The hard Pomeron impact on the high-energy elastic scattering of nucleons

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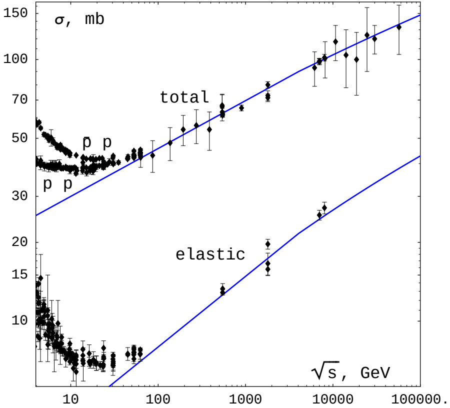
The soft Pomeron

The soft Pomeron is a Reggeon which absolutely dominates in the elastic scattering forward at collision energies higher than 100 GeV.

$$\alpha_{\rm SP}(0) - 1 \approx 0.1$$



The soft Pomeron eikonal approximation for elastic *pp*-scattering

$$T(s,t) = 4\pi s \int_0^\infty db^2 J_0(b\sqrt{-t})\,\frac{e^{2i\delta(s,b)}-1}{2i}\,,$$

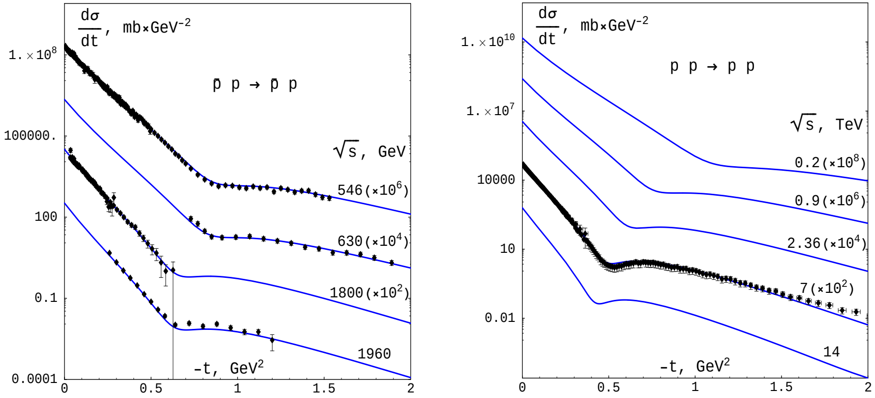
$$\delta(s,b) = \frac{1}{16\pi s}\int_0^\infty d(-t) J_0(b\sqrt{-t})\,\delta_{\rm SP}(s,t)\,,$$

$$\delta_{\rm SP}(s,t) = \xi(\alpha_{\rm SP}(t))\,g^2_{\rm SP}(t)\,\pi\alpha'_{\rm SP}(t)\left(\frac{s}{2s_0}\right)^{\alpha_{\rm SP}(t)}\,,$$

$$\xi(\alpha) \equiv i + \tan\frac{\pi(\alpha-1)}{2}\,.$$

Description of the high-energy differential cross-sections

A.A. Godizov, Eur. Phys. J. C **75** (2015) 224



The hard Pomeron

The hard Pomeron is a Reggeon which absolutely dominates in the low-x deep inelastic scattering on protons at the incoming photon virtualities $Q^2 > 100$ GeV^2.

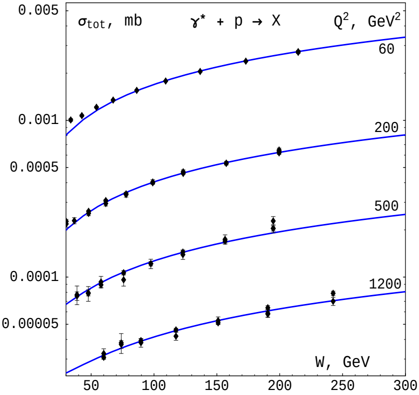
$$\sigma_{tot}^{\gamma^* p}(W, Q^2) \approx \frac{4\pi^2\alpha_e}{Q^2(1-x)} F_2^p(x, Q^2) \quad \left(x = \frac{Q^2}{W^2 + Q^2 - m_p^2}\right) ,$$

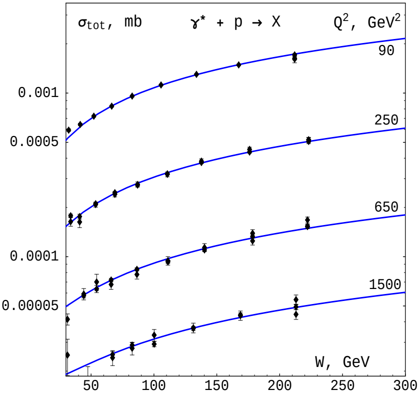
$$\sigma_{tot}^{\gamma^* p}(W, Q^2) \sim \left(W^2 + Q^2\right)^{\alpha_{\rm HP}(0)-1} .$$

The power growth of the $\gamma^* p$ total cross-sections

A.A. Godizov, Nucl. Phys. A **927** (2014) 36:

$$\alpha_{\rm HP}(0) - 1 = 0.32 \pm 0.03$$





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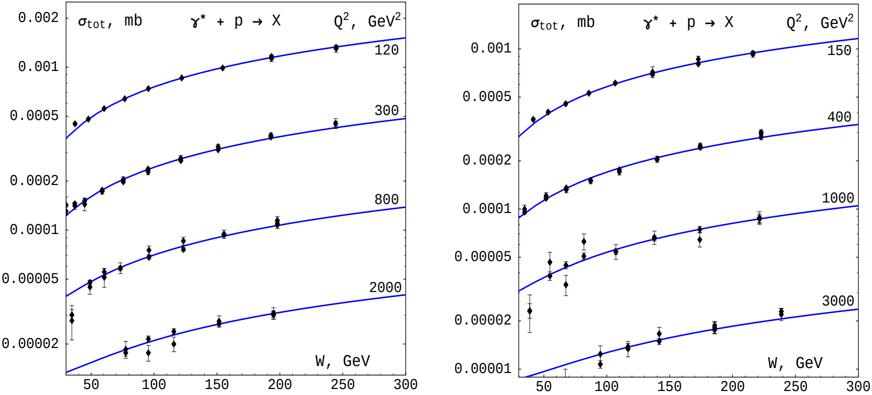


The main question

Why does not the hard Pomeron dominate in the high-energy elastic scattering?

R. Kirschner and L.N. Lipatov, Z. Phys. C **45** (1990) 477:

$$\alpha_{\mathrm{KL}}^{(n_r)}(t) = 1 + \frac{12\ \ln 2}{\pi}\,\alpha_s(\sqrt{-t}) \times$$

$$\times \left[1 - \alpha_s^{2/3}(\sqrt{-t})\left(\frac{7\zeta(3)}{2\ \ln 2}\right)^{1/3}\left(\frac{3/4 + n_r}{11 - 2/3\,N_f}\right)^{2/3} + \ldots\right] .$$

If $\alpha_s(M_Z) = 0.118$ and $N_f = 5$ or 6, then $\alpha_{\mathrm{KL}}^{(0)}(-M_Z^2) \approx 1.28$.

The slope of the HP Regge trajectory

If $\alpha^{(0)}_{\rm KL}(t) \equiv \alpha_{\rm HP}(t)$ and $\alpha_{\rm HP}(0) = 1.32$, then

$\alpha'_{\rm HP}(-M_Z^2) \approx 2 \cdot 10^{-6}$ GeV^{-2} and

$\frac{\alpha_{\rm HP}(0)-\alpha_{\rm HP}(-M_Z^2)}{M_Z^2} \approx 5 \cdot 10^{-6}$ GeV^{-2}.

Conclusion: both the functions $\alpha_{\rm HP}(t)$ and $\alpha'_{\rm HP}(t)$ evolve very slowly in the interval $-M_Z^2 < t < 0$.

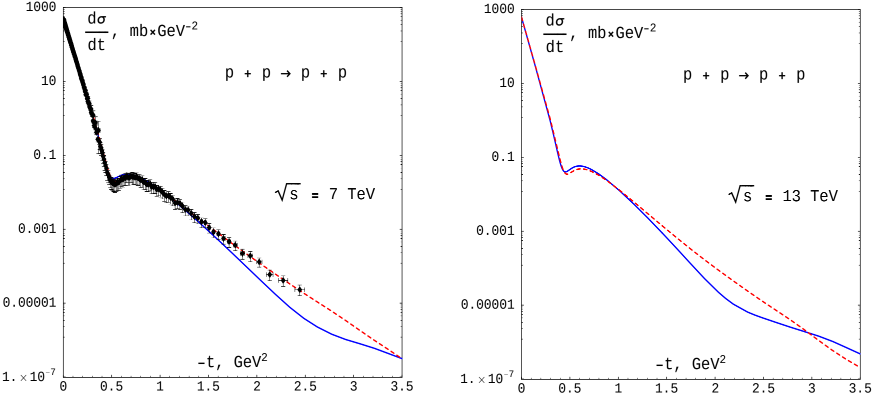
Born amplitude in the two-Pomeron eikonal model

$$\delta(s,t) = \delta_{\rm SP}(s,t) \to \delta_{\rm SP}(s,t) + \delta_{\rm HP}(s,t)\,,$$

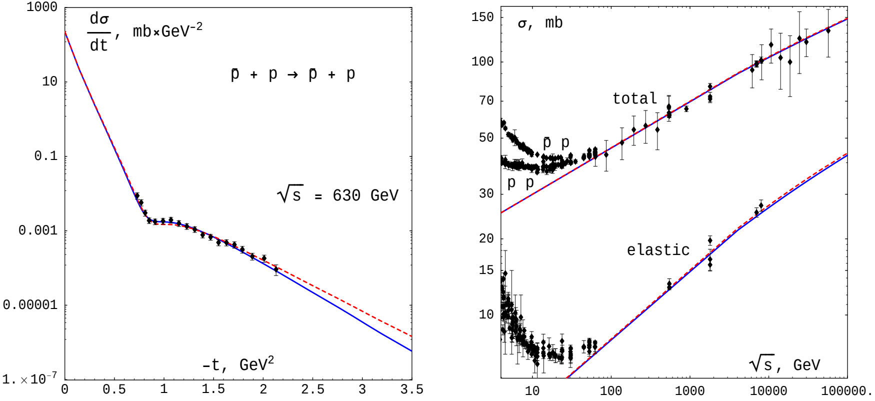
$$\delta_{\rm HP}(s,t) = \xi(\alpha_{\rm HP}(0))\,\beta_{\rm HP}(t)\left(\frac{s}{2s_0}\right)^{\alpha_{\rm HP}(0)}\,,$$

$$\alpha_{\rm HP}(0) - 1 = 0.32\,.$$

The hard Pomeron in elastic scattering



The hard Pomeron in elastic scattering



The hard Pomeron coupling to proton

The hard Pomeron residue:

$$\beta_{\rm HP}(t) = g_{\rm HP}^2(t)\,\pi\alpha'_{\rm HP}(t)\,.$$

Assuming that $\frac{\alpha'_{\rm HP}(0)}{\alpha'_{\rm HP}(-M_Z^2)} < 100$, we obtain

$$g_{\rm HP}(0) \sim g_{\rm SP}(0)\,.$$

Conclusions

- The interpretation of the hard Pomeron as the leading Reggeon of the Kirschner-Lipatov series is quite compatible with the available data on the high-energy elastic scattering of nucleons.
- Its "invisibility" at collision energies lower than 2 TeV is related to the extremely weak t-behavior of its Regge trajectory in the diffractive scattering region.

A.A. Godizov, Phys. Rev. D **96** (2017) 034023

Thank you for attention!