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UNDERSTANDING THE TRANSVERSE TARGET SINGLE SPIN ASYMMETRIES AT HERMES

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The HERMES data on transverse target single spin azimuthal asymmetries are confronted with results from our approach which was able to explain satisfactorily data from longitudinal target single spin asymmetries.

1 Introduction

The azimuthal single spin asymmetries (SSA) in semi-inclusive deeply inelastic scattering (SIDIS) [1,2,3] are a rich source of information on new distribution and fragmentation functions – among others the chirally odd $h_1^a(x)$, $h_L^a(x)$ and $e^a(x)$ [4], the "naively time reversal odd" Sivers function [5,6], and the chirally and "time reversal odd" Collins fragmentation function [7]. The longitudinal SSA observed by HERMES [1] and CLAS [2] are power suppressed ("twist-3") effects and their theoretical description is involved [8]. Transverse target SSA seem easier to describe theoretically. However, only most recently first preliminary results were reported [9,10]. Therefore the challenge to understand SSA in SIDIS began with the more involved longitudinal target SSA [11,12,13]. In this proceeding we shall critically review the attempts made in [13,14] in light of the recent HERMES data. Since the data [9] are preliminary our discussion is to be understood as intermediate resumee.

2 Longitudinal SSA

Fig. 1 shows how the HERMES data [1] are described in the approach of [13] which is based on the following ingredients. (i) Assumption that the process factorizes, is due to Collins effect and the tree-level description [8] applies. (ii) A simplified description of transverse momenta as $f(x,\mathbf{k}_T^2) \approx f(x)G(\mathbf{k}_T^2)$. This would not be necessary if the counting rates were adequately weighted [8]. (iii) Predictions for $h_1^a(x)$ and $h_L^a(x)$ from chiral quark-soliton model [15] and instanton vacuum model [16] which is a consistent and successful field theoretical approach [17]. (iv) Neglect of unfavoured fragmentation with $\langle H_1^{\perp\rm fav}\rangle/\langle D_1^{\rm fav}\rangle \approx (12-14)\%$ for $\langle z\rangle = 0.4$ at HERMES [13] which is not unreasonable in view of the results from DELPHI [18] or the model calculation [19].

As demonstrated in Fig. 1 this approach, which has no adjustable parameters, yields a satisfactory description – though it soon became clear that the assumption "the process is due to Collins effect only" is not correct: The Sivers effect contributes also to $A_{UL}^{\sin\phi}$ [6]. Since it seems possible to nicely describe the HERMES data [1] in terms of the Collins effect only, does it then mean that the Sivers effect is small?

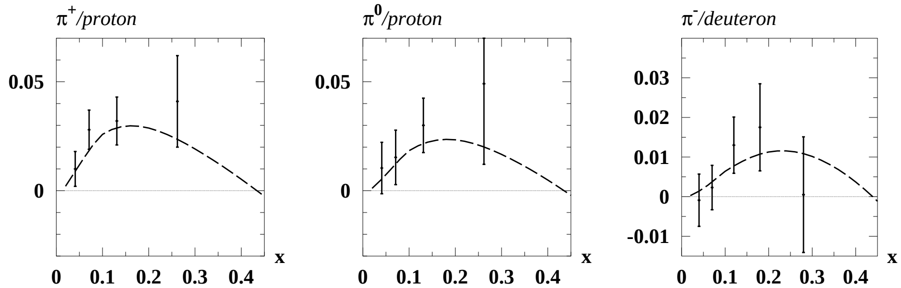

Figure 1. The longitudinal target azimuthal SSA $A_{UL}^{\sin\phi}$ in the production of π^+ and π^0 from a proton and π^- from a deuteron target. Data are from [1], theoretical curves are from [13].

Possibly yes [20]. However, as observed in [21], the contribution of the Sivers effect could not resolved within error bars of the data [1] even if the Sivers function were as large as allowed by model independent positivity bounds [22].

Let us mention that encouraging preliminary data from CLAS indicate a negative $A_{UL}^{\sin 2\pi}$ for π^+ [23] as in our approach [13]. On the basis of this understanding of longitudinal target SSA in [24] a first extraction of $e^a(x)$ from the CLAS data on $A_{LU}^{\sin\pi}$ [2] was attempted. The analysis of [24] could be, however, incomplete. Previously unconsidered distribution functions seem of importance also here [25].

3 Sivers effect transverse target SSA

Preliminary results from HERMES [9] indicate that the Sivers effect is not small. In Fig. 2 we compare the preliminary HERMES data with the parameterization of the Sivers function obtained by Anselmino *et al.* [26] assuming that the SSA in $p^\uparrow p \to \pi X$ is due to the Sivers effect only. Considering that there are competing mechanisms [7,27] in this reaction one finds the effects comparable, cf. Fig. 2.

The size of the effect hints at that the "$A_{UL}^{\sin\phi}$-without-Sivers-effect-analyses" [11,12,13] should be reconsidered.

4 Collins effect transverse target SSA

Based on our understanding of the longitudinal target SSA [13] we made estimates for the Collins effect transverse target SSA $A_{UT}^{\sin(\phi+\phi_s)}$ [14]. Of course, since the theoretical description of the power suppressed ("twist-3") longitudinal SSA [13] is involved and we made simplifications, which are difficult to control, one cannot expect that we accurately predict the overall magnitude of the effect. However, one could have a certain confidence that the *shape* of $A_{UT}^{\sin(\phi+\phi_s)}(x)$ is described satisfyingly, as it is dictated by the model prediction for $h_1^a(x)$ [15] and the approximation of favoured flavour fragmentation only. As can be seen in Fig. 3 our results [14] do not even describe the shape of the preliminary HERMES data [9]. Why not?

Apparently some assumption(s) we made must be incorrect. The first suspicion is favoured fragmentation [9].

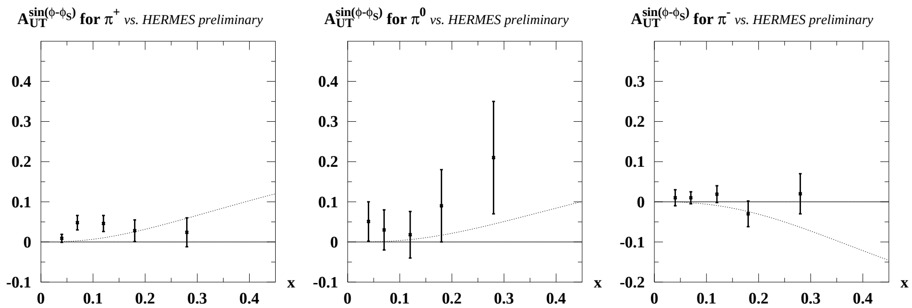

Figure 2. The Sivers effect transverse target SSA $A_{UT}^{\sin(\phi+\phi_s)}$ in the production of π^+, π^0 and π^- from a proton target. *Preliminary* data are from [9], theoretical curves from [14].

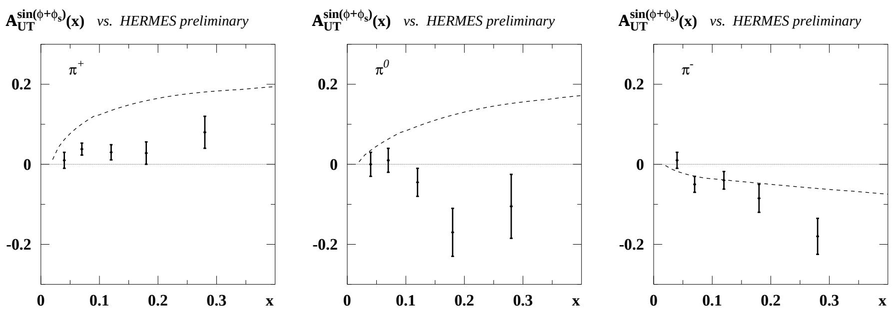

Figure 3. The Collins effect transverse target SSA $A_{UT}^{\sin(\phi+\phi_s)}$ in the production of π^+, π^0 and π^- from a proton target. *Preliminary* data are from [9], theoretical curves from [14].

5 Favoured vs. unfavoured Collins fragmentation

Charge conjugation and isospin invariance relate pion fragmentation functions as

$$H_1^{\perp u/\pi^+} = H_1^{\perp \bar{d}/\pi^+} = H_1^{\perp d/\pi^-} = H_1^{\perp \bar{u}/\pi^-} \equiv H_1^{\perp \rm fav}\ , \tag{1}$$

$$H_1^{\perp d/\pi^+} = H_1^{\perp \bar{u}/\pi^+} = H_1^{\perp u/\pi^-} = H_1^{\perp \bar{d}/\pi^-} \equiv H_1^{\perp \rm unf}\ , \tag{2}$$

$$H_1^{\perp u/\pi^0} = H_1^{\perp \bar{u}/\pi^0} = H_1^{\perp d/\pi^0} = H_1^{\perp \bar{d}/\pi^0} \stackrel{!}{\equiv} \frac{1}{2}(H_1^{\perp \rm fav} + H_1^{\perp \rm unf})\ . \tag{3}$$

A comment is in order on relation (3). Of course, there is only *favoured* fragmentation of the flavours u, $\bar{u}$, $d, \bar{d}$ into a π^0. Nevertheless, as a consequence of flavour SU(2) symmetry, the "favoured" π^0 fragmentation is given as the average of favoured and *unfavoured* $\pi^\pm$ fragmentation functions.[a]

Let us focus on the SSA for π^0 which according to Eq. (3) is given by

$$\underbrace{A_{UT}^{\sin(\phi+\phi_s)}(\pi^0)}_{<0 \text{ in experiment}} \propto \underbrace{\textstyle\sum_a e_a^2 h_1^a(x)}_{>0 \text{ in models}} \langle H_1^{\perp \rm fav} + H_1^{\perp \rm unf}\rangle \quad \Longrightarrow \quad \langle H_1^{\perp \rm fav} + H_1^{\perp \rm unf}\rangle < 0\ , \tag{4}$$

where $\langle \ldots \rangle$ means the average over $0.2 \le z \le 0.7$ at HERMES.

[a] In the talk presented at the conference this point was treated incorrectly.

If we combine the experimental observation that the π^0 SSA is negative, cf. Fig. 3, and the observation that in all available models the "structure function" $\sum_a e_a^2 h_1^a(x)$ is positive, then we arrive at the remarkable conclusion that the sum of favoured and unfavoured Collins fragmentation functions is negative, c.f. Eq. (4).

In order to explain SSA of charged pions the option $H_1^{\perp\rm fav} < 0$ can be ruled out, unless $(4h_1^u + h_1^{\bar d}) < (h_1^d + 4h_1^{\bar u})$ which would contradict models, e.g. [15]. Thus, the option $H_1^{\perp\rm fav} > 0$ is clearly preferred – as was so far commonly assumed [7,11,12,13] or observed in the model calculation of Ref. [19].

Then, with the remaining option $H_1^{\perp\rm fav} > 0$, we can draw two interesting conclusions from the observation in Eq. (4). Firstly, $H_1^{\perp\rm unf}$ has opposite sign with respect to $H_1^{\perp\rm fav}$. This could have a natural explanation, in particular in the HERMES kinematics with low particle multiplicity jets [9]. Secondly, the absolute value of $H_1^{\perp\rm unf}$ has to be larger than the absolute value of $H_1^{\perp\rm fav}$ which, if confirmed, will be more difficult to understand.

6 Conclusions

The present situation is paradoxical. We have a reasonable understanding of A_{UL} SSA, but we know that it possibly is based on an incomplete theoretical description of the process – with the Sivers effect and other contributions omitted. We probably have a complete description of the A_{UT} SSA, but cannot understand the *preliminary* data – unless the Collins fragmentation function exhibits unexpected properties.

However, one should keep in mind the preliminary stage of the data [9], which does not allow yet to draw definite conclusions. Further data from HERMES as well as COMPASS, CLAS, HALL-A and HALL-B experiments will contribute considerably to resolve the present puzzles and pave the way towards a qualitative and quantitative understanding of the numerous new distribution and fragmentation functions.

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