Measurements of net-charge fluctuations across various colliding systems with ALICE

Shaista Khan for the ALICE Collaboration

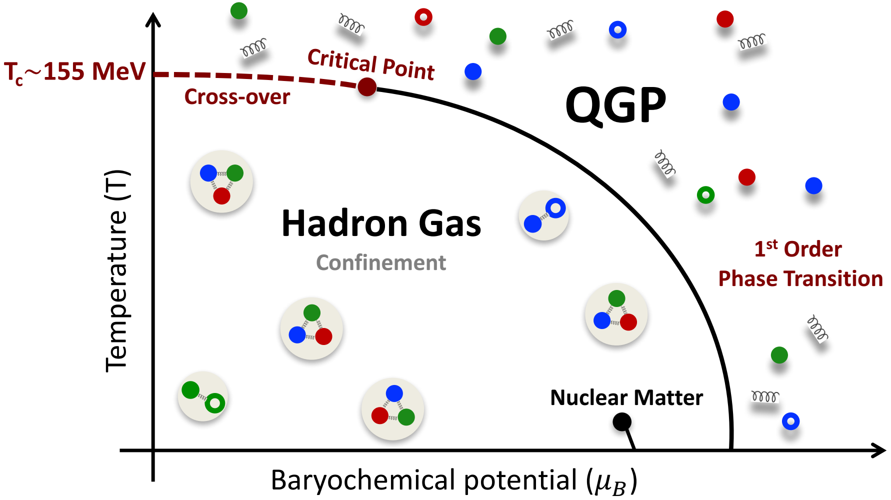
European Physical Society conference on high energy physics 2021
Online conference, July 26-30, 2021

Motivation

Why EbyE fluctuations?

- ✓ To study the properties of the phase transition
- ✓ To locate the critical endpoint

✓ Fluctuations of conserved quantities:
net charge, baryon number and strangeness



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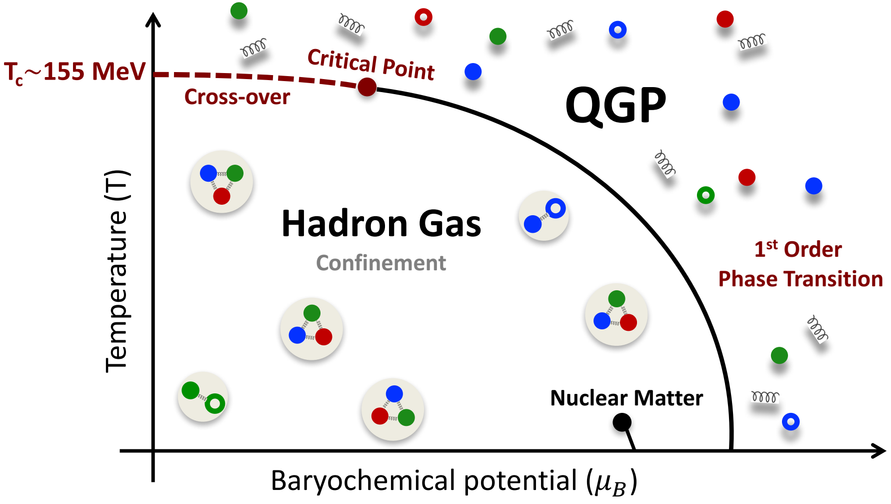

- ✓ Net-charge fluctuations differ between QGP and Hadron Gas phases

- ✓ Suppression in net electric charge fluctuations ⟶ signature of QGP

S. Jeon and V. Koch, Phys. Rev. Lett. 85, 2076 (2000)

Fluctuation observable: ν_{dyn}

Dynamical net-charge fluctuations observable is defined as:

$$\boxed{\nu_{[+-,dyn]} = \frac{\langle N_+(N_+ - 1)\rangle}{\langle N_+\rangle^2} + \frac{\langle N_-(N_- - 1)\rangle}{\langle N_-\rangle^2} - 2\,\frac{\langle N_+ N_-\rangle}{\langle N_+\rangle\langle N_-\rangle}}$$

C. Pruneau et al., Phys. Rev. C 66, 044904 (2002)

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Why ν_{dyn}?

- ✓ **Correlation** between positive and negative charged particles
- ✓ Measures deviation from **Poissonian behaviour**
- ✓ Robust against **detection efficiency losses**
- ○ Intrinsic multiplicity dependence

Connection to other fluctuation observables

- According to the Independent Source Model, **strongly intensive quantity** Σ is defined as:

$$\boldsymbol{\Sigma[N_+, N_-] = \frac{1}{\langle N_+\rangle + \langle N_-\rangle}\left[\langle N_+\rangle\omega_- + \langle N_-\rangle\omega_+ - 2\mathrm{Cov}(N_+, N_-)\right]}$$

M. I. Gorenstein and M. Gazdzicki, Phys. Rev. C 84, 014904 (2011)

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- At LHC energies, $\langle N_+\rangle \approx \langle N_-\rangle$

$$\boldsymbol{\Sigma[N_+, N_-] - 1 = \frac{\nu_{dyn}[+,-]}{\frac{1}{\langle N_+\rangle} + \frac{1}{\langle N_-\rangle}}}$$

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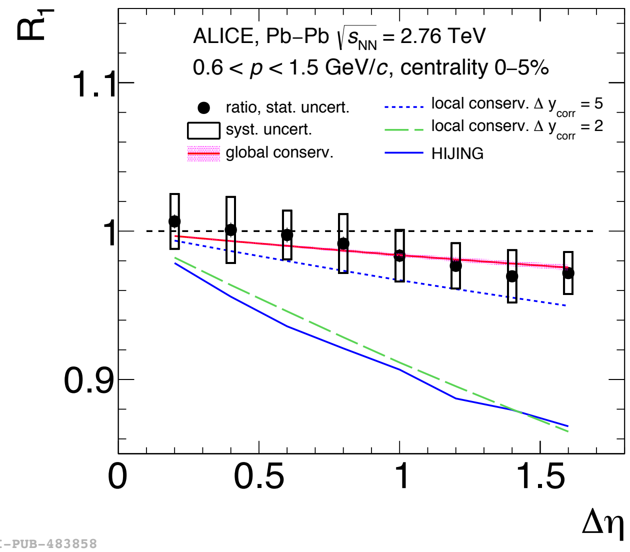
$$\Sigma[N_+, N_-] - 1 = \frac{\nu_{dyn}[+,-]}{\frac{1}{\langle N_+\rangle} + \frac{1}{\langle N_-\rangle}}$$

$$\frac{\kappa_2[N_+ - N_-]}{\langle N_+ + N_-\rangle} = 1 + \nu_{dyn}^{scaled}[+,-] = \Sigma[N_+, N_-]$$

$$\mathbf{R_1} = \kappa_2(N_p - N_{\bar{p}})/\langle N_p + N_{\bar{p}}\rangle$$

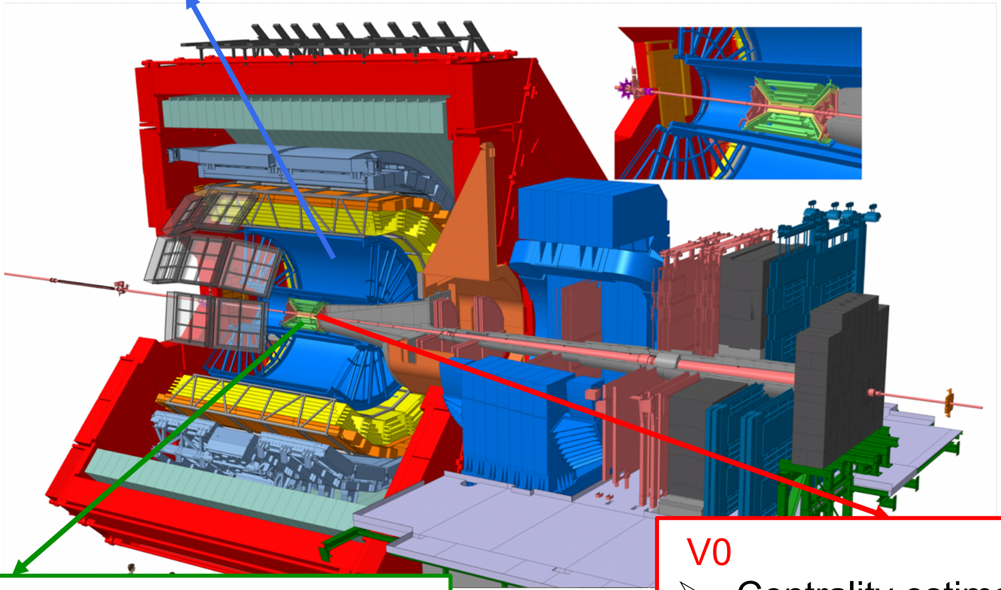


ALICE Collaboration, Phys. Lett. B 807, 135564 (2020)

ALICE detector

Time Projection Chamber (TPC)

- Tracking and PID



Inner Tracking System (ITS)

- Tracking, vertexing and triggering

V0

- Centrality estimation

  V0A $2.8 < \eta < 5.1$

  V0C $-3.7 < \eta < -1.7$

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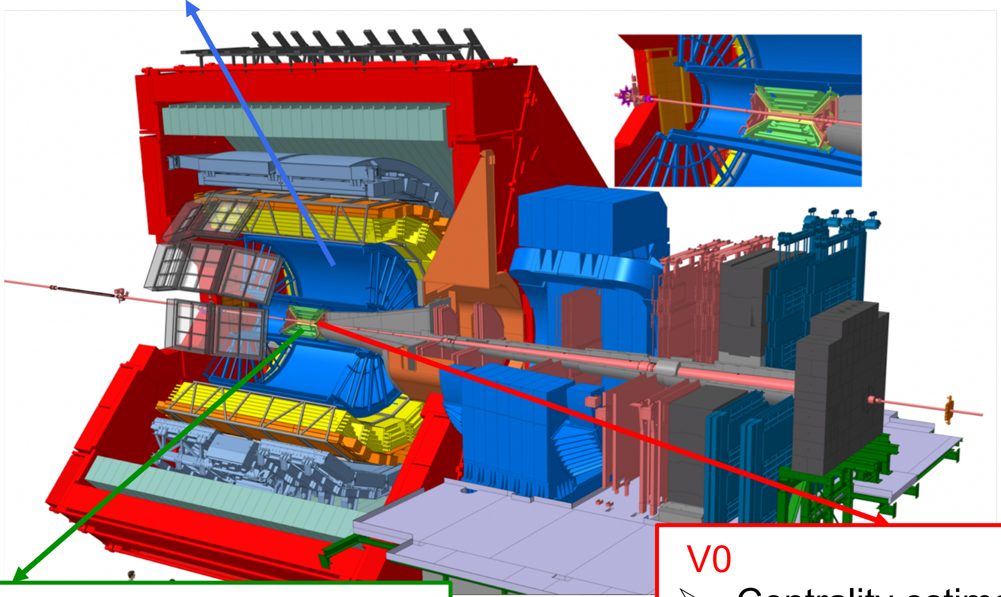

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This analysis:

System size dependence:

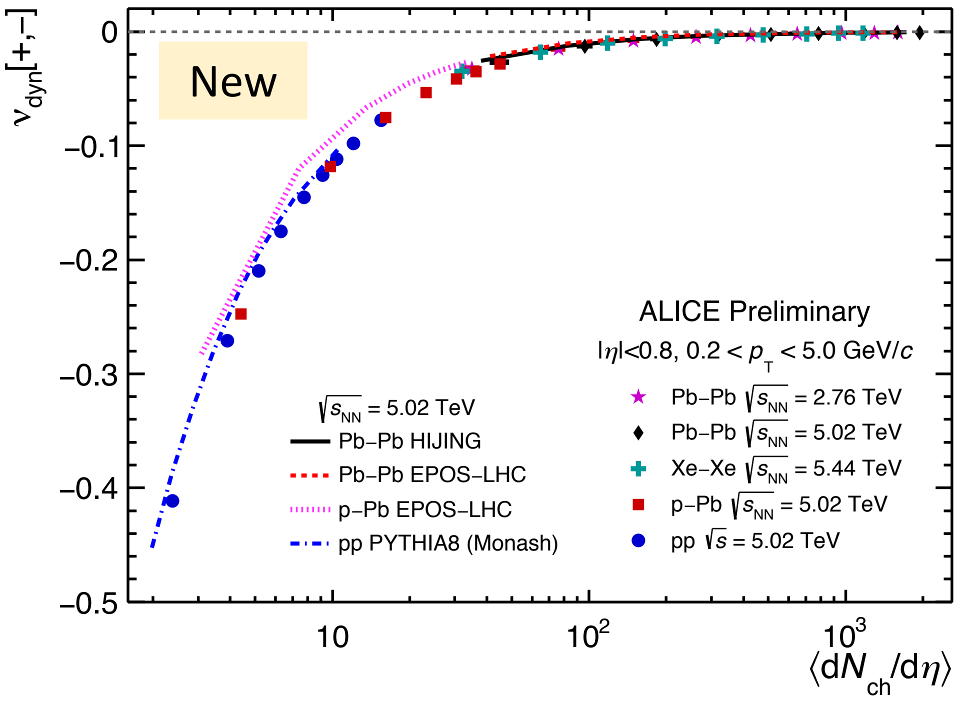
- ➢ **Pb−Pb @ 2.76 and 5.02 TeV**
- ➢ **Xe−Xe @ 5.44 TeV**
- ➢ **p−Pb @ 5.02 TeV**
- ➢ **pp @ 5.02 TeV**

Acceptance dependence

- ➢ **Pseudorapidity range:**
  - $|\eta| < 0.8$
- ➢ **Transverse Momentum range:**
  - $0.2 < p_T < 5.0$ GeV/c

Results

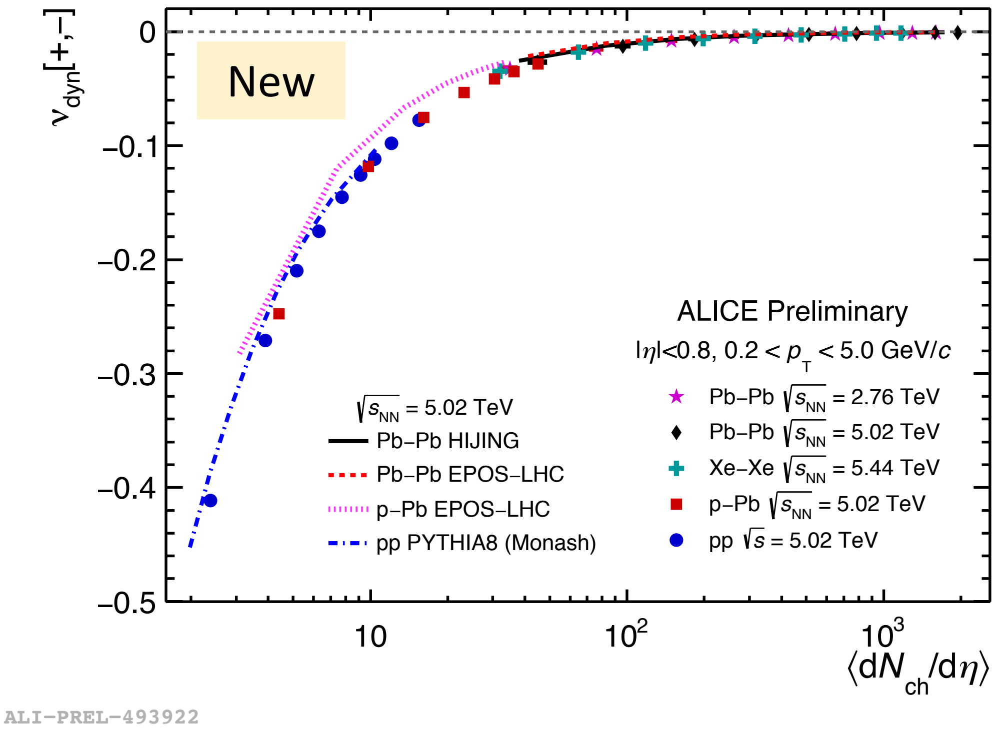
System size dependence



ALI-PREL-493922

- **Negative** $\nu_{dyn}[+,-]$ means correlation between positive and negative charged particles
- **Smooth evolution** with multiplicity across various collision systems
- MC event generators show similar centrality dependence as data

System size dependence



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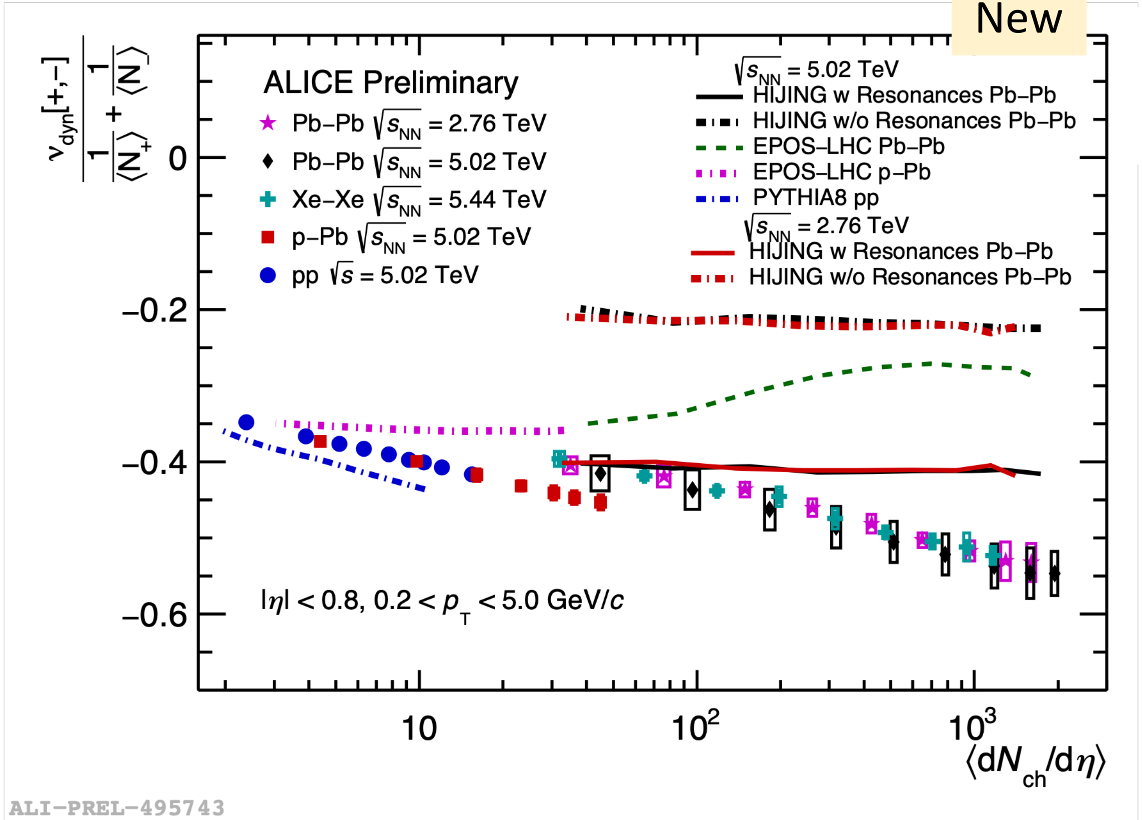
$\nu_{dyn}[+,-]$ shows intrinsic multiplicity dependence → Scaling ?

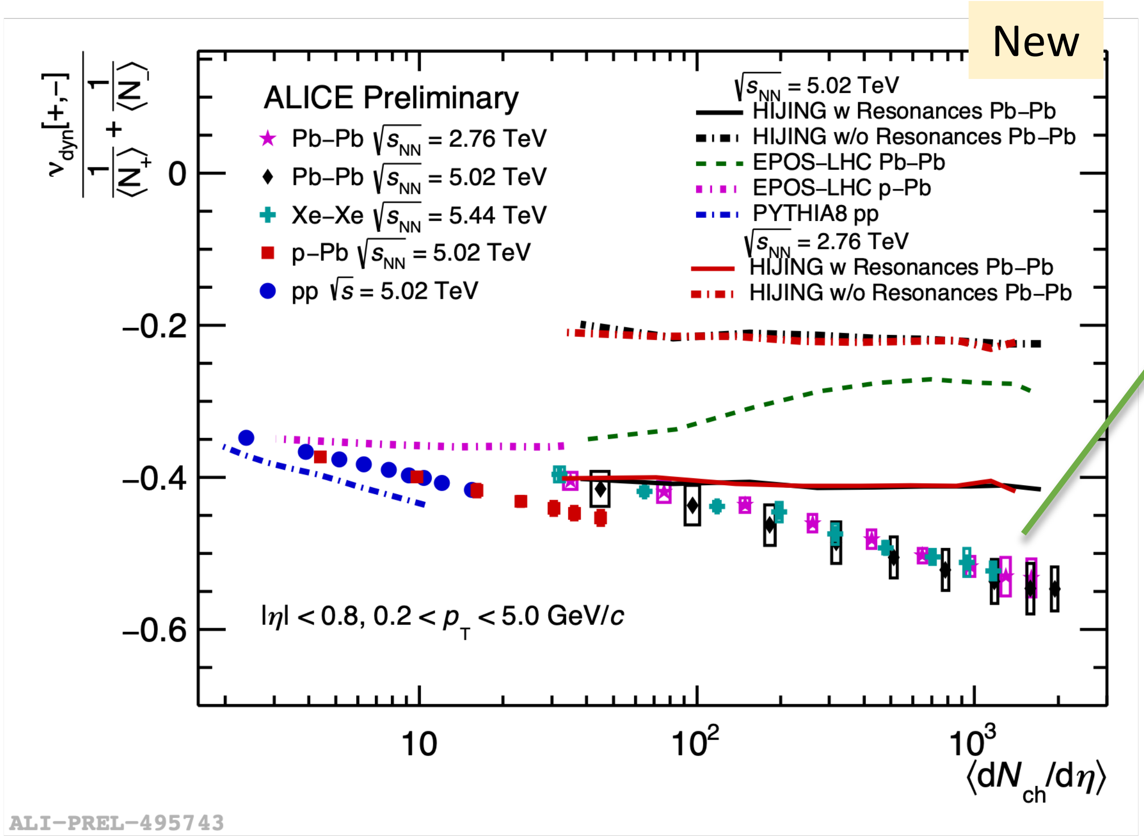
Multiplicity scaling

New



- Scaled $\nu_{dyn}[+,-]$ ⟶ strongly intensive quantity

Multiplicity scaling



- Scaled $\nu_{dyn}[+,-]$ $\longrightarrow$ strongly intensive quantity
- Observed centrality dependence in data. Charge conservation and resonance contribution coupled with radial flow and other effects?

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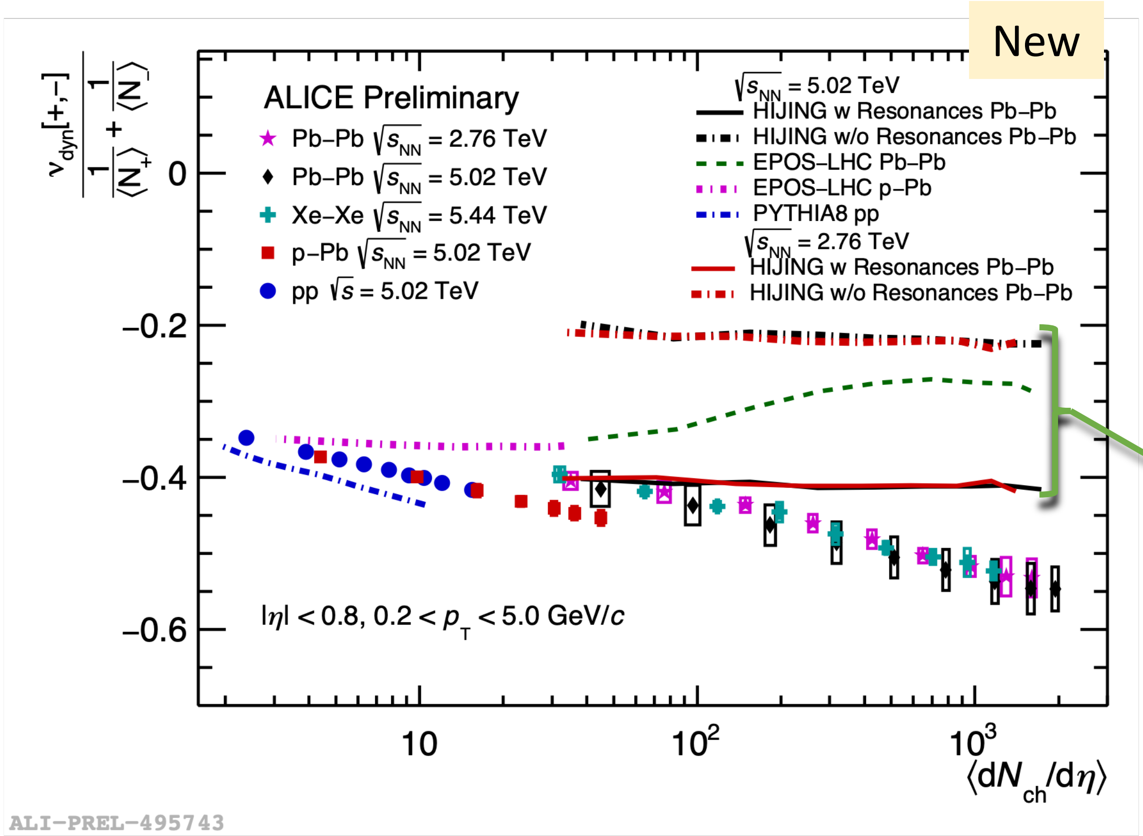

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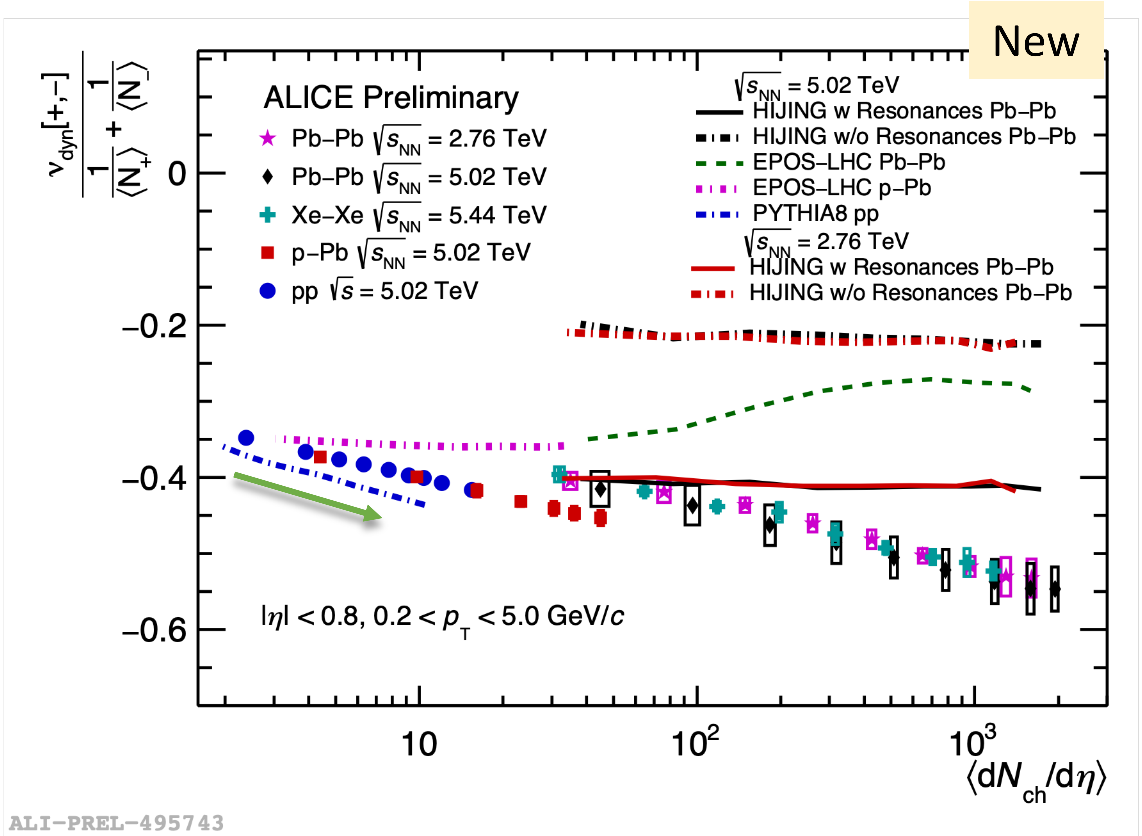

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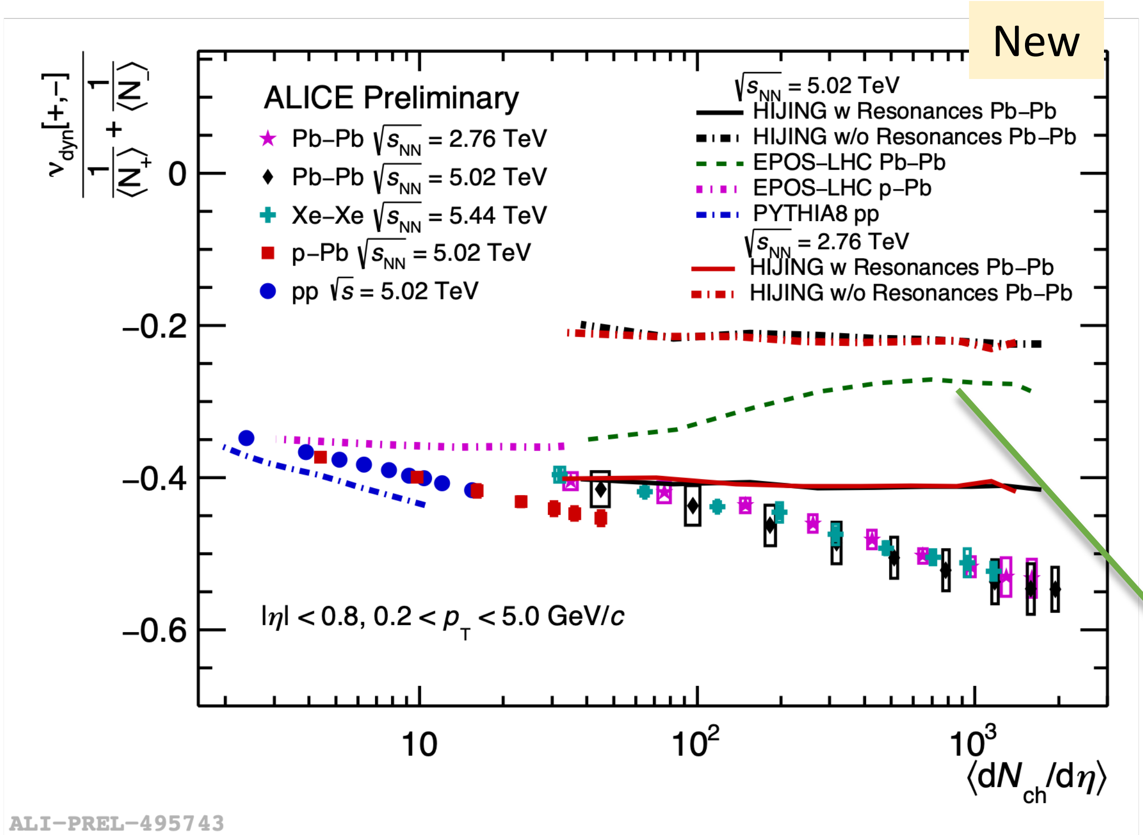
Multiplicity scaling



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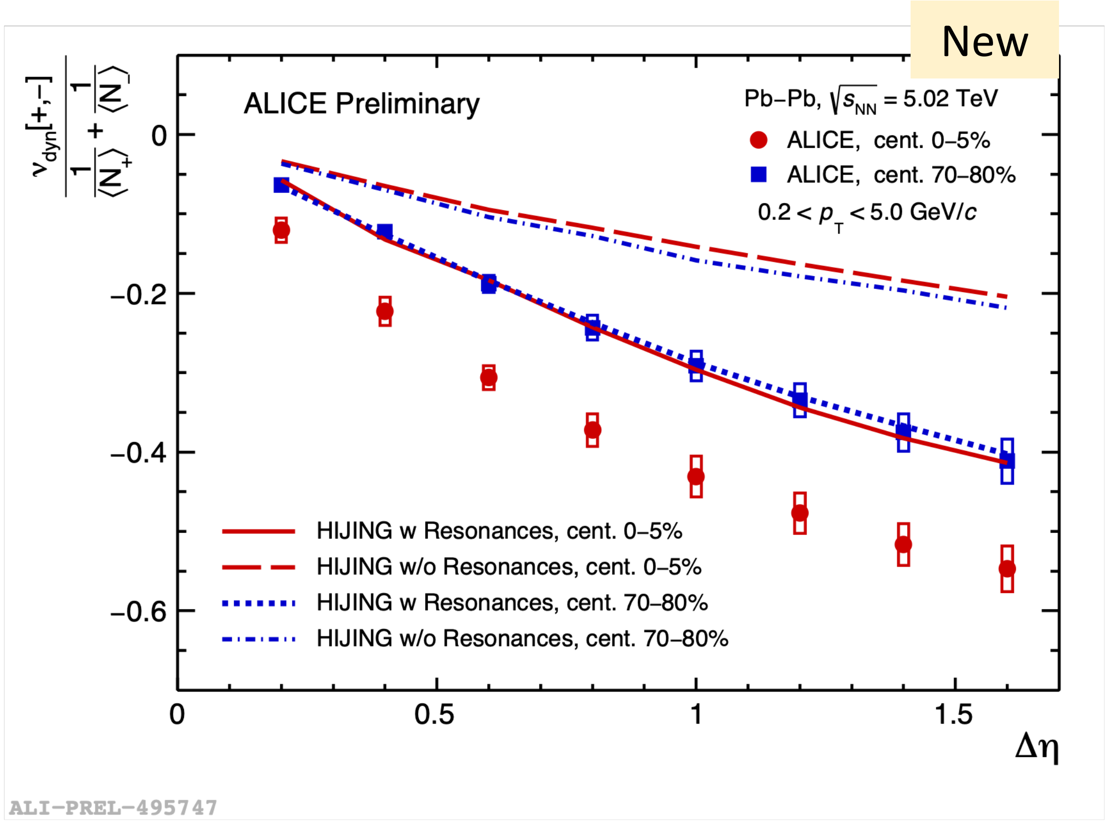
- HIJING shows no centrality dependence. Significant contribution from resonances is suggested by HIJING
- PYTHIA8 (Monash tune) qualitatively describes the trend of pp data
- EPOS-LHC fails to reproduce the centrality dependence

Pseudorapidity dependence



- Both data and HIJING approach to Poissonian limit for small acceptance
- Centrality dependence is observed in data
- HIJING shows significant contribution from resonances

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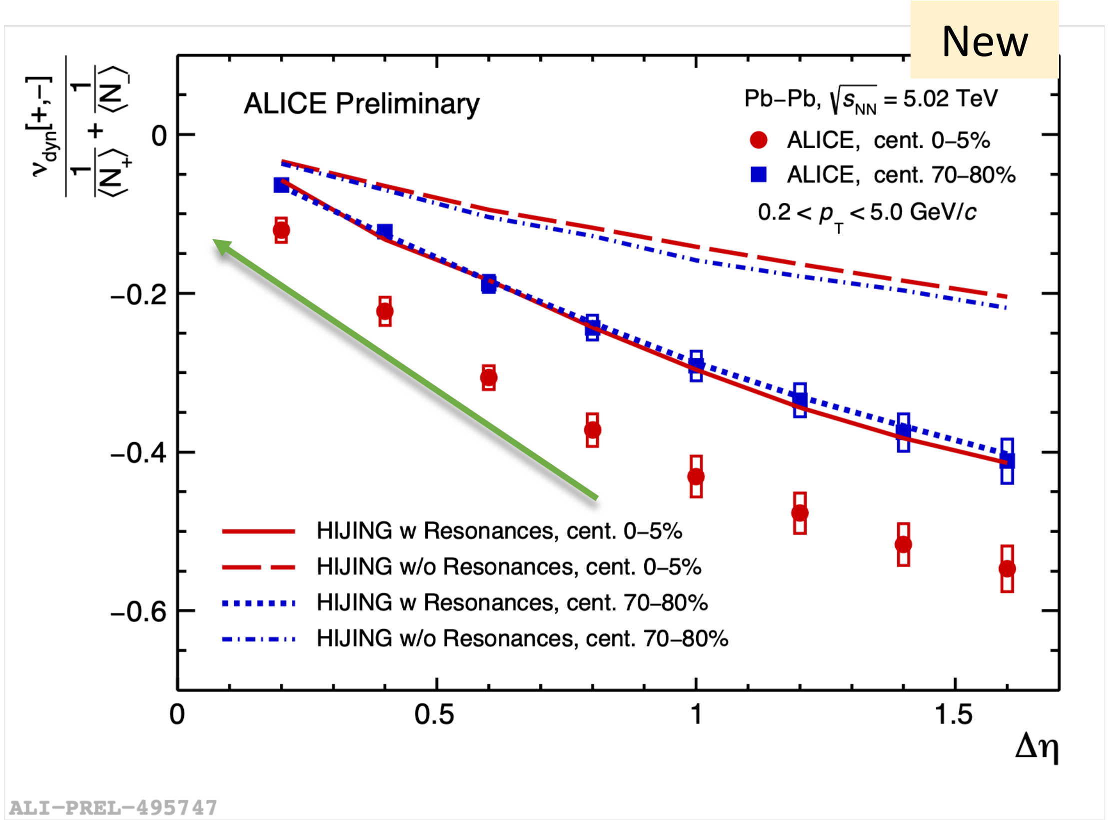

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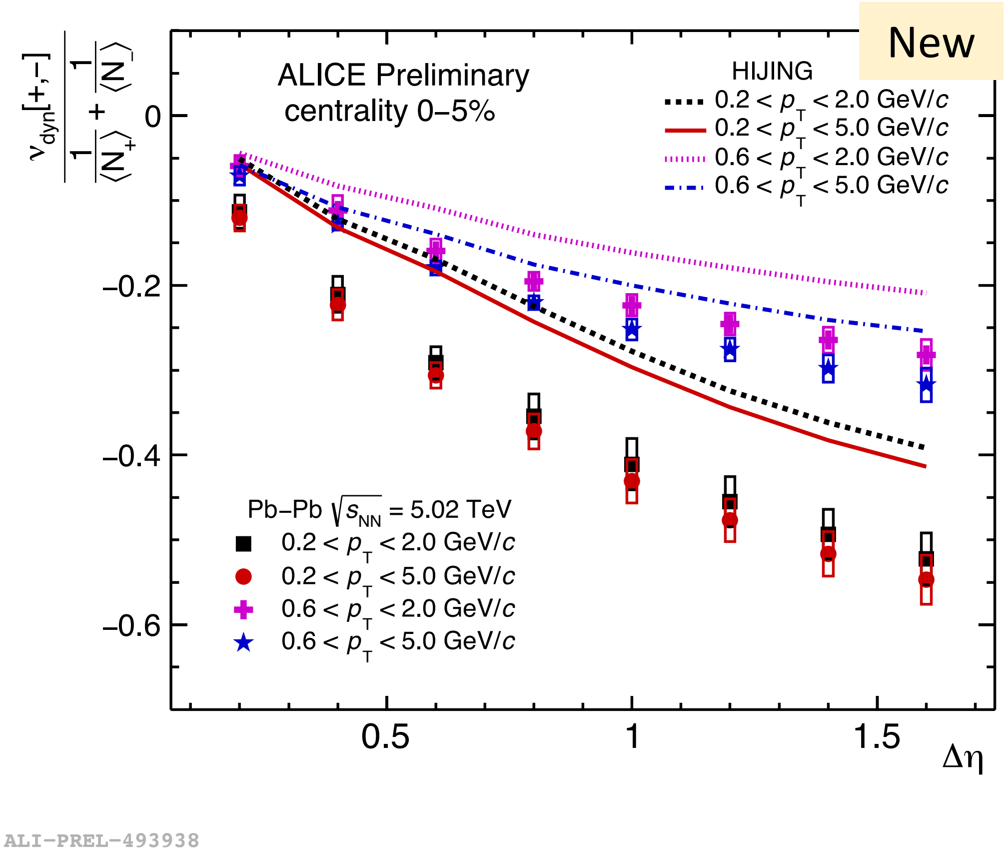
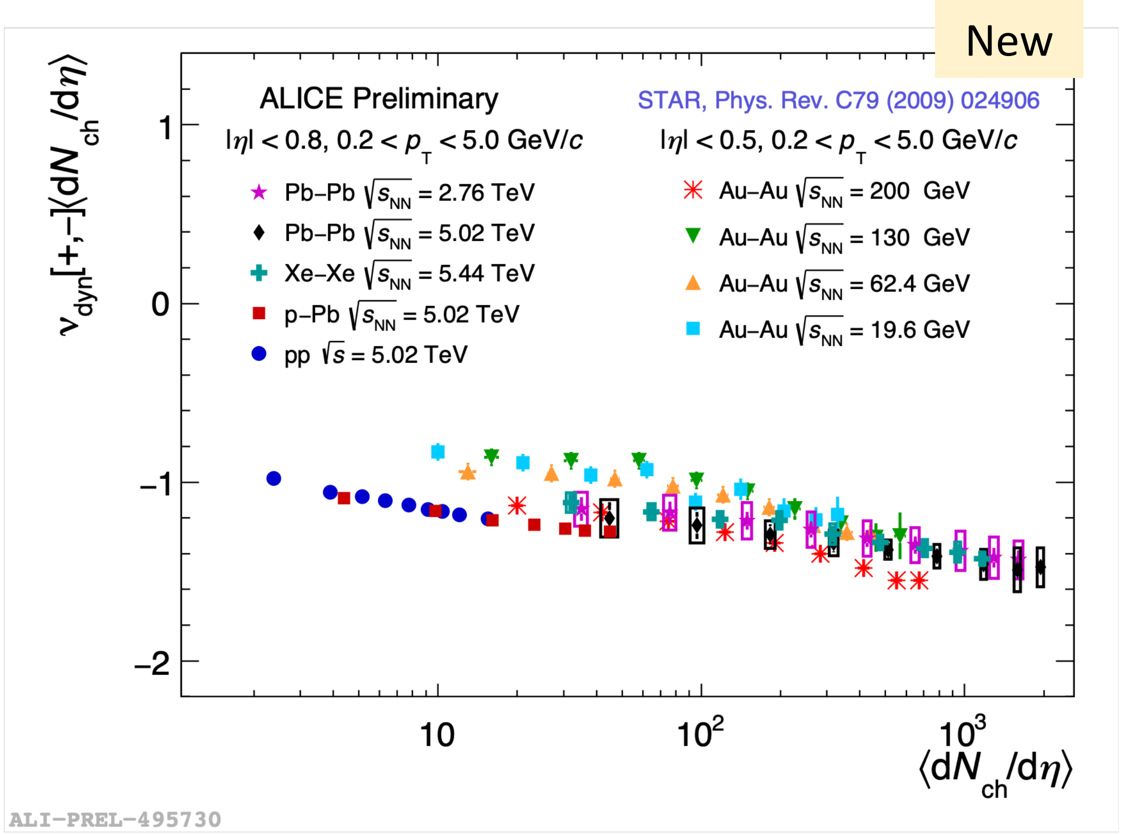
Effect of different p_T ranges



Transverse momentum ranges:
[0.2 < p_T < 5.0], [0.2 < p_T < 2.0] GeV/c
[0.6 < p_T < 5.0], [0.6 < p_T < 2.0] GeV/c

- Investigate the effect of resonances and minijets
- HIJING shows qualitatively similar behaviour as data

Comparison with lower energies



- Qualitatively similar trend as at lower energies at STAR
- Quantitative difference:
  - different acceptance
  - other reasons ?

Summary

✓ Net-charge fluctuations have been studied using the variable $\nu_{dyn}[+,-]$ for pp, p−Pb, Pb−Pb and Xe−Xe collisions for different kinematical acceptances

→ Net-charge fluctuations are strongly dominated by resonance contributions

→ Scaled $\nu_{dyn}[+,-]$ shows increasing correlations with increasing multiplicity for all systems

→ Charge conservation and resonance contribution coupled with radial flow and other effects?

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→ Scaled $\nu_{dyn}[+,-]$ shows increasing correlations with increasing multiplicity for all systems

→ Charge conservation and resonance contribution coupled with radial flow and other effects?

✓ The data is not well described by the available models

→ **HIJING:** no centrality dependence is observed

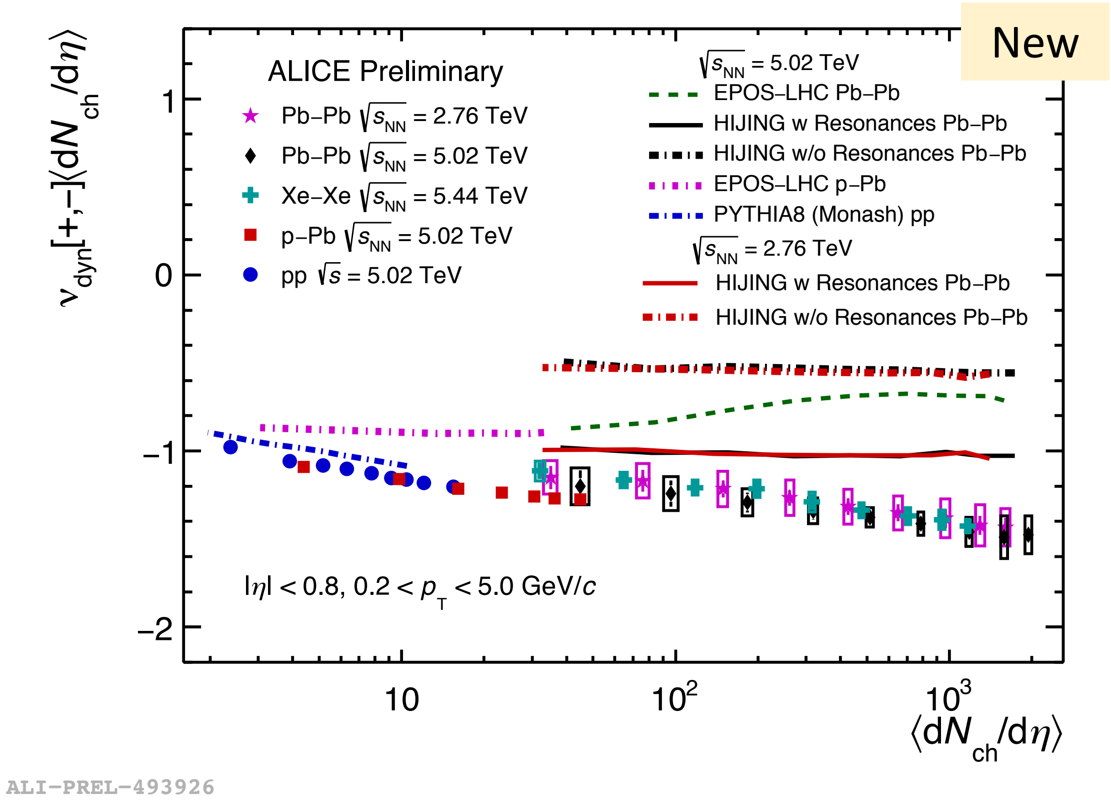
→ **EPOS-LHC:** shows opposite centrality dependence

→ **PYTHIA8:** qualitatively describes the trend of pp data

Thanks for your attention

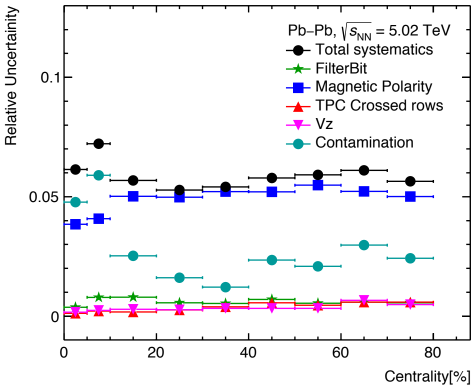
BackUp Slides

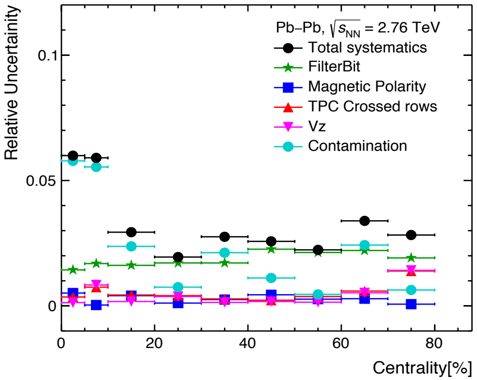
$dN_{ch}/d\eta$ scaling

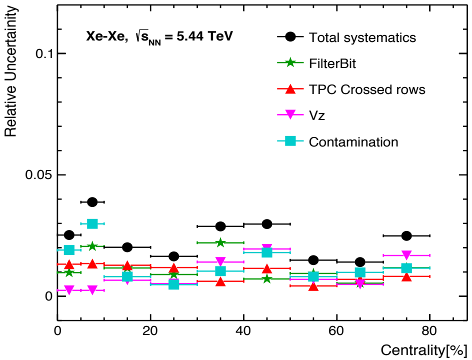


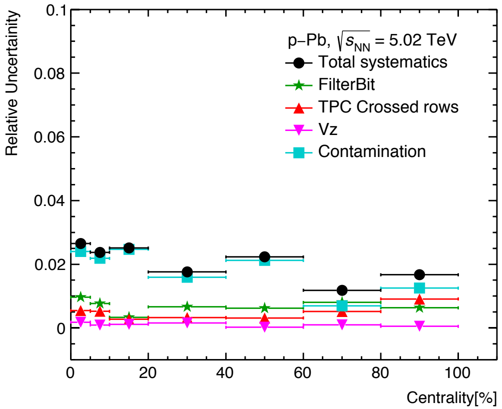
- Scaled $\nu_{dyn}[+,-]$ decreases when moving from central to peripheral collisions
- MC HIJING and EPOS-LHC fail to describe the centrality dependence
- PYTHIA8 (Monash tune) agrees fairly well with the trend of pp data
- Significant contribution from resonances is suggested by HIJING

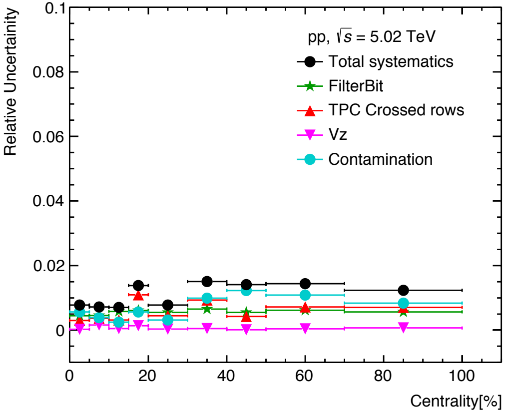
Systematic uncertainties for $\nu_{dyn}[+,-]/(1/\langle N_+\rangle + 1/\langle N_-\rangle)$







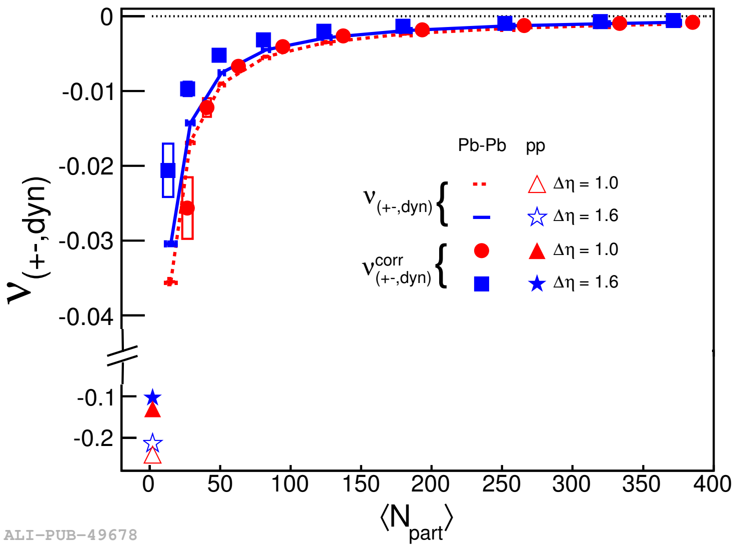




Charge fluctuations: previous studies

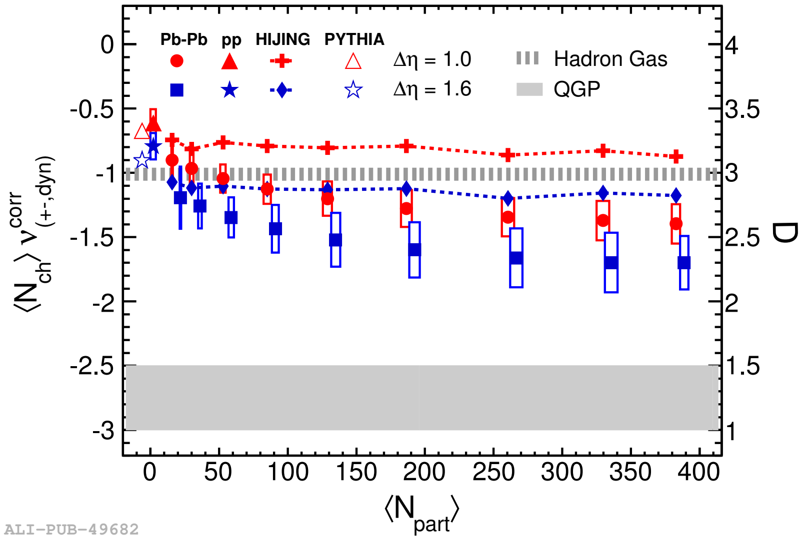
ALICE Collaboration (B. Abelev et al.), Phys. Rev. Lett. 110, 152301 (2013)

Acceptance: |η| < 0.5, 0.8 ,0.2 < p_T < 5.0 GeV/c



$$\langle N_{ch}\rangle \upsilon_{(\pm,dyn)} \approx D - 4$$

$$\nu^{corr}_{(+-,dyn)} = \nu_{(+-,dyn)} + \frac{4}{\langle N_{total}\rangle}$$



For QGP, D is ≃ 1 and ≃ 3-4 for the hadron gas.

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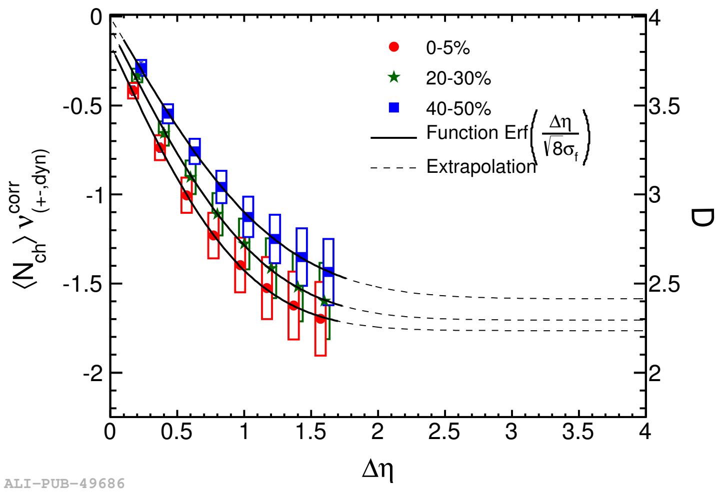

STAR Collaboration (B. I. Abelev et al.),Phys. Rev. C79, 024906 (2009)

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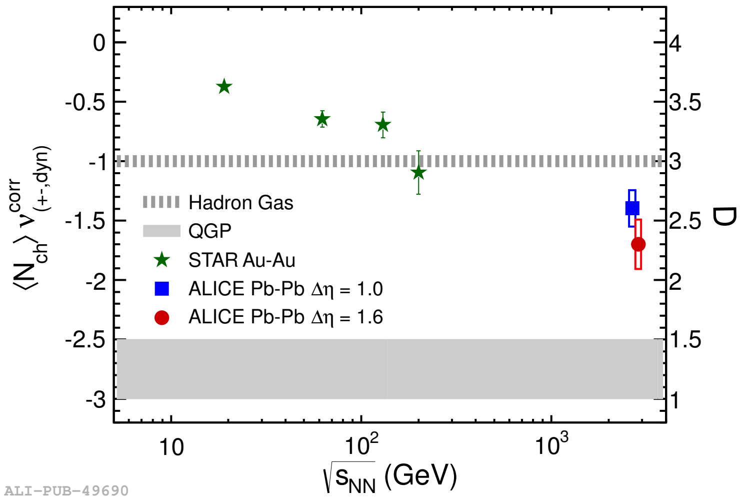

- A reduction in the magnitude of the net-charge fluctuations has been observed from RHIC to LHC.
- The fluctuations at LHC energy are smaller than the expectations for a Hadron Gas.