



Hyperon Polarizations in unpolarized SIDIS and e^+e^- annihilation

Shu-yi Wei (魏树一)
ECT*/Shandong University

K.B. Chen, Z.T. Liang, Y.L. Pan, Y.K. Song, S.Y. Wei; Phys.Lett.B816, 136217. (2021)

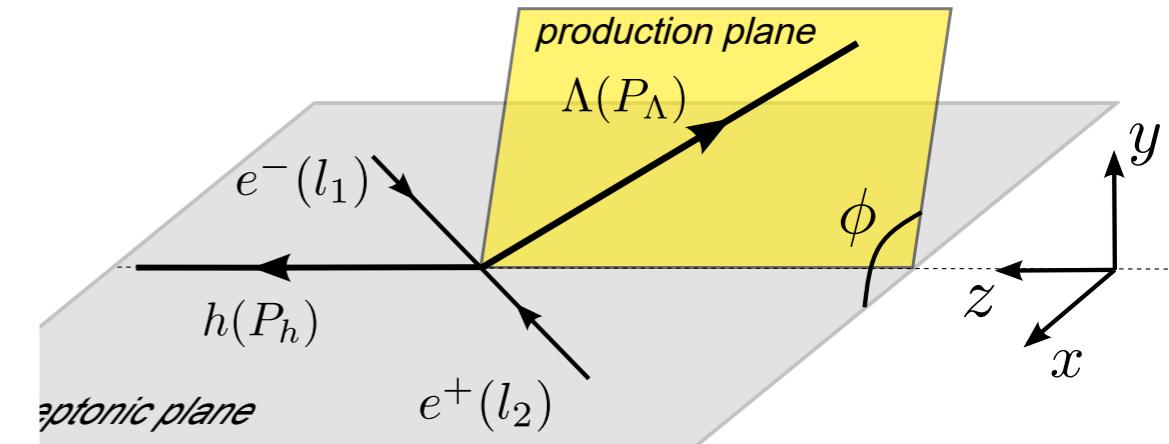
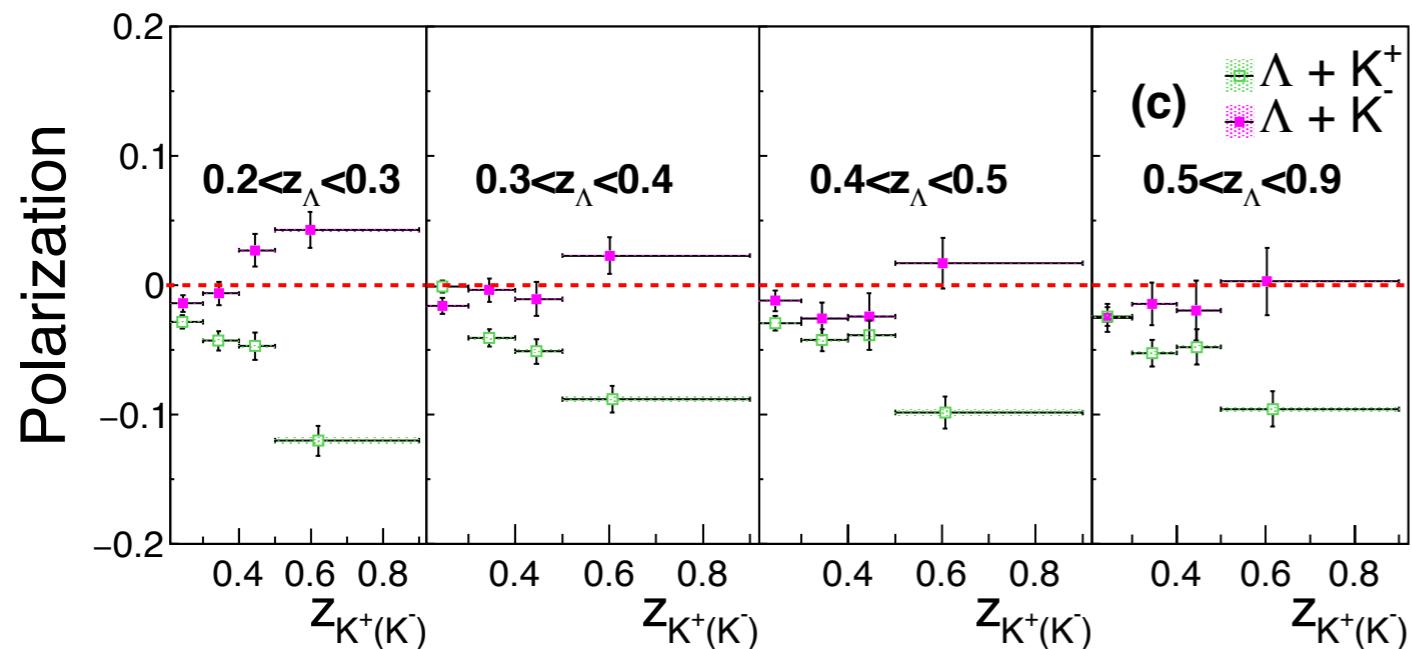
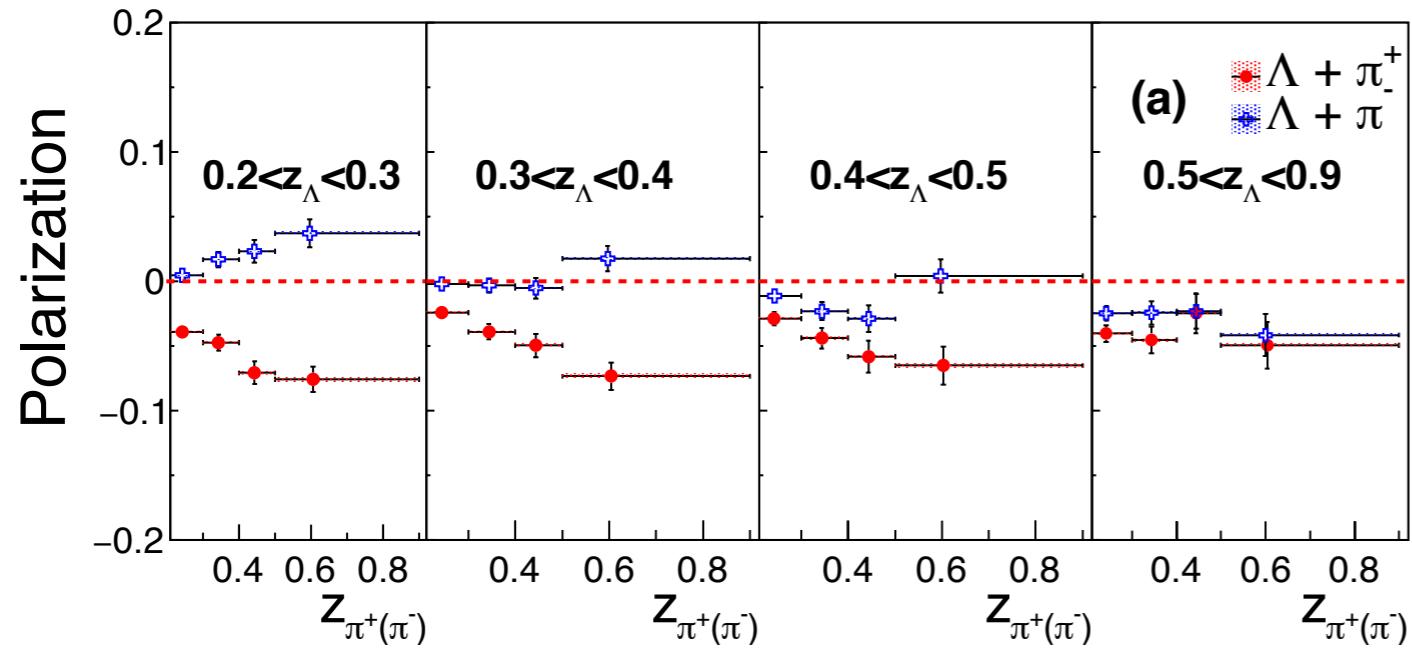
K.B. Chen, Z.T. Liang, Y.K. Song, S.Y. Wei; arXiv: [2108.07740](#)

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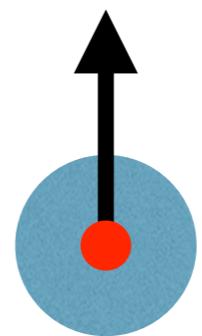
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Introduction

Transverse Polarization of Λ



$$\left[D_{1q}^\Lambda(z_\Lambda, p_T) + \frac{(\hat{\mathbf{e}}_j \times \mathbf{p}_T) \cdot \mathbf{S}_{\Lambda\perp}}{z_\Lambda M_\Lambda} D_{1Tq}^{\perp\Lambda}(z_\Lambda, p_T) \right]$$

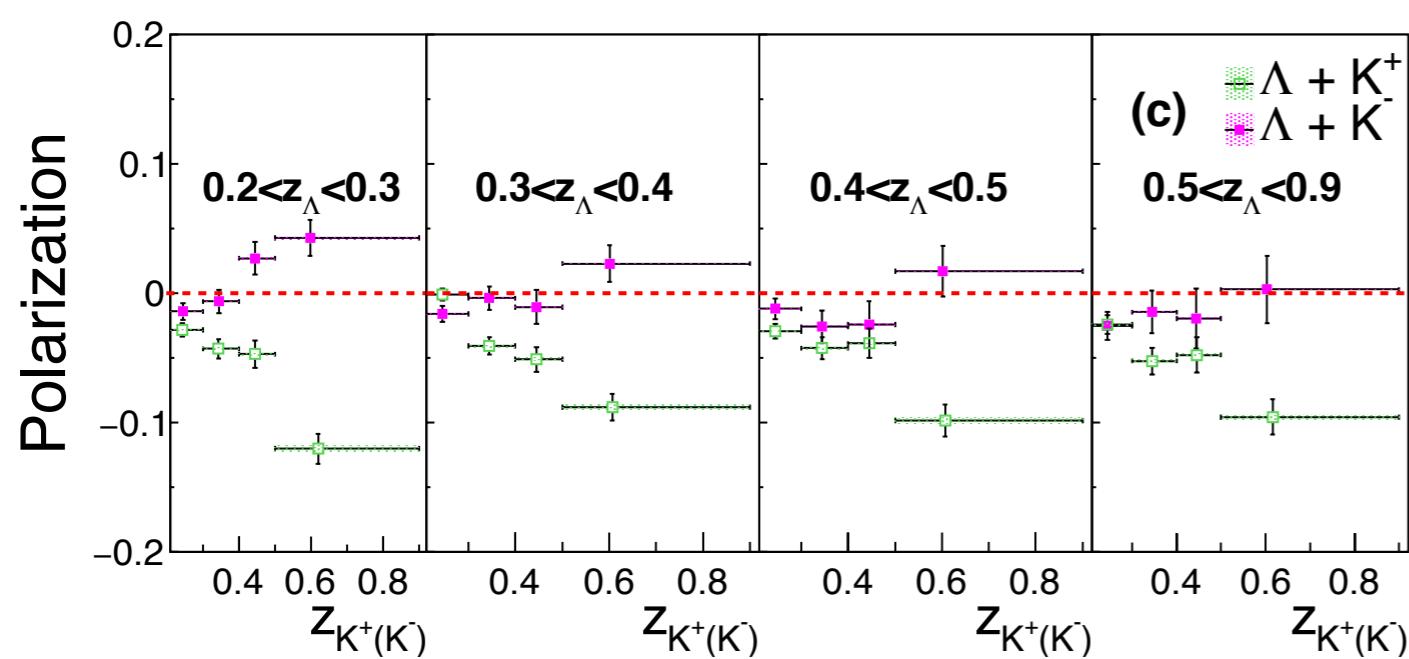
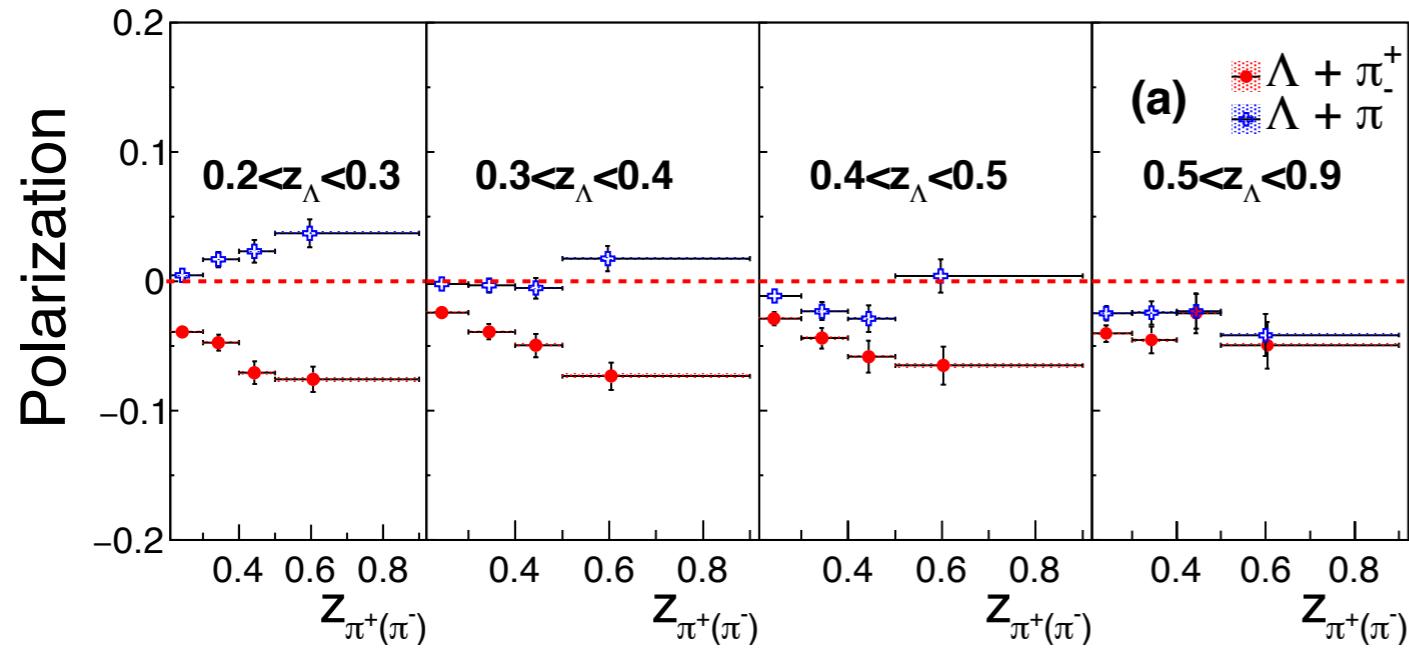


in analogue to
Sivers function
in TMD PDFs

[Belle], PRL122, 2019

Introduction

Transverse Polarization of Λ



$\pi^+ : u\bar{d}; \quad d \rightarrow \Lambda$
 $\pi^- : \bar{u}d; \quad u \rightarrow \Lambda$



$$D_{1T}^\perp(u) \neq D_{1T}^\perp(d)$$

$$D_{1T}^\perp(u) \neq D_{1T}^\perp(s)$$

$K^+ : u\bar{s}; \quad s \rightarrow \Lambda$
 $K^- : \bar{u}s; \quad u \rightarrow \Lambda$



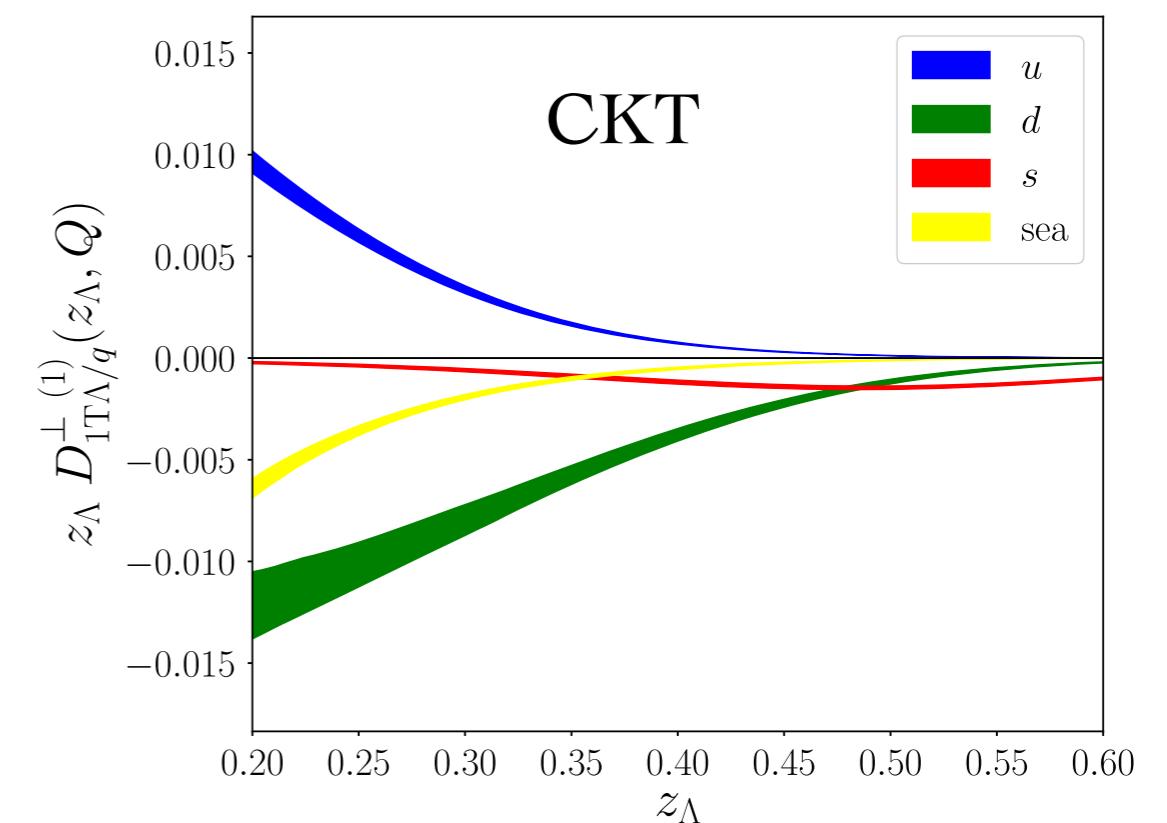
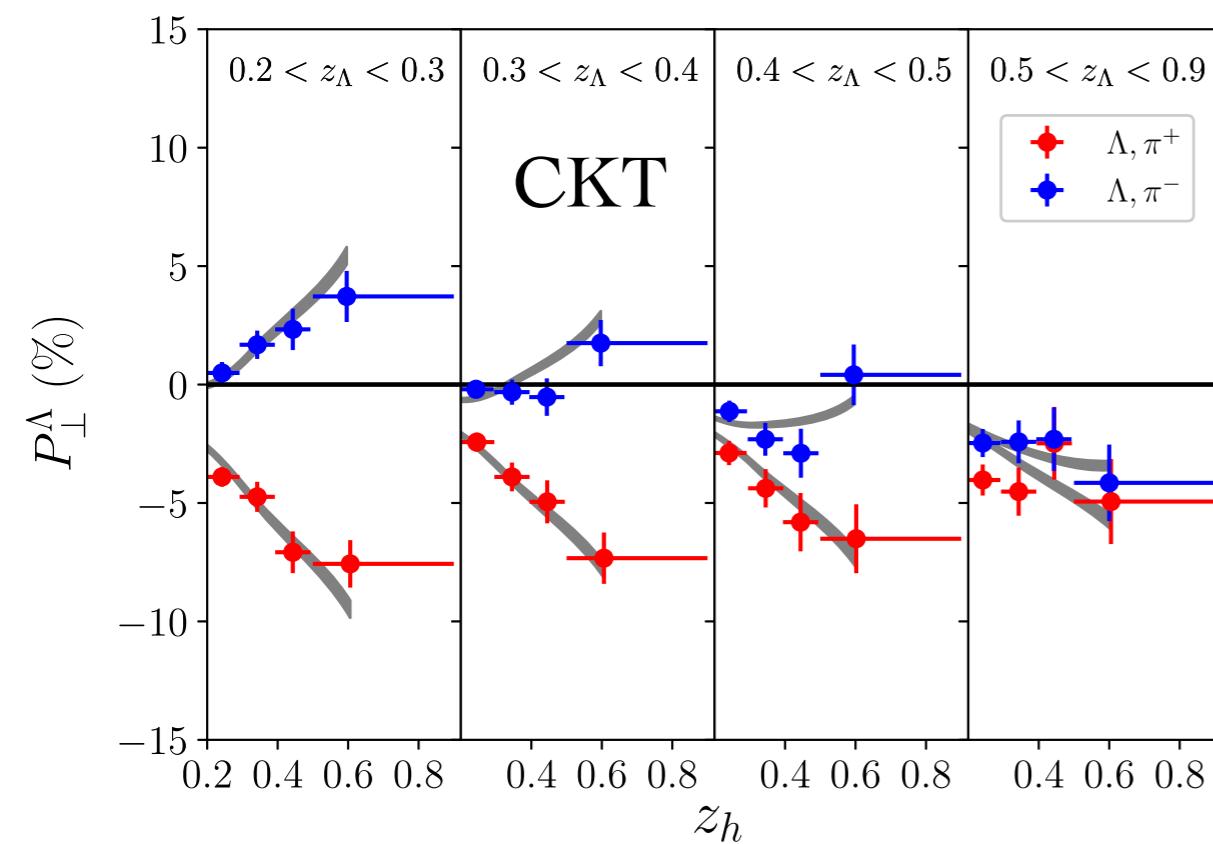
[Belle], PRL122, 2019

Introduction

Transverse Polarization of Λ

differentiate valence quarks from sea quarks

$$D_{1T}^\perp(u) \neq D_{1T}^\perp(d) \neq D_{1T}^\perp(s) \neq D_{1T}^\perp(\text{sea})$$



Strong violation of isospin symmetry

[D'Alesio, Murgia, Zaccheddu, PRD 102 \(2020\)](#)

[Callos, Kang, Terry, PRD 102 \(2020\)](#)

Isospin Symmetry

Isospin Symmetry

Robust symmetry in QCD

$$u \leftrightarrow d$$

$$\bar{u} \leftrightarrow \bar{d}$$

Example:

proton (uud) \leftrightarrow neutron (udd)

$$f_{\text{proton}}^u(x) = f_{\text{neutron}}^d(x)$$

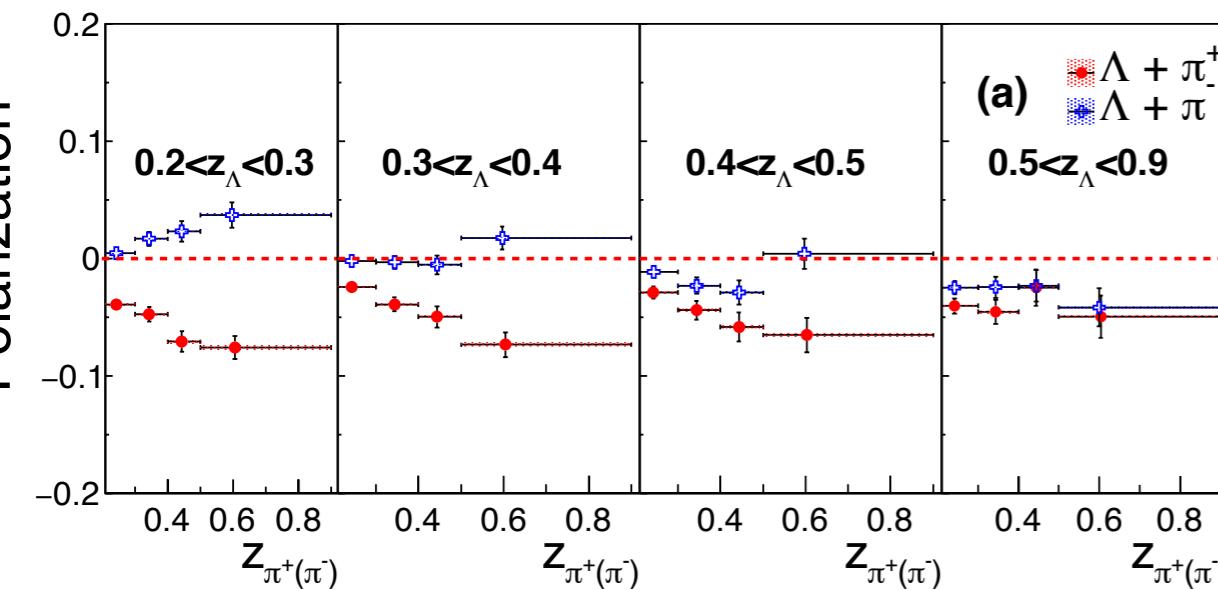
$$f_{\text{proton}}^d(x) = f_{\text{neutron}}^u(x)$$

isospin singlet

Lambda \leftrightarrow Lambda

$$\frac{1}{\sqrt{2}}(u^\uparrow d^\downarrow + u^\downarrow d^\uparrow)s^\uparrow$$

$$D_{1T}^{\perp,u \rightarrow \Lambda}(z, p_T) = D_{1T}^{\perp,d \rightarrow \Lambda}(z, p_T)$$



-  QED hard interaction
 QCD hadronization

Isospin Symmetry

differentiating valence quarks
from sea quarks

$$D_{1T}^\perp(u) \neq D_{1T}^\perp(d) \neq D_{1T}^\perp(s) \neq D_{1T}^\perp(\text{sea})$$

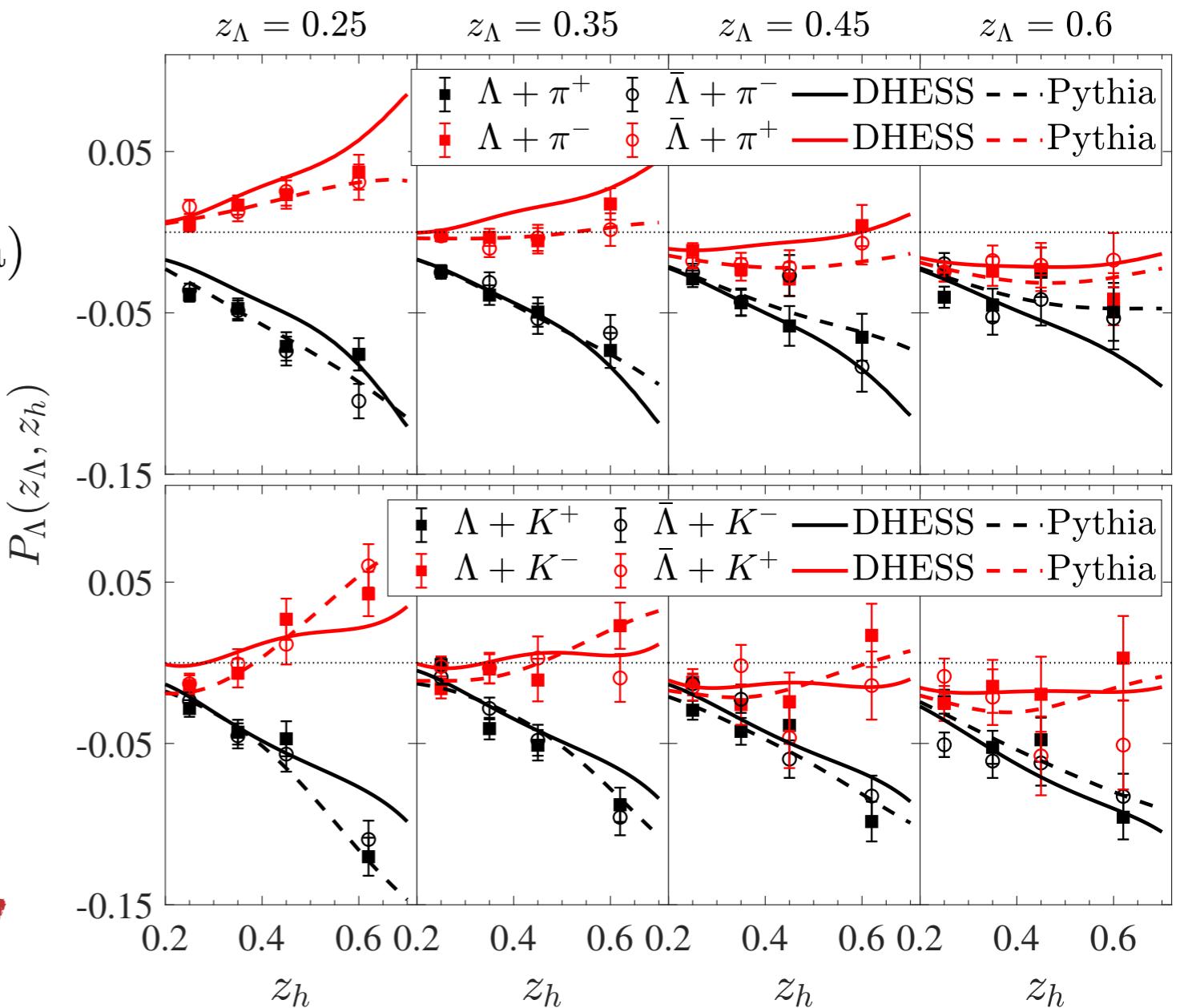
paradigm shift

enforcing isospin symmetry

$$D_{1T}^\perp(u) = D_{1T}^\perp(d)$$

$$D_{1T}^\perp(\bar{u}) = D_{1T}^\perp(\bar{u})$$

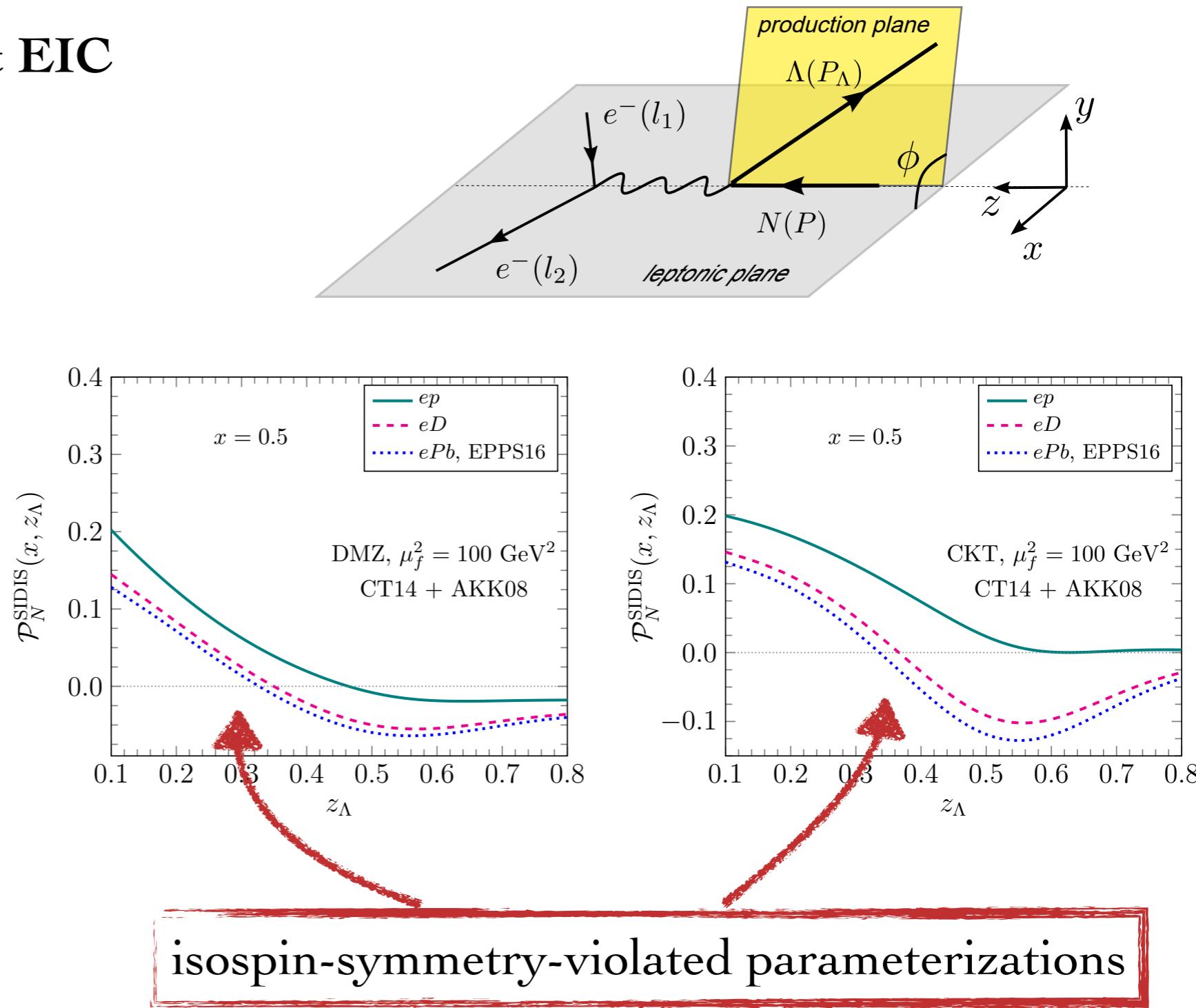
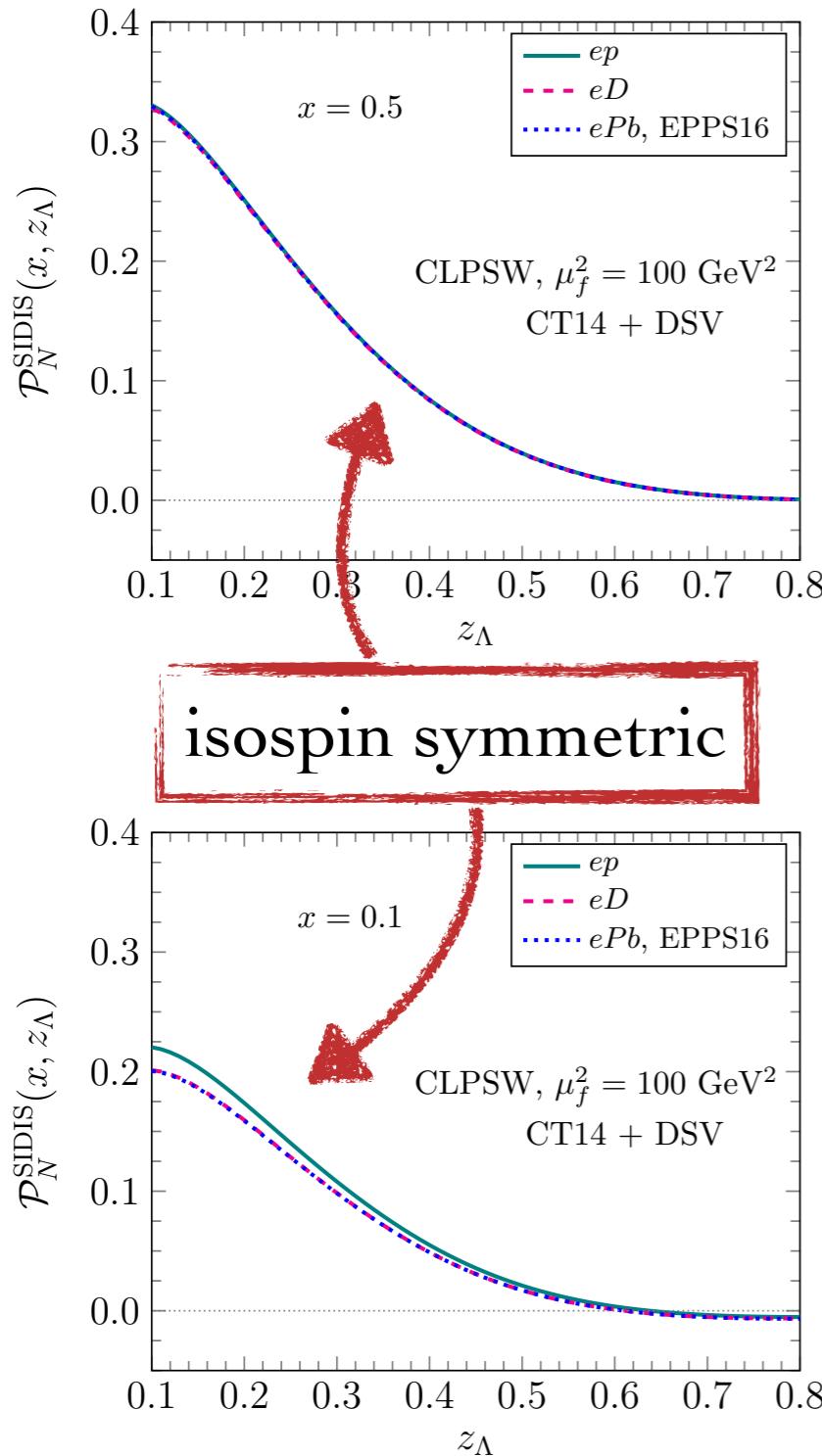
[Chen, Liang, Pan, Song, Wei, PLB816 \(2021\)](#)



Belle data does not endorse
isospin symmetry breaking.

Isospin Symmetry

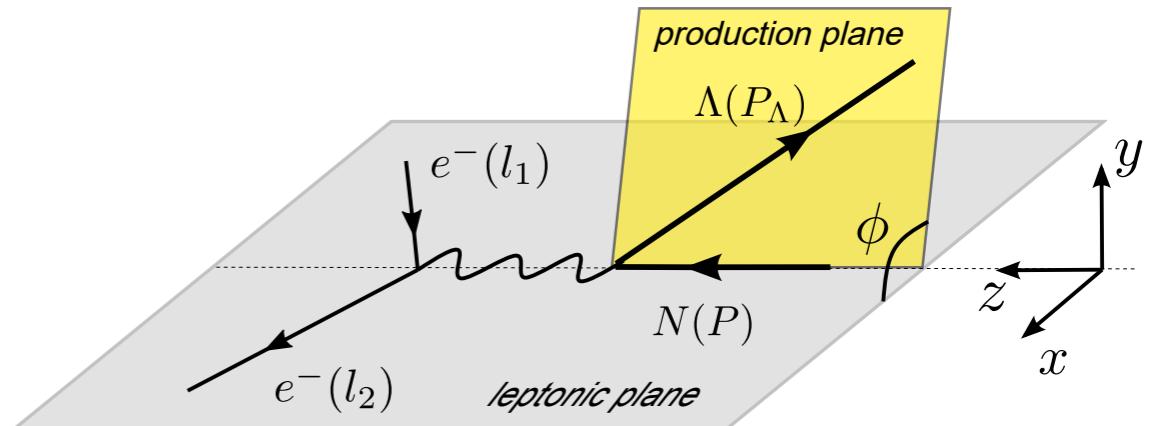
Testing Isospin Symmetry at EIC



[Chen, Liang, Song, Wei, 2021](#)

Hyperon Polarizations in unpolarized SIDIS

Kinematic Analysis



$$\frac{d\sigma^{\text{SIDIS}}}{dxdydz_\Lambda d^2\mathbf{P}_{\Lambda\perp}} = \frac{2\pi\alpha_{\text{em}}^2}{xyQ^2} \left\{ A(y)F_{UU}^T + B(y)F_{UU}^L \right. \\ + C(y)\cos\phi F_{UU}^{\cos\phi} + B(y)\cos 2\phi F_{UU}^{\cos 2\phi} \\ + \lambda_\Lambda \left[C(y)\sin\phi F_{UL}^{\sin\phi} + B(y)\sin 2\phi F_{UL}^{\sin 2\phi} \right] \\ + S_{\Lambda T} \left[C(y)\sin\phi F_{UT}^{\sin\phi} + B(y)\sin 2\phi F_{UT}^{\sin 2\phi} \right] \\ \left. + S_{\Lambda N} \left[A(y)F_{UT}^T + B(y)F_{UT}^L + C(y)\cos\phi F_{UT}^{\cos\phi} + B(y)\cos 2\phi F_{UT}^{\cos 2\phi} \right] \right\}$$

transverse polarizations

azimuthal asymmetries

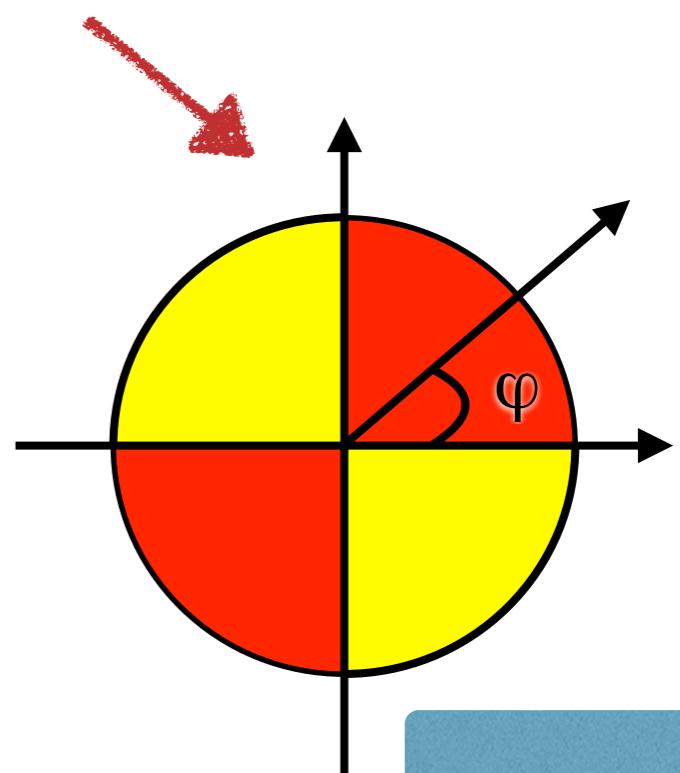
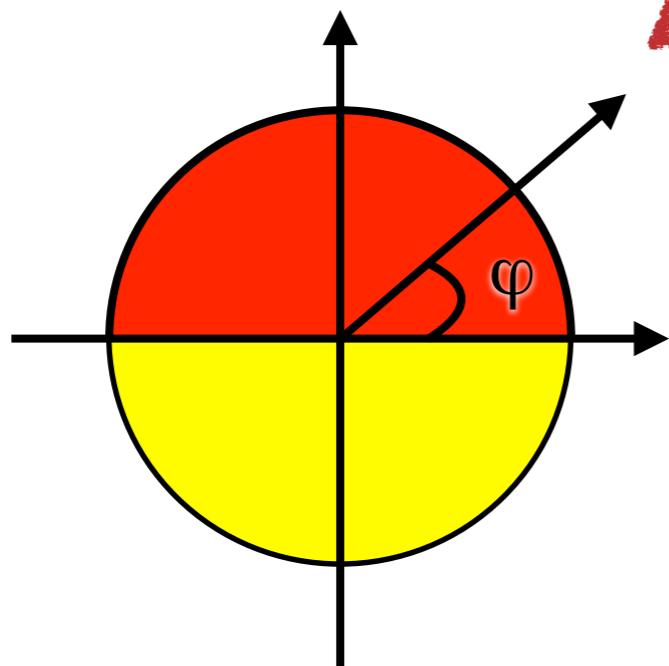
longitudinal polarization

[Arnold, Metz, Schlegel, PRD \(2009\)](#)
[Pitonyak, Schlegel, Metz, PRD \(2014\)](#)
[Chen, Yang, Wei, Liang, PRD \(2016\)](#)

Hyperon Polarizations in unpolarized SIDIS

Longitudinal Polarization

$$\mathcal{P}_L(x, y, z_\Lambda, \mathbf{P}_{\Lambda\perp}) = \frac{1}{\mathcal{F}_{UU}^{\text{tot}}} \left\{ C(y) \sin \phi F_{UL}^{\sin \phi} + B(y) \sin 2\phi F_{UL}^{\sin 2\phi} \right\}$$



Boer-Mulders
function

$$\langle \mathcal{P}_L \rangle_{\text{I+II}} = \frac{2}{\pi} \frac{C(y) F_{UL}^{\sin \phi}}{A(y) F_{UU}^T + B(y) F_{UU}^L}$$

LO

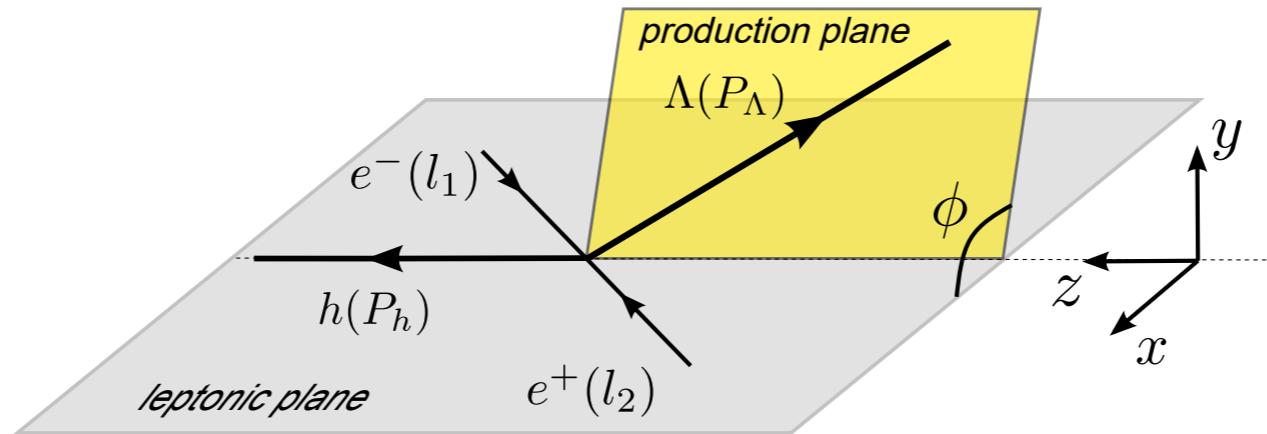
$$\langle \mathcal{P}_L \rangle_{\text{I+III}} = \frac{2}{\pi} \frac{B(y) F_{UL}^{\sin 2\phi}}{A(y) F_{UU}^T + B(y) F_{UU}^L}$$

leading twist

$$= 0$$

$$= \frac{2}{\pi} \frac{B(y) \mathcal{I}[w_2 h_1^\perp H_{1L}^{\perp \Lambda}]}{A(y) \mathcal{I}[f_1 D_1^\Lambda]}$$

Hyperon Polarizations in e^+e^- annihilation



Longitudinal Polarization

$$\mathcal{P}_L(y, z_h, z_\Lambda, \mathbf{P}_{\Lambda\perp}) = \frac{1}{\mathcal{F}_{UU}^{\text{tot}}} \left\{ \mathcal{C}(y) \sin \phi F_{UL}^{\sin \phi} + \mathcal{B}(y) \sin 2\phi F_{UL}^{\sin 2\phi} \right\}$$

$$\langle \mathcal{P}_L \rangle_{\text{I+II}} = \frac{2}{\pi} \frac{\mathcal{C}(y) F_{UL}^{\sin \phi}}{\mathcal{A}(y) F_{UU}^T + \mathcal{B}(y) F_{UU}^L}$$

$$\langle \mathcal{P}_L \rangle_{\text{I+III}} = \frac{2}{\pi} \frac{\mathcal{B}(y) F_{UL}^{\sin 2\phi}}{\mathcal{A}(y) F_{UU}^T + \mathcal{B}(y) F_{UU}^L}$$

LO
leading twist

collins function

$$= 0$$

$$= \frac{2}{\pi} \frac{\mathcal{B}(y) \mathcal{I}[\tilde{w}_2 H_1^{\perp h} H_{1L}^{\perp \Lambda}]}{\mathcal{A}(y) \mathcal{I}[D_1^h D_1^\Lambda]}$$

Summary

- Belle data does not signal the onset of isospin symmetry violation in polarized FFs.
- The isospin symmetry can be ultimately tested at the future EIC.
- Polarized FFs can be probed in unpolarized collisions.



The End