Is there life beyond the "means"

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12 August 2021. Support: NKFIH 2019-2.1.11-TET-2019-00078

Instead of introduction

Although we **believe** that we are in the strongly iteracting Quark Gluon Plasma regime we are confronted with important warnings:

Angantyr gives a reasonable description of inclusive particle production of (pp), pA and AA.Successfully extrapolates the pp dynamics of PYTHIA8 via pA to AAwithout introducing QGP dynamics"

from Leif Lonnblad – QM Leif Wuhan
https://indico.cern.ch/event/792436/contributions/3546231/attachments/1939700/3215673/QM19.pdf

The “means” may occult interesting things

Does the “mean” mortality from Covid give important information?

The response is: **no** (many different categories with different mortalities)

The “mean” content of gold in the crust is not interesting!

the situation in ALICE is similar :

Question: do we believe that every event has sQGP features?

Since the energy density is way higher than the theoretical limits at all centralities in principle the answer is YES

However!: it is **not** excluded that we have events with different temperatures belonging to different phase transitions – A.Mishrat et al. Eur. Phys.J A57 7(2021)245

If we accept that not every event is equally "sQGP" then it would be interestingt to try to:

Hunt for anomalies!

Our analyses document statistical errors without plotting the distribution of the data

The mean values are **dictated by** the majoruty of data

The majority of analyses are based on **MEANS**

mean transverse momentum,

Mean multiplicity

Mean number of binary collisions

Mean Flow

Mean eccentricty

There are also " Hidden means" – like the transverse momentum spectra that are averaged over many events. Possible outliers are hidden by the overwhelming contribution of the events mostly represented.

Accept the mean values does not make justice to the basic considerations of the QCD i.e that in the simples considerations we have to consider the contribution of the fundamental interactions gg qq and qg

However!

Wild diversity of events!

the pp collisions present diverse event shapes from jetty to isotropic ones

The quoted <pt> reflects the behavior of the the **Low** part of the transverse momentum – not of the whole range (<4GeV/c)

The nuclear modification observed and reported is in great measure due to the preponderance of the surface. We actually have little info on the partons with origin in the center

Looking for rare events

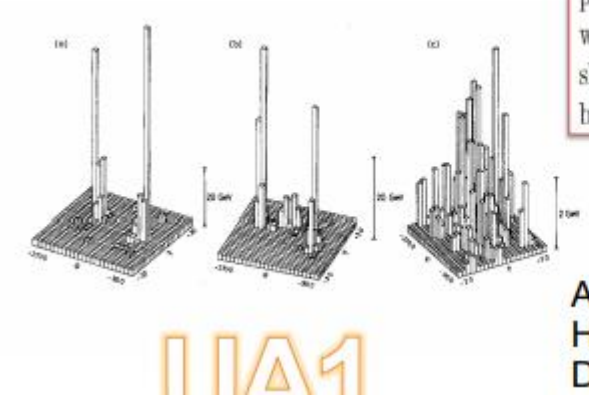
- An *outlier* is an observation that lies an abnormal distance from other values in a random sample from a population.
- The outliers are important in the search for new features.
- While we can have means that are in agreement we may have events – even classes of such events!
- The question is how do we categorize evnts that are in a way or other “rare”
- Let's see some examples:

The story of the “hedgehog events” is old but nobody cares!

Chriss Quigg: arXiv:1004.0975v1 [hep-ph]

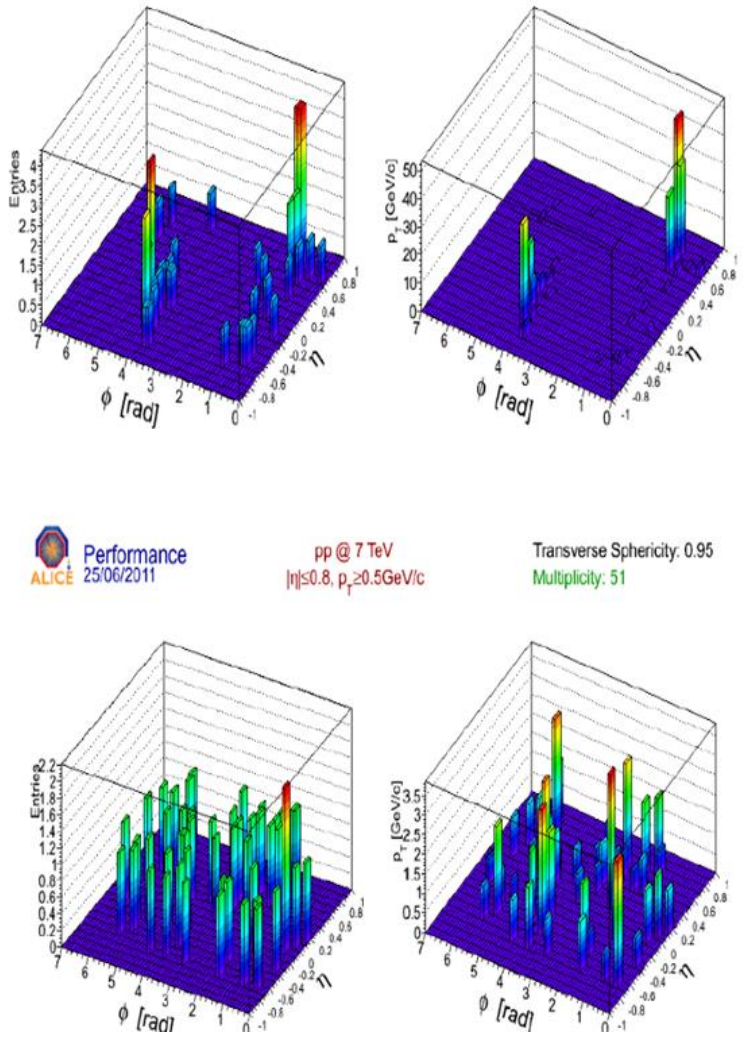
An interesting example—an *atypical* event observed in $\bar{p}p$ interactions at $\sqrt{s}$ 1.8 TeV by CDF's Run 1 detector, is shown in Figure 3.([3]) This event was accepte by a $\sum E_\perp$ trigger, without any topological requirement. The LEGO® plot sho many bursts of energy: More than a hundred active towers pass the display threshold 0.5 GeV. The total transverse energy in the event is 321 GeV, but it is not concentrat in a few sprays, it is everywhere. The central tracking chamber records about six charged particles.

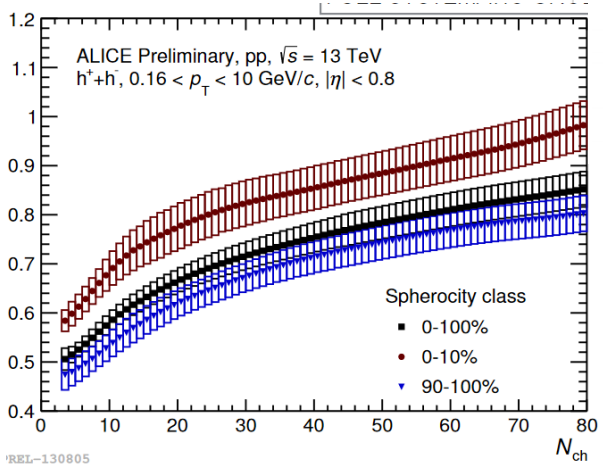
I am assured that this "hedgehog" event is authentic it is not merely coherent noi in the counters. The colleague who selected this specimen estimated similar events be about as common in the online event stream as Z^0 production and decay into lept pairs: about one in ten thousand triggers. I include this outlier as a reminder that wh we think about the strong interactions outside the realm of a single hard scattering, should think not only about the large diffractive and "multiperipheral" cross sectio but also about less common phenomena.

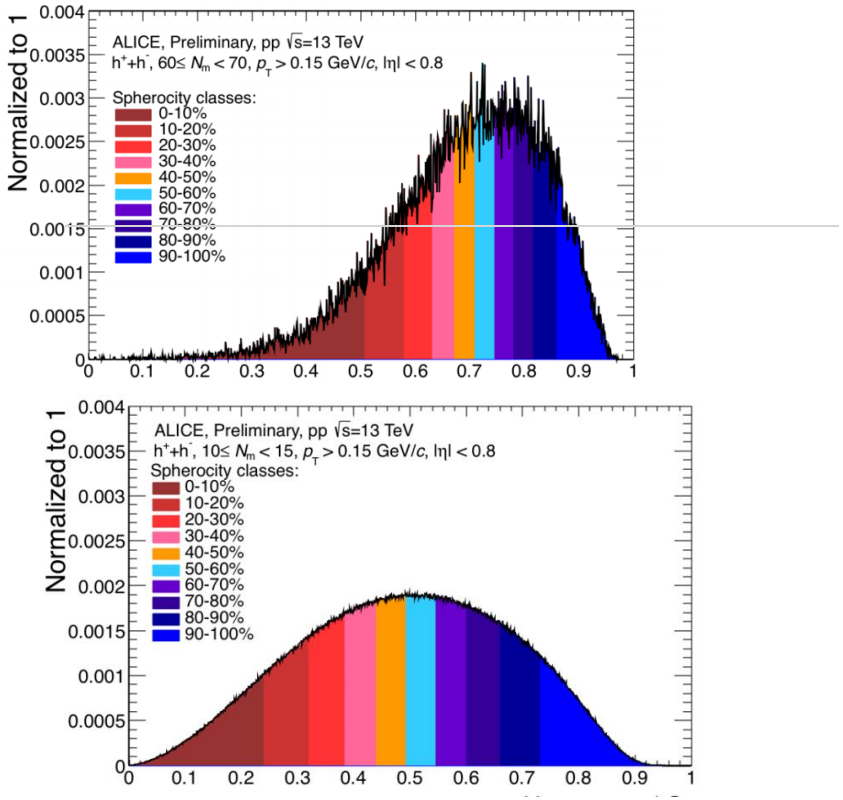


Albajar, C., et al. (UA1 Collaboration). Analysis of the Highest Transverse Energy Events Seen in the UA1 Detector at the SppS Collider. Z. Phys. C36 (1987),

the pp collisions present diverse event shapes from jetty to isotropic ones







- **Many events of completely different shape.**

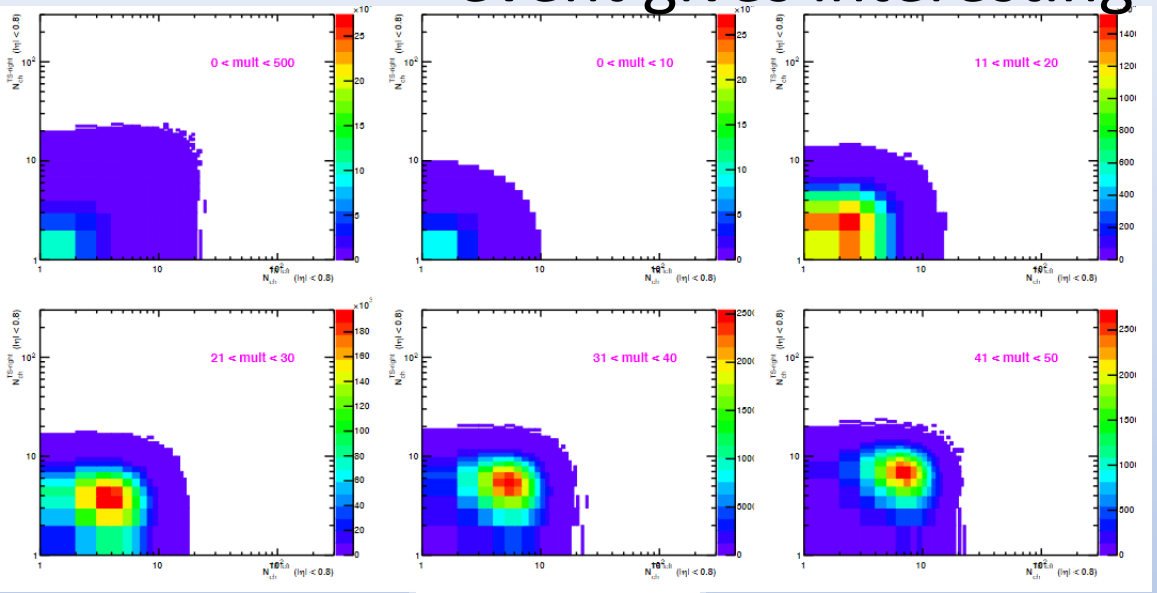
What is the message of the "mean"?

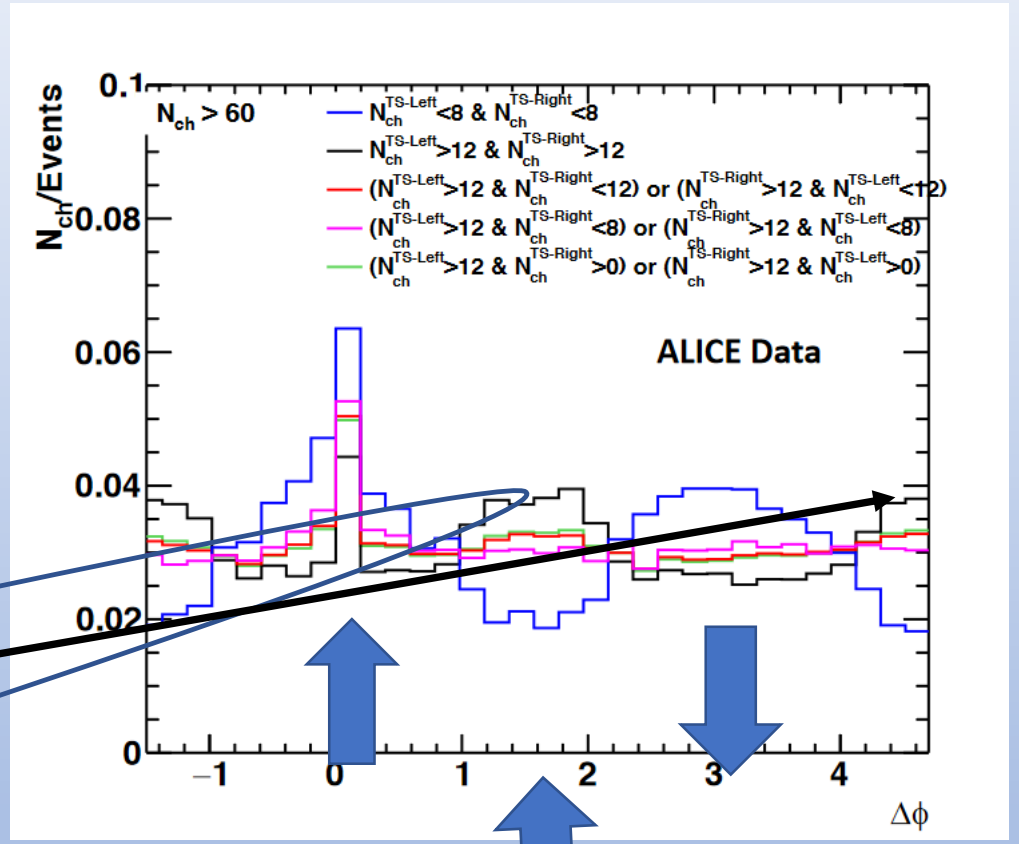
The way out…

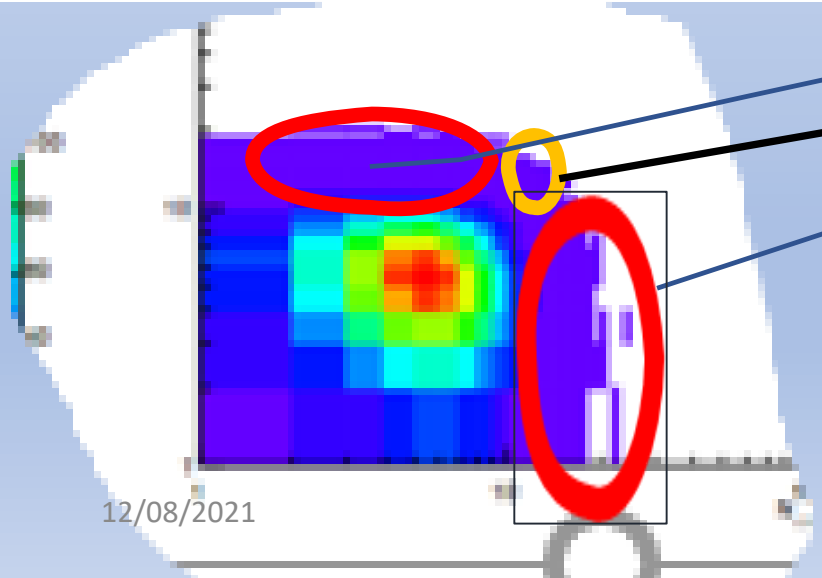
- **Scatter plots**
- A scatterplot is a type of data display that shows the relationship between two numerical variables. Each member of the dataset gets plotted as a point whose x-y coordinates relates to its values for the two variables.

- Other statistical tools….

A lot of discussions about the underlyting event but the event by event gives interesting dihadron correlations..

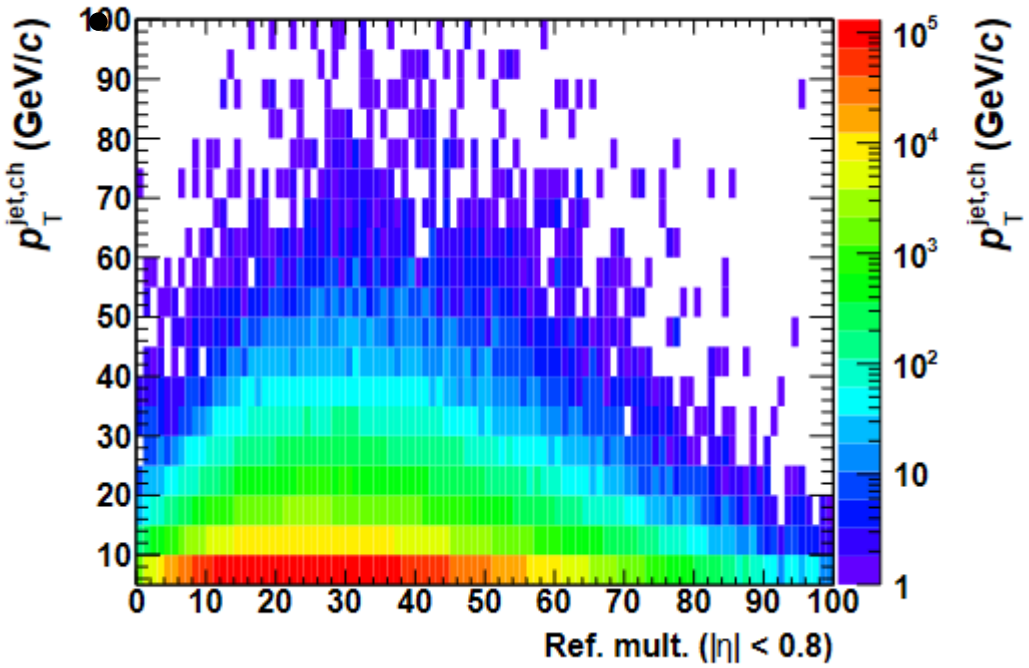


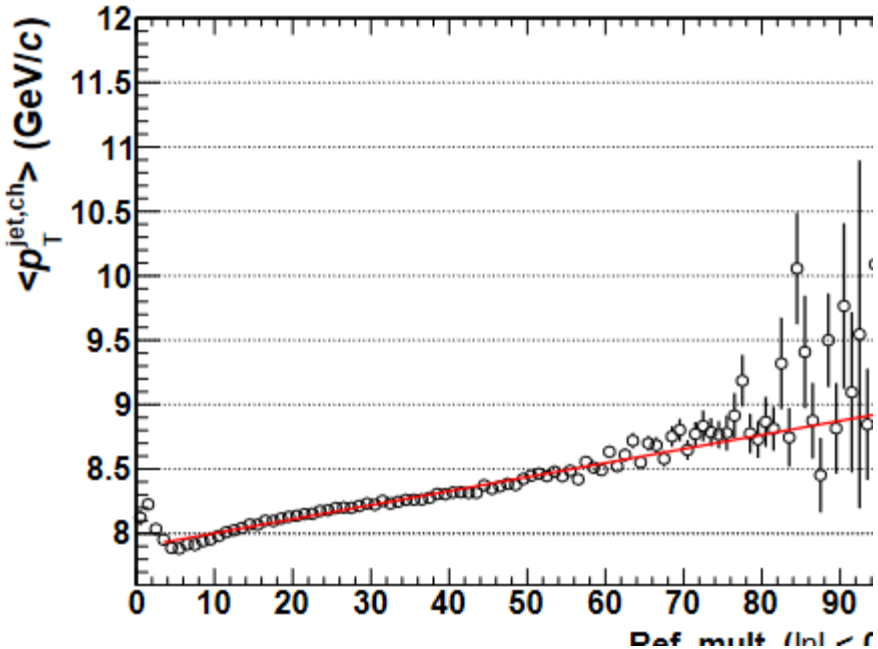




Aditya Mishra

From event to event to the mean in case of jets (from Benjamin Hess tesis)





Correlation between p jetT and multiplicity for the reference multiplicity

Different conclusions from the two graphs!

The elliptic flows have large spreads

- We do not have a clear knowledge of the behavior of the parameters in the extremes: RAA, pt..

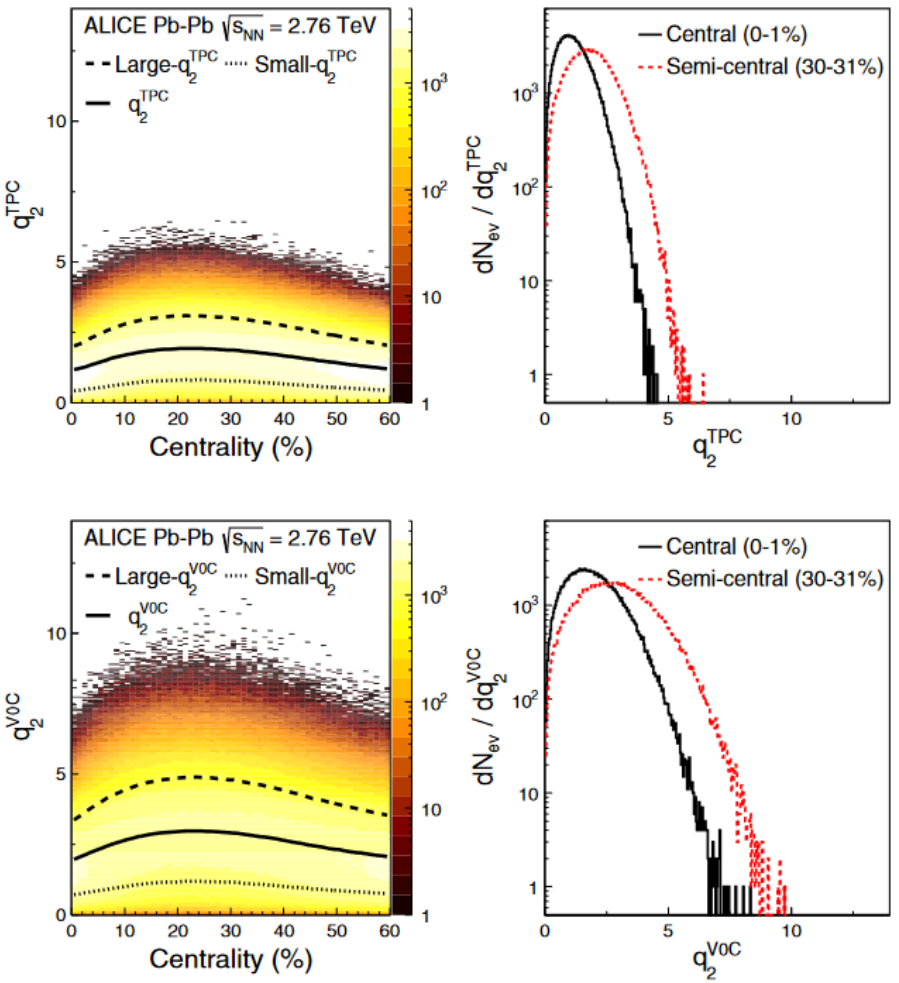
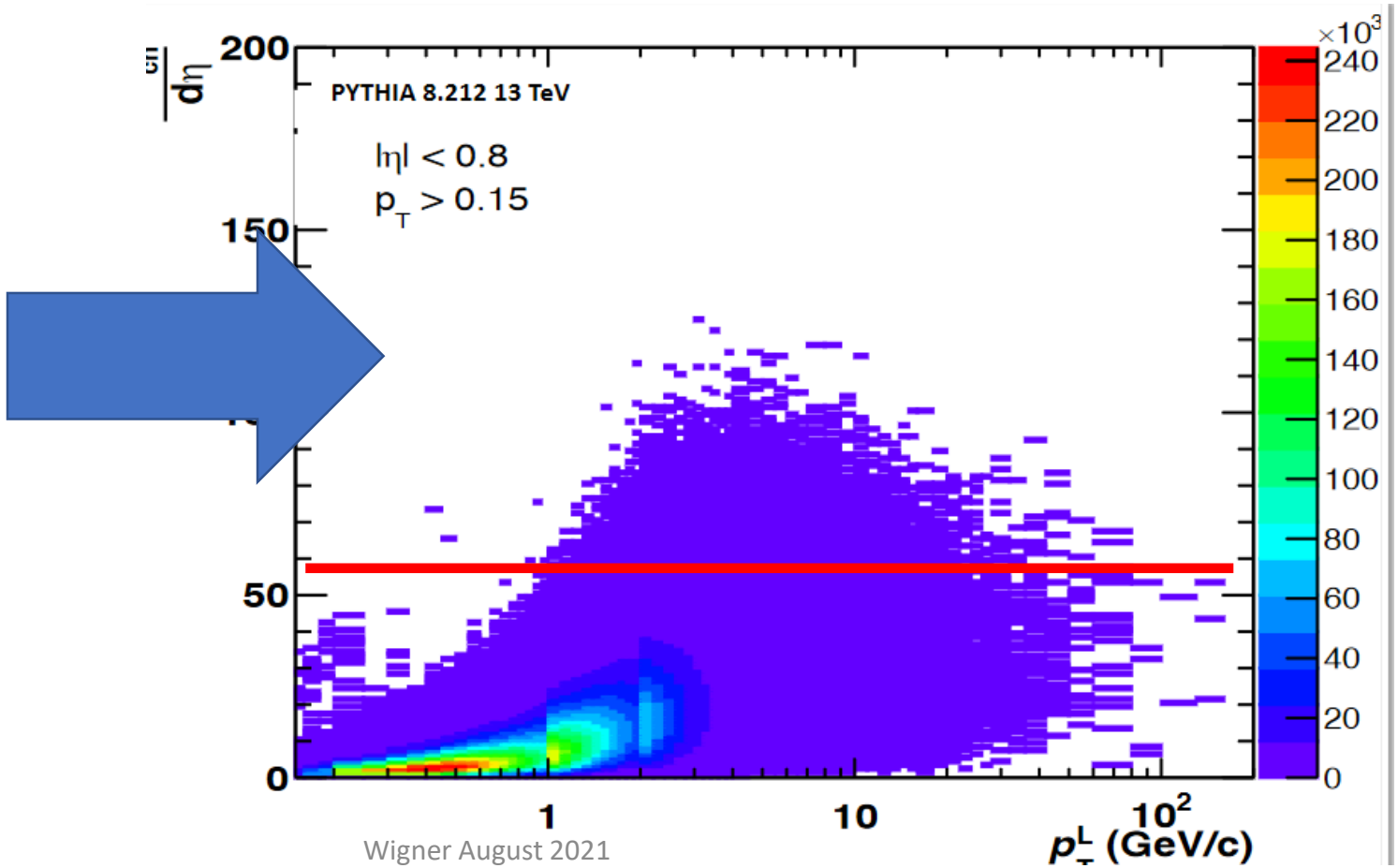


FIG. 1. Distributions of q_2^{TPC} (top row) and q_2^{V0C} (bottom row) as a function of centrality (left column) and projections for two centrality classes, 0%–1% and 30%–31% (right column). In each of the left panels the solid curve shows the average q_2 as a function of centrality, while the dashed and the dotted curves indicate the top 10% and the bottom 10%, respectively.

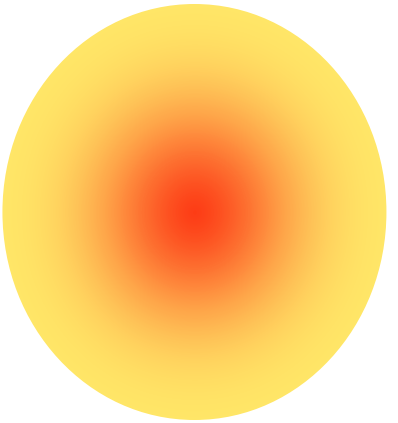
A large part of the phase space escapes our vigilance!

Very few knowledge!

Aditya Mishra



The nuclear modification factor



- This factor is our most publicized parameter as the proof of parton.

energy loss

However there again there is a lot of “means”

There are many possible origins of collisions many different lengths for reaching out in vacuum

$$R_{A-A}(p_T) = \frac{\text{Yield}_{A-A}}{\langle N_{\text{binary}} \rangle \cdot \text{Yield}_{N-N}}$$

b

The distribution of the pathlengths in the transverse direction is very large

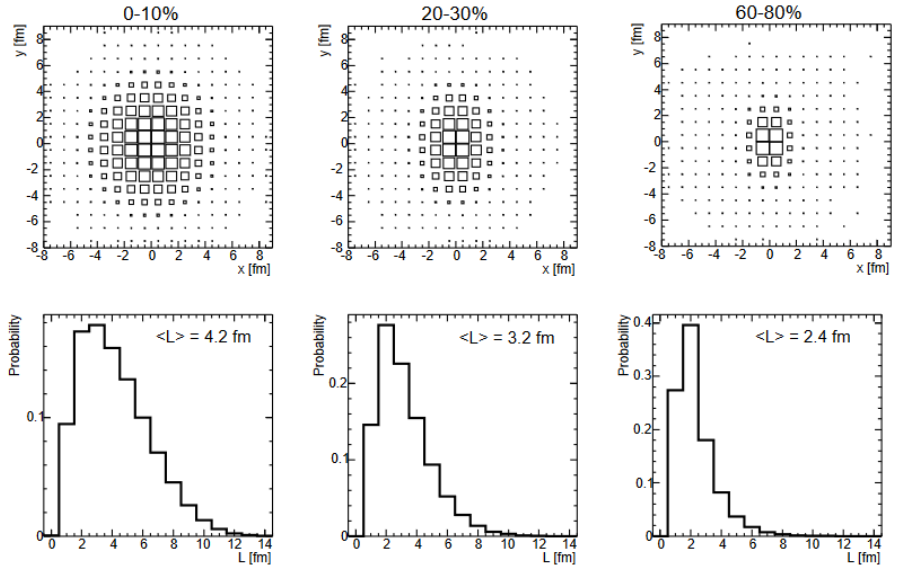


Figure 1: Distributions of parton production points in the transverse plane (upper row) and in-medium path length (lower row) in central, semi-central and peripheral Au–Au collisions. The quantity $\langle L \rangle$ is the average of the path length distribution.

- Is there a way to get information in function of the location of the hard collision?

A. Dainese, C. Loizides, G.Paic

Eur.Phys.J.C38:461-474,2005

A wide range of pathlengths!
There should be events who get out of the center with pathlengths of 6-8 fm for both. Where are those in RAA?

A possibility?

Take a single event and divide it by the MB pp spectrum.

One can imagine that the resulting RAAwill be different depending on the pathlength of the parton has to travel from the point of collision

The method could have many applicaction

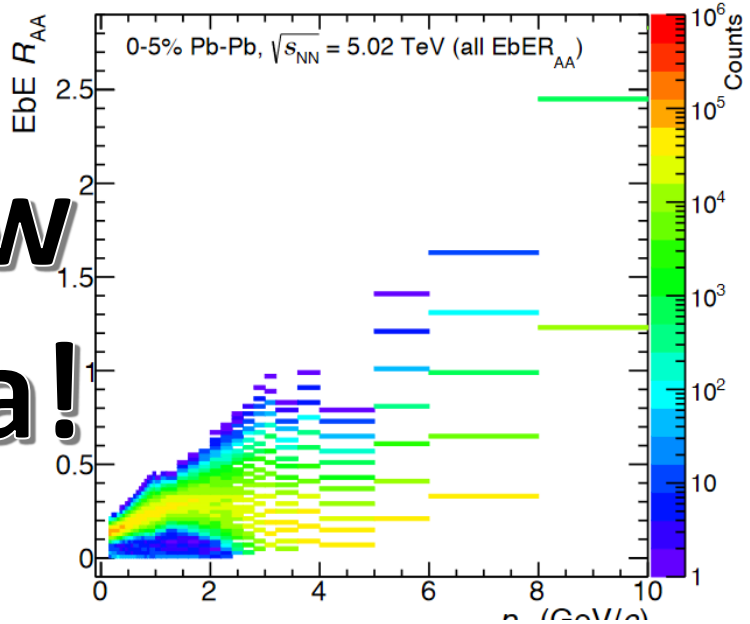
- Strangenesss,
- Baryons
- Transverse momentum etc.

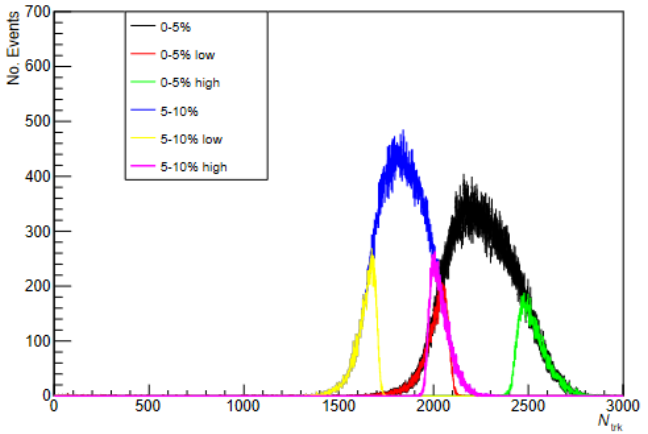
Do we have a chance to see the details of the of the RAA in function of the pathlength?

A preliminary illustration of the proposal

- A large range of RAA! – but also questions: the multiplicity of the events. Our students Oscar and Alexis have started to study the multiplicities.
- **but** an interesting point are the multiplicity distributions that is rather large even for very small bins of centrality
- This makes problematic the use of a “Mean” number of binary collisions…
- probably one has to consider on the transvese momentum distributions

Raw data!





Multiplicity distribution of the centarilty bin 0-0.1% in the central rapidity (Oscar Lara & Alexis Holman

conclusions

The collisions at the LHC energies have wide distributions in all parameters

- Flow, multiplicity, transverse momentum, particle species etc

This diversity may hide Special classes of events that pass undetected in the present ways of análisis

We should try to go to the extremes in the search of “outliers” and develop adequate tools to do so: ML , scatter plots for instance

An invitation to join the search for interesting events

https://link.springer.com/content/pdf/10.1140/epjc/s10052-016-4571-1.pdf ALICE

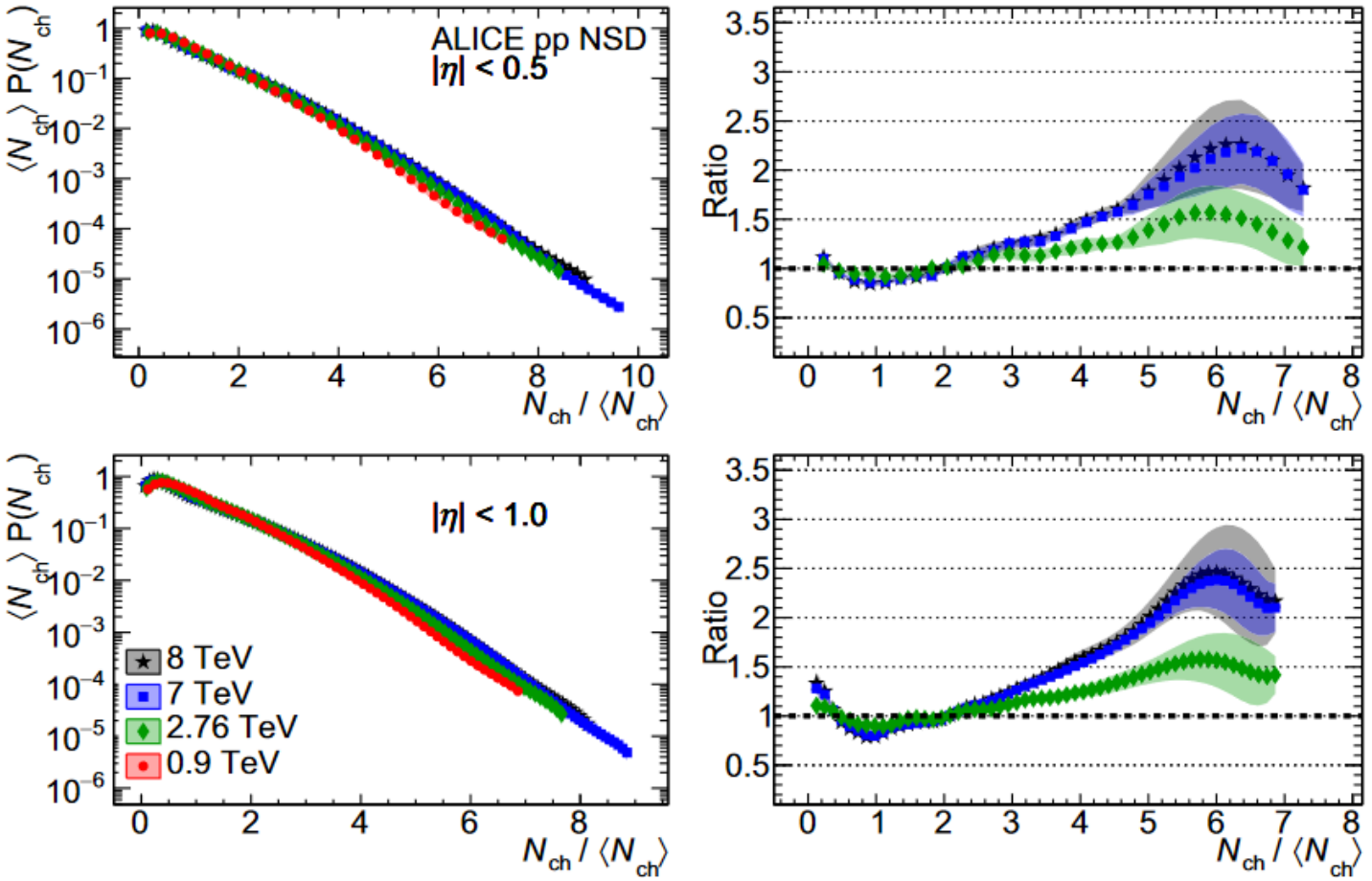


Fig. 19 KNO-scaled distribution $\langle N_{ch}\rangle P(N_{ch})$ versus the KNO variable $N_{ch}/\langle N_{ch}\rangle$ at $\sqrt{s} = 0.9$, 2.76, 7 and 8 TeV, for three pseudorapidity intervals: $|\eta| < 0.5$ (*top*), 1.0 (*middle*) and 1.5 (*bottom*). In each case, ratios to the distribution at $\sqrt{s} = 0.9$ TeV are shown, on the *right-hand side parts of the figures*. As $N_{ch}/\langle N_{ch}\rangle$ takes different values at different centre-of-mass energies, ratios were obtained by interpolating the KNO-scaled distributions, and uncertainties were taken from the nearest data point. Bands represent the total uncertainties

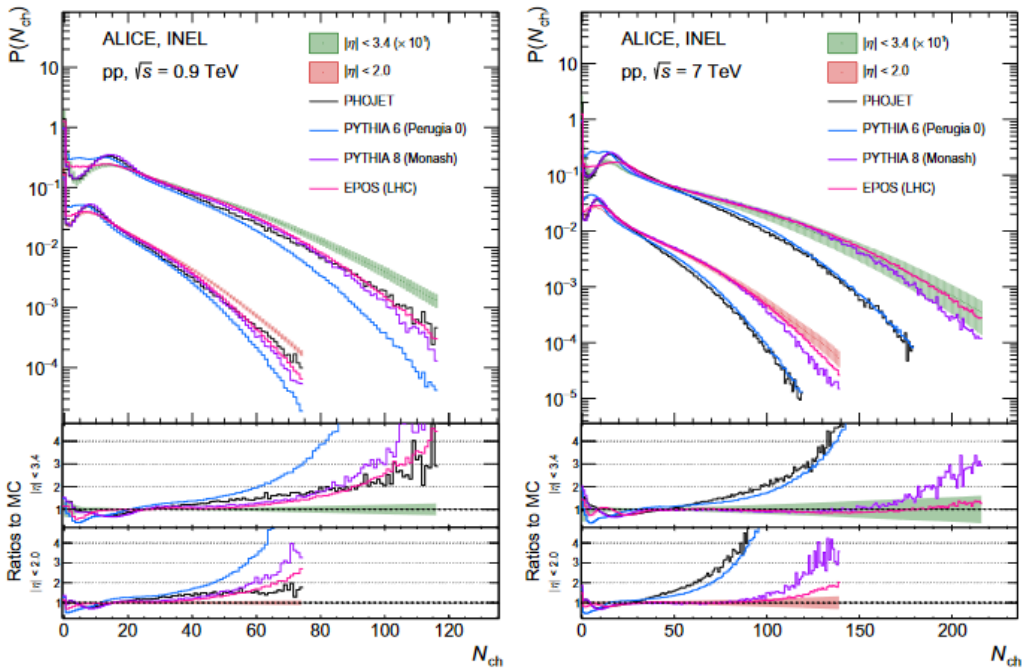
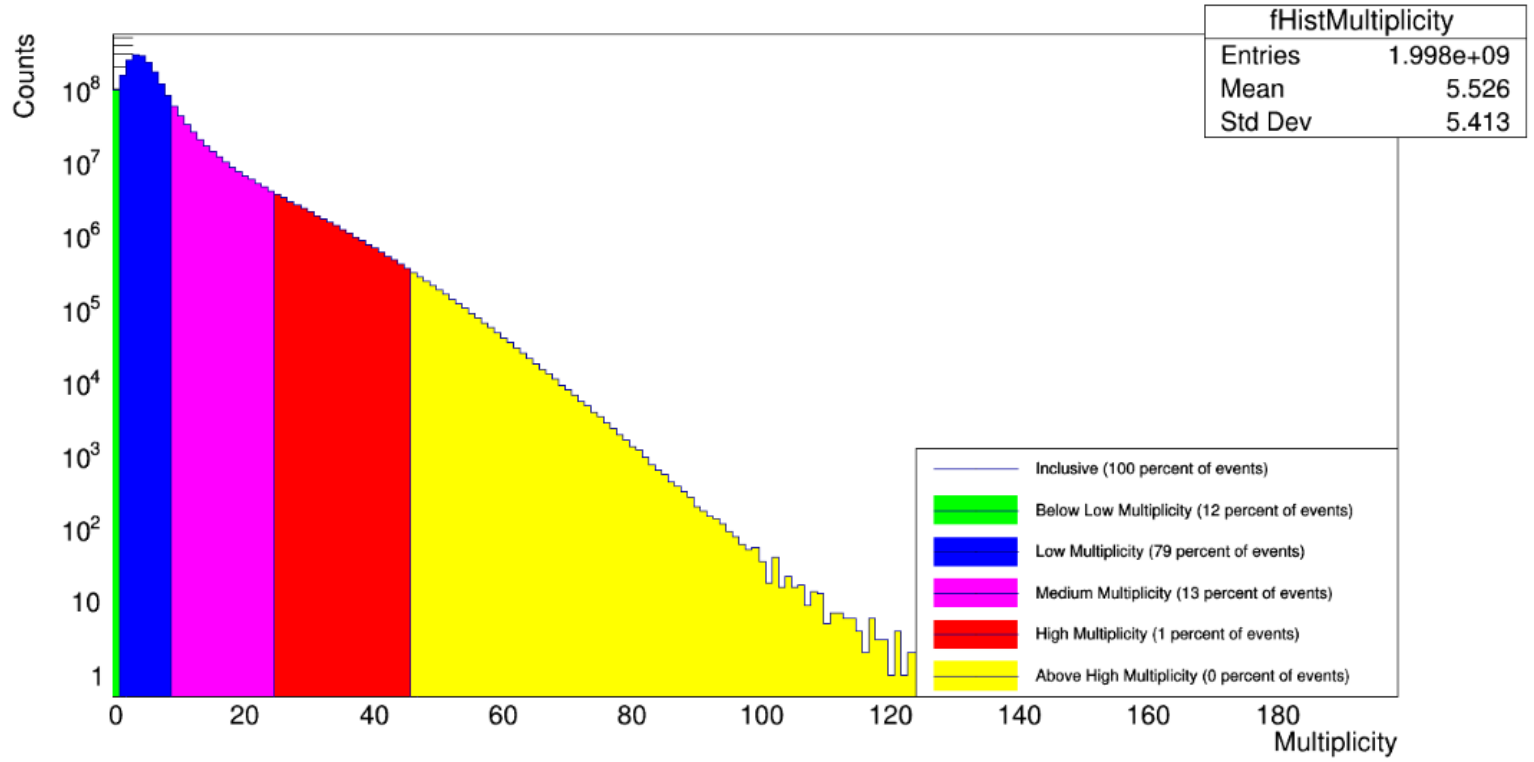


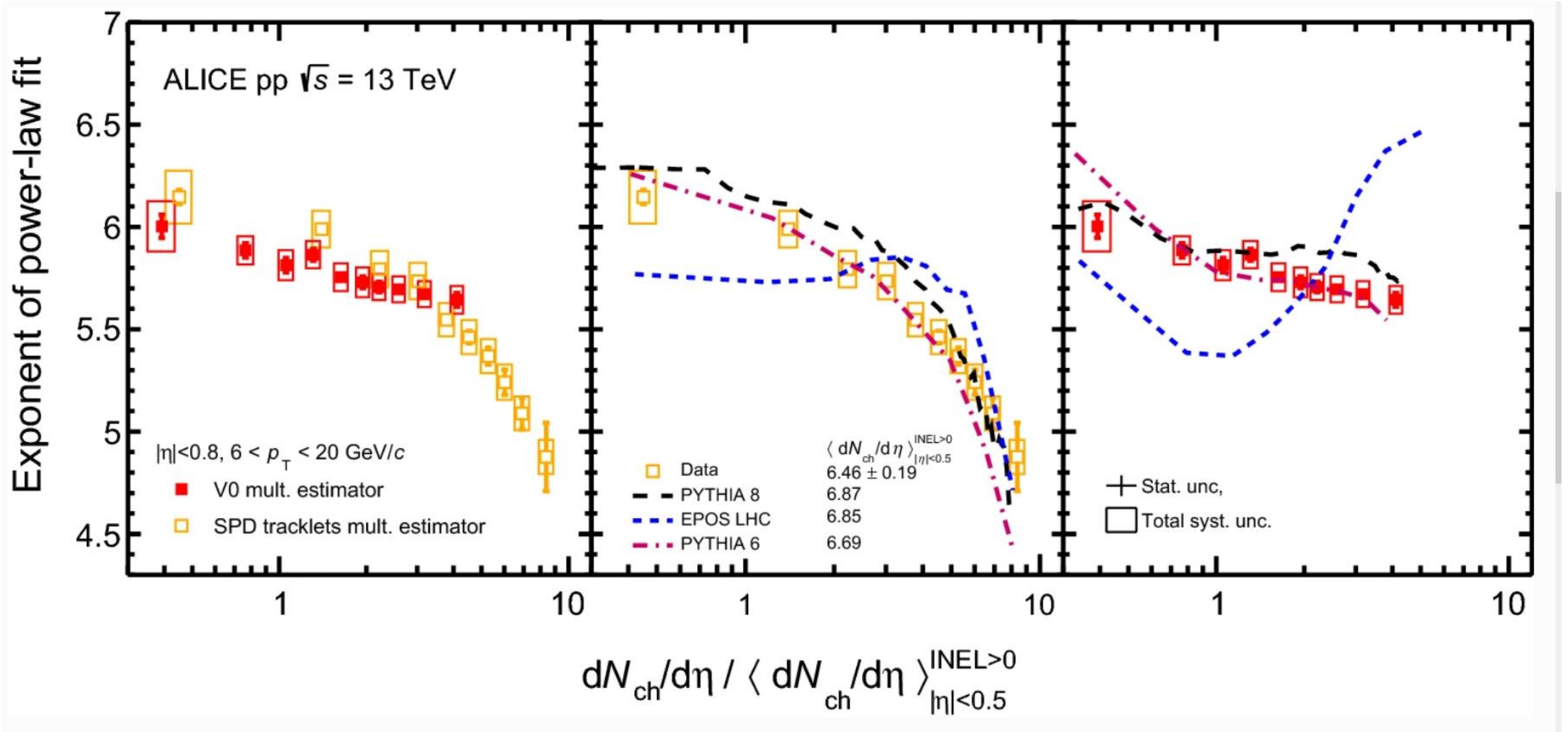
Fig. 7 Comparison of multiplicity distributions for INEL events to PYTHIA 6 Perugia 0, PYTHIA 8 Monash, PHOJET and EPOS LHC at 0.9 (left) and 7 TeV (right). Combined systematic and statistical uncertainties are shown as bands

https://hal.archives-ouvertes.fr/hal-01669766/document

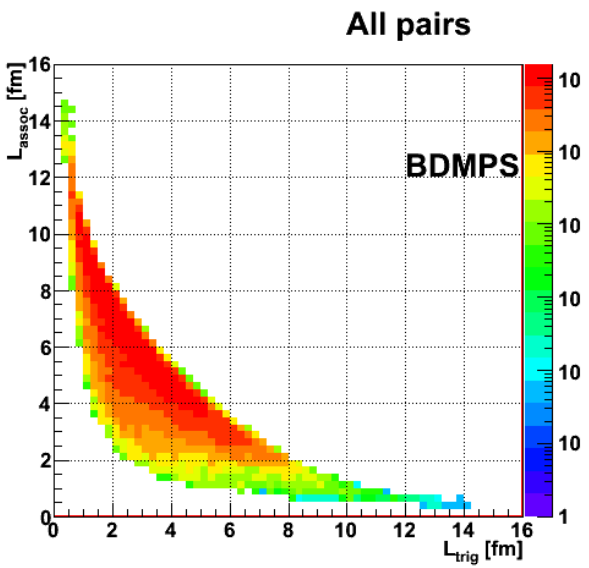
Which part of the multiplicity distribution are we paying attention?

7: Multiplicity distribution pp simulations @ 7TeV with CR for hard QCD





Eur.Phys.J. C79 (2019) no.10, 857


All pairs
BDMPS
L_{assoc} [fm]
L_{trig} [fm]
0
2
4
6
8
10
12
14
16
1
10