NN → NNπ AND QUARKS: FORMALISM AND APPLICATION TO np → ppπ⁻ AND pp → dπ⁺

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We have used the resonating-group method to investigate pion production via nucleon-nucleon scattering, i.e. $N + N \rightarrow N + N + \pi$, assuming that pion production takes place effectively at the quark level and ordinary nucleon-nucleon wave functions are interpreted as six-quark states yet to be anti-symmetrized for quarks in two different baryon [three-quark] clusters. As suggested by recent studies of the NN problem, the quark-quark interaction is taken approximately as arising from one-gluon exchange and one-pion exchange. Such formalism leads naturally to classification of pion-emission mechanisms into four distinct categories, viz.: (i) one-nucleon mechanism [ONM] where a pion is emitted from one of the two nucleon clusters; (ii) two-nucleon mechanisms [TNM] where pion emission takes place while the two nucleon clusters exchange a pion [These mechanisms include isobar currents, ρ-π currents, and pair currents.] ; (iii) pion production with quark interchange but without boson exchange; and (vi) pion production with quark interchange in addition to one-gluon or one-pion exchange. Typical diagrams for these mechanisms are illustrated in Figs. (1)-(4), respectively.

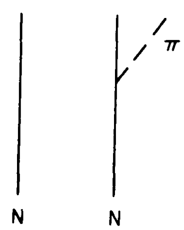

Figure 1. One-nucleon pion production.

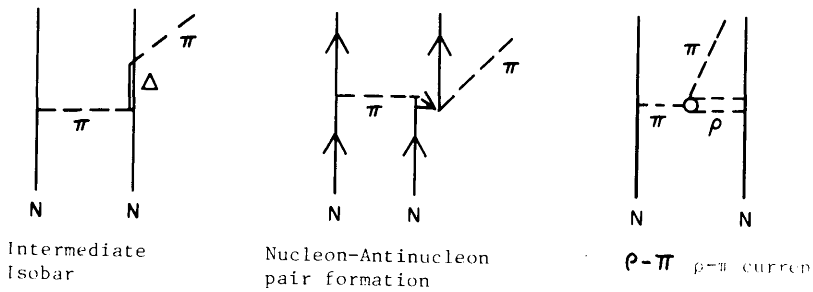

Figure 2. Two-nucleon pion production.

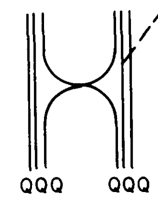

Figure 3. Pion production with quark interchange but without boson exchange.

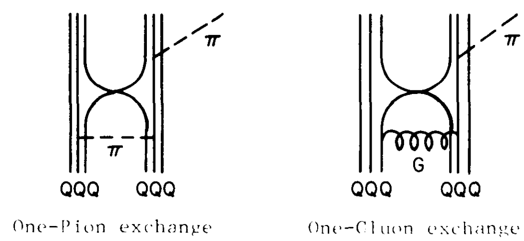

Figure 4. Pion production with quark interchange and boson exchange.

The formalism described above has been applied specifically to $n + p \rightarrow p + p + \pi^-$ and $p + p \rightarrow d + \pi^+$. The first reaction is feasible experimentally at existing laboratories [TRIUMF, SIN, LAMPF] and will be feasible at IUCF when the new Cooler ring comes into operation in 1986. Existing data on the second reaction is being used as a testing ground of the formalism. Spin observables as well as the energy-dependent characteristics of the differential cross sections are calculated in the hope of isolating those effects which are due to reaction mechanisms involving quark interchange [i.e. categories (iii) and (iv) above].

In making numerical predictions for $NN \rightarrow d\pi^+$ we have generated pion distorted waves using an optical potential that fits π-d elastic scattering data.[1] To this end, we have revised an existing code PIRK to get pion wave functions of better numerical accuracy [as well as of known normalizations]. This code has been tested by using optical potentials very close to those obtained previously by other authors[2] to reproduce the existing data for elastic pion scattering from ^{4}He and ^{12}C.

A Reid soft-core potential is used to generate the relevant nucleon-nucleon wave functions. The existing subroutines DELTWVE [originally devised by G.A. Miller at the University of Washington] and COUPLE [originally devised by one of us (Hwang)] are used to generate nucleon-nucleon wave functions from a given potential. Nevertheless, the main task has to do with evaluation of six- or seven-dimensional integrals, which enter a large number of quark-quark amplitudes involving quark interchange. To do this, we have used a Monte Carlo method,[3] which we have tested for integrands having similar characteristics. A large amount of CPU time is required in obtaining results of reasonable accuracy for these integrals. In particular, we wish to obtain [dominant] integrals to within 10% accuracy in carrying out systematic predictions on both reactions mentioned above.

Articles describing the detailed formalism together with numerical predictions are currently in preparation. This work will be a major part of the Ph.D. thesis for one of us [Cao].

1) K. Gabathuler et al., Nucl. Phys. A350, 253 (1980).

2) E.H. Auerbach, D.M. Fleming, and M.M. Sternheim, Phys. Rev. 162, 1683 (1967).

3) Masaaki Sugihara and Kazuo Murota, Mathematics of Computations, 39, No. 160, 549 (1982).