H(x) scaling and Levy description of elastic pp and ppbar scattering

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Content

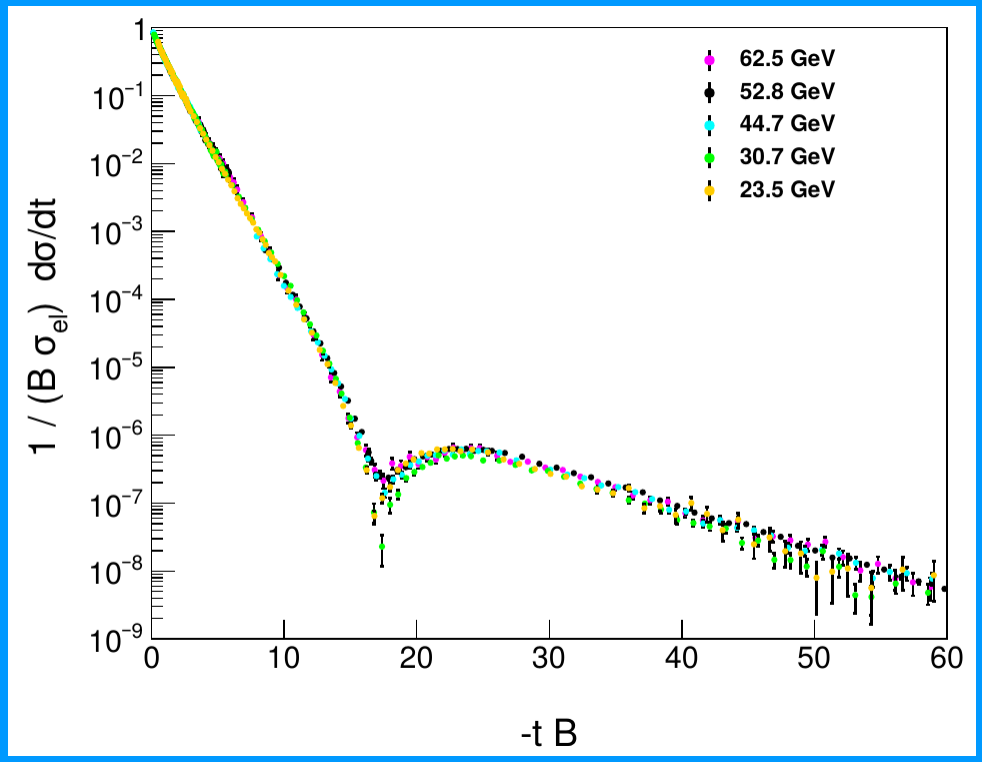
- A critical review of 3 recently published Odderon papers and methods:
  1) Model independent: H(x) scaling
     (Csörgő, Novák, Pasechnik, Ster, Szanyi, *EPJC (2021) 81:180)*
  2) Model dependent: Bialas-Bzdak model
     (Csörgő, Szanyi, *EPJC (2021) 81:611)*
  3) Semi model independent: TOTEM-D0 extrapolation
     (TOTEM-D0 Coll., *PRL (2021) 127, 062003)*
- H(x) scaling of recently released 8 TeV elastic pp data
- New Levy description of elastic pp data (preliminary)
- Conclusion pp

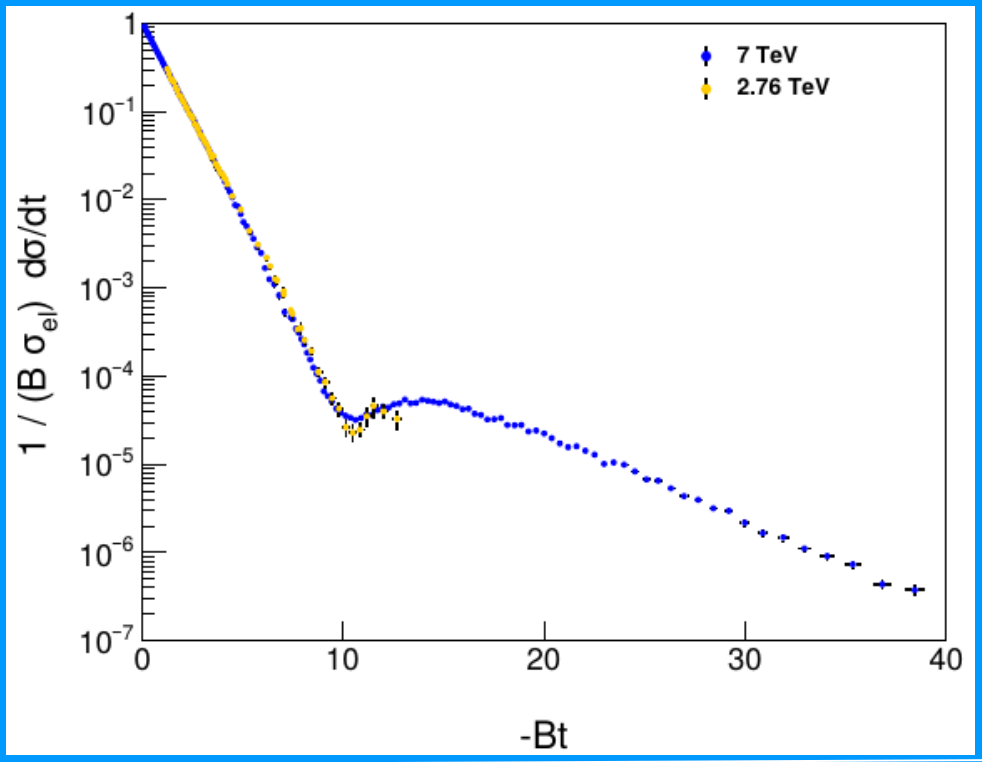
H(x) scaling

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

$$x = -tB$$

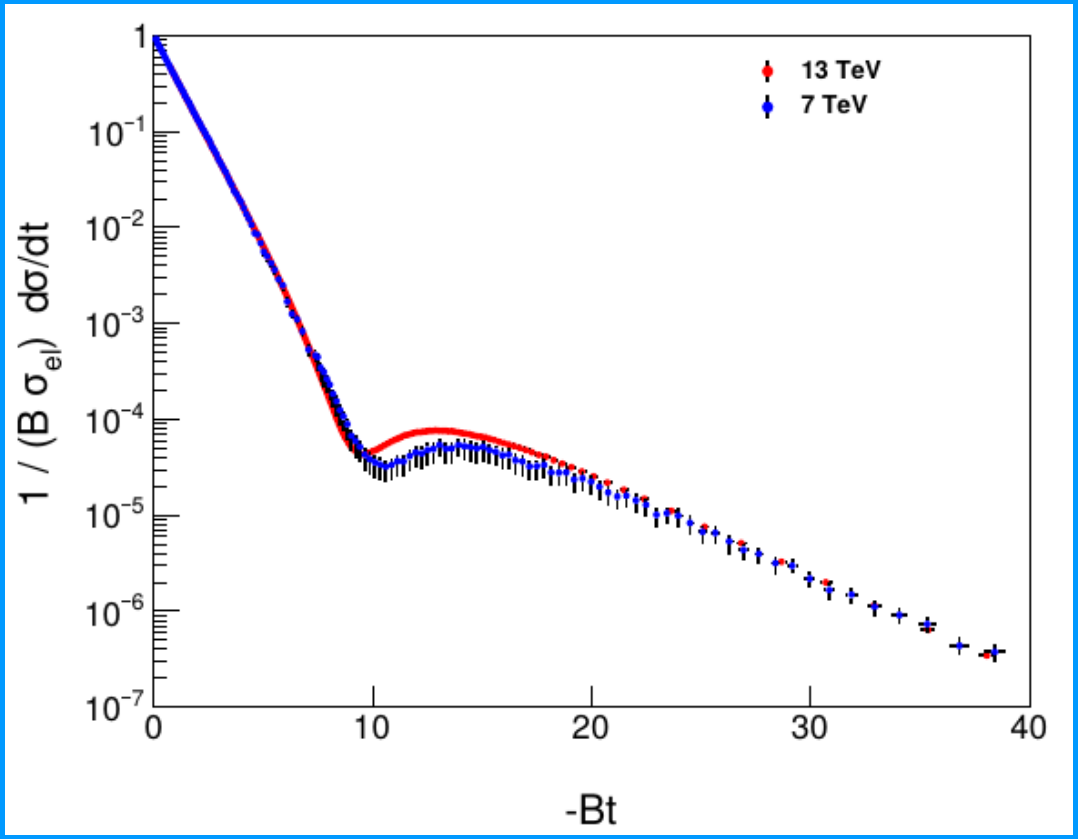
$$H(x,s) = (1/B\sigma_{\mathrm{el}})\, d\sigma/dt$$





H(x) scaling

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



Argument 1:

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

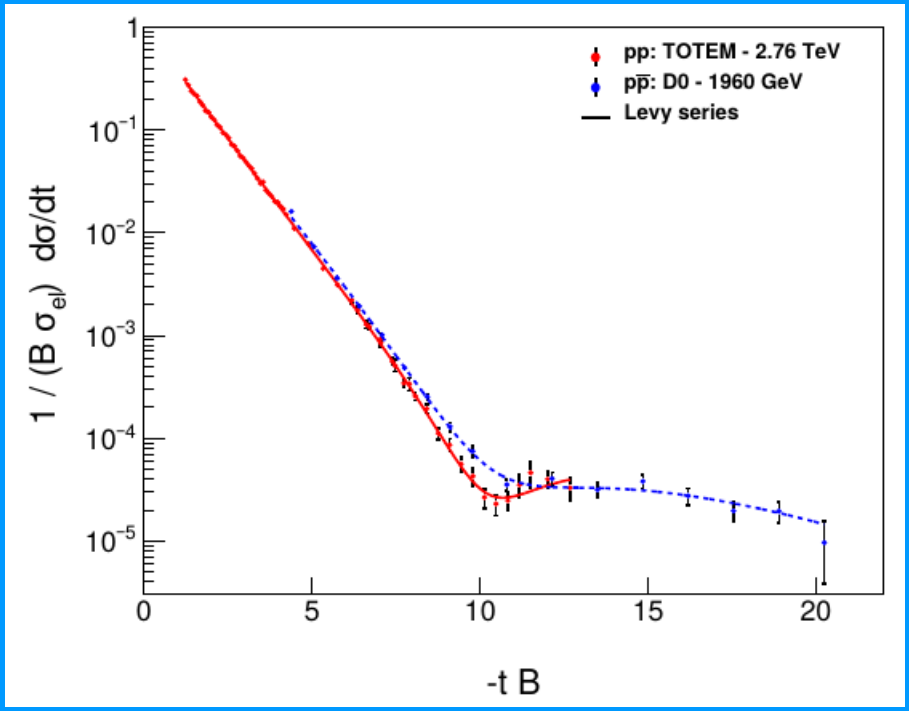
Argument 2:

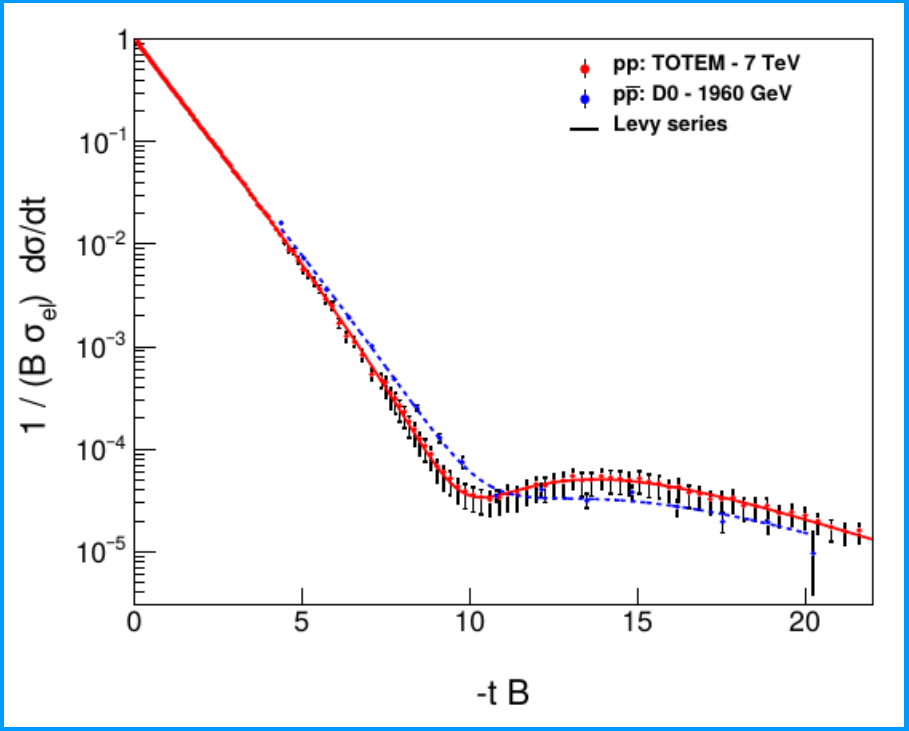
At 13 TeV other effects, like hollowness have influence, too

H(x) scaling

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

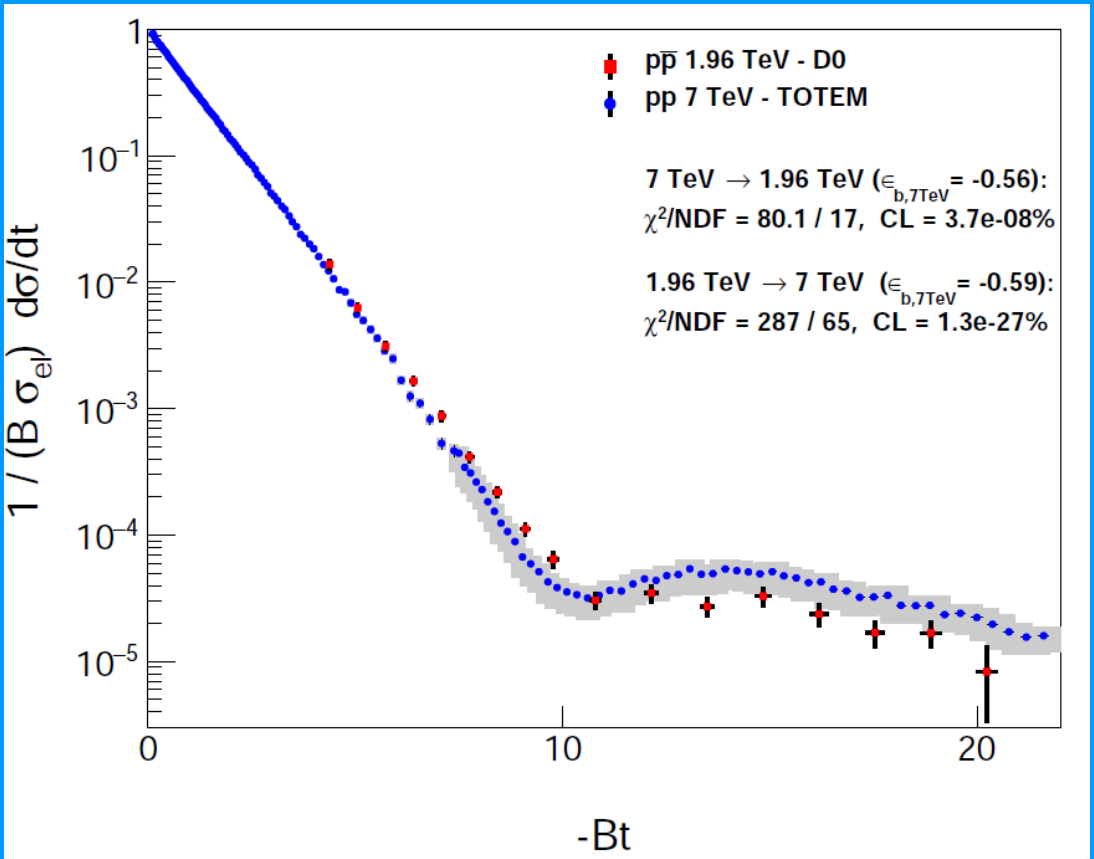
Arguments: 1) *we give detailed study about its validity in the paper.* 2) *In case of 1.96 and 7 TeV H(x) their data are within systematic errors.* 3) *In addition, the Odderon signal mainly comes from before the dip*





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

Correspondig 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*

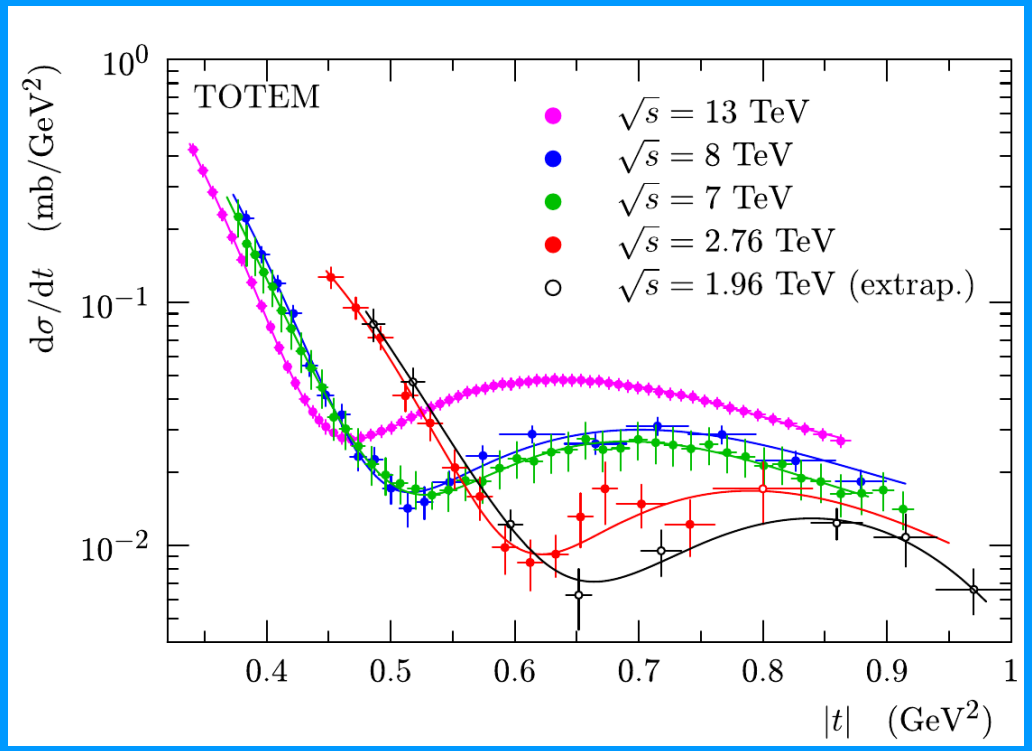
Bialas-Bzdak model

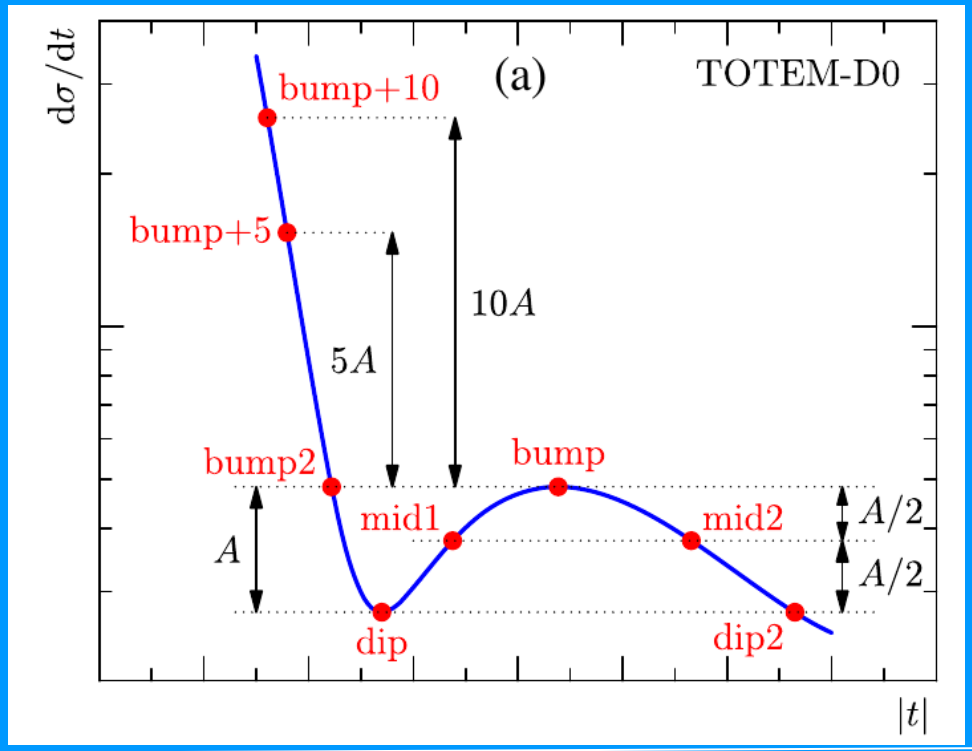
Significant Odderon effects can be extracted in an upward extrapolation from 1.96 TeV ppbar data to 2.76 and 7 TeV pp data

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 uncerties increase downwards*

TOTEM-D0 extrapolation

4 elastic scattering pp data sets at 2.76, 7, 8 and 13 TeV were 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



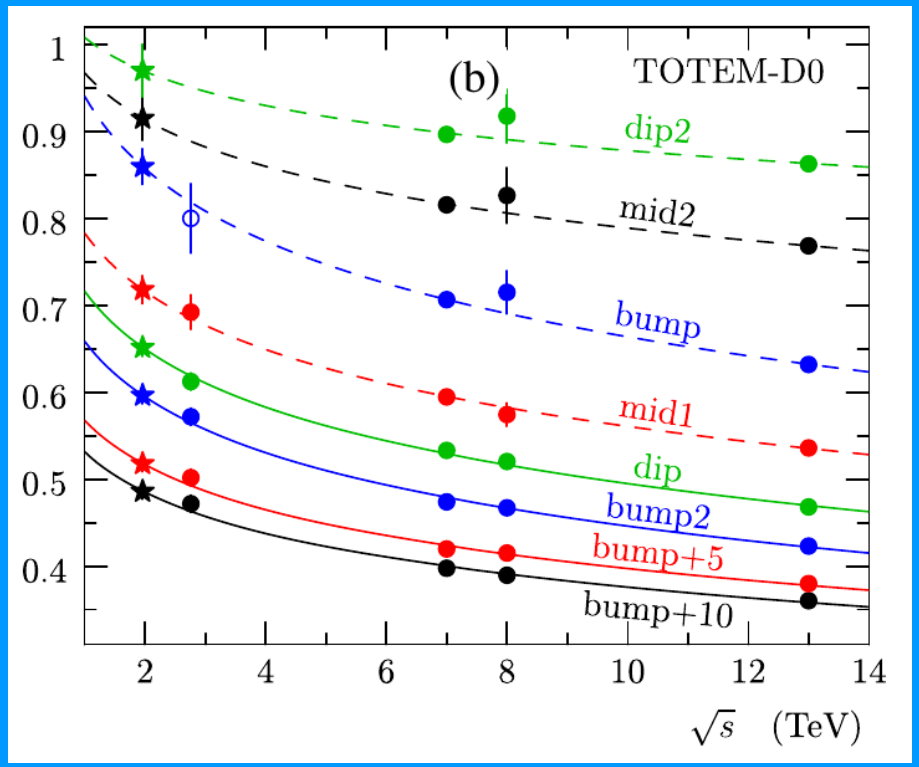


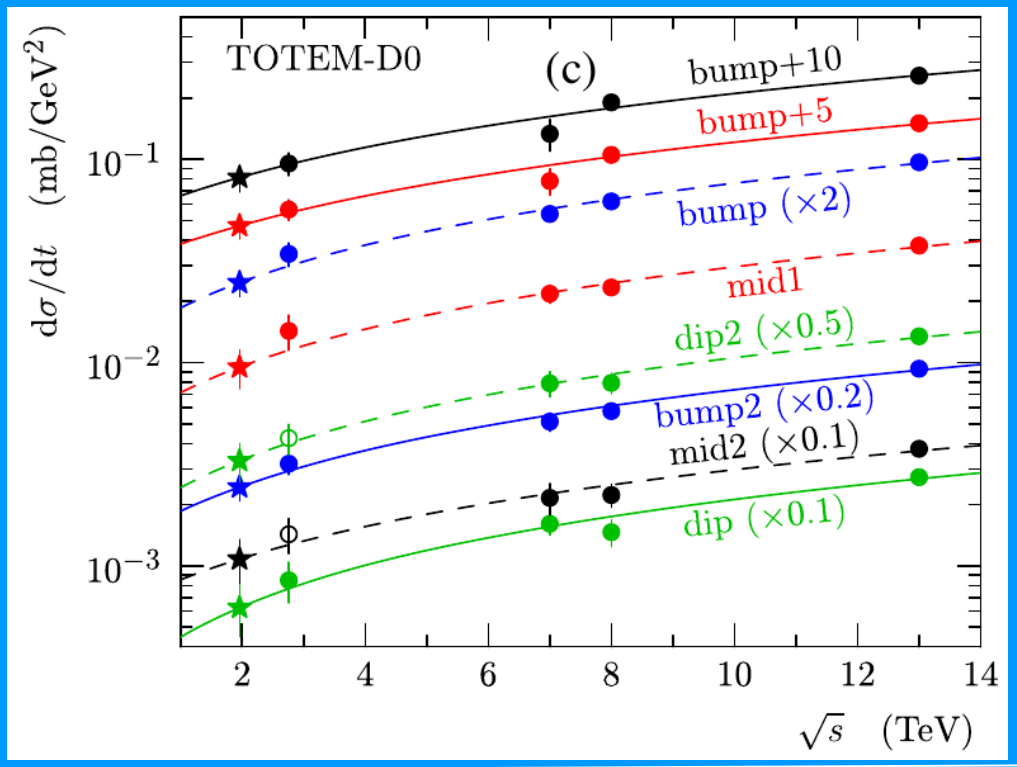
TOTEM-D0 extrapolation

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

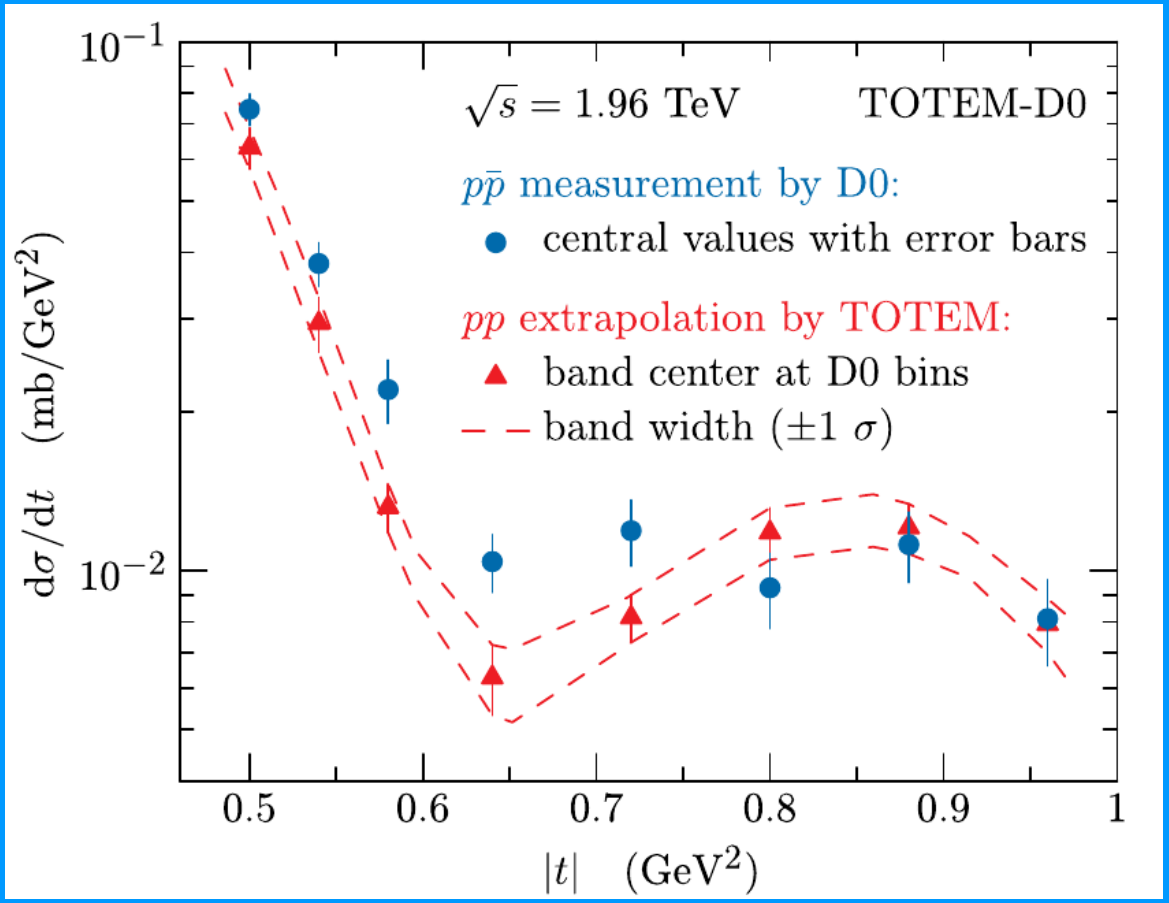
$$\sigma_{\text{tot}}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2}\left(\frac{d\sigma}{dt}(t=0)\right)$$

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

gives $\sigma_{\text{tot}}^{pp}(1.96\ \text{TeV}) = 82.7 \pm 3.1$ 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

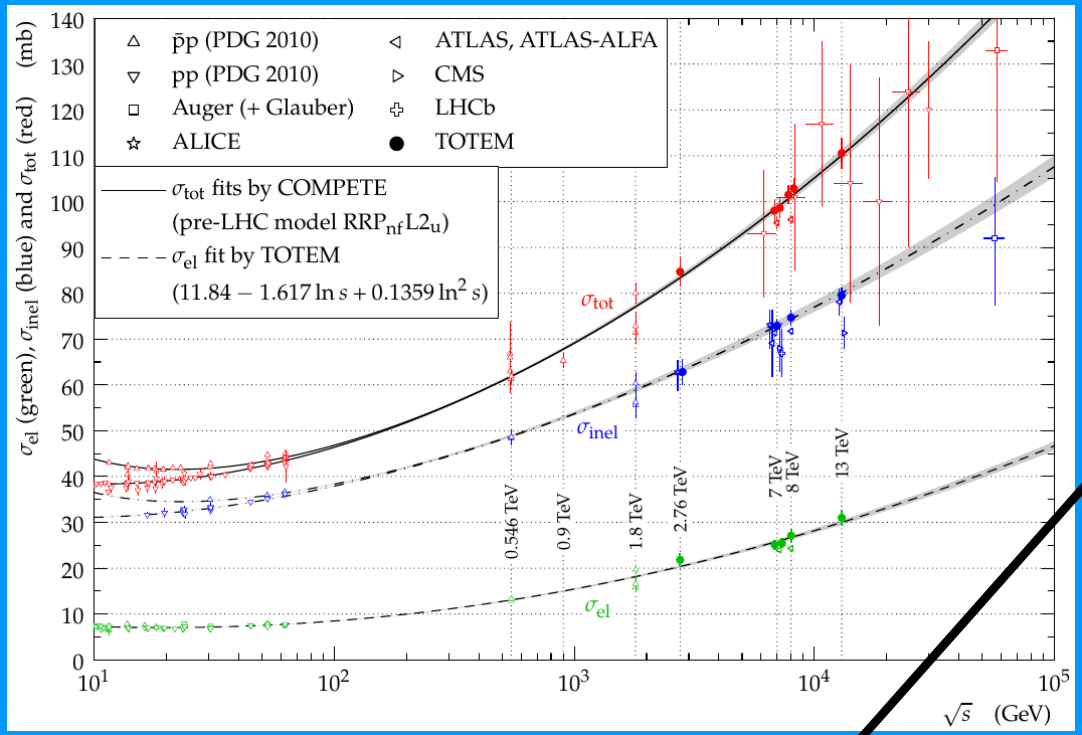
TOTEM-D0 extrapolation

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 asymtotical



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

TOTEM-D0 extrapolation



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

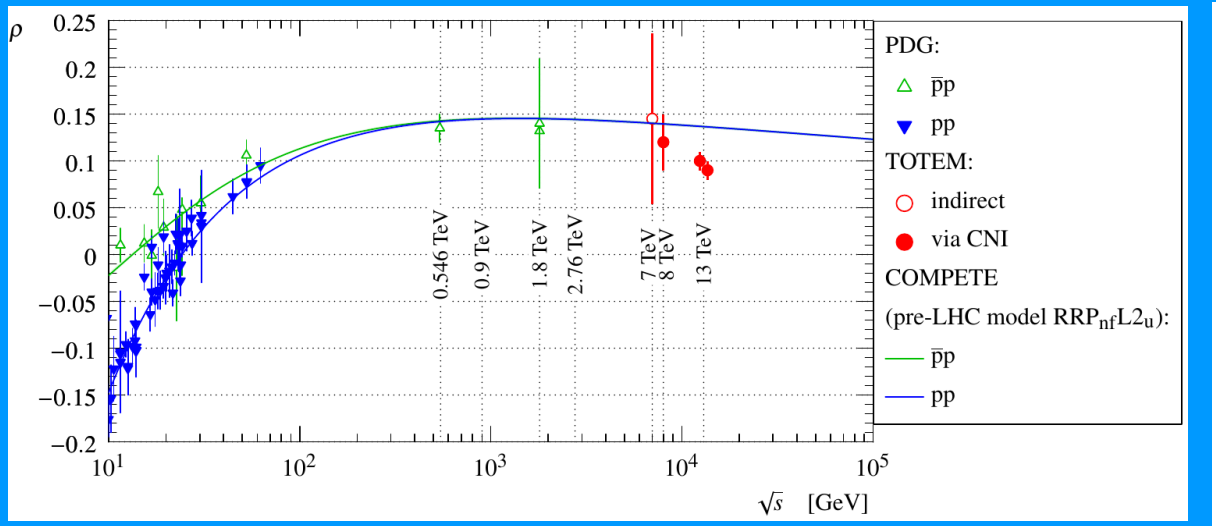
$$a + b \ln(s) + c \ln^2(s).$$

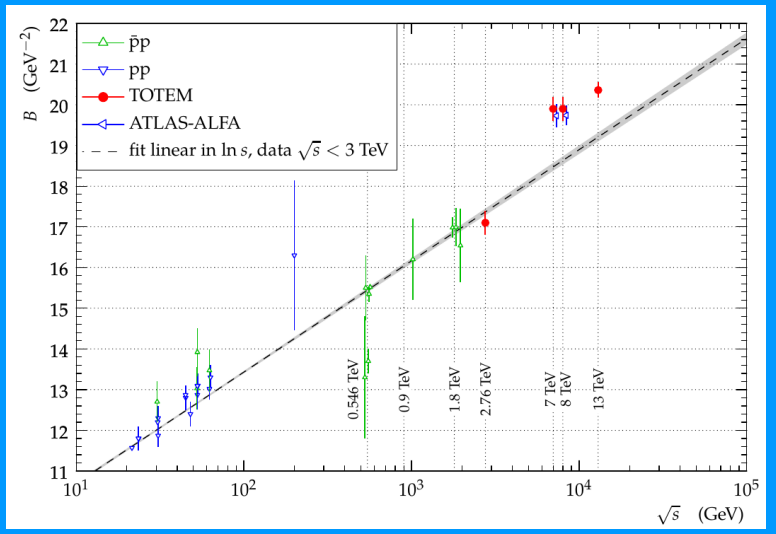
The σ_{tot}'s obtained by the two different fits are contradictory

Collab.	E_{pp}(GeV)	σ_{tot}		B		$d\sigma_{1960}/dt(t=0)$ (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

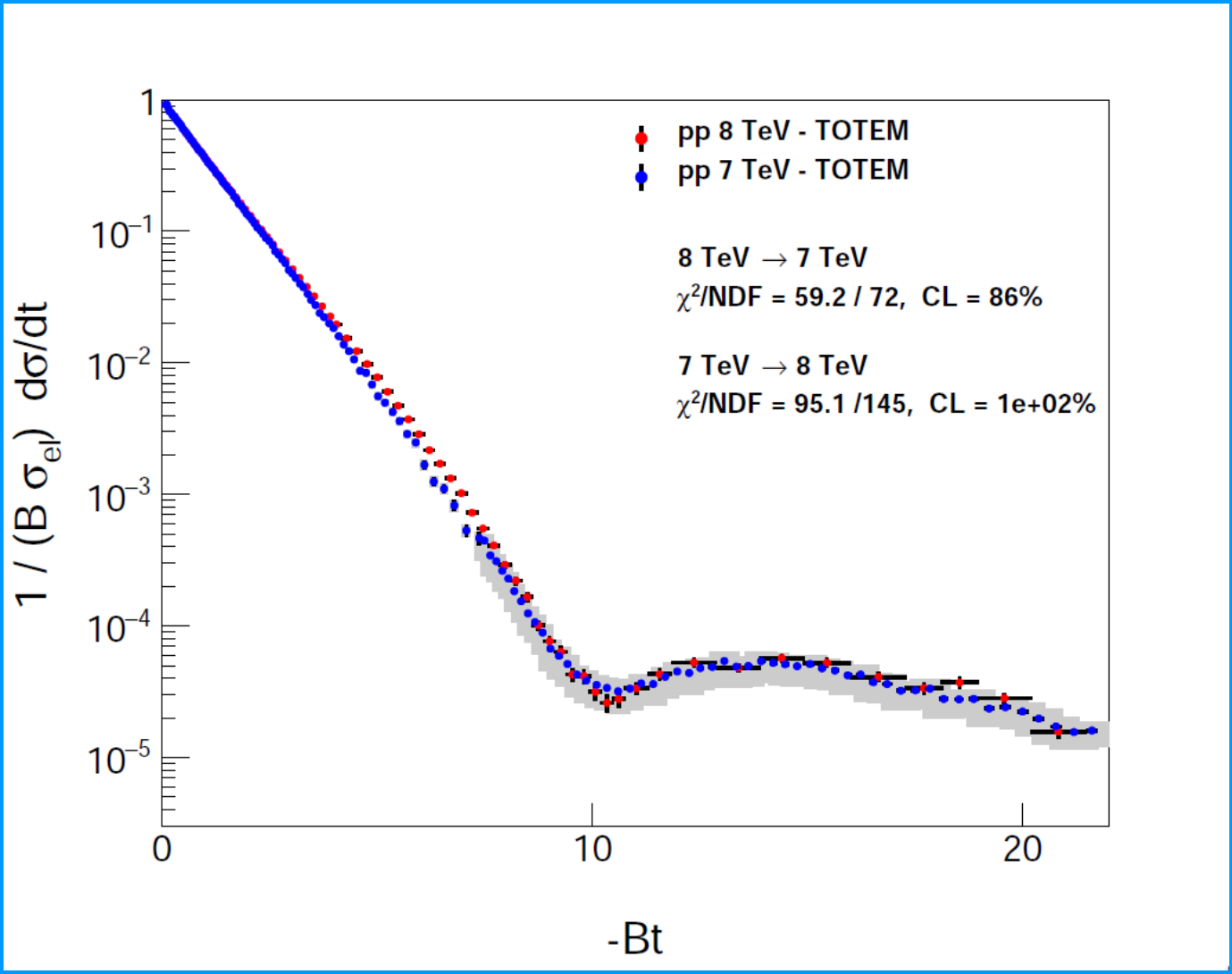
Cross-check of OP mormalization of estimated pp 1.96 TeV by H(x)





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)

H(x) scaling of recent 8 TeV elastic pp data



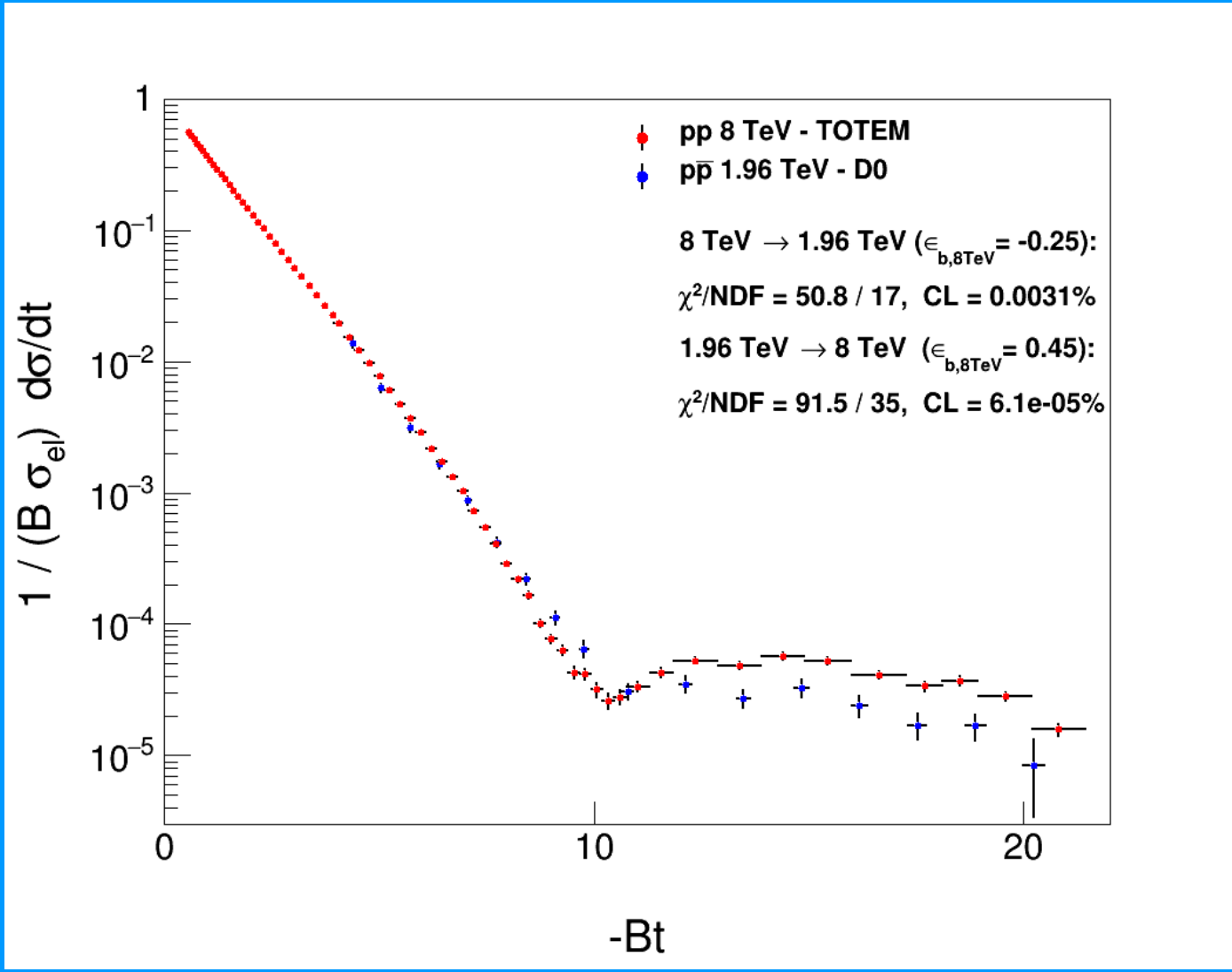
Significance of deviation in standard deviation to 7TeV:

$$\sigma_{min} = 0.18$$

With more realistic half-size x error bins:

$$\sigma_{min,} = 1.69$$

H(x) scaling of recent 8 TeV elastic pp data



Significance to 1.96 ppbar data:

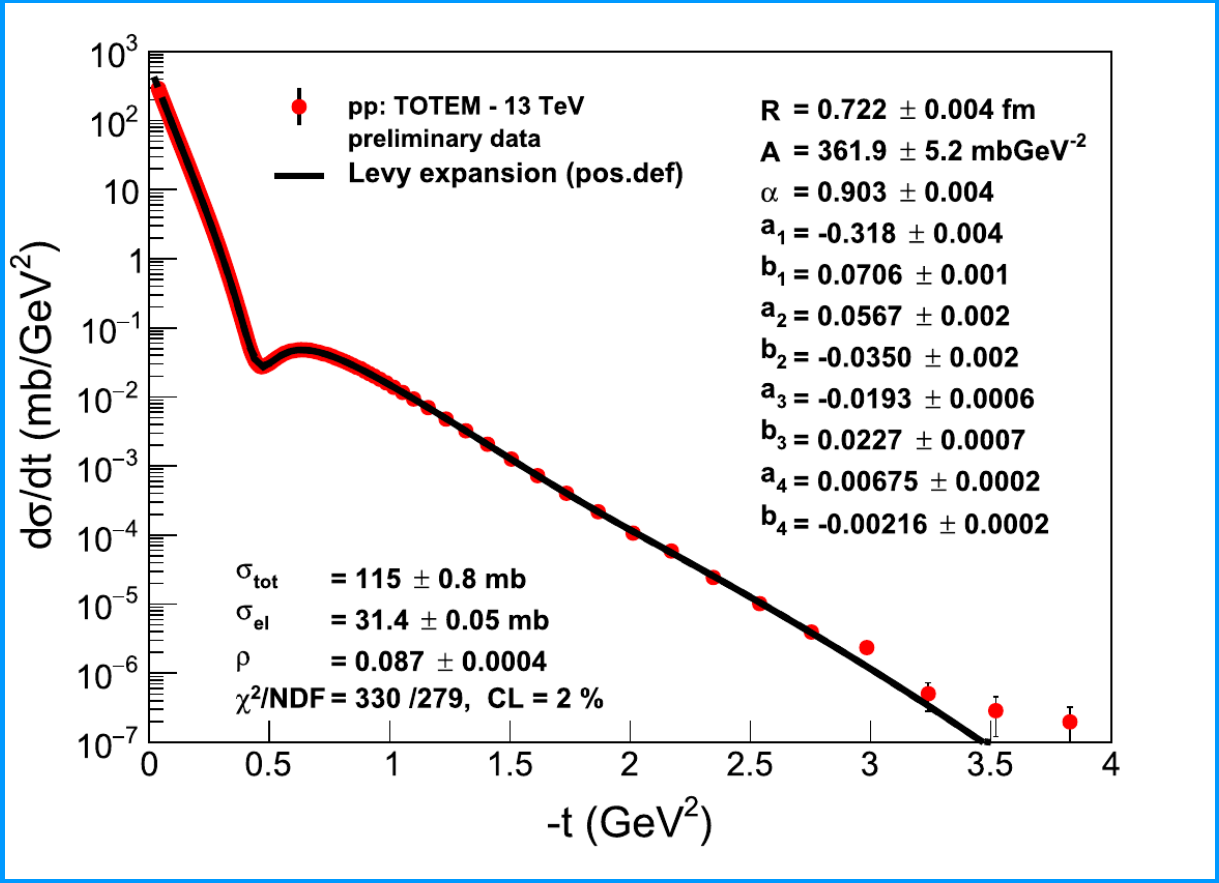
$\sigma_{min} = 4.16$

With more realistic half-size x error bins:

$\sigma_{min,} = 5.21$

Old Levy description of elastic pp data

Example of model independent orthonormal Levy parametrization up to 4th order *EPJC (2019)*, 79:62



New Levy description of elastic pp data (preliminary)

Based on Phillips-Barger model (succesful in limited –t and s regions), *Phys.Lett 46B (1973)* :

$$\frac{d\sigma}{dt} = |A_1 + A_2|^2 = |\, A\, e^{-Bt} + e^{-i\Phi t}\, C\, e^{-Dt}\,|^2$$

Generalized Phillips-Barger model by orthonormal Levy series:

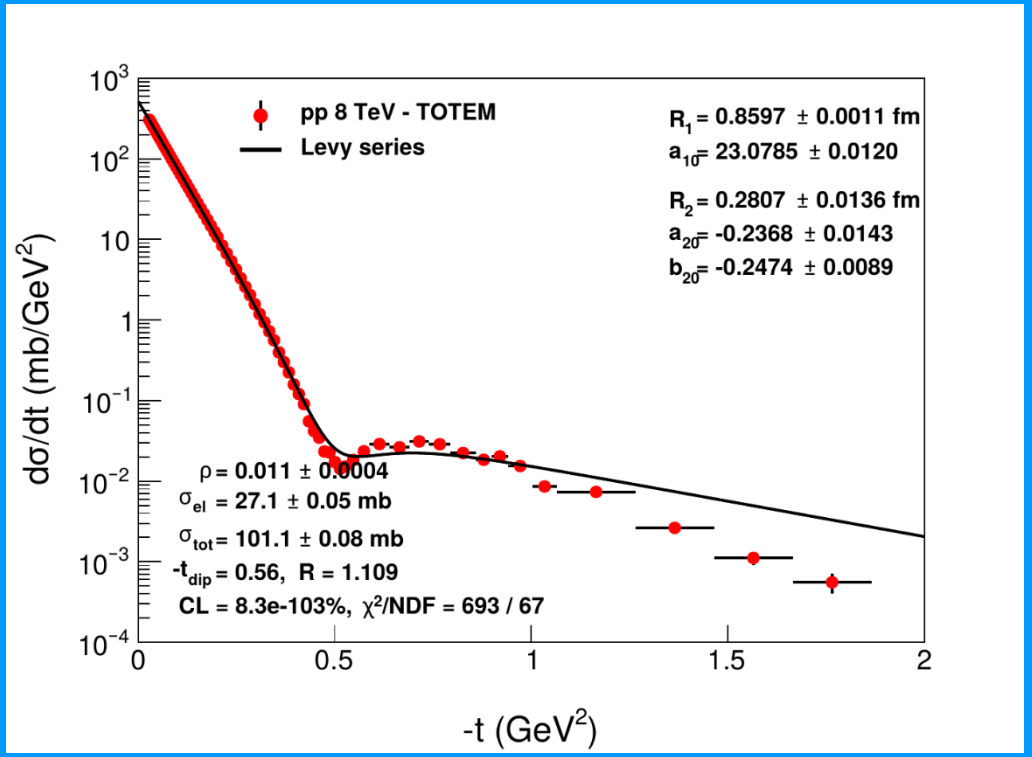
$$\frac{d\sigma}{dt} = \left| e^{-(R_1^2 t)^{\alpha 1}/2} \sum_{j=0}^{\infty} c_{1j}\, l_j + e^{-(R_2^2 t)^{\alpha 2}/2} \sum_{j=0}^{\infty} c_{2j}\, l_j \right|^2$$

where $l_j\,(R^2 t, \alpha)$ are the Levy orthonormal polynominals and $c_j = a_j + ib_j$

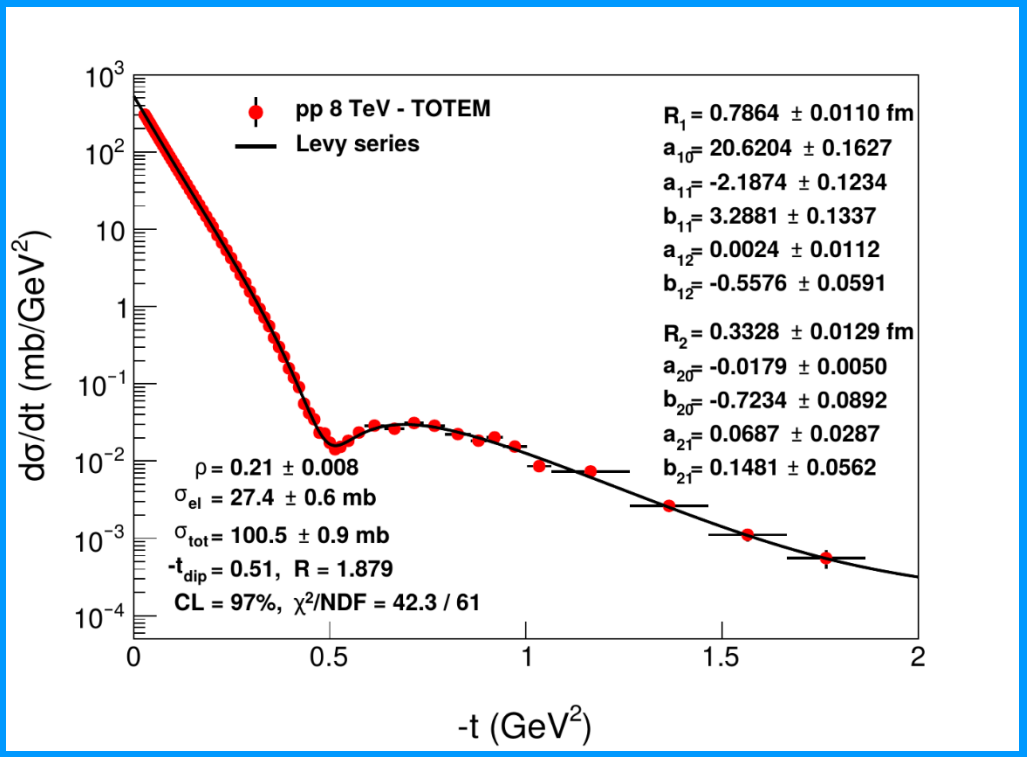
New Levy description of elastic pp data (preliminary)

Motivation: description of pp scattering data for the full coverage of the ppbar 1.96 TeV acceptance

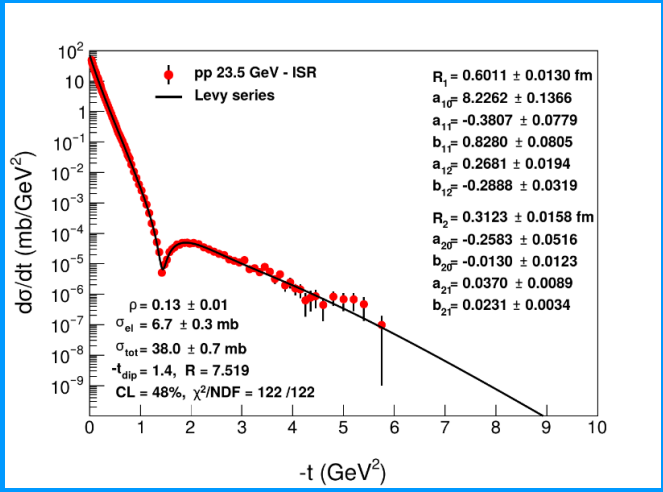
Phillips-Barger

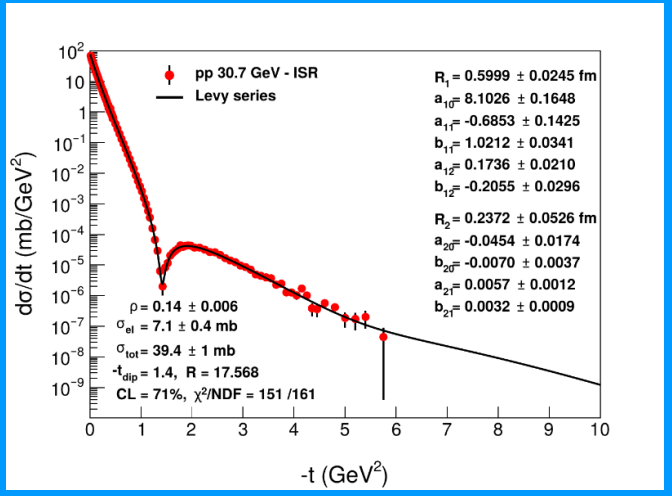


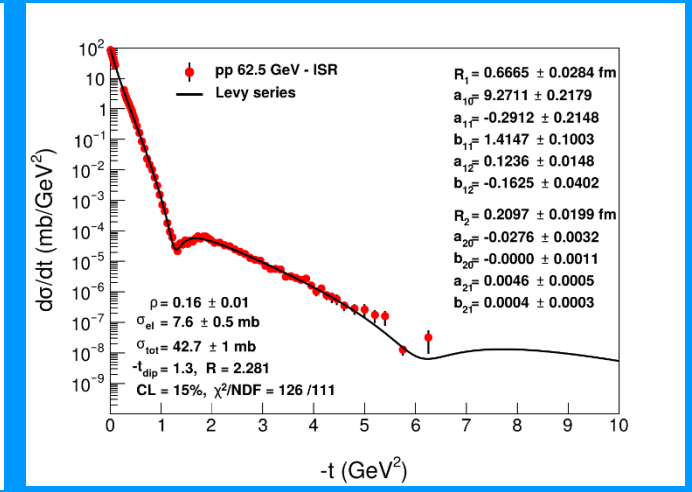
Levy generalized Phillips-Barger

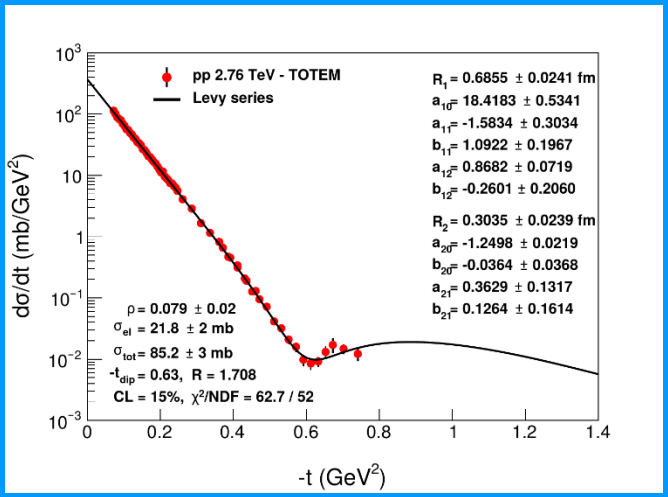


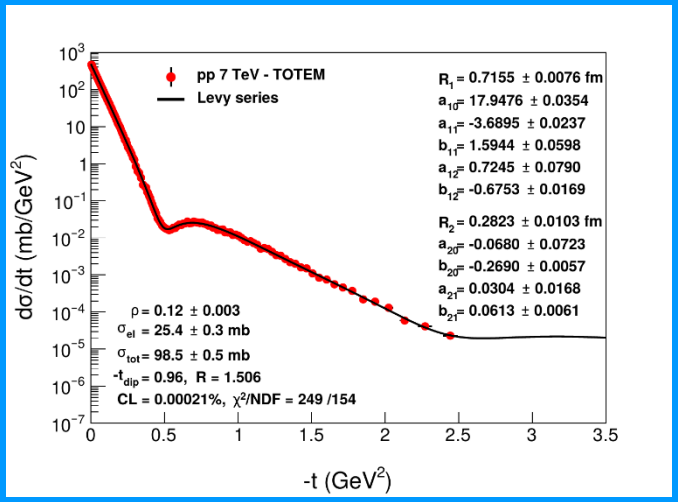
New Levy description of elastic pp data (preliminary)

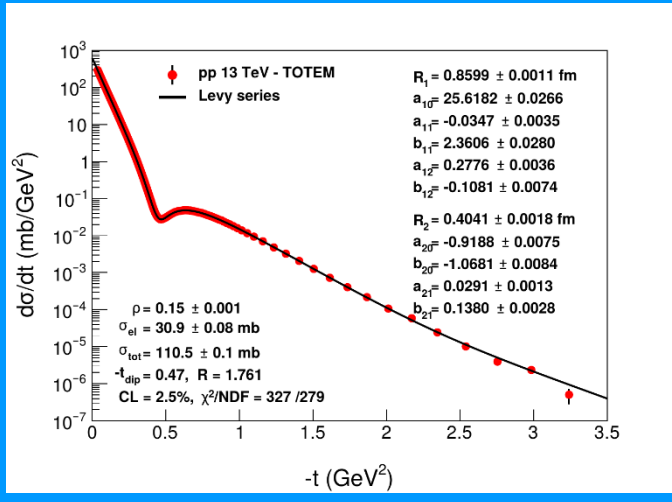












New Levy description of elastic pp data (preliminary)

Preliminary approximate values for the half spatial parameters ($R_1/2$) and ratios (R_1/R_2) (without error estimations):

23 GeV:	0.30 fm ,	1.92
30 GeV:	0.30 fm,	2.53
62 GeV:	0.33 fm,	3.18
2.76 TeV:	0.34 fm,	2.26
7 TeV:	0.36 fm,	2.54
8 TeV:	0.39 fm,	2.36
13 TeV:	0.43 fm,	2.13

The half extension values coincide with earlier assumed hard core nucleon radii (~0.40 fm) set in Glauber and DIPSY dipole simulations. It might reflect nucleon and di-quark type scattering

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

Newly released 8 TeV data confirm the Odderon signal via H(x) scaling

New Levy type expansion method was introduced to describe elasticc pp and ppbar scattering data for possible extrapolation to 1.96 TeV pp differential cross-section

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