LETTERS TO THE EDITOR

ABOUT THE CONCEPT OF FERMION GENERATION CHARGE

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(Received March 17, 1981)

The concept of the fermion generation charge is introduced. If there are only familiar intermediate bosons of the first generation, the conservation law of this charge in leptonic processes implies separate conservation laws of the electronic, muonic and tauonic numbers. Otherwise, the former is more general, allowing e.g. for the decay $\tau^- \to \mu^-\mu^-e^+$, though with a diminished rate.

PACS numbers: 12.30.Ez, 12.90.+b

As it is well known, one observes in leptonic processes the strict conservation of separate fermionic numbers: the electronic number, muonic number and probably also the tauonic number. In quark processes, the analogical fermionic numbers corresponding to the first, second and presumably also the third generation are conserved up to Cabibbo-like mixing. In this note we numerate the successive fermion generations [1] by the quantum number $N = 0, 1, 2, \ldots$, viz.

$$\begin{aligned} \nu_N &= \nu_e, \nu_\mu, \nu_\tau, \ldots \\ e_N &= e^-, \mu^-, \tau^-, \ldots \\ u_N &= u, c, (t), \ldots \\ d_N &= d, s, b, \ldots \qquad (N = 0, 1, 2, \ldots), \end{aligned} \tag{1}$$

and introduce the concept of the fermion *generation charge* defined by the operator

$$\hat{N} = \sum_N N(\hat{n}_{\nu_N} + \hat{n}_{e_N} + \hat{n}_{u_N} + \hat{n}_{d_N}), \tag{2}$$

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where $\hat{n}_{\nu_N}$, $\hat{n}_{e_N}$, $\hat{n}_{u_N}$ and $\hat{n}_{d_N}$ are the operators of the respective fermionic numbers. So the eigenvalues of $\hat{N}$ in one-fermion states of the generation N are $\pm N$ for particles and antiparticles, respectively. Then, we put forward the hypothesis that instead of the separate fermionic numbers

$$\hat{n}_{\nu_N}+\hat{n}_{e_N}, \quad \hat{n}_{u_N}+\hat{n}_{d_N} \quad (N = 0, 1, 2, \ldots) \tag{3}$$

the fermion generation charge $\hat{N}$ should be considered as a physical quantity which is conserved in fermion interactions: strictly in leptonic processes and up to Cabibbo-like mixing in quark processes.

It is evident that, in a theory like the standard model [1] where fermion interactions are mediated by bosons, the conservation of the fermion generation charge $\hat{N}$ implies immediately the conservation of *all* separate fermionic numbers (3) *if* $\hat{N}$ is conserved at each fermion-boson vertex and the lepton and baryon numbers,

$$\hat{L} = \sum_N (\hat{n}_{\nu_N}+\hat{n}_{e_N}), \quad \hat{B} = \tfrac{1}{3}\sum_N (\hat{n}_{u_N}+\hat{n}_{d_N}), \tag{4}$$

are separately considered. (If $\hat{L}$ and $\hat{B}$ as well as $\hat{F} = \hat{L}+3\hat{B}$ are not in general conserved, one can conclude from the $\hat{N}$ conservation applied at each fermion-boson vertex that only

$$\hat{n}_{\nu_N}+\hat{n}_{e_N}+\hat{u}_{u_N}+\hat{n}_{d_N} \quad \text{for} \quad N > 0 \tag{5}$$

must be conserved.) Then, the $\hat{N}$ conservation forbids not only the popular unwanted processes $\mu^- \to e^-e^-e^+$ or $\mu^- \to e^-\gamma$ and $\tau^- \to e^-e^-e^+$, $\mu^-e^-e^+$, $\mu^-\mu^-\mu^+$ or $\tau^- \to e^-\gamma$, $\mu^-\gamma$ which violate the overall $\hat{N}$ conservation, but also the processes $\tau^- \to \mu^-\nu\mu\bar{\nu}_e$, $\mu^-\mu^-e^+$ which are allowed by this overall conservation. In such a case one can say that the intermediate bosons carry $N = 0$ and so belong to the first generation $N = 0$. If, however, besides the familiar $W^\pm$ and Z with $N = 0$ there were charged and/or neutral intermediate bosons of the second generation $N = 1$, the processes $\tau^- \to \mu^-\nu_\mu\bar{\nu}_e$ and/or $\mu^-\mu^-e^+$ would not be forbidden by the conservation of the *extended* fermion and boson generation charge $\hat{N}$, applied at each fermion-boson vertex. But then, the effective Fermi interactions responsible for these decays should be diminished in comparison with the familiar ones since intermediate besons of higher generations should get larger masses. As far as semi-leptonic processes are concerned, the conservation of the extended $\hat{N}$, applied at each fermion--boson vertex, would not forbid such decays as $\Lambda \to p\mu^-\bar{\nu}_e$ and/or $n\mu^-e^+$ and $K^- \to \mu^-\bar{\nu}_e$ and/or $\bar{K}^0 = \mu^-e^+$, though it should give them a diminished rate. This rate should be presumably *much* smaller than the rate for the Cabibbo-damped, $\hat{N}$-nonconserving decays $\Lambda \to pe^-\bar{\nu}_e$, $p\mu^-\bar{\nu}_\mu$ and $K^- \to e^-\bar{\nu}_e$, $\mu^-\bar{\nu}_\mu$, all mediated by the familiar $W^\pm$ with $N = 0$.

It should be noted that, in all processes involving only leptons and quarks of the first generation $N = 0$, the fermion generation charge $\hat{N}$ is automatically conserved even if lepton and baryon numbers are arbitrarily violated. In particular, $\hat{N}$ is certainly conserved in all proton decays within the first generation. Similarly, $\hat{N}$ is conserved in the neutron oscillations.

In conclusion, we can say that the conservation law of the generation charge, introduced in this paper for fermions (and eventually extended for intermediate bosons), is a natural generalization of separate conservation laws of the fermionic numbers corresponding to successive lepton and quark generations. The former reduces to the latter if there are only familiar intermediate bosons of the first generations. Otherwise, the former is more general, allowing for exceptions to the latter, e.g. for the decay $\tau^- \to \mu^-\mu^-e^+$, though with a diminished rate due to the enhanced mass of intermediate bosons of the second generation. Of course, the conservation of the generation charge, as considered here, is valid strictly in leptonic processes and up to Cabibbo-like mixing in quark processes.

Physically, the strict conservation of the generation charge in leptonic processes may suggest that within fermions there appear some mass-excitation quanta [2, 3, 4] whose global number is strictly conserved in leptonic processes. Then, within fermions of the generation $N = 0, 1, 2, \ldots$ there are $N = 0, 1, 2, \ldots$ such quanta, respectively. *Generatons* may be a convenient term for these hypothetic quanta.

REFERENCES

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