

# Net-charge Fluctuations in pp & PbPb collisions with ALICE

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Aligarh Muslim University, Aligarh, India



ALICE-STAR INDIA collaboration meeting,  
1-4 July, 2025  
Variable Energy Cyclotron Centre, Kolkata, India

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## Outline



- Motivation
- Analysis Details
- Results
- Outlook



- When a system undergoes a transition from normal hadronic matter to QGP, it can exhibit sudden changes or fluctuations in certain physical quantities like electric charge, baryon number, strangeness etc.
- Event-by-event fluctuations of conserved quantities are considered sensitive probes of the QGP phase transition.

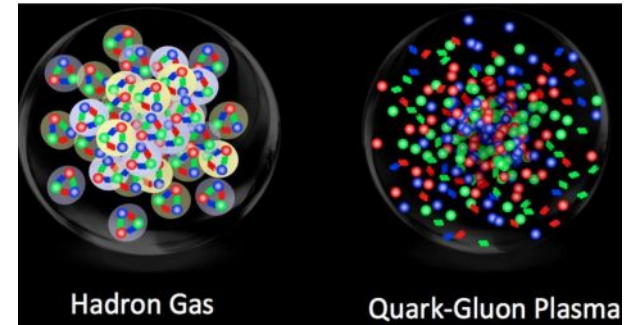
- Net-charge fluctuations:

$$\langle (\delta Q)^2 \rangle = \langle Q^2 \rangle - \langle Q \rangle^2 = q^2 (\langle N^2 \rangle - \langle N \rangle^2) = q^2 \langle (\delta N)^2 \rangle$$

- The observable  $(\delta Q)^2$  proportional to  $q^2$  (where  $q$  is electric charge)

$$\text{HG} : (\delta Q)^2 \sim 4, 1 .$$

$$\text{QGP} : (\delta Q)^2 \sim 1/9, 4/9 .$$



- Net-charge fluctuations significantly **reduced in QGP** compared to a Hadron Gas (HG).
- Serve as a potential signature to distinguish QGP from a HG.



# Dynamical net-charge fluctuations observable $v_{\text{dyn}}$

→ Defined using the number of positive ( $N_+$ ) and negative ( $N_-$ ) charged particles.

The observable  $v_{\text{dyn}}$  is given by:

$$\mathcal{V}_{[+-, \text{dyn}]} = \frac{\langle N_+(N_+-1) \rangle}{\langle N_+ \rangle^2} + \frac{\langle N_-(N_- - 1) \rangle}{\langle N_- \rangle^2} - 2 \frac{\langle N_+ N_- \rangle}{\langle N_+ \rangle \langle N_- \rangle}$$

C. Pruneau et al., Phys. Rev. C 66, 044904 (2002)

## Interpretation:

- $v_{\text{dyn}} < 0$ : Strong opposite-charge correlations.
- $v_{\text{dyn}} > 0$ : Same-charge pairs correlation dominates.
- $v_{\text{dyn}} = 0$ : No dynamical fluctuations

❖ Robust against detection efficiency losses

# Analysis details



pp  $\sqrt{s}$  = **13 TeV Run2 Converted**

Data: **LHC18bdefghijklmnop** ( ~ 3 B events)

Monte Carlo : **LHC18g4** ( ~ 40 M events)

## Events Selection

sel7

alias\_bit(kINT7)

$|V_z| < 10$  cm

Centrality and Multiplicity estimator: V0M

## Tracks Selection

Global tracks()

$|\eta| < 0.8$

$0.2 < p_T < 5.0$  GeV/c



| Cuts   | globalTrack  |
|--|--|
| min number of crossed rows TPC                       | 70   |
| min ratio of crossed rows over findable clusters TPC | 0.8  |
| max chi2 per cluster TPC                             | 4.0  |
| max chi2 per cluster ITS                             | 36.0   |
| require TPC refit                                    | true   |
| require ITS refit                                    | true   |
| max DCA to vertex z                                  | 2.0  |
| max DCA to vertex xy                                 | $0.0105 + 0.035 / p_T^{1.1}$   |
| cluster requirement ITS                              | Run 2 (Run 3): at least one hit in SPD (in 3 innermost ITS layers) [*] |
| $p_T$ range  | 0.1 - 1e10   |
| $\eta$ range   | -0.8 - 0.8   |

# Analysis details



pp  $\sqrt{s} = 13.6$  TeV

Data: **LHC22o\_apass7\_minBias\_small** ( ~ 2.3 B events)

Monte Carlo : **LHC24f3c** ( ~ 47 M events)

## Events Selection

sel8

$|V_z| < 10$  cm

Centrality and Multiplicity estimator: FT0M

## Tracks Selection

Global tracks()

$|\eta| < 0.8$

$0.2 < p_T < 5.0$  GeV/c

PbPb  $\sqrt{s_{NN}} = 5.36$  TeV

Data: **LHC23zzo\_pass5\_small** ( ~ 76 M events)

Monte Carlo : **LHC24g3\_medium** ( ~ 14 M events)

## Events Selection

sel8

$|V_z| < 10$  cm

Centrality and Multiplicity estimator: FT0C

## Tracks Selection

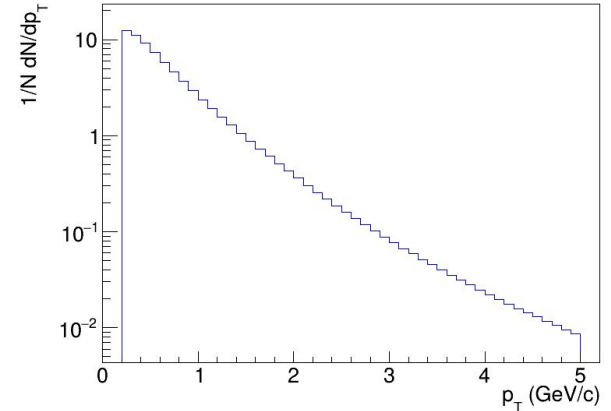
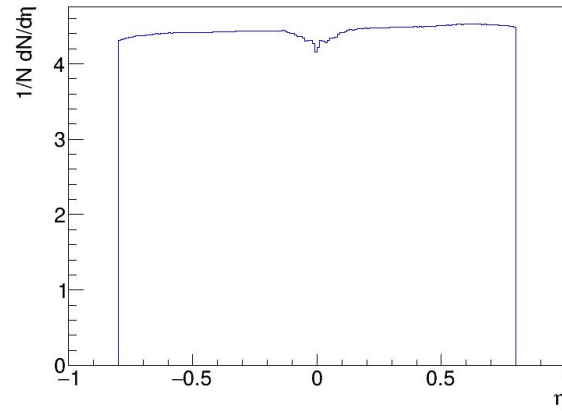
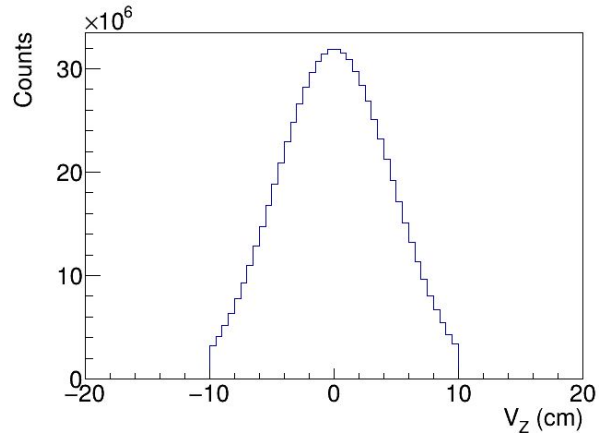
Global tracks()

$|\eta| < 0.8$

$0.2 < p_T < 5.0$  GeV/c

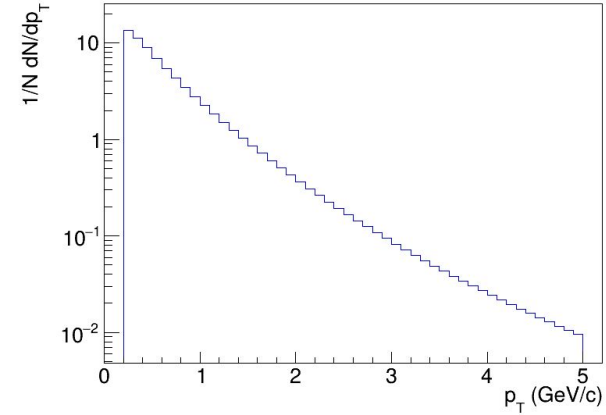
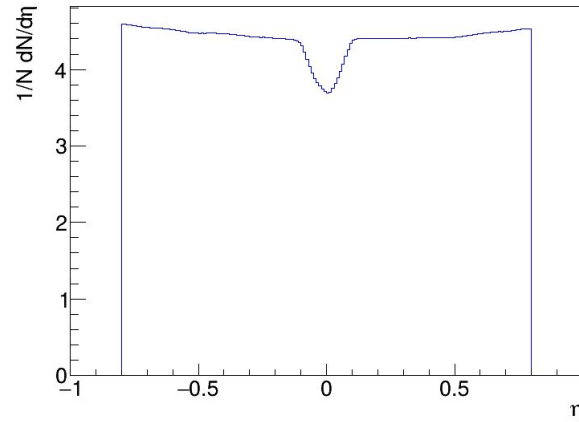
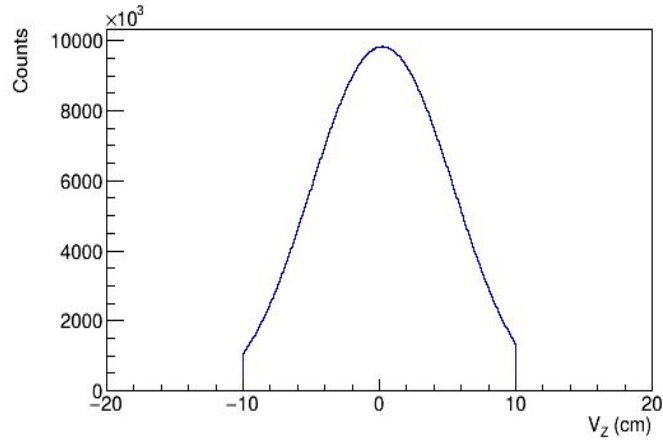


pp  $\sqrt{s} = 13$  TeV



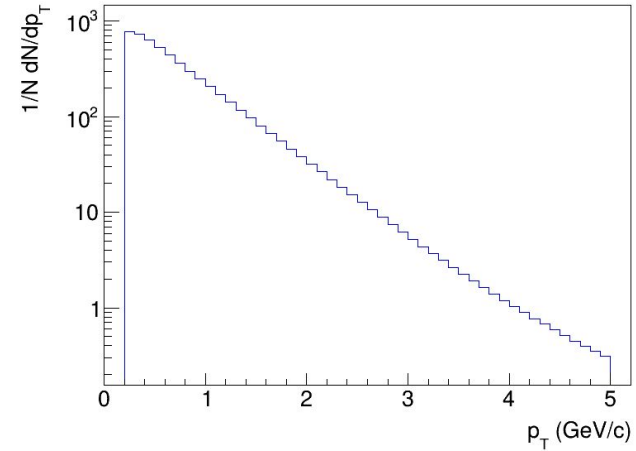
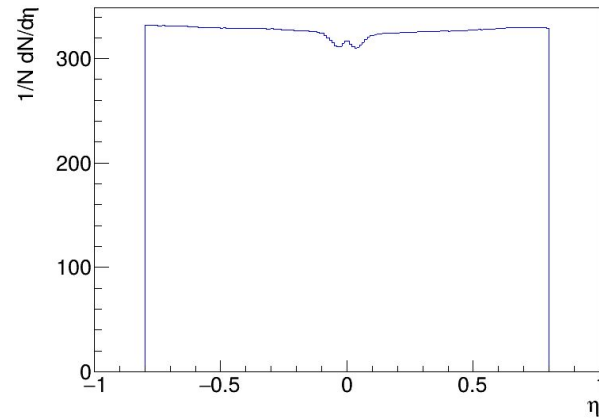
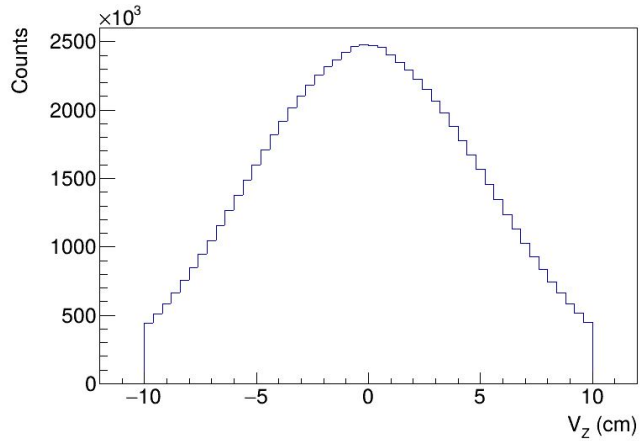


pp  $\sqrt{s} = 13.6$  TeV





PbPb  $\sqrt{s_{NN}} = 5.36$  TeV

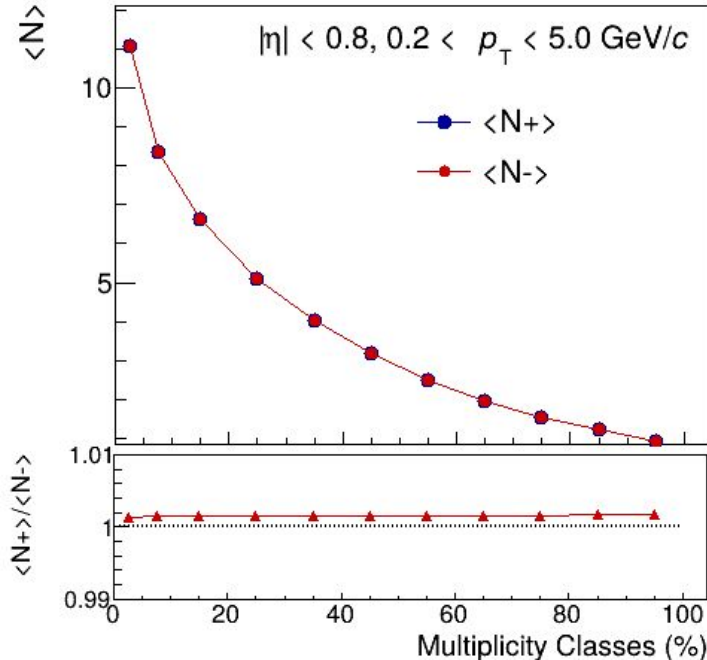


# First Moment vs Multiplicity Classes

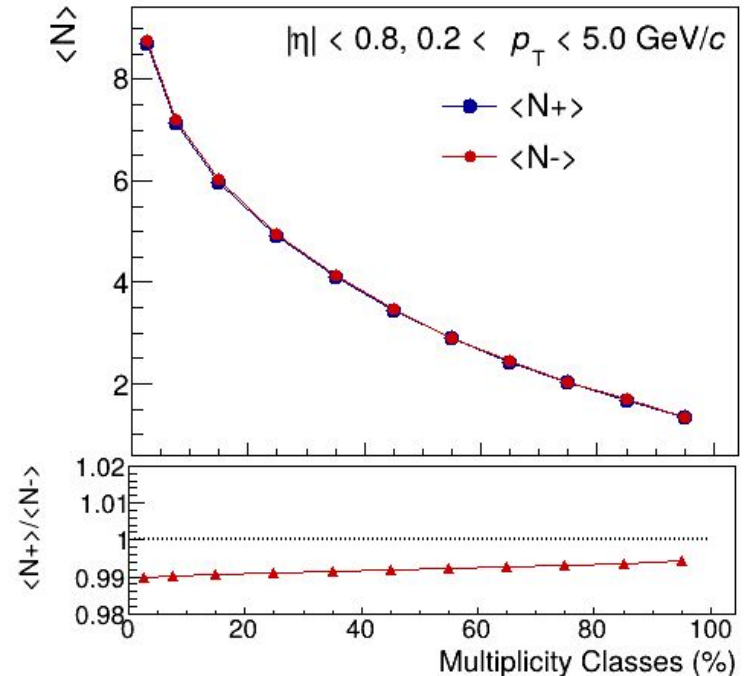


→ First moments of positive and negative charged particles vs multiplicity classes.

pp  $\sqrt{s} = 13$  TeV



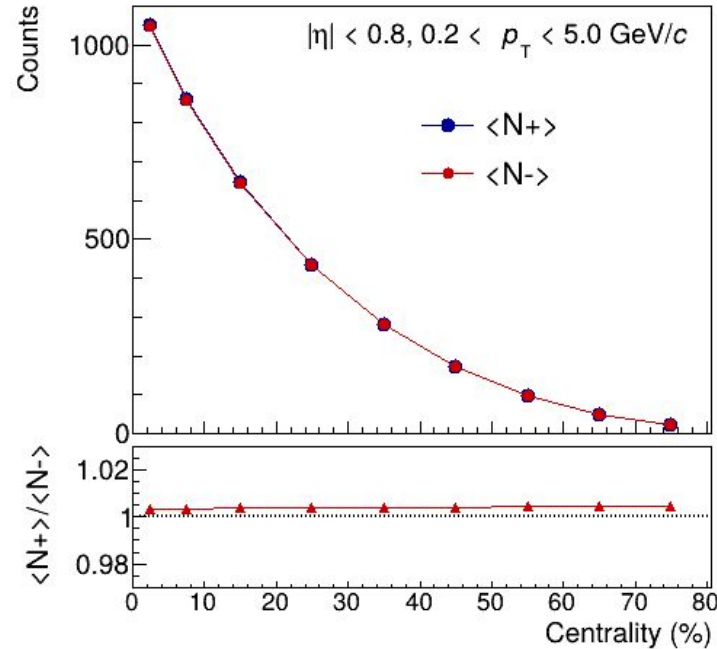
pp  $\sqrt{s} = 13.6$  TeV



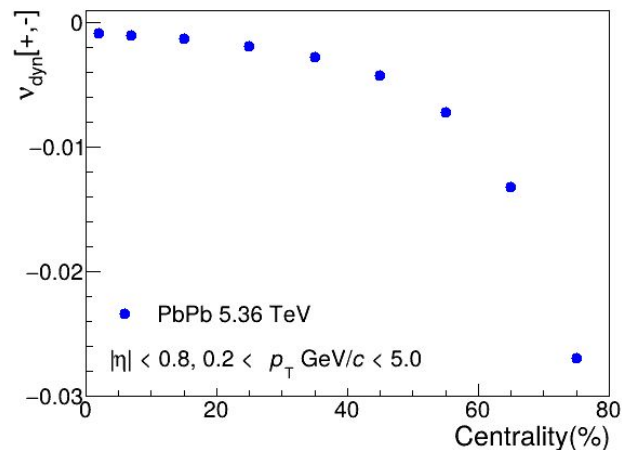
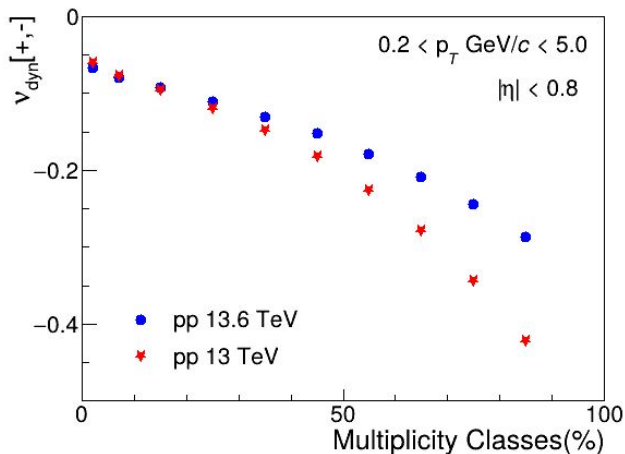
# First Moment vs Centrality



PbPb  $\sqrt{s_{NN}} = 5.36$  TeV



# Multiplicity Dependence of $v_{\text{dyn}}$



→ The magnitude of  $v_{\text{dyn}}$  becomes more negative with increasing multiplicity classes.

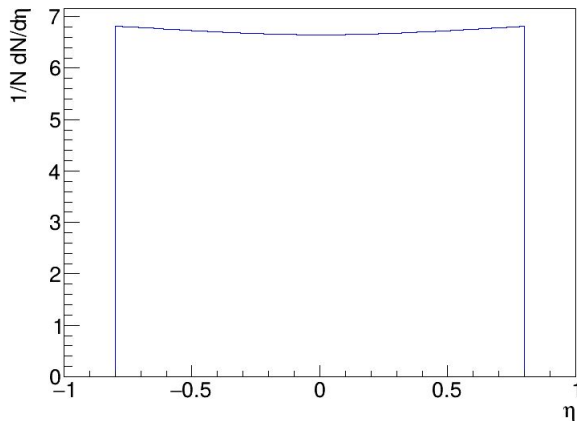
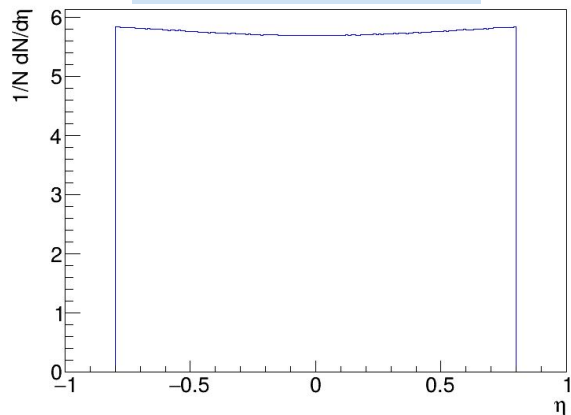
→ Indicating the dominance of opposite-charge correlations

❖ Statistical errors in  $v_{\text{dyn}}[+,-]$  are calculated using subsample method by dividing the data into 30 sub-samples.

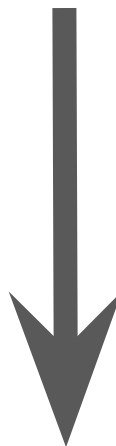
# Monte Carlo – $\eta$ distributions



Generated

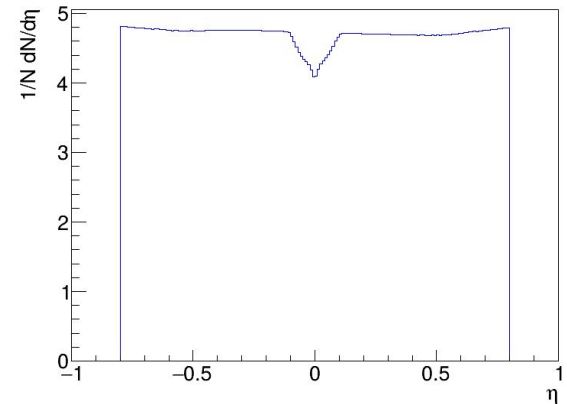
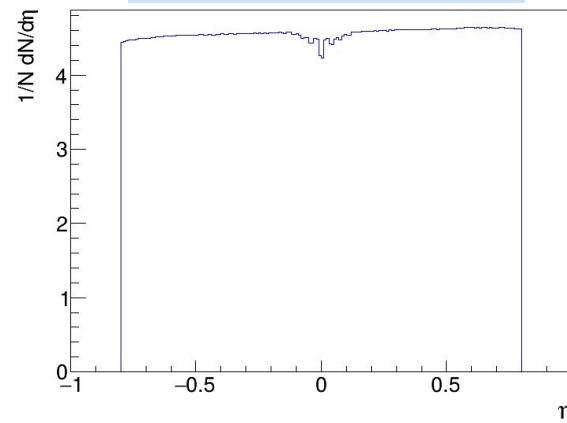


13 TeV



13.6 TeV

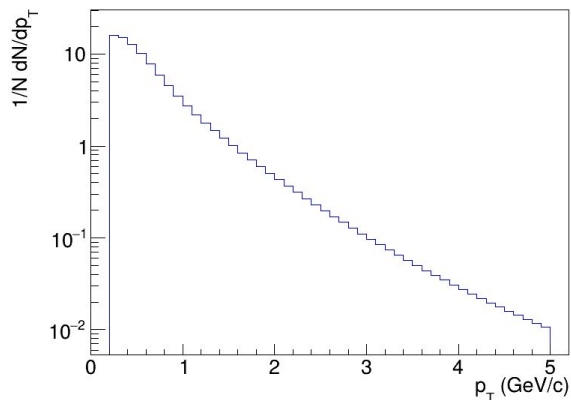
Reconstructed



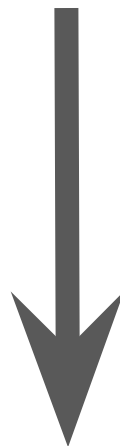
# Monte Carlo – $p_T$ distributions



Generated

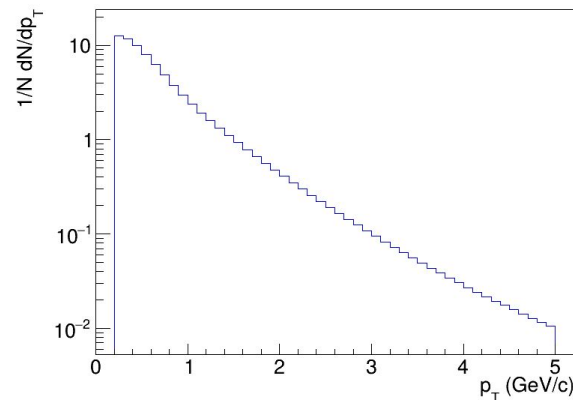
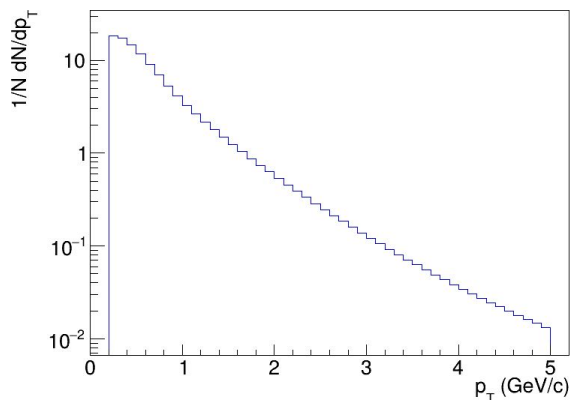
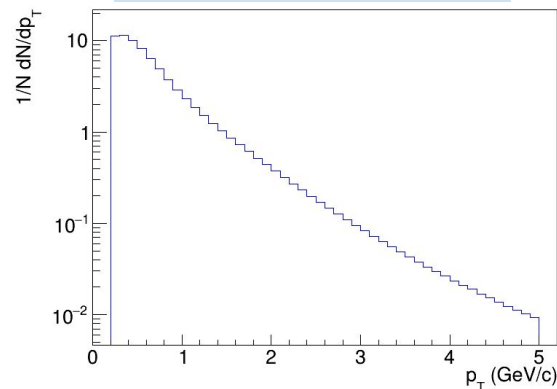


13 TeV



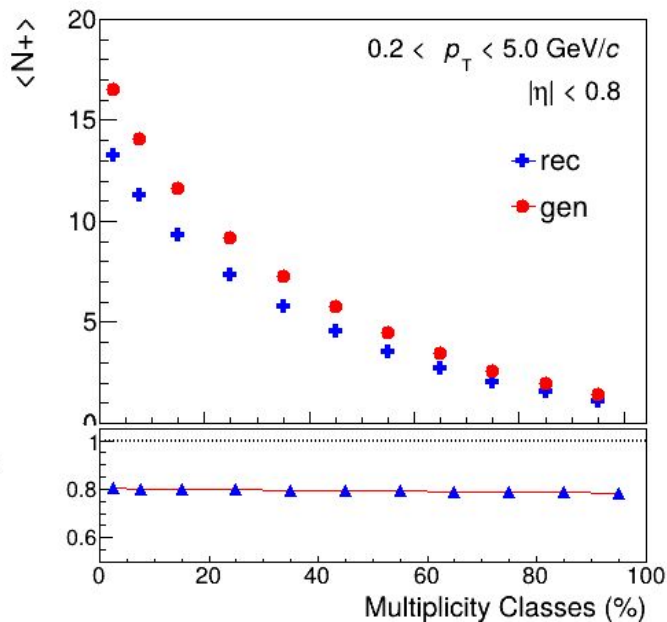
13.6 TeV

Reconstructed

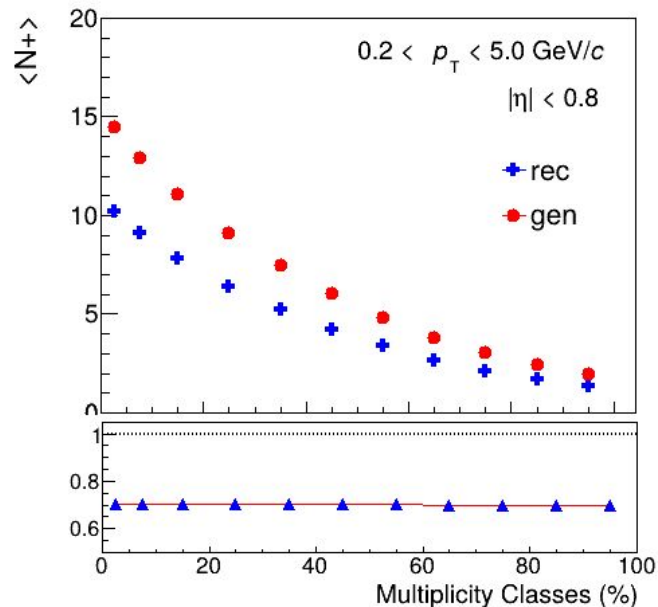




→ First moments of positive charged particles for reconstructed and generated MC data.



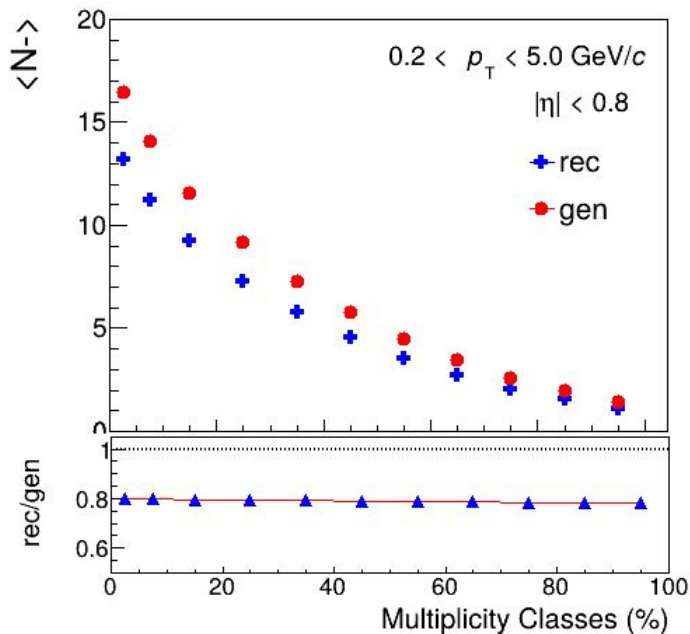
13 TeV



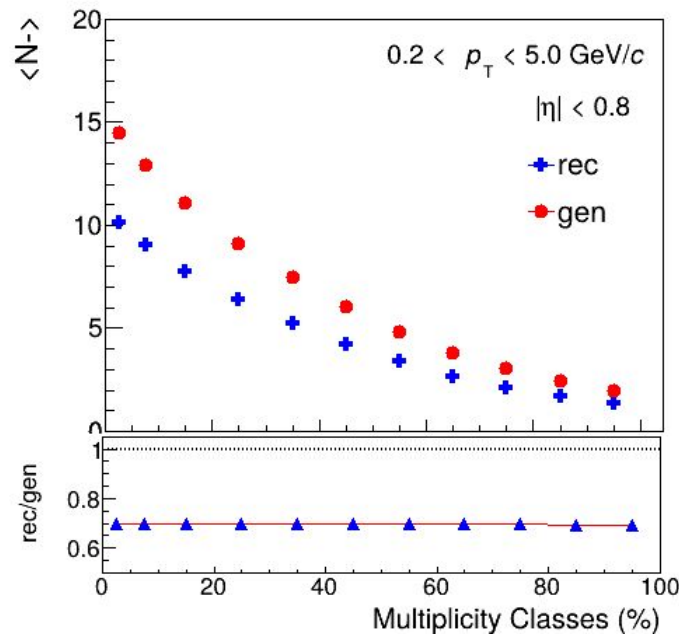
13.6 TeV



→ First moments of negative charged particles for reconstructed and generated MC data.

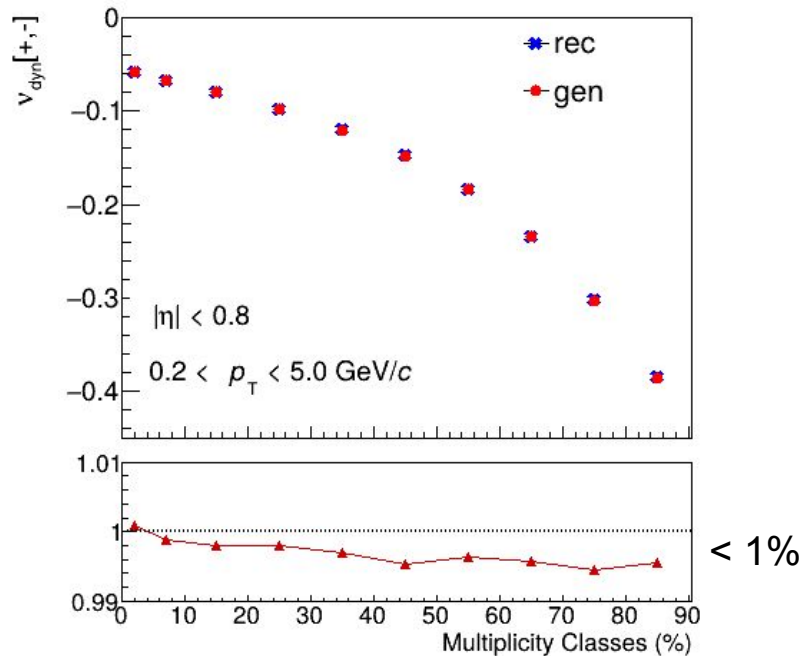


13 TeV

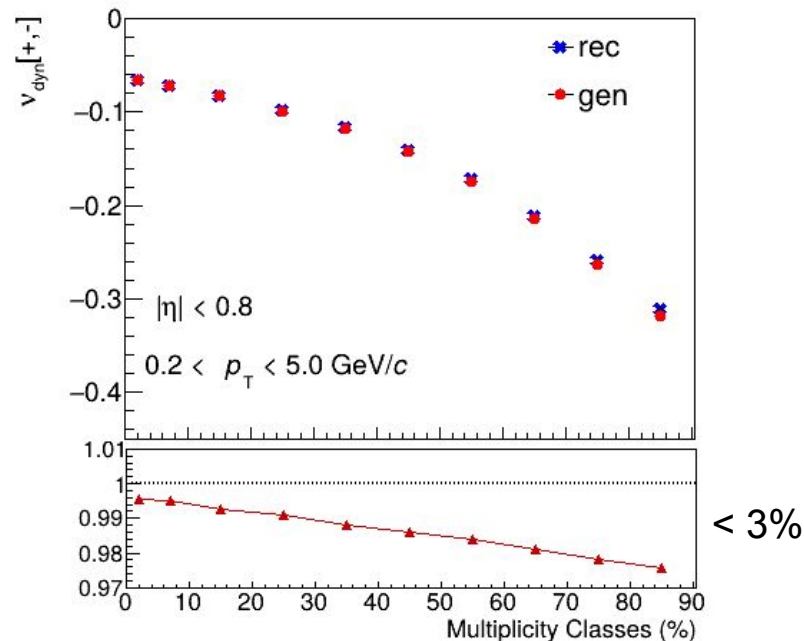


13.6 TeV

# MonteCarlo – Multiplicity Dependence



13 TeV



13.6 TeV

- Hence,  $v_{\text{dyn}}[+,-]$  is robust against detection efficiency losses
- Statistical errors are included.



→ MC closure test will be performed for Pb–Pb collisions.



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# Thank You