One-particle inclusive distribution in the unitarized pomeron models

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13th International Conference on Elastic & Diffractive Scattering,
CERN-2009

Outline

1. Unitarization of pomeron
   - Elastic scattering
   - Inclusive process
2. One-particle distribution
   - Experimental data
   - Description of the data

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Pomeron and elastic scattering

- Multiple pomeron rescattering
  Starting point: pomeron with $\alpha_P(0) = 1 + \varepsilon, \quad \varepsilon \approx 0.1$
  $\sigma_t(s) \propto s^{\varepsilon}$ - violates H-F-M-L bound: $\sigma_t \leq \frac{\pi}{m_\pi^2} \ln^2 s$
  such pomeron must be unitarized

Input amplitude

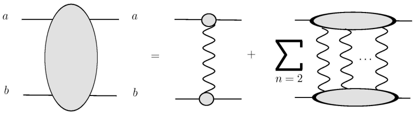
$$a(s,t) = g_a(t) g_b(t) \eta(\alpha_P(t))(s/s_0)^{\alpha_P(t)}, \quad \eta(\alpha) = \frac{1 + e^{-i\pi\alpha}}{-\sin(\pi\alpha)}$$

$$h(s,b) = \frac{1}{8\pi s} \int_0^\infty dbbJ_0(qb) a(s,t), \quad q^2 = -t$$

$$h(s,b) = \tilde{g}_a \tilde{g}_b \frac{(-is/s_0)^{\varepsilon}}{2R^2} e^{-b^2/4R^2}, \quad R^2 = B_a + B_b + \alpha'_P \ln(-is/s_0)$$

- Eikonal and *U*-matrix

$$H(s,b) = \frac{1}{2i}\sum_{n=1}^{\infty}\frac{G_a(n)G_b(n)}{n!}[2ih(s,b)]^n.$$



$$H(s,b) = \begin{cases} \dfrac{e^{2iC_aC_bh(s,b)}-1}{2iC_aC_b}, & \text{if} \quad G_{a,b}(n) = C^n_{a,b} \\ \dfrac{h(s,b)}{1+2iC_aC_bh(s,b)}, & \text{if} \quad G_{a,b}(n) = C^n_{a,b}\sqrt{n!} \end{cases}$$

In both cases unitarity (bound) is restored, at $s \to \infty$

$$\sigma_t \approx 8\pi C_a C_b \varepsilon \alpha' \ln^2(s/s_0)$$

- Alternative approach: *More hard singularities in amplitude*
  Simple pomeron pole in partial amplitude is an assumption.
  It is not confirmed by experimental data
  or it violates unitarity if $\varepsilon > 0$
- Let assume that pomeron at $t = 0$ and $j = 1$ is more hard singularity
- Simplest examples:
  Double pole (at $j = \alpha_P(t)$) $\Rightarrow \sigma_t(s) \propto \ln(s/s_0)$
  Triple pole (at $j = 1$ and $t = 0$) $\Rightarrow \sigma_t(s) \propto \ln^2(s/s_0)$
  All data on σ_t, ρ and $d\sigma/dt, \sigma_{el}$ are well described in both models.

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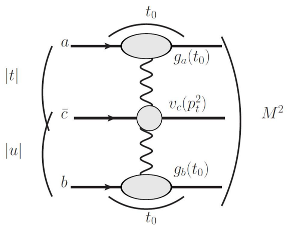
Unitarization of Pomeron contribution in central region

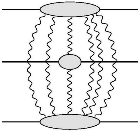
From generalized optic theorem in two-reggeon approximation

$$E\frac{d^3\sigma}{d^3p} = \tilde{g}_a(|t|/s_0)^{\varepsilon}v_c(p_t^2)(|u|/s_0)^{\varepsilon}\tilde{g}_b \approx \tilde{g}_a e^{\varepsilon(y_0-y)}v_c(p_t^2)e^{\varepsilon(y_0+y)}\tilde{g}_b$$

$$= \tilde{g}_a v_c(p_t^2)\tilde{g}_b e^{2\varepsilon y_0}, \qquad y_0 \pm y \gg 1$$



$$-1/2\ln(s/m_t^2) \le y \le 1/2\ln(s/m_t^2), \quad \text{i.e.} \quad y_0 = 1/2\ln(s/m_t^2)$$

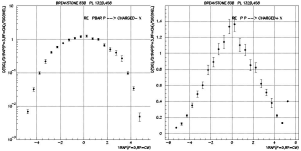


Contribution of multipomeron diagrams was calculated in the case $\alpha_P(0) > 1$ (K.Ter-Martirosyan, 1973). Due to AGK rules only input diagram with one pomeron exchange contributes.

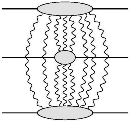
$$\frac{dn_c}{dy} = \frac{1}{\sigma_t(s)} 8\pi \tilde{g}_a \tilde{V}_c \tilde{g}_b (s/s_0)^{\varepsilon} \propto \frac{(s/s_0)^{\varepsilon}}{\ln^2(s/s_0)}$$

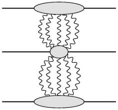
In this approximation $\frac{dn_c}{dy}$ does not depend on y.

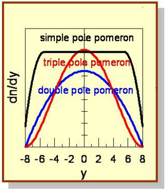
However experimental data have a bell-shaped form



More diagrams







E.M.(1985), A.Likhoded and O.Yushchenko (1989)

$$E\frac{d^3\sigma}{d^3p} = \tilde{g}_a\mathcal{F}(y_0-y)v_c(p_t^2)\mathcal{F}(y_0+y)\tilde{g}_b.$$

$$\mathcal{F}(y_0\pm y) = (y_0\pm y)^2 \quad \text{for} \quad \text{input} \quad \alpha_P(0) > 1$$

More generally:

$$\mathcal{F}(y_0 \pm y) = (y_0 \pm y)^{\lambda}, \quad 1 \leq \lambda \leq 2$$

Qualitatively solutions with $\lambda > 0$ are in better agreement with data, form and rising $dn/dy_{|y=0}$ with s

The dipole ($\lambda = 1$) and triple ($\lambda = 2$) pomeron models were compared with high-energy data.

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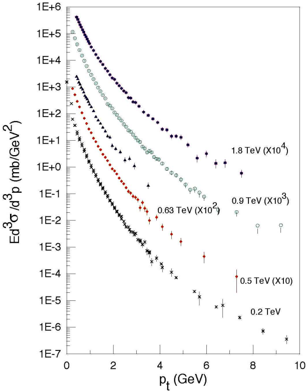
Data on $\bar{p} + p \rightarrow \text{charged} + X$ at $200 \leq \sqrt{s} \leq 1800\,\text{GeV}$



✓Slopes in p_t-dependence is changing with energy

✓Exponential dependence at small p_t is changed for a power one at $p_t > 1$ GeV

The vertex $v_c(p_t^2)$ in two-pomeron diagram does not depend on energy $\Rightarrow$

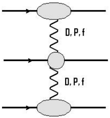
Energy dependence of slope can be described in the considered unitarized pomeron models only with a few preasymptotic terms

Outline

In dipole pomeron model

for both (upper and bottom) reggeons: D, P, f

each term with proper vertex $v_c^{(R_1,R_2)}(p_t^2)$



Cross section:

$$E\frac{d^3\sigma}{d^3p} = \{\exp(-bp_t) + \frac{c}{(1+p_t^2/m_c^2)^\nu}\} \times\{g_{dd}dd + g_{pp}pp + g_{ff}ff + g_{dp}(dp+pd) + g_{df}(df+fd) + g_{pf}(pf+fp)\}$$

where, for example,

$$dd = \frac{(y_0-y)(y_0+y)}{[1+p_t/p_0]^{\nu_{dd}}}$$

Other terms are parametrized in a similar form.

We ignore odd contributions at these energies to reduce number of parameters

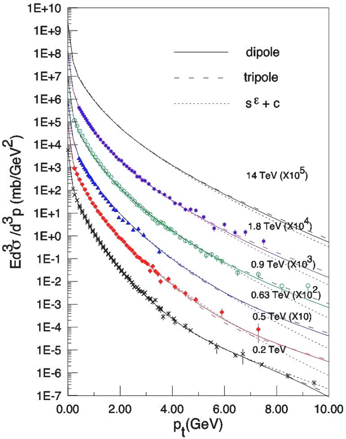
The data on

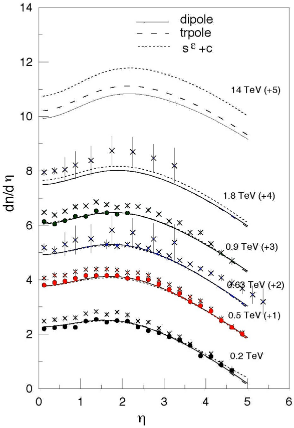
$$\frac{dn}{d\eta} \equiv \frac{1}{\sigma_{in}} \frac{d\sigma_{in}}{d\eta}$$

at $\sqrt{s} = 0.2, 0.5, 0.9$ TeV were used for fitting.
We write

$$\frac{dn}{d\eta} = \frac{2\pi}{\sigma_{in}} \int\limits_0^{p_{t,max}} \frac{p_t dp_t}{\sqrt{1 + (m_0/p_t ch(\eta))^2}} \frac{d^2\sigma_{in}}{dy dp_t}$$

Description of the data





$$\bullet - \quad \frac{dn}{d\eta} = \frac{1}{\sigma_{in}} \frac{d\sigma_{in}}{d\eta}, \qquad \times - \quad \frac{dn}{d\eta} = \frac{1}{\sigma_{nsd}} \frac{d\sigma_{nsd}}{d\eta}$$

Summary

- Unitarized pomeron models well describe the high-energy data on one-particle cross sections
- Small difference in predictions for LHC energy

- Outlook
  - More observables in a wider energy region
  - 3P-diagrams must be considered
  - Extension the model for *hA* and *AA* collisions