1960
~1961
XIV

NOTE BOOK

Manufactured with best ruled foolscap
Brings easier & cleaner writing

Sept 1960
~ Aug. 1961

Oppenheimer
Lehmann, Rosenfeld
Markov
坂田 (July, 1961)

VOL. XIV

Yukawa

Nissho Note

Oppenheimer Disc. Meeting
Sept. 19, 1960

Nakanishi, Anomalous Threshold

Ida, Rel. Boundary State Problem
B.S.
Double dispersion Relation

Kita μ-Meson Mass

$\overset{(W)}{\psi}$, $\overset{(S)}{\psi}$, χ, A_μ, $g_{\mu\nu}$

$\overset{(W)}{K} > M$

$0 \le \zeta < 1$　　$\lambda \sim 10^4 m_\mu$ $(\sim \hbar\omega^{-1})$　　$\overset{(W)}{K} \sim 10^3 m_\mu$

$\zeta \ge 1$　　$\overset{(W)}{K} > \lambda$

Takabayashi

Fukutome

Nakamura

Maki

非局所場理論

Oct. 1, 1960

片山氏
高野氏(横浜大)
indefinite metric ↔ space metric

中西氏:
村上氏(阪大) non-orthogonal linear
→ spinor, non-linear

徳岡氏:
鷹沼田氏(京大)

$H \qquad t \to T$

$P_\mu \qquad X_\mu$

松田氏: K_1^0 と K_2^0 の mass difference
$\Delta m \sim \frac{1}{\tau_1}$ → weak interaction の cut-off.

c033-656～660挟込

J. V. Lepore, C. R. & Q. M.
(P. R. 119 (1960), 821)

Galilean transf.

$p_i \to p_i - m v_i$

$x_i \to x_i - v_i t$

translation

$x_i \to x_i - a_i$

$p_i \to p_i$

(acceleration (linear)

$x_i \to x_i - \frac{1}{2} a_i t^2$

$p_i \to p_i - m a_i t$

. . . . .

$x_i \to x_i - f_i(t)$

$p_i \to p_i - m \dot{f}_i(t)$)

rotation

$x_i \to a_{ij} x_j$

$p_j \to p_j$

(rotational acceler.

$x_i \to a_{ij}(t) x_j - f_i(t)$

$p_i \to$?)

基研　　Oct. 8, 1960

I. L.R. の Discussion Meeting Program

(1) Ida, Space-Time Description in Quantum Field Theory (15分)

2. Araki,

~~3. Nakanishi~~

(4) Nakano, Transformation group and Conservation Laws (15分)

(5) Fukutome, New Ether Theory of Elementary Particles (15分)

6. Matsumoto

II. 懇談会.

Nakano,

$$\psi \to e^{ie\lambda}\psi$$

$$x^\mu \to x^\mu + \varepsilon^\mu$$

$\lambda(x)$: infinite parameters
gage transformation

$$\partial_\mu - \frac{\bar\psi\psi_{,\mu} - \bar\psi_{,\mu}\psi}{2\bar\psi\psi} \qquad \left(A_\mu \to A_\mu + \frac{\partial\lambda}{\partial x_\mu}\right)$$

conservation

$$F_{\mu\nu,\nu} = j_\mu \qquad j^{(\lambda)}_\mu = \lambda j_\mu + \lambda_{,\nu}F_{\mu\nu}$$

$$j_{\mu,\mu} = 0 \to j^{(\lambda)}_{\mu,\mu} = 0$$

$j_\mu^{(\lambda)} = \lambda j_\mu + \lambda_{,\nu} F_{\mu\nu} - \lambda_{,\mu} A_{\nu,\nu}$

$\Box \lambda = 0$

$Q(\lambda) = \int dV_x \, j_0^{(\lambda)}$ $\quad Q(1) =$ charge

$[\psi, Q(\lambda)] = i\lambda\psi$

Goldberg, P.R.

$G_\mu{}^\nu = \kappa T_\mu{}^\nu$ $\quad t_{\mu,\nu}{}^\nu = 0$

$P_\mu = \int dv g t_\mu{}^0$

Thirring, Fortschritte 1959

$g_{\mu\nu} = \delta_{\mu\nu} + \kappa \varphi_{\mu\nu}$ symmetric tensor

Mach principle?

relativity

Kita

Dirac, electric charge

electric field → filament

端のない filament → photon

端があれば pole, dipole

electron, positron

W. Thirring, Lorentz-invariante Gravitationstheorie
(Fortschritte der Physik **7** (1959), 79)

Mach Principle:

Einstein: Wenn es nur einen Körper auf der Welt gäbe, verliere der Begriff jeglicher Bewegung seinen Sinn und daher könnte es keine Beschleunigung und keine Trägheitskräfte geben. Bei zwei Körpern hat nur die Relativ-Koordinate eine physikalische Bedeutung und da es ~~keinen M~~ keinen Maßstab gibt, gibt es nur Koinzidenz oder Nicht-Koinzidenz als sinnvolle Charakteristiken.

しかし場の理論では常に背景に時空一様の場があり、virtual particles がある。従って Mach 原理は上のような意味にはとれない。むしろ時空の metric は virtual particles の continuum できまり、real particle が local fluctuation を起すと見るべきである。それから到るところ

$$T_{ik}=0$$

とすると pseudo-euclidian space に unique に決まるのか？

tensor field → gage transf.

$$\varphi_{\mu\nu} \longrightarrow \varphi_{\mu\nu} + \Lambda_{\nu,\mu} + \Lambda_{\mu,\nu} - \eta_{\mu\nu}\Lambda^{\sigma}{}_{,\sigma}$$

which makes Euler-eq. invariant.

$$\psi_{\mu\nu} = \varphi_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}\varphi_{\sigma}{}^{\sigma}$$

$$g_{ik} = \eta_{ik} + \psi_{ik}$$

Discussion Meeting
with Rosenfeld and Lamb
10.30～13.00　14.30～17.00
Oct. 13, 1960　Discussion Room
R.I.F.P.

1. M. Ida, Wave Packet Description in QFT

2. F. Araki, Measurement of Physical Quantities ~~who~~ in the presence of a conservation law

3. S. Nakano, Transf. group and conservation laws

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4. K. Matsumoto, Mass formula and its meaning

5. T. Takabayashi, General classical picture of dynamical system under special relativity and quantum mechanics

6. M. Matsumoto, Photodisint. of deuteron

35.10.29 No. 856

On the New Tamm-Dancoff Approximation Treatment of the Superconductivity Hamiltonian

K. Yamazaki

$$H = \sum \epsilon_k (a^*_{k\uparrow} a_{k\uparrow} + a^*_{-k\downarrow} a_{-k\downarrow}) - \frac{1}{\Omega} \sum_{k,k'} J_{kk'} a^*_{k\uparrow} a^*_{-k\downarrow} a_{-k'\downarrow} a_{k'\uparrow}$$

energy conserv.
momentum cons.
spin cons.
(number cons.)

$$\langle k | a^*_{k'\uparrow} a^*_{-k'\downarrow} a_{-k\downarrow} | 0 \rangle = \langle k | : a^*_{k'\uparrow} a^*_{-k'\uparrow} a_{-k\downarrow} : | 0 \rangle$$
$$+ \langle a^*_{-k'\downarrow} a_{-k\downarrow} \rangle_0 \langle k | a^*_{k'\uparrow} | 0 \rangle$$
$$\left(+ \langle a^*_{k'\uparrow} a^*_{-k'\downarrow} \rangle_0 \langle k | a_{-k\downarrow} | 0 \rangle \right)$$
$$- \langle a^*_{k'\uparrow} a_{-k\downarrow} \rangle_0 \langle k | a^*_{-k'\downarrow} | 0 \rangle$$

$$E_k = \sqrt{\epsilon_k^2 + c_k^2}$$

$$c_k = \frac{1}{2\Omega} \sum_{k'} J_{kk'} \frac{c_{k'}}{\sqrt{\epsilon_{k'}^2 + c_{k'}^2}}$$

35.10.29 Nr. 857

Bryce S. DeWitt
Quantization of Fields with Infinite Dimensional Invariant Groups

Poisson bracket is defined by means of Green's functions independently of canonical variables. P.B. or commutator is defined only for physically measurable group invariants. Green's functions give a direct description of the propagation of small disturbances arising from a pair of mutually interfering measurements.

Y. Nambu

A "superconductivity model of elementary particles and its consequences"

[illegible] EFINS-60-21

BCS. Bog.

1) analogy の [illegible]. [illegible]

2) Nambu's point of view / analogy

3) gap と cut-off ?

4) [illegible] の [illegible] と γ_5-inv.
$-m$ is indefinite metric.

$$\begin{cases}\gamma\partial\psi_1 = m\psi_2 \\ \gamma\partial\psi_2 = -m\psi_1\end{cases} ?$$

$$(\Box - m^2)\psi = 0$$

5.) $\partial_\mu(\bar\psi\gamma_5\gamma_\mu\psi) \neq 0$ for $m \neq 0$

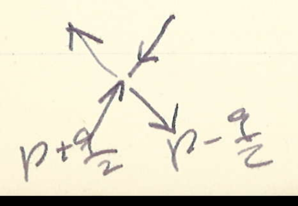
$\rightarrow$ $\Gamma_{5\mu}(p_2, p_1) = \left(\gamma_5\gamma_\mu + \frac{2mi\gamma_5 q_\mu}{q^2}\right)F(q^2)$

$q = p_2 - p_1$

$q_\mu \Gamma_{5\mu} = 0$

mass zero ps boson in form factor !!!

(γ_5 inv) gap mass $\neq 0$ $\longrightarrow$ boson mass $= 0$



6. mass degeneracy
vacuum degeneracy
due to boson of zero mass, zero energy

TERRA

Informal Discussion Meeting with Prof. Markow

Nov. 11, 1960

1. H. Fukutome, elastic ether theory of elementary particles.
   deformorphism group of general coord. trans.
   doubly connected space

2. T. Nakano, Gen. Rel. Theory in the framework of El. Part. Phys.

3. N. Nakanishi, Multiple Dispersion theory.

4. K. Matsumoto, Topics on Weak Interaction

Nov. 12, 1960

1. Y. Tanikawa, Parity, Chirality and Tensor
   $\sigma\sigma_t\sigma_s = 1$. $\sigma = \det(a_{\mu\nu})$ etc.

2. Y. Ohnuki, Sakata model
   new particle 1370 MeV $F'(0, 3/2)$

3. Z. Maki, Nagoya Model
   $\mu^- + N \rightleftarrows e^- + \Lambda$?
   because $K^0 \not\rightarrow \mu^- + e^-$

M. Markow, Indefinite metric

Nov. 15, 1960

Symposium on Nonlocal Theories

[illegible]

Nov. 16, 1960 morning

Yukawa, Idea of Nonlocal Field

Remarks

Markov

Katayama

Fukutome

Afternoon – Freedom of Nonlocal Field

Okabayasi, History and Problems

1953 Symposium

divergence — observation

nonlocal field

relativistic cut-off → nonlocal interaction

form factor [illegible]

sufficiency of cut-off

consistent S-matrix

complete set of states

negative energy

indefinite metric

Yukawa, 1949, 1950

$$F = \frac{1}{(2\pi)^8} \int d^4L\, d^4l\, e^{i\{ L_\mu (\frac{y'+y''}{2} - y''') + l_\mu (y' - y'') \}}\, \bar{G}(L, l)$$

$$\bar{G}(L, l) = \lambda \sqrt{L^2}\, \sin \lambda \sqrt{\left(l^2 - \frac{(lL)^2}{L^2}\right)}$$

(convergence [illegible])

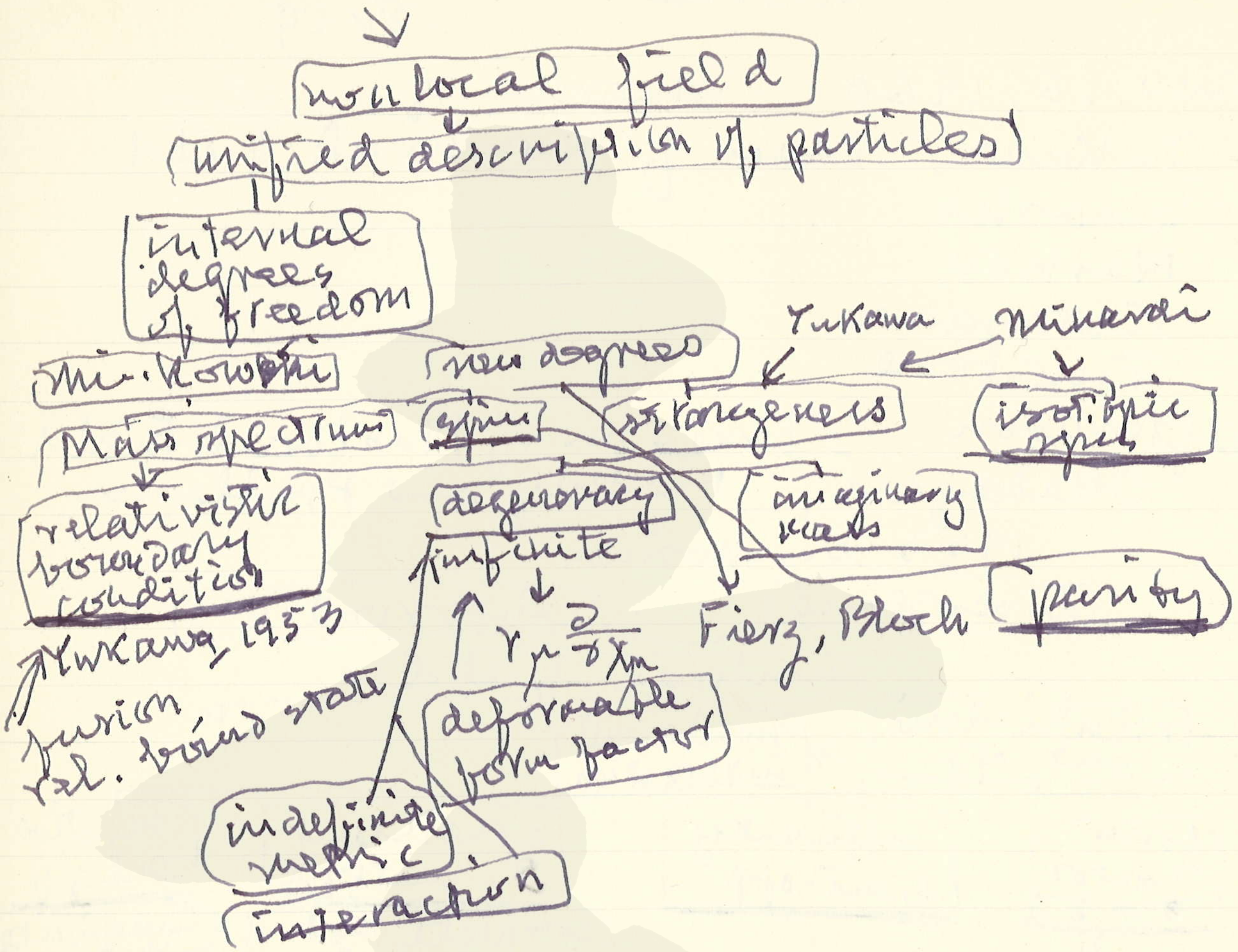
nucleon structure

mass spectrum

reciprocity

rel. bound state — Ida

fusion theory — Watanabe



Hara

$$R_{\mu\nu} = i\left(r_\mu \frac{\partial}{\partial r_\nu} - r_\nu \frac{\partial}{\partial r_\mu}\right)$$

(j, k)

$(4, i)$ $(4j) \rightarrow \vec{M}^2 \rightarrow$ mass operator

$$m^2 = \langle \vec{M}^2 \rangle = \left(\frac{\lambda}{\hbar c}\right)^2 \langle E_m^2 \rangle$$

Minardi

$$\gamma_\nu \left(\frac{\partial}{\partial x_\nu} + \frac{\partial}{\partial r_\nu}\right) \psi(x, r) = 0$$

$$-i \vec{\alpha} \vec{\nabla}_r \varphi(\vec{r}) = m \varphi(\vec{r})$$

Pauli-Gürsey transf.

Linearization:
parity violation

Remark by Markow
origin of mass

Remark by Katayama (e, μ)
$\sigma_{\mu\nu}$ Pauli term
Matsumoto

$$m_\mu = \frac{3}{2} \alpha^{-1} m_e + m_e \quad \}$$

$$m_e = m_e$$

Nakano, Rigid Body 1956 $E^2 - p^2 = m^2$
energy ~~momentum~~ → rest mass
ang. momentum → proper ang. momentum

$$\vec{m}^2 \quad = \quad \vec{\tau}^2$$

$$m_3 \qquad \tau_3$$

euclidian parameters for internal motion

$$\vec{m}^2 + \vec{n}^2 = \vec{\tau}^2 + \vec{\pi}^2 \qquad \vec{m}\vec{n} = \vec{\tau}\vec{\pi}$$

integer ↔ integer
half int. ↔ half int.

$$m_3 \qquad \tau_3$$

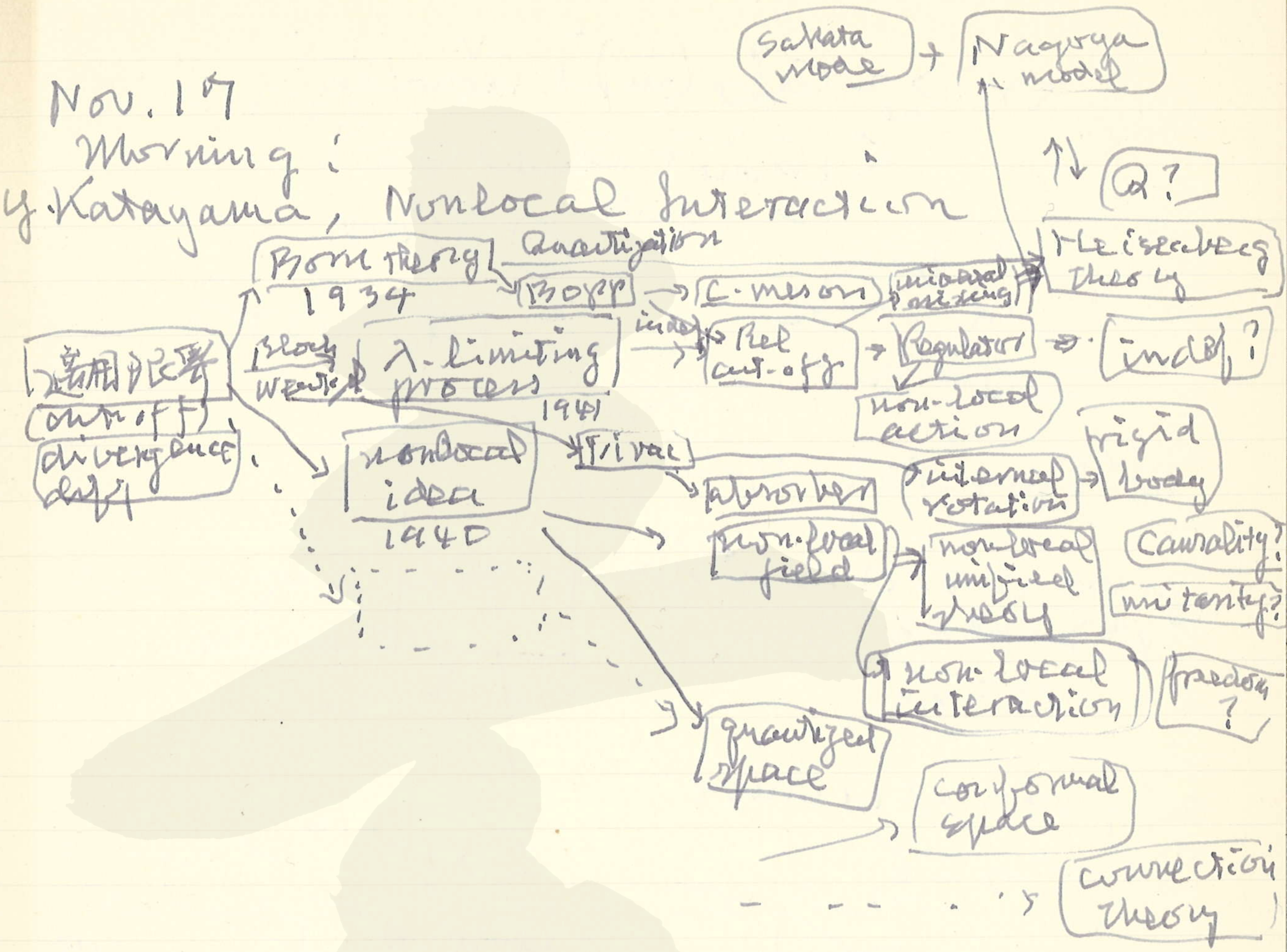
$$n_3 \qquad \pi_3$$

Quantum Field Theory with only positive energy states → Euclidian parameter
→ Feynman amplitude

Schwinger 1960 P.R.
nonlocal theory in Euclidian ~~space~~ (world)

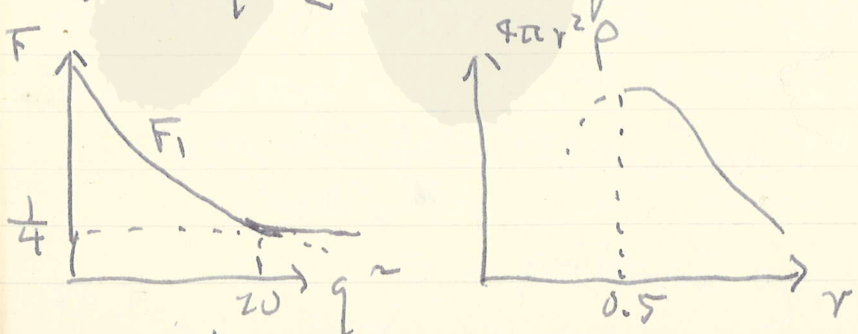
Fukutome, molecules, rigid body
and ether

Nov. 17
Morning:
Y. Katayama, Nonlocal Interaction



1) Nucleon structure
el. mg.: j_μ
i) $\langle r^2 \rangle \sim (0.84)^2$
~ 0
ii) $q^2 \lesssim 20$ exponential

$r \gtrsim 0.5$ Y
$Q \sim 60\%$



iii) $q^2 \sim 20 - 25$ flat F_1

$\langle r^2 \rangle_{out} \sim Q^s_{out} \left(\frac{1}{3\mu}\right)^2 + Q^V_{out} \left(\frac{1}{2\mu}\right)^2$

$< (Q^s_{out} + Q^V_{out}) \left(\frac{1}{2\mu}\right)^2$

$\sim$ 60% $\langle r^2 \rangle_{tot}$

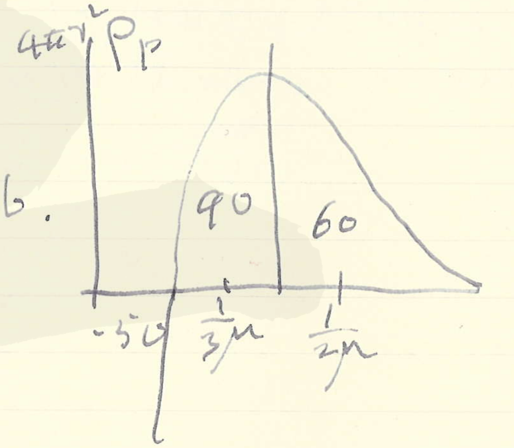
$Q^V \sim 1/2$

$Q^s \sim 1$

$Q_s + Q_V \sim 150\%$

Q^V ; pos. def. ?

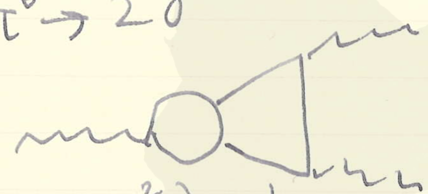
pion によるcontrib.
$\langle r^2 \rangle$ にまける
40%



2) Pion structure

i) $\pi^0 \to 2\gamma$

2×10^{-16} sec.



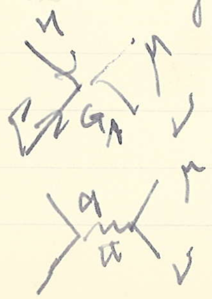
摂動論
$= \frac{1}{F_\pi^2(m_\pi^2)}$　10^{-17} sec

$F_\pi(m_\pi^2) \sim \frac{1}{2}$

0.4 ~ 0.5 y　では説明できない

$F_\pi(0) = 1$
compensation?

ii) $\pi \to \mu + \nu$　pv — divergence current
Gell-Mann & Lévy



$[d_\pi F_\pi(0)]^2 = \frac{\Gamma_{\pi\, exp}}{\Gamma_{\pi\, theor.}}$ $= \frac{1}{2}$

pv.-coupling

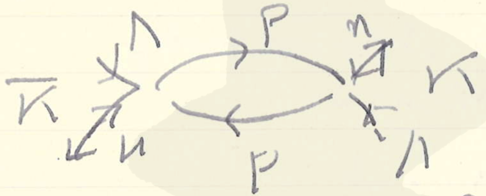
Shimodaira & Takahashi の定理:

lepton structure

3) i) high energy neutrino

$\nu + n \to p + \mu$

ii)



$\Delta S = 2$ int.

$\Delta m_{K_0} \sim$

ω^2 cut: $\lambda \sim \frac{1}{m_\pi}$

finite f^2 : ?

Non-local interaction

causality micro $x \to$ macro x

議論:

Munakata, Indefinite metric

1) Lehmann

divergence

2) Renormalization theory of 残る

Lee model $\to$ ghost state

$\to$ imag. coupling $\to$ indef. metric

Pauli-Källen.

3) probabilistic interpretation

4) causality

Bogolyubov

$\varphi(x) = \psi_p(x) + \sum_n c_n \psi_n$

$\Phi = P\Phi + (1-P)\Phi = \varphi + F$

$F(-\infty) + F(+\infty) = 0$ (conserv. of prob.)

$$\varphi(+\infty) = \tilde{S}\,\varphi(-\infty)$$

$$\Phi(+\infty) = S\,\Phi(-\infty)$$

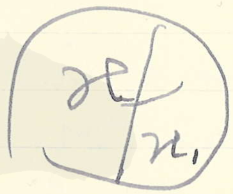
macrocausality はこわれる.

α, β: indep. systems

$$\tilde{S}_{\alpha+\beta} \neq \tilde{S}_\alpha \tilde{S}_\beta$$

$$S_{\alpha+\beta} = S_\alpha S_\beta$$

5) Nagy: local in $\mathcal{H}$
{ non-local in $\mathcal{H}_1$
{ non-linear



Shimazu:
$F(+\infty) + F(-\infty) = 0$
$\mathcal{H}_1$-space で [illegible]定義.
Hamiltonian は non-hermitian
non-local.

Heisenberg, dipole ghost
Pauli, complex conjugate root
Ferretti,

Ascoli, Minardi, non-local interaction (semi-definite)
Uhlmann

$$\lim_{\Delta E \to 0} \frac{\Phi_0(E) - \Phi_G(E+\Delta E)}{\Delta E} = \Phi_d$$

complete set: $\Phi_0(E)$, Φ_d

$\langle \Psi_0 | \Psi_0 \rangle = 0$
$\langle \Psi_a' | \Psi_a' \rangle = 0$) $\langle \Psi_0 | \Psi_a' \rangle \neq 0$

Nagi, propagator less singular

6) Markov,
$s^2 = x_0^2 - x^2 \rightarrow s'^2 = s^2 - a^2$
metric in Hilbert space $\rightleftarrows$ metric in space

Symposium on the Structure of Elementary Particles 1960

Nov. 18, Morning

質量公式の議論

沢田:

2. 質量公式 in Sakata model

$M = m_N(n_N + n_{\bar{N}}) + m_\Lambda(n_\Lambda + n_{\bar{\Lambda}})$
$+ V(N\bar{N})(n_{N\bar{N}} - n_{NN} - n_{\bar{N}\bar{N}})$
$+ V(\Lambda\bar{N})(n_{\Lambda\bar{N}} + n_{N\bar{\Lambda}} - n_{N\Lambda} - n_{\bar{N}\bar{\Lambda}})$
$+ V(\Lambda\bar{\Lambda})(n_{\Lambda\bar{\Lambda}} - n_{\Lambda\Lambda} - n_{\bar{\Lambda}\bar{\Lambda}})$

① $V(NN) = -V(N\bar{N})$

N, Λ, π, K, Ξ の mass に合わせる,

resonance levels も考えると同様に合う.

II. mass formula with I-O-O symmetry

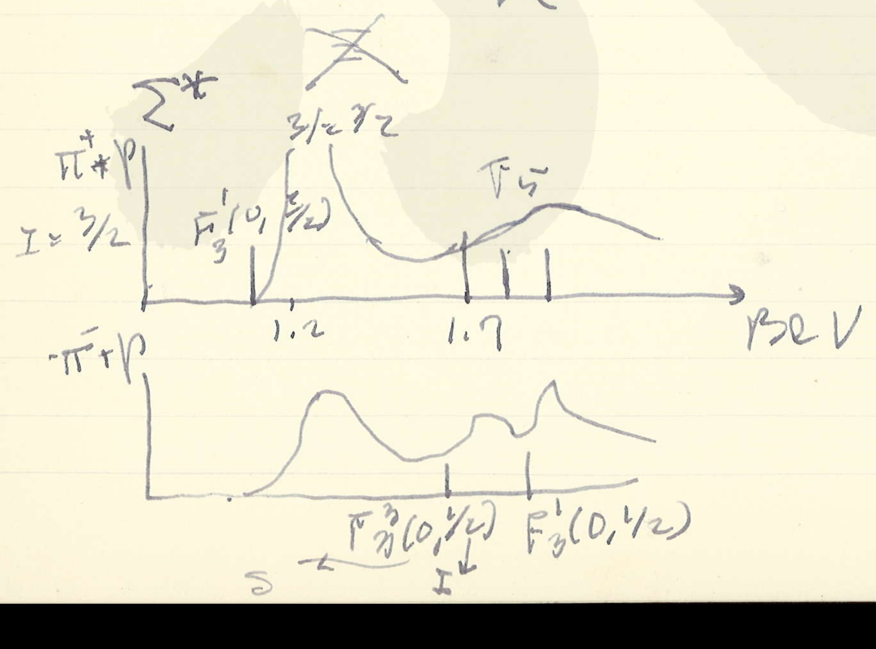
p, n, Λ の同種性 versus 異種性

$\pi^{0\prime}$: $\{-p\bar{p} - n\bar{n} + 2\Lambda\bar{\Lambda}\}/\sqrt{6}$

$m(\pi^{0\prime}) = \dfrac{m(p\bar{p}) + m(n\bar{n}) + 2^2 m(\Lambda\bar{\Lambda})}{6}$

isoparticle

② $V(\Lambda\Lambda) = V(\Lambda N) + \Delta V = V(NN) + 2\Delta V$
K　　　π



③ N-Λ 系 の configuration
④ [illegible]の統計性 (spin, isospin)
⑤ "sub-particle" (spin, isospin)

$m(F_3^1(0, \frac{3}{2})) = m(NN\bar{N}) \simeq 1230$ MeV

$m(F_3^3(0, \frac{1}{2})) = \{m(NN\bar{N}) + m(N\Lambda\bar{\Lambda})\}/2 = 1535$ MeV theory
↓
exp. 1515 MeV

$m(F_3^1(0, \frac{1}{2})) = \{m(NN\bar{N}) + 3m(N\Lambda\bar{\Lambda})\}/4 = 1685$ MeV

⑥ spin paradox? (N-Λ adiabatic?)
⑦ lowest conf. ダイ

坂田 picture
'basic particle'

basic proton: $c_0 p + \sum_k c_k p (p\bar{p} + n\bar{n} + \Lambda\bar{\Lambda})^k |0\rangle$
basic antiproton:

$(n_B, s_0, i_0; S, I, I_3)$
$S = -n_\Lambda$, $I_3 = \frac{1}{2}(n_p - n_n)$

(p, n) system:
$I = (n_{NT} - 2n_{NA})/2$

N
N $\bar{N}$

$n_{NT} = 3, 1$
n_{NA} 核子反核子 pair の数

$(|n_N| - n_{NT})\, n_{NA} = 0$

Ogawa, Isospin

1) charge multiplet

2) 合成, 分解

$\pi^- + p \to \pi^- + p$ 　　 $1/3$

$\pi^+ + p \to \pi^+ + p$ 　　 1

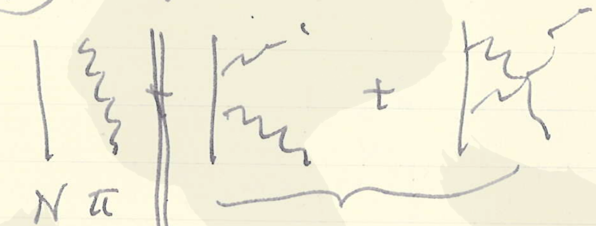
$\left\{ \begin{matrix} 2 \\ 1 \\ 0 \\ -1 \end{matrix} \right.$ 　 $I = 3/2$

$\boxed{\pi N}$

$1/2$ & $3/2$

$3 \times 2 = 6 = 2 + 4$

$\boxed{\pi | N}$ 散乱の説明

S = 

Remark

Nambu : supercond. 　 ([illegible] electrodyn.) Coulomb int.

phonon → subparticle 　 ↓ B.E?

many particle system 　 (?..)

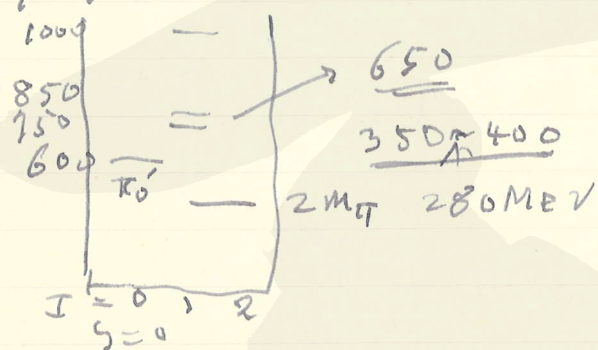
energy gap, collective motion

Sawada (つづき)
8) 二重散乱,
9) strong reaction　full sym? ×
charge independence?

afternoon:
Sawada (つづき)

2次,	8 levels	17 exp.
3	21	17
4		

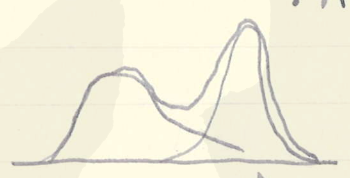
4次,



$\pi^+ + p \to 2\pi + N$
$\pi^- + p \to 2\pi + N$

S-L-model (isobar model)

$\pi + N \to F + \pi$
1 BeV　$\hookrightarrow N + \pi$



Sakata-model
$\pi + N \to B + N$
$\hookrightarrow 2\pi$

$\pi^+ + p \to 2\pi + N$　500 MeV
(3/2 3/2),　$2m_\pi$

$\frac{\pi^0 + \pi^+ + p}{\pi^+ + \pi^+ + n} = 1.5 {}^{+1.5}_{-1.0}$

6.5　(3/2, 3/2)

$I = 2 \to < 6.5$

(π-π-resonance と関係)

Ogawa: Ohmae mass formula

$$M = R\left\{\frac{1}{(n+\frac{1}{2}s')^2} - \frac{1}{(m+l+\frac{1}{2}S)^2}\right\}$$

5%の範囲. $R = 38$ MeV

nucleon series $n=4$, $m=5$, $s=s'=0$

$l=0$ $l=1$ $l=2$ $l=3$ $l=4$

nucleon $(3/2, 3/2)$ $(1/2, 3/2)$ $(1/2, 5/2)$

kaon series $n=4$, $m=5$, $s'=0$

$l=0$ $l=1$

$s=-1$ 0 1 2 1

K (nucleon) Λ, Σ Ξ Σ^* Λ^*

μ-meson $n=8$, $m=9$, $l=0$ $s'=1, s=1$

π-meson $s'=0, s=0$

P, e, ν, ν'

$M_{max} = \frac{R}{16}$

Taketani:
これきめる!!!

Matsumoto: Kat. Mat. Nak.

Sakata Model

$X\begin{bmatrix} M \\ int. \\ M_{comp} \end{bmatrix}$

Nagoya model

B basic baryon — massive active

M_B, M_C

mass formula

m_B : large
$m_{B\bar{B}}$: small
$m_{BB\bar{B}} \sim m_B + m_{B\bar{B}}$

① basic baryonic current vector int.

② very small ~ $M_0^p, M_0^n \ll M_0^\Lambda < M^N$
($0 \sim M_\nu^\nu, M^e \ll M^\mu$)

③ fluctuation energy in composite system : small

$M_0^p, M_0^n \lesssim \frac{m_\pi}{2}$
$M_0^\Lambda \lesssim \frac{2}{3} m_K$

$$L(x) = -\sum_{\alpha}^{pn\Lambda} \bar{\psi}^\alpha (\gamma\partial + M_0^\alpha)\psi^\alpha + f B_\mu B_\mu$$

$$B_\mu = \sum B_\mu^\alpha(x) = \sum_\alpha \bar{\psi}^\alpha \gamma_\mu \psi^\alpha$$

① γ_5 inv.
② × I, 0, 0) → small
× γ_5 inv.

spin paradox
small non-conservation of axial vector-current
finite m_π mass

$$M = m_B n_N^2 + 2(m_B - \Delta) n_N n_\Lambda + (m_B - \Delta') n_\Lambda^2 + \frac{m_\pi}{2}(n_N^T + n_\Lambda^T) + \Delta'' n_\Lambda^T$$

$m_N - \frac{m_\pi}{2}$ 　　 $\sim \frac{2}{3} m_K$

$M^{theor} = \langle n_B | H | n_B \rangle$

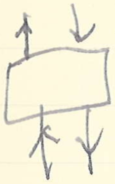
Katayama,

Mass formula
m_B large
$m_{B\bar{B}}$ small

$(m_{BB\bar{B}} \sim m_B + m_{B\bar{B}})$

$M_N^0 \sim 0$

$m_N = m_N^0 + \Delta m$



$e^{i\alpha\gamma_5}$ - invariance

$\mu_\pi^2 \propto \frac{m_N^0}{m_N}$ $4 m_N^2$

$\Delta m = m_N f(m_N^0)$

$m_N^0 m_N f(m_N^2)$

V, A

$m_N \sim m_N^0(1 + f(m_N^0))$ $m_N^0 + m_N f(m_N)$

$m_N^0 \to 0$; $m_N \to 0$ (γ_5-inv)

$\frac{\partial \bar{\psi}\gamma_\mu\gamma_5\psi}{\partial x_\mu} = 0$ $\mu_\pi^2 \to 0$

$2M_0\bar{\psi}\gamma_5\psi$

$m_N = 0$ or $f(m_N) = 1$

γ_5-inv. があれば: $\mu_\pi^2 = 0$

Schwinger model

$\gamma p f(p^2) = 0$ ψ_0

$\gamma p + M = 0$ ψ_1

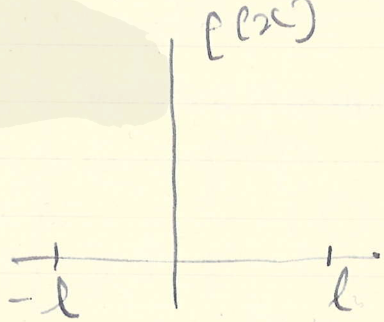
$\gamma p - M = 0$ ψ_2

$\frac{\partial \bar{\psi}_1\gamma_\mu\gamma_5\psi_1}{\partial x_\mu} + \frac{\partial \bar{\psi}_2\gamma_\mu\gamma_5\psi_2}{\partial x_\mu} = 0$

1) freedom cut に depend
negative energy
gap をもつもののこと

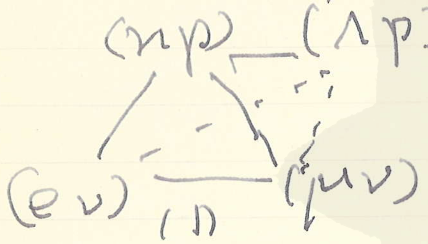
energy gap → M, -M の pair

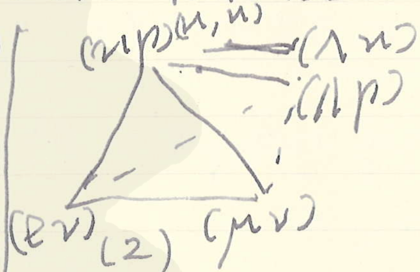
Toyoda, Hiida 氏の論文
B-matter unit
distribution は



Nov. 19, Morning

Oneda, Weak Interaction





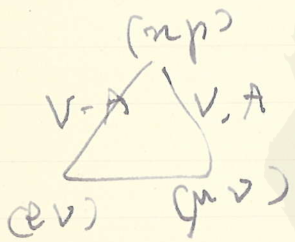
charged current onely

(3)

charged current plus neutral current

$|\Delta I| = 1/2$

(4)



β-decay　V−A　→ neg. chirality

$\bar{p}\gamma_a(1+\gamma_5)n \cdot \bar{e}\gamma_a(1+\gamma_5)\nu$

(1.25)

$\frac{\pi \to e+\nu}{\pi \to \mu+\nu} \sim 10^{-4}$

$\bar{\mu}\gamma_a(1\pm\gamma_5)\nu$

(1) current-current interaction

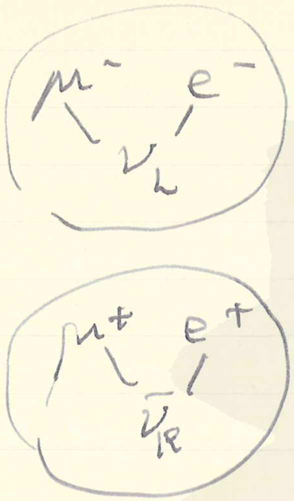
$J = (e\nu) + (\mu\nu) + (pn)$

$H = J J^* + H.C.$

→ $\bar{\mu}\gamma_a(1+\gamma_5)\nu$

すべてが V−A 型

2-comp. ν



4-comp ν

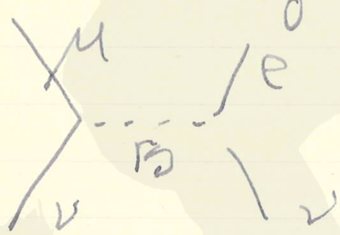
μ^+ ↕ $\bar{\omega}_R = \nu_R$　　e^- ↕ ν_L

μ^- ↕ $\omega_L = (\bar{\nu})_L$　　e^+ ↕ $(\bar{\nu})_R$

Schwinger
Nishijima
Markow

$\mu \nrightarrow e + e + e$
$\mu \nrightarrow e + \gamma$
$\mu^- + p \nrightarrow p + e^-$

(2) non-locality



$\rho_{exp} = 0.78 \pm 0.025$

$\rho_{exp} \approx 0.75 = \frac{1}{3}\left(\frac{m_\mu}{m_B}\right)^2$

Boson - Ind. Boson pair から 出発?

O^{14}: $G_V = (1.416 \pm 0.003) \times 10^{-49}$ erg.cm^3
$\tau_\mu = 2.250 \pm 0.010 \times 10^{-6}$ sec
(without rad. corr.)

$T_{exp} = 2.21 \pm 0.003$

rad. corr. を入れると life は

$\sim 4\%$ ふえる

vector boson

$$W = W_0 \left\{ 1 + \frac{3}{5} \left(\frac{m_\mu}{m_B} \right)^2 \right\}$$

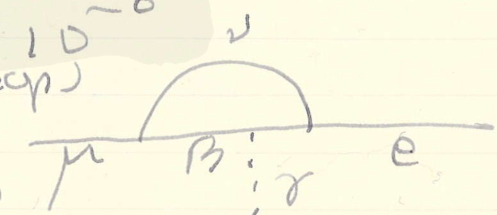
$m_B > m_K$

(3) Yang-Lee

Yukawa type

$\Delta I = 1/2$

$$\frac{\mu \to e + \gamma}{\mu \to e + \nu + \nu} < 2\times 10^{-6} \text{ (exp)}$$



◎ $\frac{\Lambda}{m_B} \leq \frac{1}{5}$ でないと → 10^{-4} (theor)

Two neutrinos で逃げる!!

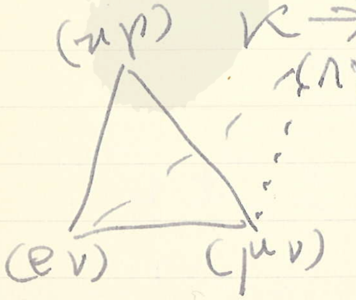
(4) Λp　　V, A

$$\frac{K \to e + \nu}{K \to \mu + \nu} \simeq 10^{-5}$$

$$\frac{K \to e + \nu + \pi}{K \to \mu + \nu + \pi} \sim 1$$

$\pi \to \mu \to e$

(νp) $K \to \mu \to e$



$\Lambda \to \begin{smallmatrix} p + \pi \\ n + \pi \end{smallmatrix}$ に対して

$\Lambda \to p + e^- + \nu$　　0.2%

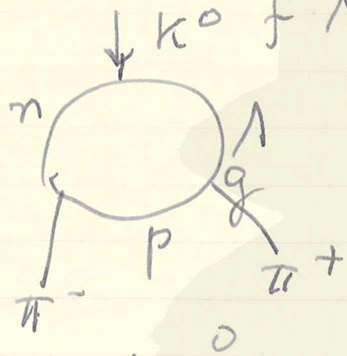
$\Sigma \to n + e + \nu$　　0.2%

∴ Λp は弱そうで!!

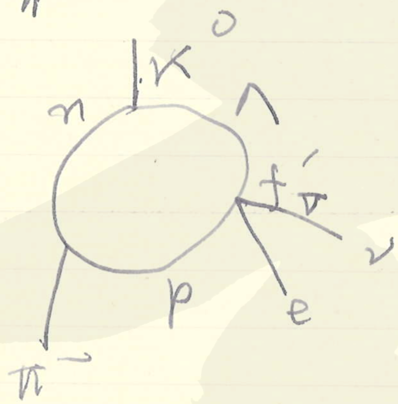
Oneda: $\Lambda^0 \to p + \pi^-$

$g\, \bar{\Lambda} \gamma_\alpha (1+\gamma_5) p \cdot \partial_\alpha \varphi_\pi$

$f'\, \bar{\Lambda} \gamma_\alpha (1+\gamma_5) p \cdot \bar{e} \gamma_\alpha (1+\gamma_5) \nu$



$\left(\frac{f'_\nu}{f}\right)^2 \approx \frac{1}{30}$



$K \to \mu + \nu$

$W_K = 4.8 \times 10^7\ \mathrm{sec}^{-1}$

$\pi \to \mu + \nu$

$W_\pi = 4.0 \times 10^7\ \mathrm{sec}^{-1}$

$\left(\frac{g_K}{g_\pi}\right)^2 \approx \frac{1}{10} \longrightarrow \left(\frac{f'_A}{f}\right)^2 \approx \frac{1}{25}$

f_F [illegible] 1.6% 5.8%

Z. Maki: $\left(f'_A / f_A\right)^2 \sim 1/16$

Gell-Mann:

(np) $n \to p + e + \nu$ $\qquad \pi \to \pi^0 + e + \nu$

(Λp) 1.0.0. $\qquad K \to \pi + e + \nu$

$\Lambda \to p + e + \nu$

$$\frac{W(\Lambda \to p + e^- + \nu)}{W_{exp}(\Lambda \to p + \pi^-)} = \frac{1}{1500}$$

(Λp) は弱い!!　　$\left(\frac{f'}{f}\right)^2 \simeq \frac{1}{20}$

(Λp)　$\frac{\Delta S}{\Delta Q} = 1$　　$I = 1/2$

$\Sigma^+ \nrightarrow n + e^+ + \nu$　forbidden

$W(K_1^0 \to e^\pm + \nu + \pi^\mp) = W(K_2^0 \to e^\pm + \nu + \pi^\mp)$

$= 2 \times 0.85\ W(K^+ \to e^+ + \nu + \pi^0)$

(実験では駄目か?　Wisconsin)

$|m_{K_1^0} - m_{K_2^0}| \sim 10^{-5}\,\mathrm{eV}$

は $\frac{\Delta S}{\Delta Q} = 1$ と consistent.

neutral current あれば $\sim 10\,\mathrm{eV}$

non-leptonic processes

$|\Delta I| = 1/2$ がよく成り立つ!!!

$$\frac{\Lambda \to p + \pi^-}{\Lambda \to n + \pi^0} \approx \frac{2}{1}$$

Σ　　$1 : 1 : 1$

$\Sigma^+ \to n + \pi^+$　$p + \pi^0$　$\Sigma^- \to n + \pi^-$

α　　0　　~ 1　　0

$K \to 2\pi$　　$K_1^0 \to \pi^+ + \pi^-$

$K^+ \to \pi^+ + \pi^0$

$$\frac{K^+ \to \pi^+ + \pi^0}{K_1^0 \to 2\pi} \sim \frac{1}{500}\ \ \text{exp}$$

$= 0$ for $|\Delta I| = 1/2$

$H = f(\bar{p}\Lambda)(\bar{n}p)$ $\qquad \Delta I = 3/2$

$= f\,\frac{1}{3}\left[\{2(\bar{p}\Lambda)(\bar{n}p) - (\bar{n}\Lambda)(\bar{n}n)\}\right.$

$\left. + \{(\bar{p}\Lambda)(\bar{n}p) + (\bar{n}\Lambda)(\bar{n}n)\}\right] + H.C.$

$\Delta I = 1/2$

(A) charged current only

$\Delta I = 1/2 \gg 3/2$ は何故か?

(B) neutral current を入れて

$f\{(\bar{p}\Lambda)(\bar{n}p) + (\bar{n}\Lambda)(\bar{n}n)\}$

Yang, Lee : intermediate boson

Kawaguchi, Iso, . . : I.O.O.

$(\bar{p}\Lambda)(\bar{n}p) + (\bar{n}\Lambda)(\bar{n}n) + (\bar{n}\Lambda)(\bar{\Lambda}\Lambda)$

① $\Delta I = 3/2$?

② baryon と lepton の対称性をやぶる

① (Λp)

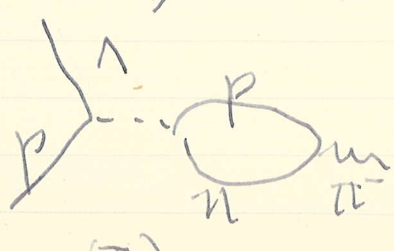
② $|\Delta I| = 1/2$

$H = J_\alpha P_\alpha$

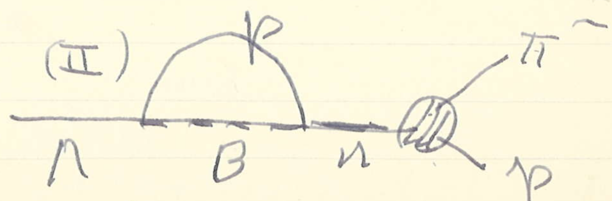
$J_\alpha = F[\bar{e}\gamma_\alpha(1+\gamma_5)\nu + \bar{\mu}\gamma_\alpha(1+\gamma_5)\omega$

$+ \bar{n}\gamma_\alpha(1+\gamma_5)p) + (\frac{F'}{F})\bar{\Lambda}\,\gamma_\alpha(1+\gamma_5)p]$

$m_B \sim 900$ $\qquad \frac{F^2}{m_B^2} = \frac{f_F}{\sqrt{2}}$



(I)



$\Lambda \to n$ $\qquad \Delta I = 1/2$

$(\mathrm{I}) \ll (\mathrm{II})$

$m_B \to \infty$ 　　$(\mathrm{II}) \to \Omega \to 0$

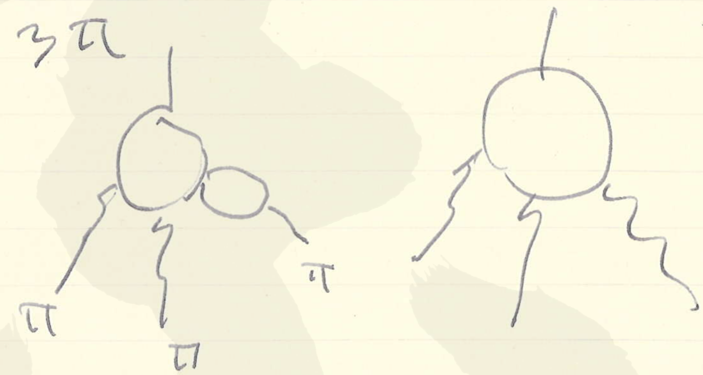
m_B : finite, (II): quadratic divergence
cut-off Λ
(I): log div.

$\left(\frac{M_{\mathrm{II}}}{M_{\mathrm{I}}}\right)^2 \sim 11$ 　for $\Lambda \doteq m_p$
~ 90 　for $\Lambda = 1.5\, m_p$

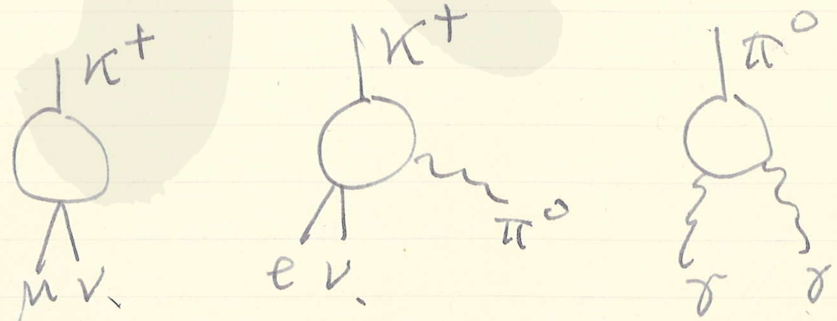
$m_K < m_B \doteq m_p$

$\alpha < 0$ 　[最近の実験と一致？]
($\Lambda \to p + \pi^-$ の asymmetry)

$K \to 3\pi$



$\pi^0 \to 2\gamma$

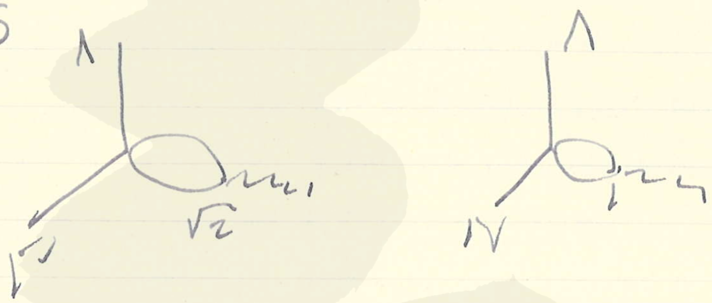


div. 　div 　　convergent

ratio
$$\frac{K^+ \to \pi^0 + e^+ + \nu}{K^+ \to \mu + \nu}$$

Σ decay
Ohnuki-Maki

Afternoon:
Maki
OMS



Sakata modelの勤務評定

優　$\Delta S/\Delta Q = +1$, Vector Current保存

良　$\Lambda \to n + \pi$

可

不可

process (model)		1 (OMS) $\Delta I = 1/2, 3/2$	2 $\lvert\Delta I\rvert = 1/2$	3 eff $\lvert\Delta I\rvert = 1/2$	4 $\Delta I = 1/2$
$\Lambda \to N + \pi$	B, R α	○ △ (α>0)	◎ △	○ ○	
$K_1^0 \to 2\pi$		×	○	○	
$K^+ \to 2\pi$				○	
$\to 3\pi$		△	△	○	
$\Sigma \to N + \pi$	B, R, α	○ or △	○?	△	
? $\Xi \to \Lambda + \pi$	B, R				

Ogawa.

Ⓟ　　Ⓝ

いろいろといわれているが π といわれる

composite system (I. M. O.)

baryon number n_B

total number n_T

n_A

n_Λ

n_{NT}　　$I = \frac{n_{NI}}{2}$

n_p

weak int. $\Lambda \to N$

$\Delta I = 1/2$ for Λ, K.

n_A, n_Λ が保存しない..
(n_{NT})

Ohnuki

$\Delta S = \pm 1$. $\leftrightarrow$ ΔI

$f(S, I) = \text{const.}$

$\Delta I = 0$
$\Delta I_3 \neq 0$
$= \pm 1/2$

macrocausality と関係!!!

$n \to p + e^- + \nu$

$p + n \to p + p + e^- + \nu$

Katayama School. I.
Dec. 6, 1960

i) γ_5-invariance   exact or approximate?
conserving current → zero mass meson plus energy gap?

ii) impossibility of ~~having~~ (deriving) a mass-like term from zero-mass Dirac ~~field~~ (Heisenberg) type equation with Fermi type interaction.
Dirac-~~Heisenberg~~-Fermi-Heisenberg type equations

interact: l^2 cut-off (invariant): l^{-2}

no odd term ~~~~ can appear!!!
mass can appear only in the form
$\gamma_\mu \partial_\mu f(\Box - m^2)\psi = g[\psi, \psi^3, \varphi]$

湯川 Dec. 15, 1960

T. 松. Matsubara, Superconductivity for elementary Particle Physicists

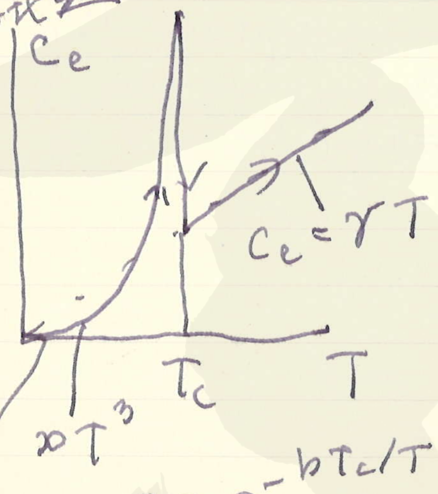
1911 発見 Kamerlingh-Onnes
1957 BCS 理論
1958 Bogoliubov 理論

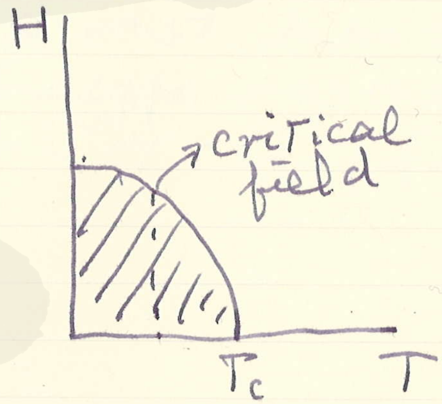
I. Superconductor の特徴 -

~~1. 熱力学的~~
~~(電子比熱~~.

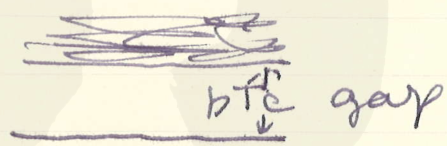
(1) 2価以上の金属. 常温で電気抵抗がやや大きい. → 格子振動とのcouplingが強い
(2) ~~m~~ non-magnetic → 他の効果がきかない. (格子振動以外)

1. 熱力学的性質
電子比熱





$C_e = a\gamma T_c e^{-bT_c/T}$



$a \sim 9$
$b \sim 1.5$

energy gap が非常に小さいこと!!!
$\sqrt{M}\, T_c = \text{const}$ → ion の運動と関係あり.
(isotope effect)

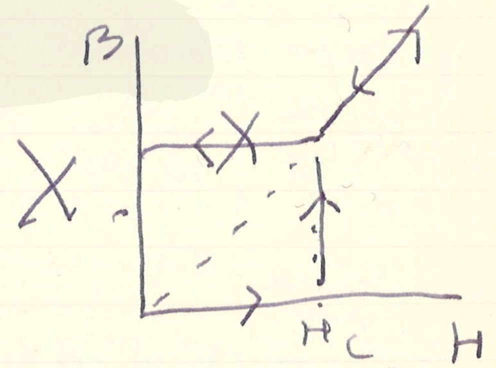
phonon との相互作用 → Fröhlich

2. 超伝導の性質
persistent current
$\sigma \to \infty \quad 1/\sigma \to 0$

$\vec{j} = \sigma \vec{E}$

$\frac{\partial \vec{J}_s}{\partial t} = \frac{ne^2}{m}\vec{E}$ London's 1st equation

$\frac{\partial}{\partial t}\left[\mathrm{curl}\,\vec{J} + \frac{ne^2}{mc}\vec{B}\right] = 0$



Meissner effect
内部の磁場は外へ押し出される.
内部では いつも $B = 0$

$\mathrm{curl}\,\vec{J}_s = -\frac{ne^2}{mc}\vec{B}$ London's 2nd eq.

$\nabla^2 \vec{B} = -\frac{1}{\lambda^2}\vec{B}$

$\nabla^2 \vec{j} = -\frac{1}{\lambda^2}\vec{j}$

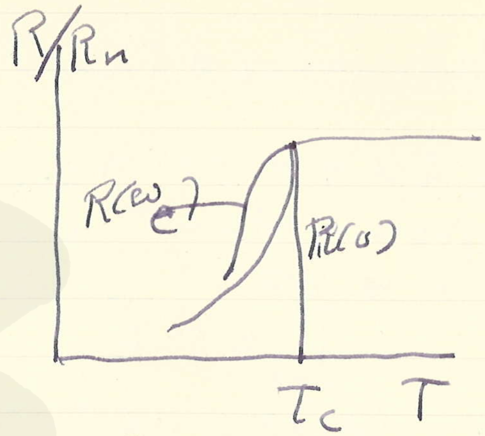
$\lambda^2 = \frac{mc^2}{4\pi ne^2} \sim 10^{-6}\,\mathrm{cm}$

$\vec{J}_s = -\frac{ne^2}{mc}\vec{A} \quad \mathrm{div}\,\vec{A} = 0$ London gage

$R(\omega)$

$\omega_c \sim \frac{\Delta E}{\hbar}$

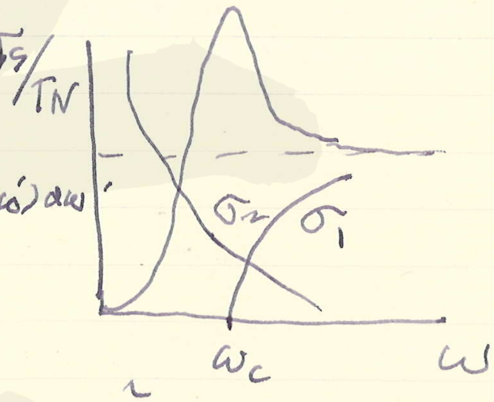
ΔE: energy gap



thin film ;

$\sigma(\omega) = \sigma_1(\omega) - i\sigma_2(\omega)$

透過係数



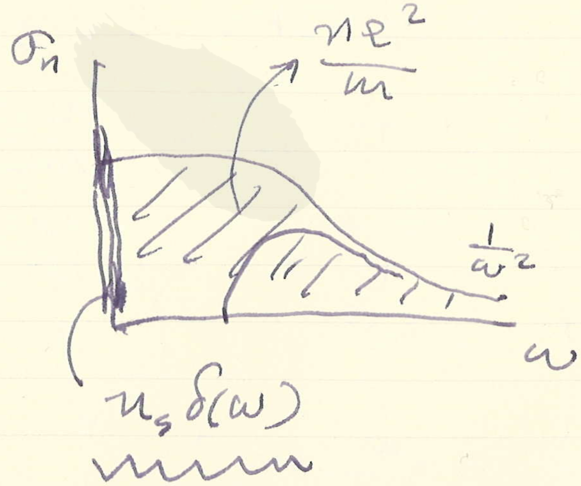
dispersion relation

$\sigma_2(\omega) = \frac{2}{\pi}\int_0^\infty \frac{\omega}{\omega'^2 - \omega^2}\,\sigma_1(\omega')\,d\omega'$

sum rule

$\frac{2}{\pi}\int_0^\infty \sigma_1(\hbar\omega)\,d\omega = \frac{ne^2}{m}$

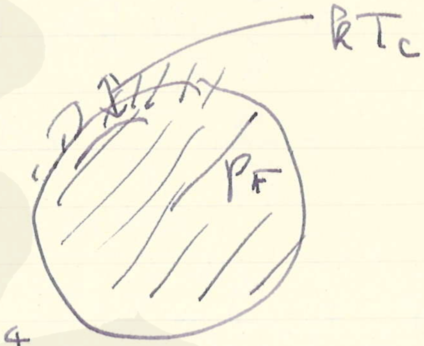
gage invariance



Pippard coherent length

$$J(r) = \int \sigma(r - r')\, E(r')\, dr'$$

$$l \sim 10^{-4}\ \mathrm{cm}$$



$$\Delta x = \frac{\hbar}{\Delta p}$$

$$\frac{p_F}{m} \Delta p = kT_c$$

$$\Delta x \sim \frac{\hbar p_F}{m k T_c} \sim 10^{-4}\ \mathrm{cm}$$

$$\vec{J}_i(q) = \sum_j K_{ij}(q) A_j(q)$$

$$\sum q_i K_{ij} = \sum K_{ij} q_j = 0$$

$$K_{ij}(q) = K(q^2)\left(\frac{q_i q_j}{q^2} - \delta_{ij}\right)$$

gage invariant

quasi-particle の他に
collective excitation

div A ≠ 0 の gage では collective excitation
が加わり、gage inv. を保つ。
(Nambu)

III BCS 理論　electron + phonon system

$$H = \sum_p \varepsilon_p (a^\dagger_{p\uparrow} a_{p\uparrow} + a^\dagger_{p\downarrow} a_{p\downarrow})$$

$$+ \sum_k \omega_k (b^*_k b_k + \tfrac{1}{2}) \qquad \omega_k = s|k|$$

$$+ \frac{g}{\sqrt{V}} \sum_{\substack{p \\ \sigma=\uparrow\downarrow}} \sum_k \sqrt{\frac{\omega_k}{2}} (b_k + b^*_{-k}) a^\dagger_{p+k,\sigma} a_{p,\sigma}$$

$$H_2 = \frac{g^2}{2V} \sum_{p+p'} \sum_k{}' \frac{\omega_k^2 \, a^*_{p'-k,\sigma'} a^*_{p+k\sigma} a_{p\sigma} a_{p'\sigma'}}{(\varepsilon_p - \varepsilon_{p+k})^2 - \omega_k^2}$$

電子間の引力 ←

$$H_2 \simeq -\frac{g^2}{2V} \sum_{p_1, p_4} \delta(p_1 + p_2 - p_3 - p_4)$$

$$a^\dagger_{p_1\uparrow} a^\dagger_{p_2\downarrow} a_{p_3\downarrow} a_{p_4\uparrow}$$

Coulomb repulsion

$$\frac{4\pi e^2}{|k|^2}$$

→ long range int. はきかない。

screen されて Coulomb rep.

$$\frac{4\pi e^2}{k^2 + k_c^2}$$

Coulomb は常に超伝導の邪魔をする

$$H_{red} = -\frac{g^2}{V} \sum_{pp'} a^\dagger_{p\uparrow} a_{-p\downarrow} a_{-p'\downarrow} a_{p'\uparrow}$$

Pair theory $\quad a^*_{p\uparrow} a^*_{-p\downarrow} \equiv c^*_p \qquad \frac{N}{2} = \nu$

$$\frac{1}{2\pi i}\oint \frac{dz}{z^{\nu+1}} \prod_p \left(\sqrt{1-\eta_p} + z\sqrt{\eta_p}\, c^*_p\right)|0\rangle \times \frac{1}{\sqrt{n}} = \Psi_g$$

$$\langle \Psi_g | \Psi_g \rangle = 1$$

$$\mathcal{N} = \left(\frac{1}{2\pi i}\right)^2 \oint\oint \frac{dz_1 dz_2}{(z_1 z_2)^{\nu+1}} \langle 0| \prod_p \prod_{p'} |0\rangle$$

$$= \left(\frac{1}{2\pi i}\right)^2 \oint\oint \frac{dz_1 dz_2}{z_1 z_2} \frac{\prod_p \{1-\eta_p + z_1 z_2 \eta_p\}}{(z_1 z_2)^\nu}$$

$\nu >> 1$:

$$W_0 = \langle \Psi_g | H_0 + H_2 | \Psi_g \rangle = 2\sum_p \varepsilon_p h_p - J \sum_{pp'} \times [h_p(1-h_p) h_{p'}(1-h_{p'})]^{1/2}$$

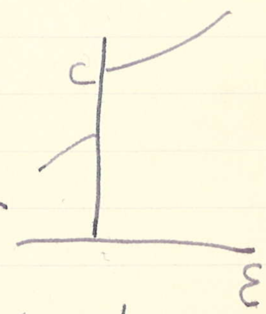
$g^2 = J$:

$$\frac{\partial W_0}{\partial h_p} = 0$$

$$h_p = \frac{1}{2}\left[1 - \frac{\varepsilon_p}{\sqrt{\varepsilon_p^2 + c^2}}\right]$$

$$c \equiv J \sum_{p'} \sqrt{h_{p'}(1-h_{p'})}$$

$$\frac{1}{J} = \sum_p \frac{1}{2\sqrt{\varepsilon_p^2 + c^2}}$$



$$c \simeq \frac{\omega_m}{\sinh\left(\frac{1}{N_F J}\right)} \sim 2\omega_m e^{-\frac{1}{J N_F}}$$

$J > 0$

energy gap !!! perturbation では出ない.

B. 議論:

Bogoliubov の方法

i) $N \to \infty$

ii) $V \to \infty$　　$\frac{N}{V} = n$: finite

iii) $v \to 0$

$$\left(\frac{E_H - E_0}{V} \right) = O\left(\frac{1}{V}\right)$$

Nambu theory of supercond.

Lagrangian formalism

gage invariance

collective motion

Matsubara, Continued
Martin-Kadanoff: Dec. 16, 1960

Temperature dependent Green's function

$a(t)$, $b(t)$

$$G_r(t,t') = -i\,\theta(t-t')\langle[a(t), b(t')]_\pm\rangle$$

$\langle\ \ \rangle$ は $\int \cdots e^{-\beta H}$ での平均.
density matrix

$$\langle b(t')a(t)\rangle = \int_{-\infty}^{+\infty} \frac{d\omega}{2\pi} I(\omega) e^{-i\omega(t-t')}$$

etc.

$$G(E) = \begin{cases} G_r(E) & \mathrm{Im}\,E > 0 \\ G_a(E) & \mathrm{Im}\,E < 0 \end{cases}$$

$$G(E) = \int_{-\infty}^{+\infty} \frac{A(\omega)}{\omega - E}\frac{d\omega}{2\pi}$$

$$A(\omega) = i\{G(\omega+i\varepsilon) - G(\omega-i\varepsilon)\}$$

$$i\frac{d}{dt}G(t-t') = \delta(t-t')\langle[a(t)\,b(t')]_\pm\rangle$$
$$+ \langle\langle[a(t), H(t)], b(t')\rangle\rangle$$

$x = r, t$: $\phi(x)$, $\vec{A}(x)$

$$\delta H = -\frac{1}{c}\int dr\, \vec{j}(x)\vec{A}(x) + \frac{e}{2mc^2}\int dr\,\rho(x)A^2(x)$$
$$+ \int dr\,\rho(x)\,\phi(x)$$

$t = -\infty$: $\quad f_0 = \dfrac{e^{-\beta H}}{\mathrm{Tr}(e^{-\beta H})}$

$$f = f_0 + \Delta f$$

$\langle \vec{J}(x) \rangle = \mathrm{Tr}\{f\, J(x)\}$

$i\frac{\partial f}{\partial t} = [H_T\, f]$ $\qquad H_T = H + \delta H$

$i\frac{\partial \Delta f}{\partial t} = [H, \Delta f] + [\delta H, f_0]$

gage invariance

$$\left.\begin{array}{l} \phi \to \phi(x) - \frac{1}{c}\frac{\partial}{\partial t}\Lambda(x) \\ A \to \vec{A}(x) + \nabla \Lambda(x) \end{array}\right\}$$

$\langle J_k \rangle \to \langle J_k \rangle + Q$

$Q = 0$ ~~が満~~ となるための条件.

(A) $\nabla_k \langle [j_k(x)\, j_l(x')] \rangle = -\frac{\partial}{\partial t}\langle [\rho(x), j_l(x')] \rangle$

(B) $\frac{e\langle \rho \rangle}{im}\nabla_k \delta(r - r') = \langle [j_k(r,t)\, \rho(r' t)] \rangle$

$$\frac{e\langle \rho \rangle}{m} = \frac{2}{\pi}\int_0^\infty d\omega\, \sigma(k^2, \omega^2)$$

$$J(k,\omega) = [\sigma(k^2,\omega^2) - i\omega\, \alpha(k^2,\omega^2)]\, E(k,\omega) + c[\chi(k^2,\omega^2) - i\omega\, \gamma(k^2,\omega^2)]\, ik \times B(k,\omega)$$

normal: $\omega \to 0$, $\alpha(k^2,\omega^2) \to 0$

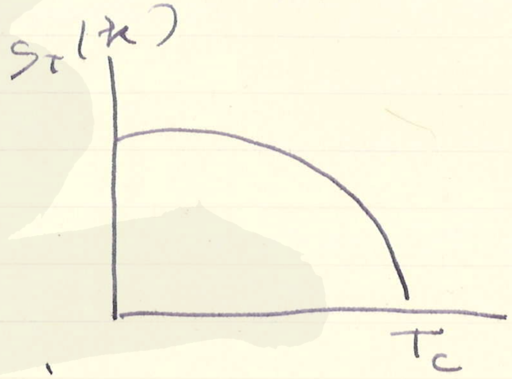
super: $\omega \to 0$ $\qquad \alpha \to \frac{1}{\omega^2}$

$$\sigma(k^2,\omega^2) = \frac{ne^2}{m}\pi\, \delta(\omega) S_T(k^2) + \sigma_n(k^2 \omega^2)$$

$$\alpha(k^2,\omega^2) = -\frac{ne^2}{m}\frac{S_T(k^2)}{\omega^2} + \alpha_n(k^2,\omega^2)$$

$$J(k,\omega) = \frac{ne^2}{m} S_T(k^2)\left[\pi\delta(\omega) + \frac{i}{\omega}\right] E(k,\omega)$$
$$+ [\sigma_n - i\omega\alpha_n] E(k,\omega)$$

const $\frac{\partial J_s}{\partial t} = E$, London の第一方程式



Long time correlation

$\langle [j(rt), \rho(r't')] \rangle$

$(t-t') \to \infty$

$\langle \rho \quad \rho \rangle \to$ diverge

$(t-t') \to \infty$

$x(t) = \frac{p}{m} t + x(0)$
$[p(t), x(0)] = -i$
$[x(t), x(0)] = -\frac{it}{m}$

} classical free electron

H = free ~~el~~ part for electrons + attractive Fermi interaction between two electrons

$G(1;1')$, $G(12;1'2')$ … 12 次まで
連立方程式.

damping:

nuclear matter
N = finite
Mottelson

energy shift

Y. Nambu and G. Jona-Lasinio
A Dynamical Model of Elementary Particles Based on an Analogy with Superconductivity. I.
(Phys. Rev.)
(Preprint received on Dec. 14, 1960)
(Reported by Katayama on Dec. 17, 1960 at RIFP)

gage gap pair correlation Coulomb int.
γ_5-gage nucleon mass pion $\mu_\pi^2 = 0$
1) other int.
2) approx.

Fermi sphere (phonon Debye cut-off
relativistic cut-off (lattice space)

Primary interactions
i) Fundamental vector field
ii) Fermi interaction

nucleon cons. $\int \bar{\psi}\gamma_4\psi = N$ $\psi \to e^{i\alpha}\psi$
Chirality cons. $\int \bar{\psi}\gamma_4\gamma_5\psi = X$ $\psi \to e^{i\alpha\gamma_5}\psi$

attraction
i) vector ~~or~~ pseudovector
attraction repulsion for particle-antipart.
mass of dimension or ...
ii) Fermi int.

$$0 < \frac{2\pi^2}{g_0\Lambda^2} < 1$$

$m = 0$, I a

~~vac~~ $\gamma\partial\psi^{(0)} = 0$

$(\gamma\partial + m)\psi^{(m)} = 0$

$\psi^{(0)} = \psi^{(m)}$ $\quad x_0 = 0$

(相互作用の cut-off
自由場の cut-off)

$E^{(m)} - E^{(0)} = -2\sum_p [(p^2+m)^{1/2} - |p|]$

$N = 0$

$X =$

N	mass	parity
0	0	0^-
0	2m	0^+
0	$3m^2 < \mu^2 < 4m^2$	1^-
±2	$2m^2 < \mu^2 < 4m^2$	0^+

$\gamma_5 \frac{1}{1 \pm J_p} \gamma_5$

$\frac{G_\pi^2}{4\pi} = 2\pi \left[\int_{4m^2}^{\Lambda^2} \frac{\left(1-\frac{4m^2}{\kappa^2}\right)^{1/2}}{\kappa^2} d\kappa^2 \right]^{-1}$

$\Lambda^2 \sim$ ~~M~~ $4m^2$

Katayama School　　Dec. 20, 1960

1. $\gamma\partial\ F(\square)\varphi = 0$

$\gamma\partial \to m=0$, $F \to \pm m$

m=0 のparticleは考えなくてもよいのか!?
±m の ~~par~~ quasi-particle を考えたければ
-m はどうなるのか?

2. cut-off
lattice space ← lattice vibration

3. $\square\varphi = F(\varphi)$

$L = -\frac{1}{2}\frac{\partial\varphi}{\partial x_\mu}\frac{\partial\varphi}{\partial x_\mu} + \int F(\varphi)\,d\varphi$

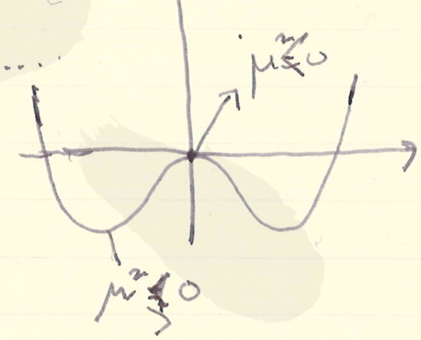
$H = -\frac{1}{2}\left(\frac{\partial\varphi}{\partial x_4}\right)^2 + \frac{1}{2}(\nabla\varphi)^2 + \int F(\varphi)\,d\varphi$

$U(c) = +\int^c F(c)\,dc$
$= -\frac{1}{2}c^2 + \frac{1}{2}c^4$

$F(c_j) = 0$

$\varphi = c_j + \chi_j$

$\square\chi_j \simeq F'(c_j)\chi_j + \cdots$



normal class?
一つのmassの値から
他のmassが出るか
どうか?

J. J. Sakurai
Theory of Strong Interaction
(Ann. Phys. 11 (1960), 1~48
conservation of baryon number
hypercharge
isospin

→ fundamental vector fields with baryon sources
$B_\mu^{(I)}$, $B_\mu^{(Y)}$, $B_\mu^{(B)}$
isospin, hypercharge, baryon

$Q = \frac{N + S}{2} + I_3$

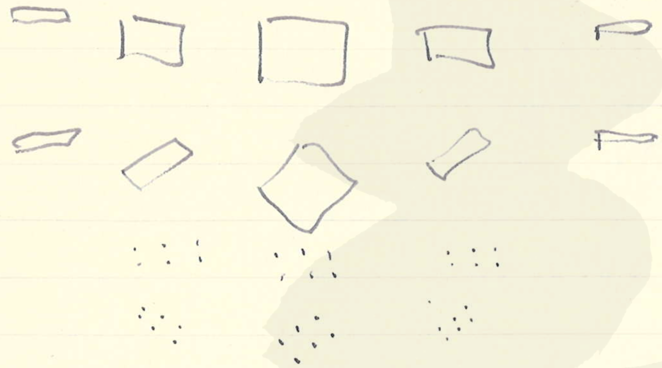
N, $2I_3$, $2Q$
$N = 0, \pm 2, \pm 4, \ldots$
$\pm 1, \pm 3, \ldots$
$2I_3 = 0, \pm 2, \pm 4, \ldots$
$\pm 1, \pm 3, \ldots$

$2Q = 0; \pm 1$

problem of rest mass of basic bosons?

Katayama school   Jan. 17, 1951

I. Yukawa:
relativity



Jan. 17, 1961

Swadavi(?)

Berkeley, strong interaction の会議 Dec. 1960

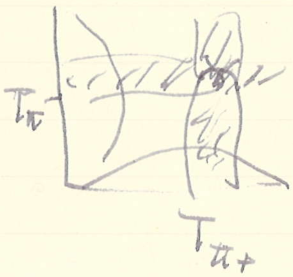
新粒子：

① Y^*　PRL 5, 520
Berkeley, Brookhaven　524　$J = 3/2$
$J = 3/2$ が強い(?)になった。
$I = 1$, $J = 1/2$ → $\Lambda + \pi$ → $S_{1/2}$
　　　　　　→ $\Sigma + \pi$
　　　　　　少ない

$$M_{Y^*} = 1385 \pm 15 \text{ MeV}$$

$$\pi(K\Lambda N) = -1$$

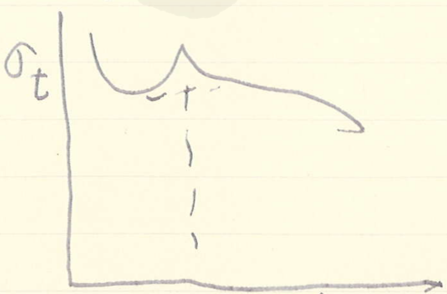
$$K_0^- + p \to \Lambda + \pi^+ + \pi^0$$
$$K^- + p \to \Lambda + \pi^+ + \pi^-$$
$$K^- + He^4 \to He^3 + \pi^* + \Lambda$$



② K^*
(Berkeley)
$$K^- + p \to K^0 + \pi^- + p$$
$$M_{K^*} = 884 \pm 15 \text{ MeV}$$
$J = ?$
$$K^{*-} \to K^0 + \pi^-$$
$$\to K^- + \pi^0$$

$R = \frac{K^0}{K^-} = 1.4$　$T = 1/2$　2.0
　　　　　　　$T = 3/2$　0.5

②′ $K + p$ (Berkeley)
$Q = 380 \pm 60$
$$K^- + p \to K^* + p$$



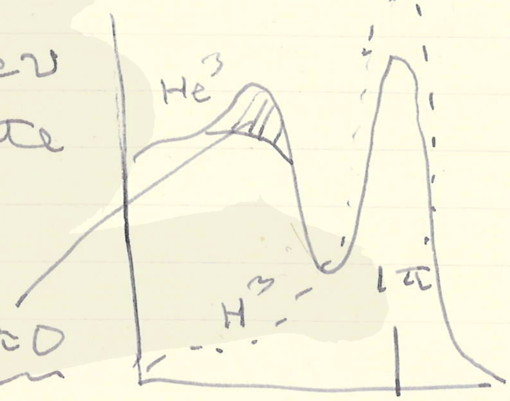
(3) π-π Rochester Conf.

PRL 5 258

p + d → 5 513 (~~p-wave~~)

I = 1/2 { $He^3 + \omega^0$ T=0, 1

→ He^3 + ( ) T = 1



M_{ω^0} = 305 MeV

T=0, で 2π-state (J=0 の)

なら τ → π+π+π

にきいてくる.

J=1 ならT=1 T=0

即ち 3π-state

(3)′ $\pi^- + p \to N + \pi + \pi$

resonance あるらしい.

(3)″ $p + \bar{p} \to \pi + \pi + \cdots$

resonance はないらしい

	I	J
Σ′	1	1/2
K′	1/2	?
ω^0	0	?

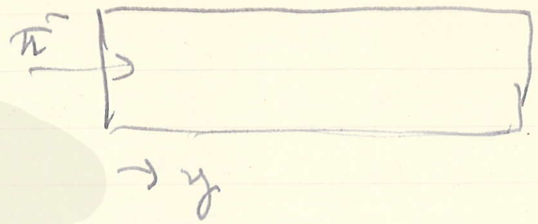
Cusp

$\pi^- + p \to K^0 + \Lambda^0$

$\pi + p \to K^0 + \Sigma^0$

$K^+ + \Sigma^-$

Berkeley



$\pi^- + p \to \Lambda^0 + K^0$

$\to \pi^- + p$

3rd resonance
900 MeV.

$d_{5/2}(\pi^- p)$
$f_{5/2}(\pi^- p)$

cusp $\quad \sigma(\theta) = \sum_l a_l P_l(\cos\theta)$
a_3

Columbia-Brookhaven
900 MeV → 914 MeV

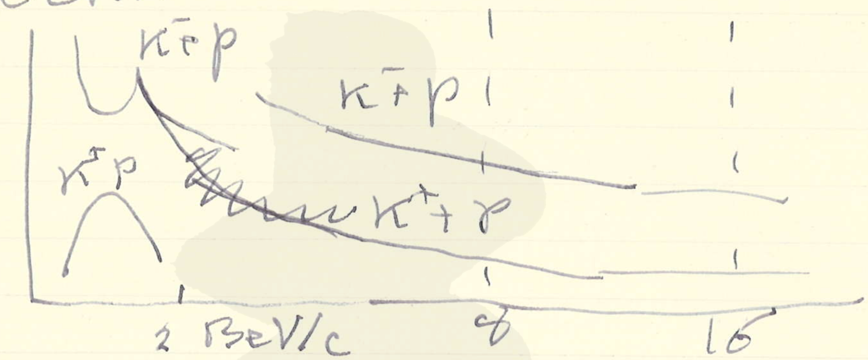
① cusp $\quad \cos^3\theta$ 項
(2) $\Lambda^0 K^0$ main contrib.
$d_{5/2}(\pi, p)$, $f_{5/2}(\pi, p)$

π-N	$p(\Lambda K N)$	Λ-K	cusp	$p(\Lambda\Sigma)$
$d_{5/2}$	+	$f_{5/2}$	$s_{1/2}$	+
$d_{5/2}$	㊀	$d_{5/2}$	$p_{1/2}$	㊀
$f_{5/2}$	+	$d_{5/2}$	$p_{1/2}$	−
$f_{5/2}$	㊀	$f_{5/2}$	$s_{1/2}$	⊕

Cross-section
① $\pi^+ + p \to \Sigma^+ + K^+$ (Yale - Brookhaven)
charge indep と矛盾しない,

$\Sigma^+ \to \pi^+ + n$ 　zero asym.
$\Sigma^+ \to \pi^0 + p$ 　positive asym.

CERN



π^+-p　310 MeV　(Berkeley)

S, P, D

× Minami　　Fermi I

× Yang　　Fermi II

π^-+p (Saclay)　　600 MeV　$J = 3/2$

~~π^0~~ → π^- + p

→ π^0 + N

→ $2\pi^0$ + N

π^+ + p

γ + p → π^0 + p (Cal, Tech)

a polarization

$P_{3/2}$, $D_{3/2}$

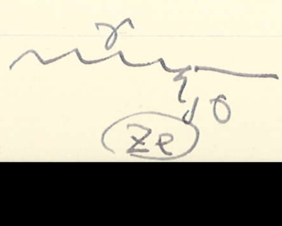
Y → $e^{\pm}$ + ...　(école polytechnique)

Σ 150　8 例.

Λ 1000

$\tau(\pi^0) \sim 1.7 \times 10^{-16}$ sec.

(±1.4



現況:

Mandelstam

Chew　　$\sigma_{E\to\infty}(E) = \mathrm{const}.$

π-π　(p) で強い

Pais

Cutkosky

Gell-Mann

Salam

Weinberg

Fubini

電子技術研究所；素粒子の理論

Jan. 24, 1961

周期律表　　約100種の素粒子
2種の相互作用　　strong　Yukawa
　　　　　　　　weak　Yukawa

symmetry of π-interaction
Ogawa
Y. S. T. ; symmetric meson theory

p　$\bar{p}$　　π^+ π^0 π^-　$\pi^{0\prime}$
n　$\bar{n}$　　K, L, D
baryon 8　　　16
anti. 8

I - conserv.　　strong
ΔI = 1/2　　　weak

$p = p,\ \frac{\Xi^0 - n}{\sqrt{2}},\ \Xi^-,\ \frac{\Xi^0 + n}{\sqrt{2}}$

$q = \Sigma^-,\ \Sigma^0,\ \Sigma^0,\ \Lambda$

$\pi = \pi^+,\ \pi^0,\ \pi^-,\ \pi^{0\prime}$

---

	fermion	boson
N-space	三次元 vector	三次元 vector
$\lvert N \rvert, N_3$	四次元 vector	四次元 self-dual
π-space	spinor	vector　K, L, D
$\lvert \pi \rvert, \pi_3$		scalar

fragile
symmetry

global symmetry πN
cosmic symmetry $K N$
$D^{\pm}$, D^{0}, $D^{0'}$, $\pi^{0'}$

q: pure imag.
D: scalar
Σ Λ: even parity

$n_1 = n_N + n_\Sigma + n_\Lambda + n_\Xi$

$n_2 = n_N + n_K + n_D$

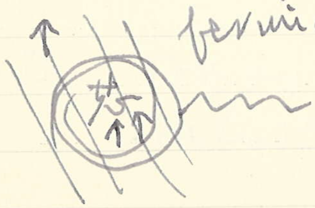
$n_3 = n_\Xi + n_L - … n_D$

$x_3 \leftarrow n_4 \equiv n_2 + n_3 = n_N + n_K + n_\Xi + n_L$

$U \leftarrow n_5 \equiv n_2 - n_3 = n_N - n_\Xi + n_K - n_L + 2n_D$
hypercharge

structure of particles

fermion



boson

mass of baryon and meson

Periodic Table

1. baryon. spin 0 - meson

δ^0 δ^-

μ^+ μ^0 μ^- $\mu^{0\prime}$

e^+ e^0

ρ^+_m

ρ^0_m

$\rho^{\pm}_m$

$\rho^{0\prime}$

Nambu
Lee-Yang
Sakurai

[8 | 8] B=0 [X] B=+1 [X⁺] B=−1

[8 | 8] K D L [ ]

[8 | 8] P [ ]

48
+64
112

Katayama
Axial Vector Current
素研談話会　Feb. 14, 1961.

Goldberger - Treiman

$\partial_\mu \mathbb{P}_\mu = i a \pi$

$G_V \cong G_A$

ps (ps) ではだめ
ps (pv) ではよい

ps(pv): $\mathbb{P}_\mu = \bar{N} \gamma_\mu \gamma_5 \tau N - \frac{1}{g_A} \partial_\mu \pi$

$\partial_\mu \mathbb{P}_\mu = - \frac{\mu_\pi^2}{g_A} \pi$

ps (ps): $f_s = g_p$
s (s)
scalar, isoscalar σ

$\mathbb{P}_\mu = \bar{N} \tau \gamma_\mu \gamma_5 N + \frac{2mi}{g_p} \partial_\mu \pi$
$+ 2i(\sigma \partial_\mu \pi - \partial_\mu \sigma \pi)$

$\partial_\mu \mathbb{P}_\mu = \frac{2mi}{g_p} \mu_\pi^2 \pi$

Gell-Mann - Levy

$f_s = g_p$
$f_p = g_s$
$G_V = G_A$

Transformation
$N \to (1 + i\gamma_5 \tau \alpha) N$

$\left.\begin{matrix} \pi \\ \sigma + \frac{m}{g_p} \end{matrix}\right\}$ vector　$\left.\begin{matrix} \rho \\ \varphi \end{matrix}\right\}$ vector

$v_\mu + \frac{g_V}{G}\partial_\mu \sigma$) tensor
$w_\mu + \frac{g_A}{G}\partial_\mu \pi$

$m \to \sigma \to \pi$

(N) ← non-linear

$\mu_\pi^2 = 0$

$\partial_\mu \Pi^0{}_\mu = 0$

$\partial_\mu W_\mu = 0$

$\mathcal{L}_1 = \frac{1}{2}\{(\bar{N}N)^2 - (\bar{N}\gamma_5 \tau N)^2\}$

$\mathcal{L}_2 = \frac{1}{2}[(\bar{N}\tau N)^2 - (\bar{N}\gamma_5 N)^2]$

$\mathcal{L}_3 = \frac{1}{2}[(\bar{N}\gamma_\mu N)^2 - (\bar{N} i\gamma_\mu \gamma_5 \tau N)^2]$

$\mathcal{L}_4 = \frac{1}{2}(\bar{N}\gamma_\mu N)^2$ $\qquad \mathcal{L}_5 = \frac{1}{2}(\bar{N} i\gamma_\mu \gamma_5 N)^2$

$\mathcal{L}_6 = \frac{1}{2}[(\bar{N}\sigma_{\mu\nu}N)^2 - (\bar{N}\sigma_{\mu\nu}\tau N)^2]$

$\mathcal{L}_0 = -\bar{N}\gamma_\mu \partial N$

$m\bar{N}N$ X

$$\left.\begin{array}{l}\mathcal{L}_1 + \mathcal{L}_2 + \mathcal{L}_4 + \mathcal{L}_5 = 0 \\ \mathcal{L}_4 - \mathcal{L}_5 - \mathcal{L}_3 = 0\end{array}\right\}$$

$$\mathcal{L}_1 - \mathcal{L}_2 - \mathcal{L}_6 = 0$$

i) $\mathcal{L}_4 - \mathcal{L}_5$ (only), $\mathcal{L}_3$ (only) から mass がでない

ii) $\mathcal{L}_6$ はでない、従って $\mathcal{L}_1 + \mathcal{L}_2$ の[illegible]

$$L = \lambda_a(\mathcal{L}_1 + \mathcal{L}_2) + \lambda_b \mathcal{L}_3 + \lambda_c \mathcal{L}_4 + \lambda_d \mathcal{L}_5$$

$$= a\mathcal{L}_4 + b\mathcal{L}_5 \qquad a \neq -b$$

$\frac{a}{b} = 1$; $ps(ps)$

$\frac{a}{b} = -1$; $ps(pv)$

Ohnuki.

Ihara:

T. Takabayashi
非局所系の量子論　　　　Feb. 25, 1961

corpuscule → point-like system
infinitesimal なひろがり.

i) corpuscule　　X_μ, q_α　　$\boxed{P_\mu = p_\mu}$ etc

ii) molecule

iii) ether

iv) drop

$[m, X_\mu] \neq 0$　　$m = -p_\mu^2$

$H = v_\mu p_\mu + H'(\xi)$

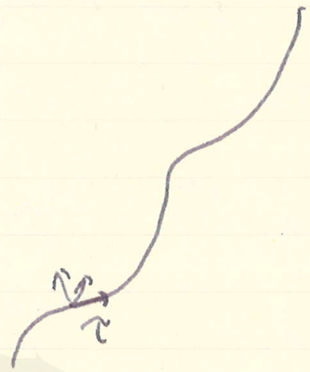
↓

$(-p_\mu^2 - M)\psi = 0$

$J_{\mu\nu} = x_{[\mu} p_{\nu]} + S_{\mu\nu}$

$\dot{x}_\mu = \frac{dx_\mu}{d\tau} = v_\mu$

$\dot{S}_{\mu\nu} = p_{[\mu} v_{\nu]}$



$\boxed{\frac{dP_\mu}{d\tau} = 0}$; 仮定

x_μ, p_μ, $S_{\mu\nu}$, v_μ

$p_\mu = \lambda v_\mu$: Newtonian particle

$\boxed{[v_\mu, x_\nu] = 0}$ 仮定　　$[v_\mu, p_\nu] = 0$

$[v_\mu, v_\nu] = ?$

$\rho = -v_\mu^2$ c-number?

$[v_\mu, v_\nu] = 0$: Bopp rotator) realistic

$[v_\mu, v_\nu] = i\, S_{\mu\nu}/\kappa$ Bhabha, pseudo-Bhabha, spinor model — Dirac, ~~Klein~~ Kemmer

$$-i\hbar \dot{F} = [H, F]$$

~~$H\psi = \lambda\psi$~~

$H \to \frac{d}{d\tau}$?

Iwata?

$\tilde{S}_{\mu\nu} v_\nu = H_\mu$

$S_{\mu\nu} v_\nu = K_\mu$

spin ← $\tilde{S}_{\mu\nu} p_\nu = w_\mu$

← $S_{\mu\nu} p_\nu = r_\mu$

radius of Zitterbew. $\zeta = w_\mu H_\mu$

$\varepsilon = v_\mu p_\mu$

$H_\mu^2 = \Theta$

$-v_\mu^2 = \rho$

$S_{\mu\nu}^2 = \Phi$

$S_{\mu\nu}\tilde{S}_{\mu\nu} = X$

P

$w_\mu^2 = \Sigma$

$\rho = 1$
$\ \ = 0$ } 若 ρ is a c-number

$\{\chi, v_\mu\} = 0 \rightarrow [\chi^2, v_\mu] = 0$ Dirac

$\{\rho - \frac{5}{2}\frac{\hbar}{2\pi}, v_\mu\} = 0$ Kemmer

Dirac: γ_μ は real vector でない.
従って v_μ は ~~vec~~ ~~real vec~~ complex vector

逆に v_μ を real vector とすると

$\chi\{v_\mu v_\nu v_\lambda + v_\lambda v_\nu v_\mu = \frac{\hbar}{2}(\delta_{\mu\nu} v_\lambda + \cdots\ )\} = 0$

~~x^2~~

$H_\mu \rightleftarrows v_\mu$ reciprocity

$v_\mu = i\,\bar{\xi}\,\gamma_\mu\,\xi$

$[\bar{\xi}_\rho, \xi_\sigma] = \delta_{\rho\sigma}$

$\{\bar{\xi}_\rho, \xi_\sigma\} = \delta_{\rho\sigma}$ → spinor model

[illegible]

Karayama school, Feb. 28, 1961

A. Das: Cellular space-time and quantum field theory
(Nuovo Cimento 18 (1960), 482)

A. Schild: Discrete Space-Time and Integral Lorentz Transformations
Canadian J. Math. 1 29 ('49)

H. S. M. Coxeter and G. J. Whitrow
World structure and non-Euclidean honeycombs
P.R.S. A 201, 417 ('50)

Integral Lorentz Transformation

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

$$x' = \mathfrak{L} x \qquad \mathfrak{L}: \text{element が整数}$$

$$\mathfrak{L}^T \eta \mathfrak{L} = \eta$$

reflection

$a_\mu \qquad \mu = 0, 1, 2, 3$

に normal な平面に関する reflection

$$x'_\mu = x_\mu - 2a_\mu (x_\nu a^\nu)/a_\kappa a^\kappa$$

	a_μ	
$\mathfrak{L}_I$	$(1, 1, 1, 1)$	$x'_\mu = x_\mu + (x_0 - x_1 - x_2 - x_3)$
$\mathfrak{L}_{II}$	$(0, 0, 0, 1)$	$x_3 \to -x_3$
$\mathfrak{L}_{III}$	$(0\ 0, 1, -1)$	$(x_2 \leftrightarrow x_3)$
$\mathfrak{L}_{IV}$	$(0\ 1, -1, 0)$	$(x_1 \leftrightarrow x_2)$

素研談話会

麦林 : Exact Treatment of Bound state Problems in Non-Rel. Q. F. T.

Feb. 28, 1961

Ohnuki
Umezawa
neutral scalar

$\varphi(1,2)$の式をexactに解いても, solutionの個数はへることはない.

(家にて (March 1, 1961))

March 1
1961

E. C. G. Sudarshan

Quantum Mechanical System
with Indefinite Metric

(P. R. in press)

neutral scalar theory with indefinite metric → attractive and repulsive potentials (Yukawa oscillator)
Lee oscillator
Pais-Uhlenbeck oscillator
Model of Quantized Field theory
two particle state with positive metric is separated from two particle state of neg. metric
convergent for $g_1^2 = g_2^2$
and positive def. for
$$(m^2-\mu_1^2)^2 > (m^2-\mu_2^2)^2$$

simple interaction (local) with indefinite metric
⇄ complicated interaction with definite metric (non-local)

complementarity
covariance v. definite metric
relativity v. q. m.

細田氏: Dar つづき

(基礎理論談話会)

March 4, 1961

$$f(x_n) = \frac{1}{(2\pi)^{1/2}} \int_{-\pi}^{+\pi} g'(k)\, e^{ikx_n}\, dk$$

Katayama. March 7, 1961

R. E. Marshak and S. Okubo

Towards a two-field theory of elementary particles (preprint)

$$Q = I_3 + \frac{S+B-L}{2}$$

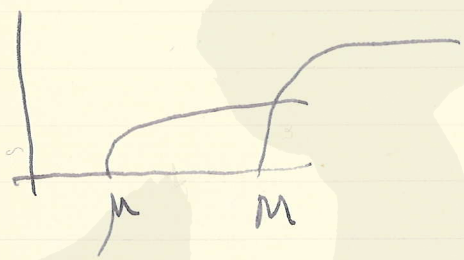
Nagoya model

$n\,(= B^+ e^-) + \bar{p}\,(= B^- \bar{\nu}) \rightarrow e^- + \bar{\nu}$?

しかし weak でよいのではないか!

non-perturbation solution

non-adiabatic solution

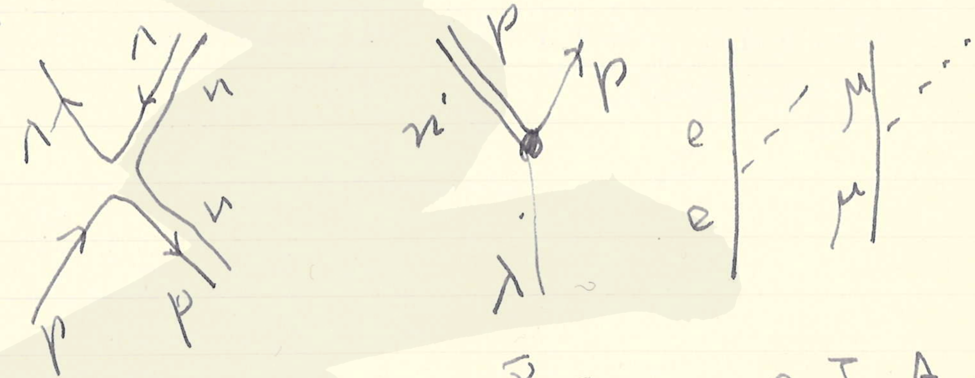


"あわよくば" 理由

藤井 ([illegible] school) March 14 1961

On the analogy between strong Int. and Electromagnetic Int.
Y. Fujii (P.T.P. 21 ('59))
Vector theory of strong int.
J. J. Sakurai (preprint)
相互作用を generate する principle が必要である。

Fujii



$e J_\mu A_\mu$

S.I.   W.I   e.I.

gauge inv.
J_μ conserv.) → $J_\mu A_\mu$

$\psi_\alpha \to e^{i g_\alpha \Lambda(x)} \psi_\alpha$ $j_\mu A_\mu$ B scalar

$A_\mu \to A_\mu + \partial_\mu \Lambda$
$B \to B - m\Lambda$
| $j_\mu = i g_\alpha \bar{\psi}_\alpha \gamma_\mu \psi_\alpha$
$\alpha \to p, n, \Lambda$

baryon charge cons. ⇄ $g_n = g_p = g_\Lambda = g$

Sakurai

$$f_W(\bar{e}\nu + \bar{\mu}\nu + \bar{p}n)V_\mu^+$$

V, A

Wigner : charge の定義

1. simple additive number, all reaction で保存
2. ~~electric~~ electromagnetic field による deflection

中西氏.

H. R. Coish: Elementary Particles in a Finite World Geometry
P. R. 114 (1959) 383

I. S. Shapiro: Weak Interactions in the Theory of Elementary Particles with Finite Space
N. P. 21 (1960) 474

~~Coish~~ (数学)
world ring 世界環
field 体

有限体

Jannefelt (1949)
Kustaanheimo (1950)
必ず可換 commutative
素体：部分体にはtrivialなものしかない。
~~有限~~素体：
素数 p を modulus とする剰余体 R_p
$a \equiv b \pmod p \Longleftrightarrow a-b = mp$
$(0, \cdots\ p-1)$
$p \neq$ prime: $ab \equiv 0 \leftarrow a \not\equiv 0,\ b \neq 0$
一般の有限体は
$a = (a_1, a_2, \cdots a_n)$　$a_i \in R_p$
とする。
位数＝元の個数 $= p^n$
位数は p^n に限り、構造は p^n だけで定まる
Galois Field　$GF(p^n)$
p^n 加法群.
$p^n - 1$ 乗法群. 巡回群.

[illegible]　$\alpha \in G$　　h

$\alpha^h = 1$

$\alpha^s = 1$　　s は h の約数.

$p^n - 1 = h$;　$\alpha^{p^n - 1} = 1$

($n = 1$; Fermat の定理)

$\alpha^{p^n} - \alpha \equiv 0$

$x^{p^m} - x = 0$

$= \prod_{i=1}^{p^n} (x - \alpha_i)$

根系、

$(a+b)^p = a^p + b^p$

原始根

$\exists \alpha_0$:　$\alpha = \alpha_0^r$

$\{0, \alpha_0, \alpha_0^2, \dots \alpha_0^{p^n - 1}\}$ cyclic

$n = 1$; $GF(p) \longleftrightarrow$ "real"

square $\longleftrightarrow$ pos

non-square $\longleftrightarrow$ neg

$\alpha \neq 0$　$\alpha \to \alpha^2$

$p - \alpha \to \alpha^2$

$2 : 1$

$p - 1$ の $\frac{p-1}{2}$

符号の法則　$(+)(+) = (+)$　　を満す

$(+)(-) = (-)$

$(-)(-) = (+)$

[illegible]の定義 : (-1) is nonsquare

α ($\alpha^{\frac{1}{2}(p-1)} = 1$) is positive

$(-1)^{\frac{1}{2}(p-1)} = -1$

$\boxed{p = 4m - 1}$

全順序　ordering できない。

$\forall\ \alpha, \beta \in GF(p)$

$\alpha \gtreqless \beta$

-1 : nonsquare

$\sqrt{-1}$ は $GF(p)$ に属さない。

$n = 2$: $\underset{i}{GF(p^2)} \longleftrightarrow$ "complex" $\sqrt{-1}$

$(a_1 a_2) = a_1 + i a_2$

$z = \alpha + i\beta \qquad \alpha, \beta \in GF(p)$

$i^p = i\, i^{p-1} = i\,(-1)^{\frac{p-1}{2}} = -i$

$z^p = (\alpha + i\beta)^p = \alpha^p + i^p \beta^p$

$= \alpha - i\beta$

$= z^*$

$\boxed{z^{p+1} = z^* z = \alpha^2 + \beta^2}$

$\alpha, \beta \in GF(p)$

$\alpha^2 + \beta^2 = -1 \rightarrow \boxed{\zeta^* \zeta = -1}$

となる $\zeta = \alpha + i\beta$ がある。

Cosm

ordering
local ordering

$p \sim 10^{(10^{81})}$

odd integer

$p = 8x\prod_{i=1}^{k} q_i - 1$

$q_1 \cdots q_k$ odd prime
3 5 7 ....

(Dirichlet の定理)

$(-q \cdots\cdots 1\ 0\ 1\ 2 \cdots\cdots q)$
ordered
$q \sim \log p$

Lorentz 群
$x_0, x_1, x_2, x_3 \in GF(p)$
$x^2 = x_0^2 - x_1^2 - x_2^2 - x_3^2$ inv
位数 $p^2(p^2+1)(p^2-1)$
+1 } proper L G
−1 }

orthogonal　$x^2 \to x^2$　ordinary
$x^2 \to -x^2$　extraordinary
extended orthogonal group

$$g = \begin{pmatrix} -\alpha & \beta & 0 & 0 \\ \beta & \alpha & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & +1 & 0 \end{pmatrix} \to x^2 \Rightarrow -x^2$$

$$(gx)^2 = -x^2$$

$$\alpha^2 + \beta^2 = -1$$

Spinor representation

$GF(p^2)$

$$X = \begin{pmatrix} x_0 + x_3 & x_1 - i x_2 \\ x_1 + i x_2 & x_0 - x_3 \end{pmatrix}$$

$$= x_0 1 + \sigma_1 x_1 + \sigma_2 x_2 + \sigma_3 x_3$$

$$\| X \| = x_0^2 - x_1^2 - x_2^2 - x_3^2$$

$$X' = a^* X a$$

$$(a^*)^* = a$$

$$\| X' \| = \| a^* \| \| X \| \| a \| = \| X \|$$

$$\| a \|^{p+1} = 1$$

$$u(-I) = \zeta \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \qquad I : x \to -x$$

$$\zeta^* \zeta = -1$$

$\omega \in GF(p^2)$ $\qquad \omega^{p+1} = 1 \qquad \| a \|^{p+1} = 1$

$$\| \omega^\alpha a \|^{p+1} = 1.$$

$\omega_0^\alpha a \qquad (\alpha = 0, 1, 2 \ldots p)$

$p+1$ 個の表現.

~~extended~~ vaord, Q. G.

$\|a\|^{p+1} = -1$.

$a(g) = \begin{pmatrix} 0 & \zeta \\ -1 & 0 \end{pmatrix}$ $\zeta^* \zeta = -1$

— 有限群の表現. Lorentz群 $(GF(p^2)) \subset GLH(2, p^2)$

Brauer - Nesbitt

Extend Q. G. $GF(p^4)$

space reflection
four spinor
S T P X
V A O

Gauge Transf.
$a \to \omega_0^\alpha a$ $(\alpha = 0, \dots p)$
$\psi \to \omega^\alpha \psi$: gauge Transf.
$\omega_0^\alpha a \to$ charge $(a = 2(n+j-k)$ integer

Combined Inversion : CP
$a \to \omega^{a\alpha} a$
$\bar{a} \to \omega^{-a\alpha} \bar{a}$

Shapiro

i) Extended LG に対する covariance を要求

φ　　$a(L)$

φ_a　　$\omega_0^a\, a(L)$

$a' = 2a^{\mathrm{ro}} + 1$
wish Shapiro

2成分理論

$g_1, g_2, g_3, g \cdots$

$g_1 g_2 g_3 g_4$ – proper L.

$a_a(g)$　　　$i^\eta\ (1 \leq \eta \leq 4)$

space-time Reflection

$g^2 = -1$

$u(g^2) = \hat{a}(T)\, \hat{a}(R)$

quantum number

j_1, j_2　　Q　　η　　λ

素粒子の構造研究会

4月21日, 1961

Maki; Marshak-Okubo, Two-Field Theory

p ν n e | Λ μ

↓ ψ ψ'

BL-symmetry

$Q = I_3 + \frac{S + B - L}{2}$

$(B^+e^-) + (B^-\nu) \nrightarrow e^- + \nu$ が何故禁止されるか?

2成分

ψ: φ1 → ν → P (φm, φ-m)

φ2 → e → N

2成分 (:)

ψ' < μ → 4成分, Λ

lepton baryon

H_0 H_{-m} H_m

electromag int で orthogonality が保たれ weak inter. がでる

N + N → N + N M

l + l → l + l 0

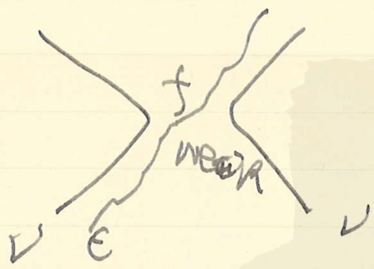
Sakatani: ε-charge, b-charge

0.1 Yukawa はわからん

ε − ν くっつく mechanism わからん

敏いつつり 〃 〃

b − ν くっつく mechanism わからん



$a, \bar{\varepsilon}$ $\quad n \to \gamma$

$b, \bar{b}$ $\quad n \to \pi$

Ogawa, Sakata model での Isobar
Full symmetry

⓪ vacuum

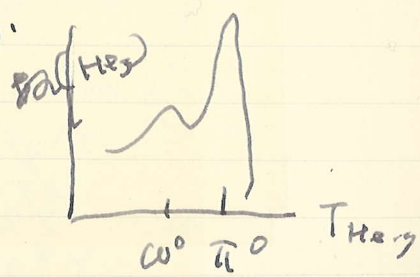
① p, n, Λ

② $B \cdot \bar{B}$ 状態のうちの 8個

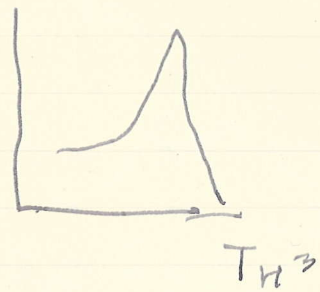
π^+
π^0
π^-
K^+
K^0
$\bar{K}^-$
$\bar{K}^0$
$\bar{K}^0$
$\pi^{0\prime}$

(π_0') $K \to e + \nu + \pi^0$
$\quad \to e + \nu + \pi^{0\prime}$ } yonezawa
$m_{\pi^{0\prime}} \sim 350$ MeV
Berkeley conf.

$p + d \to He^3 + X^0$?
$m_{\omega^0} \simeq 310$ MeV
$\Gamma/2 < 20$ MeV



$p + d \to H^3 + X^+$



$\underline{I = 0}$

$K^0 \to \pi^+ + \pi^-$ 　 10^{-10} sec

$K^+ \to \pi^+ + \pi^0$ 　 1/500

$\Delta I = 1/2$ forbidden

$K^+ \to \omega^0 + \pi^+$ allowed

life が短かくなりすぎる

(3) $BB\bar{B}$

$[BB]\bar{B}$: Ξ, Σ, Λ^*, (3,3), N^* — ? 180 MeV, 180 MeV

$K^+ + N \to (I = 1)$?

$(BB)\bar{B}$: Σ^*, N^{**} — 180 MeV

$K^+ + N \to (I = 0)$?

Σ^*

$K^- + p \to (\Lambda + \pi^-) + \pi^+$

$\to Y^* + \pi \to (\Lambda + \pi^+) + \pi^-$

$\underline{I = 1}$

$m_{Y^*} = 1380 \pm 30$ MeV

$\Gamma/2 \approx 15$ MeV

Y^* と Λ 逆 parity for $J_{Y^*} = 1/2$

$$\frac{Y^* \to \Sigma + \pi}{Y^* \to \Lambda + \pi} = 0.08 \pm 0.03$$

④ [illegible]

K^* $(S=1,\ I=1/2)$

$m_{K^*} = 884$ MeV　　　$10\,\text{MeV} < \Gamma/2 < 13\,\text{MeV}$

K^* $(S=1,\ I=3/2)$

D $(S=2$ $)$

Sumi (鷲見): 2nd, 3rd resonance

N^*　$D_{3/2}$　　mass formula から
　　　　　　　$J=1/2$

N^{**}　$F_{5/2}$　　$J=3/2$

鏡山: 超高エネルギー
多重発生

Air shower

stack

Emulsion

(Emulsion chamber)

1) 角分布　$\ln\tan\theta$ plott

$$\tan\theta = \frac{1}{\gamma_c}\frac{\sin\vartheta}{1+\cos\vartheta} = \frac{1}{\gamma_c}\tan\frac{\vartheta}{2}$$

$$\ln\gamma_c = -\ln\tan\theta + \ln\tan\frac{\vartheta}{2}$$

$$= -\frac{1}{n_s}\sum_i \ln\tan\theta_i$$

$$\gamma_L = 2\gamma_c^2 - 1$$

$\Rightarrow | \Leftarrow$

2) charge-neutral ratio
$x^{\pm} \simeq 20\%$ (π以外)
3) energy of information
e-pair
secondary interaction

1. $p_T \sim 0.35\, BeV/c \pm 0.2$
2. $\frac{d\theta}{\theta}\, d\theta$
3. x 20%
4. fluctuation { η / 角分布

次の至 (Poland, Wien, Cocconi)

storage relation
$\Delta p^* = p_{Nb}$

1. fluctuation の解析
minimum quanta
i) prong distribution $p\bar{p}$ に似ている.
— 非常に (陽子) NN の結果?
2) 角分布 $\sin^2\theta\, d\cos\theta$
(π の) dipole radiation
3) Lorentz factor γ_c をきめなおす
$\to \gamma_q = m\gamma_c$
$\tilde{\gamma}_q = \frac{1}{2}(m \pm \frac{1}{m})$

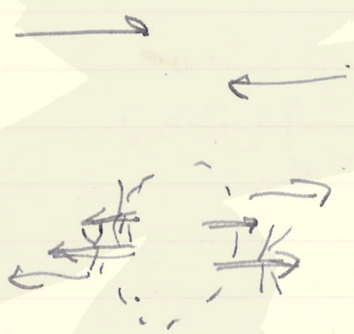
$F(\tilde{\gamma}_q) = * \frac{1}{\tilde{\gamma}_q}$

対称性を示す.

∘ $(N\bar{N})$　止まってる　エネルギー　あり　isotropic polarization

∘ $\pi : N$

∘



4月22日, 1961

坂田: Gell-Mann, ~~Global symmetry~~ {Eightfold Way}

8: Ξ Σ Λ N ⇄ $\begin{pmatrix}\Xi\\ \Sigma\\ \Lambda\\ N\end{pmatrix}$

C.I. U(2) ⟷ higher symmetry U(3) super-multiplet

Sakurai

3: ν e μ ⇄ $\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$) U(2)) U(3)

Yamaguchi $= l_\alpha$

U(2) 1, τ_1, τ_2, τ_3

U(3) 1, $\lambda_1 \cdots \lambda_8$

$\begin{pmatrix} & 1 & \\ 1 & & \\ & & \end{pmatrix}\begin{pmatrix} & -i & \\ i & & \\ & & \end{pmatrix}\begin{pmatrix}1 & & \\ & -1 & \\ & & \end{pmatrix}\begin{pmatrix} & & 1\\ & & \\ 1 & & \end{pmatrix}\cdots\begin{pmatrix} & & \\ & & -i\\ & i & \end{pmatrix}\begin{pmatrix}\frac{1}{\sqrt3} & & \\ & \frac{1}{\sqrt3} & \\ & & -\frac{2}{\sqrt3}\end{pmatrix}$

$\begin{pmatrix} & & -i\\ & & \\ i & & \end{pmatrix}\begin{pmatrix} & & \\ & & 1\\ & 1 & \end{pmatrix}$

$(m_\mu - m_e)$ $\lambda_4\ \lambda_5\ \lambda_6\ \lambda_7$ (sym) がこわれる

m_e $\lambda_1\ \lambda_2$ がこわれ

weak int. $\lambda_3\ \lambda_8$ がこわれ

I, Q だけが保存

U(3) l_α $\bar{l}_\alpha$

~~H_α~~ ~~$\bar{H}_\alpha$~~ $H_\alpha = \begin{pmatrix}D^0\\ D^{+}\\ S^{+}\end{pmatrix}$

L_α $\bar{L}_\alpha$

$$\begin{pmatrix} \Xi \\ \Sigma \\ \Lambda \\ N \end{pmatrix} = \begin{matrix} \bar{L} \cdot \lambda_{1 \ldots 8} \, l \\ \bar{L} \, 1 \, l \end{matrix}$$

Nakamura

Σ^+	$D^+\nu$
Σ^-	$D^0 e^-$
Σ^0	$\frac{D^0\nu - D^+e^-}{\sqrt{2}}$
P	$s^+\nu$
n	s^+e
Ξ^0	$D^+\mu^-$
Ξ^-	$D^0\mu^-$
Λ	$(D^0\nu + D^+e^- - 2s^+\mu^-)/\sqrt{6}$

δm_{D-s}

$\delta m_{\mu - e, \nu}$

$$\frac{1}{2}(m_N + m_\Xi) = \frac{3}{4} m_\Lambda + \frac{1}{4} m_\Sigma$$

$G \bar{N} O_A \tau_i N \pi_i$

$8 \times 8 = 64 = 1 + 8 + 8 + \cdots$

$G \bar{N} \gamma_5 F_i N \pi_i$ ← $\begin{pmatrix} \pi \\ \chi_0 \\ K \\ \bar{K} \end{pmatrix}$ $\begin{pmatrix} \rho \\ \omega_0 \\ M \\ \bar{M} \end{pmatrix}$ vector

$G' \bar{N} \gamma_\mu F_i N V_{\mu i}$

仕田： Lee-Yang, Some Considerations on Global Symmetry

Y^* 3-2 res.

$\mathbb{L}$ $\mathfrak{M}$ $\mathfrak{N}$ $\quad$ R

(p, n), (Y, Z), $(N\ \Xi)$ $\quad$ $(N\ \Xi)$ $\quad$ $(Y\ Z)$ $\quad$ $\begin{pmatrix} N \\ \Xi \\ Y \\ Z \end{pmatrix}$

$\mathbb{I} = \mathbb{L} + \mathfrak{M}$

$\frac{S+N}{2} = n_3$

$Q = T_3 + n_3 = L_3 + M_3 + n_3$

~~R~~

g_0 $\quad$ $U = \left(\begin{array}{c|c} \cdot & 0 \\ \hline 0 & \cdot \end{array} \right)$

$U = \left(\begin{array}{c|c} 0 & \cdot \\ \hline \cdot & 0 \end{array} \right)$

3つのSU(2)

$R \mathbb{L} R^{-1} = \mathbb{L}$

$R \mathfrak{M} R^{-1} = \mathfrak{N}$

$R \mathfrak{N} R^{-1} = \mathfrak{M}$

$L^2, L_3;\ M^2, M_3;\ N^2, N_3$

a) (L, M, M) $\quad$ $(2L+1)(2M+1)^2$

b) (L, M, N) $\quad$ $2(2L+1)(2M+1)(2N+1)$

$M_3 = N_3$: $\quad$ $R|\ \rangle = \delta|\ \rangle$

$N^* = \pi + N$

Baryon $(\frac{1}{2}, \frac{1}{2}, 0)$

$\pi^{+,0,-}$ $(1, 0, 0, \lambda_\pi)$ $(\frac{3}{2}, \frac{1}{2}, 0)$

K $(0, \frac{1}{2}, \frac{1}{2}, \lambda_K)$

Baryon* $(\frac{3}{2}, \frac{1}{2}, 0)$

Pais: $\pi^+ + p \to \Sigma^+ + K^+$

$K^+ + n \to p + K^0$ $\quad \rho_3 \cdot X$

K で K mixing がおこる

K に近い所に level がある.

$(0, \frac{1}{2}, \frac{1}{2})$ $\quad (1, \frac{1}{2}, \frac{1}{2})$

K^*

松田: Mass Formula

$M = m(n_B - n_{\bar{B}})^2$

$+ \Delta m \{ 2(n_\Lambda + n_{\bar{\Lambda}}) - (n_B - n_{\bar{B}})(n_\Lambda - n_{\bar{\Lambda}}) \}$

+ small term $(\cdot n_B + n_{\bar{B}} \cdot (n_\Lambda - n_\Lambda)^2)$

$\{ m \sim m_N$

$\{ \Delta m \sim m_\Lambda - m_N$

N) $\frac{1}{2}^+$ $\quad B\bar{B}$ (S) $\quad$ S.P: $B\bar{B}B$ (S S)

Λ

π) 0^-

K

① $N\bar{N}$ $S_{p.a}$

$\Lambda\bar{\Lambda}$ $A_{p.a}$

$3-3$ $\frac{3}{2}^+$

N^*(2nd) $\frac{3}{2}^-$

② l_{min}

③ SL : max.

上田：Meson [illegible]

三尾田・宗次・上田

$\pi + N \to B_4 + N$, $B_4 \to 2\pi$

$B^{1}_{4}(0,2)$ S, I

$\pi^+ + p$ 560 MeV

$\pi^- + p$ 1 BeV

1. $\dfrac{\pi^+ + p \to \pi^+ + \pi^0 + p}{\pi^+ + p \to \pi^+ + \pi^+ + n} = 1.5^{+1.5}_{-0.5}$

$m(B(0,2)) = 300 \sim 400$ MeV

2. $B^{4,6}_{4}(0,1)$

$m(B(0,1)) = 650$ MeV

3. π-p.

4. $10^{-3} = \dfrac{\tau^+ \to 3\pi}{K^0_1 \to 2\pi}$

片山：(1)e-charge

1) $\nu \to e$, $\nu \to \mu$?

2) fund. elmg int.? $\frac{g^2}{2}(\bar{e}\gamma_\mu e + \bar{\mu}\gamma_\mu \mu)^2$

3) weak int. ? $\frac{g^2}{2}\, \bar{\nu}\gamma_\mu(1+\gamma_5)(e+\mu)$
$\times(\bar{e}+\bar{\mu})\gamma_\mu(1+\gamma_5)\nu$

4) photon?

already unified
photon field
$e^{i\alpha(x)}$

$$L = -\bar{\Phi}(\gamma\partial)\Phi$$

$$\gamma_\mu \to \Sigma_\mu = \gamma_\mu - \frac{(\bar{\Phi}\partial_\mu\Phi)}{(\bar{\Phi}\Phi)}$$

$$L = -\bar{\Phi}\gamma_\mu\left[\partial_\mu - \frac{(\bar{\Phi}\partial_\mu\Phi) - \partial_\mu(\bar{\Phi}\Phi)}{2(\bar{\Phi}\Phi)}\right]\Phi$$

(Nakano)

$$\left.\begin{array}{l}\Phi \to (\bar{\Phi}\Phi)^\alpha\Phi \\ \bar{\Phi} \to \bar{\Phi}(\bar{\Phi}\Phi)^{-\alpha}\end{array}\right\} \text{ scale transf.}$$

$\langle\bar{\Phi}\Phi\rangle_0 \neq 0 \to$ dimension

(ii) e m_e
μ m_μ

Marshak–Okubo

$$m = 2\lambda\, e^{-\frac{8\pi^2}{3e^2}} \qquad \left(m_N = 2\lambda^{-\frac{c}{g^2\lambda^2}}\right.$$

$$m_e \sim \text{const.}\,\frac{e\delta}{m_e}\lambda^2 \qquad \delta \sim 10^{-5}$$

$(\sigma_{\mu\nu})$

$$m_\mu \sim \text{const.}\,\frac{e\delta}{m_e}\lambda'^2\,(\lambda' \sim 10\lambda)$$

$$\frac{c_1}{p^2+m_1^2} - \frac{c_2}{p^2+m_2^2} \qquad c_1 - c_2 = 1$$

$$\lambda^{-2} = \frac{c_1}{m_1^2} - \frac{c_2}{m_2^2}$$

indefinite metric

$\mathfrak{g}$, Φ_0

$\mathfrak{g}'$ ψ_+ ψ_- ψ_0

$\nu = a\Phi_0 + b\psi_+ + c\psi_-$

$e = \quad , \quad , \quad \underline{+c'\psi_-}$

$\mu = \quad , \quad , \quad \underline{+c''\psi_-}$

$\mathfrak{g} \times \mathfrak{g}' \rightarrow \mathfrak{g}''$

Bog?

$\psi_{+\infty} = \psi_{-\infty}$

4次元量子化,

$f(\nu, e, \mu) = 0$

$f'(e, \mu) = 0$

March 25, 1961 素粒子国際会議談話会
基研コロキウムで

福田 : Lee-Yang
藤本 : Gell-Mann

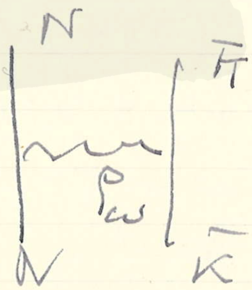
i) N-Y の spin, parity は全く同じ
π - K - χ_0 " "

ii) $\pi^+ + p \nrightarrow \Sigma^+ + K^+$

iii) $\chi_0 \to 2\gamma$
$\to 2\pi + \gamma$
$\nrightarrow 2\pi$
$\nrightarrow 3\pi$

iv) Y^*
I = 1, 0

$p + d \to He^3 + \omega_0$
310 MeV



$$\begin{pmatrix} \rho \\ \omega_0 \\ M \\ \bar{M} \end{pmatrix}$$

河辺六男　　　　　　　　　　　　　　March 28. 1961

Vector meson の renormalizability

S. L. Glashow, N.P. 10 ('59), 107
1. conventional renorm.
   modified 〃
2. partial sym. and partial conv.

$$L = \underbrace{L_K + L_I}\, + L_M$$

A. Salam, N.P. ~~2~~18 ('60), 681
Glashow の訂正.
neutral ps. ps.-coupling

$$L = -(\bar\psi\gamma\partial\psi) - \frac{1}{4}(\partial_\mu U_\nu - \partial_\nu U_\mu)^2 - ig\bar\psi\gamma_\mu\gamma_5\psi U_\mu - m\bar\psi\psi - \frac{\kappa^2}{2}U_\mu U_\mu$$

$$\begin{cases} \psi = e^{i\gamma_5 \frac{g}{\kappa}\Lambda(x)}\psi' \\ U_\mu = A_\mu - \frac{1}{\kappa}\partial_\mu\Lambda \end{cases}$$

unrenormalizable

S. Kamefuchi, 18 ('60), 691
$\partial_\mu j_\mu = 0$ or $\neq 0$ で違い.

A. Komar & A. Salam, N.P. ~~21~~ 14 ('60), 624
Yang-Mills triplet-vector　　$m=0$ と $m\neq 0$ で違う

Umezawa - Kamefuchi, N. P.

$$\mathcal{L} = -\frac{1}{4}(u_{\mu\nu} u_{\mu\nu}) - \frac{\kappa^2}{2}\sum_{i=2} u_\mu^{(i)} u_\mu^{(i)} - \frac{\kappa'^2}{2} u_\mu^{(3)} u_\mu^{(3)}$$

$- \ldots\ldots$

Kawabe,

unrenormalizable part of mass term の
[illegible]気に[illegible] !!!
weak int. + mass producing term

$$\rho = \frac{R(\mu \to e + \gamma)}{R(\mu \to e + \nu + \bar{\nu})} \leq 2 \times 10^{-6}$$

Feinberg, PR 110 (58), 1482 (L) $\rho \sim 10^{-4} (10^{-3})$
Meyer & Salzman, NC 14/6 (59), 1310
$\Lambda \leq \frac{1}{5} m_B$ $\rho < 2.7 \times 10^{-6}$

Ebel & Ernst, NC 15/2 ('60) 173.

W. E. Thirring
On alternative approach to the
Theory of Gravitation
(36.4.11. ; No 1013)

Einstein: 1) Riemannian geometry and
nonlinear equations from the beginning
2) Deduce everything from equivalence
and general covariance principles

Field theoretical (linear approach)
1) gravitation is attractive (concluded)
2) leads to Riemannian space-time
and defines the standard clocks and
rods
3) equivalence principle as the result
4) replace general covariance
by gauge invariance

[illegible]

Gyro-elastic Ether

April 17, 1961.

elastic. $\left(\nabla_\nu T^{\mu\nu} = 0 \qquad T^{\mu\nu} = T^{\nu\mu} \right.$
variation principle

Gyro-elastic: $T^{\mu\nu} \neq T^{\nu\mu}$

$$\begin{cases} \nabla_\lambda M^{\mu\nu\lambda} = 0 \\ M^{\mu\nu\lambda} = x^{[\mu} T^{\nu]\lambda} + S^{\mu\nu\lambda} \end{cases}$$

$$\downarrow \quad \nabla_\lambda S^{\mu\nu\lambda} = T^{[\mu\nu]}$$

理論は ξ^4 の取り方に invariant

$$\xi^{4'} = \xi^{'4}(\xi)$$

そういう意味で invariant な量を proper

proper derivative:

$$D_4 = \frac{1}{\sqrt{-g_{44}}} \partial_4$$

$$D_a = \partial_a + \frac{\gamma_a}{\sqrt{-g_{44}}} \partial_4 \qquad \gamma_a = \frac{-g_{4a}}{\sqrt{g_{44}}}$$

$$D_\alpha x^\mu = A^\mu{}_\alpha$$

$$A^\mu{}_4 = U^\mu$$

proper metric: $A^\mu{}_\alpha A_{\mu\beta} = \gamma_{\alpha\beta}$

$$\gamma_{ab} \qquad \gamma_{4a} = \gamma_{a4} = 0 \qquad \gamma_{44} = -1$$

proper connection (generalized vorticity)

$$D_\beta A^\mu{}_\alpha = A^\mu{}_\gamma \underline{\omega^\gamma{}_{\alpha\beta}}$$

$$\omega_{[ab]4} = A^\mu{}_a A^\nu{}_b \nabla_{[\mu} U_{\nu]}$$

$$\omega_{\alpha\beta\gamma} = D_\gamma \gamma_{\alpha\beta}$$

$$T^{\mu\nu} = \frac{1}{\sqrt{\gamma}} A^\mu{}_\alpha A^\nu{}_\beta \tau^{\alpha\beta}$$

$$S^{\mu\nu\lambda} = \frac{1}{\sqrt{\gamma}} A^\mu_\alpha A^\nu_\beta A^\lambda_\sigma \sigma^{\alpha\beta\sigma}$$

Variation principle:

$$\mathcal{K}(\gamma_{ab}, \omega_{\alpha\beta\gamma})$$

$$\mathcal{K} = \tilde{\tau}^{44} + \tilde{\sigma}^{\alpha\beta\gamma}\omega_{\alpha\beta\gamma}$$

$$\sigma^{\alpha\beta\gamma} = \frac{\partial \mathcal{K}}{\partial \omega_{(\alpha\beta)\gamma}}$$

$$\tau^{(ab)} = -2\left(\frac{\partial \mathcal{K}}{\partial \gamma_{ab}} + \omega^{(a}{}_{\alpha\beta}\,\omega^{b)\alpha\beta}\right)$$

$$\int \nabla_\nu T^{\mu\nu} \delta x_\mu \, d^4x = \delta \int \mathcal{L}\, d^4x$$

$$\left.\begin{array}{l} \nabla_\lambda \delta \neq \delta \nabla_\lambda \\ \partial_\alpha \delta = \delta \partial_\alpha \end{array}\right\}$$

$$L = -\int \mathcal{K}(\gamma_{ab}, \omega_{\alpha\beta\gamma}) \sqrt{-g_{44}}\, d^4\xi \quad \text{(particle)}$$

$$= -\int \rho(\gamma_{ab}, \omega_{\alpha\beta\gamma})\, d^4x \quad \text{(field)}$$

$$\rho = \frac{1}{\sqrt{\gamma}} \mathcal{K}$$

自由記 : 12

quadratic Lagrangian

<u>infinitesimal theory</u>

$$A^{\mu}{}_{\alpha} = \delta^{\mu}{}_{\alpha} + \underset{\text{small}}{u^{\mu}{}_{\alpha}}$$

$$\omega_{\alpha\beta\gamma} \sim \nabla_{\gamma} u_{\alpha\beta}$$

$$\gamma_{ab} \sim \delta_{ab} + u_{(ab)}$$

$$\mathcal{L} = -c_1 \omega_{[\alpha\beta]\gamma}\,\omega^{[\alpha\beta]\gamma} - c_2\,\omega_{(\alpha\beta)\gamma}\,\omega^{(\alpha\beta)\gamma}$$

$$- b_1 (\gamma_{aa} - \delta_{aa})^2 - b_2 \{ (\gamma_{aa} - \delta_{aa})^2 - (\gamma_{ab} - \delta_{ab})(\gamma_{ab} - \delta_{ab}) \}$$

Young　　　Poisson

				mass
3	$u_{[ab]}$	rot		0 (el. mg.)
3	$u_{(a4)} = v_a$	trans	$u_{(a4)} = 0$	0 (lepton)
1	u_{aa}	density	(φ)	μ } <u>ps. matter</u>
5	$u_{(ab)} - \frac{1}{3}\delta_{ab} u_{cc}$	shear	(ψ_{ab})	m }

$$\mu^2 = \frac{b_1}{c_1} \qquad m^2 = \frac{b_2}{c_2}$$

$$\mathcal{L} \to \omega_{[ab]4}\,\omega^{[ab]4}$$ Maxwell Dirac

<u>full theory</u>

$$A^{\mu}{}_{a} = L^{\mu}{}_{b}\,\varepsilon_{ab} \qquad \varepsilon_{ab} = \varepsilon_{ba}$$

$$L^{\mu}{}_{b} L_{\mu c} = \delta_{bc}$$

$$\varepsilon_{an} = \sum_{A=1}^{3} K_{aA}\, e_A\, R_{nA}$$

[illegible]

1. H. J. Schnitzer and E. C. G. Sudarshan — Q. M. S. with Indef. Metric II.
2. E. C. G. Sudarshan, Theory of leptons. I.

1. state dependent cut-off

末分式: May 8, 1981

R. Finkelstein, Ann. Phys. 12 ('61), 200
space with Torsion

curvature → gravitation int.
torsion → nuclear int.
2種の parallel transfer: ±
2種の spinor $\psi(+)$
$\psi(-)$

neutral geometry
~~pseudovector~~ scalar potential φ

1. Asymmetric Connection

$\lambda^\mu + \delta\lambda^\mu$

$$\delta\lambda^\mu = -L^\mu_{\cdot\alpha\beta}\,\delta x^\alpha \lambda^\beta \qquad (+)$$

asym: $L^\mu_{\cdot\alpha\beta} \neq L^\mu_{\cdot\beta\alpha}$

$$\delta\lambda^\mu = -L^\mu_{\cdot\beta\alpha}\,\delta x^\alpha \lambda^\beta \qquad (-)$$

$$L^\mu_{\cdot\alpha\beta} = \Gamma^\mu_{\cdot\alpha\beta} + \Omega^\mu_{\cdot\alpha\beta}$$

Γ → sym.; Ω → antisym. → torsion tensor (Schrödinger のnote)

λ^μ at x; $\lambda^\mu + \delta\lambda^\mu$ at $x + \delta x$

0-cov. der:

$$\Omega^\mu_{\cdot\alpha\beta|\gamma+} = \partial_\gamma \Omega^\mu_{\cdot\alpha\beta} + \Omega^\sigma_{\cdot\alpha\beta}\Gamma^\mu_{\cdot\sigma\gamma} - \Omega^\mu_{\cdot\sigma\beta}\Gamma^\sigma_{\cdot\alpha\gamma} - \Omega^\mu_{\cdot\alpha\sigma}\Gamma^\sigma_{\cdot\beta\gamma}$$

$$(\pm)\quad \Omega^\mu_{\cdot\alpha\beta|\gamma\pm} = \Omega^\mu_{\cdot\alpha\beta|\gamma} \pm \Sigma_{(\alpha\beta\gamma)}\Omega^\sigma_{\cdot\alpha\beta}\Omega^\mu_{\cdot\sigma\gamma}$$

$B^\mu_{\cdot\alpha\beta\gamma} \equiv$ (0)-curvature

$L^\mu_{\cdot\alpha\beta\gamma}{}^{(\pm)} \equiv$ (±)- . . .

Journal Math. Phys. 1 (1960), 440.

2. Absolute Parallelism
Uniform Torsion

$(\pm)\quad L^{\alpha}_{\cdot\beta\gamma\delta}(\pm)=0$

→ Clifford space

$\to \Omega^{\mu}_{\cdot\alpha\beta|\gamma}=\Omega^{\mu}_{\cdot\alpha\beta|\gamma+}=\Omega^{\mu}_{\cdot\alpha\beta|\gamma-}=0$

3. Neutral Space

$L^{\mu}_{\cdot\mu\beta\gamma}(+)=L^{\mu}_{\cdot\mu\beta\gamma}(-)$

$L^{\mu}_{\cdot\alpha\beta\mu}(+)=L^{\mu}_{\cdot\alpha\beta\mu}(-)$

$\Omega^{\mu}_{\cdot\alpha\beta|\gamma+}=\Omega^{\mu}_{\cdot\alpha\beta|\gamma-}$

$\Omega^{\mu}_{\cdot\mu\beta}\equiv\Omega_{\beta}=\partial_{\beta}\Omega$

4. Specification of the Torsion
vector $\Omega_{\beta}\equiv\Omega^{\mu}_{\cdot\mu\beta}$
axial vector

$\varphi^{\mu}\equiv\frac{1}{3!}\epsilon^{\mu\alpha\beta\gamma}\Omega_{\alpha\beta\gamma}$

$\Omega_{\alpha\beta\gamma}=a_{\alpha\mu}\Omega^{\mu}_{\cdot\beta\gamma}$: antisym.

$a_{\alpha\mu}=\Omega^{\lambda}_{\cdot\alpha\tau}\Omega^{\tau}_{\cdot\mu\lambda}$

5. Metrical Assumption

$g_{\alpha\beta}=g_{\beta\alpha}$

$g_{\alpha\beta|\gamma+}=g_{\alpha\beta|\gamma-}=0$ ↘

→ $\begin{cases} \Omega_\rho = 0 \\ \partial_\alpha(\sqrt{-g}\,) = 0 \end{cases}$ → $\varphi \equiv \dfrac{\theta}{\sqrt{-g}}$ pseudoscalar

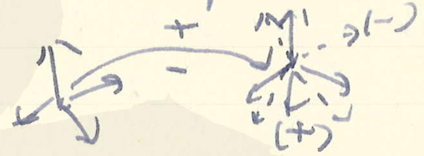
$\varphi_\alpha = (-g)^{-1/2}(\partial_\alpha \theta)$

6. Spinor Fields in spaces of Uniform Torsion

ortho-normal ennuple $a^\mu(i)$

$$\gamma_\pm^\mu = \sum_i a_\pm^\mu(i)\gamma_\pm(i)$$

$$\{\gamma_\pm^\mu, \gamma_\pm^\nu\} = 2g^{\mu\nu}$$



$$\delta\psi_\pm = [\tfrac{1}{2}\delta_\pm O(i,k)\gamma_\pm(i)\gamma_\pm(k)]\psi_\pm$$

$$\delta\gamma_\pm^\mu = -L^\mu_{\alpha\beta}(\pm)\gamma_\pm^\alpha\,\delta x^\beta$$

$$\psi_{\pm|\rho}^{\pm} = \partial_\rho\psi_\pm \pm \tfrac{1}{4}\Omega_{\mu\alpha\rho}\gamma_\pm^\mu\gamma_\pm^\alpha\psi_\pm$$

$$(\gamma_\pm^\mu\partial_\mu \pm \tfrac{1}{4}\Omega_{\mu\alpha\beta}\gamma_\pm^\mu\gamma_\pm^\alpha\gamma_\pm^\beta)\psi_\pm = 0$$

$$(\gamma_\pm^\mu\partial_\mu \pm \tfrac{3}{2}\gamma_\pm^{\mu 5}\varphi_\mu)\psi_\pm = 0$$

7. Spinor Fields in Neutral Spaces.
8. Spinor density
9. Space of lower Symmetry

4次元以下. $g_{\alpha\beta|\gamma} \neq 0$

$$\gamma^\mu[\partial_\mu + \tfrac{1}{4}(\bar{O}_{\alpha\beta\mu} - \hat{G}_{\alpha\beta\mu})\gamma^\alpha\gamma^\beta]\psi_+^{(u)} = M\psi_+^{(u)}$$

$-ieu A_\mu$

$\varphi_-^{(u)}$

時空構造 研究会．

May 15, 1961

第一回 司会．井上，

湯川: Introductory Talk

Dichotomy

Ordering

Imaginary connection

Operator space

タブー

豊田: Concepts of Space

Axiomatic

Gauss

Riemann 1854 (論文「幾何学」)

Max Jammer, Concepts of Space, 1956

{幾何 / 量子 / 運動} quanta ⇉ 離散的な構造 / 連続的な構造: 計量

確率

因果律

[illegible]

O. Veblen 1906

Weyl connection 1919

Kaluza 1920 5次元

Margenau

ether.

徳岡: 時空の量子化
A. 格子空間.

B. 時空 operator

湯迫一衛: 空間の量子化
$x = u + A$

福留: Gyro-elastic Ether

第240　5月16日
佐藤武男: 多次元空間.
Kaluza-Klein: 5次元
$g^{ik}(p_i - \frac{e}{c}\varphi_i)(p_j - \frac{e}{c}\varphi_j) + \text{const.}$
$= \gamma^{\mu\nu} p_\mu p_\nu \qquad p_0 = \frac{e}{\beta c}$
$\{\gamma^\mu, \gamma^\nu\} = 2\gamma^{\mu\nu}$
$\gamma^0 = \pm \gamma^5 - \beta \gamma^k \varphi_k$ for g^{ij}: flat

Veblen-Hoffmann: 射影幾何

Okayama

Podolanski, 6次元.
connection
negative energy field

Klein-Hara

豊田氏:
Rayski : 6次元
$x_i = \lambda x_i$
$x_\lambda' = f(x_i, x_\lambda)$

今後:
村井康男 : 共形空間.
Tokuoka space

後藤鉄男 : point-like model
内部自由度
相互作用　model となり.

小野健一 : ~~Indefinite metric~~
時空量子化.
1. 平行移動
2. Lorentz不変.

$$\{x, y, z, ct\} = \begin{vmatrix} x & y & z & ct \\ x & & & \\ \vdots & & & \end{vmatrix} = \Omega \quad \text{real}$$

reflection に対し 符号がかわる.

$t = t_1$, $A = A'$: $\psi_4 = \psi'_4$ }
$A\psi_4 = A'\psi'_4$

$t = t_2$, $B = B'$: $\psi'_4 = \psi'_4$ }
$B\psi'_4 = B'\psi'_4$

期待値 $= |\psi, \psi'|^2$

第三日　午前
統一問題：物理法則と素粒子
I. 幾何学化の現状
1. 光速不変の原理 → minkowski space
$ds^2 = 0$ でよい.
dilatation
conformal Transf.
2. 重力 → 空間の歪
3. 電磁現象 → connection
4. 波動幾何 →
No. 19 : Mimura & Hosokawa
全ての物理法則は幾何学に還元される.
Micro
Cosmology
$ds\psi = 0$
$\frac{\partial \psi}{\partial x_m} = (\Gamma_m + T_m^5 - h_m I)\psi$
積分可能性

5. 素粒子
charge, mass, isospin, strangeness,
baryon number, etc →

→ 時空
→ 時空＋空間 ↘ [illegible]
non-local

III. 空間のどんな構造に手を加えさすか？

1. 次元を増す。

2. 4次元時空

i) metric $\delta_{\mu\nu} \to g_{\mu\nu}$

ii) $ds^2 = g_{\mu\nu} dx^\mu dx^\nu \to ds = \gamma_\mu dx^\mu$

iii) ds^2 の一般. 他の函数
[illegible]の函数.

iv) metric 以外に connection
Finkelstein

[illegible]の[illegible]の関係（[illegible]）

[illegible]: spin connectionによる電磁ポテンシャルの導入.

V. Fock, Z. Phys. 57('29), 261
E. Schrödinger, Ber. Ber. ('32), 105
V. Bargmann, 〃 ('32), 346

$\frac{1}{4} Sp\, \mu\nu\, \Gamma_\mu = A_\mu$

H. S. Green, N. P. 7(58), 373

中野氏:

[illegible]氏: non-symm. $g_{\mu\nu}$

中村説：物理的な座標の導入.

field

空間の分子

現象論的な等価原理 → 重力の消去可能 → 座標

[illegible] → general covariance

isospace の general covariance

$$\Gamma_\mu = i\tau_\alpha \pi_\mu^\alpha + i g \gamma_5 \tau_\alpha \nabla_\mu \varphi^\alpha$$

isovector　　　ps (ps v)

vector meson

= ρ-meson

(Nakamura)

π-N : NNN の bound state or resonance

or ρ-meson (Takeda)

(ρ-N の bound state)

N N''

→ $D_{3/2}$　$F_{5/2}$

resonance からの結果：　　ρ-π-coupling

$m_\rho = 5 \sim 6\mu$　　$f^2/4\pi = 1 \sim 2$

5 BeV π-N inel. scatt.

	$5 \sim 6\mu$	$2.4 \sim 3.6$
F. F.	$3 \sim 4\mu$	~ 5
(Fubini, Villi)	$\sim 4.7\mu$	~ 5
1.03 BeV/c π	"	"

K^*　　$m_{K^*} \sim 6\mu$　　$(K^* = \Lambda \bar{N})$

小野氏: Spinor場について.

一般相対論　テンソル場　Bose-統計

素粒子論　スピノル場　Fermi-統計
近似的

高野氏:

1) non-holonomic space
Vranceanu.

$\bar{x}_0 = x_0 + f(x_i)$

$\bar{x}_i = g(x_i)$

$ds^2 = G_{\mu\nu} dx^\mu dx^\nu$

$x^\lambda \to x^\lambda + H^\lambda d\tau$

Pfaff: $H_\lambda dx^\lambda = 0$

$H_{\mu;\nu} + H_{\nu;\mu} = 0$　(Killing)

example: $H_\lambda = G_{\lambda 0}$

$H^\lambda = \delta^\lambda_0$

$\bar{x}^0 = x^0 + f(x^i)$

$\bar{x}^i = \bar{x}^i(x^i)$

$ds^2 = (G_{mn} - G_{0m}G_{0n}) dx^m dx^n$

$k_\mu \gamma^\mu = 0 \to G_{0\nu} dx^\nu = 0$

$\bar{x}^i = \bar{x}^i(x^i)$　　$i = 1, 2, 3, 4$

$\bar{x}^5 = x^5 + f(x^i)$

$\bar{x}^6 = x^6 + g(x^i)$

ii) Finsler space

$g_{\mu\nu}(\underset{4}{x}, \underset{3}{x'})$　　$\Gamma^\lambda_{\mu\nu} \to C^\lambda_{\mu\nu}$

$\to A_{\lambda\mu\nu}$

→ Synge, Relativity

iii) 色んな space の 確率分布

5次元: $p(a)$　　universal length l

第四回

表林の Complex Lorentz space

Invariance (4) 入門

	parameter	invariant
R_3	3	1
L_4	6	2
L_4'	10	2
共形変換	15	3
de Sitter	10	2
Complex L.	28	4

$O_4 \to R_4, L_4$ subgroup

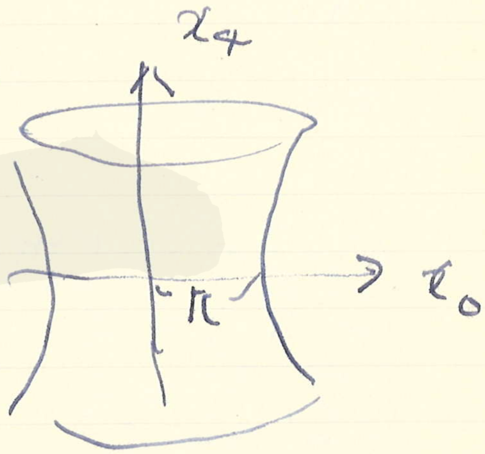
$x_1^2 + \cdots + x_4^2 = \text{inv}.$

宗像氏 de Sitter space における基礎方程式と mass spectrum

$x_0 \quad x_1 \quad x_2 \quad x_3 \quad x_4 = ct$

$x_\alpha x^\alpha = R^2$

$+ \quad + \quad + \quad + \quad -$



de Sitter group

$x_\alpha x^\alpha = \text{inv}.$

classical motion

$S = \int p^\alpha dx_\alpha$

$x^\alpha \delta x_\alpha = 0$ 　 なら の条件

$p^\alpha \to p^\alpha + x^\alpha p$ 　 gage 変換

$p^\alpha p_\alpha \neq m_0^2$

gage: $\underline{p^\alpha x_\alpha = 0}$

$p^\alpha p_\alpha = -P^2 = \text{const}.$

<u>reciprocity</u>

$dx^\alpha = \zeta R^2 p^\alpha$

$dp^\alpha = \zeta_1 P^2 x_\alpha$

$x^\alpha \rightleftarrows p^\alpha$

$R \rightleftarrows P$

constant of motion

$m_{\alpha\beta} = x_\alpha \frac{\partial}{\partial x_\beta} - x_\beta \frac{\partial}{\partial x_\alpha}$ → p_α, p_β

$m_{\alpha\beta} = \text{const}$

$\frac{1}{2} m_{\alpha\beta} m^{\alpha\beta} = R^2(-p^2) = -M^2$

$m_{\alpha\beta} =$ $m_{01}\ m_{02}\ m_{03}$ → $\vec{\pi}$ momentum

m_{04} energy

$\vec{\mu}$: $m_{12}\ m_{13}\ m_{23}$ 角運動量

$m_{14}\ m_{24}\ m_{34}$ → Energy → $\vec{\alpha}$ accel.

$m_{\alpha\beta} m_{\gamma\delta} + m_{\alpha\gamma} m_{\delta\beta} + m_{\alpha\delta} m_{\beta\gamma} = 0$

$(\vec{\mu}\, \vec{\alpha}) = 0$

$(\vec{\mu}, \vec{\pi}) = 0$

$[\vec{\pi}, \vec{\alpha}] = -\varepsilon \vec{\mu}$

独立なのは 3つ!!!

全部で 4つ!!!

$10 - 3 - 1 = 6$ の独立成分

spin

classical spin

$\frac{1}{2} s_{\alpha\beta} s^{\alpha\beta} = S^2$

$\frac{1}{2} m_{\alpha\beta} s^{\alpha\beta} = 0$

$j_{\alpha\beta} = m_{\alpha\beta} + s_{\alpha\beta}$

$$\frac{1}{2} j_{\alpha\beta} j^{\alpha\beta} = s^2 - M^2$$

$$\hat{j}_{\alpha\beta} = ~~\varepsilon_{\alpha\beta\gamma\delta}~~ j^{\gamma\delta} \qquad ?$$

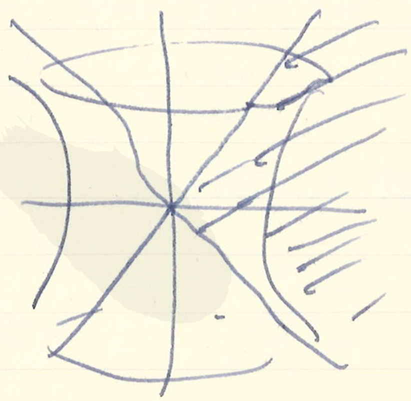
$$~~\hat{j}_{\alpha\beta} j^{\alpha\beta}~~ = -M^2 s^2$$

field theory
I. de Sitter group に対する不変性
II. self-reciprocity
III. surface wave の方程式が一意的に
~~surface wave~~ の方程式になる.

$$\left[\text{⬠} - \eta^2 \theta(s^2) s^2 \right] \rho = 0$$

$$\theta(x) = \begin{cases} 1 & x > 0 \\ 0 & x < 0 \end{cases}$$

$$[\sqrt{\eta}] = L^{-1}$$



$$\sigma = \sqrt{\eta} \cdot s$$

$$(\text{⬠}_\sigma - \sigma^2)\rho = 0$$

$$(\sigma, \alpha, \beta, \theta, \varphi)$$

$$\left[\frac{\partial^2}{\partial\sigma^2} + \frac{n-1}{\sigma}\frac{\partial}{\partial\sigma} - \left(\frac{\kappa^2}{\sigma^2} + \sigma^2 \right) \right] \rho = 0$$

$$\kappa^2 = \frac{1}{2} m_{\alpha\beta} m^{\alpha\beta} \quad (\cong -M^2)$$

surface wave

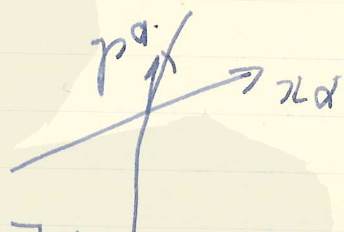
$$(K^2 + M^2)\varphi = 0$$

$$\rho = f(\sigma)\,\varphi(\alpha, \beta, \theta, \varphi)$$

M: [illegible]固有値.

$\sigma\ (0, R)$

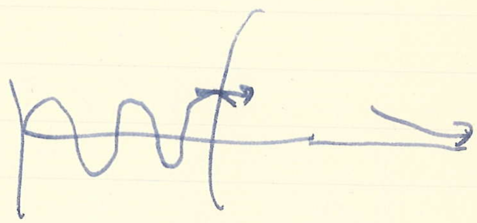
$p^\alpha x_\alpha = 0$



$$\left[\frac{\partial^2}{\partial\sigma^2} \qquad \right] f = 0$$

$$\left.\frac{\partial f}{\partial\sigma}\right|_{\sigma=\sigma_0} = 0$$

$$\left.\frac{\partial}{\partial r} J_\lambda(i\sigma r)\right|_{\sigma=\sigma_0} = 0$$



$\lambda \downarrow$ mass

$\mathfrak{M} = \mathfrak{M}_0 (2n+1)$

$n = 0 \quad \pi$

$n = 1 \quad 3\pi$

$m_0(\eta, R)$

$\eta = 10^{-16}$

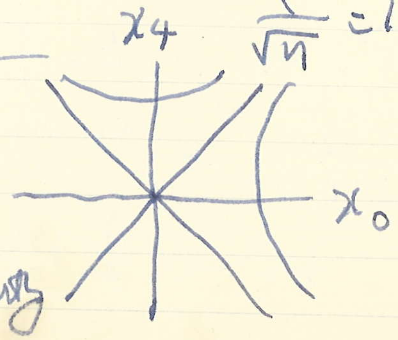
$\downarrow$

$\frac{1}{\sqrt{\eta}} = 10^8$ cm

$x_4 \to x_0$

$-x_4^2 + x_0^2 \to x_4^2 - x_0^2$

二次元 complex homog



6つのparameter

$6-1=5$

invariant (2)

nucleon-lepton

τ-spin

8成分

$\tau_3 = \pm 1$　nucleon-lepton

mass level の degeneracy?

片山；内部空間，

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

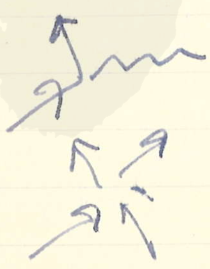
$\nu \quad e \quad e' \quad \mu' \quad \mu$

$0 \quad \frac{1}{2} \quad 1 \quad \frac{3}{2}$

$\frac{m_e + m_\mu}{2} = \frac{m_{e'} + m_{\mu'}}{2}$

regularization:

$$S_F^{reg} = \sum c_j \frac{1}{i\gamma p + m_j} \sim \frac{1}{(i\gamma p)^a}$$



$\alpha \geq 3$

$\sum c_j = 0$

$\sum c_j m_j = 0$

$a \geq 5$

$|c_j| = 1$:　$m_1 + m_3 = m_2 + m_4$

non-local spinor

$$\left.\begin{array}{l}\gamma^\mu[p_\mu, \psi] + im\psi = 0 \\ \beta^\mu[x_\mu, \psi] - \lambda\psi = 0\end{array}\right\}$$

$\frac{1 \pm \gamma_4}{2}$ $\frac{1 \pm \beta_4}{2}$

X_μ r_μ ξ_α $\psi(X, \xi)$

$r_\mu = \omega_\mu{}^\alpha \xi_\alpha$

γ^μ β^{α}

$$\frac{\psi^A_{ri}\,\gamma^\mu_{rs}\,\psi_{sj}}{\frac{1}{4}\,Tr(\psi^A\psi)} = \omega^\mu{}_\alpha\,\beta^\alpha_{ij}$$

$\psi^A = \beta_4 \psi^H \gamma_4$

$X \to LX$ $\psi \to S\psi$ $\gamma^\mu X_\mu = inv.$

$\xi \to \xi l$ $\psi \to \psi T$

$L = -\int d\xi\, \psi^A F(X, \xi)\psi$

$\to -Tr(\psi^A(\gamma\partial + M^T)\psi)$

$M = \begin{pmatrix} m_1 & & & \\ & m_2 & & \\ & & m_3 & \\ & & & m_4 \end{pmatrix}$

$j_\mu = Tr(\psi^H \gamma_\mu (1 + \gamma_5)\phi)$

electromag. interaction はためる.

$\partial_\mu j_\mu = 0$

indefinite の計量
Hilbert space $\mathcal{H}$

山崎氏: 最近の話題
Heisenberg and Dürr
Propheten
Puritaner
Zur Theorie der "seltsamen" Teilchen

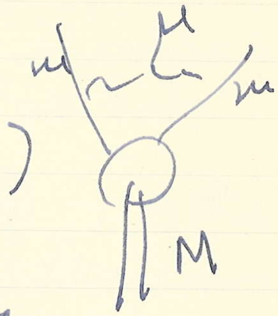
May 22, 1961

位田 石御

B.S. Amplitude

$\mu=0$: Coulomb の 4次元的 対称性.
l-degeneracy.

$\mu>0$: そういう対称性がない.



B.S. eq: real sum. (ladder appr.)
$u = \lambda K u$

<u>M=0</u> normal solution は S.rules. → invariant

松田[illegible]

May 24 1961

Vector Fields Associated with the Unitary Theory of the Sakata Model
A. Salam and J. C. Ward

Derivation of strong interactions from a gauge invariance
Y. Néeman

Yang-Mills
Salam-Ward　　N. C. XI Nr.4, 568
Sakurai

$$\psi' = S\psi$$

$$B_\mu' = S^{-1}B_\mu S + \frac{i}{\epsilon}S^{-1}\frac{\partial S}{\partial \mu})$$

$\bar{\Psi}(\partial_\mu - i\epsilon B_\mu)\psi$
$= \mathrm{inv.\,(gauge)}$

$$U(2)\ B_\mu = \sum_{i=1}^{3} \tau_i B_\mu^i$$

$$U(3)\ B_\mu = \sum_{i=1}^{8} \lambda_i B_\mu^i$$

$$\chi = \begin{pmatrix} p \\ n \\ \Lambda \end{pmatrix} \rightarrow (1+iH)\chi$$

$$\partial_\mu \rightarrow D_\mu = (\partial_\mu - iH_\mu)$$

$$\begin{pmatrix} \frac{1}{\sqrt{6}}\rho_\mu^0 + \frac{1}{\sqrt{2}}\pi_\mu^0 & \pi_\mu^+ & K_\mu^+ \\ \pi_\mu^- & \frac{1}{\sqrt{6}}\rho_\mu^0 - \frac{1}{\sqrt{2}}\pi_\mu^0 & K_\mu^0 \\ K_\mu^- & \bar{K}_\mu^0 & -\frac{2}{\sqrt{6}}\rho_\mu^0 \end{pmatrix}$$

$$\bar{\chi}\gamma_\mu \nabla_\mu \chi + \frac{Tr}{3}(D_\mu H_\nu - D_\nu H_\mu)^2$$

weak int.

$$\chi_{\substack{L\\R}} \to (1 + iH_{\substack{1\\2}})\,\chi_{\substack{L\\R}}$$

$$\chi_{\substack{L\\R}} = \frac{1}{2}(1 \pm \gamma_5)\chi$$

three vectors ?

Y. Néeman:

$$\chi = \begin{pmatrix} N \\ \Xi \\ \Lambda \\ \Sigma \end{pmatrix} \qquad \varphi = \begin{pmatrix} \pi \\ K \\ \bar{K} \\ \rho_0 \end{pmatrix}$$

U(3)-symmetry　　(Gell-Mann と独立に)

λ_i = 8行8列)

基礎理論談話会　May, 29, 1961
素粒子論部会　共催. (D会館)
山崎氏: Heisenberg 理論
(Rochester Discussions, 1960)
真空の縮退 ???

野上茂吉郎:
核子の電磁構造
基研談話会　May 30, 1961

e-n 散乱　1947
e-p　1955 Hofstadter

$$j_{\mu N}(p',p)\frac{1}{q^2}j_{\mu,e}(k',k)$$

$$j_{\mu,e}=i(-e)\bar{u}(k')\gamma_\mu u(k)$$

$$j_{\mu,N}=ie\bar{u}(p')[\gamma_\mu F_1(q^2)+\frac{\kappa}{2M}\sigma_{\mu\nu}q_\nu F_2(q^2)]\times u(p)$$

$$F_{1,2}(q^2)=\int d\mathbf{r}\,e^{i\mathbf{q}\cdot\mathbf{r}}\rho_{1,2}(\mathbf{r})$$

(CMS: $q_0=0$)

$$F_{1p}(0)=F_{2p}(0)=F_{2,n}(0)=1$$

$$F_{1,n}(0)=0$$

$$F(q^2)=1-\frac{\langle r^2\rangle}{6}q^2+\frac{\langle r^4\rangle}{120}q^4-\cdots$$

non-rel.

$$j_{0,n}\Rightarrow\frac{e}{M}\phi^*(p')\{F_1-\frac{q^2}{8M^2}[F_1+2\kappa F_2]\}\phi(p)$$

1) e-n-scatt.

$$\langle r^2\rangle_{1,2}\lesssim(0.08)^2\,y^2$$

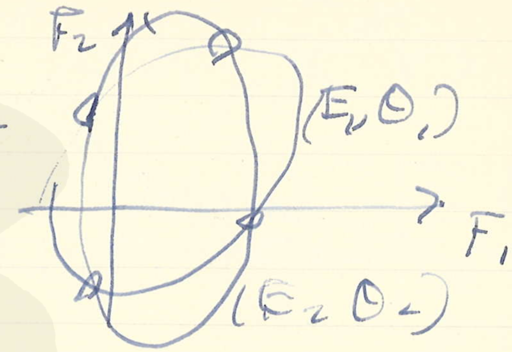
2) e-p, e-d-scatt.

Rosenbluth

$$\frac{d\sigma}{d\Omega}=\sigma_{Mott}\{F_1^2+\frac{q^2}{4M^2}[2(F_1+\kappa F_2)^2\tan^2\frac{\theta}{2}+\kappa^2F_2^2]\}$$

$a_{11}F_1^2 + a_{12}F_1F_2 + a_{22}F_2^2 = \text{const.}$

q: 一定



$\sigma_d = (1+\Delta)(\sigma_p + \sigma_n)$

$E = 550$ MeV

$\theta = 135^\circ$　　$\Delta = 0.03$

$F_{1s} = F_{1p} + F_{1n}$　　$F_{1p,n} = \frac{1}{2}(F_{1s} \pm F_{1v})$

$F_{1v} = F_{1p} - F_{1n}$

$F_{1,p}$ exponential　e^{-ar}

Clementel-Villi:

$a\,\delta(r) + a\,\frac{e^{-ar}}{r}$

$r > 0.4\,y$ では ほゞ一致.

1954年まで　$E < 650$ MeV, $\theta < 135^\circ$, $q^2 < 17\,y^{-2}$

$\langle r^2 \rangle_{1,p} = (0.80 \pm 0.04)^2\,y^2$

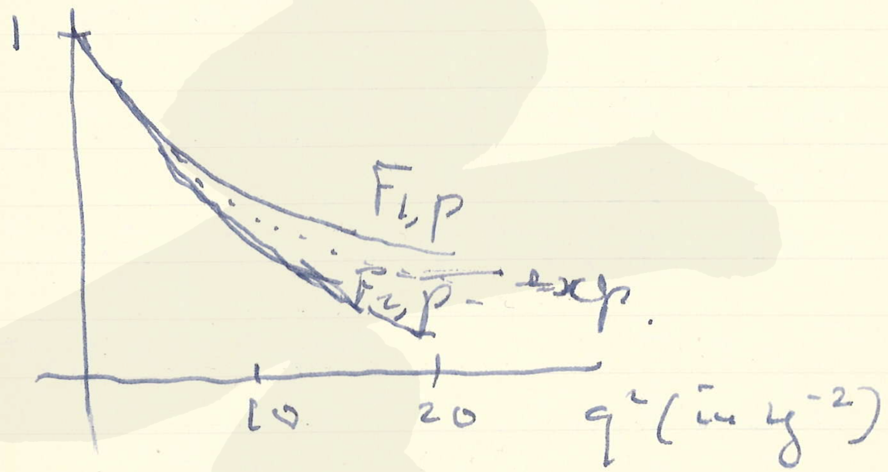
$F_{2,p}$　$\langle r^2 \rangle_{2,p} \simeq \langle r^2 \rangle_{1,p}$

$q^2 \simeq 9.3\,y^{-2}$　$\frac{F_{1p}(q^2)}{F_{2p}(q^2)} = 1.01 \pm 0.2$

$\langle r^2 \rangle_{2,n} \simeq \{ \sout{(0.85 \pm ?)^2} \; (0.80 \pm 0.1)^2 \} \, y^2$

$\langle r^2 \rangle_{1,n} \simeq 0$

1961 Cornell, Stanford: Hofstadter, P.R.L. 6., No. 6.



$F_{1s} = 0.44 + \frac{0.56}{1+0.214q^2} \rightarrow \frac{1}{(3\mu)^2+q^2}$

$F_{1v} = -0.20 + \frac{1.20}{1+0.10q^2} \rightarrow \frac{1}{(4.7\mu)^2+q^2}$

$I = J = 1$

$F_{2v} = -0.20 + \frac{1.20}{1+0.10q^2}$

$F_{2s} = 4.0 + \frac{-3.0}{1+0.214q^2}$

$F(q^2) = \frac{1}{\pi}\int dm^2 \frac{f(m^2)}{m^2+q^2}$

$$\rho(r) = \frac{1}{(2\pi)^2}\int dm^2 f(m^2)\frac{e^{-mr}}{r}$$

$$\frac{1}{6}\langle r^2\rangle = \langle\frac{1}{m^2}\rangle$$

$(0.8)^2 y^2$　　$m_r \simeq 5\mu$

$I=0$ F_S　　$(3\pi) + \cdots\cdots$

$I=1$ F_V　　$(2\pi) + (4\pi) + \cdots$

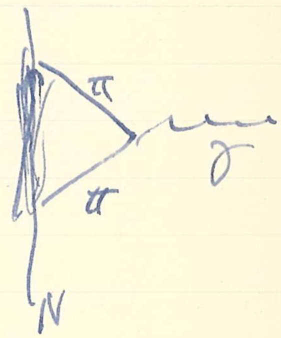
(2π)振動

resonat.　　exp.

$\langle r^2\rangle_1^V$　　$0.41 y^2 (-)$ (0.64)

$\langle r^2\rangle_2^V$　　$0.20 y^2 (+)$ (0.64)

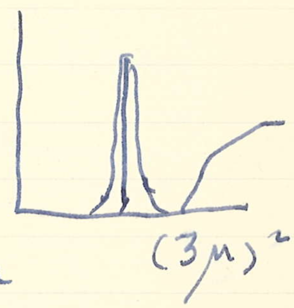
κ_V　　$0.73 (+)$ (1.85)



resonance : (2π) $m_\pi = 4.7\mu$

Frazer-Fulco : $I = J = 1$

(3π) : $m_s = 3\mu$



Nambu ρ

$I=0$　$J=1$

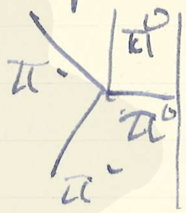
$m_\rho = 1\mu \sim 3\mu$

Chew　　$I=0$, $J=1$

$I = J = 1$ の組合せ.

Sakurai : vector meson

$\Gamma - \Gamma$ $\pi^- + p \to p + \pi^- + \pi^0$



$I = J = 1$

$\rho \to m_V^2 = 22$

Anderson et al.
P.R.L. 6 No. 7

$I = 0,\ J = 1$: ρ-meson (3π)
P.R.L. 5 No. 6

$p + d \to He^3 + \rho$

$m_\rho \cong 310$ MeV

$\Gamma \lesssim 16$ MeV

Katayama

Weak Int. Boson

May 31, 1961

講演:

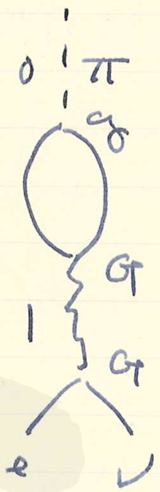
1° weak WIB — W^+ W^- — Ogawa

2° V-A — vector → spin 1.

↳ spin 0 — $\partial_\mu W_\mu \neq 0$

Sugano: $\pi \partial_\mu W_\mu$

$\partial_\mu W_\mu = 0$?



$\partial_\mu W_{\mu\nu} + \kappa^2 W_\nu = J_\nu$

$W_{\mu\nu} = \partial_\mu W_\nu - \partial_\nu W_\mu$

$\partial_\mu W_\nu = \partial_\nu J_\nu \neq 0$

3° β-decay — vector current is insensitive ~~to~~ against strong int.

axial current

$\partial_\nu J_\nu^V = 0$

$\partial_\nu J_\nu^A \approx 0$

4° $|\Delta I| = 1/2$ — W^0 — Lee-Yang

5° $M_W > M_N$

W^+ W^- W^0 $\overline{W}^0$

W^1, W^2, W^0] isovector ~~n ΛN~~

W^4 isoscalar

$\begin{pmatrix} W^+ \\ W^0 \end{pmatrix}$

$\begin{pmatrix} W^0 \\ -W^- \end{pmatrix}$

$\bar{p}\, n\, W$ — scalar — spinor

$\bar{\Lambda}\, n\, W$ — spinor ($\Delta I = 0$) $\Delta I = 1/2$ — scalar

$\Psi = \begin{pmatrix} p \\ n \\ \Lambda \end{pmatrix}$ $L = i\bar{\Psi}\gamma_\mu(1+\gamma_5)$ [ ] Ψ

Gell-Mann $\lambda_1 \cdots \lambda_8$ 3-3 matrices

$L = L_S + L_W$

i) L_S: $e^{i\sum_{i=1}^{8}\alpha_i\lambda_i}$ $e^{i\alpha_8\lambda_8}$

ii) L_W: $e^{i\omega(\lambda_3 + \frac{1}{\sqrt{3}}\lambda_8)}$ (charge)

iii) L_W^N

iv) $\Psi' = U\Psi$ $U = \sum_{i=0}^{8} u_i\lambda_i$

L_S full sym.: $\left\langle \begin{matrix} e^{i\sum_{i=1}^{8}\lambda_i\alpha_i} \\ e^{i\sum_{i=1}\gamma_5\lambda_i\alpha_i} \end{matrix} \right)$ π_0, π_i, π_0', K σ_0, σ_i, σ_8

L_W charge ind.:

$e^{i\sum_{i=1}^{3}\alpha_i(x)(1+\gamma_5)\lambda_i + i\alpha_8(x)\lambda_8}$

$\omega_1'\ \omega_2'\ \omega_3'$ ω_4'

$\sigma_0' = \sigma_0 - \frac{3m}{2g}$ $m = \frac{2m_n + m_\Lambda}{3}$

$\sigma_8' = \sigma_8 + \frac{\Delta m}{\sqrt{3}g}$ $\Delta m = m_\Lambda - m_N$

$$L_S = \bar{\Psi}\Big[(\sigma_0' + \sigma_8'\lambda_8) + i\gamma_5\sum_{i=1}^{7}\lambda_i\pi_i + i\gamma_5(\pi_0 + \pi_8'\lambda_8) + \sum_{i=1}^{7}\lambda_i\sigma_i\Big]\Psi$$

山崎氏: Zur Theorie der "Seltsamen" Teilchen

Monday, June ~~14~~ 12, 1961

H. P. Dürr und W. Heisenberg

山崎氏: 第2回　H. P.　June 19, 1961

10 φ 6 R:

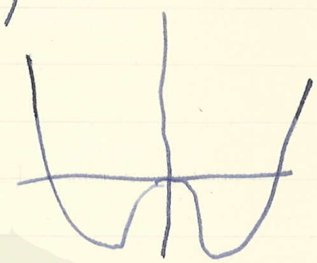
J. Goldstone

Field Theories with « superconductor » solutions (N. C. 19 (1961), 154)

$$L = \frac{1}{2}\left(\frac{\partial\varphi}{\partial x_\mu}\frac{\partial\varphi}{\partial x^\mu} - \mu_0^2\varphi^2\right) - \frac{\lambda_0}{24}\varphi^4$$

$\lambda_0 > 0$: $\qquad \frac{\mu_0^2}{2}\varphi^2 + \frac{\lambda_0}{24}\varphi^4$

$\mu_0^2 < 0$:



$$(\Box^2 + \mu_0^2)\varphi + \frac{\lambda_0}{6}\varphi^3 = 0$$

$$\varphi = \pm\sqrt{-6\mu_0^2/\lambda_0}$$

$$(\Box^2 - 2\mu_0^2)\,\delta\varphi = 0$$

$$\mu_1 = \sqrt{-2\mu_0^2}$$

$$\varphi = \varphi' + \chi \qquad \chi^2 = -\frac{6\mu_0^2}{\lambda_0}$$

$$L = \frac{1}{2}\left(\frac{\partial\varphi'}{\partial x_\mu}\frac{\partial\varphi'}{\partial x^\mu} + 2\mu_0^2\varphi'^2\right) - \frac{\lambda_0}{24}\varphi'^4 - \frac{\lambda_0\chi}{6}\varphi'^3 + \frac{3}{2}\frac{\mu_0^2}{\lambda_0}$$

$$L = \frac{\partial\varphi^*}{\partial x_\mu}\frac{\partial\varphi}{\partial x^\mu} - \mu_0^2\varphi^*\varphi - \frac{\lambda_0}{6}(\varphi^*\varphi)^2$$

$$\varphi \to \exp[i\alpha]\cdot\varphi \qquad \varphi = \varphi' + \chi$$

$$|\chi|^2 = -\frac{6\mu_0^2}{\lambda_0} \qquad = \varphi_1' + i\varphi_2' + \chi$$

χ: real

$$L = \frac{1}{2}\left(\frac{\partial\varphi_1'}{\partial x_\mu}\frac{\partial\varphi_1'}{\partial x^\mu} + 2\mu_0^2\varphi_1'^2\right)$$

$$+\frac{1}{2}\frac{\partial\varphi_2'}{\partial x_\mu}\frac{\partial\varphi_2'}{\partial x_\mu}-\frac{\lambda_0 \chi}{6}\varphi_1'(\varphi_1'^2+\varphi_2'^2)$$

$$-\frac{\lambda_0}{24}(\varphi_1'^2+\varphi_2'^2)^2$$

Remark:

$$\chi = |\chi| e^{i\alpha}$$

$$\left.\begin{array}{l}\mu_1' = \sqrt{-2\mu_0^2}\cdot\cos\alpha \\ \mu_2' = \sqrt{-2\mu_0^2}\sin\alpha\end{array}\right\}$$

ambiguity in the mass of quasi-particle

基研談話会.

田中正. (北田と岩田研究)
不安定粒子

June 20
1961

Lee model:

$\psi_V, \psi_N, \psi_\theta$: $\psi_N^{out}, \psi_\theta^{out}$ で表現できる.

Asymptotic conditions:

横山寛一君: Indefinite metric による発散の処理

June 23, 1961

diagonalization of Lagrangian

$$L = -\bar{\psi}_1(\gamma\partial + M_1)\psi_1 - \bar{\psi}_2(\gamma\partial + M_2)\psi_2$$
$$\pm \bar{\psi}_3(\gamma\partial + M_3)\psi_3$$
$$+ g\bar{\psi}_1(\psi_2 - \psi_3) + g(\bar{\psi}_2 + \bar{\psi}_3)\psi_1$$
$$+ f(\bar{\psi}_2 - \bar{\psi}_3)(\psi_2 + \psi_3)A$$

$$\{\psi_i, \bar{\psi}_j\} = S$$

$$L = -\bar{\Psi}\gamma\partial\Psi - \bar{\Psi}\begin{pmatrix} M_1 & g & -g \\ g & M_2 - fA & -fA \\ g & fA & M_3 + fA \end{pmatrix}\Psi$$

$$= -\bar{\Psi}\gamma\partial\Psi - \bar{\Psi}M\Psi$$

$$M = M^A = \eta M^H \eta$$

$f = 0$: $(M_1 - \lambda)(M_2 - \lambda)(M_3 - \lambda) + g^2(M_2 - M_3)$
$= 0$

$M_2 = M_3$: $\lambda = M_1, M_2$

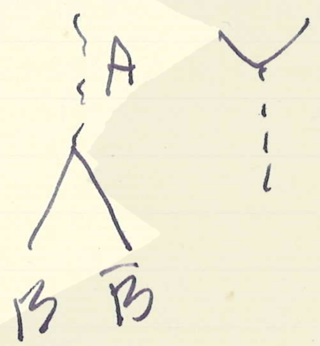
$$\chi_1 = \psi_1 - \frac{g}{M_1 - M_2}(\psi_2 - \psi_3)$$

$$\chi_2 = a(\psi_2 \cdot \psi_3)$$

$$\chi_3 = b(\psi_2 - \psi_3)$$

M. Gell-Mann, F. Zachariasen
Form Factors and Vector Mesons
山[illegible] [illegible] July 12, 1961

Model Field Theory
(isovector ρ^0 isoscalar ω^0
Sakurai Ann. Phys. 1960? 1961?
Zachariasen, P.R. 121 (1961), 1851
$\sigma\pi\pi$:



Machida model

(Relativistic model field theory with finite self-masses.

$$\mathcal{L}_{int} = g_0 \varphi_A(x)\, \varphi_B^2(x) + \lambda_0\, \varphi_B^4(x)$$

The Nature of the Axioms of
Relativistic Q.F.T.
E.C.G. Sudarshan and K. Bardakci
(to be published in J. of Math. Phys.)

Families of Wightman Fields:
(A.S. Wightman, P.R. 101 (1956), 860)

Hilbert space $\mathfrak{H}$, hermitian operators $\phi(x)$
1) Lorentz invariance
$$\phi(\Lambda x + a) = U(a,\Lambda)\,\phi(x)\,U^{-1}(a,\Lambda)$$
2) non-negative energy values, Hamiltonian being defined as the hermitian generator of time displacements.
3) local commutativity
$$[\phi(x), \phi(y)] = 0 \quad \text{for } (x-y)^2 < 0$$
4) Unique vacuum state invariant under all $U(a,\Lambda)$

Wightman functions
$$W^{(n)}(x_1, \cdots x_n) = W^{n}(\{x\}) = \langle 0|\phi(x_1)\cdots\phi(x_n)|0\rangle$$
i) $W^{(n)}(\{\Lambda x + a\}) = W^{n}(\{x\})$ (Lorentz inv.)
ii) $W^{(n)}(\{x\})$ boundary value of a complex fn $W^{(n)}(\{z\})$ analytic in the backward light cone (absence of negative energy)
(iii)
(iv)

$$W^{(n)}(\{x\}) = \lambda W_1^{(n)}(\{x\}) + (1-\lambda) W_2^{(n)}(\{x\})$$
$$0 \le \lambda \le 1$$

If Wightman field is interacting particle field?
Identification of certain linear combinations of vacuum expectation values of the fields with a scattering amplitude for "asymptotically free" particles?
Scattering amplitudes do not determine Wightman field!!!
Positive metric and unitarity are independent!!!

中西 襄

Chew, S-matrix Theory of Strong Interaction
(La Jolla Conf. June, 1961)

Field Theory はしぼんでゆく.
Symmetry
analyticity
(1) S-matrix analyticity として field theory を書き出す
(2) new principles
[illegible]
Chew-Frautschi
unitarity, analyticity
→ coupling const. is bounded

<u>saturation</u>

[illegible] July 1961

Okubo　　　　Oct. 4, 1961

$G = R_3^I \times R_2^N \times R_2^S \subset U_3 \subset R_8, G_2$

n=3　(Λ, n, p)

B

$\Lambda\ n\ p\ \mu$: Yamaguchi

$\mu\ e\ \nu\ \Lambda$:

n=4

n=3 +

dynamics　　　　strong　e.g.　weak

$\psi \to \gamma_5 \psi$　　no　　yes　　yes

~~$\psi \to e^{i\alpha\gamma_5}\psi$~~

yes とする話は → mass term をどうする

(1) Heisenberg

n=2;　$L_1 = g(\bar{\psi}\gamma_\mu\gamma_5\psi\ \bar{\psi}\gamma_\mu\gamma_5\psi)$ (φ)

(2) Nambu

n=3;　$L = g(\bar{\psi}\psi\bar{\psi}\psi - \bar{\psi}\gamma_5\psi\ \bar{\psi}\gamma_5\psi)$ (φ)

p

non-separable Hilbert space

Hilbert 空間をとかする問題!!!

self-consistent → mass values

R_8: Triality Principle

V_8

S_8 — S_8'