Regge description of high energy pion pion total cross sections

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Abstract

We have recently presented a Regge description of \( \pi\pi \) 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 \( \pi^\pm p \to X \Delta^{++} \) and \( \pi^\pm n \to Xp \).

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 \( \pi\pi \) 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 in remarkable agreement with the \( \pi\pi \) forward scattering amplitudes by: \( \sigma_{\pi\pi} = \frac{\pi^2}{s} \text{Im} F_{A+B \to A+B}(s, t) \simeq f_A(t) f_B(t) (s/\hat{s})^{\alpha_R(t)}, \quad \hat{s} = (1 \text{GeV})^2. \) (1)

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 \( NN \) total cross sections are then related to forward scattering amplitudes by: \( \sigma_{AB} = \frac{4\pi^2}{s} \text{Im} F_{A+B \to A+B}(s, 0) / \lambda^{1/2}(s, m_A^2, m_B^2) \), with \( \lambda(a, b, c) = a^2 + b^2 + c^2 - 2ab - 2ac - 2bc. \) Thus we 2 fitted the large \( \pi^\pm N \) 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 \( \pi^\pm N \) and \( NN \) experiments, but still we obtained a very precise description for \( \pi\pi \) total cross sections, that was in remarkable agreement with the \( \sigma^{\pi\pi}_{\text{tot}} \) data above 2 GeV. At lower energies these data are in conflict with the \( \sigma^{\pi\pi}_{\text{tot}} \) 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 \( \sigma^{\infty} \approx 13 \text{mb} \), together with the existing phase shifts analysis at that time, violated crossing symmetry, suggesting \( \sigma^{\infty} = 6 \pm 5 \text{mb} \). Of course this was tenable until the first high energy \( \sigma^{\pi\pi}_{\text{tot}} \) were measured, and indeed the very same authors 7 pointed out somewhat later that the central value should be raised to \( \sigma^{\infty} = 8.3 \text{mb} \). The recent studies in 3, 4 used \( \sigma^{\infty} = 5 \pm 3 \text{mb} \), following 3. Unfortunately, the \( \sigma^{\pi\pi}_{\text{tot}} \) data went largely unnoticed to our days, including to ourselves, so that in 4 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 \( \sigma_{\text{tot}}(20 \text{GeV}) = 13.4 \pm 0.6 \text{mb} \), while simultaneously respecting crossing.

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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 $\pi^\pm\pi^\mp$ 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 $\sigma_{tot}(20\text{GeV}) = 13.4 \pm 0.6$ 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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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 $\approx 7 - 10\%$.”