Study of $\sigma(750)$ and $\rho^0(770)$ production in measurements of $\pi N_\uparrow \to \pi^+\pi^- N$ on a polarized target at 5.98, 11.85, and 17.2 GeV/c

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We present a new and improved model-independent amplitude analysis of the reactions $\pi^+ n_\uparrow \to \pi^+\pi^- p$ at 5.98 and 11.85 GeV/c and $\pi^- p_\uparrow \to \pi^-\pi^+ n$ at 17.2 GeV/c measured with transversely polarized targets at the CERN Proton Synchrotron. For dipion masses below 1000 MeV the pion production process is described by two S-wave and six P-wave production amplitudes. Previous analyses suffered from the presence of unphysical solutions for moduli of amplitudes or cosines of their relative phases, causing uncertainties regarding the signal for the scalar state $I=0\ 0^{++}(750)$. To remove the unphysical solutions we use a Monte Carlo approach to amplitude analysis. In each (m,t) bin we randomly varied the input spin-density-matrix elements 30 000 times within their experimental errors and performed an amplitude analysis for each selection. Unphysical solutions were rejected and the physical solutions produced a continuous range of values for moduli, cosines of relative phases, and for partial wave intensities. A clear signal for $\sigma(750)$ resonance emerges in all four solutions for an S-wave intensity I_S at 5.98 and 11.85 GeV/c and in both solutions for an S-wave amplitude $|\bar{S}|^2\Sigma$ at 17.2 GeV/c. Its $\pi^+\pi^-$ decay width is estimated to be in the range 200–300 MeV. We find a significant suppression of ρ^0 production in the amplitudes $|U|^2\Sigma$, $|\bar{N}|^2\Sigma$ and at 17.2 GeV/c in $|L|^2\Sigma$. The mass dependence of the amplitudes $|\bar{L}|^2\Sigma$ and $|L|^2\Sigma$ shows unexpected structures within the ρ^0 mass region which correlate the mass spectra corresponding to opposite nucleon spins. These features of the P-wave moduli reveal the essential role of nucleon spin in the pion production process and contradict the factorization hypothesis. Our results emphasize the need for a systematic study of pion production on the level of amplitudes in a new generation of dedicated experiments with spin at the recently proposed high-intensity hadron facilities.

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