

**Table 41.2: 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]

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

where  $Z^{ab}, B, Y_i^{ab}$  are in mb, and  $s, s_1,$  and  $s_0$  are in  $\text{GeV}^2$ . The scales  $s_0, s_1,$  the rate of universal rise of the cross sections  $B,$  and exponents  $\eta_1$  and  $\eta_2$  are independent of the colliding particles. The scale  $s_1$  is fixed at  $1 \text{ GeV}^2$ . Terms  $Z^{ab} + B \log^2(s/s_0)$  represent the pomerons. The exponents  $\eta_1$  and  $\eta_2$  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  $\sigma,$  the measured ratios of the real-to-imaginary parts of the forward scattering amplitudes  $\rho = \text{Re}(T)/\text{Im}(T)$  were included in the fits by using  $s$  to  $u$  crossing symmetry. Global fits were made to the 2005-updated data for  $\bar{p}(p)p, \Sigma^-p, \pi^\pm p, K^\pm p, \gamma p,$  and  $\gamma\gamma$  collisions.

Exact factorization hypothesis in the form  $(Z^{\gamma p}, B^{\gamma p}) = \delta \cdot (Z^{pp}, B), (Z^{\gamma\gamma}, B^{\gamma\gamma}) = \delta^2 \cdot (Z^{pp}, B)$  was used to extend the universal rise of the total hadronic cross sections to the  $\gamma p \rightarrow \text{hadrons}$  and  $\gamma\gamma \rightarrow \text{hadrons}$  collisions. This resulted in reducing the number of adjusted parameters from 21 used for the 2002 edition to 19, and in the higher quality rank of the parameterization. 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 included data above  $\sqrt{s_{\min}} = 5 \text{ GeV}$ .

| Fits to $\bar{p}(p)p, \Sigma^-p, \pi^\pm p, K^\pm p, \gamma p, \gamma\gamma$ |                                     |             | Beam/<br>Target | Fits to groups |              |           |           | $\chi^2/dof$<br>by groups |
|--|-------------------------------------|-------------|-----------------|----------------|--------------|-----------|-----------|---------------------------|
| $Z$  | $Y_1$                               | $Y_2$       |                 | $Z$            | $Y_1$        | $Y_2$     | $B$       |                           |
| 35.45(48)  | 42.53(1.35)                         | 33.34(1.04) | $\bar{p}(p)/p$  | 35.45(48)      | 42.53(23)    | 33.34(33) | 0.308(10) | 1.029                     |
|  |                                     |             | $\bar{p}(p)/n$  | 35.80(16)      | 40.15(1.59)  | 30.00(96) | 0.308(10) |                           |
| 35.20(1.46)  | -199(102)                           | -264(126)   | $\Sigma^-/p$    | 35.20(1.41)    | -199(86)     | -264(112) | 0.308(10) | 0.565                     |
| 20.86(40)  | 19.24(1.22)                         | 6.03(19)    | $\pi^\pm/p$     | 20.86(3)       | 19.24(18)    | 6.03(9)   | 0.308(10) | 0.955                     |
| 17.91(36)  | 7.1(1.5)                            | 13.45(40)   | $K^\pm/p$       | 17.91(3)       | 7.14(25)     | 13.45(13) | 0.308(10) | 0.669                     |
|  |                                     |             | $K^\pm/n$       | 17.87(6)       | 5.17(50)     | 7.23(28)  | 0.308(10) |                           |
|  | 0.0317(6)                           |             | $\gamma/p$      |                | 0.0320(40)   |           | 0.308(10) | 0.766                     |
|  | -0.61(62)E-3                        |             | $\gamma/\gamma$ |                | -0.58(61)E-3 |           | 0.308(10) |                           |
| $\chi^2/dof = 0.971,$  | $B = 0.308(10) \text{ mb},$         |             | $\bar{p}(p)/d$  | 64.35(38)      | 130(3)       | 85.5(1.3) | 0.537(31) | 1.432                     |
| $\eta_1 = 0.458(17),$  | $\eta_2 = 0.545(7)$                 |             | $\pi^\pm/d$     | 38.62(21)      | 59.62(1.53)  | 1.60(41)  | 0.461(14) | 0.735                     |
| $\delta = 0.00308(2),$   | $\sqrt{s_0} = 5.38(50) \text{ GeV}$ |             | $K^\pm/d$       | 33.41(20)      | 23.66(1.45)  | 28.70(37) | 0.449(14) | 0.814                     |

The fitted functions are shown in the following figures, along with one-standard-deviation error bands. When the reduced  $\chi^2$  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  $p_{\text{lab}}$  or  $E_{\text{cm}}$  range used in the fits.

One can find the details of the global fits and ranking procedure, in the paper [1]. Database is practically the same as for the 2004 edition (it was slightly changed in the low energy regions not used in the fits).

Recently, the statement in [1] that the models with  $\log^2(s/s_0)$  asymptotic terms work much better than the models with  $\log(s/s_0)$  or  $(s/s_0)^\epsilon$  terms was confirmed in [2] and [3], based on matching traditional asymptotic parameterizations with low energy data in different ways. Both these references, however, questioned the statement in [1] on the universality of the coefficient of the  $\log^2(s/s_0)$  term for all processes with nucleon and gamma targets. The two references give different predictions at superhigh energies:  $\sigma_{\pi N}^{as} > \sigma_{NN}^{as}$  [2] and  $\sigma_{\pi N}^{as} \sim 2/3 \sigma_{NN}^{as}$  [3]. A broader universality of  $\sigma_{tot}^{as}$  has been recently advocated in [4] for hadron-nucleus collisions. It should be noted that asymptotic rate universality in hadron-deuteron collisions has not been established at available energies (see Table).

Computer-readable data files are available at <http://pdg.lbl.gov/current/xsect/>. (Courtesy of the COMPAS group, IHEP, Protvino, August 2005)

On-line ‘‘Predictor’’ to calculate  $\sigma$  and  $\rho$  for any energy from five high rank models is also available at <http://nuclth02.phys.ulg.ac.be/compete/predictor/>.

#### References:

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