N* AND Z* SPECTROSCOPY

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1.- NEW EXPERIMENTAL RESULTS ON $\pi N \to$ 2-BODY SCATTERING.-

1.1.- MEASUREMENT OF THE POLARIZATION PARAMETER FOR $\pi^- p \to \pi^o n$.- Measurements of the polarization parameter for the reaction $\pi^- p \to \pi^o n$ have been performed with the Berkeley Bevatron at five momenta between 1.03 and 1.79 GeV/c [1]. The experimental arrangement consists in 20 neutron counters (for time-of-flight measurements and angular information) and thick plate spark chambers to detect the γ rays from π^o decay. The detectors surround a 7 cm long propylene glycol polarized target (50% polarization). For each momentum, about 10 000 events are detected in a typically angular range : $-.78 < \cos\theta^* < .87$. The background due to quasi-elastic events into the target sample was estimated using a dummy target. Those data represent the first charge-exchange polarization angular distribution ever made in the energy domain covered by phase shift analyses.

The preliminary results (including statistical errors only) are displayed on Fig.14 of Butterworth's report with the predictions of CERN(1971)[2] and Saclay (1972)[3],(1973)[4] phase shift analyses. The general agreement is quite good, specially for the 1973 Saclay smoothed phases if one remember that small phase shift changes can considerably alter the polarizations. To show that the agreement is non-trivial we have computed, from Isospin Invariance [5], the bounds on charge exchange polarizations knowing cross-sections and polarizations in the $\pi^{\pm}p$ elastic scattering. Measurements at momenta above 1.8 GeV/c would also be particularly useful for constraining phase shift analyses.

1.2.- BACKWARD CROSS SECTIONS FOR $\pi^{\pm}p$, $\pi^o n$ AND $\eta^o n$ FINAL STATES FROM 0.6 TO 1.05 GeV/c [6].- A cusp is observed in the $\pi^- p$ elastic cross-section at exactly the η threshold (Fig.15 of Butterworth's report). The $\pi^o n$ cross-section which peaks at the η threshold represents a considerable improvement in accuracy on the previous data. This cross-section lies between the bounds given by Isospin conservation but not on the frontier, as was suggested previously [7]. (Fig.17 of Butterworth's report).

1.3.- PRELIMINARY VALUES FOR $\pi^- p \to \eta n$ FROM 1600 TO 1740 MeV [8].- These good statistics measurements show some pronounced structures for the Legendre polynomials coefficients aroung 1690 MeV. In particular, C_4 is 4 standard deviations away from 0.

1.4.- MEASUREMENT OF $\pi^- p \to \omega n$ NEAR THRESHOLD [9]. The cross-section dependence does not show the behaviour expected for a pure S wave production, but the data is consistent with isotropic c.m.s. angular distributions. Final state interactions could explain the effect.

.2. PHASE SHIFT ANALYSES OF ELASTIC (AND CHARGE EXCHANGE) $\pi^{\pm}N$ and K^+N SCATTERING.- Two analyses which treat simultaneously the data in the available channels have been submitted.

2.1.- πN SCATTERING.- The Saclay group [4] presents an analysis up to 2.4 GeV total energy which differs from the previous one [3] on two aspects :

2.1.1.- New data are included : accurate $\pi^{\pm}p$ differential elastic cross-sections [10] in the low momentum range : $180 < p < 408$ MeV/c and charge exchange angular distributions from Berkeley [6] and Saclay [11] for $1.0 < p < 2.4$ GeV/c. In these two energy domains an independent-energy phase shift analysis has been first performed, using conventional methods. A unique general solution has been obtained after applying the criteria of "minimal path" in the Argand plot.

2.1.2.- The partial waves have been parametrized separately, as functions of energy using a generalized Breit-Wigner approximation : $T = T_{RES} + T_{BACKG}$. The unitarized background amplitude differs from the previous analysis in order to maintain a correct behaviour at threshold for the partial amplitude. The main changes between the two analyses are :

- a better determination of S_{11} at low energies,
- a better determination of some structures above 1.9 GeV,

especially on the low angular momentum waves which permitted to include two more resonances of small elasticity : S_{31}(2.0 GeV) and D_{13}(2.029). These two partial waves are displayed on figure 1, with their respective speed plots.

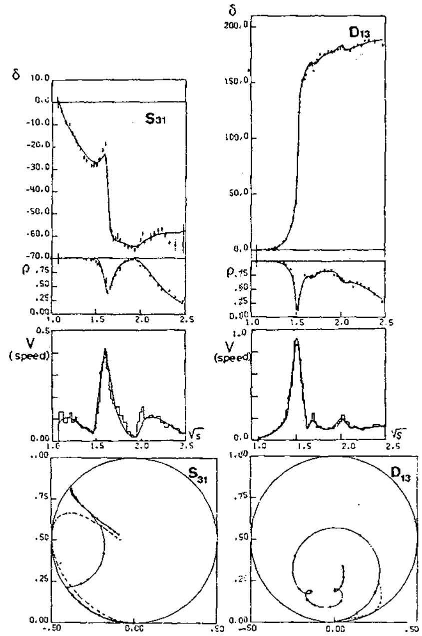

Fig.1.- S_{31} and D_{13} partial waves obtained in the 1973 Saclay phase shift analysis. Solid lines correspond to the fitted partial waves using a generalized Breit-Wigner approximation. New resonances are S_{31}(2.0 GeV) and D_{13}(2.029 GeV).

It should be noticed that the spacing between 2 energies at which phase shifts exist increases with energy. Above 2 GeV mass, the condition of 4 points along half a circle on the Argand plot to define a resonance puts Γ_{tot} > 150 to 200 MeV . New data (cross sections and polarizations) are needed to be sure that states of small elasticity and width have not been missed.

The use of a dispersion relation for the $B_{\pm}(\nu , t=0)$ invariant amplitude computed from the phase shifts has given an accurate determination of the pion-nucleon coupling constant : $f^2 = 0.0742 \pm 0.0013$ (Fig.11 of Butterworth's report).

2.2.- K^+N SCATTERING.- The BGRT collaboration has submitted the final version [12] of phase shift analyses including both I = 1 and 0 isospin states and performed up to 2.02 mass. The experimental data available contains the total, inelastic, differential cross-sections and polarizations for the K^+p (I = 1) channel. It includes $K^+n \to K^0p$ charge-exchange and $K^+n \to K^+n$ differential cross-sections, most of which were measured by this collaboration. It uses also total and total inelastic cross-sections for the I = 0 state but not the new total cross-sections from Brookhaven [13].

Three types of phase shift analyses have been performed : an energy-dependent analysis (5 parameters per wave) and two energy-dependent analyses. In one of them, the I = 1 partial waves were kept fixed at a solution coming from the analysis of the I = 1 channel alone [14].

These three methods yield similar results. In particular, 3 common families of solutions were found. Some checks with particular features of the data (new I = 0 total cross-sections and charge exchange polarization at 0.6 GeV/c) may be considered to favour the solutions which give the best Z_0^* candidate with the P_{01} wave. Fig.2 shows the corresponding Argand plots together with the ones of the best Z_1^* candidate (P_{13})

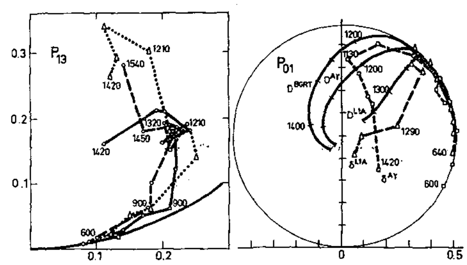

Fig.2.- Argand plots of : P_{13}, dotted line corresponds to the analysis of K^+p elastic channel alone and other lines come from the energy-independent analysis of I=0.1 states. P_{01}, energy-dependent (solid lines) and energy-independent solutions of the D class. (Numbers correspond to incident momenta (MeV/c)) .

Therefore a unique general solution is not obtained in K^+N analyses and no definite conclusion can be drawn on the existence of a Z^*. Clearly, more polarizations are needed to constrain the K^+N phase shift analyses. In particular, new deuterated polarized targets [15] open the possibility to measure polarizations in elastic and charge exchange K^+n scattering, which seems easier than the determination of A and R parameters in K^+p scattering.

3.- PARTIAL WAVE ANALYSES OF THE 3-BODY INELASTIC CHANNELS.- Three-body inelastic channels in $\pi^{\pm}p$ and K^+N scattering account for nearly all the total inelastic cross-section (about half of the total cross-section) below 2.0 GeV mass.

Two methods of analysis have been followed :

- analysis of quasi-two-body reactions, which have been isolated by cuts in Dalitz plots :

$$K^+p \to K^*(890)N \quad , \quad K\Delta(1230)$$

by a CERN-Saclay collaboration [16] : 70 000 events for $1.89 < \sqrt{s} < 2.1$ GeV .

- Generalized isobar model analyses of the whole final state, using the Deler-Valladas formalism :

$$\pi^{\pm}p \rightarrow \pi\pi N \rightarrow \pi\Delta \ , \ N\rho \ , \ N\sigma(\pi\pi)_{I=J=0}$$

Two partial wave analyses using this technique have been submitted :

- LBL-SLAC collaboration [17] : 200 000 events for $1.3 < \sqrt{s} < 2.0$ GeV (except for a 0.11 GeV gap $1.54 < \sqrt{s} < 1.65$).

- Saclay [18] : 30 000 events for $1.4 < \sqrt{s} < 1.54$ GeV.

We shall summarize these 3-energy-independent partial wave analysis, the partial waves being labelled $R_{2S}LL'_{2I,2J}$ where L is the incoming (π, K-N) angular momentum, L' the outgoing angular momentum between the resonance R : Δ, ρ, $\sigma(\pi\pi)_{I=J=0}$, $K^*(890)$ and the remaining particle (π,K or N). I and J are the isospin and total spin, S is the total intrinsic spin.

3.1.- SIMULTANEOUS PARTIAL WAVE ANALYSIS OF THE 3 FINAL STATES : K^+p , $K^*(890)N$, $K\Delta(1230)$.- Data have been measured at 4 energies covering the wide bump of the $I=1$ total inelastic cross-section.

The production angular distributions (expanded in Legendre polynomials) and the density matrix elements of the $\Delta^{++}K^o$ and $K^*(890)p$ have been used together with the data (cross-sections and polarizations) from K^+p elastic scattering. This analysis does not make use of the interference effects associated with the overlap of the K^* and Δ bands, i.e. it cannot relate in phase the two channels.

At each energy, several acceptable solutions were found, showing the following feature : the ΔK channel which is the only one for which reliable amplitudes can be obtained does not seem to be dominated by a single partial wave. Four waves were found important ; ΔSD_{31} , ΔPP_{33} , ΔDD_{35} and ΔFF_{37} .

The data were found also compatible with the duality hypothesis (all partial waves in phase) and with linear dependent energy parametrizations of the partial waves. These conclusions disagree with the analysis of the $KN \rightarrow K^*N$ scattering for which the $I=0,1$ Isospin states have been separated [22]. A peak statistically marginal is found on $\sigma_{I=0}$ near 2 GeV mass. Moreover, the $I=0,1$ interference term shows that non negligible imaginary parts of the amplitudes are present.

Clearly, a more sophisticated analysis based on the Isobar-model (which is in progress) is needed to give more precise results. In the present situation, the analysis is consistent with the non-resonant interpretation of the cross-section bump.

3.2.- ISOBAR MODEL ANALYSIS OF $\pi N \rightarrow \pi\pi N$.- The Saclay group and the LBL-SLAC collaboration are pursuing their own analysis. As noticed by C. Lovelace [19] several years ago, "Phase-shift analysis is one area where this duplication is useful. To have five groups trying to cut each others' throats is much more efficient than random searching".

The Saclay group [18] report preliminary results of an energy-independent partial wave analysis at four energies, in which they fit simultaneously the 3 reactions :

$$\pi^-p \rightarrow p\,\pi^-\pi^o \quad , \quad \pi^-p \rightarrow n\,\pi^+\pi^- \quad , \quad \pi^+p \rightarrow p\pi^+\pi^o \ .$$

Several improvements are introduced in the fits with respect to their previous analysis [18] :

- the fit of the channel $\pi^+p \rightarrow p\,\pi^+\pi^o$;
- the inclusion of unitarity limits ;
- a better parametrization of the σ and of centrifugal barrier factors.

The overall arbitrary phase is chosen by assigning to the ΔPP_{11} partial wave amplitude the phase of the elastic partial wave.

The LBL-SLAC analysis has been reported previously [20]. It utilizes the data in a very efficient way making a simultaneous maximum likelihood fit to all the events for the three channels mentionned above.

The analysis is confined to F waves or less (L, $L' \leq 3$) which allows in principle by spin-parity conservation 60 inelastic amplitudes. In fact, a quarter of them below 1520 MeV and about half of them above have been determined.

The absolute phase is specified by smoothing the solutions using a multichannel K-matrix fit of the dominant waves in three separate energy regions P_{11}(1310 - 1540 MeV), D_{15}, F_{15}(1650 - 1810), F_{35}(1810 - 1970). The overall inelastic phase is thus tied to the elastic phase.

COMPARISON OF THE RESULTS.- The Saclay group has kept more partial waves in his analysis than LBL-SLAC (24 instead of 15 around 1.5 GeV) and two of those additional waves are found to be important ρ_1PP_{11} and ΔDD_{15} .

In order to show the reliability of these analyses, we show on figure 19 of Butterworth's report the Argand plots of the 3 dominant waves for both analyses in the same energy range (1.38 - 1.54 GeV). There is a general agreement except for the ρ_1PP_{11} wave mentionned above. The differences observed indicate that these analyses have to be pursued.

Above 1500 MeV, the LBL-SLAC collaboration has recently found a <u>second</u> solution (still being explored [21] which contains three more waves than the one presented at the Batavia Conference. Those are

$\rho_1 PP_{11}$, ΔSP_{11} and ΔFF_{15} . The ΔPP_{11} has a different behaviour across the gap (see figure 22 of Butterworth's report). As a result, all other waves undergo an almost 180° rotation. Consequently, this changes the coupling signs of all the resonances above 1620 MeW relative to the low energy ones (P_{11},D_{13}) giving a good agreement between the relative signs of the $\Delta\pi$ and $\Sigma(1385)\pi$ amplitudes, as well as with the predictions of SU6 and the quark model.

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