Rapidity dependence of particle densities in pp-AA collisions

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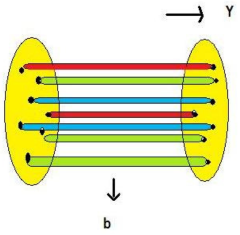
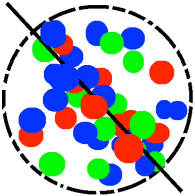
- Multi-particle production is described in terms of color of strings stretched between the partons of the projectile and target. Color strings will decay into new ones by $q\bar{q}$, $qq - \bar{q}\bar{q}$ production.
  $S_1 = \pi r_0^2$, $r_0 \sim 0.25$ fm.



- The number of strings grows with the energy and with the number of nucleons of participating nuclei.
- Color strings may be viewed as small disks in the transverse space filled with the color field created by colliding partons.
- Particles are produced by the Schwinger mechanisms.
- With growing energy and size of the colliding nuclei the number of strings grow and start to overlap forming clusters.
- At a critical density a macroscopic cluster appears and marks the percolation phase transition.

- The formation of clusters behaves like disks in the continuum two dimensional percolation.
- $\eta_c^t = 1.1 - 1.5$
- $\eta^t = N_s \frac{S_1}{S_A}$
- We assume a cluster of n strings behaves as a single string with higher color field, and momentum.
- $< \mu_n >= \sqrt{\frac{nS_n}{S_1}} < \mu_1 >$
- $< p_{Tn}^2 >= \sqrt{\frac{nS_1}{S_n}} < p_{T1}^2 >$



- In SPM the relevant quantity is the transverse impact parameter density η^t for pp collisions
- $\eta^t \equiv (\frac{r_0}{R_p})^2 \bar{N}_p^s$
- The particle density dn/dy at mid rapidity is related to the average number $\bar{N}_s$ of strings
  $\frac{dn}{dy} \sim F(\eta^t)\bar{N}_s$
  $F(\eta^t) = \sqrt{\frac{1-e^{-\eta^t}}{\eta^t}}$

- The overlap area is given by $S_{N_A} = S_A(N_A/A)^{5/3}$,

$$N_A^s \simeq N_p^s N_A^{(\alpha+1)} \quad (1)$$

with

$$N_p^s = 2 + 4\left(\frac{r_0}{R_p}\right)^2 \left(\frac{\sqrt{s}}{m_p}\right)^{2\lambda}, \quad (2)$$

Notice that it would be expected

$$N_A^s \simeq N_p^s N_A^{4/3} \quad (3)$$

instead of

$$N_A^s = N_p^s N_A^{(\alpha+1)} \quad (4)$$

but the energy in pp is $\sqrt{s}$ and in AA is $A\sqrt{s}$, therefore at not very high energy some strings have not enough energy to be formed. The number should increase from A to $A^{4/3}$ with a $\ln s$ (phase space) dependence as is has $\alpha(s)$.

- With the string density

$$\eta^t_{N_A} = \eta^t_p N_A^{(\alpha(s))} \frac{A}{N_A^{2/3}} \tag{5}$$

- $$\frac{1}{N_A}\frac{dn}{dy}\bigg|_{y=0} = \frac{dn^{pp}}{dy}\bigg|_{y=0}\left(1+\frac{F(\eta^t_{N_A})}{F(\eta^t_p)}(N_A^{\alpha(\sqrt{s})}-1)\right), \quad (6)$$

- with
$$\alpha(s) = \frac{1}{3}(1-\frac{1}{1+ln(\sqrt{s/s_0}+1)}), \quad (7)$$

and
$$\frac{dn^{pp}_{\rm ch}}{d\eta}\bigg|_{\eta=0} = \kappa\, F(\eta^t_p)\, N^s_p\,, \quad (8)$$

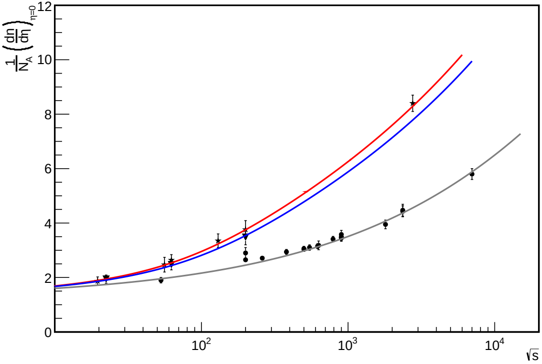
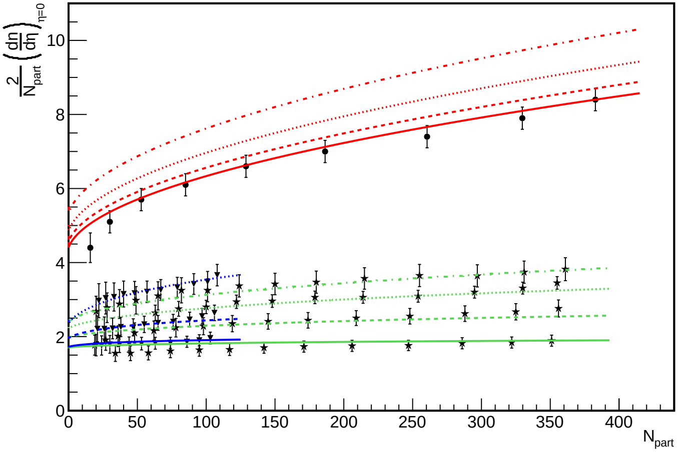


Figure: Multiplicity dependence on $\sqrt{s}$. Data from $p-p$, $Cu-Cu$, $Au-Au$ and $P-Pb$ is shown in circles, triangles and starts respectively. $(N_A = 1, A = 1)$ for is used for pp (grey line); $(NA = 50, A = 63)$ for CuCu (blue line); and $(NA = 175, A = 200)$ for AuAu/PbPb (red line)


$\frac{2}{N_{part}} \left(\frac{dn}{d\eta}\right)_{\eta=0}$
0
2
4
6
8
10
0
50
100
150
200
250
300
350
400
N_{part}

$$\bar{N}_s \sim e^{2\lambda Y}, \tag{9}$$

for the particle density, at $y \simeq 0$,

$$\frac{dn}{dy} \sim e^{\lambda Y}, \tag{10}$$

and for the full rapidity distribution,

$$\frac{dn}{dy}|_{pp} = a e^{\lambda Y} \frac{dn}{dy}|^{s}, \tag{11}$$

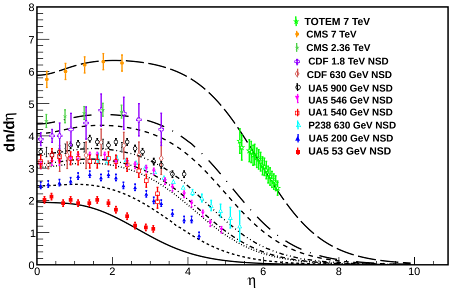
where $\frac{dn}{dy}|^{s}$ is the single string density, $\frac{dn}{d\eta}|_{pp}$

$$\frac{dn}{dy}|^{s} = \frac{1}{e^{\frac{\eta-(1-\alpha)Y}{\delta}}+1}, \tag{12}$$

$$\frac{dn}{d\eta}|_{pp} = J\frac{dn}{dy}|_{pp}, \tag{13}$$

with $J = \frac{cosh\eta}{\sqrt{k+sinh^2\eta}}$, $k = \frac{m^2+p_T^2}{p_T^2}$ and by assumption fix k at the effective value 1.2. It corresponds to $m_\pi \simeq 0.14$ GeV and $\bar{p}_\pi \simeq 0.3$ GeV.

$$\left.\frac{dn_{\rm ch}^{pp}}{d\eta}\right|_{\eta} = \kappa' J\, F(\eta_p^t)\, N_p^s \frac{1}{\exp\left(\frac{\eta-(1-\alpha)Y}{\delta}\right)+1} \qquad (14)$$



Comparison of the results from the evolution of the $\frac{dn_{ch}}{d\eta}$ with dependence in pseudorapidity for $p-p$ collisions at different energies (lines).

- Evolution in pseudorapidity for AA collisions

$$\frac{dn}{d\eta} =$$
$$\kappa' J(N_A)\frac{dn^{pp}}{dy}|_{y=0}(1+\frac{F(\eta^t_{N_A})}{F(\eta^t_p)}(N_A^{\alpha(\sqrt{s})}-1))\frac{1}{\exp\left(\frac{-\eta-(1-\alpha)Y}{\delta}\right)+1}$$

with $\kappa' = \frac{\kappa}{J(\eta=0)}(\exp\left(\frac{-(1-\alpha)Y}{\delta}\right)+1)$.

In all the computations we have used the following values of the parameters: $\kappa = 0.63 \pm 0.01$, $\lambda = 0.201 \pm 0.003$, $\sqrt{s_0} = 245 \pm 29$ GeV, $\alpha \simeq 0.34$, $\delta \simeq 0.84$ and $k_1 = 1.2$ to describe the particle density $\frac{dn}{d\eta}|_{N_A N_A}$ in the same power law as $\frac{dn}{d\eta}|_{pp}$. We had made here an extension to these descriptions to add the pseudo rapidity evolution.

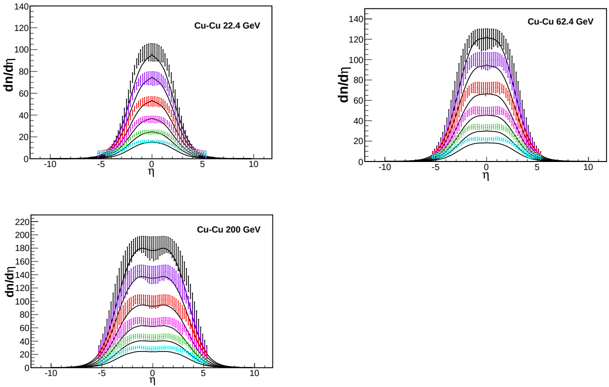


Figure: Evolution of the $dn_{ch}/d\eta$ with pseudorapidity for Cu-Cu collisions at 22.4 GeV, 62.4 GeV, and 200 GeV energies, data from ref. [1]. Error bars in color blue, green, pink, red, purple and black are used for the corresponding centralities $45-55\%$, $35-45\%$, $25-35\%$, $15-25\%$, $6-15\%$, $0-6\%$ respectively, black lines show our results.

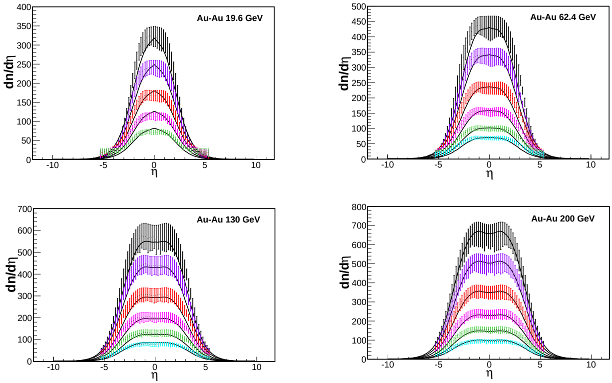


Figure: Evolution of the $dn_{ch}/d\eta$ with pseudorapidity for Au-Au collisions at 19.6 GeV, 62.4 GeV, 130 GeV and 200 GeV energies. Error bars in color blue, green, pink, red, purple and black are used for the corresponding centralities $45-55\%$, $35-45\%$, $25-35\%$, $15-25\%$, $6-15\%$, $0-6\%$ respectively, black lines are the model results [2]

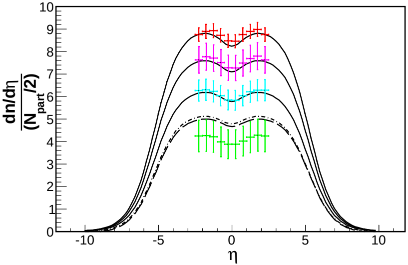


Figure: Comparison of the results CMS [3] from the evolution of the $\frac{dn_{ch}}{d\eta}\frac{1}{(N_{part}/2)}$ with the pseudorapidity for Pb-Pb collisions at 2.76 TeV. Error bars in color green, blue, pink and red are used for the corresponding centralities $85-95\%$, $50-55\%$, $0-90\%$ and $0-5\%$ respectively, lines in black are the corresponding results from the model to the respective centrality, for the smaller centrality we use the number of participants corresponding to the 85-95$\%$ showed in dot and dashed line and in dashed line is the minimum number of participants equal 2.

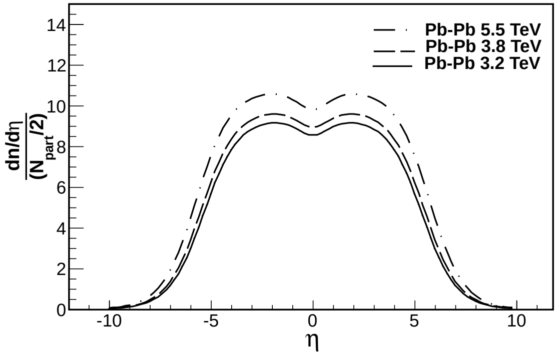


Figure: Predictions on the evolution of the $\frac{dn_{ch}}{d\eta}\frac{1}{(N_{part}/2)}$ with pseudorapidity for Pb-Pb collisions at 3.2, 3.9 and 5.5 TeV energies at $0-5\%$ centrality.

Conclusions

- We have discussed in a general way the physics of particle densities in pp and AA collisions.
- Our model gives a non-linear dependence of $\frac{1}{N_A} dn/d\eta|_{AA}$ on $dn/d\eta|_{pp}$.
- Particle densities, as a function of η and Y give a good description of Pb-Pb data at LHC in a wide region in η. The same is observed for pp in a wide range of rapidity Y.
- Notice that recent data from TOTEM experiment measurements in the charged particle pseudorapidity density $dN_{ch}/d\eta$ in pp collisions at $\sqrt{s} = 7$ TeV for $5.3 < |\eta| < 6.4$ is consistent with this results.

Thank you...

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