Ridge effect in pp collisions & events structure

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Two particle correlation function at 200 GeV/c/N from STAR experiment
Cover an acceptance of $3 < |\eta| < 4.5$ and $-180^\circ < \phi < 180^\circ$. About $5 \times 10^5$ 200-GeV and $8 \times 10^5$ 410-GeV p+p events were selected for further analysis by requiring that the main collision vertex fell within $|z_{vtx}| < 10$ cm along the beam axis.

**Charged-di-hadron distribution**

- $3$ GeV/c < $p_T^{\text{trig}}$ < $4$ GeV/c
- $2$ GeV/c < $p_T^{\text{assoc}}$ < $p_T^{\text{trig}}$
Two-particle correlation functions versus $\Delta\eta$ and $\Delta\phi$ in pp collisions
Ridge effect in pp — attempts at interpretation

Colour Glass Condensate effective theory

Hydrodynamical expansion and many flux tubes

Effect of an elliptic flow manifestation.

Momentum kick model

and many others
What are the meaning of the cuts?

For RHIC AuAu

\[ 3 \text{ GeV/c} < p_T^{\text{trig}} < 4 \text{ GeV/c} \]
\[ 2 \text{ GeV/c} < p_T^{\text{assoc}} < p_T^{\text{trig}} \]

For LHC pp

\[ 0.1 \text{ GeV/c} < \ldots < p_T < \ldots < 5 \text{ GeV/c} \]

Multiplicity N > 110
Tsallis distribution

\[ G_q(E) = C_q \left( 1 - (1 - q) \frac{E}{T} \right)^{1/(1-q)}, \]

\[ n = -\frac{1}{1 - q}. \]

\[ E \frac{d^3\sigma}{dp^3} = \frac{1}{2\pi} \frac{d\sigma}{dy} \frac{(n-1)(n-2)}{(nT + m_0(n-1))(nT + m_0)} \left( \frac{nT + m_T}{nT + m_0} \right)^{-n}. \]

Invariant differential cross sections of different particles measured in p + p collisions at \( \sqrt{s} = 200 \text{ GeV} \) in various decay modes.
Tsallis statistics

\[ \frac{1}{\sigma} \frac{d\sigma}{dp_T} \approx c p_T \int_0^\infty dp_L (1 + (q - 1)\beta \sqrt{p_T^2 + p_L^2 + m_0^2})^{-q/(q-1)} \]

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STAR & PHENIX
\( \sqrt{s} = 200 \) GeV
a) The invariant charged particle differential yield from the present analysis (solid circles) and the previous CMS measurements at $\sqrt{s} = 0.9$ TeV (stars) over the limited $p_T$ range of the earlier result.

Lower panel: the ratio of the new (solid circles) and previous (stars) CMS results to a Tsallis fit of the earlier measurement.

b) The same for $\sqrt{s} = 7$ TeV.
High & low $p_T$ hadron spectra

Interpretation?

How to distinguish
In the experiment?

Incl. Cross Section

Soft

Bulk

Hard

Jets, mini-jets

RHIC/LHC energies

4-6 GeV/c

$P_T$
pp collisions $\sqrt{s} = 7$ TeV/c

Pythia v.6-424

Charged particles
Pythia PP collisions

Pythia v.6-424

10K events $\sqrt{s} = 7$ TeV
All charged particles

hard

soft

$p_t^{\text{max}}$ GeV/c

$p_t$ GeV/c

$p_{\text{all particles}}$ GeV/c

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13/20
PP collisions

Pythia v.6-424

10K events $\sqrt{s} = 7$ TeV
All charged particles
$P_{t}^{\text{max}}$ cut = 4 GeV/c

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pp collisions $\sqrt{s} = 200$ GeV/c

50K events at $\sqrt{s} = 200$ GeV
All charged particles
pp collisions $\sqrt{s} = 200$ GeV/c

50K events $\sqrt{s} = 200$ GeV
All charged particles
$P_{t}^{\text{max}}$ cut = 2 GeV/c

Pythia v.6-424

jet

chaos
pp collisions $\sqrt{s} = 0.2$ & 7 TeV/c

All charged particles

$\sqrt{s} = 7$ TeV

$\sqrt{s} = 200$ GeV

Pythia pp $\sqrt{s} = 7$ TeV
pp collisions

Pythia v.6-424

$\sqrt{s} = 7$ TeV

$\sqrt{s} = 200$ GeV
Ridge dAu vs AuAu

2 GeV/c < $p_T^{\text{assoc}} < p_T^{\text{trig}}$

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Event structure of multiparticle collision reveals itself by the features in the inclusive spectra and various correlation phenomena