

素粒子の基礎理論研究会
 第8回

5月4日 10時～ ①

1. 田中一, 一物 題名: 素粒子論の基礎

$$(H_0 + H_1)V = V(H_0 + \langle H_1 V \rangle)$$

$$H_0 = -\frac{d^2}{dx^2} \quad H_1 = -\alpha \delta(x)$$

$$(k'^2 - k^2)(k' | V | k) - \frac{\alpha}{2\pi} \int dk'' (k'' | V | k) \\
 + \frac{\alpha}{2\pi} \int (k' | V | k'') \langle k'' | V | k \rangle dk'' dk''' = 0$$

$$(k' | V | k) = \delta(k' - k) + \frac{\alpha}{2\pi} \frac{P}{k'^2 - k^2}$$

$$(k' | V | k) = f(k') \delta(k')$$

$$f(k') = \frac{\alpha^2/4}{k'^2 + \alpha^2/4}$$

$$\psi(x) \sim e^{-\alpha/2|x|} \quad E = -\alpha^2/4$$

2. 木下 題名: Dirac の導出

3. 木下 題名: Schrödinger 場の量子化

$$[j_i(x), j_k(x')] \neq 0 \quad \text{Schrödinger} \\
 = 0 \quad \text{K.G.}$$

(2)

4. 片山・徳岡・山崎: 超弦理論の記述と第三量子化

Feynman amplitude

$$g_n(z_1, \dots, z_n) = \langle \Psi_0 | N(\phi_H(z_1) \dots \phi_H(z_n)) | \Psi \rangle$$

(inserting operator, state)

$$\{g_n(z_1, \dots, z_n)\} = \begin{pmatrix} g_0 \\ g_1(z_1) \\ \vdots \\ \vdots \end{pmatrix}$$

$$C(z) \{g_n(z_1, \dots, z_n)\} = \{ (n+1) z^{\frac{1}{2}} g_{n+1}(z_1, \dots, z_n, z) \}$$

$$C^+(z) \{g_n(z_1, \dots, z_n)\} = \{ n^{\frac{1}{2}} \sum_n \delta(z-z_n) g_{n-1}(z_1, \dots, z_{n-1}) \}$$

↓ Friedrichs

$$C^+(z) C(z') \{g_n(\dots)\} = \{ n \sum_n \delta(z'-z_n) g_n(z_1, \dots, z_{n-1}, z') \}$$

$$C(z') C^+(z) \{ \dots \} = \{ \dots \}$$

$$+ \delta(z'-z) g_n(\dots) \}$$

$$[C(z'), C^+(z)] = \delta(z'-z)$$

Third quantization: Ω -space

$\Psi(x), \bar{\Psi}(y), \Phi(z)$

$$\Omega_H = \sum \frac{1}{\sqrt{n! m! k!}} \int d^4 x_n \dots d^4 z_k g_{nmk}(z_n, \dots, z_k)$$

$\times \Omega_{nmk}$

$$\langle \Omega_{nmk}(z_k, \dots, z_n) \Omega_{n'm'k'}(z'_k, \dots, z'_n) \rangle$$

$$= \delta(z_k - z'_k) \dots \delta(z_n - z'_n)$$

$$\langle \Omega_{nmk} \Omega_{n'm'k'} \rangle = 0$$

$$C(z) \rightarrow \{ \Omega_{nmk} C(z) \Omega_{n'm'k'+1} \}$$

for $n+n'$ etc

$$C^+(z) \rightarrow \{ C^+(z) \Omega_{nmk} \}$$

$$\Omega_{nmk} = \frac{1}{\sqrt{|z_1 - z_2| |z_1 - z_k|}} c^\dagger(z_k) \dots a^\dagger(z_n) \Omega_0 \quad (3)$$

$$N_c = \int d^4z c^\dagger(z) c(z)$$

$$N_c \Omega_{nmk} = k \Omega_{nmk}$$

$$\Omega_H = (\Psi_0, N(\exp \{ a^\dagger \psi_H - \bar{\psi}_H b^\dagger + \phi_H c^\dagger \}) \Phi) \Omega_0$$

$$\Omega = (\Phi_0, N(\exp \{ a^\dagger \psi - \dots \}) \Phi) \Omega_0$$

$$(\square - \mu^2) \phi = 0$$

$$(\square - \mu^2) c \Omega = 0$$

Cocycle

$$\Omega_H = \exp \iint dx dy a^\dagger(x) S_F(x-y) b^\dagger(y)$$

$$- \frac{1}{2} \iint dx dx' c^\dagger(x) \Delta_F(x-x') c(x')$$

$$(\Psi_0, T(\exp \{ a^\dagger \psi_H \dots \}) \Phi) \Omega_0$$

$$\Omega_H = \dots (T \Phi) \Omega_0$$

$$\langle \Psi_0, T(\dots) \Phi \rangle = \frac{\langle \Phi_0, T(U) \Phi \rangle}{\langle \Phi_0, T(U) \Phi_0 \rangle}$$

$$\Omega_H = e^{\iint dx dy \dots} e^{i(L_H - L_0)} e^{-\iint \Omega}$$

$$L_H = \int S_F b^\dagger a c$$

$$e^\dagger a e^- = a - \int S_F b^\dagger = \psi$$

$$\Omega_H = e^{i \int (L_H(\psi, \bar{\psi}, \phi) - L_0)} \Omega$$

$$\left[(\square - m^2)\phi(x) + \frac{\delta \bar{L}_I(\psi \bar{\psi} \phi)}{\delta \phi(x)} \right] \Omega_H = 0 \quad (4)$$

$$\begin{aligned} \mathcal{L} = & -\frac{i}{2} \phi (\square - m^2) \phi + i \bar{\psi} (\gamma^\mu \partial_\mu + \kappa) \psi \\ & - g \bar{\psi} \gamma_5 \psi \phi \end{aligned}$$

$$[\bar{L}, c^\dagger(x)] \Omega_H = c^\dagger(x) \Omega_H$$

$$[\mathcal{L}, a^\dagger] \Omega_H = a^\dagger \Omega_H$$

$$[\mathcal{L}, b^\dagger] \Omega_H = b^\dagger \Omega_H$$

$$\boxed{\bar{L} \Omega_H = L \Omega_H}$$

$$\bar{L} a^\dagger \Omega_H = (L+1) \Omega_H$$

\mathcal{L} : non-hermitic = $-iL$

$$\frac{1}{2}(\bar{L} + \bar{L}^*) \rightarrow \mathcal{L}$$

negative energy

5. 麦林. 自由場: 固有方程式と相関関数
 particle: $[c(t), c^*(t')] = \delta(t-t')$

$$\mathcal{L} = c^*(t, \tau) i \frac{\partial}{\partial t} c(t, \tau) - c^*(t, \tau) (i \frac{\partial}{\partial t} - \omega) c(t, \tau)$$

$$L = \int \mathcal{L} d\tau$$

$$\delta L = 0$$

$$[i \frac{\partial}{\partial t} + (i \frac{\partial}{\partial t} - \omega)] c(t, \tau) = 0$$

$$\pi(t, \tau) = i c^*(t, \tau)$$

$$[c(t, \tau), c^*(t', \tau)] = \delta(t-t')$$

$$[c(t), c^*(t')] = e^{-i\omega(t-t')}$$

$$c(t) = \lim_{T \rightarrow \infty} \frac{1}{\sqrt{T}} \int_{-T/2}^{T/2} c(t-\tau) d\tau \quad (5)$$

$$U(t, \tau) = e^{-i\omega t} \delta(t-\tau)$$

$$= \frac{1}{2\pi} \int e^{-i(k\tau + \lambda t)} \delta(\tau + k - \omega) dk d\lambda$$

$$U(t, 0) = \delta(t)$$

$$[c(t, \tau), c^*(t', \tau')] = \int dt'' \underbrace{U^*(t', \tau' | t'', \tau)}_{U(t'', \tau | t', \tau')} \underbrace{[c(t, \tau), c^*(t'', \tau)]}_{\delta(t-t'')}$$

$$= \exp(-i\omega(t-\tau')) \cdot \delta(t-t'-\tau-\tau')$$

$$\int dt dt' [\quad] = e^{-i\omega(t-t')}$$

$$[c(t), c^*(t')] = \delta(t-t')$$

Consider:

$$[C(t, \tau) - c(t)] \Psi = 0$$

$$H - \int H d\tau \quad | \Psi = + c^*(t, \tau) (i \frac{\partial}{\partial t} - \omega) c(t, \tau)$$

$$[H, c(t, \tau) - c(t)] \Psi = 0$$

$$(i \frac{\partial}{\partial t} - \omega) c(t, \tau) \Psi = 0$$

$= i \frac{\partial}{\partial t} c(t, \tau)$

$$\{ \begin{aligned} & \mathcal{L} = c^*(t, \tau) i \frac{\partial}{\partial t} c(t, \tau) + c^*(t, \tau) (\frac{\partial^2}{\partial \tau^2} + \omega^2) c(t, \tau) \\ & [i \frac{\partial}{\partial t} - (\frac{\partial^2}{\partial \tau^2} + \omega^2)] c(t, \tau) = 0 \end{aligned} \}$$

$$[c(t, \tau), c^*(t', \tau')] = U(t, \tau | t', \tau')$$

$$U(t, \tau) = \sqrt{\frac{i}{4\pi\tau}} e^{-i(\omega^2 \tau + \frac{1}{4\tau})}$$

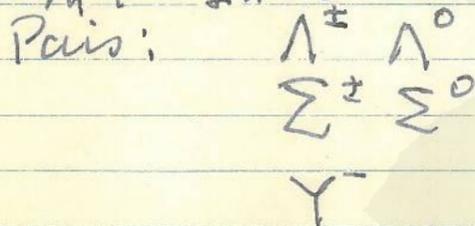
(6)

$$c(t) = \int c(t-u, \tau) \delta_+(u) d\tau du$$

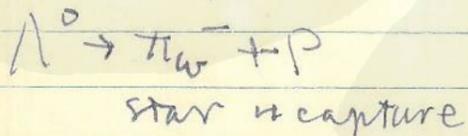
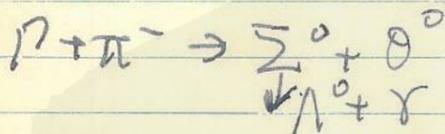
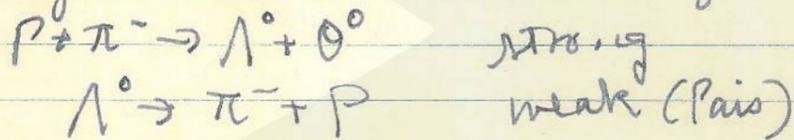
$$\gamma = \frac{1}{2\omega} (i \frac{\partial}{\partial t} + \omega) \int c(t, \tau) d\tau$$

$$[c(t), c^*(t')] = \int d\tau d\tau' \frac{1}{2} (1 + \epsilon(t-t') \epsilon(\tau-\tau')) \times |I(t, \tau | t', \tau')|$$

6. 岡山: 素粒子の弱相互作用



Okayama: mass level & charge & 宇称



b: baryon charge π_w : S or V
 l: leptonic charge