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Elastic proton-proton scattering at 13 TeV in the theoretical perspective

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KNOWLEDGE MADE USEFUL

arXiv:1712.00325

Elastic proton-proton scattering at 13 TeV

Abstract

The predictions of a model which was tuned in 2013 to describe the elastic and diffractive *pp*- and/or $p\bar{p}$-data at collider energies up to 7 TeV are compared with the new 13 TeV TOTEM results. The possibility of an odd-signature Odderon exchange contribution is discussed.

Work still in progress

Jan's talk at $\sqrt{s}=13$ TeV of the pp total cross section $\sigma_{\rm tot} = 110.6 \pm 3.4$ mb and of the ratio of the real-to-imaginary parts of the forward pp-amplitude[1], $\rho \equiv {\rm Re}A/{\rm Im}A = 0.10 \pm 0.01$ [1]. These striking 13 TeV data (in particular the indication of the possible strong decrease of ρ with increasing collider energy) were advocated as a definitive confirmation of the experimental discovery of the Odderon in its maximal form. **MO**

[1]The value $\rho = 0.10 \pm 0.01$ is obtained from data in the interval $|t| < 0.15$ GeV^2. If data are used in a more restricted interval $|t| < 0.07$ GeV^2 (corresponding to the $|t|$ range of the UA4/2 data [2]) then $\rho = 0.09 \pm 0.01$

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Abstract

The present study shows that, beyond any doubt, the new TOTEM datum $\rho^{pp} = 0.098 \pm 0.01$ can be considered as the first experimental discovery of the Odderon, namely in its maximal form.

- Long-awaited Odderon would be very welcome news for the theoretical community

- our main aim is to try to evaluate whether the new TOTEM data could be accommodated within the existing ‘conventional’ multi-Pomeron framework

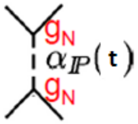
- exemplified by the untuned KMR 2013-model

V.A. Khoze, A.D. Martin, M.G. Ryskin, Eur. Phys. J. **C74** (2014) 2756 [arXiv:1312.3851].

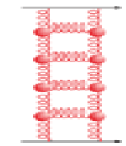
V.A. Khoze, A.D. Martin, M.G. Ryskin, Int. J. Mod. Phys. **A30** (2015) 1542004

QCD

(KMR, 2011-2014)



(Gribov-1961)



(BFKL-1975-78)

Yes, it is possible to describe all "soft" HE data

σ_{tot}, $d\sigma_{el}/dt$, $\sigma_{low\ M}$, (+ $\sigma_{high\ M}$)

from CERN-ISR → Tevatron → LHC

in terms of a single "effective" pomeron

Energy dep. of σ_{el}, σ_{tot} controlled by intercept and slope of "effective" pomeron trajectory

Diffractive dip and $\sigma_{low\ M}$ controlled by properties of GW eigenstates

High-mass diss^n driven by multi-pomeron effects

BFKL Pomeron naturally allows to continue from the 'hard' domain to the 'soft' region: after resummation of the main HO effects- the intercept weakly depends on the scale,

$$\Delta \equiv \alpha_P(0) - 1 \sim 0.3$$

- Low-mass dissociation is a consequence of the internal structure of proton. A constituent can scatter & destroy coherence of $|p\rangle$

Good-Walker: $|p\rangle = \Sigma a_i |\varphi_i\rangle$ (1960)

where φ_i diagonalize T -- have only "elastic-type" scatt

- Usually GW eigenstates assumed independent of t & s
KMR (2013) parametrize form factor $F_i(t)$ for each $\varphi_{i=1,2}$

  - Allows for $B_{el} \sim 10\ \mathrm{GeV}^{-2}$ at CERN-ISR
    $B_{el} \sim 20\ \mathrm{GeV}^{-2}$ at LHC (7 TeV)
    as well as diff^{ve} dip

- abs. corr^{ns} between intermediate parton-parton inter^{ns}
$\sigma_{abs} \sim 1/k_t^2$, suppress low k_t → mean k_t increases with s

$$k_{min}^2 \sim s^{0.28}$$

(enhanced multi-pom effects introduce dynamical infrared cutoff)

✶ Conventional RFT assumed all k_t limited and small.

KMR MODEL

$$g_i = \gamma_i \sqrt{\sigma_0} F_i(t)$$

Two-channel eikonal
effective (renormalized) Pomeron $\alpha(0) = 0.12$
slope of trajectory $\alpha'_P = 0.05\ \mathrm{GeV}^2$

Each Good-Walker eigenstate has formfactor
$F_i(t) \simeq \exp(-b_i\sqrt{t})$ (*Orear-like*)

and the coupling

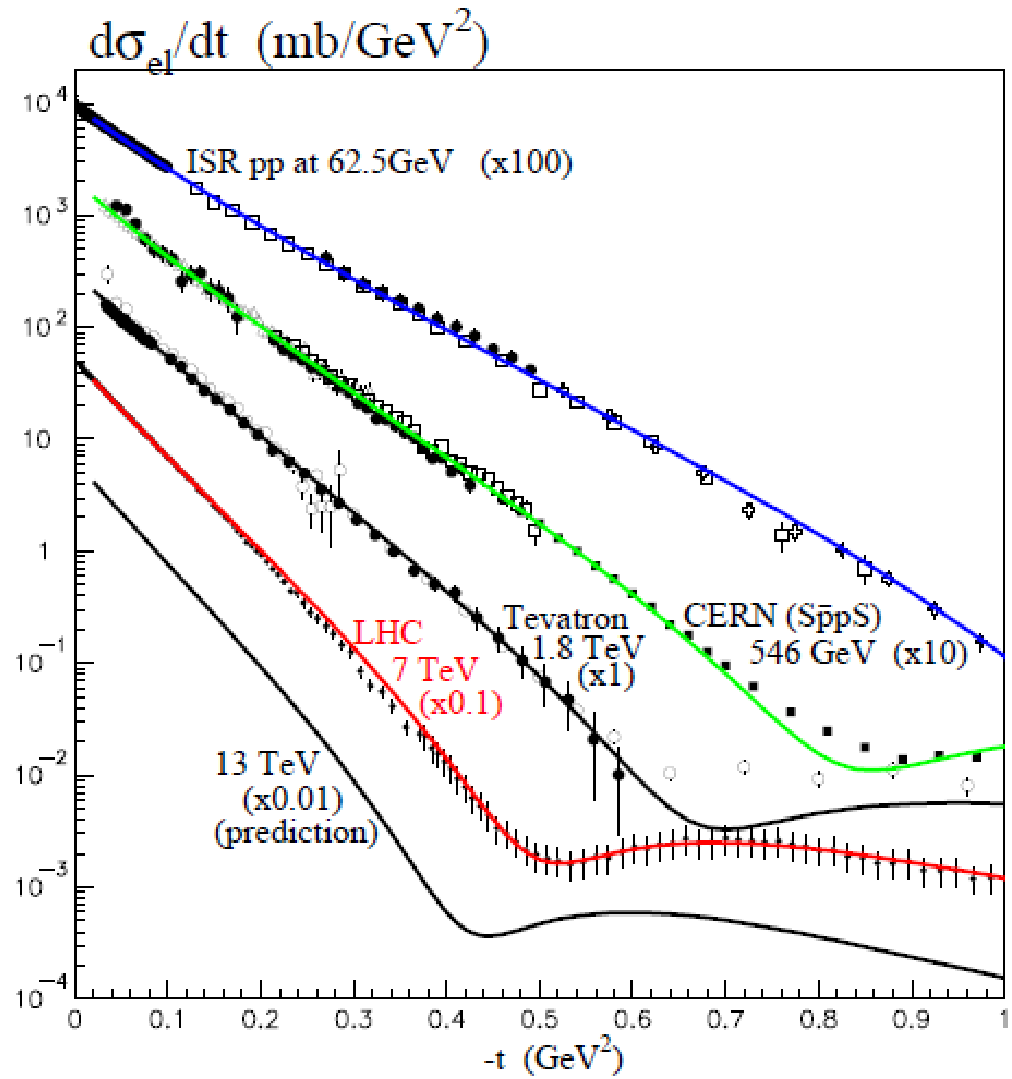
$$\gamma_i \propto N_i * k_P^2/(k_P^2 + k_i^2)$$

$k_P^2 = k_0^2 \cdot s^{0.28}$ $(\sigma \sim \alpha_s^2 \cdot r^2 \sim 1/k^2)$
(at $\sqrt{s} = 1800$ GeV we have $k_P/k_1 = 0.35$ and $k_P/k_2 = 0.17$)

Triple pomeron coupling $g_{3P} = \lambda g_N$, $\lambda \propto \frac{1}{k_t^2}$

The size of the effective Pomeron deceases with energy (screening effects)

Introduction of the theoretically motivated energy dependence of k_t within the 2-channel eikonal model allows to describe the existing HE data on the elastic $d\sigma/dt$ and SD $d\sigma/dM^2$ cross sections, including σ^{SD}_{lowM} .



Untuned 2013 predictions

Looking forward to seeing TOTEM 13 TeV results

Figure 1: The dependence of the pp (or $p\bar{p}$) elastic cross section on the momentum transferred square t compared with the present data (see [8] for the references), and the prediction for $\sqrt{s} = 13$ TeV.

$\sqrt{s}$ (TeV)	ρ	σ_{tot} (mb)	σ_{el} (mb)	$B_{el}(0)$ (GeV^{-2})	$B_{el}(\|t\| = 0.05 - 0.15 GeV^2)$ (GeV^{-2})
0.546	0.128	62.5	12.8	14.7	14.9
1.8	0.123	77.1	17.4	16.8	16.7
2.76	0.121	83.2	19.5	17.6	17.5
7.	0.117	98.8	24.9	19.7	19.4
8.	0.116	101.3	25.8	20.1	19.7
13.	**0.113**	**111.2**	**29.5**	**21.4**	**21.0**
100.	0.102	166.2	51.5	29.4	29.8

Table 1: The values of the observables given by the model

V.A. Khoze, A.D. Martin, M.G. Ryskin, Eur. Phys. J. C74 (2014) 2756 [arXiv:1312.3851].

First measurement of σ_{tot}, σ_{inel} & σ_{el} @ 13 TeV:

σ_{tot} = 110.6 ± 3.4 mb, σ_{inel} = 79.5 ± 1.8 mb, σ_{el} = 31.0 ± 1.7 mb

ρ = 0.10 ± 0.01 & ρ = 0.09 ± 0.01 (full & UA4 equivalent |t| range)

B = 20.36 ± 0.19 GeV^{-2}

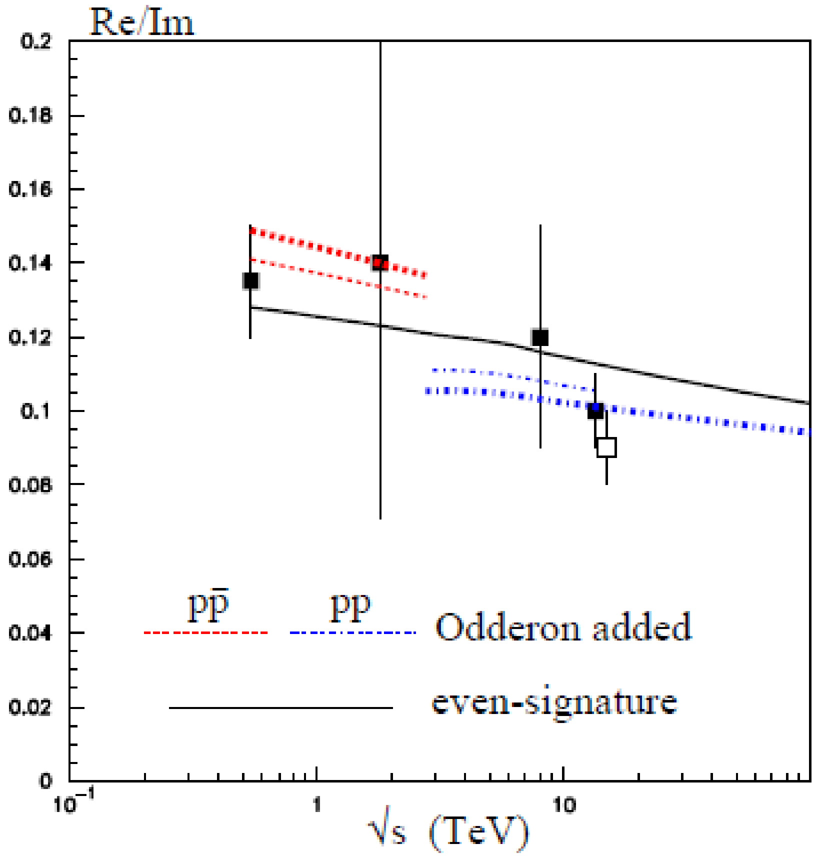


Figure 2: The energy dependence of the ρ =ReA/ImA ratio. The data are taken from [2, 18, 19, 1]; the first two data points correspond to $p\bar{p}$ scattering and the last points to pp scattering. At 13 TeV we show also by the open square the value of ρ obtained under the same conditions as that used by UA4/2 group (see footnote 1). The values of ρ given by the model [7] are shown by the solid curve. The dashed curves include a *possible* QCD Odderon contribution calculated as described in the text.

Model for Odderon: M.G. Ryskin, Sov. J. Nucl. Phys. 46 (1987) 337.

Preliminary conclusions

- Within 1σ level an overall agreement with UA4 (2) and TOTEM data in all cases

  $\Delta\rho$=0.005-0.02

- It would be very interesting to compare the 13 TeV predictions of our model (which does not contain the Odderon) with the new $d\sigma_{\rm el}/dt$ data, especially in the dip region where the imaginary part of the even-signature amplitude vanishes and the Odderon contribution should be most visible.

- Upon releasing the new TOTEM data 13 TeV on elastic cross section we plan to check whether the Odderon is providing better description

- The data at 541 GeV strongly restrict the Odderon contribution.

- More work needed (many sides, many sides )

ODDERON-1973 –asymptotic theorems

L. Lukazsuk, B. Nicolescu, Lett. Nuovo Cim. 8 (1973) 405

1975 D. Joynson, E. Leader, B. Nicolescu and C. Lopez, Nuovo Cim. A 30 (1975) 345

MO $$F_{-}^{MO}(z) = (s-2m^2)[O_1 \ln^2(-iz) + O_2 \ln(-iz) + O_3]$$

z= $(s - 2m^2)/2m^2.$

QCD J. Bartels, Nucl. Phys. B 175 (1980) 36; J. Kwiecinski and M. Praszalowicz, Phys. Lett. B 94 (1980) 413
J. Bartels, L. N. Lipatov and G. P. Vacca, Phys. Lett. B, 477 (2000) 178

Very intensive theoretical discussions :

reviews M. A. Braun, [hep-ph/9805394].

C. Ewerz, [hep-ph/0306137]; [hep-ph/0511196].

Recall:The Froissart-Martin **bound** $\sigma_{tot} \leq \text{Const} \ln^2 s.$

most models asympt.~ $\ln^2 s.$
but not a Must

Some comments on **MO**

- This procedure evidently preserves the relation between the real and imaginary partys of the amplitude and so does not formally violate the analitycity properties. However it does not look too consistent. M. Braun, hep-ph/9805394

- In CGC models the odderon contribution is decreasing with energy due to saturation effects

S. Jeon and R. Venugopalan, Phys. Rev. D 71, 125003 (2005) hep-ph/0503219
Y. V. Kovchegov, L. Szymanowski, and S. Wallon, Phys. Lett. B 586, 267 (2004) hep-ph/0309281

- Problems with the multiparticle s-channel unitarity – KMR work in progress


THANK
YOU