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Direct detection experiments search for nuclear recoil events induced by the non-relativistic scattering of Milky Way dark matter (DM) particles in low-background detectors. Current strategies for the experimental analysis and theoretical interpretation of direct detection experiments focus on two parameters: the DM particle mass, and the cross-section for DM-nucleon scattering computed under the assumption of spin-independent or spin-dependent DM-nucleon interactions. In this framework, the DM particle spin remains unconstrained. In my talk, I introduce two new analysis strategies relying on the most general classification of single mediator models for DM-quark interaction. A first strategy potentially allows to extract the DM particle spin in the presence of a signal at direct detection experiments with directional sensitivity. A second strategy shows that a signal at XENONnT together with the detection, or lack of detection, of a mono-jet signal at the LHC Run 3 would significantly narrow the range of possible DM interactions and spins.

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