XXV

NOTE BOOK

Manufactured with best ruled foolscap
Brings easier & cleaner writing

July 1968
~ Sept. 1969

VOL. XXV

H. Yukawa

Nissho Note

中川昌美 : Non-leptonic Weak Interaction
基研談話会. July 2, 1968

Current-~~Current Interaction~~ Algebra
鈴木・菅原
quark model

i) CA-PCAC
S. S. $(J \times J)_{1/2,\ 3/2}$

$\Delta I = 1/2$: Λ, Ξ, (Σ) for S-wave decay

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

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

ii) Quark Model (Chan, N.C. 45A ('66) 236)

SU(6) 56

Λ, Σ

p_0, n_0, λ_0

$\lambda_0 \to p_0 + \pi^-$
$\quad n_0 + \pi^0$

$\Lambda_- = -\Xi^-_- = \sqrt{3/2}\,\Sigma^-_-$

$\Sigma^+_+ = 0$ (S波)
(P波 ?)

0.132 : 0.169 : 0.193

[illegible]との[illegible]

$\Sigma^+ \to n + \pi^+$ p-wave amplitude が[illegible]

a) multi-particle transition

1) mass spectrum

$H = (\lambda_0^+ \lambda_0) \, \Delta m$ $\quad T_3^3$

$\langle B | T_3^3 | B \rangle = a h_a + b h_s$

$h_a / h_s \Big|_{exp} = -4.1$

~ 0.45

(Okubo - Gell-Mann)

b) $H = J \times J$ $\quad$ V-A

(仮定) i) H a SU_3 [illegible]

~~a)~~ $H = H_8 + H_{27}$ $\quad$ CP-invariance

ii) ~~a)~~ $\Delta I = 1/2$ $\quad \Delta I = 1/2, 3/2$

$||$ + $|$

b) $\begin{cases} \Delta h_a \simeq 0 \\ h_a \to 0 \end{cases}$

ψ_0 : $t \psi_0 = \bar{t} \psi_0 = 0$

ψ : ~~$t t \psi = \bar{t} \bar{t} \psi = 0$~~

~~$\bar{t} t \psi \neq 0$~~ $(a t t + b \bar{t} t + c \bar{t} \bar{t}) \psi = 0$

~~$t t t \psi = \bar{t} \bar{t} \bar{t} \psi = 0$~~

X $\psi = t^+ \psi_0 , t^+ t^+ \psi_0 \;\|\; \psi = \bar{t}^+ t^+$

$t^\dagger \gamma_\mu t \cdot t^\dagger \gamma_\nu t + t^\dagger \gamma_\nu t \cdot t^\dagger \gamma_\mu t$

$(\ast\ t^\dagger \gamma_\mu t^\dagger t \gamma_\nu t$ $\quad t^\dagger \gamma_\nu \gamma_\mu t - t^\dagger \gamma_\nu t^\dagger t \gamma_\mu t$

$t^\dagger \gamma_\mu \gamma_\nu t -$

$(a t t t + b \bar{t} t t + c \bar{t} \bar{t} t + d \bar{t} \bar{t} \bar{t}) \Psi = \Psi_0$

$\Psi = t^\dagger \Psi_0 \rightarrow a t \Psi_0$

$0 \Psi_0$

Quasi Para - Particle

$\Psi = (a t^\dagger t^\dagger t^\dagger + b \bar{t}^\dagger \bar{t}^\dagger \bar{t}^\dagger +$
$+ c \bar{t}^\dagger t^\dagger + \cdots) \Psi_0$

小林氏
e^-e^+による ρ-meson
講演 July 16, 1968
原子核研究所

storage ring
Novosibirsk　Budker
セルプホフ　70 GeV

10年以上前　storage ring の idea
Princeton
MURA

Frascati		$e^-e^+ \to e^-e^+\gamma$		1961
QED の validity				retired
250 MeV		diameter		1.5 meter
Princeton - Stanford			e^-e^-	1961
500 MeV				
Kharkov		100 MeV	e^-e^-	1963
Novosibirsk		130 MeV VEPP I	e^-e^-	1963
CERN	MSR			
Novos.	VEPP-2	700 MeV	e^-e^+	1966
Orsay	ACO	500 MeV	e^-e^+	1966
Cambridge (USA)		3 GeV	e^-e^+	1966 (test)
Frascati	Adone	1.5 GeV	e^-e^+	1967 (const.)
MURA		200 MeV	e^-e^+	1967 in use
Novosibiri.	VEPP 3	3.5 GeV	e^-e^+	1968 (const.)
Novosibi.		25 GeV	pp	(1971) (const.)
CERN		28 GeV	pp	(1972) (const.)
DESY		3 GeV	e^+e^-	(proposed)
Stanford		3 GeV	e^+e^-	(〃)

$e^+e^- \to \rho^0 \to \pi^+\pi^-$

Energy 確認 (boxed)

(Scientific Research Dec. 1967)

山口嘉夫: 自然 8月号 (1968)

入射 E　ee　electron at rest の energy | 2E

500 MeV　22 MeV　$v = \sqrt{2 m_e E}$

1.5 GeV　39 MeV　980 GeV ← 1 GeV

3 GeV　54 MeV　8800 GeV ← 3 GeV

3500 GeV ← 8 GeV

$(2E)^2 / 2m_e$

pp, $p\bar{p}$

12 GeV　300 GeV　24 GeV

28 GeV　1,700　56

300 GeV　180,000　600

生成する反応 (boxed)

$e e^+ \to 2\gamma$

$e e \to e e$

$e e \to e e \gamma$

$e e \to \mu \mu$

⋮

QED の validity 10^{-14} cm

$e^+ e^- \to \gamma \to$ hadron

$\to \rho^0 \to \pi^+ \pi^-$

$\to \varphi \to K^+ K^-$

$\to \omega \to \pi \pi \pi$

weak boson ?

quark ?

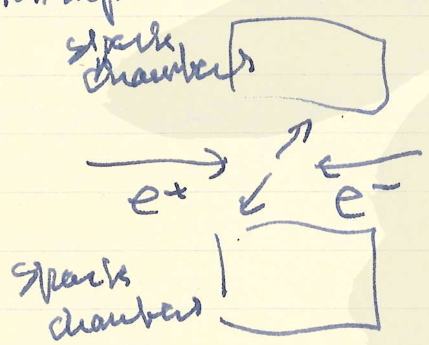
$e^- e^+ \to \rho_0$ の実験
Novosibirsk (Physics Letters 25B (1967) 433)
Orsay (PRL 20 (1968) 126)

Novo.	M_{ρ^0}	Γ_{ρ^0}	$\Gamma_{\rho^0 \to e^+e^-}$ / total Γ_{ρ^0}
Novo	764 ± 11 (MeV)	93 ± 15	(4.9 ± 0.8) ×
Orsay	775 (仮定)	(実験中)	(6.2 ± 1.0) ×

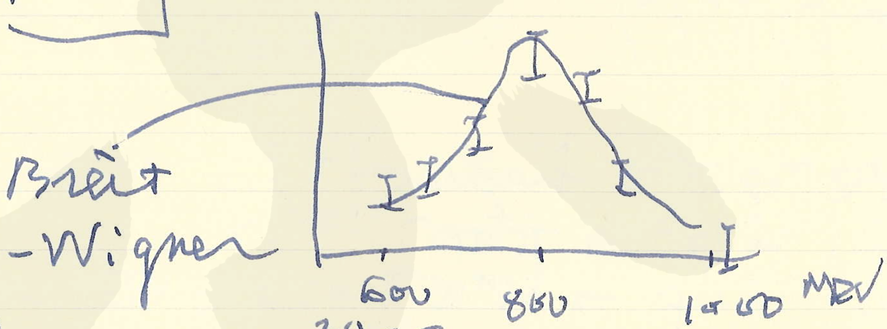
$\pi N \to \rho N$ (ρ^0) 780 ± 2 ($\rho^\pm$) 128 ± 5
$\to \rho \Delta$ ($\rho^\pm$) 774 ± 2

Chew-Low extrapol. ρ^- 755 ± 5 (ρ^-) 110 ± 9

DESY $\gamma N \to$
(6.5 ± 1.5
13 Nb,
(6.5 ± 1.1
(3.9 ± 1.
+3.



MeV
$E = 290 \sim 510$ MeV
$2E = 580$ MeV ~ 1020 MeV



luminosity 5×10^{30} 下記
99/108 の $\pi^+\pi^-$
102 e^+e^-
102 ミューオン

$$\frac{N_\pi}{N_e} \approx \frac{193}{167} = \frac{\sigma_{\pi\pi}}{\varepsilon} \frac{1}{\sigma_{ee}} \frac{1-\delta_\pi}{1-\delta_e}$$

$\sigma_{\pi\pi} = (1.53 \pm 0.25) \times 10^{-30}\ cm^2$

$= 3\pi \lambda^2 B$

$B = \Gamma_{\rho^0 \to e^+e^-} / \Gamma_{\rho^0}^{total}$

tal

10^{-5}

10^{-5}

(Breit-Wigner

$\sigma(E) = \pi \lambda^2 \frac{2J+1}{4} \frac{\Gamma_i \Gamma_f}{(2E-M)^2 + \frac{\Gamma^2}{4}}$

νe^+e^-

$= 2 \times 10^{-5}$

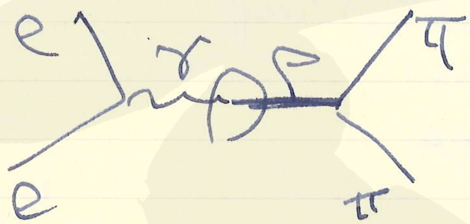
DUBNA

$1.0) \times 10^{-5}$

$1.2 / 3.9) \times 10^{-5}$

$e^+e^- \to K^+K^-$ [illegible]

$\uparrow$
φ



ヘルシンキ 第二日 4 I 2

C. Cronström and M. Noga

Bootstrap Theory of Static Pion-Baryon Scattering — July 16, 1968

Connection with Strong Coupling Theory

1. Background
2. Goebel 理論 ('64) 結合定数の群論的[illegible]
3. Bootstrap

SU$_6$ ('64) → Dynamical Symmetry (hydrogen atom → O(4))

強(理論)結合

$f = N/D$ → Bootstrap

→ Regge

↓

composite

$N, N^*, N^{**}, \ldots$

Cook, Goebel, Sakita

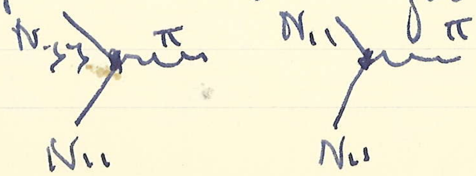
Abers, Balázs, Y. Hara ('64)

$I = J$ $(\frac{1}{2}, \frac{1}{2}), (\frac{3}{2}, \frac{3}{2}), \ldots$

$I = J \pm \frac{1}{2}$ . . .

V. Singh I

V. Singh, R. M. Udgaonkar II



$\frac{\gamma_{33}}{\gamma_{11}}$ = Chew ~~Bootstrap~~

CGS 理論

$$\pi^\alpha + N^I \to \pi^\beta + N^J$$

$$T^{JI}_{\beta\alpha}(\omega) = \sum \frac{T^*(n)\, T(n)}{\ldots}$$

$$= -\lambda^2 \sum_K \left(\frac{(A_\beta^*)^{JK} (A_\alpha)^{KI}}{M_K - M_I - \omega} + \frac{(A_\alpha^{JK})(A_\beta)^{KI}}{M_K - M_J + \omega} \right)$$

$$+ \sum_{\vec{k} K} \left(\frac{T^{KJ}_{\gamma\beta}(\omega_{\vec{p}})\, T^{KI}_{\gamma\alpha}(\omega_{\vec{p}})}{(M_K + \omega_p - M_I - \omega)} + \left(\begin{matrix} \beta \to \alpha \\ \omega \to -\omega \end{matrix} \right) \right)$$

$$M_I = M_0 + \frac{\Delta_I}{\lambda^2}$$

$[A_\beta, A_\alpha] = 0$ "bootstrap condition"

$$\Longleftrightarrow \quad G^i_K G^j_K = \sum_{K'} C^{ij}_{KK'} G^i_{K'} G^j_{K'}$$

$$\Sigma_K = C_{KK'} \Sigma_{K'}$$

crossing matrix $\quad \Sigma = C\Sigma$

$$\frac{\gamma_{33}}{\gamma_{11}} = \frac{1}{2} \quad \left(SU_6 ;\ \frac{8}{25} \right)$$

$$\frac{\mu(N^{*+}_{33})}{\mu(N^0_{33})} = \frac{\mu_p}{0} \quad \leftarrow SU_6$$

Lovelace, π-N scattering p-wave
の resonance は strong coupling
theory とよくあう。

気が揺れたことも何か

7月23日～25日：豊田信吉

25日：

湯川：

1942　　3派　{ 坂田 / 朝永 / 湯川

片山：

益川氏: Model of Minkowski space

位相空間 → 大きいところで離散

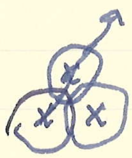
点が主役である。

近傍系

2点をつなぐ—

近傍系の元

一つの要素。

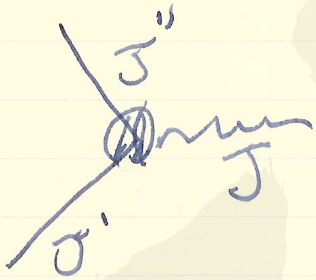


田中正氏:

Regge family

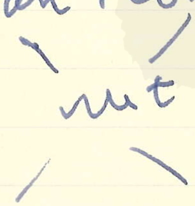
time-like p_μ : particles

space-like p_μ : かたまり



$f_{JJ'J''}$

van Hove



$$\sum_J f_J = \sum_J \frac{b(J,t)P_J}{t-m^2(J)} \sim \frac{r(\alpha,t)P_\alpha}{\sin\pi\alpha(t)} + \int$$

Fronsdal, Blankenbecler PR 129

$$\sum_{J,J',J''} f_{JJ'J''}$$

Toller

$$W_\mu^2 = P_\mu^2\, \alpha(\alpha+1)$$

$$\{P_\mu^2 + f(W_\mu^2)\}\,\Psi(X, v) = 0$$

P_μ : space-likeのときの解

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

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

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

$\nu(P_\mu^2)$ unitary spin

$$\Psi(X, v) = \sum_{m,i} \int d^4p\, A^{m\,i}_{\alpha(p^2),\nu(p^2)}(P)$$

$$\times \exp(i P_\mu X_\mu)\, \eta^m_{\alpha(p^2)}(P_\mu, v)$$

$$\times\, u^i_{\nu(p^2)}(P_\mu, v)$$

$$\to A^{m,i}_{\{\alpha,\nu\}}(X) = \int d^4P\, A^{m\,i}_{\alpha(p^2),\nu(p^2)}\, e^{ipx}$$

$$= \int_{-\infty}^{+\infty} d\kappa^2\, A^{m\,i}_{\alpha(\kappa^2)\,\nu(\kappa^2)}(X)$$

$$\begin{pmatrix} \alpha(P'^2) & \alpha(P''^2) & \alpha(P^2) \\ P'_\mu m' & P''_\mu m'' & P_\mu m \end{pmatrix}$$

$$\begin{pmatrix} \nu' & \nu'' & \nu \end{pmatrix}$$

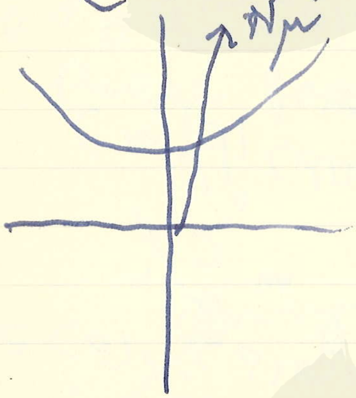
$$\langle 0 | P\{ A_{\{\alpha,\nu\}}(X),\ A^{\dagger}_{\{\alpha,\nu\}}(X')\} | 0 \rangle$$
$$= \pi \int d^4p \ \frac{a'(p^2)(2\alpha+1)}{\sin \pi a(p^2)} e^{ip(x-x')} \delta_{mm'} \delta_{ii'}$$

$P_\mu = 0$: $O(3,1)$

$P_\mu^2 = 0$: $\left\{ \begin{array}{l} O(3,1) \\ E(2) \end{array} \right.$

[illegible]:

[illegible] unbaryon



$p^2 = M^2$

[illegible]

$\int e^{-\lambda^2 (N\cdot p)^2} e^{ip\cdot x}$

時空のゆらぎ = $\Delta = \frac{2\pi\hbar}{p}$　　$\Delta^3 = v$

$l(\bar{u}u)(\bar{u}u)$

$\tilde{m} \approx 3 \frac{l^4}{M^2 v^2}$

$u \to U$

$\sigma_{AB} = \sigma_{\bar{A}B} = \sigma_{\bar{A}\bar{B}}$

Hagedorn
Fermi
Wu Yang

A.C. Josephson 効果
$\alpha_{s.s} \fallingdotseq \alpha_{f.s.}$ 10 ppm
Physical Letter

素粒子の統一的記述
研究会

Sept. 26
~28
1968

湯川

田中正

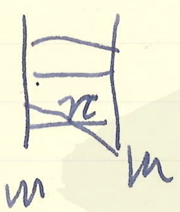
Venetiano
P. 32

宗像　B.S equation

1) { constructive force
　 { interactive force

local field theory
bootstrap

2) inelastic process
high energy



$\rightarrow P_\mu = 0$　　ひろがり $\hbar/mc$

Krish

高林:　Finsler 空間
$g_{\mu\nu}(x^\mu, \dot{x}^\mu)$
$\varphi(x^\mu, \dot{x}^\mu)$
Gauge

[illegible]:　相対論的[illegible] system
P_μ　　$M_{\mu\nu}$
relativistic bee model

(covariance
(rel. invariance

(subjective identity
(objective 〃

第2回
序論：

第3回

伊藤　4次元 ellipsoid 模型
の form factor

p-p 散乱

(中野)

坂野

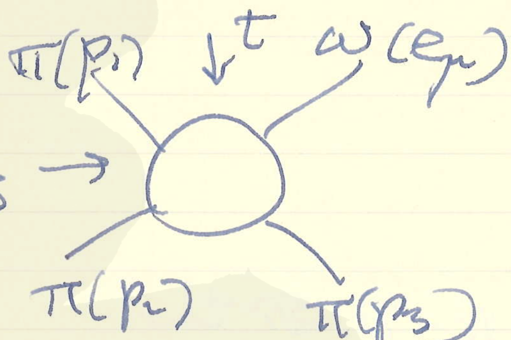
Oct. 15, 1968

梅村勲

G. Veneziano (CERN) 基研

Construction of a Crossing Symmetric, Regge Behaved Amplitude for Linearly Rising Trajectories
(N.C. Letter III sept. 1, 1968)

$\pi\pi \to \pi\omega$



$T = \varepsilon_{\mu\nu\rho\sigma} e_\mu P_{1\nu} P_{2\rho} \times P_{3\sigma} A(s,t,u)$

$s + u + t = 3m_\pi^2 + m_\omega^2$

$$A(s,t,u) = \frac{\bar{\beta}}{\pi}\Big[B(1-\alpha(t), 1-\alpha(s)) + B(1-\alpha(t), 1-\alpha(u)) + B(1-\alpha(s), 1-\alpha(u))\Big]$$

$$B(X,Y) = \frac{\Gamma(X,Y)}{\Gamma(X+Y)}$$

$\alpha(t) + \alpha(s) + \alpha(u) = 2$

$\to \alpha(-2m_\rho^2 + m_\omega^2 + 3m_\pi^2) = \alpha(-0.53\ \mathrm{BeV}^2) = 0$

$\alpha(m_\rho^2) = 1$

Duality of Regge poles and resonances

Schmidt $f = f_{Regge} + f_{Res.} - \langle f_{Res.}\rangle$

小～話

Partial Wave Amplitude
"Argand" Diagram

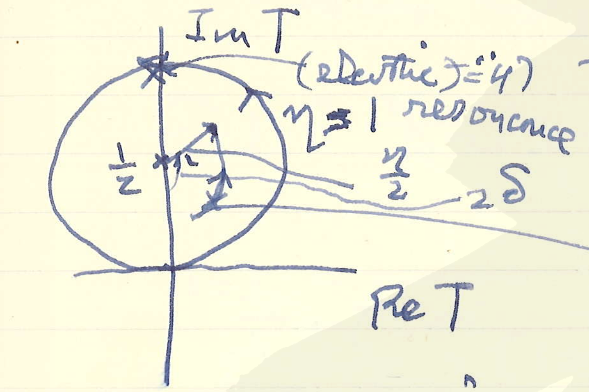
荒神 Oct 22, 1968

(1) History ~~1964∼~~

π−N scattering (1964∼)

Gauss plane → J. R. Argand (1768∼1822)

C. F. (1777−1855)



$$T = \frac{\eta e^{2i\delta} - 1}{2i}$$

$$x^2 + \left(y - \frac{\eta}{2}\right)^2 = \left(\frac{\eta}{2}\right)^2$$

1959 Adair

unitary: 円の外に出ない

causality: resonanceの近くでは、ある円に沿ってcounter clockwiseに進む

$\frac{d\delta}{dE} > -a$ (potential scattering)

Höhler: 1961

Dalitz: 1963. L, J, I に分ける

Saclay, CERN, Berkeley

$s = 0$ ~~×~~ $s = 0$: partial wave amplitude

$$T_\ell = \frac{\eta_\ell e^{2i\delta_\ell} - 1}{2i}$$

$$\sigma_{el} = \frac{4\pi}{k^2} \sum_\ell (2\ell+1) |T_\ell|^2$$

$$\sigma_{rea} = \frac{\pi}{k^2} \sum_\ell (2\ell+1)(1-\eta_\ell^2)$$

$$0 \le \eta_\ell \le 1$$

~~for~~: $s = 0$ ~~×~~ $s = \frac{1}{2}$

$$2\ell+1 \to \frac{2J+1}{(2s_1+1)(2s_2+1)} = J + \frac{1}{2}$$

$$\eta_\ell^{\pm},\ \delta_\ell^{\pm} \leftarrow J = L \pm \frac{1}{2}$$

$$M = f(\theta) + g(\theta)\,\vec{\sigma}\cdot\vec{n}$$

transition matrix

$f(\theta)$: spin non-flip amp.

$g(\theta)$: spin flip amp, $\vec{n} = \vec{k}_i \times \vec{k}_f$

$$\frac{d\sigma}{d\Omega} = |f|^2 + |g|^2$$

$$\frac{d\sigma}{d\Omega}\vec{P} = 2\,\mathrm{Re}(f g^*)\,\vec{n}$$

$$P = \frac{N(\uparrow) - N(\downarrow)}{N(\uparrow) + N(\downarrow)} P_0$$

Breit-Wigner

$\eta = 1$:
$$T = \frac{1}{\cot\delta - i}$$

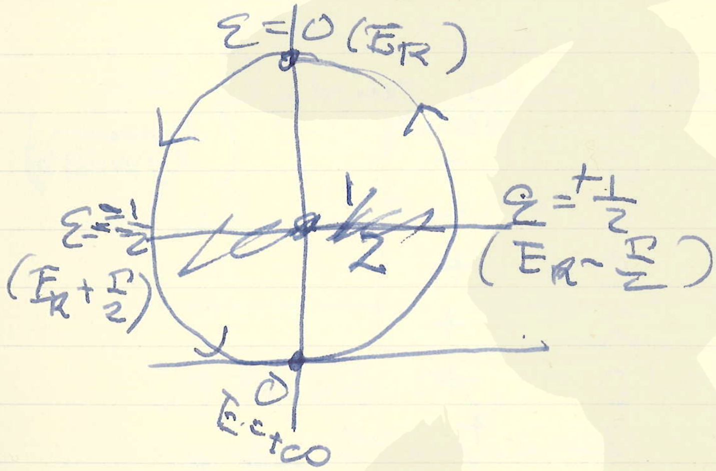
$$\cot\delta \cong (\cot\delta)_{E_r} + (E - E_r)\left(\frac{d(\cot\delta)}{dE}\right)_{E_r}$$

$(\cot\delta)_{E_r} = 0$, $\quad \left(\frac{d(\cot\delta)}{dE}\right)_{E_r} = -\frac{2}{\Gamma}$

$$T \cong \frac{1}{(E_r - E)\frac{2}{\Gamma} - i}$$

$$\sigma_{el} \cong \frac{\pi}{k^2}(J + \tfrac{1}{2}) \frac{\Gamma^2}{(E_R - E)^2 + \left(\frac{\Gamma}{4}\right)^2}$$

$$T_{el} = \frac{1}{\varepsilon - i} \qquad \varepsilon \equiv (E_R - E)\frac{2}{\Gamma}$$



$$\Gamma = \Gamma_e + \Gamma_r \qquad \Gamma_e/\Gamma \equiv x \text{ (elasticity)}$$

$$T_e = \frac{x}{\varepsilon - i}$$

$$T_r = \frac{\sqrt{x(1-x)}}{\varepsilon - i}$$

Background 有る場合
31効。有力

H. Harari, Resonances (Theory)
Wien Conference 1968

小沢G 基研 11/11, 12/10 1968

Baryon Resonances: $SU(3) \to SU(6)$

$Y_0^*, Y_1^*, \ldots\ldots$ $[SU(6), L^P]$

$(56, L=0)^+$

$(56, L=0)^+$

$(56, L=2)^+$ $56 \times 5 = 280$?

$(70, L=1)^-$ $(1+8+10, \frac{1}{2}) + (8, \frac{3}{2})$

$(1+8+8+10, \frac{1}{2}, \frac{3}{2})$

$+ (8, \frac{5}{2})$

model (q,q,q)

harmonic oscillator shell model

		SU_6	L	parity
⊔⊔⊔	$(1s)^3$	56	0	+
⊞	$(1s)^2(1p)$	70	1	−
	$(1s)^2(2s)$	56	0	+
	$(1s)^2(1d)$	56	2	+
	$(1s)(1p)^2$	70	0	+
		70	2	+
目		20	1	+

(fermion 2 W同3)

$(q\bar{q})$

Meson Resonances: → $\{35, 0\}$ 0^{-+}, 0^{--}

10 番目の ps meson $\{35, 1\}^+$ 2^{++}, 1^{++}, 1^{+-}, 0^{++}

π K^* η X E

$\uparrow$

0^-

$E \to K^*\bar{K} + \bar{K}^*K$

1420 → $\pi_N(1016)$ π

↳ $K\bar{K}$

$0^+, 1^-, 2^+, \ldots$

$A_2 \quad 2^+ \rightarrow \rho\pi$

		Γ
A_{2H}	1315	~30
A_{2L}	1270	~30

$A_1(1020) \quad 1^+$

$(A_{1.5} \quad)$

1^+	C
A_1	+
B	−

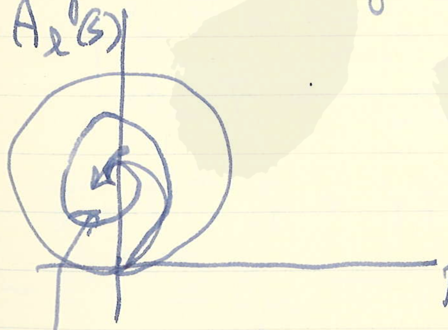
$I=1$

new Gell-Mann - Zweig -model $(q\bar{q})$
daughter trajectory
~~#~~ O_4, $O_{3,1}$

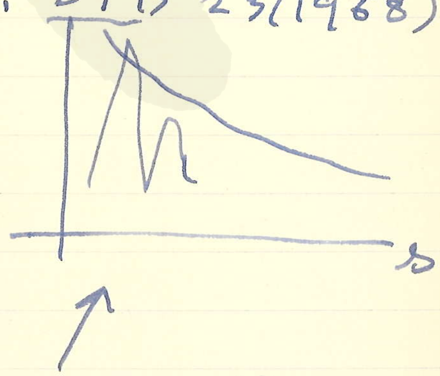
Chiral $SU(2)\times SU(2)$

河原林の (Collins, Johnson, Squires
Argand diagram P.L. 27 B 23 (1968))

Im $A_l(s)$



Re $A_l(s)$



Schmidt

Im $A(s,t) \sim s^{\alpha(t)}$

$t = 2|q|^2(1-\cos\theta)$

$$A_\ell(s) = \int P_\ell(\cos\theta)\, A(s,t)\, d(\cos\theta)$$

resonance の解析

$$A'(\nu, t) = e^{i\pi\alpha(t)}$$

~~$\nu =$~~ $s - m^2 = 2m\nu$

$\mathrm{Re}\, A_\ell(s) = \int \mathrm{Re}\, A' \cdot P_\ell$ ~~?~~ $d(\cos\theta)$: circle

spiral である!!!

(Argand diagram で)

資料究所：　　湯川　　Nov. 19, 1968

Nonlocal theory と Quark System

1. quark を導入　1-3/5 回
2. nonlocal ~~the~~ theory を応用現象論的に使う
3. Regge ?

$$(p^2+m^2)\,U(X,r)=0$$
$$(r^2+\lambda^2)\,U(X,r)=0 \qquad \text{と } X$$
$$(rp)\,U(X,r)=0 \qquad ③$$
$\longrightarrow$

$$a\ \bar{b} \longrightarrow \Phi_a^b(X,r)$$

quark-antiquark　　3×3　　4×4

Bohr-Mottelson　　12×12

$$R = r + \langle R\rangle$$

$$\rightarrow\left\{\begin{array}{l}(\beta_\mu p^\mu + \gamma\mathfrak{M})\,\Phi(X,r)=0\\ \beta'_\mu p^\mu\,\Phi = 0\\ \beta_\mu p^\mu\,\Phi = 0\end{array}\right.$$

$$\beta_\mu F = \frac{1}{2}[\gamma_\mu, F]$$
$$\beta'_\mu F = \frac{1}{2}\{\gamma_\mu, F\}$$

$$\left.\begin{array}{l}\gamma_\mu p^\mu\,\Phi + \gamma\mathfrak{M}\,\Phi = 0\\ -p^\mu\,\Phi\,\gamma_\mu + \gamma\mathfrak{M}\,\Phi = 0\end{array}\right\}$$

$$\{\beta_\lambda\beta_\mu\beta_\nu + \beta_\nu\beta_\mu\beta_\lambda = g_{\lambda\mu}\beta_\nu + g_{\nu\mu}\beta_\lambda$$

Duffin-Kemmer

$$\beta_\mu \beta_\nu + \beta_\nu \beta_\mu = g_{\mu\nu}$$

$$\Phi(x', r') = e^{\frac{i}{2}\theta_{\mu\nu}(\beta_\mu\beta_\nu - \beta_\nu\beta_\mu)} \Phi(x, r)$$

$$\mathfrak{M}' = e^{\frac{i}{2}(\quad)} \mathfrak{M} e^{-\frac{i}{2}(\quad)}$$

$$\beta^2 = \beta_\mu \beta^\mu$$

$$\begin{cases} \mathfrak{M}_V = m_0 - m_V \eta_{\mu\nu}(p^2 r^\mu r^\nu + p^{-2} \gamma^\mu \gamma^\nu) \\ \eta_{\mu\nu} = g_{\mu\nu} - \frac{p_\mu p_\nu}{p^2} \end{cases}$$

$$\mathfrak{M}_V \Phi = m \Phi$$

internal angular momentum

$$L^2 = L_\kappa L^\kappa$$

$$L_\kappa = \frac{1}{2} \varepsilon_{\kappa\lambda\mu\nu} p^\lambda (r^\mu p^\nu - \gamma^\nu p^\mu) / \sqrt{p^2}$$

$$x \frac{d^2 R_L(x)}{dx^2} + \frac{1}{2}(2L+3) \frac{d R_L(x)}{dx} - \frac{1}{4}\left(\frac{m - m_0}{4 m_V} + x\right) R_L(x) = 0$$

$$m_{KL} = m_0 + (4K + 2L + 3) m_V$$

$$K, L \geq 0$$

$$\mathfrak{M}_p = \cdots$$

$$\mathfrak{M}_{hs} =$$

小川

High Energy Weak Processes

菅原　Dec. 3, 1968

原子炉 (ν_e) 1956

加速器 (ν_μ)　BNL　1962 ~
(two neutrino)

CERN　1963 ~

ANL ZGS　1965 ~

(Serpukhov (70 GeV)
NAL (200 GeV)
(Nat. Acc. Lab)

地下のμ　Kolar Gold Fields (三宅)　1965 ~

Case-Wits-Irvine　1965 ~

Utah　1967 ~

$\nu_\mu \Rightarrow \mu$ (energy やや大)

$\pi \to \mu \Longrightarrow \mu$ (energy 大 α,

太陽などからくる ν_e (energy 小, MeV)

solar neutrino

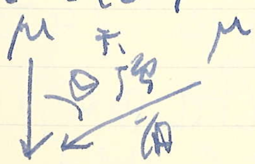
逆β　$\nu_e + Cl^{37} \to Ar^{37} + e^-$

散乱　$\nu_e + e^- \to \nu_e + e^-$

逆β　$Be^8 \to \nu_e$ flux $\lesssim 2 \times 10^9/cm^2 sec$

(予想 ν　$6 \sim 22 \times 10^6/cm^2 sec$)

Utah 1967



zenith angle dependence

10^{12} eV ~ 10^{13} eV (1 TeV ~ 10 TeV)

$40^\circ \lesssim \Theta \lesssim 80^\circ$

$I_\theta = I_{vert} \sec\theta$

$I(d, \varepsilon, \theta)$

であれば

$I_\theta = \text{const.}$

になってる。(Utah)

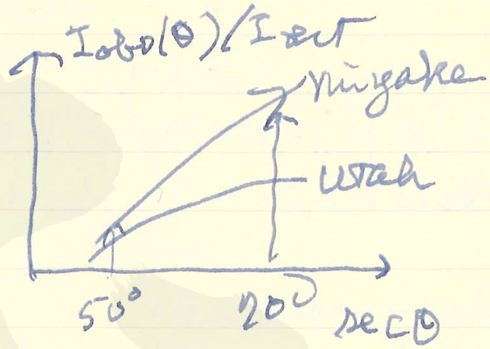
これは π, K decay した外の原因ででき[た]
μがまじってるのではないか？

① Ohkubo : その他

$g_\nu \bar{N} N W$　　　$g_\pi \bar{N} N W W$ ↓ μ

② μといっても、その中にμ以外(U)がある？
Glashow . .

参考 : Wien 報告 (1968)
$(0.5 \sim 5) \times 10^{12}$ eV



加速器
CERN　spark chamber group
μ no. の[illegible]

1963~64　$\dfrac{(\nu_\mu \to \mu^+)}{(\nu_\mu \to \mu^-)} \lesssim 1 \times 10^{-2}$

$\lesssim 5.6 \times 10^{-3}$ (90% conf.)

Heavy liquid Bubble Chamber (HLBC)

freon CF_3Br　　propane C_3H_8

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

N^{*++}?

1) Elastic scattering
$\nu N \to N \mu$

2) Inelastic
$\nu N \to N^* \mu$
$\to N \mu \pi$

3) CVC の test
4) PCAC の test
5) current algebra の test

1) $\nu_\mu + n \to p + \mu^-$

$\mathfrak{M} = \frac{G}{\sqrt{2}} \bar{\nu}_\ell \gamma_\lambda (1+\gamma_5) \nu_\nu \langle p | J_\lambda^{h} | n \rangle$
$\cos\theta$

$q = p_n - p_p$

$\langle p | J_\lambda^V | n \rangle = i \bar{u}_p (F_1(q^2)\gamma_\lambda + \cdots F_2 \sigma_{\lambda\mu} q_\mu) u_n$

$\langle p | J_\lambda^A | n \rangle = \cdots \quad -(F_A \cdots$

$F_1 = F_2 = \left(1 + \frac{q^2}{M_V^2}\right)^{-2}$ $\quad M_V = 840\ \mathrm{MeV}/c^2$

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

$M_A = 650\left(\begin{smallmatrix} +450 \\ -400 \end{smallmatrix}\right)\ \mathrm{MeV}/c^2$

2) $\nu_\mu + p \to \mu + \pi^- p$ 　　$M \sim 840$ MeV

3) CVC の test

4) PCAC 〃

5) current algebra 〃

◦實驗計画

	ν event/day
1963~64	10
67	25
69以降	>1500

(bubble chamber
gargamelle
(CERN)
の改良)

片山泰久

Nonlocal Field Theory in Two Dimensional Space-Time

[illegible] Dec. 10, 1968

charge independent interactions

2成分 → 4成分 へ拡張

$$\xi_0 = \frac{\gamma_\mu P^\mu}{p^2} \qquad \pi_0 = -\frac{g_\mu P^\mu}{p^2}$$

$$\xi_1^2 = -\gamma_\mu \gamma^\mu + \frac{(\gamma_\mu P^\mu)^2}{p^2}$$

$$\pi_1^2 = -g_\mu g^\mu + \frac{(g_\mu P^\mu)^2}{p^2}$$

$$[[\xi_1^2, \pi_1^2], \xi_1^2] = 8\xi_1^2$$

$$[[\xi_1^2, \pi_1^2], \pi_1^2] = -8\pi_1^2$$

1) $$\pi_1^2 = \underbrace{-\left(\frac{\partial}{\partial \xi_1} + \frac{1}{\xi_1}\right)^2}_{= \overset{\vee}{\pi}_1^{2}} + \frac{W_\mu W^\mu}{\xi_1^2 p^2}$$

2) Parastatistics

$$\xi_1 = \sum_{k=1}^{N} \sigma_k \xi_1^{(k)} \qquad \pi_1 = \sum \sigma_k \pi_1^{(k)}$$

$$\sigma_i \sigma_j + \sigma_j \sigma_i = 2\delta_{ij}$$

$$[\xi_1^{(k)}, \pi_1^{(l)}] = i\delta_{kl}$$

$$S_{\mu\nu} = r_\mu \xi_\nu - r_\nu \xi_\mu \to W_\mu = \frac{1}{2}\epsilon_{\mu\nu\rho\sigma} P^\nu S^{\rho\sigma}$$

$N=1, \quad N=3$

$$W_\mu W^\mu = P^2 \frac{1}{2} \sum_{k,l} (\xi_1^{(k)} \pi_1^{(k)} - \xi_1^{(l)} \pi_1^{(k)})$$

$(N-1)(N-3)$

$$r_\mu = \frac{1}{\sqrt{P^2}} (\xi_0 P_\mu + \xi_1 Q_\mu)$$

$$(2\text{次元} \quad Q_\mu = \epsilon_{\mu\nu} P^\nu)$$

$$Q_\mu P^\mu = 0 \qquad Q_\mu Q^\mu + P_\mu P^\mu = 0$$

$$L_{\mu\nu} = X_\mu P_\nu - X_\nu P_\mu$$

$$J_{\mu\nu} = S_{\mu\nu} + L_{\mu\nu} = i\left(P_\mu \frac{\partial}{\partial P^\nu} - P_\nu \frac{\partial}{\partial P^\mu}\right)$$

$$+ i\left(Q_\mu \frac{\partial}{\partial Q^\nu} - Q_\nu \frac{\partial}{\partial Q^\mu}\right)$$

$$\psi(P_\mu, r_\mu) \to \psi(P_\mu, Q_\mu, \xi_0, \xi_1)$$

$\pi_0 = +i \frac{\partial}{\partial \xi_0}$

$\pi_1 = -i \left(\frac{\partial}{\partial \xi_1} + \frac{1}{\xi_1} \right) \rightarrow -i \frac{\partial}{\partial \xi_1}$

2次元

bilinear form

F_0

F_1

⋮

F_9

isospin as set

① (F_1, F_2, F_3) $F_1^2 + F_2^2 + F_3^2 = \xi_0^2 \frac{1}{4}$

(F_{3+k}, F_{6+k}, F_0) ..

(F_{3+i}, F_{3+j}, F_k) ..

$(\quad)$.

$(F_1^2 + F_2^2 + F_3^2) \psi_{I, I_3} = I(I+1) \psi_{I, I_3}$

$F_3 \psi_{I, I_3} = I_3 \psi_{I, I_3}$

Yasushi Takahasi
Method of Hyperquantization I, II
Dec. 17, 1968

(1)

山本談: Convergent Field Theory with Complex Masses

素研. Jan. 21, 1969

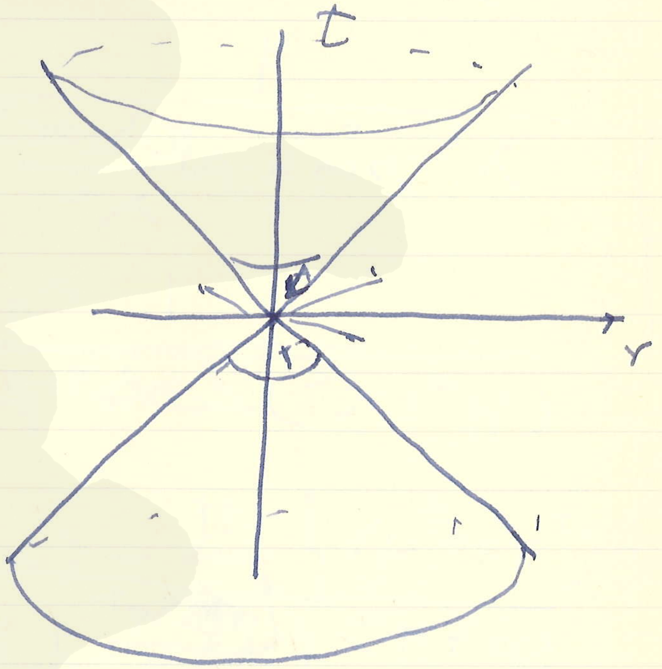
Lehmann 表示.

$$\int \frac{\sigma(m^2)}{p^2+m^2}\,dm^2$$

real mass, definite metric → divergence

micro-causality

macro-causality



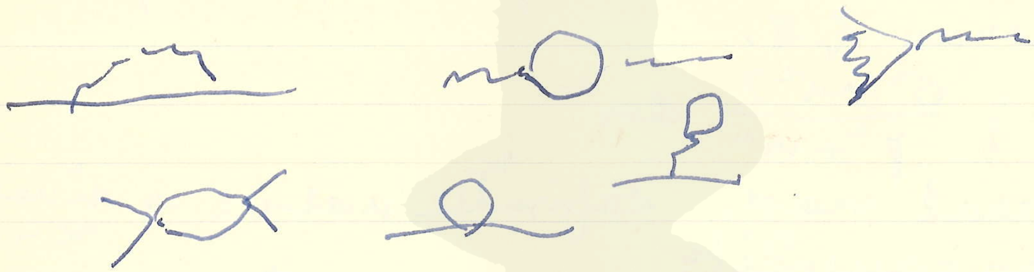
Propagator の性質

1. relativistic covariance
2. 〃 real analytic
3. one simple pole on real p^2-axis (definite norm)
4. free from infrared divergence
5. 〃 ultraviolet 〃
6. causality → macrocausality

boson: $\frac{1}{(p^2+\kappa^2)\varphi(x)}$ simple pole

$\varphi(x) \equiv \prod_i (1+a_i x + b_i x^2)$ $\quad x \equiv (p^2+\kappa^2)/\lambda^2$

$a_i^2 - 4b_i^2 < 0$



$$\left\{\begin{array}{l} \dfrac{1}{\lambda^2 \sinh \dfrac{p^2+\kappa^2}{\lambda^2}} \\[2em] \dfrac{1}{(p^2+\kappa^2)\cosh \dfrac{p^2+\kappa^2}{\lambda^2}} \end{array}\right.$$

$$\frac{1}{(p^2+\kappa^2)\left(\dfrac{(p^2)^2-\kappa^4}{\lambda^4}+1\right)} \qquad \lambda > \kappa$$

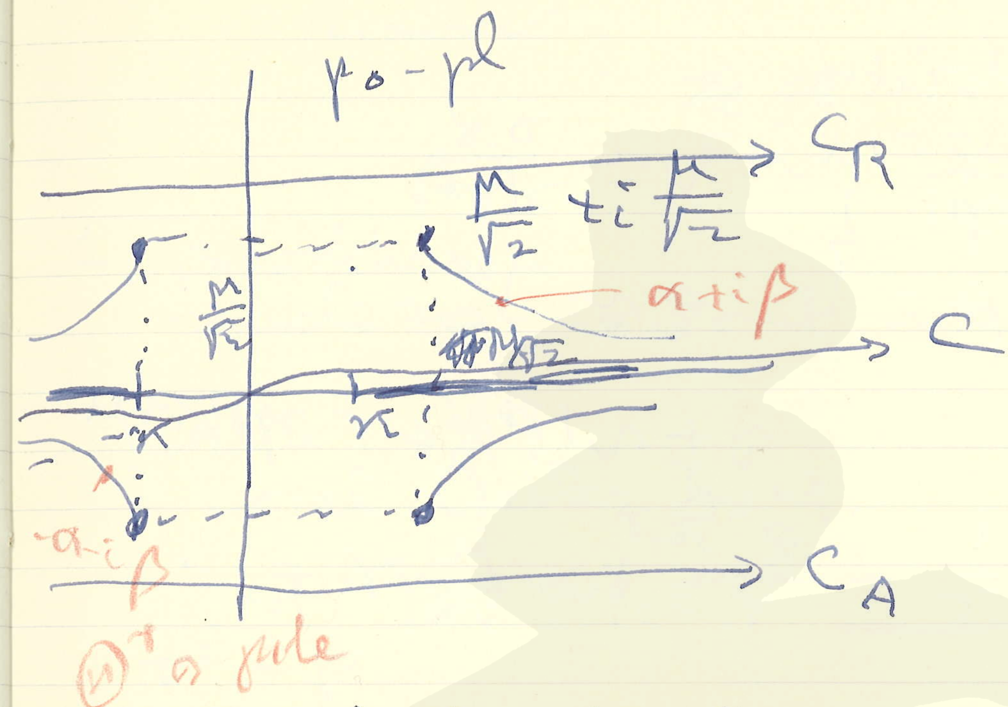
$\lambda = \kappa$: $\dfrac{\kappa^4}{p^4}$

dipole ghost

macrocausality

$\mu^4 = \lambda^4 - \kappa^4$

$$\frac{\kappa^4+\mu^4}{(p^2+\kappa^2)(p^4+\mu^4)} = \frac{1}{p^2+\kappa^2} - \frac{1}{2\mu^2}\left\{\frac{\mu^2+i\kappa^2}{p^2+i\mu^2} + \frac{\mu^2-i\kappa^2}{p^2-i\mu^2}\right\}$$



$$\int_C e^{ipx} \frac{x^4 + \mu^4}{(p^2 + x^2)(p^4 + x^4)}$$

$$\equiv \Delta_c'(x) = \Delta_c(x) - \frac{1}{2\mu^2}\left\{(\mu^2 + ix^2)(\Delta)^{+}(x) + (\mu^2 - ix^2)(\Delta)^{-}(x)\right\}$$

$$(\Delta)^{+}(x) = \frac{1}{2(2\pi)^3}\int d^3p\, \frac{1}{\alpha + i\beta} \exp(ipx + i\alpha|t| - \beta|t|)$$

$$\alpha = \sqrt{(\sqrt{p^4 + \mu^4} + p^2)/2}$$

$$\beta = \sqrt{(\sqrt{p^4 + \mu^4} - p^2)/2}$$

group velocity

$$v = \frac{\partial p}{\partial |p|} \qquad v \simeq \frac{\partial \alpha}{\partial |p_0|}$$

$$p_0 = \alpha + i\beta \qquad t \simeq 1/\beta$$

$$v < 1 \qquad vt \sim |p_0|/\mu^2 \qquad |p_0| \ll \mu$$

$$V(r) = \frac{1}{r} - \frac{e^{-\frac{\mu}{\sqrt{2}}r}}{r} \cos\frac{\mu}{\sqrt{2}} r + \cdots$$

Matsuo Sekine

Acausality

基研

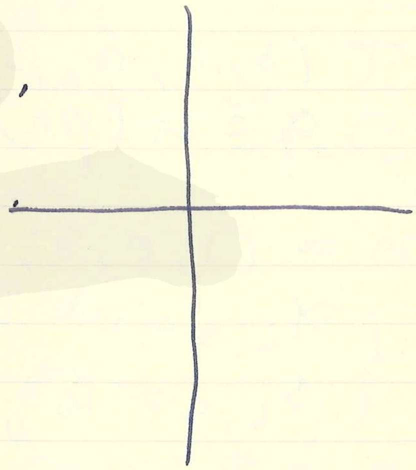
Feb. 12, 1969

1. Brookhaven
nuclear - Coulomb interference

1967年1月
Coral Gables Conf.

$f_{tot} = f_N + \alpha f_c e^{i\alpha\phi}$

$\pi^{I} - p$



2. Blokhintsev : Acausal Dispersion Relation

$T(s,t) = D + iA$

$s = p^2, \quad t = -q^2$

(I) Causality

$x^2 = (x' - x'')^2 = (t' - t'')^2 - (\vec{x}' - \vec{x}'')^2$

$x^2 < 0 : \quad [A(x'), B(x'')] = 0$

(II) spectral condition

$P_\mu P^\mu = m^2 \geq 0$

(III) $\tau(s,t) < a|s|^m$
$|s| \to \infty$

m: positive integer

unit time-like vector

$x^2 = (x^1 \cdot x^0)^2$

$R^2 = 2(nx)^2 - x^2 \geq 0$

$R \gg a$: usual theory

$R \approx a$: acausal

$T(s, t, \alpha, \beta)$

$\alpha = a(pn)$ $\beta = a(qn)$

$n = (1, 0, 0, 0)$ ts system では

$\alpha_{L.S} = a P_0 = a(E_0 + m)$

$\beta_{L.S} = a q_0 = a(E_0 - E)$

$\alpha_{CMS} = a p_0 = am(E_0 + m)$

$\beta_{CMS} = 0$

elastic e-p scattering

$a = \frac{\hbar}{Mc} = 2 \times 10^{-14}$ cm

electron energy 数 GeV

$\alpha_{L.S} \approx \beta_{L.S} \approx 1$

$\alpha_{CMS} \approx 0.02$, $\beta = 0$

Blokhintsev の仮定

I. small region で acausal
(R, n にて与える)

II. Acausal Prop. では

$$\Phi_a^{ret}(x) = \int F_c^{ret}(x-\xi)\, \rho_1(\xi, n)\, d^4\xi$$

$$\Phi_a^{adv}(x) = \int F_c^{adv}(x-\xi)\, \rho_2(\xi, n)\, d^4\xi$$

$$\rho_1(\xi, n) = \rho_2(-\xi, n)$$
real function

III. spectral condition が満たされている

$$\Phi_a = \Phi^{ret} - \Phi^{adv}$$
$$= \langle p \,|\, [J(\tfrac{x}{2}), J(-\tfrac{x}{2})] \,|\, p \rangle$$

ρ の例
(i) sharp cut-off

$$\rho(x, n) = \frac{4}{\pi^2 a^4} \int_0^{a^2} d\xi\, \delta(\xi - R^2)$$

$$\tilde{\rho}(Q, n) = \frac{8}{a^4[2(Qn)^2 - Q^2]} J_2\left(a\sqrt{2(Qn)^2 - Q^2}\right)$$

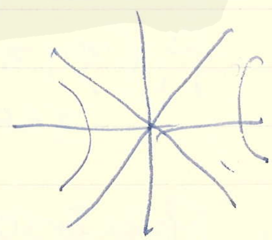
(ii) $\rho(x, n) = \frac{1}{a^4} e^{-R^2/a^2}$

$\tilde{\rho}(Q, n) = e^{-\frac{a^2}{4}[2(Qn)^2 - Q^2]}$

(iii) $\rho(x, n) = \frac{1}{8\pi a^2 R^2} e^{-R/a}$

$\tilde{\rho}(Q, n) = \frac{1}{1 + a^2[2(Qn)^2 - Q^2]}$

causality for light cone 附近 に沿って
成立しない。



山口嘉夫

CERN JAN 14~17

Topical Conf. on Weak Interaction

荒船 Feb. 12, 1969

Neutrino Meeting

○CERN ○
○BNL
ANL
25' H.B.C (1972) NAL (200 GeV)
Serpukhov

(25 million dollar)

Perkins;
ν-experiment

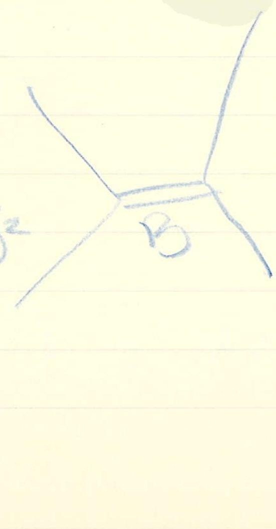
$$\frac{\nu_\mu \to \mu^+}{\nu_\mu \to \mu^-} < 4.6 \times 10^{-3}$$ (lepton No. cons.)

$m_W > 1.8$ GeV

Yoshiki resonance

$\nu_\mu n \to B \to \mu^- p$

form factor $F_A \propto \frac{1}{(1+\frac{q^2}{m_B^2})^2}$



$\sigma_{inel} = 0.5 E_\nu \times 10^{-38} cm^2$
(GeV)

$H^3 \to He^3 + e^- + \nu_e$

$m(\nu_e) < 60\,eV$

$(m(\nu_\mu) < 3\,MeV)$

J. L. Rosner
A Graphical Form of Duality
北門 A 紹介 Feb. 1969

Veneziano
Lovelace
$\alpha_\rho = \alpha_f$
π-π scattering

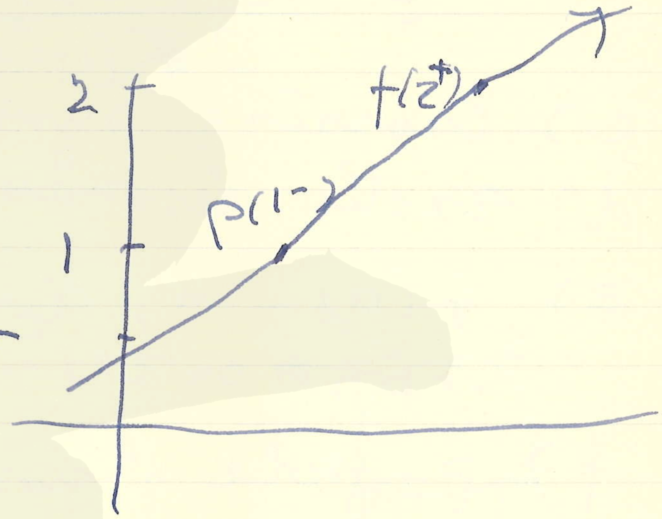
K, K_N, KY,
(I) 1^- 2^+ nonet
$\alpha_\rho = \alpha_\omega = \alpha_f$
$= \alpha_{A_2}$

$\alpha_{K^*} = \alpha_{K^{**}}$

$\alpha_\varphi = \alpha_{f'}$

{ πK
KK
$K\bar{K}$

$n(\geq 5^-)$ では
normal parity $P = (-1)^J$
abnormal 〃 $P = -(-1)^J$



abnormal trajectory
πKY(II)
coupling constant f, a でまとめる
[illegible]

Lovelace

a) linear traj.

b) asymptotic,

$\to F(s,t) = F(\alpha(s), \alpha(t))$

$$= \frac{\Gamma(1-\alpha_s)\Gamma(1-\alpha_t)}{\Gamma(1-\alpha_s-\alpha_t)}$$

c) crossing sym

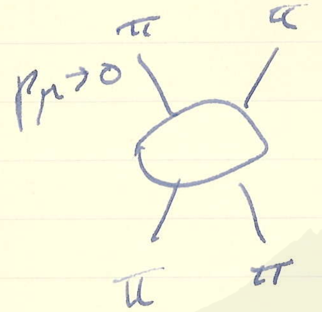
d) exotic resonance なし...

e) $F(\alpha_s - n, \alpha_t - m)$ $n, m \geq 1$

[illegible]...

f) ρ-pole で normalize

PCAC

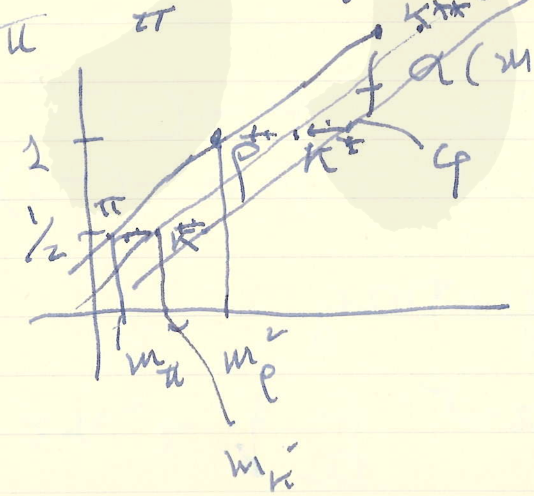


$\lim_{p_\mu \to 0} A = 0$

$s = t = u = m_\pi^2$

$1 - \alpha(m_\pi^2) - \alpha(m_\pi^2) = 0$

$\therefore \alpha(m_\pi^2) = \frac{1}{2}$



$\rho^+ \rho^0 \rho^-$ $(p\bar{n},\ p\bar{p}\text{-}n\bar{p})$

$K^+ K^0 \rho^-$ $(p\bar{\lambda},\ n\bar{\lambda})$

φ $(\lambda, \bar{\lambda})$

$$\begin{cases} m_\rho^2 = m_\omega^2 \\ m_{K^*}^2 - m_\rho^2 = m_\varphi^2 - m_{K^*}^2 \end{cases}$$

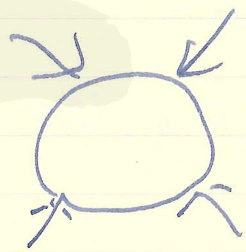
[Rosner

$\{M_1, M_2, M_3, M_4\}$

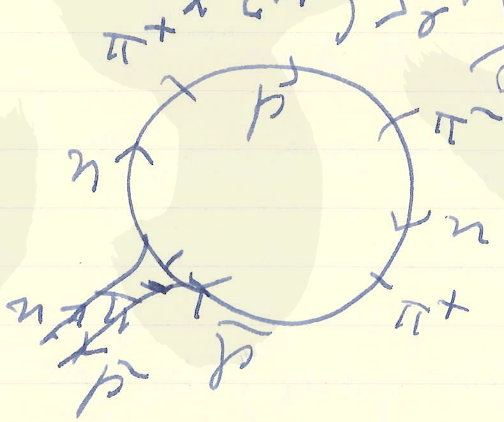
$\pi^+\pi^+ \to \pi^+\pi^+$

$\pi^+\pi^+ \to \pi^-\pi^-$

$M_1 M_2 \to \bar{M}_3 \bar{M}_4$

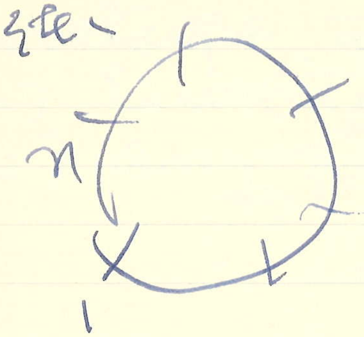


$$\{\ \} = \sum_{P(\alpha\beta\gamma)} 4\gamma_M^2 [jk], [k\bar{\ell}]_\alpha [\ell\ \bar{m}]_\beta \times [m\ \bar{j}]_\gamma F(\alpha_{j\bar{\ell}}(s_{\alpha}), \alpha_{k\bar{m}}(s_{\alpha\beta}))]$$



s と t の duality

n 3te-



$B_4 \to B_5 \to B_6 \to \cdots \to B_N$

chang

~~$B(x, y) = \int u^{-x+1}$~~

~~$B_N =$~~

$$B(\alpha_s, \alpha_t) = \int_0^1 dx\, x^{-\alpha_s}(1-x)^{\alpha_t}$$

x: iuternal coord.

$x = \alpha_N(s_{12}) = a s_{12} + b_N$

$s_{123} = (p_1 + p_2 + p_3)^2$

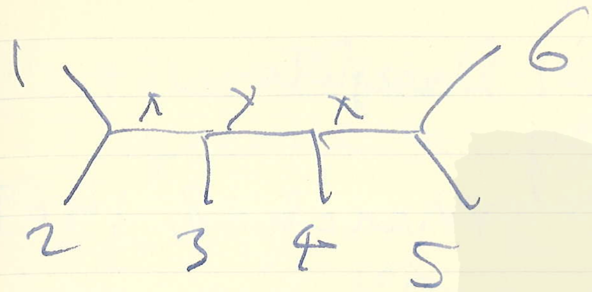
$y = \alpha_A(s_{123}) = a s_{123} + b_A$

$\alpha_N(s_{1234}) = a s_{1234} + b_N$

. . . .

$$B_6(x_i, y_j) = \int_0^1 du_1 \int_0^1 du_5 \int_0^1 dv_3$$

$$\times \left(\frac{v_3}{u_6^2}\right) \times u_1^{x_1} \times u_2^{x_2} \cdots u_6^{x_6} v_1^{y_1} v_2^{y_2} v_3^{y_3}$$



$u_1 = 1 - u_6 u_2 v_1$

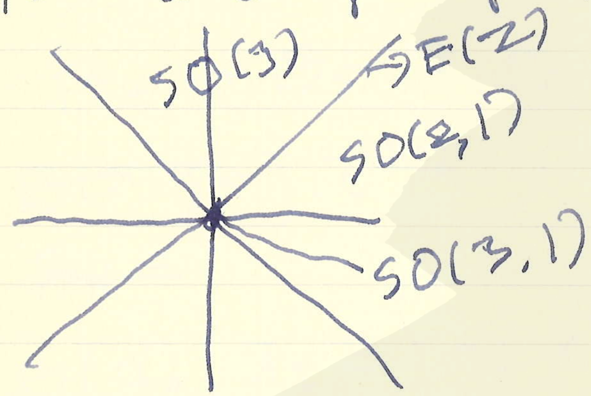
.. . .

[illegible]

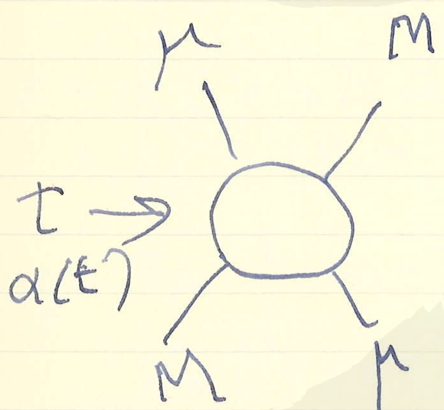
Quark模型のDaughter Trajectory

[illegible]　March 18, 1969

Poincaré group の I.R.



Regge pole



t=0の特異点をとり去れば
ℓ-plane上の ⇒ daughter traj.
[illegible]の を導入しても.

内部構造 → SO(3,1)の表現.

Mesons $q\bar{q}$

$\psi(p,q)$　　pq dependence

P: time-like $SO(3)$
space-like $SO(2,1)$

$t = (-P^2)$ $\quad L^{int} = SO(3,1)$

$$\psi(P,q) = \psi^{(0)}(q) + P^2 \frac{\partial\psi}{\partial p^2}\Big|_{t=0} + P_a \xi_a \frac{\partial \psi}{\partial (P_a \xi_a)}\Big|_{t=0}$$

"Lorentz pole"

$\hat{F}\psi = 0 \xrightarrow[O(3)]{P_\mu:\ \text{time-like}} \hat{F}(t, \alpha(t))\psi(t, \alpha(t)) = 0$

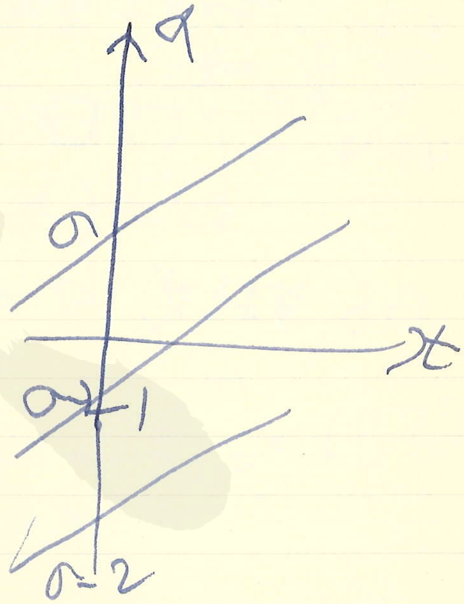
$P_\mu = 0 \downarrow L^{int}$ $\qquad t \to 0$

$\hat{F}(\sigma_H)\psi(\sigma_H, j_\kappa) = 0$

$j_\kappa = \sigma - \kappa$

$\kappa = 0, 1, 2, \ldots$

$\alpha(t) \xrightarrow[t\to 0]{} \sigma - \kappa = j_\kappa$



$(q, \bar{q})$ $\quad l_{\mu\nu} s_{\mu\nu} \to \vec{l}\,\vec{s}$
spin-orbit
[illegible]

$O(3,1) \otimes SL(2,C)$
$(1,1) \otimes (\frac{1}{2}, \frac{1}{2}) \oplus (0,0)$
$s=1$ $\quad s=0$

3

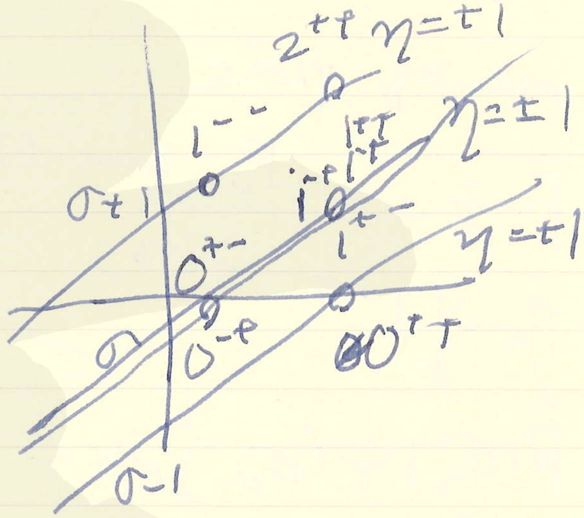
$\sigma+1$ $M=0$

σ $M=1$

$\sigma-1$ $M=0$

$\sigma=2l$

$\sigma=2l$



new Gell-Mann Zweig の scheme

non-rel. quark とどう違うか?

$l, S \Rightarrow J$

$4\times4 \rightarrow$

BS 方程式 の abnormal solution

素粒子の時空記述
研究会.
3月27日, 28日, 1969
基研

3月27日:
田中正：広がりと Lorentz pole
外部と内部を couple さすか
どうか！
quark の reality

広がりと Regge pole

$P_\mu \quad M_{\mu\nu} = l_{\mu\nu} + m_{\mu\nu}$

$P_\mu^2 = -M^2, \quad P_\mu^2 = -\alpha(\alpha+1)M^2$
$= (\epsilon_{\mu\nu\sigma\rho} P_\nu m_{\sigma\rho})^2$

$\{P_\mu^2 + F(\Gamma_\mu^2)\}\psi(x,\xi) = 0$
$\to \alpha(P_\mu^2)$

$\psi_{\{\alpha\beta\gamma\}}(x,\xi) = \sum_{m} \int d^4P\, A^m_{\alpha(\beta\gamma)}(P_\mu)\, \xi^m_{\alpha(\beta\gamma)}(P,\xi) \times e^{iPx}$

$P_{\alpha(\beta\gamma)}(-1) \propto \log\infty$

Friedmann, Wang : $P_\mu = 0$
(unequal mass)
$O(4)$

$O(3) \longleftrightarrow O(2,1)$

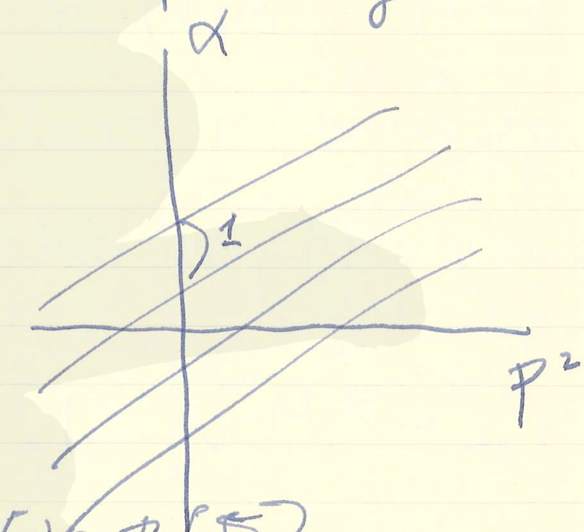
$O(3,1)$

$O(4)$

Regge pole の conspiracy

Veneziano

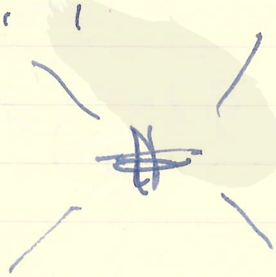
$A(s,t,u)$



$$= \frac{\Gamma(1-\alpha(s))\,\Gamma(1-\alpha(t))}{\Gamma(1-\alpha(s)-\alpha(t))}$$

t ' '　　t ' '

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



equal spacing

素粒子の[illegible]

$P_\mu^2, \quad (m_{\mu\nu})^2, \quad (\epsilon_{\mu\nu\rho\sigma} m_{\rho\sigma})^2$

(j_0, π)

$l = j_0, j_0+1, \cdots |\kappa|-1$

bilocal $\quad \psi(X_\mu, r_\mu)$

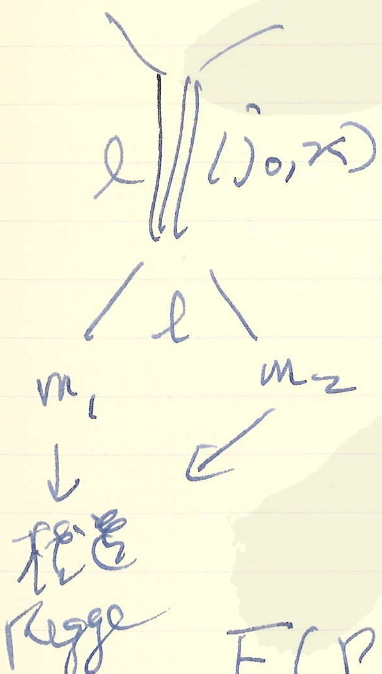
$j_0 = 0$

$\{P_\mu^2 + f(m_{\mu\nu}^2)\}\psi(X, r) = 0$

$e^{iP_\mu X_\mu} Z_{nl}^m(\hat{r}_\mu)$

$\hat{r}_\mu^2 = -1$ $\qquad n = \kappa - 1$

or $\{P_\mu^2 + \kappa(r_\sigma^2 + p_\sigma^2)\}\psi(X, r) = 0$



[illegible]

$[P_\mu^2, m_{\mu\nu}^2]$

$= P_\mu\{m_{\mu\nu}, q_\nu\} \neq 0$

for definite mass and P_μ ~~...~~ $\neq 0$

$F(P_\mu^2, q_\mu^2)\, B\left(\frac{P_\mu + q_\mu}{2}\right)$

$\times\, C\left(\frac{P_\mu - q_\mu}{2}\right) \sum_m Z^{m\,*}_{l, n(P_\mu^2)\, l}(\hat{q}_\mu)$

$\times\, A^m_{n(P_\mu^2)\, l}(\hat{P}_\mu)$

散乱振幅

$$F(p^2, q^2, q'^2)\,\Sigma_{n(p^2)}\,O\left(q_\mu - q_\mu' / q \cdot q'\right)$$

$$\times \frac{1}{\sin \pi n(p^2)}$$

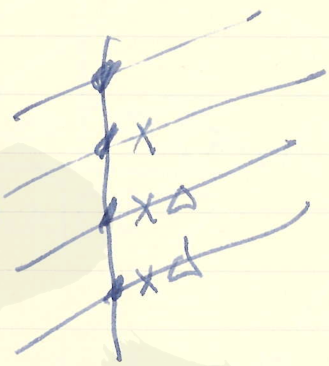
$$\text{Veneziano} = O\{(s,t) + (t,u) + (u,s)\}$$

↓

$$\frac{\Gamma(1-\alpha(s))\,\Gamma(1-\alpha(t))}{\Gamma(1-\alpha(s)-\alpha(t))}$$

$$(s,t) = \sum_{x=0}^{\infty} F_x(s)$$

$$\times\, \Sigma^{0}_{\alpha(p^2)-x,\,0}\,(q_\mu, q_\mu')$$



(Suppl. 1968)

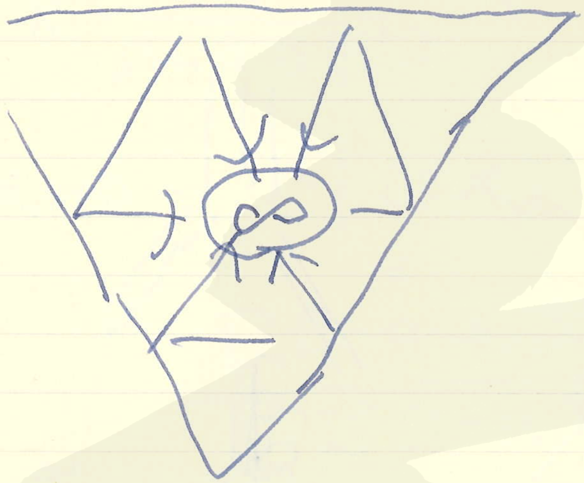
片山：相互作用の構造（小林記念号）
charge independence はどこから出るか

$\gamma_\mu p^\mu$　　$\epsilon_{\mu\nu} \gamma^\mu p^\nu$

高林氏 報(談)

ICWE

O'Raifeartaigh　1968. 1月



S.C.

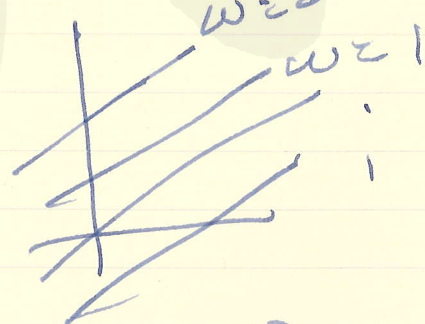
Fronsdal
成果をあげない〜で，どんどん出歩いてる

Barutology

bilocal　$P_\mu a^{\mu\nu}\psi = 0$
$m^2 = \kappa + \kappa'(J + 2\omega)$

spinor model

Nambu



$O(4, 2)$
$J,\ J_3,\ m,\ K_3 \rightarrow \frac{1}{2}(n_p - n_q)$

C, P, T
P：2種ある
CPT　$\psi(X, \xi) \to \psi^*(-X, \xi)$

Complexに於ける

space-like solution

$$\sigma_{tot}^{pp} = \frac{1}{m_N^2}$$

3月28日(金)
私の話：quarkから？へ
(I) Quark model の review

A) bound state の物理 困難
(粒の内部 → negative norm の出現,)
B) 〃　　　　現実的に有効性を判断する.

Boundness
B = 0　　　　　深部固有 non-dep) B≤1 である
≥ 1　　　　　potential 的
≥ 2

constituent の性格, principle or rule

0) strangeness　坂田模型

0') baryon number, charge　U(3)

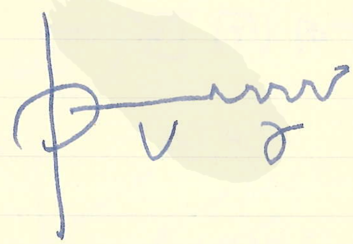
i) N_q, $N_{\bar{q}}$　independence (additivity, impulse 近似)
(確率振幅. 高エネルギー前方散乱)
(coupling const. の sum rule)
(weak int.)
(Okubo-Iizuka rule)
(strange pair suppression, 低エネルギー散乱)　(B=0)

ii) mass splitting　$\delta m_\Lambda\ \bar{\Lambda}_0 \Lambda_0$, $\delta m_n\ \bar{n}n$
(B=0)

iii) ~~SU(6)~~ spin　SU(6)　(B=0)

iv) spatial coordinate　SU(6)×O(3)
extra-form factor　(B=1)

e.m.f.f.　$\left(\frac{m^2}{m^2+k^2}\right)^2$ ←

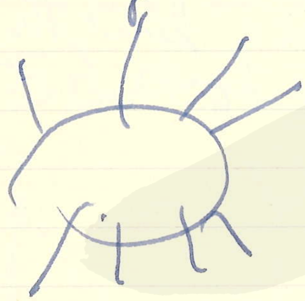


v) 統計性　粒子性　?(?)　ρ
current algebra
exchange (hard core, 低エネルギー 後方散乱)
Morrison rule　$\sigma \propto s^{-cnt}$

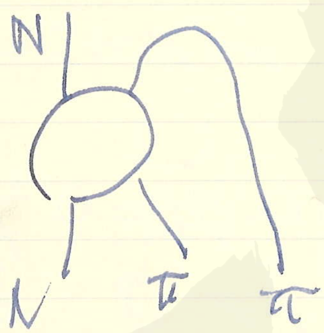
vi) substitution law ?(1)
quark [illegible]の crossing
$\bar{B}BM$ MMM

(II) Rest constraint
quark model → [ ] → Future theory
rest constraint

strong int. i) static pair suppression



すべてのボソンの $p \to 0$
$\Delta N_q = 0$
$\Delta N_{\bar{q}} = 0$



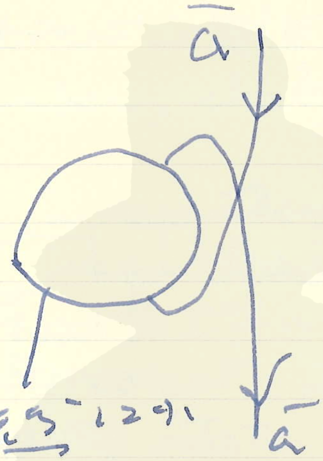
ii) static SU(6) invariant

iii)

Weak int.
non-leptonic decay
i) weak int. SU(6) 35

(1) BM scattering length
(2) πN p_{ij}
(3) hyperon non-leptonic
(4) $\bar{B}BM$, MMM

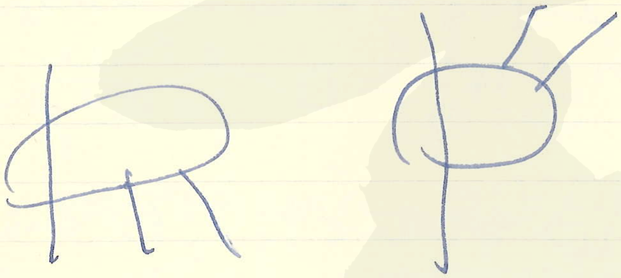
BM 散乱



$fx \to 0$ μ_a 近づけると

$M = -M$ (scattering length)

static limit ($t + \pi^0 \to t + \pi^0 \ldots$)



SU(2)

πN $\quad 2a_{3/2} + a_{1/2} = 0$

KN, $\bar{K}N$ $\quad \times$

↘ resonance

SU(3)

SU(6) $\quad a_1^{KN} = 2a_{3/2}^{\pi N}$

$a_0^{KN} = 0$

$B \to B' + \pi$ $\quad 56 \times \overline{56} \times 35$

56 56 35 $\quad$ decay parameter 24

$\bar{u}_f (A + B\gamma_5) u_i$

S波　P波

i) $\Delta I = 1/2$

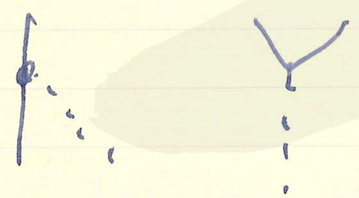
ii) Lee-Sugawara Rel.

iii) $(\Lambda \to p\pi^-) + (\Xi^- \to \Lambda\pi^-)$

$= \sqrt{\frac{3}{2}}(\Sigma^+ \to n + \pi^+)$

iv) CP inv.　$\hat{j}\cdot\hat{j}$

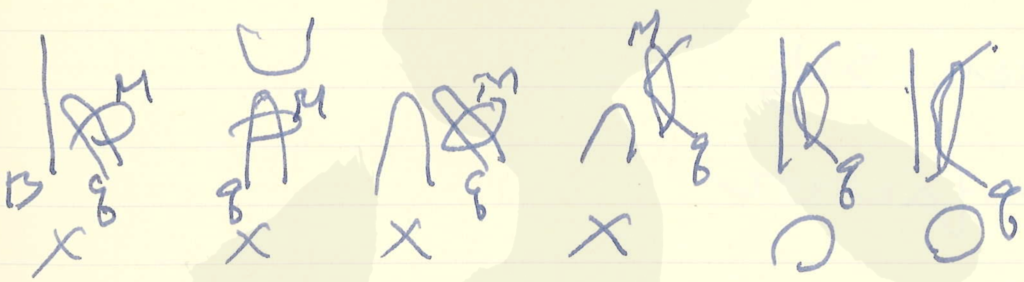
(4) BBM　　MMM



NNV　$D/F = 3/2$　×

NNP　pure F　×

substitution rule



$\bar{t}^{\pm}\,\Omega_K\, t^{\mp} \sim \Phi_K$

III. Comment

additivity だめ

原f沈 : extended particle model
と言及することの可能性
linear でない場合,

$$T = \frac{I}{4}\{\underbrace{(\dot{a}\dot{a}^T)}_{\text{spur}} + \frac{\rho}{2}\int(\dot{u} - i\omega M u)^2 dv$$

$$V = \frac{\lambda}{2}\left(\frac{\partial u^\nu}{\partial X^\nu}\right)^2 + \frac{\mu}{4}\left(\frac{\partial u^2}{\partial X^3} + \frac{\partial u^1}{\partial X^\nu}\right)^2$$

$$\lambda \operatorname{div} u + \mu\left\{\left(\frac{\partial u}{\partial r} - \frac{u}{r}\right) + \operatorname{grad}(u \cdot u) + \frac{u \, u}{r}\right\} = 0$$

$r = a$

$$H = \frac{1}{\rho}\sum P_{a^i_{JM}}^* P_{a^i_{JMk}} + \bar{V} + \frac{1}{2\Sigma}(S - L)^2$$

broken SU_3

form factor

Regge

$$E = \sqrt{\frac{\mu}{\rho}}\, S$$

$$S = \sqrt{J(J+1)}$$

~~$k = \frac{\pi}{2}(J + 2k)$~~ ×

$M_0 = \rho V$ $\quad M = \sqrt{M_0^2 + 2M_0 E}$

$$M^2 = M_0^2 + 2M_0 E \quad \cancel{\propto S} = M_0^2 + 2M_0\sqrt{\frac{\mu}{\rho}}\, S$$

$k_0 S$

武田暁 : Quark model と Regge 族

(s, α)　Poincaré 群 の Casimir operators

(R_0, c)　$\sigma = c - 1$

$= \alpha(0)$

南部　Form Factor

基研　April 16, 1968

$$G(q) \approx e^{-\frac{q}{0.6}} \quad (GeV/c)^2$$

$$\sim \frac{1}{q^4} \qquad \frac{1}{(0.7+q^2)^2}$$

$$O(4;2)$$

$$G(\vec{q}) = \int d\vec{x}\, e^{i\vec{q}\vec{x}} |\varphi(\vec{x})|^2$$

$$\sim \frac{1}{q^{1/4}} \int_0^\infty dr\, r^{3/2} J_{1/2}(qr) |\varphi(r)|^2$$

$$\varphi = N e^{-\frac{r}{a}}$$

$$\sim \frac{1}{(q^2 + \frac{4}{a})^2}$$

$$\varphi \doteq \frac{1}{\sqrt{r^2+\rho}} \qquad G(q) \sim K_{\frac{1}{2}}(q\rho)$$

$$\sim e^{-q\rho}$$

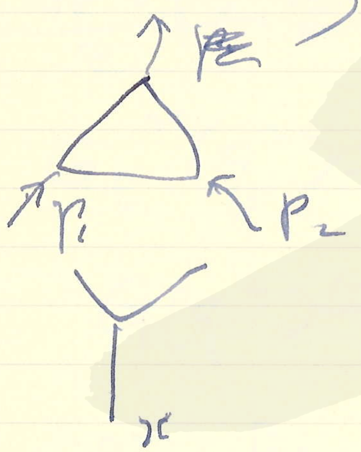
$$V(r) \sim \frac{1}{r\varphi} \frac{\partial^2}{\partial r^2}(r\varphi) \sim \frac{1}{(r^2+\rho)^2}$$

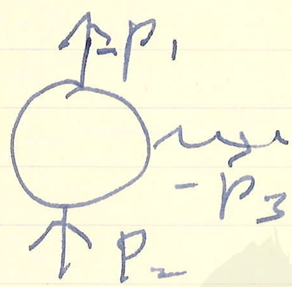
D. Itô

$\Delta_F(x^2-\rho, m^2)$

M. Markov

$$\frac{\delta(t-\sqrt{r^2+\rho})}{\sqrt{r^2+\rho}}$$





$p_1+p_2+p_3=0$

$G(p_3)=\int d\xi\, e^{i(p_3\xi)}\,F(\xi)$

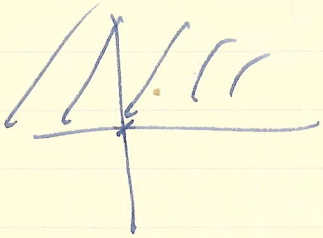
$\xi^2-\rho\sim 0$

$F(\xi)=0$

$G(p_3)\sim e^{-\rho\sqrt{p_3^2}}$

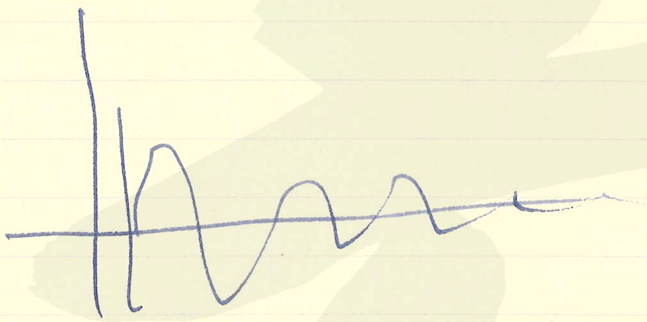
$\rho\sim 0.33\times10^{-13}$ cm

$$I(p) = \int_0^\infty e^{ipx}\,dx \sim \frac{1}{-ip}$$



$\mathrm{Im}\, p > 0$

$$\bar{I}(x, p_0) = J,$$



Y. Takano

K. Yamamoto

並木美喜雄氏: Composite から Extended Particle Model へ
[illegible] April 22, 1969

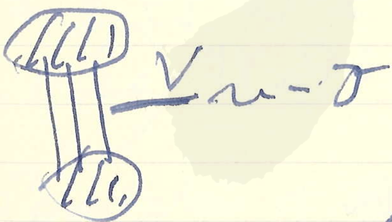
$ep \to ep$
$ep \to eN^*$

$$\begin{cases} \dfrac{G_E^p(q^2)}{e} \simeq \dfrac{G_M^p(q^2)}{\mu_p} \simeq \dfrac{G_M^n(q^2)}{\mu_n} \equiv G(q^2) \\ G_E^n(q^2) \simeq 0 \end{cases}$$

$$G(q^2) \simeq \frac{1}{\left(1 + \frac{q^2}{0.7}\right)^2}$$

dipole formula $\quad 0 \sim 30$ $(GeV/c)^2$

Machida - Namiki



Ishida Drell

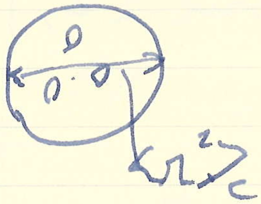
non-relat. additive composite {56}

$$G(q^2) = W(q^2) = \int e^{iqx_1} |\phi(x_1 \cdots)|^2 dx$$

vector dominance

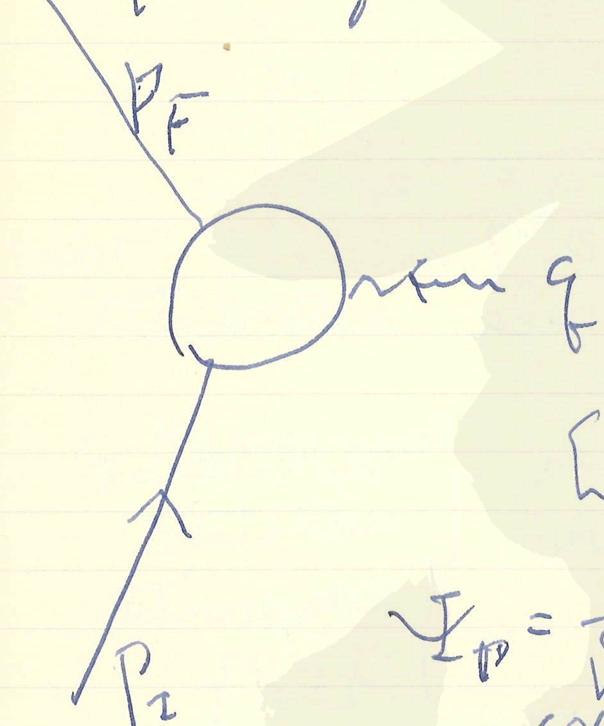
$$G(q^2) \simeq \frac{1}{1 + \frac{q^2}{m_V^2}} W(q^2)$$

ϕ : Gauss $\qquad W(q^2) = e^{-\frac{1}{6}\langle r^2\rangle_c q^2}$



q^2 と共に早くおちすぎる,

ϕ : singular



$M_t^2 \gg q^2 \gtrsim M^2$
の領域

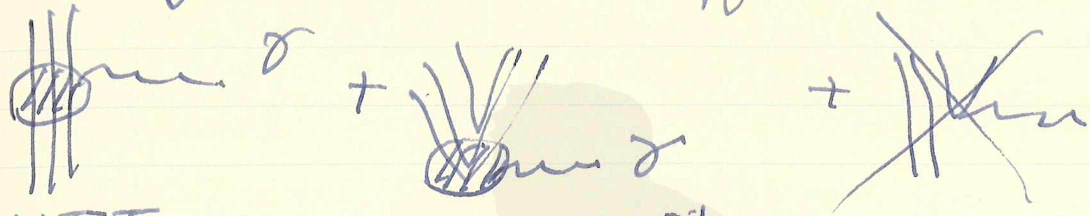
Lorentz factor

{ 内部波動関数
{ current

$$\Psi_p = \frac{1}{\sqrt{2\gamma}}\left[\sqrt{\frac{\gamma+1}{2}}\begin{pmatrix}1&0\\0&1\end{pmatrix}+\sqrt{\frac{\gamma-1}{2}}\begin{pmatrix}0&\sigma_p\\\sigma_p&0\end{pmatrix}\right] \times \begin{pmatrix}\chi\\0\end{pmatrix}\phi e^{-ip_\mu x^\mu}$$

boosting operator

Lorentz contraction の effect



EMFF

$W \to \mathcal{O}_{FI}(q^2)\, e^{-\frac{1}{6}\langle r^2\rangle_c \Sigma^{-1} q^2}$

$\to \left(\frac{1}{q^2}\right)^2$ $\qquad q^2 \neq \frac{1}{q^2}$

q^2 に indep.

$e\gamma \to e N^*$

$\mathcal{O}_{FI}(q^2)\left(\langle r^2\rangle_c q^2\right)^L e^{-*\langle r^2\rangle_c q^2}$

$\to \left(\frac{1}{q^2}\right)^2$ $\to$ q^2 に indep

dipole 型 になる!!!

[illegible] 2!!!

Panofski の 実験

meson: $\dfrac{1}{\left(1+\dfrac{q^2}{2\mu^2}\right)}$ $\quad$!!?

かも..

4次元 oscillator

$$W(q^2) = \frac{1}{\left(1+\frac{q^2}{2M^2}\right)^2} \exp\left[-\frac{1}{6}\langle r^2\rangle_c \frac{q^2}{\left(1+\frac{q^2}{2M^2}\right)}\right]$$

$\sqrt{\langle r^2\rangle_c} = 2.79 (GeV/c)^{-1}$

gehida

$$\times \frac{1}{1+\frac{1}{6}\langle r^2\rangle_V \Gamma^{-1} q^2}$$

よくあう!!!

vector cloud では、...

$\lambda = 1.4 \quad \alpha = 0.39 (GeV/c)^2$

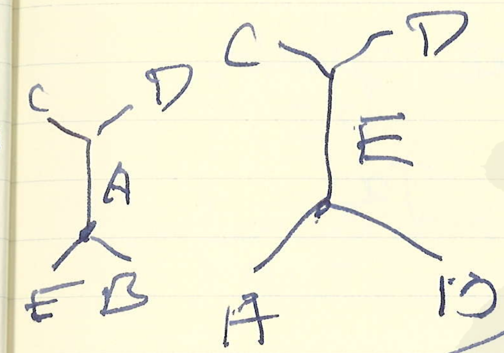
time-like osc. のひびきあらわれ

るのである。

北門　　　　　　巻紙　April 30 1969

S. Mandelstam

Rel. quark model based on Veneziano Representation



internal particle
≡ external particle
(bootstrap)

mass spectrum SU(6)
← quark model (non-rel)

trajectory SU(12), SU(6,6)

$g_{ABE} = g_{EBA}$

leading trajectory

(1) spin, unitary spin, bootstrap
(2) repulsive trajectory
(3) $\lambda_V, \lambda_\pi \to SU(8)_W$

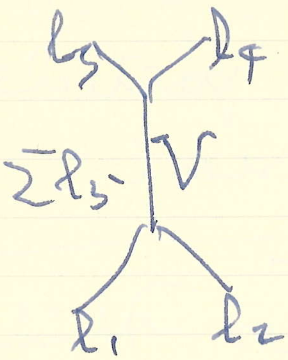
crossing matrix

$A_{l_1 l_2 l_3 l_4}(s,t) = \sum_r R^{(r)}_{l_1 l_2 l_3 l_4} W^{(r)}(s,t)$

$\to R_+ W_+ + R_- W_-$　　　$R_\pm = (R \pm CR)$

$s \leftrightarrow t : R_c - CR$　　　$W_\pm = (W_{st} \pm W_{ts})$

$R^{+}_{l_1 l_2 l_3 l_4} = \sum_{l_5} V_{l_1 l_2 l_5} V_{l_5 l_3 l_4}$

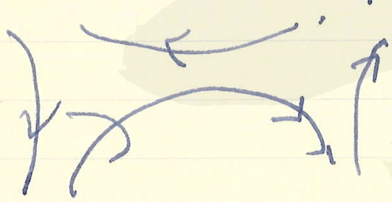


mathematical quark

$f^{\alpha_i}_{\beta_i}$　　　$f^{\beta_i}_{\alpha_i}$

$R^{\beta\cdots\beta}_{\alpha\cdots\alpha} = \delta^{\beta_2}_{\alpha_1}\delta^{\beta_4}_{\alpha_2}\delta^{\beta_3}_{\alpha_4}\delta^{\beta_1}_{\alpha_3}$

or $= \delta^{\beta_3}_{\alpha_1}\delta^{\beta_4}_{\alpha_3}\delta^{\beta_2}_{\alpha_4}\delta^{\beta_1}_{\alpha_2}$



$R^{\pm}_{l_1 l_2 l_3 l_4} = \delta \cdots + \delta \cdots$

$R_{T} = \sum_{\alpha_5 \beta_5} (V_+ V_+ + V_- V_-)$
　　　　　　D　　　F

$V_{\pm\, \alpha_1 \alpha_2 \alpha_5}^{\beta_1 \beta_2 \beta_5} = \frac{1}{2}(\delta\,\delta\,\delta \pm \delta\,\delta\,\delta)$

[illegible] [illegible]

$$A = R_t W(s,t) + R_t (s \leftrightarrow u) W(s, u)$$
$$= R_{t1} (W(s,t) + W(s,u))$$
$$+ R_{t2} (W(s,t) - W(s,u))$$

M-function
anti-boost

parity doubled

mass 不定.

関根克彦氏
くりこみ理論の数学的問題

5月6日　1969

引き算法？
くりこみの考えを一層徹底して、発散のない理論へ出す.

cut-off

$$I(K) = \int_{|k| \leq K} f(k)\, d^3k \qquad \text{finite}$$

$$\lim_{K\to\infty} I(K) = \infty$$

$$m_0 = m_0(K)$$

$$\lim_{K\to\infty} m_0(K) = \infty$$

しかし

$$\lim_{K\to\infty} \left[m_0(K) + I(K) \right] < \infty$$

QED　m_0, e_0 の2個の∞に返えてきるか;

a) combinatorics
Dyson, Symanzik
Bogoliubov, Hepp

reduction

2) m_0, e_0 の資料

Hilbert 空間 X

operator $\{H_X\}$ self-adjoint

$x \in X$

$$\frac{d}{dt} x(t) = H_K x(t)$$

$$x(t) = U_K(t) x(0) \qquad U_K = e^{-iH_K t}$$

$$D[H_K] \subset X$$

resolvent

$$H_K \qquad R_K(z) \equiv (zI - H_K)^{-1} \rightarrow \{ U_K(t), \ m, \text{ phase shift}$$

$\downarrow$ (?) $\qquad \downarrow K \to \infty$

$$H \leftarrow R(z) \longrightarrow \{ m, \text{ phase shift}$$

Theorem of Stone

Model 1.

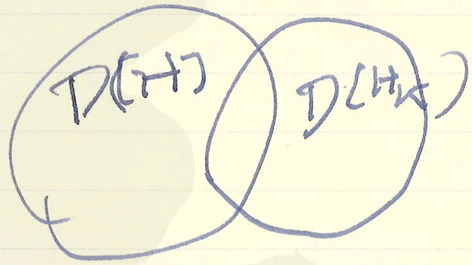
$$A + A \rightleftarrows C \quad (\text{Lee model type})$$

$$H = zI - \{R(z)\}^{-1}$$

$$H\begin{pmatrix}\alpha\\ \beta\end{pmatrix} = \begin{pmatrix}\mu\alpha + 2g_0\int\left[\beta(k) - \dfrac{g_0\alpha}{\mu - \frac{k^2}{2m}}\right]d^3k \\ g_0\alpha + \dfrac{k^2}{2m}\beta\end{pmatrix}$$

μ : C の physical mass

摂動展開



散乱問題
(H, H_0)

$$H_0\begin{pmatrix}\alpha\\ \beta\end{pmatrix} = \begin{pmatrix}\mu\alpha \\ \dfrac{k^2}{2m}\beta\end{pmatrix}$$

Dyson の公式

Model 2. $A + A \rightleftarrows A + A$

$$H\beta = \frac{k^2}{m}\beta - \frac{1}{4\pi}\lim_{p\to\infty}\frac{1}{p}\int^{p}\frac{d^3k}{\beta(k)}$$

Model 3, $A + A \rightleftarrows A + A$

Zimmermann

local field equation

A^4 ~~equation~~ interaction

$$(\Box + m^2)A(x) = \lambda\lim_{\xi\to 0} j(x, \xi)$$

$$j(x,\xi) = \frac{:A(x+\xi)A(x)A(x-\xi): - \alpha(\xi)A(x)}{g(\xi)}$$

ξ: space-like

non-rel.

H_ξ non-hermitian

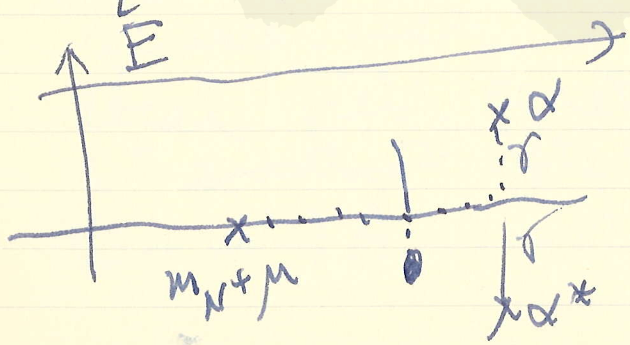
~~T. D. Lee~~
田中正男

老齋　May 13　1969

1) Negative metric and unitarity of S-Matrix
T. D. Lee and G. C. Wick,
Nucl. Phys. B9 ('69), 209
2) Unitarity in NΘΘ sector ...
Lee and Wick
3) A relativistic complex pole model with ~~indef~~ finite metric
Lee
4) A possible way to remove divergence difficulties in physics
Lee

unitary　convergent, は当り
abnormal "particle" → stable で
"

Lee-model
$m_{V}^{\circ} > m_N + \mu$
$\eta H^{\dagger} \eta = H$



$g_V'(t) = \int dz\, \tilde{g}_V'(z) \times e^{-izt}$

Fourier 変換ができない場合,
Feynman rule の modification

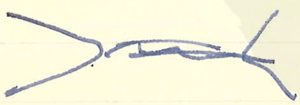
Tanaka : NN8Θ が問題
(α, α*) complex pair の導入

Nagy, N.C., Review

S. Tanaka, Towards Unified and Convergent Theory
(P.T.P. 29 (1963), 104)

$S^\dagger \eta S = \eta \xrightarrow{?} S^\dagger S = 1$

photon $\frac{1}{q^2} \to \frac{1}{q^2} - \frac{1}{q^2+m^2}$



e^+e^- $e^{2i\delta} \simeq \frac{E-m+\frac{1}{2}i\gamma}{E-m-\frac{1}{2}i\gamma}$

$H|r\rangle = E_r|r\rangle$

$H|\pm,c\rangle = E_{\pm,c}|\pm c\rangle$

直交性:

$\langle r'|\eta|r\rangle = 0$, $E_r \neq E_{r'}$

$\langle \pm,c|\eta|\pm,c\rangle = 0$

$\langle +,c|\eta|-,c'\rangle = 0$, if $E_{+c} \neq E_{-c'}^*$

$\langle r|\eta|r\rangle > 0$

$$\eta = \sum_r |r\rangle\langle r| + \sum_c |+,c\rangle\langle -,c| + \sum_c |-,c\rangle\langle +,c|$$

Interaction repres. での記述

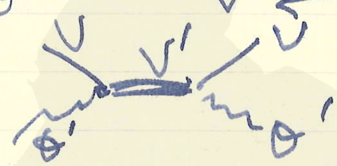
extended Lee model

~~$V \rightleftarrows N + \theta$~~

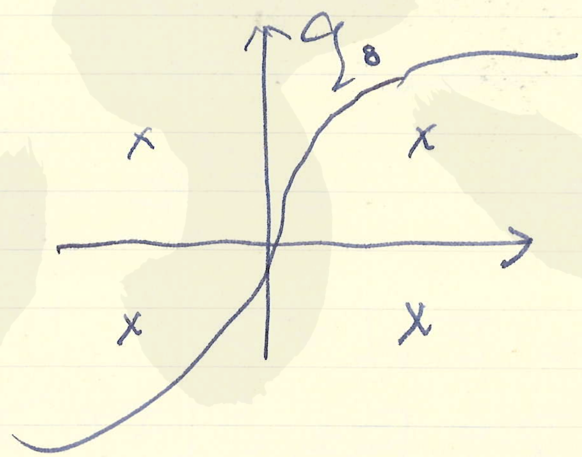
~~$V' \rightleftarrows N + \theta'$~~

$V' \rightleftarrows V + \theta'$　　$V \rightleftarrows N + \theta$

$V - \theta'$



Rel. theory



euclidean parameter

causality

優岡氏

S-Matrix in Hyperquantization

Y. Takahashi

R. Gowrishankar

長[illegible]　May 27, 1969

~~[illegible]~~ 歴史的な話

1953 Coester, Hyperquantization

$\rho = \rho'$ を仮定 (証明はできてない)

$$SS^{\dagger} \neq 1 \to \sum_n (\hat{\Omega}_n, S\Omega_2)^* (\hat{\Omega}_n, S\Omega_1)$$

$$= (\hat{\Omega}_2, \Omega_1)$$

conservation of probability

Relativistic invariance

小林君(学会)

Difficulties in Spin Treatment in the Quark Model for high energy scattering

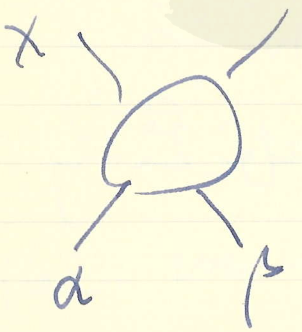
H. J. Lipkin

要約. June 3, 1969

a. hadron の中で quark は non-rel的な運動をする

b. 散乱の際 構成粒子の一つづつが相互作用する.

$A(B,M) = A(1,4) + A(2,4) + \cdots$



$\langle XY|T|\alpha\beta\rangle$

$= \sum_{ijkl} f_{ijkl} \langle X|t_{kl}|\beta\rangle \times \langle Y|t_{ij}|\alpha\rangle$

$\Rightarrow \sum f_{ijkl} \langle X_0|U_X^{+} t_{kl} U_\beta|\beta_0\rangle \times \langle Y_0|U_Y^{+} t_{ij} U_\alpha|\alpha_0\rangle$

相対論的効果

(1) Wigner rotation

spin 空間の回転

(2) bound state wave function の効果

小林 et al　$U(3,1)$

$q^2 > 2M_N^2$

SU_6 の[illegible]形式

(1) $SU(6)_p$

Pais, R.M.P. 38 (1)('66) 215.

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

σ, $p+m$ と可換な $\Sigma(P)$

(2) $SU(6)_W$

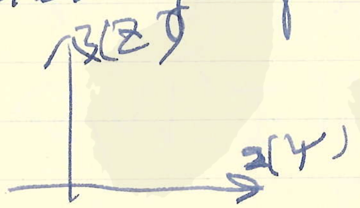
$\sigma \to$ W spin　$\frac{1}{2}\gamma_4\sigma_1$, $\frac{1}{2}\gamma_4\sigma_2$, $\frac{1}{2}\sigma_3$

3方向のLorentz変換に対しては不変にできる.

Breit system

(3) $U(6,6)$

scattering plane



W_x spin ~~[illegible]~~ の固有状態

spectator quark

$\Delta W_{xs} = 0$

$|\Delta W_{x\alpha}| = |\Delta W_{x\beta}| \leq 1$

一[illegible] quark の[illegible]

$f_1 = \langle + + \uparrow, + + \rangle$

$f_2 = \langle - - \downarrow - - \rangle$

— — — —

total spin form factor

active quark
spectator

meson

$W_x = \Sigma s_{xq} - \Sigma s_{x\bar{q}}$

$|P\rangle = \frac{1}{\sqrt{2}} \{ |q_+ \bar{q}_-\rangle + |q_- \bar{q}_+\rangle \}$

$|V\rangle = \frac{1}{\sqrt{2}} \{ \quad " \quad - \quad " \quad \}$

$\langle XY | T | P/s \rangle = \langle XY | T' | P/s \rangle \cdots$

$+ \langle XY | T' | V/s \rangle \cdots$

[illegible]

Chiral Symmetry in a Unified Fermion Field.

素研、6月30日, 1969

$$L_0 = -\bar{\psi}\gamma_\alpha \partial_\alpha \psi$$

$$\vec{V}_\alpha = i\bar{\psi}\gamma_\alpha \vec{t}\psi$$

$$\vec{A}_\alpha = i\bar{\psi}\gamma_\alpha\gamma_5\vec{t}\psi$$

$$\partial_\alpha \vec{V}_\alpha = \partial_\alpha \vec{A}_\alpha = 0$$

$$\vec{T} = \int d^3x\, \vec{V}_0 \qquad \vec{X} = \int d^3x\, \vec{A}_0$$

$$[T^a, T^b] = i\varepsilon^{abl} T^l$$

$$[T^a, X^b] = i\varepsilon^{abl} X^l$$

$$[X^a, X^b] = i\varepsilon^{abl} T^l$$

X^a: chiral transf.

$$[T^a, \psi] = -t^a\psi$$

$$[X^a, \psi] = -t^a(\gamma_5\psi)$$

$$= v^{ab}_{PS}\, t^b \psi$$

$$[X^a, \phi^b] = -i f^{ab}_{\text{scalar}}$$

$\vec{P}, i\vec{\sigma}$

$$L = -\bar{\psi}\gamma_\alpha \partial_\alpha \psi + g\, i\text{[illegible]}L + c\,\bar{\psi}\vec{t}\gamma_\alpha\gamma_5\psi(D_\alpha\vec{\phi})$$

$$-\bar{\psi}\gamma_\alpha D_\alpha \psi \qquad + \cdots\cdots$$

fermion — 元[?]

L ① chiral $SU(2)\times SU(2)$

② S波, P波

③ $(g_A/g_V)_0 = 1$

non-linear chiral transformation

$$[X^a, \psi] = \{A\,\varepsilon^{ak\ell}\,t^k p^\ell + B\,\gamma_5 t^a\}\psi$$

$$\vec{p} = i\lambda\bar{\psi}\gamma_5\vec{t}\,\psi \quad (= \Lambda\Phi + O(\Phi^3))$$

M^{-3} $\qquad v^{ab}$

$$[T^a, \psi] = -t^a\psi$$

A, B は $s = \frac{\lambda}{2}\bar{\psi}\psi$, $\vec{p}^2$ の関数

$$[X^a, \vec{p}^2 + s^2] = 0$$

$$L = -\bar{\psi}\gamma_\alpha D_\alpha\psi$$

$$[X^a, D_\alpha\psi] = v^{ab} t^b D_\alpha\psi$$

$$D_\alpha\psi = \partial_\alpha\psi + i\{M^c(\partial_\alpha P^c) + N(\partial_\alpha s) + Q_\beta(\partial_\alpha V_\beta) + R^c_{\beta 5}(\partial_\alpha V^c_\beta) + U^c_\beta(\partial_\alpha A^c_\beta) + \cdots + \cdots + \cdots\}\psi$$

$A=0$: Heisenberg equation

$$\left.\begin{aligned} A &= \frac{2}{(1-\vec{p}^{\,2}-s^2)} \\ B^{\pm} &= \pm\frac{(1\pm s)^2+\vec{p}^{\,2}}{(1-\vec{p}^{\,2}-s^2)} \end{aligned}\right\}$$

$$\vec{p} = \Lambda\vec{\Phi}$$

$\downarrow$

π-meson

CP-Violation

小沼氏

講演　June 10, 1969

実験　$K_L \to 2\pi$

η_{+-}

$$\eta_{00} = \frac{A(K_L \to \pi^0\pi^0)}{A(K_S \to \pi^0\pi^0)}$$

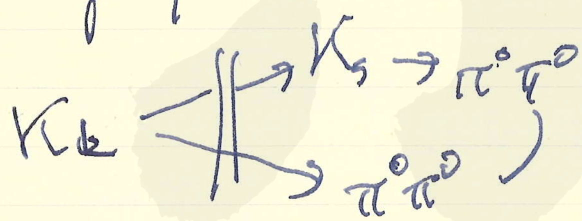
$$|\eta_{+-}| = (1.90 \pm 0.05) \times 10^{-3}$$

$$\arg \eta_{+-} = 39.8^\circ \pm 6^\circ$$

$|\eta_{00}|$

$$0.9 < \left|\frac{\eta_{00}}{\eta_{+-}}\right| < 1.6$$

$$\arg \eta_{00} = 17^\circ \pm 31^\circ$$



$K_S \to 3\pi$

$K_L \to 2\pi$

$K_L \to 3\pi$

破壊

milli strong, electromagnetic
Gell-Mann {Lee}
chimeson

milli weak
Nakagawa
Okun
Zacharias, Theory
superweak
(Wolfenstein)
CP cons.
higher
(Nakamura)

maximal CP viol.
Okubo
Nishijima

Gell-Mann
intermediate vector meson $X^{\pm}$
primed hadron h'
$n_X \equiv n_{X^+} - n_{X^-}$

neutron E.D. $\lesssim (2 \pm 2) \times 10^{-23}$ e cm

Quartet Model による Hyperon
の Nonleptonic Decay と
Baryon の β-decay

松山君

June 17, 1969 出張

$t\bar{t}$

$t\hat{t}$ χ_0

松田博嗣君

〃 [illegible]の三態

(June 17, 1969, 基研)

生体における非平衡下現象

をめぐって

重力波

佐藤文隆

基研　June 24, 1969

Evidence for Discovery of Gravitational Radiation

J. Weber, P.R. letter 22, 1320
June 16, 1969

$$\frac{d^2x_1}{d\tau^2} + \Gamma \frac{dx_1}{d\tau}\frac{dx_1}{d\tau} = 0$$

○—○　$\xi = x_1 - x_2$

$$\frac{d^2x_2}{d\tau^2} + \cdots = 0$$

$$\frac{d^2\xi}{d\tau^2} + (\Gamma') \frac{d\xi}{d\tau}\frac{d\xi}{d\tau} = 0$$

↓

$g_{\mu\nu}$の2階微分〜

↓

$R_{\alpha\beta\gamma\delta}$

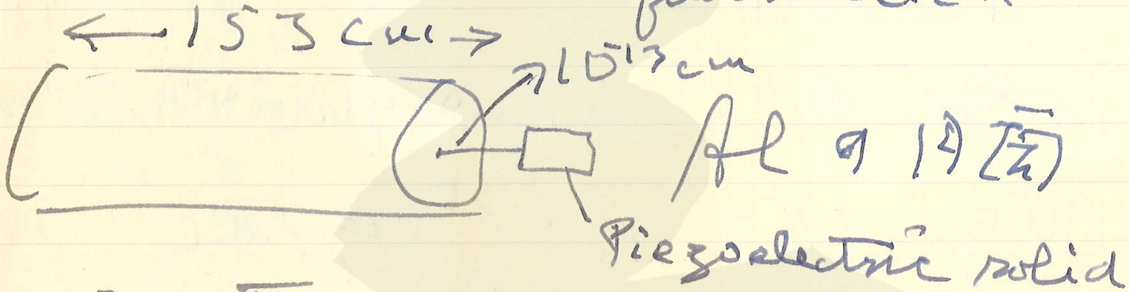
$$\frac{d^2\xi^\mu}{d\tau^2} = -mc^2 R^{\mu}{}_{0\alpha 0}\,\xi^\alpha$$

振動子

c033-829挟込

$$\frac{d^2\xi^\mu}{d\tau^2} + K\xi^\mu + H\frac{d\xi^\mu}{d\tau} = -mc^2 R\,\xi + F_\nu$$

fluctuation



diameter 60 ~ 96 cm

6 個

1) (重力波の存在検出 ?)

2) 地球の quadrupole moment

固有振動数 54 分

Maryland　　Argonne

960 km 離れた所の coincidence

0.3 sec (resolution)

(Pulsar 1 秒)

$$\frac{M\omega^2\delta^2}{2} \gtrsim \frac{1}{2}kT$$

$$\delta \gtrsim 10^{-13}\ \text{cm}$$

energy 10^4 erg/cm³ sec → 10^{-32} g cm^{-3}

binary (100 pc) 10^{-12} erg/cm^2 sec

○ galaxy (500kpc) $10^{-1} \sim 10^{3}$ erg/..

反 [illegible] a few graviton/m^2 sec

10^4 g 10^{-30} erg/sec

solid [illegible]. 10^{-13} erg/sec

($\leftarrow 10^8$ watt)

MKE atomic bomb 10^{-4} erg/sec (10^{-8} sec)

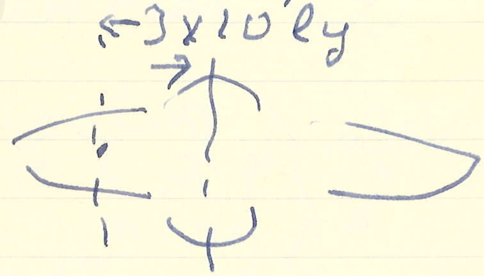
June 24 1969

Pulsar
高倉氏 (東京天文台)

1967 秋
Hewish (Cambridge)
1. パルス状電波　　~0.1 ly (26)
2. 周期一定
10^{-8}
(周期がだんだんのびる)　　radio source
3. 到着時刻 λ^2 に比例しておくれる
plasma の中を通ってきた
200光年
4. たくさんある　40 or 50
5. 直線偏光 λ^2 → Faraday rotation
$H \cong 10^{-7}\,\Gamma$ (gauss)

Feb. 1968 ~ Sept. 1968

Jodrell Bank
Pulsar 0328　♡　21 cm 吸収
Doppler absorption
10^4 光年の距離にある.



小さな天体
30 millisec
地球くらい
白色矮星
中性子星

1秒 

Pulsation > 8 sec ~~m sec~~

○ Rotation (neutron star)

Double star (neutron star)

~~0.25秒~~

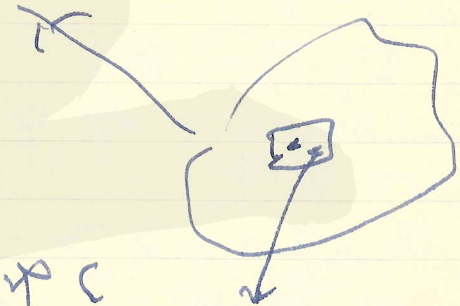
89 m sec

カニ星雲 Tau A

1054 SN

強い電波源

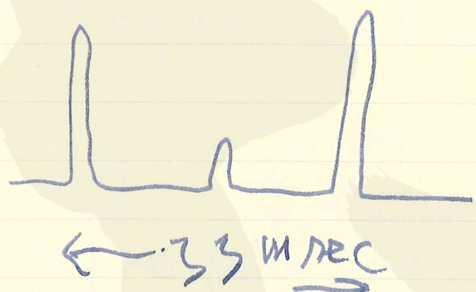
X線の source



33 m sec

だんだんのびてゆく

カニ星雲の中心の星の一つの光が pulse してる



1942 Minkowski

Vela X pulsar

数万年前の SN

89 m sec

ふつうの pulsar

sec の order　　10^7 yr.

Pulsar の応用
銀河系の構造
時計　　10^{-10}
通信

Hewish

2C
↓
3C → Ap Synth
↓　　↓ → Inter Planetary Scint.
　　↓

日本の電波望遠鏡
1. 大きさで世界の
2. unique
3. せすい

45 m 中　　30〜40 億円

64 m Parkes (Australia)

理　士
実　農
評議　工
実　商

山本祐靖

$\Delta(1236)$ と 核子の 系 ($\Gamma = 120$ MeV)

発表 7月1日 1969

実験 $M_\Delta \sim 1214$ MeV

$\Gamma_\Delta \sim 97$ MeV

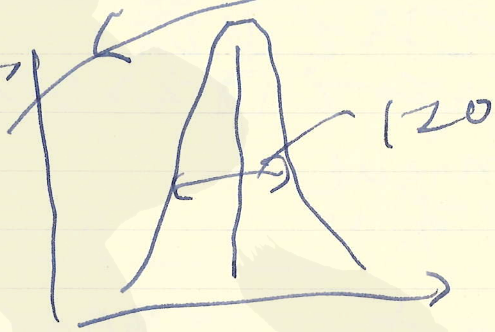
$\pi + N \to \Delta^{\pi} \to \pi + N$

$\gamma + p \to N^* \to \pi + N$

$K^+ + p \to N^* + K^0 \to K^+ + p + \pi^0$

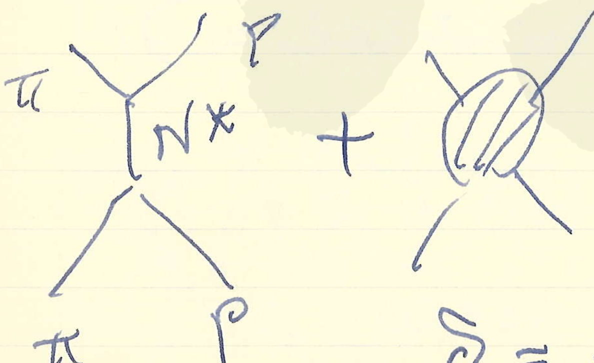
$\to K^+ + p$

$$e^{2i\delta_{33}} = \frac{E - M - \frac{i}{2}\Gamma}{E - M + \frac{i}{2}\Gamma}$$



$\delta_{33} = 90^\circ$

$\times\, e^{2i\delta}$



$\delta = -20.982^\circ$

(elastic だけ)

$$S_{ij} - i \frac{g_i h_j^*}{E - M + \frac{1}{2} i \Gamma}$$

unitary

$$\Sigma |g_i|^2 = \Sigma |h_i|^2$$

$$\Sigma S_{ij} h_j = g_i$$

$$\Sigma |g_i|^2 = \Sigma |h_i|^2 = \Gamma$$

Roper

$\gamma + p \to \pi^0 + p$
consistent

$K^+ + p \to K^* + p$
$\Omega^- \to N^* + K^0$

Ξ^* 3 MeV

Σ^* 30

Δ 100

Roper resonance

c033-830挟込

河野[illegible]: Duality, Absence of Exotic Resonances & $\Delta I = 1/2$ Rule

基研 July 8, 1969

(1) $\Delta I = 1/2$ Rule in Non-Leptonic decays

$$H = \frac{G}{\sqrt{2}} J_\mu \cdot J_\mu^\dagger \qquad J_\mu = J_\mu^h + J_\mu^{lep}$$

$$J_\mu^h = \cos\theta \, (V+A)_\mu^{1+i2} + \sin\theta \, (V+A)_\mu^{4+i5}$$

$(V+A)_\mu^{1+i2} \to$ $\Delta S = 0$, $\Delta I = 1$, $n \to p$

$(V+A)_\mu^{4+i5} \to$ $|\Delta S| = 1$, $\Delta I = 1/2$

$$J_\mu^h J_\mu^{h\dagger} \to \Delta I = 1/2, 3/2$$

a) extra Term を入れて $\Delta I = 3/2$ を消す

b) dynamical enhancement
$\Delta I = 3/2$ forbidden process

第8回

K-decays

$$R_1 = \frac{\Gamma(K^+ \to \pi^+\pi^0)}{\Gamma(K_s^0 \to 2\pi)} \sim \frac{1}{450} \sim \frac{1}{500}$$

$\pi^+\pi^0$: $I = \cancel{1}, 2$ $\Delta I = 3/2$

$$\left|\frac{A_{3/2}}{A_{1/2}}\right| \approx 0.06$$

$$R_2 = \frac{\Gamma(K_s^0 \to \pi^+\pi^-)}{\Gamma(K_s^0 \to \pi^0\pi^0)} = 2.33 \pm 0.05$$

(1968 Vienna conf.)

$$\mathrm{Re}\left(\frac{A_{3/2}}{A_{1/2}}\right) \sim 0.05 \sim 0.08$$

$K_L \to 3\pi$
$K^\pm \to 3\pi$ } charge ratio

$$\frac{\mathrm{amp}}{\mathrm{amp}} \sim 0.06 \sim 0.07$$

$\Delta I = 1/2$

Baryon Decays

$\Lambda \to p + \pi^-$ Λ^0_- $\Lambda^0_-/\Lambda^0_0 = \sqrt{2}$
$\Lambda \to n + \pi^0$ Λ^0_0

Σ —— Σ^+_0, Σ^+_+, Σ^-_- $\sqrt{2}\Sigma^+_0 + \Sigma^+_+ = \Sigma^-_-$

$\Xi \to \Xi^-_-, \Xi^0_0 \ (\Lambda + \pi)$ Σ^0_- $\Xi^-_-/\Xi^0_0 = \sqrt{2}$

$\Omega^- \to \Lambda + K \ (\Delta I = 1/2)$ Σ^0_0 $\Omega^-_-/\Omega^-_0 = \sqrt{2}$
$\ \ 3/2 \to \Xi + \pi$

SU(3)

$H = \frac{G}{\sqrt{2}} J_\mu^{h} J_\mu^{h\dagger}$

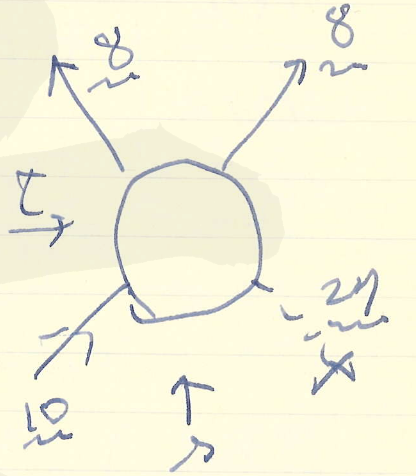
$\underset{\sim}{8} \times \underset{\sim}{8} = 1 + \underset{\sim}{8_s} + 8_a + 10 + \overline{10} + \underset{\sim}{27}$

$H \sim \underset{\sim}{8_s} + \underset{\sim}{27}$

$\Delta I = 1/2$ $\quad$ $\Delta I = 1/2$, $\Delta I = 3/2$

$\langle f | H_{27} | i \rangle = 0$

$\underset{\sim}{8} + \underset{\sim}{8}$ $\quad$ $\underset{\sim}{8}$, $\underset{\sim}{10}$



~~Duality~~

Exotic resonance はない

baryon では $\underset{\sim}{8}$, $\underset{\sim}{10}$ しかない
(↑↑↑ [illegible] $\underset{\sim}{1}$ ないし)

meson では $\underset{\sim}{1}$, $\underset{\sim}{8}$ しかない
(↑↓ しかない)

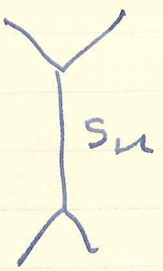
duality s と t の duality (同[illegible])

$F(s,t) = \sum_n \frac{C_n(t)}{s - s_n}$

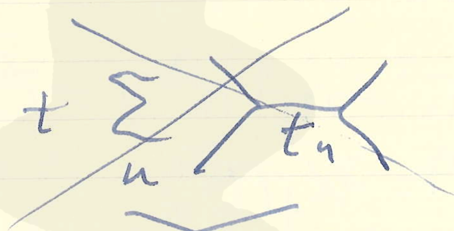
$s \to \infty$　　$F(s,t) \to s^{\alpha(t)}$

Regge behavior

$F(s,t) = \sum_n$



$+ \sum_n$

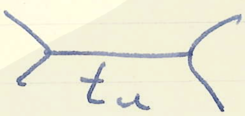


~~$+ \sum_n$ (t_n)~~

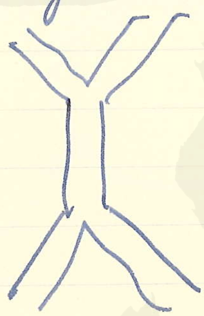
必要ない

(double counting になる…)

$= \sum_n$



Veneziano model



$$B(x,y) = \int_0^1 t^{-x}(1-t)^{-y}\,dt$$

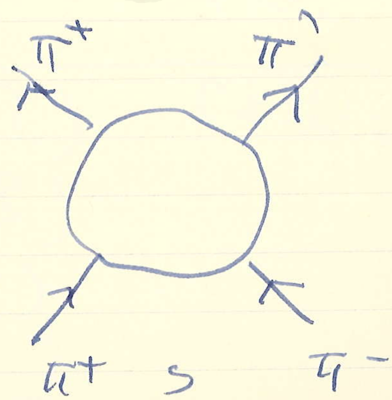
$\pi^+\pi^- \to \pi^+\pi^-$ (s)

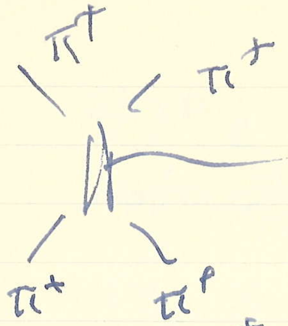
t: $\pi^+\pi^- \to \pi^+\pi^-$

u: $\pi^+\pi^+ \to \pi^+\pi^+$

$I = 2$

[illegible]こない…





exotic resonance
は存在しない

$A(\pi^+\pi^+ \to \pi^+\pi^+) = 0$

$\alpha_\rho(t) = \alpha_f(t)$

generalized exchange degeneracy

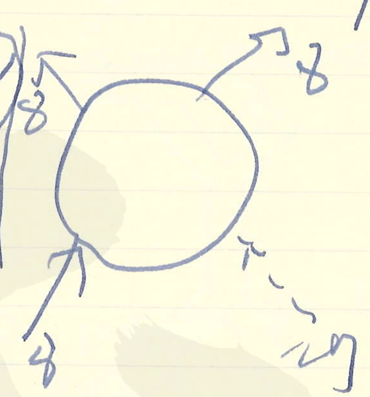
$\underset{\sim}{8} \times \underset{\sim}{27} = \underset{\sim}{8} + \underset{\sim}{10} + \underset{\sim}{\overline{10}} + \underset{\sim}{27} + \underset{\sim}{27}'$

$\underset{\sim}{8} \times \underset{\sim}{8} = 1 + 8 + 8' + 10 + \overline{10} + 27$

s: $\underset{\sim}{8}$, $\underset{\sim}{8}'$, $\underset{\sim}{10}$, ($\underset{\sim}{\overline{10}}$), ($\underset{\sim}{27}$), ($\underset{\sim}{27}'$)

t: ○ ○ ○ ○

u: ○ ○ ○



○ : exotic
○ に相当する F(s,t) は zero になる
ことになる.

SU(2)　$(\Omega^- \to \Xi + \pi)_{3/2} = 0$

$(\Sigma^- \to n + \pi^-)_{3/2} = 0$

$(K \to 2\pi)_{3/2} = 0$

$(K \to 3\pi)_{3/2} = 0$

$SU(2) \otimes SU(2)$ current algebra

① p-v (s-wave)

Λ, Ξ $\quad \Delta I = 1/2$ O.K

Σ $\quad \Delta I = 1/2$ $\times$

両方合わせると、すべて $\Delta I = 1/2$ が成り立つ

② p-c (p-wave)

$\Omega^- \to \Xi\pi$, $\Sigma \to n\pi$, $K \to 3\pi$

$\Delta I = 1/2$

$\Lambda \to n\pi$, $\Xi \to \Lambda\pi$?

(おかしい)

牧＝訪問

$\pi^0 \to 2\gamma$ の amplitude と quark model

花餅・July 22, 1969

motivation

$\tau = (0.89 \pm 0.18) \times 10^{-16}$ sec.

('68 DESY $0.6^{+0.2}_{-0.08} \times 10^{-16}$)

amplitude の sgn

(strong int $g_{NN\pi}$ との relative sign

$\pi^0(q) \longrightarrow$ (blob) $- - - k$, k'

$$M_{\mu\nu} = i \int d^4x\, e^{ikx} \langle A | T(j_\mu^\alpha(x) j_\nu^\beta(0)) | B \rangle$$

$\langle 0 |$, $| B \rangle \to | \pi(q) \rangle$

$$= \varepsilon_{\mu\nu\lambda\tau} \frac{k^\lambda k'^\tau}{m_\pi} F(k^2, k'^2)$$

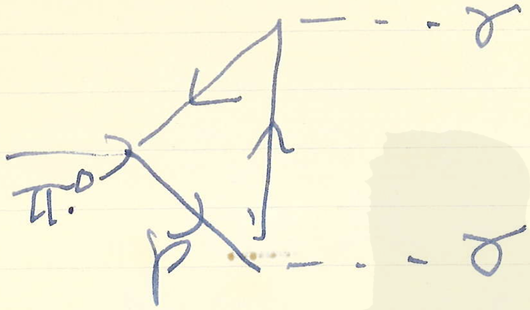
$$\Gamma(\pi^0 \to 2\gamma) = \frac{|F|^2}{64\pi} m_\pi$$

$\mathrm{sgn}(F(0,0)) = -\,\mathrm{sgn}(g_{NN\pi})$

$\omega \to \pi\gamma$ $\quad$ $\gamma p \to \pi^0 p$

Gilman

p, p, $g_{NN\pi}$, π_0



$$F(0,0) = -\frac{e^2 g_{NN\pi}}{4\pi^2 m_N}$$

$$F(t,t') = a + b\left(\frac{1}{m_\rho^2 - t} + \frac{1}{m_\rho^2 - t'}\right)$$

V: $q\ (1^-)$

$$+ \frac{c}{(m_\rho^2 - t)(m_\rho^2 - t')}$$

ρ, ω) $m_\rho \approx m_\omega$

ϕ X

$$+ \gamma(t,t')$$

high mass contrib.

(i) $a = 0$

Okubo: $c \simeq 0 \quad \gamma = 0$

$F(0,0) = -Z\frac{c_\pi}{m_\pi^2}$ $\qquad Z = \begin{cases} +1 & \text{Sakata} \\ +\frac{1}{3} & \text{quark} \\ -1 & \text{lepton triplet} \end{cases}$ X

$c_\pi \sim [g_{NN\pi}]$

$c = 3.4\times10^{-16}$ (2 written above the 3) $\qquad 0.6\times10^{-16}$

B. L. Young:

$$F(0,0) \equiv -Z\frac{c_\pi}{m_\rho^2} + \frac{2\lambda_\omega f_{\omega\pi\gamma}}{m_\rho^2}$$

$$= -2Z\frac{c_\pi}{m_\rho^2} + \frac{2\lambda_\rho\lambda_\omega g_{\rho\omega\pi}}{m_\rho^4}$$

Field algebra
$Z=0$
J. J. Sakurai

Maki;

(i) $f_{\rho\pi\gamma}(t\to\infty)=0$ とassumeする

$$F(0,0)=\frac{2\lambda_\omega f_{\omega\pi\gamma}}{m_\rho^2}+\cdots$$

$$=\frac{2\lambda_\rho\lambda_\omega g_{\rho\omega\pi}}{m_\rho^4}+\cdots$$

(ii) sgn is ?
quark SU(6) 正しくでる
Kitazoe - Teshima
Gudehus
N.R (SU(6) でも正しくでる

Gravity as Energy Source of Pulsar

武部・井川・生田・湯川
(後・鈴木)

発表. 7月25日, 1969

quasar

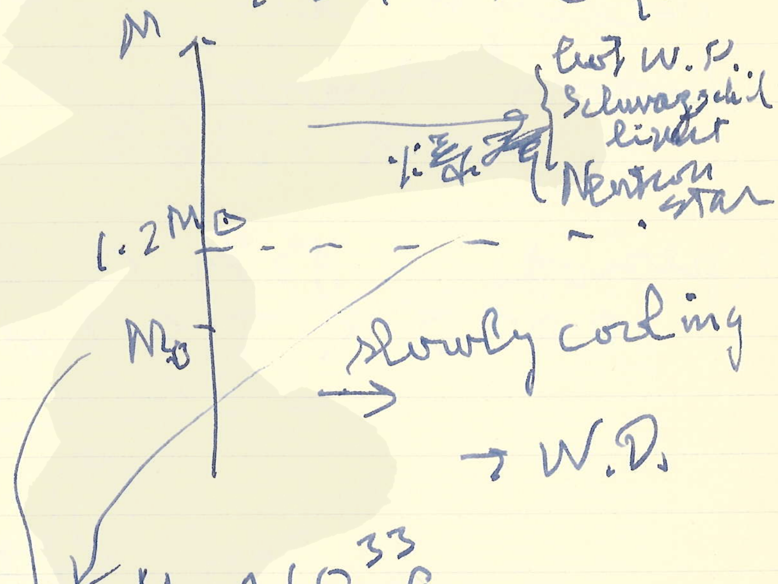
Jocelyn Bell　Aug. 1967
Antony Hewish　Sc. Am.
Oct. 1968

1. period　精度 $\sim 10^{-10}$ sec
$0.033 < T < 2$ sec

2 pulse 巾がせまい
10×10^{-3} sec $\sim 10^{-3}$ sec
3 source が小さい
3×10^{3} km $\sim 3 \times 10^{2}$ km
4 dispersion → distance
source は galaxy の中にある
5 pulsar location と super nova の remnant location
6 linearly polarized

7. lengthening in period
2倍になる時間 $10^3 \sim 10^6$ years

仮説
1. Little green man ×
2. Vibration ~~×~~ $T \sim 2\pi (G\rho)^{-1/2}$
white dwarf } $T \geq 2$ sec $\rho = 10^{5\sim6}$
neutron star $T \leq 10^{-3}$ sec $\rho = 10^{14\sim15}$

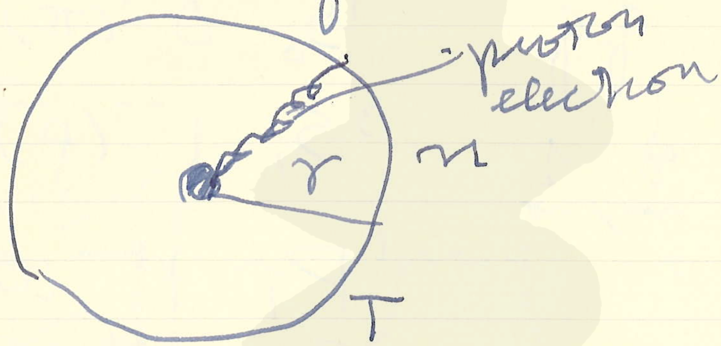


$M_\odot \sim 10^{33}$ g
$A \sim 10^{57}$

3. rotation neutron star ($R \sim 10$ km)

$R = 5$ km, $M = M_\odot$ } 全エネルギー
$V_e = 915$ MeV
$V_p = 280$ MeV
$n + p \to p + n + \pi^0$

spot-like magnetic field
thermal eq.



magneto Bremsstrahlung
(synchrotron radiation)

Exotic mesons

北川君
Sept. 16, 1969

mesons $q\bar{q}$ — $8, 1$

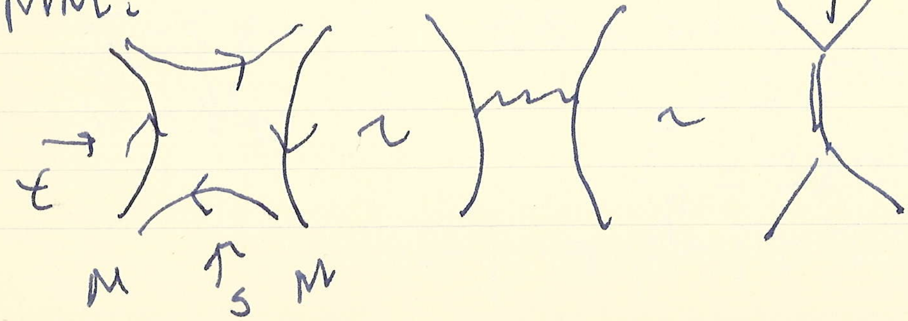
	J^{PC}
$^1S_0$	$0^{-+}(\pi)$
$^3S_1$	$1^{--}(\rho)$
$^1P_1$	$1^{+-}(B)$
$^3P_0$	$0^{++}(\sigma, \varepsilon)$
$^3P_1$	$1^{++}(A_1)$
$^3P_2$	$2^{++}(A_2)$

exotic meson
$q\bar{q}$ で出てこないもの
$2q\, 2\bar{q}$

$0^{++}(\tau)$
$1^{++}($
2^{++}
1^{+-}

1) $B\bar{B}$ [illegible]の[illegible]
2) resonance level density

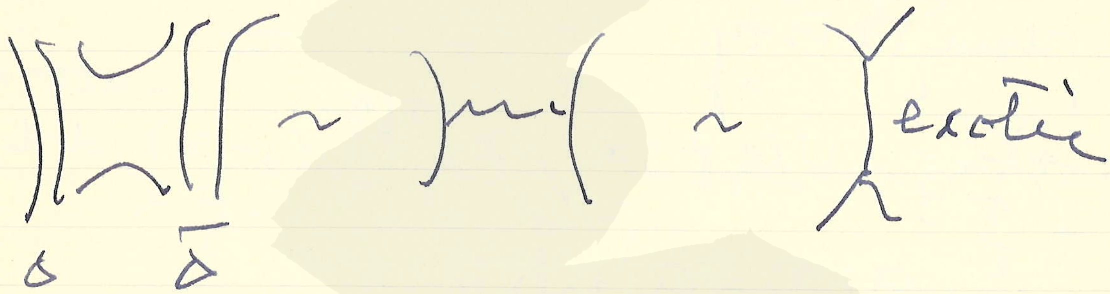
MM:

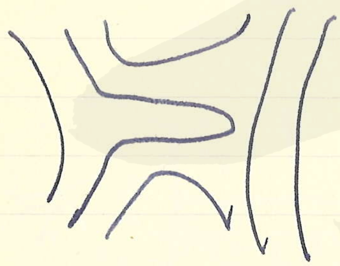


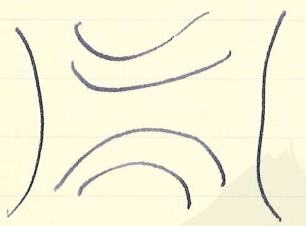
$$\sigma_T(AB) = \sigma_T(AB)_{Pomt} \; \frac{\mathrm{Im}\, A}{P_{lab}}$$

non-pom.

$B\bar{B}$:







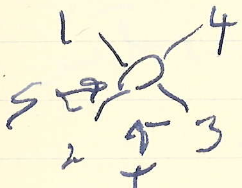
素研 Duality

基研 Sep. 16, 1969

Sakita, Kikkawa - -

Veneziano

unitarity



$$V(s,t) \propto \int_0^1 x^{-\alpha(s)-1}(1-x)^{-\alpha(t)-1}\,dx$$

$$\alpha(s) = a + b\,s$$

$s \to \infty$

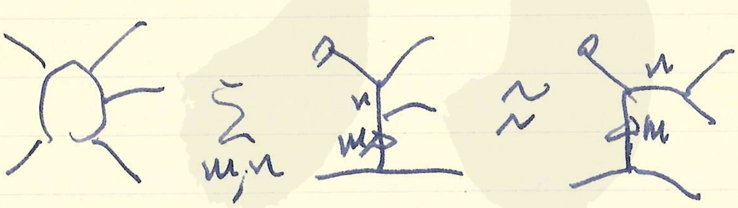
$$V \to s^{\alpha(t)}$$

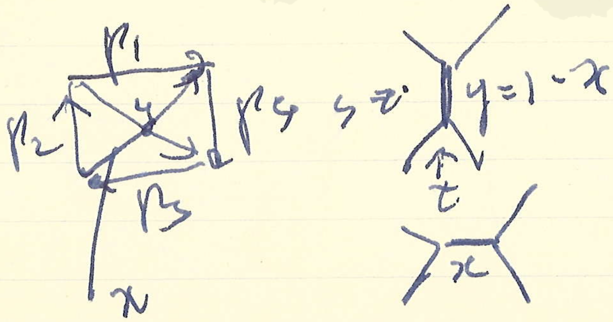
duality

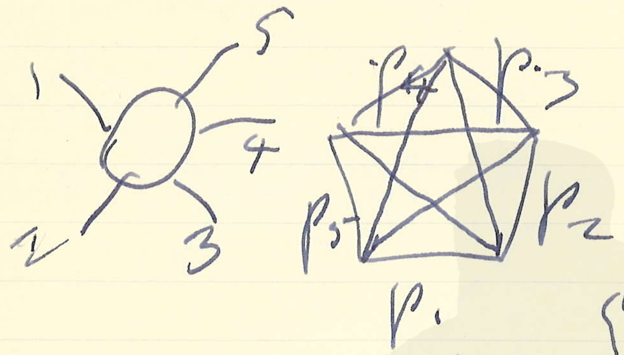
$$V(s,t) = \sum_n \frac{-f^{(n)}(0,t)}{n!}\,\frac{1}{\alpha(s)-n}\;\Big|\sum_n \ \Big|$$

$x = 1-y$

$$= \sum_n \frac{-f^{(n)}(0,s)}{n!}\,\frac{1}{\alpha(t)-n}\;\Big|\sum_n \ \Big|$$



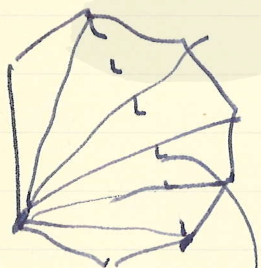




$$V_5(\cdot\cdot) = \int_0^1 x_1^{-\alpha(p_2+p_3)^2-1}\; x_2^{-\alpha(p_1+p_5)^2-1}$$

$$\times\, y_1^{-\alpha(p_3+p_4)-1}\; y_2^{-\alpha(p_4+p_5)-1}$$

$$\times\, y_{12}^{-\alpha(p_1+p_2)-1}$$

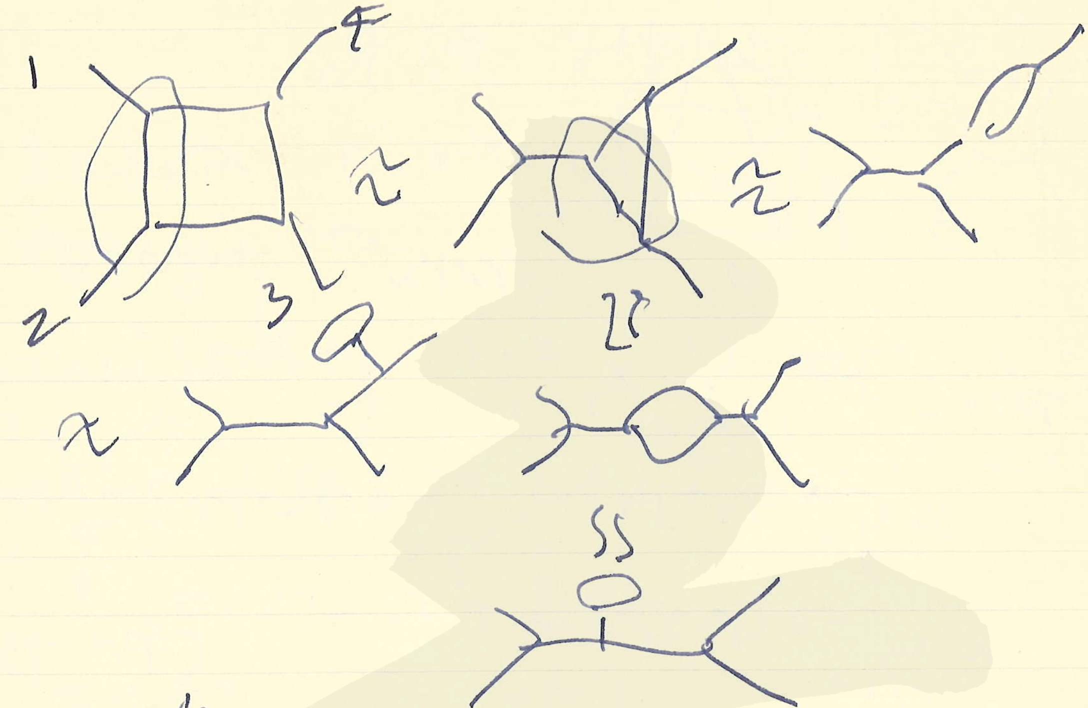


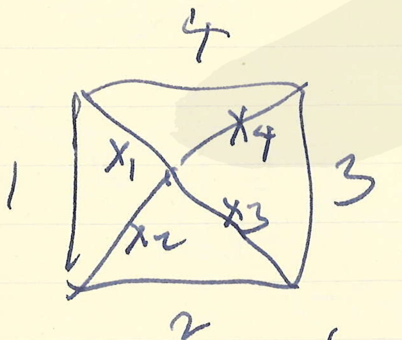
$$V_8 = \int_0^1 dx_1 \cdots dx_5 \prod_{i=1}^{5} x_i^{-\alpha(p_1+\cdots p_{i+1})^2-1}$$

$$\prod_i y_i^{\alpha(--)-1}$$

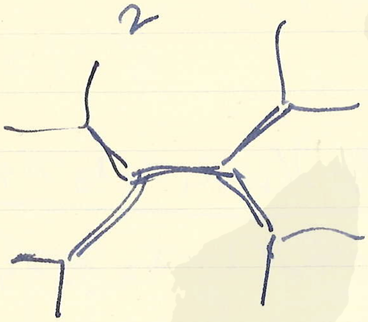
$$y_1 = \frac{(1-x_2x_3x_4)(1-x_1x_2x_3x_4x_5)}{(1-x_1x_2x_3x_4)(1-x_2x_3x_4x_5)}$$

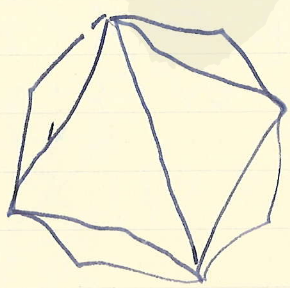
tree diagram [illegible] 三叉 て
loop がつく..





dual
diagram

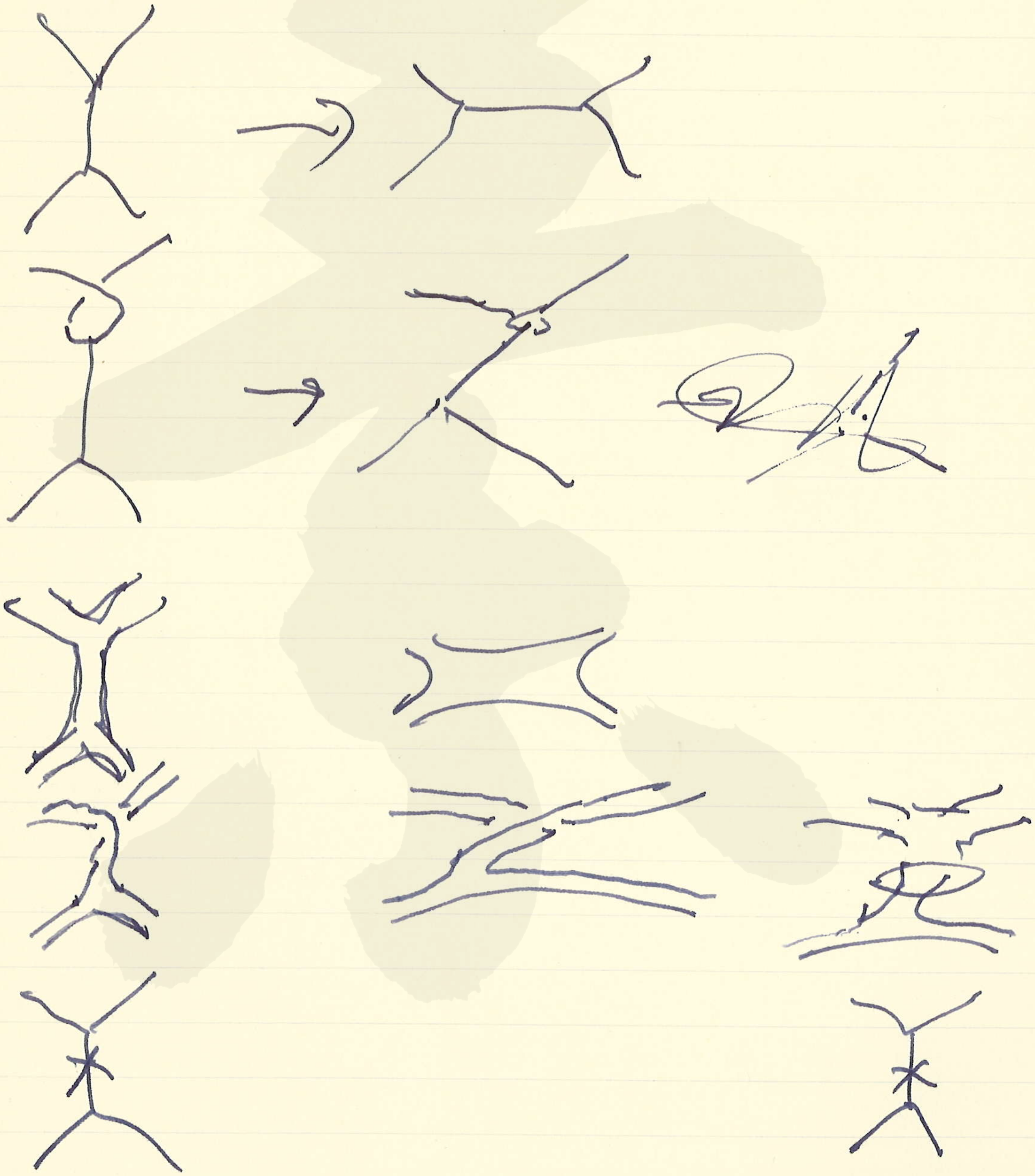




dual
diagram

I_N $\qquad$ I_0 Veneziano

N: loop number



第4日 つづき Sept. 17

non-planar diagram

high energy behavior