off factors=1, is unitary. Indeed, let us consider in a local theory the reaction matrix K related to S by

$$S=\left(1-\frac{1}{2}iK\right)\Big/\left(1+\frac{1}{2}iK\right).$$

If one introduces in K the cut-off factor G, then, since $|G|^2=G^+G^-$ is real and G^+ and G^- are hermitian conjugate, the non-local K remains hermitian and thus the non-local S is unitary.

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III-7-2. High Energy Interactions on the 'Molecular Model' of the Elementary Particles

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In this talk I intend to give a brief remark of my speculation on the structure of the elementary particles. I am going to show you that the high energy interactions of several to several thousands Gev would reveal the typical effects which can directly be related to the structure of particles. A basic premise of the present model is a variant scheme of the internal degrees of freedom for baryons in which strangeness and hyper charge are not used. In order to classify baryons we introduce three kinds of 'charge spins', τ, ζ, and κ, and assume that the third components of these 'spins' are simultaneously quantized.

Here electric charge, $Q_e=\tau_3+\zeta_3$, can independently be defined from κ-charge, $Q_\kappa=\kappa_3+1/2$, which is a substitute for hypercharge in our scheme. You may here recall the even-odd rule instead of strangeness rule because we classify nucleon and the Ξ-particles in one group with $\kappa_3=1/2$ while the Σ-and Λ-particles in the other group with $\kappa_3=-1/2$. Instead of the ordinary isotopic spin, we consider the four-dimensional one that is composed of τ and ζ. In this scheme we can define the new isotopic spin $\mathbf{J}=\boldsymbol{\tau}+\boldsymbol{\zeta}$ independently from the κ-spin. We have, however, to make sure that we can give a reasonable explanation of

Table I. Quantum numbers of baryons.

Baryons	τ_3	ζ_3	κ_3
p	$\frac{1}{2}$		
n	$-\frac{1}{2}$	$\frac{1}{2}$	
Ξ^0	$\frac{1}{2}$		$\frac{1}{2}$
Ξ^-	$-\frac{1}{2}$	$-\frac{1}{2}$	
Σ^+	$\frac{1}{2}$		
Y^0	$-\frac{1}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$
Z^0	$\frac{1}{2}$	$-\frac{1}{2}$	
Σ^-	$-\frac{1}{2}$		
$Y^0=\frac{1}{2}(\Lambda-\Sigma^0)$			
$Z^0=\frac{1}{2}(\Lambda+\Sigma^0)$			

Table II. The list of mesons and their quantum numbers.

Mesons	τ_3	τ	ζ_3	ζ	κ_3	κ
π^+	1		0		0	
π^0	0	1	0	0	0	0
π^-	−1		0		0	
$\pi^{0\prime}$	0	0	0	0	0	
K^+	0	0	1			
τ^0	0	0	0	1	1	1
L^-	0	0	−1			
θ^0	0	0	0	0		
D^+	0	0	1			
D^0	0	0	0	1	0	1
D^-	0	0	−1			
$D^{0\prime}$	0	0	0	1		
L^+	0	0	1			
$\tilde{\tau}^0$	0	0	0	1	−1	1
K^-	0	0	−1			
$\tilde{\theta}^0$	0	0	0	0		

the forbidden processes which so far have been accounted for by strangeness selection rule. It is interesting to note that the selection rules in our scheme are derived from the invariance properties of the interaction Hamiltonian. Among baryons we consider a number of Yukawa-processes of the strong interactions which are rotationally invariant in κ-space and also in the four-dimensional isotopic spin space. To do this we have to introduce sixteen kinds of mesons which are in a triplet state and in a singlet state with regard to κ, and are a self-dual tensor in the four-dimensional isotopic spin space. The list of mesons thus introduced is given in the Table II.

We can then infer the following conserved quantities:

$$\Delta\kappa_3=0 \quad \Delta\tau_3=0 \quad \Delta\zeta_3=0$$
$$\Delta\kappa=0 \quad \Delta\tau=0 \quad \Delta\zeta=0.$$

It was shown by Sato and the present author that $\Delta\kappa_3=0$ imposes us a more stringent condition than that derived from the strangeness rule. For instance, the following processes that are allowed by the strangeness rule are forbidden by our rule of $\Delta\kappa_3=0$:

$$\Xi^-+p\to\Lambda+\Lambda, \quad \Xi^0+n\to\Lambda+\Lambda.$$

We are, therefore, led to expect the existence of Ξ-hyperfragments which from the strangeness selection rule should decay instantaneously.

Analysis on the strong interactions tells us necessity of breaking down the higher symmetry in our scheme. It seems likely that instead of the separate conservation of $\Delta\tau_3=0$, $\Delta\tau=0$, and $\Delta\zeta_3=0$, $\Delta\zeta=0$ the united conservation of $\Delta J=0$, $\Delta J_3=0$ is enough to account for the strong interaction processes. If we require that the couplings of $\Sigma\Sigma D$ and $\Sigma\Lambda D$ are vanishing, *i. e.*, ($\Delta\kappa\neq0$), then our scheme covers the strangeness rule. A detailed discussion of these points will be found elsewhere.

Now I am going to suggest a model of the

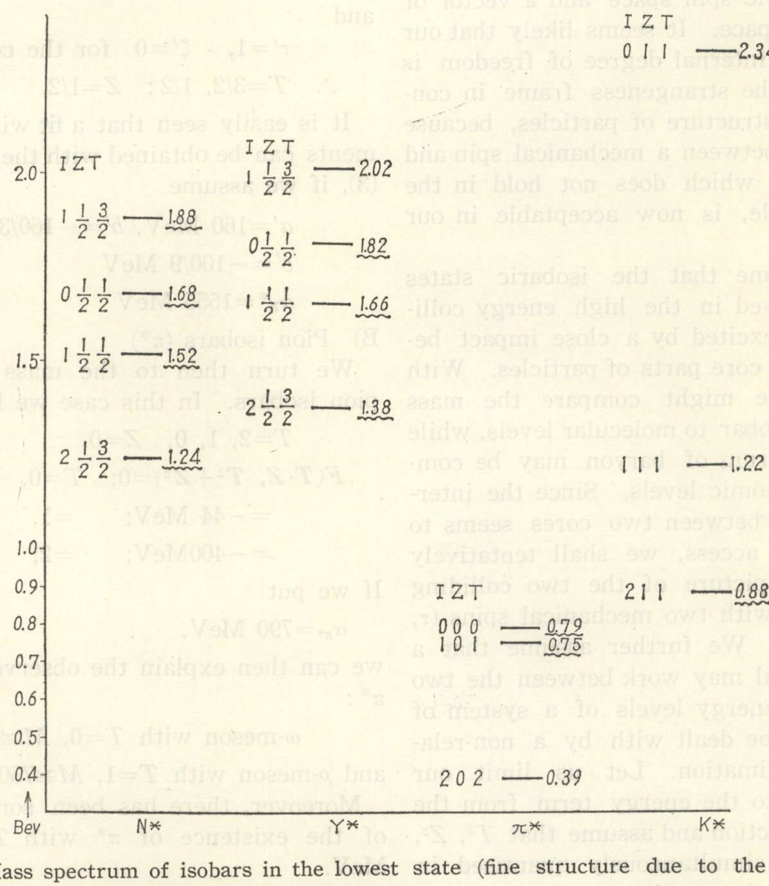

Fig. 1. Mass spectrum of isobars in the lowest state (fine structure due to the 'spin-spin' interaction). Observed levels are underlined.

structure of particles in the following manner.

1) For the structure of a baryon we assume that we can consider two parts separately; one is a 'core part' which is described by the new isotopic spins, τ and ζ and the other is a 'neutrino part' which bears a κ-spin. The core part should have a characteristic mass and a length.

2) We expect that an internal interaction between the 'neutrino part' and the 'core part' should lead us to the mass spectrum of baryon which otherwise represents one particle in a degenerate state. We may write down an experimental mass formula of baryon in the following:

$$M_B=(1/2+\kappa_3)(a\zeta_3+b)+(1/2-\kappa_3)(c\theta+d)+e. \quad (1)$$

$$\theta=1/2\sum_{i=1}^{4}\tau_i\zeta_i+1=1 \quad \text{for} \quad \Sigma$$

$$\theta=-1 \quad \text{for} \quad \Lambda$$

3) For the strong interaction of Yukawa type among baryons, we define mesons in terms of a self-dual tensor or a scalar in the new isotopic spin space and a vector or a scalar in κ-space. It seems likely that our frame for the internal degree of freedom is simpler than the strangeness frame in conjecturing the structure of particles, because a parallelism between a mechanical spin and a charge spin, which does not hold in the strangeness rule, is now acceptable in our scheme.

4) We assume that the isobaric states recently observed in the high energy collisions may be excited by a close impact between the two core parts of particles. With this model we might compare the mass spectrum of isobar to molecular levels, while the mass spectrum of baryon may be compared to the atomic levels. Since the internal interaction between two cores seems to us not easy of access, we shall tentatively try a classical picture of the two colliding particles each with two mechanical spins (τ, ζ) and (τ', ζ'). We further assume that a certain potential may work between the two cores and the energy levels of a system of two cores can be dealt with by a non-relativistic approximation. Let us limit our attention only to the energy term from the spin-spin interaction and assume that T^2, Z^2, I^2, and I_3 are simultaneously quantised in the 'inter-core' interactions:

$$T=\tau+\tau', \quad Z=\zeta+\zeta', \quad I=T+Z. \quad (2)$$

By taking an analogy to the Russel-Saunders coupling, we shall try a 'spin-spin' interaction with the invariance property in the four-dimensional (Euclidian) charge space and determine the mass spectrum of isobars.

$$E=F(T\cdot Z,\ T^2+Z^2)+\alpha_i \quad (3)$$

$$F(T\cdot Z,\ T^2+Z^2)=a'(T\cdot Z)^2 +b'(T\cdot Z)(T^2+Z^2)+c'(T^2+Z^2)^2 \quad (4)$$

where α_i is a constant which does not depend on the charge spins but which does depend on the kinds of compound cores.

A) Nucleon isobars (N^*)

We now determine the parameters in (3) by using the experimental information about the excitation energy of the nucleon isobars:

300 MeV $T=3/2$, 580 MeV $T=1/2$

740 MeV $T=1/2$, 940 MeV $T=3/2$.

By taking into account the 'spin' assignment given in the Tables I and II, we have

$\tau=1/2$, $\zeta=1/2$ for the core of nucleon,

and

$\tau'=1$, $\zeta'=0$ for the core of pion.

$$\therefore \quad T=3/2,\ 1/2;\quad Z=1/2. \quad (5)$$

It is easily seen that a fit with the experiments can be obtained with the mass formula (3), if we assume

$$a'=160 \text{ MeV},\ b'=-160/3 \text{ Mev},\ c'=-100/9 \text{ MeV},\ \alpha_{N^*}=1555 \text{ MeV} \quad (6)$$

B) Pion isobars (π^*)

We turn then to the mass spectrum of pion isobars. In this case we have

$T=2,\ 1,\ 0,\quad Z=0.$

$F(T\cdot Z,\ T^2+Z^2)=0;\quad T=0,\ I=0,\ Z=0,$

$=-44$ MeV; $=1,\ =1,\ Z=0,$

$=-400$MeV; $=2,\ =2,\ Z=0,$

If we put

$\alpha_{\pi^*}=790$ MeV,

we can then explain the observed pattern of π^*:

ω-meson with $T=0$, $M\cong 790$ MeV,

and ρ-meson with $T=1$, $M\cong 750$ MeV.

Moreover, there has been some indication of the existence of π^* with $T=2$, $M\sim 400$ MeV.

C) Hyperon isobars (Y^*)

As was mentioned above, the inter-core interaction should partially violate the symmetry of the internal interactions which are responsible for the mass spectrum of baryons: the ζ_3-dependent splitting of nucleons and the Ξ-particles, and the θ-dependent splitting of the Σ-and Λ-hyperons. We are, therefore, left with only two different cores in the presence of the inter-core interaction:

X^* (core of nucleon and Ξ-particle),

Y^* (core of Σ-and Λ-hyperon).

The spin-spin terms for X^* and Y^* are equal but the original masses of X^* and Y^* could have different values.

Now we can easily infer the F-terms for the hyperon isobars:

$T=3/2$, $1/2$, $Z=1/2$

T	Z	I	$F(T\cdot Z, T^2+Z^2)$(MeV)	M_Y*(MeV)
3/2	1/2	1	325	2025
1/2	1/2	0	125	1825
1/2	1/2	1	−35	1665
3/2	1/2	2	−315	1385

Here we put

$$\alpha_Y{}^*=1700\text{ MeV},$$

in order to equate the observed $Y_1{}^{*\pm}$ to the lowest level of four-kinds of predicted isobars.

We also cite the observed isobar $I=0$, $M=1815$ MeV and $I=1$, $M=1645$ MeV which may be compared to the above pattern.

D) Kaon isobars (K^*)

We can predict the mass spectrum of kaon isobars in the same way as was given above

T	Z	I	$F(T\cdot Z, T^2+Z^2)$(MeV)	M_K*(MeV)
1	1	0	880	2345
1	1	1	190	1225
1	1	2	−290	885

Here we put

$$\alpha_K{}^*=1175\text{ MeV},$$

in order to fit the lowest level with $I=2$ with the observed one $M_K{}^*=885$ Mev.

Finally we mention that the higher levels with the "orbital quantum number" or other quantum number (for instance, the number of cores) could exist beyond the lowest group now discussed.

If we further assume that these excited levels could occur in the extra-high energy collisions and could decay with the emission of pions, we may realize the many-fire-ball-model by Hasegawa in terms of the contribution from N^*, π^*, Y^*, K^*.

Discussion

Yamaguchi, Y.: What are your strangeness and isospin? Can you prove the isospin and strangeness conservation in your formalism?

Nakamura, S.: Hypercharge U is defined in our scheme, as

$$U=(1/2+\kappa_3)\times 2\,\zeta_3$$

for baryons. Isotopic spin is defined in terms of the four-dimensional vector which can be decomposed into two kinds of three-demensional spinors τ and ζ, in Schwinger theory. We can prove conservation of strangeness and isotopic spin in the ordinary sense as far as the typical experimental evidences are concerned, but we are led to some consequences which would give a crucial test between our scheme and the current one. (See Nakamura and Sato, Prog. Theor. Phys. **26**, (1961), 231.)

Yamaguchi: Did you use same numerical constants for a', b', c' to evaluate all resonances?

Nakamura: Yes, this is because cores of particles are all defined in terms of τ and ζ, as long as the isotopic spins are concerned.

Yamaguchi: How is the $\Sigma\pi$ resonance?

Nakamura: We can cite a spectrum for the isobaric state of Y^*, depending on I, but not of Σ^* and Λ^*.

Wataghin, G.: Is your scheme somehow related to an attempt published by J. Tiomno?

Nakamura: Our scheme may be regarded as a variant theory of higher symmetry which originated in that of J. Tiomno. But I used κ-charge, instead of hypercharge which is used by Tiomno.

Zhdanov, G. B.: Is it possible to consider your quantum numbers as the parameters of the internal motion of the particles?

Nakamura: In our scheme fermions are all described in terms of three kinds of 'charge spinors', and mesons are of 'charge vectors and scalars'. This enables us to resume that charge spins correspond to mechanical spins in the moving coordinates, which is a consequence of the rigid body models by Nakano and Fukutome.

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III-7-3. Note on the Two-Centre of Jets

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One may try to describe inelastic nucleon-nucleon collisions in the high energy region-above 500 GeV-by a simple geometrical model on the basis of the two-centre conception,[1),2)] which in contrast to other workers assumes that angular momentum is conserved as orbital angular momentum. As in geometrical optics it is assumed that rays may be constructed according to the same laws that would be obeyed by particles in classical relativistic mechanics. To each ray a value "b" of impact parameter is attributed and predictions on the statistical distribution of observable quantities are derived from the equidistribution of b^2. This is a phenomenological model as no assumptions are made on the nature of what is called "centres" or "excited nucleons" here.

Conservation of energy and momentum requires:

$$m^2=\gamma^2\left(1-\frac{p'^2}{\gamma^2-(\Delta m)^2}\right) \qquad (1)$$

where m is half of the sum of the rest masses of the excited nucleons, Δm is half of the difference of the rest masses of them, p' is the momentum of each of them in the CMS and γ is the Lorentz factor of each of the colliding nucleons in the CMS. The velocity of light and the nucleon rest mass have been set equal to one. At inelastic collisions the impact parameter b' after the collision is always greater than the impact parameter b before the collision. Now, also a maximum value a' is introduced for b': $b\leq b'\leq a'$, which may be derived by Lorentz transformation from a length "a" defined by

$$\gamma^2(a'^2-b^2)=a^2-b^2\,. \qquad (2)$$

It is found then that there is a maximum value for the total rest masses in both centres, determined by

$$m=\frac{\gamma}{\sqrt{1+\xi^2(\gamma^2-1)}}\,, \qquad (3)$$

where $\xi=b/a$, According to this relation peripheral collisions are elastic. Completely inelastic collisions are possible only in the central region.

If maximum rest mass is transferred to the centres, the transverse momentum of each of them is found to be

$$P_t=\frac{\xi\gamma\sqrt{1-\xi^2}\,\sqrt{\gamma^2-1}}{1+\xi^2(\gamma^2-1)}\,. \qquad (4)$$

This model is not applicable if P_t is comparable with the uncertainty of transverse momentum. This uncertainty, which is a consequence of the finite diameter of the nucleon, is about 1 GeV/c. Thus we must restrict our considerations to the region where ξ is small. It is seen from the formula for m that this is the region of high multiplicities of secondary particles.

We want to show now that some properties