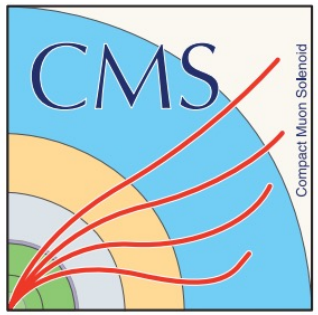
Hyperon polarization along the beam direction in pPb collisions at 8.16 TeV

CMS-PAS-HIN-24-002

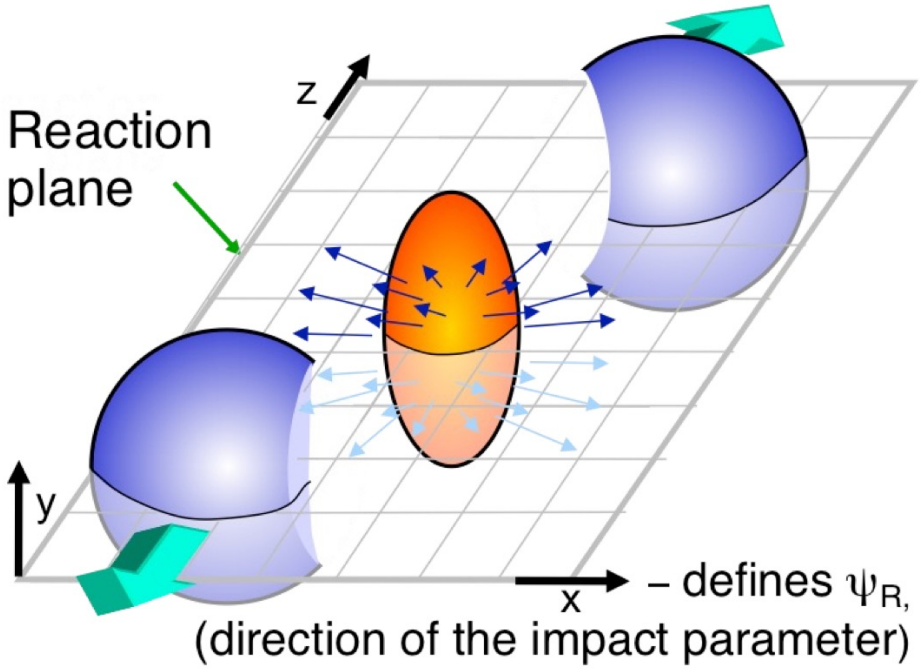
Chenyan Li (李辰艳), for the CMS collaboration

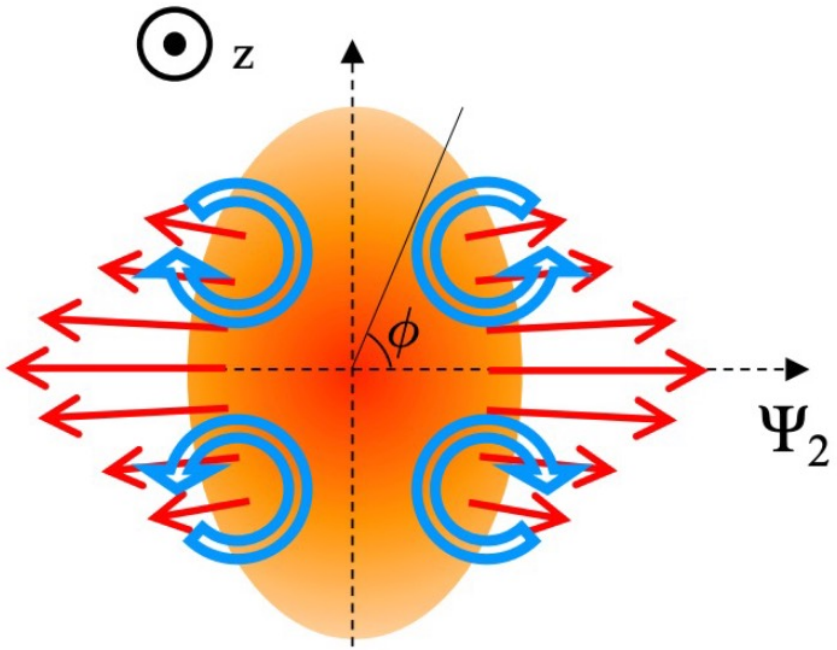
Shandong University (山东大学)



8th International Conference on Chirality, Vorticity, and Magnetic Field in Quantum Matter
July 22 - 26, 2024, Timisoara, Romania

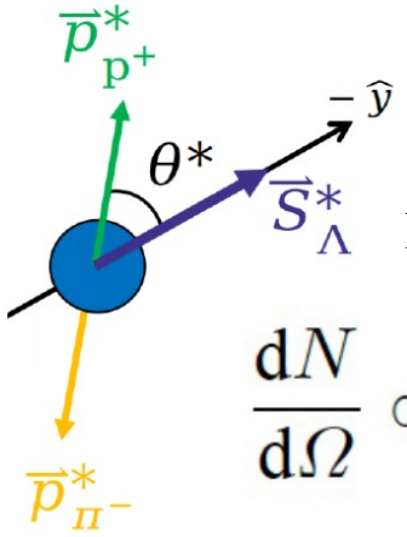
Hyperon polarization along beam direction





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

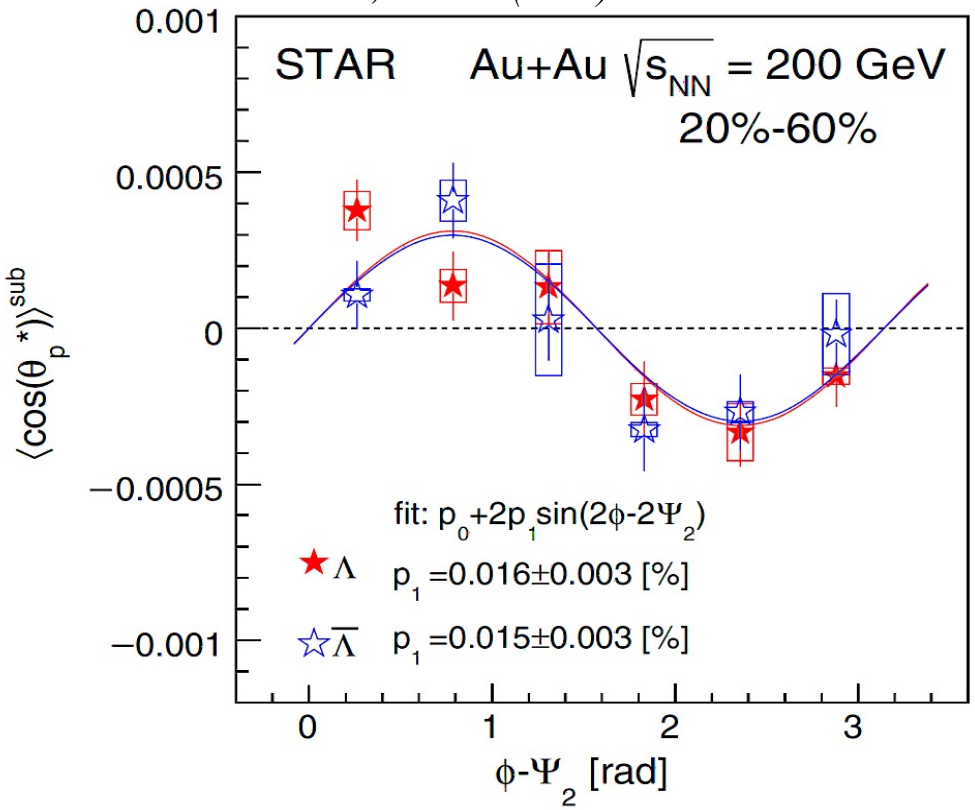


Hyperon decay parameter

$$\frac{dN}{d\Omega} \propto 1 + \alpha_\Lambda P_\Lambda \cos\theta^*$$

Hyperon polarization

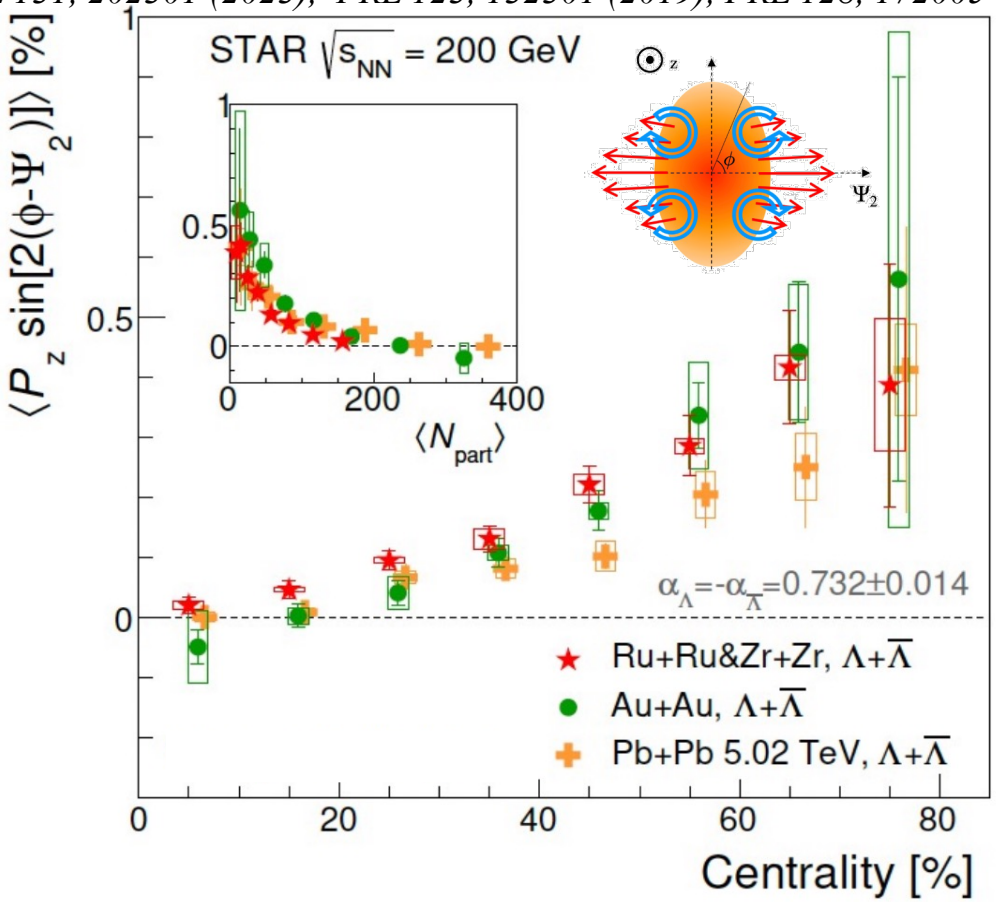
PRL 123, 132301 (2019)



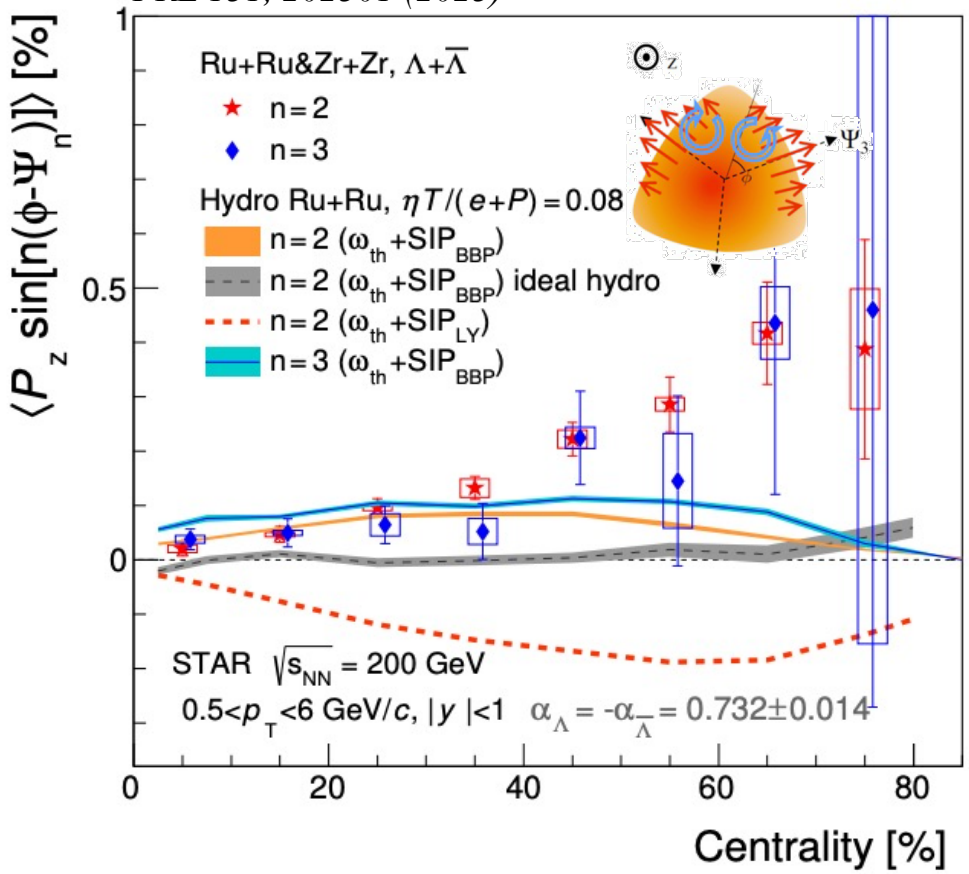
Hyperon weak decay is a simple and direct probe of polarization
Quadrupole structure of polarization observed

Hyperon polarization along beam direction in AA collisions

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



PRL 131, 202301 (2023)

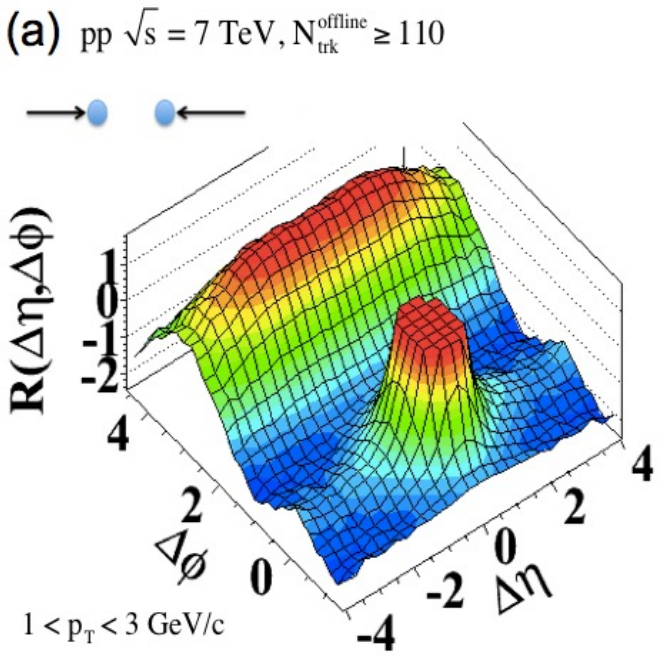


Significant P_z signal w.r.t 2nd-order and 3rd-order event plane observed in AA collisions

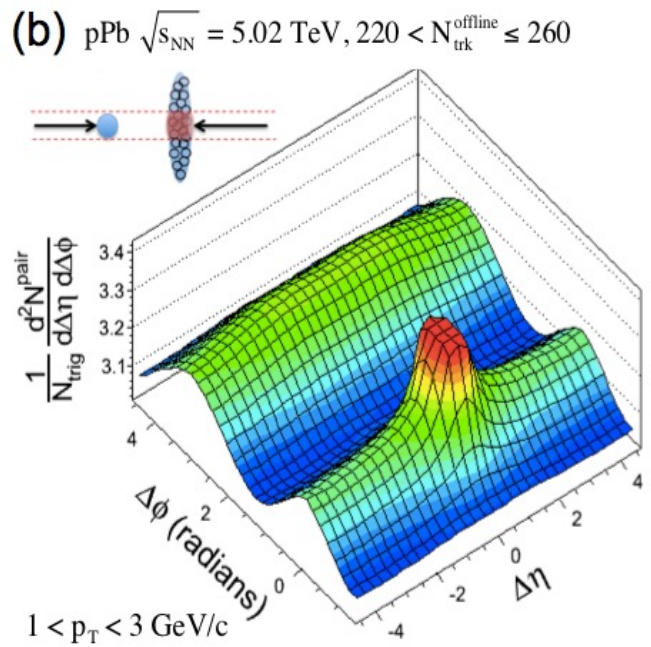
Indication of correlation between flow and polarization

Hyperon polarization along beam direction in small systems?

JHEP 09 (2010) 091



PLB 724 (2013) 213



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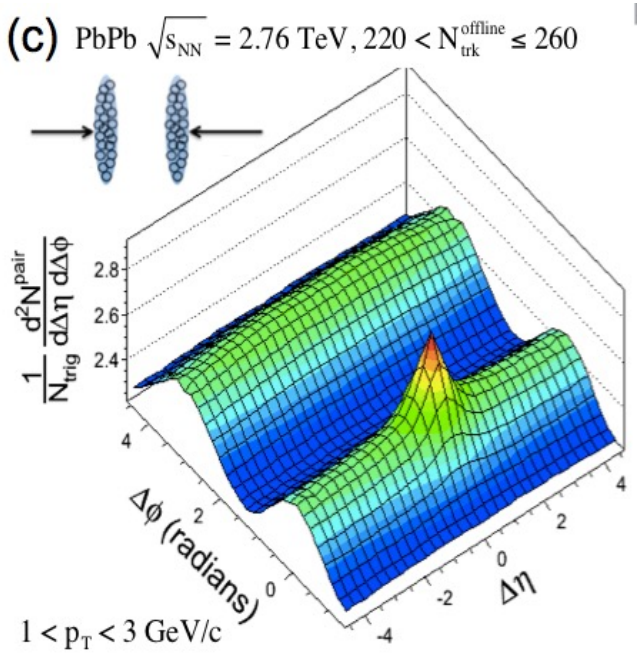
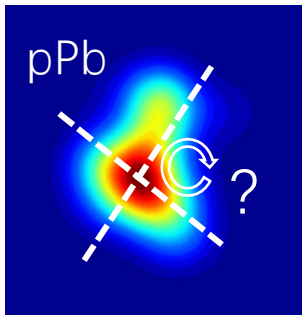




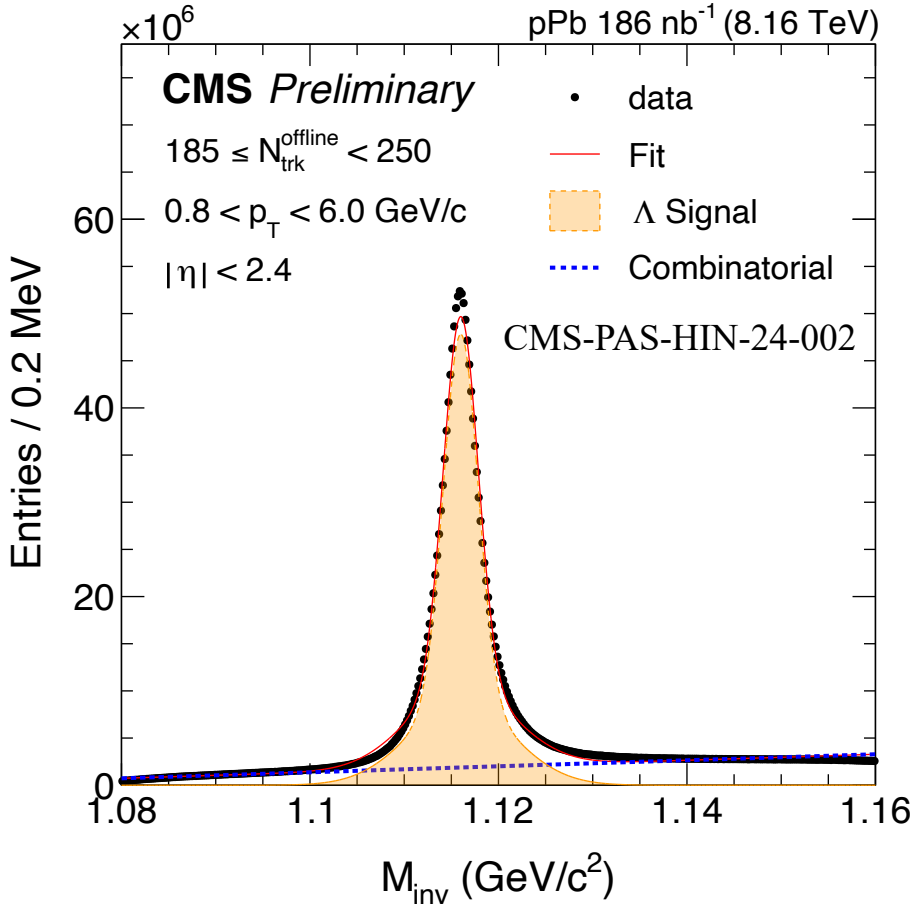
Similar collective feature in high-multiplicity pp and pPb collisions

Is a QGP droplet created in smaller collision systems?

Can Hyperon polarization along beam direction be observed?

Λ reconstruction in pPb collisions

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



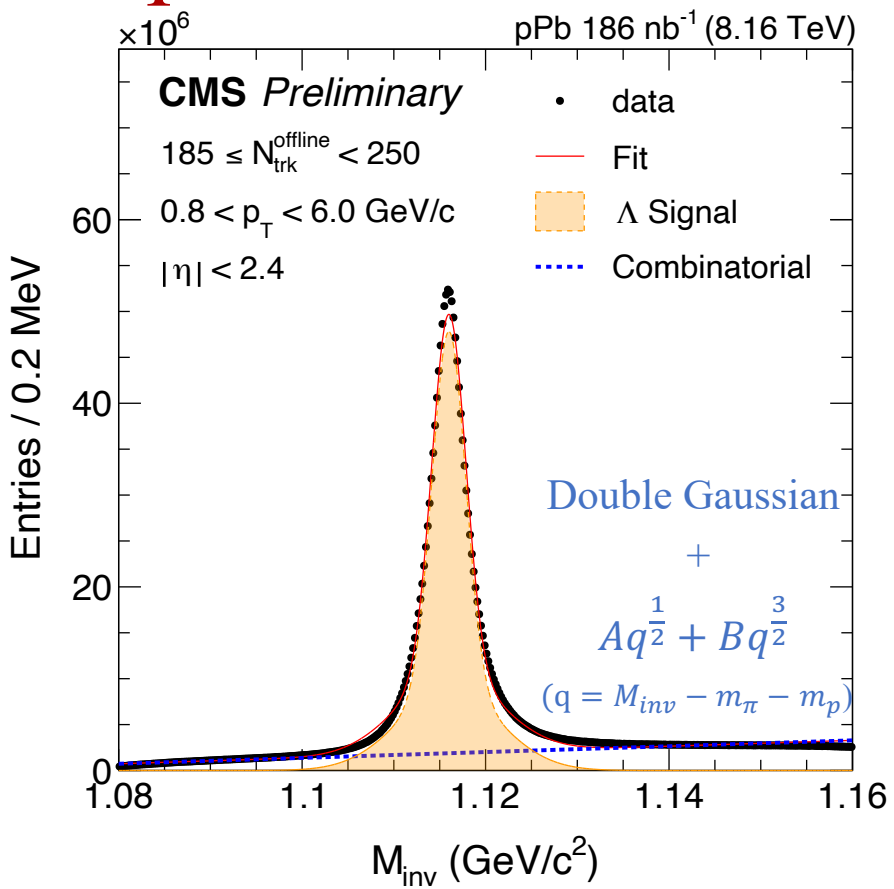
Clear signal for Λ

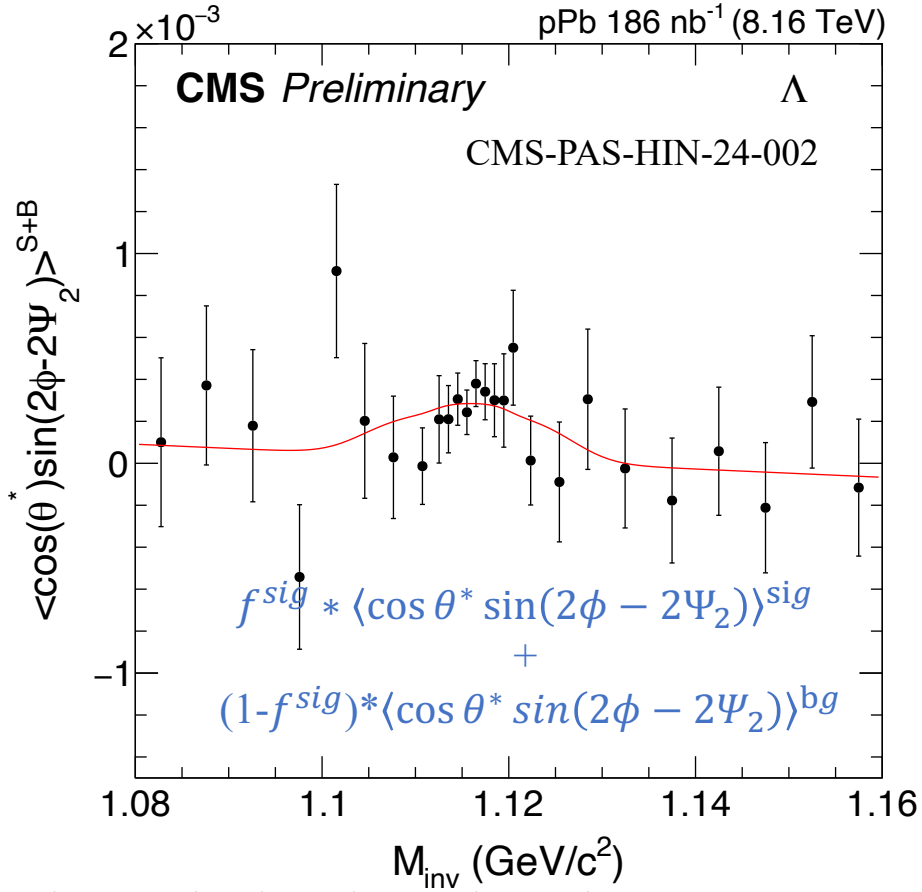
Multiplicity interval ($N_{trk}^{offline}$)	$\langle N_{trk}^{offline} \rangle$	$\langle N_{trk}^{corrected} \rangle$
$[3, 60)$	40.0	48.5 ± 1.9
$[60, 120)$	86.7	105.3 ± 4.2
$[120, 150)$	132.7	161.2 ± 6.4
$[150, 185)$	163.6	198.7 ± 7.9
$[185, 250)$	203.3	246.9 ± 9.9

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

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

Hyperon polarization extraction

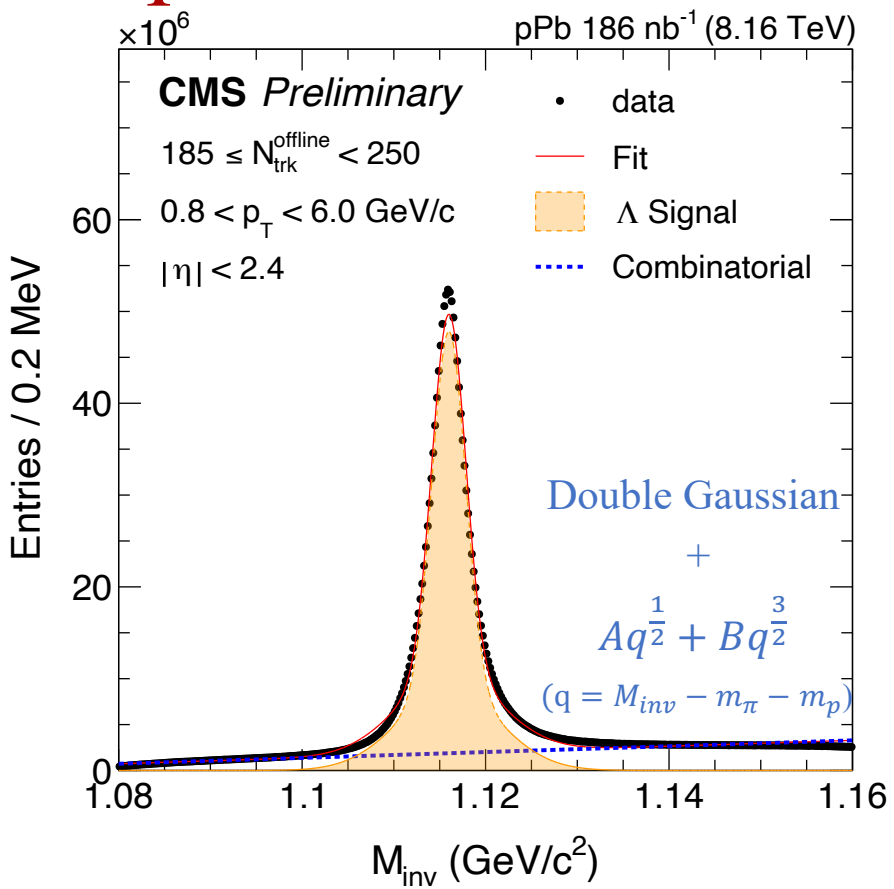


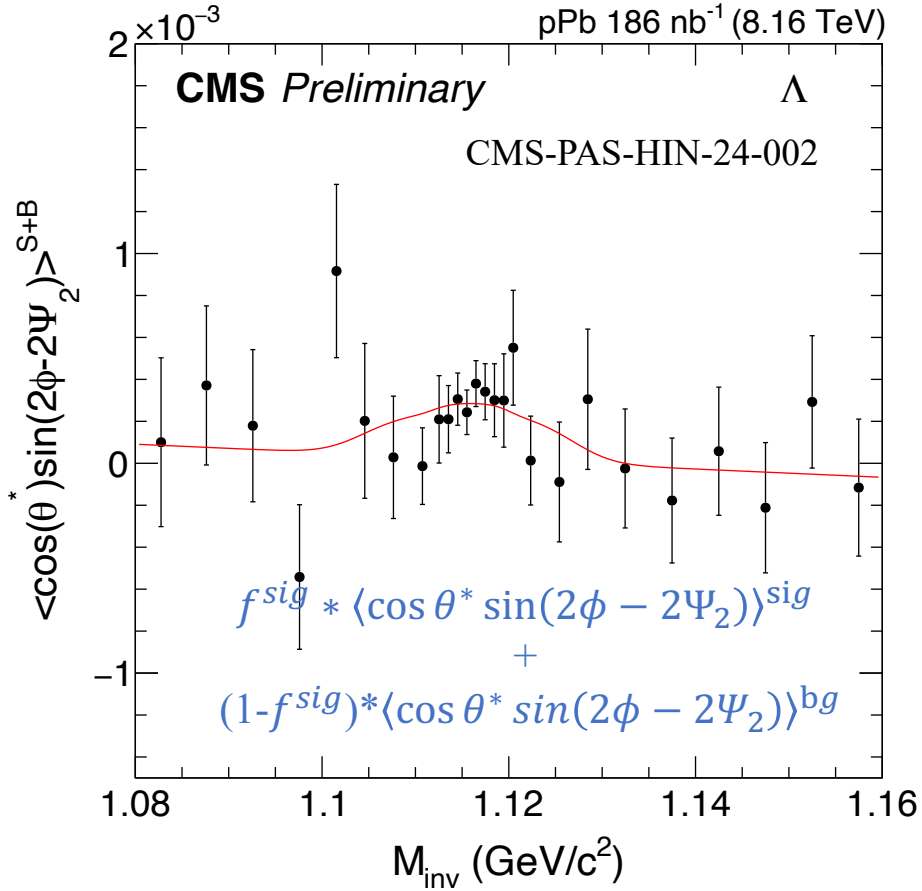


$$f^{sig} = \frac{N_{sig}}{N_{sig} + N_{bg}}$$

Simultaneous fit to extract the polarization signal

Hyperon polarization extraction





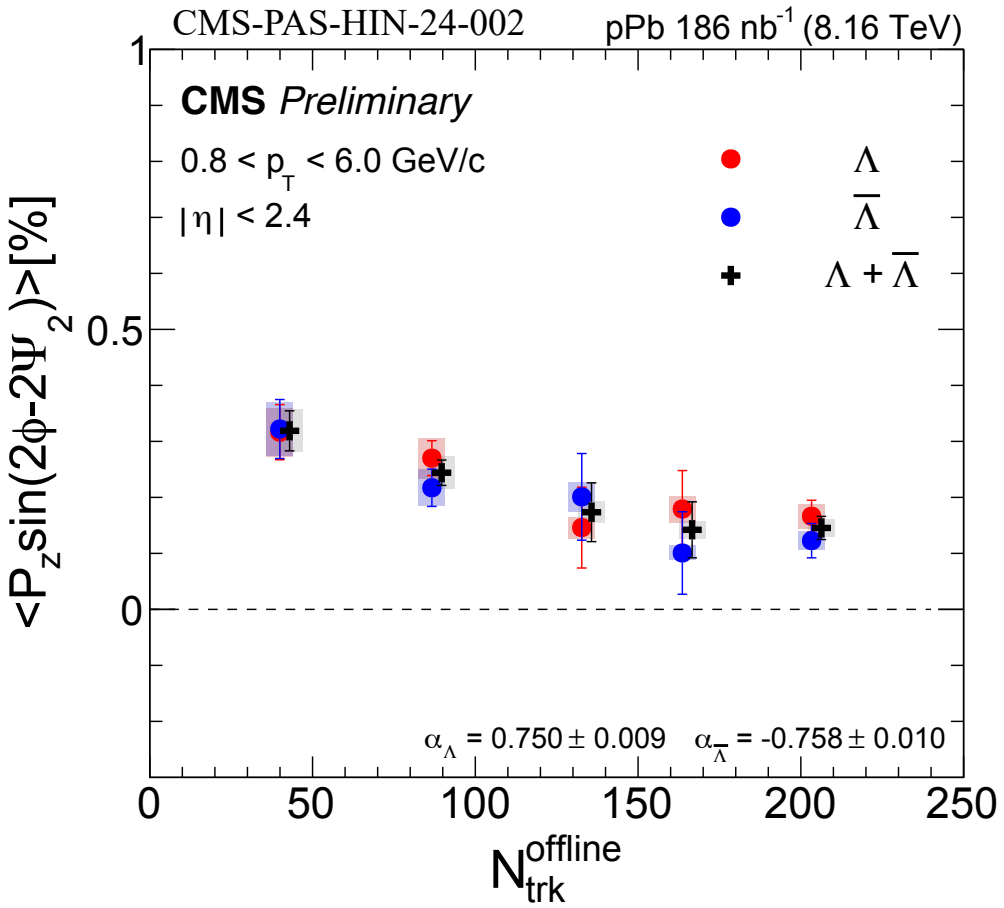
$$f^{sig} = \frac{N_{sig}}{N_{sig} + N_{bg}}$$

Simultaneous fit to extract the polarization signal

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

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

$P_{z,s2}$ in pPb collisions

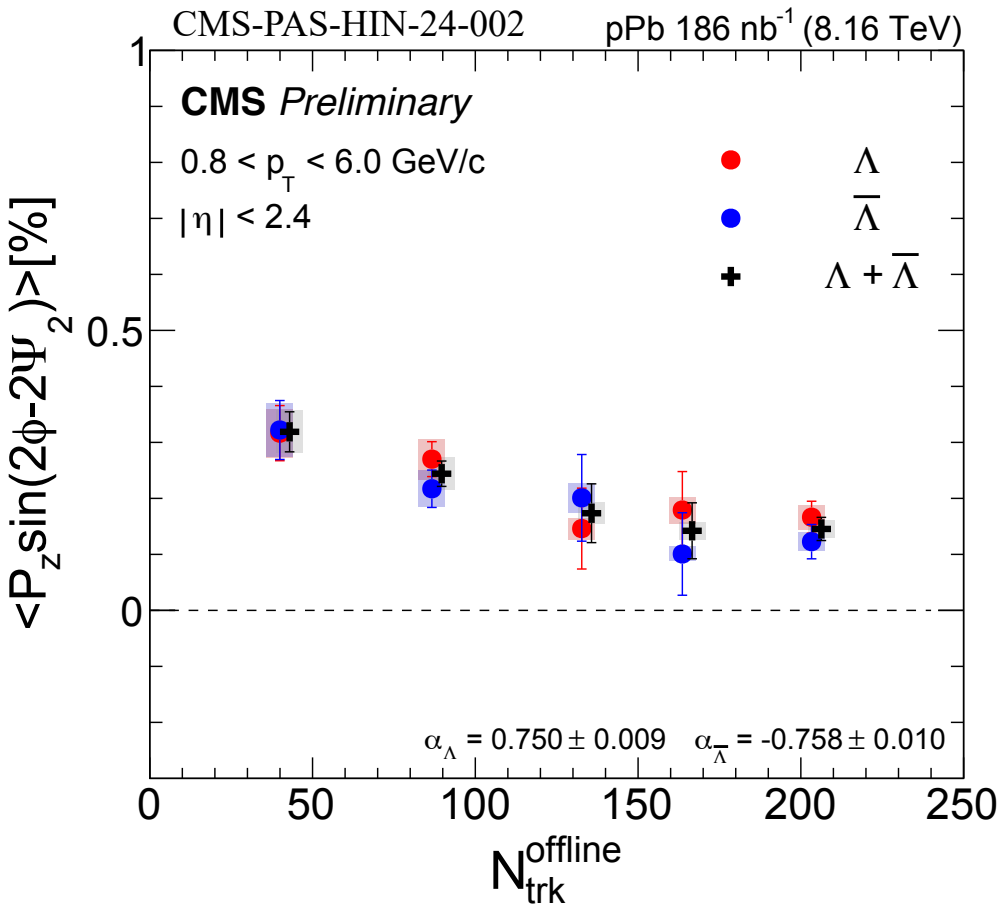


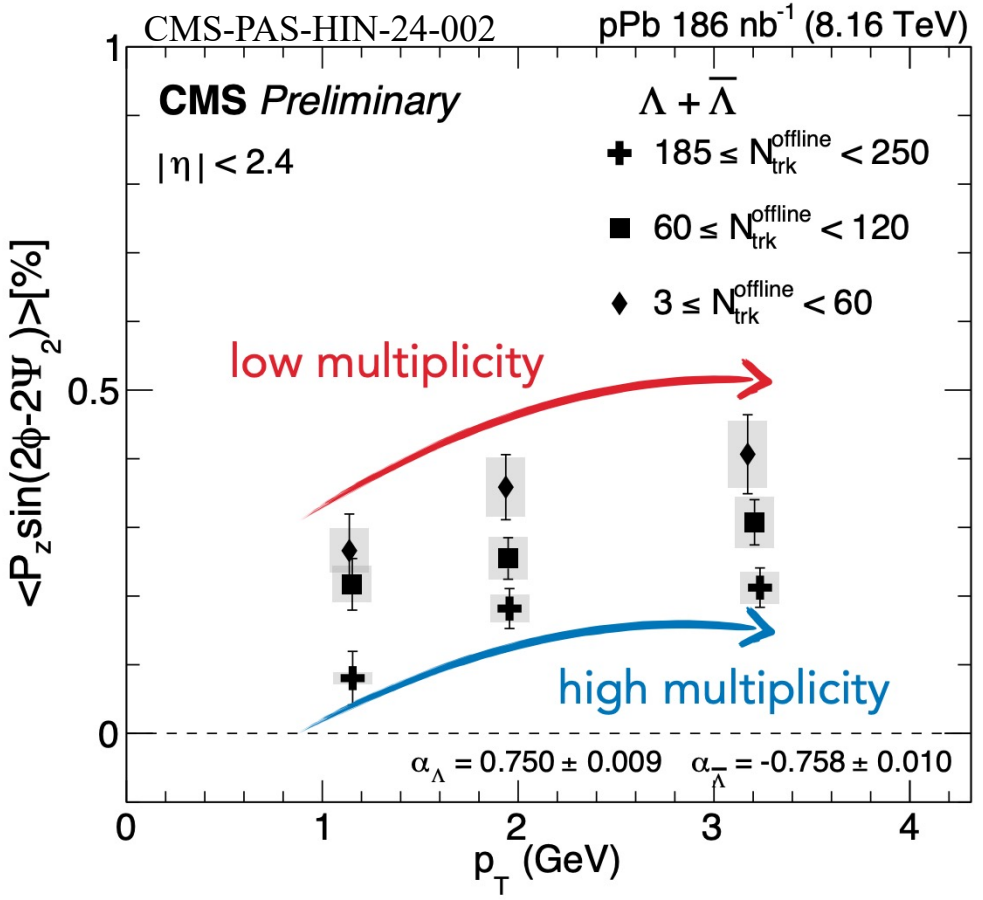
Significant positive $P_{z,s2}$ signal observed for the entire multiplicity range

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

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

$P_{z,s2}$ in pPb collisions



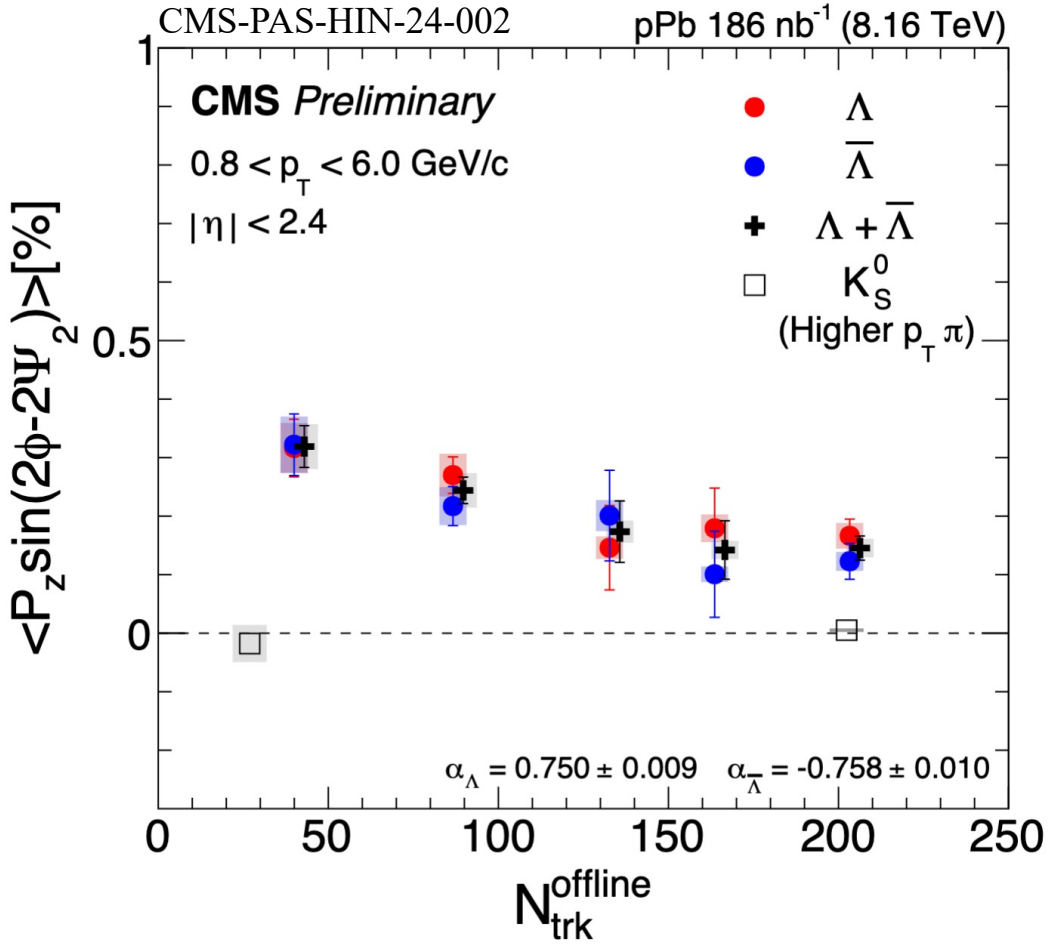


Significant positive $P_{z,s2}$ signal observed for the entire multiplicity range

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

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

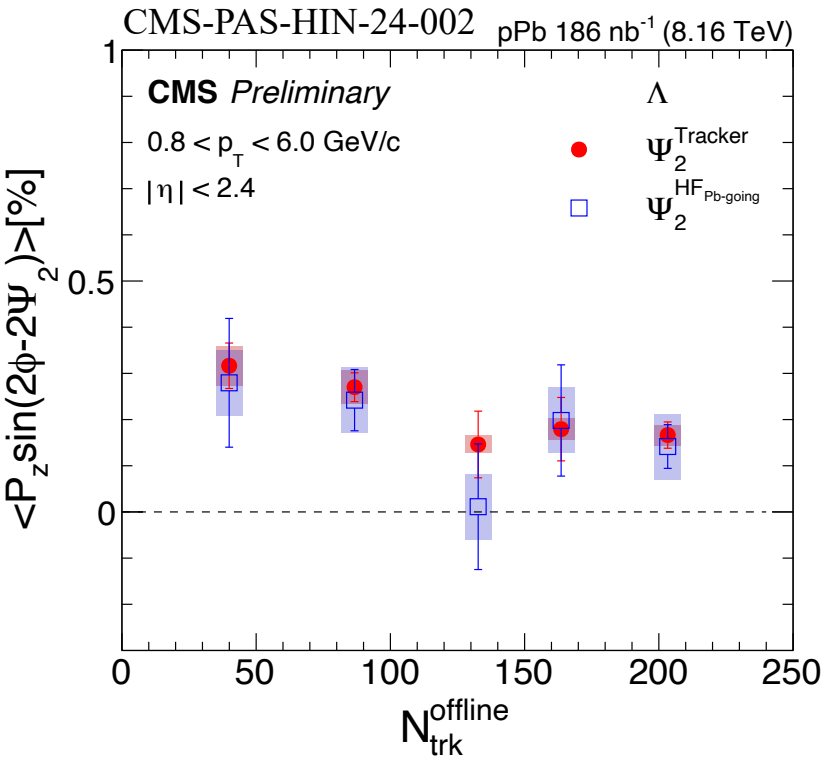
Crosscheck – K_s^0

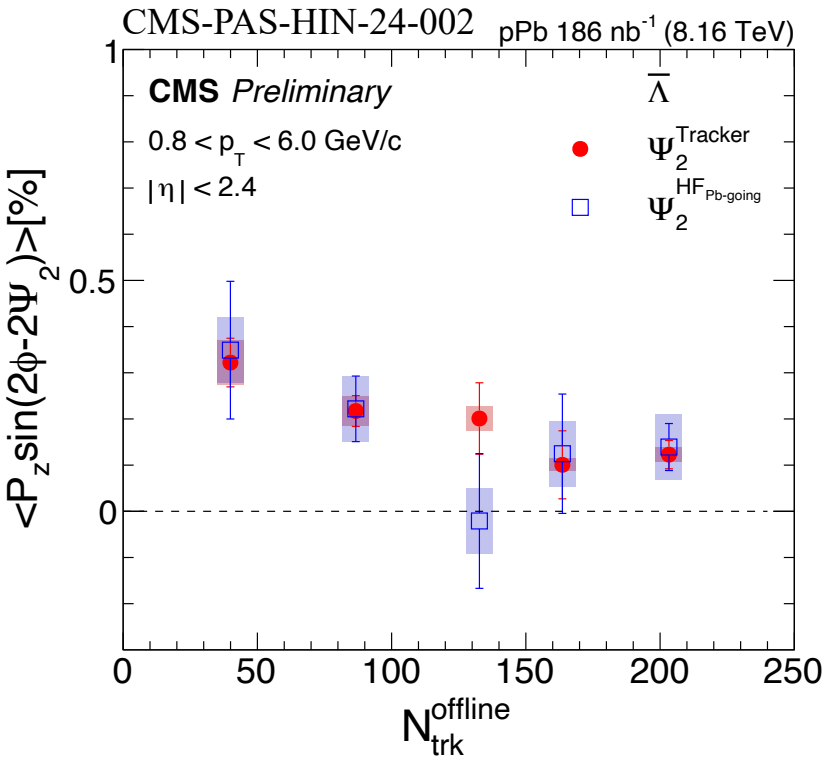


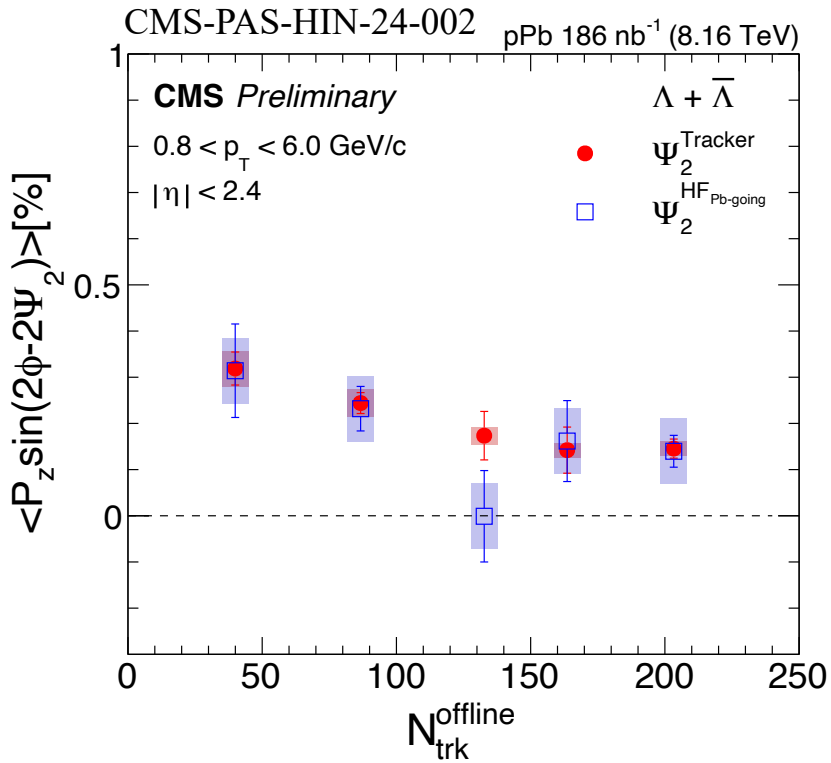
$P_{z,s2}$ values for K_s^0(spin-0 particle) are consistent with 0 as expected

No strange detector effects

Cross check – HF event plane



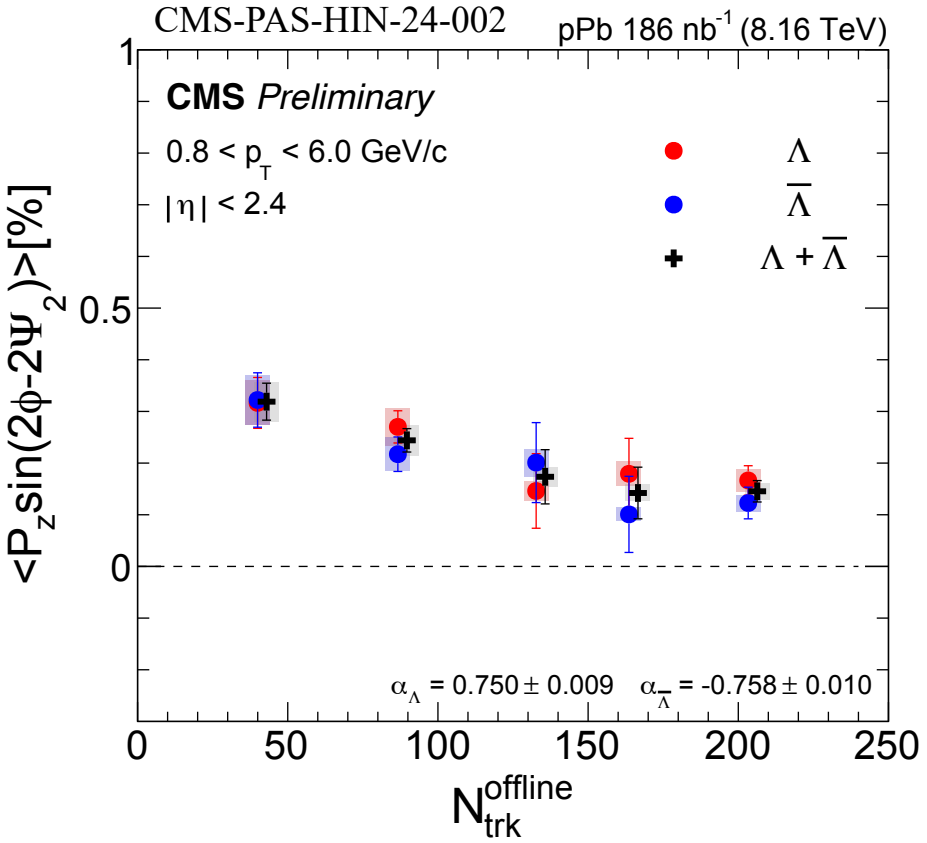




Consistent results w.r.t to forward rapidity event plane

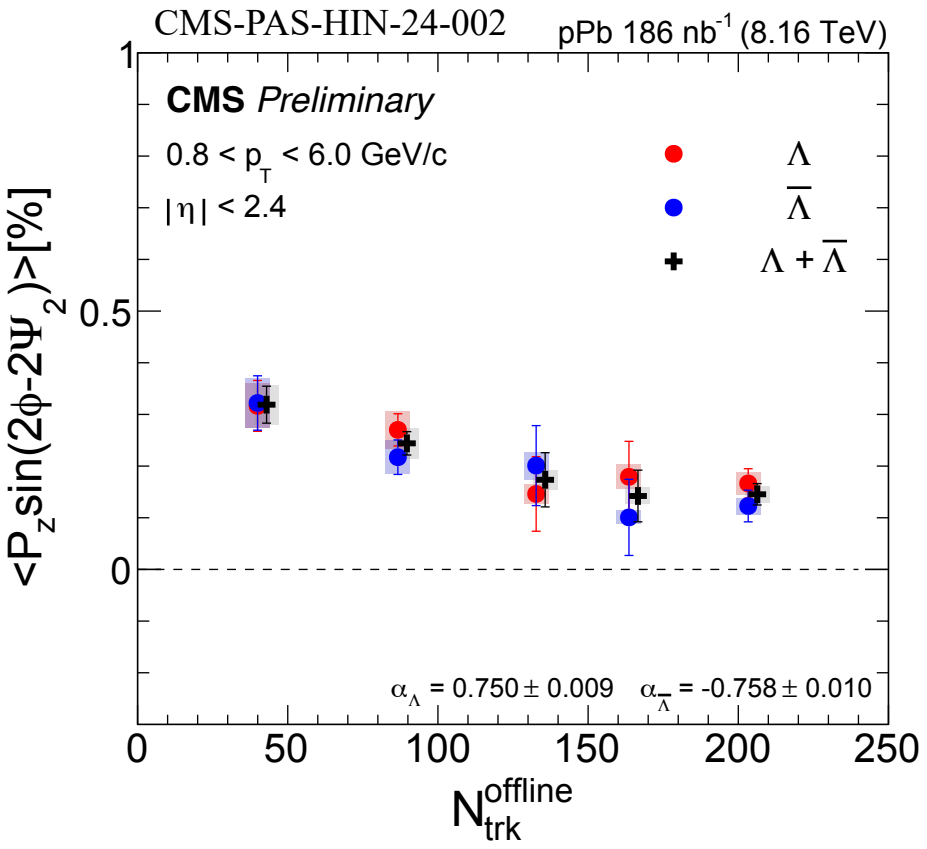
No short range/self correlation

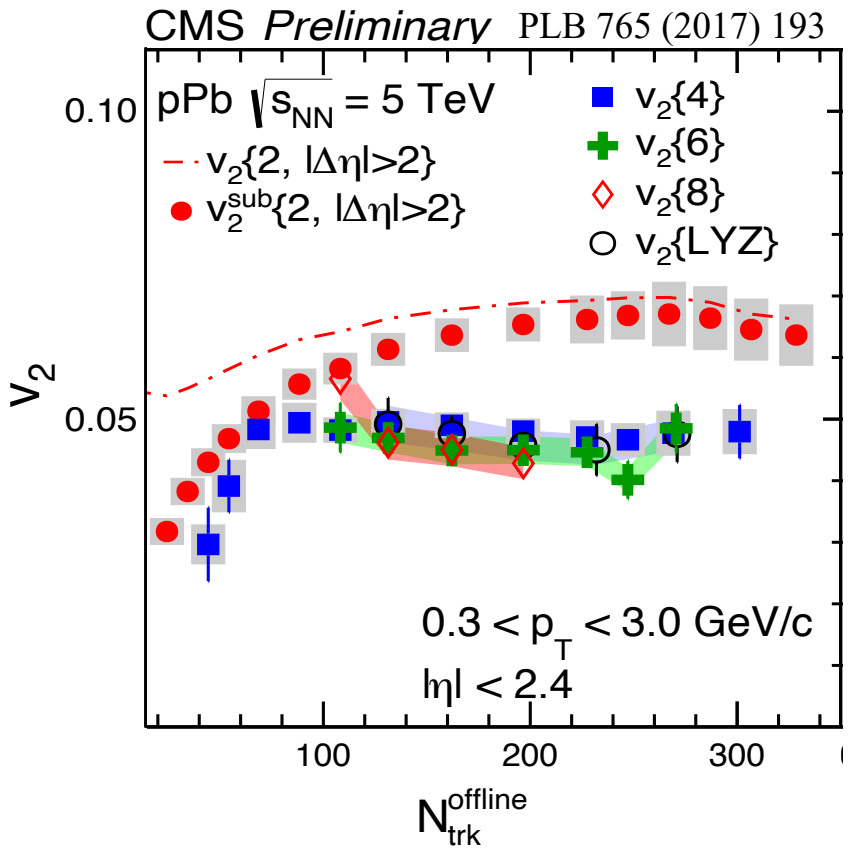
Is it from medium expansion?



Why is it increasing monotonically towards 0 multiplicity?

Is it from medium expansion?





Why is it increasing monotonically towards 0 multiplicity?

Not consistent with the trend of v_2

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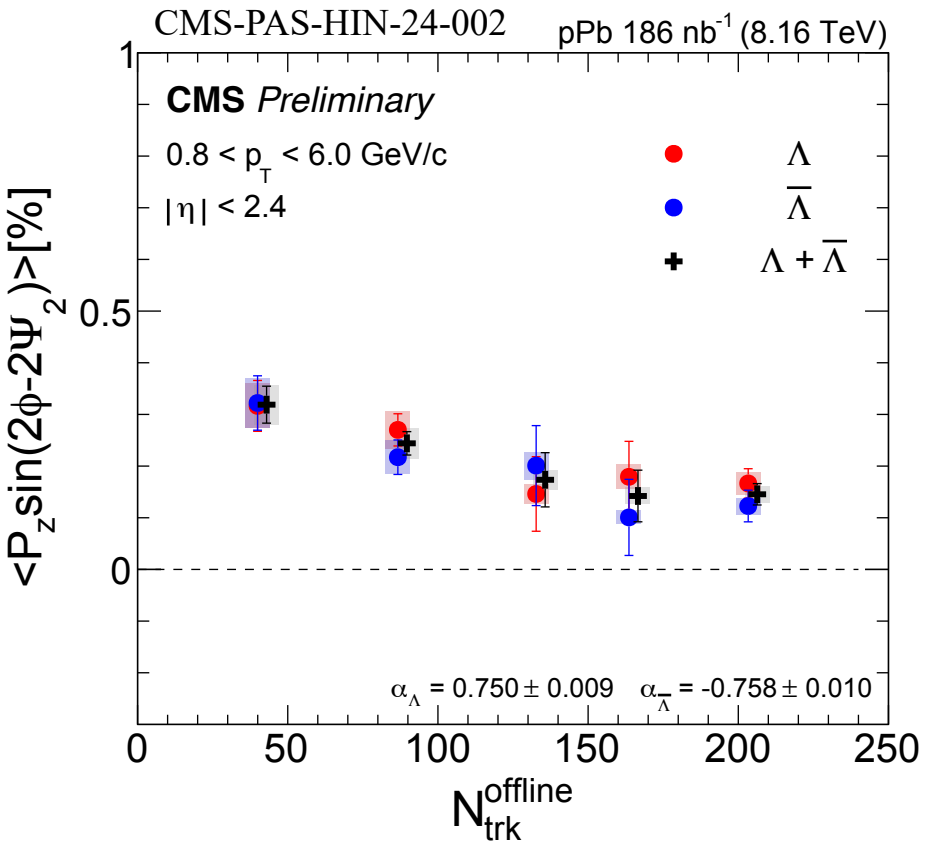
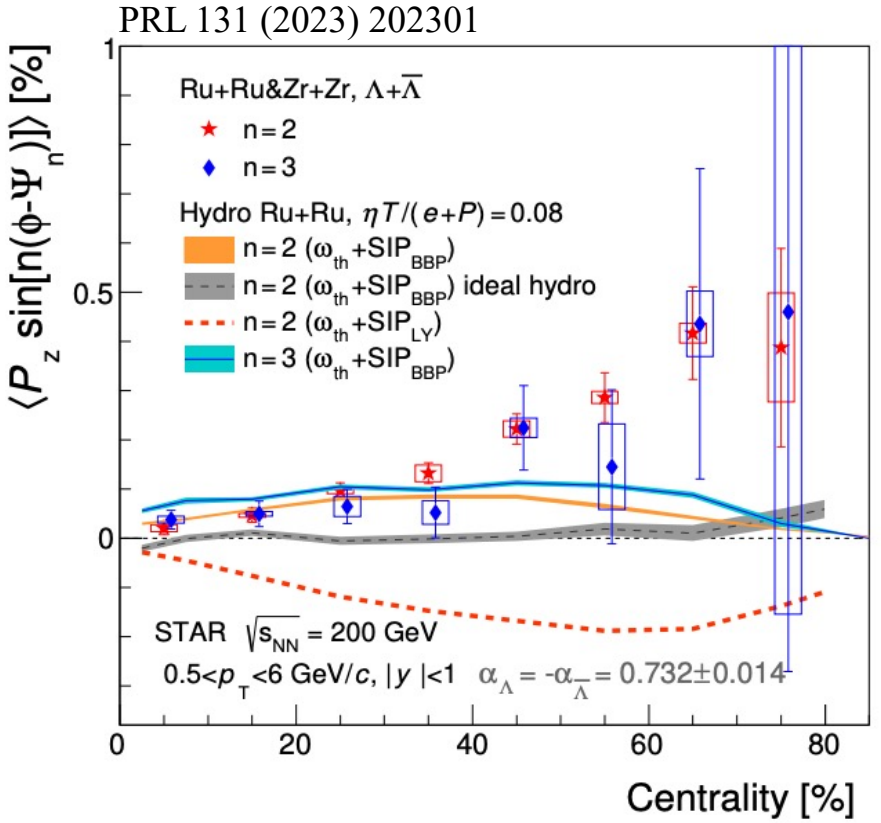




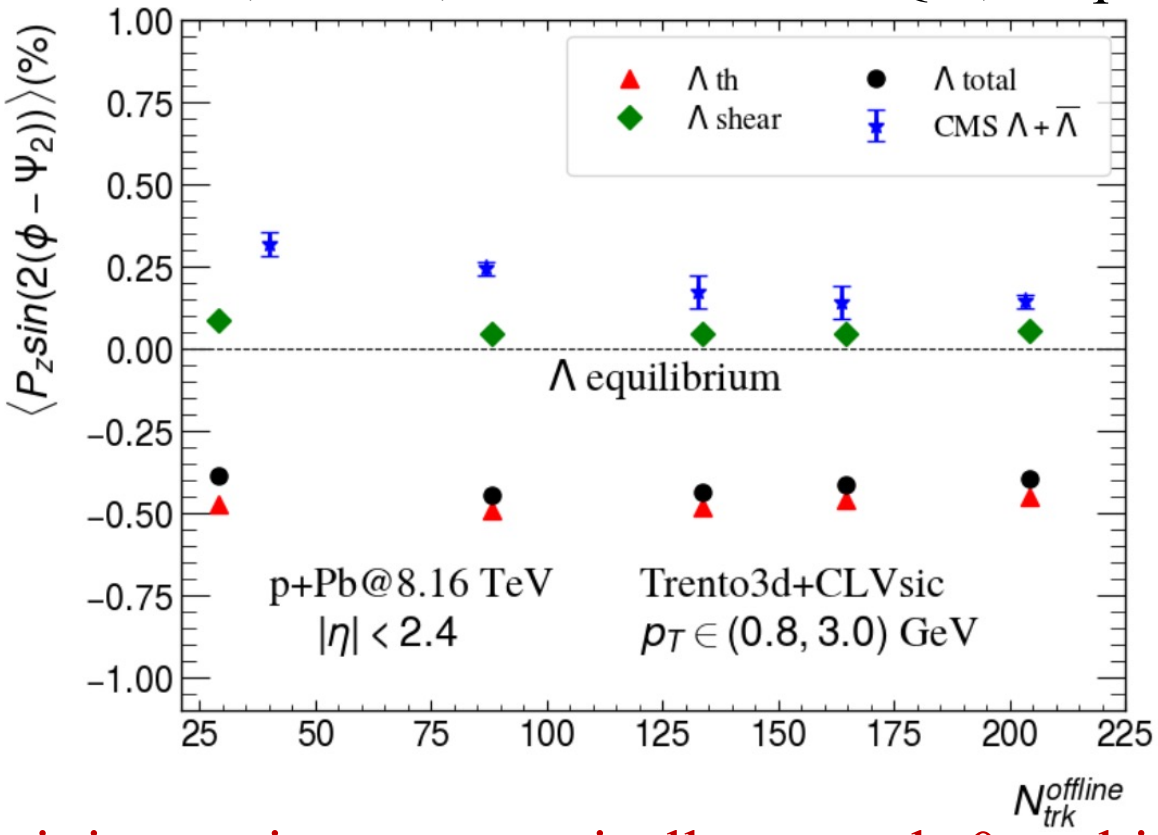
Why is it increasing monotonically towards 0 multiplicity?

Not consistent with the trend of v_2

Similar to the behavior for peripheral AA; not captured by hydro?

Is it from medium expansion?

C. Yi, X.-Y. Wu, J. Zhu, S. Pu and G.-Y. Qin, in preparation



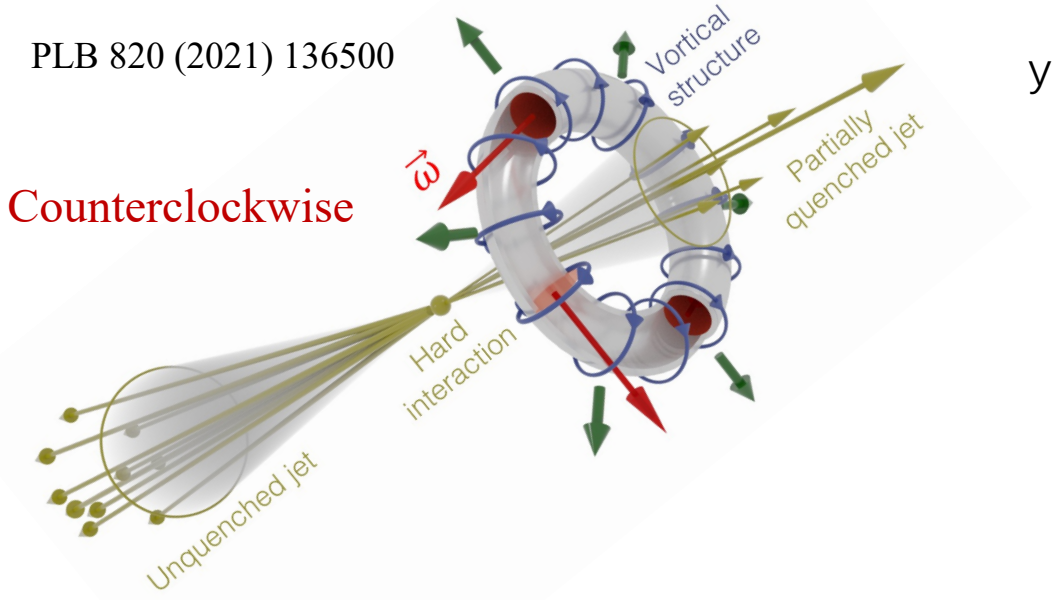
Why is it increasing monotonically towards 0 multiplicity?

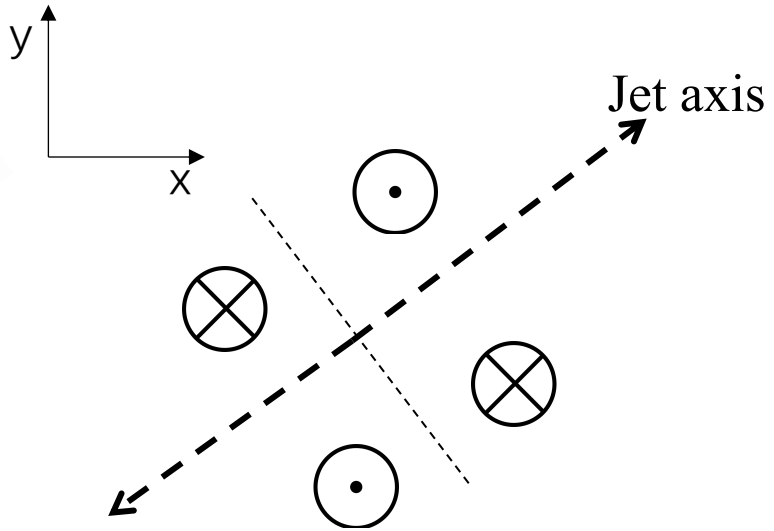
Not consistent with the trend of v_2

Similar to the behavior for peripheral AA; not captured by hydro?

A hydro calculation results in negative $P_{z,s2}$

Is it from “ring polarization” ?



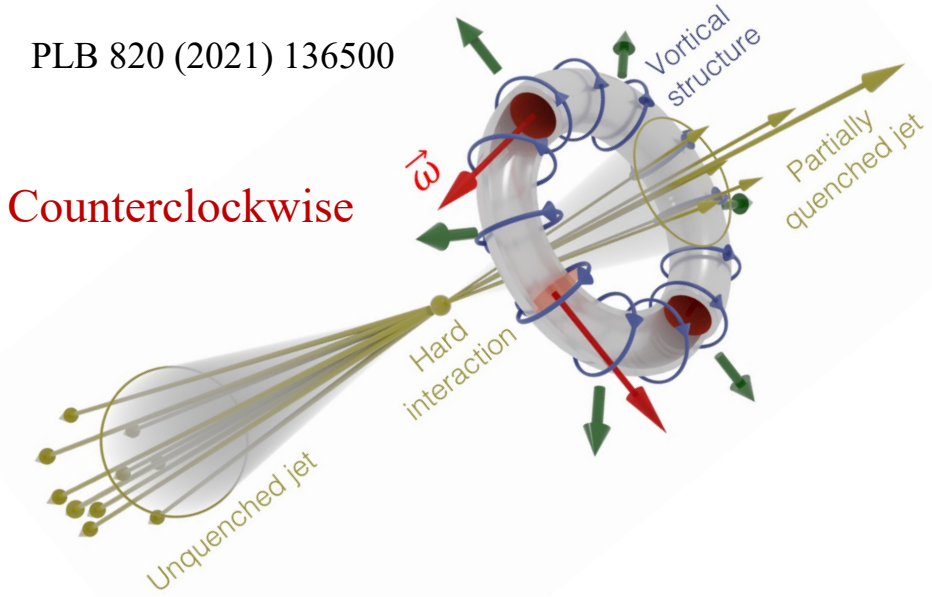


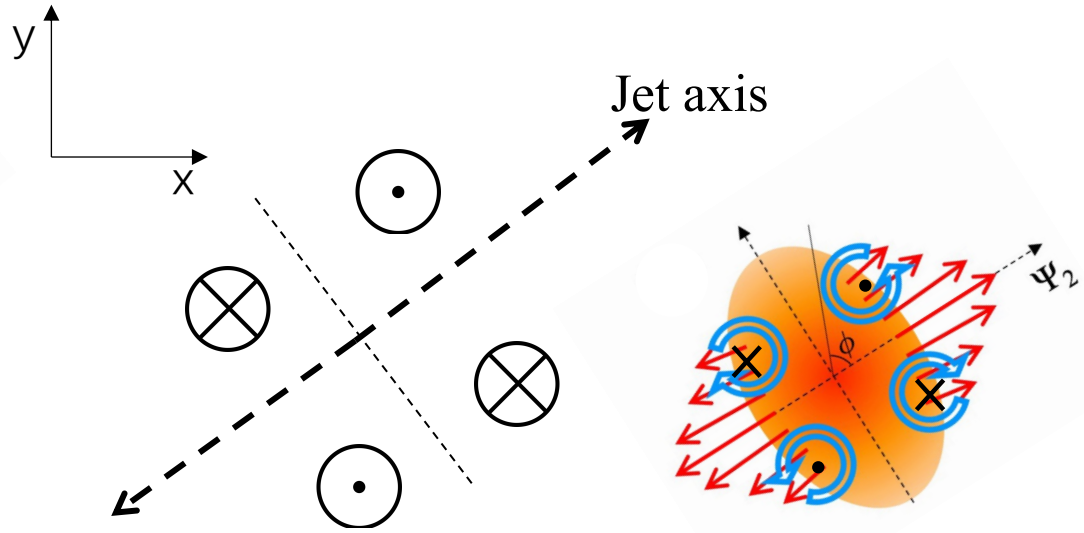
Jet passing through the “medium” could induce ring polarization

Different sensitivity to thermal & shear terms than P_z

Projection into x-y plane mimic a P_z wrt jet axis

Is it from “ring polarization” ?





Jet passing through the “medium” could induce ring polarization

Different sensitivity to thermal & shear terms than P_z

Projection into x-y plane mimic a P_z wrt jet axis

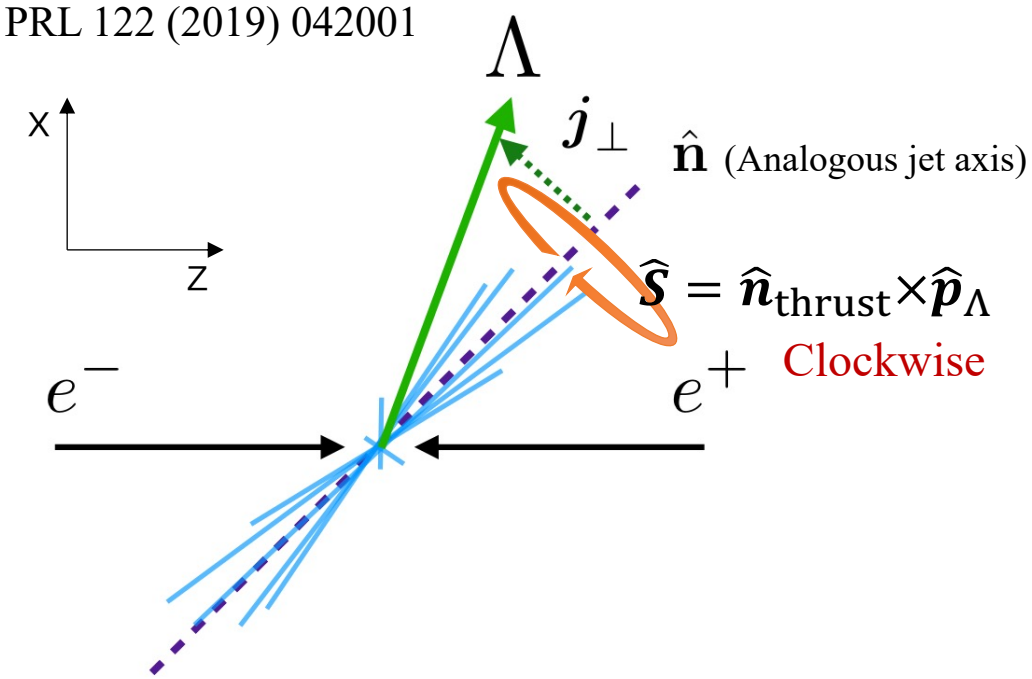
Jet axis coincide with 2nd order event plane at low multiplicity

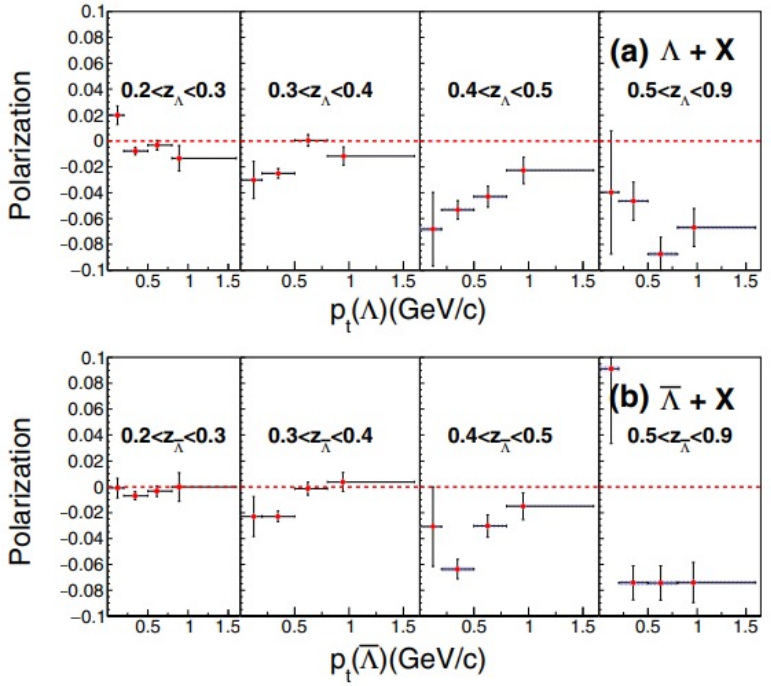
Diluted towards high multiplicity

Should have a eta dependence; no precision to test with current data

Is it from spin physics?

PRL 122 (2019) 042001



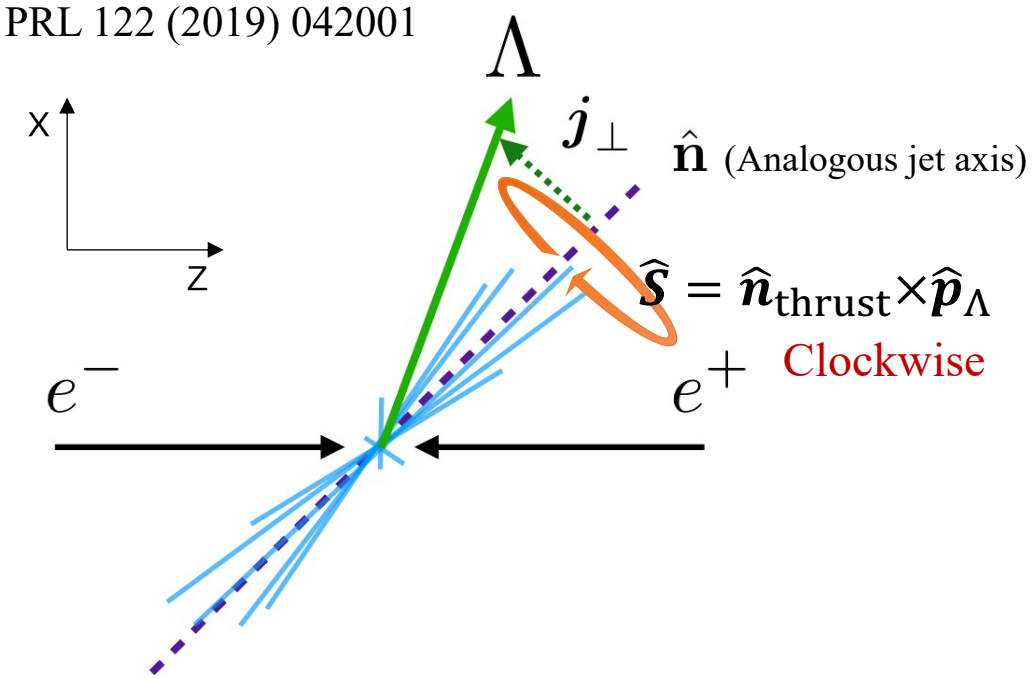


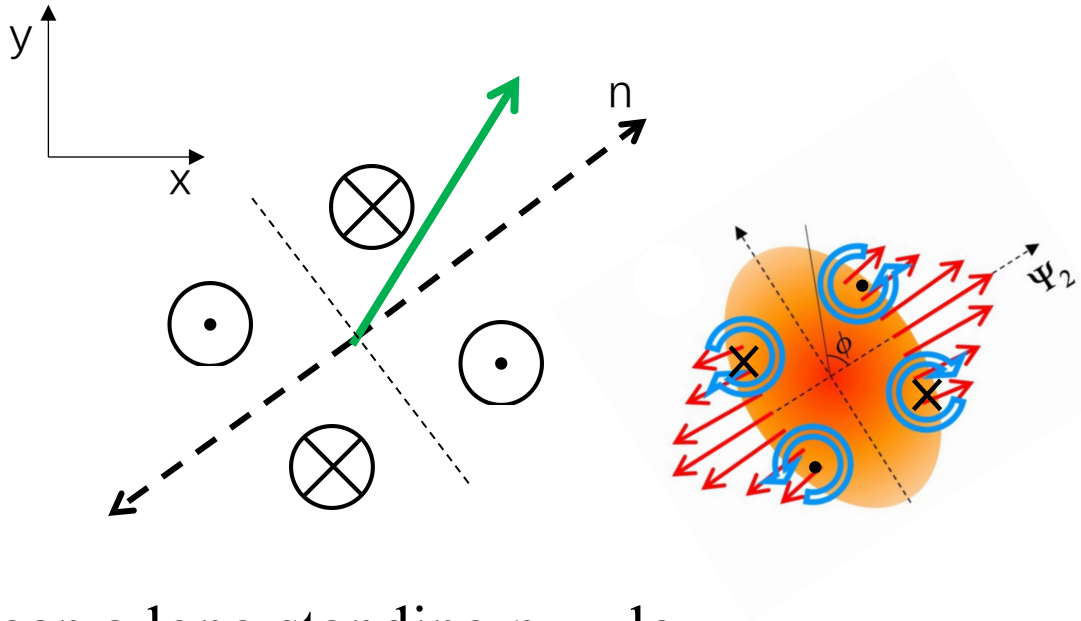
Transverse polarization of Λ has been a long standing puzzle

Recent Belle measurement in e^+e^- shows a significant signal wrt thrust axis

Is it from spin physics?

PRL 122 (2019) 042001





Transverse polarization of Λ has been a long standing puzzle

Recent Belle measurement in e^+e^- shows a significant signal wrt thrust axis

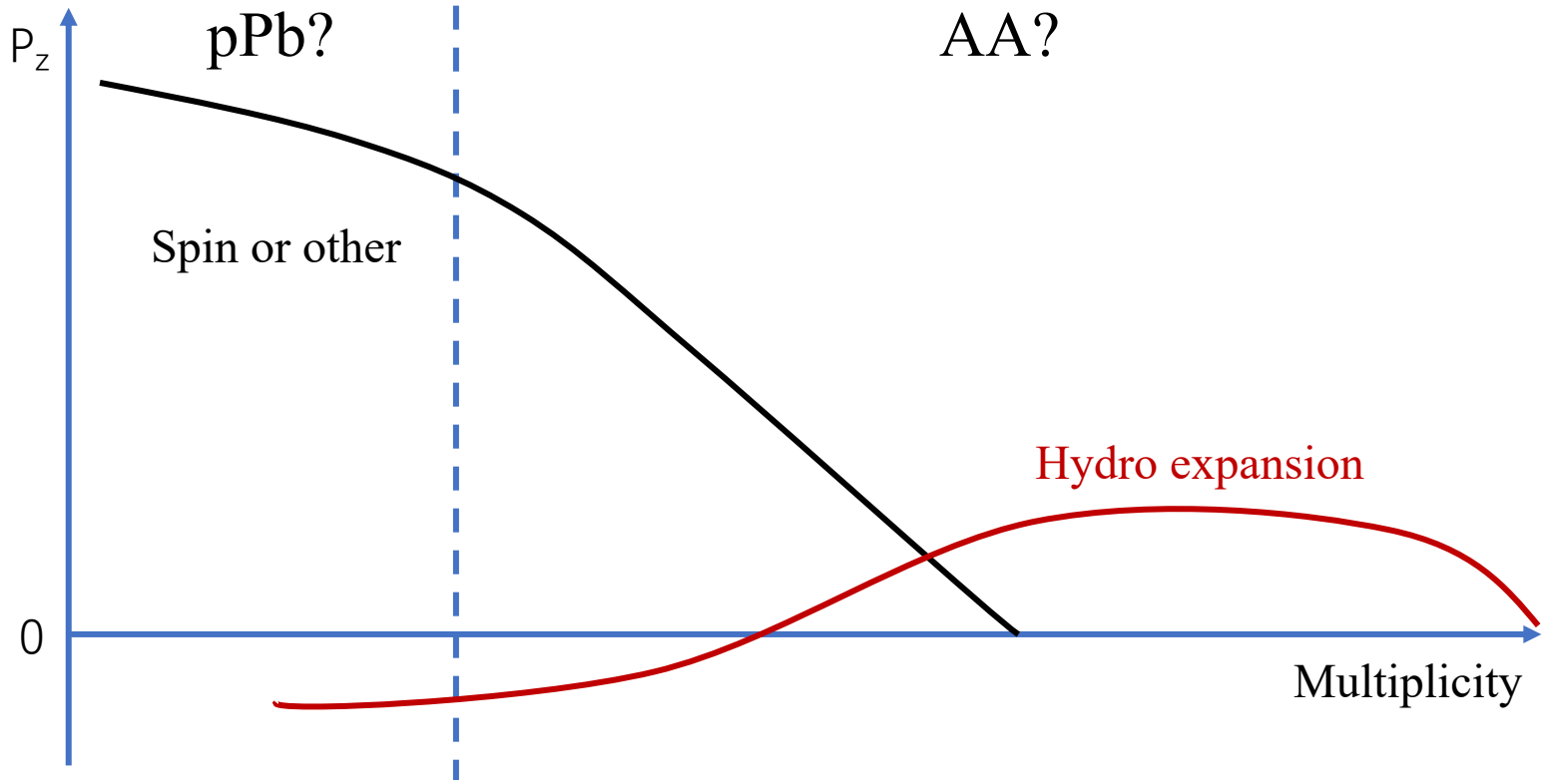
Projection into x-y plane introduce a P_z wrt thrust axis (n)

Thrust axis coincide with 2nd order event plane at low multiplicity

Opposite direction than our signal; but could have a z_Λ dependence

Diluted towards high multiplicity

Different contributions vs multiplicity?

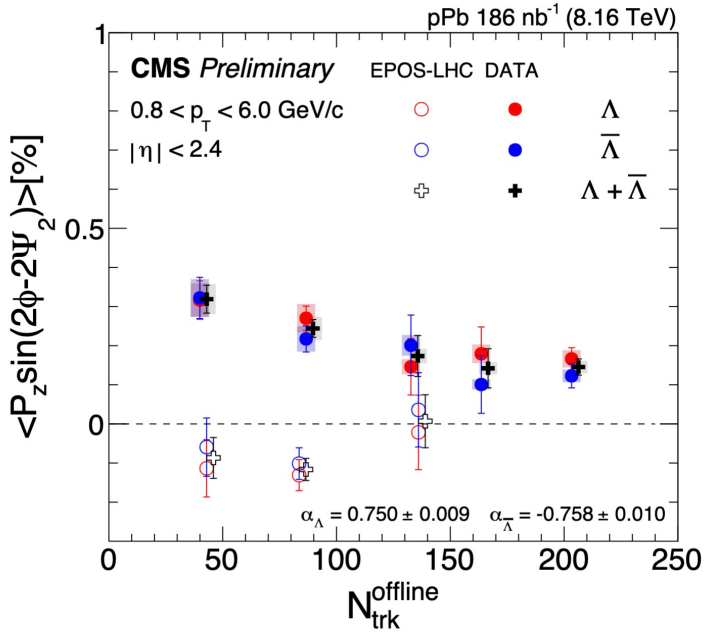


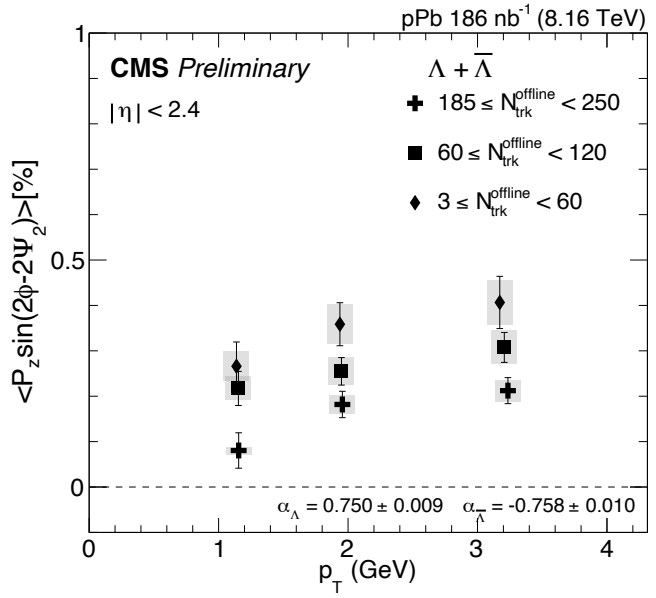
A naïve guess of the picture

Where is the switching point and what does it mean for AA?

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, which is not consistent with hydro expectation
- $P_{z,s2}$ 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





[CMS-PAS-HIN-24-002]

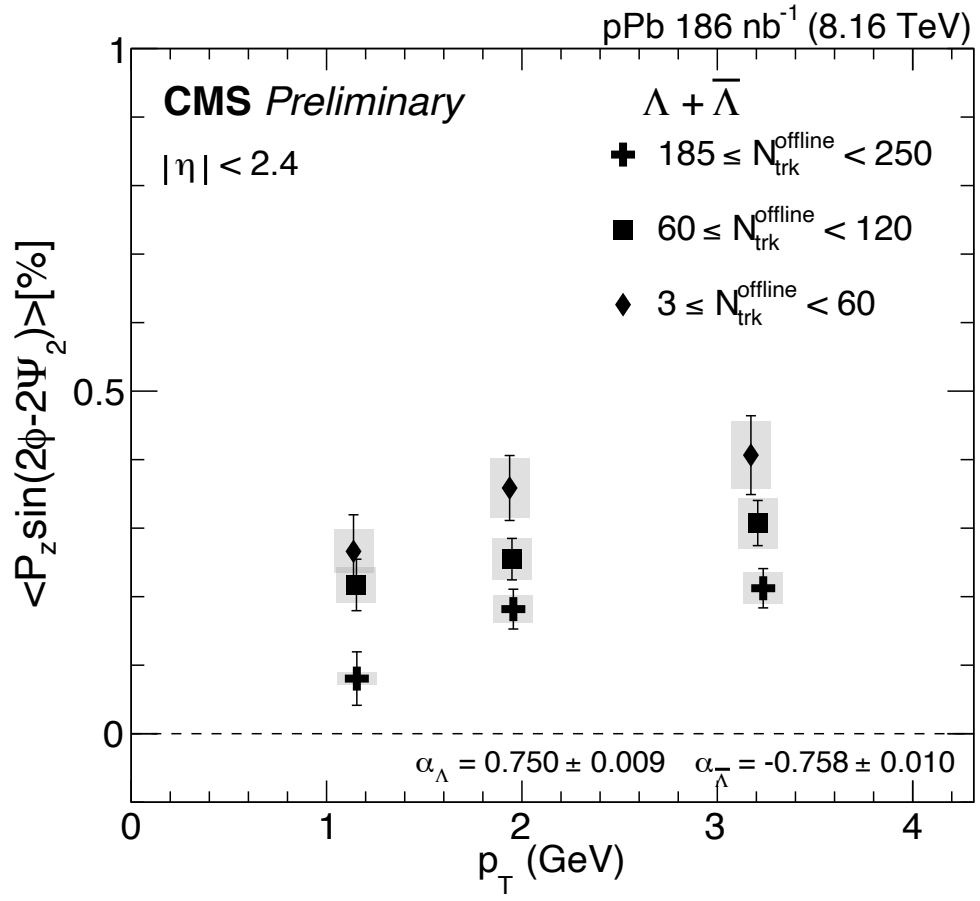
Thanks

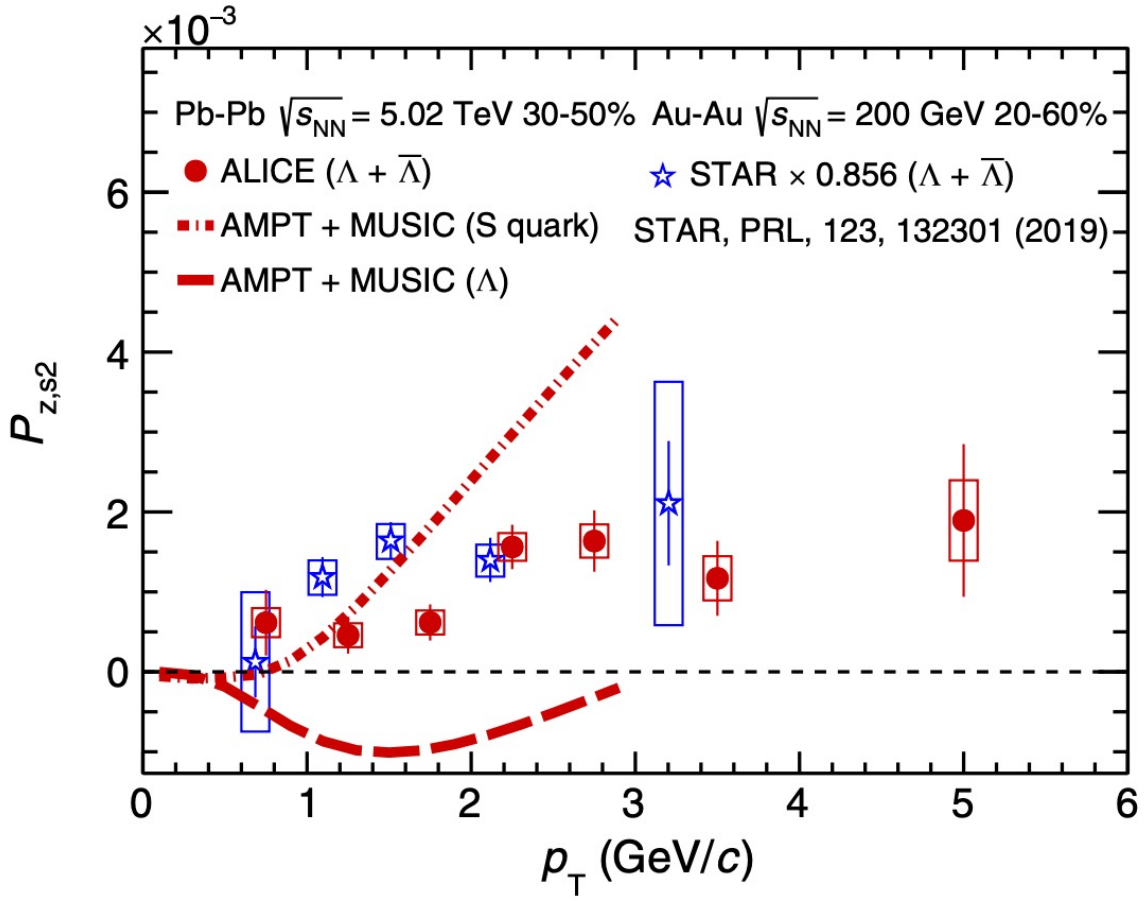
Backup

The number of events:

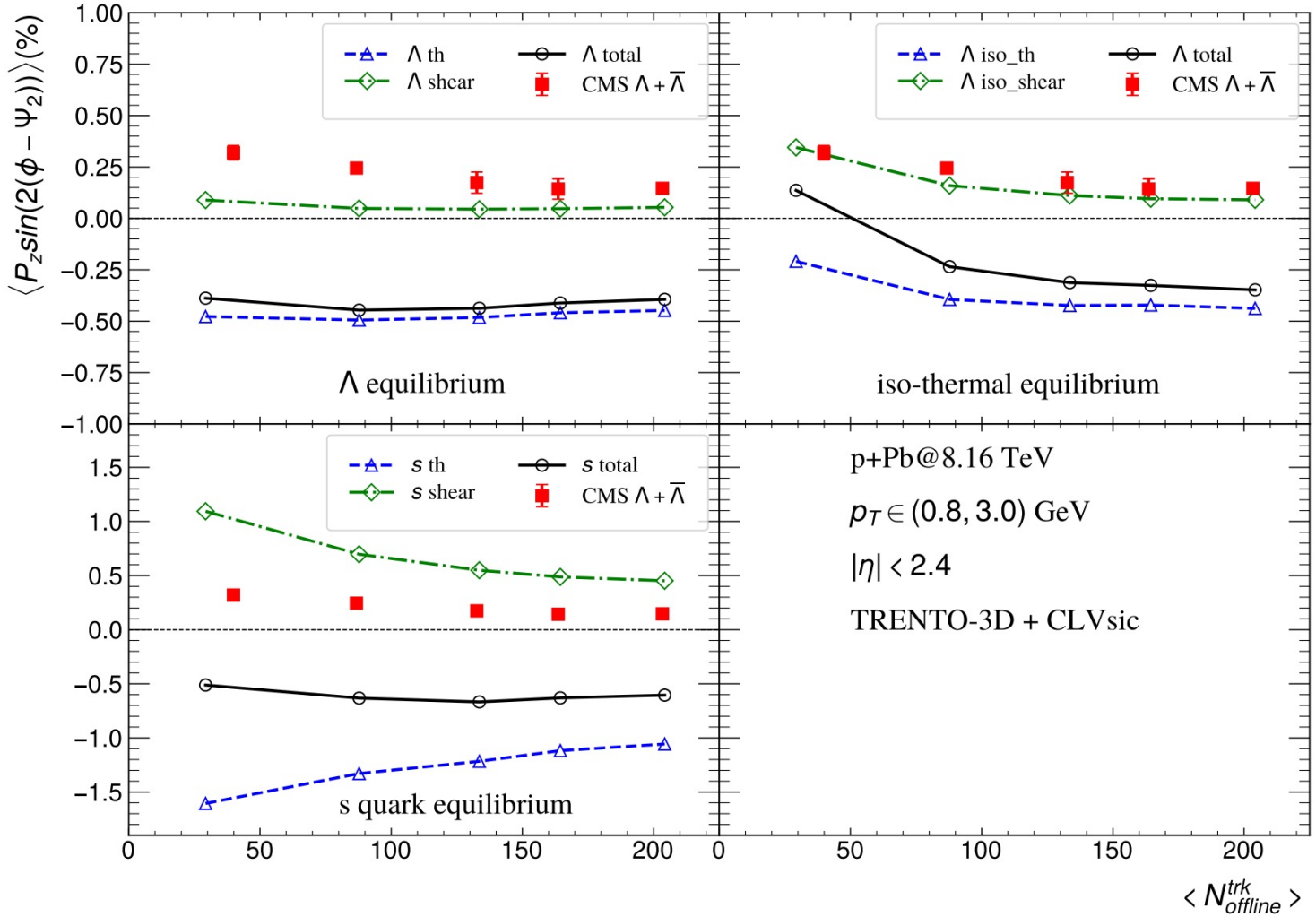
$N_{trk}^{offline}$	3-60	60-120	120-150	150-185	185-250
Events	270M	426M	58M	56M	280M

P_T dependence in pPb and PbPb





More details of hydro calculations in pPb



C. Yi, X.-Y. Wu, J. Zhu, S. Pu and G.-Y. Qin, in preparation

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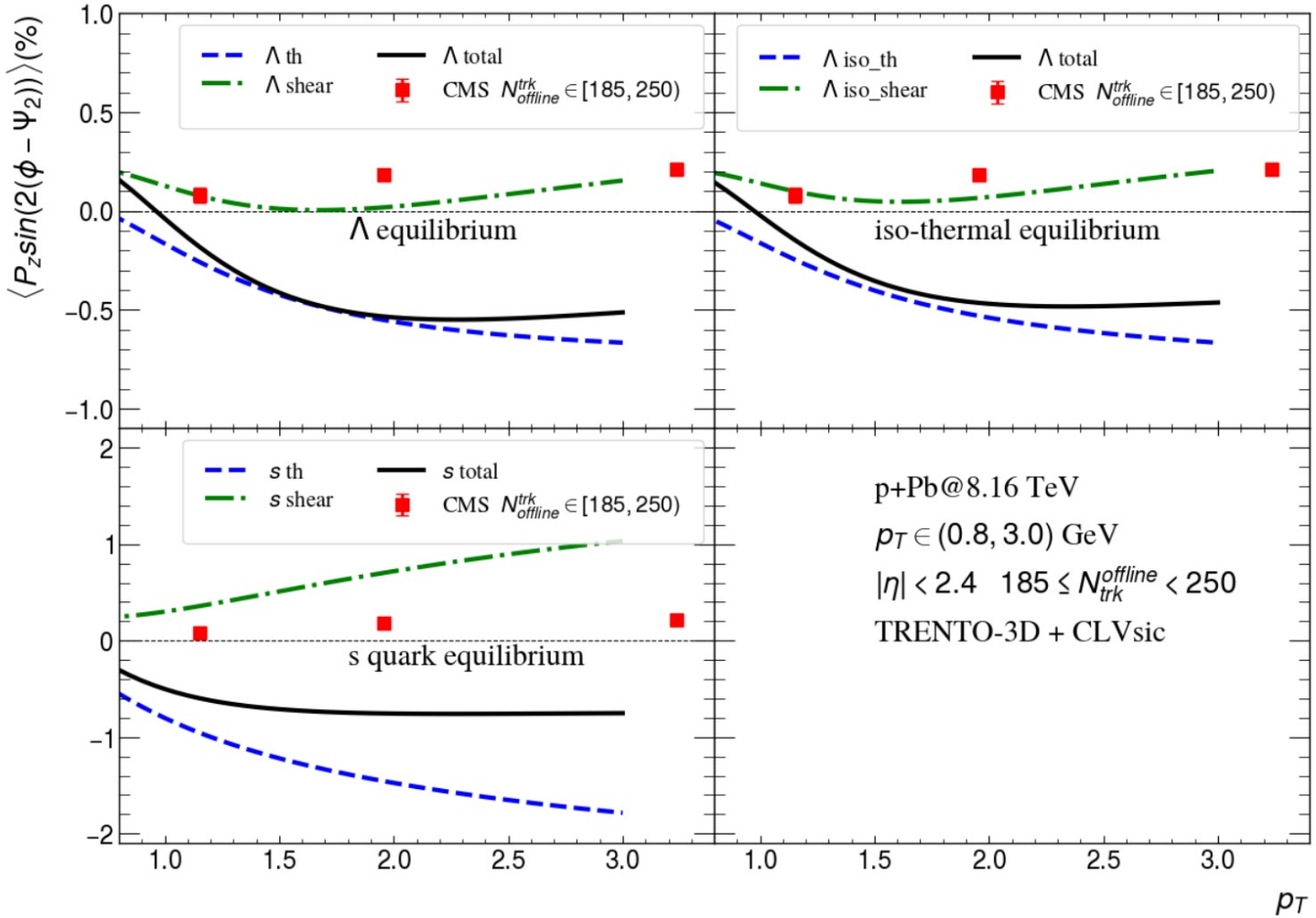

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