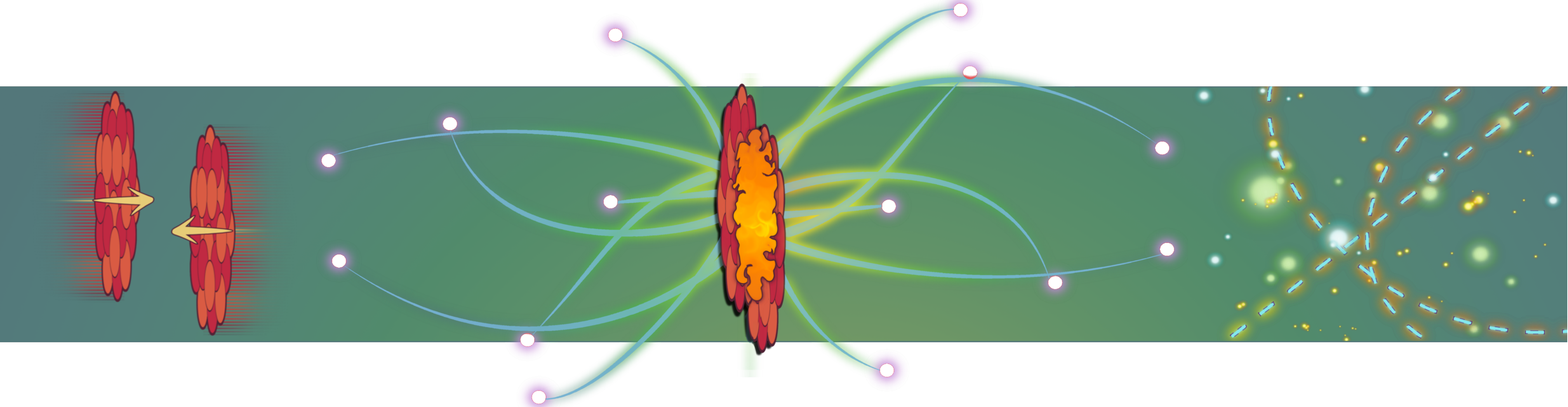
Forward-backward correlations and multiplicity fluctuations in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV from ALICE at the LHC



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Outline

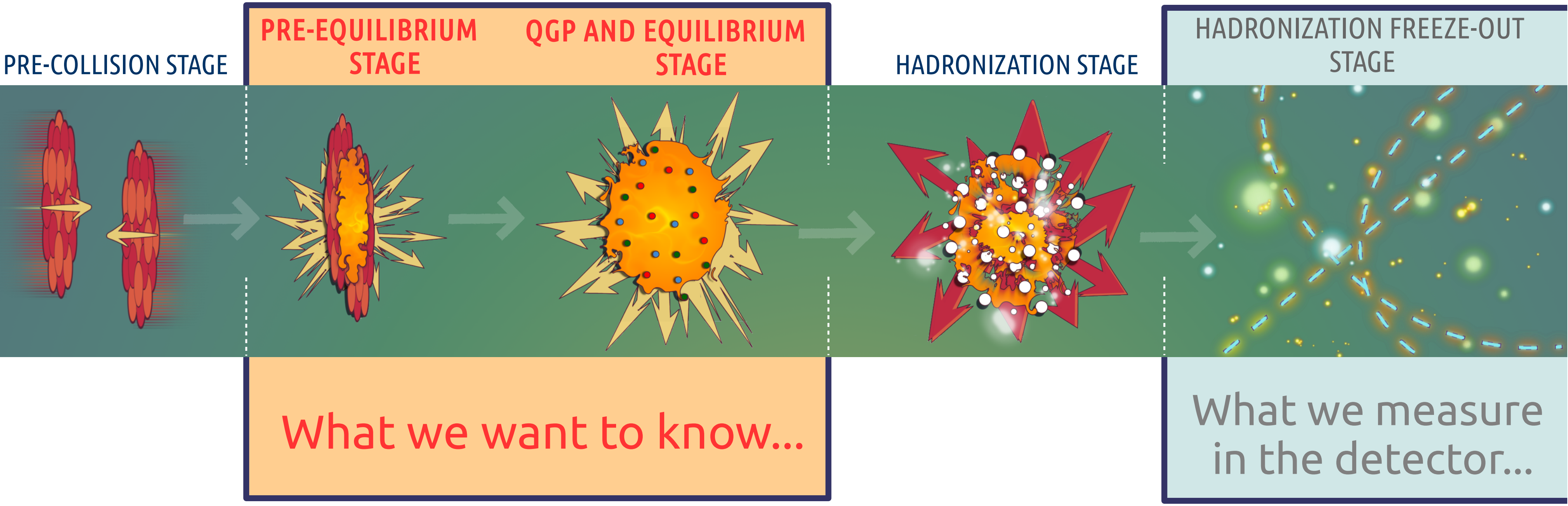
Comparative study of experimental data and MC simulations of Pb-Pb collisions at 2.76 TeV:

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

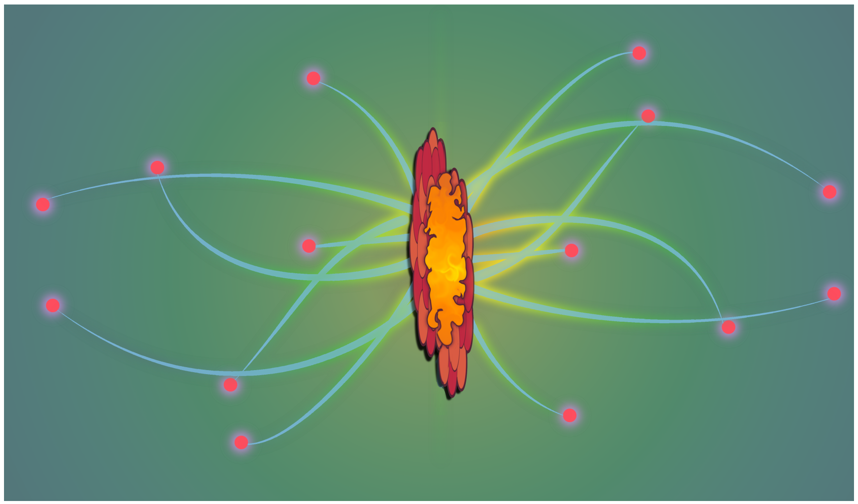
Plan:

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

Motivation: Why do we study correlations and fluctuations?



Motivation: Why do we study correlations and fluctuations?

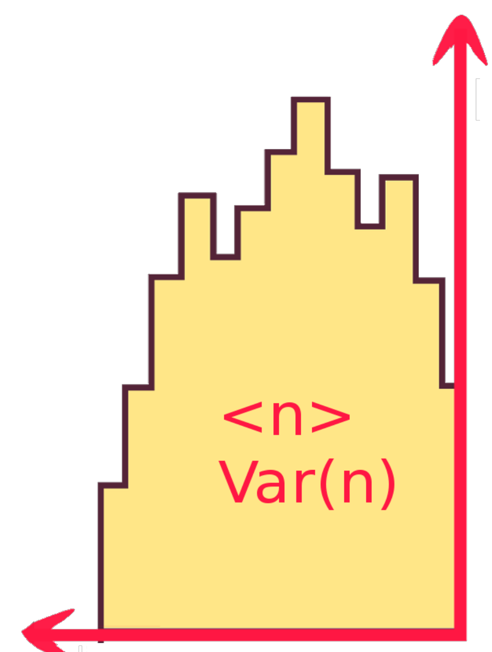


1. Study of **Long-Range Correlations** (LRC):

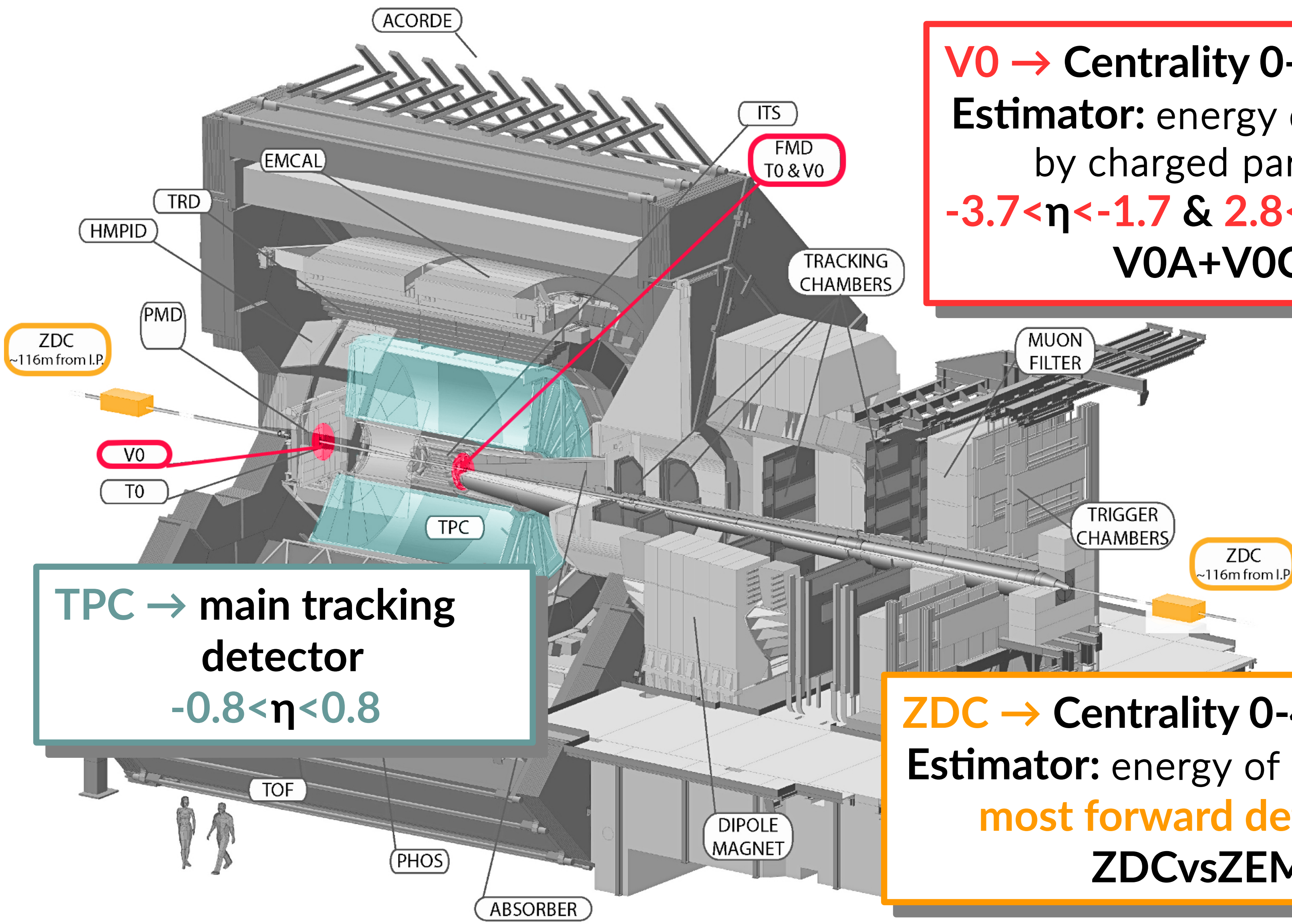
- LRC carry some **information** on the **early dynamics** of the nuclear collision.

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

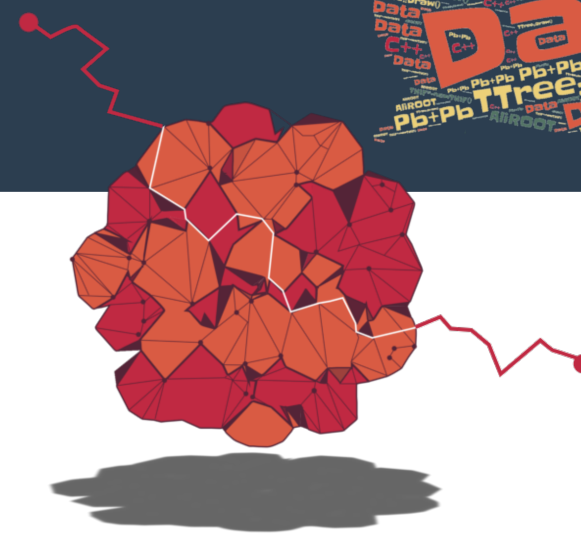


V0 → Centrality 0-80%.
Estimator: energy deposition by charged particles
$-3.7<\eta<-1.7$ & $2.8<\eta<5.1$
V0A+V0C

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



Experimental data:

Pb-Pb @ $\sqrt{s_{NN}}$=2.76 TeV (2010)

Tracks: **$-0.8<\eta<0.8$, $0.2<p_T<2.0$ GeV/c**

Centrality estimators: **V0, ZDC**

MC simulations:

MC HIJING

Pb-Pb @ $\sqrt{s_{NN}}$=2.76 TeV

Tracks: **$-0.8<\eta<0.8$, $p_T>0.2$ GeV/c**

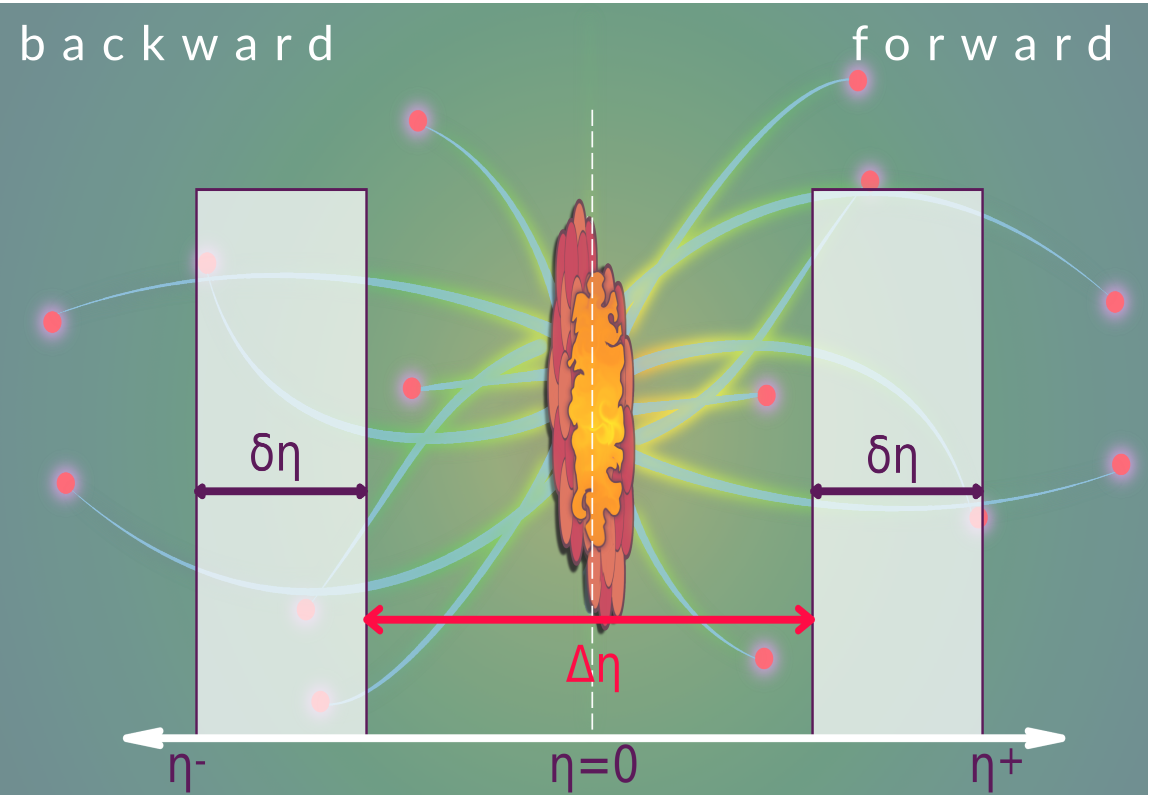
Centrality:

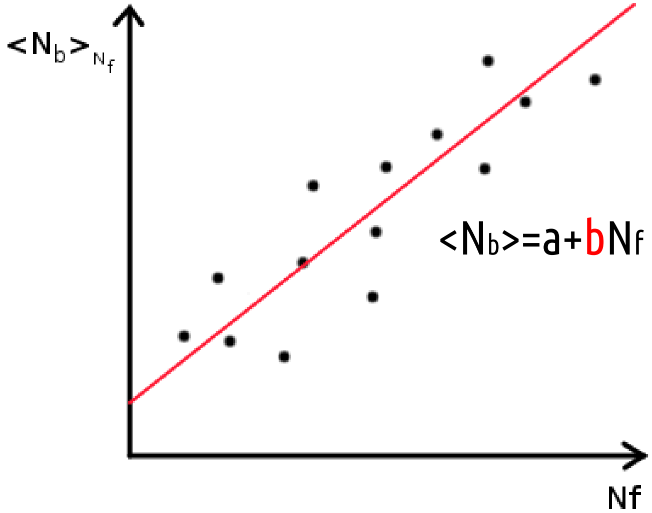
→ estimated by impact parameter

→ estimated by charged particle multiplicity in the V0 acceptance

Forward-backward correlations

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



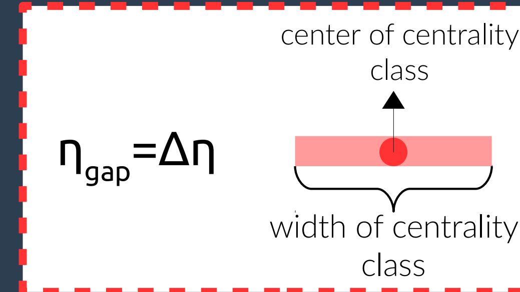


SRC
Δη<1

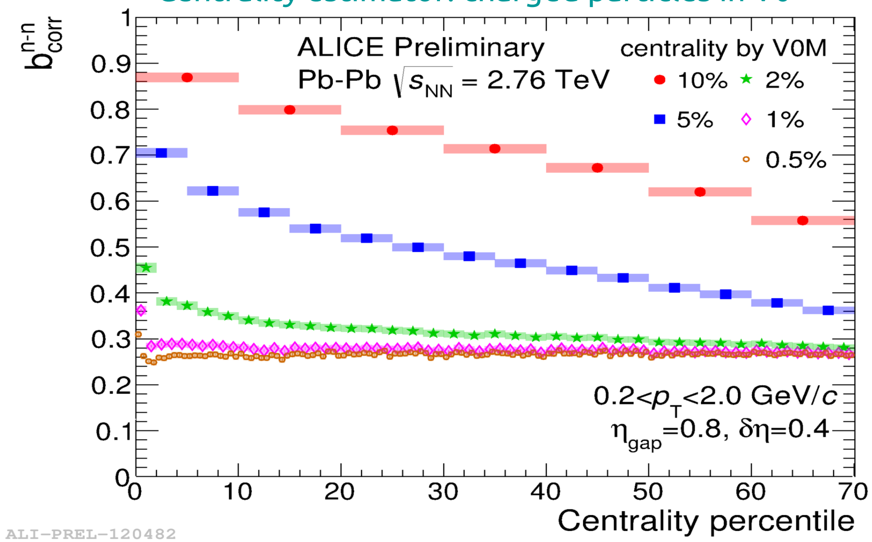
LRC
Δη>1

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

Forward-backward correlations



Centrality estimator: charged particles in V0



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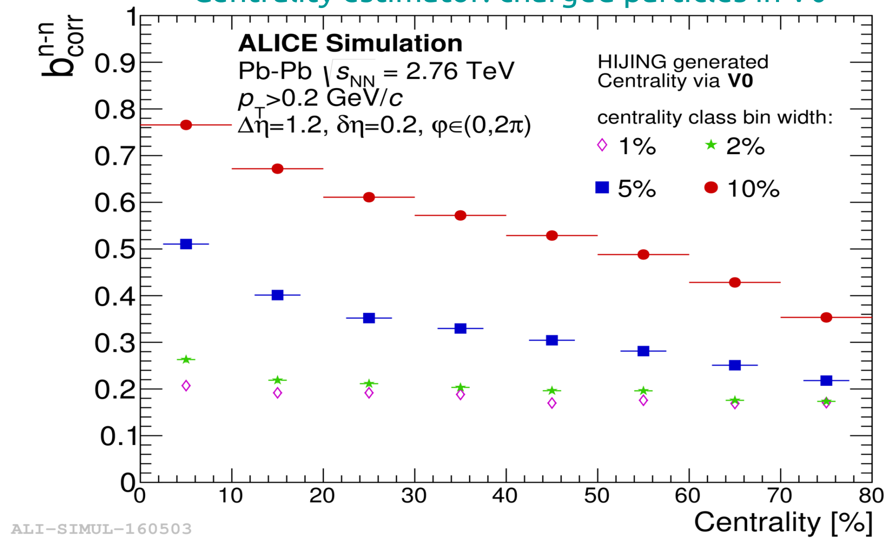
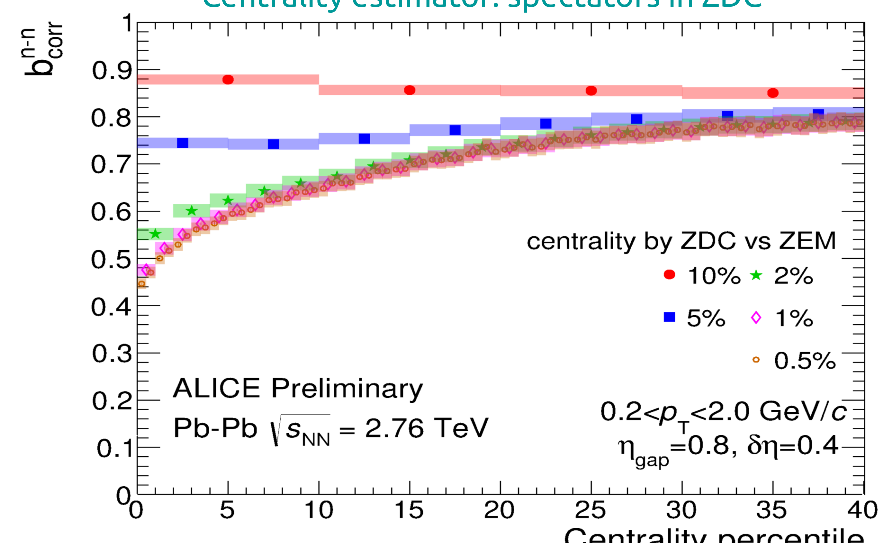
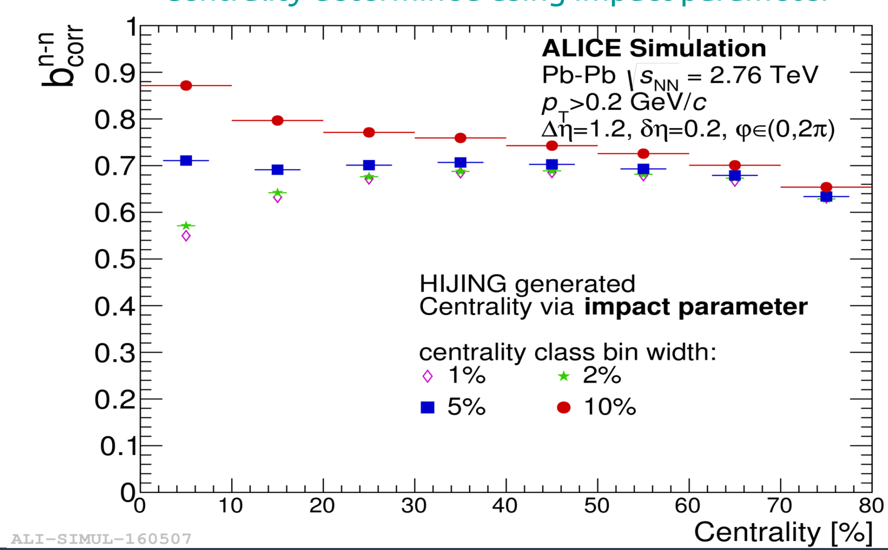


Centrality estimator: spectators in ZDC



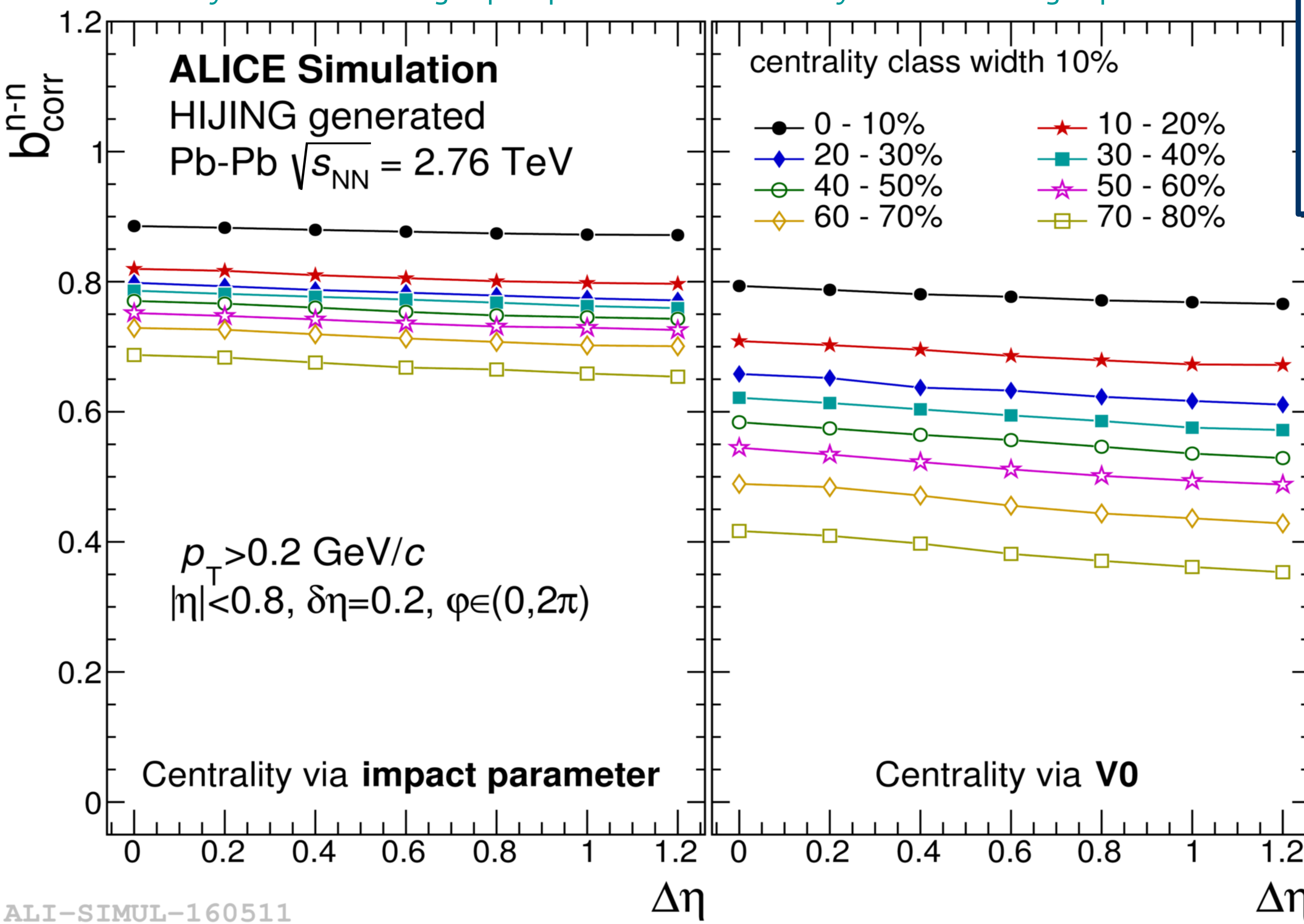
Centrality determined using impact parameter



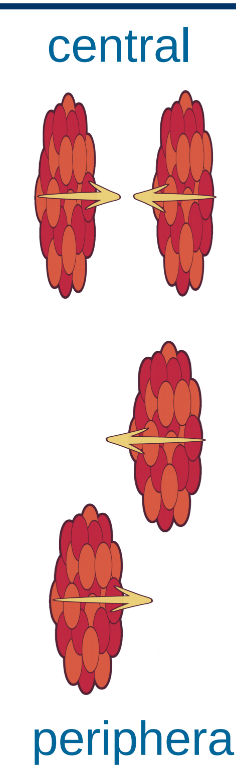
Forward-backward correlations
b_{corr}: dependence on $\Delta\eta$

Centrality determined using impact parameter

Centrality estimator: charged particles in V0



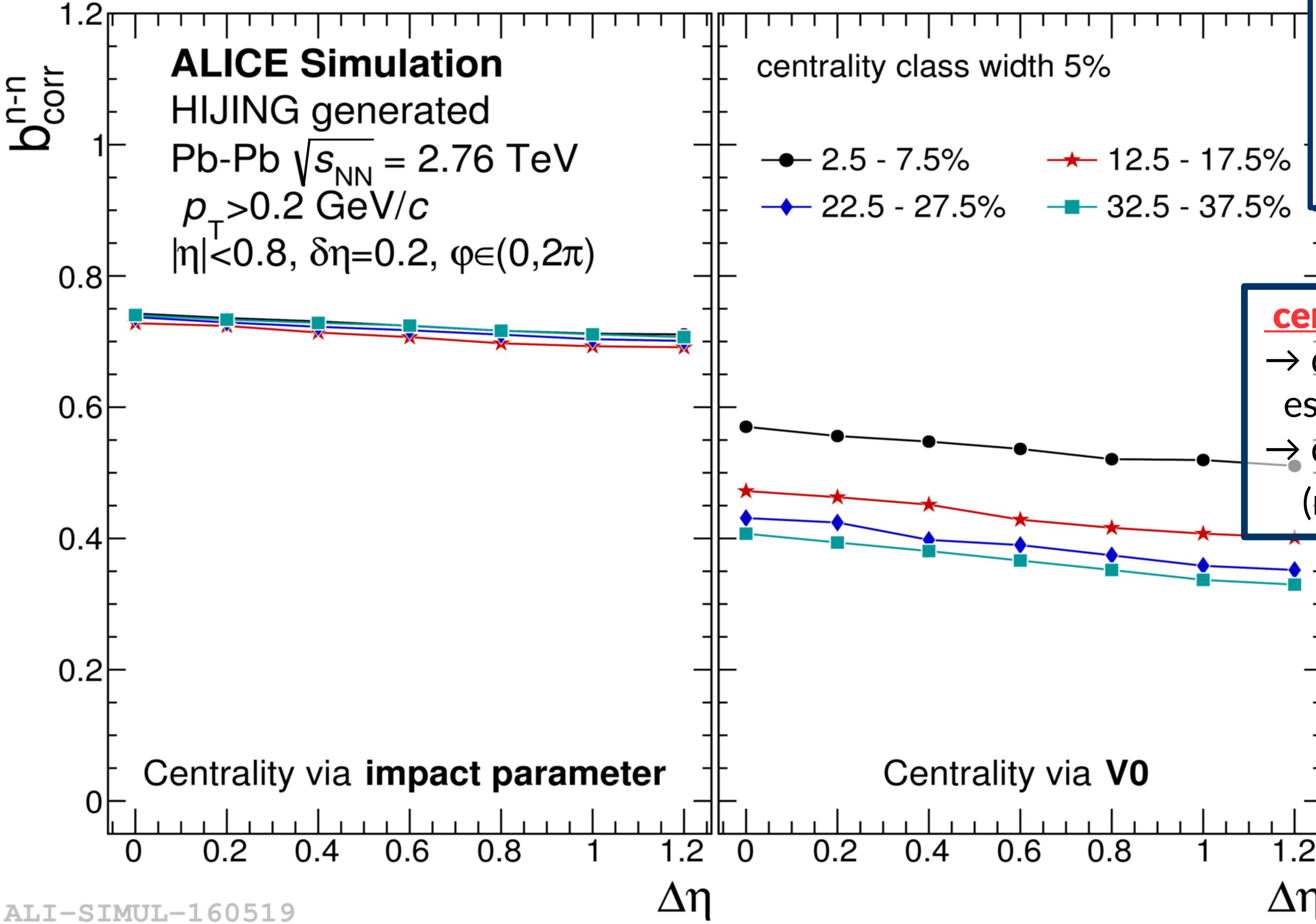
Large values of b_{corr} but large centrality bin width → **large geometrical (i.e. N_{part}) fluctuations** within a single bin of selected centrality.



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

Centrality determined using impact parameter

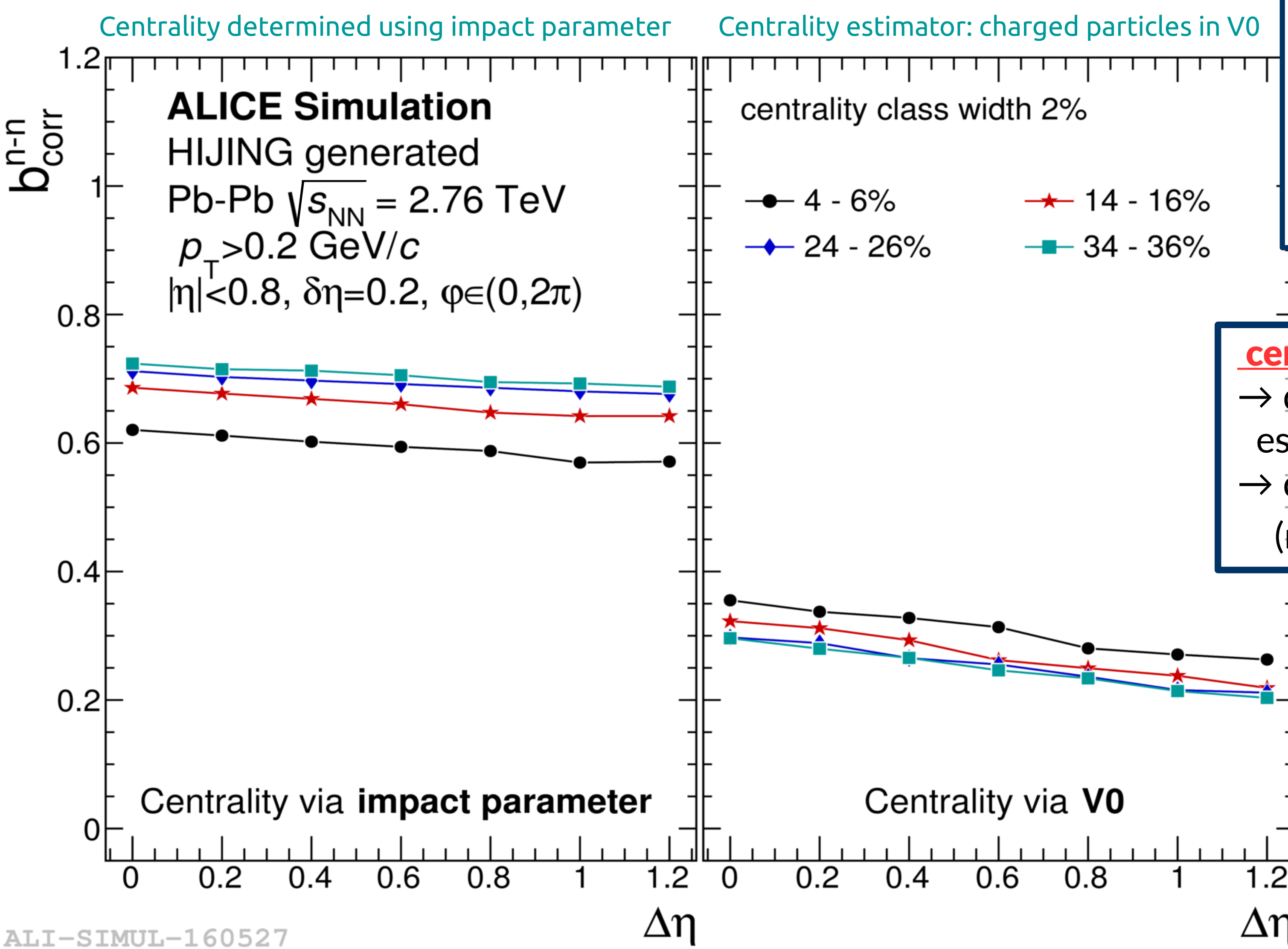
Centrality estimator: charged particles in V0



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

centrality bin width: 10% → 5%
→ dependence on centrality estimator;
→ drop of the value of b_{corr} (reduced fluctuations of N_{part}).

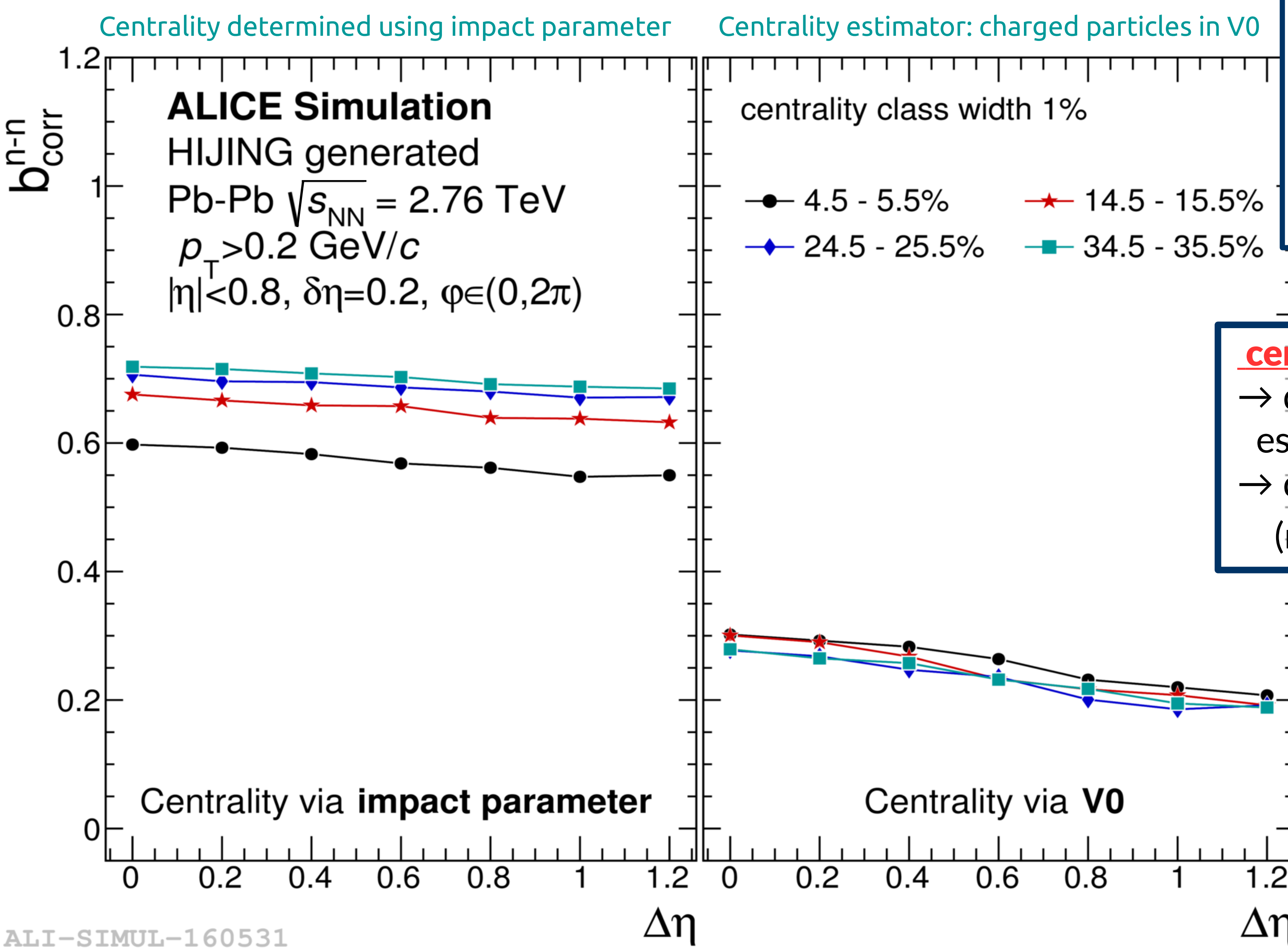
Forward-backward correlations
b_{corr}: dependence on $\Delta\eta$



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

centrality bin width: 10% → 2%
→ dependence on centrality estimator;
→ drop of the value of b_{corr} (reduced fluctuations of N_{part}).

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

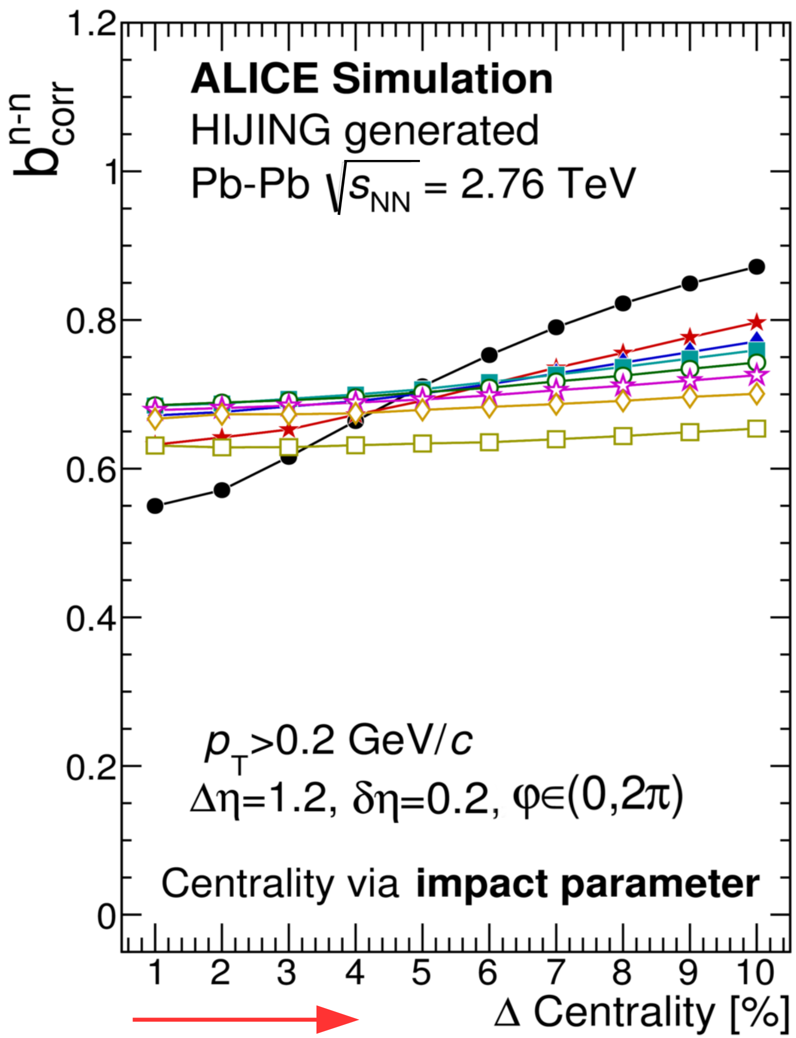


Large values of b_{corr} but large centrality bin width → **large geometrical** (i.e. N_{part}) **fluctuations** within a single bin of selected centrality.

centrality bin width: 10% → 1%
→ dependence on centrality estimator;
→ drop of the value of b_{corr} (reduced fluctuations of N_{part}).

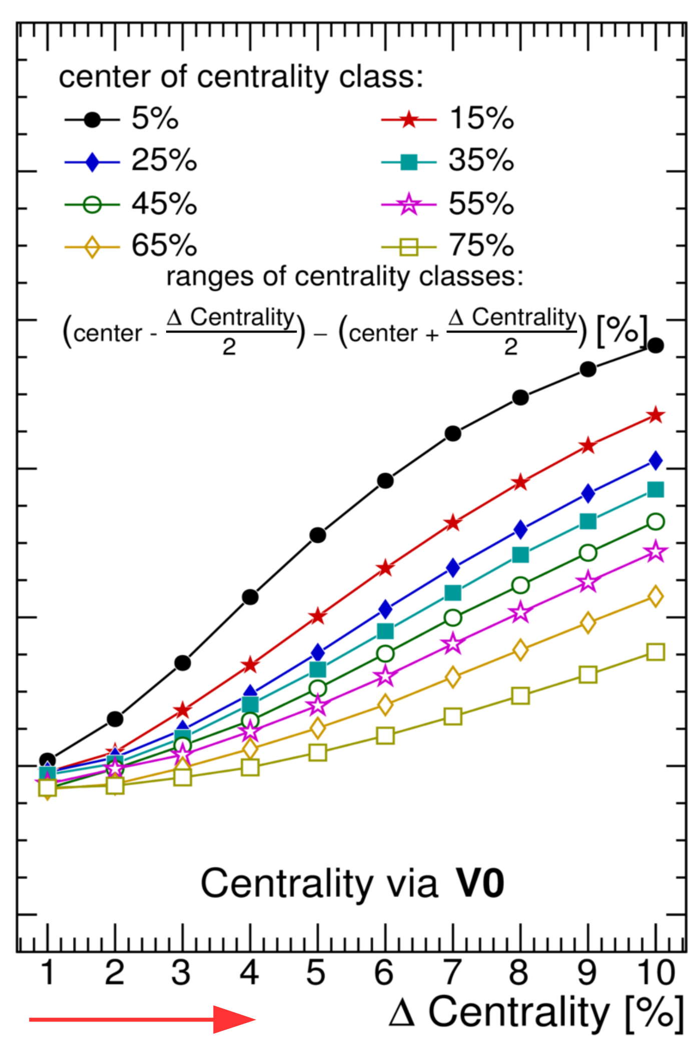
Forward-backward correlations
b_{corr}: dependence on centrality bin width

Centrality determined using impact parameter



geometrical fluctuations

Centrality estimator: charged particles in V0



geometrical fluctuations

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

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

Scaled variance of number of participants ω_{part}

Intensive quantity ω

Intensive quantities do not depend on system volume.

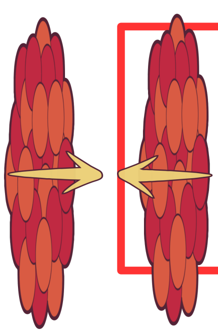
Scaled variance: $\omega_{B(F)} = \frac{Var(n_{B(F)})}{\langle n_{B(F)} \rangle}$

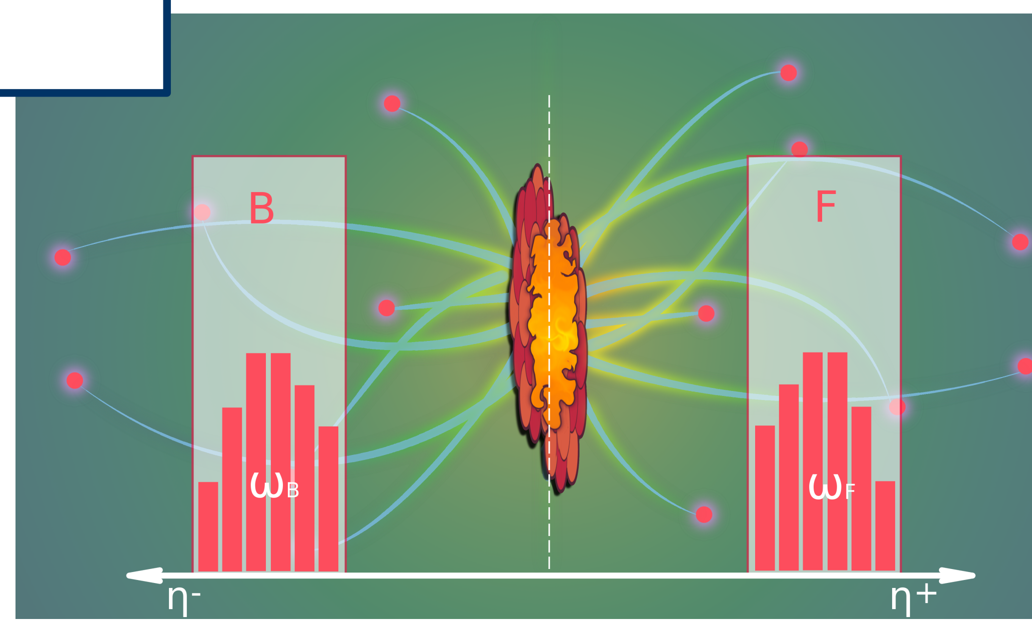
In Independent Source Model:

- **ω** independent from **$\langle N_s \rangle$** (e.g. N_{part})
- **$\omega = \omega_a + \langle a \rangle \omega_s$**

Multiplicity per source

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





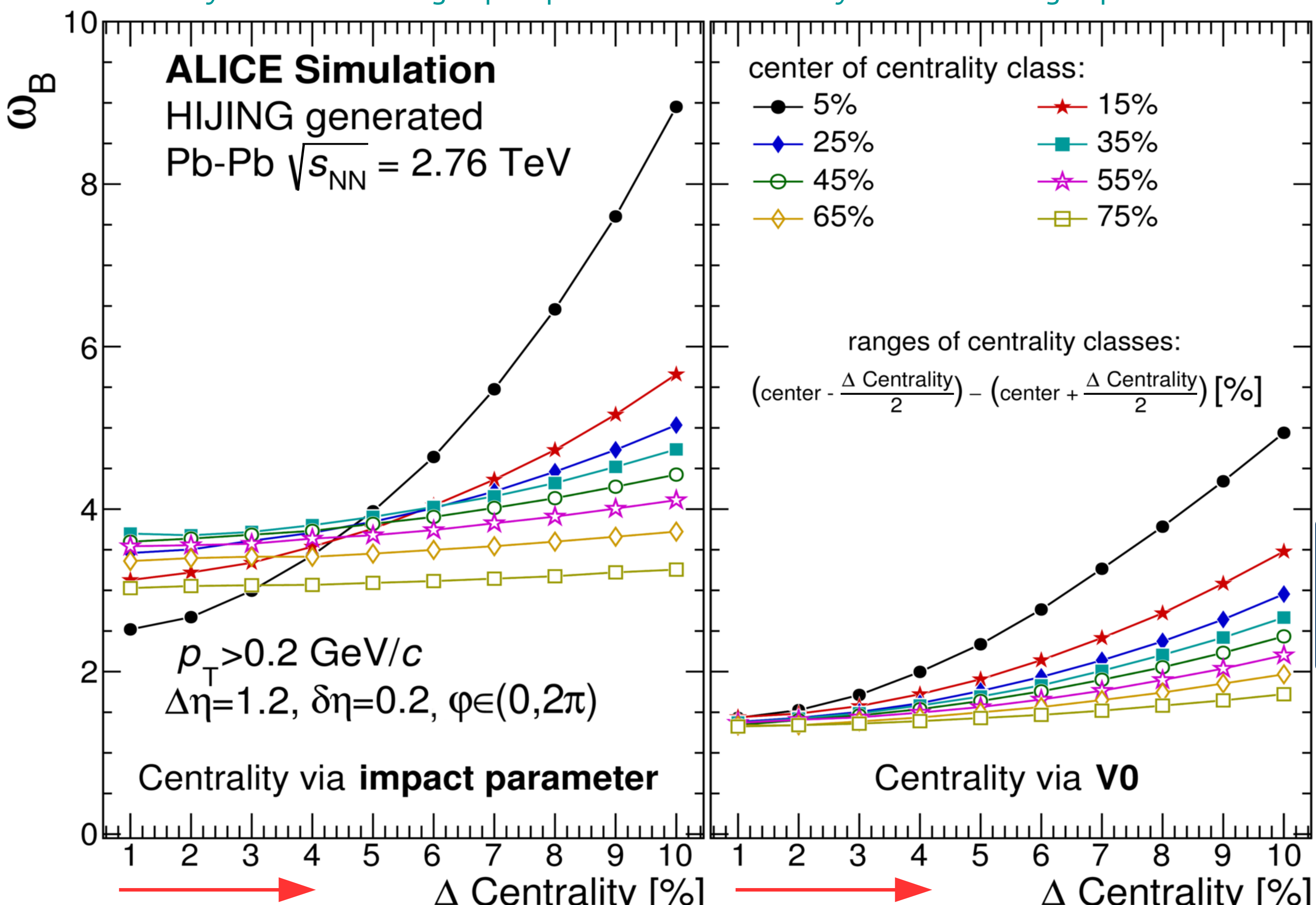
For a symmetric collision, like Pb-Pb:

$\omega_B = \omega_F$

For Poisson distribution: **ω=1**

Intensive quantity ω

Centrality determined using impact parameter — Centrality estimator: charged particles in V0



geometrical fluctuations — geometrical fluctuations

$$\omega = \omega_a + \langle a \rangle \omega_s$$

Multiplicity per source

$\omega_s \approx \omega_{part}$

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

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

Scaled variance of number of participants ω_{part}

Strongly intensive quantity Σ

Intensive quantities do not depend on system volume.

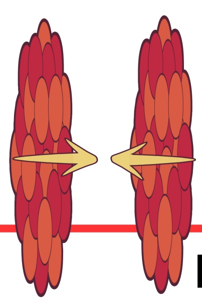
Scaled variance: $\omega_{B(F)} = \frac{Var(n_{B(F)})}{\langle n_{B(F)} \rangle}$

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),ω_s) → **Σ**

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

For a symmetric collision, like Pb-Pb:



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

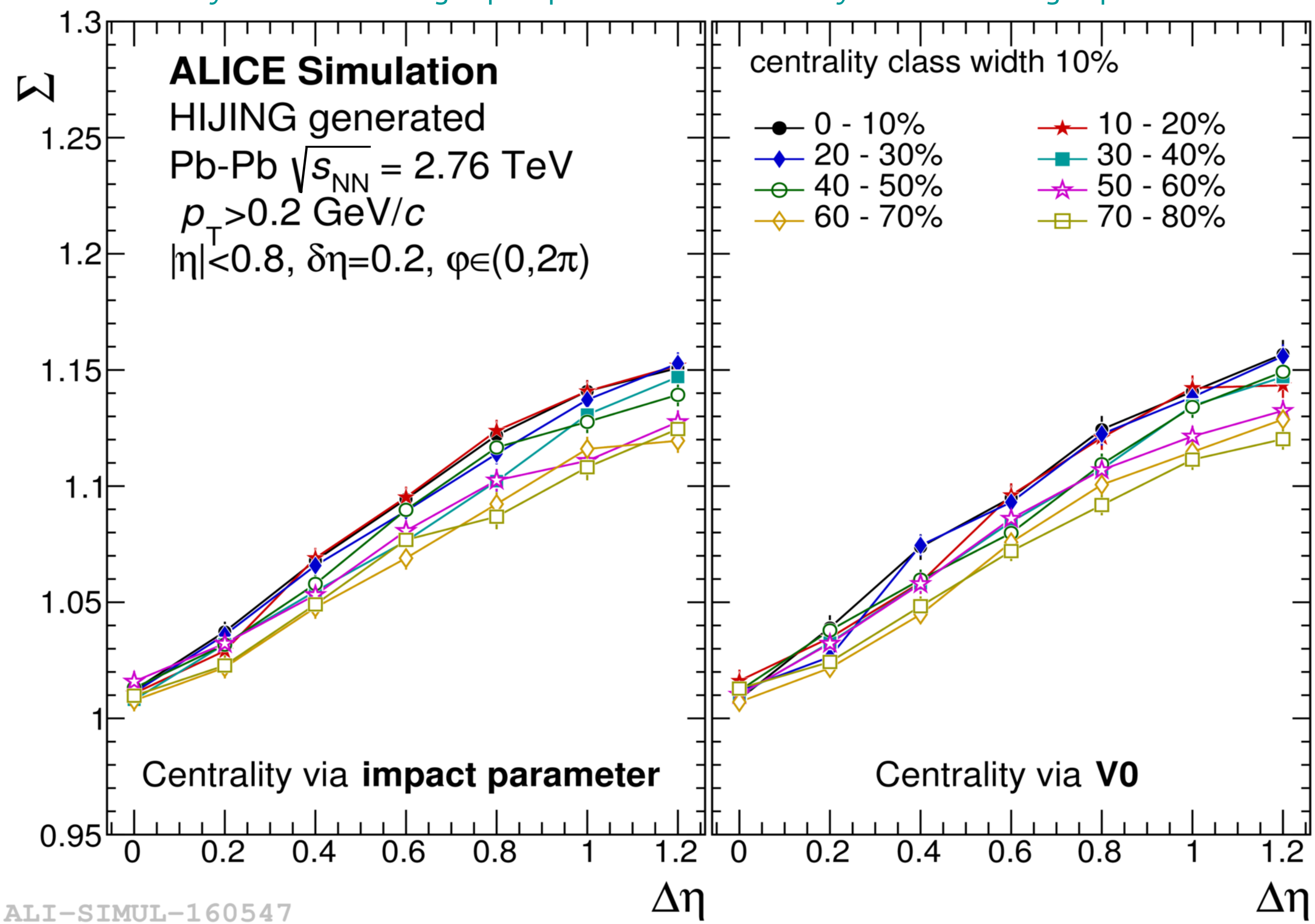
$\Sigma \approx \omega(1 - b_{corr})$

For Poisson distribution: **ω=1 & b_{corr}=0 → Σ=1**

Strongly intensive quantity
Σ: dependence on Δη

Centrality determined using impact parameter

Centrality estimator: charged particles in V0



no dependence on centrality selection!

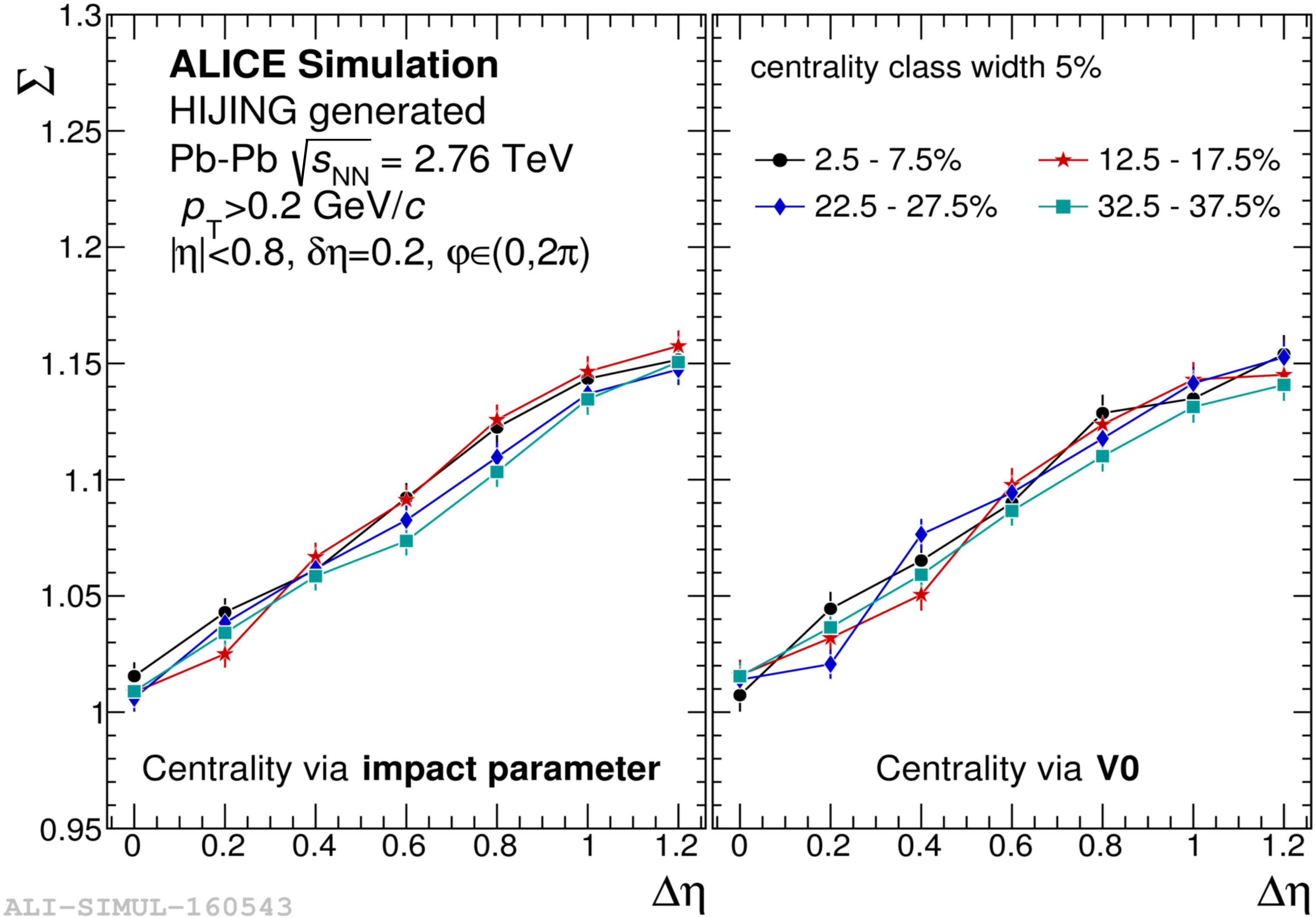
→ increase of values of Σ with Δη;

→ values of Σ>1;

Strongly intensive quantity
Σ: dependence on Δη

Centrality determined using impact parameter

Centrality estimator: charged particles in V0



no dependence on centrality selection!

→ increase of values of Σ with Δη;

→ values of Σ>1;

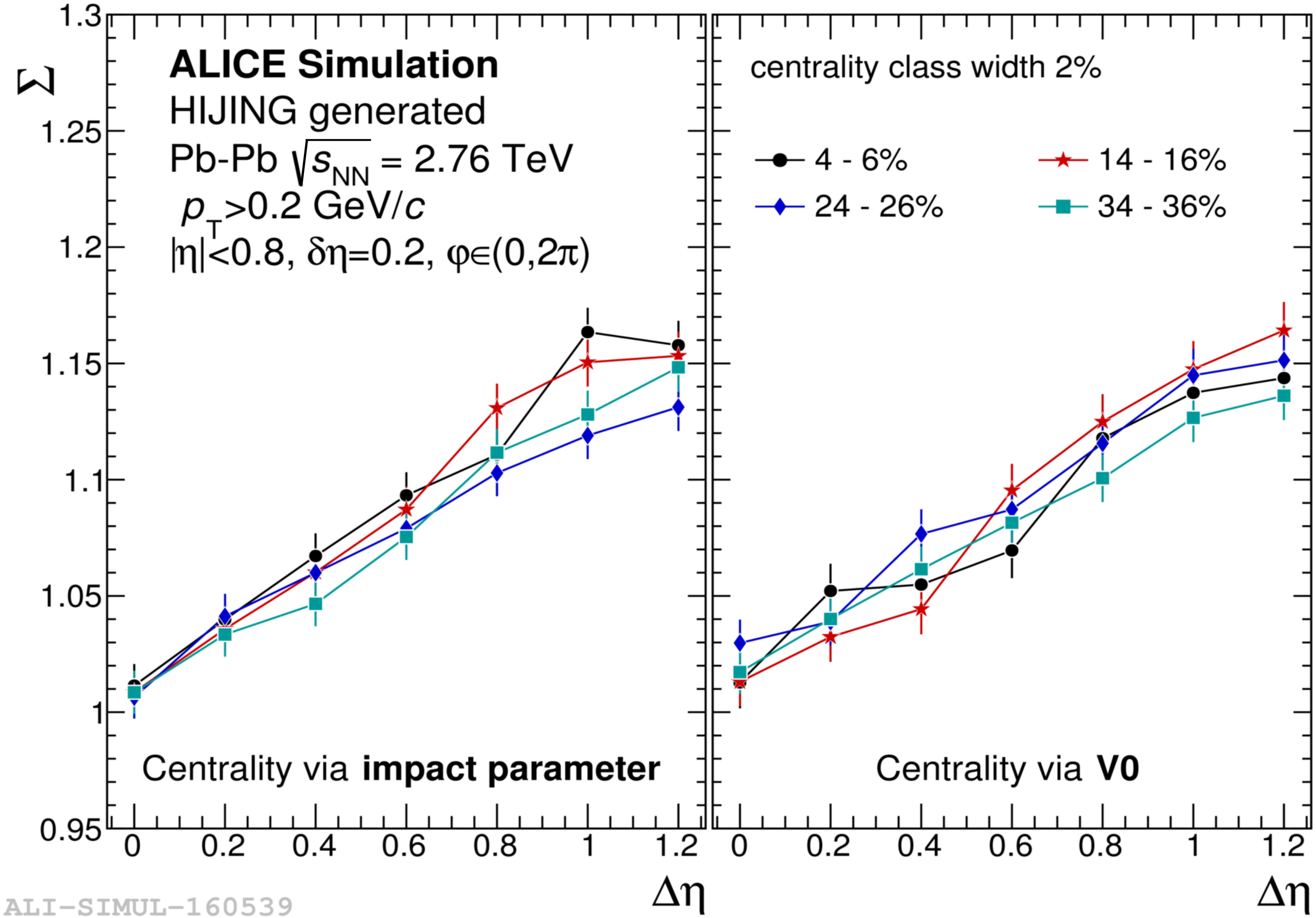
centrality bin width: 10% → 5%

Σ does not depend on centrality bin width.

Strongly intensive quantity

Σ: dependence on Δη

Centrality determined using impact parameter — Centrality estimator: charged particles in V0



no dependence on centrality selection!

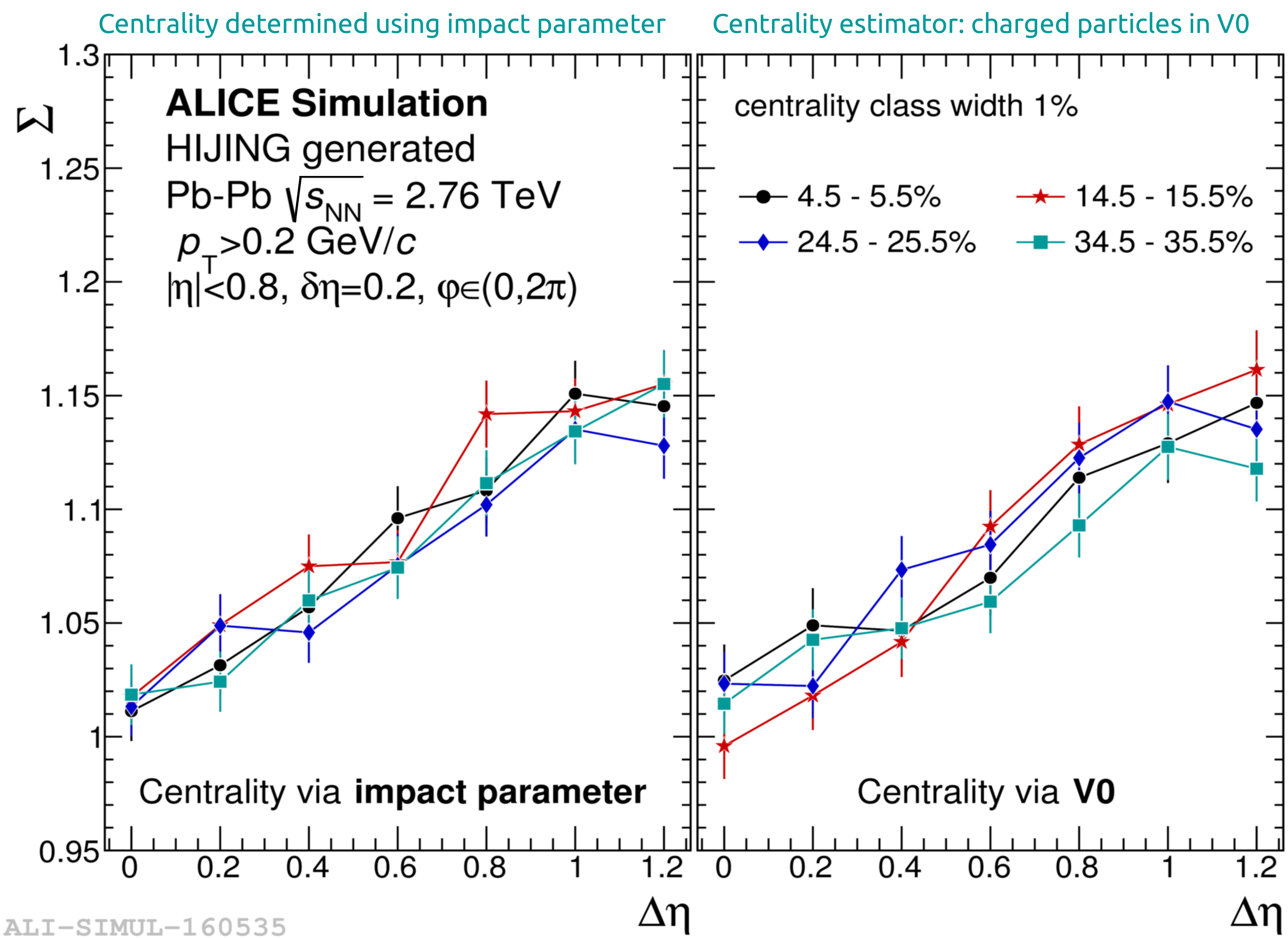
→ increase of values of Σ with Δη;

→ values of Σ>1;

centrality bin width: 10% → 2%

Σ does not depend on centrality bin width.

Strongly intensive quantity
Σ: dependence on Δη



no dependence on centrality selection!

→ increase of values of Σ with Δη;

→ values of Σ>1;

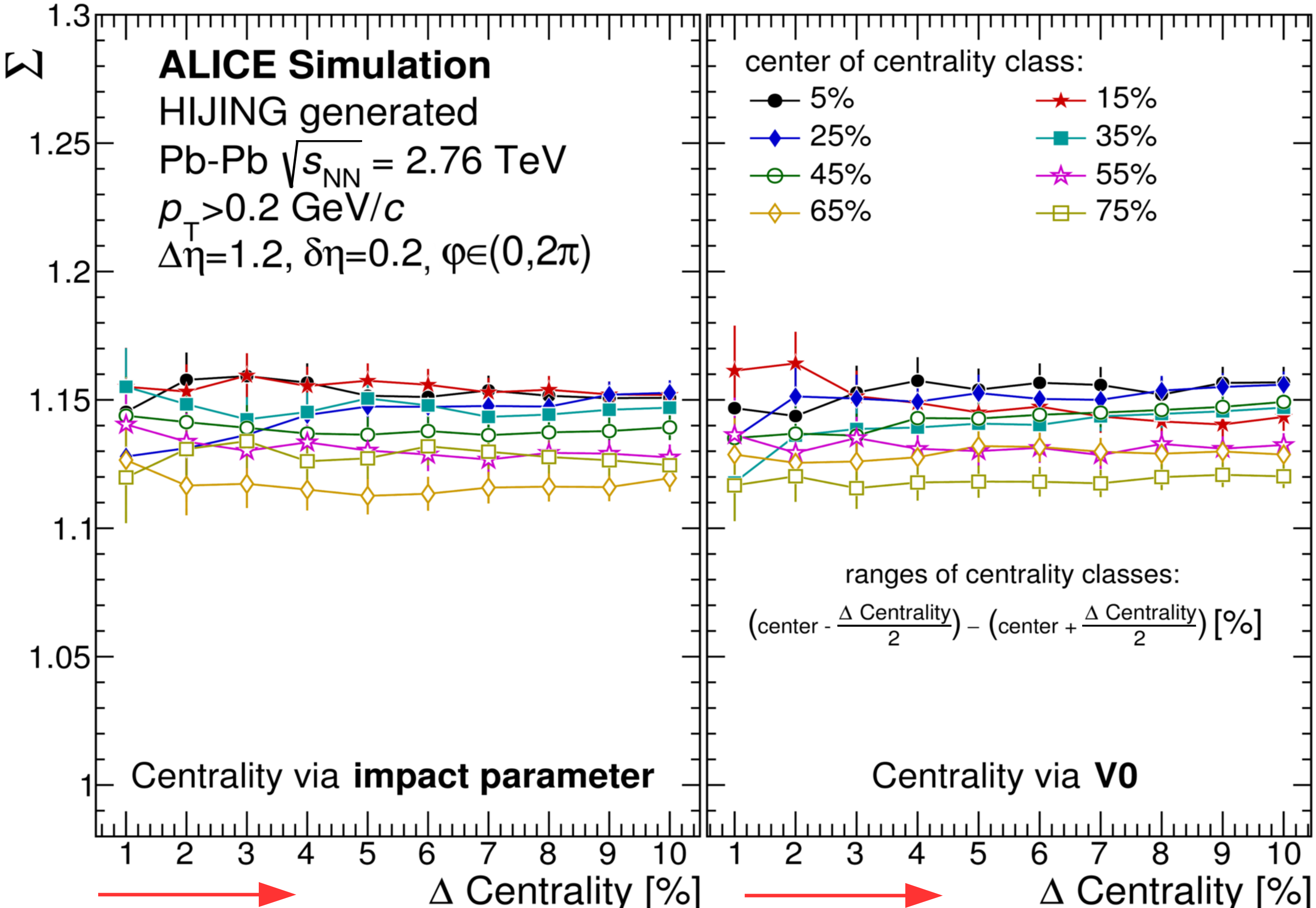
centrality bin width: 10% → 1%

Σ does not depend on centrality bin width.

Strongly intensive quantity
Σ: dependence on centrality bin width

Centrality determined using impact parameter

Centrality estimator: charged particles in V0



geometrical fluctuations

geometrical fluctuations

no dependence on centrality selection!

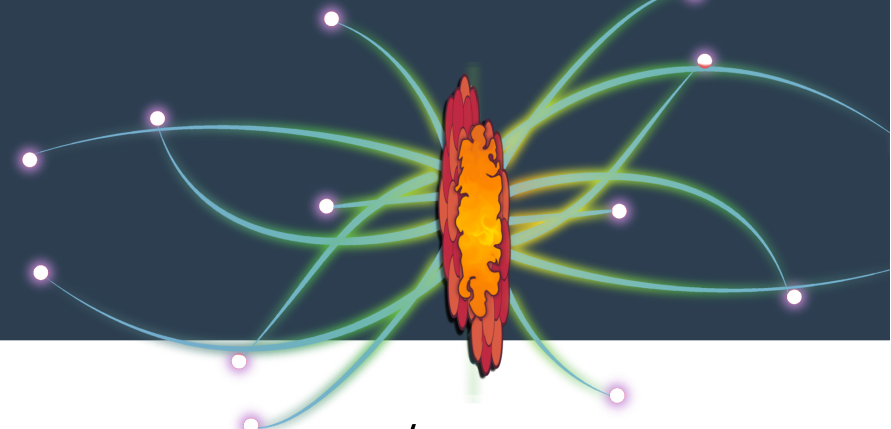
+

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. First data on forward-backward correlations (b_{corr}) in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV:
→ large dependence on centrality bin width and estimator!
→ information on early dynamics is mixed with trivial geometrical fluctuations.

2. A detailed MC analysis of the FB correlation coefficient (b_{corr}), intensive (ω), and strongly-intensive (Σ) quantities at LHC energies:
→ ω: large dependence on centrality bin width and estimator;
→ Σ: deviation from unity, increase with rapidity gap;
→ Σ: does not depend on centrality selection method nor on centrality bin width
→ these are properties of a strongly intensive quantity!

3. Experimental data on intensive (ω), and strongly-intensive (Σ) quantities in Pb-Pb collisions at LHC energies will be avaliable soon (is ongoing).
→ comparison between experimental data and MC simulations for the strongly intensive quantity Σ will bring important information on the early dynamics, unaffected by trivial geometrical fluctuations.

THANK YOU!