MEASUREMENTS OF SPIN-DEPENDENT OBSERVABLES IN THE STRONG INTERACTIONS AT INTERMEDIATE ENERGIES AT ITEP ACCELERATOR

V.P. KANAVETS for ITEP-PNPI Collaboration
Institute for Theoretical and Experimental Physics,
B. Cheremushkinskaya 25, Moscow 117259, Russia
E-Mail: KANAVETS@VITEP5.ITEP.RU

The results of several works are summarized on the measurements of spin-dependent parameters in two-body and quasy-two-body processes of pion-nucleon interaction in the resonance region fulfilled in recent years at the ITEP accelerator. The contribution of this data to the baryon spectroscopy in the second resonance region and to the light meson spectroscopy is discussed including the problem of existence and parameters of the scalar-isoscalar sigma-meson.

Three polarized proton target experiments were carried out in 1990–1997 at the pion beam of the ITEP synchrotron [1,2,3]. The general goal of these works was to measure spin-dependent observables in the two-body and quasi-two-body processes and to fulfill the amplitude analysis of the obtained data in order to study the pion-nucleon dynamics at the AMPLITUDE LEVEL. The measurements were made in the interval of baryon resonance masses (1.9÷2.2) GeV (the second resonance region). According to the PDG data there are about 20 resonant states with $I = 1/2$ and $I = 3/2$ in this region.

Dipion production by pions was studied at small transferred momenta in the vicinity of the ρ-meson peak. The results are valuable for the meson spectroscopy and for the studies of pion production mechanisms.

Spin-dependent observables were measured in the following reactions:

$$\pi^- p_\uparrow \to \pi^- p \quad (1) \qquad \pi^+ p_\uparrow \to \pi^+ p_\uparrow \quad (2) \qquad \pi^- p_\uparrow \to \pi^- \pi^+ n \quad (3)$$

The interest to such experiments is based on the well-known general properties of spin-dependent observables: on their sensitivity to the contribution of small amplitudes and on possibility of direct amplitude reconstruction from the experimental data.

The experiments (1) and (2) were stimulated by the dramatic differences in the resonance spectrum and properties by different PWAs. Their main goals:

- to enlarge the experimental database of these analyses;
- to exclude the discrete ambiguities of PWAs, originating from the lack of the "full set" of observables.

The experiment (3) was aimed at the studies of:

- spin dependence of the pion production in the resonance region;
- energy dependence of the spin density matrix elements (SDME);
- dipion production in S-state including gathering information about the existence and properties of the scalar-isoscalar σ-meson, $f_0(750)$;
- unnatural parity exchanges, which are absent in the elastic πp-scattering.

The main features of the setup, the kinematic regions of the experiments, the measured observables and the accuracy of the results are summarized in the following table:

	Process	Target	Kinematic region	Observable	Prec.
1	$\pi^- p_\uparrow \to$ $\to \pi^- p$	proton, $C_3H_8O_2$ transversely polarized, $P_t \approx 0.75$	$P_{in} = 1.4 \div 2.1$ GeV/c, step $(40 \div 80)$ MeV/c $\cos\theta_{cm}$=$(-0.92\div 0.27)$, step 0.05	A (asymmetry) $\equiv P$ (normal polarization)	$\pm(0.03$ $\div 0.04)$
2	$\pi^+ p_\uparrow \to$ $\to \pi^+ p_\uparrow$	proton, $C_3H_8O_2$ longitudinally polarized, $P_t \approx 0.75\div 0.8$	$P_{in} = 1.43$ GeV/c $\cos\theta_{cm} = -0.675$, -0.604	spin rotation parameter A polarization P	± 0.2 ± 0.1
3	$\pi^- p_\uparrow \to$ $\pi^-\pi^+ n$	• proton, $C_3H_8O_2$ transversely polarized, $P_t \approx 0.75$ • LH_2	$P_{in} = 1.78$ GeV/c $M_{\pi\pi}$=$(0.6\div 1.0)$ GeV/c^2 $-t' = t_{min} - t =$ $= (0 \div 0.1)$ $(GeV/c)^2$	normalized SDME	$\pm(0.02$ $\div 0.04)$

The experimental results for the **asymmetry in elastic $\pi^- p_\uparrow$-scattering** at 2.07 GeV/c is shown in fig. 1 in comparison with predictions of different PWA's. One could see that the experimental data on asymmetry of the scattering to the backward hemisphere satisfactorily agree only with the predictions of WI94 solution, which already contains this data in its database. It also could be supposed that these data will change properties of several N^* resonances near 2.1 GeV/c^2.

The choice of the kinematic region for **measurements of the spin rotation parameters in elastic $\pi^+ p$-scattering** was influenced by the existence of the resonance structure near $\sqrt{s} = 1.9$ GeV, which includes 7 resonances with $I = 3/2$, and the contradiction between predictions of various PWA's on the spin rotation parameters in the angular region $120 < \theta_{cm} < 140^o$.

The baryonic spectra in this region from the results of various PWAs is also very different. The $D_{33}(1940)$ resonance was only found in the CMB solution, while $S_{31}(1900)$ and $P_{33}(1920)$ were not found in SM90.

The resulting values are presented in the following table:

$\cos\theta_{cm}$	θ_{cm}	Events	A	P	$\|R\|$
-0.604	127.2^o	2842	-0.14±0.20	0.52±0.10	0.84±0.07
-0.675	132.5^o	2720	-0.58±0.20	0.47±0.11	0.67±0.19

The data is in good agreement with predictions of the PWA SM90 and contradicts to that of KH80 and CMB.

Measurements of the **normalized dipion SDME in the reaction** $\pi^- p_\uparrow \to \pi^-\pi^+ n$ were performed at 1.78 GeV/c. In the mass region $\lessapprox 1$ $(GeV/c)^2$ dipion production in S- and P-states is dominant and the spin-independent part of the crossection is determined by 5 SDME, while the spin-dependent parts by 9 other SDME. All SDME are bilinear combinations of the 8 amplitudes describing the production of vector dipion with helicities -1,0,+1 and scalar dipion with or without the nucleon spin flip.

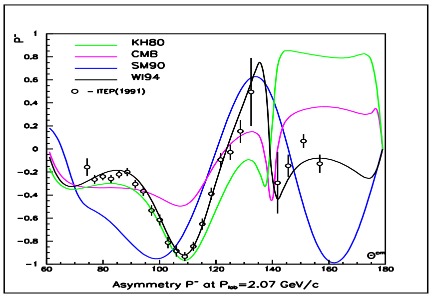

Fig. 1: Asymmetry in elastic $\pi^- p_\uparrow$ scattering at 2.07 GeV/c.

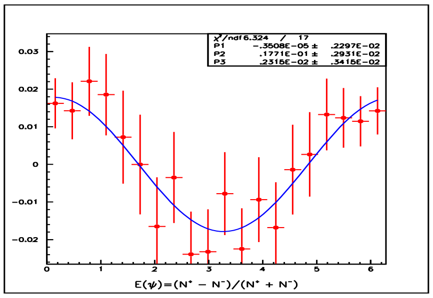

Fig. 2: Raw asymmetry in dipion production at 1.78 GeV/c.

Normalized SDME in the t-channel system were determined using the method of maximum likelihood. The data was obtained on SDME dependences on the dipion mass and momentum transferred, as well as on their energy dependence (from the comparison to the high energy data). Spin dependence of the production process was also determined.

Matrix elements $\rho_{00}+1/3\rho_{SS}$ and $\mathrm{Re}\,\rho_{0S}$, which are nonzero in the OPE model, do not reveal any essential energy dependence. On the contrary $\mathrm{Re}\,\rho_{10}$ and $\mathrm{Re}\,\rho_{1S}$ which are zero in OPE manifest significant energy dependence.

In the $t' = t - t_{min}$ interval $0.005 \div 0.1$ all these matrix elements do not manifest essential dependence on t' similarly to high energies.

The raw asymmetry as a function of the angle ψ is shown in fig. 2. The spin dependence of the production process is seen at the level of $6\sigma_{stat}$. Taking into account the target polarization value and the dilution by nonpolarized nuclei this results in the asymmetry on completely polarized protons about 0.1. The sign of the effect coincides with that measured at high energies. The SDME $(\rho^Y_{00} - \rho^Y_{11})$, ρ^Y_{1-1}, $\mathrm{Re}\,\rho^Y_{10}$, $\mathrm{Im}\,\rho^X_{10}$ that describe spin effects other than asymmetry, do not equal zero within the error. Their sign is the same as that at high energies, but the value is several times smaller. Thus a conclusion could be made that besides the dominant pion exchange, a_1- and a_2-exchanges also contribute to the process.

The results of all the three works show that the questions of the light quark spectroscopy are not at all exhausted and new precise and complete experimental data is necessary in the resonance region that could provide direct amplitude reconstruction.

The work was partially supported by Russian Fund for Basic Research and by Russian State Scientific Program “Fundamental Nuclear Physics”.

References

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