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Extraction of Collins Function and Transversity Distribution from e^+e^- Annihilation and SIDIS Data

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In this talk, we present our newest numerical result about collins function and transversity parton distribution. We extract them from the experimental data of e^+e^- annihilation to di-hadron and semi-inclusive deep inelastic scattering(SIDIS) processes.

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1. introduction

Transverse momentum dependent(TMD) parton distributions have always been an important object for our understanding the strong interaction physics and the fundamental properties of nucleon. Among them, the collins fragmentation function [1] has attracted great interests from nuclear physics community. It describes the possibility that a transverse polarized parton goes to a hadron, which leads to the collins azimuthal angle asymmetries in the SIDIS and e^+e^- to di-hadron processes. This collins effect has been observed by the HERMES, COMPASS, JLAB, BELLE and BARBAR collaborations. Especially, measuring the Collins azimuthal asymmetries in SIDIS can also be used to investigate the quark transversity distribution which describes transversely polarized pardon density in one transversely polarized hadron. The tansversity distribution can tell us the Nucleon tensor charge which is one of the fundamental properties of the proton and its determination is among the main goals of existing and future experimental facilities [2, 3, 4, 5, 6, 7].

2. energy Evolution

One of important motivations of our work is to study how the energy evolution effect modifies these collins azimuthal angle asymmetries. For example, the collins asymmetries in SIDS processes at HERMES, COMPASS and JLAB were measured with Q^2 from 1 to 6 GeV^2, while the energy Q^2 in the processes of $e^+e^- \to hh$ at BELLE and BARBAR is fixed at 110 GeV^2. Since the TMD distributions depend on Q^2, we have to evolve all the Q^2 to the same point so that we can apply the same distribution in all these processes. In this work, we apply CSS formalism [8, 9] to calculate the energy Q^2 evolution effect. The detail about this calculation has been stated in [10, 11, 12, 13, 14, 15, 16].

3. numerical result

After evolving all the Q^2 in the TMD parton distributions into the same point, we can parameterize the collinear part of transversity distribution as

$$h_1^q(x,Q_0) = N_q^h x^{a_q}(1-x)^{b_q}\frac{(a_q+b_q)^{a_q+b_q}}{a_q^{a_q}b_q^{b_q}}\frac{1}{2}\left(f_1(x,Q_0)+g_1(x,Q_0)\right) , \tag{3.1}$$

where, $\left|N_q^h\right| \leq 1$ for up and down quarks $q = u, d$, respectively, and f_1 is the unpolarized CT10 NLO quark distributions [17] and g_1 are the DSSV helicity NLO distributions [18]. In order to satisfy the Soffer bound [19, 20], the factor $\frac{(a_q+b_q)^{a_q+b_q}}{a_q^{a_q}b_q^{b_q}}$ is included. The contribution form sea quarks is not considered in our current work. Similarly, the collinear part of the favored and unfavored Collins fragmentation functions are parameterized as

$$\hat{H}_{fav}^{(3)}(z,Q_0) = N_u^c z^{\alpha_u}(1-z)^{\beta_u} D_{\pi^+/u}(z,Q_0) , \tag{3.2}$$

$$\hat{H}_{unf}^{(3)}(z,Q_0) = N_d^c z^{\alpha_d}(1-z)^{\beta_d} D_{\pi^+/d}(z,Q_0) , \tag{3.3}$$

where D is normal unpolarized fragmentation function. In addition of collinear part, we also need use an another parameter to describe the transverse momentum $k_\perp$ part in TMD parton distribution.

Finally, 13 free parameters N_u^h, N_d^h, a_u, a_d, b_u, b_d, N_u^c, N_d^c, α_u, α_d, β_u, β_d, g_c need to be fixed, where g_c is used to describe the TMD part in collins function, and we assume that the TMD part in the transversity parton distribution is as the same as the normal unpolarized parton distribution. Through fitting experimental data, we obtain the numerical values for these 13 parameters, and showed in table I. In the fit, we include all existing SIDIS data (140 points), all points in x_B, z_h, and

N_u^h	=	0.85 ± 0.09	a_u	=	0.69 ± 0.04	b_u	=	0.05 ± 0.04
N_d^h	=	-1.0 ± 0.13	a_d	=	1.79 ± 0.32	b_d	=	7.00 ± 2.65
N_u^c	=	-0.262 ± 0.025	α_u	=	1.69 ± 0.01	β_u	=	0.00 ± 0.54
N_d^c	=	0.195 ± 0.007	α_d	=	0.32 ± 0.04	β_d	=	0.00 ± 0.79
g_c	=	0.0236 ± 0.0007	(GeV^2)					

$\chi^2_{min} = 218.407$ $\qquad$ $\chi^2_{min}/n.d.o.f = 0.88$

Table 1: Fitted parameters of the transversity quark distributions for u and d and Collins fragmentation functions. The fit is performed by using MINUIT minimization package. Quoted errors correspond to MINUIT estimate.

$P_{h\perp}$ where formalism is valid (we limit $P_{h\perp} < 0.8$ GeV) for $\pi^\pm$ pion production from HERMES, COMPASS and JLAB HALL A, which are showed in Table II. For the Collins asymmetries in e^+e^- annihilation experiments we have 122 data points, measurements as function of z_{h1}, z_{h2}, and $P_{h\perp}$ (we limit $P_{h\perp}/z_{h1} < 3.5$ GeV) from BELLE [25] and BABAR [26] collaborations, which are showed in Table III. Based on the transversity quark distributions, we can predict the Nucleon tensor charge δq by the equation:

$$\delta q^{[x_{\min},x_{\max}]}\left(Q^2\right) \equiv \int_{x_{\min}}^{x_{\max}} dx\, h_1^q(x,Q^2)\ . \tag{3.4}$$

The numerical values of δq are showed in Fig I and II.

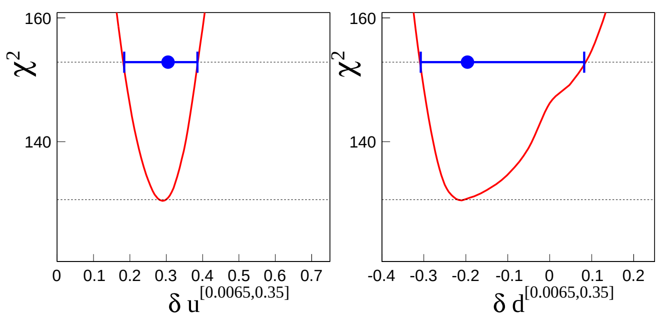

Figure 1: χ^2 profiles for up and down quark contributions to the tensor charge. The errors of points correspond to 90% C.L. interval at $Q^2 = 10$ GeV^2.

4. summary

In this talk, we present our newest numerical result about collins function and transversity par-

Experiment	hadron	Target	dependence	# ndata	χ^2	$\chi^2/ndata$
COMPASS [21]	π^+	LiD	x	9	11.16	1.24
COMPASS [21]	π^-	LiD	x	9	9.08	1.01
COMPASS [21]	π^+	LiD	z	8	3.26	0.41
COMPASS [21]	π^-	LiD	z	8	7.29	0.91
COMPASS [21]	π^+	LiD	$P_{h\perp}$	6	4.19	0.70
COMPASS [21]	π^-	LiD	$P_{h\perp}$	6	4.50	0.75
COMPASS [22]	π^+	NH_3	x	9	21.46	2.38
COMPASS [22]	π^-	NH_3	x	9	6.23	0.69
COMPASS [22]	π^+	NH_3	z	8	7.80	0.98
COMPASS [22]	π^-	NH_3	z	8	10.29	1.29
COMPASS [22]	π^+	NH_3	$P_{h\perp}$	6	3.82	0.64
COMPASS [22]	π^-	NH_3	$P_{h\perp}$	6	3.85	0.64
HERMES [23]	π^+	H	x	7	5.37	0.77
HERMES [23]	π^-	H	x	7	12.61	1.80
HERMES [23]	π^+	H	z	7	3.04	0.43
HERMES [23]	π^-	H	z	7	3.23	0.46
HERMES [23]	π^+	H	$P_{h\perp}$	6	1.60	0.27
HERMES [23]	π^-	H	$P_{h\perp}$	6	4.82	0.80
JLAB [24]	π^+	^{3}He	x	4	3.90	0.98
JLAB [24]	π^-	^{3}He	x	4	3.11	0.78
				140	130.65	0.93

Table 2: Partial χ^2 values of the global best fit for SIDIS experiments.

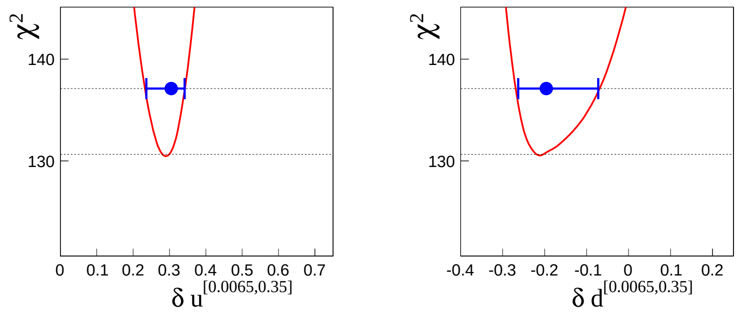

Figure 2: χ^2 profiles for up and down quark contributions to the tensor charge. The errors of points correspond to 68% C.L. interval at $Q^2 = 10$ GeV^2.

ton distribution. We extract them through the experimental data of e^+e^- annihilation to di-hadron processes at BELLE and BARBAR and semi-inclusive deep inelastic scattering(SIDIS) processes at COMPASS, HERMES and JLAB. Especially, by using the transversity parton distribution function, we can evaluate the Nucleon tensor charge which is one of the fundamental properties of the proton.

Experiment	Observable	dependence	# ndata	χ^2	$\chi^2/ndata$
BELLE [25]	A_0^{UL}	z	16	13.02	0.81
BELLE [25]	A_0^{UC}	z	16	11.54	0.72
BABAR[26]	A_0^{UL}	z	36	34.61	0.96
BABAR[26]	A_0^{UC}	z	36	15.17	0.42
BABAR[26]	A_0^{UL}	$P_{h\perp}$	9	9.09	1.01
BABAR[26]	A_0^{UC}	$P_{h\perp}$	9	4.33	0.48
			122	87.76	0.72

Table 3: Partial χ^2 values of the global best fit for e^+e^- experiments.

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