External Inversion, Internal Inversion, and Reflection Invariance

MATEJ PAVŠIČ

Institute J. Stefan, University of Ljubljana, Ljubljana, Yugoslavia

Received: 18 June 1973

Abstract

Having in mind that physical systems have different levels of structure we develop the concept of external, internal and total improper Lorentz transformation (space inversion and time reversal). A particle obtained from the ordinary one by the application of internal space inversion or time reversal is generally a different particle. From this point of view the intrinsic parity of a nuclear particle ('elementary particle') is in fact the external intrinsic parity, if we take into account the internal structure of a particle. We show that non-conservation of the external parity does not necessarily imply non-invariance of nature under space inversion. The conventional theory of beta-decay can be corrected by including the internal degrees of freedom to become invariant under total space inversion, though not under the external one.

1. Introduction

Though the concept of space inversion is clear to us from the geometrical point of view, we must be careful when applying space inversion to real physical objects. Classical examples show that classical particles have an internal structure which must also be transformed under space inversion. If only positions, translatory and angular momenta are inverted, the transformation is not a complete space inversion, but only a partial one. In the domain of nuclear particles ('elementary particles') we have become accustomed to consider space-time coordinates of particles as one thing and the eventual particle's structure in its internal space as the other thing, independent of space-time. We have believed that when reversing positions, momenta and angular momenta of particles, we have achieved complete space inversion. Experiments show that the proton has an internal electromagnetic structure. Particles do not differ among themselves only in their space-time properties (spins for instance) but also in other properties, which indicates their internal structure. There is no reason why we should not admit that this internal structure is also due to space-time transformations. We develop the concept of
We then postulate that each physical theory must be invariant under total improper Lorentz transformation, though not necessarily under an external or an internal one.

We apply these ideas to beta-decay. As is well known, the distribution of electrons emitted by oriented Co$^{60}$ nuclei at the beta-decay is asymmetric with respect to the axis of orientation (Fraunfelder et al., 1957). Polarised electrons are emitted preferentially in one direction and anti-neutrinos in the opposite direction. For electrons and anti-neutrinos have well-defined helicities, the total system has a definite handedness. The mirror picture of the beta-decay is different from the original picture. No such mirror decay was observed, and it was concluded that parity is not conserved in the beta-decay. Hence the weak interaction must contain pseudoscalar terms.

Nature, however, has always appeared to be symmetric in its basic laws, but we have suddenly an unpleasant asymmetry with respect to space inversion. Several attempts have been made in order to save the invariance. One of the proposals was (Salam, 1957) to suggest that every particle has its double which differs from it by its 'handedness'. But, unfortunately, no distinction is made between external and internal space inversion (see the following text), therefore the theory fails to be convincing for other particles than neutrinos. Our point of view is different from that of Salam. The purpose of this paper is to show how the apparent asymmetrical behaviour of the weak processes with respect to space inversion could be explained as the symmetrical behaviour by having in mind three types of space inversion: external, internal and the total one.

The symmetrical behaviour is automatically obtained if we postulate the new kind of particles that are obtained from the ordinary particles by applying to the latter the internal space inversion $P_I$. Let $a$ (or $a_+$) be an ordinary particle, say proton or neutron, etc., and $a_-$ a particle obtained by internal space inversion (a mirror particle). Two particles are related by the internal space inversion $P_I$ in the following way:

$$a_+ ightarrow a_- = P_I a_+, \quad P_I a_- = a_+$$

If a particle $a_+$ has a definite helicity $(\vec{s}, \vec{p})$, a particle $a_-$ has the same helicity, but differs from $a_+$ in its internal structure. What we would like to say is that it is not correct to assume that a mirror image of an elementary particle is generally the same and behaves in the same way in reactions as a particle. But this a priori assumption has been achieved whilst interpreting the asymmetric Co$^{60}$ beta-decay as the proof for the mirror asymmetry of the weak interaction. By saying that the mirror beta-decay is an impossible process, we tacitly assume that protons or neutrons in the mirror are the same protons or neutrons. There is no experimental evidence for such an assumption. On the contrary, the existence of the anomalous proton and neutron magnetic moments indicates the asymmetric internal structure of two particles. Hence it is possible that the mirror beta-decay exists, but protons or neutrons that decay are mirror protons or mirror neutrons. Therefore, instead of saying that