

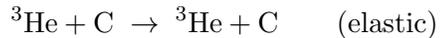
A Remark on Elastic versus Inelastic Contributions in ${}^3\text{He} + \text{C}$ Scattering

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The Problem

In ${}^3\text{He} + \text{C}$ scattering, a carbon recoil detector alone records a sample that is the superposition of two physically distinct processes:



This superposition is called an inclusive measurement, meaning no condition is placed on the forward particles. Because the breakup final state carries a different spin structure than the elastic channel, the analyzing power A_y extracted from the inclusive carbon recoil sample is a cross-section-weighted mixture of the two contributions and cannot in general be equated with the elastic A_y .

As a consequence of averaging over all undetected final states, the inclusive A_y will be reduced relative to the true elastic value, though it may remain sizable. The crucial point is that its absolute value is not known a priori, which means the carbon recoil signal alone cannot determine the absolute beam polarization. Measuring carbon recoils in coincidence with a forward ${}^3\text{He}$ tags the elastic channel specifically, suppresses the breakup contribution, and restores access to the well-defined elastic A_y . This is precisely why the forward detector arm of the polarimeter is indispensable.

Proof of Principle

A concrete demonstration that multi-body final states carry spin observables fundamentally different from two-body elastic reactions is provided by the reaction $pp \rightarrow pp\pi^0$ at 375 MeV, measured at the IUCF Cooler, in what was the first experimental observation of this effect [1]. The author of this note is honored to have been part of that effort.

In a two-body elastic reaction, the longitudinal analyzing power A_z , the component of the analyzing power along the beam axis, is strictly forbidden by two independent symmetry arguments. First, parity conservation combined with time-reversal invariance restricts the allowed single-spin observables to those with a pseudovector character perpendicular to the scattering plane. Second, invariance under reflection in the scattering plane itself requires that any component of the analyzing power lying within that plane must vanish. Together these constraints allow only A_y (normal to the scattering plane) to be non-zero, while $A_z = 0$ is an exact result for any two-body elastic reaction, independent of energy or dynamics.

Once a third particle appears in the final state, the scattering plane is no longer uniquely defined, the reflection symmetry is broken, and A_z becomes allowed. Indeed, values as large as $|A_z| = 0.3$ were observed for specific angle combinations of the outgoing protons, with the signal dominated by interference between s - and p -wave pions in conjunction with nucleon-nucleon P -waves in the final state [1].

The power of the $A_z = 0$ constraint in two-body elastic scattering is well illustrated by its use in searches for parity violation. Because A_z is exactly zero in strong-interaction elastic pp scattering, any non-zero measured value is an unambiguous signal of the weak interaction. Dedicated experiments have exploited this to measure parity-violating longitudinal analyzing powers at the level of $|A_z| \sim 10^{-7}$ [2, 3, 4]. The contrast with the value of $|A_z| \sim 0.3$ observed in the three-body final state is striking, and underscores how completely the character of A_z changes once additional particles enter the final state.

The key lesson for the polarimeter is the same: undetected particles in the final state can alter spin observables substantially and in ways that are not calculable without full knowledge of the reaction dynamics. An inclusive measurement that does not resolve the breakup kinematics is not a reliable substitute for a true elastic coincidence measurement, and the absolute beam polarization cannot be extracted from it without additional assumptions.

References

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