SINGLE SPIN ASYMMETRIES IN $p^\uparrow p$, $\bar{p}^\uparrow p$ INCLUSIVE PROCESSES

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Single spin asymmetries in $p^\uparrow(\bar{p}^\uparrow)\,p \to \pi\,X$ have been measured to be large. They can be understood within perturbative QCD by introducing new $\boldsymbol{k}_\perp$ and spin dependences in fragmentation and/or distribution functions. We discuss first how these effects in distribution functions alone can account for existing data and predict single spin asymmetries in other processes; then we see how similar effects in fragmentation functions alone can fit the existing data; finally we devise strategies to discriminate between the two contributions.

We have recently presented a formalism to evaluate single spin asymmetries (SSA) in inclusive particle production at high energy and moderately large p_T [1,2]. This formalism is based on the parton model approach and on factorization theorems, generalized to polarized reactions and to the inclusion of transverse momentum effects in the partonic distributions of the initial, polarized proton (the so-called "Sivers" effect). This requires the introduction of a new, soft, nonperturbative distribution function (non-diagonal in the helicity basis), $\Delta_N \tilde{f}$. It has been shown [1] how recent experimental results on SSA for pions in the fragmentation region [3] can be well reproduced by opportunely parametrizing $\Delta_N \tilde{f}$. This fit to $\Delta_N \tilde{f}$ has been in turn used to give predictions for SSA in several other interesting processes [2].

In this contribution we present a complete generalization of our formalism, with the inclusion of partonic transverse momentum effects *both* in the partonic distributions of the initial polarized hadron (Sivers effect) *and* in the fragmentation process (the so-called "Collins" effect). Due to space limitations, we only give the final result of our formalism, in the case of $p^\uparrow p \to \pi\,X$ processes. A more detailed discussion will be presented elsewhere [4] (see also Ref.s 1,2). At leading order in transverse momentum effects, we have:

$$2\,\frac{E_\pi\, d\sigma^{p^\uparrow p\to\pi\,X}}{d\boldsymbol{p}_\pi}\,A_N(p^\uparrow p\to\pi+X)\simeq$$
$$\sum_{abcd}\int\frac{dx_a dx_b}{\pi z}\,d^2\boldsymbol{k}_\perp\,\Delta_N\tilde{f}_{a/p^\uparrow}(x_a,\boldsymbol{k}_\perp)\,f_{b/p}(x_b)\,\frac{d\hat{\sigma}^{ab\to cd}}{d\hat{t}}(x_a,x_b,\boldsymbol{k}_\perp)\,D_{\pi/c}(z)$$

$$+\sum_{abcd}\int \frac{dx_a dx_b}{\pi z}\, d^2\boldsymbol{k}'_\perp\, \Delta_T f_{a/p}(x_a)\, f_{b/p}(x_b)\, \Delta_{NN}\hat\sigma(x_a,x_b,\boldsymbol{k}'_\perp)\, \Delta_T\tilde D_{\pi/c}(z,\boldsymbol{k}'_\perp) \tag{1}$$

The second line in Eq. (1) accounts for effects in the distribution functions (Sivers effect). It contains a new, soft distribution, $\Delta_N\tilde f_{a/p^\uparrow}(x_a,\boldsymbol{k}_\perp) \equiv \tilde f_{a/p^\uparrow}(x_a,\boldsymbol{k}_\perp) - \tilde f_{a/p^\uparrow}(x_a,-\boldsymbol{k}_\perp)$, which depends on the transverse momentum $\boldsymbol{k}_\perp$ of parton a inside the polarized proton $p^\uparrow$. Notice that $\Delta_N\tilde f_{a/p^\uparrow}$ is an odd function of $\boldsymbol{k}_\perp$, so that the Sivers effect vanishes if we let $\boldsymbol{k}_\perp \to 0$: we have to take into account $\boldsymbol{k}_\perp$ effects also in the elementary partonic cross section, which makes the total effect a twist-three contribution. At leading order in transverse momenta, we can neglect in this term $\boldsymbol{k}'_\perp$ effects in the fragmentation. Analogously, the third line in Eq. (1) refers to the Collins effect in the fragmentation process. Here we can in turn neglect $\boldsymbol{k}_\perp$ effects in the distribution functions. $\Delta_T\tilde D_{\pi/c}(z,\boldsymbol{k}'_\perp) \equiv \tilde D_{\pi/c^\uparrow}(z,\boldsymbol{k}'_\perp) - \tilde D_{\pi/c^\uparrow}(z,-\boldsymbol{k}'_\perp)$ plays the same role of $\Delta_N\tilde f_{a/p^\uparrow}$, this time in the $c^\uparrow \to \pi + X$ fragmentation process. Due to the initial polarized proton, the Collins contribution is more complicated than the Sivers' one. In particular, it involves the so-called transversity distribution $\Delta_T f_{a/p}$ (or h_1) for parton a inside the transversely polarized proton (also unknown) and $\Delta_{NN}\hat\sigma \equiv d\hat\sigma^{a^\uparrow b\to c^\uparrow d}/d\hat t - d\hat\sigma^{a^\uparrow b\to c^\downarrow d}/d\hat t$.

A simplified version of Eq. (1) is used for practical calculations [1,2]. We consider only valence parton contributions to $\Delta_N\tilde f$ and $\Delta_T D$, which is quite resonable, in particular in the fragmentation region where sizeable SSA are observed [3]. Moreover, the full dependence on transverse momentum (both for $\boldsymbol{k}_\perp$ and $\boldsymbol{k}'_\perp$) is simplified by introducing a fixed, average transverse momentum, which sets the relevant physical scale for the overall effect. The explicit x_a (z) dependence in $\boldsymbol{k}_\perp$ ($\boldsymbol{k}'_\perp$) can be deduced from theoretical information or extrapolated from experimental data. The residual x_a (z) dependence in $\Delta_N\tilde f$ ($\Delta_T D$) is in turn parametrized by simple functions of the form $Nu^a(1-u)^b$, where $u = x_a$ or z.

It has been shown [1,2] that Sivers effect alone is able to reproduce the pion SSA with quite a reasonable parametrization for $\Delta_N\tilde f$. In Fig. 1 we show preliminary results indicating that a comparatively good fit to the data can be obtained when only Collins effect is active.

It is difficult, however, with the presently limited amount of experimental information, to understand if and to what extent one of the two contributions is more effective than the other in a given process. To this end, more experimental data are clearly required on different processes. A possible strategy which can help in discriminating between Sivers and Collins effect is the following: *i)* One can first consider the process $p^\uparrow p \to \gamma X$. In this case there is no Collins

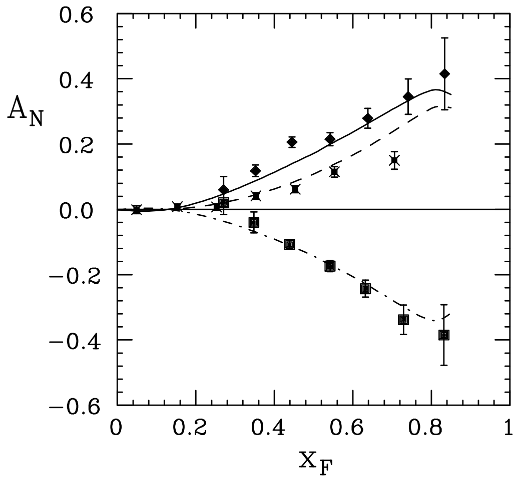

Fig. 1: Fit to experimental data on pion single spin asymmetry with the Collins contribution; the upper, middle, and lower sets of data and curves refer respectively to π^+, π^0, and π^-.

contribution at all, and the process gives information on $\Delta_N \tilde{f}$. Predictions for this process have been given (with $\Delta_N \tilde{f}$ coming from the fit to pion data, when only Sivers effect is active) [2]. *ii)* As a second step, one can consider meson production in semi-inclusive polarized DIS, *e.g.* $\ell p^\uparrow \to \ell' \pi X$. In this case Sivers effect is ruled out by necessary initial state interactions, and one can get unambiguous information regarding Collins contribution and $\Delta_T D(z)$. Work in this direction is in progress. *iii)* Finally, one can again consider meson production, *e.g.*, $p^\uparrow p \to \pi X$, etc., and check if and to what extent a simultaneous fit of the three processes is possible, with physically reasonable parametrizations of $\Delta_N \tilde{f}$ and $\Delta_T D(z)$.

Let us stress that our formalism is the only one that consistently accounts for two of the possible mechanisms suggested as explanation for sizeable SSA in the fragmentation region. A combined theoretical and experimental analysis of several processes involving different final particles should allow to discriminate between Sivers and Collins effect and help to test our model and other alternative proposed models.

References

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