XVIII

NOTE BOOK

Manufactured with best ruled foolscap
Brings easier & cleaner writing

Feb. 1964 ~ May. 1964
模型と構造研究会(つづき)—
C, etc. Boson Resonances

VOL. XVIII

湯川

Nissho Note

日習 G A 50

核子と核理論研究会（つづき）

1964
2月5日午后
菅原：mass Formula と Unitary symmetry

U.S.

巾（baryon 1^+ / 1^{st} reson $\frac{3}{2}^+$ / N^* ....）

ps. meson 0^-
vector meson 1^-

$$m = m_\Lambda \{ 1 + aY + b(\vec{T}^2 - \frac{Y^2}{4}) \}$$

$$a^2 = b$$

$$-Y \Longrightarrow J - \frac{1}{2} - Y$$

J の unit は π
Y 〃 e

$$m^{(+)} = m_\Lambda + \frac{m_\omega}{4}(J - \frac{1}{2} - Y) + \frac{m_\pi}{4}(\vec{T}^2 - \frac{Y^2}{4})$$

$$m^{(-)} = Y_0^* + \quad \cdot \quad \prime$$

$\frac{1}{2}^+ \uparrow$ —— $\uparrow 0^-$

$$J - \frac{1}{2} = \frac{2}{3}(1 + \vec{L}\vec{S})$$

ps. meson
vector meson)

$T = Y = B = Q = 0$

ABC – η – ω – (φ) – f 　　若間隔.

235 MeV

$\frac{235}{3}$ MeV の間隔

0^- 1^- 1^- 2^+

0^- 1^- (1^-) 2^+

$\eta - \omega - (\varphi) - f$

$a + b J(J+1)$

Chew: Regge

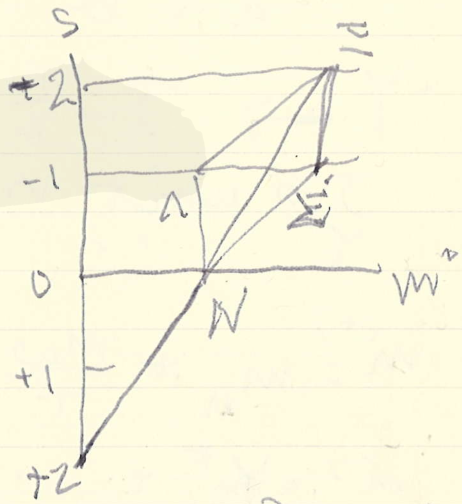
$m^2 = \alpha + \beta J$?

$\Delta J = 2$

$m^2_{bar} = A(2-S) \pm B(2T-1)$

$N^2 + \Xi^2 = \Lambda^2 + \Sigma^2$

$\Xi^2 = 2N^2$



$m^2_{ps} = A'(2-S) - B'(2T-1)$

$(\eta, \bar{K}, \pi)$

$K^2 = \frac{3}{4}(\eta^2 + \pi^2)$

$(\omega\ \bar{K}^*\ \rho)$

$m^2_v = A''(3-S) - B''(2T-1)$

$K^{*2} = \frac{2}{3}(\omega^2 + \rho^2)$

$A'' + B'' = A' + B'$

$$m_M^2(J^P, S, T) = C(1-2T) + A_{J^P}(J - S + 2T + 1)$$

$J^P = 2^{+}$: f_0 にあわす　2^{++}
$J^P = 2^{+}$: $\rho' = 1420$ MeV となる

$$\xi = J - \frac{B}{2} + 2 - S$$
$$\xi \geq 2$$
$$\xi = J + \frac{B^2}{2} + 2 - BY + (1 - B^2)Y^2$$

原治: Extended Particle Model,
Isotopic spin and Electromagnetic field
rotator の body fixed 系 component
が isospin
すると $Q = eI_3$ が説明できない
i) 場の理論との関係
ii) 素粒子の多様性?　(理論? 模型)
iii) 質量をどうしてきめる.

Kaluza-Klein

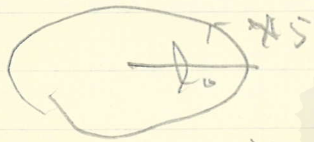
$$x_5 \to x_5 + \frac{1}{\beta} f(x)$$
$$\beta = \sqrt{\kappa} \qquad \Delta x_5 = \frac{f}{\beta}$$
$$A_\mu \to A_\mu + \partial_\mu f$$
$$\psi \to e^{i\frac{e}{\hbar c}f}\psi = e^{i\frac{\Delta x_5}{l_0}}\psi$$
$$l_0 = \left(\frac{e^2}{\hbar c}\right)^{-\frac{1}{2}}\sqrt{\kappa}\,\hbar c \sim 10^{-31}\ \mathrm{cm}$$

$\boxed{x_5 = l_0\varphi}$

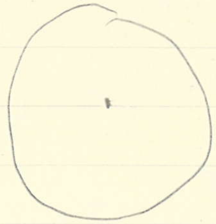
Gauge 変換
$$\psi \to e^{iI_3\Delta\varphi}\psi$$

disc or circle

sphere



→



$\gamma_5 \to$ charge

Scale ○○○○○○

直角は ピタゴラスの定理

角度は $\tan\theta = y/x$

x_μ, θ, φ, χ で一意的に定まる.

$$ds^2 = dx^2 + r_0 (d\chi\, d\varphi) + r_d (d\varphi)^2$$

$$ds^2 = \gamma^{(x)}_{\mu\nu} dx^\mu dx^\nu$$

Relativistic rotator?

小山(浩正) Lepton → Hadron

超伝導 → Nambu model

$e \sim \nu_e$ l_1, $\mu \sim \nu_\mu$ l_2) massless $l = \begin{pmatrix} l_1 \\ l_2 \end{pmatrix}$

$l = \frac{1+\gamma_5}{2}\varphi$

$P_C : l^{P_C} = i\sigma_2 \times \tau_3 l^+$) τ-space

超伝導

$\Phi = \begin{pmatrix} a_1(\vec{p}) \\ a_2(\vec{p}) \end{pmatrix}$

gap : $\Delta \cdot \Phi^+ \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \Phi$

$\varphi = \begin{pmatrix} l_1 \\ i\sigma_2 l_2^+ \end{pmatrix}$

λ-space

$C_e : l^{C_e} = \tau_1 l$

$\gamma_i = \sigma_i \otimes \tau_2$

$\gamma_4 = 1 \otimes \tau_1$

$\gamma_5 = 1 \otimes \tau_3$

① ψ ϕ comm. rel

② L. invariance

⓪ $\longrightarrow$ Dirac 粒子 C_s, P_s

$C_s = C_e, \quad P_s = P_c \times C_e$

$C_s P_s = P_c \; (= PC)$

$L_I = -G(\bar{l}_1 \gamma_\mu l_1)(\bar{l}_2 \gamma_\mu l_2)$

$\downarrow$

$L_I = -\frac{1}{2} G \{ (\bar{\psi}\psi)^2 + (i\bar{\psi}\gamma_5\psi)^2 \}$

$m \neq 0 \qquad G < 0$

$\Lambda \gtrsim 10^3 M_p$

lepton — O

2種の真空

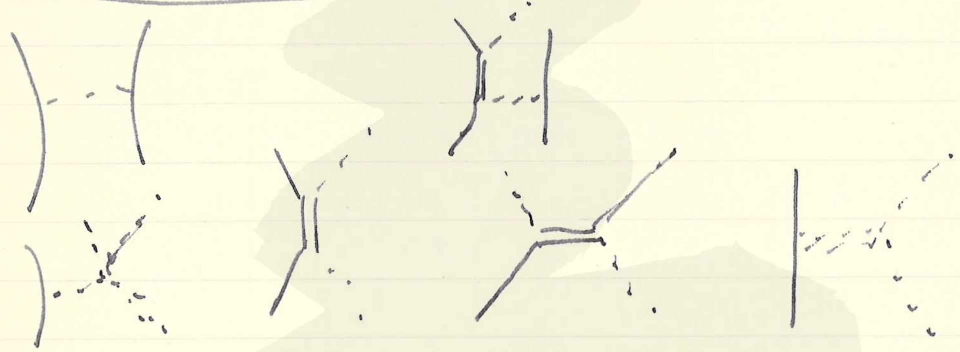
hadron — Ω

論文(論題): i) BEC model and π-N scattering

I) strong ~~int~~ Reactions $\longleftrightarrow$ stable or unstable hadron

II) damping effect 以外の higher order が効えるか

III) strong reaction v. closed loops による分析: Feynman diagram に対応する matrix element の和



resonance type	fermion exchange type	boson exchange type
N, N^*, N^{**}	N, N^*, N^{**}	$\rho\ (I=1, J^P=1^-)$ ABC $(I=0, J^P=0^+)$ $f_0\ (I=0, J^P=2^+)$

$$0.4 \lesssim f/g \lesssim 0.5$$

$$-3.0 \lesssim f/g \lesssim -2.0$$

~~[illegible]~~ 2月6日 午前

湯川：空間・時間

李白（天地は万物の逆旅
　　光陰は百代の過客）

理論物理　内から外から

　も 物理で行って困る．

素粒子は終る

（御）← 素粒子をとり

粒子に固有
の時計

我々 (i) Prediction

(ii) pair creation の片々は我々が無視

(iii) 反粒子

(iv) dichotomy

素粒子論と宇宙論と手に手
と手に、物理 それ故人

$$\xi \quad \eta \quad \zeta$$

$$\pm\tfrac{1}{2} \quad \pm\tfrac{1}{2} \quad \pm\tfrac{1}{2} \; : \; \left\{\begin{matrix} P, N, \Lambda, X \\ \bar{P}, \bar{N}, \bar{\Lambda}, \bar{X} \end{matrix}\right\}$$

$$P, N, \Lambda : \; \xi_3 + \eta_3 + \zeta_3 = \tfrac{1}{2}$$

$$X : \; \xi_3 + \eta_3 + \zeta_3 = \tfrac{3}{2}$$

江沢：素粒子と物理の深層．

素粒子論は終らない．

Formgrund　　symmetry の ground として物理．

Urteilchen　　数・文字

Chew 理論

Lorentz ~~群論~~ → 物理~~的基礎~~の理論

ether 理論

（華厳 別明
　偏会 別眼）（毛沢東が引用）

octet

$\left\{\begin{array}{ll} p \;\; n \;\; \Lambda & \text{物質} \\ \pi \;\; \Sigma \;\ldots & \text{中間物質} \\ \bar{p} \;\; \bar{n} \;\; \bar{\Lambda} & \text{反物質} \end{array}\right.$

U_3 (a) "p" "n" "Λ" ; χ_0 $(B_0)B^+)$
Gell-Mann–Hara:
(b) "p" "N" "Λ" Σ^+ (B^+)
(a') "Ξ^0" "Ξ^-" "Λ" χ_0 (B_0B^+)
(b') "Ξ^0" "Ξ^-" "Σ^-" $\cancel{\chi_0}$ $\chi^{Z^0}_0$ (B^0)

中野 : x_n parameter
Lorentz 変換 : $+$

植松

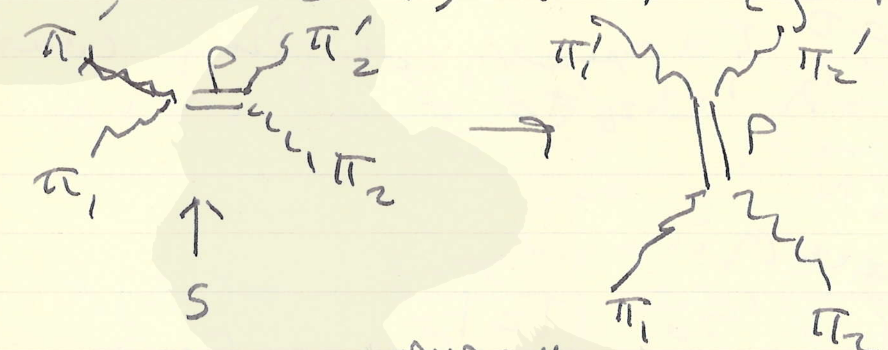
S行列理論での複合粒子

基礎理論講演会, 基研　Feb. 10, 1964

S行列理論の中には
素粒子
複合粒子) 区別する原理はない.
従って すべて同等と考え得る. (民主粒子)
不安定粒子: pole が explicit に導入されていない. 従って 2体に入ったとき pole があるかどうか きめられる筈.
例: π-N resonance　N と N^*_{33}
(N を交換する力が強い引力, 特に 33 状態で強い → N^*_{33})

Chew Bootstrap

π-π　J=1, T=1 (ρ-meson)



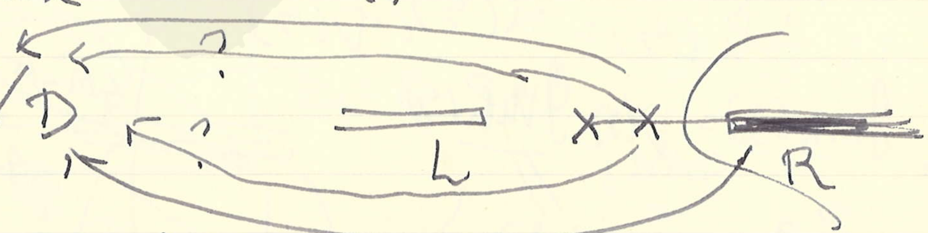
ρ m_ρ
ρππ γ

energy 領域を かえる

ρ meson による resonance

N/D-method　m_ρ, γ の~~関係が出るこ~~がきまる.

$h = N/D$



1. unitarity が満足されている. (右に切断)

c033-714挟込

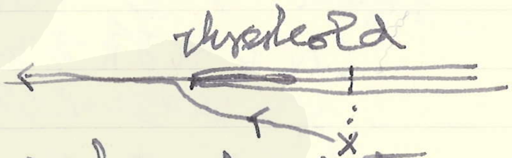
2. analyticity を満たす
3. crossing symmetry を犠牲にする.

$$k \cot \delta(k) = -\frac{1}{a} - r k^2$$

$r > 0$: effective range

a : ($a < 0$ 引力) : scattering length

k : imaginary の resonance → bound state



resonance ⟺ bound state

⟺ 素粒子

$\left. \begin{array}{l} D = 0 \\ \frac{dD}{ds} = \lambda \end{array} \right\}$ meson, coupling constant をきめる.

$\pi = N\bar{N}$

[illegible]の例:

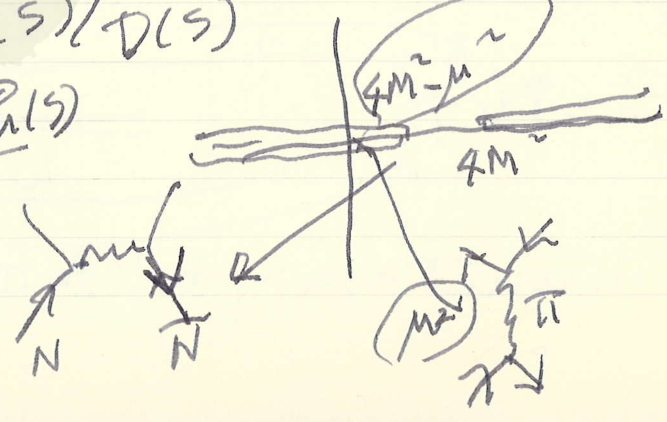
$N\bar{N}$ $^1S_0$, $T = 1$

$$h(s) = \frac{1}{\rho(s)} e^{i\delta(s)} \sin \delta(s)$$

$$\rho(s) = \frac{P}{W} = \sqrt{\frac{s - 4M^2}{s}}$$

$$h(s) = N(s)/D(s)$$

$$\mathrm{Im}\, N(s) = D(s)\, \underline{\mathrm{Im}\, h(s)}$$
$$\quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \;\; \| $$
$$\quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad V(s)$$



$$h(s) = \frac{g^2 s}{\mu^2 - s}$$

$$g^2\mu^2 = N(\mu^2) \Big/ \frac{1}{\pi}\int_R ds' \frac{\rho N(s')}{(s'-\mu^2)^2}$$

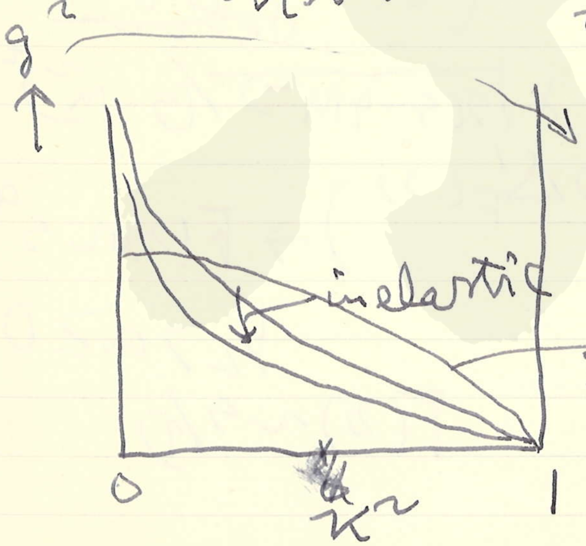
$$= 1 \Big/ \frac{1}{\pi}\int_R ds' \frac{\rho\, n(s')}{(s'-\mu^2)^2}$$

$$\kappa^2 = \frac{\mu^2}{4M^2};$$

$$g^2\kappa^2 = 1 \Big/ \frac{1}{\pi}\int_1^\infty ds' \frac{\rho\, n(s')}{(s'-\kappa^2)^2} \qquad (1)$$

$$n(s) = 1 + \frac{s-\kappa^2}{\pi}\int_{-\infty}^{1-\kappa^2} ds' \frac{v(s')\,\cancel{ds'}\,d(s')}{(s'+\kappa^2)(s'-s)}$$

$$d(s') = -\frac{s-\kappa^2}{\pi}\int_1^\infty ds' \frac{\rho(s')\,n(s')}{(s'-\kappa^2)(s'-s)}$$



$g^2_{NN\pi} = 35$

$v(s)$: π, ρ, ω

併 行 3]

$$\left.\begin{array}{l} g^2_{NN\rho} = 2 \\ g^2_{NN\omega} = 8 \end{array}\right\}$$

Lagrangian の (?) の equivalence

Jouvet 4 fermi ⟷ Yukawa

Weinberg ↓

~~(?)~~ ← $Z_3 = 0$

Vaughn et al : Lee Model

pair cheng K_ξ^ξ K_m^ξ ↓ $Z_V = 0$

Zachariasen

Dowker

Pole equation ($D=0$)

Residue equation ($\frac{dD}{ds} = \lambda$) equivalent $Z = 0$

$$\Delta_F'(s) = \frac{1}{M^2 - s} + \frac{1}{\pi}\int \frac{\rho(s')}{s'-s}\,ds'$$

$$\rho(s) = g^2 |F(s)|^2 \times \sqrt{s(s-4M^2)}/(s-\mu^2)^2$$

$$Z_3^{-1} = \lim_{s\to\infty} (\mu^2 - s)\Delta_F'(s)$$ } → $F(s) \sim s^a$

引き算なし

$\frac{1}{2} > a \geq 0$

$\Delta_F' = D_F(s)/D(s)$

$F(s) \sim s/D$

$$Z(s) = 1 + \frac{s-\mu^2}{\pi}\int ds' \frac{g^2\sqrt{\cdots}\,|\Gamma(s')|^2}{(s'-\mu^2)(s'-s)} \quad \varepsilon C\frac{s-\mu^2}{s_0-s}$$

$0 \leq C < 1$

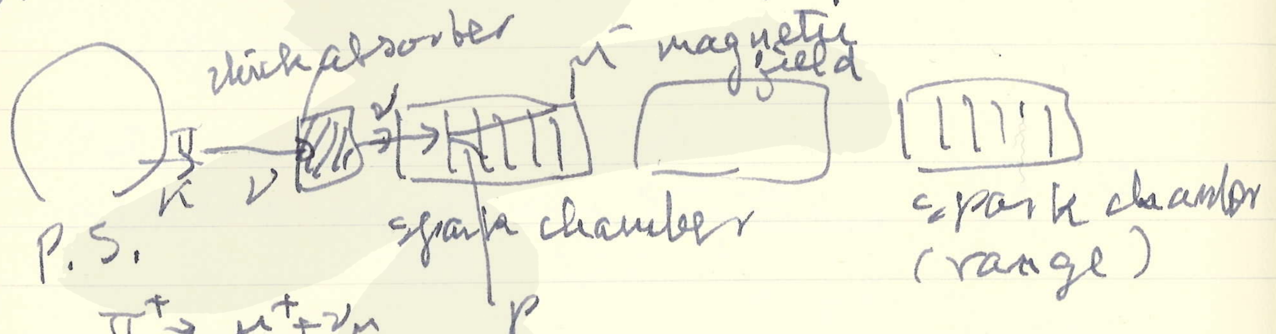
$Z_3 = \lim_{s\to\infty} Z(s) = 0$ とすると

(1)と違った式になる。

[illegible]氏：
CERNの ν W 関係実験
[illegible] Feb. 17, 1969

Sienna Conference, Sept.~Oct. 1963
Bernardini et al. (Fukui)
(spark chamber)
Bingham et al. (Yoshiki)
(Bubble chamber)

(A) Bernardini et al. (spark chamber)



P.S.

$\pi^+ \to \mu^+ + \nu_\mu$
$\pi^- \to \mu^- + \bar{\nu}_\mu$
$K_{e3} \to \nu_e$

$\nu_\mu + n \to p + \mu^-$
$\bar{\nu}_\mu + p \to n + \mu^+$

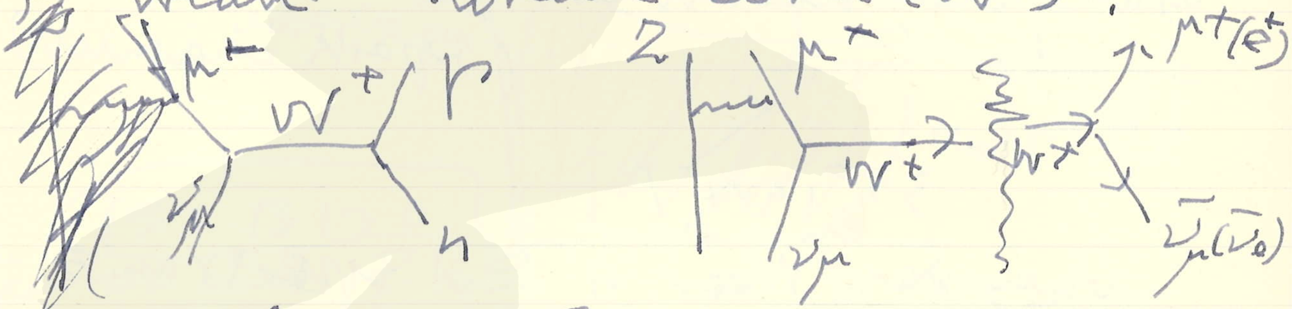
(1962 Brookhaven
$\nu + n \to p + \mu^-$ 30
$\to p + e^-$ 0)

3000 ν-events ($\bar{\nu} \lesssim 10\%$)
~150 $\bar{\nu}$-events ($\nu \sim 10 \sim 30\%$)

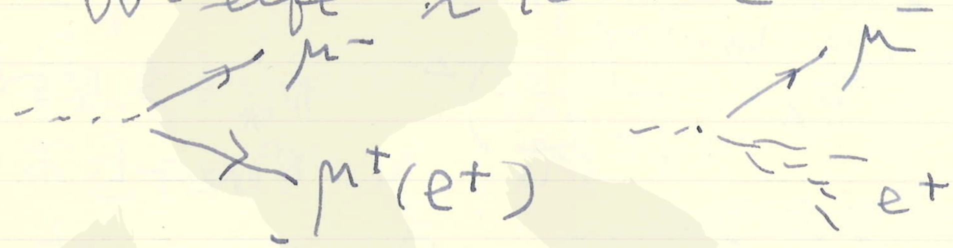
1. $\nu_\mu \mp \nu_e$ 2000 ν-events
e^- (13±5) → $K_{e3} \to \nu_e$ (1%)
μ^- (1150)

2. neutrino flip はない。
$K_{\mu 2} \to \mu + \nu_e$?
8% の e^- が expect される筈.
$E_\nu > 4$ GeV は $K_{\mu 2}$ から出るもの多い
観測: $18\mu : 1e$

3. W-boson
strong Yukawa boson (π)
weak Yukawa boson (W) ?



Lee-Yang の計算
W-life ≈ 10^{-17} sec



Muon pair
2100 events 中　32 pairs (1%)
μ^--e^+ pair
2100 events 中　19 pairs (1%)

⑬ Bingham et al: (Bubble chamber)
136 events.　0 electron
$\nu_\mu \neq \nu_e$ はよい.

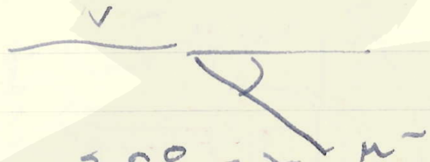
136 件 { elastic 68 ($\nu + n \to p + \mu^-$ 等)
inelastic 68 (π などがでている場合)

K^0 1 例
K^+ 1
Λ 1
$\Lambda + K^0$ 1

pair 1 例.

○ W-boson の間接的 check

a) angular distribution



(spark chamber)

35° 以内 μ^-

van der Meer の E_ν spectrum を仮定.

i) $F_A = F_V$ → stanford　$M_W = \infty$　でよく合う

ii) form factor

$$F_A = \left(\frac{1}{1+\frac{q^2}{M_*^2}}\right)^2$$

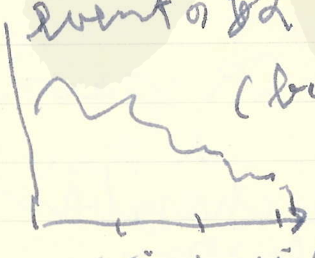
$M_* = 3.75$ GeV
$M_W = 1.3$ GeV

でもあう.

(F_V: stanford)

b) ν-events 62 例

event の数



(bubble chamber)

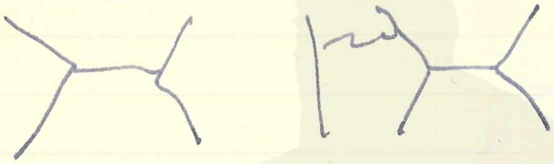
0.5　1　1.5　q^2 $(\mathrm{GeV}/c)^2$

i) $F_A = F_V$, $M_W = \infty$ であう

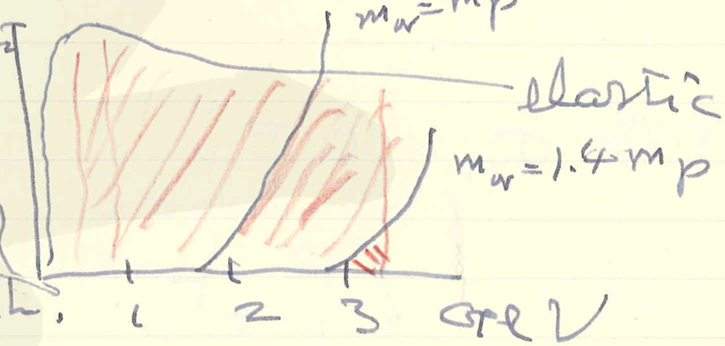
ii)′ $F_V = F_A = F_{em}$, $M_W = 1.3$ GeV

(又, $M_A = \infty$, $M_W = \infty$ は合わない)

(C) Bell et al. : CERN Experiments から の Conclusions

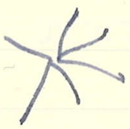


$M_W = M_p$ なら 35% pairs
$M_W = 1.3$ GeV 6% pairs
$M_W \gtrsim 1.3$ GeV である



(D) Glashow et al : P.R.L. 133 B130
6 ete fermi :
$\nu' + p \to \mu + W + p$
$\lambda^3 \frac{G}{\sqrt{2}} (\bar\mu \nu')(\bar\nu e)(\bar p p)$
$\lambda \gtrsim 150$ MeV
$\frac{f_0}{M_I} \sim \sqrt{10} \sim 3$ (lauger)
$\left(\frac{m_\mu}{\lambda}\right)^3 \lesssim 1$

(E) Yoshiki, bubble chamber
68 elastic の中 17例をとりだす
p_ν に peak がある, 0.68 ± 0.10 GeV/c
total energy 1.44 GeV

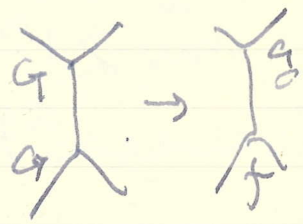


Tanikawa boson?
Yoshiki → 中する

$\sigma \sim 4\pi \lambda^2$

$\lambda = \dfrac{2M_B}{M_B^2 - m_p^2}$

$\sigma \sim 2.5 \times 10^{-27}\ \mathrm{cm}^2$
(semi-weak)



実験 $\sigma_\pi \sim C E_\nu^2$
(W-boson
6次 fermi?)
↙ E_ν^4

lepton conserv. もよい

$m_{\nu_e} < 250\ \mathrm{eV}$ (Langer)
β-decay の上限の意

$m_{\nu_\mu} < 3.5\ \mathrm{MeV}$
$\pi \to \mu + \nu$
Dirac 4 comp σ_4
massless 2 comp σ_2 ($\mu \to e + \nu + \bar{\nu}$)
$\nu + n \to p + \mu^-$ (P-value
$\sigma_2 = 2\sigma_4$ (detailed balance)

$\Delta S = \Delta Q$, $\Delta I = 1/2$ の check

$$\frac{\Sigma(\bar{\nu} + n \to \Sigma^- + \mu^+)}{\Sigma(\bar{\nu} + p \to \Sigma^0 + \mu^+)} = \frac{2}{1}$$

octet model での branching ratio

Feb. 19 [illegible]:　　　Feb. 19, 1969

中嶋貞雄　　Broken symmetry

1°. symmetry

2°. Long Range Order を表わす parameter α

free energy: $\Omega(T, \alpha)$

$\alpha \to \alpha'$: $\Omega(\alpha) = \Omega(\alpha')$

condensation

magnet

superconductivity

(superfluidity

gauge transformation

超流動

Bogoliubov Model

boson 斥力

$$H = \int \psi^\dagger(\vec{r}) \frac{p^2}{2m} \psi(\vec{r})\, d\vec{r} + \frac{g}{2} \int \psi^\dagger(\vec{r}) \psi^\dagger(\vec{r}) \psi(\vec{r}) \psi(\vec{r})\, d\vec{r}$$

$$g > 0$$

$$= \sum \varepsilon_p a_p^\dagger a_p + \frac{g}{2V} \sum a^\dagger_{p_1+q} a^\dagger_{p_2-q} a_{p_2} a_{p_1}$$

$$\varepsilon_p = \frac{p^2}{2m}$$

$$a_p^\dagger a_p = \begin{cases} N & p = 0 \\ 0 & p \neq 0 \end{cases}$$ (Bose condensation)

$$\langle a_0^\dagger a_0 \rangle = N_0 \sim N$$

$$\frac{N}{V} = n : 一定 \qquad N, V \to \infty$$

$$\left[\frac{a_0}{\sqrt{V}}, \frac{a_0^\dagger}{\sqrt{V}}\right] = \frac{1}{V} \xrightarrow[V\to\infty]{} 0$$

$$\frac{a_0}{\sqrt{V}} = \frac{a_0^\dagger}{\sqrt{V}} = \sqrt{\frac{N_0}{V}}$$

一般には $\dfrac{a_0}{\sqrt{V}} = \Phi$, $\dfrac{a_0^\dagger}{\sqrt{V}} = \Phi^*$: c-number

Green 函数: (松原式)

$$\psi(x) = e^{\mathcal{H}\tau}\,\psi(\vec{r})\,e^{-\mathcal{H}\tau}$$

$$0 < \tau < \beta$$

$$\mathcal{H} - \mu\int \psi^\dagger\psi\, d\vec{r}$$

μ: chemical potential

$$-\frac{\partial\psi}{\partial\tau} = \left(\frac{p^2}{2m} - \mu\right)\psi + g\,\psi^\dagger\psi\psi$$

$$\langle\psi(x)\rangle = \Phi(\vec{r})$$

$$\langle\psi^\dagger(x)\rangle = \Phi^*(\vec{r})$$

$\neq 0$ (for bose condensation)

$$\psi(x) = \Phi(\vec{r}) + \phi(x)$$

$$\left(\frac{p^2}{2m} - \mu\right)\Phi + g\{|\Phi|^2\Phi + 2\Phi\langle\phi^\dagger(x)\phi(x)\rangle + \Phi^*\langle\phi(x)\phi(x)\rangle + \langle\phi^\dagger(x)\phi(x)\phi(x)\rangle\} = 0$$

$$G(x, x') = -\langle P\,\phi(x)\phi^\dagger(x')\rangle$$

$$F^\dagger(x, x') = \langle P\,\phi^\dagger(x)\phi^\dagger(x')\rangle$$

$$-\frac{\partial G(x,x')}{\partial \tau} = \delta(x-x') + \left(\frac{p^2}{2m} - \mu + 2g|\Phi|^2\right)$$
$$\times G(x,x') - g\Phi^2 F^\dagger(x,x')$$

$$\frac{\partial F^\dagger(x,x')}{\partial \tau} = \left(\frac{p^2}{2m} - \mu + 2g|\Phi|^2\right)F^\dagger$$
$$- g\Phi^{*2} G(x,x')$$

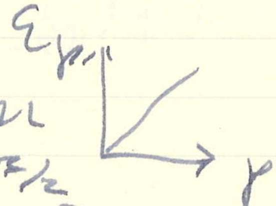
$$\left(\frac{p^2}{2m} - \mu\right)\Phi + g|\Phi|^2\Phi = 0$$

$\left.\begin{array}{l}\Phi \to e^{i\alpha}\Phi \\ \phi \to e^{i\alpha}\phi\end{array}\right\}$ に対して invariant

$\Phi = \sqrt{n_0} \Rightarrow \mu = g n_0$

$$G(p) = \frac{u_p^2}{i\omega - E_p} - \frac{v_p^2}{i\omega + E_p}$$

$$E_p = [\varepsilon_p(\varepsilon_p + 2gn_0)]^{1/2} \to \left(\frac{gn_0}{m}\right)^{1/2} p$$



$$\langle \psi^\dagger \psi \rangle = |\Phi|^2 + \langle \phi^\dagger(x)\phi(x)\rangle = n$$

$$|\Phi|^2 = n\left(1 - \frac{1}{6\pi^2}\frac{(4mgn)^{3/2}}{n}\right)$$

n が小さい所で cond. が多い。

$$\Phi = \sqrt{n_0}\, e^{ikx} \qquad \mu = gn_0 + \frac{k^2}{2m}$$
([illegible])

$$G(x, x') = e^{ik(x-x')} G_k(x - x')$$

mass flow

$$\langle \vec{j} \rangle = \frac{1}{2i} \langle \psi^+ \frac{\partial \psi}{\partial \vec{r}} - c.c. \rangle$$

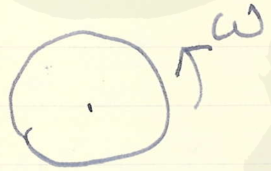
$$= \frac{1}{2i} \left(\Psi^* \frac{\partial \Psi}{\partial \vec{r}} - c.c. \right)$$

$$+ \lim_{\vec{r} = \vec{r}'} \frac{1}{2i} \left(\frac{\partial}{\partial r'} - \frac{\partial}{\partial r} \right) G(r, \tau; r'\tau)$$

$$= (m \cdot n - \rho_n) \left(\frac{\vec{k}}{m} \right)$$

Landau:

$$\rho_n \frac{\vec{k}}{m} = - \int \frac{d\vec{p}}{(2\pi)^3} \, \mathbf{p} \, \frac{(\mathbf{k}\mathbf{p})}{m} \frac{\partial N(E_p)}{\partial E}$$



$$\langle \vec{j} \rangle = \rho_n (\vec{\omega} \times \vec{r})$$

超伝導

$$H_{BCS} = \sum \varepsilon_p a^+_{p\sigma} a_{p\sigma}$$

$$- \frac{g}{V} \sum_p \sum_{p'} a^+_{p'\uparrow} a^+_{-p'\uparrow} a_{-p\downarrow} a_{p\uparrow}$$

一般に $V \to \infty$ で 0 になる

超伝導状態では　これが finite になる.

$$S(\alpha) = \sum_{\vec{p}} \theta_p \left(e^{-i\alpha} b^+_p - e^{i\alpha} b_p \right)$$

$$b_p = a_{-p\downarrow} a_{p\uparrow}$$

$$|\alpha\rangle = e^{S(\alpha)} | \rangle$$

$$E_p = [\epsilon_p^2 + |\Delta|^2]^{1/2}$$

$$\Delta = \frac{g}{V}\langle b_p \rangle$$

$\langle \alpha' | \alpha \rangle \to 0$ for $V \to \infty$

$$|N\rangle = \int_0^{2\pi} \frac{d\alpha}{2\pi} e^{\frac{iN\alpha}{2}} |\alpha\rangle$$

とすれば particle number が一定になる.
gap は g と $\epsilon_F \to n$ が必要

Feb. 19 金曜
荒木不二洋: observable, C^* 代数の Hilbert space の表現
norm と連続 $|\phi(A)| \leq C \|A\|$
弱く連続
ϕ の近傍系. $N(\phi) = \{\phi_1 ; |\phi_1(A_j) - \phi(A_j)| < \epsilon_j\}$
$A_1 \cdots A_N$
$\epsilon_1 \cdots \epsilon_N$
convex combination
$\{\lambda\phi_1 + (1-\lambda)\phi_2 ; 0 \leq \lambda \leq 1\}$
ρ: trace class $\mathrm{tr}(\rho A) = \phi_\rho(A)$
表現の核.
$J_R = \{R(A) = 0$ となる A の全体$\}$

Fell の定理：表現の有り関係は

$\mathfrak{R}_1 \subset \mathfrak{R}_2$

$\overline{\mathrm{conv}\,\omega(\mathfrak{R}_1)} \subset \overline{\mathrm{conv}\,\omega(\mathfrak{R}_2)}$

$J_{\mathfrak{R}_1} \supset J_{\mathfrak{R}_2}$

弱位相 weak neighbourhood をきめる

C* 代数.

例 1, 場の理論
有限な時空領域 B を指定しておく

B → Hilbert空間の operator → C* 代数 $\mathfrak{A}(B)$

$$\mathfrak{A} = \bigcup_B \mathfrak{A}(B)$$

global な量はふくまれていない.
（例えば全電荷）電荷の数

$$H = \sum_{n=-\infty}^{+\infty} H_n \qquad n: \text{電荷の数}$$

$$\int \psi^*(x)\psi(y)f(x,y)\,dx\,dy$$

$\mathfrak{A} \rightarrow H_n$：既約表現

H_0
H_{-1}

$n, \bar{n}$

$n, \bar{n}\,\bar{n}$

例2. 確認か否

i) free vacuum であるかどうかを確認
ii) 粒子が一対として生じているかを確認
iii) 全系が変わっているかを確認.

Haag et al.

$B \to \mathfrak{A}(B)$

1) Isotony $B_1 \supset B_2 \Rightarrow \mathfrak{A}(B_1) \supset \mathfrak{A}(B_2)$

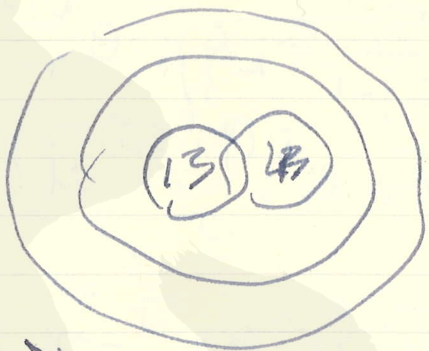
2) Locality B_1 と B_2 が spacelike

$\Rightarrow \mathfrak{A}(B_1), \mathfrak{A}(B_2)$ が可換.

3) Lorentz invariance

$B \to LB$ $\qquad\qquad$ $\mathfrak{A}(B) \to \mathfrak{A}(LB)$

$\mathfrak{A} \to \mathfrak{A}$ $\qquad\qquad$ L: Poincaré 群



4) causality

5) spectrum.

Feb. 20日 午前

荒木：交換関係

$$[q_j, p_k] = i\delta_{jk}$$

$$[\phi(\vec{x}), \pi(\vec{y})] = i\delta(\vec{x}-\vec{y})$$

distribution

$$\phi + i\pi = a$$

$$\phi - i\pi = a^{\dagger}$$

$\phi(\pi)$: distribution

$$\phi(f) = \int \phi(x) f(x)\, dx$$

$$\pi(g) = \int \pi(x) g(x)\, dx$$

$$e^{i\phi(f)} = U(f)$$ (self-adjointなら)

$$e^{i\pi(g)} = V(g)$$

$$A = \sum_{i=1}^{N} c_i U(f_i) V(g_i)$$ $N, \{c_i\}\{f_i\}\{g_i\}$

$$A \cdot A' = \sum_{i,j=1}^{N,N'} c_i c'_j e^{i(f'_j g_i)} U(f_i + f'_j) V(g_i + g'_j)$$

$$A^* = \sum_{i=1}^{N} \bar{c}_i e^{i(f_i g_i)} U(-f_i) V(-g_i)$$

$\|A\|$

Banach 代数 → C^*代数. $\mathfrak{A}$

$f, g \in \mathcal{D}$

無限自由度では inequivalent な表現がたくさんある。

$\mathfrak{A}$ の state ⇒ [illegible]

$\mathfrak{A} \xrightarrow{\tau} \mathfrak{A}$ [illegible] automorphism

$A \in \mathfrak{A} \to A^\tau = e^{iH\tau} A e^{-iH\tau}$ Heisenberg 表示

$\Phi(A^\tau) = \Phi_\tau(A)$

$\Phi \to \Phi_\tau$: Schrödinger 表示

例 1) Free field

2) $V(r)$, $T=0$, ground state

1) Free field (Haag, ISCS)

vacuum $\Phi(u(f)v(g)) = E(f,g)$

$E_f(f,g) = e^{-\frac{1}{4}(f,f)^0 - \frac{1}{4}(g,g) - \frac{i}{2}(f^0,g)}$

a) $T=0$; $E(f,g) = E_F(f,g) \times$

ρ: finite $\times J_0(\sqrt{2\rho(\tilde{f}(0)+\tilde{g}(0)^2})$

$\tilde{f}(0) = \int f(x)\, d^3x$

$J_0(\sqrt{x^2+y^2}) = \int_0^{2\pi} e^{i(x\cos\theta + y\sin\theta)} \frac{d\theta}{2\pi}$

$E(f,g) = \int_0^{2\pi} E_\theta(f,g) \frac{d\theta}{2\pi}$ θ

$\mathcal{H} = \int^\oplus \mathcal{H}_\theta \frac{d\theta}{2\pi}$ と commutative なもの

$R(\mathfrak{A}) = \int^\oplus R(\mathfrak{A}_\theta) \frac{d\theta}{2\pi}$ $R(\mathfrak{A}')$

$\hat{\alpha}$

$R(\mathfrak{A}')$: $\lim_{V\to\infty} \frac{1}{V} \int_V \phi(x) = A$, $\lim_{V\to\infty} \frac{1}{V} \int_V \pi(x) = B$ $\frac{1}{\sqrt{2\rho}}(A+iB) = e^{i\alpha}$

$a \to e^{i\theta_0} a$; $e^{i\alpha} \to e^{i(\alpha+\theta_0)}$

既約表現 a それぞれは gage によって動く。

$R(\alpha)$ on $\mathcal{H}$ mixture

$R_\theta(\alpha)$ on $\mathcal{H}_\theta$ $0 \le \theta \le 2\pi$ 既約

$R_\theta(\alpha)$: cluster decomposition property をもつ。

$$E(f_1+f_2, g_1+g_2) \approx E(f_1,g_1)\,E(f_2,g_2)$$

$R(\alpha)$ は この性質をもたない。
(condensation がある場合)

b) $T \neq 0$: condensation なし。
grand canonical ensemble μ

$$E(f,g) = E_F(f,g)\, e^{-\frac{1}{2}\{(f,\rho f)+(g,\rho g)\}}$$

$$(f \rho f) = \int |\tilde{f}(k)|^2 \rho(k)\, dk$$

$$\rho(k) = \frac{1}{e^{\frac{k^2}{2m}-\mu}-1}$$

c) : a), b) が mix した場合。

例 2) Interaction のある場合。

$$H_V = \int_V a(x)^\dagger \left(-\frac{\Delta_x}{2m}\right) a(x)\, d^3x + \frac{1}{2}\int_V a^\dagger(x) a^\dagger(y)\, V(x-y)\, a(x) a(y)\, dx\, dy$$

$T=0$: $G = \lim_{V\to\infty} \frac{H_V}{V}$ 最小

$$N_V = \int_V a^+(\vec{x}) a(\vec{x}) d^3x$$

$$\lim_{V\to\infty} \frac{N_V}{V} = \rho \quad 一定.$$

cluster decomposition property
を E っ
translational invariance

$$\Phi(a(\vec{x})) = c, \quad \Phi(a(x)^+) = c^*$$

$$\Phi(a(\vec{x})^+ a(y)) = \varphi_2(x-y) + |c|^2$$

$$\Phi(a(\vec{x})\, a(y)) = \varphi_1(x-y) + c^2$$

φ_2, φ_1 : 遠方で小さくなる.

$\tilde{\varphi}_2(k), \tilde{\varphi}_1(k)$: 性質のいい函数.

$\Phi(\cdots)^T = 0$ という近似をする.

$$\rho = |c|^2 + \varphi_2(0)$$

$$\epsilon = -\frac{\Delta_x}{2m} \varphi_2(\vec{x})\Big|_{x=0} + \frac{1}{2}\rho \tilde{V}(0)$$

$$+\frac{1}{2}\int (|\varphi_1(x)|^2 + |\varphi_2(x)|^2) V(x) d^3x$$

$$\left(\tilde{V}(0) = \int V(\vec{x}) d^3x \right)$$

$$+ |c|^2 \int \varphi_2(x) V(x) d^3x + \mathrm{Re}\, c^{*2} \int \varphi_1(x) V(x) d^3x$$

$$\tilde{\varphi}_2(k)(\tilde{\varphi}_2(k)+1) \geq |\tilde{\varphi}_1(k)|^2$$

午後

加藤氏 : scattering, fixed source

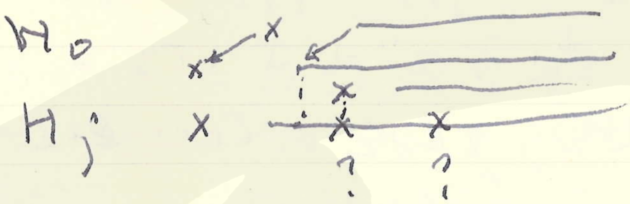
$$\varepsilon \int dt\, e^{-\varepsilon t}\, U_j(t)\,\Phi_0 = \lim_{\varepsilon \to 0} \frac{i\varepsilon}{H_\lambda - E_j + i\varepsilon}\,\Phi_0$$

$\lim \varepsilon \to 0$

$$= (\Psi_j, \Phi_0)\,\Psi_j$$

strong limit

$$H_j^{(0)} = H_0 + E_j \qquad (H_\lambda - E_j)\Psi_j = 0$$



亀淵氏 : broken symmetry

neutral boson

$\phi(x)$: neutral scalar field

V : finite

Λ : cut-off

$$\phi(x) = \frac{1}{\sqrt{V}} \sum_{k} \frac{1}{\sqrt{2\omega_k}} [a_k e^{ikx} + a_k^\dagger e^{-ikx}]$$

$$\omega_k = \sqrt{k^2 + m^2}, \quad [a_k, a_l^\dagger] = \delta_{kl}$$

$$a_k \Omega = 0$$

$$\alpha_k = \cosh\theta_k \cdot a_k + e^{i\varphi_k} \sinh\theta_k\, a_{-k}^\dagger$$

$$\alpha_{-k}^\dagger = e^{-i\varphi_k} \sinh\theta_k \cdot a_k + \cosh\theta_k \cdot a_{-k}^\dagger$$

(fermionなら $\cos\theta_k$, $\sin\theta_k$)

$0 \le \theta_k < \infty, \qquad 0 \le \varphi_k < 2\pi$

(Bogoliubov 変換)

$\alpha_k = G_1 a_k G_1^{-1}$

$G_1 = \exp\left[\frac{1}{2}\sum_k \theta_k \left(e^{-i\varphi_k} a_k a_{-k} - e^{i\varphi_k} a_k^\dagger a_{-k}^\dagger\right)\right]$

$\Phi_0(\theta, \varphi) = G_1 \Omega$

$\alpha_k \Phi_0 = 0$

$\lim_{V\to\infty} (\Phi_i(\theta,\varphi), \Phi_j(\theta',\varphi')) = 0$

$(\Omega, \Phi_0(\theta,\varphi)) = \exp\left\{-\frac{V}{(2\pi)^3}\int d^3k \log\cosh\theta_k\right\}$

translation $\quad \phi \to \phi + \chi$

$\alpha_k = G_2 a_k G_2^{-1} = a_k - \sqrt{V}\,\frac{m}{2}\,\bar\chi\,\delta_{k0}$

$(\Omega, \Phi_0(\chi)) = \exp\left[-\frac{1}{4}Vm|\bar\chi|^2\right]$

$a_k = \cosh\theta_k \cdot \alpha_k - e^{i\varphi_k}\sinh\theta_k \cdot \alpha_{-k}^\dagger$
$\quad + \sqrt{V}\sqrt{\frac{m}{2}}\,\bar\chi\,\delta_{k,0}$

$a_{-k}^\dagger = -e^{-i\varphi_k}\sinh\theta_k \cdot \alpha_k + \cosh\theta_k\, \alpha_{-k}^\dagger$
$\quad + \sqrt{V}\sqrt{\frac{m}{2}}\,\bar\chi^*\,\delta_{k,0}$

$\phi(x) = \bar\chi + \varphi(x), \quad \varphi(x) = \frac{1}{\sqrt{V}}\sum_k \left(u_k a_k e^{ikx}\right.$
$\quad \left. + u_k^* a_{-k}^\dagger e^{-ikx}\right)$

$u_k(\omega_k, \theta_k, \varphi_k)$ etc.

m: $\Phi^{in}(x)$

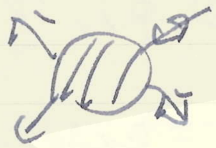
$$P_\mu(\Phi) = P^0_\mu(\Phi^{in}) + Q_\mu(\Phi^{in})$$

transition matrix

$$Q_\mu|0\rangle = 0$$

$$Q_\mu|1\rangle = 0$$

$$\lim_{V\to\infty} \langle j|Q|i\rangle = 0$$



$$\left(\frac{1}{\sqrt{V}}\right)^4 = 0$$

$$V\text{-lim}\,[:\varphi(x_1)\varphi(x_2)\cdots:] = 0$$

$$V\text{-lim}\left[\int d^3x :\varphi(x)^n:\right] = 0 \qquad n \geq 3$$

$$V\text{-lim}\left[\int d^3x\,(\varphi(x))^2\right] = \int d^3x :(\varphi(x))^2: + \text{c-number}$$

$$V\text{-lim}\left\{\int d^3x\,(\varphi(x))^3\right\} = 3C(\theta,\varphi)\int d^3x\,\varphi(x) + \text{c-no}$$

$$V\text{-lim}\left\{\int d^3x\,(\varphi(x))^4\right\} = 6C(\theta,\varphi)\int :\varphi(x)^2: + \text{c-no}$$

$$C(\theta,\varphi) = (\Phi_0(\theta,\varphi), (\varphi(x))^2\,\Phi_0(\theta,\varphi))$$

$$= \frac{1}{2(2\pi)^3}\int d^3k\,\frac{1}{\omega_k}(\cosh 2\theta_k - \cos\varphi_k \sinh 2\theta_k)$$

$$H = H_0 + H' + c\text{-数}$$

$$H_0 = \sum_k \omega_k a_k^\dagger a_k$$
$$\qquad\qquad \downarrow \quad \downarrow$$
$$\qquad\qquad \alpha_k \quad \alpha_k$$

$$H' = \int d^3x \left[f(\varphi^{in}(x))^2 + g\varphi^{in}(x) \right]$$

f, g は θ, φ, χ の函数,

$$V\text{-}\lim H = \sum_k E_k \alpha_k^\dagger \alpha_k \qquad E_k = \sqrt{k^2 + M^2}$$

$$\cosh 2\theta_k = \frac{1}{E_k}\left(\omega_k + \frac{f}{\omega_k}\right)$$

$$\sinh 2\theta_k = \frac{1}{E_k} \frac{|f|}{\omega_k}$$

$$\varphi_k = \begin{cases} 0 & \text{for } f > 0 \\ \pi & \text{for } f < 0 \end{cases}$$

$$\chi = \bar{\chi} = -g/m^2$$

$$\underbrace{M^2 = m^2 + 2f(M)}_{\text{mass equation}}$$

$$L = -\frac{1}{2}(\partial_\mu \phi \partial_\mu \phi + m^2 \phi^2) - \frac{\lambda}{24}\phi^4$$

$\phi \to -\phi$ に invariant でない・・場合もある
(J. Goldstone)

$$\phi(x) = \chi + \varphi^{in}(x) + \cancel{\lambda \int} \cdot$$

$$H = H_0 + H_1$$

$$H_0 = \sum_k \omega_k a_k^\dagger a_k$$

$$H_1 = \frac{\lambda}{24}\int d^3x\, \phi^4(x) = \frac{\lambda}{24}\int d^3x \Big[\varphi^4(x) + 4\chi\varphi^3(x) + 6\chi^2\varphi^2(x) + 4\chi^3\varphi(x)\Big]$$

V-lim:

$$H_1' = \text{V-lim}\, H_1 = \frac{\lambda}{4}\{C(0,\varphi) + \chi^2\}\int d^3x\, \varphi^2 + \frac{\lambda}{6}\{\chi^3 + 3\chi C(0,\varphi)\}\int d^3x\, \varphi(x)$$

$$f = \frac{\lambda}{4}\{C(0,\varphi) + \chi^2\}$$

$$g = \frac{\lambda}{6}\{\chi^3 + 3\chi C(0,\varphi)\}$$

$$\begin{cases} M^2 = m^2 + \dfrac{\lambda}{2}\left[\dfrac{1}{2(2\pi)^3}\displaystyle\int \dfrac{d^3k}{E_k} + \chi^2\right] \\ \chi\left\{\chi^2 + \dfrac{3}{2(2\pi)^3}\displaystyle\int \dfrac{d^3k}{E_k} + \dfrac{6m^2}{\lambda}\right\} = 0 \end{cases}$$

(i) $\chi = 0$, $M^2 = m^2 + \dfrac{\lambda}{2}\left[\dfrac{1}{2(2\pi)^3}\displaystyle\int \dfrac{d^3k}{\sqrt{k^2+M^2}}\right]$

摂動論

(ii) $\chi^2 = \dfrac{6m^2}{(-\lambda)} - \dfrac{3}{2(2\pi)^3}\displaystyle\int \dfrac{d^3k}{\sqrt{k^2+M^2}}$ $\quad \chi = \pm|\chi|$

$$M^2 = -2m^2 + \frac{(-\lambda)}{2(2\pi)^3}\int \frac{d^3k}{\sqrt{k^2+M^2}}$$

$\phi \to -\phi$ に対して invariant では..

$m^2 \lessgtr 0$ でないと困らない。

Q.E.D. の検討.　(e, γ)

$A_\mu \to a_\mu$　　$M \neq m$

$M = 0$ or $M > 2m_e$

Yang-Mills field

isotriplet - vector fields

M_1, M_2, M_3 の値が等しくない

$M_3 = 0$, $M_1 = M_2$ はあり得る.

Nambu-model

$\psi(x) = \psi^{\cdots}(-x)$

Feb. 21.　午前

島本氏:　QED の Convergence?

Landau et

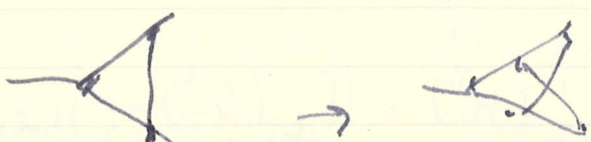
Bogoliubov and Shirkov

$$L = -\bar{\psi}(\gamma p - m)\psi + (\partial_\mu A_\nu)^2 + e\bar{\psi}\gamma_\mu A_\mu \psi$$

$$S(x, x') = i < T(\psi(x)\psi^{+}(x')) >$$

$$D_{\mu\nu}(x, x') = i < T(A_\mu(x) A_\nu(x')) >$$

$$\int \cdots \Gamma_\mu(x, y, z) = < T(\psi(x), \psi^{+}(y), A_\mu(z)) >$$



$(e^2 \log \Lambda^2)^2$　→　$(e^2 \log \Lambda^2)^n$

Landau gage

$$D_{\mu\nu}(k^2) = \frac{d_t(k^2)}{k^2}\left(\delta_{\mu\nu} - \frac{k_\mu k_\nu}{k^2}\right) + \frac{d_\ell(k^2)}{k^2}\frac{k_\mu k_\nu}{k^2}$$

$$A_\mu(x) \to A'_\mu(x) + \partial_\mu \lambda(x)$$

$$\langle A\ A\rangle \to \langle A'\ A'\rangle + \langle \partial_\mu\lambda\ \partial_\nu\lambda\rangle$$

$$S(p) \to \frac{\beta(p^2)}{\not p}$$

$$\Gamma_\mu(p, p-l, l) \to \gamma_\mu \alpha(p^2)$$

$\beta(p^2)\alpha(p^2) = 1$ (Ward's identity

$$\Gamma(p, p, 0) = \frac{\partial S^{-1}(p)}{\partial p}$$

$$\alpha(p^2) = \exp\left(\frac{e^2}{16\pi^2}\int^{\xi} d_\ell(\xi)\,d\xi\right)$$

$$\xi = \ln\left(-\frac{p^2}{m^2}\right)$$

$$\alpha(p^2) = \left(\frac{\Lambda^2}{p^2}\right)^{\frac{e^2}{16\pi^2}d_\ell} = Z_2$$

$d_\ell = 0$ というgageをとれば Z_1, Z_2 の発散はあらわれない。

Z_3 については

$$\Pi'_{\alpha\tau}(k^2) = \Pi_{\alpha\tau}(k^2) - \Pi_{\alpha\tau}(0)$$

$$d_t(k^2) = \frac{1}{1 + \frac{e^2}{12\pi^2} \ln\left(\frac{\Lambda^2}{k^2}\right)}$$

$$e^2 = e_1^2 \lim_{k^2 \to 0} d_t(k^2)$$

$$e^2 = \frac{e_1^2}{1 + \frac{e_1^2}{12\pi^2} \ln\left(\frac{\Lambda^2}{m^2}\right)}$$

$$e_1^2 = \frac{e^2}{1 - \frac{e^2}{12\pi^2} \ln\left(\frac{\Lambda^2}{m^2}\right)}$$

$$Z_3 = \frac{e_1^2}{e^2}$$

$$m(\xi) = m(0)\left(1 - \frac{e^2}{12\pi^2}\xi\right)^{\frac{9}{4}}$$

$$\xi = \ln\left(\frac{-p^2}{m^2}\right)$$

$m(0)$: finite as $m(\xi) \to 0$

$$\Lambda \sim e^{-30} m$$

gravitation

Baker–Johnson

$d_e = 0$ $\quad \Pi_{ac}'(k^2) = \Pi_{ac}(k^2) - \Pi_{ac}(0)$

$m_1 = 0$ (mechanical mass of electron)

(Källen, h.S.Z.,)

$S^{-1}(p) = \gamma p + O(p^3)$

$\Gamma_\mu = \gamma_\mu + \cdots$

$D^{-1}_{\mu\nu}(k) = k^2 + O(k^4)$

Goldstone boson

Nambu model

γ_5 不変を破る → zero mass boson が出る (p3)

宮沢
討論: Comments.

物性　　　　　　　素粒子

自由度 N　　　　∞　　　　連続的対称性 / 不可侵性

↓ 有限　　　　　　↓　　　　　　　↓ 解 break down

$N \to \infty$

無限

空間 long range order → ?　　四次元運動量空間

$m^2 = p_\mu^2$ は一種の long range order?

1958 Geneva High Energy Conference

$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\varphi + m^2\varphi = 0 \quad -\lambda^2\varphi^3$

$\varphi = \pm\frac{m}{\lambda} + \varphi' \qquad \left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\varphi' - 2m^2\varphi' \simeq 0$

$V \gtrsim (\lambda/m)^2$ が素粒子のひろがり?　for $|\varphi'| < \frac{m}{\lambda}$

Ω^- の発見　　　Feb. 21, 1964

Brookhaven　　　$\Omega^- \to \Lambda^0 + \bar{K}^-$

$\tau \sim 10^{-10}$ sec

[illegible]

[illegible]

核力研究会　　コロキウム室
世話人：亘，　荒木　3.23〜25, 1964

3月
23日　午前
細田：3O-potential
岩崎・内田：

$V_Q \cdot \frac{1}{2}\{(L\sigma_1)(L\sigma_2)+(L\sigma_2)(L\sigma_1)\} \to -[(LS)^2-\delta_\pi L^2]$

L^2

52 MeV
310 MeV
660 MeV

大機：$\langle V_Q \rangle > 0$
OPE　pv
TPE　ps
O-vector exchange
○ {970 MeV　H-wave ; 660 MeV　F-wave}　$\langle V_Q \rangle > 0$))
○ 210, 310 MeV
○ 150 MeV
○ 95, 65, 52 MeV
np-polarization　24 MeV, 16 MeV　) YLAM'
○ Effective range theory (S-wave)

堀：Two π-exchange?
range の変化
中間状態のエネルギー difference の) min.

$Mc^2 - \frac{E}{2} \to \kappa = \kappa_0(1-\frac{E}{2\mu})$

互作用 = ps or pv

$$\left.\begin{matrix} V_a \\ V_{LL} \end{matrix}\right\} \rightarrow \left\{\begin{matrix} \lambda = +1 & (pv) \text{ or } 1 > \lambda > 0 \\ \lambda = -1 & (ps) \text{ or } 0 < \lambda < -1 \end{matrix}\right.$$

region II で $3\mu_s^r \gtrsim 0$ なら $\lambda > 0$

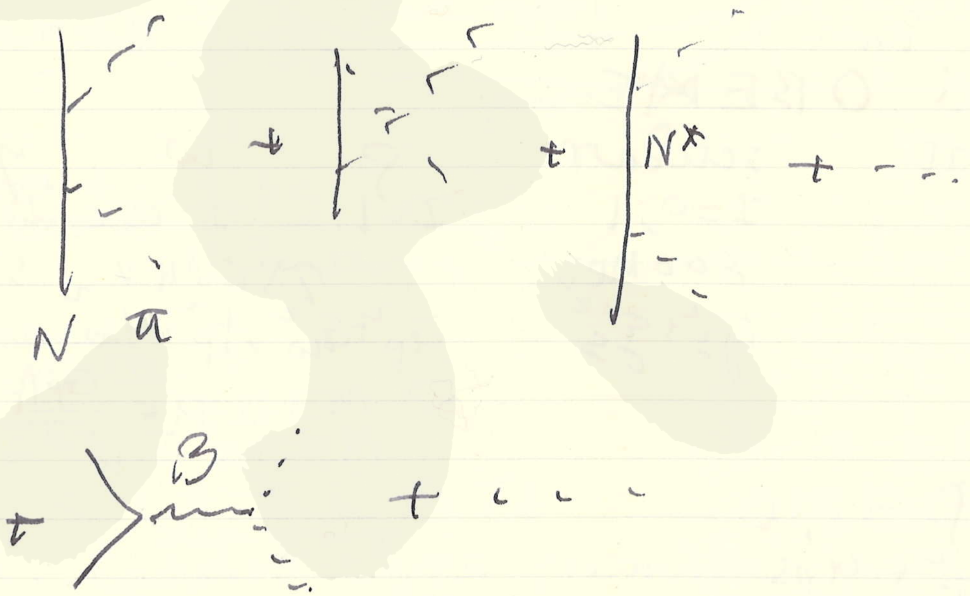
結論: OBEM

$(f+g)^2 = 14.4$ $\quad \left\{\begin{matrix} f = pv \\ g : ps \end{matrix}\right.$

$C = f^2 + 2gf$

$0.4 < f/g < 0.5$

$-3.0 < f/g < -2.0$

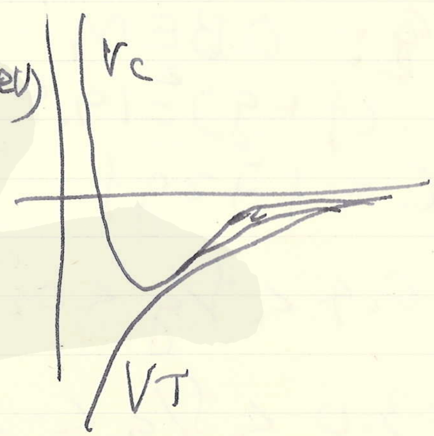


Deuteron Problem

核力： OBEP-model　くりかえし入り
OBEC-model　くりかえしなし；
(non-static effect を
bound して…)

○ OBEP ~~+ π, σ, e~~ Recoil. Effect σ + LS.
$\boxed{\text{OBE-model}}$

π　ρ　ω　5 (560 MeV)
750 MeV



24日 9時.
核力： OBEMC

π	scalar	ρ	ω	η
	I=0,1	I=1	I=0	I=0,1
	600 MeV		750 MeV	550 MeV
	$g_s^2 + g_s'^2$	$G_\rho^2 + G_\omega^2$, $f_\rho^2 + f_\omega^2$		

$R = \frac{G_\rho f_\rho + G_\omega f_\omega}{\sqrt{\ }}$

φ
$G_{ps}^2 + G_{ps}'^2$

$g_s^2 = 13.1 \pm 0.9$　(13.7 ± 1.0)　$({}^3P_J, {}^3D_2, {}^3D_3, {}^1P_1)$
$G_{ps}^2 = 0$　(5.0)　(Fig. 1, 2, 3, 4)

ω-meson (I = 0)

G_V^2	$(G_T)_V$	f_V^2
(20~13)	(3.5~0)	(0.6~0)
16~12	2~0	0.2~0

(〃)

ρ-meson (I = 1)

(16~20)	(12~14)	(9~7)
12~16	8~10	6~7

Region	I	II	III
		0.7~0.6	$(m_\pi)^{-1}$
small phase shift	OPE OBEC	^3P_J →	higher mass boson? or 近距離を考えるか？
↓ Born の悪さ	$^3P_0$ 60~200MeV		
phase shift 大	$^1S_0$ →		
~~bound state~~	$^3S_1$ deuteron →		$^3S_1$

bound state

BEM { OBEM の
MBEM

OBEM { 1. くりかえしがない　OBEC
2. ladder type (damping, nonlocal, potential的)
MBEM 3. 全てのくり返し.
OBE Approximation

~~[illegible]~~ 福田: f^0 の contribution

$2^+(?)$ 1260 MeV $\quad$ 2π-decay $(I=0?)$

$$\begin{cases} \phi_{\mu\nu} = \phi_{\nu\mu} \\ \partial_\mu \phi_{\mu\nu} = 0 \\ \phi_{\nu\nu} = 0 \end{cases}$$

$$[\phi_{\mu\nu}(x), \phi_{\alpha\beta}(x')] = \frac{1}{2i}\left(d_{\mu\alpha} d_{\nu\beta} + d_{\mu\beta} d_{\nu\alpha} - \frac{2}{3} d_{\mu\nu} d_{\alpha\beta}\right) \Delta(x - x')$$

$$d_{\mu\nu} = \delta_{\mu\nu} - \frac{\partial_\mu \partial_\nu}{\kappa^2} \qquad (\kappa : f^0\text{-mass})$$

$$L_{int} = -\frac{g}{m} \bar{\psi} \gamma_\mu (\partial_\nu \psi) \phi_{\mu\nu}$$

LS

central $\quad$ 引力

24日 金曜

武市 (立教): OBEC と dispersion の比較.

$$h_\ell(\nu) = \frac{1}{p(\nu)} e^{i\delta_\ell(\nu)} \sin \delta_\ell(\nu)$$

$$\nu = \vec{p}^2$$

dispersion

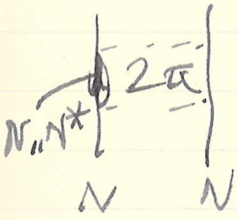
$$h_\ell(\nu) = \frac{1}{\pi} \int^{-\mu^2/4} \frac{d\nu'}{\nu' - \nu - i\epsilon} \operatorname{Im} h_\ell(\nu')$$

$$+ \frac{1}{\pi} \int_0^{\infty} \frac{d\nu'}{\nu' - \nu - i\epsilon} \operatorname{Im} h_\ell(\nu')$$

$$\nu \geq 0 : \quad \operatorname{Im} h_\ell(\nu) = \rho(\nu) |h_\ell(\nu)|^2$$

g^4: $h^{(a)} + \tau^{(1)}\tau^{(2)} h^{(b)}$

$I=0$	$I=1$
scalar	π
ω	ρ
φ	

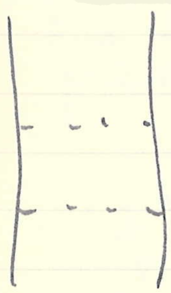


S-wave	P-wave
P-wave	F-wave
⋮	⋮

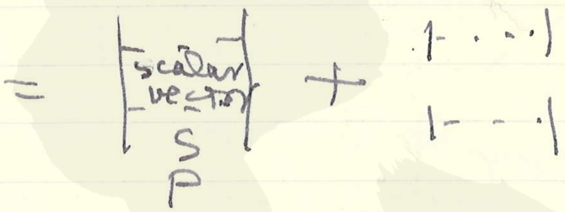
$|\mathrm{Im}\, h^{(a)}| \gg |\mathrm{Im}\, h^{(b)}|$

HM.　　33 の弱さ

"くりかえし"の計算.　　neutral scalar



振動 → 部分波　$h_\ell(\nu)$



$$\left[Q_\ell\left(1+\frac{\mu^2}{2\nu}\right)\right]^2 = \int_{4\mu^2+\frac{\mu^4}{\nu}}^{\infty} \frac{dt}{\sqrt{t\left(t-4\mu^2-\frac{\mu^4}{\nu}\right)}}\, Q_\ell\left(1+\frac{t}{2\nu}\right)$$

?

湯之：金岡：(九大)

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

2π contribution

π-π

○ dispersion
○ inelastic は無視
○ s-state, p-state (d-state以上無視)
○ ABC: mass Γ 　実験値
　ρ: 〃 〃

ABC	310 MeV	16 MeV
ρ	751	110

π-N

form factor?

木下 (九大) (植村)
vector particle と nucleon の相互作用
φ-meson (1020 MeV, I=0, J=1)
　820 ~ 1380 MeV
ρ-meson (750 MeV)
ω-meson (782 MeV)

$$F_1^p(q^2) = 1 - q^2\left[\frac{a}{q^2+m_\rho^2} + \frac{b}{q^2+m_\omega^2} + \frac{c}{q^2+m_\varphi^2}\right]$$

$A^s \to j^s \to \omega,\ \varphi$

$A^v \to j^v \to \rho$

$a \propto g_{\rho NN}$

$\langle r_{1n}^2 \rangle \simeq 0$

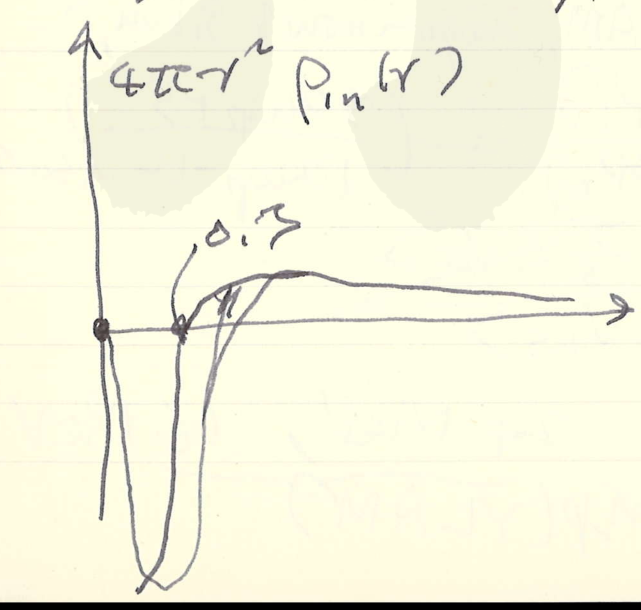
$$\frac{a}{m_\rho^2} \simeq \frac{b}{m_\omega^2} + \frac{c}{m_\varphi^2}$$

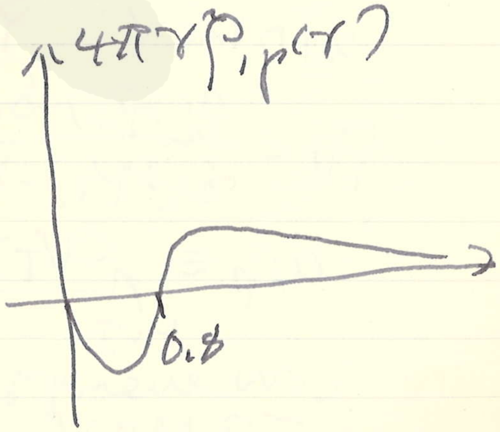
$F_2^p(q^2) \to x,\ y,\ z$
(F_2^v)

parameter の数: 6 個
$a,\ b,\ x,\ y,\ z,\ m_\varphi$

$q^2 \simeq 0.29 \sim 50$

34 点.　$\chi^2 = 12$





$f_\rho/g_\rho \simeq 0.333$

$f_\omega/g_\omega \simeq 0.357$

$f_\phi/g_\phi \simeq 2.22$

核力 III. LS potential, V_T
one vector particle

$$V_{LS} = -G_V\left(1+\frac{1}{x_V}\right)\frac{e^{-x_V}}{x_V^2}$$

$$x_V = \begin{cases} 5.5x & \rho, \omega \\ 7.3x & \phi \end{cases}$$

$G_V > 0$

$$\lambda_p \equiv \frac{1}{12}\left(2\delta(^3P_0)+3\delta(^3P_1)-5\delta(^3P_2)\right)$$

$\cong -\langle V_{LS}\rangle_{Born}$ Signell

210 MeV: YLAM, Kazarinow & Silin,

$$\rho_P = \frac{\delta(^3P_0)-\delta(^3P_1)}{\delta(^3P_1)-\delta(^3P_2)} = -\left(\frac{30\omega_p+5}{12\omega_p-10}\right)_{Born}$$

$$\omega_p \equiv \frac{\langle V_T\rangle \cancel{- \frac{5}{6}\langle V_a\rangle}}{\langle V_{LS}\rangle}$$

H.J.

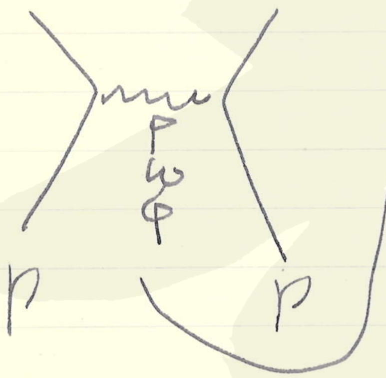
low energy
52 MeV, 29 MeV, 16 MeV
η_p(YLAM)

$\lambda_p = -0.21 \pm 0.01$

$\omega_p = \begin{cases} \text{YLAM} & -1.86 \\ \text{核研} & -4.34 \end{cases}$

LS力は one vector particle exchange だけでは説明できない…？

核力 II. (OBEM)



$M = \dots + C(\sigma_1 + \sigma_2)\cdot L + \dots$

J. J. Sakurai

やはり 210 MeV と 5〜MeV
とconsistentでない

いずれにしても LS力は low energy でつよい。

[illegible]氏: pp-scattering の potential analysis.
E < 100 MeV と E > 100 MeV と smooth につながらない。

$^1S_0$

1) Coulomb に対する vacuum polarization の補正.
2) Coulomb + $V_{p,p}$
3) effective range theory での $^1S_0$ について の議論.

$^3P_0$

西村 (核研):

[illegible] ([illegible]):
970 MeV p-p
$I(\theta)$, $P(\theta)$
Birmingham の新しい data (Dowell et al.)
Coulomb interference

25日: 午前
西村 (核研):
$^3P_0$ の評価.

TPE → OBE
unified model = {OPE + TPE + …}

$$TPE = a(E_p)\cdot TPE_{non} + \{1 - a(E_p)\}\, OBE$$

[illegible] ? [illegible] で [illegible]
評価になる.

大概: (Hard or Soft) Core ([illegible])

$^1S_0$: $V(x) = -\frac{f^2}{4\pi}\mu\,\frac{e^{-x}}{x}\left\{1 + A\,\frac{e^{-x}}{x} + B\,\frac{e^{-2x}}{x^2}\right\}$

$$\times \underbrace{\left[1 - e^{-5(x-x_c)}\right]}_{\text{cut}} \qquad x > x_c$$

$V_{core} = G\,\frac{e^{-\kappa x}}{\kappa x}$ Yukawa

$= G\mu\, e^{-(\kappa x)^2}$ Gauss

$= G\mu\, e^{-(\kappa x)^4}$ Modified-Gauss

Yukawa (long-tailed)

$\kappa = M_n$ $\qquad x = \frac{M_n}{2}$

ぐらいと[illegible].

$|V|\left(\frac{k}{M}\right)^2$ 程度のenergy dependence
があれば良い.

hard core $0.3\sim0.4/\mu$

soft core $0.4\sim0.5/\mu$

$V\sim0 \rightarrow$ $2\sim4$ GeV

高さ

Seiler, P.R.L. 10/8 (1963)

$p > 8$ GeV/c

(Regge (t: 小さい) : $\frac{d\sigma}{dt} = f(t)\left(\frac{s}{2M^2}\right)^{2\alpha(t)-2}$

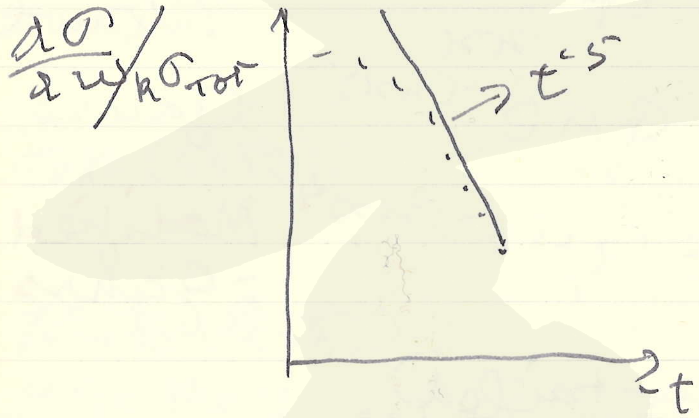
$\sim f(t) \exp\left[-2|t|\alpha' \ln \frac{s}{2M^2}\right]$

$s = (\text{c.M. energy})^2$

~~Tlab~~ $T_{lab} = \frac{s-4M^2}{2M}$

$-t = (\text{c.M. mom. transfer})^2$)

$\therefore -t = 0.2 \sim 5\ (\text{GeV}/c)^2$



optical model → t^{-6}

$\propto \frac{1}{x}$

Auerbach-Brown, P.R.L. 6/1

Krisch, P.R.L. 11/5 $\frac{d\sigma/dt}{(d\sigma/d\Omega)_0} = X(s,\tau)$

$p_\perp = p \sin\theta$

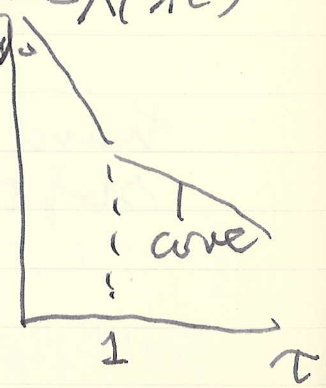
$p_\perp^2 = \tau = -t\left[1 + \frac{t}{s-4M^2}\right]$

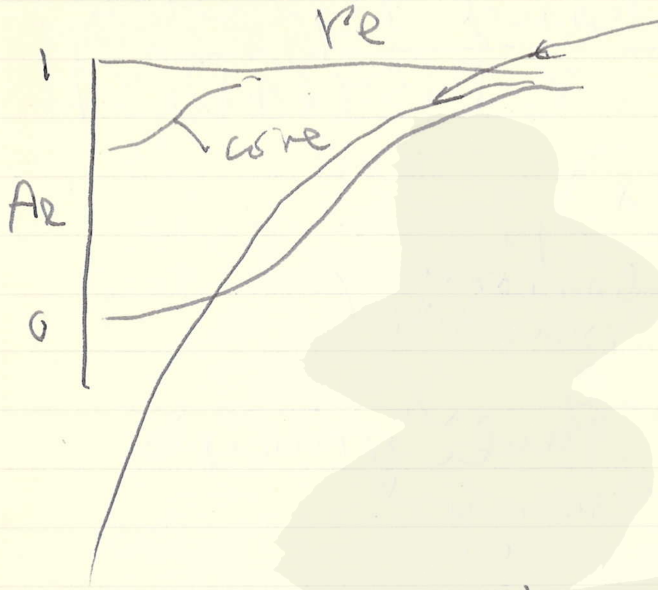
10 GeV 以上で

$\tau = 1.2 \sim 7\ (\text{GeV}/c)^2$

$X(s,t) = 0.999\, e^{-8.93\tau}$

$+ 0.001\, e^{-2.07\tau}$





$A_\ell = e^{-}$
物質の厚み

Orear, P.R.L. 12/4

$X = e^{-\frac{p_\perp}{0.151 (\mathrm{GeV}/c)}}$

$\tau = 1.7 \sim 13\ (\mathrm{GeV}/c)^2$
30 Gev's　90%　　4×10^{-15} cm

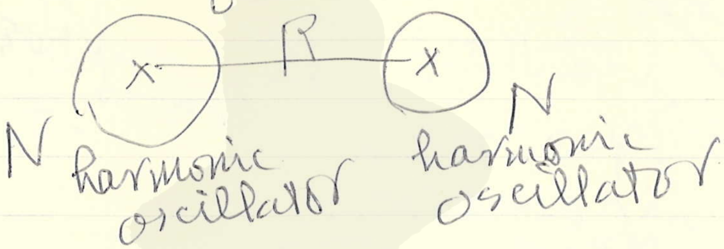
high energy で吸収の方が大きくなる
(中心近く)

Core
　low energy　repulsion
　high energy　absorption

peripheral + core
　P (polarization) ≠ 0
mecuar

① 多体系　exchange repulsion

H. Margenau　P. R. 59 ('41), 37



Rが小さくなると Pauli principle により Kinetic energy

$\frac{3}{2}\omega + \frac{\omega}{2}$

↓

free

$\alpha - \alpha$

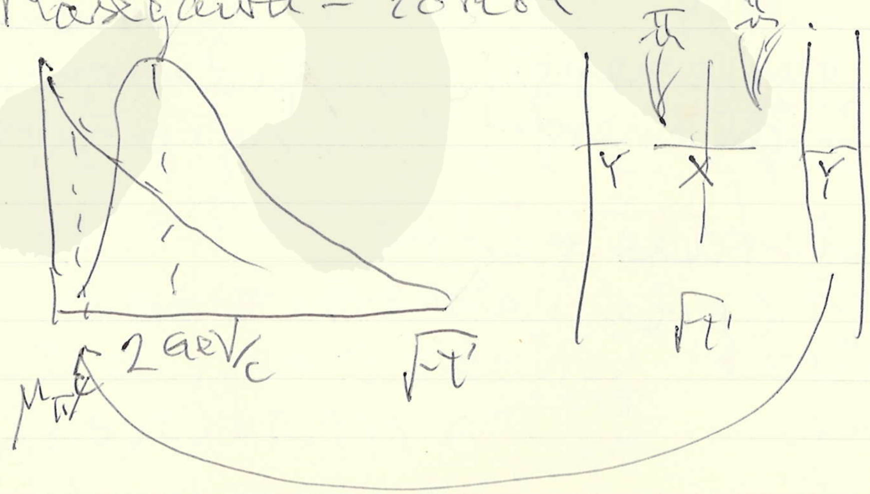
$\alpha - p$.

②

low　high　extreme high

momentum のかわり Mの結合

Hasegawa - Yokoi



$H' = XY\pi\pi\pi\pi$

$H' = XX\pi\pi \cdots$

$M_X \sim \mathrm{GeV}$

$M_Y \sim$ meson

fire ball の存在 even

$N\bar{N}Y$ O.K.

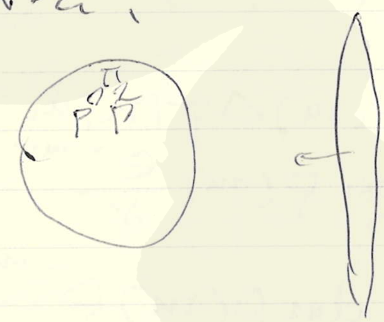
$N\bar{N}X$ No.

$I_X \gg 1$

Thana: X の mass imaginary

$$\frac{}{t' - M_X^2}$$

討論：



25日：午前

午後：相互作用の形態

OPBEC　　Analyticity　　3次元 momentum 空間の potential

"[illegible]"　○　　○　　○

4次元的 (potential?)

○

研究費用 → 大

(3) 3次元 moment
potentialogy と荒路の関係の
irrelat X

(4)
4次元空間との方法
をみやすい。

4次元的

$$(\gamma\partial + m^{(1)})(\gamma\partial + m^{(2)})\Psi(x_1, x_2)$$
$$= \int dx_3 dx_4\, K(x_1, x_2; x_3\, x_4)\Psi(x_3\, x_4)$$

(or $= K(x_1 - x_2)\Psi(x_1, x_2)$

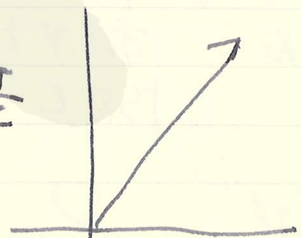
hard core

$$V(\vec{x}) = \int_{-\infty}^{\infty} dt\, K(\vec{x}, t)$$

$$K(x) = \int_0^{\infty} dm\, \rho(m)\Delta_F(x, m)$$
$$V(r) = \int_0^{\infty} dm\, \rho(m)\frac{e^{-mr}}{r}$$

$$U(r) = rV(r) = \int_0^{\infty} dm\, \rho(m) e^{-mr}$$

$$\lim_{r\to\infty} U(re^{i\varphi}) = 0$$
$|\varphi| < \frac{\pi}{2}$



例

$$U(r) = r^{\mu} e^{-ar^{\nu}}$$

$\nu \neq 0$　　$a > 0$　　$\nu \leq 1$　　μ: arb.
　　　　　$a < 0$　　$\nu < 0$

$\nu = 0$　　$\mu < 0$

e^{-r^2} に排除されたら

gauss type → imaginary mass

例えば

$$G_\pm(x) = \int \frac{e^{ipx}}{p^2 - \varkappa^2 \mp i\varepsilon}\, dp$$

$$= \bar{G}(x) \pm \pi i\, G(x)$$

⇓ 三次元化

$$G_\pm(\vec{x}, \varkappa) \sim \frac{e^{i\varkappa r}}{r} = \frac{\cos \varkappa r}{r} \pm i \frac{\sin \varkappa r}{r}$$

$$\int_0^\infty G_\pm(\vec{x}, \varkappa) e^{-\varkappa^2/4\Lambda^2} d\varkappa \sim \frac{e^{-\Lambda^2 r^2}}{r}$$

$$\times \left(1 + \frac{2}{\sqrt{\pi}} \int^{\Lambda r} e^{-x^2} dx\right)$$

$$\int_0^\infty G(\vec{x}, \varkappa) e^{-\varkappa^2/4\Lambda^2} \varkappa\, d\varkappa = e^{-\Lambda^2 r^2}$$

西村：実験計画，
中間子ビーム
20 ～ 30 MeV　polarized beam

藤田：北京ジムポジウム

湯川：素粒子の内部構造と対称性

1. 基研談話会 March, 1964
2. 核力の会 March, 1964
3. 物理学会分科会(素粒子論) April
4. 基研談話会(理研) April 1964
5. 阪大談話会 May 1964

核研: Broken U(4) Symmetry
in Baryon - Meson System
素研談話会
May 11, 1964

Hama, Tanaka, Matsumoto

N. G. $U(2)\times U(1) \downarrow$

Sakata model ← 3つの構成要素

→ $U(3)$ → Baryon octuplet?

↓

$SU(3)$

modified Sakata

Maki, Sogami, Hara

$\chi(\chi_1, \chi_2, \chi_3, \chi_4)$

$l \xrightarrow{B^+, B^0}$ p_0 n_0 Λ_0 Λ_0

Ξ_0^0 Ξ_0^- Λ_0 Λ_0'

$l \xrightarrow{B^+}$ p_0 n_0 V_0^+ Λ_0

$l \xrightarrow{B^0}$ Ξ_0^0 Ξ_0^- V_0^- Λ_0

ν ⇄ 丘

(核粒子)　(丘相)

Broken $U(3)\times U(1)$

Broken $U(4)$

$\chi\bar{\chi}$: $4\times 4^* = 15 + 1 = (3\times 1')\times(3^* + 1'^*)$

$= 8 + 1 + 3\times 1'^* + 1'\times 3^* + 1'\times 1'^*$

$$4 \times 4 \times 4^* = \underbrace{20 + 4}_{} + \underbrace{36 + 4}_{}$$

$$(\underset{6}{[4\times 4]} + \underset{10}{\{4 \times 4\}}) \times 4^* = 24 + 40$$

$$20 + 4 = [3 \times 3] \times 3^* + [3 \times 3] \times 1'^*$$
$$\underbrace{[3 \times 1'] \times 3^*}_{\underline{8+1}} + [3 \times 1'] \times 1'^*$$

$SU(3)$ $\Delta M \propto T_3{}^3$

$U(4)$ $\Delta M \propto T_4{}^4$

Hama:

$$\Delta M = a' + b' S' + c' (M_2 - S'^2)$$

$U(4)$ a infinitesimal generator: $A_\mu{}^\nu$

$$2M \equiv M_2 = \sum_{i,j=1}^{3} A_j{}^i A_i{}^j$$

$$M_1 \equiv -N = A_i{}^i$$

$$M_3 = A\,A\,A$$

$$M'(M_1, M_2, M_3)$$

$$T_3{}^3 = a + b A_3{}^3 + c A_i{}^3 A_3{}^i$$

(Okubo)

$$T_4{}^4 = a' + b' A_4{}^4 + c' A_\mu{}^4 A_4{}^\mu + d' A^4 A A_4$$

$$[A_\rho^\alpha, A_\nu^\mu] = \delta_\rho^\mu A_\nu^\alpha - \delta_\nu^\alpha A_\rho^\mu$$

中間子論における弱い相互作用
研究会　　5.13～5.14, 1964
基研

13: 10.30～12.30　~~西田~~ 小川　(町田)
14.00～15.30　小川 町田　(伊丹)
16.00～17.00　　(宮川)
14　10.30～12.30　中村　
14.00～　谷川　(小川)

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(1) 町田: 弱い相互作用の保存則
(3) 中村. 堂地: lepton と相互作用する
gauge vector meson
(2) 谷川 安孫: non-leptonic decay
(6) 伊丹 西山 中野: High energy neutrino
Process
(4) 山口: Weak の現象論
中村. 谷川: 谷川 boson はあるかないか
(7) 小川: W-boson はあるらしくない
湯川　{ [illegible]
坂田　{ まとめ
武谷　{ 将来の展望
(5) 有山: High energy neutrino process

13日(金)

野田：弱い相互作用の対称性

対称性　Interm. boson　構造

弱い相互作用の方が 対称 素性 悪い. 対称性悪い.

強い相互作用に対する対称性　C_s

弱い 〃 〃　C_w

は反可換.

$$\{C_s, C_w\} = 0$$

I, Y, P

chiral boson
(Tanikawa - Watanabe)

nonleptonic decay　　Y　I

isospace の inv.

$$\Phi \to \Phi' = \{(-1)^Y\}\Phi = \begin{cases} +\Phi & \text{even 場} \\ -\Phi & \text{odd 場} \end{cases}$$

double inversion

$$Q = I_3 + \frac{Y}{2}$$

isochirality

$$\sigma_3 = (-1)^Y \qquad \sigma_1, \quad \sigma_2$$

σ_1 の eigenstate と W.

p, n, Λ の 2種 current　J^*

だけでは　$L_{int} \sim J^* W$

はつくれない.

↗ isospinor　　　　↗ isospinor
isovector　　　　　is-scalar

$p_0, n_0, \Lambda_0, \chi_0^0$

$$\mathcal{L}_{int} = (J + S)\underset{\cos\delta\,?}{W^*} + (j^0 + S^0)\underset{\sin\delta\,?}{N^{0*}} + h.c.$$

$$J + S = (\bar{n}p) + (\bar{\Lambda}p)$$

$$j^0 + S^0 = \frac{1}{2}\{(\bar{p}p) - (\bar{n}n)\}$$

$$+ \frac{i}{2}[(\bar{\chi}_0^0\Lambda) + (\bar{\Lambda}\chi_0^0)] + (\bar{\Lambda}n)$$

commutative + anticommutative

$\cdots\sigma_1 + \cdots\sigma_3$

baryon current の neutral part は何故 lepton current の neutral part に couple ~~る~~ しているのか?

佐川·麦林 : non-leptonic decay of Hyperon

chirality の定義

space parity　　　space chirality

± 1　　　　　± 1

V I A

(Tanikawa-Watanabe)

Tanikawa boson である.

$J_3 = G^2 = \pm 1$　　　$G = e^{i\frac{\pi}{2}\tau_2} \times C$

$(-1)^Y$　　N, Ξ　　Σ, Λ

(iso parity)　-1　　$+1$

J_1, J_2 : isochirality $J_1 = \pm 1$

(Machida)

$$\overbrace{\begin{pmatrix} p \\ n \end{pmatrix} \pm \begin{pmatrix} \Sigma^+ \\ Y^0 \end{pmatrix}}^{N_1}, \quad \overbrace{\begin{pmatrix} Z^0 \\ \Sigma^- \end{pmatrix} \pm \begin{pmatrix} \Xi^0 \\ \Xi^- \end{pmatrix}}^{N_2}$$

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

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

weak interaction については lepton に関係している。

$$(\bar{N}_1 l_1) B_1 + (\bar{N}_2 l_2) B_2$$

B_i : $i = 1, 2$ iso-chirality

		B	l
$l_1 = \begin{pmatrix} e^+, \mu^+ \\ \nu_e^c, \nu_\mu^c \end{pmatrix}$	B_1	1	-1
$l_2 = \begin{pmatrix} \nu_e & \text{or} & \nu_\mu \\ e & & \mu \end{pmatrix}$	B_2	1	$+1$

$$\Big[\underset{\Delta I = 1/2}{(\bar{p} e^+)} \pm \underset{\Delta I = 1}{(\bar{\Sigma}^+ e^+)} \pm \underset{\Delta I = 1}{(\bar{Y}^0 \nu^c)} \Big] B_1^0$$

$$\underset{\Delta I = 1/2}{(\bar{n}\, \nu^c)}$$

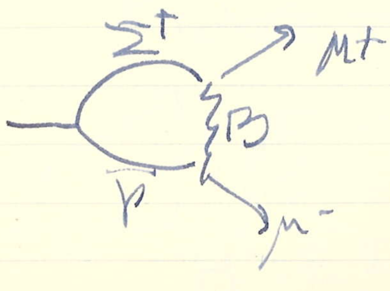
(以下つづく)

$$K_1^0 \nrightarrow \nu + \nu^c$$

$$\nrightarrow e + e^+$$

$$K_2^0 \nrightarrow \mu + \mu^+ \quad ?$$

$$K^\pm \to \pi^\pm + \nu + \nu^c$$



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

$\quad \to n + \pi^0$

Λ spin

$\uparrow \nearrow \pi \qquad \alpha_\Lambda = -0.62$

$\Sigma^+ \to n + \pi^+ \qquad \alpha_+ \simeq 0.05 \pm$

$\quad \to p + \pi^0 \qquad \alpha_0 \simeq +0.78$

$\Sigma^- \to n + \pi^- \qquad \alpha^- \simeq 0.1$

$\Xi^- \to \Lambda + \pi^- \qquad \alpha_\Xi \simeq 0.6 \sim 0.7$

5月14日 午前
小川[illegible]氏)

$$Q = \frac{I_3 + E}{2}$$

SU(2)	ur baryon	lepton	Q	S	I_3
1 [illegible]	χ^0	ν_1	0	−1	+1
1 [illegible]	Λ^0	μ^-	−1	−1	−1
2 [illegible]	n^0	e^-	−1	0	−1
	p^0	ν_2	0	0	+1

global (a) or cosmic (n) → broken SU(3)

trio invariance

[illegible]の sym. group S_3

$$(1)_s + (1)_a + (2)$$

$$\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix} \to \Lambda^0 \ (1), \quad \begin{pmatrix} n^0 \\ p^0 \end{pmatrix} (2)$$

$$V_4 \to \chi^0 \ (1)$$

$$n^0 = \frac{2V_1 - V_2 - V_3}{\sqrt{6}}$$

$$p^0 = \frac{-V_2 + V_3}{\sqrt{2}}$$

$$\Lambda^0 = \frac{V_1 + V_2 + V_3}{\sqrt{3}}$$

$\Delta N = 0$

S_3-inv.

~~$\Delta Q = 0$~~

	I	S
(n^0, p^0)	1/2	0
Λ^0	0	−1

change [illegible]: $\Delta Q = 0 \to$

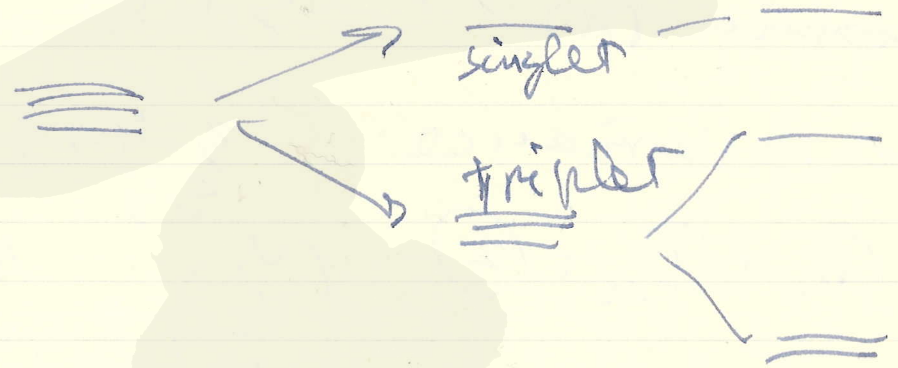
H : C.I.

$\Delta S = 0$

$$H_{int} = a(\bar{p}p + \bar{n}n)^2 + b(\bar{p}p + \bar{n}n)\bar{\Lambda}\Lambda$$
$$+ c\{(\bar{p}n)(\bar{n}p) + \tfrac{1}{2}(\bar{p}p - \bar{n}n)$$
$$\times(\bar{p}p - \bar{n}n) + (\bar{n}p)(\bar{p}n)\}$$
$$+ d(\bar{\Lambda}\Lambda)^2 + f\{(\bar{p}\Lambda)(\bar{\Lambda}p) + (\bar{n}\Lambda)$$
$$\times(\bar{\Lambda}n)\}$$

2 {"Trio spinor" / Pauli spinor} particle system

SU(4)　　SU(3)　　splitting



SI ⟷ space rot + refl

WI ⟷ Lorentz Transf.

$V \to TV$　　$V \propto i\bar{\psi}\gamma_\mu\psi$

$\psi \to t\psi$

$\bar{\psi} = \psi^\dagger\gamma_4 \to \psi^\dagger t^\dagger \gamma_4$

SI は $V_1 V_2 V_3$ の間の置換

WI は V_4 も動かす

WIの拡張.

$\mathfrak{J} \times W$

$\mathfrak{J}_3 \quad \mathfrak{J}_1 \quad \mathfrak{J}_2$

$\{\mathfrak{J}_i, \mathfrak{J}_j\} = 2\delta_{ij}$

χ^0	ν_1	0	-1	$+1$
p^0	ν_2	0	0	$+1$
Λ^0	μ^-	-1	-1	-1
n^0	e^-	-1	0	-1
$\downarrow$	$\downarrow$			
$\mathcal{B}$				

$$2Q - E = \bar{\mathcal{B}} \mathfrak{J}_3 \mathcal{B}$$

$$g[\bar{\mathcal{B}} \mathfrak{J}_1 \mathcal{B} W_1 + \bar{\mathcal{B}} \mathfrak{J}_2 \mathcal{B} W_2]$$

$$\mathfrak{J}_3 = \begin{pmatrix} I & 0 \\ 0 & -I \end{pmatrix} \qquad \mathfrak{J}_1 = \begin{pmatrix} 0 & \omega \\ \omega^{-1} & 0 \end{pmatrix}$$

$$\mathfrak{J}_2 = \begin{pmatrix} 0 & -i\omega \\ -i\omega^{-1} & 0 \end{pmatrix} \qquad \omega: \text{unitary, unimodular}$$

$$\mathcal{B} = \begin{pmatrix} N \\ C \end{pmatrix} \qquad \frac{W_1 \pm i W_2}{2} = \begin{cases} W \\ W \end{cases}$$

$$g[\bar{C}(\omega N) W + h.c.]$$

$$\bar{C}(\omega N) = \bar{\mu}\nu_\mu + \bar{e}\nu_e \qquad \omega \begin{pmatrix} \nu_1 \\ \nu_2 \end{pmatrix} = \begin{pmatrix} \nu_\mu \\ \nu_e \end{pmatrix}$$

(Cabibbo angle)
(1955 or 1958)

$W_{\not{g}} = u^{-1} t u$ S_3 の spinor

2×2

S_3 の (2) を作る

$W\,I$: isospinor

$6 \times 6 = 36$

$|\tan\theta| = \frac{w_{12}}{w_{22}}$ $|\theta| = 15^\circ$

$\tan\theta = 2-\sqrt{3}$

$= 2 - 1.7320508$

$= 0.268$

$\Delta a = \pm 1$

$\Delta s = 0$ and ± 1

	Lorentz	Internal
D	Dirac spinor	scalar
V	Vector	int "spinor"

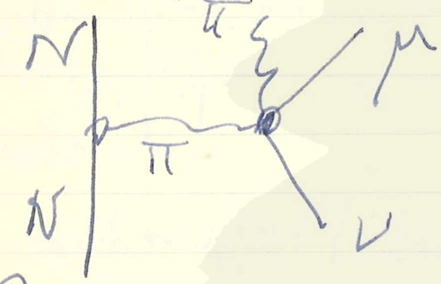
$\overline{D}$ (quartet × quartet) = baryons

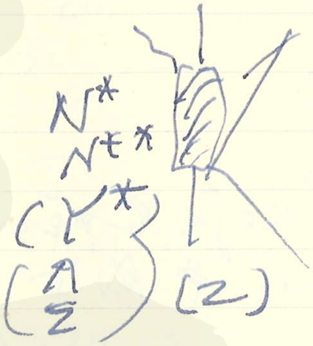
~~[illegible]~~

府ami Neutrino 実験

inelastic cross-section

$$\nu_\mu + N \to \mu^- + N + \pi$$





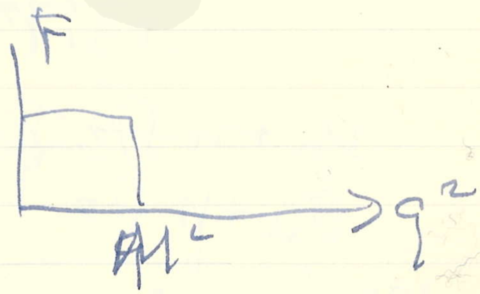
(1) peripheral

W^+ $\begin{cases} \nu + e \\ \nu + \mu \\ \pi + \pi \\ p + \pi \end{cases}$

[illegible]

		BeV			
(1)	k_ν	1	3.0	5.0	
	σ_{tot}	0.1	0.3	0.4	$\times 10^{-38}\,\mathrm{cm}^2$

form factor



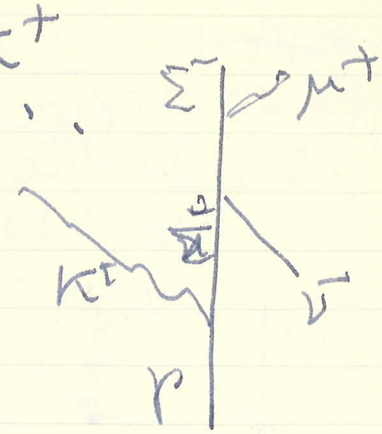
(2) N*	k_ν	3	5
	σ	0.8	1.3

$\sigma(\pi^+) : \sigma(\pi^0) : \sigma(\pi^-) \doteq 1 : 4 : 5$ ↓ $\cancel{Y_1^*}$

$\nu + N \to \mu + \left\{ \begin{matrix} \Lambda \\ \Sigma \end{matrix} \right\} + \pi^c$ $\quad Y_1^* (\Lambda \Sigma)$

$\bar{\nu} + p \to \mu^+ + \Sigma^- + K^+$

peripheral vertex...



14日午後;

仲田; high Energy ν Process と
弱い中間子.

spin 0
V − A　　$H_0 = \{f_0 \bar{p}(1-\gamma_5)\mu^+ + g_0 \bar{n}(1-\gamma_5)\nu_\mu\}$
$\times B^0 + h.c.$

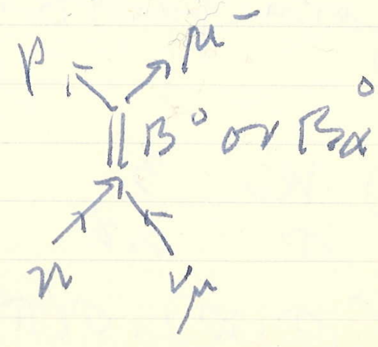
V + A　　$H_0 = \{f_0' \bar{n}(1+\gamma_5)\mu^- + g_0' \bar{p}(1+\gamma_5)\nu_\mu\}$
$\times B^+ + h.c.$

spin 1
V + A　　$H_1 = i\{f_1 \bar{p}\gamma_\alpha(1+\gamma_5)\mu^+$
$+ g_1 \bar{n}\gamma_\alpha(1-\gamma_5)\nu_\mu\} B_\alpha^0 + h.c.$

V − A　　$H' = i\{f_1' \bar{n}\gamma_\alpha(1+\gamma_5)\mu^-$
$+ g_1' \bar{p}\gamma_\alpha(1+\gamma_5)\nu_\mu\} B_\alpha^+ + h.c.$

$\nu_\mu + n \rightleftarrows p + \mu^-$
$\bar{\nu}_\mu + p \rightleftarrows n + \mu^+$

resonance



$\mu^-(\mu^+)$ の角分布 (C.M.S.)

spin 0 : 等方

spin 1 : $I(\theta) \propto a + b\cos\theta + c\cos^2\theta$

		spin 0	spin 1
$M_B = 1.5$ BeV	$\sigma^{(res)}$	1.5×10^{-27} cm^2	4.4×10^{-27} cm^2
	$\sigma^{(eff)}$	2.2×10^{-32} cm^2	2.7×10^{-32} cm^2

幅 200 MeV

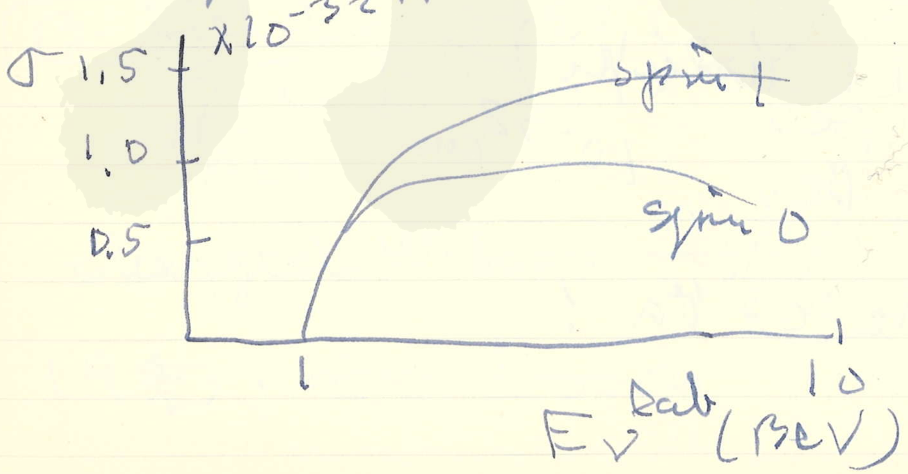
	Γ_ν	Γ_μ
spin 0	1.5 keV	1.4 keV
spin 1	0.63	0.6

$$\nu_\mu + n \rightleftarrows (B) \rightleftarrows p + \mu$$

Γ_ν Γ_μ

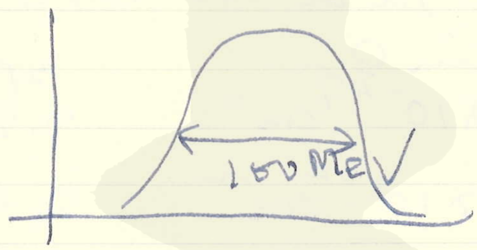
$$\Gamma_\nu = \frac{M_B}{M_N}\frac{1}{\tau_\nu}$$

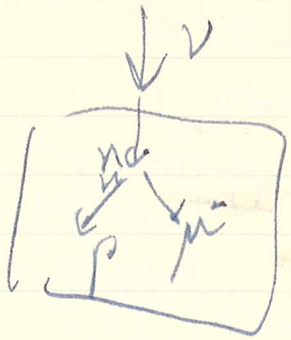
inelastic process



荒川：Cowanの実験

Cosmic ray ν

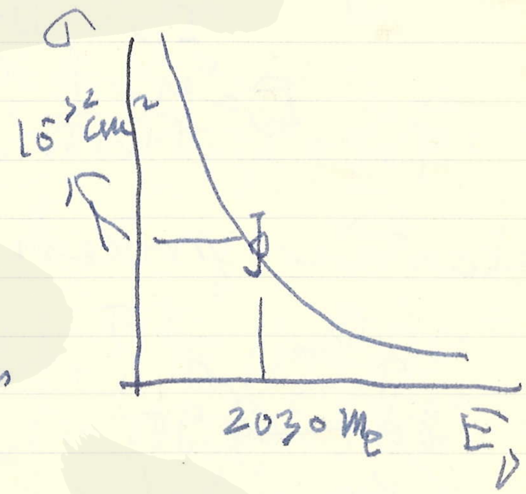




$m_W = 2130\ m_e$ or $2030\ m_e$

$\sigma \sim 10^{-27}\ cm^2$

Crowe
(Berkeley)



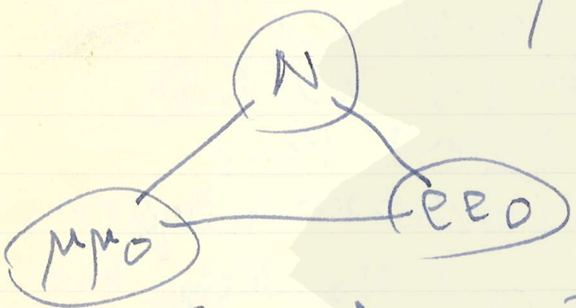
Inelasticの方が困る.

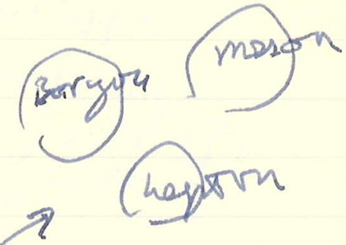
CERN (Yoshiki)

1.3 BeV
1.8 BeV　$10^{-38}\ cm^2$

2[illegible]00 me と一致？

※小川: W boson はあるかないか
1956　Oneda, Ogawa, Okonogi
Fermi interaction の universality
old particle
$N, \mu, \mu_0, e\nu$



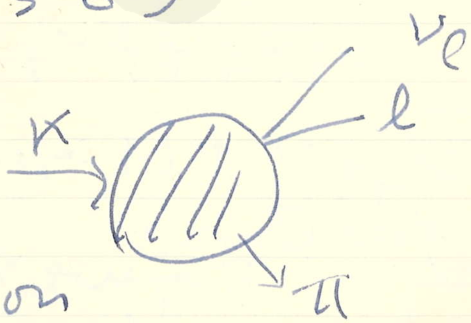


Oneda, Family の考え (1952)
β-F interaction
(1) $g\bar{\psi}O_\mu\psi\psi$　不変性

V, A　$\pi \to \mu\nu$
$\Lambda \to p\pi$
$\pi \to e\nu$　小さい　(1958 Feynman-Gell-Mann)
(2) $e\bar{\psi}\gamma_\mu\psi A_\mu$

Fermi int: $\mu \to e + \nu + \nu$
$\boxed{\beta\text{-field}}$: 1955 (小川氏)
S, T, P → (1956)
K_{e3}

charged W-boson



1943: 谷川 boson

interm. field　　　(Nagoya) model

Y　　　T　　　○

○　　　△　　　△

○　　　　　　　△

chirality　　chiral boson　△

universality (C. V. C)

parity problem (V-A)

① β-l　　[illegible]　　② ○ I = 1/2

　　　　　　　　　　③ △ S ≠ 0　lepton

　　　　　　　　　　N_p　π_{e3}　$\pi_{\mu e}$

　　　　　　　　　　Λ_p　K_{e3}　$K_{\mu e}$

	Y	T	
①	△	△	○
②	○	○	△
③	△	△	△

中村: Yukawa boson はあるか.

1. low energy weak interaction
   weak boson
2. high energy weak interaction
   semi-weak coupling

$$g^2/4\pi \lesssim 10^{-12}$$

$$\nu + N \rightarrow N' + \mu + L + \nu$$

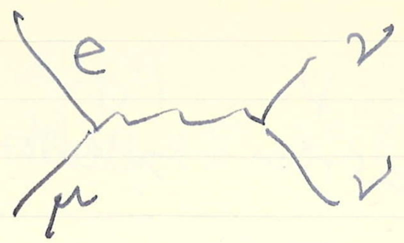
(B)

T? $\nu + N \rightarrow N' + \mu + \pi$

T: (L)

(ν)

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



湯川: Wentzel 1937
遠隔 ~~局地~~ 隔地
外 4 = 3+1
内 4 = 2+1+1 (内部空間)
ether ? 局地的
indefinite metric

坂田:
…… 一基本粒子 → 亜素粒子 ?…
F — Y — F — Y — … ? …
fermion → boson ?
{ baryon → lepton
charged particle → neutral particle

武谷:
素粒子: pair creation
陽 → π
光 → photon
弱 / 重 → } W 重 ∴ continuous mass indef.

ν σ e μ

neutrino sakatorino

Boson Resonances

河辺六男　講演

May 18, 1964

1^- singlet	0^- octet	1^- octet
ω (782)	η (548.5)	ϕ (1020)
	K	K^* (888)
	π	ρ (~~54~~ 757)

2^- octet　　3^- octet

ABC ~ 300

σ	395 ± 10	(250 ± 20)
	520 ± 20	(70 ± 30)
ζ	575 ± 20	
κ	730 ± 10	(≤ 20)
f	1260 ± 35	$(100 \sim 170)$ ≤ 200
$(\pi\omega)$ B	1220	(100)
	1215	(170)
$(K\pi\pi)$ C	1175 ± 50	(40 ± 15)
	1230 ± 10	(80 ± 10)
$(K\bar{K}\pi)$	1410	(60)

§1, C 2° Octet

a) T. P. Wangler, A. R. Erwin & W. D. Walker PL 9/1 (64), 71 (Wisconsin)

30 GeV π^- → BNL 20" ch

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

($K\pi\pi$) の mass distribution
$I = 1/2$ C-neutral かもしれない

1) 1175 MeV (± 50 MeV の巾)
2) $\Gamma = 40 \pm 15$ MeV
3) X C → $K^*\pi$
4) X C → $K\pi$

V. Belekov CERN Conf (62) p. 336
C-charge

b) R. Armenteros et al (14名) (CERN, Collège de France)
PL 9/2 (64), 207
$\bar{p} + p \to K_1^0 + K_1^0 + \pi^+ \pi^-$ 770 events
1) no ($K_1^0 K_1^0$)
2) no K^*(880), κ(725)
3) no $K_1^0 K_1^0 \pi^\pm$
4) ($\pi^+\pi^-$) distribution → high effective ($\pi^+\pi^-$) mass → ρ peak
$\bar{p} + p \to$ において $^3S_1$ で起こる

5) ($K_1^0 \pi^+ \pi^-$) 1230 GeV resonance
1220 ~ 1280 MeV
Γ = 60 ~ 100 MeV
从 $\bar{p} p \to K_1^0 C$
$C \to K_1 + \rho^0$
$J^P = 1^+$? (もしも $\bar{p} + p$ or $^3S_1$ とすれば)

$J^P = 2^-$? 2^- octet?
($\eta\omega$) 1150
C($K\omega$) 1175
B($\omega\pi$) 1260

$K^2 = \frac{3\eta^2 + \pi^2}{4}$

quantum number
A (Bronzan & Low)

0^- or 1^+ octet?
η' 1410
Q 1365
B 1260
A = +1

§2. Resonance states の数. 90?
boson ≥ 34
$\beta(\frac{1}{2})^-$-singlet $\alpha(\frac{1}{2})^+$-octet $\gamma(\frac{3}{2})^-$-octet
$\delta(\frac{3}{2})^+$-decuplet $\frac{5}{2}^+$-octet $\frac{7}{2}^-$-octet
$\frac{7}{2}^+$-decuplet baryon ≥ 45 × 2
= 90

strongly $\geq$ 124
depend $= 4 \times 2 = 8$
W.T - . -

§3. B の $J^P = 1^-$?
$B = f^0$?
$\rho' \to \pi\omega$ B
$\to \pi\pi$ f^0

(W. Fraser et al. P.R.L. 12/7(64), 178)
$f^\pm \to \pi^\pm \pi^0$?

§4. $I = 0$, 400 0^+ $\pi\pi$-resonance
0^+-octet
σ
κ
$\tilde{N}(I=1)$ 1275

§5. κ, ABC, $K\bar{K}\pi$
κ $I = 1/2$ $K^-\pi^+$ { 730 MeV no enhancem.
$= 3/2$ $K^-\pi^-$ 260 small
230

$K^- p \to K^- p \pi^+ \pi^-$
$K^- + p \to Y_0^* + \pi^-$
$\to Y^* + \pi^+$
$\to Y_0^* + \pi^-$

ABC $p + d \to He^3 + 2\pi$ or $H^3 + 2\pi$
$p + "n" \to d + 2\pi$ $I = 0, 1$.
$p + p \to d + 2\pi$ $I = 1$

$K\bar{K}\pi$ $p \to \omega$