Spin alignment measurements using vector mesons with ALICE detector at the LHC

Sourav Kundu (For the ALICE collaboration)

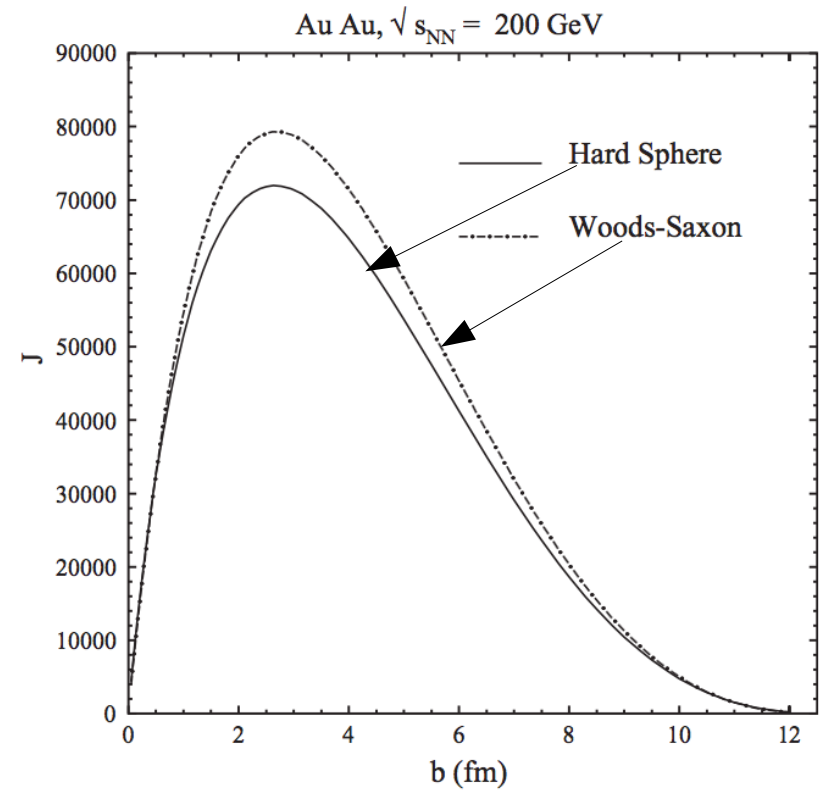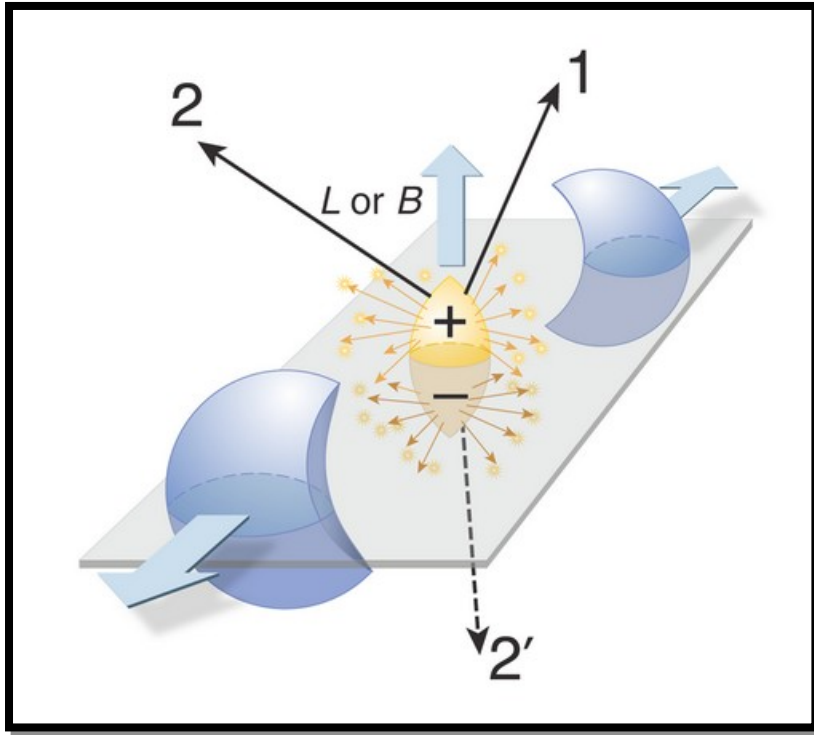National Institute of Science Education and Research, HBNI, Jatni, INDIA

Outline:
- ❖ Physics Motivation
- ❖ ALICE detector setup
- ❖ Results
    - ρ_{00} of K*^{0} w.r.t. Production plane
    - ρ_{00} of K*^{0} w.r.t. Event plane
- ❖ Summary

ICHEP2018 SEOUL
XXXIX INTERNATIONAL CONFERENCE ON *high energy* PHYSICS
JULY 4 - 11, 2018 COEX, SEOUL

Introduction

Au Au, $\sqrt{s_{NN}} = 200$ GeV

Hard Sphere

Woods-Saxon

F. Becattini, F. Piccinini and J. Rizzo
Phys.Rev.C 77, 024906 (2008)

- ✔ Large initial angular momentum is created in non-central heavy-ion collisions

- ✔ Vector mesons (spin=1) can be polarized due to spin-orbit interaction

- ✔ Spin alignment/polarization is a sensitive probe to vortical structure of QGP, and particle production mechanisms

Goal: Look for signature of these in measurements

2

Angular distribution of vector mesons

K*0 Vector meson
- Mass: 896 MeV/c^2
- Lifetime: 1.38×10^{-23} s
- Spin: 1
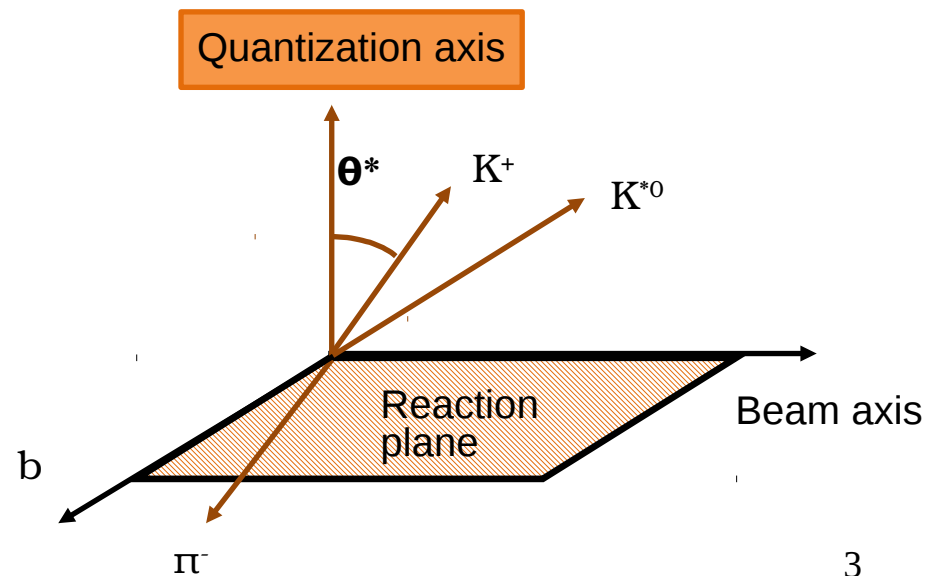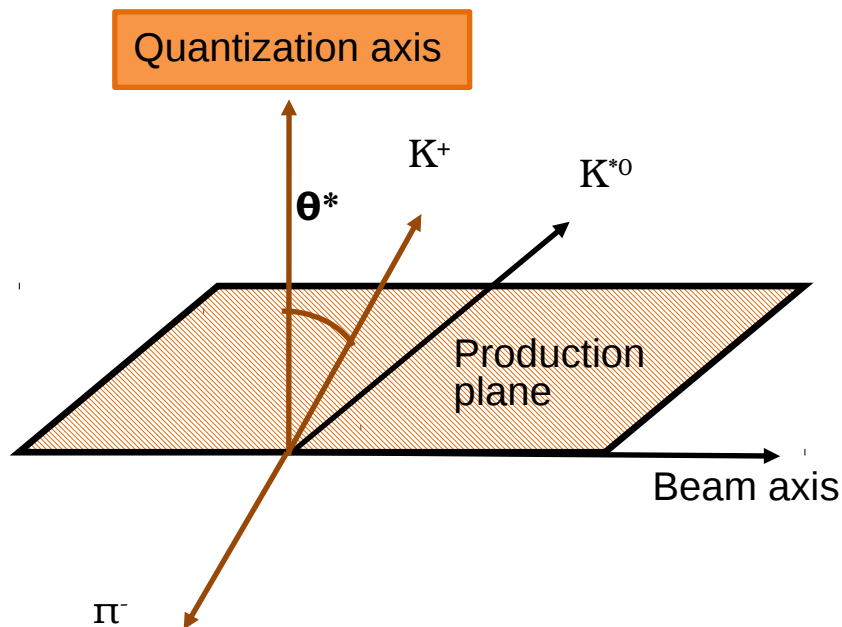- Decays to K^+ and π^- (B.R. ~ 66.6%)
- Quark content (d,sbar)

ρ_{00} = Element of spin density matrix
= 1/3 --> No spin alignment

$$\frac{\mathrm{d}N}{\mathrm{d}\cos\theta^*} = N_0 \left[1 - \rho_{00} + \cos^2\theta^* (3\rho_{00} - 1) \right]$$
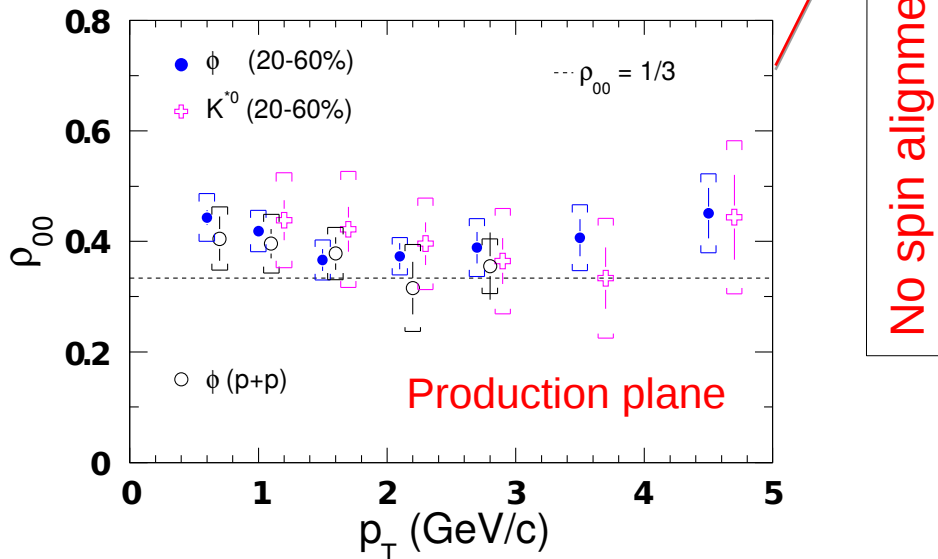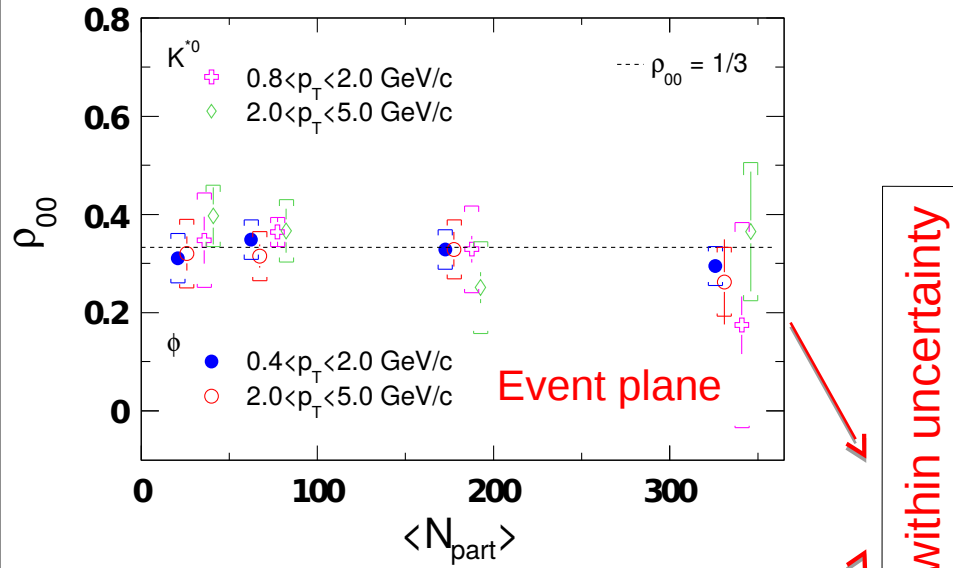
Quantization axis
➢ Normal to production plane
➢ Normal to reaction plane

K. Schilling, P. Seyboth and G. Wolf, Nucl. Phys. B 15, 397 (1970)
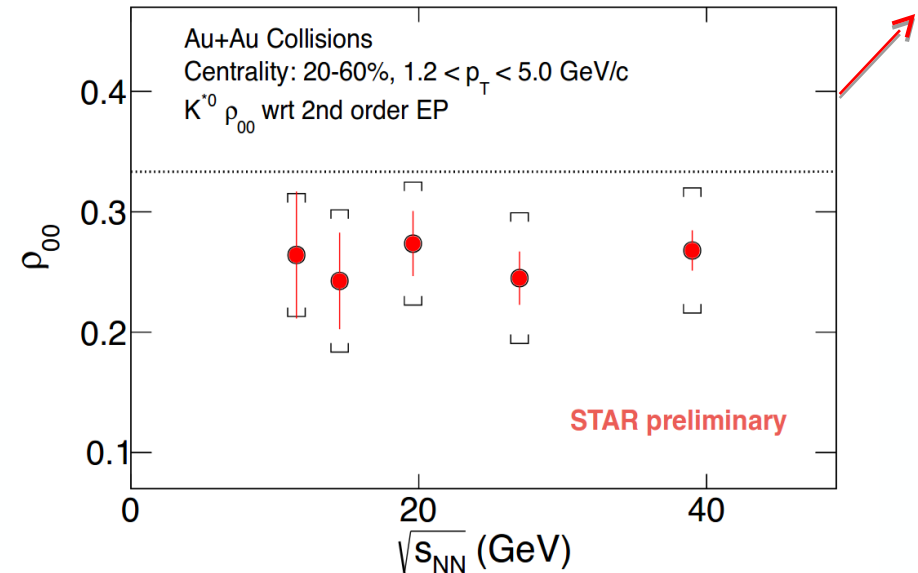

3

spin alignment results at RHIC

Previous STAR measurements

Event plane

Production plane

STAR: Phys.Rev. C77, 061902 (2008)

No spin alignment within uncertainty

Recent STAR measurements (QM2018)

Au+Au Collisions at $\sqrt{s_{NN}}$=39 GeV
Centrality: 20-60 %
K^{*0} ρ_{00} wrt 2nd order EP

STAR preliminary

Au+Au Collisions
Centrality: 20-60%, 1.2 < p_T < 5.0 GeV/c
K^{*0} ρ_{00} wrt 2nd order EP

STAR preliminary
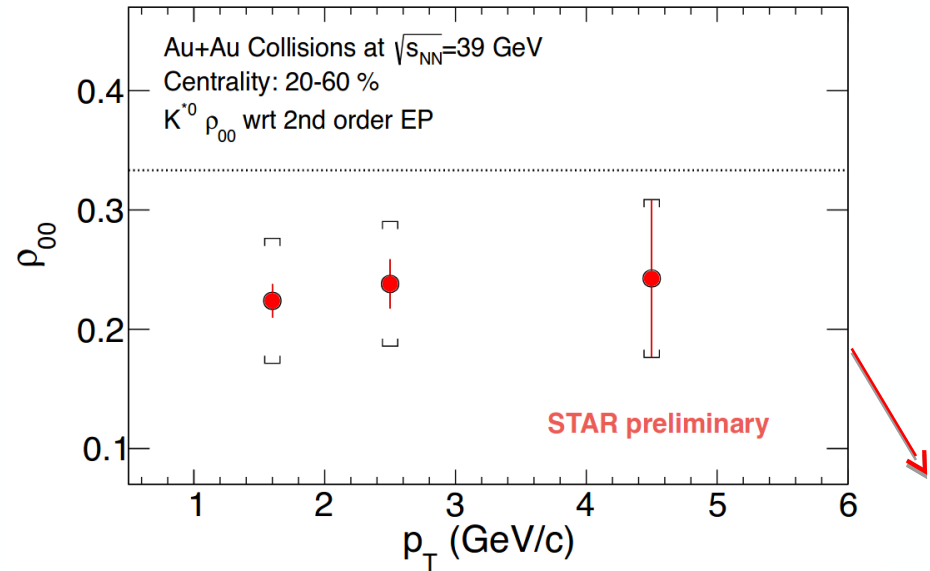
Hint of spin alignment

https://indico.cern.ch/event/656452/contributions/2869774/
attachments/1650217/2638893/chensheng_qm2018.pdf

4

ALICE detector

TPC : $|\eta| < 0.9$ Tracking and particle identification
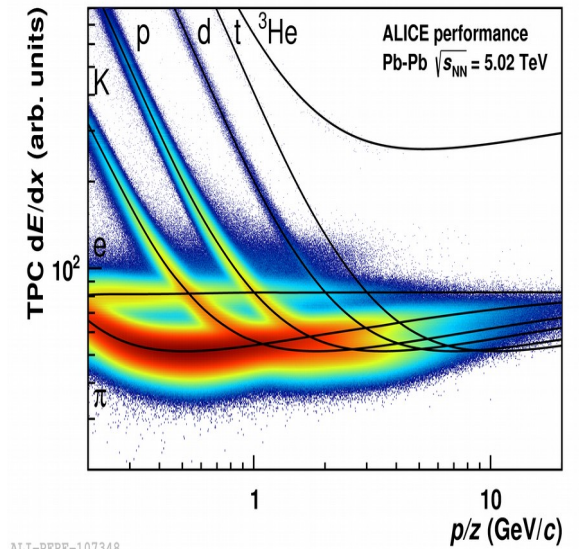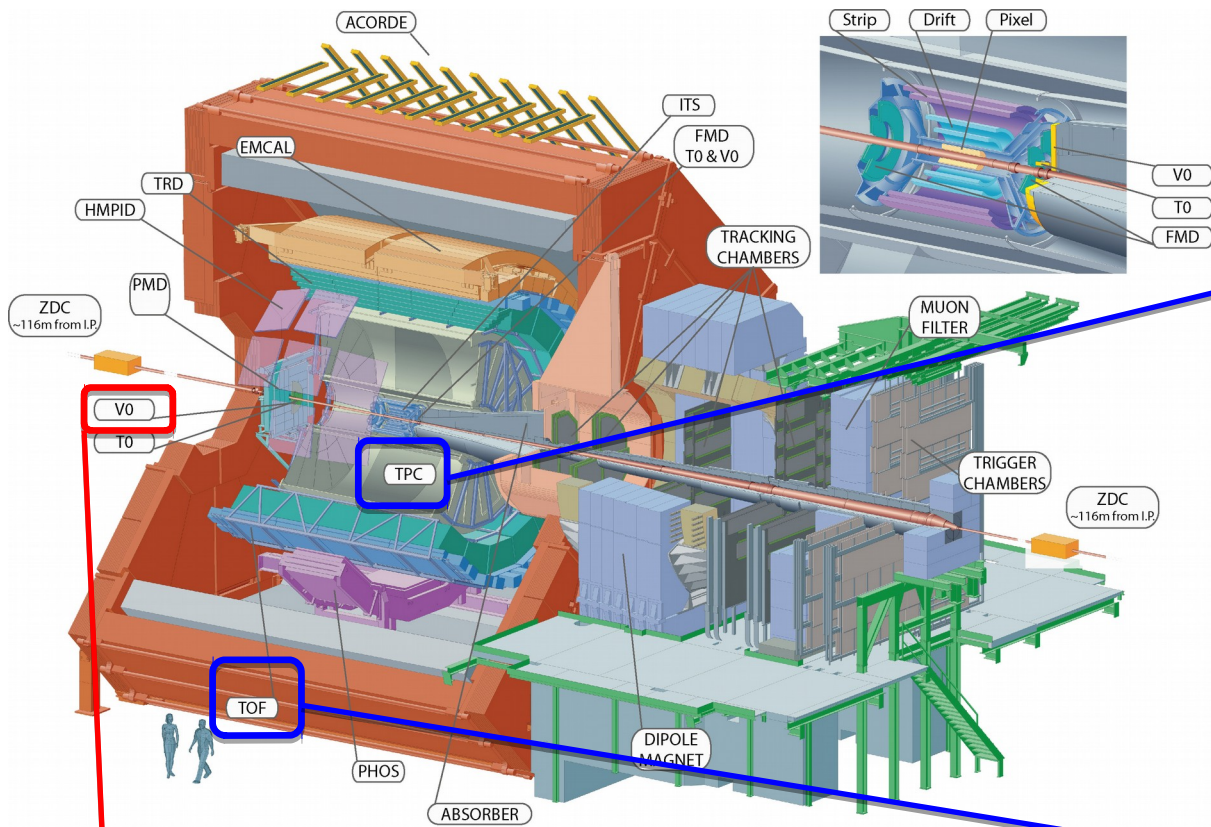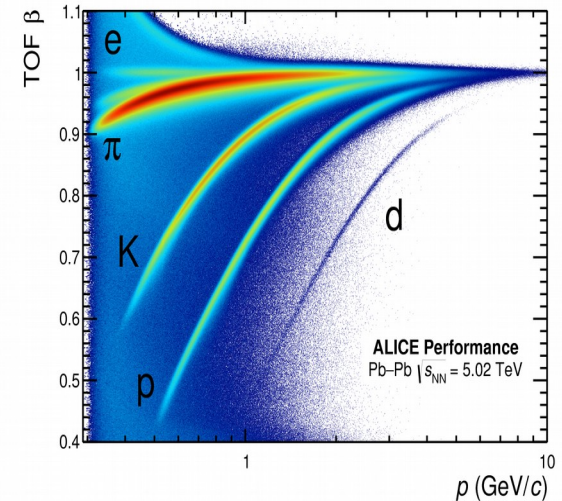
V0 : $-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$
Trigger and event centrality
Event plane estimation

Time of Flight : $|\eta| < 0.9$ Particle identification

Data set

pp collisions

Collision system and energy	pp at 13 TeV, Minimum bias
Rapidity	$|y| < 0.5$
No. of events	~ 43 M
Hadrons	K^{*0}
Background	Mixed events
Efficiency x acceptance	Corrected
Quantization axis	Normal to Production plane

Heavy-ion collisions

Collision system and energy	Pb-Pb at 2.76 and 5.02 TeV
Rapidity	$|y| < 0.5$
No. of events	~ 14 M (2.76 TeV), ~30 M (5.02 TeV)
Collision Centrality	K^{*0}:10-50, 0-10, 10-30, 30-50, 50-70, 70-90 and 50-80%, K^0_S:20-40%
Hadrons	K^{*0} and K^0_S
Background	Mixed events
Efficiency x acceptance	Corrected
Quantization axis	Normal to Production plane and Event plane

Goal: Measure $dN/d\cos\theta^*$ vs. $\cos\theta^*$ and extract ρ_{00} value as a function of p_T and centrality for K^{*0}

Invariant mass reconstruction of K*0 vector meson
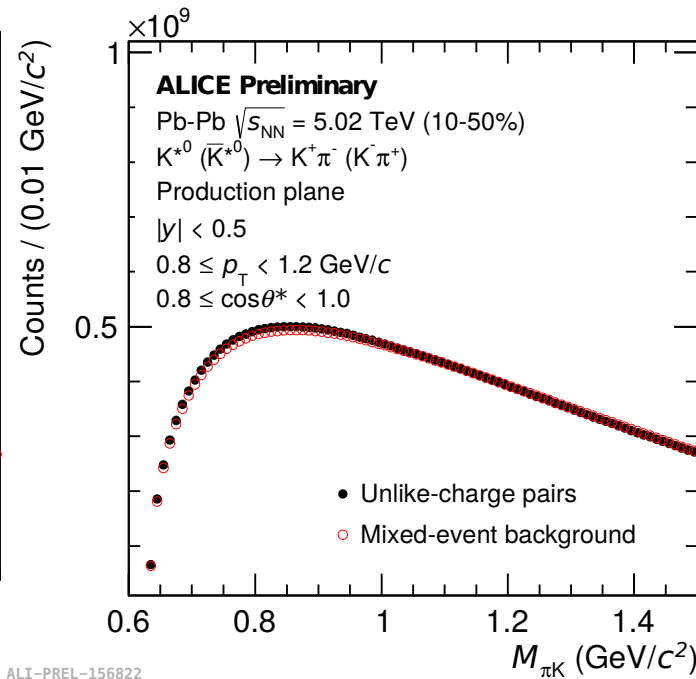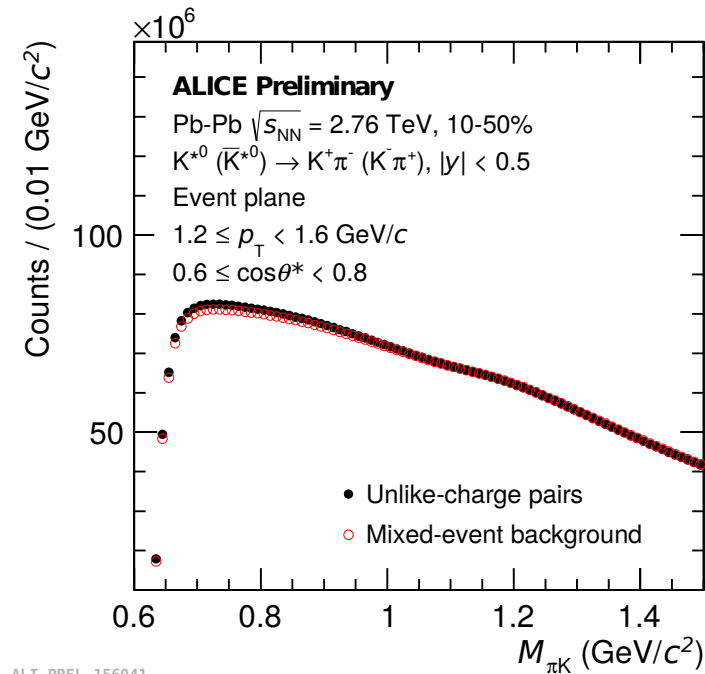
Same event (signal+bkground) and mixed event (bkground) distributions
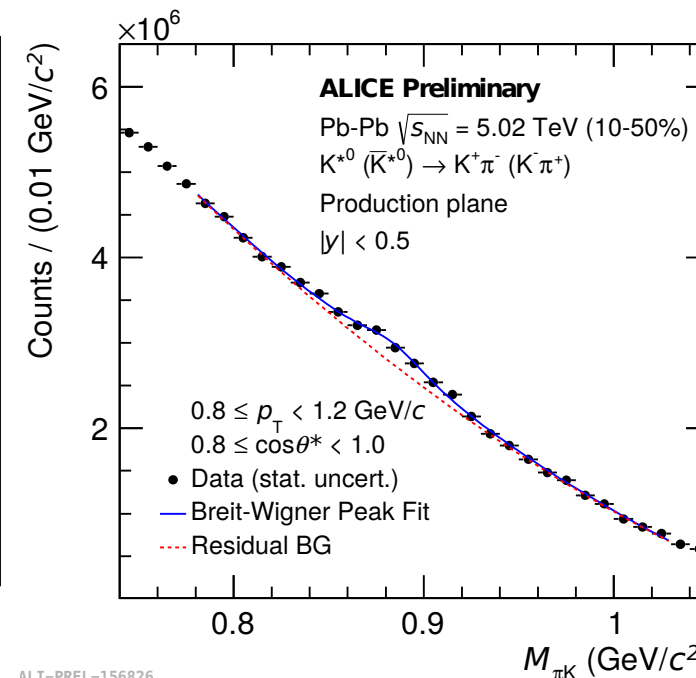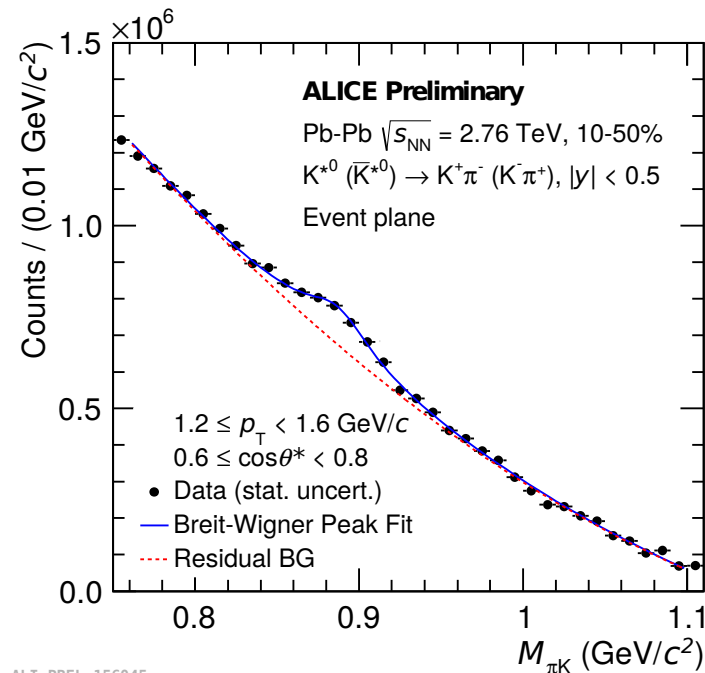
Same event distribution after mixed event background subtraction

Yield is the area under Breit-Wigner distribution

7

Angular distribution

ALICE Preliminary
pp $\sqrt{s}$ = 13 TeV
K^{*0} ($\overline{K}^{*0}$) → $K^+\pi^-$ ($K^-\pi^+$)
$|y| < 0.5$
$1.2 \leq p_T < 1.8$ GeV/c

• Data (stat. uncert.)
--- N_0 [(1 - ρ_{00}) + (3ρ_{00} - 1) $\cos^2\theta^*$]

ALI−PREL−130360

ALICE Preliminary
Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV (10-30%)
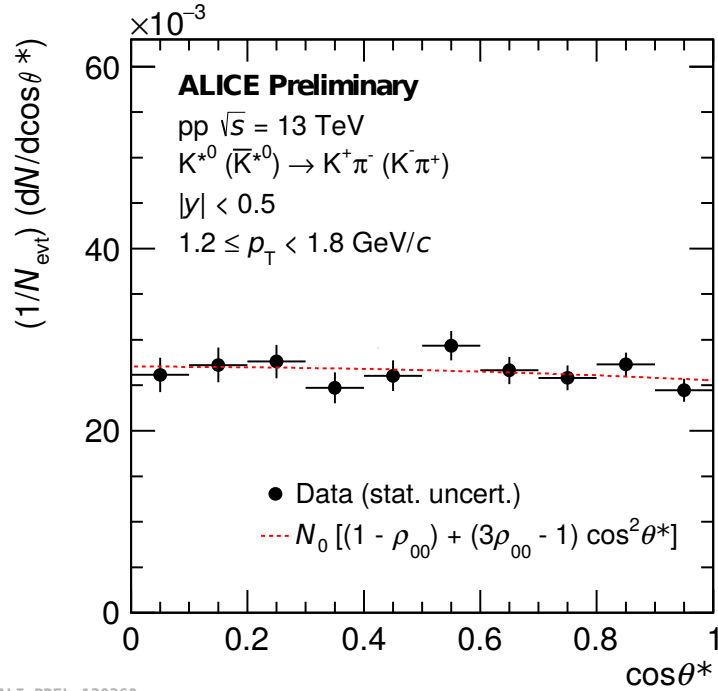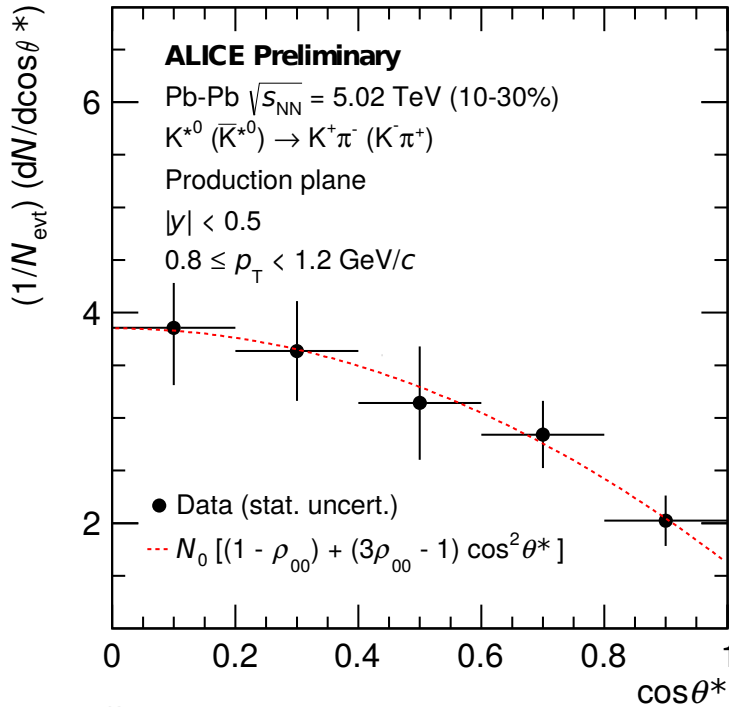K^{*0} ($\overline{K}^{*0}$) → $K^+\pi^-$ ($K^-\pi^+$)
Production plane
$|y| < 0.5$
$0.8 \leq p_T < 1.2$ GeV/c

• Data (stat. uncert.)
--- N_0 [(1 - ρ_{00}) + (3ρ_{00} - 1) $\cos^2\theta^*$]

ALI−PREL−155831

ALICE Preliminary
Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV, 10-30%
K^{*0} ($\overline{K}^{*0}$) → $K^+\pi^-$ ($K^-\pi^+$), $|y| < 0.5$
Event plane
$0.8 \leq p_T < 5$ GeV/c

• Data (stat. uncert.)
--- N_0 [(1 - ρ_{00}) + (1/R)(3ρ_{00} - 1) $\cos^2\theta^*$]
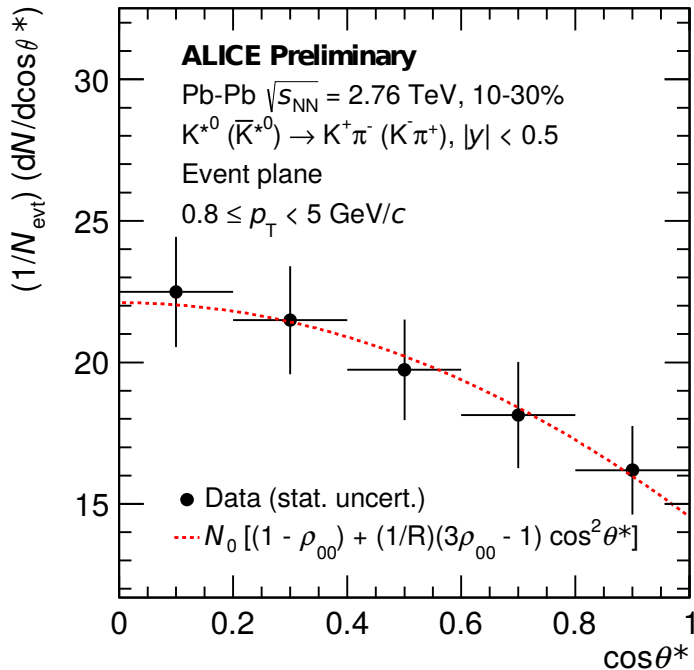
ALI−PREL−156009

Two parameters (N_0 and ρ_{00}) fit to cosθ* distributions measured in different p_T bins

$$\frac{dN}{d\left(\cos\theta^*\right)} = N_0 \times \left[\left(1 - \rho_{00}\right) + \left(1/R\right)\left(3\rho_{00} - 1\right)\cos^2\theta^*\right]$$

R=1 for Production plane measurement

R is the second order event plane resolution for event plane measurement

8

Spin density matrix element (ρ_{00}) vs. p_T : Production Plane

ALICE Preliminary

□ K^{*0}, pp $\sqrt{s}$ = 13 TeV (min. bias)

■ K^{*0}, Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV (10-50%)
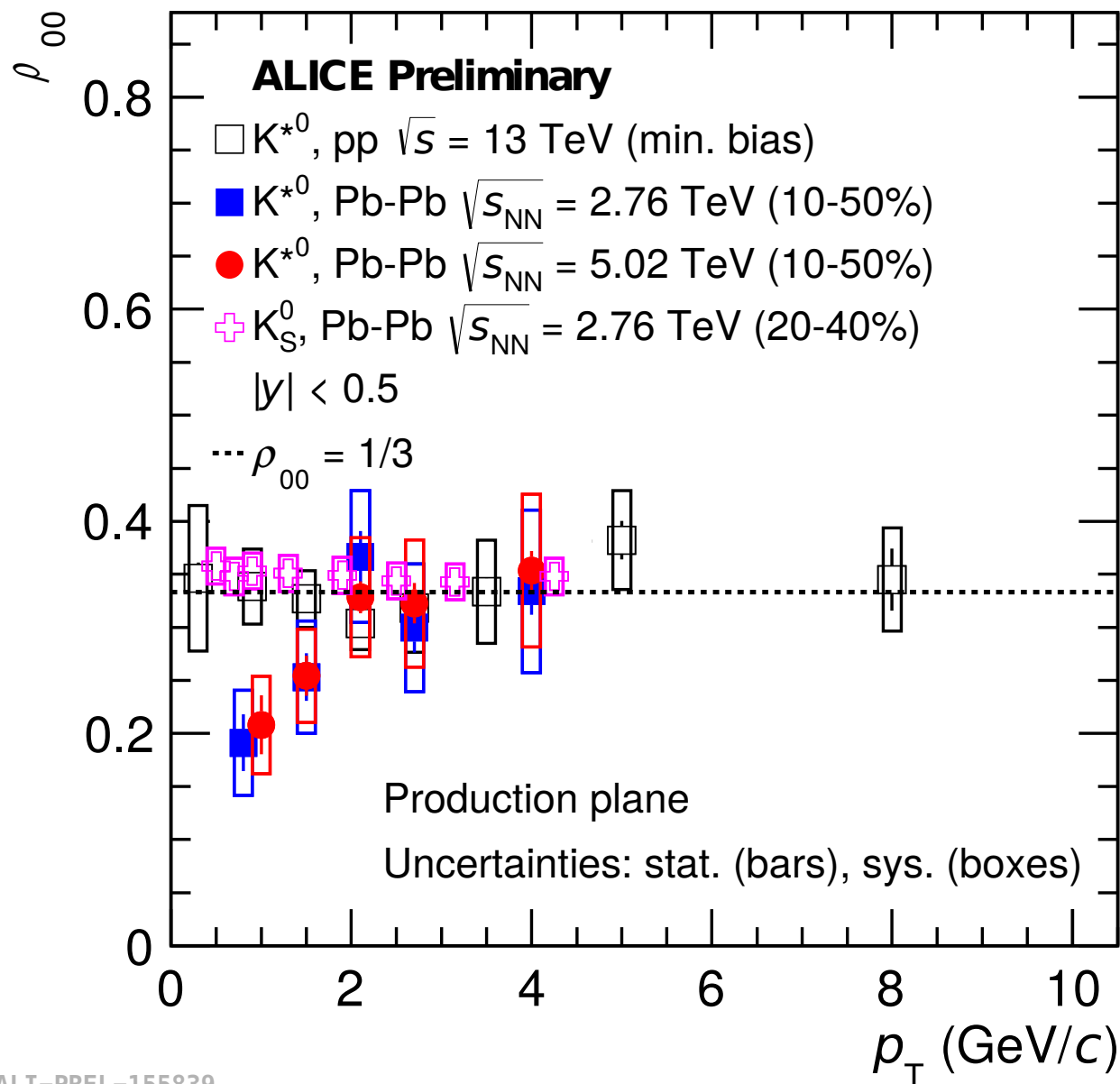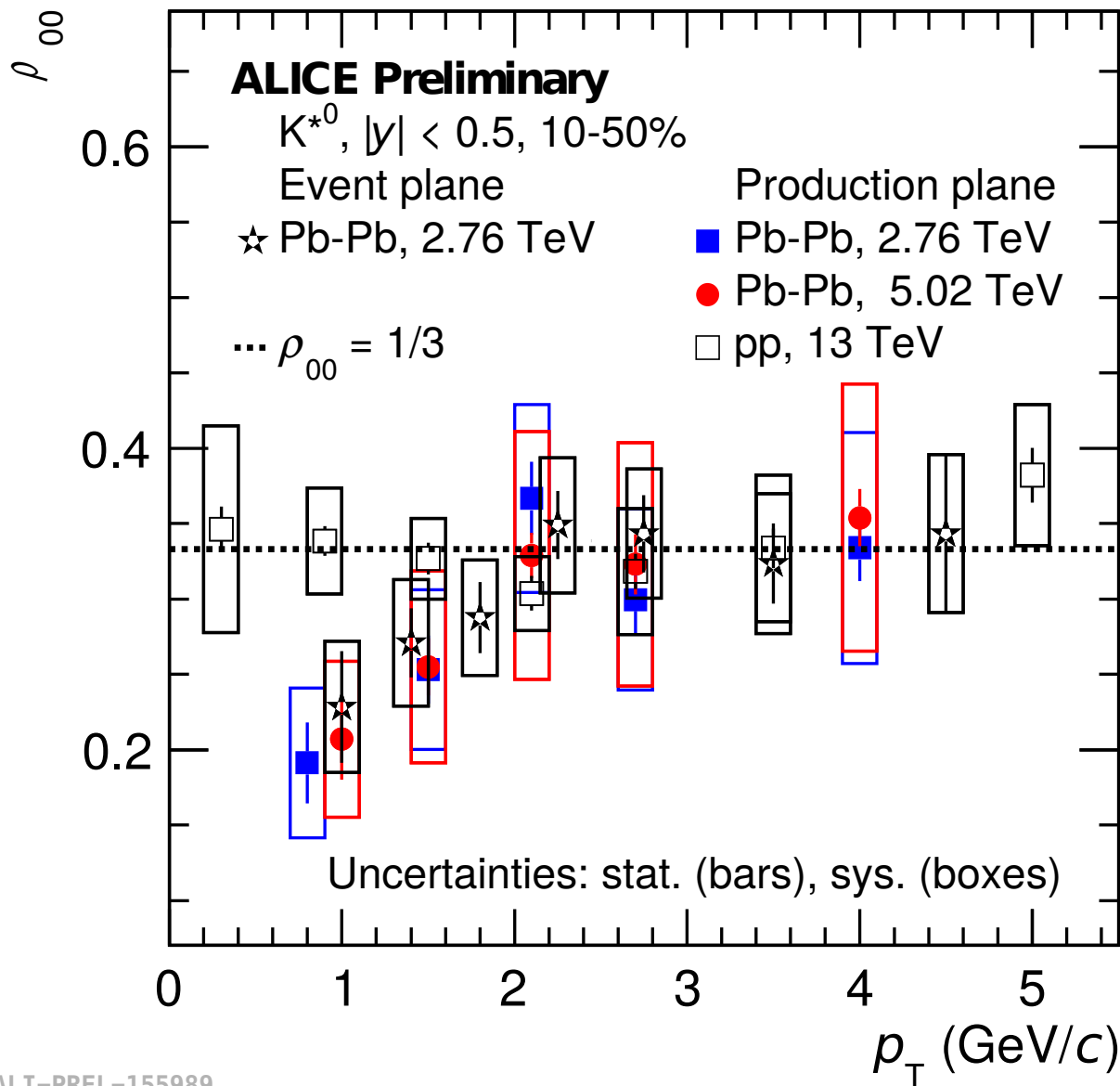
● K^{*0}, Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV (10-50%)

✛ K^0_S, Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV (20-40%)

$|y|$ < 0.5

··· ρ_{00} = 1/3

Production plane

Uncertainties: stat. (bars), sys. (boxes)

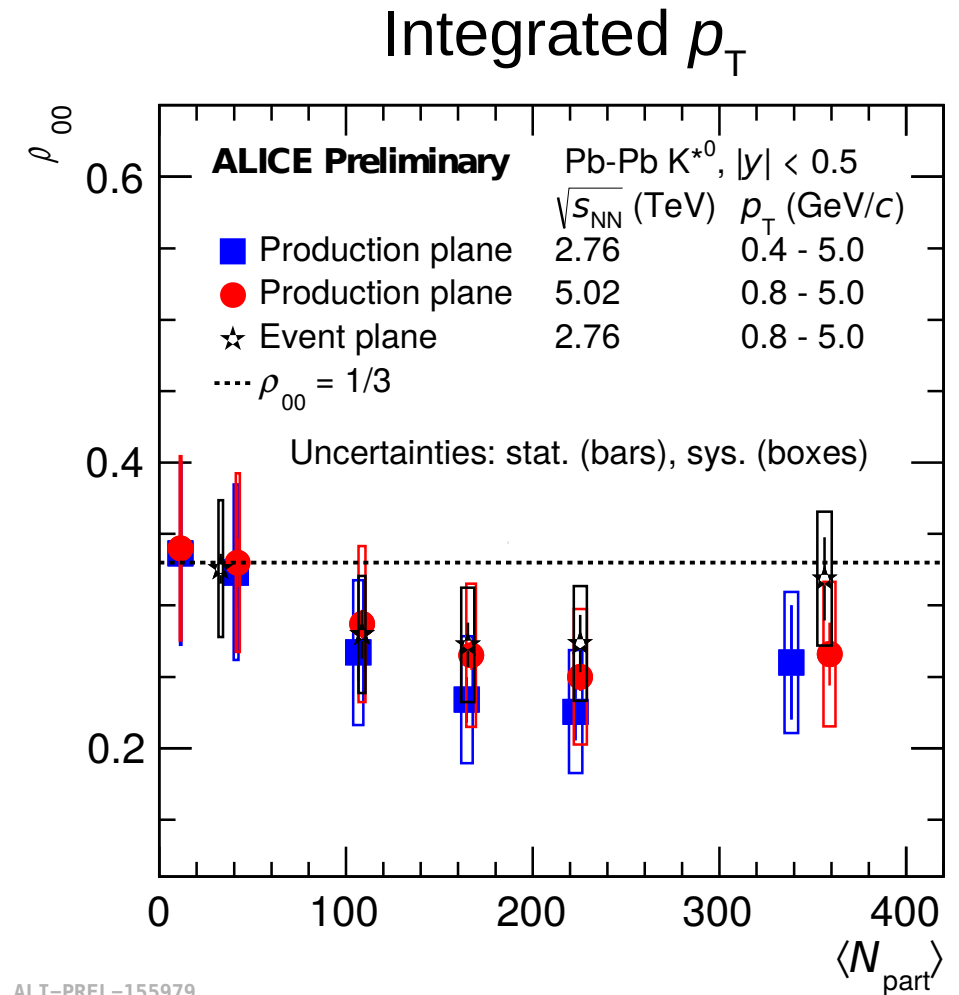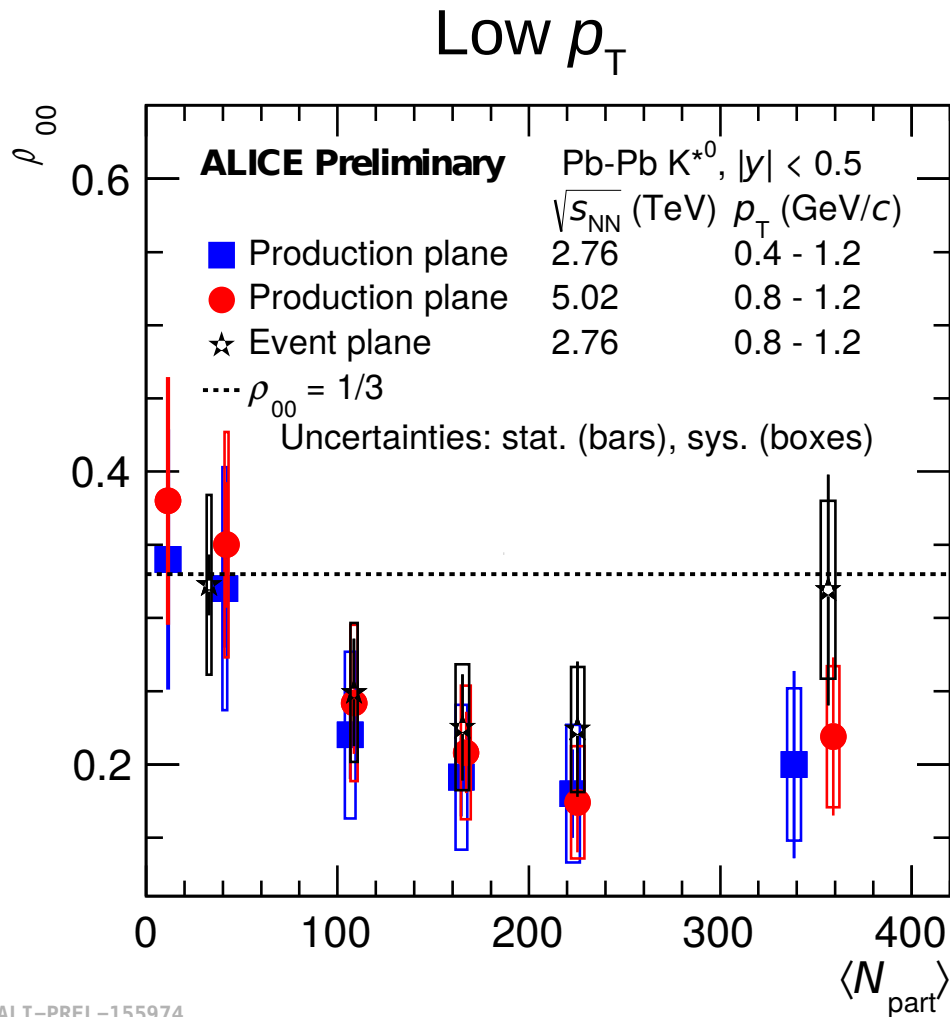- ✔ ρ_{00} = 1/3 in pp collisions for all measured p_T region

- ✔ ρ_{00} = 1/3 in Pb-Pb collisions for p_T > 2 GeV/c

- ✔ ρ_{00} < 1/3 in Pb-Pb collisions for p_T < 2 GeV/c

- ✔ ρ_{00} measurements are consistent in Pb-Pb collisions at 2.76 and 5.02 TeV

- ✔ No spin alignment observed for spin 0 hadron K^0_S

9

Spin density matrix element (ρ_{00}) vs. p_T : Event Plane

Centrality dependence of ρ_{00} : Production plane vs. Event plane

Low p_T

ALICE Preliminary — Pb-Pb K^{*0}, $|y| < 0.5$

	$\sqrt{s_{NN}}$ (TeV)	p_T (GeV/c)
■ Production plane	2.76	0.4 - 1.2
● Production plane	5.02	0.8 - 1.2
☆ Event plane	2.76	0.8 - 1.2
···· $\rho_{00} = 1/3$		

Uncertainties: stat. (bars), sys. (boxes)

ALI−PREL−155974

Integrated p_T

ALICE Preliminary — Pb-Pb K^{*0}, $|y| < 0.5$

	$\sqrt{s_{NN}}$ (TeV)	p_T (GeV/c)
■ Production plane	2.76	0.4 - 5.0
● Production plane	5.02	0.8 - 5.0
☆ Event plane	2.76	0.8 - 5.0
···· $\rho_{00} = 1/3$		

Uncertainties: stat. (bars), sys. (boxes)

ALI−PREL−155979

✔ ρ_{00} shows centrality dependence and maximum deviation from 1/3 for centrality class 10-30%

✔ Similar values of ρ_{00} are observed at both the energies

✔ Within statistical and systematic uncertainties ρ_{00} values are similar in both Production and Event plane method

11

Summary

- $\rho_{00} \sim 1/3$: Spin alignment **not** observed in proton-proton collisions at 13 TeV

- $\rho_{00} \sim 1/3$ (within systematic errors) : Spin alignment **not** observed for K^0_S (spin 0) w.r.t. Production plane in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

- $\rho_{00} < 1/3$ w.r.t. both Event and Production plane in Pb-Pb collisions for $p_T < 2.0$ GeV/c in mid-central collisions

- In 10-30% centrality for first p_T bin, ρ_{00} values about 2.5σ and 3.0σ w.r.t. Production plane at 2.76 and 5.02 TeV respectively, about 1.7σ w.r.t. Event plane at 2.76 TeV. The systematic uncertainties are likely correlated

- ρ_{00} consistent with 1/3 for higher p_T in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ and 5.02 TeV in ALICE @ LHC

- ρ_{00} shows centrality dependence and maximum deviation for mid-central collisions in both Event and Production plane

- ρ_{00} values are similar at both $\sqrt{s_{NN}} = 2.76$ and 5.02 TeV

Outlook
- Spin alignment studies with respect to event plane in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
- Spin alignment studies for ϕ meson

12

THANK YOU

Back Up