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Dimuons in Neutrino Telescopes: New Predictions and First Search in IceCube

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Neutrino telescopes allow powerful probes of high-energy astrophysics and particle physics. Their power is increased when they can isolate different event classes, e.g., by flavor, though that is not the only possibility. Here we focus on a new event class for neutrino telescopes: dimuons, two energetic muons from one neutrino interaction. We make new theoretical and observational contributions. For the theoretical part, we calculate dimuon production cross sections and detection prospects via deep-inelastic scattering (DIS; where we greatly improve upon prior work) and W-boson production (WBP; where we present first results). We show that IceCube should have ⊠400 dimuons (⊠8 from WBP) in its current data and that IceCube-Gen2, with a higher threshold but a larger exposure, could detect ⊠1200 dimuons (⊠30 from WBP) in 10 years. These dimuons are almost all produced by atmospheric neutrinos. For the observational part, we perform a simple but conservative analysis of IceCube public data, finding 19 candidate dimuon events. Subsequent to our paper appearing, visual inspection of these events by the IceCube Collaboration reveals that they are not real dimuons, but instead arise from an internal reconstruction error that identifies some single muons crossing the dust layer as two separate muons. To help IceCube and the broader community with future dimuon searches, we include the updated full details of our analysis. Together, these theoretical and observational contributions help open a valuable new direction for neutrino telescopes, one especially important for probing high-energy QCD and new physics.

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