Measurements of $\pi^\pm, K^\pm, p(\bar{p})$ in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.36 TeV

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Physics Motivation

Why study hadrons?

Understanding the production of hadrons in high energy collisions is crucial for probing the fundamental properties of matter under extreme conditions of density and temperature.

They serve as essential probes for studying the **Q**uark-**G**luon **P**lasma (**QGP**), a state of matter believed to have existed shortly after the Big Bang, where quarks and gluons are not confined within hadrons.

Impact of this study

The precise measurement of π, K, and p production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.36 TeV provides a comprehensive picture of the particle production mechanisms and the properties of the QGP. By comparing these results with previous data from different collision energies and systems, we can trace the evolution of the QGP and gain deeper insights into the strong force governing hadronic matter. This study contributes to the broader effort of understanding the fundamental nature of matter and the early universe's conditions.

Why study π, K, and p in Pb-Pb Collisions?

➢ **QGP formation:**
Understanding how π, K, and p are produced helps us decipher the dynamics of this hot and dense medium

➢ **Hadronization process:**
This process provides valuable information about the confinement mechanism in **Q**uantum **C**hromo**D**ynamics (**QCD**)
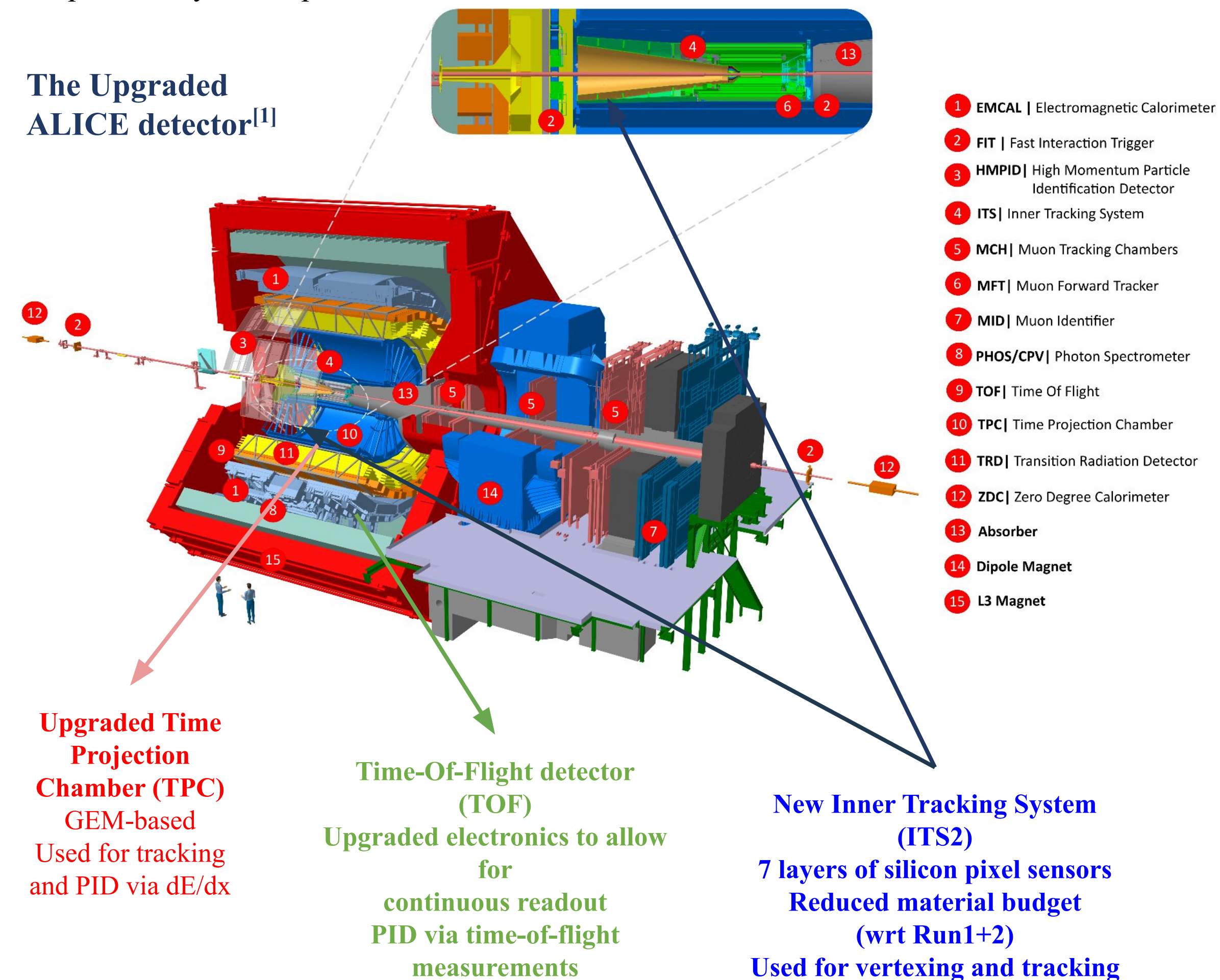
➢ **Strangeness enhancement:**
Kaons, containing strange quarks, are particularly interesting for studying strangeness enhancement, a phenomenon observed in heavy-ion collisions. This enhancement serves as a signature of QGP formation and provides insights into the strangeness production mechanisms.
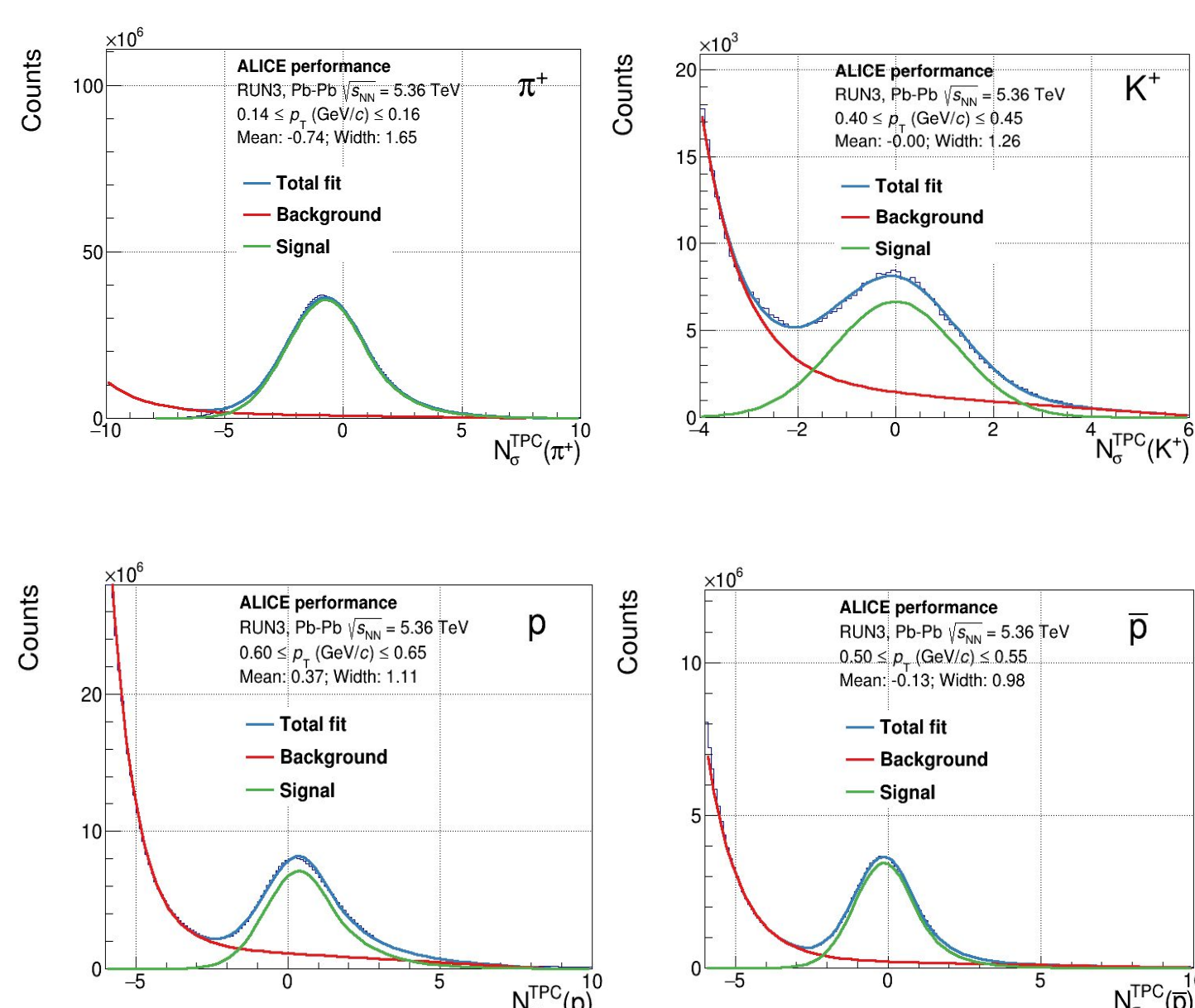
The ALICE detector at the LHC RUN 3

The main physics goal of the **A** **L**arge **I**on **C**ollider **E**xperiment (**ALICE**) is the study of the dense and hot matter created in ultra-relativistic heavy-ion collisions: the **QGP**

The excellent **P**article **ID**entification (**PID**) capabilities of ALICE apparatus allow to identify particles down to very low transverse momentum (~100 MeV/c) exploiting different complementary techniques

The Upgraded ALICE detector[1]

1. **EMCAL** | Electromagnetic Calorimeter
2. **FIT** | Fast Interaction Trigger
3. **HMPID** | High Momentum Particle Identification Detector
4. **ITS** | Inner Tracking System
5. **MCH** | Muon Tracking Chambers
6. **MFT** | Muon Forward Tracker
7. **MID** | Muon Identifier
8. **PHOS/CPV** | Photon Spectrometer
9. **TOF** | Time Of Flight
10. **TPC** | Time Projection Chamber
11. **TRD** | Transition Radiation Detector
12. **ZDC** | Zero Degree Calorimeter
13. Absorber
14. Dipole Magnet
15. L3 Magnet

Upgraded Time Projection Chamber (TPC)
GEM-based
Used for tracking and PID via dE/dx

Time-Of-Flight detector (TOF)
Upgraded electronics to allow for continuous readout
PID via time-of-flight measurements

New Inner Tracking System (ITS2)
7 layers of silicon pixel sensors
Reduced material budget (wrt Run1+2)
Used for vertexing and tracking

Methodology

The particle number in a given p_T interval is determined by taking the integral of the $n_{\sigma,TPC(TOF)}$ distributions which are defined as follows:
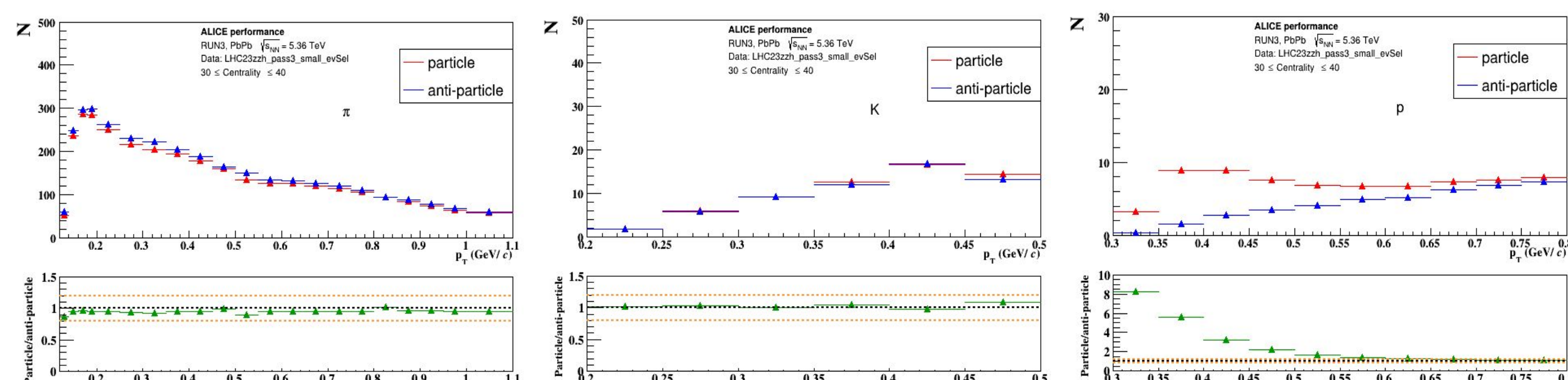
$$n_{\sigma,TPC} = (dE/dx - \langle dE/dx \rangle_i)/\sigma_{dE/dx}$$
$$n_{\sigma,TOF} = (\Delta t - \Delta t_i)/\sigma_{TOF};$$
where, $i = \pi^+, K^+, p(\bar{p})$

To ensure accurate measurements, the n_σ distributions are divided into different p_T bins before undergoing the unfolding procedure. Unfolding is performed using a combination of linear, polynomial, and Gaussian functions, enabling the extraction of the particle spectra.

Results

The comparison of raw yields ($\pi^\pm, K^\pm$) reveals parity between positive and negative particles, albeit with a slight predominance of negative counts. This phenomenon is consistent with theoretical expectations, attributing the surplus of anti-particles to the decay processes of heavier particles. While for p, presence of secondaries from material enhance the raw yield as compared to $\bar{p}$.
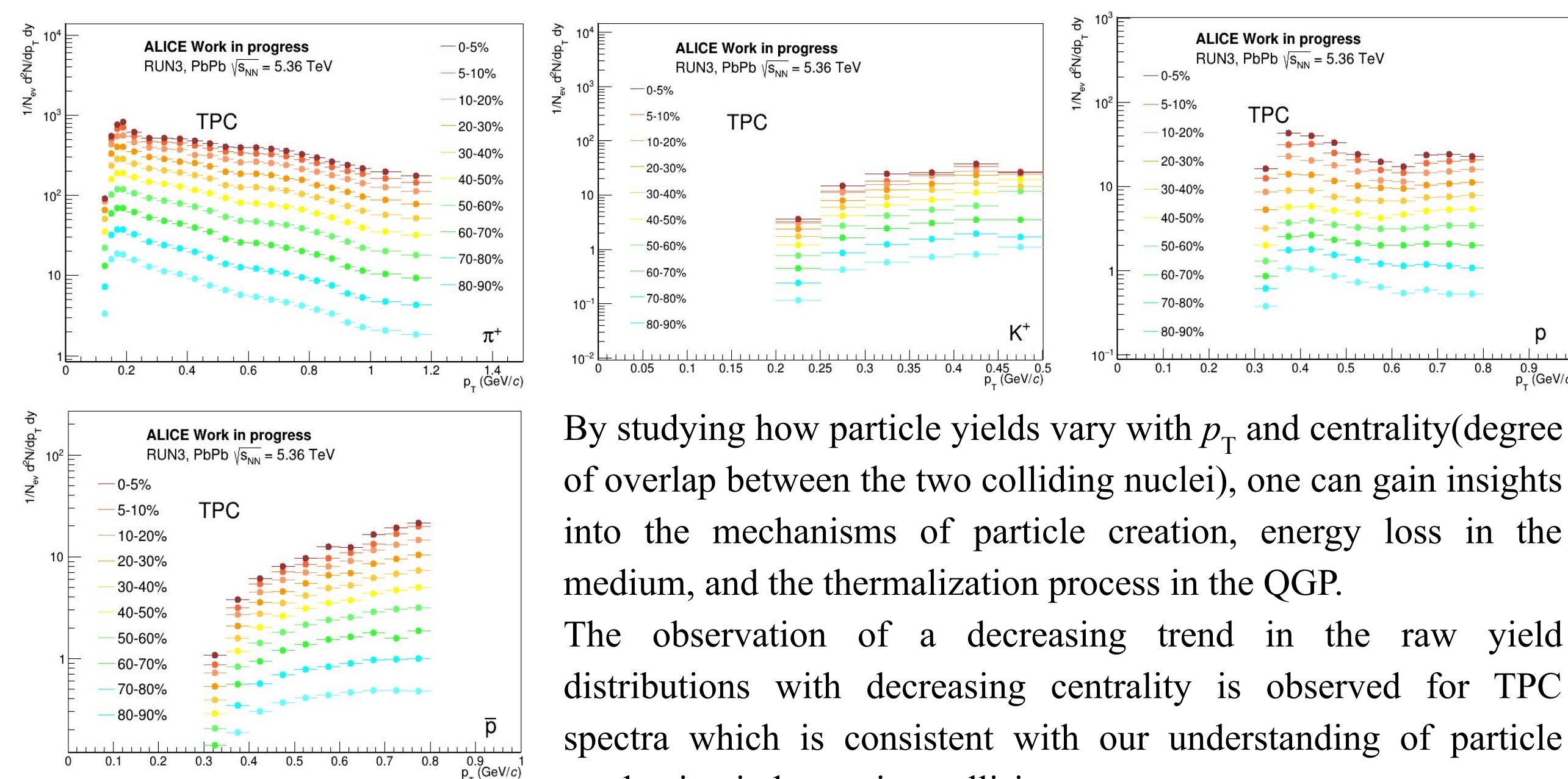

By studying how particle yields vary with p_T and centrality(degree of overlap between the two colliding nuclei), one can gain insights into the mechanisms of particle creation, energy loss in the medium, and the thermalization process in the QGP.

The observation of a decreasing trend in the raw yield distributions with decreasing centrality is observed for TPC spectra which is consistent with our understanding of particle production in heavy-ion collisions.
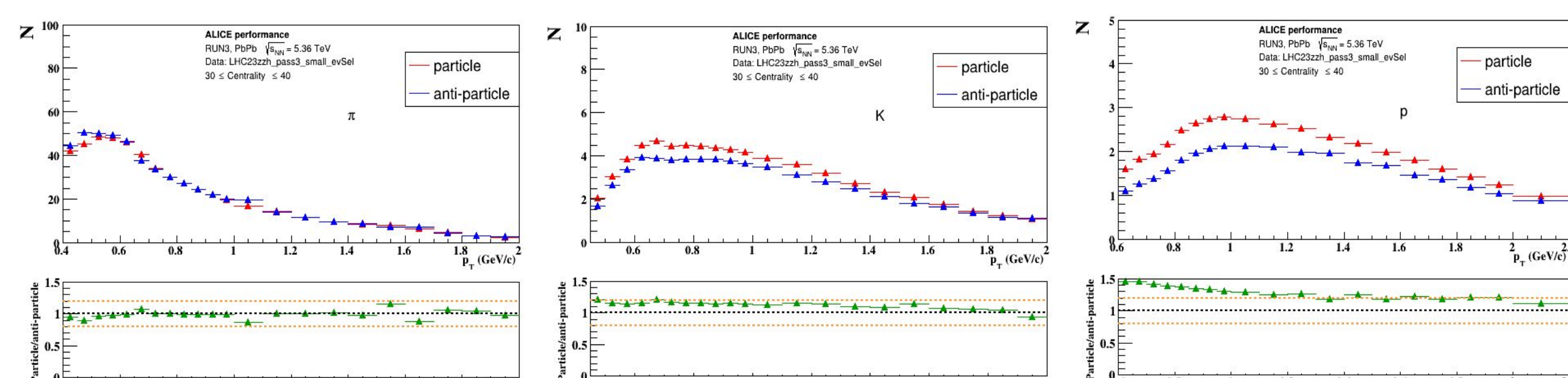
The analysis reveals balanced π^+ and π^- production, suggesting symmetrical generation mechanisms. However, an unexpected increase in K^+ compared to K^- warrants further investigation. Additionally, asymmetry between p and $\bar{p}$ at lower p_T suggests secondary contributions, impacting p and $\bar{p}$ yields.
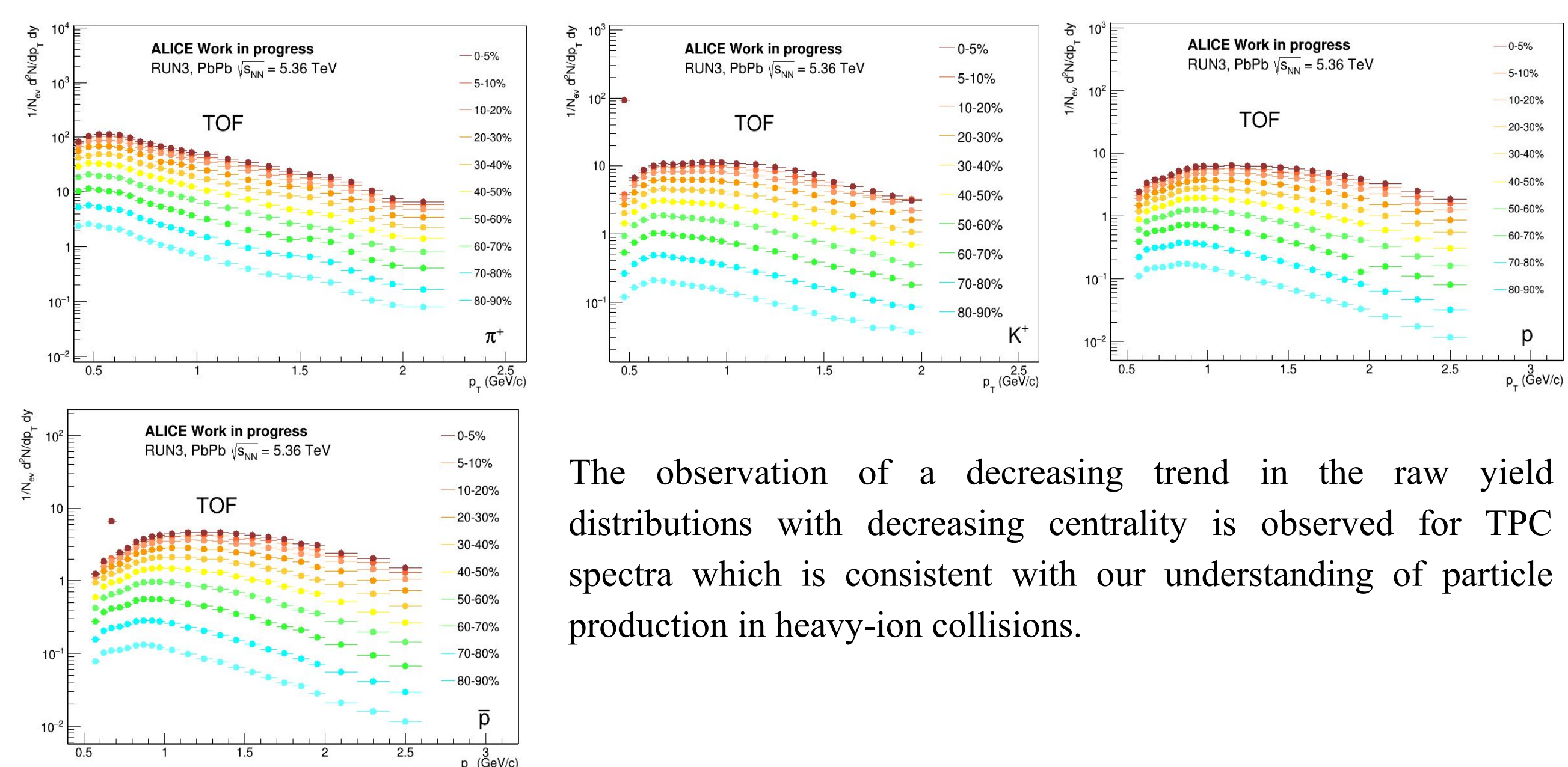
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Future Plans

Now that we have acquired the raw spectra, the next step will be to apply correction procedures to refine and validate our data. Beginning with a meticulous consideration of detector efficiencies in both the TPC and TOF systems, we will quantify the detectors' ability to reconstruct particle trajectories accurately. Subsequent steps will involve calculating the matching efficiency, crucial for ensuring coherence in our measurements. Additionally, we will address the presence of secondary particles by adjusting the spectra accordingly. These corrected spectra will serve as the foundation for rigorous data analysis, allowing for a deeper understanding of the complex physics processes involved. In short, the corrected spectra can be obtained as follows:

TPC correction : (TPC Raw spectra × fraction of primaries) / TPC efficiency

TOF correction : (TOF Raw spectra × fraction of primaries) / (TPC efficiency × TOF efficiency)

References

[1] B Abelev et al., J. Phys. G41 (2014) 087001