ALICE

Presentation On

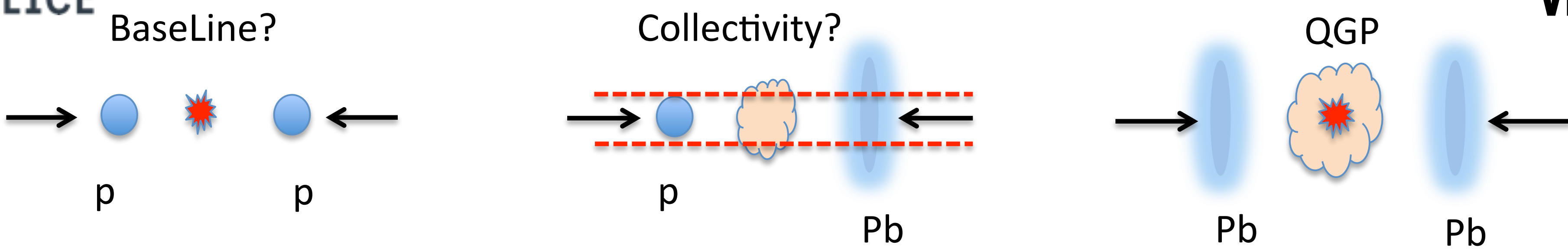
VECC

Event-by-event fluctuation and correlation measurements at the LHC energies in ALICE

XLV International Symposium on Multiparticle Dynamics (ISMD)
Wildbad Kreuth (Germany), 4-9 October 2015

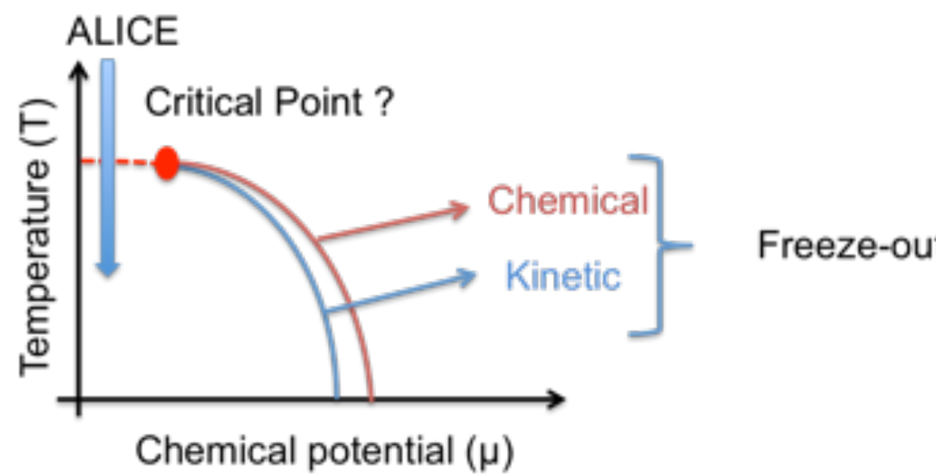
Sumit Basu

(on behalf of the ALICE collaboration)



At high energy nuclear collisions, several observables could be studied on an Event-by-Event (E-by-E) basis.

E-by-E fluctuations → contain information on the dynamics and correlations in pp, p-A and A-A collisions.



ALICE experiment at LHC → small μ_B and high Temperature (T).

So → Possibility of chiral phase transition is in the crossover region.

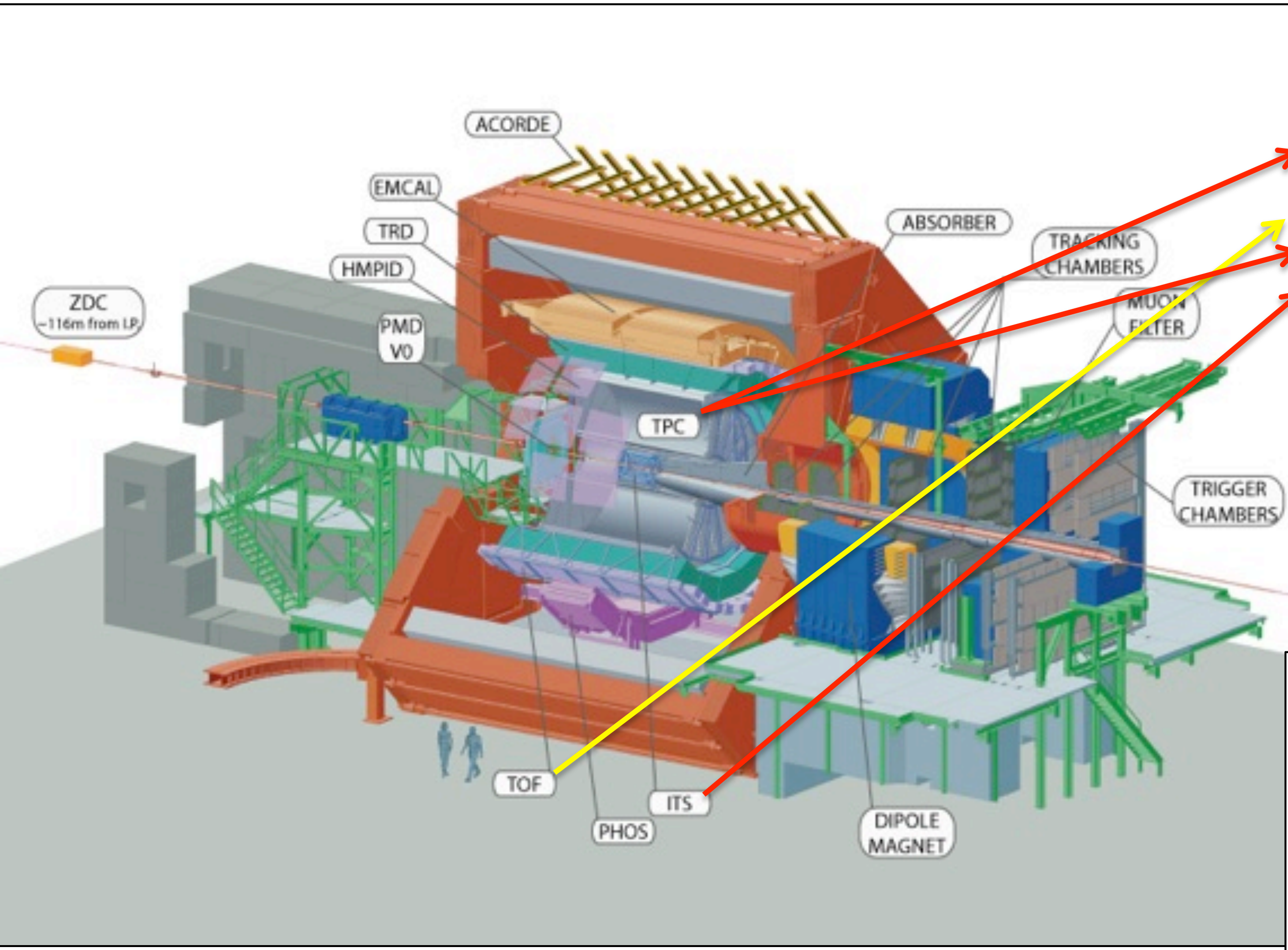
→ Study of E-by-E fluctuations of conserved quantities

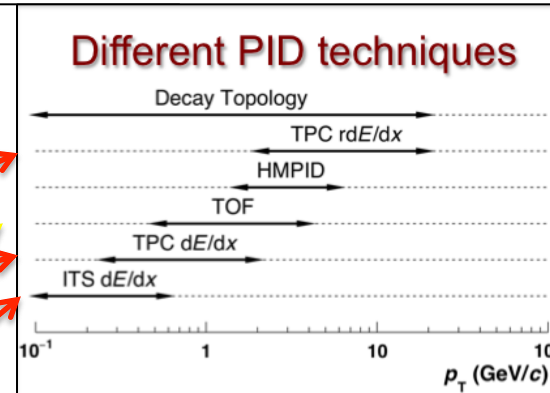
→ nature of matter produced at the collision and evolution of fluctuation.

Outline

- ALICE: Experimental Setup
- ALICE Results :
  - ☑ Mean p_T Fluctuations
  - ☑ Net Charge Fluctuations
  - ☑ Balance Function
  - ☑ Multiplicity Fluctuations
  - ☐ Particle Ratio Fluctuations
  - ☐ Higher Moments Studies
  - ☐ Temperature Fluctuations
- Summary and Outlook

ALICE Experiment





Antonios Otiz (ALICE Collaboration)
QM 2015

❖ **Main Detectors used for E-by-E observables :**

- TPC + ITS & TOF
  (For Tracking and PID)
- ITS (For Vertex)
- V0 (For Centrality)

❖ **Data Taken :**

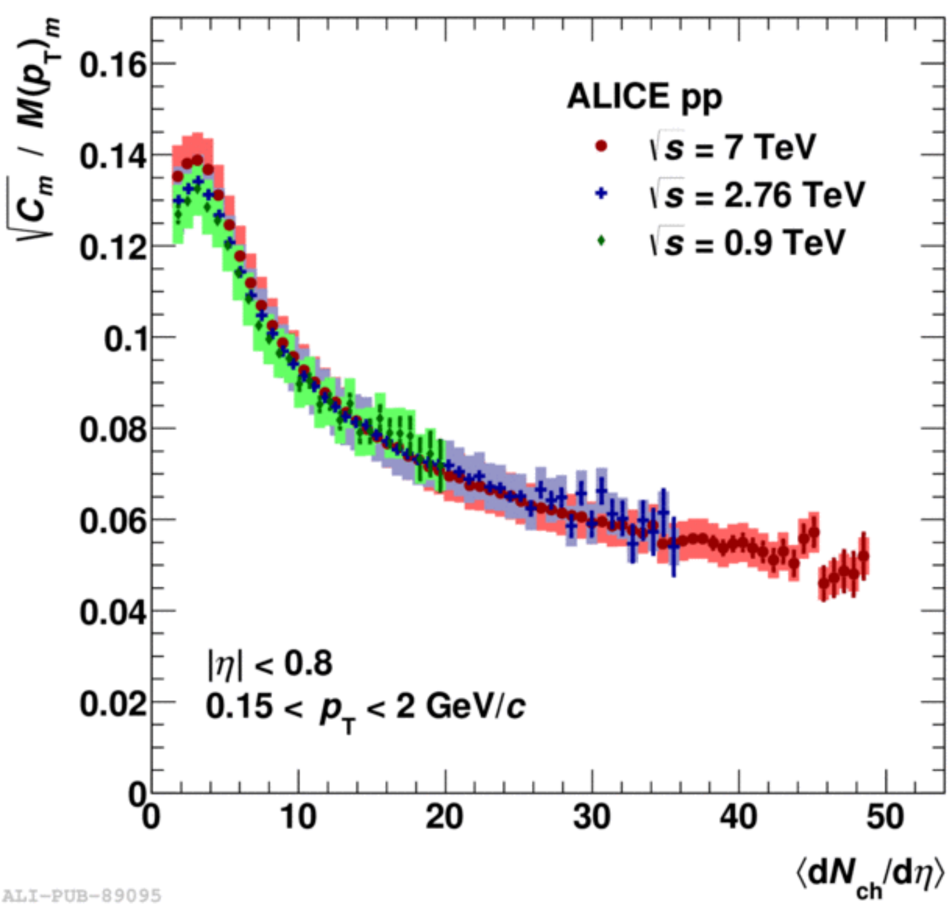
- Pb-Pb @ $\sqrt{S_{NN}}$ = 2.76TeV |
- p-Pb @ $\sqrt{S_{NN}}$ = 5.02TeV |
- pp @ $\sqrt{S}$ = 0.9, 2.76, 7 TeV.

As the total energy is conserved and almost all the particles are produced in transverse directions, study of E-By-E mean p_T fluctuations of charged particles → energy fluctuation

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

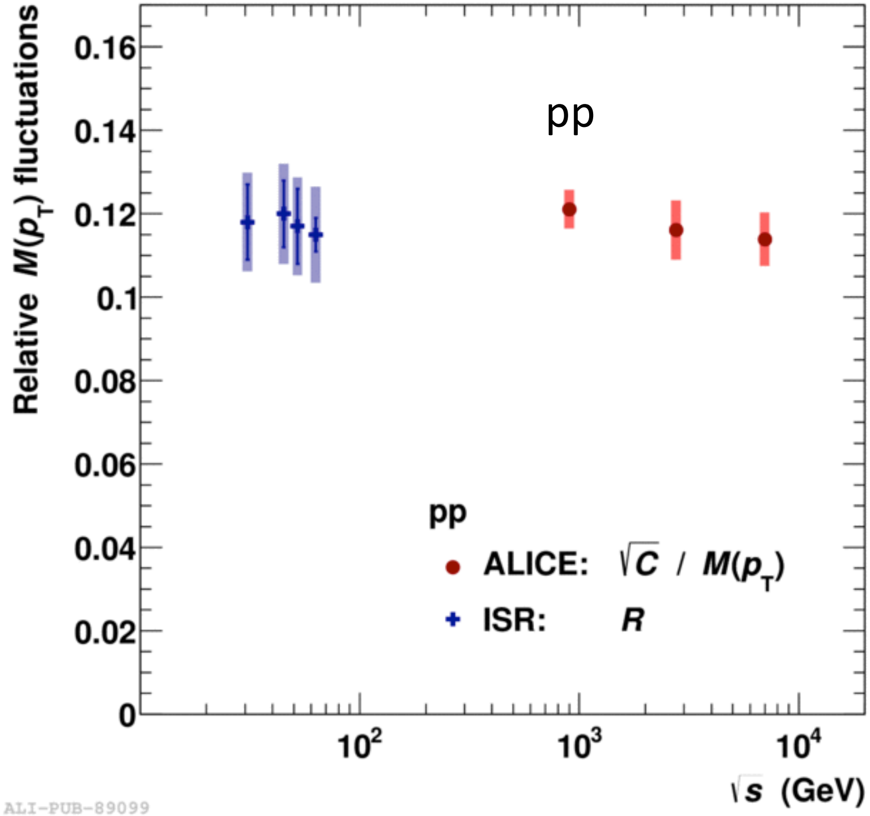
$$\sigma^2_{dyn} = C_m = \langle \Delta p_{T,i}, \Delta p_{T,j} \rangle = \frac{1}{\sum_{k=1}^{n_{ev}} N_k^{pairs}} \cdot \sum_{k=1}^{n_{ev}} \sum_{i=1}^{N_k} \sum_{j=i+1}^{N_k} (p_{T,i} - \langle p_T \rangle_m) \cdot (p_{T,j} - \langle p_T \rangle_m)$$

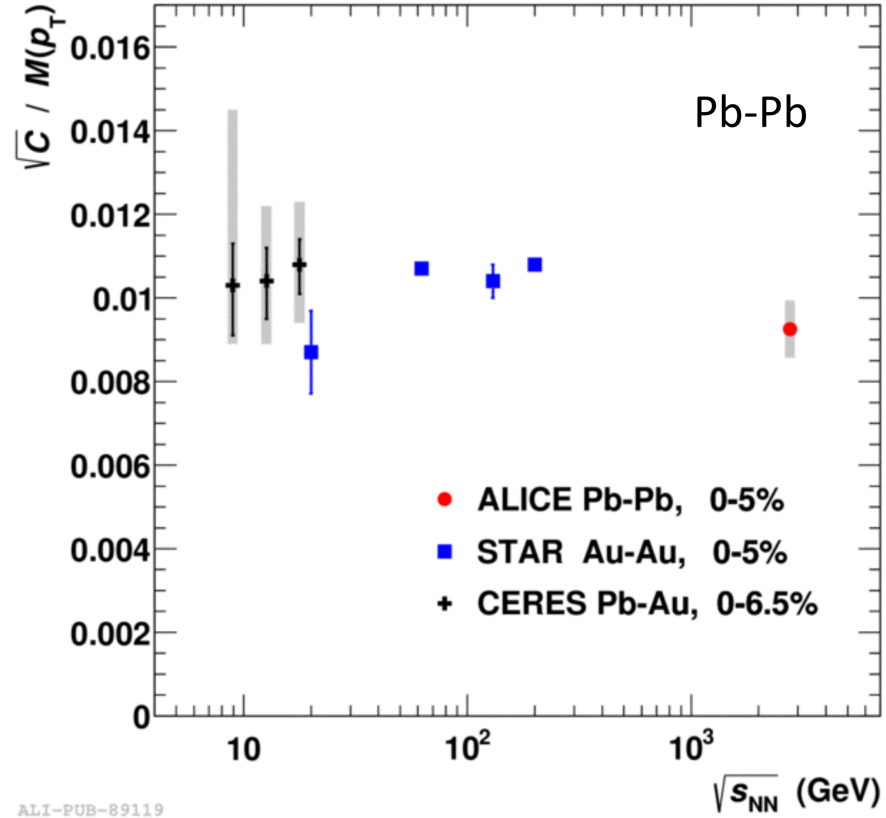
$C_m = 0$ for statistical fluctuations.



- Significant non-statistical fluctuations at low multiplicity
- Dynamical fluctuation "dilution" with multiplicity
- No significant collision energy dependence

Eur. Phys. J. C 74 (2014) 3077

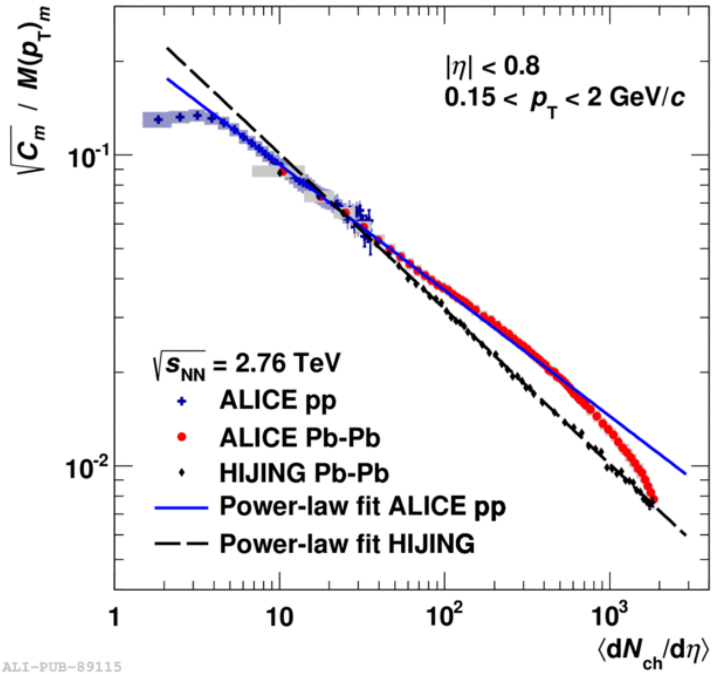


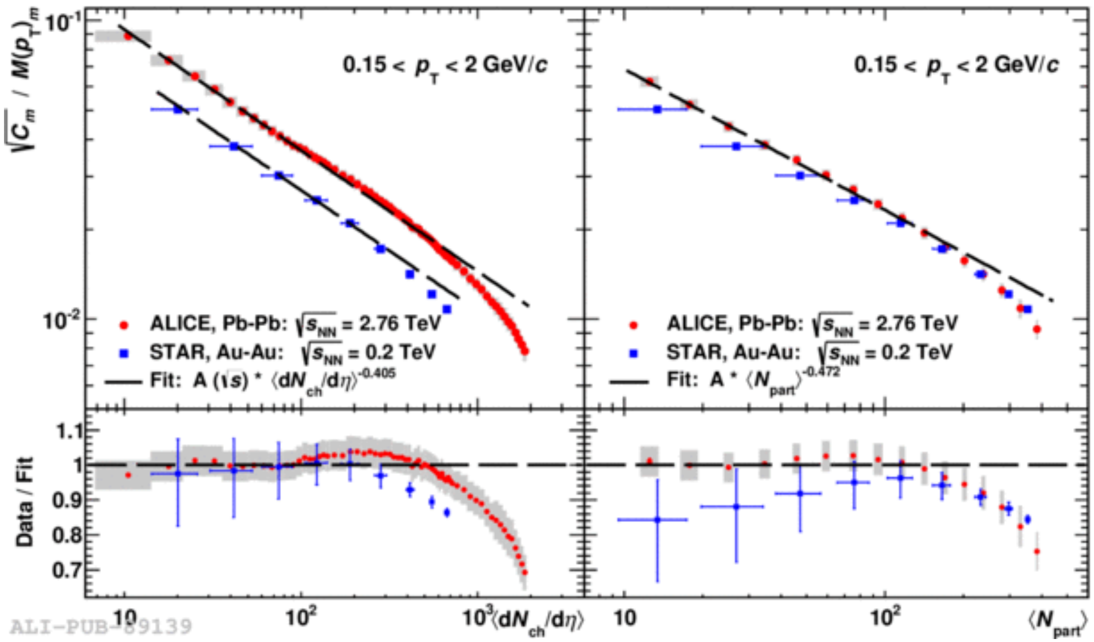


Both in pp and heavy-ion data → No significant dependence on the collision energy is observed.

Eur. Phys. J. C 74 (2014) 3077

Mean p_T Fluctuation





[ALICE collaboration, Eur. Phys. J. C 74:3077 (2014)]

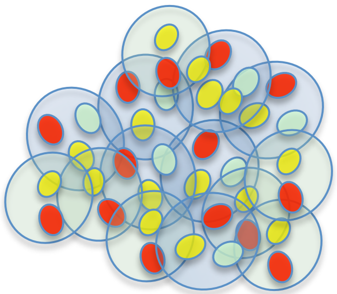
→ power law fit could describe both the pp and Pb-Pb data with same parameters.

→Peripheral AA system in agreement with pp baseline.

→ Relative fluctuations for STAR and ALICE energies are described well by the pp baseline fit. Deviations are seen at higher multiplicities.

→ As a function of <N_{part}>, data from both experiments start to deviate from the power-law fit at the same centrality.

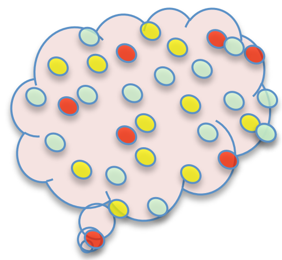
Net-Charge with full phase space → ZERO as charge is conserved.



Hadron Gas

charge q = ±1

=> $q^2 = 1$



QGP

charge q = ± 1/3 or ±2/3

=> q^2 =1/9 or 4/9

How it behaves with limited rapidity window?

What will be the beam energy dependence?

What will be the centrality dependence?

Definition → Dynamical charge fluctuations,

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

$$\Updownarrow$$

$$D = 4\frac{\left\langle (\delta Q)^2 \right\rangle}{N_{ch}} \approx \langle N_{ch}\rangle\langle \nu_{dyn}\rangle - 4 \approx \begin{cases} \boxed{4,(HG)} \\ \boxed{3,(HRG)} \\ \boxed{1-1.5,(QGP)} \end{cases}$$

For, Global Charge Conservation (GCC).

$$\nu_{(+-,dyn)} = \frac{-2}{\langle N_+\rangle} = \frac{-4}{\langle N_{total}\rangle}$$

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

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Net-charge Fluctuations

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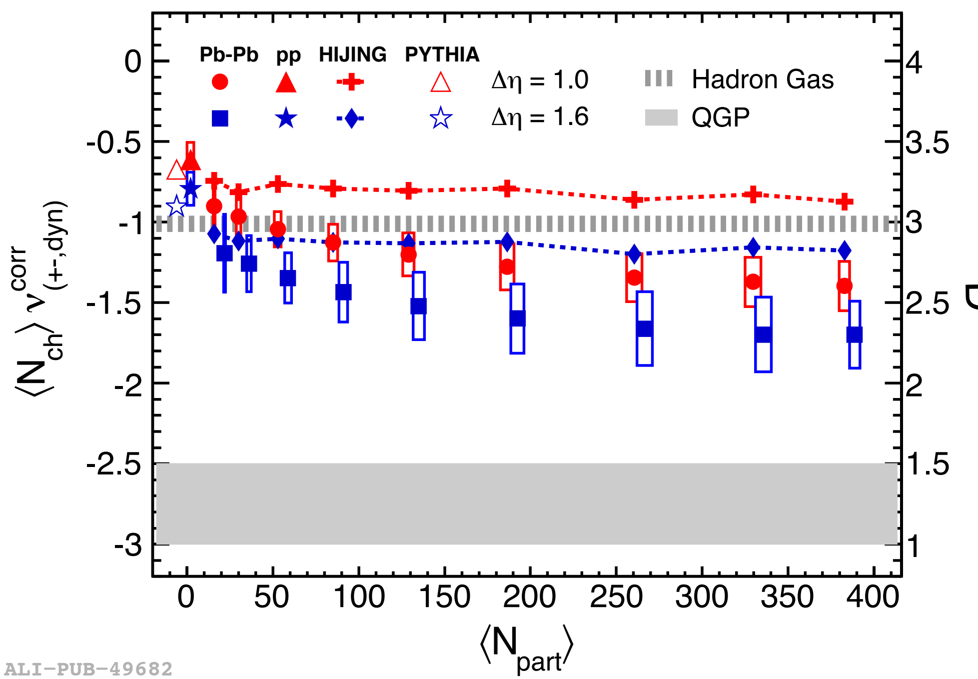
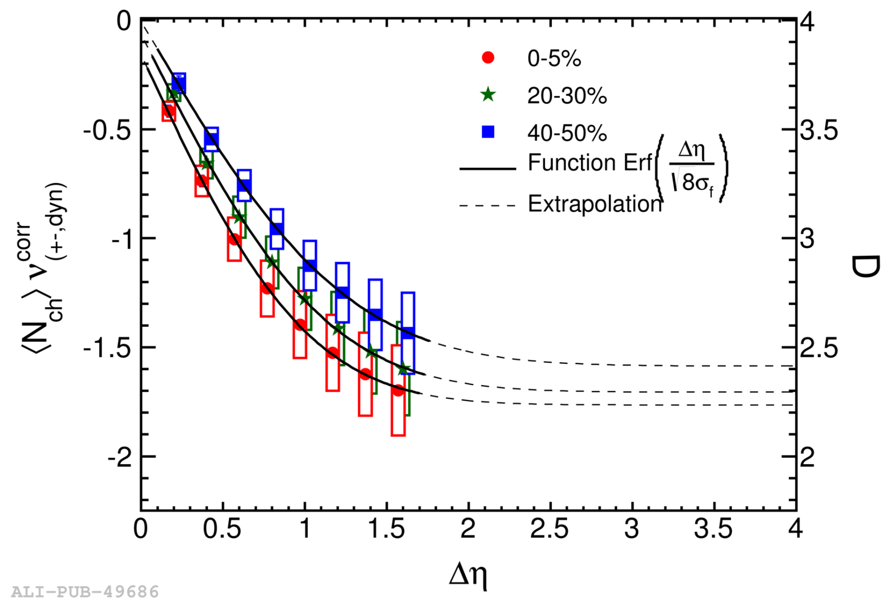
Centrality Dependence



Unlike sign pairs →more correlated
HIJING: little or no centrality dependence

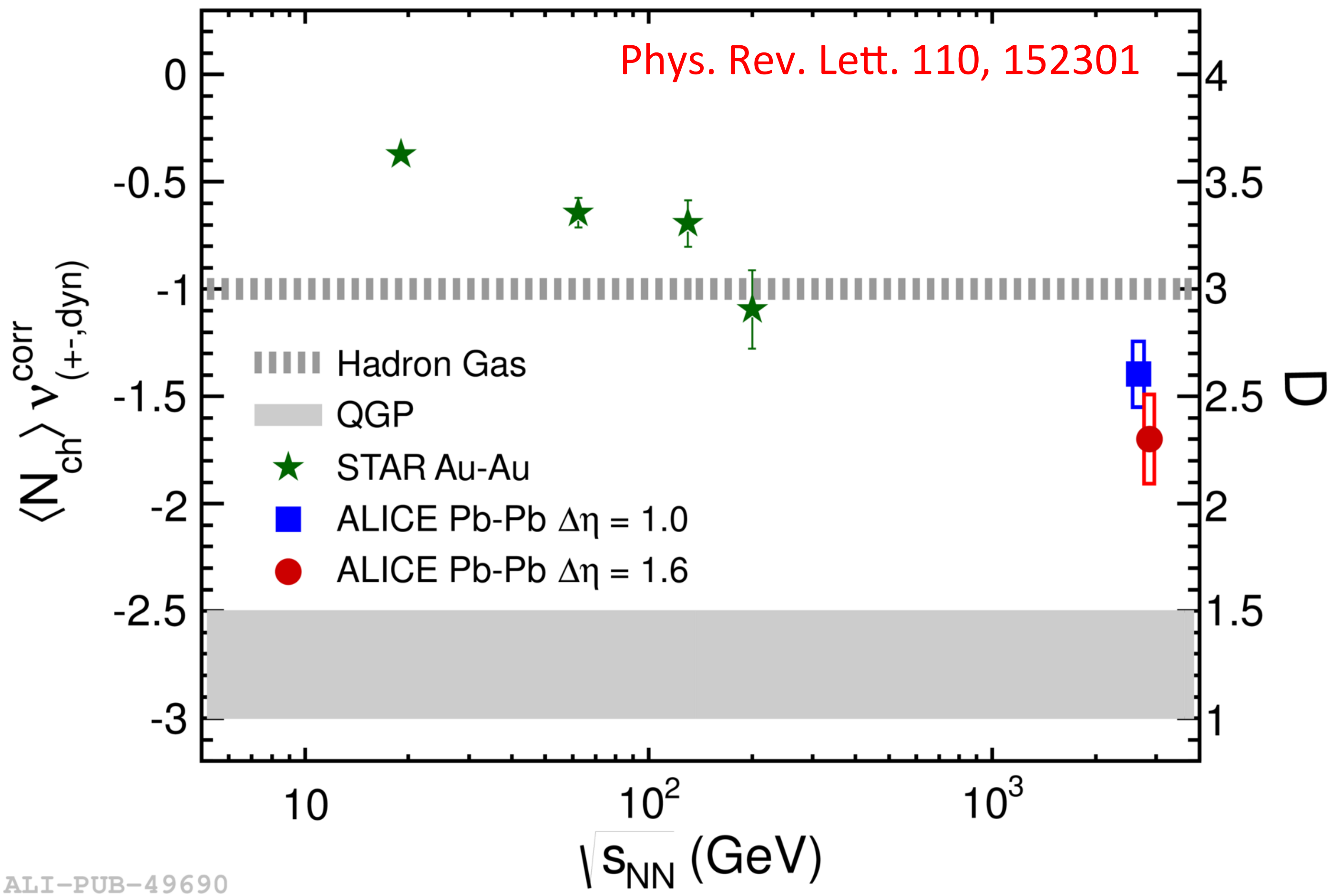
Δη Dependence



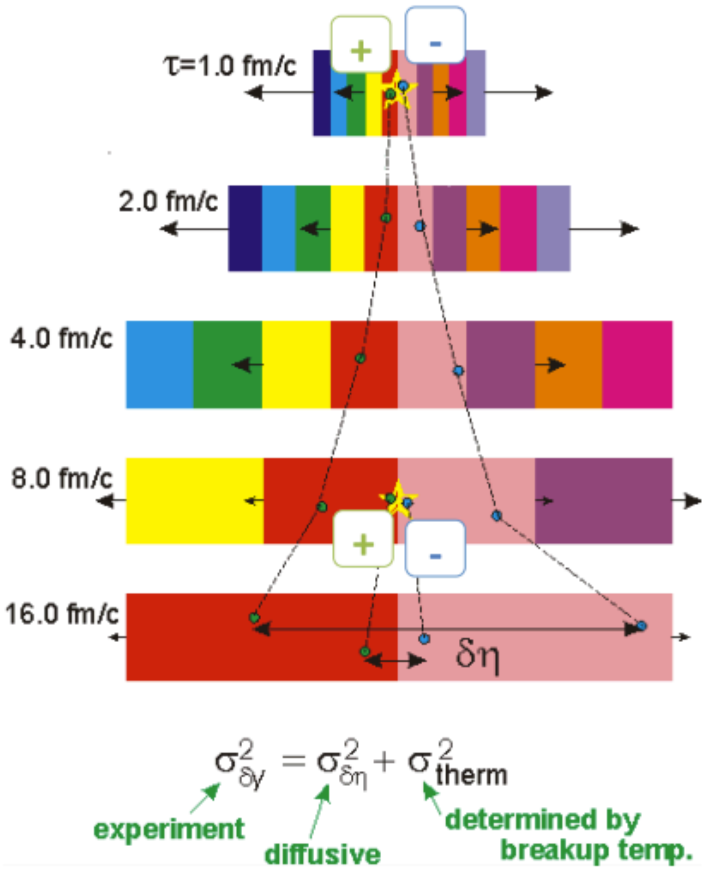
correlation increases with Δη and the curve saturates at a value of Δη~2.3.

The ‘function’ is according to M.A. Aziz and S. Gavin PRC 70, 034905 (2004).

Phys. Rev. Lett. 110, 152301



Beam energy dependence of net charge fluctuations



Creation of balancing charges in rapidly expanding medium

Definition used :

$$B(\Delta\eta,\Delta\varphi)=\frac{S(\Delta\eta,\Delta\varphi)_{US}}{B(\Delta\eta,\Delta\varphi)_{US}}-\frac{S(\Delta\eta,\Delta\varphi)_{LS}}{B(\Delta\eta,\Delta\varphi)_{LS}}$$

Where, $US = +-/-+$

$LS = ++/--$

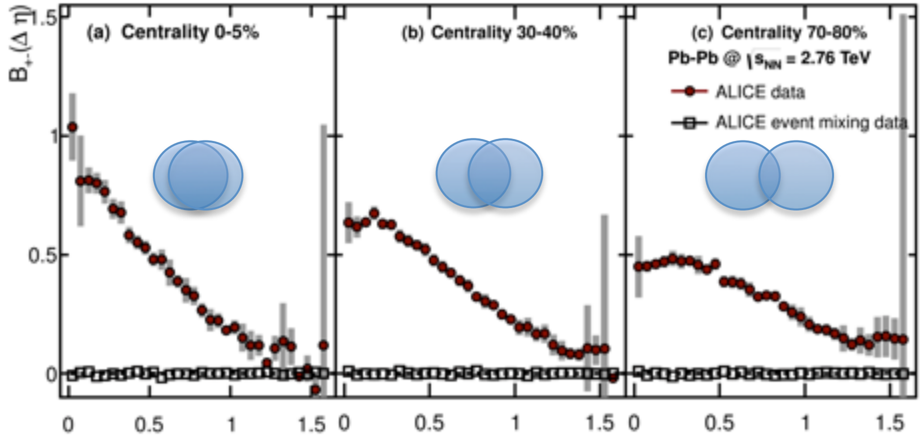
Early stage creation: larger final separation, wider balance functions.

Late stage creation: pairs more correlated, narrower balance functions.

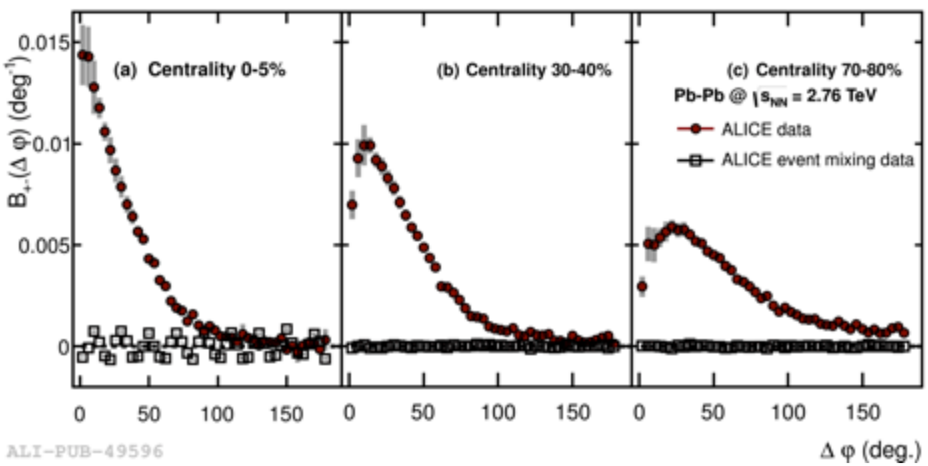
S. Bass, P. Danielewicz and S.Pratt
Phys. Rev. Lett 85, 2689

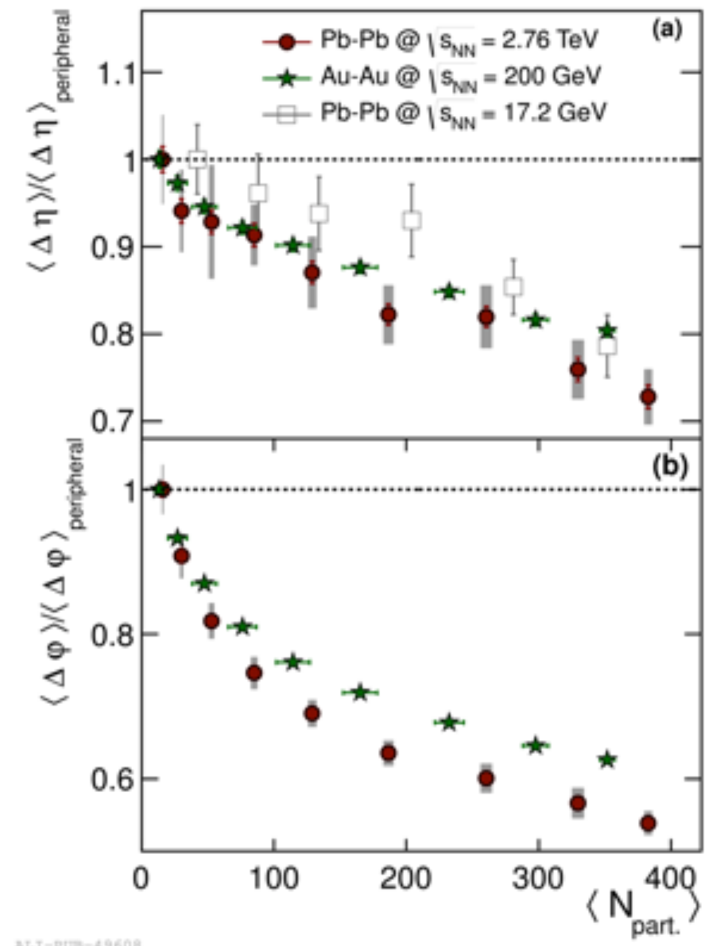
- But: stronger flow → pairs also more correlated, narrower balance functions.

Balance Function



ALICE collaboration PLB,723(2013),267

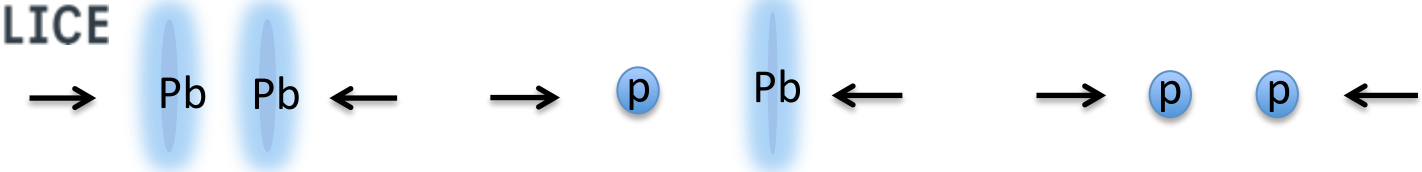




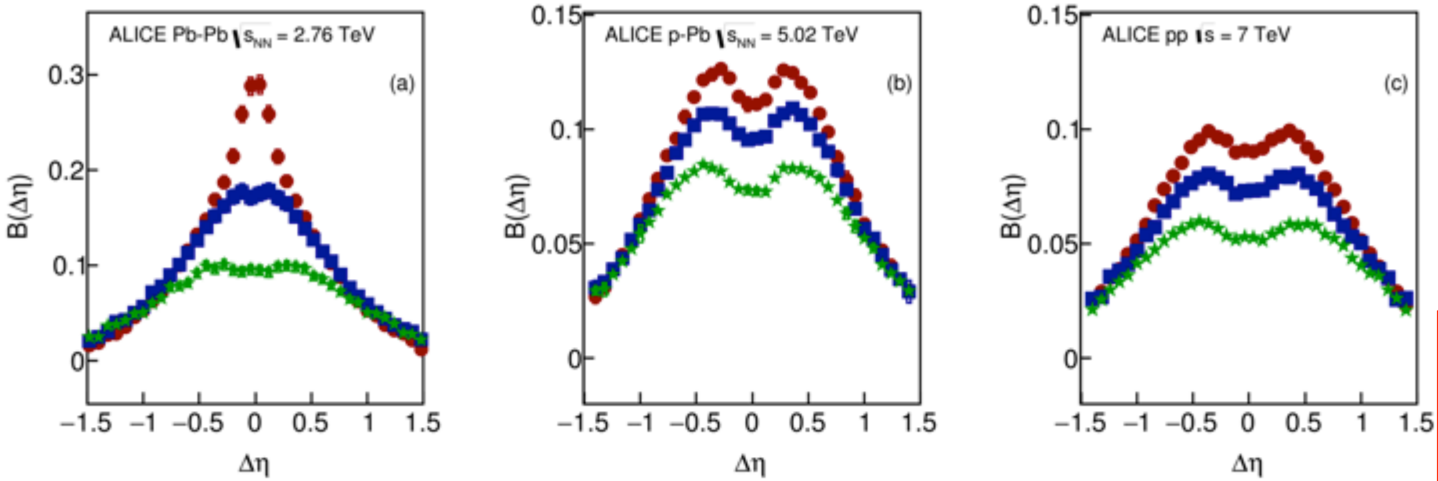
→ Centrality dependence: both narrowing in $\Delta\eta$ and $\Delta\varphi$ from peripheral to central => Suggests expanding/flowing medium.

→ Width remains almost similar in both RHIC and LHC energy.

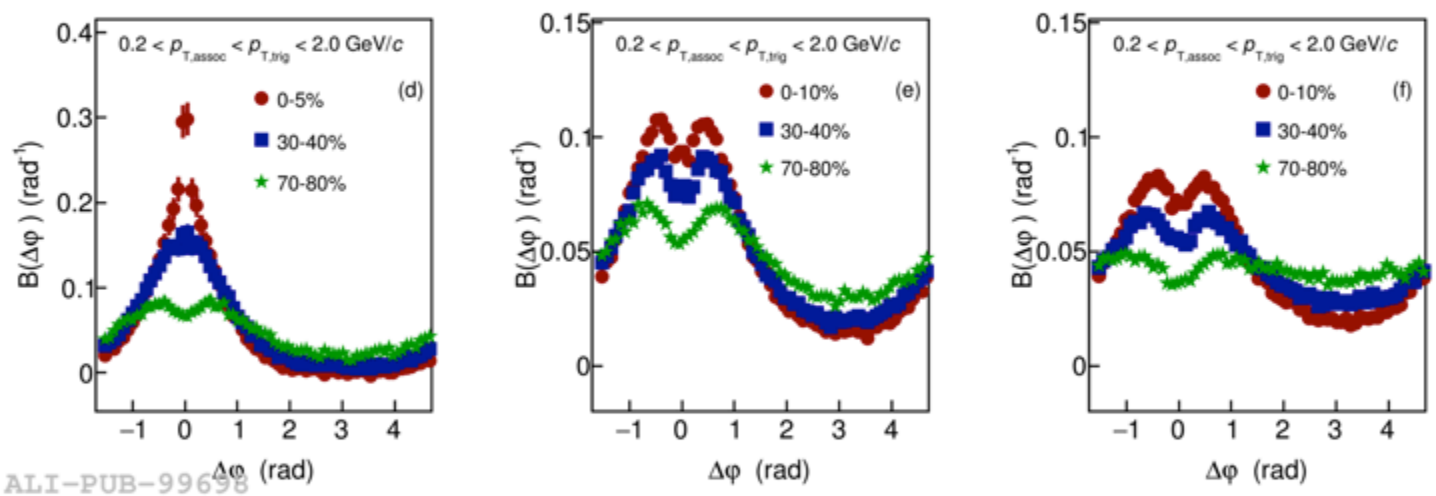
Balance Function



System Size dependence



ALICE Collaboration, arXiv:1509.07255



Centrality Dependence
Δη

Narrowing of Balance function with increasing multiplicity in both Δη and Δφ in low p_T region.

Centrality Dependence
Δφ

Multiplicity Fluctuations

→ Characterized by scaled variances. So by definition,

$$\omega_{N_{ch}} = \frac{<N_{ch}^2> - <N_{ch}>^2}{\langle N_{ch} \rangle} = \frac{Var(N_{ch})}{\langle N_{ch} \rangle}$$

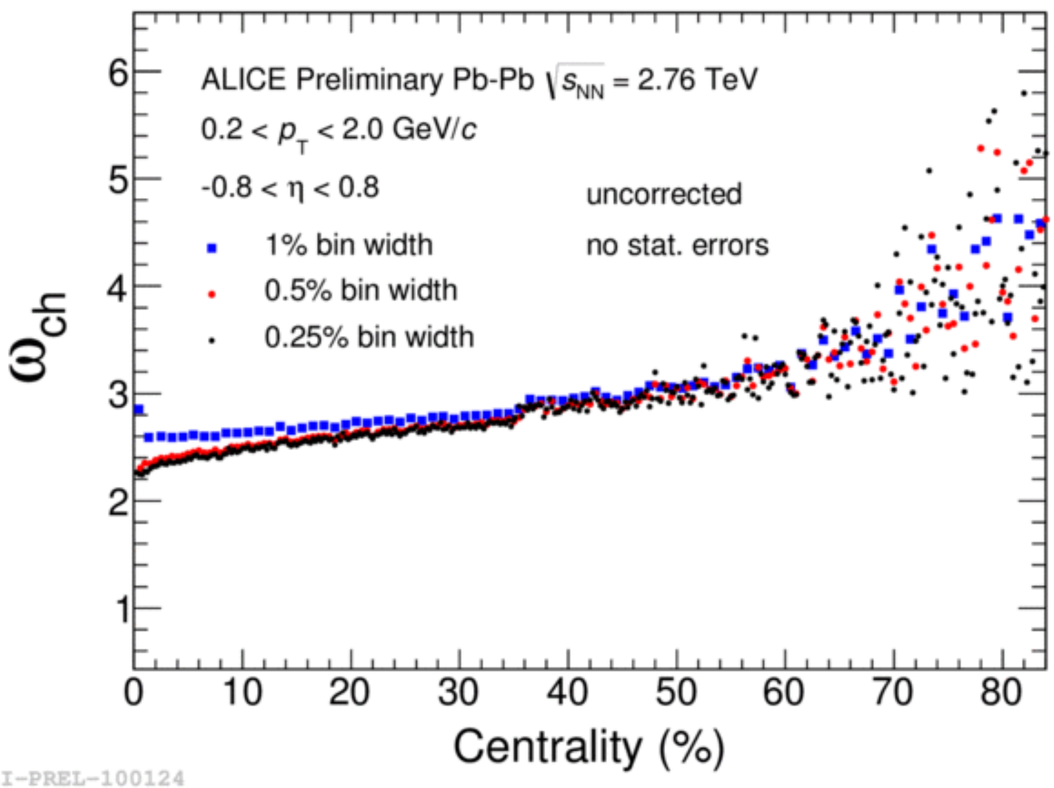
Where,

$$<N_{ch}> = \frac{\sum N_{ch}}{n}$$

$$Var(N_{ch}) = \sigma_{ch}^2 = <N_{ch}^2> - <N_{ch}>^2$$

→ Dynamical fluctuations (other than the statistical fluctuation and fluctuation in the number of participants)

→ may provide insights on the intrinsic mechanisms of the particle production.



Selection of centrality window:
Bin-Width Correction

$$X = \frac{\sum_i^k n_i X_i}{\sum_i^k n_i} = \sum_i^k w_i X_i$$

Multiplicity Fluctuations

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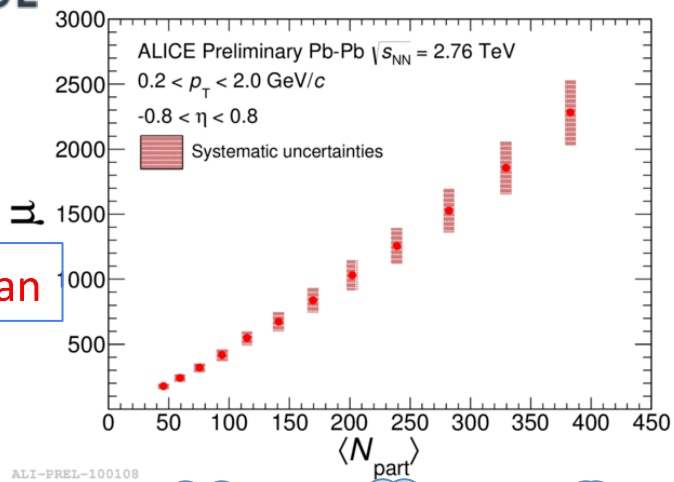
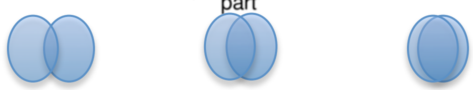
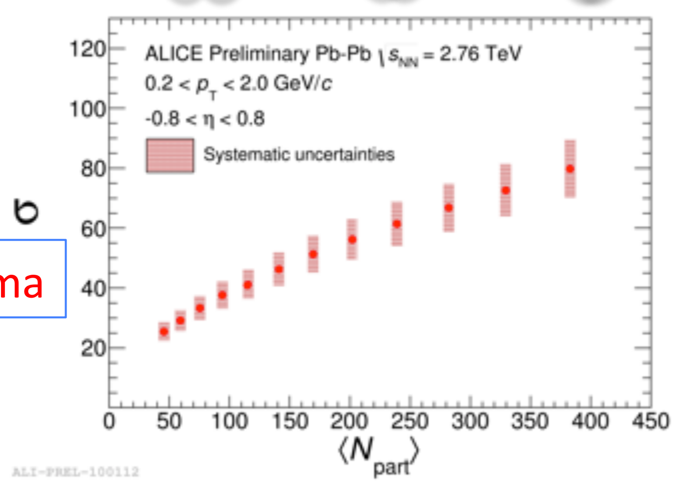
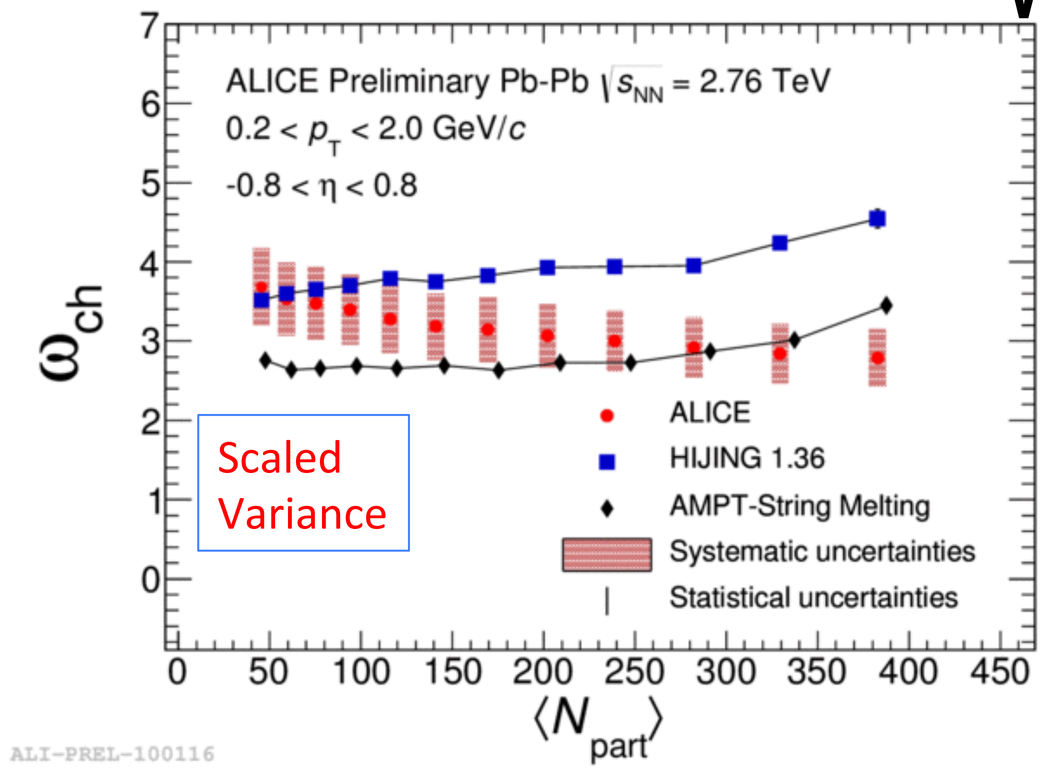
mean



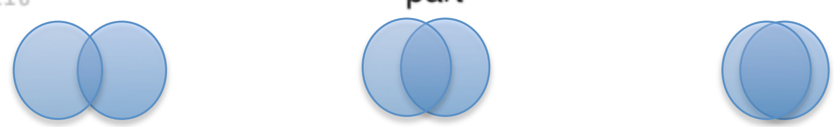


sigma





Scaled Variance



- The centrality dependence of scaled variance is shown, which decreases from peripheral to central.
- The dynamical fluctuation for multiplicity, ranges within ~ 2-4.
- Neither AMPT or HIJING is following the trend like data.

Remaining Fluctuations

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- ☐ Particle Ratio Fluctuations

  → See Mesut's poster presentation.

  (New Results)

- ☐ Higher Moments Studies (of net-charge)

  → Results are almost final, coming soon.

- ☐ Temperature Fluctuations

  → Analysis ongoing, coming soon.

Summary & Outlook

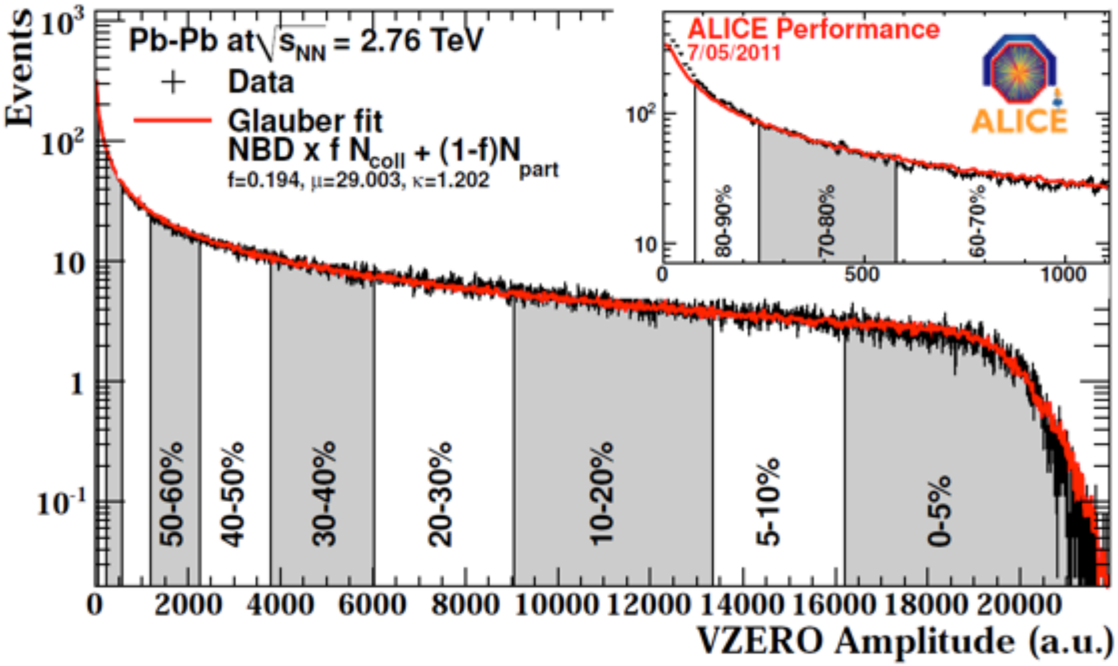
- We have presented recent results on Event-by-event correlation and fluctuations for ALICE experiment at LHC energy for different observables from different systems (from pp to p-Pb to Pb-Pb systems).

- Many more results for pp @ $\sqrt{S}$ = 8 TeV and 13 TeV will come soon. We have collected a very good data set in recent runs.

- Data for Pb-Pb @ $\sqrt{S_{NN}}$ = 5 TeV will be taken in November 2015. So, Stay tuned…

THANK YOU ALL

Back Up



Assume the particle production increases monotonically with the overlap

→ categorize events in centrality percentiles through Glauber model, in which nuclear density profile and nucleon-nucleon cross section to link centrality to

→ number of participants (N_{part})

&

→ number of binary collisions (N_{coll})

The centrality is selected using the VZERO amplitude as the default estimator

- Centrality bins: 0-5%, 5-10%, 10-20%,..., 70-80%
- Different centrality estimators (TPC tracks, SPD clusters).