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Quark Model Calculations of Symmetry Breaking in Parton Distributions

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*0.9cm Using a quark model, we calculate symmetry breaking effects in the valence quark distributions of the nucleon. In particular, we examine the breaking of the quark model SU(4) symmetry by color magnetic effects, and find that color magnetism provides an explanation for deviation of the ratio $d_V(x)/u_V(x)$ from 1/2. Additionally, we calculate the effect of charge symmetry breaking in the valence quark distributions of the proton and neutron and find, in contrast to other authors, that the effect is too small to be seen experimentally.

footnote0 footnote Introduction

Symmetries have traditionally played a central role in our understanding of hadrons1. When the symmetry is unbroken, we use it to make predictions without reference to any model for the underlying wavefunctions. Better still, when the symmetry *is* broken we can often use it as a filter with which to study the wavefunction itself, and thus are provided with a sensitive probe of the underlying dynamics.

In this talk, we shall operate in the second of these modes by examining the effect of symmetry breaking on the valence quark distributions of the nucleon. To begin, we give a brief description of the rationale and method used to relate the phenomenological wavefunctions of a quark model to the parton distributions measured in high energy scattering experiments. The following section describes the application of our method to breaking of the quark model SU(4) spin-isospin symmetry by color magnetic interactionsJF, and how this symmetry breaking manifests itself in the well known difference between the u and d valence quark distributions in the nucleon. Finally, we look at the case of charge symmetry breaking by quark mass differences and by electromagnetic effects. This effect has not yet been looked for experimentally, but may play a small role in the determination of $\sin^2\theta_W$ in ν-nucleon scattering2. Although it has been suggested by some authors3 that (relatively) large effects are to be expected, we do not find this to be the case.

Quark Model Valence Distributions

We begin with a statement of the rationale that allows us to use quark models in the study of parton distributions. Clearly, any such attempt cannot consist of a simple evaluation of the relevant matrix elements in terms of quark model wavefunctions, since the only degrees of freedom in those models are the valence quarks and (sometimes) a phenomenological representation of the confining interaction. This picture clashes miserably with the diverse parton distributions required by high energy experiments, which receive large contributions from both gluons and sea quarks. How can these two very different pictures of a hadron be reconciled?

A possible answer lies in the renormalization group approach of Jaffe and Ross4. They argue that at large momentum scales, a hadron is, as the data indicates, a very complicated object. But as the renormalization scale is decreased, most or all of the glue/sea found in the hadron is reabsorbed into the valence quarks until, at very low momentum scales, the picture changes to one in which only a relatively few degrees of freedom are required to describe the hadron. It is this simplified picture which one may reasonably hope to represent by a quark model.

In the calculations described here, we shall adopt this prescription, and proceed by evaluating the twist two contribution to the quark distributions using quark model wavefunctions. The resulting distributions will then be interpreted as the twist two contribution to $q_V(x)$ evaluated at a very low renormalization scale μ_{bag}^2, and next to leading order QCD perturbation theory5 will be used to evolve the distributions to high Q^2, where they can be compared to experiment.

The matrix elements that determine the shape of the valence quark distributions are given by eqnarray

$$\mathrm{q(x)} = 1 \frac{}{4\pi \int d\xi^- \, e^{iq^+\xi^-} <N|\bar{\psi}(\xi^-)\gamma^+\psi(0)|N>|_{LC} \bar{q}(x) = -\frac{1}{4\pi} \int d\xi^- \, e^{iq^+\xi^-} <N|\bar{\psi}(0)\gamma^+\psi(\xi^-)|N>|_{LC}}$$