Model-(in)dependent Odderon results

including ATLAS and TOTEM data

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Introduction: Odderon exchange in elastic pp

Model independent results:

Significance at least 6.26 σ

Model dependent results:

Significance at least 7.08 σ

New results at 8 TeV

1: H(x) scaling

2: ReBB Model vs ATLAS and TOTEM

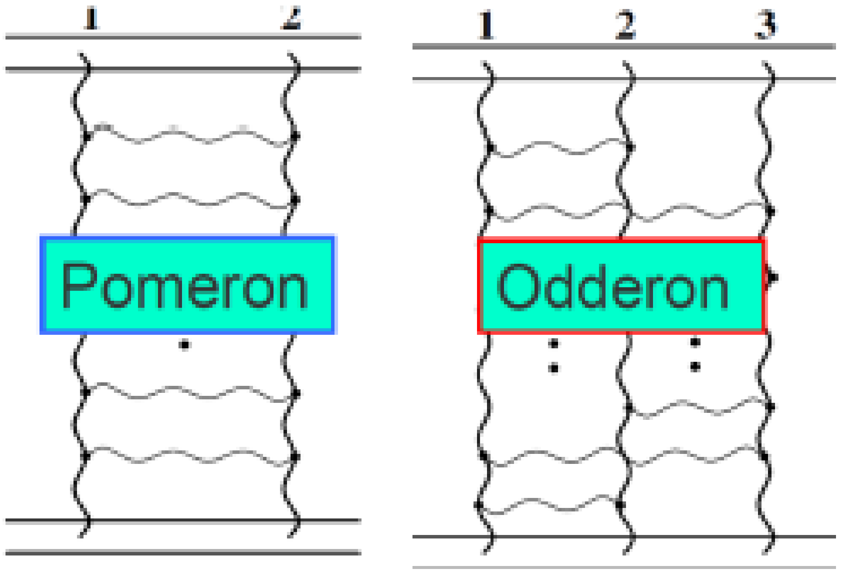
3: Extended Pomeranchuk theorem

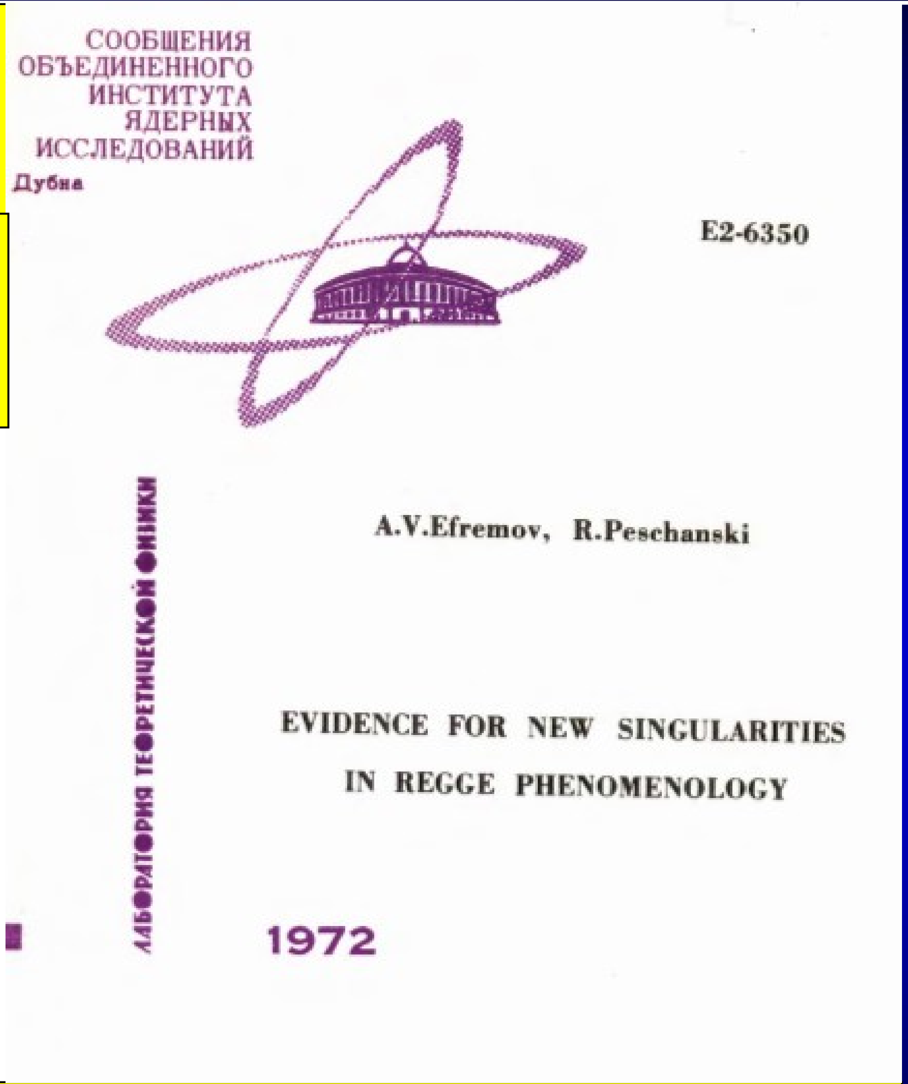
Universe 2024, ***10***(3), 127 — arXiv:2312.01621 [hep-ph]
Universe 2024, ***10***(6),264; — arXiv:2405.06733 [hep-ph]

Odderon: extremely elusive, for 48 years

Odderon: L. Lukaszuk, B. Nicolescu,
Lett. Nuovo Cim. 8, 405 (1973)
Received: **31 July 1973**

Odderon is an odd component of
elastic scattering:
Changes sign for crossing




СООБЩЕНИЯ
ОБЪЕДИНЕННОГО
ИНСТИТУТА
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
Дубна

E2-6350

ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

A.V.Efremov, R.Peschanski

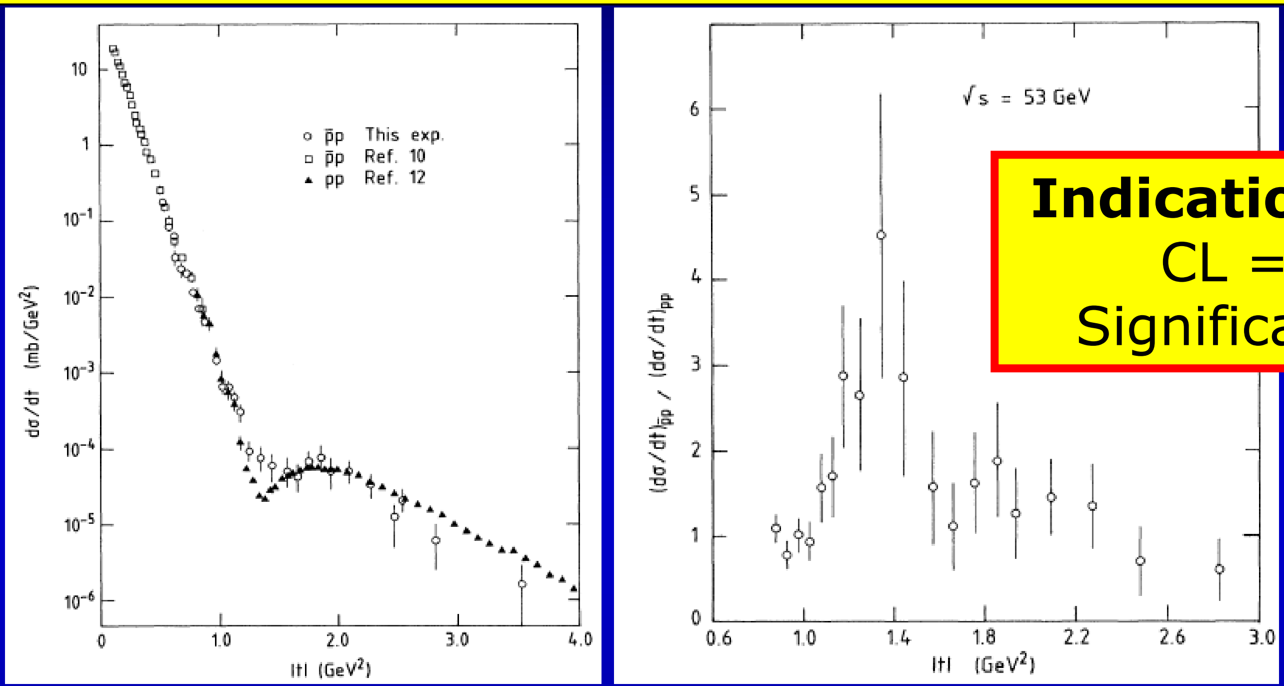
EVIDENCE FOR NEW SINGULARITIES
IN REGGE PHENOMENOLOGY

1972

Odderon name coined: D. Joynson, E. Leader, B. Nicolescu, C. Lopez,
Nuovo Cim. 30A, 345 (1975) - Well established in QCD by now !
Honorable mention: A. V. Efremov, R. Peschanski, JINR-E2-6350 (1972)

Odderon: elusive experimentally

Odderon search at ISR: indication but no conclusive result
Breakstone et al, Phys. Rev. Lett. 54, 2180 (**1985**): CL = 99.9 %



Indication of Odderon
CL = 99.9 %,
Significance: 3.35 σ

Terminology for **this** talk:
Agreement if statistical significance is < **3 σ**
Indication of signal if **3 σ** ≤ significance < **5 σ**
Evidence or observation of signal if **5 σ** ≤ significance
Discovery of signal if **5 σ** ≤ significance, **for the first time**.
Accepted: Discovery if Clay Mathematical Institute (CMI) criteria satisfied.
Miscovery if CMI criteria for Millenium Prize Problems are **not** satisfied.

Odderon: well established in QCD

Odderon proposed in Regge phenomenology:
L. Lukaszuk, B. Nicolescu, Lett. Nuovo Cim. 8, 405 (1973)

Three Gluon Integral Equation and Odd c Singlet Regge Singularities in QCD
BKP evolution equation
J. Bartels, Nucl. Phys. B 175 (1980) 365-401
J. Kwiecinski, M. Praszalowicz, Phys.Lett.B 94 (1980) 413-416

A new Odderon intercept from QCD:
R. A. Janik, J. Wosiek, Phys. Rev. Lett. 82 (1999) 1092

Odderon in QCD:
J. Bartels, L.N. Lipatov, G. P. Vacca: Phys. Lett. B (2000) 178

Odderon in QCD with running coupling:
J. Bartels, C. Contreras, G. P. Vacca, *JHEP* 04 (2020) 183

For an excellent theory intro/review, see Yu. Kovchegov's
CTEQ Webinar, April 28, 2021
http://youtu.be/yHBO3zcB3V4

Odderon: first observation with > 5 σ

EPJ Web of Conf. (2020) **235**: 06005
https://doi.org/10.1051/epjconf/202023506002

Proton Holography -- Discovering Odderon from Scaling Properties of Elastic Scattering #4

T. Csorgo (Wigner RCP, Budapest and Eszterhazy Karoly U., Eger), T. Novak (EKU KRC, Gyongyos), R. Pasechnik (Lund U. and Rez, Nucl. Phys. Inst.), A. Ster (Wigner RCP, Budapest), I. Szanyi (Wigner RCP, Budapest and Eotvos U.) (Apr 15, 2020)

Published in: *EPJ Web Conf.* 235 (2020) 06002 • Contribution to: ISMD 2019 • e-Print: 2004.07095 [hep-ph]

First publication of an at least 5.0 σ (6.26 σ) Odderon exchange effect:
published on **May 11, 2020**,
EPJ Web of Conf. 235 (2020) 06002
in an **anonymously refereed / peer reviewed** conference proceedigs.
(Proc. ISMD 2019, Santa Fe, USA)

BUT: „*Never be the first! It is too early!*"
P. Carruthers ~ 1990

First journal publications, Odderon > 5 σ

Evidence of Odderon-exchange from scaling properties of elastic scattering at TeV energies

#5

T. Csörgő (Wigner RCP, Budapest and CERN), T. Novak (Unlisted, HU), R. Pasechnik (Lund U., Dept. Theor. Phys.), A. Ster (Wigner RCP, Budapest), I. Szanyi (Wigner RCP, Budapest) (Dec 26, 2019)

Published in: *Eur.Phys.J.C* 81 (2021) 2, 180 • e-Print: 1912.11968 [hep-ph]

Online attention

- 26 tweeters
- 15 news outlets
- 3 Mendeley
- 4 blogs
- 4 Wikipedia page
- 2 Facebook pages

This article is in the 98th percentile (ranked 6,037th) of the 428,075 tracked articles of a similar age in all journals and the 99th percentile (ranked 1st) of the 231 tracked articles of a similar age in *The European Physical Journal C*

Hungarian-Swedish team:
Eur. Phys. J. C (2021) **81**: 180, Published: 23 February 2021
https://doi.org/10.1140/epjc/s10052-021-08867-6

Observation of Odderon effects at LHC energies: a real extended Bialas–Bzdak model study

#2

T. Csorgo (Wigner RCP, Budapest and EKU KRC, Gyongyos), I. Szanyi (Eotvos U. and Wigner RCP, Budapest) (May 28, 2020)

Published in: *Eur.Phys.J.C* 81 (2021) 7, 611 • e-Print: 2005.14319 [hep-ph]

Hungarian team, Polish-Hungarian model:
Eur. Phys. J. C (2021) **81**:611 , Published: 13 July 2021
https://doi.org/10.1140/epjc/s10052-021-09381-5

Odderon Exchange from Elastic Scattering Differences between pp and $p\bar{p}$ Data at 1.96 TeV and from pp Forward Scattering Measurements

TOTEM and D0 Collaborations • V.M. Abazov (Dubna, JINR) et al. (Dec 7, 2020)

Published in: *Phys.Rev.Lett.* 127 (2021) 6, 062003 • e-Print: 2012.03981 [hep-ex]

SUMMARY | News | Blogs | Twitter | Wikipedia | Dimensions citations

Title: Odderon Exchange from Elastic Scattering Differences between pp and pp̄ Data at 1.96 TeV and from pp Forward Scattering Measurements
Published in: Physical Review Letters, August 2021
DOI: 10.1103/physrevlett.127.062003
Pubmed ID: 34420329
Authors: V. M. Abazov, B. Abbott, B. S. Acharya, M. Adams, T. Adams, J. P. Agnew, G. D. Alexeev, G. Alkhazov... [show]

TWITTER DEMOGRAPHICS | MENDELEY READERS

D0 and TOTEM Collaborations:
Phys. Rev. Lett. **127** (2021) 6, 062003, Published: 4 August 2021
https://doi.org/10.1103/PhysRevLett.127.062003

2022 observations of Odderon with > 5 σ

Characterisation of the dip-bump structure observed in proton–proton elastic scattering at $\sqrt{s}$ = 8 TeV #1

TOTEM Collaboration • G. Antchev (Pilsen U.) et al. (Nov 23, 2021)

Published in: *Eur.Phys.J.C* 82 (2022) 3, 263 • e-Print: 2111.11991 [hep-ex]

Online attention

1

1 tweeters

This article is in the 1st percentile (ranked 279,419th) of the 343,918 tracked articles of a similar age in all journals and the 1st percentile (ranked 73rd) of the 114 tracked articles of a similar age in *The European Physical Journal C*

TOTEM Collaboration:
8 TeV: EPJ C (2022) 82, 263 (2022). Published: March 26, 2022
https://doi.org/10.1140/epjc/s10052-022-10065-x
Publishes final data for D0-TOTEM PRL published in 2021

The ReBB model and its H(x) scaling version at 8 TeV: Odderon exchange is a certainty #1

I. Szanyi (Eotvos U. and Wigner RCP, Budapest and Karoly Robert U. Coll.), T. Csörgő (Wigner RCP, Budapest and Karoly Robert U. Coll.) (Apr 21, 2022)

Published in: *Eur.Phys.J.C* 82 (2022) 9, 827, *Eur.Phys.J.C* 82 (2022) 827 • e-Print: 2204.10094 [hep-ph]

Online attention

3

1 Wikipedia page

This article is in the 64th percentile (ranked 57,525th) of the 166,532 tracked articles of a similar age in all journals and the 99th percentile (ranked 1st) of the 1 tracked articles of a similar age in *The European Physical Journal C*

Hungarian team, model of Polish origin:
New TOTEM 8 TeV data vs ReBB model predictions:
EPJ C 82 (2022) 9, 827. Published: Sept 19, 2022
In the ReBB model, Odderon exchange is a certainty
Presented at Zimányi'22 by I. Szanyi

What about model independent results?

2023-24: new O observations with > 5 σ

Model-independent Odderon Results Based on TOTEM data on Elastic Proton–Proton Scattering at 8 TeV #2

T. Csörgő (Wigner RCP, Budapest and Karoly Robert U. Coll.), T. Novák (Karoly Robert U. Coll.), R. Pasechnik (Lund U.), A. Ster (Wigner RCP, Budapest), I. Szanyi (Wigner RCP, Budapest and Karoly Robert U. Coll. and Eotvos U.) (Feb 9, 2023)

Published in: *Acta Phys.Polon.Supp.* 16 (2023) 5, 2 • Contribution to: Difflowx2022, 2, Difflowx2022 • e-Print: 2302.04930 [hep-ex]

Hungarian – Swedish team, new TOTEM data at 8 TeV:
Model-independent H(x) scaling method
Proc. Diffraction and Low-x 2022 by T. Csörgő
8 TeV data confirm and strengthen the Odderon signal

Model-independent Odderon results based on new TOTEM data on elastic pp collisions at 8 TeV #1

T. Csörgő (Budapest, RMKI and Karoly Robert U. Coll.), T. Novák (Karoly Robert U. Coll. and Budapest, Tech. U.), R. Pasechnik (Lund U.), A. Ster (Budapest, RMKI), I. Szanyi (Budapest, RMKI and Karoly Robert U. Coll. and Eotvos U.) (May 10, 2024)

Contribution to: ISMD23 • e-Print: 2405.06733 [hep-ph]

Hungarian – Swedish team, scaling method:
New TOTEM 8 TeV data vs H(x) scaling:
MDPI Universe (2024) 10(6), 264;
Full description, detailed peer reviewed paper

Universe **2024**, *10*(6),264;
https://doi.org/10.3390/universe10060264

arXiv:2405.06733 [hep-ph]

What about domain of validity, model independently?
-- stay tuned… coming soon

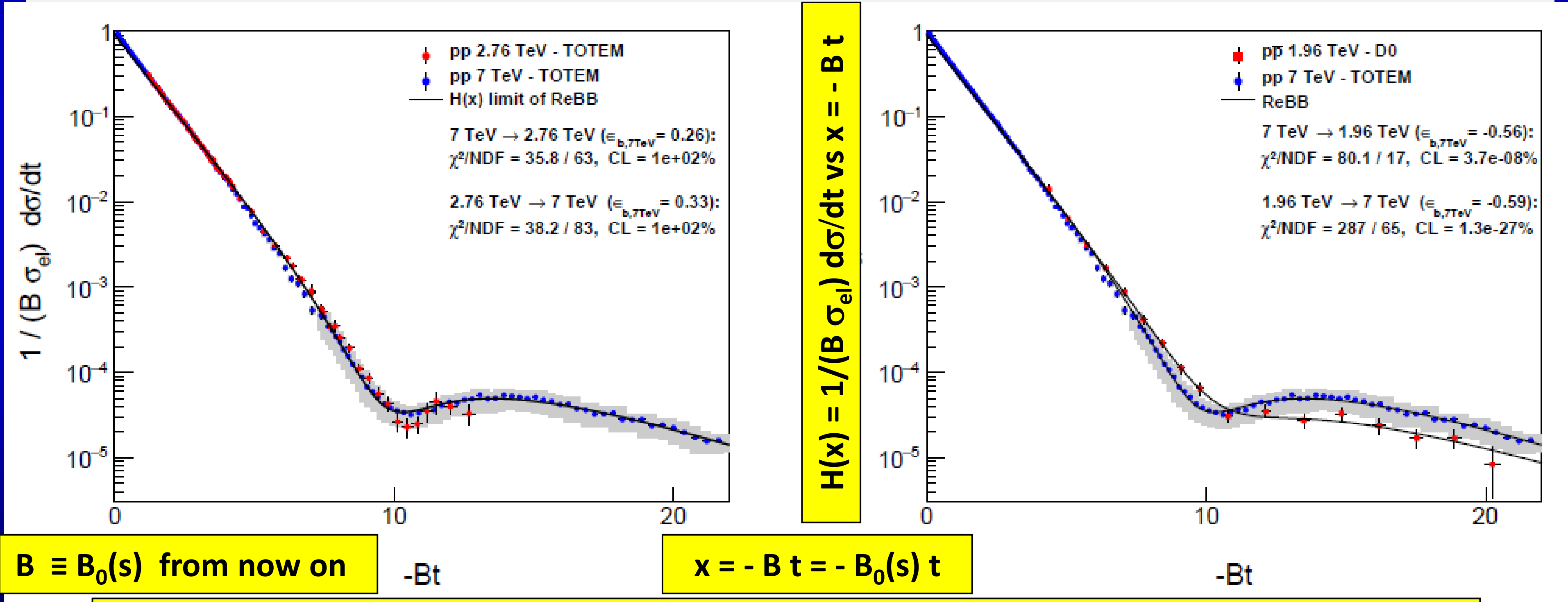
Hungarian-Swedish team, Odderon > 6.26 σ

Evidence of Odderon-exchange from scaling properties of elastic scattering at TeV energies #5

T. Csörgő (Wigner RCP, Budapest and CERN), T. Novak (Unlisted, HU), R. Pasechnik (Lund U., Dept. Theor. Phys.), A. Ster (Wigner RCP, Budapest), I. Szanyi (Wigner RCP, Budapest) (Dec 26, 2019)

Published in: *Eur.Phys.J.C* 81 (2021) 2, 180 • e-Print: 1912.11968 [hep-

Eur. Phys. J. C (2021) **81**: 180, published February 2021
https://doi.org/10.1140/epjc/s10052-021-08867-6



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

$B \equiv B_0(s)$ from now on

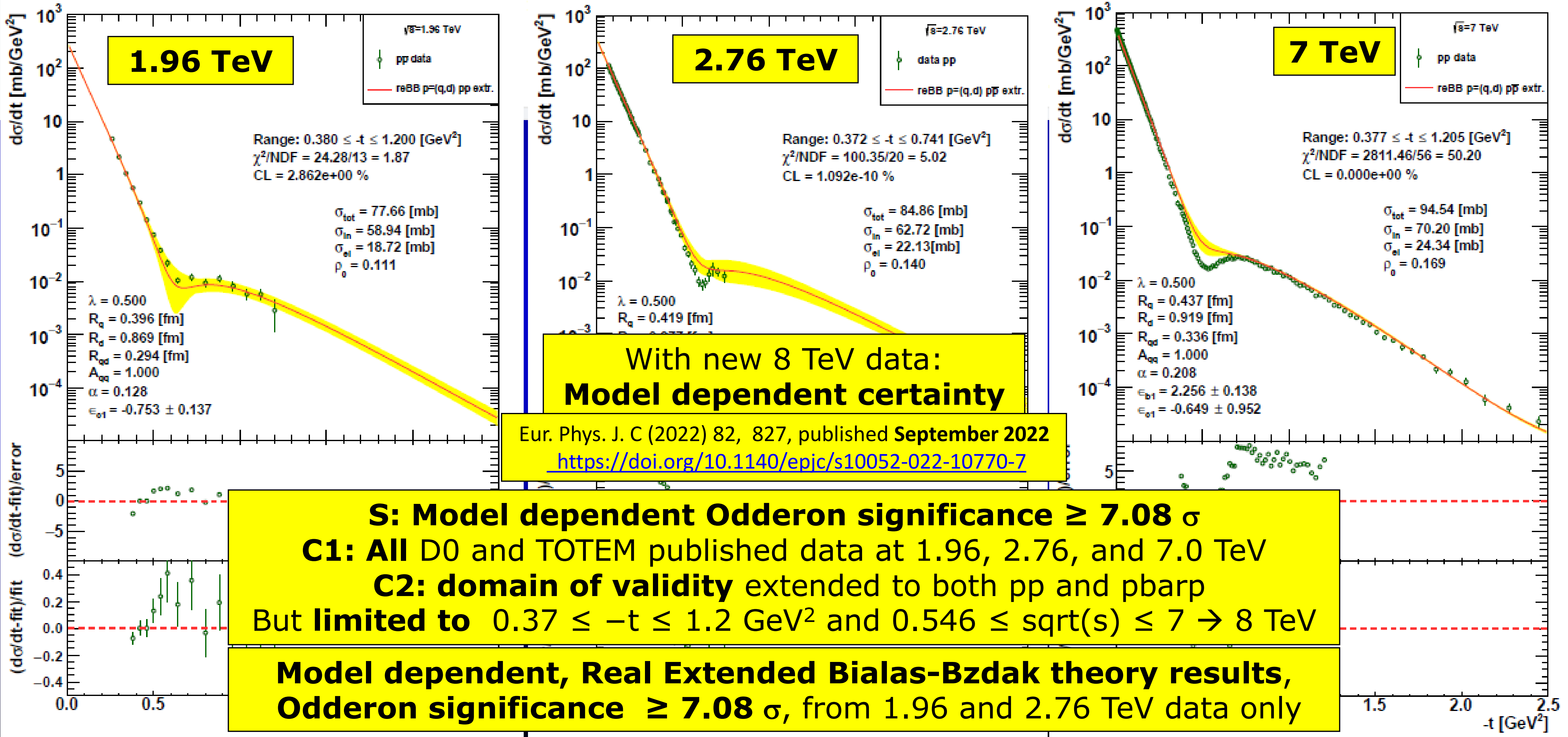
$x = -Bt = -B_0(s)\,t$

S: Model independent Odderon significance ≥ 6.26 σ
C1: All D0 and TOTEM published data at 1.96, 2.76 and 7.0 TeV
C2: domain of validity is still determined **model dependently**.

Hungarian team, Polish-Hungarian model, Odderon > 7.08 σ

Observation of Odderon Effects at LHC energies -- A Real Extended Bialas-Bzdak Model Study

Eur. Phys. J. C (2021) **81**:611, published July 2021
https://doi.org/10.1140/epjc/s10052-021-09381-5



With new 8 TeV data:
Model dependent certainty

Eur. Phys. J. C (2022) 82, 827, published **September 2022**
https://doi.org/10.1140/epjc/s10052-022-10770-7

S: Model dependent Odderon significance ≥ 7.08 σ
C1: All D0 and TOTEM published data at 1.96, 2.76, and 7.0 TeV
C2: domain of validity extended to both pp and pbarp
But **limited to** 0.37 ≤ −t ≤ 1.2 GeV² and 0.546 ≤ sqrt(s) ≤ 7 → 8 TeV

Model dependent, Real Extended Bialas-Bzdak theory results,
Odderon significance ≥ 7.08 σ, from 1.96 and 2.76 TeV data only

Formalism: elastic scattering

$$\frac{d\sigma(s)}{dt} = \frac{1}{4\pi}|T_{el}(s,\Delta)|^2, \qquad \Delta = \sqrt{|t|}.$$

$$\sigma_{el}(s) = \int_0^\infty d|t| \frac{d\sigma(s)}{dt}$$

$$A(s) = \lim_{t\to 0} \frac{d\sigma}{dt}(s,t)$$

$$\sigma_{\rm tot}(s) \equiv 2\,{\rm Im}\, T_{el}(\Delta = 0, s)$$

$$\rho(s) \equiv \rho_0(s) = \lim_{t\to 0} \rho(s,t)$$

$$B(s) \equiv B_0(s) = \lim_{t\to 0} B(s,t),$$

$$B(s,t) = \frac{d}{dt} \ln \frac{d\sigma(s)}{dt}$$

$$\rho(s,t) \equiv \frac{{\rm Re}\, T_{el}(s,\Delta)}{{\rm Im}\, T_{el}(s,\Delta)}$$

$$A(s) = \frac{1}{16\pi}(1+\rho_0^2(s))\sigma_{tot}^2(s)$$

Basic problem: dσ/dt measures an amplitude, *modulus squared*.
If Odderon exists: signals in elastic scattering at t = 0 and at –t > 0.

Formalism in b space

$$\frac{d\sigma(s)}{dt} = \frac{1}{4\pi}|T_{el}(s,\Delta)|^2, \qquad \Delta = \sqrt{|t|}.$$

$$t_{\rm el}(s,b) = \int \frac{d^2\Delta}{(2\pi)^2} e^{-i\boldsymbol{\Delta b}} T_{\rm el}(s,\Delta) =$$
$$= \frac{1}{2\pi}\int J_0(\Delta\, b)\, T_{\rm el}(s,\Delta)\, \Delta\, d\Delta,$$
$$\Delta \equiv |\boldsymbol{\Delta}|, \quad b \equiv |\boldsymbol{b}|.$$

$$t_{\rm el}(s,b) = i\left[1 - e^{-\Omega(s,b)}\right]$$

$$P(s,b) = 1 - \left|e^{-\Omega(s,b)}\right|^2$$

Impact parameter or b space:
elastic scattering interferes with propagation w/o collisions: Genuine quantum physics.
Complex opacity function Ω(s,b) (eikonal, from unitarity)
0 ≤ P(s,b) ≤ 1 : *inelastic* scattering has a probabilistic interpretation

Looking for Crossing-Odd(eron) effects

$$T_{\rm el}^{pp}(s,t) = T_{\rm el}^{+}(s,t) - T_{\rm el}^{-}(s,t),$$
$$T_{\rm el}^{p\bar{p}}(s,t) = T_{\rm el}^{+}(s,t) + T_{\rm el}^{-}(s,t),$$
$$T_{\rm el}^{+}(s,t) = T_{\rm el}^{P}(s,t) + T_{\rm el}^{f}(s,t),$$
$$T_{\rm el}^{-}(s,t) = T_{\rm el}^{O}(s,t) + T_{\rm el}^{\omega}(s,t).$$

$$T_{\rm el}^{P}(s,t) = \frac{1}{2}\left(T_{\rm el}^{pp}(s,t) + T_{\rm el}^{p\bar{p}}(s,t)\right)$$
$$T_{\rm el}^{O}(s,t) = \frac{1}{2}\left(T_{\rm el}^{p\bar{p}}(s,t) - T_{\rm el}^{pp}(s,t)\right)$$

$$\text{for } \sqrt{s} \geq 1 \text{ TeV},$$

Three simple consequences:

$$T_{el}^{O}(s,t) = 0 \implies \frac{d\sigma^{pp}}{dt} = \frac{d\sigma^{p\bar{p}}}{dt} \quad \text{for } \sqrt{s} \geq 1 \text{ TeV}$$

$$\frac{d\sigma^{pp}}{dt} = \frac{d\sigma^{p\bar{p}}}{dt} \quad \text{for } \sqrt{s} \geq 1 \text{ TeV} \;\not\Longrightarrow\; T_{el}^{O}(s,t) = 0.$$

$$\frac{d\sigma^{pp}}{dt} \neq \frac{d\sigma^{p\bar{p}}}{dt} \quad \text{for } \sqrt{s} \geq 1 \text{ TeV} \implies T_{el}^{O}(s,t) \neq 0$$

Odderon differential cross-section from pp and ppbar collisions, Reggeized Philips-Barger:
A. Ster, L. Jenkovszky, T. Cs., **arxiv:1501.03860,** *Phys.Rev.D* **91** (2015) 7, 074018

Odderon search: a possible strategy

Known trivial s-dependences in
$\sigma_{tot}(s)$, $\sigma_{el}(s)$, $B(s)$, $\rho(s)$

Try to scale this out
Data collapsing (scaling)

Look for scaling violations

In the TeV energy range:
Odderon is equivalent with
a crossing-odd component
Look for violations of C-symmetry

Scaling in the diffractive cone region

$$\frac{d\sigma}{dt} = A(s) \exp\left[B(s)t\right]$$

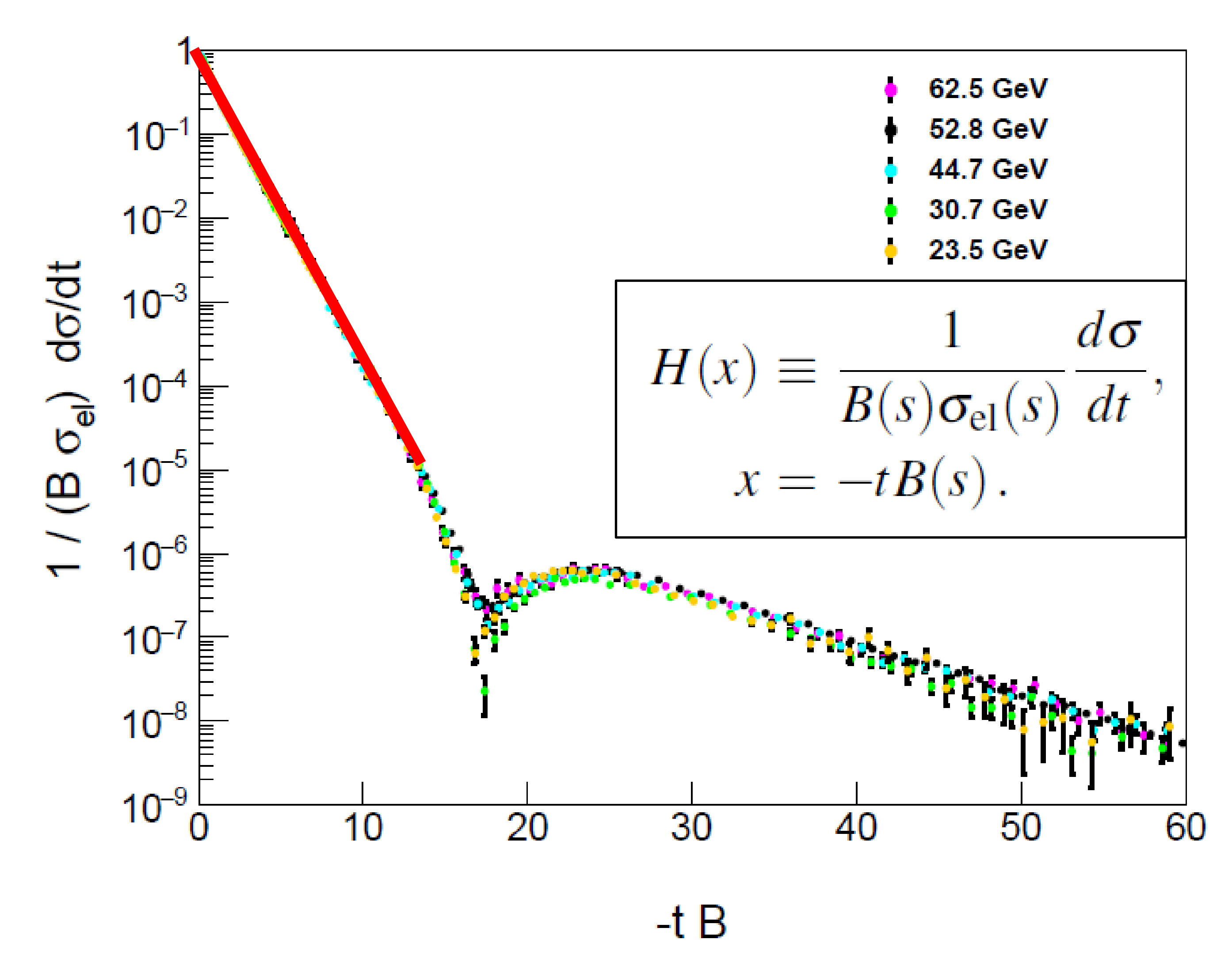
$$A(s) = B(s)\,\sigma_{\text{el}}(s) = \frac{1+\rho_0^2(s)}{16\,\pi}\,\sigma_{\text{tot}}^2(s),$$

$$\frac{1}{B(s)\sigma_{\text{el}}(s)}\,\frac{d\sigma}{dt} = \exp\left[tB(s)\right]$$

$$H(x) \equiv \frac{1}{B(s)\sigma_{\text{el}}(s)}\,\frac{d\sigma}{dt},$$
$$x = -tB(s).$$

Advantages:
1) H(x) ~ exp(-x) in the diffractive cone
2) Start from a place that you know
3) Measurable both for pp and pbarp

Test of the H(x) scaling at ISR



H(x) = exp(-x) in the cone
Works better than expected, even in the bump/tail region!

Derivation of H(x) scaling for all x

$$t_{el}(s, \mathrm{b}) = (i + \rho_0)\, r(s) E(\tilde{\mathrm{x}}).$$

$$\begin{aligned}
\mathrm{Re}\, \exp\left[-\Omega(s, b)\right] &= 1 - r(s) E(\tilde{\mathrm{x}}), \\
\mathrm{Im}\, \exp\left[-\Omega(s, b)\right] &= \rho_0\, r(s) E(\tilde{\mathrm{x}}), \\
\tilde{\mathrm{x}} &= \mathrm{b}/R(s), \\
R(s) &= \sqrt{B(s)},
\end{aligned}$$

$$\frac{d\sigma}{dt} = \frac{1}{4\pi} |T_{el}(\Delta)|^2 = \frac{1 + \rho_0^2}{4\pi} r^2(s) R^2(s) |\tilde{E}(R(s)\Delta)|^2$$

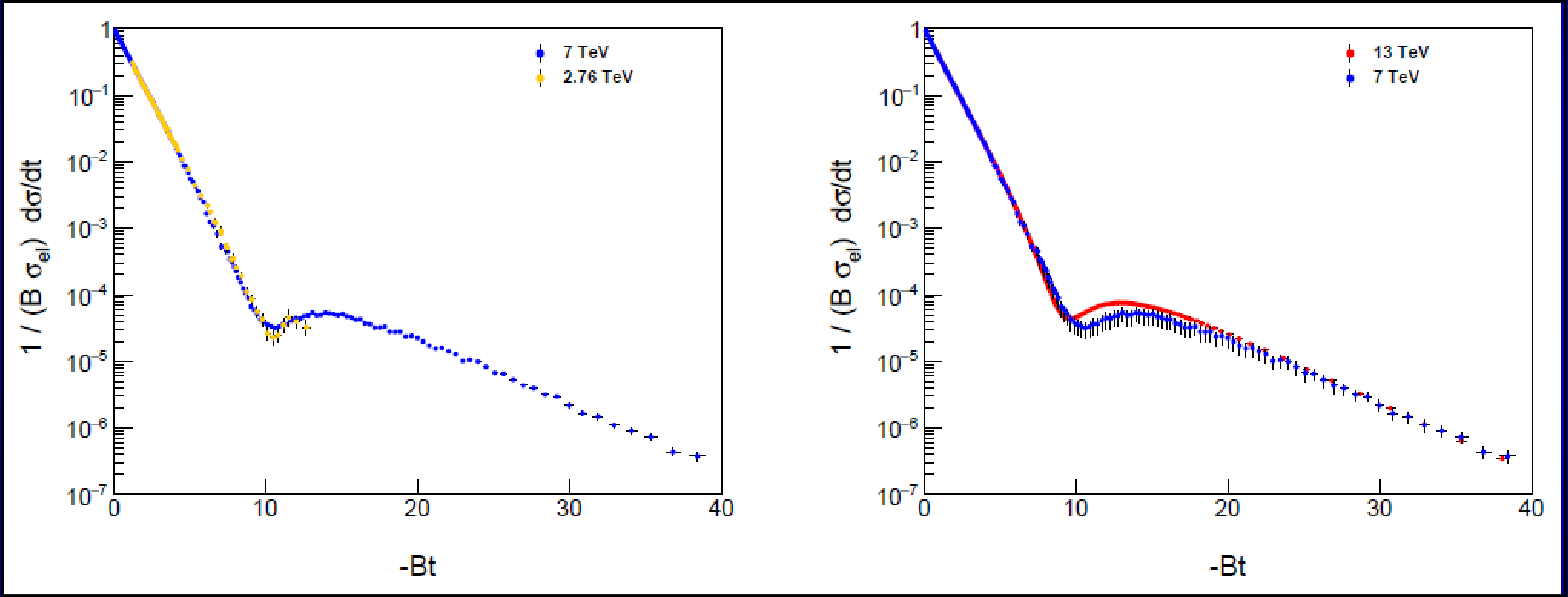
$$A = \left.\frac{d\sigma}{dt}\right|_{t=0} = \frac{1 + \rho_0^2}{4\pi} r^2(s) R^2(s) |\tilde{E}(0)|^2,$$

$$\frac{1}{A}\frac{d\sigma}{dt} = \frac{|\tilde{E}(\sqrt{x})|^2}{|\tilde{E}(x = 0)|^2} = H(x),$$

Advantages:
H(x) ≠ exp(-x) arbitrary positive def. in the dip-bump region
Measurable both for pp and p-antip. Normalized as H(0) = 1.

Test of the H(x) scaling at 7 vs 2.76 TeV

$$H(x) \equiv \frac{1}{B(s)\sigma_{\rm el}(s)} \frac{d\sigma}{dt},$$
$$x = -tB(s).$$



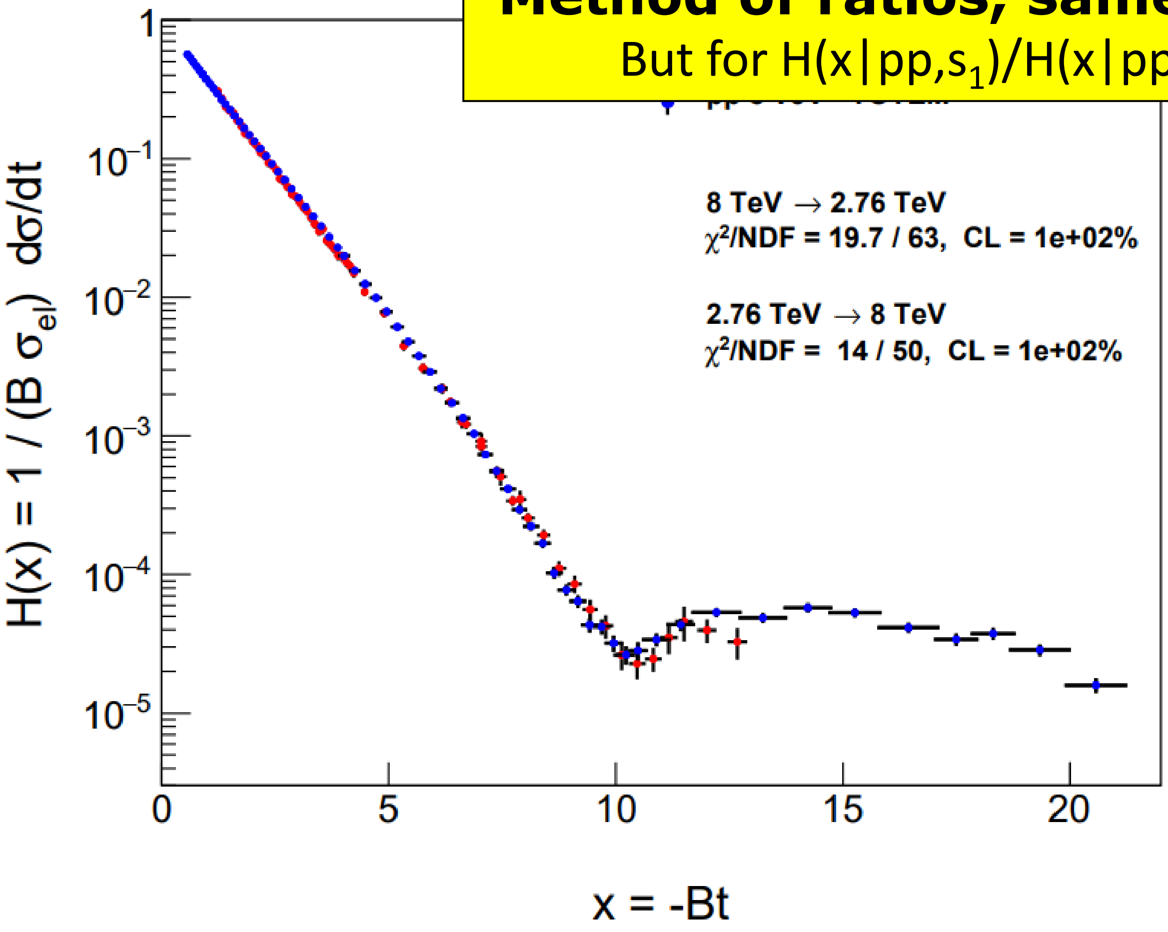
Valid between 2.76 and 7 TeV, even with stat errors only,
H(x) scaling valid even in the bump/tail region!
Between 8 and 13 TeV, scaling limited to the cone, but scaling **violated** beyond stat+syst errors in dip/dump/tail region!

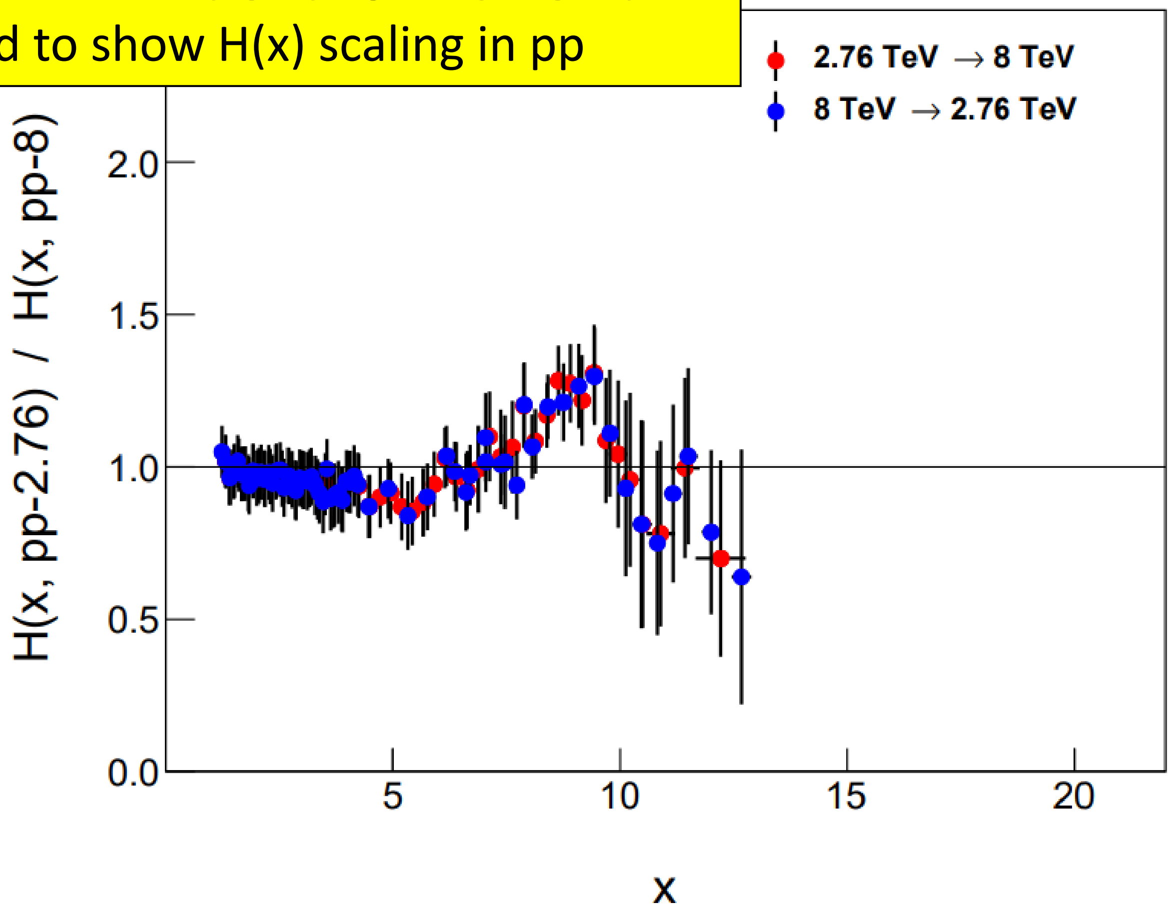
NEW RESULTS 1

H(x) SCALING, USING 8 TeV

Test of H(x) scaling: 8 vs 2.76 TeV

Method of ratios, same as in M. Praszalowicz's talk
But for $H(x|pp,s_1)/H(x|pp,s_2)$ and to show H(x) scaling in pp

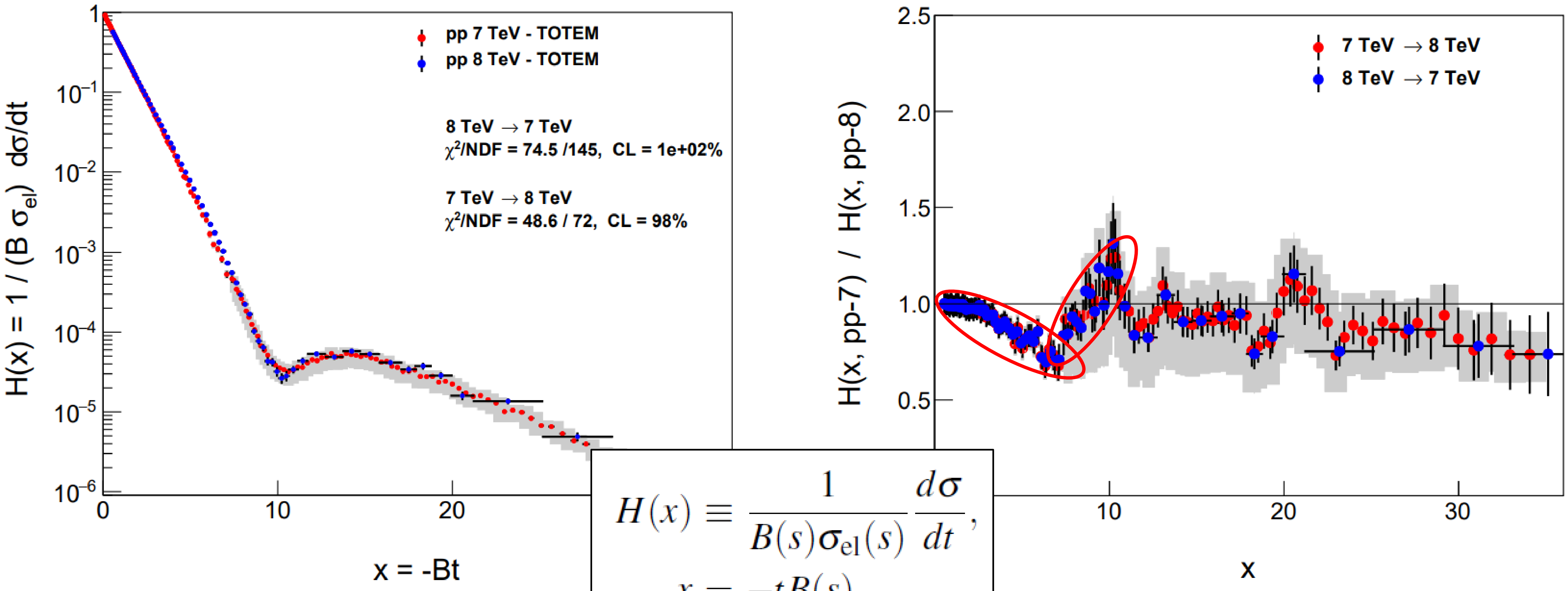




Between 2.76 and 8 TeV, H(x) scaling observed!
Hungarian-Swedish team, e-Print: 2405.06733 [hep-ph],
MDPI Universe **2024**, *10*(6), 264

$$H(x) \equiv \frac{1}{B(s)\sigma_{\rm el}(s)}\frac{d\sigma}{dt},$$
$$x = -tB(s).$$

Test of H(x) scaling: 8 vs 7 TeV TOTEM



$$H(x) \equiv \frac{1}{B(s)\sigma_{el}(s)} \frac{d\sigma}{dt},$$
$$x = -tB(s).$$

Between 7 and 8 TeV, H(x) scaling observed, but ...

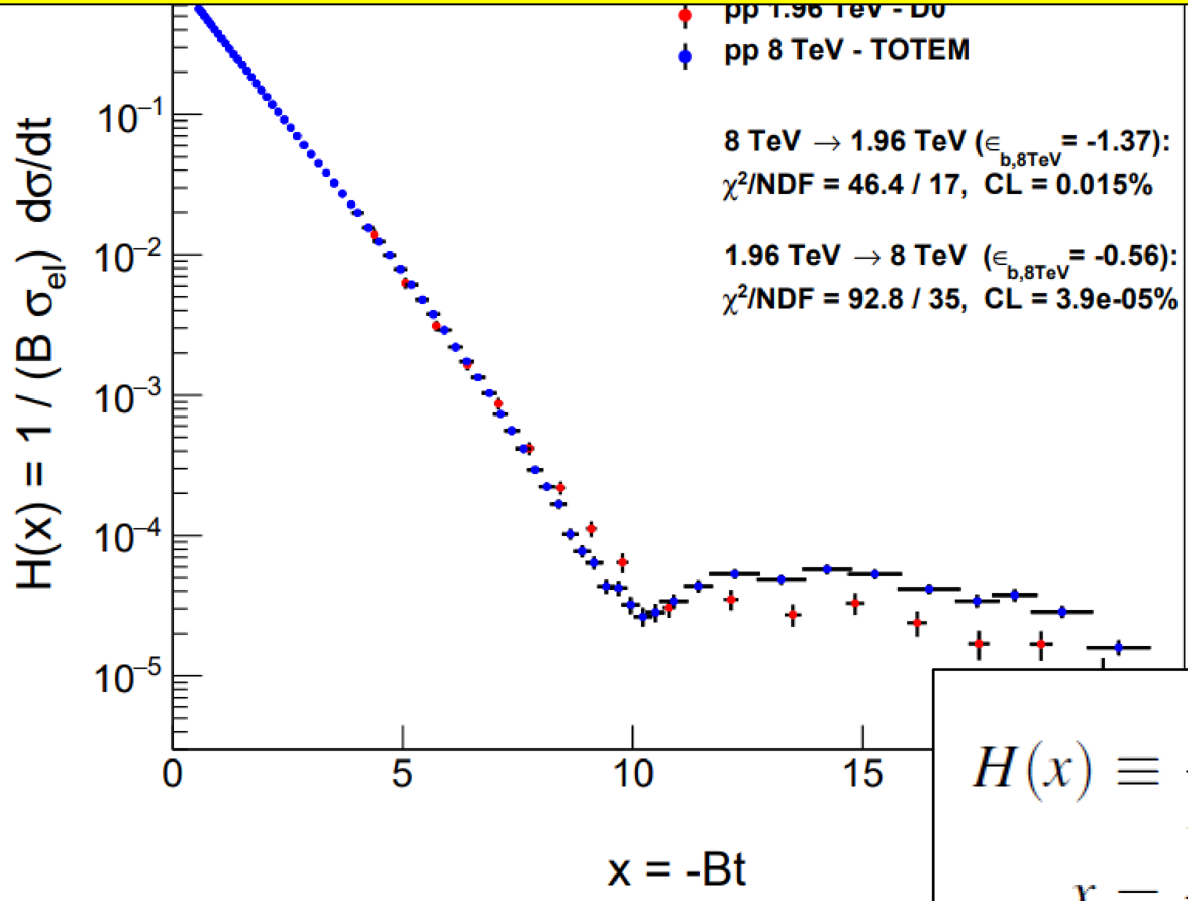
Hungarian-Swedish team, e-Print: 2405.06733 [hep-ph],

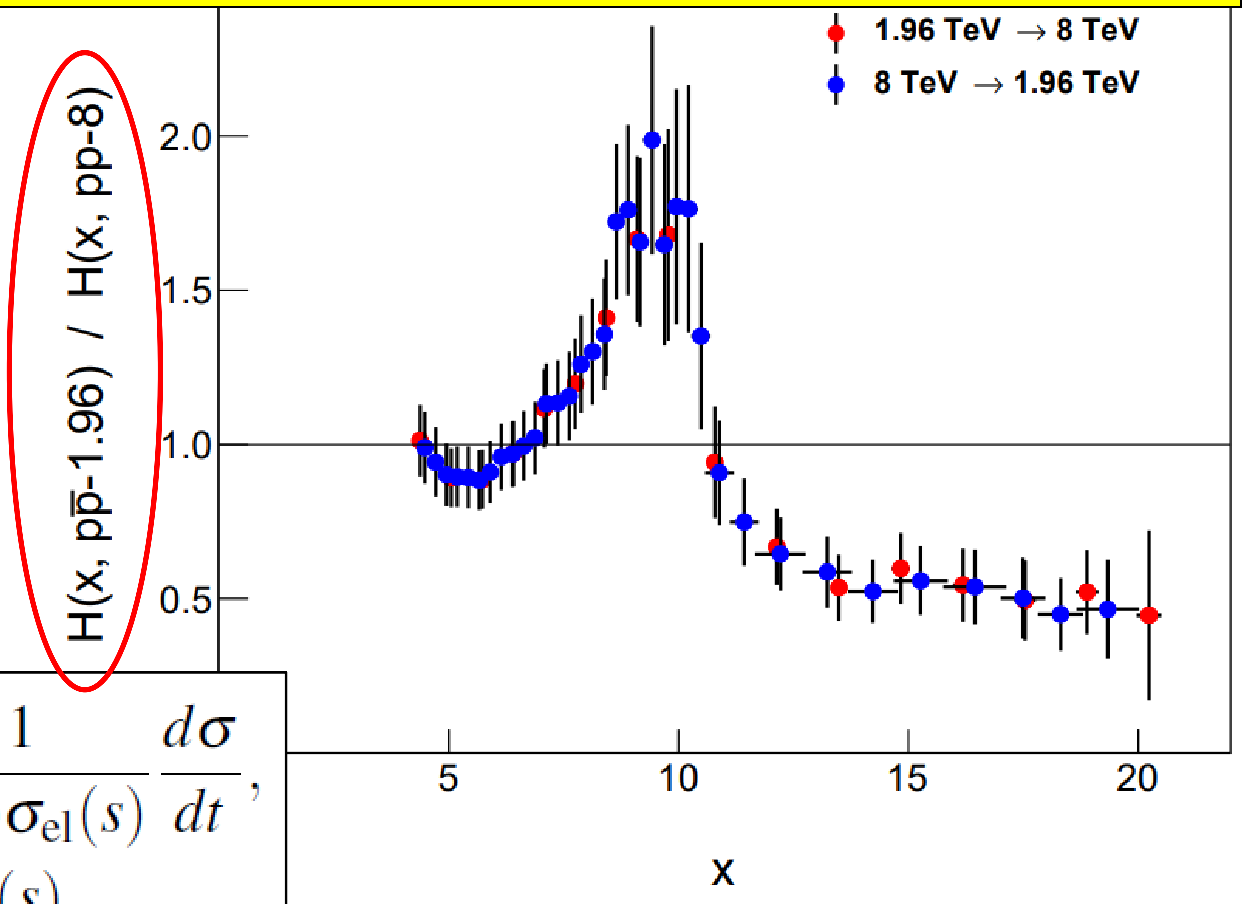
MDPI Universe **2024**, *10*(6), 264

Odderon of H(x) scaling: 8 vs 1.96 TeV

Method of ratios, same as in M. Praszalowicz's talk at Diffraction and Low-x 2024

But for H(x|pbarp)/H(x|pp) and to show the Odderon signal





$$H(x) \equiv \frac{1}{B(s)\sigma_{\rm el}(s)} \frac{d\sigma}{dt},$$
$$x = -tB(s).$$

Between 1.96 and 8 TeV, H(x|s,pp) and H(x|s,pbarp) are clearly different, with 3 < 3.79 < 5 σ

Hungarian-Swedish team, e-Print: 2405.06733 [hep-ph], MDPI Universe **2024**, *10*(6), 264

Odderon significances from H(x) scaling

$\sqrt{s}$ (TeV)	χ^2	NDF	CL	significance (σ)
1.96 vs. 2.76	3.85	11	9.74×10^{-1}	0.03
1.96 vs. 7	80.1	17	3.681×10^{-10}	6.26
1.96 vs. 8	46.4	17	1.502×10^{-4}	3.79

$\sqrt{s}$ (TeV)	χ^2	NDF	CL	χ^2/NDF method	combined σ Stouffer's method
1.96 vs 2.76 & 8	50.25	28	6.064×10^{-3}	2.74	2.70
1.96 vs 2.76 & 7	83.95	28	1.698×10^{-7}	5.22	4.44
1.96 vs 2.76 & 7 & 8	130.35	45	2.935×10^{-10}	6.30	5.81
1.96 vs 7 & 8	126.5	34	1.415×10^{-12}	7.08	7.10

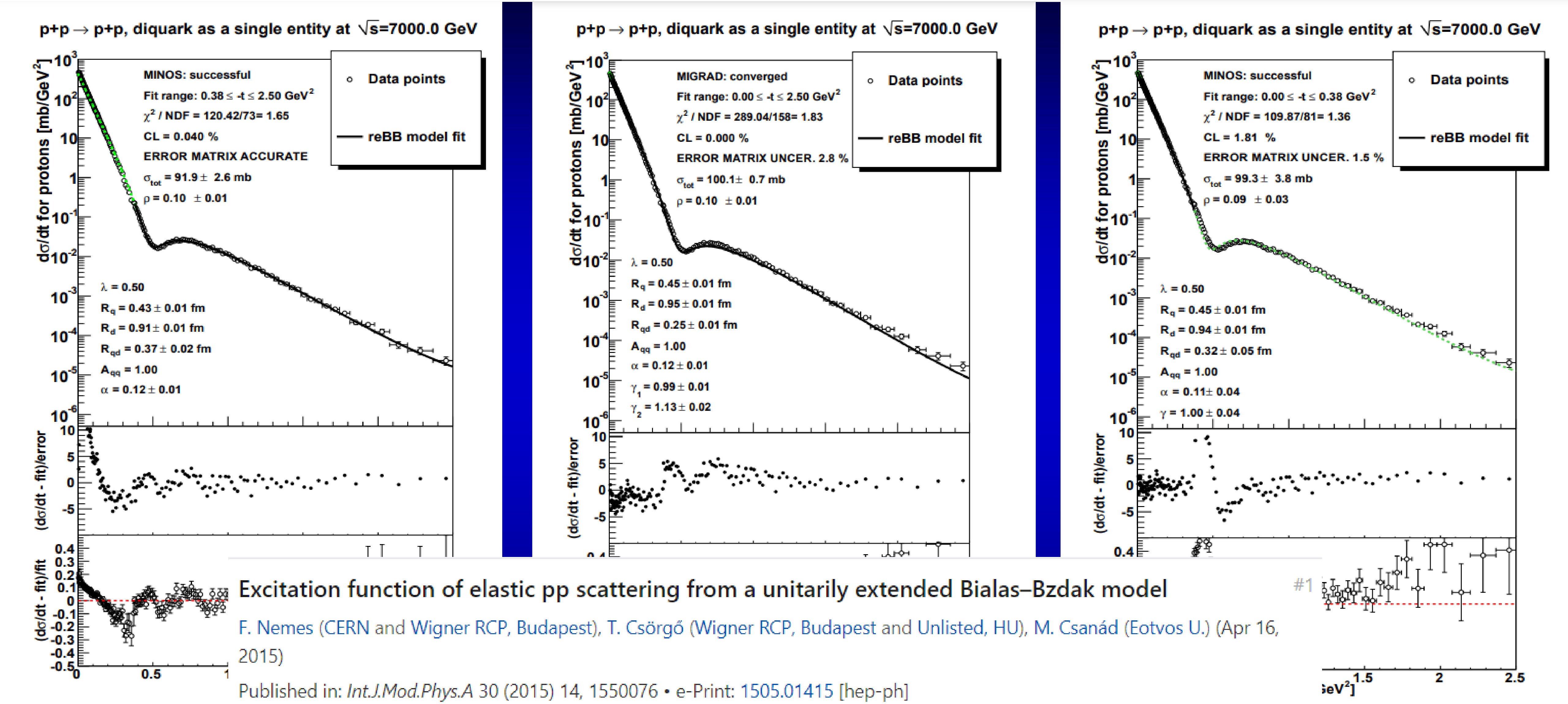
If 1.96, 2.76, 7 and 8 TeV data are combined, H(x) significances on all data results in 5 < 5.8 σ
If 1.96, 7 and 8 TeV data are combined, at least 7.08 σ.

Hungarian-Swedish team, e-Print: 2405.06733 [hep-ph],
MDPI Universe **2024**, *10*(6), 264

NEW RESULTS 2

Low-t extension of ReBB
7 and 8 TeV pp
(cross-check, without Levy)

Statement of the problem, with old χ^2



Excitation function of elastic pp scattering from a unitarily extended Bialas–Bzdak model #1

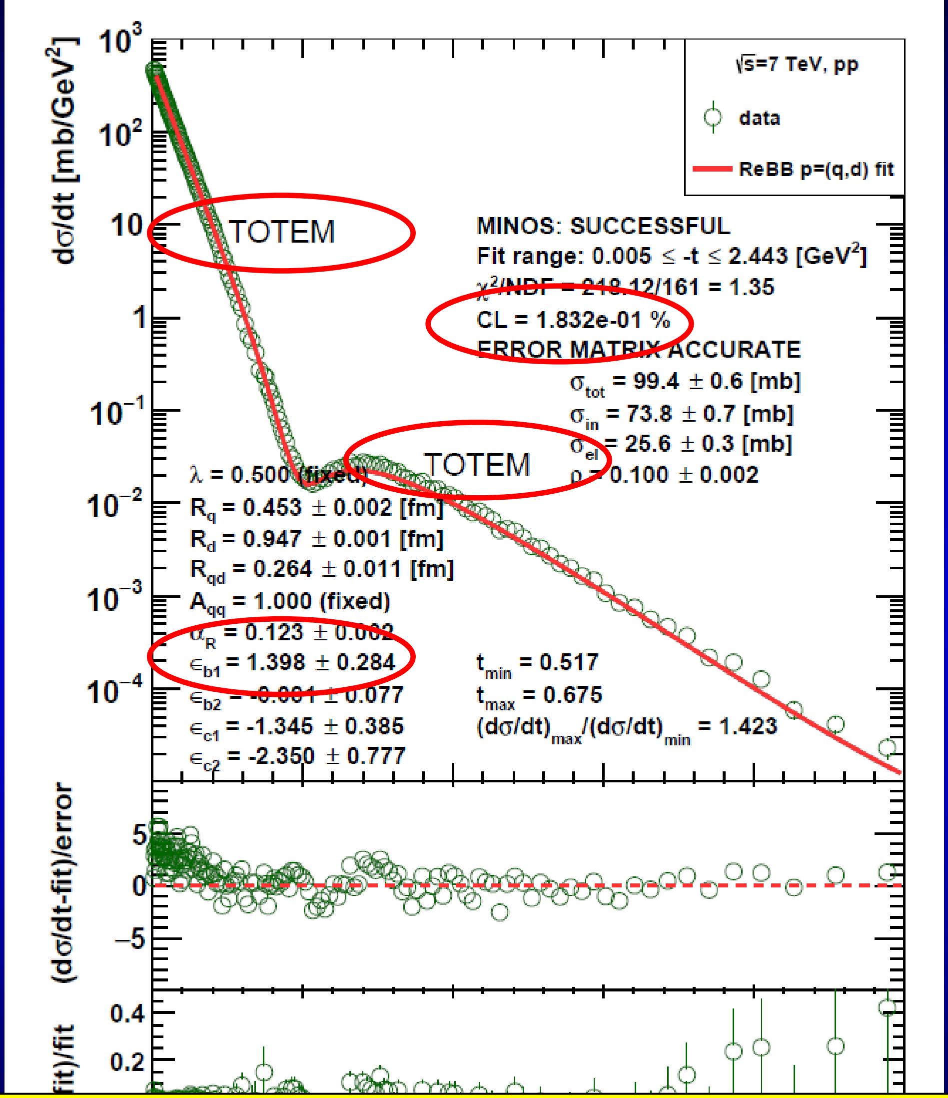
F. Nemes (CERN and Wigner RCP, Budapest), T. Csörgő (Wigner RCP, Budapest and Unlisted, HU), M. Csanád (Eotvos U.) (Apr 16, 2015)

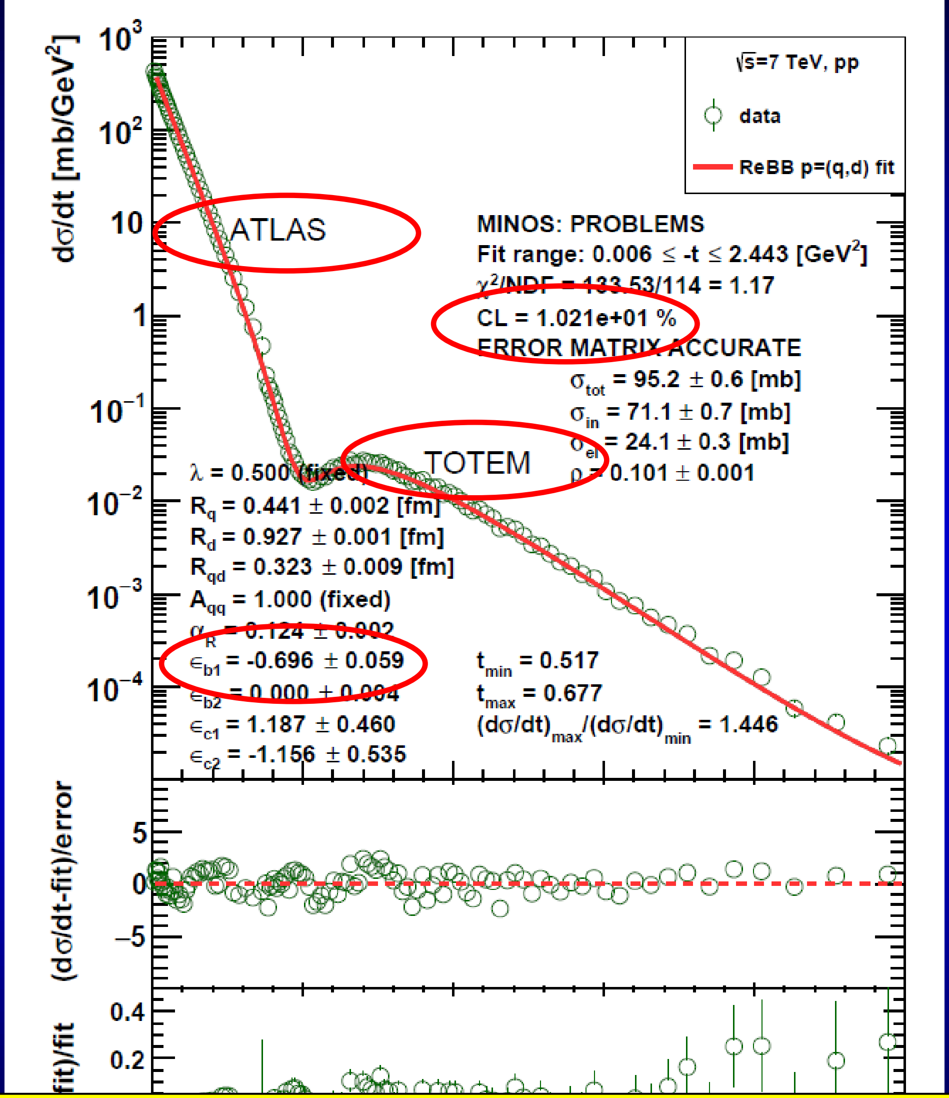
Published in: *Int.J.Mod.Phys.A* 30 (2015) 14, 1550076 • e-Print: 1505.01415 [hep-ph]

ReBB fits to both TOTEM low-t and TOTEM-large-t fit acceptable at 7 TeV, but

The two datasets could not be ReBB fitted simultaneously, without an advanced χ^2 definition !

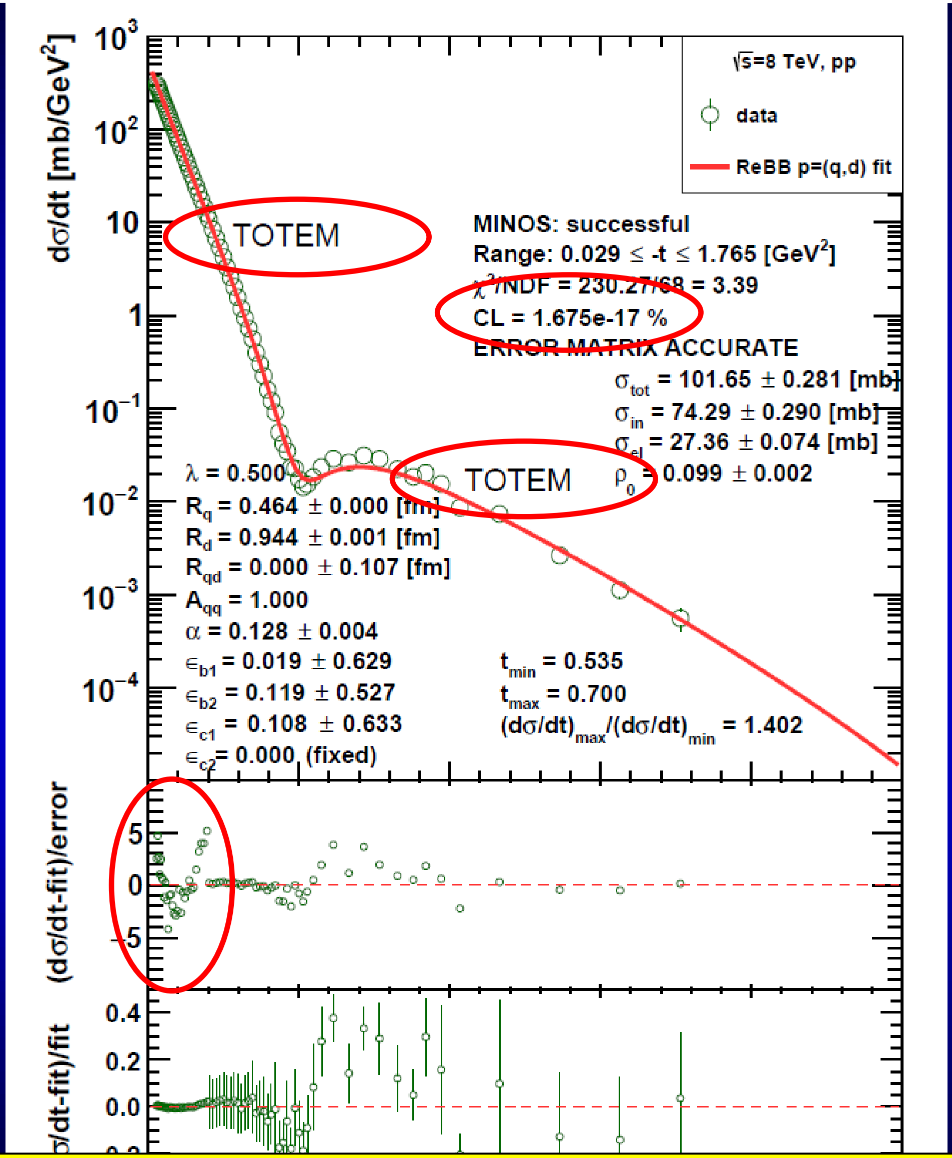
ATLAS and TOTEM: ReBB model to low –t, 7 TeV

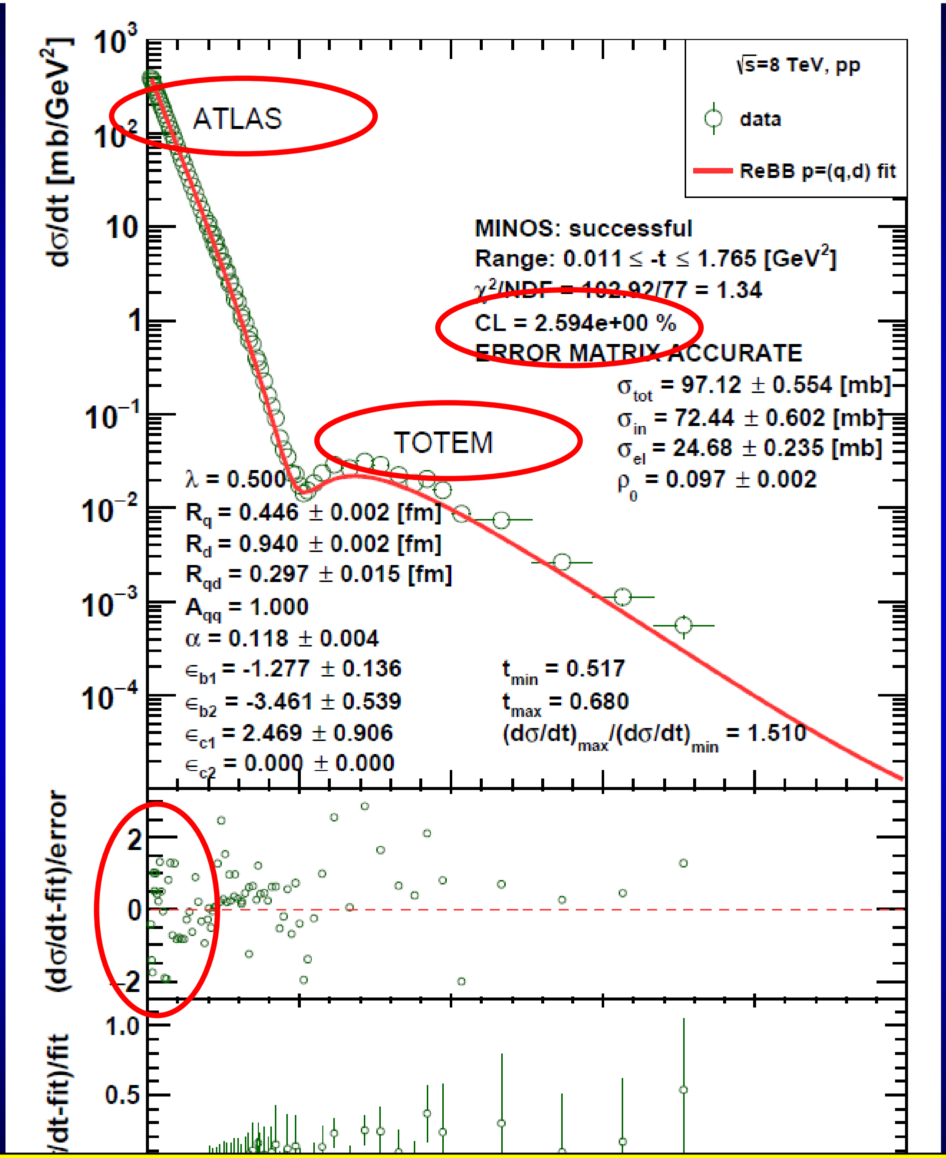




TOTEM low-t vs TOTEM-large-t fit acceptable at 7 TeV, obtained with advanced PHENIX χ^2 definition, but with ε_B > 1, outside expected range (-1,1) …
ATLAS low-t vs TOTEM-large-t fit successful (CL = 10.2 %) at 7 TeV !

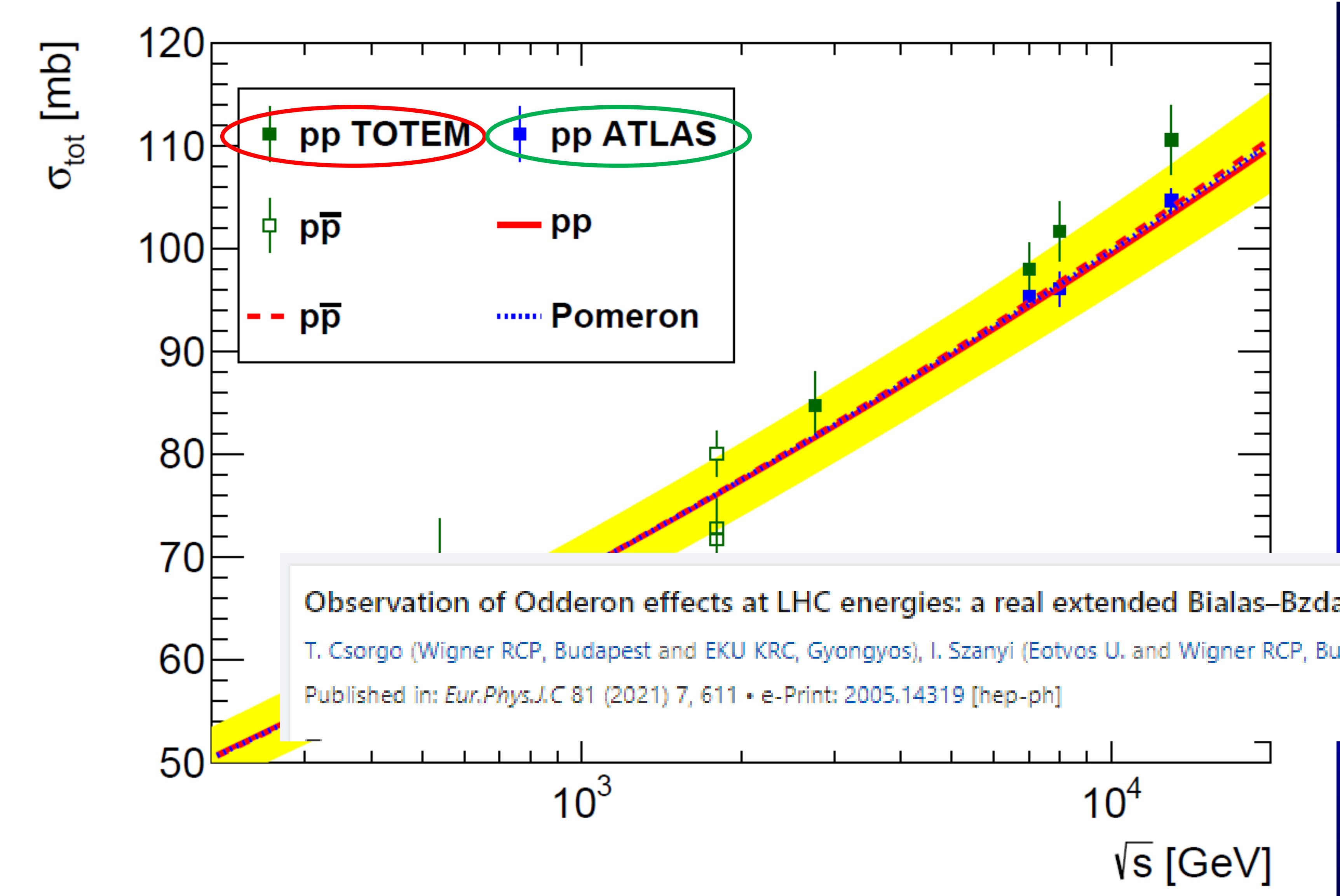
ReBB model extension to low −t, 8 TeV





TOTEM low-t vs TOTEM-large-t fit FAILS at 8 TeV, but …
ATLAS low-t vs TOTEM-large-t fit SUCCESSFUL with CL = 2.59 % at 8 TeV !

ReBB model prediction of σ_{tot} vs TOTEM and ATLAS



Observation of Odderon effects at LHC energies: a real extended Bialas–Bzdak model study

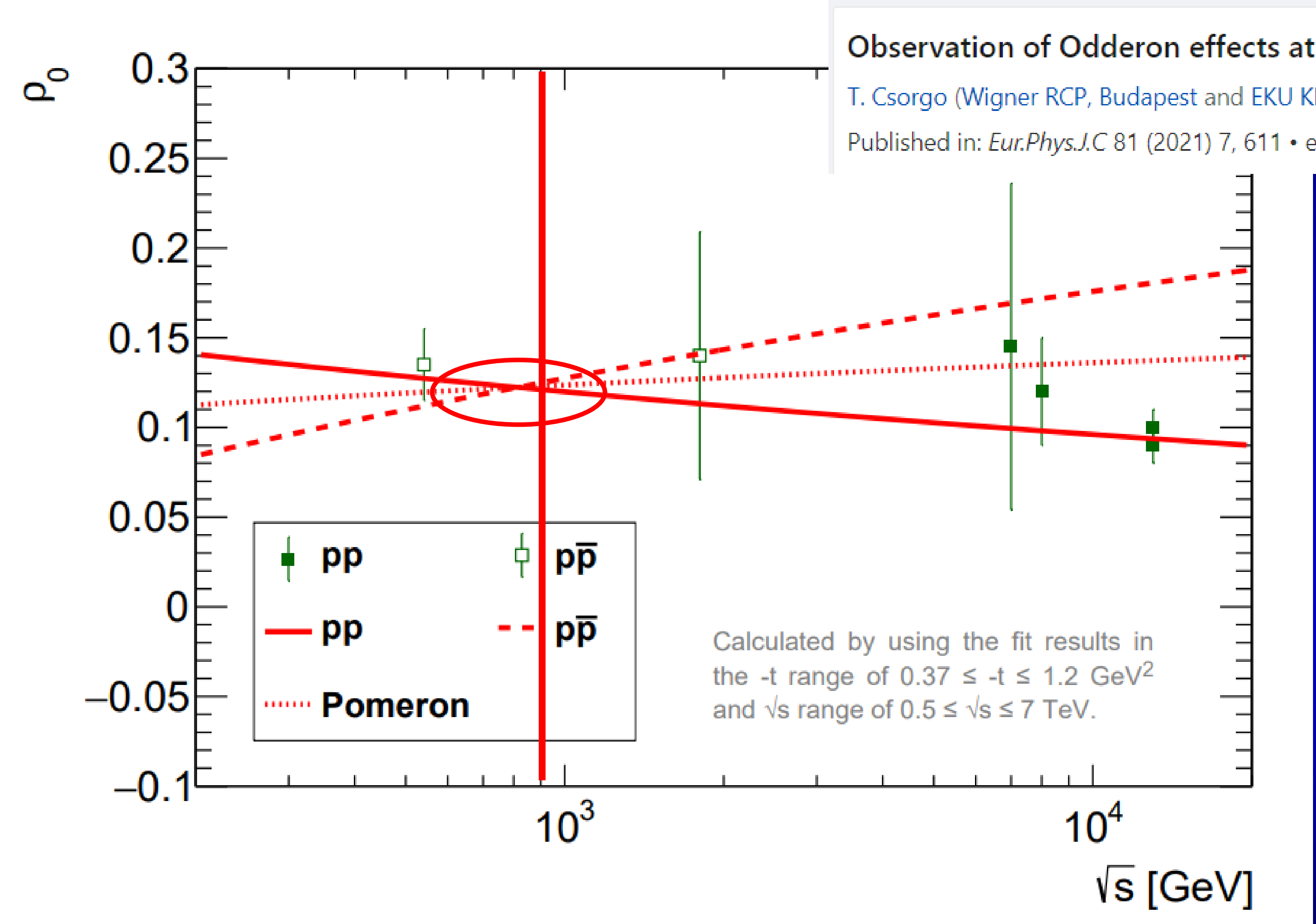
T. Csorgo (Wigner RCP, Budapest and EKU KRC, Gyongyos), I. Szanyi (Eotvos U. and Wigner RCP, Budapest) (May 28, 2020)

Published in: *Eur.Phys.J.C* 81 (2021) 7, 611 • e-Print: 2005.14319 [hep-ph]

TOTEM data on σ_{tot} are systematically above ReBB result, but …

ATLAS σ_{tot} data agree with ReBB result, published in EPJ C81 (2021) 7, 611

ρ_0 from ReBB fits to data



Observation of Odderon effects at LHC energies: a real extended Bialas–Bzdak model study

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Published in: *Eur.Phys.J.C* 81 (2021) 7, 611 • e-Print: 2005.14319 [hep-ph]

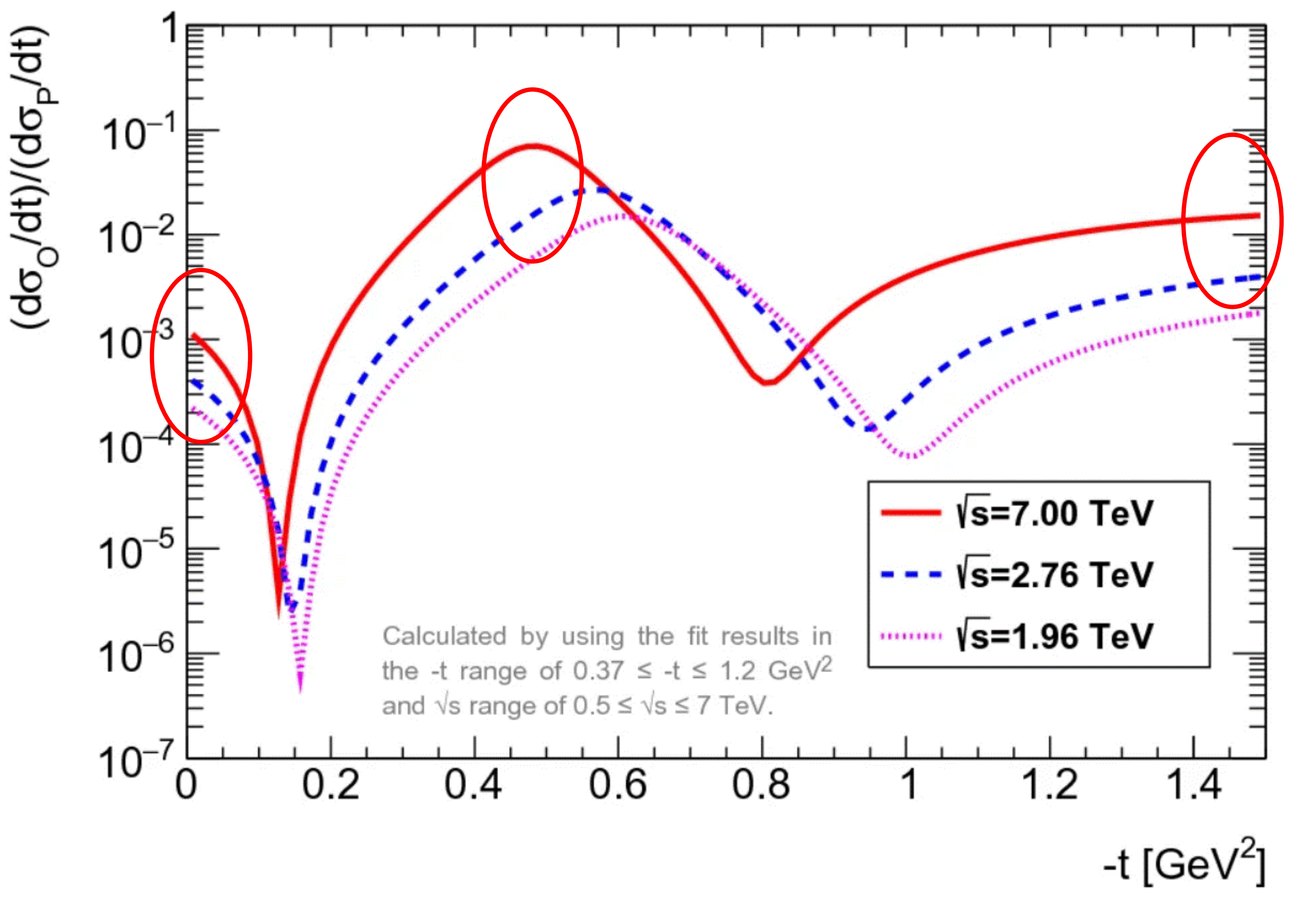
$$\rho_0^{pp}(s) \neq \rho_0^{p\bar{p}}(s),$$

except at √s ~ 0.9 TeV

ReBB fits: R_q, R_d, R_{qd} is the same in pp and pbarp, but $\rho(s)$ is not !
ReBB predicts: at √s ~ 0.9 TeV, $\rho(s)$ is the same in pp and pbarb !

ReBB model: where to look for Odderon?

Recent review of Ryskin: asks for Odderon amplitude, intercept etc.
But this has been done (for ReBB) already in 2021!



Current Status of the Odderon
Mikhail G. Ryskin (St. Petersburg, INP) (Aug 4, 2024)
e-Print: 2408.01990 [hep-ph]

Modulus and phase
for both Odderon and Pomeron
Extracted from UA4, D0 and TOTEM data using ReBB fit

Best @ dip/bump: ~ 10%
Second best @ large –t: 1 %
Most difficult @ t=0: 0.1%

NEW RESULTS 3

Simple Levy fits at small –t

(For details, see the poster of I. Szanyi)

Review: Elastic scattering at small -t

$$\frac{d\sigma}{dt}(s,t) \simeq A(s)\exp(tB(s))$$

$$\sigma_{el}(s) = \int_0^\infty d|t| \frac{d\sigma(s)}{dt}$$

$$A(s) = \frac{1}{16\pi}(1+\rho_0^2(s))\sigma_{tot}^2(s)$$

$$\sigma_{\mathbf{el}}(s) = \frac{1}{16\pi}(1+\rho_0^2(s))\frac{\sigma_{tot}^2(s)}{B_0(s)}$$

If Odderon exists: signals possible both at t = 0 and at –t > 0.
Where the significance of the signal is coming from?

Odderon Search at small -t

$$T_{\rm el}^{O}(s,t) = \frac{1}{2}\left(T_{\rm el}^{p\overline{p}}(s,t) - T_{\rm el}^{pp}(s,t)\right)$$ **valid for** $$\sqrt{s} \geq 1\ {\rm TeV},$$

Some simple consequences at small –t, Gaussian sources:

$$\frac{d\sigma}{dt}(s,t) \simeq A(s)\exp(tB(s))$$

If any of

$$\begin{aligned} A^{pp}(s) &\neq A^{p\bar{p}}(s), \\ B^{pp}(s) &\neq B^{p\bar{p}}(s). \end{aligned}$$

$$\begin{aligned} \rho_0^{pp}(s) &\neq \rho_0^{p\bar{p}}(s), \\ \sigma_{el}^{pp}(s) &\neq \sigma_{el}^{p\bar{p}}(s), \\ \sigma_{tot}^{pp}(s) &\neq \sigma_{tot}^{p\bar{p}}(s). \end{aligned}$$

is statistically significant

$$\text{for } \sqrt{s} \geq 1\,{\rm TeV} \implies T_{el}^{O}(s,0) \neq 0$$

Odderon Search at small -t

$$T^{O}_{\rm el}(s,t) = \frac{1}{2}\left(T^{p\bar{p}}_{\rm el}(s,t) - T^{pp}_{\rm el}(s,t)\right)$$ **valid for** $$\sqrt{s} \geq 1\,\text{TeV},$$

Some simple consequences at small –t, Levy sources:

$$\frac{d\sigma}{dt}(s,t) \simeq a(s)\exp\left[-(tb(s))^{\alpha_L/2}\right]$$

If any of

$$\begin{aligned} a^{pp}(s) &\neq a^{p\bar{p}}(s), \\ b^{pp}(s) &\neq b^{p\bar{p}}(s), \\ \alpha_L^{pp} &\neq \alpha_L^{p\bar{p}}, \end{aligned}$$

$$\begin{aligned} \rho_0^{pp}(s) &\neq \rho_0^{p\bar{p}}(s), \\ \sigma_{el}^{pp}(s) &\neq \sigma_{el}^{p\bar{p}}(s), \\ \sigma_{tot}^{pp}(s) &\neq \sigma_{tot}^{p\bar{p}}(s). \end{aligned}$$

is statistically significant

$$\text{for } \sqrt{s} \geq 1\,\text{TeV} \implies T^{O}_{el}(s,0) \neq 0$$

Lévy α-Stable Model for the Non-Exponential Low-|t| Proton–Proton Differential Cross-Section #1

Tamás Csörgő (Karoly Robert U. Coll. and Budapest, RMKI), Sándor Hegyi (Budapest, RMKI), István Szanyi (Karoly Robert U. Coll. and Budapest, RMKI and Eotvos U., Dept. Atomic Phys.) (Aug 3, 2023)

Published in: *Universe* 9 (2023) 8, 361, *Universe* 9 (2023) 361 • e-Print: 2308.05000 [hep-ph]

Levy generalized Bialas-Bzdak Model

Simple results at small -t:

$$a(s) = \frac{81}{16}\pi\left(2R_q^{\alpha_L(s)}(s)\right)^{4/\alpha_L}\left(1+4\alpha_R^2(s)\right)$$

$$b(s) = \frac{1}{36}\left(\frac{4}{3}\right)^{2/\alpha_L(s)}\left(\left(2+2^{\alpha_L(s)}\right)R_{qd}^{\alpha_L(s)}(s) + 3^{\alpha_L(s)}\left(2R_d^{\alpha_L(s)}(s) + R_q^{\alpha_L(s)}(s)\right)\right)^{2/\alpha_L(s)}$$

$$\rho_0(s) = 2\alpha_R(s)$$

$$\sigma_{tot}(s) = 9\pi\left(2R_q^{\alpha_L(s)}(s)\right)^{2/\alpha_L(s)}$$

$$\sigma_{el}(s) = \frac{a(s)}{b(s)}\Gamma\left(\frac{2+\alpha_L(s)}{\alpha_L(s)}\right)$$

From data fits: R_q, R_d, R_{qd}, α_L is same in pp and pbarb

35

But!

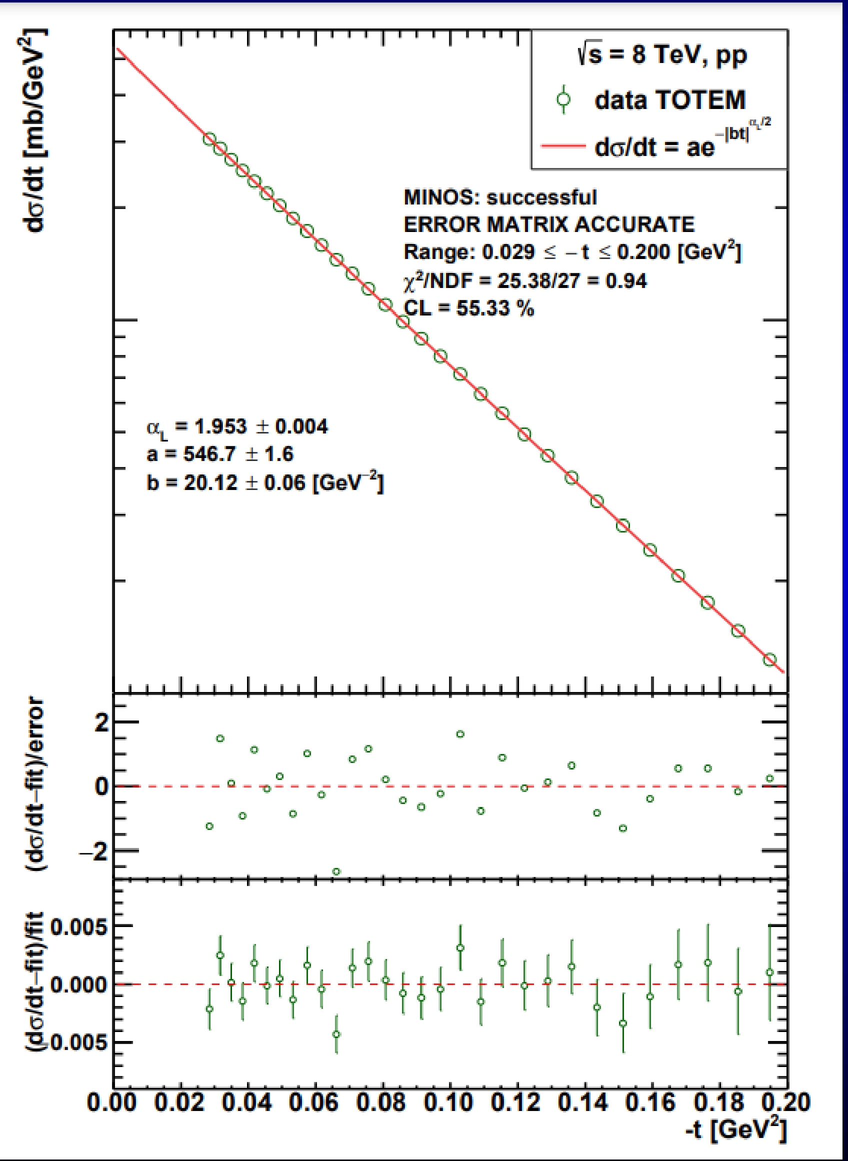
$$\rho_0^{pp}(s) \neq \rho_0^{p\bar{p}}(s),$$

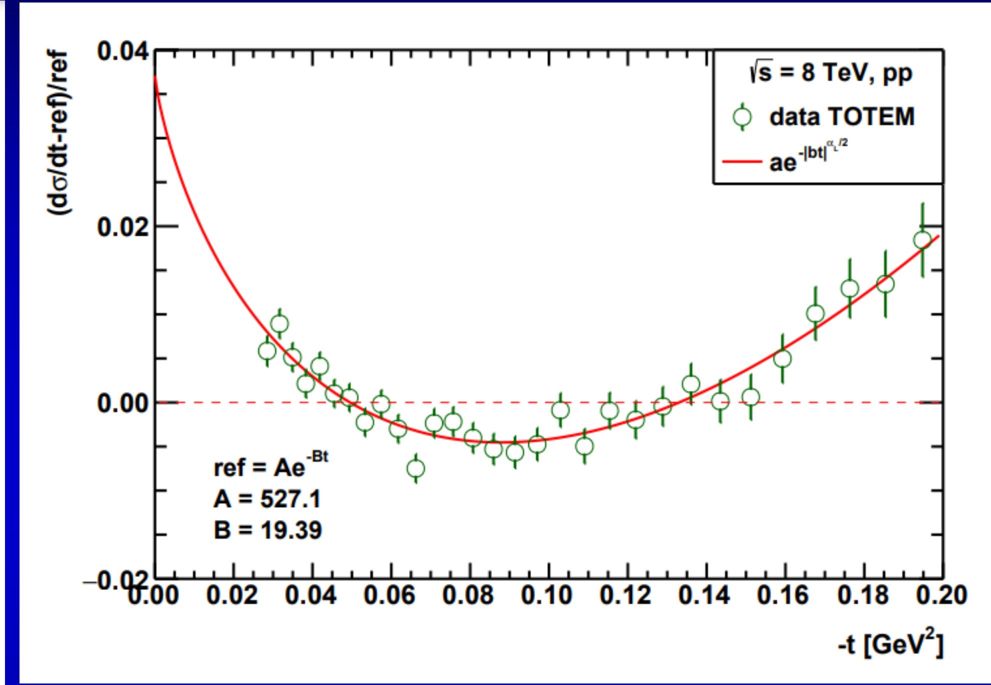
Lévy α-Stable Model for the Non-Exponential Low-|t| Proton–Proton Differential Cross-Section

#1

Tamás Csörgő (Karoly Robert U. Coll. and Budapest, RMKI), Sándor Hegyi (Budapest, RMKI), István Szanyi (Karoly Robert U. Coll. and Budapest, RMKI and Eotvos U., Dept. Atomic Phys.) (Aug 3, 2023)

Published in: *Universe* 9 (2023) 8, 361, *Universe* 9 (2023) 361 • e-Print: 2308.05000 [hep-ph]

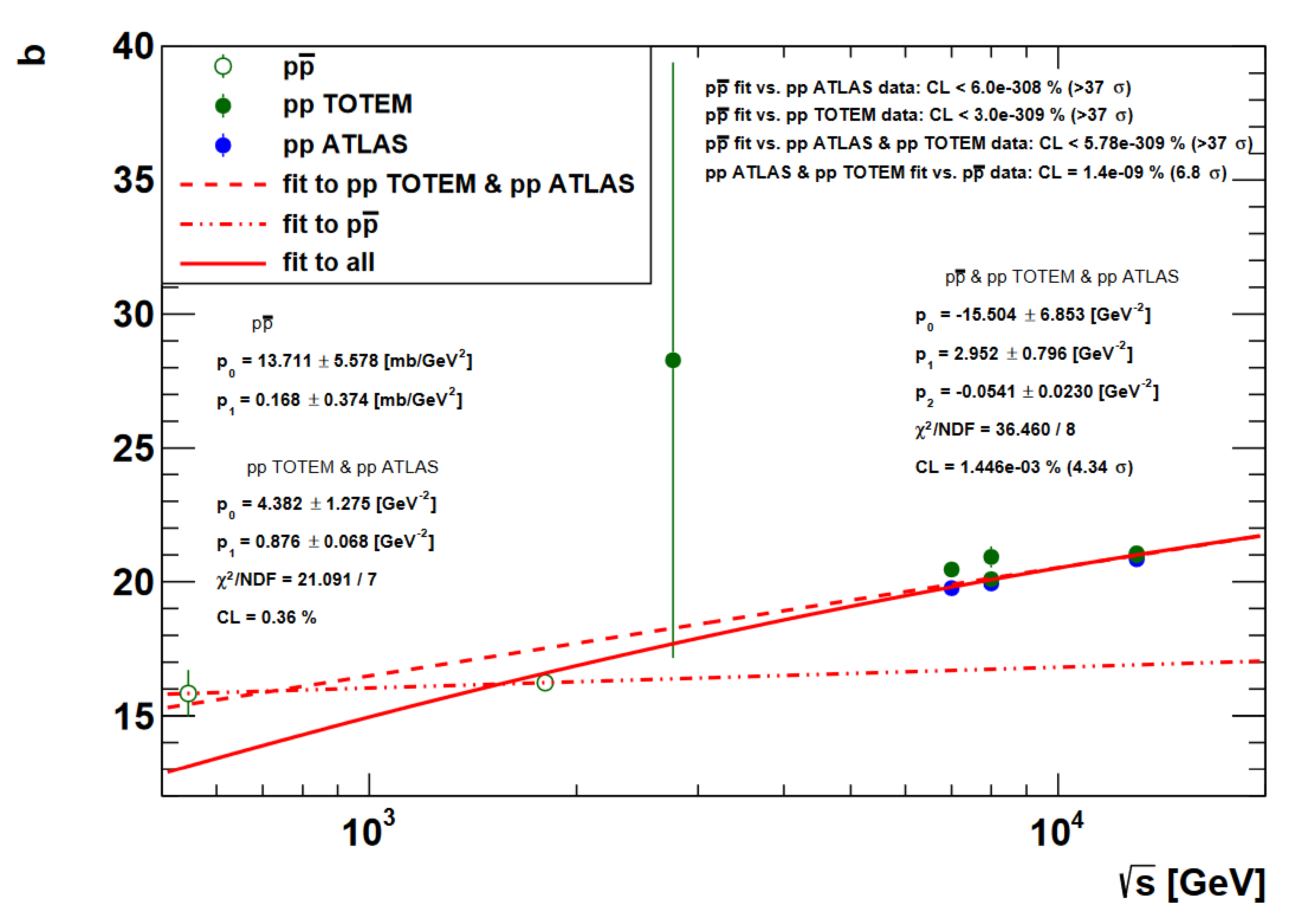




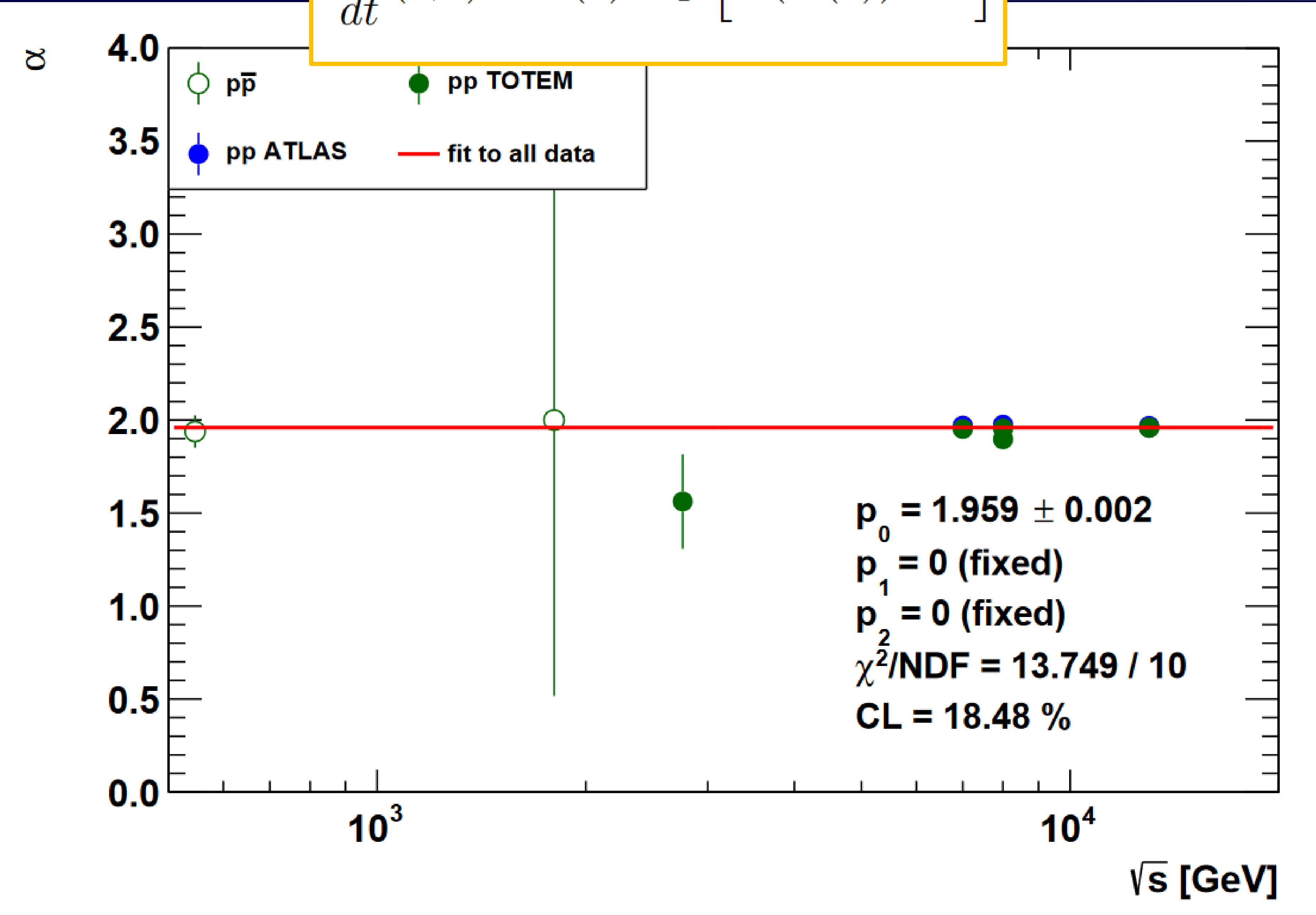
$$\frac{d\sigma}{dt}(s,t) \simeq a(s)\exp\left[-(tb(s))^{\alpha_L/2}\right]$$

From Glauber's theory, p=(q,d)
Good quality fits at 8 TeV and also at every low –t dataset for pp, pbarp

$$\frac{d\sigma}{dt}(s,t) \simeq a(s)\exp\left[-(tb(s))^{\alpha_L/2}\right]$$



$$\frac{d\sigma}{dt}(s,t) \simeq a(s)\exp\left[-(tb(s))^{\alpha_L/2}\right]$$



Levy + Bialas-Bzdak at small t

$$\frac{d\sigma}{dt}(s,t) \simeq a(s)\exp\left[-(tb(s))^{\alpha_L/2}\right]$$

$$\begin{aligned} b^{pp}(s) &= b^{p\bar{p}}(s), \\ \sigma^{pp}_{tot}(s) &= \sigma^{p\bar{p}}_{tot}(s). \end{aligned}$$

$$\begin{aligned} a^{pp}(s) &\neq a^{p\bar{p}}(s), \\ \rho^{pp}_0(s) &\neq \rho^{p\bar{p}}_0(s), \\ \sigma^{pp}_{el}(s) &\neq \sigma^{p\bar{p}}_{el}(s), \end{aligned}$$

Dramatic consequences:
Strong form of Pomeranchuk theorem!

Signals of odderon exchange in

- **optical point,**
- **ρ and**
- **elastic cross-section!**

Tests are needed…

Lévy α-Stable Model for the Non-Exponential Low-|t| Proton–Proton Differential Cross-Section #1

Tamás Csörgő (Karoly Robert U. Coll. and Budapest, RMKI), Sándor Hegyi (Budapest, RMKI), István Szanyi (Karoly Robert U. Coll. and Budapest, RMKI and Eotvos U., Dept. Atomic Phys.) (Aug 3, 2023)

Published in: *Universe* 9 (2023) 8, 361, *Universe* 9 (2023) 361 • e-Print: 2308.05000 [hep-ph]

Summary and conclusions

New 8 TeV TOTEM data strenghten
Odderon signal using H(x) scaling method

New 8 TeV TOTEM data strenghten
Odderon signal using ReBB model

ReBB fit range can be extended to low –t at
8 TeV, if ATLAS data are used
instead of TOTEM low –t data

Levy generalization of ReBB model in progress
to fit TOTEM+TOTEM data at 8 TeV

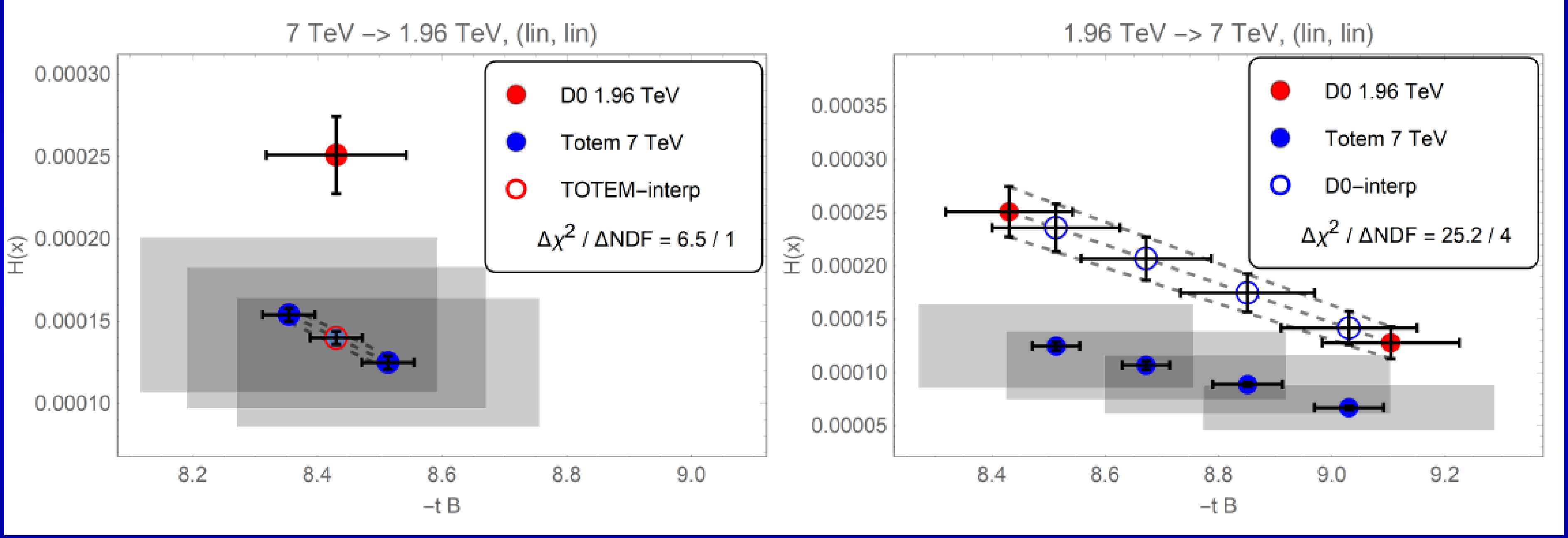
Levy ReBB suggest a strong form of the
Pomeranchuk theorem

THANK YOU !

QUESTIONS?

H(x) rebin: linear interpolations in x

Need for a comparison of different data sets measured at different values of x:
Linear interpolation to the same x = -t B



Errors: both vertical AND horizontal, type A, B, C
type A: point-to-point fluctuating error
type B: point-to-point 100 % correlated error
type C: point independent overall correlated error

Model independent results since ISMD'19

Evidence of Odderon-exchange from scaling properties of elastic scattering at TeV energies #3

T. Csörgő (Wigner RCP, Budapest and CERN), T. Novak (Unlisted, HU), R. Pasechnik (Lund U., Dept. Theor. Phys.), A. Ster (Wigner RCP, Budapest), I. Szanyi (Wigner RCP, Budapest) (Dec 26, 2019)

e-Print: 1912.11968 [hep-ph]

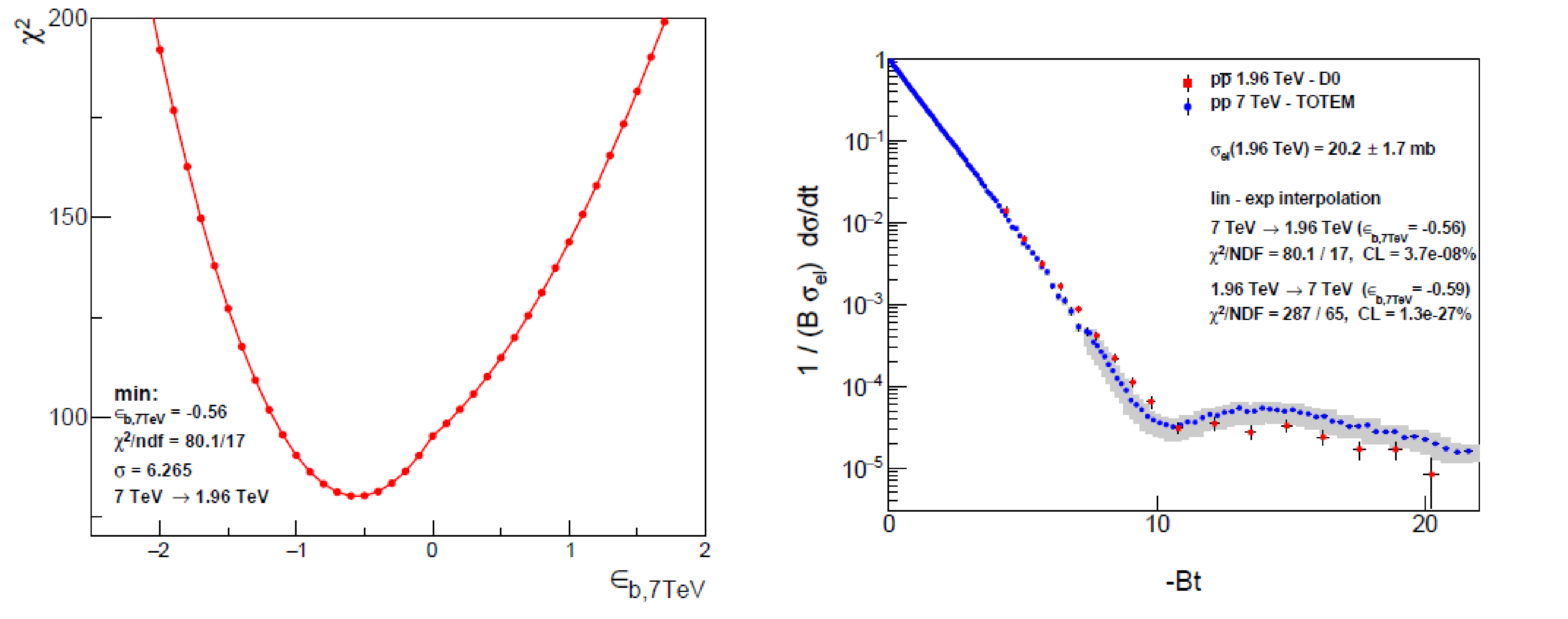


Fig. 13 Left panel indicates that as a function of $\varepsilon_{b,7\ \text{TeV}}$, the $\chi^2 \equiv \tilde{\chi}^2_{21}$ distribution has a unique minimum and nearly quadratic minimum. The minimum value is $\chi^2/\text{NDF} = 80.1/17$, corresponding to a statistically significant difference between the pp and $p\bar{p}$ $H(x)$ scaling functions. at the level of 6.26σ. The right panel shows the comparison of the $H(x)$ data using the values of $\varepsilon_{b,7\ \text{TeV}}$ corresponding to such a minimum, both for the case of the $7 \to 1.96$ TeV and for the case of $1.96 \to 7$ TeV projections.

T. Cs, R. Pasechnik, T. Novák, A. Ster, I. Szanyi, Eur. Phys. J. C (2021) **81**: 180
https://doi.org/10.1140/epjc/s10052-021-08867-6 , 1912.11968 [hep-ph]

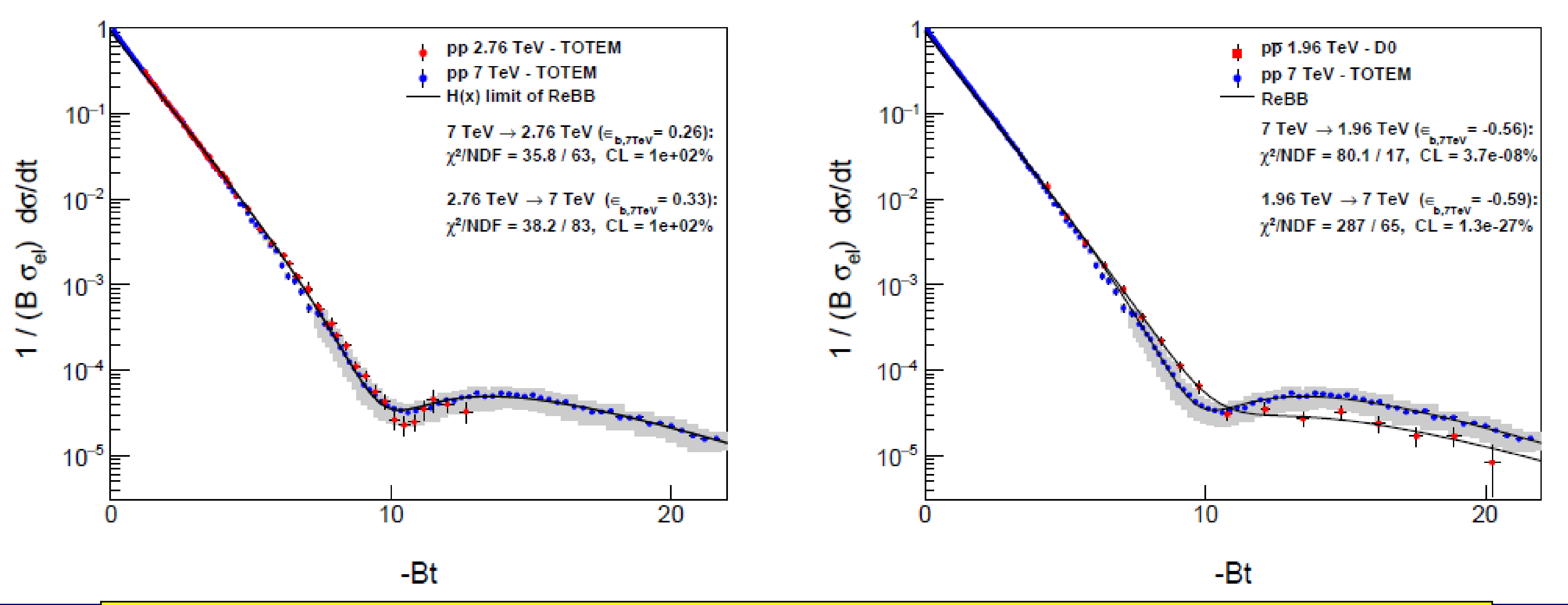
Model independent results since ISMD’19

Scaling of high-energy elastic scattering and the observation of Odderon #3

T. Csörgő (Wigner RCP, Budapest and Eszterhazy Karoly U., Eger), T. Novák (EKU KRC, Gyongyos), R. Pasechnik (Lund U., Dept. Theor. Phys.), A. Ster (Wigner RCP, Budapest), I. Szanyi (Wigner RCP, Budapest and Eotvos U.) (Apr 15, 2020)

e-Print: 2004.07318 [hep-ph]

pdf cite 3 citations



arXiv:2004.07318v2

Model independent Odderon significance 6.26 σ

11 pages, 2 figures, synthesis of data analysis and theory results

But: **domain of validity** is still determined **model dependently**.

Model independent results since ISMD'19

Scaling of high-energy elastic scattering and the observation of Odderon #3

T. Csörgő (Wigner RCP, Budapest and Eszterhazy Karoly U., Eger), T. Novák (EKU KRC, Gyongyos), R. Pasechnik (Lund U., Dept. Theor. Phys.), A. Ster (Wigner RCP, Budapest), I. Szanyi (Wigner RCP, Budapest and Eotvos U.) (Apr 15, 2020)

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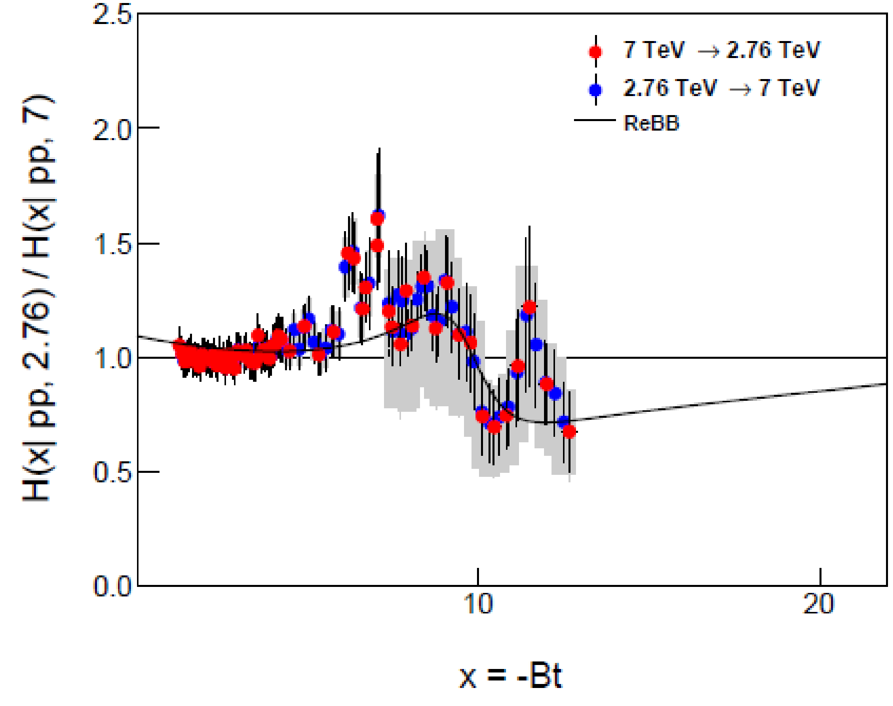
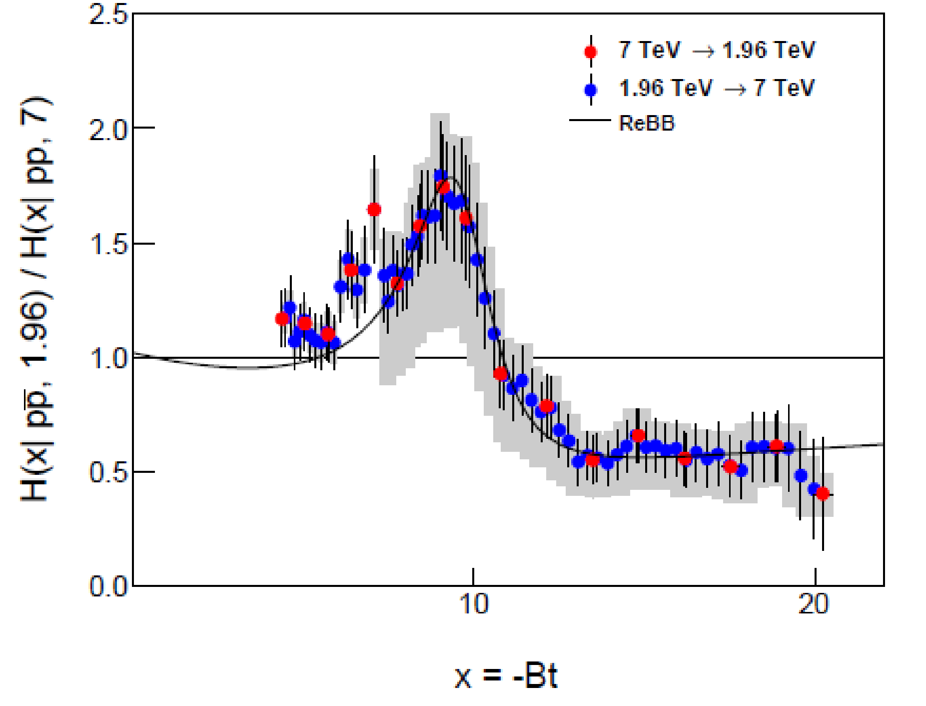
pdf cite 3 citations





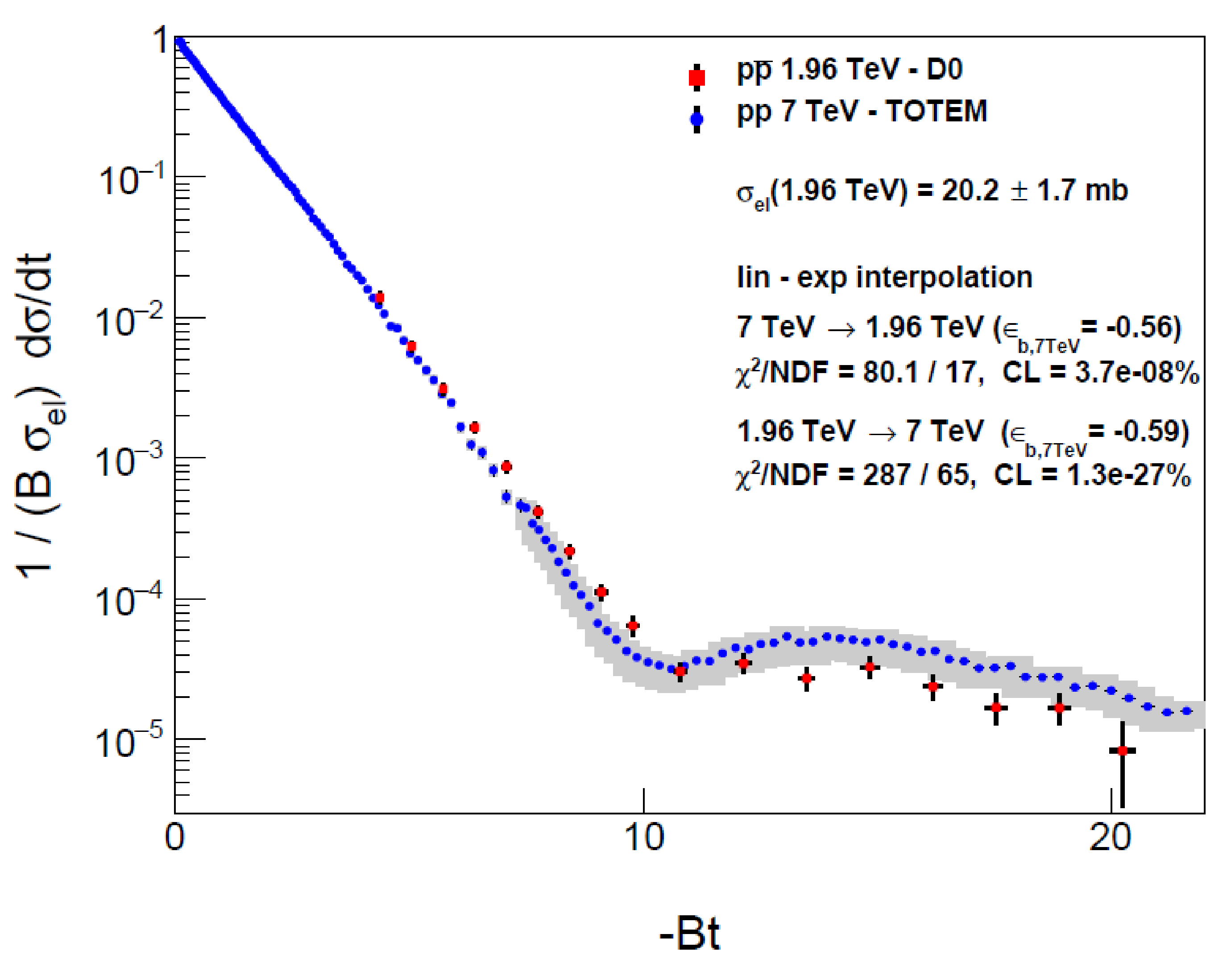
arXiv:2004.07318v2

Model independent Odderon significance 6.26 σ

11 pages, 2 figures , synthesis of data analysis and theory results

New result presented in this talk: domain of validity model independently

Model independent result



H(x|pp)
s-independent:
2.76 – 7(8) TeV

H(x|pp, 7 TeV)
≠
H(x|pantip,
1.96 TeV)

Odderon,
IF scaling holds
in pp down to
1.96 TeV

6.26 σ
Odderon effect

Energy range: tested both model independently and with modelling.
Modelling is useful, but model independent tests more important!

Asymmetry parameter for C-violation

$$A(x|p\bar{p},s_1|pp,s_2) = \frac{H(x|p\bar{p},s_1) - H(x|pp,s_2)}{H(x|p\bar{p},s_1) + H(x|pp,s_2)},$$

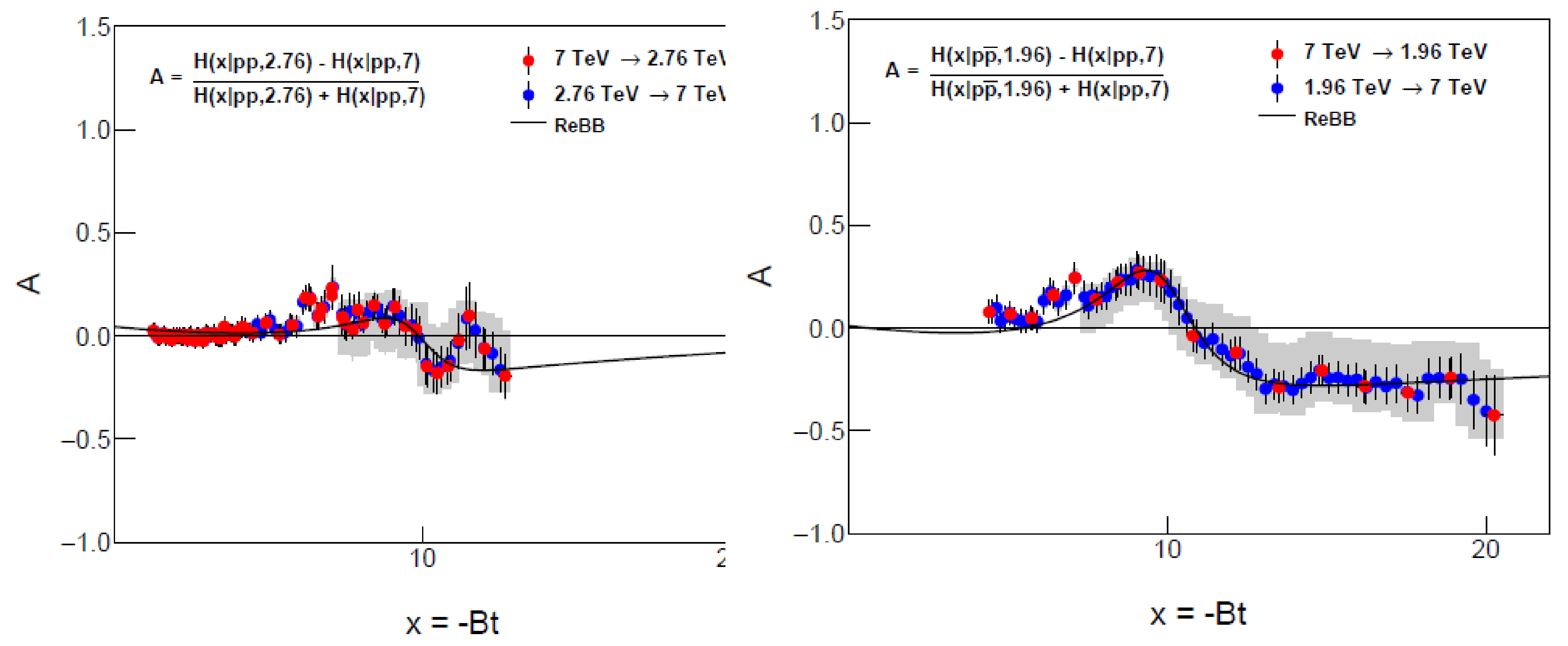
$$A(x|pp,s_1|pp,s_2) = \frac{H(x|pp,s_1) - H(x|pp,s_2)}{H(x|pp,s_1) + H(x|pp,s_2)}.$$

$A(x|pbarp,s_1|pp,s_2)$
does NOT vanish
for a C-symmetry violation AND

$A(x|pp,s_1|pp,s_2)$
vanishes if
H(x) scaling valid

Energy range: HAS to be tested carefully

Main result of A



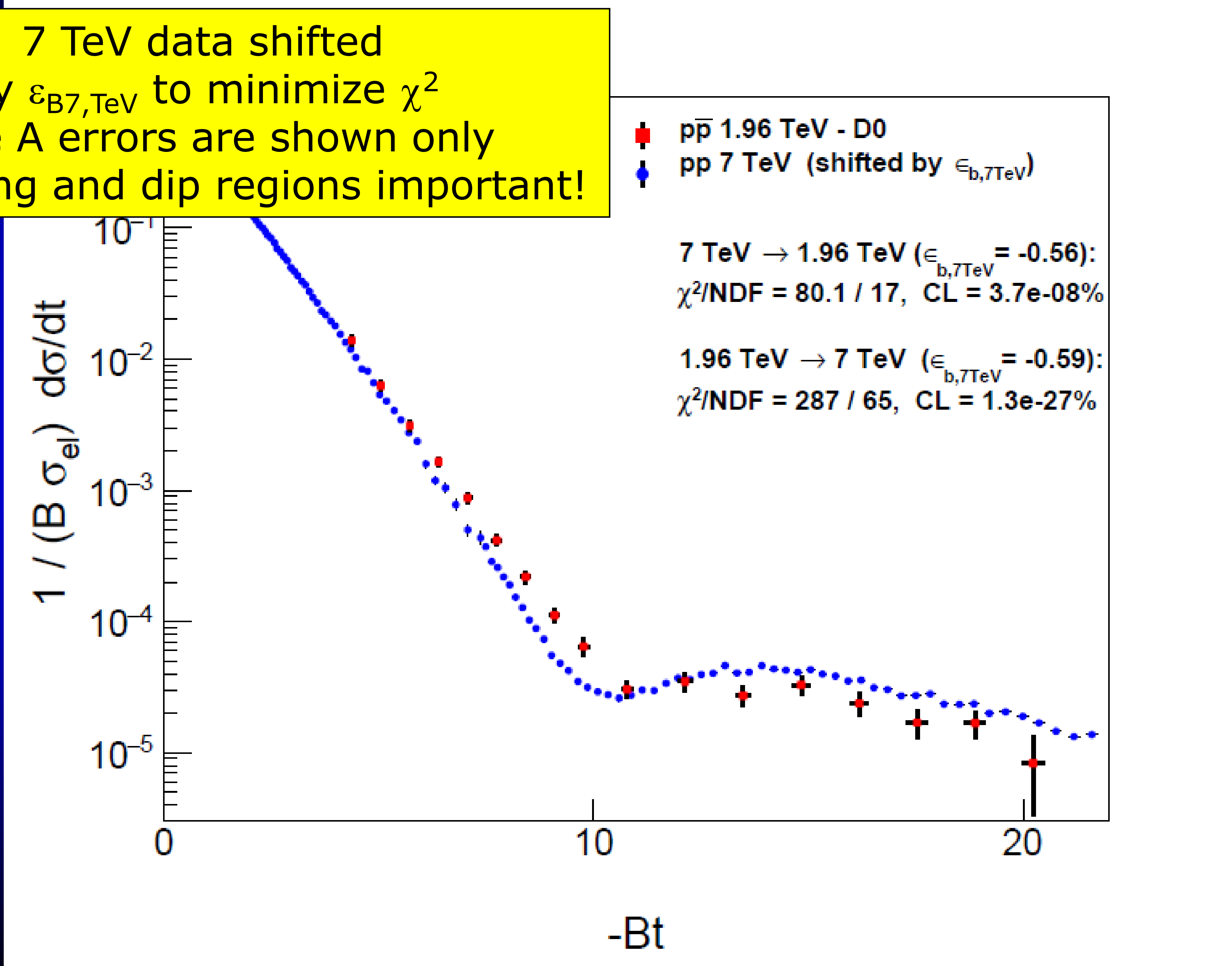
$A(x|pp,s_1|pp,s_2) \sim 0$
vanishes if
H(x) scaling valid

$A(x|pbarp,s_1|pp,s_2) \neq 0$
does NOT vanish
if Odderon term is present

Scaling violations: under theoretical control:
Model calculations by solid line, see e-Print: 2005.14319 [hep-ph]

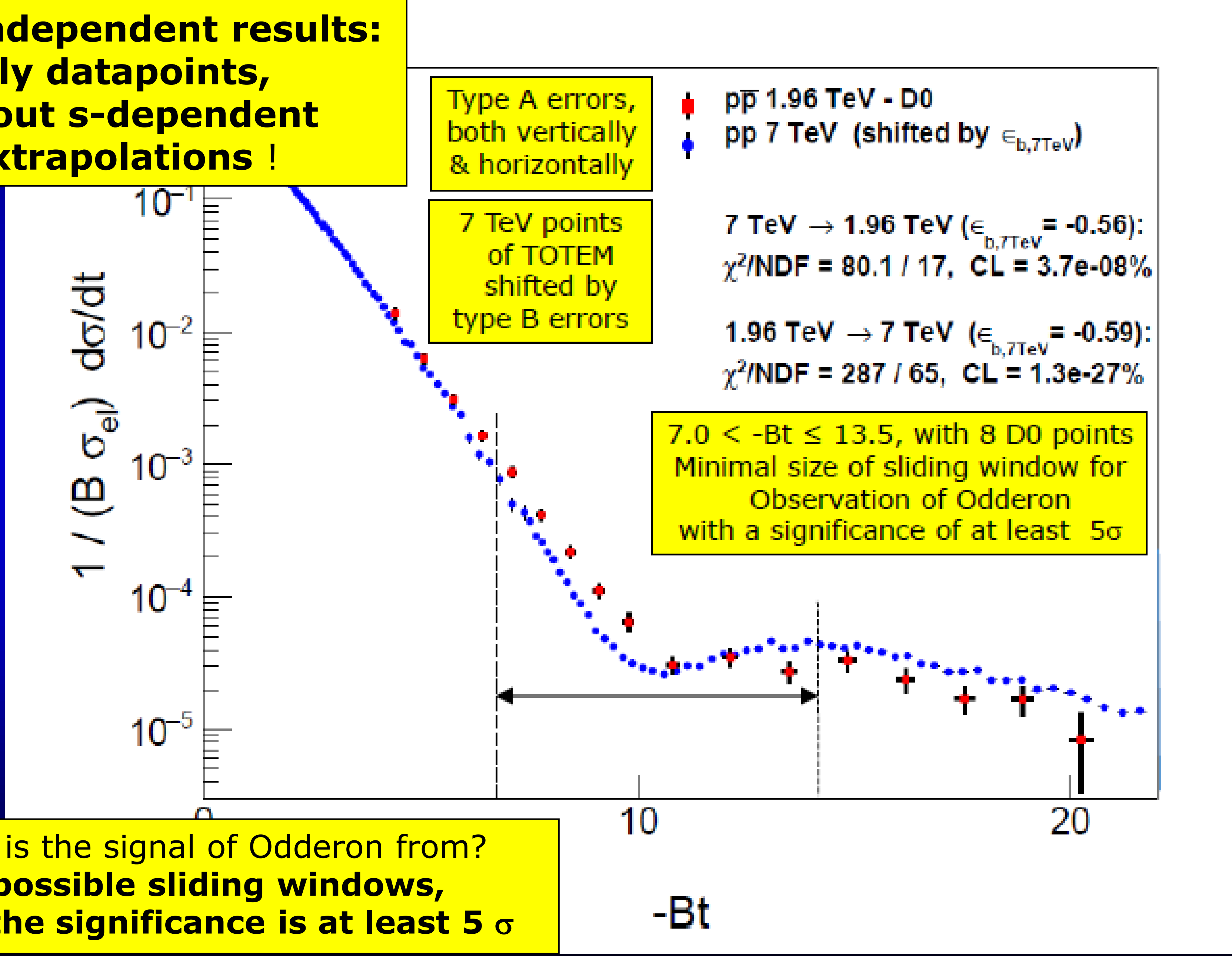
OBSERVATION OF ODDERON

7 TeV data shifted
by $\varepsilon_{B7,TeV}$ to minimize χ^2
Type A errors are shown only
Both swing and dip regions important!



SLIDING WINDOW for 5 σ

Model independent results: only datapoints, without s-dependent extrapolations !



Where is the signal of Odderon from?
All possible sliding windows, where the significance is at least 5 σ

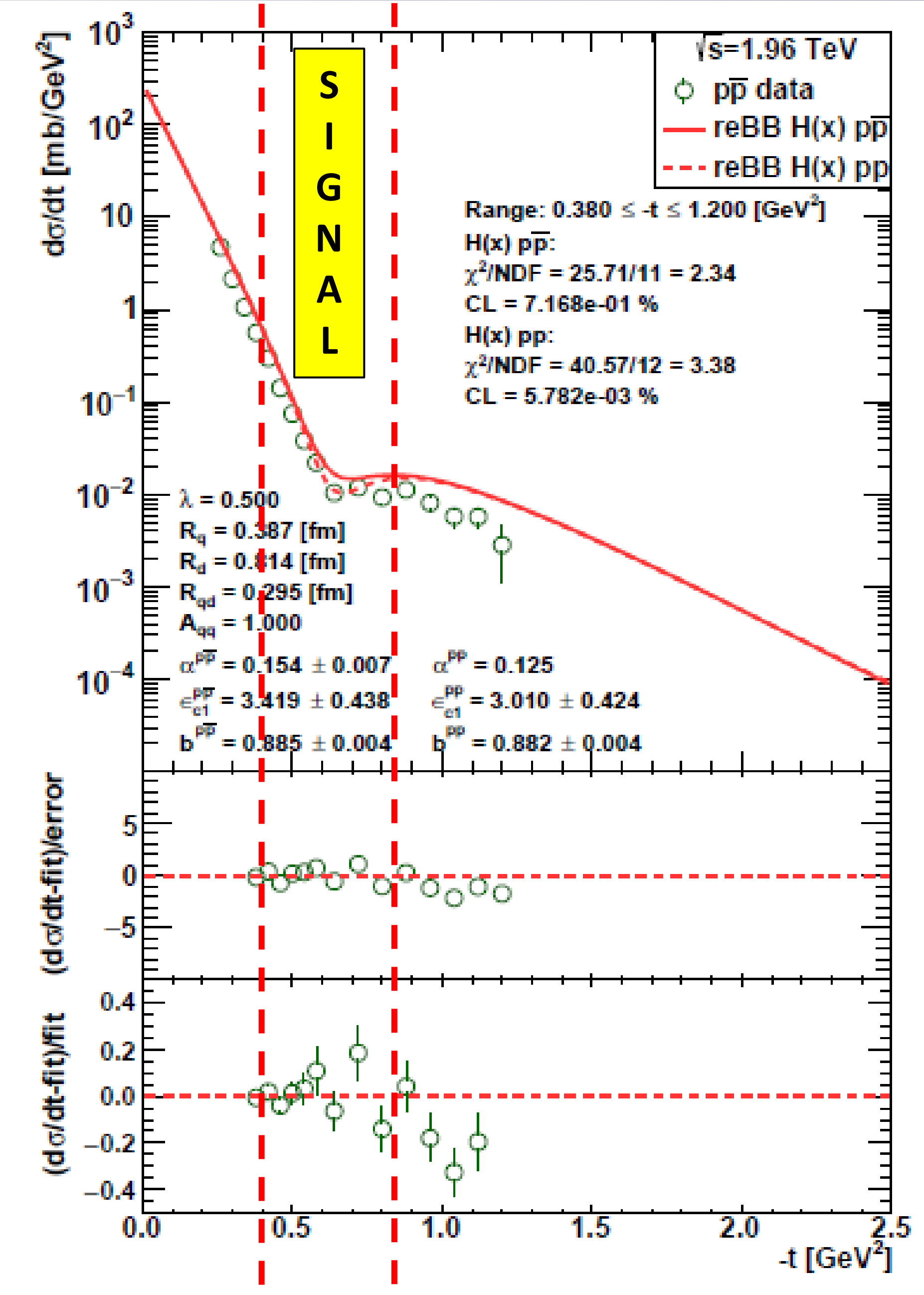
Is H(x,s) = H(x) at 1.96 TeV?

MODEL INDEPENDENTLY: YES!
In the background of the Odderon signal, defined as $x \leq 7.0$ in union with $x > 13.5$
H(x|pp,7 TeV) ~ H(x|pbarp, 1.96 TeV)
Agreement: a significance of 2.39 σ

Results for the background: $x \leq 7.0$ in union with $x > 13.5$ for ε_{B21}(7 TeV) = -1.1 that minimizes signal in the background				
x_{max}	ε_{B21} of min[χ^2(background)]	$\Delta\chi^2$(background)	NDF(background)	σ (background)
20.2	-1.10	20.20	9	2.39

New MODEL INDEPENDENT result

Is H(x,s) = H(x) at 1.96 TeV?



MODEL DEPENDENTLY: Yes
1.96 TeV
Highest energy where p+antip data are available

H(x) scaling limit:
in the Bialas-Bzdak model

Fits pbarp data up to largest -t
(red line, dashed line: pp)

Pull plots:
(data-fit)/error
(data-fit)/fit

t_{max}(1.96 TeV, pp) > 1.2 GeV^2

→ x_{max}(1.96 TeV, pp) > 20

Safely above the 5 σ threshold

Role of the H(x) scaling violations
Do they decrease the signal or not?

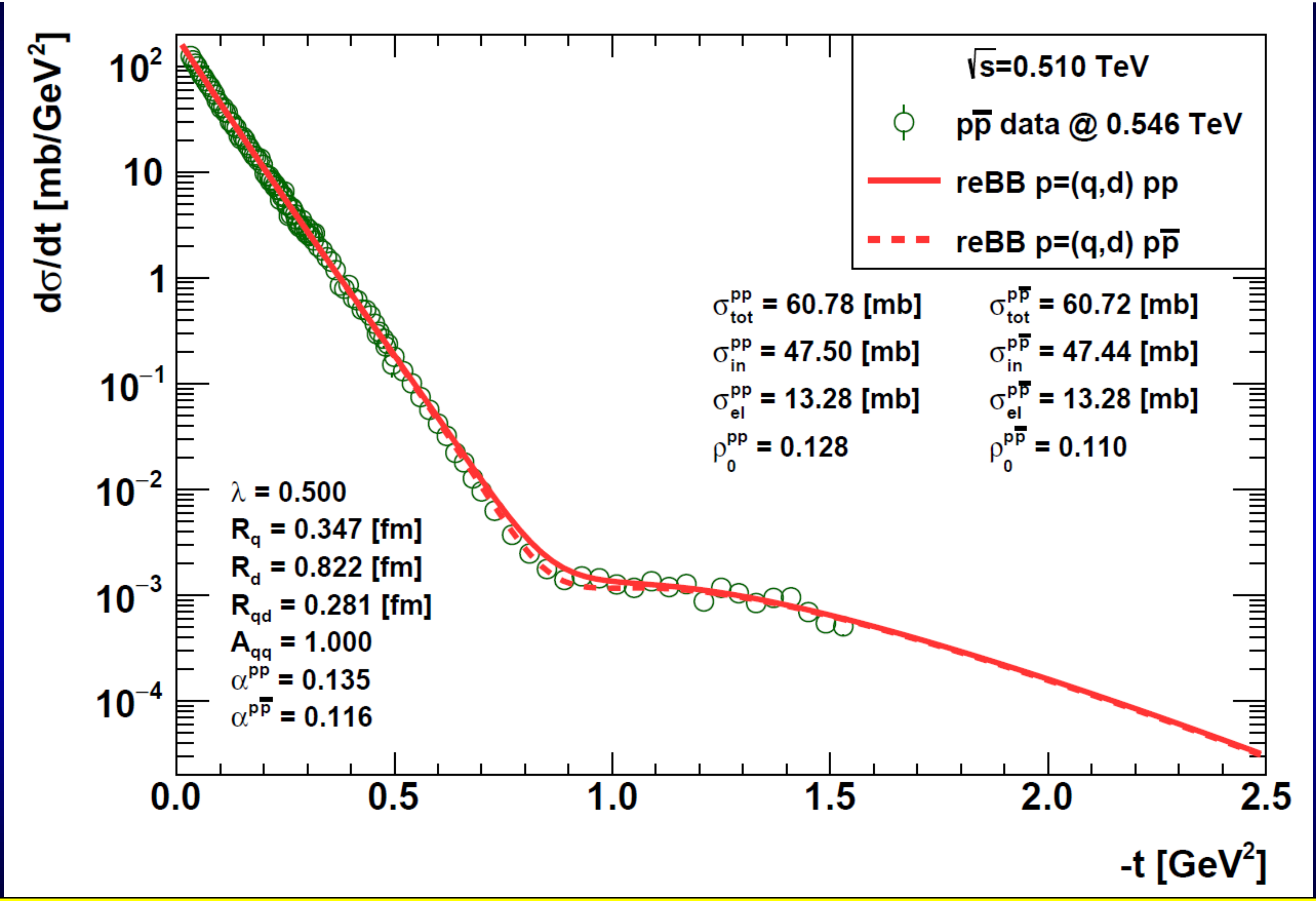
√s (TeV)	χ^2	NDF (ReBB)	σ (ReBB)
1.96	24.28	13	2.19
2.76	100.35	20	7.12
1.96 and 2.76	124.63	33	7.08

H(x) scaling: allows to project pp data ONLY
Scaling violations decrease significance at 1.96 TeV
BUT
Also allow to evaluate pbarp data at 2.76 TeV

Trade-off effect!

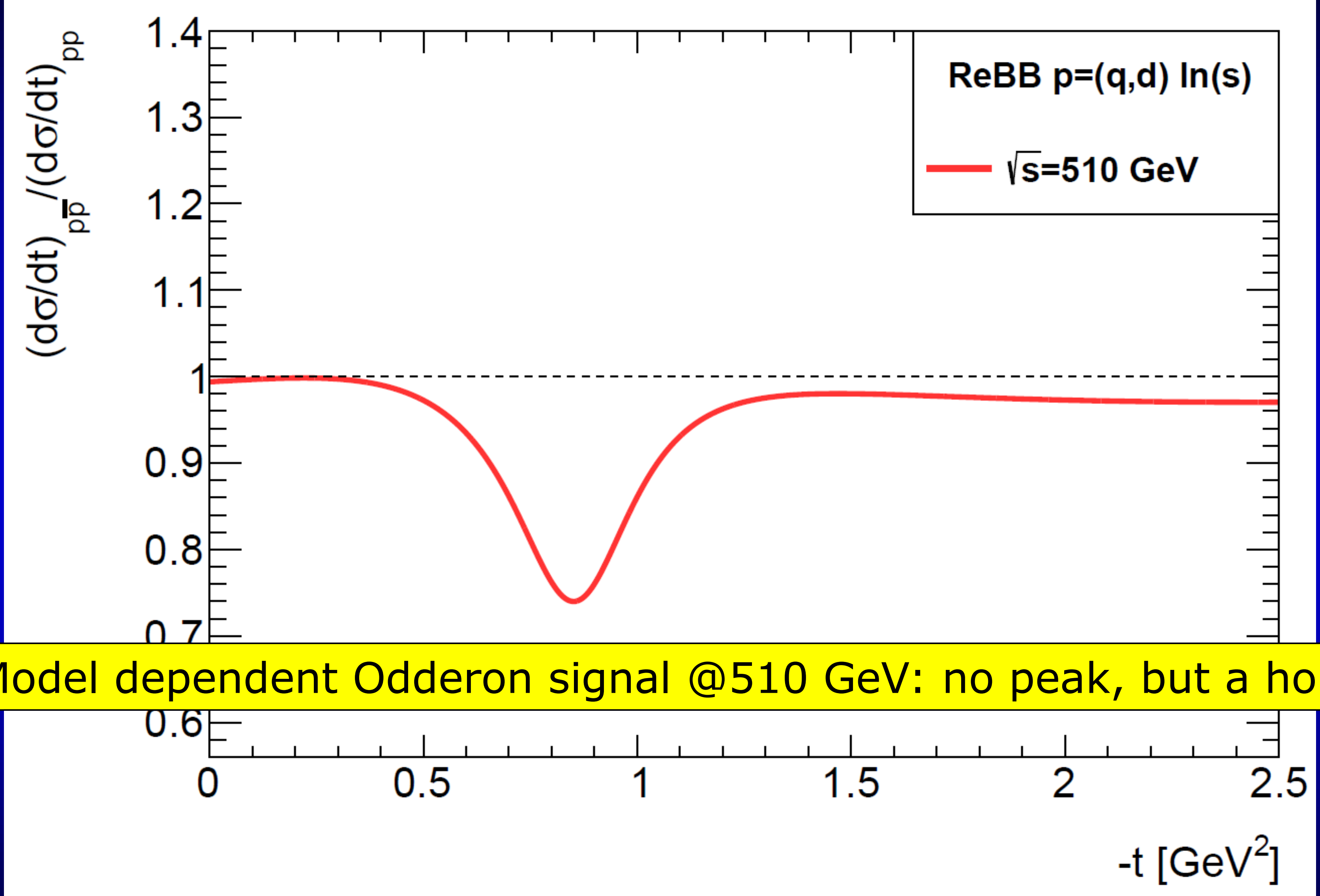
Odderon significance increases from 6.26 to 7.08 σ .

Predictions for pp and pbarp dσ/dt @ 510 GeV



Model dependent Odderon signal @510 GeV: pp above pbarp !

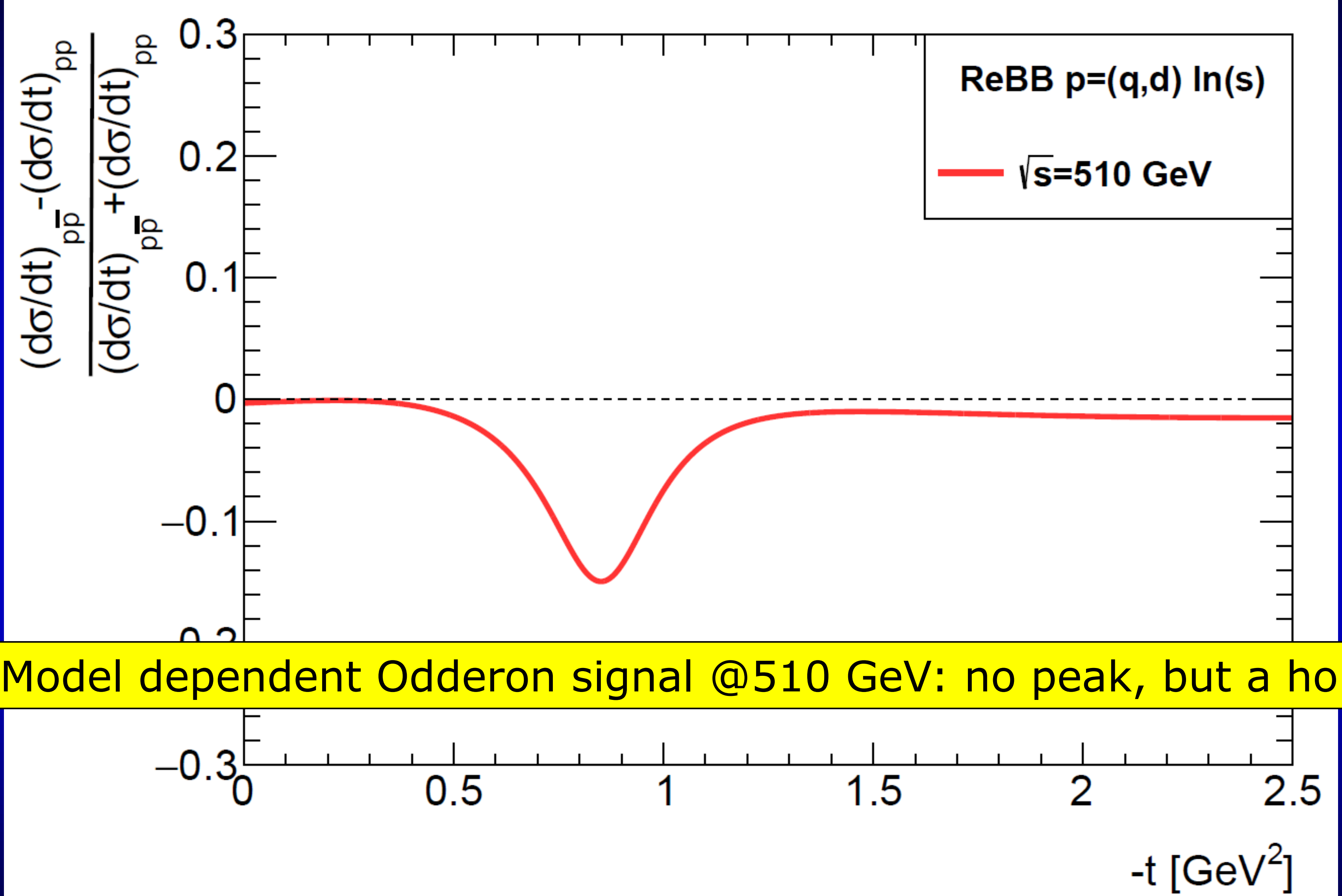
Ratio of pbarp to pp cross-sections @ 510 GeV



Model dependent Odderon signal @510 GeV: no peak, but a hole

Scaling violations: dominant @510 GeV
Model dependent Odderon signal: pbarp dσ/dt ~ 25 % below pp !!

Asymmetry parameter @ 510 GeV



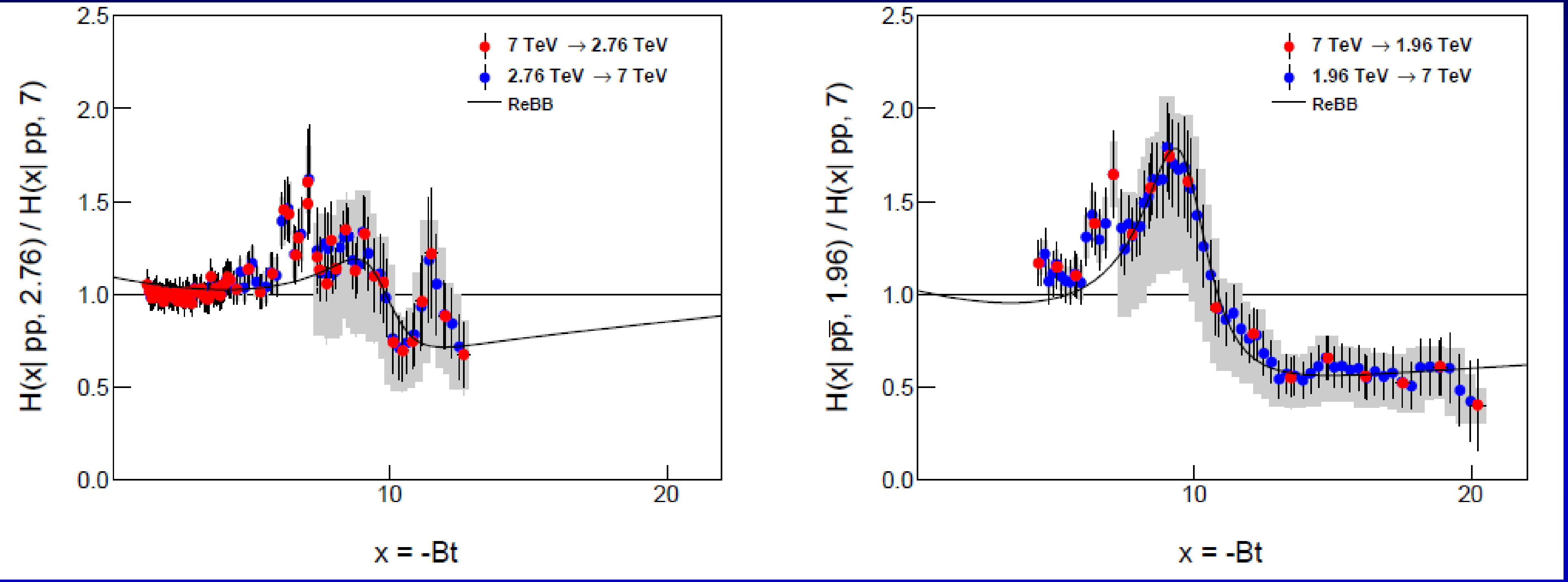
Model dependent Odderon signal @510 GeV: no peak, but a hole

Scaling violations: dominant @510 GeV

Model dependent Odderon signal: A ~ - 15 % @ -t ~ 0.85 GeV^2

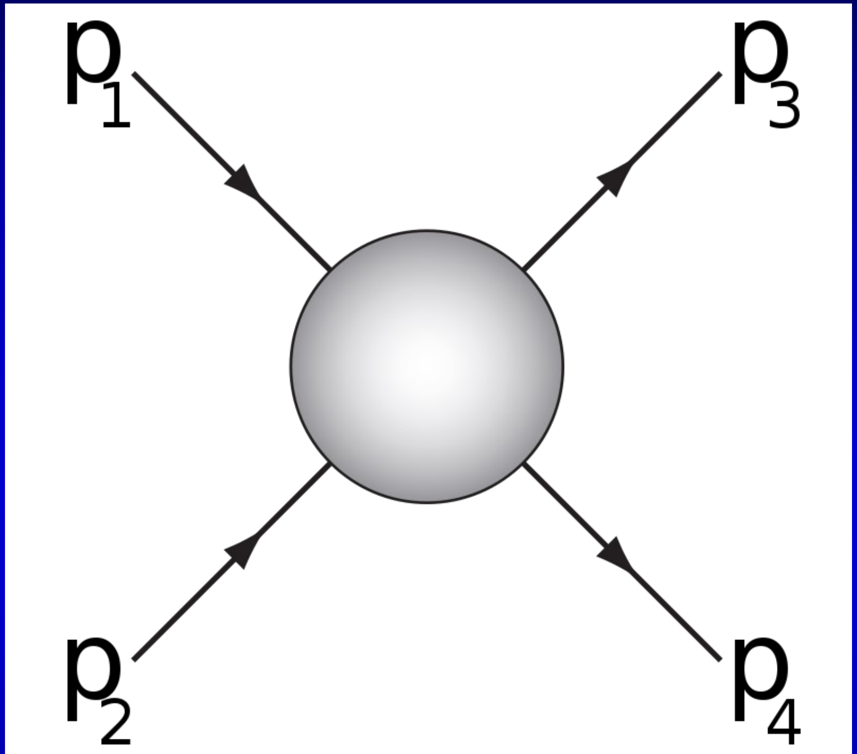
SUMMARY: AT LEAST 6.26 σ ODDERON

An at least 6.26 σ Odderon effect



A discovery level, **model independent** Odderon effect at TeV scale.
Published: Eur. Phys. J. C **81**, 180 (2021).
https://doi.org/10.1140/epjc/s10052-021-08867-6
Domain of validity of H(x) scaling: full x =-tB range of D0 at 1.96 TeV.
Published result confirmed with NEW, model INDEPENDENT result !
Model dependent results, using the ReBB model
Significance ≥ 7.08 σ , see e-Print: 2005.14319 [hep-ph]

Mandelstam variables



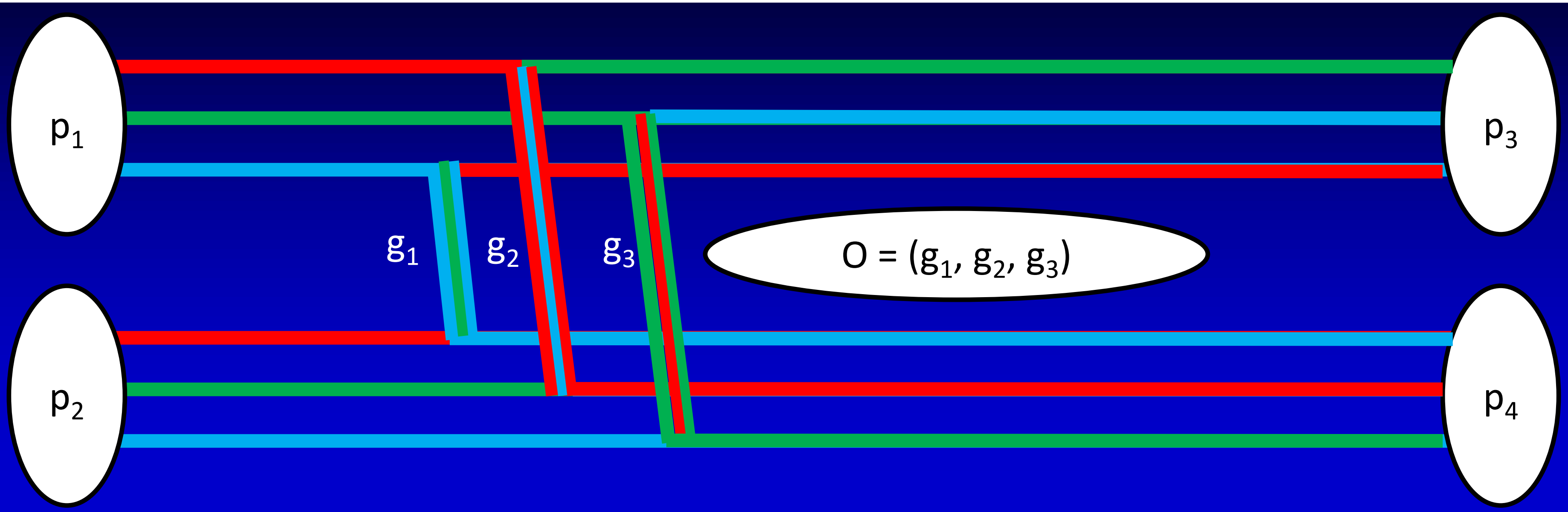
$$s = (p_1 + p_2)^2 = (p_3 + p_4)^2$$
$$t = (p_1 - p_3)^2 = (p_4 - p_2)^2$$
$$u = (p_1 - p_4)^2 = (p_3 - p_2)^2$$

p_1,p_2: four-momenta before elastic scattering

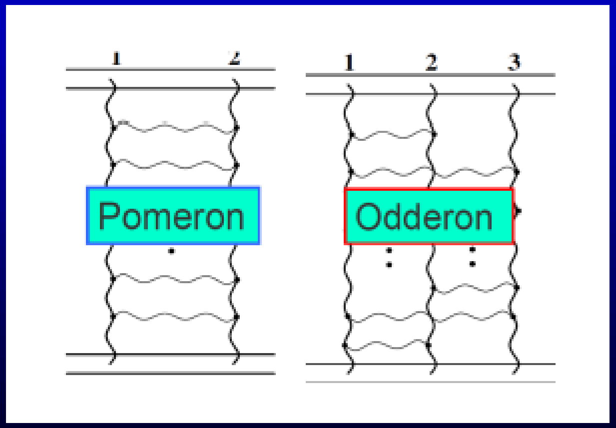
p_3,p_4: four-momenta after elastic scattering

s: square of the cms energy
t: square of four-momentum transfer

Odderon and QCD in Laymen’s Terms



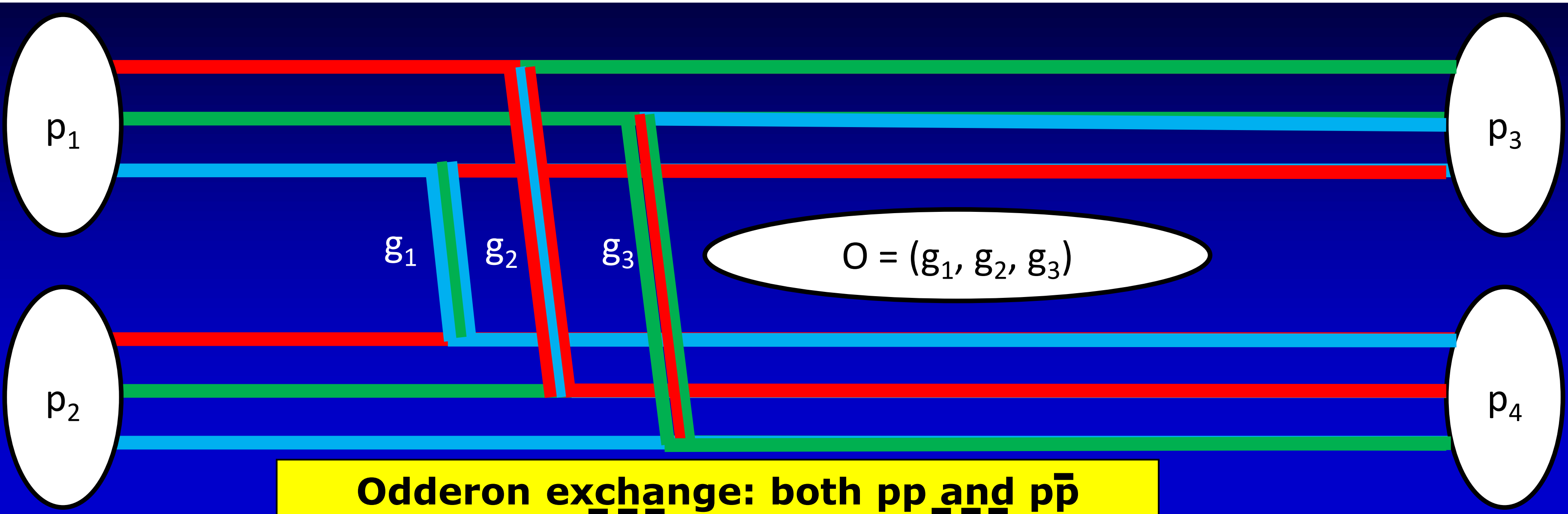
$g_1 = B\bar{R}+R\bar{B}$ $g_2 = R\bar{G}+G\bar{R}$ $g_3 = G\bar{B}+B\bar{G}$



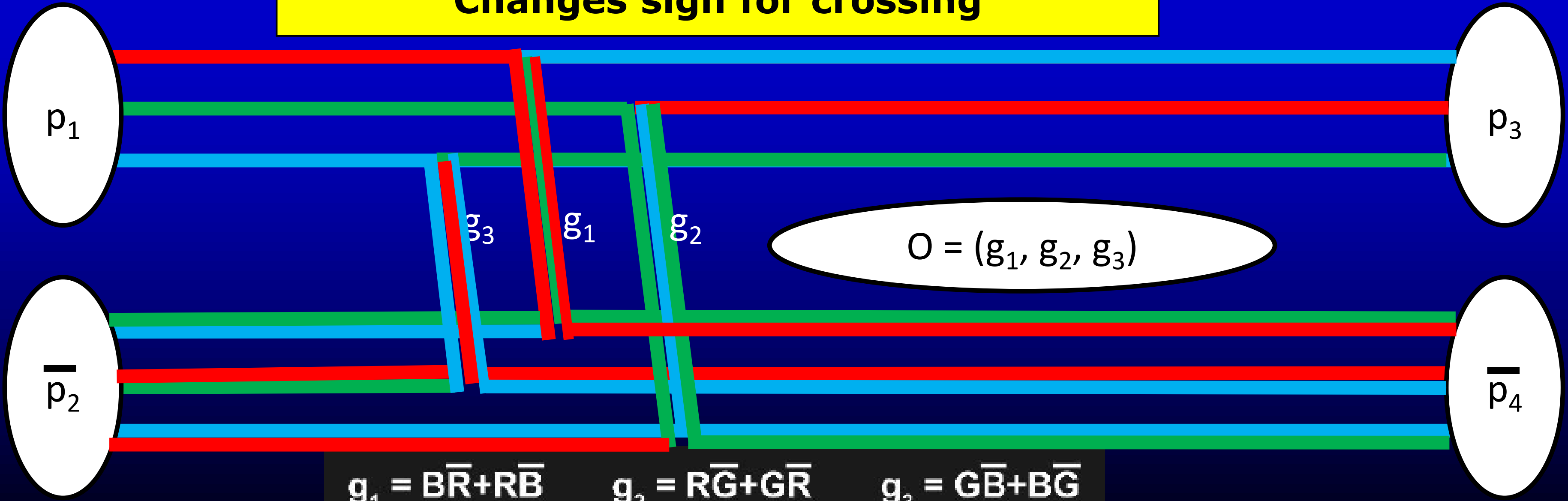
Pomeron (2+4+…) gluon in pp:
(RGB)+(RGB) → (GRB)+(GRB)

Odderon (3+5+… gluon) in pp:
(RGB)+(RGB) → (GBR)+(BRG)
Well established in QCD

Odderon and elastic collisions



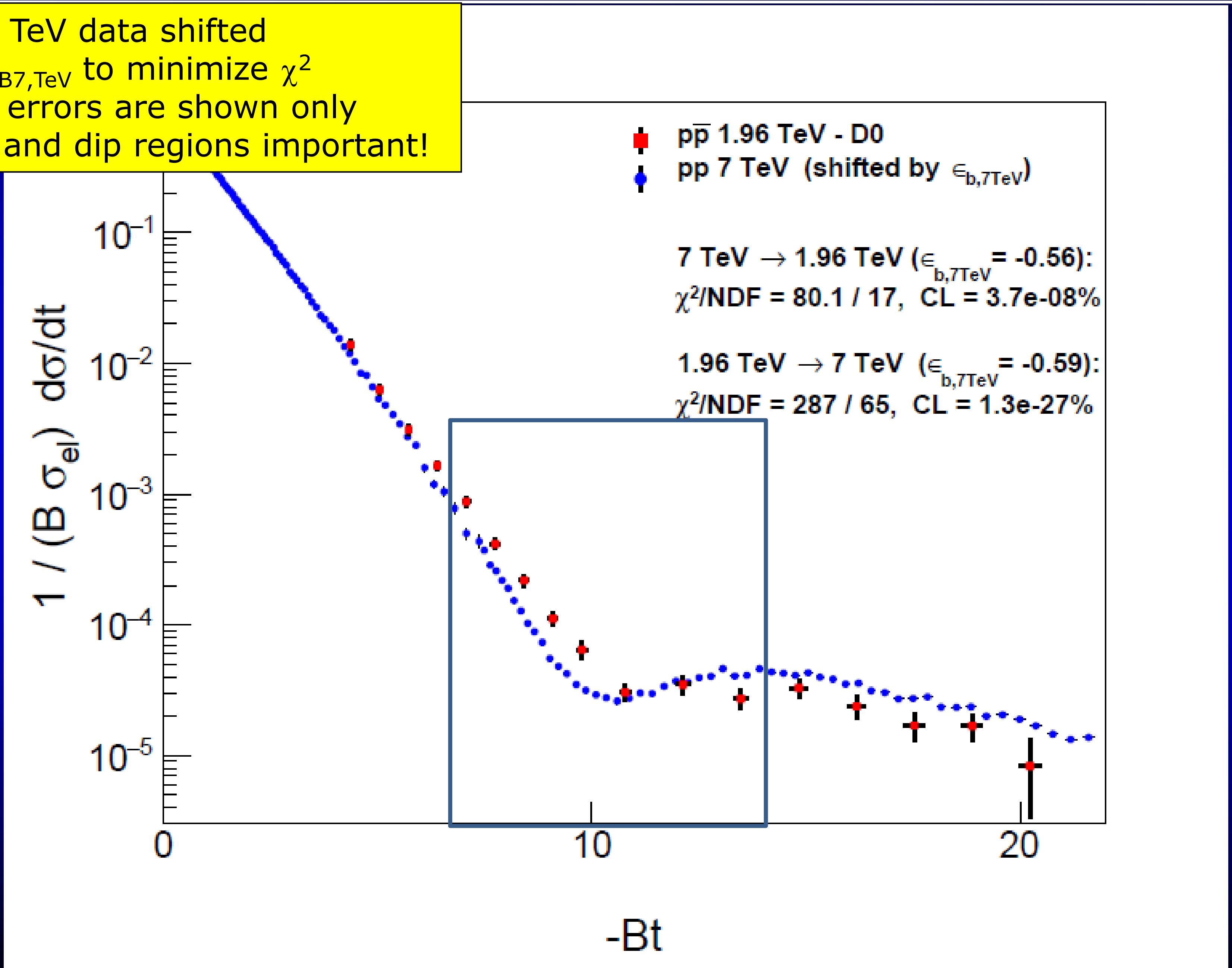
Odderon exchange: both pp and $p\bar{p}$
(RGB)+($\bar{R}\bar{B}\bar{G}$) → (BRG)+($\bar{B}\bar{G}\bar{R}$)
Changes sign for crossing



$g_1 = B\bar{R}+R\bar{B}$ $g_2 = R\bar{G}+G\bar{R}$ $g_3 = G\bar{B}+B\bar{G}$

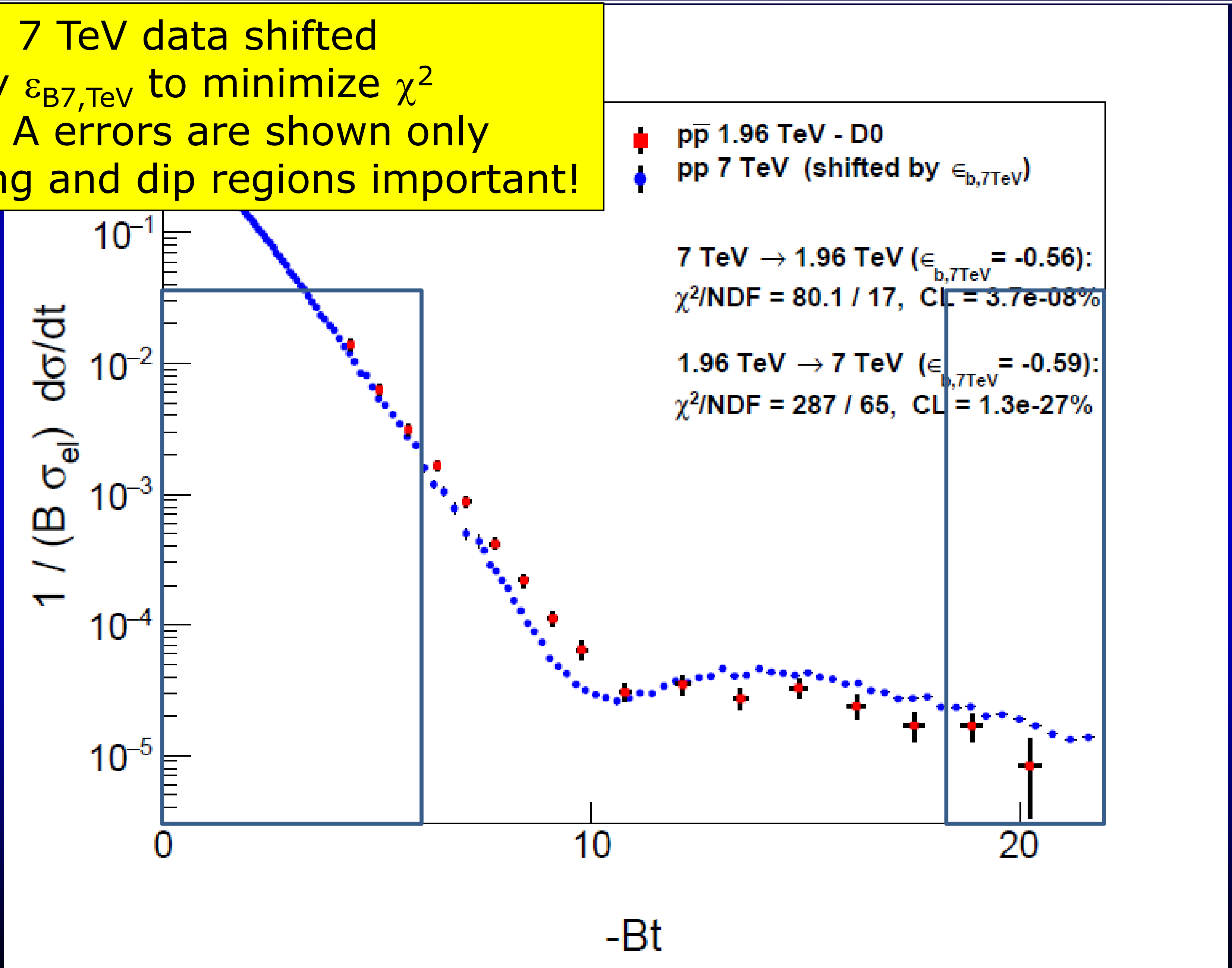
SLIDING WINDOWS

7 TeV data shifted
by $\varepsilon_{B7,TeV}$ to minimize χ^2
Type A errors are shown only
Both swing and dip regions important!



CLOSING DOORS

7 TeV data shifted
by $\varepsilon_{B7,TeV}$ to minimize χ^2
Type A errors are shown only
Both swing and dip regions important!



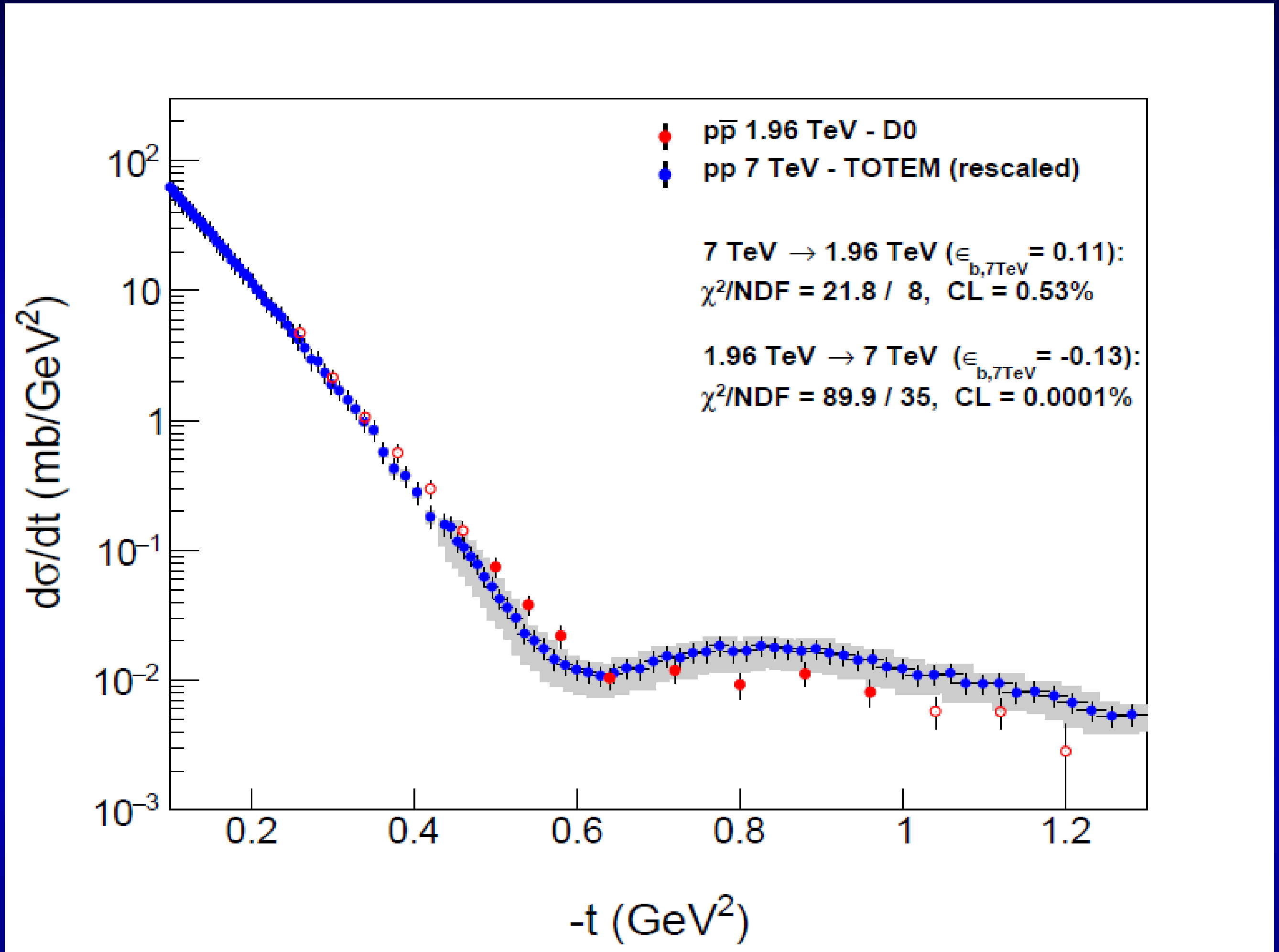
RESULTS FOR CLOSING DOORS

Two sliding doors of size n and size m:
(n,m): Leaving out the first n and last m D0 point

Sliding door technique with two wings (n,m) Left door excludes the first n, right door excludes the last m D0 points			
n	m	Odderon signal	Background
2	2	6.27 σ	1.68 σ
3	2	6.33 σ	1.70 σ
4	2	6.21 σ	2.37 σ
2	1	6.11 σ	TBD
2	2	6.27 σ	TBD
2	3	5.90 σ	TBD

New MODEL INDEPENT RESULT
Odderon signal at least 6.33 σ

D0/TOTEM FIRMS UP OUR RESULTS



If we study dσ/dt and limit **our analysis to the same range as D0/TOTEM:** Significance reduces to **5.01 σ effect**, due to leaving out 9 D0 points

If we add D0's 14.4 % overall correlated error to fluctuating errors, for all D0 data: Our *published* value is **3.27 σ**

If we conservatively optimize coefficient $\varepsilon_{B,7TeV}$ of point-to-point correlated errors: **2.79 σ**
Significance of D0/TOTEM for dσ/dt: **3.4 σ**

Recent results from D0/TOTEM

including our contributions

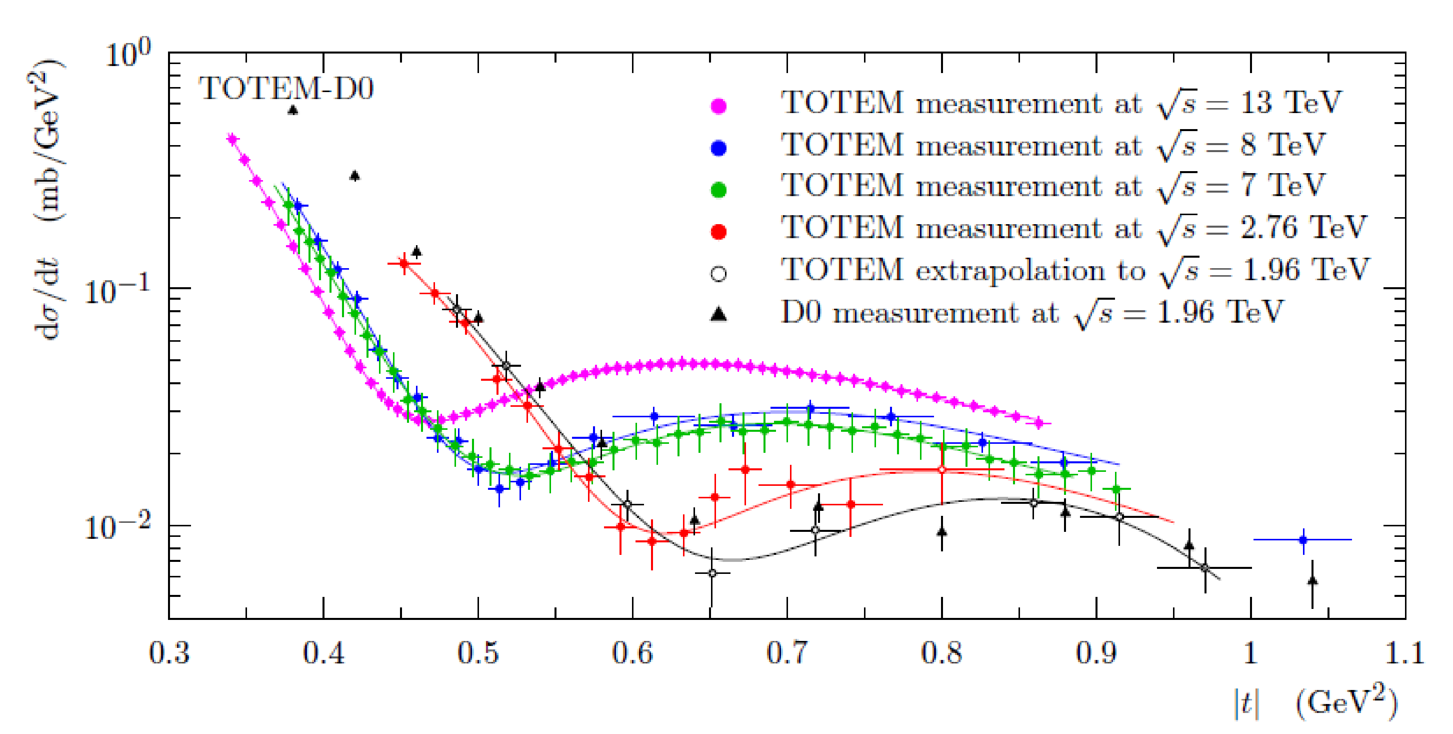
Comparison of pp and $p\bar{p}$ differential elastic cross sections and observation of the exchange of a colorless C-odd gluonic compound #1

D0 and TOTEM Collaborations • V.M. Abazov (Dubna, JINR) et al. (Dec 7, 2020)

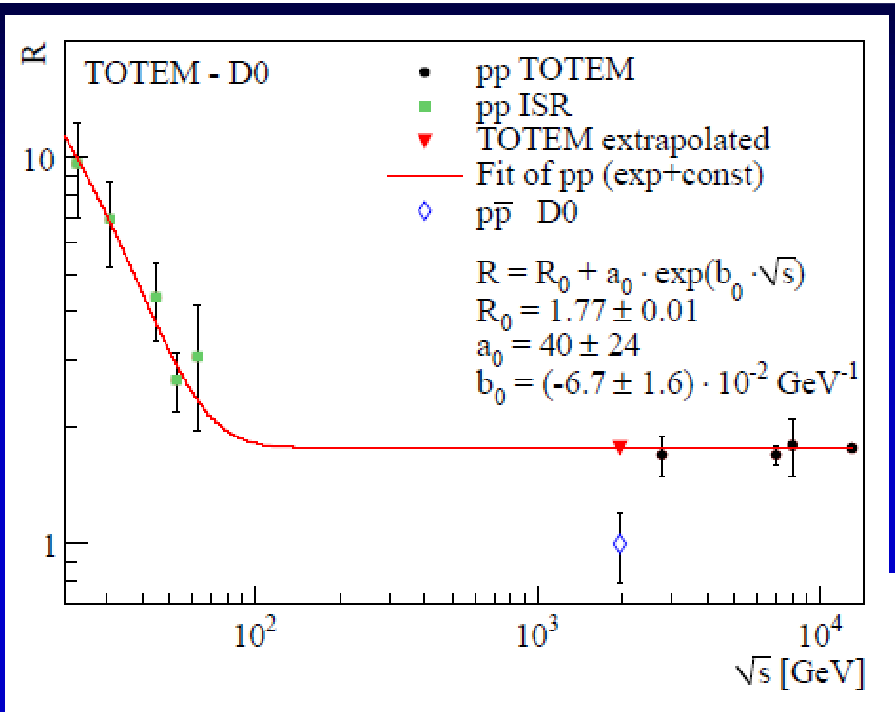
e-Print: 2012.03981 [hep-ex]

pdf links cite

Submitted to PRL in December 2020.
Uses *13, 8*, 7 and 2.76 TeV TOTEM data,
limited in -t to the dip-bump structure.



APPENDIX: D0/TOTEM Fig. 2 OK



Our cross-test of Fig. 2 of arxiv:2012.03981:
Fits ISR and LHC data with *separate* lines

$p_1^{LHC} = 0.034 \pm 0.050$

Consistent with 0 → fix it to 0!

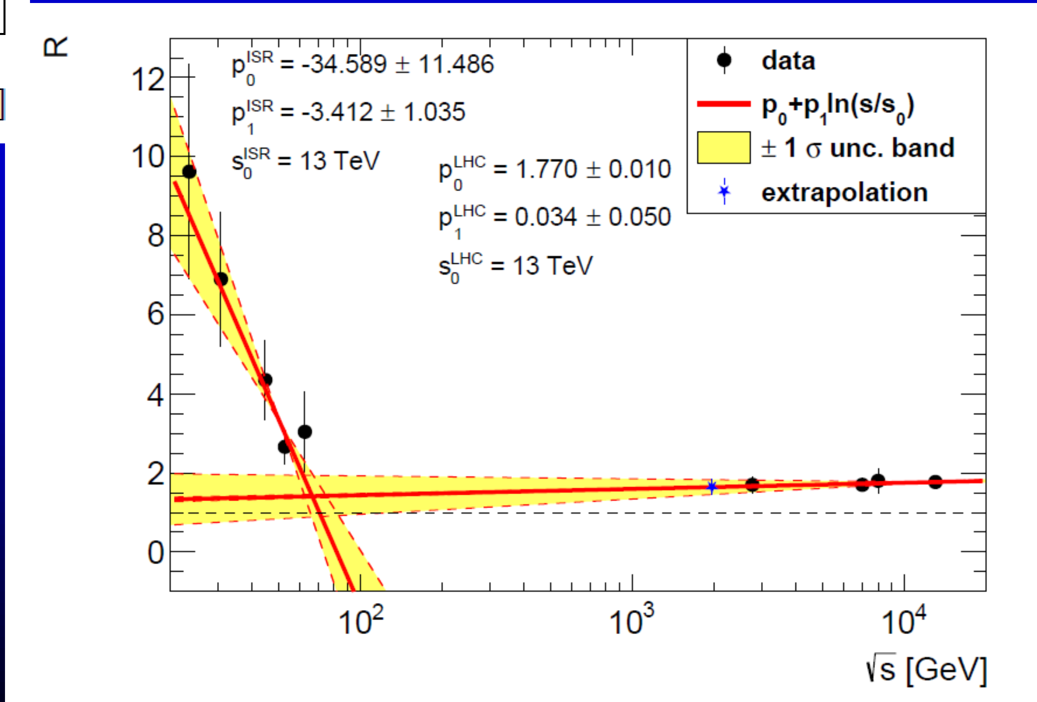
R(pp) = 1.77 ± 0.01 @ 1.96 TeV

→ Reggeon effects negiligble @ 1.96 TeV, OK.

Fig. 2 of arxiv:2012.03981:
Fits ISR and LHC data with *same* curve

R(pp) = 1.77 ± 0.01 @ 1.96 TeV

Reggeon effects from ISR? Test this!



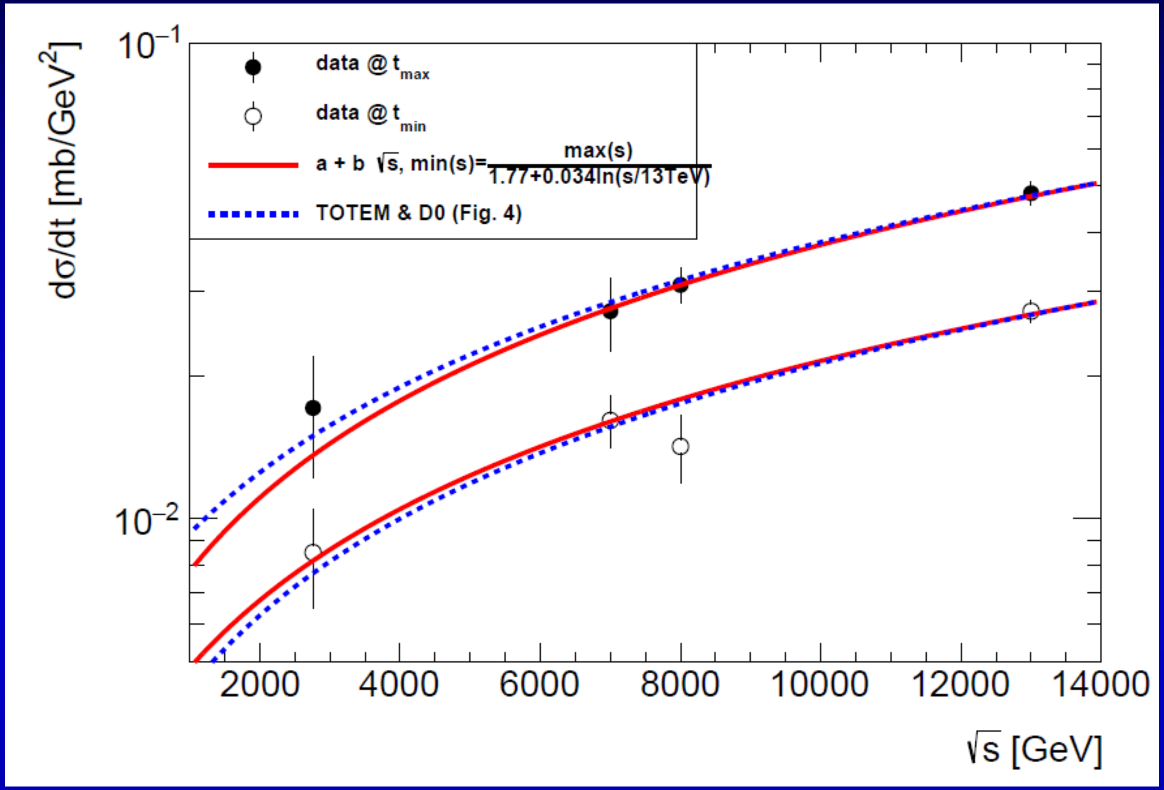
APPENDIX: D0/TOTEM FIG. 3 OK

Our cross-test of
Fig. 3 of arxiv:2012.03981:
Fits to max(s) and min(s) neglect the constraint of Fig. 2:

R(s|pp) = max(s|pp)/min(s|pp)

measured to be 1.77 ±0.01 !

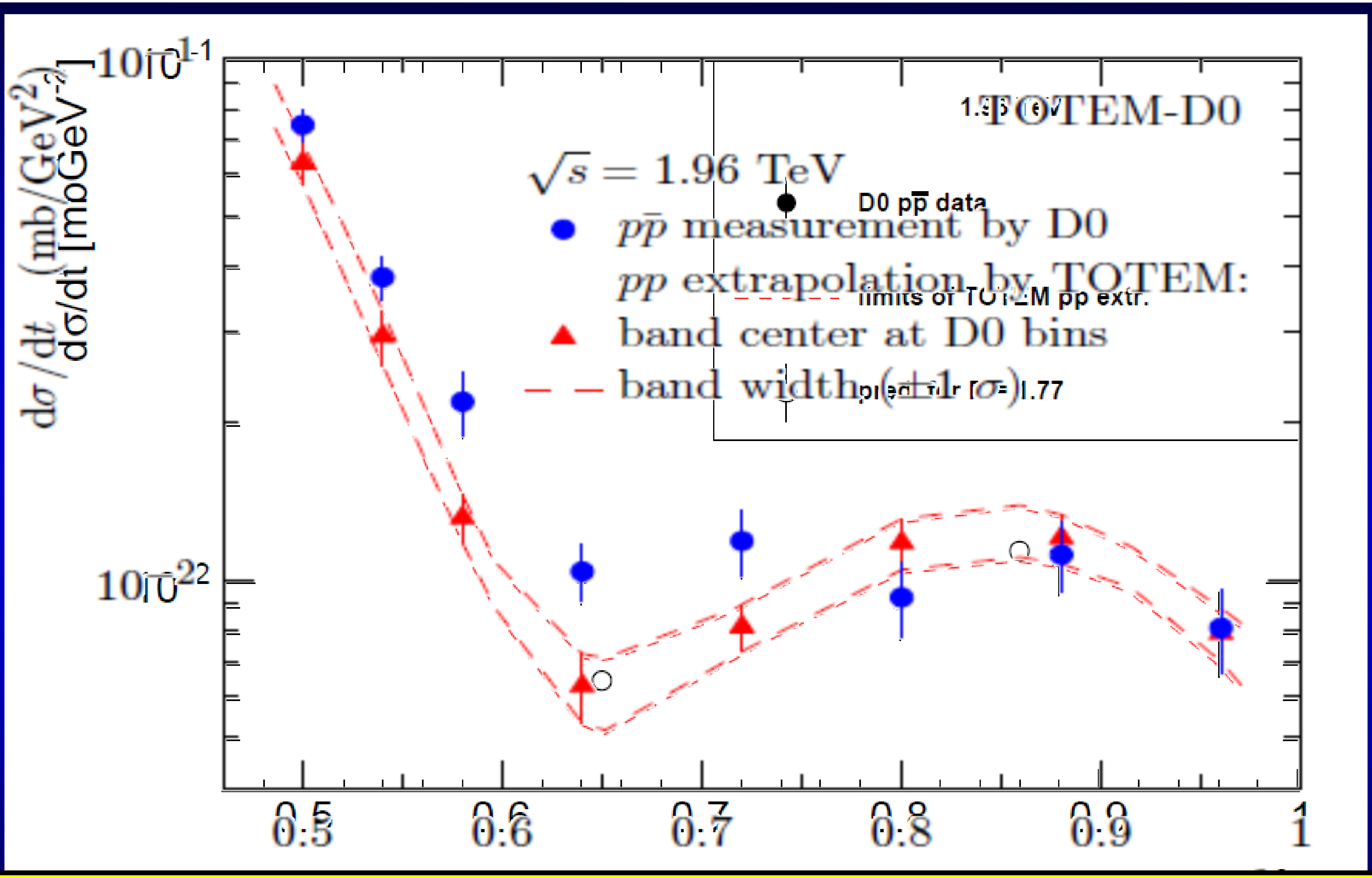
What about constrained fits?



Only two out of three quantities can be fitted independently :
max(s), min(s) and R(s) = max(s) / min(s)
Red lines: min(s|pp) = max(s|pp)/R(s|pp) constrained fits

→ Fig. 3. of D0/TOTEM OK within 1 σ

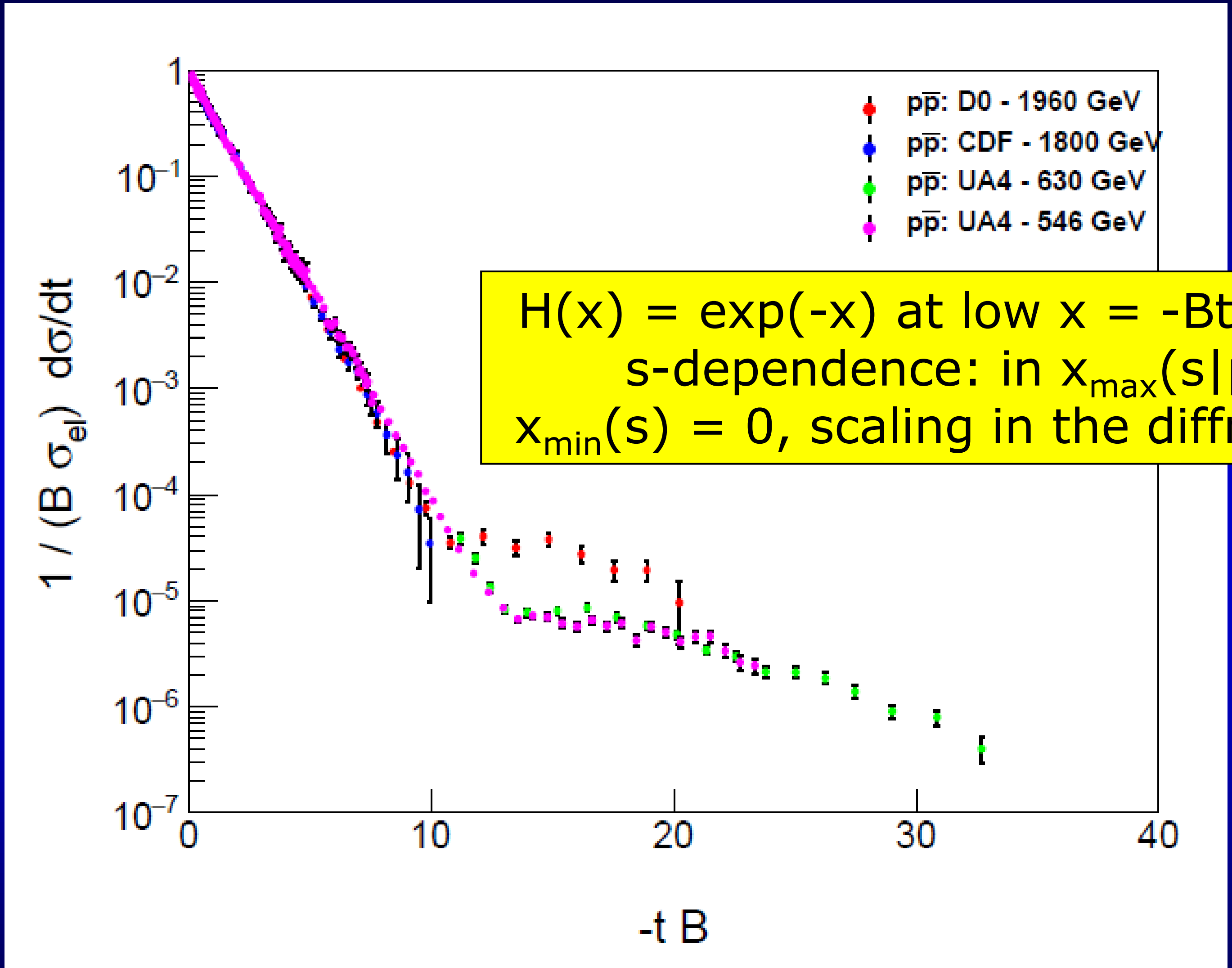
CROSS-CHECK OF D0/TOTEM FIG. 5



Empty circles from min(s|pp) = max(s|pp)/R(s|pp) constrained fits

→ Fig. 5. of D0/TOTEM OK within 1 σ

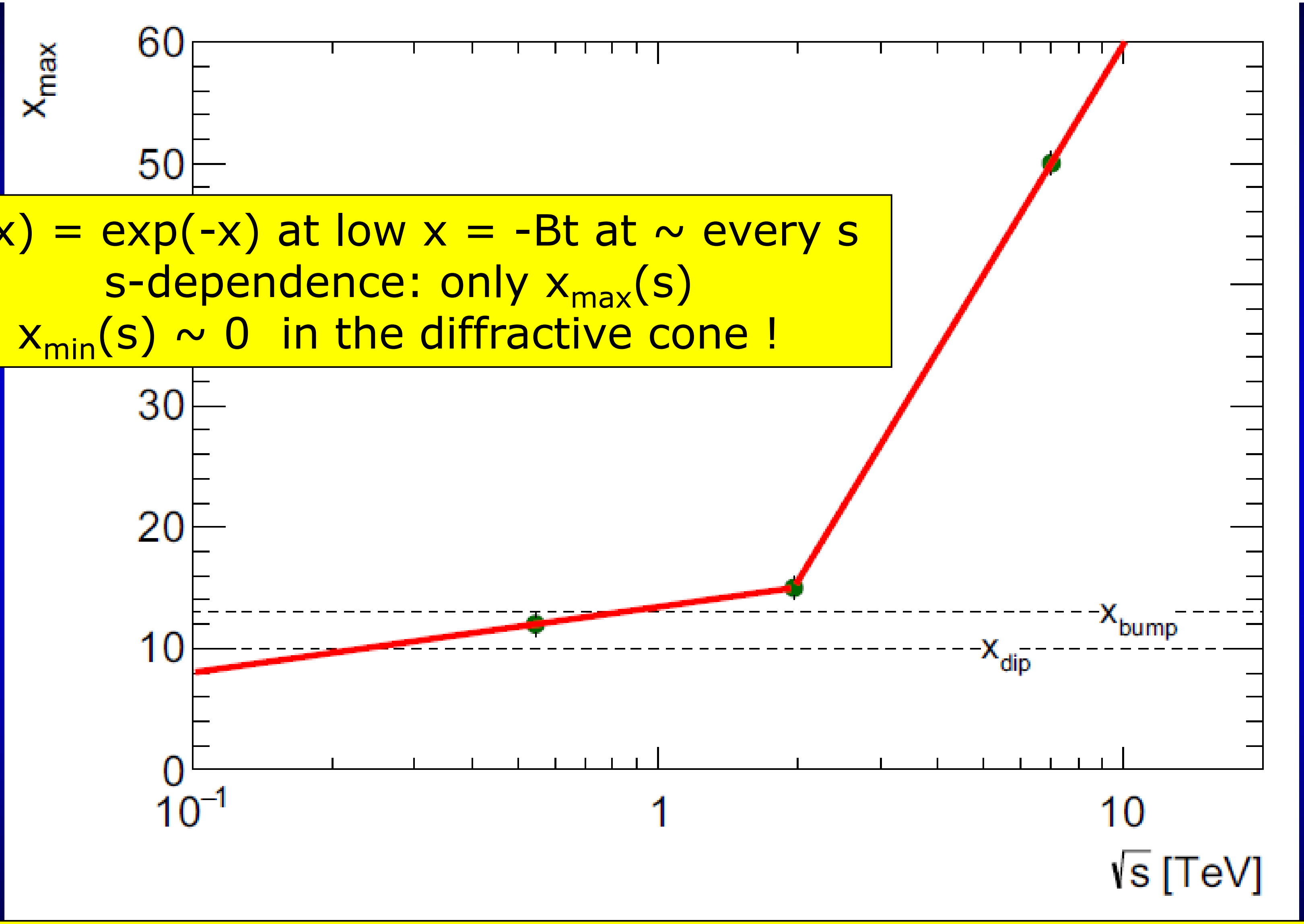
H(x) scaling for p antip scattering



$H(x) = \exp(-x)$ at low $x = -Bt$ at ~ every s
s-dependence: in $x_{max}(s|p+antip)$
$x_{min}(s) = 0$, scaling in the diffractive cone !

Energy range: 546 GeV – 1.96 TeV
Qualitatively different from pp: scaling in the cone only for p+antip

pp: model dependent limit on H(x)



H(x) = exp(-x) at low x = -Bt at ~ every s
s-dependence: only $x_{max}(s)$
$x_{min}(s)$ ~ 0 in the diffractive cone !

Energy range: 200 GeV – 8 TeV (nearly factor of 40)
With decreasing s, the x = -Bt range for H(x) scaling decreases

Where is the Odderon signal from?

Swing, interference, tail regions
Interference region is dominant

Partial significances from the swing, interference, tail and all regions, characterized by $x_{min} < x \le x_{max}$					
x_{min}	x_{max}	ε_{B21} of min $\Delta\chi^2$ in $x_{min} < x \le x_{max}$	$\Delta\chi^2$ in $x_{min} < x \le x_{max}$	NDF in $x_{min} < x \le x_{max}$	σ in $x_{min} < x \le x_{max}$
5.1	8.4	1.90	4.19	5	0.64
8.4	13.5	-0.49	25.31	5	3.84
13.5	20.2	-1.39	1.79	5	0.15
5.1	13.5	0.28	48.27	10	5.01
8.4	20.2	-0.96	35.79	10	3.91
5.1	20.2	-0.60	75.41	15	6.23

Model dependent evidence for Odderon

Observation of Odderon Effects at LHC energies -- A Real Extended Bialas-Bzdak Model Study #1

T. Csorgo (Wigner RCP, Budapest and EKU KRC, Gyongyos), I. Szanyi (Eotvos U. and Wigner RCP, Budapest) (May 28, 2020)

e-Print: 2005.14319 [hep-ph]

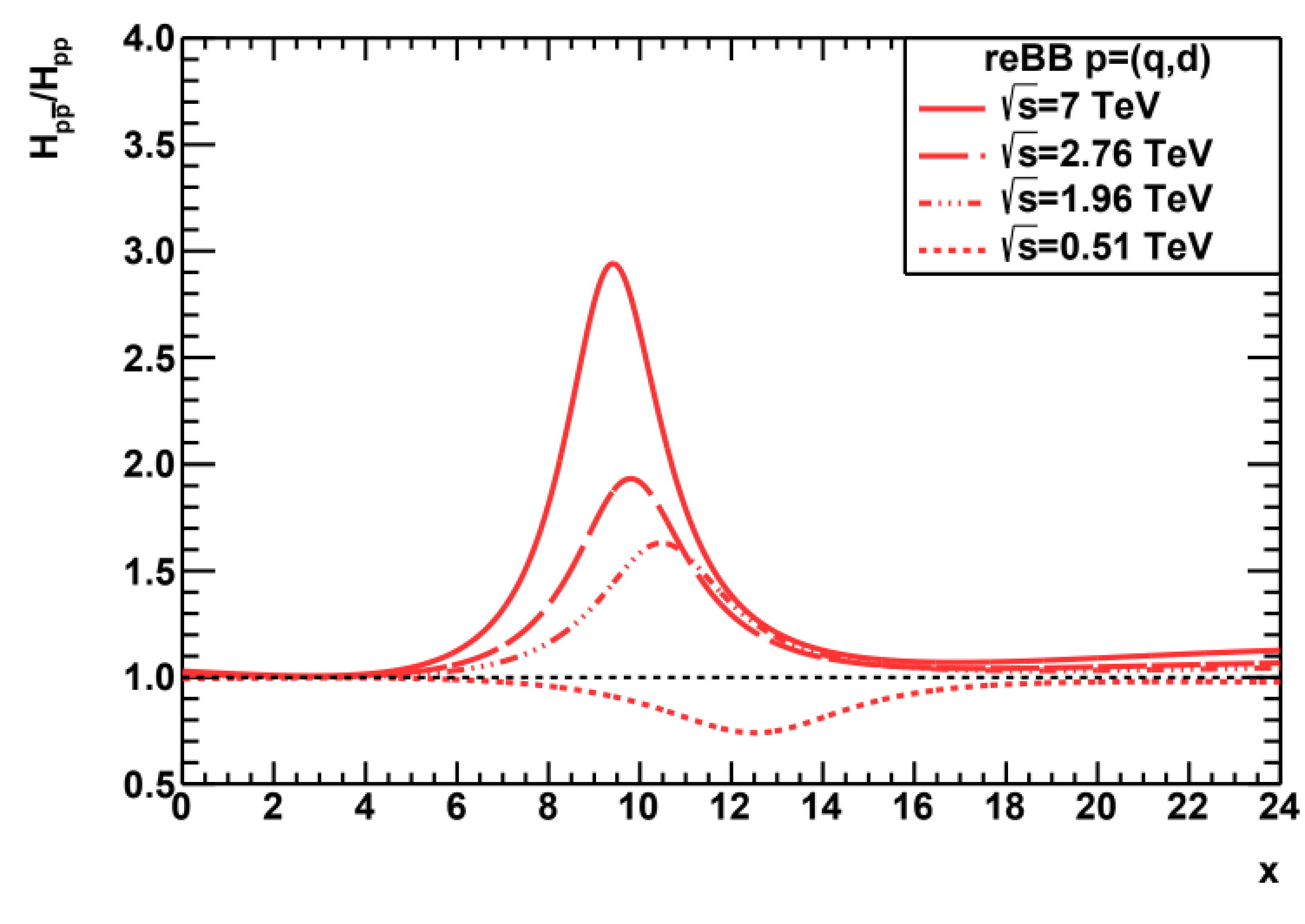
pdf cite 1 citation

Structure:
Introduction,
Fits with CL > 0.1 % to published pp and pbarp data function
In the dip/bump region (large –t fits)
Linear excitation function in TeV range: $p_0 + p_1 \ln(s/s_0)$
Sanity tests: Validation of the trends
Extrapolations both for pp and pbarp data
Odderon significance from pp and pbarp comparisions
From combined 1.96 and 2.76 TeV analysis:
Odderon seen at 7.08 σ
Cross-checks (quadratic trend, ISR data)

82 pages, 31 figures, model dependent Odderon significance 7.1 σ, submitted for publication, see also talk by I. Szanyi @ Zimányi'2020

OBSERVATION OF ODDERON

2020 → 2O2O



Prediction for 510 GeV pp @ RHIC: scaling violations

Three Oldest Hungarian Universities

UP Story - 650 years

Home » University » UP Story 650 years

The history of higher education in Pécs dates back to 1367, when Louis th

e episcopal city of Pécs. As a result of an integration proc

d, which has become one of the most famous, prestigiou

on. It has ten faculties which cover the full spectrum of h

1367

University of Pécs: 1367

University of Pécs:
S: Oldest, C: in Hungary

The University o institution of higher education in the country operated continuously in the same city, is one of the research universities of na gary offering the widest spectrum of educational programs in 14 faculties and 24 doctoral schools.

education and cu

the *gerundium*,

showing respect

University of Debrecen: 153

University of Debrecen:
S: Oldest, C: in Hungary,
operating continuously and in the *same city*

(S,C) structure evident,
S: statement, valid if
C: condition is satisfied
See talk of R. Dardashti at ISMD21
Condition changes → Statement changes (!!)

Eötvös University:
S: Oldest, C: in Hungary,
teaching continuously

in Nagyszombat in 1635 (sixteen thirty-five) by Archbishop of Esztergom, Péter Pázmány, and it is the oldest Hungarian university where the teaching has continued uninterrupted since its inception. More than sixty years

Eötvös Loránd University: 1635

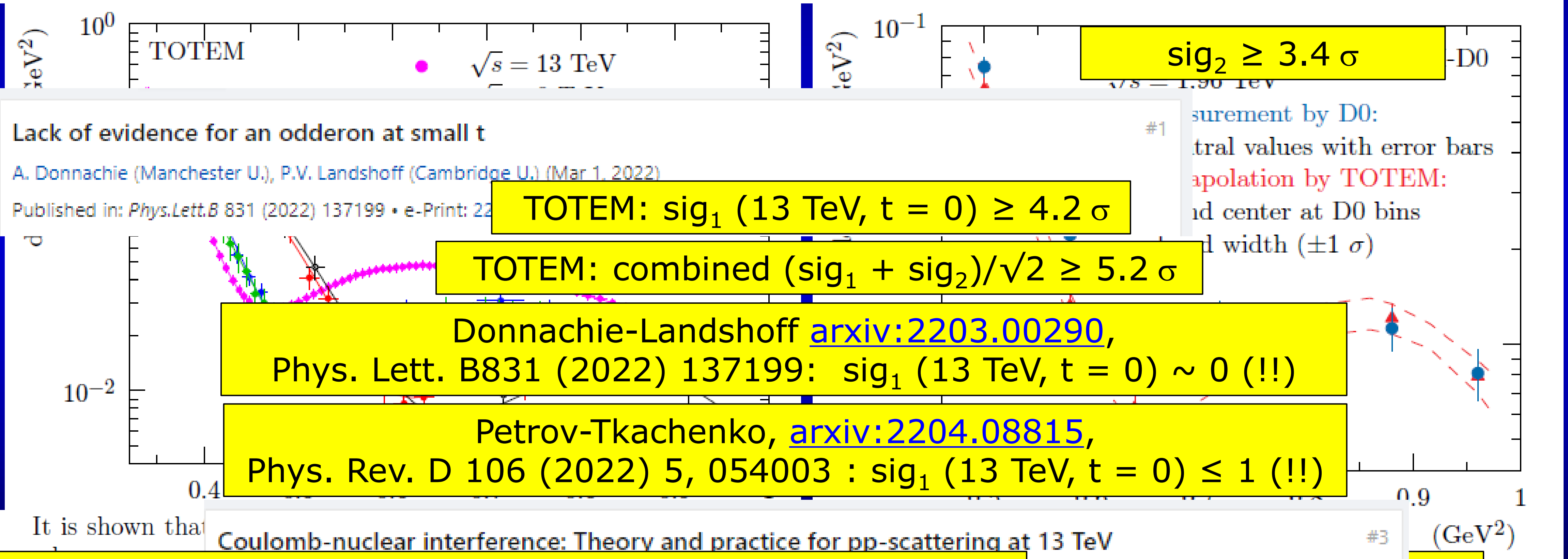
Status of D0-TOTEM Odderon search

Odderon Exchange from Elastic Scattering Differences between pp and $p\bar{p}$ Data at 1.96 TeV and from pp Forward Scattering Measurements #1

TOTEM and D0 Collaborations • V.M. Abazov (Dubna, JINR) et al. (Dec 7, 2020)

Published in: *Phys.Rev.Lett.* 127 (2021) 6, 062003 • e-Print: 2012.03981 [hep-ex]

Phys. Rev. Lett. **127** (2021) 6, 062003, Published: 4 August 2021
https://doi.org/10.1103/PhysRevLett.127.062003



$sig_2 \geq 3.4\ \sigma$

Lack of evidence for an odderon at small t #1

A. Donnachie (Manchester U.), P.V. Landshoff (Cambridge U.) (Mar 1, 2022)

Published in: *Phys.Lett.B* 831 (2022) 137199 • e-Print: 22

TOTEM: sig_1 (13 TeV, t = 0) ≥ 4.2 σ

TOTEM: combined $(sig_1 + sig_2)/\sqrt{2} \geq 5.2\ \sigma$

Donnachie-Landshoff arxiv:2203.00290,
Phys. Lett. B831 (2022) 137199: sig_1 (13 TeV, t = 0) ~ 0 (!!)

Petrov-Tkachenko, arxiv:2204.08815,
Phys. Rev. D 106 (2022) 5, 054003 : sig_1 (13 TeV, t = 0) ≤ 1 (!!)

It is shown that

Coulomb-nuclear interference: Theory and practice for pp-scattering at 13 TeV #3

TOTEM – D0 detailed response :
in preparation, see also
K. Österberg's talk at LHC Forward Physics meeting, Oct 2022

$\rho = 0.10 \pm 0.04,$
$0.01 \lesssim |t| \lesssim 0.05\ \mathrm{GeV}^2.$

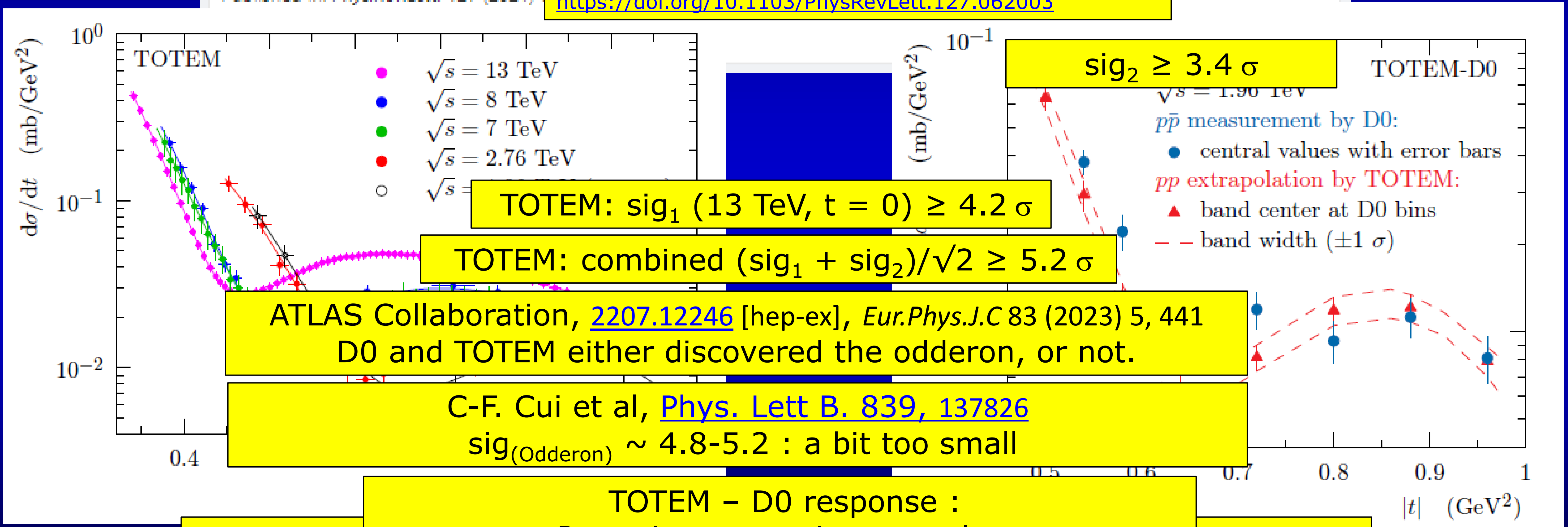
Status of D0-TOTEM Odderon 2.0

Odderon Exchange from Elastic Scattering Differences between pp and $p\bar{p}$ Data at 1.96 TeV and from pp Forward Scattering Measurements #1

TOTEM and D0 Collaborations • V.M. A

Published in: *Phys.Rev.Lett.* 127 (2021) 6

Phys. Rev. Lett. **127** (2021) 6, 062003, Published: 4 August 2021
https://doi.org/10.1103/PhysRevLett.127.062003



sig$_2$ ≥ 3.4 σ

TOTEM: sig$_1$ (13 TeV, t = 0) ≥ 4.2 σ

TOTEM: combined (sig$_1$ + sig$_2$)/√2 ≥ 5.2 σ

ATLAS Collaboration, 2207.12246 [hep-ex], *Eur.Phys.J.C* 83 (2023) 5, 441
D0 and TOTEM either discovered the odderon, or not.

C-F. Cui et al, Phys. Lett B. 839, 137826
sig$_{(Odderon)}$ ~ 4.8-5.2 : a bit too small

C0: i … TeV

TOTEM – D0 response :
Paper in preparation, see also
K. Österberg's talk at ISMD 2023
in August 2023 and at Diffraction and Low-x 2024