ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА

E2 - 10276

E.Okonov, M.Shirokov

ON THE PROTON-ANTIPROTON CHARGE PARITY

1976

E2 - 10276

E.Okonov, M.Shirokov

ON THE PROTON-ANTIPROTON CHARGE PARITY

Submitted to "Physics Letters"

Оконов Э.О., Широков М.И. E2 - 10276

О зарядовой четности пары протон-антипротон

Наблюдаемая азимутальная асимметрия реакции $\tilde{p}p \to \pi^+\pi^-$ с поляризованной мишенью свидетельствует о том, что зарядовая четность пары $\tilde{p}p$ совпадает с предсказываемой уравнением Дирака.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Препринт Объединенного института ядерных исследований
Дубна 1976

Okonov E.O., Shirokov M.I. E2 - 10276

On the Proton-Antiproton Charge Parity

The observed azimuthal asymmetry of the reaction $\tilde{p}p \to \pi^+\pi^-$ with the polarized target implies that the charge parity of the proton-antiproton pair is the same as predicted by the Dirac equation.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

Preprint of the Joint Institute for Nuclear Research
Dubna 1976

Recently Kalogeropoulos et al.[1] have stressed that azimuthal asymmetry of the differential cross section $\sigma(\theta,\phi)$ of the reaction $\tilde{p}p \to \pi^+\pi^-$ with polarized proton[2] proves that the product $\xi\tilde{\xi}$ of the intrinsic spatial parities of the $\tilde{p}$ and p is equal to -1. Just this value of $\xi\tilde{\xi}$ follows if p and $\tilde{p}$ are described by a Dirac field ψ (Stapp in [3] asserts that $\xi\tilde{\xi} = -1$ follows also from general postulates of the S -matrix ideology, including analyticity and cross-symmetry). The asymmetry observed[2] means that $\sigma(\theta,\phi=0) \neq \sigma(\theta,\phi=\pi)$, where ϕ is the angle between the polarization vector of the target proton and the normal to the reaction plane.

The purpose of this letter is to show that this asymmetry implies also that the charge parity of the $\tilde{p}p$ pair is the same as predicted by the Dirac equation. In 1960 we proposed [4] some experiments with two-meson annihilation $\tilde{p}p \to \pi\pi$ in order to check not only the spatial, but also the charge parity of the $\tilde{p}p$ pair (other annihilations were discussed for this purpose in [5,6]). We suggested a generalized definition of the charge conjugation operator U_c:

$$U_c\,|p\rangle = \eta\,|\tilde{p}\rangle, \quad U_c\,|\tilde{p}\rangle = \tilde{\eta}\,|p\rangle; \quad |\eta| = |\tilde{\eta}| = 1.$$

Here $|\tilde{p}\rangle$ denotes a one-antiproton state with the same momentum and spin as a one-proton state $|p\rangle$. Local theories, describing p and $\tilde{p}$ by means of a Dirac field ψ are invariant under the usual charge conjugation, which coincides with the one defined above if $\eta\tilde{\eta} = 1$ (see, e.g., eqs. (8.120) in[7]).). When $\eta\tilde{\eta} = -1$ the $\tilde{p}p$ charge parity is equal to $-(-1)^{\ell+s}$ [4] (ℓ and s are the $\tilde{p}p$ angular momentum and total spin) and annihilation into pions is still possible. Four variants $\xi\tilde{\xi} = \mp 1$, $\eta\tilde{\eta} = \pm 1$ were discussed in[4]. The variant $\xi\tilde{\xi} = -1$, $\eta\tilde{\eta} = -1$ is rejected by the very existence of the two-meson annihilation channel[4]. The variant $\xi\tilde{\xi} = +1$, $\eta\tilde{\eta} = +1$ is just the "non-Dirac" one discussed and rejected in[1].

There remains the variant $\xi\tilde{\xi} = +1$; $\eta\tilde{\eta} = -1$. In this case annihilation $\tilde{p}p \to \pi^+\pi^-$ proceeds from the $\tilde{p}p$ triplet state as in the "Dirac" variant (see[4]). But a detailed analysis shows that now the ϕ -dependence can be anisotropic only if both p and $\tilde{p}$ are polarized, having in this case the form $\sigma(\theta,\phi) = A(\theta) + B(\theta)\sin 2\phi + C(\theta)\cos 2\phi$*. So, even if the $\tilde{p}$ beam is also polarized, the equality $\sigma(\theta,\phi) = \sigma(\theta,\pi+\phi)$ must hold. The observed asymmetry[2] $\sigma(\theta,\phi=0) \neq \sigma(\theta,\phi=\pi)$ therefore rejects the latter "non-Dirac" variant $\xi\tilde{\xi} = +1$, $\eta\tilde{\eta} = -1$.

In conclusion we would like to note that this variant is rejected also by the observed behaviour of the differential cross section $\sigma(\theta)$ of the low-energy annihilation $\tilde{p}p \to \pi^+\pi^-$ [8]. The observed $\sigma(\theta)$ increases when $\theta \to 0$ while in the case $\xi\tilde{\xi} = +1$, $\eta\tilde{\eta} = -1$ it is expected to vanish as $\sin^2\theta$ (see[4]).

REFERENCES

1. *T.E.Kalogeropoulos, C.B.Chiu, E.C.G.Sudarshan. Phys. Rev.Lett., 37, 1037 /1976/.*
2. *R.D.Erlich et al. Phys. Rev.Lett., 28, 1147 /1972/.*
3. *H.P.Stapp. Phys. Rev., 128, 1963 /1962/.*
4. *M.I.Shirokov, E.O.Okonov. JETP, 39, 285 /1960/; Soviet Phys. JETP, 12, 209 /1961/.*
5. *E.O.Okonov. JETP, 40, 1728 /1961/.*
6. *M.I.Shirokov. JETP, 41, 190 /1961/; Soviet Phys., JETP, 14, 138 /1962/.*
7. *S.S.Schweber. An Introduction to Relativistic Quantum Field Theory. Row, Peterson and Co., N.Y., 1967.*
8. *R.Bizzarri et al. Lett. Nuovo Cim., 1, 749 /1969/.*

Received by Publishing Department on December, 7, 1976.

---

* In this variant $\sigma(\theta,\phi)$ can be anisotropic in ϕ only due in the interference of the annihilation amplitudes with total spin projections $s_z = +1$ and $s_z = -1$, the case $s_z = 0$ being forbidden because of the property $\langle 10\ell 0|\ell 0\rangle = 0$ of the Clebsch-Gordan coefficients.