

第一届强相互作用自旋物理会议

The 1st Conference on Strong-Interaction Spin Physics



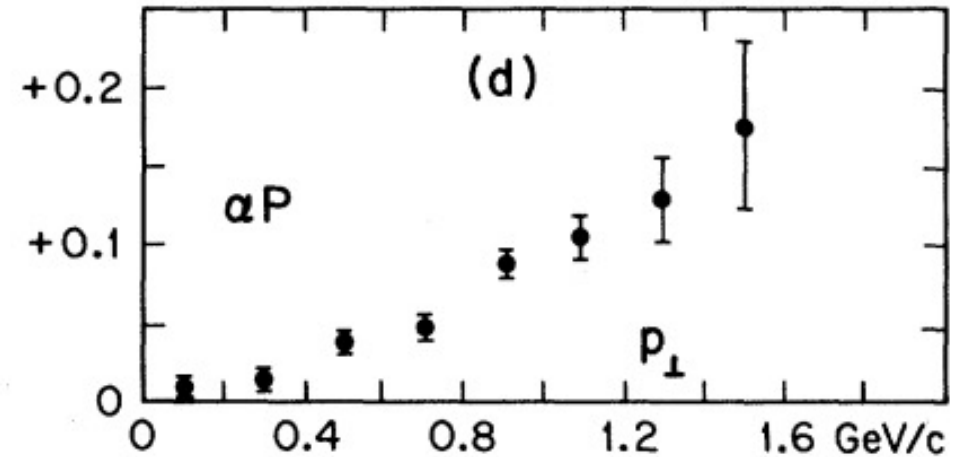
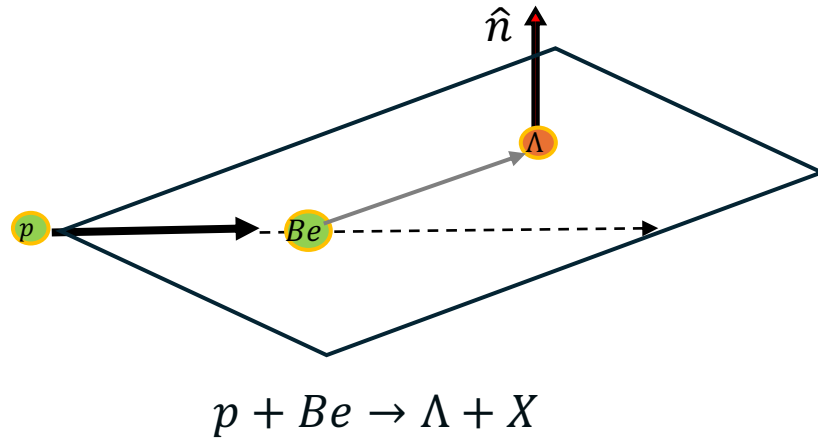
Transverse polarization of Λ inside jet in pp collisions

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July 29, 2026



Λ Transverse Polarization Puzzle



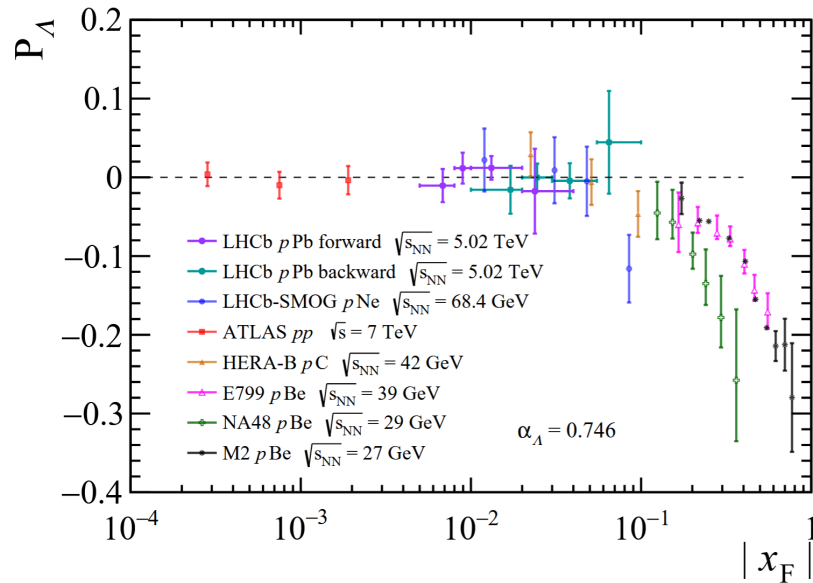
G. Bunce et al. PRL 36, 1113 (1976)

- Large transverse polarization of Λ hyperon first observed in 1976 in unpolarized hadron scatterings
- Polarization direction: transverse to production plane
- Increasing with p_T and x_F
- pQCD calculation: ~ 0

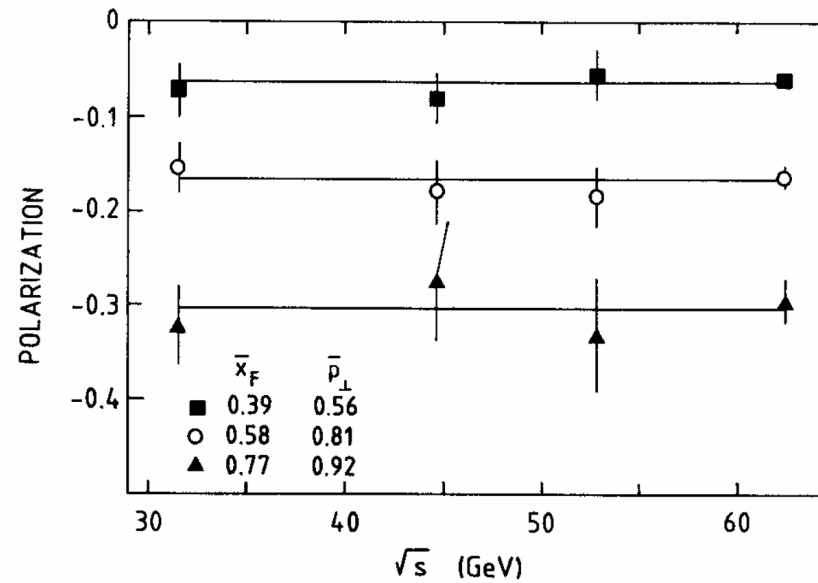
Λ Transverse Polarization Puzzle

A lot of follow-up experiments confirm significant transverse polarization of Λ

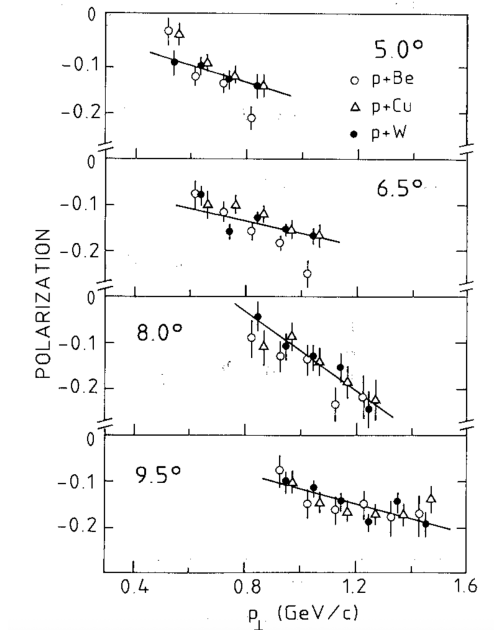
- Significant x_F dependence
- No energy dependence
- Weak target dependence



Aaij, Roel and others. *Phys. Rev. D* 112 112022 (2025)



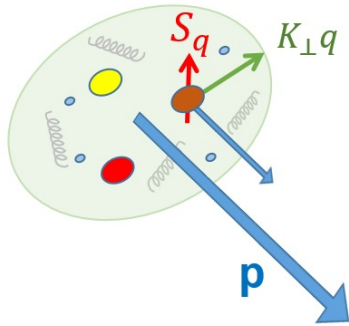
A.D. Panagiotou, *Int.J.Mod.Phys.A* 5, 1197 (1990)



A.D. Panagiotou, *Int.J.Mod.Phys.A* 5, 1197 (1990)

QCD Framework

Initial state

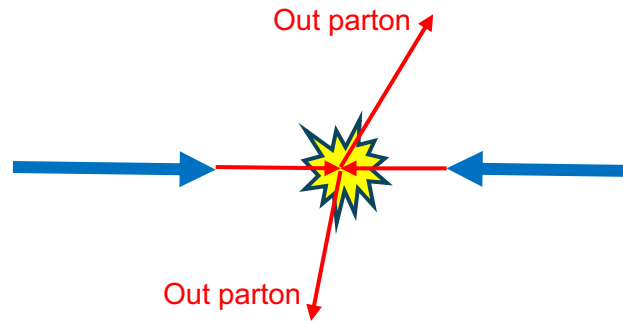


Boer and Mulders, PRD 57, 5780 (1998)

- Boer-Mulders function
- Twist-3 chiral-odd distributions

Kanazawa, Koike, PRD 64, 034019 (2001)

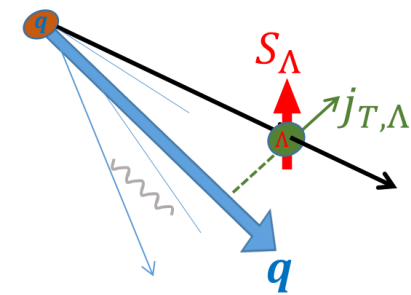
Hard scattering



Kane, Pumplin & Repko, PRL 41, 1689 (1978)

- pQCD calculation predicted ~ 0 polarization from hard-scattering

Final state



Mulders, Tangerman, Nucl. Phys. B 461, 197 (1996)

- Polarizing fragmentation function (PFF)
- Twist-3 fragmentation function

*Koike, Metz, Pitonyak, Yabe, and Yoshida
Phys. Rev. D 95 114013 (2017)*

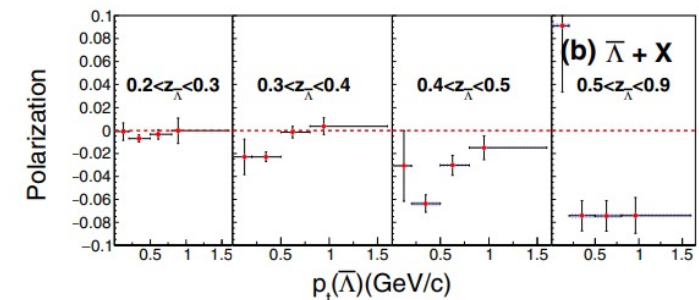
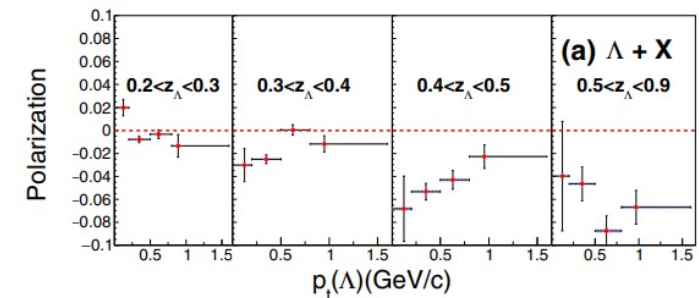
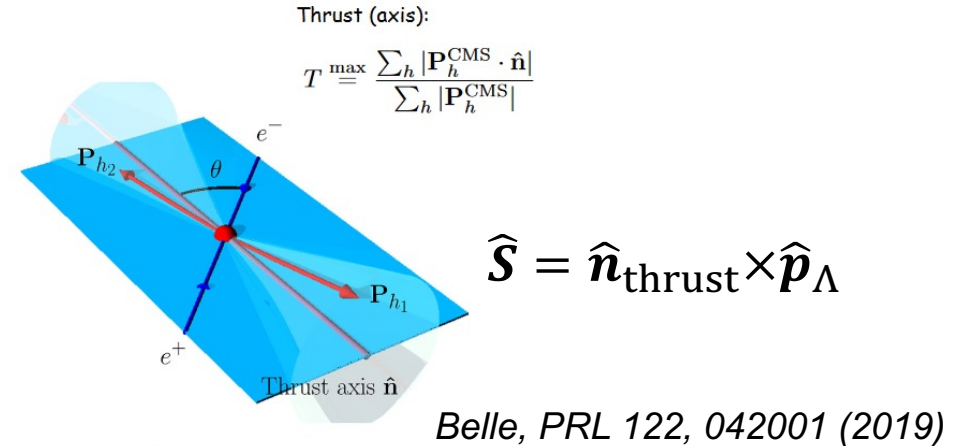
Λ Polarization in e^+e^- Annihilation

- At LEP ($\sqrt{s} = 90$ GeV)
 - ALEPH $P_T^{\Lambda, \bar{\Lambda}} = 0.016 \pm 0.007$
ALEPH, PLB 374, 319 (1996)
 - OPAL $P_T^{\Lambda} = 0.019 \pm 0.014$ ($p_T > 0.3$ GeV/c)
OPAL, EPJC 2, 49 (1998)
- At Belle ($\sqrt{s} = 10.6$ GeV)
 - Significant polarization with z dependence
 - Using π, K mesons tag quark flavor
- Extraction of polarizing Fragmentation Function (PFF)

Callos, Kang, Terry, PRD 102, 096007 (2020)

D'Alesio, Murgia, Zaccheddu, PRD 102, 054001 (2020)

Chen, Liang, Pan, Song, Wei, PLB 816, 136217 (2021)



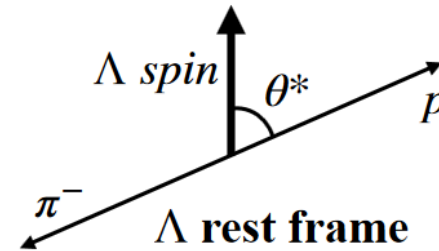
Λ Polarization inside jet in pp Collisions

Boer et al, PLB 671, 91-98 (2008)

Polarizing fragmentation functions (PFF) can be accessed by transverse polarization of Λ -in-jet in pp collision

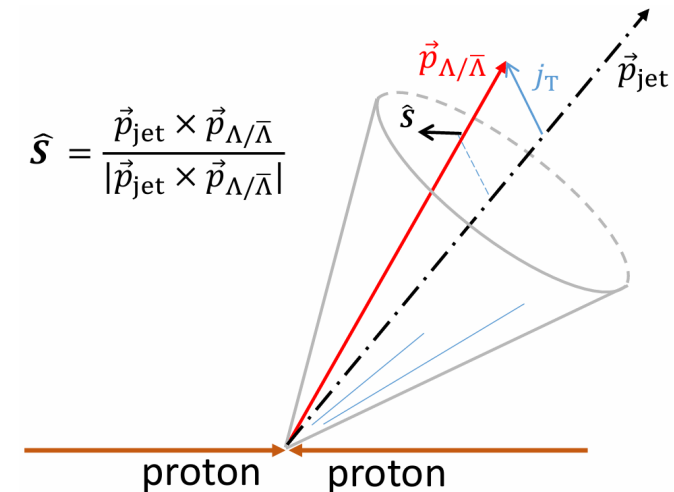
Kang, Lee, Zhao, PLB 809, 135756 (2020)

- Measure transverse polarization of Λ as function of jet p_T covering a wide range : 5~50 GeV/c
- Study contribution from gluon polarizing fragmentation function
- Test universality of PFF (combined with Belle's results)

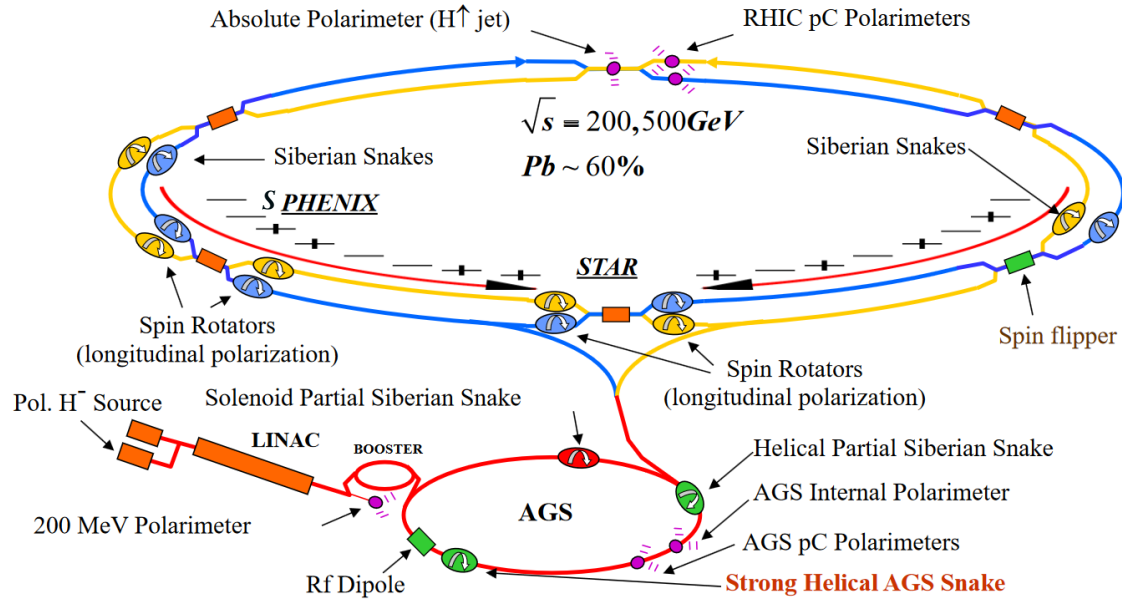


$$\frac{dN}{d \cos \theta^*} \propto A(\cos \theta^*) (1 + \alpha P \cos \theta^*)$$

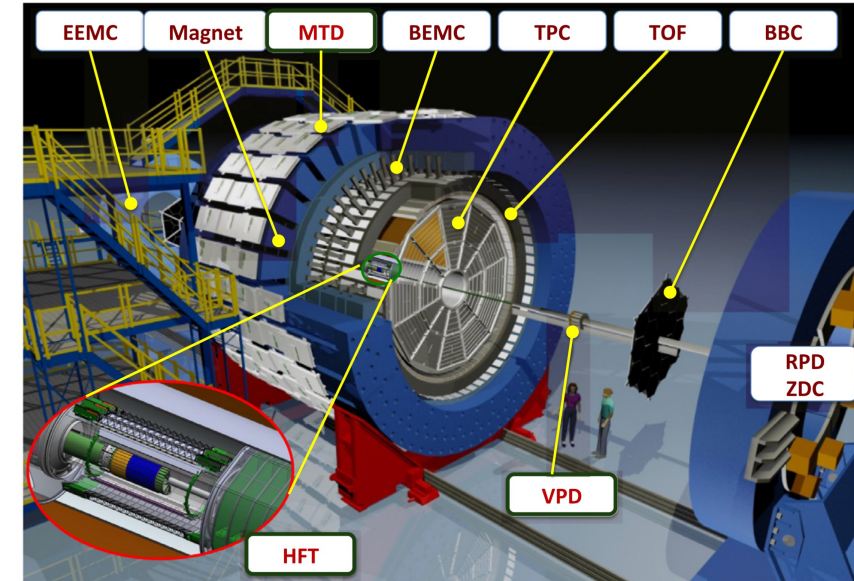
- $A(\cos \theta^*)$: acceptance function
- $\alpha_\Lambda = 0.747 \pm 0.009$, $\alpha_{\bar{\Lambda}} = -0.757 \pm 0.004$
- P : Λ polarization
- θ^* : angle between p and spin direction in the Λ rest frame



Relativistic Heavy Ion Collider (RHIC) and STAR



- The world's first and only polarized proton collider
- Bunch-by-bunch spin flip → effectively unpolarized polarized collisions (after averaging)
- Datasets: pp 200 GeV; pp 500 GeV; $p\text{Au}$ 200 GeV



TPC (Time Projection Chamber):

- Used for charge track reconstruction
- Particle identification by energy loss
- $-1 < \eta < 1, \phi \in [0, 2\pi]$

Barrel and Endcap E.M. Calorimeter :

- BEMC coverage: $-1 < \eta < 1, \phi \in [0, 2\pi]$.
- EEMC coverage: $1.086 < \eta < 2, \phi \in [0, 2\pi]$.
- Used for energy deposit detection
- Trigger system

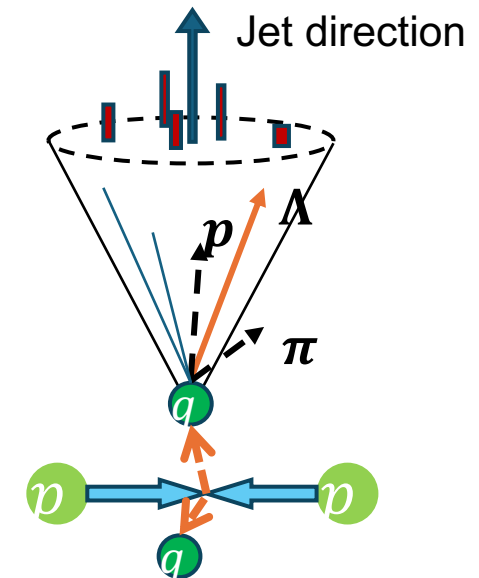
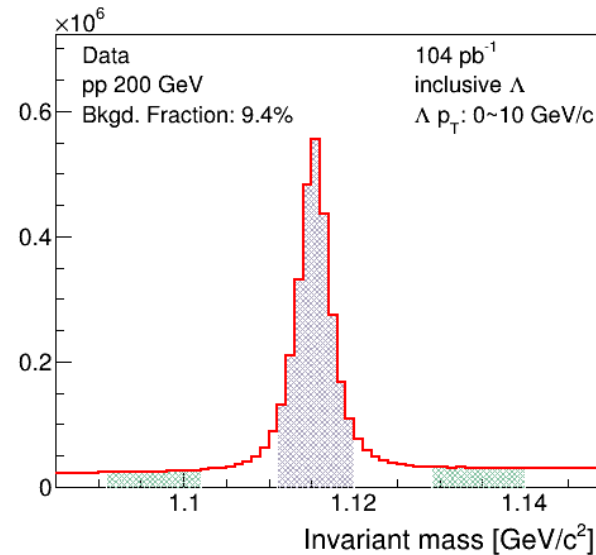
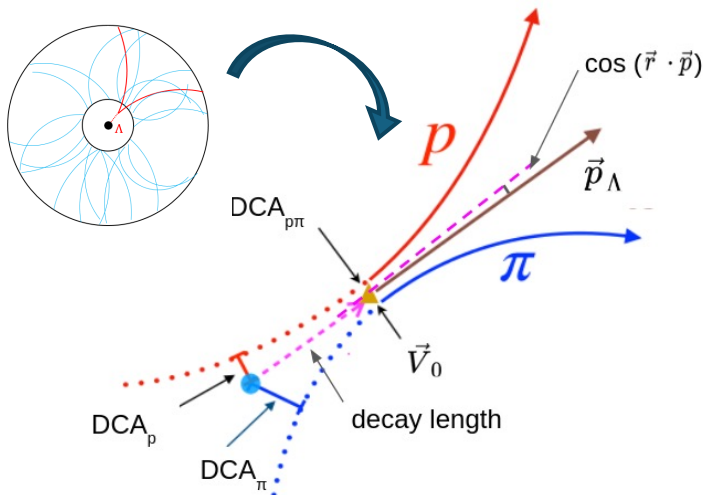
Λ and Jet Reconstruction

- Λ reconstruction:

- ✓ $\Lambda \rightarrow p + \pi^-$; $\bar{\Lambda} \rightarrow \bar{p} + \pi^+$
- ✓ Track reconstruction and particle identification by TPC
- ✓ Topological criteria

- Jet reconstruction

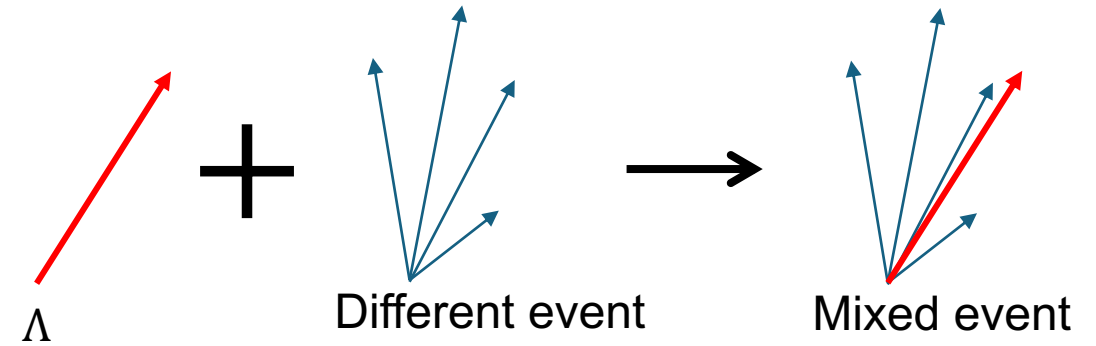
- ✓ Anti- k_T with $R = 0.6$
- ✓ Reconstructed $\Lambda, \bar{\Lambda}$ as inputs
- ✓ Including tracks and tower energies



Detector Acceptance Correction

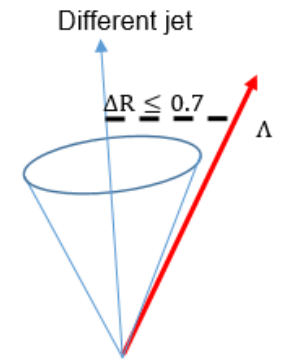
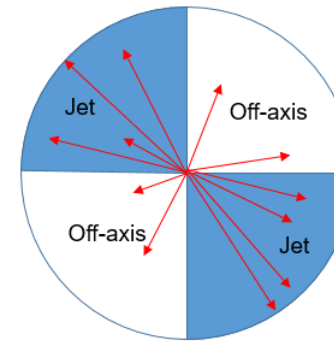
Mixed-event (ME) method

- Breaking physic correlation between Λ and jet
- Maintaining detector acceptance effects



Mixed-events criteria

- Require same triggers
- Require $|\Delta z_{\text{vertex}}| < 5 \text{ cm}$
- Mixed Λ and jet from different event with $\Delta R \leq 0.7$
- Reconstruction jet including Λ



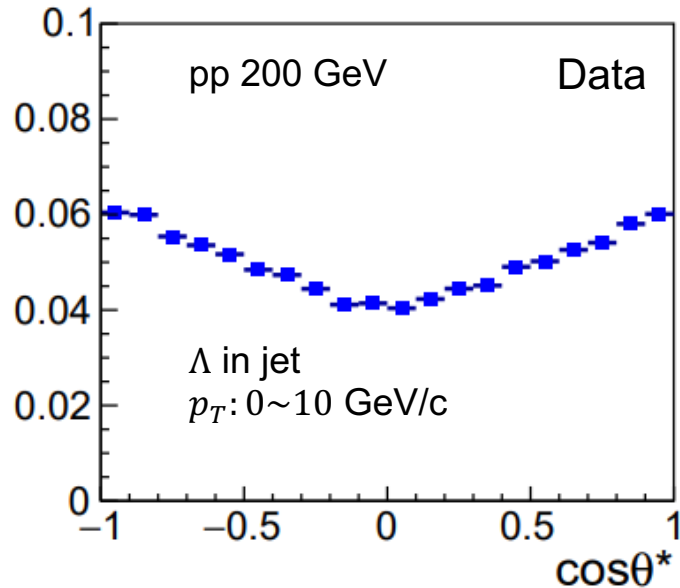
Polarization Extraction



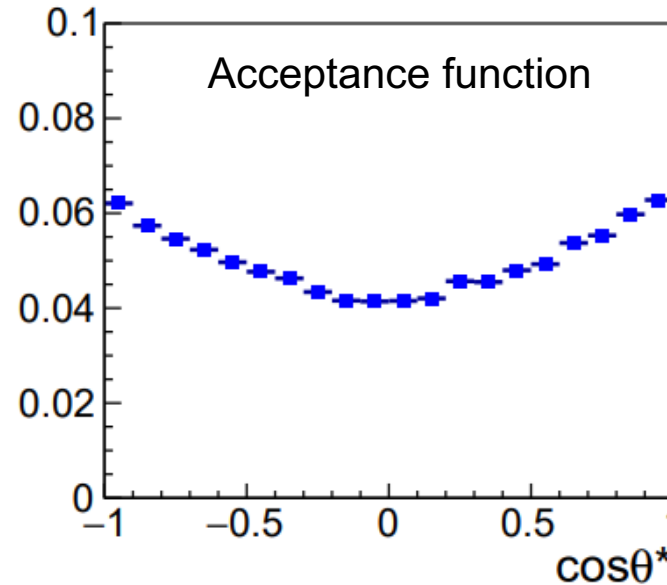
$$\frac{dN}{d \cos \theta^*} \propto A(\cos \theta^*)(1 + \alpha P \cos \theta^*)$$

$$\frac{N(\cos \theta^*)_{Data}}{A(\cos \theta^*)_{ME}}$$

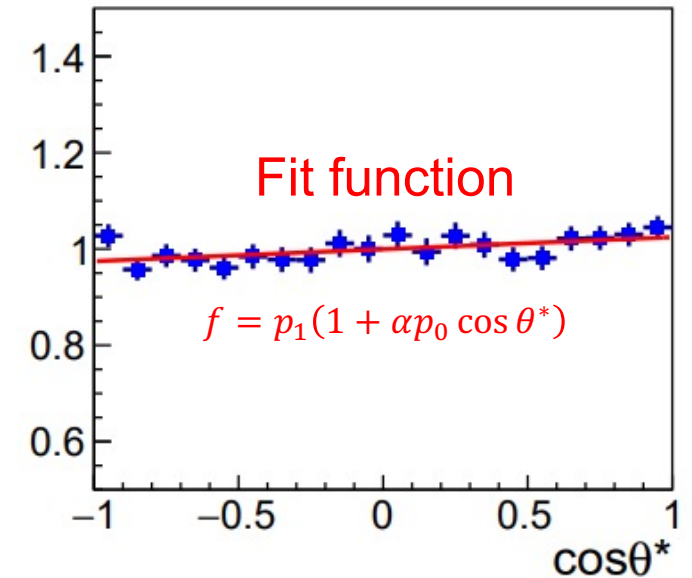
Before correction



Acceptance function



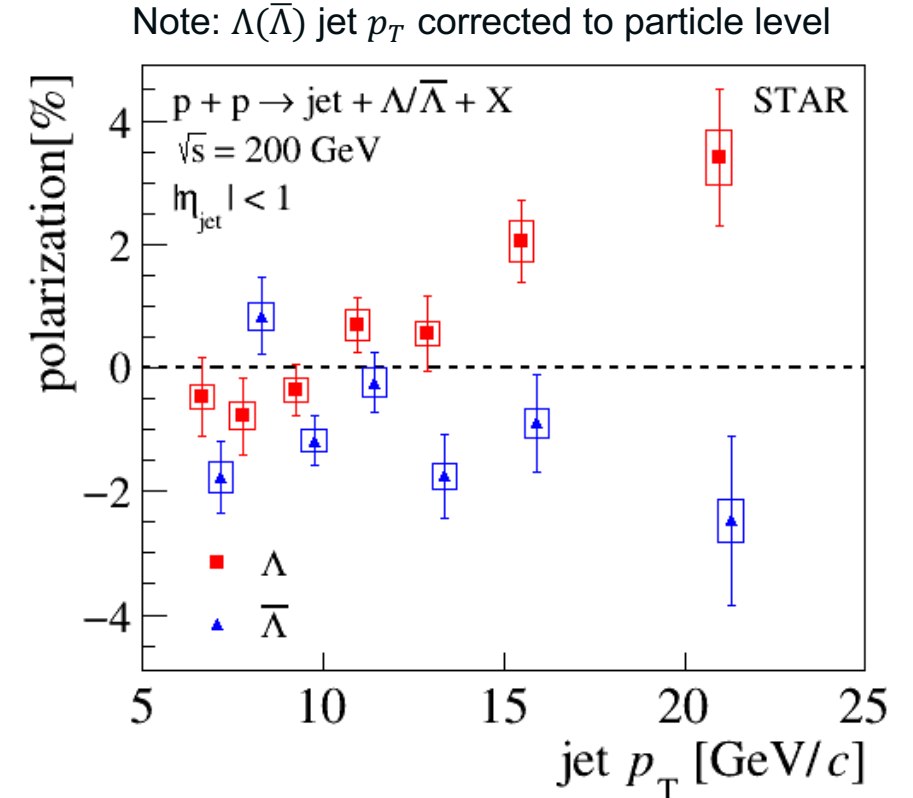
After correction



Polarization as Function of Jet p_T

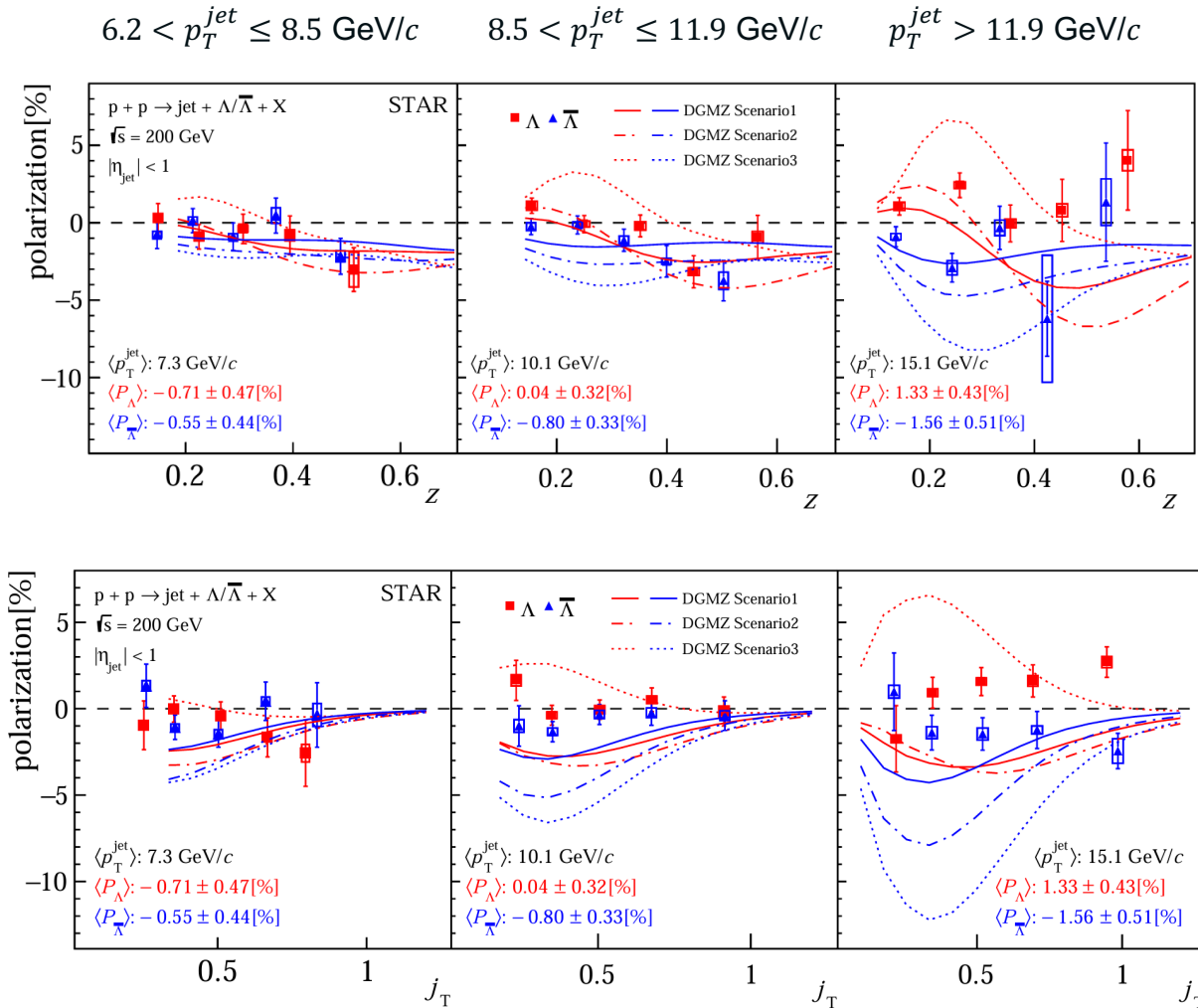
Jet p_T dependence

- The first measurement of Λ transverse polarization inside jet (6~50 GeV/c)
- Indication of p_T^{jet} dependence of Λ polarization
- Difference for Λ and $\bar{\Lambda}$
- Flavor dependence
- Providing the first experimental constraints for PFFs from pp collisions
- Mean polarization
 - $P_\Lambda = 0.24 \pm 0.19(stat.) \pm 0.09(sys.)[\%]$
 - $P_{\bar{\Lambda}} = -0.77 \pm 0.20(stat.) \pm 0.09(sys.)[\%]$



STAR JHEP 06 (2026) 050

Polarization as Function of Jet z, j_T



- Possible z dependences are observed
- No significant dependence on j_T
- Opposite sign of Λ and $\bar{\Lambda}$ polarization at high jet p_T
- Better agreement between data and model at low jet p_T ranges

DGMZ model:

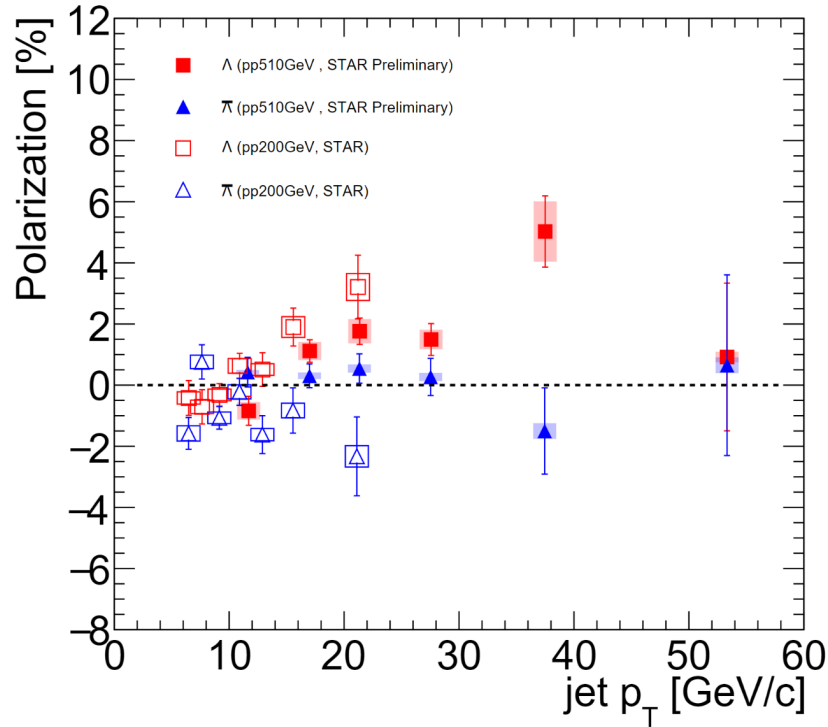
*D'Alesio, Gamberg, Murgia, Zaccheddu,
 Phys. Lett. B 851 (2024) 138552*

Scenario 1: Different PFF for u, d, s and their antiquarks

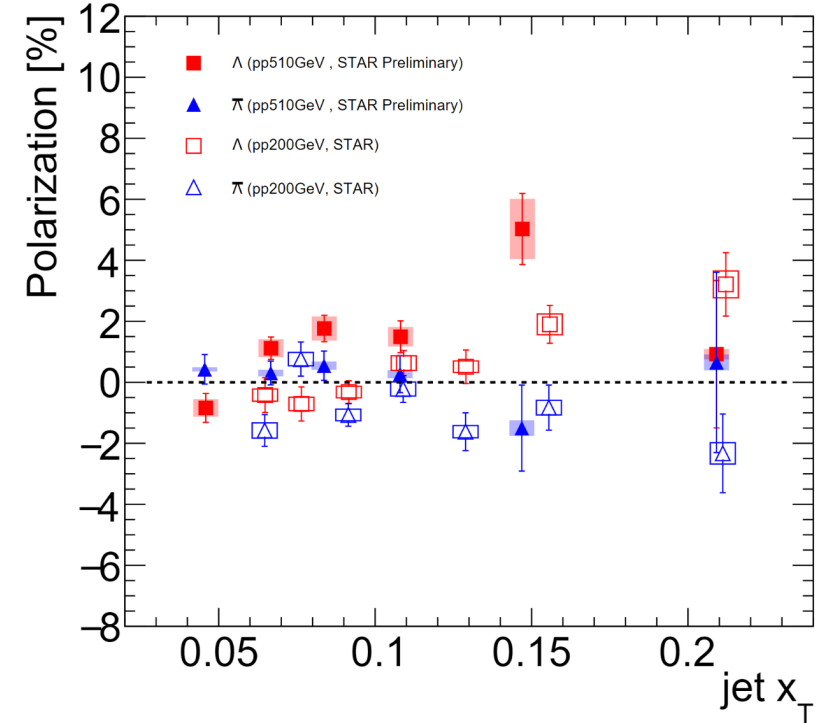
Scenario 2: Same as in Sc. 1 including charm in unpolarized x-section

Scenario 3: Including $SU(2)$ isospin symmetry based on Sc. 2

Energy Dependence of Λ Polarization inside Jet

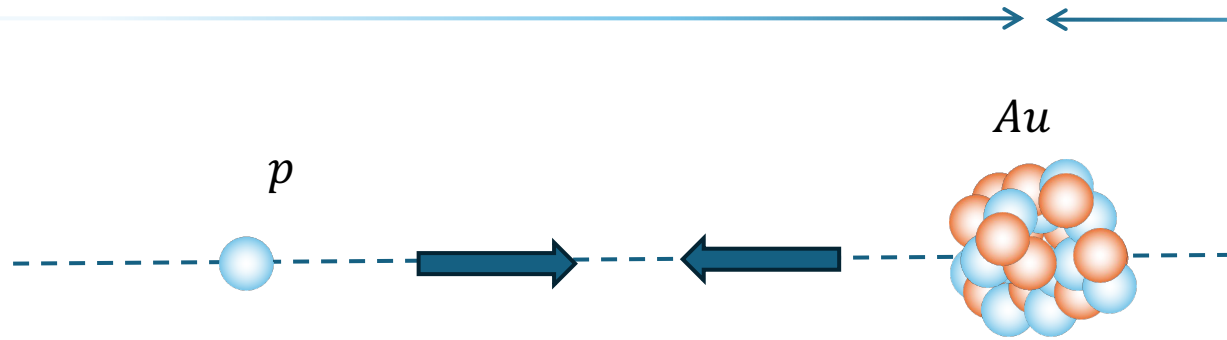


$$x_T = \frac{2p_T^{jet}}{\sqrt{s}}$$

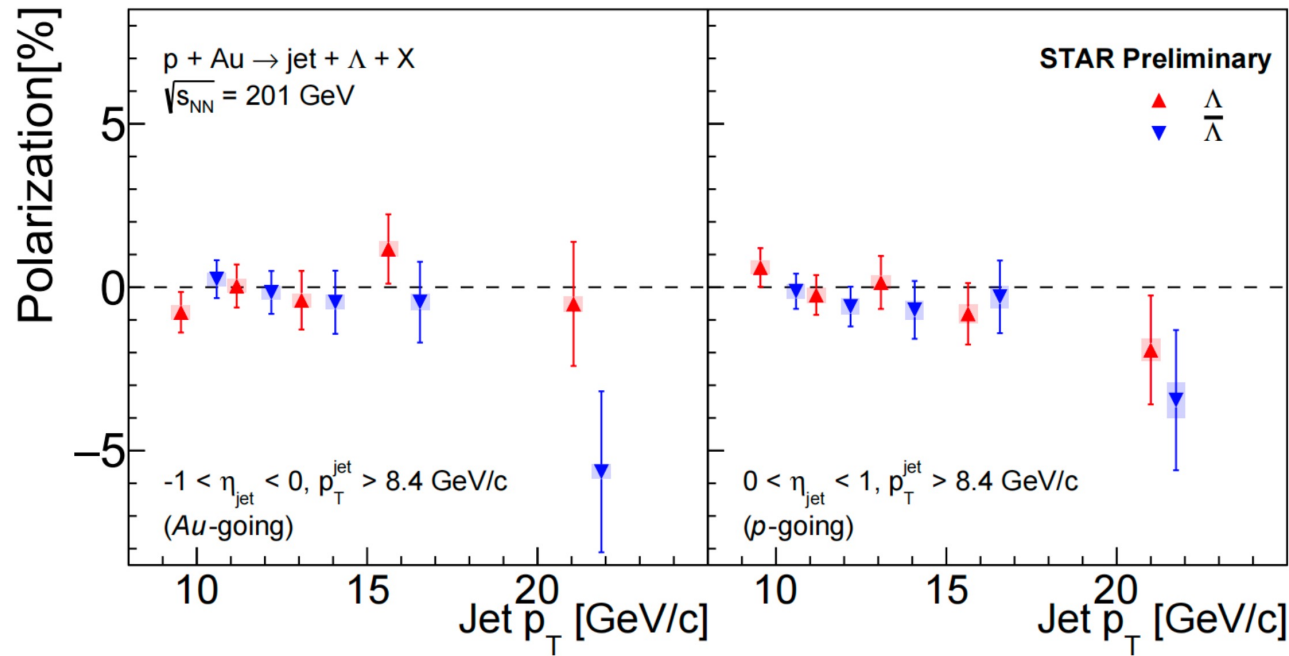


- Jet p_T dependence of Λ polarization is consistent between $\sqrt{s} = 200$ and 510 GeV
- The comparison between 200 and 510 GeV at same x_T probe the scale dependence over a factor of 2.55 in the hard scale

Λ Polarization inside Jet in p -Au



- Transverse polarization is studied separately
 - For Au -going: $\eta < 0$
 - For p -going: $\eta > 0$
- No significant transverse polarization is observed in p -Au collisions
- An indication of nuclear medium effects that suppress transverse polarization relative to pp in p -Au collisions



Summary

- First measurement of transverse polarization of Λ inside jet in pp collisions
- Indication of jet p_T dependence of transverse polarization and different for Λ and $\bar{\Lambda}$
- Consistent results between 200 and 510 GeV pp collisions
- Indication of nuclear medium effects for transverse polarization of Λ in p -Au collisions
- Results provide constraints for PFF:
 - Flavor dependence, especially for gluon
 - TMD evolution effect
 - Universality (combined with Belle's results)