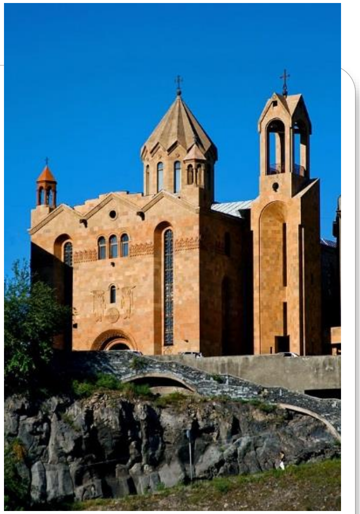
ARMENIA (Yerevan)
September, 11-14

International Conference on High Energy Physics



Data-driving high precision analysis of new effects in elastic nucleon scattering at high energies

O.V. Selyugin
BLTPh, JINR

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Contents

* Elastic hadron scattering – new data LHC
* Total cross sections
* The real part of the scattering amplitude from the data
* Comparing the data with High Energy Generalized structure model (HEGS)
  * New term with large slope
  * Oscillation term
* Results and Summery

Scattering process described in terms of Helicity Amplitudes ϕ_i

All dynamics contained in the Scattering Matrix M

(Spin) Cross Sections expressed in terms of

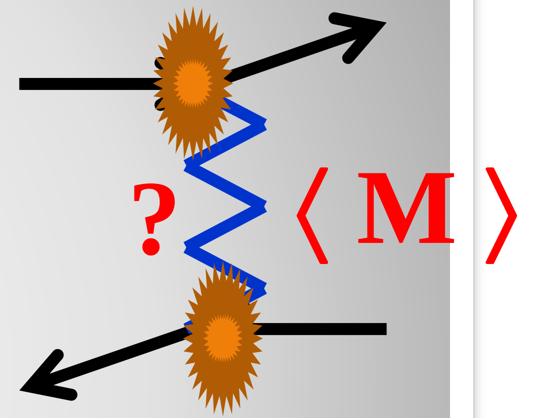
observables:

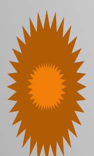
3 ×-sections

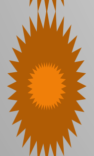
5 spin asymmetries

- spin non–flip $\phi_1(s,t) = \langle ++ | M | ++ \rangle$
- double spin flip $\phi_2(s,t) = \langle ++ | M | -- \rangle$
- spin non–flip $\phi_3(s,t) = \langle +- | M | +- \rangle$
- double spin flip $\phi_4(s,t) = \langle +- | M | -+ \rangle$
- single spin flip $\phi_5(s,t) = \langle ++ | M | +- \rangle = -\langle ++ | M | -+ \rangle$

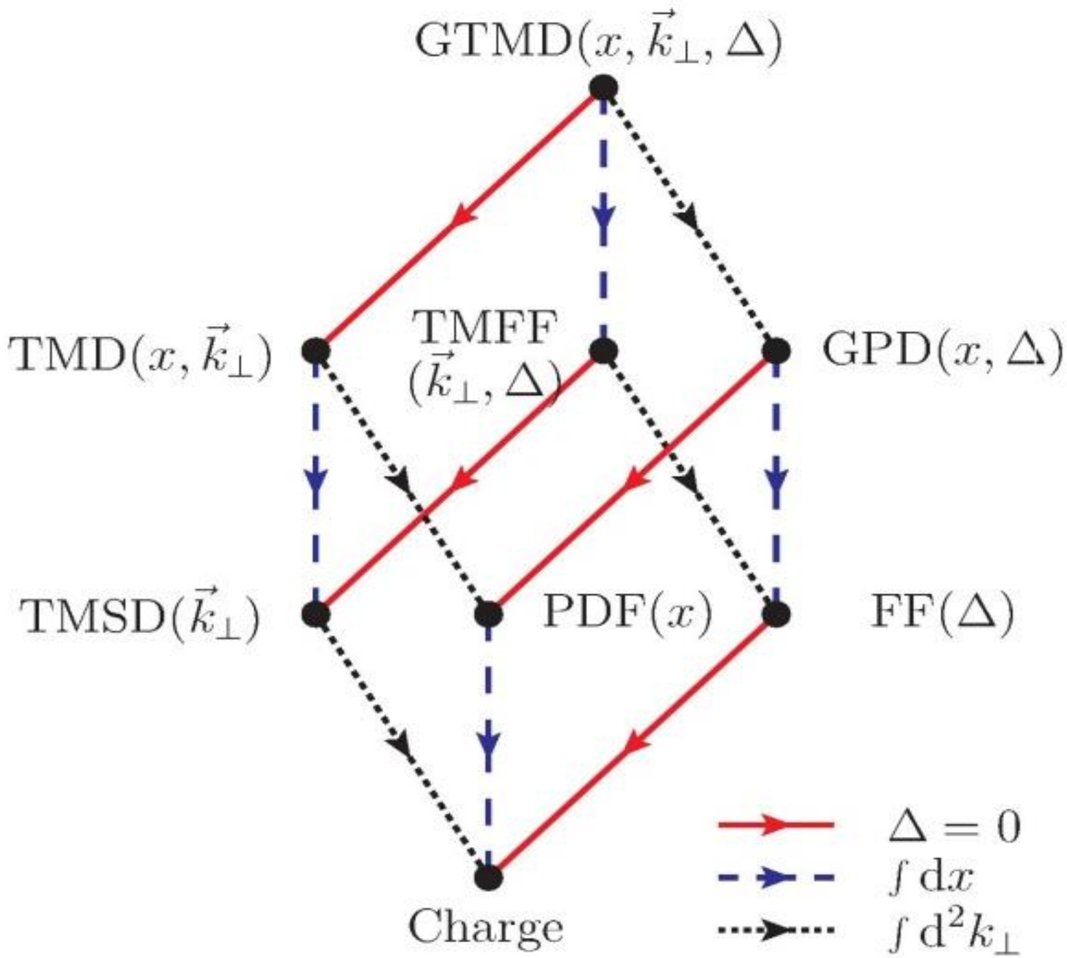
identical spin ½ particles



 - GPDs → electromagnetic FF

 - GPDs → gravimagnetic FF

M. Burkhardt, B. Pasquini, EPJ (2015)



General Parton Distributions (GPDs)

GPDs

$$lmit\ Q_\gamma^2 = 0,\ and\ \xi = 0$$

$F_{x=0}(x;t) = F(x;t)$

$$F_1^q(t) = \int_{-1}^{1} dx\ H^q(x,\xi,t);$$

X.Ji Sum Rules (1997)

$$F_2^q(t) = \int_{-1}^{1} dx\ E^q(x,\xi,t);$$

$H^q(x;t) = H^q(x,0,t) + H^q(-x,0,t)$

$$F_1^q(t) = \int_{0}^{1} dx\ \mathcal{H}^q(x,\xi,t);$$

$E^q(x;t) = E^q(x,0,t) + E^q(-x,0,t)$

$$F_2^q(t) = \int_{0}^{1} dx\ \mathcal{E}^q(x,\xi,t);$$

$$\int_{-1}^{1} dx\ x[H^q(x,\xi,t) + E^q(x,\xi,t)] = A_q(\Delta^2) + B_q(\Delta^2);$$

Why it is need know the t-dependence of GPDs in the wide region of the momentum transfer?

•Form factors in the wide region of t (x^{n-1})

(Compton - zero momentum - x^{-1}

electromagnetic, - first momentum - x^{0}

gravitomagnetic - second momentum – x^{1}

* Tomography of the nucleons

(impact parameter representation)

require the integration on the whole region of t

Elastic scattering amplitude

$p\,p \rightarrow p\,p$ $\qquad$ $p\bar{p} \rightarrow p\bar{p}$

$$\frac{d\sigma}{dt} = 2\pi[|\Phi|_1^2 + |\Phi|_2^2 + |\Phi|_3^2 + |\Phi|_4^2 + 4|\Phi|_5^2]$$

$$\Phi_i(s,t) = \Phi_i^h(s,t) + \Phi_i^e(t)\, e^{i\alpha\varphi}$$

$$\varphi(s,t) = \mp[\gamma + \ln(B(s,t)\,|t|/2) + \nu_1 + \nu_2]$$

$\gamma = 0{,}577\ldots$ *(the Euler constant)*

ν_1 *and* ν_2 *are small correction terms*

Hard Pomeron $f(s) \approx s^{\Delta} \quad (\Delta_h = 0.4)$

Odderon $f(s) \approx ? \;\; [\, 1/\sqrt{s}; \quad const.; \quad s^{\Delta} \quad (\Delta_s = 0.1) \quad]$

$$F(s,t) \approx t/(r^2 - t)\; s^{\Delta_s} \exp[\, B\,t\,]\; G^2_{gr.}(t)$$

Spin-flip $f(s) \approx ? \;\; (1/\sqrt{s}; \quad cons; \quad Ln(s) \;\;)$

$$F^{+-}(s,t) \approx q^3 \exp[B_{sf}\; t] G^2$$

Impact parameter representation

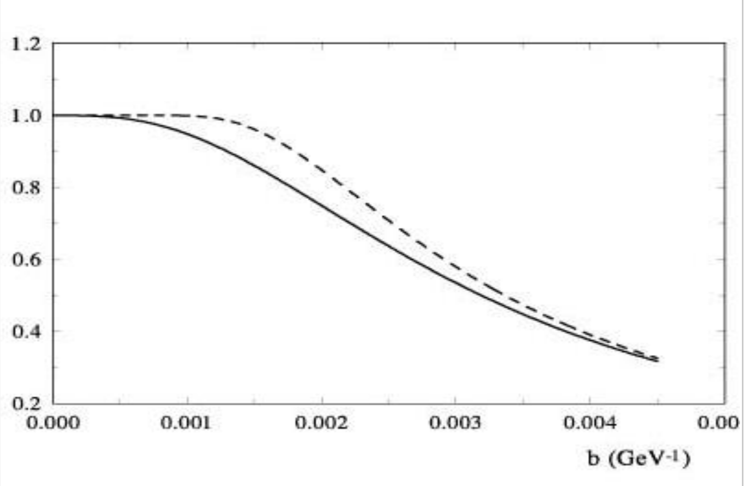
$$\chi(s,b) = 2\pi \int_0^\infty q\ J_0(bq)\ M_B(s,q)\, dq$$

Saturation and non-linear equation

J.-R. Cudell, E.Predazzi, O.V. S., Phys.Rev.D79(2009)

J.-R. Cudell, O.S., Phys.Rev.Lett.102 (2009)

$$\frac{dN}{dy} = (-Ln[1-N])\ (1-N);$$



$$T(s,t) = is \int_0^\infty b\, db\, J_0(bq)\ (1-\exp[i\,\chi(s,b)])$$

High energy hadron elastic scattering

High Energy Generelized Structure (HEGS) model

O.V. S., O.V. Teryaev, Phys.Rev. D 79, 033003 (2009).

O.V.S. - Eur. PhysJ. C 72: 2073 (2012)

O.V.S. Nucl.Phys. A 903 54 (2013)

O.V. S., Phys. Rev., D 89, 093007 (2014) .

O.V. S, Nucl. Phys. A 922, 180 (2014)

O.V. S., Phys. Rev., D 91, 113003 (2015)

O.V. S. Part. Nucl. Lett, 13, 03(2016)

O.V. S., Nucl.Phys. A 959, 116 (2017).

O.V. S. Acta Phys. Pol. B 12 741 (2019)

O.V. S., Symmetry, v.13, 00164 (2021)

O.V. S., Phys.Lett. B 797, 134870 (2019).

O.V. S, Mod..Phys.Lett. A, 36, (2021) 2150148

O.V. S., Symmetry, v.15, 760 (2023)

t = 0

Pomeron $\operatorname{Im} F_{+}(s,t=0) \sim s(\ln s)^2; \qquad \operatorname{Re} F_{+}(s,t=0) \sim s(\ln s);$

Odderon $\operatorname{Re} F_{+}(s,t=0) \sim s(\ln s)^2; \qquad \operatorname{Im} F_{+}(s,t=0) \sim s(\ln s);$

$$\rho_{\pm}(E)\,\sigma_{\pm}(E) = \frac{C}{P} + \frac{E}{\pi P}\int_{m}^{\infty} dE'\,P'\left[\frac{\sigma_{\pm}(E')}{E'(E'-E)} - \frac{\sigma_{\mp}(E')}{E'(E'+E)}\right].$$

Extansion of the model

(HEGS)

$$9 \le \sqrt{s} \le 8000\, GeV;$$

$$\hat{s} = s / s_0\, e^{i\pi/2};$$

$$n = 980 \to 3416; \qquad 0.00037 < |t| < 15\ GeV^2; \qquad s_0 = 4m_p^2.$$

$$F_1^B(s,t) = h_2 G_{em}(t)\ (\hat{s})^{\Delta_1} e^{\alpha' t \ln(\hat{s})}; \quad F_3^B(s,t) = h_3 G_A(t)^2\ (\hat{s})^{\Delta_1} e^{\alpha'/4 t \ln(\hat{s})};$$

$$F^B(\hat{s},t) = F_1^B(\hat{s},t)(1 + R_1/\sqrt{\hat{s}}\ )]\ + F_3^B(\hat{s},t)(1 + R_2/\sqrt{\hat{s}}\ )]$$

$$+\ F_{odd}^B(s,t); \qquad \alpha'(t) = (\alpha_1 + k_0\, q\, e^{k_0 t \ln\hat{s}})\ln\hat{s}.$$

$$F_{Odd}^B(s,t) = h_{Odd}\ G_A(t)^2\ (\hat{s})^{\Delta_1}\ \frac{t}{1 - r_o^2 t} e^{\alpha'/4 t \ln(\hat{s})};$$

$$F^{+-}(s,t) = h_{sf}\ q^3\ G_{em}(t)^2\ e^{\mu t};$$

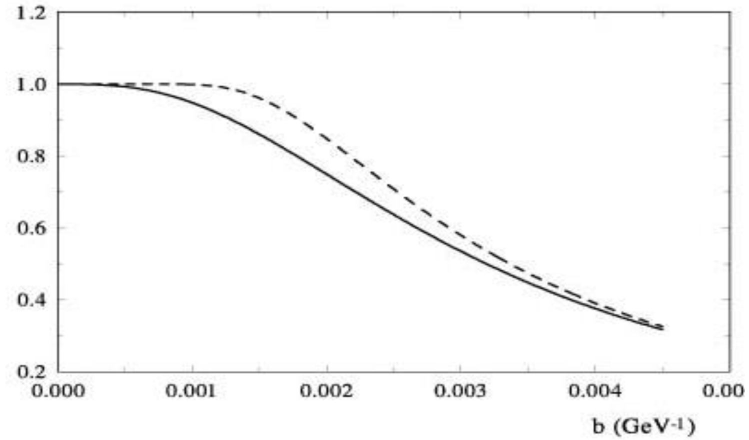
M.Galynskii, E.Kuraev, JETP Letters (2012)

$$\chi_0(s,\rho) = \frac{1}{2ip}\int_{-\infty}^{\infty} dz V_0(\rho,z);$$

$$\chi_0(s,b) = 2\pi\int_0^{\infty} q\, e^{i\vec{q}\vec{b}}\;\; F_0^B(s,q)\, dq$$

$$J_0(x) = \frac{1}{2\pi}\int_0^{2\pi} d\vartheta\, e^{ix\vartheta\cos\vartheta};$$

$$F_0(s,t) = -ip\int_0^{\infty}\rho d\rho\, J_0(\rho q)(e^{\chi_0(s,\rho)}-1);$$



$$\chi_5(s,b) = 2\pi\int_0^{\infty} q\, e^{i\vec{q}\vec{b}}\;\; F_5^B(s,q)\, dq$$

$$F_5(s,t) = -ip\int_0^{\infty} bdb\, J_1(bq)\;\; \chi_5(s,b)\;\; e^{\chi_0(s,b)};$$

$$J_1(x) = -\frac{1}{2\pi}\int_0^{2\pi} d\vartheta\, e^{ix\vartheta\cos\vartheta}\sin\vartheta;$$

$$\Delta_1 = 0.11 - \ fixed; \qquad \alpha_1 = 0.24 - \ fixed;$$

$$h_1 = 0.814; \ \ h_2 = 0.314; \quad R_1 = 52;3 \ \ R_2 = 4.56;$$

$$k_0 = 0.17 \ ; \quad h_{Odd} = 0.18 \ ; \ \ r_o^2 = 3.76 \ ;$$

$$h_{sf} = 0.05; \quad \mu_{sf} = 0.16;$$

$$9 \leq \sqrt{s} \leq 8000\, GeV; \quad N = 3416;$$

$$\sum \chi^2 / \mathrm{N} = 1.28$$

BSW_1 - C. Bourrely, J. Soffer, T.T. Wu - ( )

BSW_2 - C. Bourrely, J. Soffer, T.T. Wu - ( )

$HEGS_0$ – O.V.S. -

$HEGS_1$ – O.V.S. -

$HEGS_2$ – O.V.S. -

	BSW_1	BSW_2	$HEGS_0$	$HEGS_1$	$HEGS_2$
N_{exp}	369	955	980	3416	4047
N_{par}	7+Regge	11+Regge	3+2	5+4	5+4+4
$\sqrt{s}$, GeV	24 ÷ 630	13.4 ÷ 1800	52 ÷ 1800	9 ÷ 8000	6 ÷ 13000
Δt, GeV²	0.1 ÷ 2.6	0.1 ÷ 5	$8.7\cdot10^{-4}$ ÷ 10	$3.7\cdot10^{-4}$ ÷ 15	$3.7\cdot10^{-4}$ ÷ 15
$(\Sigma\chi^2)/N$	4.45	1.95	1.8	1.28	1.3

New LHC data 7 – 13 TeV
(TOTEM and ATLAS)

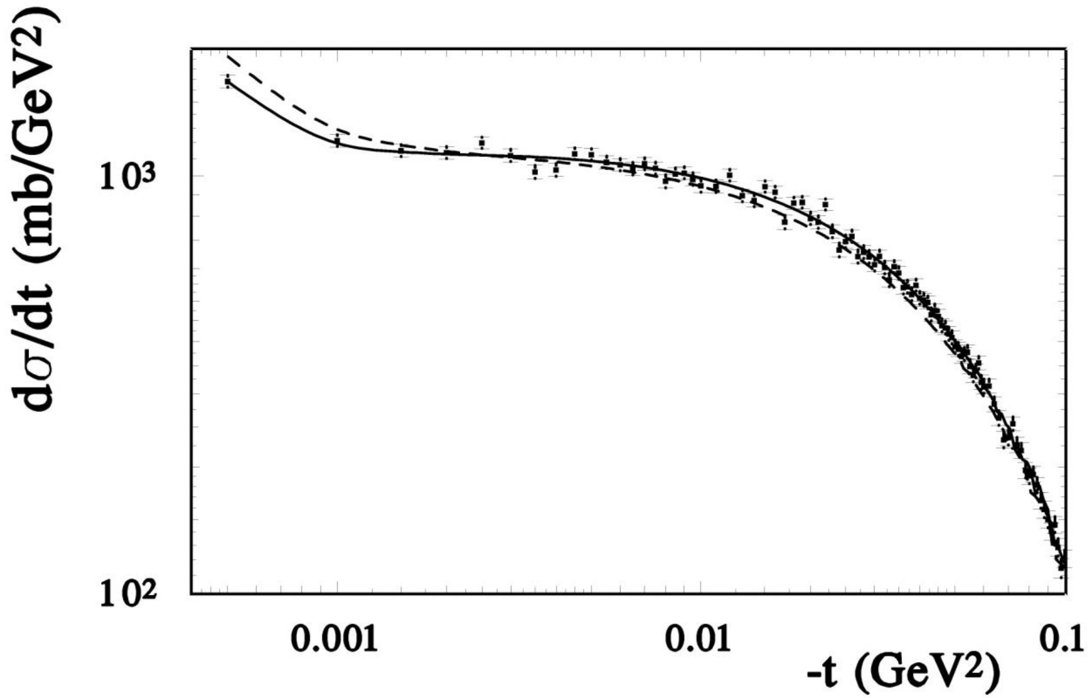
Seminar in the TOTEM O.V.S. (2009) ;

LHC and Phys.Rev.Lett. (2009) 14 TeV

N=90

Simulation of the experimental data by the model with non-exponential behavior of B(s,t) and r(s,t)

$\Delta t = [0.0005 \div 0.1]$



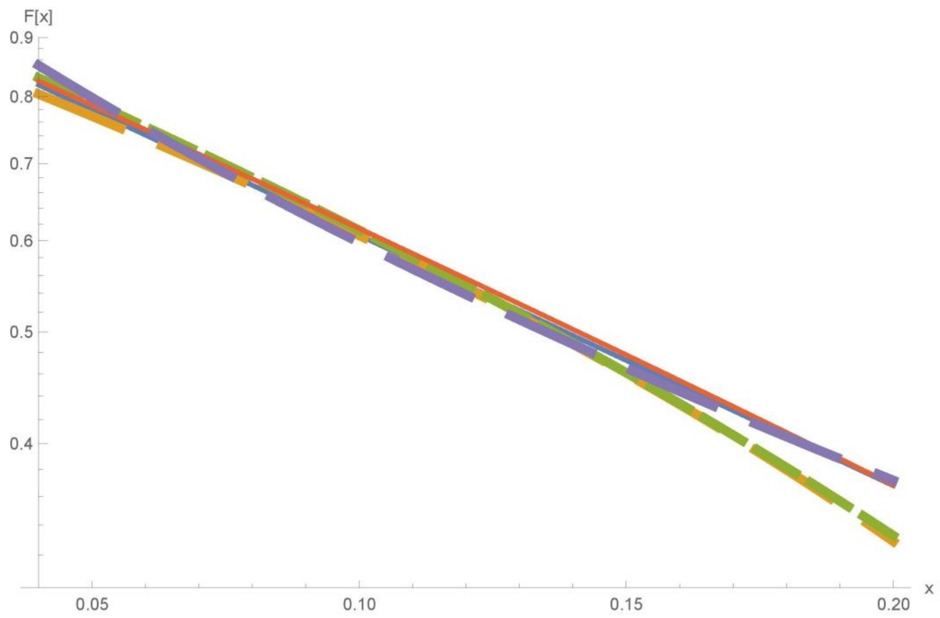
$$\Gamma(b) = e^{-b^2/R^2}; \quad \rightarrow \quad F_1(t) \approx e^{5t};$$

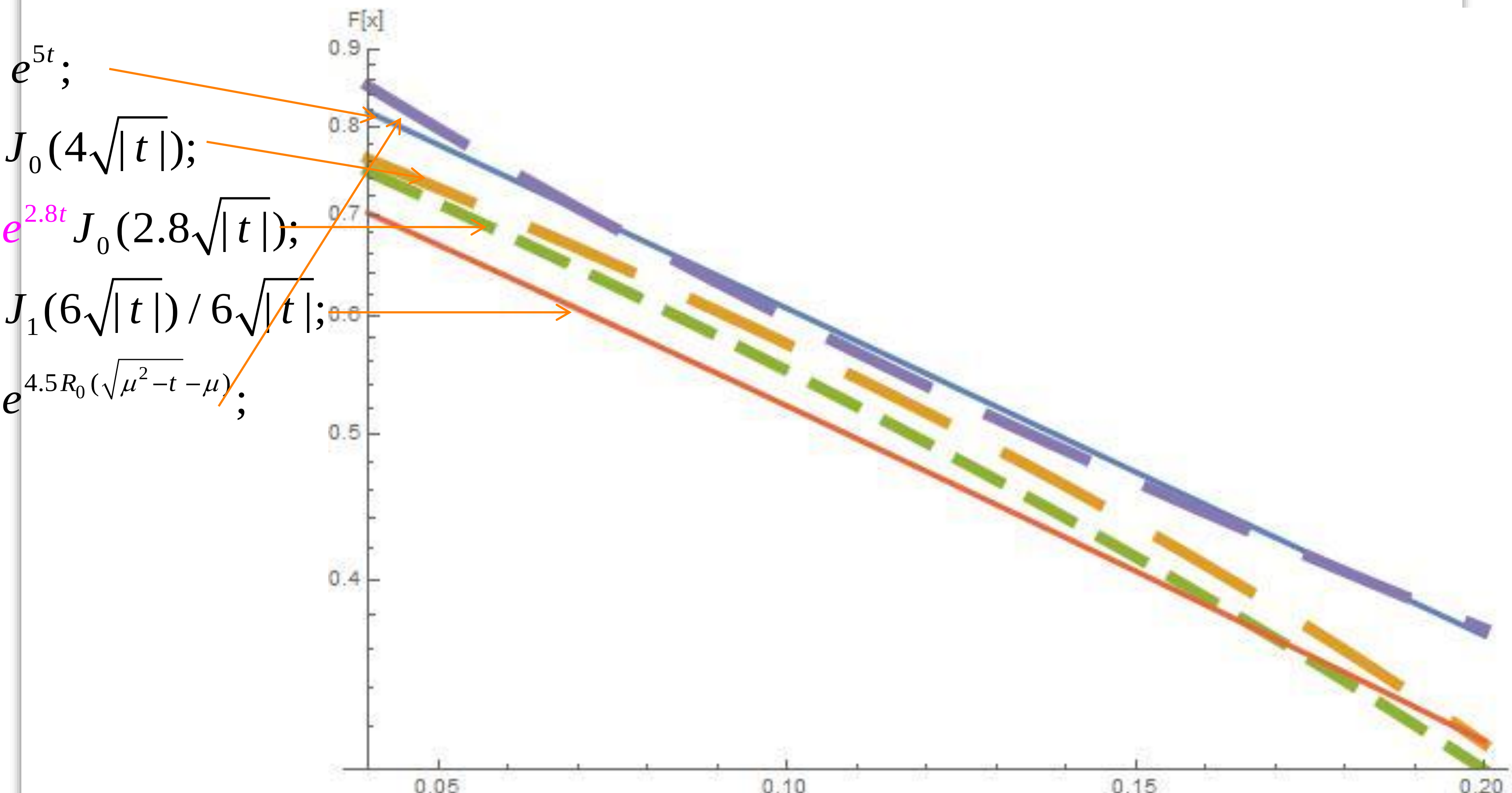
$$\Gamma(b) = \delta(R_0); \quad \rightarrow \quad F_1(t) \approx J_0(R\sqrt{|t|});$$

$$\Gamma(b) = e^{-(b-R_0)^\wedge 2/R_0^2}; \rightarrow \quad F_1(t) \approx e^{2.8t} J_0(2.8\sqrt{|t|});$$

$$\Gamma(b) = C(0-R_0); \quad \rightarrow \quad F_1(t) \approx J_1(R_0\sqrt{|t|}) / R_0\sqrt{|t|};$$

$$\Gamma(b) = e^{-\mu(\sqrt{4R_o^2 - t})}; \quad \rightarrow \quad F_1(t) \approx e^{-5R_0(\sqrt{\mu^2 - t} - \mu)};$$

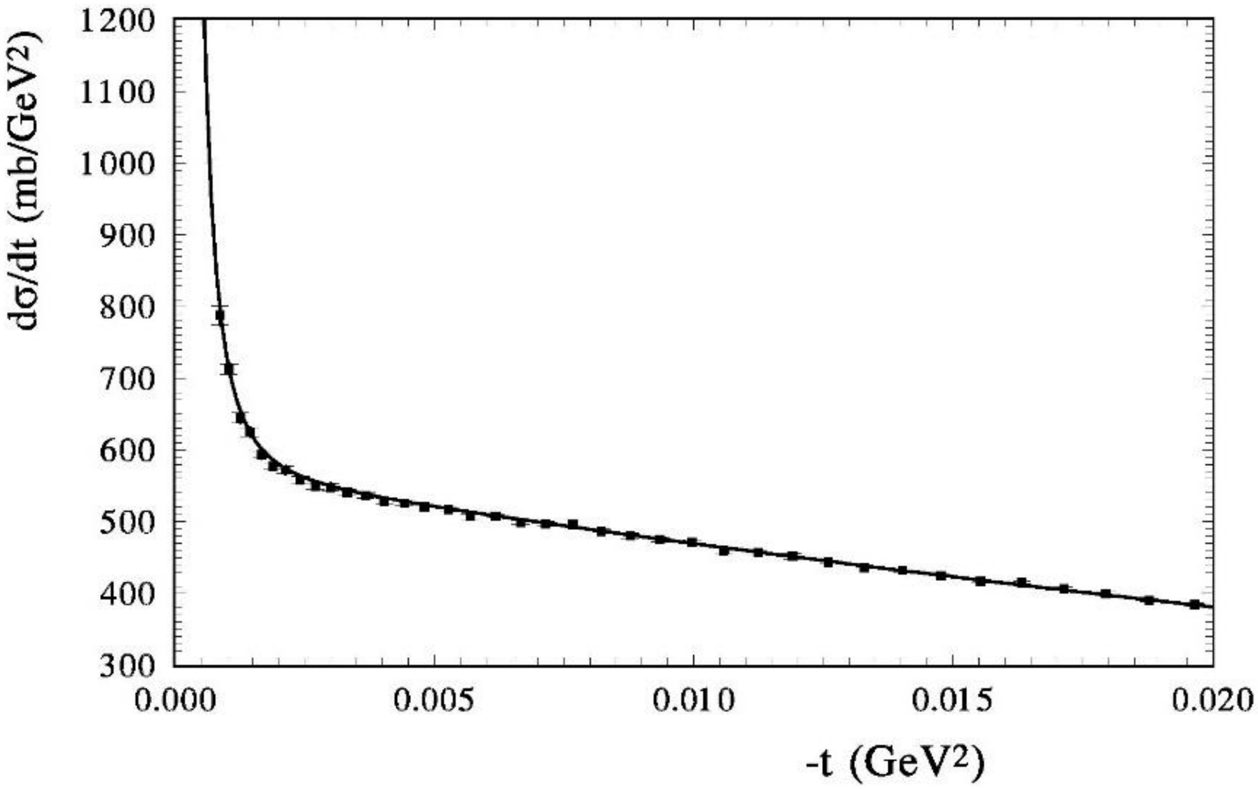



F[x]
0.9
0.8
0.7
0.6
0.5
0.4
0.05
0.10
0.15
0.20
e^{5t};
$J_0(4\sqrt{|t|})$;
$e^{2.8t} J_0(2.8\sqrt{|t|})$;
$J_1(6\sqrt{|t|}) / 6\sqrt{|t|}$;
$e^{4.5 R_0 (\sqrt{\mu^2 - t} - \mu)}$;

Nucl.Phys. A,959 (2017);

t [0.0008 – 0.019]   n=0.9

√s = 13 TeV, β* = 2500 m



Modern Physics Letters A, V. 36, No. 18 (2021) 2150148.

The result was obtained with a sufficiently large addition coefficient of the normalization $n = 1/k = 1.135$. It can be for a large momentum transfer, but unusual for the small region of t.

Let us put the additional **normalization coefficient to unity and continue to take *into account in our fitting procedure***
only statistical errors.

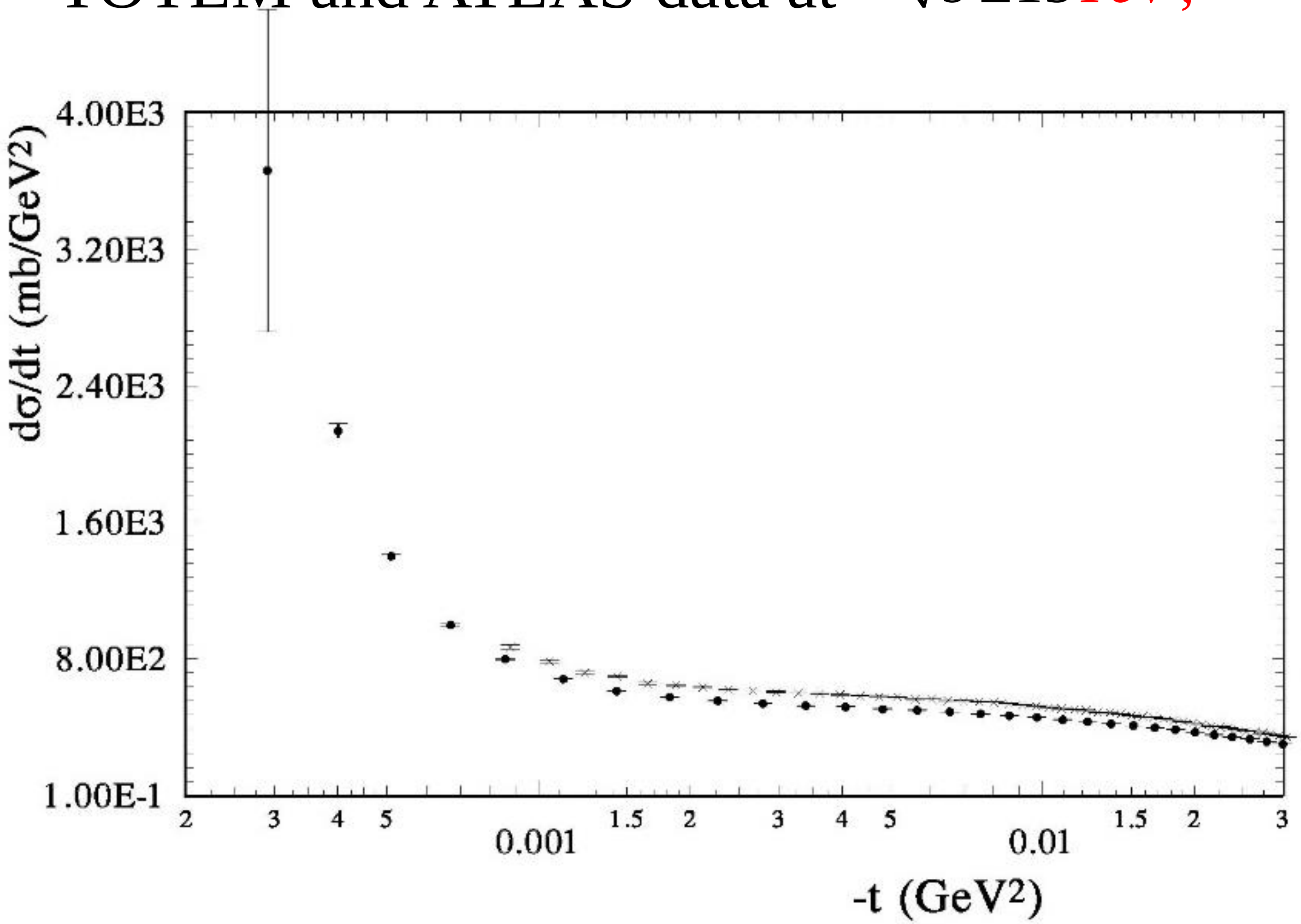
We examined two different forms. One is the simple exponential form

$$F_d(t) = h_d (i + \rho) e^{B_d t^d \; Ln(s)};$$

The parameters of the additional term are well defined

$h_d = 1.7 \pm 0.01$; $\rho_d = -0.45 \pm 0.06$; $B_d = 0.616 \pm 0.026$; $d = 1.119 \pm 0.024$.

TOTEM and ATLAS data at $\sqrt{s} \leq 13 TeV;$

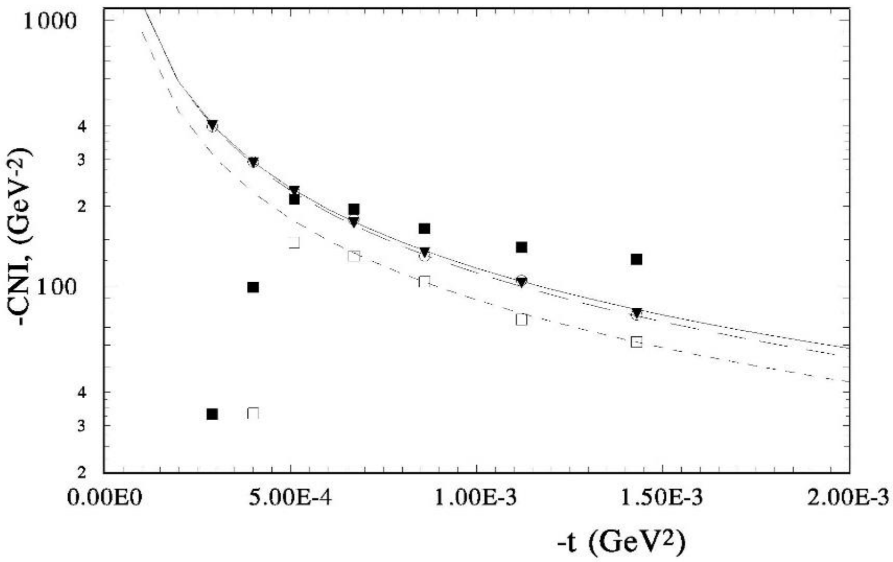


Let us extract from the differential cross section of elastic scattering
the term of Coulomb-nuclear interference
which is determined by the contribution of the pure Coulomb amplitude and
the contribution of the pure hadron amplitude

$$\frac{d\sigma}{dt}\Big|_{CNI} = \frac{d\sigma}{dt}\Big|_{\exp er.} - \frac{d\sigma}{dt}\Big|_{F_C} - \frac{d\sigma}{dt}\Big|_{F_h^2} \quad ;$$

Table 2. Δ CNI = dσ/dt CNI mb/GeV 2

− t (GeV2)	dσ/dt ATLAS	− Δ CNI	dσ/dt mod	− Δ CNI
0.00029	3662	-33	3291	417
0.0004	2136	33	1952	296
0.00051	1401	146	1396	229
0.00067	998	130	1034	166
0.00086	797	104	846	130
0.00112	680	75	731.1	98
0.00143	610.6	62	620.7	75



Δ CNI extracted from experimental data: open squares and full squares - with different sizes of $\sigma_{tot}(s_{13TeV}) = 104\,mb$ and $\sigma_{tot}(s_{13TeV}) = 110\,mb$ with ATLAS form of F_h (t);

circles - extracted from the model representation of TOTEM data;

hard line - representation of the CNI-term in the form

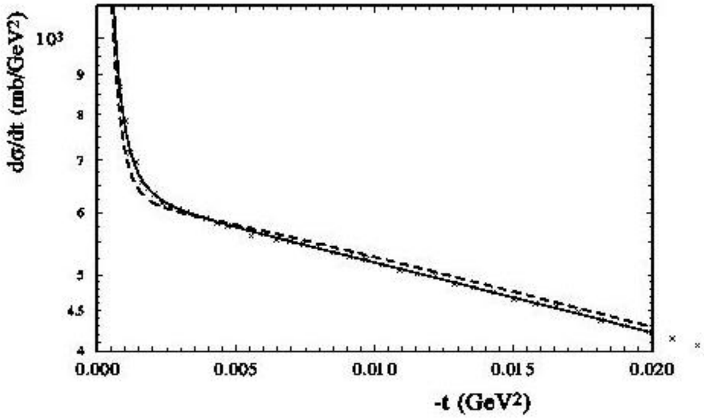
$$F_h(t) = 8\alpha_{em}/t;$$

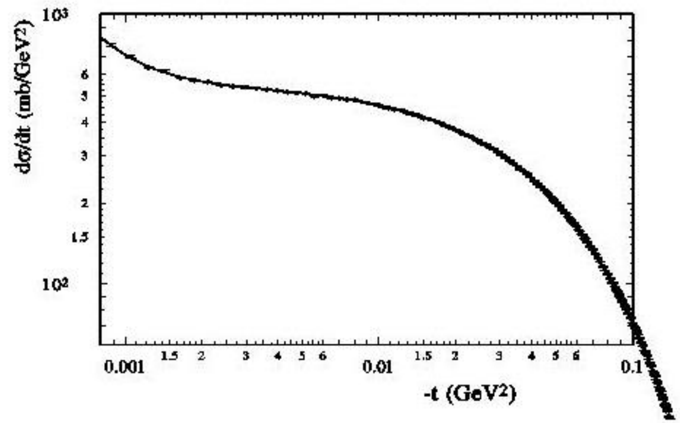
long dashed line - HEGS model calculations of the CNI term;

short dashed line - model calculations with ATLAS phenomenological fit of F_h (t)

Taking into account only statistical errors

O.V.S. Mod.Phys.Lett.





$$F_{an}(s,t) = i h_{an} G^2_{em}(t)\, Ln(\hat{s}/k)\; e^{-\alpha_{an}(|t|+(2t)^2)\ln(\hat{s})}; \quad \alpha_{an} = 0.5\, GeV^{-2};$$

√s = 13 TeV,

$$h^a_{an} = 1.7 \pm 0.05\, GeV^{-2};$$

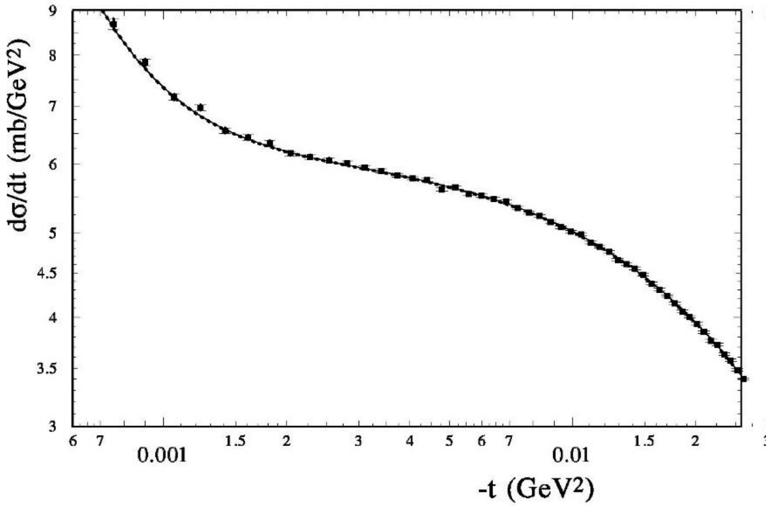
√s = 13 TeV -- 7 TeV,

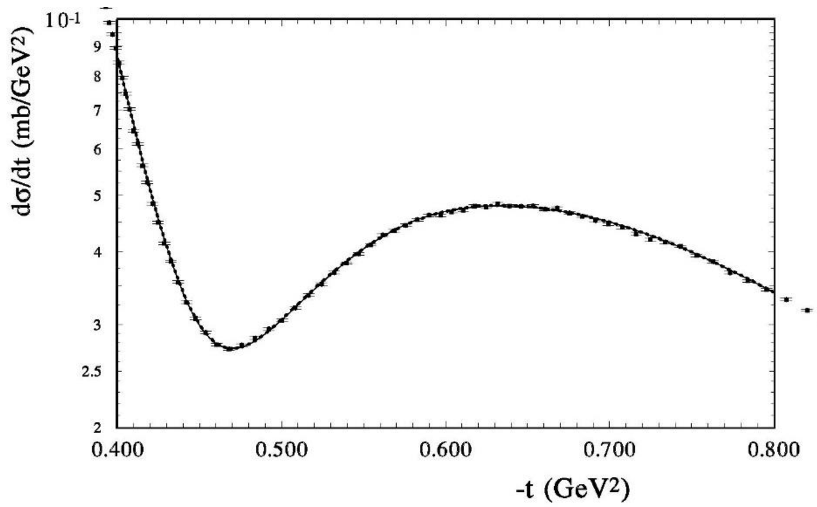
$$h^b_{an} = 1.54 \pm 0.08\, GeV^{-2};$$

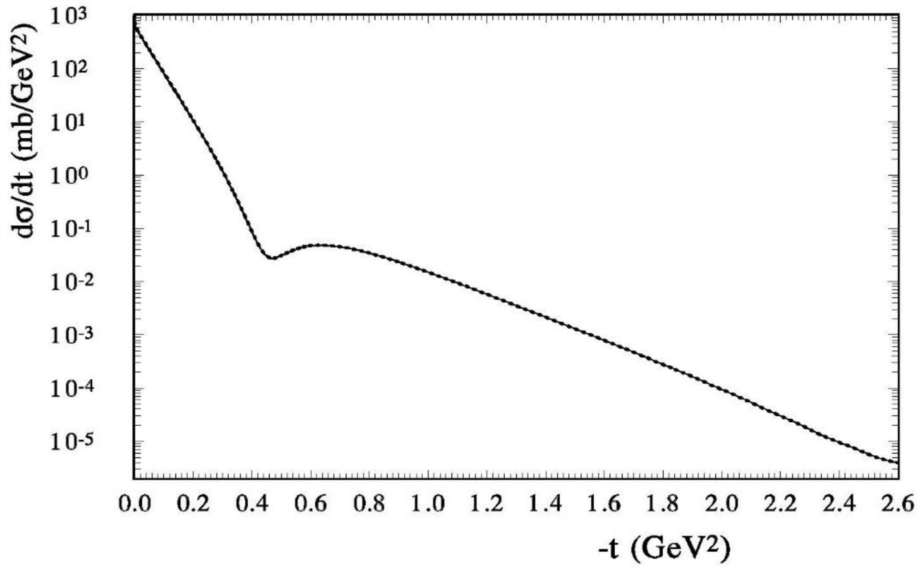
$$h^c_{an} = 2.27 \pm 0.05\, GeV^{-2};$$

√s > 540 GeV [pp and (anti)p]

TOTEM LHC 13 TeV

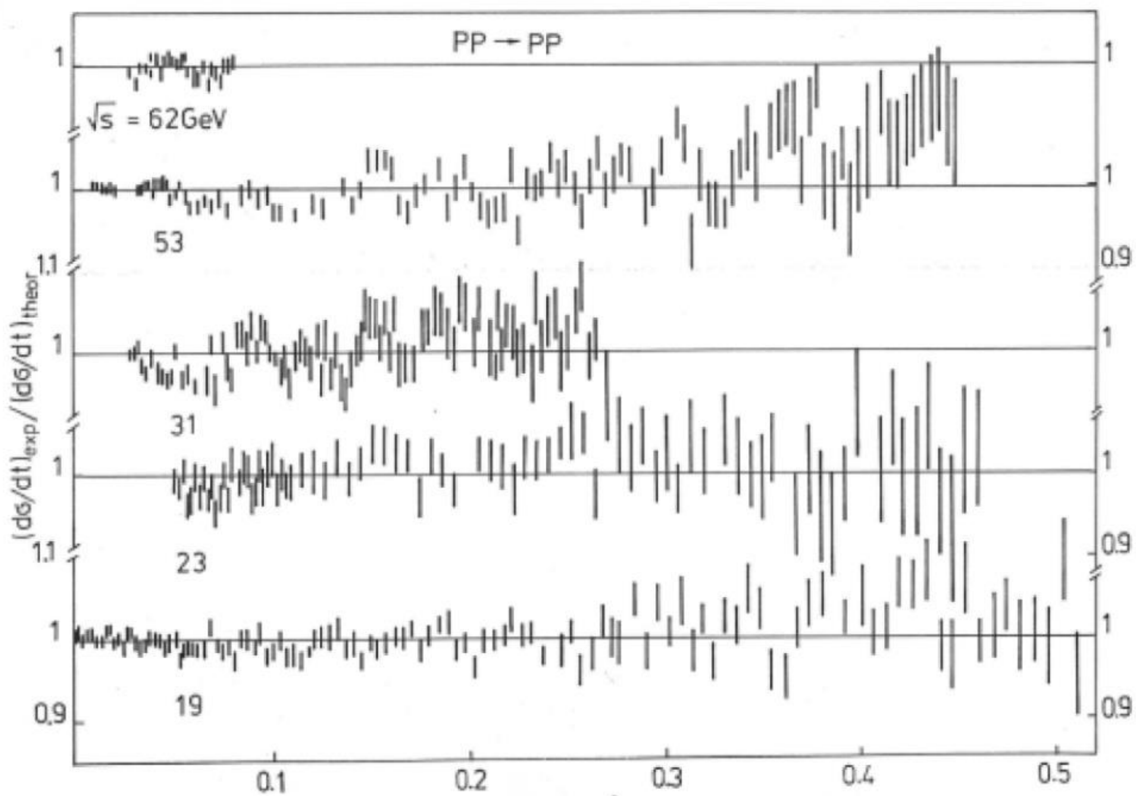




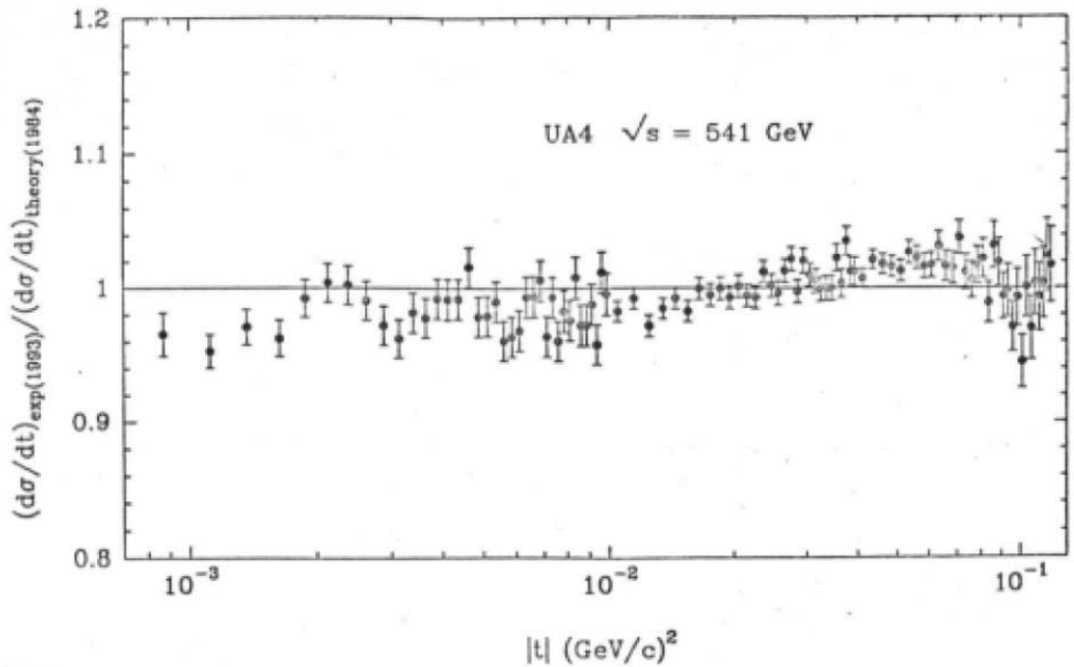


NEW EFFECTS
(oscillations)

$$Del = \frac{d\sigma / dt_{data.} - d\sigma / dt_{theor-\exp.}}{d\sigma / dt_{theor-\exp.}}$$



-t GeV^2



UA4 $\sqrt{s}$ = 541 GeV
1.2
1.1
1
0.9
0.8
10^{-3}
10^{-2}
10^{-1}
$(d\sigma/dt)_{exp(1993)}/(d\sigma/dt)_{theory(1984)}$
$|t|$ (GeV/c)^2

Fig. 2

V.A. Tzarev Model of complex Regge poles

Preprint NAL-Pub-74/17, 1974; DAN-USSR, v.95 (1977)

$$T_k^{Pol}(s,t) = \left(\begin{smallmatrix}-1\\ i\end{smallmatrix}\right) 2\pi\sqrt{\alpha'}\,F(t)\,e^{\lambda(\alpha_0+r_0^2)}(-\alpha' t)^{k+1/2}\,\frac{1}{\alpha_I}\times$$

$$\times\{ish\frac{\pi\alpha_I}{2}cos(\vartheta(t)+\alpha_I(t)\log s)-ch\frac{\pi}{\alpha_I}\sin(\vartheta(t)+\alpha_I(t)\log s)];$$

$$\alpha_I=-\frac{1}{2}\alpha' F\sqrt{-(F^2+4t)};\;\; \vartheta = arctg\frac{\alpha_I}{r_0^2};\;\; r_0^2=\alpha'(t+F/2)^{-1}.$$

$$\frac{d\sigma}{dt} \square \left(\frac{d\sigma}{dt}\right)_{midl}[1+C\,cos(\vartheta(t)+\operatorname{Im}\alpha(t)\log s)];$$

$$If\quad \operatorname{Im}\alpha(t)=\alpha(0)(1-t/t_0),\quad \vartheta(t)=\vartheta(0)=0$$

$$oscillations\quad with\quad \Delta t=\frac{2\pi t_0}{\operatorname{Im}\alpha(0)\ln s}$$

K. Chadan, A. Martin: "Scattering theory and dispersion relations for a class of long-range oscillating potentials", CERN (1979)

$$V(r) \sim \sin[\exp(\mu r)]/(1+r^2)^2;$$

2. a) Van-der-Waals potential $V_{ad} \sim h/r^4$

b) F. Ferrer, M. Nowakowski (1998)
(Golstoun boson – long range forces) $V_{ad} \sim h/r^3$

3. S-L interaction

$$F_C(s,t) + F_{ad}(s,t) = is\int_0^\infty b\,db\,J_0(bq)[(1-e^{\chi_c(s,b)}) + \chi_{LS}^2(s,b)]$$

4. N-dimensional gravipotential (ADD-model)
Oscillations"- I. Aref'eva [1007.4777:arXiv-hep-ph]

$$F_{ad}(s,t) \sim \frac{s}{M_d^2};$$

Universal scenario?

Two statistical independent choices

$$\mathbf{x}_{n_1}^{'} \quad \text{and} \quad \mathbf{x}_{n_2}^{''}$$

of values of the quantity X distributed around a definitely value of A with the standard error equal to 1, The arithmetic mean of these choices

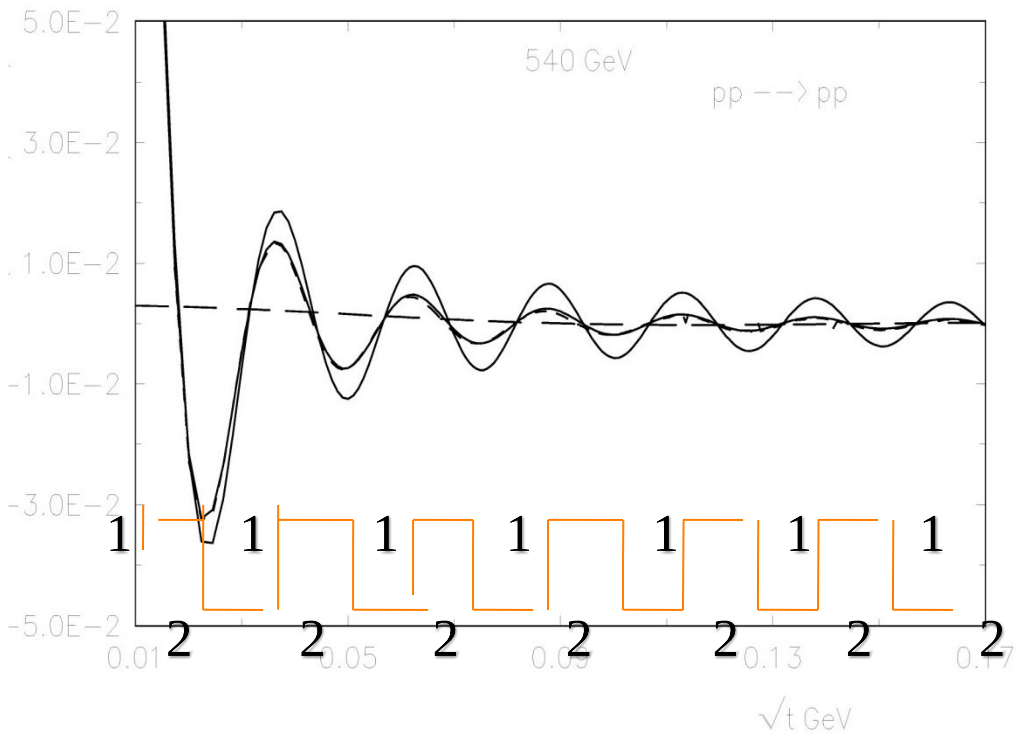
$$\mathbf{\Delta X} = (\mathbf{x}_1^{'} + \mathbf{x}_2^{'} + \ldots \mathbf{x}_{n1}^{'})/\mathbf{n_1} - (\mathbf{x}_1^{''} + \mathbf{x}_2^{''} + \ldots \mathbf{x}_{n2}^{''})/\mathbf{n_2} = \overline{\mathbf{x}_{n_1}^{'}} - \overline{\mathbf{x}_{n_2}^{''}}.$$

The standard deviation

$$\delta_{\overline{\mathbf{x}}} = [\mathbf{1}/\mathbf{n_1} + \mathbf{1}/\mathbf{n_2}]^{1/2}$$

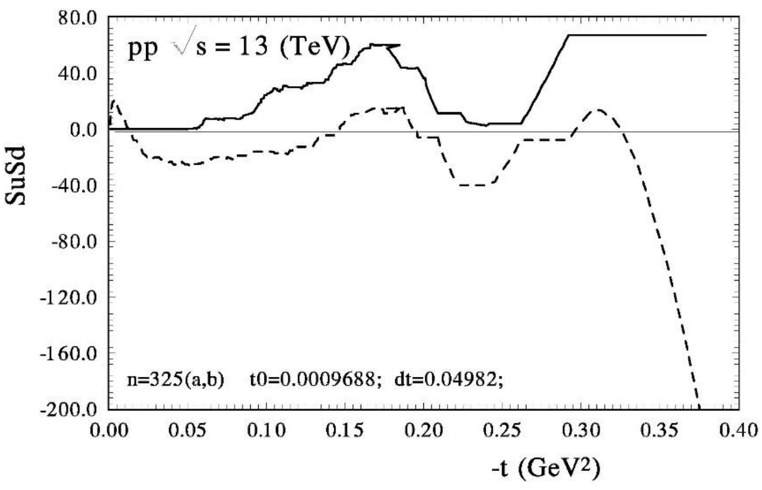
If $\mathbf{\Delta X}/\delta_{\overline{\mathbf{x}}}$ is large than 3

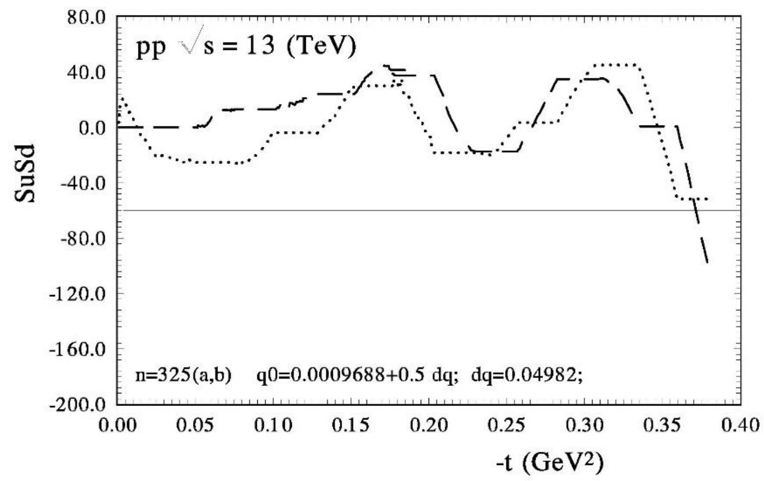
that the difference between these two choices has with the 99% probability



540 GeV
pp −−> pp
5.0E−2
3.0E−2
1.0E−2
−1.0E−2
−3.0E−2
−5.0E−2
0.01
0.05
0.13
√t GeV
1
1
1
1
1
1
1
2
2
2
2
2
2
2

O.V. Selyugin, Phys.Lett. B 797, 134870 (2019).





$$r = \frac{\overline{\Delta S}}{\overline{\overline{\delta S}}} = \frac{\overline{S_{up}} - \overline{S_{dn}}}{(1/[1/n_1 + 1/n_2]^{1/2})} = \frac{1.7 + 0.5}{0.53} = 4.15;$$

O.V.S. Phys.Lett.

HEGS model analysis

$$F_N^{ad}(s,t) = F_{HEGS\,0}(s,t) + F_{osc}^{ad}(s,t);$$

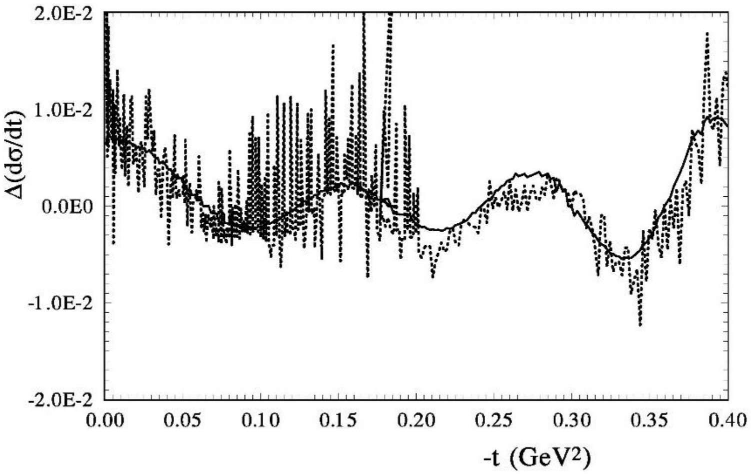
$$F_{osc}^{ad}(s,t) = \pm h_{osc}\, J_1[\tau]/\tau; \quad \tau = \pi(\varphi_0 - t)/t_0;$$

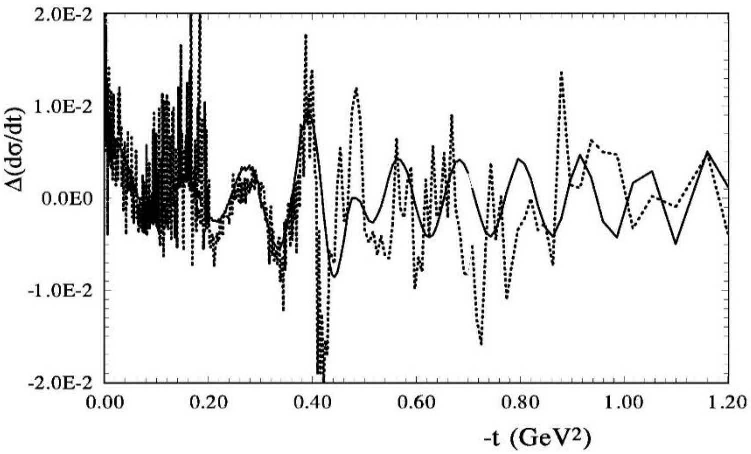
Results:with F(osc) $\chi^2_{dof} = 1.24;$

Without F(osc) $\chi^2_{dof} = 2.7;$

$$R_i\Delta_{th} = [(d\sigma/dt)_{th+osc} \; - \; (d\sigma/dt)_{th0}] \; / \; (d\sigma/dt)_{th0}; \;\; -- \; line$$

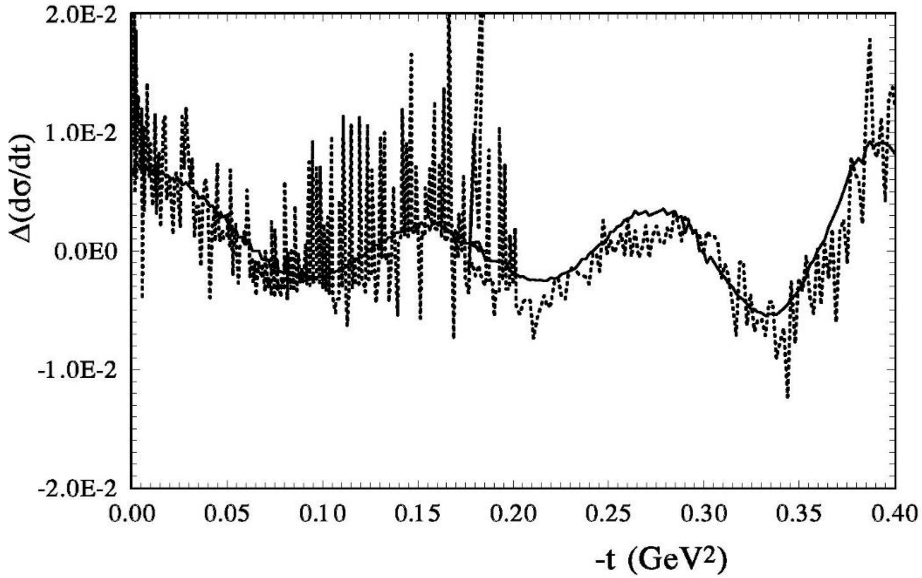
$$R_i\Delta_{EXP} = [(d\sigma/dt)_{EXP} \; - \; (d\sigma/dt)_{th0}] \; / \; (d\sigma/dt)_{th0}; \;\; by\,experiment\;data$$

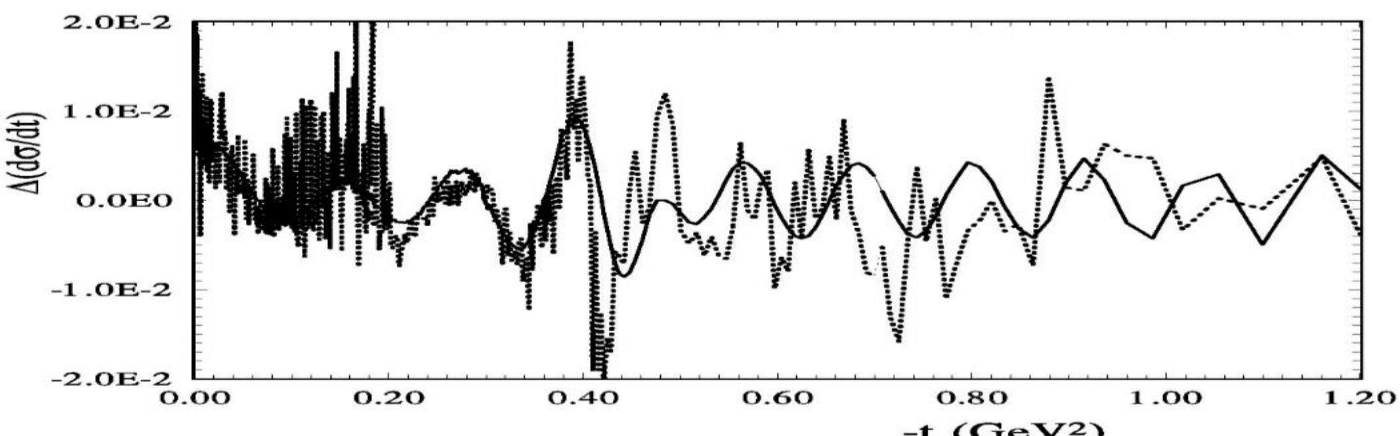


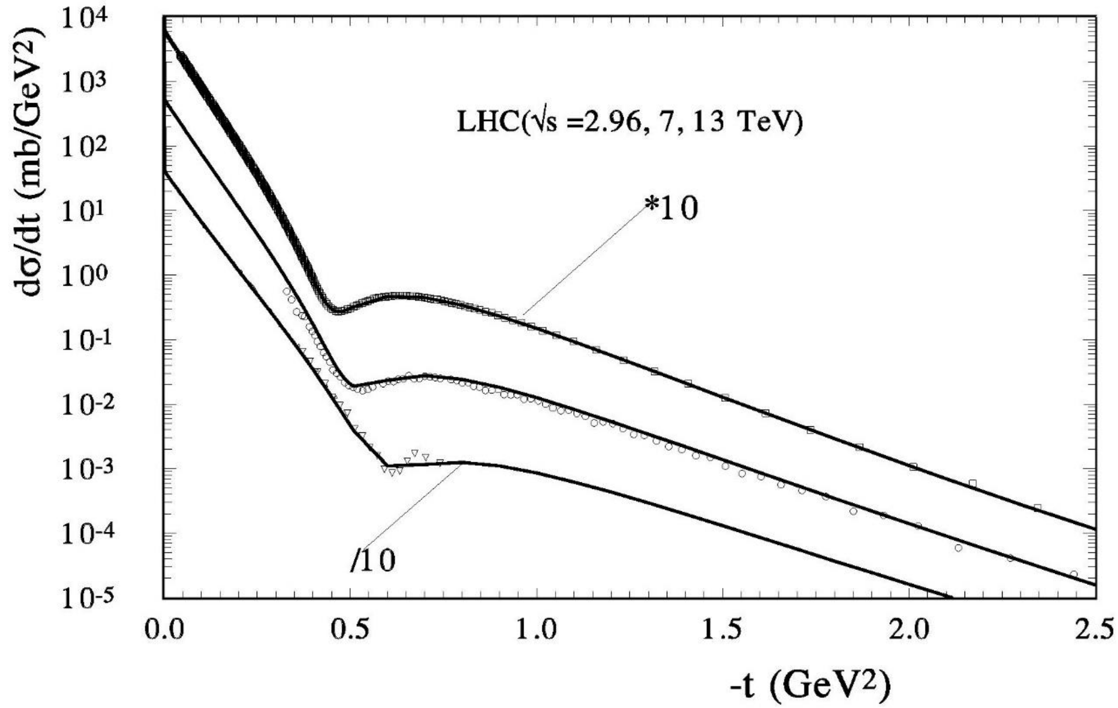


O.V.S. Phys.Lett. B 797 (2019)

New feature in the differential cross sections at 13 TeV measured at the LHC

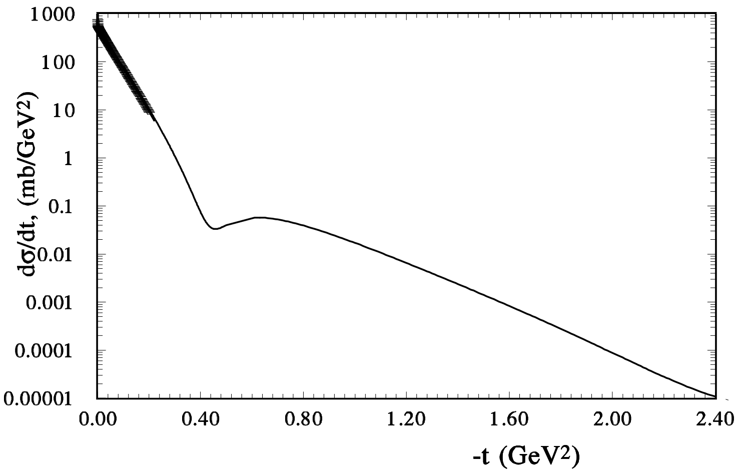


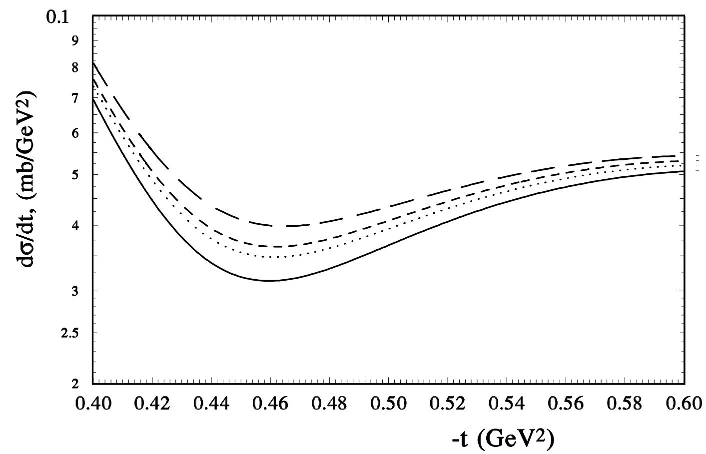




dσ/dt (mb/GeV2)
-t (GeV2)
LHC(√s =2.96, 7, 13 TeV)
*10
/10

Odderon and LHC data





hard line pp; *long dushed* $p\bar{p}$ (*HEGSh*);

short – dashed pp; *dotted –* $p\bar{p}$ (*without Odderon*);

$$HEGSh \rightarrow -t_{\min} = 0.46\,GeV^2;\ -t_{\max} = 0.62\,GeV^2;\ R = 1.78;$$

$$TOTEM \rightarrow -t_{\min} = 0.47\,GeV^2;\ -t_{\max} = 0.638\,GeV^2;\ R = 1.78;$$

Summary

The elastic scattering reflects the generalized structure of the hadron.

The our model GPDs leads to the well description of the proton and neutron electromagnetic form factors and its elastic scattering simultaneously.

The model leads to the good coincides the model calculations with the preliminary data at 13 TeV -- 500 GeV.

- The anomalous term with large slope has Log(s) dependence
- The new oscillation term has cross-odd properties
- The small period of the "oscillation" is related with the long hadron screening potential at large distances.

5. The standard eikonal approximation works perfectly from

   Sqrt(s}=6 GeV up to 13 TeV.

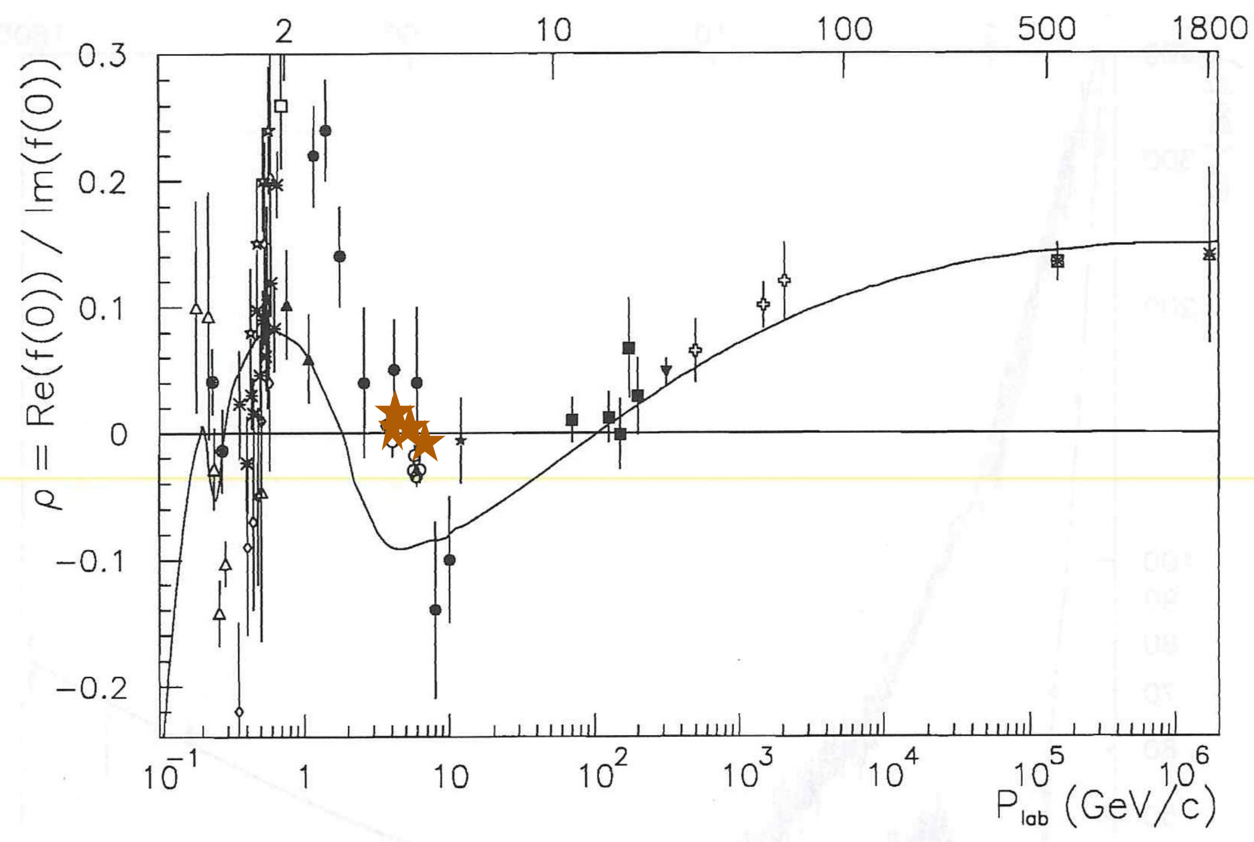
Thanks
for your
attention

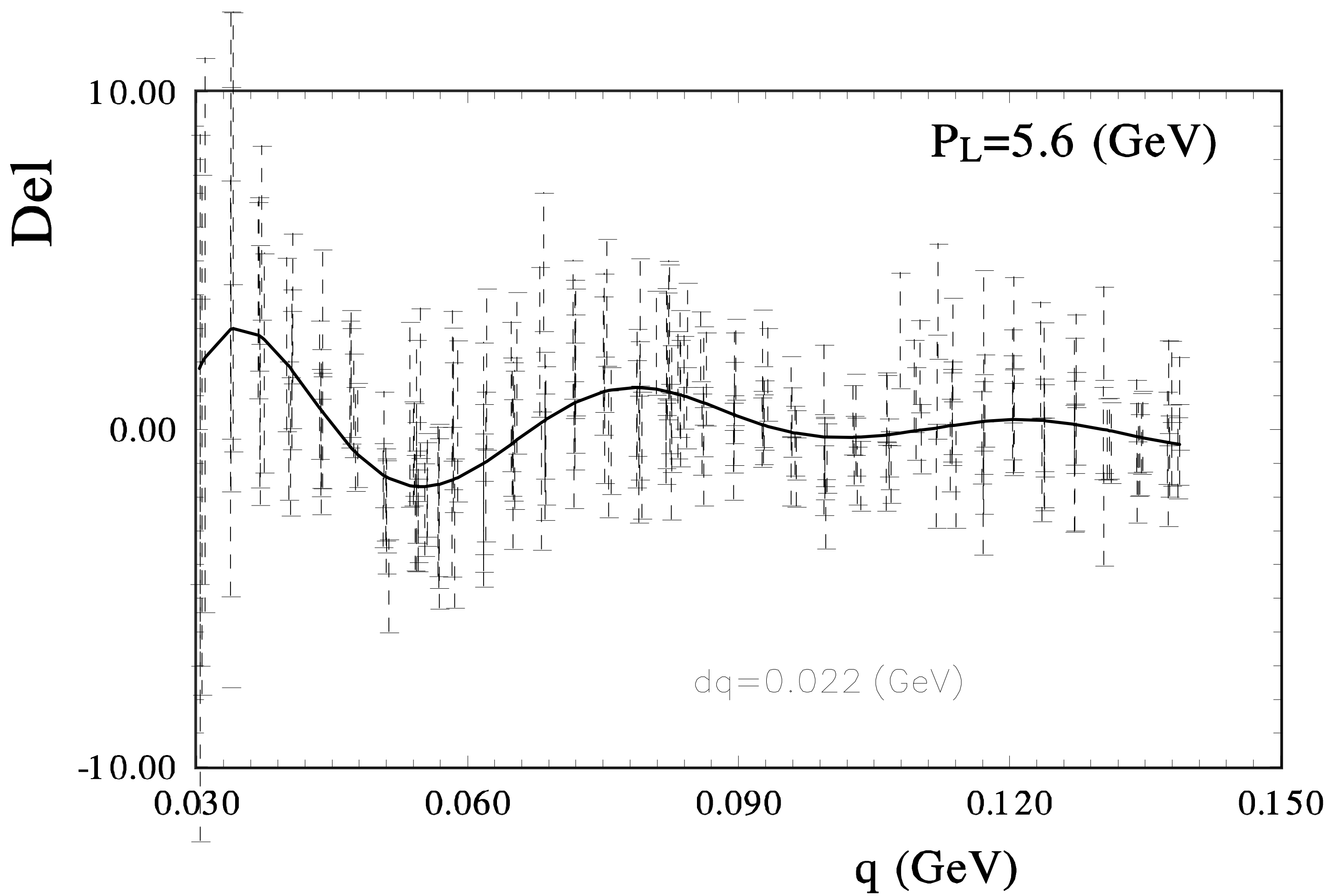
FERMILAB

Precision Measurements of Antiproton-Proton Elastic Scattering at Small Momentum Transfers

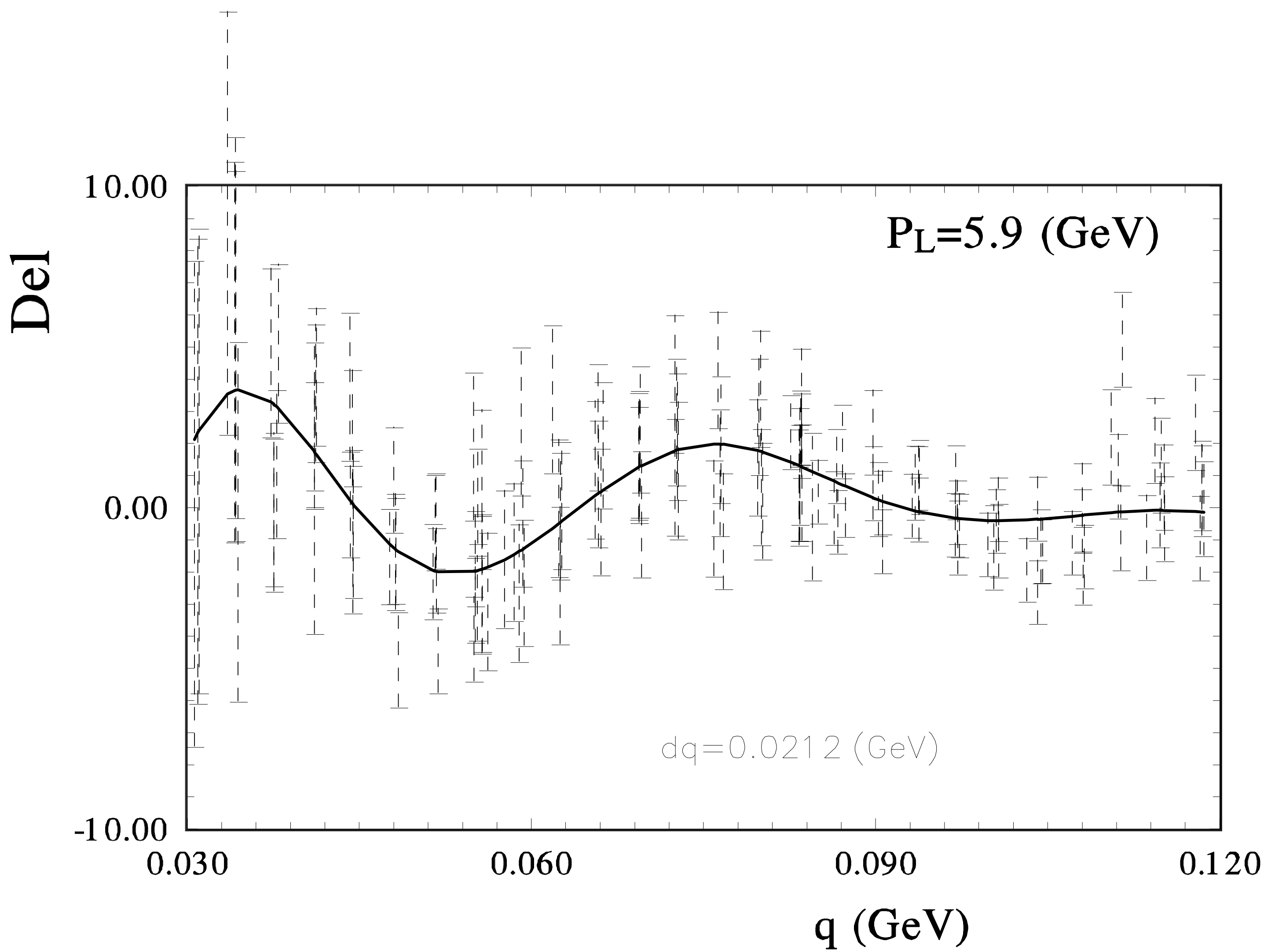
$$0.001 \leq |t| (GeV/c)^2 \leq 0.02$$

$$at \;\; P_L = 3.45 \;\; to \;\; 6.23 \;\; GeV/c$$


2
10
100
500
1800
0.3
0.2
0.1
0
−0.1
−0.2
ρ = Re(f(0)) / Im(f(0))
10^{-1}
1
10
10^2
10^3
10^4
10^5
10^6
P_{lab} (GeV/c)



Del
10.00
0.00
-10.00
0.030
0.060
0.090
0.120
0.150
q (GeV)
P_L=5.6 (GeV)
dq=0.022 (GeV)



Del
10.00
0.00
-10.00
0.030
0.060
0.090
0.120
q (GeV)
P_L=5.9 (GeV)
dq=0.0212 (GeV)

Born Regge spin-flip amplitude

$$F_5^B(s,t) = i\, q\, G_{em}(t)^2\, (h_1^{sf} + h_2^{sf}(\hat{s})^{-\Delta sf})\, e^{k_{sf}\alpha' t \ln(\hat{s})};$$

$$F_5(s,t) = -ip \int_0^{\infty} b\,db\, J_1(bq)\, \chi_5(s,b)\, e^{\chi_0(s,b)};$$

Predazzi, E.; Selyugin, O.V. Behavior of the hadronic potential at Large Distances. Eur. Phys. J. A 2002, 13, 471–475.

$B_{(sf.)} >= 2B_{(nf.)}$

O.S., O.Teryaev, Phys.Rev. D79, (2009)

General Parton Distributions -GPDs

Electromagnetic form factors
(charge distribution)

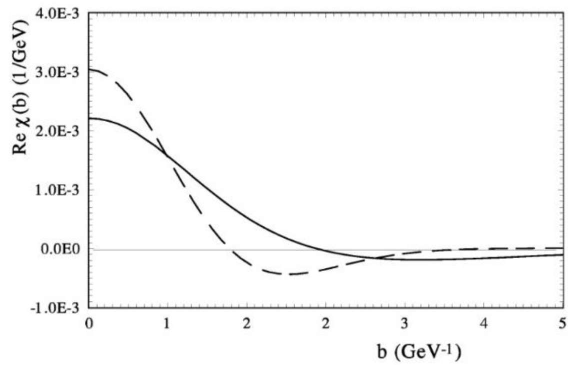
Gravitation
form factors
(matter distribution)

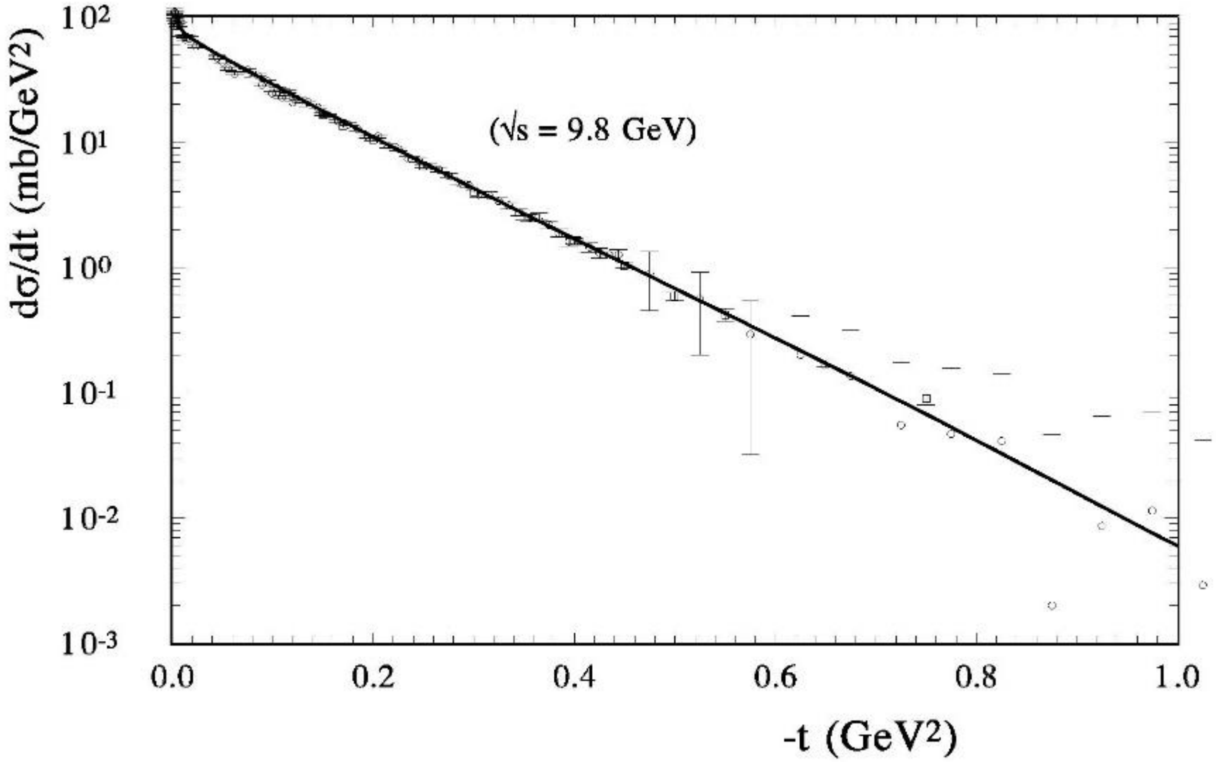
$$F_1^D(t) = \frac{4M_p^2 - t\mu_p}{4M_p^2 - t} G_D(t);$$

$$G_D(t) = \frac{\Lambda^4}{(\Lambda^2 - t)^2};$$

$$G_A(t) = \frac{\Lambda_A^4}{(\Lambda_A^2 - t)^2};$$

$$\chi_{sf}(s,b) = 2\pi i \int_0^{\infty} q\, e^{i\vec{q}\vec{b}}\, J_0(b\,q)\, F_{sf}{}^{B}(s,q)\, dq$$





10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
dσ/dt (mb/GeV2)
(√s = 9.8 GeV)
0.0
0.2
0.4
0.6
0.8
1.0
-t (GeV2)

Analysing power

$$A_N = \frac{\sigma^{\Uparrow} - \sigma^{\Downarrow}}{\sigma^{\Uparrow} + \sigma^{\Downarrow}}$$

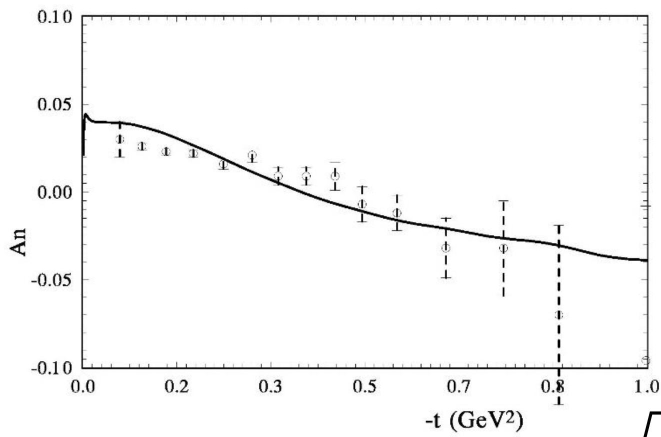
$$\frac{d\sigma}{dt} = \pi \, |e^{i\alpha\varphi} F_C(t) + F_N(s,t)|^2$$

$$A_N \frac{d\sigma}{dt} = \frac{4\pi}{s^2} \operatorname{Im}[F_{nfl} \, F_{fl}^*]$$

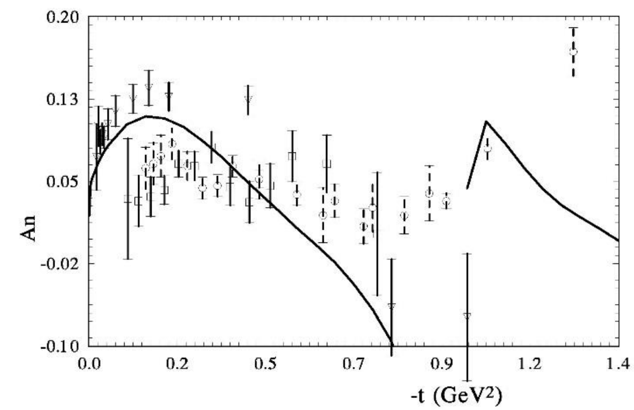
$$A_N \frac{d\sigma}{dt} = \frac{4\pi}{s^2} |F_{nfl}||F_{fl}^*| \sin(\varphi_1 - \varphi_2)$$

PRELIMINARY

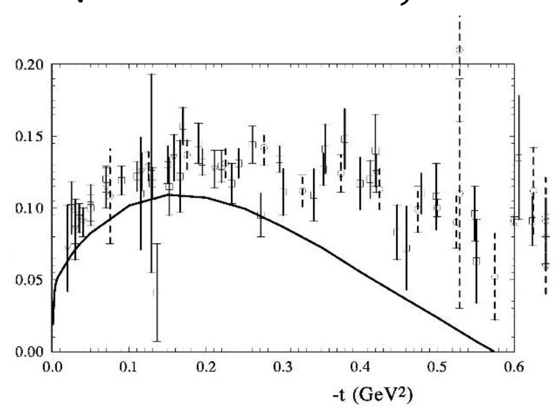
$\sqrt{s} = 9.23\,GeV\,;$



$\sqrt{s} = 4.9\,GeV\,;$



$\sqrt{s} = 3.6\,GeV\,;$



LHC

Final results (or) the beginning new story

* The new data bounded essentially the limints of the models..

- Regge aproache is working
- GPDs open the new way to connections of the elastic and inelastic intaractions

.But: where is the hard Pomeron?; t and s dependence of the Odderon?

* The problems of the determinaton of r(s,t) and S_{total}.

Unitarization – eikonal?

- The thin structure of the slope - B(s,t), (non-exponentinal, oscillations)
- Asymptotic of the scattering amplitude - wide region

Wait the high precision of the new data at small t and 13 TeV

TOTEM;
ATLAS

Analysis of the all LHC data (666 experimental points)

$\sqrt{s} \leq 8\, TeV; \ \ (TOTEM - 2\ sets;\ ATLAS - 1\, set)$

$\sqrt{s} \leq 7\, TeV; \ \ (TOTEM - 2\ sets;\ ATLAS - 1\, set)$

$\sqrt{s} \leq 13\, TeV; \ \ (TOTEM - 2\ sets\ \ (independent));$

$$N = 666;\ \sum_{i,j}^{N,n} \chi^2_{i,j} = 884;\ \ \chi^2_{dof} = 1.35$$

$$F_d(\hat{s},t) = i\, h_d\, Ln(\hat{s})^2 G^2_{em}(t)\ \ e^{-(B_d|t| + C_d t^2)\ln(\hat{s})};$$

$$h_d = 2.4 \pm 0.1;$$

$$h^{pp}_{osc} = 0.18 \pm 0.007;\ \ h^{pp}_{osc} \approx h^{p\bar{p}}_{osc};$$

	BSW_1	BSW_2	AGN	MN	HESG0	HESG1
N_exp.	369	955	1728+238	2600+300	980	3090
n_par.	7+Regge	11	36	36+7	3+2	6+3
$\sqrt{s}\ GeV$	23.4-630	13.4 - 1800	9.3-1800	5-1800	52-1800	9-7000
$\Delta t\ GeV^2$		0.1 - 5	0,1-2.6	0.1-16	0.000875-10	0.00037-15
$\sum \chi_i^2 / N$	4.45	1.95	1.16	1.23	2.	1.28

Summary

- In the framework of the HEGS model the differential cross sections at large momentum transfer are described well in a wide energy region and up to –t=15 GeV^2.
- The hard pomeron is not visible
- The anomalous term has Log(s) dependence
- The new oscillation term has cross-odd properties
- The examined low energy spin-flip amplitude has small energy independent part
- It is proportional to the electromagnetic form factor.
- It has not cross-odd part.