

Critical review of recent Odderon results

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Content

- Review of 3 recently published Odderon papers and methods with emphasis on possible influential conditions on the results.

1) **Model independent:** $H(x)$ scaling

(Csörgő, Novák, Pasechnik, Ster, Szanyi, *EPJC* (2021) 81:180)

2) **Model dependent:** Bialas-Bzdak model

(Csörgő, Szanyi, *EPJC* (2021) 81:611)

3) **Semi model independent:** TOTEM-D0 extrapolation

(TOTEM-D0 Coll., *PRL* (2021) 127, 062003)

Critical remarks are **highlighted** and answered

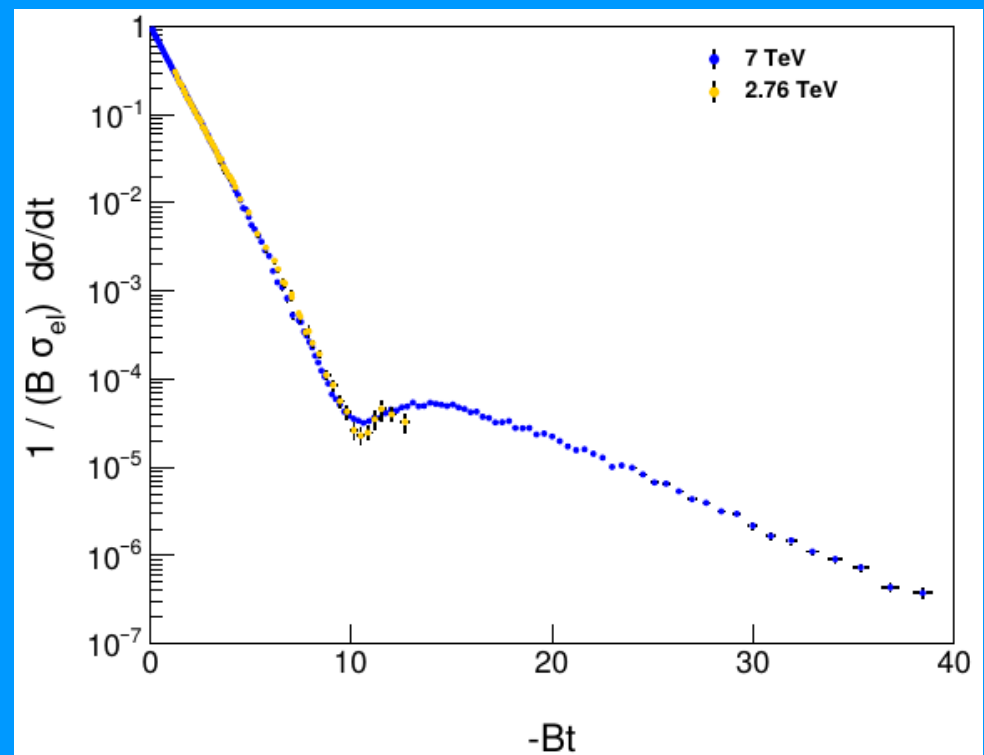
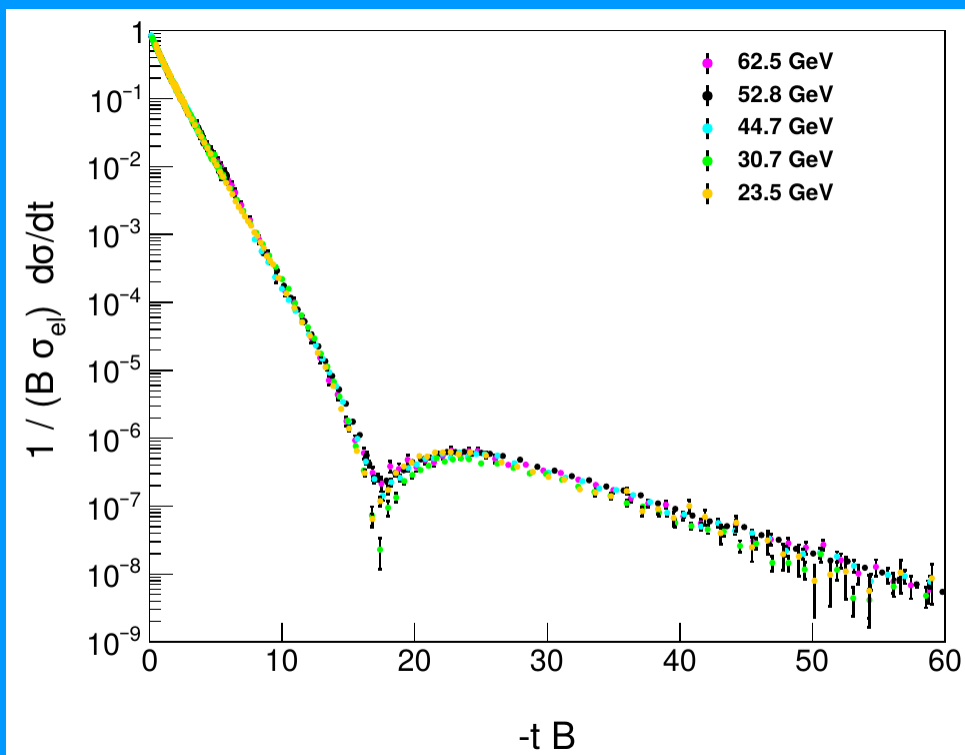
- Conclusion

H(x) scaling

The scaling eliminates collision energy (s) dependencies and overall normalization problems (see example plots)

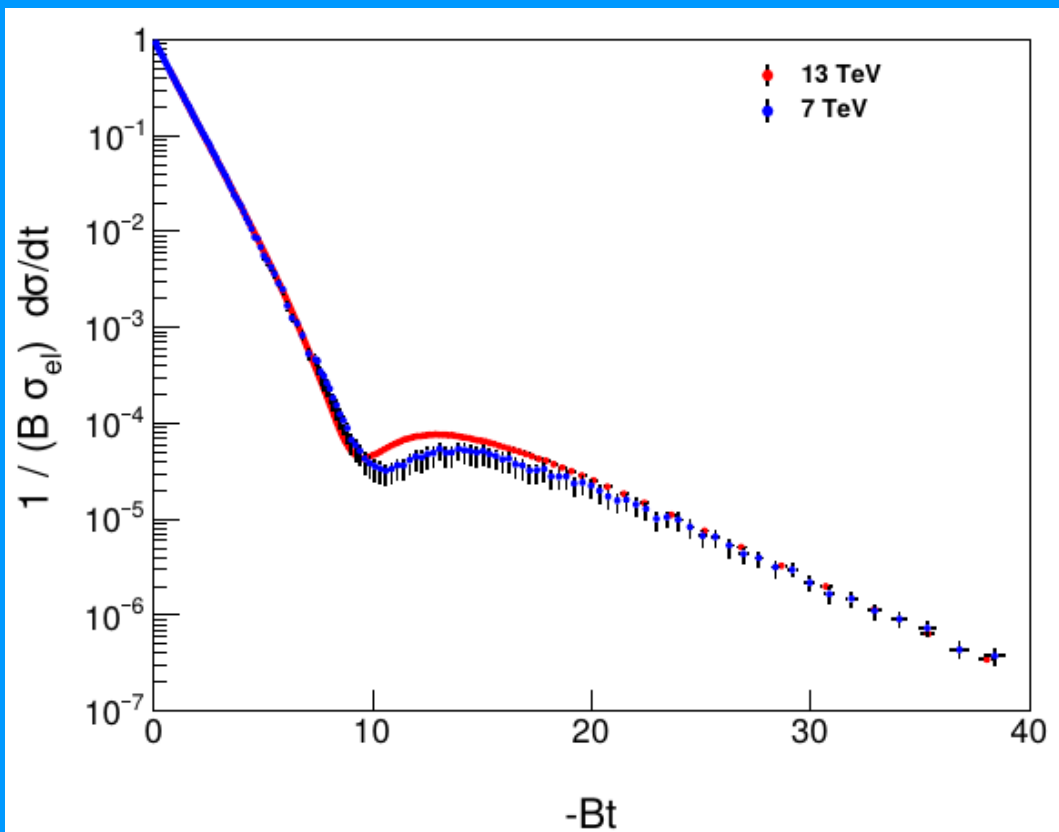
$$H(x,s) = (1/B\sigma_{el}) d\sigma/dt$$

$$x = -tB$$



H(x) scaling

Scaling is approximate and fails above 3-4 factors in energy



Argument 1:

Studies can be limited within a few TeV region from 1.96 to 8 TeV

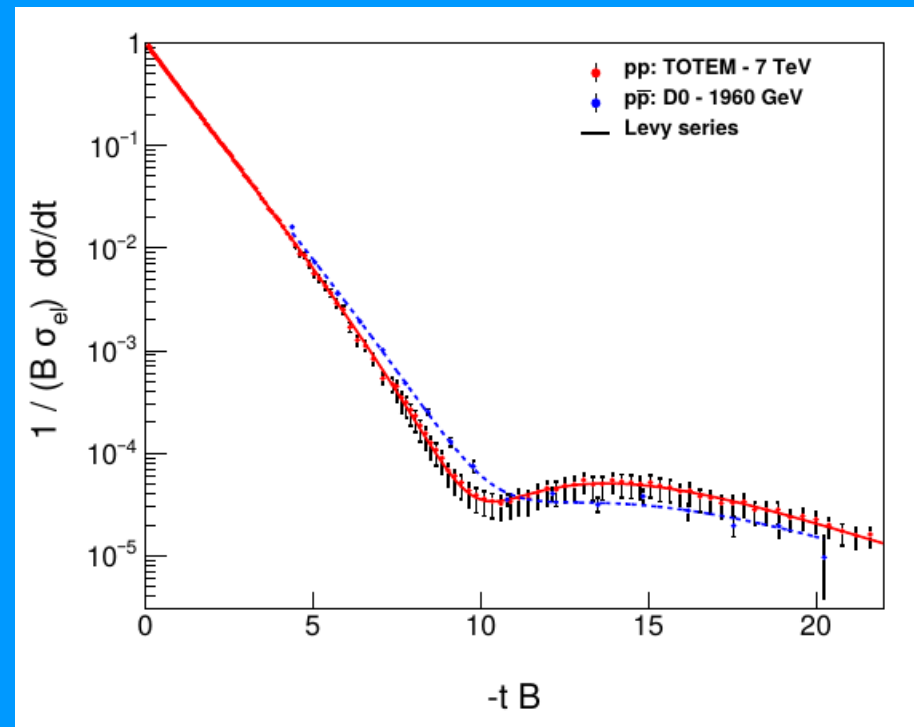
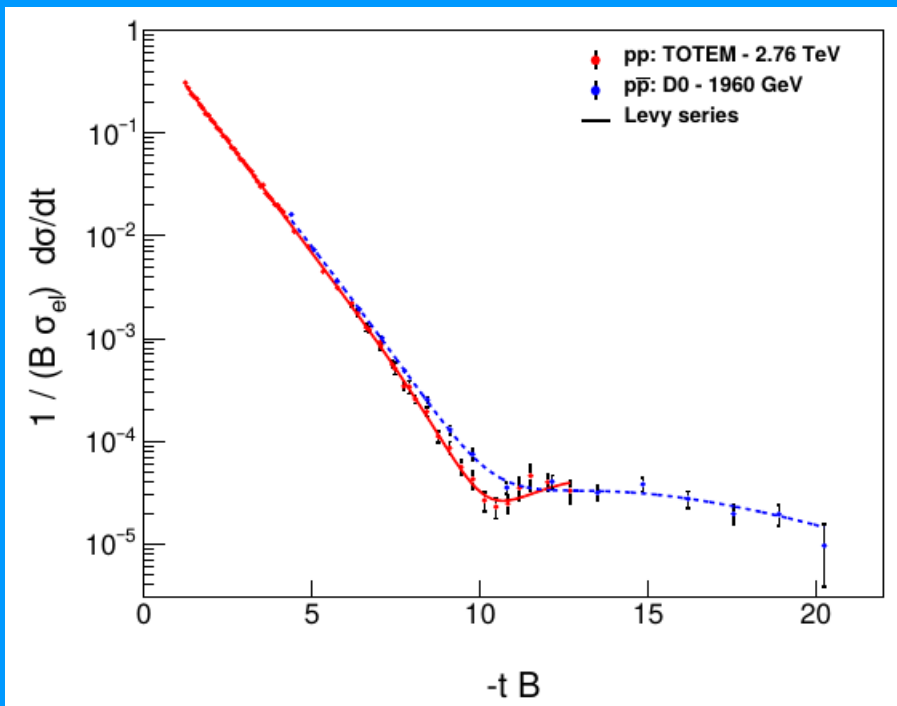
Argument 2:

At 13 TeV other effects, like hollowness have influence, too

H(x) scaling

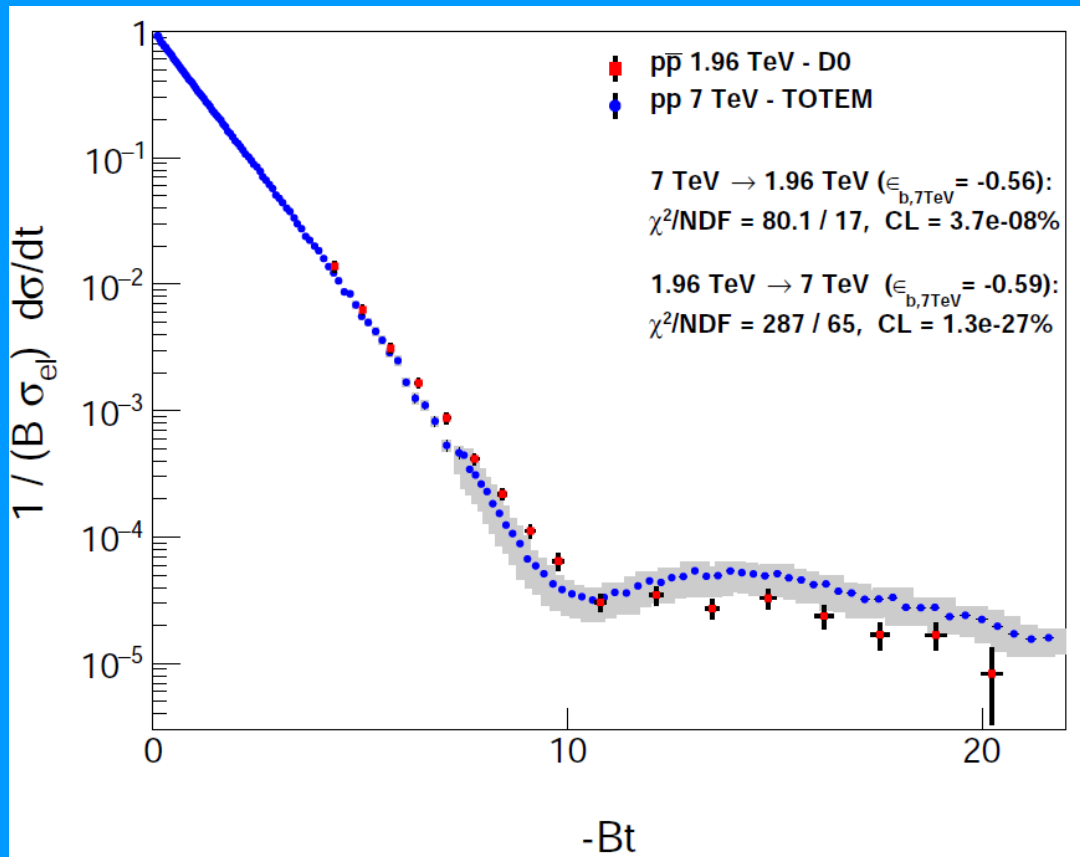
Scaling is not justified well enough beyond the dip and bump region

Arguments: 1) we give detailed study about its validity there. 2) In case of 1.96 and 7 TeV H(x) data are within systematic errors. 3) In addition, the Odderon signal mainly comes from before the dip



H(x) scaling

The significance of Odderon (6.26σ) is influenced by a not exact scaling



Argument 1:

It was shown, within a few factors in energy $H(x)$ distributions are within 1σ

Argument 2:

The final significance is the least value within the systematic errors of the $H(x)$'s. (Worst case scenario)

Bialas-Bzdak model

The model extrapolates pp and ppbar elastic scattering cross sections in a few TeV energy domain via the extrapolations of its model parameters extracted from fits to existing data sets

Corresponding fits, results and their plots can be seen in I. Szanyi's talk

The model does not work at very low- t region of elastic scattering
Argument: *relevant 1.96 TeV ppbar data are above this small - t region*

It can not extrapolate to ISR energies and to 13 TeV
Argument: *Odderon search is concentrated in a few TeV region*

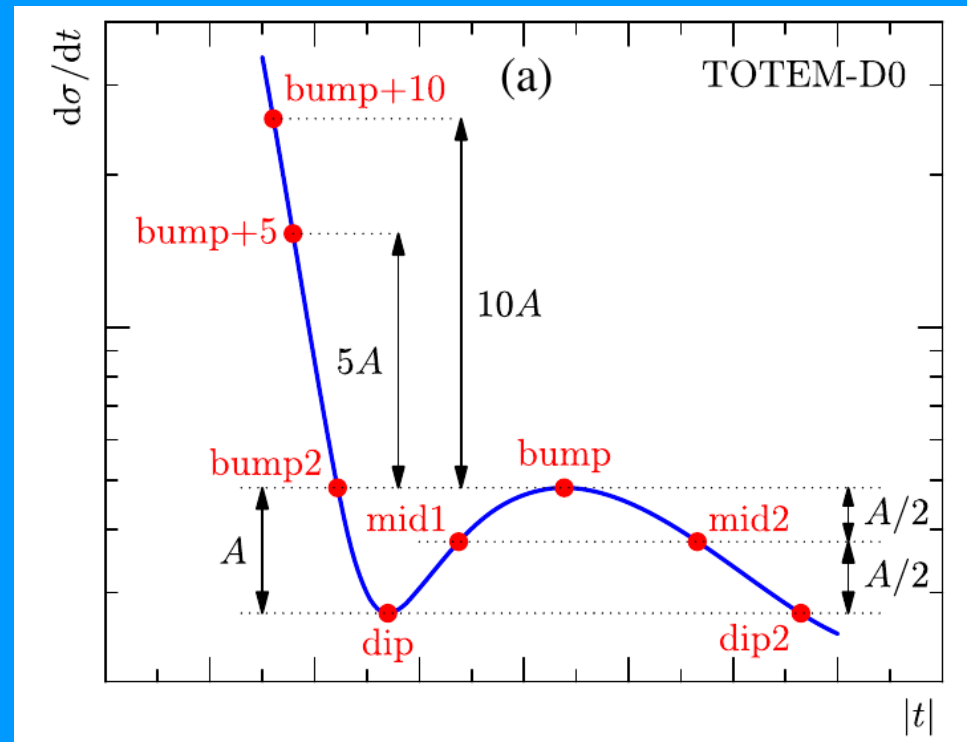
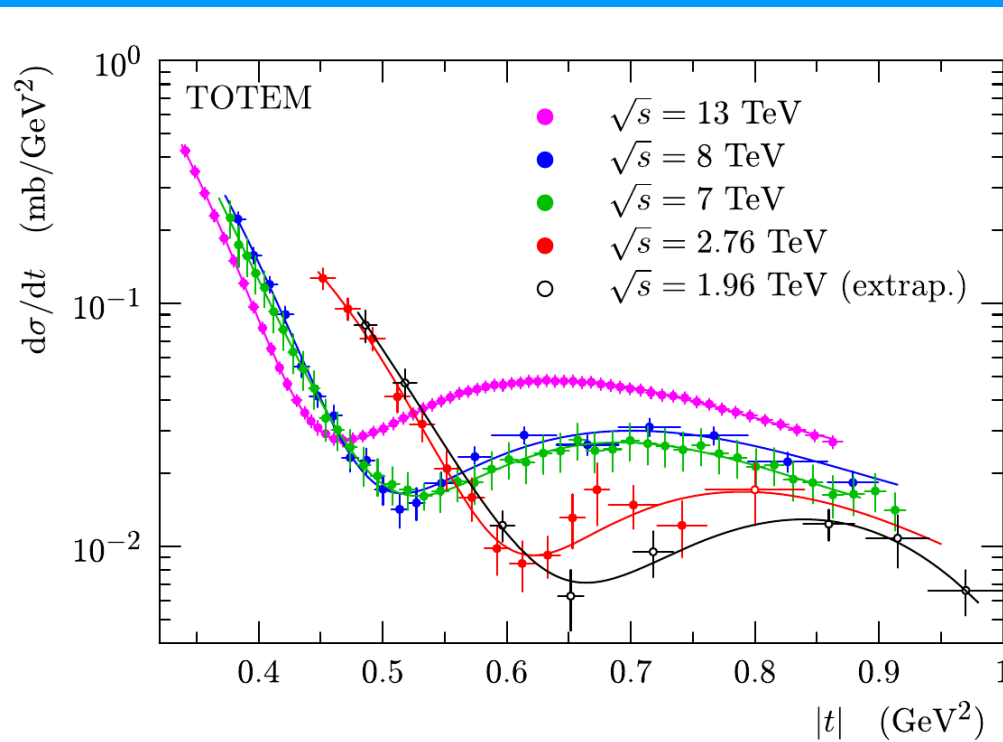
Bialas-Bzdak model

Significant Odderon effects can be extracted in an upward extrapolation from 1.96 TeV ppbar data to 2.76 and 7 TeV pp data

Argument: It depends on the the error bars of data and on the extrapolated data which is different in the two extrapolation directions since the extrapolation uncertainties increase downwards

TOTEM-D0 extrapolation

4 elastic scattering pp data sets at 2.76, 7, 8 and 13 TeV are used to extrapolate to 1.96 TeV pp to be able to compare with 1.96 TeV ppbar data measured by D0 Collaboration. 8 characteristic points were selected in each double exponential fits

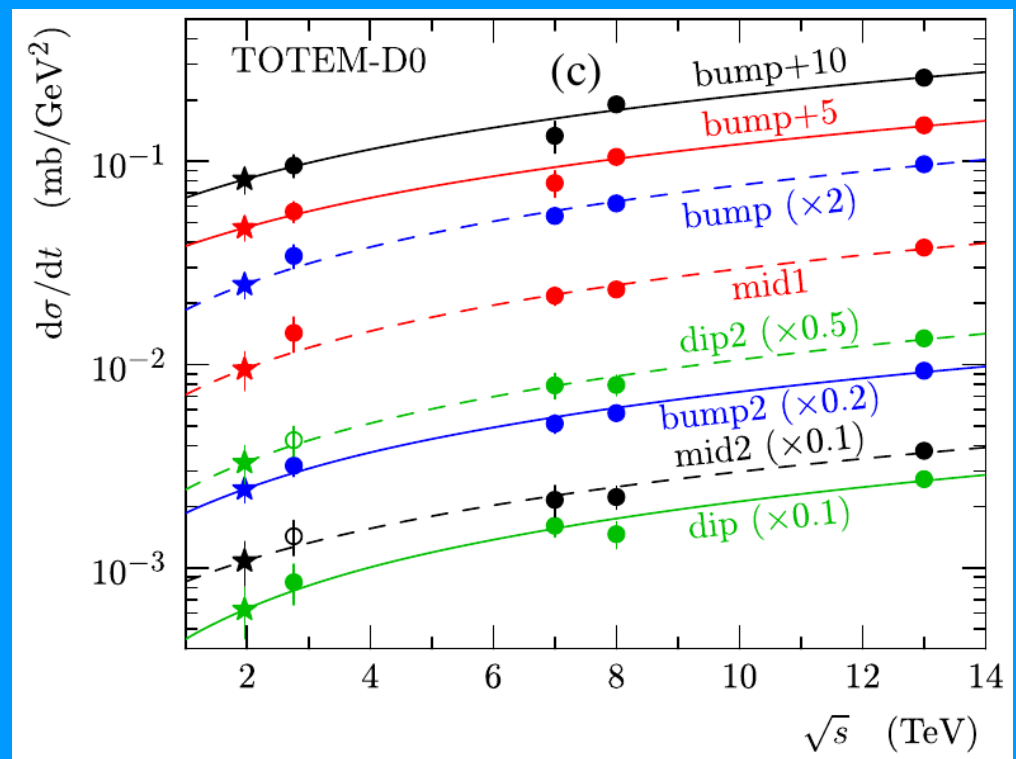
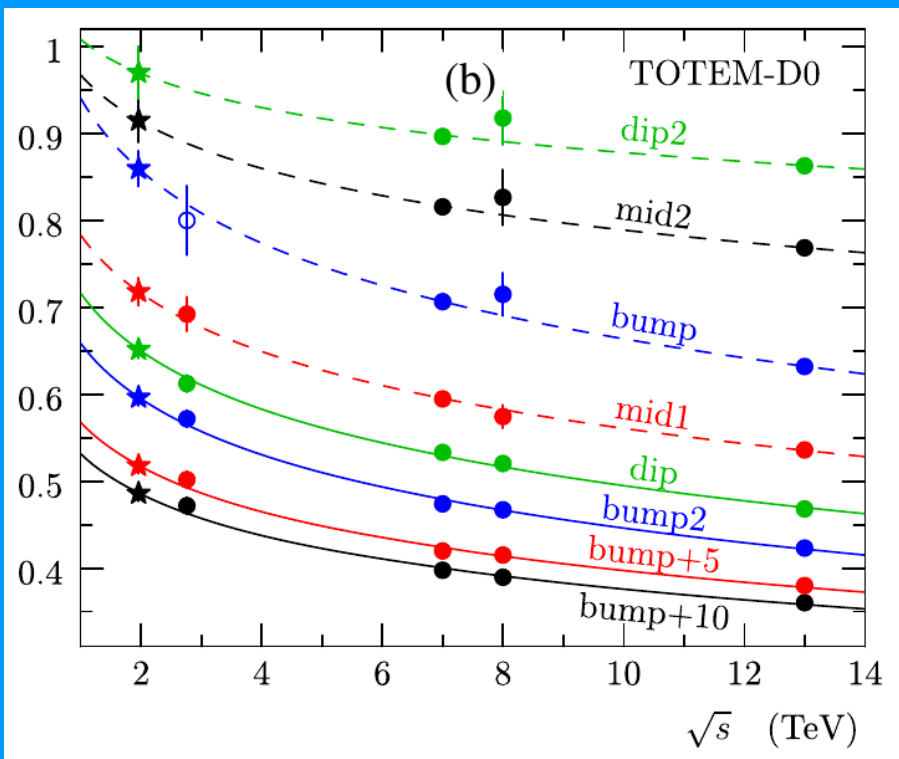


TOTEM-D0 extrapolation

Extrapolations in s are model dependent (sounded at conf.s, too)

Argument: *They are rather parametrizations*

$$|t| = a \log(\sqrt{s}) + b \text{ and } (d\sigma/dt) = c\sqrt{s} + d$$



TOTEM-D0 extrapolation

For normalization, an extrapolation of σ_{tot} 's to 1.96 TeV is model dependent

Argument: It is rather a parametrization

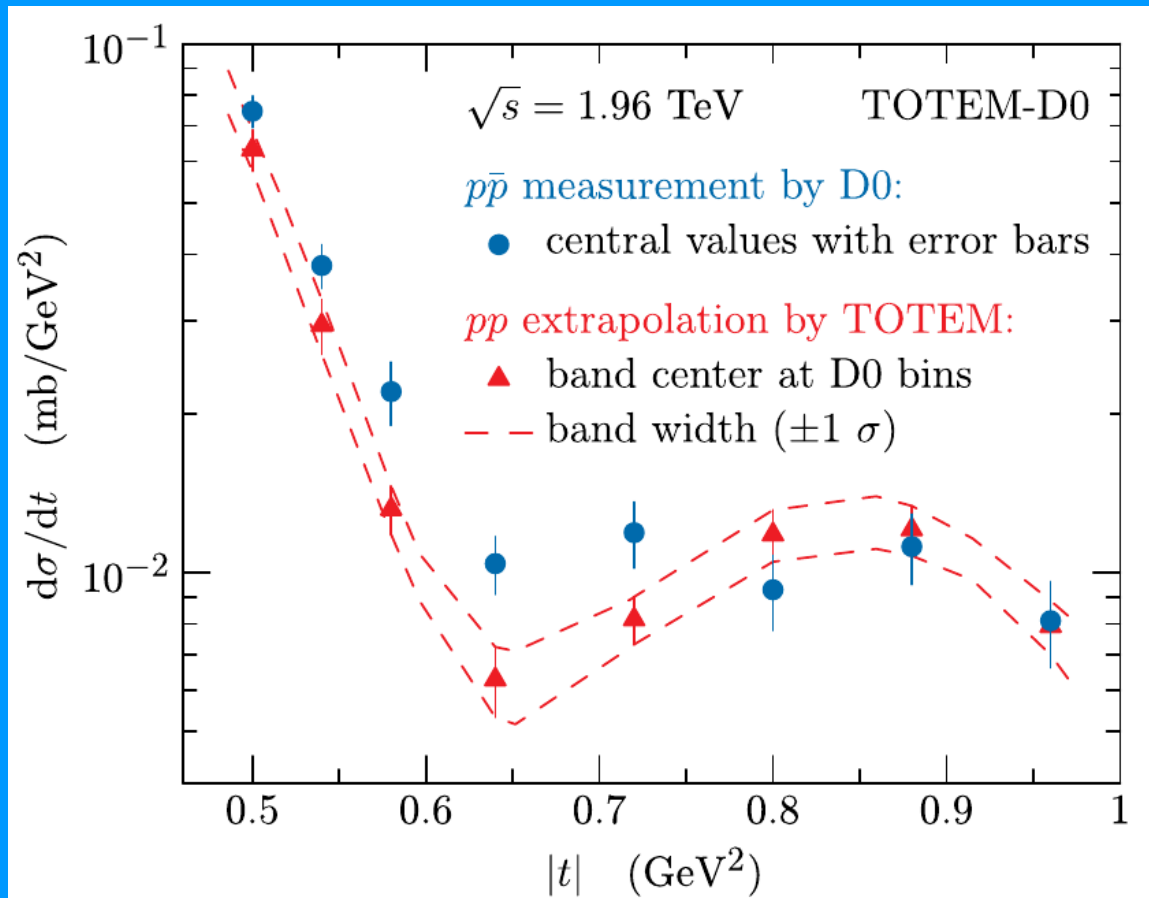
$$\sigma_{\text{tot}}^2 = \frac{16\pi(\hbar c)^2}{1 + \rho^2} \left(\frac{d\sigma}{dt} (t = 0) \right)$$

$$\sigma_{\text{tot}} = b_1 \log^2(\sqrt{s}/1 \text{ TeV}) + b_2 \quad (2)$$

gives $\sigma_{\text{tot}}^{pp}(1.96 \text{ TeV}) = 82.7 \pm 3.1 \text{ mb}$ [43]. The extrapolated cross section is converted to a differential cross section $d\sigma/dt = 357 \pm 26 \text{ mb/GeV}^2$ at $t = 0$ using the optical theorem

TOTEM-D0 extrapolation

The equality of Optical Points at $-t = 0$ of the two 1.96 TeV data sets (pp and ppbar) is an assumption. In the ref. it is asymptotical



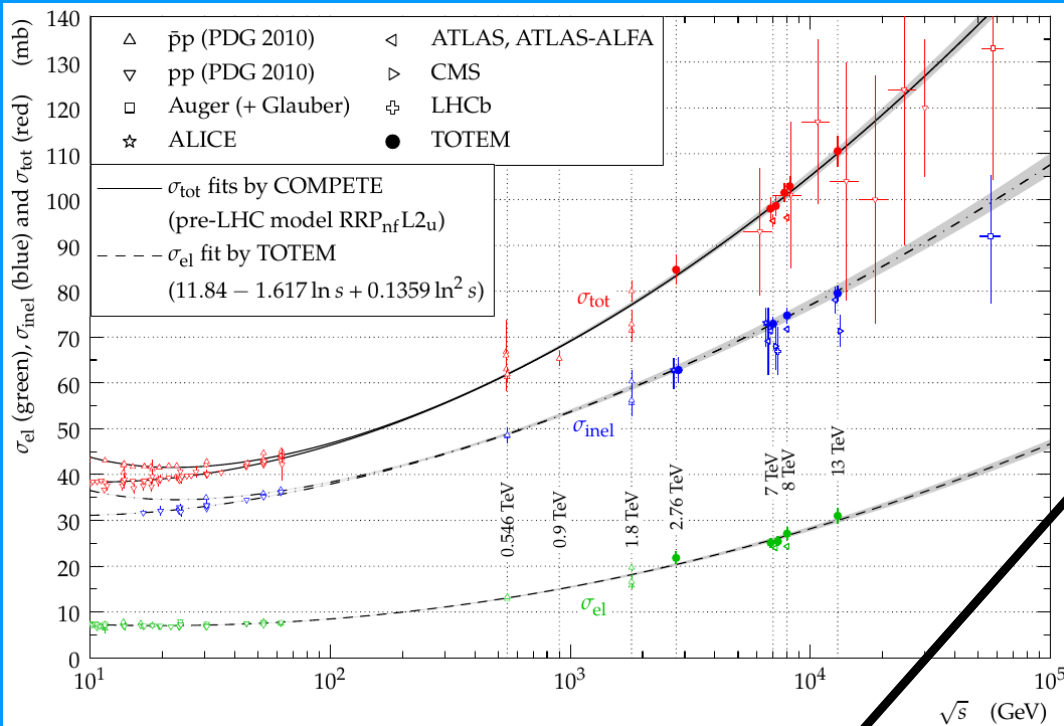
Argument: *we are in the asymptotical region of energies*

TOTEM-D0 extrapolation

In all other TOTEM publications σ_{tot} 's are fitted by

$$a + b \ln(s) + c \ln^2(s).$$

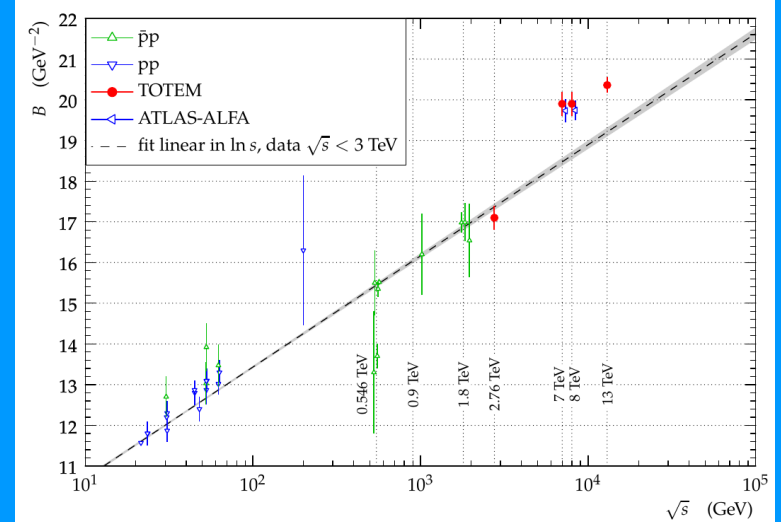
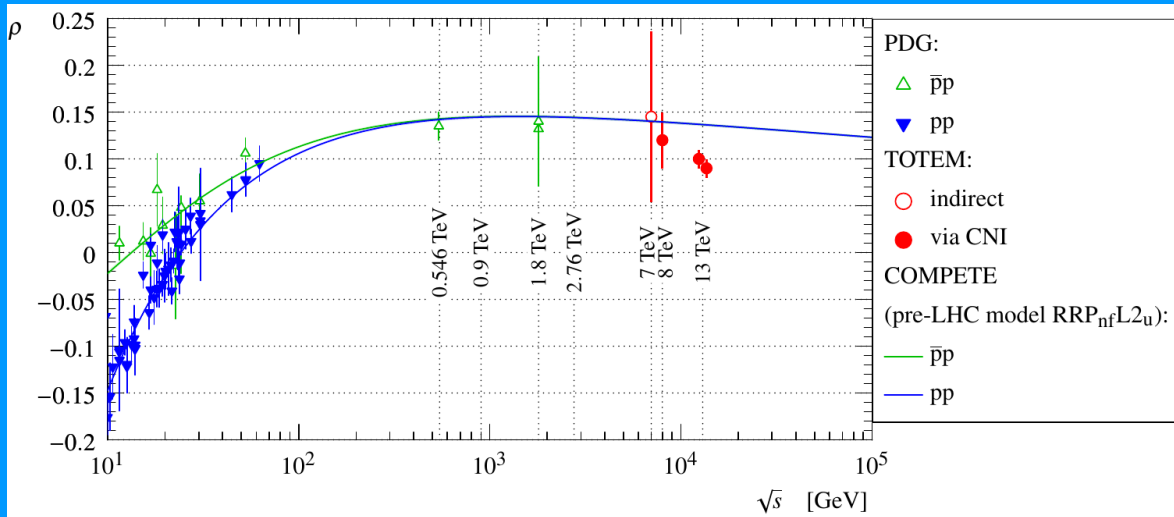
The σ_{tot} 's obtained by the two different fits are contradictory



Collab.	E_{pp} (GeV)	σ_{tot}	ρ	$d\sigma_{1960}/dt(t=0)$ (OP)	Δ_{1960}	Ref.			
D0-ppbar	1960			341	49	0,0%	PRD 86 (2012), PRL 127 (2021), EPJC 81 (2021)		
TOTEM-D0	1960	82,7	3,1	0,145	0,10	357	26	-4,6%	PRL 127 (2021) (pub. Odderon; extrapolated)
TOTEM	1960	78,0	0,2	0,145	0,10	317	2	6,9%	EPJC 79 (2019) (pub. 13TeV, etc; extrapolated)

TOTEM-D0 extrapolation

Cross-check of OP normalization of estimated pp 1.96 TeV by H(x)



Collab.	E_{pp} (GeV)	σ_{tot}	ρ	$d\sigma_{1960}/dt(t=0)$ (OP)	Δ_{1960}	σ_{el}	B	$d\sigma/dt(t=0)$ (OP)	Ref.				
D0-ppbar	1960			341	49 0,0%	20,2	1,7	16,86	0,22	PRD 86 (2012), PRL 127 (2021), EPJC 81 (2021)			
TOTEM-D0	1960	82,7	3,1	0,145	0,10	357	26 -4,6%			PRL 127 (2021) (pub. Odderon; extrapolated)			
TOTEM	1960	78,0	0,2	0,145	0,10	317	2 6,9%	18,5	0,2	17,00	0,10	EPJC 79 (2019) (pub. 13TeV, etc; extrapolated)	
H(x) scaled	2760	84,7	3,3	0,145	0,10	316		21,8	1,4	17,10	0,30	374	EPJC 80 (2020), PoS DISM2017 (2018) 059
H(x) scaled	7000	98,6	2,2	0,145	0,10	316		25,4	1,1	19,89	0,03	507	EPL 101 (2013)
H(x) scaled	8000	102,9	2,3	0,120	0,03	316		27,1	1,4	20,14	0,15	549	EPJC 76 (2016), PRL 111 (2013)
H(x) scaled	13000	110,6	3,4	0,100	0,01	315		31,0	1,7	20,36	0,19	631	EPJC 79 (2019)

TOTEM-D0 extrapolation

Definitions of d.o.f. contradict each other In TOTEM-D0 and PHENIX

$$\chi^2 = \sum_{\text{points } i,j} \left\{ \left(\frac{d\sigma_{el,i}^{pp}}{dt} - \frac{d\sigma_{el,i}^{p\bar{p}}}{dt} \right) C_{i,j}^{-1} \left(\frac{d\sigma_{el,j}^{pp}}{dt} - \frac{d\sigma_{el,j}^{p\bar{p}}}{dt} \right) \right\} + \frac{(A - A_0)^2}{\sigma_A^2} + \frac{(B - B_0)^2}{\sigma_B^2}$$

• where $C_{i,j}$ covariance matrix and A & B two constraints \Rightarrow 8 points, 6 d.o.f.

PHENIX

$$\tilde{\chi}^2(\epsilon_b, \epsilon_c, p) = \left[\left(\sum_{i=1}^n \frac{(y_i + \epsilon_b \sigma_{b_i} + \epsilon_c y_i \sigma_c - \mu_i(p))^2}{\tilde{\sigma}_i^2} \right) + \epsilon_b^2 + \epsilon_c^2 \right]$$

For any fixed values of ϵ_b , ϵ_c , Eq. **3** follows the χ^2 distribution with $n + 2$ degrees of freedom, for testing the theoretical predictions $\mu_i(p)$, because it is the sum of $n + 2$ Gaussian distributed random variables. The

Conclusion

Published Odderon results have been critically scrutinised

Assumptions and conditions with possible influence on results were shown and investigated in each of the 3 different methods

Careful studies are needed in each case to address some existing uncertainties about the full correctness of the determination of Odderon effects

Possible corrections are expected to not question the existence of the Odderon