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BASIC SYMMETRIES

M. Simonius

Institut für Mittelenergiephysik der ETH Zürich
CH-8093 Zürich, Switzerland

Contributions to this symposium on basic symmetries are discussed. They concern isospin and charge symmetry breaking including second class currents in weak interaction, parity violation in non-weak processes and time reversal invariance at the strong interaction level.

§1. Introduction

Most of the material discussed here was presented in poster session 6 on basic symmetries but some of the contributions were to be found in session 7. The symmetries addressed are isospin and charge symmetry of strong and weak interaction, parity non-conservation outside β-decay, and time reversal invariance at the strong (or millistrong) level. I shall discuss here only those papers and aspects pertaining to the basic symmetries themselves bypassing contributions addressing nuclear structure problems in connection with isospin breaking etc.

§2. Isospin and Charge Symmetry

2.1. Charge Symmetry

Charge symmetry, i.e. the invariance under the operation $\exp\{i\pi I_2\}$ in isospin space, which interchanges protons and neutrons, requires that in n-p scattering the analysing power A_n and A_p for polarizied initial neutrons and protons be equal, $A_n = A_p$, at the same scattering angle.

Testing this relation has the unique feature not to require a correction for the otherwise important Coulomb point interaction. Experiments have been or are being done at TRIUMF and at the Indiana Cyclotron. The result of the TRIUMF measurement was discussed by Davison[1] in a plenary session and will not be discussed in detail here. I only recall that the problem of absolute polarization normalization for neutrons and protons was bypassed by determining the difference in zero crossing angle for A_p and A_n. The result obtained is of the order of magnitude expected from various corrections (mass differences, magnetic moments and indirect electromagnetic effects) but opposite in sign. The experiment at the Indiana cyclotron[2] looks at the angular distribution of $A_n - A_p$ in order to be independent of the normalization of beam (neutron) and target (proton) polarization. No results are reported yet.

2.2. Charge Independence

At the nuclear interaction level charge independence or isospin symmetry is not as good a symmetry as charge symmetry since it is broken already by the $\pi^{\pm}$-π^{0} mass difference which gives different range to the n-p and p-p or n-n pion exchange interaction. Nevertheless detailed study of charge independence would still be of interest in order to test the completeness of our understanding of its breaking mechanisms. An experiment has been performed at LAMPF[3] comparing proton analysing powers in two isospin related channels in

$$\vec{p} + d \;\begin{cases} \longrightarrow {}^{3}H + \pi^{+} \\ \longrightarrow {}^{3}He + \pi^{0} \end{cases}$$

at 733 MeV incident energy and $\theta_{lab}=12^0$ where the average analyzing power is 0.37. The difference between the two analyzing powers found is $\Delta A=A_y(^3H)-A_y(^3He)=0.018\pm0.005$. ^3H and ^3He are measured alternatively with different setting of the same spectrometer which renders the experiment fairly insensitive to systematic errors. On the other hand, however, it should be clear that the two exit channels have different Coulomb interaction (and masses) for which corrections must be applied which is not a simple task. It is expected that this experiment is sensitive to spin-orbit isospin violation of the forms $[\tau_3(1)-\tau_3(2)]\ (\vec{\sigma}(1)-\vec{\sigma}(2)\cdot\vec{\ell}$ and $[\vec{\tau}(1)\times\vec{\tau}(2)]_3\ (\vec{\sigma}(1)\times\vec{\sigma}(2))\cdot\vec{\ell}$.

2.3. Second Class Currents in β Decay

The quest for second class currents addresses unconventional isospin behaviour of the weak nucleon currents. They are absent in gauge theories of weak and electromagnetic interactions and cannot be obtained from vertex corrections due to isospin invariant strong interactions. Experiments are notoriously difficult. New results for $^{12}B\rightarrow^{12}C$ and $^{12}N\rightarrow^{12}C$ were presented by Minamisono[4] in a plenary session. The result is $f_T/f_W=-0.03\pm0.05$ where f_W represents the weak magnetism term required by CVC (conserved vector current hypothesis) and f_T the second class current contribution. In spite of the great efforts this is not yet a very strong limitation. The theoretical analysis of these measurements is presented in an other contribution to this conference[5].

§3. Parity Violation in Non-Weak Processes

The object of studies of parity violation in the nuclear interaction is to experimentally investigate matrix elements of purly hadronic weak interactions for strongly interacting systems. The emphasis lies on increasing precision in order to obtain restrictive quantitative information on quark model calculations of weak meson-nucleon coupling constants.

3.1. $\vec{p}$-p Scattering at 45 MeV

Two new measurements are reported:

SIN[6] $A_z = (-1.63\pm0.37)\times10^{-7} \rightarrow A_z^{tot}=(-1.7\pm0.4)\times10^{-7}$

Berkeley[7] $A_z = (-1.63\pm1.03)\times10^{-7}$

Here A_z is the longitudinal analyzing power averaged over the acceptance of the apparatus and A_z^{tot} the corresponding helicity dependence of the total nuclear cross section usually analyzed theoretically. The SIN measurement is being continued; its high precision implies besides improved statistics careful re-assessement of systematic uncertainties. I think it is very important that independent measurements be done and the agreement is satisfying. $\vec{p}$-p scattering is sensitive only to vector meson exchange, π-exchange being forbidden by CP invariance.

3.2. ^{18}F; Circular Polarization P_γ of γ-decay

Two new results are reported

Queen's[8] $P_\gamma = (1.6\pm5.6)\times10^{-4}$

Florence[9] $P_\gamma = (2.7\pm5.7)\times10^{-4}$

The previous world total was $(-8\pm10)\times10^{-4}$ leading to a new average $P_\gamma = (1.1\pm3.8)\times10^{-4}$ total.

P_γ here depends only on the ΔI=1 part of the parity violating interaction which is expected to be dominated by π-exchange. The new total then gives a rather low upper limit on the corresponding coupling constant[9]:

$$|f_\pi| \leq 1.5\times10^{-7}$$

The analysis is largely independent of nuclear calculations since the relevant nuclear matrix elements are all determined experimentally from γ- and analog β-decays.

3.3. $\vec{p}+{}^{19}F\rightarrow{}^{20}Ne(J^{\pi}=1^{+},T=1)\rightarrow\alpha+{}^{16}O_{g.s.}$

Measurements are reported[10] of the two parity violating analyzing powers A_x and A_z. Around the resonance in ^{20}Ne these must have a dispersion like behaviour from which its strength A^{PNC} is deduced by a two parameter fit and f_π is extracted using R-matrix theory[10]:

$$A_z \longrightarrow A^{PNC} = (15.0\pm 7.6)\times10^{-4} \qquad f_\pi=(0.5\pm1.8)\times10^{-7}$$

$$A_x \longrightarrow A^{PNC} = (10 \pm10)\times10^{-4} \qquad f_\pi \ (0.3\pm1.1)\times10^{-7}$$

Unlike the case of ^{18}F the analysis has considerable theoretical uncertainty which to some extent is reflected in the error quoted for f_π. More complete calculations should be done; in particular $2\hbar\omega$ excitations should be included as found to be crucial in ^{18}F.

3.4. Theoretical analysis and the parity violating πNN coupling constant f_π.

The previous two sets of experiments place rather stringent limits on f_π. They should be compared to the following theoretical values:

$f_\pi = 4.6\times10^{-7}$	DDH best value[11]
$f_\pi = (0.6\div3.0)\times10^{-7}$	Dubovik and Zenkin[12]
$f_\pi = -(2.5\div5.5)\times10^{-7}$	Nardulli[13]

it should be emphasized that the sign of f_π cannot be determined from ^{18}F since the sign of one of the γ-transition matrix elements is unknown. The new results, however, indicate that the often cited DDH best value is somewhat too large. This is in contrast to results from $\vec{p}$-α, ^{19}F and ^{21}Ne who's analysis yields values consistent with DDH and with a positive sign, where it should be emphasized, however, that this conclusion rests heavily on the theoretical analysis of ^{21}Ne for which no experimental cross-check as for ^{18}F or ^{19}F is available. No "direct" evidence for a non-zero f_π has actually been found yet.

The negative value of f_π predicted by Nardulli[13] is due to the inclusion of a so called continuum contribution calculated dispersion theoretically using Regge theory as input. In the analysis presented to this conference[13] he claims consistency with the data on $\vec{p}$-α, ^{19}F and ^{21}Ne (as well as the old value of ^{18}F). However, agreement is only obtained at the price of large compensation by isovector exchange ρ contribution, $h_\rho^{1\prime} \approx -10^{-5}$. This is completely at odds with general expectation that this coupling is negligible compared to the others which are $O(10^{-7})$. This way out is hardly acceptable.

§4. Time Reversal Invariance in Strong Processes

Time reversal violation has up to now been established ("beyond reasonable doubt") only in neutral K decay and is supposed to be a weak (or superweak) interaction effect though historically so-called millistrong or electromagnetic interactions were considered also as a possible origin. Actually in gauge theories it is not possible to introduce time reversal violation without parity and/or flavour non-conservation at the same level which is $O(10^{-7})$[14]. From the purely experimental point of view, however, the restrictions on time reversal violation in the nuclear interaction are astonishingly weak[15].

4.1. p-p Scattering at 200 MeV

Time reversal invariance implies that $p_y=A_y$ i.e. the polarization p_y, of a proton say produced in a reaction with unpolarized initial states is equal to the analyzing power for a polarized beam of protons in the inverse reaction. This has been checked for the first time at a level below 1 % in p-p scattering in an experiment performed at TRIUMF and reported to this conference[16]: At an incident energy of 200 MeV and 16.5^0 lab. scattering angle a value

$$p_y - A_y = 0.0005 \pm 0.003 \pm 0.002$$

is obtained consistent with zero. Angle and energy were chosen such that the maximal possible effect allowed by the spin flip cross section ratio S is Max=2S≈0.8. The limit obtained is thus 0.011 from the kinematically allowed maximum[16]. A closer look at the possible interpretation of this result shows, however, that it is by far not as significant as this might indicate: Calculations with time reversal violation at the full strong interaction level yield at this energy and angle[17] $p_y - A_y \approx 3$ %, only a factor 3 higher than the experimental limit. While above calculation was based on a specific model due to Sudarshan a general analysis[18] shows that this is the only possible model, essentially, and that suppression of any effect is due to kinematic restrictions implied largely by parity conservation (which is tested to much higher accuracy as seen above), and in the case of p-p scattering the Pauli principle, which together imply that the lowest possible time reversal odd partial wave amplitude is the $^3P_2$-$^1D_2$ transition. Proton proton scattering is unfortunately no good testing ground for time reversal invariance. Indeed a 1 % effect in the measurement above would imply an electric dipole moment of the neutron of the order $\lesssim 10^{-21}$ e.cm as compared to the experimental limit $< 4 \times 10^{-25}$. Thus the electric dipole moment of the neutron gives a roughly three orders of magnitude more stringent limit on time reversal violation in strong interactions than such measurements.

4.2. $P_y(^3He, \vec{p})$ vs. $A_y(\vec{p}, {}^3He)$

Measurements where $p_y(^3He, \vec{p}) \neq A_y(\vec{p}, {}^3He)$ have been presented to the last polarization symposium in Santa Fe. Since then some of the measurements were checked with different results indicating no violation of p=A. Nevertheless, the controversy goes on and arguments supporting time reversal violation in such reactions have been presented to the present conference[19]*. In addition new discrepancies, though not as large, have been reported in $^{13}C(^3He,p)^{15}N$[20]. No definite conclusions can obviously be drawn in view of the controversial nature of the experimental results which should be checked extremely carefully. I repeat my claim above: No time reversal violation has been established "beyond reasonable doubt" except in neutral K decay.

* With respect to the model calculations discussed by Sloboderian showing that p-A may strongly be violated without correspondingly strong violation of detailed balance, it should be noted that in this example parity is violated also. As mentioned before, however, it is the fact that parity is <u>conserved</u> at this level which makes all tests so disappointingly insensitive.

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