AMPLITUDE ANALYSIS OF THE DIPION PRODUCTION ON THE POLARIZED TARGET

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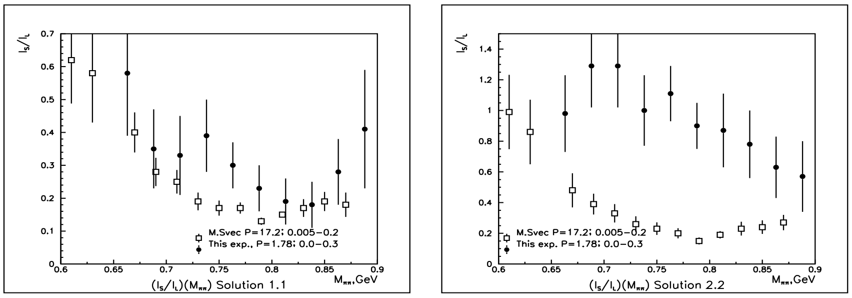
The whole set of spin density matrix elements of the reaction $\pi^- p \to \pi^- \pi^+ n$ was measured at ITEP in the scattering of pions with momentum 1.78 GeV/c on polarized proton and liquid hydrogen targets. The data covers the region of dipion masses near the mass of rho-meson and small 4-momenta transferred $|t| < 0.2$ (GeV/c)^2. We observed spin dependence of the dipion generation process at the level of 10%. This measurement allowed nearly complete model-independent reconstruction of all 8 complex transversity amplitudes of the reaction. In comparison of our results with the data obtained at high energies (6, 12 and 17 GeV/c) we came to the following conclusions:

- our data contained physical reasons to solve "UP-DOWN" ambiguity of pion-pion partial wave analysis in favour of the "UP" solution.
- our data supported the conclusion made by M.Svec in his analysis of the data at high energies about existence of relatively narrow S-wave meson $\sigma(750)$ under the peak of rho-meson. Our estimation of its parameters is $M = 744 \pm 5$ MeV and $\Gamma = 77 \pm 22$ MeV.

The interest to this experiment was inspired by a large spin effects found in experiments on polarized targets at 6, 12 [1] and 17 GeV/c [2]. Our idea was to trace energy dependence of the reaction in a wide range. Another interesting advantage given by measurements on a polarized target is an opportunity of a model-independent reconstruction of all transverse amplitudes with the exception of two phases. This supplyes a new data to the problem of the existing "UP-DOWN" ambiguity of the partial wave analysis of pion-pion scattering (partial wave analysis by R. Kaminski[3]; amplitude analyses M. Svec[4]). This data also provides a new information on the problem of possibly existing $\sigma(750)$-meson ($0^+0^+(J^PI^G)$), which was originally proposed by M. Gell-Mann and M. Levy[5]. In the last issue of Review of Particle Physics[6] this state is presented as $f_0(400\text{–}1200)$ with width 600–1000 MeV. Such very uncertain estimation reflects all the existing data and its contradicting analyses.

The formalism used can be found elsewhere[4,7]. Here we want only to stress that the bilinear equations connecting spin density matrix elements (which were measured in our experiment[7]) and transverse amplitudes can be split into



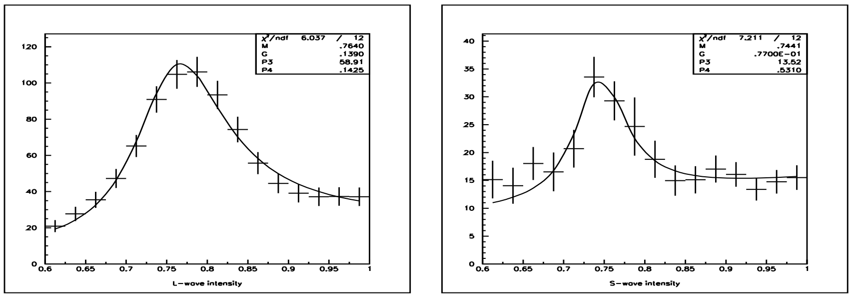
a) Solution 2. b) Solution 2.

Figure 1: S- to L-wave intensities ratio.

2 similar sets of equations, which contains amplitudes with different recoiled nucleon transversity. Each of these two sets results in a cubic equation in L^2. The equation has two positive roots which gives a two-fold ambiguity for partial waves or four-fold for the intensities.

The normalized amplitudes obtained as a result of our analysis are roughly constant as function of $M_{\pi\pi}$ for both solutions. For all energies and both recoiled nucleon transversities a clear signature of the solutions is observed for all the experiments (1.78, 6, 12 and 17 GeV/c). Particularly, in the solution 1 the phase shift between L- and S-waves is very close to zero, while for the solution 2 it varies in the range 30–50^o, and the phase shift between L- and U-waves is near 180^o for the solution 2 and in the range 100–160^o for the solution 1. Spin effects observed in our experiment were 4–5 times smaller than that at higher energies and are mostly seen in the difference between the amplitudes of L-wave with different recoiled nucleon transversities. Because at our energy spin effects are small it looks extremely improbable that for waves with different recoiled nucleon transversities different kinds of solution are realised in the nature. This reduces overall ambiguity from 4 (1.1, 1.2, 2.1, 2.2 in M. Svec terms) to 2 (1.1 and 2.2). L- and S-wave intensities of solution 1 are similar at all energies, while for solution 2 a strong energy dependence is observed (see fig. 1), which is very difficult to explain. In Regge model the ratio between S- and L-waves is energy independent. Another strange feature of the solution 2 at our energy is that S-wave given is unbelievably large. These reasons allow us to consider only solution 1 as physically justified.

In both solutions phase shift between S- and L-waves is roughly constant under the peak of ρ-meson and the intensities ratio has only a slight slope. But, L-wave is dominated by a strong resonance — ρ-meson. This evidences in favour of existing of a S-wave resonance with similar properties. We made an attempt to estimate its properties coming from the solution 1, assuming that there is no spin dependence. This assumption allowed us to perform



a) L-wave. b) S-wave.

Figure 2: Breit-Wigner fit of the absolute intensities.

an amplitude analysis (model-dependent) in a wider range over mass of di-pion. The absolute intensities of L- and S-waves, shown in fig. 2, were obtained as a product of our normalized intensities by absolute cross sections from 4π-measurements by Reynolds et al.[8]. The Breit-Wigner fits with constant background are shown also. The parameters of ρ-meson from our fit ($M_\rho = 764 \pm 3$ MeV and $\Gamma_\rho = 139 \pm 14$ MeV) are in reasonable agreement with PDG ($M_\rho = 770.0 \pm 0.8$ MeV and $\Gamma_\rho = 150.7 \pm 1.1$ MeV). The table below summarizes the parameters of σ-meson given by amplitude analyses of the data obtained on polarized target.

P, GeV/c	Reaction	M_σ, MeV	Γ_σ, MeV	Exp.	Anal.
1.78	$\pi^- p_\uparrow \to \pi^+\pi^- n$	744 ± 5	77 ± 22	this work	
5.98	$\pi^+ n_\uparrow \to \pi^+\pi^- p$	746 ± 16	145 ± 69	1	4
11.85	$\pi^+ n_\uparrow \to \pi^+\pi^- p$	782 ± 16	117 ± 26	1	4
17.2	$\pi^- p_\uparrow \to \pi^+\pi^- n$	771 ± 13	161 ± 22	2	4
Average		750 ± 4	119 ± 13	our estimation	

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