π ratios at pp s = 13 TeV HM results confirm the trend.
- Ratios at high multiplicity of small system reach results of AA systems.

Ratio of p_T spectra of HM pp (K/π and p/π)





- K/π and p/π compared among different multiplicity events of pp system.
- High multiplicity results shows similar trend in the given p_T range . The ratio to V0M-X class shows an enhancement of p/π with increasing p_T – similar effect to radial flow.

Summary

- π, K and p spectra results for pp high multiplicity events presented and compared with published results and p/π compared among different multiplicity events of pp system.
- High multiplicity small system exhibits features of AA collisions.
- • Radial flow effect can be observed from mass dependent p_T spectra.
  • Multiplicity dependent p_T shows mass ordering followed in small system - radial flow.
  • Hadron chemistry driven by multiplicity and not by collision energy nor system.
- • Enhancement of p/π of p_T spectra at low p_T similar to AA system.

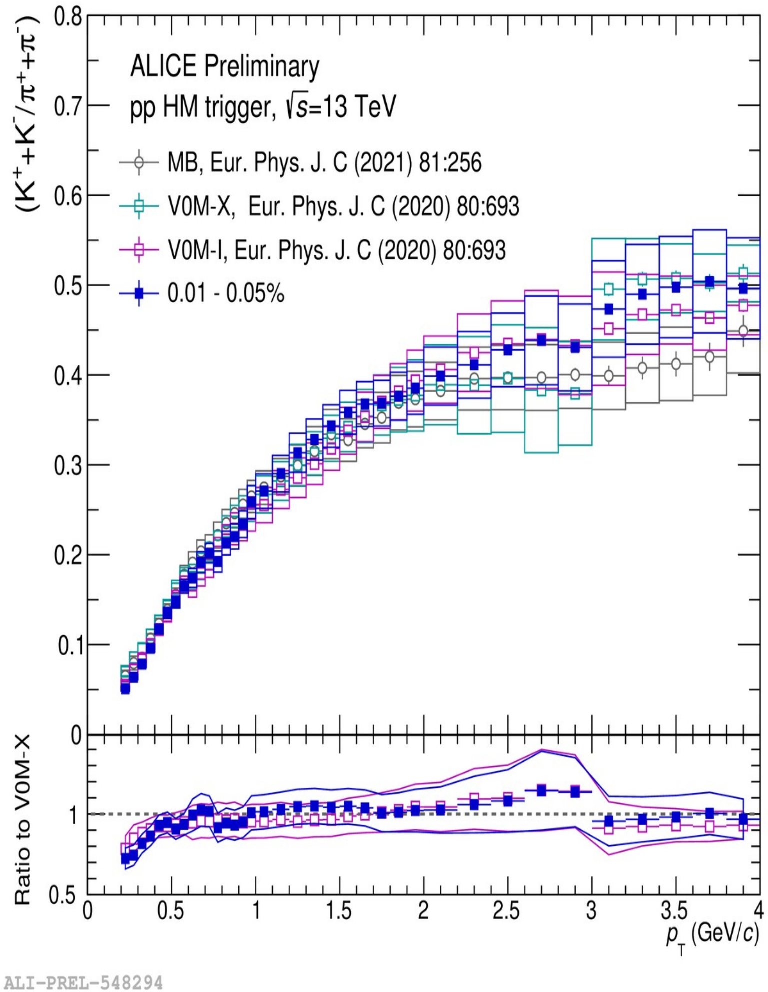
Outlook

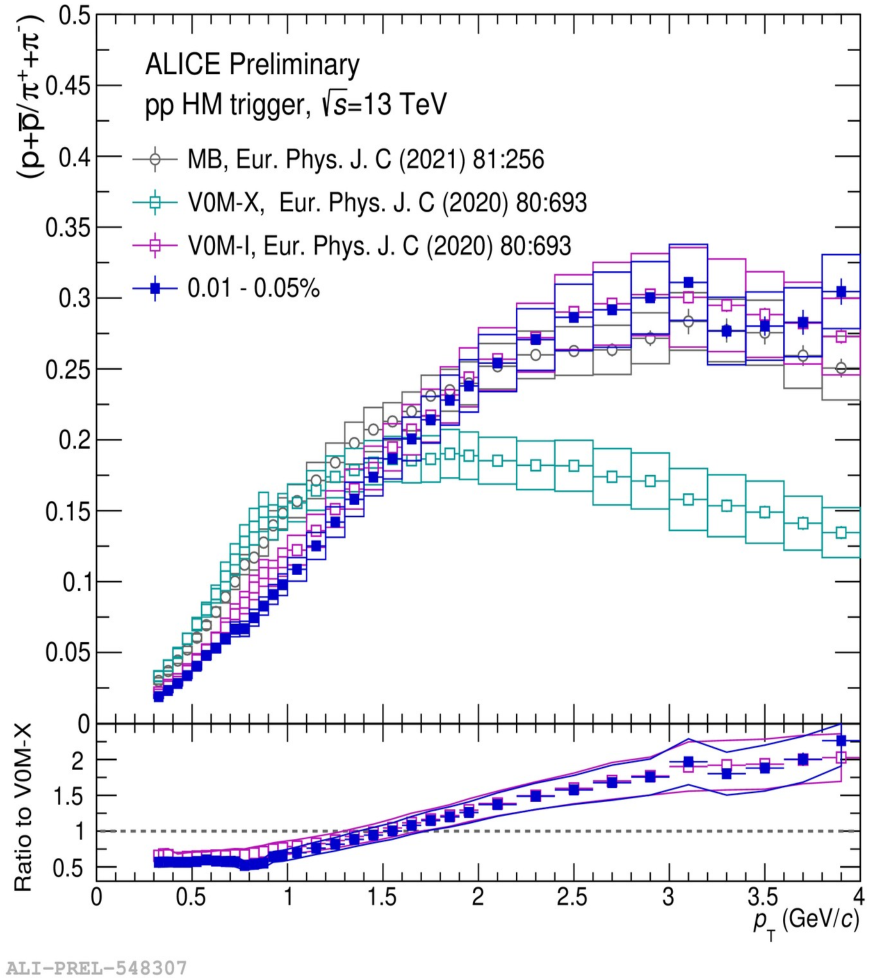
◆Obtain the physics results and proceed with the paper proposal.

Thank You

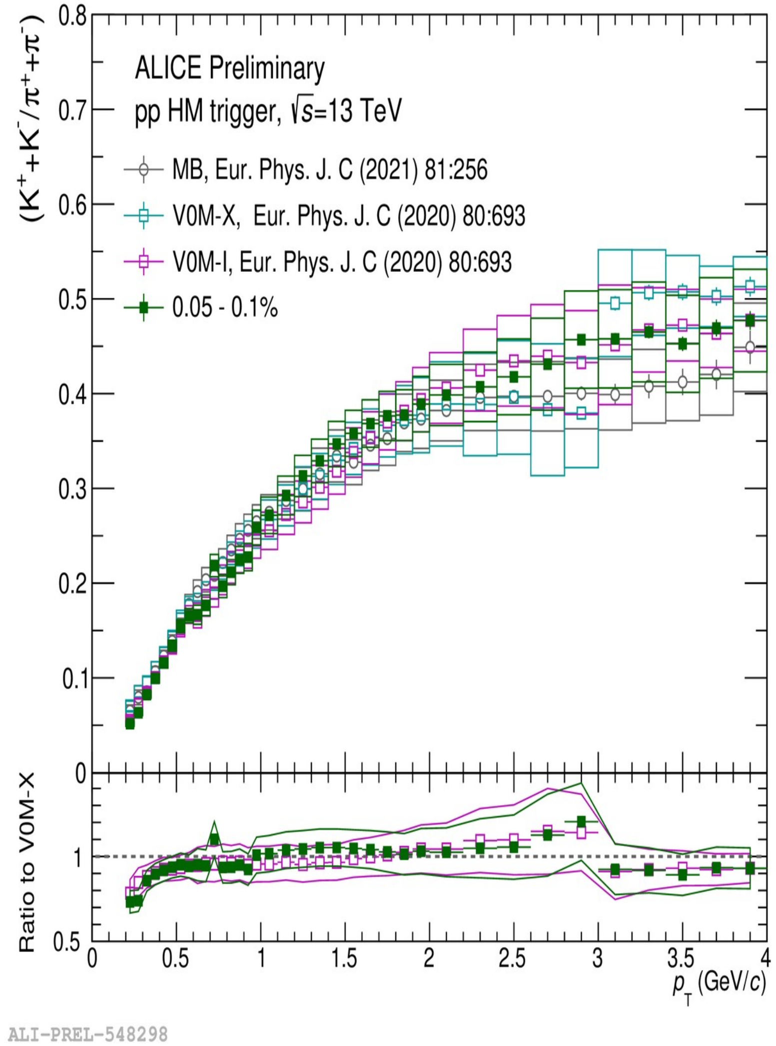
Backup

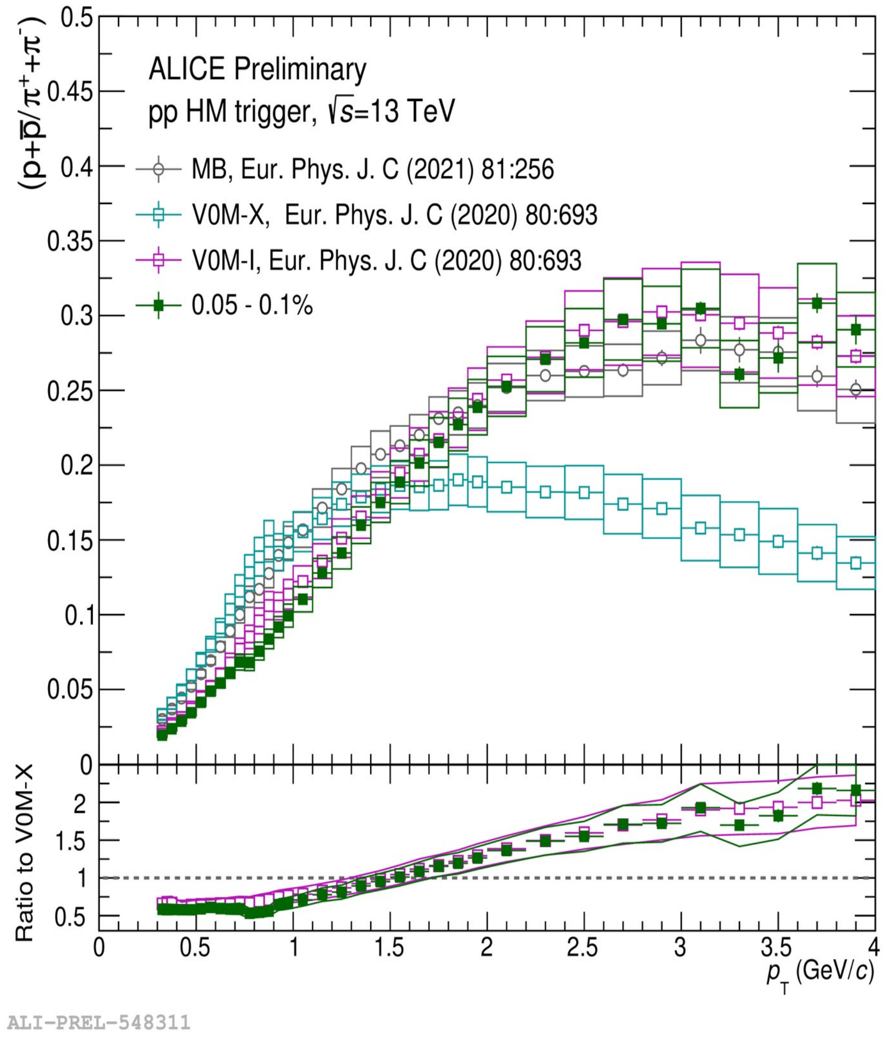
Ratio of p_T spectra of HM pp (K/π and p/π)





Ratio of p_T spectra of HM pp (K/π and p/π)





Corrections

- $tracking\, efficiency = \frac{No.\, of\ reconstructed\ tracks}{No.\, of\ generated\ tracks}$
- $PID\, efficiency = \frac{N_{rec,PID}(p_T, \eta)}{N_{rec,tot}(p_T, \eta)}$
- Z-Vertex corrections: $C_{zvtx} = \left(\frac{N^{MC}_{|z|<10}}{N^{MC}_{gvtx}}\right) / \left(\frac{N^{data}_{|z|<10}}{N^{data}_{gvtx}}\right) = 1.0029.$
- Secondary Corrections: Data-driven procedure is used to determine the fraction of secondaries.

TOF and TPC Analysis details

- For PIDs we use both TOF and TPC detctors
- In this analysis we use two dimensions fit method
  - Major problems: The distance between the peaks in the PID signal is not fixed. (It is a function of p_T and η)
  - Since we are doing the 2D fits therefore corressponds to each fit we have six parameters.
  - TPC response: $T_i = t - \langle t \rangle_i \qquad i \in \{\pi, \kappa, p\}$
  - TOF reponse: $X_i = \frac{dE}{dx} - \left\langle \frac{dE}{dX} \right\rangle_i$
  - $\langle a \rangle_i = expected\ value\ of\ parameter\ a\ given\ the\ reconstructed\ momentum$
  - The TPC signal is well described as:

$$\frac{dN_j}{dX_i} = \frac{N_{j,tot}}{\sqrt{2\pi}\sigma_{j|i}} \exp\left(\frac{-(X_i - \mu_{j|i})}{2\sigma^2_{j|i}}\right)$$

  - The TOF signal is described as:

$$\frac{dN_j}{dT_i} = \frac{N_{j,tot} A_{j|i}}{\sqrt{2\pi}\sigma_{j|i}} \begin{cases} \exp\left(\frac{-(T_i - \mu_{i|j})^2}{2\sigma^2_{j|i}}\right) & T_i < \kappa_{j|i} + \mu_{j|i} \\ \exp(-\lambda_{j|i}(T_i - \mu_{j|i})) + B_{j|i} & T_i > \kappa_{j|i} + \mu_{j|i} \end{cases}$$

Contd ... **TOF Mismatch**

- A template is included in the fit for TOF mismatch.
- The template is generated by assigning a random time to each track.

$$T_{randomhit} = fT0Fill \rightarrow GetRandom() - tofill + currentRndTime$$

- The fill time is: t0fill = -1.26416 * 10^4 ps.
- $$curretRndTime = \frac{currentRndlength}{c}$$
- CurrentRndlength is the distance (straight) from the interaction point to the cluster.

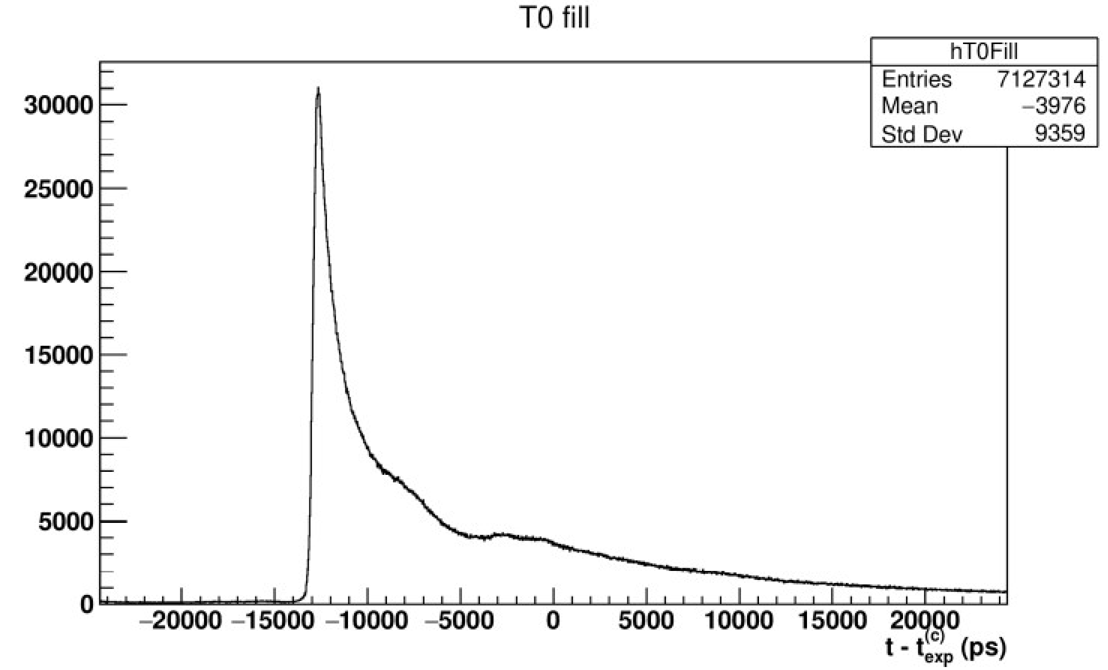


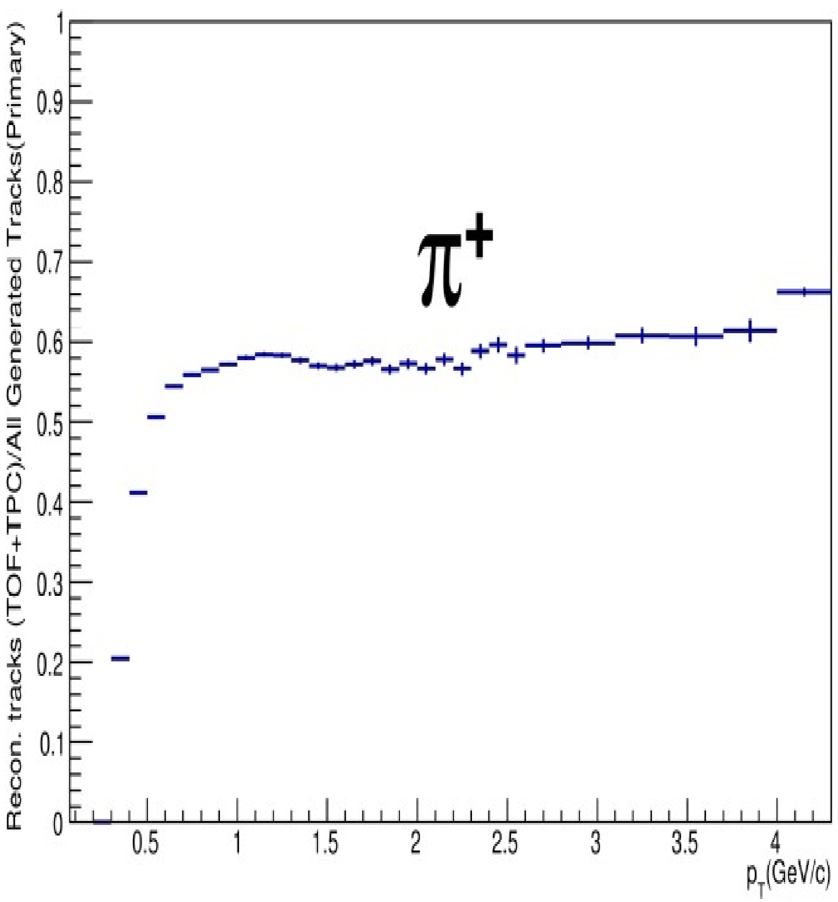
Fig. Examples of TO fill Histogram (run 116571)

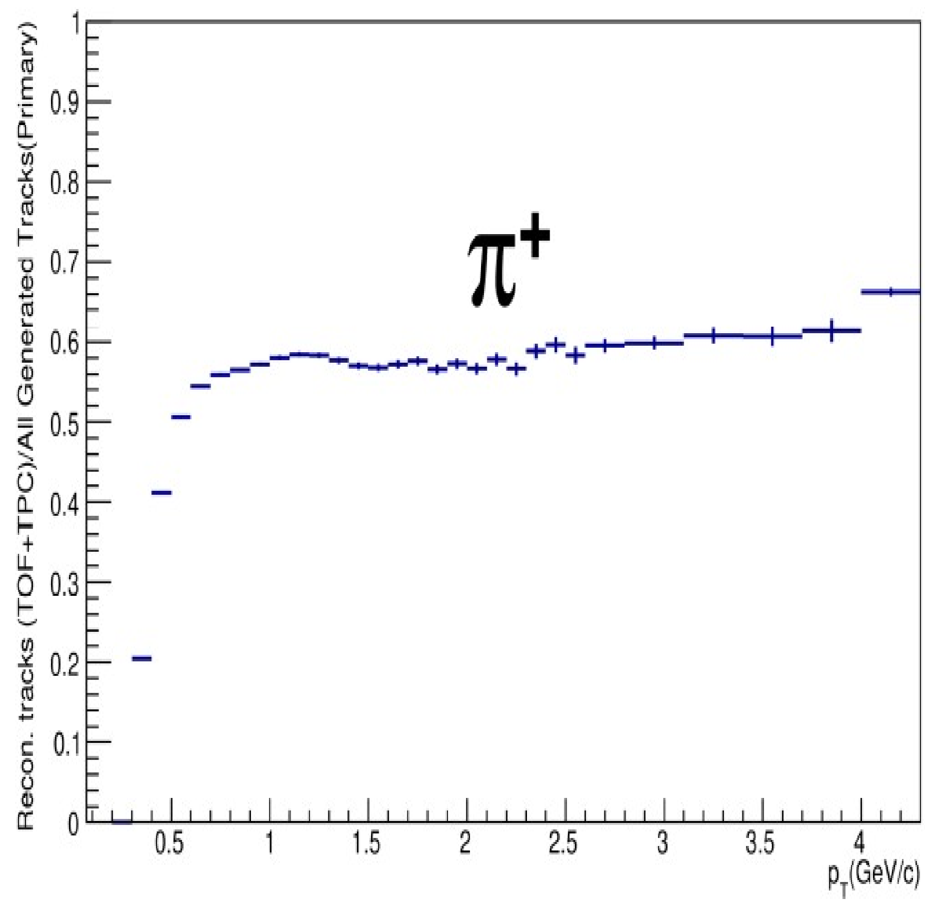
Corrections

PID Efficiency (Pions)

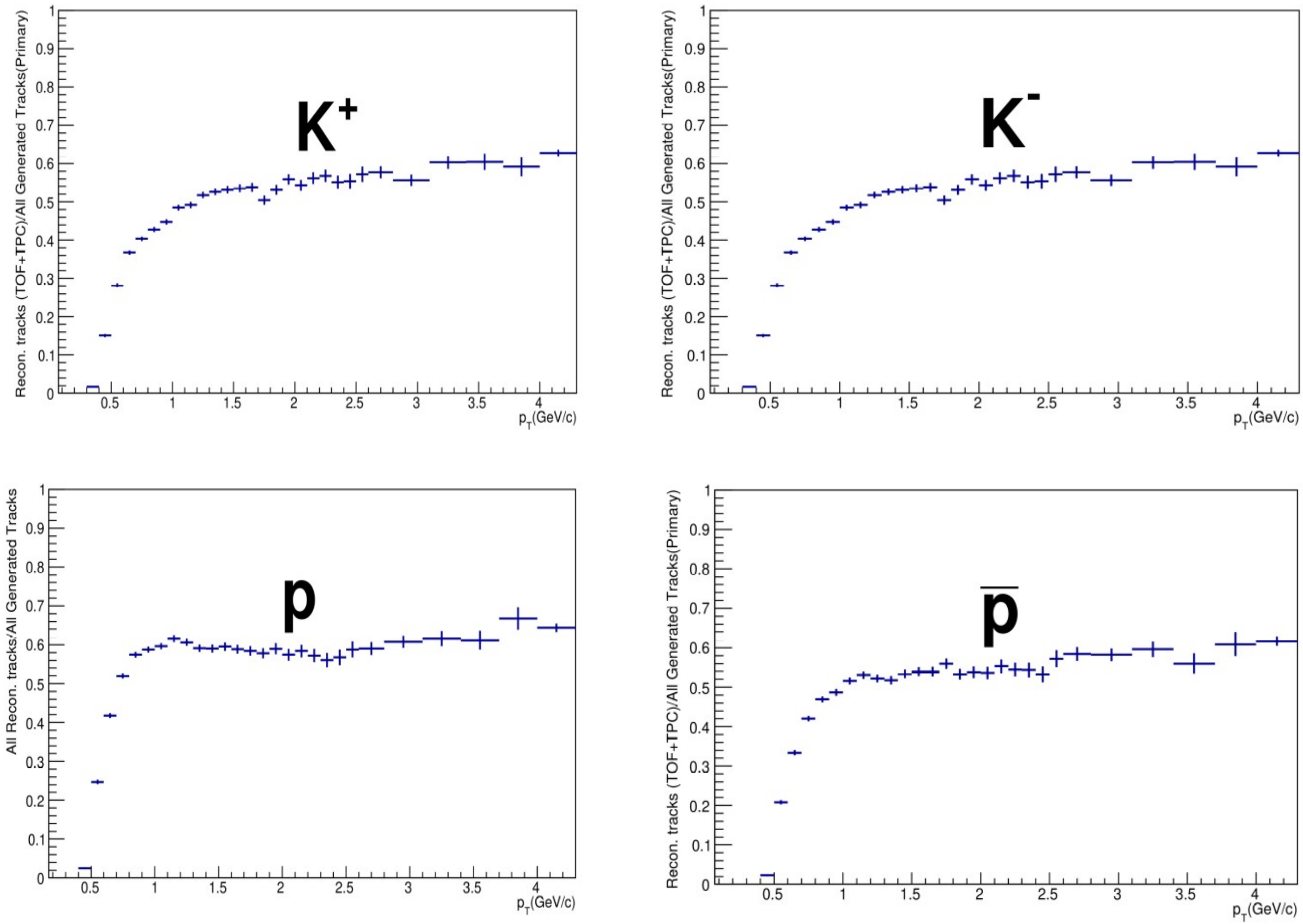
$$\varepsilon = \frac{Reconstructed\, tracks\, with\, PID\, signal}{Total\, number\, of\, reconstructed\, tracks}$$

Have you check how you calculated the tracking efficiecy.





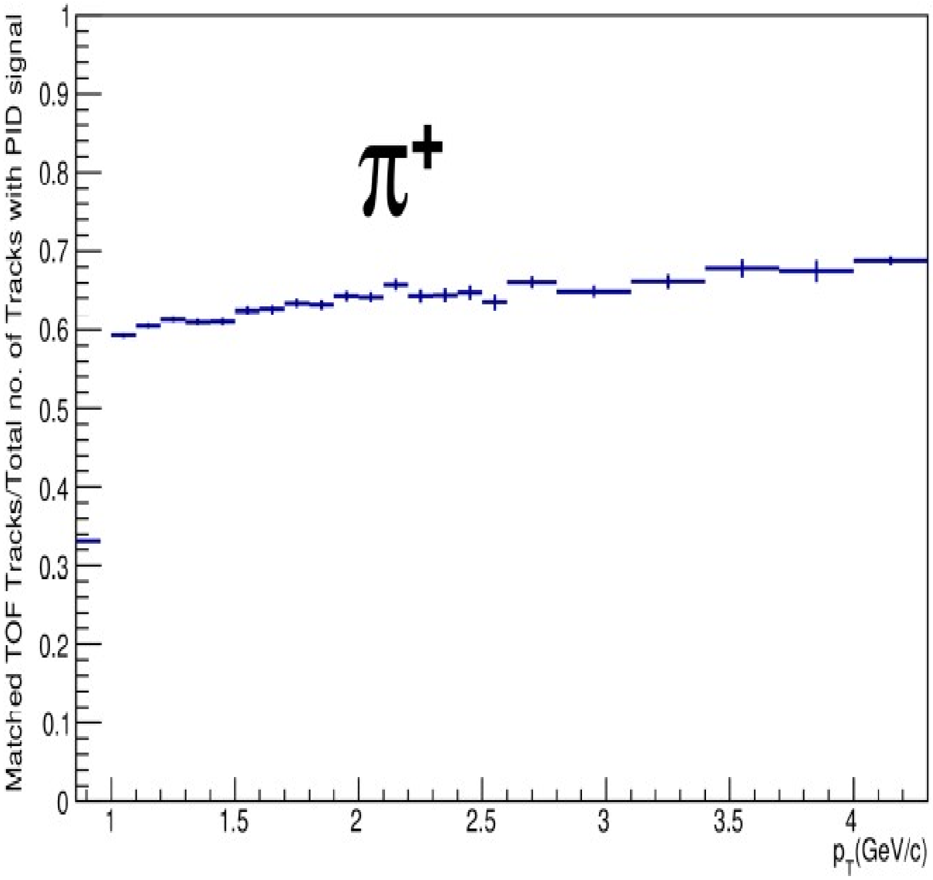
PID Efficiency (kaons and protons)

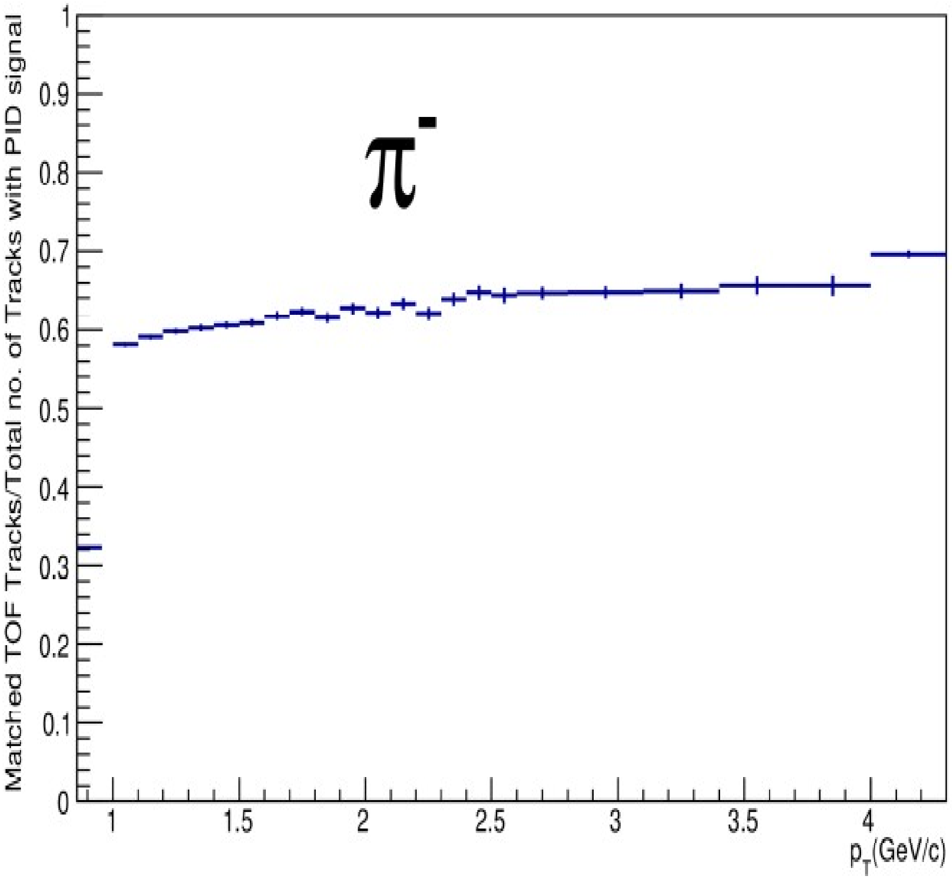


Corrections

TOF Matching Efficiency (Pions)

$$\varepsilon = \frac{Correctly\ matched\ tarcks}{Total\ Number\ of\ tracks\ with\ PID\ signal}$$





Secondary Corrections

Loose DCA cut on data.

$$\frac{\sqrt{x_{DCA}^2 + y_{DCA}^2}}{2.4\text{cm}} + \frac{z_{DCA}}{3.2\text{cm}} < 1$$

Tight DCA cut on data.

$$\sqrt{x_{DCA}^2 + y_{DCA}^2} < \left(0.0182 + \frac{0.0350}{p_T^{1.01}}\right)\text{cm}$$

To achieve the high purity of the sample we apply a strict cut on TOF and TPC as:

$$\sqrt{(n\,\sigma_{TOF})^2 + (n\,\sigma_{TPC})^2} < 1$$

The fractions of primaries after the DCA cut:

- $$f_{\text{prim}}^{\text{tight}} = \frac{\alpha_{\text{prim}} f_{\text{prim}}^{\text{loose}}}{\alpha_{\text{prim}} f_{\text{prim}}^{\text{loose}} + \alpha_{\text{weak}} f_{\text{weak}}^{\text{loose}} + \alpha_{\text{mat}} f_{\text{mat}}^{\text{loose}}}$$
- Where $\alpha_{prim}(p_T) = \frac{N_{prim}^{tight}}{N_{prim}^{loose}}$