

A. SOME TOPICS RELATED TO NUCLEAR PHYSICS

A1 Study of Nuclear Structure with π Mesons

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A2 Some Rules in High Energy Physics

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A3 Parity Nonconserving Potentials

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The parity nonconserving nuclear potential (PNCP) emerging from the product of two strangeness conserving hadronic currents, is a logical, although not a necessary extension^{1,2)} of the standard description of nonleptonic decays of baryons. It has been suggested that PNCP can be used as a probe in the structure of weak Lagrangians, which is otherwise inaccessible.³⁾ Extensive calculations have been made recently concerning contributions to PNCP due to pion and vector meson exchange. Pion exchange has been calculated using either current algebra combined with SU(3) symmetry^{4,5)} or SU(3) symmetry alone.⁶⁾ Both approaches lead to essentially the same result:

$$V_{\pi} = \frac{G_{\omega} g}{2M} (\vec{\sigma}_1 + \vec{\sigma}_2) [\vec{p}_{21}, f(r)] \cdot (\tau_{1+} \tau_{2-} - \tau_{1-} \tau_{2+}) \eta;$$

$$G_{\omega} = 1.92 \cdot 10^{-7}, \quad \frac{g^2}{4\pi} = 14.4,$$

$$f(r) = \frac{1}{4\pi} \frac{e^{-m_{\pi} r}}{r}.$$

Here the factor η depends on a particular weak interaction Lagrangian model.

Vector meson exchange (i. e. ρ , ω , φ) was first calculated in factorization approximation.⁷⁾ A later attempt using the current algebra approach to estimate the weak ρ meson nucleon vertex⁸⁾ led to very interesting results:

a) The only contribution in the current algebra limit can come from the Schwinger term.⁹⁾ As all other contributions strictly vanish due to CP conservation, this has so far been a unique result in current algebra application.

b) When the current field identity model is used to estimate the Schwinger term¹⁰⁾ (this being the only model with a finite Schwinger term) results are in agreement with the factorization approximation. This potential is of the general form

$$\begin{aligned}
 V_{\rho} = & \frac{Gm_{\rho}^2}{4\pi m_N \sqrt{2}} \left\{ i\vec{\sigma}_1 \times \vec{\sigma}_2 \cdot [\vec{p}_{12}, \exp(-m_{\rho} r_{12})/r_{12}]_- \cdot \left\{ (1 + \mu_p - \mu_n) \cdot \right. \right. \\
 & \cdot \left[T_{12}^{(+)} + \frac{B}{4} \tau_1^{(z)} \tau_2^{(z)} + \frac{C\xi}{4} (\tau_1^{(z)} + \tau_2^{(z)}) \right] + (1 + \mu_p + \mu_n) \frac{\sqrt{3}}{8} C' (\tau_1^{(z)} + \tau_2^{(z)}) + \frac{\sqrt{3}}{2} D\xi \left. \right\} + \\
 & + (\vec{\sigma}_1 - \vec{\sigma}_2) \cdot [\vec{p}_{12}, \exp(-m_{\rho} r_{12})/r_{12}]_+ \cdot \left\{ T_{12}^{(+)} + \frac{B}{4} \tau_1^{(z)} \tau_2^{(z)} + \frac{\sqrt{3}}{3} D\xi \right\} + \\
 & + [\vec{p}_{12}, \exp(-m_{\rho} r_{12})/r_{12}]_+ \cdot \left\{ \frac{\sqrt{3}}{4} C' (\vec{\sigma}_1 \tau_1^{(z)} - \vec{\sigma}_2 \tau_2^{(z)}) + \frac{C\xi}{2} (\vec{\sigma}_1 \tau_2^{(z)} - \vec{\sigma}_2 \tau_1^{(z)}) \right\} \Big\}; \\
 & T_{12}^+ = \tau_{1+} \tau_{2-} + \tau_{1-} \tau_{2+}.
 \end{aligned}$$

Here $\xi \approx 1/(6\sqrt{3})$, while the factors B , C , C' and D depend on the particular weak interaction Lagrangian.

Experimental data can be extracted from, e. g.

a) few-nucleon experiments as

$$n + p \rightarrow d + \gamma^{11,6)}$$

or

$$n + d \rightarrow t + \gamma^{12),}$$

where one can measure the circular polarization of γ quanta, or the γ asymmetry when neutrons are polarized. There are theoretical arguments¹²⁾, though already contradicted¹³⁾, that the effect can be enhanced in the second reaction. For this reason, this experiment is now in preparation.

b) the circular polarization of γ quanta emitted by heavy nuclei, where quite a few experiments have been performed^{14, 15)}. A theoretical analysis⁷⁾ has been made averaging over PNCP and by approximating its radial dependence with the Dirac delta function. A newer approach¹⁶⁾ attempted to remedy the neglect of short range nuclear correlations by making the average over the radial dependence in nuclear matter and using that as a correction factor. One attempt¹⁷⁾ calculated the parity admixture to nuclear wave functions using the Nilsson model, but it neglected the potential V_{ρ} and also the short range

correlations. As an indication of the present state of theoretical analysis, below are the theoretical and experimental results concerning the decay of ^{181}Ta (482 keV)

Circular polarization in units 10^{-4}

Experimental	d'Espagnat model	Cabibbo's model
$-(0.06 \pm 0.01)^{14)}$	$-0.155^{17)}$	$-0.008^{17)}$
$-(0.1 \pm 0.4)^{15)}$	$-1.0^{16)}$	$-0.2^{16)}$

The reason for the poor agreement between the theoretical and experimental values is not yet understood.

c) The effect was successfully detected by measuring γ asymmetry after bombardment of ^{114}Cd with polarized neutrons^{18,19)}.

d) In principle, PNC effects can also be detected by measuring $\beta\gamma$ correlations.²⁰⁾

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A 4 On CP-Parity Violations

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Symmetry has always been appreciated. An ancient example: Gods live on Earth, and therefore Earth has to have the most perfect shape — a sphere. A modern example: After CPT invariance¹⁾ had been demonstrated, it was commonly believed that Nature was invariant under C, P and T transformations. When P-parity had been found to be violated²⁾, CP-invariance³⁾ was left to save the symmetry. When the decay of a long-lived kaon into two pions ($K_L^0 \rightarrow 2\pi$) had been observed⁴⁾, the question of CP-violating interaction arose. Many interactions have been proposed⁵⁾ and many experiments performed to ascertain the appropriate one.

We decided to look for vector meson decays into photon and electron-positron pairs⁶⁾. This process could test the noninvariance of the electromagnetic interaction under charge conjugation⁵⁾. The vector meson namely, cannot decay into two photons⁷⁾, and one of them being virtual, the process is forbidden by invariance under charge conjugation. The estimated partial width for $\omega \rightarrow \gamma e^+ e^-$ is about 4 eV, and the total width about 11 MeV.

A number of indirect tests of CP violations have been proposed. Neutron polarization according to the electron-positron plane in

$$\pi^- + p \rightarrow n + e^+ + e^-$$

was estimated⁸⁾ up to 1%. A similar process

$$K^- + p \rightarrow \Lambda + e^+ + e^-$$

could give more asymmetry. Yet, this process can have real (on-mass-shell) intermediate states ($\Sigma\pi$, e. g.). They contribute to the imaginary part of the matrix element, producing the asymmetry of Λ 's according to the electron-positron plane⁹⁾.

The present experimental situation does not yet permit determination of the appropriate CP-violating interaction. Moreover, the experimental data does not contradict even CP-invariant models¹⁰⁾.