Analytic Amplitudes for Hadronic Forward Scattering: COMPETE update *

B. Nicolescu and P. Gauron

LPNHE†, Université Pierre et Marie Curie, Tour 12 E3,

4 Place Jussieu, 75252 Paris Cedex 05, France

J. R. Cudell

Institut de Physique, Bât. B5, Université de Liège,

Sart Tilman, B4000 Liège, Belgium

V. V. Ezhela, Yu. V. Kuyanov, S. B. Lugovsky, E. A. Razuvaev, and N. P. Tkachenko

COMPAS group, IHEP, Protvino, Russia

K. Kang

Physics Department, Brown University, Providence, RI, U.S.A.

E. Martynov

Bogolyubov Institute for Theoretical Physics, 03143 Kiev, Ukraine

(COMPETE Collaboration)

* Talk given by B. Nicolescu at the 31st International Conference on High Energy Physics (ICHEP 2002), Amsterdam, July 24-31, 2002.

† Unité de Recherche des Universités Paris 6 et Paris 7, Associée au CNRS

COmputerised

Models and

Parameter

Evaluation for

Theory and

Experiment

COMPETE : project and collaboration
-create computerized phenomenological knowledge base in particle physics

Here : only the results for forward scattering

J. R. Cudell et al. (COMPETE Coll.) Phys. Rev. D65 (2002) 074024 hep-ph/0206172

MOTIVATION

Try to cure as much as possible the high degree of arbitrariness in the phenomenology:

- Excessive focus on pp an $\bar{p}p$ scattering
- Important physical constraints mixed with less general or even ad-hoc properties
- Cut-off in energy differs from author to author
- Arbitrary exclusions of experimental data
- No rigurous connection between number of parameters and number of data points
- No attention paid to stability of parameter values vs different blocks data/observables
- Huge gaps in data low energy vs high energy

TOOLS

THEORETICAL (non-perturbative)

- analytical parametrizations of scattering amplitudes
- implement as much as possible general principles: analyticity, unitarity, crossing-symmetry, positivity
- Regge relation poles-resonance masses
- when possible, inspiration from pQCD

EXPERIMENTAL (COMPAS databasis)

- use both σ and ρ
- all data pp, $\bar{p}p$, π^+p, π^-p, K^+p, K^-p, Σ^-p, γp, $\gamma\gamma$

COMPUTER TECHNOLOGY

- Web-predictor
  http://www.ihep.su/~tka4ehko/CS/MODELS/

NUMERICAL INDICATORS AND RANKING PROCEDURE

- χ^2/dof ≤ 1.0
- Applicability indicator A ⇒ range of energy where fit has CL > 50%
- Confidence-1 indicator C_1 ⇒ CL whole area of applicability of a model
- Confidence-2 indicator C_2 ⇒ CL intersection of areas of applicability of all models
- Uniformity indicator U ⇒ variation of χ^2/nop from bin to bin
- Rigidity indicator R_1 ⇒ measure of number data points vs number of adjustable parameters
- Reliability indicator R_2 ⇒ measure of the goodness of the parameter error matrix
- Stability-1 indicator S_1 ⇒ stability of the fit in terms of the variation of the cut-off in energy
- Stability-2 indicator S_2 ⇒ combined stability: cut-off in energy and fitting only σ

RANK P ⇒ number of points attributed to one models when comparing its indicators with the indicators of the other models ⇒ higest P means best models

THE FORM OF THE FORWARD SCATTERING AMPLITUDE

$\mathrm{Im}\, F^{ab} = s\sigma_{ab}(s) = P_1^{ab}(s) + P_2^{ab}(s) + R_+^{ab}(s) \pm R_-^{ab}(s)$

$R_\pm(s) = Y_\pm (s/s_1)^{\alpha\pm}$, s_1=1 GeV^2 ⇒ contribution of the ((f, a_2), (ρ, ω)) secondary reggeons ⇒ RR

$P_1^{ab}(s) = C_1^{ab}(s/s_1)^{\alpha_{P1}}$, $\alpha_{P1} = 1$ ⇒ contribution of the first-component of the Pomeron: simple Regge pole ⇒ P

$P_2^{ab}(s)$ is the second component of the Pomeron

a) Regge simple-pole contribution (DL type)
$P_2^{ab}(s) = C_2^{ab}(s/s_1)^{\alpha_{P2}}$, $\alpha_{P2} = 1 + \varepsilon$, $\varepsilon > 0$ ⇒ E

b) Regge double-pole contribution
$P_2^{ab}(s) = s\,[\, A_{ab} + B_{ab} \ln (s/s_1)\,]$ ⇒ L

c) Regge triple-pole contribution (Heisenberg type)
$P_2^{ab}(s) = s\,[\, A_{ab} + B_{ab} \ln^2 (s/s_0)\,]$ ⇒ L2
where s_0 is an arbitrary scale factor

MODELS STUDIED:

1-component Pomeron classes of models
RRE, RRL, RRL2

2-component Pomeron classes of models
RRPE, RRPL, RRPL2

Number of data points
904, 742, 648, 569, 498, 453, 397, 329
corresponding to the cut-off in energy
3, 4, 5, 6, 7, 8, 9, 10 GeV

256 variants of the above models studied
(Regge exchange-degeneracy, quark counting rules, factorisation, universality)

21 variants have nonzero area of applicability

Best model: $RRPL2_u$
u means universality : B_{ab} is not depending on a and b (when a and b are hadrons) and s_0 is the same in all reactions

Model Code	P_{A^M}	$P_{C_1^M}$	$P_{C_2^M}$	P_{U^M}	$P_{R_1^M}$	$P_{R_2^M}$	$P_{S_1^M}$	$P_{S_2^M}$	Rank P^M
$RRPL2_u(19)^*$	42	26	42	42	34	28	12	4	230
$RRP_{nf}L2_u(21)$	44	36	44	40	15	31	10	2	222
$RRL_{nf}(19)^*$	30	42	26	24	34	18	18	30	222
$(RR_c)^d\ PL2_u(15)$	34	20	36	20	28	24	28	14	204
$(RR)^d\ P_{nf}L2_u(19)$	40	8	40	22	34	22	16	12	194
$[R^{qc}\ L^{qc}]R_c(12)$	14	32	18	10	42	6	24	38	184
$(RR_c)^d P^{qc} L2_u(14)$	20	16	10	36	19	36	22	22	181
$(RR)^d P^{qc} L2_u(16)$	18	14	8	38	8	38	30	26	180
$RR_c\ L2^{qc}(15)$	6	30	6	4	6	44	44	40	180
$(RR)^d\ P_{nf}L2(20)^*$	38	2	28	32	25	31	14	8	178
$(RR)^d\ PL2_u(17)$	36	0	34	18	30	26	20	10	174
$RRPL(21)^*$	2	34	32	44	15	16	6	24	173
$RR_c\ L^{qc}(15)$	24	38	24	8	10	4	32	32	172
$RRL2^{qc}(17)$	10	28	4	2	2	42	40	42	170
$[R^{qc}\ L2^{qc}]R_c(12)$	12	18	0	6	22	40	38	34	170
$RRL^{qc}(17)$	28	6	20	30	44	12	4	18	162
$RRPE_u(19)$	22	44	12	16	4	20	34	6	158
$[R^{qc}L^{qc}]R(14)$	16	24	14	12	19	14	36	20	155
RRL2(18)	8	22	2	0	0	34	42	44	152
$RR_cPL(19)$	4	12	38	14	12	0	26	36	142
RRL(18)	26	10	16	26	39	8	8	0	133

Table 2 : Ranking of the the 21 models having nonzero area of applicability.

2002 Review of Particle Physics, K. Hagiwara et al., Phys. Rev. D 66 (2002) 01001

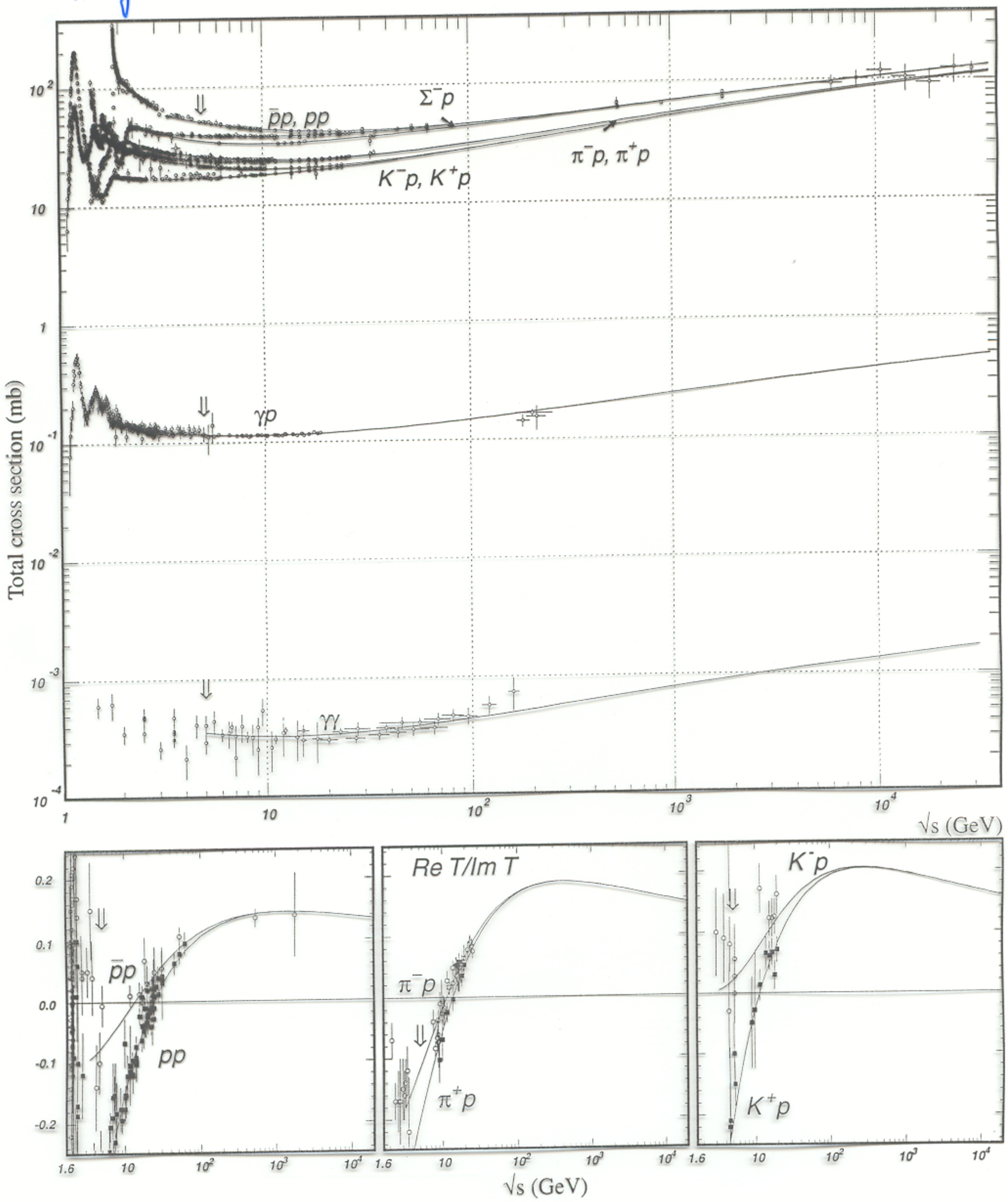

Figure 39.11: Summary of hadronic, γp, and $\gamma\gamma$ total cross sections, and ratio of the real to imaginary parts of the forward hadronic amplitudes. Corresponding computer-readable data files may be found at `http://pdg.lbl.gov/xsect/contents.html` (Courtesy of the COMPAS group, IHEP, Protvino, Russia, July 2001.)

— 10 —

2002

Review of Particle Physics

Table 39.2: Total hadronic cross section. Analytic S-matrix and Regge theory suggest a variety of parameterizations of total cross sections at high energies with different areas of applicability and fits quality.

A ranking procedure, based on measures of different aspects of the quality of the fits to the current evaluated experimental database, allows one to single out the following parameterization of highest rank[1]

$$\sigma^{ab} = Z^{ab} + B\log^2(s/s_0) + Y_1^{ab}(s/s_1)^{-\eta_1} - Y_2^{ab}(s/s_1)^{-\eta_2}\ , \qquad \sigma^{\bar{a}b} = Z^{ab} + B\log^2(s/s_0) + Y_1^{ab}(s/s_1)^{-\eta_1} + Y_2^{ab}(s/s_1)^{-\eta_2}$$

where Z^{ab}, B, Y_i^{ab} are in mb, s, s_1, and s_0 are in GeV^2. The scales s_0, s_1, the rate of universal rise of the cross sections B, and exponents η_1 and η_2 are independent of the colliding particles. The scale s_1 is fixed at 1 GeV^2. Terms $Z^{ab} + B\log^2(s/s_0)$ represent the pomerons. The exponents η_1 and η_2 represent lower-lying C-even and C-odd exchanges, respectively. Requiring $\eta_1 = \eta_2$ results in somewhat poorer fits. In addition to total cross sections, the measured ratios of the real-to-imaginary parts of the forward-scattering amplitudes were included in the fits by using s to u crossing symmetry and differential dispersion relations. Global fits were made to the 2001-updated data for $(\bar{p})pp, \Sigma^-p, \pi^{\pm}p, K^{\pm}p, \gamma p$, and $\gamma\gamma$. Exact factorization hypothesis was used to extend the universal rise of the total hadronic cross sections to the $\gamma p \to hadrons$ and $\gamma\gamma \to hadrons$ collisions. The price of this universality is one extra "asymptotic" parameter $\delta = \sigma^{\gamma p}/\sigma^{pp}$ for $s \gg s_0$. The asymptotic parameters thus obtained were then fixed and used as inputs to a fit to a larger data sample that included cross sections on deuterons (d) and neutrons (n). All fits were produced to data above $\sqrt{s_{\rm min}} = 5$ GeV.

Fits to $\bar{p}(p)p$, Σ^-p, $\pi^{\pm}p$, $K^{\pm}p$, γp, $\gamma\gamma$			Beam/	Fits to groups				χ^2/dof
Z	Y_1	Y_2	Target	Z	Y_1	Y_2	B	by groups
35.49(47)	42.65(1.35)	33.36(1.04)	$\bar{p}(p)/p$	35.49(47)	42.65(23)	33.36(33)	0.307(10)	
			$\bar{p}(p)n$	35.83(16)	40.27(1.6)	30.01(96)	0.307(10)	1.03
35.22(1.45)	−206(106)	−271(129)	Σ^-/p	35.22(1.40)	−206(88)	−271(114)	0.307(10)	0.56
20.88(40)	19.25(1.22)	6.03(19)	$\pi^{\pm}/p$	20.88(3)	19.25(18)	6.03(9)	0.307(10)	0.96
17.93(36)	7.1(1.5)	13.46(40)	$K^{\pm}/p$	17.93(3)	7.10(25)	13.46(12)	0.307(10)	
			$K^{\pm}/n$	17.88(6)	5.12(50)	7.24(28)	0.307(10)	0.67
0.1075(16)	0.0410(81)		γ/p	0.1075(9)	0.0410(64)		0.307(10)	
2.83(18)E−4	0.32(13)E−3		γ/γ	2.83(17)E−4	0.32(14)E−3		0.307(10)	0.67
$\chi^2/dof = 0.968$,	$b = 0.307(10)$ mb,		$\bar{p}(p)/d$	64.45(38)	130(3)	85.6(1.3)	0.534(31)	1.43
$\eta_1 = 0.460(17)$,	$\eta_2 = 0.545(7)$		$\pi^{\pm}/d$	38.66(21)	59.82(1.54)	1.60(41)	0.460(14)	0.73
$\delta = 0.0039(3)$,	$\sqrt{s_0} = 5.38(50)$ GeV		$K^{\pm}/d$	33.43(20)	23.72(1.45)	28.72(37)	0.449(15)	0.81

The fitted functions are shown in the following figures, along with one-standard-deviation error bands. When the reduced χ^2 is greater than one, a scale factor has been included to evaluate the parameter values, and to draw the error bands. Where appropriate, statistical and systematic errors were combined quadratically in constructing weights for all fits. On the plots, only statistical error bars are shown. Vertical arrows indicate lower limits on the $p_{\rm lab}$ or $E_{\rm cm}$ range used in the fits.

One can find the details of the global fits (all data on proton target and $\gamma\gamma$ fitted simultaneously) and ranking procedure as well as the exact parameterizations of the total cross sections and corresponding ratios of the real to imaginary parts of the forward-scattering amplitudes in the recent paper of COMPETE Collab[1]. The database used in the fits now includes the recent OPAL[2] and L3[3] (LEP) $\gamma\gamma$ data, new highest-energy data for π^-p and Σ^-p from SELEX (FNAL)[4] experiment, and cosmic-ray data from the Fly's Eye[5] and AKENO (Agasa)[6] experiments.

The parameterization of the previous edition can still produce acceptable fits to updated total cross sections database, but only for $\sqrt{s} > 10$ GeV.

The numerical experimental data were extracted from the PPDS accessible at `http://wwwppds.ihep.su:8001/ppds.html` Computer-readable data files are also available at `http://pdg.lbl.gov`. (Courtesy of V.V.Ezhela, Yu.V.Kuyanov, S.B.Lugovsky, E.A.Razuvaev, N.P.Tkachenko, COMPAS group, IHEP, Protvino, Russia, August 2001.)

References:

1. J.R. Cudell *et al.* (COMPETE Collab.), Phys. Rev. **D65**, 074024 (2002).
2. G. Abbiendi *et al.*(OPAL Collab.), Eur. Phys. J. **C14**, 199 (2000).
3. M. Acciarri *et al.*(L3 Collab.), Phys. Lett. **B519**, 33 (2001).
4. U. Dersch *et al.*(SELEX Collab.), Nucl. Phys. **B579**, 277 (2000).
5. R.M. Baltrusaitis *et al.*, Phys. Rev. Lett. **52**, 1380 (1984).
6. M. Honda *et al.*, Phys. Rev. Lett. **70**, 525 (1993).

$$
\begin{aligned}
\sigma_{pp} &= Z_{pp} + B \ln^2\left(\frac{s}{s_0}\right) + Y^{pp}_{+} s^{-\eta_+} - Y^{pp}_{-} s^{-\eta_-}, \\
\sigma_{\bar{p}p} &= Z_{pp} + B \ln^2\left(\frac{s}{s_0}\right) + Y^{pp}_{+} s^{-\eta_+} + Y^{pp}_{2-} s^{-\eta_-}, \\
\sigma_{\pi^+p} &= Z_{\pi p} + B \ln^2\left(\frac{s}{s_0}\right) + Y^{\pi p}_{+} s^{-\eta_+} - Y^{\pi p}_{-} s^{-\eta_-}, \\
\sigma_{\pi^-p} &= Z_{\pi p} + B \ln^2\left(\frac{s}{s_0}\right) + Y^{\pi p}_{+} s^{-\eta_+} + Y^{\pi p}_{-} s^{-\eta_-}, \\
\sigma_{K^+p} &= Z_{Kp} + B \ln^2\left(\frac{s}{s_0}\right) + Y^{Kp}_{+} s^{-\eta_+} - Y^{Kp}_{-} s^{-\eta_-}, \\
\sigma_{K^-p} &= Z_{Kp} + B \ln^2\left(\frac{s}{s_0}\right) + Y^{Kp}_{+} s^{-\eta_+} + Y^{Kp}_{-} s^{-\eta_-}, \\
\sigma_{\gamma p} &= Z_{\gamma p} + \delta B \ln^2\left(\frac{s}{s_0}\right) + Y^{\gamma p}_{+} s^{-\eta_+}, \\
\sigma_{\gamma\gamma} &= Z_{\gamma\gamma} + \delta^2 B \ln^2\left(\frac{s}{s_0}\right) + Y^{\gamma\gamma}_{+} s^{-\eta_+}, \\
\sigma_{\Sigma^-p} &= Z_{\Sigma p} + B \ln^2\left(\frac{s}{s_0}\right) + Y^{\Sigma p}_{+} s^{-\eta_+} - Y^{\Sigma p}_{-} s^{-\eta_-}, \\
\rho_{pp}\sigma_{pp} &= \pi B \ln\left(\frac{s}{s_0}\right) - \frac{Y^{pp}_{+} s^{-\eta_+}}{\tan\left[\frac{1-\eta_+}{2}\pi\right]} - \frac{Y^{pp}_{-} s^{-\eta_-}}{\cot\left[\frac{1-\eta_-}{2}\pi\right]}, \\
\rho_{\bar{p}p}\sigma_{\bar{p}p} &= \pi B \ln\left(\frac{s}{s_0}\right) - \frac{Y^{pp}_{+} s^{-\eta_+}}{\tan\left[\frac{1-\eta_+}{2}\pi\right]} + \frac{Y^{pp}_{-} s^{-\eta_-}}{\cot\left[\frac{1-\eta_-}{2}\pi\right]}, \\
\rho_{\pi^+p}\sigma_{\pi^+p} &= \pi B \ln\left(\frac{s}{s_0}\right) - \frac{Y^{\pi p}_{+} s^{-\eta_+}}{\tan\left[\frac{1-\eta_+}{2}\pi\right]} - \frac{Y^{\pi p}_{-} s^{-\eta_-}}{\cot\left[\frac{1-\eta_-}{2}\pi\right]}, \\
\rho_{\pi^-p}\sigma_{\pi^-p} &= \pi B \ln\left(\frac{s}{s_0}\right) - \frac{Y^{\pi p}_{+} s^{-\eta_+}}{\tan\left[\frac{1-\eta_+}{2}\pi\right]} + \frac{Y^{\pi p}_{-} s^{-\eta_-}}{\cot\left[\frac{1-\eta_-}{2}\pi\right]}, \\
\rho_{K^+p}\sigma_{K^+p} &= \pi B \ln\left(\frac{s}{s_0}\right) - \frac{Y^{Kp}_{+} s^{-\eta_+}}{\tan\left[\frac{1-\eta_+}{2}\pi\right]} - \frac{Y^{Kp}_{-} s^{-\eta_-}}{\cot\left[\frac{1-\eta_-}{2}\pi\right]}, \\
\rho_{K^-p}\sigma_{K^-p} &= \pi B \ln\left(\frac{s}{s_0}\right) - \frac{Y^{Kp}_{+} s^{-\eta_+}}{\tan\left[\frac{1-\eta_+}{2}\pi\right]} + \frac{Y^{Kp}_{-} s^{-\eta_-}}{\cot\left[\frac{1-\eta_-}{2}\pi\right]};
\end{aligned}
$$

where $\eta_\pm = 1 - \alpha_\pm$ and $Z_{ab} \equiv C_1^{ab} + A^{ab}$.

Model	RRPL2_u	
χ^2/dof	0.973	
CL[%]	67.98	
Parameter	Mean	Uncertainty
s_0	34.0	5.4
B	0.3152	0.0095
α_+	0.533	0.015
α_-	0.4602	0.0064
Z_{pp}	35.83	0.40
$Z_{\pi p}$	21.23	0.33
Z_{Kp}	18.23	0.30
$Z_{\Sigma p}$	35.6	1.4
$Z_{\gamma p}$	0.109	0.021
$Z_{\gamma\gamma}$	0.075	0.026
Y_+^{pp}	42.1	1.3
Y_-^{pp}	32.19	0.94
$Y_+^{\pi p}$	17.8	1.1
$Y_-^{\pi p}$	5.72	0.16
Y_+^{Kp}	5.72	1.40
Y_-^{Kp}	13.13	0.38
$Y_+^{\Sigma p}$	-250.	130.
$Y_-^{\Sigma p}$	-320.	150.
$Y_+^{\gamma p}$	0.0339	0.0079
$Y_+^{\gamma\gamma}$	0.00028	0.00015
δ	0.00371	0.00035

$B \leq \frac{\pi}{m_\pi^2} \simeq 60\,mb$ (Lukaszuk-Martin bound)

1. The numerical values of the free parameters, χ^2/dof and the confidence level CL in the case of the RRP2_u (21) model ($\sqrt{s} \geq 5$ GeV).

⇓

	Region of validity	Numerical value of the rank points	$\alpha_+ - \alpha_-$	Remarks
$\text{RRPL2}_u(21)$	$\sqrt{s} \geq 5$ GeV	222	$\simeq 0.07$	–
RRPL(21)	$\sqrt{s} \geq 5$ GeV	173	$\simeq 0.33$	$Z_{pp}, Z_{\pi p}, Z_{Kp} < 0$
$\text{RRPE}_u(19)$	$\sqrt{s} \geq 8$ GeV	158	$\simeq 0.20$	$Z_{\pi p}, Z_{Kp} < 0$

Table 3. Comparison between 3 high-rank representative models.

Predictions: J. R. Cudell et al. (COMPETE Coll.), hep-ph/0206172

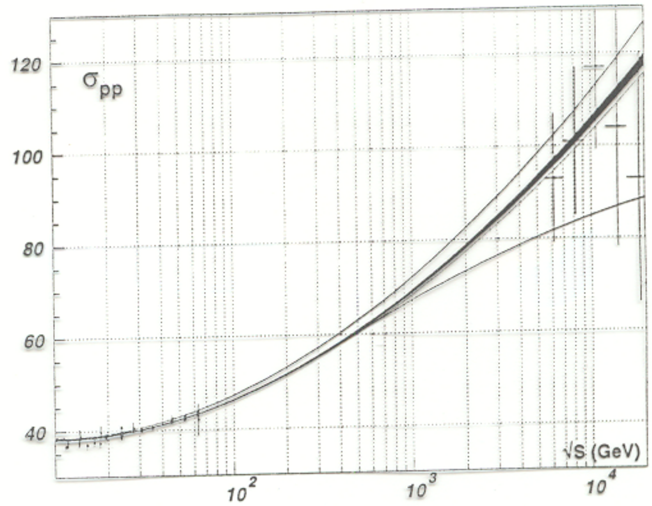

FIG. 1: Predictions for total cross sections. The black error band shows the statistical errors to the best fit, the closest curves near it give the sum of statistical and systematic errors to the best fit due to the ambiguity in Tevatron data, and the highest and lowest curves show the total errors bands from all models considered in this paper (note that the upper curve showing the systematic error is indistinguishable from the highest curve in this case).

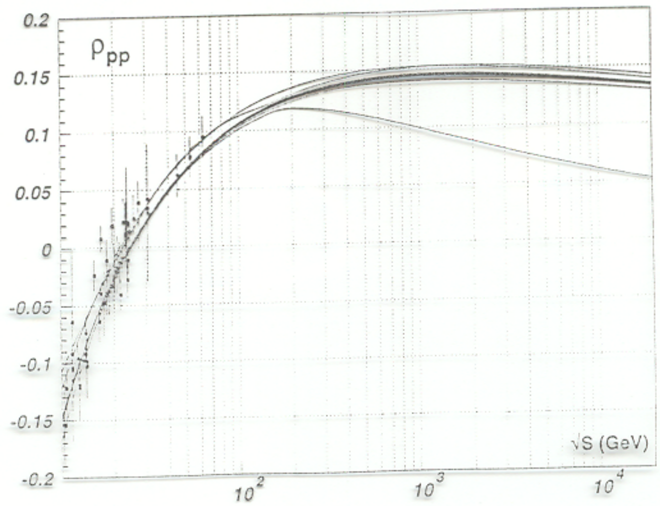

FIG. 2: Predictions for the ρ parameter. The curves and band are as in Fig. 1.

TABLE II: Predictions for σ_{tot} and ρ, for $\bar{p}p$ (at $\sqrt{s} = 1960$ GeV) and for pp (all other energies). The central values and statistical errors correspond to the preferred model RRPL2$_u$, and the systematic errors come from the consideration of two choices between CDF and E-710/E-811 $\bar{p}p$ data in the simultaneous global fits.

$\sqrt{s}$ (GeV)	σ (mb)	ρ
100	$46.37 \pm 0.06 \, {}^{+0.17}_{-0.09}$	$0.1058 \pm 0.0012 \, {}^{+0.0040}_{-0.0021}$
200	$51.76 \pm 0.12 \, {}^{+0.39}_{-0.21}$	$0.1275 \pm 0.0015 \, {}^{+0.0051}_{-0.0026}$
300	$55.50 \pm 0.17 \, {}^{+0.57}_{-0.30}$	$0.1352 \pm 0.0016 \, {}^{+0.0055}_{-0.0028}$
400	$58.41 \pm 0.21 \, {}^{+0.71}_{-0.36}$	$0.1391 \pm 0.0017 \, {}^{+0.0056}_{-0.0030}$
500	$60.82 \pm 0.25 \, {}^{+0.82}_{-0.45}$	$0.1413 \pm 0.0017 \, {}^{+0.0057}_{-0.0030}$
600	$62.87 \pm 0.28 \, {}^{+0.94}_{-0.48}$	$0.1416 \pm 0.0018 \, {}^{+0.0058}_{-0.0031}$
1960	$78.27 \pm 0.55 \, {}^{+1.85}_{-0.96}$	$0.1450 \pm 0.0018 \, {}^{+0.0057}_{-0.0030}$
10000	$105.1 \pm 1.1 \, {}^{+3.6}_{-1.9}$	$0.1382 \pm 0.0016 \, {}^{+0.0047}_{-0.0027}$
12000	$108.5 \pm 1.2 \, {}^{+3.8}_{-2.0}$	$0.1371 \pm 0.0015 \, {}^{+0.0046}_{-0.0026}$
14000	$111.5 \pm 1.2 \, {}^{+4.1}_{-2.1}$	$0.1361 \pm 0.0015 \, {}^{+0.0058}_{-0.0025}$

TABLE III: Predictions for σ_{tot} for $\gamma p \to hadrons$ for cosmic-ray photons. The central values, the statistical errors and the systematic errors are as in Table II.

p^{γ}_{lab} (GeV)	σ (mb)	
$0.5 \cdot 10^6$	0.243 ± 0.009	$+0.011$ -0.010
$1.0 \cdot 10^6$	0.262 ± 0.010	$+0.013$ -0.011
$0.5 \cdot 10^7$	0.311 ± 0.014	$+0.019$ -0.015
$1.0 \cdot 10^7$	0.333 ± 0.016	$+0.021$ -0.017
$1.0 \cdot 10^8$	0.418 ± 0.022	$+0.030$ -0.024
$1.0 \cdot 10^9$	0.516 ± 0.029	$+0.042$ -0.032

TABLE IV: Predictions for σ_{tot} for $\gamma\gamma \to hadrons$. The central values, the statistical errors and the systematic errors are as in Table II.

$\sqrt{s}$ (GeV)	σ (μ b)	
200	0.546 ± 0.027	$+0.027$ -0.027
300	0.610 ± 0.035	$+0.037$ -0.035
400	0.659 ± 0.042	$+0.044$ -0.042
500	0.700 ± 0.047	$+0.050$ -0.048
1000	0.840 ± 0.067	$+0.073$ -0.069

A POSSIBLE THEORETICAL INTERPRETATION OF THE BEST RRPL2 MODEL: THE HEISENBERG'S $\ln^2 s$ INCREASE OF σ

50 years ago, Heisenberg - the first to introduce the $\ln^2 s$ dependence of σ, 9 years before the Froissart bound

W. Heisenberg, Zeit. Phys. 133, 65 (1952)

Main assumption: fraction of energy in the meson field proportional to the overlap of the meson fields in the nucleon

Finite-energy result (not asymptotic):

$\sigma = B \ln^2 s + D \ln s + E$,

where $B = \pi/(4\, m_\pi^2) \approx 15$ mb

Recent modification of the Heisenberg model:

H. G. Dosch, P. Gauron and B. Nicolescu, hep-ph/0206214

Main ingredient: pion is not relevant at high energies ($\alpha_\pi \approx 0$) as compared with the Pomeron ($\alpha_P \approx 1$) $\Rightarrow$ glueballs

Result (with $m_G \approx 1.4 - 1.7$ GeV):

$B = \pi/(4\, m_G^2) \approx 0.11 - 0.14$ mb

to be compared with the COMPETE value $B \approx 0.32$ mb, the Heisenberg's value 15 mb and the Lukaszuk-Martin bound $\pi/m_\pi^2 \approx 60$ mb

The $\ln^2 s$ increase of σ was recently derived in:

- calculations based on AdS/CFT dual string-gravity theory

S. B. Giddins, hep-th/0203004

- Colour Glass Condensate approach

E. Ferreiro, E. Iancu, K. Itakura, and L. McLerran, hep-th/0206241

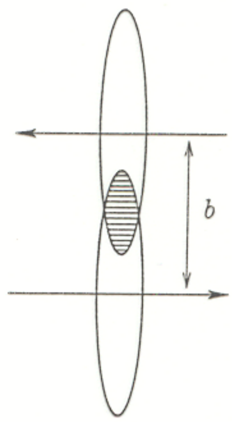

FIG. 3: Scattering of two Lorentz contracted hadrons in the centre of mass system; the interaction region is shaded.

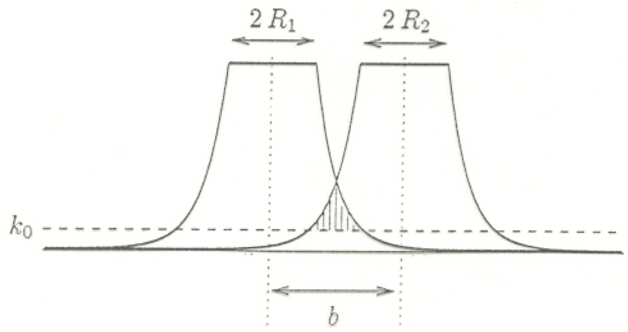

FIG. 4: Interaction region (shaded) of two hadrons in the modified Heisenberg model of high energy scattering.

FUTURE PROSPECTS

- new data - could change the ranking of the best models
$\Rightarrow$ new effects?

- the present algorithm can be applied to a variety of other problems:
  - non-forward scattering
  - jet physics
  - diffractive scattering
  - DIS

- develop the ranking scheme

- periodic cross assessments of data and models be available to the community