Event by Event $\langle p_T \rangle$ Fluctuations of Identified Particles in pp Collisions at $\sqrt{s} = 13.6$ TeV in Run-3 Data

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Outline of the talk

1. Motivation
2. Observable
3. Event and Track Selection Criterion
4. Particle Identification
5. Results

Motivation

- "Dynamical" fluctuations reflect the dynamics and responses of the system
- Help to characterize the properties of the bulk description of the system
- Mean transverse momentum fluctuation is sensitive to temperature/energy fluctuation
- $\langle p_T \rangle$ is independent of the volume as volume fluctuates from one event to the other due to fluctuations of the impact parameter

Motivation

- Fluctuations of $\langle p_T \rangle$ arise from many kinds of correlations among the p_T of the final-state particles, such as resonance decays, jets etc...
- So, E-by-E $\langle p_T \rangle$ fluctuations in pp collisions can be used as a model-independent baseline to search for non-trivial fluctuations in heavy-ion collisions
- By studying this for idenfied particles, one can get an insight into the production and dynamics of the specific particles

Observable

Moments of $\mathrm{p_T}$

$$Q_n = \Sigma_{i=1}^{N_{ch}} (p_i)^n$$

Mean $\mathrm{p_T}$

$$\langle\langle p_T \rangle\rangle_{star} = \langle \frac{Q_1}{N_{ch}} \rangle$$

Two Particle Correlator

$$\langle \Delta p_i \Delta p_j \rangle_{star} = \langle \frac{Q_1^2 - Q_2}{N_{ch}(N_{ch} - 1)} \rangle - \langle \frac{Q_1}{N_{ch}} \rangle^2$$

- Angular brackets denote an average over events in a multiplicity class

https://journals.aps.org/prc/pdf/10.1103/PhysRevC.103.024910

Observable

$\frac{\sqrt{\langle \Delta p_i \Delta p_j \rangle}}{\langle\langle p_T \rangle\rangle} \rightarrow$ Dynamical $\langle p_T \rangle$ fluctuations relative to $\langle p_T \rangle$

- Reduces the dependence on the detection efficiency

Event Selection Criterion

pp Collisions

- $\sqrt{s} = 13.6$ TeV

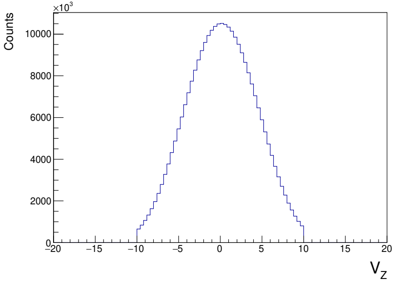
Data Set

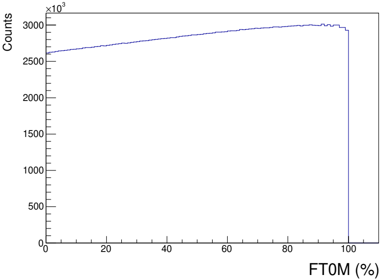
- LHC22m_apass4
- Number of Events ≈ 285 M

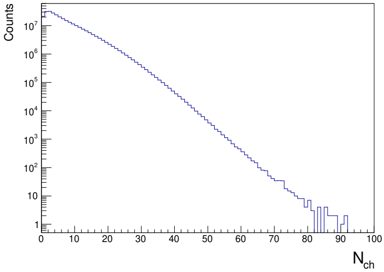
Event Selections

- $|\mathrm{V_Z}| < 10$ cm
- sel8() (T0A + T0C)

Event Selection





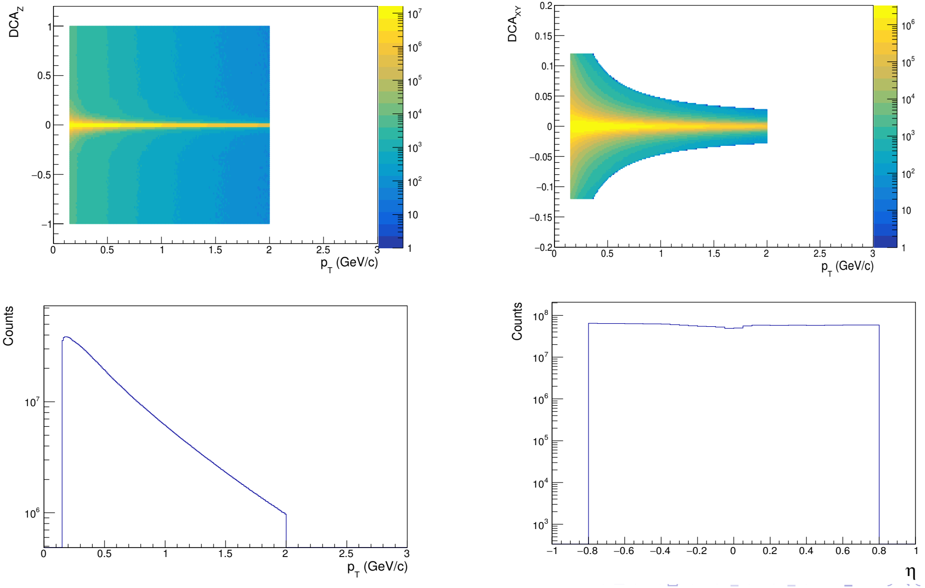


Track Selection Criterion

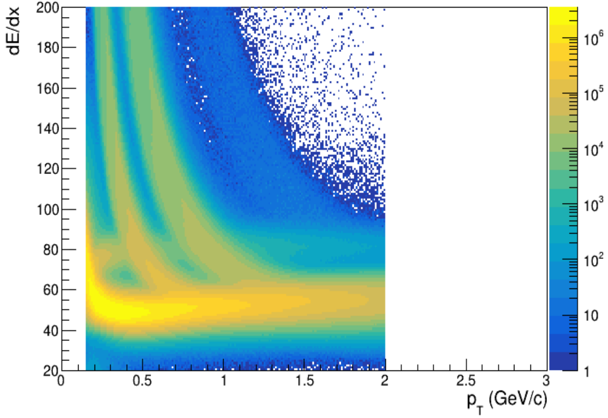
Track Selections

- $0.15 < \mathrm{p_T} < 2.0\ \mathrm{GeV/c}$
- $|\eta| < 0.8$
- $|\mathrm{DCA}_z| < 1.0\ \mathrm{cm}$
- $|\mathrm{DCA}_{xy}| < 0.12\ \mathrm{cm}$
- GlobalTracks()

Track Selection



PID Selection



- To identify the particles, we used TPC signal (i.e. radiation loss per unit length)
- at 0.55 GeV/c: pions and kaons start merging
- at 0.9 GeV/c: protons start merging with the other particles
- there is also electron contamination

PID Selection

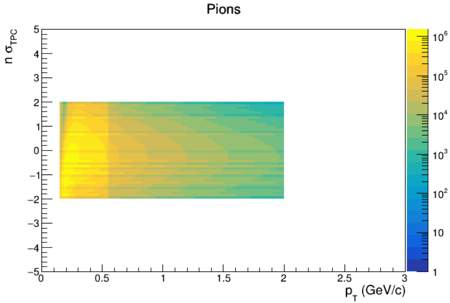
- TOF is used to identify those particles which could not be classified by only TPC
- Pions and Kaons can be classified after 0.55 GeV/c
- Protons can be classified after 0.9 GeV/c

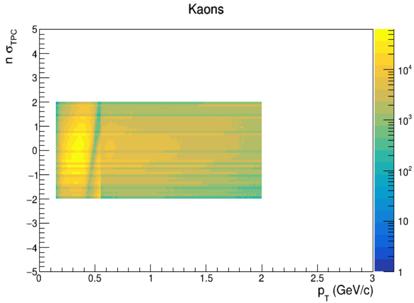
PID Selection

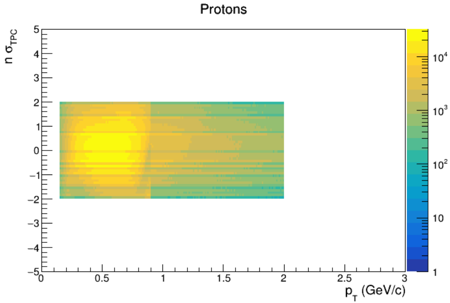
PID Selections

- only TPC cuts
  - To minimize electrons contamination : $|\mathrm{n}\sigma|_{TPC} > 2$
  - $|\mathrm{n}\sigma|_{TPC} < 2$ (Pion: $\mathrm{p_T} \leq 0.55$ GeV/c)
  - $|\mathrm{n}\sigma|_{TPC} < 2$ (Kaon: $\mathrm{p_T} \leq 0.55$ GeV/c)
  - $|\mathrm{n}\sigma|_{TPC} < 2$ (Proton: $\mathrm{p_T} \leq 0.9$ GeV/c)
- TPC+TOF cuts
  - $|\mathrm{n}\sigma|_{TPC} < 2$ & $|\mathrm{n}\sigma|_{TOF} < 2$ (Pion: $\mathrm{p_T} > 0.55$ GeV/c)
  - $|\mathrm{n}\sigma|_{TPC} < 2$ & $|\mathrm{n}\sigma|_{TOF} < 2$ (Kaon: $\mathrm{p_T} > 0.55$ GeV/c)
  - $|\mathrm{n}\sigma|_{TPC} < 2$ & $|\mathrm{n}\sigma|_{TOF} < 2$ (Proton: $\mathrm{p_T} > 0.9$ GeV/c)

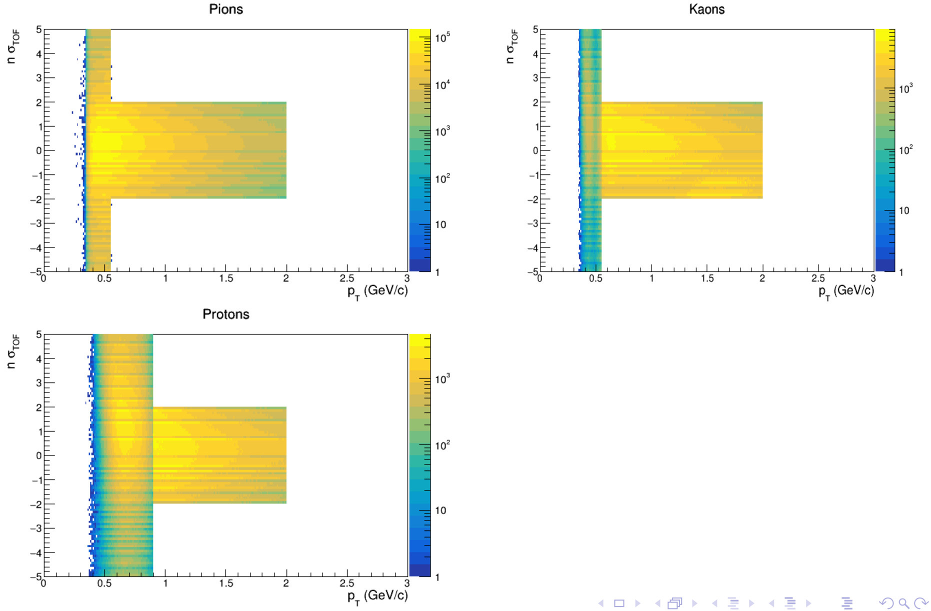
$n\sigma_{TPC}$ vs p_T



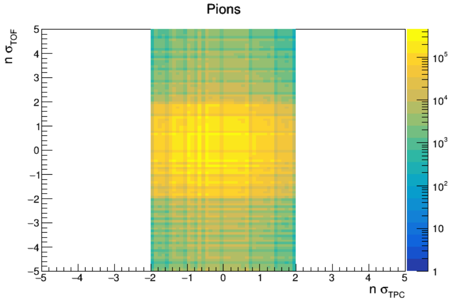


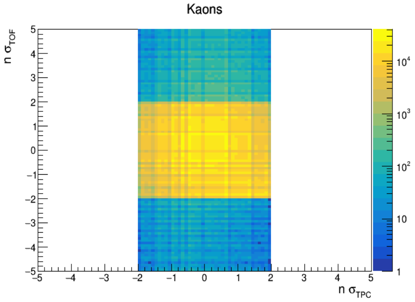


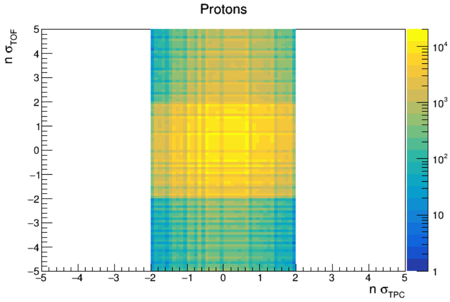
$n\sigma_{TOF}$ vs p_T



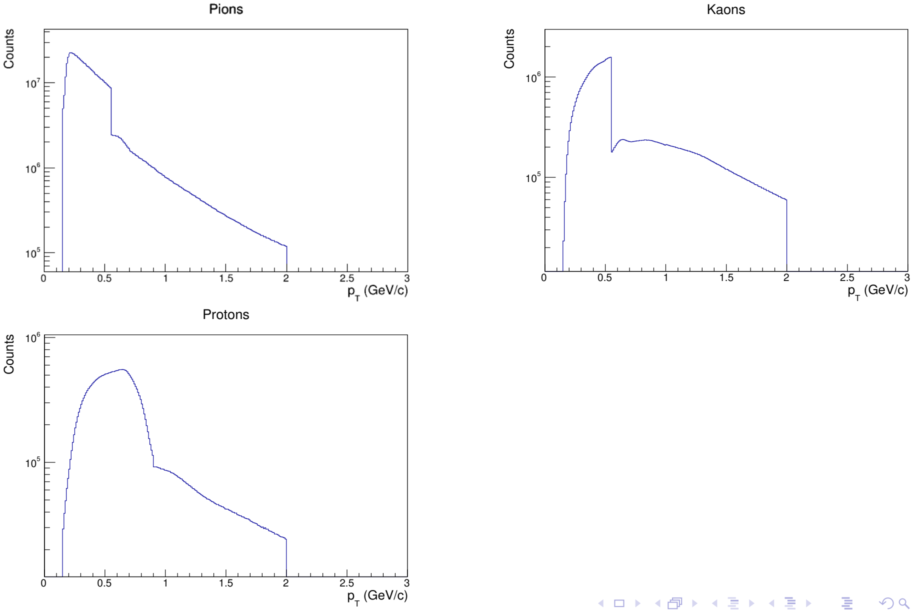
$n\sigma_{TOF}$ vs $n\sigma_{TPC}$



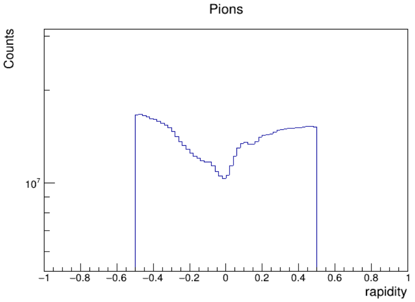


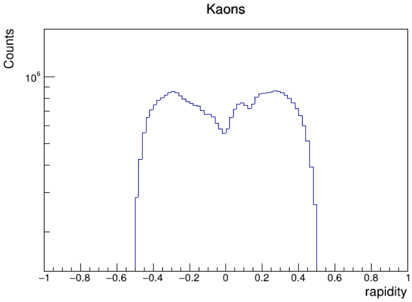


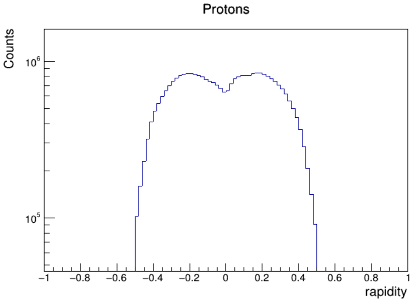
p_T Distribution



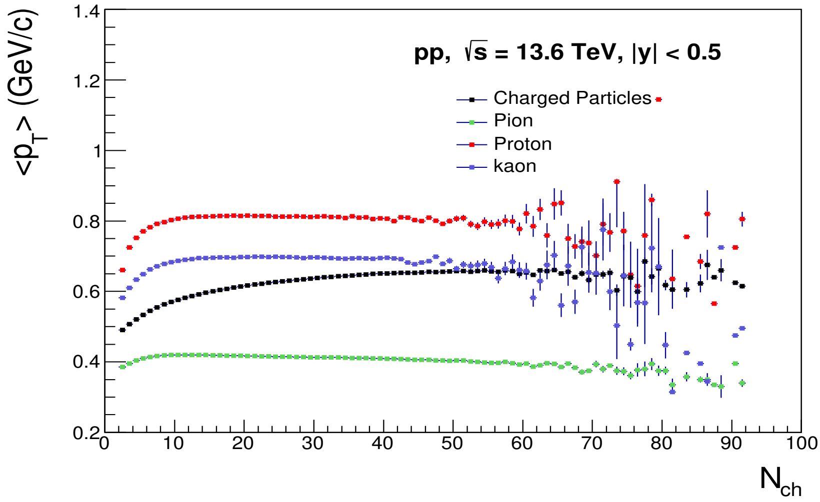
Rapidity (y) Distribution



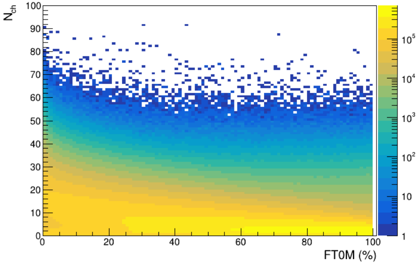


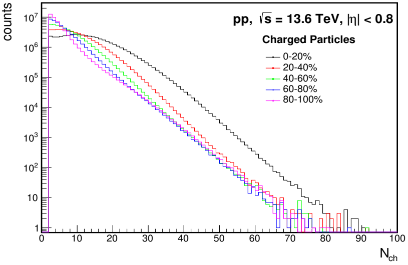


$\langle p_T \rangle$ Distribution

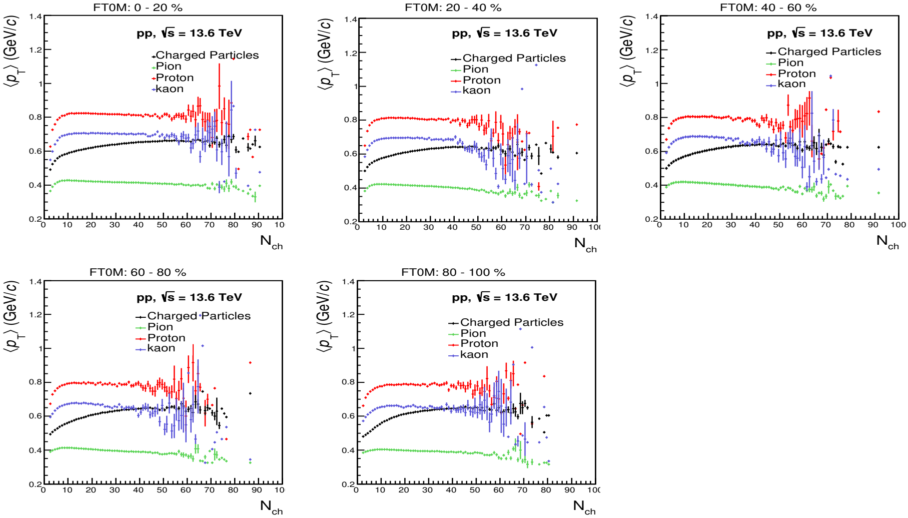


N_{ch} Distribution in Different FT0M Multiplicity Classes

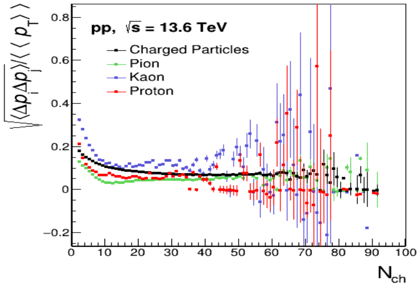


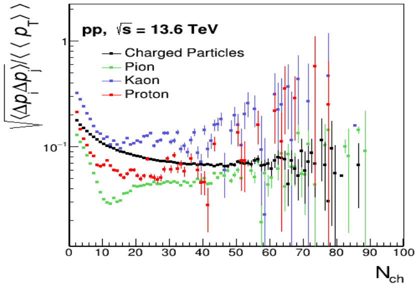


$\langle p_T \rangle$ Distribution in Different Multiplicity Classes

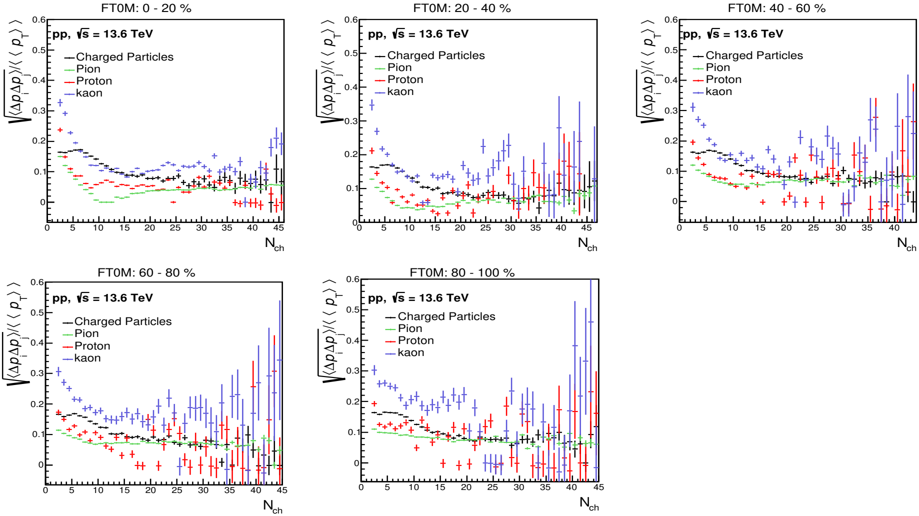


Relative Dynamical Fluctuation: $\sqrt{\langle \Delta p_i \Delta p_j \rangle} / \langle \langle p_T \rangle \rangle$





$\sqrt{\langle\Delta p_i \Delta p_j\rangle}/\langle\langle p_T\rangle\rangle$ Distribution in Different Multiplicity Classes



Summary

- E-by-E $\langle p_T \rangle$ fluctuations for identified particles (π, K and p) measured by ALICE
- Observable: Two-particle correlator
- Significant dynamical fluctuations decreasing with multiplicity
- Dynamical fluctuations is significantly large for Kaons

Future Work

- MC closure test to extract efficiencies
- Other observables: three and four-particle correlators
- Study of these observables in Pb-Pb collisions
- All 3 observables as a fuction of spherocity in pp collisions


THANK YOU!

Motivation

Statistical fluctuation

$$F(k) = e^{-\lambda}\frac{\lambda^k}{k!} \implies \langle F(k) \rangle = \lambda$$

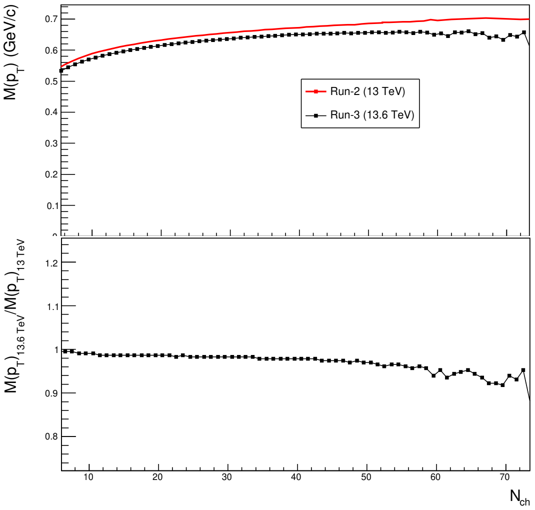
$$Cov(x, y) = E[x, y] - E[x]E[y] \rightarrow C_m \text{ (Two particle Correlator)}$$

$$\implies \lambda_1\lambda_2 - \lambda_1\lambda_2 = 0 \rightarrow C_m$$

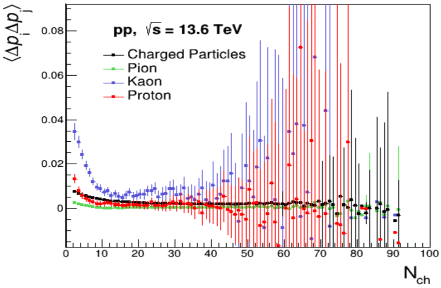
Presence of Correlation

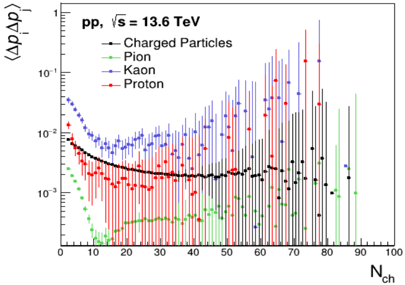
Non-zero value of $\langle \Delta p_i \Delta p_j \rangle$ indicates contribution from non-statistical fluctuation

Comaprison with Run-2 mean p_T results

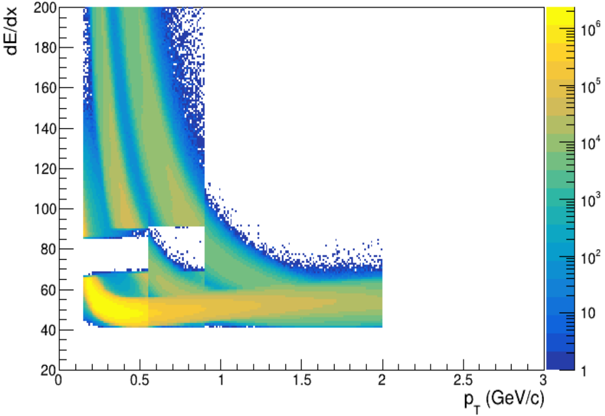


Two particle correlator: $\langle \Delta p_i \Delta p_j \rangle$





PID Selection



- TPC signal after applying PID selection cuts