TENSION IN THE LHC DIFFRACTIVE DATA ?

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- Basic formalism of the GLM Model and other models based on RFT

- Discrepancies in σ_{tot} data and lessons learnt

- "Tension" in diffractive data at LHC energies ?

- Current Models for Soft Interactions at LHC energies

- Conclusions

Good-Walker Formalism

The Good-Walker (G-W) formalism, considers the diffractively produced hadrons as a single hadronic state described by the wave function Ψ_D, which is orthonormal to the wave function Ψ_h of the incoming hadron (proton in the case of interest) i.e. $< \Psi_h | \Psi_D >= 0$.

One introduces two wave functions ψ_1 and ψ_2 that diagonalize the 2x2 interaction matrix $\mathbf{T}$

$$A_{i,k} = < \psi_i \, \psi_k | \mathbf{T} | \psi_{i'} \, \psi_{k'} >= A_{i,k} \, \delta_{i,i'} \, \delta_{k,k'}.$$

In this representation the observed states are written in the form

$$\psi_h = \alpha \, \psi_1 + \beta \, \psi_2 \,,$$
$$\psi_D = -\beta \, \psi_1 + \alpha \, \psi_2$$
$$\text{where, } \alpha^2 + \beta^2 = 1$$

The s-channel Unitarity constraints for (i,k) are analogous to the single channel equation:

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

$G^{in}_{i,k}$ is the summed probability for all non-G-W inelastic processes, including non-G-W "high mass diffraction" induced by multi-$I\!P$ interactions.

A simple solution to the above equation is:

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

The opacities $\Omega_{i,k}$ are real, determined by the Born input.

Good-Walker Formalism-3

Amplitudes in two channel formalism are:

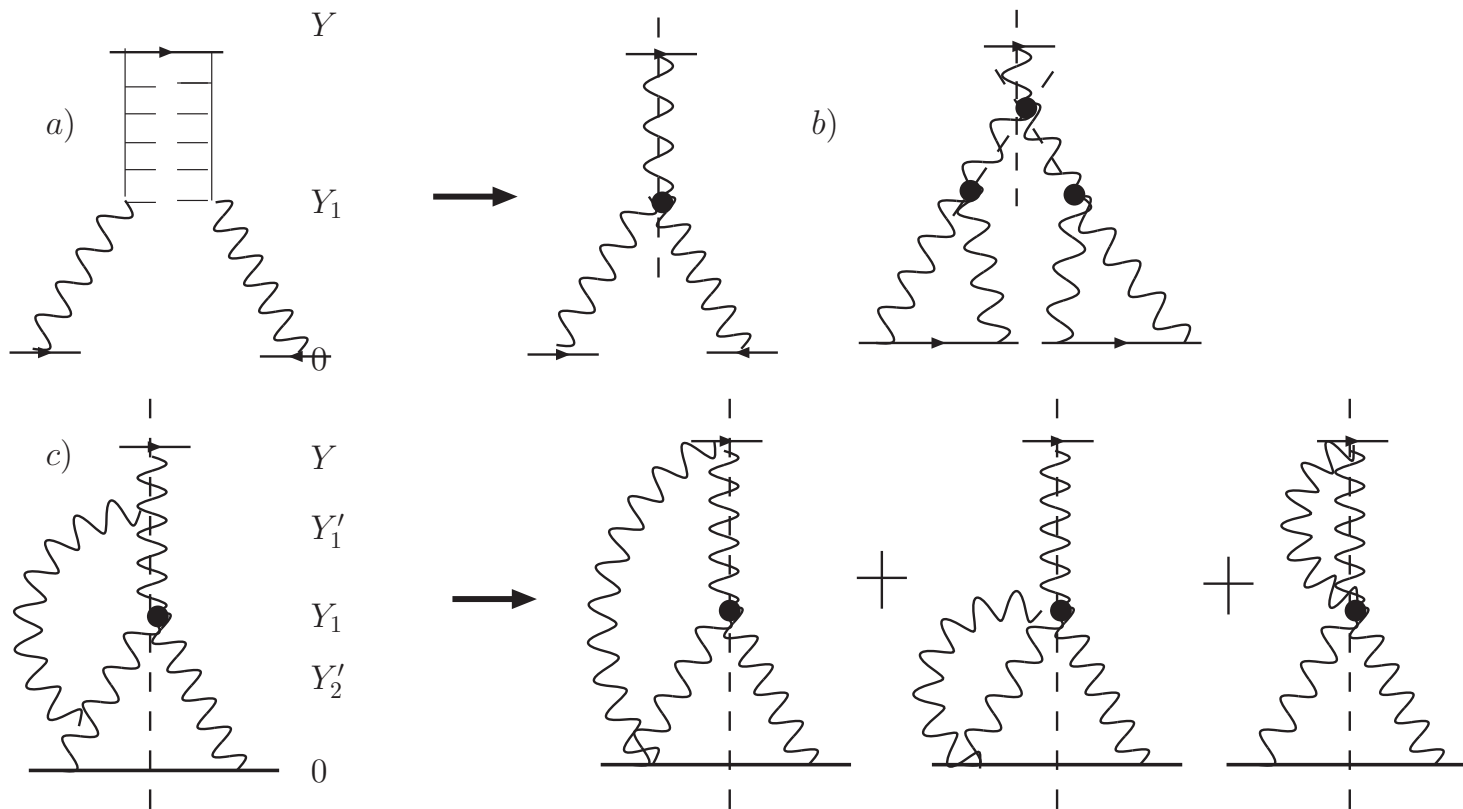$$A_{el}(s,b) = i\{\alpha^4 A_{1,1} + 2\alpha^2\beta^2 A_{1,2} + \beta^4 A_{2,2}\},$$

$$A_{sd}(s,b) = i\alpha\beta\{-\alpha^2 A_{1,1} + (\alpha^2 - \beta^2)A_{1,2} + \beta^2 A_{2,2}\},$$

$$A_{dd}(s,b) = i\alpha^2\beta^2\{A_{1,1} - 2A_{1,2} + A_{2,2}\}.$$

With the G-W mechanism σ_{el}, σ_{sd} and σ_{dd} occur due to elastic scattering of ψ_1 and ψ_2, the correct degrees of freedom.

Examples of the

Pomeron diagrams that lead to a different source of the diffractive dissociation that cannot be described in the framework of the G-W mechanism. (a) is the simplest diagram that describes the process of diffraction in the region of large mass $Y - Y_1 = \ln(M^2/s_0)$. (b) and (c) are examples of more complicated diagrams in the region of large mass. The dashed line shows the cut Pomeron, which describes the production of hadrons.

What can we learn from past discrepancies in data?

As an example consider the value of $\sigma_{\text{tot}}(p\bar{p})$ at W = 1.8 TeV.
The earliest measurement was that of the E710 colaboration (N.N. Amos et al)
[Phys. Lett. B243,158 (1990)] who found
$$\sigma_{\text{tot}}(p\bar{p}) = 72.1 \pm 3.3 \text{ mb.}$$

Next was the CDF collaboration (F. Abe et al)[Phys. Rev. D50,5550 (1994)]
whose result was
$$\sigma_{\text{tot}}(p\bar{p}) = 80.03 \pm 2.24 \text{ mb.}$$
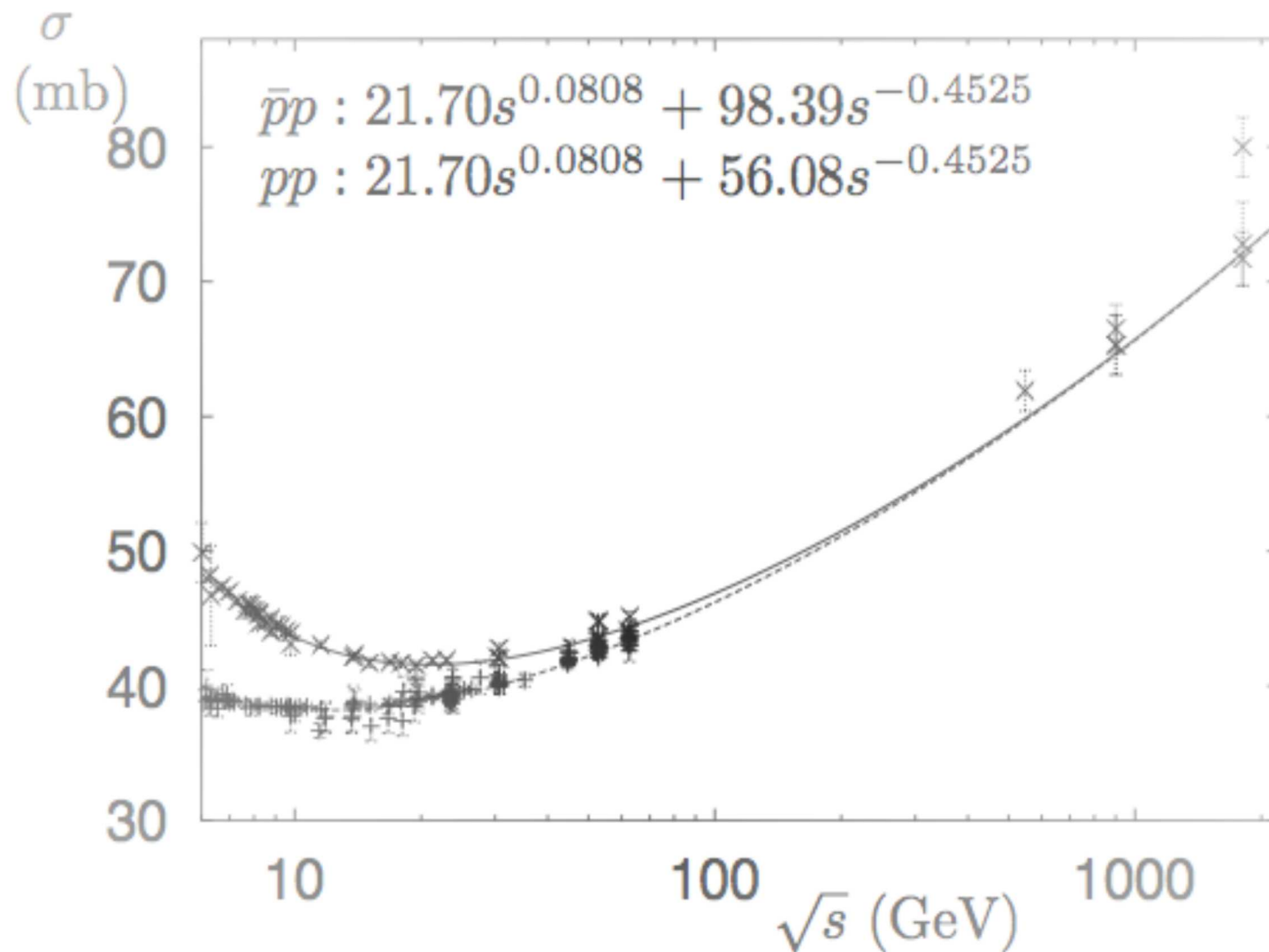
The third measurement was by E811 collaboration (C.Avila et al)[Phys.
Letts.B537,41 (2002)] who measured
$$\sigma_{\text{tot}}(p\bar{p}) = 72.42 \pm 1.55 \text{ mb.}$$

The fact that the classical Donnachie-Landshoff model with $\alpha_{I\!P} = 1.08$ and
$\alpha'_{I\!P} = 0.25$ was consistent with $\sigma_{\text{tot}}(p\bar{p}) \approx 72$ mb
cast doubt on the CDF result at the time.

In addition the fits of the COMPETE collaboration also went through the E710
point.

$$\bar{p}p : 21.70s^{0.0808} + 98.39s^{-0.4525}$$
$$pp : 21.70s^{0.0808} + 56.08s^{-0.4525}$$

Model predictions PRIOR to appearance of LHC results

W (TeV)	GLM[1]		KMR[2]		Ostap(C)[3]	
	$\sigma_{\text{tot}}(mb)$	$\sigma_{\text{el}}(mb)$	$\sigma_{\text{tot}}(mb)$	$\sigma_{\text{el}}(mb)$	$\sigma_{\text{tot}}(mb)$	$\sigma_{\text{el}}(mb)$
1.8	74.4	17.3	72.8	16.3	73.0	16.8
7	91.3	23.0	89.0	21.9	93.3	23.6
14	101.	26.1	98.3	25.1	105.	28.2

(1) GLM Eur.J.P.,C71, 1563 (2011)

(2) KMR Eur.J.P.,C71, 1617 (2011)

(3) S.Ostapchenko, Phys. Rev.,D81, 114028 (2010)

After the publication of the TOTEM results at W = 7 TeV

The publication of the TOTEM measurement [G. Antchev et al., Europhys. Lett. 101, 21002 (2013)] caused an "upheaval".

It suggested that $\sigma_{\text{tot}}(pp)$ in the Tevatron-LHC energy range grew FASTER than at lower energies.

This resulted in

- An "overhaul" of existing models e.g Donnanchie + Landshoff

- or the suggestion of new parametrization e.g. Ciesielski and Goulianos.

D and L introduced an ADDITIONAL HARD POMERON and used an EIKONALIZED Regge pole model with Pomerons and Reggeons:

The values of the parameters were determined by making a simultaneous fit to pp scattering data and to DIS lepton scattering for low x.

Their results can be summarized:

SOFT POMERON
$$\alpha_S^{I\!\!P} = 1.093 + 0.25t$$

HARD POMERON
$$\alpha_H^{I\!\!P} = 1.362 + 0.1t$$

Coupling strength: $X_1 = 243.5$ $X_0 = 1.2$

At 7 TeV $\sigma_{tot}(\text{soft}) = 91$ mb $\sigma_{tot}(\text{hard} + \text{soft}) = 98$ mb
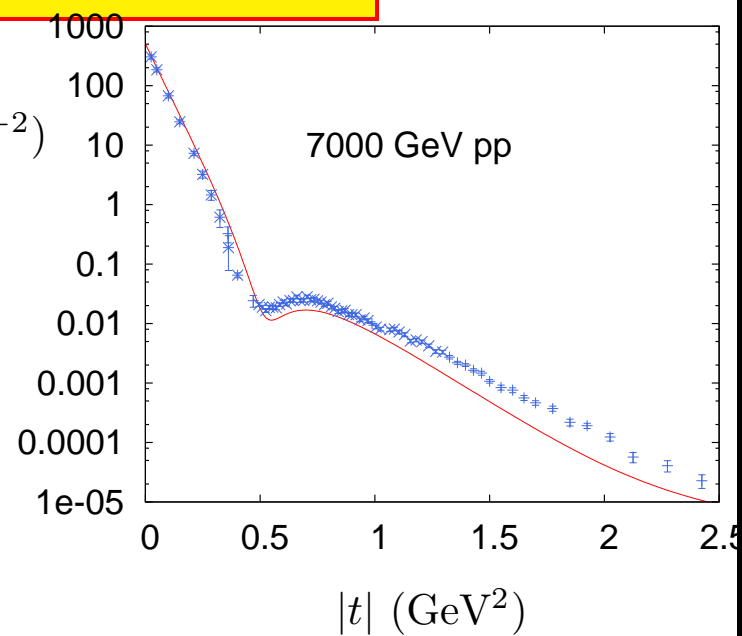
From Donnachie and Landshoff arXiv:1112.2485
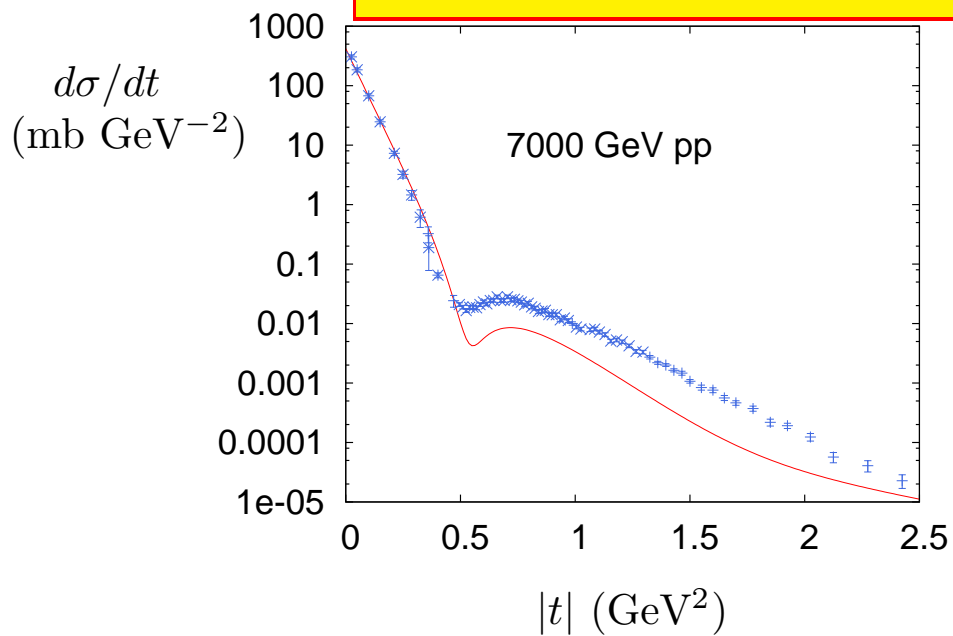
ONLY SOFT POMERON

(SOFT + HARD) POMERON

The $\sigma_{\text{tot}}^{p^{\pm}p}(s)$ cross sections at a pp center-of-mass-energy $\sqrt{s}$ are calculated as follows:

$$\sigma_{\text{tot}}^{p^{\pm}p} = \begin{cases} 16.79s^{0.104} + 60.81s^{-0.32} \mp 31.68s^{-0.54} & \text{for } \sqrt{s} < 1.8 \text{ TeV}, \\ \sigma_{\text{tot}}^{\text{CDF}} + \frac{\pi}{s_0}\left[\left(\ln\frac{s}{s_F}\right)^2 - \left(\ln\frac{s^{\text{CDF}}}{s_F}\right)^2\right] & \text{for } \sqrt{s} \geq 1.8 \text{ TeV}, \end{cases}$$

The energy at which "saturation" occurs $\sqrt{s_F} = 22$ GeV, and $s_0 = 3.7 \pm 1.5\,GeV^2$.

Their "event generator" follows Dino's "renormalized Regge-theory" model,
and their numbers are based on the MBR-enhanced PYTHIA8 simulation.

There are a number of parametrizations e.g. Block + Halzen and the COMPETE collaboration
who have successfully described the $\sigma_{tot}(pp)$ cross section over the whole energy range by using

$(lns + ln^2 s)$ terms in addition to the Reggeon term.

Models based on the dipole formalism e.g. Kopeliovich et al have also successfully predicted p-p
cross sections. (More details later).

Model predictions AFTER appearance of LHC results

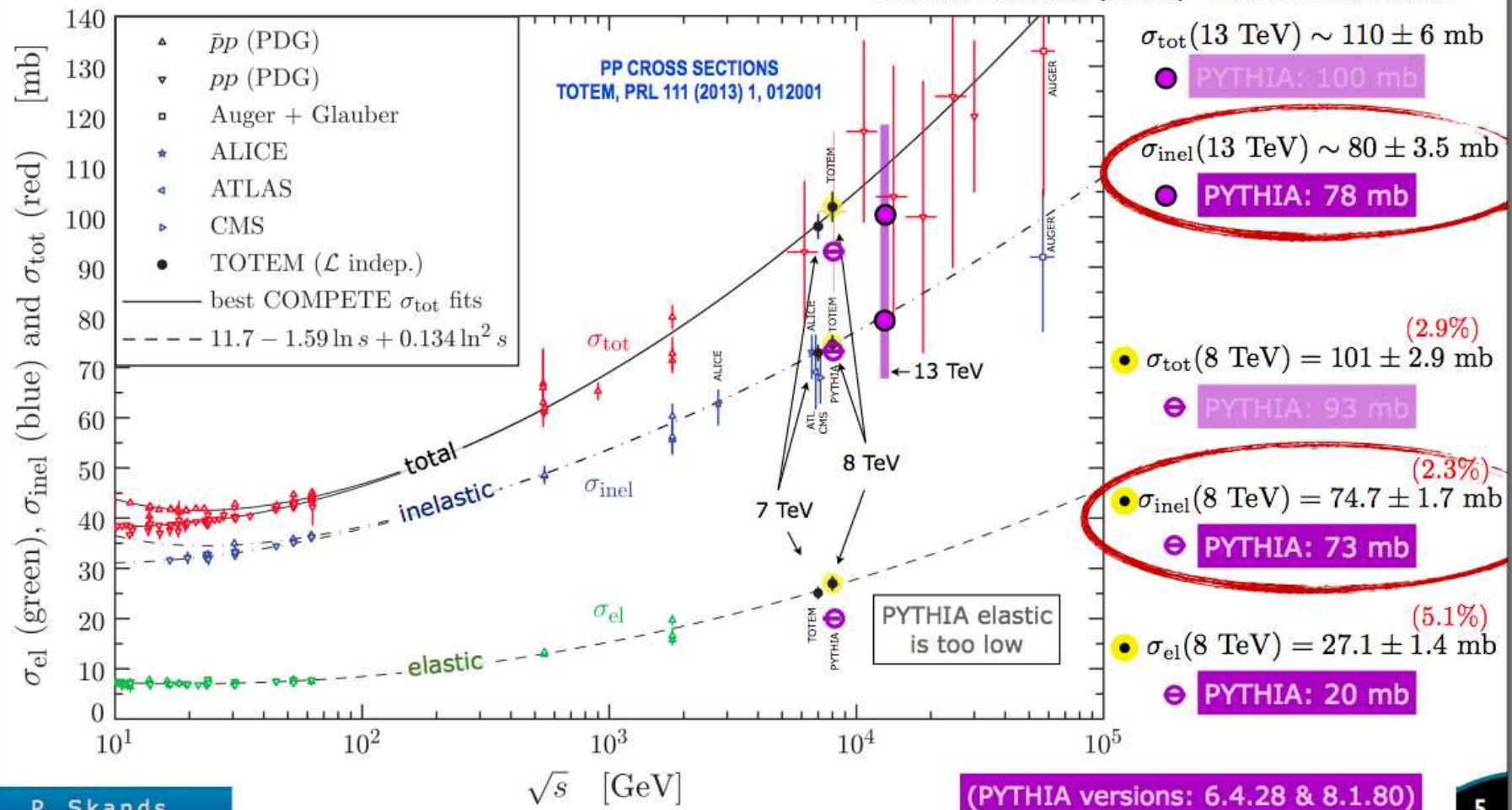| W (TeV)	GLM^4		KMR^5		MBR^6	
	$\sigma_{\text{tot}}(mb)$	$\sigma_{\text{el}}(mb)$	$\sigma_{\text{tot}}(mb)$	$\sigma_{\text{el}}(mb)$	$\sigma_{\text{tot}}(mb)$	$\sigma_{\text{el}}(mb)$
1.8	79.2	18.5	77.0	17.4	81.03	19.97
7	98.6	24.6	98.7	24.9	98.3	27.2
14	109.	27.9	112.7	30.1	109.5	32.1

(4) GLM Phys. Letts.B716,425 (2012)

(5) KMR Eur.J.P.C74, 2756 (2014)

(6) R. Ciesielski and D. Goulianos, arXiv:1205.1446

Summary of Elastic pp scattering today (borrowed from Peter Skands)

Pileup rate $\propto \sigma_{\text{tot}}(s) = \sigma_{\text{el}}(s) + \sigma_{\text{inel}}(s) \propto s^{0.08}$ or $\ln^2(s)$?

Donnachie-Landshoff (0.096?)   Froissart-Martin Bound

$\sigma_{\text{tot}}(13\ \text{TeV}) \sim 110 \pm 6$ mb
PYTHIA: 100 mb

$\sigma_{\text{inel}}(13\ \text{TeV}) \sim 80 \pm 3.5$ mb
PYTHIA: 78 mb

$\sigma_{\text{tot}}(8\ \text{TeV}) = 101 \pm 2.9$ mb   (2.9%)
PYTHIA: 93 mb

$\sigma_{\text{inel}}(8\ \text{TeV}) = 74.7 \pm 1.7$ mb   (2.3%)
PYTHIA: 73 mb

$\sigma_{\text{el}}(8\ \text{TeV}) = 27.1 \pm 1.4$ mb   (5.1%)
PYTHIA: 20 mb

PYTHIA elastic is too low

(PYTHIA versions: 6.4.28 & 8.1.80)

P. Skands

Plot legend:
- $\bar{p}p$ (PDG)
- pp (PDG)
- Auger + Glauber
- ALICE
- ATLAS
- CMS
- TOTEM ($\mathcal{L}$ indep.)
- best COMPETE σ_{tot} fits
- $11.7 - 1.59 \ln s + 0.134 \ln^2 s$

PP CROSS SECTIONS
TOTEM, PRL 111 (2013) 1, 012001

σ_{el} (green), σ_{inel} (blue) and σ_{tot} (red) [mb]

$\sqrt{s}$ [GeV]

5

Can anything be learnt from the discrepancy in the $\sigma_{\text{tot}}(pp)$?

- Most models and parametrizations that agree with the TOTEM values for σ_{tot} at the LHC
  are closer to the CDF value than to the E710 and E811 values at the Tevatron.

- Does this mean that the CDF value is the correct one at W = 1.8 TeV ?

- Since parameters of the Monte Carlo's and models are determined by fitting to the available experimental data.

- Their efficacy is determined by the accuracy of the data.

- e.g. The GLM model prior to the LHC measurements had $\alpha_{I\!P} = 0.21$ and gave a value of $\sigma_{tot} = 74.9$ mb for W = 1.8 TeV

  To be consistent with the TOTEM value measured at W = 7 TeV, we needed to increase the Pomeron intercept to $\alpha_{I\!P} = 0.23$
  which increased the value of
  $\sigma_{tot} = 79$ mb at W = 1.8 TeV and 98.6 mb for W = 7 TeV.

E710 measurements of SD cross section at the Tevatron
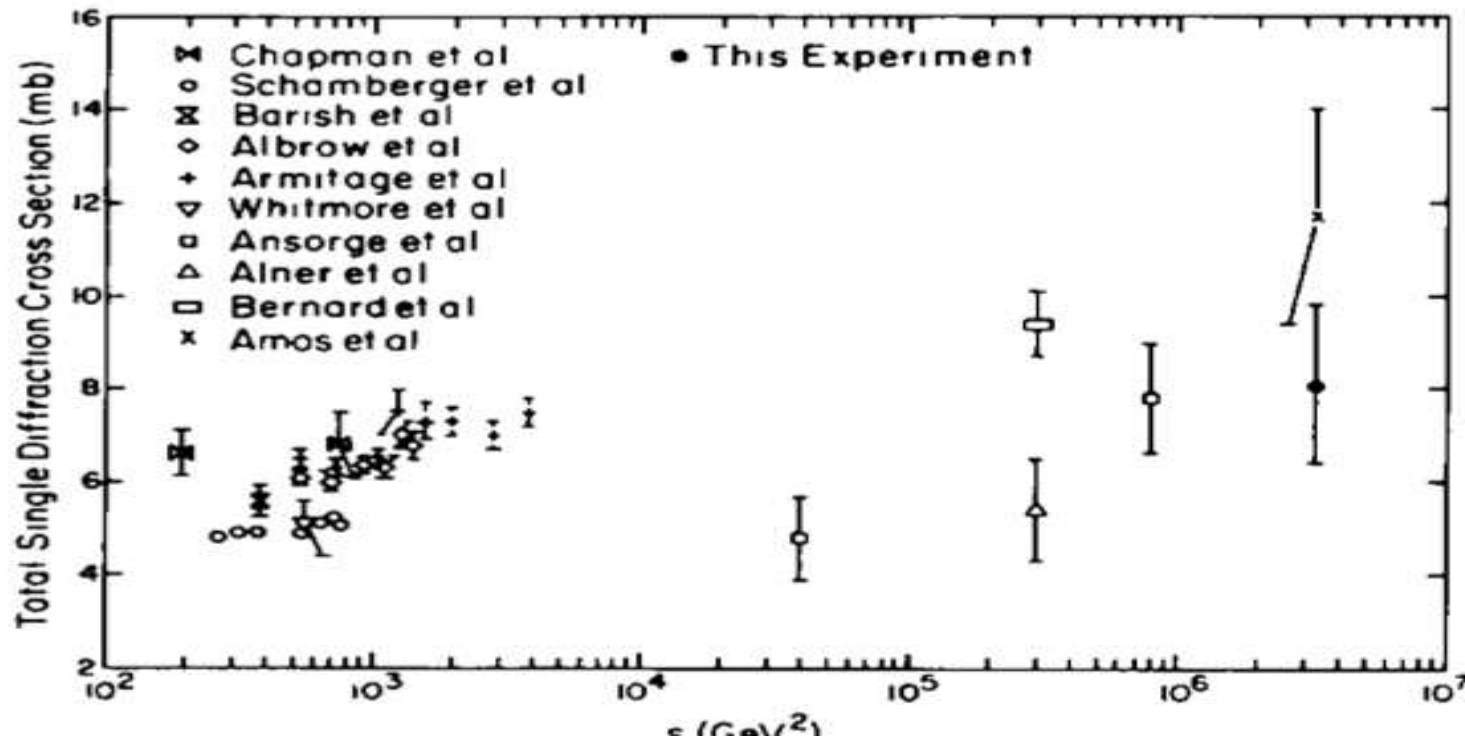
E710 made two measurements of σ_{sd} at W $= 1.8$ TeV

The first [N.A. Amos et al Phys. Lett. B243,168 (1990)] was a luminosity independent measurement with the result $\sigma_{sd} = 11.7 \pm 2.3$ mb

The second [N.A. Amos et al Phys. Lett. B301,313 (1993)], measured data in the range $3 < M_X < 200$ GeV and for $0.05 \leq |t| \leq 0.11 GeV^2$

ASSUMING that M_X and t are INDEPENDENT they EXTRAPOLATED the behaviour of the cross section to all values of t, for 2 GeV$^2 < M_X^2 < 0.05$s yielding a value $\sigma_{sd} = 8.1 \pm 1.7$ mb

Since the two measurements were independent they combined them to give a value $\sigma_{sd} = 9.4 \pm 1.4$ mb

Experiment	Energy	Mass	$\sigma_{sd}(pp)$
	[TeV]	[GeV]	[mb]
TOTEM	7	3.4 - 1100	6.5 ± 1.3
(preliminary)			
CMS	7	12 - 394	4.27 ± 0.04 (sta) $^{+0.65}_{-0.58}$ (sys)
ALICE	2.76	0 - 200	$12.2 \, ^{+3.9}_{-5.3}$
ALICE	7	0 - 200	$14.9 \, ^{+3.4}_{-5.9}$

Values of the single diffractive $\sigma_{sd}(pp)$ cross section as measured by
TOTEM M. Deile (for the TOTEM Collaboration),XXII Int. Workshop on DIS and Related
Subjects, Warsaw, (April 2014).
CMS (CMS Collaboration) CMS-PAS-FSQ-112-005,(2013)
ALICE (ALICE Collaboration), B. Abelev et al,Eur.Phys.J. C73,2456 (2013).

TOTEM also have their results for the different mass bins:

Mass interval (GeV)	3.4 - 8	8 - 350	350 - 1100
Totem data [mb]	1.8 ± 0.36	3.3 ± 0.66	1.4 ± 0.28

Monte Carlo Predictions for Diffraction at LHC at W = 7 TeV

Process	PYTHIA 6	PYTHIA 8	PHOJET
σ_{ND}(mb)	48.5	50.9	61.6
σ_{SD}(mb)	13.7	12.4	10.7
σ_{DD}(mb)	9.2	8.1	3.9
σ_{CD}(mb)	0.0	0.0	1.3
Tuned $f_{ND}\%$	70.0	70.2	70.2
Tuned $f_{SD}\%$	20.7	20.6	16.1
Tuned $f_{DD}\%$	9.3	9.2	11.2
Tuned $f_{CD}\%$	0.0	0.0	2.5

Monte Carlo Predictions for Diffraction at LHC at W = 7 TeV contd.

Ostapchenko [Phys.Rev.D89, 074009 (2014)]
has recently compared the results of QJSJET-II-04 for σ_{SD} with the TOTEM* measurements:

M_X range	< 3.4 GeV	3.4-1100 GeV	3.4 - 7 GeV	7 - 350 GeV	350 -1100 GeV
TOTEM *[mb]	2.62 ±2.17	6.5 ± 1.3	≈ 1.8	≈ 3.3	≈ 1.4
QGSJET-II-04 [mb]	3.9	7.2	1.9	3.9	1.5
KMR(2014) [mb]		7.7	2.3	4.0	1.4

* F. Oljemark (for the TOTEM Collaboration) 15th Int. Conf. on Elastic and Diffractive
Scattering (Saariselka) Finland, September 2013.

Poghosyan [arXiv:1208.1055] using the Kaidalov-Poghosyan model has estimates that for
$1.08 \leq M_X \leq 3.4$ GeV , $\sigma_{SD} \approx 4$ mb

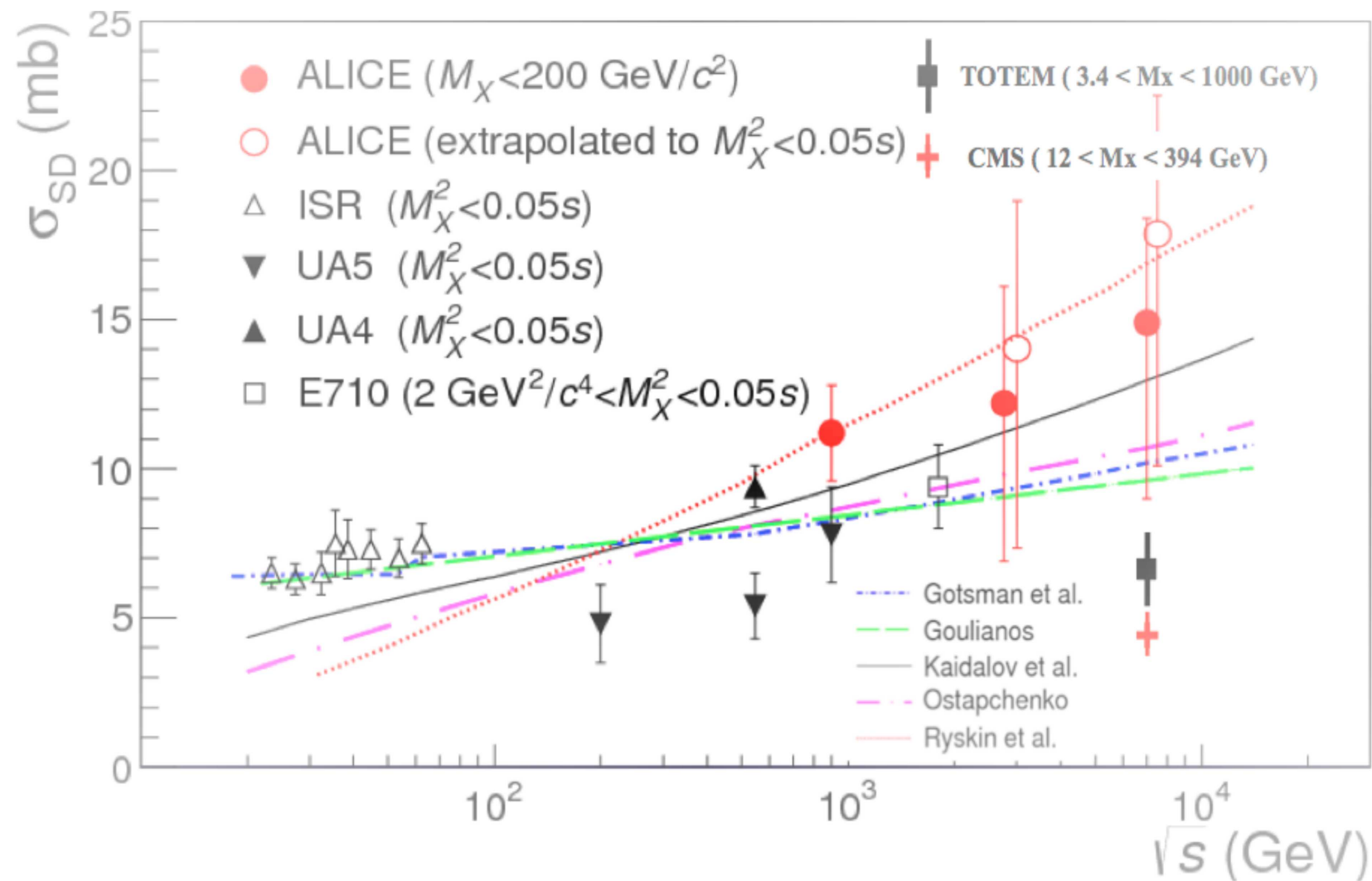CMS have data in the mass interval $12 \leq M_x \leq 394$ GeV,
Experiment measures $\sigma_{SD} = 4.3 \pm 0.6$ mb
QGSJET-II-04 predicts 3.0 mb
Dino [K.Goulianos, EDS2013,Saariselca] finds after extrapolating the CMS measurements into
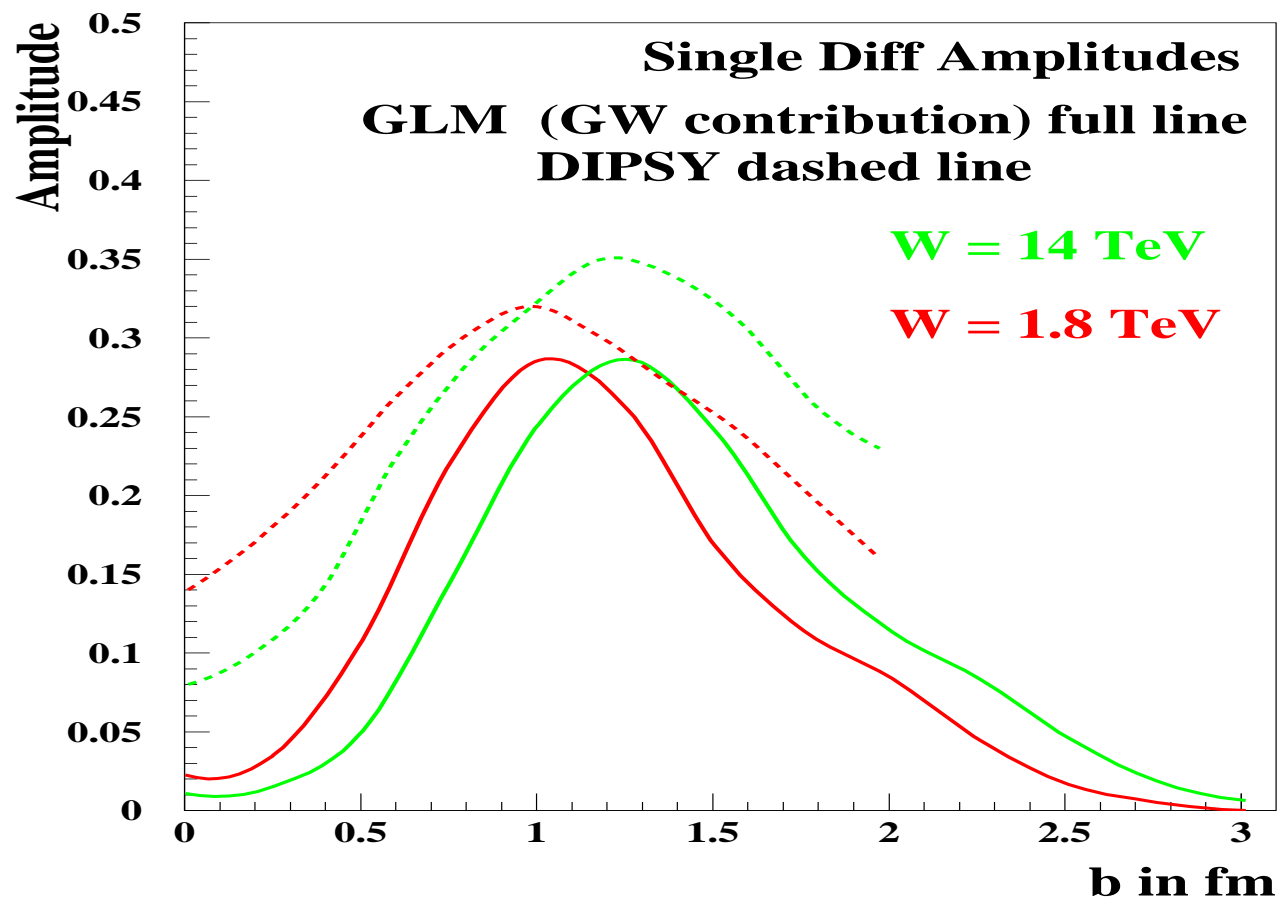low ξ region using the MBR model that for $\frac{M_X^2}{s} < 0.05$:
$$\sigma_{SD} \approx 9.3^{+1.6}_{-1.3} \text{ mb}.$$

DIPSY (including enhanced and semi-enhanced)

and GLM (only GW) S.D. amplitudes

Single Diff Amplitudes
GLM (GW contribution) full line
DIPSY dashed line

W = 14 TeV

W = 1.8 TeV

LHC Data on Double Diffraction

Experiment	Mass [GeV]	$\sigma_{dd}(pp)$ [mb]
TOTEM (preliminary)	$3.4 < M_{diff} < 8$	0.116 ± 0.025
PYTHIA 8		0.159
PHOJET		0.101
CMS	$M_X, M_Y > 10 : \Delta\eta > 3$	$0.93 \pm 0.01\ ^{+0.26}_{-0.22}$
ALICE	0 - 200	9.0 ± 2.6

For $\dfrac{M_i^2}{s} < 0.05,\ (i = X, Y)$
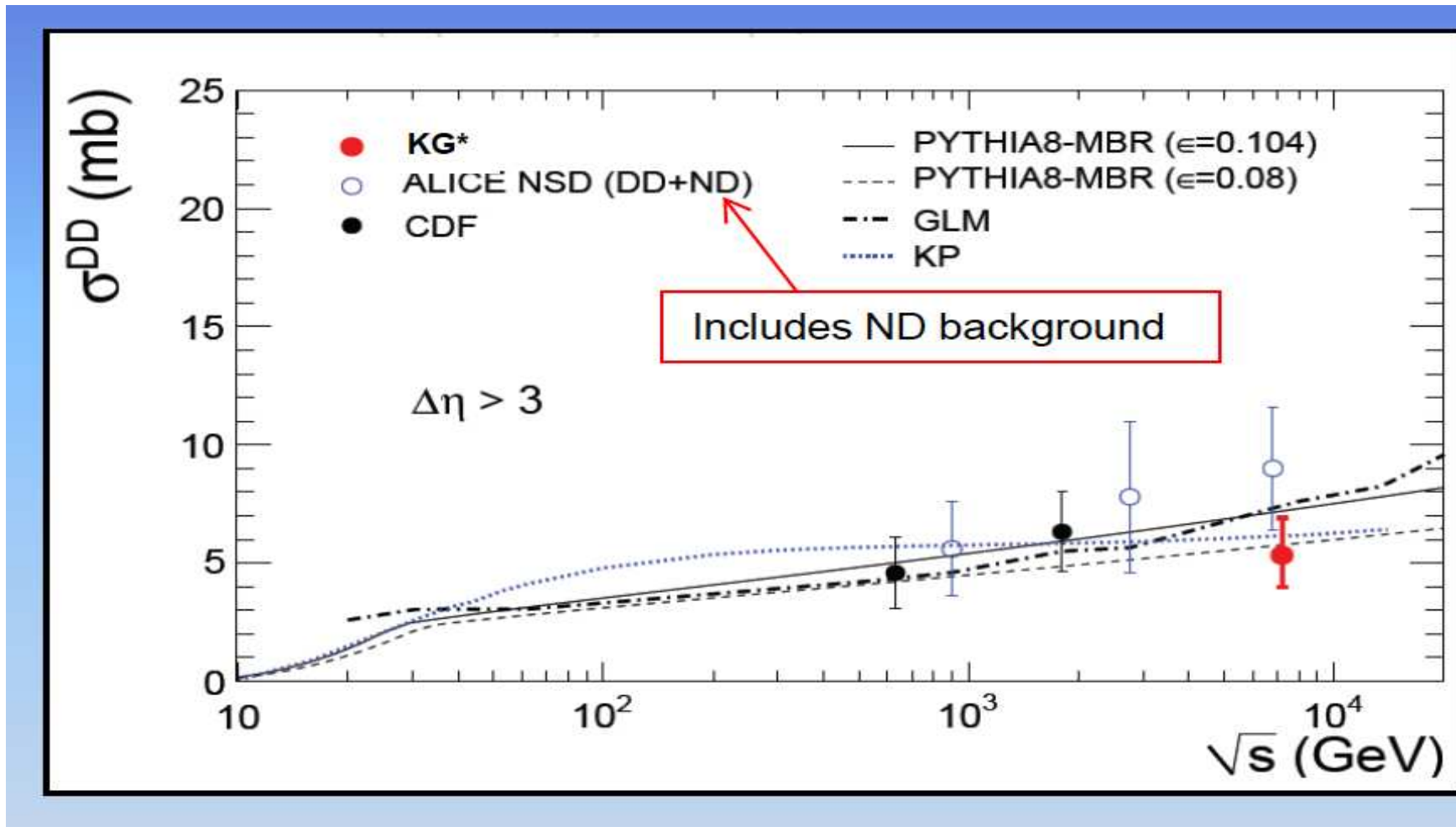
Pythia 8 predicts $\sigma_{DD} = 8.1$ mb

Phojet predicts $\sigma_{DD} = 3.9$ mb

Dino [K.Goulianos, EDS2013,Saariselca] finds after extrapolating the CMS measurements into low ξ region using the MBR model that:

for $\dfrac{M_i^2}{s} < 0.05,\ (i = X, Y)$ and $\Delta\eta > 3$

$$\sigma_{DD} \approx 5.7^{+1.2}_{-1.6} \text{ mb}$$

Plot of Diffractive DD data from Dino's talk at DIS2013

Ostapchenko (Phys.Rev.D81,114028(2010)) [pre LHC] has made a comprehensive calculation in the framework of Reggeon Field Theory based on the resummation of both enhanced and semi-enhanced Pomeron diagrams.

To fit the total and diffractive cross sections he assumes TWO POMERONS: (for SET C)
"SOFT POMERON" $\alpha^{Soft} = 1.14 + 0.14t$ "HARD POMERON" $\alpha^{Hard} = 1.31 + 0.085t$

The Durham Group (Khoze, Martin and Ryskin) (Eur.Phys.J.C73,2503 (2013)) suggested a TWO channel eikonal model where the Pomeron couplings to the diffractive eigenstates depend on the collider energy. They have four versions of the model. The parameters of the Pomeron of their "favoured version" Model 4 are:

$$\Delta_{I\!P} = 0.11; \; \alpha'_{I\!P} = 0.06 \; GeV^{-2}$$. I will refer to this as KMR2C.

KMR have recently updated their model ((Eur.Phys.J.C74,2756 (2014)) to be consistent with the TOTEM diffractive data, (energy dependent coupling constants). I refer to this version as KMR14.

Kaidalov-Poghosyan have a model which is based on Reggeon calculus, they attempt to describe data on soft diffraction taking into account all possible non-enhanced absorptive corrections to 3 Reggeon vertices and loop diagrams. It is a single $I\!P$ model and with secondary Regge poles, they have

$$\Delta_{I\!P} = 0.12; \; \alpha'_{I\!P} = 0.22 GeV^{-2}.$$

Dipole Approach to Soft Scattering

KPPP (Kopeliovich, Potashnikova, Povh and Predazzi (Phys.Rev.D63,054001 (2001))
calculated the elastic hadron amplitude
using the non-perturbative light-cone dipole representation for gluon brehmsstralung

A two scale structure of the light hadrons was assumed
a SOFT scale of the order of the confinement radius $R_c \approx \frac{1}{\Lambda_{QCD}} \approx 1$ fm
a SEMI-HARD scale ≈ 0.3 fm characterizing non-perturbative interactions of gluons
This is reflected in their two term expression for
σ_{tot} = large constant term (from soft interactions) + steeply rising term (related to gluon
radiation [$\sim s^\Delta$ with $\Delta = 0.17$])

K+P + Schmidt [Phys.Rev.C73,034901(2006)] have extended the model to proton-nucleus plus
p + p $\rightarrow$ p + X.
Their results for σ_{SD} have not been updated to compare with LHC energies.

K + P + Povh [Phys.Rev.D86,051502 (2012)] compare the results of their approach with the
TOTEM (LHC) elastic data, and show excellent agreement with the predictions made eleven
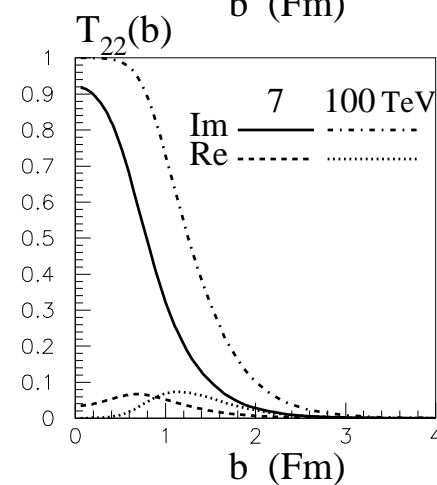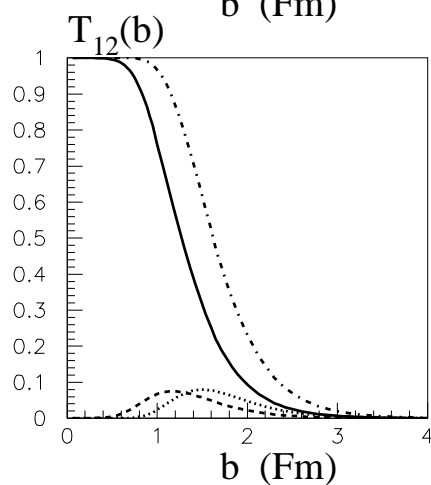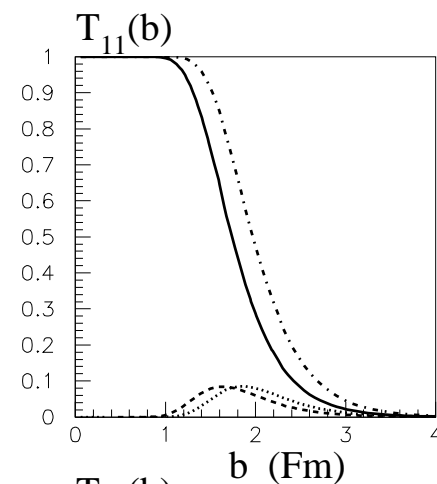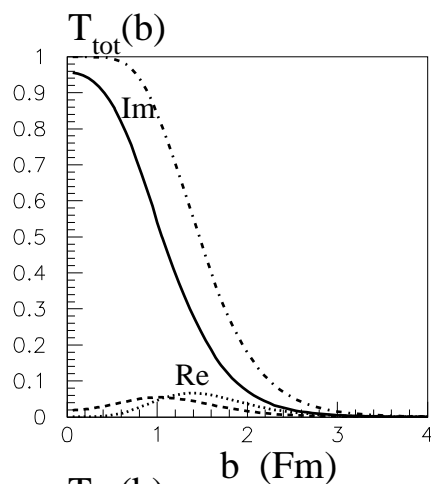years previously.

Comparison of results of various models

W = 1.8 TeV	GLM	KMR14	KMR2C	Ostap(C)	MBR*	KP	KPP
$\sigma_{\text{tot}}(mb)$	79.2	77.0	77.2	73.0	81.03	75.0	76.
$\sigma_{\text{el}}(mb)$	18.5	17.4	17.4	16.8	19.97	16.5	18.
$\sigma_{SD}(mb)$	11.27	3.4(LM)	2.82(LM)	9.2	10.22	10.1	
$\sigma_{DD}(mb)$	5.51	0.2(LM)	0.14(LM)	5.2	7.67	5.8	
$B_{el}(GeV^{-2})$	17.4	16.8	17.5	17.8			17.

W = 7 TeV	GLM	KMR14	KMR2C	Ostap(C)	MBR	KP	KPP
$\sigma_{\text{tot}}(mb)$	98.6	98.7	96.4	93.3	98.3	96.4	98.0
$\sigma_{\text{el}}(mb)$	24.6	24.9	24.0	23.6	27.2	24.8	25.6
$\sigma_{SD}(mb)$	14.88	3.6(LM)	3.05(LM)	10.3	10.91	12.9	
$\sigma_{DD}(mb)$	7.45	0.2(LM)	0.14(LM)	6.5	8.82	6.1	
$B_{el}(GeV^{-2})$	20.2	19.7	19.8	19.0		19.0	19.4

W = 14 TeV	GLM	KMR14	KMR2C	Ostap(C)	MBR	KP	KPP
$\sigma_{\text{tot}}(mb)$	109.0	112.7	108.	105.	109.5	108.	111.
$\sigma_{\text{el}}(mb)$	27.9	30.1	27.9	28.2	32.1	29.5	30.4
$\sigma_{SD}(mb)$	17.41	3.5(LM)	3.15(LM)	11.0	11.26	14.3	
$\sigma_{DD}(mb)$	8.38	0.2(LM)	0.14(LM)	7.1	9.47	6.4	
$B_{el}(GeV^{-2})$	21.6	21.6	21.1	21.4		20.5	20.8

GLM and KMR14 ELASTIC profiles
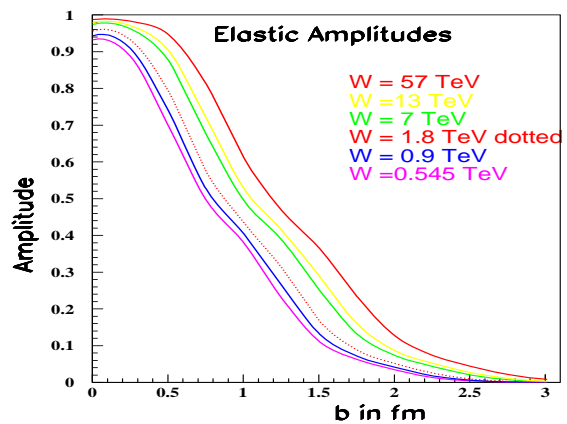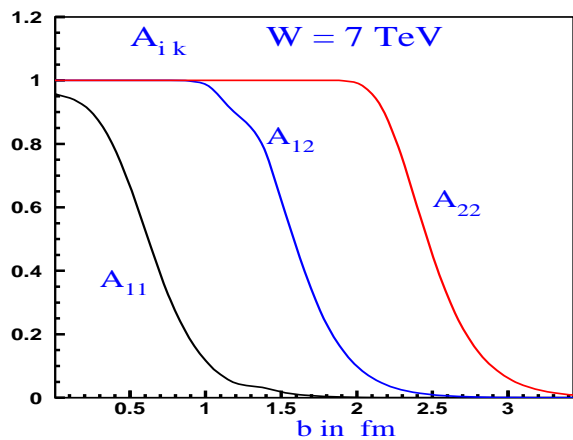
GLM and KMR14 DIFFRACTIVE amplitudes

Single Diff Amplitudes (G-W contribution)

W = 57 TeV
W = 13 TeV
W = 7 TeV
W = 1.8 TeV dotted
W = 0.9 TeV
W = 0.545 TeV

$d\sigma_{el}(b)/db^2$

$\sqrt{s}$=1.8 14 100 TeV

$d\sigma_{SD}(b)/db^2$ (low M)

DD Amplitudes (G-W contribution)

W = 57 TeV
W =13 TeV
W = 7 TeV
W = 1.8 TeV dotted
W = 0.9 TeV
W =0.545 TeV

$d\sigma_{DD}(b)/db^2$ (low M)

$d\sigma_{SD}(b)/db^2$ (high M)
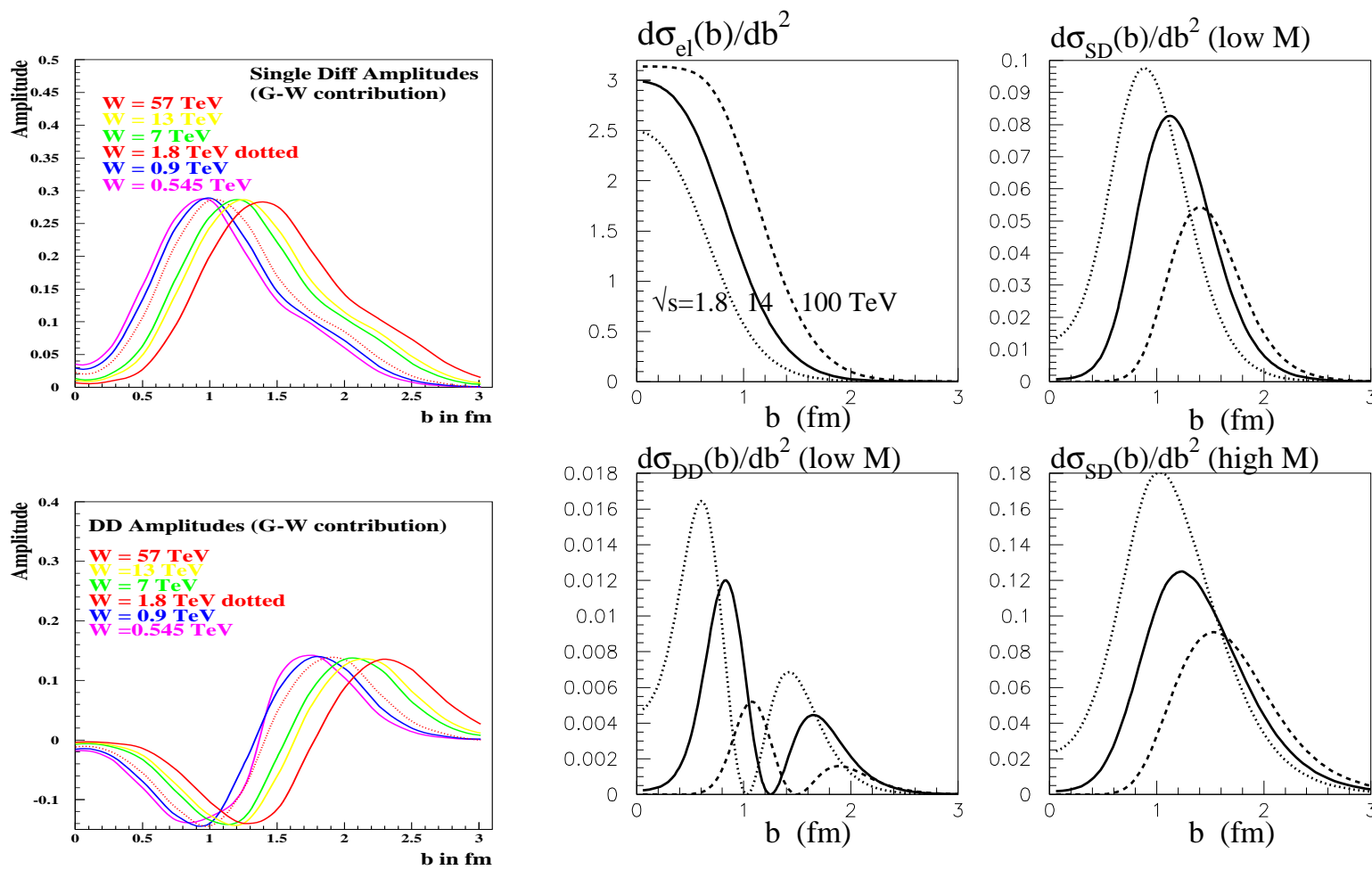
Conclusions

- Experimental measurements of σ_{SD} have been made over a limited region of M_X and then EXTRAPOLATED using Monte Carlos to obtain σ_{SD} for $\frac{M_X^2}{s} \leq 0.05$

- It appears that there is enough "slack" present in the diffractive data to release any "tension" that there might be.

- My best guess is that for W = 7 TeV, the result for single diffractive cross section in the above range of M_X^2 is $\sigma_{SD} \approx 10$ - 11 mb.

- The question that is still open:-

  HAVE WE REACHED AN ENERGY REGIME WHERE σ_{SD} EXHIBITS A CHANGE IN IT'S BEHAVIOUR FROM THAT AT LOWER ENERGIES ?

Results of GLM model

$\sqrt{s}$ TeV	1.8	7	8
σ_{tot} mb	79.2	98.6	101.
σ_{el} mb	18.5	24.6	25.2
$\sigma_{sd}(M \le M_0)$ mb		$10.7 + (2.8)^{nGW}$	$10.9 + (2.89)^{nGW}$
$\sigma_{sd}(M^2 < 0.05s)mb$	$9.2+ (1.95)^{nGW}$	$10.7 + (4.18)^{nGW}$	$10.9 + (4.3)^{nGW}$
σ_{dd} mb	$5.12 + (0.38)^{nGW}$	$6.2 + (1.166)^{nGW}$	$6.32 + (1.29)^{nGW}$
$B_{el}\ GeV^{-2}$	17.4	20.2	20.4
$B_{sd}^{GW}\ GeV^{-2}$	6.36	8.01	8.15
σ_{inel} mb	60.7	74.	75.6
$\frac{d\sigma}{dt}\|_{t=0}\ mb/GeV^2$	326.34	506.4	530.7

$\sqrt{s}$ TeV	13	14	57
σ_{tot} mb	108.0	109.0	130.0
σ_{el} mb	27.5	27.9	34.8
$\sigma_{sd}(M^2 < 0.05s)$ mb	$11.4 + (5.56)^{nGW}$	$11.5 + (5.81)^{nGW}$	$13.0 + (8.68)^{nGW}$
σ_{dd} mb	$6.73 + (1.47)^{nGW}$	$6.78 + (1.59)^{nGW}$	$7.95 + (5.19)^{nGW}$
$B_{el}\ GeV^{-2}$	21.5	21.6	24.6
σ_{inel} mb	80.7	81.1	95.2
$\frac{d\sigma}{dt}\|_{t=0}\ mb/GeV^2$	597.6	608.11	879.2

Predictions of our model for different energies W. M_0 is taken to be equal to $200 GeV$ as ALICE measured the cross section of the diffraction production with this restriction.

ATLAS results from ICHEP2014

The total cross section
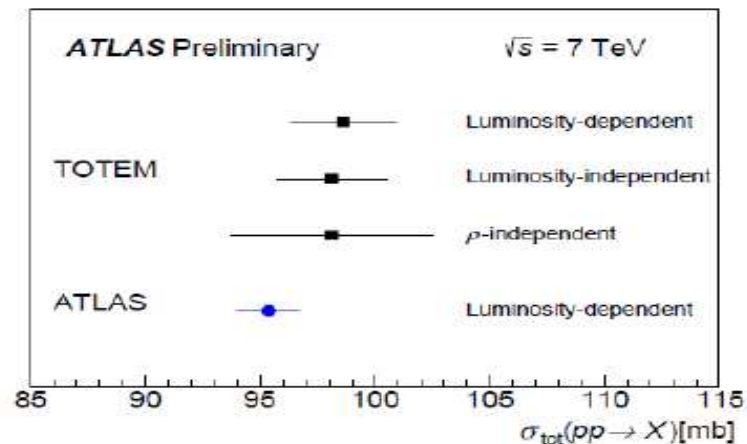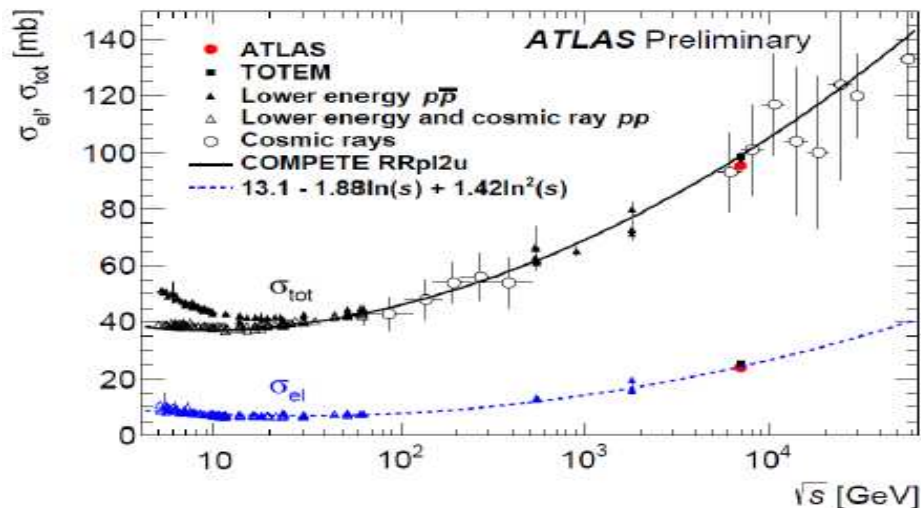
Energy evolution of σ_{tot}

Comparison with TOTEM measurements

$$\sigma_{tot} = 95.4 \pm 1.4 \, \text{mb}$$
$$\sigma_{el} = 24.0 \pm 0.6 \, \text{GeV}^{-2}$$

total error

Elastic cross section from the integrated fit-function (nuclear part)

$$\sigma_{el} = \frac{\sigma_{tot}^2}{B} \frac{1+\rho^2}{16\pi(\hbar c)^2}$$

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GLM Formalism

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

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

$P(s) \;=\; s^{\Delta_{I\!P}}$ and $g_i(b)$ is the Pomeron-hadron vertex parameterized in the form:

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

$S_i(b)$ is the Fourier transform of $\frac{1}{(1+q^2/m_i^2)^2}$, where, q is the transverse momentum carried by the Pomeron.

The Pomeron's Green function that includes all enhanced diagrams is approximated using the MPSI procedure, in which a multi Pomeron interaction (taking into account only triple Pomeron vertices) is approximated by large Pomeron loops of rapidity size of $\ln s$.
The Pomeron's Green Function is given by

$$G_{I\!P}(Y) \;=\; 1 \;-\; \exp\left(\frac{1}{T(Y)}\right) \frac{1}{T(Y)} \Gamma\left(0, \frac{1}{T(Y)}\right),$$

where $T(Y) \;=\; \gamma\, e^{\Delta_{I\!P} Y}$ and $\Gamma(0, 1/T)$ is the incomplete gamma function.

Fits to the Data

The parameters of our first fit GLM1 [EPJ C71,1553 (2011)] (prior to LHC) were determined by fitting to data
$20 \leq W \leq 1800$ GeV. We had 58 data points and obtained a $\chi^2/d.f. \approx 0.86$.

This fit yields a value of $\sigma_{tot} = 91.2$ mb at W = 7 TeV.

Problem is that most data is at lower energies (W ≤ 500 GeV) and these have small errors, and hence have a dominant influence on the determination of the parameters.

To circumvent this we made another fit GLM2 [Phys.Rev. D85, 094007 (2012)] to data for energies W > 500 GeV (including LHC), to determine the Pomeron parameters. We included 35 data points.

For the present version in addition we tuned the values of $\Delta_{I\!P}$, γ the Pomeron-proton vertex and the $G_{3I\!P}$ coupling, to give smooth cross sections over the complete energy range
$20 \leq W \leq 7000$ GeV.

$\Delta_{I\!P}$	β	$\alpha'_{I\!P}(GeV^{-2})$	$g_1\,(GeV^{-1})$	$g_2\,(GeV^{-1})$	$m_1\,(\text{GeV})$	$m_2\,(\text{GeV})$
0.23	0.46	0.028	1.89	61.99	5.045	1.71
$\Delta_{I\!R}$	γ	$\alpha'_{I\!R}\,(GeV^{-2})$	$g_1^{I\!R}\,(GeV^{-1})$	61.99	5.045	1.71
$\Delta_{I\!R}$	γ	$\alpha'_{I\!R}\,(GeV^{-2})$	$g_1^{I\!R}\,(GeV^{-1})$	$g_2^{I\!R}\,(GeV^{-1})$	$R_{0,1}^2\,(GeV^{-1})$	$G_{3I\!P}\,(GeV^{-1})$
- 0.47	0.0045	0.4	13.5	800	4.0	0.03

- $g_1(b)$ and $g_2(b)$ describe the vertices of interaction of the Pomeron with state 1 and state 2

- The Pomeron trajectory is $1 + \Delta_{I\!P} + \alpha'_{I\!P}\text{t}$

- γ denotes the low energy amplitude of the dipole-target interaction

- β denotes the mixing angle between the wave functions

- $G_{3I\!P}$ denotes the triple Pomeron coupling

Predictions of KMR (Eur.J.P. C74, 2756 (2014)

$\sqrt{s}$ (TeV)	σ_{tot} (mb)	σ_{el} (mb)	$B_{\text{el}}(0)$ (GeV^{-2})	$\sigma_{SD}^{\text{low}M}$ (mb)	$\sigma_{DD}^{\text{low}M}$ (mb)	$\sigma_{SD}^{\Delta\eta_1}$ (mb)	$\sigma_{SD}^{\Delta\eta_2}$ (mb)	$\sigma_{SD}^{\Delta\eta_3}$ (mb)	$\sigma_{DD}^{\Delta\eta}$ (μb)
1.8	77.0	17.4	16.8	3.4	0.2				
7.0	98.7	24.9	19.7	3.6	0.2	2.3	4.0	1.4	145
8.0	101.3	25.8	20.1	3.6	0.2	2.2	3.9	1.4	139
13.0	111.1	29.5	21.4	3.5	0.2	2.1	3.8	1.3	118
14.0	112.7	30.1	21.6	3.5	0.2	2.1	3.8	1.3	115
100.0	166.3	51.5	29.4	2.7	0.1				

What is unique about this version is that it has one pomeron pole, and also includes multi-pomeron interactions with "coupling constants" which decrease with energy due to the growth of k_T of intermediate partons along the $I\!P$ exchange ladder.

Thus the energy dependence of the cross sections depend on BOTH ;

- parameters of the pomeron trajectory

- energy dependence of the proton-pomeron coupling.