Mev and experimentally it was found to be 37 Mev, but since the distance traveled in the emulsion was only 100μ the possibility of the π's having 27 Mev cannot be excluded.

Next, the production of the τ's was discussed. Amaldi noted that all except one of the particles observed were produced at mountain altitudes under considerable amounts of absorber. The Bristol τ's were observed under 10 and 30 cm of lead respectively. The London τ's were found in plates exposed under 1 - 3 meters of ice. The Padua τ was observed under aluminium. The only exception known until now is the Rome τ which was observed in a plate flown at 25,000 meters with very little material surrounding the plate.

THEORETICAL DISCUSSION OF PHOTOMESIC PRODUCTION AND PION-NUCLEON SCATTERING

Friday afternoon (Part II), Prof. J. R. Oppenheimer presiding.

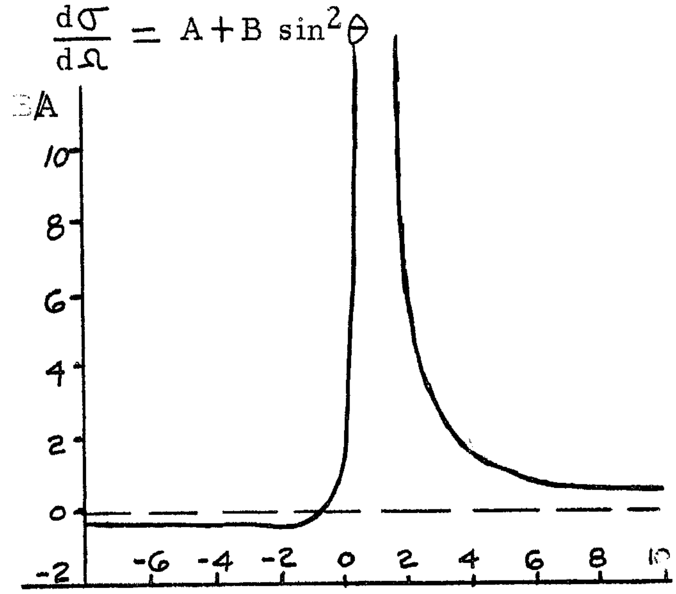
The session was opened by Oppenheimer who requested comments from Feld, Chew and Dyson. Feld discussed the interpretation of the photoproduction of mesons, that is, the processes $\gamma + p \to \pi^+ + n$ and $\gamma + p \to \pi^0 + p$. The point of view adopted is that of Brueckner and Watson, namely, to correlate photoproduction to pion-nucleon scattering. The most important processes are those involving three states of the pion and nucleon characterized by the total angular momentum J and the parity of the pion with respect to the proton, as summarized in the table.

Transition caused by:	J	Parity	Amplitude
electric di	1/2	-	a
magnetic di	1/2	+	b
magnetic dipole (or electric quadrupole)	3/2	+	c

The possibility of electric quadrupole pion production in a 3/2 state is neglected because the observed angular distribution corresponds to magnetic dipole transitions. The most general angular distribution possible for these three states is given by

$$\frac{d\sigma}{d\Omega} = |a|^2 + |b|^2 + |c|^2 (1+1.5 \sin^2\theta)$$
$$+ 2 \operatorname{Re} \left[a (b-c)^*\right] \cos\theta$$
$$-2 \operatorname{Re} bc^* (3/2 \cos^2\theta - 1/2)$$

Which terms are the most important? In the production of π^0 mesons we can drop the electric dipole term since close to threshold the matrix element depends on the cube of the momentum of the π^0 meson. Hence, the π^0 meson is being emitted into a p state and since it is pseudoscalar, it can only come from a positive parity state. Therefore, the only remaining question is the ratio of the $p_{1/2}$ and $p_{3/2}$ contributions. It turns out that because of the interference term, if we describe the cross section as $(A + B \sin^2\theta)$, then the ratio B/A gives a sensitive test of this mixture. Actually, the ratio B/A depends on three constants: b, c, and the relative phase between them; for simplicity we neglect the phase, that is, assume it to be 0 or 180°. The resulting dependence of the ratio B/A on the admixture of $p_{1/2}$ and $p_{3/2}$ is given below.



Ratio of $p_{1/2}$ to $p_{3/2}$ contributions = b/c

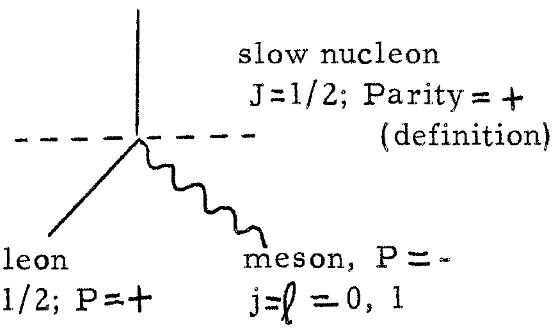
The most striking feature of this curve is its extreme sharpness in the region of the experimentally observed values. This allows a very precise determination of the $p_{1/2}$ to $p_{3/2}$ ratio from a very inaccurate measurement of B/A. For example, the best experiments only limit the ratio B/A to the range 1 - 7; nevertheless, this implies that the $p_{1/2}$ to $p_{3/2}$ ratio lies between 0 and 0.4. The second point to note is the double-valued nature of the curve, that is, it is impossible to exclude in this way a large $p_{1/2}$ to $p_{3/2}$ ratio rather than vice versa, just as it is impossible at the present stage to exclude the Yang type phase shifts as compared to the Fermi type phase shifts. Feld suspects that the scattering is a better way to determine experimentally which ratio in fact holds. The effect of electric dipole production of charged mesons has already been dis cussed.

The second point Feld made had to do with the resonance in the neutral photo-meson production so strongly indicated by the Cal. Tech. data. If there is a true resonance, it will in fact make itself felt even at the threshold, that is, in distorting the p^3 dependence of the meson matrix element. Thus even if the resonance were of zero width and occured with a peak at 300 Mev, the resonance factor $\frac{1}{(E-E_r)^2}$ would contribute at threshold. The effect of this term is indicated on page in comparison with Goldschmidt-Clermont's excitation curve. The data is not yet good enough to say whether or not the resonance manifests itself near threshold, but it is conceivable that a considerable improvement in experimental accuracy could settle this point. Finally, the resonance may not be as strong as one would think at first sight. Thus, the Cal. Tech. measurement has been made at 90°; if the magnetic dipole dependence $(1+1.5 \sin^2\theta)$ is most important, this gives a maximum at 90 However, the possibility which we neglected at lower energy of electric quadrupole production in the 3/2 positive parity state could occur at the higher energies with its angular dependence of $(1+\cos^2\theta)$ which has a minimum at 90°. Further, the interference effects have not been calculated. Hence, part of the reduction in the cross section beyond the maximum could be due to the reduced contribution at 90° due to the increasing importance of the electric quadrupole term. This might perhaps explain a factor 2 but not the observed decrease of a factor 4.

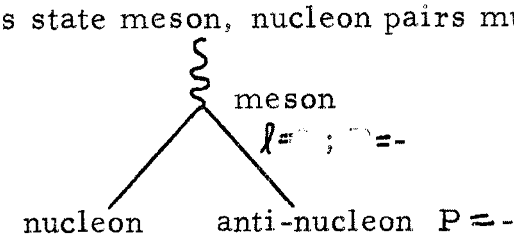
Marshak injected one word of warning about the photoproduction resonance. The rise in the cross section comes only from dropping the recoil terms in the usual perturbation theory calculation and even a weak coupling calculation would predict a drop in cross section beyond a certain energy. Oppenheimer added that the drop is a pretty major thing and thought that though it might in part have to do with the instrumentation and in part with the importance of recoil and in part with the shifting importance of quadrupole and dipole terms, it also does suggest that there is a maximum at a rather special energy for the system. Bethe commented with regard to the double valuedness of the $p_{1/2}$ to $p_{3/2}$ ratio, that if you replace Fermi's phase shifts by Yang's phase shifts, you do get exacly the same angular distribution in scattering.

Brueckner commented that the charge independence arguments which were discussed yesterday also show that if S wave is not active for neutral mesons, then the S wave photoproduction for charged mesons would be the same for neutrons and protons, and that these are very intimately connected together. Hence, if one could actually show the absence of that term in the neutral photoproduction for both neutrons and protons then one could conclude that the equality of the charged meson production is not at all surprising.

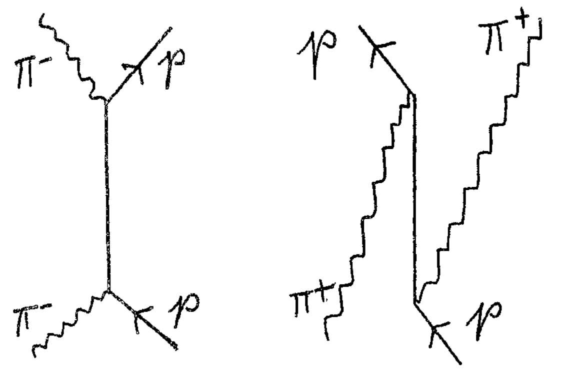
The discussion now shifted to the pion-nucleon scattering problem. Chew began this discussion with what he characterized as a simple-minded theoretical attempt to understand the problem on the basis of Yukawa's fundamental idea. He had agreed to make the following rather glib statements only with the understanding that Dyson and Bethe would not contradict him at this session, but would take up these points in the technical theoretical session. The main feature of the Yukawa theory is that the fundamental process consists of the emission or absorption of a single pion. If we assume that the motion of the nucleon is unimportant compared to the motion of the pion, that is, that nucleon pairs are not important, then the large interaction between the nucleon and pion must be in p states. This can be seen by considering the following diagram:



The slow nucleon has angular momentum 1/2 and we arbitrarily define its intrinsic parity P as positive. Then the emitted nucleon continues to have j=1/2 and positive parity, and we can ask what must be the angular momentum and parity of the emitted meson. Clearly it can only have angular momentum equal to either 0 or 1, and since its intrinsic parity is negative with respect to the proton, the parity of the angular momentum state must be negative. Therefore parity restricts us to $\ell=1$, that is, to p states. It is clear that in order to absorb an s state meson, nucleon pairs must be employed as indicated in the second diagram. This is clear since the parity of the initial state is odd and the intrinsic parity of a nucleon pair is odd for Dirac particles; therefore, the same argument applies. Consequently, if we ignore nucleon pairs we need discuss only p wave interactions. Chew has reason to believe that the coupling is in fact intrinsically weak, although these arguments are certainly controversial; however, one can start out by being optimistic and see where this leads.



The problem is, therefore, to discuss the basic meson-nucleon interaction using only these fundamental ideas from the Yukawa theory. The two basic processes are then schematized in the following diagram. The first diagram indicates



the absorption of a negative meson by a proton followed subsequently by the reemission of the negative meson. The second diagram consists of the emission of the final positive meson prior to the absorption of the initial positive meson by a proton. The second process is less controversial since it does not involve the difficulties with the self energy of the nucleon. Therefore, the discussion will be limited to the process in which the final pion is emitted before the absorption. We characterize the p wave coupling by a symbol f and ask what phase shift it will give rise to if it is small. By using a straightforward perturbation theory and charge independence, it is then possible to break down the p wave scattering into four non-interacting states characterized by angular momentum 3/2 and 1/2 and isotopic spin 3/2 and 1/2. The corresponding phase shifts have been called by Fermi α_{33}, α_{31}, α_{13}, and α_{11}, where the first index is twice the isotopic spin and the second index is twice the angular momentum. The result of the calculation is given in the table below:

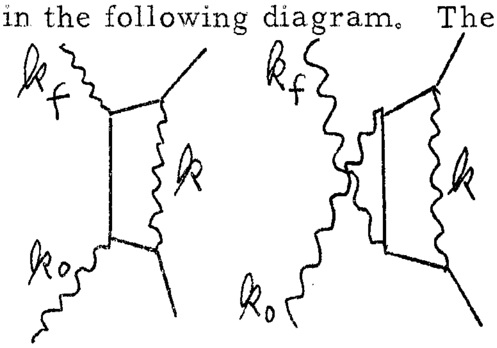
$$\alpha_{33} = 2x \qquad \text{where } x = \frac{2\, f^2\, k_o^3}{3\mu^2\, w_o} \qquad \text{and} \quad k_o = \text{meson momentum}$$

$$\alpha_{31} = -x = \alpha_{13} \qquad\qquad \mu = \text{meson rest mass}$$

$$\alpha_{11} = -4x \qquad\qquad w_o = \text{meson energy } (\mu^2 + k_o^2)^{1/2}$$

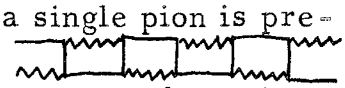
These are the well known weak coupling results for the p wave Yukawa scattering and are in disagreement with experiment; for example, they predict that the sc er-ing of positive or negative mesons have the same cross section while the charge exchange scattering is smaller; further, that the angular distributions are isot for the ordinary scattering and $\cos^2\theta$ for the charge exchange scattering. So it was formerly thought that the weak coupling approach could not possibly explain the experimental results.

However, Chew was more optimistic because of the indications that the interaction is in fact essentially weak and calculated the fourth order non-relativistic corrections, which are relatively simple. He wishes to emphasize that this should not be characterized as a pseudovector meson theory calculation since it is based only on momentum and parity arguments and not on a statement about the basic nature of the coupling. Two of the basic higher order processes can be schematized in the following diagram. The first describes the emission of a virtual meson of



momentum k, the absorption of the initial meson with momentum k_o, the emission of the final meson with the momentum k_f, and finally the reabsorption of the irtual meson with momentum k; clearly this diagram must be summed over all virtual momenta k. The second diagram indicates a similar process in which the final meson is emitted before the initial meson is absorbed. Both are proportional to f^4 and both contain an integration over intermediate momenta. It soon became apparent that there is a very basic difference in the size of the contribution from each of these two diagrams. In the first case only one meson is present at a time, while in the second case there are two additional mesons present. That means that in a perturbation calculation the energy denomenator which is associated with the intermediate state in the first case can become very much smaller than it can in the second case, because one can have an intermediate meson with an energy quite close to the energy of the initial meson. Therefore, when this energy approaches the energy of the incident meson, one will get an unusually large contribution to the scattering. This is well known from ordinary scattering calculations. For example, if you try to calculate the nuclear force according to meson theory and find the matrix element for nucleon-nucleon scattering, and calculate the scattering with it you obtain a very poor answer; but if the matrix element is used to derive a potential and this potential is then used to calculate the scattering [illegible] answer obtained is much better. The reason is simply that the second procedure takes into account higher order states which can have energies quite close to the initial state.

(Discussion was choked off at this point by Oppenheimer with the comment that Bethe and Dyson have renounced all our rights to make any comment.)

The procedure is therefore to take into account a sequence of higher order terms characterized by intermediate states in which only a single pion is present. This can be schematized by the following diagram: 
The first thing we find is that we should be calculating the tangent of the phase shift instead of the phase shift. This well known result is due to Heitler and corresponds to picking out just the intermediate state with the value of the momentum of the intermediate meson equal to the initial momentum. In our approach we propose to keep in addition those values of k in the same neighborhood as the initial momentum and not just that value which is precisely equal to it. The result is that the original formulae are damped in the following way:

$$\tan \alpha_{33} = \frac{2x}{1 - 2\Delta}$$

$$\tan \alpha_{31} = -\frac{x}{1+\Delta} = \tan \alpha_{13}$$

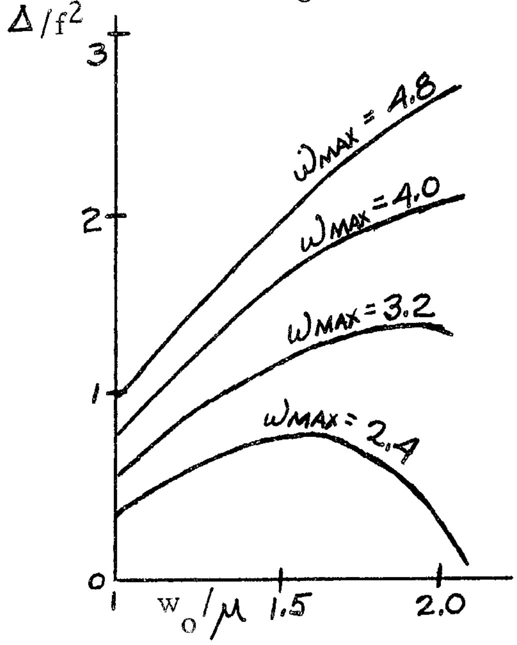
$$\tan \alpha_{11} = -\frac{4x}{1+4\Delta}$$

Here Δ is the integration over intermediate meson momenta or, as Chew calls it, the reaction term in the scattering, given by the formula:

$$\Delta = \frac{2}{3}\,\frac{f^2}{\mu^2} \int_0^{k_m} \frac{d^3k}{(2\pi)^2}\,\frac{k^2}{w^3} \left[\frac{w_0}{w - w_0}\right]$$

This integral is divergent as it stands and so it is necessary to give a maximum value to k_m to cut-off the integral; the divergence is due to the omission of the recoil energy of the nucleon. For the energies now under investigation, [illegible] is intrin[illegible]ally positive [illegible] reasonably high values of the cut-off momentum; this, of course, adds twice as many parameters to the theory as we had initially. It is seen that all but $_{33}$ are decreased by the reaction. There is a simple correlation which explains this, namely, positive phase shifts are increased by the reaction while negative phase shifts are decreased by the reaction, the change being proportional to the original size of the phase shift. The above formulae are based on one of Schwinger's variational principles. They are valid so long as the non-relativistic cut-off approach is valid, and even if the cut-off approximation fails they will indicate correctly the direction and order of magnitude of the reaction effects. As Dyson will point out, if the high frequency pions cannot be eliminated, then the variational formula is quantitatively inadequate for the 33 state when a resonance occurs. The values of the parameters, f^2 and k_m, which are used here to fit the data as shown correspond to the resonance being approached but not reached.

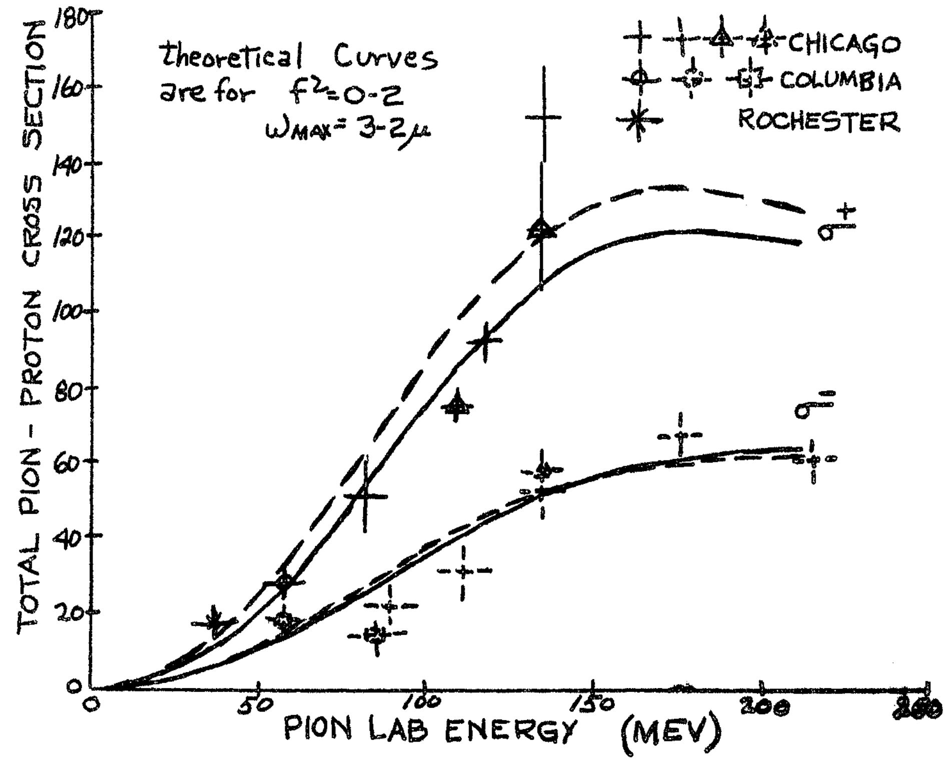
Physically, our method corresponds to saying that there exists a potential between the meson and the nucleon which is giv[illegible] by the first order matrix element of the interaction. The iteration of this potential then gives [illegible]ive corrections. The sign of the matrix element gives the sign of the potential, a positive sign corresponding to a repulsive potential. An attractive potential gives a positive phase shift, in this case α_{33}, and as usual the reactive effects for an attractive potential are larger than for a repulsive potential. It is clear that the scattering will have a resonance in the 3/2-3/2 state if the reaction Δ is equal to 1/2. If the cut-off is fixed, the resulting behavior of Δ is indicated below. In the present experimental region Δ is increasing and we are approaching a resonance in a certain sense. It is still necessary to see if an appropriate choice of the cut make the higher order terms negligible. First, it is shown that the two parameters can be chosen to obtain agreement with experiment for $f^2 = 0.2$ and $k_m = 3.2\mu$. The agreement obtained is not a critical test of the parameters, since if α_{33} is given correctly by some combination of f^2 and k_m, another combination which also fits α_{33} will produce little change in the results. The cross sections and phase shifts calculated for these parameters are given in the table below, in comparison with the experimental values given by Anderson, Fermi, et al, Phys. Rev. 86, 793 (1952).

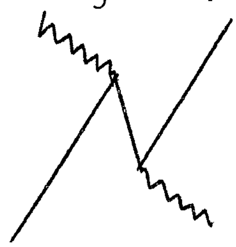


$$\frac{d\sigma}{d\Omega} = a + b\cos\theta + c\cos^2\theta \quad \text{(millibarns per steradian)}$$

Process	a	b	c
$\pi^+ \to \pi^+$	3.8 ± 2.2 (6.3)	-6.8 ± 2.7 (0)	17.5 ± 6.6 (9.4)
$\pi^- \to \pi^-$	1.2 ± 0.2 (1.2)	$-0.1 \pm .3$ (0	0.3 ± 0.7 (0.4)
$\pi^- \to \pi^0$	1.1 ± 0.6 (1.0)	-2.5 ± 0.5 ([illegible]	6.3 ± 1.9 (5.1)

Theoretical values for $f^2 = 0.2$, $w_{max} = 3.2\mu$ are given within the parentheses. Note that the old bad feature of $\sigma(\pi^+) = \sigma(\pi^-)$ has been overcome. If the S wave is small, it shows up only in the interference so that the correctness of this theory for the p wave is checked approximately by comparing with a and c alone. Hence the gross disagreement of the theoretical predictions with experiment has been eliminated; further, the approach is consistant since the terms which have been dropped are (with the above choice of parameters) only about 10% of those retained. Graphical comparison with experiment is given in the accompanying figure. The connection of Chew's approach to a more sophisticated theory will concentrate on the discussion of k_m. Chew used to be skeptical that the conventional γ_5 theory would give a sufficient cut-off but he is no longer so skeptical of this point. However, heavy mesons may well spoil complete agreement, so that Chew feels that it is sensible to work with a cut-off theory until a complete relativistic calculation is available. So far the s wave terms have been omitted in this theory. If we are to believe the pseudoscalar γ_5 theory with nucleon pairs, then the basic diagram is sketched below:



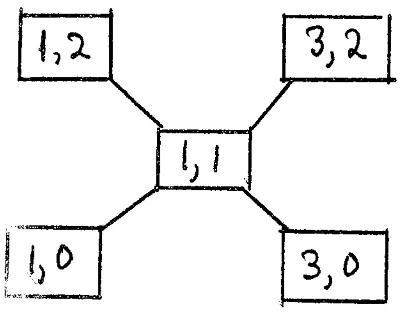


The s wave scattering gives a repulsive potential for both states and the result $\tan \delta_0 = G^2(k_0/M) \,/\, (1 + 0.35\, G^2)$ where M is the nucleon mass. The numerator is the weak coupling result with the nucleon mass appearing due to the pair creation. The denominator due to reactive effects has been estimated from the fourth order calculation of Ashki[illegible] Simon and Marshak. If the value of G^2 is as large as proposed by Lévy, then $\tan\delta_0$ is essentially independent of G^2 and is given by $\sim 3\, k_0/M$. Chew assumed that the damping would be the same in both isotopic spin states since the potential is the same for both, but this may well be incorrect. Damping does cut down the s wave scattering (which is in fact that due to a repulsive potential of short range) in spite of the large coupling constant, although it does not reproduce the difference between the two isotopic spin states or the rapid energy dependence. The discussion of these points will be left to Dyson. Chew's own feeling is that only the p wave calculation is believable since it does not involve the relativistic properties of the nucleon.

Dyson then described the investigation of the pion-nucleon scattering problem by the theoretical group at Cornell, which was started as a direct consequence of hearing what Chew had done. The people working on this are Bethe, Dyson, Salpeter, Ross, Sundaresan, Schweber, Mitra, and Visscher. We attempt to carry out the calculation of the meson-nucleon interaction using the full blooded relativistic theory, and in particular take seriously the relativistic properties of the nucleons. The method adopted is due to Tamm and Dancoff and will be explained briefly here. If we use the relativistic meson theory we find that a complete description of the meson-nucleon system cannot be expressed in terms of a single particle or a two particle wave function; one needs a wave function which represents a mixture of states with all kinds of numbers of particles present. That is,

$$\psi = \begin{array}{l} \psi_{1,1} + \psi_{1,2} + \psi_{1,0} + \cdots\cdots\cdots \\ + \psi_{3,1} + \psi_{3,2} + \psi_{3,0} + \cdots\cdots\cdots \\ + \psi_{5,1} + \cdots\cdots\cdots \end{array}$$

Here the first subscript refers to the number of nucleons present and the second to the number of mesons present, so that the first line corresponds to a single nucleon with 1, 2, 0 mesons, etc. present while the second line corresponds to three nucleons present with 1, 2 or 0 mesons, etc. The fundamental equation of the theory is the simple Schroedinger equation $H\psi = E\psi$ where $H = H_0 + H_1$ and H_0 corresponds to the non-interacting particle Hamiltonian, that is, H_1 corresponds to the energy of interaction. When this equation is expressed in terms of the components of the wave function, it becomes a complicated infinite array of coupled integral equations, and there is no chance of obtaining an exact solution. The basic idea is to restrict all considerations to a certain portion of the wave function, but to calculate the matrix elements exactly within this subspace. If we draw a coupling scheme, the states directly coupled to the initial state can be schematized as follows:



The approximation therefore consists in throwing away all other states. When this is done we find, for example, an equation for the one meson part of the wave function $\psi_1(k)$ defined by the equation $(H_0 - E_k - E)\psi_1 = \int dk' \; H_1(k, k')\,\psi_2(k, k')$. Here $\psi_2(k, k')$ is a wave function for two mesons of momenta k and k'. There will then be a second equation which defines ψ_2 in terms of ψ_1, and in general other wave functions as well, which are however dropped by our fundamental approximation. It is therefore possible to substitute the expression for ψ_2 into the original equation and obtain an equation for ψ_1 alone. This is precisely Lévy's procedure in the neutron-proton system, only he has carried it much further. However, we stopped here as it was not clear how to go any further. The main complication in the pion scattering problem is that the relativistic behavior of the nucleons is taken seriously. In Lévy's analysis of the neutron-proton system, he could make a consistent non-relativistic approximation, that is, he assumed that the nucleon wave function only contained low momenta and his final result confirmed this assumption. This is by no means the case for pion-nucleon scattering.

We were able to write down an integral equation for the ψ_1 part of the wave function alone, which restates the Schroedinger equation in our approximation. We were able to derive individual equations for each scattering state much as Chew has done. The phase shifts have been computed from these equations by means of a variational principle used by Chew. They confirm Chew's results very well. The relativistic properties do give cut-off at momenta comparable to the nucleon rest mass. Therefore we find the same qualitative behavior as Chew for α_{33}, namely a strong attractive potential close to resonance which is sensitive to the strength of the interaction. The other phase shifts are insensitive functions of the energy.

We have also tried to solve the isotopic spin 3/2 integral equations numerically in order to get a check on the general behavior of the space wave function and to estimate the accuracy of the variational principles used. It turns out that the estimates made by the Chew method for the α_{33} phase shift are very bad. For example, for $G^2 = 10$ at 110 Mev, the Born approximation result (2x) is approximately 5^o. The estimate by Chew's method gives a denominator of approximately 1/5 and hence a phase shift of about 25^o. But the exact solution yields 9^o. The reason is simply that the wave function is far from correctly given by the Born approximation. The reactive terms are greatly overestimated by such a variational principle. Therefore, it is difficult to get solutions for the α_{33} phase shift, which are accurate enough to be useful, even if we ignore the inaccuracy of the starting equations.

Actually, Bethe has performed a rather complete calculation which will be discussed in the theoretical session tomorrow. However, the results will be reported here to the full group. He used a coupling constant $G^2 \approx 14$ and obtained phase shifts approximately as a function of en rgy. The difficulty is that the actual energy of scattering occurs as a parameter and hence one has to solve the integral equation for each energy, which makes the amount of work very great. However, by approximate methods, Bethe finds that with this value of the coupling constant, the experimental values of the α_{33} phase shifts are fairly well represented; they go through a resonance at about 200 Mev and come down very sharply on the high energy side. This fall is much more rapid than a single term resonance formula would give, and is apparently in cated experimentally in the photoproduction, although the exact connection to the photoproduction is not at all clear.

Salpeter has also obtained a solution for the s states which confirm the results of Drell and Henley. That is, he finds a spin independent short range repulsion. Th s one has the scattering by a small hard sphere of radius roughly twice the Compton wave length of the nucleon, and the results are in good agreement with theirs. The results are, however, not in good agreement with the experiment. As Chew has said, the s phase shift is proportional to the momentum and the order of magnitude is correctly given as 15 to 20^o at 135 Mev. But the energy dependence is quite wrong. Furthermore, isotopic spin 1/2 phase shift is not calculated consist ntly. Experimentally it should be small; theoretically we don't know what it is. But the theory is unambiguous for the isotopic spin 3/2 s phase and gives a variation linear with the momentum. Therefore, if the phase shift is large enough at 135 Mev, it is much too large at 80 Mev and this is not by any means a consequence of our way of doing things. The point is, it does not matter to what order of perturbation theory you go, it does not matter how you set up your equations, as long as the meson must come in and interact with the proton, then the interaction has a range which is of the order of the proton Compton wave length, and a repulsive interaction of this range cannot give you phase shifts which are essentially different from hard sphere phase shifts. So the experiments re are certainly very interesting because they show unmistakably that there is a force of some kind of longer range than that. is is not included in our theory and if you went to better approximations would still not be included. Therefore, in S states at least we have something in the nature of a long range force acting in addition to the direct interaction of meson and proton. This is understandable only as a direct interaction of the incident meson with the meson in the meson cloud, which extends out to 10^{-13}cm from the proton. This would possibly explain the rapid energy variation of the s phase shift but this calculation has not been made exact as yet. So we cannot expect quantitative agreement without the inclusion of the long range term.

Oppenheimer asked Dyson to comment on the one parameter character of his theory and the problem of renormalization. Dyson said that one parameter is certainly an advantage. With regard to renormalization, we have to pay the penalty for a relativistic theory, with the result that so far this difficulty has not been overcome in the isotopic spin 1/2 state. The value of the coupling constant will certainly be strongly influenced by what is done about the renormali tion and it is already known that the α_{33} phase shift is extremely sensitive to the value of the coupling constant; for example, the resonance at 200 Mev which is obtained with a coupling constant of 14 is reduced to zero energy if the cou ling constant is increased to only 14.6.

DISCUSSION OF FERMI'S NEW PHASE SHIFTS; FURTHER INFORMATION ABOUT MEGALOMORPHS.

Saturday morning, Professor Oppenheimer presiding.

Oppenheimer opened the session by remarking that he thinks it is hardly necessary to say in behalf of everyone who has spoken on nuclear forces and π-mesons that it is not of course a question of getting a complete description of what goes on from the pseudoscalar meson theory. No one has any notion, for instance, of how one could in this way understand the masses of proton and neutron, or the magnetic moments of proton and neutron, or the difference between them, or the electrical properties of neutron, and no one understands how one will in detail get the small deviations from charge symmetry, but there have been big changes in the last few years. These are, that instead of on the one hand using manifestly inadequate mathematical tools to find out what this theory predicts, and on the other hand waving generally in the direction of the unknown, one has now found some way of getting a little closer to what the theory predicts. I think no one is sure that one can even read the theory with arbitrary accuracy; that is, that something better than a ough solution which cannot be impro d upon exists. This is an open question and I have no wisdom to add to it. But the point now is that one can recognize in the consequences of the theory some things which bear a remote resemblance to what is found in real life. So the comparison is instructive, and a good example is just the deviations from charge symmetry. If one had not thought of charge symmetry, one would not have noticed the 1% deviation. That is a problem for the future. In the same way if the p ogram outlined by Lévy, or the pro am outlined by Dyson should be successful, the success would be in indicating what was wrong. You couldn't do that before, ce there was no similarity between what seemed to be implied by these equations and anything anyone ever found, and it is only in that very general sense that it seems to me that an immense progress may have been started.