The Current Stage of Understanding and Description of Hadronic Elastic Diffraction

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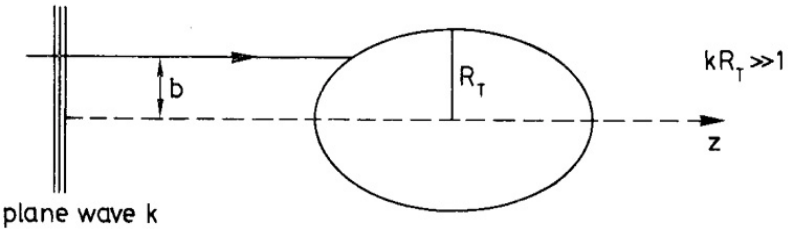
The Transverse Size of the Hadron Interaction Region

$$R_T \sim \Delta x_T \geq \frac{1}{\sqrt{- < t >}}$$



Scattering Amplitude, Born Term ("Eikonal") and Regge Trajectories

$$T_{12\to12}(s,t) = 4\pi s\int_0^\infty db^2 J_0(b\sqrt{-t})\frac{e^{2i\delta_{12\to12}(s,b)}-1}{2i}\,,$$

$$\delta_{12\to12}(s,b) = \frac{1}{16\pi s}\int_0^\infty d(-t)J_0(b\sqrt{-t})\delta_{12\to12}(s,t) =$$

$$= \frac{1}{16\pi s}\int_0^\infty d(-t)J_0(b\sqrt{-t})\times$$

$$\times\left\{\sum_n\left(i+\mathrm{tg}\frac{\pi(\alpha_n^+(t)-1)}{2}\right)\Gamma_n^{(1)+}(t)\Gamma_n^{(2)+}(t)s^{\alpha_n^+(t)}\mp\right.$$

$$\left.\mp\sum_n\left(i-\mathrm{ctg}\frac{\pi(\alpha_n^-(t)-1)}{2}\right)\Gamma_n^{(1)-}(t)\Gamma_n^{(2)-}(t)s^{\alpha_n^-(t)}\right\}\,.$$

Regge Trajectories and QCD. The BFKL Approach

J. Kwiecinski, Phys. Rev. D **26** (1982) 3293:

$$\alpha_{\bar{q}q}(t) = \sqrt{\frac{8}{3\pi}\alpha_s(\sqrt{-t})} + o(\alpha_s^{1/2}(\sqrt{-t}))$$

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

$$\alpha_{gg}(t) = 1 + \frac{12\ln 2}{\pi}\alpha_s(\sqrt{-t}) + o(\alpha_s(\sqrt{-t}))$$

V.S. Fadin and L.N. Lipatov, Phys. Lett. B **429** (1998) 127,
M. Ciafaloni and G. Camici, Phys. Lett. B **430** (1998) 349:

$$\alpha_{gg}(0) = 1 + \frac{12\ln 2}{\pi}\alpha_s(\mu)\left(1 - \frac{20}{\pi}\alpha_s(\mu)\right) + o(\alpha_s^2(\mu))$$

Regge Trajectories and QCD. The Lovelace Approach

C. Lovelace, Nucl. Phys. B **95** (1975) 12:

$$(\alpha_{\phi\phi}^{(k)}(0)+1)(\alpha_{\phi\phi}^{(k)}(0)+2)(\alpha_{\phi\phi}^{(k)}(0)+3)=\frac{16}{3(2k+1)}$$

D. Heckathorn, Phys. Rev. D **18** (1978) 1286:

$$\alpha_{gg}^{(k)}(0)(\alpha_{gg}^{(k)}(0)+1)(\alpha_{gg}^{(k)}(0)+2)=\frac{24N_c}{(2k+1)(11N_c-2n_f)}$$

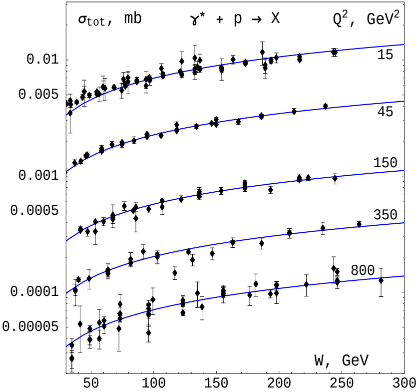
A. Godizov, Phys. Rev. D **81** (2010) 065009:

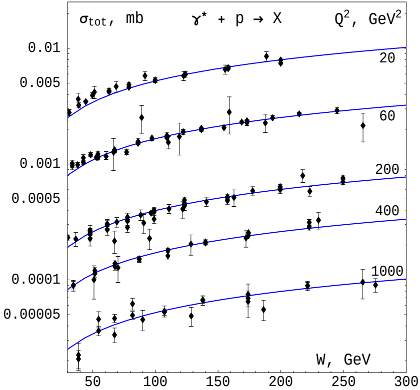
$$\alpha_{\bar{q}q}^{(k)}(0)=\frac{9(N_c^2-1)}{(2k+1)N_c(11N_c-2n_f)}-1$$

Extraction of the Pomeron Intercept from the DIS Data

There exists a wide kinematical range where the $\gamma^* p$ total cross-sections can be well-described by formula ($W_0 \equiv 1$ GeV)

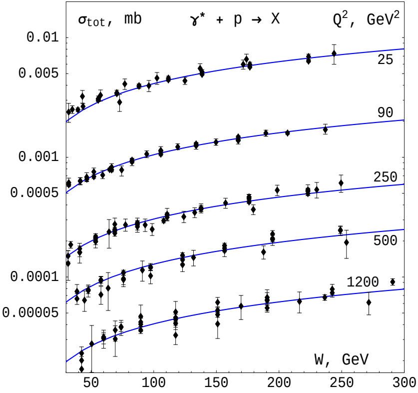
$$\sigma_{tot}^{\gamma^* p}(W^2, Q^2) \approx \beta(Q^2) \left(\frac{W}{W_0}\right)^{2\delta}$$

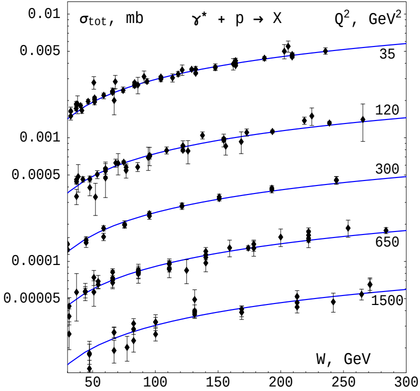




This universal parameter can be associated with the intercept of the pomeron trajectory:

$$\delta = \alpha_{\mathrm{P}}(0) - 1$$





Extraction of the Pomeron Intercept from the DIS Data

$$N_{DOF} = 548, \quad \frac{\chi^2_{min}}{N_{DOF}} = 0.991, \quad \delta = 0.3041^{+0.0552}_{-0.0542} \; \left(\Delta\left[\frac{\chi^2}{N_{DOF}}\right] = 1\right)$$

Set of data	$\beta_{min}(Q^2)$, mb	Number of points	χ^2_{min}
$Q^2 = 25$ GeV^2, $W > 50$ GeV	0.0002509	24	26.9
$Q^2 = 35$ GeV^2, $W > 50$ GeV	0.0001799	38	40.0
$Q^2 = 45$ GeV^2, $W > 50$ GeV	0.0001376	25	23.5
$Q^2 = 60$ GeV^2, $W > 50$ GeV	0.0001006	33	20.8
$Q^2 = 90$ GeV^2, $W > 40$ GeV	0.00006384	29	16.7
$Q^2 = 120$ GeV^2, $W > 40$ GeV	0.00004522	36	37.9
$Q^2 = 150$ GeV^2, $W > 30$ GeV	0.00003485	32	22.1
$Q^2 = 200$ GeV^2, $W > 30$ GeV	0.00002408	44	47.6
$Q^2 = 250$ GeV^2, $W > 30$ GeV	0.00001853	46	37.2
$Q^2 = 300$ GeV^2, $W > 30$ GeV	0.0000151	18	13.0
$Q^2 = 350$ GeV^2, $W > 30$ GeV	0.00001233	22	22.1
$Q^2 = 400$ GeV^2, $W > 30$ GeV	0.00001041	22	14.2
$Q^2 = 500$ GeV^2, $W > 30$ GeV	0.000007773	30	31.4
$Q^2 = 650$ GeV^2, $W > 30$ GeV	0.000005539	41	40.6
$Q^2 = 800$ GeV^2, $W > 30$ GeV	0.000004295	43	55.4
$Q^2 = 1000$ GeV^2, $W > \sqrt{Q^2}$	0.000003167	22	28.2
$Q^2 = 1200$ GeV^2, $W > \sqrt{Q^2}$	0.000002467	35	36.4
$Q^2 = 1500$ GeV^2, $W > \sqrt{Q^2}$	0.000001849	27	29.0

Reggeon Models

Single-reggeon exchanges + eikonalization:

C. Bourrely, J. Soffer, and T.T. Wu, Eur. Phys. J. C **28** (2003) 97

V.A. Petrov and A.V. Prokudin, Eur. Phys. J. C **23** (2002) 135
A. Godizov, Phys. Lett. B **703** (2011) 331

Models without eikonalization:

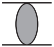
P. Desgrolard, M. Giffon, and L.L. Jenkovszky, Z. Phys. C **55** (1992) 637
P. Desgrolard, M. Giffon, and E. Martynov, Eur. Phys. J. C **18** (2000) 359
E. Martynov, Phys. Rev. D **76** (2007) 074030
L.L. Jenkovszky, A.I. Lengyel, and D.I. Lontkovskyi,
Int. J. Mod. Phys. A **26** (2011) 4755

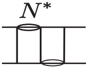
R.F. Avila, P. Gauron, and B. Nicolescu, Eur. Phys. J. C **49** (2007) 581
E. Martynov and B. Nicolescu, Eur. Phys. J. C **56** (2008) 57

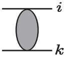
Models Using Reggeon Field Theory

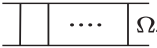
E. Gotsman, E. Levin, U. Maor, Eur. Phys. J. C **71** (2011) 1553
M.G. Ryskin, A.D. Martin, V.A. Khoze, Eur. Phys. J. C **71** (2011) 1617
S. Ostapchenko, Phys. Rev. D **83** (2011) 014018

(a) Elastic amplitude

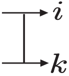
$\mathrm{Im}\, A_{\mathrm{el}} =$  $= 1 - e^{-\Omega/2} = \sum_{n=1}^{\infty}$  $\Omega/2$

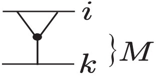
(b) Inclusion of low-mass dissociation 

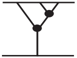
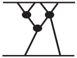
$\mathrm{Im}\, A_{ik} =$ 

$= 1 - e^{-\Omega_{ik}/2} = \sum$  $\Omega_{ik}/2$

(c) Inclusion of high-mass dissociation

$\Omega_{ik} =$ 

$+$ 

$+$  $+ \ldots$  $+ \ldots$

Non-Reggeon Models

Models not appealing to QCD:

R.F. Avila, S.D. Campos, M.J. Menon, and J. Montanha,
Eur. Phys. J. C **47** (2006) 171

P. Brogueira and J. Dias de Deus, J. Phys. J **37** (2010) 075006

"QCD-inspired" models:

M.M. Islam, R.J. Luddy, and A.V. Prokudin,
Int. J. Mod. Phys. A **21** (2006) 1

C. Flensburg, G. Gustafson, and L. Lönnblad,
Eur. Phys. J. C **60** (2009) 233

M.M. Block and F. Halzen, Phys. Rev. D **83** (2011) 077901

Models vs. TOTEM. The *pp* Total Cross-Section

The TOTEM Collaboration, Europhys. Lett. 96 (2011) 21002:

$$\sigma_{tot}^{pp}(7\ TeV) = (98.3 \pm 0.2^{stat} \pm 2.8^{syst})\ mb$$

The Model	$\sigma_{tot}^{pp}(7\ TeV)$, mb
P. Desgrolard, M. Giffon, L.L. Jenkovszky, Z. Phys. C **55** (1992) 637	87 $(6\ TeV)$
A. Donnachie, P.V. Landshoff, Phys. Lett. B **296** (1992) 227	91
P. Desgrolard, M. Giffon, E. Martynov, Eur. Phys. J. C **18** (2000) 359	95
V.A. Petrov, A.V. Prokudin, Eur. Phys. J. C **23** (2002) 135	97 ± 4
C. Bourrely, J. Soffer, T.T. Wu, Eur. Phys. J. C **28** (2003) 97	93
R.F. Avila, S.D. Campos, M.J. Menon, J. Montanha, Eur. Phys. J. C **47** (2006) 171	94
M.M. Islam, R.J. Luddy, A.V. Prokudin, Int. J. Mod. Phys. A **21** (2006) 1	97.5
E. Martynov, Phys. Rev. D **76** (2007) 074030	91
R.F. Avila, P. Gauron, B. Nicolescu, Eur. Phys. J. C **49** (2007) 581	108

Models vs. TOTEM. The *pp* Total Cross-Section

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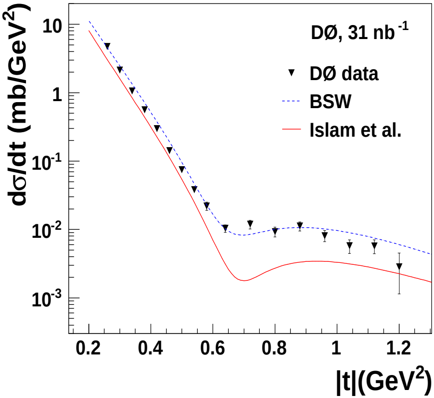
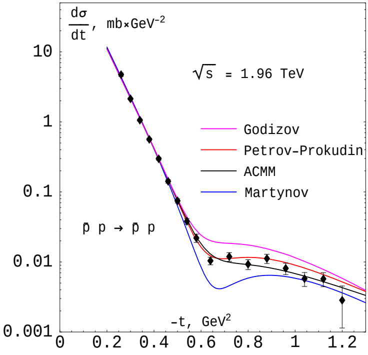
The Model	$\sigma_{tot}^{pp}(7\ TeV)$, mb
E. Martynov, B. Nicolescu, Eur. Phys. J. C **56** (2008) 57	95
C. Flensburg, G. Gustafson, L. Lönnblad, Eur. Phys. J. C **60** (2009) 233	98 ± 9
P. Brogueira, J. Dias de Deus, J. Phys. J **37** (2010) 075006	110
M.M. Block, F. Halzen, Phys. Rev. D **83** (2011) 077901	95.5 ± 1
L.L. Jenkovszky, A.I. Lengyel, D.I. Lontkovskyi, Int. J. Mod. Phys. A **26** (2011) 4755	98 ± 1
E. Gotsman, E. Levin, U. Maor, Eur. Phys. J. C **71** (2011) 1553	91
M.G. Ryskin, A.D. Martin, V.A. Khoze, Eur. Phys. J. C **71** (2011) 1617	89
S. Ostapchenko, Phys. Rev. D **83** (2011) 014018	93
A. Godizov, Phys. Lett. B **703** (2011) 331	110

Models vs. D0. The $\bar{p}p$ Differential Cross-Section

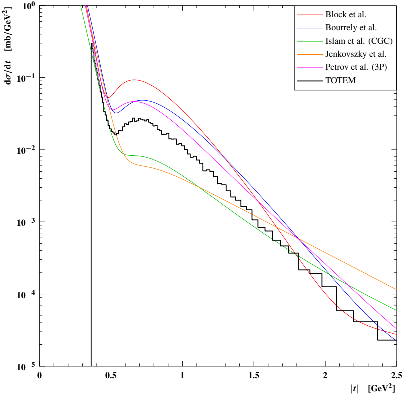
The D0 Collaboration, arXiv: 1206.0687 [hep-ex]

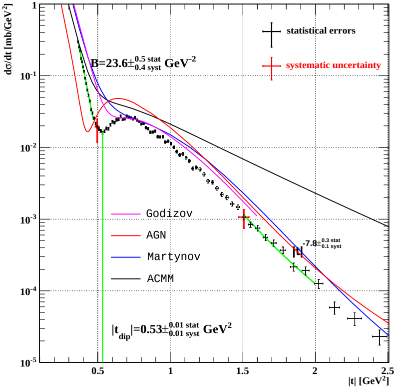




Models vs. TOTEM. The *pp* Differential Cross-Section

The TOTEM Collaboration, Europhys. Lett. 95 (2011) 41001





The Most Recent Papers on Elastic Diffractive Scattering

V. Uzhinsky and A. Galoyan, arXiv: 1111.4984 [hep-ph]
A. Donnachie and P.V. Landshoff, arXiv: 1112.2485 [hep-ph]
T. Wibig, J. Phys. G **39** (2012) 085003
C. Merino and Yu.M. Shabelski, JHEP **1205** (2012) 013
M.G. Ryskin, A.D. Martin, and V.A. Khoze, Eur. Phys. J. C **72** (2012) 1937
O.V. Selyugin, Eur. Phys. J. C **72** (2012) 2073
D.A. Fagundes, E.G.S. Luna, M.J. Menon, and A.A. Natale, Nucl. Phys. A **886** (2012) 48
I.M. Dremin and V.A. Nechitailo, Phys. Rev. D **85** (2012) 074009
A. Grau, S. Pacetti, G. Pancheri, and Y.N. Srivastava, Phys. Lett. B **714** (2012) 70
C. Bourrely, J.M. Myers, J. Soffer, and T.T. Wu, Phys. Rev. D **85** (2012) 096009
F. Nemes and T. Csörgő, arXiv: 1204.5617 [hep-ph]
D.A. Fagundes, M.J. Menon, and P.V.R.G. Silva, arXiv: 1204.5646 [hep-ph]
A.I. Lengyel and Z.Z. Tarics, arXiv: 1206.5837 [hep-ph]
E. Gotsman, E. Levin, and U. Maor, arXiv: 1208.0898 [hep-ph]
B.Z. Kopeliovich, I.K. Potashnikova, and B. Povh, arXiv: 1208.5446 [hep-ph]

Conclusion

We need deeper interrelation of phenomenological models with QCD. This requires developing powerful non-perturbative QCD techniques which should allow to deal with diffractive (large distance) domain of strong interaction.

Conclusion

First of all, we need development of some techniques for calculation of Regge trajectories in the non-perturbative domain of QCD.

Thank You for Attention!

The DIS Data are Taken from

http://durpdg.dur.ac.uk/hepdata/online/f2/structindex.html

H1 Collaboration (I. Abt *et al.*), Nucl.Phys. B **407** (1993) 515
ZEUS Collaboration (M. Derrick *et al.*), Phys.Lett. B **316** (1993) 412
H1 Collaboration (T. Ahmed *et al.*), Nucl.Phys. B **439** (1995) 471
ZEUS Collaboration (M. Derrick *et al.*.), Z.Phys. C **65** (1995) 379
ZEUS Collaboration (M. Derrick *et al.*), Z.Phys. C **69** (1995) 607
H1 Collaboration (S. Aid *et al.*), Nucl.Phys. B **470** (1996) 3
ZEUS Collaboration (M. Derrick *et al.*), Z.Phys. C **72** (1996) 399
ZEUS Collaboration (J. Breitweg *et al.*), Eur.Phys.J. C **7** (1999) 609
H1 Collaboration (C. Adloff *et al.*), Eur.Phys.J. C **13** (2000) 609
H1 Collaboration (C. Adloff *et al.*), Eur.Phys.J. C **19** (2001) 269
H1 Collaboration (C. Adloff *et al.*), Eur.Phys.J. C **21** (2001) 33
ZEUS Collaboration (S. Chekanov *et al.*), Eur.Phys.J. C **21** (2001) 443