The New Charge Symmetry

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The traditional formulation of charge symmetry at the nucleon level requires that nuclear (rather than electromagnetic) properties and processes remain unchanged when protons and neutrons are swapped. Charge symmetry between the neutron and proton is broken by the charge, which appears only on the proton, and to a lesser extent by other properties such as the neutron-proton mass difference and the difference in the proton-proton and neutron-neutron scattering lengths (a_{pp}–a_{nn} = 1.5±0.5 fm). Measurements at three energies also show a difference between the analyzing powers for scattering polarized protons from neutrons and polarized neutrons from protons. In all of these cases, the effect is explained by terms incorporated into meson exchange models of the nucleon-nucleon interaction, including isobaric multiplet mass differences (neutron-proton, charged-uncharged pion, etc.) and meson isospin mixing (ρ^0–ω), as well as electromagnetic effects.

In parallel with the nucleon level, charge symmetry also requires that the down and up quarks are interchangeable with no effects on purely nuclear (strong interaction) properties and processes. With the advent of effective field theories based on nucleons and pions as the only constituents, it has become possible to consider charge symmetry breaking effects that arise directly from the difference in the down and up quark masses and electromagnetic effects involving these quarks. These new effects should appear most straightforwardly in charge symmetry breaking reactions that involved pion production. Two new experiments have recently produced results. A group at TRIUMF reports the first measurement of the fore-aft asymmetry of A_{fb} = –0.0017±0.0010 in the cross section angular distribution for n+p →d+π^0. A group at IUCF reports the first observation of the forbidden d+d → ^{4}He+π^0 reaction just above threshold at 228.5 MeV (σ_{TOT} = 12.7±2.2 pb) and 231.8 MeV (σ_{TOT} = 15.1±3.1 pb). The theoretical analysis of these new results is continuing. It is clear that while contributions from the quark mass difference are substantial, it is also essential to include meson isospin mixing effects (π^0–η–η' as well as ρ^0–ω) and other sources of charge symmetry breaking. The status of these efforts and future prospects will be reviewed.