Z. Phys. A - Atoms and Nuclei 308, 363-364 (1982)

Zeitschrift für Physik A Atoms and Nuclei

Short Note

Enhancement of *T*-Noninvariant Effects in Neutron-Induced Nuclear Reactions

V.E. Bunakov and V.P. Gudkov
Leningrad Institute of Nuclear Physics, Gatchina, Leningrad district, USSR

Received September 27, 1982

Abstract: The previously developed approach to P-nonconservation in nuclear reactions is applied to the investigation of P- and T-noninvariant effects in neutron-induced reactions. Dynamical and resonance enhancement effects for T-noninvariant quantities are considered. The estimate is given of the expected effect in the compound-nucleus p-resonance.

The possible measurements of simultaneous P- and T-voilation in the transmission of polarized neutron beam through a target with polarized nuclei were considered recently/1,2/. These effects arize from the P- and T-noninvariant combination of the target spin $\vec{I}$, neutron spin $\vec{\sigma}$ and neutron momentum $\vec{p}$ in the scattering amplitude: $\vec{\sigma}[\vec{p}\times\vec{I}]$. One of the effects leads to a precession of $\vec{\sigma}$ around the $[\vec{p}\times\vec{I}]$ axis. When the target polarization is perpendicular to $\vec{p}$ the component of $\vec{\sigma}$ in the $(\vec{p},\vec{I})$ plane will be rotating with "velocity"

$$\frac{d\chi}{dz}=\frac{4\pi N}{K}\mathrm{Re}(f_x-f_{-x})$$

where z is the sample length, k is the neutron wave vector, N is the density of target nuclei in a sample, while f_x and f_{-x} are the zero angle scattering amplitudes for neutrons polarized along and against the $[\vec{p}\times\vec{I}]$ axis respectively.

The second effect consists in observing the difference between the total neutron cross-sections for $\vec{\sigma}$ parallel and antiparallel to $[\vec{p}\times\vec{I}]$ which is

$$\Delta_T=\frac{4\pi}{K}\mathrm{Im}(f_x-f_{-x})$$

We are going now to find the expressions for (1),(2) demonstrating the possible enhancement mechanisms arising in nucleon-nucleus reactions. Using the formalism of /3/ and the microscopic theory of nuclear reactions /4/ we can follow the procedure of /5/ to obtain the expression for f in the first Born approximation in weak interaction W. Then

$$\frac{d\chi}{dz}=\frac{4\pi NG}{K^2}\frac{w(\Gamma_s^n\Gamma_p^n)^{1/2}}{[s]\,[p]}\left[(E-E_s)(E-E_p)-\frac{\Gamma_s\Gamma_p}{4}\right]$$

$$\Delta_T=-\frac{2\pi G}{K^2}\frac{w(\Gamma_s^n\Gamma_p^n)^{1/2}}{[s]\,[p]}\left[(E-E_p)\Gamma_s+(E-E_s)\Gamma_p\right]$$

Here $G\approx1$ is the spin factor (omitted further on), $w=\mathrm{Im}\int\Psi_s W\Psi_p d\tau$ is the P- and T-violating part of the weak interaction matrix element between the s- and p-compound resonance wave functions admixed to each other; $E_{s,p}$ and $\Gamma_{s,p}$ are the positions and widths of these resonances; $[s,p]=(E-E_{s,p})^2+\Gamma_{s,p}^2$.

It is often convenient to use the angle χ observed for a sample thickness equal to the mean free path $l_{m.f.}$ and the relative value $\eta=\Delta_T/2\sigma_{tot}$. Now we are able to relate these values to the corresponding values of P-violating effects (see /5/) Φ and P obtained for neutrons with opposite helicities and unpolarized target. Since the letter effects are essentially defined by the T-invariant part v of the weak interaction matrix element $v=\mathrm{Re}\int\Psi_s W \Psi_p d\tau$ we use the procedure of /5/ to get

$$\chi = \Phi \cdot \frac{w}{v} \qquad \eta = P \cdot \frac{w}{v}$$

Thus we get for the effects caused by the T- and P-violating interaction in the processes going through compound resonances the same two enhancement factors as for P-violating caused by v /5, 6/, namely the dynamical enhancement factor w/D arising from small spacing D between the admixed s- and p-resonances and the resonance enhancement factors D/Γ or $(D/\Gamma)^2$ arising from the resonance propagators in (3). The quantities χ and η (contrary to $d\chi/dz$ and Δ_T) would feel resonance enhancement only in the vicinity of p-resonance (see the analogous property of Φ and P in /5/). Mind that the net enhancement for P was proved both theoretically and experimentally to reach 5-6 orders of magnitude (see e.g. /5/ and references therein). In order to estimate the absolute values of χ and η one needs to estimate the ratio $r= w/v$. To do this one can use the resonable hypothesis that the ratio of nuclear matrix elements equals the ratio of the corresponding nucleon-nucleon interaction constants. According to the theories of spontaneous CP-violation in weak interaction /7/ which describe satisfactory experimental data on K-meson decays this ratio is

$$r \sim \frac{m_q^2}{m_H^2} \cdot \frac{m_N}{m_q}$$

Where m_q, m_N and m_H are the masses of quark, nucleon and the light Higgs' boson responsible for the CP-noninvariant interaction with quarks. Reasonable estimates of m_q and m_H give us $r \sim 10^{-2}-10^{-3}$.

With this estimate we obtain for the p-compound resonance, say in ^{139}La (where experiment showed /8/ a large value of $P \approx 0{,}1$):

$$\eta(\mathrm{La}) \sim 10^{-3}-10^{-4} \qquad \chi(\mathrm{La}) \sim 10^{-3}-10^{-4}\ \mathrm{rad}$$

Finding the effects would unambiguously indicate the presence of "milliweak" interaction which violates T-invariance. One can point that resonance behaiour of η and χ allows to separate the real effects from possible background caused, say, by internal fields in solid target sample.

We are indebted to Professor A.A. Anselm, A.N. Moskalev and R.M. Ryndin for helpful discussion.

References

1. Kabir, P.K.: Phys. Rev. 25D, 2013 (1982)
2. Stodolsky, L.: Nucl. Phys. 197B, 213 (1982)
3. Baldin, A.M., Goldansky, V.I., Maksimenko, V.M., Rosental, I.L.: Kynematika yadernych reakciy. Moscow: Atomizdat, 1968
4. Mahaux, C., Weidenmüller, H.A.: Shell-model approach to nuclear reactions. Amsterdam-London: North-Holland, 1969
5. Bunakov, V.E., Gudkov, V.P.: Z. Phys. 303A, 285 (1981)
   Bunakov, V.E., Godkov, V.P.: LINP Preprint No. 763, Leningrad, 1982
6. Blin-Stoyle, R.J.: Phys. Rev. 120, 181 (1960)
   Shapiro, I.S.: Usp. Fiz. Nauk, 95, 647 (1968)
   Lobov, G.A.: Izv. ANSSSR (ser. phys.), 34, 1141 (1970)
   Sushkov, O.P., Flambaum, V.V.: Pisma v ZhETP, 32, 377 (1980)
7. Weinberg, S.: Phys. Rev. Lett., 37, 657 (1976)
   Anselm, A.A.: High Energy Physics (Proceedings of the XIII Winter School), p. 42. Leningrad. LINP, 1978)
8. Alfimenkov, V.P., Borzakov, S.B., Vo Van Thuan, Mareev, Y.D., Pikelner, L.B., Rubin, D., Khrykin, A.S., Sharapov, E.L.: Pisma v ZhETP, 35, 42 (1982)