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Recent progress on TMDs and PDFs of spin-1 hadrons

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There was recent theoretical progress on transverse-momentum-dependent parton distribution functions (TMDs) and parton distribution functions (PDFs) for spin-1 hadrons at twists 3 and 4. We expect that the field of structure functions for spin-1 hadrons will become an interesting topic in 2020's and 2030' due to experimental projects at the Jefferson Laboratory, the Fermilab, the NICA, the LHCspin, and the electron-ion colliders in US and China.

We explain TMDs and PDFs for spin-1 hadrons up to twist 4 [1,2,3]. Decomposing a quark correlation function with the conditions of the Hermiticity and parity invariance, we found 30 new structure functions at twists 3 and 4 [1]. There are also new fragmentation functions in the spin-1 hadrons. Integrating the TMDs over the transverse momentum, we found new collinear PDFs. A twist-2 relation and a sum rule exist for the tensor-polarized PDFs f_{1LL} and f_{LT} [2]. In these studies, we also showed that twist-3 multiparton distribution functions F_{LT}, G_{LT}, $H_{LL}^{\perp}$, and H_{TT} exist for tensor-polarized spin-1 hadrons. Relations among these collinear parton- and multiparton-distribution functions were derived by using the equation of motion for quarks [3]. Useful relations were obtained (1) for the twist-3 PDF f_{LT}, the trasverse-momentum moment PDF $f_{1LT}^{(1)}$, and the multiparton distribution functions $F_{G,LT}$ and $G_{G,LT}$; (2) for the twist-3 PDF e_{LL}, the twist-2 PDF f_{1LL}, and the multiparton distribution function $H_{G,LL}^{\perp}$. There is also a Lorentz-invariance relation for $f_{1LT}^{(1)}$, f_{1LL}, f_{LT}, and $F_{G,LT}$. These studies will be useful in future investigations on the spin-1 structure functions.

[1] S. Kumano and Qin-Tao Song, Phys. Rev. D 103 (2021) 014025.
[2] S. Kumano and Qin-Tao Song, JHEP 09 (2021) 141.
[3] S. Kumano and Qin-Tao Song, Phys. Lett. B 826 (2022) 136908.

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