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— NOTE BOOK —

貴元君・坂井等
典門

II

Sept., 1957
~ Nov. 1957
Jan.

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京都大学基礎物理学研究所 湯川記念館史料室

Hee-Model and Quantization of Non-linear Field Equations by W. Heisenberg

(preprint)

Heisenberg の論文に試みた非線形場の
量子化の方法 (第17. I 号紙)

~~Hee model~~ Hee model は Hilbert 空間
II 空間を postulate している。そして
Hee model の場合について、total Hilbert
space に positive metric をおける部
分と dipole-ghost ~~を除去して~~
部分に分け、Hilbert space を
この state による Summation の
unitary であるとする。
Causality of 物理と「海」の4次元。

* constant (運動量 $h\nu$), particle
と ghost の mass が $\pm i\epsilon$ である。
Y. Remark は A. E. D. の場合の interaction
を考察があり、Coulomb interaction
が成り立つ。そして ϵ が 0 になる
と $\sqrt{0}$ の問題がある。
2. 電磁気学 Lorentz 条件、2 階の
場の方程式 $\square A_\mu = 0$ 、 $\square A_0 = 0$ 、
 $\square A_i = 0$ 、 $\square A_0 = 0$ 、
dipole field が $\square A_\mu = 0$ の解として
、2 階の Heisenberg の formulation
の中へ入れることができるか。

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V. Kallen-Pauli (cont.)
(Y. Munakata Sept. 11, 1957)

$$g^2 = g_0^2 / (1 + \frac{g_0^2}{g_c^2}), \quad g_0^2 = \frac{g^2}{1 - \frac{g^2}{g_c^2}}$$

$$\lim_{\omega \rightarrow \infty} g_c^2 \rightarrow 0$$

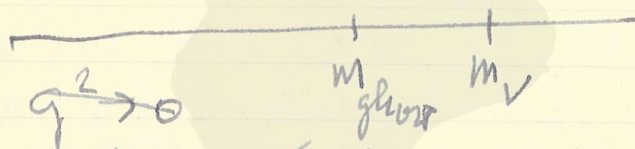
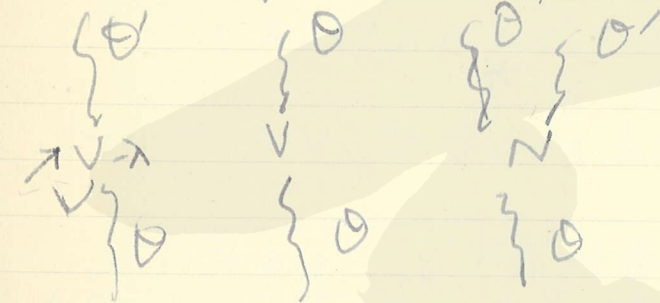
g^2 : finite if $g < g_c$ and ∞ if $g > g_c$
 $g^2 > g_c^2$ for g_0 is ∞ or ∞
 imaginary part of g^2 is ∞ or ∞
 meromorphic in g^2 is ∞ or ∞
 indefinite

$$\langle V | \eta | V \rangle = -1$$

$$\langle V | V \rangle = 1$$

$$\langle V | V \rangle = -1$$

$$S^* S \neq 1$$



$$g^2 \rightarrow 0$$

$$m_{ghost} < m_\nu$$

$$g^2 \rightarrow \infty$$

$$m_{ghost} \rightarrow -\infty$$

$$g^2 \rightarrow +\infty$$

$$m_{ghost} \rightarrow m_\nu$$

$\therefore$ $m_{ghost} = m_\nu$ is a necessary condition for the existence of a ghost state.

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Jubilee of Relativity Theory

Bern, 11 ~ 16 July, 1955

(Helvetica Physica Acta
Supplement IV, 1956)

1. O. Klein, Generalization of Einstein's theory of Grav. Considered from the point of view of Quantum Field Theory.

a. 5 dimensional theory:

Inclusion of charged fields. —

Periodicity with respect to the extra coordinate x^5 , conjugate to the electric charge

$$l = \sqrt{2\pi} \hbar c / e \approx 0.8 \times 10^{-30} \text{ cm}$$

$$\kappa = 8\pi \gamma / c^4$$

$$e/l \sim \hbar \quad [e'] = [l^{-1}]$$

gauge invariance, charge conserv.

- b. Feynman's action integral

$$\exp(iS)$$

$$\text{with } S = \int h d^4x / \hbar c$$

$$S = \frac{1}{\hbar c} \int (h + \frac{1}{2\kappa} G) d^4x$$

$$\kappa \kappa = l_0^2 \gamma^2$$

$$k = 1, 2, 3, 4$$

$$h = \frac{\hbar c}{l_0^2} h_0$$

$$G = \frac{1}{l_0^2} G_0$$

l_0, G_0 being dimensionless functions
dimensionless $\varphi = l_0^{3/2} \psi$ and

$$S = \int d^4x (h_0 + \frac{l_0^2}{2\kappa \hbar c} G_0)$$

$$l_0 = \sqrt{2\pi \hbar c} \approx 1.1 \times 10^{-3} \text{ cm}, \quad l = 2\pi \sqrt{\frac{\hbar c}{e^2}} \cdot l_0$$

c. To connect a and b is equivalent to determine $\hbar c/e^2$. A possibility is to assume that the ~~unrenormalized~~ e_0 is simply connected with $\sqrt{\mu c}$, if e_0 is chosen as the unit of length.

d. Particle $\rightarrow$ wave packet λ
Compton wave length $\lambda_C = \hbar/mc$, energy is $\hbar c/\lambda$, $\lambda \rightarrow \lambda_C$
mass is $\hbar/c\lambda$ of λ_C particles.
gravitation potential is center & edge $\sim \hbar/c\lambda^2$ 違う. $\lambda \rightarrow \lambda_C$
 $\hbar/c\lambda^2 \ll c^2$ or $\lambda \gg \sqrt{\hbar/c} \sim \lambda_C$
curvature, metric a change is negligible. $\therefore$ it is linear approximation. wave length λ is λ_C or $\lambda > \lambda_C$.
Pauli's ghost state of energy $\sim \hbar c/\lambda_C$ estimate $\sim \lambda_C$ is not $\hbar c/\lambda_C$ (hand and $\sqrt{\hbar/c}$)

e. $\varphi(x^0, x) = \psi(x) e^{i p_0 x^0}$
 $p_0 = \frac{q}{\beta c}$ $f_0(x) = -\beta f(x)$

Dimension of β = reciprocal potential
 q : electric charge of the particle
 φ is invariant $\pi^0 = \pi^0 + f_0(x)$
(charge conservation) corresponding
to $\pi^k = \pi^k + f_k(x)$
(the $U(1)$ -momentum conservation)

f.
$$\gamma^\mu \left(\frac{\partial}{\partial x^\mu} - \Gamma_\mu \right) \psi + \frac{mc}{\hbar} \psi = 0$$

$$[\gamma^\lambda, \{\gamma^\mu, \gamma^\nu\}] = 0, \quad \lambda, \mu, \nu = 0, 1, 2, 3, 4$$

$$\gamma_\mu \gamma^\nu = \delta_\mu^\nu$$

$$\gamma_{\mu\nu} = \frac{1}{2} [\gamma_\mu, \gamma_\nu]$$

$$\gamma_\mu = \gamma_{\mu\rho} \gamma^\rho$$

$$\frac{1}{2} \{\gamma_\mu, \gamma^\nu\} = \delta_\mu^\nu$$

Γ_μ : fun of γ^μ, γ_μ and their first derivatives.

$$\Delta_\mu \psi = \left(\frac{\partial}{\partial x^\mu} - \Gamma_\mu \right) \psi : \text{spinor}$$

$[\Delta_\mu, \Delta_\nu] \neq 0$: linear, homogeneous in the components of the curvature tensor of the Riemann space, whose metric tensor is $\gamma_{\mu\nu}$.

$$\gamma_{i0} = \gamma_{00} \beta A_i$$

$$\gamma_{ik} = g_{ik} + \gamma_{00} \beta^2 A_i A_k$$

$$\kappa = \frac{1}{2} \gamma_{00} \beta^2$$

$$\gamma_{00} : \text{const}$$

$$\gamma_{00} = 1 : \beta = \sqrt{2\kappa}$$

g.

$$x^0 = x^0 + f_0(x^0, x)$$

$$U_n(x^0) = \frac{1}{\sqrt{2\pi}} e^{i n x^0} \quad n = 0, \pm 1, \pm 2, \dots$$

$$\psi(x^0, x) = \sum_n \psi_n(x) U_n(x^0)$$

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$$(n' | F(x^0, x) | n'') = F_{n'-n''}(x)$$

where $F(x^0, x) = \sum_n F_n(x) e^{i n x^0}$

$$(n' | p_0 | n'') = n' \delta_{n'-n''}$$

$$x^0' = x^0 + \epsilon \sum_n \xi_n(x) e^{i n x^0}$$

$$U_n(x^0') = U_n(x^0) \left| \frac{dx^0}{dx^0'} \right|^{1/2}$$

$$= U_n(x^0) - i \epsilon \sum_n \frac{n+n'}{2} \xi_{n-n'} U_n(x^0)$$

$$\bar{\Psi}(x^0', x) = \sum_n \bar{\Psi}_n(x) U_n(x^0')$$

$$\bar{\Psi}(x^0, x) = \sum_n \bar{\Psi}_n U_n(x^0)$$

$$\Psi_n'(x) = \sum_{n'} (\delta_{nn'} + \epsilon \bar{Q}(n | Q | n')) \Psi_{n'}(x)$$

$$(n' | Q | n'') = -i \frac{n'+n''}{2} \xi_{n'-n''}$$

$$\text{For } \xi_n(x) = \xi_{-n}^*(x)$$

$1 + \epsilon Q$ is unitary

$$p_0 = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

$$Q = -i \begin{pmatrix} \xi_0 & \frac{\xi_1}{2} \\ \xi_1^*/2 & 0 \end{pmatrix}$$

$$\bar{Q} = -\frac{i}{2} \begin{pmatrix} \xi_0 & \xi_1 \\ \xi_1^* & -\xi_0 \end{pmatrix}$$

$$= -\frac{i}{2} \left(\frac{\xi_1 + \xi_1^*}{2} T_1 + i \frac{\xi_1 - \xi_1^*}{2} T_2 + \xi_0 T_3 \right)$$

(infinitesimal rotation in isotropic spin space)

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$(n'|F|n'')$: field connected with the charge n', n'' .

$$(n'|[p_0, F]|n'') = (n' - n'')(n'|F|n'')$$

Discussion (p. 68)

W. Pauli:

$$\log \frac{P^2}{m^2 c^2} \sim \frac{1}{\alpha} \approx 137$$

$$P \sim \frac{\hbar}{\lambda_0} \quad \lambda_0 = \sqrt{2\pi\hbar c} : \pi P^2 \sim 1$$

(Landau)

W. Heitler:

Cut-off momentum for meson theory is of the order of nucleon mass!!!

2. P. G. Bergmann: Quantisierung allgemein-Kovarianter Feldtheorien (p. 79)

a. canonical quantization (1) (2) EIL

b. spin $\gamma_\mu \gamma_\nu + \gamma_\nu \gamma_\mu = 2\delta_{\mu\nu}$ $\gamma_\mu \gamma_\mu = 2$ $\gamma_\mu \gamma_\nu = -\gamma_\nu \gamma_\mu$ $\gamma_\mu \gamma_\mu = 4$

$$\frac{1}{2}(\gamma_\mu \gamma_\nu + \gamma_\nu \gamma_\mu) = \delta_{\mu\nu}, \quad \gamma_\mu \gamma_\mu = \gamma^\mu \gamma_\mu = 4$$

$$\gamma_\mu \gamma_\nu = \frac{1}{2}(\gamma_\mu \gamma_\nu + \gamma_\nu \gamma_\mu) + \frac{1}{2}(\gamma_\mu \gamma_\nu - \gamma_\nu \gamma_\mu) \text{ commute!}$$

$$\gamma_\mu \gamma_\nu = \frac{1}{2}(\gamma_\mu \gamma_\nu + \gamma_\nu \gamma_\mu) \text{ commute!}$$

$$g_{\mu\nu} = \frac{1}{2}(\gamma_\mu \gamma_\nu + \gamma_\nu \gamma_\mu)$$

γ^μ contravariant, γ_μ covariant, $\gamma^\mu \gamma_\mu = 4$ $\gamma^\mu \gamma_\nu = -\gamma_\nu \gamma^\mu$ $\gamma^\mu \gamma_\mu = 4$

$$\gamma^\mu \gamma_\mu = g_{\mu\mu} \gamma^\mu \gamma_\mu = 4$$

$$\frac{1}{2}(\gamma^\mu \gamma_\nu + \gamma_\nu \gamma^\mu) = g_{\mu\nu} \gamma^\mu \gamma_\nu = g_{\mu\nu} g^{\mu\nu} = \delta_\nu^\nu = 4$$

Remark:

$$\frac{1}{2}[\gamma_\mu, \gamma^\nu + \gamma^\nu \gamma_\mu] = \frac{1}{2}[\gamma g_{\mu\lambda} \gamma^\lambda \gamma^\nu + \gamma^\nu g_{\mu\lambda} \gamma^\lambda]$$

$$= \frac{1}{2} g_{\mu\lambda} g^{\nu\lambda} = \delta_\mu^\nu$$

~~$$\left\{ \frac{1}{2} [\tau_\mu, \tau_\nu + \tau_\nu, \tau_\mu], \frac{1}{2} [\tau_\kappa, \tau_\lambda + \tau_\lambda, \tau_\kappa] \right\}$$~~

$= g_{\mu\nu} g_{\mu\nu} \delta^{\mu\nu} \delta_{\mu\nu}$ (because $g^{\mu\nu} \delta^{\mu\nu} \delta_{\mu\nu}$)
 & commute to $\delta^{\mu\nu} \delta_{\mu\nu} = 4$
 $\frac{1}{2}(\delta_{\mu\nu} \delta^{\mu\nu}) = g_{\mu\nu}$

$$\left(\text{or } \frac{1}{2} (\gamma^\mu \gamma^\nu + \gamma^\nu \gamma^\mu) = g^{\mu\nu} \right)$$

$\tilde{x} \sim g_{\mu\nu} \tilde{x}^\mu$ $g_{\mu\nu}$ is diagonal $\tilde{x}^\mu = \frac{1}{\sqrt{g_{\mu\mu}}} \tilde{x}^\mu$

$\frac{1}{2} \{ \tilde{x}^\mu, \tilde{x}^\nu \} = \delta_{\mu\nu}$

$$\left. \begin{aligned} x_\mu &= \sqrt{g_{\mu\mu}} \cdot x'_\mu & x'^\mu &= \frac{1}{\sqrt{g_{\mu\mu}}} x'_\mu \\ \frac{1}{2} \{x'_\mu, x'_\nu\} &= \delta_{\mu\nu} \end{aligned} \right\}$$

[illegible]

microscopic / space-time structure
 ψ は x^μ に依存する。 $\psi(x)$
 γ_μ, γ^{μ} を Dirac の vector field とし、
 γ_μ は γ^{μ} の adjoint, γ_μ の const. field の値は
 γ_μ Dirac matrices とし、これは Minkowski
 $\eta_{\mu\nu}$ の値と等しい。

by E. P. Wigner
(Address of retiring president
of A. K. S., Jan. 31, 1957)

Reflection Symmetry

Major Co a β -decay の experiment
 120112 magnetic field が ring
 current によって生じた $\vec{B}$ の $\vec{L}$ に対して、
 symmetry plane が存在する。この平面は、
 $\vec{L}$ と $\vec{B}$ が一致する。 β -decay の distribution
 は asymmetry が存在する。 $\vec{L}$ と $\vec{B}$ が一致する。 $\vec{L}$ と $\vec{B}$ が一致する。
 この $\vec{L}$ と $\vec{B}$ が一致する。 reflection の
 operation は $\vec{L}$ と $\vec{B}$ が一致する。 matter & anti-matter
 120112 operator を使う。 $\vec{L}$ と $\vec{B}$ が一致する。 $\vec{L}$ と $\vec{B}$ が一致する。
 P.S. matter の mirror image は
 anti-matter である。 $\vec{L}$ と $\vec{B}$ が一致する。 $\vec{L}$ と $\vec{B}$ が一致する。

Time inversion 時間反転
meta-matter 超物質
その性質が通常の物質とは異なる
その性質が通常の物質とは異なる
その性質が通常の物質とは異なる

[illegible]

Quantum limitations of the Concept of General Relativity

General relativity in coordinates is a space-time points specifying and labeled by space-time of events. Two events of space-time coincidence is a scale to clock. Macroscopic phenomena are observed in a macroscopic framework. Micro-systems are observed in a microscopic framework. A coincidence is observed in a collision matrix.

Micro-system of a particle observable is observed in a region of space-time. Quantum concept is a region of space-time. General relativity is a region of space-time. A boundary is a logically defined region.

Time Reversal

1. T. D. Lee, R. Oehme and C. N. Yang

Phys. Rev. 106 (1957), 340

2. F. Coester, P. R. 107 (1957), 299

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Reformulation of the Majorana Theory of the Neutrino

by K. M. Case

(P.R. 107 (1957), 302)

Dirac: $(\gamma^\mu \partial_\mu + \kappa) \psi = 0$

$$\gamma^\mu \gamma^\nu + \gamma^\nu \gamma^\mu = 2g^{\mu\nu}$$

$$g_{00} = -1, \quad g_{ij} = \delta_{ij}$$

$$C \gamma^\mu C^{-1} = \gamma^{\mu*}, \quad C = \bar{C}, \quad C^* = C^{-1}$$

(charge conj.)

$$(\gamma^\mu \partial_\mu + \kappa) C^{-1} \psi^* = 0$$

$$\gamma^5 = i\gamma^0\gamma^1\gamma^2\gamma^3$$

$$\gamma^5 \gamma^\mu = -\gamma^\mu \gamma^5, \quad C^{-1} \gamma^5 C = -\gamma^{5*}$$

$$\psi_\pm = \frac{1}{2}(1 \pm \gamma^5) \psi$$

$$\gamma_\pm^\mu \partial_\mu \psi_\mp + \kappa \psi_\pm = 0$$

$$\gamma_\pm^\mu \partial_\mu C^{-1} \psi_\mp^* + \kappa C^{-1} \psi_\mp^* = 0$$

Majorana: $\psi_- = C^{-1} \psi_+^*$

$$\gamma_-^\mu \partial_\mu \psi_+ + \kappa C^{-1} \psi_+^* = 0$$

$$\gamma_+^\mu \partial_\mu C^{-1} \psi_+^* + \kappa \psi_+ = 0$$

$$\text{or } \begin{cases} \eta^\mu \partial_\mu \phi + \kappa \phi^* = 0 \\ \eta^{\mu*} \partial_\mu \phi^* + \kappa \phi = 0 \end{cases} \quad \left\{ \begin{array}{l} \eta^\mu = C \gamma^\mu \\ \phi = \psi_+ \end{array} \right.$$

*: complex conj; ~: transpose

$\frac{1}{2}(1+\gamma^5) \sim 1$ in two-dimensional space of ψ_+

and $\eta^\mu \gamma^\mu + \eta^\nu \gamma^\nu = 2g^{\mu\nu}$

hence $(\square - \kappa^2)\phi = 0$

let $\eta^\mu = -iA\sigma^\mu$ ($\sigma^0 = 1$)

$$i\frac{\partial\phi}{\partial t} = \frac{i}{2}\sigma\nabla\phi + \kappa A\phi^*$$

$$i\frac{\partial}{\partial t}A\phi^* = \frac{i}{2}\sigma\nabla A\phi^* + \kappa\phi$$

($A\sigma^i A^{-1} = -\sigma^i$, $A = -\tilde{A}$, $A = A^{-1} = \tilde{A}^*$)
The case $\kappa = 0$ reduces to two-component theory.

Transformation properties of Majorana field:

a. Proper h.T.

$$\phi'(x') = \Lambda\phi(x)$$

Rot, $\Lambda = \exp(\frac{1}{2}\theta\sigma\sigma\sigma)$ (angle θ around $\hat{q}$)
h.T. with velocity $\vec{v}$ in $\hat{q}$ direction

$$\Lambda = \exp(\frac{1}{2}\vec{v}\sigma\hat{q})$$

b. Spatial reflection:

$$x^i = -x^i, \quad t = t$$

$$\phi'(x') = \Lambda\phi^*(x), \quad \Lambda = \varepsilon A$$

($\varepsilon = i$ or $-i$, ρ : real number)

c. Time Reversal

$$x^i = x^i, \quad t = -t$$

$$\phi'(x') = \Lambda\phi^*(x), \quad \Lambda = \mu A$$

μ : real for $\kappa \neq 0$.

Comparison with the case of electromagnetic field:

$$\nabla \times \mathbf{H} = \partial \mathbf{E} / \partial t$$

$$\nabla \times \mathbf{E} = -\partial \mathbf{H} / \partial t$$

$$\nabla \cdot \mathbf{H} = 0$$

$$\nabla \cdot \mathbf{E} = 0$$

$$\psi = \mathbf{H} \cdot \mathbf{i} - i \mathbf{E} \cdot \mathbf{a} \cdot \mathbf{i}$$

$$i \frac{\partial \psi}{\partial t} = \frac{1}{2} \nabla \psi$$

$$(S^i)_{jk} = i \epsilon_{ijk}$$

$$\mathbf{S} \cdot \nabla \psi = \nabla \psi$$

$\mathbf{q}$: arbitrary space vector
 $x^i \rightarrow -x^i, t \rightarrow t, \psi \rightarrow \psi^*$
 or $\mathbf{H} \rightarrow -\mathbf{H}, \mathbf{E} \rightarrow \mathbf{E}$

Quantization of Majorana field:

$$[\phi_\alpha(x, t), (A\phi^*)_\beta(x', t')]_+$$

$$= \{(-\frac{\partial}{\partial t} + \sigma \cdot \nabla) A\}_{\alpha\beta} D(x-x', t-t')$$

$$[\phi_\alpha(x, t), \phi_\beta(x', t')]_+$$

$$= -[(A\phi^*)_\alpha(x, t), (A\phi)_\beta(x', t')]_+$$

$$= -i\kappa A_{\alpha\beta} D.$$

Transformation (properties in q -number theory):
 S, R : unitary (anti-unitary in c -number theory)
 T, R : additional operation of taking complex conj. (Wigner T, R)
 anti-unitary (in both c - and q -number theory)

Lagrangian:

$$\mathcal{L} = \frac{1}{2i} \{ \phi^\dagger \sigma^\mu \partial_\mu \phi - \partial_\mu \phi^\dagger \sigma^\mu \phi \} + \frac{1}{2} \kappa \{ \phi^\dagger A \phi^\dagger + \phi A \phi \}$$

$$\delta \mathcal{L} = \delta \phi^\dagger \left\{ \frac{1}{2i} \sigma^\mu \partial_\mu \phi \right\} + \frac{1}{2} \kappa \delta \phi^\dagger A \phi^\dagger + \frac{1}{2} \kappa \phi^\dagger A \delta \phi^\dagger$$

$$\phi^\dagger A \delta \phi^\dagger = - \delta \phi^\dagger (\phi^\dagger A) = - \delta \phi^\dagger \tilde{A} \phi^\dagger = \delta \phi^\dagger A \phi^\dagger$$

$$T_\mu^\nu = \frac{1}{2i} \{ \phi^\dagger \sigma^\mu \partial_\nu \phi - \partial_\nu \phi^\dagger \sigma^\mu \phi \}$$

$$\partial T_\mu^\nu / \partial x^\nu = 0$$

β -decay:

$$H = \sum_i 2C_i (\psi_p^\dagger, 0; \psi_n) (\psi_e^\dagger, 0; \psi_\nu)$$

parity conjugate of H :

$$\psi_{p,n,e}(x') = \gamma_{p,n,e} \beta \psi_{p,n,e}(x)$$

$$\beta = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \quad \alpha = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$

$$\phi' = \varepsilon A \phi^\dagger : \psi' = \begin{pmatrix} \varepsilon A \phi^\dagger \\ 0 \end{pmatrix}$$

$$H' = \sum_i 2C_i (\psi_p^\dagger, 0; \psi_n) (\psi_e^\dagger, 0; \psi_\nu) \times \eta_p^* \eta_n \eta_e^*$$

$$\beta \psi' = \begin{pmatrix} 0 \\ i \varepsilon A \phi^\dagger \end{pmatrix}$$

$H+H'$: parity inv. conserving, if we take $\eta_p^* \eta_n \eta_e^* = i, \varepsilon = i$

with no asymmetry in β -decay
H: maximum asym in β -decay
and minimum double β -decay.

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Subtle of Relat. Theory (Continued)

3. ^{E.} Corinaldesi, On the Two-Body Problem of G.R. (p. 125)
(S.N. Gupta, P.R. 96 (1954), 1683)
Gupta's arguments for the peculiarity of gravitational field:

Start from

$$\square^2 U_{\mu\nu} = 0$$

with ϵ, c .

$$\partial U_{\mu\nu} / \partial x_{\mu} = 0$$

then

$$\square^2 U_{\mu\nu} = \kappa \Theta_{\mu\nu}$$

where $\Theta_{\mu\nu}$ should be the total energy-momentum tensor including the gravitational field itself.

In order to derive ~~both~~ the field equations (and the ~~energy-momentum~~ tensor) from a Lagrangian, the latter ~~could~~ should consist of infinitely many terms involving higher and higher powers of gravit. field.

These terms altogether constitute the ~~gravitational~~ gravitational field which is now in the Riemannian curved space.

4. E. Wigner, Rel. Invariance of Q.M. Equations

A possibility of a field theory without the use of coordinates.

Start from fields satisfying Klein-Gordon equations and then eliminate the coordinates by the help of two of such fields φ_1, φ_2 :

$$\frac{\partial \varphi_a}{\partial x_\kappa} = \sum_{i=1}^2 \frac{\partial \varphi_i}{\partial x_\kappa} \frac{\partial \varphi_a}{\partial \varphi_i}$$

$$\frac{\partial^2 \varphi_a}{\partial x_\kappa^2} = \sum_{i,j=1}^2 \frac{\partial \varphi_i}{\partial x_\kappa} \frac{\partial \varphi_j}{\partial x_\kappa} \frac{\partial^2 \varphi_a}{\partial \varphi_i \partial \varphi_j} + \sum \frac{\partial^2 \varphi_i}{\partial x_\kappa^2} \frac{\partial \varphi_a}{\partial \varphi_i}$$

$$m_a^2 \varphi_a = \sum_{i,j} g_{ij} \frac{\partial^2 \varphi_a}{\partial \varphi_i \partial \varphi_j} + \sum_i m_i^2 \varphi_i \frac{\partial \varphi_a}{\partial \varphi_i}$$

$$g_{ij} = \sum_\kappa \frac{\partial \varphi_i}{\partial x_\kappa} \frac{\partial \varphi_j}{\partial x_\kappa}$$

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Spinor Calculus and General Relativity

1. L. Infeld and S. B. L. van der Waerden, Sitzber. preuss. Akad. 128 (1933), 380 (1933)
2. W. L. Bade and H. Jehle, R. M. P. 25 (1953), 714.

spinor: a^{μ} $a'^{\lambda} = \Lambda^{\lambda}_{\mu} a^{\mu}$
 $\text{Det} |\Lambda^{\lambda}_{\mu}| \neq 0$
 $a_{\lambda\mu} = \epsilon_{\lambda\mu} \in (\text{hermitian})$
 $[a^{\mu} = \sigma^{\mu}_{\lambda\mu} a_{\lambda\mu}]$ ($\sigma^{\mu}_{\lambda\mu} = \sigma^{\mu}_{\lambda\mu}$)
 world vector $[a^{\mu}]$

In general relativity, $\sigma^{\mu}_{\lambda\mu}$ are arbitrary fns of coordinates

$$a_{\mu} = a^{\rho} \sigma_{\rho\mu} \quad a^{\mu} = \sigma^{\mu\rho} a_{\rho}$$

$$a_{\lambda\mu} = a^{\rho\sigma} \sigma_{\rho\lambda} \sigma_{\sigma\mu} \quad a^{\lambda\mu} = \sigma^{\lambda\rho} \sigma^{\mu\sigma} a_{\rho\sigma}$$

$$a_{\lambda\mu} = a^{\rho\sigma} \sigma_{\rho\lambda} \sigma_{\sigma\mu}$$

$$\sigma_{\lambda\mu} = -\sigma_{\mu\lambda}$$

$$\sigma_{12} = -\sigma_{21}, \quad \sigma_{11} = \sigma_{22} = 0$$

$$\sigma_{12} = -\sigma_{21} = \frac{1}{2}, \quad \sigma_{11} = \sigma_{22} = 0$$

$$a_{\lambda\mu} a^{\lambda\mu} = \sigma^{\lambda\rho} \sigma^{\mu\sigma} a_{\rho\sigma} a_{\lambda\mu}$$

$$g_{\lambda\mu} a^{\lambda} a^{\mu} = \sigma^{\lambda\rho} \sigma^{\mu\sigma} a_{\rho\sigma} a_{\lambda\mu}$$

$$x a_{\lambda\mu} a^{\lambda\mu} = \sigma^{\lambda\rho} \sigma^{\mu\sigma} a_{\rho\sigma} a_{\lambda\mu}$$

$$g_{\alpha\beta} \sigma^{\kappa\lambda\mu} \sigma^{\rho\sigma} = \delta^{\lambda\rho} \delta^{\mu\sigma}$$

$$\sigma^{\kappa\lambda\mu} \sigma^{\kappa\rho\sigma} = \delta^{\lambda\rho} \delta^{\mu\sigma}$$

$$a_{\lambda\mu} = \sigma_{\kappa\lambda\mu} a^{\kappa}$$

$$\sigma^{\kappa\lambda\mu} \sigma_{\lambda\mu} = \delta^{\kappa}$$

$$g^{\kappa\lambda} = \sigma^{\kappa\lambda\mu} \sigma_{\lambda\mu}$$

$$\sigma_{\lambda\mu} \sigma^{\kappa\lambda} + \sigma^{\kappa\lambda\mu} \sigma_{\lambda\mu} = g^{\kappa\lambda} \delta^{\mu}$$

$$\sigma_{\lambda\mu} \sigma^{\kappa\lambda} + \sigma^{\kappa\lambda\mu} \sigma_{\lambda\mu} = g^{\kappa\lambda} \delta^{\mu}$$

Covariant derivative

$$\psi_{\alpha;\kappa} = \partial_{\kappa} \psi_{\alpha} - \Gamma_{\alpha\kappa}^{\rho} \psi_{\rho}$$

$$\psi^{\alpha}_{;\kappa} = \partial_{\kappa} \psi^{\alpha} + \Gamma^{\alpha}_{\rho\kappa} \psi^{\rho}$$

$$a_{\lambda\mu;\kappa} = \partial_{\kappa} a_{\lambda\mu} - \Gamma_{\lambda\kappa}^{\rho} a_{\rho\mu} - \Gamma_{\mu\kappa}^{\rho} a_{\lambda\rho}$$

$$\text{The real, } \sigma^{\kappa\lambda\mu}_{;\rho} = \partial_{\rho} \sigma^{\kappa\lambda\mu} + \Gamma^{\kappa}_{\rho\sigma} \sigma^{\sigma\lambda\mu} + \Gamma^{\lambda}_{\rho\sigma} \sigma^{\kappa\sigma\mu} + \Gamma^{\mu}_{\rho\sigma} \sigma^{\kappa\lambda\sigma} = 0$$

$$\text{is equivalent to } a^{\kappa}_{;\kappa} = \sigma^{\kappa\lambda\mu} a_{\lambda\mu;\kappa}$$

$$\text{Further simplification } \Gamma^{\kappa}_{\rho\sigma} = \Gamma_{\sigma\rho}^{\kappa} = \{ \begin{matrix} \kappa \\ \sigma\rho \end{matrix} \}$$

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$$\Gamma_{\alpha s}^{\alpha} - \Gamma_{\alpha s}^{\alpha} = 2i\Phi_s$$

Φ_s : arbitrary real functions.

Curvature Tensors
Riemannian space:

$$R_{kps}^r = -\partial_s \Gamma_{kp}^r + \partial_p \Gamma_{ks}^r \\ - \Gamma_{kp}^h \Gamma_{hs}^r + \Gamma_{ks}^h \Gamma_{hp}^r$$

Spin space:

$$P_{kps}^M = -\partial_s \Gamma_{kp}^M + \partial_p \Gamma_{ks}^M \\ - \Gamma_{kp}^P \Gamma_{ps}^M + \Gamma_{pp}^M \Gamma_{ks}^P$$

$$P_{pps}^P = i(\partial_p \Phi_s - \partial_s \Phi_p) \\ = i\Gamma_{ps}$$

Dirac equation:

$$\sigma_{\mu\nu} \gamma_{\mu} \psi_{\nu} = \alpha \gamma_{\mu} \psi_{\mu} \\ \sigma_{\mu\nu} \gamma_{\mu} \chi_{\nu} = -\alpha \psi_{\mu}$$

or

$$i\gamma^{\mu} \partial_{\mu} \psi = mc\psi \\ \gamma^{\mu} \gamma^{\nu} + \gamma^{\nu} \gamma^{\mu} = 2g^{\mu\nu}$$

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Remarks: There are many possible ways of departure from Riemannian space, if we start from affine connection for spinors.

γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 a vector γ^μ , γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$
 である。 γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 field of γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 particle field of γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 と $\gamma^\mu(x_\mu)$ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 or field operator γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 of occupation operator γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 for γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 field of γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 space-time world of γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 として γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 と γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 である。 γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 particles of γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 for γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 field of γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$
 space-time world of γ^μ と x_μ の区別は x_μ と $x_\mu + i\epsilon$, $x_\mu + i\epsilon - \epsilon$

general case

Four dimensional manifold
containing matter

Simplest Case

next case
Minkowski world
containing spurious

particles ^{kind of} with each particle associated
the operators which transform linearly
field under general coord. transf.

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Space-Time Reflections and Isobaric Spin by J. C. Taylor (Nuclear Physics 3(1957), 606)

1. 2-Component Neutrino and Space-Reflection:

$$L = i\phi^* \left(\frac{\partial \phi}{\partial t} + \sigma_k \frac{\partial \phi}{\partial x_k} \right) - i \left(\frac{\partial \phi^*}{\partial t} + \frac{\partial \phi^*}{\partial x_k} \sigma_k \right) \phi \\ - i \left(\frac{\partial \phi}{\partial t} + \frac{\partial \phi}{\partial x_k} \sigma_k^T \right) \phi^* + i \phi \left(\frac{\partial \phi^*}{\partial t} + \sigma_k^T \frac{\partial \phi^*}{\partial x_k} \right)$$

is invariant under

$$S: \quad t \rightarrow t, \quad x_k \rightarrow -x_k \quad \phi \rightarrow \sigma_2 \phi^* \\ (\sigma_2^T = -\sigma_2) \quad \left(\begin{array}{l} \phi^* \rightarrow -\sigma_2 \phi \\ \text{or } \phi^* \rightarrow \phi \sigma_2 \end{array} \right)$$

because $\sigma_2 \sigma_k \sigma_2 = -\sigma_k^T$ the similarity transformation, $S = S \times C$

applied to el. mag. field gives

$$\left. \begin{array}{l} A_0 \rightarrow -A_0, \quad A_k \rightarrow A_k \\ F_{ij} \rightarrow -F_{ij}, \quad F_{0k} \rightarrow F_{0k} \end{array} \right\}$$

~~muon~~ decay:

$$A(\bar{\psi}_\mu \gamma_\alpha \psi_e)(\phi^* \sigma_\alpha \phi) + B(\bar{\psi}_\mu \gamma_\alpha \gamma_5 \psi_e) \\ \times (\phi^* \sigma_\alpha \phi) \quad (\sigma_0 = 1)$$

For $A=B$, μ and e interact with ν via their components $(1+\gamma_5)\psi$

In the representation with γ_5 -diagonal, they are two components of ψ which transform like ϕ under proper hor. trans.

this hypothesis implies that ρ -decay goes through a mixture of S, T, P only,

2. Time-Reversal

T, T^* :

$$L \rightarrow L^T$$

(S-

Superscript T : Transposed Hilbert-space operator.

$$\langle A | B \rangle \rightarrow \langle B | A \rangle$$

(anti-unitary)

Schwinger time reversal T :

$$\psi \rightarrow V \psi^T$$

$$V^* V = 1, V^{-1} \sigma_0 V = -\sigma_0, V^{-1} \sigma_z V = \sigma_z$$

下澤 隆人 (数学者)
素粒子の量子力学 (1948年6月)
(物理科学雑誌 45巻 4号 454-464号)
読了、1948年6月

$$(S_3, \frac{\partial}{\partial \bar{z}_1} + S\eta, \frac{\partial}{\partial \eta_1} + S_3^* \frac{\partial}{\partial \bar{z}_2^*} + S\eta_2^* \frac{\partial}{\partial \eta_2^*}) \psi$$

$$= -\eta \psi$$

$S_3, S_3^*, S\eta, S\eta_2^*$: Kemmer の β, π の
の $m \eta m \eta$ の spin matrix

$(\bar{z}_1, \eta_1) (\bar{z}_2, \eta_2)$ は Lorentz 変換で
- の変換を受ける。

$$x + iy = \bar{z}_1^* \eta_1 + \bar{z}_2^* \eta_2$$

$$x - iy = \eta_1^* \bar{z}_1 + \eta_2^* \bar{z}_2$$

$$z + ct = \bar{z}_1^* \bar{z}_1 + \bar{z}_2^* \bar{z}_2$$

$$-z + ct = \eta_1^* \eta_1 + \eta_2^* \eta_2$$

$+$: 時間軸

$-$: 空間軸

$$(\because ct^2 - z^2 = (\eta_1^* \eta_1 + \eta_2^* \eta_2)(\bar{z}_1^* \bar{z}_1 + \bar{z}_2^* \bar{z}_2)$$

$$\oplus \quad ct^2 - z^2 > 0$$

$$ct^2 - x^2 - y^2 - z^2$$

$$= (\eta_1^* \bar{z}_1 + \bar{z}_2^* \bar{z}_2)(\eta_1^* \eta_1 + \eta_2^* \eta_2)$$

$$= (\bar{z}_1^* \eta_1 + \bar{z}_2^* \eta_2)(\eta_1^* \bar{z}_1 + \eta_2^* \bar{z}_2)$$

$$= \bar{z}_1^* \bar{z}_1 \eta_1^* \eta_1 + \bar{z}_1^* \bar{z}_2 \eta_2^* \eta_1 + \bar{z}_2^* \bar{z}_1 \eta_1^* \eta_2 + \bar{z}_2^* \bar{z}_2 \eta_2^* \eta_2$$

$$= \pm \{ \bar{z}_1^* \eta_2^* - \bar{z}_2^* \eta_1^* \} \{ \bar{z}_1 \eta_2 - \bar{z}_2 \eta_1 \}$$

$$\mathcal{L} = \frac{1}{2} \{ \bar{\psi}_1 \gamma_1 \psi_1 \pm \bar{\psi}_2 \gamma_2 \psi_2 + \eta_1^* \bar{\psi}_1 + \eta_2^* \bar{\psi}_2 \}$$

$$\frac{\partial \mathcal{L}}{\partial \bar{\psi}_1} = \frac{1}{2} \eta_1^* \frac{\partial}{\partial x} - \frac{1}{2} i \eta_1^* \frac{\partial}{\partial y} + \frac{1}{2} \bar{\psi}_1 \frac{\partial}{\partial t}$$

物理元空間

complex 2-dim. space

4 real numbers

$$\begin{pmatrix} \bar{\psi}_1^* \\ \bar{\psi}_2^* \\ \eta_1^* \\ \eta_2^* \end{pmatrix} \begin{pmatrix} 1 \\ \pm i \\ \pm i \\ 1 \end{pmatrix} \begin{pmatrix} \psi_1 \\ \psi_2 \\ \eta_1 \\ \eta_2 \end{pmatrix} = \chi$$

$$\begin{pmatrix} \bar{\psi}_1^* \\ \bar{\psi}_2^* \\ \eta_1^* \\ \eta_2^* \end{pmatrix} \begin{pmatrix} 1 \\ \pm i \\ \pm i \\ 1 \end{pmatrix} = \gamma$$

$$\begin{pmatrix} \pm i \\ \pm i \\ 1 \\ 1 \end{pmatrix}$$

$$\begin{pmatrix} \sigma_x \\ \sigma_y \\ \sigma_y \\ \sigma_z \end{pmatrix}$$

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η_1^*
 η_2^*

ξ_1
 ξ_2

$$\frac{\partial \psi_s}{\partial \xi_r} - \frac{\partial \psi_r}{\partial \xi_s} = \psi_{rs}$$
$$\frac{\partial \psi_{rs}}{\partial}$$

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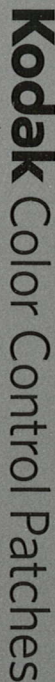
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(P.R. 101 (1956), 1597)

$\dots$ parameter α depends on the choice of group, i.e. L field system or invariant α is arbitrary, α is arbitrary functions, α is arbitrary group, i.e. L invariance of postulate α is arbitrary.

Yang-Mills 15



Two Component Spinors in General Relativity

(Phys. Rev. 107 (1957), 624)

spin matrices on field of Riemannian manifold

4 spin matrices on λ is metric tensor

$$\psi(x) = \begin{pmatrix} \psi^1(x) \\ \psi^2(x) \end{pmatrix}$$

2-dim 4-dim
 $\begin{pmatrix} \psi^1 \\ \psi^2 \end{pmatrix} \leftrightarrow x$

$$\psi^a \leftarrow \psi'(x) = a(x) \psi(x)$$

$$||a|| = a^1, a^2, a^1 a^2 = 1$$

$$\bar{\psi}' = \bar{a} \bar{\psi}$$

$$\psi'^{\dagger} = \psi^{\dagger} a^{\dagger} \rightarrow \psi^{\dagger}$$

$$\chi' = \chi a^1 \rightarrow \chi_a$$

$$(or \chi'^{\dagger} = a^{\dagger} \chi^{\dagger}) \rightarrow \chi_{\dot{a}}$$

(= or $\psi^a, \psi_{\dot{a}}, \chi_a, \chi_{\dot{a}}$ are used)

$$\epsilon = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$$

$$\epsilon = a \epsilon a^{\dagger}$$

$$\epsilon = a^{-1 \dagger} \epsilon a^{-1}$$

$$\epsilon = \bar{a} \epsilon a^{\dagger}$$

$$\epsilon = a^{\dagger} \epsilon \bar{a}^{-1}$$

Postulate i)

$$\sigma^{\mu'} = \left(\frac{\partial x^{\mu'}}{\partial x^{\mu}} \right) a^{\dagger} \sigma^{\mu} a^{-1}, \quad \sigma^{\mu} = \begin{pmatrix} \sigma^0 & \sigma^i \\ \sigma^i & \sigma^0 \end{pmatrix}$$

$$\tau^{\mu'} = \left(\frac{\partial x^{\mu'}}{\partial x^{\mu}} \right) a \tau^{\mu} a^{\dagger}, \quad \tau^{\mu} = \epsilon \sigma^{\mu} \epsilon$$

$$\sigma^0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \quad \sigma^i = \begin{pmatrix} \sigma^i & 0 \\ 0 & \sigma^i \end{pmatrix}$$

$$\tau^0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \quad \tau^i = \begin{pmatrix} 0 & \sigma^i \\ \sigma^i & 0 \end{pmatrix}$$

$$g^{\mu\nu} = -\frac{1}{2} (\tau^{\mu} \sigma^{\nu} + \tau^{\nu} \sigma^{\mu})$$

$$= \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}$$

Local Lorentz transf.

$$\sigma'^{\mu\nu} = \gamma^\mu_\alpha \gamma^\nu_\beta \sigma^{\alpha\beta} = a^{\alpha\mu} a^{\beta\nu} \sigma^{\alpha\beta}$$

$$\tau^\mu_\rho \gamma^\nu_\sigma g^{\rho\sigma} = g^{\mu\nu}$$

$$\gamma^\mu_\nu = -\frac{1}{2} (a^{\alpha\mu} \sigma_\alpha a^\nu_\beta \tau^\beta + \sigma_\nu a^\alpha_\beta \tau^\beta a^{\mu\alpha})$$

(proper & ReS4C3)

$$T: \sigma^{\mu\nu} = \tau^\mu \rightarrow u \rightarrow -u$$

$$P: \sigma^{\mu\nu} = -\tau^\mu \rightarrow a \rightarrow -a, \beta \rightarrow -\beta, \gamma \rightarrow -\gamma$$

$$T: \psi' = \epsilon \psi, \quad \chi' = \epsilon \bar{\chi}$$

Spin-affine Connection

$$\psi_{;\rho} = \psi_{,\rho} + \Gamma_\rho \psi$$

$$\psi'_{;\rho} = a \psi_{;\rho} \rightarrow \Gamma'_\rho = (a \Gamma_\rho - a_{,\rho}) a^{-1}$$

$$\epsilon_{;\rho} = 0 \rightarrow \Gamma_\rho^T \epsilon + \epsilon \Gamma_\rho = 0$$

$$\rightarrow \Gamma_\rho^T = -\epsilon \Gamma_\rho \epsilon^{-1} \rightarrow \text{tr } \Gamma_\rho = 0$$

$$\Gamma_\rho = \frac{1}{4} (\tau^\mu_{,\rho} + \{ \alpha_\rho \} \tau^\alpha) \sigma_\mu$$

Spin curvature: $P_{\rho\kappa} = \frac{1}{4} \tau^\mu \sigma^\nu P_{\rho\kappa\mu\nu}$
 $\text{tr}(P_{\rho\kappa}) = 0$

$$T, P: \Gamma'_\mu = -\Gamma_\mu^T, \quad P'_{\rho\kappa} = -P_{\rho\kappa}^T$$

Gauge Transf.: $U a U = e^{2i\theta}$

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$$\frac{\Sigma^-}{4} : \frac{\Sigma^+}{2} : \frac{\Sigma^0}{2} : \frac{\Lambda^0}{1/2}$$

仙波
牧
小次郎
常
郎

Lepton number
Parity of $1/2, 5/2$
Spin of $1/2, 5/2$. $4/2, 6/2$
Global symmetry
Interaction or systematization
Model of the ~~the~~

(K_{e2}?)

$K\pi$, $K\pi$ or energy distribution

(I) K^+ -nucleon scattering

Rochester conference

(I) K^+ -p scattering:

1) σ_t 40 ~ 200 MeV (14242 ^{energy} in ^{indep})
 $\sigma_t \sim 15 \text{ mb} \approx \frac{1}{4} \sigma_{\text{geo}}$

Glaser

20 ~ 90 MeV

$\sigma_t \sim 10 \text{ mb}$

energy & σ_t & σ_{geo} & $\sigma_{\text{per nucleon}}$

Puppi

λ_m

σ (per nucleon)

30 ~ 90

1.22

9

90 ~ 160

0.89

10

160 ~ 210

0.6

12

面分布

K -N-force

Osborn: 31力 (1956)

Puppi & IT力 (1957)

Davis

(Coulomb & constructive)

Hervarez: Rochester

MIT:

K -nucleon & hyperon

Gell-Mann:

K -scalar π 's

K -N: 31力

K : π s & π 's

$I=1$

$I=0$

$K^+p \rightarrow K^+p$

4

0

$K^+n \rightarrow K^+n$

1

1

$\rightarrow K^0p$

1

1

(exch)

$= \frac{1}{5}$

$\frac{1}{5}$

(ord)

$\frac{1}{5}$

$\frac{1}{5}$

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Goldhaber

$$\frac{\sigma_{\text{ch}}}{\sigma_{\text{tot}}} = 0.16 \pm 0.06 \quad (20 \sim 100 \text{ MeV})$$

$$0.24 \pm 0.09 \quad (150 \sim 200 \text{ MeV})$$

II, K^- -nucleon

1) $\sigma_{\text{tot}} \quad 30 \sim 120 \text{ MeV}$ (sea)

$\sigma_{\text{tot}} > 50 \text{ mb}$ (scattering)

$$\sigma(K^+ p \rightarrow \pi^+ + \Sigma^+) = \frac{1}{5} \sigma(K^+ p \rightarrow K^+ p)$$

$\Lambda_0, \Sigma_0, \Lambda_1, \Sigma_1, \dots \sim \frac{2}{5} \sigma$

2) $K^- + p \rightarrow K^- + p$ and π^0 distribution:

π^0 is isotropic (0 ~ 120 MeV)

3) K^- at rest

$$\Sigma^- : \Sigma^0 : \Sigma^+ : \Lambda = 4 : 2 : 2 : \frac{1}{2}$$

Dilworth (nucleon)

$$\frac{K^- + n \rightarrow \Sigma^- + \pi^0}{K^- + p \rightarrow \Sigma^- + \pi^+} \approx 0.6$$

$$\frac{K^- + n \rightarrow \Sigma^- + \pi^0}{(K^- + n \rightarrow \Sigma^- + \pi^0) + (K^- + n \rightarrow \Lambda^0 + \pi^0)} \approx 0.7$$

White

$$\frac{K^- + p \rightarrow \Sigma^- + \pi^+}{K^- + p \rightarrow \Sigma^- + \pi^0} = 2$$

free

bound

$$0.83 \pm 0.25$$

理論:

$K^+ - p$: Bernstein

$$\frac{g_{K\pi}^2}{4\pi} = \frac{1}{3}$$

$K - \pi$ -interaction (Schwinger)

$$\frac{g_{N\pi}^2}{4\pi} = 10$$

Chew:

$$i) \quad K \bar{K} \pi \rightarrow g$$

$$N \bar{N} \rightarrow f$$

$$ii) \quad K = \Lambda - N \rightarrow g$$

$$\Sigma \rightarrow g \Sigma$$

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Lee-model $T=1$ 模型

$$\frac{G^2}{4\pi} = \frac{G^2}{4\pi} = 0.3 \quad (\text{scalar})$$

中核

Photo-production (Rochester)

$E_V \sim 1 \text{ BeV}$

$\sigma^*(0)$ per photo $\sim 0.2 \times 10^{-30} \text{ cm}^2/\text{ster}$
(π photo-production $\sim 1/10$ 程度)

K's Charge independence & 対称性
charge multiplet
charge symmetry

binding ratio $K^+ N$ (T=1)
binding energy

β -decay 衰変

1. STP VA

Lee, Wu, Morita
Nakamura, Fujita

1) Fierz condition γ_5 条件

2) Time reversal 時間反転

$$C_S' = -C_S$$

$$C_V' = +C_V$$

$$C_T' = -C_T$$

$$C_A' = +C_A$$

$$(C_P' = -C_P)$$

(γ_5 条件 γ_5 の方向)

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$$n \rightarrow p + e^- + (\bar{\nu}_e)$$

$$\cancel{p \rightarrow n + e^+ + (\nu_e)}$$

$$\cancel{V_R = \frac{1}{2}(1 - \gamma_5) \gamma}$$

$$V_R = \frac{1}{2}(1 - \gamma_5) \gamma$$

S, T, P
V, A

1) Electron Polarization

$F_{\text{elect.}}$	V_R	S, T, P	V, A
$T, \text{ point.}$	V_L	$\frac{1}{2} \frac{V}{c}$	$\frac{1}{2} \frac{V}{c}$
		$\pm \frac{V}{c}$	$\frac{1}{2} \frac{V}{c}$

2) e^- -decay:

Y_{90}	$2 \rightarrow 0^+$	$\sim \frac{V}{c}$
Am_{98}	$2 \rightarrow 2^+$	$\sim \frac{V}{c}$
Co_{60}	$5^+ \rightarrow 4^+$	
P_{32}	$1^+ \rightarrow 0^+$	
Pr_{144}	$0^- \rightarrow 0^+$	
Sc_{46}	$4^+ \rightarrow 4^+$	

e^+ -decay:

Cl_{34}	$0^+ \rightarrow 0^+$	$\sim \frac{V}{c}$
Na_{22}	$3^+ \rightarrow 2^+$	$\pm ?$
Ga_{66}	$0^+ \rightarrow 0^+$	$\sim \frac{V}{c}$

(β^+ decay: $+e$: V, A
 $-e$: S, T, P)

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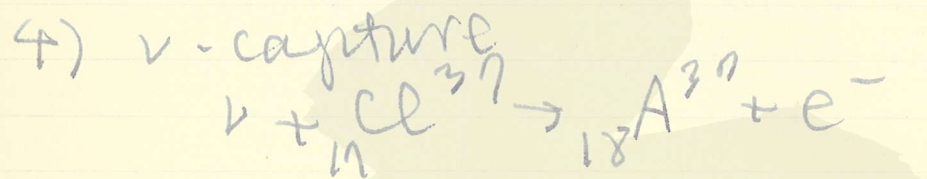
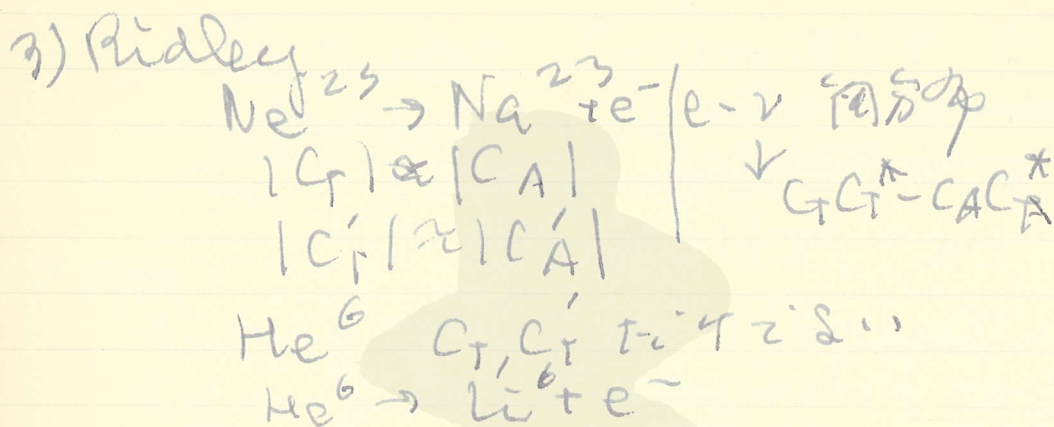
Magenta

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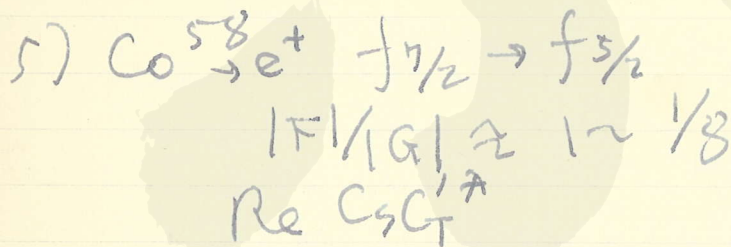
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$(\tilde{\nu} + Cl^{37} \rightarrow S^{37} + e^+)$
 $\sigma \approx 1.1 \times 10^{-45} \text{ cm}^2$
 (10^{-44} cm^2)
 (Davis)

Majorana ν と $\tilde{\nu}$ の区別は不可能。



either $\begin{cases} C_S' = -C_S \\ C_T' = -C_T \\ (C_P' = -C_P) \end{cases}$
 or $\begin{cases} e^- : STP \\ e^+ : VA \end{cases}$

$\begin{cases} C_U' = C_U \\ C_A' = C_A \end{cases} \quad \text{Ridley}$

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$A^{35} \rightarrow e^+$
 Ne^{23}

V, A transitions

$\bar{\nu} + p \rightarrow Ne e^+$ a cross-section
 is 2.5% of $\bar{\nu} + n \rightarrow p e^+$

gauge:

gauge:

1) $\pi^+ N \rightarrow \pi^+ K$

$\sin^2 \theta$

g_{KNY} : scalar

$g_K \approx 3$

2) Lederman (?) or new result

$\pi^+ \rightarrow \mu^+ \bar{\nu}$

lepton number is conserved
 (two comp.: $\pi^+ \rightarrow \mu^+ \nu$)

第 2 回

※ 第 2 回: Weak Interaction

1. Weak Interaction group
2. Unwanted process
3. model

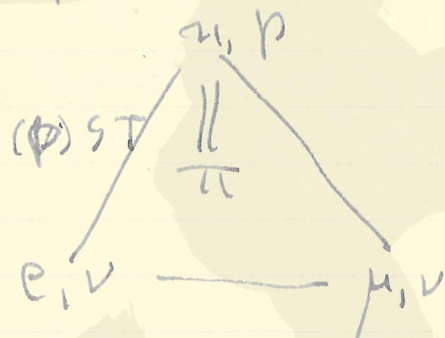
Universal Fermi (Klein 48)

2. unwanted processes

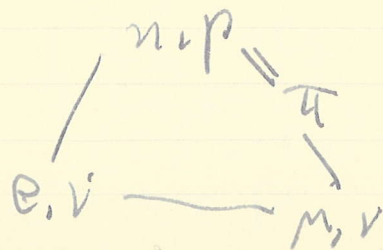
a) $\frac{\pi \rightarrow e + \nu}{\pi \rightarrow \mu + \nu} < 5 \times 10^{-5}$

$\frac{\mu \rightarrow e + \pi + \pi}{\mu \rightarrow e + \nu + \nu} < 10^{-4}$

$\frac{\bar{\mu} + p \rightarrow e + p}{\mu + p \rightarrow \nu + N} < 10^{-4}$



$\frac{\pi \rightarrow e + \nu}{\pi \rightarrow \mu + \nu} = \begin{cases} 1.5 \times 10^{-4} (2M) \\ 3.8 \times 10^{-5} (5M) \end{cases}$



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$$\tau_L = c = \frac{1}{\mu_\pi} = 1 : \quad 2 \text{ unwanted processes}$$

$$\pi^\pm \rightarrow e^\pm + \nu + \pi^0$$

$$K \rightarrow \pi + \pi + \mu + \nu$$

$$g_{eff} = 10^{-12} \sim 10^{-14}$$

$$10^{-3}$$



$$\frac{\Lambda \rightarrow N \pi e + \nu}{\Lambda \rightarrow p \pi} = 1/50 \text{ for } T.$$

金沢大: 7 x 10¹⁰ is (diffusion chamber)

'47 V '49 T → 3π '51 V (Λ⁰, K_{π2}, ≡) '53 H F '54 K⁺Σ⁻ '55 K⁰Σ⁰

(G-5) (Cosmotron) (G-stack) (Elevation)

'56 bubble chamber '57 K⁺ pionic excess

收時氏：香菸的紙

1. Atomistik

2. Energetik

3. Neo-Atonistik

1882年の改訂 — 江戸時代(巻)

第 140

Sept. 27, 1952

200. 武山

Strongly interacting particles (heavy particles)

題名錄後：

Schwinger

Gell. Marin

is what

4. 10. 1940
Schwinger: Zell-Mann

PUZZLE

$\text{Mao} \rightarrow \text{Gell-Mann}$

— $\left\{ \begin{array}{l} \square \\ \Sigma \\ \Lambda \\ N \end{array} \right.$

兀

>>

K

三三三

PNT

$$\Sigma^+ \gamma^0 \pi$$
$$\sum -z^0 \pi$$

4. Euclid の 13 の

25 8/10 12.

$$T_3 = \frac{1}{2} (T_{12} + T_{34})$$

doublet

$\downarrow$
 $\Sigma^0 \rightarrow \Sigma^+ \Sigma^-$
 $\Sigma^0 \rightarrow \Sigma^0 \Sigma^0$

対称性... 相互作用... 弱相互作用...

$\pi - K - \gamma - \text{weak}$

Hyperon

Hyperon: $84 = 2 \times 2 \times 2$

$I + J + J'$

3重 π : 1
4重 π : 2

η 重 π : 3

π 4
 K

$\Sigma \times \Sigma \rightarrow \pi$

三つの相互作用:

(i) $\Delta I = \text{half odd}$

$\Delta(I + I') = \text{integral}$ 122900

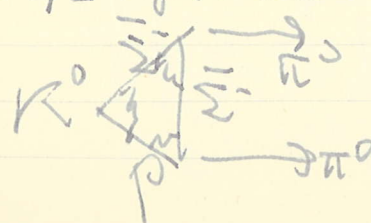
(ii) $\Delta I = 1/2$

Λ	$(1/2)$	$3/2$	$5/2$
Σ	$(1/2)$	$(3/2)$	$5/2$
K	$(1/2)$	$(3/2)$	$5/2$

$\Delta I = 1/2$ の割合: 5%

$\Delta I = 1/2, 3/2$ の割合: 14%

$\Delta I = 3/2$ の割合: electromagnetic interaction?



magnetic interaction
 $\propto \langle \frac{1}{r^3} \rangle$

(iii) gauge invariance & isospin space
 $\alpha(X) \downarrow$ $\uparrow \alpha(Y)$
 Y

④ $\Phi \in \mathcal{H}$: isospin eigenstate i.e.

$\vec{T} \Phi \rightarrow \vec{T} \Phi$ (isospin)

$$\{ \gamma_\mu \partial_\mu + F(\vec{\sigma}_5, \vec{T}, \partial_a) \} \Psi(x_\mu, x_a) = 0$$

$$\Psi(x'_\mu, x_a) = A(\vec{\sigma}_5, \vec{T}, x_a) \Psi(x_\mu, x_a)$$

isospin: $A(\vec{\sigma}_5) \Psi$

$$\bar{\Psi} \pi (\alpha + \beta \vec{\sigma}_5) \Psi$$

$$(\gamma_\mu \partial_\mu + \chi) \Psi = 0$$

$$\chi'_\mu = A \chi_\mu A^{-1} \rightarrow \Psi'$$

$$\text{boson: } (\beta_\mu \partial_\mu + \kappa) \Phi = 0$$

$$\beta_\mu = (\gamma_\mu \gamma_5 - 1) \gamma'_\mu$$

$$(\beta'_\mu \partial_\mu + \kappa) \Phi' = 0$$

$$\beta'_\mu = (\gamma'_\mu \gamma_5 - 1) \gamma'_\mu$$

$$\Psi' = A \Psi$$

$$\Phi' = A \Phi$$

($\gamma'_\mu \gamma_5 = \gamma_\mu \gamma_5$ unitary & γ_5 is γ_5)

$$\bar{\Psi}' = \Psi'^* \Gamma_4$$

$$\Gamma_4 = A^{-1} \gamma_4 A^{-1}$$

$$\begin{cases} G \bar{\Psi} \pi \Psi \\ G \bar{\Psi}' \pi' \Psi' \\ G \bar{\Psi}' \pi' \Psi' \end{cases}$$

$$\pi \rightarrow \sigma_5 \Phi \pi + \sigma_5 \gamma_\mu \Phi \pi$$

Time reversal (case)

$$g F \underbrace{(1 + \gamma_5)}_{\phi} \psi$$

$$+ F \sigma_2 \phi^*$$

$P_4 \phi = \psi \rightarrow$ time reversal invariant.

strangeness 2 a 粒子:

$$\phi' = A^2 \phi A^{-1}$$

$$\Sigma^2 = A^2 \psi^0$$

$$\Sigma^2 \phi' \Sigma^1$$

朴記: strangeness と内部自由度.

- ① charge space 2 次元 (strangeness)
- ② strangeness 0 (isospin) と parity

chirality

Korben-Klein: charge 2 operator

spin

$$\Psi_e(x, \theta) = U_e(\theta) \Psi_e$$

$$(\partial_\mu \Gamma + \partial_\theta \Gamma_s + m) \Psi_e = 0$$

$$\frac{1}{i} M \partial_\theta$$

$$U_e = \exp[i M \eta_e \theta]$$

$$m_e^2 = m_e^2 + n_e^2$$

$$\frac{1.68 \times 10^{-18}}{E, M}$$

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大帶氏。
(國瑞氏)。

4th. hepton-1211112 process

π type, polarization.
 π - μ -e polarization.

$\{ \text{条件列} \} :$
 $\begin{matrix} \vee A \\ \vee B \end{matrix}$
 $\begin{matrix} \vee A \\ \vee B \\ \vee A \end{matrix}$

$$\sum (N_i - \bar{N}_i) = 0$$
$$N_R - N_L + \sum_{i=1}^3 q_i (N_i - \bar{N}_i) \rightarrow \text{const}$$

(conservation of spinality)
 $q_i = \pm 1$ (neutrino charge)

Double β -decay

$$\hat{\nu} + \text{Cl}^{37} + \text{A}^{37} + e^- \quad \text{no (Davis 1956)}$$
$$\tilde{\nu} + \text{Ce}^{3+} \rightarrow \text{Sn} + \text{e}^- \quad \text{yes?}$$
$$\bar{\nu} + p \rightarrow n + e^+$$
$$n \rightarrow p + e^- + \begin{pmatrix} \nu_1 \\ \nu_2 \end{pmatrix} \rightarrow (V_R, \tilde{V}_L) \{ \tau \mu \}$$

(β -interaction) $\rightarrow$ $\Gamma_{\beta\beta} \approx 3 \cdot 10^{-4}$

Majorana $\psi = \psi^\dagger$

$$(v_1, v_2) \mapsto (v_R, \tilde{v}_R)$$

e-	STP	V(A)
e+	VA	STP

~~大塚氏: 同中子陽子相互作用~~

~~小林氏: 大塚氏と同様~~

T: He^6 a (e, v) angular correlation
S: ^{14}C RME: $|C_S|^2/|C_T|^2$
P: Ce^{144} $0^- \rightarrow 0^+$

$$W(\theta) = 1 + \alpha \cos \theta$$

$$\alpha = \frac{-|C_S|^2 + |C_V|^2}{|C_T|^2 + |C_A|^2} (M_F)^2$$

$$^{35}Ar(e^+) \quad \frac{1}{3} \frac{|C_T|^2 - |C_A|^2}{|C_T|^2 + |C_A|^2} (M_{GT})^2$$

$\alpha > 0$: $|C_V| > |C_S| \rightarrow V$
 $Ne^{23} \rightarrow A.$

$$He^6: \quad \frac{1}{3} |C_V| > |C_A|$$

$$Ne^{23}: \quad |C_V| \approx |C_A|$$

e^- STP ?

e^+ STP ?

$\rightarrow$ 2成分2"2"

electron spin flip

$\tau_L \nu_L$ or $\tau_R \nu_R$

$\nu \tau_L \nu_L$ or $\nu \tau_R \nu_R$

spiralities of τ and ν ...

$$\tau^+ \rightarrow \mu^+ \nu$$

$$\mu \rightarrow L \nu ?$$

$$\mu^+ \rightarrow e^+ \nu + \nu$$

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2-component theory ν (2-component theory)

$$\mu^+ \rightarrow e^+ + \nu + \bar{\nu}$$

anti. particle
 $\pi^+ \rightarrow \mu^+ + \bar{\nu}$
particle

spiralities of ν & $\bar{\nu}$

	ν	$\bar{\nu}$	
$\pi^+ \rightarrow \mu^+ + \nu$	$N-N$	$NA-N_L$	ρ
$\mu^+ \rightarrow e^+ + \nu_R + \bar{\nu}_R$			0
$\rightarrow e^+ + \nu_R + \bar{\nu}_L$			$3/4$
$\rightarrow e^+ + \nu_L + \bar{\nu}_L$			0
$\rightarrow \nu_R + \bar{\nu}_R$			$1/2 \rho \geq 0$
$\nu_R + \bar{\nu}_L$			$3/4$
$\nu_L + \bar{\nu}_R$			$1/2 \rho \geq 0$
$\nu_L + \bar{\nu}_L$			0
$\bar{\nu}_R + \bar{\nu}_R$			$3/4$
$\bar{\nu}_R + \bar{\nu}_L$			0
$\bar{\nu}_L + \bar{\nu}_L$			

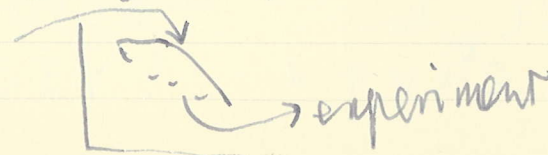
↑ ν $\bar{\nu}$

$\pi^+ \rightarrow \mu^+ + \nu_R$ 両方 yes の場合あり

1 ν_R $\bar{\nu}_L$

$^{144}\text{Ce} (0^- \rightarrow 0^+) e^-$ -emitter

T 117 (30%)
P 44.1% ν $\bar{\nu}$



$\mu\mu\mu$: weak interaction systematization

- 1) interaction of $\mu\mu\mu$ is $\mu\mu\mu$ and $\mu\mu\mu$
- 2) primary int.

F.-int.
B-F-int.



Majorana or coupling
particle or Dirac.

Lee-Yang
Chen

$$\psi = \begin{pmatrix} \phi \\ \chi \end{pmatrix}$$

$$\text{Majorana } \psi = \psi^c$$

ϕ : $\mu\mu\mu$
 χ : $\mu\mu\mu$

$$\begin{aligned} \phi &= -\sigma_2 \chi^+ \\ \chi &= \sigma_2 \phi^+ \\ \phi(t) &= \sqrt{2} \begin{pmatrix} \phi \\ \sigma_2 \phi^+ \end{pmatrix} \\ \phi(-1) &= \sqrt{2} \begin{pmatrix} -\sigma_2 \chi^+ \\ \chi \end{pmatrix} \end{aligned}$$

$$\frac{1}{2}(1-\sigma_5)\phi(-1) = \frac{1}{\sqrt{2}}(1-\sigma_5)\psi$$

$$\frac{1}{2}(1+\sigma_5)\phi(-1) = \frac{1}{\sqrt{2}}(1+\sigma_5)\psi$$

$$\begin{cases} \frac{1}{2}(1-n\sigma_5)\phi(n) = \frac{1}{\sqrt{2}}(1-n\sigma_5)\psi \\ \frac{1}{2}(1+n\sigma_5)\phi(n) = \frac{1}{\sqrt{2}}(1+n\sigma_5)\psi \end{cases}$$

Mode (I)

- (a) SLP theorem valid
- (b) l.n., l.n. $\mu\mu\mu$
- (c) $\mu\mu\mu$

unwanted processes

$$\pi \rightarrow e + \nu$$

$$K \rightarrow e + \nu?$$

$$\mu^+ \rightarrow e^+ + e^- + e^+$$

$$p + \mu^- \rightarrow p + e^-$$

$$K^0 \rightarrow \nu + \nu?$$

$$K \rightarrow e + \mu + \gamma?$$

~~第5回. Sept. 28, 1957~~

湯川: 素粒子論

素粒子

field

particle

quantization

graviton

gravitation

$$g_{\mu\nu} = \begin{pmatrix} 1 & & \\ & 1 & \\ & & -1 \end{pmatrix} + g_{\mu\nu}$$

Minkowski space

constant field

(1, p₁, p₂, p₃)

parity of vacuum

localization of P₁ etc.

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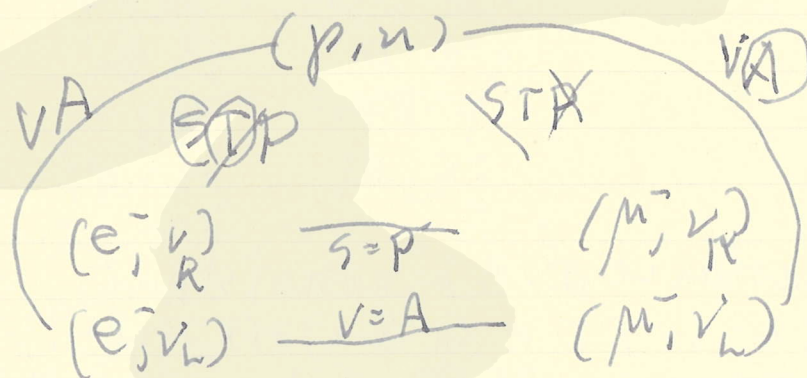
第5回 Sept. 28 '57
主: P-KC

Individual γ^5 -transformation

主題: Lepton
 μ, e & ν of spirality.

STP
VA

ν_R
 ν_L



$$1 - \frac{1}{3} \cos \theta$$

$$P = \frac{3}{4}$$

$$\psi_e (1 + \gamma^5) \psi_\nu$$

$$\psi$$

$$(\psi_e^\dagger - 0 \psi_{\nu_R}) (\psi_{\nu_R}^\dagger 0 \psi_\mu -)$$

$$O(1 + \gamma^5) \psi_e$$

$$O(1 + \gamma^5) \psi_\mu$$

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baryon spin $\frac{1}{2}$ (derivat. coupl.)

$(1 \pm \gamma_5) \psi_N$

weak

$(1 \mp \gamma_5) \psi_{\Sigma}$

$\bar{N} N \pi$

$(1 \pm \gamma_5) \psi_{\Xi}$

$\Xi N \pi \times$

第6回 Sept, 30, '57
先生: 中野 邦子
Symmetry

baryon
原.
田中 吉
佐々木
中野 邦子
湯川

hepton
(中野 邦子)
佐々木
湯川

- 1) CP invariance T-NZ consistent
- 2) 12 次元? (T の同値性? あるいは?)
- 2) 物理 space の性質, (4次元? 5次元?)
- 3) isotropy $\rightarrow$ angular momentum
homogeneity $\rightarrow$ energy momentum
parity と空間の対称性
- 4) Int. の対称性 Symmetry とは何か?
- ① 5) 質量スペクトル, charge, spin
- ② 6) π^+, μ^0, e^0 の可能性
- ③ 7) 粒子線 a と b の方.
- 8) 表示の問題.

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Is ~~the~~ ^{is not} ~~vi~~ ^{space} ~~space~~ の類型を.

{ 対称性:

- 0 1) Energy-momentum
- 0 2) Angular momentum
- 0 3) charge
- 0 4) ~~strong reflection~~ Baryon number
- (5) ~~Time reversal~~ Probability)
- ? 6) ~~Strong reflection~~

- 7) Time reversal
- 8) Lepton number
- 9) Parity
- 10) charge symmetry
- 11) charge independence
- 12) Strangeness
- 13) Spirality
- 14) charge conjugation
- 15) ~~isospin~~

3) charge conserv.

$$x_\mu \rightarrow x_\mu + \epsilon_{\mu\nu} x_\nu$$

$$\psi \rightarrow (1 + \frac{i}{2} \vec{T} \cdot \vec{\epsilon}) \psi$$

$$\begin{cases} \psi \rightarrow e^{i\alpha} \psi \\ A_\mu \rightarrow A_\mu - i \frac{\partial \alpha}{\partial x_\mu} \end{cases}$$

4. Baryon number.

6. strong reflection
mass, life

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?7. Time reversal
Wigner
weak?

?8. Lepton number
double β

?9. Parity

?10. Charge symmetry

?11. Charge independence

?12. Strangeness

?13. Spirality

?14. Charge conjugation

?15. 統計.

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第2回 Oct. 1, 1957

~~相互作用~~ ~~の~~ ~~性質~~ の3点と
Symmetry の関係

立場 I: 85年4月2日の部内に出るもの、
すべての相互作用を、~~すなわち~~、~~85年4月2日の~~
図には対称性が共通であるので「~~同じ~~」か、
~~ある~~ ~~力~~ ~~場~~ ~~の~~ ~~場合~~ ~~でも~~、~~それ~~ ~~が~~ ~~ある~~ ~~い~~
と考えるべきで、~~85年4月2日の~~ Minkowski
空間に同じな対称性が ~~ある~~ ~~べき~~ ~~で~~ ~~ある~~
と、~~85年4月2日の~~ ~~場合~~ ~~でも~~ ~~それ~~ ~~が~~ ~~ある~~ ~~い~~
この立場では、~~85年4月2日の~~ ~~場合~~ ~~でも~~ ~~それ~~ ~~が~~ ~~ある~~ ~~い~~
は。

1. ~~85年4月2日の~~ Minkowski の内部空間に
関係してのことであるという意味で、
一般性を失って対称性 (primary symmetry)

2. Minkowski の対称性として
理解すべきもの (図解のもの、

(~~85年4月2日の~~ isospin)

それは中身に関係して、~~85年4月2日の~~
素粒子に共通のものである。

そして、~~85年4月2日の~~ depend する対称性
を ~~85年4月2日の~~ composite model によって
~~85年4月2日の~~ primary のものに reduce
(~~85年4月2日の~~ ~~場合~~ ~~でも~~ ~~それ~~ ~~が~~ ~~ある~~ ~~い~~、~~85年4月2日の~~
Minkowski の対称性 ~~85年4月2日の~~ ~~場合~~ ~~でも~~ ~~それ~~ ~~が~~ ~~ある~~ ~~い~~
かという。

今のところ、~~85年4月2日の~~ ~~場合~~ ~~でも~~ ~~それ~~ ~~が~~ ~~ある~~ ~~い~~ ~~成功~~ ~~して~~
いない。 ~~85年4月2日の~~ ~~場合~~ ~~でも~~ ~~それ~~ ~~が~~ ~~ある~~ ~~い~~ ~~成功~~ ~~して~~
~~85年4月2日の~~ ~~場合~~ ~~でも~~ ~~それ~~ ~~が~~ ~~ある~~ ~~い~~ ~~成功~~ ~~して~~
ものとして残っている。

3. charge conservation,
電荷の保存は Minkowski
空間 (つまり $3+1$ の Minkowski
空間) の中にある 粒子
の 4-元組として記述されるが、
これは charge と isospin 関係して
isospin 空間に 2 重に 2 重に
これ Minkowski 空間の 4-元組
に 2 重に 2 重に 2 重に 2 重に
ある。

4. π -meson 族に 電荷保存と
後者をいさしめる: isospin 族である。
4. lepton 族 isospin が $1/2$ 以下
なく、baryon-meson family
に $1/2$ 以下 $1/2$ 以下 $1/2$ 以下
と、~~破綻~~ 相互作用の強さと相対性
は 陽子に $1/2$ 以下 $1/2$ 以下 $1/2$ 以下
が、Minkowski 的 内部構造
は baryon-meson 族と、
 N, Λ, π, K 等の違いを
そういう意味での構造の違いに
対応させる。
しかし $1/2$ 以下 $1/2$ 以下 $1/2$ 以下
に $1/2$ 以下 $1/2$ 以下 $1/2$ 以下

5. もう一つ、こういうことで、最も
破綻が $1/2$ 以下 $1/2$ 以下 $1/2$ 以下
で $1/2$ 以下 $1/2$ 以下 $1/2$ 以下
weak interaction での P, C, T

$$\begin{aligned} \pi^+ &\rightarrow \pi^+ + \pi^+ + \pi^- \\ &\rightarrow \pi^+ + \pi^0 \end{aligned}$$

(足す) として、 ZnPO は強い酸性溶液
~~で溶解する~~ で、 H_2PO_4^- の Winkler's
 試験の弱い symmetry (C, P, T) を
 成すもの、isopin, strangeness,
 とからみあつて ZnPO の「足す」。

この場合 Γ の経路として $\gamma = \gamma_1$,
 γ_2 の方が Γ の critical w
になる。

主成分 I: 同 1500 の主成分であるが、
 相互作用の対称性により小さく
 ので、電磁相互作用の成分と見做すことが
 できる。
 しかし、この成分は、 β -decay の成分
 の干渉を説明するに、 γ の成分と
 neutral pion の成分の両方を用いる
 必要がある。

定理 II. Minkowski空間 q 対
軸 x_1 上の q 次元 primary 元の
集合 $\mathcal{P}$ は, q 次元空間 $\mathcal{P}$ 上の q 次元
元 $\mathcal{P}$ であり primary 元 $\mathcal{P}$ である。

これ等の2つの区間が50%にも重なり
ない限り $\boxed{[100, 200]}$ を含む解が存在
しない。 これは2つのideaがある。

[illegible]

金剛經の「空」の立場に「般若」を「戒」する

追加 III. ~~この~~ Minkowski 空間の
スケールの scale で増えるべきで、
この意味では、追加 II と似ていて、
追加 I のように強い相対性を用いて
inspiring である。しかし、相対性を用いて
計算すると、強い相対性を用いて
~~cut-off~~ 10^{13} cm 程度の

の値を ϵ とし、 cut-off は、その値に
 近、これより中、それより小さい値がある。
 この値は ϵ の scale $\epsilon^{\frac{1}{d}}$ 以内で選べる。
 相違の space が $\epsilon^{\frac{1}{d}}$ に示される。
 ここから isospace の存在を示す (true)。

I. 4次元
 ↓ Higgs field の作用

II. spinor 空間

III. ↓ Min Rowski 空間
 ↓ 質量と Hilbert 空間の
 相互関係。

↑ 空間の中で x と y の space の距離 $d(x, y)$ は
 1. charge に比例 (A. の場合)
 weak interaction の y の $d(x, y)$ は c の
 1/2 程度 $d(x, y) = \frac{1}{2} \ln \frac{1}{1 - v/c}$ 程度。

Special Relativity

Quantum Mechanics

Minkowski

Hilbert

Elementary Particle System
 in M and H

→ M と H の関係
 Hilbert system
 1. M と H の関係
 2. M と H の関係

(i) local field (with degrees of freedom indifferent to M not violating H)

↑ M と H の関係
 Hilbert system
 1. M と H の関係
 2. M と H の関係

(ii) non local in M (and in H ?)

space M と H の関係

space M と H の関係

↑ M と H の関係
 Hilbert system
 1. M と H の関係
 2. M と H の関係

↑ M と H の関係
 Hilbert system
 1. M と H の関係
 2. M と H の関係

↑ M と H の関係
 Hilbert system
 1. M と H の関係
 2. M と H の関係

↑ M と H の関係
 Hilbert system
 1. M と H の関係
 2. M と H の関係

宇崎: $\pi^0 \rightarrow \gamma \gamma$ と $\pi^0 \rightarrow e^+ e^-$

g C.I.
 e (C.S.) I_3
 g'

宇崎: 1) 素子の ρ の
2) π の

$$\{P_\mu, P_\nu\} = 2\delta_{\mu\nu}$$

Pais-Picconi

$$\begin{pmatrix} \Sigma^+ \\ \Sigma^0 \\ \Sigma^- \\ \Xi^- \\ \Xi^0 \\ \Xi^- \end{pmatrix} \quad \begin{pmatrix} \pi \\ K \\ \bar{K} \end{pmatrix}$$

宇崎

1. hepton の $\neq$ と $\approx$ - π の
2. hepton の systematization { π } π

1. π の double β
inverse β

$$A^2 \rightarrow A^{2\pm 2} + 2e^\mp \quad (\text{no})$$

$$\bar{\nu} + p \rightarrow n + e^+ \quad (\text{yes})$$

$$\bar{\nu} + n \rightarrow p + e^- \quad (\text{no?})$$

β -decay

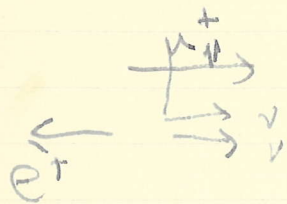
$e^\mp$ の polarization: $\mp v/c$

π - μ - e -decay:

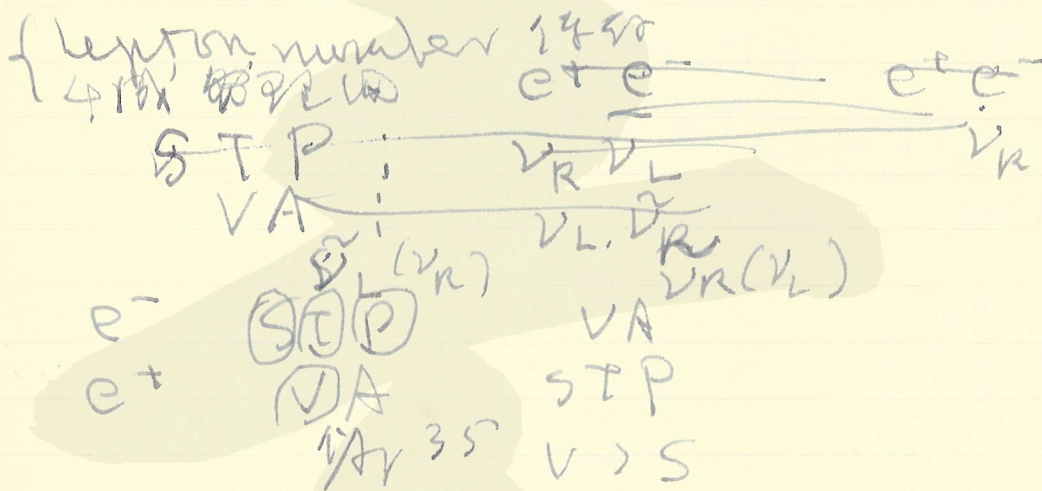
$$\leftarrow \frac{v_R}{v_L} \pi^+ \mu^+ \rightarrow$$

μ^+

$$\frac{1 \mp \gamma_5}{2} \psi_V : \quad \begin{cases} \nu_R, \bar{\nu}_L \\ \nu_L, \bar{\nu}_R \end{cases}$$



$\rho = 3/4$
 $\mu \rightarrow e + \nu$



$$\begin{aligned} 1. \text{STP} & \quad \mu^+ \rightarrow e^+ + \nu \\ 2. \text{STP} & \quad C_i = -C_i' \\ & \quad VA \quad C_i = C_i' \\ 3. e^-: \text{STP} & \quad e^+ : VA \text{ (non-local)} \end{aligned}$$

Gauge Invariance

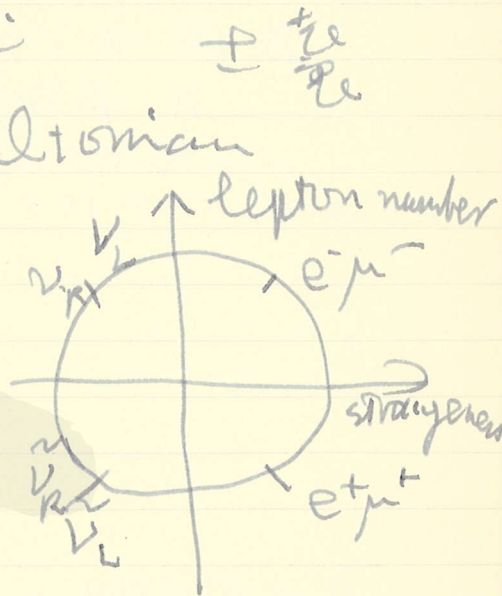
$$R - L + \sum_j q_j (N_j - \bar{N}_j) = 0$$

2.10: Lepton or Symmetrization

Lepton a $q.m.$
 $\tilde{Z}_a = \sqrt{2} e^{\pm(2m_a \pm 1/2)\pi i}$

$\sum_a \tilde{Z}_a = 0$ in Hamiltonian

	m_a	$\tilde{Z}_a$
$\{e^-, \mu^-, \nu_e, \nu_\mu\}$	0	$1+i$
	0	$1+i$
	1	$-(1-i)$
$\{e^+, \mu^+, \nu_e, \nu_\mu\}$	0	$1-i$
	0	$1-i$
	1	$-(1+i)$



$e^+e^-, \mu^+\mu^-, \nu+\bar{\nu}$ is forbidden

$\boxed{e^-\bar{\nu}_L}, \boxed{e^+\nu_R}$
 $\mu_L^-, \mu_R^+, \nu_R^+$
 STP

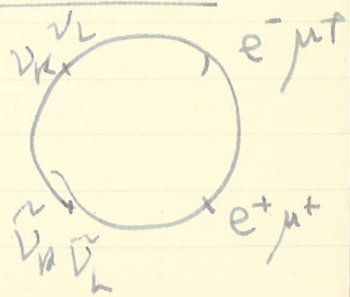
$e^-\bar{\nu}_R, e^+\nu_L$
 $\mu_R^-, \mu_L^+, \nu_L^+$
 $\boxed{\mu_L^+}, \boxed{\nu_L^+}$
 VA

STP
 $e^-\bar{\nu}_L, \mu_L^-, \mu_L^+$

VA
 $e^+\nu_L, \mu_L^+, \mu_L^+$

$e^-\bar{\nu}_L, \mu_L^-, \mu_L^+$
 $\mu_L^-, \mu_L^+, \nu_L^+$
 STP

$e^+\nu_L, \mu_L^+, \mu_L^+$
 $\mu_L^+, \mu_L^+, \nu_L^+$
 VA



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photon

和氏: 24年分
Z ν 20 44 100
 $\pi \rightarrow e + \nu$
 $K \rightarrow e + \nu$

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White

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Black

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日知物理学会 年会

鎌倉市立

(東北大学)

10, 18, 1957

1. 湯川: 物理理論の発展とその応用

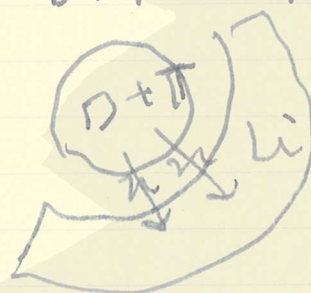
2. 湯川: 湯川理論の発展とその応用

1. 湯川: a. Alvarez

M-D-D-reaction

b. $D+T \rightarrow n + He$

$Li^6 + n \rightarrow T + He \dots$



c. $D+D$

2. Maxwell 分布の応用とその応用

3. 湯川: 10^{21} watt/cm²

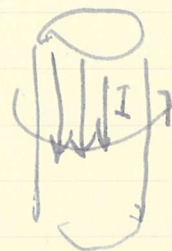
10^{21} watt/cm²

湯川理論の発展とその応用

Spitzer: $P_{fusion} = 64 \times 10^{-34} Z^2 n^2 T^{1/2}$ watt/cm³

K. Siegelman: 湯川理論の発展とその応用

Minimum temperature: $D+D \rightarrow 2 \times 10^8 K$
 $D+T \rightarrow 5 \times 10^7 K$



4. 圧力: Pinch 効果

$I^2 = 2NkT$

3×10^{25} nuclei/cm³ $10^8 K$

10^{10} atom $\rightarrow 10^3$ ampere

Khurchatov

U.S. Princeton
Los Alamos
Livermore
Oak Ridge

U.K. Harwell
A.E.I.
Aldermaston

USSR Moshkov

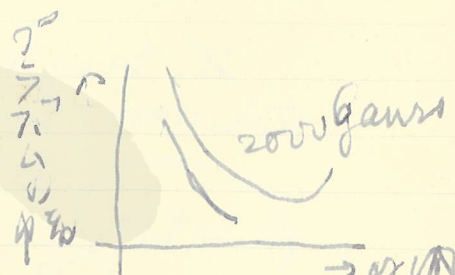
France Fontenay

Germany Hamburg
Aachen
Göttingen
Kiel

Sweden Stockholm
Uppsala

5. Phenomena of instability
magnetic field of π beam in the direction of apply π .
overstabilization

Perhapsatron



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高エネルギー加速器 研究

10月18日 16時30分頃

1. 大河434 : 加速器の加速器

high intensity
 high energy

1. HP の加速器 H: 加速器

$P = 10^{15} \sim 10^{16} \text{ eV}$

2. Target nucleus の recoil

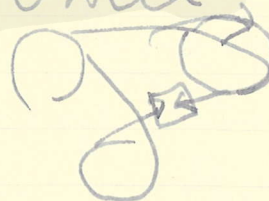
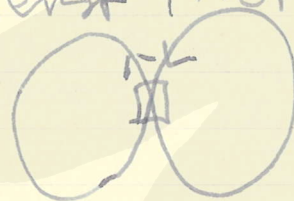
加速器のエネルギー : 10^3 BeV

3. $\rightarrow \leftarrow$ high intensity が 4 倍

$15 \text{ BeV} \quad 15 \text{ BeV} \sim 500 \text{ BeV}$ equivalent

Kerst (MURA)

O'Neil



Yield $\propto n_1 n_2$
 加速器の反粒子 (anti-proton)



magnet

100 GeV

e^-e^- scattering

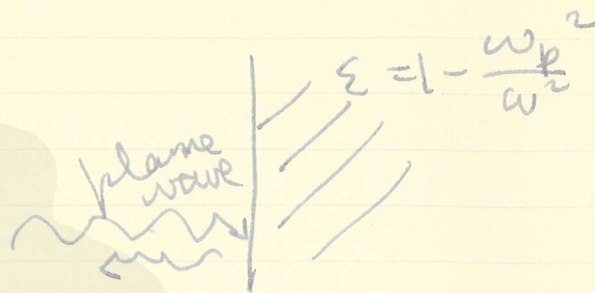
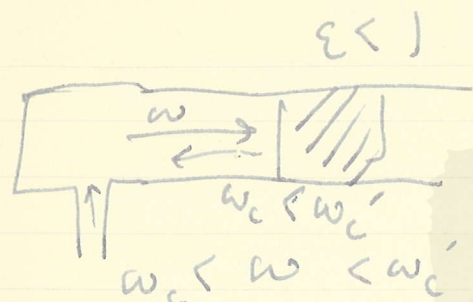
Soviet (Geneva, 1956)

Veksler : Acceleration

Buncker : Guide Field

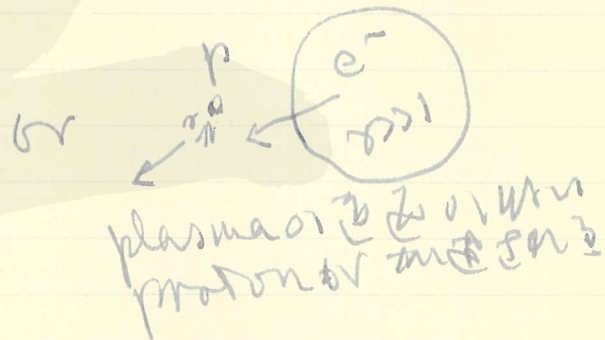
0 Veksler

$$\begin{aligned} \sigma &\sim \pi r_0^2 \\ \sigma &\sim \frac{(Ne)^2}{N m a} \\ \sigma &\sim \pi N^2 r_0^2 \end{aligned}$$

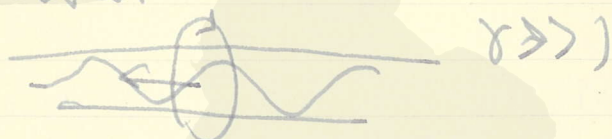


$\omega_c < \omega < \omega_c'$
 $\epsilon < 1$
 $2m$

200 mA 2 MeV proton current



o Boulder:



$$\frac{d(p_{\text{mass}})}{dt} = +[\text{scattering}] - [\text{radiation}]$$

$$\frac{d\gamma}{dt} = -[\text{scattering}] + [E]$$

$\gamma = 30 \rightarrow 15 \text{ MeV}$

$b \approx 4 \times 10^{-3} \text{ cm}$

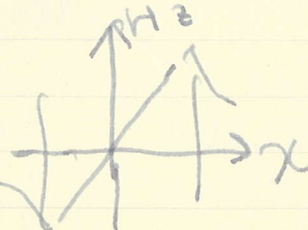
$I \sim 1700 \text{ Amp.}$

$$B = \frac{2I}{b}$$

$R \sim 1 \text{ m}$

proton: 3 BeV

$E = 1 \text{ volt/cm}$



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Red

Magenta

White

3/Color

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2. 長島 - 男: 宇宙線 1280' の加速機構.

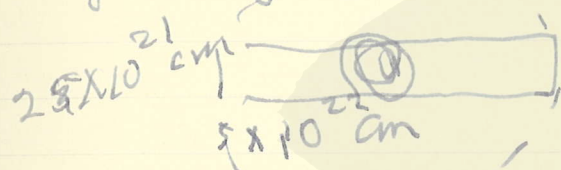
$$I \sim 0.3 / \text{cm}^2 / \text{sec} / \text{sterad}.$$

$$N(E) \sim E^{-1.75} \text{ (integral spectrum)}$$

$$\begin{matrix} P & H & e & h\nu \\ 50 & 20 & < 1\% \end{matrix}$$

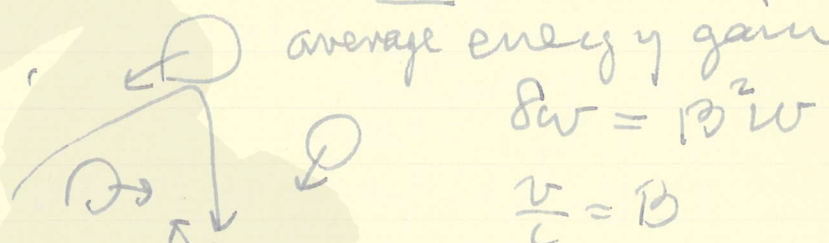
$$E_{\text{max}} \sim 10^{18} \sim 10^{19} \text{ eV}$$

Galaxy - a few 10¹⁷ to 10¹⁸ eV



$$\sim 10^{-6} \sim 10^{-5} \text{ gauss}$$

Fermi P.R. 75 (1949), 1.



$$\delta w = B^2 w$$

$$\frac{v}{c} = B$$

$$w = M c^2 \exp(B^2 / v)$$

$$= M c^2 \exp(B^2 t / c)$$

$$\text{for } t \text{ to } t + dt: \exp(-t/\tau) dt / \tau$$

$$n(w) dw \sim w^{-(1 + \tau / B^2 T)} dw$$

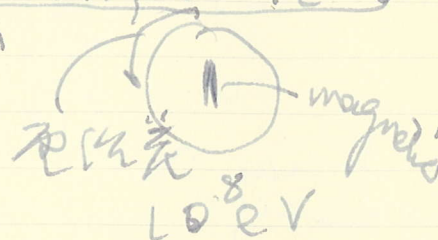
injection energy
proton 200 MeV
 α 1 BeV
O 20 BeV

Injection mechanism

1. Electromagnetic acceleration

a) E.S. ~~strong~~ electric conductivity of H_2O

① unipolar induction



② H. Akén



$E \parallel H$

③ Discharge

Giovanelli, Dungey, Bierman

b) E.M. Induction

W. F. G. Swann

L. Ridolfi & Butler

$10^{13} \sim 10^{15} \text{ eV}$

proton heavy

1. H_2O の H^+ の (particle density of H^+)

c) E.M. Wave

low frequency

McMillan

Menzel & Salisbury

super novae origin

Zwicky

spitzer

$1/100 \text{ yr.}$
radiation pressure

Murphy - Gold - Mayakawa



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Yellow

Red

Magenta

White

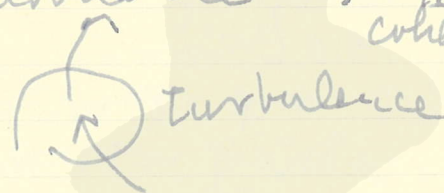
3/Color

Black

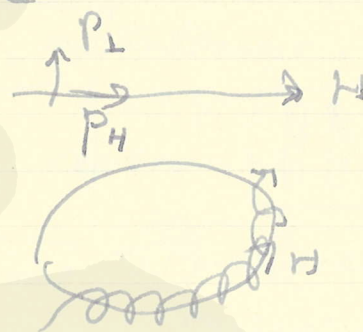
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Fermi (D) turbulent field ϕ 's energy $\approx$
transfer

(a) turbulence $\rightarrow$ $\overline{E}$ $\rightarrow$ Acceleration
(b) coherent



(2)



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Green

Yellow

Red

Magenta

White

3/Color

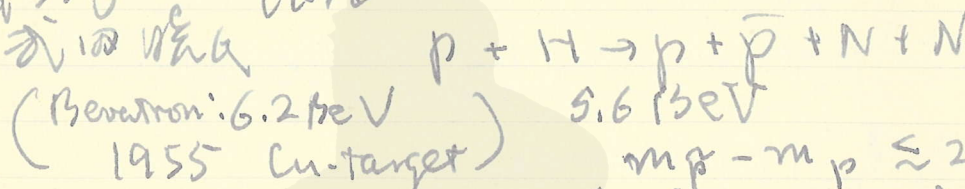
Black

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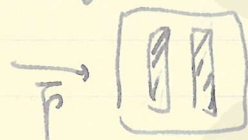
素粒子-核反応の形成

Oct. 19, 1957

反陽子 陽子
核反応



size, momentum, velocity selection



Leveleau

attenuation
annihilation

scattering

$\bar{p} \sim 450 \text{ MeV}$

att.

$p \quad 105 \pm 8$
 $n \quad 112$

15 of 488

(1) 1242/8

(2) annihilation of
with $t \ll T$

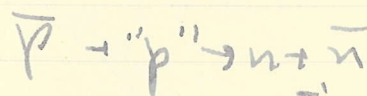
$$\sigma_{An} \sim \pi a^2$$

$$\sim \pi(a + \lambda)^2$$

$$a \sim \frac{2}{3} \frac{\hbar}{m\pi c}$$



simulation



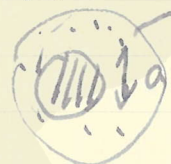
anti-neutron

$$\sigma_{\bar{p}n} \sim 80 \text{ mb.}$$

diffraction (10° or so) scattering

annih.

$89 \pm 7 \text{ mb}$
74



π cloud

$$\frac{\hbar}{2mc^2} \ll \frac{2\hbar}{\langle \omega \rangle}$$

$\langle \omega \rangle$: average
meson energy

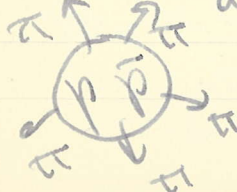
(classical)

(quantum) $\rightarrow$ diffraction ~ 3

$$r_{\text{core}} \sim \frac{1}{3} \frac{\hbar}{m\pi c}$$

$$\sigma_{\text{diff.}} \sim \frac{1}{4} \sigma_A$$

(80% of total)



statistical equil. $n_{\text{meson}} \sim 3$

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$$n_{\pi} = n_{\text{cloud}} + n_{\text{produced}}$$

$$n_{\text{cloud}} = 1.3$$

木村氏: Comment

1. $\sin R \text{ v.s. } t < 2 \theta$ Param. $\text{v.s. } t < 100$

2. $K/\pi \sim 30\%$ (Fermi) 5% (exp.)

π - π -correlation

resonance

式谷氏: Comment

$V+iW$

π : $\frac{h}{mc}$?

Core decay:

木村氏: accidental or π

式谷氏: π -beam

Cut-off: 1.3 BeV.

新粒子

式谷氏: π -beam

中野氏

Venice: Szalay et al

πe^0 : $1 + \frac{10}{c} \alpha \cos \theta_{\text{ev}}$

correl. $d = 0.17 \pm 0.1$

μ or mag. mom (charmin)

$q = 2(1.0024 \pm 0.0008)$

$q_{\text{char.}} = 2(1.001165)$

$\pi^+ \rightarrow \mu^+ \rightarrow e^+$ right handed

$\pi^+ \rightarrow \mu^+ \rightarrow e^+$

asymmetry

$a = -0.31 \pm 0.03$

(Venice Conf.)

$\pi^+ \pi^+ N \rightarrow \Lambda + K^0$ (parity violation)

π^0 up-down asymmetry

1958: Lepton
I. β -decay interaction

(1) 1. Fierz cond.

$$C_i C_{i+1}^* = 0$$

$$i = e, \nu, \tau, \mu$$

$$C_i' C_{i+1}'^* = 0$$

2. RaE , Cs^{137}

T が 100% の 5 分 45 秒
V が 100% の 12 分 45 秒

3. Co^{60}

(1) 4. Longitudinal polarization

5. $e-\nu$ -angular correlation

1, 2, 3, (4) が 5 の 5 分 45 秒

$$\begin{aligned} \text{for } e^- & p = -\frac{v}{c} \\ \text{for } e^+ & p = +\frac{v}{c} \end{aligned}$$

4 possible cases

1. e^- STP
VA

ν_L
 ν_R

$He^6 (e^-) (C_+ \gg C_-)$
 $Ne^{23} (e^-) (C_+ \gg C_-)$

e^+ STP
VA

ν_R
 ν_L

$A^{35} (C_+ \gg C_-)$
 He^6 Ne^{23}

2. e^- STP
VA

ν_L
 ν_L

3. e^+ STP
STP

ν_L
 ν_R

A^{35}
 He^6 Ar^{39}
 A^{35} He^{356}

4. e^- VA
VA

ν_R
 ν_L

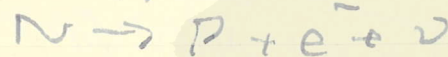
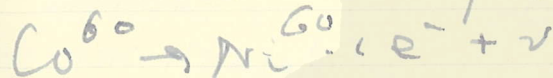
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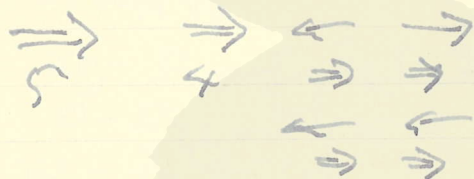


μ : left
 e^+ : right

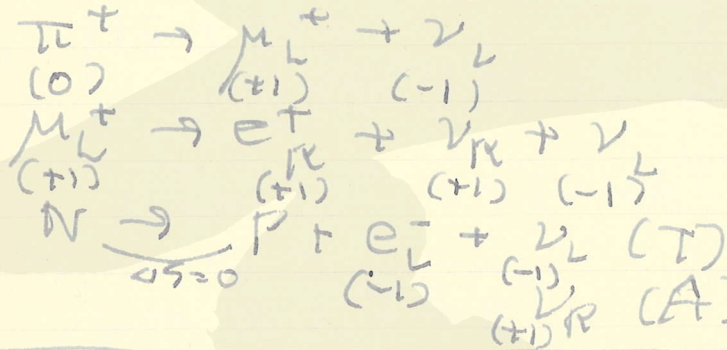
7. $e^+ \nu \mu$ interaction



e^- is polar.
 $p = -\frac{v}{c}$



(5)

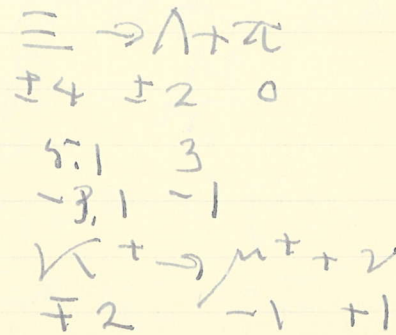
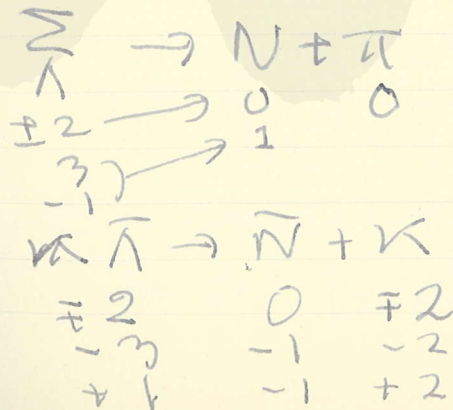


Feynman
-gell-Mann

螺旋性: chirality of helicity
(Pauli, Umezawa-Konuma)

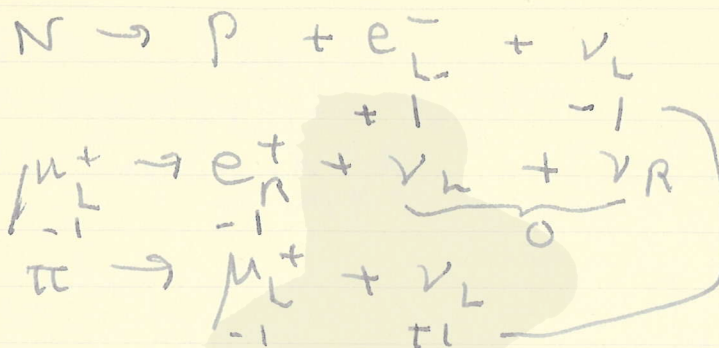
(A, V) is 5. L is 1. He^6 is 3/2.

$\Delta S = 0, \pm 2$ is strong.
 $\Delta S = \pm 2$ weak
 $\Delta S = 0$ strong



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21B15
21B15
lepton number
の保存則
or 21B15, 21B16

4成分2重 $\Delta S = \pm 2, \Delta n = \mp 2$ } $\begin{matrix} \tau^- - \tau^+ \\ \mu^- - \mu^+ \\ e^- - e^+ \end{matrix}$

$C = n + s$ の交換

2成分2重と、
4成分2重との結合
gauge 変換

$\exp(i(\alpha + \beta \gamma_5))$
 $\alpha = \pm \beta$
 $\pi \rightarrow \begin{matrix} \mu + \nu_\mu \\ e + \nu_e \end{matrix}$ (81B15)

	N	exp
C	2	0
n	1	-1
s	1	+1

standing: $\frac{M}{m} = \frac{g \pi}{2 \theta}$

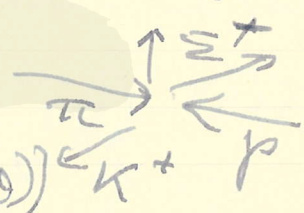
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T. D. Lee, J. Steinberger, G. Feinberg,
P. K. Kabir and C. N. Yang
Possible Detection of Parity
Nonconservation in Hyperon Decay
 $\pi^- + p \rightarrow \Sigma^+ + K^+$
(1132 eV) $\sim 60 \text{ MeV}$
S, P wave

$$I(\theta) = |a + b \cos \theta|^2 + |c|^2 \sin^2 \theta$$

θ = angle between $p_{\pi}^{(in)}$ and p_{Σ}
(centre of mass system)
Polarization of Σ^- is in the direction
of $p_{\pi} \times p_{\Sigma}$:

$$P(\theta) = [I(\theta)]^{-1} \times 2 \sin \theta \times \text{Im} \{c^*(a + b \cos \theta)\}$$


$$\begin{aligned} \text{spin of } \Sigma^- &= 1/2 \\ \text{spin of } K^+ &= 0 \\ \Sigma^- &\rightarrow n + \pi^- \end{aligned}$$

R : component of decay π -momentum
in the direction of $p_{\pi}^{(in)} \times p_{\Sigma}$
Distribution of R :

$$W(\theta, z) d\Omega dz = I(\theta) d\Omega \cdot \frac{1}{2} [1 + \alpha P(\theta) z]$$

$$z = R/R_{\max} \approx R/(100 \text{ MeV}/c)$$

$$\alpha = \frac{2 \text{Re}(A^* B)}{|A|^2 + |B|^2}$$

A, B : amplitudes of $s_{1/2}$ and $p_{1/2}$
in the final state of $(n + \pi^-)$

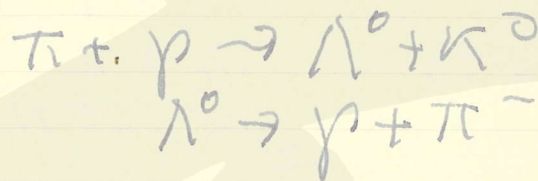
(1) time reversal $\Rightarrow P \rightarrow -P$ invariant $\Rightarrow S$

$$\alpha = \pm \frac{2|A||B|}{|A|^2 + |B|^2} \cos(\delta_P - \delta_S)$$

(2) charge conj. $\Rightarrow P \rightarrow -P$ invariant $\Rightarrow S$

$$\alpha = \pm \frac{2|A||B|}{|A|^2 + |B|^2} \sin(\delta_P - \delta_S)$$

Thus, if $|\alpha| > |\sin(\delta_P - \delta_S)|$
both G, C , and parity are not
conserved in the decay of Σ^- .



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3/Color

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S. Blumstein and A. Klein
Phenomenological Analysis of μ -Decay
(Aug. 27, 1957)

Non-local interaction of 1st kind
Lee and Yang

general form of matrix element

$$M = \bar{u}(p) O_\mu u(P) \bar{u}(q) \gamma_\mu \frac{1}{2} (1 - \gamma_5) v(q)$$

for $e^- \rightarrow e^- + \nu + \bar{\nu}$

in two-component theory with lepton number conservation, because

$\bar{\psi}_\nu \gamma_\mu \frac{1}{2} (1 - \gamma_5) \psi_\nu$ is the only covariant
formed out of ψ_ν and $\bar{\psi}_\nu$.

$$O_\mu = (g_V - g_A \gamma_5) \gamma_\mu - \frac{1}{M^2} (G_V - G_A \gamma_5) P_\mu$$

$$- \left(\frac{1}{M^2} \right) (G'_V - G'_A \gamma_5) (\not{q} - \not{q}) \gamma_\mu \quad (\text{Miyamoto})$$

$$- \left(\frac{1}{M^2} \right) (G_T - G_A \gamma_5) (\not{q} - \not{q}) P_\mu$$

q' , and q' are μ 's of

$$\left. \begin{aligned} Q_I &= (q + \bar{q})^2 / M^2 = 2(q \cdot \bar{q}) / M^2 \\ Q_{II} &= (p + \bar{q})^2 / M^2 = 2(p \cdot \bar{q}) / M^2 \\ Q_{III} &= (p + q)^2 / M^2 = 2(p \cdot q) / M^2 \end{aligned} \right\}$$

$$1 + Q_I + Q_{II} + Q_{III} = 0$$

1st kind nonlocality:

Q_I (L. and $\bar{\nu}$) (ν , $\bar{\nu}$) and (μ , e) interact
at different points and momentum

or $(q + \bar{q})$ is propagated between pairs.
or Q_{II}
or Q_{III}

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Yellow

Red

Magenta

White

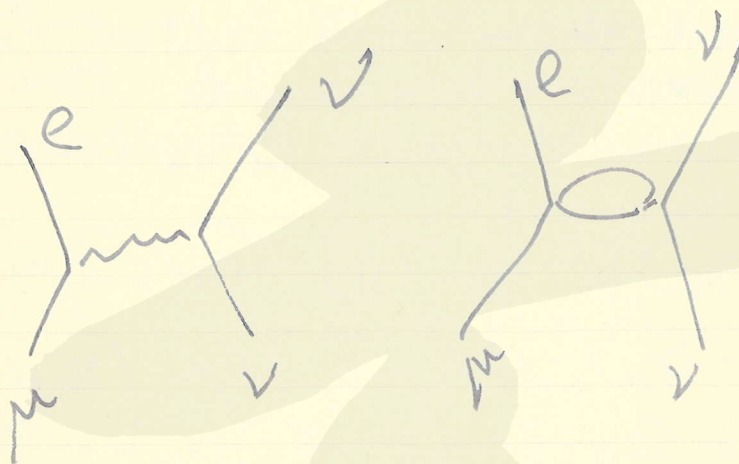
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deviation of $\rho = 3/4$ ($\rho_{\text{exp}} = 0.68$)
nonlocal interaction of range $\sim 0.6 \times 10^{-13}$ cm
intermediate boson mass $\sim 600 m_e$

2nd kind non-locality



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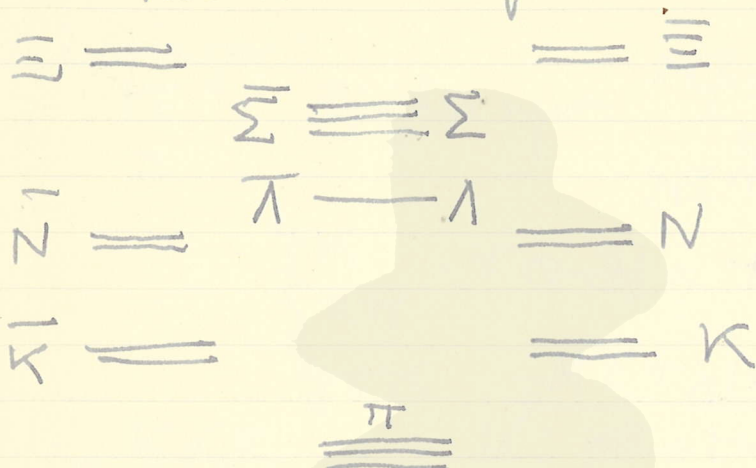
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宇野 正: Global Symmetry Rochester Conference 1957



$$Q = I_3 + \frac{1}{2}(S+N) \\ = I_3 + \frac{1}{2}Y$$

-1 0 1 $Y \equiv S + N$
hypercharge

1. Invariance property
2. Conservation law & coupling (Wigner)
3. Coupling of N and π & symmetry of π

Gell-Mann:

$$\begin{cases} g_{\Lambda K}^2 < g_{N\pi}^2 \\ g_{\Lambda\pi}^2 \sim g_{N\pi}^2 \end{cases}$$

strong (VS MS)

g_{π} : highest global sym.
lower sym.

$\leftarrow \pi-K$

$\leftarrow$ hyperfragment

π -coupling
 K -coupling

$$\pi \begin{pmatrix} (P_n) \\ \left(\begin{matrix} \Sigma^+ \\ \Sigma^0 \\ \Sigma^- \end{matrix} \right) \end{pmatrix} \left(\begin{matrix} \Lambda^0 \\ \Sigma^0 \\ \Sigma^- \end{matrix} \right) \right) \text{ mass 1741 MeV, } \Sigma^+ \rightarrow \pi^+ + n$$

$$Y^0 = \frac{1}{\sqrt{2}}(\Lambda^0 - \Sigma^0)$$

$$Z^0 = \frac{1}{\sqrt{2}}(\Lambda^0 + \Sigma^0)$$

N	$g_{\Lambda K}$	$g_{\Sigma K}$
Ξ	$h_{\Lambda K}$	$h_{\Sigma K}$

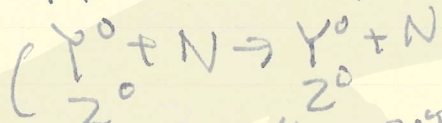
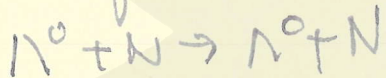
charge independent viz. $\pi^0 \pi^0$.

$$\frac{M_N + M_{\Xi}}{2} = \frac{M_{\Lambda} + 3M_{\Sigma}}{4}$$

M_{N+190}

$$M_N + 235 \text{ MeV} \quad (\text{Kの4倍})$$

2) Y-N force



$$V_{NN} = A + B \pi_1 \pi_2$$

$$V_{in} = A$$



$$s\Lambda + \pi | \Lambda \rangle \otimes | p \rangle$$

π -N system & matrix element interactions.

N- π resonance

$$J = \frac{3}{2}, I = \frac{3}{4}$$

$$\Lambda_{\Sigma} \cdot \pi$$

$$J = \frac{3}{2}$$

$$I = \frac{1}{2} I$$



$$J = \frac{2}{\pi}, I = 1.$$

Schwinger:

K
 π

higher sym.

I, I'

$\frac{1}{2} \rightarrow \frac{1}{2} \rightarrow \frac{1}{2} \rightarrow \frac{1}{2}$

g_K

$g_{\pi N}$

$g_{\pi K}$

$K\pi\pi$

K : parity doublet

π -decay

K -decay

$\frac{1}{2} \rightarrow \frac{1}{2}$ or gell-Mann $\times$ $\frac{1}{2} \rightarrow \frac{1}{2} \rightarrow \frac{1}{2} \rightarrow \frac{1}{2}$

parity:

π +

η +

Λ +

Σ +

K - (+)

Ξ

ψ $\frac{1}{2}$

ϕ 0

dimensionless interaction

1. $\psi\psi\phi$

2. $\phi^2\phi^2$

4. $\frac{1}{2}$ isospin space

$I = 0, 1$

$\frac{1}{2} \frac{1}{2}$

$\Lambda \Sigma$

$N \Xi$

fermion

self-dual

π

$K \bar{K}$

meson

antisym

tensor

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9 dec π^0 C.P.
 π'^0 +
 -

Diagram:

ψ 8
 ϕ 7

$g \bar{\psi} \gamma_\mu \phi \gamma_5 \psi$

$\mu = 1, 2, \dots, 7$

3-dim. isospin space

4-hypercharge space
 J, J'

$$Q = I_3 + J_3$$

$$Y = J_3 + J'_3$$

$$\begin{pmatrix} p \\ n \end{pmatrix} \xrightarrow{I} \begin{pmatrix} \Sigma^+ \\ \Sigma^- \end{pmatrix}$$

$$\begin{pmatrix} \Sigma^+ \\ \Sigma^- \end{pmatrix} \xrightarrow{J} \begin{pmatrix} \Xi^0 \\ \Xi^- \end{pmatrix}$$

baryon isospin is $\frac{1}{2}$.

I, J, J' の値は $\frac{1}{2}, 1, \frac{3}{2}, 2, \dots$

meson

$M \quad r_1 \dots r_m \rightarrow I\text{-space}$

$\lambda_1 \dots \lambda_n \rightarrow J, J'\text{-space}$

$$m+n \leq 1$$

$$m=1, n=0 \quad \pi$$

$$m=0, n=1 \quad K$$

$$(m=0, n=0 \quad ?)$$

$$\psi = \begin{pmatrix} \psi_1 \\ \psi_2 \end{pmatrix}$$

$$i(\bar{\psi} \gamma_5 \psi) \pi$$

$$\bar{\psi} \gamma_\mu \psi K^\mu$$

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$$P = \begin{pmatrix} 0 & \tau \\ \tau & 0 \end{pmatrix} \quad P_4 = \begin{pmatrix} 0 & i \\ i & 0 \end{pmatrix}$$

$$\psi = \begin{pmatrix} N \\ \Xi \end{pmatrix}$$

$$\varphi_L = \begin{pmatrix} \Sigma_a \\ \Sigma_b \end{pmatrix}$$

$$g_K \{ \bar{N} (1 + i \Sigma \tau) K + \Xi (1 + i \Sigma \tau) \bar{K} \} + h.c.,$$

$$\Delta M = A + (B + C \gamma_3) (1 + P_5) \xrightarrow{N, \Xi} \\ + (D + E \tau \gamma_3) (1 - P_5) \xrightarrow{N, \Xi}$$

$$P_5 \psi = \begin{pmatrix} \psi_1 \\ \psi_2 \end{pmatrix}$$

(strong
interm.
weak)

g
 P

global sym X
 P, C, X

$$e: \bar{\varphi}_2 \frac{\tau + \gamma_3}{2} \varphi_2 \pi \\ e (\Sigma \times \Sigma) \pi$$

$$\begin{matrix} e \\ \Sigma \end{matrix} \begin{matrix} \pi \\ \Sigma \end{matrix}$$

$$2 e \bar{\varphi}_1 \tau \gamma_3 \varphi_1 \pi$$

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Conference on the Role of Gravitation in Physics Jan. 18~23, 1957 (I)

V. h. Ginzburg, U.F.N. (1956)

Satellite, i.e., gravitational effects in
the (in the in D)

Seminar I: Unquantized G.R.

J. Wheeler:

1. 地球. 42.56 ± 0.94	theory 43.15
地球 4.6 ± 2.7	3.84
人地球 400 km	1450" / century 0.06

2. 光の曲り: 1952: 1.79 ± 0.06
地球: 1.751"
太陽: 1.87" ± 0.08"

3. 恒星の赤い shift	theory	obs.
white dwarf 40 Eri B	17 ± 3	21 ± 4
Sir. B.	79	60 ~ 80
人地球 blue shift		

$$\frac{\Delta \nu}{\nu} = 1.09 \times 10^{-18} h \left(1 - \frac{h}{r_0}\right)$$

$\sim 10^{-10}$

II. Gravitation & Electromagnetism Mach principle

R. H. Dicke
inertia mass & gravitational mass
or equivalence

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Session 4:
Cosmology:
T. Gold: Measurable Quantities

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W. G. Meyer and V. L. Telegdi
 "Twin" Neutrinos

$$\begin{aligned}
 (1 + \gamma_5) \psi_\nu &= \nu_L = \nu_L & \tilde{\nu}_L &= (\tilde{\nu})_R \\
 (1 - \gamma_5) \psi_\nu &= \nu_R = \nu_R & \tilde{\nu}_R &= (\tilde{\nu})_L \\
 n \xrightarrow{S(A)} p + e + \tilde{\nu}_1; & n \xrightarrow{T(V)} p + e + \tilde{\nu}_2 \\
 p \xrightarrow{S(A)} n + \tilde{e} + \nu_1; & p \xrightarrow{T(V)} n + \tilde{e} + \nu_2
 \end{aligned}
 \left. \vphantom{\begin{aligned} n \xrightarrow{S(A)} p + e + \tilde{\nu}_1; \\ p \xrightarrow{S(A)} n + \tilde{e} + \nu_1; \end{aligned}} \right\}$$

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Nov. 5, 1957

1. Hilbert Space
2. $\forall \alpha \in \mathbb{R} \rightarrow \exists \beta \in \mathbb{R}$ such that $\alpha \leq \beta$
i) $\alpha = 0 \rightarrow \alpha \neq 0 \rightarrow \alpha \leq \beta$
ii) h.s.z.

Kallen, Lehmann, Landau
Gell-Mann - how, Boglen'ov, Taylor
Lee model Umezawa

2. H.S.
separable $\Rightarrow$ H.S.
i) momentum Volume $\propto \frac{1}{k}$
ii) 01001... $\propto \frac{1}{k^2}$

excited state of $\text{Co}^{IV} \text{THF}$,
van Hove
Cooper, Infinite matrix

2. ~~Cooker~~ 1) h. I. 2) P_m 3) Polylux
4. 5. hor. Cond.
Kallen: $\langle \sigma \rangle = \pi^2/4$ at 0 and ∞ .

Kälten; $\Delta' = \int p \Delta$
L. 5. 2.

$$\lim_{k \rightarrow \infty} E_k(p_1, p_2) \rightarrow 0$$

$$R = p_1 - p_2$$

Kumagi ~~for~~ $\frac{1}{2}$
handau: ~~for~~ $\frac{1}{2}$ $\frac{1}{2}$ or asymp. perm
 $I(k,l) \sim \delta d(f)$ $f = \max k, l.$

Umezawa
Aramaki

系図 15 Nr. 2.

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gravitation cold. II.

6. Quantized General Relativity p. 174

Mergmann: Why quantize?

Generally covariant theory & quantization.

(1) Canonical Hamiltonian (Dirac)

(2) Lagrangian (Schwinger)

(3) Path integral (Feynmann)

1. Hyperquantized particle field
vs. particle as singularity of
g-d. grav. fld.2. grav. fld & fermion
3. grav. fld & other fld

4. el. particle theory & unified fld theories

5. Conservation of en. mom. (& coord. trans.
inv.) & other strong conservation
laws (other inv. groups)

Measurement:

space-time distance - curvature of $g_{\mu\nu}$ i.e. $g_{\mu\nu}$ q.m. of $g_{\mu\nu}$ grav. mass or $g_{\mu\nu}$ principle of equivalence $\rightarrow$ el. pt.? $m = \sqrt{c^3/G} \approx 10^{-5} \text{ g.}$ mass of lower limit
2.8 $\times 10^{-5} \text{ g.}$

Salecker: Clock of Z-10.

clock is $\sim$ space-like distance & $\sim$ $\sim$ $\sim$ (scale of $\sim$ is essentially macroscopic)
measuring rod

$$s^2 = c^2(t_2 - t_A)(t_A - t_1)$$

statistical clock

$$\Delta t_{\min} = \frac{h}{mc^2} \sim 10^{-29} \text{ sec.}$$

m: clock $\approx$ $\approx$ $\approx$ elem. particle or mass

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- 1) $g_{\mu\nu}$ の存在 → 測地線
- 2) $\left\{ \begin{matrix} \sigma \\ \mu\nu \end{matrix} \right\} \leftarrow$ geodesic
- 3) curvature

proton mass, a gravitational field
 $\Delta M = 10^{-24} \text{ g.} \sim M$

Feynman:

hypothetical atom

- 1) grav. force
- 2) inverse square $1/r^2$ 力

Rosenfeld:

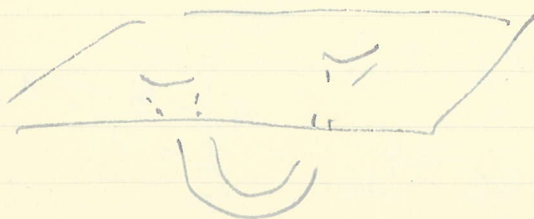
Wheeler: Organic unity !!
 gravi-dynamics
 10^{-13} cm

10^{-31} cm

10^{-33} cm

$< 10^{-33} \text{ cm}$

foam-like structure



worm-hole

$$\begin{aligned} \text{el. mag. field.} \quad \Delta E \sim \hbar^3 = \hbar c/L &\rightarrow \text{grav. en.} \quad \hbar^2 G/c^2 L^3 \\ &= \\ L = \sqrt{\hbar G/c^3} &\approx 10^{-33} \text{ cm} \end{aligned}$$

- (i) Misner (ii) metric tensor & electromagnetic field ~~etc~~ of (E, Z)
- (ii) geon
- (iii) charge without charge
- (iv) spin without spin: $\sqrt{2}$ or double valuedness
- (v) elementary particles without el. particles

Gold: answer without answer

Rosenfeld: $\Delta g_{00} \sim \Delta x$, $\Delta g_{0i} \sim \Delta p$?

Belinfante:

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金沢大
 Chapel Hill Conf. on Grav. i. Physics
 Session 2 (Conti)
 Unquantized General Relat.
 Variation principle

$$\delta \int \frac{1}{2} \dot{x}^2 dt = 0$$

$$\left. \dot{x} \delta x \right|_1^2 - \int_1^2 \ddot{x} \delta x dt = 0$$

2 3 4
 $\dot{x} \delta x$

- 1) $\ddot{x} = 0$
- 2) $\delta x = 0$

$$\delta \int \ddot{x} \delta x dt = 0$$

$$(x \dot{x} - \ddot{x} \delta x) \Big|_1^2 + 2 \int_1^2 \ddot{x} \delta x dt = 0$$

2 3 4
 $\dot{x} \delta x$

- 1) $\ddot{x} = 0$
- 2) $\delta \left(\frac{\dot{x}}{x} \right) = 0$

$t=0$: $g_{\mu\nu}$, $\frac{\partial g_{\mu\nu}}{\partial t}$
 constraint

Session 3
 Gravitational Wave
 el. mag. wave

radiator $\rightarrow$ energy absorber

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Hida
 11/8/30

Conf. on Grav. in Physics
 (Conti.)

Quantization

Ses. 7: Canonical formalism $n=2$
 11/8/30

Feynman quantization

1. de Witt: action & n constraint
2. DeSer, hawrent path integral

$$\frac{\delta^2 L}{\delta \phi_\mu \delta \phi_\nu} = g_{\mu\nu} \text{ or } \text{const.} \dots$$

2つの ϕ の $\delta^2 L$ - 2つの ϕ の $\delta^2 L$ の関係は？

19 or measurable time or ?

Bergmann: Feynman 4.5.0
 4.5.0 4.5.0

Ses. 8: Necessity of Quantization
 Kursunoglu: 1次元の重力場
 4次元の重力場

Feynman の 4.5.0 8.8.1:

$$\Delta g = \sqrt{\frac{\hbar G}{c^3 L^2}} \quad g = \frac{GM}{Lc^2}$$

$$\Delta M \times 10^{-5} \text{ gm}$$

Ses. 9. Closing Session

DeSer: Divergence π P^2

Feynman's Comment:

1. Classical rel. gravitation
 の $g_{\mu\nu}$ の m, c .

Hida:
 11/13/04

Conf. on Grav. in Physics
 (Conti.)

Quantization

Ses. 7: Canonical formalism is not
 ...

Feynman quantization

1. de Witt: action & n constraint
2. DeSer, Laurent path integral

$$\frac{\delta^2 L}{\delta \phi_\mu \delta \phi_\nu} = g_{\mu\nu} \text{ or } \text{const.} \dots$$

... 2つの... - ...

Is it measurable ...?

Mergmann: Feynman ...

Ses. 8: Necessity of Quantization
 Kursunoglu: ...

Feynman ...

$$\Delta g = \sqrt{\frac{\hbar G}{c^3 L^2}} \quad g = \frac{GM}{Lc^2}$$

$$\Delta M \times 10^{-5} \text{ gm}$$

Ses. 9. Closing Session

DeSer: Divergence ...

Feynman's Comment:

1. Classical rel. gravitation

2. Cosmology or general theory
 3. Anything new
 4. Philosophy
 5. Curiosity
- i) math. rigor
Schwarzschild solution?
- ii) intuition

Gupta:
Feynman:

$$\left(\begin{array}{c} R \\ \leftarrow \quad \circ \quad \circ \quad \circ \quad \rightarrow \\ \hline 1 \\ \gamma R^3 \end{array} \right)$$

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2. Iwanenko and H. Sokolik
Unified description of
Ordinary and Isotopic space
(Nuovo Cimento 6(1957),
226)

$$h_i \frac{\partial \psi}{\partial x_i} + \kappa \psi + (\sigma_j I_j / \Lambda) \psi = 0$$

$$i = 1, 2, 3, 4$$

$$j = 1, 2, 3$$

$$E_i \frac{\partial \psi}{\partial x_i} + \kappa \psi = 0 \quad i = 1, 2, \dots, n$$

n -dimensional group of rotation
and inversion

reduction of $\frac{\partial \psi_i}{\partial x_j}$ $i, j = 1, 2, \dots, n$

$n=8$: ordinary spin
isospin
strangeness

(A. Salam and I.C. Polkinghorne,
Nuovo Cimento 2(1955), 685)

Condition of Inversion Invariance
 K -meson parity
parity corresponds to inversion
in 8-space

† On the Classification of Fundamental Particles

	π_3	μ_3		π_3	μ_3
N	$\frac{1}{2}, -\frac{1}{2}$	$\frac{1}{2}$	π	$1, 0, -1$	0
$\bar{N}$	$\frac{1}{2}, -\frac{1}{2}$	$-\frac{1}{2}$	$\bar{\pi}$	0	$1, 0, -1$
Λ	$1, 0, -1$	0	π^+, π^0	$\frac{1}{2}, -\frac{1}{2}$	$\frac{1}{2}$
	0	0	π^0, π^-	$\frac{1}{2}, -\frac{1}{2}$	$-\frac{1}{2}$

湯川記念館史料室

Jan. 25, 1958

井口

Naito: $2 = \frac{1}{2}$

$g = 0$ jumping!!!

state vector の 解析的性質
complex distribution

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