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Transverse Quark Spin Effects in SIDIS and Drell Yan Scattering

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The connection between quark orbital angular momentum and final state interactions for transversely polarized quarks in unpolarized hadrons suggests significant azimuthal asymmetries in pion production in semi-inclusive deep inelastic scattering (SIDIS) ($e p \rightarrow e' X \pi$) as well as in di-lepton production in Drell Yan ($p \bar{p} \rightarrow \ell^+ \ell^- X$ and $\pi^- p \rightarrow \ell^+ \ell^- X$) scattering. When transverse momentum of the reaction, P_T is on the order of or less than Λ_{qcd} , that is $P_T \sim k_T$ where k_T is intrinsic transverse quark momentum, these effects are characterized in term of naive time reversal odd (so called T -odd) transverse momentum dependent (TMD) parton distribution and fragmentation functions. At these moderate transverse momentum scales we estimate the size of the $\cos 2\phi$ azimuthal asymmetry in SIDIS and Drell Yan scattering in the parton spectator framework. In the former case we consider this so called “Boer-Mulders” effect for a proposed experiment at the upgraded CLAS-12 GeV detector at Jefferson LAB. In the latter case we consider this asymmetry for proton anti-proton collider, as well as π nucleon fixed target experiments. We also consider competing contributions to these asymmetries from perturbative QCD (pQCD) contributions which emerge when $P_T > \Lambda_{\text{qcd}}$. Evidence of a strong dependence on transverse momentum would indicate the presence of T -odd structures in *unpolarized* SIDIS and Drell Yan scattering, implying that transversity properties of the nucleon can be accessed without invoking beam or target polarization.