39. G. D. Novelli and F. Lipmann, *ibid.* **182**, 213 (1950).
40. E. R. Stadtman, G. D. Novelli, and F. Lipmann, *ibid.* **191**, 365 (1951).
41. E. R. Stadtman and H. A. Barker, *ibid.* **184**, 769 (1950).
42. F. Lipmann and L. C. Tuttle, *ibid.* **158**, 505 (1945).
43. M. Doudoroff, H. A. Barker, and W. Z. Hassid, *ibid.* **168**, 725 (1947).
44. T. C. Chou and F. Lipmann, *ibid.* **196**, 89 (1952).
45. F. Lynen, E. Reichert, and L. Rueff, *Ann.* **574**, 1 (1951).
46. H. Chantrenne, *J. Biol. Chem.* **189**, 227 (1951).
47. D. Schachter and J. V. Taggart, *J. Biol. Chem.* **203**, 925 (1953).
48. P. A. Srere and F. Lipmann, *J. Am. Chem. Soc.* **74**, 4874 (1953).
49. J. Bonner and B. Arreguin, *Arch. Biochem.* **21**, 109 (1949).
50. F. Lynen, *Harvey Lectures* **48**, 212 (1954).
51. D. E. Green, S. Mii, and H. R. Mahler, *J. Biol. Chem.* **206**, 1 (1954).
52. S. Ochoa, *Advances in Enzymol.* **15**, 183 (1954).
53. D. Shemin and C. S. Russel, *J. Am. Chem. Soc.* **75**, 4873 (1953).
54. M. E. Jones *et al., ibid* **75**, 3285 (1953).
55. M. E. Jones *et al., Biochem. et Biophys. Acta* **12**, 141 (1953).
56. M. E. Jones, *Federation Proc.* **12**, 708 (1953).
57. W. K. Maas, *ibid.* **12**, 241 (1953).
58. W. K. Maas and G. D. Novelli, *Arch. Biochem. Biophys.* **43**, 236 (1953).
59. F. Lipmann, in *Mechanism of Enzyme Action,* W. D. McElroy and B. Glass, Eds. (Johns Hopkins Press, Baltimore, 1954), p. 599.

This morning, looking out of our window, I was deeply moved to see that the flags had come out to honor men whose only claim to fame may seem that they succeeded in finding answers to some of the mysteries of nature. Their purpose often may be none but just to push back a little the limits of our comprehension. Their findings mostly have to be expressed in a scientific language that is understood by only a few. We feel, nevertheless, that the drive and urge to explore nature in all its facets is one of the most important functions of humanity. To make the general public truly aware of such seems to me one of the great achievements of the Nobel Institution.—[Remarks by Fritz Lipmann at the Nobel banquet, 10 Dec. 1953. See page 855.]

International Conference on Nuclear Physics in Glasgow

Rolf M. Steffen

Department of Physics, Purdue University, Lafayette, Indiana

ABOUT 300 physicists representing some 20 countries attended an international conference on nuclear physics held at the University of Glasgow 12–17 July. Sponsored by the International Union of Pure and Applied Physics and UNESCO, the conference was magnificently organized by the staff of the Glasgow Physics Department headed by P. I. Dee.

During the first 2 days of the conference attention was focused on problems of nuclear forces and nuclear scattering as well as on discussions of nuclear spectroscopy and on the understanding of nuclear data in view of the different nuclear models. After ample time for informal discussions provided by a river cruise on the third day, the conference continued with a somewhat more diversified program for the remaining days. The topics discussed included beta- and gamma-ray transitions, photodisintegration, theory of nuclear-energy levels, field theory, meson theory in general, π-mesons, high-energy experiments, and the production of heavy mesons and hyperons.

Neither spectacular progresses in theory nor excitingly new experimental results were reported in the 105 papers that were presented, but the conference offered an excellent opportunity for reviewing and summarizing the present position of nuclear and meson theory in view of the recently accumulated experimental data. Considering the wealth of material presented, only a limited number of papers can be discussed here in detail. A comprehensive report of the conference will be found in *Proceedings of the International Conference on Nuclear Physics, Glasgow 1954* (Pergamon Press, London), in press.

Following the welcome address by Dee, the first session, which was devoted entirely to the subject of *nuclear forces and nuclear scattering,* was opened by H. S. W. Massey (University College, London) with a review of the present status of the empirical study of nuclear forces. The information on these forces extracted from *low-energy* (up to 10 Mev) two-body phenomena such as proton-proton (p-p) and neutron-proton (n-p) scattering seems to be consistent with the charge-independence hypothesis of nuclear forces. The experimentally observed difference in the singlet scattering lengths of the p-p scattering and the n-p scattering can be accounted for by electromagnetic effects. Concerning the noncentral aspects of the nuclear forces, characterized by the tensor component, and in the low-energy region best evidenced by the nonspherical charge distribution (quadrupole-moment) of the deuteron, the decision concerning the charge independence is far more complicated and no decisive answer can be obtained from the low-energy data available at present.

Studies of the angular distributions in the p-p, p-d, and d-p scattering processes by means of photographic emulsions using a 9.5-Mev proton beam and a 19-Mev deuteron beam were reported by J. Rotblat (St. Bartholomew's Hospital, London). The differential cross sections were found to be about 15 percent lower than those measured by the Los Alamos group at the same energies. The analysis of the variation with angle of the p-p scattering seems to indicate a Yukawa type of potential for the p-p interaction. Absolute differential cross-section measurements for the elastic scattering of 20.6-Mev protons from deuterons were described by D. O. Caldwell (U.C.L.A.). The cross-sections show, in addition to the familiar deep minimum near 130°, a shallower minimum near 20° owing to Coulomb-nuclear interference. In the opinion of the speaker this should allow fitting the data with a unique set of phase shifts and, hence, provide a more stringent test for the theory than previous low- or intermediate-energy nucleon-deuteron scattering experiments.

The crucial problem in *high-energy phenomena,* as pointed out by Massey in his review talk, is again the question of the charge independence of nuclear forces and the character of the exchange forces. Accurate nucleon-nucleon scattering experiments at high energies and their interpretation provide the key to the solution of these problems. Results of measurements of the cross section and the angular distribution of the p-p, n-p, and p-d scattering between 40 and 95 Mev were reported by N. Ramsey (Harvard). The angular distribution of the p-p scattering shows an 8-percent rise between 90° and 40° in the center-of-mass system. The scattering cross section, measured at 90° in the center-of-mass system as a function of energy, varied smoothly between 11.5 millibarn/steradian at 40 Mev and 4.5 millibarn/steradian at 90 Mev and is consistent with the Berkeley and Chicago data. The results on the angular distribution of the neutron-proton scattering are in satisfactory agreement with earlier experiments. Similar measurements on the angular distribution of neutrons scattered by a liquid hydrogen target and detected by a large liquid scintillator were reported by R. Wilson (Oxford).

Massey also showed that the experimental *n-p scattering* data at high energies can be fitted by using the nuclear force parameters computed from the low-energy data, provided that the odd states do not contribute to the scattering. This is possible if the nuclear forces between the neutron and the proton are assumed to be half ordinary and half exchange forces (Serber force).

As far as the *p-p scattering* at high energies is concerned, the almost uniform scattering with angle and the slow variation of the cross-section with energy can be understood on the basis of the low-energy data. However, strong polarization effects of the protons in double-scattering experiments cannot be reconciled by using the same model.

At present there is not even a phenomenological model that adequately describes the simple scattering processes and at the same time satisfactorily explains the strong polarization effects observed on neutron and proton beams.

The polarization of a nucleon beam by a scattering process is due to the noncentral character of the nuclear interaction forces. Experimentally, the degrre of polarization of the scattered nucleon beam is observed by the azimuthal anisotropy in a second scattering process. Experiments on high-energy double scattering were described by B. Rose (Harwell), who reported on recent work on high-energy nucleon polarization at Harwell, where a polarized beam of 133-Mev protons having a polarization of 70 percent was obtained by scattering from a carbon target. This beam was then used to study the variation with angle of the polarization in p-p scattering and of the polarization in the elastic scattering of protons from various nuclei. Similar experiments with higher proton energies have been carried out at Berkeley and were discussed by A. C. Helmholtz. There it was also found that a deuteron beam, elastically scattered from carbon, becomes strongly polarized. J. B. Platt (Rochester) reported measurements with a polarized beam of neutrons, obtained from a Be or C target bombarded with a high-energy internal proton beam. Small but significant azimuthal anisotropies were detected for the recoil protons emitted in the second scattering process where the polarized neutron beam struck CH_2 or C targets. The effects were not markedly dependent on the proton energy.

Information on nuclear forces can also be obtained by considering the interaction between more than two bodies. Massey discussed the binding-energy calculations for H^3 and He^2 and in particular the split state of the He^5 nucleus, which is due to an inverted P doublet. The question arises whether this inversion is the result of a noncentral force of the tensor type or of a force with strong spin-orbit interaction. In order to explain the data satisfactorily by the latter type of interaction, a very large spin-orbit coupling must be assumed.

Also in the first session, a survey of the present status of the meson theory of the two-nucleon interaction was given by R. E. Marshak (Rochester). He pointed out that at present we do not have even the rudiments of a satisfactory theory. For some time the renormalizable charge independent theory for the pseudoscalar π-meson field using pseudoscalar coupling looked rather promising, although difficult calculations (owing to the fact that γ_5 is the fundamental operator) are involved. Fourth-order interaction terms have to be taken into account, owing to the large coupling constant ($G^2/\hbar c \approx 10$) and higher order terms seem to be of the same order of magnitude as the second- and fourth-order interaction. (Compare later paper by H. A. Bethe). Modifications of the theory, proposed by M. Levy in 1952 and further developed by A. Klein, were not very successful in eliminating these difficulties.

The next three sessions of the conference were devoted to *nuclear models and nuclear spectroscopy.* Very appropriately, this discussion was opened by J. A. Wheeler (Princeton) with a survey of nuclear models. The paper was centered around the question of how to reconcile the liquid-drop aspect of the nucleus, as evidenced by the formation of a compound nucleus in nuclear reactions, with the independent-particle aspect of the nucleus, as shown by the successes of the nuclear shell model. Why do the nucleons behave as though they are strongly interacting as in the liquid-drop model and at the same time show independent-particle motion? This question may be answered partially by the recent work of K. A. Brueckner, who derives an effective nuclear potential from the phase shifts for nucleon-nucleon scattering. Owing to the motion of the scattering centers (that is, the nucleons in the nucleus) there occurs a Doppler effect from which a refractive index of the nuclear matter can be calculated without knowing in detail the potential of the nucleon-nucleon interaction. This refractive index describes the effect of the (infinite) nuclear medium on the individual nucleon in a manner similar to the way the optical index of refraction characterizes the behavior of a beam of light in an optical medium. As a result of this approach, it may be shown that only nucleons near the surface show a spin-orbit coupling, a fact that helps in reconciling the strong-interaction and the independent-particle model of the nucleus. Wheeler also discussed the interweaving between the motion of a single particle and the collective modes of the nucleon motion. As particular problems related to this description of the nucleus, the following were mentioned: (i) the influence of deformations on the order of nuclear-energy levels, (ii) the preponderance of positive quadrupole moments, (iii) the selective emission in alpha decay of even-even nuclei, (iv) fluctuations in the dependence of effective surface tension and moment of inertia upon atomic number, and (v) correlation in direction between fission fragments and bombarding particle.

Further evidence of the collective motion of the nucleons in the nucleus was presented by A. Bohr (Copenhagen) who discussed the level structure in even-even nuclei owing to the rotational motion of waves on the nuclear surface. In numerous cases, particularly for heavy nuclei, the energy values calculated for these rotational states are in extremely good agreement with the experimental values. The speaker also discussed briefly the problems involved in the mathematical description of the nucleus on the basis of the unified collective and individual particle model (A. Bohr and B. R. Mottelson).

The rotational states of nuclei are easily excited by the Coulomb field of fast charged particles passing near the nucleus. Reports on these Coulomb excitation processes by alpha particles were presented by G. M. Temmer and N. P. Heydenburg (Carnegie Institution, Washington, D.C.). Some 130 energy levels in 60 nuclei were investigated, and in the great majority of the cases the level positions were in good agreement with the predictions of rotational states according to Bohr-Mottelson. A number of levels due to single-particle excitation, however, especially in medium heavy nuclei, were also observed with the technique of Coulomb excitation. These levels were distinguished from the rotational states by considerably smaller excitation cross sections.

An approach to the understanding of nuclear structure different from the unified collective-motion individual-particle model is the idea of mixed configuration states, where a particular nuclear state is described by a mixture of different individual-particle wave functions. Results of structure calculations for nuclei of mass 18 and 19 using the mixed configuration idea were presented by B. H. Flowers (Harwell). The calculated numerical results for the energies and radiative widths of low-lying even-parity states and the magnetic moment of F^{19} seem to agree quite well with experimental studies on the low-lying levels of this nucleus by Coulomb excitation and by the beta-decay of O^{19}, which were reported by D. H. Wilkinson (Cambridge).

Mixed configurations were considered by two more speakers to explain certain nuclear data. A. M. Lane (Harwell) pointed out that the individual-particle model, when extended to cover mixed configurations, offers a simple explanation of the striking difference between the reduced nucleon widths of resonance levels formed by *s* and *d* nucleon waves, on one hand, and of the levels formed by *p* nucleon waves, on the other hand. Slow-neutron cross-section data were discussed by J. M. Scott (Cambridge) on the basis of a model of the compound nucleus, which somewhat resembles the individual particle model but in which (i) mixed configurations and (ii) a potential well with sloping sides and an exponential tail were considered. Pronounced regularities in the observed magnetic moments emphasizing the importance of the individual particle aspect were discussed by K. M. Guggenheimer (Glasgow).

A general survey of the present status of the experimental knowledge of nuclear-energy levels and of the methods of determining their basic properties, such as the energy, angular momentum and parity, and lifetime, was given by S. Devons (Imperial College, London). The progress concerning the accuracy of nuclear measurements made in recent years and the applicability of new techniques in nuclear measurements—for example, stripping reactions, heavier bombarding particles, polarized particle beams, Coulomb excitation, resonance fluorescence—was emphasized. Of particular interest was Devons' discussion of his method of measuring extremely short lifetimes of nuclear levels. By measuring the difference in the Doppler energy shift of gamma radiation emitted from a nucleus that recoils by virtue of a preceding nuclear process and is stopped in different mediums, the lifetime of the nuclear state from which the gamma radiation is emitted can be determined. The method works best for lifetimes between 10^{-13} and 10^{-15} sec.

Following this excellent survey there were several experimental papers on nuclear reaction studies. W. W. Buechner (M. I. T.) discussed work on the energy levels of various nuclei with particular reference to results for the isotopes of beryllium, aluminum, and calcium. The levels were investigated by high-resolution magnetic analysis of the products of nuclear reactions. A survey of the type of information obtained from experiments on deuteron stripping was given by J. R. Holt (Liverpool), and some experimental results on (d, n) reactions were discussed. The role of the isotopic spin concept (related to the charge independence of nuclear forces) was clearly emphasized in a paper by K. W. Allen (Liverpool), who reported on a systematic study of the disintegration of light elements bombarded with 1-Mev He^3-particles and tritons. High-resolution neutron spectroscopy, as applied to an extensive study of the widths and spacings of resonances in heavy nuclei, was the subject of a talk by D. H. Hughes (Brookhaven). The experimental results for the ratio of the average reduced neutron width to the average level spacing of a single angular momentum state of the compound nucleus indicated a somewhat larger absorption-to-scattering ratio of nuclear matter in heavy nuclei than that assumed in the Feshbach-Weisskopf-Porter (cloudy crystal) model of the nucleus. E. R. Rae (Harwell) reported on studies of gamma-ray yields from the resonant capture of slow neutrons, using the Harwell linear electron accelerator as a pulsed neutron source in time-of-flight measurements.

A nice example of an experiment requiring techniques from very different fields of physics and chemistry is the alignment and polarization of nuclear magnetic moments by high magnetic fields at very low temperature on which S. Bernstein (Oak Ridge) reported. Making use of the hyperfine coupling between nucleus and shell in paramagnetic substances, a nuclear polarization of Mn^{55} and Sm^{149} nuclei to the extent of about 15 percent was achieved with magnetic fields of several thousand oersteds at temperatures of about 0.2°K. The samples containing the polarized nuclei were bombarded with a beam of polarized thermal neutrons, and the capture cross-sections of Mn^{55} and Sm^{149} were studied as a function of relative spin orientations of incident and bombarded particles.

After the numerous, sometimes conflicting, theoretical papers on nuclear models and the equally numerous reports on experimental studies relevant to these models, the excellent summary of the status given by V. F. Weisskopf (M.I.T.) was greatly appreciated. According to Weisskopf, the basic problem of nuclear structure—namely, the question whether the forces between the nucleons in nuclear matter and the forces between free nucleons are the same or not—is not yet decided. The individual-particle approach to the problem of nuclear structure is rather successful near closed shells, whereas between closed shells, where the core is highly deformable, the collective model of Bohr and Mottelson gives amazingly satisfactory results. Weisskopf was rather doubtful that we really understand the success of this model in predicting the exact energy values of excited nuclear states. Another problem about which the theoreticians are much concerned is the problem of nuclear radii. Experiments involving the charge distribution of the nucleus (electron scattering, mesic-atom experiments) give nuclear radii that follow rather closely the relationship $R = 1.1 \times 10^{-13}\ A^{1/3}$. On the other hand, nuclear radii determined on the basis of nuclear interactions (for example, nuclear cross-section data, radii used in shell model calculations) demand a considerably larger value: $R = 1.5 \times 10^{-13}\ A^{1/3}$. Thus the positive charge of the nuclei seems to be more concentrated toward the center of the nucleus as compared with the average nucleon density. There is also the possibility of reconciling the data by assuming nuclear shapes very different from the usual square well.

The program of session IV consisted of papers on *beta and gamma transitions*. In his review of the main current problems in beta- and gamma-ray spectroscopy, K. Siegbahn (Upsala) underlined the importance of very high resolution and high accuracy in the measurement of beta- and gamma-ray spectra. As the detection methods become more refined, the complexity of nuclear decay schemes becomes more and more evident, and high resolution is necessary to resolve the details of the spectra. An iron-free spectrometer of a momentum resolution of $1 : 10^4$ was discussed. With this instrument one can measure the natural width of conversion lines and determine the width of the levels from which the conversion electrons are ejected. The relative accuracy in electron-momentum measurements has been improved to 1.5 parts in 10^5, an accuracy that allows precise evaluation of atomic constants from beta-spectrometric data.

A paper distinguished by its clarity of presentation was given by C. S. Wu (Columbia) on the interaction in beta decay. The number of possible interaction operators between the nucleons and the leptons (electrons, positrons, neutrinos) can be reduced to five by requiring relativistic invariance. In view of their transformation properties, the coupling terms are called scalar S, pseudoscalar P, vector V, axial-vector A, and tensor T. The experiment must decide which interaction or which linear combination of interactions is predominant in beta decay. The assumption of either an A or T interaction leads to the Gamow-Teller selection rule for allowed beta transitions ($\Delta I = \pm 1$ or 0, no $0 \rightarrow 0$ transitions) of which the He^6 beta decay is an example, whereas the occurrence of the now well-established $0 \rightarrow 0$ transitions require a selection rule (Fermi) that can be explained only by assuming an S or V interaction. The momentum distribution of all spectra (except RaE) can be explained by any one of these interactions. The occurrence of both interaction terms A and T would give rise to the so-called Fierz interference term, which was not found experimentally. Thus either of the two must be much stronger than the other. Experiments on the electron-neutrino angular correlation of the He^6 beta decay (J. S. Allen and W. V. Jentschke, Illinois) showed that the T interaction is the predominant term. Similar arguments lead to the conclusion that the S interaction is the important one in the cases obeying the Fermi selection rule. The question now arises concerning the relative contributions of the S and T interaction. From a study of the super allowed beta transitions it follows that these two interactions are of about equal strength.

The notorious case of the beta-ray spectrum of RaE now seems to allow a satisfactory explanation. First, the angular momentum I of RaE was recently measured by K. Smith (Cambridge) using the atomic-beam method; the result, $I = 1$, showed that the RaE transition is not a $0 \rightarrow 0$ transition, as was assumed originally. Second, Yamada reinvestigated the effect of the finite nuclear size on the shape of the RaE spectrum and found satisfactory agreement with a combination of the S and the T interaction. Thus, considering the recent developments, the theory of beta decay seems to be in a quite satisfactory state at present.

Beta decay and the shell model was the subject of a talk by L. W. Nordheim (Duke), who presented statistics for comparative lifetime values in the light of the shell model. For allowed beta transitions and not too low A values, there is for odd A a distinction between "one-particle" and "many-particle" transitions, and for even A between "pairs" and "many-particle" configurations. In first forbidden transitions there is a favored group near the doubly magic 82 protons-126 neutrons configuration and a grouping according to the magnitude of spin change. There is furthermore a fairly marked distinction between nuclei with A below and above ~ 40.

M. Goldhaber (Brookhaven) presented a critical comparison of gamma-transition probabilities with the predictions of the extreme individual-particle model (Weisskopf formula). It seems that only magnetic 2^4 pole transitions, which have fairly uniform matrix elements throughout the periodic table, agree fairly well with the expectation for a single proton transition. Most other gamma transitions, however, are considerably slower than calculated on the basis of the single-particle model. In some electric gamma transitions the reduced transition probabilities can be explained because neutron jumps are involved or because more than one particle must rearrange in the transition. Gamma lifetimes considerably shorter than what the theory gives for single-proton transitions are found in the fast transitions between low-lying states, in particular for even-even nuclei far removed from closed shells. The increased transition probabilities and the regular dependence of their magnitude on A indicate again cooperative phenomena involving deformations of the nucleus as a whole. (See the discussion of the collective model of the nucleus.)

A direct measurement of gamma-transition probabilities—for example, by delayed coincidences—is difficult in most cases because of the short lifetimes of the nuclear states involved. Gamma-transition probabilities from a particular excited nuclear level can also be computed from the cross section for the resonance absorption of a photon exciting this nuclear state and subsequently being emitted from this state. Obviously this "resonance fluorescence" process is of observable magnitude only if the energy of the photon to be absorbed is extremely close to the excitation energy of the nuclear level. F. Metzger (Bartol Research Foundation) reported his cross-section measurements of resonance absorption in the scattering of Hg^{198}, Hg^{199}, and Tl^{203} gamma radiation by the same nuclei. A high linear speed, mechanically attained, compensated for the energy lost to recoil in emission and absorption. Also, Doppler broadening owing to thermal motion was employed to increase the absorption cross section. The magnetic dipole transition probabilities in the Hg^{199} and Tl^{203} were found to be between 100 and 1000 times slower than those calculated from the single-particle model. Similar resonance-fluorescence measurements on Cu^{63} were reported by Ilakovac (Birmingham).

Information on the relative gamma-transition probabilities can be obtained by determining the intensity ratio of the multipole components in mixed gamma transitions. This can be done very accurately by angular correlation methods, owing to the occurrence of interference terms in the correlation function. Measurements of mixed dipole-quadrupole transitions in even-even nuclei by means of angular correlation experiments were reported by R. M. Steffen (Purdue). In all cases investigated the relative intensity of the electric quadrupole radiation, as compared with the competing magnetic dipole radiation, was found to be about 1000 times larger than predicted by the independent-particle model. Several electric dipole transitions with very small admixtures of magnetic quadrupole radiation were also reported, a fact that speaks for a considerable reduction of the electric dipole matrix element in low-energy gamma transitions.

H. Albers-Schonberg (Zurich) discussed the influence of extranuclear fields on angular correlation measurements. It is well known that static and time-dependent electric or magnetic fields may cause a reorientation of the nucleus within the lifetime of the intermediate nuclear state and thus may change the correlation appreciably. The speaker reported on measurements of the gamma-gamma correlation of the Cd^{111} cascade using different delays in the coincidence arrangement, thus, on the average, exposing the nucleus for different lengths of time to the interacting fields. The delayed angular correlation displayed by solid sources (mainly static quadrupole interaction) shows the expected dependence on the delay time. Dilute aqueous solutions (mainly time-dependent quadrupole interaction), however, exhibited the same anisotropy with zero delay and with a delay of 4 times the lifetime of the intermediate nuclear state. This result would indicate no attenuating interaction in this type of source, a fact that is incompatible with earlier investigations on viscous liquid sources.

π-Mesons and their characteristics were the subject of session V, which was opened by H. A. Bethe (Cornell) with a general survey of the theoretical problems. Whereas there seems to be little doubt that the π-meson has spin zero and odd parity, the question of the coupling of the π-meson to the nucleon field is still far from a satisfactory answer. In fact, little progress could be reported on this extremely important and difficult problem. In general, two coupling schemes are considered: (i) the pseudoscalar coupling which gives finite results for every process in any approximation, because it is possible in this theory to use renormalization; and (ii) the pseudovector coupling which gives finite results in first-order approximation, but for which the higher order approximations are infinitely large and infinities cannot be removed by a renormalization process.

The coupling between the π-meson and the nucleon field can be explored experimentally by studying the scattering of π-mesons by nucleons or, in a somewhat more complex way, by studying the photoproduction of mesons which involves electromagnetic interactions as well. Still more complex is the production of mesons in nucleon-nucleon collisions.

Experimentally the cross section for the scattering of π-mesons on protons shows a rather sharp maximum near 200 Mev, and the analysis of the angular distribution shows that the scattering is predominantly due to P-waves. The latter could be understood in terms of the pseudoscalar coupling, whereas a further assumption is needed to explain the sharp maximum in the total cross section. In a perturbation theory calculation using only the first term in a power series in $G^2/\hbar c$, the pseudoscalar coupling predicts an almost uniform cross section with energy, whereas pseudovector coupling would give a cross section that rapidly and continuously rises with increasing energy. In addition, there is the difficulty that the observed cross sections for π^+ scattering are about 3 times larger than the corresponding cross sections for the scattering of π^-, whereas the theory based on the two coupling schemes gives roughly the same cross section for both cases. An assumption that seems to explain these and other data rather satisfactorily has been put forward by Brueckner and Watson and is based on the idea that the meson scattering is governed by the existence of a virtual $P_{3/2}$ compound state of the meson and the nucleon with total angular momentum $J = 3/2$ and isotopic spin $T = 3/2$. If it is assumed that the meson-nucleon compound state is about 350 Mev higher than the nucleon ground state, then the scattering cross section should have a broad resonance maximum near this state, as observed. The Brueckner-Watson model also predicts the 3-to-1 ratio of the total cross sections for positive and negative π-meson scattering and explains the observed ratio of the cross sections for charge exchange scattering ($\pi^- + p \rightarrow \pi^0 + n$) and ordinary scattering of negative mesons. The compound meson-nucleon state also seems to play an essential role in the explanation of the cross-section data for the photoproduction of mesons, for example, $\gamma + p \rightarrow n + \pi^+$.

A second maximum at about 1000 Mev was recently observed in the scattering of negative π-mesons on protons. No evidence of such a second maximum was found in the scattering of positive π-mesons. Thus one is tempted to attribute this second maximum in the π-p scattering cross section to a state of isotopic spin $T = \frac{1}{2}$. Preliminary calculations based on the Tamm-Dancoff theory, however, give no resonance for this state.

In the next paper R. R. Hildebrand (Chicago) reported on experimental investigations of π-meson production in nucleon-nucleon collisions. He gave further strong evidence for the charge independence hypothesis in π-meson production on the basis of a comparison of the energy and angular dependence of the cross section for the reactions $p + p \rightleftharpoons \pi^+ + d$ and $n + p \rightleftharpoons \pi^0 + d$. Again, the phenomenological model of Brueckner and Watson can explain the experimental results satisfactorily, except that in these reactions the deuterons are formed less often than predicted in the bound state, but rather individual neutrons and protons are observed.

Absolute total cross-section measurements of negative and positive π-mesons in hydrogen were discussed by J. Ashkin (Carnegie Tech.). The measured cross sections for the π^+ followed very well the curve representing 3 times the total π^- cross section, indicating that, in the measured energy range, the dominant interaction between π-mesons and nucleons occurs for $T = 3/2$. Comparison of the experimental π^- cross section with the maximum cross section $\sigma = (8/3)\pi(\lambda\text{-bar})^2$ calculated for the interaction involving the $P_{3/2}$, $T = 3/2$ state, again supports the idea that this state is especially prominent in the scattering process.

A. M. Thorndike (Brookhaven) described total π-p cross-section measurements at meson energies up to 1500 Mev with cosmotron-produced mesons. For the scattering of positive π-mesons on protons the cross section drops to about 27 millibarns at 450 Mev and is roughly constant at higher energies. The corresponding cross section for negative π-mesons drops to 25 millibarns but then rises to twice this value at 1000 Mev and drops again to 34 millibarns at 1500 Mev. This second broad maximum in the π-scattering curve is the one attributed to a $T = 1/2$ state, as discussed by Bethe. Cloud chamber and emulsion observations show that at the lower energies elastic scattering predominates, but at 1500 Mev many interactions lead to the production of secondary π-mesons. Several cases were observed where two secondary π-mesons were produced. Similarly, two π-mesons are frequently emitted in the production of mesons by nucleon-nucleon collisions at about 2000 Mev. The observations seem to be inconsistent with Fermi's statistical theory. The energy and angular distribution data suggest that the $P_{3/2}$ compound state may have a large influence on the π-meson production.

A study of interactions induced by 1500 Mev π-mesons in photographic emulsions, reported by Platt, revealed that the most common process at this energy appears to be the inelastic collision with single meson production. The analysis of the process seems to give further evidence of the π-meson-nucleon compound state.

The charge independence hypothesis in the meson-nucleon interaction predicts a ratio of 2 for the two competing processes $p + d \rightarrow n^+ + T$ and $p + d \rightarrow \pi^0 + He^3$, while Mayer and Bandtal at Berkeley found the experimental result 2.3 ± 0.3. Helmholtz reported on this and other recent π-meson work at Berkeley. There, Crawford and Stevenson observed a definite left-right asymmetry in the reaction $p + p \rightarrow \pi^+ + d$ with a polarized proton beam of 314 Mev.

Session VI was divided into four sections in which papers on *nuclear decay schemes and mesic x-rays,* on *photodisintegration,* on *detailed theories of nuclear models,* and on *field theory* were presented. Particular interest was displayed for the paper on measurements of x-rays due to meson transitions in the atomic orbits. Steinberger (Columbia) in his review of recent meson work at Columbia and Ashkin discussed the capture of μ-mesons in atomic orbits and the subsequent emission of x-rays involved in the transition of the μ-mesons from one atomic state to another one. Since the mass of the μ-meson is 207 times larger than the electron mass, the mesic atomic orbits have a correspondingly reduced Bohr radius, and the energy of the μ-meson x-rays is larger. From an accurate measurement of the x-ray energy the mass of the μ-meson can be computed. For these calculations electromagnetic corrections are important, especially the vacuum polarization due to virtual pair formation and annihilation in the electric field. Thus measurements of mesic x-rays provide an indirect check of the methods of quantum electrodynamics. Also π-mesons can be captured in atomic orbits and give rise to "π-meson" x-rays. The width of the atomic π-meson levels, however, is considerably larger than the width of the μ-meson levels owing to the strong interaction of the π-mesons with the nucleons in the nucleus. Quantitative information on the relative probability of radioactive transitions and nuclear capture of the π-meson in the atomic levels is obtained by measuring the fraction of stopped π-mesons which give rise to the mesic x-rays. Such measurements on K x-rays in Be, B, C, N, and O and of L-series x-rays in a range of elements from C to Fe were described by Platt. Similar measurements by DeBenedetti, Stearns, and Stearns and Leipuner were also reported by Ashkin. The Carnegie Institute of Technology group measured rather accurately, by means of the critical absorber technique, the energy of mesic L- and M-lines, for which nuclear effects are negligible at low atomic number Z, and obtained for the mass of the π-meson a value between 272.3 and 273.7 electron masses. The main part of the error is due to uncertainties in the K-edge energies of the critical absorbers used for the energy determination and in the vacuum polarization correction. Owing to the proximity of the mesic K-orbits and the nucleus, specific nuclear interactions may play an important role in determining the energies of the mesic K-levels. There are indications that the energy of the mesic $2p$-$1s$ transition of Be is lowered, apparently owing to a specifically nuclear repulsion between the π-mesons and the Be nucleus, whereas that of the $2p$-$1s$ transition of B seems to be raised owing to an attraction between the π-meson and the B nucleus.

Among the papers on *detailed meson theory,* on *details of high-energy experiments,* and on *nuclear data* presented in three concurrent groups of session VII, the report of Hildebrand on the observation of nuclear events in the new Glaser bubble chamber particularly attracted the interest of experimentalists. The bubble chamber makes use of the unstable system of a superheated liquid. As soon as ionizing radiation enters the system, gas bubbles are formed and the liquid starts to boil almost immediately. If, however, a picture of the bubble formation is taken a few microseconds after the ionizing event takes place, then the bubbles formed along the path of the ionizing radiation give a beautiful track. The high density of the medium (liquid), the almost complete absence of undesired tracks, and the possibility of taking pictures in rapid sequence make the bubble chamber an extremely versatile instrument for the study of high-energy events.

The last session of the conference was devoted to a discussion of *heavy mesons and hyperons* and was opened with a critical survey of the properties of these new and strange particles by C. C. Butler (Imperial College, London). The speaker was quite successful in his attempt to distinguish between conclusions based on indisputable experimental facts and those based on preliminary evidence. The heavier particles are classified into two groups according to their mass values: the *hyperons,* generally designated by the letter Y, have a mass between the proton and the deuteron mass; and the particles having mass values larger than the π-meson but lower than the proton, are called heavy mesons or *K-particles.* In addition, the "normal" or "light" mesons with masses below (and including) the one of the π-mesons are now classified as *L-mesons.* At present the π- and the μ-mesons are the sole representatives of this class. Among the hyperons, the existence of neutral and charged particles with a V-decay is well established. The following characteristics are observed: $Y^0 = \Lambda^0 \rightarrow p + \pi^- + 37$ Mev (neutral Y-particles are designated by Λ!), $Y^+ \rightarrow p + \pi^0 + 116$ Mev, $Y^\pm \rightarrow L^\pm + n + 114$ Mev. There is also evidence of a negative Y^- particle that decays according to $Y^- \rightarrow \Lambda^0 + \pi^- + 65$ Mev. Among the K-mesons, the existence of the positive and negative τ-meson $[m^\tau = (966 \pm 4) m_e]$ is well established: $\tau^\pm \rightarrow \pi^\pm + \pi^+ + \pi^-$ and possibly $\tau^\pm \rightarrow \pi^\pm + \pi^0 + \pi^0$. The positive τ^+ is observed much more frequently than the τ^-. There is some provisional evidence of a neutral τ-meson that decays according to $\tau^0 \rightarrow \pi^+ + \pi^- + \pi^0$. A neutral particle, which has about the same mass $[m = (965 \pm 5) m_e]$ as $\tau^\pm$ and which could be the neutral counterpart is frequently observed and is provisionally baptized as a θ^0 particle. Its decay, $\theta^0 \rightarrow \pi^\pm + L^\mp$, has been studied extensively by Thompson (Indiana). The interpretation of some observed events speaks for the existence of additional K-mesons with masses around 1200 m_e. Leprince-Ringuet (Paris) presented some evidence of a K-meson with a mass of $m_k = (912 \pm 20)\ m_e$ whose decay involves a μ-meson. This K_μ-meson decays according to $K_\mu \rightarrow \mu +$ neutral particle (neutrino?) and is positive. A negative counterpart may have been observed. The existence of a χ-meson ($\chi \rightarrow \pi +$ neutral particle) with a mass between 950 and 980 m_e seems likely. A χ-meson that decays into a μ-meson and two or more neutral particles seems to be rather well established. Some neutral K-mesons that are not θ^0 mesons have been observed also.

Most of the observations on the "strange" particles mentioned in the preceding paragraph were made in cosmic-ray experiments. Some of the particles may also be produced by high-energy proton, neutron, and π-meson beams available in the Brookhaven cosmotron. Thorndike reported observations with this machine on the production of K-mesons and on a few V-events. The events are rare, however. A π-meson beam is most effective for producing these "strange" particles.

Two main problems confront the theoreticians in explaining the behavior of the strange particles: (i) Why is there such a variety of particles? (ii) Why is the lifetime of the particles 10 and more orders of magnitude larger than expected from their large production probability in high-energy events? Some theoretical speculations concerning especially the latter of the two questions were discussed by M. Gell-Mann (Chicago) and A. Pais (Princeton). One of two quite different assumptions may explain the puzzling behavior. The first one postulates that the matrix elements for the production and decay are very strongly energy-dependent, for example, because of high angular momentum, which would give copious production at very high energies and a slow decay of the particle, the latter being a low-energy event. The high angular momentum should manifest itself in the angular distribution of the events. The second model starts from the point of view that the strange particles—for example, Λ^0-particles, are produced, two at a time, by π-meson-nucleon or nucleon-nucleon collisions through a strong interaction. The decay of the particle, however, owing to certain selection rules (isotopic spin!) would be forbidden and therefore would proceed slowly.

After this rather controversial topic of the theory of the strange particles, W. Heisenberg (Göttingen) closed the conference with some remarks. In retrospect, he mentioned the way the problems in atomic spectroscopy were solved whose understanding seemed to present unsurmountable difficulties 33 years ago. Perhaps some unexpected development in the future may do for the present somewhat unsatisfactory state of meson physics what the quantum theory did for the understanding of atomic physics.

News and Notes

International Union Against Cancer and the 6th International Cancer Congress

The council of the International Union Against Cancer met on 21–22 July in São Paulo, Brazil. The official delegates from the United States were Harold L. Stewart, chairman, Charles S. Cameron, and George T. Pack. A completely revised constitution was adopted which greatly improves and simplifies the operation and organization of the union. For the first time, provision is made for the rotation of the presidency and for the office of president-elect. The headquarters of the union will remain in Paris, but it will be moved from 6, Avenue Marceau, where it has been associated with the French League against Cancer, to the Curie Foundation, 26, Rue d'Ulm, where office space will be furnished gratis. Permanent committees were established to assist in organizing future congresses and to consider problems concerned with the publication of *Acta,* the official journal of the union.

The following officers were reelected for another term: president, J. Maisin (Belgium); secretary-general, Harold Dorn (United States); assistant secretary-general, Pierre Denoix (France); and treasurer, Philip Peacock (Scotland). V. R. Khanolkar (India) was elected president-elect. The five vice-presidents of the union and the areas they represent are as follows: Antonio Prudente (Brazil), Latin America; O. H. Warwick (Canada), British Empire; Paul E. Steiner (U.S.A.), United States; Tomizo Yoshida (Japan), Asia; and Leiv Kreyberg (Norway), Europe. Plans were made to hold the next cancer congress in London in 1958.

Under the auspices of the union, the 6th International Cancer Congress was held 23–29 July in connection with the 4th centennial of São Paulo. Of the more than 1000 people registered, 400 were from outside Brazil and approximately 135 were from the United States. The program was divided into 6 concurrent sections consisting of 2 lectures, 4 conferences, 10 panel discussions, 15 symposiums on special subjects, 22 films, and 339 scientific papers, making a total of more than 500 individual presentations. Representatives of 48 countries, including the U.S.S.R., participated in the program. Although it is impossible to report in detail on the numerous papers presented, some points of particular interest are mentioned here.

H. Runge (Germany), using primarily radium and x-ray in the treatment of carcinoma of the cervix, reported an absolute recovery rate of 45 percent after 5 yr and 40 percent after 10 yr. In Russia, complete clinical recovery was obtained in the treatment of cancer of the cervix with radiotherapy in 75.1 per-