Does Charged-Pion Decay Violate Conservation of Angular Momentum?

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1 Problem

Charged-pion decay, such as $\pi^+ \rightarrow \mu^+ \nu_\mu$, is considered in the Standard Model to involve the annihilation of the constituent quarks, $u\bar{d}$, of the $\pi^+$ into a virtual $W^+$ gauge boson, which materializes as the final state $\mu^+ \nu_\mu$. While the pion is spinless, the $W$-boson is considered to have spin 1, which appears to violate conservation of angular momentum.

What’s going on here?

2 Solution

I don’t have a solution for this puzzler.

My colleague Steve Gubser notes that the $W$-boson gets its mass from the Higgs field, whose quanta are considered to be spinless, so in some sense the nominally spin-1 $W$-boson is associated with spin-0 particles.

Your challenge is to expand such comments into an actual solution.\(^1\)

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\(^1\)Gubser’s comments seem to be supported by N. Nakanishi, *T*-Product and False Nonconservation of Angular Momentum in the Pion Decay, Mod. Phys. Lett. A 17, 89 (2002), [http://physics.princeton.edu/~mcdonald/examples/EP/nakanishi_mpla_17_89_02](http://physics.princeton.edu/~mcdonald/examples/EP/nakanishi_mpla_17_89_02). There it is argued that charged-pion decay does not take place via the $W$ boson, but via a massless, spinless Nambu-Goldstone boson that arises from the Higgs mechanism.