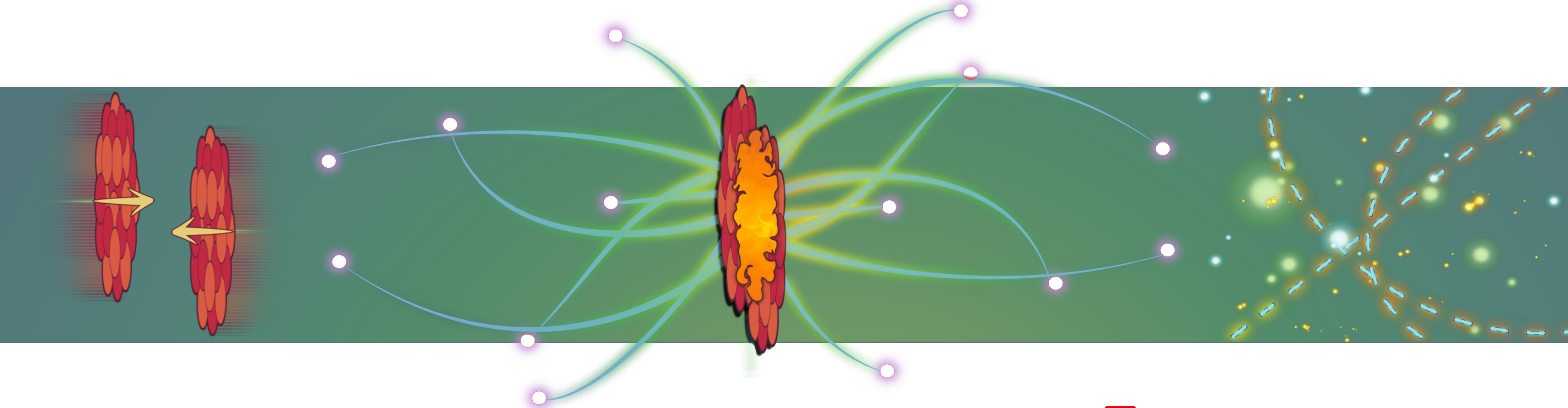
Forward-backward correlations and multiplicity fluctuations in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV from ALICE at the LHC



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Outline

ALICE

Comparative study of experimental data and MC simulations of Pb-Pb collisions at 2.76 TeV:

- Forward-backward correlation coefficient b_{corr}
- Strongly intensive quantity sigma Σ

Plan:

1. Motivation;
2. Analysis;
3. Results;
4. Summary.

Motivation: Why do we study correlations and fluctuations?

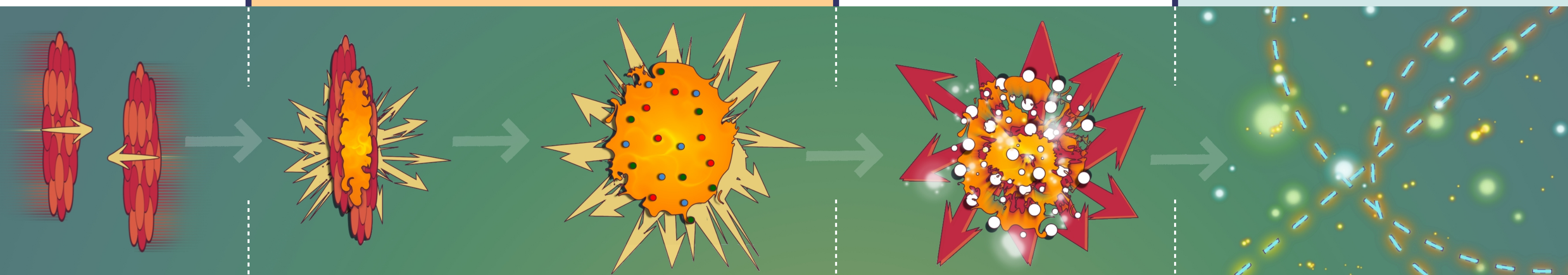
PRE-COLLISION STAGE

PRE-EQUILIBRIUM STAGE

QGP AND EQUILIBRIUM STAGE

HADRONIZATION STAGE

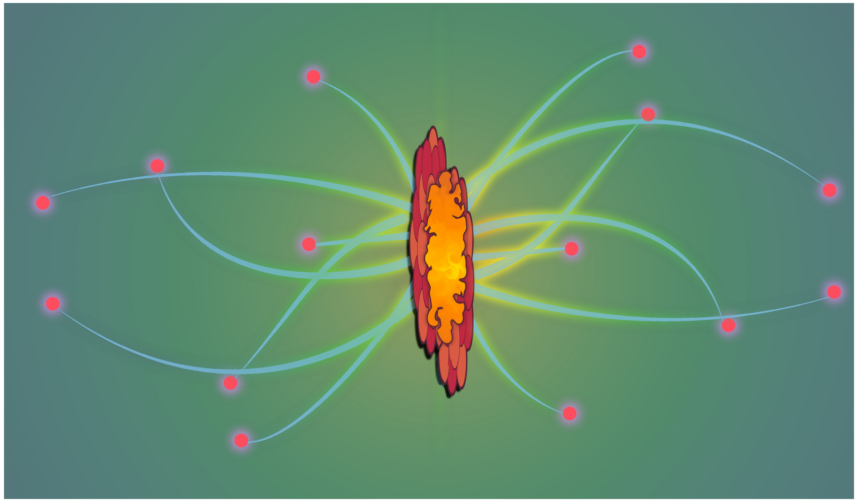
HADRONIZATION FREEZE-OUT STAGE



What we want to know...

What we measure in the detector...

Motivation: Why do we study correlations and fluctuations?

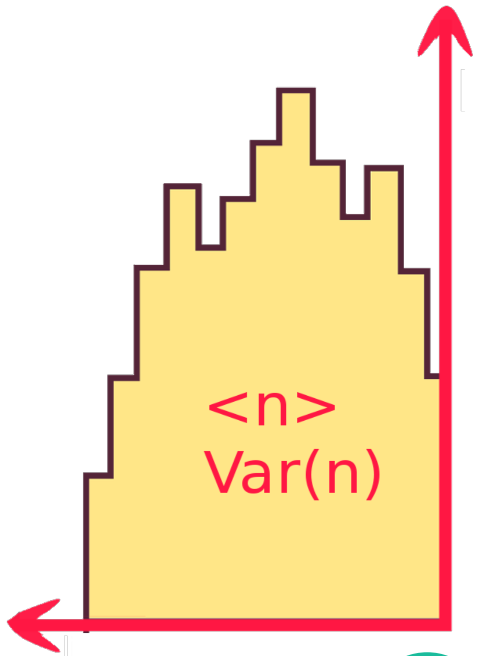


1. Study of **Long-Range Correlations** (LRC):

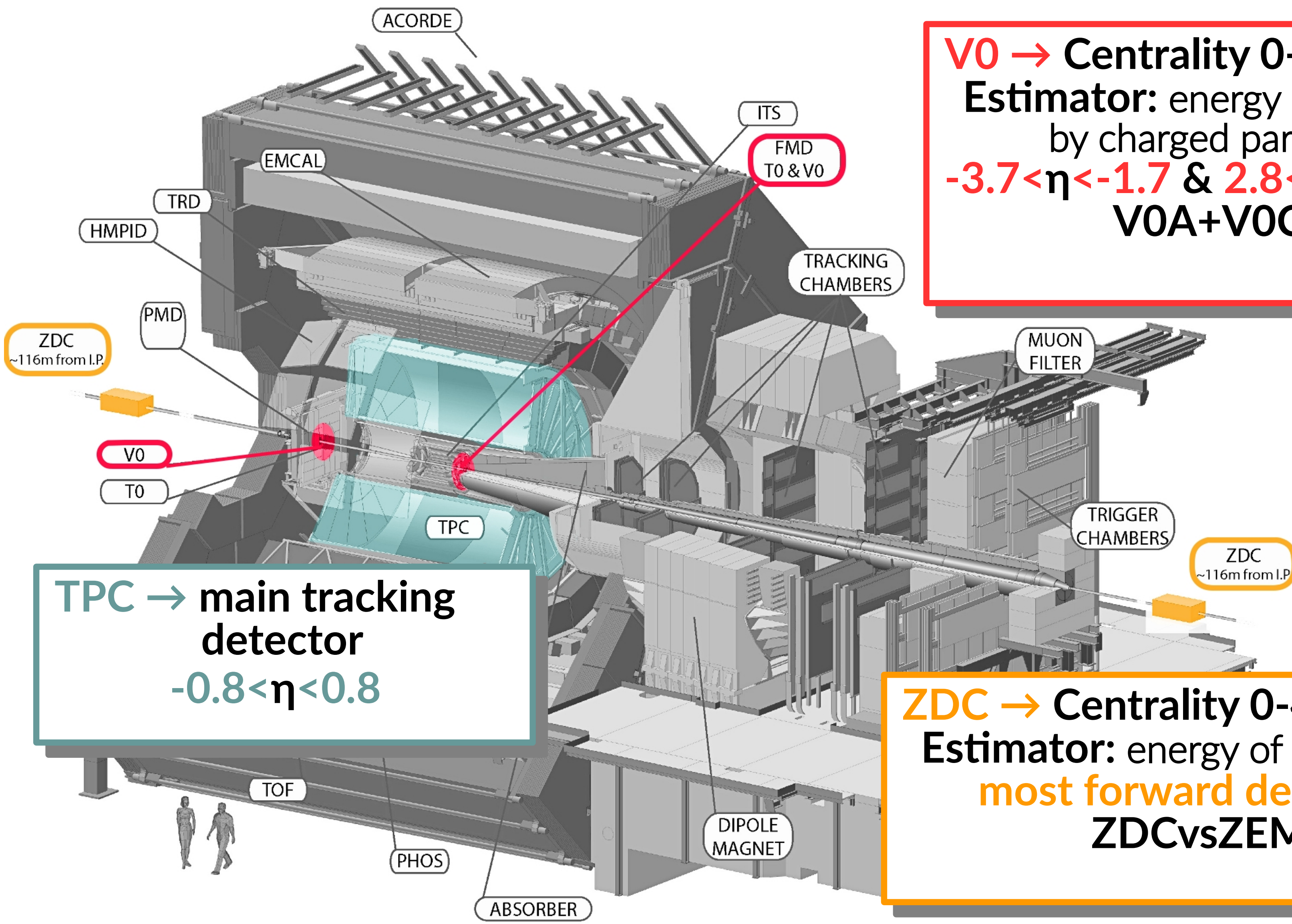
- LRC carry **information** on the **early dynamics** of the nuclear collision.

2. Analysis of **fluctuations** in the number of particles produced in nucleus-nucleus collisions:

- A good way to check dynamical models of particle production.
- Gives a chance to study observables sensitive to the early dynamics of the collision, independent of geometrical fluctuations.



The Analysis: ALICE Experiment



V0 → Centrality 0-80%.
Estimator: energy deposition by charged particles
$-3.7<\eta<-1.7$ & $2.8<\eta<5.1$
V0A+V0C

TPC → main tracking detector
$-0.8<\eta<0.8$

ZDC → Centrality 0-40%.
Estimator: energy of spectators
most forward detector
ZDCvsZEM

The Analysis: Data Sample

ALICE

Experimental data:

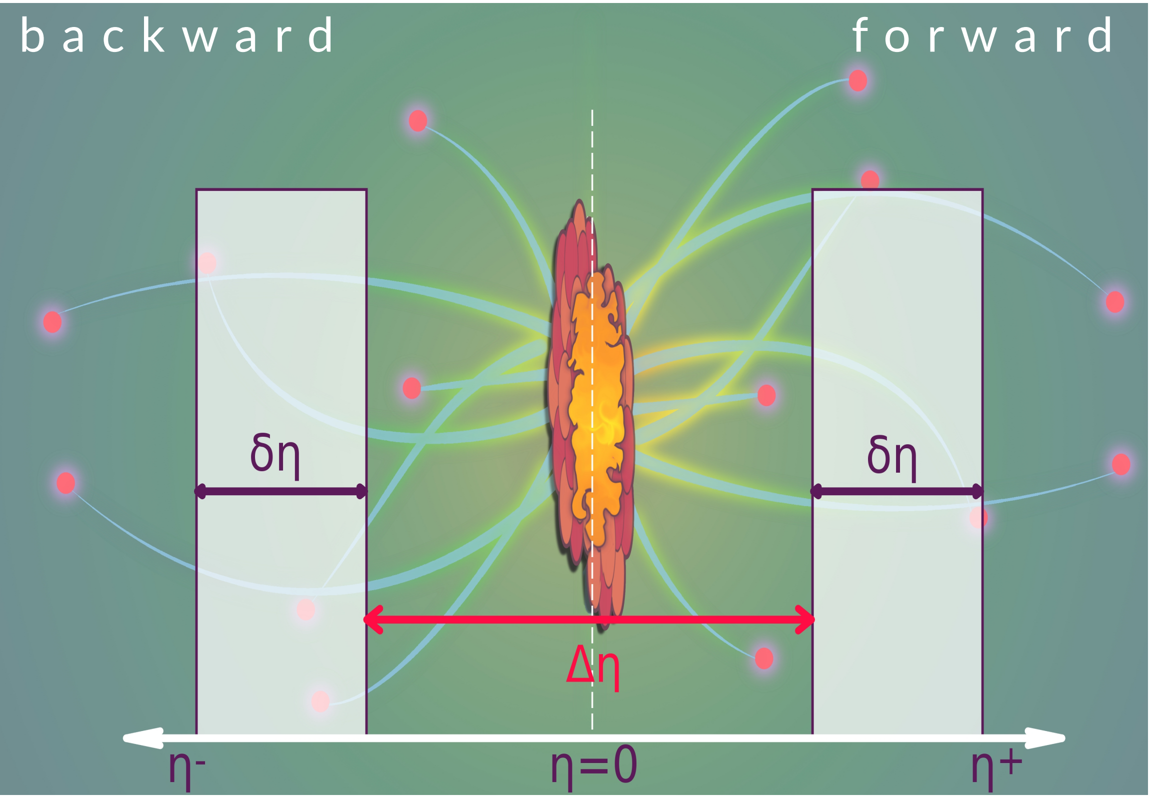
Pb-Pb @ $\sqrt{s_{NN}}$=2.76 TeV (2010)
Tracks: **-0.8<η<0.8, p_T>0.2 GeV/c**
Centrality estimators: **V0, ZDC**

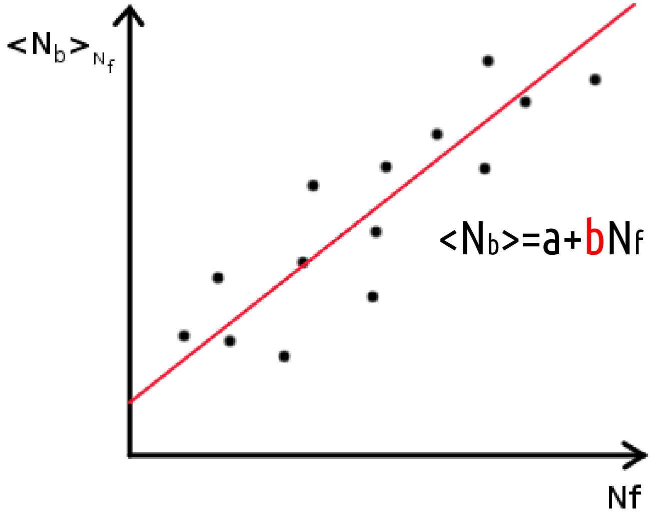
MC simulations:

MC HIJING
Pb-Pb @ $\sqrt{s_{NN}}$=2.76 TeV
Tracks: **-0.8<η<0.8, p_T>0.2 GeV/c**
Centrality:
→ **estimated by impact parameter**
→ **estimated by charged particle multiplicity in the V0 acceptance**

Forward-backward correlations

$$b_{corr} = \frac{\mathrm{Cov}(n_F, n_B)}{\sqrt{\mathrm{Var}(n_F)\,\mathrm{Var}(n_B)}}$$





SRC
Δη<1

LRC
Δη>1

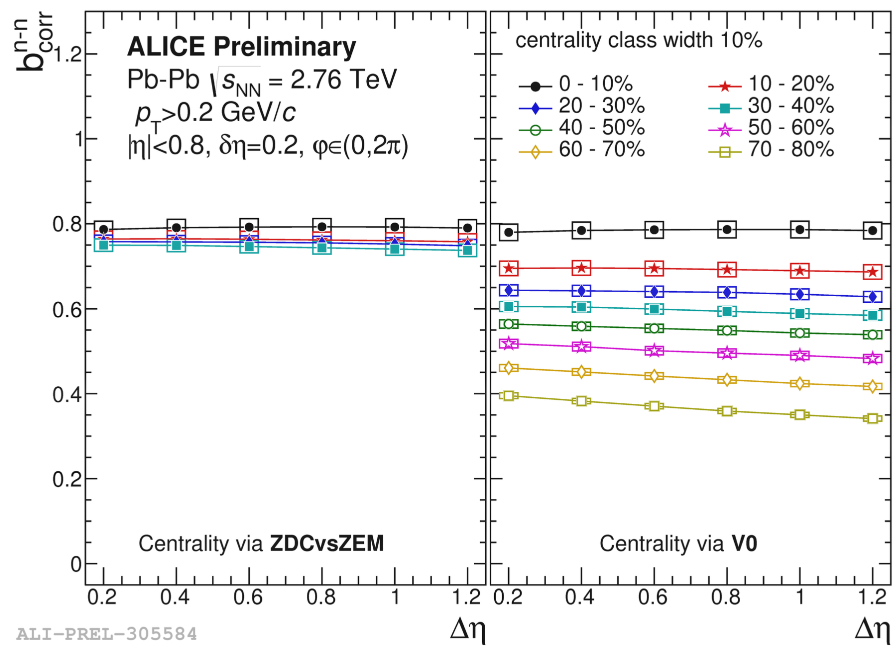
Challenge → "depends on everything":
- Dynamics (SRC+LRC) ;
- "trivial" system size (~N_{part}) ;
- "trivial" (Glauber) fluctuations
 (→ dependence on centrality bin width).

Forward-backward correlations
b_{corr}: dependence on $\Delta\eta$

10%

Centrality estimator: spectators in ZDC

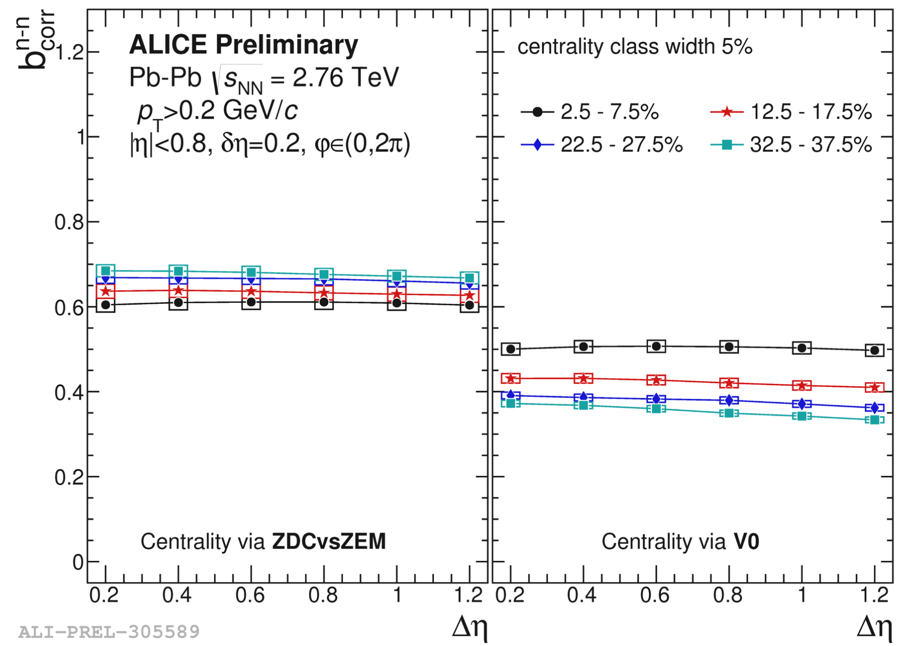
Centrality estimator: charged particles in V0



5%

Centrality estimator: spectators in ZDC

Centrality estimator: charged particles in V0



- **Large values of b_{corr}** but large centrality bin width → **large geometrical (N_{part}) fluctuations** within a single bin of selected centrality.

Forward-backward correlations b_{corr}: dependence on $\Delta\eta$

10%

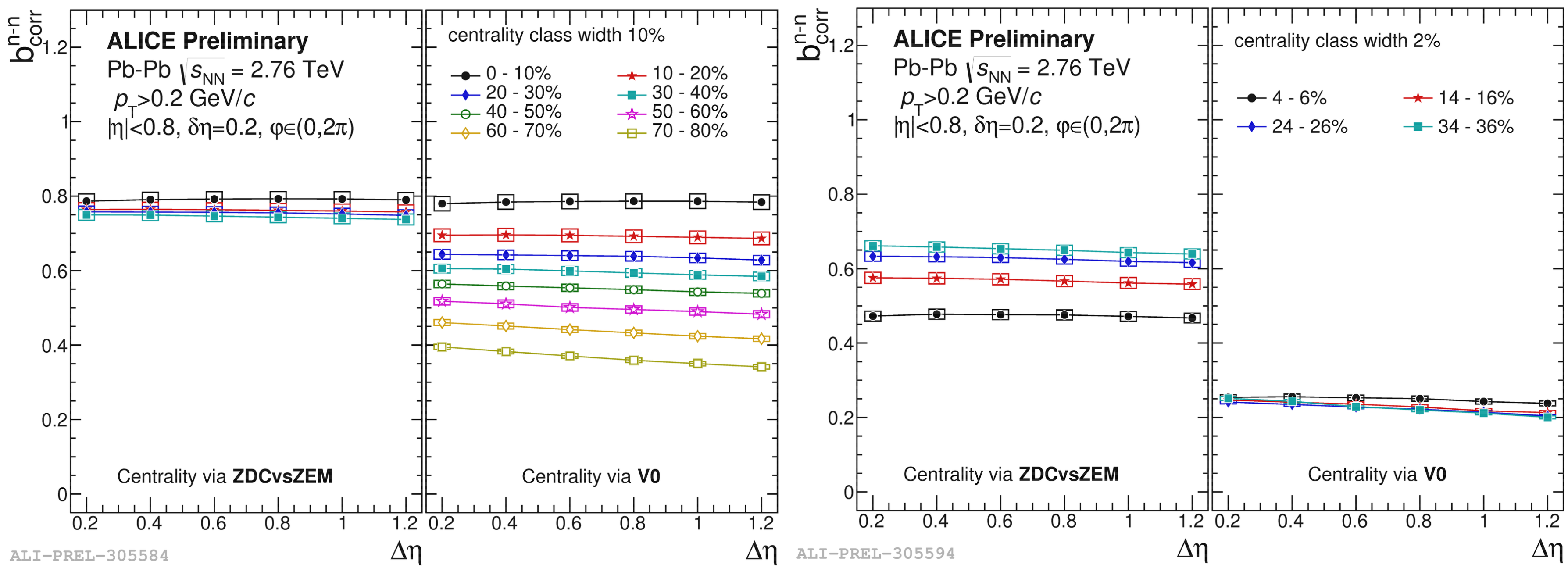
2%

Centrality estimator: spectators in ZDC

Centrality estimator: charged particles in V0

Centrality estimator: spectators in ZDC

Centrality estimator: charged particles in V0

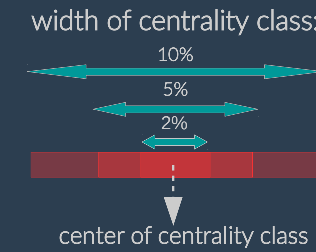


- **Large values of b_{corr}** but large centrality bin width → **large geometrical (N_{part}) fluctuations** within a single bin of selected centrality.

centrality bin width: 10% → 5%→ 2%:

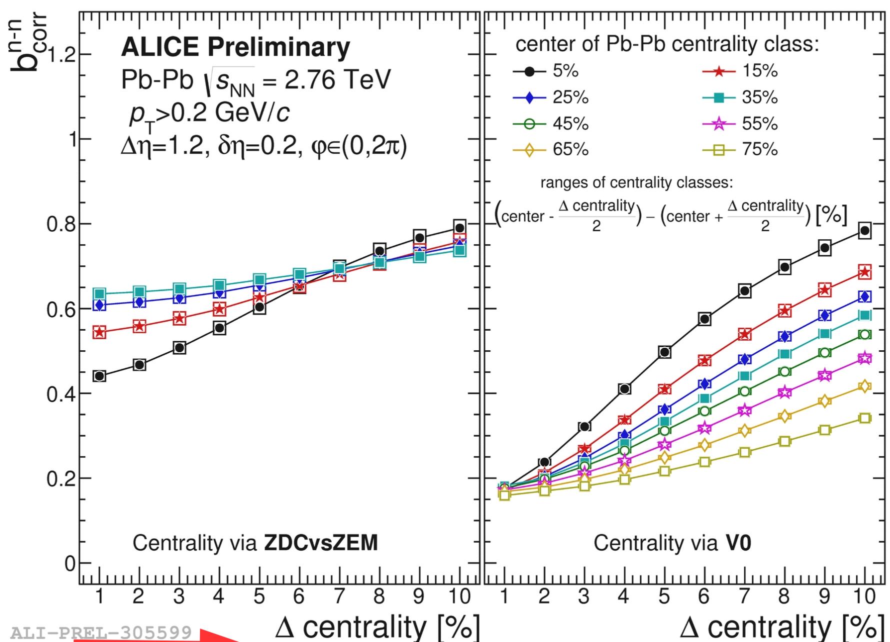
- dependence on centrality estimator;
- drop of the value of b_{corr} (**reduced fluctuations of N_{part}**).

Forward-backward correlations
b_{corr}: dependence on centrality bin width



Centrality estimator: spectators in ZDC

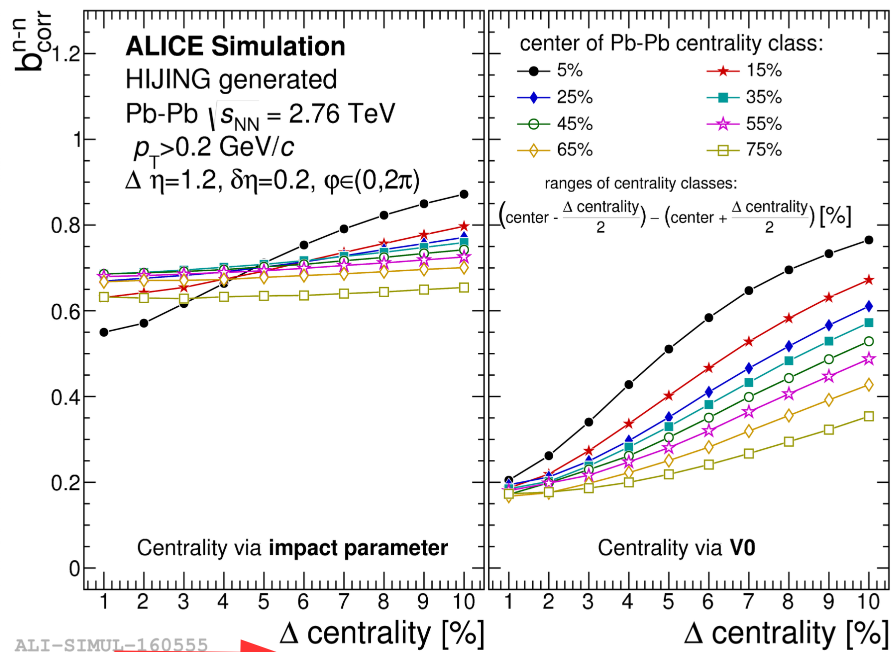
Centrality estimator: charged particles in V0



geometrical fluctuations

Centrality determined using impact parameter

Centrality estimator: charged particles in V0



geometrical fluctuations

- **Large values of b_{corr}** but large centrality bin width **→ large geometrical (N_{part}) fluctuations** within a single bin of selected centrality.
- Theoretical predictions:

$$b = 1 - \left[1 + \frac{\bar{n}}{4}\left(\frac{2}{k} + \frac{\langle w^2\rangle - \langle w\rangle^2}{\langle w\rangle}\right)\right]^{-1}$$

→ Scaled variance of number of participants ω_{part}

A. Bzdak, Phys. Rev. C 80 (2009) 024906

Strongly intensive quantity Σ

Intensive quantities do not depend on system volume.

Scaled variance: $$\omega_{B(F)} = \frac{Var\left(n_{B(F)}\right)}{\langle n_{B(F)} \rangle}$$

Gaździcki, Gorenstein, Phys.Rev. C84 (2011) 014904

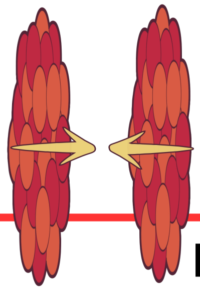
Strongly Intensive quantities do not depend on system volume nor system volume fluctuations (i.e. $Var(N_s), \omega_s$) → **Σ**

$$\Sigma = \frac{1}{\langle n_B \rangle + \langle n_F \rangle}\left[\langle n_F \rangle \omega_B + \langle n_B \rangle \omega_F - 2\,Cov\left(n_F, n_B\right)\right]$$

For a symmetric collision, like Pb-Pb:

$\omega_B = \omega_F$ and $\langle n_F \rangle = \langle n_B \rangle$

$$\Sigma \approx \omega(1 - b_{corr})$$



For Poisson distribution: $\omega = 1$ & $b_{corr} = 0 \rightarrow \Sigma = 1$

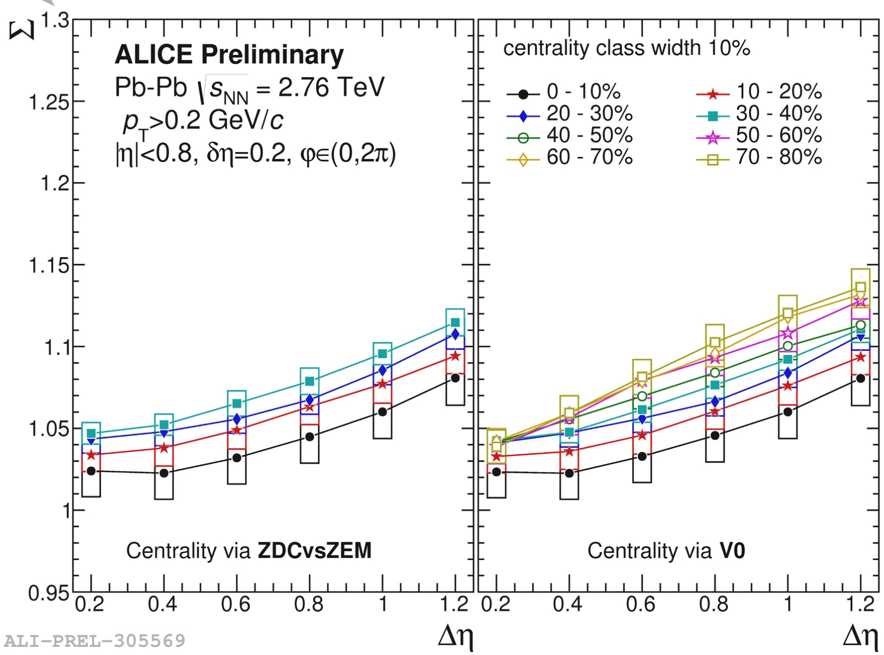
Strongly intensive quantity Σ: dependence on Δη

10%

5%

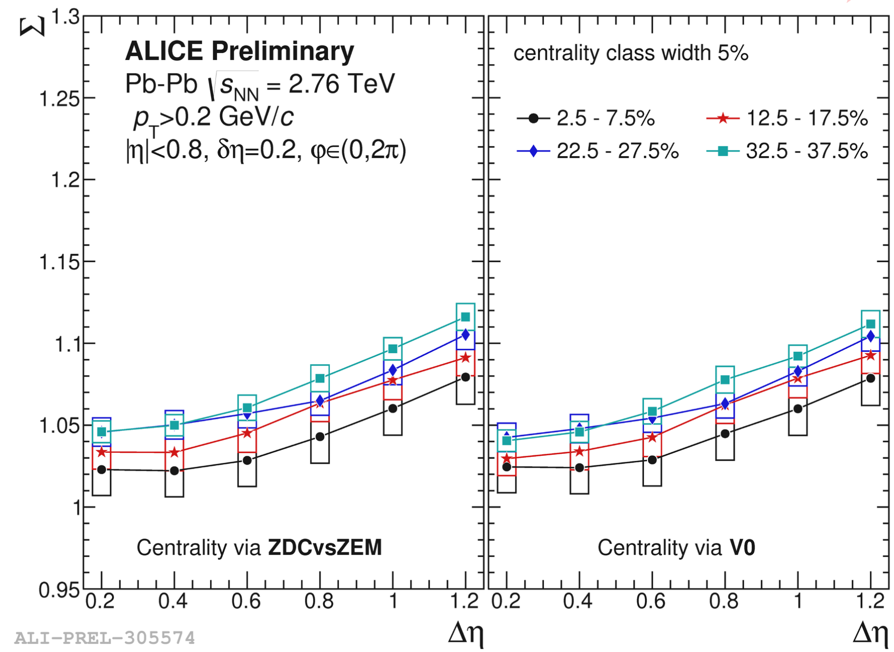
Centrality estimator: spectators in ZDC

Centrality estimator: charged particles in V0



Centrality estimator: spectators in ZDC

Centrality estimator: charged particles in V0



- increase of values of Σ with Δη;
- values of Σ>1;

→ **no dependence on centrality selection!**

→ centrality bin width: 10% → 5%

- Σ does not depend on centrality bin width.

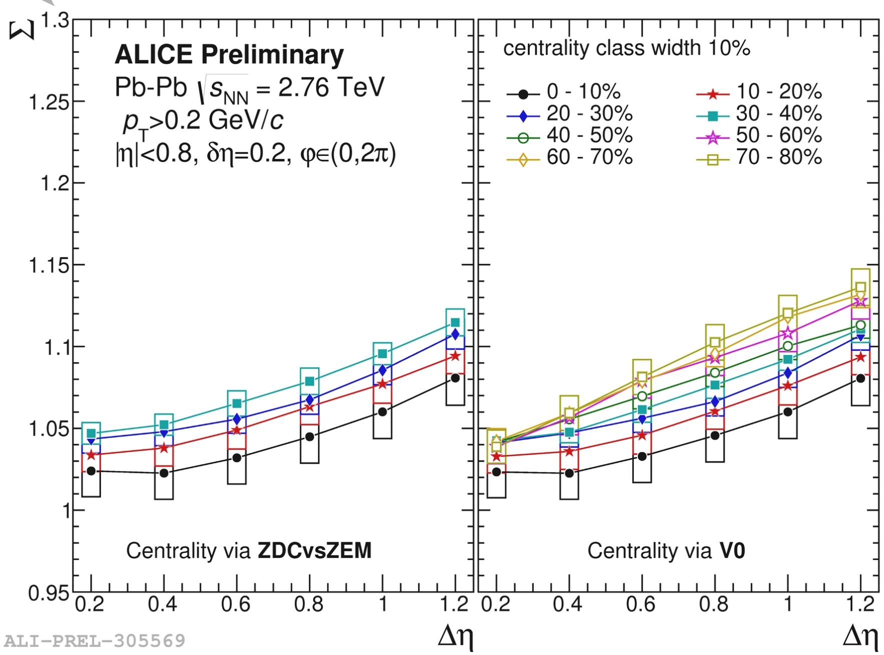
Strongly intensive quantity Σ: dependence on Δη

10%

2%

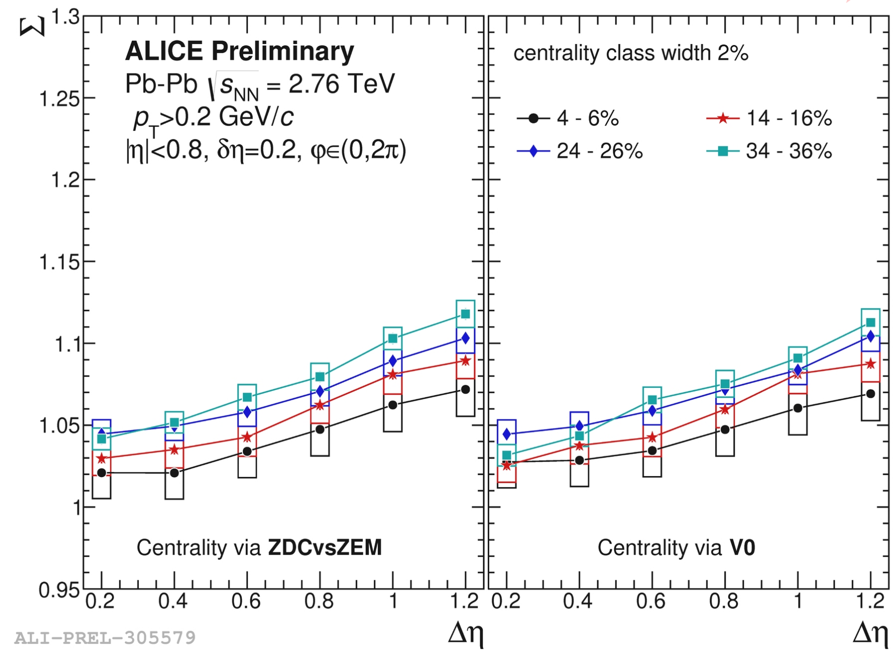
Centrality estimator: spectators in ZDC

Centrality estimator: charged particles in V0



Centrality estimator: spectators in ZDC

Centrality estimator: charged particles in V0



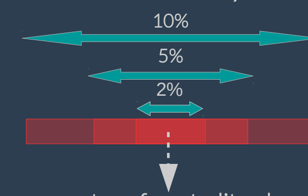
- increase of values of Σ with Δη;
- values of Σ>1;

→ **no dependence on centrality selection!**

→ **centrality bin width: 10% → 5%→ 2%**

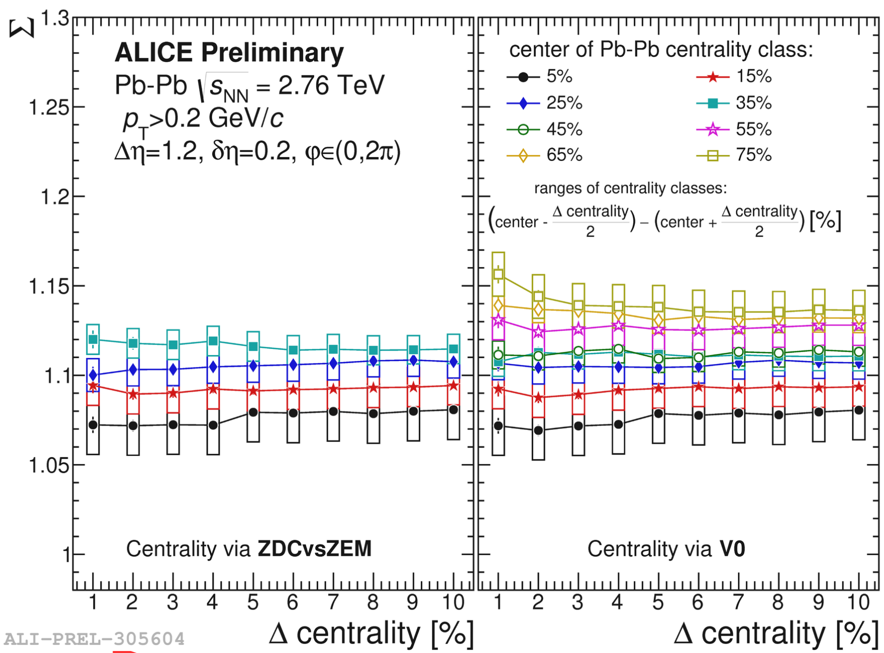
- Σ does not depend on centrality bin width.

Strongly intensive quantity
Σ: dependence on centrality bin width



Centrality estimator: spectators in ZDC

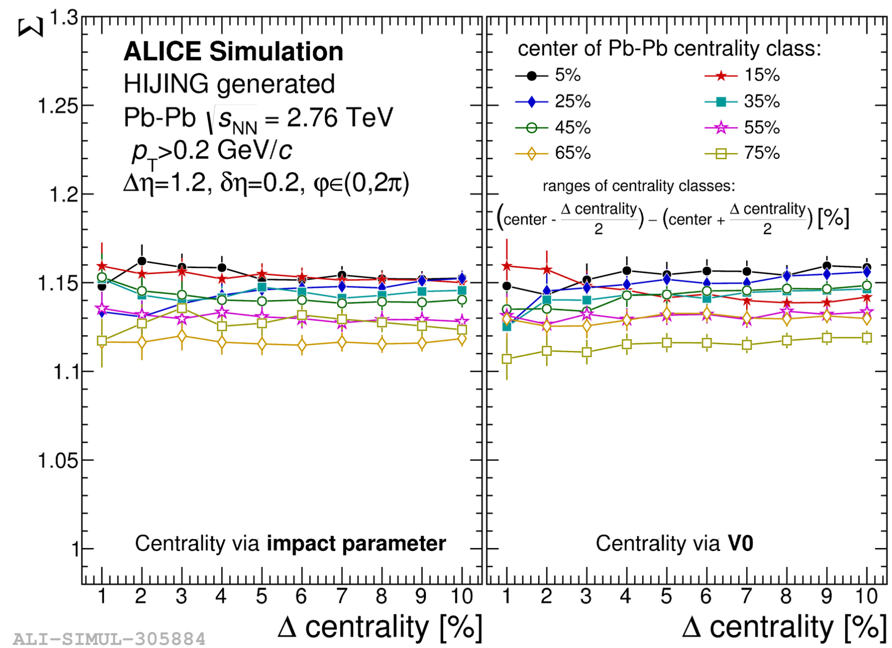
Centrality estimator: charged particles in V0



geometrical fluctuations

Centrality determined using impact parameter

Centrality estimator: charged particles in V0



geometrical fluctuations

no dependence on centrality selection!

+

centrality bin width: 10% → 1%

Σ does not depend on centrality bin width.

→

Σ indeed shows the properties of a strongly intensive quantity !

Summary

1. Data on forward-backward correlations (b_{corr}) and first experimental data on strongly intensive (Σ) quantity in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV:

→ b_{corr}: large dependence on centrality bin width and estimator!

→ b_{corr}: information on early dynamics is mixed with trivial geometrical fluctuations.

→ Σ: deviation from unity, increases with rapidity gap;

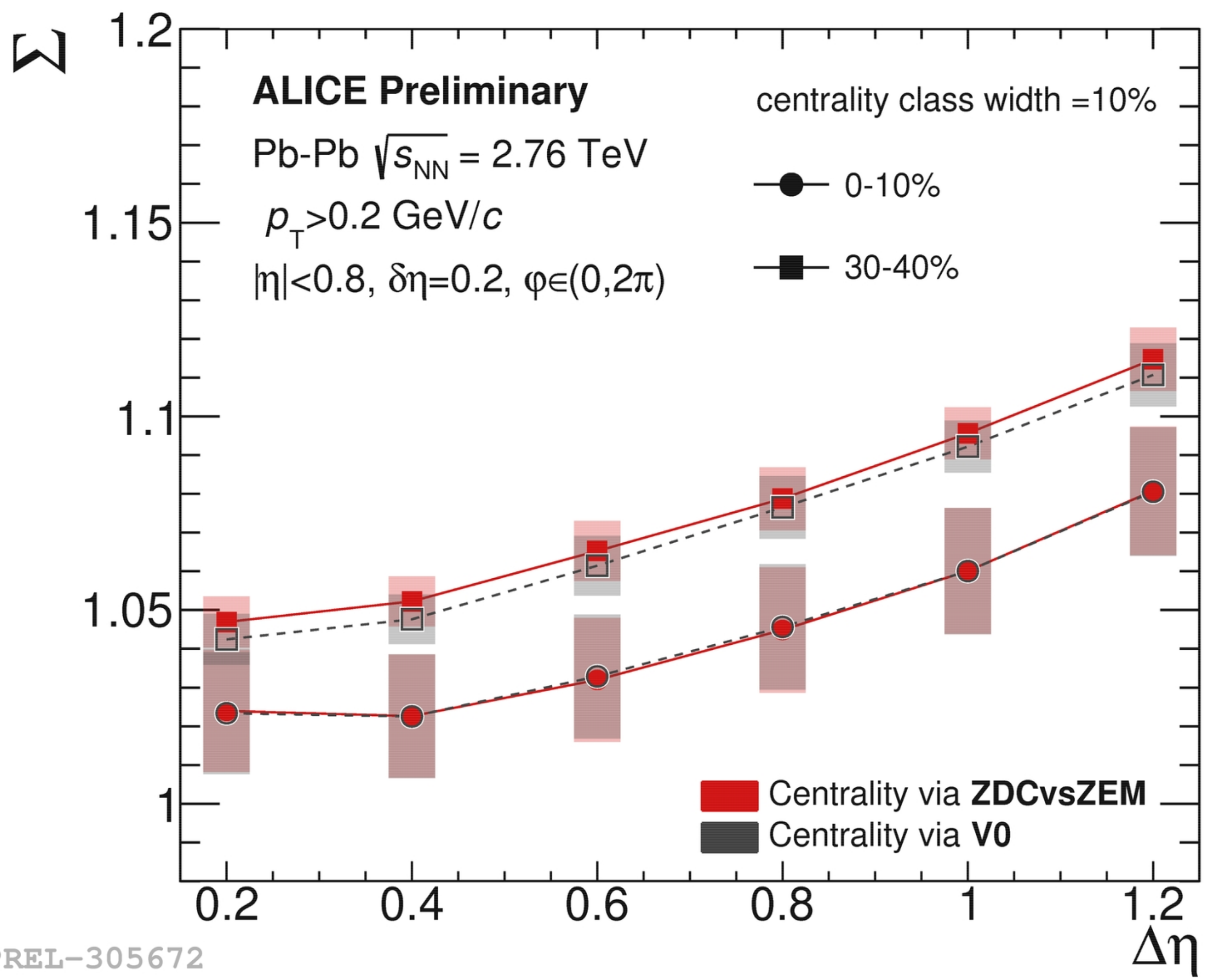
→ Σ: does not depend on centrality selection method nor on centrality bin width (true for experimental data and MC HIJING simulations)

→ these are properties of a strongly intensive quantity!

2. The comparison between experimental data and MC simulations for the strongly intensive quantity Σ shows different ordering of the values of Σ with centrality→ possible hint about the early dynamics?

Thank you!

Extra slides



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no dependence on centrality selection