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(1)

Fundamental Problems of Nonlocal Field Theory

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(1.) "The concept of nonlocal field" was introduced in 1940 by M. Markov in order to find the way out of the divergence difficulty in local field theory.† Local field theory is essentially a relativistic extention of quantum mechanics of many point-particle system. The image of a point particle in classical dynamics is ~~represented~~ replaced in quantum field theory by the field operators ψ, ϕ, ... which* are ~~to~~ defined at any point x_μ of the space-time world*. What is ~~the~~ most fundamental ~~assumption of~~ in the nonlocal field theory ~~in the narrow sense~~ is the abandonment of or renunciation (renouncement) of the ~~possibility of a~~ point character of the elementary particle. Thus, the field operator can no longer be determined simultaneously with the determination of a space-time point. In a broad sense, we can say that a nonlocal field theory is dealing with objects which have their own internal structure. A nonlocal field theory in the narrow sense assumes the existence of field operators which are not commutative with the operators x_μ which represents the totality of space-time points:

$$[x_\mu, \psi] \neq 0$$

* and which satisfy commutation relations ~~corresponding~~ leading to the particle density or charge density with point singularities.

(2.) "The problem of divergence"

The divergence of self-energy of a particle ~~is~~ due to its own field has been a serious difficulty since the time of classical electron theory by Lorentz.

† M. Markov,

Since 1946, ~~to~~ nonlocal field theory ~~is~~ has been developed with the new aim of describing various kind of particles in a unified way.

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(of the self-energy of a classical point particle, either neutral or charge)

Very recently, the possibility of avoiding infinity by considering gravitational field was considered by Arnowitt and others[†]. (App. I)
However, there ~~are~~ divergences due to quantum nature of field as well as of particles in question. In particular, in the case of an electron, the effects of vacuum polarization changes the nature of the problem itself. Thus, linear divergence is to be replaced by a logarithmic divergence. ~~Landau~~[*]
However, according to Landau[*]

$$e_r^2 \simeq [(\frac{\nu}{12\pi^2}) \log\{(\hbar/mc)/a\}]^{-1}$$

and, if we put (for very small a) $a \sim e\gamma^{1/2}$, one obtains ($\nu \sim 10$)

$$e_r^2 \sim 10^{-2}$$

independent of the bare charge e.

In quantum field theory, mixed field theory in which includes only realistic field failed to eliminate divergence, while formalistic theory by Pauli and Villars was unsatisfactory in that the auxiliary fields ~~could not have~~ we could not give to a physical meaning in the framework of orthodox theory. Later the general construction of orthodox field theory was clarified by Lehmann ~~Lande and we were~~ convincing us that the above conclusions ~~were~~ are inevitable.

Non-local field theory was shown to be reducible to the totality of (local) particles with nonlocal interactions. Thus, if we ~~take~~ started from ~~the~~ ~~idea~~ a

† R. Arnowitt, S. Deser and C. W. Misner, P.R. Oct. 1, 1960, Vol 120 (#313).

* Landau,

a (local field) particle interacting nonlocally with another field, we could have a finite self-energy, at least, in the lower order calculations by taking a suitable form factor f in

$$f(x', x'', x''')\,\bar{\psi}(x')\,\varphi(x'')\,\psi(x''')$$

as shown by Møller and Christensen * without ~~violating~~ contradicting special theory of relativity. However, there come out two ~~two~~ new sorts of difficulties;

(i) Problem of causality　　　macrocausality ?

(ii) Problem of infinite degeneracy

There ~~the~~ are two ways out of these difficulties:

(a) Indefinite metric in Hilbert space

(b) change in ~~the~~ space-time structure

In other words, the change in the properties of objects in a conventional framework is not sufficient, but such a change seems to lead us also to the change in the ~~entire~~ framework itself. (either of Hilbert space or space-time world) Now, the ~~change~~ change in space-time structure might be ~~space~~ so drastic that it could no longer be a continuum.

(3.) "~~Problem of~~ Unification or systematization of Known Particles and Prediction of Unknown Particles" was the second aim of the nonlocal theory. Around 1949, I thought nonlocal field is wide enough to cover the whole body of new particles. But, since then more and more particles came to our notice and we ~~at~~ know now that

* Christensen and Møller

the nonlocal field operator

$$\varphi(x', x'') \equiv f(X, \xi)$$

$$X = \frac{x'+x''}{2}, \quad \xi = x'-x''$$

does not have ~~enough~~ enough degrees of freedom at its disposal. We can regard it a relativistic diatomic molecule.

Thus, relativistic rigid rotator has been considered by Nakano, Vigier and others.† However, even a rigid rotator did not seem sufficient particularly because of its inability of account for the actual relation between spin and isospin. So relativistic deformable body or medium was investigated by Fukutome.*

On the other hand, there ~~were~~ appeared ~~two~~ other models and theories. Among them are

(i) composite model, ~~by Sakata~~ in particular ~~and~~ Nagoya model, Taketani-Katayama model

(ii) Urmaterie by Heisenberg

Both theories have the following point in common:

Nature consists of ~~out of~~ only one ~~ty~~ kind of fermion of spin ½ (with perhaps no mass) with an interaction which cannot be described in the framework of orthodox theory. Namely,

(i) nonorthodox S-matter etc!

(ii) nonorthodox metric in Hilbert space.

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† Nakano.

* Fukutome

④ Relation between ~~nonlinea~~ indefinite metric and nonlocality

⑤ ~~For~~ Role of gravitational ~~field~~ (electromagnetism) and neutrino ~~s~~ field (high energy neutrinos) both would be important for the structure of small scale world as well as of largest scale world.

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App. I.

(A1)

I. The Problem of divergence

a. Divergence of self-energy of a point particle in classical theory.

self-energy of a ~~point part~~ charge particle (Lorentz electron theory) due to electromagnetic field

→ mixed field theory, formalistic ~~and~~ vs. realistic → negative energy indefinite metric etc.

gravitational field → negative contribution, self-consistency †

neutral: $mc^2 = m_0c^2 - \frac{1}{2}\gamma m^2/\varepsilon$

$$m = \gamma^{-1}c^2[-\varepsilon + (\varepsilon^2 + \frac{2\gamma m_0\varepsilon}{c^2})^{1/2}]$$

$\varepsilon \to 0$ $\quad m \to 0$

charged: $mc^2 = m_0c^2 - \frac{1}{2}\gamma m^2/\varepsilon + \frac{1}{2}e^2/\varepsilon$

$$m = \gamma^{-1}c^2[-\varepsilon + \{\varepsilon^2 + \frac{2\gamma m_0\varepsilon}{c^2} + \frac{e^2\gamma}{c^4}\}^{1/2}]$$

$\varepsilon \to 0$ $\quad m \to e\,\gamma^{-1/2}$

effective cut-off: $a = \frac{1}{2}e\gamma^{1/2}c^{-2}$

$\gamma \sim 6.67 \times 10^{-8}\ gm^{-1}\,cm^3\,sec^{-2}$

$e \sim 4.8 \times 10^{-10}\ gm^{1/2}\,cm^{3/2}\,sec^{-1}$

$m \sim 10^{-9}\ gm \sim 10^{18}\ m_e$

$a \sim 10^{-33}\ cm$ ($10^{-32} \sim$)

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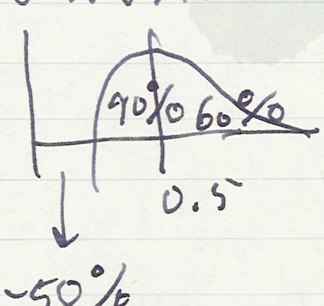
Nov. 16 a.m. Yukawa, Idea of Nonlocal Field
p.m. Okabayasi, Nakano, Freedom of Nonlocal field
17 a.m. Fukutome, Katayama Nonlocal Interaction
p.m. Munakata Indefinite Metric
18 a.m. Sawada Mass Formula of El. Part.
p.m. Comments
19 a.m. Oneda Problems in weak int.
p.m. Discussions for "Supple"

Remarks by Markow? J. Theor. exp. Phys. (1946~7)
λ limiting process
$\lambda \ll 10^{-58}$ cm

weak int.
$r \sim \sqrt{\frac{G}{\hbar c}} \sim 0.6 \cdot 10^{-16}$ cm

Rigidity or Deformability
liquid drop model
S-matrix
subquantum: more strange
Wigner and Newton, R.M.P. 1949

Remark by Katayama on nucleon ~~structure~~
charge distribution



Remark by Fukutome on S-matrix theory