A Large Ion Collider Experiment

Event-by-event mean p_T fluctuations in pp and Pb–Pb collisions at the LHC

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on behalf of the ALICE Collaboration

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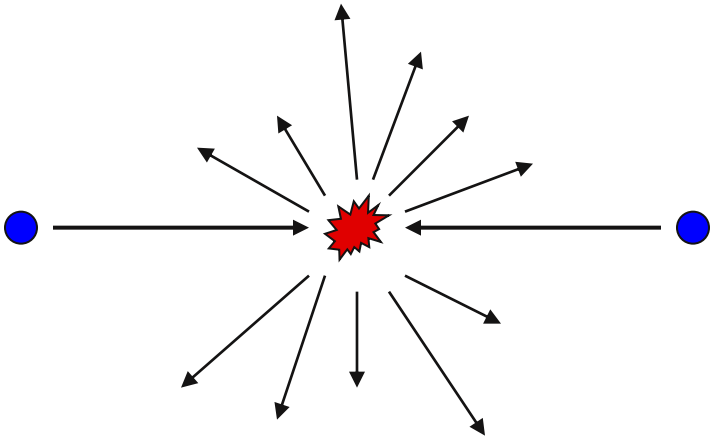
H-QM | Helmholtz Research School Quark Matter Studies

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

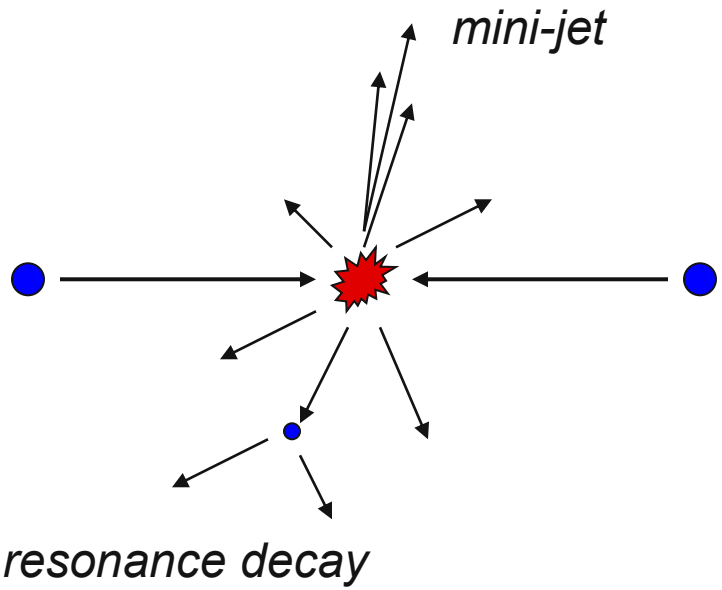
Motivation: pp collisions

Event-by-event fluctuations of the mean transverse momentum

Statistical fluctuations:

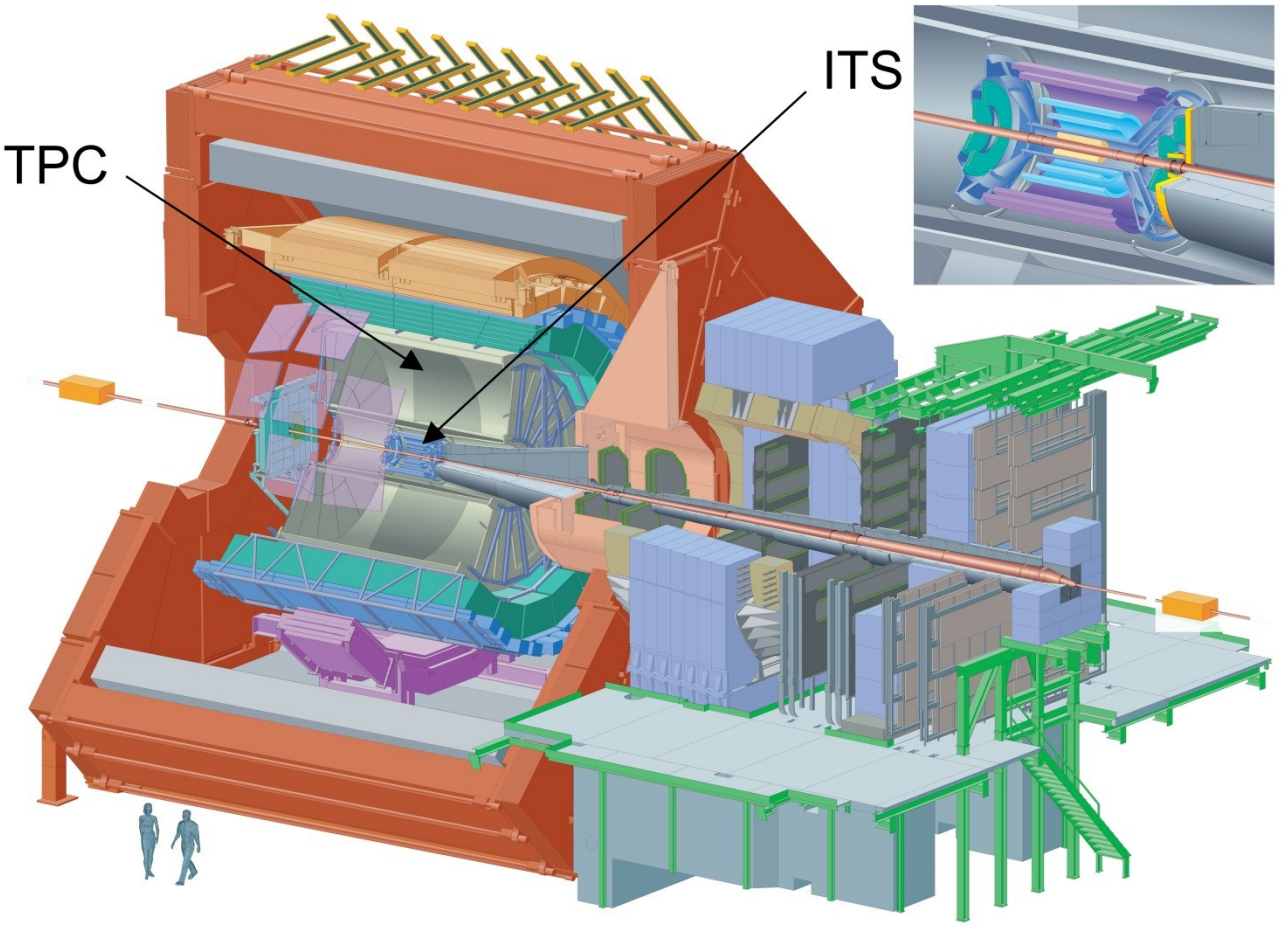


Dynamical fluctuations:



pp collisions also interesting as reference measurement for heavy-ion collisions

ALICE detector setup



Main detectors used in this analysis:

Time
Projection
Chamber

(Tracking, Vertex)

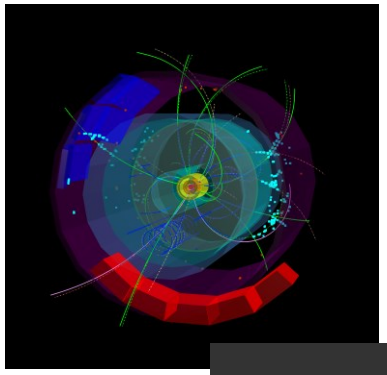
Inner
Tracking
System

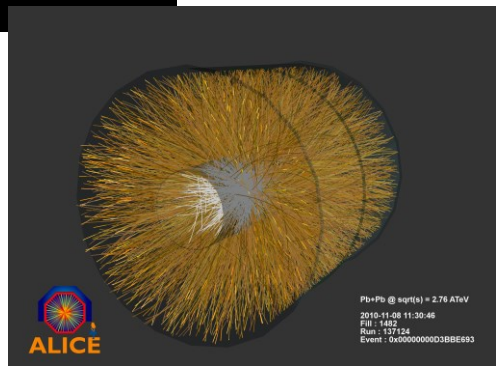
(Vertex)

Data sets and acceptance

pp collisions:

- $\sqrt{s}$ = 0.9 TeV, 6.9 M events
- $\sqrt{s}$ = 2.76 TeV, 66 M events
- $\sqrt{s}$ = 7 TeV, 290 M events





Pb–Pb collisions:

- $\sqrt{s_{NN}}$ = 2.76 TeV, 19 M events

Acceptance:

Pseudorapidity range: $|\eta| < 0.8$

Transverse momentum range: $0.15 < p_T < 2$ GeV/c

Two-particle correlator

The mean of covariances of all particle pairs i and j

$$C = \left\langle \Delta p_{\mathrm{T,i}}, \Delta p_{\mathrm{T,j}} \right\rangle = \frac{1}{\sum_{\mathrm{k}=1}^{n_{\mathrm{ev}}} N_{\mathrm{k}}^{\mathrm{pairs}}} \cdot \sum_{\mathrm{k}=1}^{n_{\mathrm{ev}}} \sum_{\mathrm{i}=1}^{N_{\mathrm{k}}} \sum_{\mathrm{j}=\mathrm{i}+1}^{N_{\mathrm{k}}} \left(p_{\mathrm{T,i}} - M(p_{\mathrm{T}}) \right) \cdot \left(p_{\mathrm{T,j}} - M(p_{\mathrm{T}}) \right)$$

n_{ev}: Number of events

N_{k}: Number of particles in event *k*

$N_{\mathrm{k}}^{\mathrm{pairs}} = 0.5 \cdot N_{\mathrm{k}} \cdot \left(N_{\mathrm{k}} - 1 \right)$: Number of pairs in event *k*

$M(p_{\mathrm{T}})$: Mean p_{T} of all tracks in all events

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$C = 0$ for only statistical fluctuations

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$$\frac{\sqrt{C}}{M(p_{\mathrm{T}})}$$

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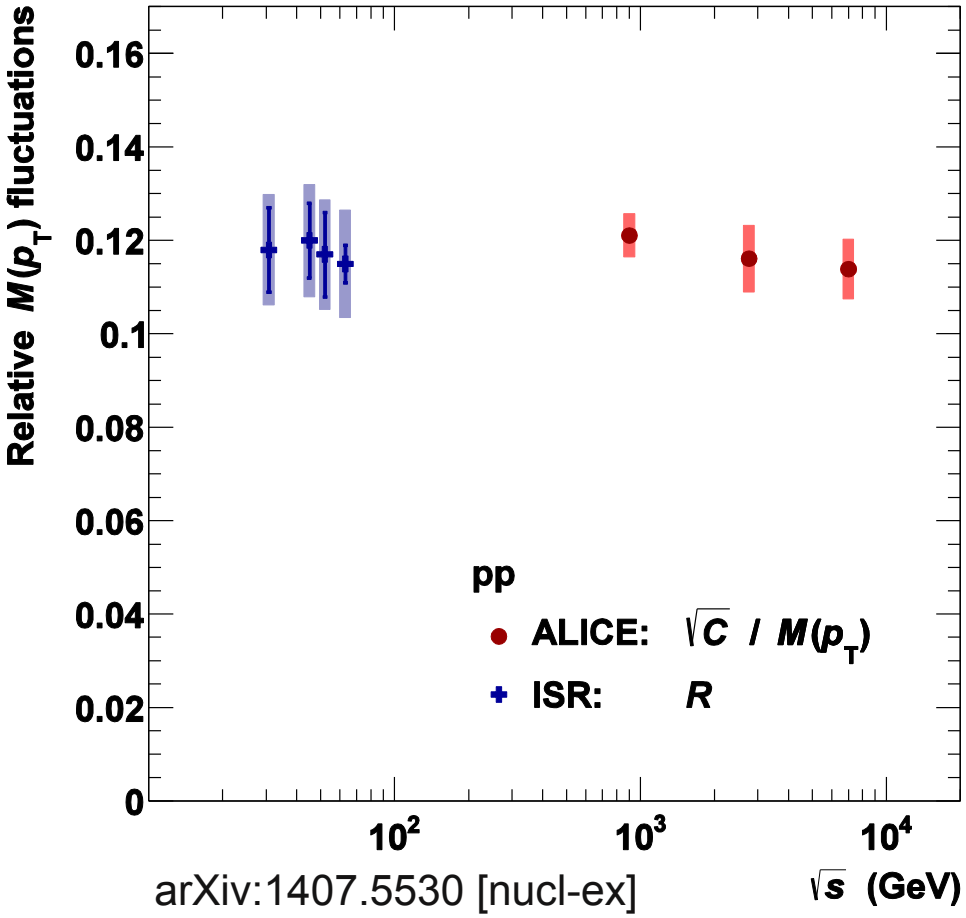
$M(p_{\mathrm{T}})$: Mean p_{T} of all tracks in all events

Measure fluctuations relative to $M(p_{\mathrm{T}})$

Results in pp collisions

Inclusive results as a function of $\sqrt{s}$

- Significant dynamical fluctuations
- ALICE measures no significant dependence on collision energy
- Comparison to a similar quantity from ISR [1]
- No significant dependence over a large range of collision energies



arXiv:1407.5530 [nucl-ex]

[1] K. Braune *et al*., Phys.Lett. **B123** (1983) 467

Two-particle correlator

As a function of multiplicity

- First measurement of mean p_T fluctuations as a function of multiplicity in pp collisions!
- Differential studies can bring more insight in the origin of the fluctuations
- Effects of multi-parton interactions, color reconnections, …

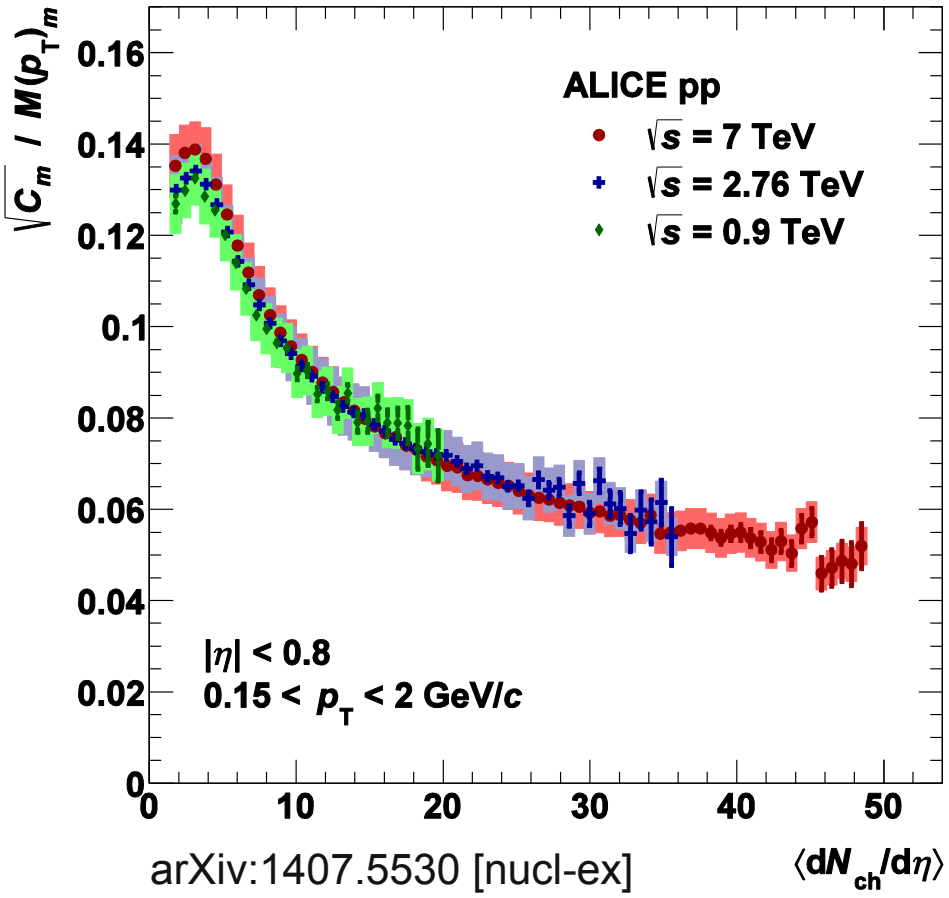
$$C_m = \left\langle \Delta p_{T,i}, \Delta p_{T,j} \right\rangle_m = \frac{1}{\sum_{k=1}^{n_{ev}} N_k^{pairs}} \cdot \sum_{k=1}^{n_{ev}} \sum_{i=1}^{N_k} \sum_{j=i+1}^{N_k} \left(p_{T,i} - M(p_T)_m\right) \cdot \left(p_{T,j} - M(p_T)_m\right)$$

$C_m = 0$ for only statistical fluctuations

$$\frac{\sqrt{C_m}}{M(p_T)_m}$$

Results in pp collisions

As a function of the charged-particle multiplicity density

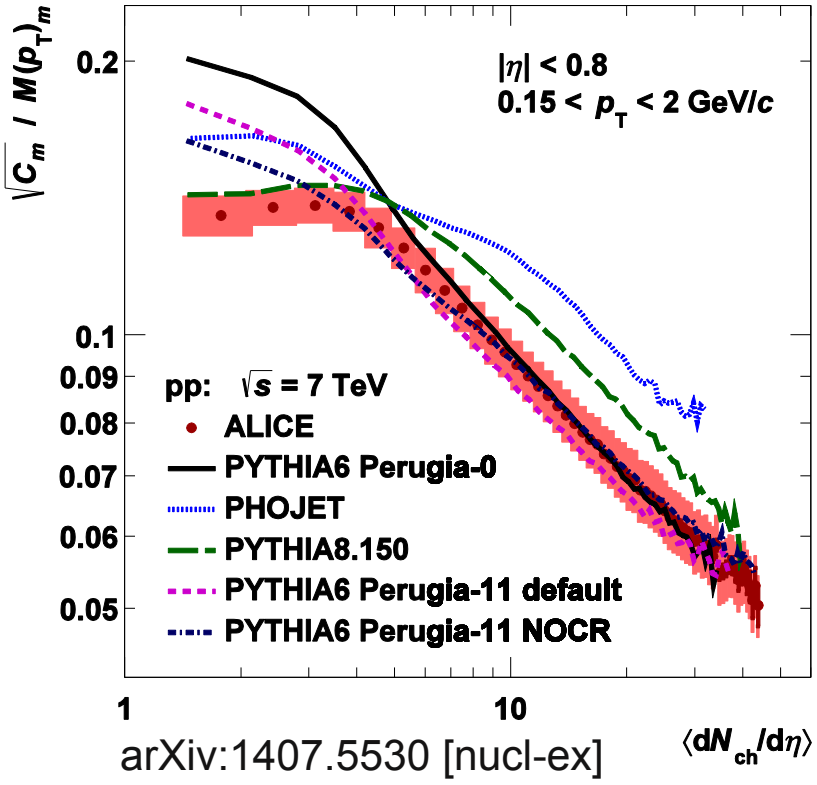


arXiv:1407.5530 [nucl-ex]

- Significant dynamical fluctuations
- Strong decrease with multiplicity
- Inclusive value of ≈ 12% has underlying structure
- No significant collision energy dependence

Results in pp collisions

Comparison to Monte Carlo generators



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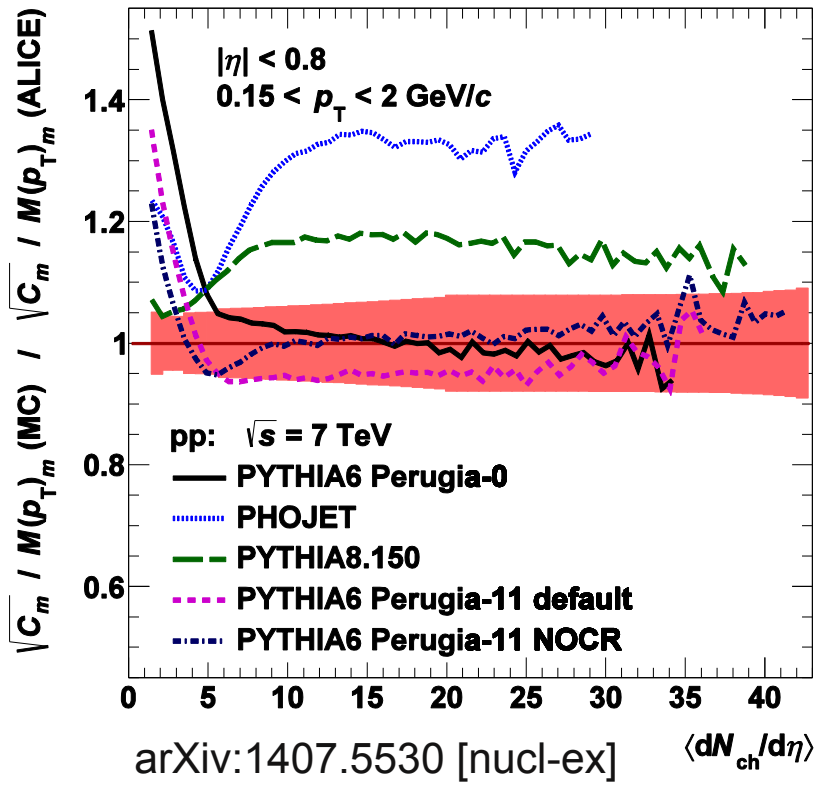
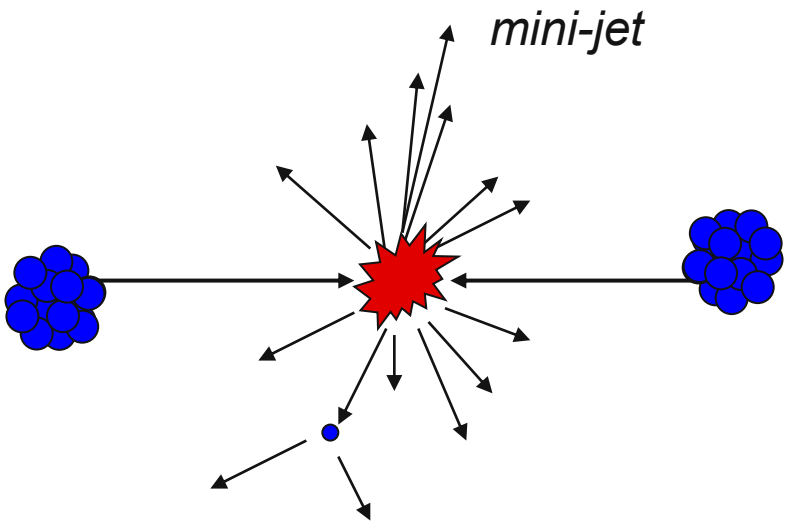


arXiv:1407.5530 [nucl-ex]

For $\langle dN_{ch}/d\eta \rangle > 5$:
- Reasonable description by most of the generators
- Color reconnections have no influence on the slope!

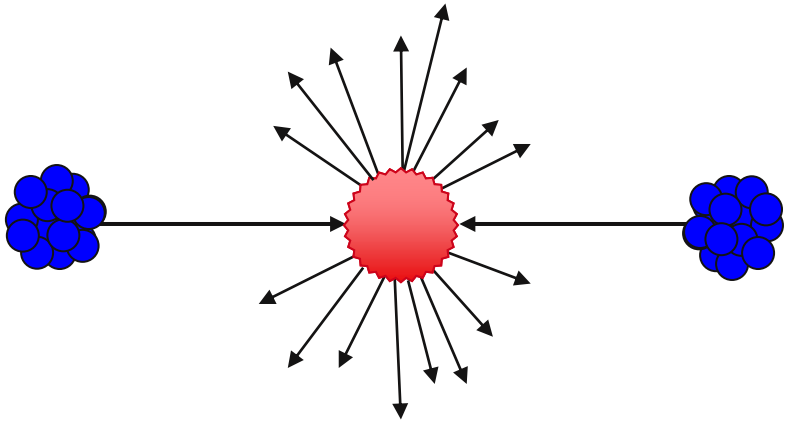
Motivation: From pp to Pb–Pb collisions

Contributions also observed in pp collisions:



pp collisions important as reference measurement!

Contributions unique to heavy-ion collisions:

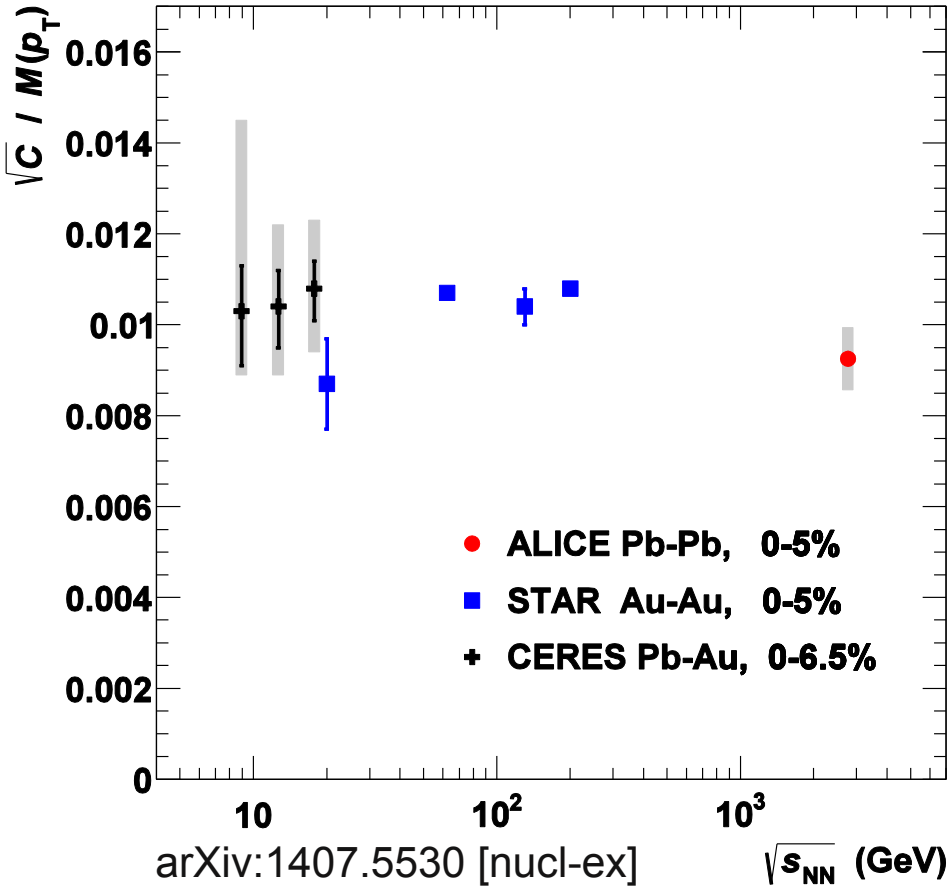


- Thermalization
- Collectivity
- Phase transitions
- Initial state fluctuations
- …

Results in Pb–Pb collisions

Central A–A collisions as a function of $\sqrt{s}$

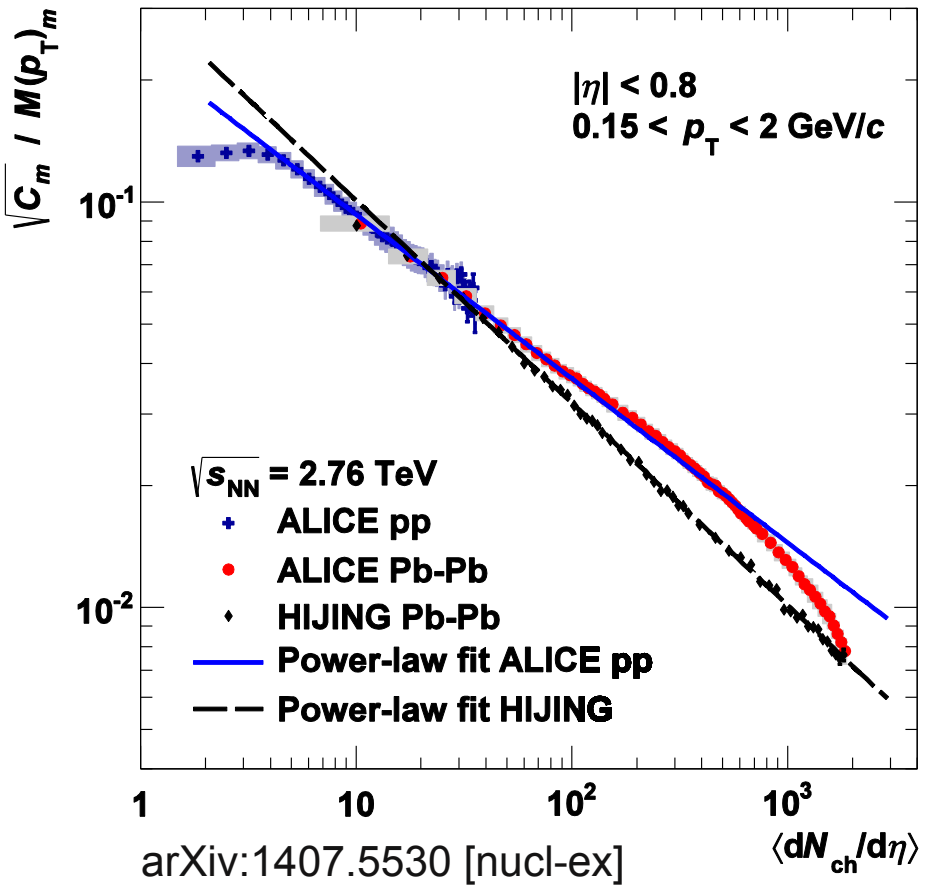
- Significant dynamical fluctuations
- Comparison to data from CERES [2] and STAR [3]
- No significant collision energy dependence



[2] D. Adamová *et al*., Nucl.Phys. **A811** (2008) 179
[3] J. Adams *et al*., Phys.Rev. **C72** (2005) 044902

Results in Pb–Pb collisions

Comparison to pp collisions as a function of the multiplicity



arXiv:1407.5530 [nucl-ex]

- Peripheral Pb–Pb in agreement with pp baseline:

$$\propto \langle \mathrm{d}N_{\mathrm{ch}} / \mathrm{d}\eta \rangle^{b}$$

$$b = -0.405 \pm 0.002(\mathrm{stat.}) \pm 0.036(\mathrm{syst.})$$

- Deviation in central Pb–Pb

- Not described by HIJING:

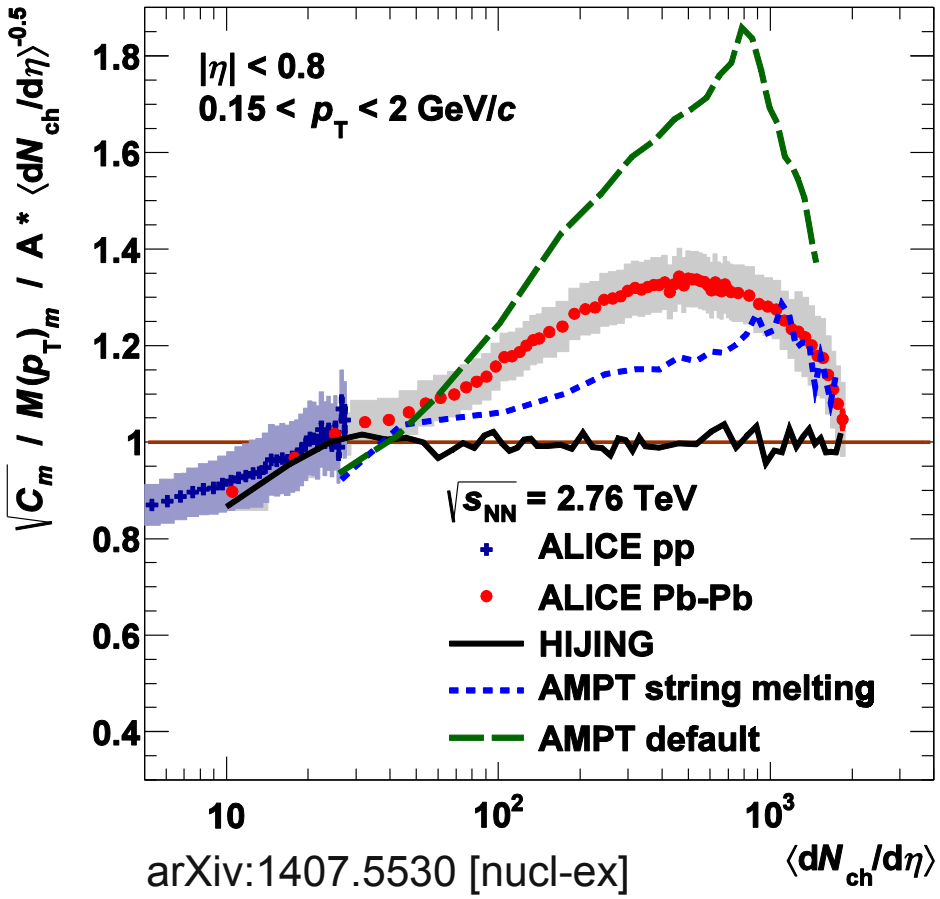
$$b = -0.499 \pm 0.003(\mathrm{stat.}) \pm 0.005(\mathrm{syst.})$$

corresponds to simple superposition expectation

Results in Pb–Pb collisions

Comparison to Monte Carlo generators

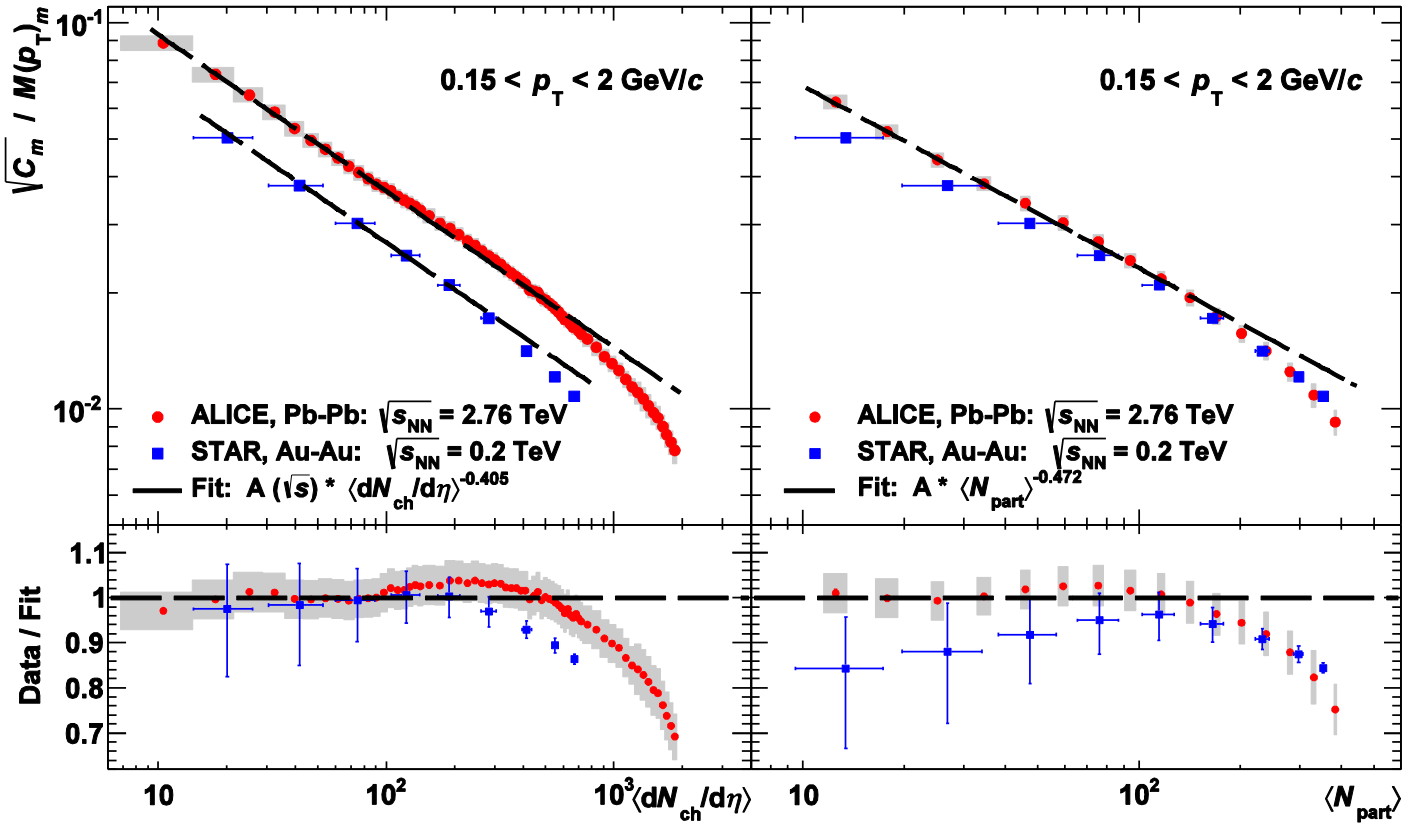
- HIJING shows behaviour $\propto \langle \mathrm{d}N_{\mathrm{ch}} / \mathrm{d}\eta \rangle^{-0.5}$ and cannot describe the data
- AMPT (includes collective effects) both versions:
  - Increase above simple superposition expectation
  - Decrease towards central events
  - Fail in terms of absolute values



arXiv:1407.5530 [nucl-ex]

Results in Pb–Pb collisions

Comparison to STAR [3] results in Au–Au collisions



arXiv:1407.5530 [nucl-ex]

Left:

Power of fits from ALICE pp:

$$\left\langle \mathrm{d}N_{\mathrm{ch}} / \mathrm{d}\eta \right\rangle^{-0.405}$$

Right:

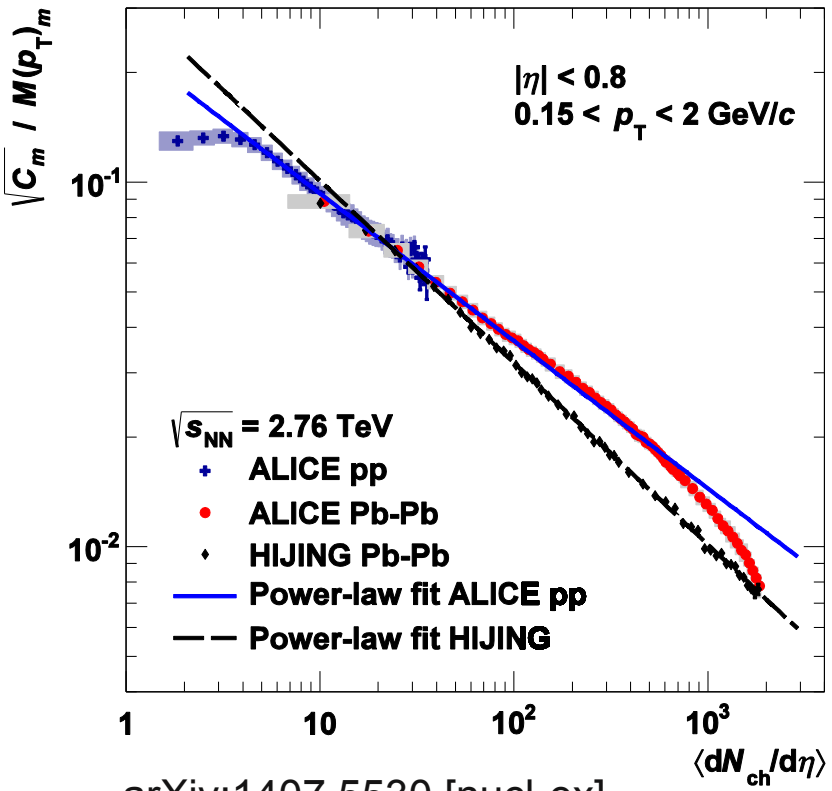
In terms of $\left\langle N_{\mathrm{part}} \right\rangle$

Deviation from fit at same centrality

[3] J. Adams *et al.*, Phys.Rev. **C72** (2005) 044902

Conclusions

- Significant dynamical fluctuations decreasing with multiplicity observed in pp and Pb–Pb collisions.
- No significant energy dependence found in pp and Pb–Pb collisions.
- Peripheral Pb–Pb agrees with a pp extrapolation, central Pb–Pb deviates significantly.
- Monte Carlo generators describe pp rather well, Pb–Pb is not described by HIJING, but qualitatively by AMPT.



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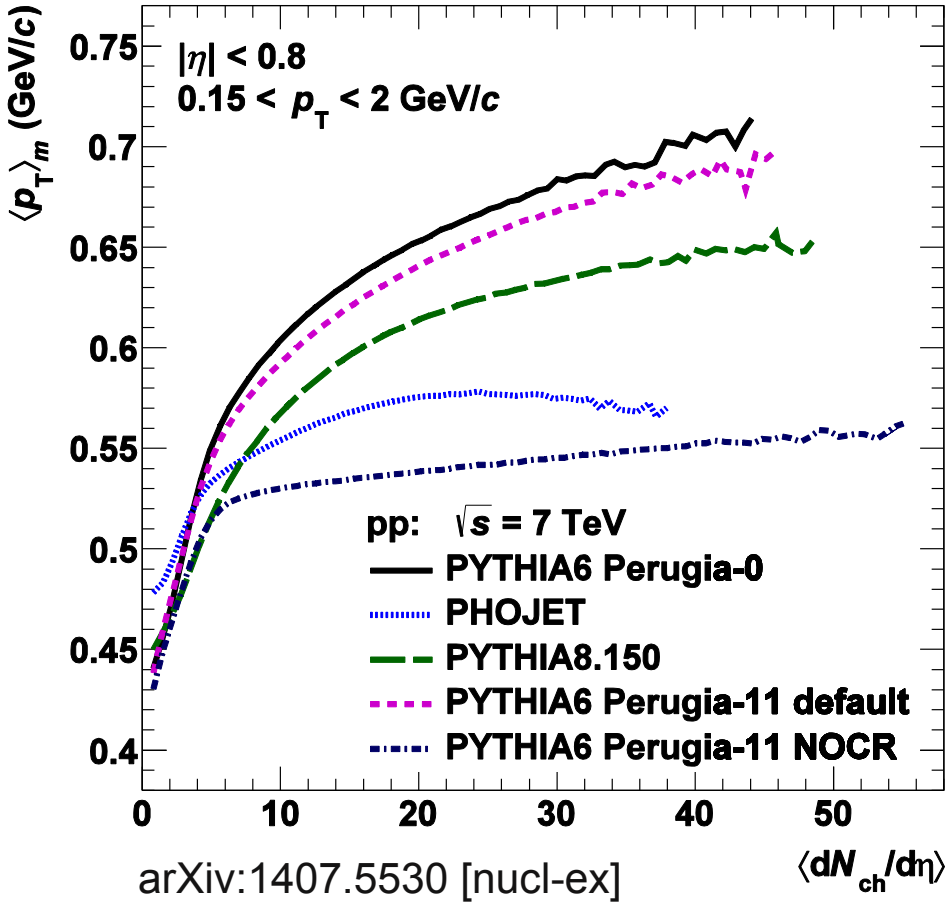
BACKUP

Mean p_T in pp collisions

From the Monte Carlo event generators



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