A.H. Compton
Ryerson Physical Laboratory
University of Chicago
Chicago Ill.

With regard to immediate concentration approve of standxxfx expressed by Anderson and Zinn.

B. Feld

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JOHN SIMON GUGGENHEIM MEMORIAL FOUNDATION
551 FIFTH AVENUE • NEW YORK 17 • N. Y.

December 19, 1952

The papers attached hereto are of an applicant for a Guggenheim Fellowship who has referred us to you this year. For your critical advice upon his candidacy we shall be grateful; and I assure you that anything you may say will be held in the strictest confidence.

Please accept our thanks for helping us to make the difficult decisions we must make.

Sincerely yours

Henry Allen Moe

Dr. L. Szilard

Dr. Feld and I have been very closely associated for a number of years in the Manhattan Project, and I have a very high regard both for his ability as physicist and for what you might call his moral fiber. Feld has always been widely read and up to date in his knowledge of those branches of physics which are under active development.

Feld's dissertation which was published after the war established his status as a mature scientist. Among his more recent contributions is his analysis of spin and parity of nuclear levels based on the study of the angular correlation of nuclear fragments in disintegration. This work is both experimental and theoretical, whereas his recent study of the inelastic scattering of neutrons is theoretical.

Even today, with a large increase in the number of both experimental and theoretical physicists, there are still very few who unite the ability of doing good experiments with the ability of handling modern theory. The importance of this group hardly has to be stressed and in view of Dr. Feld's scientific standing in this group as well as in view of the "Plans for Research" which he has submitted, I wish to recommend him strongly for a Guggenheim fellowship.

Dr. Leo Szilard

Institute of Radiobiology and Biophysics - University of Chicago

Plans for Research

PLEASE RETURN TO
JOHN SIMON GUGGENHEIM
MEMORIAL FOUNDATION

Bernard T. Feld

If granted a fellowship, I intend to engage in research (mainly theoretical) on the properties of high energy nuclear interactions, especially those involving meson production. In particular, my program would concentrate on investigating the extent to which it is possible to develop a phenomenological theory of such interactions without specific and direct recourse to meson field theories. The phenomenological theory would include the possibility of "resonance" interactions through the intermediary of nucleon "isobar" states. One of the main advantages of this approach is that it permits of the use of many of the techniques which have previously been successfully applied to the understanding of nuclear reactions in the "low-energy" range. The primary purpose of this investigation is to extract from the available evidence those features and physical aspects which are independent of any special meson theory and which must ultimately be included in any future successful meson field theory.

This program would include the following aspects:

(1) A review and consolidation of available experimental evidence, from cosmic-ray studies as well as from high energy accelerators, on the properties of nucleon-nucleon, meson-nucleon, and photon-nucleon interactions, especially insofar as they indicate the "selection rules" and form of "potential" necessary to describe the interactions. During the past year, I have been involved in experimental investigations on some aspects of photomeson production (refs. 16 and 17) and, more recently, I have made a start on the program of analyzing the photomeson production results according to the philosophy outlined above. The first results of this investigation are summarized in the attached note, which has been submitted for publication, as a Letter to the "ditor, to The Physical Review. My immediate program of research is to apply these techniques to the analysis of other high energy interactions.

(2) A consideration of the limitations, imposed by general considerations of relativistic invarience, etc., on the possibility of a simple description of high energy interactions. In particular, the effect of nucleon recoils may be to cause a breakdown of "selection rules" and a mixing of states, so that it may not be possible to ascribe a given reaction to a definite "intermediate state". For this part of the program, it will be necessary to familiarize myself with some of the techniques of meson field theories; I am especially interested in the so-called "strong coupling" theories, which lead to the prediction of nucleon "isobars" and which, consequently, hold forth the possibility of resonance reactions.

(3) Some consideration of the types of future investigations, especially with the ultra-high energy accelerators now in prospect, which may be expected to aid in the development of and to serve as tests of the

validity of a phenomenological approach as described above. It is, of course, not possible to predict in advance the most useful direction for research in a new energy range. However, it is not too early to begin to plan for the most effective utilization of the new tools which will so soon be in operation.

(4) Finally, and most important, I would like to investigate the possible relationships between the phenomena involved in π-meson interactions and other nuclear phenomena, both at low and at high energies. Thus, it is of interest to consider the production of other types of meson, V-particles, etc., from the same point of view. At the other energy extreme, it is important to try to understand the properties of nuclear forces at low energies--especially those aspects which may cast some light on the success of the independent particle model of nuclear structure.

The above represents a rather ambitious program, which could certainly occupy many physicists for many years. I would expect, during the year of my fellowship, to be able to make substantial progress in aspects (1) and (2), to obtain some results on aspect (3), and perhaps to obtain some slight insight into some of the questions included under aspect (4).

I intend to spend the fellowship year, during which I would be on leave from MIT, at the Cavendish Laboratory at Cambridge University, England, or at the University of Rome, or both. I have been invited to use the facilities of the Physics laboratories at both institutions. Both of the above mentioned laboratories have members who have been interested in the experimental and theoretical aspects of high energy nuclear physics. One of the main reasons for my choice of place of study is the fact that both of the above institutions are involved in the planning of a new cooperative European high energy physics laboratory; I would be most pleased if, as a result of my experiences in high energy nuclear research at MIT, I could make some contribution to the success of this venture.

On the Angular and Energy Distributions in Photomeson Production*

Bernard T. Feld, Physics Department and Laboratory for Nuclear Science, Massachusetts Institute of Technology

The experiments[1] on the production of neutral π-mesons by the reaction $\gamma + p \rightarrow p + \pi^0$, as well as the known features of positive π-meson photoproduction, appear to be describable in terms of a phenomenological (isobar) theory as developed by Brueckner and Watson.[2] However, since their theory adopts certain features of various meson field theories, it is of interest to consider the extent to which it may be possible to extract from the experimental information those aspects which are independent of any special meson theory. It must be emphasized in advance that all of the results of the following considerations are contained, either implicitly or explicitly, in the paper of Brueckner and Watson. It is perhaps worthwhile, however, to restate some of their results in a different form which may help to emphasize the general character of the conclusions and to highlight their physical significance.

In particular, as is well known, it can easily be demonstrated by the methods first developed by Hamilton[3] that, provided a reaction goes through an intermediate state of definite angular momentum, the angular distribution of the reaction products in independent of most of the specific features of the interaction. Let us consider the reaction $\gamma + p \rightarrow p + \pi^0$.

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* This work was supported in part by the joint program of the ONR and AEC.

1. See previous letter by Goldschmidt-Clermont, Osborne and Scott, which also contains references to other experiments.

2. K. A. Brueckner and K. M. Watson, Phys. Rev. 86, 92? (1952)

3. D. R. Hamilton, Phys. Rev. 58, 122 (1940)

Suppose that the proton absorbs a magnetic-dipole γ-ray ($\ell_\gamma = 1$, no parity change) and goes to an intermediate state of $J = 3/2^+$. (The positive parity is with respect to the parity of the proton.) The decay of the intermediate state, to a proton and π^0-meson, requires that the meson be in a p-state ($\ell_\pi = 1$), since the π-meson is known to have negative parity with respect to the proton (pseudoscalar) and since the next highest possible value of ℓ_π, three units of angular momentum, could not lead to the $j = \frac{1}{2}$ of the proton from a state of $J = 3/2^+$. Following the method of Hamilton, which permits the angular distribution to be expressed in terms of the most general quantum mechanical features of angular momentum vectors, we take the incident γ-ray to define the z-axis. The angular distribution of the reaction is then given by

$$W(\theta) = \sum_{m_i}\sum_{m_\pi}\sum_{m_\gamma} \Big| a(j_i \ell_\gamma : J ; j_f \ell_\pi)\,(j_i, m_i ; \ell_\gamma, m_\gamma / j_i, \ell_\gamma ; J, m = m_i + m_\gamma)\, D_{\ell_\gamma}^{m_\gamma}(0)\, \cdot$$

$$\cdot\, (j_f, \ell_\pi ; J, m / j_f, m - m_\pi ; \ell_\pi, m_\pi)\, Y_\ell^{m_\pi}(\theta, \varphi) \Big|^2 \qquad \ldots (\;)$$

where a is the matrix element (amplitude) for the reaction; D and Y are the vector and ordinary spherical harmonics, respectively: $j_i = \frac{1}{2}, m_i$ represents the initial proton state, $j_f = \frac{1}{2}, m_f$ the final proton state, J, m the intermediate state angular momentum quantum numbers; and $(j_1, m_1, j_2, m_2 / j_1, j_2 ; J, m = m_1 + m_2)$ are the Clebsch-Gordon coefficients, tabulated by Condon and Shortley.[4] These calculations have been carried out for a number of possibilities and the results are given in Table I. Also given in (the last column of) Table I is the expected dependence of the cross section, or $|a|^2$, near threshold on the momentum, p, of the π-meson in the c.m. system (i.e., neglecting the dependence on γ-ray energy).

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4. E. U. Condon and G. H. Shortley, The Theory of Atomic Spectra, p. 76, Cambridge University Press (1935)

Table I

Angular and Energy Distributions in the Photoproduction of π-mesons on nucleons

γ-ray absorbed	intermediate state	ℓ of π-meson	$W(\theta)$	π-momentum dependence
mag. dipole	$\frac{1}{2}^{+}$	1	constant	p^3
mag. dipole	$3/2^{+}$	1	$2+3\sin^2\theta$	p^3
elect. dipole	$\frac{1}{2}^{-}$	0	constant	p
elect. dipole	$3/2^{-}$	2	$2+3\sin^2\theta$	p^5
elect. quad.	$3/2^{+}$	1	$1+\cos^2\theta$	p^3
elect quad.	$5/2^{+}$	3	$1+6\cos^2\theta-5\cos^4\theta$	p^7

An interesting feature of the above results is that $W(\theta)$ depends only on the values of J and ℓ_γ. This is easily understood if one considers the inverse process; an incident π-meson along the z-axis cannot alter the m-value of the system and therefore, irrespective of the value of ℓ_π, leads always to the same intermediate states.

The ambiguity can, of course, be resolved by an observation of the energy dependence of the cross section near threshold. In the case of π^0-production, this turns out experimentally to be $\propto p^3$ of the meson (in the c.m. system) which, taken together with the angular distribution, indicates that the process is magnetic dipole absorption to a $J = 3/2^+$ intermediate state. In the case of $\pi^{\pm}$-production there is, however, strong indication of a first power p-dependence near threshold, which requires electric dipole absorption to a $\frac{1}{2}^-$ intermediate state.

As can be seen from Table I, there are a variety of possible reactions, even if we confine ourselves to dipole-absorption processes. Furthermore, if more than one of these processes occurs in the same reaction, it is possible to have interference effects.[5] We confine our attention to two possibilities only: magnetic dipole absorption to $J = 3/2^+$ and electric dipole absorption to $J = \frac{1}{2}^-$. The expected angular distribution is, then,

$$W(\theta) = |a|^2 + 2\,\mathrm{Re}\,(a b^*) \cos\theta + \tfrac{1}{2}|b|^2 (2 + 3\sin^2\theta) \qquad \ldots (2)$$

where b and a are, respectively, the amplitudes for the two processes.[6]

Now, the above analysis appears, at first sight, not to allow for the experimentally observed difference between π^0- and π^+-production on protons, since angular momentum considerations alone do not distinguish between the charge states of the meson and nucleon. Here, we can invoke the assumption of charge independence which introduces an additional quantum number into the system -- the isotopic spin. The two reactions

$$\gamma + p \rightarrow p + \pi^0$$

and

$$\gamma + p \rightarrow n + \pi^+$$

differ only in the relative amplitudes of the final state wave function in the isotopic spin 3/2 and $\frac{1}{2}$ components. In general, the reaction amplitudes are

$$a_J^{\pi^0} = \sqrt{\tfrac{2}{3}}\, a_{J,T=3/2} + \sqrt{\tfrac{1}{3}}\, a_{J,T=1/2} \qquad \ldots (3a)$$

for the first reaction, and

$$a_J^{\pi^+} = \sqrt{\tfrac{1}{3}}\, a_{J,3/2} - \sqrt{\tfrac{2}{3}}\, a_{J,1/2} \qquad \ldots (3b)$$

---

5. $W(\theta)$ is now computed by an additional summation, in Eq. (1), taken inside the absolute value signs and over the possible intermediate J-values.

6. It is also possible to include terms corresponding to magnetic dipole absorption to a $J = \frac{1}{2}^+$ state, which gives rise to an interference term $\propto (3/2\cos^2\theta - \frac{1}{2})$ which, however, does not lead to any asymmetry about 90° and which is not needed for the interpretation of the experiments now available.

for the second. Following Brueckner and Watson[2], we can choose $\sqrt{2}\, a_{\frac{1}{2}, 3/2} = -a_{\frac{1}{2}, \frac{1}{2}}$. With this choice (made only on the basis of the experimental evidence on π^0-production), the dipole-absorption and the interference terms vanish for the π^0 process, but remain for the π^+ process. We are still left with two arbitrary amplitudes for the magnetic-dipole process, i.e., $a_{3/2, 3/2}$ and $a_{3/2, \frac{1}{2}}$. There is, on the basis of the present photomeson experiments, no way of choosing these. However, the evidence from π-meson scattering on hydrogen has been interpreted[7] as indicating that $a_{3/2, 3/2} >> a_{3/2, \frac{1}{2}}$. The relative values of these two constants could also be obtained from a comparison of the cross sections for those parts of the π^0 and π^+ photoproduction reactions corresponding to magnetic dipole absorption (the $2 - 3 \sin^2\theta$ terms). In particular, for the assumption of $T = 3/2$ production only, the π^0-cross section would be twice as great as the π^+ cross section.

While the evidence is as yet by no means conclusive, the results on π^0-production taken together with the relative magnitudes of the $\pi^\pm$-scattering processes are suggestive of a resonance corresponding to a proton "isobar" state of angular momentum 3/2 in both ordinary and isotopic spin space.[2,6] However, the shape of the π^0 photo-excitation cross section is not well enough known to permit an evaluation of the "isobar resonance" constants. Further measurements, both on photoproduction and scattering, with improved accuracy and extended energy range, are required before an unambiguous answer can be given to the questions of the existence and properties of the isobar.

February 22, 1962

Professor Bernard Feld
Department of Physics
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Bernie:

I am enclosing two sets of press clippings and mail samples. Please ask your secretary to keep one set in your office which must not be loaned out and the other set she may loan to people at your instructions who want to take it home and read it overnight.

Sincerely,

Leo Szilard

Enclosures

Washington, D. C.
March 3, 1962

Professor Bernard Feld
Department of Physics
Massachusetts Institute
of Technology
Cambridge, Massachusetts

Dear Bernie:

The attached letter is meant for you and those others whose names are listed in the memo, "The Next Step". I should be very grateful to you for reading the attached letter and the enclosures, and for advising me as soon as possible whether you are willing to serve as an Associate.

I hope very much that you are willing to serve as a Fellow and that you are not going to disqualify yourself from serving on the Board of Directors of the Council.

Sincerely,

Leo Szilard

Hotel Dupont Plaza
Washington 6, D. C.
Telephone: HUdson 3-6000

Enclosures

P.S. I am enclosing the revised and final version of my speech, which will be printed in the April issue of the Bulletin of the Atomic Scientists.

LS

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WESTERN UNION

TELEGRAM

W. P. MARSHALL, PRESIDENT

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HAVE JUST LEARNED THAT WAYNE MORSE RECEIVED ONLY FIVE THOUSAND DOLLARS FROM SENATE DEMOCRATIC CAMPAIGN COMMITTEE AND NEEDS FUNDS STOP YOU HAVE PREVIOUSLY EXPRESSED INTEREST IN MORSE AND MIGHT WISH TO SWITCH YOUR SUPPORT TO HIM STOP IN THIS CASE PLEASE MAKE OUT YOUR CHECK TO MORSE AND AIRMAIL IT TO COUNCIL FOR ABOLISHING WAR 1500 NEW HAMPSHIRE AVENUE NW WASHINGTON DC

BERNARD T FELD PRESIDENT ALLAN FORBES DR VICE PRESIDENT.

COPIED FROM ORIGINAL IN THIS COLLECTION

29 January, 1964

Professor Bernard Feld
Department of Physics
Massachusetts Institute of Technology
Cambridge 38, Mass.

Dear Bernie:

Enclosed is a response, which I received from Frank Long, on my paper of January 2, which will appear in the March issue of The Bulletin of the Atomic Scientists.

Sincerely,

Leo Szilard

LS:jm

Enc.