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QGP in pp and pPB ?

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Experimental equation of state in pp and p$\bar{p}$ collisions and phase transition to quark gluon plasma

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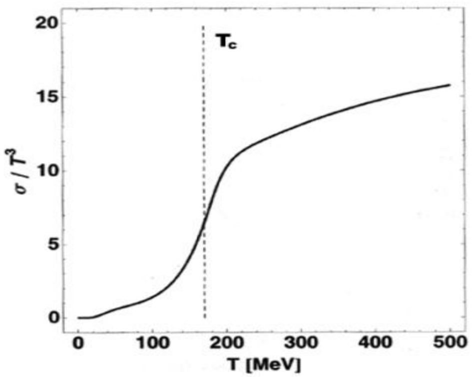
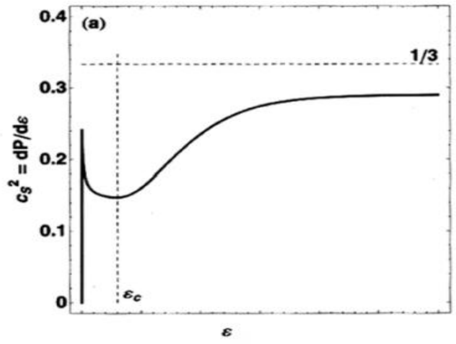
Entropy, Temperature, Sound velocity



(a)



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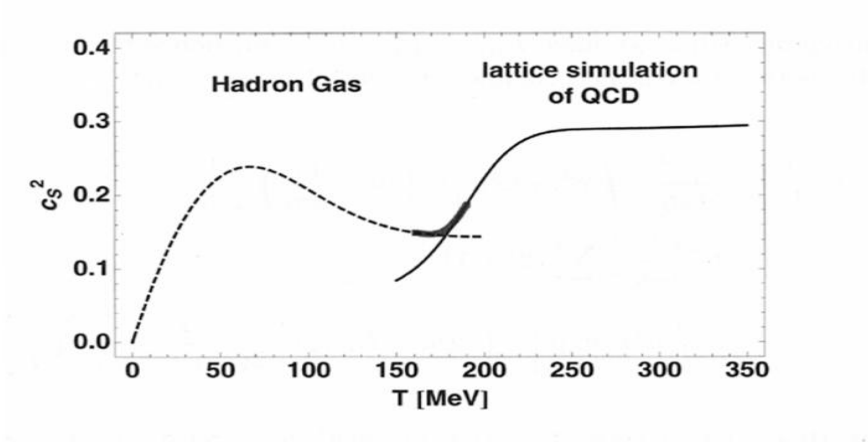


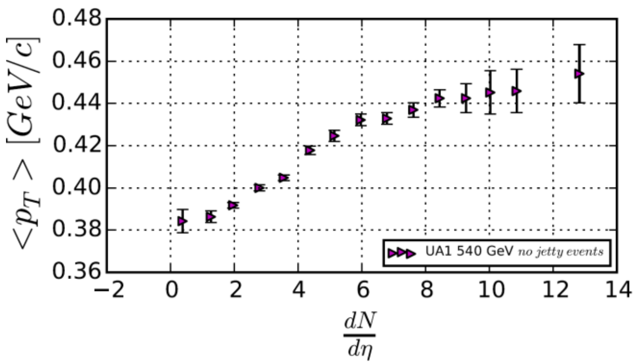
(c)

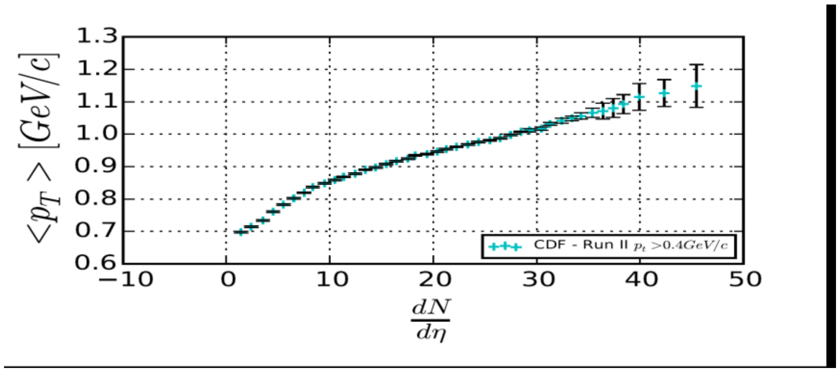
Results from <Pt> vs dn/dη and from Transverse Radius vs dn/dη

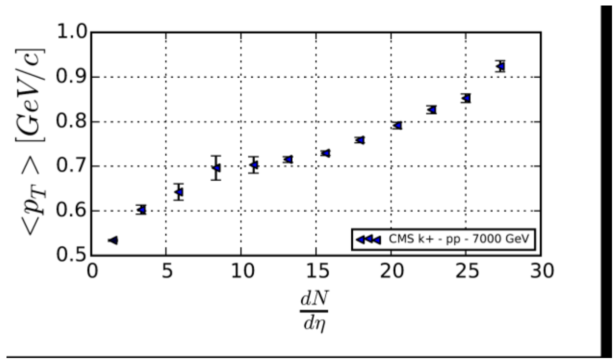
- From 31 GeV to 7 TeV there is a slope change in the <Pt> vs dn/dη at dn/dη around 6 (some examples in next slides)

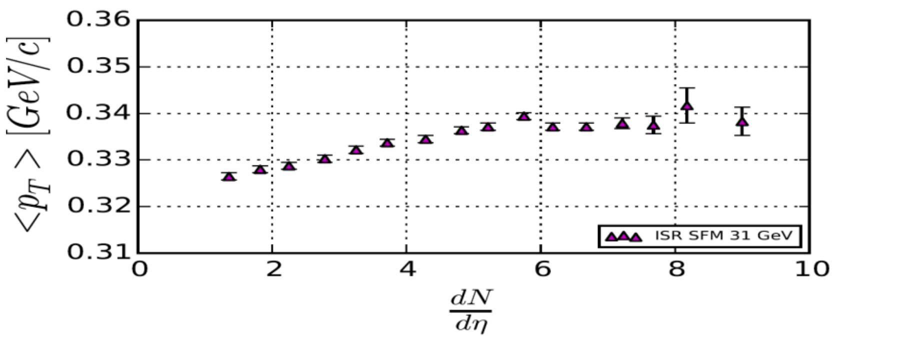
. From FEMTOSCOPY: the transverse Radius Rside is independent from KT (mt) in events with dn/deta <7

Average Transverse Momentum vs pseudorapidity density,some examples

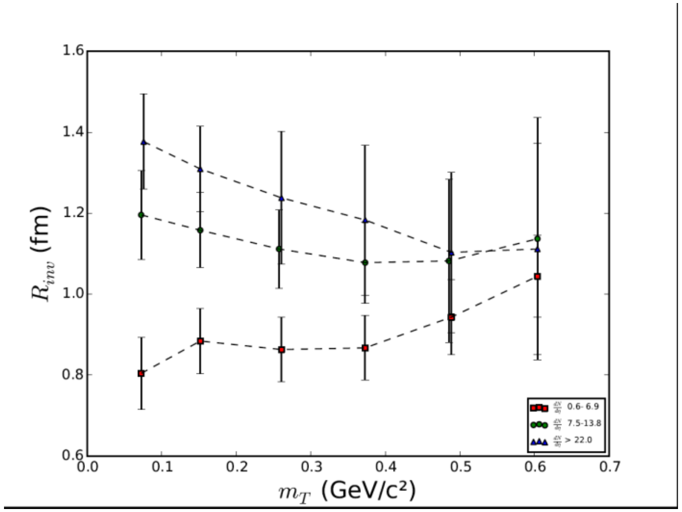


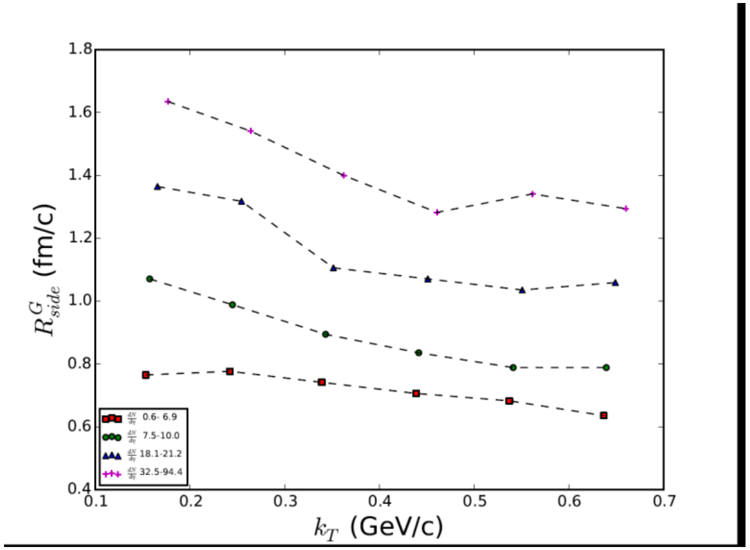






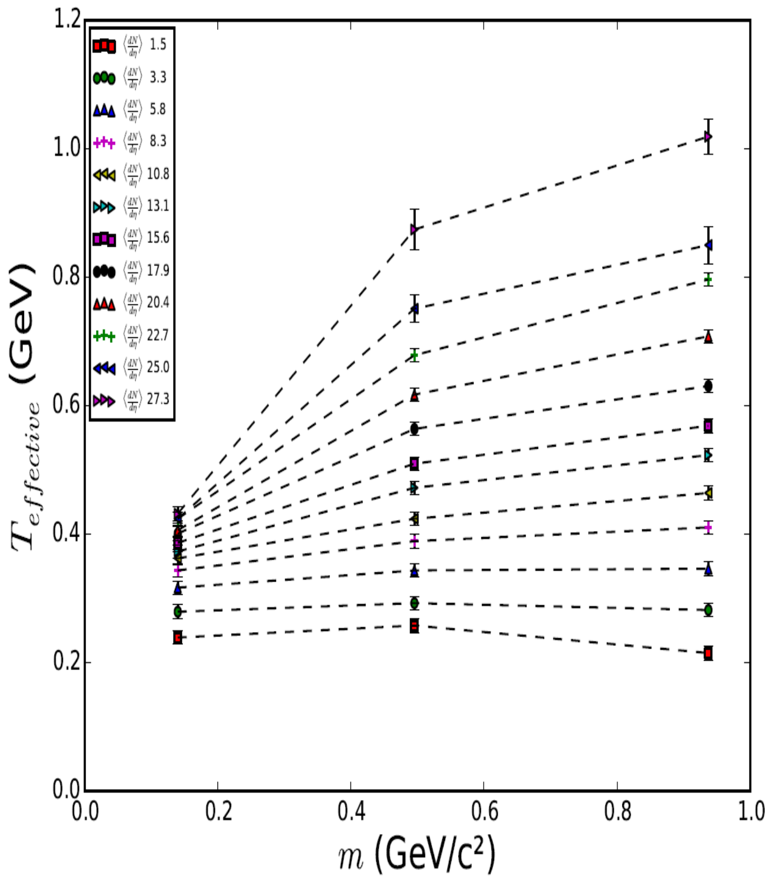
ALICE pion pion femtoscopy in pp events 7 TeV,Rinv and Rgside vs KT in events at different dn/deta

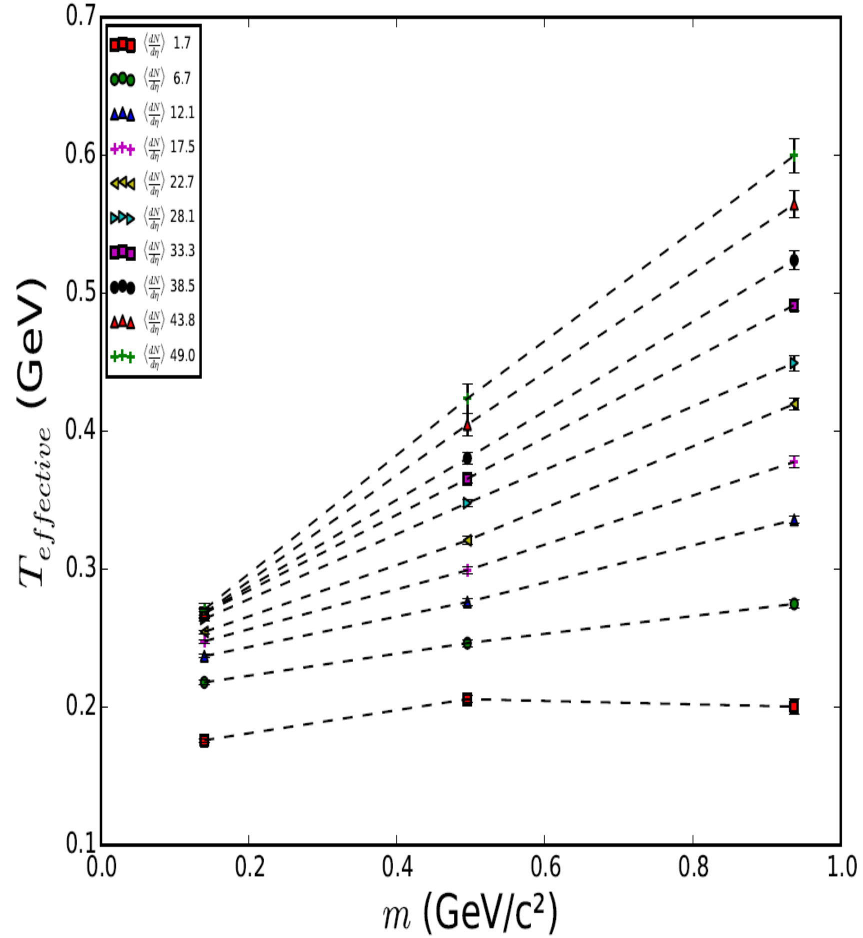




Teff changes with mass only in events with dn/dη > about 7 (in pp, left and in pPb,right)

TRANSVERSE EXPANSION ONLY IN EVENTS WITH dn/dη about 7





$$\sigma_S / \langle p_T \rangle^3 \ \ vs \ p_T$$

2.2. Entropy Density Estimation

The initial energy density in the rest system of a head-on collision has been argued to be [6]:

$$\epsilon \simeq \frac{\frac{dN_{ch}}{d\eta} \cdot \frac{3}{2}\langle p_T \rangle}{V}$$

V denotes the volume into which the energy is deposited. Similarly the initial entropy density is [2]:

$$\sigma \simeq \frac{\frac{dN_{ch}}{d\eta} \cdot \frac{3}{2}}{V}$$

As a result, ϵ is equal to $\sigma \cdot \langle p_T \rangle$. The volume V may be estimated as $V = S \cdot ct$, where S is the interaction area and ct is a longitudinal dimension we can traditionally consider to be about 1 fm long.

In order to study our system, we will use the quantity

$$\sigma_S = \frac{\frac{dN_{ch}}{d\eta} \cdot \frac{3}{2}}{S}$$

as an estimation of entropy density. In models like color glass condensate and percolation, the system physics depends on σ_S [36, 37, 38]. For the estimation

$\sigma_S/\langle p_T\rangle^3$ *vs* p_T

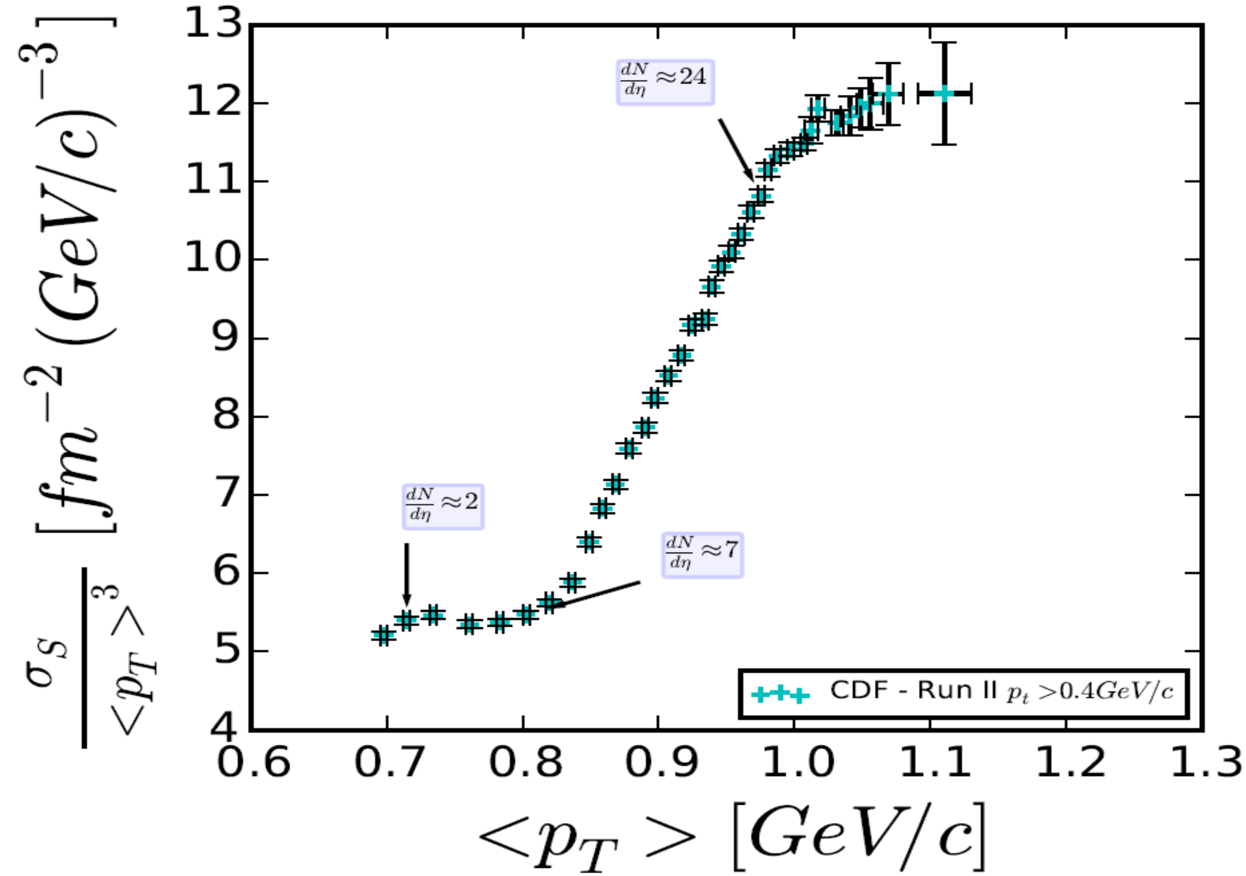
2.4. $\sigma_S/\langle p_T\rangle^3$ *vs* p_T

Using the estimated σ_S, the relation $\langle p_T\rangle$ vs σ_S can be studied. A slope change in $\langle p_T\rangle$ vs σ_S plots is found at σ_S between 2.5 and 3 fm^{-2}, depending on the method used for the estimation of area S and corresponds directly to the slope change seen in $\langle p_T\rangle$ vs $\frac{dN_{ch}}{d\eta}$ at $\frac{dN_{ch}}{d\eta} \simeq 6$.

Starting from σ_S and $\langle p_T\rangle$, we plotted $\sigma_S/\langle p_T\rangle^3$ vs $\langle p_T\rangle$ curves, as an experimental approximation of σ/T^3 vs T curves. See Figs. 3 and 4. We obtained very similar $\sigma_S/\langle p_T\rangle^3$ vs $\langle p_T\rangle$ curves from other pp and p$\bar{\text{p}}$ experiments [27, 29, 30, 31] (not shown).

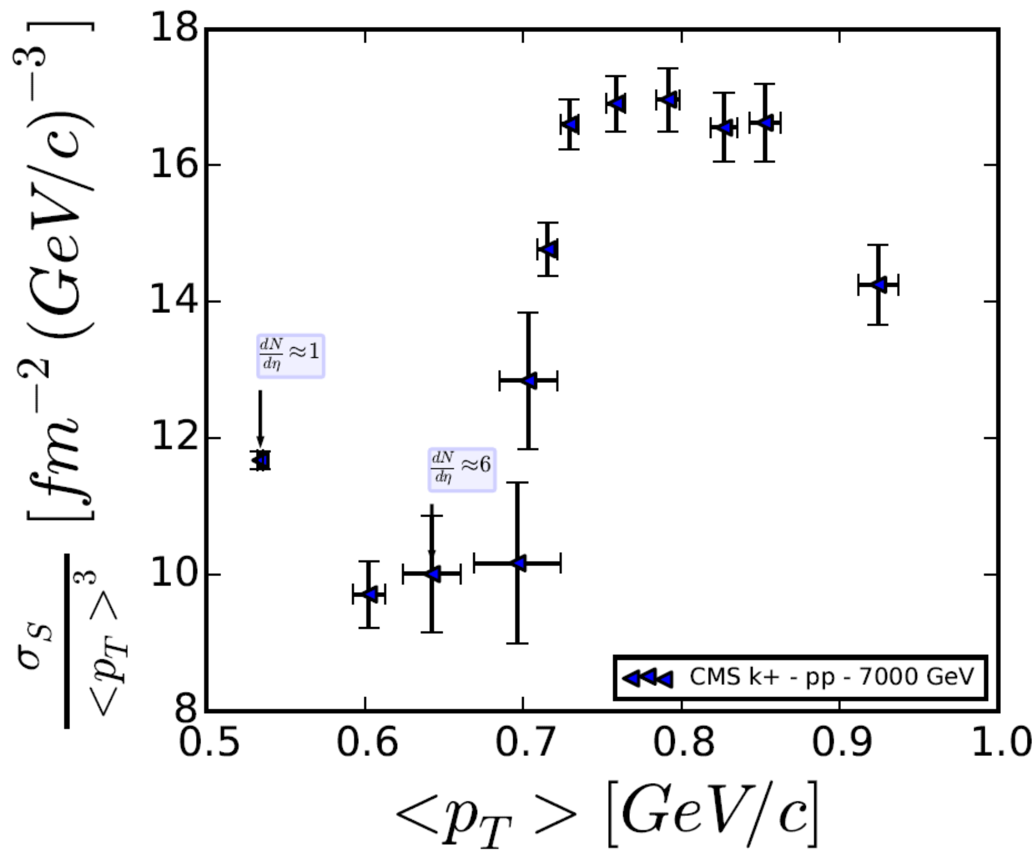
$\sigma_S/\langle p_T\rangle^3 \;\; vs \;\; p_T$

CDF 1.96 TeV
CHARGED



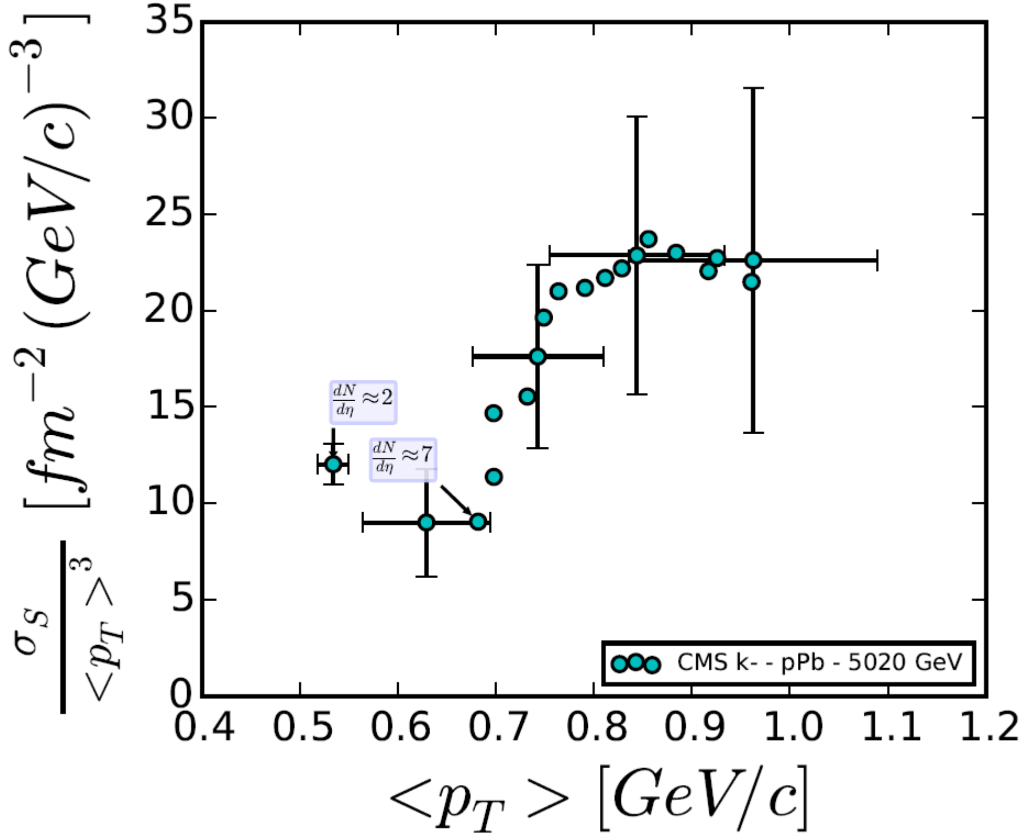
$\sigma_S/\langle p_T\rangle^3$ vs p_T

CMS pp 7 TeV K+



$\sigma_S/\langle p_T\rangle^3$ vs p_T

CMS pPb 5.02 TeV K-



SOUND VELOCITY $c_s^2 = \frac{\sigma}{T} \cdot \frac{dT}{d\sigma}$

2.5. Sound velocity c_s^2

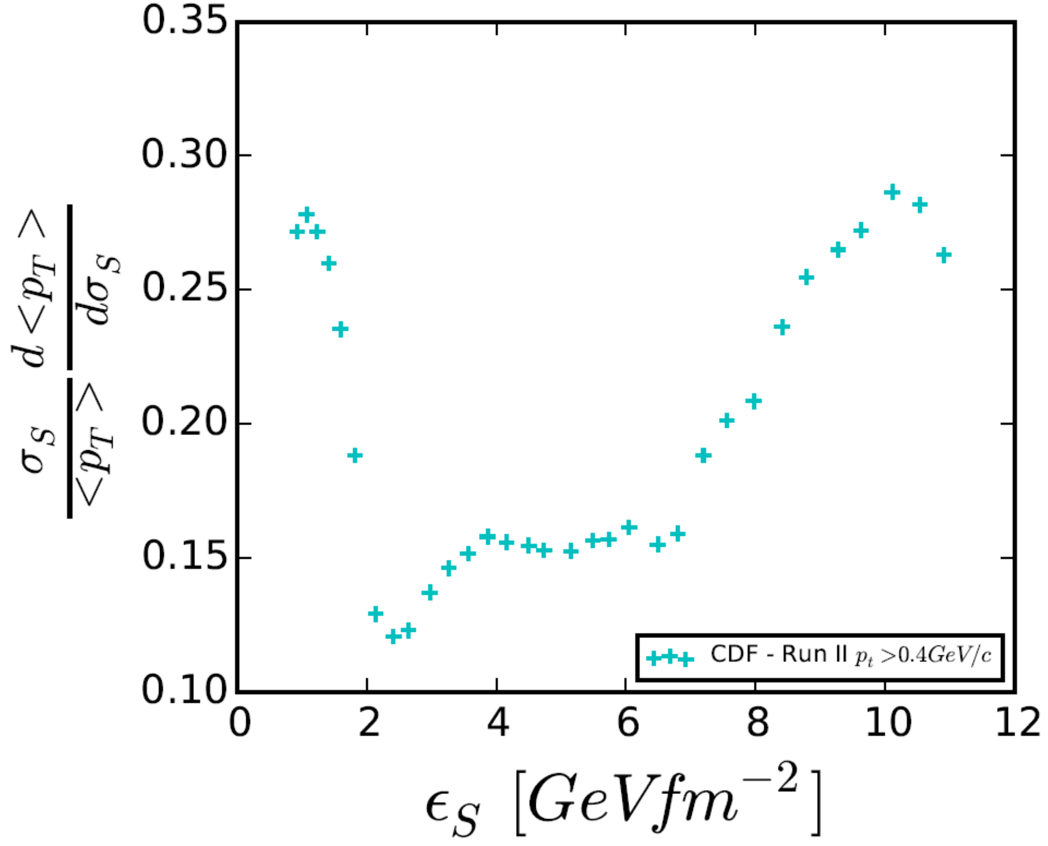
One of the physical quantities used to characterize the state of a system is its squared sound velocity, defined as $c_s^2 = \frac{\sigma}{T} \cdot \frac{dT}{d\sigma}$, for constant V [11]. In our study, we approximate it with $c_s^2 = \frac{\sigma_S}{\langle p_T \rangle} \cdot \frac{d\langle p_T \rangle}{d\sigma_S}$. It is really interesting that if $\langle p_T \rangle$ is proportional to T and if σ_S is proportional to the entropy density, then the c_s^2 value obtained in this approximation is equal to the right value of $c_s^2 = \frac{\sigma}{T} \cdot \frac{dT}{d\sigma}$, because proportionality constants cancel out. In order to obtain our c_s^2 estimation, from $\langle p_T \rangle$ vs $\frac{dN_{ch}}{d\eta}$ curves and from σ_S values, we compute the curve p_T vs σ_S, to which we apply numerical derivation. We cope with the statistical fluctuation in data points using a combination of Gaussian and Savitzky-Golay filters [43]. Examples of c_s^2 vs $\langle p_T \rangle$ curves are shown in Figs. 5a and 5c.

SOUND VELOCITY

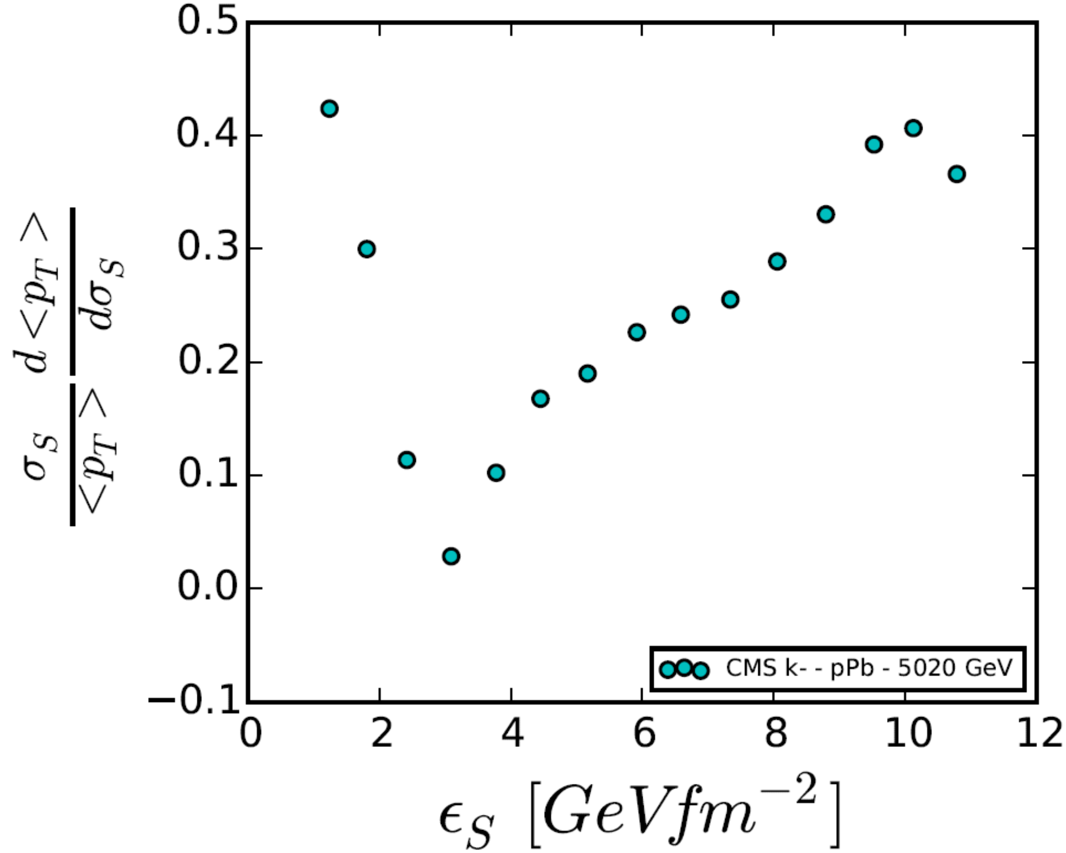
The so obtained c_s^2 estimation resembles the typical shape of a phase transition or a crossover: a descent, a minimum region and a following rise, as it's also obtained analytically from EOSs which present a phase transition or a crossover. The minimum value reached by the estimation of c_s^2 in the different experimental curves varies from 0.08 to 0.18 and could correspond to what it's called the EOS softest point [17].

Recently Refs. [44, 45, 46] estimate c_s^2 minimum value for realistic EOS to be around 0.14. From $\epsilon_S \simeq \langle p_T \rangle \cdot \sigma_S$ we compute c_s^2 vs ϵ_S curves, that are approximations of c_s^2 vs energy density. We report these curves in Figs. 5b and 5d.

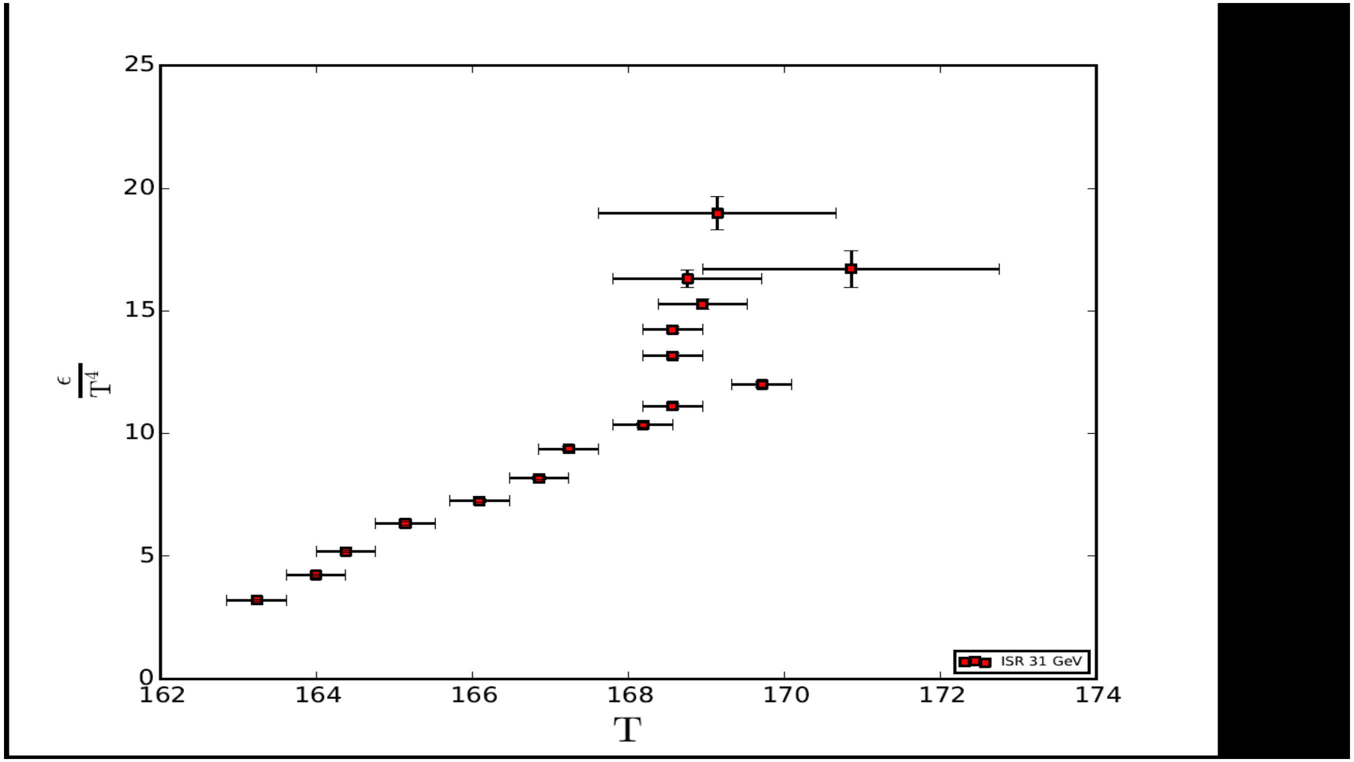
SOUND VELOCITY CDF pp 1.96 TeV



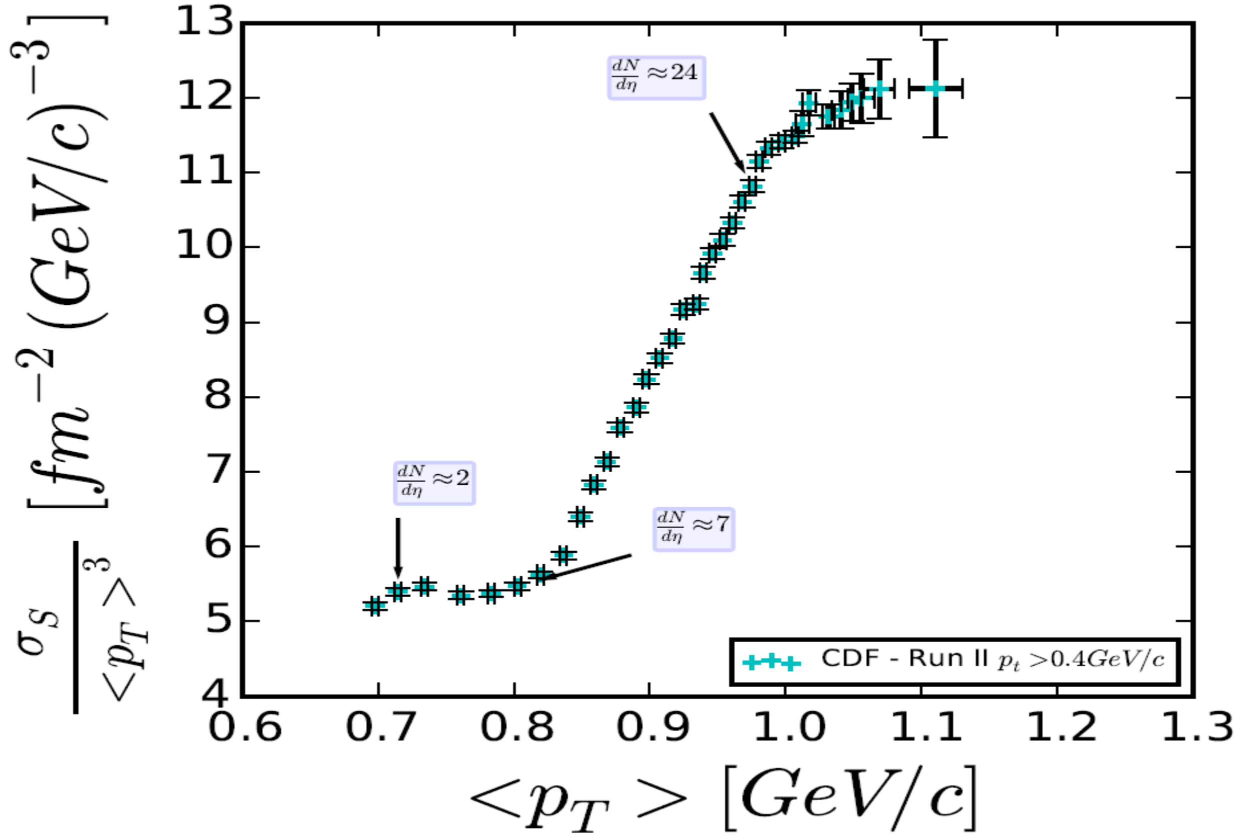
SOUND VELOCITY CMS K- pPb 5.02 TeV



- AT LOW ENERGY (31 GeV) IN EVENTS WITH LOW : NO JETS, NO TRANSVERSE EXPANSION→ TRANSVERSE MOMENTUM MEASURES TEMPERATURE! (exponential or Hagedorn Model)



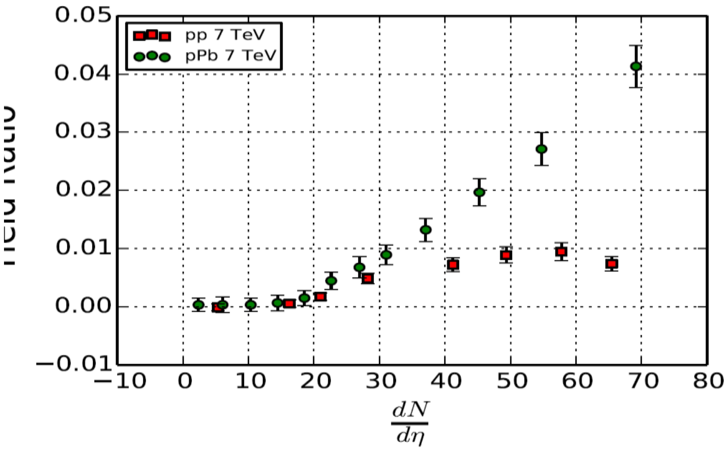
CROSSOVER FROM dn/deta 6 to about 24?



WHAT HAPPENS IN EVENTS with dn/deta in the range 6 - 24?

- Ridge
- Multiparticle correlations
- Particle yield
- Y(3s)/Y(1S) ;y(2s)/y(1s) ratio

Ridge,multiparticle correlations



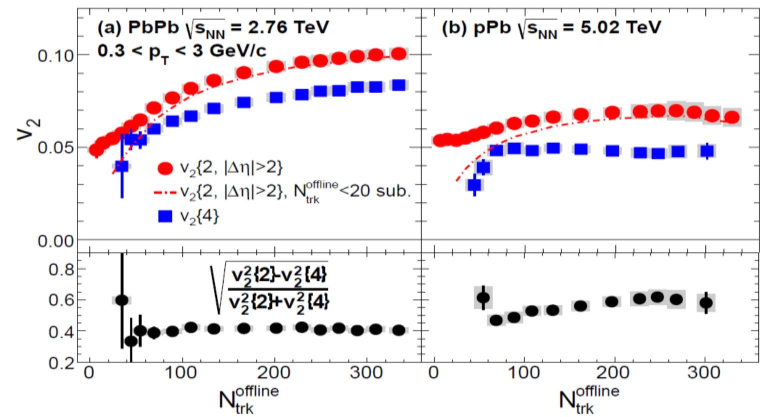


Figure 9: Top: the $v_2\{2, |\Delta\eta| > 2\}$ (circles) and $v_2\{4\}$ (squares) values as a function of $N_{trk}^{offline}$ for $0.3 < p_T < 3\,GeV/c$, in 2.76 TeV PbPb collisions (left) and 5.02 TeV pPb collisions (right). Bottom: upper limits on the relative v_2 fluctuations estimated from $v_2\{2\}$ and $v_2\{4\}$ in 2.76 TeV PbPb collisions (left) and 5.02 TeV pPb collisions (right). The error bars correspond to statistical uncertainties, while the shaded areas denote the systematic uncertainties. Results after subtracting the low-multiplicity data ($N_{trk}^{offline} < 20$) are also shown (curves).

Multi-particle azimuthal correlations in p–Pb and Pb–Pb collisions ALICE Collaboration

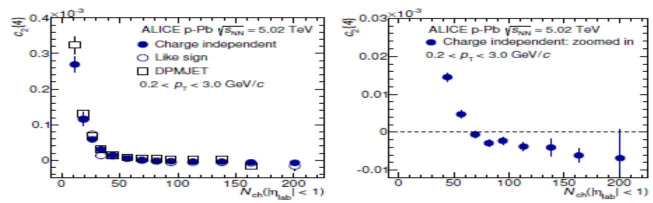


Fig. 4: Mid-rapidity ($|\eta| < 1$) measurements of $c_2\{4\}$ as a function of multiplicity for p-Pb collisions. Only statistical errors are shown as these dominate the uncertainty. See table 1 for systematic uncertainties. The right panel shows a zoomed in version of the solid points in the left panel.

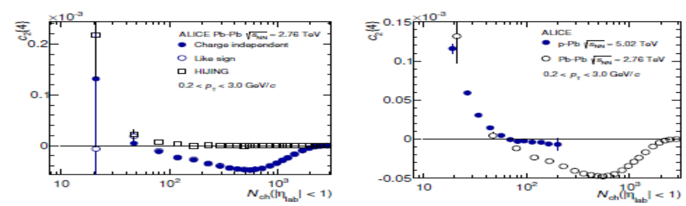
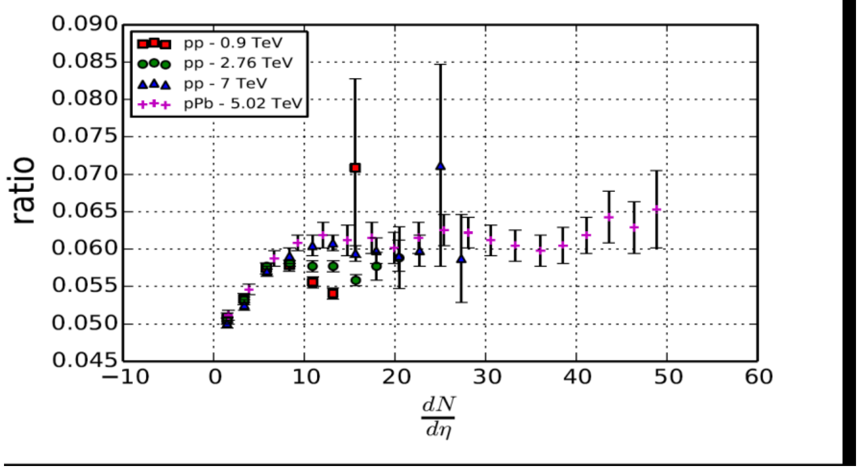


Fig. 5: Left Panel: Mid-rapidity ($|\eta| < 1$) measurements of $c_2\{4\}$ as a function of multiplicity for Pb-Pb collisions. Right Panel: Comparison of $c_2\{4\}$ for p-Pb and Pb-Pb collisions. Only statistical errors are shown as these dominate the uncertainty. See table 1 for systematic uncertainties.

(proton +antiproton)/pions in pp and pPb v , D meson production in pp,Y (ns)/Y(ms) vs dn/deta



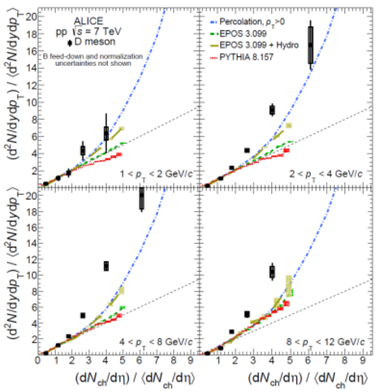
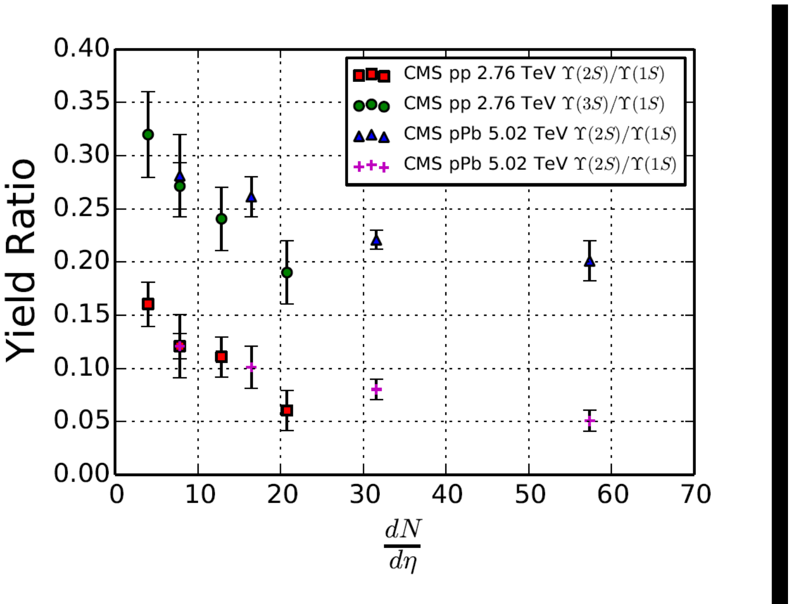


Figure 10: Average D-meson relative yield as a function of the relative charged-particle multiplicity at central rapidity in different p_T intervals. The systematic uncertainties on the data normalisation ($+6\%/-3\%$), on the $(dN_{ch}/d\eta)/\langle dN_{ch}/d\eta \rangle$ values ($\pm 6\%$), and on the feed down contribution are not shown in this figure. Different calculations are presented: PYTHIA 8.157 [30, 31], EPOS 3 with and without hydro [71, 72] and a p_T-integrated percolation model [41, 73]. The coloured lines represent the calculation curves, whereas the shaded bands represent their statistical uncertainties at given values of $(dN_{ch}/d\eta)/\langle dN_{ch}/d\eta \rangle$. The diagonal (dashed) line is shown to guide the eye.

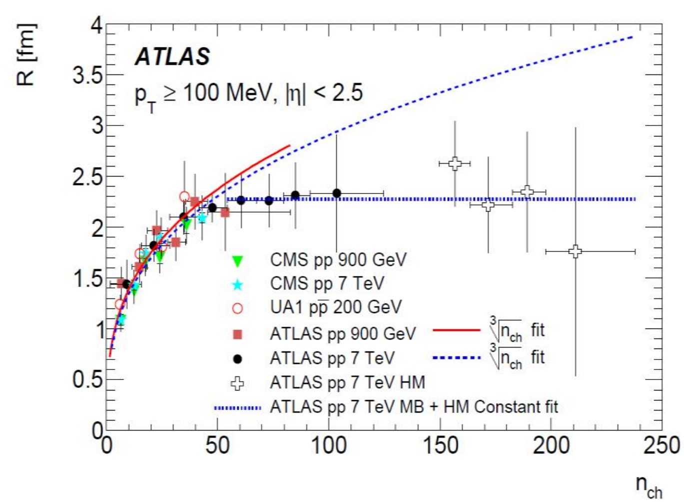


Possible saturation of particle ratios and Y(ns)/Y(ms) ratio at high dn/deta. Volume effect? Does the volume saturate as well?

CERN-PH-EP-2014-264
Submitted to: Eur. Phys. J. C

Two-particle Bose–Einstein correlations in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV measured with the ATLAS detector

The ATLAS Collaboration



(b)

Fig. 3. Multiplicity, $n_{\rm ch}$, dependence of the parameters (a) λ and (b) R obtained from the exponential fit to the two-particle double-ratio correlation functions $R_2(Q)$ at $\sqrt{s}$ =0.9 and 7 TeV, compared to the equivalent measurements of the CMS [38, 39] and UA1 [67] experiments. The solid and dashed curves are the results of (a) the exponential and (b) $\sqrt[3]{n_{\rm ch}}$ for $n_{\rm ch} < 55$ fits. The dotted line in (b) is a result of a constant fit to minimum-bias and high-multiplicity events data at 7 TeVfor $n_{\rm ch} \geq 55$. The error bars represent the quadratic sum of the statistical and systematic uncertainties.