N99

R. II.

NOTE BOOK

Manufactured with best ruled foolscap
Brings easier & cleaner writing

July, 1971
~

VOL. R. II.

Nissho Note

N99

INDEX

CHAPTER	DESCRIPTIONS	PAGE

大貫義郎氏
非線形量子力学における
正準形式
1971.7.19. 基研

Lagrangian (古典論)
→ 量子化
菅野氏. デカルト座標ではないが
極座標ですでに問題

$\overset{2}{q}_{\sigma}$ → 座標の関数の場合

Schwinger $<[\mathcal{L}(\dot{q}, q)]>$
量子論
矛盾を生じる

non-linear の意味
$\mathcal{L} = \bigcirc\,\dot{q}\,\bigcirc\,\dot{q}\,\bigcirc$
q の関数.

H.E. Liu, W.C. Liu & Sugano:

例題: $\mathcal{L} = \frac{1}{2}\sum_{\alpha=1} \dot{q}_\alpha \cdots \dot{q}_\alpha$

$\sum_{\alpha=1}^{4} q_\alpha q_\alpha = 1$

q_α = Cayley-Klein parameter

$$\mathcal{L}(q, \dot q) = \frac{1}{2}\sum_{j,r,s} A^{(j)}_{r}(q)\,\dot q_r\, B^{(j)}_{rs}(q)$$

$$\times\, \dot q_s\, C^{(j)}_{rs}(q) - V$$

$$\swarrow$$

$$p_r = \frac{\partial \mathcal{L}}{\partial \dot q_r}$$

$\dot q_r$ を $\mathcal{L}$ からひとつ落す

$$H = \sum_r \left(\dot q_r \frac{\partial}{\partial \dot q_r}\right)\mathcal{L} - \mathcal{L}$$

$$\sum_r \left[\dot q_r \frac{\partial}{\partial \dot q_r}\right](XY) = \left(\sum\left[\dot q_r \frac{\partial}{\partial \dot q_r}\right]X\right)Y$$

$$+ X\left(\sum_r \left[\dot q_r \frac{\partial}{\partial \dot q_r}\right]Y\right)$$

$$\sum_r \left[\dot q_r \frac{\partial}{\partial \dot q_r}\right]\dot q_s = \dot q_s$$

$$\sum_r \left[\dot q_r \frac{\partial}{\partial \dot q_r}\frac{d}{dt}(f(q))\right] = \frac{d f(q)}{dt}$$

$$q_s = f_s(q') \rightarrow H \rightarrow H$$

$$(1)\quad p_r = \frac{1}{2}\sum_{j,s}\left(A^{(j)}_r B^{(j)}_{rs}\, \dot q_s\, C^{(j)}_{rs} + A^{(j)}_r\, \dot q_s\, B^{(j)}_{sr}\, C^{(j)}_{sr}\right)$$

(2) $H = \frac{1}{2}\sum_{j,rs} A^{(j)}_{rs}\dot{q}_r B^{(j)}_{rs}\dot{q}_s C^{(j)}_{rs}$
$+ V$

(3) $[p_r, q_s] = \hbar/i \, \delta_{rs}$
$[p_r, p_s] = [q_r, q_s] = 0$
$[\dot{q}, q] = F(q)$

canonically equivalent
Lagrangian
(1), (2), (3) が同じになる
もの。

$i\hbar\dot{q}_r = [q_r, H]$ は出てくる

$i\hbar\ddot{q}_r = [\dot{q}_r, H]$ } は成立する
or
$i\hbar\dot{p}_r = [p_r, H]$
Action Principle から出る !!,

だからきいてくる.

tree approx. は だい結局には pole の

一般の議論.

field theory

$[\partial_\mu \varphi(x), \varphi(x)]$ non-covariant

1) covariance

2) CTP

chiral dynamics

$$\partial_\mu T_{\mu\nu} = \begin{cases} 0 & \nu = 4 \\ i\, \frac{\partial}{\partial x_k} \delta^3(0) \end{cases}$$

保池会
山本邦夫
7月22日, 1971

{ 田地
菊池

局所場における発散のない
非局所理論
(一般相対論的不変性とゲージ不変性)

1. renorm. const　∞

2. Lorentz inv.　self-stress
gauge inv.　photon self-energy

3. 自由度
(hadronの話)

1, Lorentz invariance
2, ∞を消す
3, T.S. equation の integrability

$$H = j_\mu A_\mu$$

$$[H(x), H(y)] \neq i \frac{\delta H(x)}{\delta \sigma(y)} - i \frac{\delta H(y)}{\delta \sigma(x)} = 0$$

$$[j_\mu(x), j_\nu(y)] \neq 0$$

$$j_\mu = \bar{\psi}\gamma_\mu\psi$$

1. Lorentz Invariance

point model

$\bar{\psi}(x)\gamma_\mu\psi(x')$ → vector

積の交換性

$$\bar{\psi}(x)\gamma_\mu\psi(x+\Delta) = j_\mu^{(1)}(x,\Delta) + j_\mu^{(2)}(x,\Delta)$$

space-like

Δ→0で　Δ→0で

~~[illegible]~~ ≠0　Δに依る

$$H_q(\varepsilon_i) = ie\,\bar{\psi}(x+\Delta\varepsilon_i)\gamma_\mu\psi(x-\Delta\varepsilon_i) \times A_\mu(x)$$

$$H = \sum_i b_i H_q(\varepsilon_i)$$

$\sum b_i = 1$　　b_i : real

$\varepsilon_i = q$ の odd の多項式

$H^*(\varepsilon) = H(-\varepsilon)$

発散項

$$\sum \frac{b_i b_j}{(\varepsilon_i+\varepsilon_j)^2}$$

$$\sum \frac{b_i b_j}{\varepsilon_i+\varepsilon_j}$$

$$\sum b_i b_j \log|\varepsilon_i+\varepsilon_j|$$

は消せる。

PTP: 45, 1993 (1971)

ただし $\frac{(\Delta_i+\Delta_j)_\mu(\Delta_i+\Delta_j)_\nu}{(\Delta_i+\Delta_j)^2}$

のような項が残る ↓

4次元では $\frac{1}{4}\delta_{\mu\nu}$

3次元空では $\frac{1}{3}\delta_{ij}$

A, B, C: scalar field

$H(\xi_i) = g A(x+\xi_i\Delta_1) B(x+\xi_i\Delta_2)$

$\times C(x+\xi_i\Delta_3)$

$T_{\mu\nu}(x) = \text{free} - \delta_{\mu\nu} g \sum_i b_i A(x+\xi_i\Delta_1)$

$\times \cdots\cdots$

S-matrix

の non-covariance

→ integrability condition

→ normal dependent H

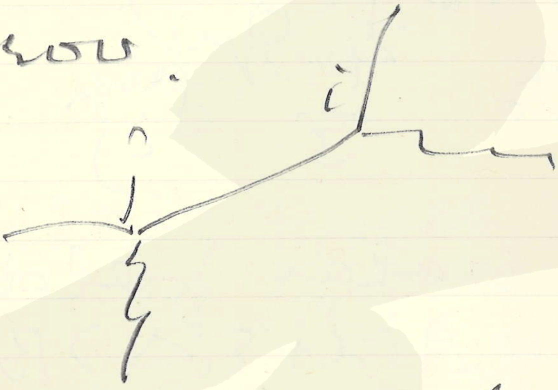
2次元 Q.E.D. (4次元 Q.E.D.)

← gauge invariance

Adler の anomalous divergence equation
(pseudo-vector

regulator

(ホイち
Markov



$S_F(x-y) \to S_F(x_\mu - y_\mu + \Delta_\mu(\xi_i - \xi_j))$

$\Delta_F(x_\mu) \to$

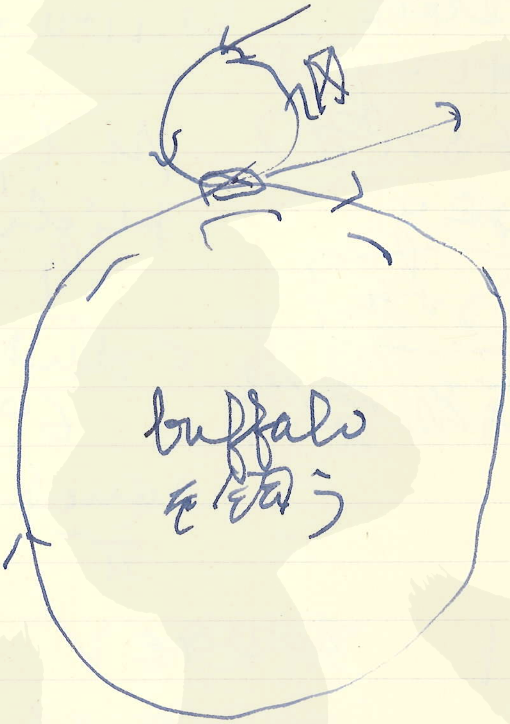
大加速器
National Accelerator Laboratory
8月20日, 1971.

High Energy
200 GeV
Weston
(⊖ Batavia)
(Enrico Fermi
Laboratory)
USA (40大学)
| Ramsey
R. R. Wilson
|
[illegible]

Medium Energy
LASL
(meson factory)
LAMPF
MeV
0 ~ 150 / Alvarez Linac
150 ~ 800 MeV /
wave guide
μ (g-2)
High intensity
1 ma (time average)
duty factor
6% ~ 12%
cancer research
π^-

9/8 1971　200 GeV
[illegible]　↓　500 GeV
5×10^{13} p/pulse
3 ~ 4 sec
(従来の accel. ↘ 10^{12})

C. W. 0 — 750 keV
Linac — 200 MeV 150 meter
Booster — 8 GeV R ≅ 75 m
(AGS)
Main Ring { dipole 774
(separate) { quadrupole 200
R ≅ 1 km



7/31 1971
Linac 200 MeV 100 ma
Booster 7 GeV
Main Ring: ~ 8 turn

search and secure 50 min.
人影がないこと

最初 200 GeV
2×10^10 個/pulse

敷地 6,800 エーカー
1エーカー＝1,200坪
[illegible]の10倍.

サービス機関,
物理屋 ～70人 (Ph.D)
engineer ～150人
technician ～400人
定員 900人

電算機 12時間.
不景気

$200M～250M

実験 0. 山内~~[illegible]~~実験(internal target)
1. Caltech 西島
neutrino ν → W
2. 山内実験
quark
3. Adair quark

出席. 山田英治 (MR)

[illegible] (MR)

山田作衛 (Exp)

三~~森~~田

高島

渡辺

superconducting magnet を入れて.

500 GeV → 1000 GeV ?

1 pulse/10 sec.

水が足りてない…

野上幸久氏 (McMaster Univ.)
三体の核力について
基研談話会 1971.9.14.

核子間の相互作用 ⇔ 核構造、核反応
→ 核物質

inverse problem

$\delta(k)$ $0 \leq k \leq \infty$

$l=0$ ⟶ $V(r)$

bound state があると 困 → 解けない。

核物質

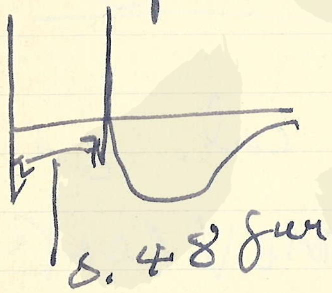
Weizsäcker の mass formula

16 MeV binding energy per nucleon

0.17 fm^{-3} density

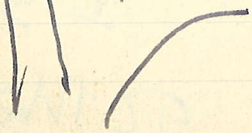
H.J. potential

spring 8 MeV



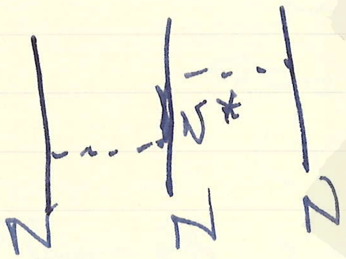
Reed potential

spring 13 MeV



1) 多体力 ?

2) effective force in many body system ?



三体力　　±5 MeV (Nogami)

(Brown ?)

OPEP = c + t

(Brown - Green ± 10 MeV)

↓ 3 MeV　○

---

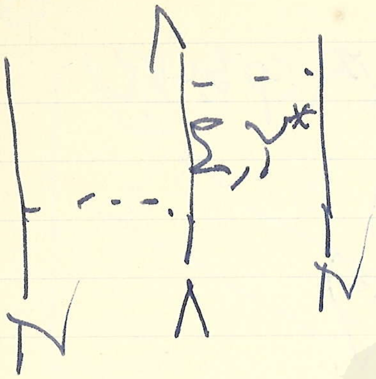
hypernuclei

$^{5}_{\Lambda}He = \alpha + \Lambda$　　cal. 6 ~ 5 MeV

$B_\Lambda = 3.0$ MeV (exp)

Λ + nuclear matter　exp: $\{$ $B_\Lambda \sim 30$ MeV ± 3 MeV

cal. 50 MeV

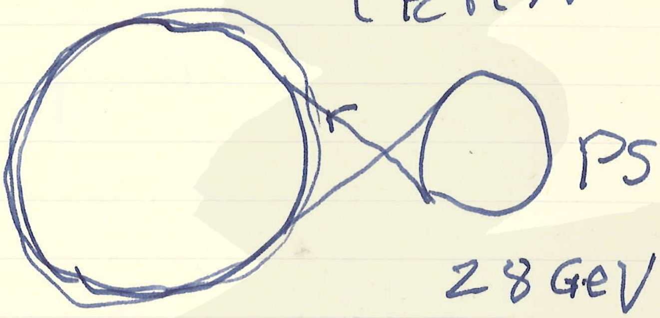


10 MeV
attr.

X

伊原拓氏
Amsterdam 国際会議の報告
基研談話会
Sept. 21, 1971

(Intersecting Storage Rings)
[I] ISR　　CERN



28 GeV → 1500 GeV
equivalent

$p + p \to p + p$

$\left.\begin{array}{l}\to p + \text{anything}\\ \to \pi + \quad ''\end{array}\right\}$

inclusive
reaction

$\frac{d\sigma}{dt}$:

A) Rubbia (Orito) large t
→ small t

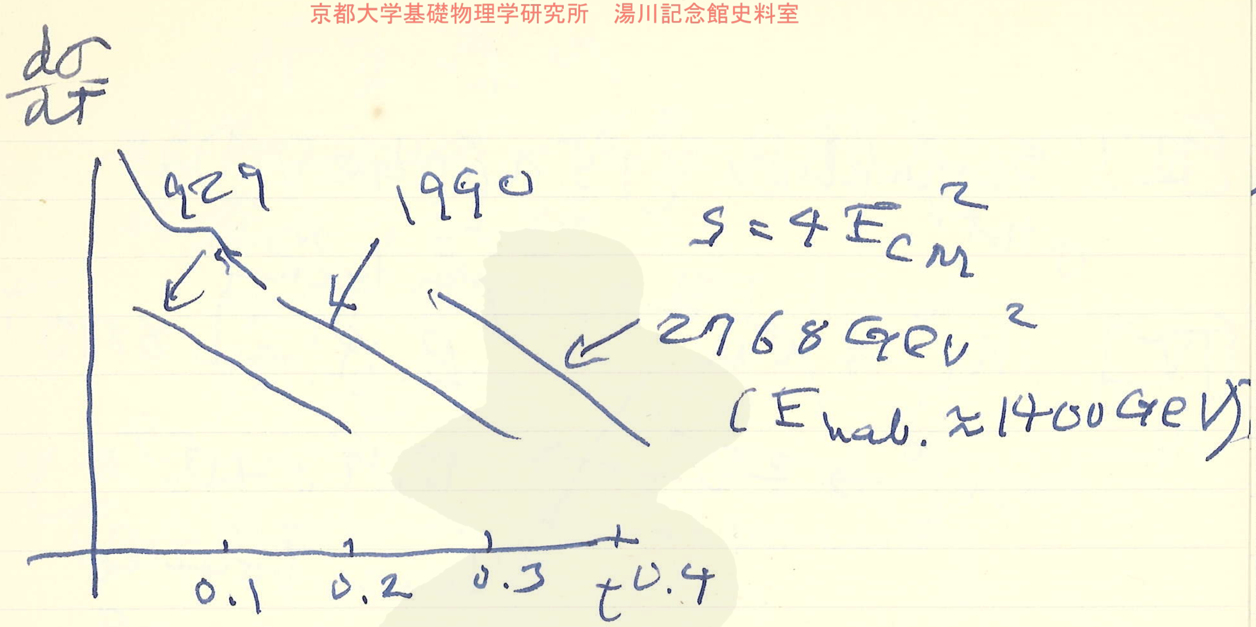
B) Amaldi et al. small t

$\frac{d\sigma}{dt} = Ae^{bt}$

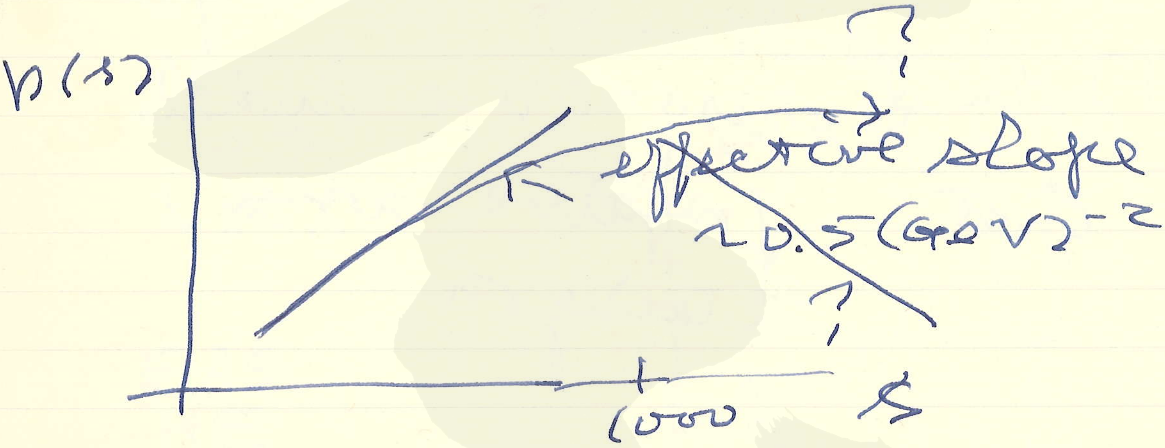
small
$0.01 \le |t| \le 0.15\ (\mathrm{GeV}/c)^2$
large
$0.15 \le |t| \le 0.3$

$t \sim \sqrt{s}\,(1 - \cos\theta)$

1A ~ 3A

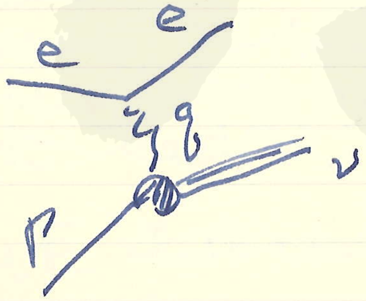


$b(s) \sim \alpha' \ln s$



[II] Deep inelastic $(\nu W_2)^n/(\nu W_2)^p = R$

$R = 2/3$: quark-parton model



[III] Serpukhov (15 ~ 60 GeV)
σ_{tot}

[IV] $K_L^0 \to \mu^+\mu^-$ upper bound B.R. ~ 1.8×10^{-9}

$K_L^0 \to 2\gamma$ → B.R. ~ 10^{-4}

lower bound ~ $6. \times 10^{-9}$

[V] chiral symmetry breaking

[VI] dual resonance model

ghost $\left\{ \begin{array}{l} \text{negative norm} \\ \text{tachyon} \end{array} \right.$

丹生潔の
超高エネルギー現象の研究についての最近の話題
Sept. 27, 1971
談話会.
タスマニア会議　8月16日〜25日
Tasmania University

250人
日本　11人
1論文：　5分
⋮
EAS
HE
μν
Quark
Heavy particle
Speculation on new particle
HE hadron

HE interaction

論文数(60)(HE)	
ソ	22
日	11
米	10
インド	5
英	4
⋮	⋮

Rapporteur

< 5 TeV N.A. Dobrotin → Y. Sitte
> 5 TeV Y. Fujimoto
→ C.M.G. Lattes

< 5 TeV 実験
E_{1ry} calorimeter
1ry particle の識別
Cerenkov detector
p と π の区別

結果
g-lines
K_γ 5 TeV まで 0.25
10 TeV で 0.4 に近い

σ
⟨n⟩

model
火の玉 isobar
H, SH, UH
multiperipheral

> 5 TeV
Japan-Brazil Emulsion chamber
light and usual fire ball
heavy f.b.
superheavy f.b.
Zhdanov emulsion $M \fallingdotseq 20 \sim 25\,\mathrm{GeV}$

水平 shower HAS → sub-muon
　機構で見つけた
再生 particle

中西襄君

場の量子論におけるComplex Ghost

1971, 10. 12　基研

IMHS

(1) $\langle a|a\rangle \geq 0$

(2) $\langle a|a\rangle = 0 \Longleftrightarrow |a\rangle = 0$

はやめる

$\langle a|b\rangle^* = \langle b|a\rangle$

$\langle a|a\rangle$: real

は残す　↓ norm

norm ≤ 0 ; ghost

non-degenerate metric

$\forall |b\rangle \quad \langle b|a\rangle = 0 \Longleftrightarrow |a\rangle = 0$

η-formalism は古い.

Banach space

operator　$T : |a\rangle \to |b\rangle$

$T^\dagger : \langle b|T^\dagger|a\rangle = \langle a|T|b\rangle^*$

$T^\dagger = T$: hermite

$T^\dagger T = TT^\dagger = 1$ unitary

state vector

physical state　　normal >0

initial state or physical ⇄ final ~~state~~ or physical
(physical state condition)

$$S_{phys} = P_{phys}\, S\, P_{phys}$$

Theorem　H: hermite
physical state cond. } S_{phys} is unitary

$$S_{phys}^{\dagger} S_{phys} = S_{phys} S_{phys}^{\dagger} = P_{phys}$$

$$S^{\dagger} S = S S^{\dagger} = 1$$

$$S^{\dagger}\{P_{phys} + \cancel{(1-P_{phys})}\} S = 1$$

H; hermite
finite dimensional

Ⓐ $n \geq 2$:　$(H-E)^{n}|a\rangle = 0$
$(H-E)^{n-1}|a\rangle \neq 0$

E complex
E^{*}

4全のて complete set
generalized eigenstate

Theorem

$\mathrm{Im}\, E^{*} \neq 0 \Rightarrow E^{*}$ も eigenvalue

$\because\ (H-E)|a\rangle = 0$

$(H-E')|b\rangle = 0 \qquad E'^{*} \neq E$

$0 = \langle b|H-H|a\rangle$

$= \langle b|(E'^{*}-E)|a\rangle$

$\therefore\ \langle b|a\rangle = 0$

$E'^{*} = E \ ;\ \langle a|a\rangle = 0$

$E \quad |a\rangle$

$E^{*} \quad |a^{*}\rangle$

$\langle a^{*}|a\rangle = 1$

$\frac{1}{\sqrt{2}}(|a\rangle \pm |a^{*}\rangle)$ norm ± 1

Ascoli-Minardi theorem

H a) eigenstate o' $\begin{cases}\text{phys.}\\ \text{complex ghost}\end{cases}$

$\Rightarrow$ phys. state cond.

$\Rightarrow$ S_{phys} : unitary

$\underbrace{E + E^{*}}_{\text{real}} \qquad |a\rangle \otimes |a^{*}\rangle$

Lee model

$\{\psi_V, \psi_V^{+}\} = -1$

$\{N, n\theta\}$ sector　unitary

$\{2N, 3\theta\}$　S_{phys}: non-unitary

$(\underset{V}{N+\theta}, \underset{V^{*}}{N+\theta})\ \theta$

Lee-Wick　Nuclear Physics

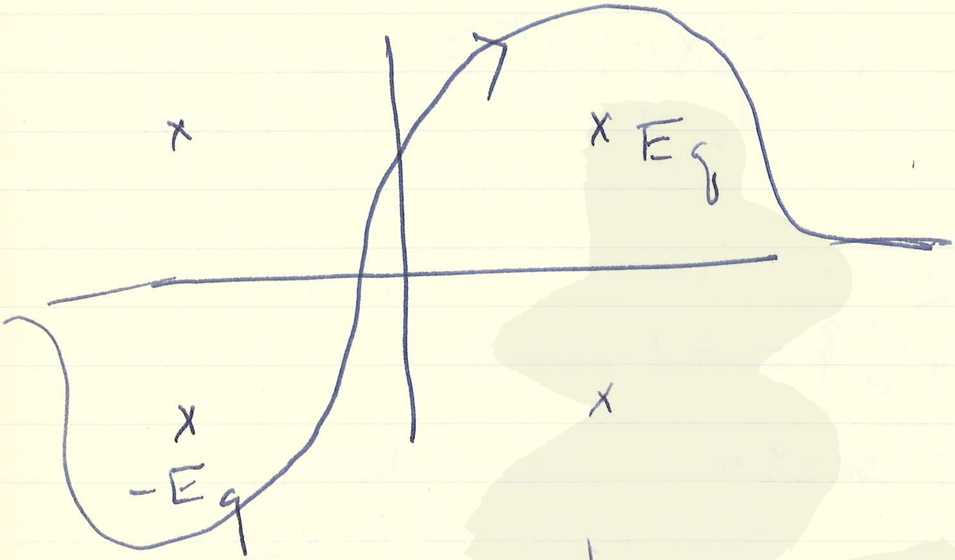
I, II.　1968 or 69

$\lim\limits_{\substack{t \to +\infty \\ t' \to -\infty}} U(t, t') = S'$ はいかん

$\longrightarrow$ 極限が存在しない

$S_{phys} = \{\langle in | out \rangle\}$

$\left.\begin{matrix} |out\rangle \\ |in\rangle \end{matrix}\right\} = [1 - (H - E \mp i\varepsilon)^{-1} H_1] |E\rangle$

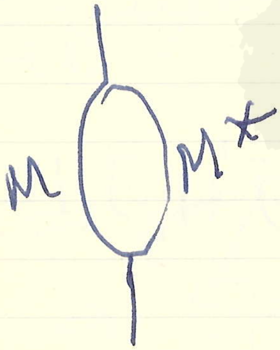


$$\int dq \int dq_0 \frac{1}{q_0^2 - E_q^2}$$

$$\sqrt{M^2+q^2}$$

(H. Yamamoto : non-hermite)

Coleman-Glashow の Ill·fy　$E+E^*$
Lee　relativistic theory



$$I(p) = \int dq \int dq_0 \frac{1}{(q_0^2-E_q^2)\{(p_0-q_0)^2 - E^{*2}_{pq}\}}$$

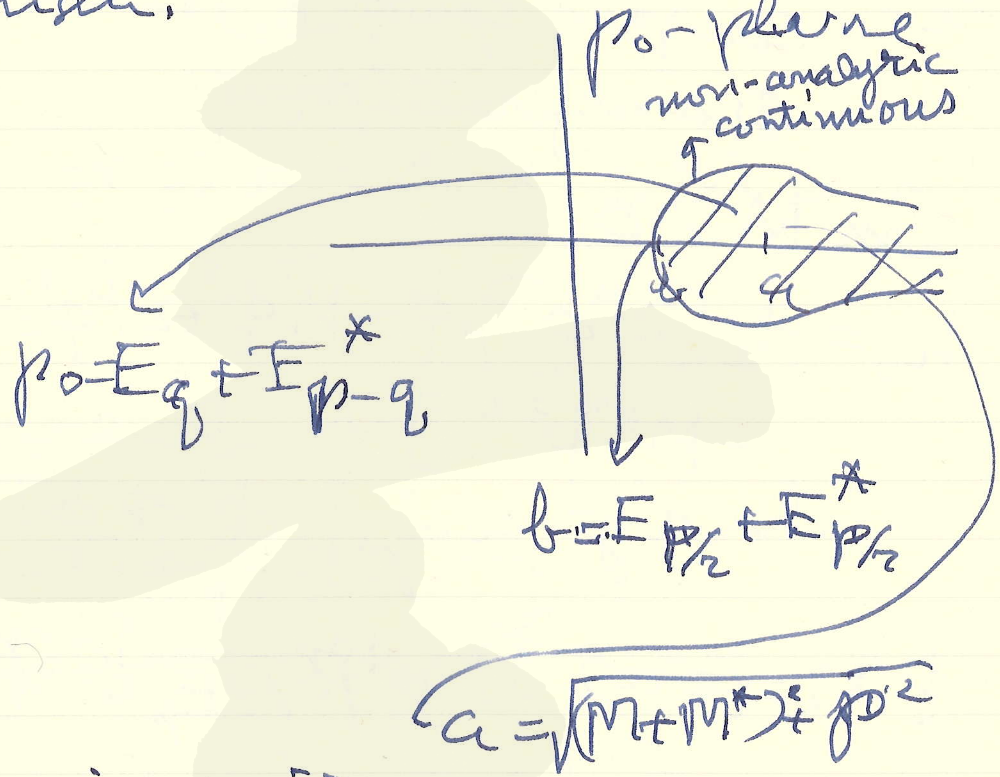
C

I(p) : real　no cut

M, M* pair creation は起らない

Lee : Lorentz invariant ✗

Nakanishi:



$$p_0 = E_q + E^*_{p-q}$$

$$b = E_{p/2} + E^*_{p/2}$$

$$a = \sqrt{(M+M^*)^2 + p^2}$$

b は invariant でない,
I(p) は Lorentz non-invariant

Lee:
CLOP
p : real spatial mom ?

○ Nakanishi:
~~Lorentz~~ S-matrix の invariance を示す

1° Lagrangian : Lorentz inv.
S non-invariant ?

2° complex ghost & Fourier transformation ?

Im M > 0

$$L_0 = \frac{1}{2}[\partial^\mu\phi\,\partial_\mu\phi - M^2\phi^2 + \partial^\mu\phi^\dagger\partial_\mu\phi^\dagger - M^{*2}\phi^{\dagger 2}]$$

charge conj. $\phi \to \phi^\dagger$

$$\phi(x) = (2\pi)^{-3/2}\int dp \frac{1}{\sqrt{2E_p}}[\alpha(p)e^{\cdots} + \beta^\dagger(p)e^{-\cdots}]$$

$$[\alpha(p), \beta^\dagger(q)] = [\beta(p), \alpha^\dagger(q)] = \delta(p-q)$$

$$H_0 = \int dp[E_p\beta^\dagger(p)\alpha(p) + E_p^*\alpha^\dagger(p) \times \beta(p)]$$

$P_\mu, M_{\mu\nu}$ $\quad i\partial\phi(x)/\partial x_0 = [\phi(x), H_0]$

ϕ : Lorentz scalar

plane wave $\xrightarrow{\text{Lorentz transf.}}$ non-plane wave

$[\phi(x), \phi(y)] = i\Delta(x-y, M^2)$

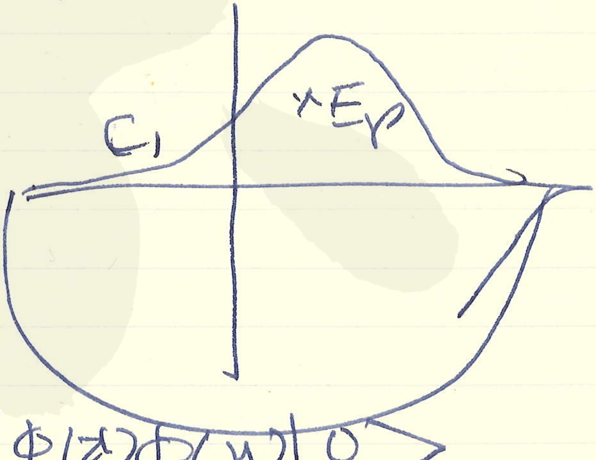
〃 — 〃

〃 〃

(Lorentz inv.)

$\langle 0|\phi(x)\phi(y)|0\rangle = \cdots$

$\alpha(p)|0\rangle = \beta(p)|0\rangle = 0$



$\Delta_F(x-y) = \langle 0|T\phi(x)\phi(y)|0\rangle$

=

Lee. Wick

S-matrix

$$H_I(x_0) \equiv e^{iH_0 x_0} H_1 e^{-iH_0 x_0} e^{-\varepsilon^2 x_0^2}$$

$$S = \lim_{\substack{x_0 \to +\infty \\ \hat{x}_0 \to -\infty}} U_\varepsilon(x_0, \hat{x}_0)$$

$$H_I(x_0) = \int dx\, \mathcal{H}_I(x)$$

$$S = T \exp\left[-i \int d^4x\, \mathcal{H}_I(x)\right]$$

$\varepsilon \to 0$ → Schwarz dist,

Lorentz inv. or violation

討論会

10月28日(木), 1971

荒河

1. 町田茂氏. composite model

mathematical quark model

U unitary spin

S spin

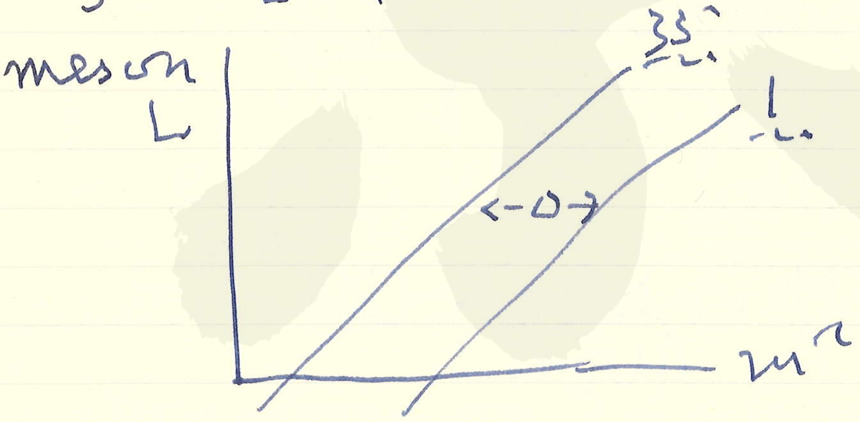
space properties

$$\left\{\begin{array}{l} M_A{}^B(x) = u_A(x)\,\overset{\circ}{\wedge}\,\bar{u}^B(x) \\ M_A{}^B(x_1, x_2) = \quad \cdot \quad \hat{} \end{array}\right\} \underline{どちらか}$$

↓

higher spin

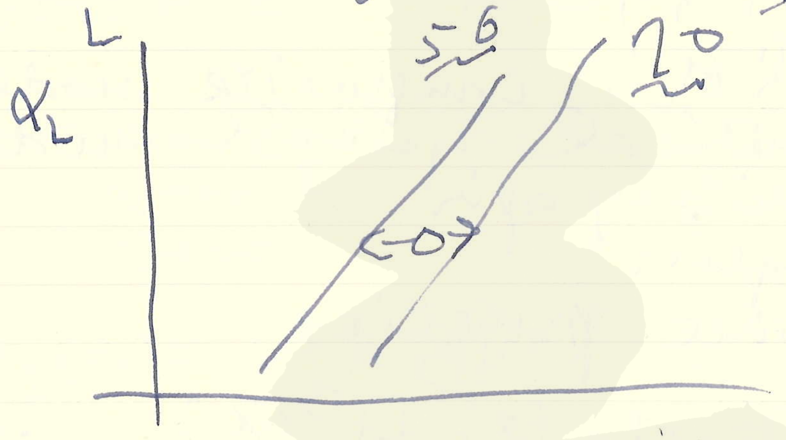
$\alpha_J = \alpha_{L\pm1},\ \alpha_L$



$\alpha_L = 0.945 - 0.63$ 3S

$= \quad '' \quad - 0.9$ 1L

baryon　L = even → 5~6
　　　　　odd → 20



baryon α_L', Δ は meson のと同じ ~~(Δ = [illegible])~~ とし:
$(\Delta = 0.5\ (\mathrm{GeV}))$

$$M^2 = M_0^2 + \Delta(U_E + S_E)$$

$$U_E = \frac{2\sum \rho^{(i)}\rho^{(j)} + 1}{3}$$

$$S_E = \frac{2\sum \sigma^{(i)}\sigma^{(j)} - 1/2}{3}$$

meson

$$M^2 = M_0^2 + \Delta S_E) + \alpha L$$
$((U_E +)$

報告: Nūn-particle の研究
Quartet Model

Ogawa

$X^{ch} \to \varepsilon^{ch} + \pi^0$

$\tau \sim 10^{-14}$ sec

new quantum number
SU(3) $(\vec{I}, Y)$ 以外のもの?

$p, n, \Lambda \to p'$ を加える

$Q = I_3 + \frac{1}{2}(Y + Z)$
$\downarrow$
supercharge

ζ

$p \; n \; \lambda \; {}''p'$
$\nu \; e \; \mu \quad \nu'$

1962
MNS (Nagoya)
KMTY (Kyoto)

fractional charged quartet

lepton-baryon symmetry

$j_\lambda^L = (\bar{\nu}_e e)_\lambda + (\bar{\nu}_\mu \mu)_\lambda$

$j_\lambda^H = (\bar{p}_e n_e)_\lambda + (\bar{p}_\mu n_\mu)_\lambda$

$$\begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix} \xrightarrow{\Theta_p} \begin{pmatrix} p \\ \xi \end{pmatrix}$$

$$\begin{pmatrix} e \\ \mu \end{pmatrix} \xrightarrow{\Theta_n} \begin{pmatrix} n \\ \lambda \end{pmatrix}$$

$$\Theta_w = \Theta_p - \Theta_n$$

[名古屋　4×3 ○

3×3 X

$SU(4) \subset U(4)$

$$4 \times 4^* = \underbrace{1}_{} + \underbrace{15}_{}$$

$4 \times 4 \times 4^*$

$4 \times 4 \times 4$ ○

bare mass

$$\begin{pmatrix} \nu_\mu \\ \nu_e \\ e_\mu \end{pmatrix} \to \begin{pmatrix} \xi \\ p \\ \lambda \end{pmatrix}$$

$$\begin{pmatrix} \nu_\mu \\ \nu_e \\ e \\ \mu \end{pmatrix} \to \begin{pmatrix} \lambda \\ p \\ n \\ \xi \end{pmatrix}$$

$p \to 10$ MeV

$\lambda \to 100$ MeV

$\xi \to 1000$ MeV

chiral sym.

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

$$\downarrow$$

$$U(3) \times U(3)$$

$$\downarrow$$

$$U(4) \times U(4)$$

$\underline{\Gamma(\eta \to 2\gamma)}$

Ida(4) 0^+

$\epsilon \to \pi\pi$

dilaton

中西襄
場の理論の基礎についての
最近の研究
Dec. 2, 1971　基研
談話会

dipole ghost

Heisenberg (1957)
Lee model
$(H-E)|0\rangle=0 \quad \langle 0|0\rangle=0$
$(H-E)|D\rangle=0 \quad \langle 0|D\rangle\neq 0$
S-matrix の unitarity

Ascoli-Minardi (1959)
Nagy (1965)

Nakanisi (1967)
QED general cov. gauge

$$\frac{g_{\mu\nu}}{-k^2-i\varepsilon}+\frac{\alpha k_\mu k_\nu}{(-k^2-i\varepsilon)^2}$$

~ dipole ghost

$\partial^\mu j_\mu=0 \rightarrow$ S_{phys}-matrix unitary
$\partial^\mu j_\mu\neq 0 \rightarrow$ non-unitary

Dürr, Feinberg (1968) (Rochester conf.)

Nagy (1970)
Lee + Froissart

phys. S-matrix → non-unitary

Nakanishi, Phys. Rev. (1971)
Dipole-Ghost Scattering states
V, N ⊖
A ——→ 0-norm
B ——→ dipole ghost

S-matrix is unitary でない

素粒子の時空記述

12月20日～12月22日, 1971

午前 10.30～12.30 午後 2.00～4.30

20日 拡がりと相互作用 後藤(阪大) (谷川)　谷川, 宮沢, 中村 田藤 (宮)

21日 並木, 田地 (宮沢)　時空の中での 電磁・重力場, 仲, 浅井, (田地)

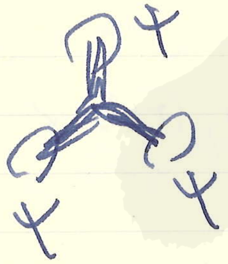
22日 場の理論における時空 代数と幾何 山本, 横山 (後藤)　まとめ) 高林・菅原, 湯川 (菅原) (田中正)

20日午後

後藤：拡がった粒子の相互作用,

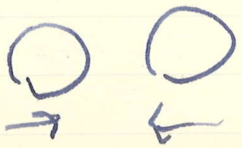
non-local field

三点成分 場　$C_{abc}\psi_a^{(x)}\psi_b^{(y)}\psi_c^{(z)}f(x,y,z)$



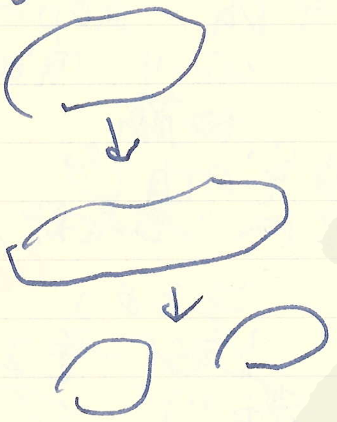
$H_{int.} = \int \psi\psi\psi f$

固有値問題の解答

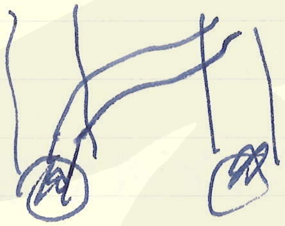


S ← potential

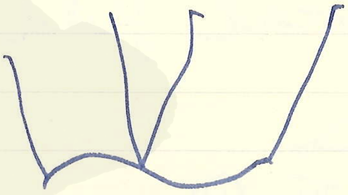
liquid drop から出発.



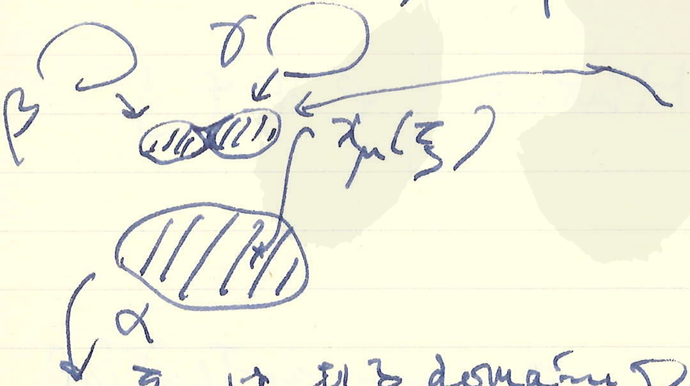
伊藤方式:



鈴木: ひも
が二つに切れる



Nambu, Copenhagen Lecture 1970

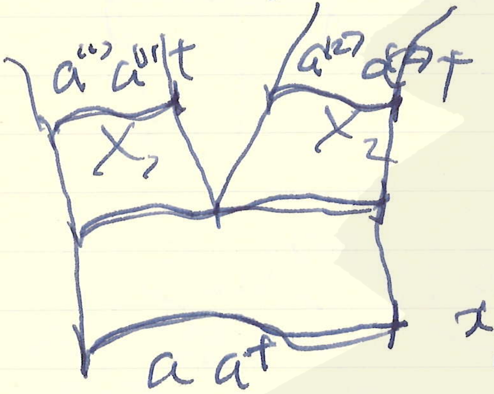


$D_\alpha = D_\beta \oplus D_\gamma$

ξ は ある domain D_α
の中にある.

$$\int \Psi[F_\alpha^{(1)} \cdots \overset{F_\alpha^{(k)}(\xi)}{F_\alpha^{(k)}} \cdots]\, \Psi[F_\rho^{(k)}(\xi)]$$

$$\times \Psi[F_\gamma^{(k)}(\xi)]\, \mathcal{D} F$$



$x_\mu(\sigma)$

$(\sigma_0, \sigma_i)\ (\sigma_i, \sigma_f)$

$\sigma_i - \sigma_0 = L_1 \quad \sigma_f - \sigma_i = L_2$

(σ_0, σ_f)

$\sigma_f - \sigma_0 = L$

$L_1 + L_2 = L$

$$x(\sigma) = x^{(1)}(\sigma) \quad (\sigma_0 < \sigma < \sigma_i)$$

$$= x^{(2)}(\sigma) \quad (\sigma_i < \sigma < \sigma_f)$$

$$x(\sigma) = \sum \overset{(\sigma)}{f_n}(\sigma)\, x[n]$$

$$p(\sigma) = \sum \quad p[n]$$

$$[a_\mu(n), a_\nu^\dagger(n')] = -g_{\mu\nu}\delta_{nn'}$$

$$a^{(1)}(n) = \sum[u_-(n\,n')a + u_+(n\,n')$$
$$\times a^\dagger(n')]$$

$$a^{(2)}(n) = \quad v_- \qquad\qquad v_+$$

$$a(n) = \sum(u_-^T a^{(1)} + u_+^T a^{(1)\dagger}$$
$$+ v_-^T a^{(2)} + v_+^T a^{(2)\dagger})$$

$+ f_1 \overline{X} + f_2 \overline{P}$

$\overline{X} = x_1 - x_2$

$(a^{(1)}\ a^{(2)}\ a^{(1)\dagger}\ a^{(2)\dagger}\ \overline{X}\ \overline{P})$

$\Updownarrow$

$a \quad a^\dagger$

$\langle p, n| \qquad |p^{(1)}, \underbrace{n_1\rangle \otimes |p^{(2)}}_{\parallel}, n_2\rangle$

$\sum \Gamma_{\{m\}} |m\rangle$

$\langle p, n| \qquad \overbrace{|p^{(1)}, 0\rangle \times |p^{(2)}, 0\rangle}$

$= \langle n| e^{ipX}\ e^{-ip^{(1)}x^{(1)} - ip^{(2)}x^{(2)}} \quad |0\rangle$

$\times |0\rangle$

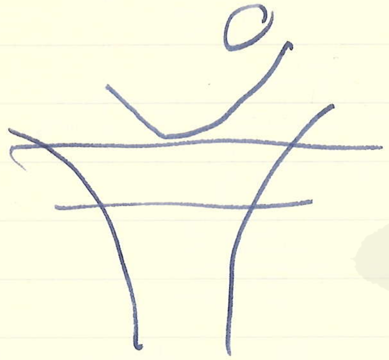
$$\left.\begin{aligned} a^{(1)}\ |0\rangle_1 \times |0\rangle_2 &= 0 \\ a^{(2)} \qquad\qquad &= 0 \\ \overline{P} \qquad\qquad &= 0 \end{aligned}\right\}$$

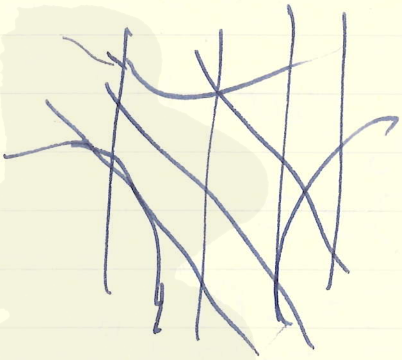
$|0\rangle_1 \times |0\rangle_2 = N e^{-\frac{1}{2} a^\dagger K a^\dagger} \quad |0\rangle$

$\langle n| e^{-iqX}\ e^{-\frac{1}{2} a^\dagger K a^\dagger} \quad |0\rangle \swarrow$

zero-point fluctuation

duality





(σ, τ)

それ： 若い：
積極い、引張、

kinematics

$$[x^\mu(\sigma), p^\mu(\sigma')] = i g^{\mu\nu} \delta(\sigma - \sigma')$$
$$0 \leq \sigma < 1$$

$$[x^\mu(0), p^{(\nu)}(0)]$$
$$= [x^\mu(1), p^\nu(1)] = i g^{\mu\nu}$$

$\mu, \nu = 0, 1, 2, 3$

$$H(\sigma) = \frac{1}{2}\left(p(\sigma)^2 + \left(\frac{\partial x}{\partial \sigma}\right)^2\right)$$
$$0 \leq \sigma \leq 1$$

boundary condition

$$\left.\frac{\partial x}{\partial \sigma}\right|_{0,1} = 0$$

$$\left.\frac{\partial p}{\partial \sigma}\right|_{0,1} = 0$$

$$p^\mu(0) p_\mu(0)$$
$$= p(1) p(1) = 0$$

$$T(\sigma) = \frac{1}{2}\left(p^\mu(\sigma) \frac{\partial x_\mu}{\partial \sigma} +\right.$$

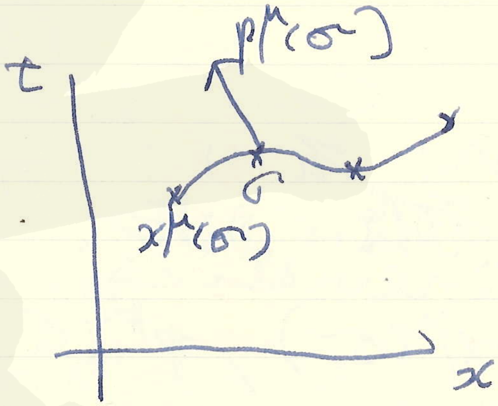
$$H = \int_0^1 H(\sigma) d\sigma$$

$$T = \int_0^1 T(\sigma) d\sigma$$

$$[H, T] = 0$$

$$[x^\mu, H] = i p^\mu$$

$$[x^\mu, T] = i \frac{\partial x^\mu}{\partial \sigma}$$



$x^\mu(\sigma)$ [illegible]

space-like

$$\left(\frac{\partial x}{\partial \sigma}\right)^2 < 0$$

$(p^\mu(\sigma))^2 \geq 0$: time-like

causality $\quad H(\sigma) \geqq 0$

$$H \geqq 0$$

$$X^\mu = \int x^\mu(\sigma) d\sigma$$

$$P^\mu = \int p^\mu(\sigma) d\sigma$$

$$[H, P^\mu] = 0$$

P^μ, $\quad v = P/p^0$

$$\ell y = \frac{H'}{\sqrt{1-v^2}}$$

$$i\frac{\partial\Psi(t)}{\partial t} = H_g\Psi(t)$$

$$d\tau = \frac{dt}{\sqrt{1-v^2}}$$

$$i\frac{\partial\Psi}{\partial\tau} = H\Psi$$

点の静止系　$v=0 \rightarrow \tau = t$

(流本: proper time formulation)

Heisenberg表示へ移す

$$U_H(\tau) = \exp iH\tau$$

$$x^\mu(\sigma,\tau) = U_H\,x^\mu(\sigma)\,U_H^{-1}$$

$$p^\mu(\sigma,\tau) = \quad \cdot \quad -$$

$$\frac{\partial\Psi_H}{\partial\tau} = 0$$

$$i\dot{x}_\mu = [x_\mu, H] = i p_\mu$$

$$i\dot{p}_\mu = [p_\mu, H] = i\frac{\partial^2 x}{\partial\sigma^2}$$

$$\frac{\partial^2 x^\mu}{\partial\tau^2} - \frac{\partial^2 x^\mu}{\partial\sigma^2} = 0$$

$$\mathcal{L} = \frac{1}{2}\left\{\left(\frac{\partial x}{\partial\tau}\right)^2 - \left(\frac{\partial x}{\partial\sigma}\right)^2\right\}$$

$$H = \frac{1}{2}\left\{\left(\frac{\partial x}{\partial\tau}\right)^2 + \left(\frac{\partial x}{\partial\sigma}\right)^2\right\}$$

$\xi_0 = \tau \qquad \xi_1 = \sigma$

$g^{\alpha\beta} = 1, -1$

$$T^{\alpha\beta}(\xi) = \frac{\partial \mathcal{L}}{\partial\left(\frac{\partial x}{\partial \xi_\alpha}\right)} \frac{\partial x}{\partial \xi^\alpha} - g^{\alpha\beta}\mathcal{L}(\xi)$$

$$\frac{\partial T^{\alpha\beta}}{\partial \xi^\alpha} = 0$$

$$T^{00} = T^{11} = H(\sigma) \qquad \left\{ \begin{array}{l} T^{\alpha\beta} = T^{\beta\alpha} \\ T^\alpha{}_\alpha = 0 \end{array} \right\}$$

$$T^{01} = T^{10} = T(\sigma)$$

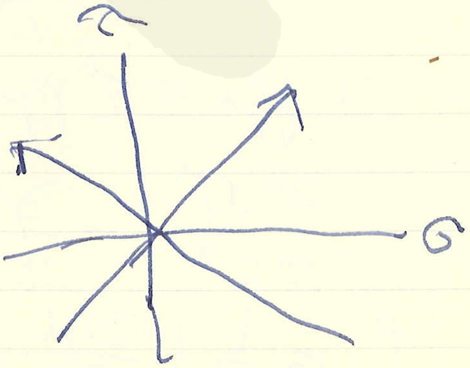
$$x^\mu = f(\tau+\sigma) + g(\tau-\sigma)$$

$$\left.\begin{array}{l} H = \int T^{00} d\sigma = \int H(\sigma) d\sigma \\ T = \int T^{10} d\sigma = \int T(\sigma) d\sigma \end{array}\right\}$$ 保存量

$$m^{[\alpha\beta]\gamma} = \xi^{[\alpha} T^{\beta]\gamma}$$

$$\frac{\partial m^{[\alpha\beta]\gamma}}{\partial \xi^\gamma} = 0$$

$$[H, M] = 0$$



$$D^\sigma(\xi) = \xi^\alpha T_a^\sigma(\xi)$$

$$\frac{\partial D^\sigma}{\partial \xi^\sigma} = 0$$

$$D = \int D^0 d\sigma = \tau \cdot H + \int \sigma \cdot T(\sigma) d\sigma$$

dilatation

$(\tau, \sigma) \to (a\tau, a\sigma)$ τ σ

conformal invariance

$[H, D] = 0$

R　τ, σ に対する Euclid rotation
(T=θ とすれば) → τ, σ を[illegible]している,

$[H, R] = 0$

detailed wave equation
(Takabayasi)

$$(H(\sigma) + i\,T(\sigma))\Psi = x\Psi$$

は次の~~式~~式でないか?

$$\begin{cases} i\dfrac{\partial H(\sigma)}{\partial \tau} = [H(\sigma), H] \\ i\dfrac{\partial T(\sigma)}{\partial \tau} = [T(\sigma), H] \end{cases}$$

$$i\frac{\partial T(\sigma)}{\partial\sigma} = [H(\sigma), H]$$

$$i\frac{\partial H(\sigma)}{\partial\sigma} = [T(\sigma), H]$$

$$\left.\begin{aligned} i\frac{\partial H(\sigma)}{\partial\sigma} &= [H(\sigma), T] \\ i\frac{\partial T(\sigma)}{\partial\sigma} &= [T(\sigma), T] \end{aligned}\right\}$$

$H(\sigma), T(\sigma)$ for closed algebra をつくる.

$T(\sigma), \sin r\sigma \to T^r$

$H(\sigma), \cos r\sigma \to H^r$

$$irT^r = [H^r, H^0]$$

$$-irH^r = [T^r, H^0]$$

$$\Lambda^r_\pm = \sqrt{\frac{\pi}{2}}(H^r \pm iT^r)$$

$$[H^0, \Lambda^r_\pm] = \pm r\Lambda^r_\pm$$

$$[\Lambda^r_+, \Lambda^s_-] = \bigcirc$$

$$\left.\begin{aligned} [\Lambda^1_+, \Lambda^1_-] &= -2H^0 \\ [\Lambda^\pm, H^0] &= \pm\Lambda^\pm \end{aligned}\right\} O(2,1)$$

$$\frac{\Lambda_+ + \Lambda_-}{2} = K_1$$

$$\frac{\Lambda_+ - \Lambda_-}{2} = K_2$$

$$H^0 = K_3$$

$$\left.\begin{aligned}[K_1, K_2] &= -K_3 \\ [K_2, K_3] &= K_1 \\ [K_3, K_1] &= K_2\end{aligned}\right\} \rightarrow H^0 \Psi = E \Psi$$

O(2,1) の既約表現

$$I = K_3^2 - K_1^2 - K_2^2$$

$$H^0 = m \delta_{mm'}$$

$$I \leqq 0$$

$$I > 0$$

Regge trajectory

相互作用

$$H(\sigma) = H_0(\sigma) + H'(\sigma)$$

$$T(\sigma)$$

$$\frac{\partial T^{a\mu}(\xi)}{\partial \xi^a} = 0$$

Dual amplitude

Virasoro condition

$$\langle \Phi_0 | H' | \Psi_0 \rangle$$

$$\Lambda_-^{(1)} | \Psi_0 \rangle = 0$$

$$x^\mu(\tau, \xi_1, \xi_2, \xi_3)$$

中野氏;

SU(3)　8 meson がつくれてないが、

quadri-local

baryon 4-local spinor field

$$\psi(x_\mu, x_\mu^r) \quad {\scriptstyle 1,2,3} \rightarrow a_\mu^r, a_\mu^{r\dagger}$$

⇓

meson　$\varphi(X_\mu, y_\mu^r, z_\mu^r)$

$$B_s^r = A_s^r - \frac{1}{3}\delta_{rs} A_u^u$$

$$A_s^r = a_\mu^{s\dagger} a_\mu^r + \delta_{rs}$$

宮島：いかなる方向に沿って相互作用を考えたらよいか。

1. 場の理論的

infinite comp. theory

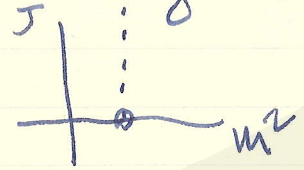
mass spectrum

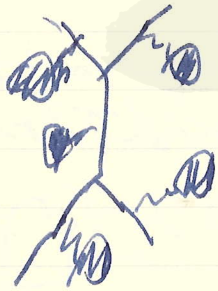
Majorana, Nambu

Takabayashi, Gatto

no-go theorem

互限と矛盾





tad-pole

2. モデル的

guiding principle

high energy

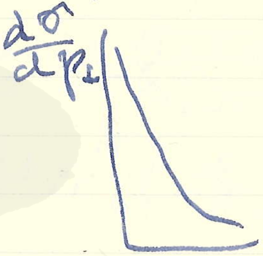
① total cross-section

$\xrightarrow[s\to\infty]{}$ const.

elastic も const. になる

(Pomeron だけとの関係)

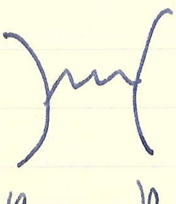
② $p_\perp$ の cut-off



③ p cross-section の $p_\parallel$ index

④ Wu-Yang conjecture

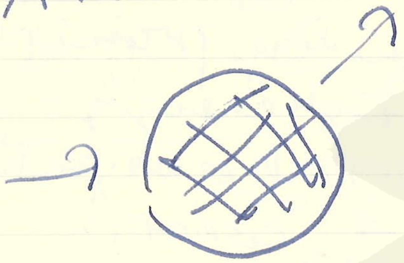
$$\frac{d\sigma}{dt} \propto F^4(t)$$

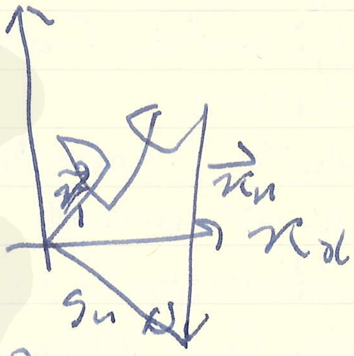


$$= \text{Regge term} + \frac{1}{(t-0.7)^2}$$

①' $\langle n \rangle \sim (0.75 \sim 8) \ln (E/M_p^2)$

{5} Random Flights による
Geometrical Model
AB → AB





$x^2 = -t$

$P_n(x)\delta x = \frac{\partial Q_n(x)}{\partial x}\delta x$

$Q_n(x)$

$\sum_{n=1}^{\infty} Q_n(x) =$

$P(x)\delta x = x\delta x \int b\,db\, J_0(xb)$

$\times\left[e^{\frac{2}{R^2}\int_0^R \rho\, d\rho\, J_0(\rho b)\sigma^2(-\rho^2)} - 1\right]$

$\frac{d\sigma}{dt} =$

21日：午前

田中：Matter at Ultrahigh Density

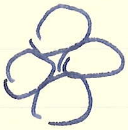
Oppenheimer, Volkoff

太陽の2倍以下ならば止.

$p = p(\rho)$

一気に収縮するか？

final density ρ_f



密度を大きくすると

粒子の運動エネが大きくなる.

圧力が非常に大になる.

Hadronic Matter

hadronでつくってる matter

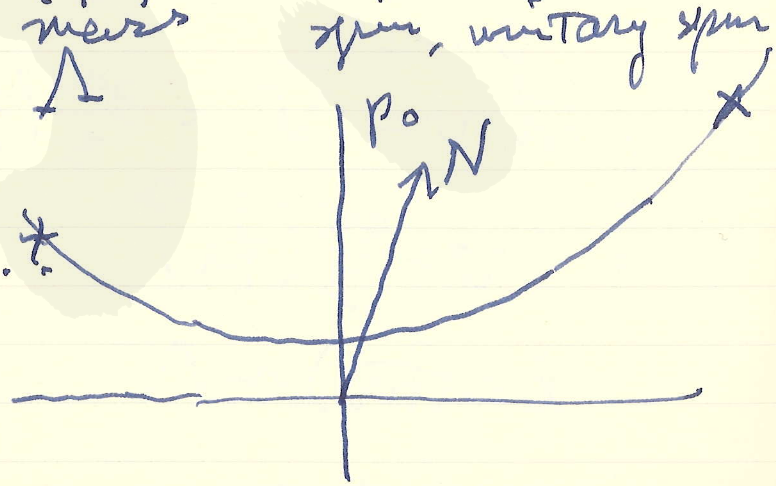
ρ_f, P_f : 有限

Pauli原理,

ψ: $\psi\psi\psi\psi$

m, mass

cut-off length Λ



$H\Psi_R = E_R \Psi_R$

$= c_0 \varphi_0 + c.\varphi.\tau.\cdots$

Fermi gas

$\delta(\Psi_R H \Psi_R) = 0$

$\delta(\Psi_R, \Psi_R) = 0$

中間結合法.

$C_n = \frac{\alpha^n}{\sqrt{n!}} C_0$　　$\sum_n |C_n|^2 = 1$

Poisson分布: $e^{-\bar{n}}$

x-space

$6\pi^2 \Lambda^3 = v$

基本長さ

l, $\frac{1}{M}$, Λ

$\alpha = \beta l^2 / v M$

$\beta \sim 10$

$$\left\{\begin{array}{l} \bar{n} v = \bar{V} = \frac{4\pi}{3}\left(\frac{1}{M_N}\right)^3 \\ v = \frac{4\pi}{3}\left(\frac{1}{M}\right)^3 \end{array}\right.$$

$l \sim \left(\frac{1}{M}\right) \sim \Lambda$　　$\Lambda = 10^{-15}$ cm

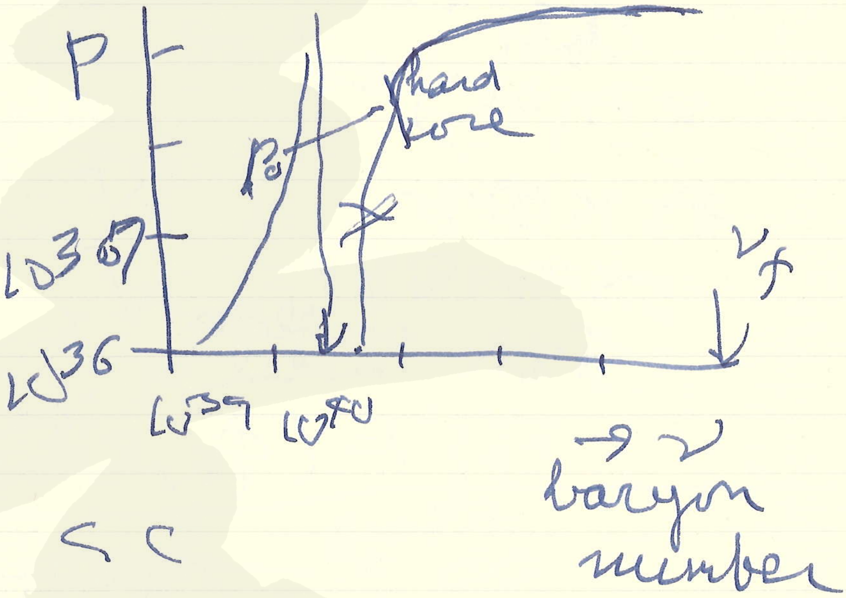
$H = H_0 + H_1$

$= H_0' + H_1'$

$\bar{n} \approx 10^3 \quad \sim 10^4$

密度を大きくすると
pair はつぶれる

$\frac{6}{v}$



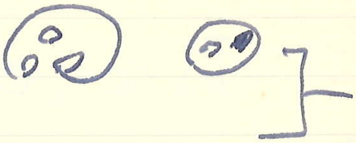
$$\sqrt{\frac{dP}{d\rho}} = v < c$$

音速函数

$P \leq \frac{1}{3}\rho$ (Landau)

$r_{max} = 10^5$

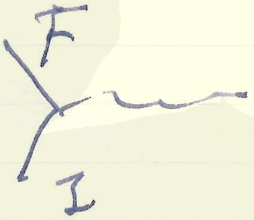
並木氏：量子数の話・〜



内部自由度
分らない

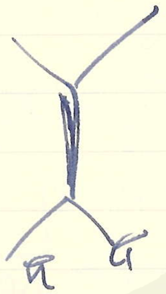
→ 強結合粒子模型
素朴
ひろがり

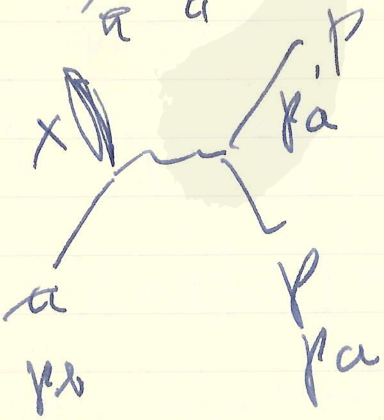
形状因子
三次元(調和振動
模型 oscillator model



$$F(q^2) = (\Phi_F, e^{iq\cdot x}\Phi_I)$$

$$= \frac{1}{\left(1+\frac{q^2}{2m^2}\right)^2}\exp\left[- \quad \right]$$





$$M_x^2 = (p_a' - p_a + p_b)^2$$

$$\frac{d\sigma}{dt\,dM_x} - \left[\frac{d\sigma}{dt\,dM_x}\right]_{B} = \left[\frac{d\sigma}{dt\,dM_x}\right]_{MM}$$

cluster 描像

linear trajectory に乗ってると.

peak number $n \Rightarrow L+1$

main peak

$L=0$　π η
　　　ρ

$L=1$　A_2

$L=2$　R

fine peak

[illegible]
∞

hyperfine peak

⇓ $E \simeq 15$ MeV　level ↓ (へってくる)

fine peak

⇓ $E \simeq 50$ MeV

giant peak

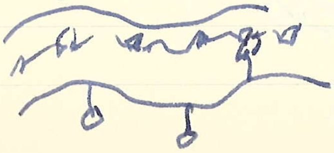
⇓ $E \simeq$ 数百 MeV

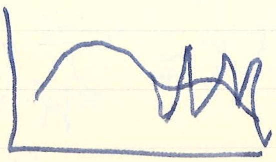
[illegible]の gross feature

---

collective mode (single particle)

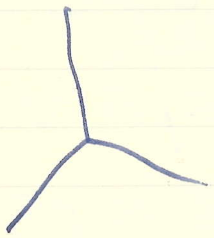
不[illegible]的振る子 ([illegible])

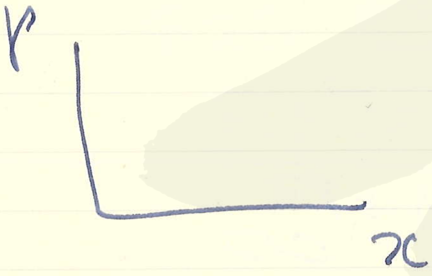




21世紀
過去の科学：物質の記述

物理事象 → 情報 → 記述
↓
粒子の運動
位置、時刻
x , t
p





有限次元の complex Hilbert space

Boole lattice (束)

spin σ_x, σ_y の測定
2次元の複素空間.

$x, p \rightarrow x', p'$

$$H = \sum_k (x_k^2 + p_k^2)$$
$= $ 一定

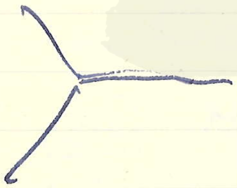
[illegible]：// 四元の一意化

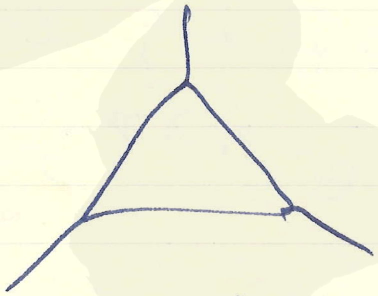
~~[illegible]~~：湯川記録：四元の Minkowski だというが Euclid的なその方が満足する

Snyder
Tamm

Stückelberg-Wanders

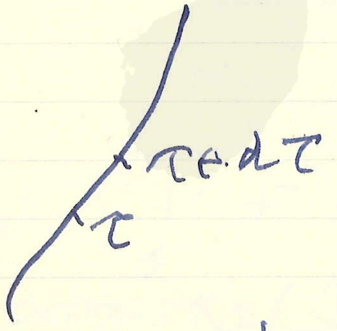
$$S_n + S_n^{\dagger} = \sum_{m=1}^{n-1} S_m^{\dagger} S_{n-m}$$





仲：非分析的式とDRM

$$L = -\frac{mc}{2}[g_{\mu\nu} Dx^{\mu} \times D^{\nu}x^{\nu} + 1]$$



$$\Downarrow \quad \left(D \equiv \frac{d}{d\tau}\right)$$

$$L_{\lambda} = -\frac{mc}{2}\{g_{\mu\nu} Dx^{\mu} f(\lambda D) \times Dx^{\nu} + 1]$$

$$x \to x + \delta x$$

$$D^n \delta x \Big|_{\tau_1}^{\tau_2} = 0$$

$$S_\lambda = \int_{\tau_1}^{\tau_2} L_\lambda d\tau$$

$$f(\lambda D) D^2 x = 0$$

$$f(z) = \frac{\sinh \pi z}{\pi z}$$

$$\sinh(\pi \lambda D) \cdot D x = 0$$

$$\frac{1}{2\pi\lambda}\{e^{\pi\lambda D} - e^{-\pi\lambda D}\} x^\mu = 0$$

$$\lim_{z \to 0} f(z) = 1$$

$$f_1(z) = \frac{\tanh \pi z}{\pi z}$$

$$f(z) = 1 + 2z^2 \sum_{n=1}^{\infty} \frac{(-1)^n}{(z^2 + n^2)}$$

free motion + oscillations

22日；宮本：Tachyonの量子化
統計も
quark = tachyon
spinと統計も逆転.

canonical formalismはやめて
運動方程式から出発.

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

$J \qquad J+1, \ldots, \infty$
$\qquad -J-1, \ldots, -\infty$

$$[\phi(x), P^\mu] = -i\partial^\mu\phi(x)$$

i) metric $\quad [\eta\Lambda(\partial)]^\dagger = \eta\Lambda(-\partial)$

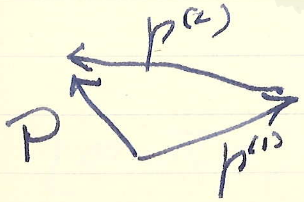
$$\tilde{\phi}(x) = \phi^\dagger(x)\eta$$

$$\tilde{\phi}(x)\Lambda(-\overleftarrow{\partial}) = 0$$

ii) $\Lambda(\partial)d(\partial) = \partial_\mu\partial^\mu + \mu^2$

iii) $V^\dagger\eta\Lambda(-\partial)V = \rho\eta\Lambda(\partial)$

CPT
↓
PT



2体，3体

fusion

共鳴粒子

山本滋史：不安定粒子のおかげで場の理論が収束しているのではないか……

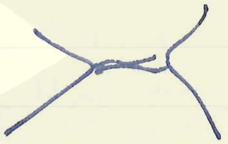
hamiltonian の hermiticity を破る。

安定粒子 ― 形式的（固有値と扱）

complex mass

$m = x + i\gamma$

$\tau \sim 1/\gamma$



γ：共鳴幅

photon

$e \xrightarrow{?}$ ρ^0, ω

$p \xrightarrow{??}$ μ

ν_e — n

$\bar{\nu}_\mu$ — Λ

$e^{/+}$ — p

μ^+ — Nin

横山：不定計量と確率解釈.

$$P_{b\leftarrow a} = \frac{|\langle b|S|a\rangle|^2}{\langle b|b\rangle\langle a|a\rangle}$$

$$\mathcal{L}_{\mathrm{int}}(A(x)) \rightarrow \mathcal{L}_{\mathrm{int}}(A(x)+B(x))$$

$$[A(x), A(y)] = i\Delta(x-y; m)$$

$$[B(x), B(y)] = -i\Delta(x-y, M)$$

$$S \rightarrow \tilde{S}$$

↳ A(x)だけ unitary

Bogolyubov's unitarization の方法

$$|\Psi\rangle = |\mathrm{I}\rangle + |\mathrm{II}\rangle$$

$$|\mathrm{in}\rangle = |\overline{\mathrm{in}}(+)\rangle + |\mathrm{in}(-)\rangle$$

$$|\mathrm{out}\rangle = |\mathrm{out}(+)\rangle + |\mathrm{out}(-)\rangle$$

$$= S|\mathrm{in}\rangle$$

$$|\mathrm{out}(+)\rangle = S^{+}|\mathrm{in}(+)\rangle + S^{-}|\overline{\mathrm{in}}(-)\rangle$$

$$|\mathrm{out}(-)\rangle = S^{-}|\overline{\mathrm{in}}(+)\rangle + S^{+}|\overline{\mathrm{in}}(-)\rangle$$

$$\lim \left(A(x) - B(-x) \right)$$

$$\downarrow$$

$$S'$$

$$S^{\pm} = \frac{1}{2}(S \pm S')$$

$$|out(-)\rangle = U|in(-)\rangle$$

boundary condition

Bogoliubov $U = -1$

$$|in(-)\rangle = \frac{1}{U - S^{+}} S^{-} |in(+)\rangle$$

$$|out(+)\rangle = \tilde{S}\,|in(+)\rangle$$

$$\tilde{S} = S^{+} + S^{-} \frac{1}{U - S^{+}} S^{-}$$

$$\tilde{S}^{\dagger} \tilde{S} = 1$$

$B(x) \to -B(-x)$ ↓

$S \to S'$ ↗

$S^{+} \to S^{+}$

$S^{-} \to -S^{-}$

$\tilde{S} \to \tilde{S}$

causality

$$\tilde{U}(t) = U^{+}(t) + U^{-}(t)\Lambda$$

$$\Lambda = \frac{1}{U - S^{+}} S^{-}$$

$$U^{\pm} = \frac{1}{2}(u \pm u')$$

$$i\frac{d\tilde{u}}{dt} = H^{+}\tilde{u} + H^{-} v$$

$$i\frac{dv}{dt} -$$

$$\begin{pmatrix} \tilde{S} \\ U\Lambda \\ = -\Lambda \end{pmatrix} \leftarrow \begin{pmatrix} 1 \\ \Lambda \end{pmatrix}$$

macro-causality

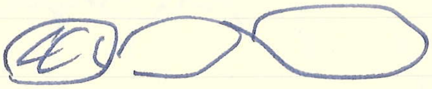
$$H = H_{\alpha} + H_{\beta}$$

$$[H_{\alpha}, H_{\beta}] = 0$$

$$S_{\alpha+\beta} = S_{\alpha} S_{\beta}$$

$$\tilde{S}_{\alpha+\beta} \neq \tilde{S}_{\alpha} \tilde{S}_{\beta}$$

$$\tilde{S}_{\alpha\beta} = \tilde{S}_{\alpha} S_{\beta}$$



大槻昭一郎

Urbaryon 描像図にもとづく
研究の方法について
1972年2月1日.
基研・コロキウム

URD
Rearrangement　1956　Hayakawa
Urbaryon　1967　Iwachi
-Sawada

Quark counting

$$\sigma_T(MB)/\sigma_T(BB) = \frac{2\times3}{3\times3} \qquad \textcircled{n_T}$$

Morrison rule

$\sigma \propto s^{-}$▨

quantum number
と表れる・含る

γ n_A

Diagram
1963~1964　色々な形の模型
をめぐって

subquantum level

$$\text{Meson}\quad 0^- \quad \overbrace{1^- \quad 2^+}^{\text{の EXD}}$$

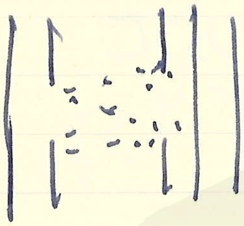
$$\underbrace{0^- \quad 1^-}_{\text{の } SU(6)}$$

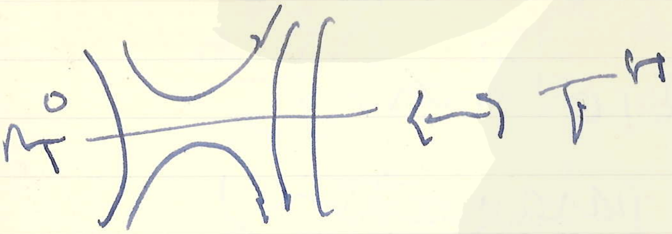
$$V({}^1S_0) \cong V({}^3S_0) \quad (SU(4))$$

○ chiral

上限 : 2体 → 3体 production
0^- は resonance と dual に
ならない。

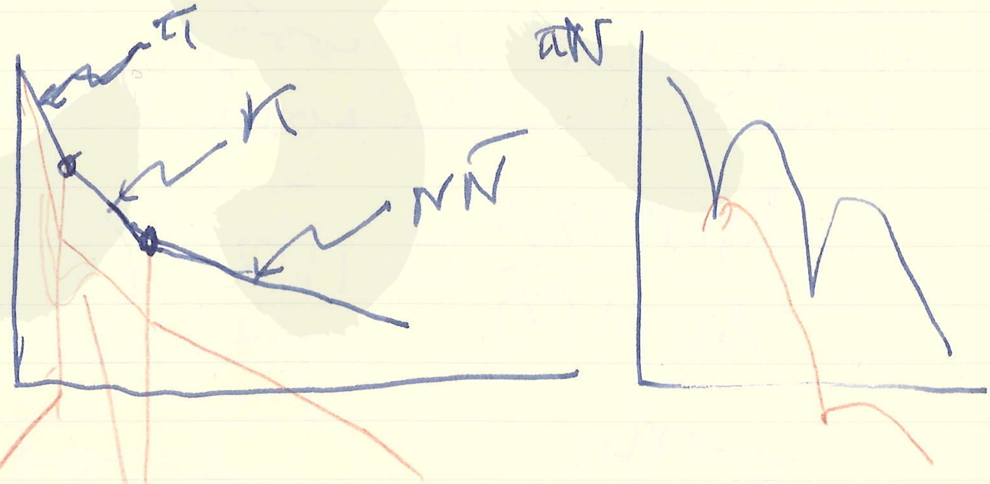
歴史的
OBE → Regge → duality





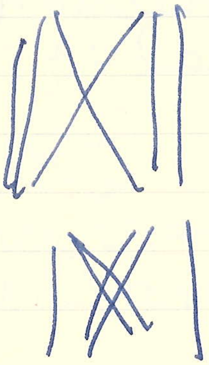
n_t

pp $\frac{d\sigma}{dt}$
三段配



$P_L \sim 1$ GeV shoulder-like
structure

Chou-Yang
van Hove: $B\bar{B}$ channel



$$F^{H}_{\sigma\lambda} = A_{\sigma\lambda} f_{\sigma\lambda}(s,t) e^{B_{\sigma\lambda}(s)t}$$

$J \sim \sqrt{s}$

resonance

$b_0 = 1 \times 10^{-13}$ cm

(impact parameter)

nonsense school
radius school

$$\frac{b_0(B\bar{B})}{b_0(M\bar{B})} \simeq 1.2 \quad \left(= \frac{3+3}{2+3}\right)$$

$s^{-\alpha_R}$

内山龍雄氏

一般相対論における運動方程式
(一元論的取扱)
(談話会、1972年2月17日)

Einstein, Hoffmann, Infeld

$$G^{\mu\nu} = -8\pi G/c^4 \, T^{\mu\nu}$$

$$\| \quad R^{\mu\nu} - \frac{1}{2} g^{\mu\nu} R$$

compatibility

$$\frac{d^2\xi^\mu}{d\tau^2} + \Gamma^\mu_{\alpha\beta}\frac{d\xi^\alpha}{d\tau}\frac{d\xi^\beta}{d\tau} = 0$$

$$\Gamma(x)_{x=\xi} \overset{d}{\equiv} \tilde{\Gamma}$$

Bianchi identity

$$\underline{g^{\mu\nu}{}_{;\nu} = 0}$$

N個の粒子。

integrability condition

non-linearity

self-force

test particle m_A : $g_{\mu\nu}$: regular at $x = \xi_A$

$m_{A(\text{inert})} = m_{A(\text{grav})}$

passive

一般には

$\overset{A}{\hat{g}}$ = finite value を assign する

$m_{A(\text{inert})} \neq m_{A(\text{grav})}$

equivalence Principle は成り立たない.

必然的に point particle でない (Einstein-Infeld)

Dirac $\delta(x)$ → good δ-function $\hat{\delta}$

Successive Approximation

Action integral

相対論的量子力学

長谷英二

3月29日(水), 1972

学士会.

一般的枠組.

1939 Wigner Poincaré group の unitary representation

→ 相対論的場の方程式

P_ρ, $M_{\mu\nu}$ (P_4, M_{4l} : anti-hermitian)

$$U(\varepsilon_\rho, \varepsilon_{\mu\nu}) = 1 + i\varepsilon_\rho P_\rho - \frac{i}{2}\varepsilon_{\mu\nu} M_{\mu\nu} + O(\varepsilon^2)$$

$$[P_\mu, P_\nu] = 0$$

$$[M_{\mu\nu}, P_\rho] = i\delta_{\mu\rho}P_\nu - i\delta_{\nu\rho}P_\mu$$

$$[M_{\mu\nu}, M_{\rho\sigma}] = i\delta_{\mu\rho}M_{\nu\sigma} - i\delta_{\nu\sigma}M_{\nu\rho} + i\delta_{\nu\sigma}M_{\mu\rho} - i\delta_{\nu\rho}M_{\mu\sigma}$$

1. creation, annihilation operators (p-表示)
2.

~~Model~~ I.

$$P_\mu^{(0)} = \int \frac{dq}{q_0} q_\mu A^\dagger(q) A(q)$$

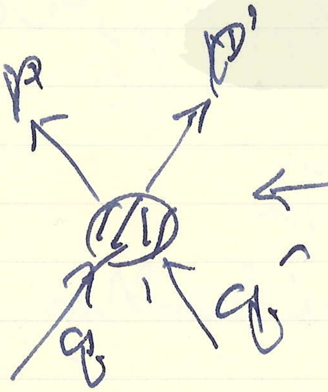
$$M_{lm}^{(0)} = \frac{i}{2}\int \frac{dq}{q_0}\left\{ q_l \frac{\partial A^\dagger(q)}{\partial q_m} A(q) \right.$$

$$- \quad - \quad + \quad \}$$

$$- \quad - \quad -$$

$$[A(q), A^\dagger(q')] = q_0\,\delta(q-q')$$

$$q_0 = \sqrt{\mu^2 + q^2}$$



$$\longleftrightarrow \quad P_4^{(1)} = \frac{\lambda}{4}\iint \frac{dp \cdots dq'}{p_0 \cdots q_0'}$$

$$\times\, \delta(p+p'-q-q')\, F^{(1)}(p,p'|q,q')$$

$$\times\, A^\dagger(p) \cdots A(q')$$

$$P_4 = P_4^{(0)} + \sum_{n=1}^{\infty} P_4^{(n)}$$

$$M_{4l} = M_{4l}^{(0)} + \sum_{n=1}^{\infty} M_{4l}^{(n)}$$

$$F^{(1)}(p,p'|q,q') = F^{(1)}(p',p|q,q') = \cdots\cdots = F^{(1)}(q,q'|p,p')$$

→ (P. T. P. <u>35</u> ('66), 934)

$$\overset{(2)}{P}_4 = \cdots\cdots < 0$$

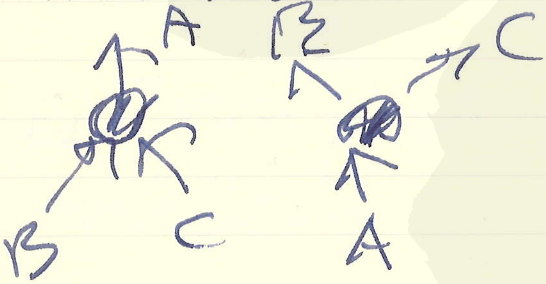
$$\overset{(1)}{F} = f(p_0 + p_0' - q_0 - q_0')$$

self-energy は正でない、

(P. T. P. <u>39</u> ('68), 1533)

model II.

Lee model の modification



m_A, m_B, m_C

self-energy

$$P_4 = \overset{(0)}{P}_4 + \overset{(1)}{P}_4 + \overset{(2)}{P}_4$$

$$\overset{(2)}{P}_4 = i\int \frac{dp_0}{80}\overset{(2)}{X}(p)\,A^\dagger(p_0)A(p_0)$$

$$\overset{(2)}{X}(p) = -\frac{1}{2^3 p_0}\iint \frac{dq\,dk}{q_0 k_0}\frac{\delta(p-q-k)}{p_0-q_0-k_0}$$

$$\times\overset{(1)}{F}(p_0|q,k)\overset{(1)}{F}(q,k|p_0) + \frac{a}{p_0}$$

Huang [illegible]
D2('70), 1364
model I.

Urciton scheme

石田晋
April 27, 1972
討論会

I. a) Quark模型の問題点
relativistic bound state
i) static $p\to 0$ で strong bound
ii) spin 1/2. Bose 統計か:
baryon SU(3) <u>56</u> 次元
symmetric state
weak interaction
non-leptonic decay
<u>8</u>

b. exciton picture
Ur-citon　　phenomenological

II. a) アイディア　素子を考えて　　Fock space

$$\begin{tikzcd} x \arrow[d] & \psi(x) \arrow[d] & \Phi_n(x_1, x_2 \cdots x_n) \arrow[d] \\ \xi_\mu & \psi_A(p, \xi) \arrow[d] & \Phi_{A_1 A_2 \cdots}(p\, \xi_1 \xi_2 \cdots \xi_n) \\ & \text{Dirac spinor} & \end{tikzcd}$$

内の状態
$n=1, 2, \cdots$

$$i p_\mu \gamma_\mu \psi^{(\pm)}(p, \xi) \pm \sqrt{-p^2}\, \psi^{\pm}(p, \xi) = 0$$

p : time-like

$$[\psi_A^{(\pm)}(p, \xi), \bar{\psi}^{(\pm), A'}(p', \xi')] = \Lambda^{(\pm)\alpha'}_{\alpha}(p)\, \delta_{pp'}\, \delta^{a'}_{a}\, \delta(\xi - \xi')$$

$|0\rangle$ ~~[illegible]~~ :

$$\psi^{(+)}(p,\xi)|0\rangle = \overline{\psi}^{(-)}(p,\xi)|0\rangle = 0$$

$$|\Psi(p)\rangle = \cdots + \int \overline{\psi}^{+A}(p,\xi) \cdots$$

$$+ \int \psi \quad \psi$$

$$+ \int \psi \quad \psi \quad \psi \cdots$$

Eq. of motion:

$$(p^2 + S_0 + \tilde{S})|\Psi(p)\rangle = 0$$

$$\tilde{S} = \tilde{S}^{(+)} + \tilde{S}^{(-)}$$

$$\tilde{S}^{(\pm)} = \pm \int d^3\xi \, \overline{\psi}^{(\pm)}(p,\xi)\, m^2(\xi)\, \psi(p,\xi)$$

generalized Bargmann-Wigner

	quark 模型	$\tilde{U}(12)$	urciton
SU(6)	○	○	○
O(3)	○	×	○
relat.	×	○	○
統計	×	D	○
triality exotic	×	×	×

第3量子化　　Φ_A などの量子化

d) 相互作用

{ creation op. [illegible]
additivity

connection: Γ

$$\Gamma = \exp\left\{\sum_{p_1, p_2} \int \Phi^A(p_1, \xi) \, \Psi_A(p_2, \xi) \, d\xi \right]$$

自然哲学者の世界のIsaac Newton

河辺六男氏

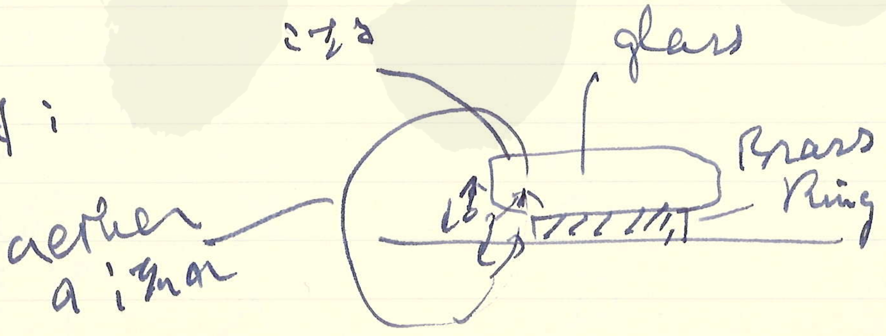
1972年5月12日

30歳ごろの物質観
エーテルに依存する考え.
17世紀のエーテル：微細粒子物質の
集合体.

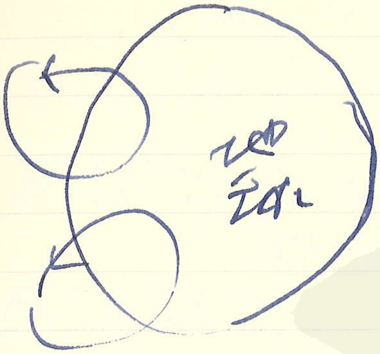
1675 (33歳) 7th Dec.
Newton to Oldenburg
〃 〃 〃

1678 to Boyle
Principia (1686) general scholium
Opticks Query 16〜24.
酸の性質について(1692)

電気：



重力：



Descartes の aether
Vortex theory
近接論、機械論的　（世界論
（哲学原理
[illegible]
Principia

Trichotomy

太陽　第一元素（火）
恒星　速い　（微小）

subtile（浸透性 流体、）― 空の元素、重さを持たぬ

天 ← 第二元素（気）
中位（中位）

流体）　粘性

惑星、地球、彗星）第三元素（地）
遅い　（粗大）

渦動説
① 中心の大きさ
② 同じ運動
③ 空の物と同じ渦

重力　早くから分っている

Democritus の
atomistic の考え
不可分の粒子の存在の考え
無限分割の可能性
~~[illegible]~~ 考えは否定しない（連続的な考え
方はしない）

談話会

山崎和夫

Heisenberg の理論と其之の発展

1972年6月5日

Magnon —— antiferromagnetism

Heisenberg and Yamazaki:

Nuovo Cimento to be published

$$H = H_\alpha + H'_\beta + H_\mu + H_\gamma + H_\varepsilon$$

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

$$H_\beta = \beta \sum_n (\vec{\sigma}_n \vec{\tau}_n + 1)$$

$$\rightarrow H'_\beta = \beta \left\{ (N + \frac{1}{N} (\sum_n \vec{\sigma}_n)(\sum_m \vec{\tau}_n) \right\}$$

n $\uparrow \vec{\sigma}_n$ $a^*_{n\lambda} \rightarrow$ 作る

$\downarrow \vec{\tau}_n$ $b^*_{n\lambda} \rightarrow$ 消滅する

$\downarrow$

spurion

$$H_\mu = \mu \sum (a^*_{n\lambda} a_{n\lambda} + b^*_{n\lambda} b_{n\lambda})$$

$$H_\gamma = -\gamma \sum (a^*_{n\lambda} a_{n+\delta,\lambda} + b^*_{n,\lambda} b_{n+\delta,\lambda})$$

$$H_\varepsilon = \varepsilon \sum \left\{ (a^* \vec{\sigma} a)_n \vec{\tau}_n + (b^* \vec{\tau} b)_n \vec{\sigma}_n \right\}$$

保存量

$N_\alpha, N_b, \vec{P}, M_z, \vec{M}^2$

Vacuum $N_a = N_b = 0$

one magnon state

↓

strange particle ?

Karowski, Zs Naturf.
('69) 510

(dipole ghost
non-local int.

light cone singularity
scale invariance

$\psi \sim l^{-1/2}$ $\quad \psi\hat{\Phi}\psi \sim \cancel{\Phi}\, l^{-3/2}$

$\gamma_\mu \partial_\mu \psi \sim l^{-3/2}$

談話会

林憲二 : Yang-Mills Field
と重力場

1973年 11月 8日 (木)
基研. 212号 [illegible]室,

gauge-Field : $A_\mu(x)$
Internal Symmetry : local $U(1)$

grav. Field : $b_\alpha^\mu(x)$
S-T-symmetry : local $GL(4R)$

Y.-M. Field : $B_\mu^a(x)$
Internal sym. : local $SU(2)$

spin-gauge Field

Einstein-Cartan
1922
Poincaré Gauge Theory

(Energy-Momentum Tensor
(Spin Angular-Momentum Tensor

(Curvature
Torsion

local $GL(4, \mathbb{R})$

Poincaré group

$P = T_4 \underline{\otimes} SL(2, C)$

c033-939挟込

素粒子の時空記述
研究会

Dec. 13, 14, 15, 1973

基研.

片山氏；プログラム.

午前 10.30～1.00　　午後 2.00～5.00

13日(木) 湯川 Introductory (因果律)　　谷川　豊田：確率時空
高林　田地：因果律　　長谷部：量子時空
淡本：Tachyon

14日(金)　　(山崎：string)
中西　原 deformable body　　後藤　谷川：3次元的時空 / fabric
田中 string model　　沢田：Mag. Monopole
山本：二重時空

15日(土)
豊田　湯川 gauge　　中野　生駒：模型との関連
片山 QED　　湯川：

湯川：因果律

Microcausality ―― MacroCausality

cut-off ―― 時空

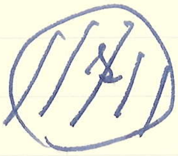
Micro C.

1) $[j(x), j(y)] = 0$　$x-y$ space-like

2) Bogoliubov:

$$\frac{\delta S}{\delta g_i(x)} = j(x). \quad \frac{\delta j(x)}{\delta g_i(y)} = 0 \begin{cases} x-y \text{ space-like} \\ \text{time-like} \\ x_0 \lesssim y_0 \end{cases}$$

cluster Property
S-Matrix



$$S(1+2) \to S(1)S(2)$$

indefinite metric
auxiliary field

$$S \to \tilde{S}(\text{physical})$$

$$\hat{S}(1+2) \underset{?}{\to} \tilde{S}(1)\hat{S}(2)$$

Bogoliubov

$$\psi(x) = \varphi(x) + \sum_{1} c_n \varphi_n(1)$$

$$\tilde{S} = PS\frac{1}{1-(1-P)S}P$$

$$\left.\begin{array}{l}\hat{S}^{\dagger}\hat{S} = 1\\ \tilde{S}(1+2) = \tilde{S}(1)\tilde{S}(2)\end{array}\right\}$$

振幅のところ
にこれと満足する
てない!!!

Uhlmann-Geyer

$$\begin{array}{ccc}H & \to & \hat{H}\\ \downarrow & & \downarrow\\ S & & \tilde{S}\end{array}$$

cluster O.K.,
divergence は no!!!

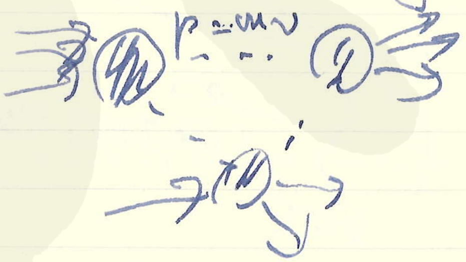
Hepp: almost local

$$S = T e^{i\int \underset{H_1+H_2}{H_{int}} d^4x}$$

Macro-Causality

weak asymp. causality

strong asymp. causality



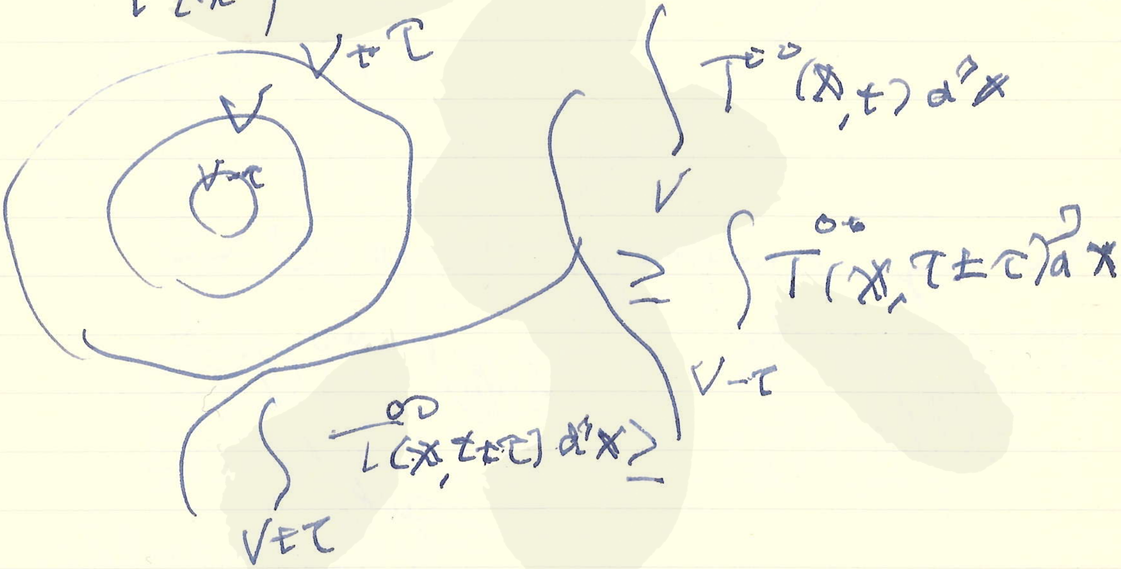
causal diagram

1) energy-momentum が有限部分にまとまって のが Macro-distance 離れる
2) そうでないなら amp → fall-off

Stapp
1) formulation が難
2) asymp → analyticity
3) positive α. Landau surface は [illegible]
= singularity はない , ,

Wave Packet Type
[illegible]
Blokhintsev

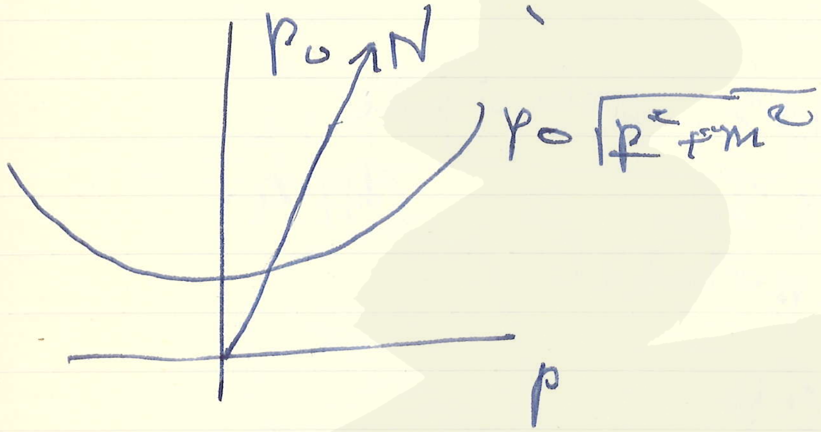
Field Theory Type
$T^{00}(x)$



$$\int T^{00}(\mathbf{x},t)\,d^3\mathbf{x}$$
$$\int_{V} \geq \int T^{00}(\mathbf{x},\tau\pm\tau)\,d^3\mathbf{x}$$
$$\int_{V\pm\tau} T^{00}(\mathbf{x},t\pm\tau)\,d^3\mathbf{x} \geq$$

[illegible]:
Strong Asymp. Causality

四次: ゆらぎと cut-off
QFT. の中での自由場
自由場の概念



$(\Box - m^2)\varphi(x) = 0$

$P_\mu = P_\mu^{(0)} + \delta_{\mu 0} H$

Lorentz invariant では..?

$P_\mu = P_\mu^{(0)} + N_\mu H$

cut と ゆらぎ構造

条件:
covariant
micro acausal

確率的物理記述

豊田利幸：Newton からの
causality を保障するから
解の一意決定性
Poincaré
collision
Huyghens' principle　　剛体、
完全[illegible]
δ-fn型 potential
連続
Brown 運動

path $(\vec{x}, t, \omega)$

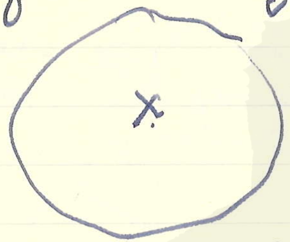
$\omega : \Omega$: Merkmalraum
標識空間

$E(\ \mid \mathfrak{F})$　期待値

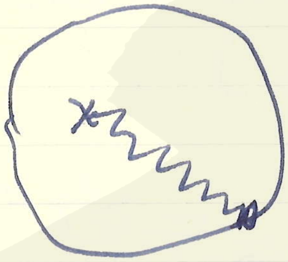
$$\lim_{h\to 0} \frac{E(^{t+h} \mid \mathfrak{F}) - E(^{t} \mid \mathfrak{F})}{h}$$

Markof である
Martingale <
Doob

analyticity



$$f(x)=\frac{f(x+iy)+f(x-y)}{2}$$



れらの差

最近読み、活動関数の数学性に
微分的試み.

$$\rho(\Lambda x) \neq \rho(x)$$ (Euclid No)

沼本: Tachyon 2:1 ⇒ tardyon

$$[\phi(x), \phi^\dagger(y)]_+ = \Sigma_1(x-y)$$

$$\ddot{\Delta}_1(x-y)$$

$$m^2 \to -m^2$$

$$[\Psi(x), \Psi^\dagger(y)]_- \propto i\Delta(x-y)$$

光のneutrino仮説 de Broglie-Jordan

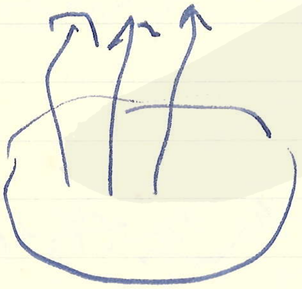
$$\phi(x) = \int d^4p\, a(p) e^{ipx} \delta(p^2-\mu^2)$$

$$[\phi(x), \phi^\dagger(y)]_+ = \Sigma_1(x-y)$$

$$\delta(p^2-\mu^2)\delta$$

流体：こんにゃく model

$$x^\alpha(\tau_0, \sigma_1\ \sigma_2\ \sigma_3)$$



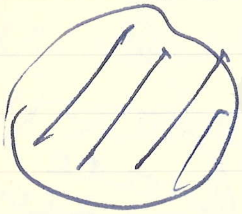
$$\frac{\partial^2 x^\alpha}{\partial \tau^2} - \sum_i \frac{\partial^2 x^\alpha}{\partial \sigma_i^2} = 0$$

Lorentz covariance

$$P = \sum_i \frac{\partial x^\alpha}{\partial \sigma_i} \frac{\partial x_\alpha}{\partial \sigma_i}$$

12月14日(金)
原治; ひもがついた粒子の相互作用

relativistic !!!

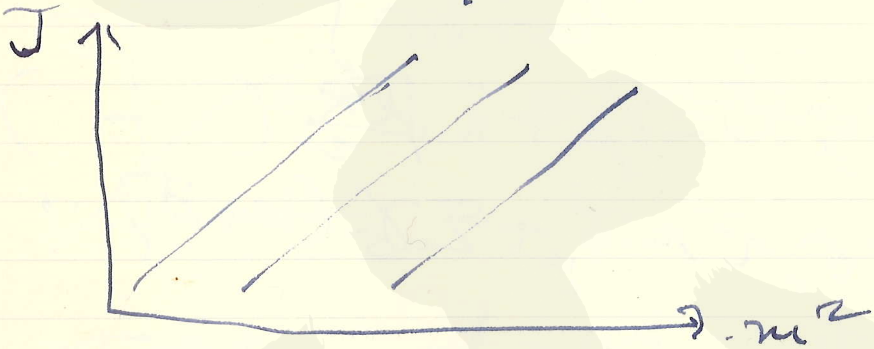


$P_\mu \to X_\mu$

$u(x) \to \xi_\alpha(\sigma)$
π^α

zero frequency mode

quark
(mass spectra
(Bose 統計)



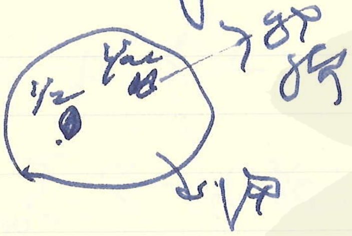
mass = quark + string
→ (Bose)

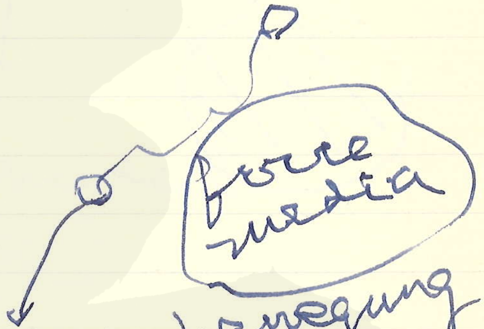
duality

田中正 : string model と spin

scaling　　　　SU$_6$

locality





Zitterbewegung

$$x_\mu(\sigma,\tau) = X_\mu + 2\sum \frac{1}{\sqrt{2l\pi}}(a_\mu^{(l)} + a_\mu^{\dagger(l)}) \cos l\sigma$$

$$p_\mu(\sigma,\tau) = P_\mu + i\sqrt{\frac{l\pi}{2}}(\ -\ )$$

$$\Gamma_\mu(\sigma,\tau) = \gamma_\mu + \sum \gamma_5 (b + b^\dagger) \cdot\cdot$$

$$\left[i\int_0^\pi \Gamma_\mu(\sigma,\tau)\, p_\mu(\sigma,\tau)\, d\sigma + m \right]\psi = 0$$

[illegible]

[illegible]

近会: duality と string model $x_\mu(\tau, \sigma)$

scaling $x_\mu \to \lambda x_\mu$

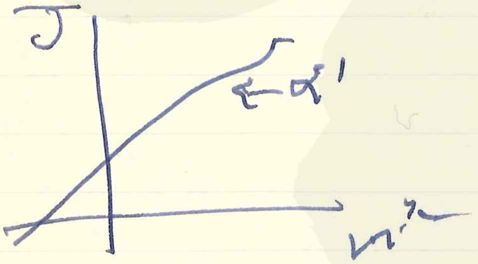
off mass shell Green fn

to scale

on mass shell amplitude

Feynman Scaling に対応

$$L = \frac{1}{2}\left\{\left(\frac{\partial x_\mu}{\partial \tau}\right)^2 - \underset{[L]^{-2}}{\kappa_0}\left(\frac{\partial x_\mu}{\partial \sigma}\right)^2\right\}$$



$\kappa_0 \sim \frac{1}{\alpha'}$

$\kappa_0 \to 0$　　$\alpha' \to \infty$

$x_\mu(0,\sigma) \to U(\lambda)\, x_\mu(0,\sigma)\, U(\lambda)^{-1}$

$U(\lambda) = \lambda^{iD}$　　$= \lambda\, x_\mu(0,\sigma)$

$[D, x_\mu(0,\sigma)] = -i\, x_\mu(0,\sigma)$

$D = \int d\sigma\, x_\mu p_\mu$

$[D, H] = 2iH - 2i\kappa_0^2 \int d\sigma \left(\frac{\partial x_\mu}{\partial \sigma}\right)^2$

$$U(\lambda) x_\mu(\tau, \sigma) U(\lambda)^{-1} = \lambda x_\mu\left(\frac{\tau}{\lambda^2}, \sigma\right)$$

$$e^{iH\tau} D e^{-iH\tau} = D(\tau)$$

$\begin{cases} \alpha' = 1 \\ \text{High energy i dominant} \end{cases}$

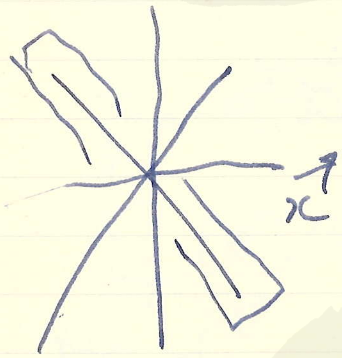
$$\Rightarrow \tau \to 0$$

$$x_\mu(\tau, \sigma) = x_\mu(0, \sigma) + \tau p_\mu(0, \sigma)$$

$$p_\mu = \frac{\partial x_\mu}{\partial \tau}$$

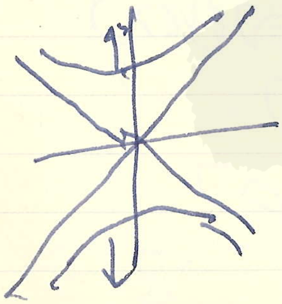
$$\sim \lambda x_\mu(\tau, \sigma)$$

$\neq 0$



$$x^2 = \tau^2$$

Fubini et al



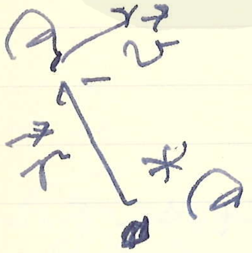
第VII : Magnetic monopole

$$\frac{|e_p|-|e_e|}{|e_e|} < 40\times10^{-21}$$

1931 : Dirac

$$\left.\begin{array}{l} E \to H \\ H \to -E \end{array}\right\}$$

$$\left.\begin{array}{l} \rho \to {}^*\rho \\ {}^*\rho \to -\rho \end{array}\right\}$$



$$m\dot{\vec v} = Q\left(\vec E + \frac{1}{c}\vec v\times\vec H\right)$$

$$= Q\,{}^*Q\,\frac{\vec v\times\vec r}{r^3}\frac{1}{c}$$

$$\frac{d}{dt}(\vec r\times m\vec v) = {}^*Q\,Q\,\frac{1}{c}\frac{d}{dt}\left(\frac{\vec r}{r}\right)$$

$$\frac{d}{dt}\left(\vec r\times m\vec v - {}^*Q\,Q\,\frac{1}{c}\,\frac{\vec r}{r}\right) = 0$$

$$\frac{Q^*Q}{\hbar c} = \frac{n}{2} \qquad n = 0, \pm1, \pm2, \cdots$$

$$\frac{e}{\sqrt{\hbar c}_{e.m.}} = \frac{1}{\sqrt{137}} \qquad \frac{g_0^2}{\hbar c} = \frac{137}{4}$$

strong ______

e.m. ______

weak ______

gr. ______

magnetically
neutral atom
Schwinger model

中野 : Mag. monopole

$$\partial_\nu F_{\mu\nu} = j_\mu$$

$$\partial_\nu \tilde{F}_{\mu\nu} = {}^*j_\mu$$

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu + \partial_\lambda B_{\lambda\mu\nu}$$

$$\tilde{F}_{\mu\nu} = \partial_\lambda A_{\lambda\mu\nu} + \partial_\mu \tilde{B}_\nu - \partial_\nu \tilde{B}_\mu$$

片山

中西 講演 : 金曜会　極論をおこなえば
Lorentz covariance) とする
Unitarity of S　破る、
Sのunitarity を保つ方法.
Causal性犠牲
physical state condition
quasi-unitary : $S^*S = 1$

12月15日(I)

横山: QEDの gauge Formalism

$$i D_{\mu\nu}(k,a) = \left(\delta_{\mu\nu} - (1-a)\frac{k_\mu k_\nu}{k^2 - i\epsilon}\right) \times \frac{1}{k^2 - i\epsilon}$$

a=1 : Feynman(-Fermi) gauge

a=0 : Landau gauge

Nakanishi-Lautrup

$$\Box A_\mu - \partial_\mu \partial_\nu A_\nu = \partial_\mu B_0 - j_\mu$$

$$\partial_\mu A_\mu = a B_0$$

$$\Box B_0 = 0$$

$a \to \hat{a}$:

$$A_\mu \to \hat{A}_\mu = A_\mu + (\hat{a} - a)\partial_\mu B$$

$$\Box B = B_0 \qquad \Box^2 B = 0$$

$\uparrow N_\mu$

$$B = \frac{1}{2\Delta}\left(x_0 \partial_0 B_0 - \frac{1}{2} B_0\right)$$

$$\Delta = \partial_{k}^2$$

$$L(A_\mu, B_0, a) \neq L(\hat{A}_\mu\ B_0\ \hat{a})$$

$$A_\mu(x,a) = Z_3^{1/2} A^r_\mu(x, a^r)$$

$$Z_3 a^r = a$$

$$\left\{\begin{array}{ll} A_\mu, & B_1 \\ B, & B_2 \end{array}\right.$$

$$L = L_0 + L_\varphi$$

$$L_0 = -\frac{1}{4} F_{\mu\nu} F_{\mu\nu} + B_1 \partial_\mu A_\mu$$

$$- \partial_\mu B \partial_\mu B_2 - \frac{1}{2}\varepsilon (B_2 + \alpha B_1)^2$$

$$[B(x), B(y)] = i\varepsilon \hat{D}(x-y)$$

次に; gauge formalism 続き

$$L = -\frac{1}{4} F_{\mu\nu} F_{\mu\nu} - \partial_\mu B \partial_\mu C_2$$

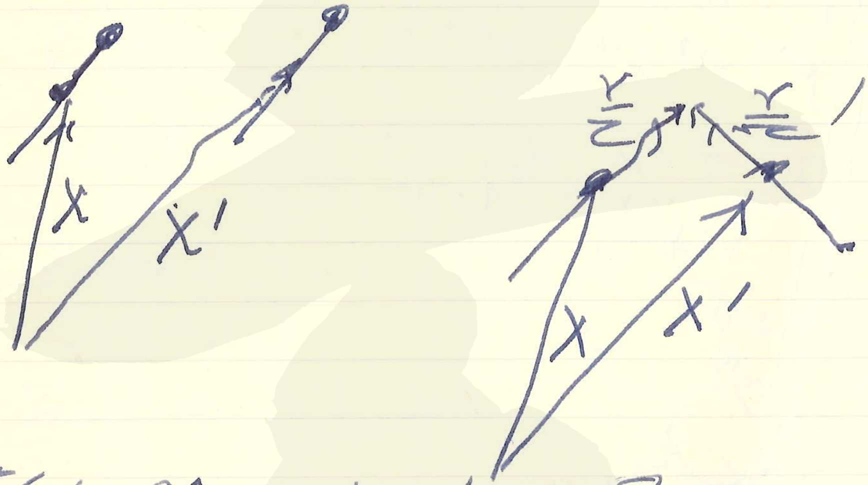
$$+ C_1 (\partial_\mu A_\mu) - \frac{1}{2}\alpha_1 C_1^2$$

$$- \frac{1}{2}\alpha_2 C_2^2 - \alpha_3 C_1 C_2 + L_\varphi$$

$$\left\{\begin{array}{ll} A_\mu & C_1 \\ B & C_2 \end{array}\right.$$

Ad. : non-local QED

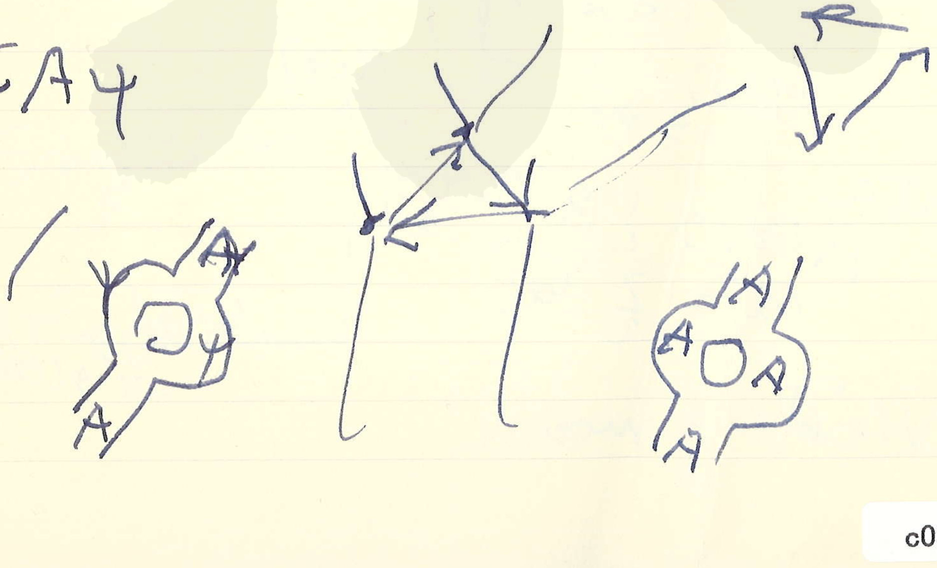
$$[\psi(x,r)\bar{\psi}(x',r')]$$
$$= S(x-x', r, r')$$
$$= S(x-x')\,\delta^4(r-r')$$



$\delta^4(x+\frac{r}{2}, x'-\frac{r'}{2})$?

$+\delta^4(x-\frac{r}{2}, x'+\frac{r'}{2})$

$\bar{\psi}A\psi$



~~[illegible]~~

物理：構成子の[illegible]・[illegible]

constituent

column ↑

$$\begin{array}{c|cccc} & p^{(3)} & n^{(3)} & \lambda^{(3)} & \zeta^{(3)} \\ SU''(4) & p^{(2)} & n^{(2)} & \lambda^{(2)} & \zeta^{(2)} \\ & p^{(1)} & n^{(1)} & \lambda^{(1)} & \zeta^{(1)} \\ \hline \end{array}$$

$\xrightarrow[SU(4)]{\nu,\ e\quad \mu}$ row

(i) $\pi^0 \to 2\gamma$

(ii) SU(6) "56" → B_8

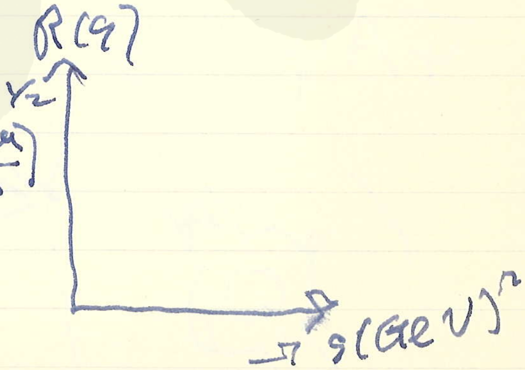
(iii) $$R = \frac{(e^+e^- \to \text{hadron})}{(e^+e^- \to \mu^+\mu^-)}$$

$$R(s) \xrightarrow[s\to\infty]{} R_0$$

Muta

$$R(s) \le \sum R_0 \left(1-\frac{4m^2}{s}\right)^{1/2}$$

$$Q^2 = \sum_i Q_i^2$$



(iv) Weinberg model

Pati-Salam
[illegible]
$SU'(4) \times SU''(4)$

Row: $SU(2) \to SU(3) \to SU(4) \to \cdot\cdot$

Column:
γ_3: trio symmetry
$O(5)$: Tati
$SU''(3)$: H. N,

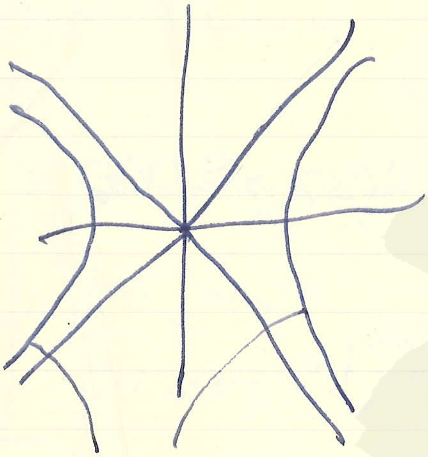
bilocal
$SU(2,C)$
Fick → gluon

Tamm

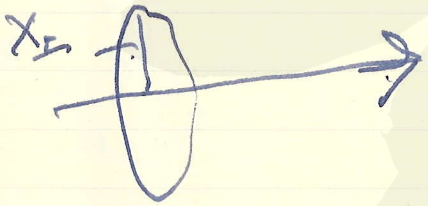
Snyder

Gol'fand

結論;



$$\Delta(x) = \frac{1}{x^2 + R^2 + i0}$$



$$[j(x), j(0)] = 0 \qquad x^2 < -R^2$$

$f(v)e^{ivR}$; analytic