Measurements of Λ hyperon spin correlation in pp and pPb collision at CMS

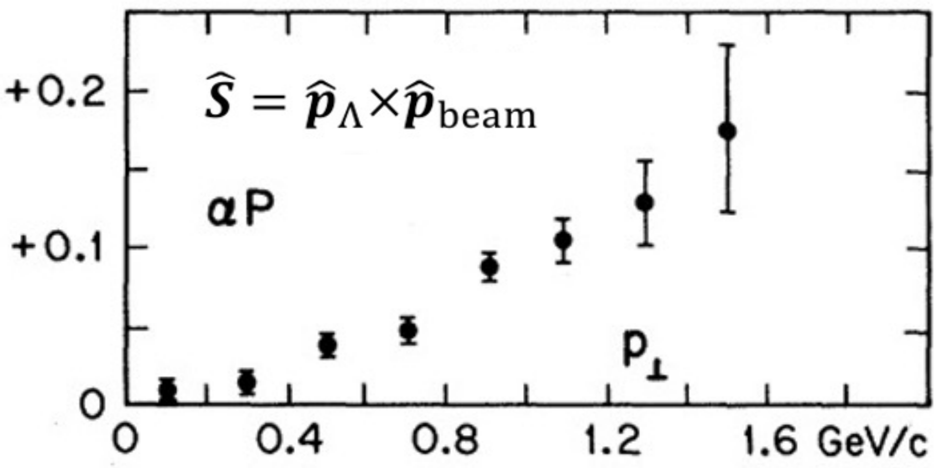
CMS-PAS-HIN-26-002

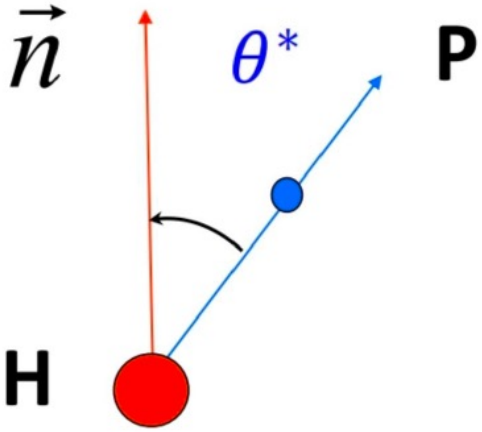
Jieke Wang(汪杰克) on behalf of the CMS collaboration

Shandong University (山东大学)

Spin and polarization

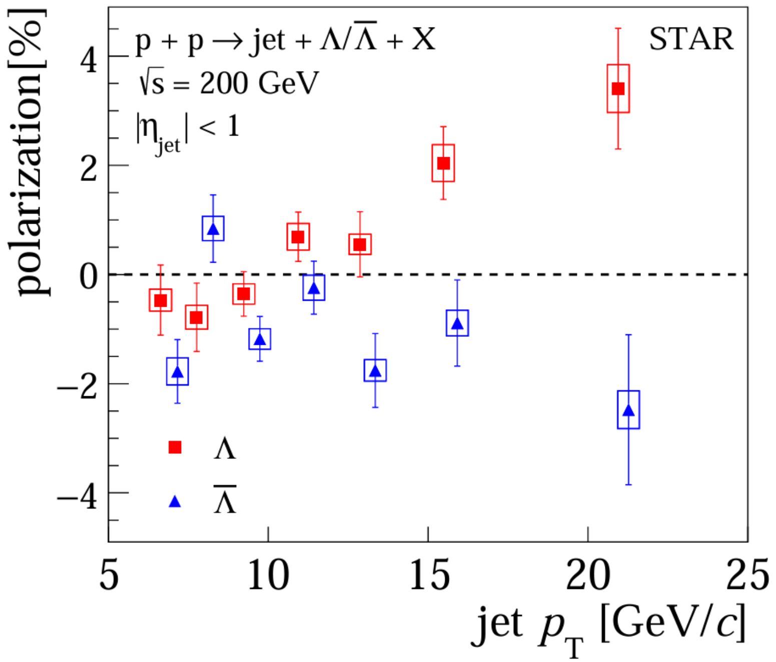
PRL 36,1113(1976)





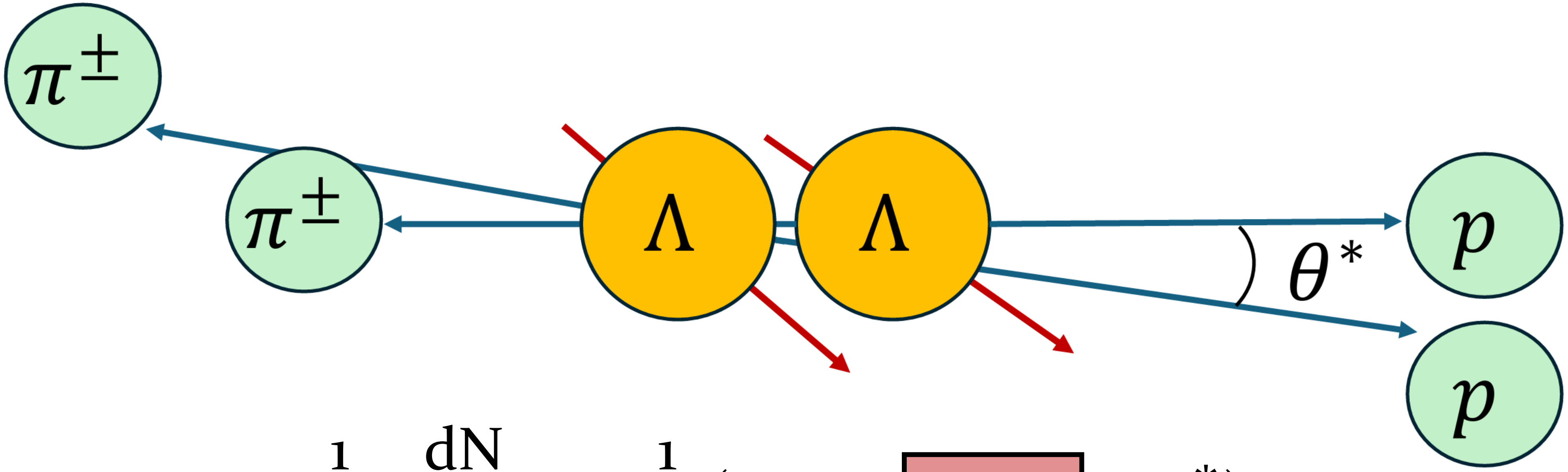
$$\frac{dN}{d\cos(\theta^*)} = 1 + \alpha P_\Lambda \cos(\theta^*)$$

arXiv:2509.17487



Origin of polarization is a long standing puzzle
Λ hyperon is a self-analyzing probe of spin polarization
Recent measurements focus mainly on single Λ observables

Λ spin correlation



Picture : Zhoudunming Tu

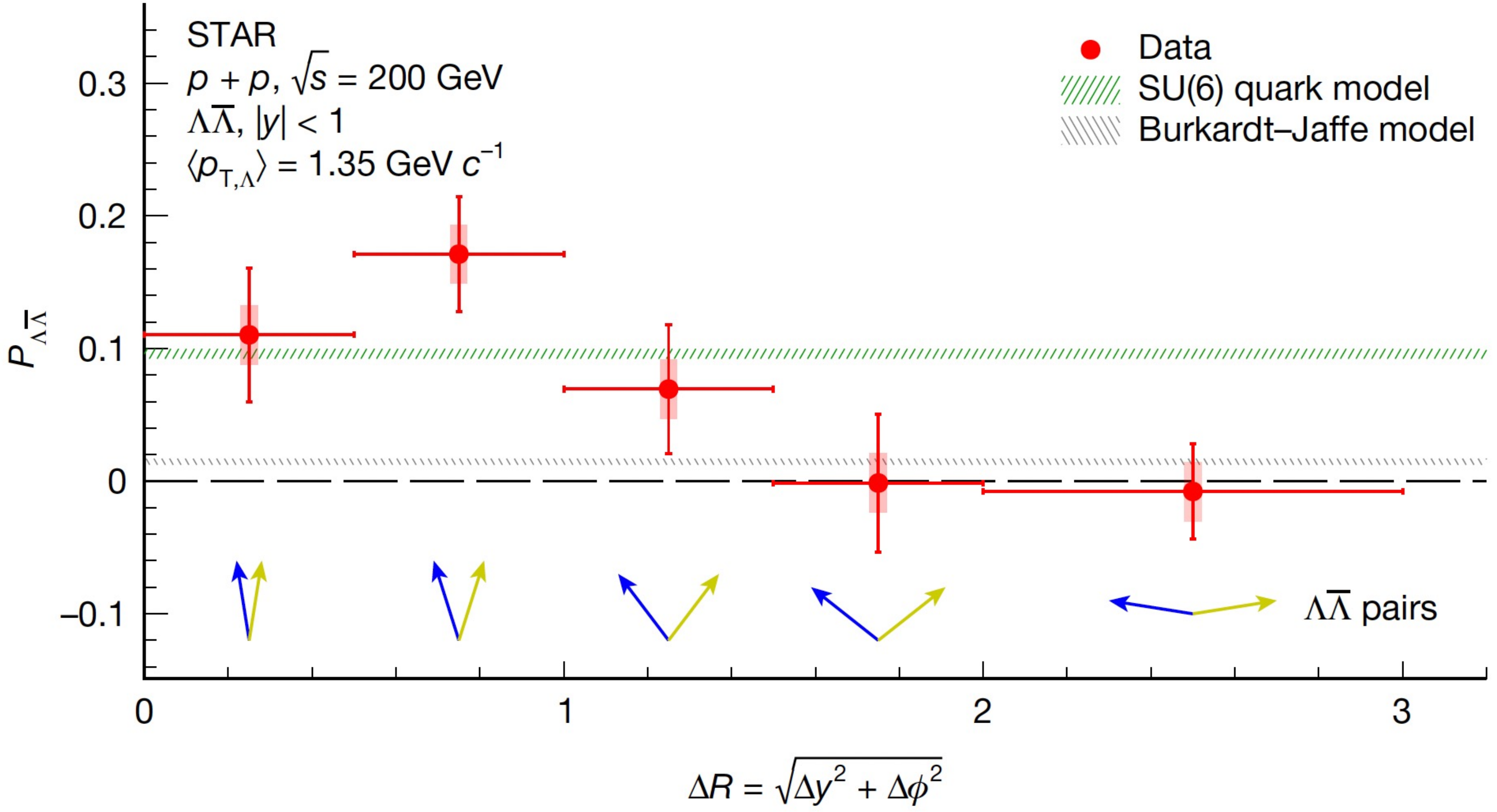
$$\frac{1}{N}\frac{dN}{d\cos\theta^*} = \frac{1}{2}\left(1+\alpha_1\alpha_2 P_{\Lambda_1\Lambda_2}\cos\theta^*\right)$$

Correlation of Λs′ spin

Correlation of two Λ's spin can be probed
by the angle between (anti-)protons in the rest frames of Λs

Λ spin correlation

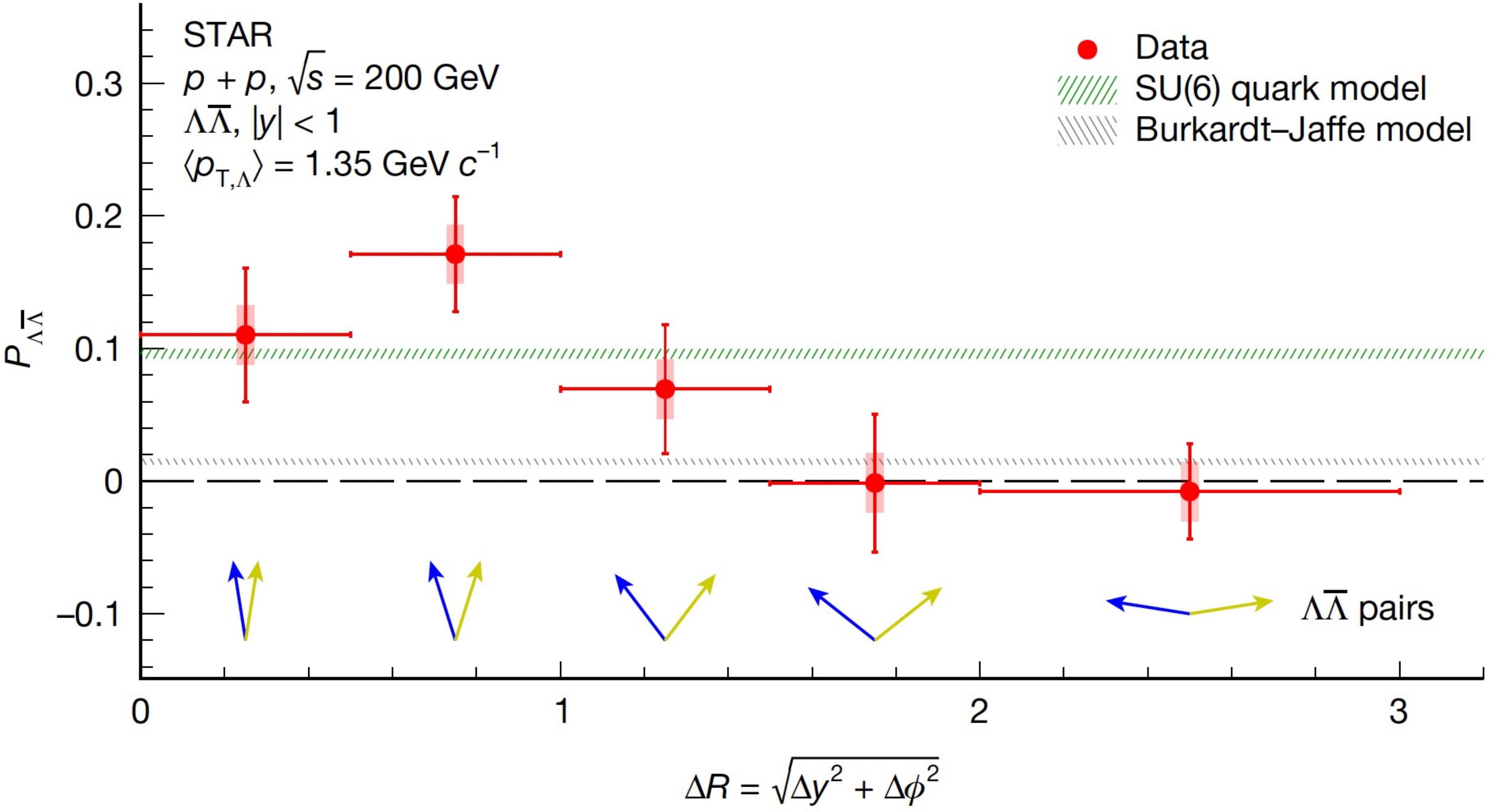
Nature 650, 44-45 (2026)



Significant $\Lambda\bar{\Lambda}$ correlation at small ΔR

Λ spin correlation

Nature 650, 44-45 (2026)



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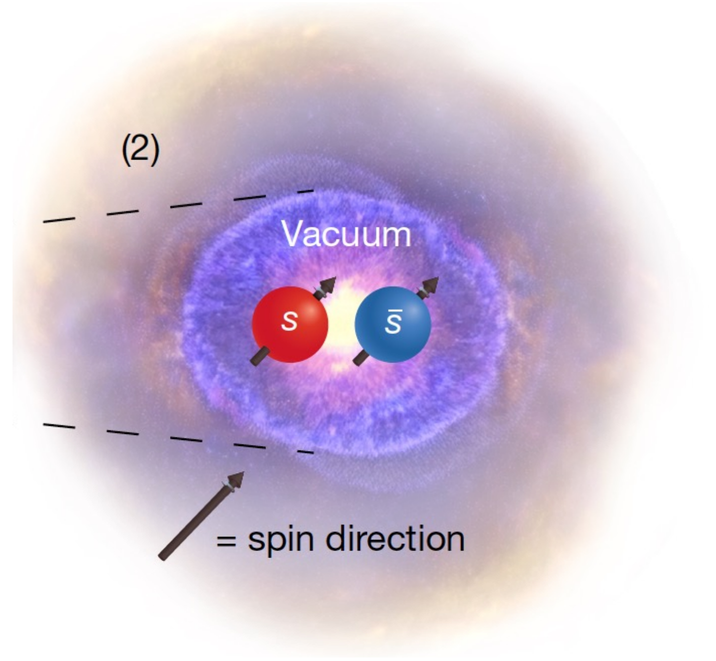
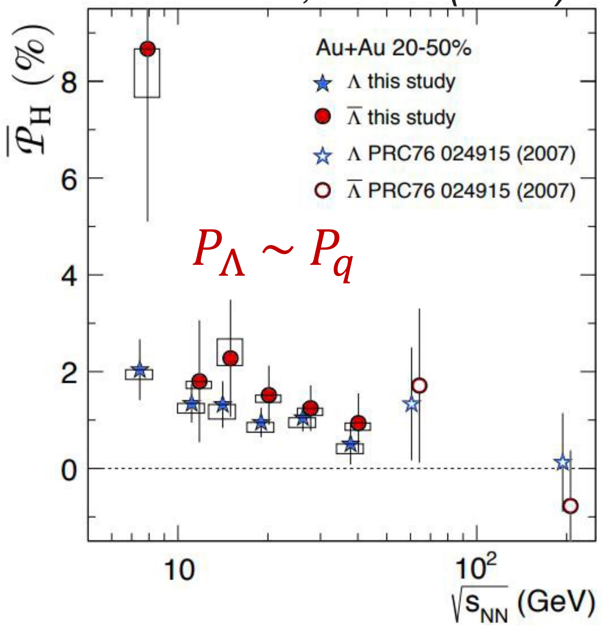


vacuum production : $J^{\mathcal{P}C} = 0^{++}$

$s\bar{s}$ in spin triplet state

Spin correlation in Heavy Ion Physics

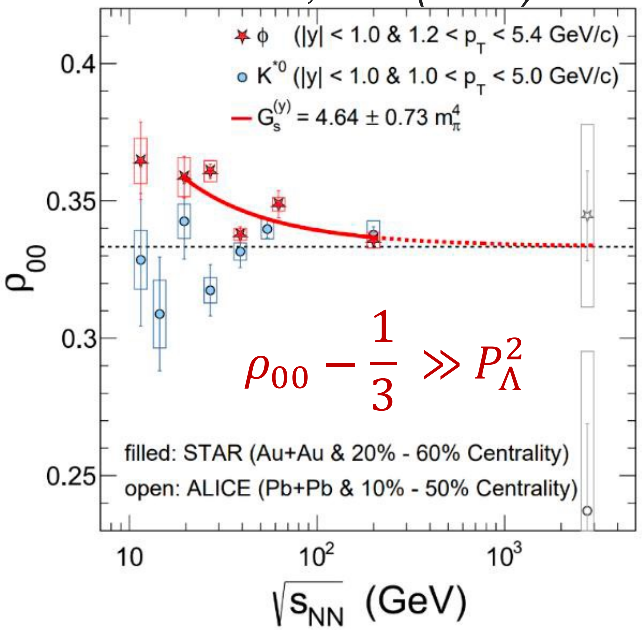
Nature 548, 62-65 (2017)



$P_\Lambda \sim P_q$

$P_H = P_{\bar{H}} = P_q = P_{\bar{q}}$

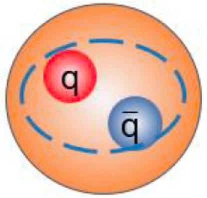
Nature 614, 244 (2023)



$\rho_{00} - \frac{1}{3} \gg P_\Lambda^2$

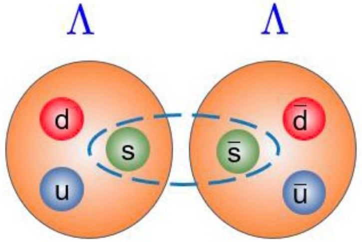
$$\rho_{00}^V = \frac{1-P_{q_1\bar{q}_2}}{3+P_{q_1\bar{q}_2}} \sim \frac{1}{3}\left(1-\frac{4}{3}P_q^2\right)$$

Phys.Rev.D 109 (2024) 11, 114003



$\langle p_q p_{\bar{q}} \rangle \neq \langle p_q \rangle \langle p_{\bar{q}} \rangle$

local spin correlations

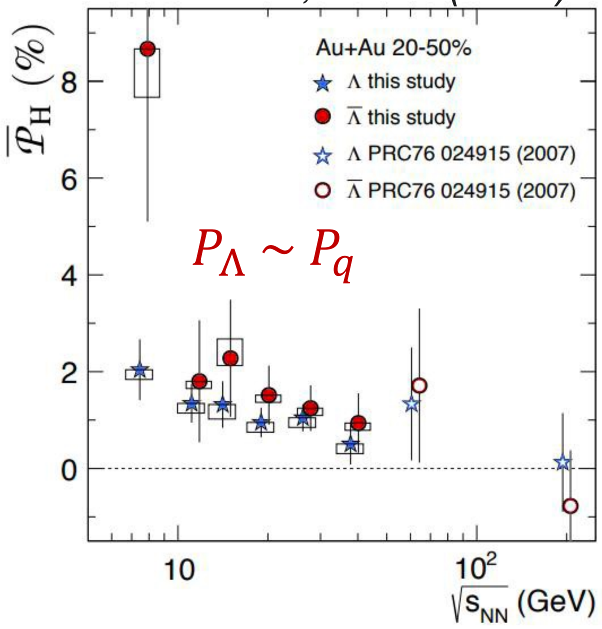


long range spin correlation

Spin correlation proposed to simultaneously explain global polarization & spin alignment

Spin correlation in Heavy Ion Physics

Nature 548, 62-65 (2017)



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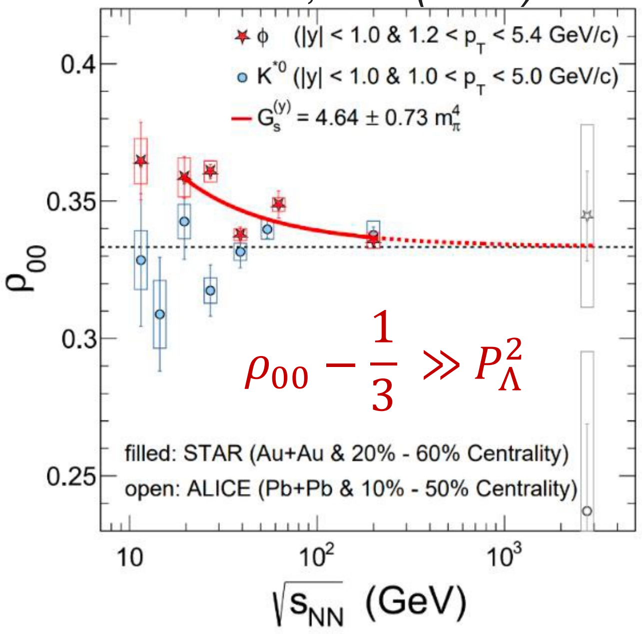

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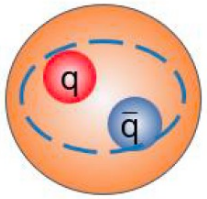

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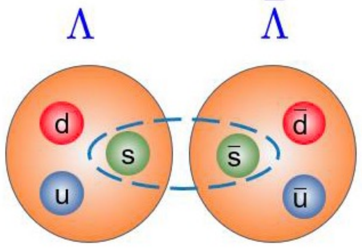


long range spin correlation

Spin correlation proposed to simultaneously explain global polarization & spin alignment

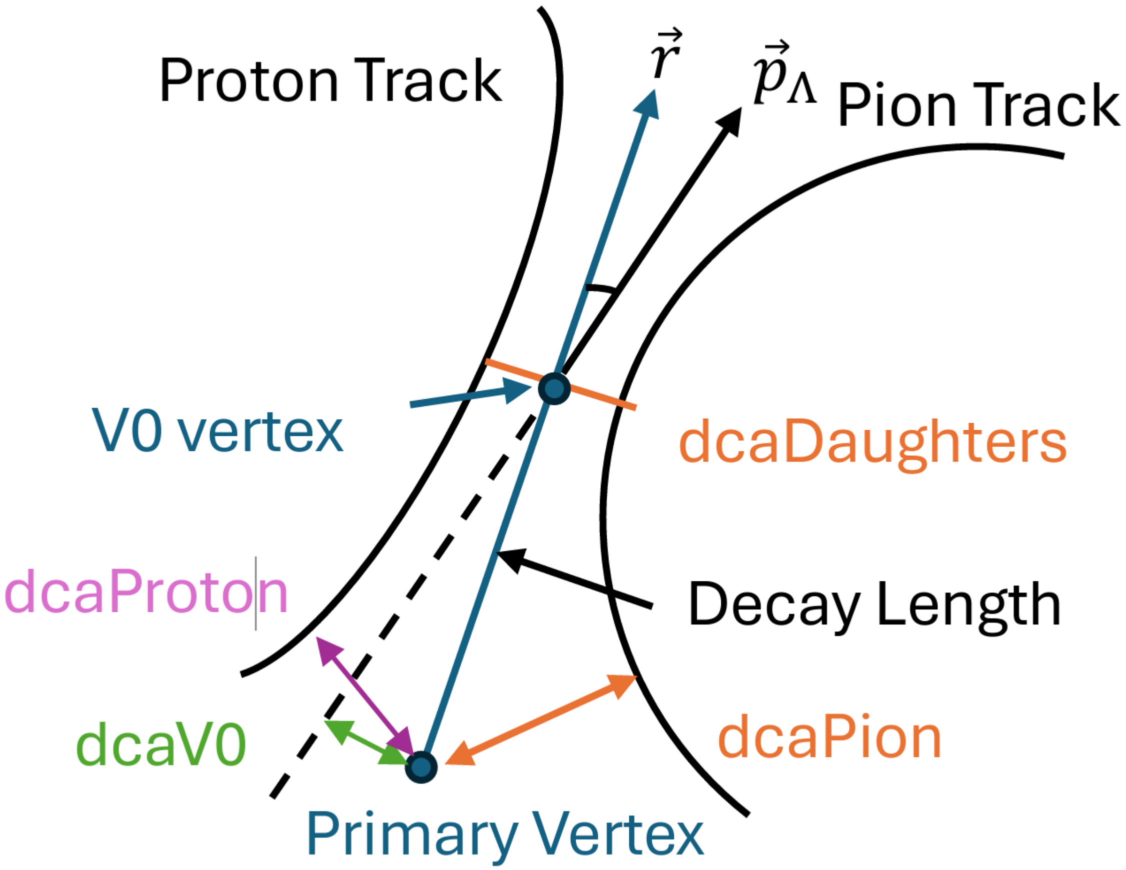
Λ spin correlation measurement at CMS in pp and pPb collisions

- ◉ Energy and collision system dependence
- ◉ Baseline for measurements in heavy ion collisions

Dataset and Λ reconstruction

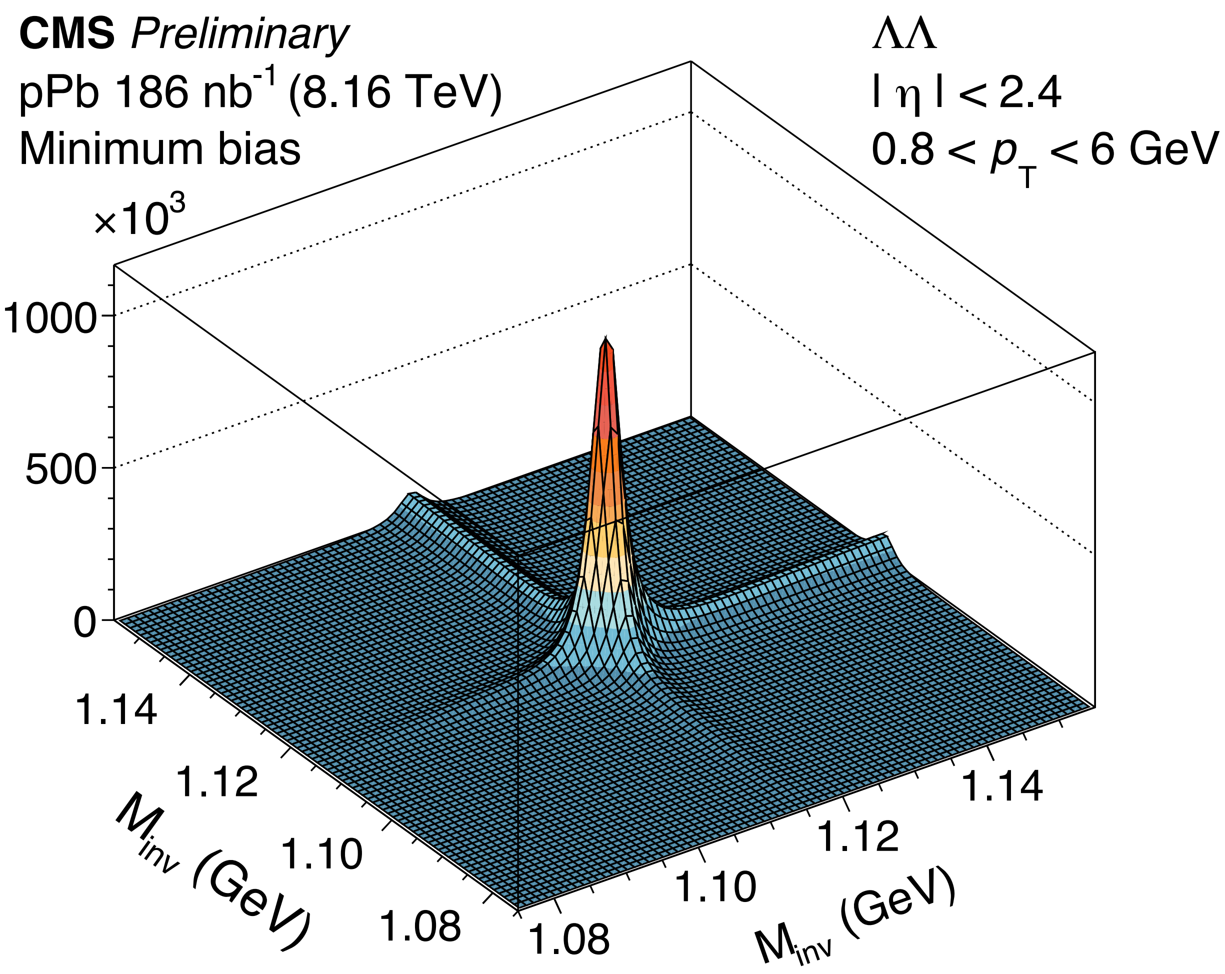
- 8.16 TeV pPb minimum bias data collected by CMS experiment with L_{int} = 186 nb^{-1}

- 13 TeV pp minimum bias data with L_{int} = 28.6 pb^{-1}



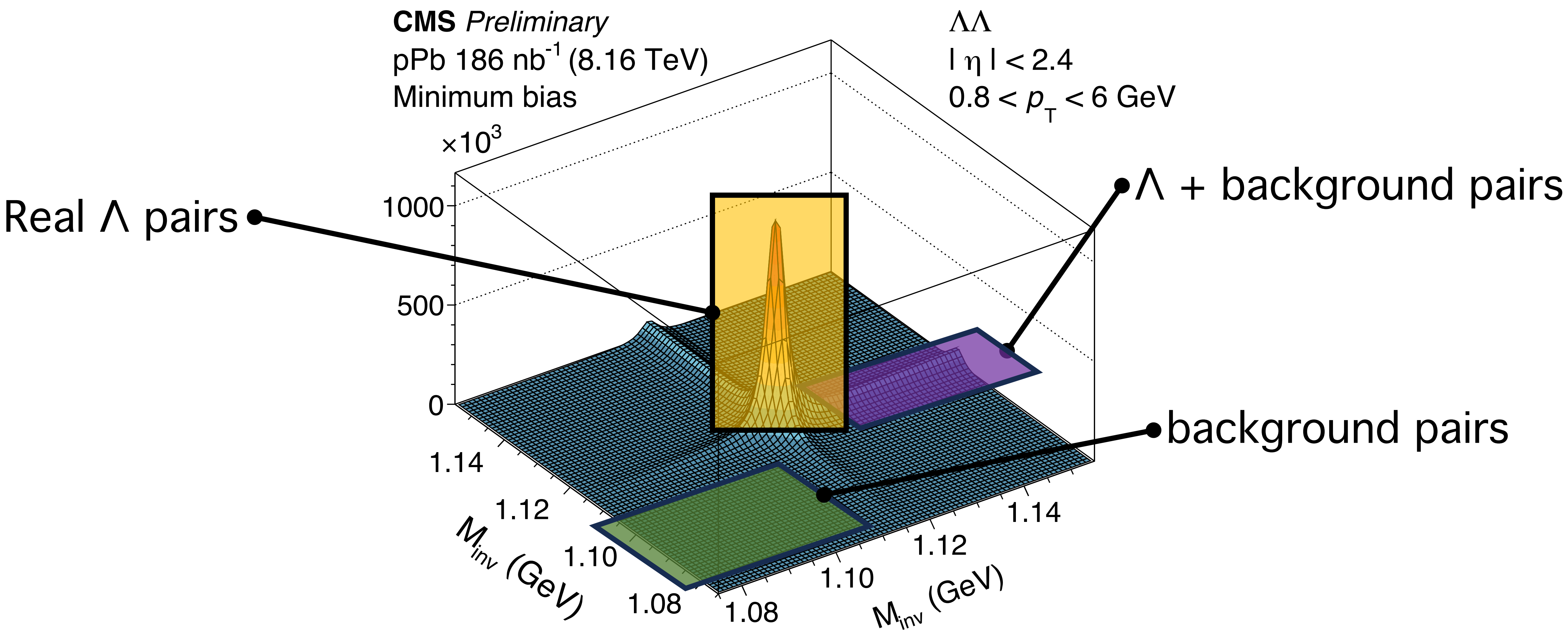
Λ reconstruction

Λ pair reconstruction



Significant Λ pair peak

Pair yield extraction



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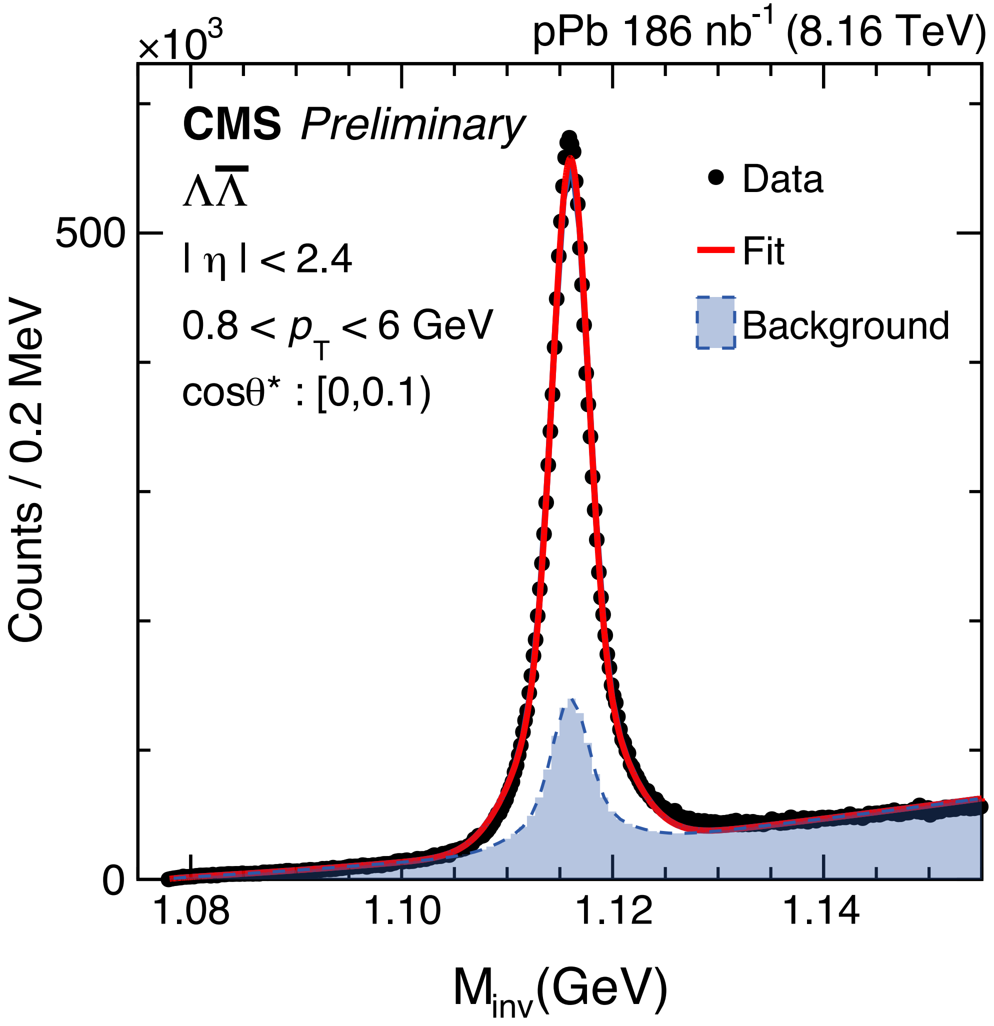


- For single Λ candidates

  $f(m) = f_{signal} + f_{background}$

  f_{signal}: Double Gaussian function

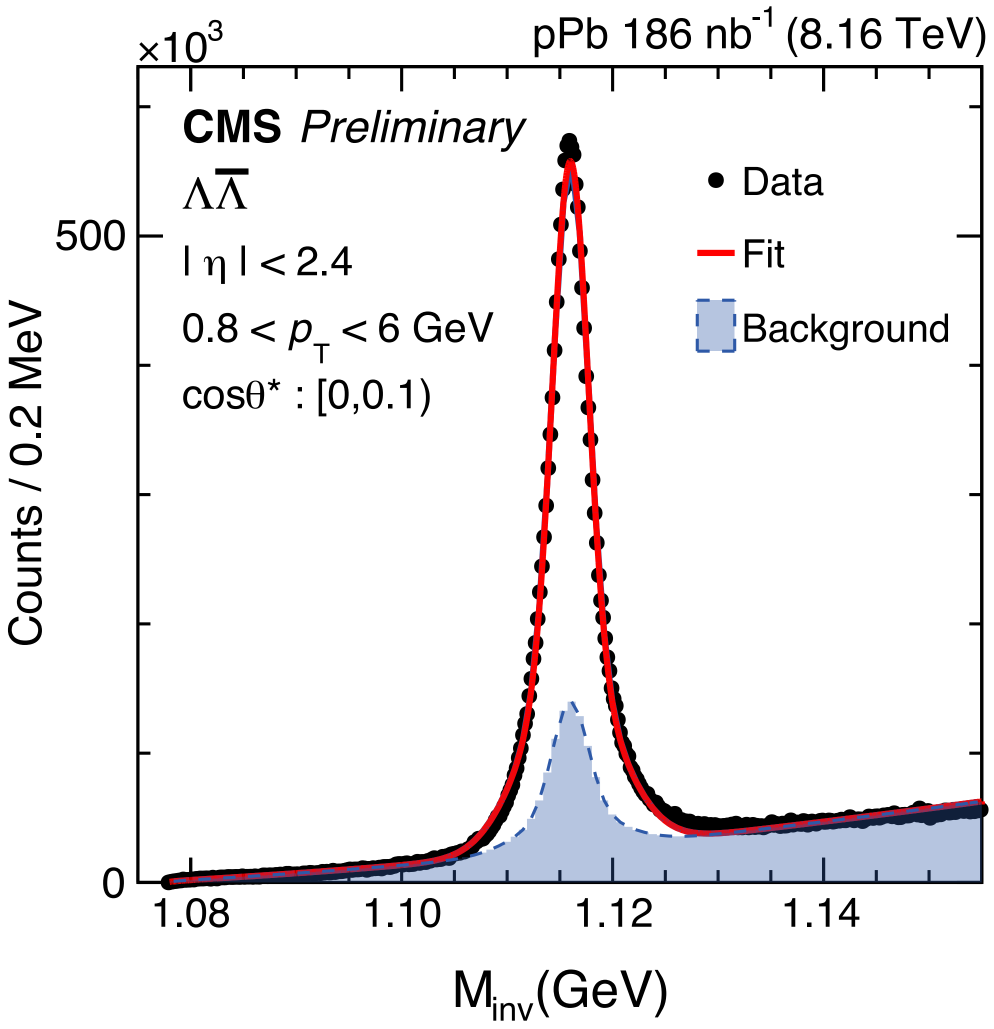
  $f_{background}$: $Aq^{\frac{1}{2}} + Bq^{\frac{3}{2}}$, $q = m - (m_{\pi} + m_p)$

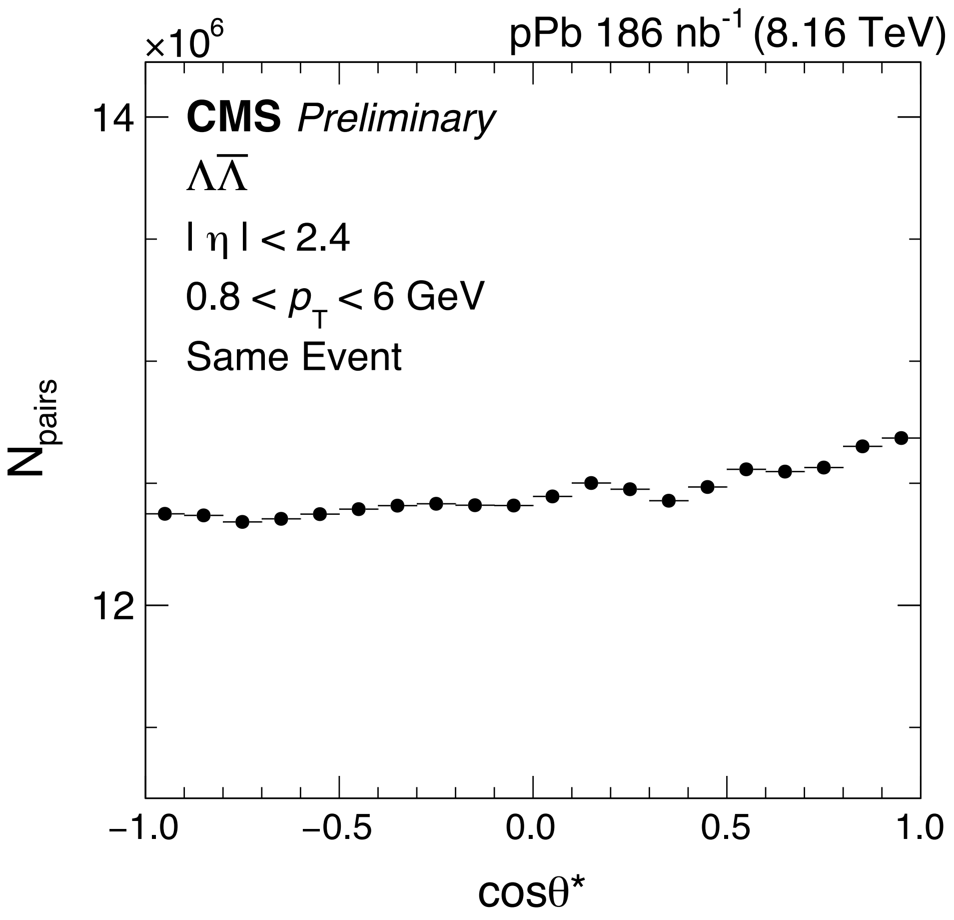
- For Λ pair candidates

  $f(x, y) = f(x) \times f(y)$

Fit the projected distribution to extract yield of real Λ pairs

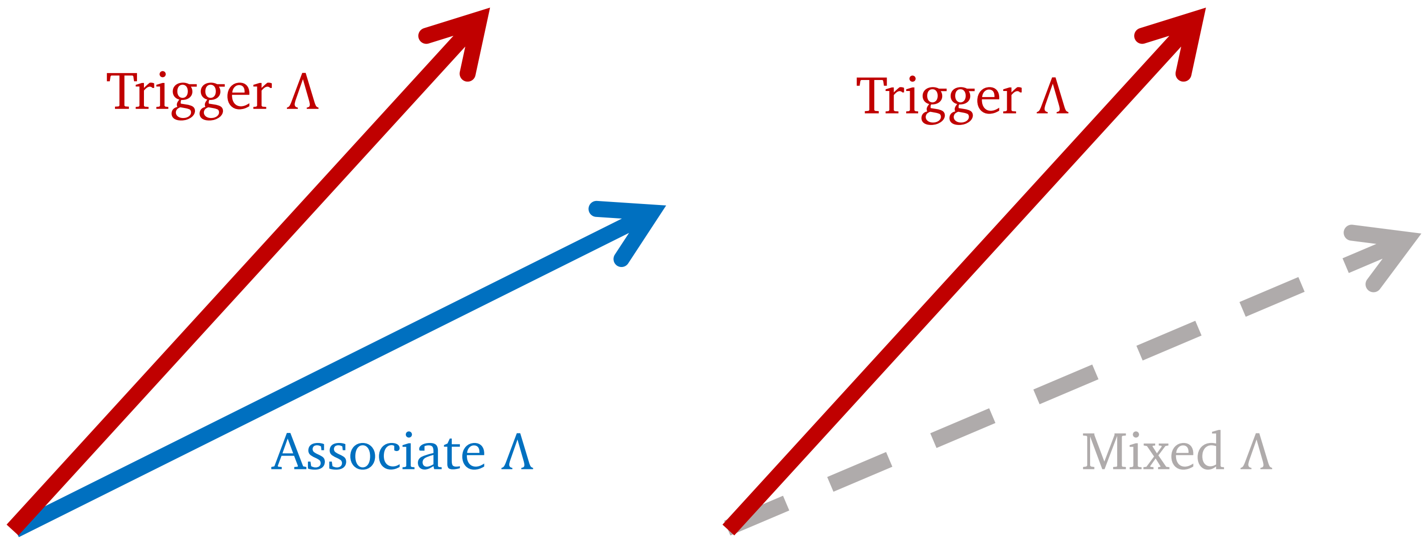
Pair yield extraction

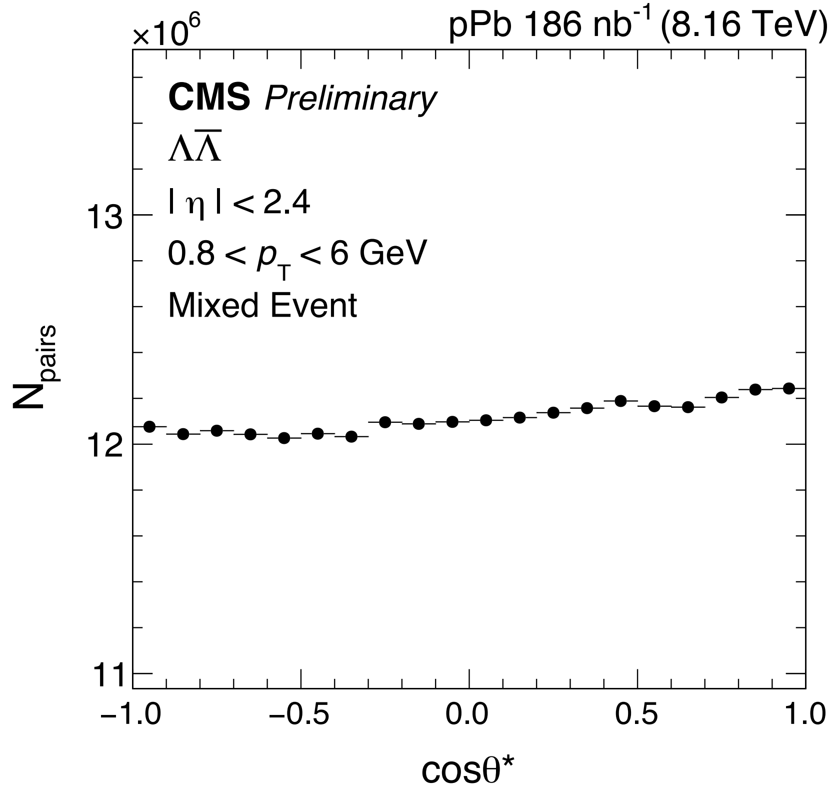




Need to correct detector effect for the $dN/dcos\theta^*$ distribution

Mixed event correction



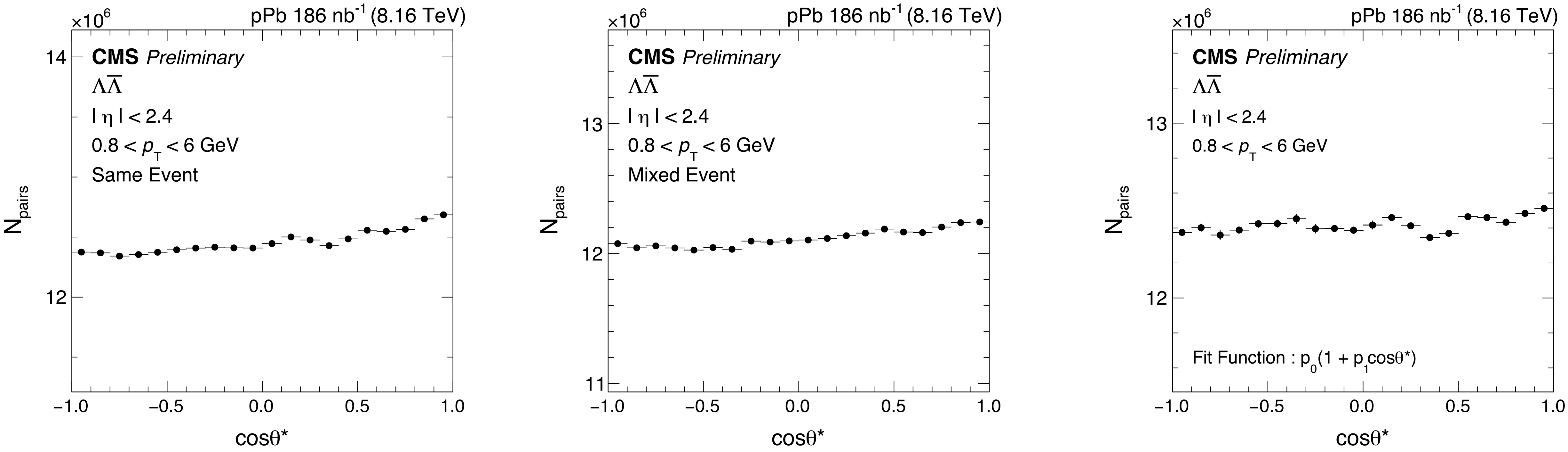


Replace one Λ with another Λ from random events with requirements

$$|\Delta v_z| < 2cm\ ,\left|\Delta N_{trk,offline}\right| < 5$$

$$|\Delta p_T| < 0.1, |\Delta\eta| < 0.1, |\Delta\phi| < 0.1$$

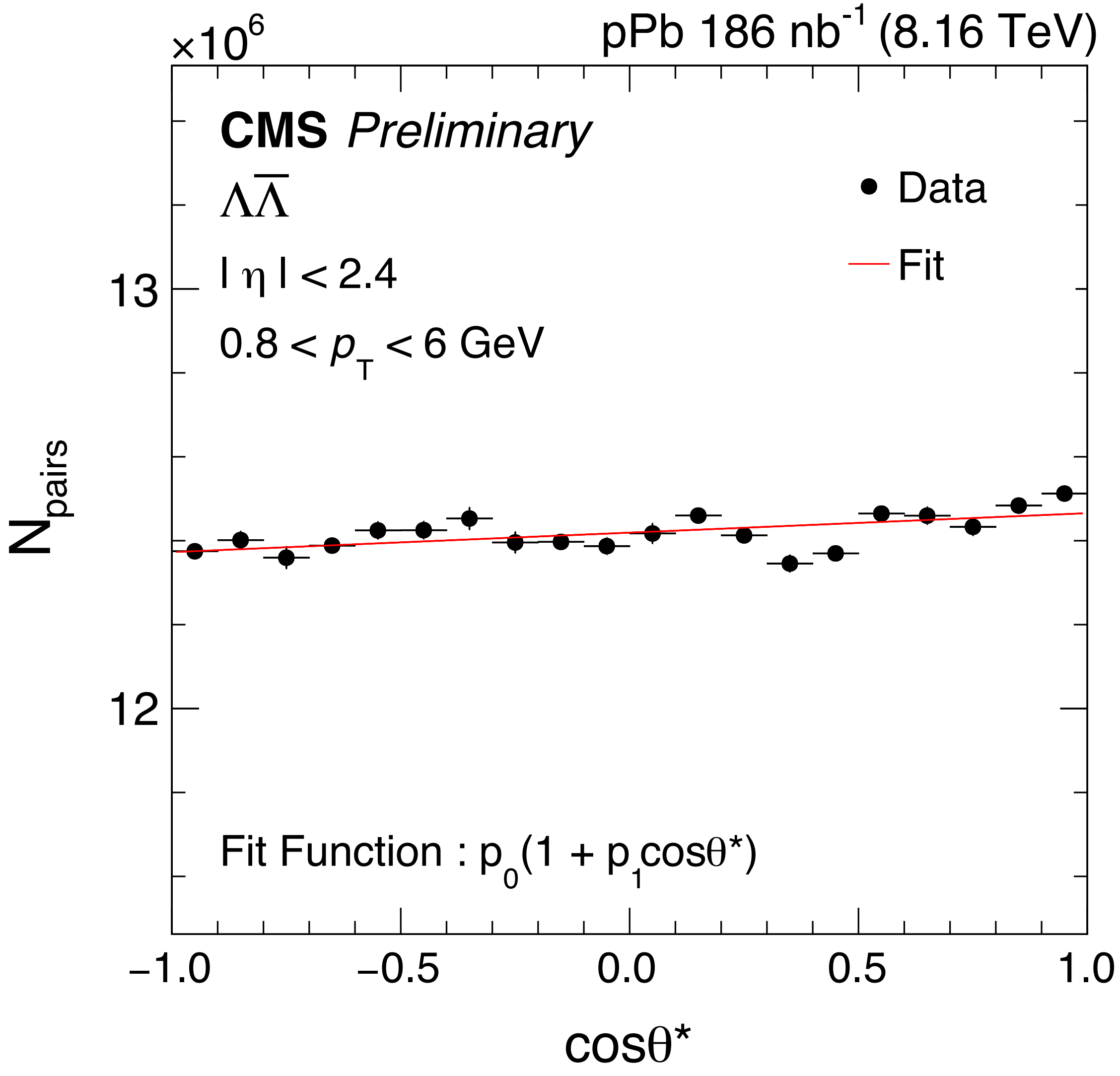
Mixed event correction



Same event / Mix event = Final $cos\theta^*$ distribution

Correct the same event $cos\theta^*$ with mixed event

Spin correlation $P_{\Lambda\Lambda}$ extraction



$P_{\Lambda\Lambda}$ is extracted by the fitting to the Final $cos\theta^*$ distribution

$$N_{pairs} = p_0(1 + p_1 cos\theta^*)$$

$$p_0 = N_{pairs}/2$$

$$p_1 = \alpha_1\alpha_2 P_{\Lambda\Lambda}$$

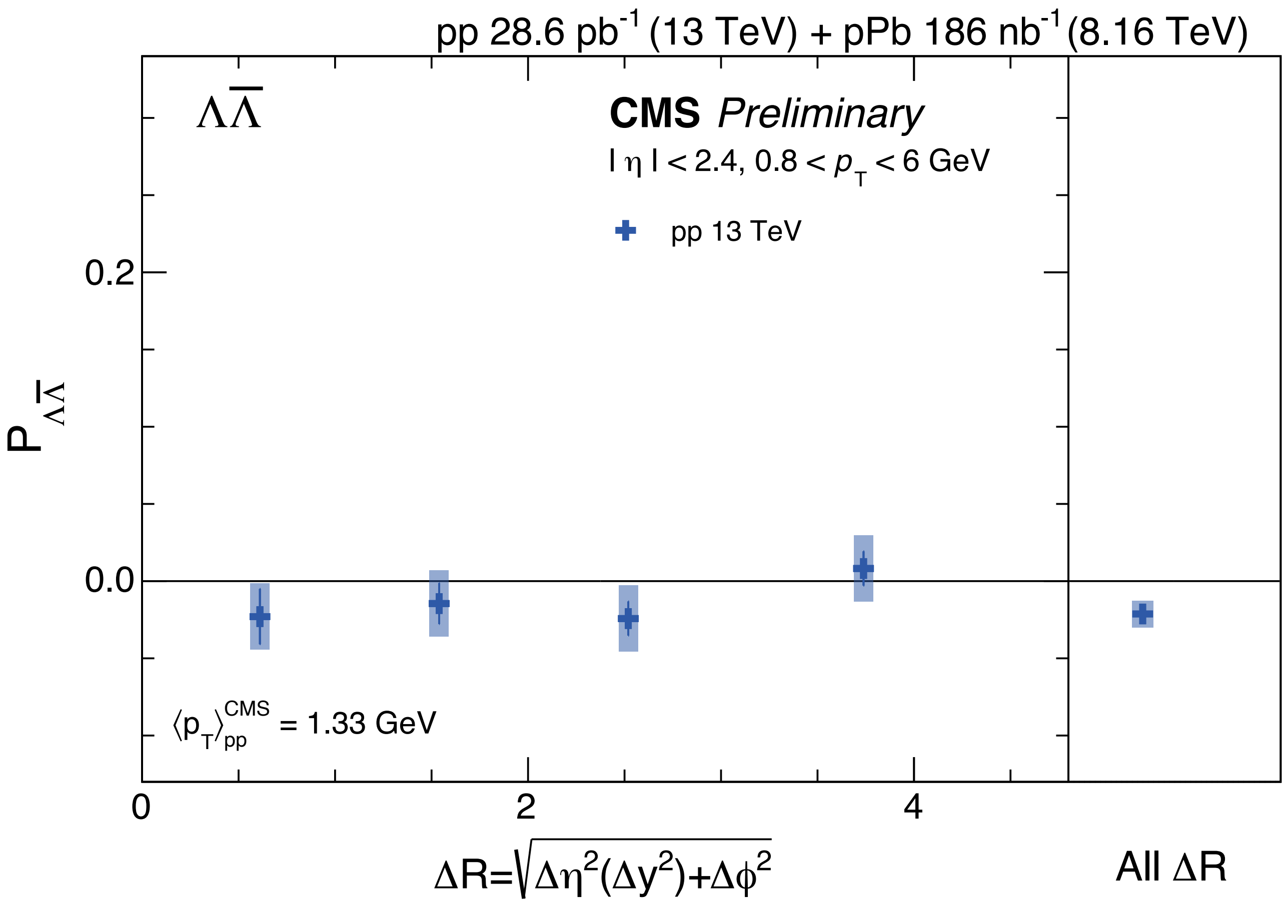
$$\alpha_\Lambda = 0.750 \pm 0.009,$$

$$\alpha_{\bar{\Lambda}} = -0.758 \pm 0.010$$

(Nature Phys. 15 (2019) 631)

Spin correlation of $\Lambda\bar{\Lambda}$ pairs

pp 13TeV



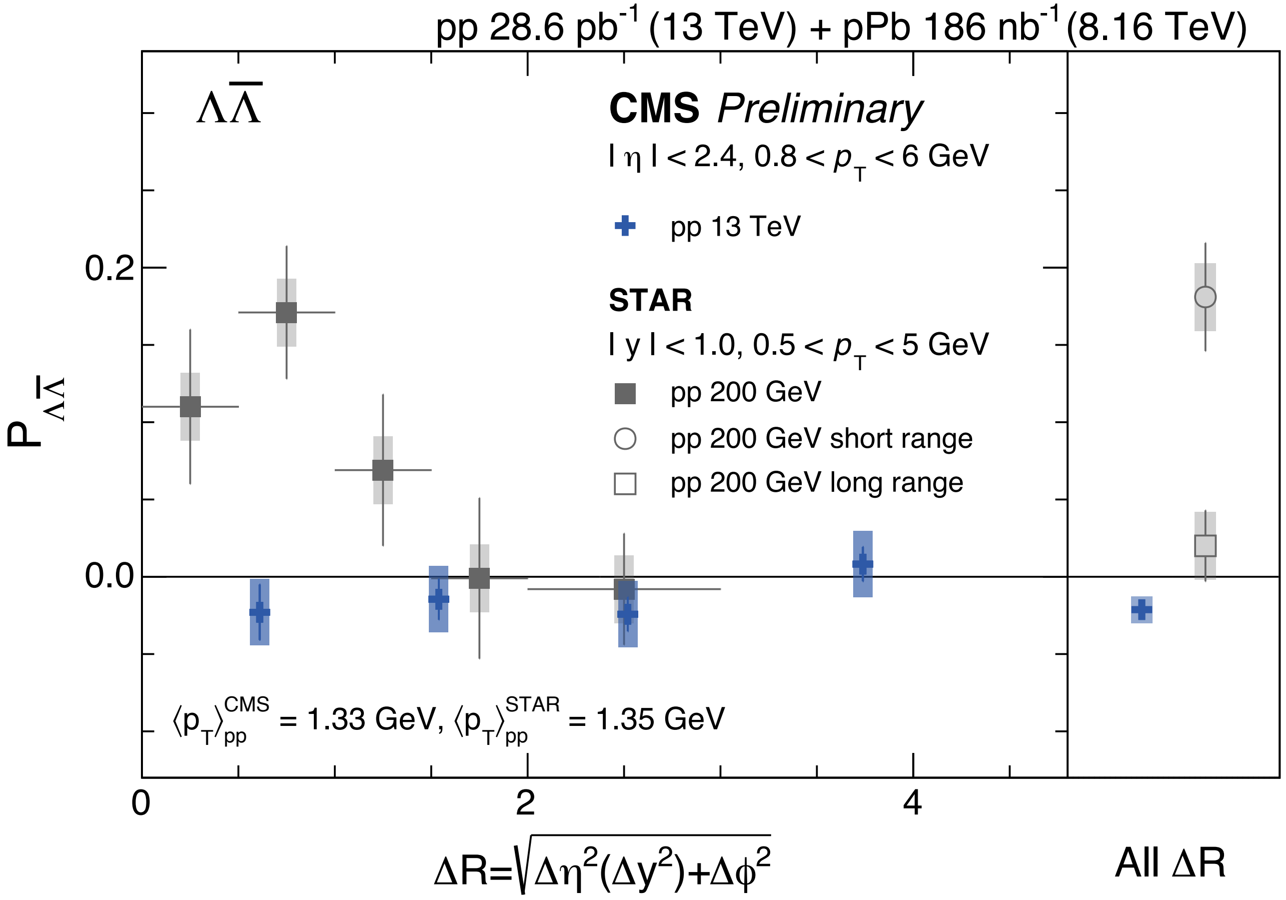
ΔR differential results are consistent with zero within uncertainties

Integrated result shows a hint of negative value

Spin correlation of $\Lambda\bar{\Lambda}$ pairs

pp 13TeV

pp 200GeV



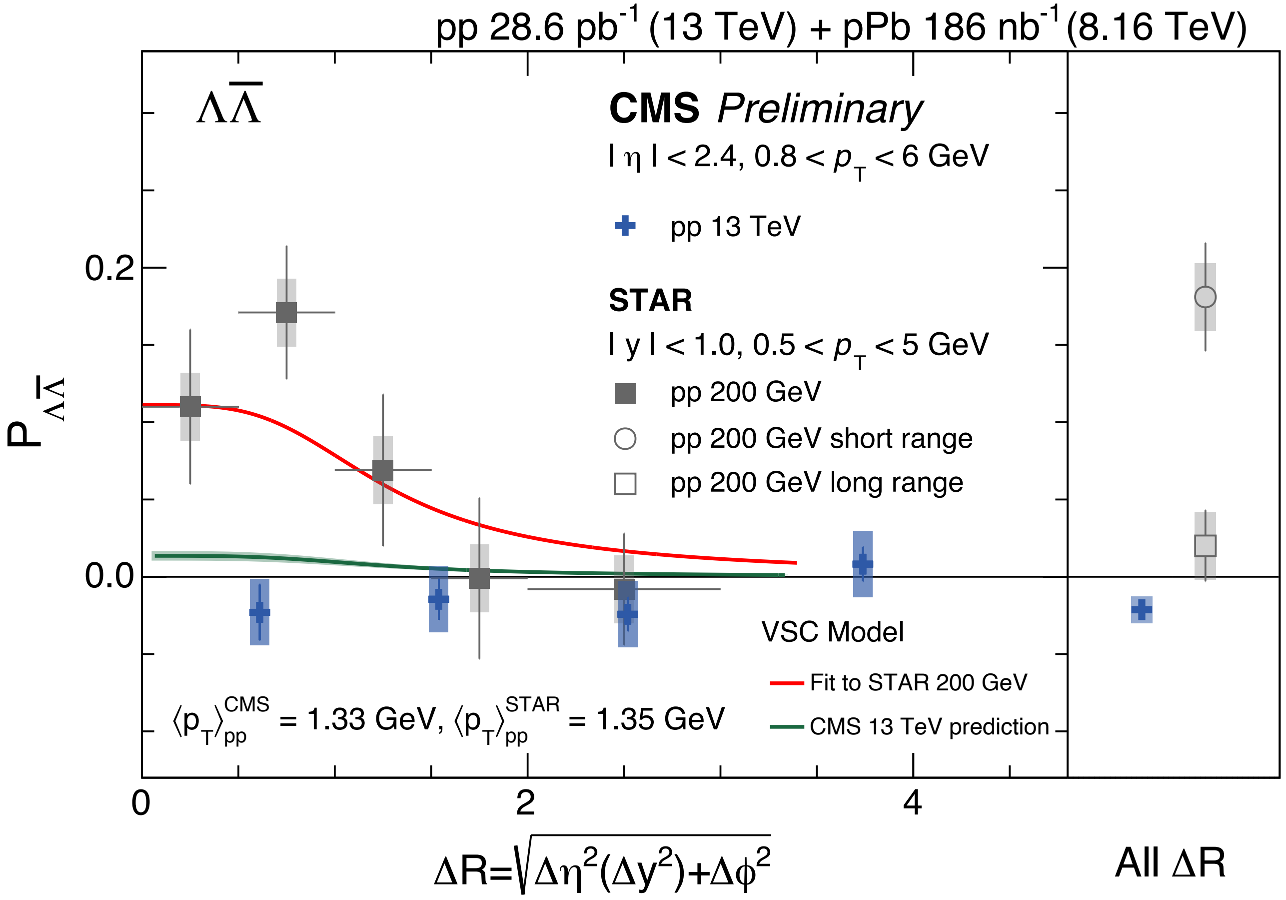
Different behavior from STAR measurements at 200GeV

Might be due to different production mechanism at RHIC and LHC energies

Spin correlation of $\Lambda\bar{\Lambda}$ pairs

pp 13TeV

pp 200GeV



VSC model

F.Liu, Z.Tu

work in progress

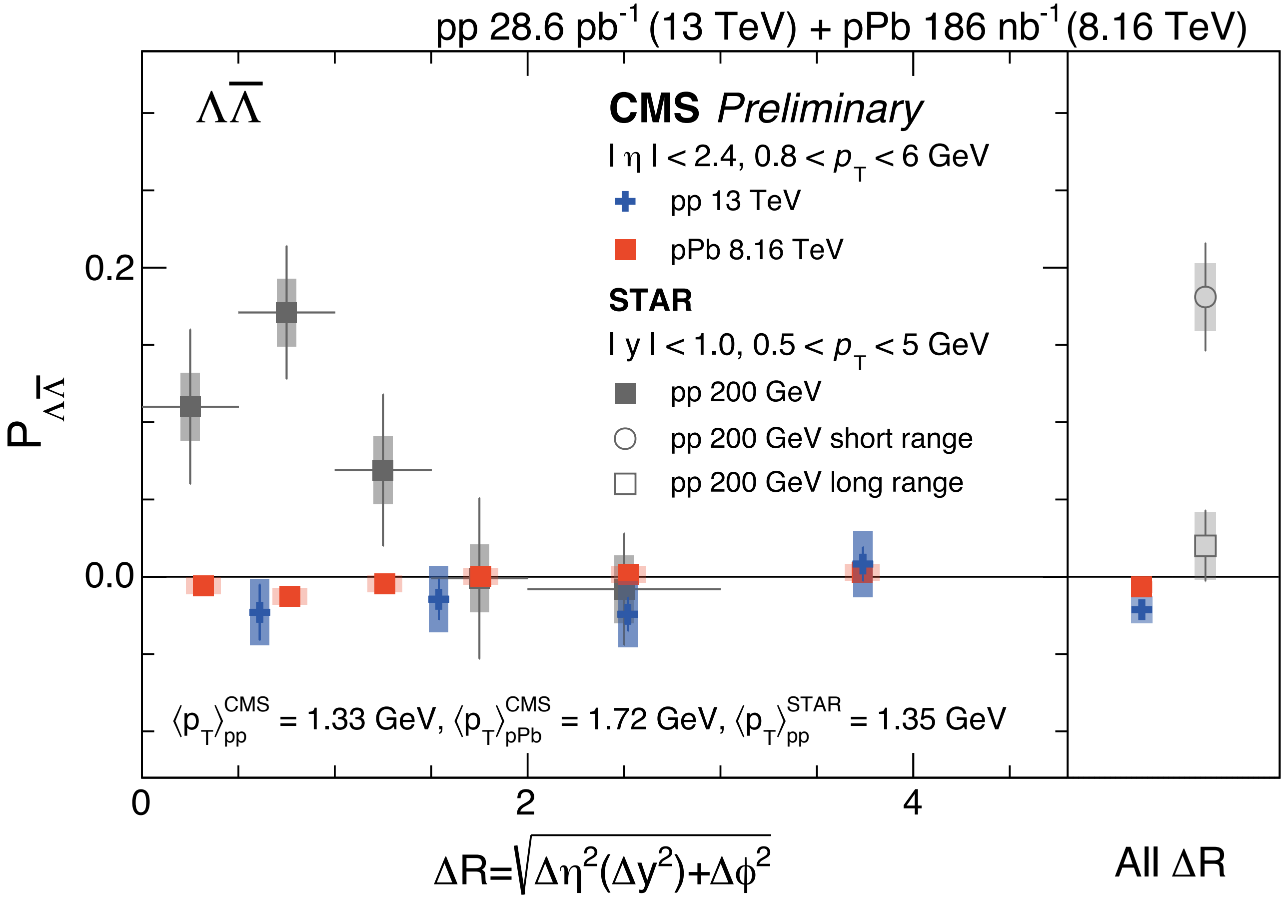
Different behavior from STAR measurements at 200GeV

Might be due to different production mechanism at RHIC and LHC energies

VSC(vacuum-spin-chain) model predicts small positive values

Spin correlation of $\Lambda\bar{\Lambda}$ pairs

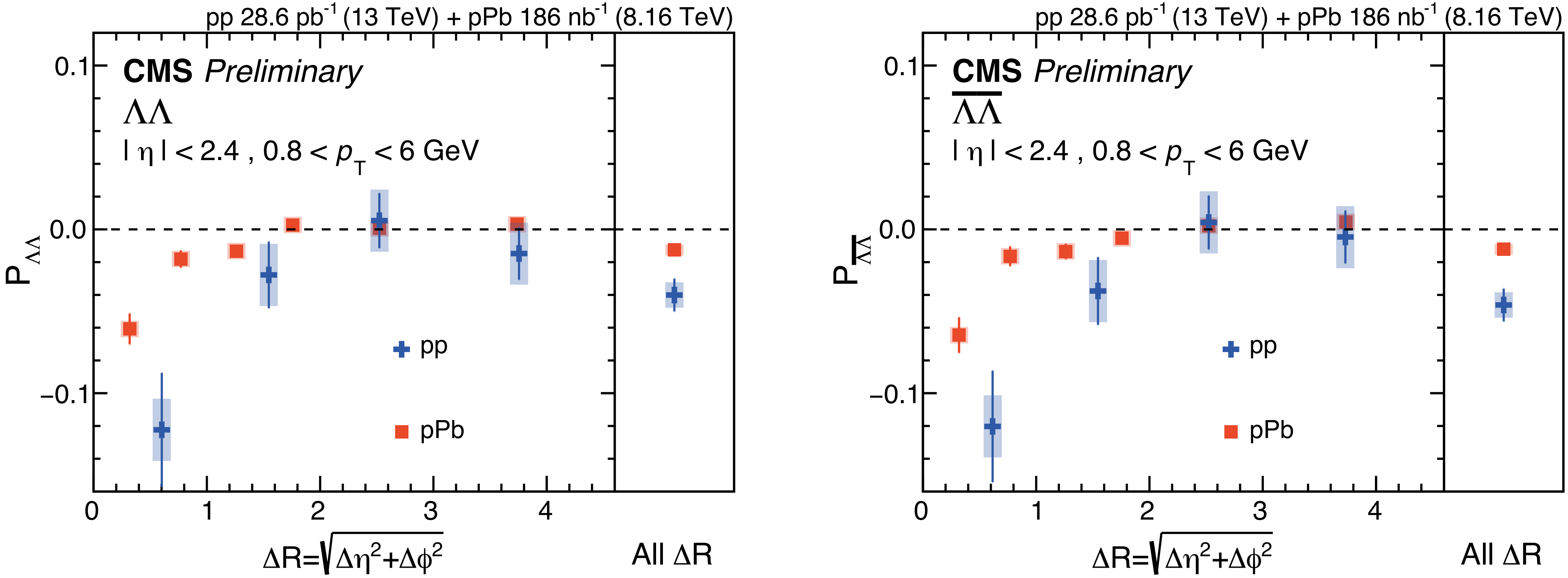
pp 13TeV
pp 200GeV
pPb 8.16TeV



pPb results similar to pp

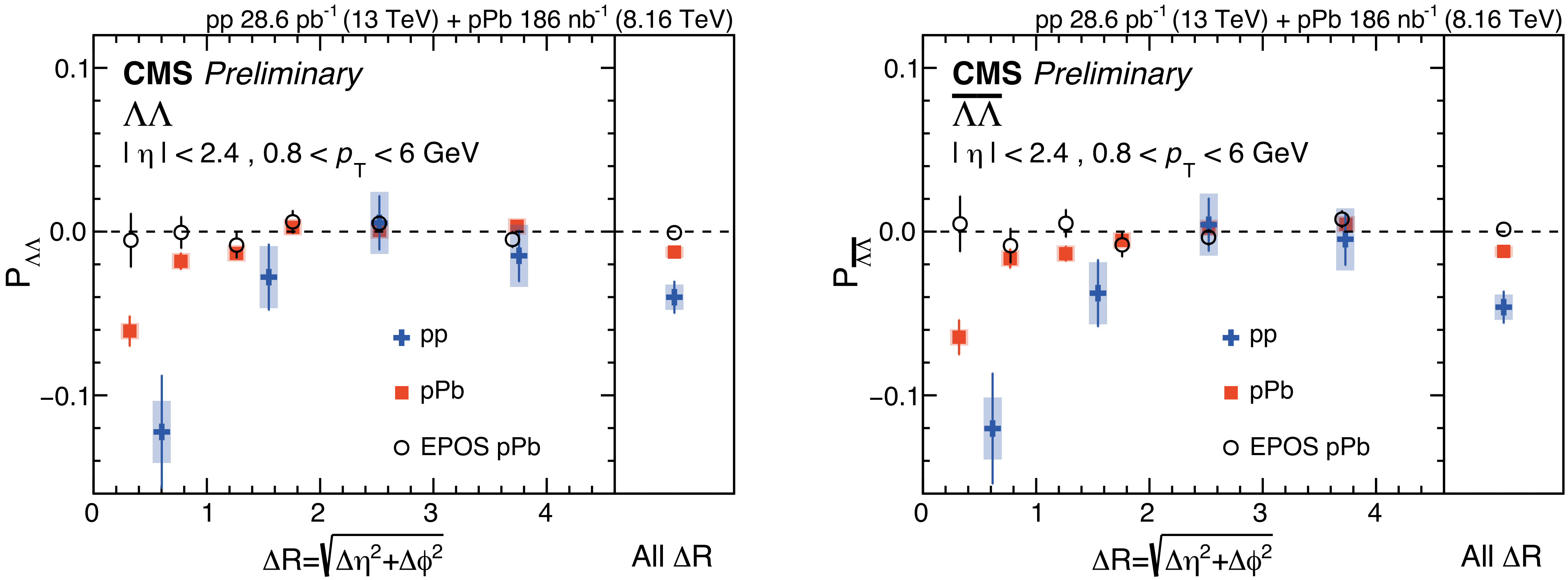
Average multiplicity for pPb ~101, where collectivity behavior emerges

Spin correlation of ΛΛ and $\bar{\Lambda}\bar{\Lambda}$ pairs



Negative spin correlation observed at small ΔR for ΛΛ and $\bar{\Lambda}\bar{\Lambda}$ pairs
Converge to zero at large ΔR value
A hint of larger magnitudes in pp than pPb

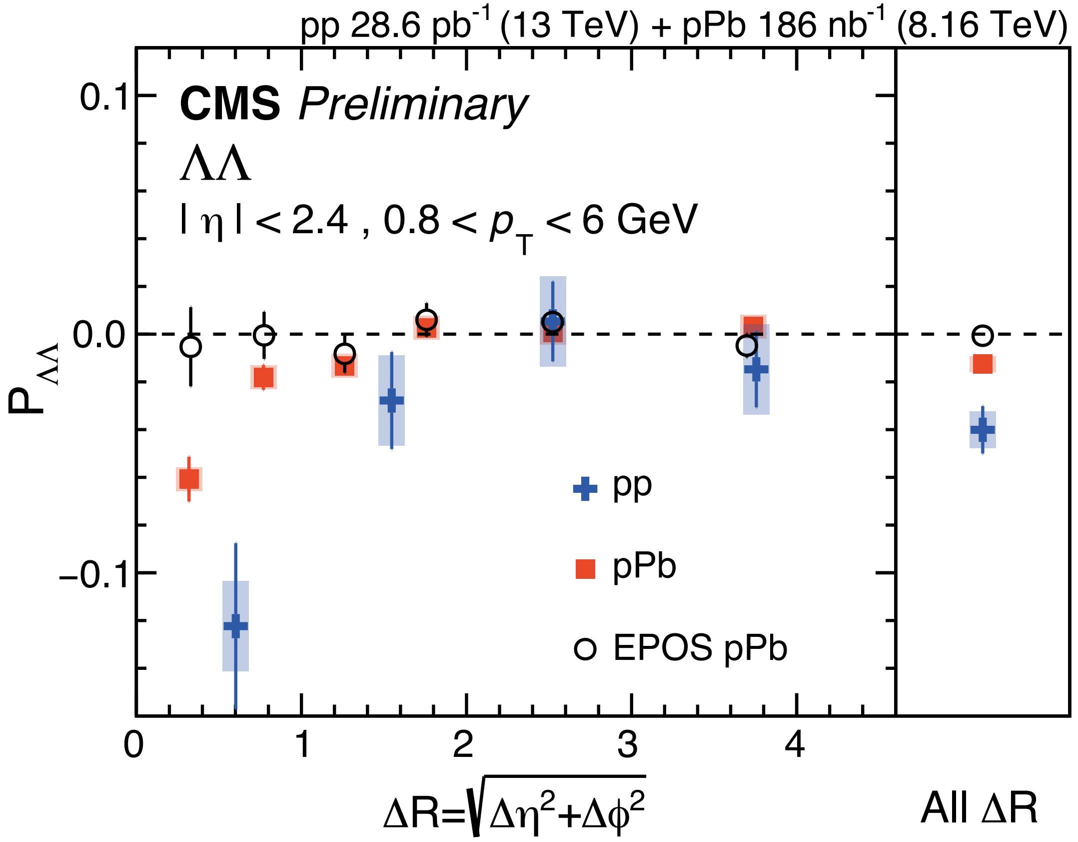
Spin correlation of $\Lambda\Lambda$ and $\bar{\Lambda}\bar{\Lambda}$ pairs

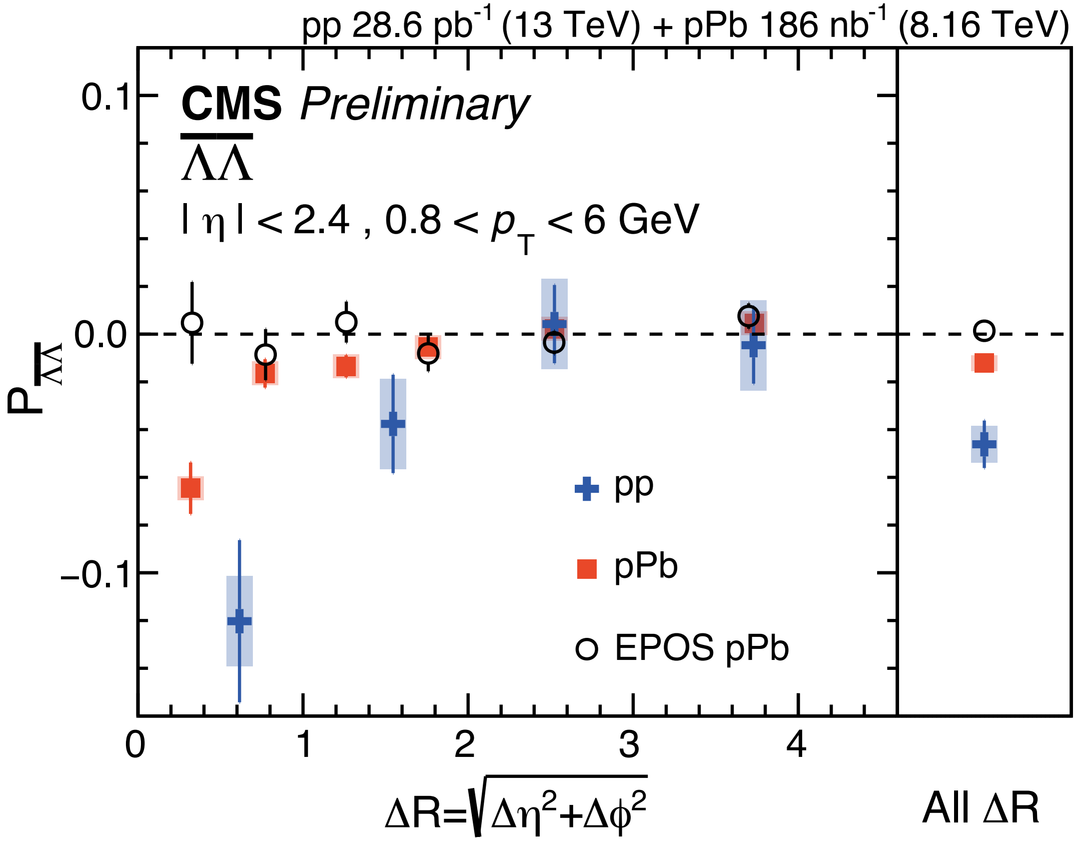


Same measurements in EPOS LHC are consistent with zero as expected

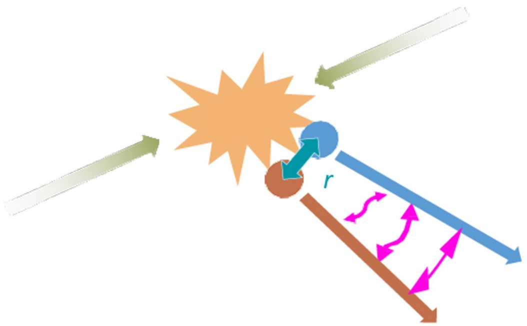
No spin degree of freedom

Spin correlation of $\Lambda\Lambda$ and $\bar{\Lambda}\bar{\Lambda}$ pairs



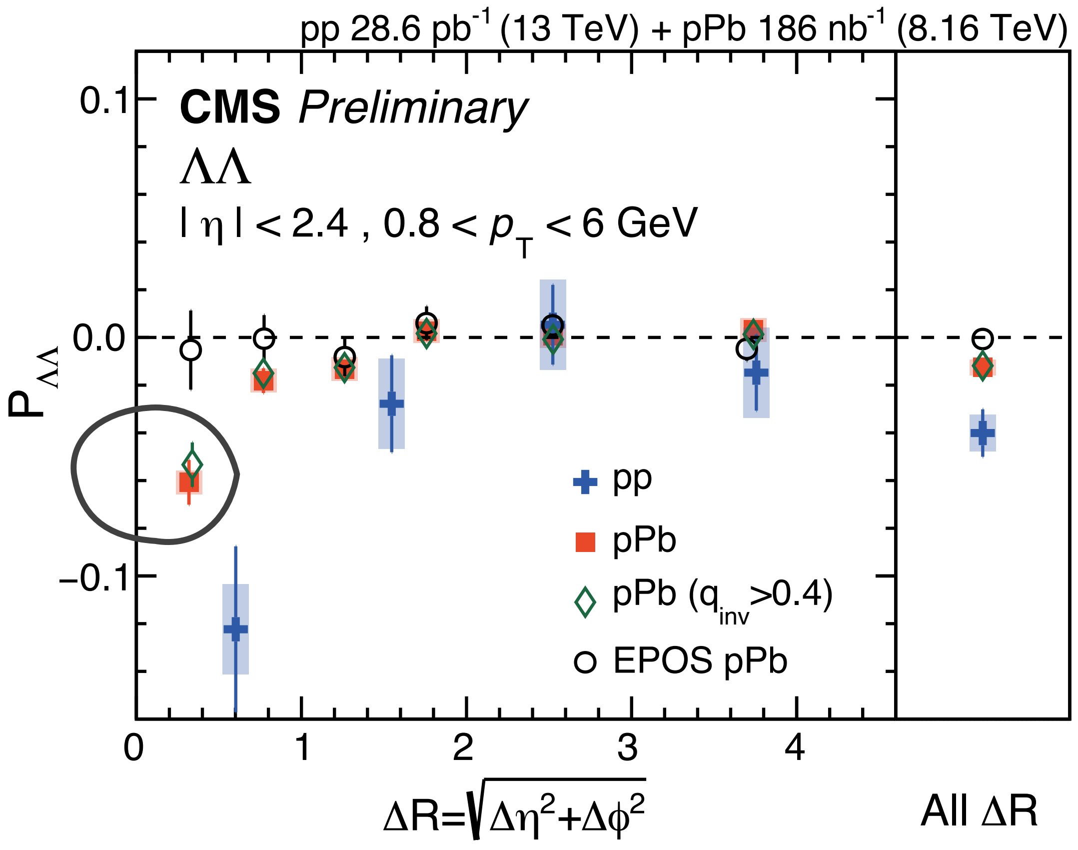


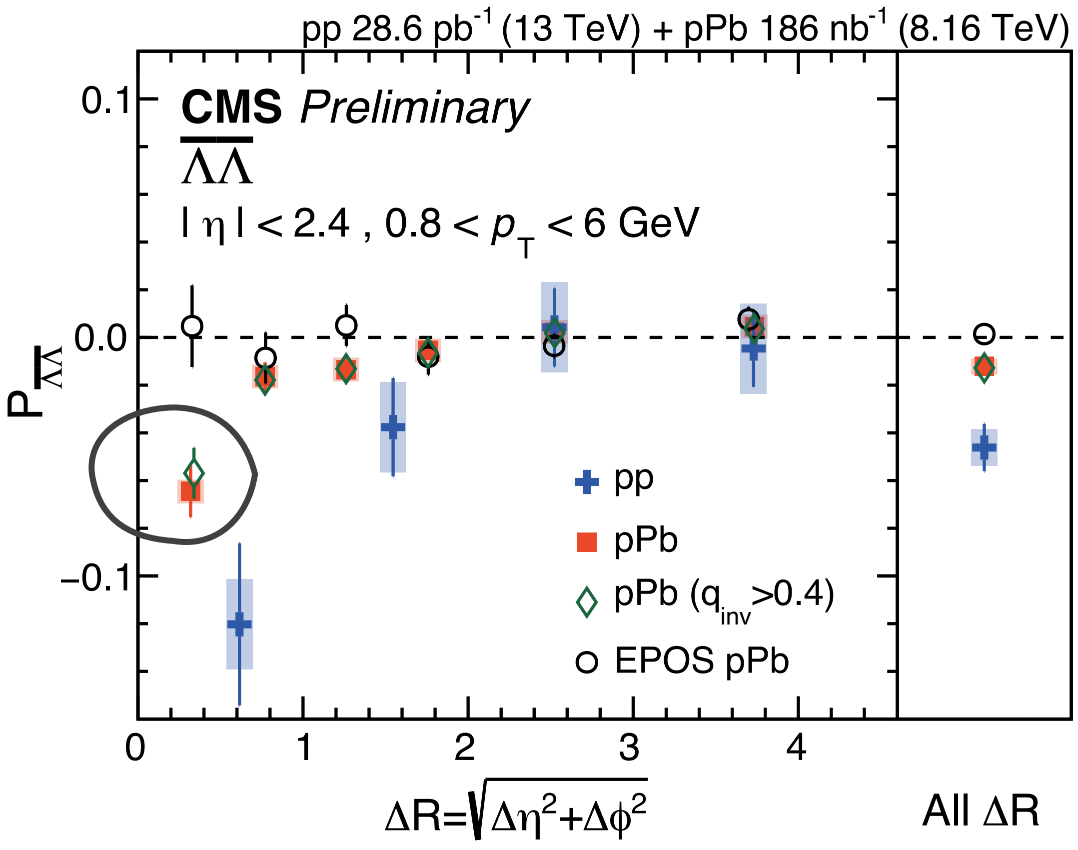
HBT (Hanbury-Brown-Twiss) effect



$$q_{inv} = \sqrt{M_{\Lambda\Lambda}^2 - 4m_{\Lambda}^2}$$

Spin correlation of $\Lambda\Lambda$ and $\bar{\Lambda}\bar{\Lambda}$ pairs





Same measurements in EPOS LHC are consistent with zero as expected

Results with $q_{inv} > 0.4$ GeV consistent with default

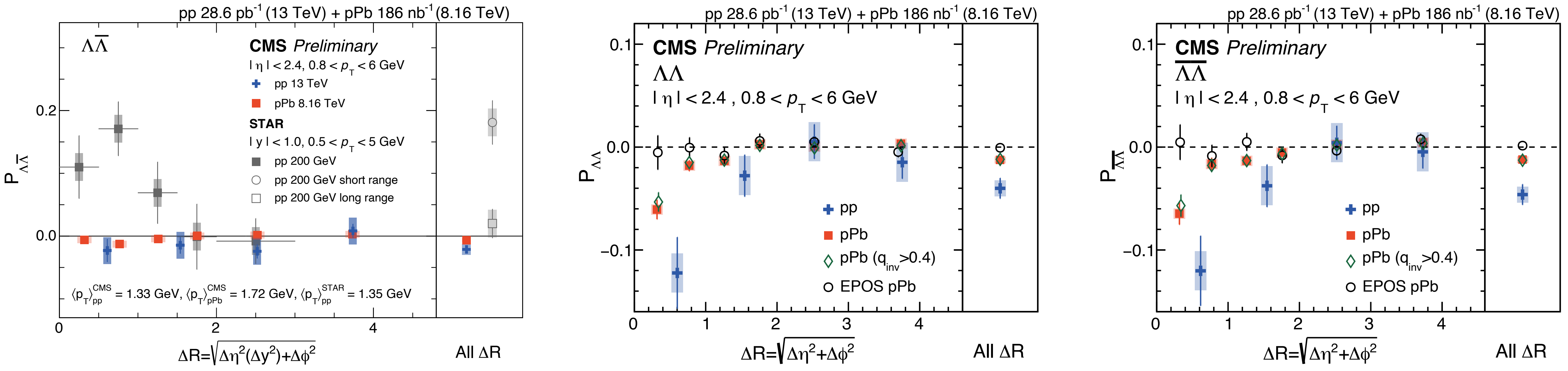
Indicate the signal is not dominated by simple HBT effects

Summary

- First Λ spin correlation measurement in pp and pPb at LHC
- $\Lambda\bar{\Lambda}$ spin correlation consistent with zero, with a hint of negative value
  - different from STAR measurements
- Negative correlations found for ΛΛ and $\bar{\Lambda}\bar{\Lambda}$ at small ΔR
  - converge to zero for large ΔR
- The underlying mechanism remains an open question

CMS-PAS-HIN-26-002

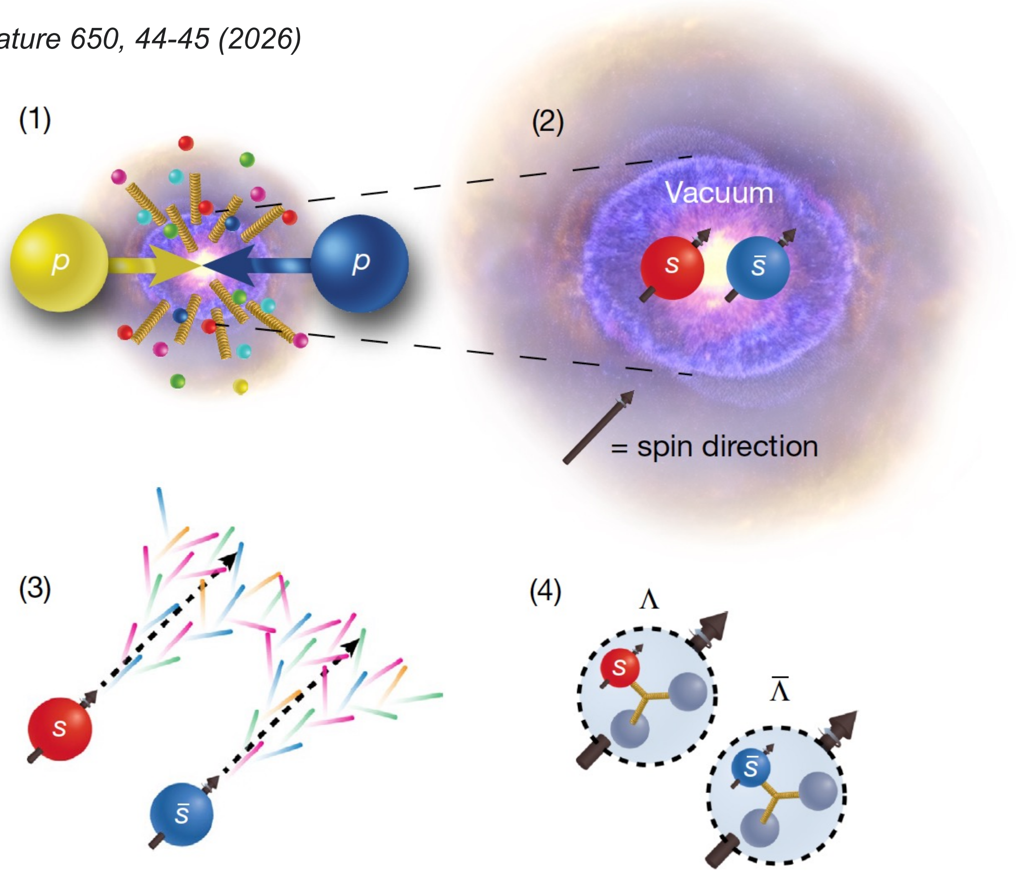
Plenty of new experimental results, need of theoretical input



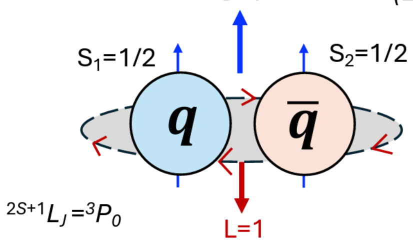
Backup

Hepyron spin correlation

Nature 650, 44-45 (2026)



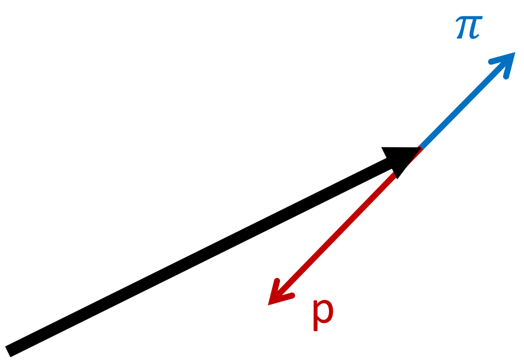
(Ellis, Kharzeev, Kotzinian 1995)



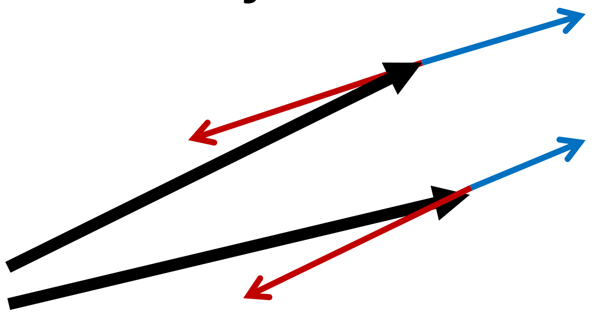
- P = $(-1)^{L+1}$ → L = 1
- J = 0 = L+S → S = 1
- J = L+S, where L and S are orbital and spin angular momentum

Impact of acceptance effect

Single Λ decay



Λ piars decay



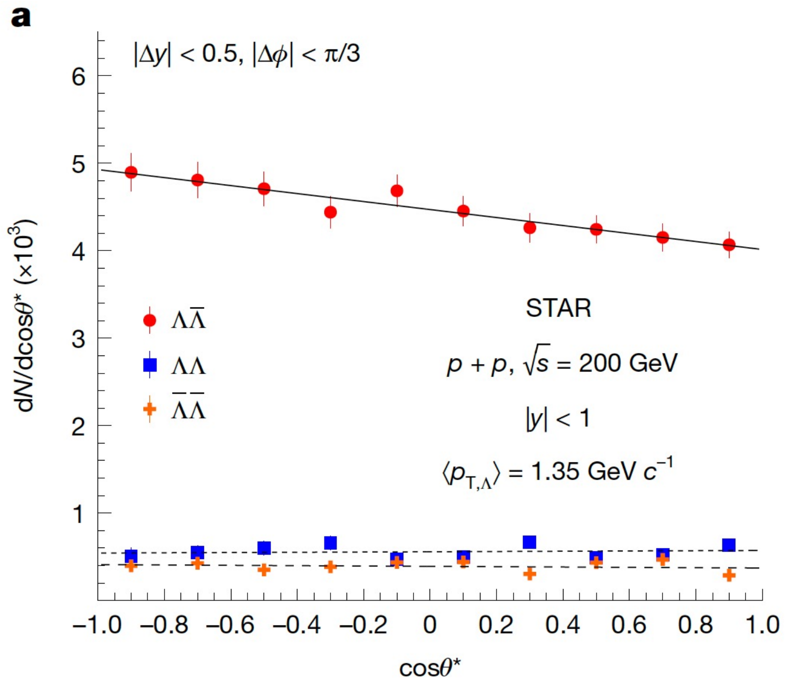
Λ decay (rest frame)

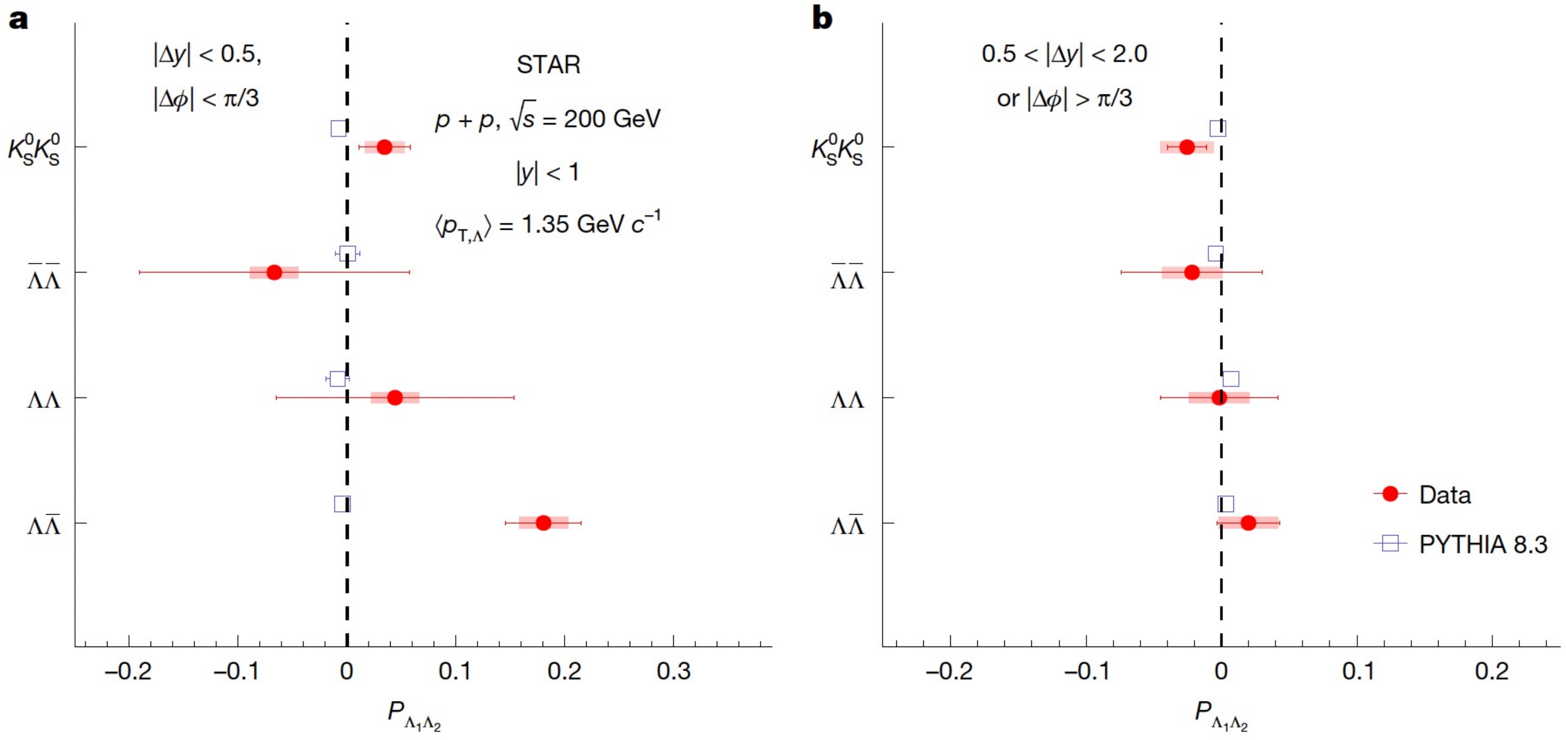
π will gain a boosted p_T in lab frame,resulting higher reconstrction efficiency of this π and this Λ

Λ piars decay (in both rest frame)

Considering the effect , if you pick close Λs , their proton trend to have the same momentum direction in rest frame, thus $\cos\theta^{*} \sim 1$

STAR Results

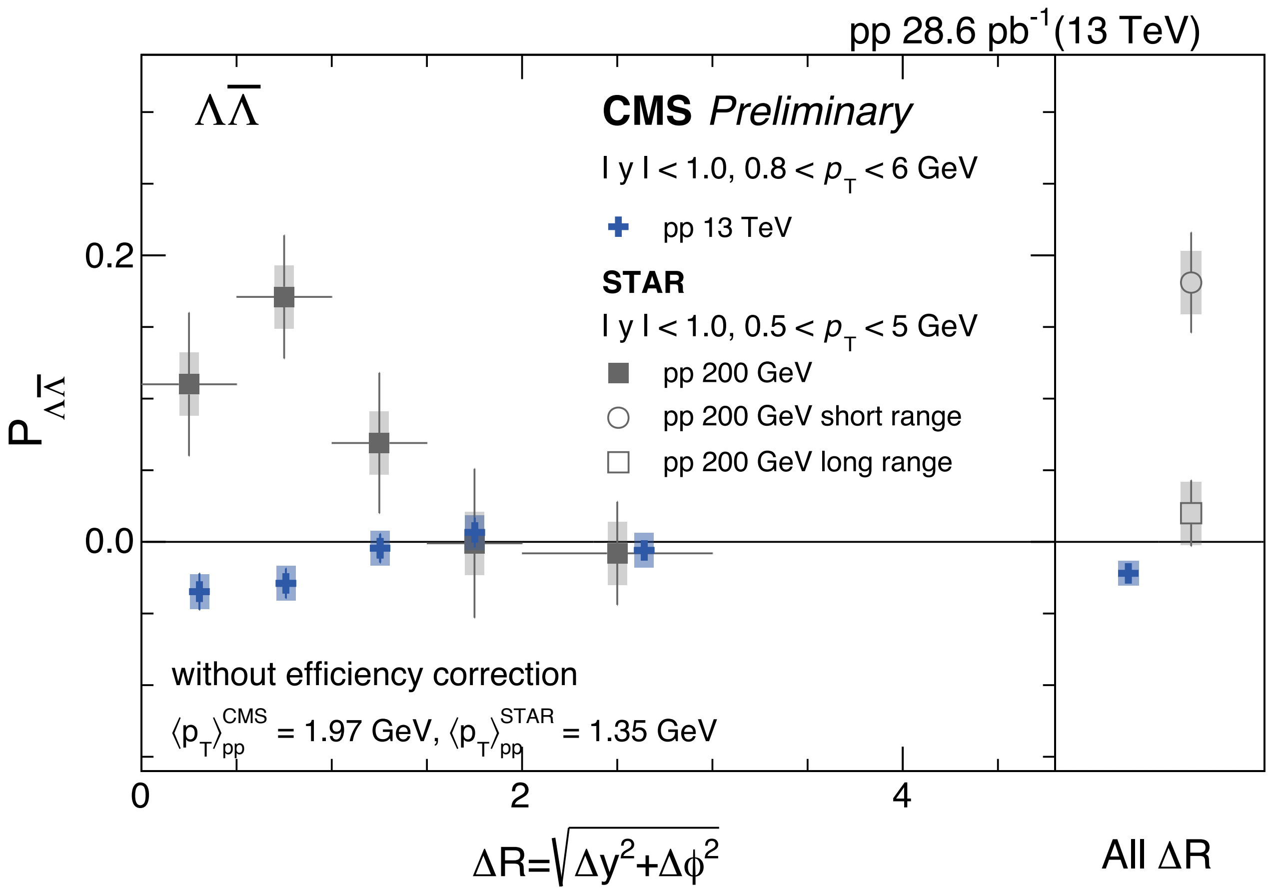




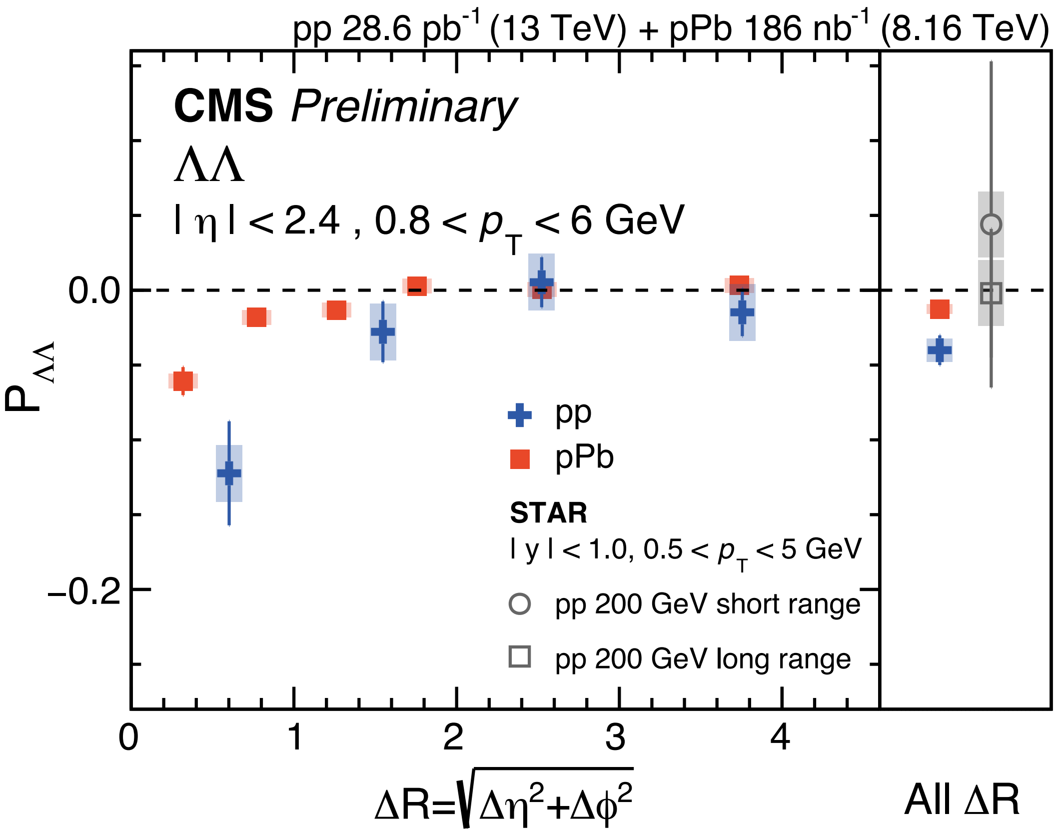
Short range

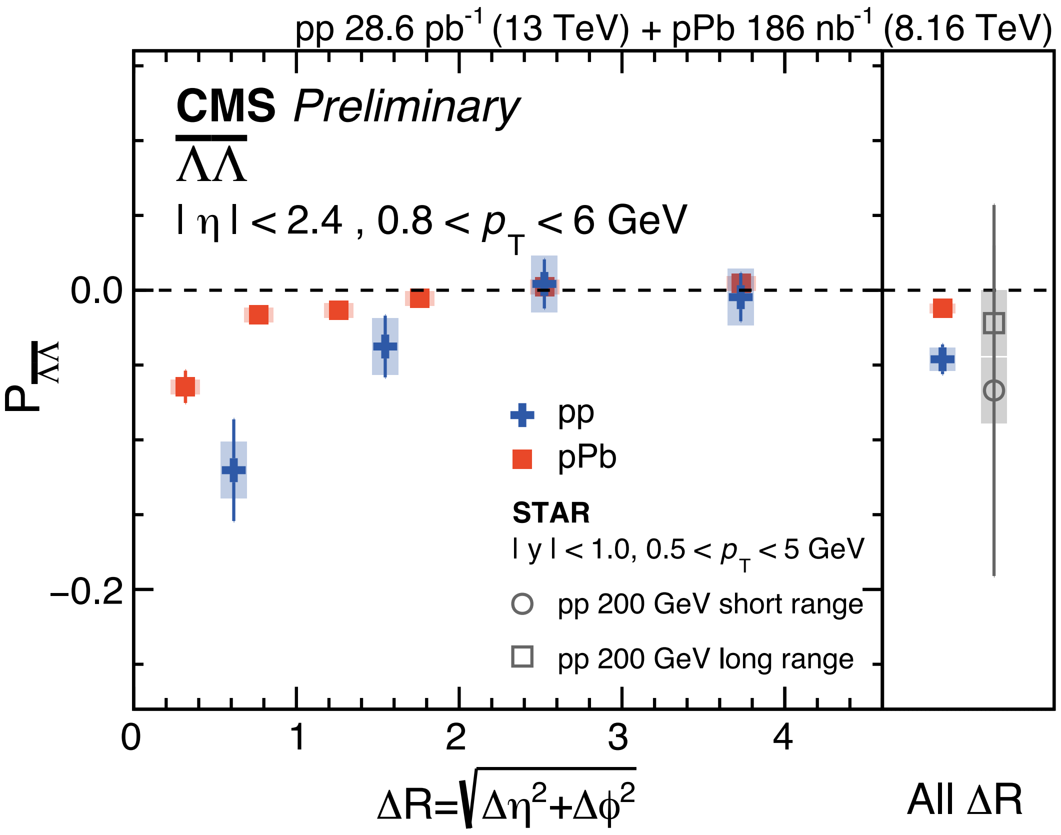
Long range

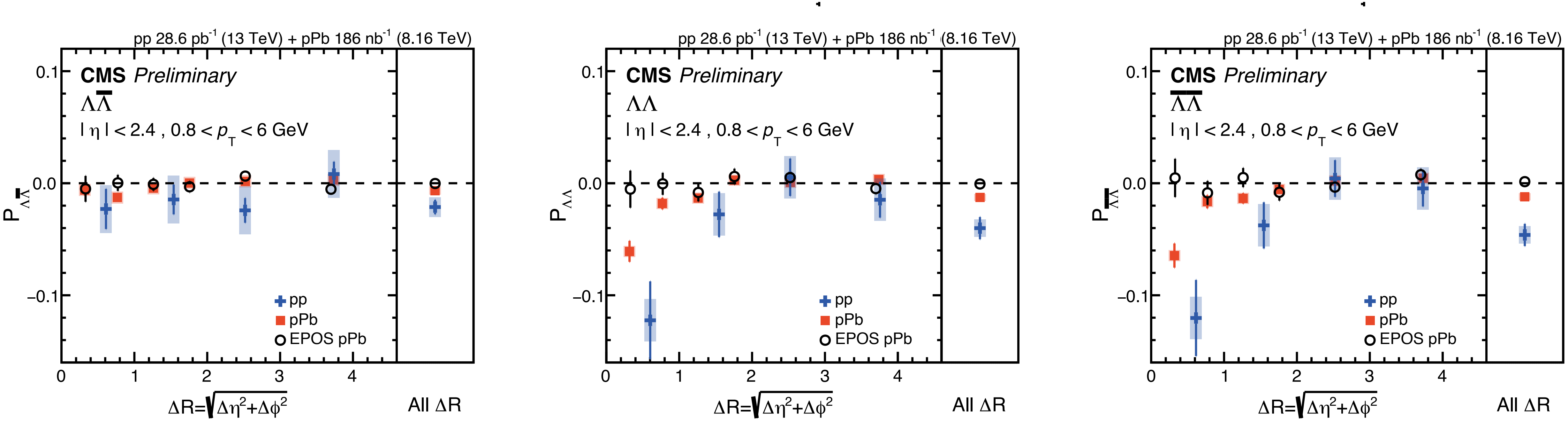
Comparison with STAR(w/o eff corr)



Comparison with STAR $\Lambda\Lambda$ and $\bar{\Lambda}\bar{\Lambda}$






pp 28.6 pb-1 (13 TeV) + pPb 186 nb-1 (8.16 TeV)
CMS Preliminary
ΛΛ̄
| η | < 2.4 , 0.8 < pT < 6 GeV
pp
pPb
EPOS pPb
0.1
0.0
−0.1
0
1
2
3
4
ΔR=√(Δη²+Δφ²)
All ΔR
PΛΛ̄
ΛΛ
PΛΛ
Λ̄Λ̄
PΛ̄Λ̄