15th International Conference on Elastic & Diffractive Scattering
(15th "Blois Workshop")

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Some problems of the determination of sigma_tot at LHC

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Contents

Elastic scattering amplitude

$$pp \to pp \qquad\qquad p\bar{p} \to p\bar{p}$$

$$\frac{d\sigma}{dt} = 2\pi [\,|\Phi_1|^2 + |\Phi_2|^2 + |\Phi_3|^2 + |\Phi_4|^2 + 4|\Phi_5|^2\,]$$

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

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

$\gamma = 0,577...$ (*the Euler constant*)

ν_1 *and* ν_2 *are small correction terms*

$$\frac{dN}{dt} = \mathcal{L}\left[\frac{4\pi\alpha^2}{|t|^2}G^4(t) - \frac{2\alpha\left(\rho(s,t)+\phi_{CN}(s,t)\right)\sigma_{tot}G^2(t)e^{-\frac{B(s,t)|t|}{2}}}{|t|} + \frac{\sigma_{tot}^2(1+\rho(s,t)^2)e^{-B(s,t)|t|}}{16\pi}\right] \quad (1$$

Usual assumptions

$$\mathrm{Im}\, F_N(s,t) = \sigma_{tot} / (0.389 \cdot 4\pi)\; e^{Bt/2}$$

$$\mathrm{Re}\, F_N(s,t) \approx \sigma_{tot} / (0.389 \cdot 4\pi)\; e^{Bt/2} \qquad B^{\mathrm{Re}}(s,t) = B^{\mathrm{Im}}(s,t)$$

$$\sigma_{tot}(s_j) = f(s_j)_{\mathrm{exp.}}$$

$\sigma_{tot}(s_j) - \; fix. \;\; from\ other\ \exp eriment$ UA4/2

TOTEM

or $\rho(s_j) - \; fix. \;\; from\ other\ \exp eriments$ $\quad or - \; fix. \;\; from\ theory$

Corrections: Form-factors; Coulomb-hadron phase

Problem: contribution of the spin-flip amplitude

$$F_1^{em}(t) = \alpha f_1^2(t) \frac{s-2m^2}{t}; \quad F_3^{em}(t) = F_1^{em};$$

and for spin-flip amplitudes:

$$F_2^{em}(t) = \alpha \frac{f_2^2(t)}{4m^2} s; \quad F_4^{em}(t) = -F_2^{em}(t),$$

$$F_5^{em}(t) = \alpha \frac{s}{2m\sqrt{|t|}} f_1(t)\ f_2(t),$$

where the form factors are:

$$f_1(t) = \frac{4m_p^2 - (1+k)\ t}{4m_p^2 - t} G_d(t);$$

$$f_2(t) = \frac{4m_p^2\ k}{4m_p^2 - t}\ G_d(t);$$

The hadron spin non-flip amplitude was chosen in the form

$$F^h(s,t) = (i+\rho)\frac{\sigma_{tot}}{4\pi\, 0.38938} e^{Bt/2 + C(\sqrt{4\mu^2 - t} - 2\mu)]}$$

$$0.005 \le |t| \le 0.31 \ \ GeV^2; \quad N = 86 \ .$$

i	N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	σ_{tot}, mb
1	86	287.	0.14 fix	20.	$0.fix$	98.87 ± 0.1
2	86	287	$0.05 fix$	20.	$0.fix$	99.7 ± 0.1
3	86	287	0.146 ± 0.3	20.	$0.fix$	98.8 ± 0.4
4	86	220.5	$0.14 fix$	21.7	-1.4 ± 0.2	97.9 ± 0.2
5	86	220.	0.05 ± 0.4	21.8	-1.4 ± 0.2	$98.76 \pm 4.$

Table 1: The basic parameters of the model are determined by fitting experimental data without the electromagnetic contributions and with free σ_{tot}.

$$0.005 \le |t| \le 0.1 \ \ GeV^2; \quad N = 47 \ .$$

i	N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	σ_{tot}, mb
1	47	64.96	0.176 ± 0.2	19.9	$0.fix$	98.05 ± 1.7
2	47	64.96	0.15fixed	19.9	$0.fix$	98.47 ± 0.1
3	47	64.96	0.14fixed	19.9	$0.fix$	98.6 ± 0.1
4	47	64.96	$0.1fix$	19.9	$0.fix$	99.1 ± 0.1
5	47	64.96	$0.05fix$	19.9	$0.fix$	99.44 ± 0.1
6	47	64.96	$0.0fix$	19.9	$0.fix$	99.57 ± 0.1
7	47	64.96	$-0.05fix$	19.9	$0.fix$	99.44 ± 0.1
8	47	61.09	$0.14fix$	18.5	1.05 ± 0.54	98.99 ± 0.2
9	47	61.09	$0.1fix$	18.5	1.06 ± 0.54	99.47 ± 0.2
10	47	61.09	$0.0fix$	18.5	1.07 ± 0.54	99.97 ± 0.2
11	47	60.08	-0.03 ± 0.1	18.4	1.07 ± 0.54	99.94 ± 0.4

Table 2: The basic parameters of the model are determined by fitting experimental data without the electromagnetic contributions and with free σ_{tot}.

N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	σ_{tot}, mb
86	281.	0.14fixed	20.	$0.fix$	99.4 ± 0.1
86	281.	$0.1fix$	20.	$0.fix$	99.7 ± 0.1
86	288.	$0.fix$	20.	$0.fix$	99.8 ± 0.1
86	245.	$0.14fix$	21.3	-1.03 ± 0.2	98.6 ± 0.2
86	215.	$0.0fix$	21.8	-1.2 ± 0.2	98.7 ± 0.2
86	175.	-0.41 ± 0.1	23.2	-2.77 ± 0.2	$89.1 \pm 3.$

Table 3: The basic parameters of the model are determined by fitting experimental data with free σ_{tot}.

N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	σ_{tot}, mb
47	87.1	0.2fixed	20.1	$0.fix$	98.5 ± 0.1
47	77.1	0.14fixed	20.	$0.fix$	99.2 ± 0.1
47	71.6	$0.1 fix$	20	$0.fix$	99.5 ± 0.1
47	61.1	-0.069 ± 0.05	19.8	$0.fix$	98.93 ± 0.8
47	61.2	$0.1 fix$	17.7	1.66 ± 0.54	100.1 ± 0.2
47	60.6	$0.0 fix$	18.8	0.82 ± 0.54	99.8 ± 0.2
47	60.6	0.01 ± 0.1	18.9	0.74 ± 0.8	99.7 ± 0.8

Table 4: The basic parameters of the model are determined by fitting experimental data with free σ_{tot}.

N	$\sum_{i=1}^{N}\chi_i^2$	ρ	B	C	σ_{tot}, mb
40	78.8	$0.2 fix$	20.1	$0. fix$	98.6 ± 0.12
40	70.4	$0.14 fix$	20.	$0. fix$	99.29
40	65.8	$0.1 fix$	20	$0. fix$	99.55 ± 0.12
40	56.6	-0.076 ± 0.06	19.8	$0. fix$	98.83 ± 0.12
40	54.7	$0.1 fix$	16.3	2.63 ± 0.8	100.3 ± 0.27
40	54.9	$0.0 fix$	17.8	1.47 ± 0.8	99.96 ± 0.26
40	54.6	0.06 ± 0.01	16.9	2.17 ± 1.4	100.3 ± 0.3

Table 5: The basic parameters of the model are determined by fitting experimental data with free σ_{tot}.

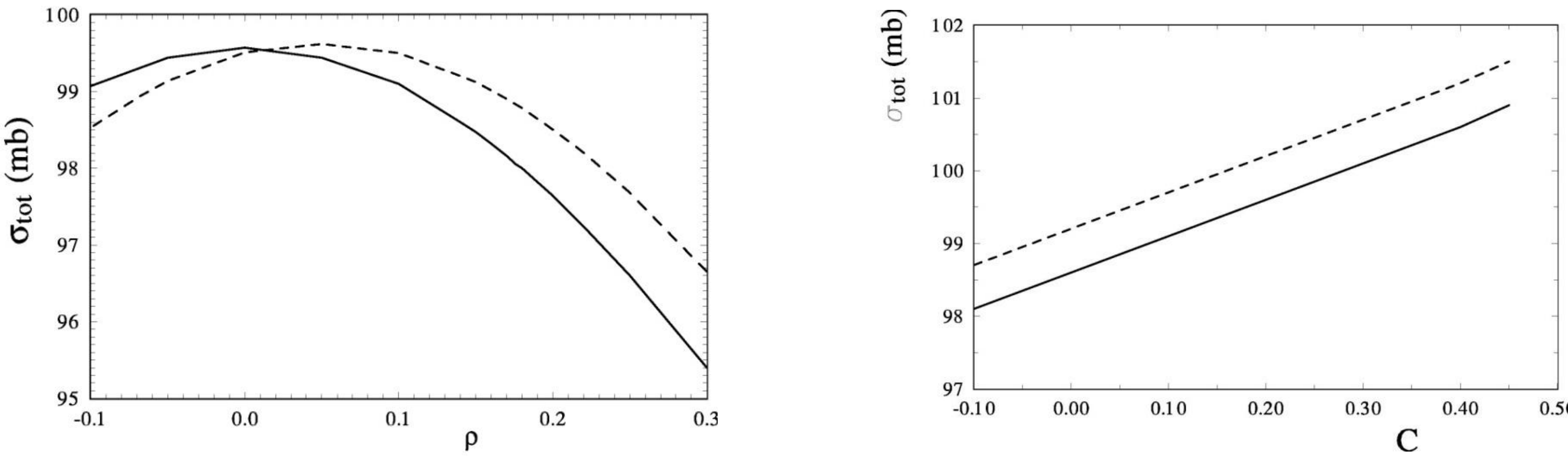


Figure 1: Size of σ_{tot} a)(left) over ρ and b) (right) over C (hard line - without electromagnetic interaction and dashed line with electromagnetic interaction).

O.S. – J. Nucl.Phys. (Yad.Phys.) v.55 (1992)

$$ReF^h(t) = \quad -ReF_c(t) \quad (9)$$
$$+ \quad [[\frac{d\sigma}{dt}|_{exp.} - k\pi * (ImF_c + ImF_h)^2]/(k\pi)]^{1/2}.$$

let us take the imaginary part of the hadron scattering amplitude in the simple exponential form with the parameters obtained by the TOTEM Collaboration

$$ImF^h(t) = \sigma_{tot}/(4k\pi)e^{Bt/2}, \quad (10)$$

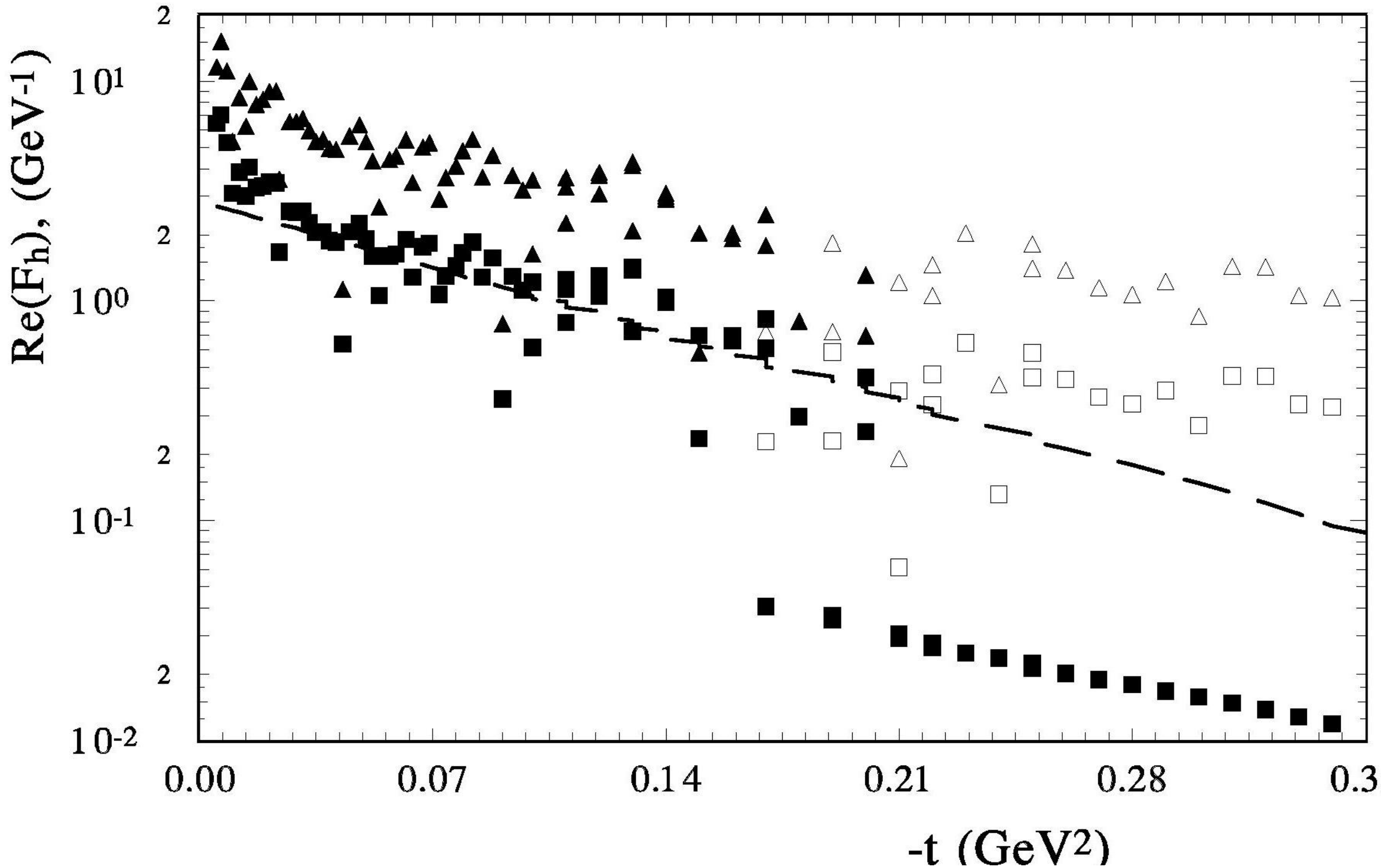


Figure 2: Real part of the hadronic amplitude calculated by (eq.9)(triangles and squared without and with F_c; solid and empty represent real and imaginary parts of (eq.9) see text). (long dashed line - the calculations by (eq.11)).

N	$\sum_{i=1}^{N}\chi_i^2$	ρ	B	C	σ_{tot}, mb
47	134.5	0.14fixed	19.8	$0. - fixed$	98.4
47	174.7	$0.1 fix$	19.7	$0. fix$	98.4
47	88.1	0.203 ± 0.01	20.1	0.fixed	98.4
47	105.3	0.14fixed	22.9	-2.3 ± 0.3fixed	98.4
47	61.4	-0.105 ± 0.02	20.	-0.14 ± 0.4	98.4

Table 6: The basic parameters of the model are determined by fitting experimental data with fixed σ_{tot}.

N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	σ_{tot}, mb
40	88.17	0.203 ± 0.007	20.1	$0. - fixed$	98.4
40	88.2	0.2fixed	20.	$0. - fixed$	98.4
40	125.6	0.14fixed	19.7	$0. - fixed$	98.4
40	157.7	$0.1 fix$	19.6	$0. fix$	98.4
40	102.4	$0.14 fix$	22.4	-1.75 ± 0.4	98.4
40	56.9	-0.106 ± 0.01	19.8	$0. fix$	98.4
40	56.8	-0.11 ± 0.02	19.7	0.1 ± 0.7	98.4

Table 7: The basic parameters of the model are determined by fitting experimental data with fixed σ_{tot}.

N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	n	σ_{tot}, mb
47	77.1	0.14fixed	20.	$0. - fixed$	1.017 ± 0.002	98.4
47	71.6	$0.1 fix$	20.	$0. fix$	1.022 ± 0.002	98.4
47	63.1	$0.14 fix$	17.2	2.1 ± 0.5	1.034 ± 0.012	98.4
47	61.1	-0.071 ± 0.05	19.8	$0. fix$	1.01 ± 0.013	98.4
47	60.6	-0.01 ± 0.09	18.9	0.72 ± 0.9	1.02 ± 0.02	98.4

Table 8: The basic parameters of the model are determined by fitting experimental data with fixed σ_{tot} and with additional normalization coefficient n.

N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	n	σ_{tot}, mb
40	70.4	0.14fixed	20.	$0. - fixed$	1.018 ± 0.0025	98.4
40	65.8	$0.1 fix$	20.	$0. fix$	1.024 ± 0.0025	98.4
40	55.1	$0.14 fix$	15.7	3.1 ± 0.77	1.037 ± 0.005	98.4
40	56.6	-0.077 ± 0.06	19.8	$0. fix$	1.009 ± 0.015	98.4
40	54.6	0.06 ± 0.08	16.9	2.18 ± 0.4	1.044 ± 0.02	98.4

Table 9: The basic parameters of the model are determined by fitting experimental data with fixed σ_{tot} and with additional normalization coefficient n.

N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	n	σ_{tot}, mb
47	77.84	0.14fixed	20.0	$0. - fix$	1.05	96.8 ± 0.1
47	71.65	$0.1ffix$	20.	$0.fix$	1.05	97.1 ± 0.1
47	66.3	$0.05fix$	20.	$0.fix$	1.05	97.2 ± 0.1
47	62.8	$0.fix$	19.4	$0.fix$	1.05	97.1 ± 0.1
47	63.1	0.14fixed	17.2	2.1 ± 0.5	1.05	97.56 ± 0.2
47	61.9	$0.1fix$	17.7	1.87 ± 0.5	1.05	97.7 ± 0.2
47	61.0	$0.05fix$	18.2	1.24 ± 0.5	1.05	97.7 ± 0.2
47	60.6	$0.fix$	18.8	0.8 ± 0.5	1.05	97.4 ± 0.2
47	60.8	$-0.05fix$	19.3	0.4 ± 0.5	1.05	96.9 ± 0.3
47	61.1	-0.064 ± 0.05	19.8	$0.fix$	1.05	96.57 ± 0.58
47	60.6	-0.011 ± 0.09	18.9	0.7 ± 0.9	1.05	97.3 ± 0.9

Table 10: The basic parameters of the model are determined by fitting experimental data.

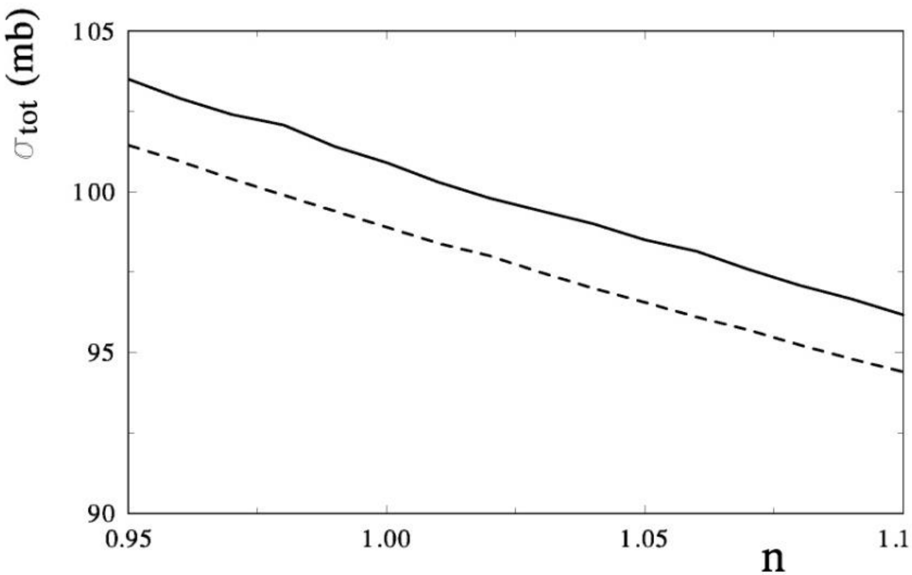


Figure 3: Size of σ_{tot} over n in two variants a) (hard line) - with free slope C and b) (dashed line) with $C = 0$.

F_C	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	n	σ_{tot}, mb
-	64.96	$0.15 fix$	19.9	$0. fix$	1.	98.47 ± 0.1
-	61.1	0.002 ± 0.2	18.4	1.07 ± 0.5	1.	99.9 ± 1.4
+	60.6	-0.01 ± 0.09	18.9	0.74 ± 0.8	1.	99.7 ± 0.8
+	60.6	-0.01 ± 0.09	18.9	0.72 ± 0.9	1.02 ± 0.004	$98.4 fix$
+	60.6	-0.01 ± 0.09	18.9	0.7 ± 0.9	$1.05 fix$	97.3 ± 0.9

Table 12: The basic parameters of the model are determined by fitting experimental data.

$$F^h(s,t) = ih\hat{s}^{\Delta} \; f_1(t)^2 \frac{\sigma_{tot}}{4\pi \, 0.38938} e^{\alpha' t + \alpha_2' (\sqrt{4\mu^2 - t} - 2\mu) Ln(\hat{s})}$$

$$h \operatorname{Re} \widehat{s} = 1$$

with the electromagnetic form factor $f_1(t)$ (7) and $\hat{s} = se^{-i*\pi/2}$; μ is the pion mass.

$\Delta = 0.1$	$\rho(\sqrt{s} = 7\text{ TeV}, t = 0) = 0.156$			
N	$\sum_{i=1}^{N} \chi_i^2$	α'_1	α'_2	σ_{tot}, mb
47	65.2	0.325	$0.fix$	99.7 ± 0.15
47	65.1	0.328	-0.002 ± 0.015	99.6 ± 0.2
40	58.1	0.324	$0.fix$	99.6 ± 0.05
40	55.8	0.276	0.037 ± 0.02	99.9 ± 0.26
47	204	0.314	$0.fix$	$98.4 fix$
47	95.3	0.427	-0.075 ± 0.008	$98.4 fix$
40	154	0.312	$0.fix$	$98.4 fix$
40	90.1	0.437	-0.08 ± 0.01	$98.4 fix$

Table 13: The basic parameters of the Regge amplitude are determined by fitting experimental data with free σ_{tot}.

$\Delta = 0.08$	$\rho(\sqrt{s} = 7\ \text{TeV}, t = 0) = 0.128$			
N	$\sum_{i=1}^{N} \chi_i^2$	α'_1	α'_2	σ_{tot}, mb
47	64.4	0.325	$0.fix$	100.0 ± 0.1
47	64.3	0.338	0.008 ± 0.003	99.9 ± 0.1
40	56.4	0.323	$0.fix$	99.9 ± 0.12
40	55.3	0.299	0.005 ± 0.004	100.2 ± 0.3
47	285	0.310	$0.fix$	$98.4 fix$
47	106.7	0.455	-0.096 ± 0.008	$98.4 fix$
40	211	0.307	$0.fix$	$98.4 fix$
40	99.6	0.473	-0.108 ± 0.011	$98.4 fix$

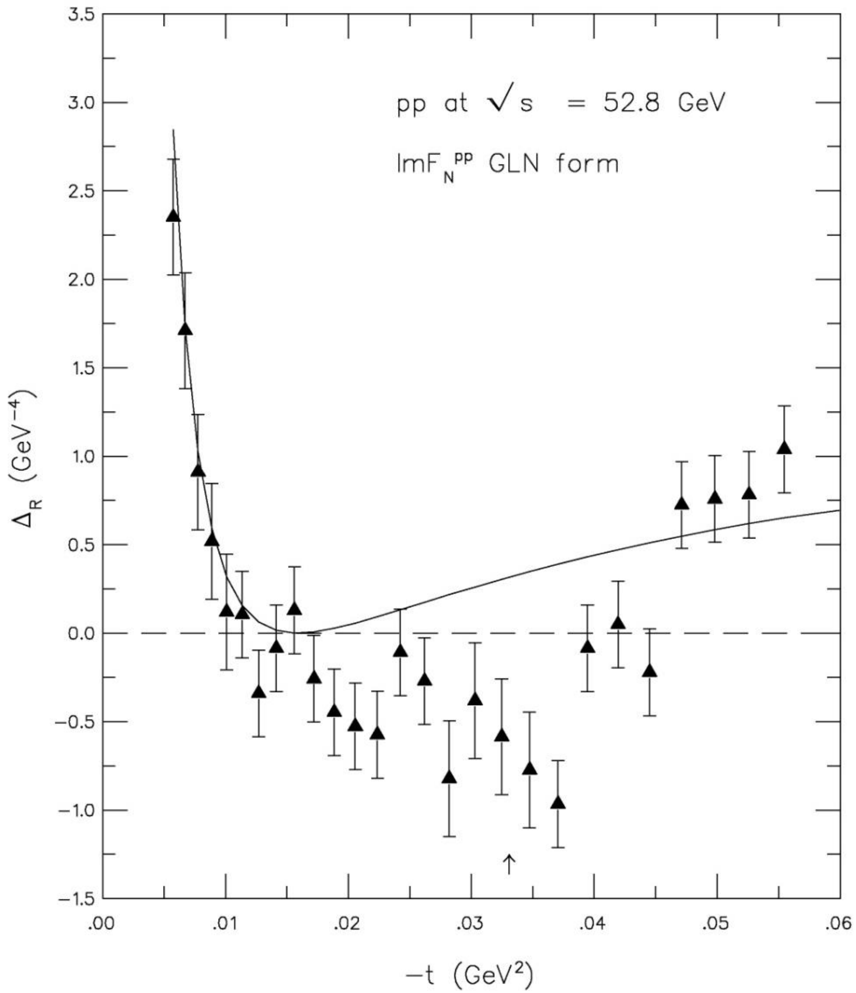
Table 14: The basic parameters of the model are determined by fitting experimental data with free σ_{tot}.

O.S. - New methods for calculating parameters of the diffraction scattering amplitude, "VI Intern. Conf. On Diffraction...", Blois, France,(1995).

O.S. "Additional ways to determination of structure of high energy elastic scattering amplitude" arxiv.org:[hep-ph/0104295]

P. Gauron, B. Nicolescu, O.S. "A New Method for the Determination of the Real Part of the Hadron Elastic Scattering Amplitude at Small Angles and High Energies" Phys.Lett. B629 (2005) 83-92

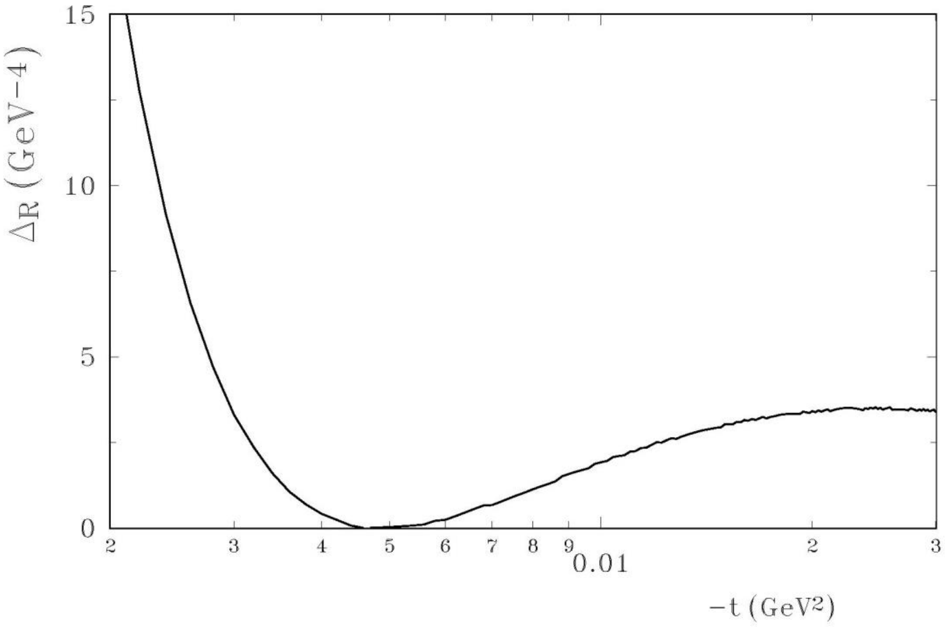
$$\Delta_R(t) = [\mathrm{Re}\,F^h(t) + \mathrm{Re}\,F^{\tilde{N}}(t)]^2 = [\frac{d\sigma}{dt}|_{\mathrm{exp.}} - k\pi(\mathrm{Im}\,F^h(t) + \mathrm{Im}\,F^C(t)] / (k\pi)$$



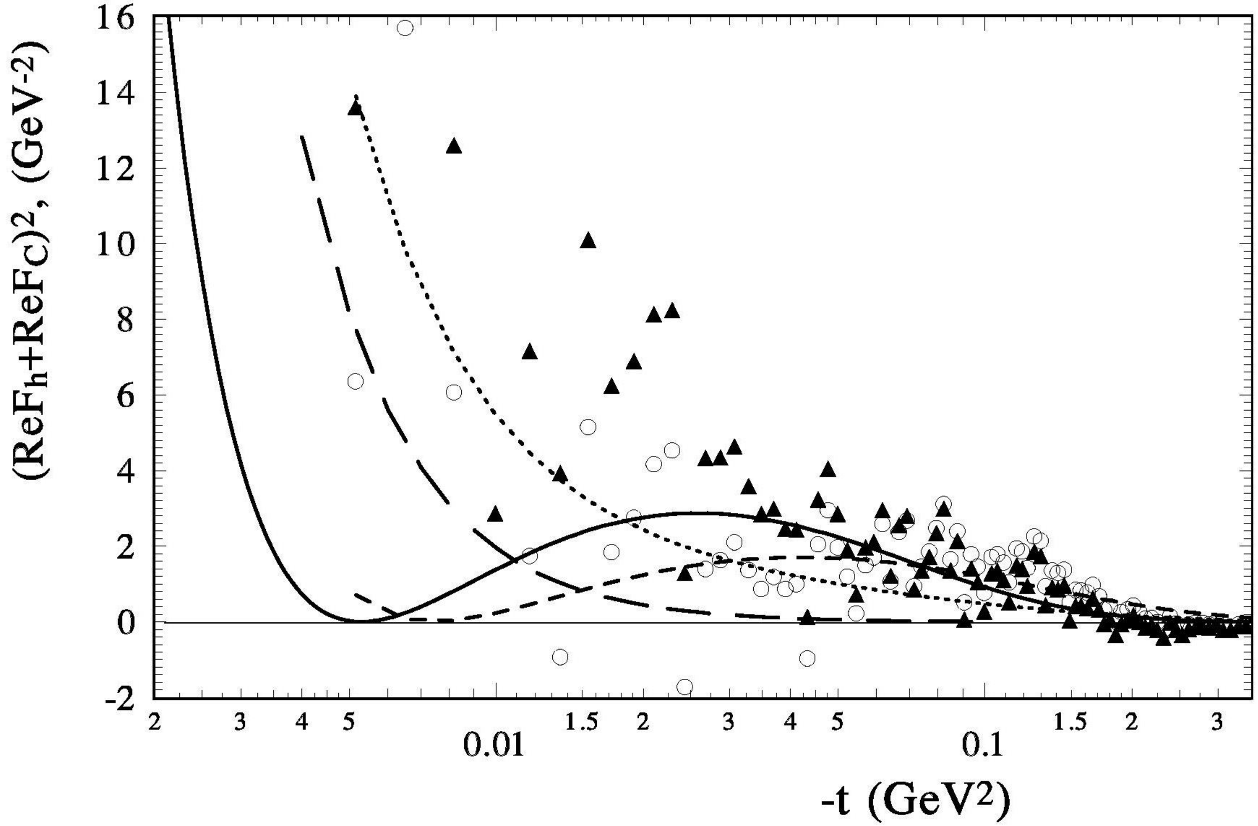
pp at √s = 52.8 GeV
ImF_N^pp GLN form
Δ_R (GeV⁻⁴)
−t (GeV²)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
.00
.01
.02
.03
.04
.05
.06

O.S. - Talk on X-th Blois Workshop (Xelsinki-2003)-
hep-ph: hep-ph/0306256

pp – 4 TeV



pp - 7 TeV
(TOTEM)



- TOTEM parameters

♦♉♦□♦=96.4 mb B=20.3 GeV-2; C=-0.05; n=1.08

TOTEM parameters; ❐=0.141

- - - - ; ♦tot=96.4 mb; B=19.9 GeV-2; ❐=0.1 ❐= 0

. . . . ♦tot=96.4 mb; B=19.9 GeV-2; ❐= -0.05 ;

Summary

* The analysis of the new experimental data (TOTEM) shows there are some additional specific moments which are to be taken into account to determine the size of the total cross sections

1. we can not neglect the electromagnetic interaction;

2. the deviation of the form of the scattering amplitude at small t can be taken into account by the part of the slope proportional q;

3. the errors of the luminocity can be taken into account by an additional normalization coefficient;.

4. it is need to check out the obtained, during the fitting procedure, the real part by using the t-dependence of extracted

   R = (ReF_h+ReF_c)^2.

5. Our analysis of the TOTEM data at 7 TeV shows that

the size of ❐☎t 🖫🗀✆ , very likely, near zero or -0.05.

It is most likely that there is or some problems with normalization

or there is some problems with the form of scattering amplitude

(for example, the oscillation term)

* The best way to decrease the impact of the different assumption

consist in the determination of the sizes of ♦ and ❐

simultaneously in one experiment.

END

THANKS
FOR YOUR ATTENTION

N	$\sum_{i=1}^{N} \chi_i^2$	ρ	B	C	n	σ_{tot}, mb
47	77.35	0.14fixed	20.03	$0. - fix$	1.08	95.49 ± 0.1
47	71.6	$0.1 fix$	20.	$0. fix$	1.08	95.76 ± 0.1
47	62.75	$0. fix$	19.4	$0. fix$	1.08	95.74 ± 0.1
47	60.89	0.14fixed	19.0	0.45 ± 0.11	1.08	97.69 ± 0.1
47	60.56	$0.1 fix$	19.15	0.37 ± 0.11	1.08	97.57 ± 0.1
47	60.49	$0. fix$	19.52	0.17 ± 0.11	1.08	96.54 ± 0.1
47	60.9	$-0.05 fix$	19.7	0.07 ± 0.11	1.08	95.71 ± 0.1
47	61.14	-0.064 ± 0.05	19.8	$0. fix$	1.08	97.18 ± 0.2
47	60.6	-0.007 ± 0.09	18.9	0.73 ± 0.9	1.08	96.0 ± 0.8

Table 11: The basic parameters of the model are determined by fitting experimental data.

$$\frac{dN}{dt} = \mathcal{L}\left[\frac{4\pi\alpha^2}{|t|^2}G^4(t) - \frac{2\alpha\left(\rho(s,t) + \phi_{CN}(s,t)\right)\sigma_{tot}G^2(t)e^{-\frac{B(s,t)|t|}{2}}}{|t|} + \frac{\sigma_{tot}^2(1+\rho(s,t)^2)e^{-B(s,t)|t|}}{16\pi}\right] \quad (1$$

$$ImF^h(t) = \sigma_{tot}/(4k\pi)e^{Bt/2},$$

$$ReF^h(t) = \rho\ \sigma_{tot}/(4k\pi)e^{Bt/2},$$

Standard definitions

$$G_{Ep}(0) = 1; \; G_{En}(0) = 0; \quad G_M(0) = (G_E(0) + k) = \mu;$$

$$\mu_p = (1+1.79)\frac{e}{2M}; \qquad k_p = 1.79;$$

$$F_1^D(t) = \frac{4M_p^2 - t\,\mu_p}{4M_p^2 - t} G_D(t); \qquad F_2^P(t) = \frac{1}{1 - t/4M_p^2} G_D(t);$$

$$G_D(t) = \frac{\Lambda^2}{(\Lambda - t)^2}; \qquad \Lambda = 0.71 GeV^2;$$