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Experimental Meson Spectroscopy - 1972

(Third Philadelphia Conference)

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PREFACE

The biennial International Conference on Experimental Meson Spectroscopy was held for the third time at the University of Pennsylvania in Philadelphia on April 28 and 29, 1972. It was attended by about 200 particle physicists representing most of the groups working on particle properties, and including some theorists. Speakers were given two months to update and submit their papers, and of course some of these papers now contain more than was actually presented at the conference.

The Organizing Committee consisted of Jules Halpern (Chairman) and C. Baltay, H. Brody, Kwan-Wu Lai, A. H. Rosenfeld, P. E. Schlein, and W. Selove; Lai was chairman of the program committee, assisted by S. M. Flatté, D. Garelick, U. E. Kruse, and G. Zweig. The meeting again enjoyed the sponsorship of the University of Pennsylvania and the support of its Department of Physics, whose chairman, Max Caspari, made available the resources of the department and its administrative assistant, John Rappolt. J. Bensinger also gave very valuable assistance. We also thank Technical Information Division, at LBL, Berkeley, for its help with the editing, and in particular, Mr. Charles Pezzotti.

Jules Halpern, the able chairman of these conferences, died unexpectedly on May 13. With sadness over a personal loss, and a loss to physics, we dedicate these Proceedings to his memory.

Kwan-Wu Lai
Arthur H. Rosenfeld

July 1972

Julius Halpern

1912-1972

Jules Halpern, to whose memory these Proceedings are dedicated, was born on February 4, 1912 in Norfolk, Virginia, and received his undergraduate and graduate training in Physics at the Carnegie Institute of Technology. Jules' doctoral dissertation was directed by one of the great experimental physicists of the first half of this century, Otto Stern. Stern, the developer of the method of atomic and molecular beams and the discoverer of the directional quantization of atomic systems, was an impressionist artist in science and his aesthetic approach to the solution of problems in physics was extremely congenial to Jules, who possessed the same instincts and was quick to appreciate the touch of a master. Jules' work in Stern's laboratory culminated in his first important contribution to nuclear physics—the direct experimental demonstration, on the basis of the analysis of the scattering of slow neutrons in liquid ortho- and parahydrogen, of the spin dependence of the nuclear forces. After leaving Carnegie Tech, Jules worked for three years at the University of Michigan with Crane, pioneering in the development of nuclear-recoil methods for the detection of beta decay neutrinos. Investigations of the Halpern-Crane type, suitably extended and refined, have played a vital role in all further work in this field.

After his stay in Michigan, Jules was called by E. O. Lawrence to work in nuclear physics at the Berkeley cyclotron and then, at the end of 1941, was again invited by Lawrence to participate in the radar project at M. I. T. There, and also in England, and in France just behind the battle lines, Jules spent four years in work that was extremely imaginative technologically and of great military importance. It was also on a variety of occasions during this period that Jules exposed himself to considerable personal danger since he always insisted on direct observation of his equipment under typical field conditions.

After the war, overcoming the strong blandishments of Lawrence to return to Berkeley, Jules accepted Gaylord Harnwell's invitation in 1946 to join the Penn Physics Department. Here he resumed his research in nuclear physics, collaborating with Mann and with Stephens and directing the work of several students in what are now recognized as classic investigations on various aspects of photo-nuclear reactions. Then in about 1959, Jules decided to leave the domain of nuclei and to conduct research in the logically neighboring, though instrumentally, and to some extent conceptually, different domain of elementary particles. Jules' work in particle physics was highlighted by his definitive studies with Frankel, Wales, Chamberlain, and others in the early 1960's of the forbidden decays of the muon; these studies still provide some of the best evidence in support of lepton conservation. More recently, Jules and his collaborators investigated the neutral decay modes of the η-meson, of the ω-meson and, especially, of the ϵ-meson, employing effectively an ingenious version of the time-of-flight technique. It is obvious even from this brief account that Jules was active on the frontiers of particle physics research until his very last moment.

Jules' scientific career was officially honored by a fellowship from the National Science Foundation and by the distinguished alumnus award from Carnegie Tech. One must also recall Jules' vital role in the establishment of the Princeton-Pennsylvania Accelerator which did so much good work during its rather short lifetime and his leadership in bringing to Penn the International Conferences on Meson Spectroscopy.

Jules was a man of absolute integrity and invariably refused any compromise on matters of principle; because of this he was considered cantankerous by some and difficult by others, but it cannot be said that these judgments caused him much concern. In the late 1940's and early 1950's Jules was active in the campaigns against the unrestricted stockpiling of nuclear weapons and in 1952 he was chairman of the Federation of American Scientists. Jules was a devoted member of the scholarly community and spent many hours on University committees dealing with faculty rights and with academic freedom. Jules' death is indeed a grievous and irreplaceable loss to physics in this country.

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COMMENTS ON THE ππ SESSION

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ABSTRACT

Recent experiments have removed the long standing ambiguities in the s-wave I=0 ππ phase shift, δ_0^0. There is good evidence for a very sharp threshold-resonance effect near 980 MeV, and for a broad near-90° effect in the 700 MeV region.

Recent experimental progress from experiments of higher statistics has improved our knowledge of ππ phase shifts. The progress comes principally from the mainstay reactions $\pi N \to \pi\pi N$ and $\pi N \to \pi\pi\Delta$. While the extrapolation problem is still a complicated one (see P.K. Williams report[1]), and the full richness of new information on ππ angular distributions in these reactions is not yet thoroughly analyzed, we do have important new results bearing on the long troublesome s-wave isoscalar phase shift δ_0^0. The long-standing "up-down" ambiguities for δ_0^0 in the mass region from about 500 to 1000 MeV appear to have been resolved to a large extent, even if our knowledge of ππ phase shifts in this mass region is not yet totally precise.

The first step in this progress came from the Saclay group, who have reported[2] an extrapolation analysis that indicates unambiguous choice of the generally "down" type solution for δ_0^0 in the region 500 to 700 MeV. This analysis, and similar later results from other groups, indicates that δ_0^0 in this region is rising fairly rapidly, starting from 30° - 40° and rising to 50° - 70°, rather than following the considerably higher and flatter values of the "up" type solution.

These results were obtained by the Saclay group from an experiment with statistics some 4 to 5 times as large as any single previous experiment. With statistics again 2 to 3 times larger still, the Berkeley group[3] has found further new details which appear to resolve the up-down ambiguity in the higher mass region, particularly in the 900-1000 MeV region. They find very sharp features in $< Y_1^0 >$ and $< Y_2^0 >$ in a 10-MeV band at 980, and an accompanying shoulder effect in the mass spectrum at around 950, followed by a very rapid drop within 20 to 30 MeV. (These features have been confirmed in the still higher statistics CERN-Munich experiment.[4])

These new features in the 900-1000 MeV region lead to a very convincing interpretation that δ_0^0 is not far from 90° around 950 MeV, and thus rule out the old "up" solution in that mass region. It also seems clear that the s-wave I=0 amplitude undergoes a very rapid transition to a heavily inelastic value as the $K\bar{K}$ threshold

is passed, and that this sudden onset of inelasticity, accompanied probably by an immediately preceding rapid change in δ_0^0, is to be associated with the step-like change in $< Y_1^0 >$.

The precise behavior of the s-wave in the 900-1000 MeV region will presumably be determined when more complete analyses are made. A major tool in that final determination will probably be the use of information on the $\pi^0\pi^0$ mass spectrum in $\pi N \to \pi^0\pi^0 N$ reactions. These are difficult experiments, from the standpoint of statistics, isobar effect particularly at lower beam energies, and problems with background subtraction from multiple-π^0 events. Some data exist at higher beam energies, where some of these problems are less severe.[5,6] Examination of the results reported by Shibata et al[5,7] indicates that the fact that the $\pi^-\pi^+$ spectrum shows a shoulder at 900-950 MeV while the $\pi^0\pi^0$ spectrum drops steadily from 800 to 1000 Mev can probably be understood quantitatively if δ_0^2 continues to grow negatively to -25° or -35° at 950 MeV, as indicated by the Saclay work.[2] A definite determination of the behavior of δ_0^0 in the 900 to 980 MeV region would be strongly aided by an accurate measurement of the $\pi^0\pi^0$ spectrum in that mass region, at reasonably high beam energy.

The detailed behavior of δ_0^0 between 700 and 900 MeV is not known at this time. It is not possible that it follows the old "up" solution for any appreciable distance and then goes back toward 90° -- this would be incompatible with the $\pi^0\pi^0$ mass spectrum, which would then have a dip above 700 or 750 MeV. Whether, however, δ_0^0 simply grows slowly up toward 90° around 900 MeV, or instead goes slightly beyond 90° and remains almost stationary, is not known. If one takes the extrapolation-type phase shift analysis seriously, the former is true. Improved $\pi^0\pi^0$ data will probably give an answer to this question.

Meanwhile, Gutay[8] has pointed out that the isotropic term in the $\pi\pi$ angular distribution for $\pi N \to \pi^-\pi^+ N$ shows a peak at the ρ^0 mass that does not have a totally convincing interpretation as coming from the (absorption-"depolarized") ρ^0 itself, and he accordingly suggests reserving judgment on the detailed δ_0^0 solution given for the ρ^0 mass region by Protopopescu et al.[3] His cautionary note is appropriate, though one should be cautious both ways-both as regards the phase-shift results of the Berkeley group, and as regards the question whether the peak in the isotropic term, which is a very small fraction of the dominant $\cos^2\theta_{\pi\pi}$ term, really indicates an s-wave effect. Extrapolation procedures which seem on the face of it very reasonable may give very inaccurate results---a noteworthy example is for the $\omega^0 \to \pi^-\pi^+$ effect, which should disappear in a correct extrapolation to the pion pole, but which the Berkeley group point out is enhanced when they extrapolate their data to the pole.

I remark here on Odorico's discussion[9] of another interpretation of the rapid step in $< Y_1^0 >$ at 980 MeV. His interpretation both relates this step to known variations in $< Y_1^0 >$ in other reactions, and suggests a particular type of behavior of dips in angular distributions more generally. It will certainly be interesting to see how his predictions compare with further experimental

results. Meanwhile, as concerns the 980 MeV effect in the $\pi\pi$ system, it seems clear that this effect is very strongly an s-wave effect, while Odorico's mechanism would appear to predict simultaneous effects in many partial waves, and in particular would appear to predict a sudden decrease in the $\pi\pi$ p-wave cross section perhaps larger than in the s-wave cross section. There seems to be no evidence of such a p-wave decrease.

Thus we appear to have evidence for a very sharp behavior of the 0^+ I = 0 system near 980 MeV. This sharp behavior is certainly associated with the opening of the $K\bar{K}$ channel. Is a distinction possible between a purely threshold effect and a "real" resonance? That is, should one attempt to distinguish between S-matrix pole effects occurring sharply near a threshold, and other poles not obviously identifiable with any sharp threshold effect? Perhaps this question has no practical meaning. Without a full dynamical theory, however, perhaps we should keep open the possibility that "energy levels" corresponding to poles at threshold may not fit into mass relationships of unitary symmetry groups in the same way as other "energy levels." Any theoretical enlightenment on this question would be welcome. Meanwhile, pending such enlightenment, and perhaps pending more precise experimental information on the $K\bar{K}$ and $\pi\pi$ systems above 980 MeV, "the" Tables should certainly include a listing, near this mass, of a 0^+ I = 0 "effect" -- and a similar listing of an $\epsilon(700)$ effect.

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ππ PHASE-SHIFT ANALYSIS FROM AN EXPERIMENT $\pi^- p \to \pi^-\pi^+ n$ AT 17.2 GeV/c

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(Presented by W. Männer)

ABSTRACT

The ππ phase-shifts have been determined by a Chew-Low extrapolation in the ππ mass region from 500 to 1500 MeV using data of a spark chamber experiment on $\pi^- p \to \pi^-\pi^+ n$ at 17.2 GeV/c, which yielded 318,000 events. We find an I = 0 s-wave phase shift which increases slowly, passing through 90° near 900 MeV, and then rises very rapidly. The old "up" solution is eliminated on the basis of fits in the mass region from 900-1000 MeV.

INTRODUCTION

We present a ππ phase-shift analysis from an experiment observing $\pi^- p \to \pi^-\pi^+ n$ at 17.2 GeV/c, which yielded 318,000 good events. The experiment was performed at the CERN Proton Synchrotron using magnetostrictive wire spark chambers. A description of the apparatus and details of the moment analysis have been published elsewhere[1-4].

DISCUSSION OF THE DATA

Extensive Monte Carlo calculations were performed to correct for losses due to the limited acceptance of the apparatus. Using a least squares fit we determine the spherical harmonic moments $\langle \mathrm{Re}\, Y_\ell^m \rangle$ defining the differential cross-section as

$$\frac{d^4\sigma}{dM dt d\Omega} = N \sum_{\ell=0}^{\ell_{max}} \left\{ \langle Y_\ell^0 \rangle \, Y_\ell^0(\Omega) + 2 \sum_{m=1}^{m_{max}} \langle \mathrm{Re}\, Y_\ell^m \rangle \cdot \mathrm{Re}\, Y_\ell^m(\Omega) \right\} , \qquad (1)$$

where $N \propto d^2\sigma/(dMdt)$ is the number of events produced per (M,t) bin.

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