Regge description of high energy pion pion total cross sections

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Abstract

We have recently presented a Regge description of ππ total cross sections valid above 1.4 GeV, consistent with the few existing experiments, factorization and crossing symmetry. In this note we show how it also describes a further large data sample obtained from an analysis of experiments on \( \pi^+p \rightarrow X\Delta^{++} \) and \( \pi^+n \rightarrow Xp \).

1 Regge description of \( \pi\pi \) total cross sections

In references \[1\] \[2\], we have shown how it was possible to obtain a precise Regge description of high energy total ππ scattering down to \( E_{\text{kin}} \approx 1.1 \) GeV. Apart from the interest in itself, there has been a renewed interest in this high energy region because the imaginary part of the \( \pi\pi \rightarrow \pi\pi \) amplitude is needed for dispersive studies aiming at a precise description of ππ data at low energies \[3\] \[4\] \[1\].

A relevant property of our description is that it respects factorization. This means that, for instance, the imaginary part of an amplitude \( F_{A+B \rightarrow A+B} \) is:

\[
\text{Im} \, F_{A+B \rightarrow A+B}(s,t) \simeq f_A(t) f_B(t)/(s/\hat{s})^{\alpha_R(t)}, \quad \hat{s} = (1 \text{ GeV})^2.
\]

The \((s/\hat{s})^{\alpha_R(t)}\) behavior comes from the so-called Regge pole \( R \). All poles have \( \alpha_R < 1 \) and thus vanish for large \( s \), except the Pomeron that scales like \( s \) up to around 15 or 20 MeV, where it dominates all other pole contributions, giving a common prediction \( \sigma^\infty \) for all \( \pi\pi \) channels. For larger energies it increases logarithmically. As a matter of fact there could be many Regge poles exchanged in each channel, all them with their corresponding \( f_i(t) \) factors depending on \( R \) and the particles in the initial state. Using factorization, it is thus possible to obtain the \( \pi\pi \) Regge amplitudes from those of \( \pi N \) and \( N N \). Total cross sections are then related to forward scattering amplitudes by: \( \sigma_{AB} = 4\pi^2 \text{Im} \, F_{A+B \rightarrow A+B}(s,0)/\lambda^{1/2}(s, m_A^2, m_B^2) \), with \( \lambda(a, b, c) = a^2 + b^2 + c^2 - 2ab - 2ac - 2bc \). Thus we \[2\] fitted the large \( \pi^+N \) and \( NN \) data compilation of the COMPASS group as given in the Particle Data Tables \[5\], and the few \( \pi\pi \) data \[6\] points known to us down to \( E_{\text{kin}} \approx 1.1 \) imposing factorization. The fit parameters are largely dominated by the \( \pi^+N \) and \( NN \) experiments, but still we obtained a very precise description for \( \pi\pi \) total cross sections, that was in remarkable agreement with the \( \sigma^\text{tot} \) data above 2 GeV. At lower energies these data are in conflict with the \( \sigma^\text{tot} \) reconstructed \[2\] from lower energy phase shifts analysis and our results fall somewhere in-between. We refer to our paper \[2\] for further details.

In addition, we have also checked that our high energy results together with fits \[1\] to the low energy satisfy two crossing symmetry sum rules. This is again of relevance because in the seventies \[7\] there was a suggestion that the predictions of factorization \( \sigma^\infty \simeq 13 \) mb, together with the existing phase shifts analysis at that time, violated crossing symmetry, suggesting \( \sigma^\infty = 6 \pm 5 \) mb. Of course this was tenable until the first high energy \( \sigma^\text{tot} \) were measured, and indeed the very same authors \[7\] pointed out somewhat later that the central value should be raised to \( \sigma^\infty = 8.3 \) mb. The recent studies in \[3\] \[4\] used \( \sigma^\infty = 5 \pm 3 \) mb, following \[3\]. Unfortunately, the \( \sigma^\text{tot} \) data went largely unnoticed to our days, including to ourselves, so that in \[1\] the use of factorization was only based on QCD considerations. In \[2\] we “rediscovered” four different experimental works \[9\] that we used in a reanalysis to find \( \sigma_{\text{tot}}(20\text{GeV}) = 13.4 \pm 0.6 \) mb, while simultaneously respecting crossing.

2 Comparison with further data

Following the discussions of my talk on this MESON2004 conference I came to know that there was another analysis [8] of $\pi\pi$ total cross sections. In that work, a triple reggeon model is used to analyze several sets of experimental data on $pp \rightarrow X\Delta^{++}$ and $pn(p) \rightarrow Xp(n)$, and obtain Regge parameters with whom to extract total $\pi^\pm\pi^-$ cross sections from $\pi^\pm p \rightarrow X\Delta^{++}$ and $\pi^\pm n \rightarrow Xp$. The most relevant contribution of this paper is the inclusion of absorptive corrections in the last two reactions, which seems to decrease the results by about 10 to 15%. In Fig.1, we show how our Regge description, and in particular, our value $\sigma_{tot}(20\text{GeV}) = 13.4 \pm 0.6 \text{mb}$ indeed provides a good description of this data, which strongly disfavors a value more than two times smaller. Following the authors we display only the statistical errors. Systematic errors were estimated at the $7-10\%$ level.

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References

Figure 1: The continuous line stands for our Regge representation and the gray band for the associated uncertainty. Data are from [8] and the error bars are just statistical, however, the authors pointed out a "possible systematic error of $\simeq 7 - 10\%$".