Forward-backward multiplicity correlations in pp collisions at LHC within the QGSM

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Outline

- Forward-backward multiplicity correlations in hadronic interactions
- Quark-gluon string model (QGSM)
- FB correlations at intermediate energies
- Origin of FB correlations at LHC energies; comparison with data
- Conclusions
I. Forward-backward multiplicity correlations in hadronic interactions
Observation of strong correlations (ISR)

S. Uhlig et al., NPB 132 (1978) 15

central region

fragmentation region
Main results

\[ \langle n_F(n_B) \rangle = a + b_{corr} n_B \]

\[ b_{corr} = \frac{\langle n_F n_B \rangle - \langle n_F \rangle^2}{\langle n_F^2 \rangle - \langle n_F \rangle^2} \]

The FB multiplicity correlations are positive

Correlations are stronger for anti-pp collisions compared to pp ones (at energies below 100 GeV)

No sizeable FB correlations were found in e^+e^- annihilation up to 93 GeV

Correlations are due to central region |x_F| < 0.1
(some) references
theory/models

A.~Capella, J. Tran Thanh Van, ZPhC 18 (1983) 85.
J.~Dias~de~Deus, PLB 100 (1981) 177.
N.S.~Amelin et al., PRL 73 (1994) 2813.
Y.-L.~Yan et al., NPA 834 (2010) 320c.

II. Quark-Gluon String Model (QGSM)
Because of the different sets of diagrams for pp and anti-pp collisions (particularly, annihilation) there should be a difference in FB multiplicity correlations for these two reactions.
Diagrams at ultrarelativistic energies

(a) -- multi-cylinder
(b) – semihard (+ soft) Pomeron
(c) – single diffraction of large mass
(d) – single diffraction of small mass
(e) – double diffraction of small mass
(f) – double diffraction of large mass

At ultrarelativistic energies only few diagrams are left, whereas cross sections of annihilation and pre-asymptotic processes quickly drop => No difference between pp and anti-pp collisions
III. FB multiplicity correlations at intermediate energies
(anti)pp @ 32 GeV/c (data)


<table>
<thead>
<tr>
<th>Reaction</th>
<th>( a )</th>
<th>( b )</th>
<th>( \chi^2 \text{/deg. fr.} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inelastic interactions</td>
<td>2.03±0.02</td>
<td>0.192±0.007</td>
<td>22/(10−2−1)</td>
</tr>
<tr>
<td>Nondiffraction interactions</td>
<td>2.18±0.04</td>
<td>0.177±0.010</td>
<td>24/(10−2−1)</td>
</tr>
<tr>
<td>Particles with (</td>
<td>x</td>
<td>&lt; 0.1 ) in inelastic interactions</td>
<td>1.09±0.01</td>
</tr>
<tr>
<td>Particles with (</td>
<td>x</td>
<td>&gt; 0.1 ) in inelastic interactions</td>
<td>1.144±0.008</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Reaction</th>
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<th>( b )</th>
<th>( \chi^2 \text{/deg. fr.} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inelastic interactions</td>
<td>2.07±0.04</td>
<td>0.098±0.016</td>
<td>92/(11−2−1)</td>
</tr>
<tr>
<td>Nondiffraction interactions</td>
<td>2.25±0.05</td>
<td>0.07±0.02</td>
<td>36/(11−2−1)</td>
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<tr>
<td>Particles with (</td>
<td>x</td>
<td>&lt; 0.1 ) in inelastic interactions</td>
<td>1.11±0.04</td>
</tr>
<tr>
<td>Particles with (</td>
<td>x</td>
<td>&gt; 0.1 ) in inelastic interactions</td>
<td>1.262±0.009</td>
</tr>
</tbody>
</table>

No long-range correlations between the fragmentation regions
(anti)pp @ 32 GeV/c vs. QGSM

antiproton-proton  proton-proton

Closed points: inelastic collisions
Open points: non-diffractive collisions
Solid curves: QGSM
Dashed curve: Lund
(anti)pp @ 32 GeV/c vs. QGSM

antiproton-proton

Open points: inelastic collisions
Solid curves: QGSM
Dashed curves: Lund

(a) $|x| > 0.1$

(b) $|x| < 0.1$

proton-proton

No long-range correlations

Positive FB correlations come from the region $|x| < 0.1$ corresponding to $|y| < 1$, i.e. midrapidity region

FB correlations within the subprocesses

(a) – cylindrical diagrams

(b) – undeveloped cylinder

(c) – diffraction diagrams

(d) – annihilation diagrams

(e) – planar diagrams

No correlations in individual processes, however, addition of all these processes with different $<n_F>$ leads to appearance of positive correlations $<n_F>(n_B)$
IV. Origin of FB multiplicity correlations in QGSM at LHC energies
pp @ 20 GeV to 14 TeV in QGSM

(1) The slope is almost linear; (2) no difference between pp and anti-pp at high energies; (3) slope parameter $b$ increases with rising energy; (4) saturation of the increase at high multiplicities. Why?
Rel. weight of soft and hard Pomerons

The ratio hard/soft increases from $0.29 : 1.14$ (900 GeV) to $1.10 : 1.54$ (13 TeV)
Contribution of soft and hard Pomerons

Soft Pomerons

Hard Pomerons
Change of the slope with energy

The slope increases. Also, the distributions are more horizontal at very small and very high multiplicities. Why?
Contributions of $n$-Pomeron processes

If we select processes going via $1, 2, \ldots, N$ Pomerons, then the distributions are remarkably flat (no FB correlations). However, average multiplicities are different. This leads to positive correlations when one adds all processes together. The same is true for the diffraction, but the slope is not so steep, therefore $b_{\text{NSD}} > b_{\text{inel}}$. 
more details ...
Comparison with LHC data

Agreement is good, however, comparison with LHC data might require fine tuning.
In $pp$ and $\bar{p}p$ collisions positive forward-backward correlations of the multiplicity of particles are observed in QGSM in a broad energy range from 8 GeV to 14 TeV.

At energies below 100 GeV the correlations are higher for $\bar{p}p$ interactions.

The observed dependences are due to hadrons coming from the central area $|x_F| < 0.1$.

No correlations are observed for events corresponding to the same mechanism of particle production.

At lowest and highest multiplicities the distributions are more flat.

The analysis shows that these correlations are not “true” correlations due to the mechanism of particle production but arise as a consequence of the addition of events corresponding to different production mechanisms with different average multiplicities of secondary hadrons. This is in line with the observations of other models.
Back-up Slides