TESTING A $\Delta$-ISOBAR RESCATTERING MODEL OF PION PRODUCTION WITH THE $^3$He$(p,p')^4$He REACTION

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In the proceeding contribution to this annual report, we discuss a microscopic approach to proton-induced exclusive pion production on nuclei at energies well below the $3\pi$-resonance. We focus on these energies because of the wealth of available data and because, from the standpoint of nuclear dynamics, this is the most informative energy regime. There is a price to be paid, however, which results from the complexity of the model near the pion threshold. In contrast to scattering energies near the $3\pi$-resonance, where the $\Delta$-isobar dominates the nuclear dynamics, at very low energies there is no clearly outstanding agency in the reaction mechanism. Consequently, for a quantitative description of the production process, many elements - such as s-wave rescattering, resonant and nonresonant p-wave rescattering, heavy meson-exchange and short range correlations, medium corrections, proton and pion distortions, pionic radiation - to name only the most prominent ones, have to be incorporated in a microscopic model. Besides a dependence on many parameters, the application of such a model requires a large technical apparatus and extensive numerics.

Such a high degree of complexity, both in the formalism and particularly in the coding, necessitates extensive testing. To keep initial tests of the mathematical apparatus and the numerics transparent, we break the model into various pieces and start by applying it to simple nuclear systems. As a first step, we investigate various aspects of the two-nucleon re-scattering model in the context of pion production on $^3$He. Explicitly, we keep only the leading microscopic term involving $\pi$ meson exchange and isobaric degrees of freedom in the baryonic sector. In spite of its reactive character, such a model covers a large portion of the physics of the $(p,p')$ reaction. Beyond that, it represents the most complex piece in the transition amplitude. By applying it to a target and a residual nucleus with dominant is configurations, we obtain a stringent test for the general formulae. Furthermore, this case allows a simple analytical evaluation of the various invariants for comparison with the numerical results from the computer code. Finally, comparison with recent data provides already a first, though crude, test of various ingredients in the isobar rescattering model.

Realistic $^3$He and the $^4$He wave functions involve significant p and d wave components. For a detailed comparison with experiment these subtle pieces in the nuclear wave function should be kept in the transition amplitude. Particularly, the d-state may have a significant influence on both the cross section and the asymmetry. At this stage, however, we keep only the s-wave parts of the nuclear wave functions.

The optical model codes SNOOPY and WPIES were used to generate the proton and pion distorted waves. Both the proton-nucleus and the pion-nucleus optical potentials employed fit elastic scattering data for the corresponding nuclei at the appropriate scattering
energies. For practical purposes, we use the technique
of Charlton$^6$ to expand each partial distorted wave in a
Bessel function series.

Figure 1 shows the results of calculations for the
$^3\text{He}(p,\pi^+)^4\text{He}$ reaction and recent IUCF data.$^3$ The proton
distortions lower the cross section by about a factor
of three, without changing the angular distribution
very much. The pion distortions, on the other hand,
produce a surprisingly large effect, in view of the
fact that most of the momentum sharing is incorporated
microscopically in the two-nucleon reaction mechanism.

![Graph showing calculated and experimental differential
cross sections and analyzing powers for the reaction
$^3\text{He}(p,\pi^+)^4\text{He}$.

Even with this large enhancement, the calculated cross
sections are below the data by a factor of about 10.

The above results show that the resonant $p$-wave
(intermediate $\Delta$) rescattering mechanism does not
dominate the $^3\text{He}(p,\pi^+)^4\text{He}$ reaction at 200 MeV
bombarding energy. Competing processes such as $s$-wave
and non-resonant $p$-wave rescattering, as well as the
one-nucleon mechanism, must be taken into account. The
two-nucleon mechanism is expected to dominate the
one-nucleon mechanism because of the more favorable
momentum sharing; however, recently Sakamoto et al.$^7$
have shown that this is not the case for the
$^4\text{He}(\pi^-,n)^3\text{H}$ reaction (which is related to $^3\text{He}(p,\pi^+)^4\text{He}$
by charge symmetry and time reversal invariance). For
this case, the two mechanisms compete because of
large momentum components of the overlap function
$\langle \omega_3 | \phi_4 \rangle$ which determine the one-nucleon
contribution. Work is in progress to add the
one-nucleon term to our code.

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