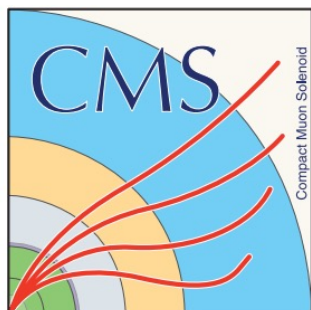


# Azimuthal dependence of hyperon polarization along the beam direction in pPb collisions at 8.16 TeV

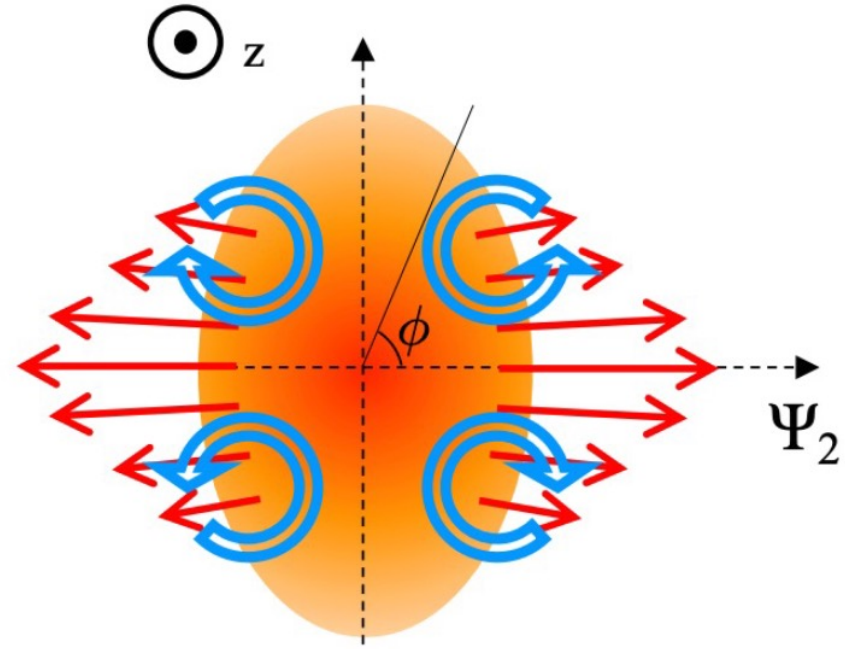
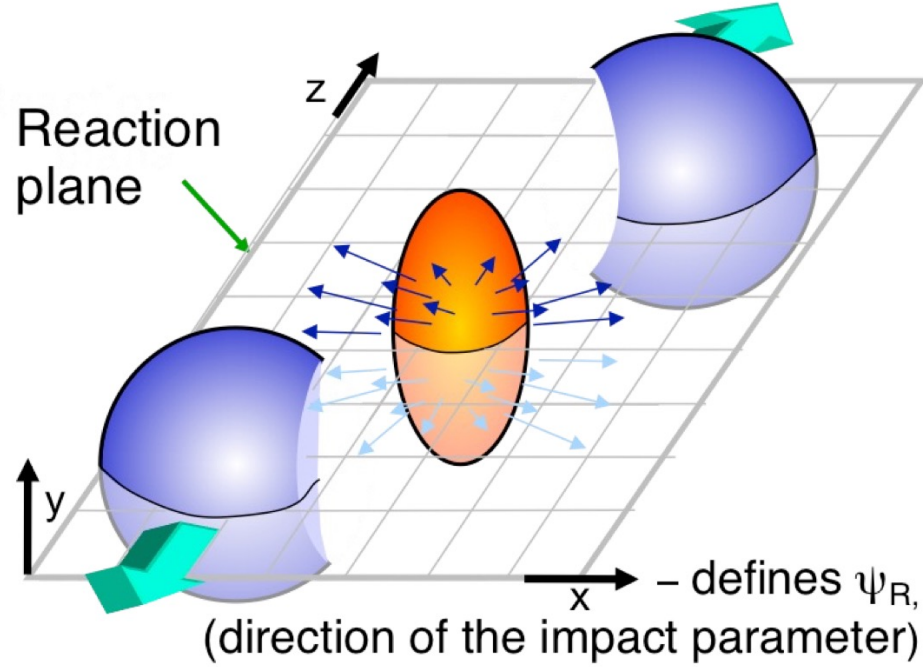
CMS-PAS-HIN-24-002

Chenyan Li (李辰艳), for the CMS collaboration

Shandong University (山东大学)



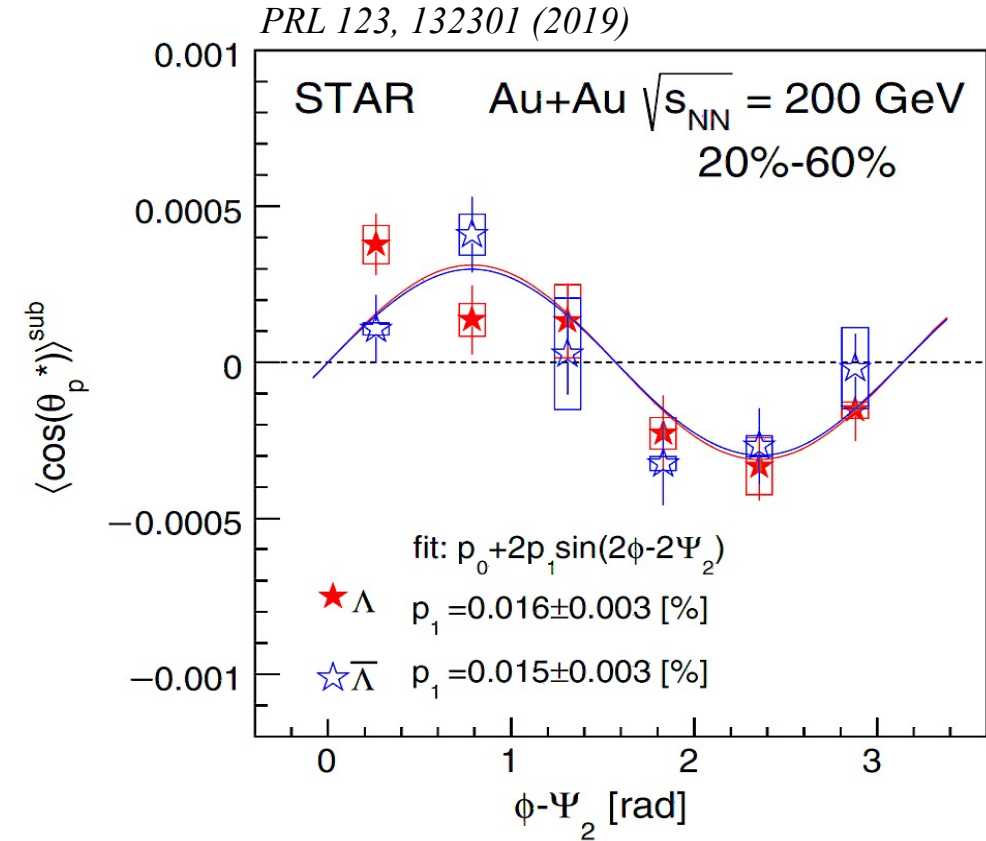
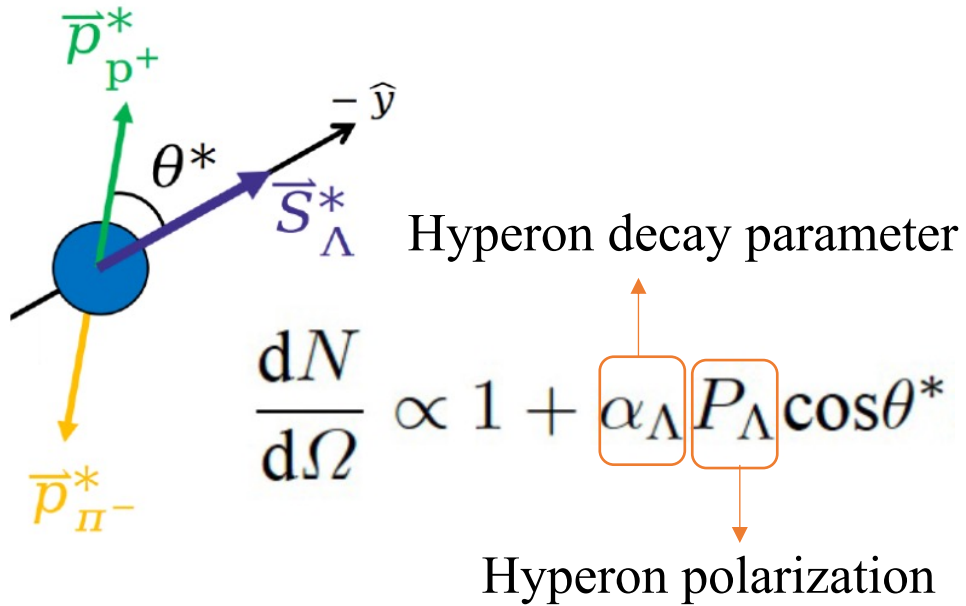
# Hyperon polarization along beam direction



The collective flow generates non-zero vorticity along the beam ( $z$ ) direction

Non-zero vorticity results in particle polarization via spin-orbit coupling

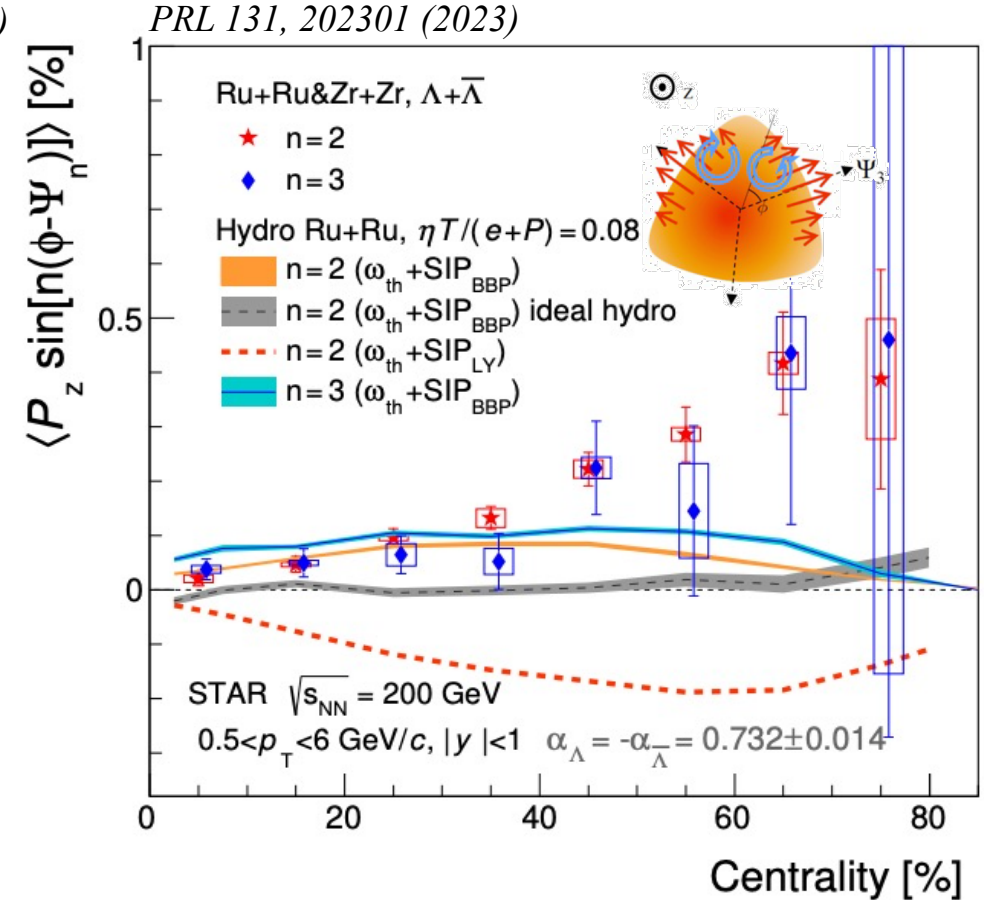
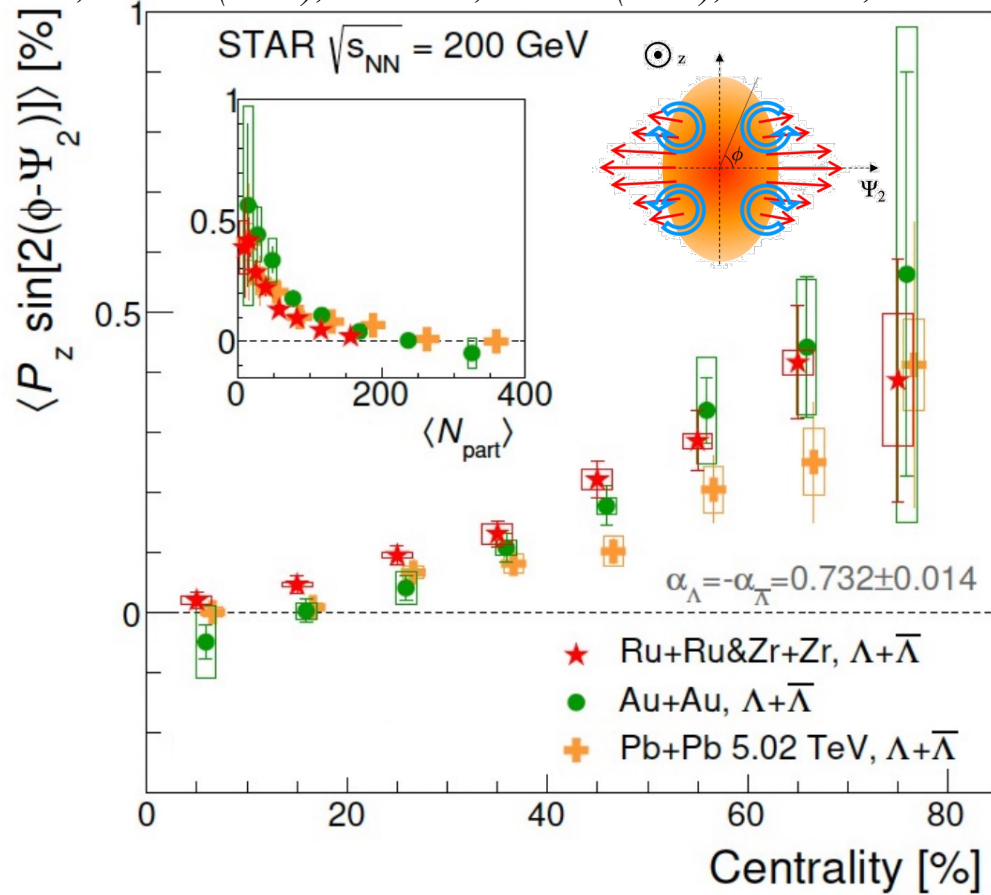
# Hyperon polarization along beam direction



Hyperon weak decay is a simple and direct probe of polarization  
 Quadrupole structure of polarization observed

# Hyperon polarization along beam direction in AA collisions

PRL 131, 202301 (2023), PRL 123, 132301 (2019), PRL 128, 172005 (2022)



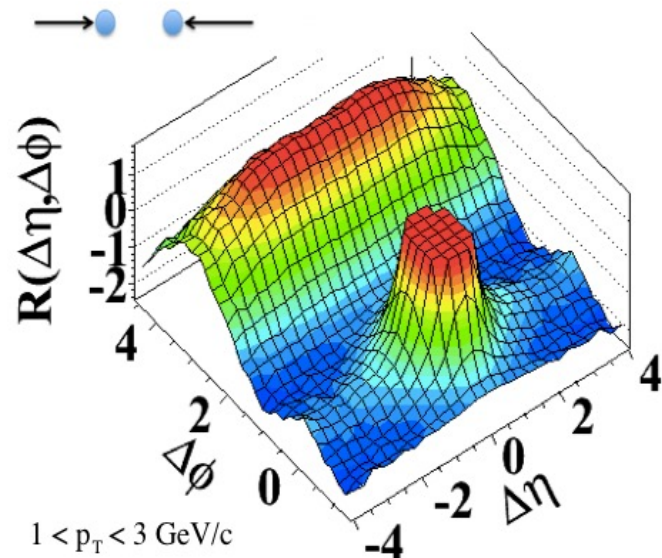
Significant  $P_z$  signal w.r.t 2nd-order and 3rd-order event plane observed in AA collisions

Indication of correlation between flow and polarization

# Hyperon polarization along beam direction in small systems?

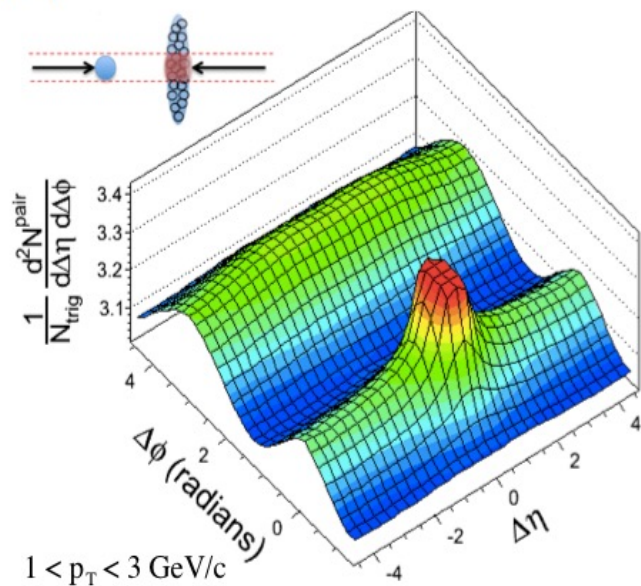
*JHEP 09 (2010) 091*

(a) pp  $\sqrt{s} = 7$  TeV,  $N_{\text{trk}}^{\text{offline}} \geq 110$



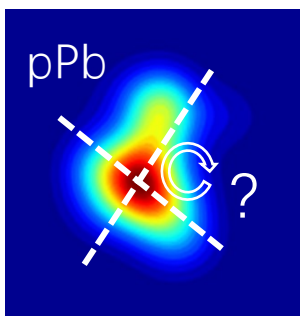
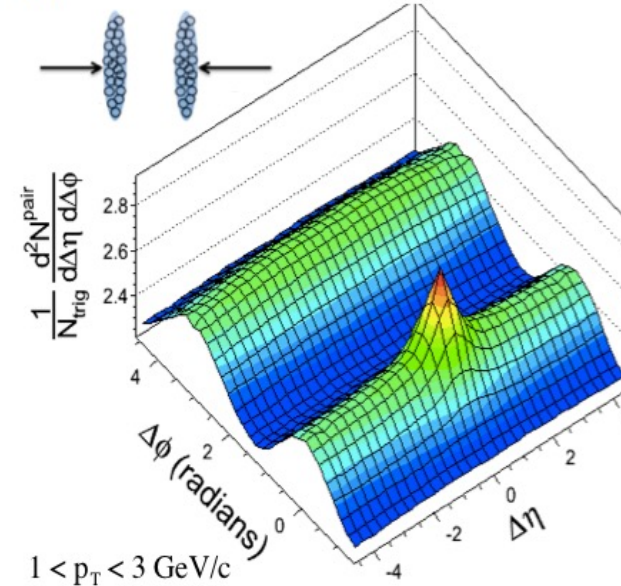
*PLB 724 (2013) 213*

(b) pPb  $\sqrt{s_{\text{NN}}} = 5.02$  TeV,  $220 < N_{\text{trk}}^{\text{offline}} \leq 260$



*PLB 724 (2013) 213*

(c) PbPb  $\sqrt{s_{\text{NN}}} = 2.76$  TeV,  $220 < N_{\text{trk}}^{\text{offline}} \leq 260$



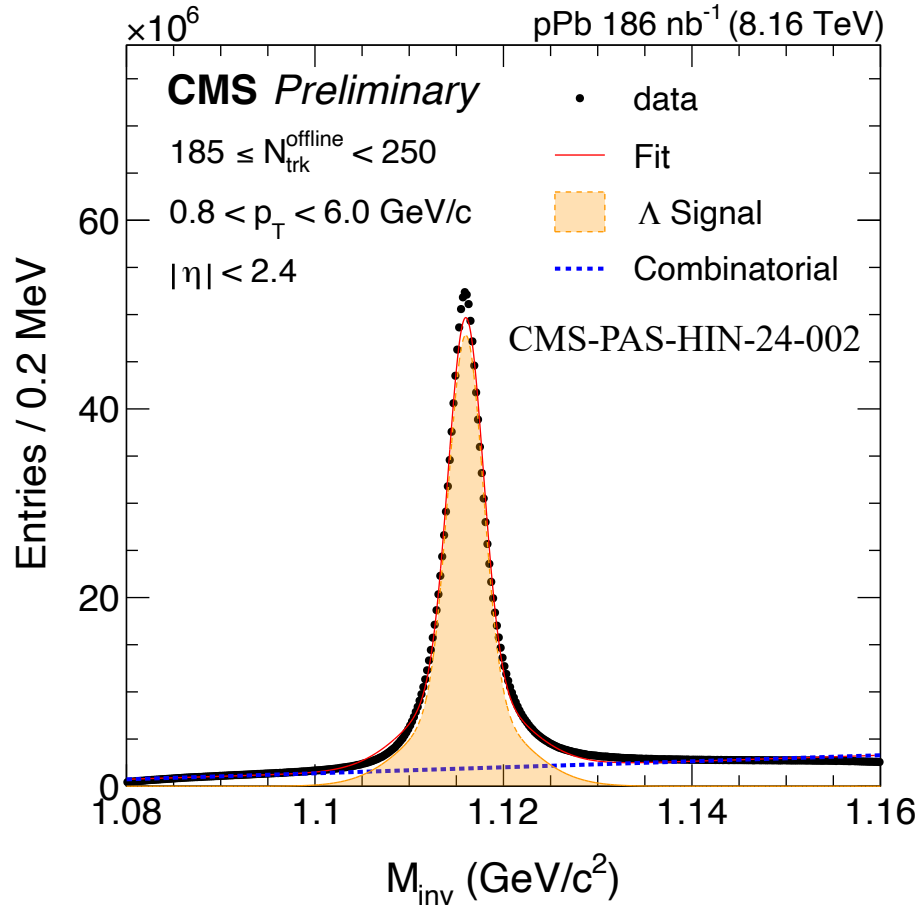
Similar collective feature in high-multiplicity pp and pPb collisions

Is a QGP droplet created in smaller collision systems?

Can Hyperon polarization along beam direction be observed?

# $\Lambda$ reconstruction in pPb collisions

8.16 TeV pPb data collected by CMS experiment with  $L_{\text{int}} = 186 \text{ nb}^{-1}$



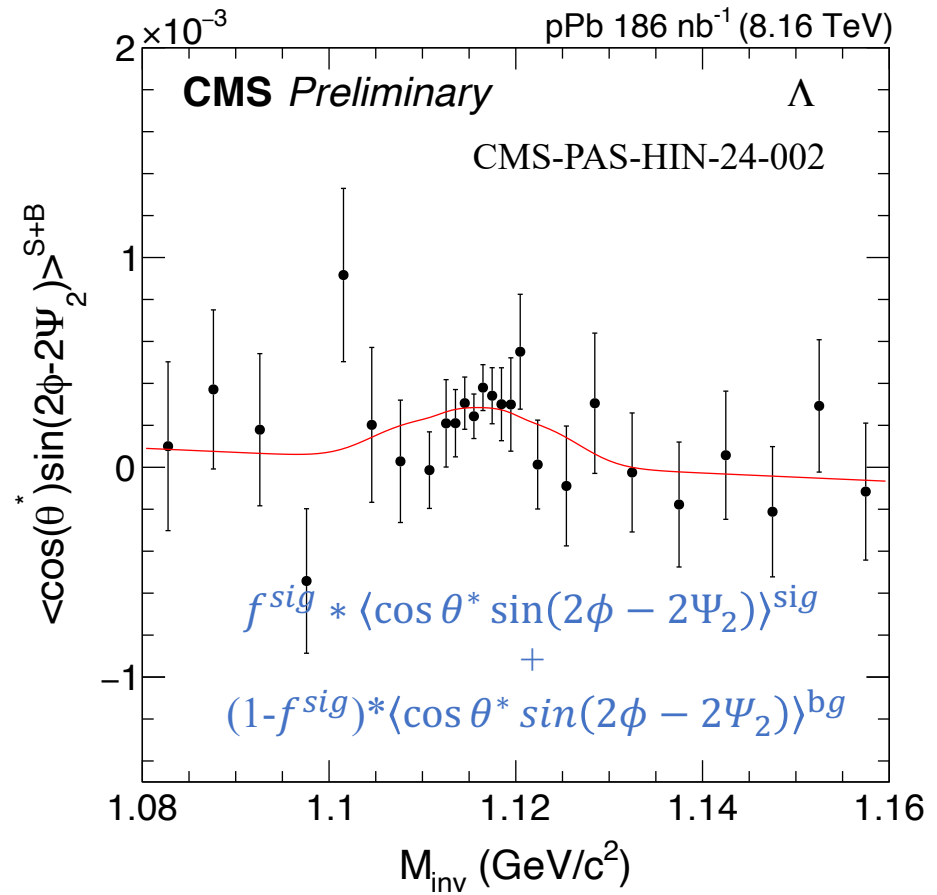
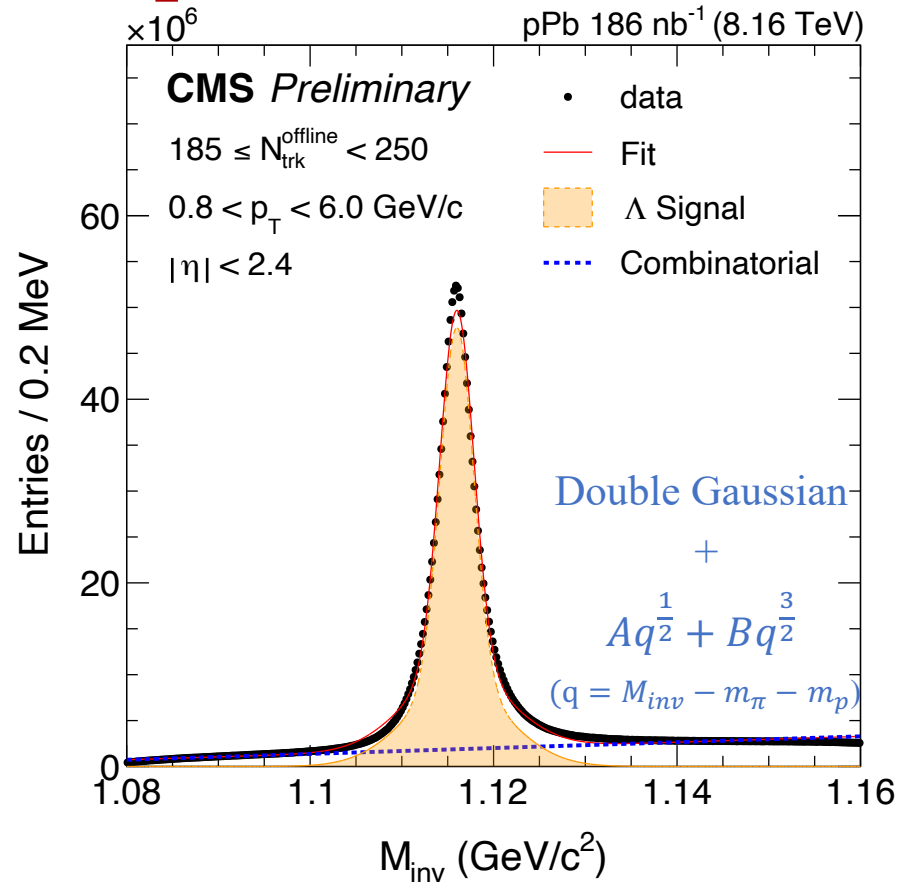
Clear signal for  $\Lambda$

Multiplicity interval ( $N_{\text{trk}}^{\text{offline}}$ )	$\langle N_{\text{trk}}^{\text{offline}} \rangle$	$\langle N_{\text{trk}}^{\text{corrected}} \rangle$
[3, 60)	40.0	$48.5 \pm 1.9$
[60, 120)	86.7	$105.3 \pm 4.2$
[120, 150)	132.7	$161.2 \pm 6.4$
[150, 185)	163.6	$198.7 \pm 7.9$
[185, 250)	203.3	$246.9 \pm 9.9$

$\langle N_{\text{trk}}^{\text{offline}} \rangle$ : average track multiplicity ( $p_T > 0.4 \text{ GeV}$ ,  $|\eta| < 2.4$ ), requiring at least one reconstructed  $\Lambda$  ( $\bar{\Lambda}$ ) candidate in event.

$\langle N_{\text{trk}}^{\text{corrected}} \rangle$ :  $\langle N_{\text{trk}}^{\text{offline}} \rangle$  after efficiency correction.

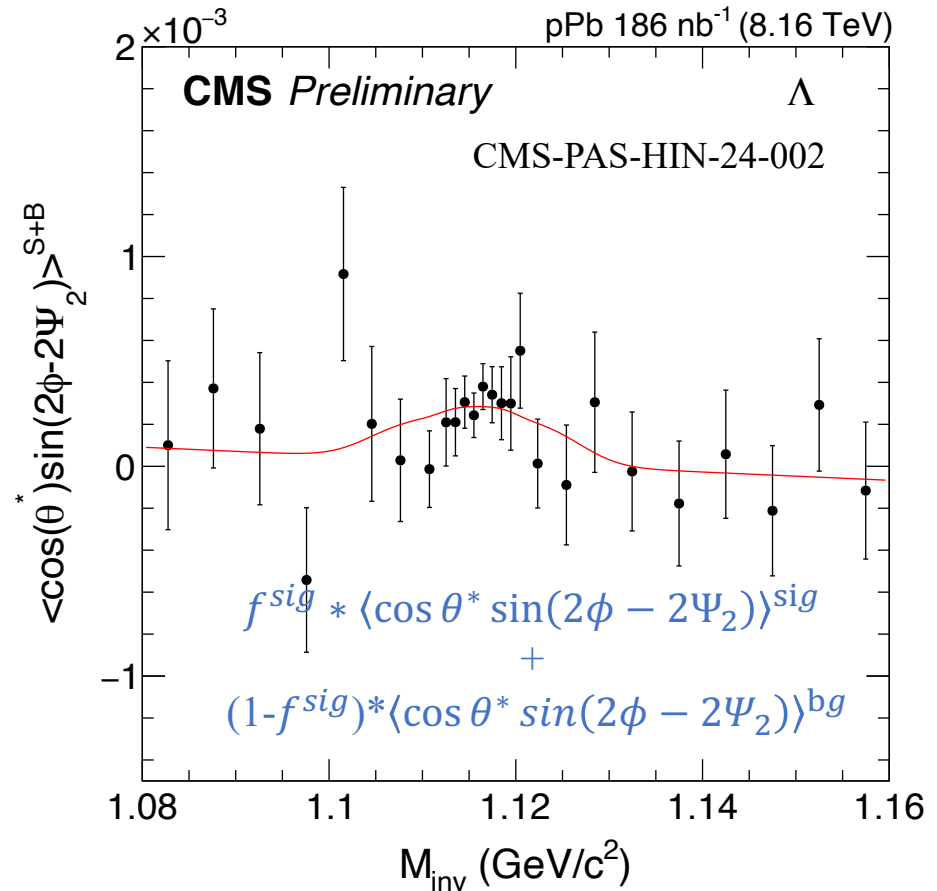
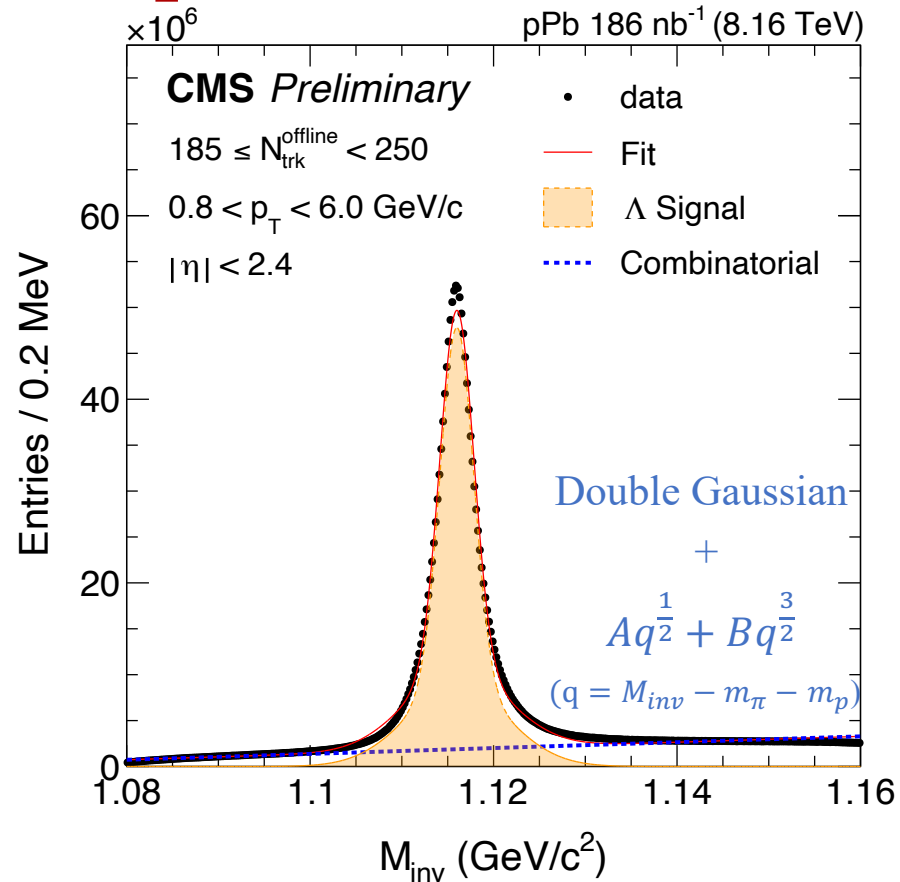
# Hyperon polarization extraction



$$f^{\text{sig}} = \frac{N_{\text{sig}}}{N_{\text{sig}} + N_{\text{bg}}}$$

Simultaneous fit to extract the polarization signal

# Hyperon polarization extraction



$$f^{sig} = \frac{N_{sig}}{N_{sig} + N_{bg}}$$

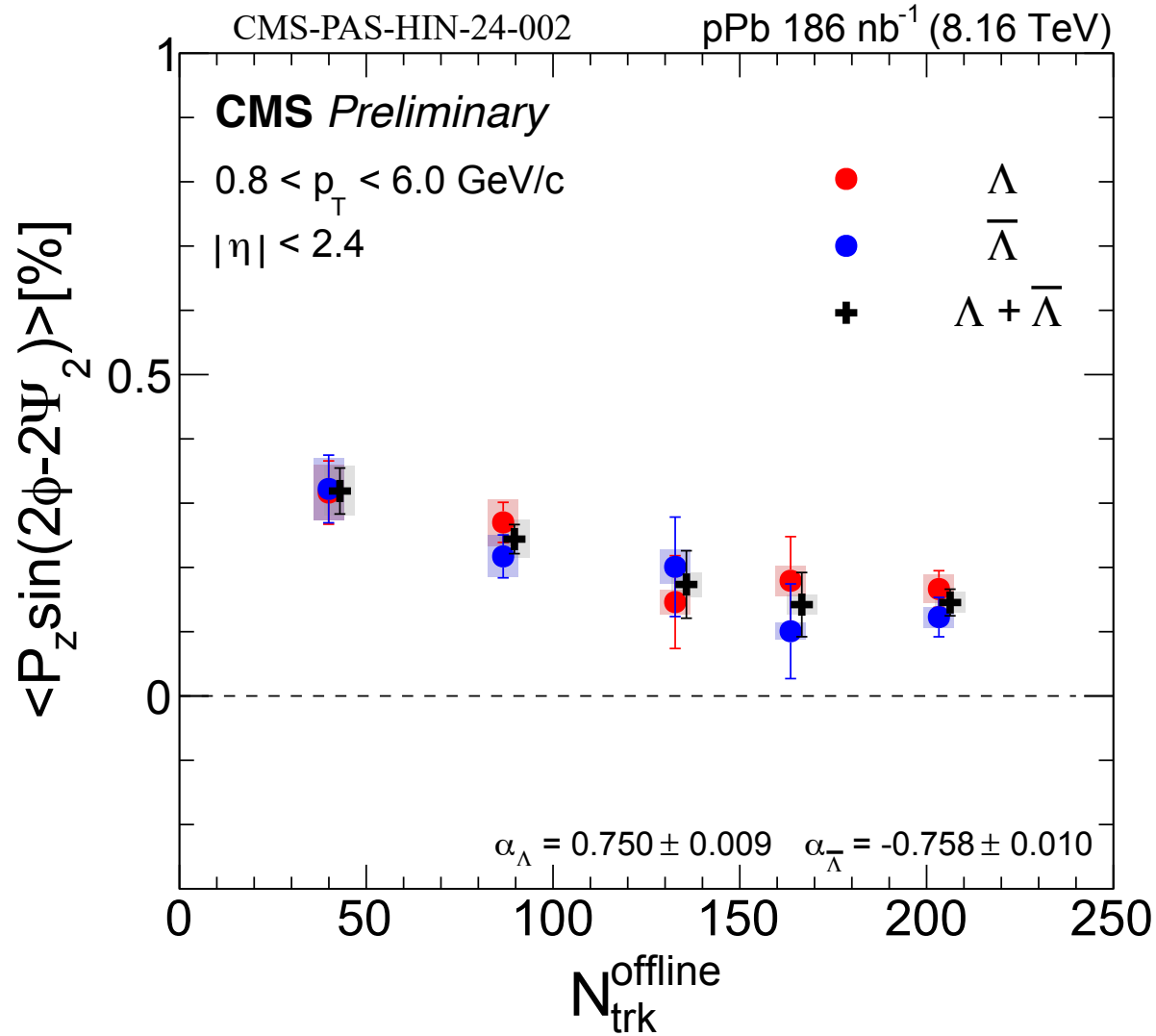
Simultaneous fit to extract the polarization signal

$$P_{Z,s2} = \frac{\langle \cos \theta^* \sin(2\phi - 2\Psi_2) \rangle^{sig}}{\langle \cos^2 \theta^* \rangle \alpha_H \text{Res}(\Psi_2)}$$

$$(\alpha_H: \alpha_\Lambda = 0.750 \pm 0.009, \alpha_{\bar{\Lambda}} = -0.758 \pm 0.010 \text{ Nature Phys. 15 (2019) 631-634})$$



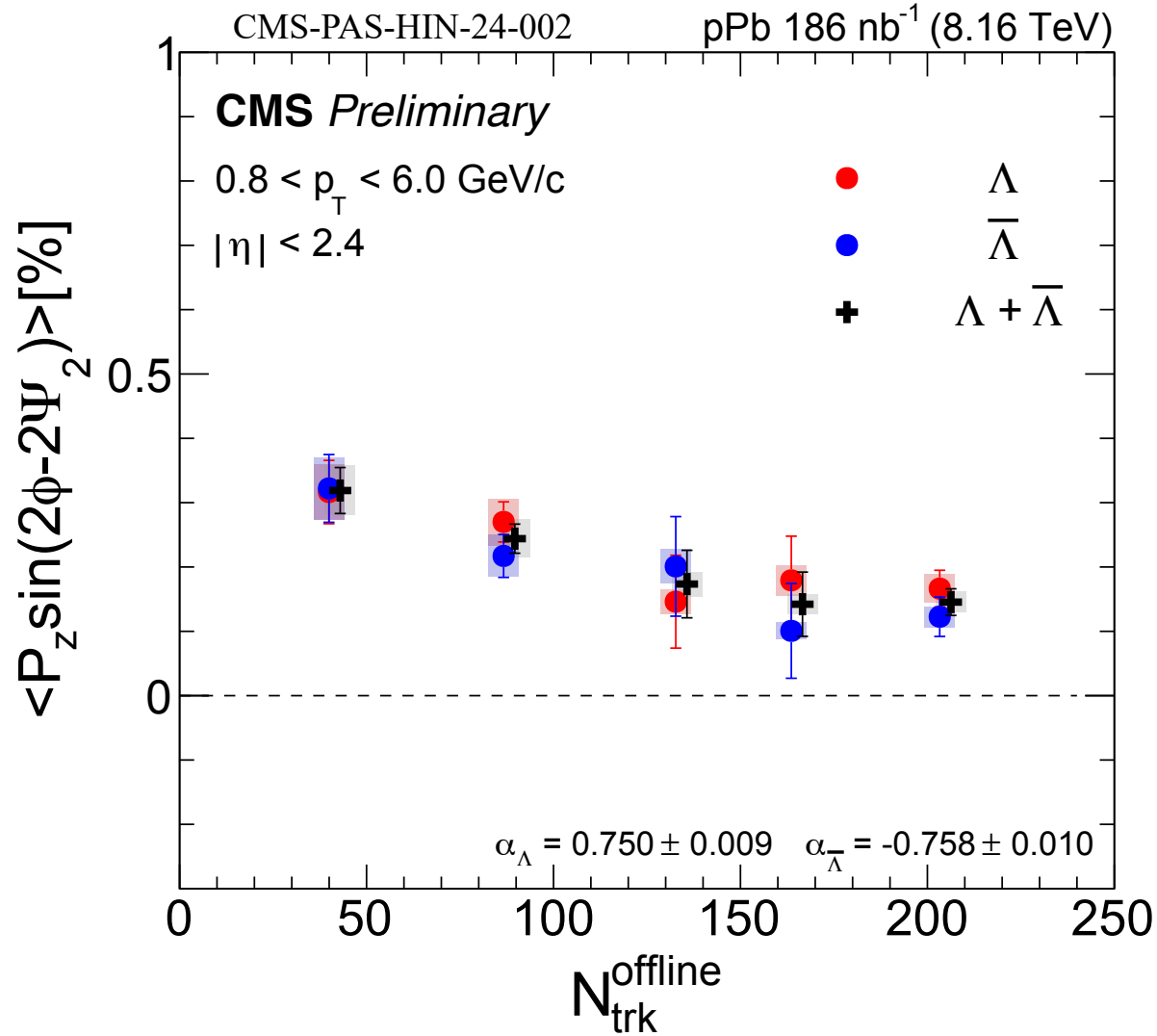
# $P_{z,s2}$ in pPb collisions



Significant positive  $P_{z,s2}$  signal observed for the entire multiplicity range

$P_{z,s2}$  values for  $\Lambda$ ,  $\bar{\Lambda}$  are consistent

# $P_{z,s2}$ in pPb collisions



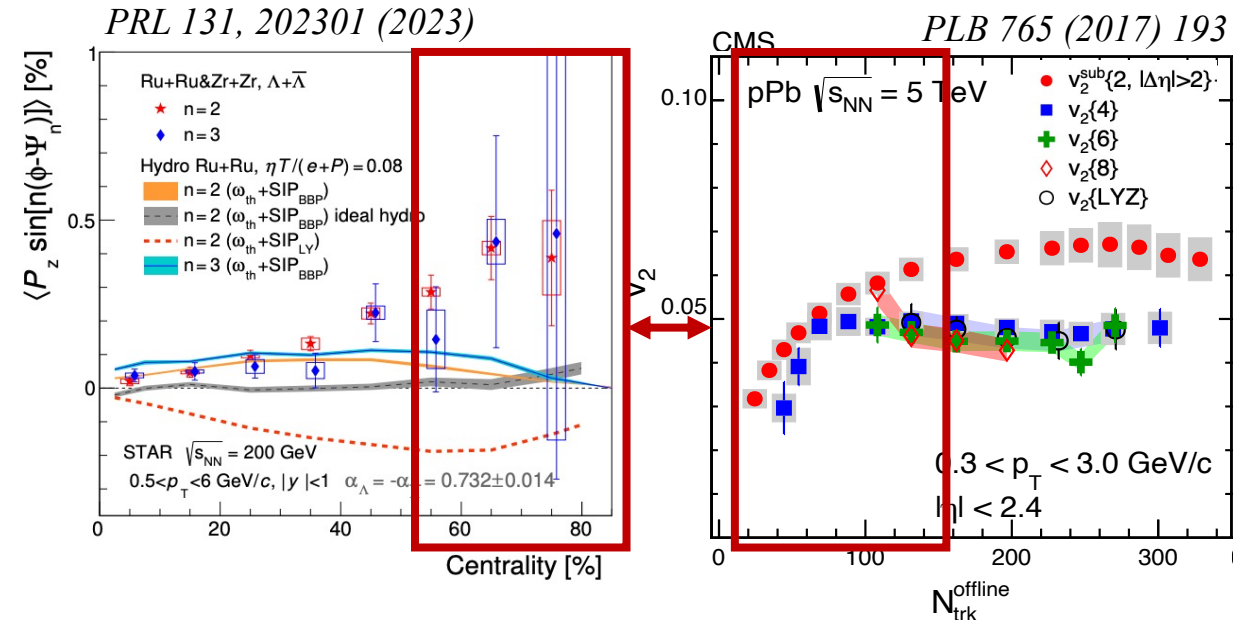
Significant positive  $P_{z,s2}$  signal observed for the entire multiplicity range

$P_{z,s2}$  values for  $\Lambda$ ,  $\bar{\Lambda}$  are consistent

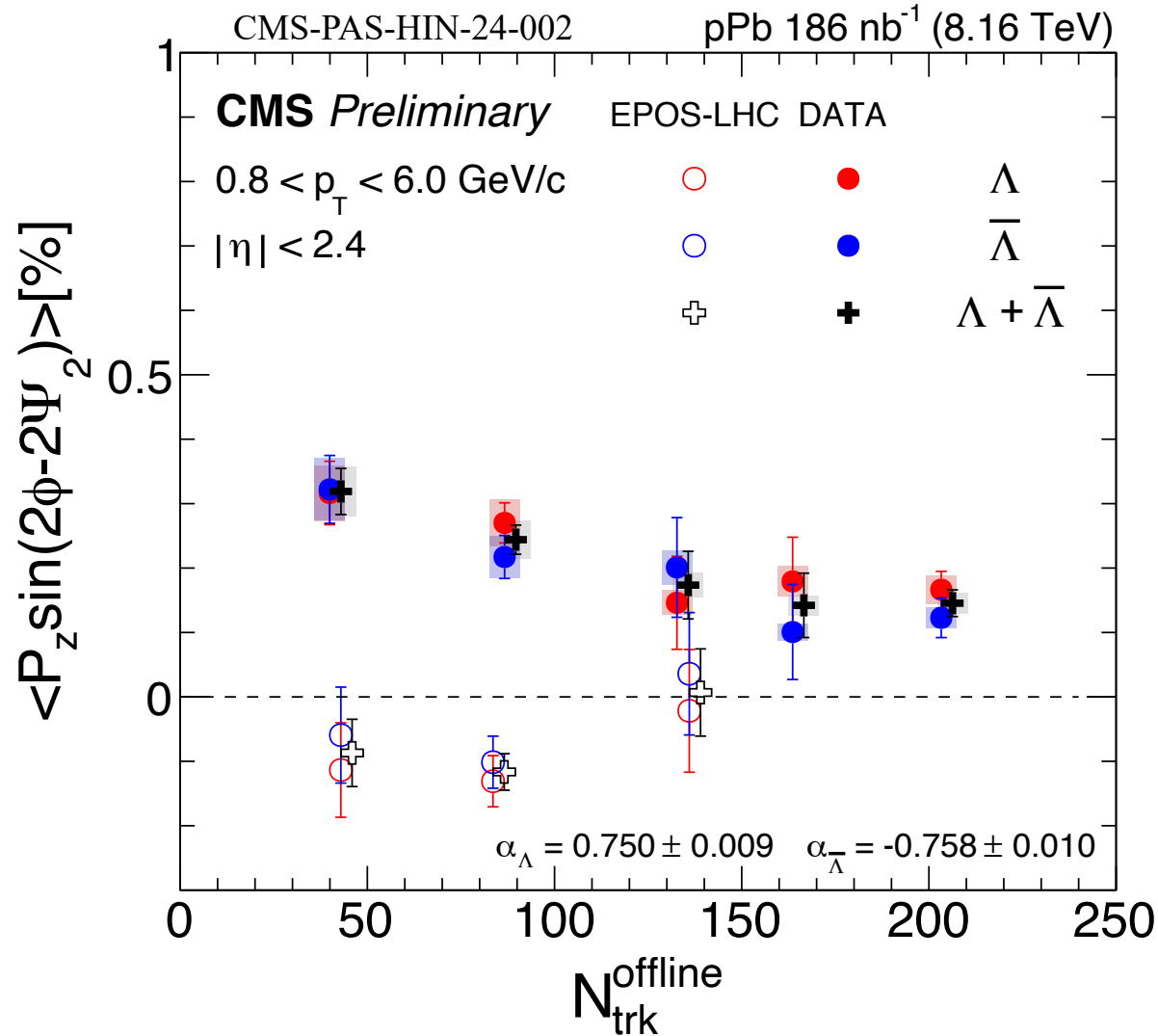
$P_{z,s2}$  decrease as function of multiplicity

Similar to AA collisions

Different from trend of  $v_2$  and hydro calculation



# $P_{z,s2}$ in pPb collisions



Significant positive  $P_{z,s2}$  signal observed for the entire multiplicity range

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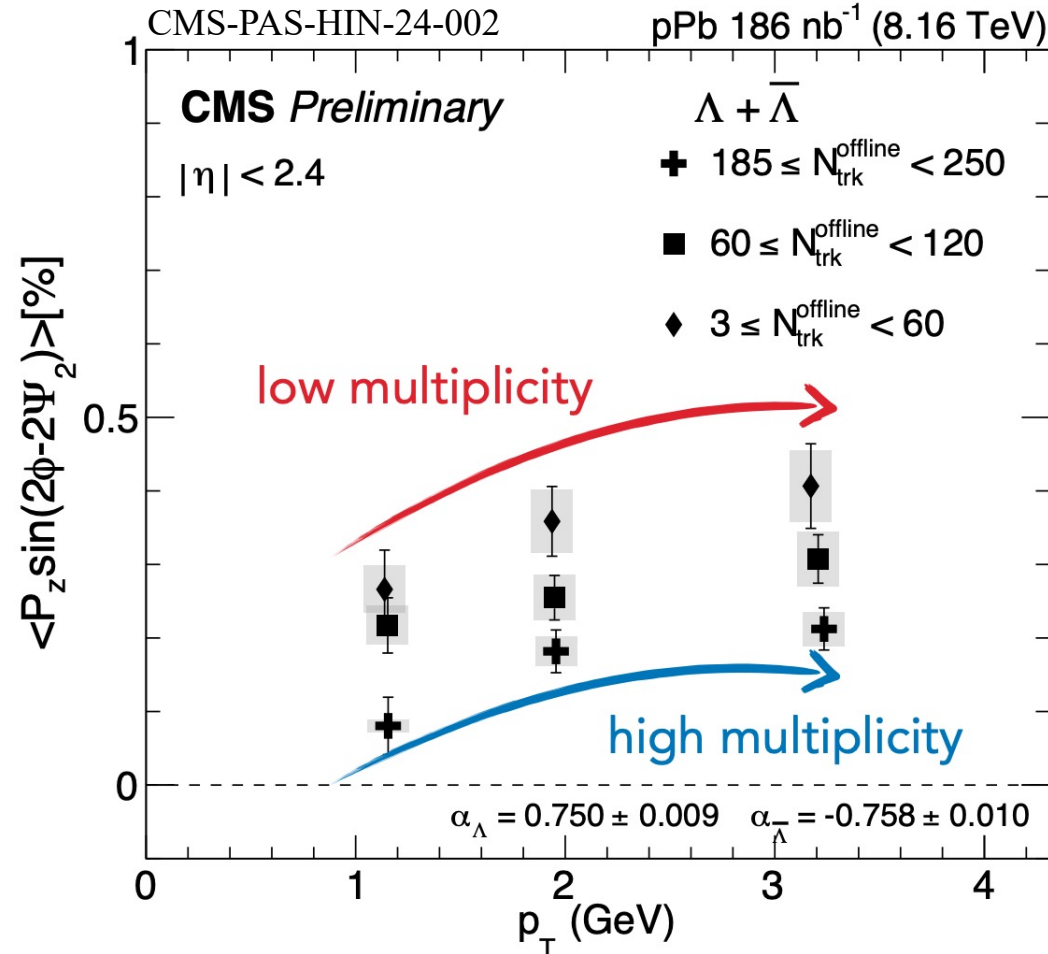
$P_{z,s2}$  decrease as function of multiplicity

Similar to AA collisions

Different from trend of  $v_2$  and hydro calculation

Negative  $P_{z,s2}$  in EPOS LHC

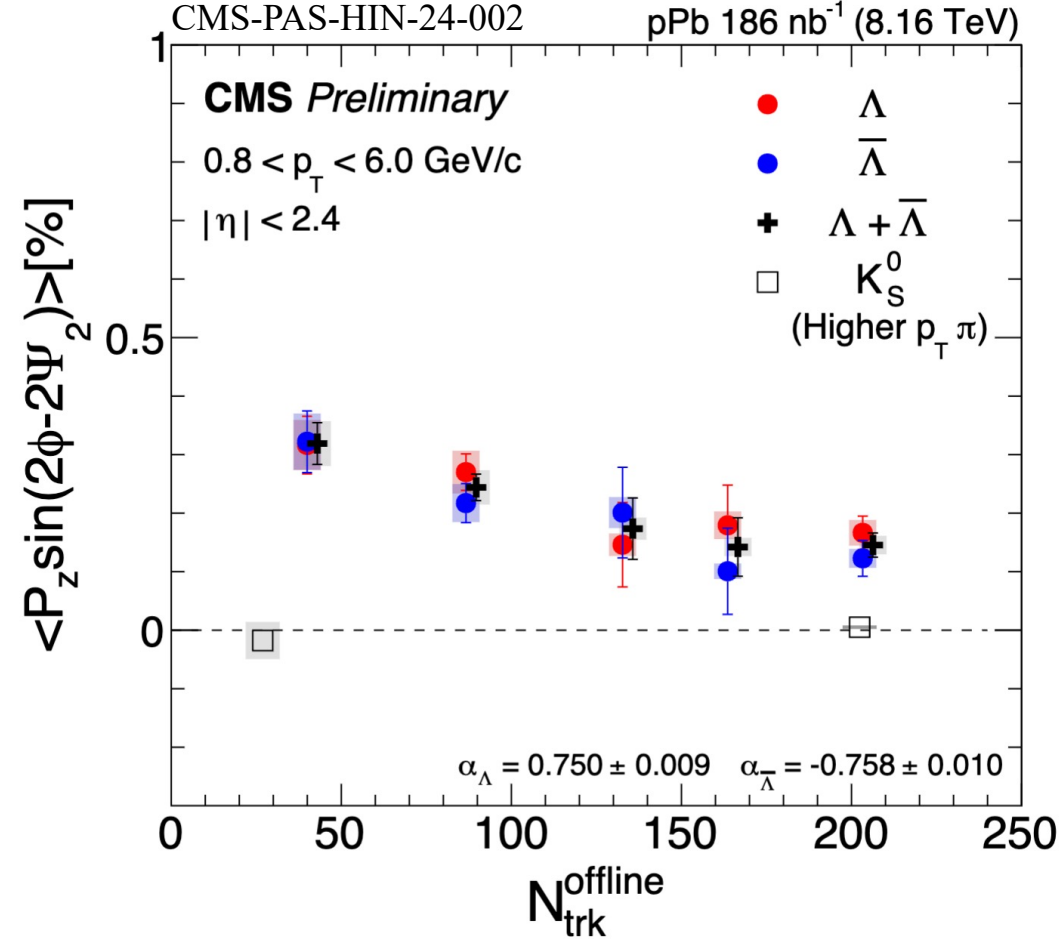
# $P_{z,s2}$ in pPb collisions



$P_{z,s2}$  increase as function of  $p_T$

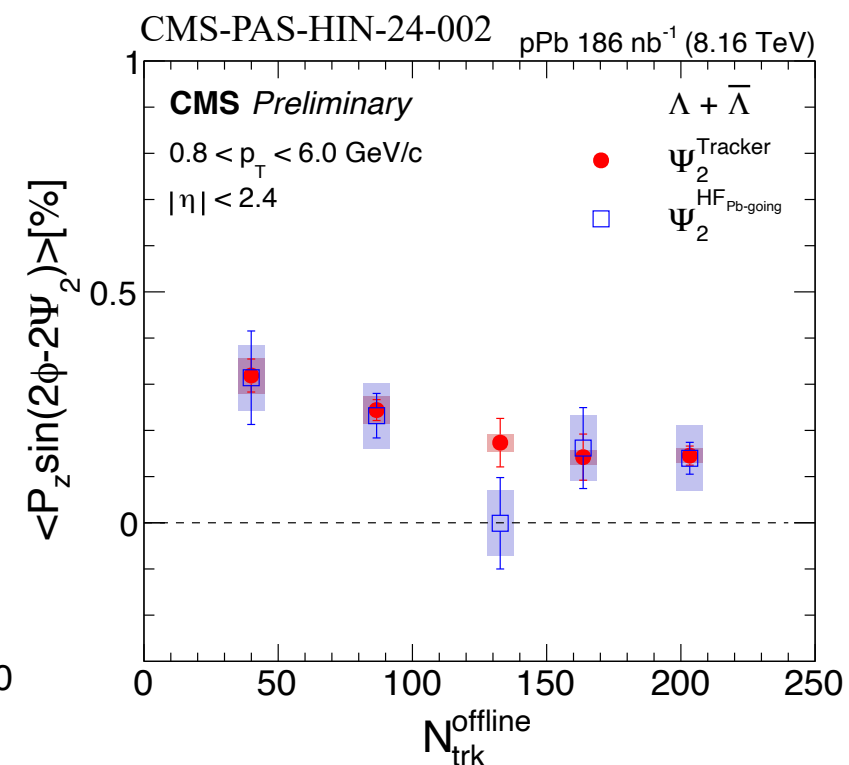
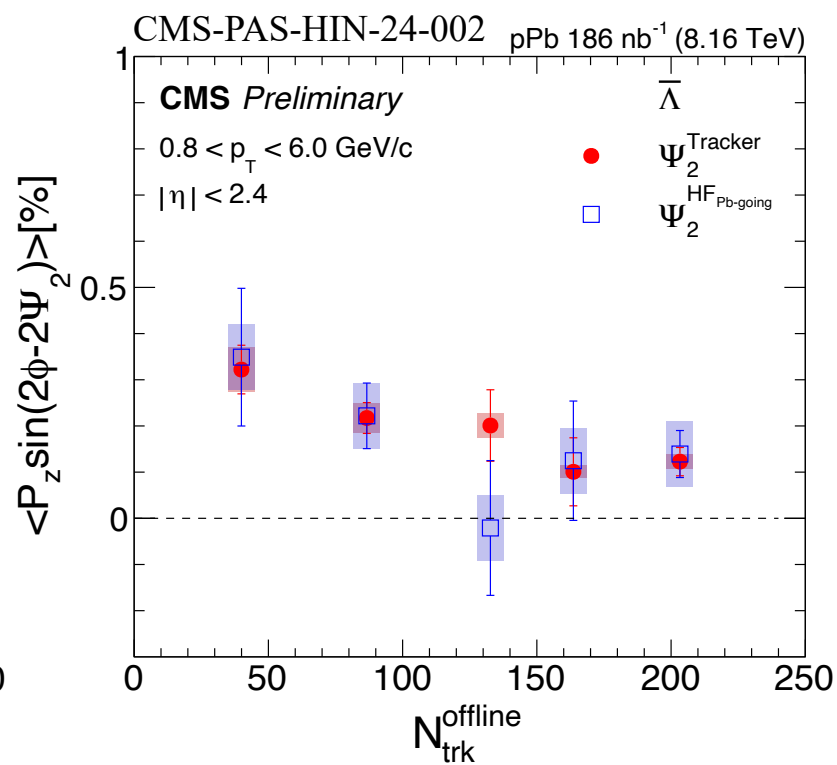
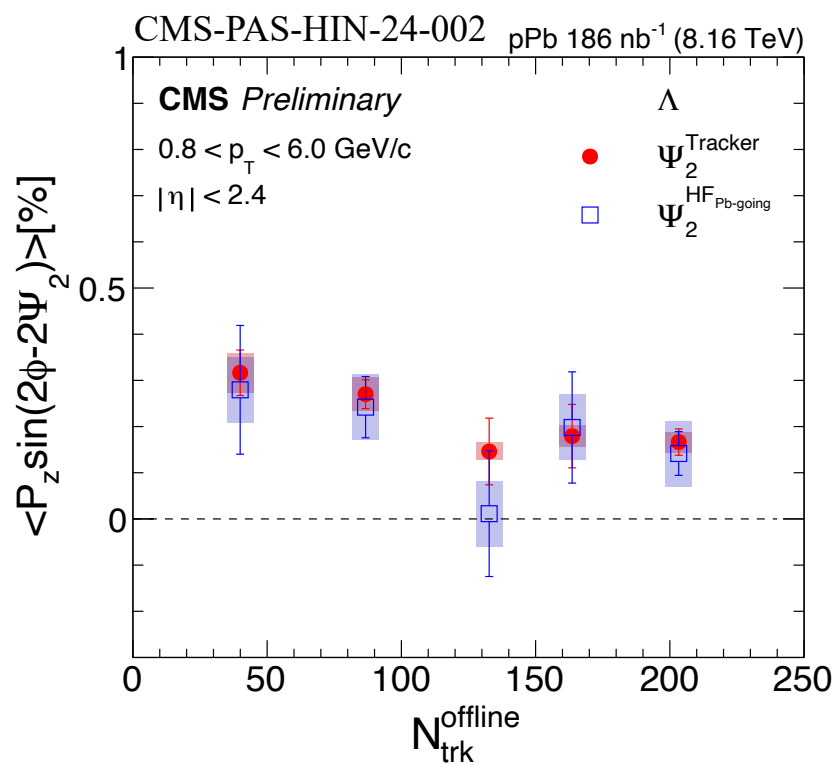
Similar trend as  $v_2$

# Crosscheck – $K_S^0$



$P_{z,s2}$  values for  $K_S^0$  (spin-0 particle) are consistent with 0 as expected

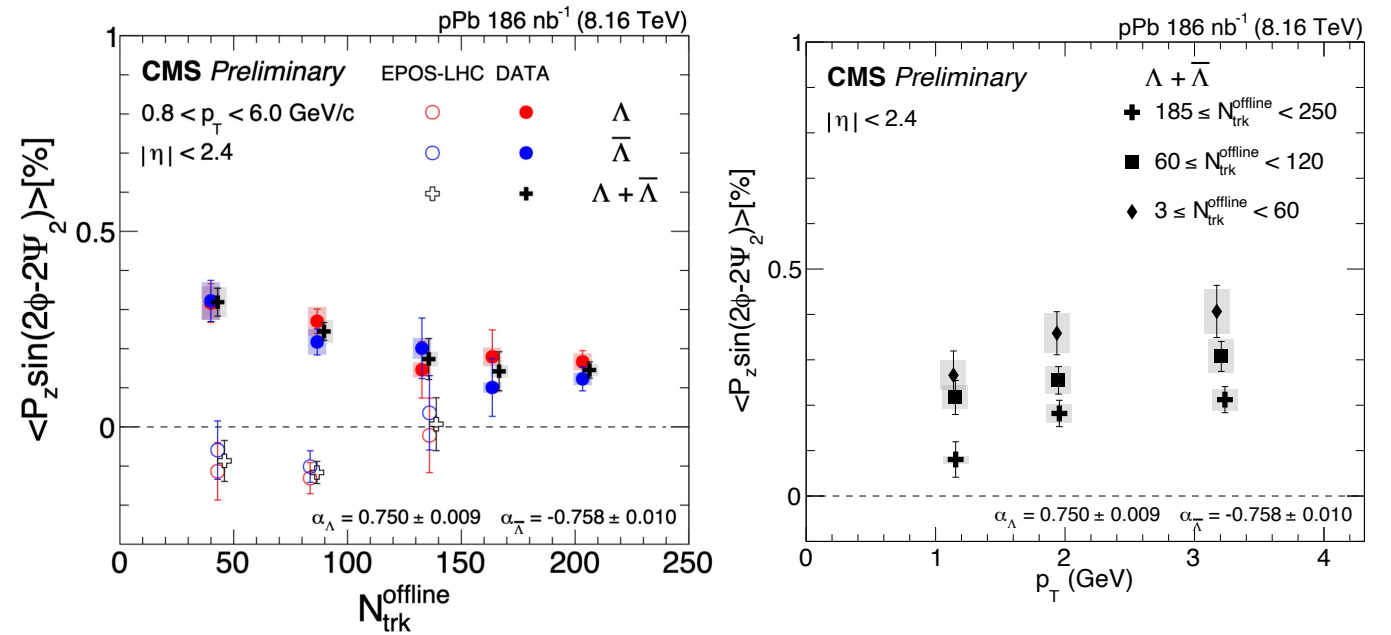
# Cross check – HF event plane



Consistent results w.r.t to forward rapidity event plane

# Summary

- First measurement of hyperon polarization along the beam direction in pPb collisions
- Significant positive  $P_{z,s2}$  observed for the entire multiplicity range from 3 to 250
- $P_{z,s2}$  decrease as function of multiplicity and increase as function of  $p_T$
- The results might indicate complex vorticity structures in pPb collisions
- It remains to be seen how different polarization mechanisms contribute to the observed signal



Call for theoretical calculations !

[CMS-PAS-HIN-24-002](#)

# Backup



## The number of events:

$N_{trk}^{offline}$	3-60	60-120	120-150	150-185	185-250
Events	270M	426M	58M	56M	280M

# $P_T$ dependence in pPb and PbPb

