TES HEP 2023

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

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TES HEP 2011

Me :-), after 1st year of my PhD...

Analysis of Pb+air Reactions

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This note presents the analysis of charged pions produced in Pb+air collisions. The Pb+air reactions were the background to peripheral Pb+Pb collisions at the energy 158 GeV/nucleon, studied at the NA49 experiment at CERN SPS. I focused on the distortion of the π^+/π^- ratio in Pb+air reactions induced by the electromagnetic interaction between charged pions and the spectator system. The reference point for the results from Pb+air collisions were peripheral Pb+Pb reactions and Monte Carlo simulations.

NA49 was a fixed target experiment at CERN SPS. It studied hadron-hadron, hadron-nucleus and nucleus-nucleus collisions (i.e. Pb+Pb) in wide range of beam energies from 20 GeV/nucleon to 158 GeV/nucleon. In Pb+Pb collisions at the energy of 158 GeV/nucleon the lead target was not contained in vacuum. Some non-target (ăĂIJbackgroundăĂİ) events of Pb+air reactions entered the sample of Pb+Pb collisions, and it was possible to select those events. This paper presents the results of studies of Pb+air reactions where the observed charged particle multiplicity was 150-300, the same as the cut defining peripheral Pb+Pb collisions [1].

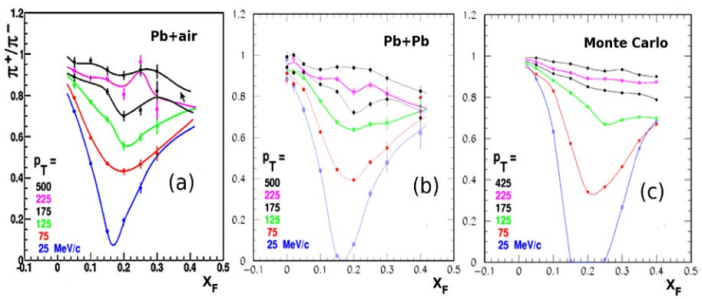
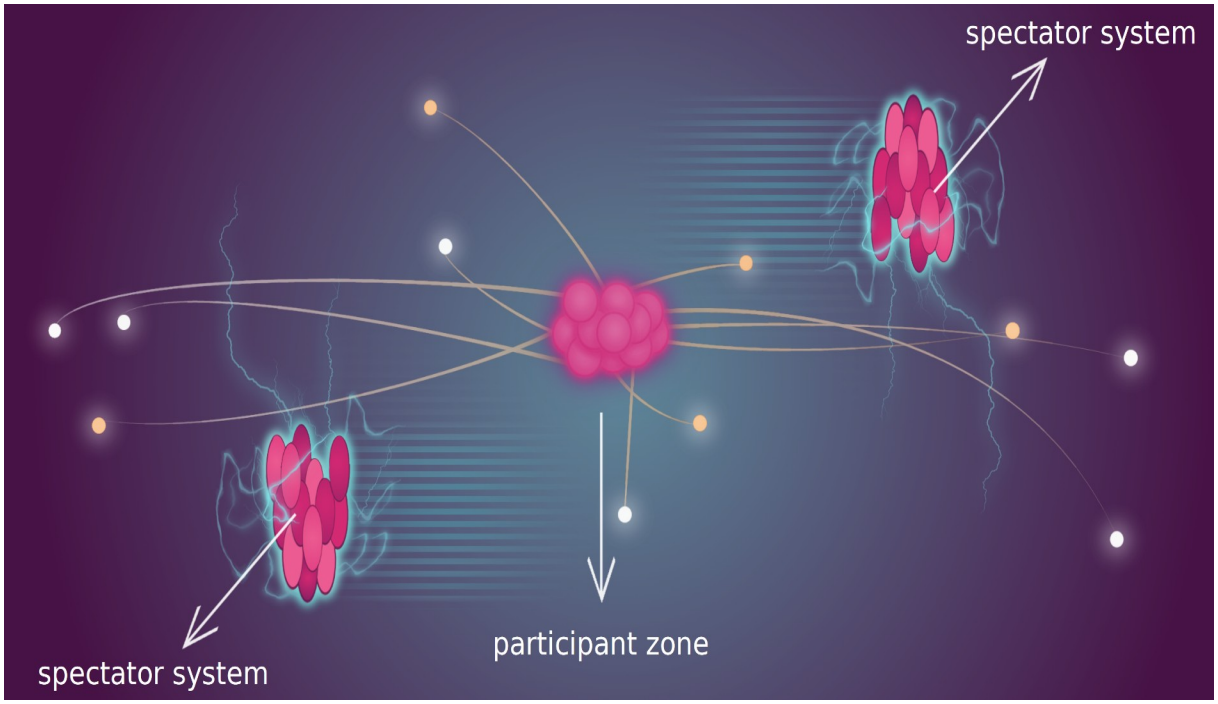


Figure 1: π^+/π^- ratios drawn as a function of the Feynman variable $x_F = 2p_L/\sqrt{s_{NN}}$ (nucleon-nucleon c.m.s.) at several values of p_T for: (a) experimental data from Pb+air collisions and (b) peripheral Pb+Pb reactions and (c) the results of MC simulation for peripheral Pb+Pb collisions. Both figures (b) and (c) come from [2].



Outline

interesting

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:

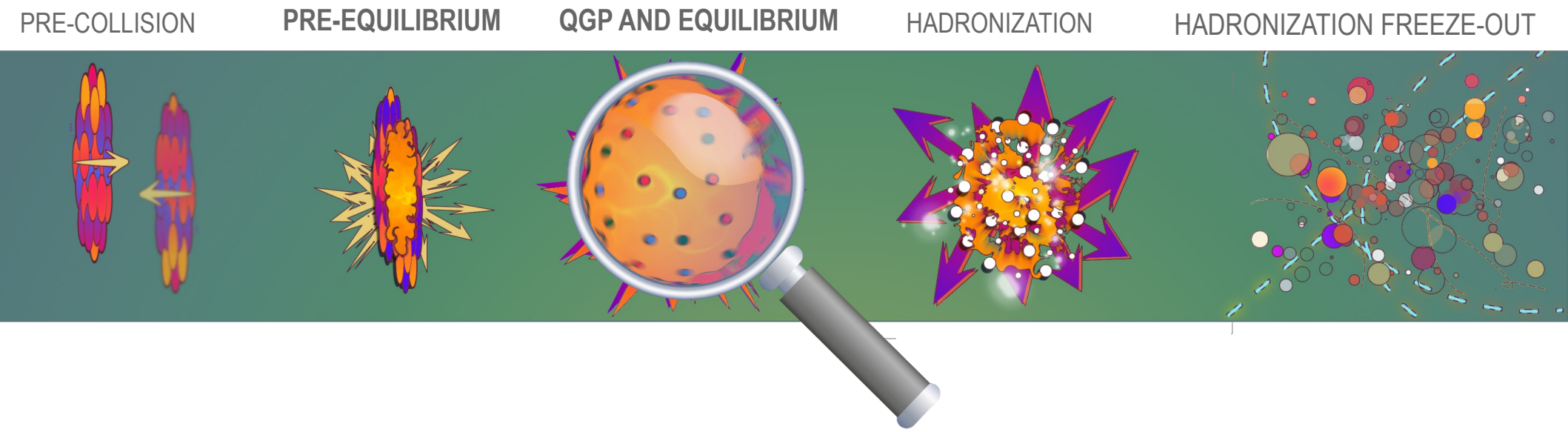
1. Motivation;

2. Analysis;

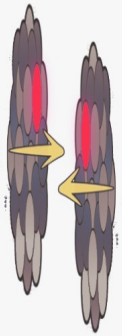
3. Results;

4. Summary.

Heavy-ion collisions



ENERGY OF THE COLLISION IN THE C.M.S.

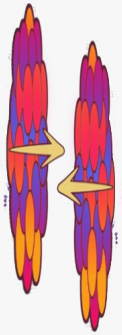


PER NUCLEON PAIR

Pb-Pb

$\sqrt{s_{NN}}$ = 2.76 TeV

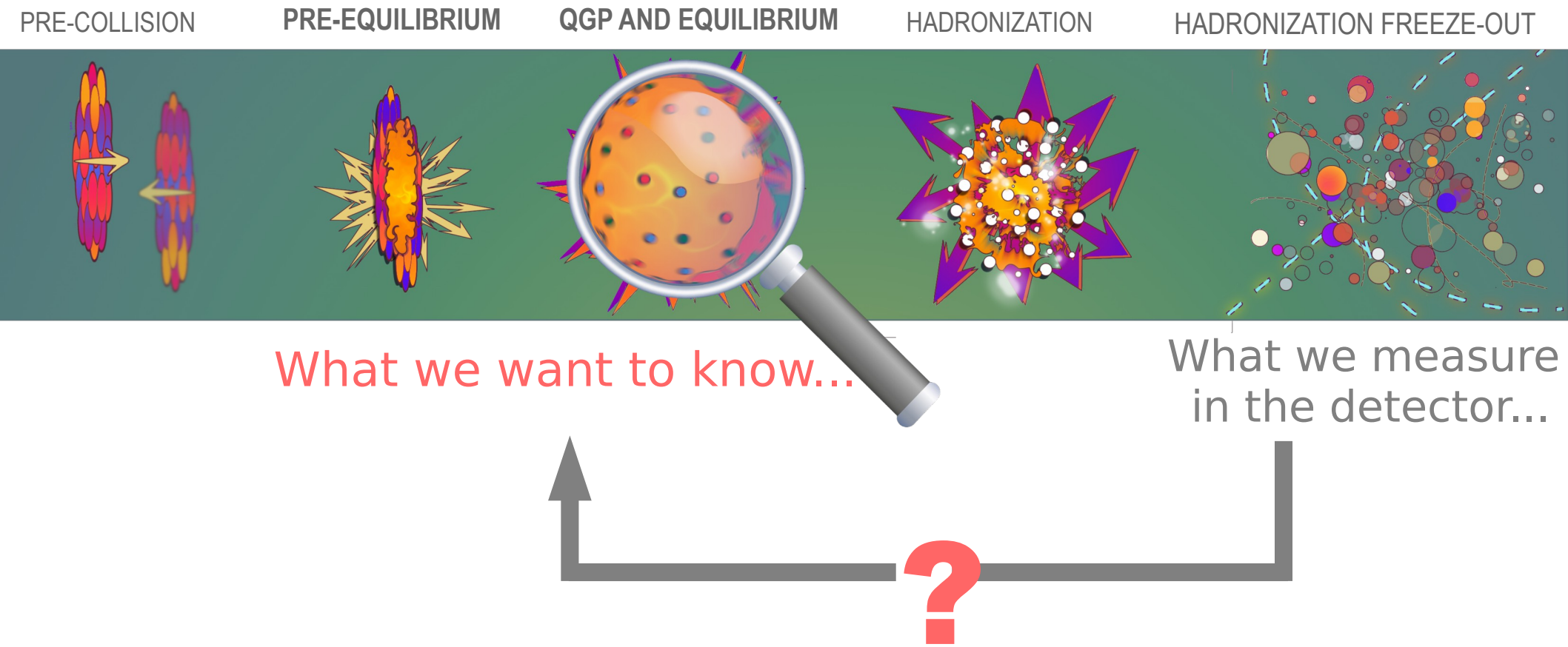
PER NUCLEUS



Pb-Pb

$\sqrt{s}$ = 574 TeV = 574 $\cdot 10^6$ MeV

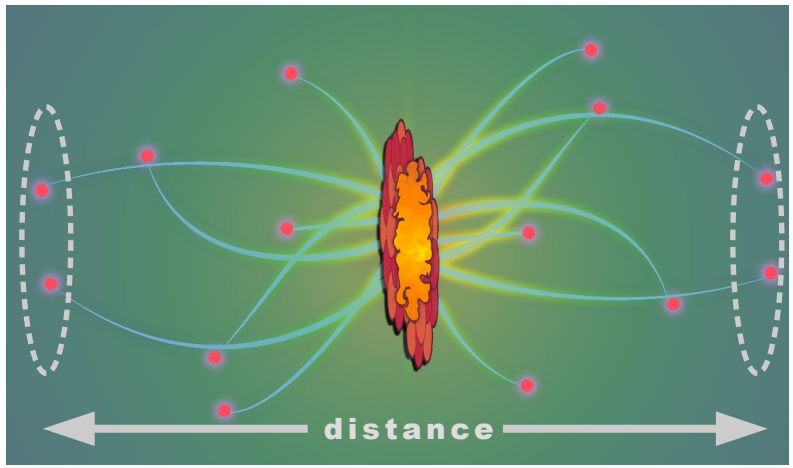
Heavy-ion collisions



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):

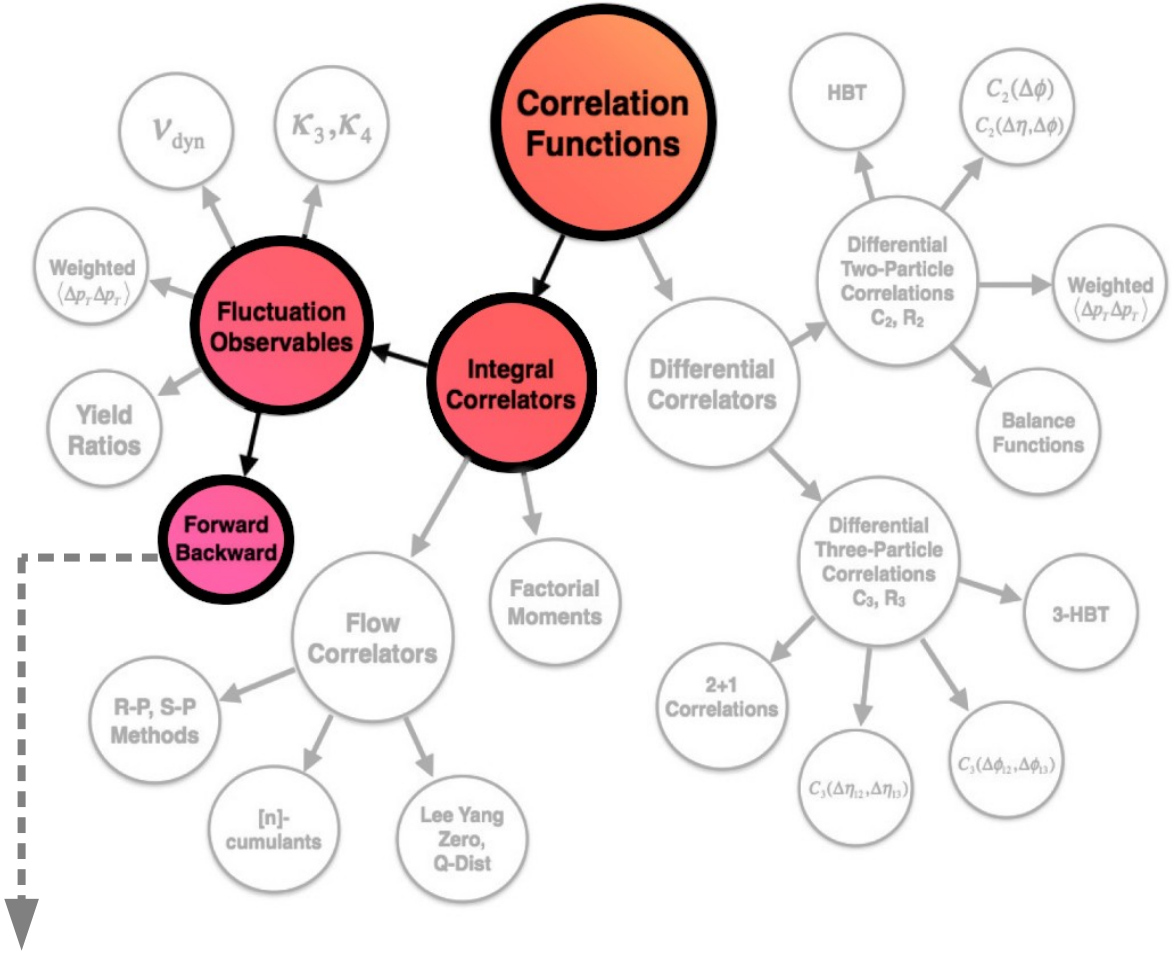


- LRC carry **information** on the **early dynamics** of the nuclear collision.

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.

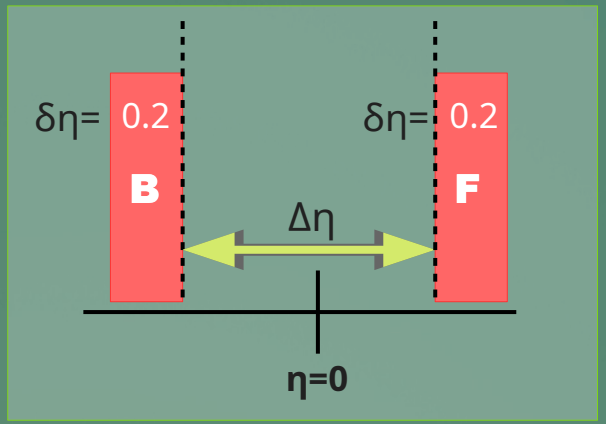
The Analysis: How do we study correlations and fluctuations?

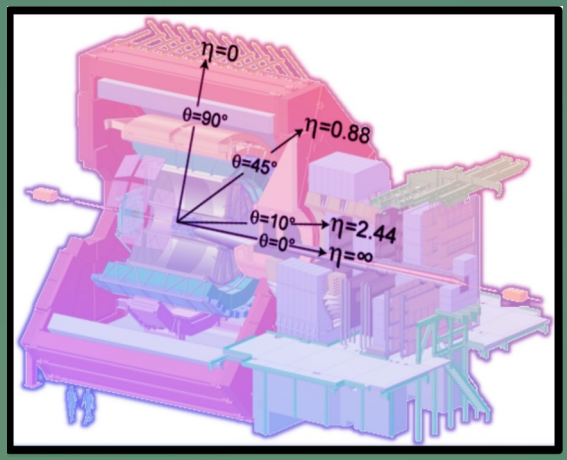


We are here!

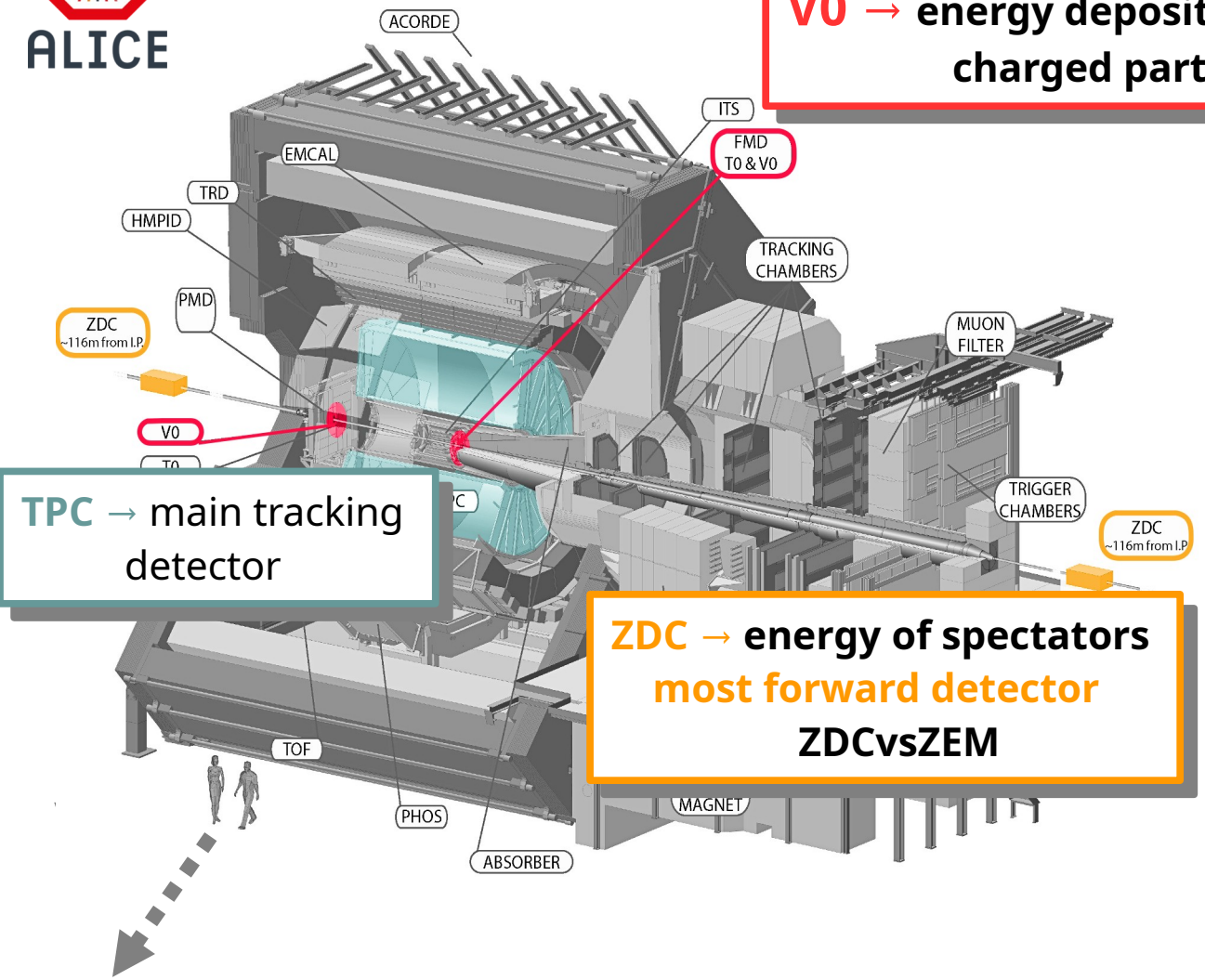
Picture from: Claude A. Pruneau, Data Analysis Techniques for Physical Scientists, 2017, Cambridge University Press.

The forward-backward (FB) correlation:





The Analysis: How do we study correlations and fluctuations?



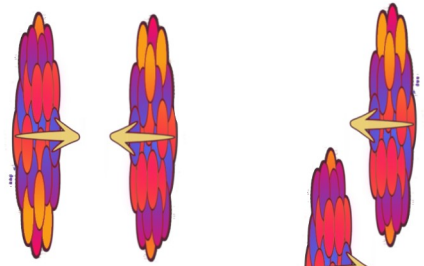
V0 → energy deposition by charged particles

TPC → main tracking detector

ZDC → energy of spectators
most forward detector
ZDCvsZEM

You are here!

centrality [%] & centrality bin width



central

centrality class:
0-10%→ ΔCent.=10%
4.5-5.5%→ ΔCent.=1%

peripheral

centrality class:
70-80%→ Δcent.=10%
74.5-75.5%→ ΔCent.=1%

Experimental data:

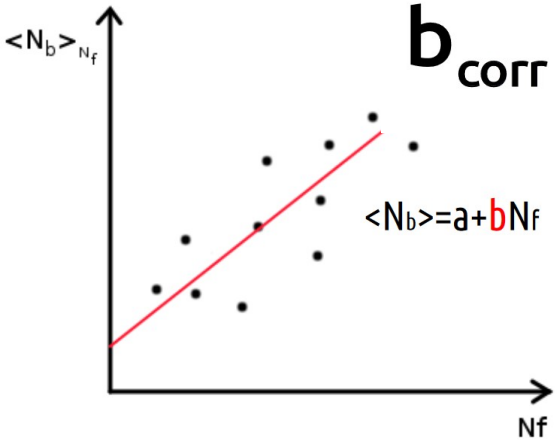
→ Pb–Pb @ $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV

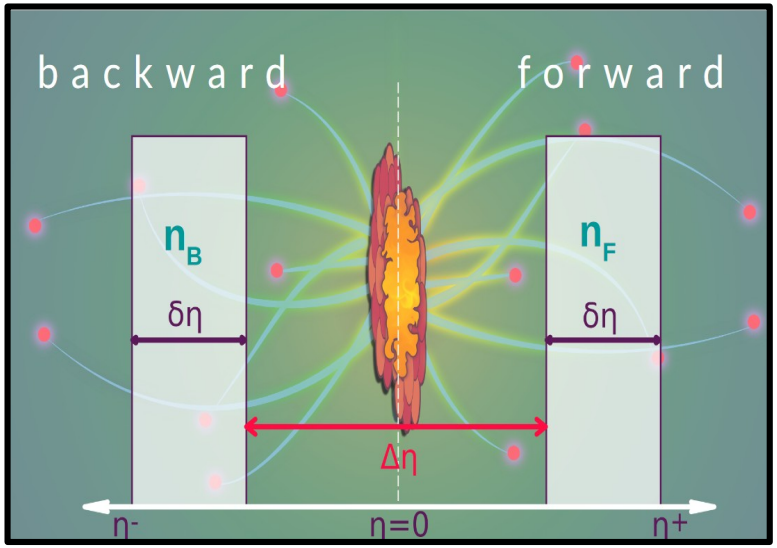
→ Xe–Xe @ $\sqrt{s_{NN}}$ = 5.44 TeV

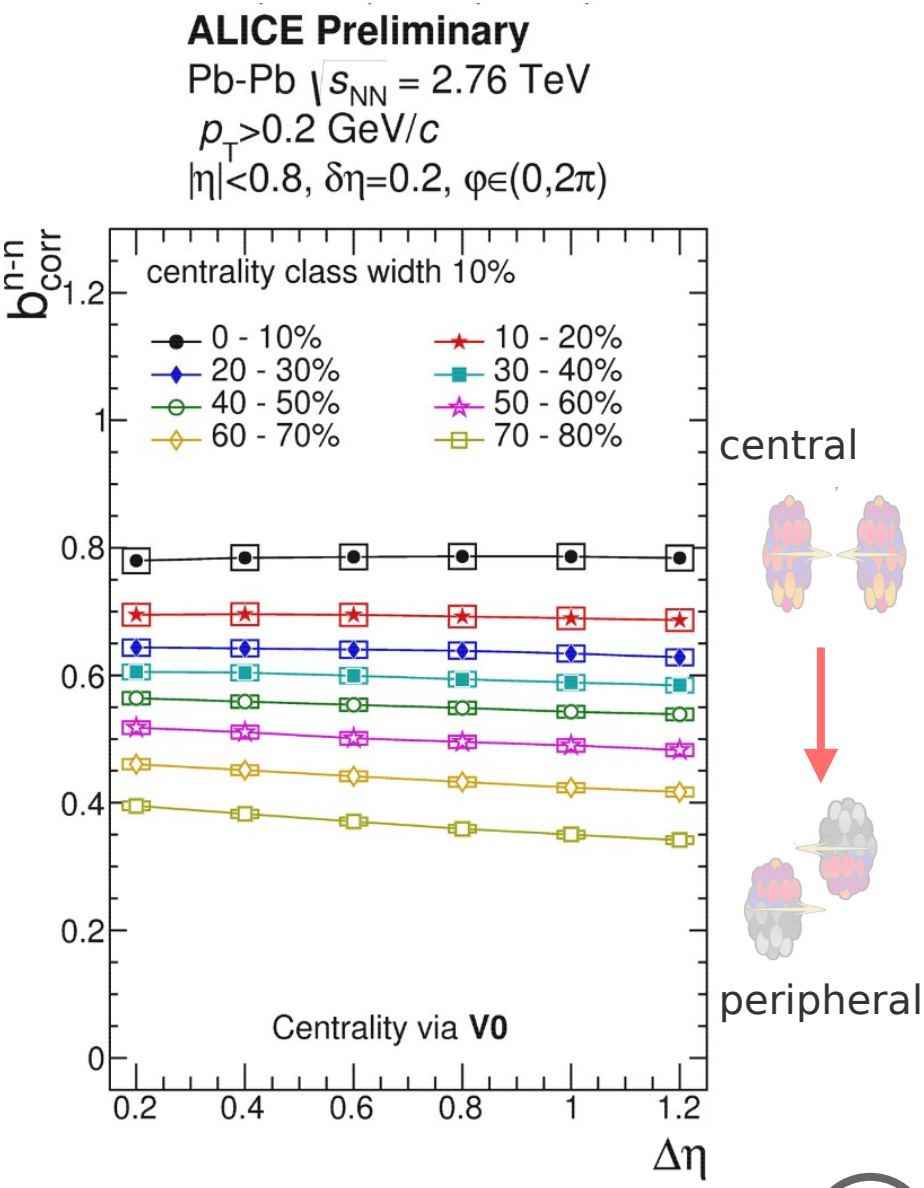
The Analysis: FB correlations

Correlation coefficient:

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







I.Sputowska. [ALICE], MDPI Proc. 10 (2019) 1, 14
DOI: 10.3390/proceedings2019010014

The Analysis: FB correlations

Schoolchildren

W. Krzanowski,Principles of Multivariate Analysis, Oxford U. Press, 2000

b_{corr}(**weight**, **IQ**) ≈ **0.62**

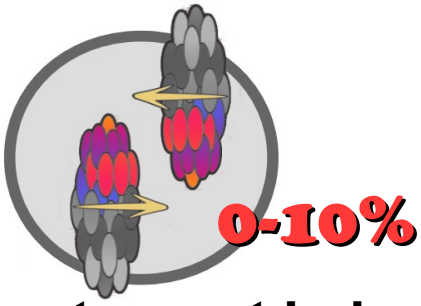
age fluctuation

Large correlations

Heavy-ion collisions

sample of most central Pb-Pb events

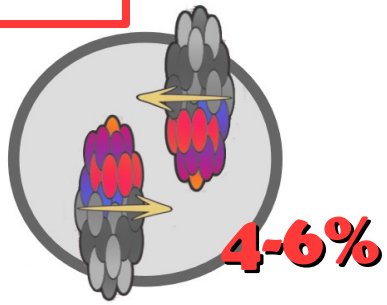
b_{corr}(**nF**, **nB**) ≈ **0.8**



event geometrical fluctuation

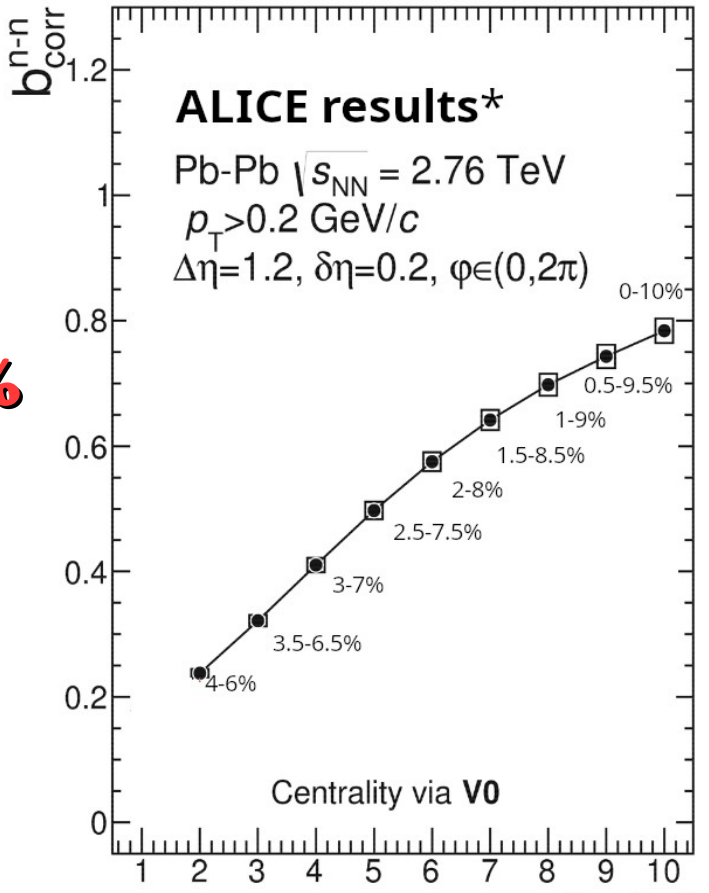
Spurious effect of external variable leads to absurd conclusions!

strict age selection



narrow centrality classes

*redrawn form
I.Sputowska. [ALICE], MDPI Proc. 10 (2019) 1, 14
DOI: 10.3390/proceedings2019010014



centrality bin width %

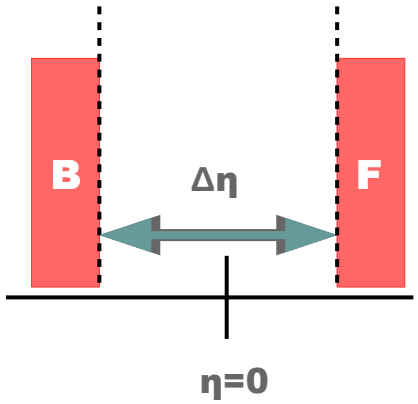
The Analysis: FB correlations with strongly intensive quantity Σ

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

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

- Strongly intensive quantity Σ in symmetric A-A collisions:

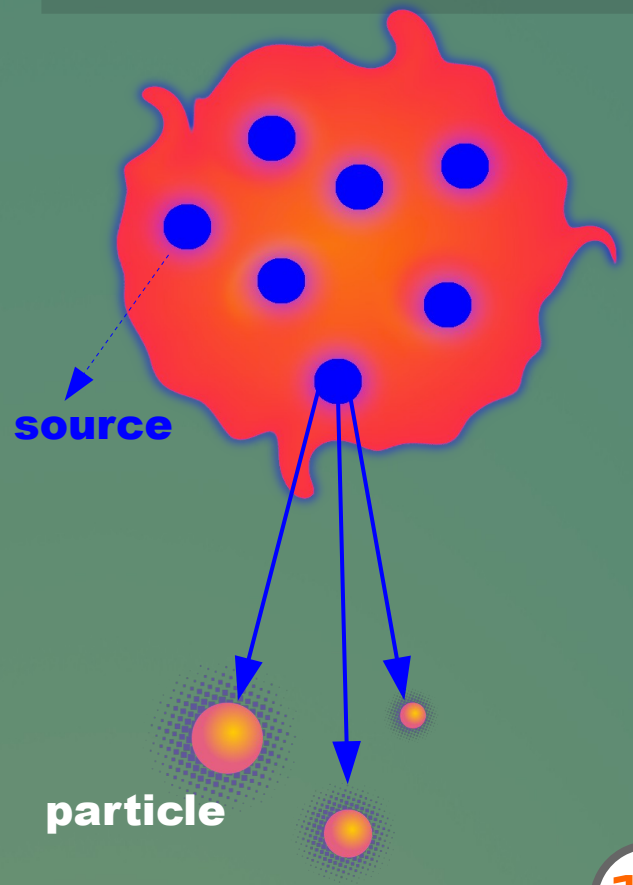
$$\Sigma \approx \omega(1-b_{corr})$$



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

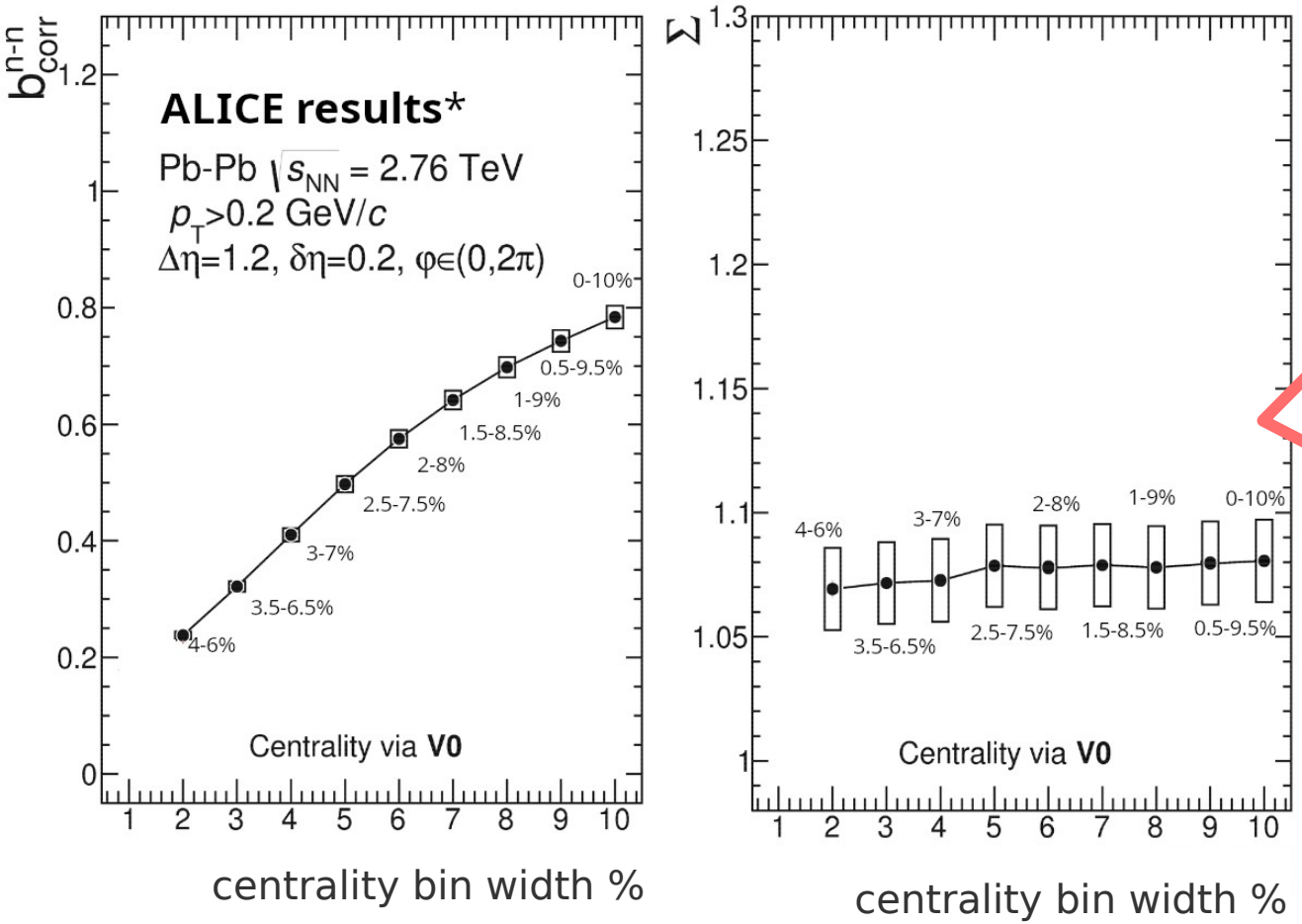
Independent source model:

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



The Analysis: FB correlations with strongly intensive quantity Σ

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

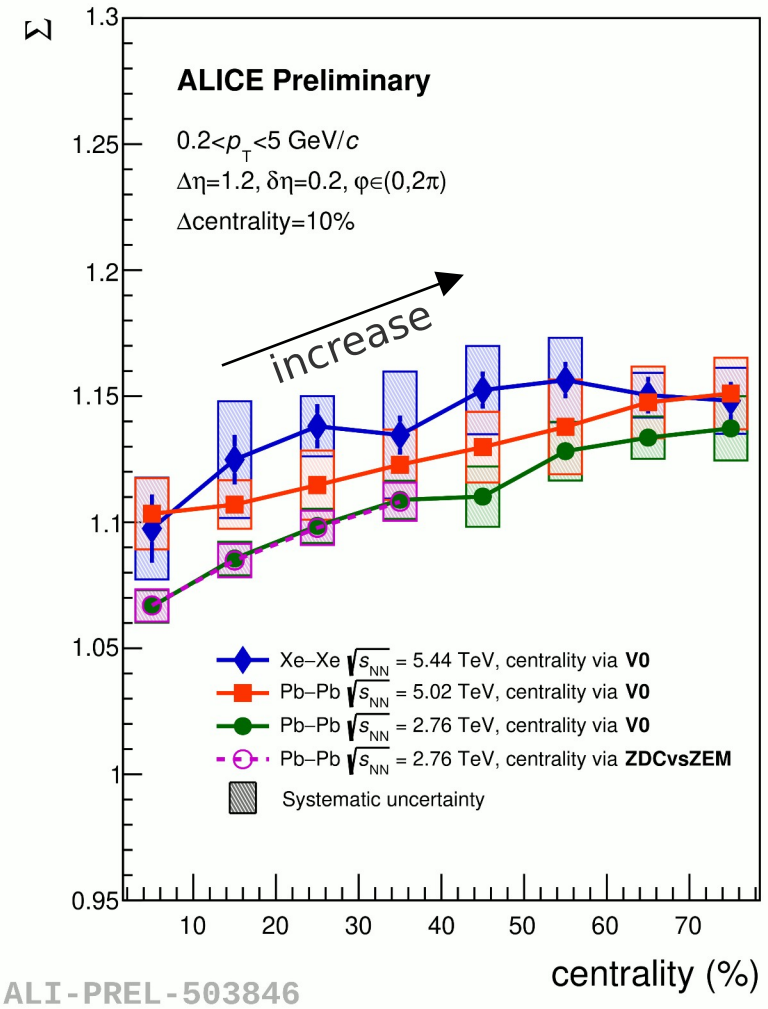


Σ does not depend on centrality bin width → free form effect of volume fluctuations!

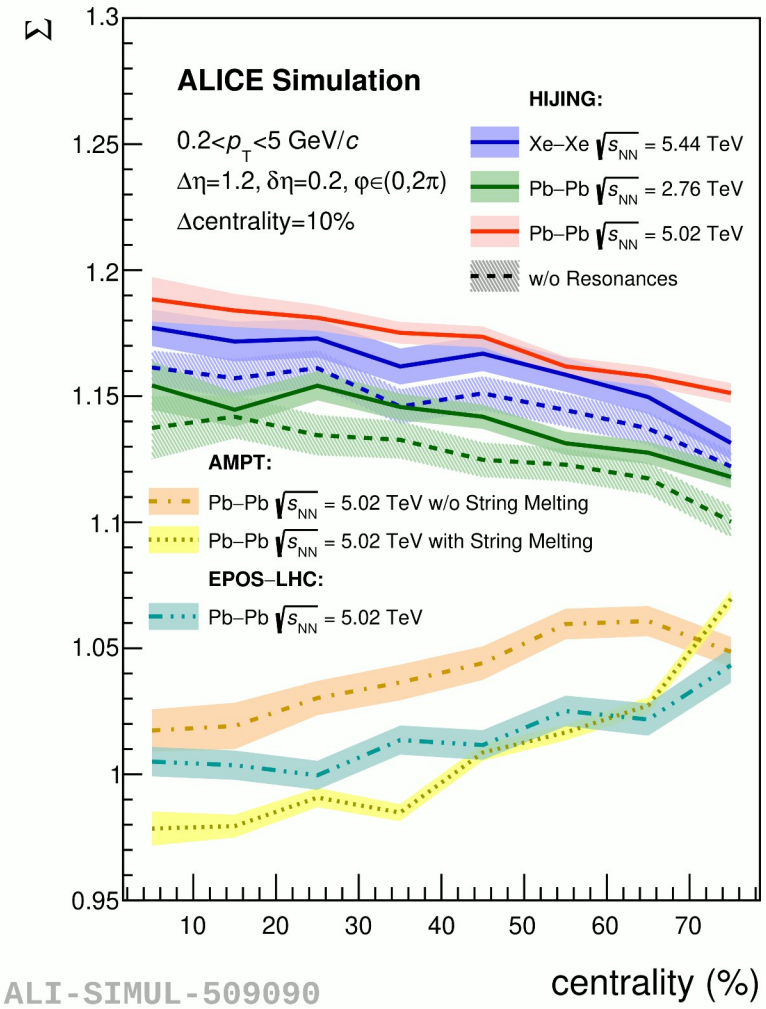
In ISM: Σ → gives direct information about characteristics of **single source distribution!**

*redrawn form
I.Sputowska. [ALICE], MDPI Proc. 10 (2019) 1, 14
DOI: 10.3390/proceedings2019010014

Results: Σ as a function of centrality



ALI-PREL-503846



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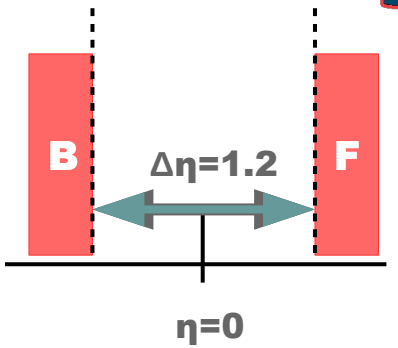


- **Σ increases with energy;**
- **Σ increases with decreasing centrality** in experimental data

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 mechanism of particle production.

Summary

What did we learn studing FB correlation with Σ ?

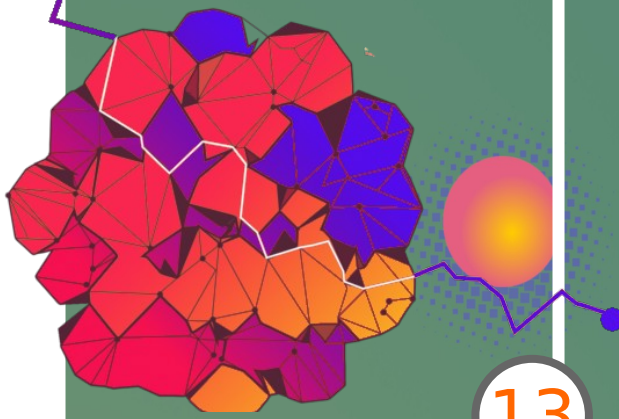
- **Σ increases with energy and with decreasing centrality** in experimental data, **contrary** behavior noted for MC HIJING results.
- AMPT and EPOS reproduce the dependence on centrality **qualitatively** but **not quantitatively**.
- From results for AMPT it is evident that Σ is sensitive to the mechanism of particle production.
- The comparison of **centrality ordering** in A–A reactions versus theoretical models, may provide new insight into the underlying dynamics of the collision.
- **What model can reproduce Σ behavior?**
  → Wounded Nucleon Model, but... Σ is no longer strongly intensive quantity → see: Phys.Rev.C 108 (2023) 1, 014903

Σ dependence on centrality selection and volume fluctuations
I. Sputowska (ALICE), MDPI Proc. 10, 14 (2019)

Σ in AA and pp collisions
I. Sputowska (ALICE), I. A. Sputowska, EPJ Web Conf. 274, 05003 (2022).

Strongly Intensive Quantities
M. I. Gorenstein and M. Gazdzicki, Phys. Rev. C 84, 014904 (2011), arXiv:1101.4865 [nucl-th.

Σ in WNM
I. Sputowska, Phys.Rev.C 108 (2023) 1, 014903



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