and the indirect coupling is of the required form, giving for the constant k_i,

(68) $$k = f\check{f}\,a/\varkappa^2,$$

a being a factor $(\frac{1}{2}\sqrt{2}) \leqslant a \leqslant 2$, dependent on the nature of the meson. The equivalent direct coupling for *Ss* mesons is g_1, for *Vv* mesons g_2, for *Vt* or *At* mesons g_3, for *Aa* or *Pa* mesons g_4, and for mesons g_5.

The lifetime $\tau_{\pi\varepsilon}$ is given (except for *Pa* and *Sv* mesons) by

(69) $$1/\tau_{\pi\varepsilon} = a'\check{f}^2\varkappa/4\pi$$

with $a' = 1$ for *Ss* or *Pp* mesons, $= 2/3$ for *Vv* or *Aa* mesons, $= 1/3$ for *Vt* or *At* mesons. For *Pa* or *Sv* mesons,

(70) $$1/\tau_{\pi\varepsilon} = m^2 f'^2/4\pi\varkappa$$

(for calculations of $\tau_{\pi\varepsilon}$ see Yukawa *et al.* [1938a], Bethe and Nordheim [1940], Chang [1942], and for all cases Sakata [1941a]). We know the value of k and the magnitude of f, it is therefore possible, by eliminating $\check{f}$ between (68) and (69) or (70), to find the value of $\tau_{\pi\varepsilon}$. For *Pa* (or *Sv*) mesons,

(71) $$\tau_{\pi\varepsilon} = 4\lambda \cdot 10^{-6} \text{ sec.}$$

(λ has been defined in (43)), and for the other cases

(72) $$\tau_{\pi\varepsilon} = \tfrac{1}{2}\, a\lambda \cdot 10^{-10} \text{ sec.},$$

i.e. it is $\varkappa^2/a$ times smaller. (This result is essentially the object of Rozental's [1941b] paper where it was shown that the lifetime of the cosmic ray meson was only compatible with *Pa* mesons!). Therefore only *Pa* charged π-mesons can be acceptable for coupling scheme (3) (see Fig. 11).

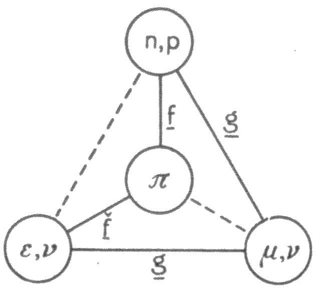

Fig. 11. Coupling scheme (3)
---- indirect coupling.

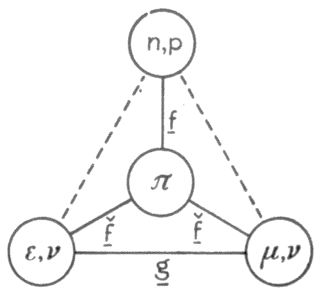

Fig. 12. Coupling scheme (4)
---- indirect coupling.

Moreover, in this case (Marty and Prentki [1948], Lopes [1948]) if π-mesons have the same coupling $\check{f}'_p$ with (μ, ν) and (ε, ν), we have $\tau_{\varepsilon\nu} \gg \tau_{\mu\nu}$ [18] and therefore, as in § 4. 2, a possible alternative to scheme (3) is scheme (4) (Fig. 12).

If π is pseudoscalar (as is likely, see § 2. 3), in schemes (3) and (4) the indirect coupling for β-radioactivity is equivalent to a g_4 direct coupling (n, p)(ε, ν); this gives the G—T selection rules. However, we have seen (§ 3. 4) that the Fermi rules seem also necessary at least for the O^{14} decay, and also probably for some forbidden shape spectra which can be explained only by a mixture of Fermi and G—T interactions, g_1, g_3 or g_2, g_4 or even g_2, g_3. Therefore a direct coupling g_2 must be added or, if one wants to avoid this direct coupling, one has to postulate the existence of another charged nuclear meson giving an indirect coupling equivalent to g_2. It must therefore be a vector meson, and according to § 2. 6 it cannot be the $V^{\pm}$-meson. The lifetime of this postulated meson X (rest mass $\varkappa$) for the process $X \to \varepsilon^{\pm} + \nu$ would be

$$t = 1.6 \times 10^{-10} f^2/\varkappa^5 \text{ sec.,} \tag{73}$$

where f is its nuclear coupling. Of course if f is small enough and/or x is large enough, this meson would not be observable!

4. 4 Summary

It is to be expected that we shall soon have more knowledge of the nature of the V and V′ mesons, and also on the terms of the β-radioactivity direct (or equivalent indirect) coupling. The coupling scheme (1) will be ruled out if this interaction is not g_2, g_4 (other mixtures compatible with the scheme are forbidden in the discussion § 3. 4), or if π-mesons are not pseudoscalar (but this is most unlikely).

When the nature of the terms of the interaction for β-radioactivity (direct) coupling are known more precisely, it will be possible, by the study (still in progress) of the μ-meson decay spectrum, to determine whether this spectrum can be satisfactorily accounted

[18] For the equivalence of the direct coupling (n, p) (μ, ν) and the indirect coupling π-(n, p) and π-(μ, ν) we did not distinguish between *Pa* mesons and the other possibilities because the ratio of $\tau_{\pi\mu}$ is then no longer χ^2/a but only $\chi^2/\mu^2 a \approx 1.7/a$.

for by the same coupling terms. It now seems more difficult to visualize μ-meson capture experiments decisive for the choice of coupling schemes.

5. Conclusion

At present, the study of the coupling properties of particles is only descriptive. Physicists observe and classify couplings in much the same way as botanists do species! No essentially new ideas (outside electrodynamics) have been successfully put forward since Fermi's β-radioactivity and Yukawa's mesons, now over fifteen years old. Predictions from these ideas have been very helpful, but not completely so, as was expected.

Meson theories have had great success, but this is outside the field of nuclear interaction. Nuclear physics has developed quite independently of meson theories (for instance, the droplet model, shell structure, and the phenomenological potential for nucleon-nucleon interaction), and even for the simple nucleon-nucleon interaction meson theories fail at high energy. However the discovery of the π°-meson, so badly needed for meson theories of nuclear forces, was a notable success, and its decay into two photons gives more confidence to the application of hole theory for nucleons. The $\pi^\pm$ and π°-mesons are probably pseudoscalar, and experiments now in progress with artificially created mesons (mainly concerning interactions with hydrogen and deuterium) may be expected soon to give a still better answer to the question, and allow one to decide in favour of Pa and/or Pp coupling for this symmetrical pseudoscalar set of mesons.

Today, direct coupling seems necessary for β-radioactivity, and experimental agreement is satisfactory (the main difficulty is C^{14}). The study of spectra with forbidden shape (conjugated with spin measurements), of electron neutrino angular correlation, of neutron decay, etc. should fairly soon allow one to specify which terms $g_i J_i$ form the direct coupling. It is for μ-meson decay however, in the present state of affairs, that direct coupling is absolutely necessary and gives perfect agreement with experiment.

As long as coupling scheme (1) is not ruled out, it is remarkable that one may be able to explain all interactions between particles by adding only one coupling to the already known nuclear, electromagnetic and gravitational interactions.

Especially for the problem of coupling properties of particles, many answers are pending because in these cases the theory cannot give reliable quantitative results. Too often in the literature the existence of these particular cases is claimed to be excluded because of such difficulties [19]; it seems necessary to recall (as did ROSENFELD [1950]) Fresnel's sentence: "La Nature se joue de nos difficultés analytiques".

The opposite attitude is no better. The elegance of a theory is no guarantee of its applicability to natural phenomena. Since elegance cannot be decisive in accepting or rejecting a theory, it cannot be significant as a criterion for the choice of alternatives within the arbitrariness of a theory (as the choice of coupling [20] here). Experiments give the final answer. Of course one has to make and test first the simplest hypotheses (with the least possible arbitrariness). But only a completed theory can be put in an elegant form; theories in evolution are necessarily unsatisfactory, and this is true for the present theory of elementary particles which, (besides the lack of a successful intermediate coupling method) probably breaks down at very short distances or at very high energies. The realistic point of view of regularization could have been a solution, since it emphasizes the necessity of treating all fields together, but it failed (see, for instance, PAIS and UHLENBECK [1950]).

However, the future is very promising; new heavy particles (V and/or V′) have been discovered in cosmic rays and may soon be produced artificially. These probably have some bearing on the unsolved problems of nuclear forces. Finally, the techniques of observation of very high energy nuclear events have been greatly developed, and will offer important data for testing improvements or fundamental modifications of the theory of the interactions between particles. Cosmic rays will for many years be our only source of such events.

---

[19] This has even been invoked against the existence of direct coupling because of the $\sim r^{-5}$ second order *static* interaction potential between any two of the involved fermions!

[20] As, for instance, the symmetry principle of DE GROOT and TOLHOEK [1950]; this principle restricts the direct coupling of β-radioactivity to a mixture of either g_2, g_3 or g_1, g_4, g_5.

ACKNOWLEDGEMENTS

I am very grateful to Professor Niels Bohr for his kind hospitality. I wish to thank Professor Rosenfeld, Dr Mottelson, Dr Kofoed–Hansen and all the physicists of the Copenhagen Institute for Theoretical Physics and of the University of Manchester for many stimulating discussions.

I am indebted to the French Service des Poudres, whose generosity and understanding have made possible my stays abroad.

REFERENCES

AAMODT, L., J. HADLEY and W. PANOFSKY, 1950, Phys. Rev., **80**, 282.

ABRAGHAM, A. and J. J. HOROWITZ, 1951. Private communication.

AIDZU, K., Y. FUJIMOTO, N. FUKUDA, S. HAYAKAWA, K. TAKAYANAGI, G. TAKADA and Y. YAMAGUCHI, 1950, Progr. Theor. Phys., **5**, 931.

ALLEN, J. S., H. R. PANETH and A. H. MORRISH, 1949, Phys. Rev., **75**, 570.

ALIKHANIYAN, A. I., E. M. SAMOILOVICH, I. I. GUREVICH and K. P. BABAYAN, 1949, J. Exp. Theor. Phys., **19**, 667.

ANDERSON, C. D., 1932, Science, **76**, 238.

ARAKI, G., 1950, Progr. Theor. Phys., **5**, 507.

ARMENTEROS, R., K. H. BARKER, C. C. BUTLER, A. CACHON and A. H. CHAPMAN, 1951, Nature, Lond., **167**, 501.

ASHKIN, J., A. SIMON and R. E. MARSHARK, 1950, Progr. Theor. Phys., **5**, 634.

BARRETT, J. H., 1950, Phys. Rev., **79**, 907.

BENOIST–GUEUTAL, P., J. PRENTKI and J. RATIER, 1950, J. Phys. Radium, **11**, 553.

BETHE, H. A., 1935, Proc. Camb. Phil. Soc., **31**, 108.

BETHE, H. A. and L. W. NORDHEIM, 1940, Phys. Rev., **57**, 998.

BETHE, H. A., 1947, Elementary Nuclear Theory. (New York; John Wiley and Sons).

BETHE, H. A., 1949, Phys. Rev., **76**, 191.

BLOCH, F. and C. MØLLER, 1935, Nature, Lond., **136**, 911.

BHABHA, H. J., 1949, Rev. Mod. Phys., **21**, 451

BOROWITZ, S. and W. KOHN, 1949, Phys. Rev., **76**, 818.

BRODA, E., N. FEATHER and D. H. WILKINSON, 1947, Phys. Soc. Camb. Conf. Report, p. 114.

BROWN, R., U. CAMERINI, P. H. FOWLER, H. MUIRHEAD, C. F. POWELL and D. M. RITSON, 1949, Nature, Lond., **163**, 82.

BRUECKNER, K. A., 1950a, Phys. Rev., **79**, 641.

BRUECKNER, K. A. and K. M. WATSON, 1950b, Phys. Rev., **79**, 187.

CARLSON, A. G., J. E. HOOPER and D. T. KING, 1950, Phil. Mag., **41**, 701.

CASE, K. M., 1948, Phys. Rev., **74**, 1884.

CASE, K. M., 1949a, Phys. Rev., **76**, 1.

CASE, K. M., 1949b, Phys. Rev., **76**, 14.

CASE, K. M. and A. PAIS, 1950, Phys. Rev., **80**, 203.

CHADWICK, J., 1932, Nature, Lond., **129**, 312.

CHAMBERLAIN, O., R. F. MOZLEY, J. STEINBERGER and C. WIEGAND, 1950, Phys. Rev., **79**, 396.

CHANG, T. S., 1942, K. Danske Vidensk. Selsk. Mat.-fys. Medd., **19**, no. 10.

CHANG, W. Y., 1949, Rev. Mod. Phys., **21**, 167.

CHAO, C. Y., 1949, Phys. Rev., **75**, 581.

CHESTON, W. B., 1951, Phys. Rev., **82**, 335.
CHRISTY, R. F. and S. KUSAKA, 1941, Phys. Rev., **59**, 414.
COCCONI, G. and V. COCCONI–TONGIORGI, 1951, Phys. Rev., **82**, 335.
CONFORTO, A. M., R. D. SARD, 1951, Phys. Rev., **82**, 335.
CONVERSI, M., E. PANCINI and O. PICCIONI, 1945, Phys. Rev., **68**, 232.
CONVERSI, M., E. PANCINI and O. PICCIONI, 1947, Phys. Rev., **71**, 209.
CONVERSI, M. and O. PICCIONI, 1946, Phys. Rev., **70**, 859.
CRANDALL, W. E., B. J. MOYER and H. F. YORK, 1950, Phys. Rev., **78**, 89.
CRANE, H. R., 1948, Rev. Mod. Phys., **20**, 279.
CRITCHFIELD, L. and E. WIGNER, 1941, Phys. Rev., **60**, 412.
See also L. CRITCHFIELD, 1943, Phys. Rev., **63**, 417.
CROUCH, M. F., 1951, Phys. Rev., **81**, 164.
CURRAN, S. C., J. ANGUS and A. L. COCKCROFT, 1949, Phys. Rev., **76**, 853.
DAUDIN, J., 1950, J. Phys. Radium, **11**, 25.
DYSON, F. J., 1948, Phys. Rev., **73**, 929.
DYSON, F. J., 1949, Phys. Rev., **75**, 485 and 1736.
DAVIES, J. H., W. O. LOCK and H. MUIRHEAD, 1949, Phil. Mag., **40**, 1251.
ENATSU, H., 1950, Progr. Theor. Phys., **5**, 102.
EVANS, J. and E. P. GEORGE, 1949, Nature, Lond., **164**, 21.
FEER, D. B., 1949a, Phys. Rev., **75**, 731.
FEER, D. B., 1949b, Phys. Rev., **76**, 306.
FERMI, E., 1934, Z. Phys., **88**, 161.
FERRETTI, B. and S. GALLONE, 1950, Phys. Rev., **77**, 153.
FIERZ, M., 1937, Z. Phys., **104**, 553.
FINKELSTEIN, R. J., 1947, Phys. Rev., **72**, 415.
FIREMAN, L., 1949, Phys. Rev., **75**, 323.
FORSTER, H. H., 1950, Phys. Rev., **78**, 92.
FRETTER, W. B., 1948, Phys. Rev., **73**, 41.
FRETTER, W. B., 1949, Phys. Rev., **76**, 511.
FRETTER, W. B., 1951, Phys. Rev., **82**, 294.
FRIEDMAN, H. L. and J. RAINWATER, 1951, Phys. Rev., **81**, 644.
FUKUDA, H. and Y. MIYAMOTO, 1949a, Progr. Theor. Phys., **4**, 347.
FUKUDA, H., Y. MIYAMOTO, T. MIYAZIMA and S. TOMONAGA, 1949b, Progr. Theor. Phys., **4**, 385.
FUKUDA, H. and Y. MIYAMOTO, 1949c, Progr. Theor. Phys., **4**, 389.
FUKUDA, H. and Y. MIYAMOTO, 1949d, Progr. Theor. Phys., **4**, 391.
FUKUDA, H., S. HAYAKAWA and Y. MIYAMOTO, 1950a, Progr. Theor. Phys., **5**, 283.
FUKUDA, H., S. HAYAKAWA and Y. MIYAMOTO, 1950b, Progr. Theor. Phys., **5**, 352.
FUKUDA, H. and Y. MIYAMOTO, 1950c, Progr. Theor. Phys., **5**, 147.
FUKUDA, H. and Y. MIYAMOTO, 1950d, Progr. Theor. Phys., **5**, 148.
FURRY, W. H., 1937, Phys. Rev., **51**, 125.
FURRY, W. H., 1939, Phys. Rev., **56**, 1184.
GAMOW, G. and E. TELLER, 1936, Phys. Rev., **49**, 895.
GERJUOY, E., 1951, Phys. Rev., **81**, 62.
GREISEN, K. I., 1948, Phys. Rev., **73**, 521.

GROETZINGER, G. and G. W. McCLURE, 1948, Phys. Rev., **74**, 341.
DE GROOT, S. R. and H. A. TOLHOEK, 1950, Physica, **16**, 456.
HAMILTON, D. R., 1947, Phys. Rev., **71**, 456.
HANAWA, S. and T. MIYAZIMA, 1950, Progr. Theor. Phys., **5**, 459.
HARDING, J. B., 1950, Phil. Mag., **41**, 405.
HEITLER, W. and S. POWER, 1947, Phys. Rev., **72**, 266.
HINCKS, E. P. and B. PONTECORVO, 1950, Phys. Rev., **77**, 102.
HINCKS, E. P., 1951, Phys. Rev., **81**, 313.
HOPPER, V. D. and S. BISWAS, 1950, Phys. Rev., **80**, 1098.
HORNYAK, W. F., T. LAURITSEN, P. MORRISON and W. A. FOWLER, 1950, Rev. Mod. Phys., **22**, 291.
INGHRAM, M. G. and J. H. REYNOLDS, 1949, Phys. Rev., **76**, 1264.
INGHRAM, M. G. and J. H. REYNOLDS, 1950, Phys. Rev., **78**, 822.
JARKOV, K. B., 1950, J. Exp. Theor. Phys., **20**, 492.
JASTROW, R., 1951, Phys. Rev., **81**, 165.
KAPLON, M. F., B. PETERS and H. L. BRADT, 1949, Phys. Rev., **76**, 1735.
KISSINGER, C. W. and D. COOPER, 1948, Phys. Rev., **74**, 349.
KLEIN, O., 1948, Nature, Lond., **161**, 897.
KONOPINSKI, E. J. and G. E. UHLENBECK, 1935, Phys. Rev., **48**, 7.
KONOPINSKI, E. J., 1943, Rev. Mod. Phys., **15**, 209.
KRAUSHAAR, W. L., J. E. THOMAS and V. P. HENRI, 1950, Phys. Rev., **78**, 486.
LAGARRIGUE, A. and C. PEYROU, 1951, J. Phys. Radium, to be published and C. R. Acad. Sci., Paris, 233, 478.
LANDAU, L. D., 1948, Dokl. Akad. Nauk. SSSR., **60**, 207.
LANGER, L. M. and R. J. D. MOFFAT, 1951, Phys. Rev., **82**, 333 and 635.
LATTES, C. M. G., G. P. S. OCCHILIANI and C. F. POWELL, 1947, Nature, Lond., **160**, 453.
LAWSON, J. S., Jr., 1951, Phys. Rev., **81**, 299.
LE COUTEUR, K. J. and L. ROSENFELD, 1949, Phil. Mag., **40**, 151.
LEE, T. D., M. ROSENBLUTH and C. N. YANG, 1949, Phys. Rev., **75**, 905.
LEIGHTON, R. B., C. D. ANDERSON and A. J. SERIFF, 1949, Phys. Rev., **75**, 1432.
LEPRINCE-RINGUET, L. and M. L'HÉRITIER, 1944, C. R. Acad. Sci., Paris, **219**, 618.
LEPRINCE-RINGUET, L., 1949, Rev. Mod. Phys., **21**, 43.
LEVINE, C. A., A. GHIORSO and G. T. SEABORG, 1950, Phys. Rev., **77**, 296.
LEVY, M., 1951, Proc. Roy. Soc. A, to be published.
LEWIS, H. W., J. R. OPPENHEIMER and S. A. WOUTHYSEN, 1948, Phys. Rev., **73**, 127.
LODGE, A. S., 1948, Nature, Lond., **161**, 809.
LONGMIRE, C., C. S. WU and C. H. TOWNES, 1949, Phys. Rev., **76**, 695.
LOPES, J. L., 1948, Phys. Rev., **74**, 1722.
LUTTINGER, J. M., 1949a, Phys. Rev., **75**, 309.
LUTTINGER, J. M., 1949b, Phys. Rev., **75**, 1277.
McMILLAN, E. M. and J. M. PETERSON, 1949a, Science, **109**, 438.
McMILLAN, E. M., J. M. PETERSON and R. S. WHITE, 1949b, Science, **110**, 579.

MAJORANA, E., 1937, Nuovo Cim., **14**, 171.
MANLEY, J. H. and S. MILLMAN, 1937, Phys. Rev., **51**, 19.
MARSHAK, R. E., 1949a, Phys. Rev., **75**, 513.
MARSHAK, R. E. and A. S. WIGHTMAN, 1949b, Phys. Rev., **76**, 114.
MARSHAK, R. E., 1949c, Phys. Rev., **76**, 1736.
MARSHAK, R. E., S. TAMOR and A. S. WIGHTMAN, 1950, Phys. Rev., **80**, 765.
MARTINELLI, E. A. and W. K. H. PANOFSKY, 1950, Phys. Rev., **77**, 464.
MARTY, C. and J. PRENTKI, 1948, J. Phys. Radium, **9**, 147.
MARTY, C. and J. PRENTKI, 1950a, C. R. Acad. Sci., Paris, **230**, 54.
MARTY, C. and J. PRENTKI, 1950b, C. R. Acad. Sci., Paris, **230**, 1508.
MICHEL, L., 1949, Nature, Lond., **163**, 959.
MICHEL, L., 1950a, Proc. Phys. Soc., **A63**, 514 and 1371.
MICHEL, L., 1950b, Nature, Lond., **166**, 654.
MICHEL, L., 1951, to be published.
NAHMIAS, M. E., 1935, Proc. Camb. Phil. Soc., **31**, 99.
NAKAMURA, S., H. FUKUDA, K. ONO, M. SASAKI and M. TAKETANI, 1950, Progr. Theor. Phys. **5**, 740.
NELSON, E. C., 1941, Phys. Rev., **60**, 830.
NERESON, N., 1948, Phys. Rev., **73**, 565.
NISHIJIMA, K., 1950, Progr. Theor. Phys., **5**, 187.
O'CEALLAIGH, C., 1950, Phil. Mag., **41**, 838.
OGAWA, S. and S. KAMEFUCHI, 1950a, Progr. Theor. Phys., **5**, 311.
OGAWA, S. and E. YAMADA, 1950b, Progr. Theor. Phys., **5**, 503.
ONEDA, S., S. SASAKI and S. OZAKI, 1950, Progr. Theor. Phys., **5**, 165.
OZAKI, S., S. ONEDA and S. SASAKI, 1949, Progr. Theor. Phys., **4**, 524.
OZAKI, S., 1950, Progr. Theor. Phys., **5**, 373.
PAIS, A. and G. E. UHLENBECK, 1950, Phys. Rev., **79**, 145.
PANOFSKY, W. K. H., L. AAMODT and H. F. YORK, 1950a, Phys. Rev., **78**, 825.
PANOFSKY, W. K. H., L. AAMODT, J. HADLEY and R. PHILLIPS, 1950b, Phys. Rev., **80**, 94.
PAULI, W., 1941, Rev. Mod. Phys., **13**, 203.
PAULI, W. and F. VILLARS, 1949, Rev. Mod. Phys., **21**, 434.
PEASLEE, D. C., 1950, Helv. Phys. Acta, **23**, 845.
PETERSON, V. Z., 1950, Phys. Rev., **79**, 407.
PEYROU, C. and A. LAGARRIGUE, 1950, J. Phys. Radium, **11**, 666.
PICCIONI, O., 1948, Phys. Rev., **74**, 1754.
PONTECORVO, B., 1947, Phys. Rev., **72**, 247.
POWELL, C. F., 1950, Rep. Phys. Soc. Progr. Phys., **13**, 350.
POWER, S., 1949, Phys. Rev., **76**, 865.
PRENTKI, J., 1951, C. R. Acad. Sci., Paris, **232**, 940.
PUPPI, G., 1948, Nuovo Cim., **5**, 587.
PUPPI, G., 1949, Nuovo Cim., **6**, no. 3.
RACAH, G., 1937, Nuovo Cim., **14**, 322.
RETALLACK, S. G. and R. B. BRODE, 1949, Phys. Rev., **75**, 1716.
RICHARDSON, J. R., 1948, Phys. Rev., **74**, 1720.
ROBSON, J. M., 1950, Phys. Rev., **78**, 311.

ROBSON, J. M., 1951, Phys. Rev., **81**, 297.
ROCHESTER, G. D. and C. C. BUTLER, 1947, Nature, Lond., **160**, 855.
ROSENBLUTH, M. N., 1949, Phys. Rev., **75**, 532.
ROSENFELD, L., 1948a, Nuclear Forces (Amsterdam: North-Holland Publishing Co.)
ROSENFELD, L., 1948b, Rep. Solvay Conf.
ROSENFELD, L., 1950, Progr. Theor. Phys., **5**, 519.
ROZENTAL, S., 1941a, K. Danske Vidensk. Selsk. Mat.-fys. Medd., **18**, no. 7.
ROZENTAL, S., 1941b, Phys. Rev., **60**, 612.
ROZENTAL, S., 1945, K. Danske Vidensk. Selsk. Mat.-fys. Medd., **23**, no. 11.
RUDERMAN, M. and R. FINKELSTEIN, 1949, Phys. Rev., **76**, 1458.
SAKATA, S., 1941a, Proc. Phys.-Mat. Soc., Japan, **23**, 283.
SAKATA, S., 1941b, Proc. Phys.-Mat. Soc., Japan, **23**, 291.
SARD, R. D., W. B. ITTNER, A. M. CONFORTO and M. F. CROUCH, 1948, Phys. Rev., **74**, 91.
SARD, R. D., A. M. CONFORTO and M. F. CROUCH, 1949, Phys. Rev., **76**, 1134.
SASAKI, S., S. ONEDA and S. OZAKI, 1949, Science Rep. Tohoku Univ., **33**, 77.
SASAKI, S., S. ONEDA and S. OZAKI, 1950, Progr. Theor. Phys., **5**, 25.
SCHOENBERG, M., 1941, Phys. Rev., **60**, 468.
SCHWINGER, J., 1948, Phys. Rev., **73**, 416.
SCOTT, J. M. C. and E. W. TITTERTON, 1950, Phil. Mag., **41**, 318.
SERIFF, A. J., R. B. LEIGHTON, C. HSIAO, E. W. COWAN and C. D. ANDERSON, 1950, Phys. Rev., **78**, 290.
SHERR, R., H. R. MUETHER and M. G. WHITE, 1949, Phys. Rev., **75**, 282.
SIGURGEIRSSON, T. and K. A. YAMAKAWA, 1947, Phys. Rev., **71**, 319.
SIGURGEIRSSON, T. and K. A. YAMAKAWA, 1949, Rev. Mod. Phys., **21**, 124.
SLOTNICK, M. and W. HEITLER, 1949, Phys. Rev., **75**, 1645.
SMITH, F. M., W. H. BARKAS, A. S. BISHOP, H. BRADNER and E. GARDNER, 1950, Phys. Rev., **78**, 86.
SNELL, A. H., F. PLEASONTON and R. V. MCCORD, 1950, Phys. Rev., **78**, 310.
STEINBERGER, J., 1948, Phys. Rev., **74**, 500.
STEINBERGER, J., 1949a, Phys. Rev., **75**, 1136.
STEINBERGER, J., 1949b, Phys. Rev., **75**, 1180.
STEINBERGER, J., W. K. H. PANOFSKY and J. STELLER, 1950, Phys. Rev., **78**, 802.
STELLER, J. S. and W. K. H. PANOFSKY, 1951, Phys. Rev., **81**, 649.
SUN, K. H., 1949, Phys. Rev., **76**, 1266.
TAKETANI, M., S. NAKAMURA and M. SASAKI, 1949, Phys. Rev., **76**, 852.
TAMOR, S. and R. E. MARSHAK, 1950, Phys. Rev., **80**, 766.
TANIKAWA, Y., 1947, Progr. Theor. Phys., **2**, 31.
TICHO, H. K., 1947a, Phys. Rev., **72**, 255.
TICHO, H. K. and M. SCHEIN, 1947b, Phys. Rev., **72**, 248.
TICHO, H. K. and M. SCHEIN, 1948a, Phys. Rev., **73**, 81.
TICHO, H. K. and M. SCHEIN, 1948b, Phys. Rev., **74**, 492.
TICHO, H. K. and M. SCHEIN, 1948c, Phys. Rev., **74**, 1337.
TIOMNO, J., J. A. WHEELER and R. R. RAU, 1949a, Rev. Mod. Phys., **21**, 144.
TIOMNO, J. and J. A. WHEELER, 1949b, Rev. Mod. Phys., **21**, 153.

TIOMNO, J., 1949c, Phys. Rev., **76**, 856.
TOMONAGA, S. and G. ARAKI, 1940, Phys. Rev., **58**, 90.
TRIGG, G. L., 1951, Phys. Rev., **82**, 325.
VALLEY, G., 1947, Phys. Rev., **72**, 772.
VALLEY, G. and B. ROSSI, 1948, Phys. Rev., **73**, 177.
VAN HOVE, L., 1949, Phys. Rev., **75**, 1519.
VAN WYCK, C. B., 1949, Proc. Phys. Soc., **A62**, 697.
VAN WYCK, C. B., 1950a, Proc. Phys. Soc., **A63**, 350.
VAN WYCK, C. B., 1950b, Phys. Rev., **80**, 487.
WAGNER, N. and D. COOPER, 1949, Phys. Rev., **76**, 449.
WATSON, K. and J. V. LEPORE, 1949, Phys. Rev., **76**, 1157.
WENTZEL, G., 1949, Phys. Rev., **75**, 1810.
WHEELER, J. A., 1947, Phys. Rev., **71**, 320.
WHEELER, J. A., 1949, Rev. Mod. Phys., **21**, 132.
WICK, G. C., 1934, Atti. Accad. Naz. Lincei., **19**, 319.
WIGHTMAN, A. S., 1950, Phys. Rev., **77**, 521.
WIGNER, E., 1927, Göttingen Nachr., p. 375.
WIGNER, E., 1939, Phys. Rev., **56**, 519.
WU, C. S., 1950, Rev. Mod. Phys., **22**, 386.
YANG, C. N., 1950a, Phys. Rev., **77**, 242.
YANG, C. N., 1950b, Phys. Rev., **77**, 722.
YANG, C. N. and J. TIOMNO, 1950, Phys. Rev., **79**, 495.
YUKAWA, H., 1935, Proc. Phys.-Mat. Soc. Japan, **17**, 48.
YUKAWA, H., S. SAKATA and M. TAKETANI, 1938a, Proc. Phys.-Mat. Soc. Japan, **20**, 720.
YUKAWA, H., S. SAKATA, M. KOBAYASI and M. TAKETANI, 1938b, Proc. Phys.-Mat. Soc. Japan, **20**, 720.
YUKAWA, H., 1949, Rev. Mod. Phys., **21**, 474.