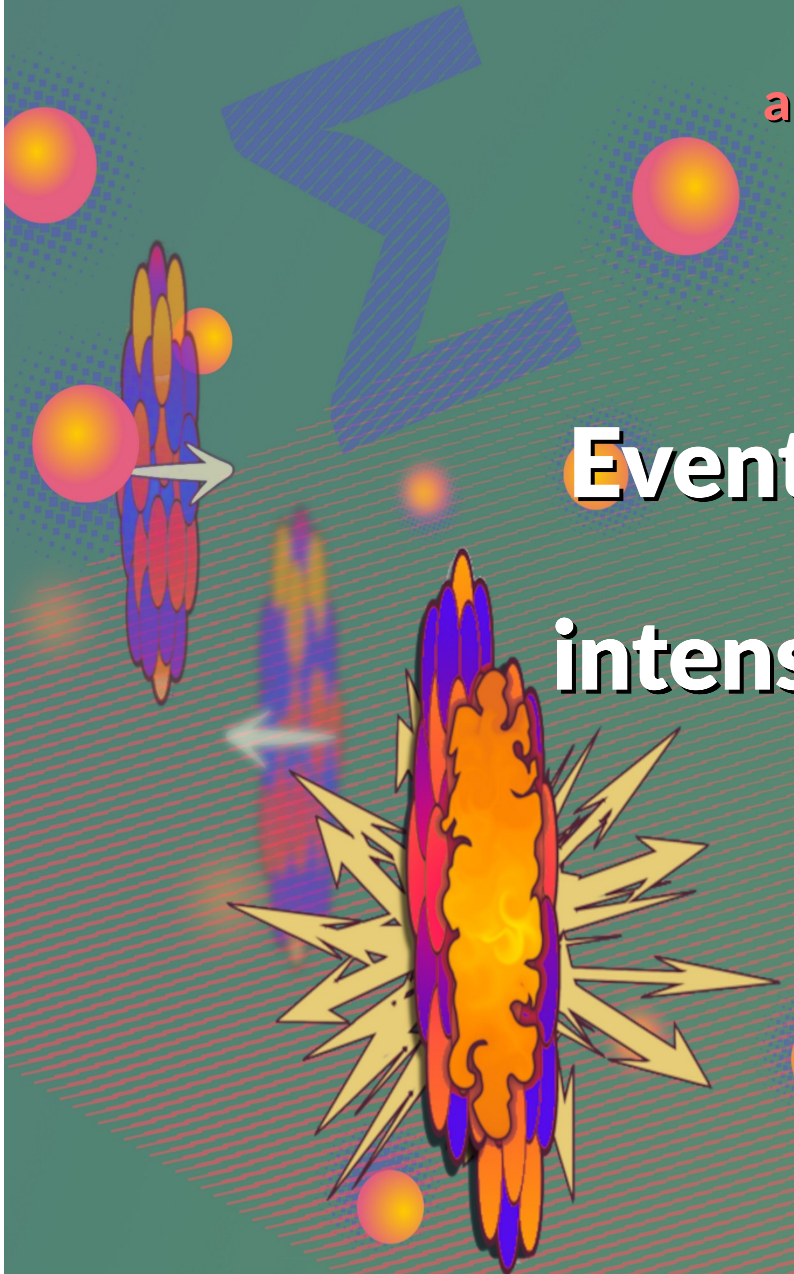
The XVth Quark confinement
and the Hadron spectrum conference

Stravanger, 01 – 06 August, 2022



Event-by-Event correlations and fluctuations with strongly intensive quantities in heavy-ion collisions with ALICE

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Outline

Overview of the ALICE measurement of the **strongly intensive quantity** Σ in terms of forward-backward correlations analysis…

…in various colliding systems and energies.

Plan:

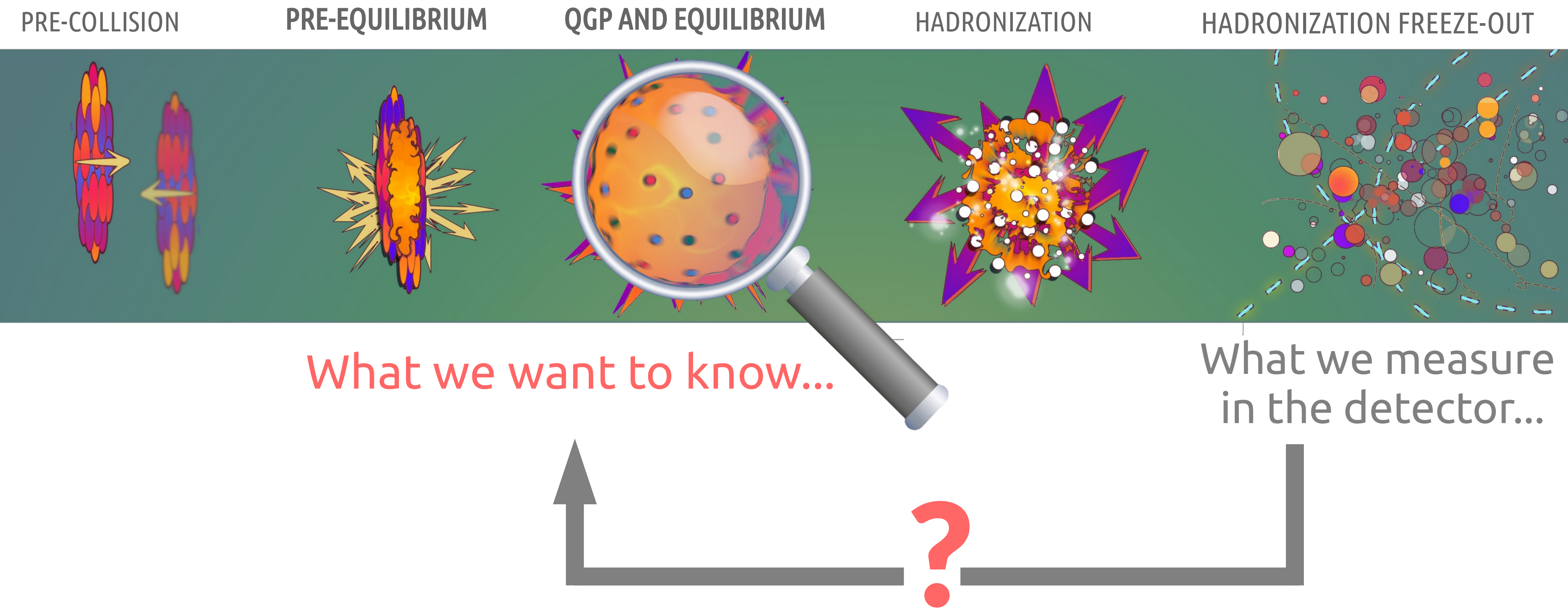
1. Motivation;

2. Analysis;

3. Results;

4. Summary.

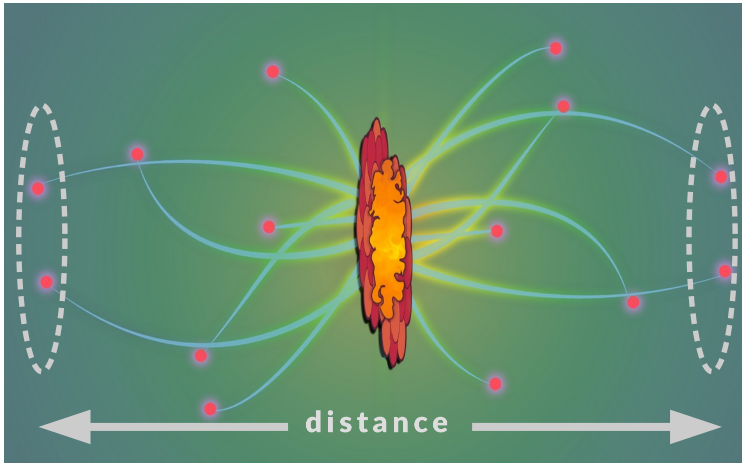
Motivation: Why do we study correlations and fluctuations?



Analysis of correlations and fluctuations can provide information about **the early stages of heavy-ion collisions.**

Motivation: Why do we study correlations and fluctuations?

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

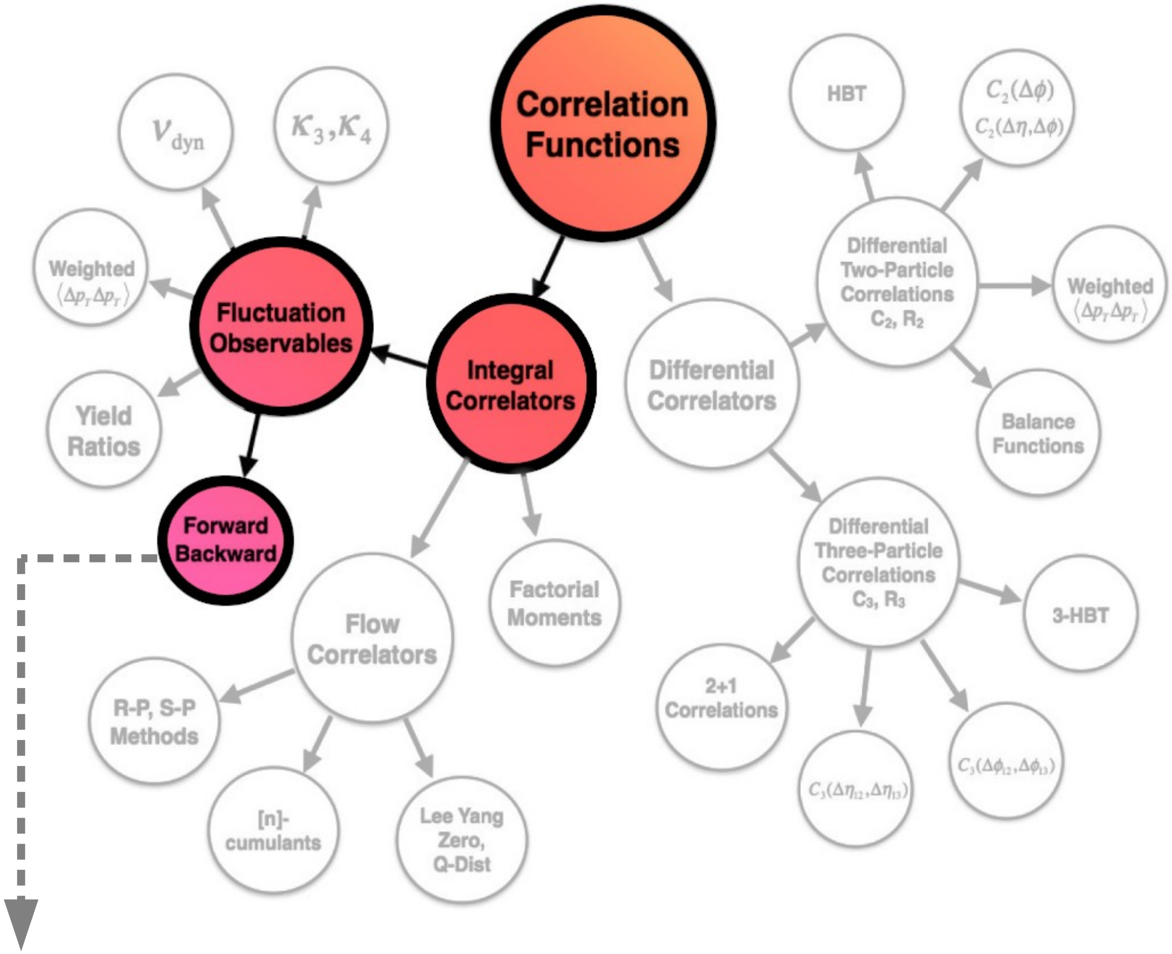


- LRC carry **information** on the **early dynamics** of the nuclear collision.

2. Analysis of **fluctuations** in the number of particles produced in A–A 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 trivial fluctuations of the volume of the system.

The Analysis: How do we study correlations and fluctuations?

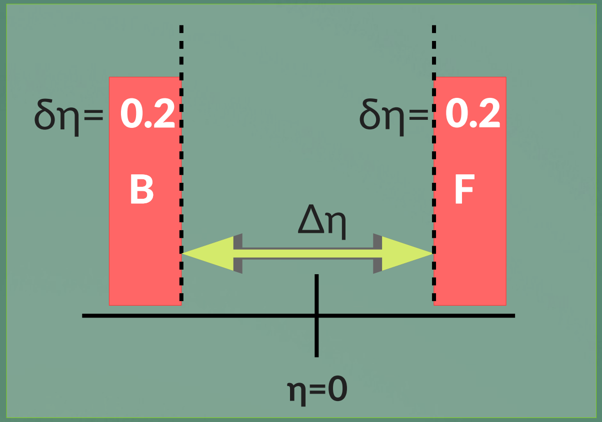


We are here!

Picture from: Claude A. Pruneau, Data Analysis Techniques for Physical Scientists, 2017, Cambridge University Press.

ALICE

The forward-backward (FB) correlation:



A popular technique:

The FB **correlation coefficient** b_{corr} is:

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

- largely influenced by **geometrical (volume) fluctuations.**
- dependent on **centrality estimator.**

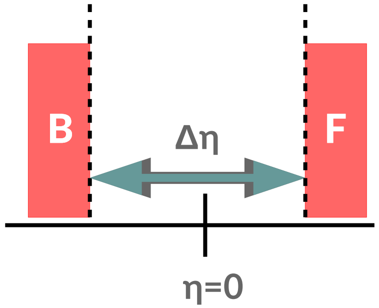
The Analysis: FB correlations with strongly intensive quantity Σ

- **Strongly intensive quantities** do not depend on system volume nor system volume fluctuations.

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

STRONGLY INTENSIVE QUANTITY Σ:

$$\Sigma = \frac{\langle n_F\rangle \omega_B + \langle n_B\rangle \omega_F - 2\mathrm{Cov}(n_F, n_B)}{\langle n_F\rangle + \langle n_B\rangle}$$



- For a symmetric collision $\omega_B = \omega_F$ and $\langle n_F\rangle = \langle n_B\rangle$,

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

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

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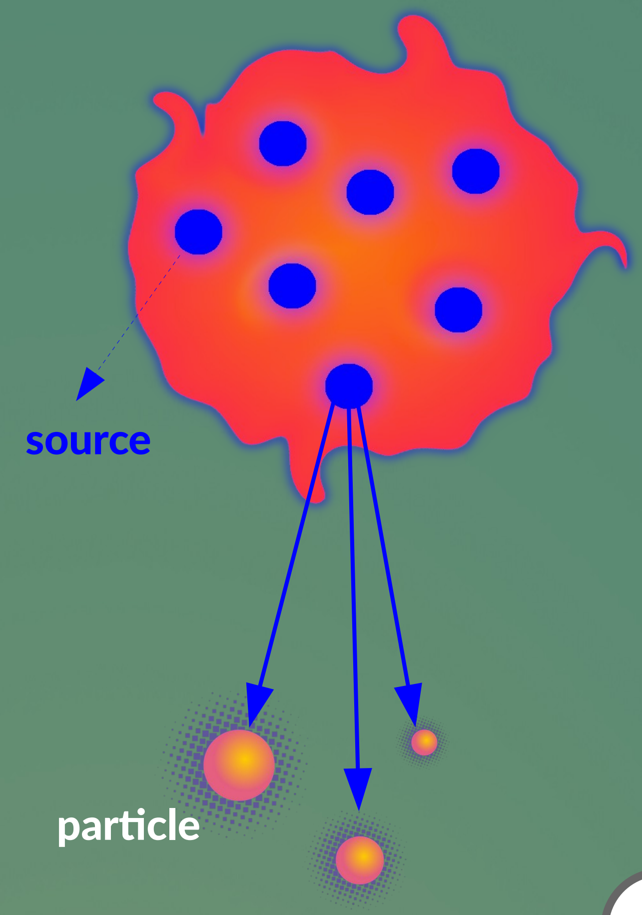
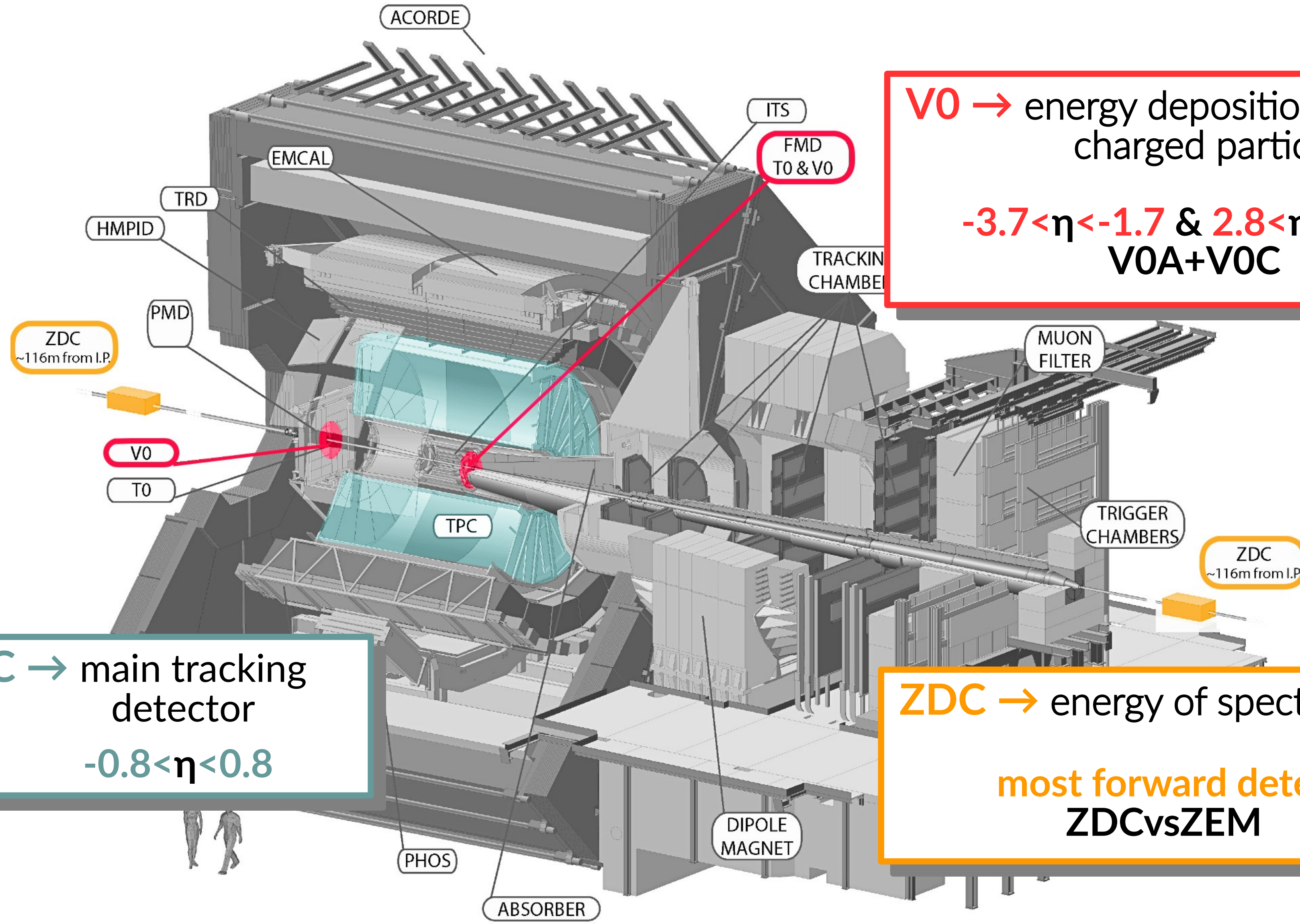
Independent source model:

Σ → gives direct information about characteristics of **single source distribution!**



The Analysis: ALICE experiment



V0 → 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 → energy of spectators

most forward detector

ZDCvsZEM

The Analysis: Data Sample

Experimental data:

→ **Pb−Pb @ $\sqrt{s_{NN}}$= 2.76 and 5.02 TeV**

→ **Xe−Xe @ $\sqrt{s_{NN}}$ = 5.44 TeV**

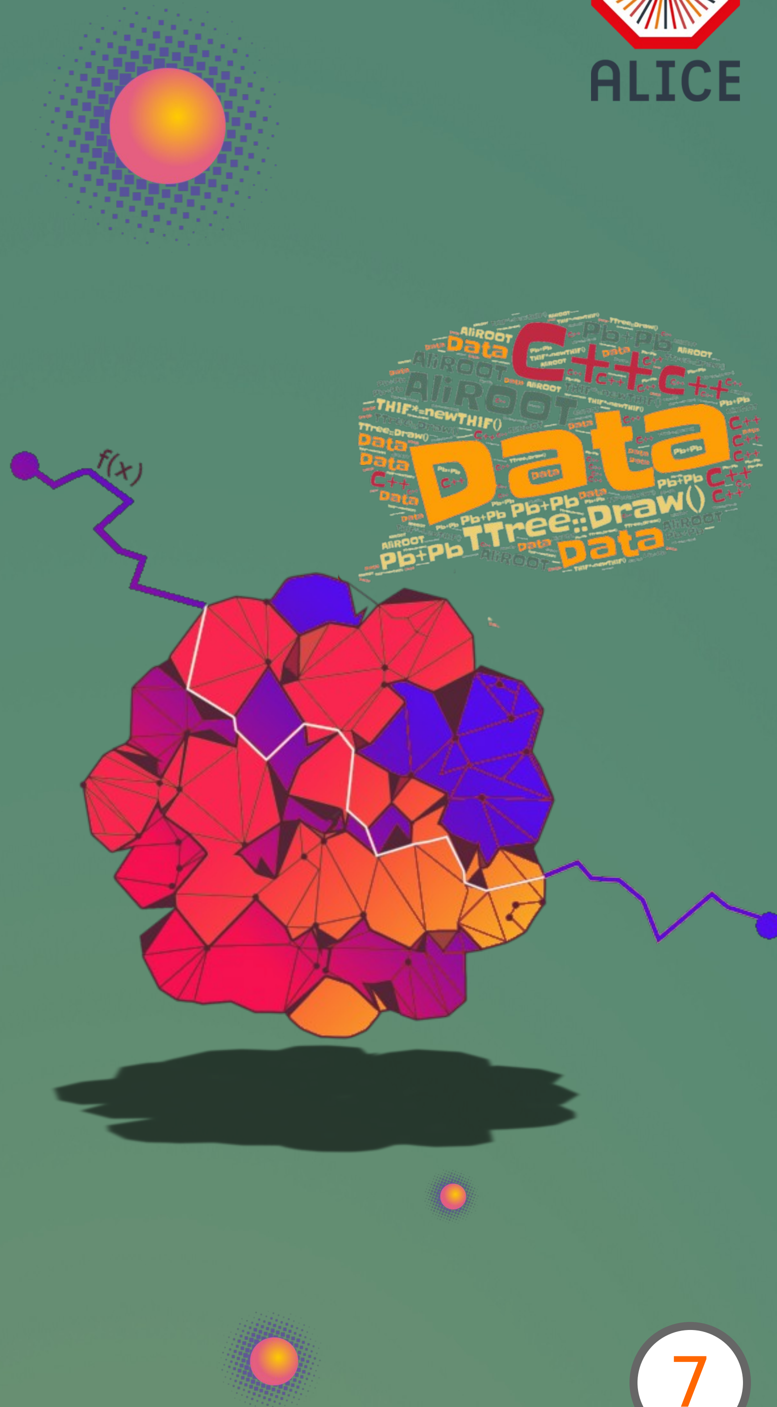
→ **pp @ $\sqrt{s}$ = 13 TeV**

Tracks: **-0.8<η<0.8,**

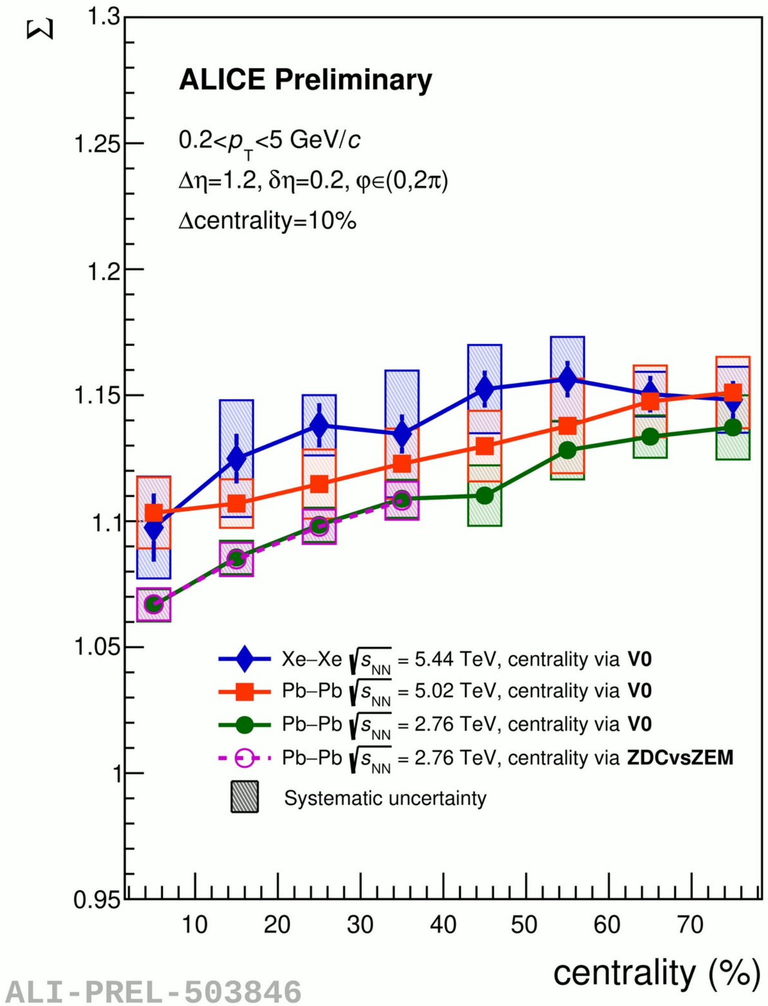
pp analysis→ **0.2 <p_T<2 GeV/c**

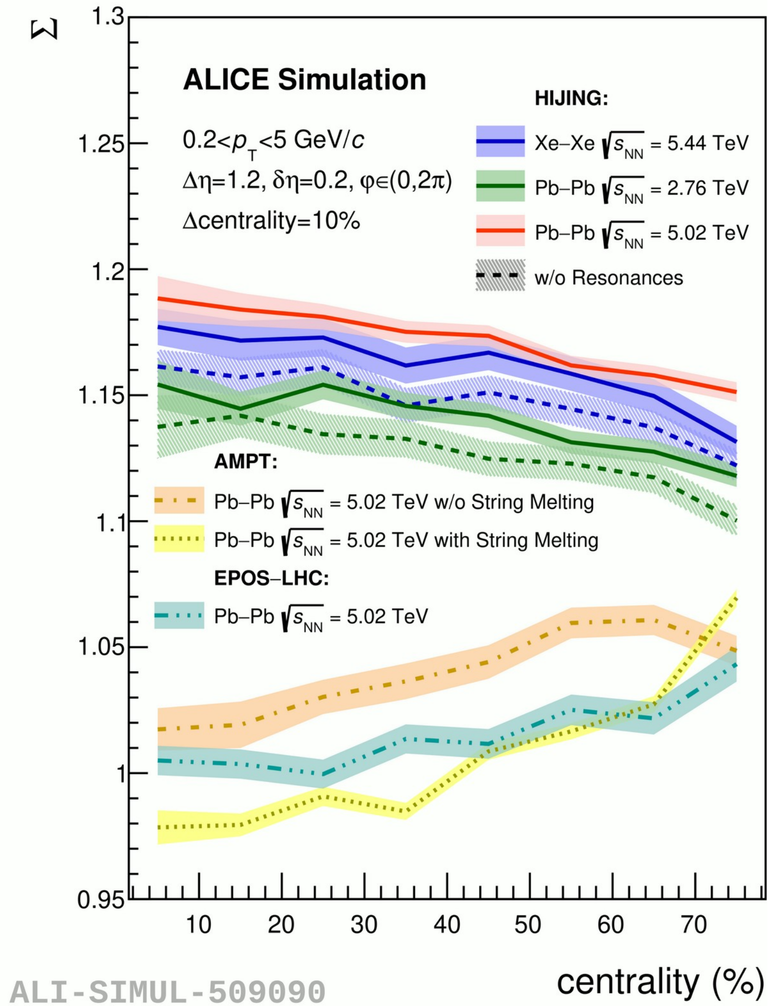
A-A analysis→ **0.2 <p_T<5 GeV/c**

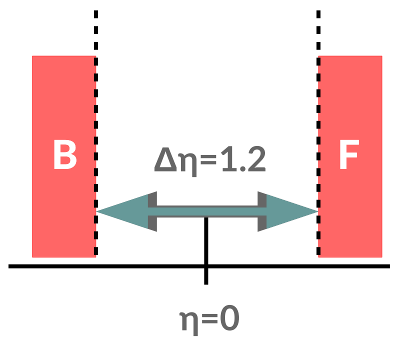
Centrality estimators: **V0 ($N_{charged}$),**
ZDC ($N_{spectators}$)



Results: Σ as a function of centrality



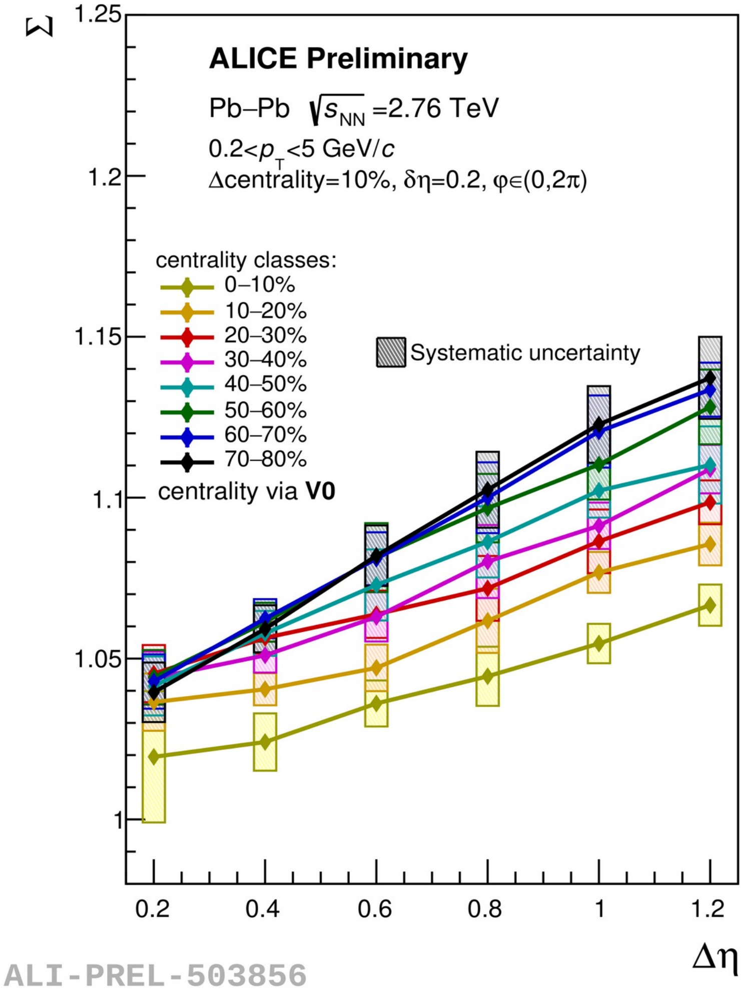


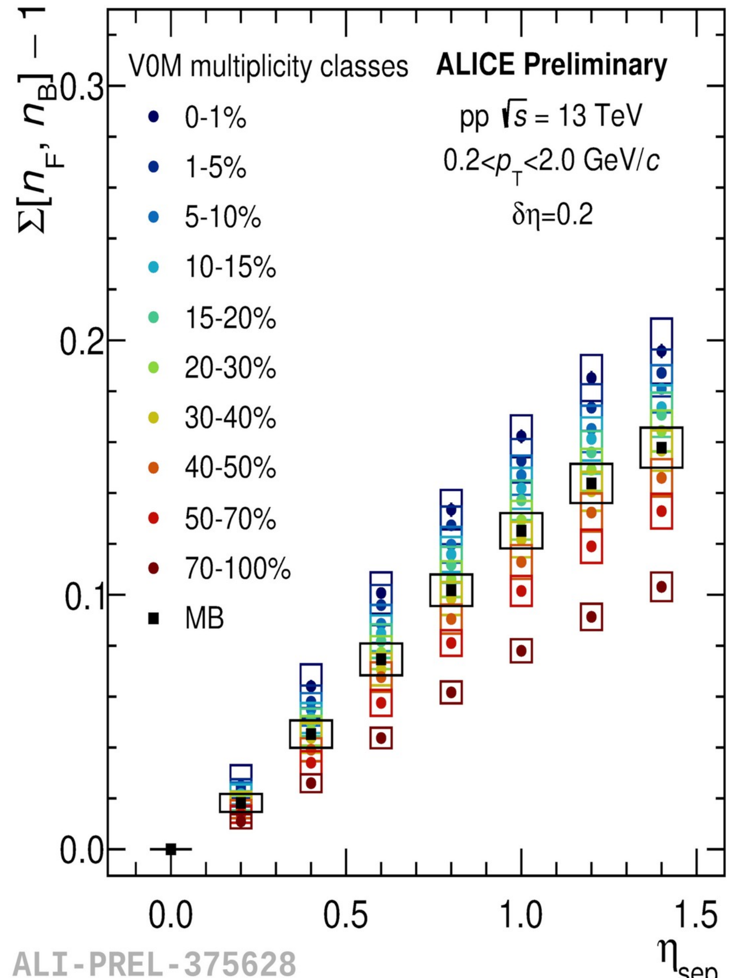


V0 ≈ ZDCvsZEM
→ no dependence
on centrality estimator!

- Values of Σ **increase with energy** and **increase with decreasing centrality** in experimental data, contrary behavior noted for MC HIJING results.
- MC AMPT and MC EPOS reproduce dependence on centrality qualitatively but not quantitatively.
- From results for MC AMPT it is evident that Σ is sensitive to the initial conditions.

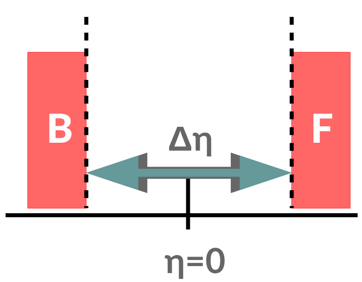
Results: Σ as a function of Δη



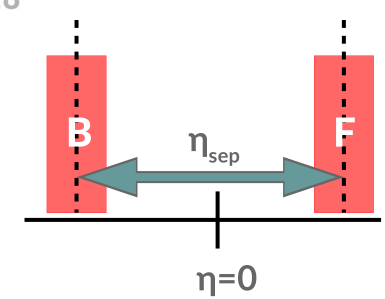


- **increase** with Δη;
- **Pb–Pb: decrease** of Σ with increasing centrality class;
- **pp:** Σ **grows** with the increase of forward event multiplicity; contrary to Pb–Pb.

Different ordering of Σ with centrality for Pb–Pb and pp.



$\eta_{sep} = \Delta\eta + 0.2$



Summary

New results for measurement of the FB correlation with the strongly intensive quantity Σ have been presented:

- **Σ increases with energy and with decreasing centrality** in experimental data, contrary behavior noted for MC HIJING results and experimental pp collisions.
- Removal of the resonances contribution does not change the dependence (ordering) of Σ with centrality.
- MC AMPT and EPOS reproduce the dependence on centrality **qualitatively** but **not quantitatively**.
- From results for MC AMPT it is evident that Σ is sensitive to the initial conditions.
- The comparison of **centrality ordering** in A−A reactions versus theoretical models, and experimental pp data, may provide new insight into the underlying dynamics of the collision.
- **What model can reproduce Σ behavior?**

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ALICE

LEARN MORE ABOUT Σ:
with one "click"

Strongly Intensive Quantities

Σ in pp with ALICE

Dependence on centrality selection and volume fluctuatations

Σ in A-A with ALICE