NEUTRAL CURRENTS IN ^{14}N-NUCLEUS

Dan Mihailescu

Department of Plasma Physics and the Structure of Matter
"Al.I. Cuza" University, 6600, Iasi, Romania
e-mail: `dmihail@uaic.ro`

Daniel Radu

Department of Theoretical Physics
"Al.I. Cuza" University, 6600, Iasi, Romania
e-mail: `dradu@uaic.ro`

and $\boxed{\text{Ovidiu Dumitrescu}}$

Department of Theoretical Physics, Institute of Atomic Physics
Institute of Physics and Nuclear Engineering
Magurele, P.O. Box MG-6, 76900, Bucharest, Romania

(Received January 18, 2001)

The parity and isospin forbidden p_0-decay from ^{14}N$^*(J^\pi{=}2^+;T{=}1;$ $E_x = 9.17225$ MeV) to ^{13}C (g.s.) has been theoretically investigated via ^{13}C$(\vec{p},p)^{13}$C resonance scattering of polarized protons. Considering various strong and weak interaction models, the longitudinal (A_L) and the irregular transverse (A_b) analyzing powers have been calculated in the energy range around the $2^+, E_x = 9.17225$ MeV-resonance in ^{14}N*. Energy anomalies for the expected interference effects, relevant for the experiments, have been found to be $A_L = (0.19 \div 1.82) \times 10^{-5}$ and $A_b = (0.6 \div 5.6) \times 10^{-5}$. In addition, the circular polarizations of the 2.36018 and 9.3893 MeV γ-rays, populating the 2^+0, $E_x = 7.02912$ MeV and the ground state in mbox ^{14}N-nucleus, have been found to be $(0.22 \div 2.07) \times 10^{-3}$ and $(0.20 \div 1.89) \times 10^{-3}$, respectively.

PACS numbers: 21.60.Cs, 24.80.–x, 27.30.+t, 12.15.Ji

1. Introduction

According to the standard theory, the neutral current contribution to $\Delta S = 1$ and $\Delta C = 1$ weak processes is strongly suppressed [1, 2] and therefore, the neutral current weak interaction between quarks can only be studied in flavor conserving processes which can be met in the low energy nuclear physics only [3]. These studies can be related to the Parity NonConservation (PNC) in different nuclear physics processes such as asymmetries in the radioactive transitions and nuclear collisions.

The search for PNC in complex nuclei, and especially in the cases where an enhancement effect is expected from the existence of Parity Mixed Doublets (PMD) has a long history [3–13]. The enhancement of any PNC effect is predicted by several reasons, the most important being the small level spacing between states of the same spin and opposite parity in the excited nucleus involved. The second one arises from the expected increase of the ratio between parity-forbidden and parity allowed transition matrix elements caused by the nuclear structure of the states involved. Usually, such enhancements are offset due to correspondingly large theoretical uncertainties in the extraction of the PNC–NN parameters from the experimental data. As a matter of fact the same conditions which generate the enhancement complicate a reliable determination of the nuclear matrix elements, theoretically. Therefore, it is necessary to select exceptional cases, in which the nuclear structure problem can be solved. This is the case for closely spaced doublets of the same spin and opposite parity levels situated far away from other similar levels. In this case the parity impurities are well approximated by simple two state mixing, which simplifies the analysis and isolates specific components of the PNC–NN interaction.

For the PMD's we defined [5] a specific enhancement factor:

$$F = 10^8 \times \frac{M_{\mathrm{PNC}}}{\Delta E} f\,,$$

where f is a ratio of the decay (formation) amplitude corresponding to the unnatural parity level to that of the natural parity level.

The controversy [3, 14–17] in calculating weak meson–nucleon coupling constants in nuclei greatly stimulates the investigation of possible experiments sensitive to different components of the PNC interaction Hamiltonian (H_{PNC}), that depend linearly on seven such weak coupling constants: $h^{\Delta T}_{\mathrm{meson}}(h^1_\pi,\, h^0_\rho,\, h^1_\rho,\, h^2_\rho,\, h^1_{\rho'},\, h^0_\omega,\, h^1_\omega)$. Various linear combinations of these constants can, in principle, be extracted in different experiments, and among these are those for the parity mixed doublets (PMD) [3,5,13]. Since the PMD has definite isospins, the transition "filters out" specific isospin components of PNC weak interaction.

In the excitation spectrum [18] of the ^{14}N nucleus there are two PMD's lying at $E_x \simeq 8.7\,\mathrm{MeV}$ and $E_x \simeq 9.3\,\mathrm{MeV}$ excitation energy:

PMD1

$$J^\pi T = 0^- 1,\ 8.776\ \mathrm{MeV}; \quad \Gamma^{0^-1} = 410\,\mathrm{keV},$$
$$J^\pi T = 0^+ 1,\ 8.618\,\mathrm{MeV}; \quad \Gamma^{0+1} = 3.8\,\mathrm{keV},$$
$$M_{\mathrm{PNC}} = 1.04\,\mathrm{eV}[12], \quad f = \sqrt{\frac{\Gamma^{0^-1}}{\Gamma^{0^+1}}} = 10.4, \quad F \simeq 3200\,,$$

PMD2

$$\begin{aligned} J^\pi T &= 2^- 0, 9.388\,\mathrm{MeV}; \qquad \Gamma^{2^-0} = 13\,\mathrm{keV}, \\ J^\pi T &= 2^+ 1, 9.17225\,\mathrm{MeV}; \quad \Gamma^{2^+1} = 0.122\mathrm{keV}\ , \end{aligned}$$

$$M_{\mathrm{PNC}} \simeq 0.5\,\mathrm{eV}[21], \quad f = \sqrt{\frac{\Gamma^{2-0}}{\Gamma^{2+1}}} = 10.3\,, \quad F \simeq 2400\,.$$

The difference between the two PMD's is that the **PMD1** is essentially of isoscalar type, while the **PMD2** is of isovector type being at the same time an interesting case in searching for neutral currents in the structure of the weak hadron–hadron interaction [7].

In a recent work of Kniest, Horoi, Dumitrescu and Clausnitzer [7], an application of a general parity nonconserving theory of resonance nuclear reactions (developed in Ref. [8]) to the polarized proton induced PNC resonance reaction has been done.

In the present paper we continue this type of investigations by studying the second above mentioned PMD with the help of the resonance elastic scattering of polarized protons on the unpolarized ^{13}C nucleus in which are populated the two mentioned PMD's. Considering various strong and weak interactions model, the longitudinal (A_L) and the irregular transverse (A_b) analyzing powers have been calculated in the energy range around the 2^+, $E_x = 9.17225$ MeV-resonance in ^{14}N*. In addition, the circular polarizations of the 2.3589 and 9.388 MeV γ-rays, populating the 2^+0, $E_x = 7.02912\,\mathrm{MeV}$ and the ground state in ^{14}N-nucleus has been estimated. In this conditions, a thorough investigation of all PNC matrix elements and of their signs has been performed.

The paper is organized as follows. The general formulae of the analyzing powers and gamma asymmetries are presented in Sections 2 and 3. Discussions concerning the weak interaction models and the corresponding PNC matrix elements are given in Section 4. Section 5 is devoted to the analysis of the particular behavior of the cross section and analyzing powers, both the regular (PC = Parity Conserving) and irregular (PNC) ones, as well as the circular polarization of the 2.3589 and 9.388 MeV gamma rays. Section 6 will contain the conclusions.

2. Parity nonconserving analyzing powers

Consider a proton beam with the polarization vector $\vec{P} = \left\langle 2\vec{S}_p \right\rangle$ which travels along the z-axis to the unpolarized target nucleus of spin $I = \frac{1}{2}$. In this case the resonance reaction cross section is [7, 8, 22, 23]:

$$\frac{d\sigma}{d\Omega} = \sigma_{\text{un}} \left(1 + \vec{A} \cdot \vec{P}\right) , \tag{1}$$

where

$$\sigma_{\text{un}} = \text{Tr}\left(f f^{+}\right) = \sigma_0^{(0)} \tag{2}$$

is the cross section for the resonance reaction induced by an unpolarized proton beam expressed in terms of scattering amplitudes (f). The vector analyzing powers are given by

$$\vec{A} = \sigma_{\text{un}}^{-1} \text{Tr}\left(f\, 2\, \vec{S}_p\, f^{+}\right) = 2 \sum_k \sigma_k^{(1)} \vec{e}^{\,k} \left(\sigma_0^{(0)}\right)^{-1} , \tag{3}$$

with

$$\begin{aligned} A_L &= 2\,\text{Re}\left[\sigma_0^{(1)} \left(\sigma_0^{(0)}\right)^{-1}\right] , & (4)\\ A_b &= -2\sqrt{2}\,\text{Re}\left[\sigma_1^{(1)} \left(\sigma_0^{(0)}\right)^{-1}\right] , & (5)\\ A_n &= -2\sqrt{2}\,\text{Im}\left[\sigma_1^{(1)} \left(\sigma_0^{(0)}\right)^{-1}\right] . & (6) \end{aligned}$$

A_L is the PNC longitudinal, A_b is the PNC transverse and A_n is the PC transverse analyzing powers. In the relation (3),

$$\begin{aligned} \vec{e}^{\,1} &= -2^{-1/2} \left(\vec{e}_b - i\vec{e}_n\right) , \\ \vec{e}^{\,0} &= \vec{e}_L , \\ \vec{e}^{\,-1} &= 2^{-1/2} \left(\vec{e}_b + i\vec{e}_n\right) \end{aligned} \tag{7}$$

are the cyclic contravariant unit vectors [8] and

$$\begin{aligned} \vec{e}_L &= \vec{k}_i \left(\left|\vec{k}_i\right|\right)^{-1} , \\ \vec{e}_n &= \vec{k}_i \times \vec{k}_f \left(\left|\vec{k}_i \times \vec{k}_f\right|\right)^{-1} , \\ \vec{e}_b &= \vec{e}_n \times \vec{e}_L \end{aligned} \tag{8}$$

are the unit vectors of the reference frame given by the Madison convention. The common quantity in Eqs. (2)–(6) is defined as follows:

$$\sigma_k^{(v)} = \mathrm{Tr}\left(f\, O_k^{(v)}\, f^{\dagger}\right). \tag{9}$$

Introducing the decomposition

$$\sigma_k^{(v)} = \sum_{i=c,n} \sum_{j=c,n} \left(\sigma_k^{(v)}\right)_{i,j} , \tag{10}$$

where c stands for the Coulomb part of the f-scattering amplitude and n stands for the nuclear part of the f-amplitude, we find (for a reaction $\beta \to \beta_1$) the following explicit formulae:

$$\left(\sigma_k^{(v)}\right)_{cc} = \delta_{v0}\delta_{k0}\delta_{\beta\beta_1} k_i^{-2} \left|C\left(\theta\right)\right|^2 , \tag{11}$$

$$\begin{aligned}\left(\sigma_k^{(v)}\right)_{cn} &= i\left(-1\right) k_i^{-2}\delta_{\beta\beta_1} \sum_{Jlsl_1s_1} [f_k^{\,v}\left(Jlsl_1s_1\right) C\left(\theta\right) \left(T^{J}_{J\beta ls\beta_1 l_1 s_1}\right)^* \\ &\quad - f_{-k}^{\,v}(Jlsl_1s_1) C\left(\theta\right)^* T^{J}_{J\beta ls\beta_1 l_1 s_1}] Y_{lk}\left(\pi, \varPhi = 0\right) ,\end{aligned} \tag{12}$$

$$\begin{aligned}\left(\sigma_k^{(v)}\right)_{nn} &= k_i^{-2}\delta_{\beta\beta_1} \sum_{Jlsl_1s_1J'l'l_2s_2L} F^{(v,k)}_{Jlsl_1s_1,\,J'l'sl_2s_2}\left(L\right) P_L^k\left(\cos\theta_f\right) \\ &\quad \times T^{J^\pi}_{\beta ls,\beta_1 l_1 s_1} \left(T^{J^\pi}_{\beta' l' s,\beta_2 l_2 s_2}\right)^* ,\end{aligned} \tag{13}$$

where

$$C(\theta) = \frac{\eta}{2\sin\left(\frac{\eta}{2}\right)} \exp\left(-2i\eta \ln\left[\sin\left(\frac{\theta}{2}\right)\right]\right),$$

with $\eta = Z_1 Z_2 m e^2/\hbar k$ and $P_L^k\left(\cos\theta\right)$ are the associated Legendre polynomials. In the relations (12) and (13),

$$\begin{aligned} f_k^{\,v} &= \sqrt{\pi}\left\langle \tfrac{1}{2}\left\| O^v \right\| \tfrac{1}{2}\right\rangle \sum_j \left(-1\right)^{v+s+j+j_i+s_1+l+l_1} \widehat{s}\widehat{s}_1\widehat{j}\widehat{J}^2\widehat{j}^2\widehat{l}_1 \\ &\quad \times W\left(j_i j_i l_1 l;\, v j\right) \begin{pmatrix} l & v & l_1 \\ -k & k & 0 \end{pmatrix} \begin{Bmatrix} j_i & I_i & s_1 \\ l & s & J \\ j & j_i & l_1 \end{Bmatrix} \end{aligned} \tag{14}$$

and

$$F^{(v,k)}_{Jlsl_1s_1,J'l'sl_2s_2}(L) = \left(4\widehat{j}_i^2\widehat{I}_i^2\right)^{-1}\left\langle\frac{1}{2}\left\|O^{(v)}\right\|\frac{1}{2}\right\rangle$$
$$\times\ (-1)^{(I_i-j_i+v-k+J-s-l_2+s_2+2s_1)}\,\widehat{l}_1\widehat{l}_2\widehat{s}_1\widehat{s}_2\widehat{l}\widehat{l'}\widehat{L}^2\widehat{J}^2\widehat{J}'^2$$
$$\times\sqrt{\frac{(L-k)!}{(L+k)!}}W\left(JlJ'l';\,sL\right)W\left(\frac{1}{2},\frac{1}{2},s_1s_2;\,v\frac{1}{2}\right)$$
$$\times\begin{pmatrix} l & l' & L\\ 0 & 0 & 0\end{pmatrix}\sum_j(-1)^j\widehat{j}^2\begin{pmatrix} L & v & j\\ k & -k & 0\end{pmatrix}\begin{pmatrix} l_1 & l_2 & j\\ 0 & 0 & 0\end{pmatrix}\begin{Bmatrix} l_1 & l_2 & j\\ s_1 & s_2 & v\\ J & J' & L\end{Bmatrix} \tag{15}$$

are the corresponding geometrical coefficients [8], with

$$O^{(v)} = \begin{cases} 1, & v=0\\ \vec{S}, & v=1\end{cases} \tag{16}$$

and

$$\left\langle\frac{1}{2}\left\|1\right\|\frac{1}{2}\right\rangle = 1,$$
$$\left\langle\frac{1}{2}\left\|S^{(1)}\right\|\frac{1}{2}\right\rangle = \frac{\sqrt{3}}{2}.$$

The quantities β denote the rest of quantum numbers that specify the channel states (*e.g.* names, spin and parities of the fragments). The nuclear PC and PNC amplitudes are linear combinations of PC and PNC T-matrices, respectively.

In our case the general form of the PC resonance T-matrix elements is

$$T^{J^\pi}_{pls,p_1l_1s_1} = \frac{i\exp\left(i\xi_{pls}\right)\sqrt{\Gamma^{J^\pi}_{pls}}\sqrt{\Gamma^{J^\pi}_{p_1l_1s_1}}\exp\left(i\xi_{p_1l_1s_1}\right)}{E-E^{J^\pi}+\frac{i}{2}\Gamma^{J^\pi}}, \tag{17}$$

while the PNC T-matrix elements have the following expression:

$$T^{J^\pi,-\pi}_{pls,p_1l_1s_1} = \frac{i\exp\left(i\xi_{pls}\right)\sqrt{\Gamma^{J^{-\pi}}_{pls}}\left\langle J^{-\pi}\left|H_{\rm PNC}\right|J^\pi\right\rangle\sqrt{\Gamma^{J^\pi}_{p_1l_1s_1}}\exp\left(i\xi_{p_1l_1s_1}\right)}{\left(E-E^{J^{-\pi}}+\frac{i}{2}\Gamma^{J^{-\pi}}\right)\left(E-E^{J^\pi}+\frac{i}{2}\Gamma^{J^\pi}\right)}, \tag{18}$$

where ξ_{pls}, E^{J^π} and Γ^{J^π} stand for the channel phases, resonance energies and total resonance widths, respectively. The quantities $\sqrt{\Gamma^{J^\pi}_{pls}}$ are the amplitudes of the channel widths, which also contain the signs.

3. Circular polarization

The degree of circular polarization of the emitted γ-rays is given [24] by a sum of parity nonconserving (PNC) and parity conserving (PC) contributions:

$$P_\gamma(\cos\theta) \equiv \frac{W_{\rm right}(\theta) - W_{\rm left}(\theta)}{W_{\rm right}(\theta) + W_{\rm left}(\theta)} = (P_\gamma)_0 \; R_\gamma^{\rm PNC}(\cos\theta) + R_\gamma^{\rm PC}(\cos\theta) \; . \tag{19}$$

The circular polarizations for unpolarized initial nucleus with zero and finite mixing ratios, respectively, are:

$$(P_\gamma)_0 = 2\,\frac{M_{\rm PNC}}{\Delta E}\sqrt{\frac{b_+\,\tau_-}{b_-\,\tau_+}\,\left(\frac{E_\gamma^-}{E_\gamma^+}\right)^3} \tag{20}$$

and

$$(P_\gamma)_{\rm un} = (P_\gamma)_0\,\sqrt{\frac{1+\delta_-^2}{1+\delta_+^2}}\,. \tag{21}$$

$R_\gamma^{\rm PNC}$ is a multiplier due to the existence of the orientation of the nucleus in the initial excited state when the mixing ratios do not vanish. For example, in the case of 2.3589 MeV γ-decay from the 2^-0, $E_x = 9.3893$ MeV to the 2^+0, $E_x = 7.02912$ MeV state in ^{14}N-nucleus, the expression for $R_\gamma^{\rm PNC}$ is:

$$\begin{aligned} R_\gamma^{\rm PNC}(\cos\theta) \;=\; & \sqrt{\frac{1+\delta_-^2}{1+\delta_+^2}}\Big\{\sum_{v=0,2,4} P_v(\cos\theta)\,B_v(2)\,[F_v(1122) + F_v(2222)\,\delta_+\delta_+ \\ & +F_v(1222)\,(\delta_- + \delta_+)]\Big\}\Big\{\sum_{v=0,2,4} P_v(\cos\theta)\,B_v(2)\,[F_v(1122) \\ & +F_v(2222)\,\delta_-^2 + 2F_v(1222)\,\delta_-]\Big\}^{-1}, \end{aligned} \tag{22}$$

where the F_v coefficients are defined by

$$\begin{aligned} F_v\left(LL'I'I\right) \;=\; & (-1)^{I'+3I-1}\left[(2I+1)\,(2L+1)\left(2L'+1\right)\right]^{\frac{1}{2}} \\ & \times C\left(LL'v;\,1-10\right) W\left(LL'II;\,vI'\right)\,. \end{aligned} \tag{23}$$

C is the Clebsch–Gordan coefficient $C\,(J_1J_2J_3;\,M_1M_2M_3)$ and W is the Racah coefficient. The parity conserving (PC) γ-asymmetry is given by [24]:

$$R_\gamma^{\rm PC}(\cos\theta) = \\ \left\{ \sum_{v=1,3} P_v(\cos\theta)\, B_v(2) \left[F_v(1122) + F_v(2222)\,\delta_-^2 + 2F_v(1222)\,\delta_-\right] \right\} \\ \times \left\{ \sum_{v=0,2,4} P_v(\cos\theta)\, B_v(2) \left[F_v(1122) + F_v(2222)\,\delta_-^2 + 2F_v(1222)\,\delta_-\right] \right\}^{-1}, \tag{24}$$

where

$$B_v(2) = \sum_M (2v+1)^{1/2}\, C(2v2;\, M0M)\, p(M)\ . \tag{25}$$

$p(M)$ is the polarization fraction of the M-state, which determines the degree of the orientation of the nucleus.

In order to measure a PNC effect one must find situations for which the $R_\gamma^{\rm PC}$ part in Eq. (19) vanishes. Two particular cases have this property:

(i) the case of an initially unpolarized nucleus for which $B_0(2) = 1$, $B_{v\neq 0}(2) = 0$ and $F_0(LL'22) = \delta_{LL'}$. In this particularly simple case P_γ reduces to the well known expression of the circular polarization, $(P_\gamma)_{\rm un}$.

(ii) one may prepare a polarized state by choosing $p(M) = \delta_{M0}$ for which $B_{v=1,3}(2) = 0$ and $R_\gamma^{\rm PC}$ part vanishes.

Another observable which measures a PNC effect is the forward–backward asymmetry of the emitted gamma rays by polarized nuclei

$$A_\gamma(A) \equiv \frac{W(\theta) - W(\tau - \theta)}{W(\theta) + W(\tau - \theta)}\,. \tag{26}$$

This observable has been successfully used in the ^{19}F case [25, 26] in order to avoid the small efficiency of the Compton polarimeters when one measures the degree of circular polarization. If the mixing ratios are small (δ_+, $\delta_- \ll 1$) one can show that [20]

$$A_\gamma(\theta) \simeq (P_\gamma)_0 \cdot R_\gamma^{\rm PC}(\cos\theta)\ . \tag{27}$$

The angular distribution described by this formula has a maximum for $\theta = 0^\circ$ [20]. It has the advantage that the parity conserving (PC) circular polarization, $R_\gamma^{\rm PC}(\theta)$ in Eq. (27) can be measured experimentally. For all these cases the $(P_\gamma)_0$ quantity essentially describes the PNC effect. In all the above formulae, θ represents the angle between the emitted photon and the axis of polarization (if any).

4. Shell model predictions for parity mixing matrix element

In order to determine the range and the amplitude of the A_L and A_b around the excitation energy of the 2^+1 excited state in ^{14}N($E_p = 1747.6$ keV), we have made a shell model estimate of the PNC matrix element

$$M_{\mathrm{PNC}} = \sum_{k,s=\pi,\rho,\omega} F_{k,s} M_{k,s} = \left\langle 2^-0, 9.388\,\mathrm{MeV}\, |H_{\mathrm{PNC}}|\, 2^+1, 9.17225\,\mathrm{MeV} \right\rangle . \tag{28}$$

In this purpose, we used the OXBASH code in the Michigan State University version [27] which includes different model spaces and different residual effective two-nucleon interaction [28–45].

A sample of the values for the weak coupling constants are given in Table I, while the values for the $F_{k,s}$-coefficients are given in Table II. The abbreviations DDH, KM, AH and DZ stand for the models developed in Refs. [3, 14, 16] and [15], respectively.

TABLE I

Weak meson-nucleon coupling constants (in units of 10^{-7}) calculated within different weak interaction models. The abbreviations are: KM = Kaiser and Meissner [16], DDH = Desplanques, Donoghue and Holstein [14], AH = Adelberger and Haxton [3] and DZ = Dubovik and Zenkin [15].

$h^{\Delta T}_{\mathrm{meson}}$	KM	DDH	AH(fit)	DZ
h^1_π	+0.19	+4.54	+2.09	+1.30
h^0_ρ	−3.70	−11.40	−5.77	−8.30
h^1_ρ	−0.10	−0.19	−0.22	+0.39
h^2_ρ	−3.30	−9.50	−7.06	−6.70
$h^1_{\rho'}$	−2.20	0.00	0.00	0.00
h^0_ω	−6.20	−1.90	−4.97	−3.90
h^1_ω	−1.00	−1.10	−2.39	−2.20

The abbreviation PSD should be understood as the model space in which $1s_{\frac{1}{2}}$ is filled and the active (valence) particles were restricted to $1p_{\frac{3}{2}}$, $1p_{\frac{1}{2}}$, $2s_{\frac{1}{2}}$, $1d_{\frac{3}{2}}$ and $1d_{\frac{5}{2}}$ orbits. In the calculations presented in this paper, however, the nucleons have been considered to be partially (six nucleons) frozen in the $1p_{\frac{3}{2}}$ orbit, while in the $1d_{\frac{3}{2}}$ and $1d_{\frac{5}{2}}$ we consider up to maximum four nucleons. Within PSDMK, the PSD model space is used, as well as the following interactions:

TABLE II

The expressions of the $F_{k,s}$-coefficients multiplying the matrix elements $M_{k,s}$ given in Table III are reminded in the first column. Numerical values (in units of 10^{-6}) are given for the "best values" of the PNC meson-nucleon couplings in the DDH approach [14], as well as for the values obtained by Kaiser and Meissner [16] and Adelberger & Haxton [3]. The strong coupling constants values ($g_\pi = 13.45$, $g_\rho = 2.79$, $g_\omega = 8.37$) are taken from Ref. [3].

$F_{k,s}$	KM	DDH	AH(fit)
$F_{0,\pi} = \frac{1}{2\sqrt{2}} g_\pi h_\pi^1$	0.090	2.16	0.995
$F_{1,\rho} = -\frac{1}{2} g_\rho h_\rho^1$	0.014	0.027	0.805
$F_{2,\rho} = -\frac{1}{2} g_\rho h_\rho^1 (1+\mu_v)$	0.066	0.127	0.144
$F_{3,\rho} = \frac{1}{2} g_\rho h_\rho^1$	−0.014	−0.027	−0.031
$F_{1,\omega} = -\frac{1}{2} g_\omega h_\omega^1$	0.437	0.480	1.000
$F_{2,\omega} = -\frac{1}{2} g_\omega h_\omega^1 (1+\mu_s)$	0.384	0.423	0.880
$F_{3,\omega} = -\frac{1}{2} g_\omega h_\omega^1$	0.437	0.480	1.000
$F_{4,\rho} = -g_\rho h_\rho^0 (1+\mu_v)$	4.850	14.94	7.566
$F_{5,\rho} = -g_\rho h_\rho^0$	1.032	3.180	1.610
$F_{6,\omega} = -g_\omega h_\omega^0 (1+\mu_s)$	4.568	1.408	3.661
$F_{7,\omega} = -g_\omega h_\omega^0$	5.190	1.6	4.160
$F_{0,\rho} = -\frac{1}{2} g_\rho h_\rho^1$	0.307	0.00	0.00
$F_{8,\rho} = -\frac{1}{2\sqrt{6}} g_\rho h_\rho^2 (1+\mu_s)$	0.886	2.542	1.888
$F_{9,\rho} = -\frac{1}{2\sqrt{6}} g_\rho h_\rho^2$	0.189	0.541	0.402

— for P-space, the Cohen–Kurath interaction [34];

— for SD-space, the Preedom–Wildenthal interaction [35];

— for the coupling matrix elements between P- and SD-spaces, the Millener–Kurath interaction [36].

The PSDMWK uses the same PSD model space, the only difference in comparison with the PSDMK being that, in the SD-space, the Wildenthal [32, 38] interaction is used. For the SU3-interaction (see Ref. [27]), the center of mass components have been removed using the Gloeckner–Lawson [39] procedure.

Since all the components (see *e.g.* [46]) of $H_{\rm PNC}$ are short range two-body operators, to calculate correctly their matrix elements, it is necessary to use shell model wave functions including short range correlations (SRC), bearing in mind that the behavior of the shell model wave functions at short relative NN distances is wrong. The correlations were included by multiplying the harmonic oscillator wave functions (with $\hbar\omega = 16\,{\rm MeV}$) by the Jastrow factor:

$$1 - \exp\left(-ar^2\right)\left(1 - br^2\right); \quad a = 1.1\,{\rm fm}^{-2}; \quad b = 0.68\,{\rm fm}^{-2}, \tag{29}$$

given by Miller and Spencer [47]. This procedure is consistent with results obtained by using more elaborate treatments of SRC such as the generalized Bethe–Goldstone approach [9, 46]. By including SRC, the PNC pion exchange matrix element decreases by $40\% \div 50\%$, while the $\rho\,(\omega)$ exchange matrix elements also decrease by a factor of $3 \div 7$.

To test the standard model, one needs to calculate the weak meson–nucleon vertices. Only a few calculations based on the quark model [14, 15] exist. These calculations start from the observation that there are essentially three types of diagrams, which can be categorized as factorization, quark-model and sum-rule contributions. Renormalization group techniques and baryon wave functions based on models are needed to evaluate them. This introduces a variety of uncertainties, which lead DDH (in Ref. [14]) to introduce a "reasonable range" for the values of the weak meson–nucleon coupling constants. In particular, the weak pion–nucleon coupling constant (h_π) is very sensitive with respect to this uncertainties, for instance, the values of h_π differ by a factor of 3 in Refs. [14] and [15] whereas $h_{\rho(\omega)}$ are more stable. By using a nonlinear chiral effective Lagrangian which includes π, ρ and ω mesons and treating nucleons as topological solitons, Kaiser and Meissner [16] obtained different values for strong and weak meson-nucleon coupling constants as compared to other results [14, 15]. For comparison, we inserted in the calculations of the PNC matrix element above mentioned, the coupling constants of the weak meson-nucleon vertices h_π, h_ρ and h_ω. This coupling constants are listed in Table I, within different models of weak interactions. The first column contains $h_m^{(\Delta T)}$ obtained by Kaiser and Meissner (KM) [16] using the following model parameters: the pion decay constant $f_\pi = 93\,\mathrm{MeV}$, the "gauge" coupling constant $g_{g\pi\pi} = 6$, the pion mass $m_\pi = 138\,\mathrm{MeV}$ and three pseudo-scalar-vector coupling constants. The second column contains the often used Desplanques–Donoghue–Holstein (DDH) [14] "best" values, obtained within a quark plus Weinberg–Salam model. Adelberger and Haxton's values [3] for $h_m^{(\Delta T)}$, obtained by fitting some experimental data, are presented in the third column. In the last column the values obtained by Dubovik and Zenkin (DZ) [15] within a more sophisticated quark plus Weinberg–Salam ($\mathrm{SU}\,(2) \otimes \mathrm{U}\,(1) \otimes \mathrm{SU}\,(3)_c$)- model are included.

The nuclear structure part ($M_{k,s}$) (see Ref. [48]) of the PNC matrix elements, calculated by using the models included in the OXBASH code and short range correlations (SRC), are given in Table III.

TABLE III

The first row presents the single particle contributions to the $M_{k,s}$, the second row — the two particle contributions and the last row — the sum of the two above mentioned (single- and two-particle) contributions giving the total value (in MeV) of the nuclear structure part ($M_{k,s}$) of the PNC matrix element. For the abbreviations concerning different interactions see the text.

Interactions	PSDMK	PSDMWK	SU3PSD
$M_{0\pi}$	−0.2776 −0.1229 −0.4006	−0.2146 −0.1185 −0.3331	0.2069 0.0181 0.2250
$M_{1\rho}$	−0.0111 −0.0183 −0.0294	−0.0085 −0.0151 −0.0236	0.0086 0.0074 0.0160
$M_{2\rho}$	−0.0166 −0.0205 −0.0371	−0.0128 −0.0174 −0.0302	0.0123 0.0040 0.0169
$M_{3\rho}$	−0.0111 −0.0148 −0.0259	−0.0085 −0.0115 −0.0200	0.0025 0.0061 0.0150
$M_{1\omega}$	−0.0105 −0.0172 −0.0246	−0.0080 −0.0142 −0.0222	0.0081 0.0069 0.0150
$M_{2\omega}$	−0.0157 −0.0195 −0.0352	−0.0121 −0.0166 −0.0287	0.0117 0.0044 0.0161
$M_{3\omega}$	−0.0105 −0.0139 −0.0243	−0.0080 −0.0108 −0.0188	0.0081 0.0060 0.0141
$M_{0\rho}$	−0.0166 −0.0159 −0.0325	−0.0128 −0.0132 −0.0260	0.0123 0.0042 0.0166

The values in Table IV have been obtained by multiplying the $M_{k,s}$-quantities presented in the Table III by the $F_{k,s}$-coefficients given in Table II. The partial contribution of the π-exchange meson together the $\rho\,(\omega)$-mesons parts are also shown in Table IV, while in Fig. 1 are plotted the π meson contributions only. As we can see, these contributions are 20% in KM model, in opposition to AH and KM models in which the π mesons play a more important role.

TABLE IV

The PNC matrix element (in eV) calculated within different weak and strong interactions. The abbreviations are discussed in the text.

	DDH			AH			KM		
Interactions	V_π	$V_{\rho(\omega)}$	$V_{\rm tot}^{\rm DDH}$	V_π	$V_{\rho(\omega)}$	$V_{\rm tot}^{\rm AH}$	V_π	$V_{\rho(\omega)}$	$V_{\rm tot}^{\rm KM}$
PSDMK	−0.865	−0.043	−0.909	−0.401	−0.041	−0.442	−0.036	−0.150 (-0.113)	−0.186
PSDMWK	−0.720	−0.032	−0.752	−0.333	−0.030	−0.363	−0.030	−0.118 (−0.090)	−0.148
SU3PSD	+0.487	+0.012	+0.499	+0.225	+0.011	+0.236	+0.020	+0.076 (+0.058)	+0.096

5. Analysis of possible observables for studying the second parity mixed doublet in ^{14}N

In the case of the $^{13}\mathrm{C}\,(\vec{p},\,p_0)^{13}\mathrm{C}$ resonance scattering via the 2^+1, $E_x = 9.17225\,\mathrm{MeV}$ level in ^{14}N it is found that the PNC transition amplitude of 2^+1 level shows a large interference only with those allowed transition amplitudes corresponding to the 2^-0, $E_x = 9.388\,\mathrm{MeV}$ resonance level, while the PC transition amplitudes corresponding to the

$$0^+1,\ E_x = 8.618\,\mathrm{MeV}, \quad 0^-1,\ E_x = 8.776\,\mathrm{MeV}, \quad 1^-1,\ E_x = 8.062\,\mathrm{MeV},$$
$$2^+0,\ E_x = 8.980\,\mathrm{MeV}, \quad 2^-0, E_x = 7.9669\,\mathrm{MeV}, \quad 3^-1,\ E_x = 8.907\,\mathrm{MeV},$$

resonance levels, are incorporated in the background.

From all nonzero PC and PNC T-matrices participating in our scattering process, 26 of the transition matrices $T^{J^\pi}_{pls,p_1l_1s_1}$ are parity conserving (PC) transition amplitudes:

$$\begin{aligned}
t_1 &= \left(T^{0^+1}_{p11,p11}\right)_{8.618}, & t_2 &= \left(T^{0^-1}_{p00,p00}\right)_{8.776},\\
t_3 &= \left(T^{1^-1}_{p01,p01}\right)_{8.062}, & t_4 &= \left(T^{1^-1}_{p01,p21}\right)_{8.062},\\
t_5 &= \left(T^{1^-1}_{p21,p01}\right)_{8.062}, & t_6 &= \left(T^{1^-1}_{p21,p21}\right)_{8.062},\\
t_7 &= \left(T^{2^+0}_{p11,p11}\right)_{8.980}, & t_8 &= \left(T^{2^+1}_{p11,p11}\right)_{9.17225},\\
t_9 &= \left(T^{2^+0}_{p31,p11}\right)_{8.980}, & t_{10} &= \left(T^{2^+1}_{p31,p11}\right)_{9.17225},\\
t_{11} &= \left(T^{2^+0}_{p11,p31}\right)_{8.980}, & t_{12} &= \left(T^{2^+1}_{p11,p31}\right)_{9.17225},\\
t_{13} &= \left(T^{2^-0}_{p31,p31}\right)_{8.980}, & t_{14} &= \left(T^{2^+1}_{p31,p31}\right)_{9.17225},\\
t_{15} &= \left(T^{2^-0}_{p20,p20}\right)_{9.388}, & t_{16} &= \left(T^{2^-0}_{p20,p20}\right)_{7.9669},\\
t_{17} &= \left(T^{2^-0}_{p20,p21}\right)_{9.388}, & t_{18} &= \left(T^{2^-0}_{p20,p21}\right)_{8.9669},\\
t_{19} &= \left(T^{2^-0}_{p21,p20}\right)_{9.388}, & t_{20} &= \left(T^{2^-0}_{p21,p20}\right)_{7.9669},\\
t_{21} &= \left(T^{2^-0}_{p21,p21}\right)_{9.388}, & t_{22} &= \left(T^{2^-0}_{p11,p21}\right)_{7.9669},\\
t_{23} &= \left(T^{3^-1}_{p21,p21}\right)_{8.907}, & t_{24} &= \left(T^{3^-1}_{p21,p41}\right)_{8.907},\\
t_{25} &= \left(T^{3^-1}_{p41,p21}\right)_{8.907}, & t_{26} &= \left(T^{3^-1}_{p41,p41}\right)_{8.907},
\end{aligned}$$

and 8 of them are PNC transition amplitudes:

$$\begin{array}{ll} T_1 = T^{2^-,+}_{p20,p11}\,, & T_2 = T^{2^-,+}_{p21,p11}\,, \\ T_3 = T^{2^+,-}_{p11,p20}\,, & T_4 = T^{2^+,-}_{p11,p20}\,, \\ T_5 = T^{2^-,+}_{p20,p31}\,, & T_6 = T^{2^-,+}_{p21,p31}\,, \\ T_7 = T^{2^+,-}_{p31,p20}\,, & T_8 = T^{2^+,-}_{p31,p20}\,. \end{array}$$

The channel phases are obtained as $\xi_{pls} = \tan^{-1}\frac{F_l}{G_l}$, where F_l and G_l are the regular and irregular scattering wave functions for the M3Y folding potential. The amplitudes of partial channel widths are obtained by using the latest compilation [18] (see Table V) and the theoretical estimations concerning the spectroscopic factors within the shell model code (OBXBASH) [27] are:

$$\theta^{J^\pi}_{pls} = \sum_{nj} \widehat{j}\widehat{s}\,(-1)^{l+s-J}\,W\left(\frac{1}{2}\,\frac{1}{2}\,J\,l;\;s\,j\right)\theta^{(\mathrm{OXBASH})}_{nlj}(J^\pi\,T;\;E(\mathrm{MeV})).$$

TABLE V

The resonance parameters inserted in the calculation of the PNC analyzing powers studied in this paper.

$I^\pi T$	E_p(MeV)	$E^*_{^{14}\mathrm{N}}$(MeV $\pm$ keV)	Γ(keV)	Γ_p(keV)	open channels
2^-0	1.980	9.388 ± 3.0	13 ± 3	13	p
2^+1	1.7476	9.17225 ± 0.12	0.135	0.135 ± 0.008	γ, p
2^+0	1.540	8.980 ± 3.0	8 ± 2	8	γ, p
0^-1	1.320	8.776 ± 7.0	410 ± 20	410	γ, p
0^+1	1.152	8.618 ± 2.0	3.8 ± 0.3	3.8	γ, p
1^-1	0.551	8.062 ± 1.0	23 ± 1	23	γ, p
2^-0	0.4485	7.9669 ± 0.5	0.0025 ± 0.0007	0.0024	γ, p
3^-1	1.462	8.907 ± 3.0	16 ± 2	16	γ, p

In the vicinity of the 2^+1 narrow resonance, the A_L and A_b analyzing powers have the following simple expression:

$$A_{L(b)} = D_{L(b)}\frac{1}{2}\Gamma^{2+}\left(E - E^{2+} + \frac{i}{2}\Gamma^{2+}\right)^{-1}\exp[i(\Phi_{L(b)} + \Phi_{\mathrm{PNC}})]\,, \quad (30)$$

where

$$D_{L(b)} = 2\frac{|M_{\mathrm{PNC}}|}{\left|\left(E - E^{2-} + \frac{i}{2}\Gamma^{2-}\right)\right|}\sqrt{\frac{\Gamma^{2-}_p}{\Gamma^{2+}_p}}\,\left|C_{L(b)}\right|\,, \quad (31)$$

and

$$C_{L(b)} = \left|C_{L(b)}\right| \mathrm{e}^{i\Phi_{\mathrm{PC}}^{L(b)}} = \frac{\left|\left(E-E^{2^-}+\frac{i}{2}\Gamma^{2^-}\right)\right| \sum_l P_l^{(k)}(\cos\theta)\left[\sum_n c_n^l(L(b))\, iC(\theta)\, \tilde{t}_n^* + \sum_{mn} b_{mn}^l(L(b))\left(\tilde{t}_m\, t_n^* + \tilde{t}_m^*\, t_n\right)\right]}{\sqrt{\Gamma^{2^-}\Gamma^{2^+}} \sum_l P_l(\cos\theta) \sum_{mn} a_{mn}^l\, t_m\, t_n^*} \tag{32}$$

is a function on the PC transition matrix elements only (for $L : k = 0$, for $b : k = 1$, $\widetilde{t}_n = T^{2^+1}_{pls,pl_1s_1} \exp i(\xi_{pls} - \xi_{pl's'})$). The coefficients $a_{mn}^{(l)}\,(L\,(b))$, $b_{mn}^{(l)}\,(L\,(b))$, and $c_n^{(l)}\,(L\,(b))$ are simple specific values of the $f^{\,(v,k)}$, $F^{(v,k)}$ geometrical coefficients (see Eqs. (14) and (15)) for the case we are investigating now.

Defining by $\Delta A_{L(b)}$ the distance between the minimum and the maximum of the PNC analyzing powers in the excitation function, we find out that this quantity is equal to $D_{L(b)}$ defined in Eq. (31) and it does not depend on the PNC matrix element phase-Φ_{PNC} and PC quantity phase-Φ_{PC}. The main result of the present paper could be condensed in the following formula:

$$D_{L(b)} = D^0_{L(b)} \sum_{s=\pi,\rho,\omega} V_s^{\mathrm{PNC}}\,(\Delta T) = \sum_{k,s} F_{k,s} M_{k,s}\,, \tag{33}$$

where $V_s^{\mathrm{PNC}}\,(\Delta T)$ (in eV) are different meson contributions to the total PNC shell model matrix element.

The quantity $D^0_{L(b)}$ (in eV^{-1}),

$$D^0_{L(b)} = 2\left(E - E^{2^-} + \frac{i}{2}\Gamma^{2^-}\right)^{-1} \sqrt{\frac{\Gamma_p^{2^-}}{\Gamma_p^{2^+}}}\left|C_{L(b)}\right|\,, \tag{34}$$

has the following values: for $\theta_{\mathrm{cm}} = 120^0$, $D_L^0 = 2.2 \times 10^{-5}\,\mathrm{eV}^{-1}$ and $D_b^0 = 2.04 \times 10^{-5}\,\mathrm{eV}^{-1}$, while for $\theta_{\mathrm{cm}} = 150^0$, $D_L^0 = 0.90 \times 10^{-5}\,\mathrm{eV}^{-1}$ and $D_b^0 = 6.4 \times 10^{-5}\,\mathrm{eV}^{-1}$.

In figure 2 we reproduced on expanded horizontal scale the predicted size of the quantities relevant for an experiment designed to determine the PNC matrix element by measurement of A_L and/or A_b around the narrow 2^+1 resonance. The shell model PNC matrix element has been taken to be equal to 0.5 eV. Results for all the models given in the Table IV can be obtained by a straightforward multiplication. In figure 3 we plotted the angular distribution at the protons energy $E_p = 1.7476\,\mathrm{MeV}$.

Because of the small width of the 2^+1 level ($0.122\,\mathrm{keV}$), the energy anomaly of the PNC analyzing powers (of the order of maximum some units above 10^{-5}) is a nonzero quantity in a very small energy range ($\leq 1\mathrm{keV}$) only, and it is hard to be measured, although not impossible [49].

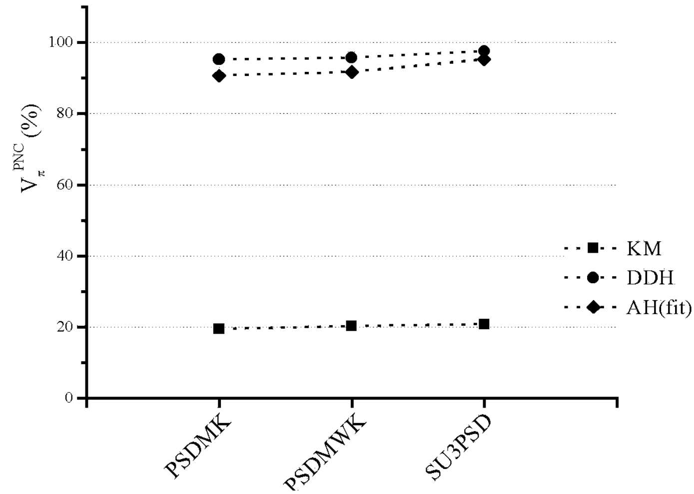

Fig. 1. The π meson contributions (in percents) to the total PNC matrix element (M_{PNC}) within different models of weak and strong interactions. The abbreviations

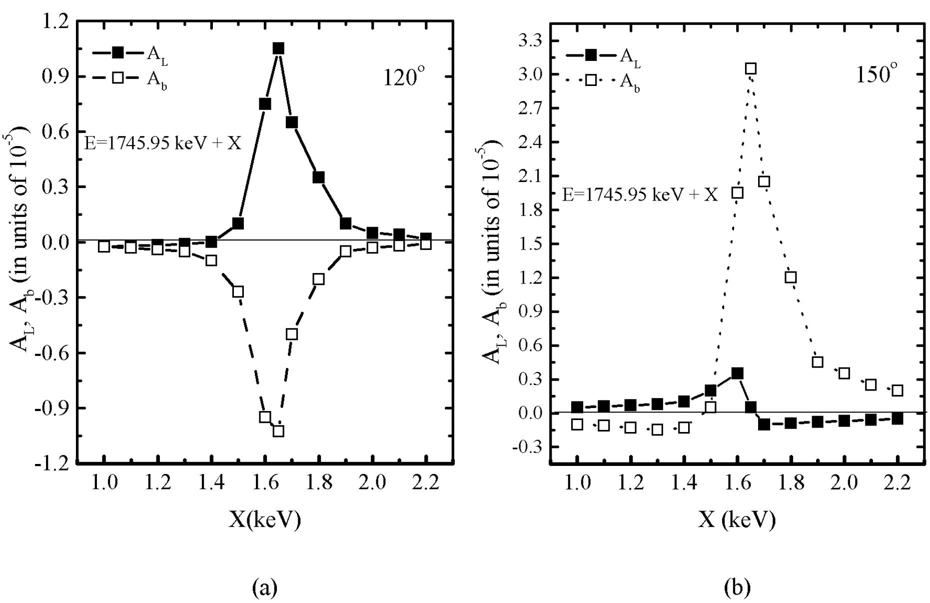

Fig. 2. The predicted size of the irregular analyzing powers ($A_{L(b)}$) reproduced on expanded horizontal scale around the narrow 2^+1 resonance for (a) $\theta = 120^o$ and (b) $\theta = 150^o$($M_{\mathrm{PNC}} = 0.5$ eV).

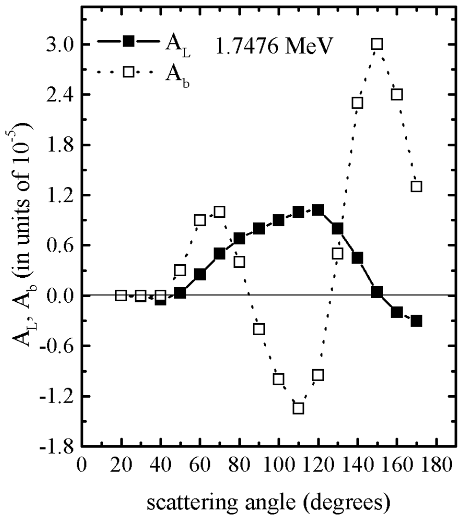

Fig. 3. The predicted size of the angular distributions of the irregular analyzing powers ($A_{L(b)}$) at the narrow $2^{+}1$ resonance ($M_{\rm PNC} = 0.5$ eV).

If considering the $2^{\pm}$ PMD in ^{14}N to be analyzed via circular polarization of 9.388 MeV and 2.3589 MeV γ-rays we came to realize that these observables are $P_\gamma = (0.20 \div 1.89) \times 10^{-3}$ and $P_\gamma = (0.22 \div 2.07) \times 10^{-3}$, respectively, in the case of an unoriented $2^{-}T = 0$ state with zero mixing ratios. These values are obtained by calculating, within OXBASH code (Millener–Kurath interaction), the 9.388 MeV E1 + M2 γ-emission probability $\left(2.886 \times 10^{12}{\rm s}^{-1}\right)$ and the 9.17225 M1 + E2 γ-emission probability $(3.036 \times 10^{16}\ {\rm s}^{-1})$. The gamma width for 9.17225 M1 + E2 γ-transition, calculated with the corresponding emission probability $(3.036 \times 10^{16}\ {\rm s}^{-1})$ is $\Gamma_\gamma = 16.8$ eV and it is in satisfactory agreement with the measured value ($\Gamma_\gamma = 7$ eV) [49]. Unfortunately there is no measured value for the E1 + M2 γ-emission. The high values of the calculated circular polarization are interesting for experiment but, unfortunately, there are important experimental difficulties, because of an almost 100% proton decay probability of the $2^{-}0$, 9.4 MeV-state. The estimated proton flux necessary to produce a gamma asymmetry of 10^{-3} is of the order of 10^{15} protons/cm^2 s, four orders of magnitude larger than in the case of ^{19}F experiment performed in Seattle laboratories. The large parity admixture in the analyzed PMD is still interesting and search for other observables is necessary. Also, interesting could be the analysis of the gamma asymmetry of the gamma rays emitted from the residual ^{14}N-nucleus obtained in the reaction ^{17}O $(\vec{p}, \alpha)^{14}$N.

6. Conclusions

In the excitation spectrum [18] of the ^{14}N nucleus there is an isovector PMD lying at 9.3 MeV excitation energy ($J^{\pi}T = 2^{-}0$, 9.388 MeV; $\Gamma^{2^{-}0} =$ 13 keV and $J^{\pi}T = 2^{+}1$, 9.17225 MeV; $\Gamma^{2^{+}1} = 0.122$ keV) for which the enhancement factor $\sqrt{\frac{\Gamma^{2^{-}0}}{\Gamma^{2^{+}1}}}$ is 10.3. Within OXBASH code, with PSDMK (Millener–Kurath), PSDMWK (Wildenthal) and SU3PSD interactions, we calculated the PNC matrix element, PNC analyzing powers $\left(A_{L(b)}\right)$ and the circular polarization (P_{γ}) of some γ-rays. In this calculations the nucleons have been considered to be partially (six nucleons) frozen in the $1p_{\frac{3}{2}}$ orbit, while in the $1d_{\frac{3}{2}}$ and $1d_{\frac{5}{2}}$orbits we considered up to maximum four nucleons. The maximum in the energy anomaly of the PNC analyzing powers $\left(A_{L(b)}\right)$ we got to be some units above the 10^{-5} (figure 2), value considered to be in agreement with the last measurements [13]. We also calculated the circular polarization of 9.388 and 2.3589 MeV, γ-rays leaving the $2^{-}T = 0$, $E_x = 9.388$ MeV excited state of ^{14}N and populating the ground and respectively the $2^{+}T = 0$, $E_x = 7.02912$ MeV excited state of ^{14}N. Their values are $P_{\gamma} = (0.20 \div 1.89) \times 10^{-3}$ and $P_{\gamma} = (0.22 \div 2.07) \times 10^{-3}$.

The parity mixing between members of the second parity mixed doublet in ^{14}N is of particular interest because:

(1) The mixing is sensitive to the $\Delta T = 1$ components of $H_{\rm PNC}$ and especially to the part describing weak pion exchange, if taking the quark model picture (see Table IV and figure 1). In this case we may have quantitative informations about neutral current contributions to $H_{\rm PNC}$. There are few experiments which are sensitive only to the $\Delta T = 1$ components of the PNC–NN weak interaction and which can be studied with polarized protons. In the ^{20}Ne experiment [50], for example, the PNC longitudinal analyzing power value $[(1.5 \pm 0.76) \times 10^{-3}]$ is, in our opinion, too large. However, the interpretation of this experimental result is clouded by nuclear structure uncertainties.

(2) The observable provides a precise way to measure the PNC matrix elements. The energy anomaly in the PNC analyzing powers A_L and A_b is magnified by nuclear structure effects also, in addition to the 216 keV energy difference between the levels involved in the mentioned doublet and the ratio of the proton widths corresponding to the levels of the PMD. The magnification arises because of coherent contribution of proton PNC channels. The quantity $C_{L(b)}$ is essentially a ratio between the PC T matrix contribution to the PNC analyzing powers and the cross section $\sigma_{\rm unpol.}$ for the (p,p) reaction induced by unpolarized proton beam.

(3) The normal PC analyzing power is negligibly small around 90°.

(4) The PNC p_0-transition can be studied via $^{13}\mathrm{C}\,(\vec{p},\,p_0)^{13}\mathrm{C}$ resonance scattering with two different observables, independently, namely the PNC longitudinal A_L and PNC transverse A_b analyzing powers which sometimes show different energy anomaly as function of the scattering angle (see Fig. 3).

(5) The theoretical models included in the OXBASH code are reasonably good, at least for the levels which are members of the mentioned doublet.

Because of the small width of the 2^+1 level (0.122 keV) the energy anomaly of the PNC analyzing powers (of the order of maximum some units above 10^{-5}) is a nonzero quantity in a very small energy range (≤ 1 keV) only, and it is hard to be measured, although not impossible [49].

The large parity admixture in the analyzed PMD is still interesting and search for other observables is necessary. Also interesting could be the analysis of the gamma asymmetry of the γ-rays emitted from the residual ^{14}N nucleus obtained in the reaction $^{17}\mathrm{O}\,(\vec{p},\,\alpha)^{14}\mathrm{N}$.

The authors would like to thank Prof. B.A. Brown for providing the OXBASH code used in the present investigations.

REFERENCES

[1] S.L. Glashow, G. Iliopoulos, L. Maiani, *Phys. Rev.* **D2**, 1285 (1970).

[2] M. Kobayashi, T. Maskawa, *Prog. Theor. Phys.* **49**, 652 (1973).

[3] E.G. Adelberger, W.C. Haxton, *Annu. Rev. Nucl. Part. Sci.* **35**, 501 (1985).

[4] O. Dumitrescu, *Nucl. Phys.* **A535**, 94 (1991).

[5] O. Dumitrescu, G. Clausnitzer, *Nucl. Phys.* **A552**, 306 (1993).

[6] O. Dumitrescu, G. Stratan, *Nuovo Cim.* **A105**, 901 (1991).

[7] N. Kniest, M. Horoi, O. Dumitrescu, G. Clausnitzer, *Phys. Rev.* **C44**, 491 (1991).

[8] O. Dumitrescu, M. Horoi, F. Carstoiu, G. Stratan, *Phys. Rev.* **C16**, 1462 (1990); preprint ICTP Trieste, IC/89/8 (1989).

[9] M. Gari, *Phys. Rep.* **C6**, 317 (1973).

[10] D. Tadic, *Rep. Prog. Phys.* **43**, 67 (1980).

[11] D. Mihailescu, D. Radu, *Acta Phys. Pol.* **B31**, 2085 (2000).

[12] M. Horoi, G. Clausnitzer, B.A. Brown, E.K. Warburton, *Phys. Rev.* **C50**, 775 (1994).

[13] V.J. Zeps, E.G. Adelberger, A. Garcia, C.A. Gossett, H.E. Swanson, W. Haeberli, P.A. Quin, J. Sromicki, *Phys. Rev.* **C51**, 1494 (1995).

[14] B. Desplanques, J.F. Donoghue, B.R. Holstein, *Ann. Phys. (NY)* **124**, 449 (1980).

[15] V.M. Dubovik, S.V. Zenkin, *Ann. Phys. (NY)* **172**, 100 (1986); V.M. Dubovik, S.V. Zenkin, I.T. Obluchovskii, L.A. Tosunyan, *Fiz. Elem. Chastitz. At. Yadra* **18**, 575 (1987); *Sov. J. Part. Nucl.* **18**, 244 (1987).

[16] N. Kaiser, U.G. Meissner, *Nucl. Phys.* **A489**, 671 (1988); **A499**, 699 (1989); **A510**, 759 (1990); *Mod. Phys. Lett.* **A5**, 1703 (1990).

[17] V.M. Khatsymovsky, Preprint 84–164, Inst. Nucl. Phys. Novosibirsk; Yad. Phys. (USSR) **42**, 1236 (1985); *Sov. J. Nucl. Phys.* **42**, 781 (1985).

[18] F. Ajzenberg-Selove, *Nucl. Phys.* **A523**, 1 (1991); `www.tunl.duke.edu/nucldata`.

[19] E.G. Adelberger, P. Hoodbhoy, B.A. Brown, *Phys. Rev.* **C30**, 456 (1984); **C33**, 1840 (1986).

[20] M. Horoi, G. Clausnitzer, *Phys. Rev.* **C48**, 522 (1993).

[21] M. Preiss, R. Baumann, F. Carstoiu, C. Doerrenbach, O. Dumitrescu, R. Euler, S. Heine, M. Horoi, G. Keil, M. Mildner, E. Pfaff, G. Clausnitzer, A New Parity Mixed Doublet in ^{14}N, Vortragsanmeldung fuer die tagung der Deutschen Physicalischen Gesellsschaft, E.V. vom 24.02 bis 28.02 (1992) in Salzburg, Physik der Hadronen und Kerne.

[22] A.M. Lane, R.G. Thomas, *Rev. Mod. Phys.* **30**, 257 (1958).

[23] G.R. Satchler, *Direct Nuclear Reactions*, Clarendon Press, Oxford-New York 1983.

[24] R.J. Blin-Stoyle, *Fundamental Interactions and the Nucleus*, North-Holland, Amsterdam 1973.

[25] E.G. Adelberger, M.M. Hindi, C.D. Hoyle, H.E. Swanson, R.D. Von Linting, W.C. Haxton, *Phys. Rev.* **C27**, 2833 (1983).

[26] K. Elsener, W. Gruebler, V. Koenig, C. Schweitzer, P.A. Schmeltzbach, J. Ulbricht, F. Sperisen, M. Merdzan, *Phys. Lett.* **B117**, 167 (1982); *Phys. Rev. Lett.* **52**, 1476 (1984).

[27] B.A. Brown, A. Etchegoyen, W.D.M. Rae, M S U–N S C L Report, 524 (1985); B.A. Brown, W.E. Ormand, J.S. Winfield, L. Zhao, A. Etchegoyen, W.M. Rae, N.S. Godwin, W.A. Richter, C.D. Zimmerman, M S U–N S L L Report, Michigan State University version of the OXBASH code, 524 (1988).

[28] B.A. Brown, R. Radhi, B.H. Wildenthal, *Phys. Rep.* **101**, 313 (1983).

[29] J.B. McGrory, B.H. Wildenthal, *Phys. Rev.* **C7**, 954 (1973); *Annu. Rev. Nucl. Sci.* **30**, 383 (1980).

[30] B.A. Brown, W.A. Richter, N.S. Godwin, *Phys. Rev. Lett.* **45**, 1681 (1980).

[31] B.A. Brown, B.H. Wildenthal, *Annu. Rev. Nucl. Part. Sci.* **38**, 29 (1988); *Phys. Lett.* **198B**, 29 (1987); *Phys. Rev.* **C27**, 1296 (1983).

[32] B.H. Wildenthal, *Progr. Part. Nucl. Phys.* **11**, 5 (1984), ed. by D.H. Wikinson, Pergamon-Oxford.

[33] K.K. Seth *et. al.*, *Phys. Rev. Lett.* **33**, 233 (1974).

[34] S. Cohen, D. Kurath, *Nucl. Phys.* **A73**, 1 (1965).

[35] O. Preedom, B.H. Wildenthal, *Phys. Rev.* **C6**, 1633 (1972).

[36] D.J. Millener, D. Kurath, *Nucl. Phys.* **A255**, 315 (1975).

[37] P. Federman, S. Pittel, *Phys. Rev.* **186**, 1106 (1969).

[38] B.A. Brown *et al.*, *Ann. Phys. (N.Y.)* **182**, 191 (1988).

[39] D.H. Gloekner, D.R. Lawson, *Phys. Lett.* **53B**, 313 (1974).

[40] W.C. Haxton, B.F. Gibson, E.M. Henley, *Phys. Rev. Lett.* **45**, 1677 (1980).

[41] M. Bini, P.G. Bizzeti, P. Sona, *Phys. Rev.* **C23**, 1265 (1980).

[42] A.P. Zuker, B. Buck, J.B. McGrory, *Phys. Rev. Lett.* **21**, 39 (1968).

[43] T.T.S. Kuo, G.E. Brown, *Nucl. Phys.* **85**, 40 (1966).

[44] T.T.S. Kuo, *Annu. Rev. Nucl. Part. Sci.* **24**, 101 (1974); *Nucl. Phys.* **A103**, 71 (1967).

[45] B.S. Reehal, B.F. Wildenthal, *Part. Nucl.* **6**, 137 (1973).

[46] O. Dumitrescu, M. Gari, H. Kuemmel, J.G. Zabolitzky, *Z. Naturforsch.* **27A**, 733 (1972); *Phys. Lett.* **35B**, 19 (1971).

[47] G.A. Miller, J.E. Spencer, *Ann. Phys. (N.Y.)* **100**, 562 (1976).

[48] B. Desplanques, O. Dumitrescu, *Nucl. Phys.* **A565**, (1993) 18.

[49] W. Biesiot, Ph.B. Smith, *Phys. Rev.* **C24**, 2443 (1981).

[50] N. Kniest, E. Huettel, E. Pfaff, G. Reiter, G. Clausnitzer, P.G. Bizzeti, P. Maurenzig, N. Taccetti, *Phys. Rev.* **C27**, 906 (1983); J. Ohlert, O. Traudt, H. Waeffler, *Phys. Rev. Lett.* **47**, 475 (1981).