First extraction of the Λ polarizing fragmentation function from Belle e^+e^- data

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We present a thorough phenomenological analysis of the experimental data from Belle Collaboration for the transverse Λ and $\bar{\Lambda}$ polarization, measured in e^+e^- annihilation processes, for the case of associated (with a light charged hadron) and inclusive (plus a jet) production. Within a transverse momentum dependent (TMD) approach we show how this intriguing phenomenon can be accounted for. This allows for the *first ever* extraction of the quark polarizing fragmentation function for a Λ hyperon, a TMD distribution giving the probability that an unpolarized quark fragments into a transversely polarized spin-1/2 hadron.

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I. INTRODUCTION

The internal structure of the nucleon as well as the parton fragmentation mechanism into hadrons are key issues in hadron physics. In the last years, it has become clear that a deeper understanding of these phenomena requires a more complete view. This can be achieved by moving from a collinear picture to a three-dimensional description, i.e., introducing transverse momentum dependent distributions (TMDs). Concerning the distribution sector, when also spin degrees of freedom are included, the most studied TMD function is the Sivers function [1,2]. This gives the azimuthal asymmetry in the distribution of quarks or gluons within a fast moving transversely polarized nucleon. In the fragmentation sector an analogous role is played by the Collins fragmentation function (FF) [3], giving the asymmetric azimuthal distribution of an unpolarized hadron in the fragmentation of a transversely polarized quark. In both cases a clear evidence has been reached and a rich phenomenology has been developed.

Despite its relevance, a much less explored TMD is the so-called polarizing fragmentation function (pFF), giving the distribution of a transversely polarized spin-1/2 hadron coming from the fragmentation of an unpolarized quark. Among its main properties, we recall that it is T-odd, but chiral even. This allows us to access it directly without any unknown, chiral-odd, counterpart.

Introduced in Ref. [4], it was studied phenomenologically in Ref. [5], where the longstanding, puzzling transverse polarization data for the inclusive production of Λ hyperons in unpolarized hadron-hadron collisions [6,7] were considered. Within a simplified TMD model, some of its interesting features were tentatively extracted and a good description of data was achieved. Notice that for such processes, TMD factorization is not proven and other competing contributions could be at work.

After this pioneering work, the lack of additional experimental information prevented any further theory development.

The new available data from the Belle Collaboration at KEK [8] on transverse $\Lambda/\bar{\Lambda}$ hyperon polarization in e^+e^- processes have therefore triggered a renewed interest.

Indeed, for processes like $e^+e^- \to \Lambda h + X$, where two well separated energy scales are present, the large Q^2 of the virtual photon and the small relative transverse momentum between the Λ and the hadron, a TMD factorization approach is formally proven [9,10]. Notice that the transverse Λ polarization in a process with these features, namely $\ell p \to \ell' \Lambda^\uparrow + X$, was discussed in Ref. [11].

As we will show, Belle data allow for the first ever extraction of the pFF in a clear way. Since no other contribution from the initial state could play a role, this is the best process to access this TMD-FF. A preliminary phenomenological study, even though in a simplified scheme, has been discussed in Ref. [12]. Here we present a detailed analysis of Belle data at a level of accuracy very close to that of current studies on other relevant TMDs.

We will start by fitting the associated production (Λh) data set alone, for which TMD factorization holds.

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For completeness, in a separate full-data fit we include also the Λ-jet data. Even if this configuration presents some difficulties experimentally and could imply a more complex TMD factorization structure [13], it represents a unique source of information on the explicit $p_\perp$ dependence of the TMD pFF. For this reason, we will study it adopting a simplified phenomenological TMD scheme.

The paper is organized as follows: in Sec. II we present, in a condensed form, the theoretical formalism, while in Sec. III we show the results of the fits, discussing in detail our main findings. Finally, in Sec. IV we gather our concluding remarks.

II. FORMALISM

We consider the processes $e^+e^- \to h_1 h_2 + X$ and $e^+e^- \to h_1(\text{jet}) + X$, where h_1 is a spin-1/2 hadron and the second (light and unpolarized) hadron, h_2, is produced almost back-to-back with respect to h_1. The detailed calculation, within the helicity formalism, of all accessible azimuthal correlations and spin observables, with a complete classification of all leading-twist quark and gluon TMD-FFs for a spin-1/2 hadron, as well as a comparison with the corresponding findings in Ref. [14], is in progress and will be presented elsewhere [15]. Here we timely focus only on the very intriguing case of the transverse hyperon polarization.

This quantity is defined as

$$\mathcal{P}_T = \frac{d\sigma^\uparrow - d\sigma^\downarrow}{d\sigma^\uparrow + d\sigma^\downarrow} = \frac{d\sigma^\uparrow - d\sigma^\downarrow}{d\sigma^{\text{unp}}}, \qquad (1)$$

where $d\sigma^{\uparrow(\downarrow)}$ is the differential cross section for the production of a hadron transversely polarized along the up(down) direction with respect to the production plane and $d\sigma^{\text{unp}}$ is the unpolarized cross section.

For inclusive production (within a jet), the polarization is measured orthogonally to the *thrust plane*, containing the jet (more precisely the thrust axis, $\hat{\boldsymbol{T}}$) and the spin-1/2 hadron momentum, $\boldsymbol{P}_{h_1}$, that is along $\hat{\boldsymbol{T}} \times \boldsymbol{P}_{h_1}$. For the associated production with a light hadron, h_2, one considers the *hadron plane*, containing the two hadrons, and the transverse polarization is measured along $(-\boldsymbol{P}_{h_2} \times \boldsymbol{P}_{h_1})$.

For the first case, in a leading order approach, we choose a frame so that the $e^+e^- \to q\bar{q}$ scattering occurs in the $\widehat{xz}$ plane, with θ being the angle between the back-to-back quark-antiquark (identifying the z axis) and the e^+e^- directions. The three-momentum of the hadron h_1, with mass m_{h_1}, light-cone momentum fraction, z_1, and intrinsic transverse momentum, $\boldsymbol{p}_{\perp 1}$, with respect to the direction of the fragmenting quark, is given as

$$\boldsymbol{P}_{h_1} = \left(p_{\perp 1}\cos\varphi_1, p_{\perp 1}\sin\varphi_1, z_1\frac{\sqrt{s}}{2}(1 - a_{h_1}^2/z_1^2)\right), \qquad (2)$$

with $p_{\perp 1} = |\boldsymbol{p}_{\perp 1}|$ and $a_{h_1}^2 = (p_{\perp 1}^2 + m_{h_1}^2)/s$. For such a configuration, $d\sigma^\uparrow$ in Eq. (1) stands for $d\sigma^{e^+e^-\to h_1^\uparrow(\text{jet})+X}/d\cos\theta dz_1 d^2\boldsymbol{p}_{\perp 1}$.

The transverse polarization, simplifying a common factor $(1+\cos^2\theta)$ in the numerator and the denominator, is then given as [15]

$$\mathcal{P}_T(z_1, p_{\perp 1}) = \frac{\sum_q e_q^2 \Delta D_{h_1^\uparrow/q}(z_1, p_{\perp 1})}{\sum_q e_q^2 D_{h_1/q}(z_1, p_{\perp 1})}, \qquad (3)$$

where the sum runs over quark and antiquarks, and $\Delta D_{h_1^\uparrow/q}$ is the pFF, also denoted as $D_{1T}^{\perp q}$. These are related as follows [16]:

$$\Delta D_{h^\uparrow/q}(z, p_\perp) = \frac{p_\perp}{z m_h} D_{1T}^{\perp q}(z, p_\perp). \qquad (4)$$

More precisely, for a hadron with polarization vector $\hat{\boldsymbol{P}} \equiv \uparrow$, coming from the fragmentation of a quark with momentum $\boldsymbol{p}_q$, the pFF is defined as

$$\begin{aligned}\Delta\hat{D}_{h^\uparrow/q}(z, \boldsymbol{p}_\perp) &\equiv \hat{D}_{h^\uparrow/q}(z, \boldsymbol{p}_\perp) - \hat{D}_{h^\downarrow/q}(z, \boldsymbol{p}_\perp) \\ &= \Delta D_{h^\uparrow/q}(z, p_\perp)\hat{\boldsymbol{P}}\cdot(\hat{\boldsymbol{p}}_q \times \hat{\boldsymbol{p}}_\perp). \qquad (5)\end{aligned}$$

Equation (3) is obtained by integrating the numerator and the denominator in Eq. (1) over φ_1 and refers to the transverse polarization in the hadron helicity frame (i.e., transverse with respect to the plane containing the fragmenting quark and the hadron h_1). At leading order, this coincides with the thrust-plane frame defined above.

For massive hadrons, two further scaling variables are usually introduced: the energy fraction $z_h = 2E_h/\sqrt{s}$ (adopted in Belle analysis), and the momentum fraction $z_p = 2|\boldsymbol{P}_h|/\sqrt{s}$. These are related as:

$$z_{h,p} \simeq z[1 \pm m_h^2/(z^2 s)], \qquad (6)$$

$$z_p = z_h[1 - 4m_h^2/(z_h^2 s)]^{1/2}, \qquad (7)$$

where the expression (6) is valid at $\mathcal{O}(p_\perp/(z\sqrt{s}))$, for $p_\perp \sim \Lambda_{\text{QCD}}$. We will use this approximation, while keeping, for Λ hyperons, the full dependence on m_h.

For the associated production we adopt the following configuration: the produced unpolarized hadron, h_2, identifies the z direction $[\boldsymbol{P}_{h_2} = -|\boldsymbol{P}_{h_2}|\hat{z}]$ and the $\widehat{xz}$ plane is determined by the lepton and the h_2 directions (with the e^+e^- axis at angle θ_2). The other plane is determined by $\hat{\boldsymbol{z}}$ and the direction of the spin-1/2 hadron, h_1, $[\boldsymbol{P}_{h_1} = (P_{1T}\cos\phi_1, P_{1T}\sin\phi_1, P_{1L})]$. For such a case, $d\sigma^\uparrow$ in Eq. (1) stands for $d\sigma^{e^+e^-\to h_1^\uparrow h_2+X}/d\cos\theta_2 dz_1 dz_2 d^2\boldsymbol{P}_{1T}$. More details on the kinematics for this configuration for the production of two pseudoscalar light mesons can be found in Refs. [17,18].

In this case, the transverse polarization of h_1, in its helicity frame, as reached from the helicity frame of the fragmenting quark, is not directed along $\hat{\boldsymbol{n}} \propto (-\boldsymbol{P}_{h_2} \times \boldsymbol{P}_{h_1})$ and has therefore to be projected out along this direction. Moreover, two independent contributions appear: one driven by the pFF, convoluted with the unpolarized TMD-FF for the hadron h_2, and another one driven by the Collins FF for the hadron h_2. This manifests specific modulations in ϕ_1 and vanishes upon integrating over it, like in the present analysis [15]. Here we give directly the final expression for the transverse polarization along $\hat{\boldsymbol{n}}$, integrated over $\boldsymbol{P}_{1T}$ and adopting a Gaussian Ansatz for the TMD-FFs. This choice, largely adopted in TMD phenomenology, allows to carry out the integrations over intrinsic transverse momenta analytically and, at the same time, is good enough to describe the low-$p_\perp$ dependence. As it will be shown below, this is indeed the region where the observed transverse Λ polarization is sizeable. In particular we use:

$$D_{h/q}(z, p_\perp) = D_{h/q}(z)\,\frac{e^{-p_\perp^2/\langle p_\perp^2\rangle}}{\pi\langle p_\perp^2\rangle}, \tag{8}$$

$$\Delta D_{h^\uparrow/q}(z, p_\perp) = \Delta D_{h^\uparrow/q}(z)\,\frac{\sqrt{2e}\,p_\perp}{M_{\rm pol}}\,\frac{e^{-p_\perp^2/\langle p_\perp^2\rangle_{\rm pol}}}{\pi\langle p_\perp^2\rangle}, \tag{9}$$

with $\langle p_\perp^2\rangle_{\rm pol} = \frac{M_{\rm pol}^2}{M_{\rm pol}^2+\langle p_\perp^2\rangle}\langle p_\perp^2\rangle$. By imposing $|\Delta D(z)| \le D(z)$ the positivity bound for the pFF, Eq. (5), is automatically fulfilled. The transverse polarization, simplifying again a common factor $(1+\cos^2\theta_2)$, is then given as

$$\mathcal{P}_n(z_1, z_2) = \sqrt{\frac{e\pi}{2}}\,\frac{1}{M_{\rm pol}}\,\frac{\langle p_\perp^2\rangle_{\rm pol}^2}{\langle p_{\perp 1}^2\rangle}\,\frac{z_2}{\{[z_1(1-m_{h_1}^2/(z_1^2 s))]^2\langle p_{\perp 2}^2\rangle + z_2^2\langle p_\perp^2\rangle_{\rm pol}\}^{1/2}} \times \frac{\sum_q e_q^2 \Delta D_{h_1^\uparrow/q}(z_1) D_{h_2/\bar q}(z_2)}{\sum_q e_q^2 D_{h_1/q}(z_1) D_{h_2/\bar q}(z_2)}. \tag{10}$$

For its importance we give the first $p_\perp$-moment of the pFF:

$$\Delta D^{(1)}_{h^\uparrow/q}(z) = \int d^2\boldsymbol{p}_\perp \frac{p_\perp}{2zm_h}\Delta D_{h^\uparrow/q}(z, p_\perp) = D_{1T}^{\perp(1)}(z) = \sqrt{\frac{e}{2}}\,\frac{1}{zm_h}\,\frac{1}{M_{\rm pol}}\,\frac{\langle p_\perp^2\rangle_{\rm pol}^2}{\langle p_\perp^2\rangle}\Delta D_{h^\uparrow/q}(z), \tag{11}$$

where the last expression is obtained by using Eq. (9). Notice that $\mathcal{P}_n$, Eq. (10), is directly sensitive to this quantity.

III. FIT AND RESULTS

We can now proceed, using Eqs. (3) and (10), with the analysis of Belle polarization data for Λ and $\bar\Lambda$ production, measured at $\sqrt{s} = 10.58$ GeV [8]. As already said, two sets are available: one for the associated production of Λ with light hadrons (π and K), as a function of z_Λ and $z_\pi(z_K)$ (128 data points) and one for the inclusive production as a function of $p_\perp$ (the Λ transverse momentum with respect to the thrust axis), for different energy fractions, z_Λ, (32 data points). Notice that here we consider the transverse polarization for inclusive Λ particles, namely those directly produced from $q\bar q$ fragmentation and those indirectly produced from strong decays.

We parameterize the z-dependent part of the pFF as

$$\Delta D_{\Lambda^\uparrow/q}(z) = N_q z^{a_q}(1-z)^{b_q}\,\frac{(a_q+b_q)^{(a_q+b_q)}}{a_q^{a_q} b_q^{b_q}}\,D_{\Lambda/q}(z), \tag{12}$$

where $|N_q| \le 1$ and $q = u, d, s$, sea. This guaranties that $|\Delta D(z)| \le D(z)$.

For the unpolarized FFs we adopt the DSS07 set [19], for pions and kaons, and the AKK08 set [20] for Λ's. Since all data are at fixed energy scale no evolution is implied in this extraction. For the unpolarized Gaussian widths we use $\langle p_\perp^2\rangle = 0.2$ GeV^2 [21], both for light and heavy hadrons (varying this value has a little effect in the final results). Concerning the Λ FF set, all available parametrizations are given for $\Lambda + \bar\Lambda$, including the AKK08 set, which adopts z_p as scaling variable. We then separate the two contributions assuming

$$D_{\bar\Lambda/q}(z_p) = D_{\Lambda/\bar q}(z_p) = (1-z_p)D_{\Lambda/q}(z_p). \tag{13}$$

This is a common way to take into account the expected difference between the quark and antiquark FF with a suppressed Λ sea at large z_p with respect to the valence component. Other similar choices have a very little impact on the fit.

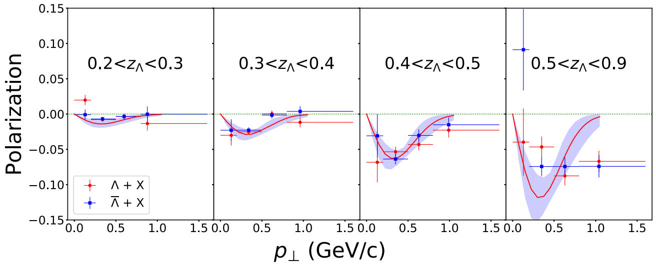

FIG. 1. Best-fit estimates of the transverse polarization for inclusive Λ and $\bar{\Lambda}$ production in $e^+e^- \to \Lambda(\mathrm{jet}) + X$ (thrust-plane frame) as a function of $p_\perp$ for different z_Λ bins, compared against Belle data [8]. The statistical uncertainty bands, at 2σ level, are also shown. Notice that curves for Λ and $\bar{\Lambda}$ coincide and data in the rightmost panel are not included in the fit.

Notice that all transformations among the different scaling variables (z, z_h, z_p) involved, Eqs. (6), (7), are properly taken into account.

In order to access the $p_\perp$ dependence of the pFF, data in the thrust-plane frame would be ideal. On the other hand, the experimental accuracy in extracting them, requiring the reconstruction of the thrust axis, is more problematic. Moreover, as already pointed out, the use of a TMD approach is technically more subtle [13,22]. The analysis of associated production data, extremely powerful in accessing flavor separation, experimentally easier and on a more firm theoretical ground, is however phenomenologically more complex. We have therefore performed first a fit of the associated production data alone and then attempted a full fit of both data sets, paying special attention to large-z_h data. In particular, for the associated production we exclude data where the energy fractions for both hadrons are too large, while for the inclusive production we cut out the largest z_Λ bin (0.5-0.9). We have then imposed the following cuts: $z_{\pi,K} \leq 0.5$ for the associated production and $z_\Lambda \leq 0.5$ for the Λ-jet data set. This leaves us with $96 + 24 = 120$ data points, still allowing to probe, at least in the Λh data set, large values of z_Λ. Notice that the cut on z_π has no impact on the quality of the fit.

Concerning the z-dependent part, Eq. (12), the best fit is obtained adopting the following parameter set:

$$N_u, \quad N_d, \quad N_s, \quad N_{\mathrm{sea}}, \quad a_s, \quad b_u, \quad b_{\mathrm{sea}}, \qquad (14)$$

with all other a and b parameters set to zero. This means that, with $\langle p_\perp^2 \rangle_{\mathrm{pol}}$ [Eq. (9)], we have 8 free parameters. We have indeed tried many different combinations of parameter sets and this choice represents a sort of balance between the number of parameters and the statistical significance of the fit.

Notice that *simpler* fits with only two pFFs, for $u = d$ and s quarks, or without any sea contribution, give much higher χ^2_{dof}'s. The same happens if no appropriate modulation in z is included. See comments below.

Table I reports the values of the best-fit parameters for the full-data analysis. The corresponding estimates, compared to Belle data [8], are shown in Figs. 1 and 2, respectively for the inclusive and associated Λ hadron ($\pi^\pm$, $K^\pm$) production. The quality of the fit is reasonable with a $\chi^2_{\mathrm{dof}} = 1.94$ and with $\chi^2_{\mathrm{points}} = 2.75$, 1.55, 1.61 for jet, pion and kaon data subsets. Notice that a fit of associated production data alone gives a $\chi^2_{\mathrm{dof}} = 1.26$ with $\chi^2_{\mathrm{points}} = 0.8$, 1.5 for pion and kaon data subsets. The shaded areas, corresponding to a 2σ uncertainty, are computed according to the

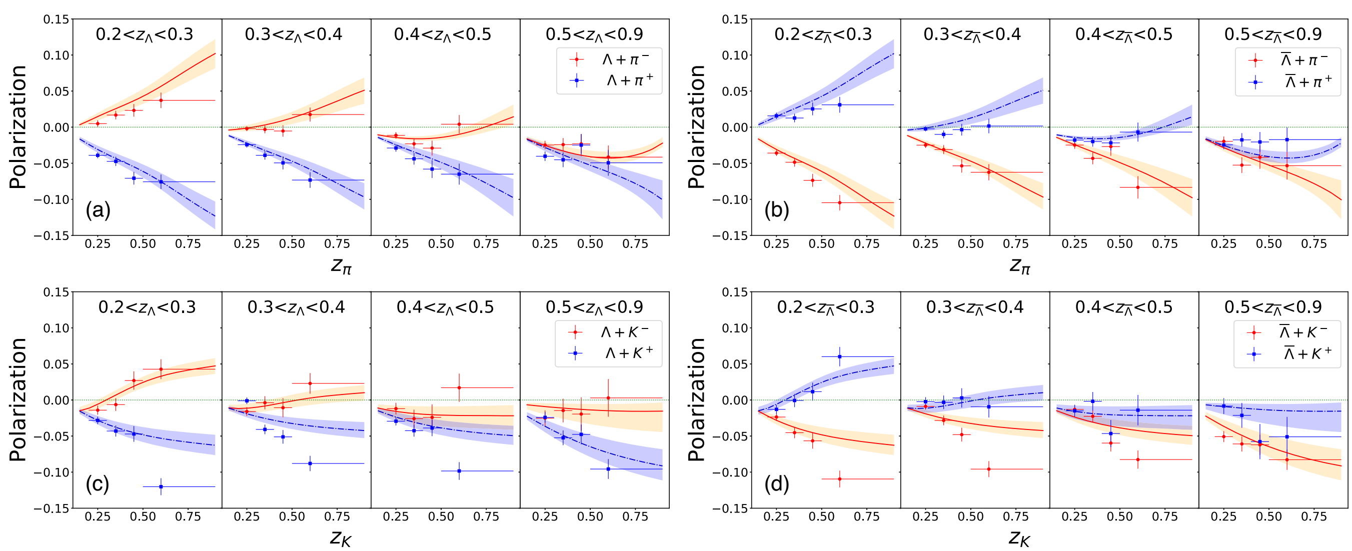

FIG. 2. Best-fit estimates, based on the full-data set, of the transverse polarization for Λ and $\bar{\Lambda}$ production in $e^+e^- \to \Lambda(\bar{\Lambda})h + X$, for $\Lambda\pi^\pm$ (a), $\bar{\Lambda}\pi^\pm$ (b), $\Lambda K^\pm$ (c), $\bar{\Lambda}K^\pm$ (d), as a function of z_h (of the associated hadron) for different z_Λ bins. Data are from Belle [8]. The statistical uncertainty bands, at 2σ level, are also shown. Data for $z_{\pi,K} > 0.5$ are not included in the fit.

TABLE I. Best values of the 8 free parameters fixing the pFF [Eqs. (9), (12)] for u, d, s and sea quarks, as obtained by fitting the full set of Belle data [8]. The statistical errors correspond to the shaded uncertainty areas in Figs. 1, 2, and 3, as explained in the text.

$N_u = 0.47^{+0.32}_{-0.20}$	$N_d = -0.32^{+0.13}_{-0.13}$
$N_s = -0.57^{+0.29}_{-0.43}$	$N_{\rm sea} = -0.27^{+0.12}_{-0.20}$
$a_s = 2.30^{+1.08}_{-0.91}$	
$b_u = 3.50^{+2.33}_{-1.82}$	$b_{\rm sea} = 2.60^{+2.60}_{-1.74}$
$\langle p_\perp^2\rangle_{\rm pol} = 0.10^{+0.02}_{-0.02}$ GeV^2	

procedure explained in the Appendix of Ref. [23] and result in the statistical errors quoted in Table I. More precisely, we have allowed the set of best fit parameters to vary in such a way that the corresponding new fits have a total $\chi^2 \leq \chi^2_{\rm min} + \Delta\chi^2$. All the associated new curves, around two hundred thousand, lie inside the shaded area. The chosen value of $\Delta\chi^2 = 15.79$, for our eight-parameter fit, is such that the probability to find the true result inside the shaded band is 95.45%.

As mentioned above, a fit restricted to associated production data gives a much better result. Even though the resulting best-fit parameters are a bit different, the corresponding first moment, Eq. (11), is quite stable and the two extractions lead to consistent results. This is shown in Fig. 3, where we present the first moments as obtained in the full-data fit (red solid lines) and by fitting only the associated production data (blue dot-dashed lines), together with their positivity bounds (black dotted lines). As one can see, they are well consistent within their uncertainty bands, and in two cases (down and strange quarks) almost indistinguishable. In Fig. 4, we show, for the full-data fit, the ratios of the absolute value of the first moments with respect to their positivity bounds.

Some comments are in order. For the inclusive production case, the description is clearly less good. On the other hand, one would expect $\mathcal{P}_T = 0$ at $p_\perp = 0$, as well as $\mathcal{P}_T(\bar\Lambda) = \mathcal{P}_T(\Lambda)$, a feature not clearly visible in the data (Fig. 1). This increases the tension with the other data set, reducing the quality of the full-data fit.

Moving to the associated production data set, we observe that charge-conjugation symmetry implies $\mathcal{P}_n(\Lambda h^+) = \mathcal{P}_n(\bar\Lambda h^-)$; in this respect data are quite consistent (Fig. 2). Focusing on medium $z_{\pi,K}$ values, where the valence unpolarized FFs dominate, $\Lambda\pi^-$, $\Lambda\pi^+$ and ΛK^+ data give direct information on the pFFs respectively for u, d and s quarks. In fact, in this region $\mathcal{P}_n(\Lambda\pi^-)$ is positive [see Fig. 2(a)] and dominated by the contribution from the pFF of the up quark, while $\mathcal{P}_n(\Lambda\pi^+)$ is negative and dominated by the pFF of the down quark, [Figs. 3(a), 3(b)]. Moreover, the strong reduction in size of $\mathcal{P}_n(\Lambda\pi^-)$ with increasing z_Λ implies a large suppression of the up pFF for such values, see Fig. 4 (red solid line), in contrast to the down quark pFF.

At small z_Λ, sea quark FFs start playing some role, becoming important around $z_\Lambda \leq 0.3$. For instance, for

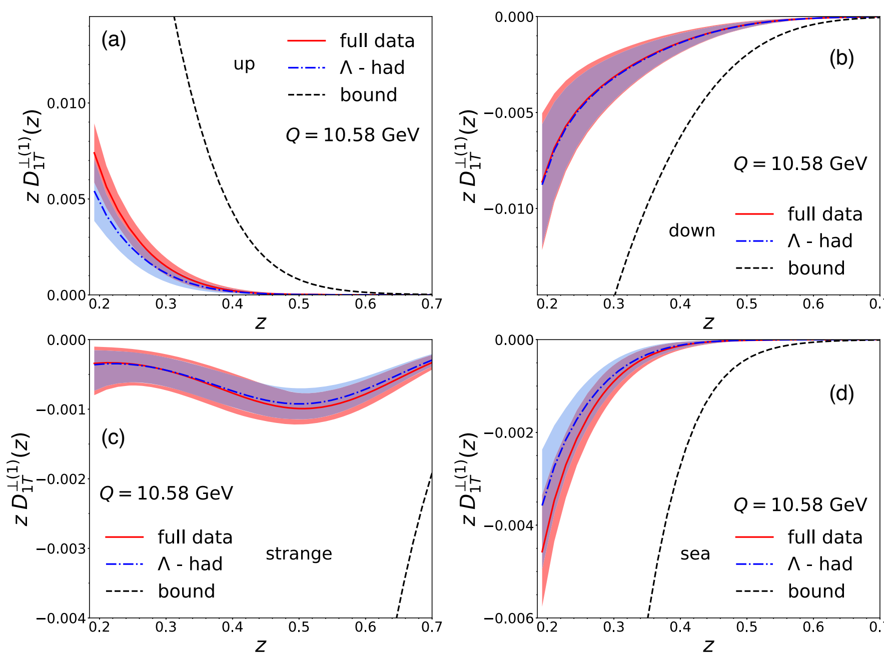

FIG. 3. First moments of the pFFs, see Eq. (11), for the up (a), down (b), strange (c) and sea (d) quarks, as obtained from the full-data fit (red solid lines) and the Λ-hadron fit (blue dot-dashed lines). The corresponding statistical uncertainty bands (at 2σ level), as well as the positivity bounds (black dashed lines), are shown.

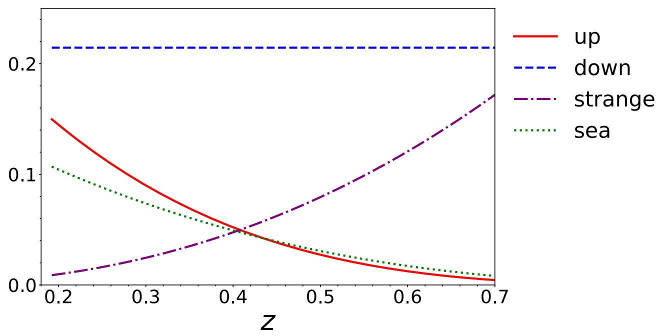

FIG. 4. Ratios of the absolute values of the first moments of the pFFs with respect to their positivity bounds for the u (red solid line), d (blue dashed line), s (purple dot-dashed line), and sea (green dotted line) quarks, as obtained from the full-data fit.

$\mathcal{P}_n(\Lambda\pi^+)$, where the up and down pFF contributions almost cancel each other for these z_Λ values, it is the negative sea polarizing FF that leads to large, and negative, values of the transverse polarization. Similarly, in $\mathcal{P}_n(\Lambda\pi^-)$, still for $z_\Lambda \leq 0.3$, this pFF is responsible for the partial reduction of the very large piece driven by the up polarizing FF, coupled to the favored unpolarized π^- FF and weighted by a large relative charge factor. We can then understand the emerging of a negative sea polarizing FF [Fig. 3(d)] and its strong suppression at large z (Fig. 4, green dotted line).

The description of Λ-kaon data follows a similar pattern. We can easily understand the negative values of $\mathcal{P}_n(\Lambda K^+)$ at medium z_Λ, being driven by a sizeable and negative $\Delta D_{\Lambda^\uparrow/s}$ [Fig. 3(c)], coupled to the leading FF $D_{K^+/\bar{s}}$. When moving to smaller z_Λ, this contribution is suppressed (see Fig. 4, purple dot-dashed line) and once again it is the negative sea quark polarizing FF, $\Delta D_{\Lambda^\uparrow/\bar{u}}$, which leads to large and negative $\mathcal{P}_n(\Lambda K^+)$ values. For $\mathcal{P}_n(\Lambda K^-)$ at medium-large z_Λ all contributions are negligible, mainly for two reasons: (i) the large-z suppression of the up and sea quark polarizing FFs coupled to the leading unpolarized kaon FFs; (ii) the coupling of the other pFFs to sub-leading sea unpolarized K^- FFs. On the other hand, at small z_Λ the up quark pFF dominates, leading to large and positive $\mathcal{P}_n$, slightly reduced by the negative sea polarizing FF, $\Delta D_{\Lambda^\uparrow/\bar{s}}$, coupled to the leading unpolarized FF $D_{K^-/s}$.

Similar reasonings apply to the $\bar{\Lambda}h$ data set.

These quantitative findings are in perfect agreement with the qualitative expectations discussed in Ref. [8], with extra information on the size of the down pFF.

IV. CONCLUSIONS

The recent data from Belle Collaboration for the transverse $\Lambda/\bar{\Lambda}$ polarization have been used, within a TMD approach, to extract, for the first time, the polarizing fragmentation function of Λ hyperons. A clear separation in flavors has been achieved, supporting the need for three different valence pFFs, with their relative sign and size determined quite accurately. The need of a sea-quark pFF is well supported. Within a Gaussian factorized Ansatz first indications on their $p_\perp$ dependence have been extracted. New data with higher statistics, as well as complementary studies in other processes, will certainly help toward a deeper understanding of this important TMD-FF, and eventually, in solving the longstanding puzzle of the observed spontaneous transverse hyperon polarization.

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Note added.—During the reviewing of this paper a similar analysis [24] has appeared.

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