Event-by-event mean p_T fluctuations in pp and Pb-Pb collisions measured by the ALICE experiment at the LHC

Stefan Heckel
for the ALICE collaboration

Quark Matter 2011 - Annecy

Motivation

Event-by-event fluctuations of mean transverse momentum contain information on the dynamics and correlations in pp and heavy-ion collisions.

Reference measurements in pp serve as a baseline with ‘known‘ physics like p_T correlations due to resonance decays, HBT, (mini-)jets etc.

In heavy-ion collisions, fluctuations may also be related to other effects like a critical behaviour of the system in the vicinity of a phase boundary or the onset of thermalisation of the system.

E-by-e fluctuations of mean p_T:

$$\sigma^2_{\text{total}} = \sigma^2_{\text{stat}} \pm \underbrace{\sigma^2_{\text{pp}} \pm \sigma^2_{\text{AA}}}_{\sigma^2_{\text{dyn}}}$$

$$\sigma^2_{\text{dyn}} = \textbf{Two-particle correlator } C_{\text{m}}$$

Two-particle correlator

'Mean of covariances' of all pairs of particles i and j in the same event wrt. the inclusive $\langle p_T \rangle$ in multiplicity class m.

$C_m = 0$ for only statistical fluctuations.

$$\sigma^2_{dyn} = C_m = \left\langle \Delta p_{T,i}, \Delta p_{T,j} \right\rangle = \frac{1}{\sum_{k=1}^{n_{ev}} N_k^{pairs}} \cdot \sum_{k=1}^{n_{ev}} \sum_{i=1}^{N_k} \sum_{j=i+1}^{N_k} \left(p_{T,i} - \langle p_T \rangle_m \right) \cdot \left(p_{T,j} - \langle p_T \rangle_m \right)$$

n_{ev} : Number of events in a given multiplicity range m

N_k : Number of particles in event k

$N_k^{pairs} = 0.5 \cdot N_k \cdot (N_k - 1)$: Number of pairs in event k

$\langle p_T \rangle_m$: Average p_T over all events in the given multiplicity range

Data sets, detectors and acceptance

Data sets:

- pp data: $\sqrt{s}$ = 0.9, 2.76 and 7 TeV
- Pb-Pb data: $\sqrt{s_{NN}}$ = 2.76 TeV

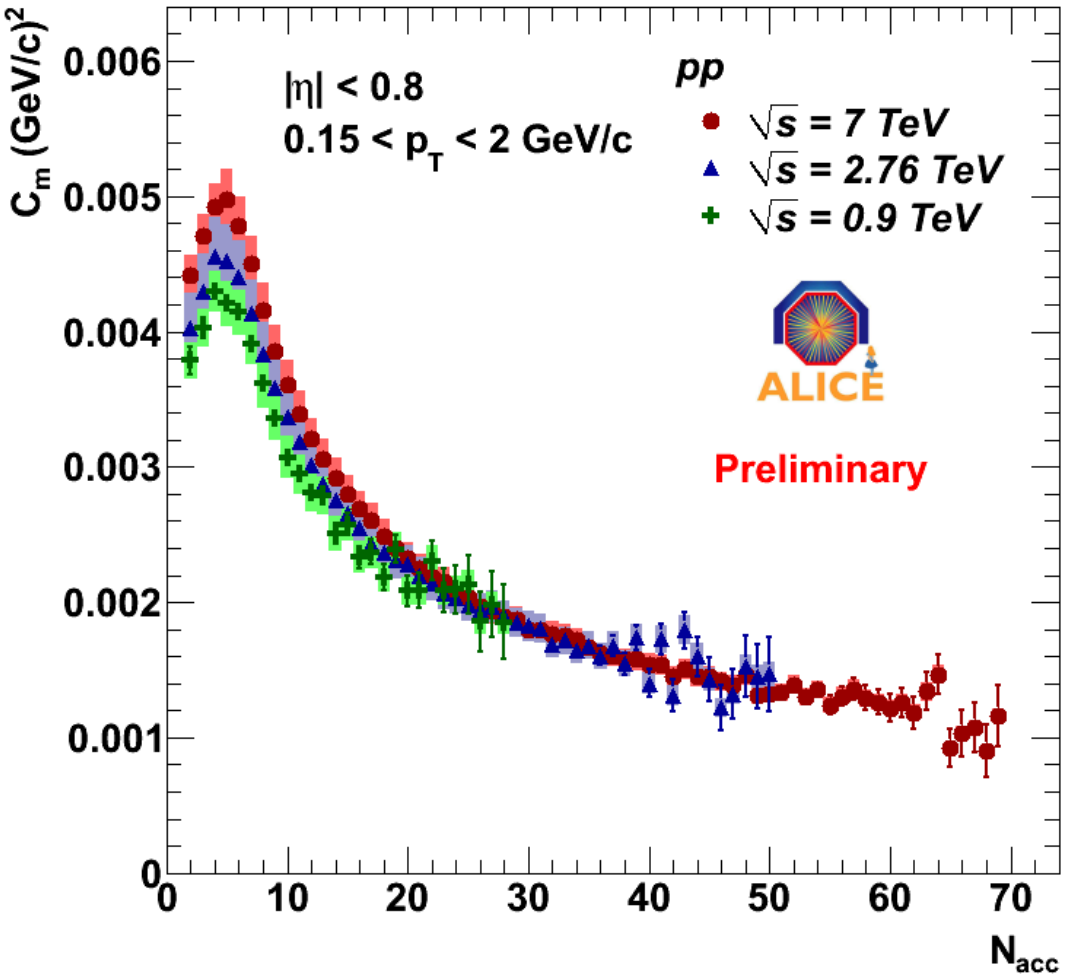
Detectors used:

- **T**ime **P**rojection **C**hamber (Tracking, Vertex)
- **I**nner **T**racking **S**ystem (Vertex in pp)

Acceptance:

- Pseudorapidity range: $|\eta| < 0.8$
- Transverse momentum range: $0.15 < p_T < 2$ GeV/c
- Multiplicity definition used: Number of accepted tracks N_{acc}

The two-particle correlator in pp collisions



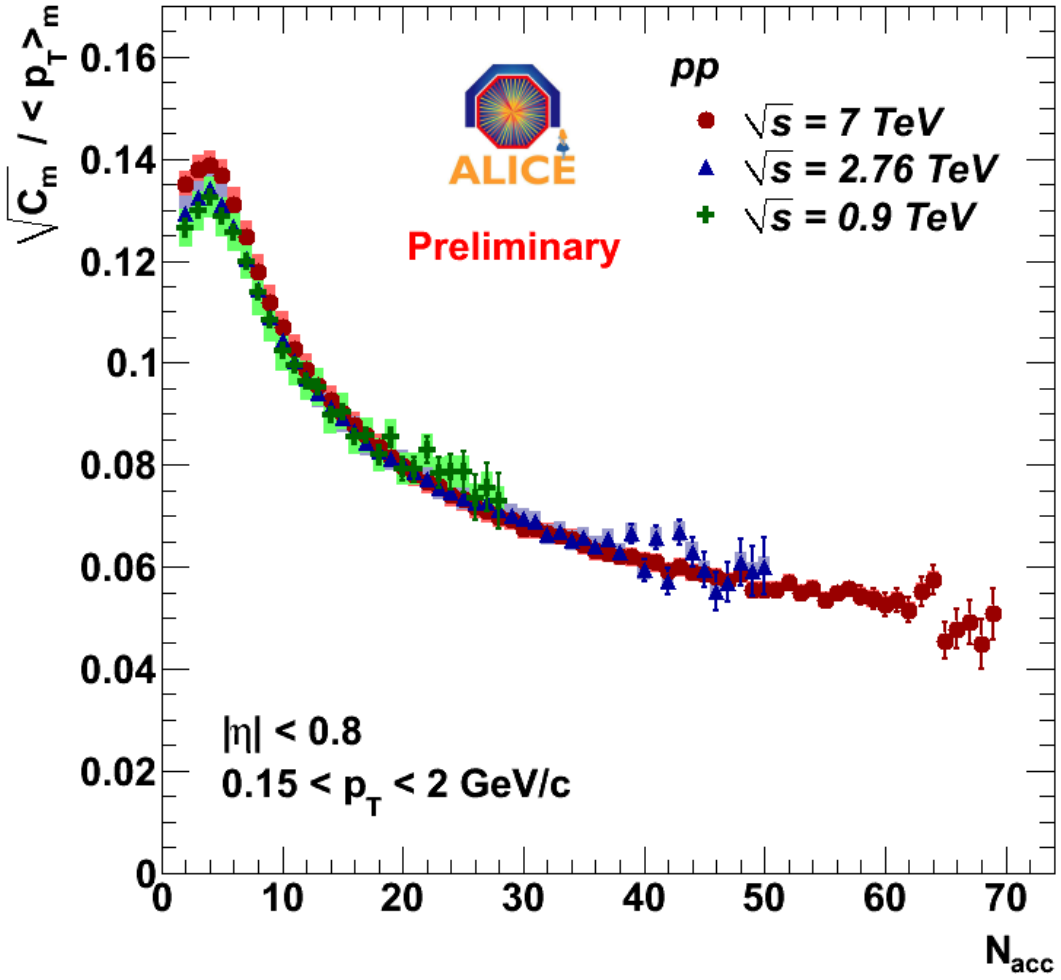
First multiplicity dependent analysis of dynamical mean p_T fluctuations in pp!

Significant non-statistical fluctuations

'Dilution' with multiplicity

Moderate energy dependence

Relative fluctuations



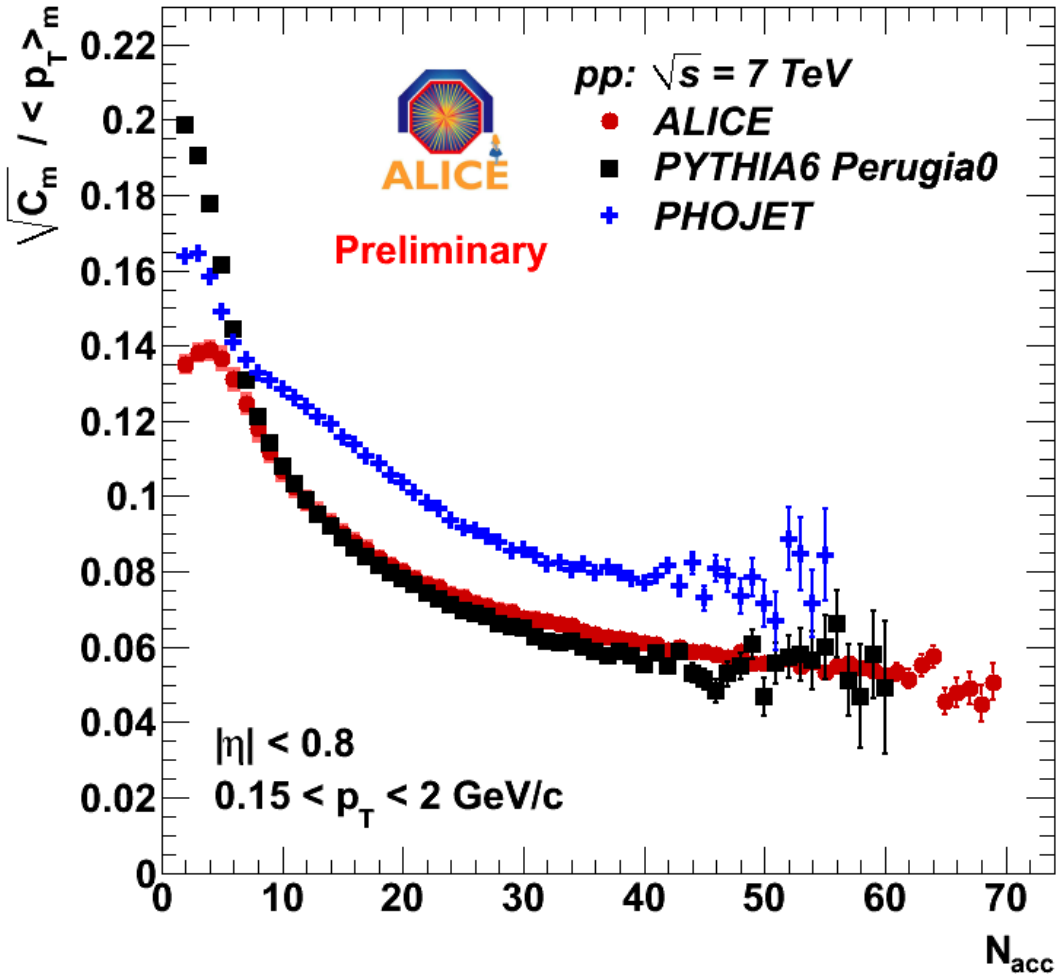
Relative fluctuations:

$$\frac{\sqrt{C_m}}{\langle p_T \rangle_m} = \frac{\sigma_{dyn}}{\langle p_T \rangle}$$

Looks universal at LHC
(except very small Nacc)

Note: Would not work
for $z = N_{acc} / \langle N_{acc} \rangle$

Comparison to event generators

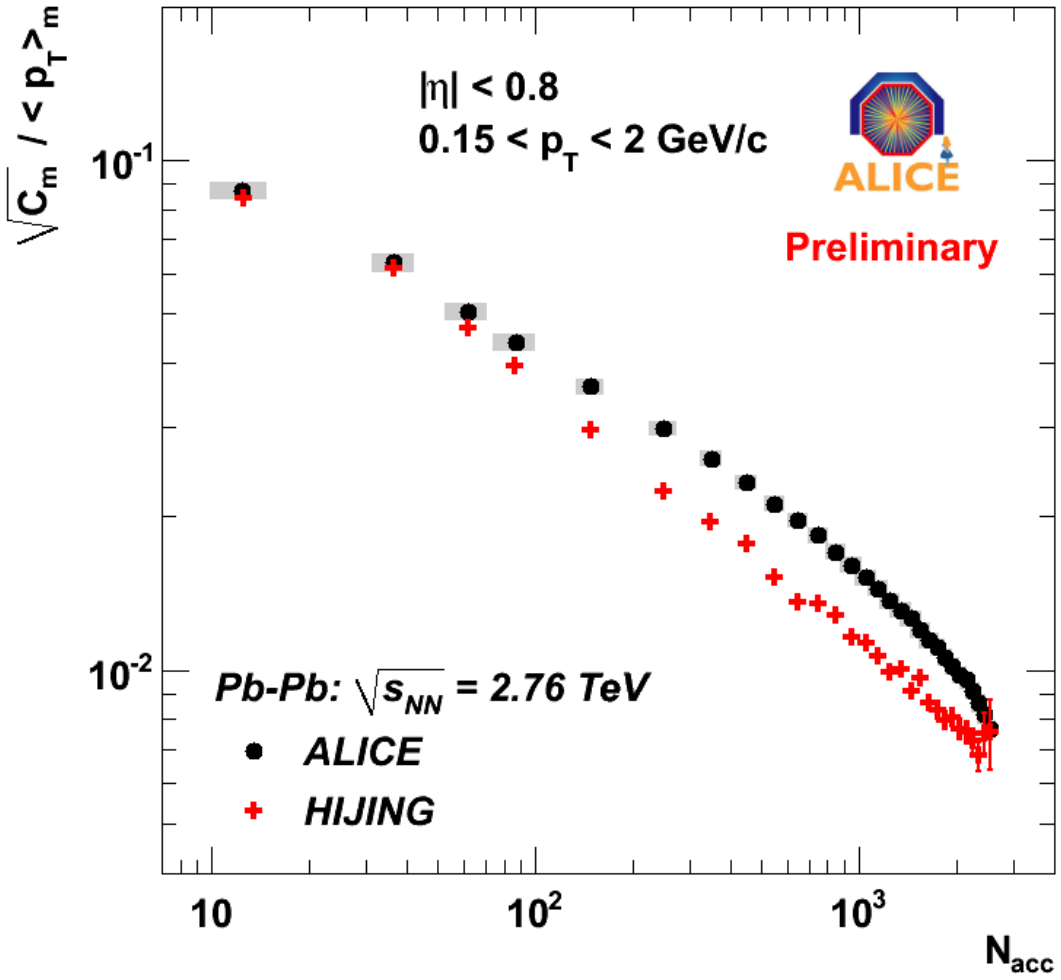


Reasonable description by PYTHIA6 for $N_{acc} \geq 7$

Slightly stronger decrease with N_{acc}

PHOJET does not fit well

Relative fluctuations in Pb-Pb collisions

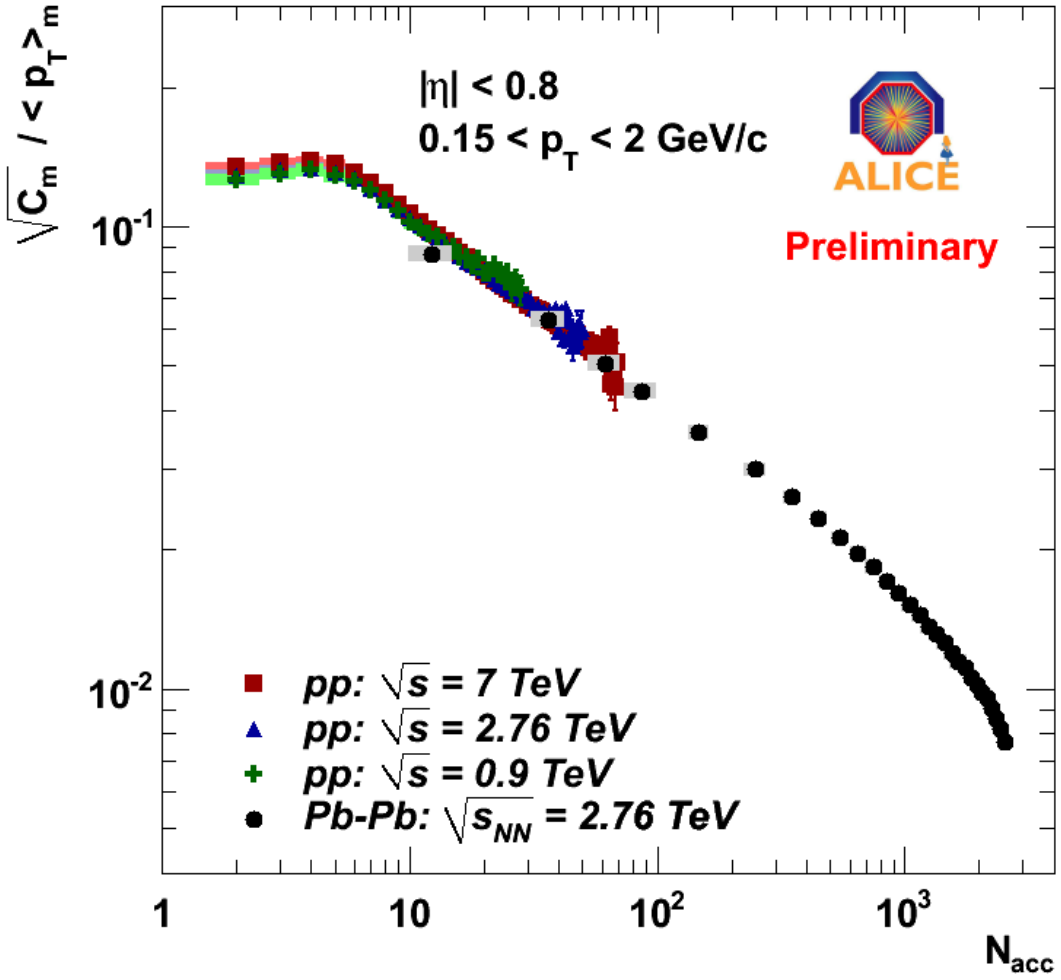


Same analysis as for pp

Like in pp: Significant non-statistical fluctuations and ‘Dilution‘ with multiplicity

Shape not described by HIJING

Comparison of pp and Pb-Pb

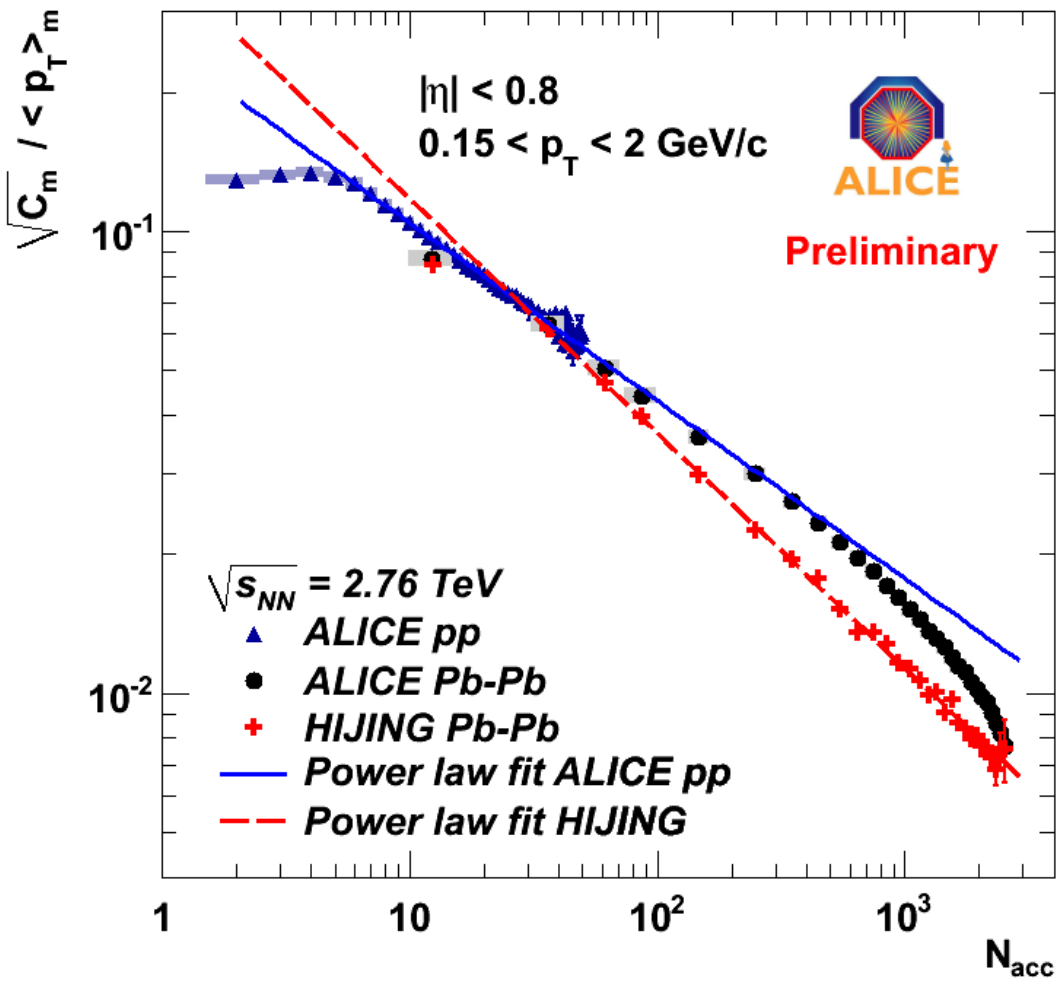


Pb-Pb and pp data comparable in overlapping region

Pb-Pb data follow the trend up to $N_{acc} \approx 600$ ($\approx$ 30-40% centrality)

pp data serves as baseline for Pb-Pb

Comparison of pp and Pb-Pb data to HIJING



Power law fit to pp data

$$\propto N_{acc}^{-0.385 \pm 0.003}$$

Fit-range: $8 \leq N_{acc} \leq 40$, stat. uncert. only

Pb-Pb data agree with pp baseline for $N_{acc} \leq 600$

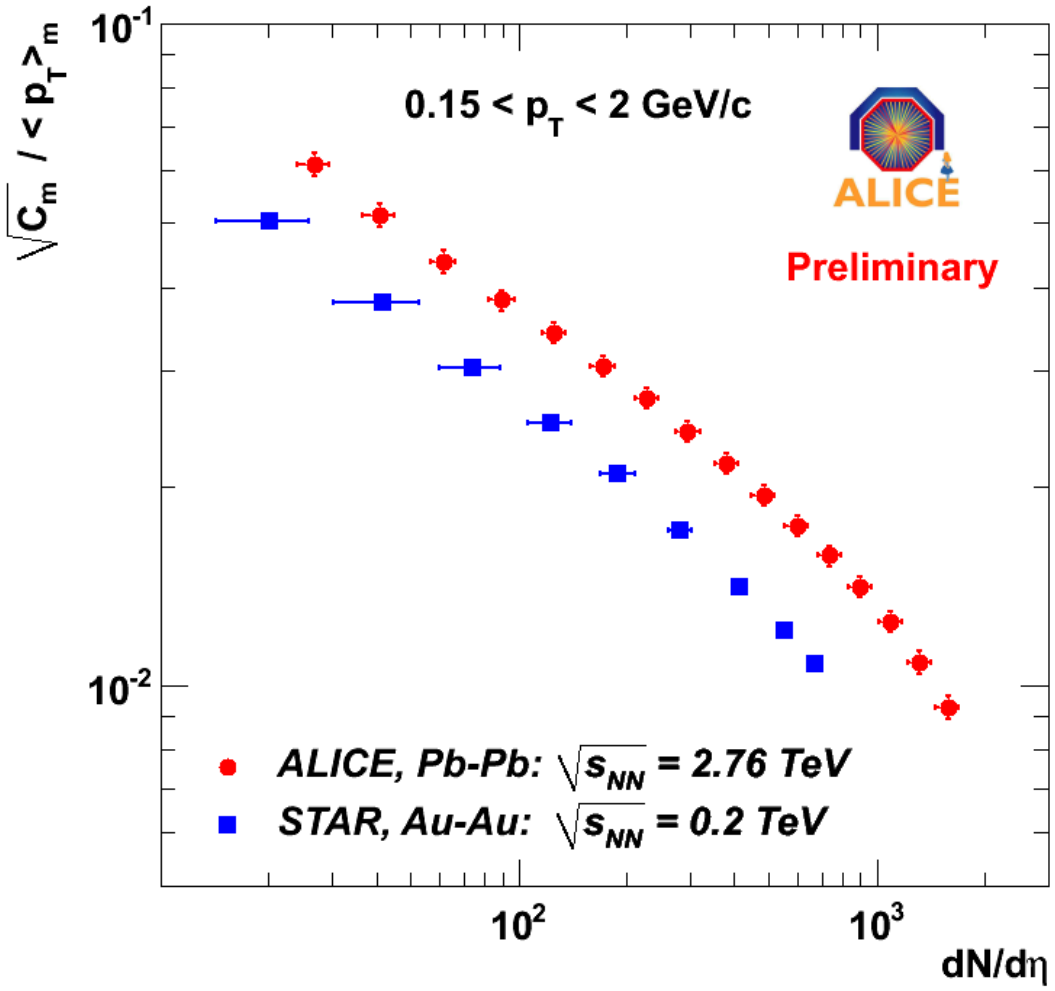
Significant reduction of fluctuations in central Pb-Pb wrt. the pp baseline

HIJING has steeper power

$$\propto N_{acc}^{-0.508 \pm 0.004}$$

No indication for deviation in central events in HIJING

Comparison to STAR data

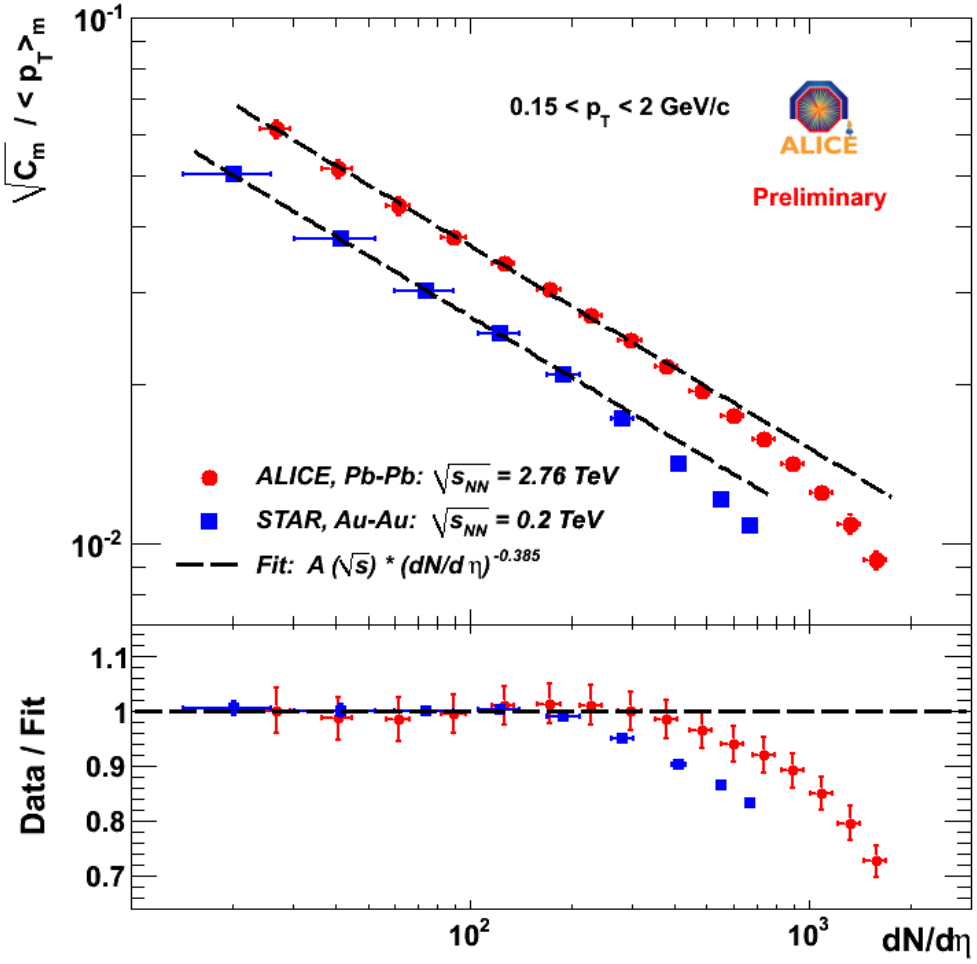


Centrality definition in terms of dN/dη to get a similar picture as in N_{acc}

Slopes of ALICE and STAR data are similar

Additional decrease in central collisions also in STAR?

Qualitative comparison pp and heavy-ions



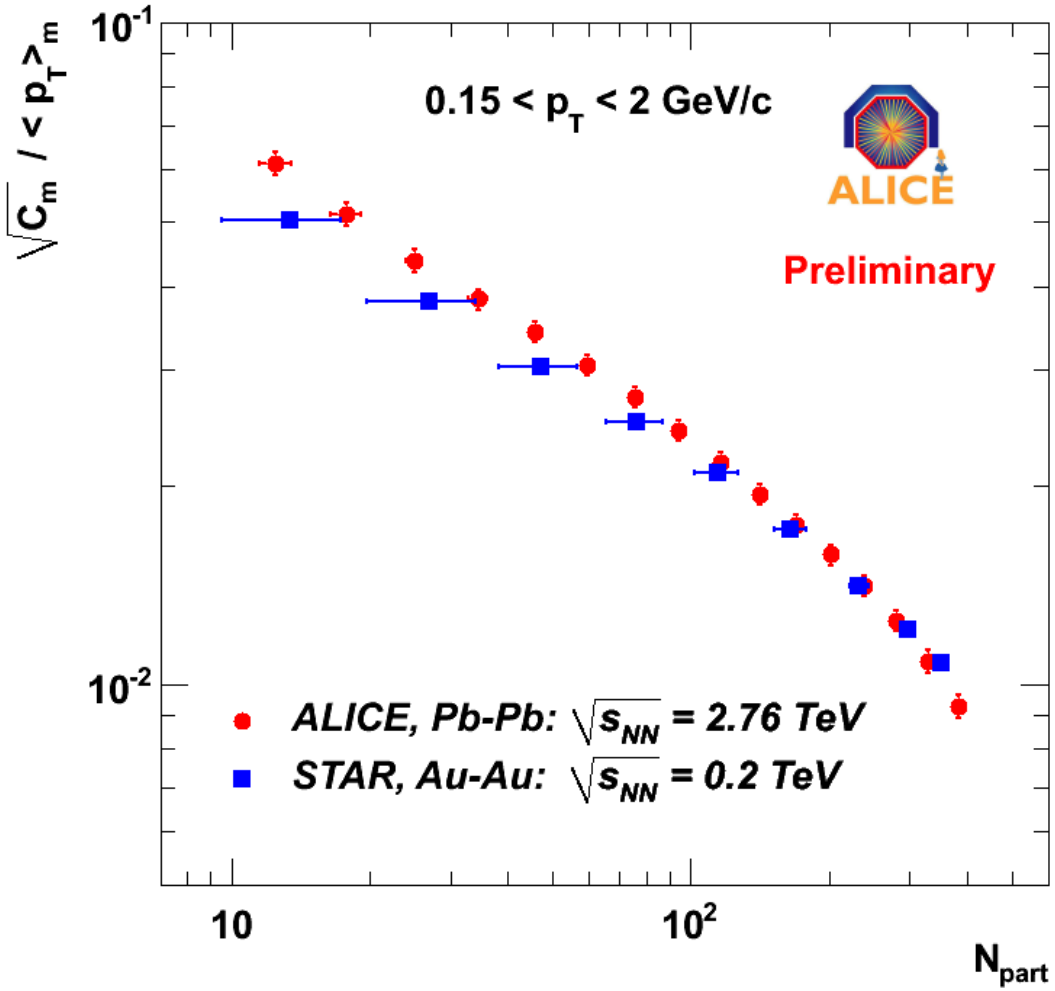
Power of fits taken from ALICE pp data:

$$A(\sqrt{s}) * dN/d\eta^{-0.385}$$

Power of multiplicity dependence in peripheral collisions agrees in ALICE and STAR

Deviation for central collisions more pronounced in ALICE data

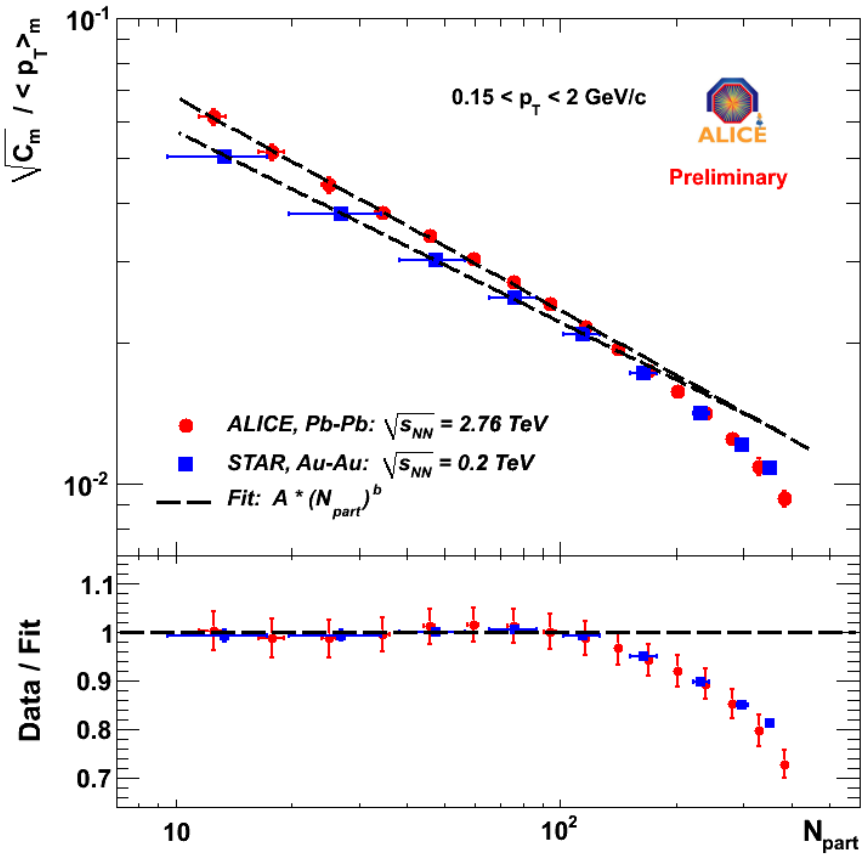
Comparison to STAR in terms of N_{part}



Centrality definition in terms of N_{part} to compare same centralities

Similar trend, but in detail ALICE data above STAR at small N_{part}, crossing around $N_{part} \approx 250$

Qualitative comparison pp and heavy-ions II

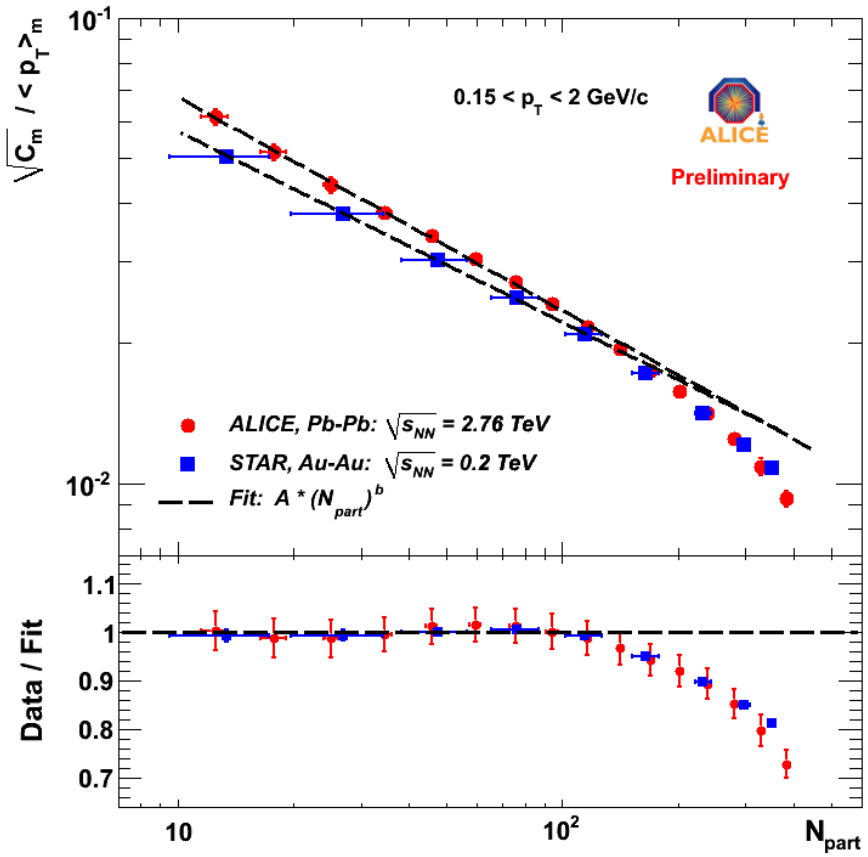


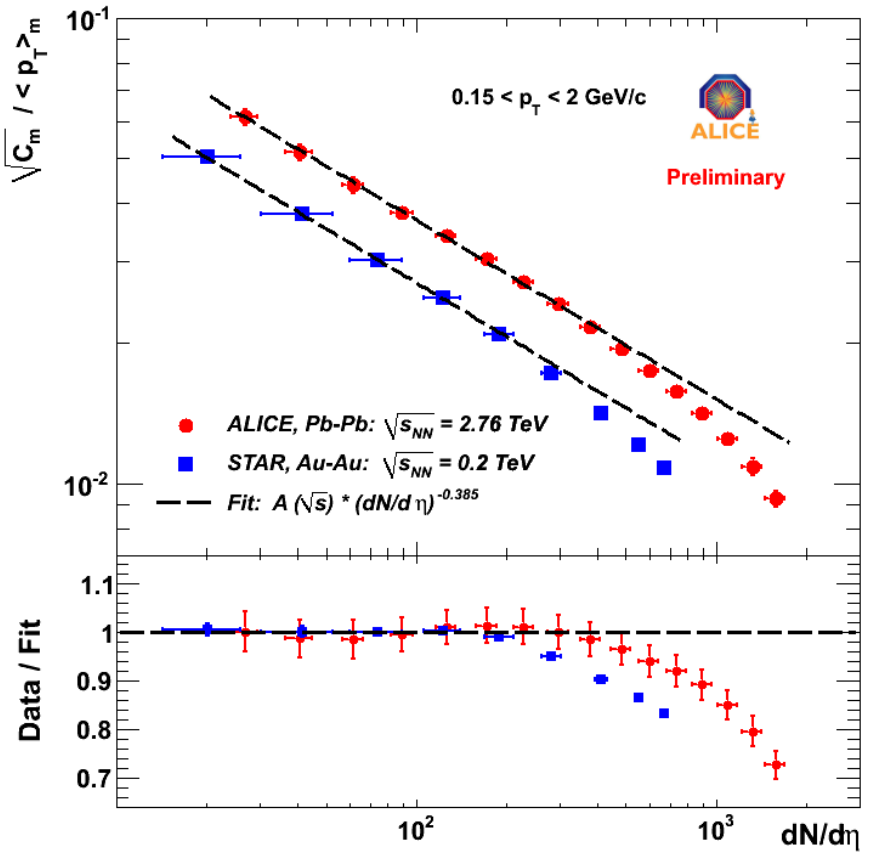
In terms of N_{part} ALICE and STAR data are closer

Slightly different powers: Fits done with free fitting parameters

In the ratio Data/Fit ALICE and STAR data agree

Qualitative comparison pp and heavy-ions II





Free fitting parameters

ALICE and STAR data agree in terms of N_{part}

Slope of fits taken from ALICE pp data

Deviation more pronounced in ALICE data

Conclusions

Mean p_T fluctuations in pp and Pb-Pb collisions have been studied.

Relative fluctuations in pp collisions at the LHC are almost independent of the collision energy.

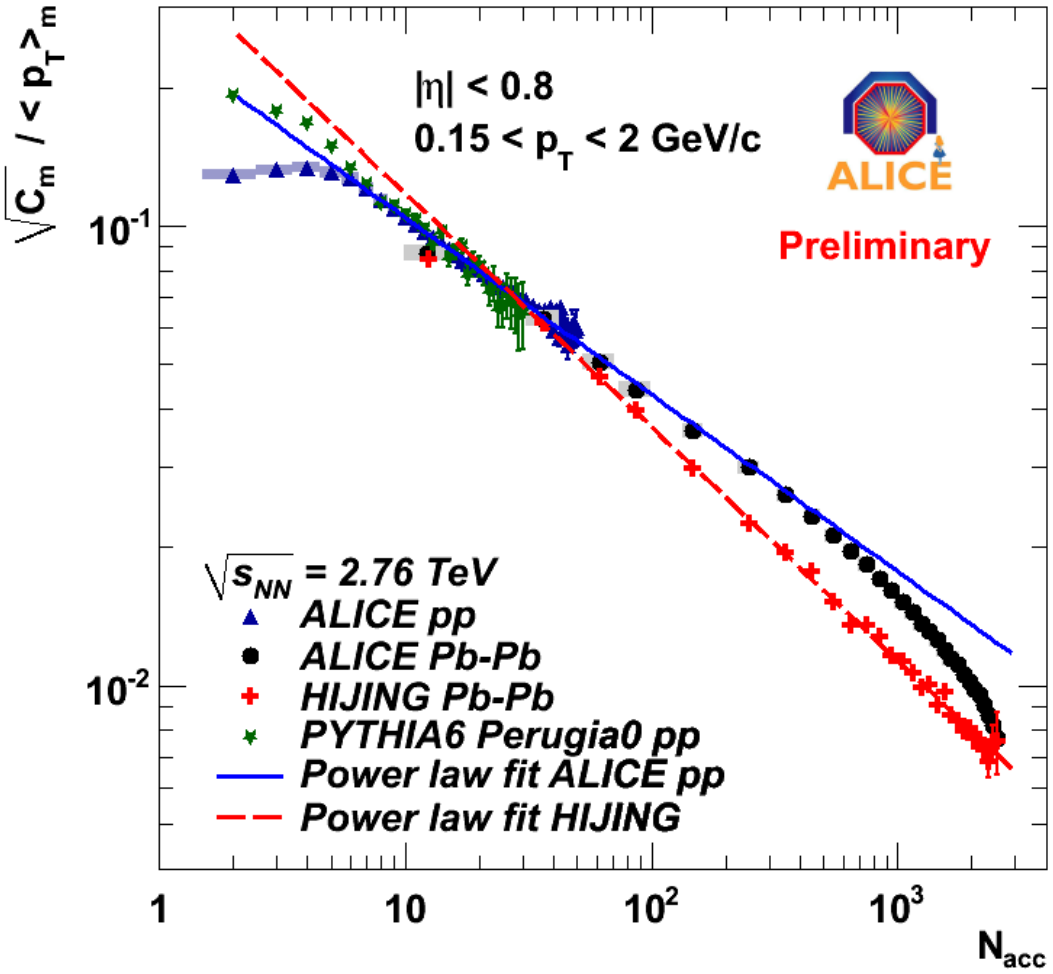
Multiplicity dependence in pp and peripheral Pb-Pb collisions follows a common trend at the LHC.

In central Pb-Pb a significant additional decrease of mean p_T fluctuations is observed, which might be related to effects like the onset of thermalisation.

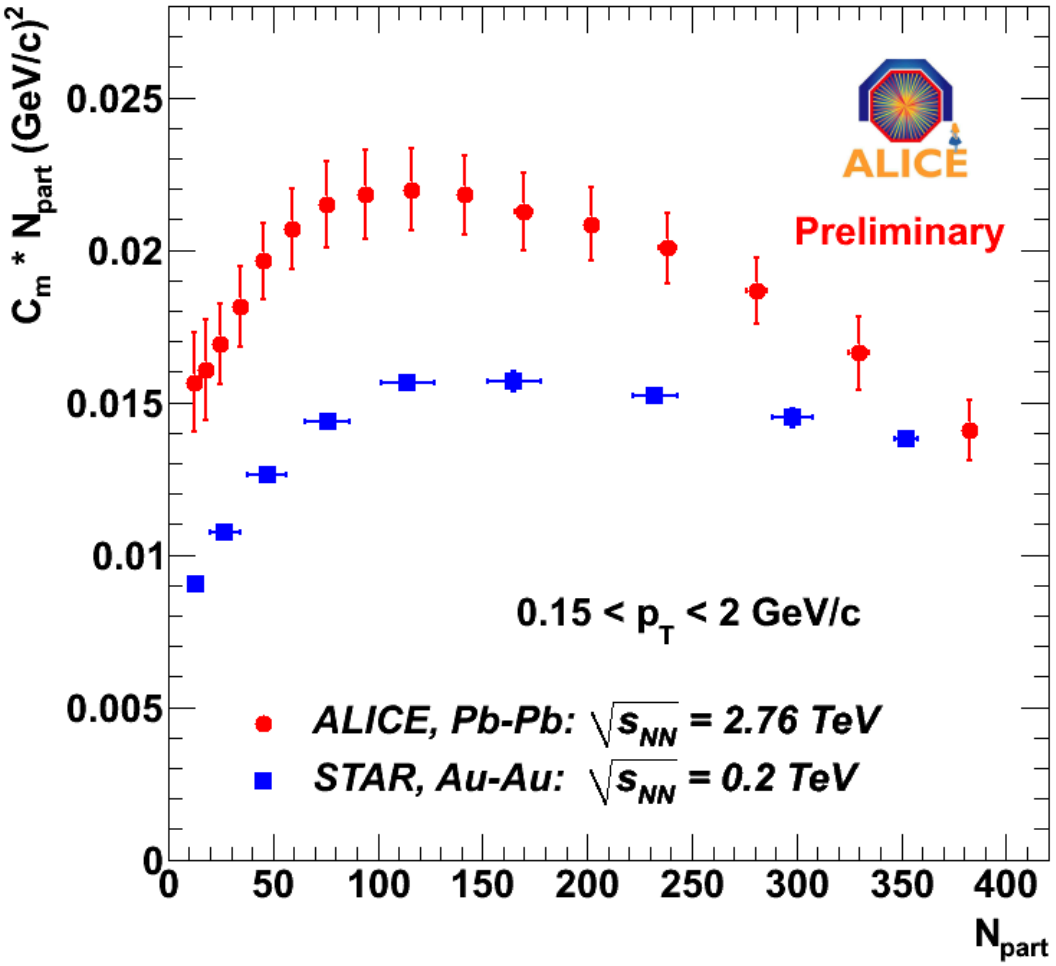
ALICE Pb-Pb results have been compared to Au-Au measurements of the STAR experiment at RHIC:
- The power of multiplicity dependence in peripheral collisions agrees.
- The deviation in central collisions is more pronounced in ALICE data.

BACKUP

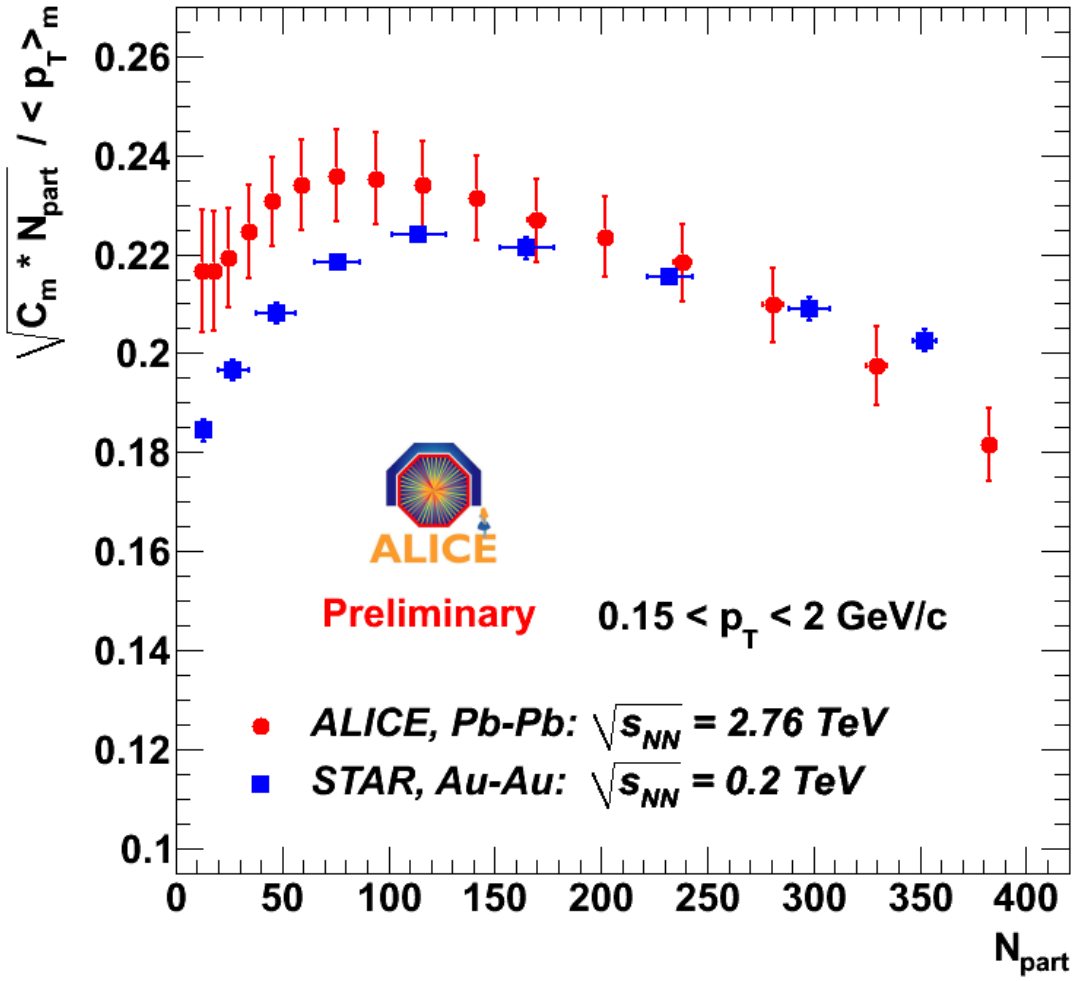
Comparison of data to HIJING and PYTHIA6



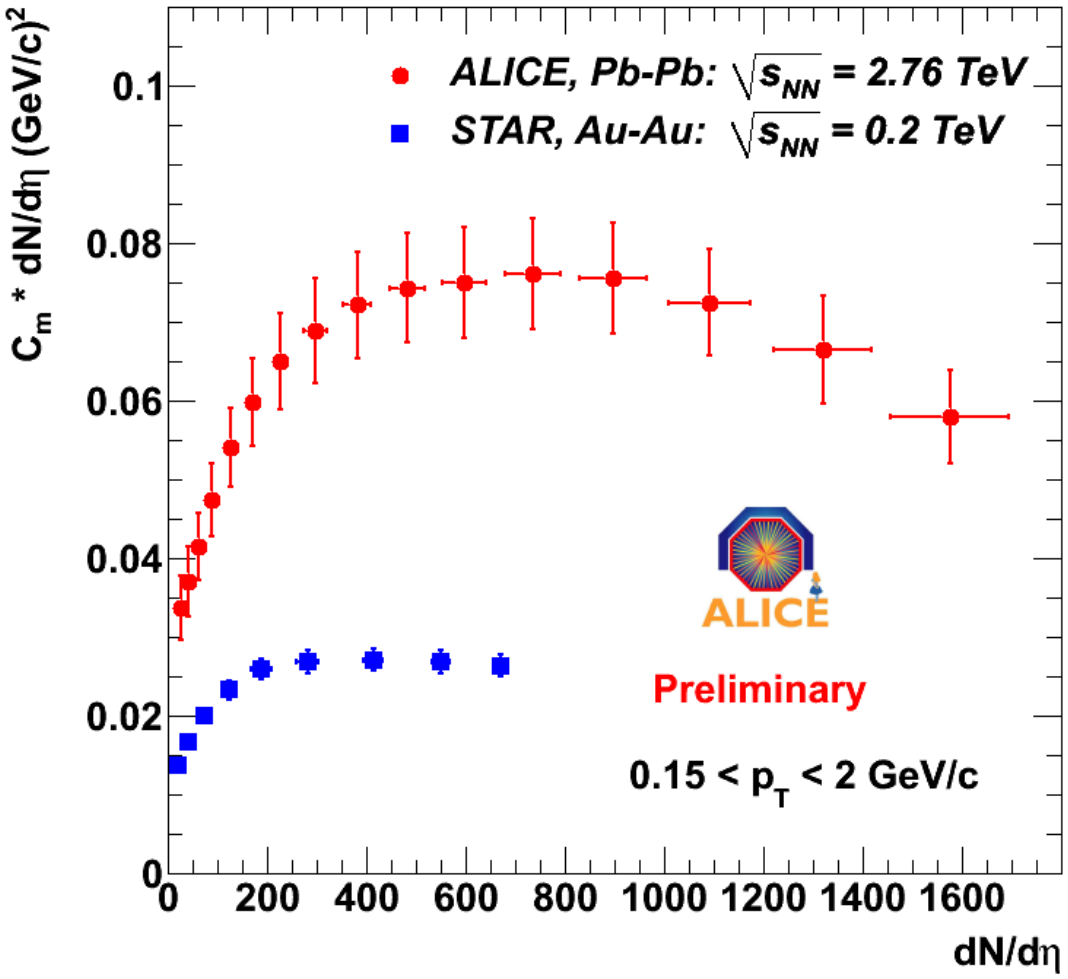
Correlator times N_{part} in terms of N_{part}



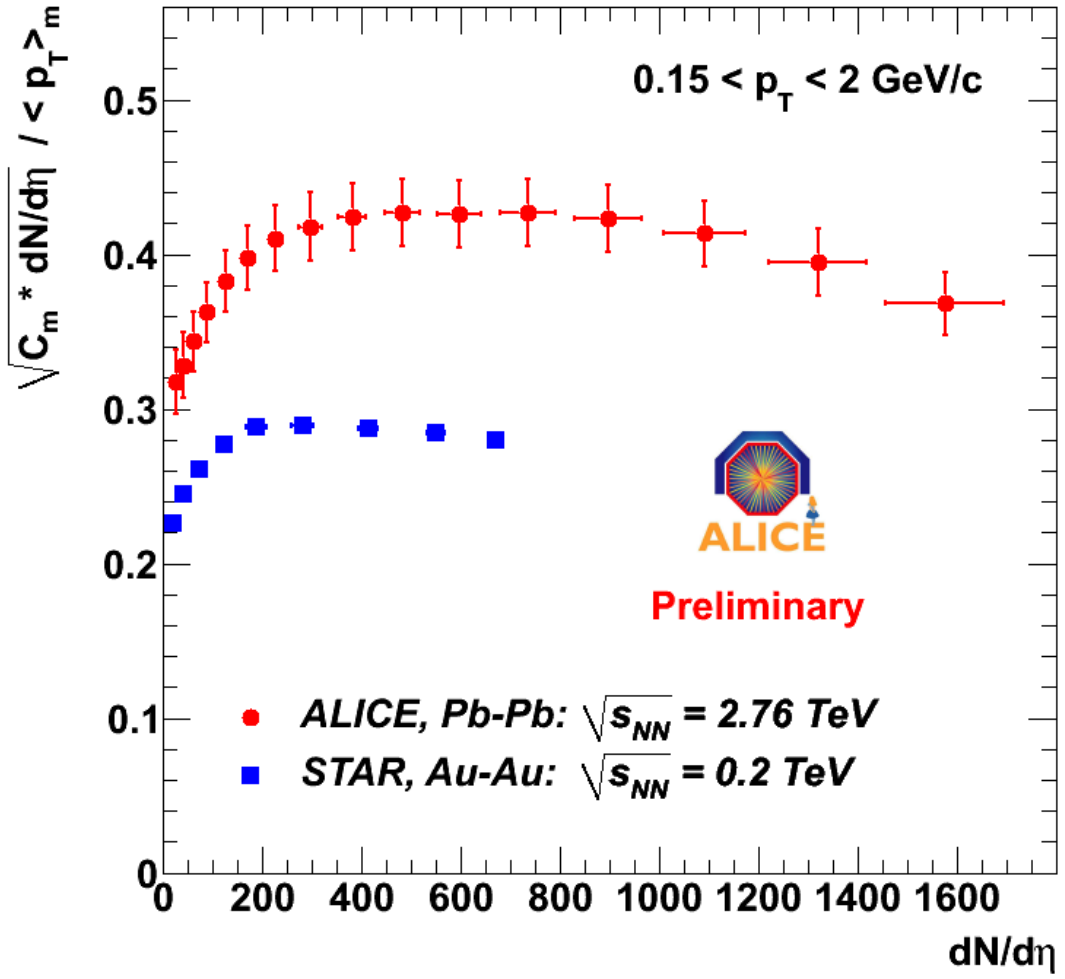
Relative fluc. times N_{part} in terms of N_{part}



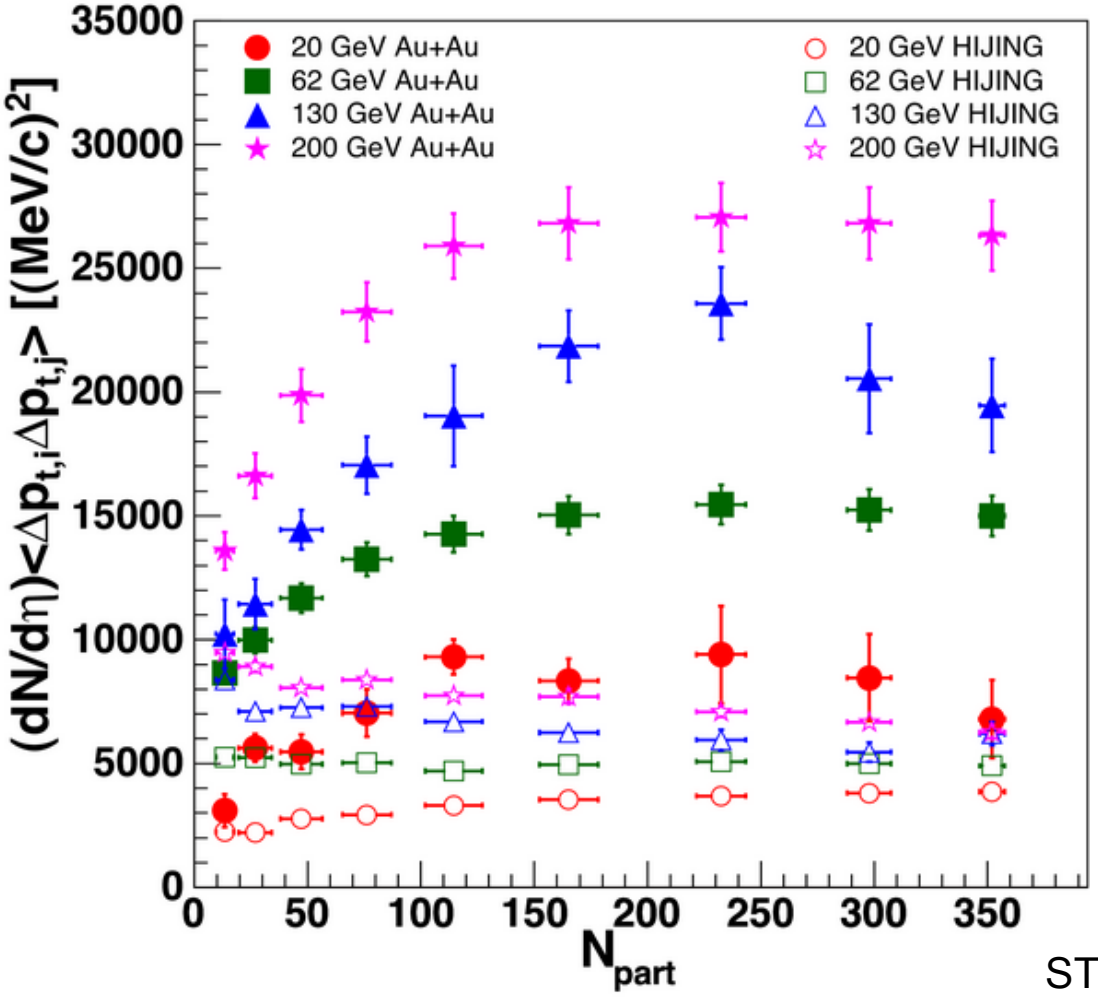
Correlator times dN/dη in terms of dN/dη



Relative fluc. times dN/dη in terms of dN/dη



STAR data and HIJING at different energies



STAR, Phys. Rev. C **72** (2005) 044902