Event-by-event fluctuation of mean transverse momentum in Pb–Pb and Xe–Xe collisions with ALICE

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On behalf of the ALICE Collaboration

Indian Institute of Technology Bombay, India

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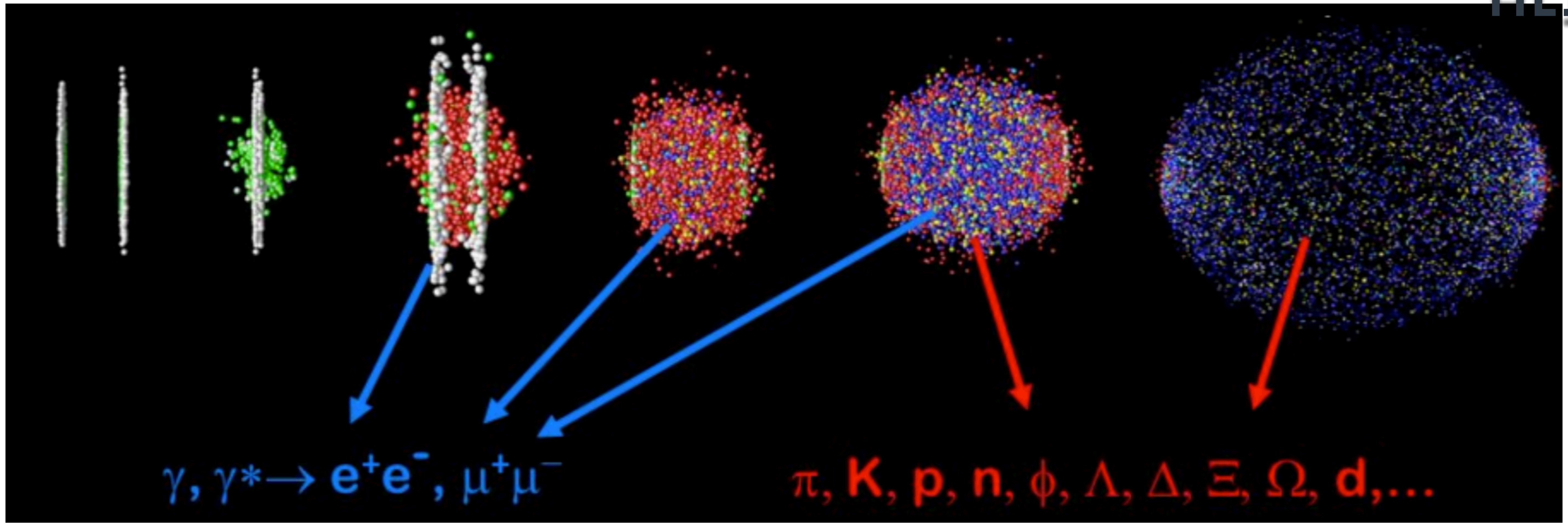
XXV DAE-BRNS HEP SYMPOSIUM 2022, IISER Mohali

Why e-by-e fluctuation?

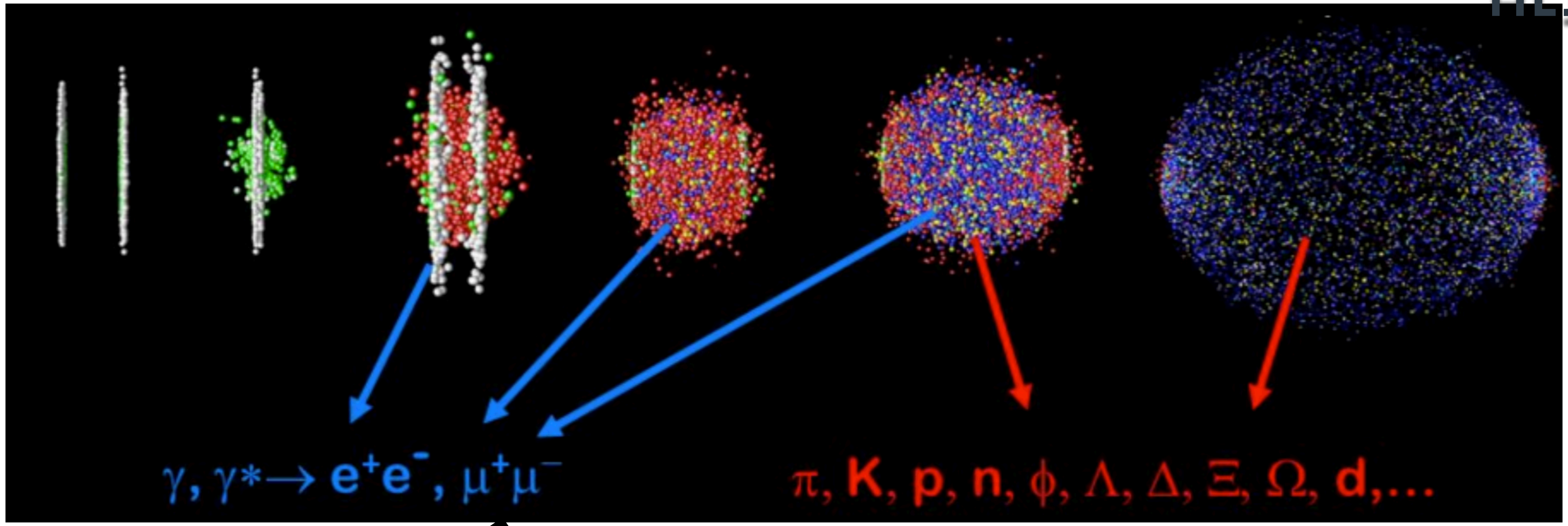
Introduction and motivation

Why e-by-e fluctuation?



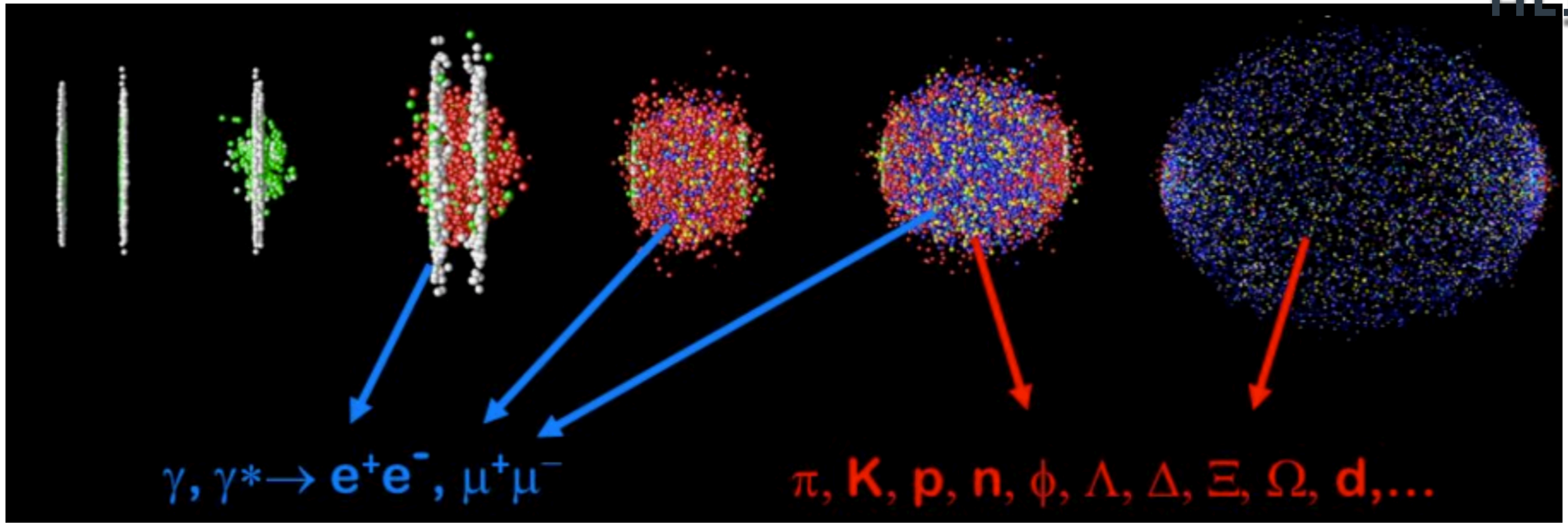
Introduction and motivation

Why e-by-e fluctuation?



Large number of particles per event

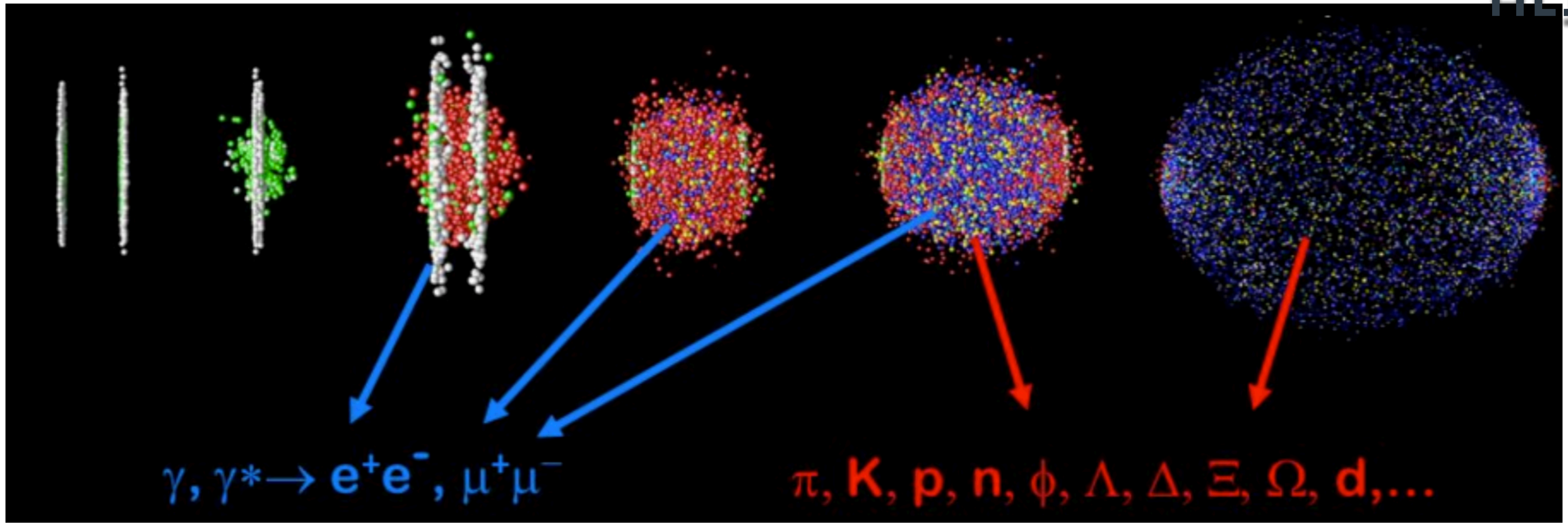
Introduction and motivation



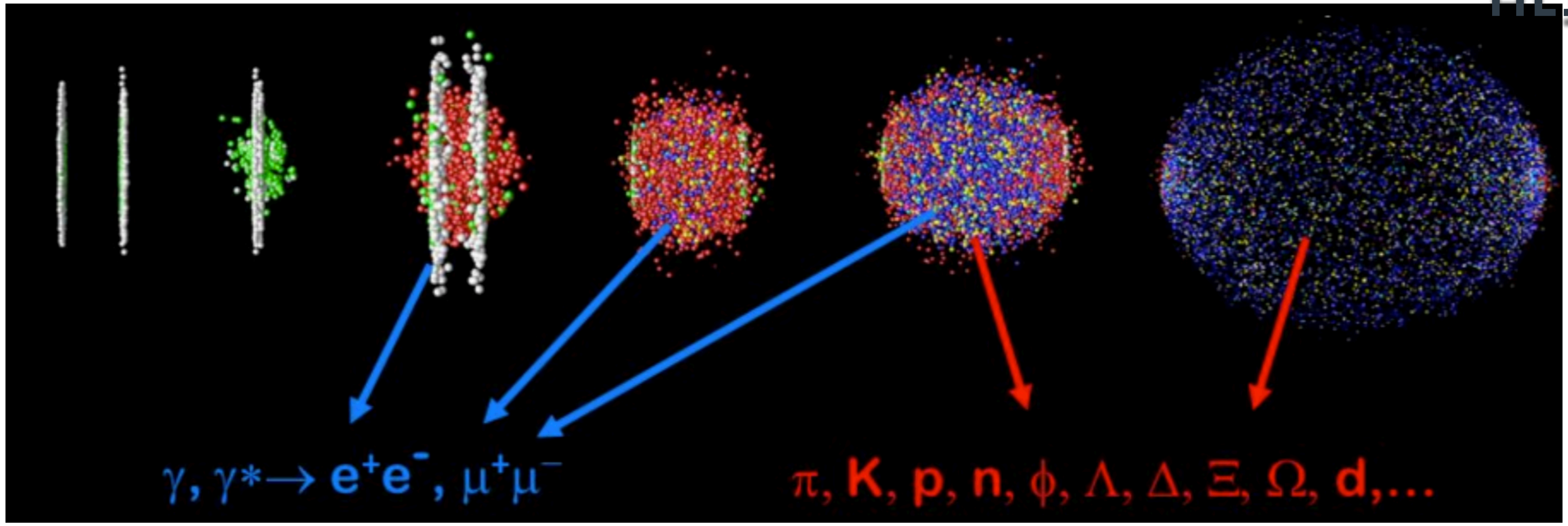
Why e-by-e fluctuation?

Large number of particles per event → Thermodynamic state

Why e-by-e fluctuation?



Large number of particles per event → Thermodynamic state → Local temperature (T_{chem})



Why e-by-e fluctuation?

Large number of particles per event → Thermodynamic state → Local temperature (T_{chem})

The energy and particles can be exchanged : Grand canonical ensemble

$$(\Delta T)^2 = \overline{(T - \overline{T})^2}$$

$$C^{-1} = \frac{(\Delta T)^2}{T^2}$$

Introduction and motivation

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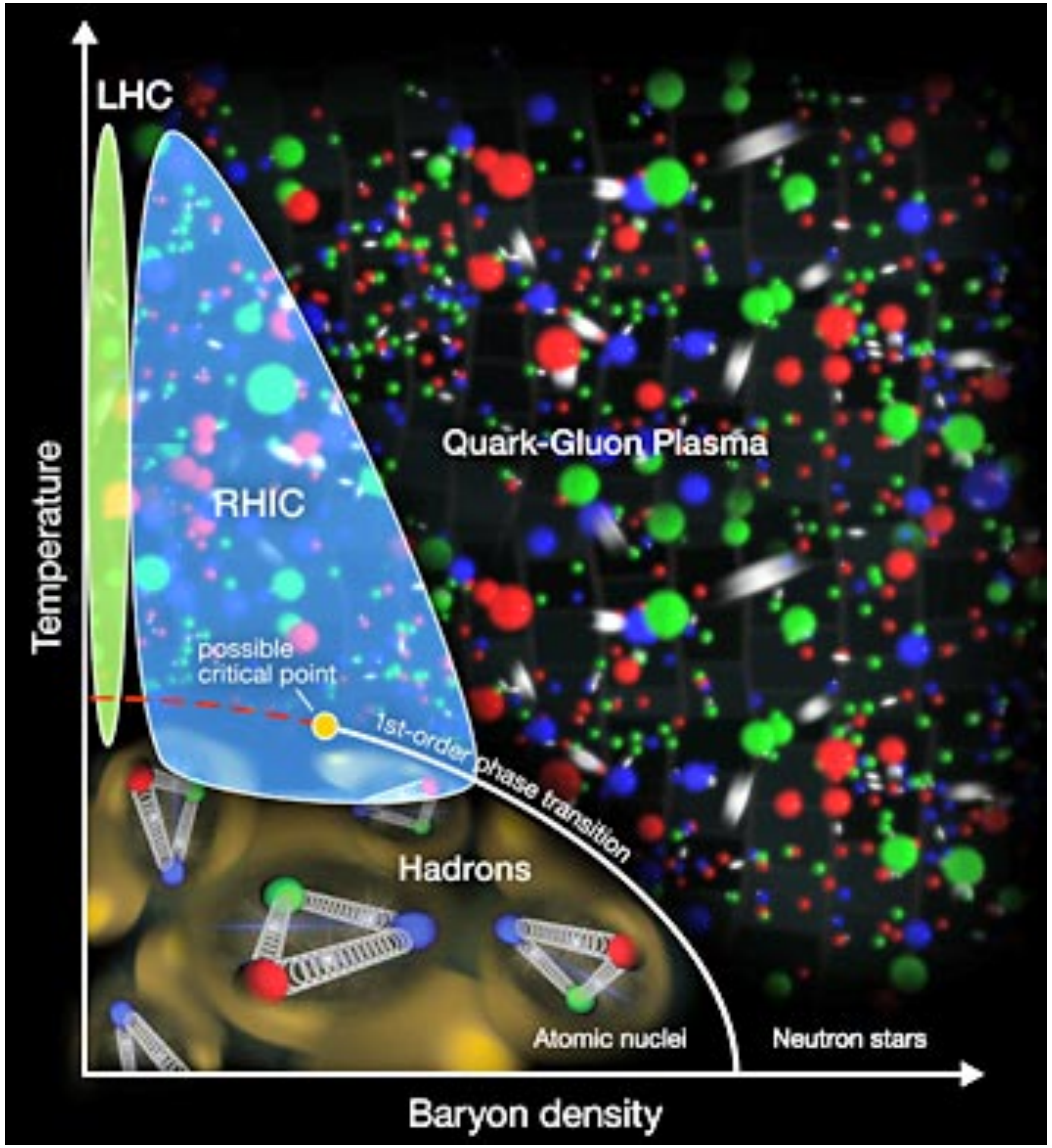
Critical end point



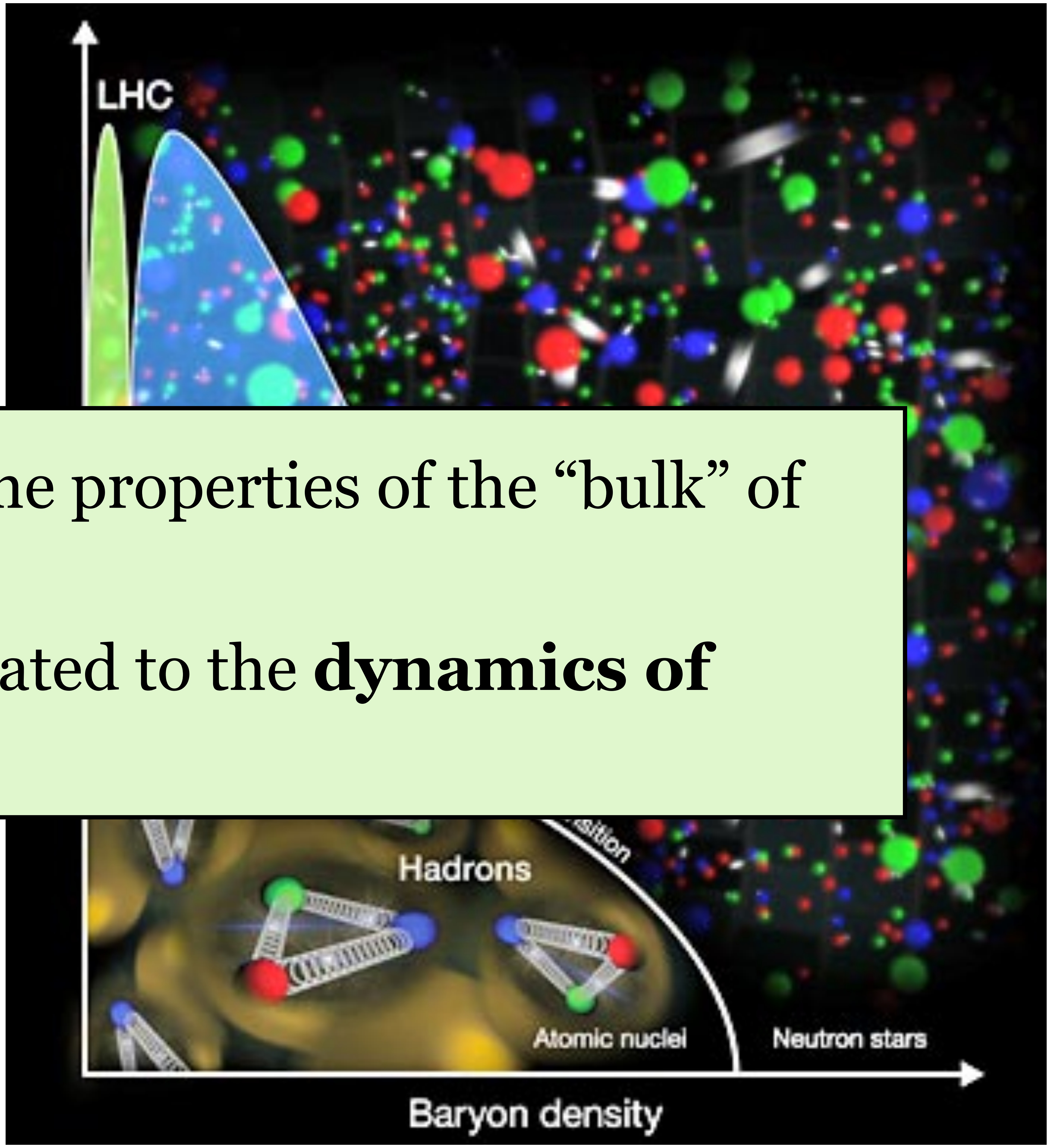
Irregular behaviour of C is the characteristic of phase transition.

Introduction and motivation

$(\Delta T)^2 = \overline{(T - \overline{T})^2}$

- They help to characterise the properties of the "bulk" of the system.
- Fluctuations are closely related to the **dynamics of the phase transitions.**

end point



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Introduction and motivation

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Irregular behaviour of

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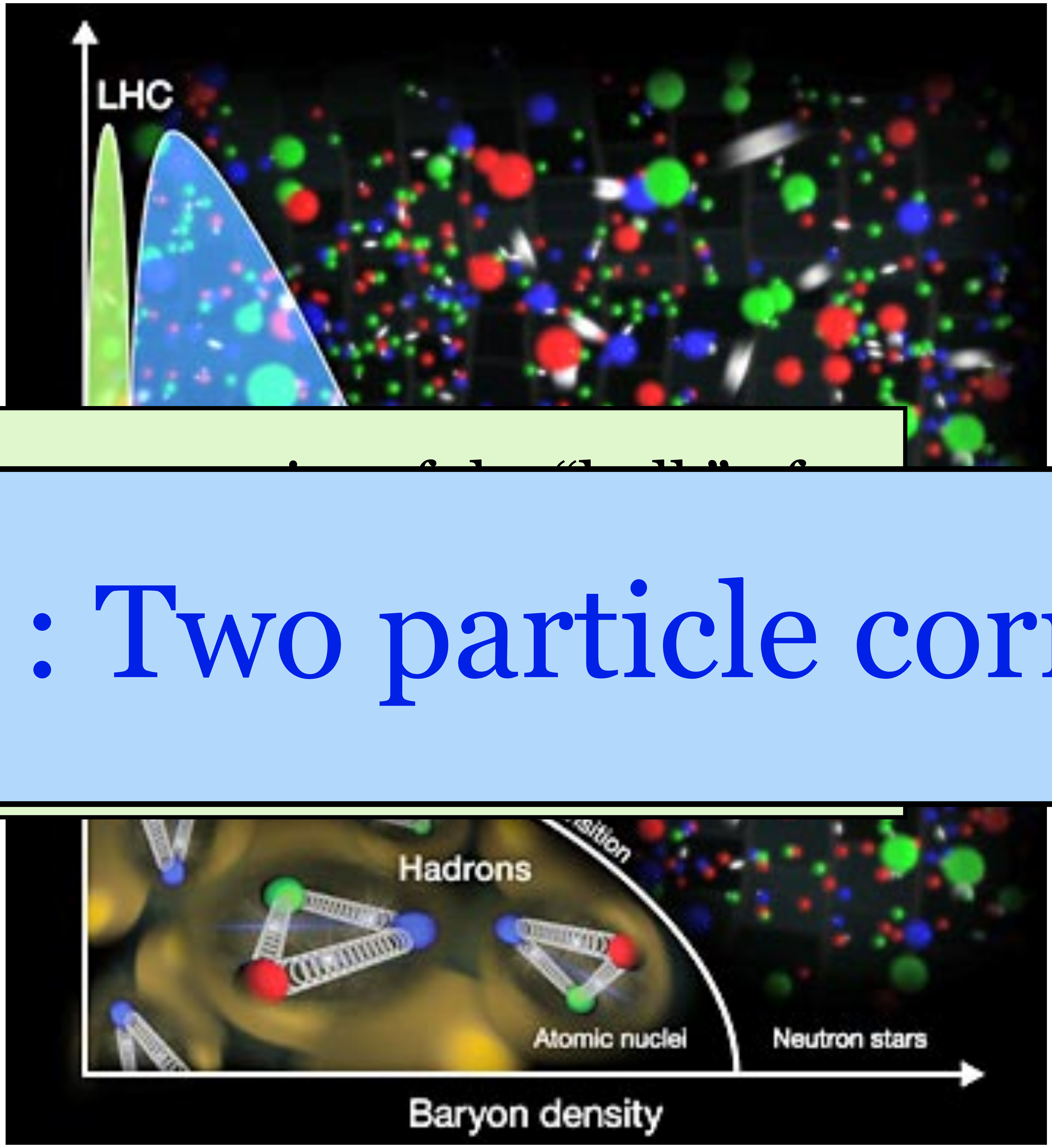

Observable : Two particle correlator

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$$f(E) = \frac{1}{Ae^{E/kT}}$$

Introduction and motivation

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$\langle p_{\mathrm{T}} \rangle$ is a proxy for a local temperature of the system.

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$$\langle \Delta p_i \Delta p_j \rangle = \left\langle \frac{\sum_{i,j \neq i} (p_i - \langle p_T \rangle)(p_j - \langle p_T \rangle)}{N_{ch}(N_{ch} - 1)} \right\rangle$$

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$$\Longrightarrow \langle \Delta p_{\rm i} \Delta p_{\rm j} \rangle = \left\langle \frac{(Q_1)^2 - Q_2}{N_{\rm ch}(N_{\rm ch} - 1)} \right\rangle - \left\langle \frac{Q_1}{N_{\rm ch}} \right\rangle^2$$

G. Giacalone, Phys. Rev. C 103, 024910 (2021)

where, $Q_{\rm n} = \sum_{i=1}^{N} (p_{\rm i})^n$

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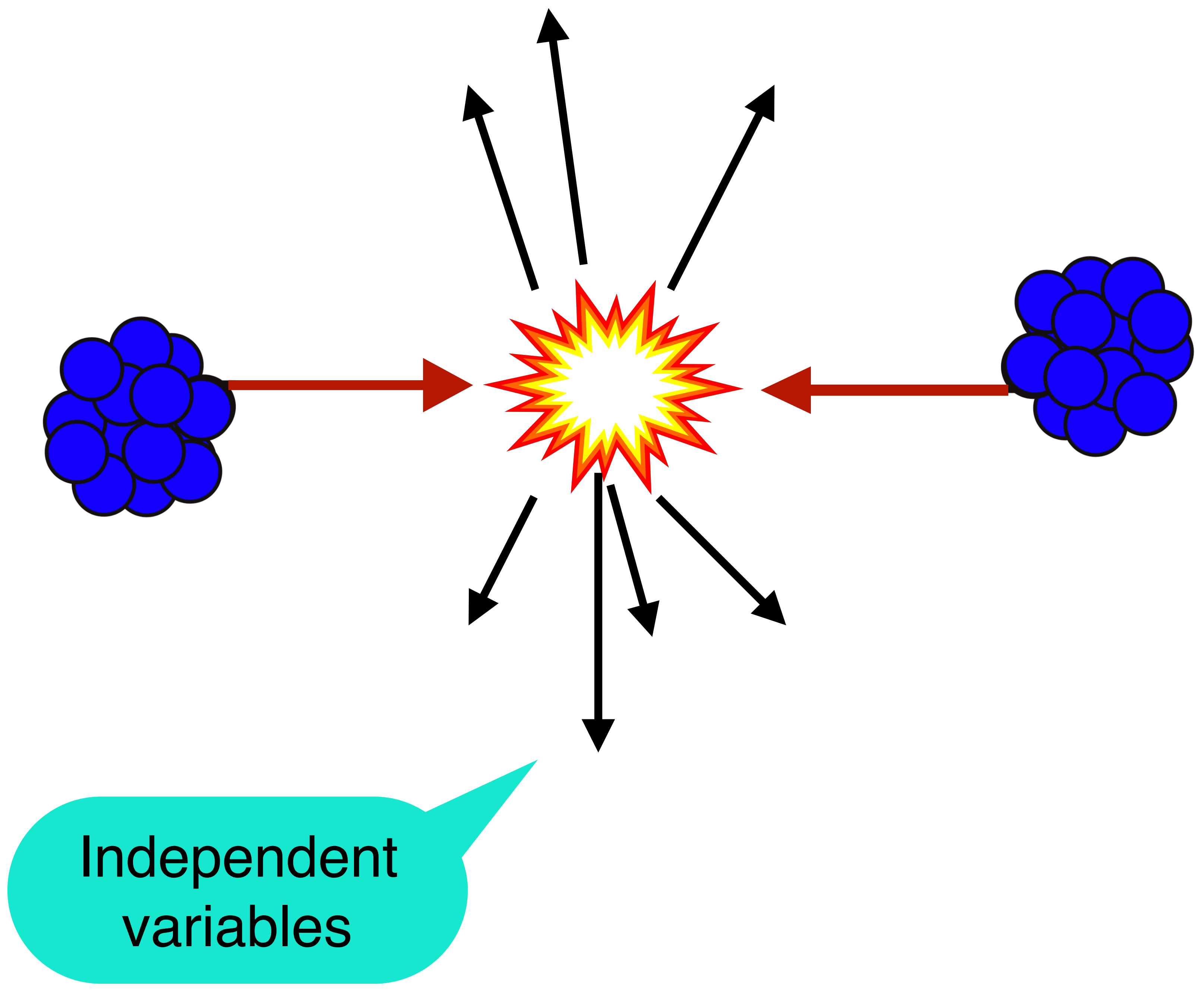
$$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle \langle p_T \rangle \rangle$$

Observable : Two particle correlator

Statistical fluctuation



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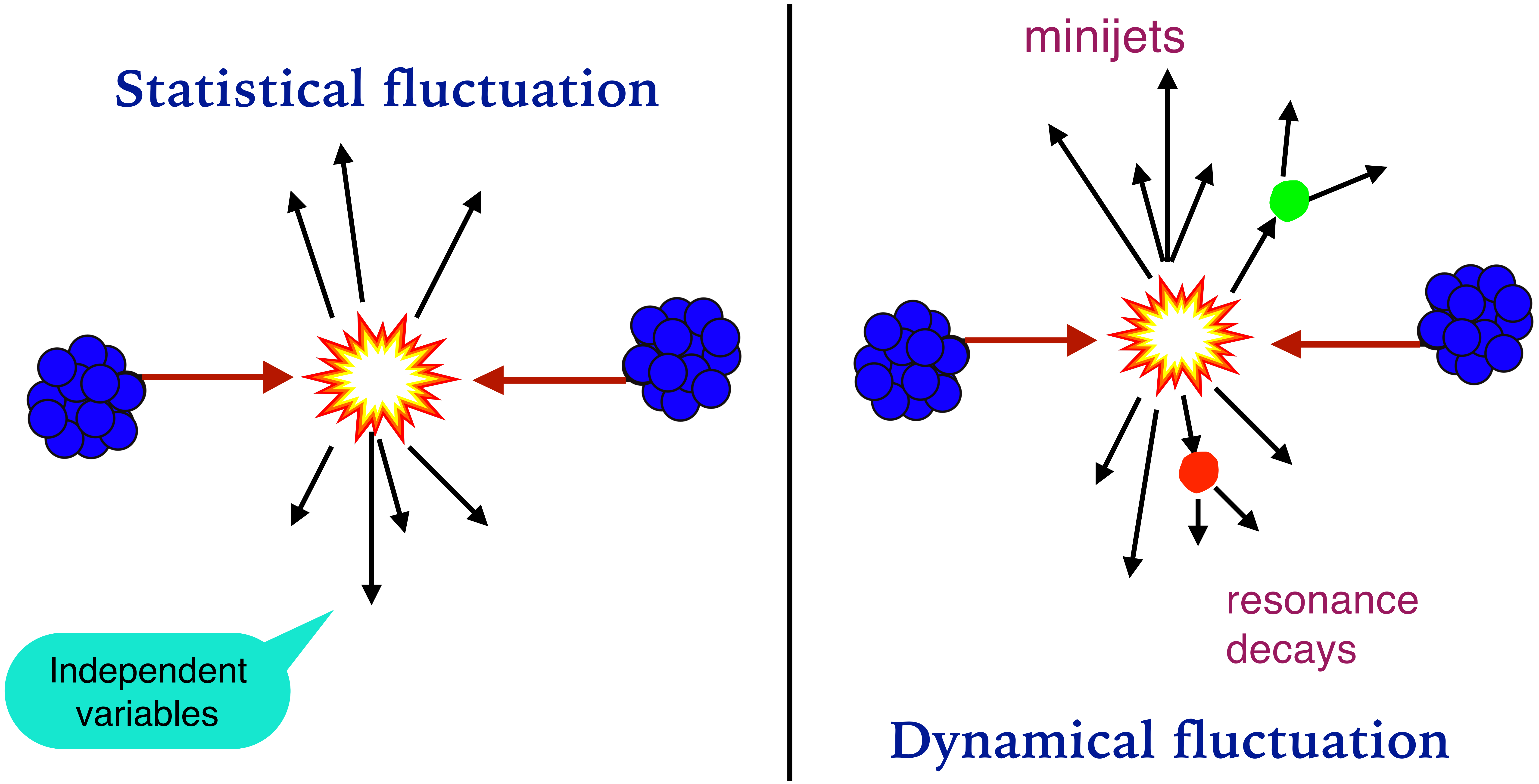

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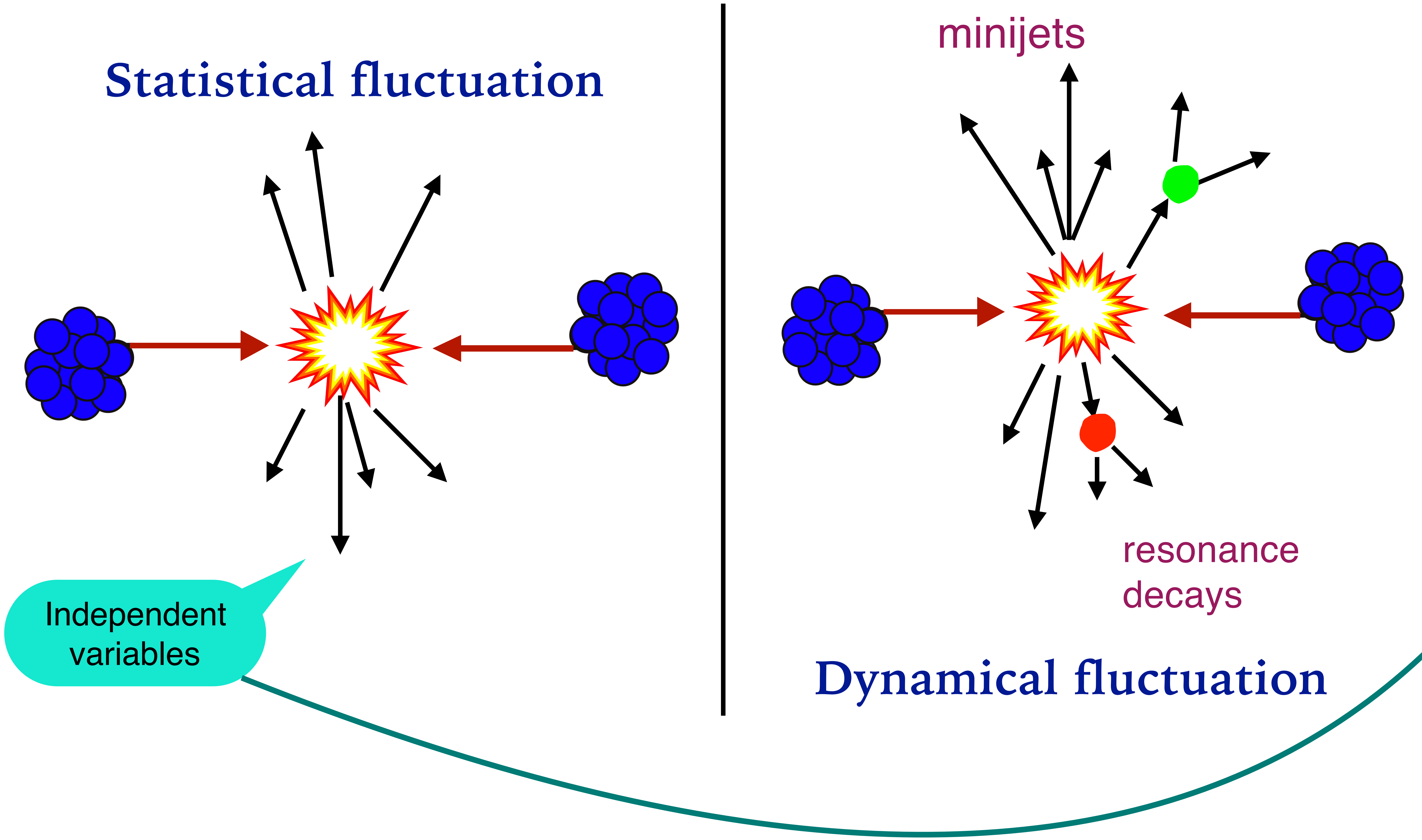
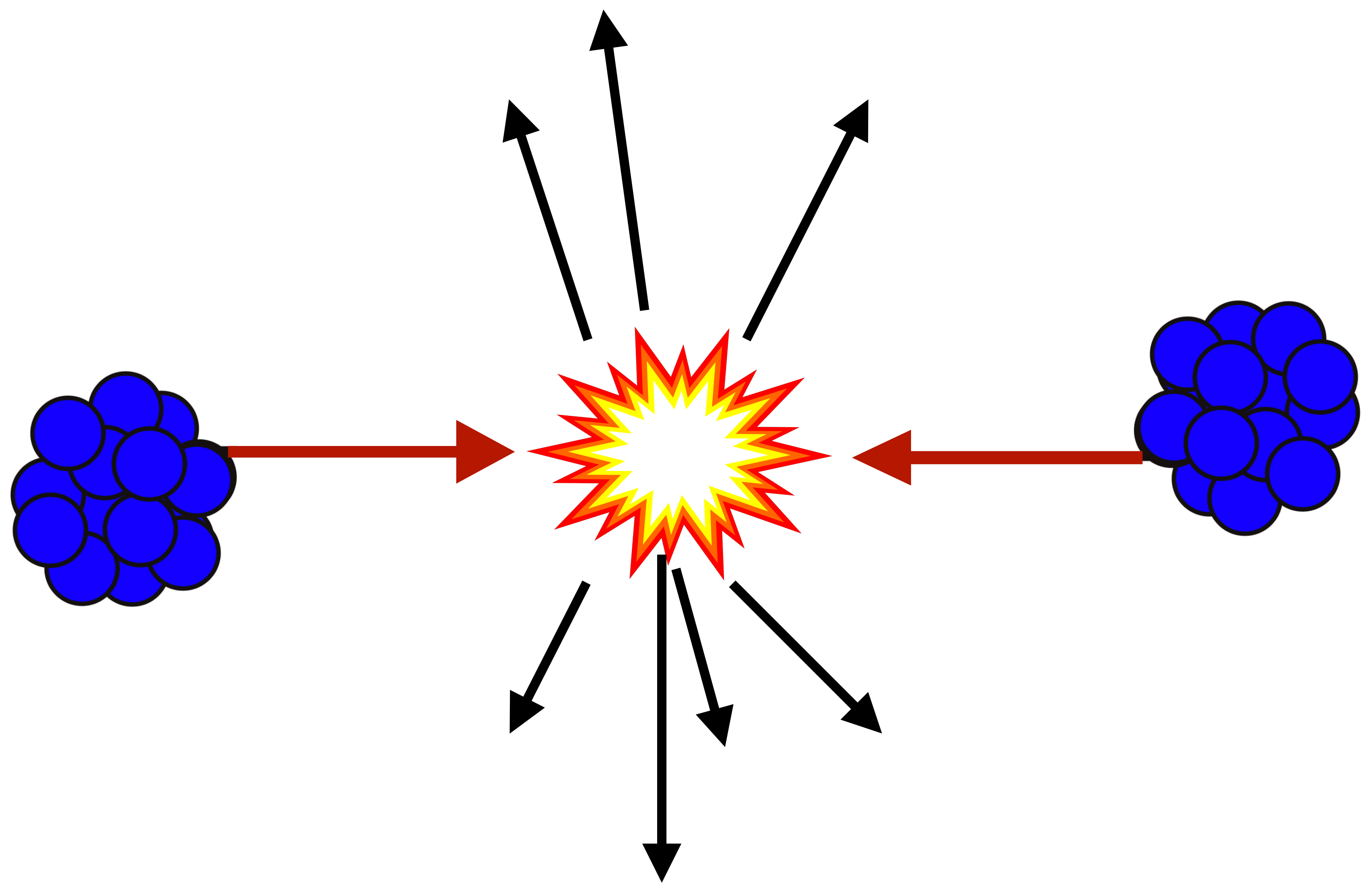


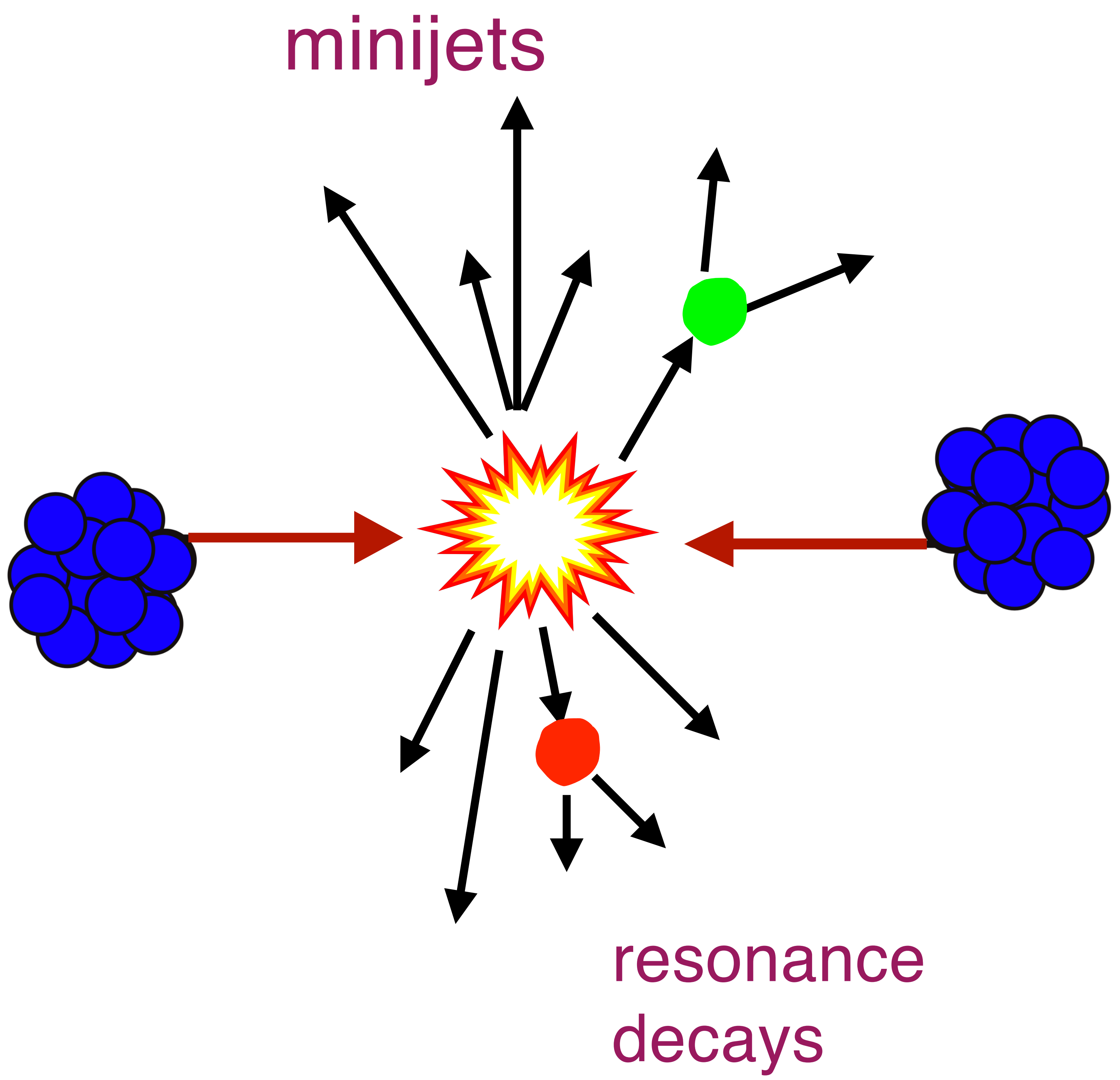
$$F(k) = e^{-\lambda}\frac{\lambda^k}{k!}$$

Introduction and motivation

Statistical fluctuation



Independent variables



Dynamical fluctuation

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

$$\Longrightarrow < F(k) > = \lambda$$

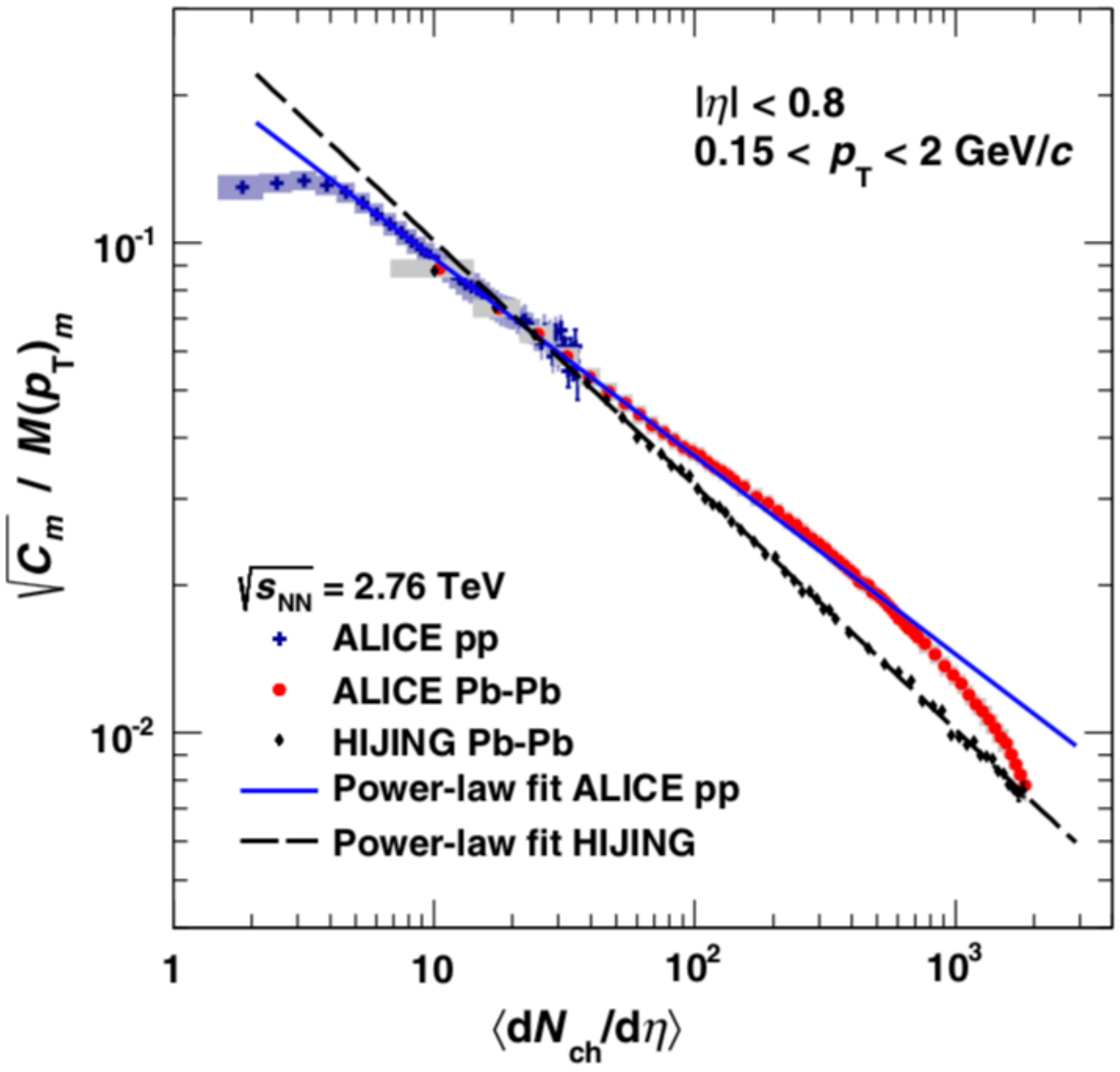
$$Cov(x, y) = E[x, y] - E[x]E[y]$$

$$\Longrightarrow \lambda_1\lambda_2 - \lambda_1\lambda_2 = 0$$

C=0

No **statistical** fluctuation

Introduction and motivation



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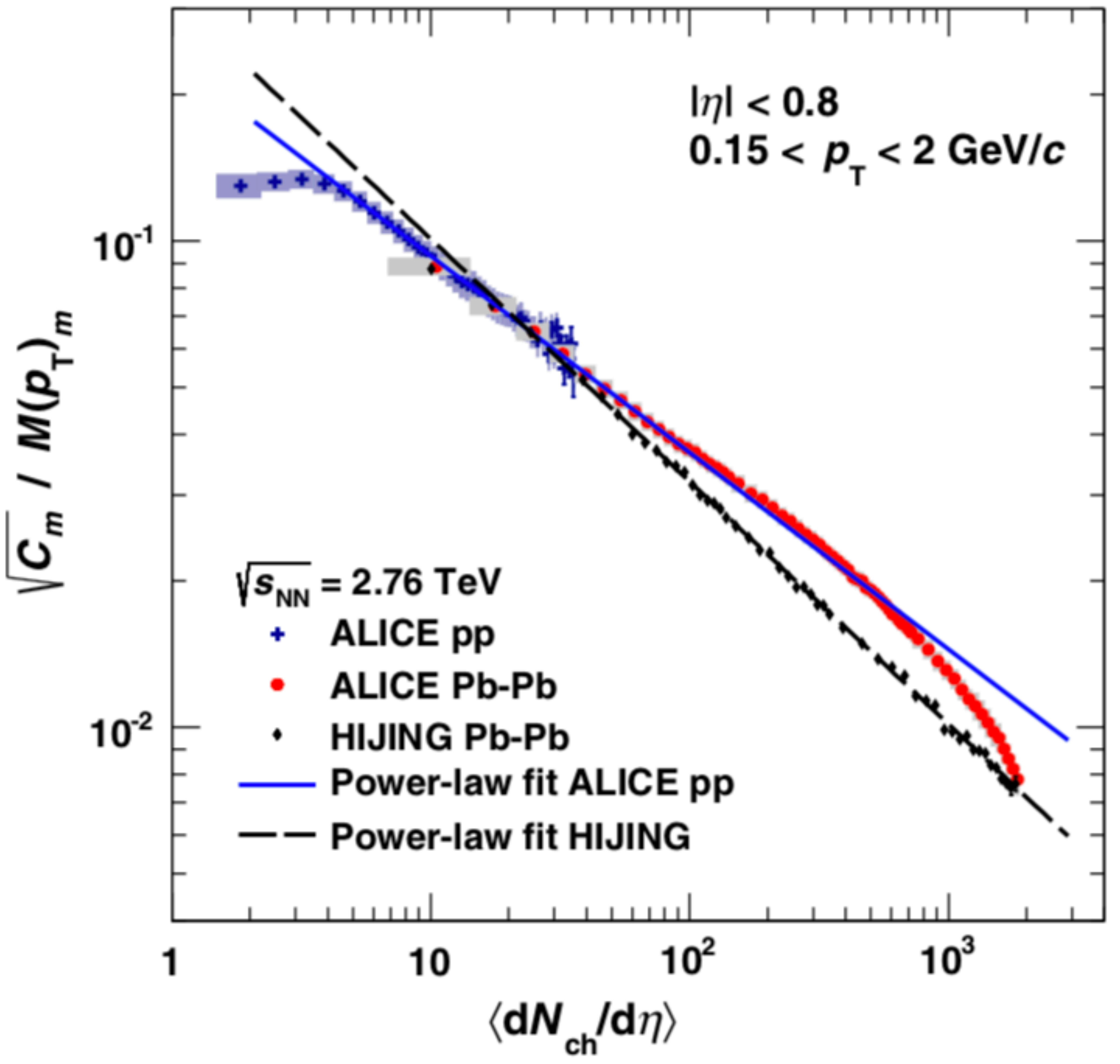
- In peripheral collisions the Pb–Pb results are in very good agreement with the extrapolation of a power-law fit to pp data.
- At larger multiplicities, the Pb–Pb results deviate from the pp extrapolation.

[1] Phys.Lett. B727 (2013) 371–380,



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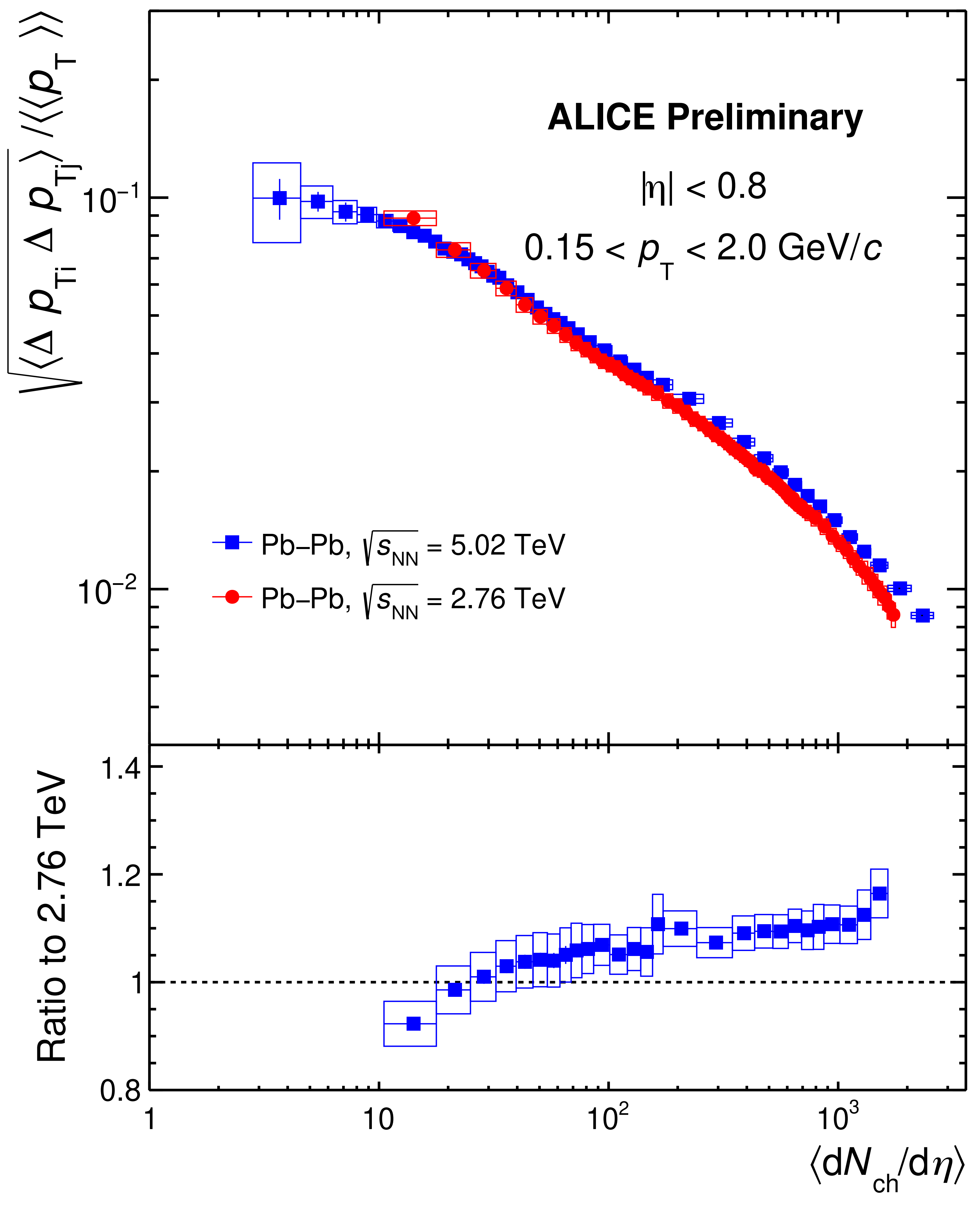
- Analysis of the dependence of fluctuations on collision energy and system size:
  - Measurements in Xe-Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV and Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.

[1] Phys.Lett. B727 (2013) 371–380,

$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle p_T \rangle$ vs $\langle dN_{ch}/d\eta \rangle$ (Collision energy comparison in Pb-Pb collision)



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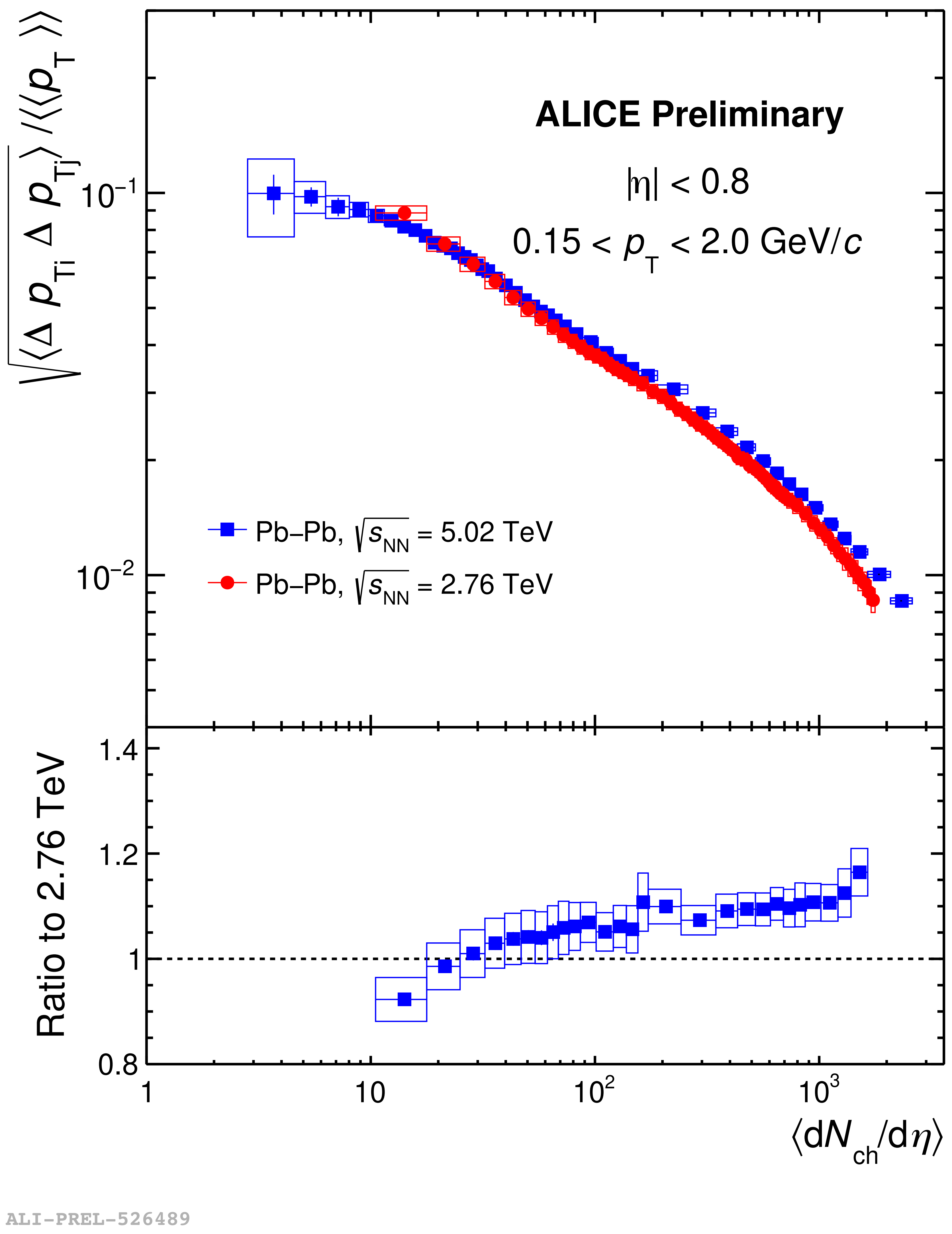

- Significant dynamical fluctuations;

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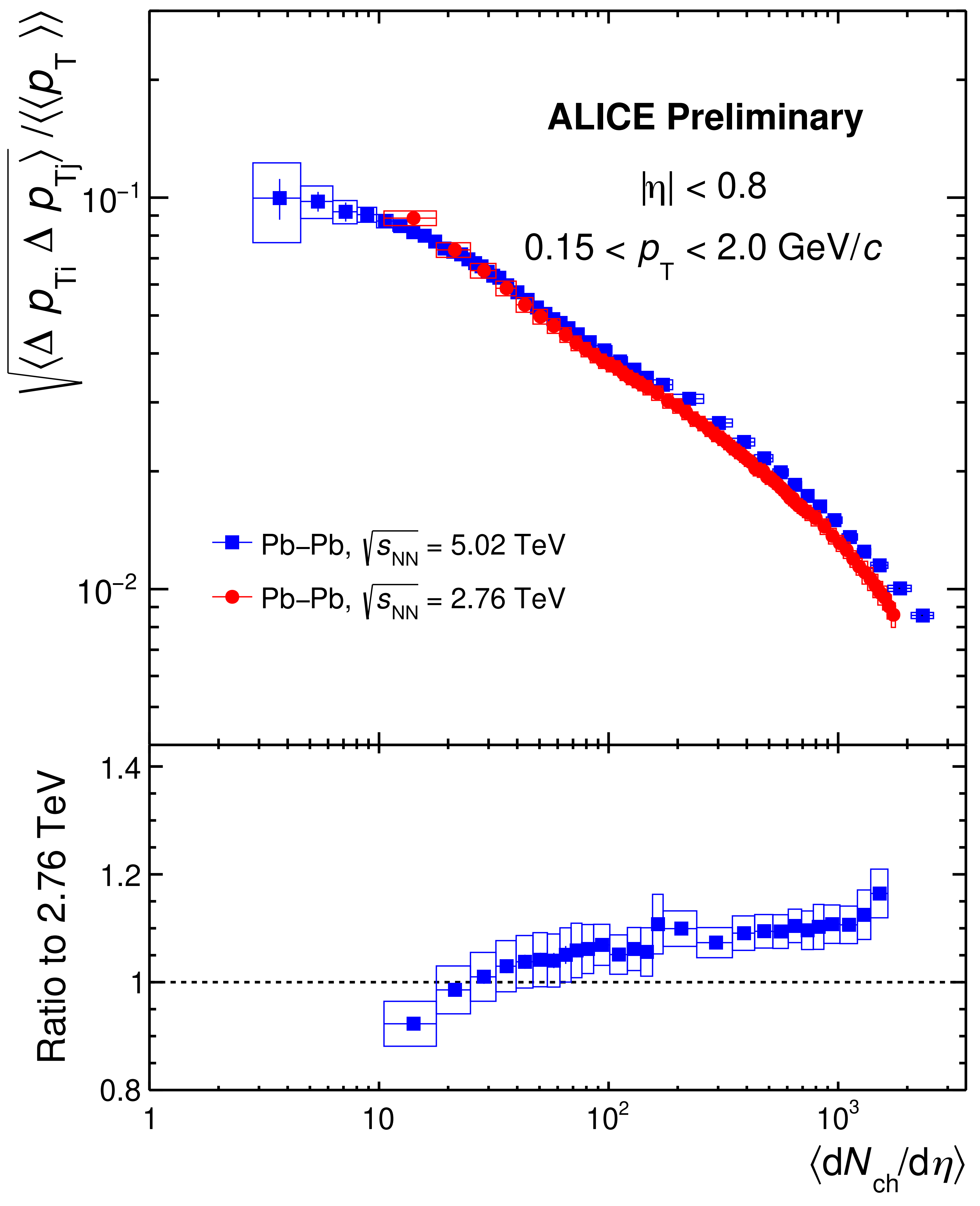

- Significant dynamical fluctuations;
- Fluctuations decrease with increasing multiplicity;

$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle p_T \rangle$ vs $\langle dN_{ch}/d\eta \rangle$ (Collision energy comparison in Pb-Pb collision)

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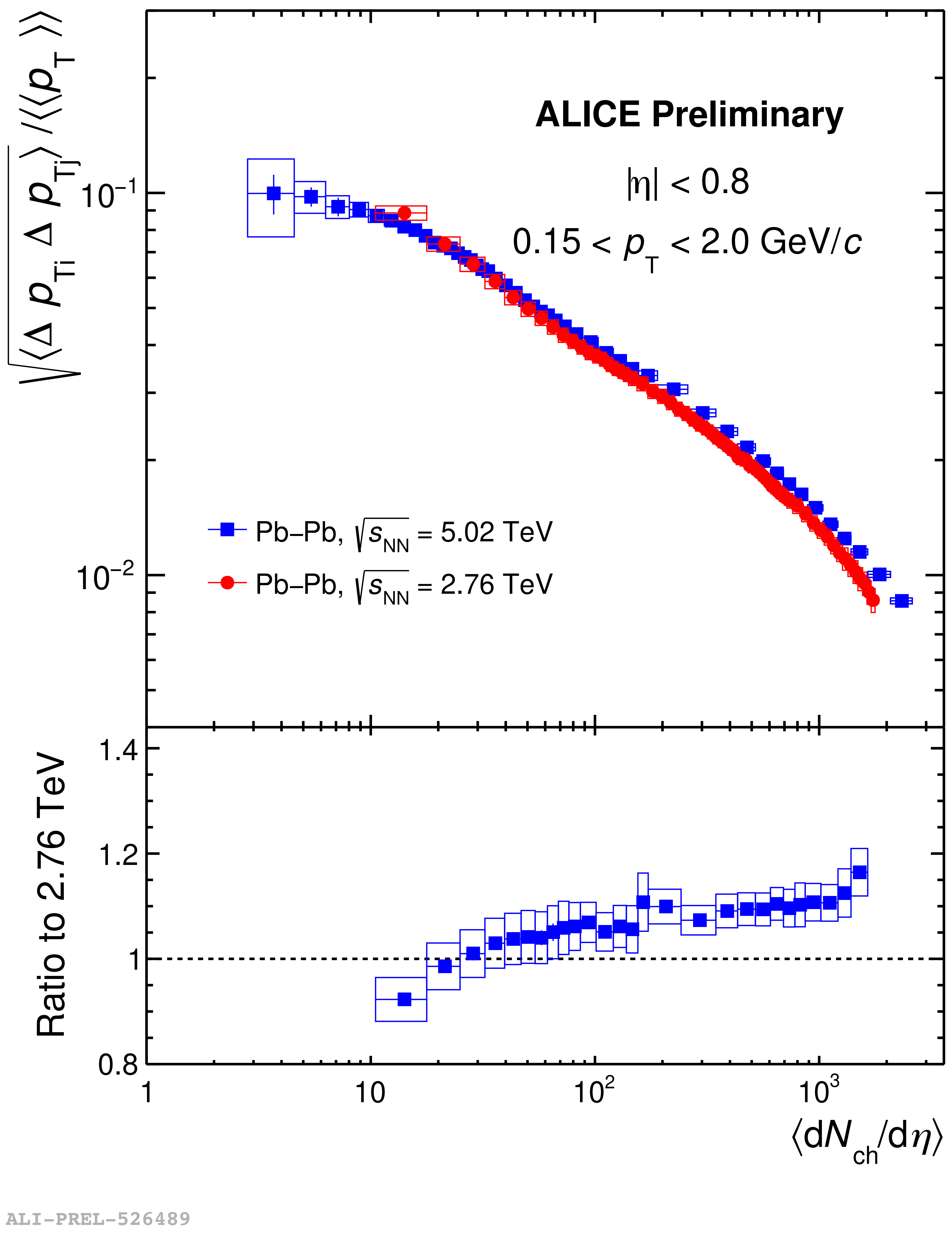
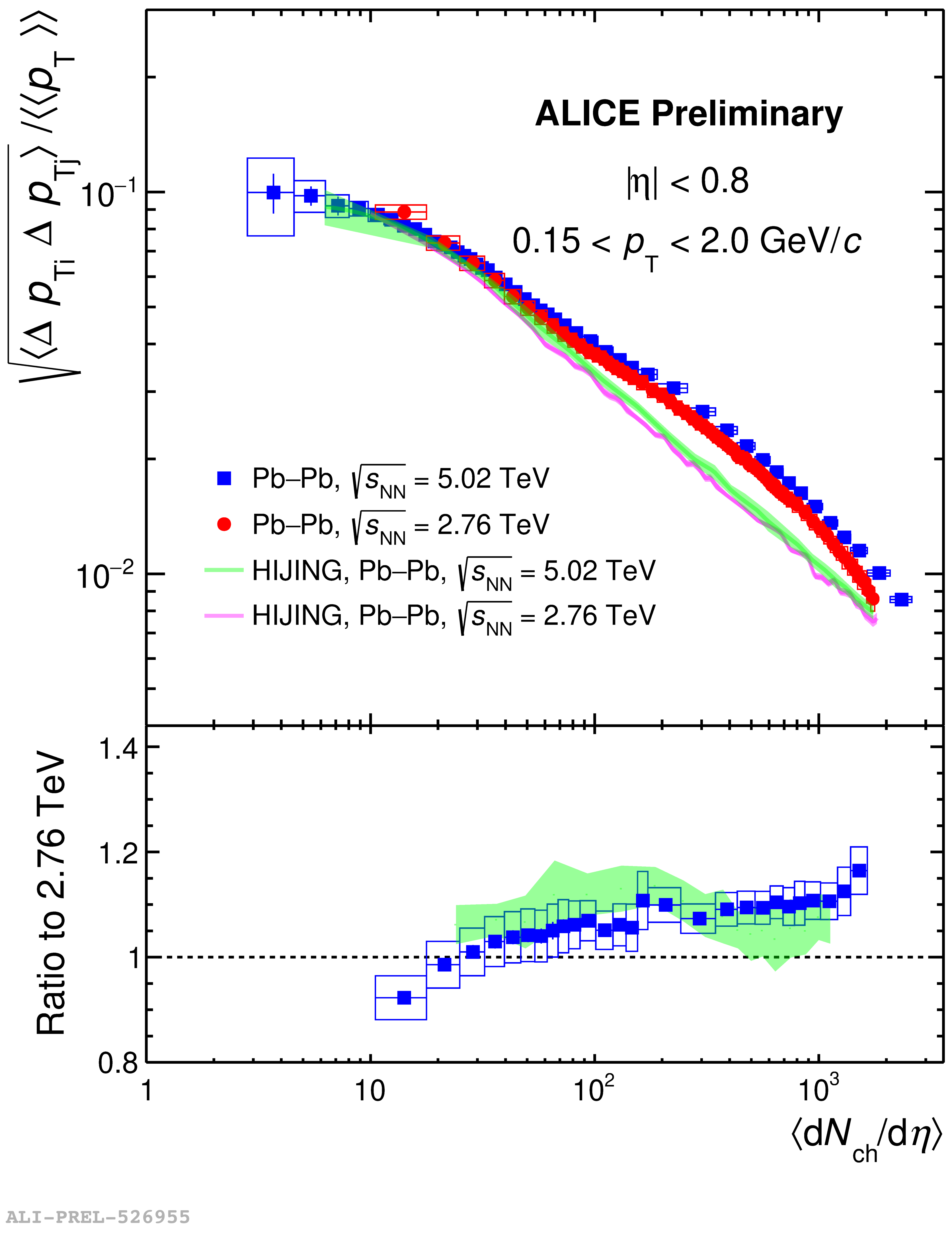


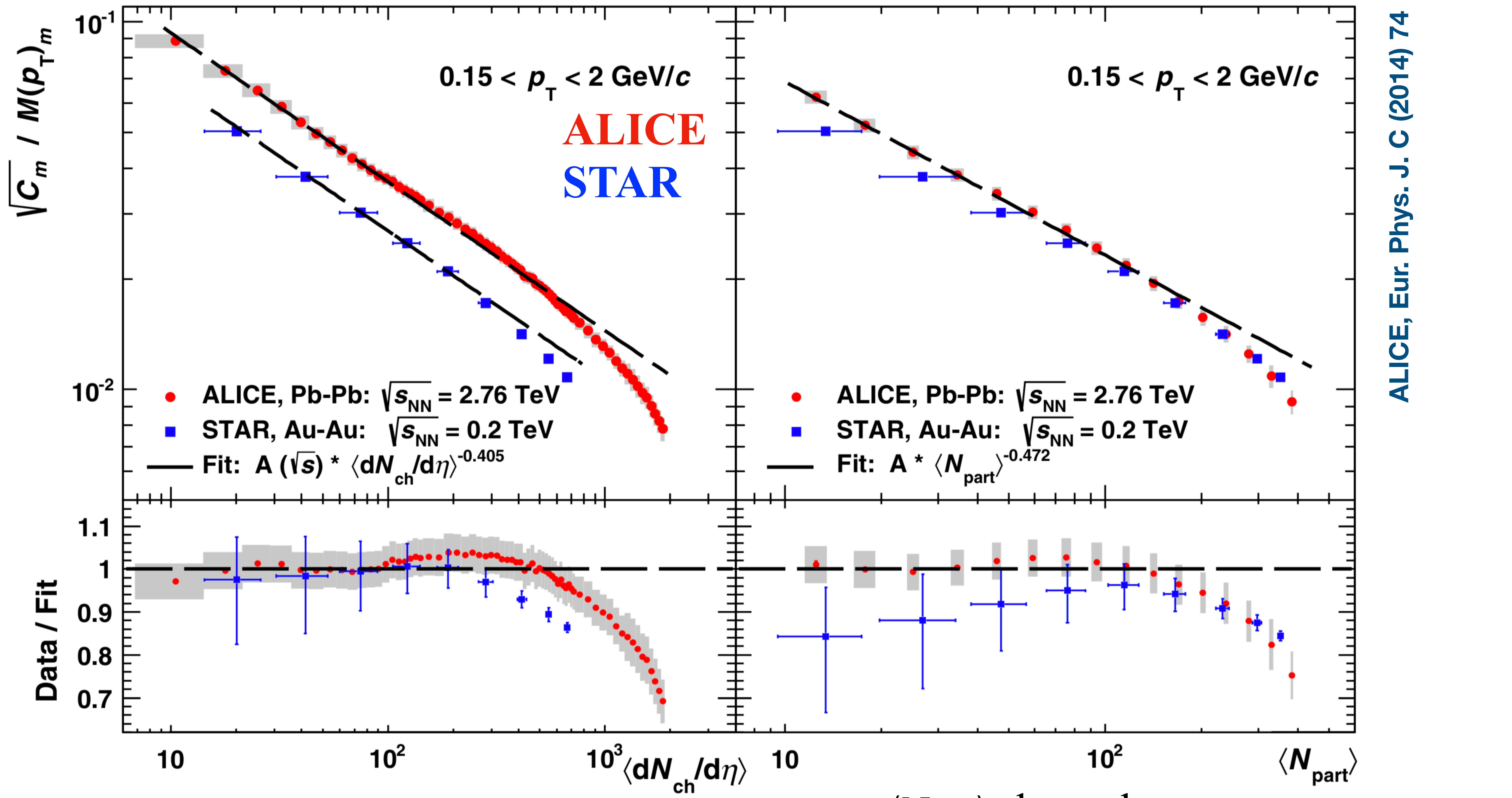
- Significant dynamical fluctuations;
- Fluctuations decrease with increasing multiplicity;
- Clear dependence of correlator on collision energy is observed for central Pb-Pb collisions.

$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle p_T \rangle$ vs $\langle dN_{ch}/d\eta \rangle$ (Model comparison)



- Energy dependence is described by the HIJING model.

$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle p_T \rangle$ vs $\langle N_{part} \rangle$



$\langle dN_{ch}/d\eta \rangle$ dependence

$\langle N_{part} \rangle$ dependence

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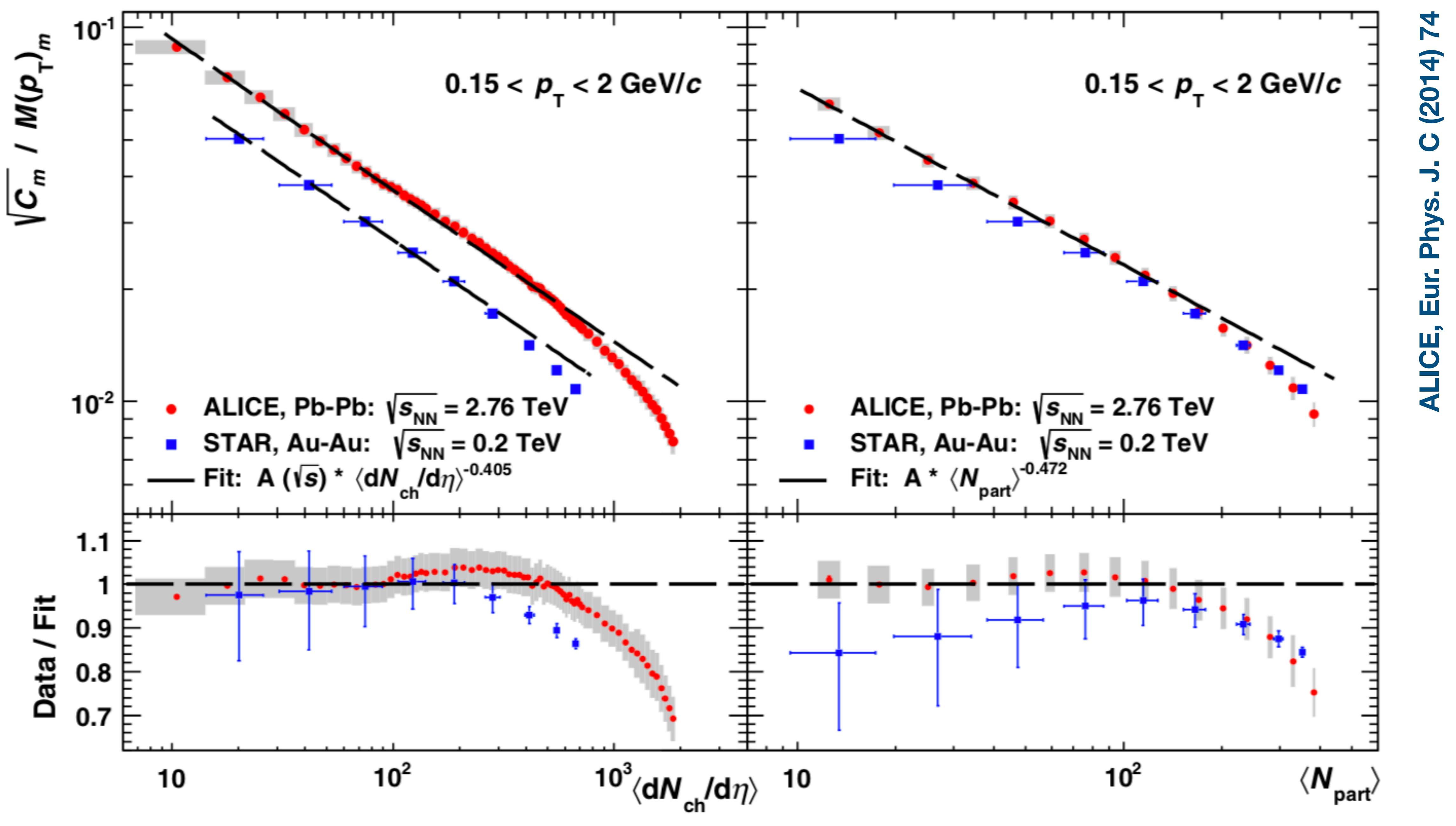
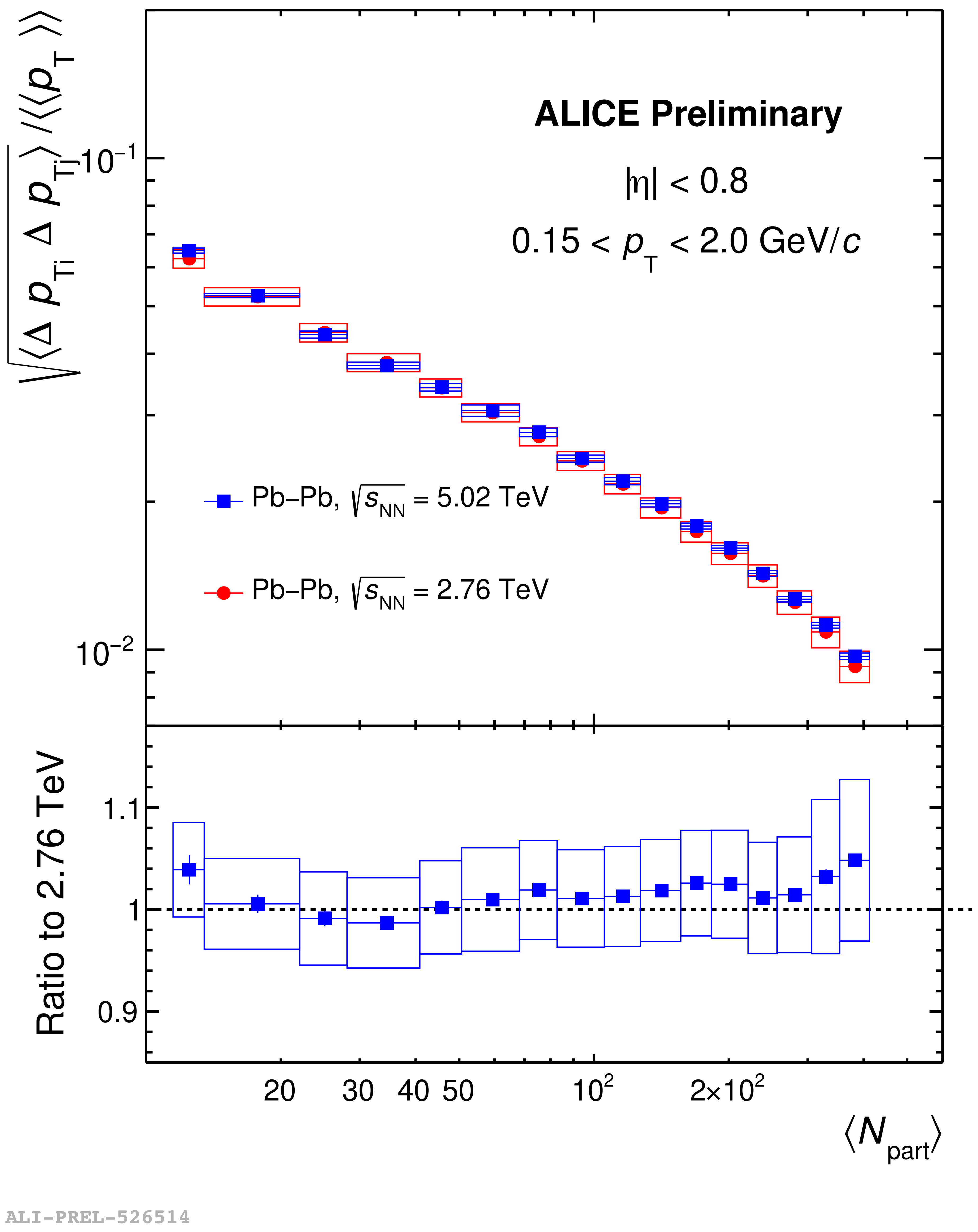
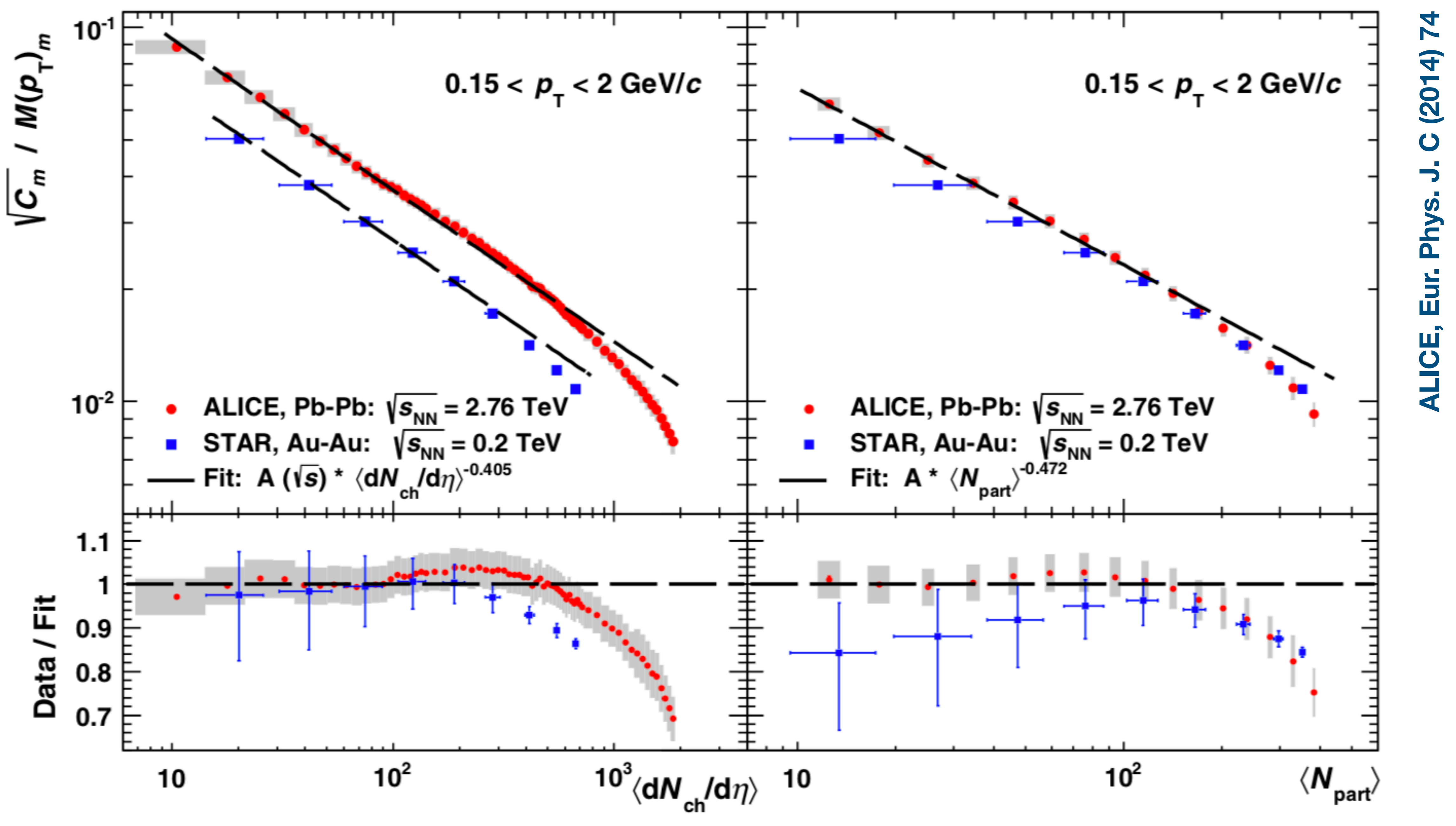


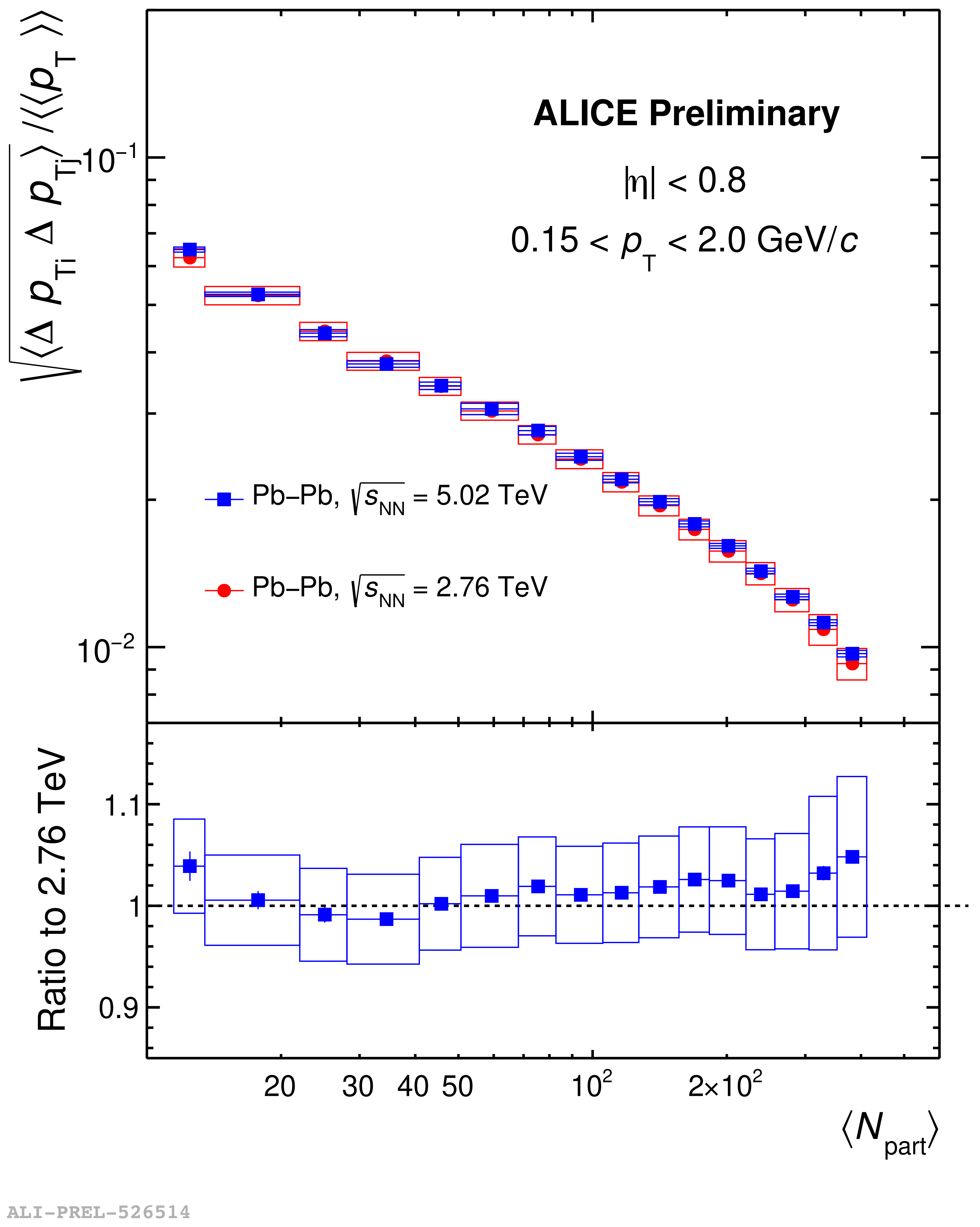


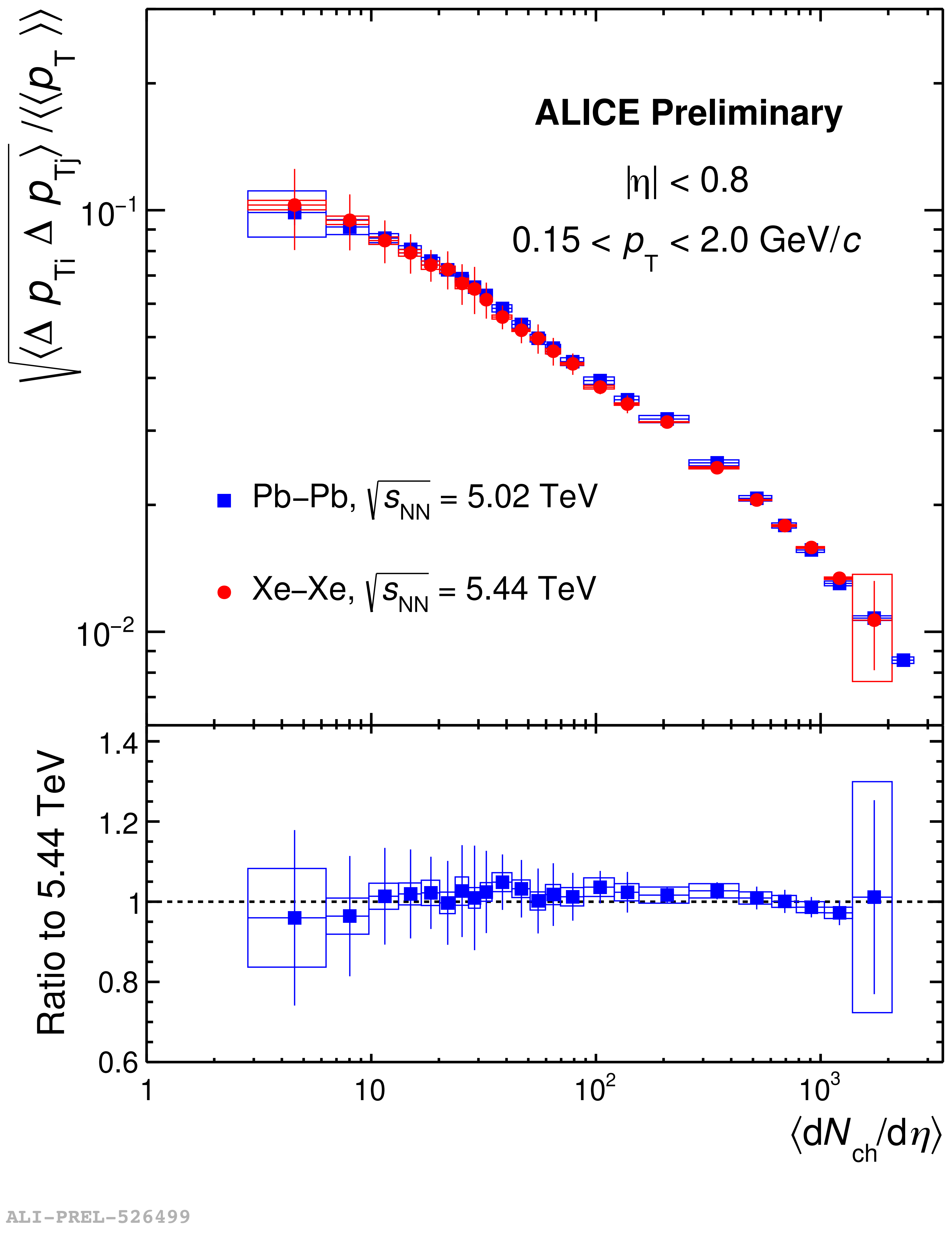
- Clear dependence of correlator vs $\langle dN_{ch}/d\eta \rangle$ on collision energy is observed for central Pb-Pb collisions.

$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle p_T \rangle$ vs $\langle N_{part} \rangle$



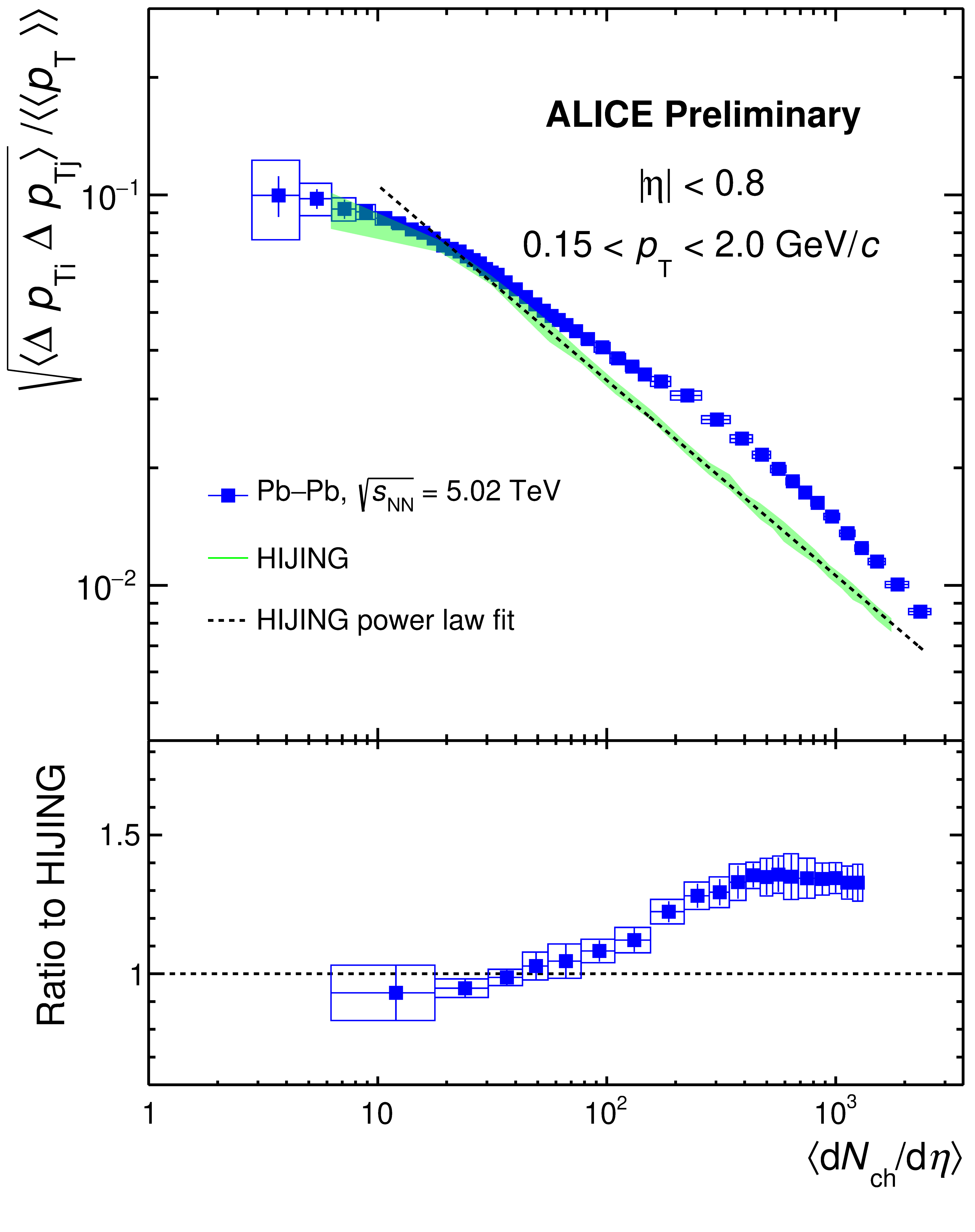
- Clear dependence of correlator vs $\langle dN_{ch}/d\eta \rangle$ on collision energy is observed for central Pb-Pb collisions.
- The dependence on collision energy disappears when plotted as a function of $\langle N_{part} \rangle$.





- Values of the correlator for Xe-Xe and Pb-Pb collisions quantitatively agree with each other.

$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle p_T \rangle$ vs $\langle dN_{ch}/d\eta \rangle$ (Model comparison)



- Power law fit :

$$\propto \langle dN_{ch}/d\eta \rangle^{b} \quad (b = -0.5)$$

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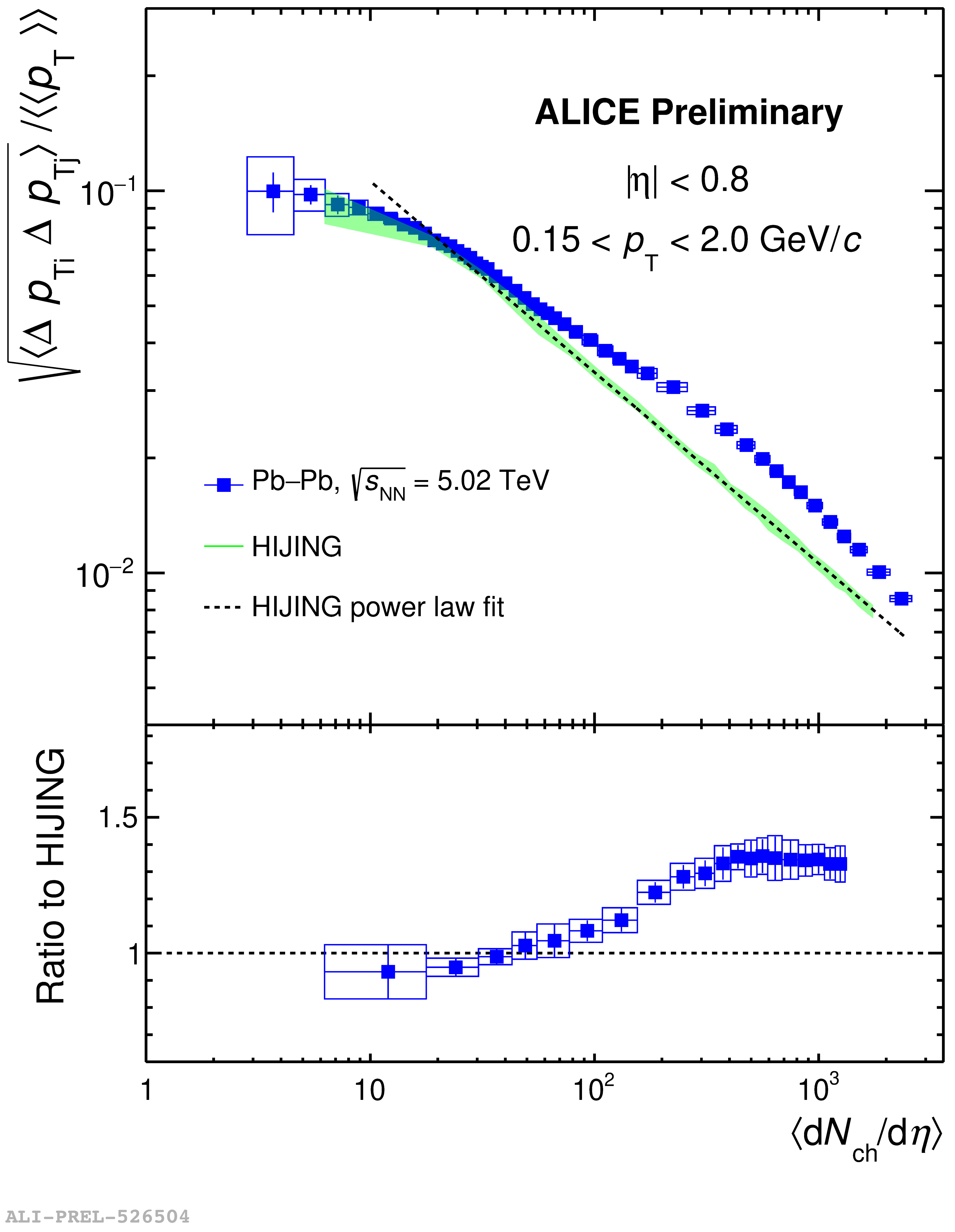

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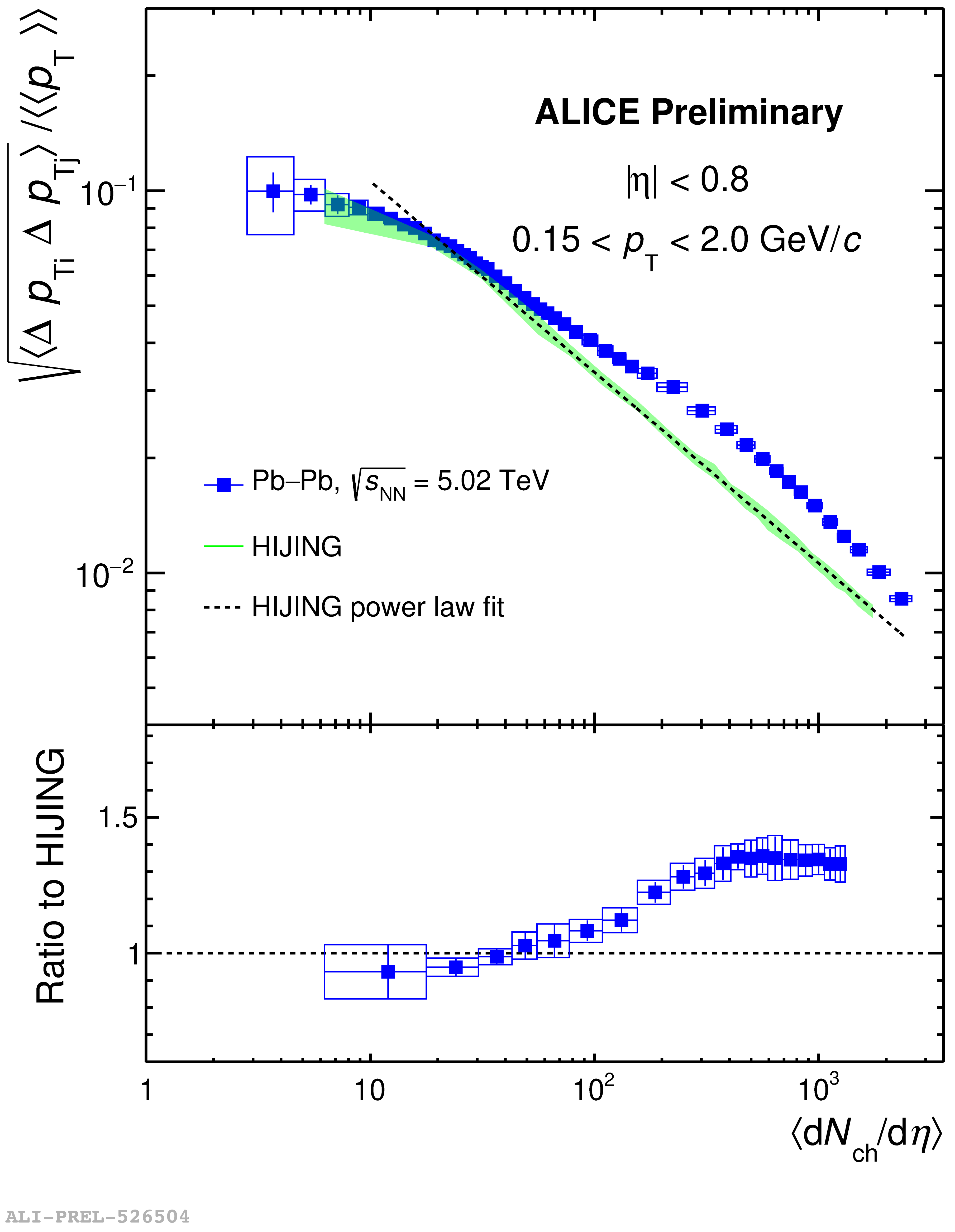

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- Deviation in central Pb-Pb collisions.

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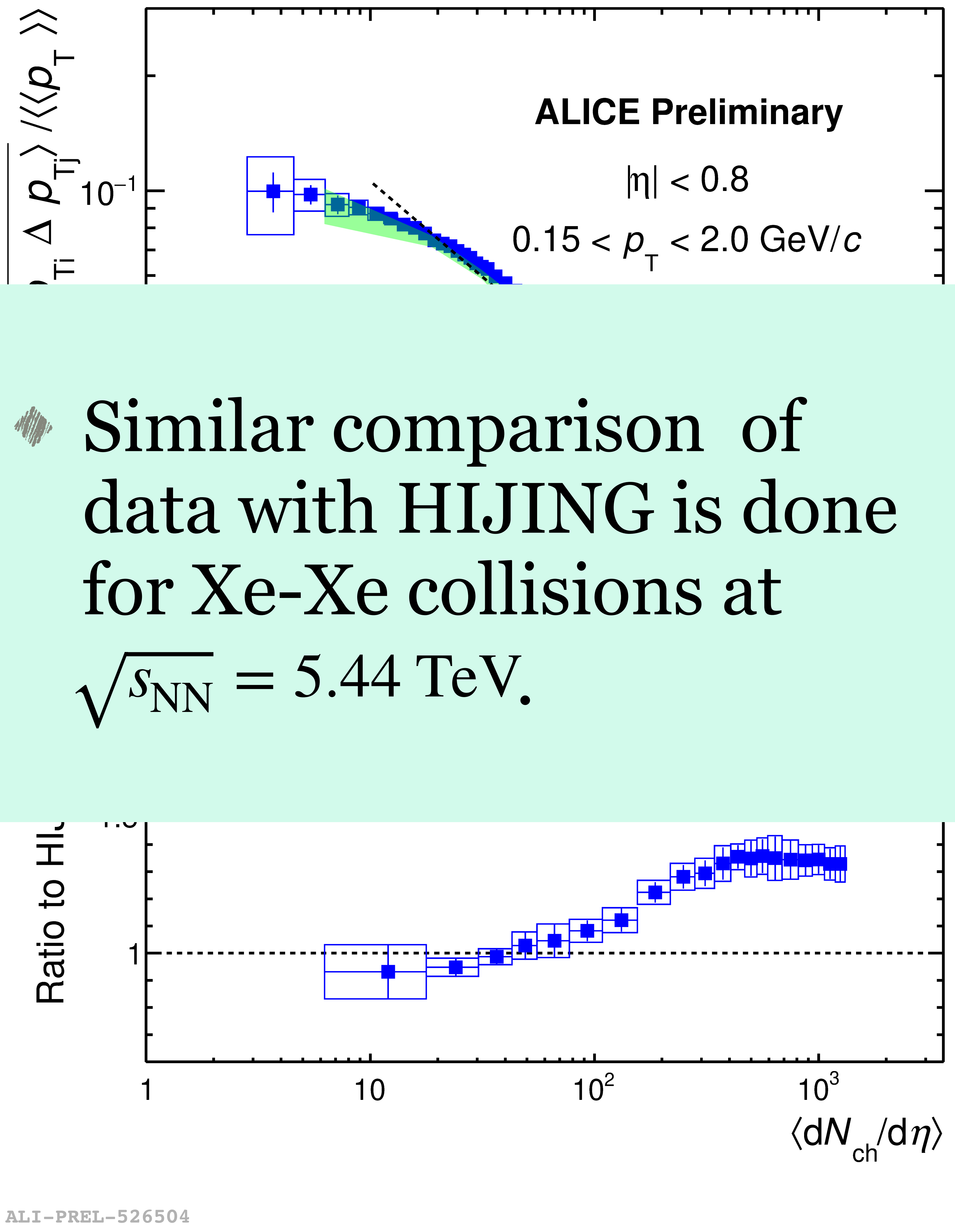

- Similar comparison of data with HIJING is done for Xe-Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV.

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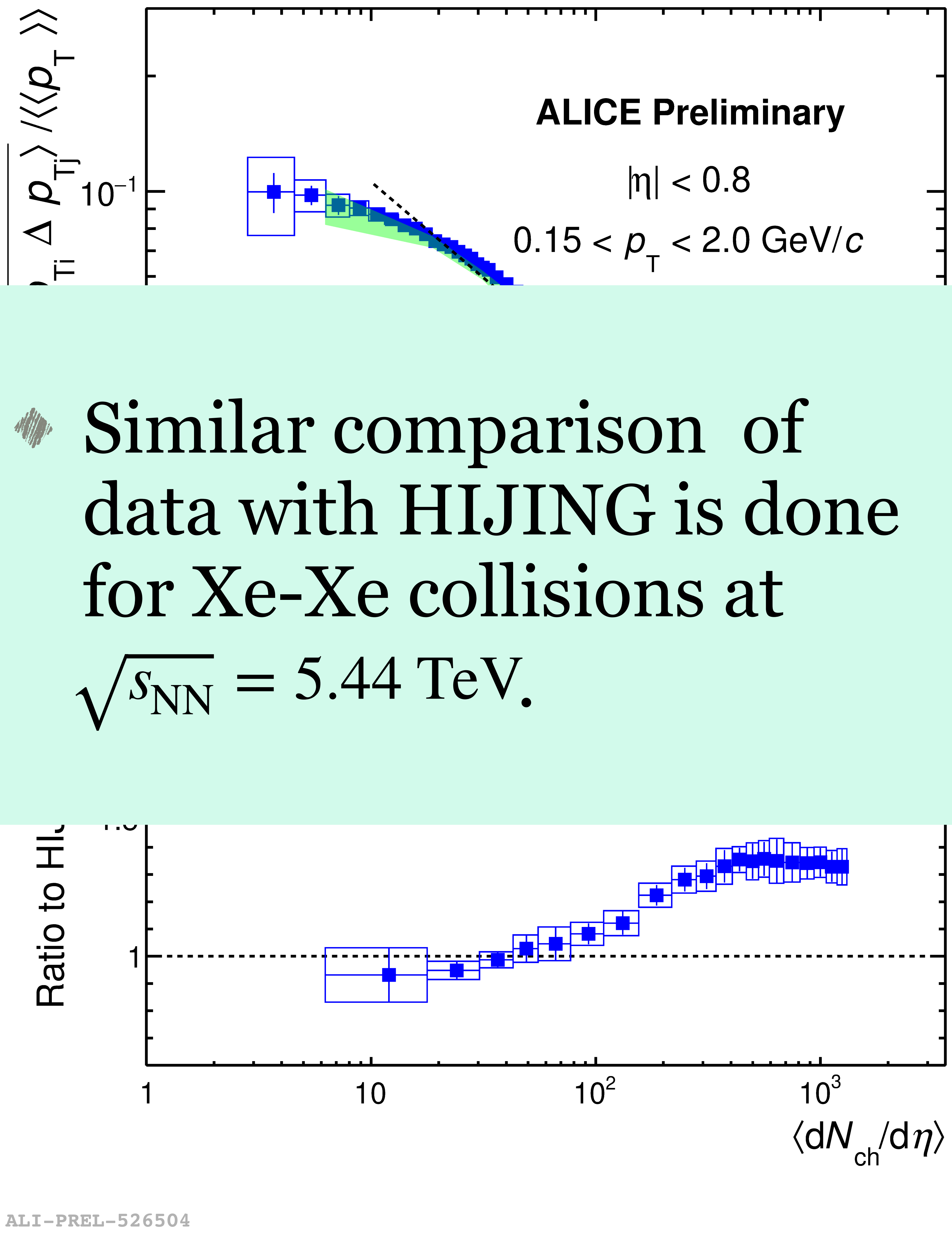

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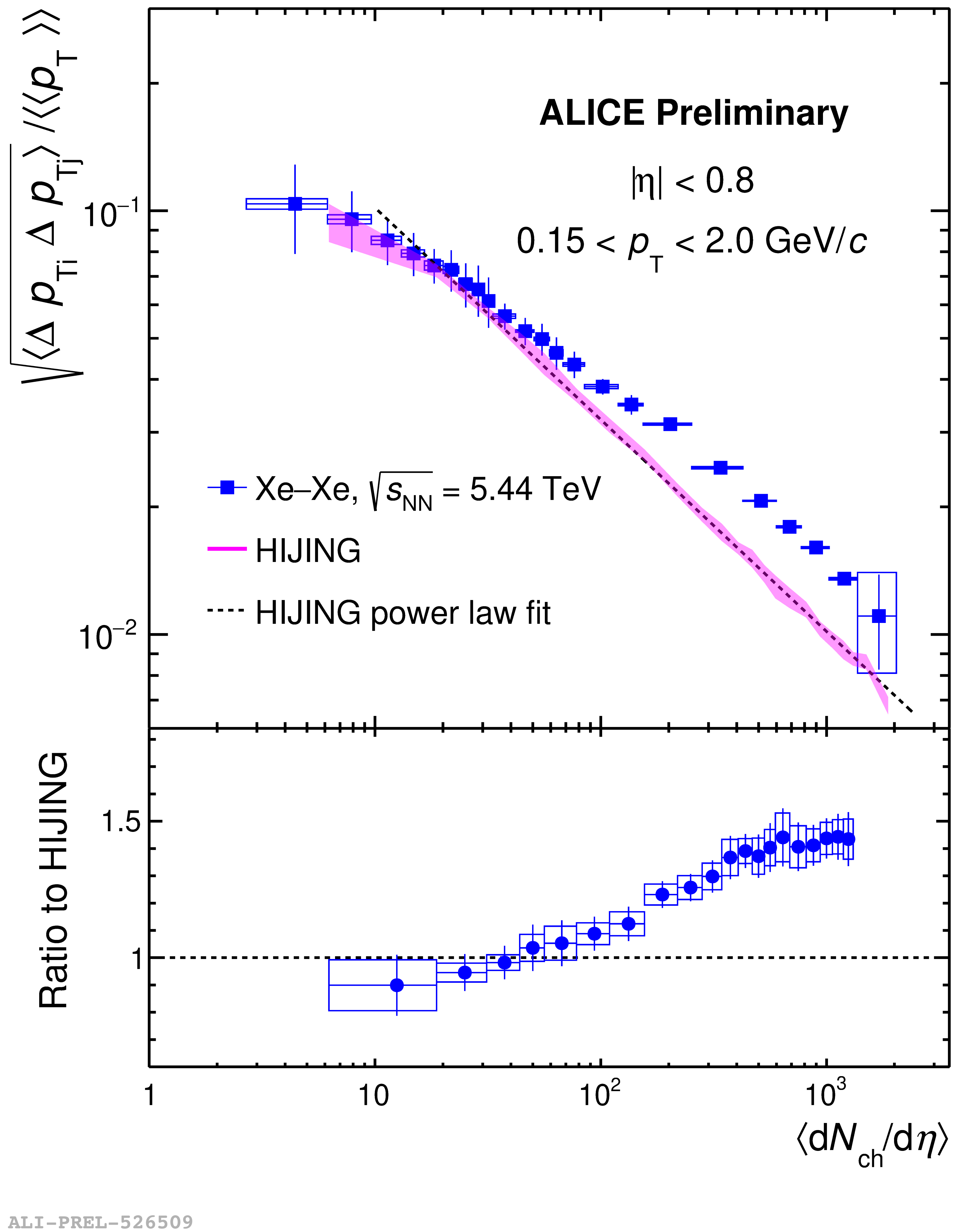

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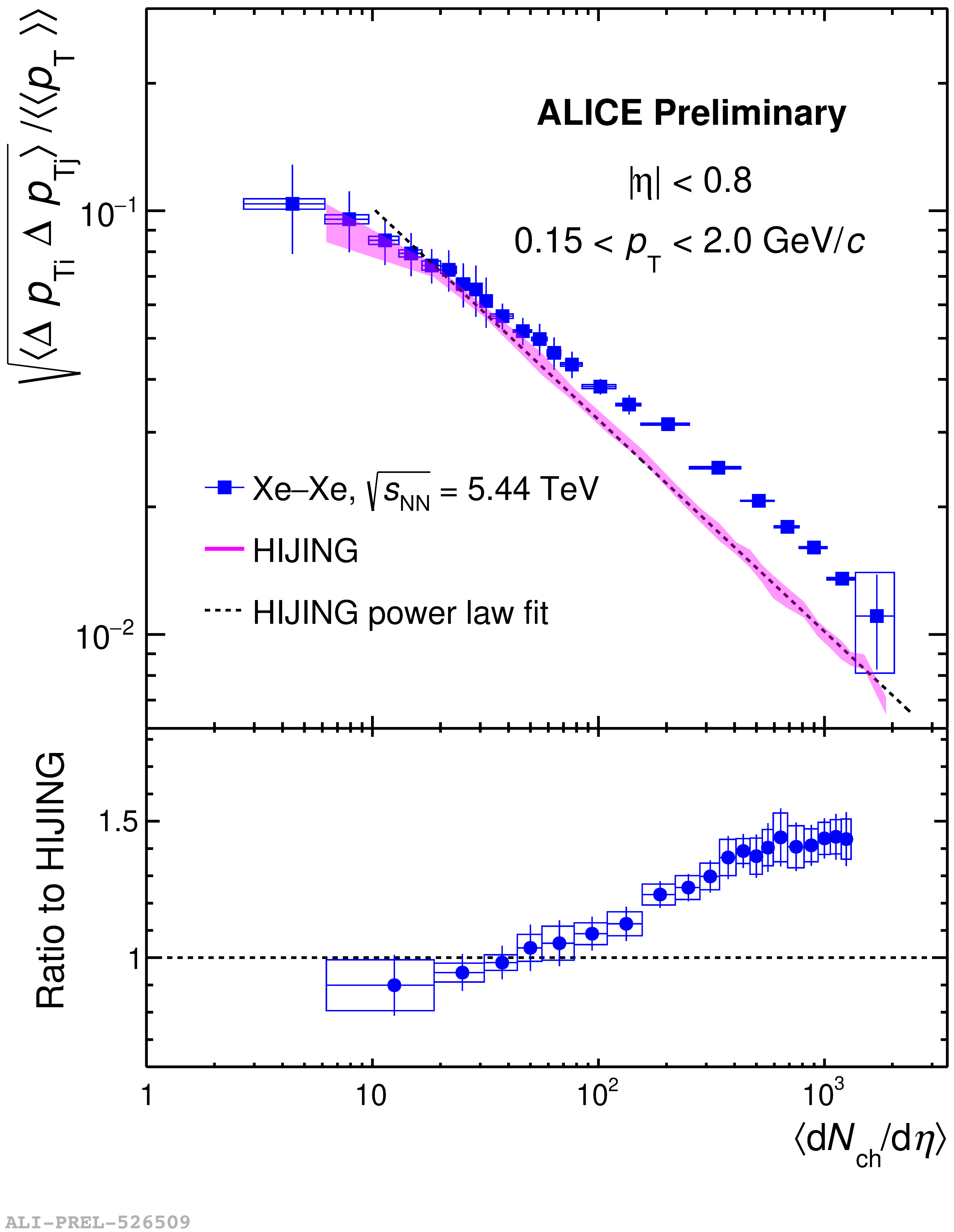
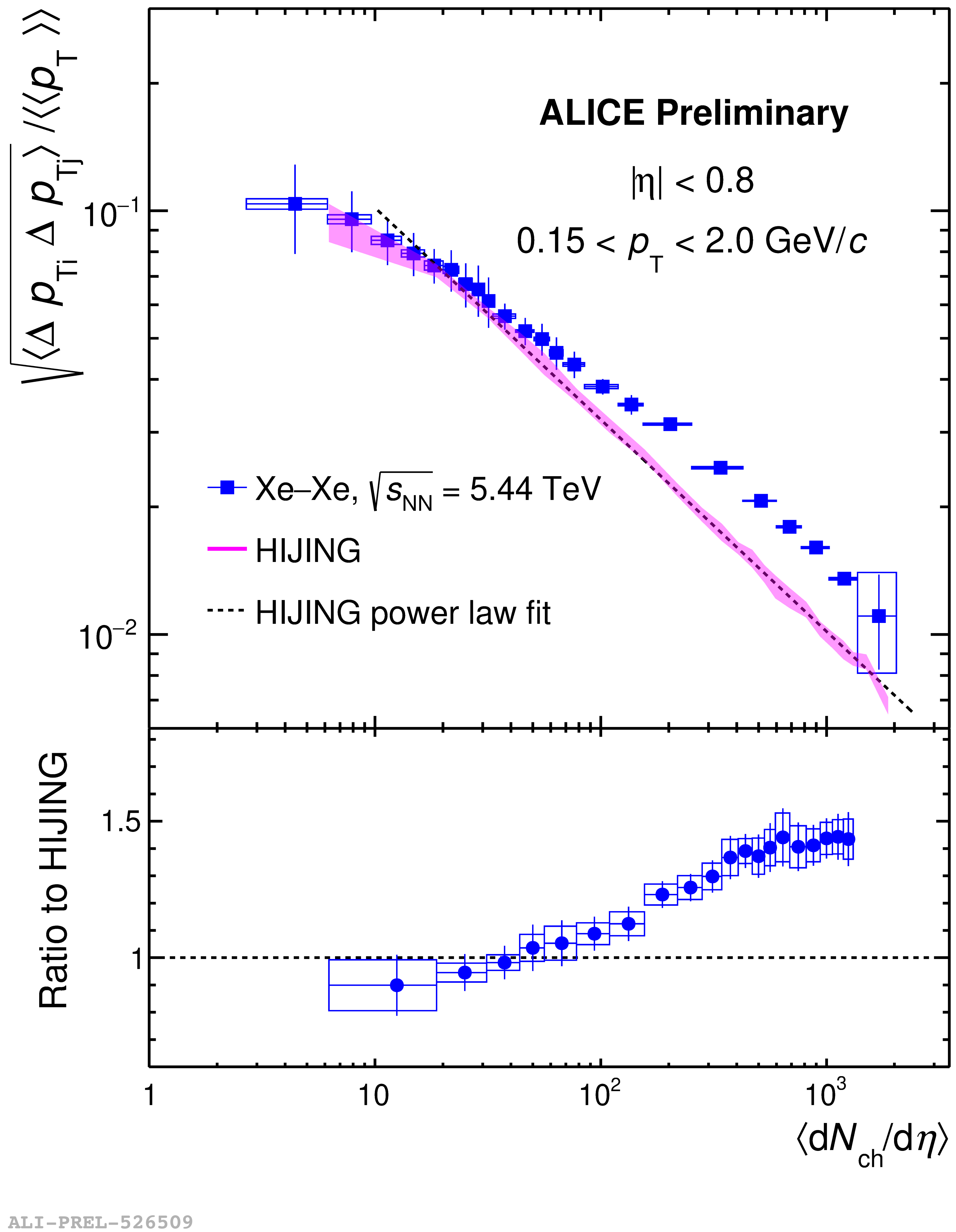


- Deviation from simple superposition scenario is observed in central Xe-Xe collisions.
- This could be indicative of sources like radial flow.



Summary

- The event-by-event fluctuations of the $\langle p_{\mathrm{T}} \rangle$ of charged particles in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and Xe—Xe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV at the LHC are presented.

- The trend in Pb—Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV is in qualitative agreement with the previous measurement at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV.

- The two particle correlator quantified by $\sqrt{\langle \Delta p_{\mathrm{Ti}} \Delta p_{\mathrm{Tj}} \rangle} / \langle \langle p_{\mathrm{T}} \rangle \rangle$ decreases with increasing multiplicity.

- In both Xe—Xe and Pb—Pb collisions, a clear deviation from simple superposition scenario of particle emitting sources is observed as a function of multiplicity.

- $\sqrt{\langle \Delta p_{\mathrm{Ti}} \Delta p_{\mathrm{Tj}} \rangle} / \langle \langle p_{\mathrm{T}} \rangle \rangle$ has been compared with HIJING model. The model underestimates the data for higher multiplicities.

~Thank You~