CORNELL UNIVERSITY
LABORATORY OF NUCLEAR STUDIES
ITHACA, NEW YORK

March 12, 1958

Dear Dr. Gürsey:

I am very sorry that you couldn't come to Cornell while you were still in the East. There were several points I wished to discuss with you.

As I understand the main point of your paper, although the ordinary Dirac Eq.

$$D\bar{\Psi}^{+} = im\Psi\sigma_3 \qquad (1)$$

is not invariant under R (hence not invariant under Pauli (II)) when the mass is finite, we can write down two coupled equations

$$D\bar{Z}^{+} = imX \qquad (2a)$$

$$D\bar{X}^{+} = -imZ \qquad (2b)$$

invariant under R. (2a) and (2b) are completely equivalent to a set of two Dirac Eq. of the type (1) for the proton and the neutron if we identify

$$X = \begin{pmatrix} \psi_1^{p} & \psi_1^{n} \\ \psi_2^{p} & \psi_2^{n} \end{pmatrix} \qquad \bar{X}^{+} = \begin{pmatrix} \psi_2^{n*} & -\psi_2^{p*} \\ -\psi_1^{n*} & \psi_1^{p*} \end{pmatrix}$$

$$Z = \begin{pmatrix} \psi_4^{n*} & -\psi_4^{p*} \\ -\psi_3^{n*} & \psi_3^{p*} \end{pmatrix} \qquad \bar{Z}^{+} = \begin{pmatrix} \psi_3^{p} & \psi_3^{n} \\ \psi_4^{p} & \psi_4^{n} \end{pmatrix}$$

and R is now identified with the familiar rotation operator in isotopic spin space.

Evidently (2a) and (2b) transform into each other under

$$Z \rightarrow X, \qquad X \rightarrow -Z \qquad (3)$$

I should like to point out that the transformation (3) corresponds to G conjugation (the product of charge symmetry operation and charge conjugation) considered by several authors in connection with the nucleon - anti - nucleon annihilation. This assertion can be readily proved since under charge symmetry $R_T = \exp(i\pi \sigma_2/2)$ we have

$$X \longrightarrow \begin{pmatrix} \psi_1^n & -\psi_1^p \\ \psi_2^n & -\psi_2^p \end{pmatrix}$$

$$Z \longrightarrow \begin{pmatrix} -\psi_4^{p*} & -\psi_4^{n*} \\ \psi_3^{p*} & \psi_3^{n*} \end{pmatrix}$$

and under charge conjugation

$$\begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \end{pmatrix} \longrightarrow \begin{pmatrix} \psi_4^* \\ -\psi_3^* \\ -\psi_2^* \\ \psi_1^* \end{pmatrix}$$

in the representation in which γ_5 is diagonal.

We may now introduce the charge triplet π field, which is an eigenstate of G. Under G

$$\underset{\sim}{\pi} \longrightarrow -\underset{\sim}{\pi}$$

We may note that the G conjugation number of the pion field is (charge triplet) -1 regardless of the intrinsic parity of the pion. ($^1S_0^3$ and $^3P_0^3$ states of the nucleon - anti - nucleon system have the same G number -1) The equations for the nucleon interacting with the pion field via γ_5 have been written as

$$D\bar{Z}^+ = iX(m + ig\,\underset{\sim}{\sigma}\cdot\underset{\sim}{\pi}) \qquad g \text{ real}$$

$$D\bar{X}^+ = -iZ(m - ig\,\underset{\sim}{\sigma}\cdot\underset{\sim}{\pi})$$

which are again G conjugate to each other as they should be.
Similarly for $S(S)$ coupling

The scalar [illegible] is $D\bar{Z}^{+} = iX(m + f\vec{\sigma}\cdot\vec{\pi})$, $D\bar{X}^{+} = -iZ(m + f\vec{\sigma}\cdot\vec{\pi})$

$$D\bar{Z}^{+} = iX(m + f\,\underline{\sigma}\cdot\underline{\pi}) \qquad f \text{ real} \qquad (4)$$
$$D\bar{X}^{+} = -iZ(m - f\,\underline{\sigma}\cdot\underline{\pi})$$

?

Now it follows from the TCP theorem that G invariance and R invariance taken together with invariance under time reversal are sufficient to guarantee the parity conservation of the pion-nucleon interaction. This fact is particularly transparent in your formalism since if we allow f to be complex in (4) and thereby admit the possibility of mixing scalar and pseudoscalar pions, we are led to

$$H_{int} = |f|\cos\lambda\, \bar{\Psi}\,\underline{\tau}\,\Psi\,\underline{\phi} + i|f|\sin\lambda\, \bar{\Psi}\gamma_5\,\underline{\tau}\,\Psi\,\underline{\phi}$$

which is not invariant under time reversal unless $\lambda = 0, \pm\frac{\pi}{2}, \pi$.

As is well known, G conjugation, (which in your representation corresponds to the simple ~~exchange~~ interchange of X and Z) can be regarded as an inversion of all three axes in isotopic spin space. It is interesting to observe that an inversion in the ordinary space leads also to a mixing of X and Z

$$X \to -i\bar{Z}^{+}$$
$$Z \to i\bar{X}^{+}$$

whereas neither a rotation in the ordinary space nor a rotation in isotopic spin space leads to such mixings. These considerations indicate a very close analogy between the ordinary space and isotopic spin space.

Although all this may sound rather trivial, it may be worth writing a short note for Nuovo cimento. But I won't submit a manuscript on this subject until I hear your opinion and criticism.

I am also concerned with the question whether we might be able to extend your scheme to strange particles. For K we may try

$$\chi_K = K^+(1+\sigma_3) + K^0(\sigma_1 + i\sigma_2)$$

This is amusing since it bears some resemblance to the chirality representation of the K particle introduced by Watanabe. But for Λ and Σ I have not yet found 2×2 wave matrices which respectively transform like isoscalar and isovector. So once we break down Gell-Mann's global symmetry, I have no good ways of extending your wave matrix formalism. I would be very glad to hear about any idea you may have along this line.

Hoping to hear from you soon,

Sincerely

J. J. Sakurai

UNIVERSITY OF CALIFORNIA

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July 15, 1958

Dear Dr. Gürsey:

I have just read Bershay's paper on the Λ-Σ parity; I see that you're working along this line.

I should like to withdraw what I said about this relative parity; it is much more natural to have it even in my new scheme especially if baryon-meson interactions involve derivatives (i.e. either s-v or ps-pv). There are seven points I am making in my forthcoming paper on <u>Symmetry Laws and Strong Interactions</u>.

(1) For non-derivative pion-nucleon interactions CP invariance and charge independence are sufficient to guarantee the separate conservation of P and C as previously pointed out by Feinberg, Gupta, Gell-Mann and many others.

(2) For derivative-type pion-nucleon interactions charge independence and G invariance require not only that parity (and CP) be conserved but also that the charge-triplet pion be pseudoscalar.

(Note

$$\bar{p}\gamma_\mu n \xrightarrow{G} \bar{p}\gamma_\mu n \quad \text{but} \quad \pi^+ \xrightarrow{G} -\pi^+ \;)$$

regardless of π parity

(3) For the K couplings conditions analogous to (1) and (2) cannot be obtained from the usual assumption of charge independence alone.

(4) If the K couplings (rather than the π couplings) exhibit higher internal symmetries, the foregoing symmetries in addition to charge independence in the usual sense imply parity conservation both for CP invariant nonderivative K interactions and for G invariant derivative K interactions; for the latter

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case we can further deduce that all baryon-meson interactions must be of ps-pv type.

(5) This theoretical argument seems to me to be strong enough to suggest that the conjecture of Gell-Mann and Schwinger is wrong. (My scheme resembles Schwinger's <u>earlier</u> scheme.)

(6) For strangeness nonconserving processes G conjugation carry charge-conserving interactions into inadmissible interactions that do not conserve electric charge; hence if we take the point of view that parity-conserving interactions are generated by G conjugation, we have some understanding of the puzzling fact that strangeness conservation and parity conservation have the same domain of validity. (I no longer have to assume CP invariance to start with to get parity-conservation.)

(7) It is conjectured that all interactions that occur in the quantum field theory are of V and/or A. (~~See~~ cf. Feynman & Brown).

More details later! I'd like to hear about your work.

The working condition here is very pleasant.

Regards,

J. J. Sakurai

$N_1 \leftrightarrow N_3$

$N_2 \leftrightarrow N_4$

$K_+ \leftrightarrow K_-$

$K_0 \leftrightarrow K_0$

$N_1 = \begin{pmatrix} p \\ n \end{pmatrix}$

$N_2 = \begin{pmatrix} \Sigma^+ \\ Y^0 \end{pmatrix}$

$N_3 = \begin{pmatrix} \Sigma^0 \\ \Sigma^- \end{pmatrix}$

$N_4 = \begin{pmatrix} \Xi^0 \\ \Xi^- \end{pmatrix}$

$N_1 \to N_2$

$N_3 \to N_4$

$K_+ \leftrightarrow K_+$

$K_0 \to K_0^+$

P. $K^- \to K^-$

invariance C and P from CP.

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Sakurai Blg. 50

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PAR AVION VIA AIR MAIL CORREO AEREO

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Nov. 28, 1959

Dear Feza:

Today I feel more confident about my theory. So I feel like writing to you again. First of all, the theory answers the following question, which has troubled me ever since the time of my first contact with field theory: Why is it that in case of electromagnetism the very structure of the coupling, and, in a certain sense, the very existence of it are determined and necessitated by the requirement that the gauge transformation, invariance under which leads to the conservation of electric charge, be local in character whereas no analogous argument is known for Yukawa-type couplings of spin zero fields? or put it in a more picturesque way. "Why is it that the Creator was so supremely imaginative when he declared "Let there be Light!", but did not use any imagination whatsoever (except for relativistic invariance) when he switched on the γ_5 coupling of the pion field to the nucleon field?" (Of course, Bethe and Schweber would argue that the γ_5 coupling is as well-founded as the electromagnetic coupling because they are both renormalizable in the Dyson sense. Shouldn't the purpose of a textbook to teach students how to think creatively rather than to teach them dogmas?) The answer my theory gives to this question: Yukawa couplings of pions & K particles are not "fundamental."

Secondly it is amusing that my theory satisfies simultaneously almost all the

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Oh, Pauli would have liked This! See p. 140 CERN Conf. report!

principles that have been proposed on simple theoretical grounds by various "deep" thinkers of elementary particle physics. The theory is, in a certain sense, founded on Heisenberg's conviction that besides the selection rules and the invariance principles the only other guiding principle should be simplicity, it exploits the idea "anticipated" by Schwinger that internal attributes such as baryonic charge and hypercharge should have "dynamical manifestations," it fulfills Wigner and Gell-Mann's dream that there ought to exist a universal coupling related to baryon conservation, it answers Pauli's question in January 1957 "Why is parity conserved in strong interactions?" and at the same time satisfies (or rather calm down) Lee and Yang who argue, with their dominating voices, that an answer to Pauli's question should not depend on the detailed structure of the interaction Lagrangian (such as restrictions to nonderivative couplings only), it is fully compatible with Pais' principle of economy of constants, and it somehow reminds me of Feynman's remark that one should generate new ideas by asking what would have happened if history were different (i.e. if the Yukawa theory had never been invented).

I suggest that every conceivable attempt be made to detect various B particles experimentally. Frascati-type experiments ($\gamma + p \to p + X^0$) become more difficult at higher energies. They should study the Q values of pions in multiple pion production. There has not been a single good experiment along this line. The experimental verification of the existence of the 3 kinds of B particles would be far more significant than that of the antiproton. If these particles are discovered, a new epoch will begin in elementary particle physics whereas the work of Segre et. al. has not altered our theoretical thinking

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at all. (They would have deserved a triple Nobel Prize if they had shown that the antiproton didn't exist!)

Whatever the final outcome may be this is one theory on which I'm willing to stake my reputation as a mad physicist and position as an underpaid baby professor.

So much for today. Pauli would have said at this moment. "Please show this letter to everybody." Since I'm not of Pauli's stature, I refrain myself from making such a remark. But I hope other members of the Institute will be ~~eventually~~ pleasantly amused when the final paper eventually appears.

As ever,

John

J. J. Sakurai

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March 31, 1960

Dear Feza:

Originally I have planned to see you next Thursday (April 7) at Princeton, since I am giving a popular talk at Penn. Wednesday, but then I've realized that I have to be right back.

There is one thing I want to tell you. I now belive (more strongly than before) that the B quanta do exist in the same sense as π and K exist except that they are so short-lived that some may prefer to call them "resonances". I have three or four different methods of determining the masses of the various B quanta, all of which give $3\mu_\pi$ — $5.5\mu_\pi$.

(A) If you believe that the electromagnetic form factor for the nucleon needs no subtraction (whatever that means physically!) so that

$$F^{(s)\,\text{or}\,(V)}(q^2) = \int \frac{\rho(\xi^2)\,d\xi^2}{\xi^2+q^2} \quad \text{subject to} \quad F^{(s)\,\text{or}\,(V)}(q^2) = \frac{e}{2}$$

and that ρ is completely dominated by the "resonance" contributions, $\langle r^2\rangle^{\frac{1}{2}} = 0.8 \times 10^{-13}$ cm implies $\mu = 4.3\,\mu_\pi$ as first pointed out by Chew.

(B) I have noted that the Wolfenstein C amplitude (coefficient of $(\underset{\sim}{\sigma}^{(1)} + \underset{\sim}{\sigma}^{(2)})\cdot\hat{\underset{\sim}{n}}$) in pp scattering at 310 Mev is almost purely imaginary for SYM Solutions 1 & 2 (which are the <u>only</u> acceptable solutions anyway), which is precisely one of the necessary conditions that "polology" be applicable. From the range of the spin-orbit force I have determined the average mass of the vector mesons giving rise to the spin-orbit force, and this turns out to be about $3\mu_\pi$

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to $4\mu_\pi$.

(C) I have new interpretations ~~of~~ for *all* high energy peaks in πN interactions including the one recently discussed by Carruthers; all except the highest are nothing more than threshold effects ("Wigner cusps") due to the B quanta. We get

$T=0$, $J=1$ odd G $\mu = 4.1\,\mu_\pi$
" " $\mu = 5.4\,\mu_\pi$

$T=1$, $J=1$ even G. $\mu = 5.2\,\mu_\pi$

(d) In the $T=1$, $J=1$ case a recent experiment by Marado (CERN) gives $\mu \approx 3 - 4\,\mu_\pi$. You'll hear more about all these.

Regards to people at the Institute

John

J. J. Sakurai