

# TOTEM – Hungary: an odd discovery of odderon exchange

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<sup>1</sup> Wigner RCP, Budapest, Hungary

<sup>2</sup> MATE KRC, Gyöngyös, Hungary

Statistically Significant Observations of Odderon in 2021

**Model independent results:**

Significance  $\geq 6.26 \sigma$

**Model dependent results:**

Significance  $\geq 7.08 \sigma$

**D0-TOTEM results:**

Significance  $\geq 5.2 \sigma$



Supported by NKFIH:

NK 73143, K 74458,

NK 101438, K133046

2020-2.2.1-ED-2021-00181

Circles of Knowledge Club,

Hungary

**New in 2022:**

**TOTEM data at 8 TeV published**

**In the Bialas-Bzdak model**

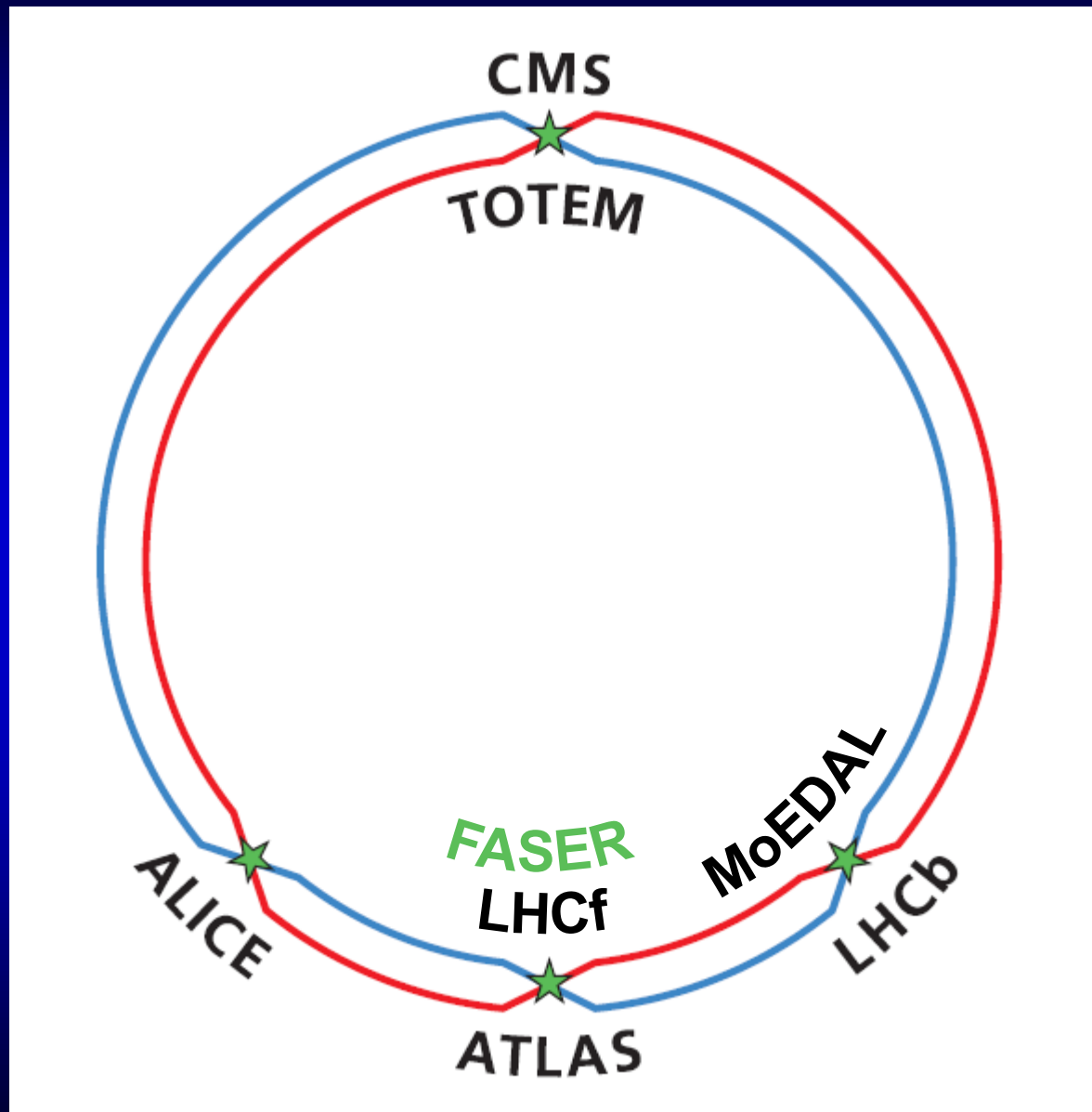
**Odderon Significance  $\geq 35 \sigma$**

**Valid in  $0.541 \leq s \leq 8 \text{ TeV}$**

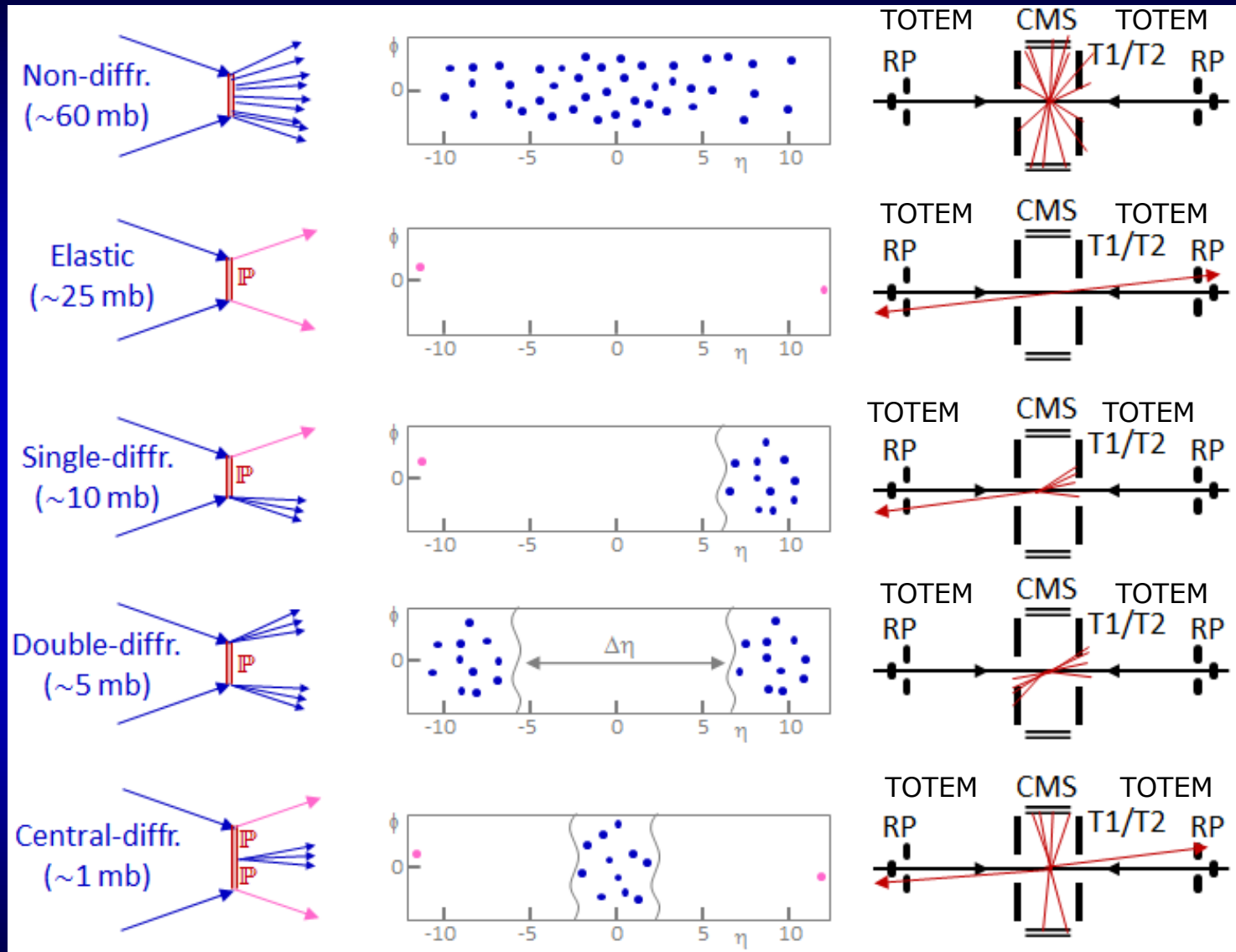
**and  $0.377 \leq -t \leq 1.2 \text{ GeV}^2$**



# EXPERIMENTS AT CERN LHC



# SOFT DIFFRACTION AT LHC, IP5



Elastic, single and double diffractive, central exclusive production:  
colorless exchange.

# Members of TOTEM-Hungary

## Munkatársaink



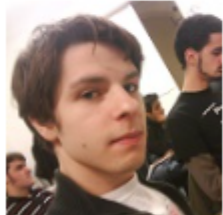
**Csörgő Tamás (MTA Wigner FK és KRF (2015-)),** TOTEM tag 2008 óta; TOTEM-Magyarország vezetője, TOTEM Collaboration Board tag, LHC TOTEM Resource Review Board tag, TOTEM upgrade,  $d\sigma/dt$  skálaviselkedésének vizsgálata, adatok értelmezése, részvétel az adatok felvételében.



**Sziklai János (MTA Wigner FK),** TOTEM tag 2008 óta; A TOTEM Detector Control System (DCS) fejlesztése, a DCS remote control system távoli vezérlése a Wigner FK-ból, részvétel az adatok felvételében.



**Novák Tamás (KRF),** TOTEM tag 2008 óta; TOTEM Detector Control System boxok építése, p+Pb teljes és differenciális hatáskeresztmetszetek méréséhez referencia számítások végzése, részvétel az adatok felvételében.



**Lucsányi Dávid (BME és MTA Wigner FK),** TOTEM tag 2013-2016 között; BSc és MSc témavezetője Sziklai János, PhD témavezetője Csörgő Tamás, kutatásait ösztöndíj nélkül, egy fél tanéven keresztül folytatta csoportunkban.



**Szanyi István (Ungvári Nemzeti Egyetem),** TOTEM tag 2018-tól



**Nemes Frigyes (ELTE és MTA Wigner FK),** TOTEM tag 2009 óta; PhD hallgató, a TOTEM finanszírozásában folyamatosan a CERN-ben, az LHC optika rekonstrukciója, Roman Pot és egyéb upgrade detektorok szimulációja, részvétel az adatok felvételében, a  $d\sigma/dt$  adatok értelmezése.



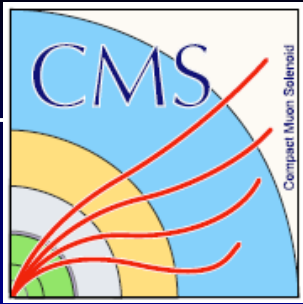
**Ster András (MTA Wigner FK),** TOTEM tag 2007-2010; TOTEM front-end elektronika programozása, p+Pb adatokhoz  $d\sigma/dt$  és  $\sigma_{tot}$  DIPSY Monte Carlo szimulációk és Glauber számítások végzése.



**Csanád Máté (ELTE),** TOTEM tag 2008 óta; TOTEM adatfelvétel rendszer, adatkiolvasás és az adatformátum fejlesztése,  $dN/d\eta$  adatok értelmezése, részvétel a p+Pb adatfelvételben.



**Dénes Ervin (MTA Wigner FK),** TOTEM tag 2008-2009; a TOTEM DCS fejlesztésében vett részt. Fájdalommal vettük tudomásul, hogy elhunyt 2015. június 10-én.



# CT-PPS: CMS-TOTEM Precision Proton Spectrometer



TOTEM-TDR-003



CMS-TDR-13

CERN-LHCC-2014-021

September 8, 2014

## CMS-TOTEM Precision Proton Spectrometer Technical Design Report

The CMS and TOTEM Collaborations



# TOTEM Run Operations in 2015

**“Roman Pots” detectors (CT PPS & TOTEM) installed in LHC tunnel**

**CERN, 2015**



**Collimators TCL 4 & TCL 6  
TOTEM upgraded detectors (12 RPs)  
New CT-PPS detectors (12 + 2 RPs)  
New BP elements: vacuum chambers, ionic pumps and cartridges, BLMs, ...**

# Highlighted recognition



## TOTEM Collaboration

### *2018 Achievement Award*

To :

*The Hungarian team and Ferenc Tamas Csorgo, head*

for the exceptional contribution to the TOTEM physics analysis and results.

*7<sup>th</sup> January 2019*

*Geneva, Switzerland*

S.Giani, TOTEM Spokesperson

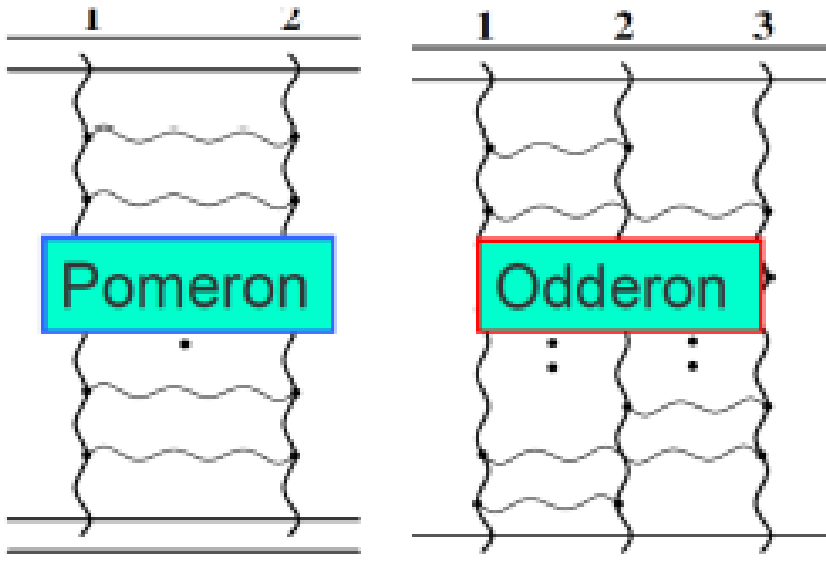
A.Scribano, TOTEM Chairman Coll. Board



# Odderon: 48 years old scientific puzzle

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

A.V.Efremov, R.Peschanski

EVIDENCE FOR NEW SINGULARITIES  
IN REGGE PHENOMENOLOGY

1972

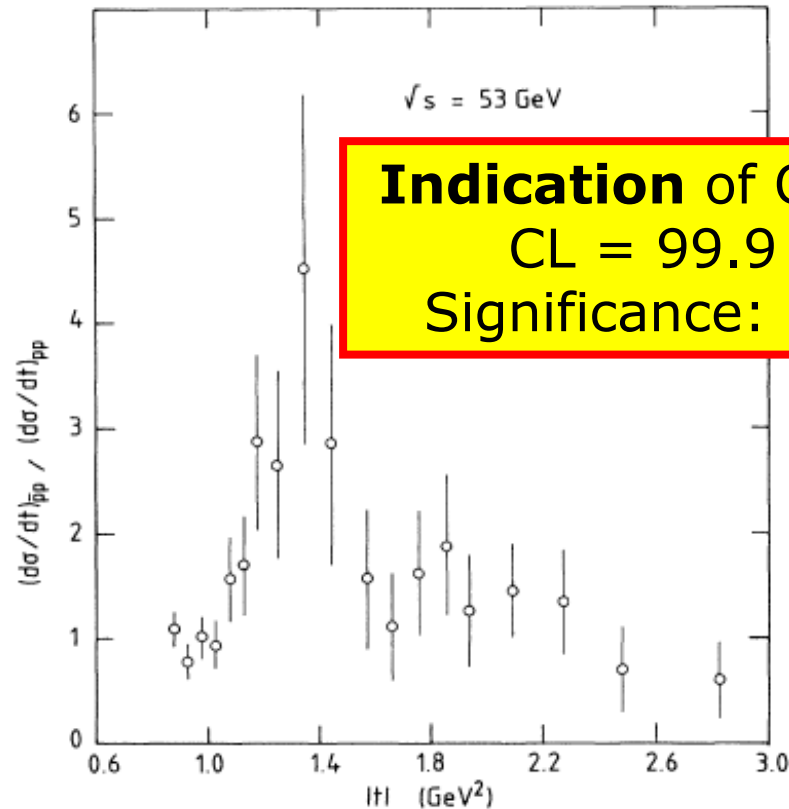
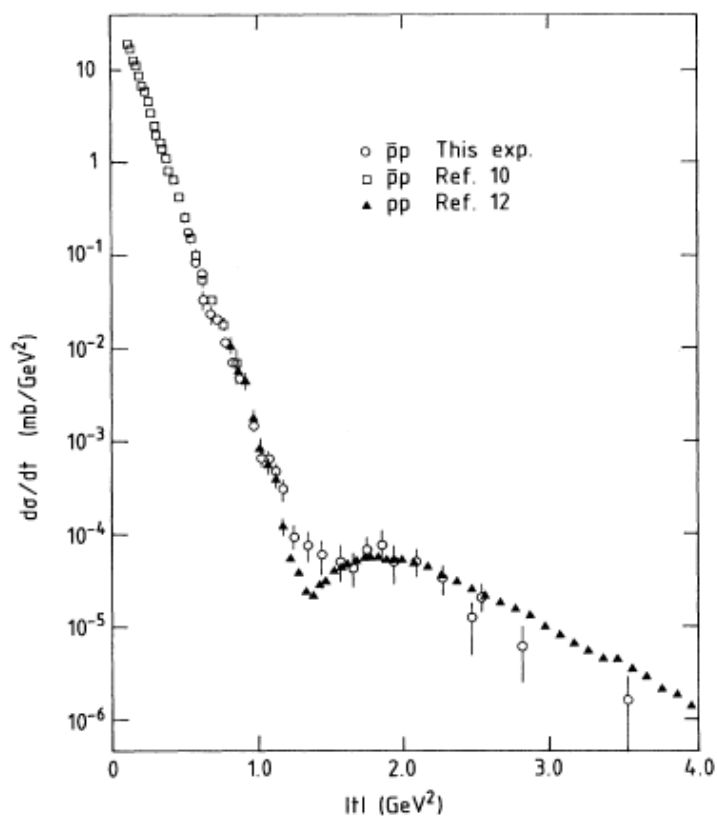
ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

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:  $3.35 \sigma$

**Terminology** for **this** talk:

**Agreement** if statistical significance is  $< 3 \sigma$

**Indication of signal** if  $3 \sigma \leq \text{significance} < 5 \sigma$

**Evidence or observation** of signal if  $5 \sigma \leq \text{significance}$

**Discovery** of signal if  $5 \sigma \leq \text{significance}$  **for the first time.**

# 2021 observations of Odderon with $> 5 \sigma$

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

T. Csörgő (Wigner RCP, Budapest and CERN), T. Noyak (Unlisted, HU), R. Pasechnik (Lund U., Dept. Theor. Phys.), A. Szei (Wigner RCP, Budapest), J. 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 98<sup>th</sup> percentile (ranked 6,037<sup>th</sup>) of the 428,075 tracked articles of a similar age in all journals and the 99<sup>th</sup> percentile (ranked 1<sup>st</sup>) of the 231 tracked articles of a similar age in *The European Physical Journal C*

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

### Online attention



3 tweeters  
1 Mendeley  
1 Wikipedia page

## 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]



SUMMARY	News	Blogs	Twitter	Wikipedia	Dimensions citations
Title	Odderon Exchange from Elastic Scattering Differences between pp and p\bar{p} 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. Aghew, G. D. Alexeev, G. Alkhasov, ... [show]				

pdf links DOI cite

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

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

## a real extended Bialas–Bzdak model study #2

anyi (Eotvos U. and Wigner RCP, Budapest) (May 28, 2020)

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

6 citations

# 2022 observations of Odderon with $> 5 \sigma$

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



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

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



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

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**

# Three Oldest Hungarian Universities

UP Story - 650 years

Home » University » UP Story 650 years



## University of Pécs: 1367

The history of higher education in Pécs dates back to 1367, when Louis the Great initiated the establishment of a university in the episcopal city of Pécs. As a result of an integration process of several stages, the University of Pécs was founded, which has become one of the most famous, prestigious institutions having a leading role in regional education. It has ten faculties which cover the full spectrum of high-quality higher education.

1367

The University of Debrecen, the oldest institution of higher education in the country operated continuously in the same city, is one of the research universities of national excellence in Hungary offering the widest spectrum of educational programs in 14 faculties and 24 doctoral schools.

## University of Debrecen: 1538



Its history of higher education in the city reach all the way back to the 16<sup>th</sup> century and the foundation of the Reformed College of Debrecen in 1538. The College played a central role in Hungarian education and culture for centuries. This is the date featured on the symbol of the university as well, the *gerundium*, a tool originally used by the students of the Reformed College to put out fires, showing respect for ancestors and traditions.

(S,C) structure evident,

S: statement, valid if

C: condition is satisfied

See talk of [R. Dardashti](#) at ISMD21

Eötvös Loránd University: 1635

*The* predecessor of Eötvös Loránd University (ELTE) was founded 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



# Hungarian-Swedish Odderon, 2019 -

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

#5

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

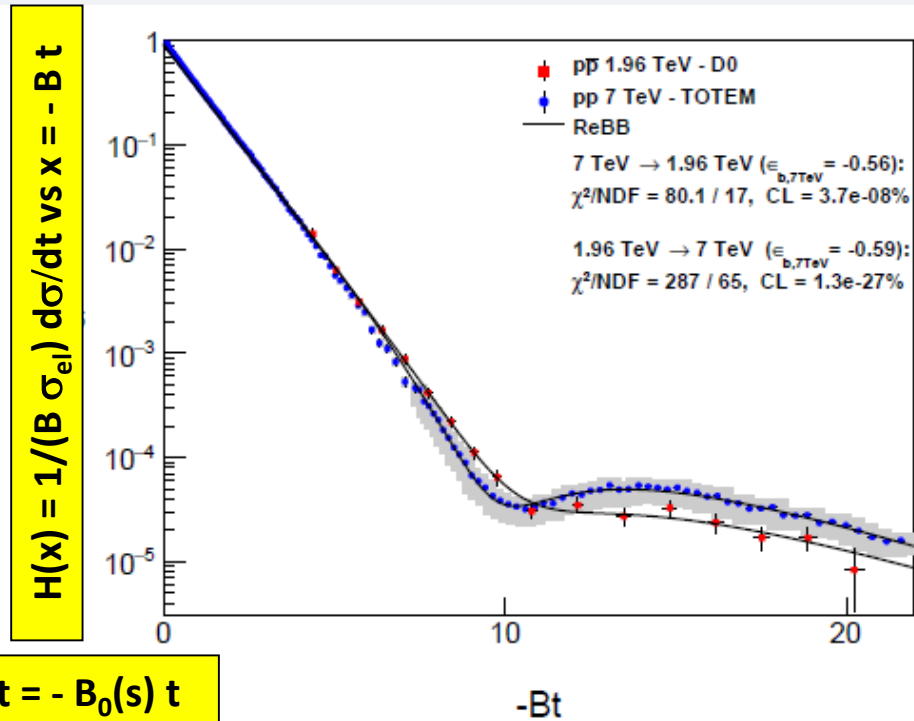
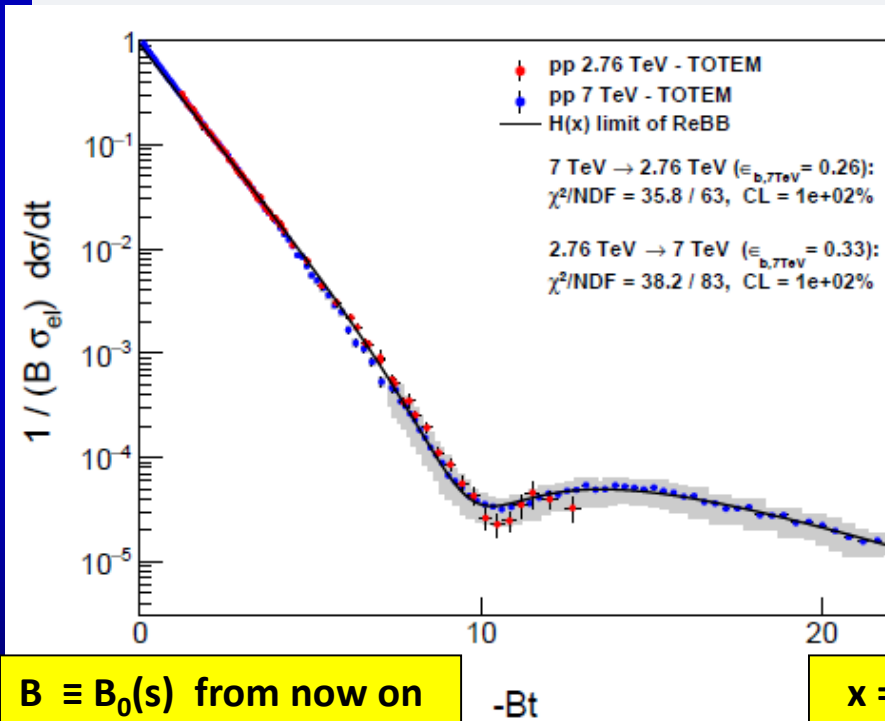
Published in: *Eur.Phys.J.C* 81 (2021) 2, 180 • e-Print: 1912.11968 [hep

Eur. Phys. J. C (2021) 81: 180

<https://doi.org/10.1140/epjc/s10052-021-08867-6>

pdf DOI cite

15 citations



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

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

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

**S: Model independent Odderon significance  $\geq 6.26 \sigma$**   
**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.**

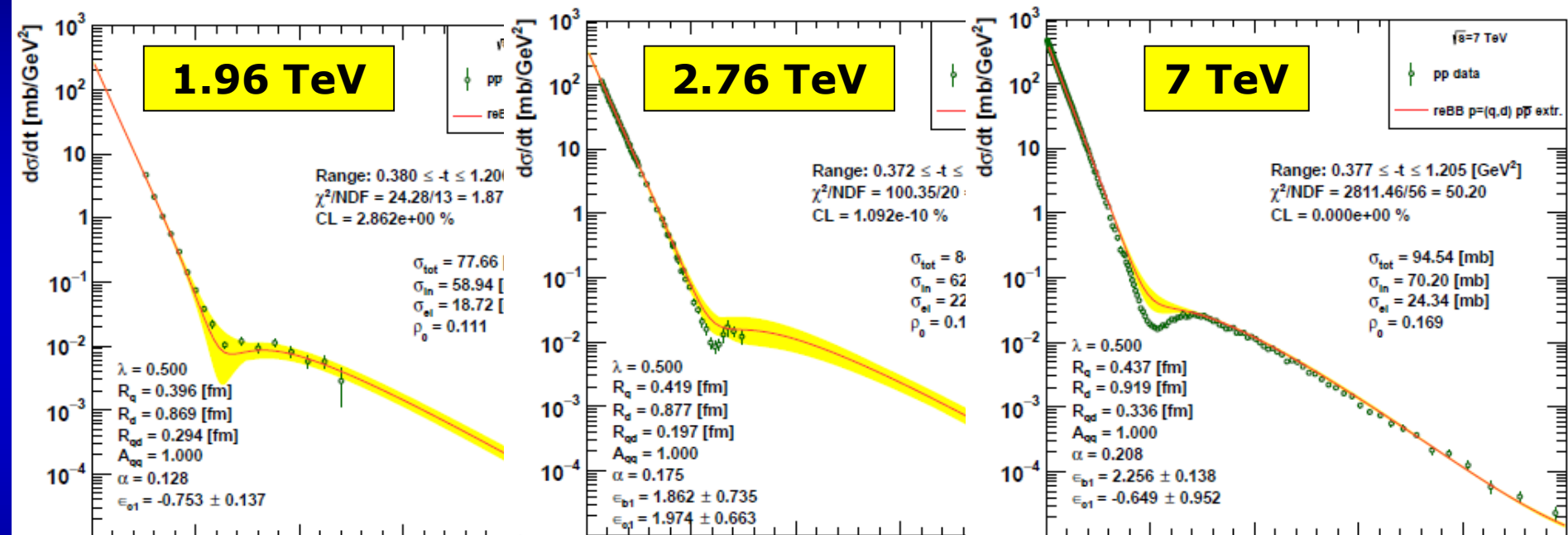
# Hungarian-Polish Odderon, 2020-

Observation of Odderon Effects at LHC energies -- A Real Extended Bialas-Bzdak Model Study #2

T. Csorgo (Wigner RCP, Budapest and EKI KRC, Gyongyos), I. Szanyi (E

e-Print: 2005.14319 [hep-ph]

Eur. Phys. J. C (2021) 81:611, detailed by I. Szanyi  
<https://doi.org/10.1140/epjc/s10052-021-09381-5>



**S: Model dependent Odderon significance  $\geq 7.08 \sigma$**

**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  $0.37 \leq -t \leq 1.2$  GeV<sup>2</sup> and  $0.546 \leq \sqrt{s} \leq 8$  TeV

**Model dependent, Real Extended Bialas-Bzdak theory results, Odderon significance  $\geq 7.08 \sigma$ , from 1.96 and 2.76 TeV data only**

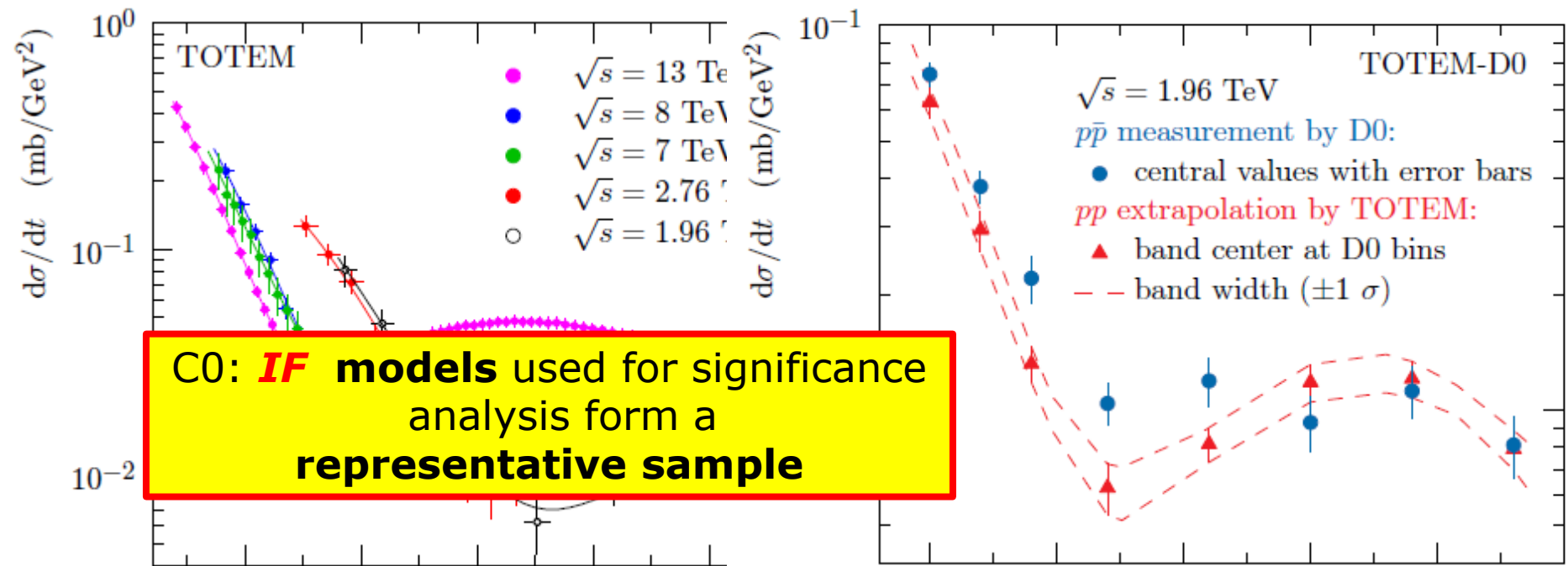
# D0-TOTEM Odderon, 2020-

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.  
Published in: *Phys.Rev.Lett.* 127 (2021) 6, 062003 • e-Print: 2008.08111

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



**S: Odderon significance  $\geq 5.2 \sigma$ , IF**

**C1: if almost model independently combined**

with  $\sqrt{s} = 13$  TeV data at  $t = 0$ :  $\sigma_{\text{tot}}$  and  $\rho_0$

**C2: if a new  $pp$  dataset at 8 TeV and a new data point at 2.76 TeV,**

**C3: if only 8 out of the 17 D0 points are used**

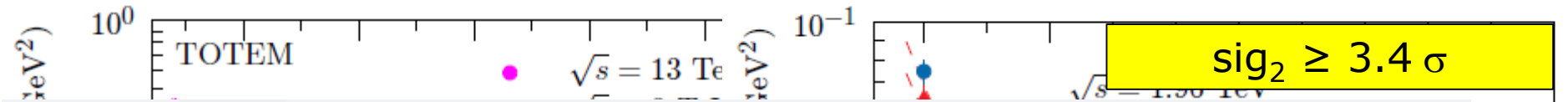
**C4: if D0  $p\bar{p}$  data and TOTEM  $pp$  extrap.data are assumed to be equal at  $t=0$**

# 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

TOTEM and D0 Collaborations • V.M. A  
Published in: *Phys.Rev.Lett.* 127 (2021)

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



$\text{sig}_2 \geq 3.4 \sigma$

Lack of evidence for an odderon at small  $t$

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

Published in: *Phys.Lett.B* 831 (2022)

TOTEM:  $\text{sig}_1(13 \text{ TeV}, t = 0) \geq 4.2 \sigma$

TOTEM: combined  $(\text{sig}_1 + \text{sig}_2)/\sqrt{2} \geq 5.2 \sigma$

3 citations

Donnachie-Landshoff [arxiv:2203.00290](https://arxiv.org/abs/2203.00290),

*Phys. Lett. B* 831 (2022) 137199:  $\text{sig}_1(13 \text{ TeV}, t = 0) \sim 0$  (!!)

Petrov-Tkachenko, [arxiv:2204.08815](https://arxiv.org/abs/2204.08815),

*Phys. Rev. D* 106 (2022) 5, 054003 :  $\text{sig}_1(13 \text{ TeV}, t = 0) \leq 1$  (!!)

$\rho = 0.10 \pm 0.04$ ,

$0.01 \lesssim |t| \lesssim 0.05 \text{ GeV}^2$ .

Coulomb-nuclear interference

TOTEM – D0 detailed response :  
in preparation, stay tuned

Vladimir A. Petrov (Serpukhov, IHEP)

Published in: *Phys.Rev.D* 106 (2022) 5, 054003 • e-Print: [2204.08815](https://arxiv.org/abs/2204.08815) [hep-ph]

pdf DOI cite

0 citations



# Model dependent results: 8 TeV, 2022

New final TOTEM result at 8 TeV

Odderon observation: a certainty ( $> 35 \sigma$ )

$\sqrt{s}$ (TeV)	$\chi^2$	NDF	CL	significance ( $\sigma$ )
1.96	24.283	14	0.0423	2.0
2.76	100.347	22	$5.6093 \times 10^{-12}$	6.8
7	2811.46	58	$< 7.2853 \times 10^{-312}$	$> 37.7$
8	426.553	25	$1.1111 \times 10^{-74}$	$\geq 18.2$

**Table 1** Summary on Odderon signal observation significances in the ReBB model analysis. The significances higher than  $8 \sigma$  were calculated by utilizing an analytical approximation schema, detailed in [Appendix A](#).

$\sqrt{s}$ of combined data (TeV)	$\chi^2$	NDF	CL	combined significance ( $\sigma$ )	combined significance ( $\sigma$ )
				$\chi^2$ /NDF method	Stouffer's method
1.96 & 2.76	124.63	36	$1.0688 \times 10^{-11}$	6.7	6.3
1.96 & 2.76 & 7	2936.09	94	$< 9.1328 \times 10^{-312}$	$> 37.7$	$> 26.9$
1.96 & 2.76 & 8	551.183	61	$4.6307 \times 10^{-80}$	$> 18.9$	$> 15.7$
1.96 & 2.76 & 7 & 8	3362.64	119	$< 8.0654 \times 10^{-312}$	$> 37.7$	$> 32.4$

**Table 2** Summary on combined Odderon signal observation significances in the ReBB model analysis. The significances higher than  $8 \sigma$  were calculated by utilizing an analytical approximation detailed in [Appendix A](#).

**S: Model independent Odderon significance  $\geq 37.7 \sigma$**

Dominant signal: at 7 TeV

**C1: All D0 and TOTEM published data at 1.96, 2.76, 7.0 + new 8 TeV data (2022)**

**C2: ReBB model dependent result**

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]

# Hungarian-Swedish Odderon: CORDIS

→ ↻ [cordis.europa.eu/article/id/429667-particle-physics-milestone-achieved-at-cern](https://cordis.europa.eu/article/id/429667-particle-physics-milestone-achieved-at-cern)

Alkalmazások  CERN  ET  Wigner  Conf  Stabil-Invest Kft.  Szanyi István

 Follow the latest news and projects about COVID-19 and the European Commission's coronavirus response.

 European

CORDIS

English 

For most of us, physics terms such as odderon are – and will always remain – firmly lodged in the science fiction realm. Not so for the scientific community, whose determined members spent nearly half a century searching (without much success) for this mythical particle.

Now, a research team including physicists from Hungary and Sweden has discovered the odderon by analysing experimental data from the [Large Hadron Collider \(LHC\)](#) at Switzerland's European Organization for Nuclear Research, better known as CERN. Supported by the EU-funded MorePheno project, the physicists have published a [paper](#) describing their findings in the 'The European Physical Journal C'.

## Particle physics milestone achieved at CERN

After 50 years of research, physicists have found evidence that the elusive subatomic quasiparticle called odderon actually exists.

# D0-TOTEM odderon: Nature, CERN

Check for updates

Nature Reviews Physics

CERN Accelerating science



ABOUT

NEWS

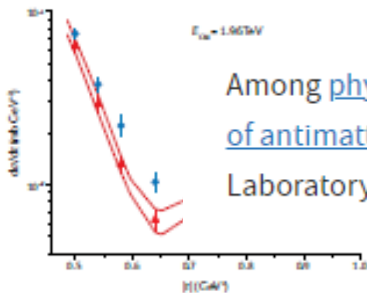
News › News › Topic: Knowledge sharing

*Voir en français*

## Relive 2021 at CERN

Highlights of the year at CERN, from exciting particle physics results to accelerator milestones and much more

21 DECEMBER, 2021



Credits: CERN, for the DØ and TOTEM collaborations, under a Creative Commons License: CC BY 4.0

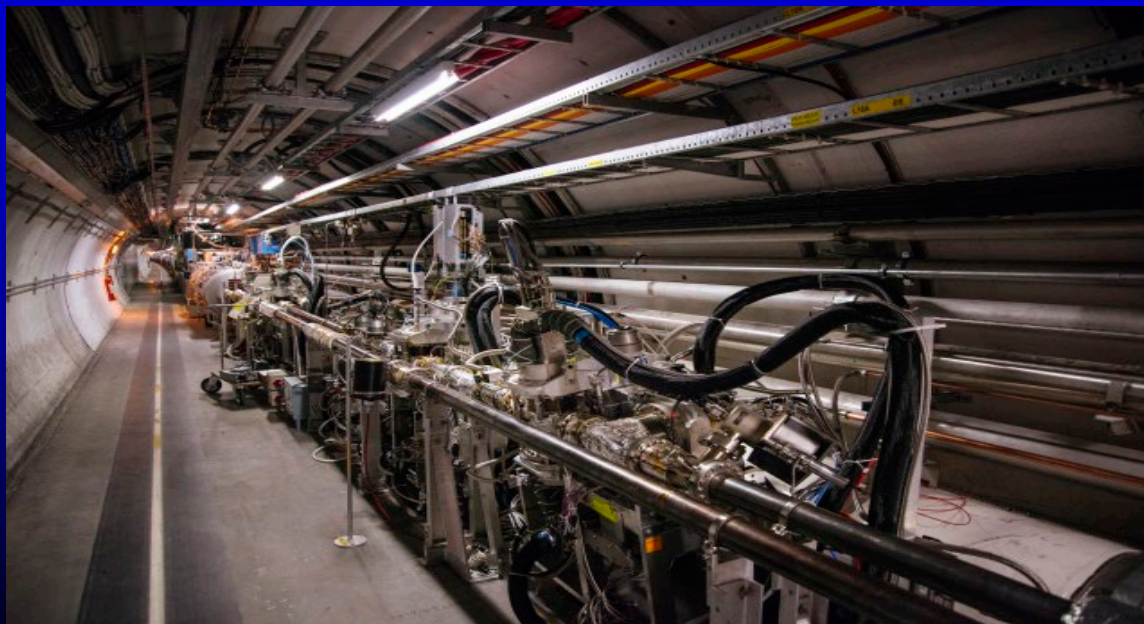
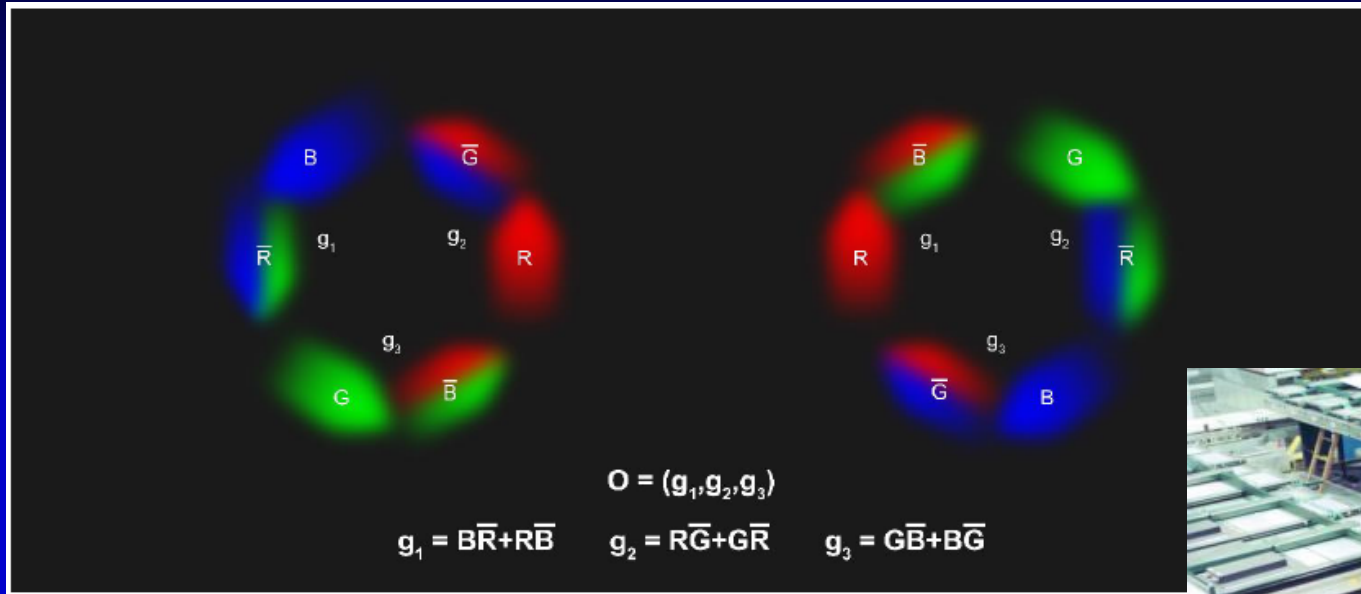
community was that this was not of differential cross-sections

Among [physics](#) results, the discovery of the [odderon](#) by the TOTEM and DØ collaborations, the [first laser-cooling of antimatter](#) at ALPHA and [first candidate collider neutrinos](#) at FASER are only a few that generated awe at the Laboratory. [CLOUD](#), [BASE](#), [AMS](#), [LHCb](#), [CMS](#), [ATLAS](#), [ALICE](#), [ISOLDE](#) and [NA64](#) also had exciting news in store.

process. The most direct way to demonstrate the existence of the odderon is to compare  $\sigma_{pp}$  and  $\sigma_{p\bar{p}}$  at equal and sufficiently high

**RELATED ARTICLES** [Alessio V. M. et al. Odderon exchange from elastic scattering differences in proton-proton collisions at 1.96 TeV and heavy forward scattering measurements. Phys. Rev. Lett. 127, 092001 \(2021\)](#)

# Illustrations: Odderon, TOTEM, D0





# **OBSERVATION OF ODDERON**

**2020 → 2020**

**THANK YOU FOR YOUR  
ATTENTION**

# BACKUP SLIDES

# Passion for Discovery: Odderon

$$p + \bar{p} \rightarrow p + \bar{p}$$

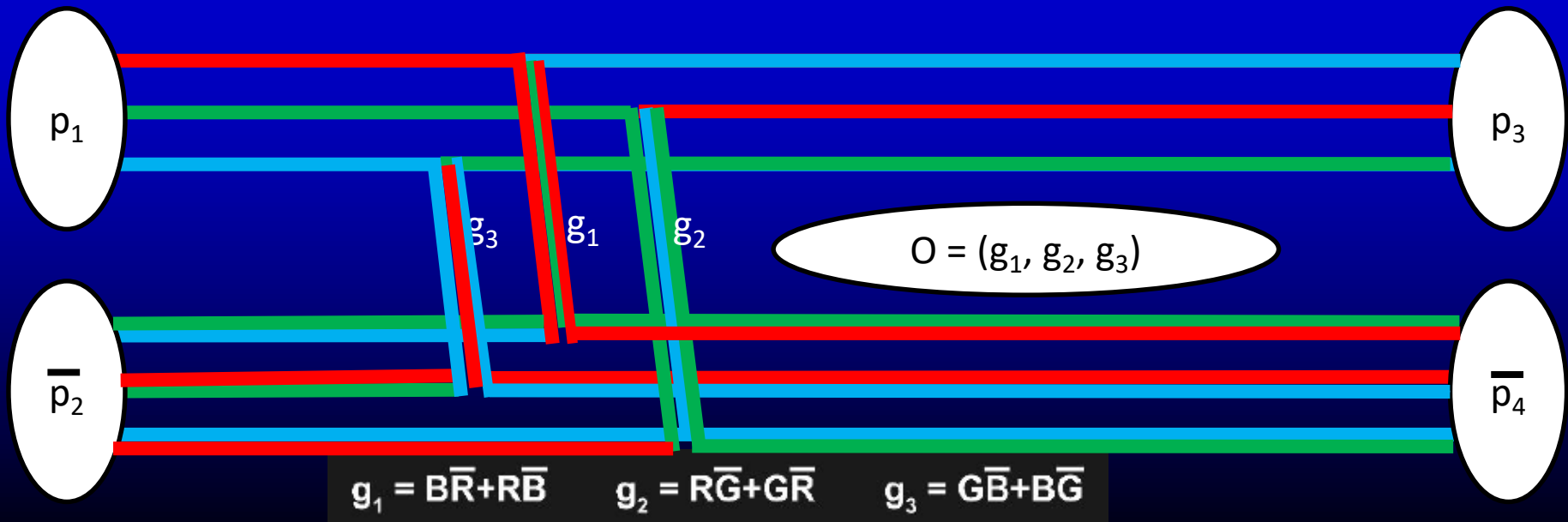
$$(RGB) + (\bar{R}\bar{B}\bar{G}) \rightarrow (BRG) + (\bar{B}\bar{G}\bar{R})$$

-

$$p + p \rightarrow p + p$$

$$(RGB) + (RGB) \rightarrow (GBR) + (GBR)$$

23



# R. J. Glauber at TOTEM/CERN, 2009





# R. J. Glauber at Wigner, 2012



# 3+2 Oldest Hungarian Universities

## Why Eszterházy Károly Catholic University (EKCU)?

Eszterházy Károly Catholic University is one of the oldest higher educational institutions in Hungary. Opened in 1774 it has served the Northern Hungarian region for nearly three centuries. Now the university offers potential students the opportunity to work towards their BA, BSc, MA, MSc or doctorate

Eszterházy Károly Catholic University:  
1774 (or, 2020?)

## History of MATE

With the foundation Hungarian University of Agriculture and Life Sciences (MATE), one of the largest agricultural-focused, multi-disciplinary higher education institutions in Europe was established on 1 February 2021.

With such a long history and legacy of excellence, Hungarian University of Agriculture and Life Sciences stands as a central pillar of higher education in Hungary and throughout the region.

### Milestones in the history of MATE:

1787 Faculty of Veterinary Medicine founded

1880 Ybl Miklós Technical College founded

1917 Teacher Training College, Jászberény founded

1920 University of Agriculture was founded in Budapest

1950 University of Agriculture moved to Gödöllő

2000 Szent István University founded

2011 institutional integration to 7 faculties

2016 integration of 3 faculties (Food Science, Horticultural Science and Landscape Architecture and Urbanism) of Corvinus University of Budapest; and the disintegration of the Faculty of Veterinary Medicine

2020 integration of Kaposvár University, Eszterházy University's Károly Róbert Campus (Gyöngyös) and Pannon University's Georgikon Faculty in Keszthely

MATE: 2021 (or, from 1787)

# Honorable mentions: Odderon, qualitatively

## Proposal for LHC to hunt down the Odderon:

Extracting the Odderon from  $pp$  and  $p\bar{p}$  scattering data #1

Andras Ster (Budapest, RMKI), [Laszlo](#)  
Budapest, RMKI) (Jan 15, 2015)

Published in: *Phys.Rev.D* 91 (2015) 7,

Searching for the odderon in  $pp \rightarrow ppK^+K^-$  and  $pp \rightarrow pp\mu^+\mu^-$  reactions in the  $\phi(1020)$  resonance region at the LHC #2

Piotr Lebiedowicz (Cracow, INP), Otto Nachtmann (U. Heidelberg, ITP and Rzeszow U.), [Antoni Szczurek](#) (Cracow, INP) (Nov 5, 2019)  
Published in: *Phys.Rev.D* 101 (2020) 9, 094012 • e-Print: 1911.01909 [hep-ph]

## Qualitative Odderon signals: in t-dependence of $B(s,t)$ and $\rho(s,t)$

Odderon and proton substructure from a model-independent Lévy imaging of elastic  $pp$  and  $p\bar{p}$  collisions #6

T. Csörgő (Wigner RCP, Budapest)  
Ster (Wigner RCP, Budapest) (Jan 15, 2015)  
Published in: *Eur.Phys.J.C* 79 (2019) 6, 461 • e-Print: 1808.08580 [hep-ph]

Analytical representation for amplitudes and differential cross section of  $pp$  elastic scattering at 13 TeV #1

E. Ferreira (Rio de Janeiro Federal U.), A.K. Kohara (SENAI/CETIQT, Rio de Janeiro), T. Kodama (Rio de Janeiro Federal U. and Niteroi, Fluminense U.) (Nov 26, 2020)  
Published in: *Eur.Phys.J.C* 81 (2021) 4, 290 • e-Print: 2011.13335 [hep-ph]

Odderon effects in the

Evgenij Martynov (Kiev, INR), Basarab Nicolescu (Babes-Bolyai U.) (Aug 15, 2019)  
Published in: *Eur.Phys.J.C* 79 (2019) 6, 461 • e-Print: 1808.08580 [hep-ph]

Ratio  $\rho_{pp}^{pp}(s)$  in Froissaron and maximal odderon approach

E. Martynov (BITP, Kiev), [G. Tersimonov](#) (BITP, Kiev) (Nov 15, 2019)  
Published in: *Phys.Rev.D* 100 (2019) 11, 114039 • e-Print: 1911.06873 [hep-ph]

New physics from TOTEM's recent measurements of e

[István Szanyi](#) (Uzhgorod Nat. U.) (Sep 4, 2021)  
Published in: *J.Phys.G* 46 (2019) 6, 063501 [hep-ph]

Froissaron and Maximal Odderon with spin-flip in  $pp$  and  $p\bar{p}$  high energy elastic scattering #1

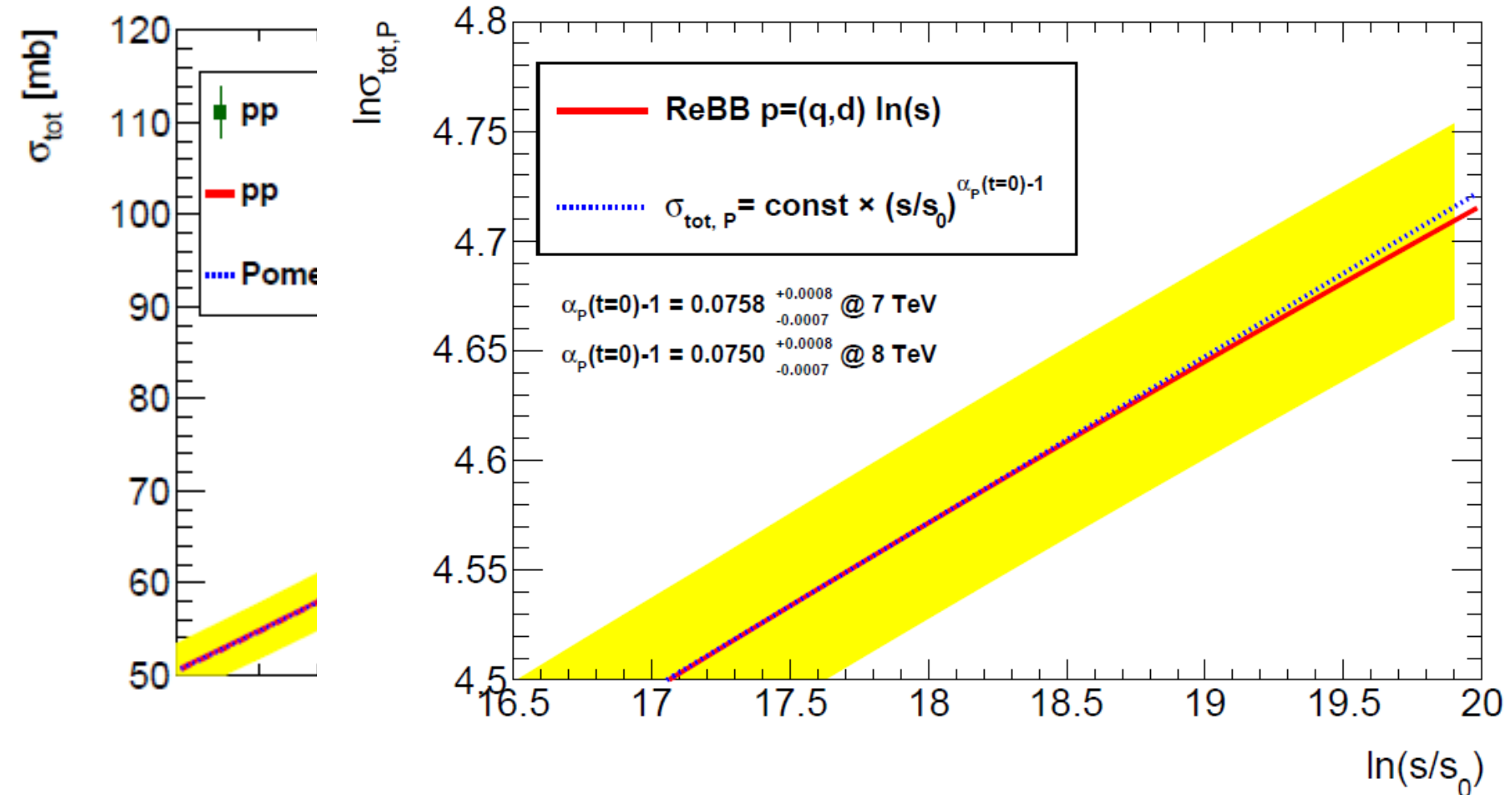
N. Bence (Uzhgorod Nat. U.), A. Lengyel (Unlisted, UA), Z. Tarics (Unlisted, UA), E. Martynov (BITP, Kiev), G. Tersimonov (BITP, Kiev) (Sep 4, 2021)  
Published in: *Eur.Phys.J.A* 57 (2021) 9, 265

# POMERON PROPERTIES

MODEL RESULT BASED ON EPJC 81 (2021) 7, 611

1<sup>st</sup> property:

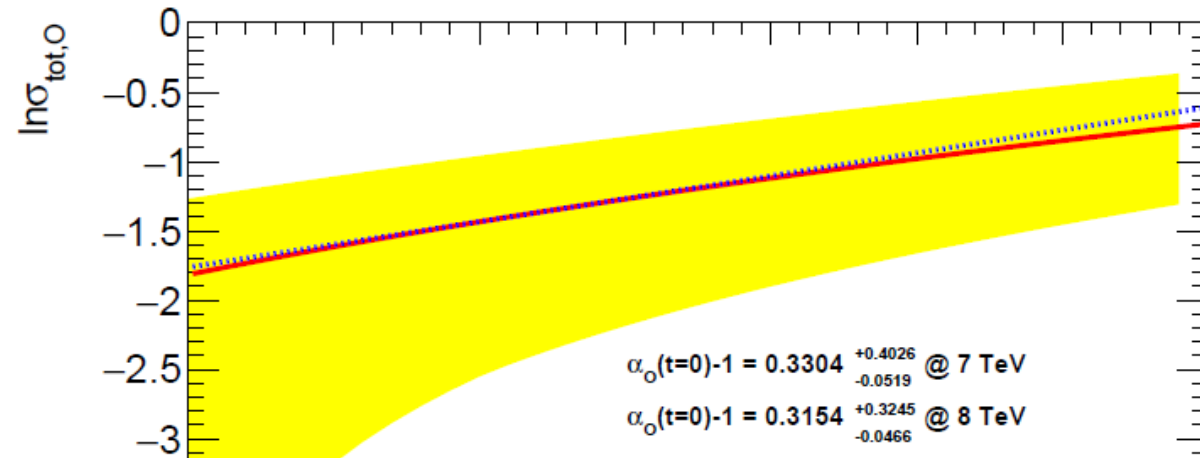
Pomeron intercept normal:  $\alpha_P(0)-1 = 0.075 \pm 0.001$





# ODDERON PROPERTIES

EPJC 81 (2021) 7, 611



**1<sup>st</sup> property:**

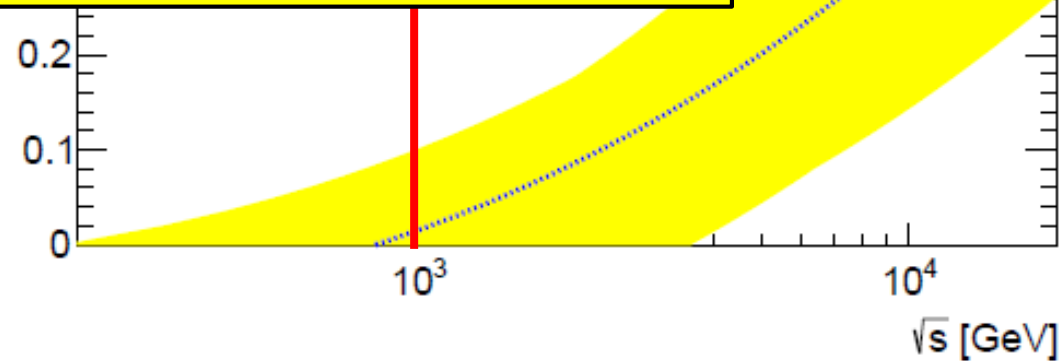
**Odderon intercept is large,  $\alpha_o(0)-1 = 0.32^{+0.32}_{-0.06}$**

**Threshold effect, slowly decreases with  $s$ , but**

**Pomeron intercept normal:  $\alpha_p(0)-1 = 0.075 \pm 0.001$**

**2<sup>nd</sup> property:**

**1 TeV  $\sim$  threshold energy**





# **SUMMARY: ODDERON DISCOVERED IN 3 PAPERS, NEW: FOCUS ON ITS PROPERTIES**

**Bialas-Bzdak  $p = (q,d)$  model: certain Odderon effect  
statistical significance  $\gg 5 \sigma$**

**Odderon first discovered in three published papers:  
three different analysis, each with a statistical significance  $> 5 \sigma$**

**(S,C) structure evident,  
Scientific Statement S is valid if Condition C is satisfied**

**0<sup>th</sup> property: Odderon exists! (Questioned: where, at 13 TeV and  $t=0$ ?)**

**Odderon properties: from Bialas-Bzdak model, so far  
valid in a limited  $s$  and  $-t > 0.37 \text{ GeV}^2$  range only**

**Odderon intercept is large,  $\alpha_O(0)-1 = 0.32^{+0.32}_{-0.06}$   
Pomeron intercept normal:  $\alpha_P(0)-1 = 0.075 \pm 0.001$**

**1.96 TeV – 8 TeV:  
Threshold effect, just appearing**

**Ongoing debate: what is the significance of the D0-TOTEM PRL?  
Is there any evidence for Odderon at  $t=0$ ? Response is coming...**

# ODE TO ODDERON → OBERON

## Ode to Odderon

Let's be truly happy,  
for what we've come upon:  
We have just discovered  
the elusive odderon!

For forty-eight years,  
forging a ring of colors white:  
Odd number of gluons  
has been hiding in plain sight!

*"Discovery consists of seeing what everybody has seen,  
and thinking what nobody has thought."*

*Albert Szent-Györgyi*

## OBERON POETRY MAGAZINE

So happy together,  
with love for science and research:  
Happiness and pleasure  
must not slow down the search!

Let's live in harmony,  
and in equanimity:  
Let's make light of the fight,  
gloom is our true enemy!

© by *Tamás Csörgő*

*Gyöngyös, Hungary, March 11 – April 11, 2021*

# Odderon: origin of its name

Odderon name coined in 1975:  
D. Joynson, E. Leader, B. Nicolescu, C. Lopez  
Nuovo Cim. 30A, 345 (1975)

IL NUOVO CIMENTO

VOL. 30 A, N. 3

1 Dicembre 1975

## **Non-Regge and Hyper-Regge Effects in Pion-Nucleon Charge Exchange Scattering at High Energies.**

D. JOYNSON (\*), E. LEADER (\*\*) and B. NICOLESCU

*Division de Physique Théorique (\*\*\*)*, *Institut de Physique Nucléaire (\*,\*) - Paris*  
*Laboratoire de Physique Théorique des Particules Élémentaires - Paris (\*,\*)*

C. LOPEZ (\*,\*)

*Laboratoire de Physique Théorique et Hautes Energies - Paris (\*,\*)*

(ricevuto il 24 Giugno 1975)

# 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

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>

# First three Odderon Proceedings, $> 5 \sigma$

## Proton Holography -- Discovering Odderon from Scaling Properties of Elastic Scattering #2

T. Csorgo (Wigner RCP, Budapest and Eszterhazy Karoly U., Eger), [T. Novák](#) (EKU KRC, Gyongyos), R. Pasechnik (Lund U. and Rez, Nucl. Phys. Inst.), [A. Steer](#) (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: 2004.07305 [hep-ph]




 pdf  DOI  cite

**EPJ Web Conf. 235 (2020) 06002, proc. ISMD 2019**  
<https://doi.org/10.1051/epjconf/202023506002>

## Scaling of high-energy elastic scattering and the observation of Odderon #1

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

Published in: Gribov-90 Memorial Volume, pp. 69-80 (2021) (World Scientific, Singapore, ed. Yu. Dokshitzer, P. L'evai, \A. Luk'acs and J. Nyiri) • e-Print: 2004.07318 [hep-ph]




 pdf  DOI  cite

**Gribov'90 Memorial Volume, pp. 69-80 (2021)**  
[https://doi.org/10.1142/9789811238406\\_0012](https://doi.org/10.1142/9789811238406_0012)

## Comparison of differential elastic cross sections in $pp$ and $p\bar{p}$ collisions as evidence of the existence of the colourless $C$ -odd three-gluon state #1

D0 and Totem Collaborations • [Christophe Royon](#) (Kansas U.) for the collaborations. (Dec 5, 2020)

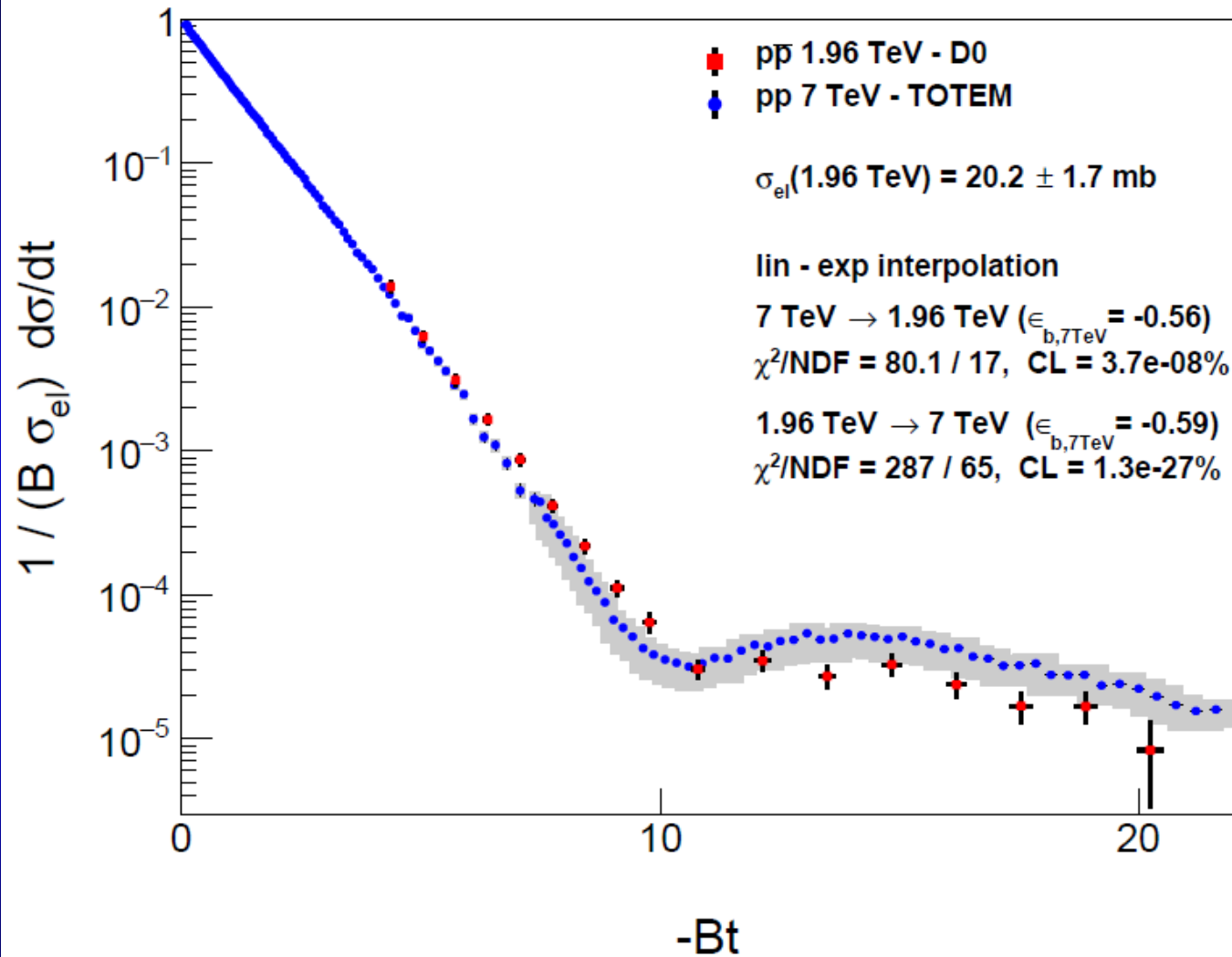
Published in: *PoS ICHEP2020* (2021) 496 • Contribution to: ICHEP2020, 496 • e-Print: 2012.03150 [hep-ex]

 pdf  DOI  cite

**PoS ICHEP 2020 (2021)**  
<https://doi.org/10.22323/1.390.0496>



# Back to Scaling: Model independently



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

$H(x|pp, 7 \text{ TeV})$   
 $\neq$   
 $H(x|p\bar{p}, 1.96)$

Odderon,  
**IF** scaling holds  
in pp down to  
1.96 TeV

**6.26  $\sigma$**   
**Odderon effect**

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