Comparison of the data on proton-proton and proton-antiproton interactions at high energies on basis of the Low Constituents Number Model

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Introduction

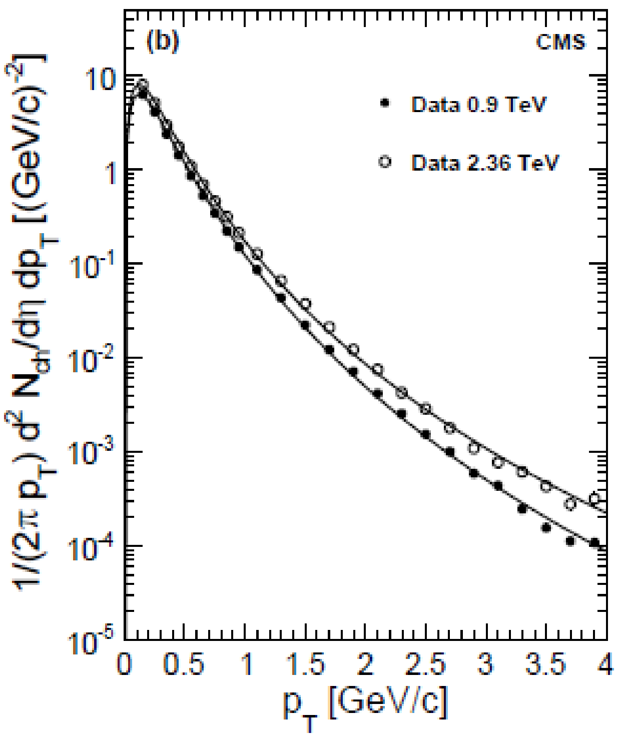
Total cross sections in p+p and p+pbar are equal at high energies.

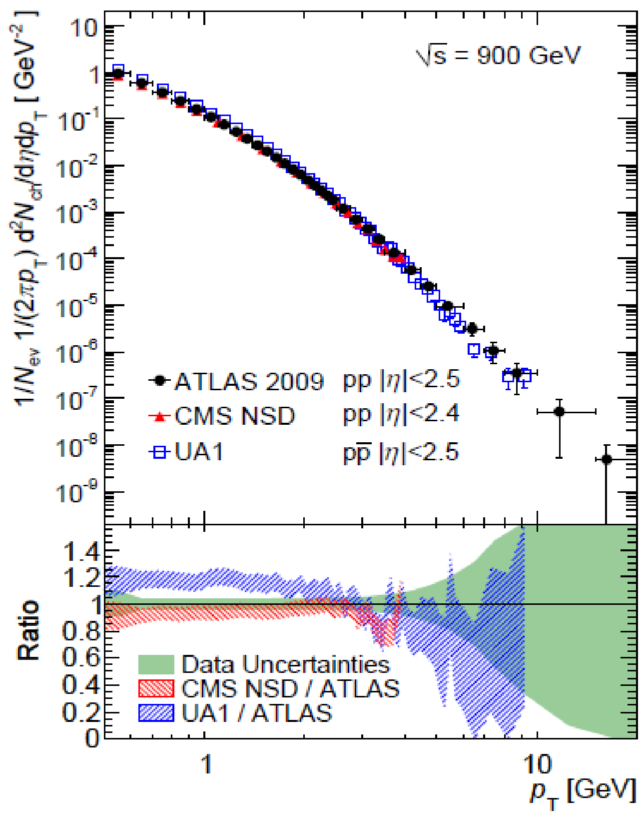
Is there difference between these 2 reactions in the other observables:

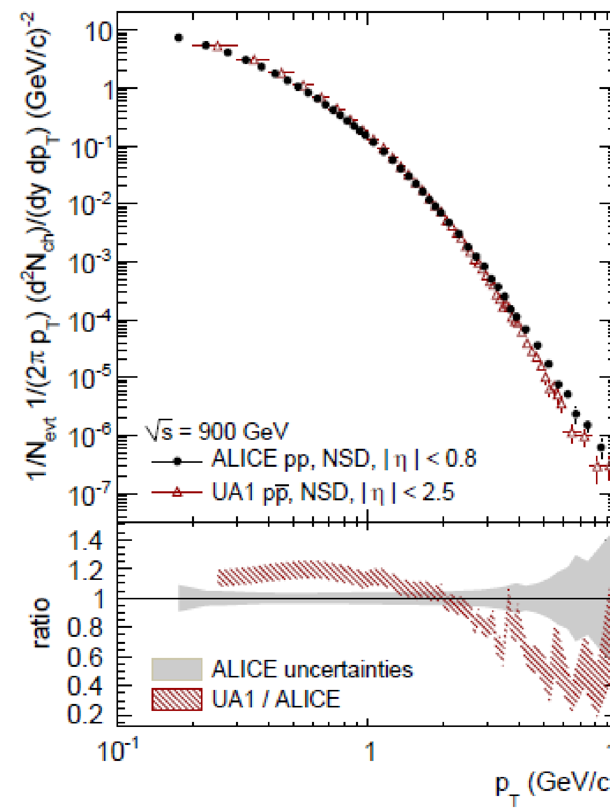
- inclusive cross sections $E\frac{d^3\sigma}{dp^3}$
- multiplicity distributions P_n
- pseudorapidity densities $\frac{dN}{d\eta}$

?

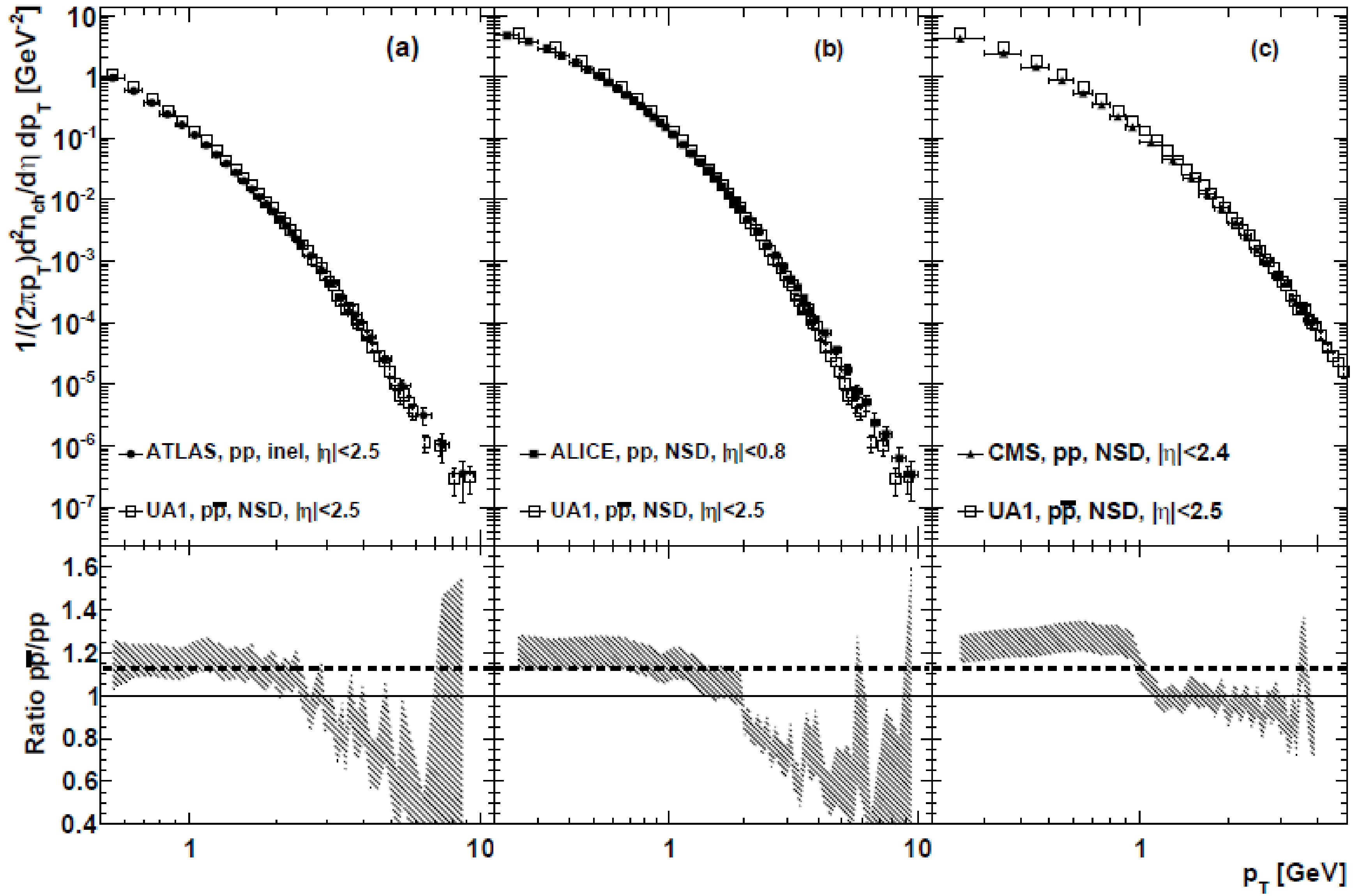
- CMS, ATLAS and ALICE Collaborations have published inclusive distributions on transverse momentum in p+p interactions for $\sqrt{s} = 900$ GeV.
- The Collaborations are given in order of priority.
- ATLAS and ALICE have compared their results with the UA1 distribution on p+pbar, CMS did not published the comparision.



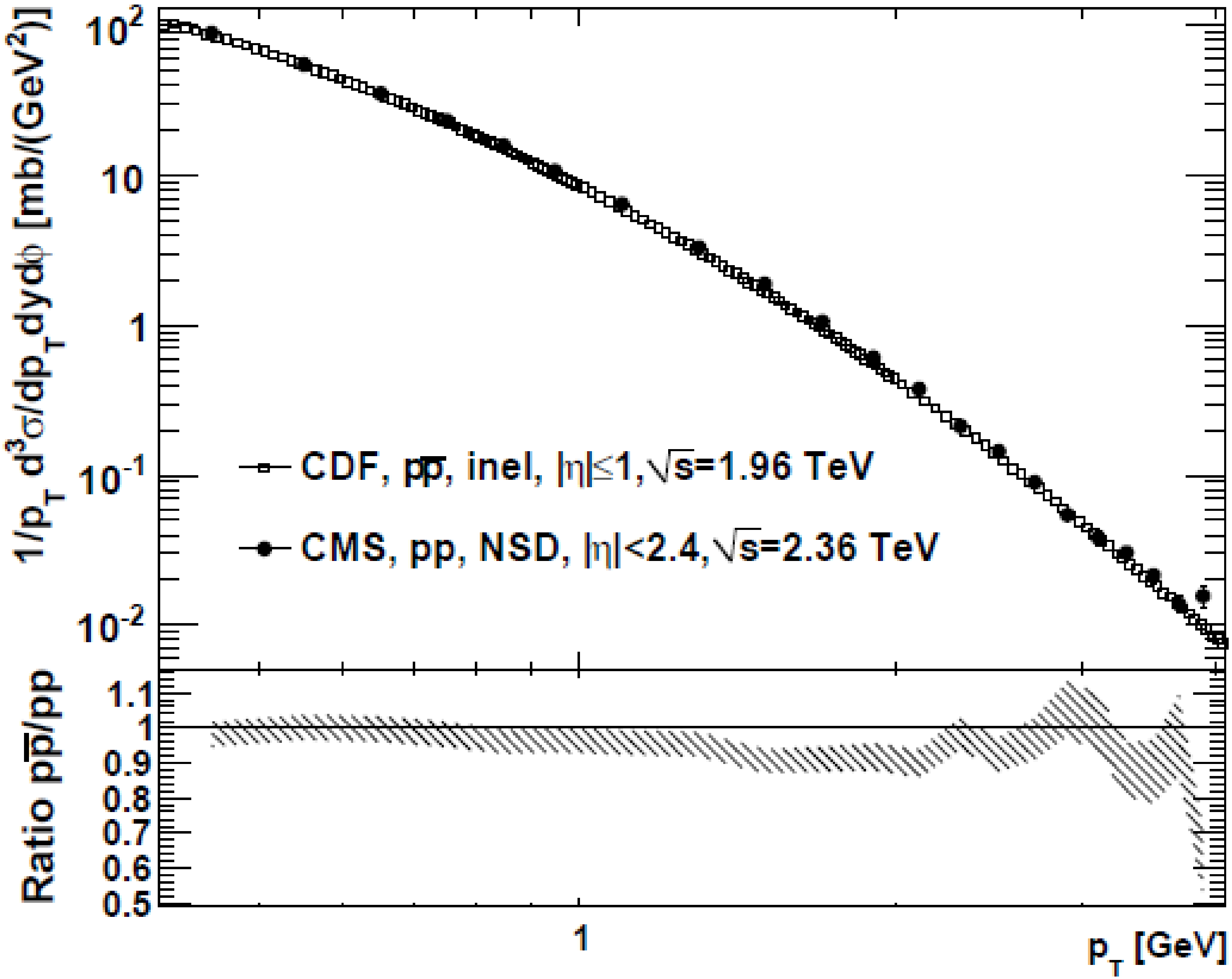




The UA1 data (p+pbar) exceeds the ATLAS and ALICE data in 1.2 times and the CMS data in 1.3 times.



The CDF data (p+pbar) at lower energy coincides with the CMS data, their ratio is close to 1.



ATLAS and ALICE Coll. insist that the difference is determined by inefficiency of the UA1 trigger.

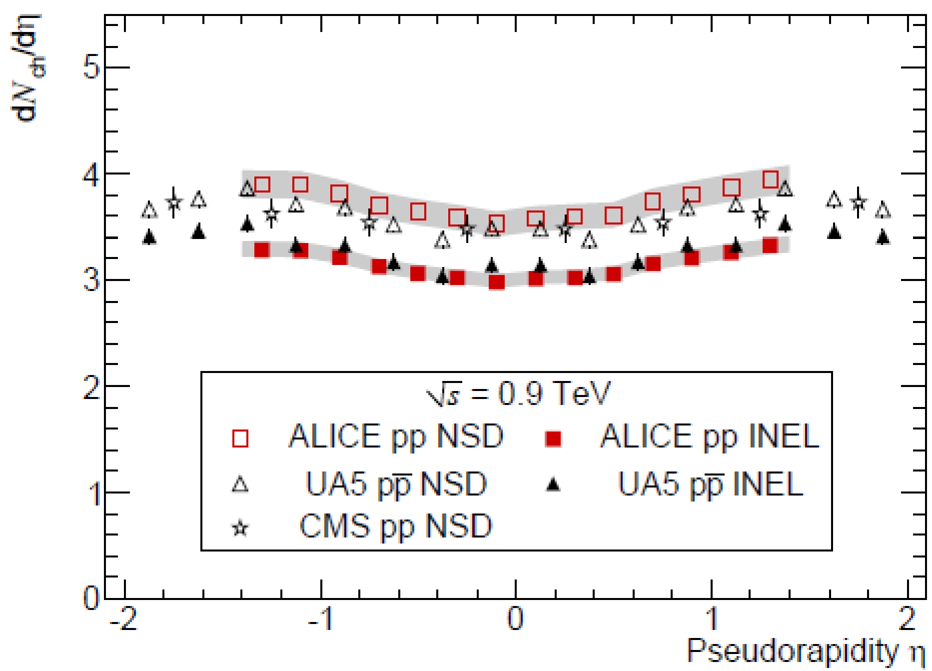
ATLAS
Phys. Lett. B 688 (2010) 21-42

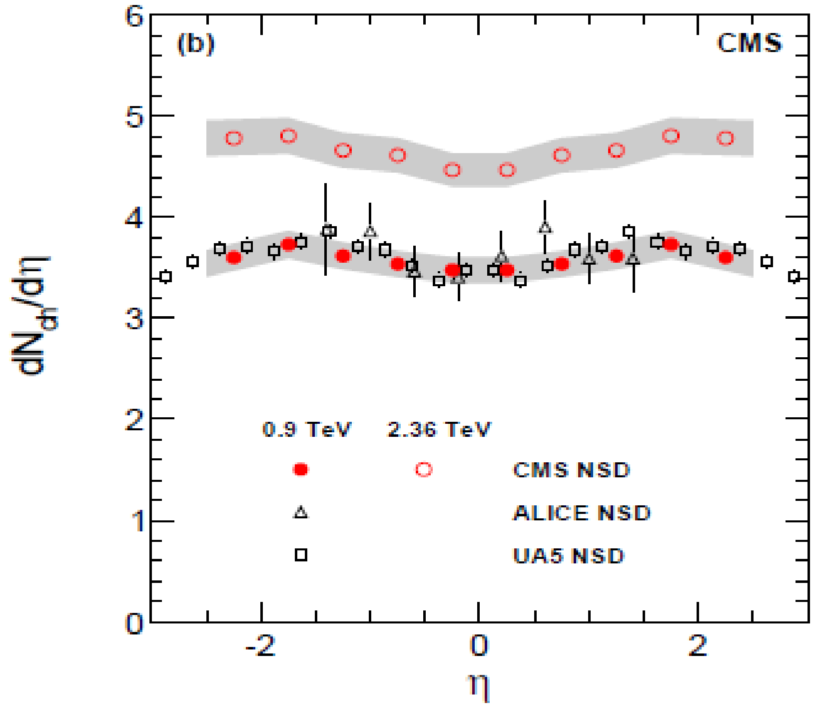
The UA1 [5] results, normalised by their associated cross section measurement, are also overlaid. They are approximately 20% higher than the present data. A shift in this direction is expected from the double-arm scintillator trigger requirement used to collect the UA1 data, which rejected events with low charged-particle multiplicities.

ALICE
Phys. Lett. B 693 (2010) 53-68

In the right panel of Fig. 3, the normalized invariant yield in NSD events is compared to measurements of the UA1 collaboration in $p\bar{p}$ at the same energy [21], scaled by their measured NSD cross section of 43.5 mb. As in the previous comparison to ATLAS and CMS, the higher yield at large p_T may be related to the different pseudorapidity acceptances. The excess of the UA1 data of about 20% at low p_T is possibly due to the UA1 trigger condition, which suppresses events with very low multiplicity, as pointed out in [19].

The experimentalists say that «the results at 900 GeV are in agreement with previous measurements and confirm the expectation of near equal hadron production in p+pbar and p+p collisions». The basis for this statment is the equality of psedorapidity densities, the data for p+pbar are taken from the UA5 Coll., which is considered trustworthy.





- The LHC Collaborations did not published their estimation of the trigger effects in the UA1 data. Our calculation of triggers is presented in the next talk, these effects can not explain the whole difference.

- The distributions on transverse momentum are more sensitive to small effects than the integrated distribution on pseudorapidity.

- We argue that the observed difference is the manifistatiion of different procesess of hadrons production in p+p and p+pbar.

Low Constituents Number Model (LCNM)

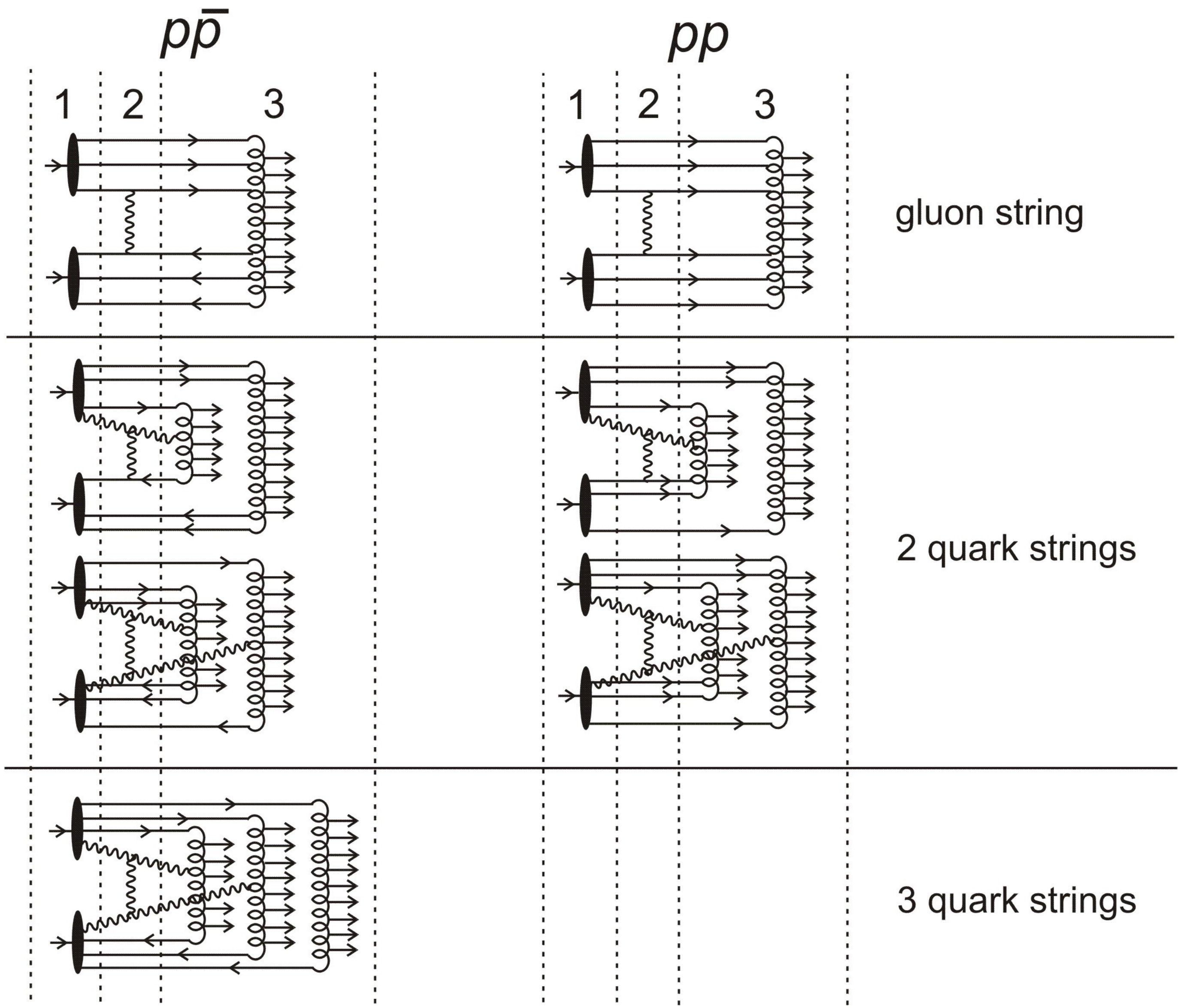
1. On the first step before the collision there is small number of constituents in initial hadrons. In every hadron this is component either with only valence quarks or with valence quarks and one additional gluon.

2. On the second step the hadrons interaction is carried out by gluon exchange between the valence quarks and initial gluons. The hadrons gain the color charge.

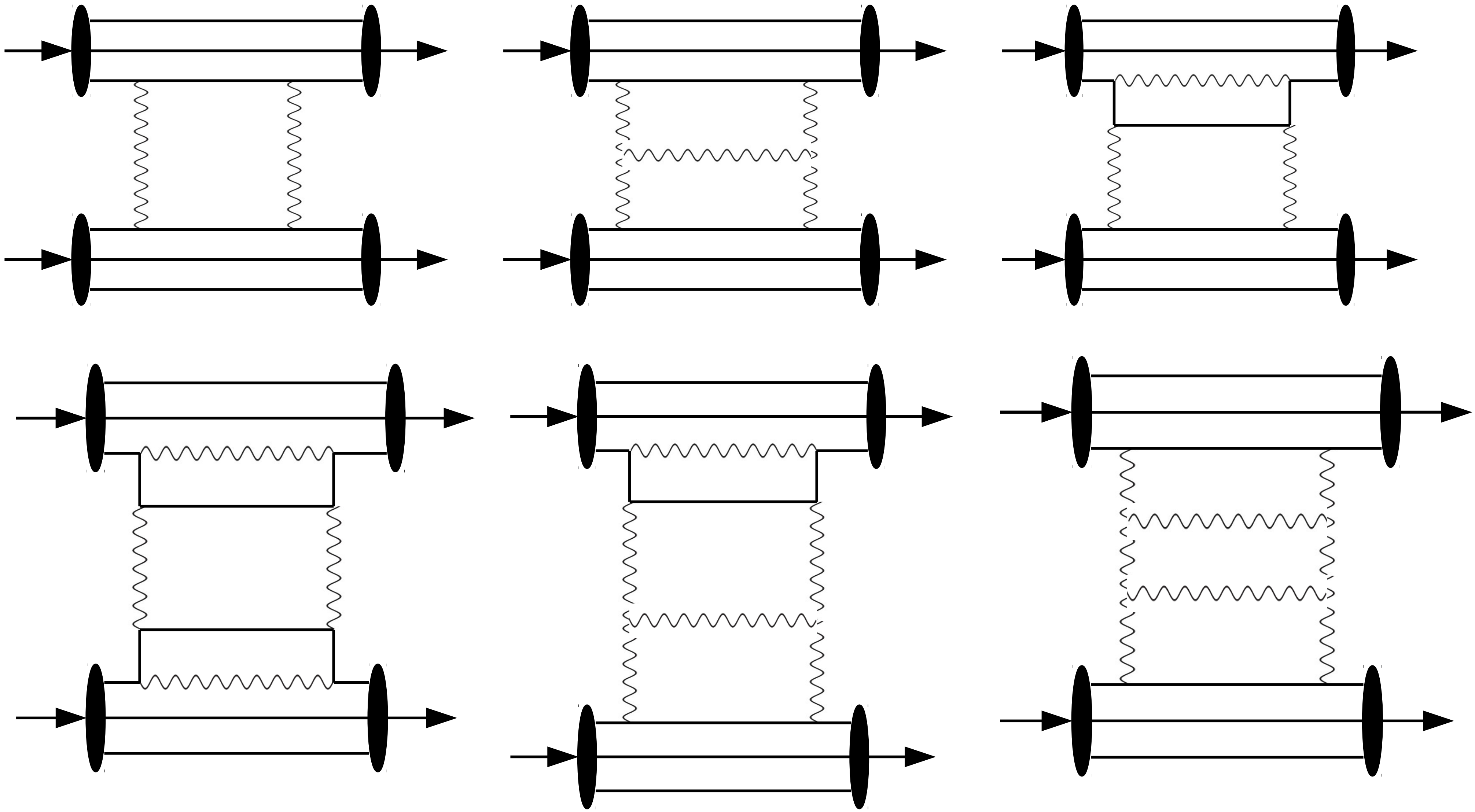
3. On the third step after interaction the colored hadrons move apart and when the distance between them becomes larger than the confinement radius, the lines of color electric field gather into the string. This string breaks out into secondary hadrons.

(Abramovsky, Kancheli 1980, Abramovsky, Radchenko 2009)

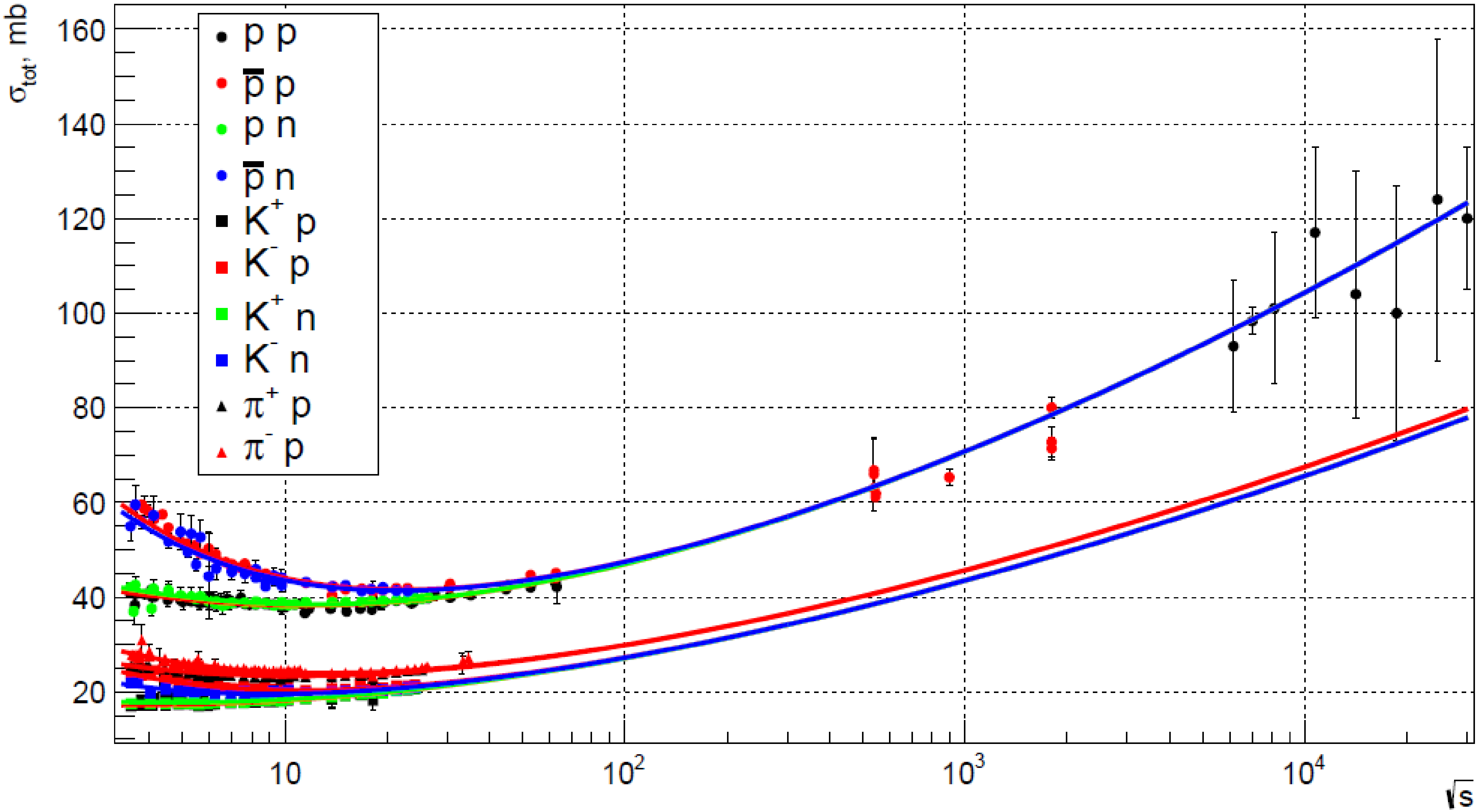
Three types of inelastic subprocesses



The diagrams of the total cross section vacuum part



$$\sigma_0[1+\frac{26}{3}w\ln(s)+\frac{26}{3}w^2(\ln(s))^2]$$



$$\sigma_{tot}(14\,TeV) = 109.9 \pm 6.6$$

Inclusive cross sections in events with fixed number of particles

Topological inclusive cross section of one charged particle production

$$(2\pi)^3 2E \frac{d^3\sigma_n^{incl}}{d^3p} = \frac{1}{(n-1)!}\sum_{m=0}^{\infty}\frac{1}{m!}\int d\tau_{n-1+m}\left|A_{2\to n+m}\right|^2$$

Total inclusive cross section and its normalization

$$(2\pi)^3 2E \frac{d^3\sigma^{incl}}{d^3p} = \sum_{n=0}^{\infty}(2\pi)^3 2E \frac{d^3\sigma_n^{incl}}{d^3p} \qquad \int d^3p \frac{d^3\sigma^{incl}}{d^3p} = \langle n\rangle \sigma^{nsd}$$

Normalization of topological inclusive cross section

$$\int d^3p \frac{d^3\sigma_n^{incl}}{d^3p} = n\,\sigma_n \qquad \sigma_n = \frac{1}{n!}\sum_{m=0}^{\infty}\frac{1}{m!}\int d\tau_{n+m}\left|A_{2\to n+m}\right|^2$$

$$\frac{1}{\sigma^{nsd}}\int d^3p \frac{d^3\sigma_n^{incl}}{d^3p} = n\,\frac{\sigma_n}{\sigma^{nsd}} = n\,P_n$$

Inclusive cross sections in bins

UA5 Coll. gave data in 9 bins of charged multiplicities:
$2 \le n \le 10$, $12 \le n \le 20$, … $72 \le n \le 80$ and $n \ge 82$.

We define inclusive cross section in this bins

$$\frac{d^3\sigma^{(1)\,incl}}{d^3p} = \sum_{n=2}^{10} \frac{d^3\sigma_n^{incl}}{d^3p}, \quad \frac{d^3\sigma^{(2)\,incl}}{d^3p} = \sum_{n=12}^{20} \frac{d^3\sigma_n^{incl}}{d^3p}, \ldots \quad \frac{d^3\sigma^{(9)\,incl}}{d^3p} = \sum_{n=82}^{\infty} \frac{d^3\sigma_n^{incl}}{d^3p}, \Rightarrow$$

$$\sum_{i=1}^{9} \frac{d^3\sigma^{(i)\,incl}}{d^3p} = \frac{d^3\sigma^{\,incl}}{d^3p}$$

Inclusive cross sections in bins are normalized as follows

$$\int d^3p \frac{d^3\sigma^{(i)\,incl}}{d^3p} = \sigma^{nsd} \sum_{n\ in\ bin} n\,P_n = \bar{n}^{(i)}\sigma^{nsd}$$

Difference in inclusive cross sections of pp and ppbar

$$\int d^3p \frac{d^3\sigma_{pp}^{(i)\,incl}}{d^3p} = \int d\eta\, d^2p_\perp \frac{d^3\sigma_{pp}^{(i)\,incl}}{d\eta\, d^2p_\perp} = \int d\eta \frac{d\sigma_{pp}^{(i)\,incl}}{d\eta} = \bar{n}_{pp}^{(i)}\sigma^{nsd} \qquad (1)$$

$$\int d^3p \frac{d^3\sigma_{p\bar{p}}^{(i)\,incl}}{d^3p} = \int d\eta\, d^2p_\perp \frac{d^3\sigma_{p\bar{p}}^{(i)\,incl}}{d\eta\, d^2p_\perp} = \int d\eta \frac{d\sigma_{p\bar{p}}^{(i)\,incl}}{d\eta} = \bar{n}_{p\bar{p}}^{(i)}\sigma^{nsd} \qquad (2)$$

$$\frac{d\sigma^{(i)\,incl}}{d\eta} = \int d^2p_\perp \frac{d^3\sigma^{(i)\,incl}}{d\eta\, d^2p_\perp}$$

Ratio of (1) to (2) gives

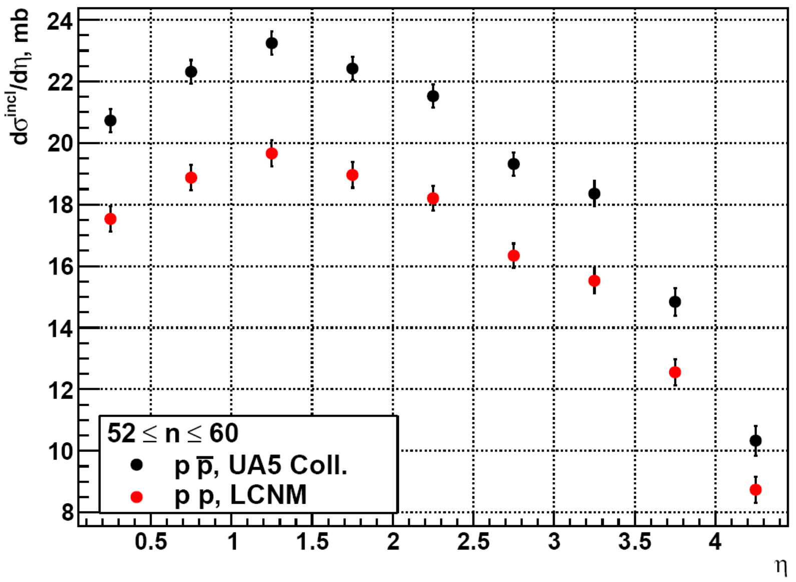
$$\int d\eta \frac{d\sigma_{pp}^{(i)\,incl}}{d\eta} = \frac{\bar{n}_{pp}^{(i)}}{\bar{n}_{p\bar{p}}^{(i)}} \int d\eta \frac{d\sigma_{p\bar{p}}^{(i)\,incl}}{d\eta} \qquad (3)$$

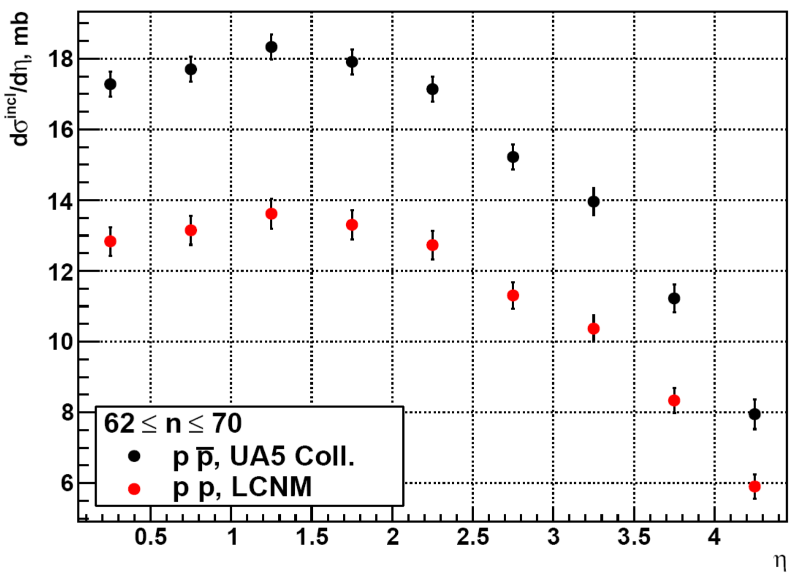
Solution of the integral equation (3) (perhaps, the only solution)

$$\frac{d\sigma_{pp}^{(i)\,incl}}{d\eta} = \frac{\bar{n}_{pp}^{(i)}}{\bar{n}_{p\bar{p}}^{(i)}} \frac{d\sigma_{p\bar{p}}^{(i)\,incl}}{d\eta} \qquad (4)$$

Inclusive cross sections in different bins

	$\overline{n}_{p\overline{p}}^{(i)} / \overline{n}_{pp}^{(i)}$
$2 \le n \le 10$	0.76 ± 0.01
$12 \le n \le 20$	0.86 ± 0.01
$22 \le n \le 30$	0.99 ± 0.01
$32 \le n \le 40$	1.09 ± 0.01
$42 \le n \le 50$	1.10 ± 0.01
$52 \le n \le 60$	1.18 ± 0.01
$62 \le n \le 70$	1.35 ± 0.02
$72 \le n \le 80$	1.45 ± 0.02
$n \ge 82$	1.26 ± 0.02





Inclusive cross sections summed over all bins

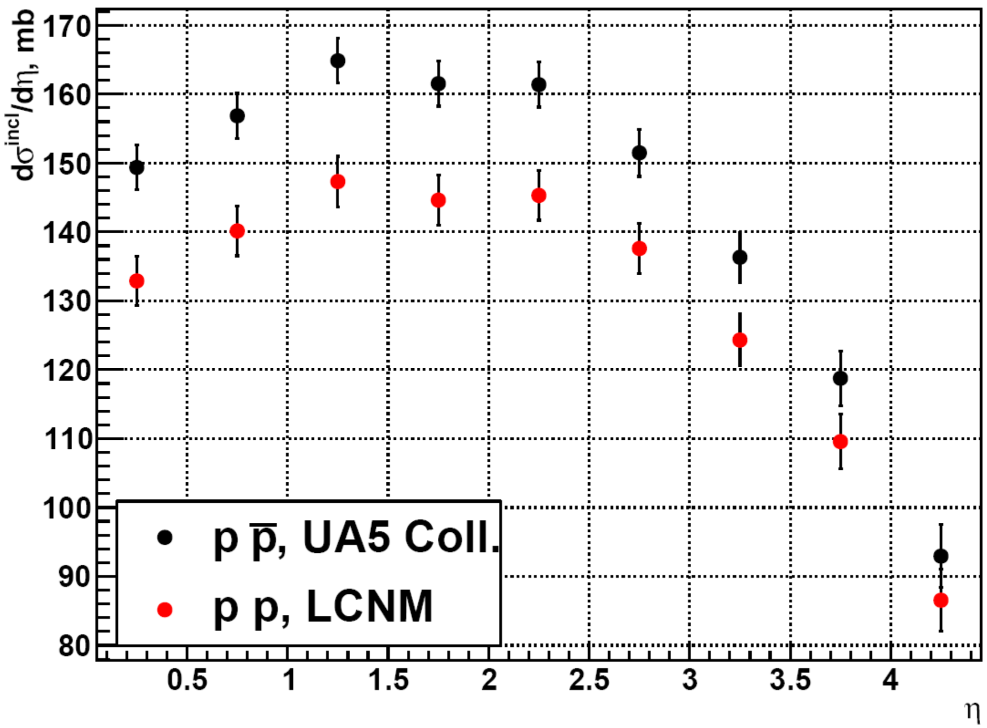
We obtained the numerical value of relation

$$\frac{d\sigma_{p\bar{p}}^{incl}}{d\eta} \Bigg/ \frac{d\sigma_{pp}^{incl}}{d\eta}$$

by summing over all nine bins of multiplicity.

For $|\eta| < 2.5$

$$\frac{d\sigma_{p\bar{p}}^{incl}}{d\eta} \Bigg/ \frac{d\sigma_{pp}^{incl}}{d\eta} = 1.12 \pm 0.01$$



This result will be used on the next slides.

Inclusive cross section with transverse momentum

From the AGK cancellation rules it follows the factorization of transverse dependence in inclusive cross section.

$$\frac{1}{2\pi\, p_\perp}\frac{d^2\sigma^{incl}}{d\eta\, dp_\perp} = f\left(p_\perp\right)\frac{d\sigma^{incl}}{d\eta}$$

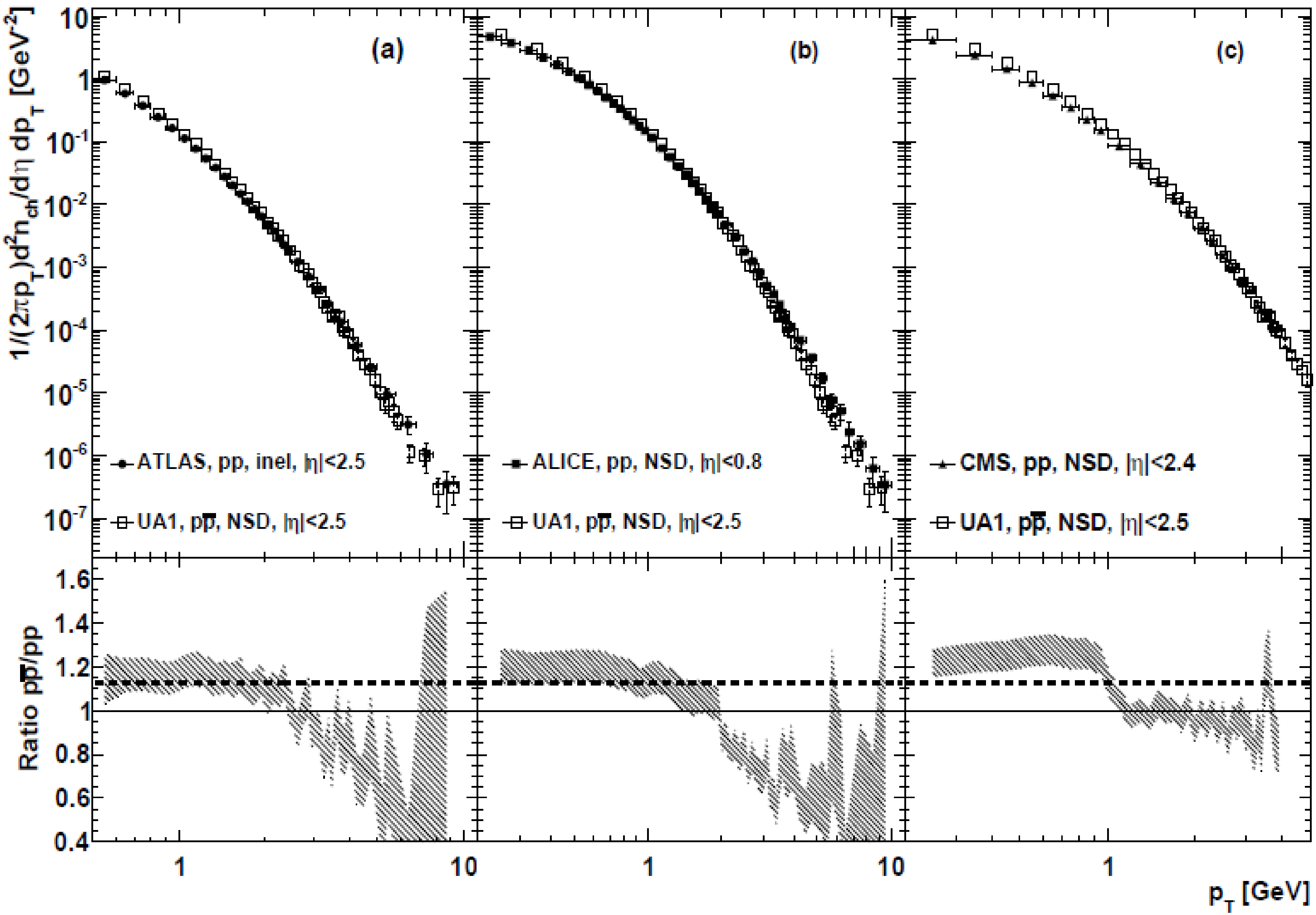
Returning to formulas (1) and (2) we can write down

$$\frac{d^3\sigma_{pp}^{(i)incl}}{d\eta\, d^2 p_\perp} = \frac{\overline{n}_{p\overline{p}}^{(i)}}{\overline{n}_{pp}^{(i)}}\frac{d^3\sigma_{p\overline{p}}^{(i)incl}}{d\eta\, d^2 p_\perp}$$

From this relation it can strictly be proved that $f_{pp}\left(p_\perp\right) = f_{p\overline{p}}\left(p_\perp\right)$

so we can obtain

$$\frac{1}{2\pi\, p_\perp}\frac{d^2\sigma_{p\overline{p}}^{incl}}{d\eta\, dp_\perp}\Bigg/\frac{1}{2\pi\, p_\perp}\frac{d^2\sigma_{pp}^{incl}}{d\eta\, dp_\perp} = \frac{d\sigma_{p\overline{p}}^{incl}}{d\eta}\Bigg/\frac{d\sigma_{pp}^{incl}}{d\eta}$$



(a)
(b)
(c)
1/(2πp_T)d²n_ch/dη dp_T [GeV⁻²]
ATLAS, pp, inel, |η|<2.5
UA1, pp̄, NSD, |η|<2.5
ALICE, pp, NSD, |η|<0.8
UA1, pp̄, NSD, |η|<2.5
CMS, pp, NSD, |η|<2.4
UA1, pp̄, NSD, |η|<2.5
Ratio pp̄/pp
p_T [GeV]

Conclusions

- The difference between proton-proton and proton-antiproton inclusive cross sections at high energies is the new physical effect.
- The process of hadron production from the three quark strings is large at high energies.
- It is necessary to take into account this difference in programs of MC modelling, particulary in Pythia.

Acknowledgement

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