XXIV

NOTE BOOK

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Oct. 1967

〜 July 1968

VOL. XXIV

湯川

Nissho Note

[illegible]

K. Takahasi, Method of indefinite quantization (Preprint 1967)

[illegible]. Oct. 3, 1967

Takah, Umez.: N. P. 51 (1954), 193

$$\Lambda(\partial) u(x) = 0$$

(A) $|\eta| \neq 0$

$$(\bar{\Lambda})^\dagger = [\eta \Lambda(\partial)]^\dagger = \eta \Lambda(-\partial)$$

(B) $$\Lambda(\partial) = \sum_{l=0}^{\infty} \underbrace{\Lambda_{\mu_1 \cdots \mu_l}}_{\text{symmetric}} \partial_{\mu_1} \cdots \partial_{\mu_l}$$

(C) $$\Lambda(\partial) d(\partial) = d(\partial) \Lambda(\partial) = \Box - m^2$$

(D) $$C^\dagger C = C C^\dagger = 1 \quad \text{charge conjugation}$$

$$[\eta \Lambda(\partial)]^{t} = \rho C^{-1} \eta \Lambda(-\partial) C$$

$$\rho = \begin{cases} 1 & \text{integer spin} \\ -1 & \text{half-odd integer} \end{cases}$$

$$\bar{d} = d \eta^{-1} ; \quad \bar{\Lambda} \bar{\partial} = \bar{d} \bar{\Lambda} = \Box - m^2$$

$$\Gamma_\mu(\partial, -\overleftarrow{\partial}) = \sum_{l=0}^{\infty} \sum_{i=0}^{l} \Lambda_{\mu\mu_1 \cdots \mu_l} \partial_{\mu_1} \cdots \partial_{\mu_i} (-\overleftarrow{\partial}_{\mu_{i+1}}) \cdots (-\overleftarrow{\partial}_{\mu_l})$$

$$= \Lambda_\mu + \Lambda_{\mu\nu} (\partial_\nu - \overleftarrow{\partial}_\nu) + \cdots$$

$$\Gamma_\mu = \partial_\mu - \overleftarrow{\partial}_\mu \quad (\text{scalar})$$

$$\Gamma_{\mu, \sigma\rho} = -\gamma_\mu$$

$$u_J^{(r)}(x) : \text{c.c.} \quad v_J^{(r)}(x) = C u_J^{(r)}(x)^*$$

(i) $-i\int d\sigma_\mu(x) u_J^{(r)\dagger}(x)\overline{\Gamma}_\mu(\partial,-\overleftarrow{\partial})\, u_{J'}^{(r')}(x)$

$= \delta_{rr'}\,\delta_{JJ'}\,\Gamma_\mu(\partial,-\overleftarrow{\partial})$

(ii) v v

$= -\rho\,\delta\,\delta\ \cdots$

(iii) v u

$= 0$

$\sum_{r,J} u_J^{(r)}(x) u_J^{(r)\dagger}(y) = i\bar{d}\cdot\Delta^+(x-y)$

v v $= -i\rho\bar{d}\,\Delta^{(-)}(x-y)$

Hyperquantization of Free Fields

$a_\alpha(x)\,a_\beta^\dagger(y) - \rho' a^\dagger_\beta(y)\,a_\alpha(x)$

$= \delta_{\alpha\beta}\,\delta^4(x-y)$

b b

$\rho' = \begin{cases} 1 & \text{boson} \\ -1 & \text{fermion}\end{cases}$

Ω-(Hilbert)-space:

$a\Omega_0 = b\Omega_0 = 0$

$P_\mu = -\frac{i}{2}\int d^4x\,\{a^\dagger(x)(\partial_\mu - \overleftarrow{\partial}_\mu)a(x)$

$+ b^\dagger(x)(\partial_\mu - \overleftarrow{\partial}_\mu)\,b(x)\}$

$Q = \int d^4x\,(a^\dagger a - b^\dagger b)$

$$-i\,\partial_\mu a(x) = [a(x), P_\mu]$$

$$\downarrow \qquad\qquad \downarrow$$

$$b \qquad\qquad b$$

$$a(x) = [a(x), Q]$$

$$\downarrow \qquad\qquad \downarrow$$

$$-b \qquad\qquad b$$

$$\left.\begin{array}{l} \bar{\Lambda}(\partial)\, a(x)\, \Omega = 0 \\ \lambda_1(x)\, \bar{\Lambda}(-\overleftarrow{\partial})\, \Omega = 0 \end{array}\right\}$$

$H = -iP_0$: $\quad H\Omega_1 = E\Omega_1$

$$H A_J^{(r)\dagger} \Omega_1 = (E_J + E) A_J^{(r)\dagger} \Omega_1$$

$H\Omega_0 = 0$: $\quad \sum_i E_{J_i} + \sum_j E_{K_j}$

ortho-normal $X \to (\Omega_1', \Omega)$

$\Omega' =$

Self-interaction

$$J(x) = g(\tilde{\phi}\phi)\phi$$

$$\tilde{J}$$

$$(\Lambda a + J)\Psi = 0 \qquad \Psi = e^{-iK}\Omega$$

$$K = -\frac{g}{2}\int d^4y\, \{\tilde{\phi}\phi\}^2$$

S-matrix の unitarity

$$S = e^{-i\bar{K}}$$

$$\bar{K} = \bar{K}^{\dagger} \quad \to \quad \rho = \rho'$$

negative energy state には必ずしも positive energy state が対応して.

unitary infinite dimensional repres.

micro causality と ~~statistics~~ でなしに spin-statistics が出てくるを いう

神吉 健: Unsubt. Dispersion Relation
in W. I. and Comp. Part.
談話会 10.3_1967

$\pi \to \mu + \nu$

$N + \bar{N} \to \mu + \nu$

G-T-relation

$2 M G_A = F(\sqrt{2}\, g_{\pi NN})$

Nishijima

Bootstrap

pion → Regge particle

Composite Particle ≡ Regge Particle

PCAC

原治: Relativistic Rigid Sphere as the Model of El. Particles
発表　Oct. 4, 1967

$P_\mu \qquad a^\xi_\mu \qquad dt = \dfrac{P_\mu dx_\mu}{P}$

$\omega_{\mu\nu} = a^\xi_\mu \dot{a}^\xi_\nu \qquad P = \sqrt{P_\mu^2}$

$\omega^{\xi\eta} = \dot{a}_\mu{}^\xi a_\mu^\eta$

X_μ は P_μ の正準共軛? $\qquad \sigma_4 = \hat{i}$

$$a^k_\mu = \frac{1}{2\sqrt{P}\sqrt{P^*}}(\xi^* \sigma_\mu \eta + \eta^* \sigma_\mu \xi)$$

⋮

$P = (\tilde{\eta}\xi) \qquad \tilde{\eta} = i\sigma_2 \eta$

CMS: $\mathbb{P} = 0$ で a^ξ_μ が non-rel. triad に一致する~~ように~~。[illegible]

$\Sigma \xi = \tilde{\eta}^*$

$$\Sigma = -\frac{P_\mu \sigma_\mu}{P}$$

$\eta^{\dot\alpha} = \Sigma \xi_\alpha \propto \partial^{\dot r s} \xi_\alpha$

$$\left.\begin{aligned} \partial^{\dot r s} \xi_s &= i\kappa \eta^{\dot r} \\ \partial_{\dot r s} \xi^{\dot r} &= i\kappa \xi_s \end{aligned}\right\}$$ Dirac eq. と同型

$a_\mu^3 (P_\mu)$

自由度 3.

(Katayama, 自由度 6)

negative energy 不安定
状態に落ちると positive energy になり.

Pauli-Gürsey 参照.
→ body frame の参照

$$L = \frac{1}{2}\int \dot{x}_\mu^2 \, dm$$

$P = 0 \to x_4 = 0$ $\qquad L = \frac{I}{2}\omega_{\mu\nu}^2 = \frac{I}{2}(\omega^{3})^2$

$\omega'^4 = 0$. $\qquad \omega' = \frac{i}{\rho}(\dot{\xi}\xi$

$$L(\xi, \dot{\xi}, \xi^*, \dot{\xi}^*; p, \dot{x})$$

$$\frac{d\xi}{dt} = \frac{P}{P_\mu \frac{dx_\mu}{ds}} \frac{d\xi}{ds}$$

$$\frac{dX_\mu}{dt} = \frac{P_\mu}{P} + \frac{P}{m}\frac{\partial L}{\partial p_\mu}$$

Zitterbewegung

Shima, Suzuki, Kobayashi, Sengi

Strange spin Formalism for Hadron

小沼 講演 Oct. 25, 1967

SU_3 X

$SU_2 \otimes SU_2 \subset SU_4$

isospin strange spin

$-2X_3 = S$ 中村理論 $-2X_3 = Y$

$SU_3 \times U_1 \subset SU_4$

		I	charge	Y	
	Z_0 (1865)	0	+	2	K^+N
?	Z_1 (1900)	1	0, +, ++	2	〃
???	Z (1960 ~2100)	1/2	0, +	1	cosmic ray

$SU_2 \times SU_2$

$D_{0,0}$ $D_{\frac12,\frac12}$ $D_{1,0}$ $D_{0,1}$

(η) 1   4 (K) (L)   (π) 3   3

$D_{\frac12,0}$ $D_{0,\frac12}$ $D_{1,\frac12}$ $D_{\frac12,1}$

(N) 2   2 (Λ)   (Σ) (Z_1)   (Ξ)

(Pais (1953) even-odd rule
O_4 $SU_2 \times SU_2$)

$SU_4 \supset SU_2 \otimes SU_2$

baryon   meson   q: baryon number 1

$B = qq\bar{q}$ $M = q\bar{q}$

$\cdots + 20 + \cdots$ $4 \times 4 = 1 + 15$

c033-809挟込

$M \times B = \ldots + \underset{\sim\sim}{20'} + \ldots$

mass formula

SU_3: $m = \underset{\text{singlet}}{a} + \underbrace{bY + c\left(I(I+1) - \frac{Y^2}{4}\right)}_{\text{octet}}$

SU_4: $m = \underbrace{a}_{1} + \underbrace{bX_3 + cK}_{15} + \underbrace{d\,(I(I+1) - X(X+1))}_{15\times 15}$

(Amati . . . Prentki → qqq)

strong interaction:

$\Delta I = 0$ $\quad \Delta I_3 = 0$

$\times\ \boxed{\Delta X = 0'}$ $\quad \Delta X_3 = 0$

	N	Λ	Σ	Ξ
X	0	1/2	1/2	1
X_3	0	−1/2	−1/2	1
K	−3/2	−1/2	−1/2	1/2

$Q = I_3 + X_3 + \frac{N}{2}$

	K	π	η	$\bar{K}$
X	1/2	0	0	1/2
X_3	1/2	0	0	−1/2
K	−1	0	0	1

N	1	1	1
Q	+, 0	+	0
	u d	t	s
I	1/2	0	0
X	0	1/2	1/2
X_3	0	1/2	−1/2
K	1/2	−1/2	−1/2

河原林研　Oct 31, 1967

Radiative Correction to Fermi part of strangeness conserving β-Decay

DNA 論文　~~1955~~

$\pi \to \pi + e + \nu$

$K \to \pi + e + \nu$

$n \to p + e + \tilde{\nu}$

$\mu \to e + \nu_e + \nu_\mu$

$V - A$

$H = \frac{G}{\sqrt{2}} t_\lambda \overline{\psi_e} \gamma_\lambda (1 + \gamma_5) \psi_\nu$

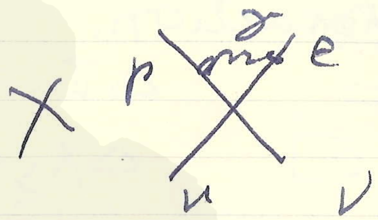
$t_\lambda = V_\lambda + V_\lambda$

$n \to p + e + \nu$

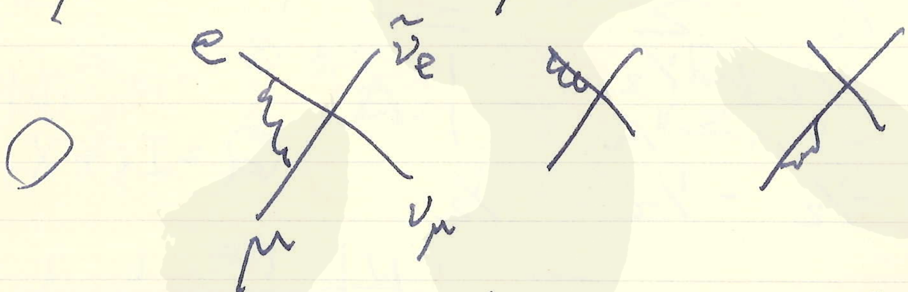
$\alpha \log \Lambda / m_e$　cancel しない.

(strong interaction をとりいれても)

(V+A だと cancel)



$\mu \to e + \nu_e + \nu_\mu$



$\alpha \log \Lambda / m_e$　cancel する

Källen　form factor をとりいれ vertex…

DNA　strong int をとりいれると

$n \to p + e + \nu$ is divergent

i) local int. $\quad H^w = \frac{G}{\sqrt{2}} j_\lambda j_\lambda$

V_λ ← isospin current の charge raising component ($\partial_\lambda V_\lambda = 0$)

ii) Minimal e.m. current ← j_λ^{em}

iii) $[\, j_0(\underset{\sim}{x}, 0), \cancel{t_\lambda}\; t_\lambda(\underset{\sim}{x}, 0)] = \delta(x)\, t_\lambda(\underset{\sim}{x}, 0)$
+ schwinger term

intermediary boson を入れても結論は変らない。

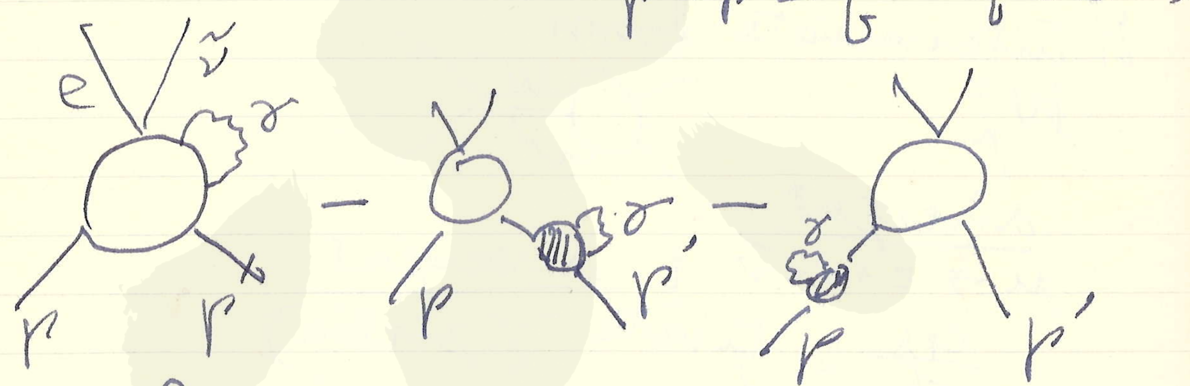
$\langle p' e \nu | H^w | p \rangle \qquad p \to p' + e + \bar{\nu}$

$\qquad\qquad\qquad\qquad\quad n \quad p$

$\qquad\qquad\qquad\qquad\quad \pi^+ \quad \pi^0$

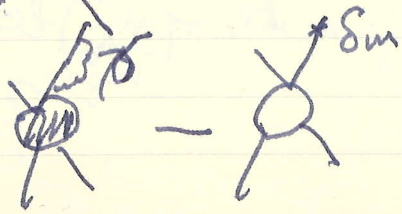
$p - p' = q \qquad q \sim O(\alpha)$

I)



II)

III)



← $\log \Lambda / m_e$

$H_{em} = -e\, j_\mu A_\mu$

model dependent divergence (or convergence)
Bjorken の 計算 : high energy
behavior の estimation

$C(\log \Lambda/m_e)\cdot(1+2\bar{Q})$

i) $\bar{Q}$: average charge

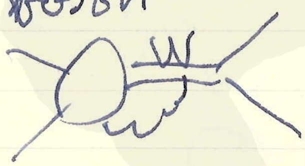
$\left.\begin{matrix} n \to p \\ \pi^+ \to \pi^0 \end{matrix}\right\}$ $\bar{Q} = \frac{1}{2}$ V−A diverg

$\boxed{\mu^- \to e+\nu+\bar{\nu} \quad \bar{Q} = -\frac{1}{2}}$ conv.

quark model $\bar{Q} = \frac{1}{6}$ div

$\boxed{\Xi^- \to \Xi^0 \quad \bar{Q} = -\frac{1}{2}}$ conv.

ii) intermediate boson
$W_\mu^\pm$



divergent

$\mu \to e+\nu+\bar{\nu}$ と divergent

$\frac{G_\beta}{G_\mu}$: finite (Sirlin)

T.D. Lee ?

mass difference の divergence (model dep.)

$\pi^+ - \pi^0$: δm_π = finite $+ \left(\frac{m_\pi^2}{m_\rho^2}\right)\cdot\log\Lambda + \cdots$

?

R. Marshak, Present Status of the universal (V, A) Theory of Weak Interactions

Nov. 8, 1967

素研談話会.

松本順一

Basic Structure of Strong Interaction of Hadrons

1967 Nov. 27

基研・コロキウム

中間報告

Constructive dynamics

S. I.

Interaction dynamics

E. M. I.

W. I.

力の space-like な伝達

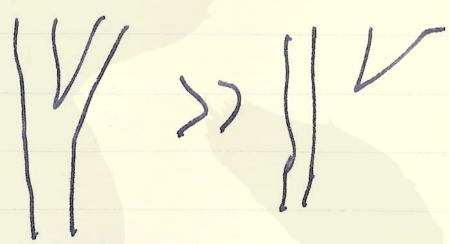
time-like なる伝達 : pair-creation

(その superposition がどうなるか)

meson の nonet は const. dyn.

の特性

Okubo-Iizuka-rule



$$H_c + \delta m_q + H_s - \delta m_q$$

小沼通二氏
$K \to 2\pi$ decay ~~について~~ の現象論
1967 Nov. 28
談話会. 基研.

$$K_S^0 \to \pi^+ + \pi^-$$
$$\quad \to \pi^0 + \pi^0$$

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

$$K_L^0 \to \pi^+ + \pi^-$$
$$\quad \to \pi^0 + \pi^0$$

$$K^0 \to \pi^+ \ell^- \bar{\nu}$$
$$\quad \to \pi^- \ell^+ \nu$$
$$\overline{K^0} \to \pi^+ \ell^- \bar{\nu}$$
$$\quad \to \pi^- \ell^+ \nu$$

$K \to \pi\pi$
$\frac{1}{2}$ 　 $0, 2$ 　 $\Delta I = 1/2, 3/2, 5/2$

$\Delta I = 1/2$: 　 $A(+-) - \sqrt{2}A(0,0) = 0$

$\Delta I = 1/2$, $\Delta I = 3/2$: 　 〃 $= 2A(+,0)$

SU_3 と CA とどう違うか.
SU_3 でも $m_K \neq m_\pi$ ならよい
F_8, T_3

σ (410 MeV) $I=0$ scalar meson ?

$\pi N \to N\pi\pi$

$m_L - m_S = 0.45$

2中間子論 25周年記念
シンポジウム
Dec. 2, Dec. 3, 1967
名大 理学部にて

P. Kabir, CP violation
Dec. 18, 1967

$$|K^0_\pm\rangle = \frac{1}{\sqrt{2}}\left(|K^0\rangle \pm CP|K^0\rangle\right)$$

$$CP|2\pi\rangle = +|2\pi\rangle$$

$K_1^0 \to 2\pi$

$K_2^0 \to 2\pi$
$\to \pi^\pm e^\mp \nu$
$\to \pi^\pm \mu^\mp \nu$

$$\frac{(K_2^0 \to \pi^- e^+ \nu) - (K_L^0 \to \pi^+ e^- \nu)}{\quad " \quad + \quad " \quad} \sim +2\cdot 10^{-3}$$

μ $\qquad \sim 4\cdot 10^{-3}$

X-interaction

$|\Delta S| = 1$ $\qquad \left(\frac{K_2^0 \to 2\pi}{K_1^0 \to 2\pi}\right)^{1/2} \sim$ $2\cdot 10^{-3}$ (charged) $\quad 4\cdot 10^{-3}$ (neutral)

$F_1 \sim 10^{-3} G$ $\qquad$ (1)

$\Lambda \to p\pi^-$

$|\Delta S| = 2$, $\quad K^0 \to \bar{K}^0$ $\qquad \frac{F_2 G}{G^2} \sim 10^{-3} G$

$K_2^0 \xrightarrow[X_2]{} K_1^0 \to 2\pi$

$F_w \sim 10^{-3} G^2 \sim 10^{-8} G$

$\frac{\pi^+\pi^-}{\pi^0\pi^0} = 2$

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

$|\Delta S| = 0$:

$K_2^0 \xrightarrow[|\Delta S|=1]{G} A \xrightarrow{X_0} 2\pi$

$CP = -1$
$(\Delta S = 0)$

$G f_0 \sim 10^{-3} G$

$f_0 \sim 10^{-3}$ Okun (2)

TDLee $\frac{\alpha}{2\pi} \sim 10^{-3}$ α

neutron dipole moment X

$d \sim e \cdot \frac{1}{m_p} G m_p^2 \sim 10^{-19}$ cm $\to 10^{-21}$ cm

experiment $< 2 \sim 3. \times 10^{-22}$ cm

$\left(\frac{K^+ \to \pi^+\pi^0}{K^0 \to 2\pi}\right)^{1/2} \sim$ ~~$\frac{1}{400}$~~ 0.05 $(\Delta I = \frac{1}{2})$

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

中川公子

Symmetry Breaking and Weak Interactions

基研・談話会 12.19.1967

Nambu model

Umegawa

$$H = \int d^3x \left[\bar\psi(\vec\gamma\vec\partial)\psi + \frac{\lambda}{2}\{(\bar\psi\psi)^2 - (\bar\psi\gamma_5\psi)^2\} \right]$$

$$\psi \to \exp[i\chi\gamma_5]\psi$$

$$j_\mu^{(5)} = i\bar\psi\gamma_\mu\gamma_5\psi$$

$$\partial_\mu j_\mu^{(5)} = 0$$

φ : $M \neq 0$

$$J_\mu^{(5)} = i\bar\varphi\gamma_\mu\gamma_5\varphi$$

$$\partial_\mu J_\mu^{(5)} \neq 0$$

proper self-energy :

$$\frac{2\lambda M}{(2\pi)^3}\int\frac{d^3k}{E_k}$$

$$E_k = \sqrt{k^2+M^2}$$

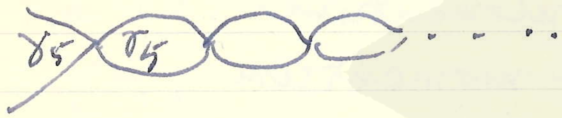
mass eq. $M\left(1+\frac{2\lambda}{(2\pi)^3}\int\frac{d^3k}{E_k}\right)=0$

I. $M=0$

II. $(\qquad)=0$ $\qquad \lambda<0 \qquad M\neq 0$

$$j_\mu^{(5)} = \left(\delta_{\mu\nu} - \frac{\partial_\mu \partial_\nu}{\Box}\right) J_\nu^{(5)} + 2M\sqrt{R(0)}\,\partial_\mu B$$

$$(\psi = Z\varphi + z'(\bar{\varphi}\varphi)\varphi + B\varphi + \cdots$$



$B\varphi$: zero mass bound state
spin zero boson (ps boson)

$$\psi \to \varphi \to \varphi, B$$

$$U = e^{i\chi N^{(5)}}$$

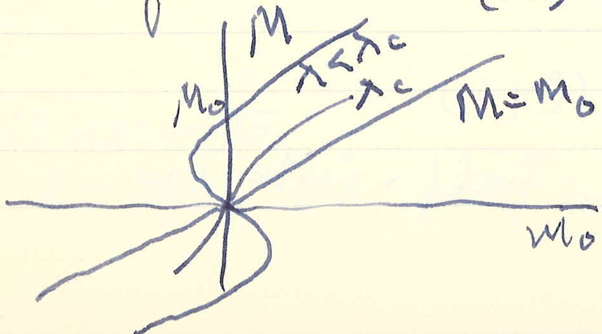
$$\varphi \to \varphi$$
$$B \to B + 2M\sqrt{R(0)}\,\chi$$

Dynamical Rearrangement

Intrinsic Breaking

$$H' = m_0 \bar{\psi}\psi$$

Mass eq. $M\left(1 + \frac{2\lambda}{(2\pi)^3}\int \frac{d^3k}{E_k}\right) = m_0$



$$1 + \frac{2\lambda_c}{(2\pi)^3}\int \frac{d^3k}{k} = m_2$$

$$\mu^2 = \frac{m_0}{(-\lambda)MR(\mu^2)}$$

田中正君
Complex unitary spins
基研コロキウム
Dec. 20, 1967

Complex angular momentum
space-like four momentum

L. Sertorio and M. Toller, N. C. 1964

Delbourgo, Physics Letter 1967
Salam etc.

Spontaneous breakdown
of SU(3) etc symmetry

I. L. G. Poincaré $(P_\mu, M_{\mu\nu})$

P_μ^2 $\quad \Sigma_\mu^2 = \frac{1}{2i}\epsilon_{\mu\nu\sigma\rho}M_{\nu\sigma}P_\rho$

$\quad\;\; \| \qquad\qquad \|$

$-m^2 \qquad m^2\sigma(\sigma+1)$

time-like $\quad P_\mu = (0,0,0,m)$

$\Sigma_0 = 0 \qquad \vec{\Sigma} = m\vec{S}$

$[S_i, S_j] = i\varepsilon_{ijk}S_k$

$SU(2), \quad O(3)$

$-\Sigma_0^2 = \vec{\Sigma}^2 = m^2 l(l+1)$

l = integer, half-integer

space-like $\quad P_\mu = (0, 0, m, 0)$

$\Sigma_3 = 0 \qquad \Sigma_1, \Sigma_2, \Sigma_0$

$$[T_0, T_1] = i T_2$$

$$[T_0, T_2] = i T_1$$

$$[T_1, T_2] = -i T_0$$

$$\Lambda = \frac{\Sigma_0^2}{m^2} = T_0^2 - T_1^2 - T_2^2$$

$SU(1,1) \qquad SO(2,1)$

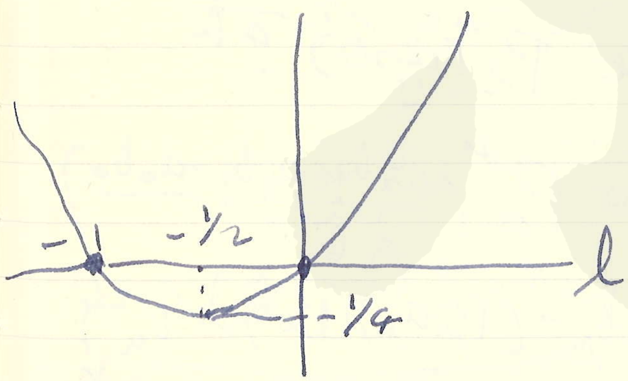
$$T^\pm = T_1 \pm i T_2$$

$$T^+|l, m\rangle = \sqrt{m(m+1) - l(l+1)}\;|l, m+1\rangle$$

$$T_0|l, m\rangle = m|l, m\rangle$$

$$m = 0, \pm\tfrac{1}{2}, \pm 1, \cdots$$

$$T^- T^+ |l, m\rangle = \{m(m+1) - l(l+1)\}|l, m\rangle$$

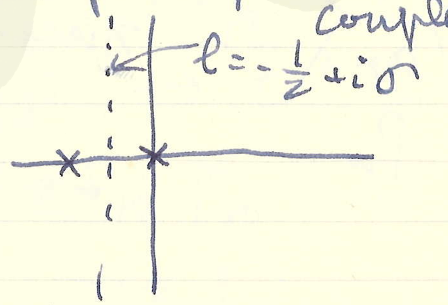


$l(l+1)$: real

unitary repres.

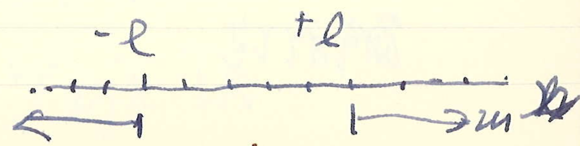
(i) principal series

complex l-plane



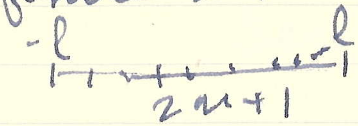
(ii) discrete

l = int. or half int.



non-unitary

(i) finite dimension



(ii) ~~無~~限次元　irreducible

l: complex

complex ang. mom.

O(3) group

Popov & Dolinsky, 1964?

Bertra... N.C. 1967

local representation

$(E = \theta, \psi, \varphi)$

$$U(E)|\alpha, m\rangle = \sum_{m'} D^{\alpha}_{m'm}(E)|\alpha, m'\rangle$$

$$|\alpha, m\rangle \approx Y_{\alpha}^{m}(\vec{n})$$

↓ complex

time-like $P_l^m(\cos\theta)$ $\quad \dfrac{\vec{a}\,\vec{b}}{a\,b}$

space-like $P_\alpha^m\left(\dfrac{a_x b_x + a_y b_y - a_0 b_0}{\hat{a}\,\hat{b}}\right)$

$$z = \frac{\{a_\mu b_\mu - (P_\mu a_\mu)(P_\mu b_\mu)/P_\mu^2\}}{\{a_\mu^2 - (P_\mu a_\mu)^2/P_0^2\}^{1/2}\{b\ \ \}^{1/2}}$$

解析性

$$[P_\mu^2 + F(P_\mu^2)]\, U(x_\mu, r_\mu) = 0$$

$$f(P_\mu) \qquad U(P_\mu, r_\mu)$$

$$P_\mu^2 = m^2 = -F(m^2, l(l+1))$$

$$\alpha(P_\mu^2)$$

unitary spin

$$SU(3) \to SU(2,1)$$

$$T_i = (a^\dagger\ b^\dagger)\, \sigma_i \begin{pmatrix} a \\ b \end{pmatrix}$$

$$a = (\eta + i p_\eta)/\sqrt{2}$$

$$b = (x - i p_x)/\sqrt{2}$$

$$[\eta, p_\eta] = [x, p_x] = i$$

(t) (s)

$$\eta^2 = r_\mu^2 - (P_\mu r_\mu)^2/P_0^2 \to r^2,\ r_1^2 + r_2^2 - t^2 \gtrless 0$$

(t)

$$x^2 = (P_\nu r_\nu)^2/P_0^2 \to t^2,\ -r_3^2$$

(t) $[T_0, T_j] = i\varepsilon_{ijk} T_k$

(s) (A) T_0, T_1, T_2 $O(2,1)$

(M) $[\qquad] = -i\varepsilon_{ijk} T_k$

$G = \exp t\, g$

$g = \sum \alpha_i T_i$

α_i real
complex

oscillator function → complex にすると
Weber function

$D_{\alpha+m}(\eta^2)\, D_{\alpha-m}(\pi^2)$

伊藤君　Bilocal Field
の Propagator
基礎工スキー Jan. 16, 1968

Regge pole model
$s^{\alpha-1}$
peripheral model (particle exch.)
Green's fn.
$F\,\psi(X, r) = 0$
$F\,D(X-X', r, r') = \delta(x-x')\delta(r-r')$

$D(k, q, q')$

k^2	time-like	$SO(3)$
	space-like	$SO(2,1)$
	$k^2 = 0$	E_2
	$k = 0$	L_4

$-k^2 = s > 0$ $SO(3)$
$\vec{k} = 0$ $D(\vec{k}=0, s; q, q')$

$$D = \sum \frac{2l+1}{2} P_l(z) D_l(\vec{k}=0, s; |\vec{q}|, q_0, |\vec{q}'|, q_0')$$

$$z = \vec{q}\vec{q}' / |\vec{q}|\cdot|\vec{q}'|$$

$s < 0$ $SO(2,1)$
$\theta \to i\theta$ $\vec{l} \to \tilde{l}$ (q_0, q_1, q_2)
$Y_{lm}(\theta, \varphi)$

町田茂：複合系と Regge Pole

素研　Jan. 23, 1968

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

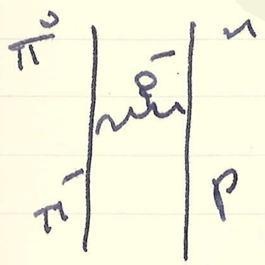
$$\rho$$

$$\frac{d\sigma}{dt} \sim s^{2J-2}$$

$$J \to \alpha(t)$$

exchange される粒子が Regge の性質をもつ.

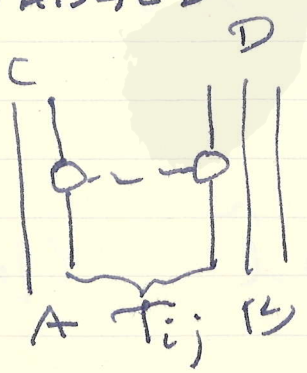
$$V = \sum_{i=1}^{6} S_i V_i(r, p^2, L)$$

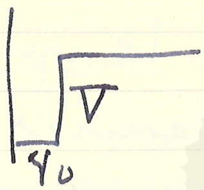


$$T(s,t) \sim \frac{\beta(t)\, s^{\alpha(t)}}{\sin \pi\alpha(t)}$$

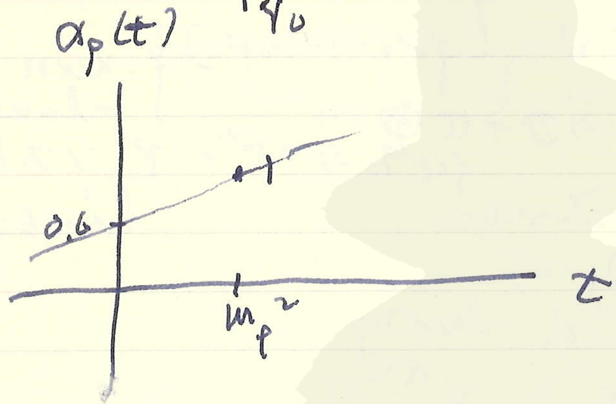
$$A + B \to C + D$$

$$T_{AB\to CD}(s,t) = \sum_{i,j} f_i^{AC}(s,t)\, f_j^{BD}(s,t) \times T_{ij}(s,t)$$



$V(r) =$ 

$m_q = 4.47\ \mathrm{GeV}$
9.72
21.42



2 GeV ~ 17 GeV

[illegible]研究会

[illegible].

11月30日 :

T. [illegible] : Chiral Dynamics

(i) [illegible]で閉じる (ps-meson) } non-linear

(ii) $\gamma_5 \to \varphi$ [illegible] 化学のスピン・アイソスピン

(iii) chiral partner linear

$O(4) \sim SU(2) \times SU(2)$

Lagrangian field theory

Current $[V^i, V^j] = i\epsilon_{ijk} V^k$

$[A^i, V^j] = i\epsilon_{ijk} A^k$

$[A^i, A^j] = i\epsilon_{ijk} V^k$

$\vec{V} = \int \vec{V}_0 d^3x$

$\vec{A} = \int \vec{A}_0 d^4x$

Gauge particle (Schwinger)

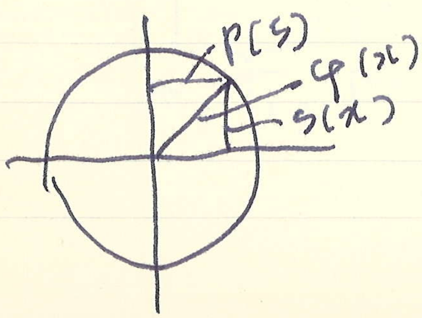
Yang-Mills field

$m \neq 0$

field-current identity (Lee)

$\vec{V}_\mu \propto \vec{j}_\mu^{(v)}$

ps. meson の current として vector meson が出る.



$\mathcal{L} = -\frac{1}{2}((\partial_\mu p)^2 + (\partial_\mu s)^2)$

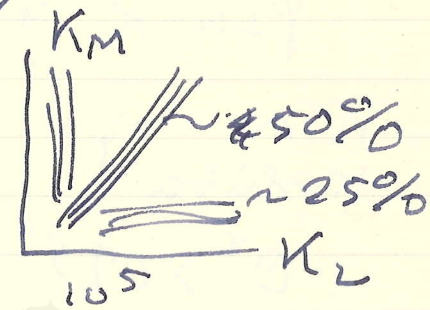
$= -\frac{1}{2}(\partial_\mu \varphi(x))^2$

$\left.\begin{array}{l}\partial_\mu \Phi_\mu = 0 \\ \Box \Phi_\mu = 0\end{array}\right\}$ $V_\mu = \partial_\mu \varphi$

一般相対論
曲率テンソル.

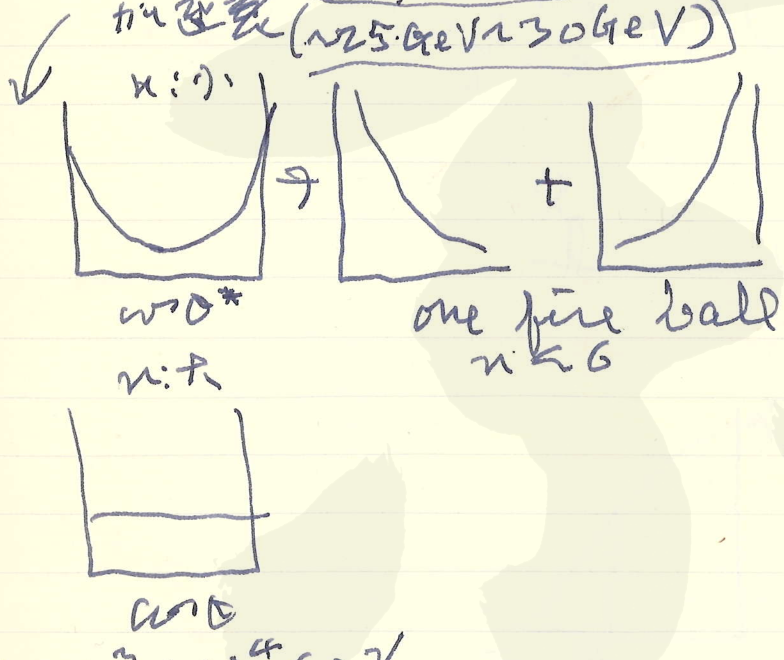
実験: 超高エネルギー —

○ $0 \sim 10^2$ GeV Dobrotin et al ('60)
asymmetry jet (one fire ball)
$m_{FB} \sim 3 \sim 4$ GeV



1 GeV　10　10^2　10^3　10^4　10^5

キリバエ
Emulsion stack (charged)
加速器 (~25 GeV ~ 30 GeV)
ECC (γ ray)



○ $10^3 \sim 10^4$ GeV
ICEF Project] → Poland Group ('66) $E < 10$ GeV
Branchy (Niu) 2 fire ball

$E > 10^4$ GeV
multifire ball　　H-quantum model ('61)

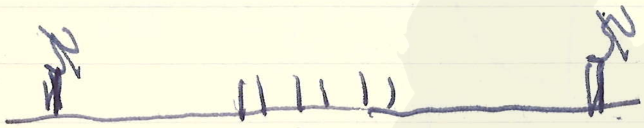
$p_{\perp N} \gtrsim$ GeV

Kim, Koshiba } $K/\pi \sim 0.2 \sim 0.25$
$X/\pi \sim 0.28$

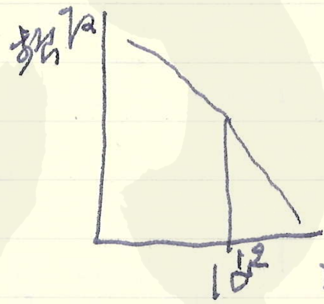
$\theta^* > 175°$　$\pi : K : p : \gamma = 7 : 9 : 10 : 1$ (K/π =

$\theta^* < 175°$　$\pi : K : B = 46 : 9 : 0$ ($K/\pi \sim 0.2$)

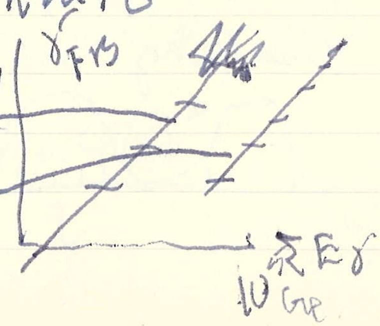
X (2 GeV) ($\to n + \varphi$, $n + \eta'$)



$E_0 \sim 10^4$ GeV
ECC(γ)



F.B., H-quantum の検証
one F.B.,　m_H　m_{FB}
$m_{FB} \sim 2 \sim 3$ GeV
H : $n \sim 6$
SH : $n > 6$
$m_{SH} \sim 5\,m_H$



$SH \to nH$ $\quad \overline{\gamma_H}$ (in SH) ~ 2.0

$\quad\quad \hookrightarrow n\pi$

analytic continuation [illegible] → 連続スペクトル
real　　discrete
imaginary
(0は多少怪しい)

1月31日
(午前 研究会)

(田中正氏
2"2": Infinite Comp. Wave Eq.
Regge pole 的分配表示式
hadron level の統一理解
群論的 S-matrix
ある方程式
Poincaré group (但し time-like momentum の領域に制限)
space-like solution
1) homogeneous Lorentz group:

$M_{\mu\nu} = L_{\mu\nu} + m_{\mu\nu}$

$\{F, G\}$　　$F = M_{\mu\nu} M_{\mu\nu} = \vec{K}^2 - \vec{L}^2$

$\vec{K} = M_{ij}$　　$\vec{L} = M_{0i}$

$G = \varepsilon_{\kappa\lambda\mu\nu} M_{\mu\nu} M_{\sigma\rho}$

$G = \vec{K}\vec{L}$

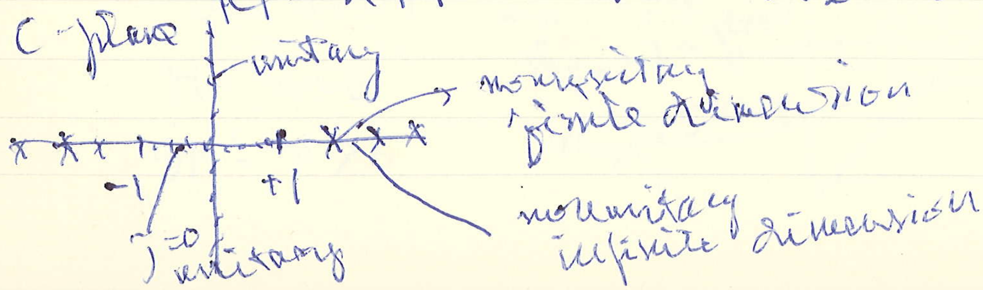
$|\sigma_H, k, m\rangle$

$\sigma_H \equiv (j, c)$　　$F = j^2 + c^2 + 1$

$G = -icj$

$j = k_{min}$

$|c| = n + 1$　　n -- k_{max} (nonunitary)



Dirac: $\sigma_H = (\frac{1}{2}, \frac{3}{2})$

2.7 Poincaré Group

$P_\mu, M_{\mu\nu}$

$\{P_\mu^2, \Sigma_\mu^2\}$　　$P_\mu^2 = M^2$　　$\Sigma_\mu^2 = M^2 l(l+1)$

$\Sigma_\mu = \frac{1}{2i}\epsilon_{\mu\nu\sigma\rho} M_{\nu\sigma} P_\rho$

0 time-like　$\vec{P} = 0$, $\Sigma_0 = 0$, $\Sigma_\mu^2 = \vec{\Sigma}^2 = M^2 s(s+1)$

s: 整数・半整数　　O(3)

~~$|\sigma_p, \; |\sigma_p, \alpha, m\rangle$~~

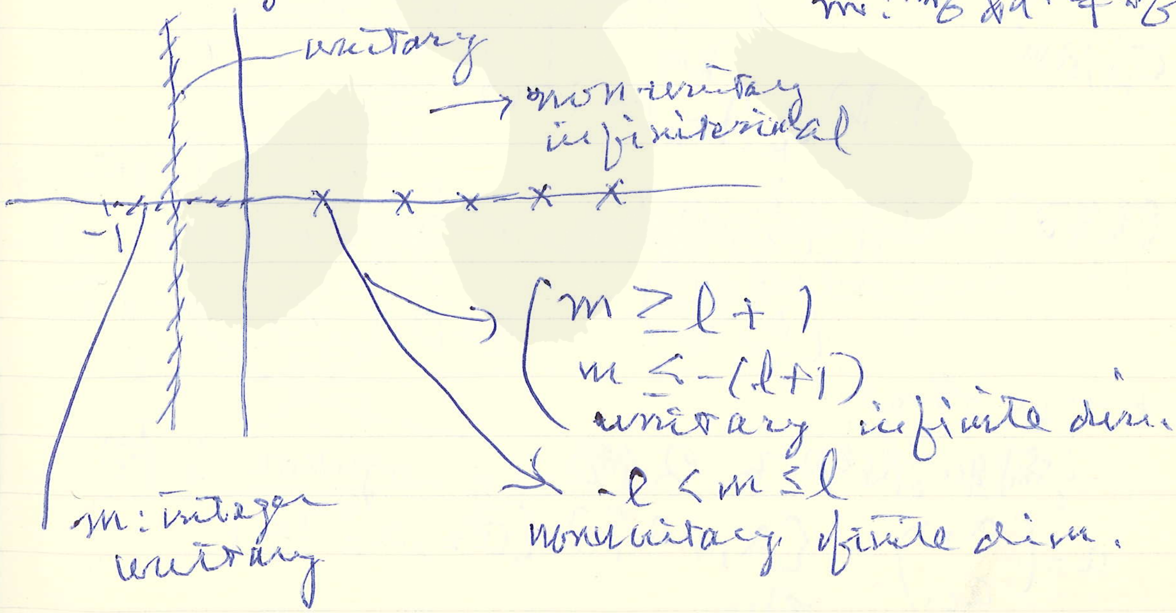
$|P_\mu^2, s, s_z\rangle$

1 space-like　P_3　$\Sigma_3 = 0$, $(\Sigma_1, \Sigma_2, \Sigma_0) \to O(2,1)$

$\Sigma_\mu^2 = \Sigma_1^2 + \Sigma_2^2 - \Sigma_0^2 = M^2 \alpha(\alpha+1)$

α-plane　　$|\sigma_p, \alpha, m\rangle$

m: 整数・半整数



space-like τ non-unitary

→ time-like τ unitary

§ Infinite Component

$$A^{km}_{\sigma_H}(x) = \int \theta(p_0)\, d^4p \sum_{s, s_3} f(s, p_\mu^2)$$

$\downarrow$

(j, c)

$j \leq k, \cdots \infty$

$$\langle \sigma_H, k, m \,|\, \sigma_p, p_\mu, s, s_3 \rangle \quad \rightarrow \text{C. G 係数}$$

$$\times e^{-ip_\mu x_\mu} \,|\, \sigma_p ; p_\mu, s, s_3 \rangle$$

$$\downarrow$$

$$A^{s, s_3}_{\sigma_p}(p_\mu)$$

Majorana Equation

$$(i\Sigma_\mu \partial_\mu + M)\,\psi(x) = 0$$

$$\sum_{\sigma_H', k', m'} i \langle \sigma_H, k, m \,|\, \Sigma_\mu \,|\, \sigma_H', k', m' \rangle\, \partial_\mu A^{k'm'}_{\sigma_H'}(x)$$

$$+ M_{\sigma_H} A^{km}_{\sigma_H}(x) = 0$$

[illegible]: $\sigma_H = (\tfrac{1}{2}, 0)$ $\quad s = \tfrac{1}{2}, \tfrac{3}{2}, \cdots$

$(0, \tfrac{1}{2})$ $\quad s = 0, 1, 2, \cdots$

[illegible]

[illegible] 2個 $\quad$ spinor 1個

$$a = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \quad [a_1, a_1^*] = [a_2, a_2^*] = 1$$

[illegible]

$$I_0 = a^\dagger a + 1$$

$$\vec{I} = \frac{i}{2}\left(a^\dagger \vec{\sigma} \sigma_2 a^\dagger - a \sigma_2 \vec{\sigma} a\right)$$

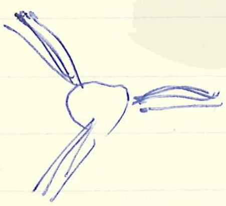
Nambu: Takabayasi

$$a = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \qquad b = \begin{pmatrix} b_1 \\ b_2 \end{pmatrix}$$

mass spectrum (Majorana)

$$m_s = \frac{M}{s + \frac{1}{2}}$$

§ 相互作用



A [x] についての local interaction

A [x] B (x) C (x)　　C.G. 係数.

↓　　non-local

$A_{\sigma_p}(y)$

§ 問題点

① mass-spin relation がよくない
(Takabayasi)

A
B

② spin と統計

$$[A_{\alpha_n}(x), A_{\alpha_n}(y)]_{\pm} = 0$$

space-like

Majorana ± のどちらかを選ばねばならぬ

但し space-like relation を入れない

と completeにならない

③ space-like solution

∂_μ 一階
mass 縮退なし
unitary repr.
} → space-like solution (mass conti.)

$$[P_\mu^2 + F(\Sigma_\mu^2)]U(x, r) = 0$$

P_μ space-like で議論

$I_\mu^2 = \alpha(\alpha+1)$

$\alpha(P_\mu^2)$

Time-like の方へ移ってゆくと

いろいろな spin の superposition

大貫氏：Urbaryon の統計
spin 半整数
統計：hadron $\begin{cases} \text{Fermi} \\ \text{Bose} \end{cases}$

para Fermi 統計から出発．order p

$p=1$ Fermi

$p=2$

non-rela で構やか

$p=1$　　$p=3$　　($p=2$ では fermion はできない)

$$[\phi(x), [\phi^\dagger(y), \phi(z)]] = 2\delta(x-y)\phi(z)$$

$$[\phi(x), [\phi^\dagger(y), \phi^\dagger(z)]] = 2\delta(x-y)\phi^\dagger(z) - \delta(x-z)\phi^\dagger(y)$$

$$[\phi(x), [\phi(x), \phi(z)]] = 0$$

$$\phi(x)|0\rangle = 0$$

$$\phi(y)\phi^\dagger(x)|0\rangle = p\,\delta(x-y)$$

H : causal (macro)

bound state a statistics

$a=0$　bose statistics

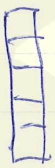
$\boxed{\vdots}$ → bose でも fermi でもない…

p　$\begin{cases} \text{bose} & p:\text{even} \\ \text{fermi} & p:\text{odd} \end{cases}$

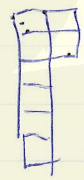
大貫氏: Urbaryon の統計
spin 半整数.
京氏: hadron $\begin{cases}\text{Fermi}\\ \text{Bose}\end{cases}$

para Fermi 統計から考. order p

$p=1$ Fermi



$p=2$



non-rela で 緩やか
$p=1$ $p=3$ ($p=2$ では fermion は出てこない)

$$[\phi(x), [\phi^\dagger(y), \phi(z)]] = 2\delta(x-y)\phi(z)$$

$$[\phi(x), [\phi^\dagger(y), \phi^\dagger(z)]] = 2\delta(x-y)\phi^\dagger(z) - \delta(x-z)\phi^\dagger(y)$$

$$[\phi(x), [\phi(x), \phi(z)]] = 0$$

$$\phi(x)|0\rangle = 0$$

$$\phi(y)\phi^\dagger(x)|0\rangle = p\,\delta(x-y)$$

H: causal (macro)
bound state の statistics
$a=0$ bose statistics

→ bose でも fermi でもない...

p $\begin{cases}\text{bose} & p: \text{even}\\ \text{fermi} & p: \text{odd}\end{cases}$

p = even

a = 0

両方統計

?

a = p

p = odd

a = 0　bose

fermion

a = p　fermi

p = 3

a = 0　bose
1　order 3 の para f.
2　order 3 の para b.
3　fermi

p = 4, 5 ... は para 統計で表せない bound state があらわれる.
"free Hamiltonian が個々の量の二次形式で表せる"という前提から para 統計

$$\frac{d\varphi}{dt} = i[H_0, \varphi]$$

causal:

$[H(x), \varphi(y)] = 0$　for large space-like $x-y$

両方統計は non-para の一種.

十分 [illegible] ていて、ゆっくりと動き出す。回転すると spin が生ずる。しかし電荷はあまり動かない。

報告: Strong Interaction の Mechanism
constructive dynamics
Fierz 教授

2月1日(木)
9~11 時: Weak Interaction

VA

1959: 素粒子模型の研究会
5.16~20 九大. π^0, B-L sym. mass formula
View
9. 箱根 100 mass
12. Nagoya model
1960: 素粒子の構造 — 複合模型と 基本粒子模型の研究.
1960~1961 supplement

Chew

1961: 模型と構造 (京都) SU_3 Regge
'62 〃 (名古屋) two neutrino, modified Nagoya
'63.3 〃 (九州) (p_0, n_0, Λ_0) Urbaryon quartet
'64.10.15~17 SU_6 (京都) quartet
'65 3月
7月 → Iizuka rule 30周年 国際会議
'66
'67 relat. bound state cluster
'68

current algebra
high energy
chiral dynamics
(quark counting) (additivity)

SU(6)

parity odd meson	Ps	0
	V	1
parity even baryon	N	1/2
	N^*	3/2

$$\frac{g_A}{g_V} = \frac{5}{3}$$

ω-φ mixing

$$\frac{\mu_p}{\mu_n} = -\frac{3}{2}$$

Another convergent
relat. model theory
of interacting particles

H. Kita

基研コロキウム Feb. 13, 1968

素領域

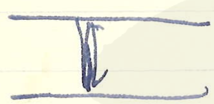
基研 Feb. 13, 1968

素粒子論における新しい相互作用

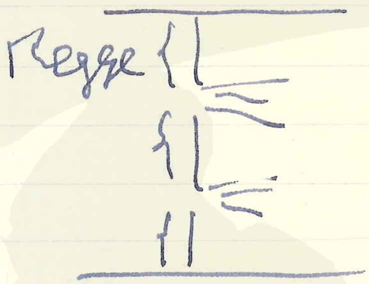
山口嘉夫, collisions,
High Energy Scattering of Hadrons
講演. Feb. 15, 1968

Topical Conference
Jan. 15~18 (1968)
CERN

Theory
Regge
Super convergence
spin flip amplitude of $\pi^{\pm} p$
quark model
PCAC



$\sim s^{\alpha(t)}$



$\pi^{\pm} p$ 12 GeV

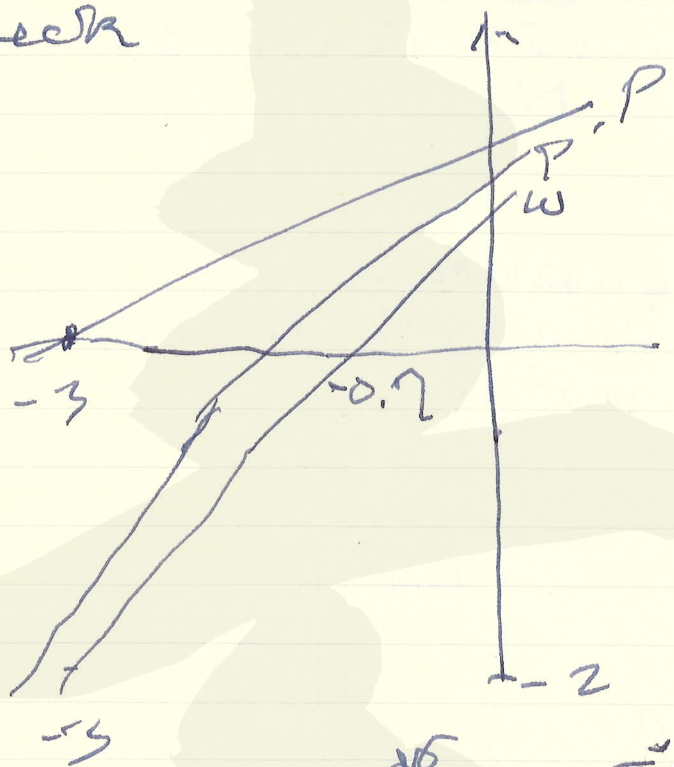
σ_t $\dfrac{d\sigma_{el}}{dt}$

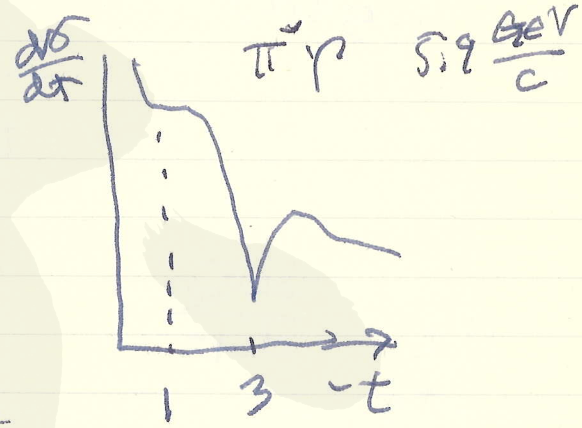
$$\begin{cases} 2^+ s \\ 2^+ n \\ 1^- n \end{cases}$$

$$\alpha = \left.\frac{\mathrm{Re}\, f}{\mathrm{Im}\, f}\right|_{\theta=0}$$

$\Delta(a,b) \equiv \sigma_t(\bar{a}b) - \sigma_t(ab)$

SU_3 of check





$\left(\frac{d\sigma}{dt}\right)_{pp} \propto (F_{em}(t))^4$　Wu-Yang

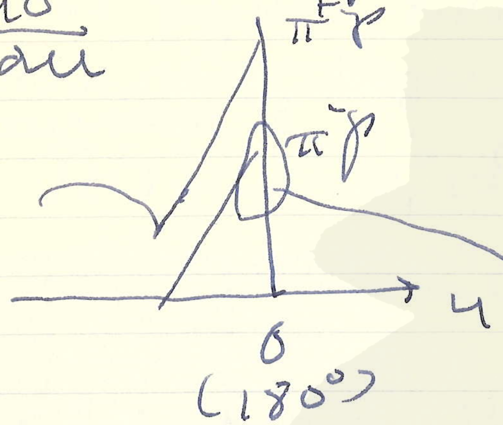
$s \to \infty$　asymptotic

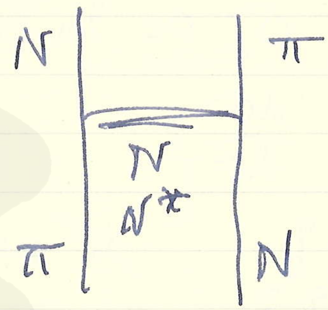
$\frac{d\sigma}{dt}(a + A \to b + B) \propto e^{bt}$

$\sigma(a + A \to b + X) \propto P_L^{-n}$

Back scattering

$\frac{d\sigma}{du}$





$\frac{d\sigma}{du}$ $\pi^+ p$ no shrinkage 話題

$e^{-15|u|}$

$\pi^- p$

$e^{-4|u|}$

· small $|t|$

$\left(\frac{d\sigma}{dt}\right)_{np} \fallingdotseq \left(\frac{d\sigma}{dt}\right)_{pp}$

$\left(\frac{d\sigma}{dt}\right)_{np} \Big/ \left(\frac{d\sigma}{dt}\right)_{pp}\Big|_{90°} = 1.01 \pm 0.09$

---

27 GeV neutron beam ← $p + Be \to n + \dots$ (24.1 - 28 GeV)

np n-nuclei

$\sigma_t(np) \neq \sigma_t(pd) - \sigma_t(pp)$

Quark model

$$\sigma_t \propto \mathrm{Im}\, F(0)$$

$$\frac{d\sigma}{dt} \qquad F(t)$$

meson $\bar{q}\, q$
baryon $q\, q\, q$

spin flip, non-flip を分けて考える

$0^-\ \frac{1}{2}^+ \to 0^-\ \frac{1}{2}^+$ ①
$\to 1^-\ \frac{1}{2}^+$
$\to 0^-\ \frac{3}{2}^+$ ②
$\to 1^-\ \frac{3}{2}^+$

charge change
strangeness change) が変わると、よくあわない。

$$\frac{\sigma(\pi N \to \pi N \ n\pi)}{\sigma(NN \to NN \ n\pi)} = \frac{6}{9} = \frac{2}{3}$$

$$\rho_L^\pi = \frac{2}{3}\rho_L^N$$

Serpukhov PS 78 GeV
(CERN 10^{12} p/pulse/2.5 sec)
10^{10} 〃 /12 sec
CERN 300 GeV 300倍内 年内
×6 = 1800くらい

河野林研　　基研 1967 Feb. 27

M. Gell-Mann, Current Algebra の表現.
at Infinite Momentum

D. Horn, J. Weyers

Integrated C. A.

$$V^a(t) = -i\int v_4^a(x,t)\,d^3x$$

$$A^a(t) = -i\int a_4^a(x,t)\,d^3x$$

$$[V^a, V^b] = i\varepsilon_{abc}V^c$$

$$[V^a, A^b] = i\varepsilon_{abc}A^c$$

$$[A^a, A^b] = i\varepsilon_{abc}V^c$$

$a, b, c = 1, 2, 3$

$SU(2)\otimes SU(2)$

Local C. A.

$$[v_0^a(\underset{\sim}{x},0),\ v_0^b(\underset{\sim}{y},0)] = i\varepsilon_{abc}v_0^c(\underset{\sim}{x},0)\,\delta(\underset{\sim}{x}-\underset{\sim}{y})$$

etc

$$\Rightarrow [v_0^a(\underset{\sim}{k}),\ v_0^b(\underset{\sim}{k}')] = i\varepsilon_{abc}v^c(\underset{\sim}{k}+\underset{\sim}{k}')$$

one particle state 上の表現

$$\langle\beta|v_0(\underset{\sim}{k})|\alpha\rangle$$

$|\alpha\rangle$: one particle state

矢崎紘一

Pion-Pion Interaction

発表 1968.2.27

$\pi\pi$ $\quad\pi K\quad$ $K\bar{K}$

$I=0$ $\quad I=1/2\quad$ $I=0$

$I=1$

$K \to 3\pi$

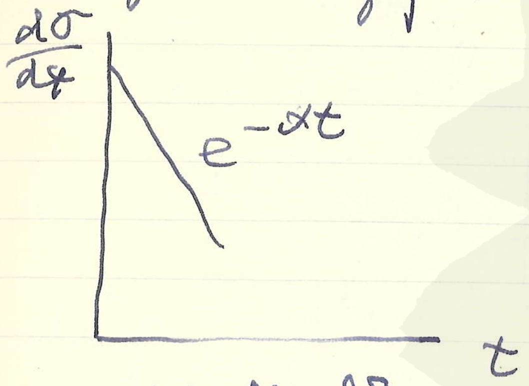
$\eta \to 3\pi$

$\pi\pi$ $\quad\sigma(410)\quad$ $\varepsilon(700\sim1000)$

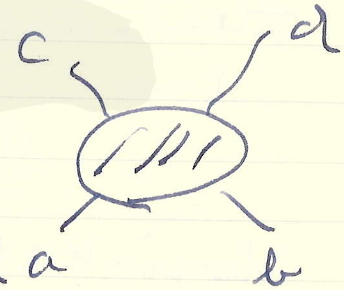
$I=0$

坂東昌子
Regge Poleの話
基研　1968.3.13.

high energy 現象

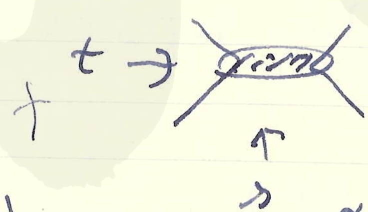


t-dependence
$\frac{1}{m^2-t}$
form factor
absorption model



s-dependence
$\pi^- p \to \pi^0 n$
$\frac{d\sigma}{dt} \sim s^{-1}$

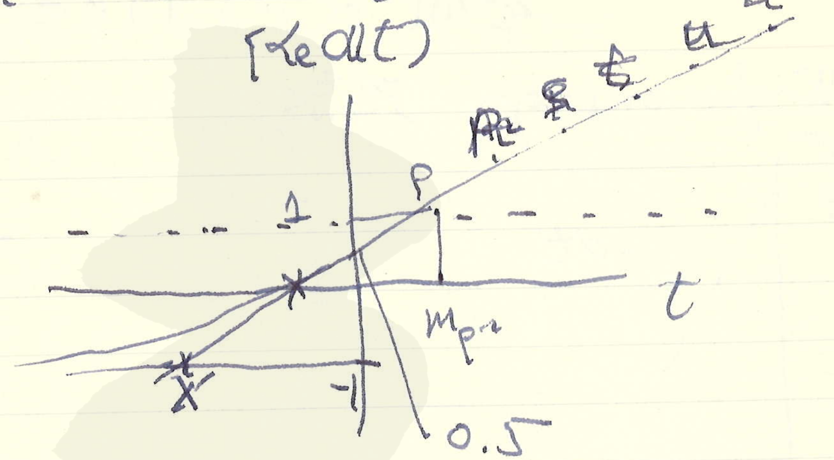
Regge pole



$$f = \left(\frac{1 \pm e^{i\pi\alpha(t)}}{2}\right)\frac{\beta(t)}{\sin\pi\alpha(t)}\left(\frac{s}{s_0}\right)^{\alpha(t)}$$

$\alpha(t)$: trajectory
$\beta(t)$: residue

① $t > 0$: $\alpha(t)$ resonance



$\alpha(t)$

Real-imag. ratio

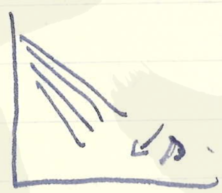
$t = 0$: $\pi^- p \to \pi^0 n$

$Re/Im = 1$ [illegible]

shrinkage

$\alpha(t) = \alpha(0) + \alpha' t$

$\left(\frac{s}{s_0}\right)^{\alpha(0)} e^{-\alpha' \ln(s/s_0) t}$



asymptotic power law

$s^{\alpha(t)}$

Residue $\beta(t)$

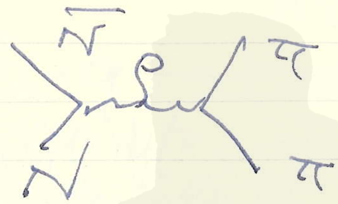
ghost killing

$\alpha(t) = 0, -1, \ldots$

$\alpha(t) = 0$:　　$\beta(t) = \frac{\alpha(t)}{\sin \pi\alpha(t)}$

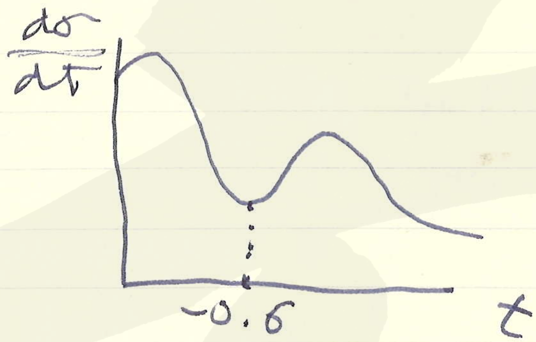
sense, nonsense

$t \rightarrow$



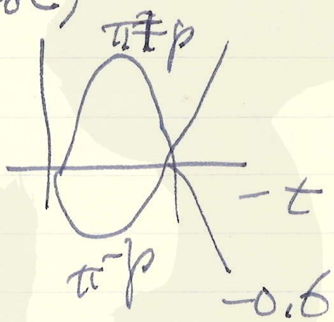
$t = 0$: conspiracy

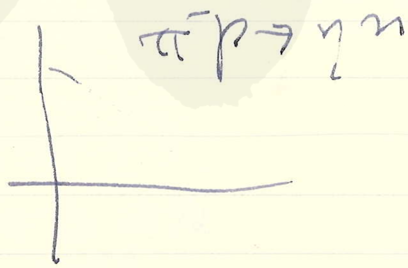
dip
πN



$\alpha_\rho(-0.6) = 0$

P(pol)





backward

困ったこと

① polarization

$\pi^- p \to \pi^0 n \leftarrow \rho$

$P_{CE} = 0$　実験は 0 でない

② $pn \to np$　　$p\bar{p} \to n\bar{n}$

(ρ, R)　　π

s^{-1}　　s^{-2}

解答

① ρ R の structure　{ non-local / composite

(研究中)

$t > 0$: partial wave 展開ができる

$t < 0$:

② $t \to \;\underset{J}{g_J}$　　$f = \sum \frac{g_J}{t - m_J} P_J(z_t)$

③ 理論的

(研究中)

素粒子の時空像

片山氏　　基研　　4.9.1968

[illegible]

$\psi(\cdot) \Rightarrow \psi(\cdot\ \cdot) \longrightarrow \psi(\cdot\ \cdot \cdots \cdot)$

内部自由度　isospin　$\rho(x) = \sum_N \delta(x - x_N)$

(回転度)振動度　integer

素領域　$\psi(D)$

$$V = i \int d^4x\, \rho(x)$$

$$X_\mu = \frac{-i}{V} \int d^4x\, x_\mu\, \rho(x)$$

$$I^{(n)}_{\mu_1 \cdots \mu_n} = \frac{-i}{V} \int d^4x\, (x_{\mu_1} - X_{\mu_1}) \cdots (x_{\mu_n} - X_{\mu_n})\, \rho(x)$$

$X_\mu,\ I^{(2)}_{\mu\nu},\ I^{(3)}_{\lambda\mu\nu} \xrightarrow[\text{条件つき}]{} \text{bilocal}$

Half integer spin

Born-Haag：全内部自由度を入れて考える．

δに関する積分が消える

<u>δ部の凍結が起ってる</u>

<u>ことが大事</u>

$r \quad \delta \quad r'$

1) 内部自由度

　イ．スピン

　ロ．L・不数の自由度

2) 場の ~~[illegible]~~ 運動

　イ．方程式

　ロ．量子化

$\psi(X_\mu, I_{\mu\nu})$ $\qquad$ $x_\mu = (x, it)$

$$I_{\mu\nu} = \sum_{\alpha=1}^{4} e^\alpha_\mu e^\alpha_\nu (\xi_\alpha)^2$$

$\sum_\alpha e^\alpha_\mu e^\alpha_\nu = \delta_{\mu\nu}$ $\qquad$ $(e^a_k)^* = e^a_k$

$\sum_\mu e^\alpha_\mu e^\beta_\mu = \delta^{\alpha\beta}_{\cancel{\mu\nu}}$ $\qquad$ $(e^a_4)^* = -e^{\cancel{a}a}_4$

$(e^4_k)^* = -e^4_k$

$(e^4_4)^* = e^4_4$

$\begin{pmatrix} \theta & \phi & \chi \\ \theta' & \alpha & \beta \end{pmatrix}$ Euler variables $\qquad$ $k, a = 1, 2, 3$

$\psi(X_\mu, I_{\mu\nu}) \to \psi(X_\mu, u, u^\dagger, V, \chi^2)$

Lorentz, ~~[illegible]~~ 階

$$T_{\mu\nu} = \frac{1}{2} t^\dagger \sigma_{\mu\nu} t + \frac{1}{2} \bar{t}^\dagger \sigma_{\mu\nu} \bar{t}$$

particle state $\qquad$ antiparticle state

差分方程式 → 差分方程式
→ 積分方程式

量子化
交換関係 と 差分方程式の両立性

Magnons in a model with antiferromagnetic properties
W. Heisenberg, H. Wagner and K. Yamazaki

基研 April 16, 1968

Photon
goldstone particle
vector
isospin に関して $1+C_3$
ferromag. の magnon は spin をもつ
isospin をもつ という意味で charged particle
antiparticle

ferromagnetic

$$H = -\alpha \sum_{n=1}^{N} \vec{\sigma}_n \vec{\sigma}_{n+1} \qquad \alpha > 0$$

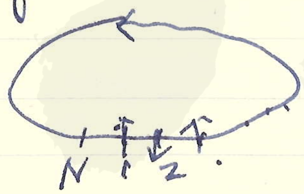
$\cdots \uparrow \uparrow \uparrow \cdots$

anti-ferro:

$$H = +\alpha \sum \vec{\sigma}_n \vec{\sigma}_{n+1} \cdots$$

$\uparrow \downarrow \uparrow \downarrow \cdots$

Ising model $\quad H = \alpha \sum_n \sigma_{2n} \sigma_{2n+1}$



Bethe-Hulthén

$$H = H_0 + H_1$$

$$H_0 = -\frac{\alpha}{2} \sum_{n,\delta} (\vec{\sigma}_n \vec{\sigma}_{n+\delta} + \vec{\tau}_n \vec{\tau}_{n+\delta} - 2)$$

$$H_1 = \beta \sum_n (\vec{\sigma}_n \vec{\tau}_n + 1) \qquad \beta \ll \alpha$$

$$\left[\sum_n (\vec{\sigma}_n - \vec{\tau}_n),\ H\right] \neq 0$$

$N \to \infty$ の極限

Goldstone Theorem

Baryon Excited States の説明

伊藤大介氏

講演 4月30日, 1968

叢書 1968

Linear Trajectory

Model I

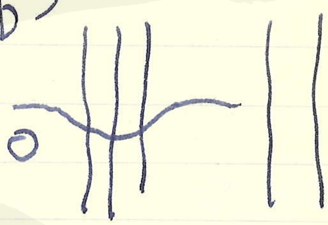
三次元の harmonic oscillator

大角運動の effective potential

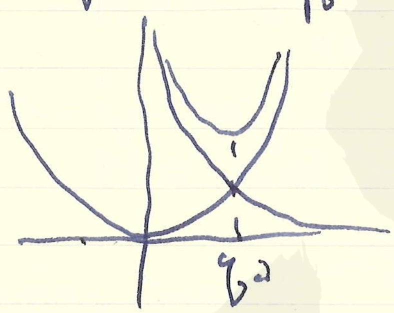
$E \sim a + bJ$

$$E = \frac{1}{2}(p^2 + \omega^2 q^2)$$

$$= \frac{1}{2}\left(p_r^2 + \frac{l(l+1)}{q^2} + \omega^2 q^2\right)$$



$$\frac{\partial E}{\partial q} = -\frac{l(l+1)}{q_0^3} + \omega^2 q_0^2 = 0$$



$$q_0^4 = \frac{\omega^2}{l(l+1)}$$

$$q_0^2 \sim l$$

$$E \sim \frac{1}{2}\left(\frac{\omega \cdot l(l+1)}{\sqrt{l(l+1)}} + \omega\sqrt{l(l+1)}\right) \sim \omega\sqrt{l(l+1)}$$

$$\sim \omega l$$

model II.

meson cloud の振動

strong coupling limit: 回転運動

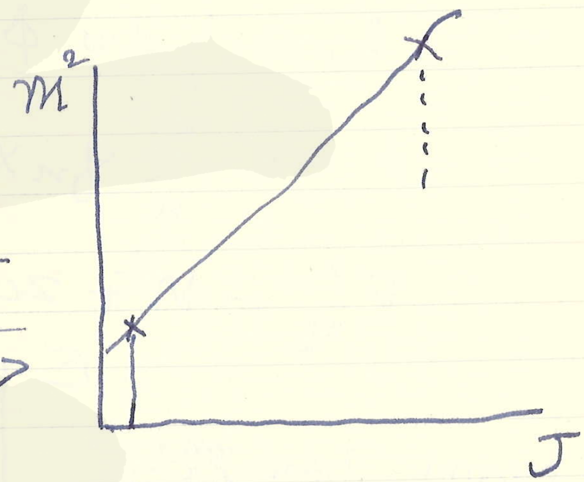
$$\Delta m = \frac{J(J+1)}{I}$$

$n_0 \simeq 1 \sim 2$
$l \gg 1$) 非E的にする

non-relativistic approximation

$$E\Psi = \Big(M + \frac{1}{2}\int dv \{\pi^2(\vec{r}) + \phi(\vec{r})(\mu^2 - \Delta) \times \phi(\vec{r})\}$$

$$- \int V(\vec{r})\phi^2(\vec{r})\Big)\Psi$$



$$\sqrt{M^2 + p^2} = \sqrt{M^2 + (\sum_i k_i)^2}$$
$$\simeq \sqrt{M^2 + N_\pi \langle k^2 \rangle}$$

$$N_\pi = \frac{H_\pi}{\omega}$$

$$E \simeq M + al$$

$$E \cdot \Psi = M\sqrt{1 + \frac{1}{M}\int dv\{\pi^2(\vec{r}) + \phi(\vec{r})\,\omega^2\phi(\vec{r}) - 2V(\vec{r})\,\phi^2(\vec{r})\}} \cdot \Psi$$

$$E^2\Psi = \Big(M^2 + M\int dv(\pi^2 + \phi\,\omega^2\phi - 2V\phi^2)\Big)\Psi$$

p-wave meson

$$\phi(\vec{r}) \propto \sqrt{\frac{\hbar c}{4\pi}} \sum_n \frac{q_n}{q_r} \frac{u_n(r)}{r}$$

$$\pi(\vec{r}) \simeq \sqrt{\frac{3}{4\pi}} \sum_n \frac{\vec{p}\,\vec{r}}{r} \frac{u_n(r)}{r}$$

p-wave ⇄ quark ?

$$q_i^{\alpha} \quad (I=1) \quad (l=1)$$

$$E^2\psi = \left(M^2 + M(p_0^2 + \omega_0^2 q_0^2)\right)\psi$$

$$L = \int dv\, \phi(\vec{r})\, \vec{r} \times \nabla \pi(\vec{r})$$

$$= \sum_n q_n \times p_n \rightarrow q_0 \times p_0$$

$$E_{nL}^2 = M^2 + 2\omega_0 M \left(L + 2n + \frac{3}{2}\right)$$

meson: base 状態

vector meson

charge [illegible]

$(3/2, 3/2)$ で引力

$$V_{ij}^{\alpha\beta}(r) = \left(\delta_{\alpha\beta} + \frac{\tau_{\alpha\beta}}{2}\right)\left(\delta_{ij} + \frac{\sigma_{ij}}{2}\right) \times V(r)$$

$$\left.\begin{array}{l} J = L + \frac{1}{2} \\ I = T + \frac{1}{2} \end{array}\right\} \left\{\begin{array}{l} (\frac{1}{2}\ \frac{1}{2}) \\ (\frac{3}{2}\ \frac{1}{2})\ (\frac{1}{2}\ \frac{3}{2}) \\ (\frac{3}{2}\ \frac{3}{2}) \end{array}\right.$$

Kirra – Rayley ?

$T=0$

$$H = 2\omega n = \omega(L + 2\nu)$$

$$L = 2n - 2\nu$$

ν – pairs

$T=1$

矢吹君: Symmetry of Dynamical Breaking

(講演 May 7, 1968)

Michel-Radicati (1968) ⇔ octet geometry algebra

1. Classical Example

$$-\mathcal{L} = -\mathcal{L}_{kin} - \mathcal{L}'$$

$$\frac{1}{2}(\partial_\mu \varphi_i)^2 \qquad m^2\varphi_i\varphi_i + \alpha^2(\varphi_i\varphi_i)^2 + \beta d_{ijk}\varphi_i\varphi_j\varphi_k$$

$$i = 1, 2, \dots 8$$

$$X = \left\{ \varphi_i ; \frac{\partial \mathcal{L}'}{\partial \varphi_i} = 0 \right\}$$

解 の orbit　　3種の解あり.

a の little group $G_a = \{ u ; u a u^{-1} = a \}$

$$\Box \varphi_i = \frac{\partial \mathcal{L}'}{\partial \varphi_i}$$

$$\varphi_i = \hat{\varphi}_i + \psi_i$$

$$\Box \psi_i = \left(\frac{\partial \mathcal{L}'}{\partial \varphi_j \partial \varphi_i} \right)_{\varphi = \hat{\varphi}_m} \psi_i$$

$$//$$

$$M = \left(\begin{array}{c|c|c|c} q\beta\rho \quad q\beta\rho \quad q\beta\rho & \pi & & \\ \hline & 0 \; 0 & K & \\ & & 0 \; 0 & \\ & & & -3\beta\rho \end{array} \right) \eta$$

1) X は orbit に分ける　（3つに分ける）

2) orbit の上の little group は equivalent
→ U(2)

3) orbit の dimension
$$\dim(O) = \dim(G) - \dim(G_a)$$

2. Cabibbo angle

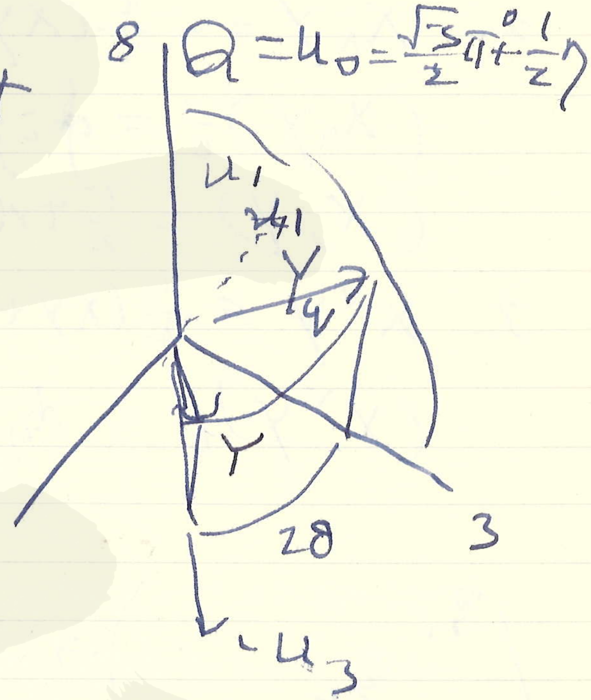
$J = \cos\theta\, \pi^+ + \sin\theta\, K^+$

$U J U^{-1} = \pi^+$

↓ $e^{2i\theta F_7}$

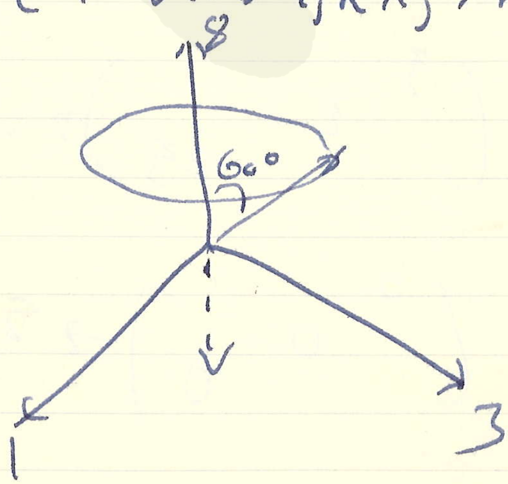
$\pi^+ \to \pi^{+\prime} = \cos\theta\, \pi^+ + \sin\theta\, K^+$

$H \cong H_{sym} + H_{e.m.} + H_w$



① sym　$X_i = a(X) X_i + b(X) d_{ijk} X_j X_k$

② sym. breaking.



3. Michel - Radicati

$$y_i - \sqrt{3}\, d_{ijk} y_j y_k + c_i + \rho\, d_{ijk} c_j' y_k = 0$$

1. Σ_8 : 3×3 $\{X\,;\ X = a_i \lambda_i\}$

8-dim. real euclid space

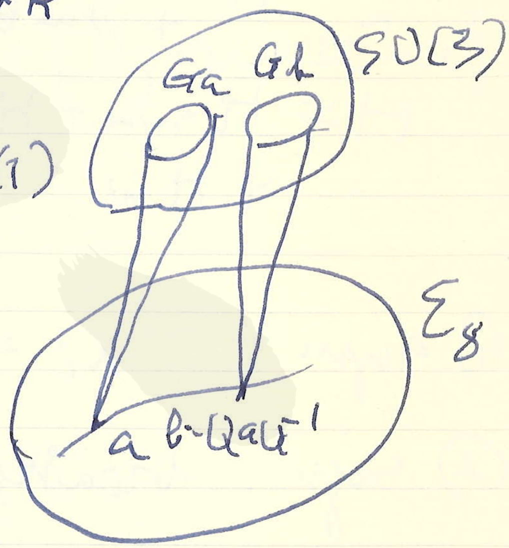
2. $X \wedge Y = -\frac{i}{2}(XY - YX)$

$(X \wedge Y)_i = f_{ijk} x_j y_k$

$(X, Y) = \frac{1}{2}\mathrm{tr}(X, Y) = x_i y_i$

3. $X \vee Y = \frac{1}{2}(XY + YX) - \frac{1}{3}\,\mathbb{1}\,\mathrm{tr}(X, X)$

$(X \vee Y)_i = d_{ijk} x_j y_k$



$\begin{pmatrix} \xi_1 & & \\ & \xi_2 & \\ & & -\xi_1 - \xi_2 \end{pmatrix} \to U(1) \times U(1)$

$\begin{pmatrix} \xi & & \\ & \xi & \\ & & -2\xi \end{pmatrix} \to U(2)$

$\begin{pmatrix} 0 & & \\ & 0 & \\ & & 0 \end{pmatrix} \to SU(3)$

$\det X = \frac{1}{3}\mathrm{tr}(X^3)$

layer
induced dynamical breaking
Cabibbo angle

Space-Time Code

David Finkelstein　　Trieste Preprint

基研. May 14, 1968

Relativistic Space-Time
space-Time measure
causal ordering

unary code
binary code

continuum — discretum
Riemann:
measure M　　$\sqrt{-g}$
ordering　　pCp'　　$\rightarrow g_{\mu\nu}$
"p cause p'"

causal space

quantum space = $*$-alg on H. S.
Q　　(Jauch)

quantum coordinate

quantum code

chronon $\tau \sim 10^{-23}$ sec.　　$x_\mu x^\mu = -c^2$
space is continuous

spin 1/2 boson

Riemann:

i) A discretum has finite properties where a continuum does not. Natural quantities are to be finite.

ii) A discretum possesses natural internal structure. A continuum must have it imposed from without. Natural law is to be unified.

iii) A continuum has continuous symmetries where a discretum does not. Nature possesses continuous symmetries.

A quantum is a system whose mechanical properties form neither a discrete nor a a continuous Boolean algebra but an algebra which is not even Boolean, being non-distributive.

河野 [illegible] ([illegible])

SU(3) Breaking

基研 May 28, 1968

Phenomenological Angle

[illegible] : Gell-Mann-Okubo T_3^3
Zweig-Iihida T_2^2 (T_1^1)

$\begin{cases} \Lambda \ (p, n) \\ n > p \end{cases}$

Meson (PS, V)
M^i_j $(i, j = 1, 2, 3)$

Weak int.
El. Mg. int.

$1 \to 1$
$2 \to 2\cos\theta$
$3 \to 3\sin\theta$

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \to \begin{bmatrix} 1 & \cos\theta & \sin\theta \\ \cos\theta & \cos^2\theta & \sin\theta\cos\theta \\ \sin\theta & \sin\theta\cos\theta & \sin^2\theta \end{bmatrix}$$

$$PS = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & \cos\theta\cdot\pi^+ & \sin\theta\cdot K^+ \\ \cos\theta\cdot\pi^- & \cos^2\theta\left(-\frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}}\right) & \sin\theta\cos\theta K^0 \\ \sin\theta K^- & \sin\theta\cos\theta \bar{K}^0 & -\frac{2}{\sqrt{6}}\sin^2\theta\cdot\eta \end{pmatrix}$$

$$V \equiv \begin{pmatrix} \frac{1}{\sqrt{2}}(\rho^0+\omega) & & \\ & \cos\theta \frac{1}{\sqrt{2}}(-\rho^0+\omega) & \\ & & -\sin\theta\,\phi \end{pmatrix}$$

A) semi-leptonic decay

$$L_{int} = \frac{G}{\sqrt{2}} Tr(J_\mu J_\mu^\dagger \lambda)$$

$$J_\mu = V_\mu + A_\mu + l_\mu$$

$$V_\mu = i\{P\partial_\mu P - \partial_\mu P \cdot P\} \equiv i[P \overleftrightarrow{\partial_\mu} P]$$

$$A_\mu = m\,\partial_\mu P$$

$$l_\mu = \bar{e}\gamma_\mu(1-i\gamma_5)\nu_e + \bar{\mu}\gamma_\mu(1-i\gamma_5)\nu_\mu$$

— — — '

— ‚ — .

Weak $\tan\theta = \frac{m_{\pi^-}}{m_{K^-}}$ or $\frac{m_{\pi^0}}{m_{K^0}}$ $\theta = 0.269$ rad

EM $\tan\theta = \frac{m_\rho}{m_\phi}$ $\theta = 0.643$ rad

$$G_V = G_F \cdot \frac{m_\pi}{m}$$

Higher Spin Propagators
& Off-shell Ambiguity
松嘉士郎(電気通信大)

発行. 6月21日(金), 1968

$$\langle T^{(\mu)}(x)\, T^{\dagger(\nu)}(y)\rangle_0 = \theta(x-y)\langle T^{(\mu)}(x) T^{\dagger(\nu)}(y)\rangle_0$$
$$+\,\theta(y-x)\langle T^{\dagger(\nu)}(y)\, T^{(\mu)}(x)\rangle_0$$

for $x \neq y$

$$T^{(\mu)}(x) = \frac{1}{(2\pi)^{3/2}}\int d^3p\, \frac{1}{2E}\sum_{\lambda=-J}^{+J}\{\epsilon^{(\mu)}(p,\lambda)\, a(p,\lambda)$$
$$\times e^{-ipx} + \epsilon^{*(\mu)}(p,\lambda)\, b^{\dagger}(p,\lambda)\, e^{ipx}\}$$

① $(\mu) = \mu_1 \cdots \mu_J$ の対称化
② $\partial_\mu T^{\mu} = 0$
③ $g_{\mu\nu} T^{\mu\nu} = 0$

$2J+1$ states

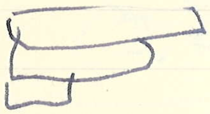
$$\begin{cases} \epsilon^{(\mu)} & \mu : \text{sym} \\ \gamma_\mu \epsilon^{\mu} = 0 \\ g_{\mu\nu}\epsilon^{\mu\nu} = 0 \end{cases}$$

$\epsilon^{(\mu)}(p,\lambda)$
helicity eigentensor

$$H = \frac{\vec{J}\,\vec{p}}{|p|} \qquad H\epsilon^{(\mu)}(p,\lambda) = \lambda\, \epsilon^{(\mu)}(p,\lambda)$$

Projection operator

GL(N)　　　Young symmetrizer



$T^{N}_{k_1 \dots k_J}$

SO(N)

$$P_\mu P_\mu + M^2(\dots, P_\mu) = 0$$

$$P_\mu^2 + \frac{a (P_\mu^2)^2}{M^2} = 0$$

$$M^2(\dots, P_\mu)$$

$$P_\mu V_\mu$$

$$\frac{P_\mu P_\nu}{M^2}$$

北門の Symmetry
Chiral ~~Dynamics~~

荒研 July 2, 1968

$SU(2)_I \sim O(3)$

$e^{i\delta\vec{\omega}\cdot\vec{\tau}/2}$ $\qquad \delta\omega = \frac{1}{2}\delta\vec{\omega}\,\vec{\tau}$

$e^{i\delta\omega}$

$\{N(J=\frac{1}{2}^+, \frac{1}{2}), \; N'(J=\frac{1}{2}^-, I=\frac{1}{2})\}$

$SU(2)_L \times SU(2)_R \to O(4)$

parity を変える angle $\delta\varphi$

$$\left.\begin{aligned} \delta\omega_L &= \delta\omega + \delta\varphi \\ \delta\omega_R &= \delta\omega - \delta\varphi \end{aligned}\right\}$$

$\psi^L = \frac{1}{2}(N + N')$

$\psi^R = \frac{1}{2}(N - N')$

$$\left.\begin{aligned} \delta\psi^L &= i\,\delta\omega^L\psi^L \\ \delta\psi^R &= i\,\delta\omega^R\psi^R \end{aligned}\right\} \qquad \left.\begin{aligned} \delta N &= i\delta\varphi N' \\ \delta N' &= i\delta\varphi N \end{aligned}\right\}$$

$M(\pi) \qquad (\frac{1}{2}, \frac{1}{2})$

$(N: \psi^L + \psi^R \qquad (\frac{1}{2}, 0) + (0, \frac{1}{2}))$

$\delta M = i\delta\omega^L \cdot M - iM\delta\omega^R$

$\delta M = i\delta\varphi\cdot M + iM\delta\varphi = i\{\delta\varphi, M\}$

$M = \sigma + i\vec{\pi}\vec{\tau} \qquad MM^\dagger = 1$

$M^\dagger = \sigma - i\vec{\pi}\vec{\tau}$

$(\sigma; \pi) \to (0^+, I=0; 0^-, I=1)$

ρ, A_1 $\quad \rho(J^P = 1^- \; I = 1)$

$A_1 (J^P = 1^+, I = 1)$

$(1, 0) \pm (0, 1)$

$N' = \gamma_5 N$ $\qquad \psi^L = \frac{1}{2}(1+\gamma_5)N$

$\psi^R = \frac{1}{2}(1-\gamma_5)N$

$-\mathcal{L} = (\bar{\psi}^L \gamma_\mu \partial_\mu \psi^L \; \bar{\psi}^R \gamma_\mu \partial_\mu \psi^R)$

$\cancel{+m}(\underbrace{\bar{\psi}^L \psi^L + \bar{\psi}^R \psi^R}_{\overset{\|}{0}})$

$m=0$ の場合しかやれぬ

$M \; (\frac{1}{2}, \frac{1}{2}^*)$ $\qquad (\bar{\psi}^L M \psi^R + \bar{\psi}^R M^\dagger \psi^L)$

$M_1 = \frac{1+if\pi}{1-if\pi}$ $\qquad M^\dagger = \frac{1-if\pi}{1+if\pi}$

$MM^\dagger = 1$

$= 1 + 2if\pi - 2f^2\pi^2 + \ldots$ $\qquad = \ldots$

Weinberg

$\begin{cases} \psi^L \to \sqrt{M}\,\psi^L \\ \psi^R \to \sqrt{M^\dagger}\,\psi^R \end{cases}$

$$\left.\begin{array}{l}\psi^{L} = \frac{1}{2}(1+\gamma_5)\sqrt{M}\,N \\ \psi^{R} = \frac{1}{2}(1-\gamma_5)\sqrt{M^{+}}\,N\end{array}\right\}$$

$$\left.\begin{array}{l}\delta N = i\,\delta u\,N \\ \delta N' = i\,\delta u\,N'\end{array}\right\} \quad \begin{array}{l}\delta u = \sqrt{M^{+}}\,\delta\varphi\,\sqrt{M} \\ \quad + i\sqrt{M^{+}}\,\delta\sqrt{M}\end{array}$$

Schwinger の N' $(=\gamma_5 N)$ に当る.

$\psi^{L} = \sqrt{M}\,N$ $\qquad N \to (\sqrt{M} + \sqrt{M^{+}})N$

$\psi^{R} = \sqrt{M^{+}}\,N$ $\qquad N' \to (\sqrt{M} - \sqrt{M^{+}})N$

or $N \to (1 + \pi^2 + \pi^4 + \cdots)N$

$N' = (\pi + \pi^3 + \cdots)N$

parity even $(N) \to N +$ even π

odd $(N' = \gamma_5 N) \to N +$ odd π

$\frac{g_A}{g_V} = 1$ にする $(= 1.2)$

Ohnuki

Kawarabayashi - Kitakado

K.S.R.F.: $g^2 = m_\rho^2 f^{-2}$ を使う $\to m_A^2 = m_\rho^2 \cdot 2$

ρ の相互作用の universality