Soft interaction model and the LHC data.

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Abstract: Most models for soft interactions which were proposed prior to the measurements at the LHC, are only marginally compatible with LHC data, our GLM model has the same deficiency. In this paper we investigate possible causes of the problem, by considering separate fits to the high energy ($W > 500\,\text{GeV}$), and low energy ($W < 500\,\text{GeV}$) data. Our new results are moderately higher than our previous predictions. Our results for total and elastic cross sections are systematically lower than the recent Totem and Alice published values, while our results for the inelastic and forward slope agree with the data. If with additional experimental data, the errors are reduced, while the central cross section values remain unchanged, we will need to reconsider the physics on which our model is built.

Keywords: Soft Pomeron, BFKL Pomeron, Diffractive Cross Sections, N=4 SYM

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1. Introduction

The new LHC data on soft interaction scattering at high energy (see Refs. [1–4]) is only marginally compatible with updated Pomeron models [5–8], which have been successful in reproducing the cross section data in the lower energy range. The implication is that, as it stands, our understanding of long distance physics at very high energies is limited. From an optimistic point of view this may imply no more than the need to adjust the Pomeron model’s parameters. From a pessimistic point of view, this may suggest the need for a comprehensive revision of the main ingredients of Pomeron models applied to high energy soft interactions.

Specifically, the model we propose [5] is built using an input Pomeron with a relatively large fitted intercept $\Delta_P = \alpha_P - 1 = 0.2$ and exceedingly small slope $\alpha'_P = 0.02 \text{GeV}^{-2}$. These values are in accord with AdS-CFT correspondence [9–13]. Note that in N=4 SYM [9], $\Delta_F = 1 - 2/\sqrt{\lambda} \approx 0.1 - 0.3$, corresponding to experimental estimates based on multiparticle production, as well as HERA DIS data [14] in which $\lambda \approx 5 - 9$. The other basic ingredients of our model are the large Good-Walker(GW) [15] contribution to diffraction production, and a small Pomeron self interaction. Both are direct consequences of the AdS-CFT correspondence.

If the present central values of the LHC cross section data points, which have relatively large errors, do not change significantly with the forthcoming, better statistics, measurements. This would suggest either of two extreme options: 1) The new LHC data do not support the main theoretical concepts of our model. This may stem from our reliance on Reggeon calculus and pQCD, which led to a single Pomeron model, rather than the traditional...
distinction between a soft and a pQCD hard Pomeron, and/or from our realization of AdS-CFT N=4 SYM ideas.

2) Our procedure for adjusting parameters may be deficient, requiring a more sophisticated data analysis which may yield satisfactory results. We note that the fitted data base [5] contains no LHC data. Moreover, the low energy \((W < 500 GeV)\) total, elastic and diffractive cross sections which constitute the major portion of the fitted data points have rather small errors. Consequently, our fitting procedure is not well balanced as the main contribution to our \(\chi^2/d.o.f.\) stems from the low energy data.

An alternate, and probably a more realistic option would be based on elements originating from the above two propositions.

In this paper we check the second option. To this end we removed the low energy data and only fitted the high energy data \((W > 500 GeV)\), including the available LHC soft cross section data points, so as to determine the Pomeron parameters. Having adjusted these parameters, we tuned the value of the Reggeon-proton vertex, which enabled us to obtain a smooth cross section behaviour through the ISR-LHC energy range. We hope that this exercise will clarify to what extent our model has intrinsic deficiencies, or do we just have a technical problem in the procedure for adjusting our free parameters.

The results of this paper can be summarized as follows: First, we show that in spite of the fact that the values of the parameters, extracted from our current fitting, are different from our previous values, the overall picture remains unchanged. Second, our updated total and elastic cross sections are slightly lower than the published TOTEM values [4], but still within the relatively large experimental error bars. Should future LHC measurements confirm the present TOTEM values, we will need to revise our dynamic picture for soft scattering.

2. Our Model

The ingredients and formulae of our model have been published (see Ref. [5]). However, in order to produce a self contained presentation, we start with a brief overview of our formalism.

As we have mentioned, one of our main input assumptions is the GW mechanism [15], which plays a significant role in the calculation of the eikonal shadowing corrections. To this end we took into account a two channel formalism in which we introduced two eigen wave functions, \(\psi_1\) and \(\psi_2\), which diagonalize the 2x2 interaction matrix \(T\),

\[
A_{i,k} = <\psi_i | T | \psi_k> = A_{i,k} \delta_{i,i'} \delta_{k,k'}.
\]  

(2.1)

In this representation the two observed states are an hadron (a nucleon in our calculations), denoted by the wave function \(\psi_h\), and a diffractive state \(\psi_D\). Note that, we replaced the rich population of the diffractive Fock states by a single state with unknown mass. This representation provides a considerable simplification of our calculations at the price of not being able to calculate the mass dependence of GW diffraction production. The two observed states can be written in the form

\[
\psi_h = \alpha \psi_1 + \beta \psi_2, \quad \psi_D = -\beta \psi_1 + \alpha \psi_2,
\]  

(2.2)
where, $\alpha^2 + \beta^2 = 1$. Using Eq. (2.1), we can rewrite the s-channel unitarity constraints in the form

$$2 \text{Im} A_{i,k}(s,b) = |A_{i,k}(s,b)|^2 + G_{i,k}^{\text{in}}(s,b),$$

(2.3)

where, $G_{i,k}^{\text{in}}$ is the contribution of all non GW inelastic processes.

In a general solution of Eq. (2.3)

$$A_{i,k}(s,b) = i \left( 1 - \exp \left( -\frac{\Omega_{i,k}(s,b)}{2} \right) \right),$$

(2.4)

$$G_{i,k}^{\text{in}}(s,b) = 1 - \exp \left( -\Omega_{i,k}(s,b) \right),$$

(2.5)

in which $\Omega_{i,k}$ are arbitrary. In the eikonal approximation $\Omega_{i,k}$ are real and amplitude $A_{ik}$ are pure imaginary.

In general we have 4 $A_{i,k}$ amplitudes, however, for pp and $\bar{p}p$ $A_{1,2} = A_{2,1}$. From Eq. (2.5) we deduce that the probability that the initial state $(i,k)$ remains intact during the interaction, is $P_{i,k}^S = \exp \left( -\Omega_{i,k}(s,b) \right)$.

The input opacity $\Omega_{i,k}(s,b)$ corresponds to an exchange of a single bare Pomeron.

$$\Omega_{i,k}(s,b) = g_i(b) g_k(b) P(s).$$

(2.6)

$P(s) = s^\Delta$ and $g_i(b)$ is the Pomeron-hadron vertex parameterized in the form:

$$g_i(b) = g_i S_i(b) = \frac{g_i}{4\pi} m_i^3 b K_1 \left( m_i b \right).$$

(2.7)

$S_i(b)$ is the Fourier transform of $\frac{1}{(1+q^2/m_i^2)^2}$, where, $q$ is the transverse momentum carried by the Pomeron. In our calculations we assume that the slope of the Pomeron trajectory is $\alpha_P' = 0$. This is compatible with the exceedingly small fitted value of $\alpha_P'$, and in accordance with N=4 SYM [9].

In our model [5], the Pomeron’s Green function that includes all enhanced diagrams is approximated using the MPSI procedure [16], in which a multi Pomeron interaction (taking into account only triple Pomeron vertices) is approximated by large Pomeron loops of rapidity size of $\ln s$.

We obtain

$$G_P(Y) = 1 - \exp \left( \frac{1}{T(Y)} \right) \frac{1}{T(Y)} \Gamma \left( 0, \frac{1}{T(Y)} \right),$$

(2.8)

in which:

$$T(Y) = \gamma e^{\Delta P Y}.$$

(2.9)

$\Gamma \left( 0, 1/T \right)$ is the incomplete gamma function (see formulae 8.35 in Ref. [17]).

Summing the net diagrams [5], we replace $g_i(b)$ by a more complicated vertex function which, together with the enhanced diagrams, results in the following expression for $\Omega_{i,k}(s,b)$:

$$\Omega_{i,k}^{P}(Y; b) = \int d^2b' \frac{g_i \left( \vec{b}' \right) g_k \left( \vec{b} - \vec{b}' \right) \left( 1/\gamma G_P \left( T(Y) \right) \right)}{1 + \left( G_3^P/\gamma \right) G_P \left( T(Y) \right) \left[ g_i \left( \vec{b}' \right) + g_k \left( \vec{b} - \vec{b}' \right) \right]}.$$ 

(2.10)

*Actually, we sum the diagrams for the Pomeron interaction considering $\alpha_P' = 0$, but introduce $\alpha_P'$ for the Pomeron exchange. Since, the output of our fit gives a small value of $\alpha_P' \approx 0.02 \text{GeV}^{-2}$, we consider that this procedure is justified a posteriori.
$G_{3p}$ is the triple Pomeron vertex, and $\gamma^2 = \int \frac{d^2b}{s} G_{3p}^2$. Note we consider $\gamma$ as an independent parameter in our fit to the data.

For the elastic amplitude we have:

$$a_{el}(b) = (\alpha^4 A_{1,1} + 2\alpha^2 \beta^2 A_{1,2} + \beta^4 A_{2,2}).$$

(2.11)

For diffraction production we introduce an additional contribution due to the Pomeron enhanced mechanism which is non GW. For single diffraction we have (see Fig. 1a):

$$A_{i;k,l}^{sd} = \int d^2b' 2 \Delta \left( \frac{G_{3p}}{\gamma} \right) g_i (\vec{b} - \vec{b}', m_i) g_l (\vec{b}', m_l) g_k (\vec{b}', m_k)$$

$$\times Q \left( g_i, m_i, \vec{b} - \vec{b}', Y_m \right) Q \left( g_k, m_k, \vec{b}', Y - Y_m \right) Q \left( g_l, m_l, \vec{b}', Y - Y_m \right),$$

(2.12)

where,

$$Q \left( g, m, b; Y \right) = \frac{G_{p}(Y)}{1 + (G_{3p}/\gamma) g G_{p}(Y) S(b,m)}.$$

(2.13)

The structure of Eq. (2.12) can be understood from Fig. 1a. $Q (g, m, b; Y)$ describes the sum of the ‘fan’ Pomeron diagrams. As shown in Fig. 1a, we have one cut Pomeron in Fig. 1a, which we express through the Pomeron without a cut, using the AGK cutting rules [18].

For double diffraction we have (see Fig. 1b):

$$A_{i,k}^{dd} = \int d^2b' 4 g_i (\vec{b} - \vec{b}', m_i) g_k (\vec{b}', m_k)$$

$$\times Q \left( g_i, m_i, \vec{b} - \vec{b}', Y - Y_1 \right) e^{2\Delta \delta Y} Q \left( g_k, m_k, \vec{b}', Y_1 - \delta Y \right).$$

(2.14)

This equation is illustrated in Fig. 1b, which displays all ingredients of the equation. We express each of two cut Pomerons through the Pomeron without a cut, using the AGK cutting rules [18].

Eq. (2.12) and Eq. (2.14) are the simplifications of the exact formulae of Ref. [5], which correspond to the diagrams of Fig. 1. We checked that they approach the values of the exact formulae reasonably well, within 5 – 10%.

For single diffraction, $Y = \ln \left( M^2/s_0 \right)$, where, $M$ is the SD mass. For double diffraction, $Y - Y_1 = \ln \left( M_2^2/s_0 \right)$ and $Y_1 - \delta Y = \ln \left( M_2^2/s_0 \right)$, where $M_1$ and $M_2$ are the masses of two bunches of hadrons produced in double diffraction. $s_0$ is the minimal produced mass, which is about 1 GeV.

The integrated cross section of the SD channel is written as a sum of two terms: the GW term, which is equal to

$$\sigma_{sd}^{GW} = \int d^2b \left| \alpha \beta \{-\alpha^2 A_{1,1} + (\alpha^2 - \beta^2) A_{1,2} + \beta^2 A_{2,2} \} \right|^2.$$

(2.15)

$A_{i,k}$ are given by Eq. (2.4). The second term describes diffraction production due to non GW mechanism:

$$\sigma_{sd}^{NGW} = 2 \int dy_m \int d^2b$$

$$\left\{ \alpha^6 A_{1,1}^{sd} e^{-\Omega_{1,1}(Y;b)} + \alpha^2 \beta^4 A_{1,2}^{sd} e^{-\Omega_{1,2}(Y;b)} + 2 \alpha^4 \beta^2 A_{1,1}^{sd} e^{-\frac{1}{2}(\Omega_{1,1}(Y;b)+\Omega_{1,2}(Y;b))} + \beta^2 A_{2,1}^{sd} e^{-\Omega_{2,1}(Y;b)} + 2 \beta^4 \alpha^2 A_{2,2}^{sd} e^{-\frac{1}{2}(\Omega_{2,1}(Y;b)+\Omega_{2,2}(Y;b))} + \beta^6 A_{2,2}^{sd} e^{-\Omega_{2,2}(Y;b)} \right\}.$$

(2.16)
Figure 1: The set of the diagrams for single (Fig. 1-a) and double (Fig. 1-b) diffraction. The wave like lines denote Pomerons. The solid horizontal lines correspond to interacting hadrons. The vertical dashed line denotes the cut that corresponds to produced particles.

The cross section of the double diffractive production is also a sum of the GW contribution,

$$
\sigma_{GW}^{dd} = \int d^2b \alpha^2 \beta^2 |A_{1,1} - 2A_{1,2} + A_{2,2}|^2,
$$

(2.17)

to which we add the term which is determined by the non GW contribution,

$$
\sigma_{nGW}^{dd} = \int d^2b \left\{ \alpha^4 A_{1,1}^{dd} e^{-\Omega_{1,1}(Y;b)} + 2\alpha^2 \beta^2 A_{1,2}^{dd} e^{-\Omega_{1,2}(Y;b)} + \beta^4 A_{2,2}^{dd} e^{-\Omega_{2,2}(Y;b)} \right\}.
$$

(2.18)

In our model the GW sector can contribute to both low and high diffracted mass, as we do not know the value of the typical mass for this mechanism, on the other hand, the non GW sector contributes only to high mass diffraction.

3. Results

Using these formulae we fit the data with energies $W = \sqrt{s} > 500\, GeV$, including the LHC data. Our best set of parameters is presented in Table 1. In the same table we also show the values of the parameters that we obtained in our previous pre LHC fit, which included the data for ($W \leq 1800\, GeV$). Although, the two sets of parameters differ somewhat, the two key parameters, the Pomeron intercept $\Delta I_P$ and the slope of the Pomeron trajectory $\alpha'_I P$, remain almost the same.

The comparison with the LHC data at $W = 7\, TeV$ is shown in Table 2. Even though we are definitely below the data points for total and elastic cross sections [4], the corresponding large experimental error bars do not enable a definitive assessment of our predictions. Our predictions for $B_{el}$ and $c_{inel}$ are compatible with the TOTEM data. TOTEM’s $\sigma_{tot}$ depends on the value of $\rho = \text{Re} A / \text{Im} A$, where $\text{Re} A$ and $\text{Im} A$ are the real and imaginary parts of the scattering amplitude $A$, and on $d\sigma_{el}/dt(t = 0)$.

In our model we assume that Pomeron exchange leads to a pure imaginary amplitude. Since, we expect that the real part of the amplitude will be much smaller than the imaginary one, we can calculate the real part using a perturbative approach.
First, we notice that for one Pomeron exchange

\[ \text{Re} A_{\Phi}(s, b) = \tan \frac{\pi \Delta_{\Phi}}{2} \text{Im} A_{\Phi} \]  

Having Eq. (3.1) in mind we can calculate the real part of the scattering amplitude as follows

\[ \text{Re} A_{ik}(s, b) = \text{Re} \Omega_{ik}/2 \exp \left( -\frac{\Omega_{ik}(s, b)}{2} \right) \]  

We use Eq. (3.1) to calculate \( \text{Re} \Omega_{ik} \).

Our value of \( \rho \) is smaller than the COMPETE [23] value which was used by TOTEM. The COMPETE \( \rho \) fit is based on an extrapolation from data in the ISR-Tevatron range. The effect of our value of \( \rho \) being smaller than the COMPETE value, implies a change in \( \sigma_{\text{tot}} \) of less than 1%.

In Table 3 we present our results for \( \sigma_{\text{tot}}, \sigma_{\text{el}}, \sigma_{\text{sd}}, \sigma_{\text{dd}}, B_{\text{el}}, B_{\text{sd}} \) and \( \sigma_{\text{inel}} \). In parenthesis we put the values of these observables obtained from our previous fit. The new fit gives higher values for the single and double diffraction, while changes in all other observables are rather small. It is interesting to note that Block and Halzen [24] have “converted” [24] a recent measurement of the Pierre Auger Observatory collaboration of proton-air collisions with \( \sigma_{\text{pp}}^{\text{air}} \) at \( W = 57 \pm 6 \) TeV to \( \sigma_{\text{pp}} \) for proton-proton collisions, and obtain the value of \( \sigma_{\text{pp}}^{\text{air}} = 90 \pm 7(\text{stat}) \pm 1.5(\text{Glauber} + 9/11(\text{syst}) \text{mb and predict } \sigma_{\text{pp}}^{\text{tot}} = 134.8 \pm 1.5 \text{ mb at this energy.} \)

It is interesting to note that at \( W = 57 \) TeV, we have that the ratio \( \frac{\sigma_{\text{pp}}}{\sigma_{\text{tot}}} = 0.74 \), while Block and Halzen [24] have the value 0.69, both far from the black disc value of 0.5.

In Table 3 we show that we obtain the same value for the inelastic cross section, while for the total cross section we have 122 \text{ mb which is smaller than has been advocated in Ref. [24].}

In Fig. 2 we show our present fit in the energy range \( 20 \leq W \leq 1800 \text{ GeV} \) energy range. We see that the description is not as good as in our previous paper [5], nevertheless, our model describes the main features of low energy data as well.

In Fig. 3 we plot the amplitudes \( A_{ik} \) at different energies as a function of the impact parameter \( b \). The structure of the \( b \) and \( s \) dependence, remains essentially the same as in our previous descriptions.
we obtained high energy scattering from the experimental data. In particular, as we have discussed at $W = 57$ TeV, to apply the simple formulae that are valid for the black disc regime, for extracting information on the cross section of the diffraction production with this restriction. However, the amplitude $A_{11}$ turns out to be smaller than that obtained previously [5]. This amplitude does not reach the unitarity bound even at $W = 57$ TeV. Recall that the unitarity black disc bound at a given $(s, b)$ is only reached when $A_{11}(s, b) = A_{12}(s, b) = A_{22}(s, b) = 1$. As seen in Fig. 3 this condition has not yet been satisfied at $W = 57$ TeV. In some sense, our model gives an example of why it is dangerous to apply the simple formulae that are valid for the black disc regime, for extracting information on the high energy scattering from the experimental data. In particular, as we have discussed at $W = 57$ TeV, we obtained $\sigma_{tot} = 122 mb$ while $\sigma_{el} = 31 mb$ in clear violation of the relation $\sigma_{el} = \sigma_{tot}/2$ for a black disc.

The impact parameter dependence shown in Fig. 3 reflects in the $t$ dependence of the elastic cross section shown in Fig. 4. One can see that we are in agreement with the experimental results for both Tevatron and LHC energies in the forward cone for $-t \leq 0.5 GeV^{-2}$. In Fig. 4 we show our prediction for $W = 14 TeV$.

A significant check for our model will be the measurement of $t$-dependence for $d\sigma_{sd}/dt$. As shown in Table 3 we predict quite a small slope $B_{sd}$ for the Good-Walker contribution of the single diffractive production. For large mass diffraction due to triple Pomeron interaction we expect that the slope will be about $B_{el}/2$, since the slope for triple Pomeron vertex is rather small $\leq 1 GeV^{-2}$. For single diffraction we obtain a value of the slope $B_{sd} = 8.01 GeV^{-2}$, (at t =0), this is compatible with the preliminary result of

### Table 2: Comparison of the predictions of our model with the experimental data at $W= 7$ TeV.

| $\sqrt{s}$ TeV | $\sigma_{tot}$ mb | $\sigma_{el}$ mb | $\sigma_{sd}(M \leq M_0)$ mb | $\sigma_{sd}(M^2 < 0.05s) mb$ | $\sigma_{tot} GeV^{-2}$ | $B_{sd} GeV^{-2}$ | $\sigma_{ncl}$ mb |
|-----------------|------------------|------------------|-----------------------------|-----------------------------|------------------------|-----------------|---------------|
| 7.8             | 75.6 (74.4)      | 22.9             | 10.5 + (2.6) $nGW$ (10.2)   | 8.97 + (1.95)$nGW$ (8.87)   | 17.6 (16.1)            | 6.36            | 57.4          |
| 7.0             | 94.2 (91.3)      | 22.9             | 10.5 + (3.9) $nGW$ (10.8)   | 10.5 + (3.4) $nGW$ (10.2)   | 19.8 $nGW$            | 8.01            | 71.7          |
| 14              | 104.0 (101)      | 26.1 (26.1)      | 11.2 + (3.3) $nGW$ (10.8)   | 11.2 + (5.5) $nGW$ (10.8)   | 21.2 (20.5)           | 8.78            | 77.9          |
| 57              | 122.0            | 31.1             | 12.8 + (3.9) $nGW$ (10.8)   | 12.8 + (8.1) $nGW$ (10.8)   | 23.8                  | 10.4            | 90.9          |

### Table 3: Predictions of our model for different energies $W$. $M_0$ is taken to be equal to 200GeV as ALICE measured the cross section of the diffraction production with this restriction.
TOTEM as presented by Risto Orava [28].

As is well known, the survival probability for the large rapidity gap crucially depends on the $b$-dependence of the amplitude. To check our $b$-dependence as well as for completeness of our presentation, we calculate the survival probability $S^2$ for a large rapidity gap using the general formulae of Ref. [26]. We obtain

$$S^2 = 9.76\%(10\%) \text{ at } W = 1.8 TeV; \quad S^2 = 5.32\%(6.3\%) \text{ at } W = 7 TeV; \quad S^2 = 3.66\%(4.4\%) \text{ at } W = 14 TeV;$$

where we indicate in parentheses the values of the survival probability calculated in our previous paper [26]. Naively, we could expect that $S^2$ would be larger than in our previous model since the larger transparency of $A_{11}$ in this approach (see Fig. 3). From Fig. 3 we see that $A_{11}(b)$ in this model is smaller, and decreases faster than this amplitude in our previous model. Both these effects lead to an increase of the survival probability due to the Good-Walker mechanism. However, the considerable increase of the values for $G_{3F}$ and $\gamma$ lead to stronger screening, due to non Good-Walker mechanism, mostly due to contribution of the enhanced diagrams (see Refs. [5, 26]). The second effect that leads to the decrease of $S^2$, is the value of $\alpha$ in this model, which is smaller than in our previous approach. Recall that $\alpha^2 = 1 - \beta^2$, and $S^2 \propto \alpha^4$, since the contribution of $A_{12}$ and $A_{22}$ to the value of the survival probability is negligibly small due to large $\Omega_{12}$ and $\Omega_{22}$ at small $b$.

4. Conclusions

We are able to reproduce the LHC experimental data within the present experimental errors and uncertainties. Therefore, we found a positive answer to the question formulated in the introduction: our model without any changes except the new set of parameters is able to describe the LHC data with a good accuracy. It is instructive to note, that we did not spoil the reasonable description of the low energy data ($W \leq 500 GeV$) being the only model on the market that is able to describe all available data on high energy scattering.

We would like to stress that our predictions for $\sigma_{tot}$ and $\sigma_{el}$ are below those published by TOTEM [4], while our values for $\sigma_{inel}$ and $B_{el}$ are in agreement with the published experimental values. If the published errors will be reduced while the central values will remains approximately the same, our approach will need essential improvements and new ideas.

As one can see from Table 1 the changes in parameters are not dramatic but three parameters: $m_1, \gamma$ and $G_{3F}$, turns out to be two to three times larger that in our previous approach [5]. These changes are driven by the LHC data and they deserve a discussion. The increase in $\gamma$ and $G_{3F}$ is a direct consequence of the large diffractive cross section measured at the LHC. At first sight we could increase them even more to obtain a better description of the of the high mass diffraction production. Unfortunately, this is not true as the sum of enhanced and net diagrams depend strongly on the value of $\gamma$ and $G_{3F}$, leading to a resulting decrease of the diffractive cross sections at larger values of these parameters.

The most striking manifestation of larger value of $m_1$ we see in Fig. 3 which shows that at ultra high energy the amplitude $A_{11}(b = 0)$ is still less that unity. The slow increase to the unitarity limit in $A_{11}$
amplitude is a typical feature of our approach. However, the fact that this amplitude is less than 1 for $b = 0$ even at $W = 57$ GeV is certainly the consequences of the LHC data in the framework of our model.

There are two lessons that we can learn from this fit. The first is that if the TOTEM collaboration will confirm their results for $\sigma_{tot}$ and $\sigma_{el}$, we will need to reconsider the main physical ideas on which our approach is built. The second one, is the fact that one has to be very careful when considering the concept of the black disc regime.

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Figure 2: Comparison with the experimental data the energy behaviour of the total (Fig. 2a), elastic (Fig. 2b), single diffraction (Fig. 2c), double diffraction (Fig. 2d) and inelastic (Fig. 2f) cross sections and elastic slope (Fig. 2e). The solid lines show our present fit. The data has been taken from Ref. [19] for energies less than the LHC energy. At the LHC energy for total and elastic cross section we use TOTEM data [4] and for single and double diffraction cross sections are taken from Ref. [1].
Figure 3: The impact parameters dependence of amplitudes $A_{ik}$ at different energies. The solid lines are the results of this model, the dashed line are the amplitudes given by the model of Ref. [5].
Figure 4: $d\sigma_{el}/dt(\text{mb}/\text{GeV}^2)$ versus $|t|$ at Tevatron (blue curve and data)) and LHC (black curve and data) energies ($W = 1.8 TeV$ and $7 TeV$ respectively) The solid line without data shows our prediction for $W = 14 TeV$. Data from Refs. [4, 27].
