

# Exploring the magnetic field in heavy-ion collisions through spin alignment measurements at ALICE



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## Outline:

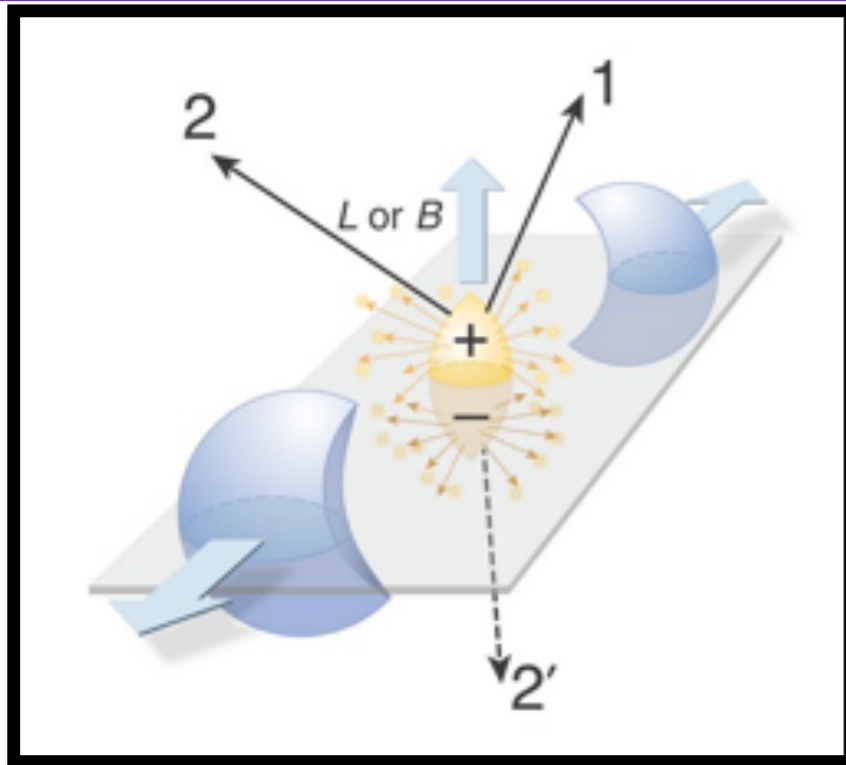
- ❖ Motivation
- ❖ Experimental observable
- ❖ Signal extraction
- ❖ Results
- ❖ Summary and outlook

**IS2021**

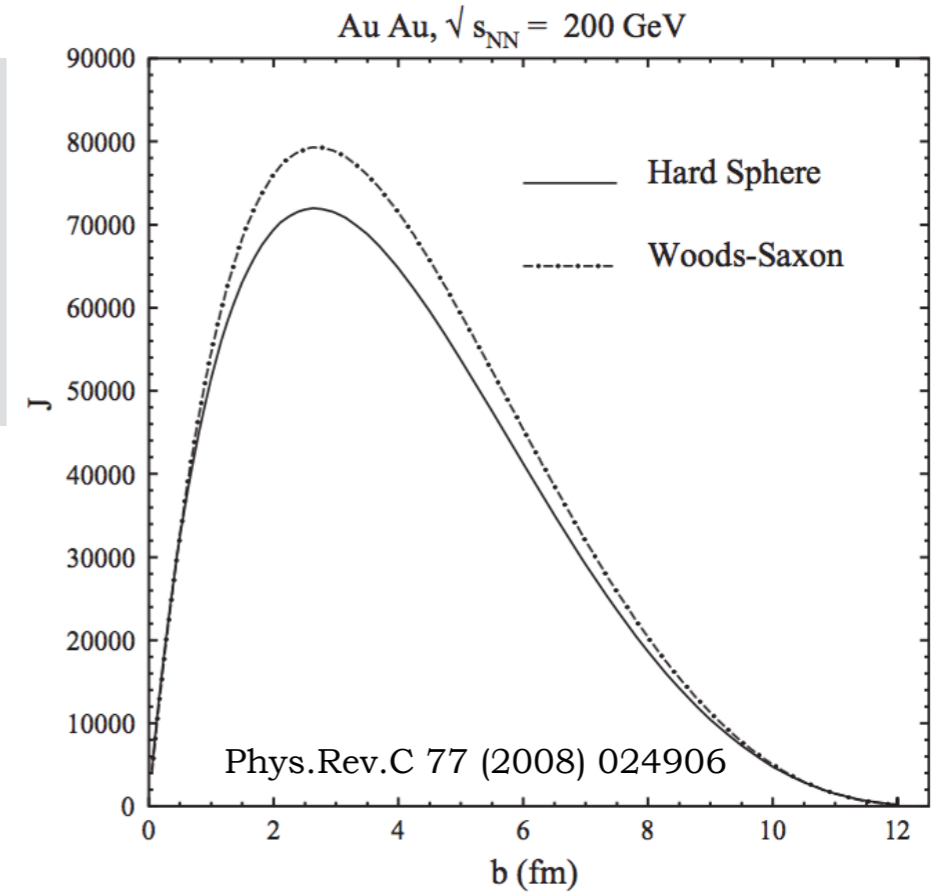
The VI<sup>th</sup> International Conference on the  
**INITIAL STAGES**  
OF HIGH-ENERGY NUCLEAR  
COLLISIONS



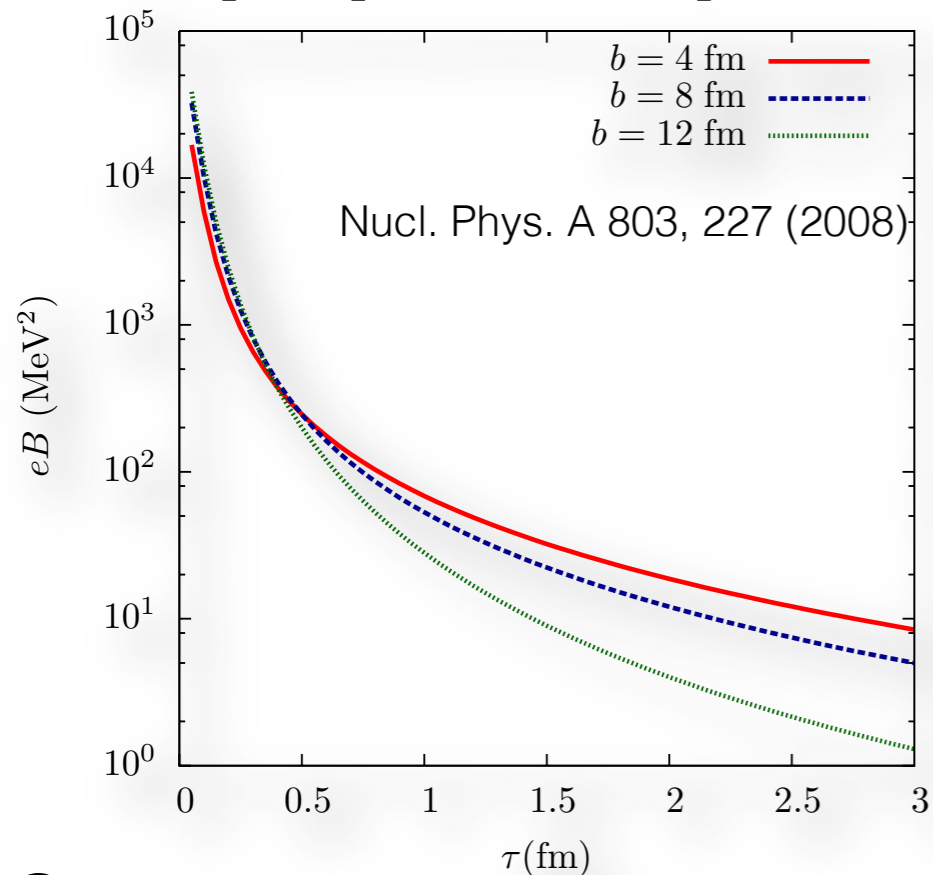
# Heavy-ion collisions and initial state



Reaction plane: Impact parameter and beam axis  
L and B perpendicular to reaction plane



Impact parameter dependence



Large magnetic field

Large angular momentum  
(Conserved quantity)

**Focus of the study is to see the effect of large angular momentum (L) and magnetic field (B) in heavy-ion collisions**

Goal : How can we probe these observables in experiments

$$M_{\pi}^2 \sim 2 \times 10^4 \text{ MeV}^2 \sim 3 \times 10^{14} \text{ Tesla} \sim 3 \times 10^{18} \text{ Gauss}$$

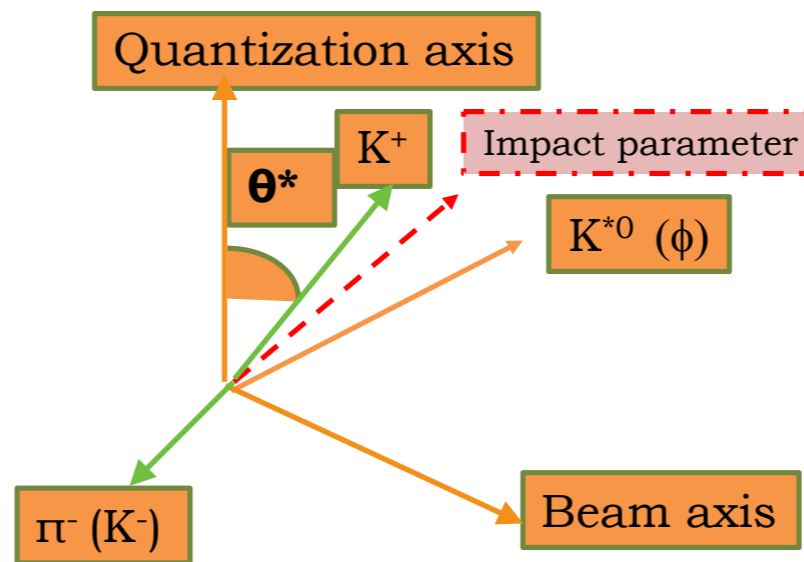
# Angular distribution of vector mesons

$K^{*0}$  Vector meson

- Mass – 896 MeV/c<sup>2</sup>
- Lifetime – 4 fm/c
- Spin 1
- Decays to  $K^+$  and  $\pi^-$  (B.R – 66%)
- Quark content ( $d, \bar{s}$ )

$\phi$  Vector meson

- Mass – 1019 MeV/c<sup>2</sup>
- Lifetime – 42 fm/c
- Spin 1
- Decays to  $K^+$  and  $K^-$  (B.R – 49%)
- Quark content ( $s, \bar{s}$ )



**Quantisation axis:**

- ▶ Normal to the production plane (Momentum of vector meson and beam axis)
- ▶ Normal to the reaction plane (Impact parameter and beam axis)

*K. Schilling et al., Nucl. Phys. B 15 (1970) 397*

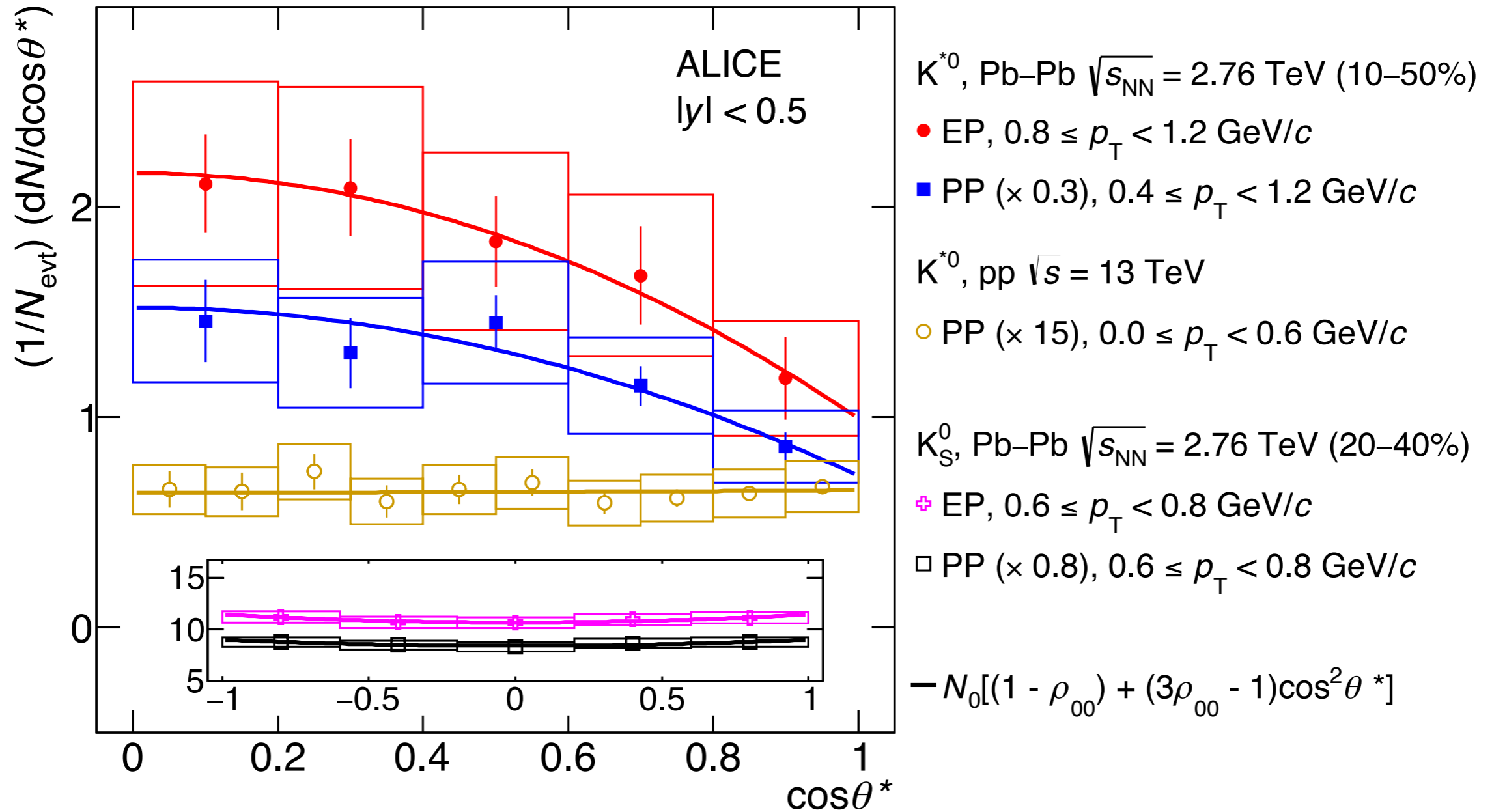
$$\frac{dN}{d\cos\theta^*} = N_0[1 - \rho_{0,0} + \cos^2\theta^*(3\rho_{0,0} - 1)]$$

$\rho_{0,0}$ : Probability that vector meson is in spin state = 0 ,  
Spin density matrix element

$\rho_{0,0} = 1/3 \rightarrow$  No spin alignment

Angular distribution of decay daughters of vector (spin=1) meson gets modified in presence of large angular momentum

# Angular distribution of vector meson and extract $\rho_{00}$



ALI-DER-342820

Here  $N_0$  = normalisation constant and  $\rho_{00}$  is spin density matrix element

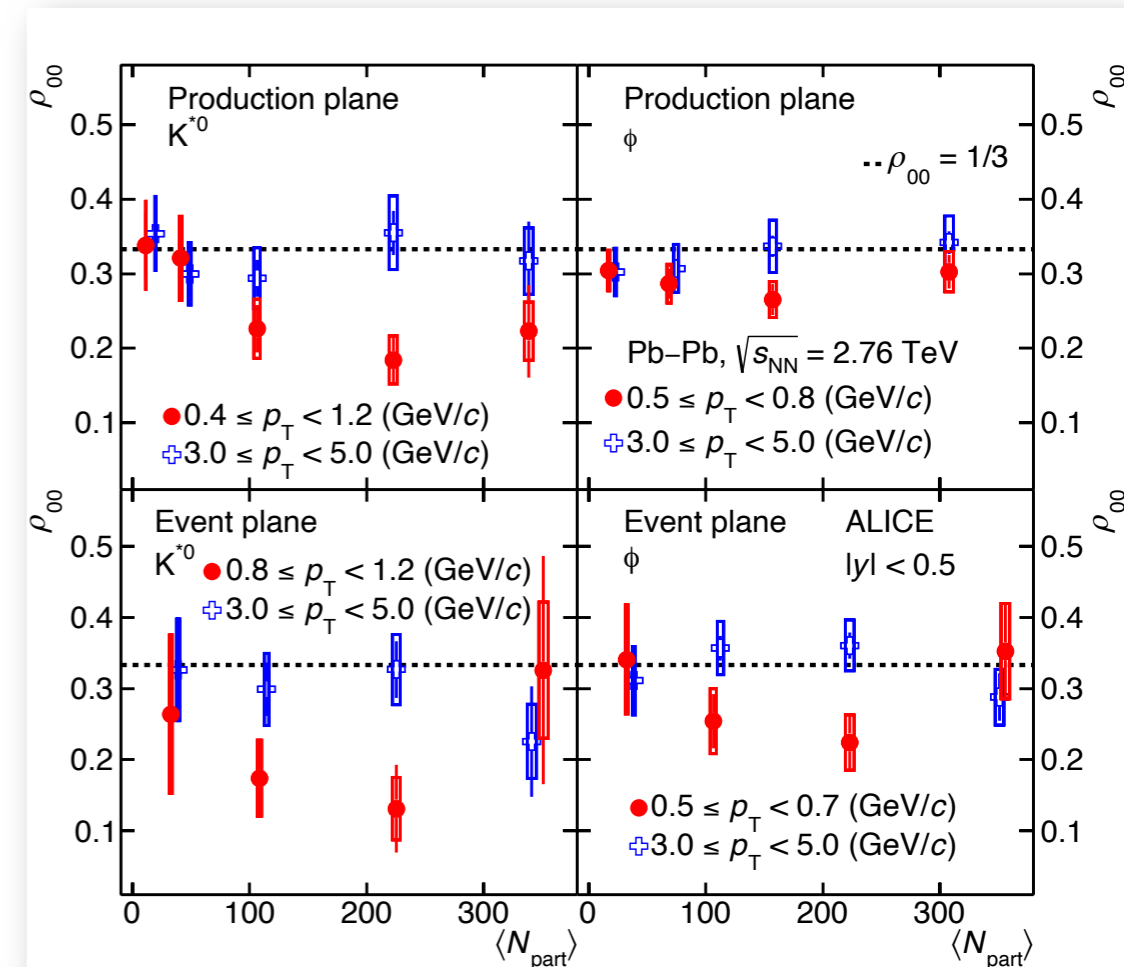
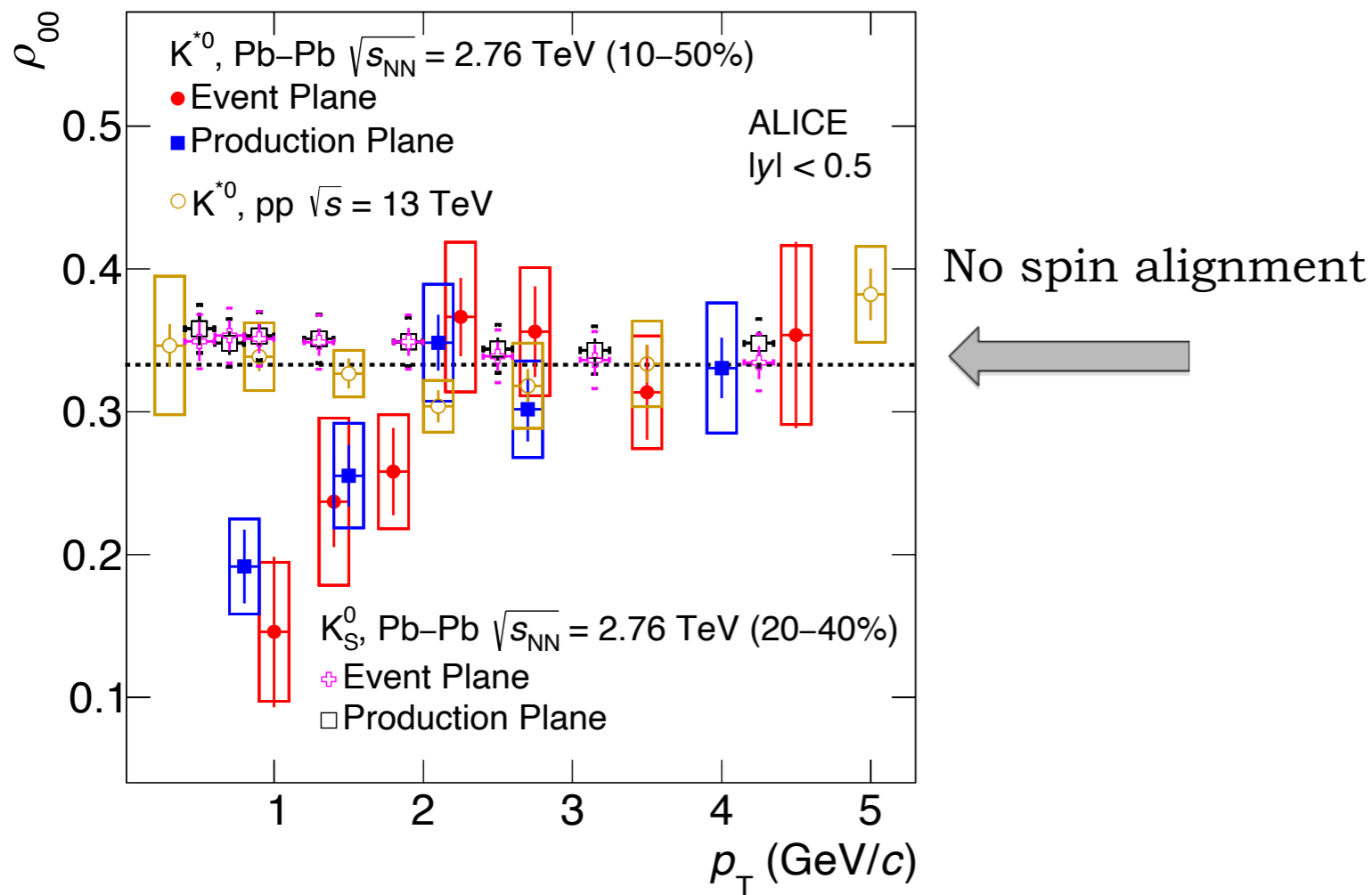
The  $\rho_{00}$  values are obtained for different  $p_T$  bins and centrality bins

# Spin alignment of vector mesons

Phys. Rev. Lett. 125, 012301

## $p_T$ dependence

## Centrality dependence

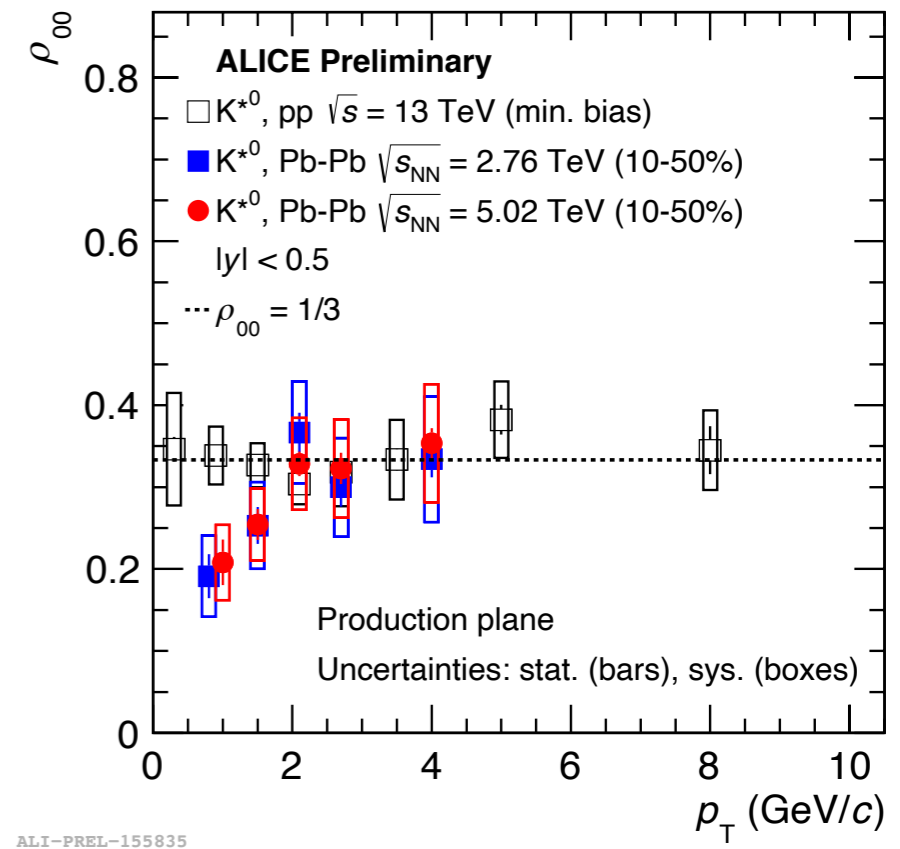


- Spin Alignment ( $\rho_{00} < 1/3$ ) observed for spin 1 particle at low momentum
- No spin alignment ( $\rho_{00} \sim 1/3$ ) observed for spin 0 particle and pp collisions

- Maximum spin alignment observed for mid-central collisions in low  $p_T$  ( $3\sigma$  for  $K^{*0}$  and  $2\sigma$  for  $\phi$ )
- $\rho_{00} \sim 1/3$  for high  $p_T$  vector mesons

# Summary and outlook

- ✓ **First** evidence of spin alignment in vector mesons in high energy heavy-ion collisions with ALICE at the LHC
- ✓ Spin alignment not observed in **proton-proton** collisions
- ✓ Spin alignment not observed for **spin 0** particles in heavy-ion collisions
- ✓ Measurement with **high statistics** Pb-Pb data at 5.02 TeV in progress
- ✓ Measurement of spin alignment with **charged K\*** (magnetic moment larger than neutral K\*) to probe **initial magnetic field effects** in progress



**THANK  
YOU**