SYMMETRY TESTS IN HADRONIC SYSTEMS

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Abstract

A parallel session of the conference was devoted to papers and discussions of symmetries in hadronic systems.

Symmetries are particularly useful for limiting and clarifying dynamics. Many symmetries are not exact and their imperfections can be used to learn about structure as well as dynamics.

In the strong interactions, chiral symmetry and charge independence (internal SU(2)) play a special role. In the strong, electromagnetic, and weak interactions, gauge symmetry plays a very important role. In all but the weak interaction, parity (P), charge conjugation (C) and time reversal (T) are conserved. Their breakdown in the weak interaction has led to the standard model.

The session was devoted primarily to presentations on mechanisms related to the breakdown of charge symmetry. This breakdown is sufficiently small in hadronic systems that theoretical studies can be carried out by means of perturbation theory. I remind the reader that charge symmetry is a weaker symmetry than charge independence. It refers to symmetry under a reflection in the plane perpendicular to the charge axis and passing through the origin of T_3 , where T_3 is the "magnetic" isospin quantum number.

$$C = e^{i\pi T_2} \quad (1)$$

where T_2 is the isospin operator in the 2-direction, (corresponding, e.g., to y in coordinate space), under this symmetry $p \leftrightarrow n$, $\pi^+ \leftrightarrow \pi^-$, $K^0 \rightarrow \bar{K}^0$, etc. The breakdown in charge symmetry is related, in part, to the well-known electromagnetic interaction, and in part to the underlying QCD. The Higgs mechanism is presumed to cause different masses for up and down quarks. At the level of hadrons, the consequences of these effects are $\lesssim 1\%$. Studies of charge independence-, and particularly the smaller charge symmetry (CS)-breaking may thus help connect quark-gluon dynamics to baryon-meson degrees of freedom.

Experimentally, considerable progress has occurred in the past few years. Charge symmetry breaking has been found in the n - p system through polarization studies at TRIUMF [1] and at IUCF [2]. These are the first experiments to uncover CS-breaking class IV forces [3]. More recently the cross section for $dd \rightarrow \alpha\pi^0$ (and $dd \rightarrow \alpha\gamma$) have been determined at Saturne [4]. These experiments have challenged theorists. The n - p results can be explained in terms of γ -exchange, meson mixing, and charge symmetry

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breakdown at meson-nucleon vertices [5]. It is thought that the meson-mixing, in turn, can be understood in terms of the up-down quark mass difference.

At the session, A.W. Thomas and K. Maltman brought up some serious concerns about this understanding. Thomas pointed out that it is assumed that the matrix element $A_{CSB} \equiv \langle \rho^0 | H_{CSB} | \omega^0 \rangle$, where H_{CSB} is the charge symmetry-breaking part of the interaction responsible for ρ - ω mixing, is constant at the value determined on-mass-shell at the ρ - ω mass, even though it is needed far away from the mass shell (at $q^2 < 0$). From analyticity, it is known that A_{CSB} must have a cut beginning at a squared momentum $q^2 = 4m_\pi^2$. Thomas and colleagues (T. Goldman and J.A. Henderson) considered the effect of the graph $\omega \leftrightarrow q\bar{q} \leftrightarrow \rho$ with a form factor at the vertices and found that it gave a value of A_{CSB} at $q^2 < 0$, smaller by about an order of magnitude than its value at $q^2 \approx m_\omega^2$. Thus, the standard result must be taken with a grain of salt.

K. Maltman pointed out that the composite nature of the mesons leads to an energy dependence, which also complicates matters. However, he argued that for π^0 - η mixing, chiral perturbation theory constrains the one-loop amplitude. He has evaluated this amplitude and found a much smaller ($\sim 10\%$) decrease in the mixing matrix from $q^2 = m_\eta^2$ to $q^2 = 0$. He intends to compare the A. Thomas and colleague approach to π - η mixing to compare results to his chiral perturbation finding.

Wim van Oers briefly reviewed the experimental CS-breaking situation in n - p scattering and its sensitivity to various terms in H_{CSB} . Thus at the energy of the first TRIUMF experiment (477 MeV), there is not too great sensitivity to ρ - ω mixing. On the other hand, at the IUCF energy (183 MeV) ρ - ω mixing is much more important and the (constant) on-mass-shell value leads to agreement with experiment [5,6].

J. Niskanen reported on the effect of two pion exchanges, including intermediate nucleons and deltas for the n - p CSB experiments. Fortunately, the effect is found to be relatively small—a few % at IUCF energies, but larger, $\sim 15\%$, at TRIUMF energies.

The discussion of these talks on the n - p polarization experiments and CS was lively, but did not challenge the conclusions of the presenters.

S.N. Yang briefly discussed his calculation of mixed QED-QCD effects, e.g. gluon and photon exchanges, radiative corrections to gluon exchange. These effects, first considered by Stephenson, Maltman, and Goldman [7] affect charge-independence and charge-symmetry-breaking effects.

The chairman was unable to elicit much discussion on parity-violation experiments, despite recent interest on experiments in light nuclei to determine some strangeness matrix elements in nucleons. Nor was there discussion of time reversal or chiral symmetries at the session.

References

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- 4 L. Goldzahl *et al.*, Nucl. Phys. A **533** (1991) 675.
- 5 A Good recent review of the field is given by G.A. Miller, B.M.K. Nefkens and I. Slaus, Phys. Rep. **194** (1990) 1.
- 6 W.T.H. van Oers (invited talk at this conference).
- 7 G.J. Stephenson, Jr., K. Maltman, and T. Goldman, Phys. Rev. D.

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