



Probing the QGP of Hadron Gas Phase Transition with Mean Transverse Momentum Fluctuations



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1. Introduction

- Event-by-event (EbyE) mean p_T fluctuations are sensitive to energy fluctuations and collectivity in heavy-ion collisions.
- These fluctuations may arise from various types of correlations, such as resonance decays, jets, quantum correlations, etc. [1].
- Higher order of the mean p_T fluctuations can probe the hydrodynamic evolution of the heavy-ion collisions and are thus a direct means to observe initial-state fluctuations [2].

A reduction in the dynamical mean p_T fluctuations with charged particle density in pp and Pb-Pb collisions have been reported by ALICE Collaboration [1]. The observed reduction is somewhat weaker than expected from independent particle emission. Moreover, hydrodynamics predicts that the mean p_T distribution has a positive skewness [2].

2. Observables

- In a multiplicity class m the two-particle correlator C_m is defined as,

$$C_m = \frac{1}{\sum_{k=1}^{n_{\text{ev}},m} N_k^{\text{pairs}}} \sum_{k=1}^{n_{\text{ev}},m} \sum_{i=1}^{N_{\text{acc},k}} \sum_{j=i+1}^{N_{\text{acc},k}} (p_{T,i} - M(p_T)_m) * (p_{T,j} - M(p_T)_m), \quad M(p_T)_m = \frac{1}{\sum_{k=1}^{n_{\text{ev}},m} N_{\text{acc},k}} \sum_{k=1}^{n_{\text{ev}},m} \sum_{i=1}^{N_{\text{acc},k}} p_{T,i}$$

- Higher-order Transverse Momentum Fluctuations up to 4th order are defined as,

Intensive Skewness

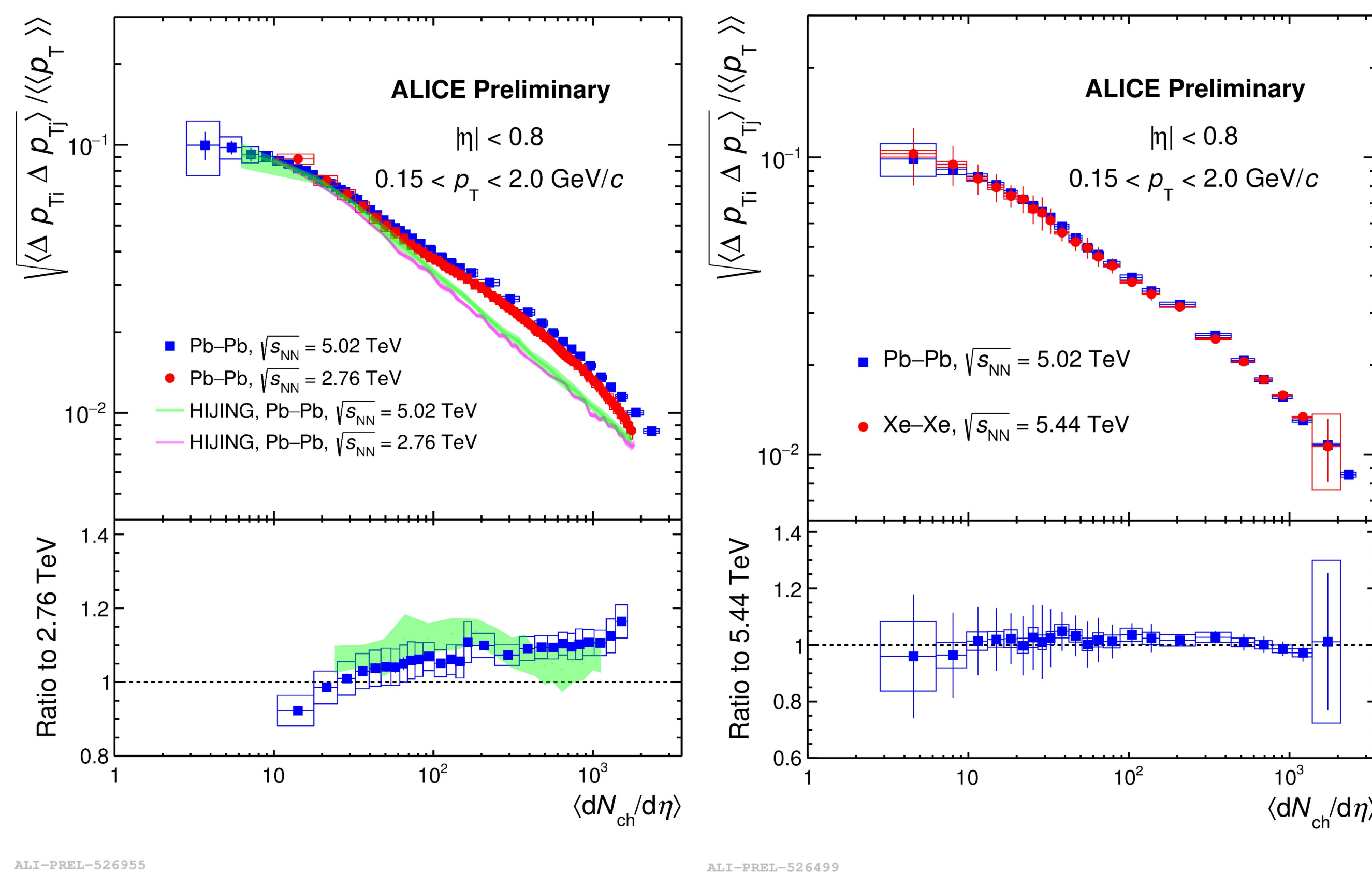
$$\Gamma_{\langle p_T \rangle} = \frac{\langle \Delta p_i \Delta p_j \Delta p_k \rangle \langle \langle p_T \rangle \rangle}{\langle \Delta p_i \Delta p_j \rangle^2}$$

Dynamic Kurtosis

$$\kappa_{\langle p_T \rangle} = \frac{\langle \Delta p_i \Delta p_j \Delta p_k \Delta p_l \rangle}{\langle \Delta p_i \Delta p_j \rangle^2}$$

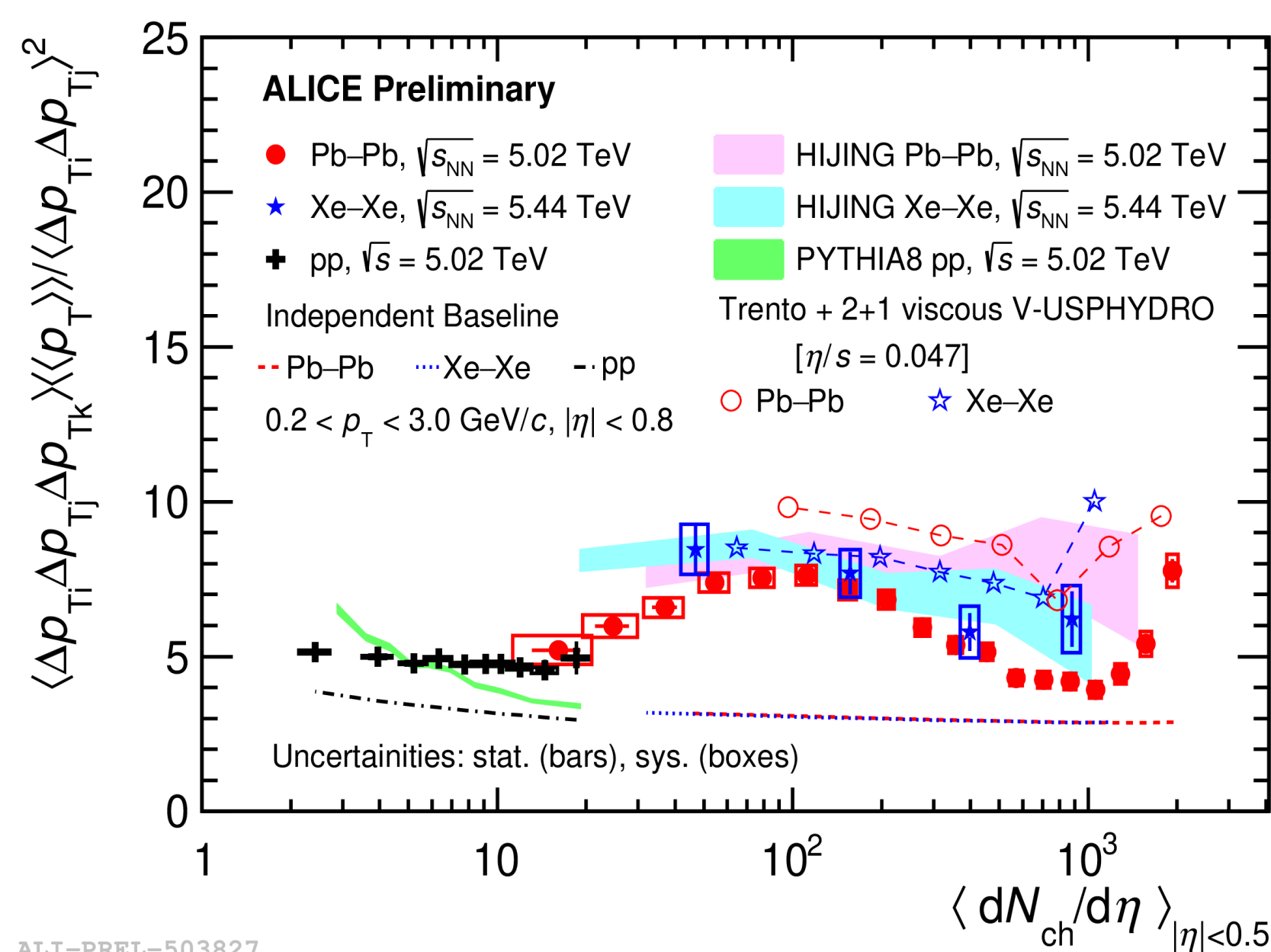
- Data set: pp collisions at $\sqrt{s} = 5.02$ and 13 TeV, Pb-Pb collisions at $\sqrt{s_{\text{NN}}} = 2.76$ and 5.02 TeV, and Xe-Xe collisions at $\sqrt{s_{\text{NN}}} = 5.44$ TeV.

3. 2nd-order mean p_T fluctuations in heavy-ion collisions

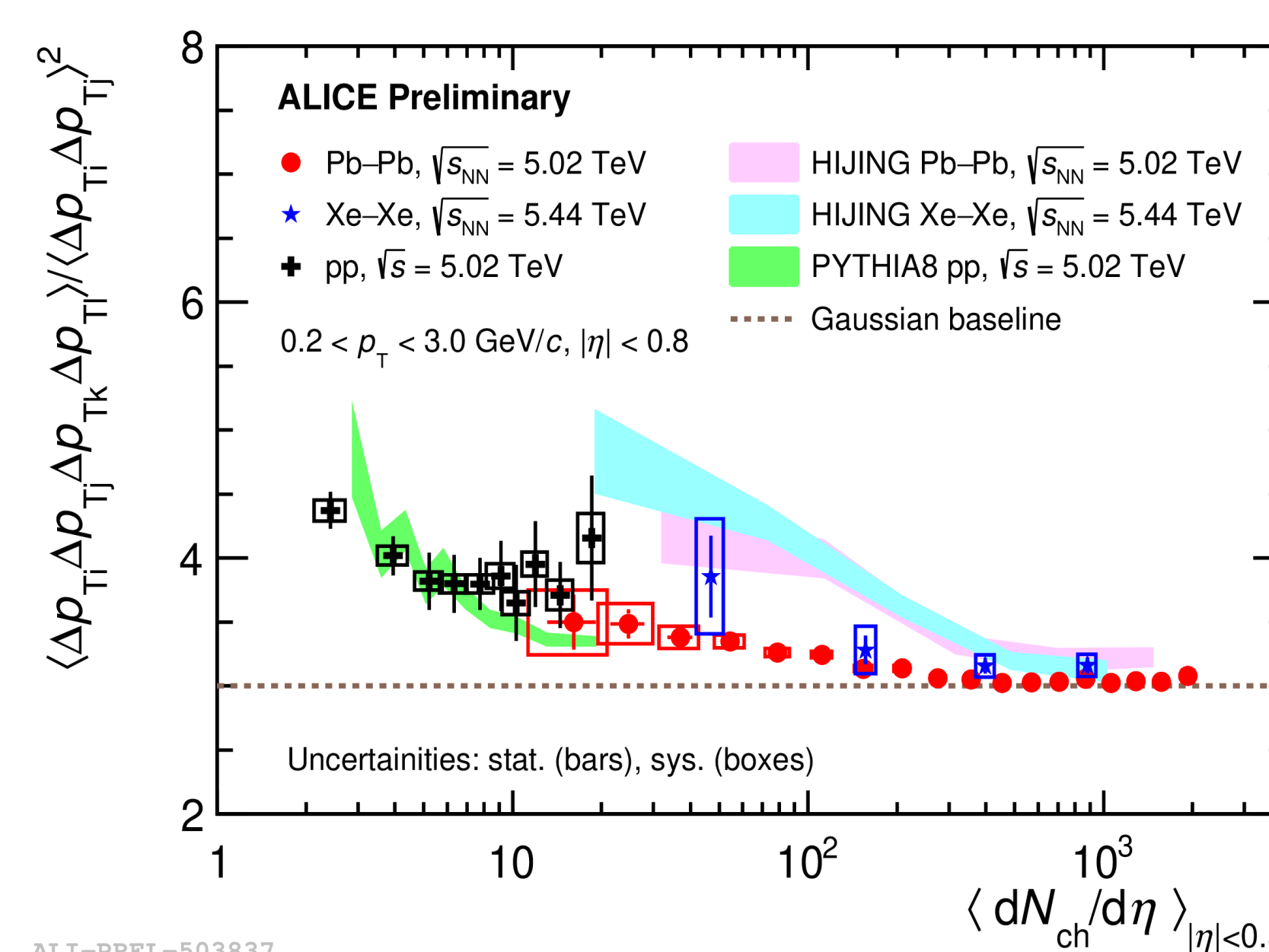


- Significant reduction in fluctuations moving from peripheral to central collisions.
- For Pb-Pb collisions, a noticeable energy dependence of the normalized correlator is observed in central collisions, which is reproduced by HIJING predictions.
- Qualitative agreement between Pb-Pb and Xe-Xe collisions.

5. Higher-order mean p_T fluctuations

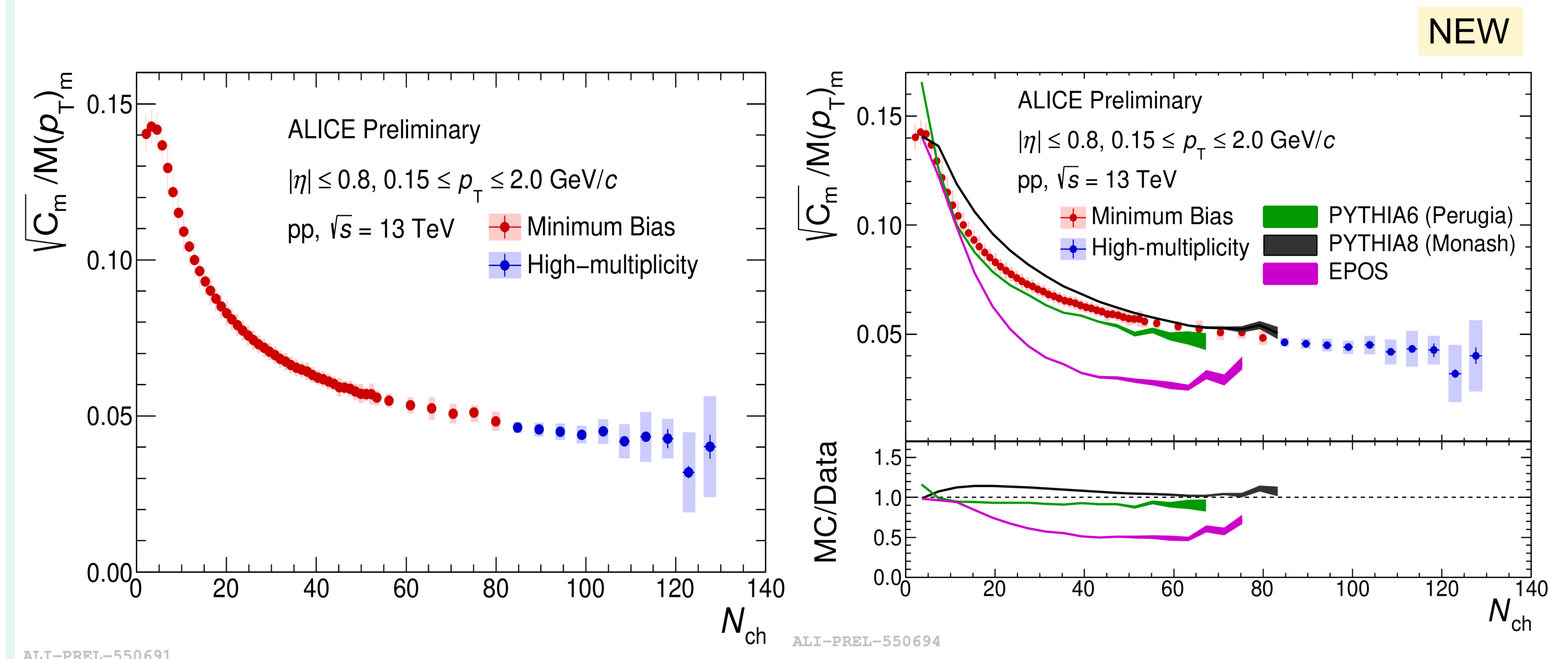


- Intensive skewness values across all collision systems are positive, as predicted by the hydrodynamical models, and remain consistently above the Gaussian baseline.

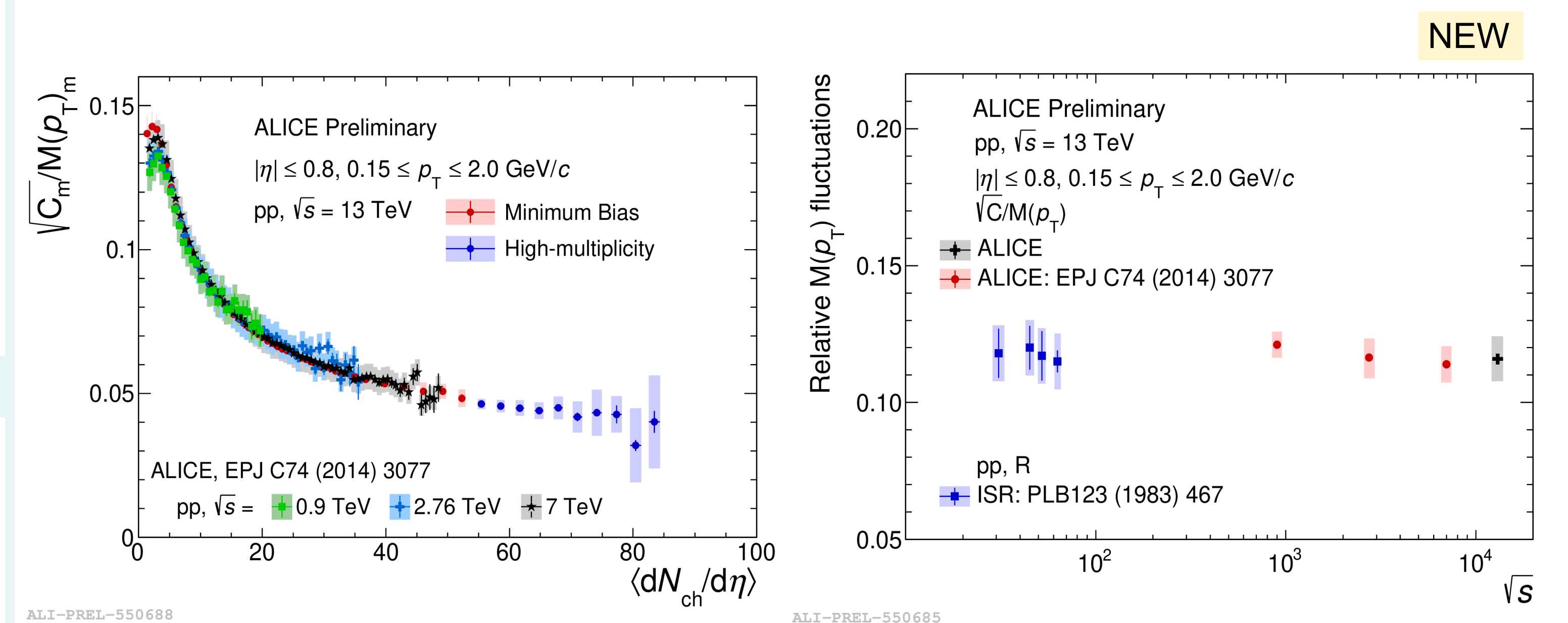


- For AA collisions, the kurtosis approaches the Gaussian baseline at high multiplicities, whereas for pp collisions, it is larger than the Gaussian baseline, indicating that the pp system is more highly correlated.

4. 2nd-order mean p_T fluctuations in pp collisions



- A decreasing trend of the correlator from minimum bias to high-multiplicity triggered events.
- This trend is described qualitatively by the two versions of the PYTHIA model, while the EPOS model significantly underestimates the data.



- Comparison of the present results with those reported for pp collisions at lower LHC energies suggests that the correlator acquires energy-independent value as a function of multiplicity, except in the region of very low multiplicities.
- Inclusive correlator values are also measured.

6. Summary and Outlook

- Second and Higher-order mean p_T fluctuations across various collision systems at LHC energies were studied.
- Decreasing mean p_T fluctuations with increasing particle multiplicity are observed in all collision systems.
- The observed positive skewness is consistent with expectations from the hydrodynamical models.
- Similar studies for identified particles are being carried.

References

- [1] ALICE Collaboration, Euro. Phys. J. C74, (2014) 3077.
- [2] G. Giacalone et al., Phys. Rev. C103, (2011) 024910.