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Hard diffractive photoproduction with rapidity gap

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Abstract

Hard diffractive photoproduction with rapidity gap is the best place for study of perturbative Pomeron. Some predictions of pQCD and the range of their applicability are described.

We discuss the production on a quark or gluon. The cross sections for the real $\gamma^* p$ processes with rapidity gap are obtained by the standard convolution with structure functions. Let $\hat{s}$ be the squared c.m.s. energy for the $\gamma^* q$ collision, $p_\perp$ – the transverse momentum of the produced meson or photon in this frame, and $\eta \approx \ln(\hat{s}/p_\perp^2)$ – the rapidity gap (from the meson to the quark or gluon). It is assumed that $\hat{s} \gg p_\perp^2, Q^2,\ p_\perp^2 \gg \mu^2 = (0.2 \div 0.3\ \text{GeV})^2$.

1. Light vector mesons $V = \rho, \phi, ..., \gamma$, $\quad Q^2 < p_\perp^2$.

1. **Hard Compton effect $\gamma q \to \gamma q$** with real photons[1], $Q^2 = 0$ [1, 3].

$$d\sigma/dp_\perp^2 \propto (1/p_\perp^4) F(s/p_\perp^2) \text{ at } p_\perp > p_{pert} \approx 1 \div 1.2 \text{ GeV}. \tag{1}$$

   The overall coefficient is given by the basic two–gluon approximation. $F \approx 1$ at $\eta < 3$. The BFKL enhancement is expected at the higher η. At $p_\perp > 2 \div 3$ GeV one can see the specific azimuthal dependence relative to electron scattering angle.

2. $\boldsymbol{\gamma q \to V q}$, $Q^2 < p_\perp^2$ [1, 3, 4].

   The produced light mesons will be polarized longitudinally at $p_\perp > p_{hel}$; $p_{hel}(Q^2 = 0) \approx 1.5 \div 2.5$ GeV for ϕ, ≈ 5 GeV for ρ. The value of p_{hel} decreases with increasing virtuality.

$$d\sigma/dp_\perp^2 \propto (1/p_\perp^6) F_1 F(s/p_\perp^2) \text{ at } p_\perp > p_{pert} > p_{hel}. \tag{2}$$

   The overall coefficient is given by the basic two–gluon approximation and F_1 depends strongly on the ratio $(Q^2/p_\perp^2)$. At $\eta < 3.5$ we expect that F_1 is given by

[1] The experimental difficulties are obvious, special work related to the extraction of this process compared with bremsstrahlung is necessary.

two–gluon approximation and $F \approx 1$. The observation of higher values of η with BFKL enhancements seem to be difficult for HERA experiments.

The quantity p_{pert} decreases fast with photon virtuality:

$$p_{pert}(Q^2 = 0) \approx 6 \div 8 \text{ GeV for } \phi, \approx 7 \div 10 \text{ GeV for } \rho; \qquad (3)$$
$$p_{pert}(Q^2 = 2.25) \approx 1.5 \div 2 \text{ GeV for } \phi \text{ and } \rho.$$

The region $p_\perp > p_{pert}$ seems beyond access of the experiments at HERA for real photons and but is observable at HERA for moderate virtualities.

3. $\boldsymbol{\gamma q \to (q\bar{q})q}$ with $M_{q\bar{q}}^2 \lesssim p_\perp^2$. That are the processes with diffractive production of two (quark) jets having the largest cross sections in comparison with previous. The cross section of such process is infrared unstable quantity due to region where momenta of quarks are almost parallel to each other.

   We consider events, in which the thrust axis is determined. Let us denote by α the angle between thrust axis and total transverse momentum of produced 2–jet system. The quantity

$$d\sigma \cdot \sin^2 \alpha \qquad (4)$$

   is infrared stable and measurable at HERA.

2. $\boldsymbol{\gamma q \to V q}$. $\boldsymbol{Q^2 > p_\perp^2}$ (all vectors), heavy mesons $\boldsymbol{(J/\Psi, \Upsilon, ..)}$ at any $\boldsymbol{p_\perp}$.

All vector mesons will be longitudinally polarized at $Q^2 > p_\perp^2$. The heavy mesons will be polarized transversely at $Q^2 < M^2$. The BFKL enhancement is expected but the argument in $\ln(\hat{s}/?)$ is not predicted within modern pQCD [1b,2].

3. What can be tested

1. *pQCD in pure form*
   - Longitudinal polarization of light V's at $p_\perp > p_{hel}$;
   - $p_\perp^2$ dependence for light V's, photons and 2–jet events at $p_\perp > p_{pert}$, $\eta < 3.5$;
   - Strong $u = Q^2/p_\perp^2$ dependence at $p_\perp > p_{pert}$, $\eta < 3.5$ for small u;
2. *BFKL pomeron in pQCD* at $p_\perp > p_{pert}$, $\eta > 3.5$. The opportunity to see pure BFKL at $p_{pert} > p_\perp > p_{hel}$ should be studied;
3. *Scales of nonperturbative effects* – positions of p_{hel} and p_{pert}.
4. *pQCD* in the polarization dependence.
5. *BFKL + additional hypothesis about argument in* $\ln(s/?)$ *dependence.*

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