ATHIC2023

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JMS Aster Plaza, Hiroshima, Japan

ALICE

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

ज्ञानम् परमम् ध्येयम्

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

Tulika Tripathy

On behalf of the ALICE Collaboration

Indian Institute of Technology Bombay, India

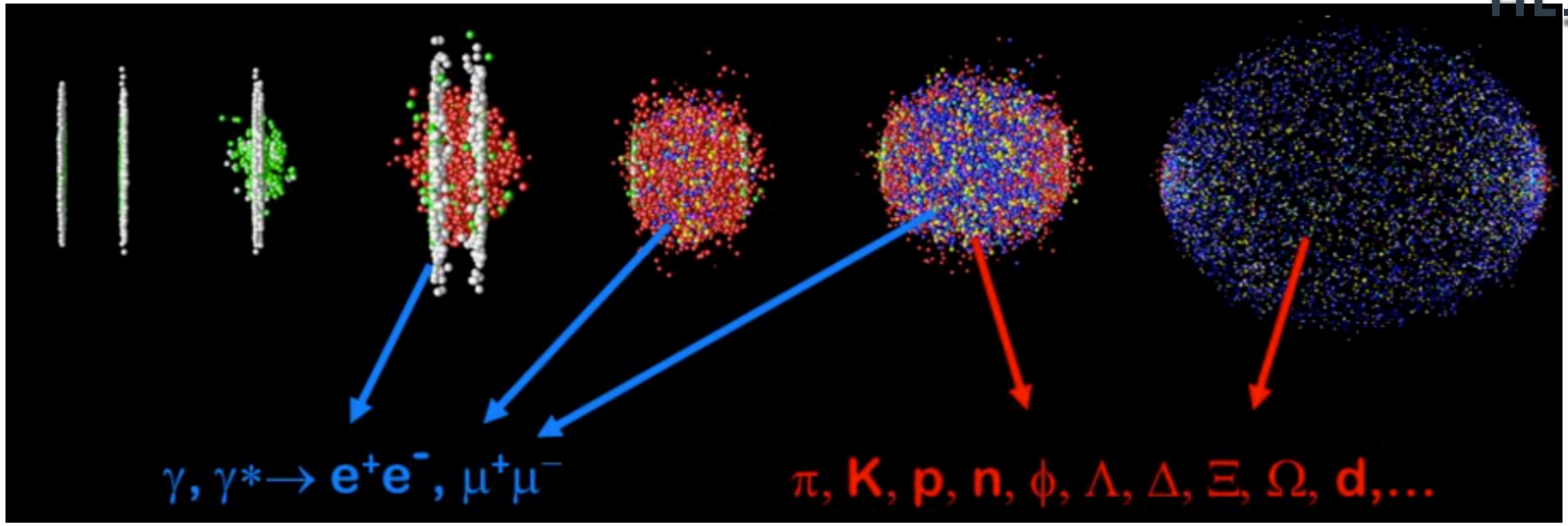
24th April 2023

Introduction and motivation

Why e-by-e fluctuation?

Introduction and motivation

Why e-by-e fluctuation?



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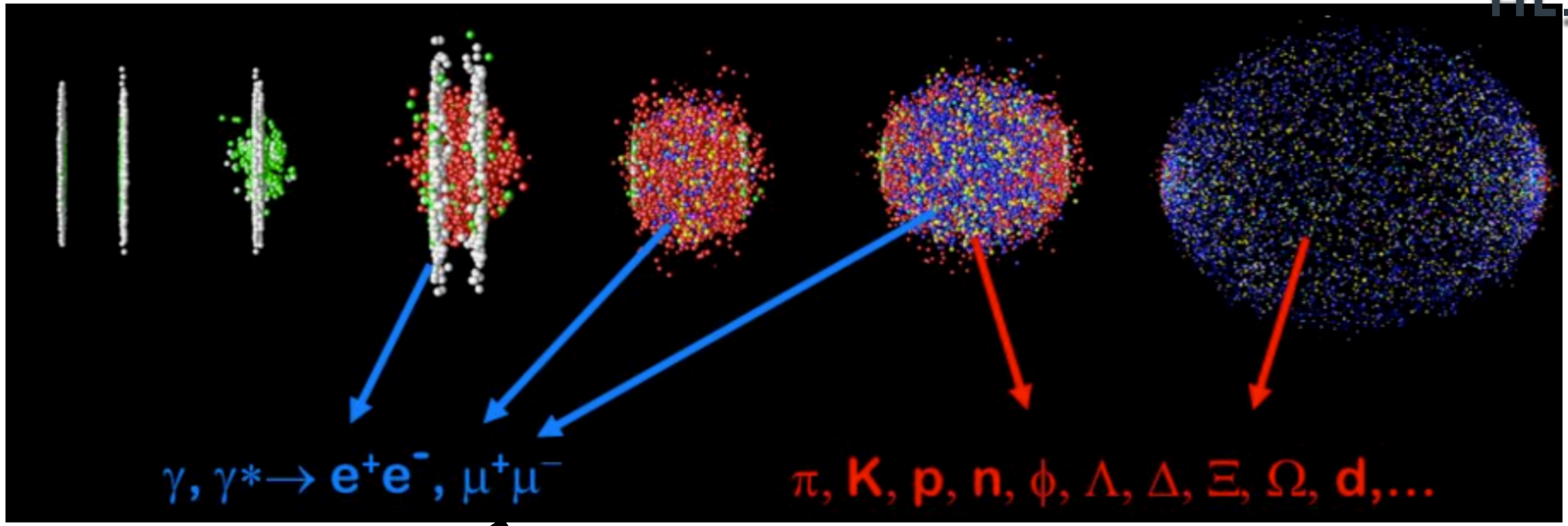
Introduction and motivation

Why e-by-e fluctuation?



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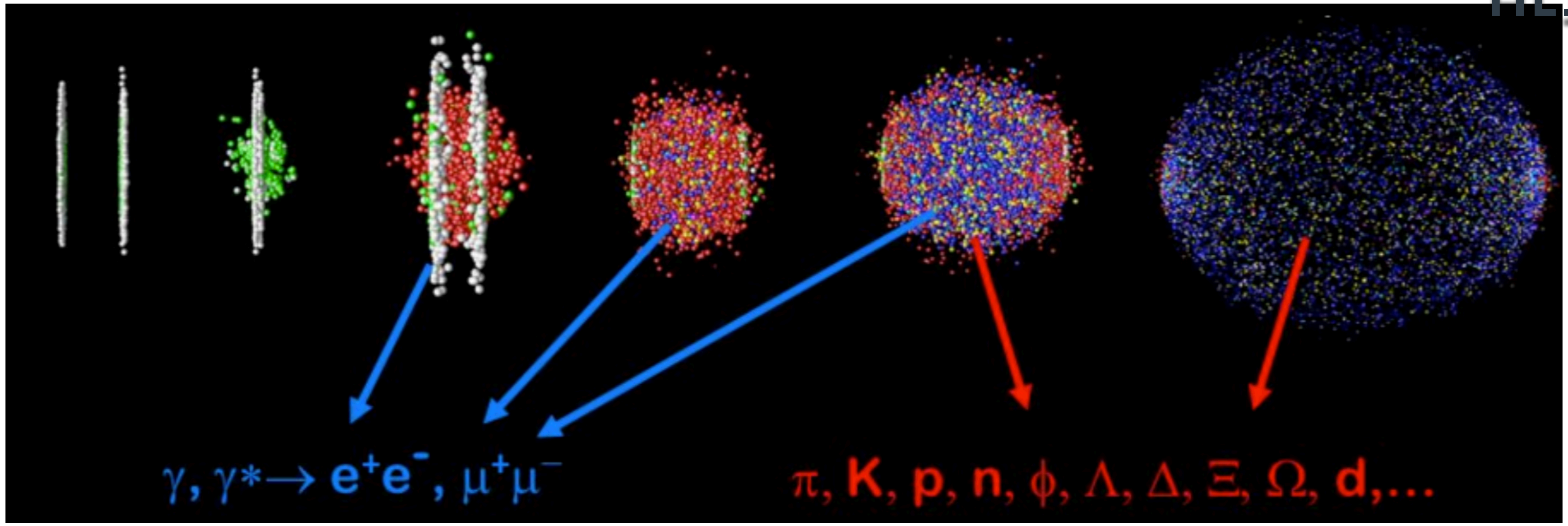
A large number of particles per event

Introduction and motivation

Why e-by-e fluctuation?



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A large number of particles per event → Thermodynamic state

Introduction and motivation

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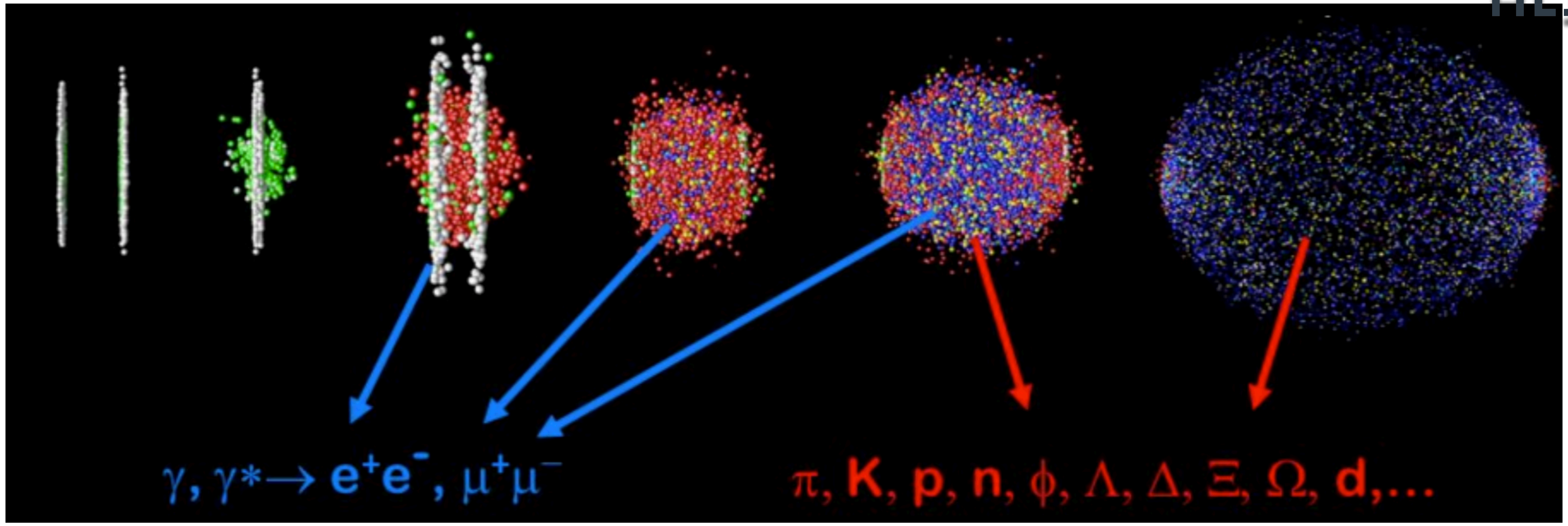

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A large number of particles per event → Thermodynamic state → Local temperature (T_{chem})

Introduction and motivation

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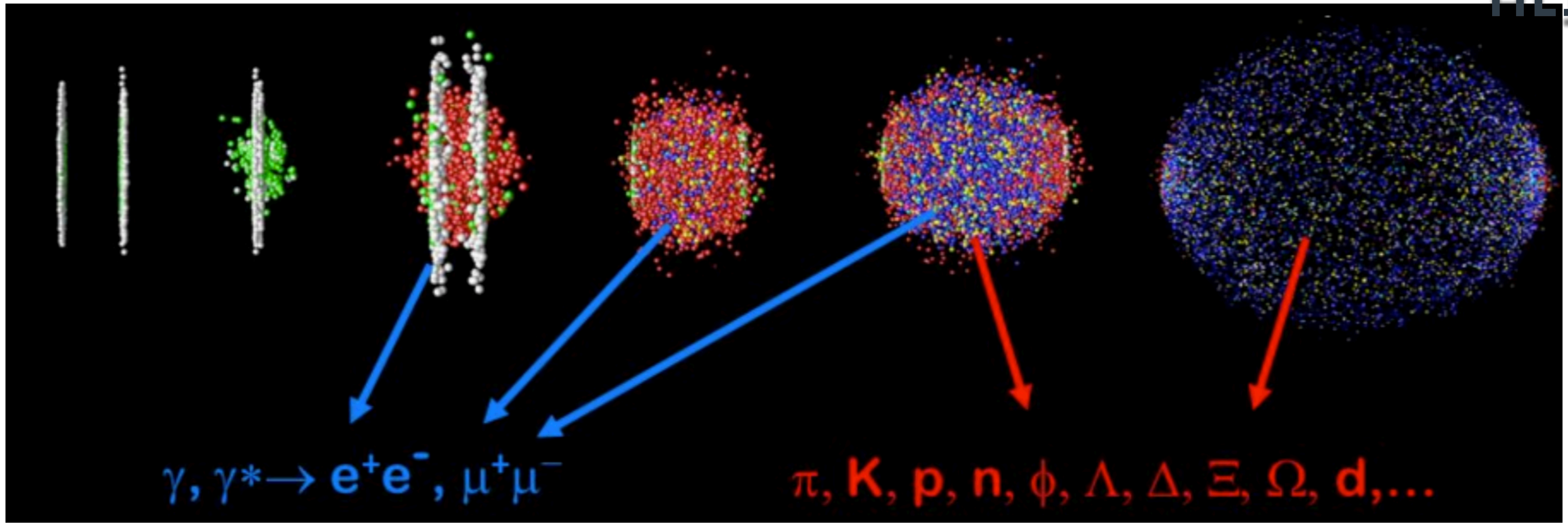

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A large number of particles per event → Thermodynamic state → Local temperature (T_{chem})

↓

The energy and particles can be exchanged: Grand canonical ensemble

←

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

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

L. Stodolsky, Phys. Rev. Lett. 75, 1044

Introduction and motivation

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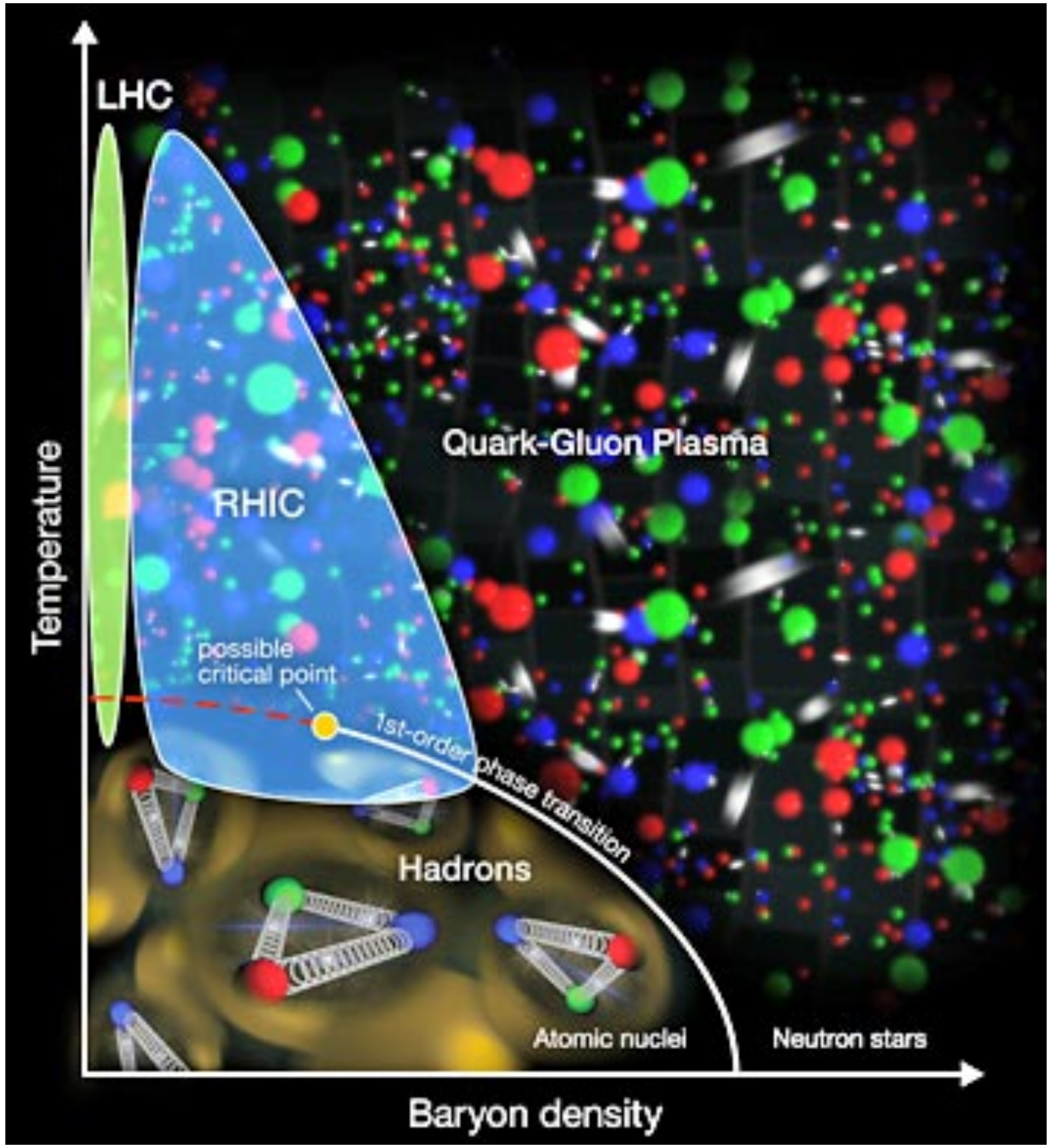
L. Stodolsky, Phys. Rev. Lett. 75, 1044

Critical end point



www.energy.gov

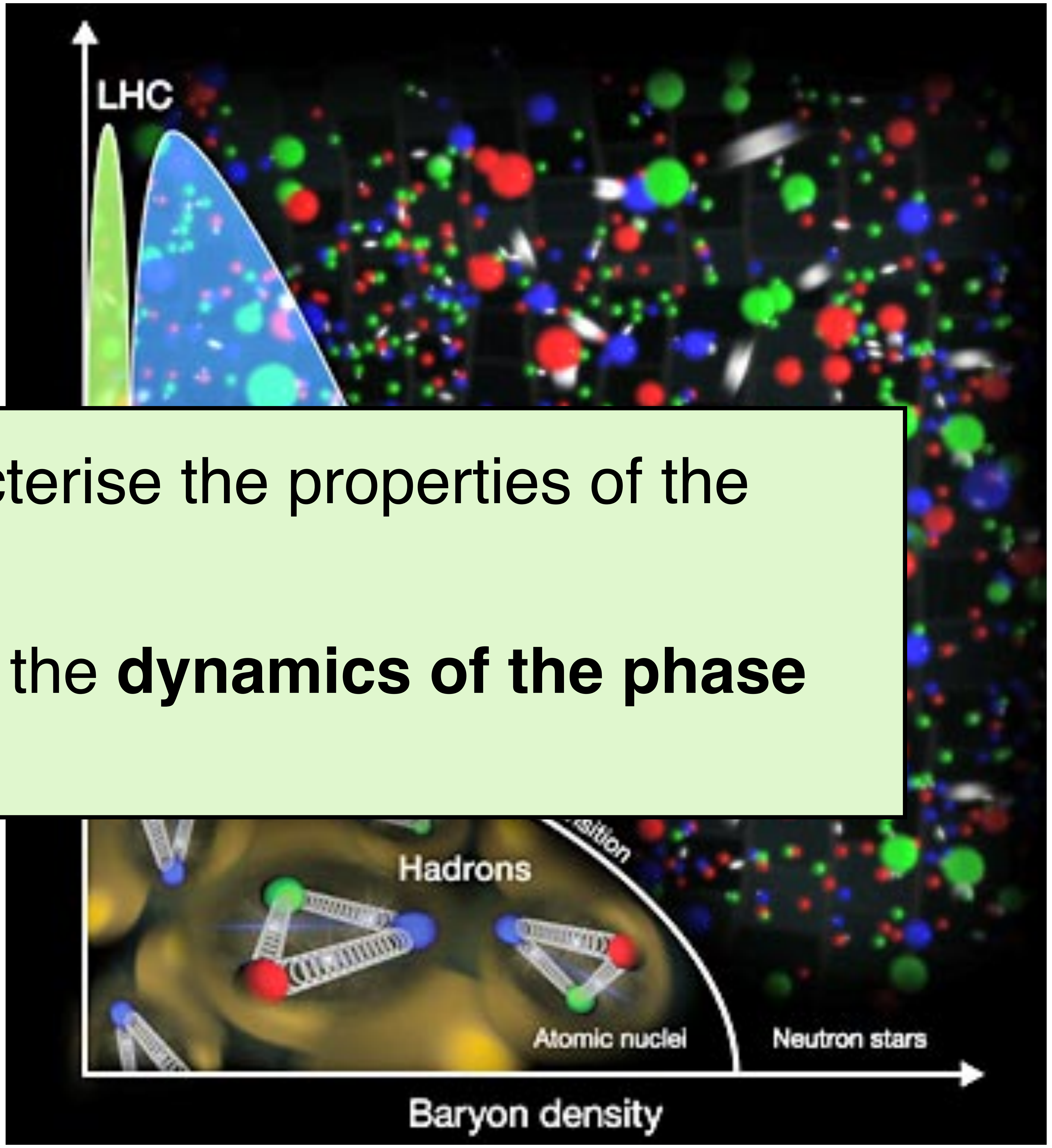
Irregular behaviour of *C* is the characteristic of phase transition.

Introduction and motivation

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

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

end point



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Irregular
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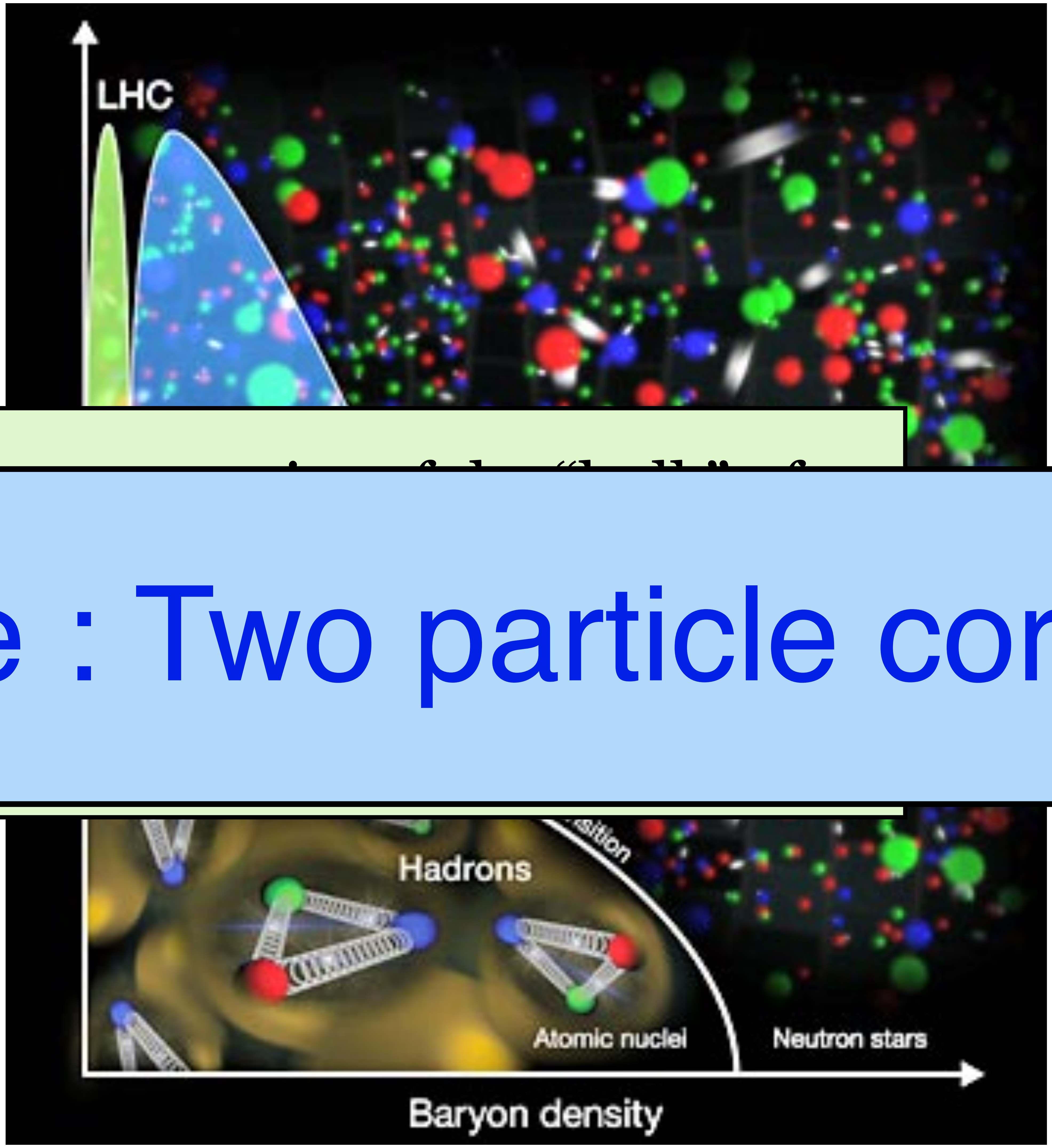

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Observable : Two particle correlator

Introduction and motivation

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The p_T distribution can be described by:

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

Observable : Two particle correlator

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Introduction and motivation

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

$$\text{where, } Q_n = \sum_{i=1}^{N} (p_i)^n$$

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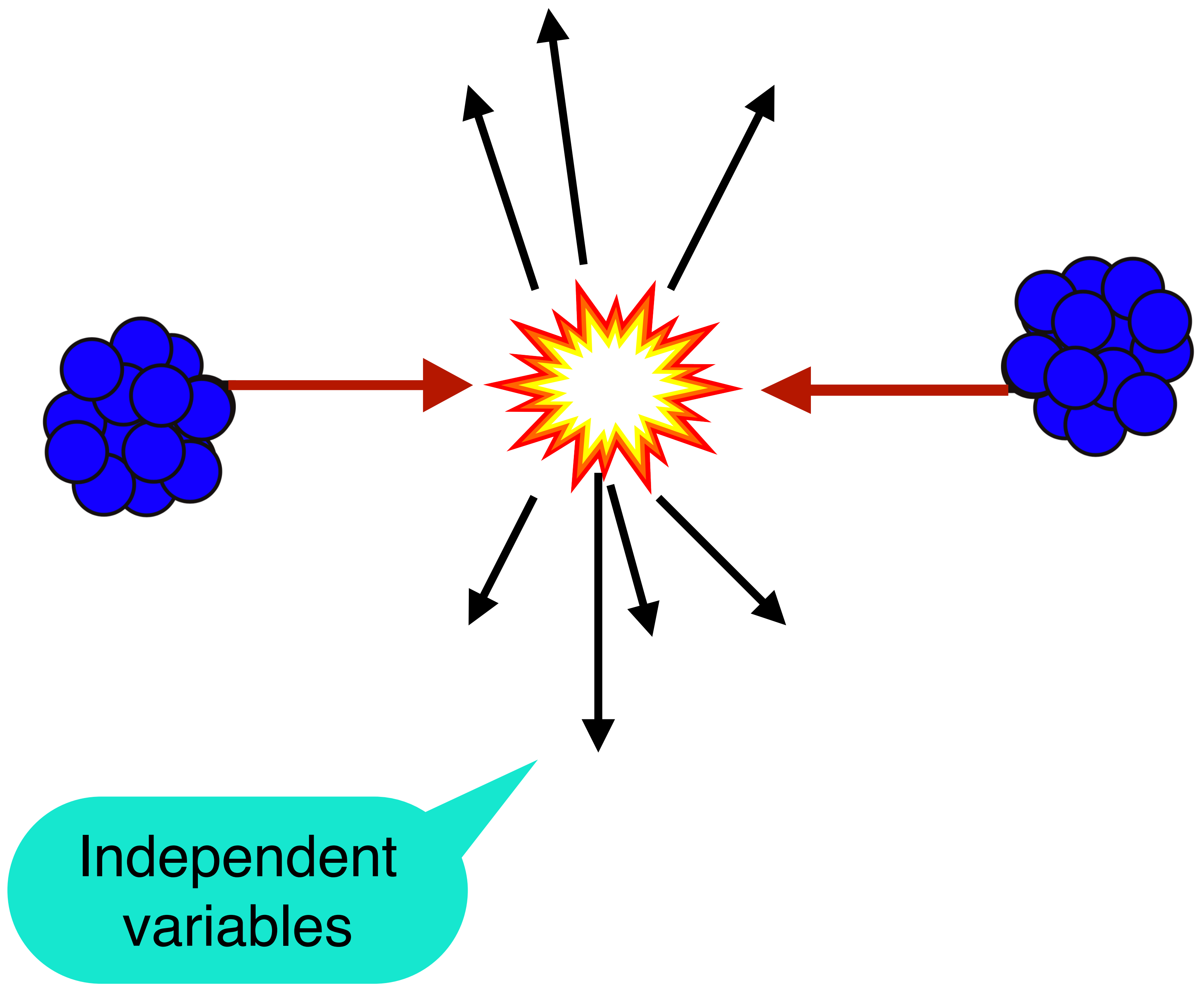
$$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle \langle p_T \rangle \rangle$$

Introduction and motivation

Observable : Two particle correlator

Statistical fluctuation



Introduction and motivation

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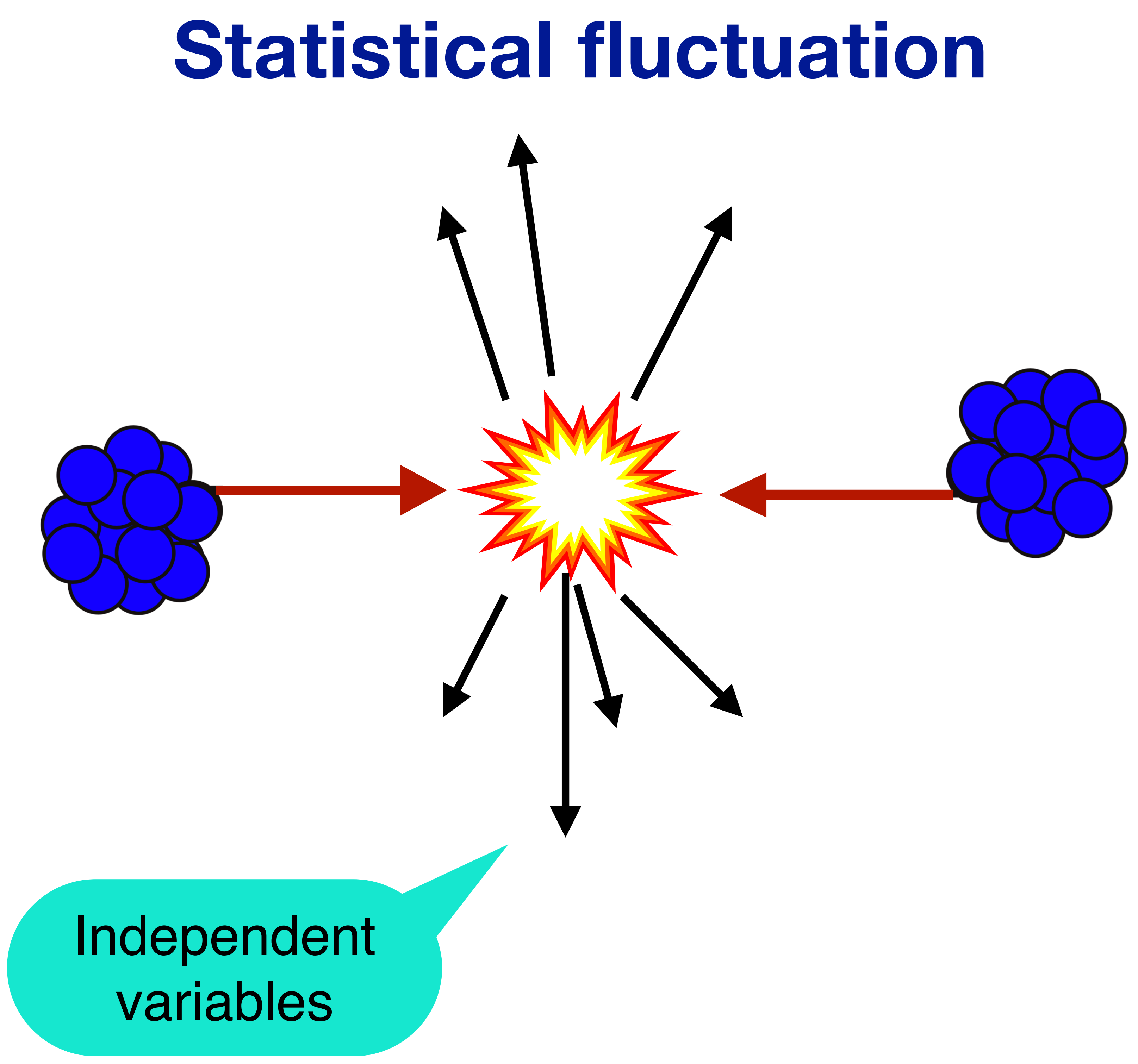

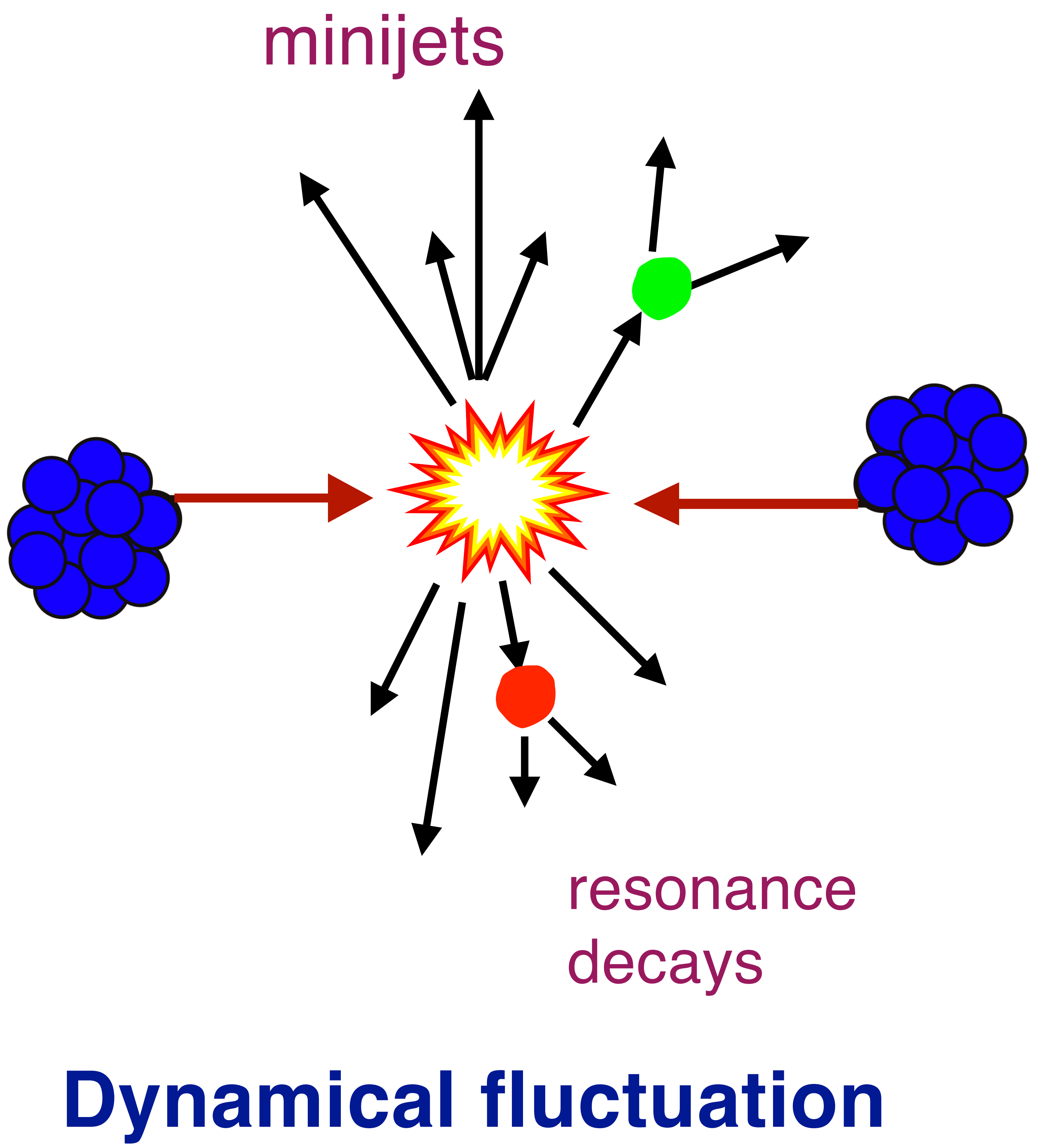

Introduction and motivation

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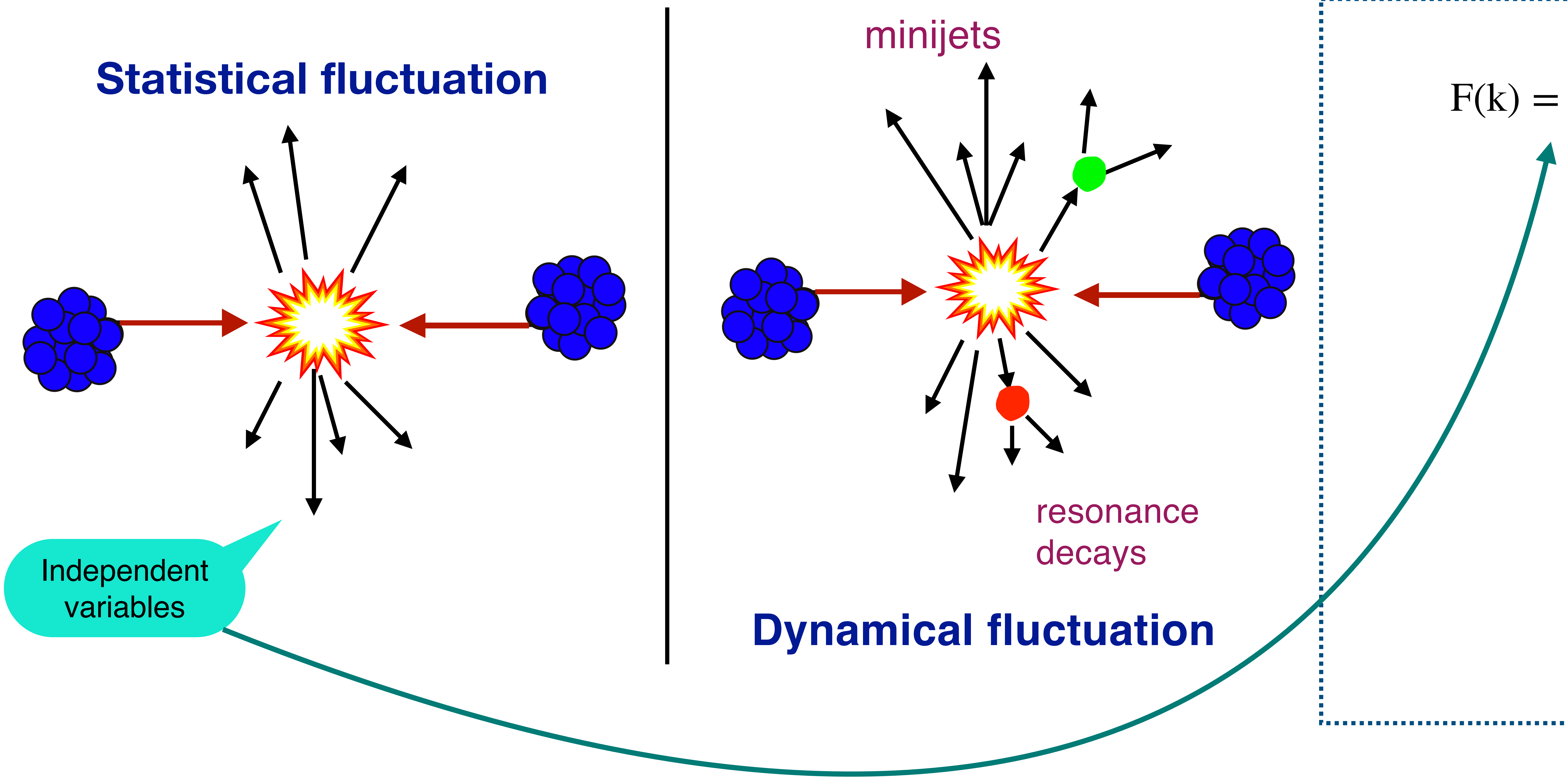
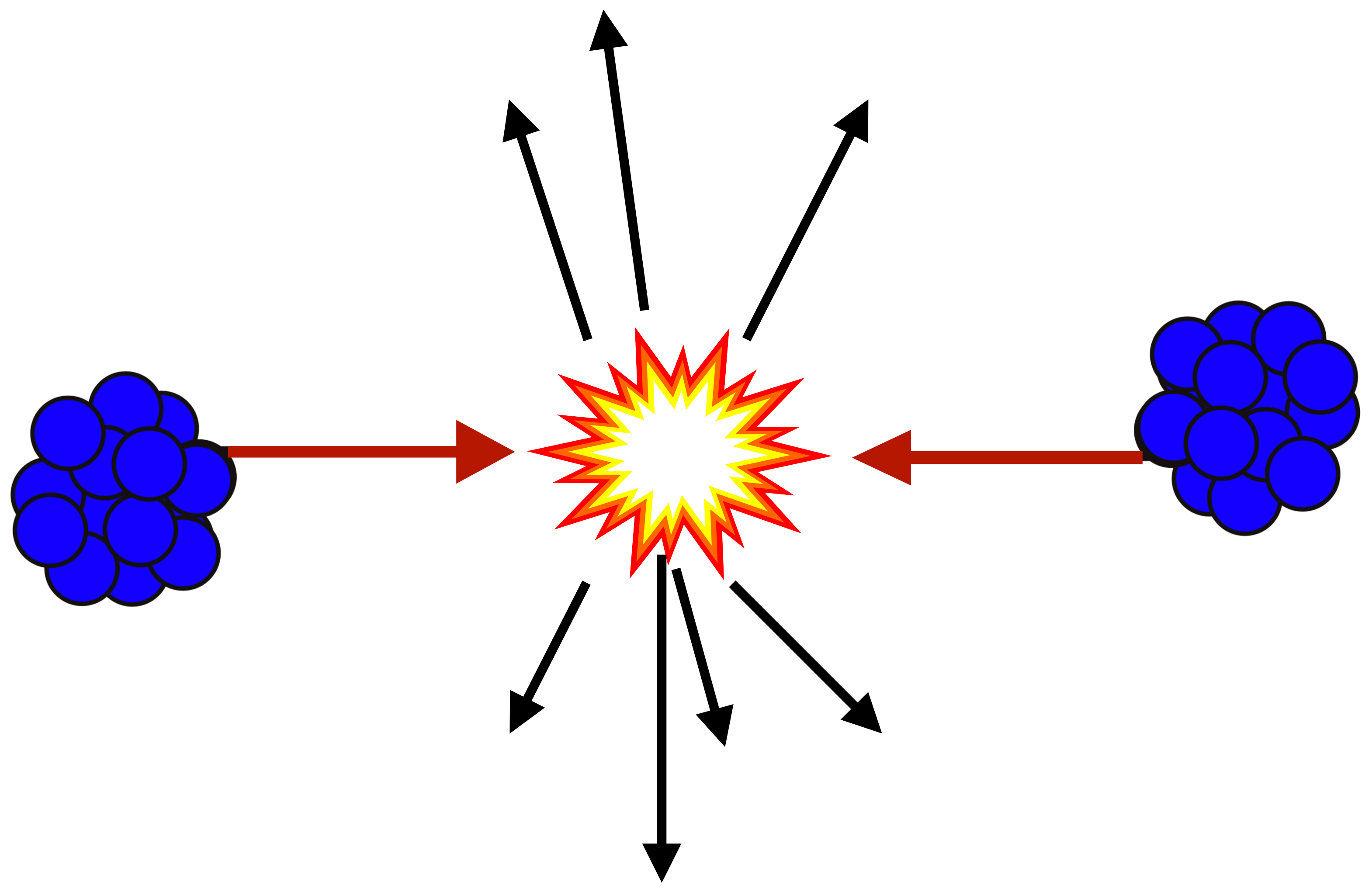


$$F(k) = e^{-\lambda}\frac{\lambda^{k}}{k!}$$

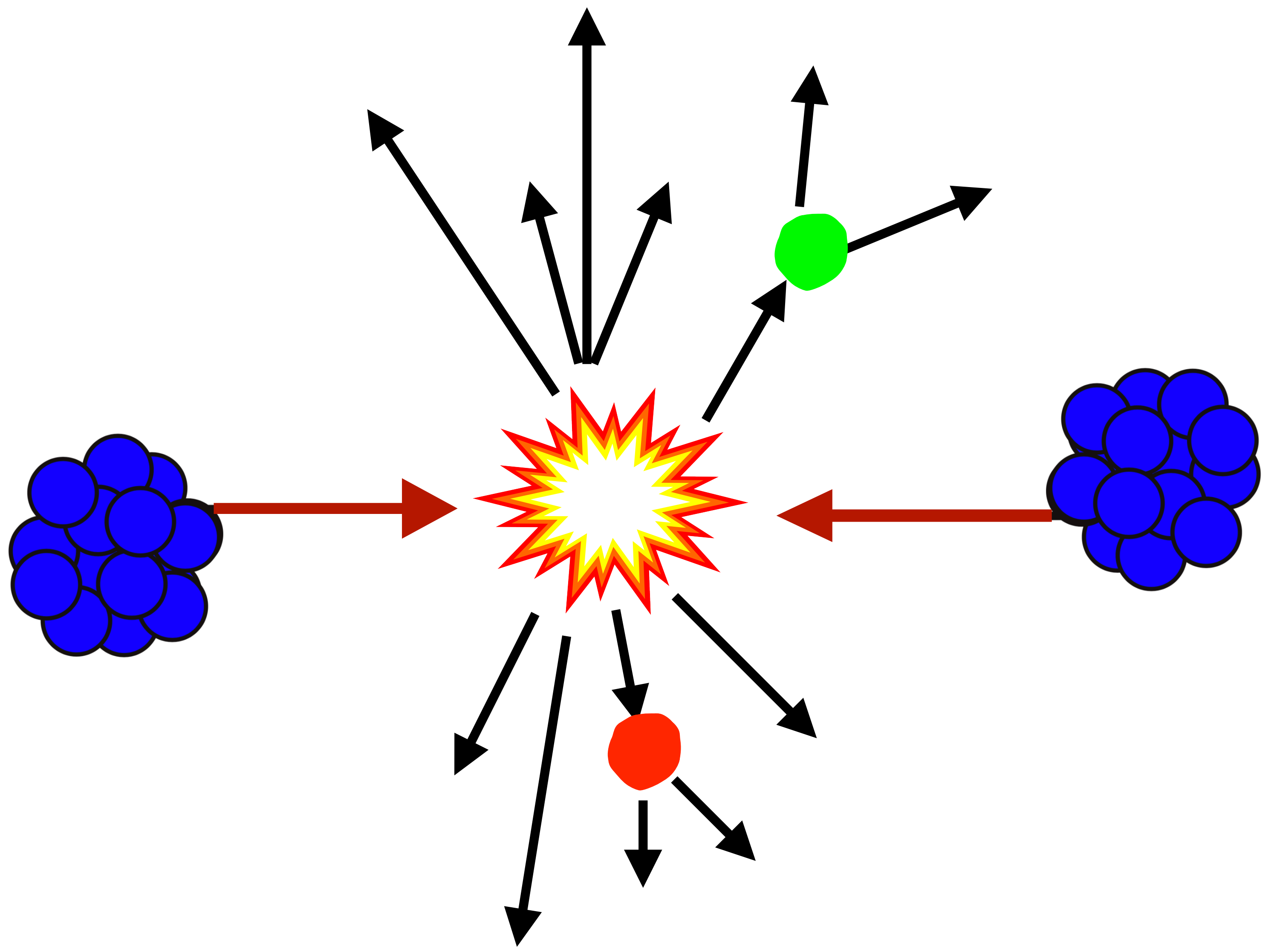
Observable : Two particle correlator

Statistical fluctuation



Independent variables

minijets



resonance decays

Dynamical fluctuation

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

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

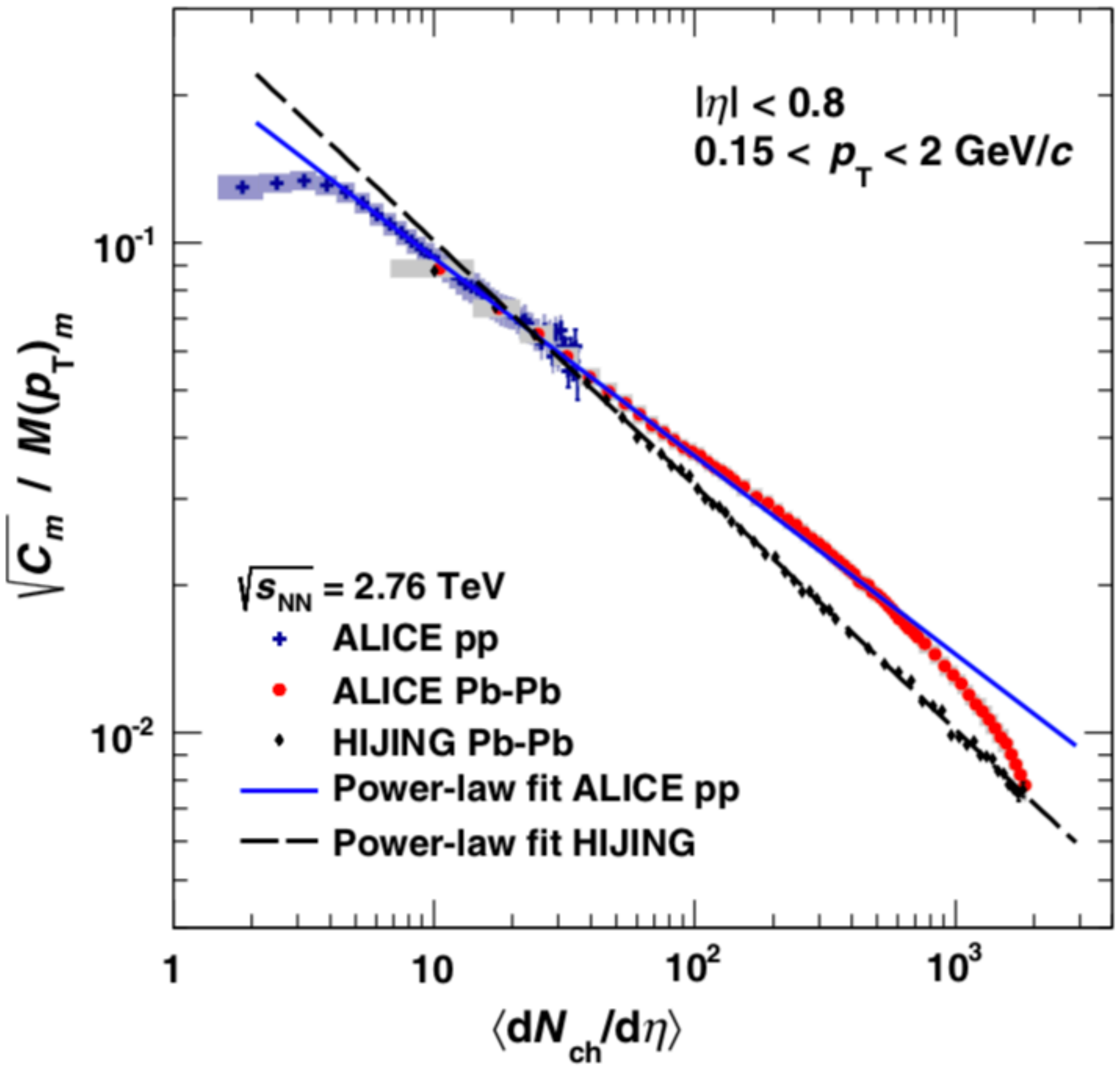
$$Cov(x, y) = E[x, y] - E[x]E[y]$$

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

$C=0$

No **statistical** fluctuation

Introduction and motivation

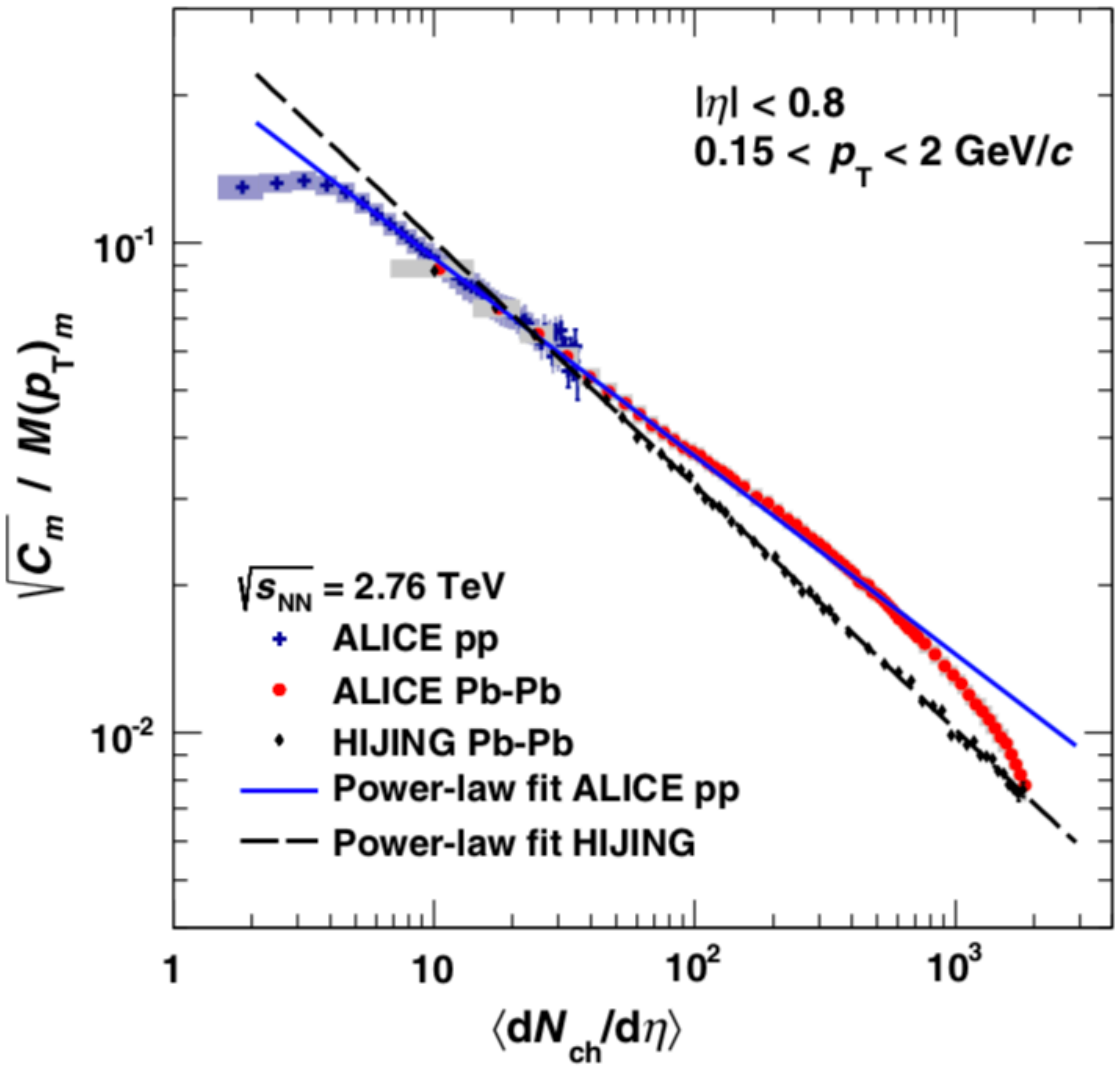


ALICE, Eur. Phys. J. C (2014) 74

- 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. B 727 (2013) 371–380,

Introduction and motivation



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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. B 727 (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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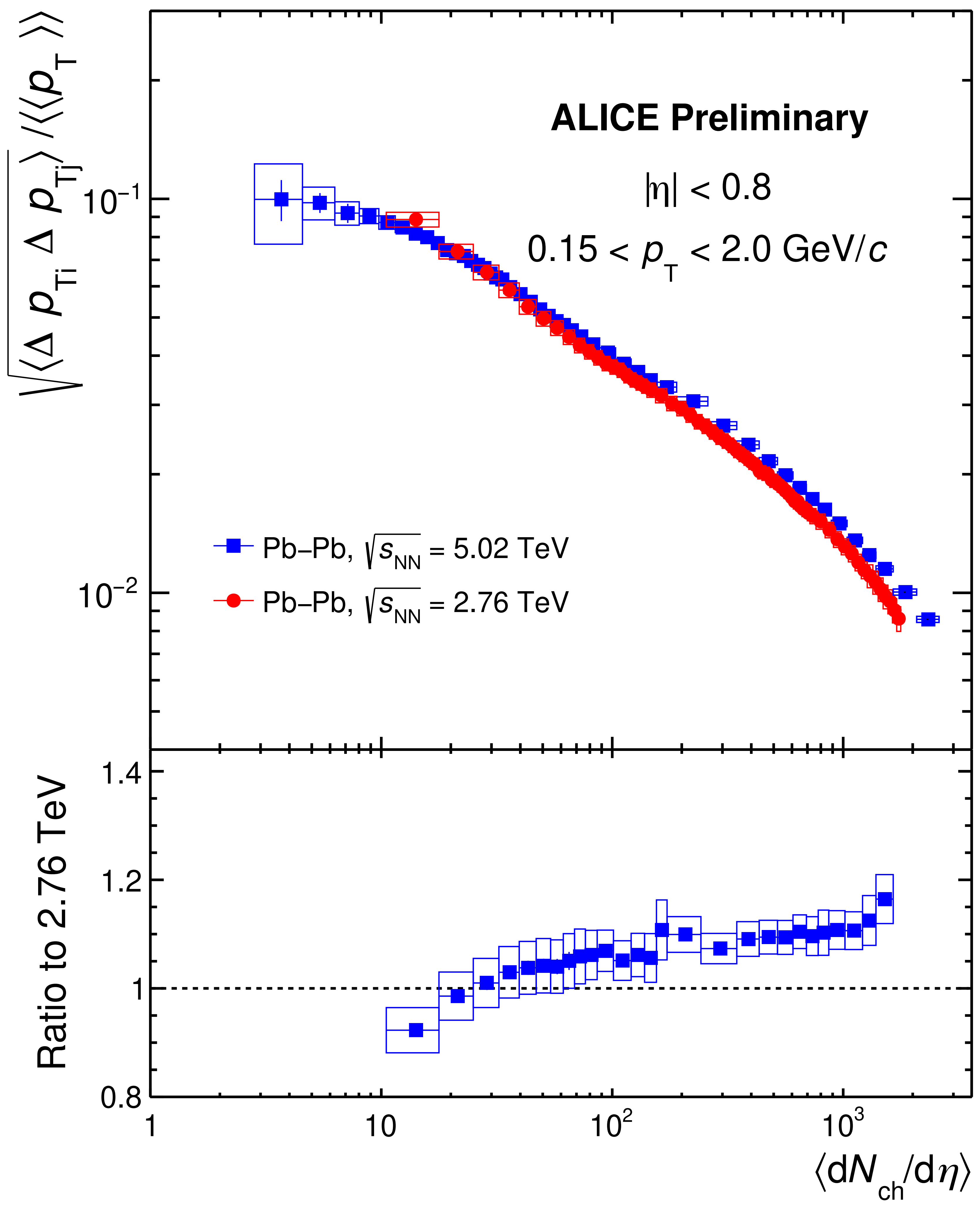

ALI-PREL-526489

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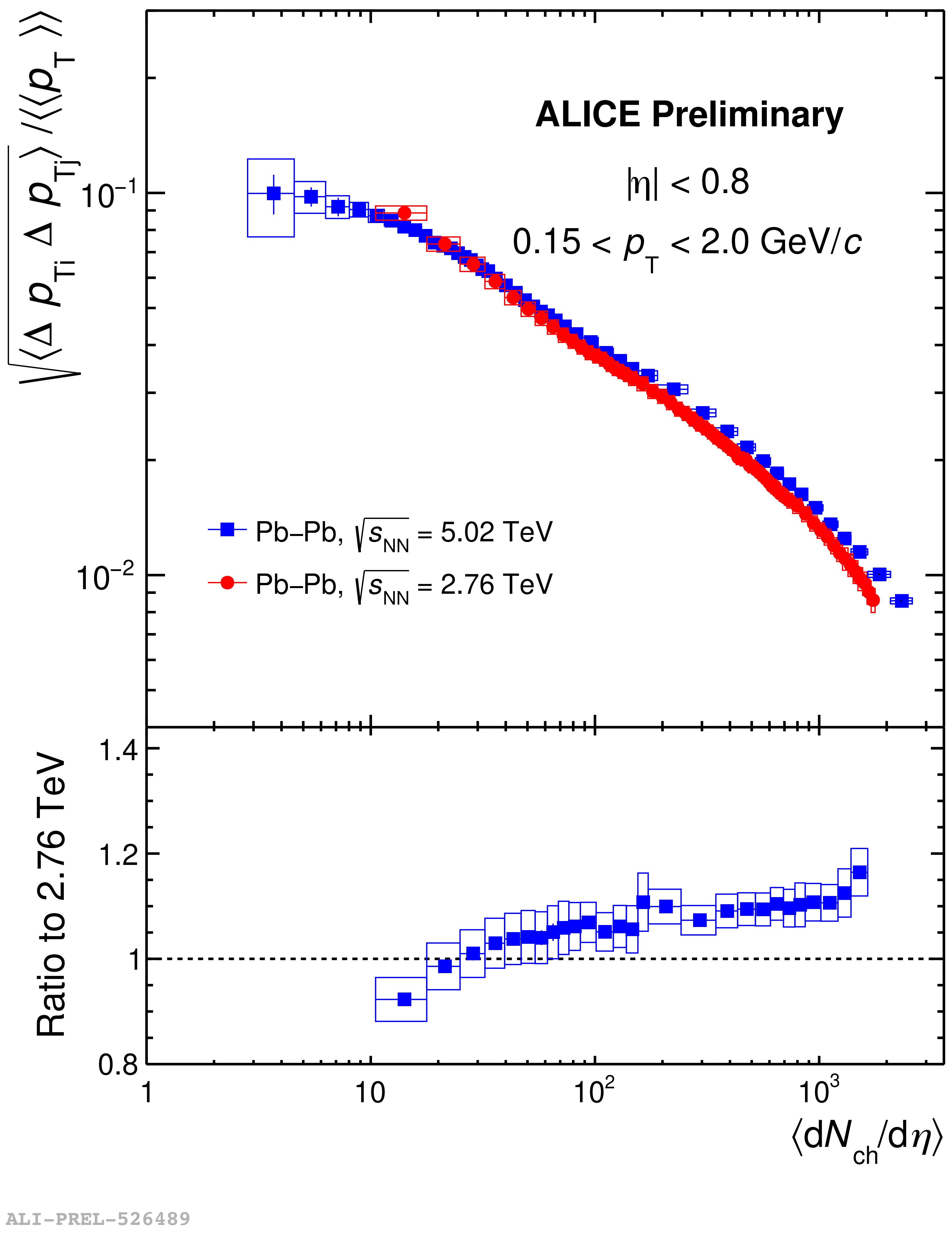
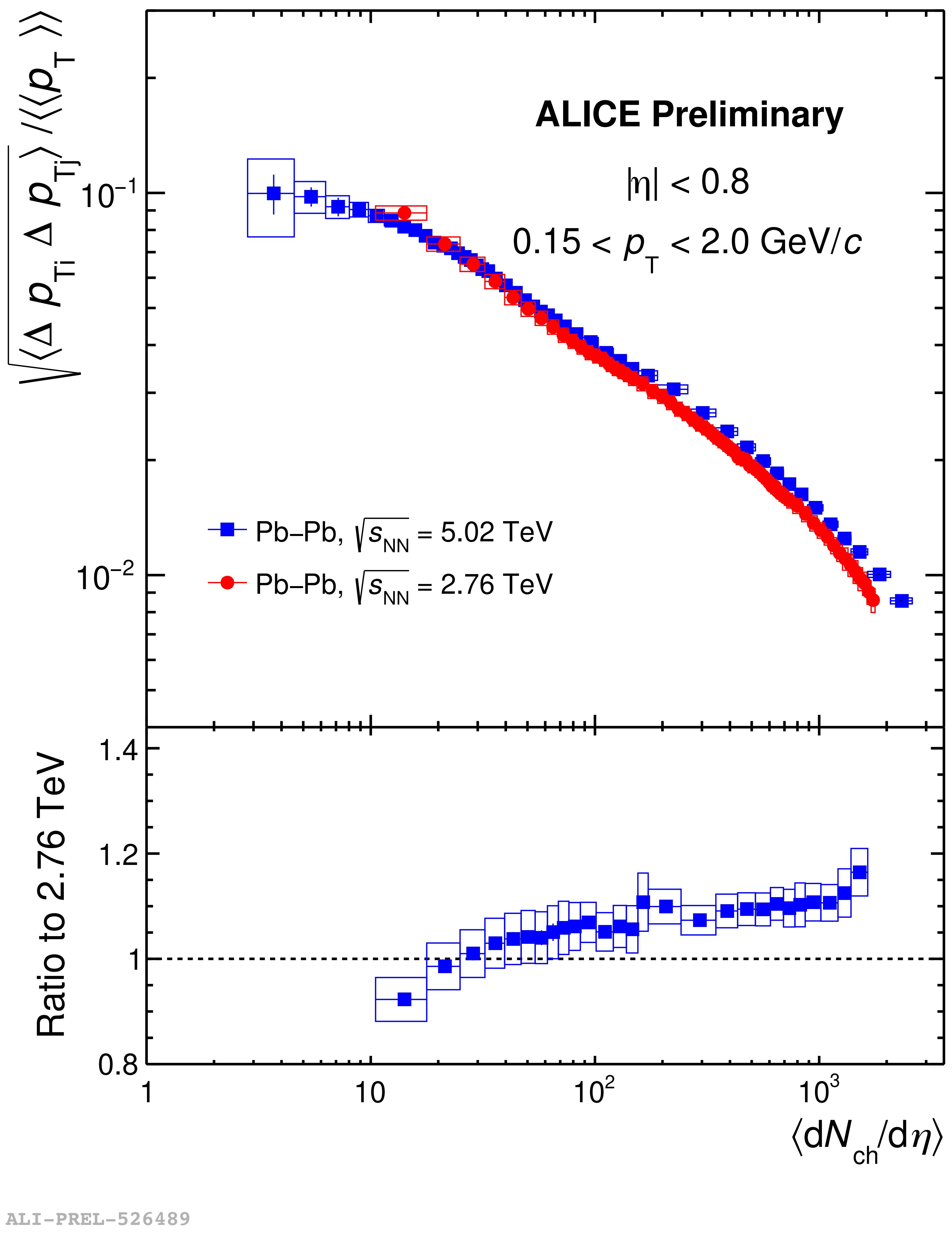


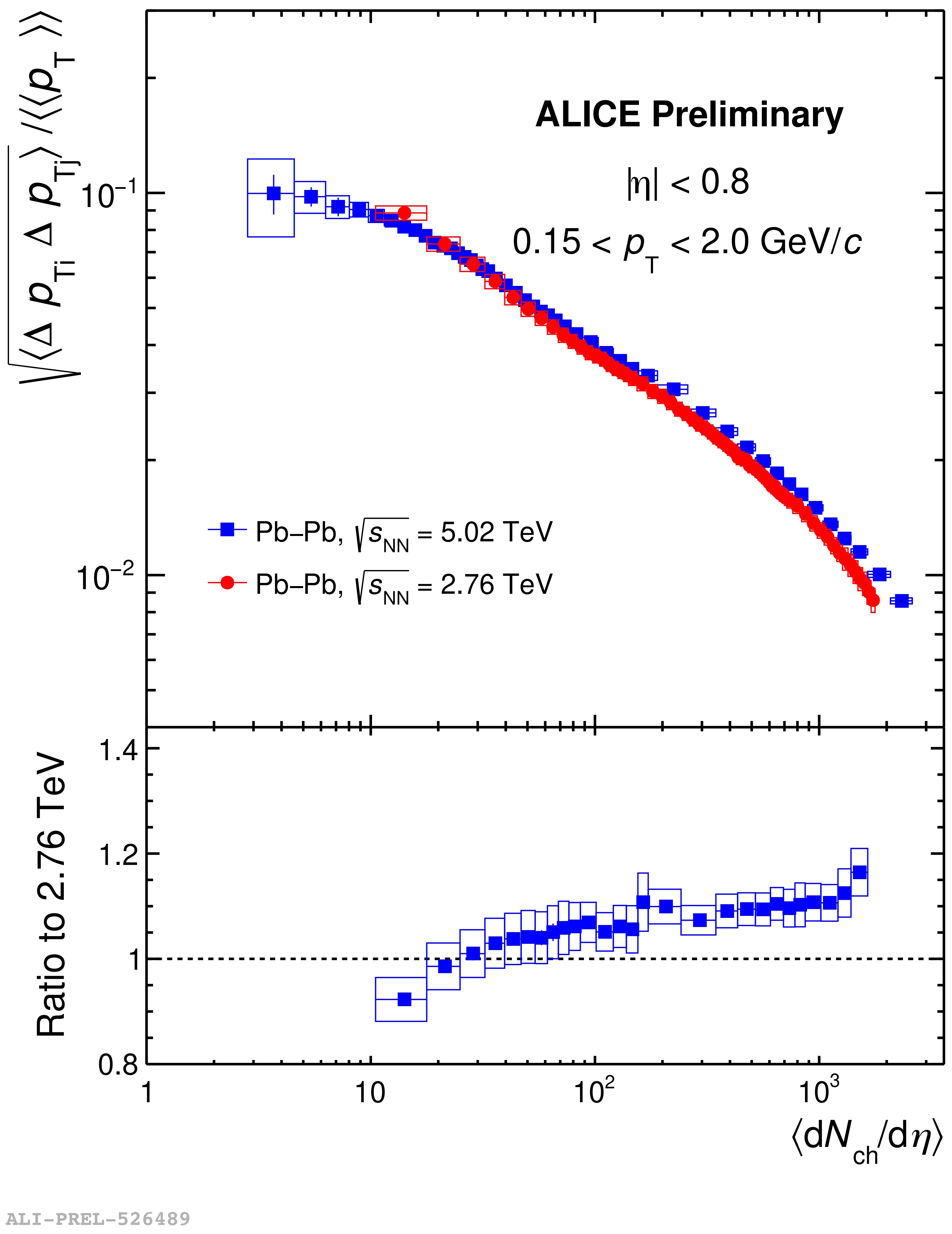
- Significant dynamical fluctuations.

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



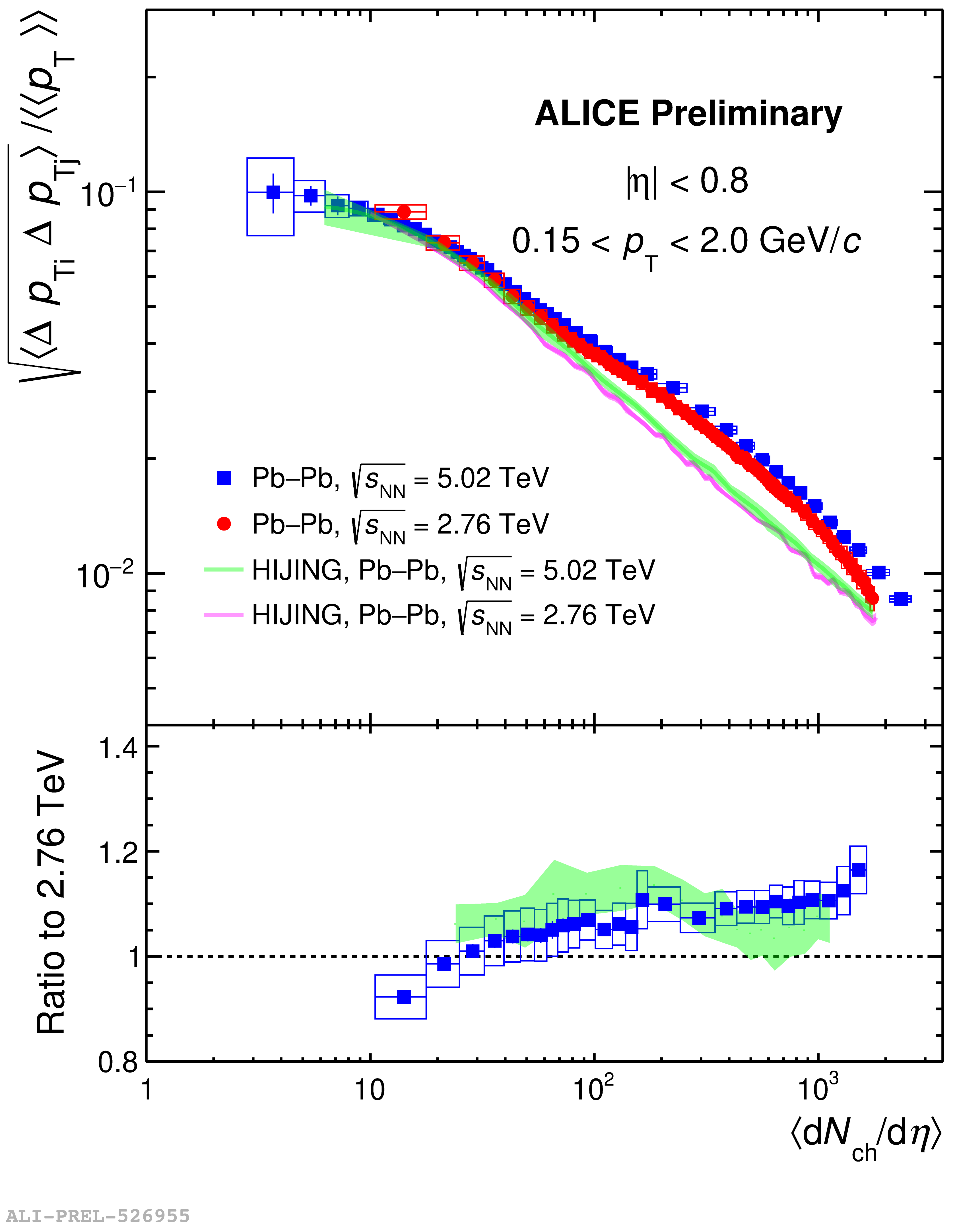
- Significant dynamical fluctuations.
- Fluctuations decrease with increasing multiplicity.

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



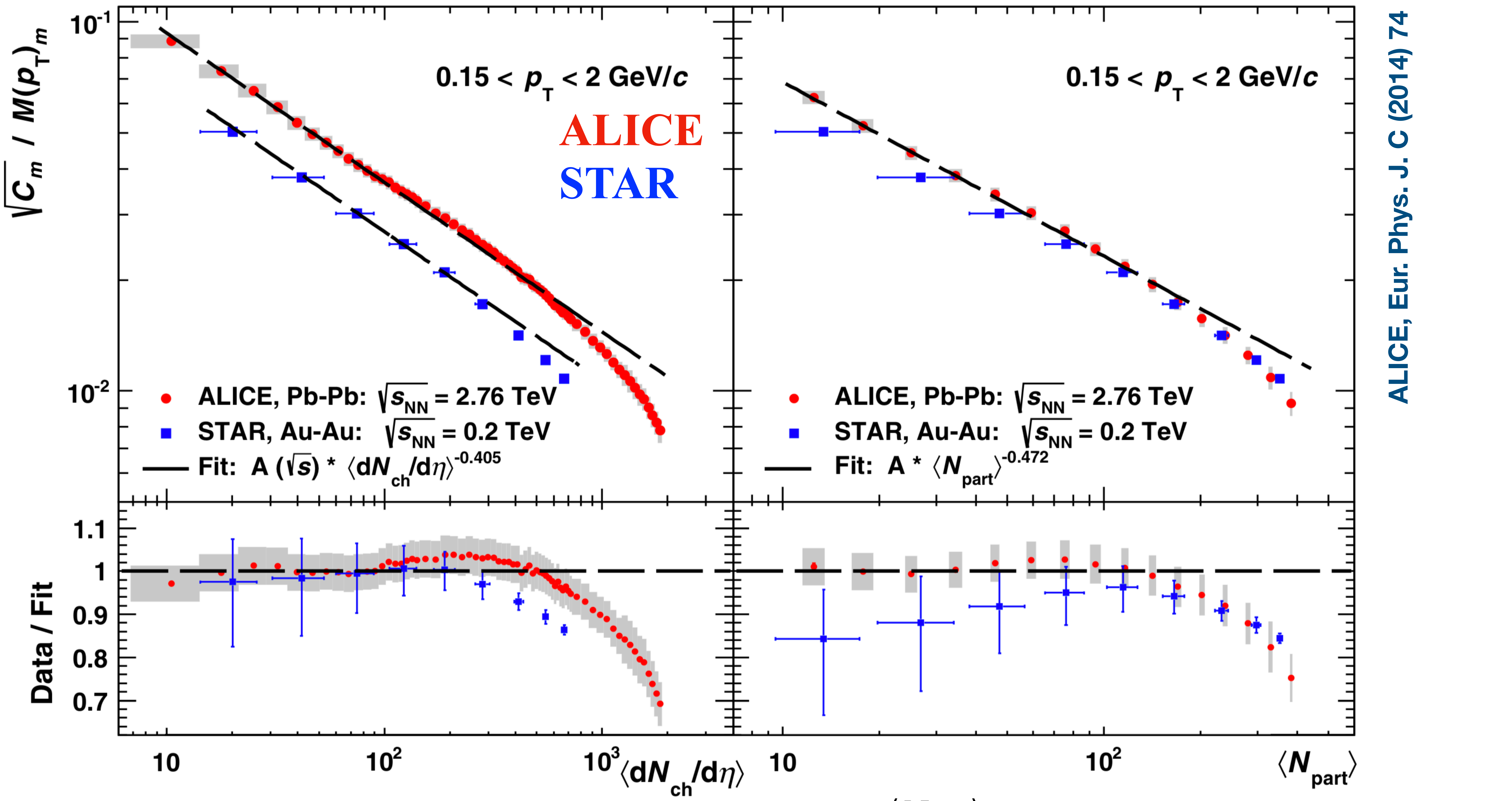
- Significant dynamical fluctuations.
- Fluctuations decrease with increasing multiplicity.
- Clear energy dependence of correlator on collision energy for large $\langle dN_{ch}/d\eta \rangle$ for central Pb—Pb collisions.

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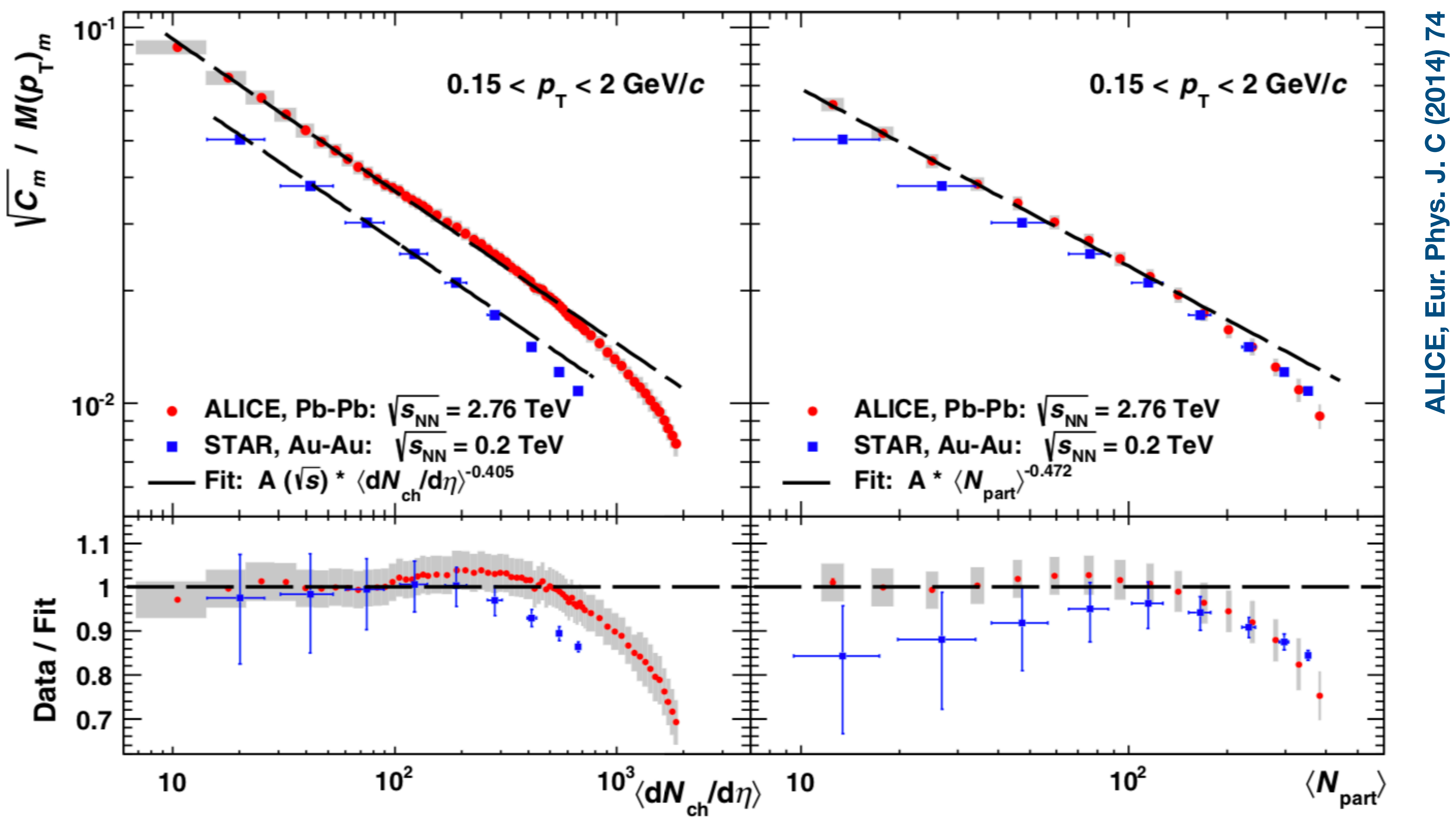
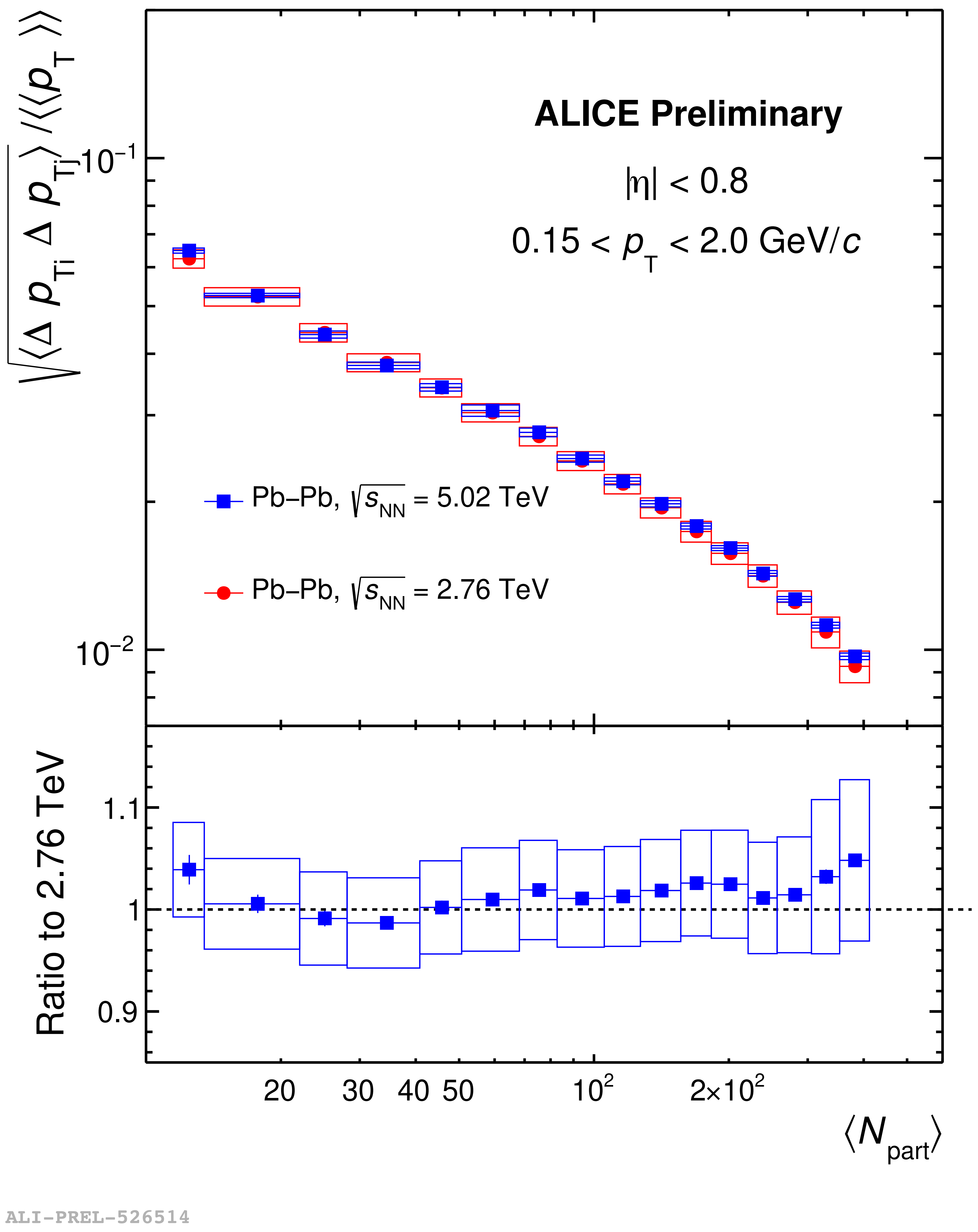
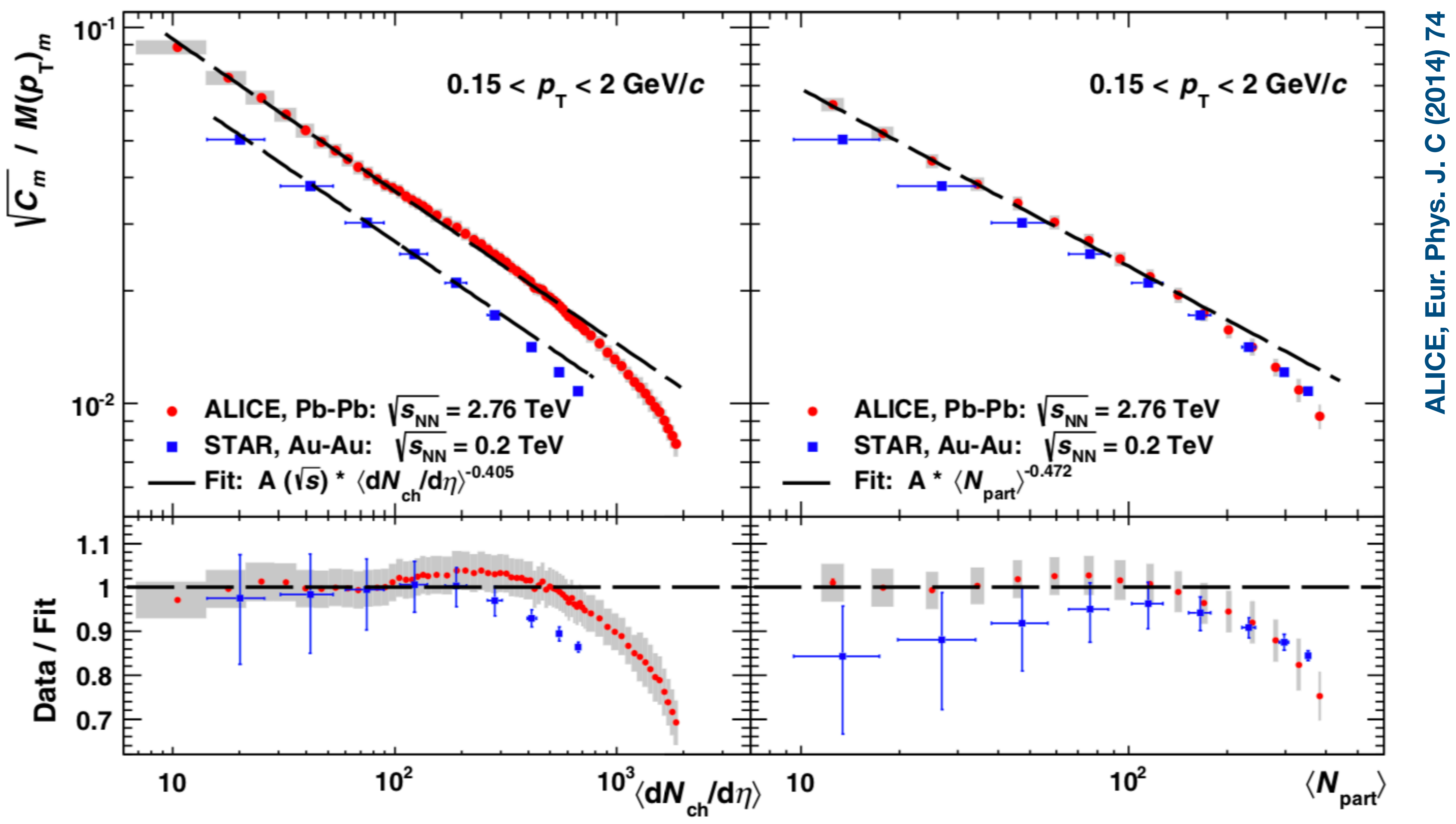
$\sqrt{\langle \Delta p_{\mathrm{T}i} \Delta p_{\mathrm{T}j} \rangle} / \langle p_{\mathrm{T}} \rangle$ vs $\langle N_{\mathrm{part}} \rangle$

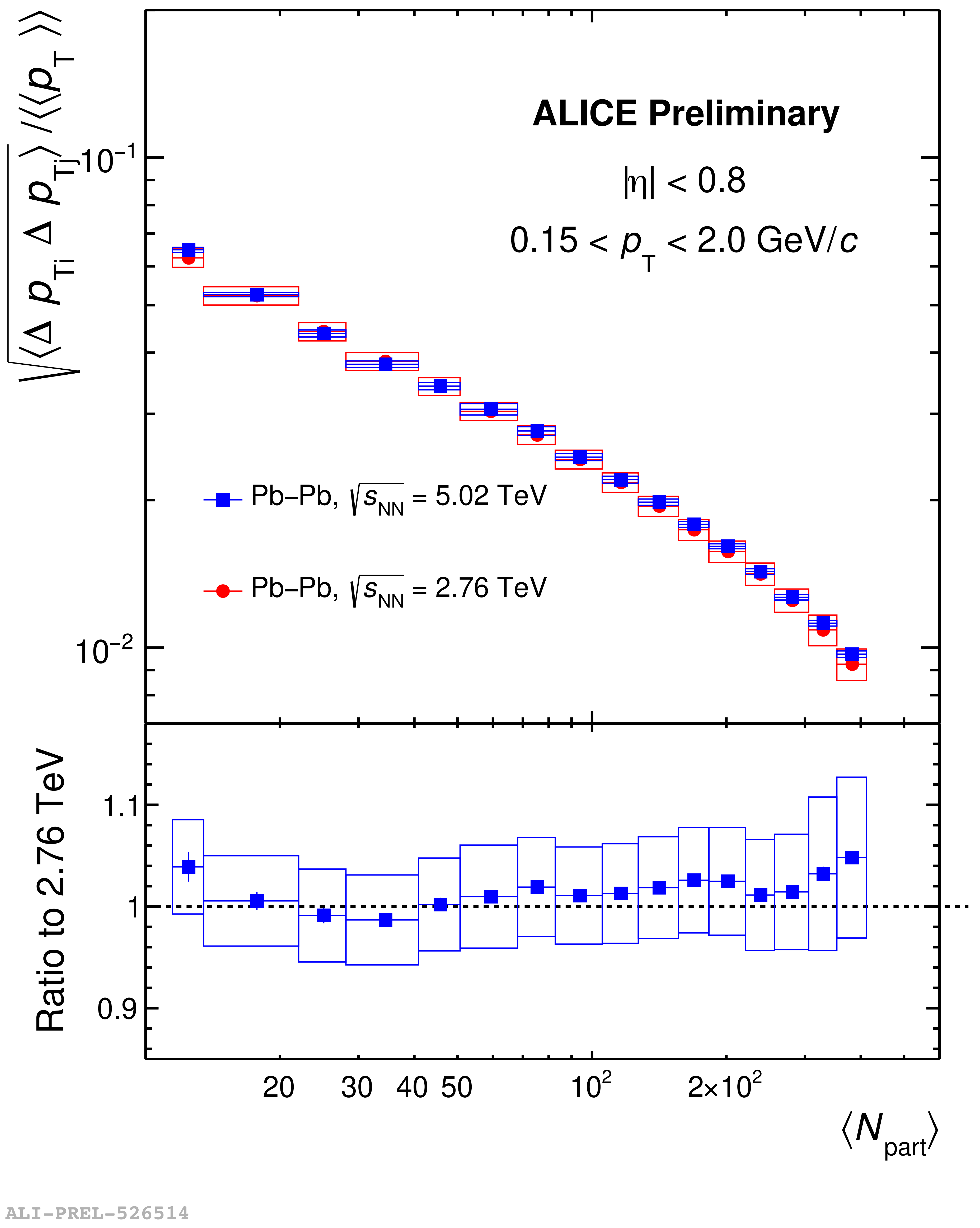


- Clear dependence of correlator vs $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$ on collision energy is observed for central Pb—Pb collisions.



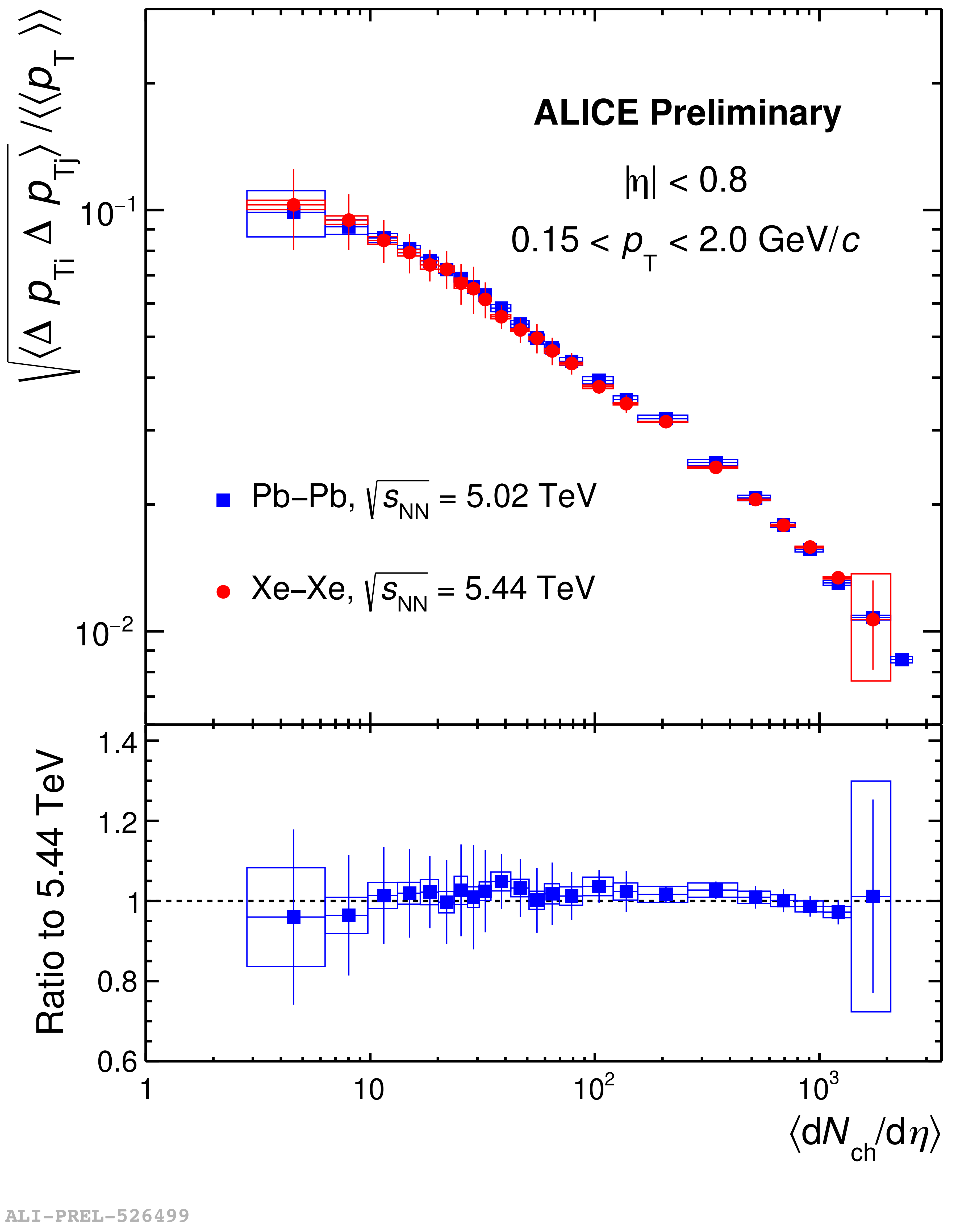
$\sqrt{\langle \Delta p_{\mathrm{T}i} \Delta p_{\mathrm{T}j} \rangle} / \langle p_{\mathrm{T}} \rangle$ vs $\langle N_{\mathrm{part}} \rangle$





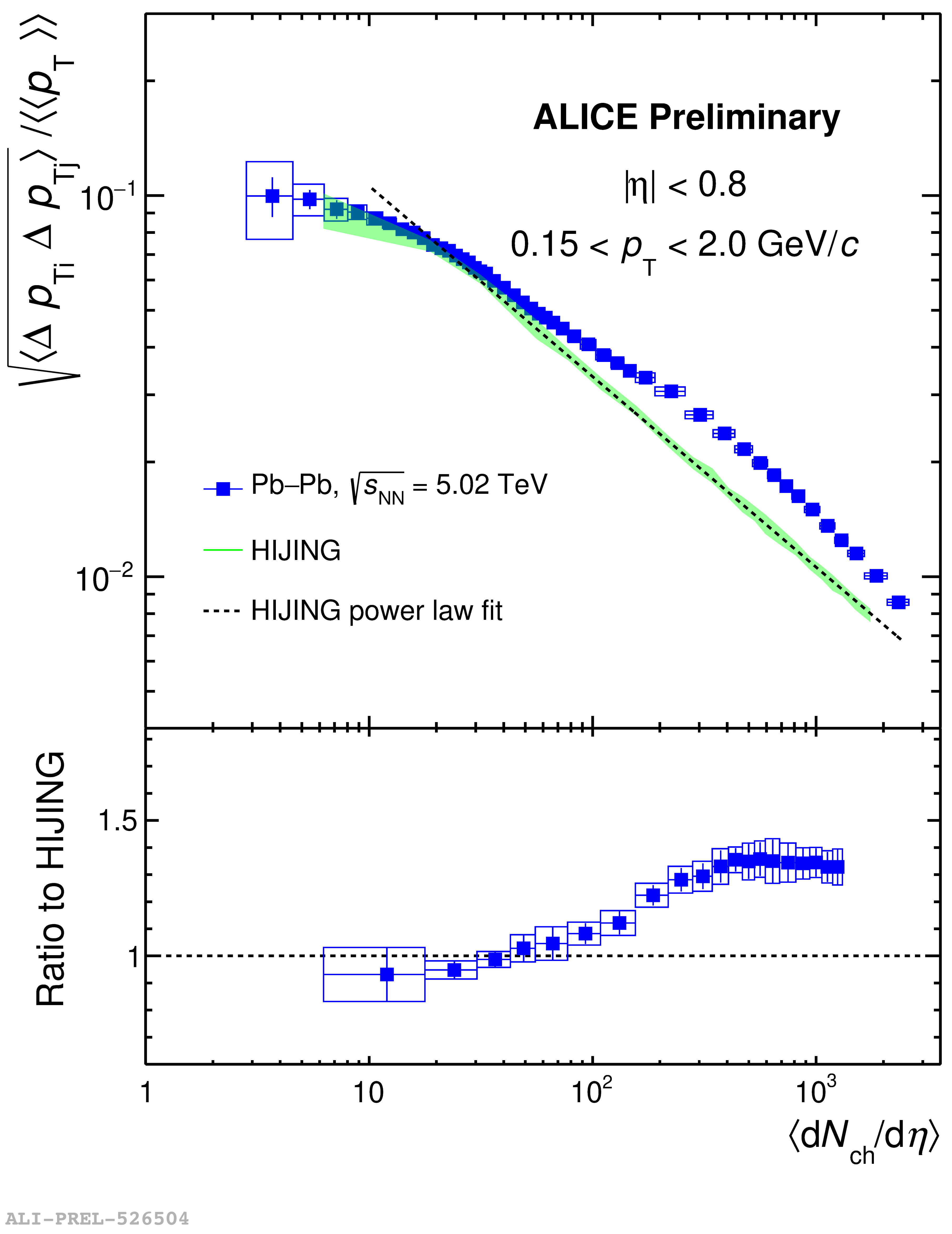
- Clear dependence of correlator vs $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$ on collision energy is observed for central Pb—Pb collisions.
- The dependence on collision energy disappears when plotted as a function of $\langle N_{\mathrm{part}} \rangle$.

$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle p_T \rangle$ vs $\langle dN_{ch}/d\eta \rangle$: Collision system comparison



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

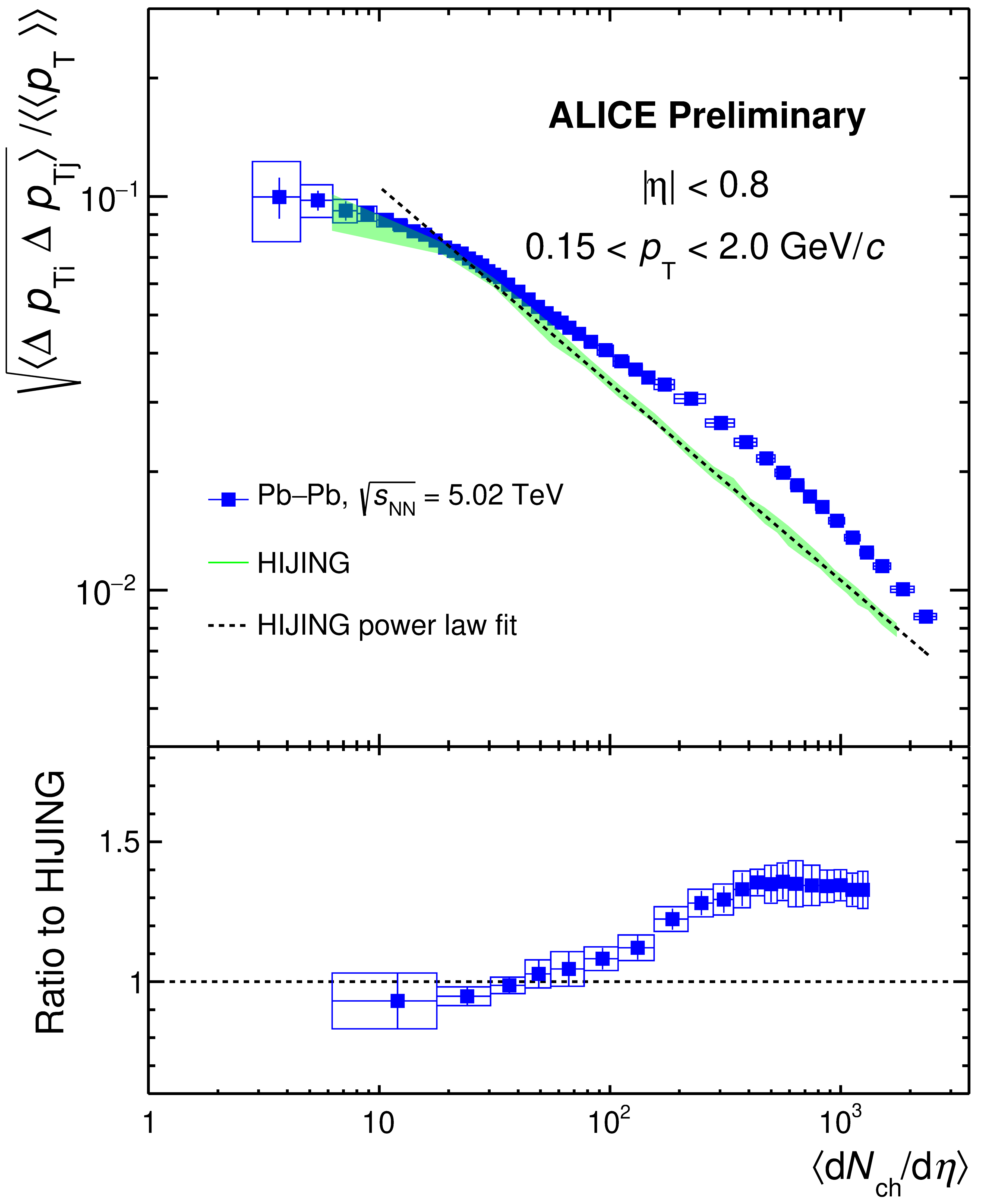
$\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj} \rangle} / \langle p_T \rangle$ vs $\langle dN_{ch}/d\eta \rangle$: Model comparison



- Power law fit:

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

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



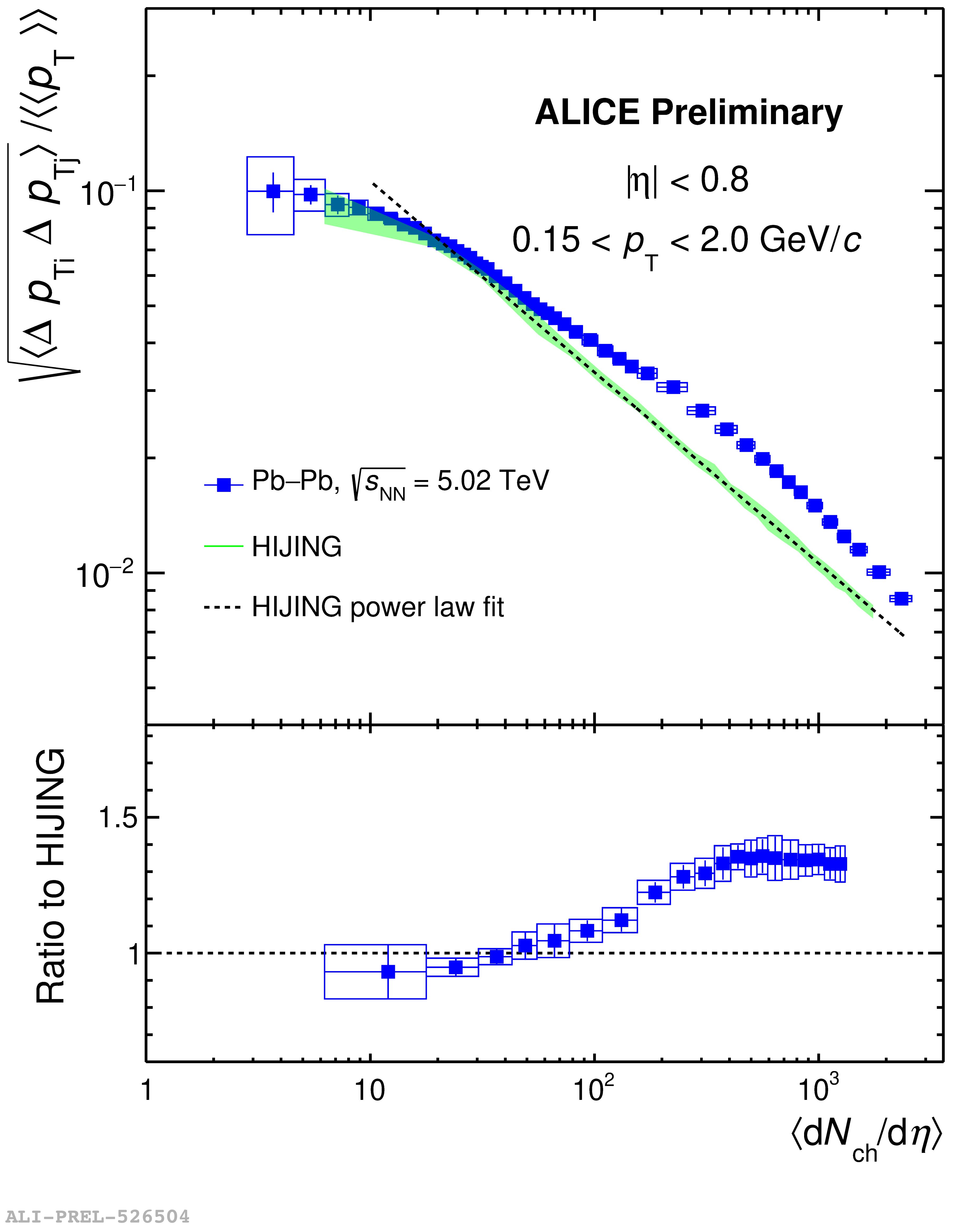
ALI-PREL-526504

- Power law fit:

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

corresponds to simple superposition scenario.

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



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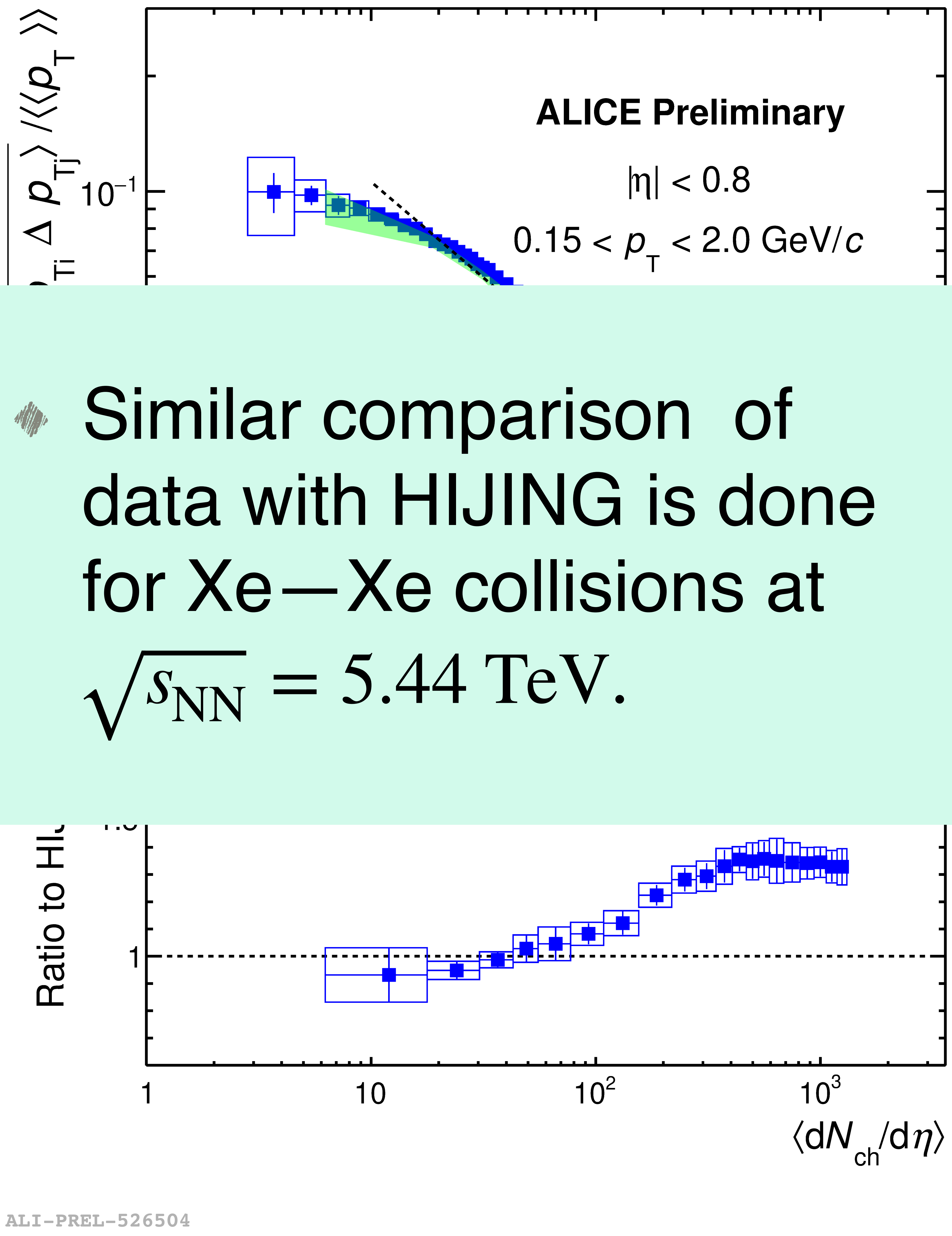
- Deviation in central Pb—Pb collisions.

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



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

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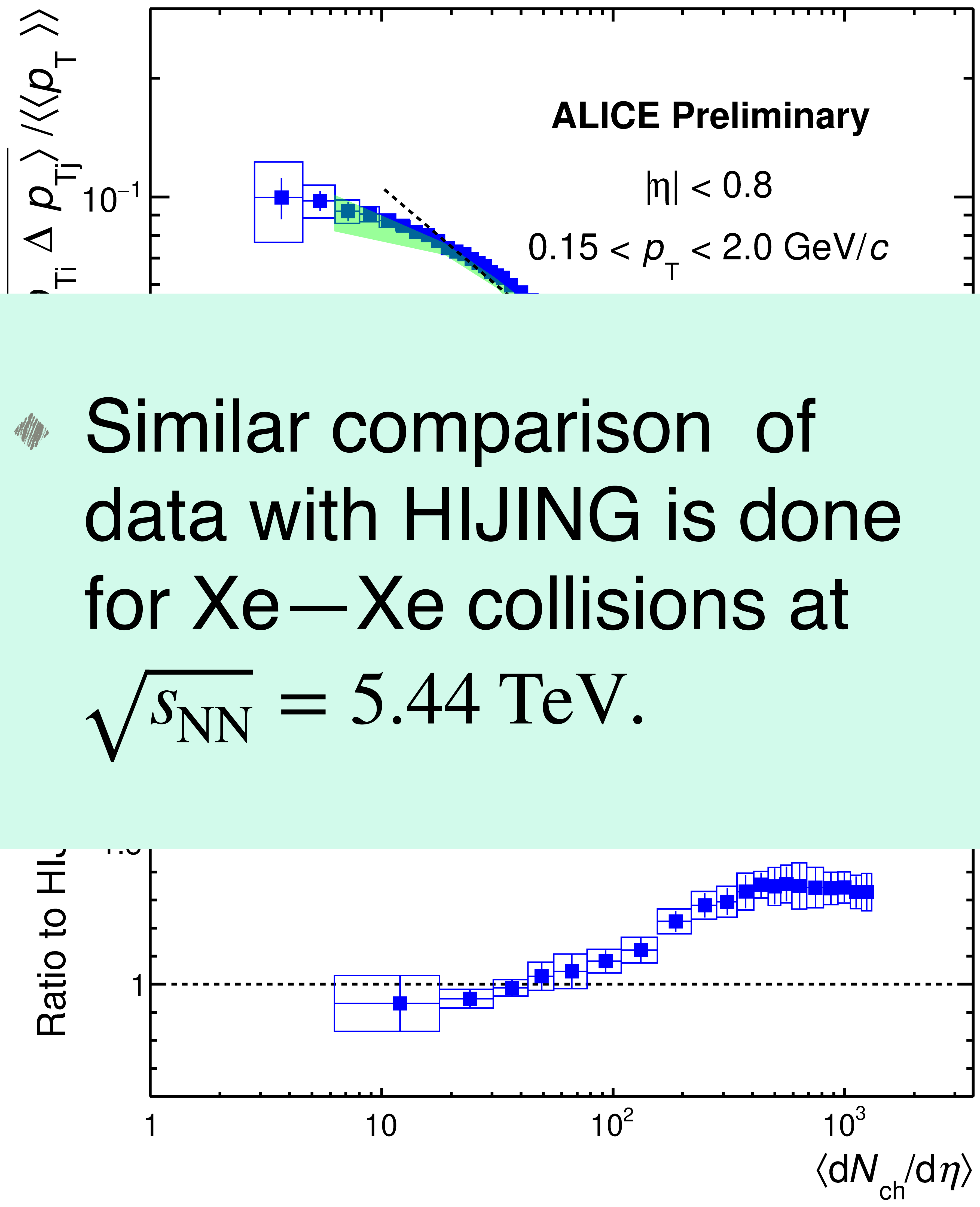

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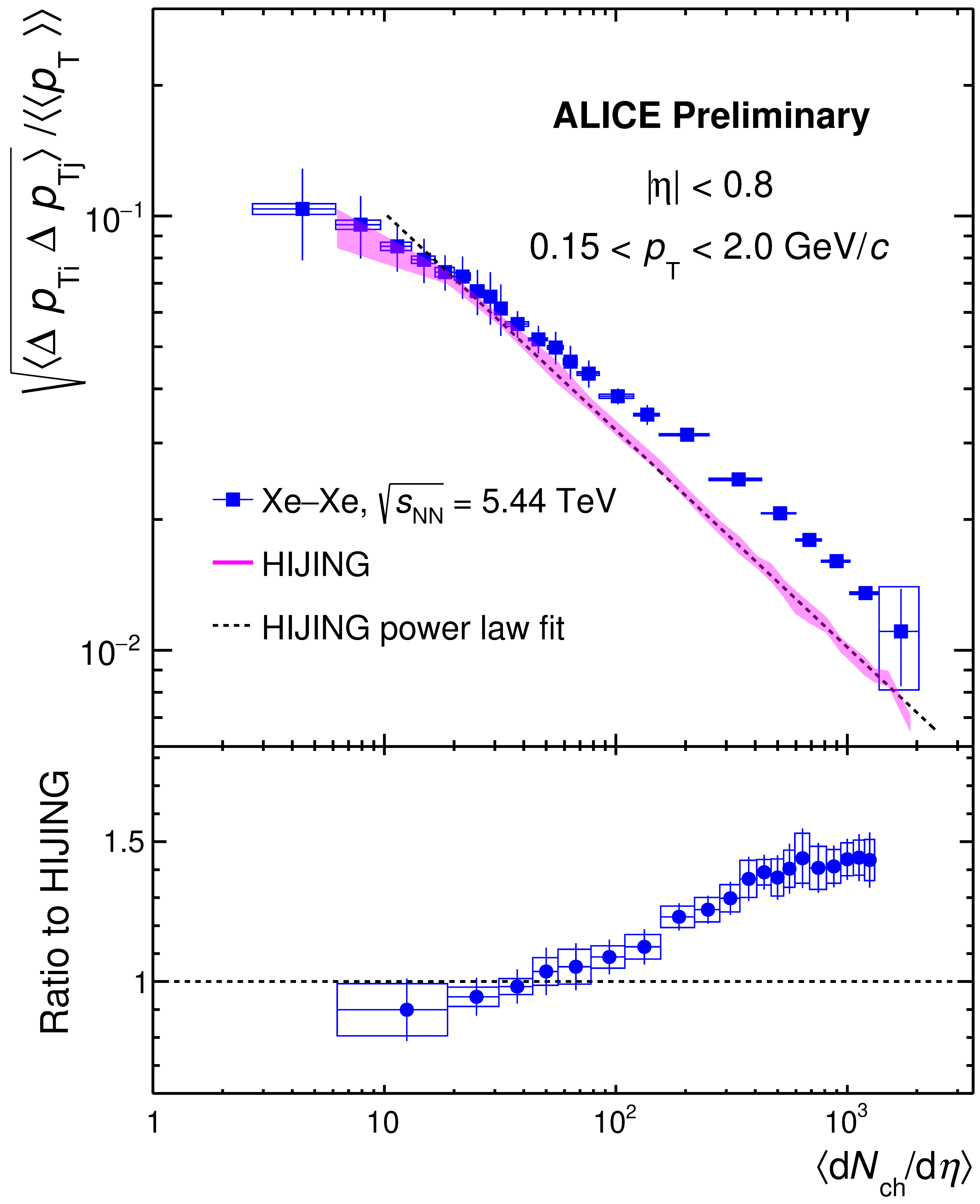
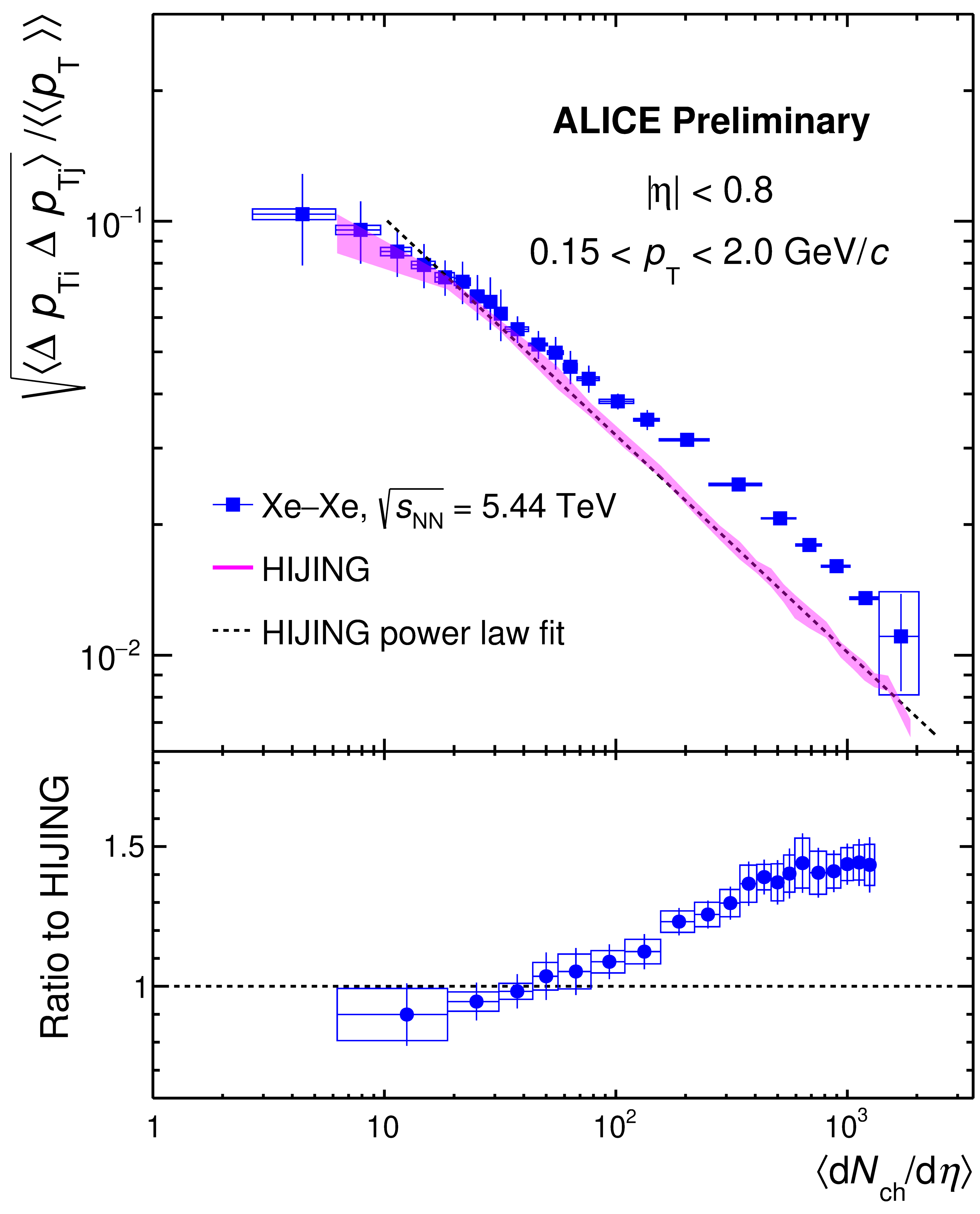


ALI-PREL-526509

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

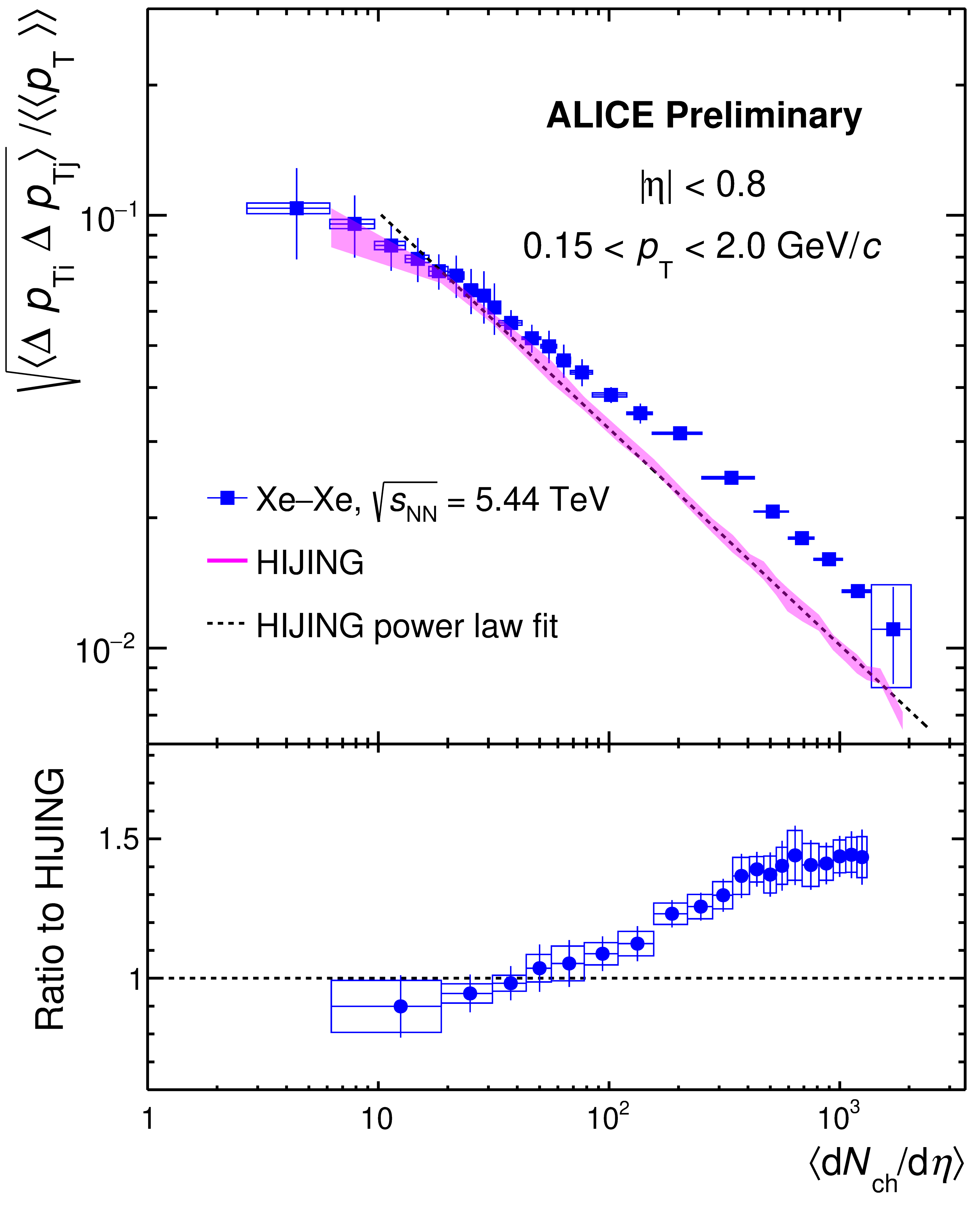
- Deviation from simple superposition scenario is observed in central Xe—Xe collisions.



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

- 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~