XX International Baldin Seminar on High Energy Physics Problems

Nucleus-nucleus collisions at low energies. The effects from non vacuum exchange

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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)

Total cross sections for nucleon-(anti)nucleon

$$\sigma_{tot}^{pp(\bar{p})} = \sigma_0^{pp} + \sigma_1^{pp} \ln s + \sigma_2^{pp} \ln^2 s + (g_f^p)^2 s^{-\Delta_f} \mp (g_\rho^p)^2 s^{-\Delta_R} \mp (g_\omega^p)^2 s^{-\Delta_R} + (g_{A_2}^p)^2 s^{-\Delta_R}$$

$$\sigma_{tot}^{p(\bar{p})n} = \sigma_0^{pp} + \sigma_1^{pp} \ln s + \sigma_2^{pp} \ln^2 s + (g_f^p)^2 s^{-\Delta_f} \pm (g_\rho^p)^2 s^{-\Delta_R} \mp (g_\omega^p)^2 s^{-\Delta_R} - (g_{A_2}^p)^2 s^{-\Delta_R}$$

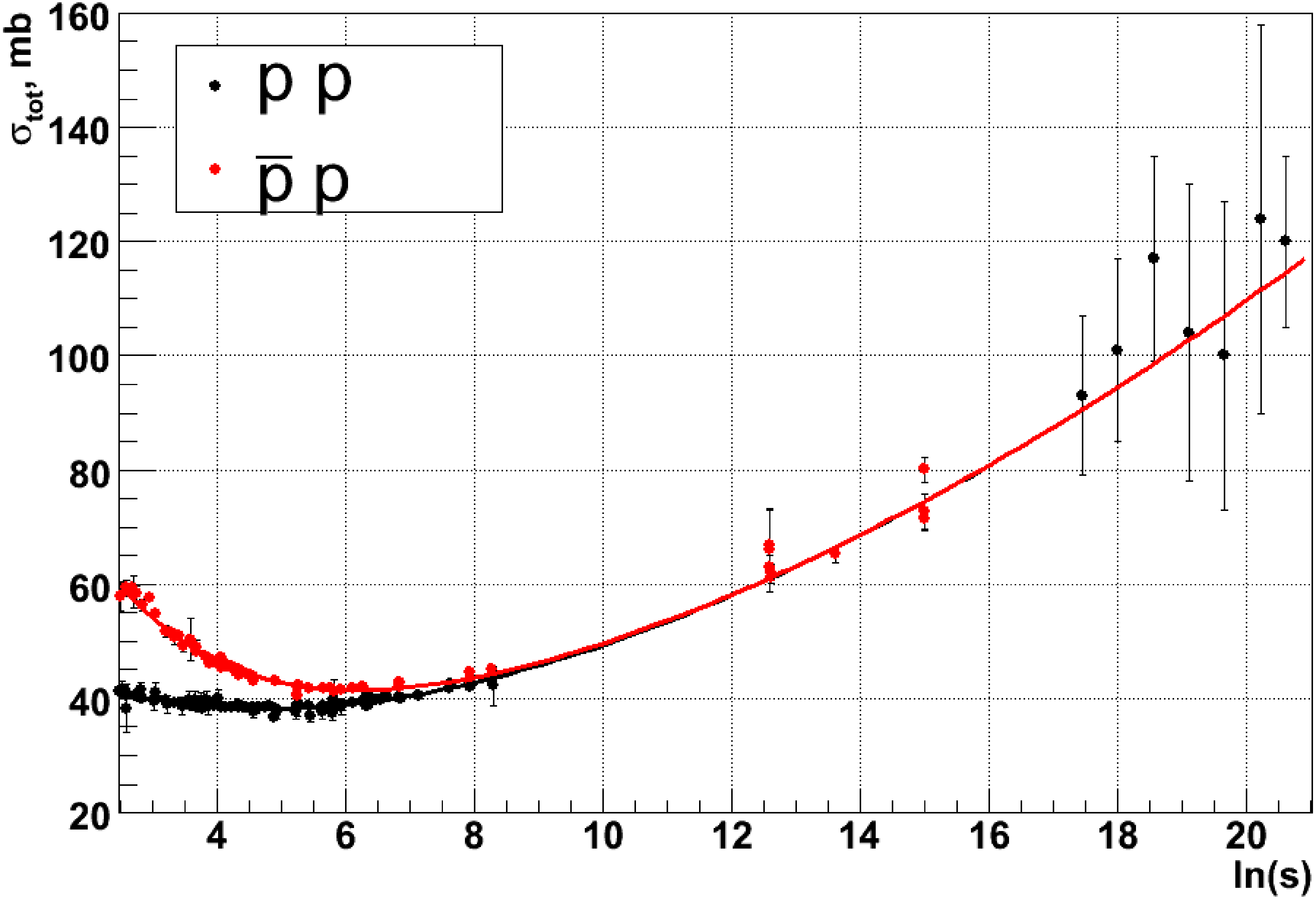
vacuum contribution

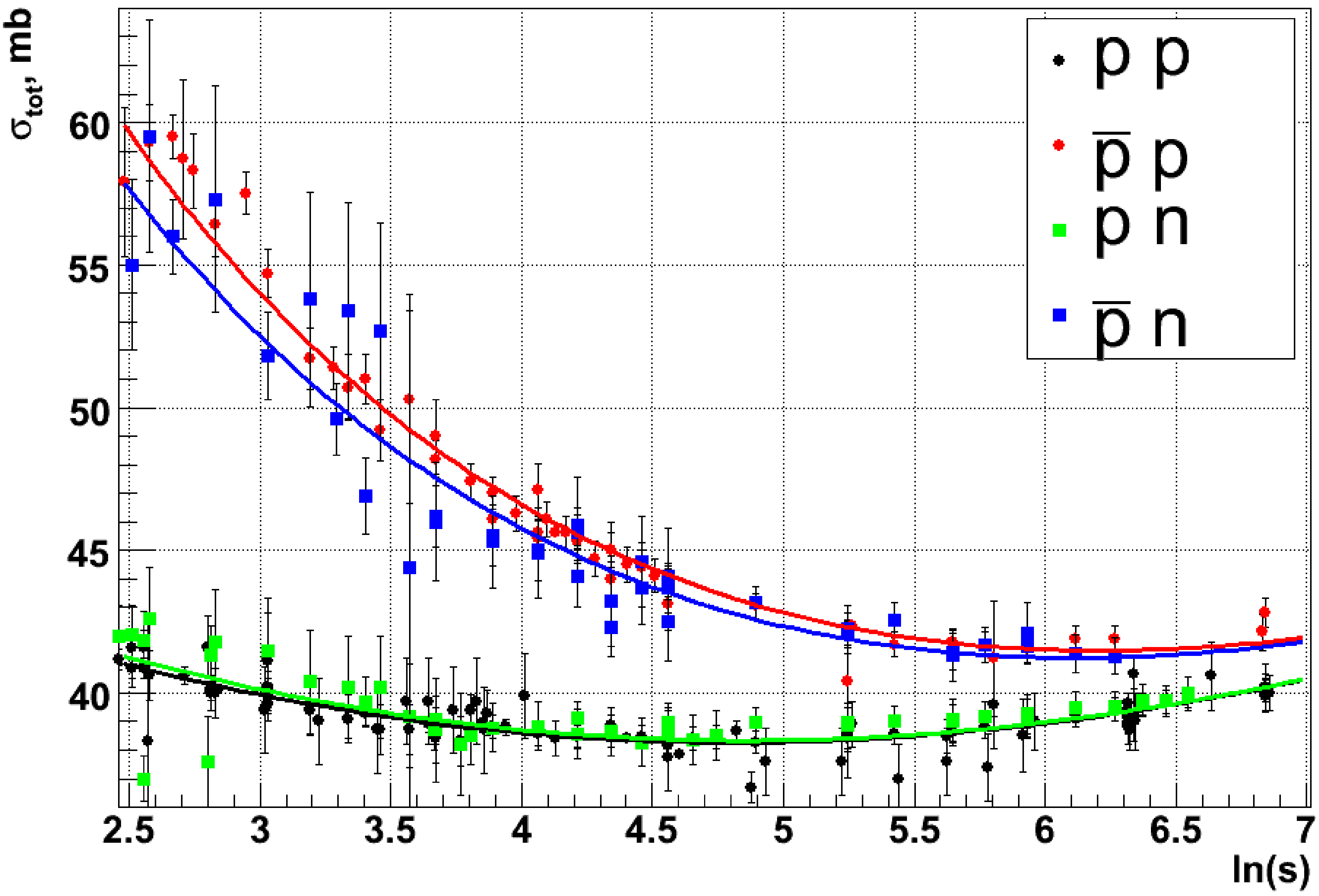
basic non vacuum reggeons

$$\sigma_0^{pp} = 21.63 \pm 1.94 \quad \sigma_1^{pp} = 0.84 \pm 0.39 \quad \sigma_2^{pp} = 0.18 \pm 0.02$$

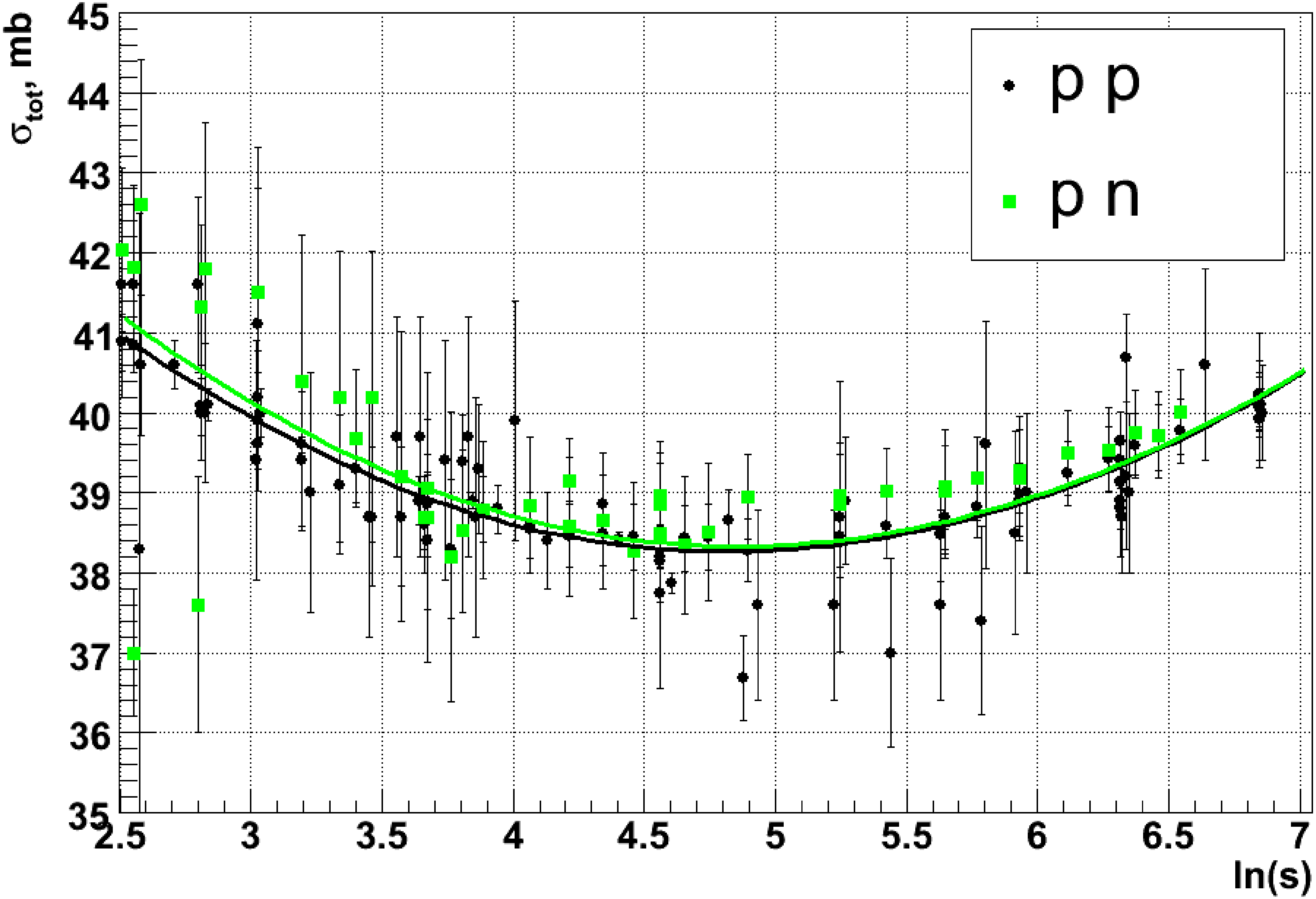
$$g_f^p = 7.85 \pm 0.20 \quad g_\rho^p = 1.51 \pm 0.21$$
$$g_\omega^p = 6.00 \pm 0.14 \quad g_{A_2}^p = 1.33 \pm 0.24$$

$$\Delta_f = 0.36$$
$$\Delta_R = 0.56 \pm 0.01$$


σ_tot, mb
p p
p̄ p
160
140
120
100
80
60
40
20
4
6
8
10
12
14
16
18
20
ln(s)



σ_{tot}, mb
60
55
50
45
40
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
ln(s)
p p
$\bar{p}$ p
p n
$\bar{p}$ n


σtot, mb
45
44
43
42
41
40
39
38
37
36
35
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
ln(s)
p p
p n

Total cross sections for kaon-nucleon

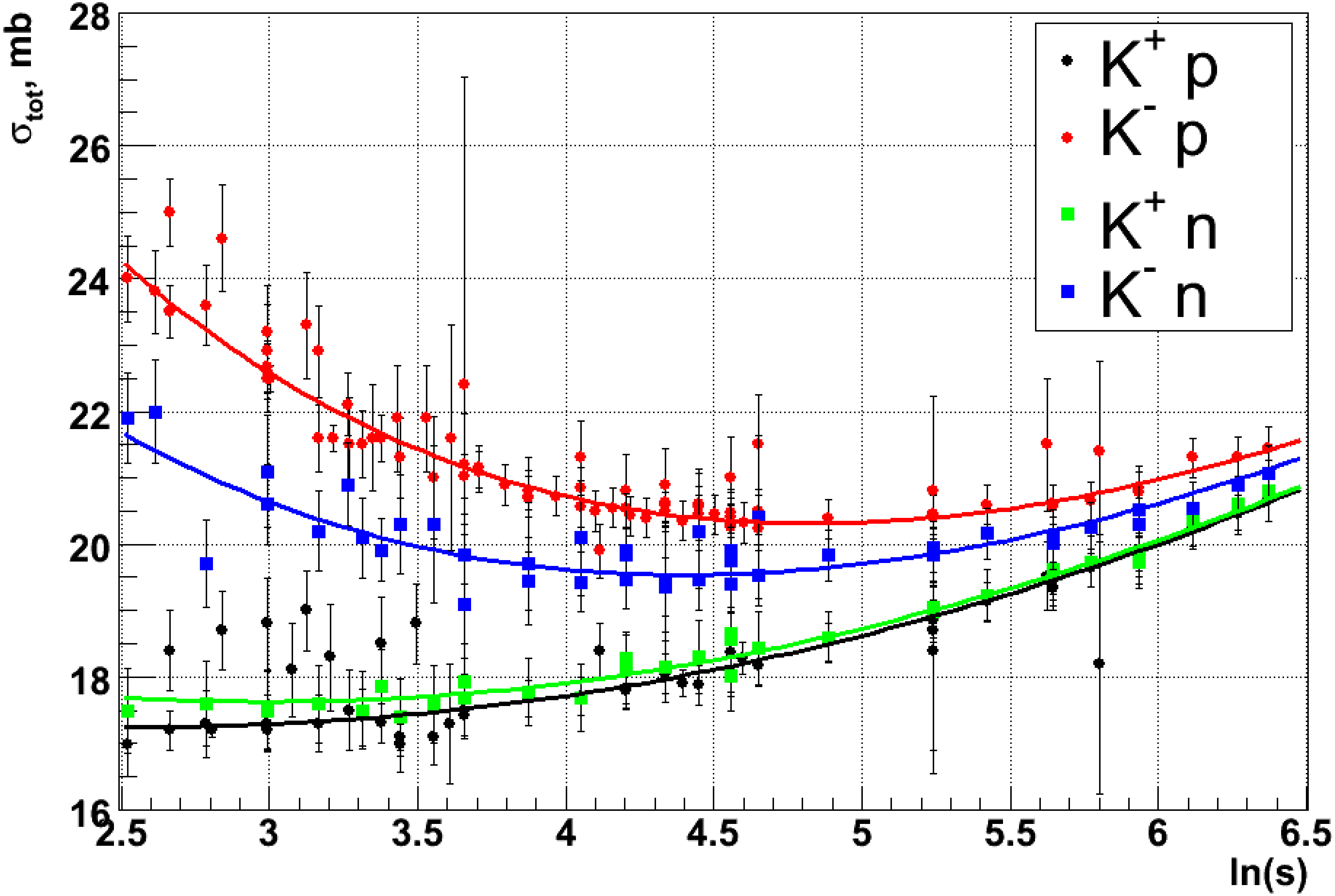
$$\sigma_{tot}^{(K^{+/-})p} = \sigma_0^{Kp}\left(1+\delta_1^{pp}\ln s+\delta_2^{pp}\ln^2 s\right)+$$
$$+g_f^K\cdot g_f^p s^{-\Delta_f}\mp g_\rho^K\cdot g_\rho^p s^{-\Delta_R}\mp g_\omega^K\cdot g_\omega^p s^{-\Delta_R}+g_{A_2}^K\cdot g_{A_2}^p s^{-\Delta_R}$$

$$\sigma_{tot}^{(K^{+/-})n} = \sigma_0^{Kp}\left(1+\delta_1^{pp}\ln s+\delta_2^{pp}\ln^2 s\right)+$$
$$+g_f^K\cdot g_f^p s^{-\Delta_f}\pm g_\rho^K\cdot g_\rho^p s^{-\Delta_R}\mp g_\omega^K\cdot g_\omega^p s^{-\Delta_R}-g_{A_2}^K\cdot g_{A_2}^p s^{-\Delta_R}$$

$$\sigma_0^{Kp}=10.43\pm0.88\quad \delta_1^{pp}=0.04\pm0.02\quad \delta_2^{pp}=0.014\pm0.002$$

$$g_f^K=2.46\pm0.15\quad g_\rho^K=2.05\pm0.35$$
$$g_\omega^K=1.88\pm0.06\quad g_{A_2}^K=1.64\pm0.38$$

$$\Delta_f=0.36$$
$$\Delta_R=0.56\pm0.01$$



σ_tot, mb
28
26
24
22
20
18
16
2.5
3
3.5
4
4.5
5
5.5
6
6.5
ln(s)
K+ p
K- p
K+ n
K- n

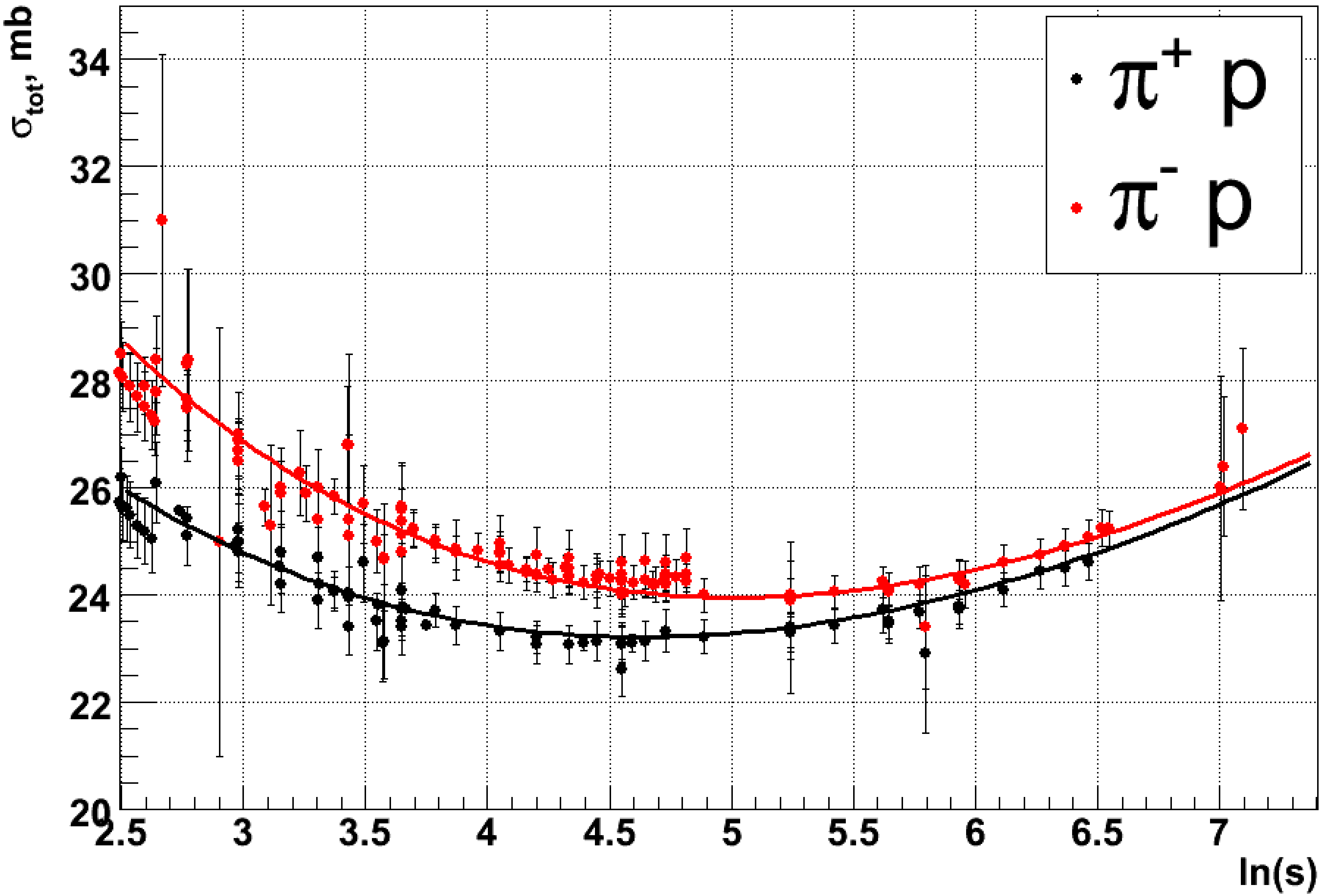
Total cross sections for pion-nucleon

$$\sigma_{tot}^{(\pi^{+/-})p} = \sigma_0^{\pi p}\left(1 + \delta_1^{pp}\ln s + \delta_2^{pp}\ln^2 s\right) + g_f^{\pi}\cdot g_f^{p} s^{-\Delta_f} \mp g_\rho^{\pi}\cdot g_\rho^{p} s^{-\Delta_R}$$

$$\sigma_0^{\pi p} = 11.52 \pm 0.93 \quad \delta_1^{pp} = 0.04 \pm 0.02 \quad \delta_2^{pp} = 0.014 \pm 0.002$$

$$g_f^{\pi} = 4.48 \pm 0.11 \quad g_\rho^{\pi} = 3.75 \pm 0.53$$

$$\Delta_f = 0.36$$
$$\Delta_R = 0.56 \pm 0.01$$


σ_{tot}, mb
34
32
30
28
26
24
22
20
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
ln(s)
$\pi^+ p$
$\pi^- p$

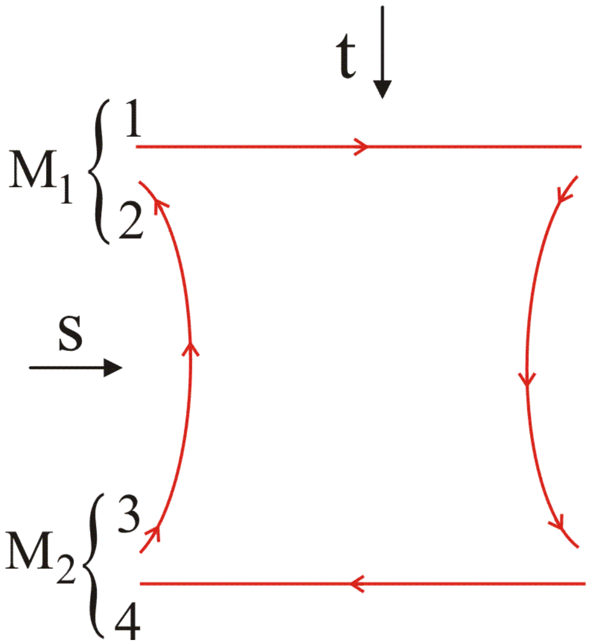
Approximate exchanged extinction of reggeon-hadron interaction vertices

	$p\,(n)$	K	π
$f-meson$	7.85 ± 0.20	2.46 ± 0.15	4.28 ± 0.11
$\rho-meson$	1.51 ± 0.21	2.05 ± 0.35	3.75 ± 0.53
$\omega-meson$	6.00 ± 0.14	1.88 ± 0.06	
$A_2-meson$	1.33 ± 0.24	1.64 ± 0.38	

Non vacuum exchange in Dual-Resonance Model

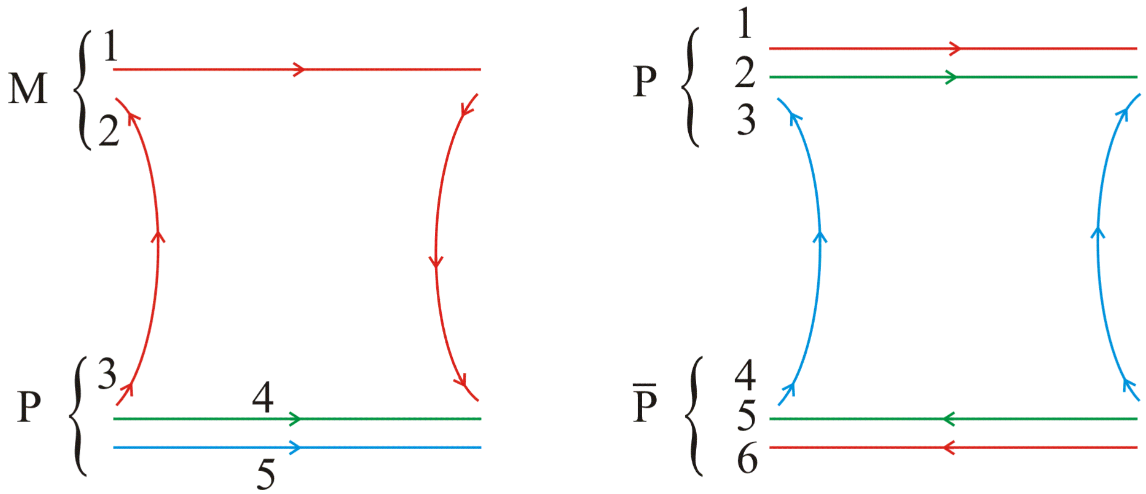
We will argue that non vacuum exchanges in *pp* and *pn* interactions lead to increase of baryon number in central part of spectrum. We are based on DRM which can not describe experimental data but gives good theoretical framework.

1. There are quark and antiquark in intermediate state in t-channel.
2. In intermediate state of s-channel there is stage with only quark string with quark 1 and antiquark 4 at its endpoints.
3. Exchanged quark and antiquark have low momentum $|p| \sim m$.



Dual diagram of DRM – two-dimensional surface drawn by quark string

Dual diagrams for meson-proton and proton-antiproton scattering

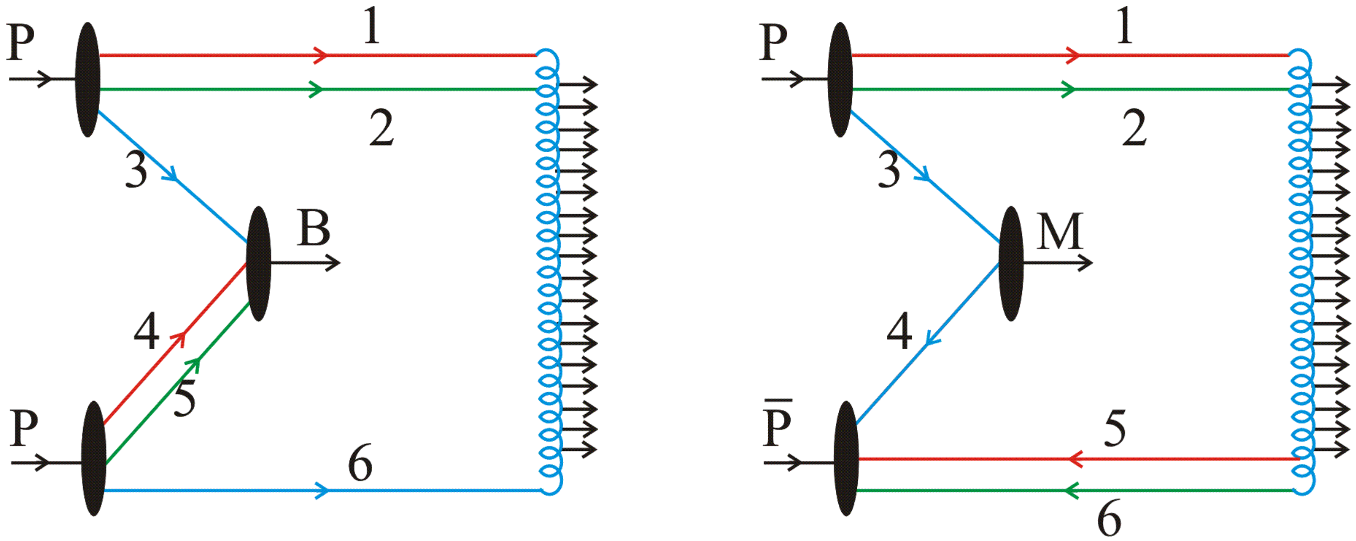


1. In t-channel intermediate state there are quark and antiquark.
2. In s-channel intermediate state there is string with quark 1 and diquark 4+5 (*MP*) or with diquark 1+2 and antidiquark 5+6 (*PPbar*) at its endpoints.

There are no such diagrams for proton-proton case.

Cuts of elastic amplitudes in s-channel correspond to inelastic processes in DRM.

Proton-proton scattering



- In order to obtain quark string in s-channel we need the following configuration: quark from one proton and diquark from another proton must have low momenta to produce colorless state. There are no other combinations.
- Diquark 1+2 and quark 6 carry almost all energy of protons. Quark 3 and diquark 4+5 have low momenta and produce colorless state B at interaction. Quark string is produced between diquark 1+2 and quark 6.
- The produced baryon B is slow in center-of-mass system and so baryon number is increased in central part of rapidity spectrum. There is no such effect in *PPbar* collisions.

Conclusions

- Non vacuum reggeons are essential at low energies in nucleus-nucleus collisions.

- Non vacuum exchange leads to increase of baryon number in central part of rapidity spectrum. This effect might be important for quark-gluon plasma experiments at facilities NICA and FAIR.

Acknowledgements

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