

©2022 YHAL, YITP, Kyoto University
京都大学基礎物理学研究所 湯川記念館史料室

Yukawa Hall Archival Library

Research Institute for Fundamental Physics

Kyoto University, Kyoto 606, Japan

N 90⁹⁰

NOTE BOOK

Manufactured with best ruled foolscap

Brings easier & cleaner writing

May, 1964 ~ March, 1965

VOL. XIX

Hideki Yukawa

Nissho Note

c033-722~740挟込

c033-721

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

Internal Structure and Symmetry of Elementary Particles

May 20, 1964

~~湯川記念館史料室~~ 湯川記念館史料室 (理研)
湯川記念館史料室

A.

Fundamental Assumption I.

Each elementary particle has its own internal ~~structure~~ structure related to its extension in space and time.

Remark 1. Usually an elementary particle is supposed to be a point in space whose motion is governed ~~by~~ statistically by quantum mechanical laws.

Fundamental Assumption II.

~~An assemblage~~ Elementary particles with extended structure can be described collectively by means of quantized fields which are no longer local, but nonlocal.

Remark 2. Simplest case of nonlocal field is bilocal field. The possibilities of more complicated nonlocal fields are not excluded.

B. Possible formulations and
interpretations of nonlocal
field theory.

Yukawa P.R. 1950

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak 2007 TM: Kodak

C. Meaning of empirical obtained
quantum numbers, ~~symm~~ ^{extra} extra
symmetries and mass ~~form~~ relations
in nonlocal field theory
(i) strangeness ~~and~~ (or hypercharge)
S or Y

Yukawa P.T.P.L. 1956

(ii) isospin I, I_3
Yukawa P.T.P.L. 1964

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak 2007 TM: Kodak

References

2. Dirac, P. A. M. Principles of Q. M.
3rd ed. (1947), Oxford

p. 152 ~ p. 153

$$r = (x^2 + y^2 + z^2)^{1/2}$$

$$p_r = r^{-1} (x p_x + y p_y + z p_z)$$

$$r p_r - p_r r = i \hbar$$

$$(\therefore r [r, p_r] = [r, r p_r] = i \hbar r)$$

$$p_r^* = (p_x x + p_y y + p_z z) r^{-1}$$

$$= (r p_r - i \hbar) r^{-1} = p_r - i \hbar r^{-1}$$

$$p_r' = p_r - i \hbar r^{-1}$$

$$p_r'^* = p_r'$$

$$p_x^2 + p_y^2 + p_z^2 = \frac{1}{r^2} p_r^2 r + \frac{m c^2}{r^2}$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

References

2. 吉田: 115 不対称体の理論 94 頁
(東京電子学研究所 29 (1964), 156)
(Vol 29, No. 2)

Heisenberg, ~~Dürer~~ は $\mathbb{Z}_2$ として, "空" の
all- $\mathbb{Z}_2$ の基底に, $\mathbb{Z}_2$ の spinion の
2 個の基底の基底を $\mathbb{Z}_2$ する.

spinion 0^+ , isodoublet $\mathbb{Z}_2$ の基底 n_s
anti-spinion $\mathbb{Z}_2$ の基底 n_a

$Y = n_s - n_a$ is identify する

$\mathbb{Z}_2$ is more formula $\mathbb{Z}_2$ の operator 0
is spinion-anti-spinion の permutation
is $\mathbb{Z}_2$ して $\mathbb{Z}_2$ の基底 $\mathbb{Z}_2$ する

$$\frac{1}{4}0 = \frac{1}{4}(\sum \vec{T}_s - \sum \vec{T}_a)^2 - f(n_s + n_a)$$

is, $n_s \rightarrow n_s - 1$, $n_a \rightarrow n_a + 1$, $T_s \rightarrow -T_a$
is $\mathbb{Z}_2$ invariant

$$\therefore \frac{1}{4}0 = \frac{1}{4}(\sum \vec{T}_s + \sum \vec{T}_a)^2 + \frac{1}{2}(\sum \vec{T}_s)^2$$

$$+ \frac{1}{2}(\sum \vec{T}_a)^2 - f(n_s + n_a)$$

~~is $\mathbb{Z}_2$ invariant~~ T_s, T_a is $\mathbb{Z}_2$ invariant
is $\mathbb{Z}_2$ invariant

$$\frac{1}{2}(\sum \vec{T}_s)^2 = 2n_s(\frac{n_s}{2} + 1) \text{ etc}$$

$$\frac{1}{2}(\sum \vec{T}_a)^2 = n_a(\frac{n_a}{2} + 1)$$

$$\frac{1}{2}(n_s^2 + n_a^2) + n_s + n_a$$

$$= + \frac{1}{4}(n_s - n_a)^2 + \frac{1}{4}(n_s + n_a)^2$$

$n_s + n_a$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

$$\frac{1}{4}D = -(\tau(\tau+1) - \frac{Y^2}{4}) + f'(n_s + n_a)$$

baryon-octet:

$$- \beta \left(6 - \tau(\tau+1) + \frac{Y^2}{4} + 11 \frac{YN}{2} \right)$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak 2007 TM: Kodak

(7) 1964 May 29 1964 May 29. Copenhagen
 Internal Structure and
 Symmetry of elementary
 Particles.
 (Royal Hotel)

Informal Talk at Institute
 for Theoretical Physics
 Copenhagen, May 29, 1964

A. Bohr, Z. Koba
 about 50 audience

Possible modifications and generalizations

1. Katayama

$$r, p_r = p_r - i/r$$

$$t, p_t$$

2. Takabayasi

Copenhagen 2 ありて 5 人
 Rosenthal

N. H. Hansen

H. Iséthe

3人

(中 10 人)

Kuus from Finland

Kodak Color Control Patches

Blue
 Cyan
 Green
 Yellow
 Red
 Magenta
 White
 3/Color
 Black

© Kodak, 2007 TM: Kodak

051130 W (土) アテネ
(Hotel Grande-Bretagne)
X. L. Messinesi (Royal National
Foundation) 等と迎へ

051831 W 午後 7.20 以下 Athens Meeting
の Opening Ceremony
King Constantine, Crown Prince
Greek Orthodox の大司教 等
Adrian 氏, Finley 氏, Tiselius 氏,
等と迎へ

7日 午後 5.30 の会合
13: 10 以下 Union

051810: 11: Press Conference
19.30: Pnyx の園にて Adrian
21: Foundation 及び Dinner (Hotel)
061820: 11: Archaeological Museum
17: フィリッパの世の王
Finley - 氏

19.30: Finley

061830
8.30: Acropolis 以下
Acropolis Museum
13: King の 8 日 以下 Royal Palace
Church
19.30: Heisenberg

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

06184 W

11.30: Democritus Laboratory (Atomic
energy 2000)
lunch (beach)

19.30: Tiresias

21.30: World Federalists in Athens
ATH Dinner (beach)

06185 W (金)

10: Hotel ... 12:30 4 1000

19.30: Yukawa, Intuition and
Abstraction in Scientific
Thinking

20.45: Hotel ... Dinner Party

06186 W

19.30: Theodorakopoulos

Aria 1000 (12L 2012)

(Egypt 1000) 1000, 1000

1000 1000 1000

20.20: Yacht Club & King 2/4
Royal Farewell Party!

○ 6月7日 (日)

8: Tiresias 船と - 午の14時まで
Delphi に行く

6月8日

7:30: Hotel を出る → Tiresias 船と同船

9: Piraeus 港の Delos (デーロス
島) まで エーゲ海の島めぐり、
乗客 高松 + 3人

15:30 Delos 島 Ptolemy の遺跡

17:30: 船 島の獅子
Mykonos 島
小教団の島

○ 6月9日

8: Rhodes 島

Lindos へ バスで行く。口々に

乗って Acropolis に上る
Rhodes の町 40分。古城と花
の町

○ 6月10日

8: Herakleion (Crete 島) 着

バスで Knossos の遺跡へ
行く

Herakleion に戻って 降参
観する

乗客 船は 40分

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

© Kodak, 2007 TM: Kodak

17.30: Santorini 島に到着,
船酔いの上には 3x 吐き出し
12に上る.

○ 6/11 11th

8: Piraeus 港に降りて下船

13.50: KLM に乗る.

16.15: Amsterdam 着.
Hague に移動 Parkhotel
に泊る.

○ 6/12 12th: 11: Press Conference

14: Miss Henning の家へ

Delft の 博物館へ行く

19.30: Scheveningen の
ホテルに泊る 田中 秀雄 氏との
会談. スタッフ.

○ 6/13 13th

14: WAWF 幹事会 & 会合

Wijngaarden, Hult-Pick

Gérard, Shri Ram

Mrs. Beumer 氏.

19: Pier-Restaurant で
WAWF 21st の Dinner

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

○ 6月14日(木)

12: Madurodam へ行く

17.15: KLM で Amsterdam
へ立つ

○ 6月15日(金)

17.30: 夕食後 2nd 回も子く

羽田着.

羽田駅に立つ

○ 6月16日(土)

14.30: 東京河の第2 工場へ

20.30: 東京河.

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

©2022 YHAL, YITP, Kyoto University
京都大学基礎物理学研究所 湯川記念館史料室

June 24, 1969

de Witt & "Falling Charges"
(Preprint)

PRL 12/20

Neutral Decay and Isotopic Spin
of the π

N. Gelfand et al. p. 567
 $I=0$ $\therefore$ B & for $\pi^0 \rightarrow \pi^+ \pi^-$

T. D. Lee: Radiative Corrections
to electromagnetic moment of
hadrons. Decays of the Intermediate
Boson W. p. 569

Meson-Baryon Resonances in
U(3) $\otimes$ U(3) Symmetry p. 570
I. Gelstein & K. T. Mahanthappa

PR 134/3B (May 11)

Departures from the Eightfold Way:
Theory of Strong Interaction
Symmetry Breakdown

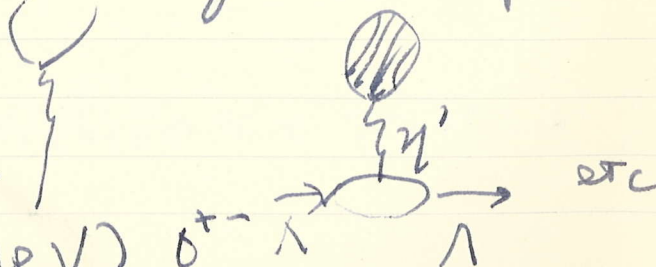
S. Coleman & G. H. Glashow, p. 1367

Tadpoles

Scalar octet

$K' \rightarrow \pi$ (730 MeV) 0^{+-}

$\pi' \rightarrow \pi$ (570 MeV) 0^+



$$\eta' \rightarrow \pi^+ \pi^- (755)$$

SU₃ Octet of Regge Poles Implied
by Bootstrap Dynamics
A. Pignotti p. B 630

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

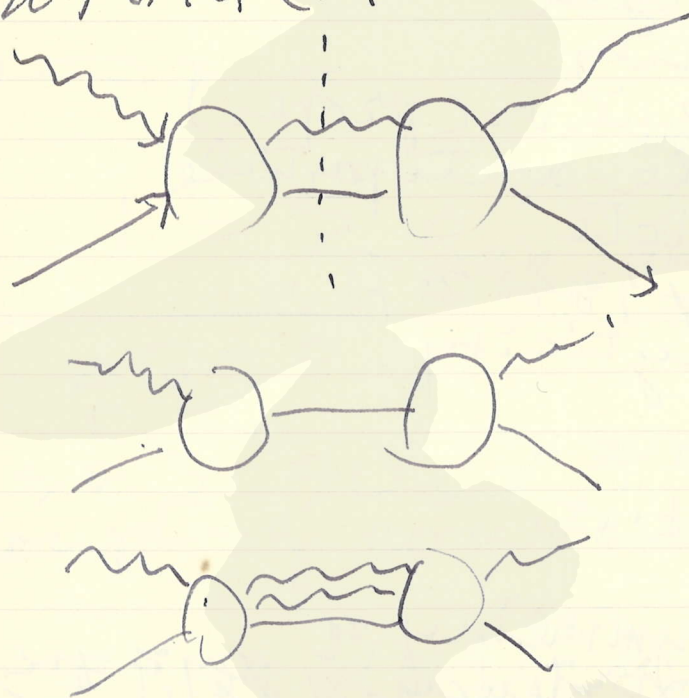
Black

© Kodak 2007 TM: Kodak

S 行の物理研究と物理研究の発展,
発行 June 26, 27, 1969

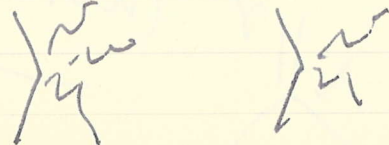
- Introductionary Talk
② H.P. Stapp, P.R. 125 (1962) 2139.
① D. Zwanziger, P.R. 133 (1964), 1036

① 光子の内部構造



- i) infrared catastrophe
光子の内部構造の photon の数が増える
と矛盾する
ii) Lorentz 変換

この数が増える場合の内部の構造をどうつけるか?



Schwinger & 数々の原理.
fictitious or source
外場の利用.

- (2) CPT 定理, spin & 統計
S 対称性 & particle & indistinguishability
S 対称性 approach
- 1) unitarity
 - 2) Lorentz inv. (proper)
 - 3) particle-antiparticle
 - 4) complete
 - 5) ~~consistency~~
 - 6) analyticity
 - 7)

T-13 1281811.

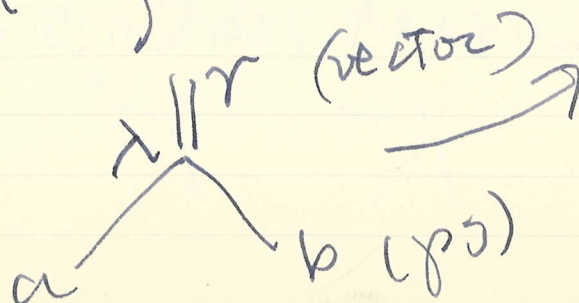
例: SU₃ symmetry &
self-consistency of π & η & μ

$$J=0 \quad \left(\begin{array}{c} \pi \\ \eta \end{array} \right) \quad \mu$$

$$J=1 \quad \left(\begin{array}{c} \rho \\ \omega \end{array} \right) \quad \mu$$

予定式 (Zachariasen 1952)
振動:

(Zachariasen 1952)



ii)

$$\lambda g_{ab}^{\sigma} = \sum_{c,d,s} g_{ac}^s g_{bd}^s g_{cd}^{\sigma}$$

$$r = r \quad \text{---} \quad \text{---} \quad \text{---}$$

$$1 = \sum_{a,b} g_{ab}^r g_{ab}^r$$

$$\Delta Q = 0$$

Compling of constant の 2 点 1 点 3 点

$$T_{cd,ab} = (N D^{-1})_{cd,ab}$$

$$g^2$$

$\rho \alpha \pi$
 $\rho \kappa \kappa$
 $\kappa^* \kappa \pi$
 $\kappa^* \kappa \nu \bar{\nu}$
 $\omega \kappa \kappa$

$$2g_{\kappa\kappa}^2 = g_{\mu\mu} g_{\nu\nu} a$$

means: elementary particle chemistry

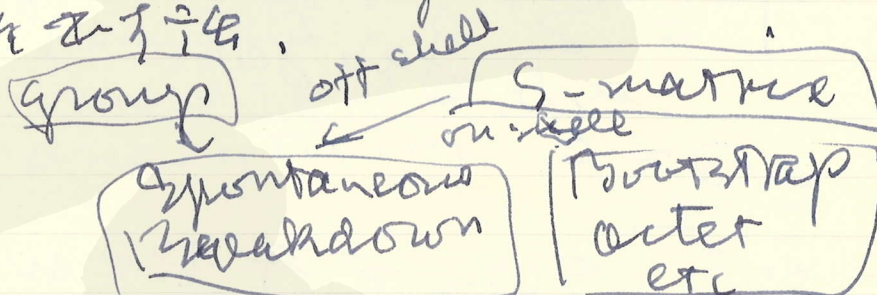
$$\sum_{r=1}^8 g_{ac}^r g_{bc}^r = \delta_{ab}$$

$$2 \geq \lambda(\lambda+1) = 2 - \frac{1}{8} \sum_{i=9}^{28} \lambda^i$$

$$1 \geq \lambda > 0$$

$$\lambda = 1 \rightarrow \lambda^i = 0 \quad i = 9, \dots, 28$$

条件: meson-baryon resonance
 $\frac{1}{2} \pm \frac{1}{2} \pm \frac{1}{2}$



Martin, Wali : P.R. 130 ('63), 2455
 N.C. 31 ('64), 1324

Ref: Preprint

$$M = \frac{N+1}{2}$$

$$m = K$$



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

baryon octet = b.o. or meson o. o.
 bound state
 $\rho = \text{decuplet}$

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

© Kodak, 2007 TM: Kodak

$$\left. \begin{array}{l} \epsilon \\ f \end{array} \right\} \begin{array}{l} \text{decuplet} = (P + P') \\ f = \text{octet exchange} \end{array}$$

Cut-off factor $\alpha \sim \frac{1}{f} \lambda$
 $0.32 < f < 0.42$

- (1) bound $P_{1/2}$ octet
 - (2) $P_{3/2}$ decuplet
 - (3) bound $S_{1/2}$ singlet
 - (4) resonant $d_{3/2}$ singlet
 - (5) marginally bound $S_{1/2}$ octet
 - (6) $d_{3/2}$ octet
 - (7) resonant $P_{1/2}$ (cut-off dep.)
- ($f \geq \frac{3}{2} \tau^2$ vanish)

ps-coupling

$$g_{\Delta\pi}^2 = g_{\Delta\kappa}^2 \quad \tau^2 < 3 \text{ or } \tau^2 > 3?$$

$$g_{N\pi}^2 = g_{\pi\pi}^2 \equiv \kappa^2$$

pv-coupling

$$g_{\pi}^2 \sim 10 g_{\kappa}^2 \rightarrow f_{\pi}^2 \sim f_{\kappa}^2$$

$$f^2 = g^2 \left(\frac{m}{M_{13} - M_B} \right)^2 = \text{const. ?}$$

off-mass shell τ^2 of $S_{1/2}$ & $P_{1/2}$
 on-mass shell τ^2 of $S_{1/2}$ & $P_{1/2}$ of π & κ ?

鈴方 (1) Spontaneous Breakdown of
SU₃

(2) 1/3 3 1/6

(1) T₈₈(SU₃) 12 8 3 = 8 1/3 1/6 の意味.

$$L = L_0^{(sym)} + L_{int}^{(asym)}$$

$$L_0 = L_0^{(sym)} + L_0^{(asym)}$$

$$L_{int} = L_{int}^{(sym)} + L_0^{(asym)}$$

unitary current

$$\partial_\mu (4 i f_{ij}^R \partial_\mu \phi_j) = 0$$

R = 1, 2, ... 8

$$L_{int}^{(W)} = J_\lambda^\dagger \times J_\lambda$$

(2) 8 13) 12 の coupling
8 11 constant.

pnλ
πκπ̄η) 4 の coupling
constant.

8 13) 12 の coupling
(i) ηππ̄ ηπ̄π̄ 8
(ii) ηππ̄ ηπ̄π̄ 8
(iii) ηππ̄ ηπ̄π̄ 8 (SU₃)

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak 2007 TM: Kodak

速報: HCU

July 8, 1964

1. Freund, Nambu: Broken $SU(5) \times SU(3)$
 $\times SU(3) \times SU(5)$ (preprint)

2. Gupta, Virendra, Singh: $SU(3)$
(preprint)

3. Groves, Klein, Vanderburg
Form factor relation in
 $K^- \rightarrow \mu + \pi^0 + \nu^-$

4. Belinfante: Harmonic-oscillator
model of ω -meson
 $\begin{matrix} 1^0 & \omega & 3^0 \pi \\ 2^0 & \pi - \pi & T=1 \\ 5^3 \end{matrix}$

葛氏漢語會, Sept. 15, 1964

G S
off the main shell
on the mass shell
on shell but not LAL's to?

$$\begin{array}{c}
 N \quad \quad E \\
 \diagdown \quad \diagup \\
 O_2 \\
 \diagup \quad \diagdown \\
 N \quad \quad E
 \end{array}$$

 ventral
 off shell

$$\begin{array}{c} \times \\ Z_2(\text{fermion}) \\ Z_3(\text{boson}) \end{array} \quad (2) \quad \left| \begin{array}{c} \sim \\ Z_1 \end{array} \right.$$

LSZ formalism

green side or analyticity
unitarity

Sym: $S = 1 + 2ip^{1/2} T p^{1/2}$

$$\operatorname{Im} T = T^* P T$$

$$\begin{aligned} \text{Im } K &= T^T P K \\ &= K^T S T \end{aligned}$$

K : form factor



Gauss:



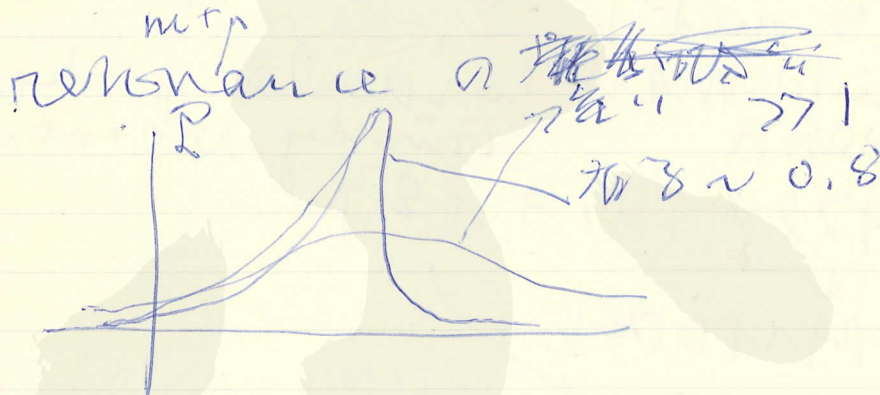
Γ : (proper) vertex

$$\Gamma_m P = U^\dagger \Gamma$$

$$\Gamma_m U = U^\dagger P U$$

$$T \cancel{P}_L = \begin{matrix} \swarrow & \nwarrow \\ \Gamma & N \\ \searrow & \swarrow \\ \cancel{P}_L & \end{matrix} + U$$

$$\int_{m_r}^{\infty} \frac{|\Gamma(w)|^2}{(w-m)^2} dw \leq 1$$



Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

Sept 16, 1964
 $\Xi^*(\frac{3}{2}^-)? \leftarrow \Xi(1403)$
 ninth η -meson? (see V)

$K_2^0 \rightarrow 2\pi$
 $CP(K_2^0) = -1$
 $CP(\pi^+\pi^-) = 1$
 $2200 \pm 45 \pm 10$

Sachs:
 K^0 or $\bar{K}^0$ $\frac{\text{leptonic decay}}{\text{non-lept decay}}$
 $\sim \frac{1}{600}$

Coester, Hammermesh, McGlinn,
 J. S. and L. I.
 SU_3 and mass formula of the
 meson Gurney, Lee et al.
 $\{3\} \times \{3\} = \{8\}$

$\downarrow$
 baryon $M \sim 1000 \text{ MeV}$
 η -meson $M \sim 0$

Kodak Color Control Patches
 Blue Cyan Green Yellow Red Magenta White 3/Color Black

片山利久: 素粒子の内部空間と対称性

1964年

Oct. 12. 荻原信雄

13 local

$$P_\mu P^\mu + M^2(K) = 0$$

$$K(T_1, T_2, T_3)$$

$$T_1 = \frac{1}{2}(p\sigma + p\eta)$$

$$T_2 = \frac{1}{2}(p\eta - \sigma p)$$

$$T_3 = \frac{1}{4}(p^2 + \eta^2 - \sigma^2 - \eta^2)$$

$$p^2 = (g^{\mu\nu} + \frac{p^\mu p^\nu}{-p^2}) \gamma_\mu \gamma_\nu$$

$$\sigma^2 = \frac{p^\mu p^\nu}{-p^2} \gamma_\mu \gamma_\nu$$

$$p = -i(\frac{\partial}{\partial p} + \frac{1}{p})$$

$$SU_2 \sim \text{group } \frac{\partial}{\partial \sigma}$$

quadrilocal: h, I, A 21 個の operator
 2変数関数 $W(x)$ に代わって x の

$$L_0 \dots L_8$$

$$\{L_i, L_j\} = \epsilon_{ijk} L_k$$

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

$$\{L_0, L_j\} = 0$$

$$SU_3 \text{ - group}$$

spinor vs spinor
 2変数

spinor
 boson

scalar
 fermion

quark?

素粒子の標準模型の発展 研究会

Oct. 15 ~ Oct. 17, 1964
金沢大 (約40名 250名)

15日午前

10: Program

11: 7:17: Dubna 報告. CERN Report.

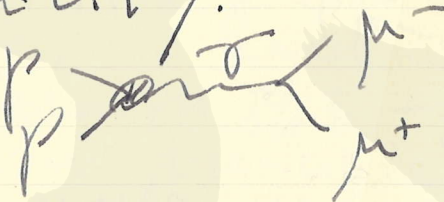
a. hard core: Otsuki, Ueda
(1 GeV 以下) is. Betheb. 10 GeV $\pi^- \pi^-$ 散乱断面積の real part

$$\left. \begin{array}{l} p-p \\ \pi-\pi \\ \pi^+-\pi \end{array} \right\} 20\% \sim 30\%$$

$$\frac{d\sigma}{ds} = 1 \frac{F_{\text{elastic}}}{|T|} + A_{\text{real}} + i A_{\text{Im}}$$

Coulomb

$$\alpha = \frac{A_{\text{Im}}}{A_{\text{real}}}$$

c. μ -meson の form factor
 $\approx 0.1\%$ 

d. W.I.



ground

Cd

asymmetry

(1/2 の寄与)

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

parity

mixing

 $F \sim 4.10$ $\{(\bar{e} \nu)(\bar{\nu} e)?$ $\{(\bar{n} \nu)(\bar{\nu} e)$

e. W.I.
 $K_2^0 \rightarrow \pi^+ \pi^-$ CP violation?
Cahn angle $\rightarrow$ Nagoya-Hypox Angle

f. W.I.
 $\Delta I = 1/2$
 $\Delta S / \Delta Q = -1$? $\rightarrow$ evidence 781.

g. v-physics
 $M_W \geq 1.8 \text{ GeV}$

例2: 非レプトン・中間子
非レプトン (非レ): non-leptonic decay and
Intermediate Meson.

$j \sim W_{\mu} + h.c.$
nonleptonic

(i) $|\Delta I| = 1/2$
8 @ 8

1 @ 8 @ 27

(ii) probability
 $|\Delta I| = 1/2$ enhancement
 $\Lambda \rightarrow p \pi$



$K \rightarrow 3\pi$: prob. of $\pi^0 \pi^0 \pi^0$ - $\pi^+ \pi^- \pi^0$
 $\rightarrow \pi^0 \pi^0 (\bar{X}_0, n_0) + \pi^+ \pi^- (\bar{X}_0, l_0)$
semi weak

例3: (定規): W.I. の変換性 & pole 近 1/2
千原 氏 の 研 究 所
Octet 変換性



Prospace: $H_{\text{elms}} \rightarrow 0$ or $\rightarrow$
 $T.P(S) \rightarrow T.P(H)$

SU_3 or U_3 or $SU_3(S)$ & $SU_3(H)$ $\rightarrow$ (F),
 (i) $\sum \text{poles} = 0$

$T.P(S) \neq T.P(H)$ ($H_{\text{elms}} \rightarrow 0$)
 中子線は、

(ii) ~~the~~ pole is in π .

$T.P(S)$ & $T.P(H)$ の間には 相互作用
 の存在と相互作用に依る... depends on
 相互作用. W.I. is symmetry and transp
 or apply to the, 左して... 右して...

基本: (1) (2) (3) Hand line
 核力, が...
 定性的に, hard core is 交換力...
 many fermion 構造 (approx) $\rightarrow$ 付力

exclusion principle

(i) structureless fermion
 $[\psi(x), \psi^\dagger(x')]_+ = \delta(x-x')$

$p=p$ is δ
 $\psi(p) \psi(p) = 0$ (exclusion for p
 $0 \rightarrow \pi$...)

(ii) cloud ~~is~~ many fermion system
 in this exclusion repulsion is

adiabatic $\frac{f}{N} \propto \frac{1}{V} \propto \frac{1}{T^3}$ (virtual phonon pair)

$$\Psi = U \Psi U^\dagger$$

$$\{\psi_p(x), \psi_p^\dagger(x')\}_+ = \delta(x-x')$$

(iii) one fermion is reduce $\rightarrow \sqrt{\omega} \psi_i$
 one fermion + boson is reduce to

17418 exclusion permafrost and permafrost

(I) 340 local fermion a bound state
a 87th ~~112074~~ ~~112074~~ ~~112074~~

(-j) $\frac{1}{2} \ln 2$

$\begin{pmatrix} 0 & 0 & 0 \\ a & b & c \end{pmatrix}$

a b c

For

$$15 \text{ } 2' 12 \text{ } 12 \rightarrow 0$$

$$\Psi_{12\mu} \xrightarrow{\lambda} 0$$

La

Caac

69 527111,

Exp $\overrightarrow{R} \rightarrow 0$

(II) 270° is a fermion $\Rightarrow$ odd $\Rightarrow$ fermion.

(ii) Salvata:

$$(p_0, \overline{p_0}, p_0)$$

OK

$$(n_0 \overline{n_0} \gamma_0)$$

(A₀ A₀ p₀)
x

(ii) Mark-Downski Quarter model

$$(p, \lambda, \chi)$$

(ii) Van move (double ~~quad~~ triplet) X

(iv) Zweig-Gr.-M.

Qualquer
Cuidado

u d s

OK

7

Selection Rule & Weak Current in Quark Model

① 302

$$\frac{1}{\sqrt{2}} d(\hat{u} - u\hat{d})$$

$$\frac{1}{\sqrt{2}} d(ds - sd)$$

Pauli

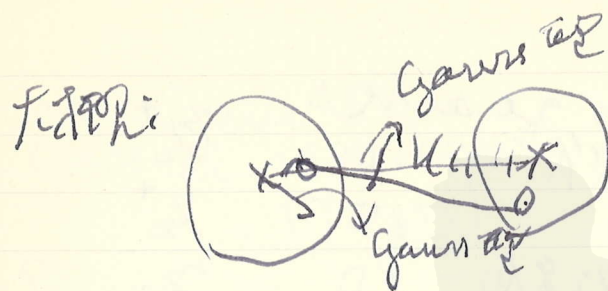
Relativistic Pauli BR?)

Hard Core

bariumの2価内塩.)

in the cytosol (relaxation)

< van Hove >



力 is Gauss π
with M even state 31 力

(α)

(α)

g-orbit

g-orbit

(α)

(α)

g(T)

g(T)

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

odd

(TT) (gg) odd 31 力
(T $\bar{g}$) (T $\bar{g}$) even 19 力
(TT) (gg) even 19 力
(T $\bar{g}$) (T $\bar{g}$) odd 31 力

$\left. \begin{matrix} \bar{g} \\ T \\ T \\ \bar{g} \end{matrix} \right\}$ even 31 力
odd 19 力

core

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

$$SU_3 \times SU_2$$

SB I $\rightarrow (3, 3^*)$ and $(3^*, 3)$ tensor

largely $\frac{3}{2}$ octet a mass $\approx \sqrt{\frac{3}{2}}$ and a plot 37

✓ 24/3/11

man's life

54) $\sum_{n=1}^{\infty} p_n(8) < s(8) < p_n(1)$

おちろの悪い

Non-leptonic decay

例: symmetry of π^0 & η meson

1. Triplet

Gell-Mann

van hier ve

Zwei g
(2 ~~12~~)

2. Quarter ^{Fig} C

$$H = H_0 + \delta H$$

U(5)

$$\delta M = \delta M \cdot \overline{\Lambda_0} \Lambda_0$$

Triplet 210V (Quarter 2') 2''

CA7 Bason: $m_{ij} = \begin{pmatrix} \pi_0 & \kappa_0 & \eta_0 & \lambda_0 \\ m_8^{13} & m_8^{13} + \delta M^{13} & m_8^{12} + \frac{4}{3} \delta M^{13} & \frac{2}{3} \sqrt{2} \delta M^{13} \\ \delta M \pi_0 \lambda_0 & \frac{2}{3} \delta M^{13} & \frac{2}{3} \sqrt{2} \delta M^{13} & m_8^{13} + \frac{2}{3} \delta M^{13} \end{pmatrix}$

$\delta M_{13} = \delta M \langle 13 | \bar{\Lambda}_0 \Lambda | 13 \rangle$

$$\delta M_p \equiv \delta M \langle B | \bar{A}_0 A | B \rangle$$

$p_s(0^-)$
 $\frac{1}{2}(2m_\eta + m_\pi) = m_K$
 $m_\pi = 2.2 \text{ MeV}$

vector

$m_\pi = m_\eta$

$m_\rho = m_\eta$
 $m_K^* = m_\eta + \delta M_\eta$
 $m_\eta = m_\eta + 2\delta M_\eta$
 $m_\omega = m_\eta$

$p_0 \quad n_0 \quad \Lambda_0$
 δM
 $u \quad d \quad s$

$m_K = m_\pi$
 $m_K = m_\pi + \delta M_\pi$
 $m_\eta = \frac{m_\pi + m_\pi}{2} + \frac{\sqrt{2}}{2}$
 $m_K = \frac{m_\pi + m_\pi}{2} + \frac{\sqrt{2}}{2}$

$m_\phi - m_\rho = 2(m_K^* - m_\rho)$
 $m_\rho = m_\omega$

(1) Baryon

(1) quartet $\bar{q}$

$\delta m_{\Lambda_0}(\Lambda_0 \Lambda_0) + \delta m_{\chi_0}(\chi_0 \chi_0)$

Nucleon:

$N_0 \bar{\Lambda}_0 \chi_0, N \Lambda_0 \bar{\chi}_0$

Ξ

$\bar{N}_0 \Lambda_0 \chi_0$

mass $\propto \sqrt{m_{\text{mix}}}$

(χ -invariant)

(2) triplet $\bar{q}$

$u \quad d \quad s$

$m = m_0 + \delta M_{RS}$

$RS = \langle \frac{M_0}{\sqrt{M_0^2 + p^2}} a^\dagger a \rangle$

$a \leftrightarrow b \gamma$

($k=1$ non-rel)

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

⑧ $\frac{1}{2}^+$	N	Λ	Σ	Ξ
exp.	940	1115	1190	1321
a+bY	940	1130	1230	1321

⑩ $\frac{3}{2}^+$	$N_{\frac{3}{2}}^*$	Y_0^*	Y_1^*	Ω
	1236			1625
	146			

⑧ $\frac{3}{2}^+$	$N_{\frac{3}{2}}^*$	Y_0^*	Y_1^*	Ξ^*
	1518	1660	1660	1810
	150		150	

ps $pdM = 340$
vector $pdM = 140 \sim 150$

$$R = \left\{ \frac{M_0}{\sqrt{M_0^2 + p^2}} \right\}$$

$$\delta M = 150 \text{ MeV}$$

R.R.: Supermultiplet
Gürsey
V Radicati: P. R. L. 13, 173 (1964)

Pais: P. R. L. 13, 175 (1964)

Gürsey, Pais, Radicati, P. R. L. 13, 299 (1964).

M. Sakhita, preprint

M. Sakhita, preprint

isospin

$\longleftrightarrow$ unitary spin

supermultiplet
(Wigner)

majorana force

$$(1 + \frac{1}{2} \sigma_i \cdot \sigma_j) (1 + \frac{1}{2} \sigma_i \cdot \sigma_j) V(r)$$

$$1 + \frac{1}{2} \sigma_i \cdot \sigma_j + \frac{1}{2} \sigma_i \cdot \sigma_j + \frac{1}{4} (\sigma_i \cdot \sigma_j)^2 = (\frac{1}{2} \sigma_i \cdot \sigma_j + \frac{1}{4} (\sigma_i \cdot \sigma_j)^2)$$

$$1 + i \frac{1}{2} \sigma_i \cdot \sigma_j + \frac{1}{4} (\sigma_i \cdot \sigma_j)^2 = 1 + i (\frac{1}{2} \sigma_i \cdot \sigma_j + \frac{1}{4} (\sigma_i \cdot \sigma_j)^2)$$

$$3 + 3 + 9 = 15 \rightarrow SU(4) \supset SU(2) \times SU(2)$$

wigner force $V(r)$

spin
 $i=1,2,3$

unitary spin
 $\lambda_i (i=1, \dots, 8)$

$$1 + i (\frac{1}{2} \sigma_i \cdot \sigma_j + \lambda_i \cdot \lambda_j + \frac{1}{2} \sigma_i \cdot \sigma_j \lambda_i \cdot \lambda_j)$$

$$35 = 3 + 8 + 24$$

$$SU(6) \supset SU(2) \times SU(3)$$

wigner $\rightarrow \{ (f^* f) (f^* f) \}$
 $(f^* f) (g^* g) \rightarrow (g^* f^*) (g f)$

$$g \rightarrow (1 + \frac{1}{2} \sigma_i \cdot \sigma_j) (\frac{1}{\sqrt{2}} \sum_{i=1}^8 \lambda_i \lambda_i)$$

$$1 + \sigma_i \cdot \sigma_j + \lambda_i \cdot \lambda_j + \sigma_i \cdot \sigma_j \lambda_i \cdot \lambda_j$$

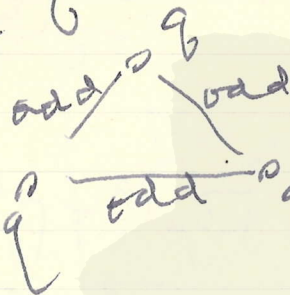
vector	singlet	3	ω
ps	octet	8	$K \pi \eta$
vector	octet	$\frac{24}{35}$	$K^* p \phi$

spin 0 $\rightarrow$ π is $\frac{1}{2}$ of the ω $\rightarrow$ π .

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

9-9-9



56 $\pi\pi\pi\pi$

u.s. spin

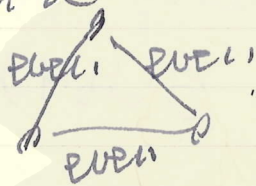
u.s. spin

$$56 = (8, 2) \oplus (10, 4)$$

baryon
 $\frac{1}{2}^+$

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

20 $\pi\pi\pi$



$$20 = (8, 2) \oplus (1, 4)$$

Mass Formula

$$H_0 + H_1 + \dots + H_n$$

$$M = M_0 + \frac{1}{2} A^2 Y + c \left(I(I+1) - \frac{Y^2}{4} \right) + A^2$$

F-type

D-type

10 $\pi\pi$: $\beta\gamma$

$$\beta = 130 \text{ MeV}$$

$$(\beta\gamma) = 135 \text{ MeV}$$

$$K^*{}^2 - K^2 = p^2 - \pi^2$$

current: 35 $\pi\pi$

$\bar{\psi} \cdot \psi$

$$56^* \times 56 = 1 + (35) + 405 + 2695$$

F/D

$\psi\psi$
 $2F + 3D$

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

$$6^* \times 6 = 1 + (35)$$

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

$$c = lt \quad \hbar = mlt \quad a = mlt$$

$$\frac{h}{f} = lt \quad \frac{h}{f} = l^2 \quad \frac{h}{f} = t^2$$

relativistic or quasi.
 gürsey and Raricati

$$L_{NM} = g \bar{\psi} \gamma_\mu \psi \omega_\mu + \bar{\psi} \gamma_\mu \tau^a \psi \rho_\mu^a$$

$$i \bar{\psi} \gamma_5 \gamma_\mu \tau^a \psi \rho_\mu^a$$

$$\varphi_\mu^a = \rho_\mu^a \pi^a$$

p.s trip π
 vector sing ω
 trip ρ

SU(4)

+ n-sept. term

SU(6)

relativistic or quasi - relativistic.

$$(\bar{\psi} \gamma_0 \psi) (\bar{\psi} \gamma_0 \psi)$$

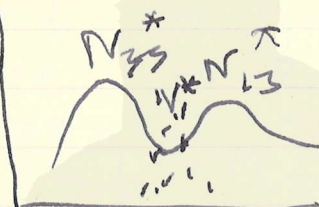
$$\gamma_\mu \quad \gamma_\mu$$

(i) p.s. A $\rightarrow m_\pi = m$ (N=2)
 π or G - parity even
 (ii) ψ, τ or γ or ψ or γ



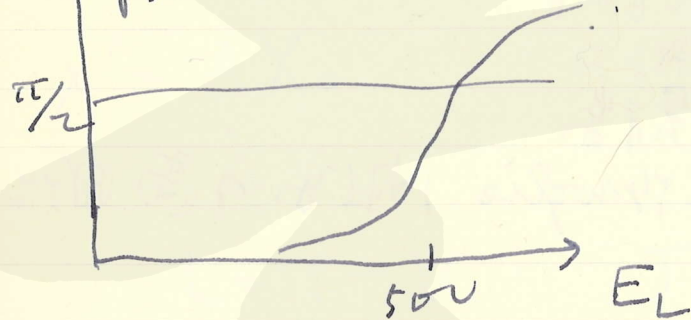
Kodak Color Control Patches
 Blue Cyan Green Yellow Red Magenta White 3/Color Black

$\pi^+ p \rightarrow \pi^+ p \pi^0$ (table)



Proper πN phase shift

$\delta_{\pi p, I=1/2}$



have data at all.
300 ~ 1400 MeV

$\pi^+ p \rightarrow \pi^+ p \pi^0$: $p + p \rightarrow n + p + \pi$

OR EC > 0.6 ~ 0.7 y

b_{eff} : impact parameter > 0.5 y
1.5 EV.

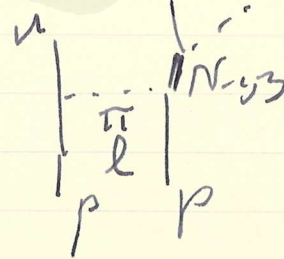
Ferrari - Selleri
peripheral model

$\pi^+ p \rightarrow \pi^+ p \pi^0$

Pion boson

$\pi^+ \rightarrow \pi^+ \pi^0 \pi^0$

400 ~ 600 MeV



Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

核力 $\sim$ 10^{-15} m 以内

Dar



同力核力

unitarity:
 π

Durand III, chin
 $m_{\pi} \sim 6 m_{\pi}$

核力: 核子間核力

Eindeil - de symple 1次元の高次元
 の図

1次元の
 片断:

quadrilateral

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

For incompressible sphere

$$\begin{aligned} a_0 + a' &\rightarrow x_0 + x' \\ b_0 + b' &\rightarrow y_0 + y' \\ c_0 + c' &\rightarrow z_0 + z' \end{aligned}$$

$$x' = \left(\frac{\partial x}{\partial a}\right)_0 a' + \left(\frac{\partial x}{\partial b}\right)_0 b' + \left(\frac{\partial x}{\partial c}\right)_0 c'$$

$$y' =$$

$$z' =$$

$$X' = A X_0$$

9 9 9 の 10 10 10 2,

$$\dot{X} = \dot{A} X_0$$

$$L = T - V$$

$$\begin{aligned} T &= \frac{1}{2} \int v^2 dm \\ &= \frac{1}{4} \text{sp}(\dot{A} \dot{A}^T) \end{aligned}$$

3 + 3 + 3
dilation
deformation

$$A = B C$$

$$B^T = B$$

$$C^T C = C C^T = 1$$

$$B = K \Lambda K^T$$

$$K^T K = K K^T = 1$$

$$\Lambda = \begin{pmatrix} 1 + \delta_1 & & \\ & 1 + \delta_2 & \\ & & 1 + \delta_3 \end{pmatrix} = 1 + \delta$$

$$\delta \ll 1:$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

変換の速さ v は c より遅いから,
velocity $v < c$

$av = \text{finite}$

$a \rightarrow 0$

a : 質量

v : 場の速度

$$T = \frac{I}{4} \text{Sp} \{ \dot{\delta}^2 + c \dot{c}^T \}$$

$$V = \lambda (\text{Sp} \delta)^2 + \mu (\text{Sp} \delta)^2$$

"same" の場合

例: 一般化 $\text{Sp} \delta = 0$ $\lambda, \mu = 0$

$$L = \frac{I}{4} \text{Sp} \{ \dot{\delta}^2 - \mu \delta^2 + c \dot{c}^T \}$$

3-ボソンの oscillation $U(3)$

$$H = H_0 + H_{\text{int}}$$

$$U(1) \quad SU(2)$$

↑

注意: Remark on Gauge Invariance
 $\psi \rightarrow e^{i\theta} \psi$

Abelian Gauge Transformations

- 1) 0-mass vector
- 2) massive $z \in \mathbb{R}$
- 3) scalar

Non-Abelian g, T_i

$$\psi \rightarrow e^{i \sum T_i \theta_i} \psi$$

$$[T_i, T_j] \neq 0$$

$T_i \rightarrow T_i$: Yang-Mills

$$\mathcal{L} = -\bar{\psi}(\gamma\partial + m)\psi - \frac{ig}{\kappa}(\bar{\psi}\gamma_\mu\vec{\tau}\psi)$$

$$\times f(-2g, \vec{\Phi}/\kappa) \partial_\mu \vec{\Phi}$$

$$S(g, \vec{a}) \cdot \vec{b} = \vec{b} - g \vec{a} \times \vec{b} + \frac{g^2}{2} \vec{a} \times (\vec{a} \times \vec{b})$$

$$f(g, \vec{a}) \vec{b} = 1 - \frac{g}{2} \vec{a} \times \vec{b} + \frac{g^2}{3!} \vec{a} \times (\vec{a} \times \vec{b})$$

$$\psi \rightarrow \psi' = e^{ig(\vec{\tau} \cdot \vec{\Lambda})} \psi$$

$$\vec{\Phi} \rightarrow \vec{\Phi}' : f(-2g, \vec{\Phi}/\kappa) \partial_\mu \vec{\Phi}$$

$$\rightarrow f(-2g, \vec{\Phi}'/\kappa) \partial_\mu \vec{\Phi}'$$

$$- \kappa f(2g, \vec{\Lambda}) \partial_\mu \vec{\Lambda}$$

$$\exp[ig(\vec{\tau} \cdot \vec{\Phi})/\kappa]$$

$$\rightarrow \exp[ig(\vec{\tau} \cdot \vec{\Phi}')/\kappa]$$

$$= \exp[ig(\vec{\tau} \cdot \vec{\Phi})/\kappa] \exp[-ig(\vec{\tau} \cdot \vec{\Lambda})]$$

$(\vec{\Phi} : \text{kinetic energy } T_3 \mathcal{L})$

$$\mathcal{L} = \mathcal{L}_1 + \mathcal{L}_2$$

$$\vec{\Phi}_1 = \vec{\Phi}_2$$

mass 0

$$\mathcal{L}_2 = -\frac{1}{2} \left[\cancel{\partial_\mu \vec{\Phi}_1} f(-2g, \vec{\Phi}_1/\kappa) \partial_\mu \vec{\Phi}_1 \right.$$

$$\left. - f(-2g, \vec{\Phi}_2/\kappa) \partial_\mu \vec{\Phi}_2 \right]^2$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

電力 $VAD = 12 \text{ kWh} \cdot \text{L} \cdot \text{h}$

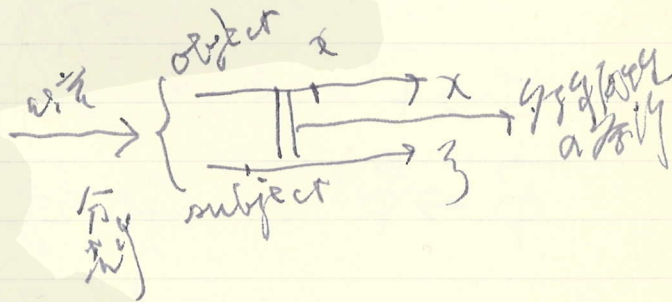
vector field kann folgendermaßen

田代: 数学物理 第 30, No. 1.
 $a(p_\mu) \rightarrow$ Fourier 変換 x_μ

X: 統計的

$$\frac{\partial \chi}{\partial c} = \{u, x\}$$

$$\frac{\partial x}{\partial z} = (P, x)$$



model:

有限性: 有限集合的个数为有限个

Turns out it's just the same old same old.

unit timelike vector $\frac{1}{\sqrt{1-\beta^2}} \mathbf{A}$.

$$f_{\text{eff}}: e^{-\lambda^2 (Np)^2} \quad \lambda \lesssim 0.1 \gamma$$

Mach 2.22

式:

bare mass

b

ε

取回:

u, d, s

$\uparrow B^+ \rightarrow$

超電荷の増減

$2, e, \mu$

van Hove

$T^T \rightarrow T^0$

$\uparrow B^+$

u, e, μ

$\downarrow B^0$

$\overline{u}, \overline{d}, \overline{s}$

$$Q = I + \frac{Y}{2} + \frac{D}{3}$$

$D=0$

$$D = N_{B^+} + 2N_{B^0}$$

第一

$\frac{1}{2}$

第二

第三

$\frac{1}{2}$

第四

$\frac{1}{2}$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

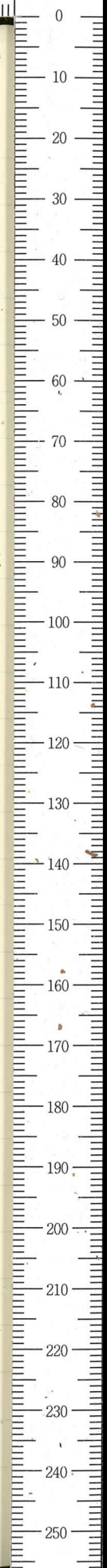
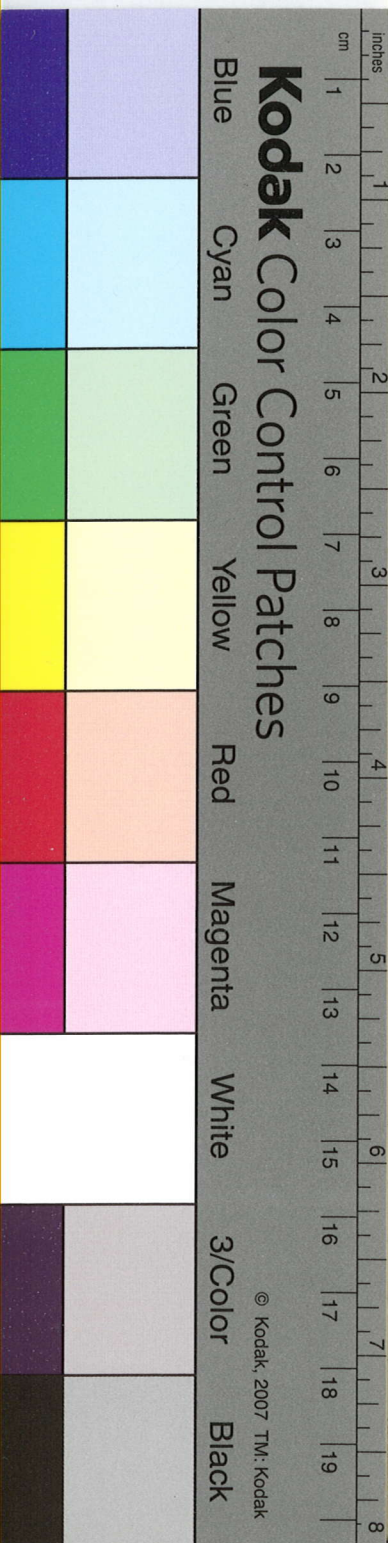
Black

© Kodak, 2007 TM: Kodak



©2022 YHAL, YITP, Kyoto University
京都大学基礎物理学研究所 湯川記念館史料室

$p \quad \nu \quad \nu \quad e \quad \left\{ \begin{array}{l} \nu \\ \nu \\ \nu \end{array} \right. \rightarrow$
 $n \quad \nu \quad e \quad e \quad \rightarrow$
 $\Lambda \quad \nu \quad e \quad \mu \quad \rightarrow$



Nov, 18, 1964

1964

M. Lévy, Non-Local Quantum
electrodynamics

(N. P. 57 (64), 152 ~ 190)

Construction Euler
I.

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

東大図書館蔵書印

Nov. 1964

物理研

新粒子の物理と構造
1. 湯川秀樹博士の粒子論.

2. 坂田模型の発展

3. 湯川博士の業績と素粒子

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

weak interaction of
核子の相互作用

神田大

12月 18 ~ 20, 1964

講演者: CVC 理論の概論

CVC is cons., & consistent
non-CVC is not? ?

$$g_V \approx g_\mu$$

g_μ の値は 2% 程度

$$\frac{g_\mu - g_V}{g_\mu} = (1.5 \sim 3.5)\%$$

Prim-Spoye NP 57 (64) 232
核子の相互作用 (CVC の概論)

(a) Fermi function

(b) em corrections

(c) charge dep. effects on $\int 1 = \sqrt{2}(1-\delta)$
0.2%

(d) W の値
 $\frac{3}{10} \left(\frac{m_\mu}{m_W} \right)^2$

(e) 核子の Cabibbo
角 θ_C

non-CVC の check

1) $\pi^+ \rightarrow \pi^0 e^+ + \nu$

CVC: $\frac{\pi^+ \rightarrow \pi^0 e^+ + \nu}{\pi^+ \rightarrow \mu^+ + \nu} = 1.06 \times 10^{-8}$

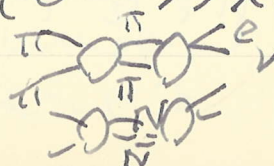
$\pi^+ K^0$

exp: 1.15×10^{-8}

non:

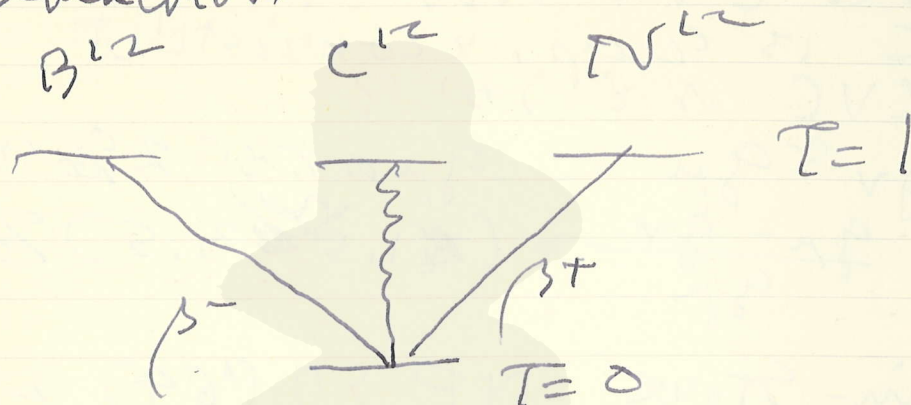


Duck, dispersion
 $= (0 \sim 3) \times 10^{-8}$



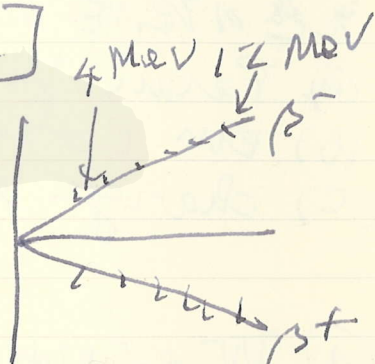
(Primakoff)

2) B^{12}



$$pE(E_0 - E)^2 [1 \pm aE]$$

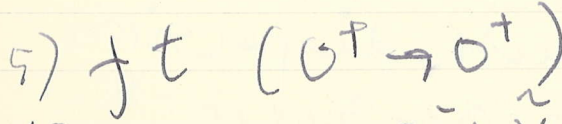
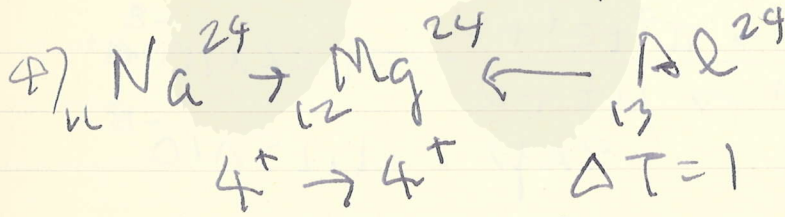
CVC



$$3) \text{CVC: } \frac{\int d\Omega}{i\pi} = [(E_0 \mp 25) E_{12} \frac{a_{12}}{R}] (\beta^{\pm})$$

$$\text{nonCVC} \left(- \langle f | \int d\Omega \frac{d\Omega}{R} | i \rangle \right)$$

1.2 2.2 3.2 4.2 5.2 6.2 ...



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

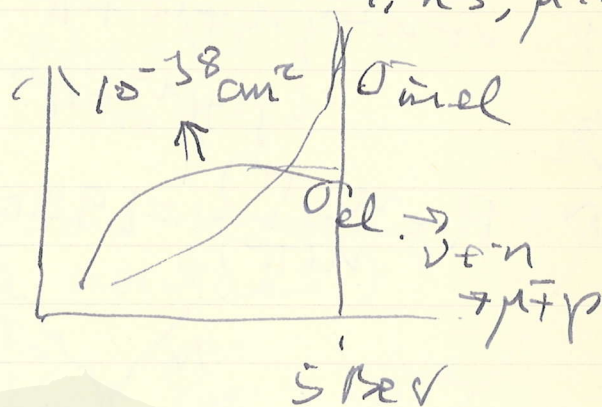
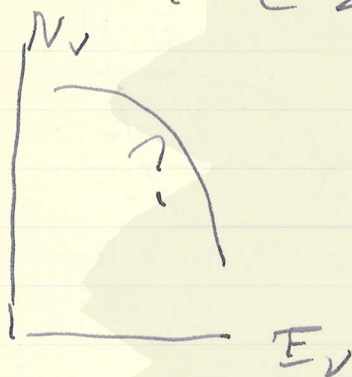
Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

小澤氏: Neutrino の実験

1. とにかく
2. 何を観測したいのか

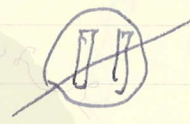
のいきさつ



$\nu + n \rightarrow p, \pi^-, \dots$
 $\gamma, K^0, \mu, \dots$

neutrino flux を 4" の 2 次元で
どうして detect するか!

1. とにかく
地球
1/2 年



2. 何を観測したいのか

$\int \nu(E_\nu) dE_\nu$
1000 Ton の 4 次元検出器
1 年以内で観測可能

金 54 万円

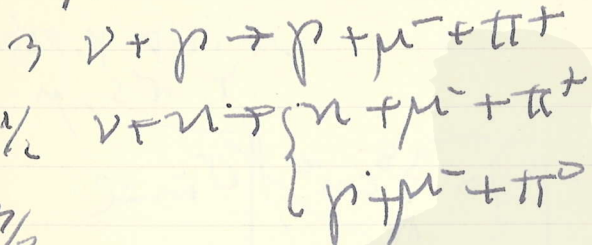
7×10^{37} の $\sim 19 \times 10^{37}$ の



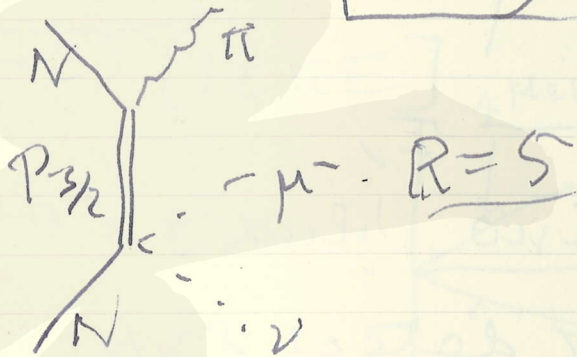
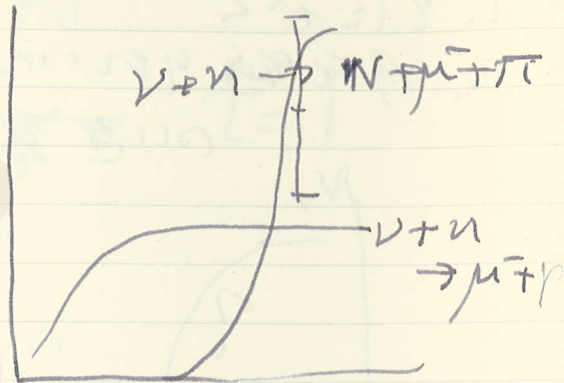
spark chamber
pulse を 検 出 する

events
1 億 54 万円

Aug 14, 1954

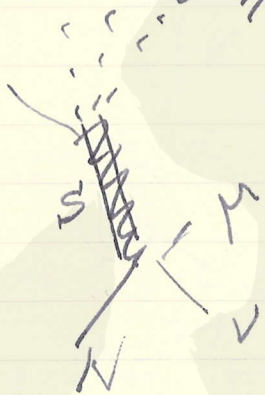


$$\uparrow R = \frac{n(\pi^+)}{n(\pi^0)} = 1.9 \pm 0.4$$


$$SU_3 \wedge SU_3$$

$d_{3/2}$ и $d_{5/2}$

$$R = 3,5 \rightarrow 3,1$$



$$\frac{d\sigma}{dq^2} = E_{\nu}^{4.5} F(q^2)$$

Dec. 2, 1964 第2回

17日: Weak Boson, superweak
 ν -interaction (Nakamura)

① WB: Yukawa $N_{13} = 0$
Tanikawa $N_{13} = 1$

spin 1

charged (like μ -decay $\rightarrow e^-$)
 $W^0, W^\pm$ - neutral

② Coupling Constant

$$g \bar{F} F B$$

$$g^2/4\pi \sim e^2/4\pi \sim 10^{-2}$$

$$f \bar{F} \nu B, f \bar{\nu} \nu B$$

$$f^2/4\pi \sim 10^{-12}$$

③ weak hypercharge Y assign
weak int. $\Delta Y = 0$

$$\begin{array}{c} \mu^+ \nu_\mu \\ \omega \end{array}$$

$$\begin{array}{c} Y \\ +1 \end{array}$$

$$0$$

(strange neutrino
+ $\bar{\nu}_\mu$)

$$\nu_e e^-$$

$$-1$$

(non-leptonic decay $\nu \rightarrow \lambda \bar{s} \dots$)

WB

Yukawa

$Y = 0, 1$

$$H_W = \{ g_W \bar{p} n + f_W (\bar{\mu}^+ \nu_\mu + \bar{\nu}_e e^-) \} W^+ + h.c.$$

$$H_B = \{ g_B \bar{p} \Lambda + f_B (\bar{\mu}^+ \omega + \bar{\nu}_e e^-) \} B^+ + h.c.$$

$$\text{Tanikawa } H_{XA} = (g_X \bar{n} e^- + f_X \bar{p} \nu_e) X_A^+ + h.c.,$$

$$H'_W = (g'_W \bar{\mu}^+ e^+ + f'_W \bar{\nu}_\mu \nu_e^c) W^0$$

$$\alpha_W = \frac{gf}{M_W^2} / \frac{G}{\sqrt{2}}$$

$$G = 1 \times 10^{-5} M^{-2}$$

$$\frac{M_W}{M} \quad 0.3$$

$$\alpha_W \quad 1.7$$

0.4	0.5
0.95	0.61



$$\alpha_X = \frac{gf}{M_X^2 - M^2} / \frac{G}{\sqrt{2}}$$

$$\frac{M_X}{M} \quad 1.4$$

$$\alpha_X \quad 0.16$$

$$1.5$$

$$0.12$$

$A \rightarrow \text{decay}$

$$\frac{M_B}{M} \quad 0.8$$

$$\alpha \quad 1.2$$

1.0	1.5
0.72	0.34

$$\frac{M_{XB}}{M} \quad 1.4$$

$$\alpha_X \quad 1.4$$

1.5	2
0.92	0.29

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

$$\nu_\mu + p \rightarrow (X_A^{t+}) \rightarrow \mu^+ + n$$

$$\sigma_{\text{bound}} \sim 3 \times 10^{-38} \text{ cm}^2$$

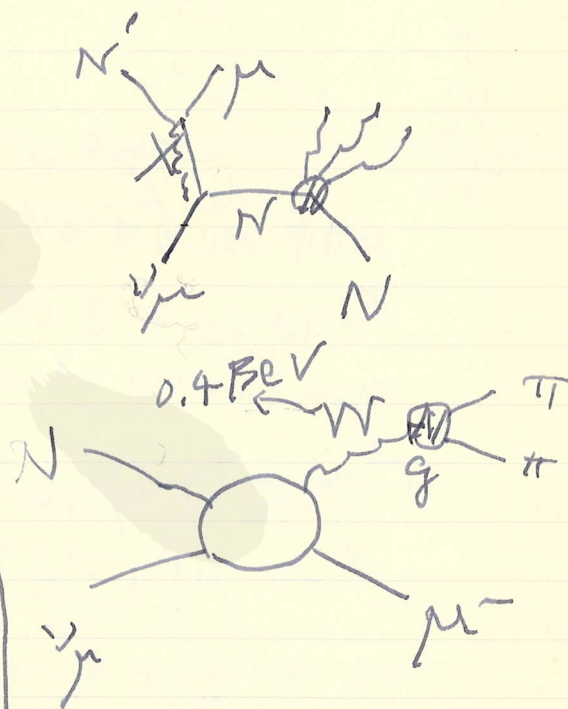
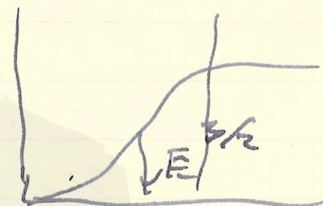
$$10^{-32} \text{ cm}^2 (\text{semi-weak})$$

$$\nu_\mu + N \rightarrow \mu + N' + \pi$$

$$\sigma \sim 10^{-38} \text{ cm}^2$$

$$10^{-32} \text{ cm}^2 (\text{semi-weak})$$

g_{2e}
 $\left\{ \begin{array}{l} \mu \\ \pi \end{array} \right.$ mag. mom.
 μ large angle scattering
 X_μ



Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

中核子: $\pi^+ \pi^-$
相互作用
mass spectrum

1. Meron theory
Yukawa type
leptonic

$\Delta S = \Delta Q$
lepton cons.
helicity

allowed transition $\Delta Y = 0$
g: electromagnetic
f: neutrino mass

$\frac{1}{2}$ $\mu^+ \mu^-$
 $\frac{1}{2}$ $e^+ e^-$

Majorana or $\mu^+ \mu^-$ (???)
Majorana or $e^+ e^-$ (???)
neutrino charge asymmetry.

$$\begin{aligned}\pi^+ &\rightarrow \mu^+ + (\mu_R^0)^c \\ K^+ &\rightarrow \mu^+ + (e_R^0)^c \\ n &\rightarrow p + e^- + (e_L^0)^c \\ \bar{e}^- &\gamma_\mu (1 + \gamma_5) \mu^0 \\ \bar{\mu}^0 &\gamma_\mu (1 - \gamma_5) \mu^+\end{aligned}$$

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

non-leptonic $\Delta Y = \pm 1$
forbidden transition

2. 核力 $\rightarrow$ meson $\rightarrow$ 山の丘の頂上
(核子式)
 β -decay $\rightarrow$ meson $\rightarrow$ 核子のI.B.

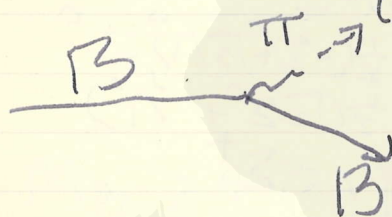
Salam, Ward, Schwinger, Matthews-
Salam:

$W^\pm, W^0, W^-$

$V-A$

核力

核子・反核子: non-leptonic decay
(hyperonの)

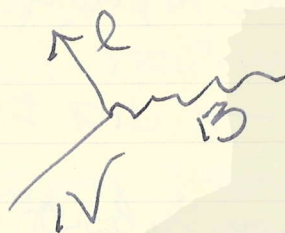


1) 核子の崩壊の割合を測定し、
その過程は $V-A$
その過程は $V+A$
その過程は V or A

核子の崩壊の割合は?

2) $\Lambda \rightarrow p + \pi$
 $\Lambda \rightarrow n + \pi$
 $\Lambda \rightarrow p + \pi$
 $\Lambda \rightarrow n + \pi$

3) Tani Kawa boson



弱相互作用
chirality conserving
interaction

(他の相互作用は
parity conserving
interaction)

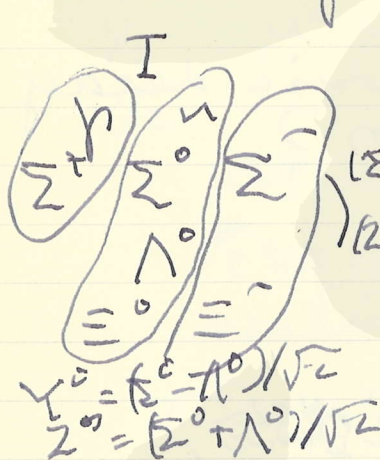
$$\Delta I = 1/2, \Delta S = \Delta Q$$

I spin

K spin

L spin

Rosen, PRL



Y_K, K

$1/2$

0

0

-1

$1/2$

$Q = -Y_K$

$\Sigma^- = \Xi^-$

$n, \frac{1}{2}(-\Sigma^0 + \sqrt{3}\Lambda^0) = 0$

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

$p, -\Sigma^+$

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

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

Madida

isoparity

$$G = e^{i\pi I_2} C$$

$$G^2 = \pm 1$$

isochirality

$$\frac{\Sigma^+ \pm \Psi}{\sqrt{2}}$$

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

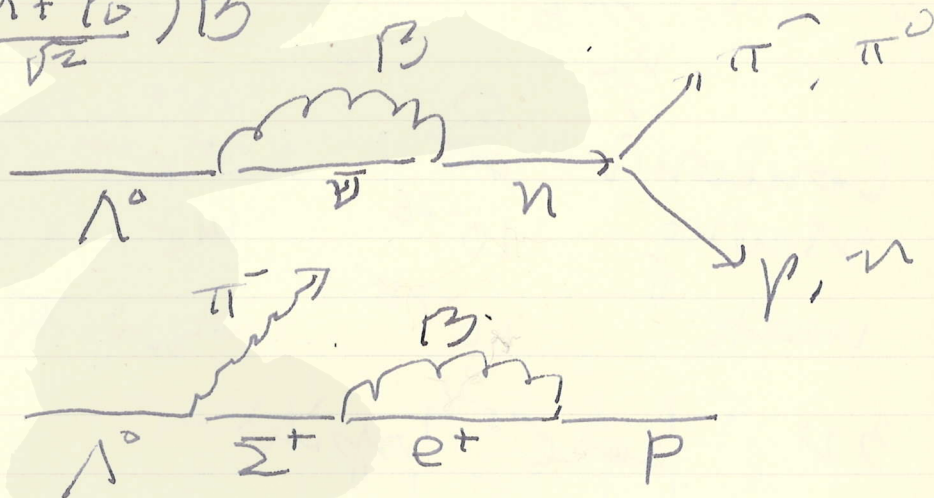
$$\begin{aligned} &(\Sigma^-, -\Xi^-) \\ &(n, \gamma_0') \\ &(Z_0', \Xi^0) \\ &(p, -\Sigma^+) \end{aligned}$$

$$\begin{aligned} \gamma_0' &= \\ Z_0' &= \end{aligned}$$

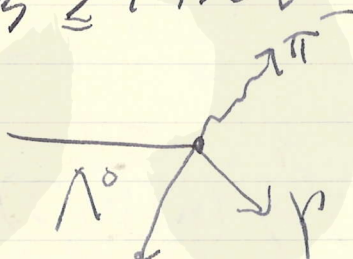
Tanikawa brown B: neutral

$$(\bar{e} \cdot \frac{\Sigma^+ + P}{\sqrt{2}}) B$$

$$(\bar{\nu} \cdot \frac{n + \gamma_0'}{\sqrt{2}}) B$$



$$M_B \geq 4 \text{ MeV}$$



$$\text{const. } \bar{p} (a + b \gamma_5) \Lambda^0 \pi$$

$$b/a = -3$$

$$\alpha_{\text{exp}} = -0.62 \rightarrow b/a = -7.5$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

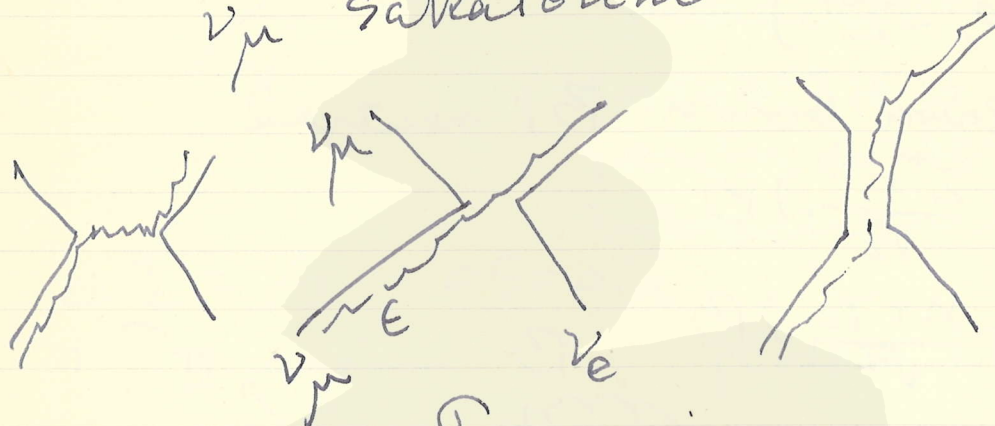
White

3/Color

Black

武蔵 (Hide): Neutrino 模型 127117
Neutrino Core Model

ν_e Paulino
 ν_μ Sakaybino



Condensed
strong
weak

σ
 ∞
 10^{-26}
 10^{-38}

$m_\gamma = 0$
 m_π
 $m_{W, Z}$

32 core spin

$\uparrow P$

$\uparrow \downarrow$
15

$J = 1/2$

Neutrino
Core

$\epsilon \downarrow (e \nu \nu) \xrightarrow{\epsilon'} (\mu \nu \nu)$

$\downarrow \epsilon N (e \nu, e \nu) \xrightarrow{\epsilon'} \Lambda \Sigma^0 \xrightarrow{\epsilon'} \Xi^0$

octet
singlet

Σ^+
 Σ^0
 Σ^-
 Ξ^0
 Ξ^-

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

© Kodak, 2007 TM: Kodak

$$\begin{array}{c} h^+ h^+ \\ l \quad l \quad l \\ \pi \quad \gamma \quad p_s \quad (S) \rightarrow \quad \nu \quad \bar{\nu} \end{array}$$

条件: (湯川・片山・山内)

i) $\lambda_{\mu\nu} \dots$ time-like vector $\sqrt{\lambda}$

ii) operator
quclid 不変

iii) $\psi(x, y)$

interference...

$$\int \dots F(x) \dots \langle 1 | 1 \rangle \dots$$

$$\int dx d\bar{x} d\bar{r} F\left(\frac{x+\bar{x}}{2}, \frac{r-\bar{r}}{2}\right) \psi^*(x+\frac{r}{2}, r) \psi(x-\frac{r}{2}, \bar{r}) \psi^*(x-\frac{r}{2}, -r) \psi(x+\frac{r}{2}, -\bar{r})$$

$$\eta_{\mu\nu} r^\mu \bar{r}^\nu = \hat{p} \hat{p} + 0 \hat{p} \hat{p} + \dots$$

$$x \times \bar{x} = 0$$

$\lambda_{\mu}(\tau' - \tau)^\mu$ depend

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

$$\rightarrow \psi^* \tau_i \psi \cdot \psi^* \tau_i \psi$$

$$\langle x_1 x_2 x_3 | \psi | x'_1 x'_2 x'_3 \rangle$$

$$4 \rightarrow \psi^* \psi \tau_i \psi \tau_i \psi \quad (\text{Trace})$$

enclid inv. $\rightarrow$ charge inv.

$\rightarrow$ 電荷 - 変換

$$\frac{p_1 p_2}{1 + \tau_3} \quad \sigma \sigma \rightarrow \text{電荷共変}$$

$p_1, p_2, \sigma, \sigma_2 = 1, 2$ linear

$$\Delta T = 1/2$$

弱相互作用

$$\gamma^\mu, \gamma^\nu$$

$$\gamma^\mu \gamma^\nu + \gamma^\nu \gamma^\mu$$

$3/2$ vector

$1/2$ scalar

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

中野重夫: Q.F.T. in terms of
Euclidean Parameters

P.T.P. 21(1959), 241

$\psi(x)$

x : Euclidean parameters

x_4 : real

$k_4 = i k_0$

vacuum expectation value

$\psi^\dagger \psi$

$\psi^\dagger = \psi^* D$

$D S_{rel} - S_{rel} D = 0$

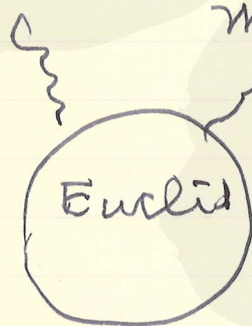
$D S_{k4} + S_{k4} D = 0$

$D^2 = 1$

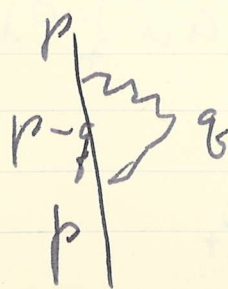
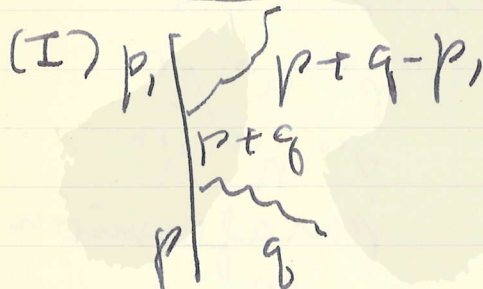
$\psi^\dagger(x) = \psi^*(x^t) D$

$x^t = (x_1, x_2, x_3, -x_4)$

Minkowski



$H_{int} = * (e^{a\tilde{\square}} \psi^\dagger(x))$
 $x (e^{a\tilde{\square}} \varphi(x)) (e^{a\tilde{\square}} \psi(x))$



$* \frac{e^{2a\tilde{\square}}}{2pq - \mu^2}$

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

10 to 12, SU6

Received. Dec. 16, 1964

SU4: Wigner, P.R. 51, 106

$\mu = \frac{1}{2}, \frac{3}{4}$ $\begin{matrix} \uparrow \\ P \\ \downarrow \\ \mu \end{matrix}$ $SU_2 \times SU_2$

SU6: Gürsey P.R.L. 13-5 173
- Radicati

Gü, Pais, Rad. P.R.L. 13-8 299

Greenberg PRL 13-20 598

φ_A $A = \frac{1}{2}, \frac{3}{2}$ $\begin{matrix} \uparrow \\ p \\ \downarrow \\ \mu \end{matrix}$ $SU_3 \times SU_2$

ψ_c $\bar{\psi} = 1, 2$ $\begin{matrix} \uparrow \\ \downarrow \end{matrix}$ SU_6

$$\psi_\mu \psi_\nu \pm \psi_\nu \psi_\mu$$

$$6 \otimes 6 = 21_{\text{sym.}} + 15_{\text{antisym.}}$$

$$21 = (6, 3) + (3^*, 1)$$

$$15 = (6^*, 1) + (3, 3)$$

Van Hove

Greenberg

p^0, n^0, Λ^0
 p'^0, n'^0, Λ'^0
parafermion

$$a_\lambda = \sum_{\alpha=1}^3 a_\lambda^{(\alpha)}$$

$$[a_\lambda^{(\alpha)}, a_\mu^{(\beta)}] = \delta_{\lambda, \mu}$$

$$[a_\lambda^{(\alpha)}, a_\mu^{(\beta)}] = 0 \quad \alpha \neq \beta$$

$$f_{\lambda\mu\nu} = [[a_\lambda^+ a_\mu^+], a_\nu^+]_+$$

図 1
45. 2. 12. (Dublin)

$$= 4 \sum_{\alpha \neq \beta \neq \gamma} a_{\alpha}^{+} a_{\beta}^{+} a_{\gamma}^{+}$$

$$[f_{\mu\nu}^{+}, a_{\sigma}^{+}]_{+} = 0$$

$$[f_{\lambda\mu\nu}^{+}, f_{\sigma\tau\eta}^{+}]_{+} = 0$$

$$6 \otimes 6 \otimes 6 = 6 \otimes (21 \times 15) \\ = 56 + 20 + 20 + 20$$

$$1 \otimes 6 \otimes 6 = 56 \quad \square \quad \square \quad \square \quad \square$$

$$20 = (1, 4) + (2, 2)_{\text{octet}}$$

$$56 = (10, 4) + (8, 2)_{\text{decuplet}}$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

Yang, K^0 -decay
CP-invariance

Jan. 8, 1965

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

Jan. 12, 1965

おひさし:

Wigner, $\epsilon \dots$ $\epsilon \dots \epsilon \dots \epsilon \dots \epsilon \dots \epsilon \dots$
etc etc

1962 or 3

JAEA

QM + SR

Poincaré group = inhom. h. E. group
h. T.

$$\psi \rightarrow \exp\left(i\frac{\omega}{2} \vec{n} \cdot \vec{N}\right) \psi$$

$$\omega = \log\left(\frac{1-v/c}{1+v/c}\right)$$

$$\vec{N} = i\hbar\left(\vec{r} \frac{\partial}{\partial \vec{r}} + \text{c.c.} \frac{\partial}{\partial \vec{r}}\right)$$

$\vec{N}$: hermite

$$\{N_x, N_y\} = -i\hbar M_z \dots$$

$$[N_x, M_y] = [M_x, N_y] = i\hbar M_z$$

$$[N_x, M_x] = 0 \dots$$

おひさし

1) $m^2 > 0$, $p_0 > 0$ ($p_0 < 0$)

$p^0 = (0, 0, 0, m)$
 $p^0 \in$ h. $\epsilon \dots \epsilon \dots \epsilon \dots \epsilon \dots \epsilon \dots$ little group
 M_x, M_y, M_z

2) $m^2 < 0$

M_z, N_x, N_y ($p^0 = (0, 0, p, 0)$ little group)

(1) $s \in \mathbb{Z}$ (integer)

(2) $s \in \mathbb{Z} + \frac{1}{2}$ (half-integer)

(3) $s \in \mathbb{Z}$ ($s, s+1, s+2, \dots$)

($-s, -s-1, -s-2, \dots$)

$s=0$

3) $m^2=0$, $p_0 > 0$ ($p_0 < 0$)

$p^\mu = (0, 0, p, p)$

$M_z, M_x + N_y = L_1$

$M_y - N_x = L_2$

$(L_1, L_2) = 0$

$[L_1, M_z] = -i\hbar L_2$

$[L_2, M_z] = i\hbar L_1$

$[p_1, p_2] = 0$

$[p_1, M_z] = -i\hbar p_2$

$[p_2, M_z] = i\hbar p_1$

- 光子の螺旋性の量子数

1) $L^2=0$

$\psi_{0,0}$

$L_1 \psi = L_2 \psi = 0$

$M_z \psi = m\hbar \psi$

$m \begin{cases} \text{integer} \\ \text{half-integer} \end{cases}$

光子

2) $L^2=0$

螺旋性の量子数

$L_1 = \begin{pmatrix} 0 & \lambda & & \\ \lambda & 0 & \lambda' & \\ & \lambda' & 0 & \\ & & & \ddots \end{pmatrix}$

$\lambda, \lambda', \dots$
任意

$L_2 = \begin{pmatrix} 0 & i\lambda & & \\ -i\lambda & 0 & i\lambda' & \\ & -i\lambda' & 0 & \\ & & & \ddots \end{pmatrix}$

$\lambda = \lambda' = \dots = \frac{\hbar}{2}$

$M_z = \begin{pmatrix} \hbar/2 & & & \\ & \hbar/2 & & \\ & & 0 & \\ & & & \ddots \end{pmatrix}$

$L^2 = -\hbar^2$

Kodak Color Control Patches

Blue Cyan Green Yellow Red Magenta White 3/Color Black

© Kodak, 2007 TM: Kodak

$$2E^2 \sim \infty$$

$$4) \quad \gamma_\mu = 0$$

Resonance
Regge Pole

$m^2 = \text{complex}$
Max. non-hermite

wave function
波函数の近近

E_1
 E_2
 E_3

x_μ } $20 \rightarrow 13$

①

$$p_\mu^2 \psi = -m^2 \psi$$

②

$$p_\mu \bar{\xi}_\mu \psi = 0$$

③

$$\bar{\xi}_\mu^2 \psi = \psi$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

梅原 氏 Sp(6)

Received Feb. 2, 1965

SU₄ 3.4V

6x6 matrix σ

$$\sigma^T J \sigma = J \quad J = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$$

$$\sigma = 1 + i \epsilon X \quad X = \begin{pmatrix} X_1 & X_2 \\ X_3 & X_4 \end{pmatrix}$$

$$\left. \begin{aligned} X_4 &= -X_1^T \\ X_2 &= X_3^T \end{aligned} \right\}$$

$$X_2^T = X_3^+$$

$$X^T J + J X = 0$$

21 個 独立

Z Y I₃ B

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak

Parastatistics 宇流会

Feb, 1965

1. 河上: Okayama, P.T.P., 1952
2. 藤井: Green, P.T.P., 1953
90, 270
3. 片山: Kamefuchi, Lecture
4. 山田: Kamefuchi-Takekoshi
5. 中村: Messiah and Greenberg,
Symmetrization Postulate

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

~~Para-Statistics~~

バリオンの特長
fermion
フェルミオン

甘田のG
電荷のG

March 8, 19, 1965

Greenberg

SU₆

56 = 27 (8 9 = 1/2)

(10 9 = 3/2)

(999)

US, S, L

8 9 = 1/2 $\begin{array}{|c|} \hline \square \\ \hline \end{array} \otimes \begin{array}{|c|} \hline \square \\ \hline \end{array} \otimes \begin{array}{|c|} \hline \square \\ \hline \end{array} = \begin{array}{|c|} \hline \square \\ \hline \end{array} + \dots$

10 9 = 3/2 $\begin{array}{|c|} \hline \square \\ \hline \end{array} \otimes \begin{array}{|c|} \hline \square \\ \hline \end{array} \otimes \begin{array}{|c|} \hline \square \\ \hline \end{array} = \begin{array}{|c|} \hline \square \\ \hline \end{array} + \dots$

US x S x L = $\begin{array}{|c|} \hline \square \\ \hline \end{array}$ L=1

$\begin{array}{|c|} \hline \square \\ \hline \end{array} \otimes \begin{array}{|c|} \hline \square \\ \hline \end{array} = \begin{array}{|c|} \hline \square \\ \hline \end{array} \oplus \begin{array}{|c|} \hline \square \\ \hline \end{array} \oplus \begin{array}{|c|} \hline \square \\ \hline \end{array}$

(1/2) (3/2) (5/2)

10 9 = 7/2 $\begin{array}{|c|} \hline \square \\ \hline \end{array} \times \begin{array}{|c|} \hline \square \\ \hline \end{array} \times \begin{array}{|c|} \hline \square \\ \hline \end{array} = \begin{array}{|c|} \hline \square \\ \hline \end{array}$

2個の... 3個 1 (S u L)

$$H = \frac{1}{2} (x_1^2 + p_1^2 + x_2^2 + p_2^2)$$

$$\begin{pmatrix} R \\ r \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$$

$$H = \frac{1}{2} (R^2 + P^2 + r^2 + p^2)$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

$$a_i = \frac{1}{\sqrt{2}} (x_i + i p_i)$$

$$H = a_1^\dagger a_1 + a_2^\dagger a_2 + 1$$

$$H = A^\dagger A + a^\dagger a + 1$$

$$a_1^{pN_1} a_2^{qN_2} |0\rangle \equiv |N_1, N_2\rangle$$

$$a_1 = \frac{1}{\sqrt{2}} (A + a)$$

$$a_2 = \frac{1}{\sqrt{2}} (A - a)$$

$$a_1^{pN_1} a_2^{qN_2} = \left(\frac{1}{\sqrt{2}}\right)^{N_1+N_2} (A^\dagger + a^\dagger)^{N_1} (A^\dagger - a^\dagger)^{N_2}$$

$$N_1 = 2, N_2 = 0$$

$$A^\dagger A^\dagger + 2A^\dagger a^\dagger + a^\dagger a^\dagger$$

$$A |N\rangle_0 = 0$$

$$|N\rangle_0 = a^\dagger \dots a^\dagger |0\rangle_0$$

$$a = \frac{1}{\sqrt{2}} (a_1 - a_2)$$

$$= \frac{1}{\sqrt{2}} (\alpha_1 - \alpha_2)$$

$$\{\alpha_1, \alpha_2\} = 0$$

$$= \frac{1}{\sqrt{2}} (\alpha_1 \pm i\alpha_2) (\alpha_1 \pm i\alpha_2)$$

$$= \beta \cdot \beta$$

$$\beta = \frac{1}{\sqrt{2}} (\alpha_1 \pm i\alpha_2)$$

Kodak Color Control Patches

Blue

Cyan

Green

Yellow

Red

Magenta

White

3/Color

Black

© Kodak, 2007 TM: Kodak