**Table 49.2D: Total hadronic cross section.** For data descriptions the $HPR_1R_2$ model of highest COMPETE–rank[1] is used. As in RPP-2012 it is modified to save the universality of the rising part in new form that explicitly includes dependence of the $s_M$ and $H$ on the initial state mass parameters and the new scale parameter $M$.

$$\sigma^{a\mp b} = H\log^2\left(s/s_M^{ab}\right) + P^{ab} + R_1^{ab}\left(s/s_M^{ab}\right)^{-\eta_1} \pm R_2^{ab}\left(s/s_M^{ab}\right)^{-\eta_2}$$

$$\rho^{a\mp b} = \frac{1}{\sigma^{a\mp b}}\left[\pi H\log\left(s/s_M^{ab}\right) - R_1^{ab}\left(s/s_M^{ab}\right)^{-\eta_1}\tan\left(\frac{\eta_1\pi}{2}\right) \pm R_2^{ab}\left(s/s_M^{ab}\right)^{-\eta_2}\cot\left(\frac{\eta_2\pi}{2}\right)\right]$$

where upper signs in formulas are for particles and lower signs for antiparticles. Adjustable parameters are as follows:

$H = \pi\frac{(\hbar c)^2}{M^2}$ in mb, where notation $H$[2] is after Heisenberg(1952,1975);

$P^{ab}$ in mb, are Pomeranchuk's(1958) constant terms;

$R_i^{ab}$ in mb are the intensities of the effective secondary Regge pole contributions named after Regge-Gribov(1961);

$s$, $s_M^{ab} = (m_a + m_b + M)^2$ are in GeV$^2$ ;

$m_a$, $m_b$, $(m_{\gamma^*} = m_{\rho(770)})$ are the masses of initial state particles, and $M$ – the mass parameter defining the rate of universal rise of the cross sections are all in GeV.

Parameters $M$, $\eta_1$ and $\eta_2$ are universal for all collisions considered. In addition to total cross sections $\sigma$, the measured ratios of the real-to-imaginary parts of the forward scattering amplitudes $\rho = \mathrm{Re}(T)/\mathrm{Im}(T)$ are included in the fits by using $s$ to $u$ crossing symmetry and differential dispersion relations.

Exact factorization hypothesis was used for both $H\log^2(s/s_M^{ab})$ and $P^{ab}$ to extend the universal rise of the total hadronic cross sections to the $\gamma\ (p,d) \rightarrow$ *hadrons* and $\gamma\gamma \rightarrow$ *hadrons* collisions. This results in one additional adjustable parameter $\delta$ with substitutions:

$$\pi H\log^2\left(s/s_M^{\gamma(p,d)}\right) + P^{\gamma(p,d)} \Rightarrow \delta\left[\pi(1,\lambda)H\log^2\left(s/s_M^{\gamma(p,d)}\right) + P^{p(p,d)}\right],$$

$$\pi H\log^2\left(s/s_M^{\gamma\gamma}\right) + P^{\gamma\gamma} \Rightarrow \delta^2\left[\pi H\log^2\left(s/s_M^{\gamma\gamma}\right) + P^{pp}\right].$$

Three fits were made to the 2013-updated data above $\sqrt{s_{min}} = 5,\ 6,\ 7$ GeV for all collisions, listed in the "Beam/Target" column of the table . Fit results are shown only for fit above 7 GeV with the best fit quality $FQ = \chi^2/NDF$ and uniformity of data descriptions by groups (last column). The total number of adjusted parameters is **35**.

| **HPR$_1$R$_2$ at $\sqrt{s} \geq 7$ GeV** | **$M = 2.076 \pm 0.016$ [GeV] $\eta_1 = 0.412 \pm 0.017$ $\delta = (3.112 \pm 0.027) \times 10^{-3}$** | | **$H = 0.2838 \pm 0.0045$ [mb] $\eta_2 = 0.5626 \pm 0.0092$ $\lambda = 1.456 \pm 0.058$** | | **FQ$_{\mathrm{Int}}$ = 0.86 FQ$_{\mathrm{Ext}}$ = 0.87** |
|---|---|---|---|---|---|
| **$P$ [mb]** | **$R_1$ [mb]** | **$R_2$ [mb]** | **Beam/Target** | **Npt=836 npt** | **$\chi^2$/npt by groups** |
| **33.73±0.33** | **13.67±0.33** | **7.77±0.18** | **$(\bar{p})p$ / $p$** | **219** | **1.09** |
| **33.77±0.38** | **14.05±0.63** | **6.93±0.29** | **$(\bar{p})p$ / $n$** | **48** | **0.39** |
| **33.20±3.90** | **-14.±47.** | **-15.±52.** | **$\Sigma^-$ / $n$** | **8** | **0.41** |
| **18.08±0.29** | **10.44±0.32** | **1.977±0.078** | **$\pi^\mp$ / $p$** | **137** | **0.91** |
| **15.84±0.20** | **5.12±0.28** | **3.538±0.095** | **$K^\mp$ / $p$** | **85** | **0.76** |
| **15.73±0.22** | **4.81±0.40** | **1.86±0.13** | **$K^\mp$ / $n$** | **48** | **0.56** |
| | **0.0132±0.0023** | | **$\gamma$ / $p$** | **34** | **0.56** |
| | **(-6.0±3.3)×10$^{-5}$** | | **$\gamma$ / $\gamma$** | **31** | **0.68** |
| | **0.0256±0.0044** | | **$\gamma$ / $d$** | **3** | **0.31** |
| **64.79±0.75** | **27.06±0.85** | **15.46±0.37** | **$(\bar{p})p$ / $d$** | **75** | **0.97** |
| **36.66±0.62** | **17.89±0.82** | **0.38±0.14** | **$\pi^\mp$ / $d$** | **81** | **0.71** |
| **32.28±0.46** | **7.02±0.71** | **5.74±0.16** | **$K^\mp$ / $d$** | **67** | **0.67** |

All fits are stable: in all cases the $FQ < 1.0$, Hessian matrices are positive definite. Quoted parameter uncertainties are obtained by direct MC-propagation of the uncertainties in each input experimental data point assuming independent normal distributions. Computer-readable data files are available at http://pdg.lbl.gov/current/xsect/. (Courtesy of the COMPAS group, IHEP, Protvino, September 2013)

[1] Physical motivations for the model and related references see in mini-review. All plots give details for Figures 49.8 and 49.9 of the mini-review.

[2] For collisions with deuteron target $H_d = \lambda H$ where dimensionless parameter $\lambda$ is introduced to test the universality of the Heisenberg rise for particle–nuclear and nuclear–nuclear collisions