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

by
L. Bravina
(University of Oslo)

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UiO : Universitetet i Oslo

FIAS Frankfurt Institute for Advanced Studies

Outline

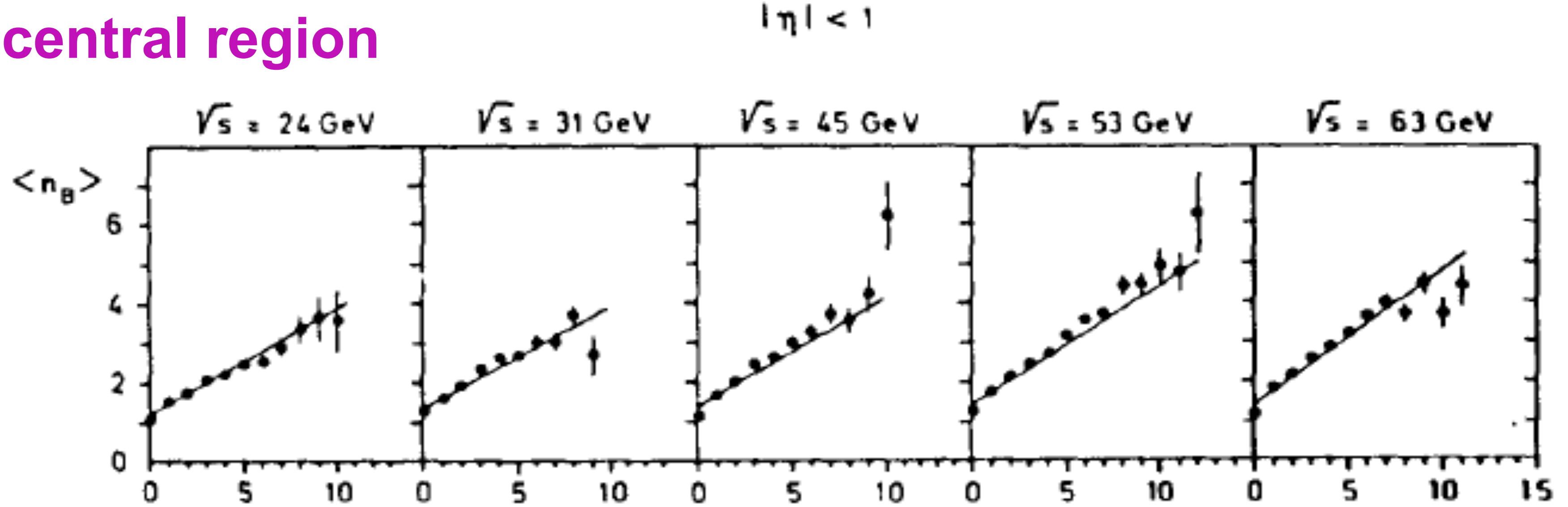
- Forward-backward multiplicity correlations in hadronic interactions
- Quark-gluon string model (QGSM)
- FB correlations at intermediate energies
- Origin of FB correlations at LHC energies; comparison with data
- Conclusions

I. Forward-backward multiplicity correlations in hadronic interactions

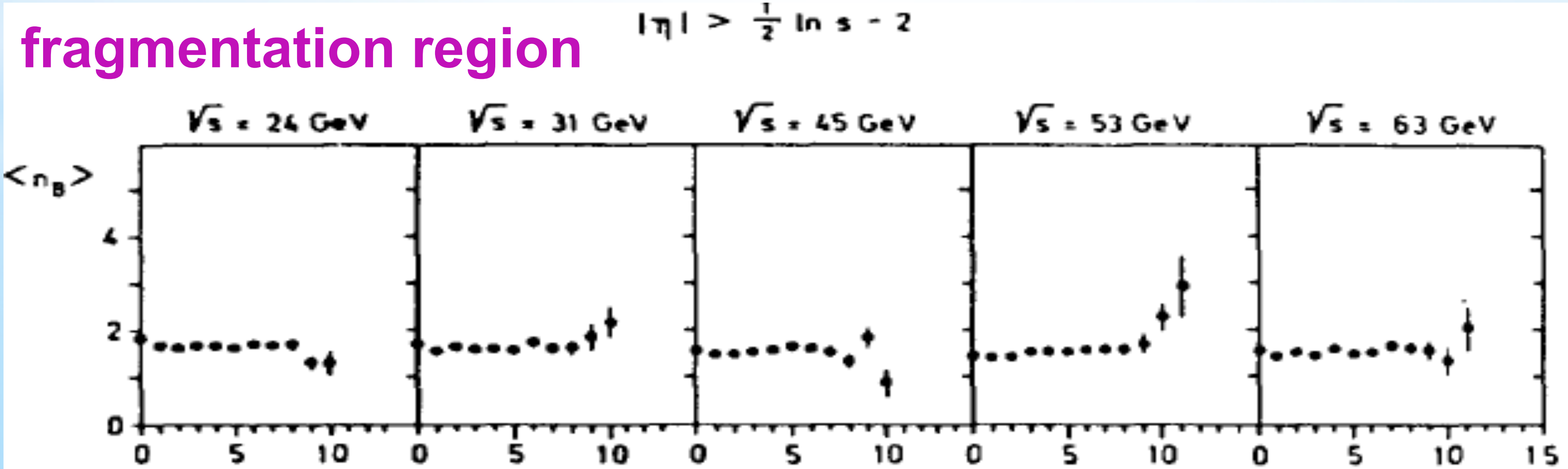
Observation of strong correlations (ISR)

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

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Experiment

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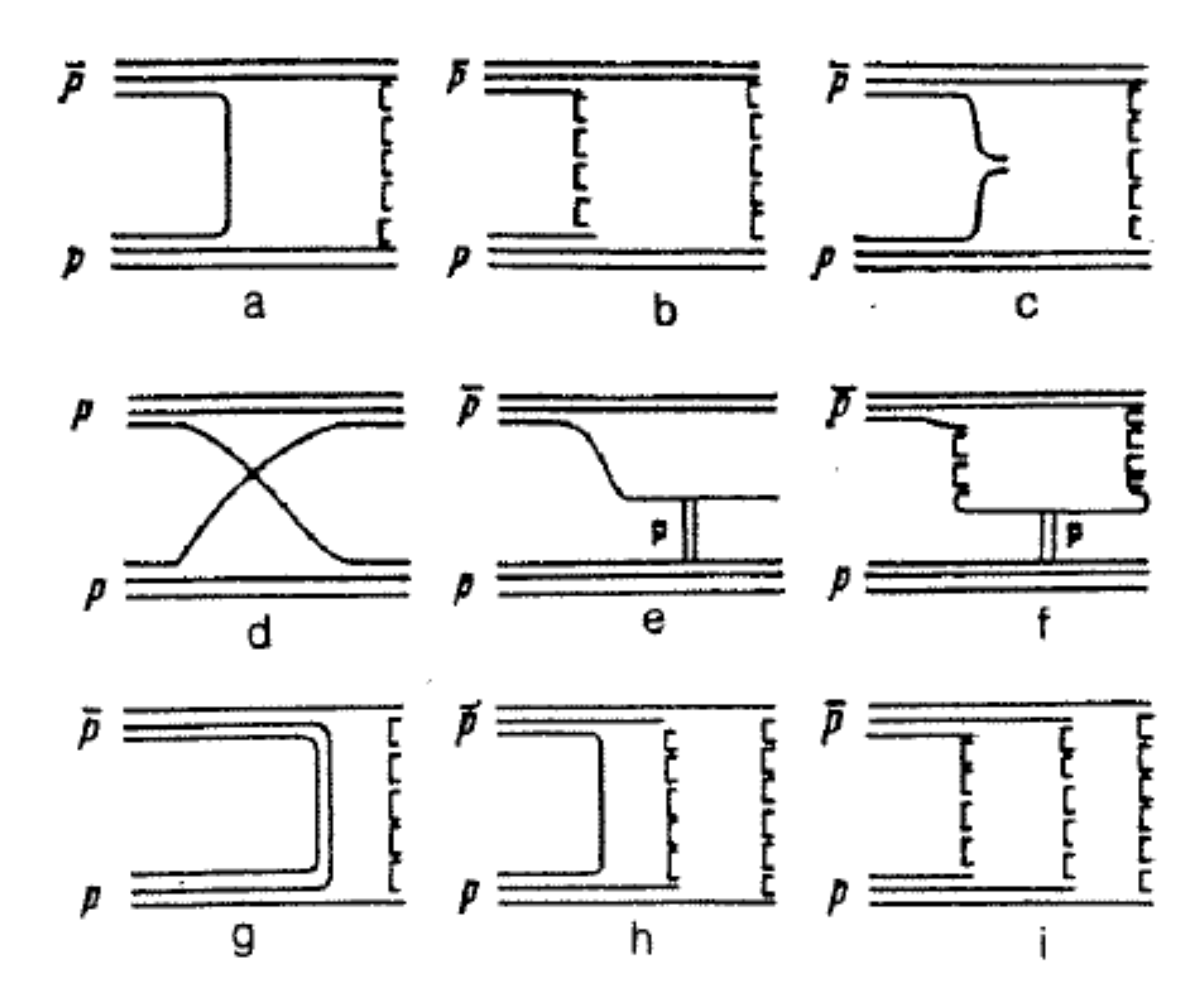
II. Quark-Gluon String Model (QGSM)

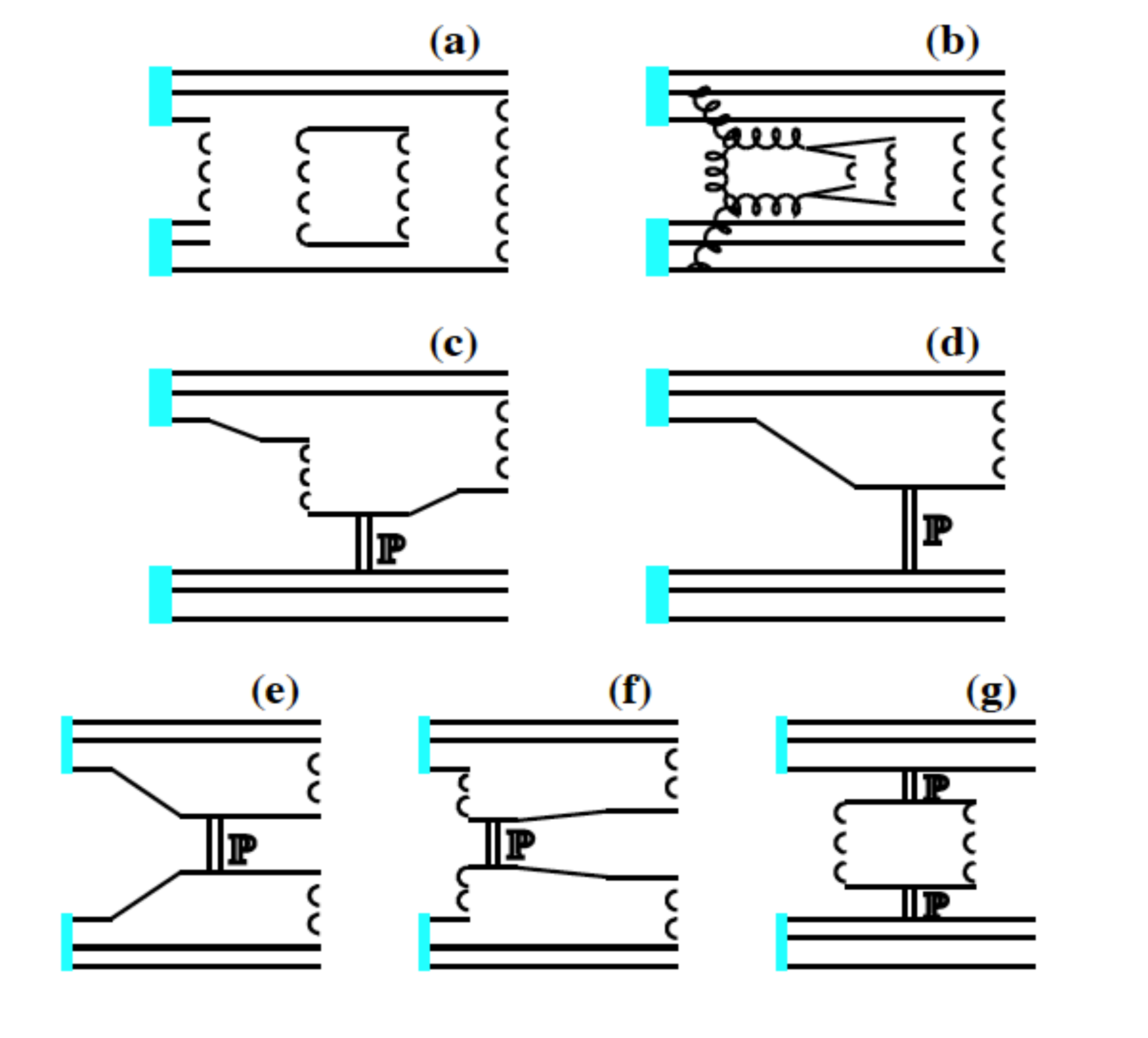
Diagrams at intermediate energies



(a) -- planar
(b) -- cylindrical
(c) – undeveloped cylinder
(d) – quark rearrangement
(e) – single diffraction of small mass
(f) – single diffraction of large mass
(g)-(i) – annihilation diagrams
+ double diffraction diagrams similar to (e), (f)

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
(g) – central diffraction

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)

L.B. et al., Sov. J. Nucl. Phys. 50 (1989) 245

TABLE I. Parameters of the approximation by the function $\langle n_F \rangle = a + b n_B$ for $\bar{p}p$ and pp interactions at 32 GeV/c.

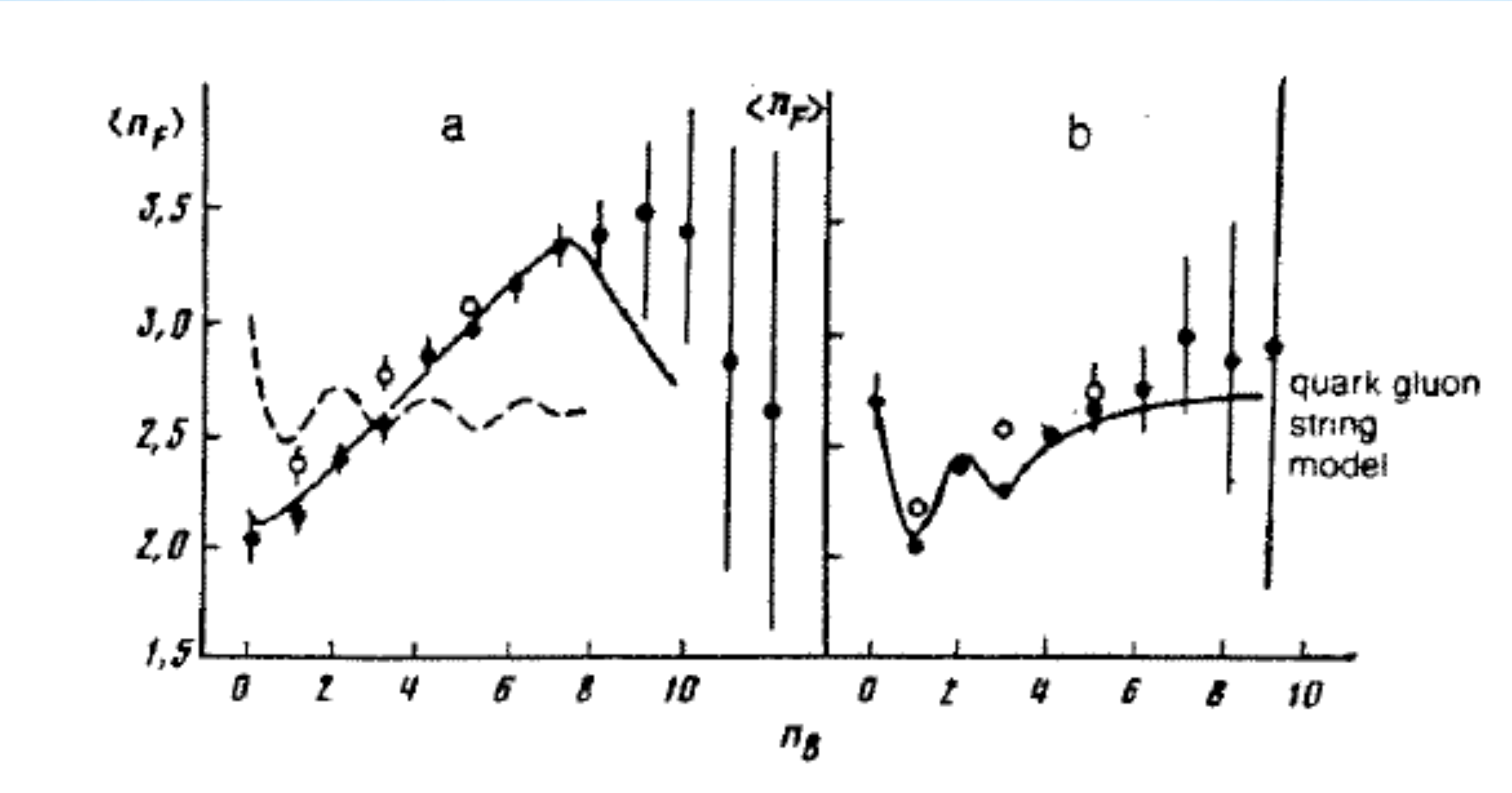
Reaction	$\bar{p}p$		
	a	b	χ^2/deg. fr.
Inelastic interactions	2,03±0,02	0,192±0,007	22/(10–2–1)
Nondiffraction interactions	2,18±0,04	0,177±0,010	24/(10–2–1)
Particles with $\lvert x \rvert < 0.1$ in inelastic interactions	1,09±0,01	0,237±0,006	23/(12–2–1)
Particles with $\lvert x \rvert > 0.1$ in inelastic interactions	1,144±0,008	0,013±0,006	0,29/(6–2–1)

Reaction	pp		
	a	b	χ^2/deg. fr.
Inelastic interactions	2,07±0,04	0,098±0,016	92/(11–2–1)
Nondiffraction interactions	2,25±0,05	0,07±0,02	36/(11–2–1)
Particles with $\lvert x \rvert < 0.1$ in inelastic interactions	1,11±0,04	0,175±0,015	19/(9–2–1)
Particles with $\lvert x \rvert > 0.1$ in inelastic interactions	1,262±0,009	–0,075±0,008	1,5/(6–2–1)

No long-range correlations between the fragmentation regions

(anti)pp @ 32 GeV/c vs. QGSM

antiproton-proton proton-proton

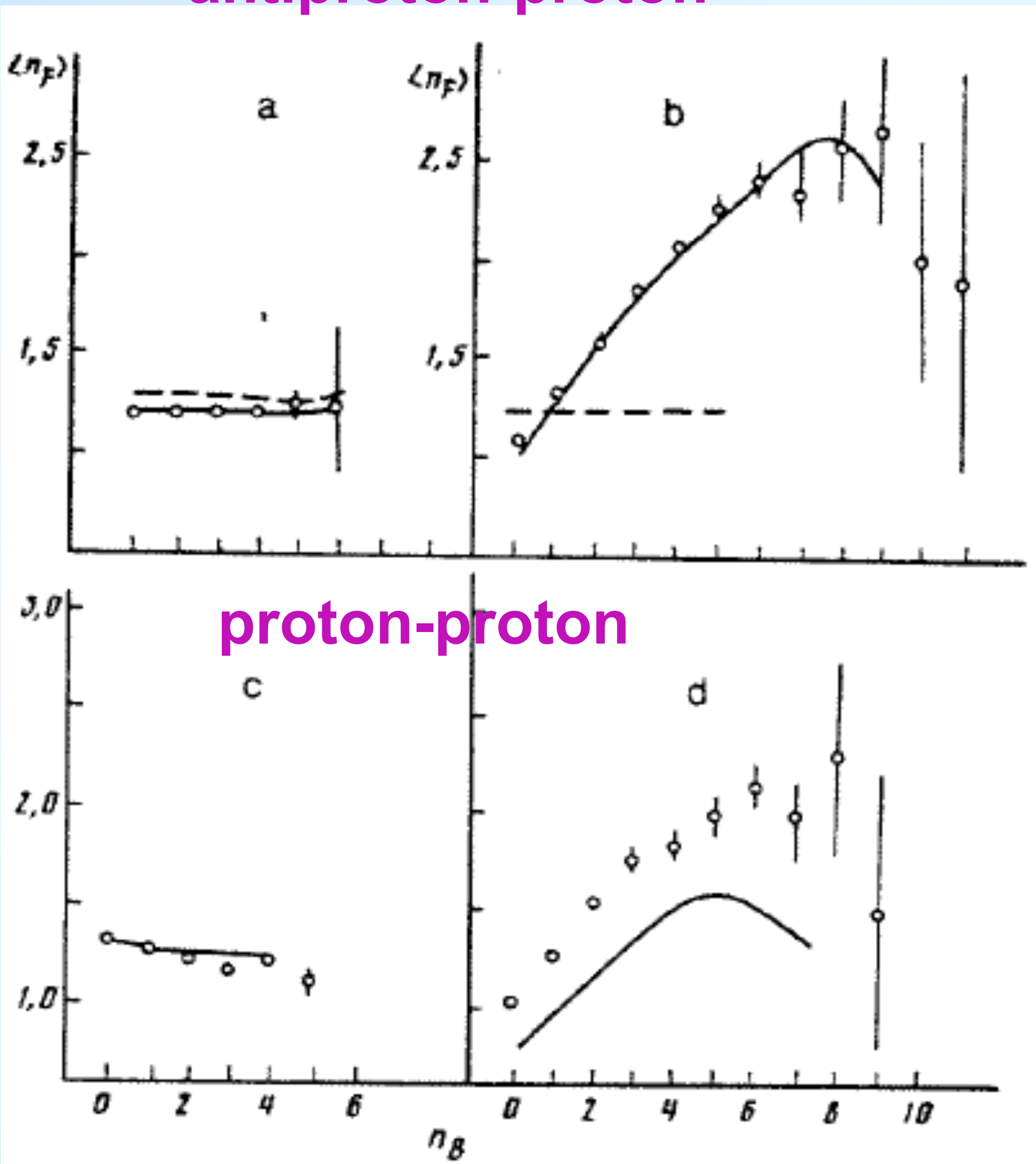


Closed points: inelastic collisions
Open points: non-diffractive collisions
Solid curves: QGSM
Dashed curve: Lund

L.B. et al., Sov. J. Nucl. Phys. 50 (1989) 245

(anti)pp @ 32 GeV/c vs. QGSM

antiproton-proton



proton-proton

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

(a) |x| > 0.1

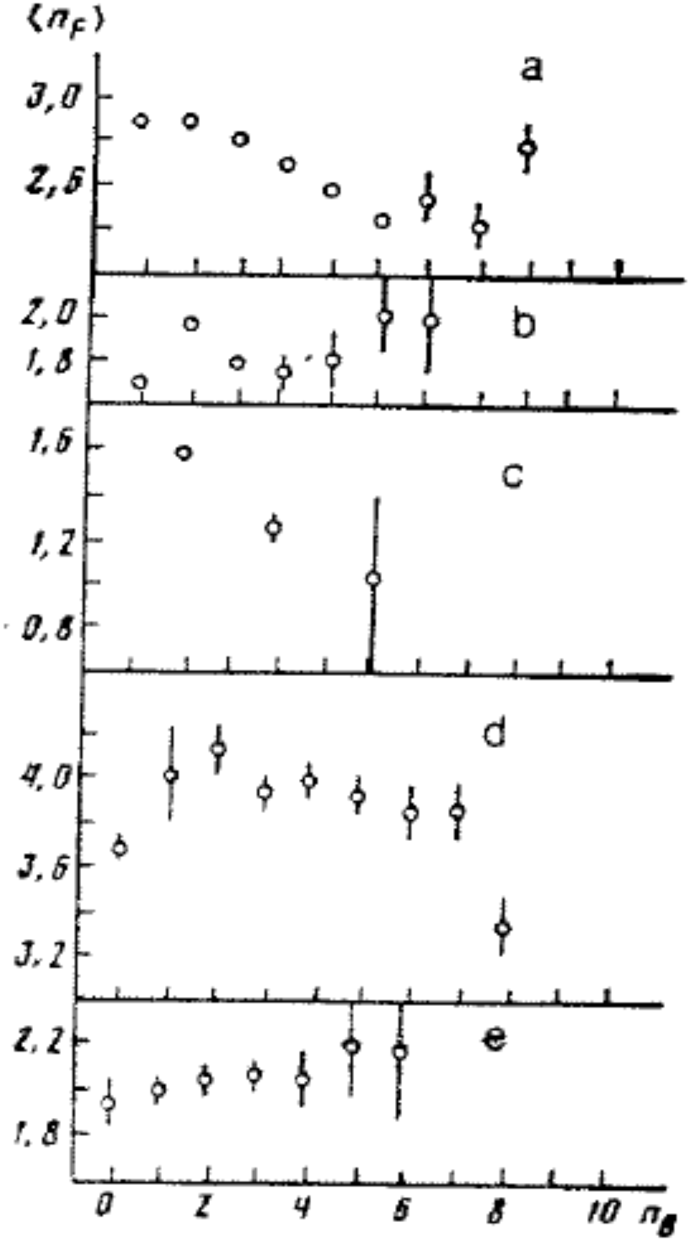
(b) |x| < 0.1

No long-range correlations

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

L.B. et al., Sov. J. Nucl. Phys. 50 (1989) 245

FB correlations within the subprocesses



(a) – cylindrical diagrams

(b) – undeveloped cylinder

(c) – diffraction diagrams

(d) – annihilation diagrams

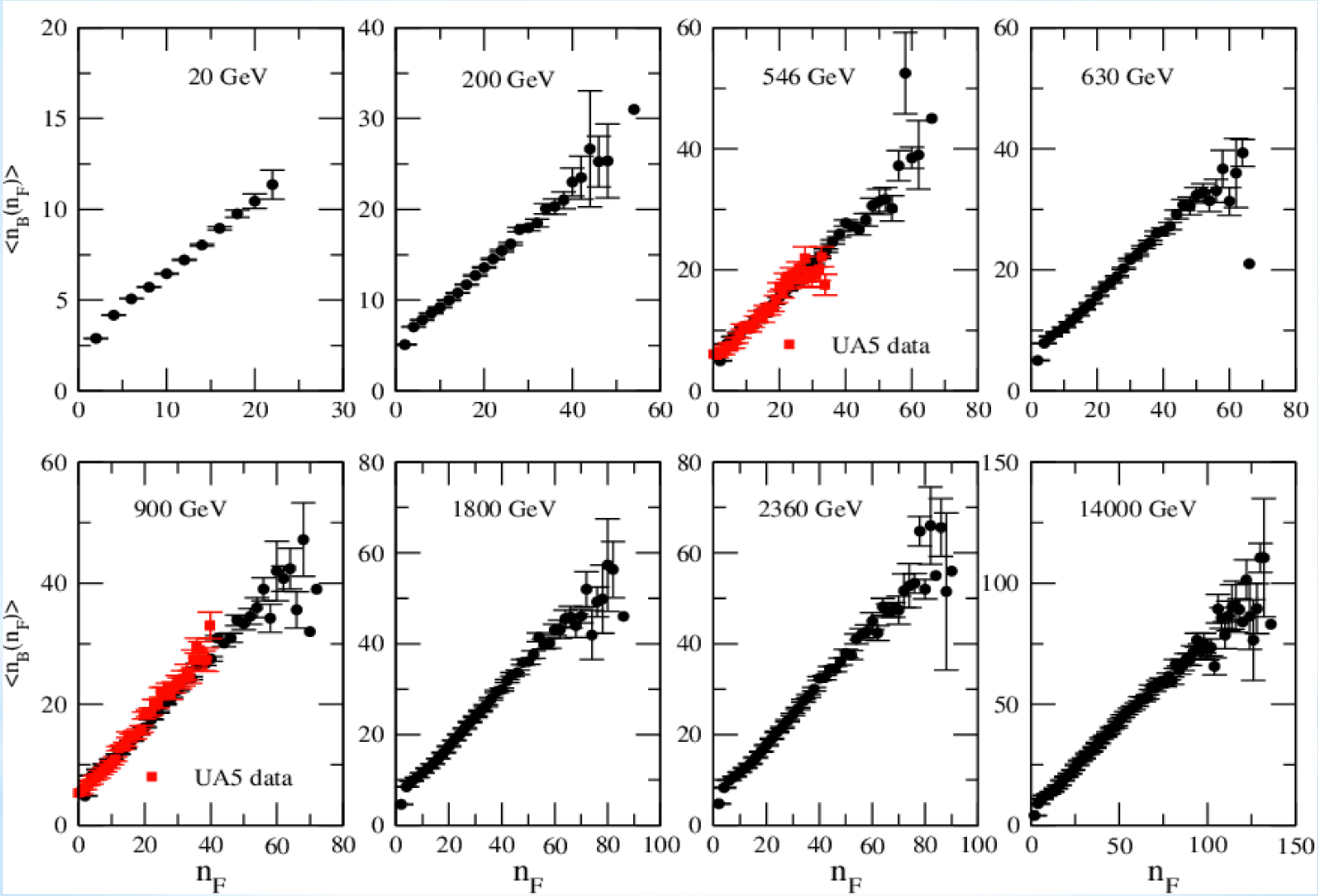
(e) – planar diagrams

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)

L.B. et al., Sov. J. Nucl. Phys. 50 (1989) 245

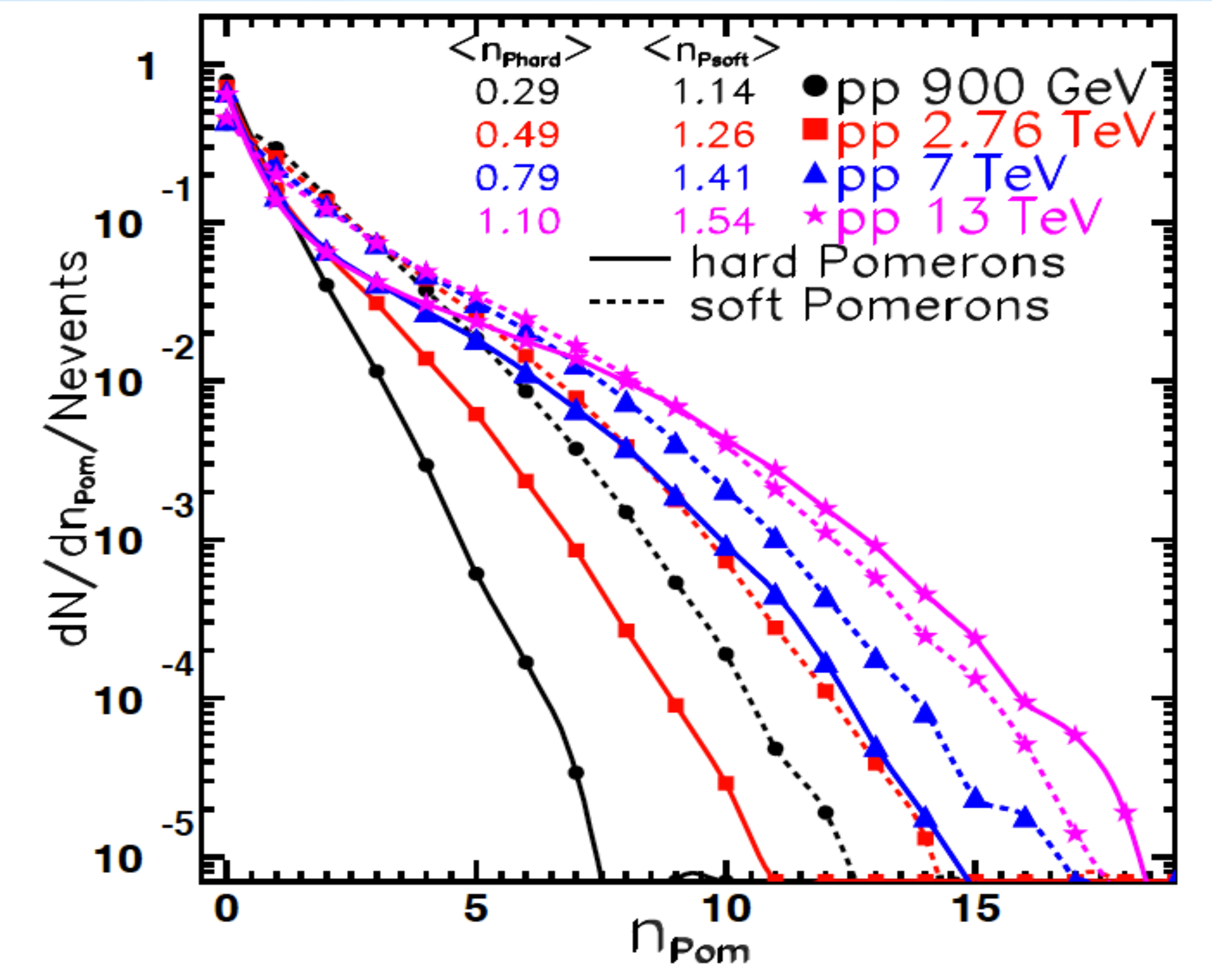
IV. Origin of FB multiplicity correlations in QGSM at LHC energies

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

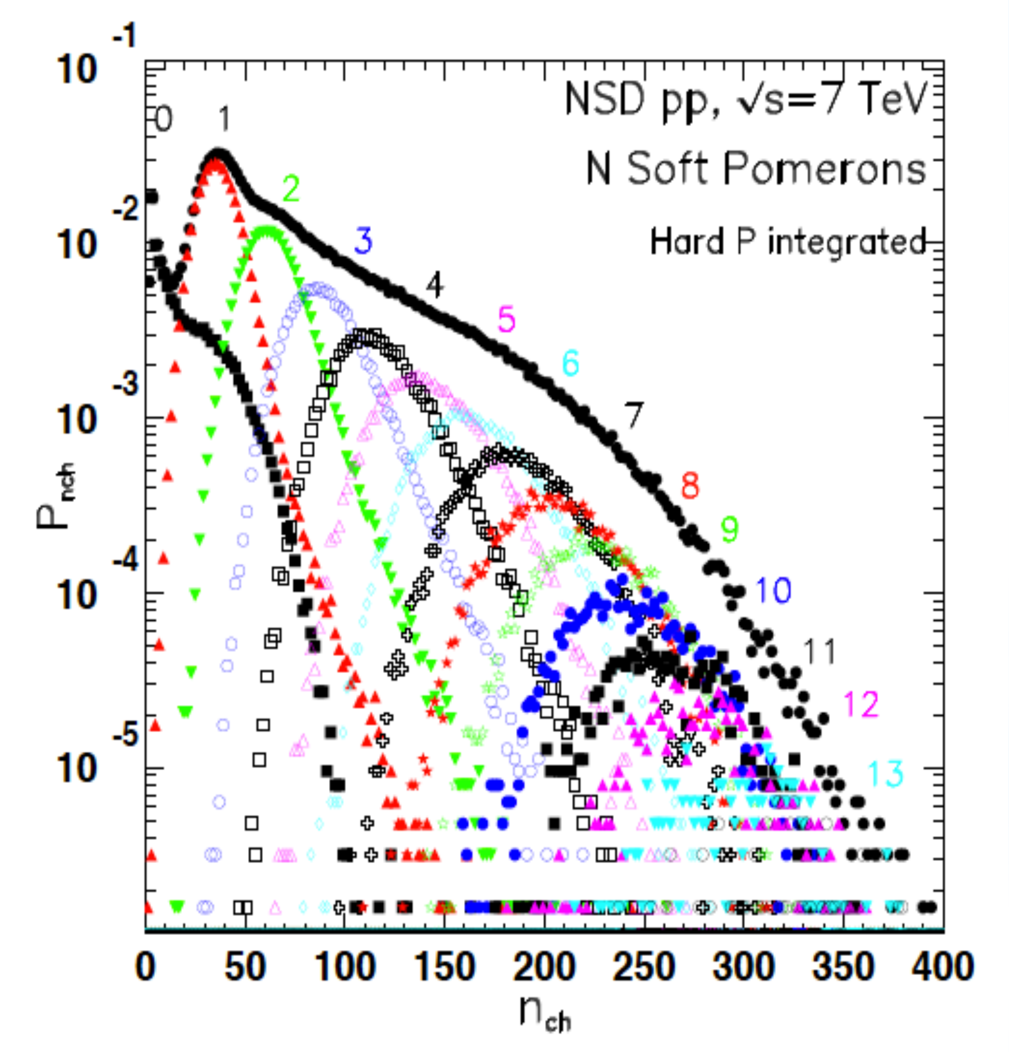


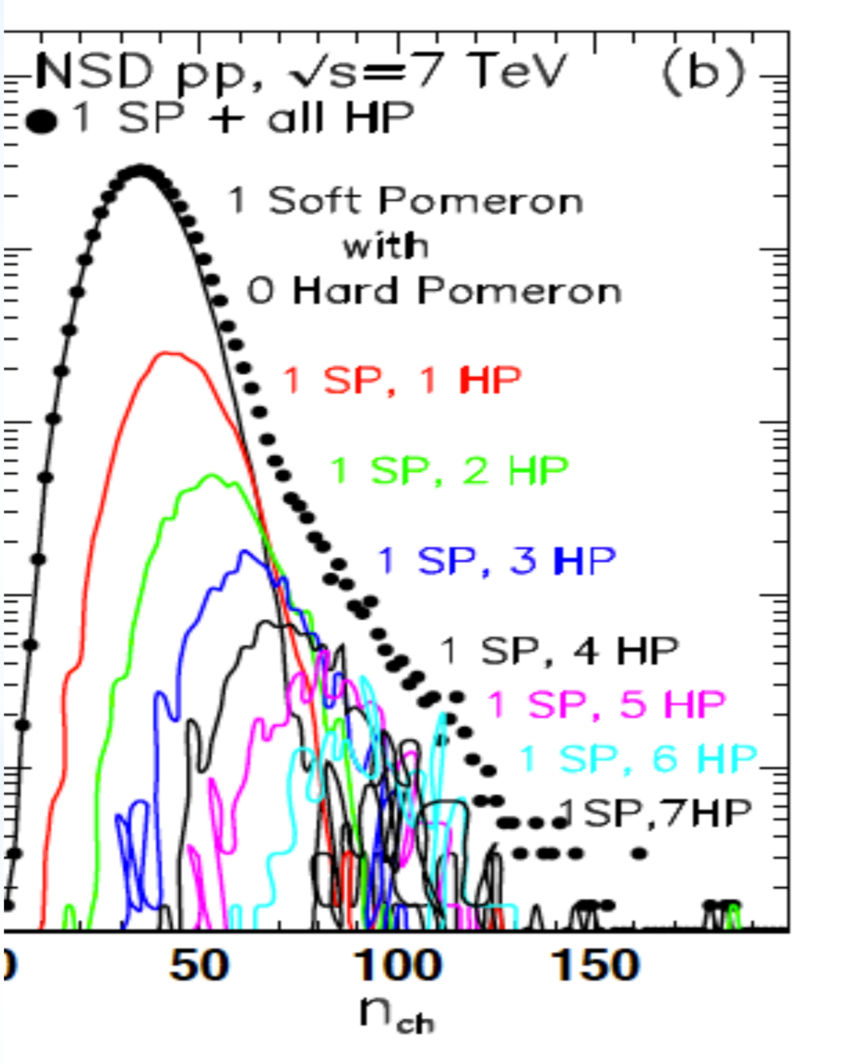
The ratio hard/soft increases from 0.29 : 1.14 (900 GeV)
to 1.10 : 1.54 (13 TeV)

Contribution of soft and hard Pomerons

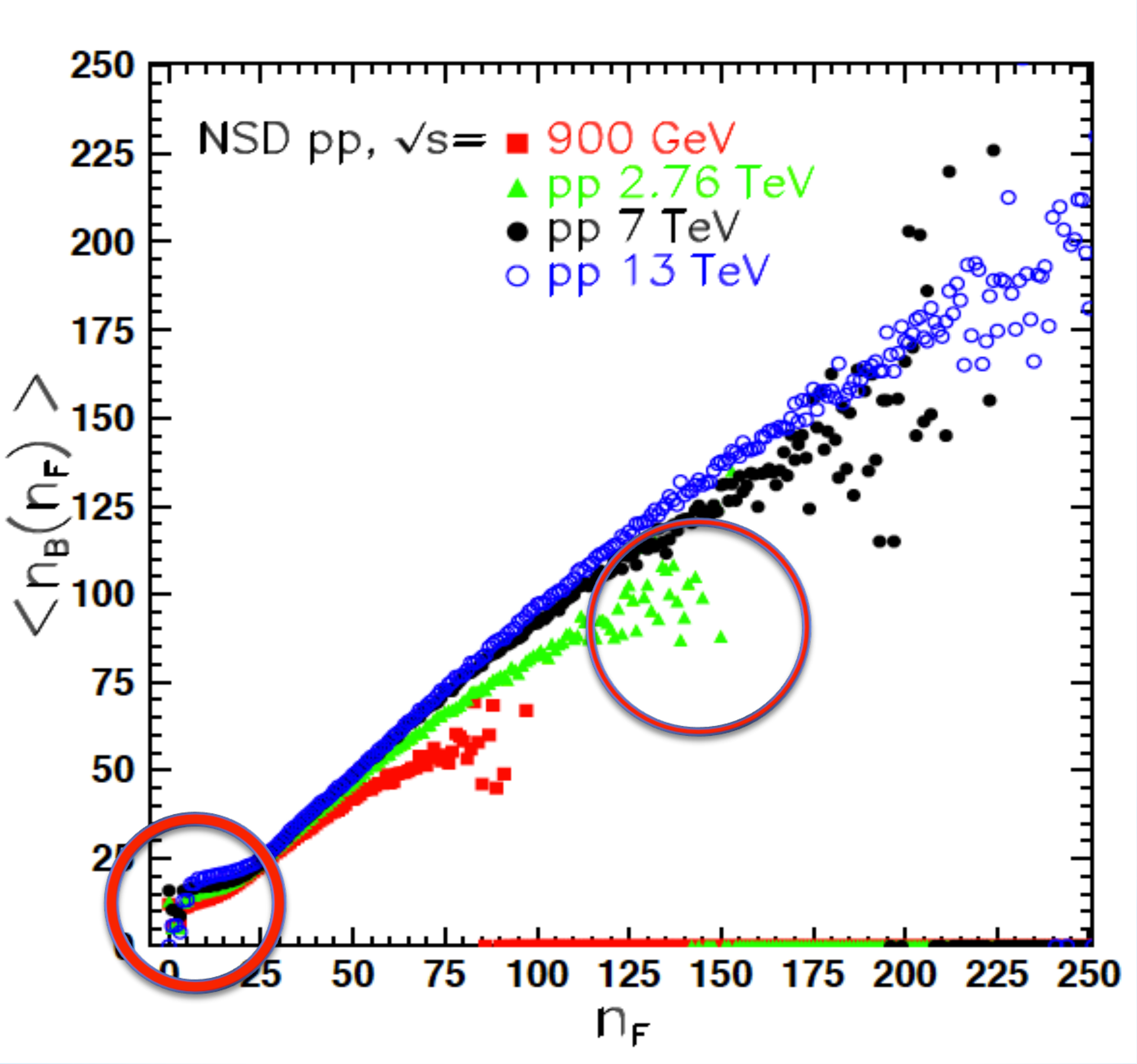
Soft Pomerons

Hard Pomerons



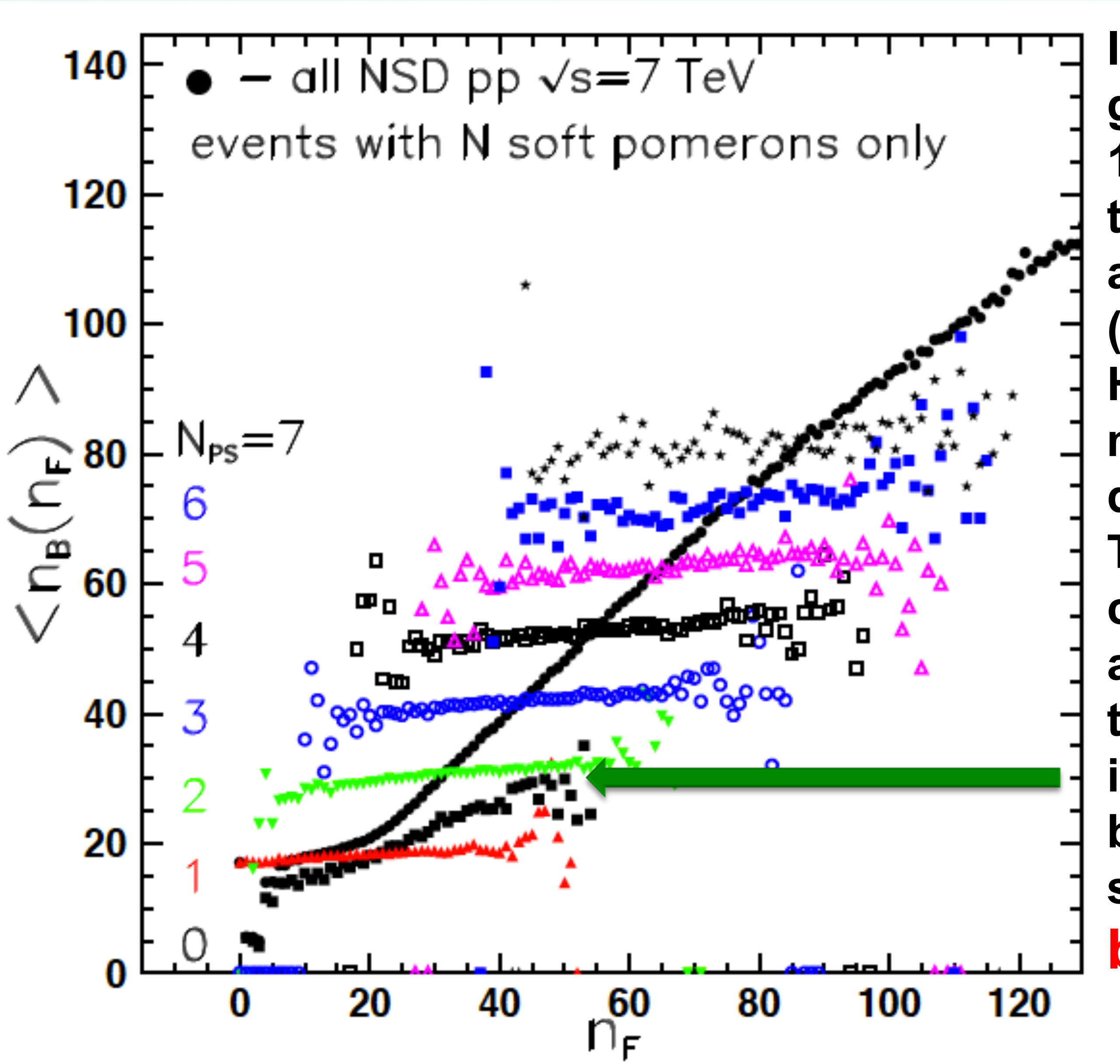


Change of the slope with energy



The slope increases. Also, the distributions are more horizontal at very small and very high multiplicities. Why?

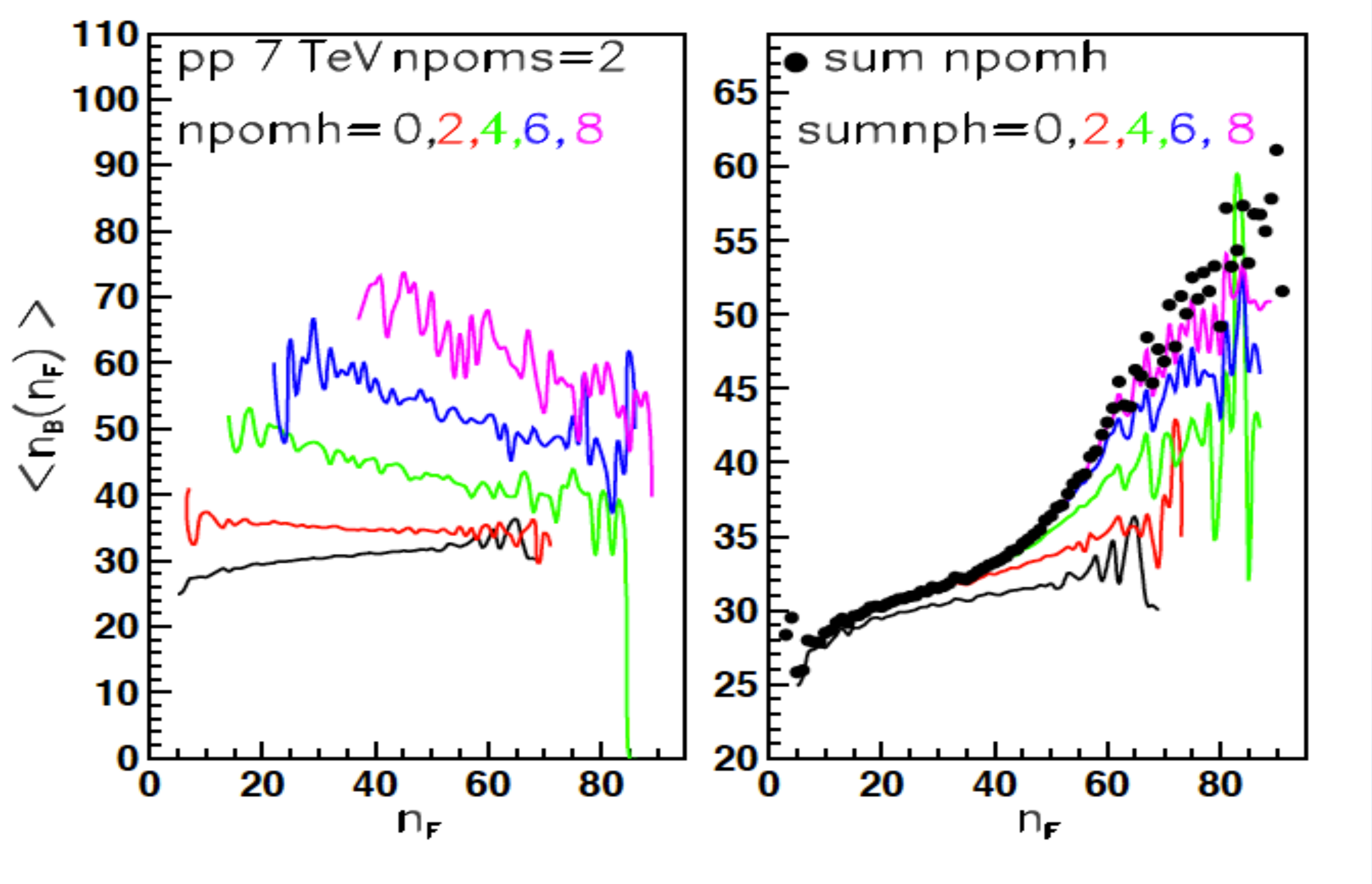
Contributions of n-Pomeron processes



If we select processes going via 1,2,…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

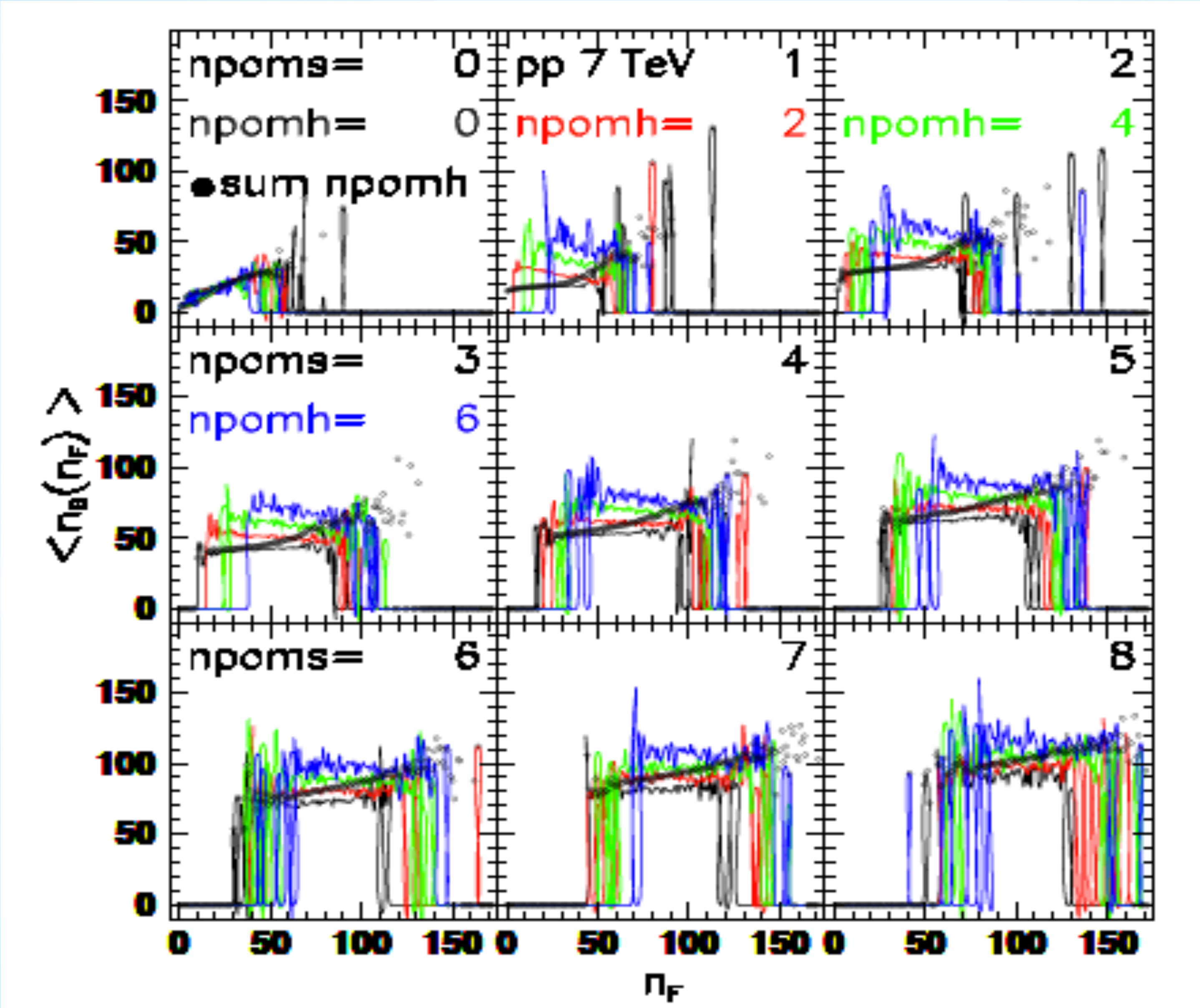
$b_{NSD} > b_{inel}$

FB correlations for hard Pomerons

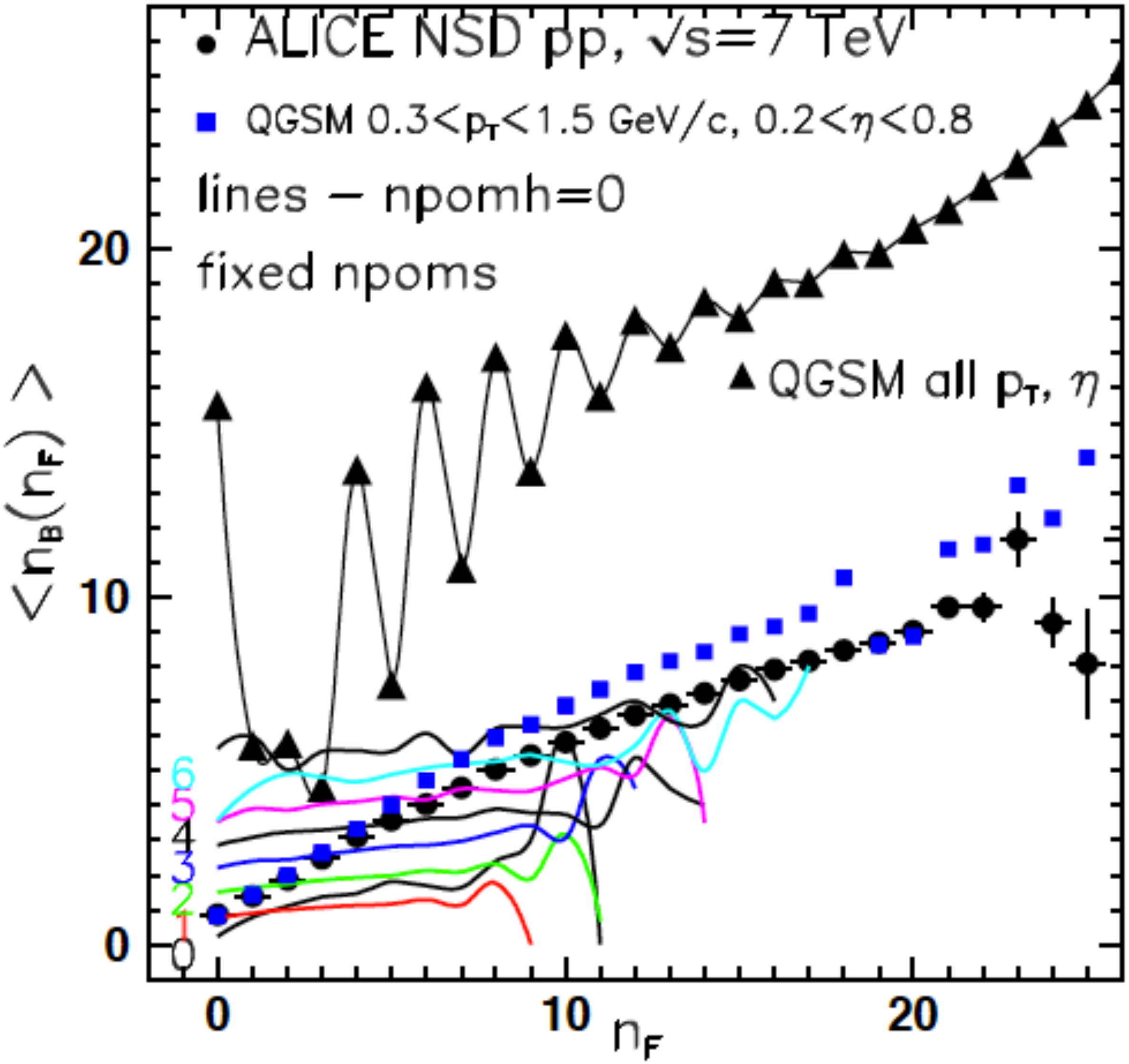


Positive FB correlations arise when we add events with different amount of hard Pomerons

more details ...



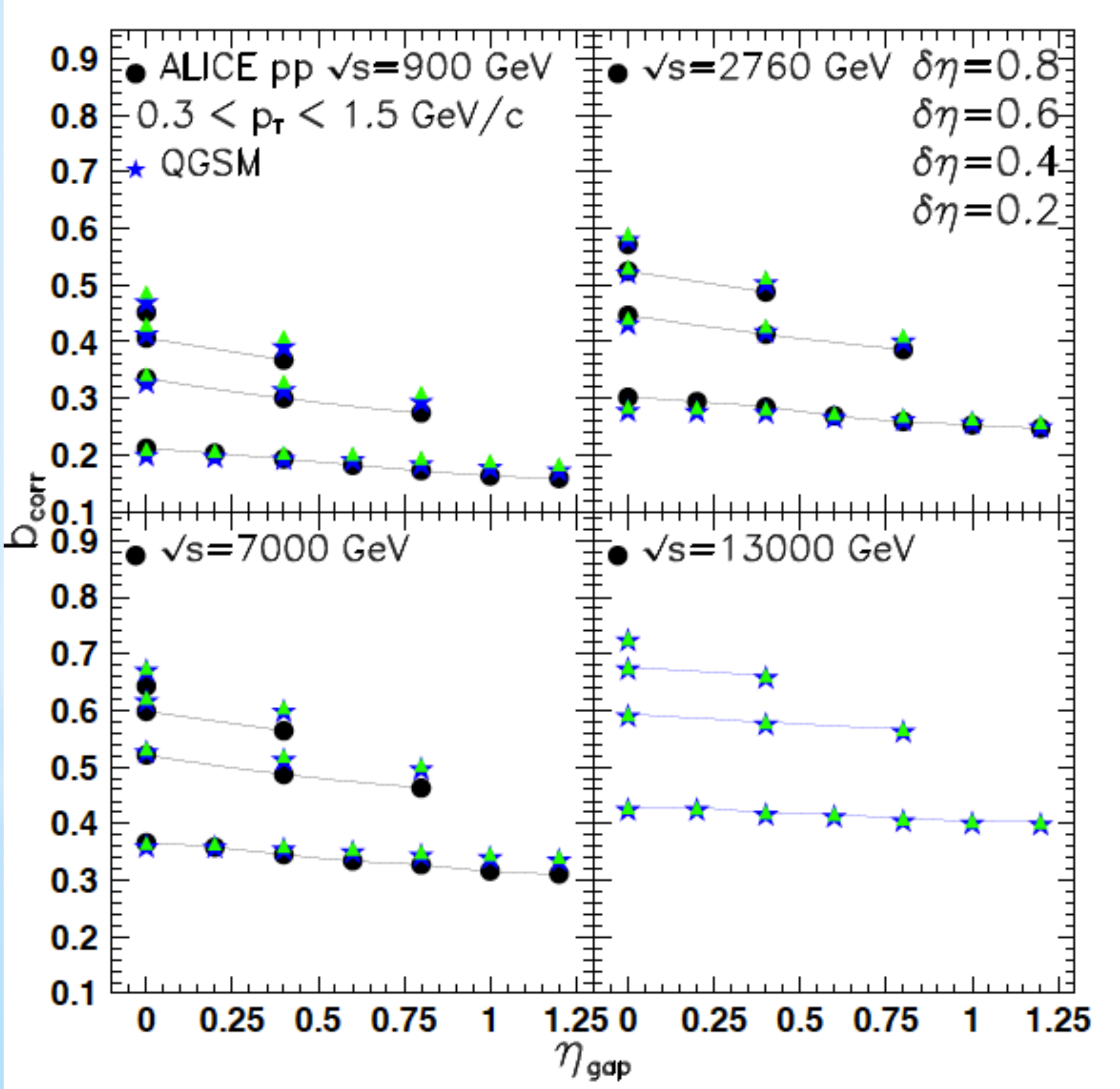
Comparison with LHC data

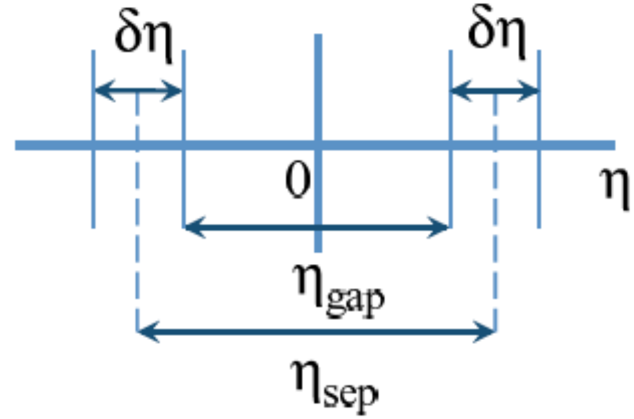


ALICE Collaboration, JHEP05 (2015) 097

Agreement is good, however, in addition to SD we drop DD events as well. Solid curve displays results for NSD events in the full phase space. The oscillations are due to DD events. This effect would be interesting to measure.

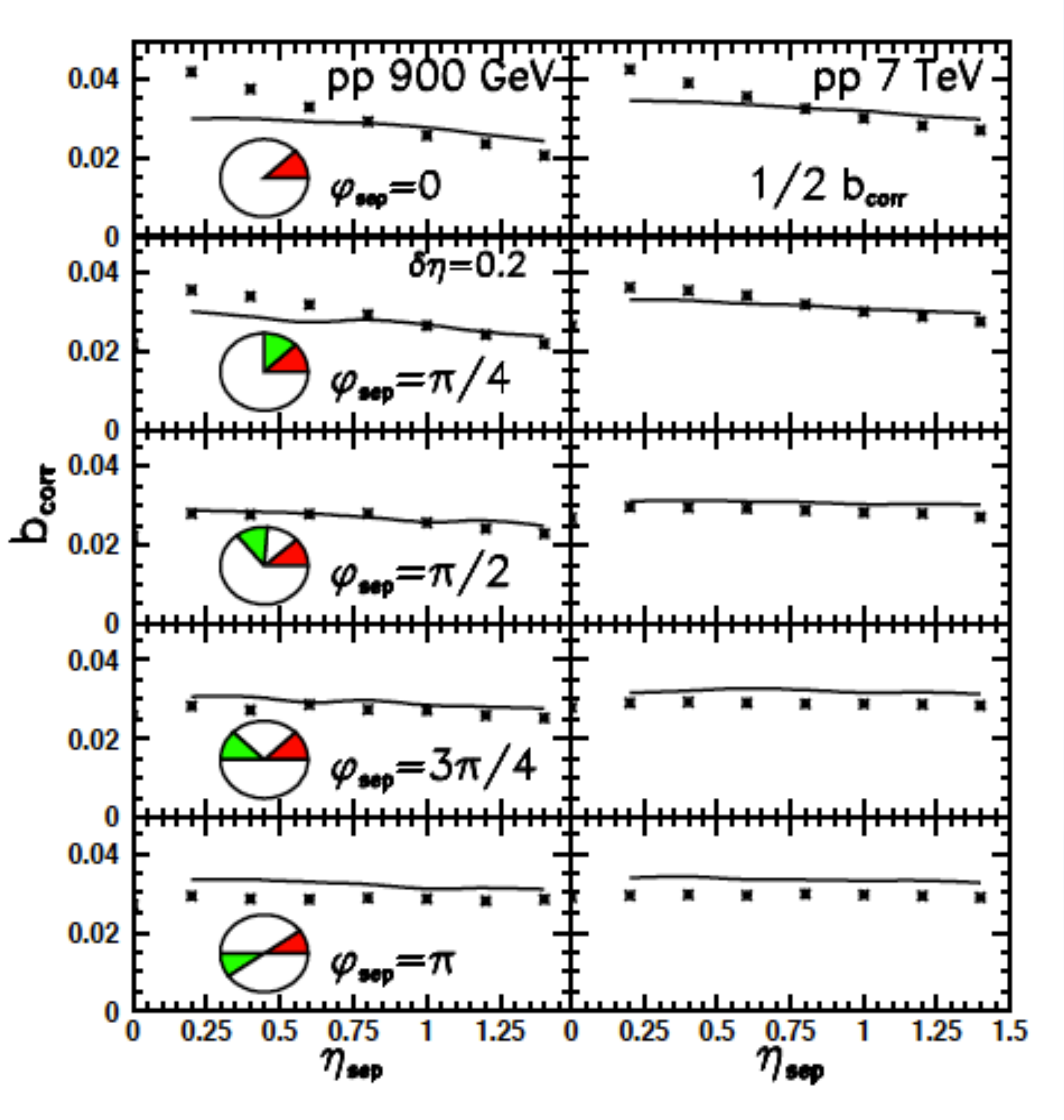
Comparison with LHC data





Dependence of b_{corr} on **$\delta\eta$ and η_{gap} is close to experiment**

Comparison with LHC data



ALICE Collaboration, JHEP05 (2015) 097

FB multiplicity correlations are studied in azimuthal sectors. Except of the absolute strength of the correlations, there is a very weak difference between the distributions at 900 GeV and 7 TeV.

CONCLUSIONS

- *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.*