Spin alignment measurements of K^{*0} vector mesons with ALICE detector at the LHC

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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

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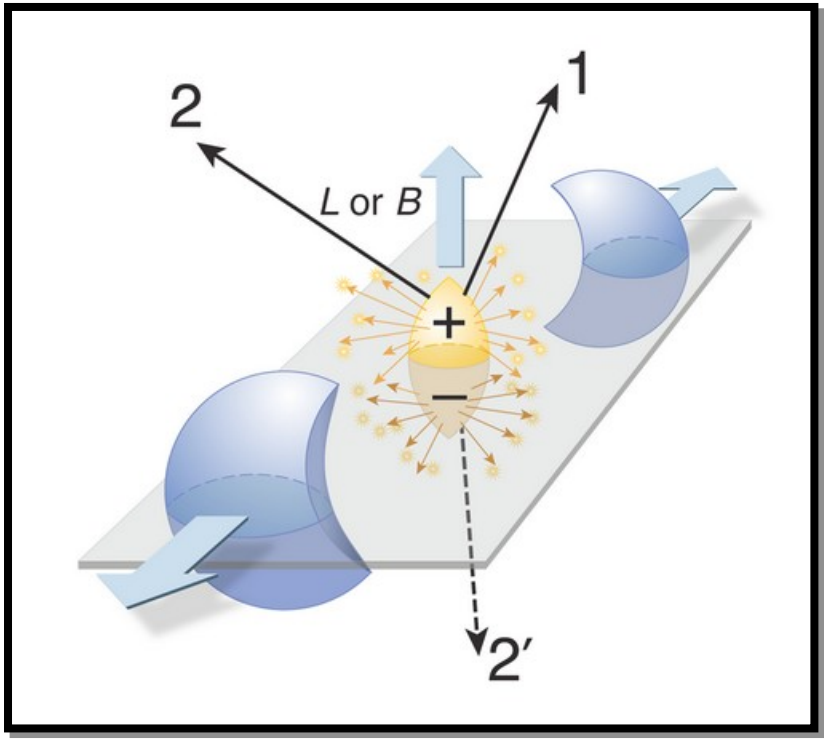
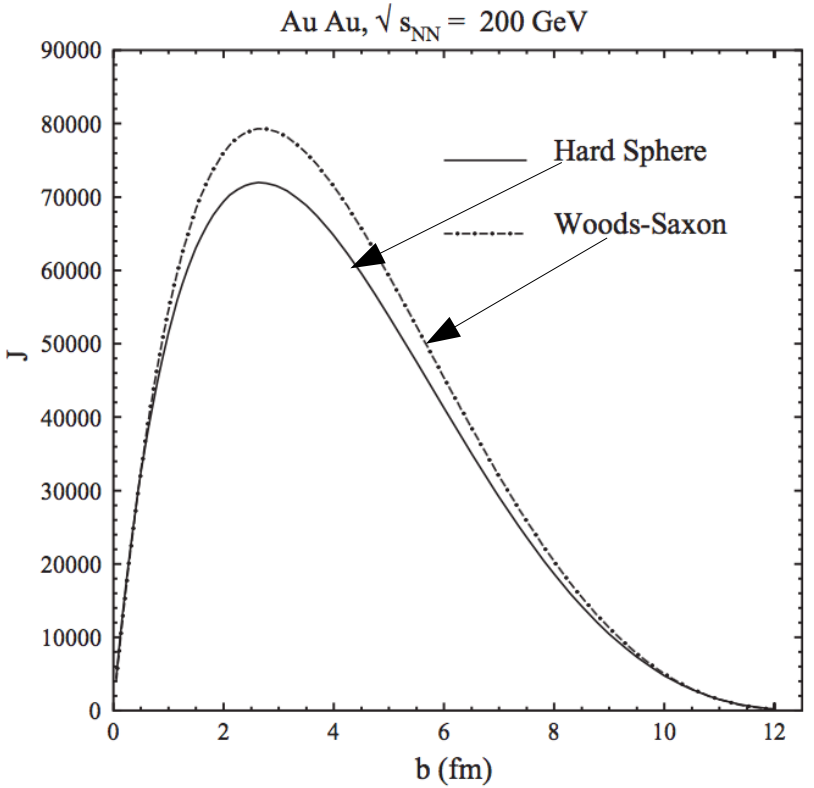
Introduction





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 experiments

Angular distribution of vector mesons

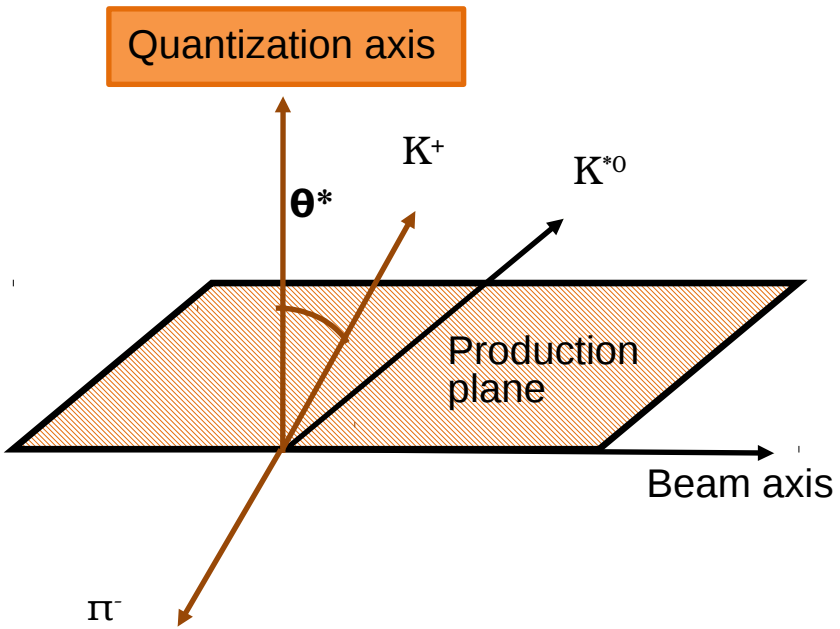
K^{*0} ($\overline{K^{*0}}$) Vector meson
- Mass: 896 MeV/c^2
- Lifetime: 1.38×10^{-23} s
- Spin: 1
- Decays to K^+ (K^-)+ π^- (π^+) (B.R. ~ 66.6%)
- Quark content (d(dbar),sbar(s))

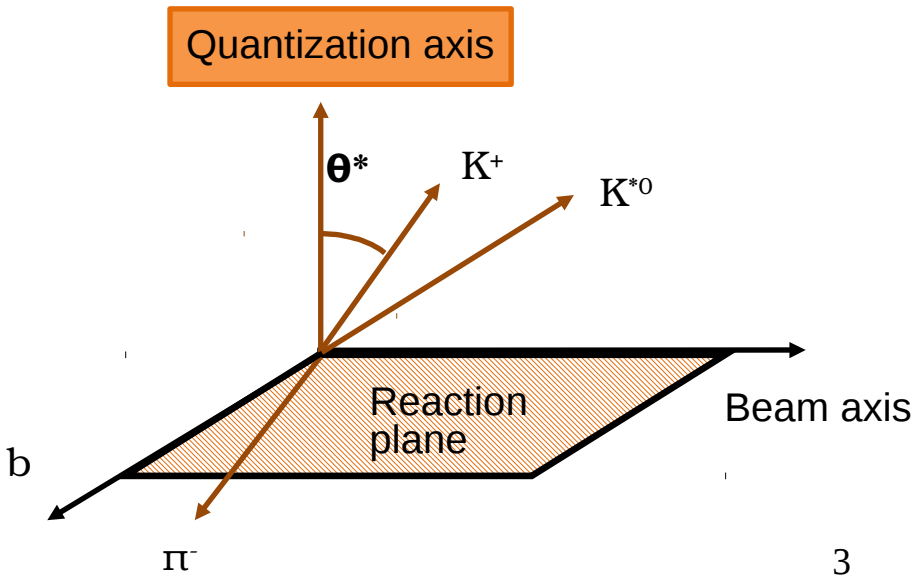
ρ_{00} = Element of spin density matrix
= 1/3 --> No spin alignment

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

Quantization axis
- Normal to production plane
- Normal to reaction plane

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





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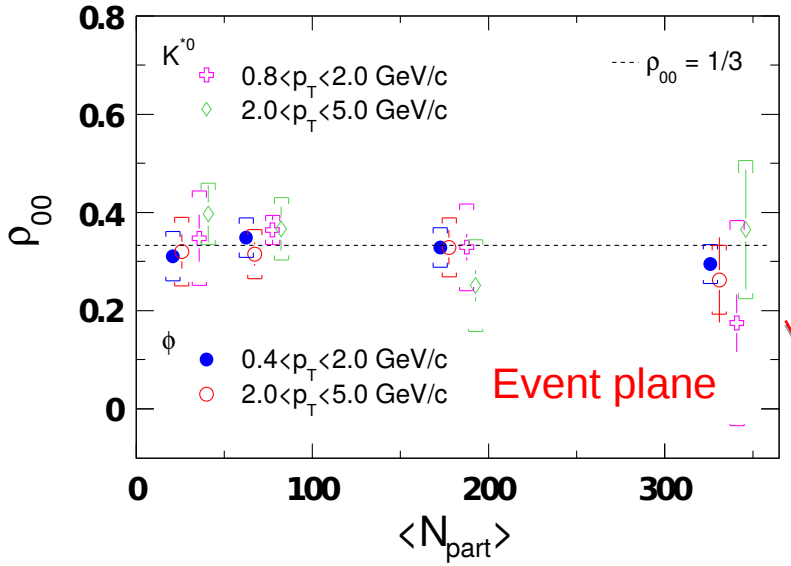
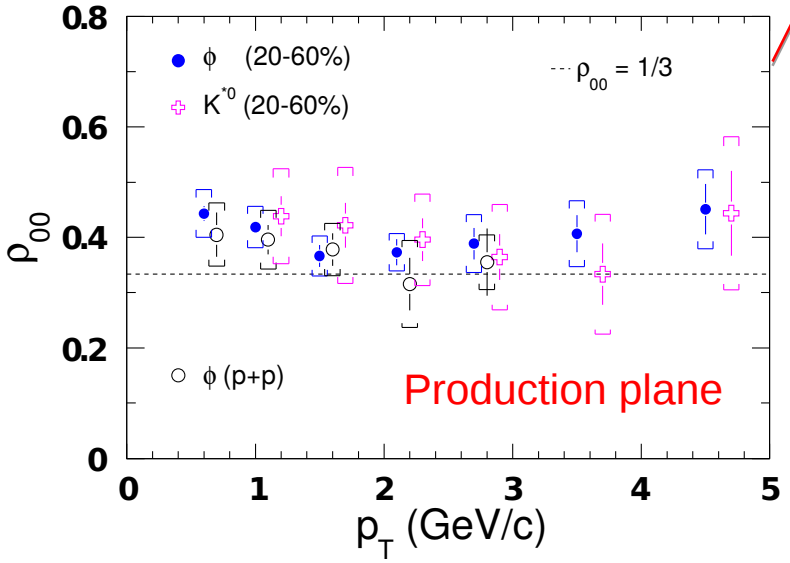
spin alignment results at RHIC

Previous STAR measurements

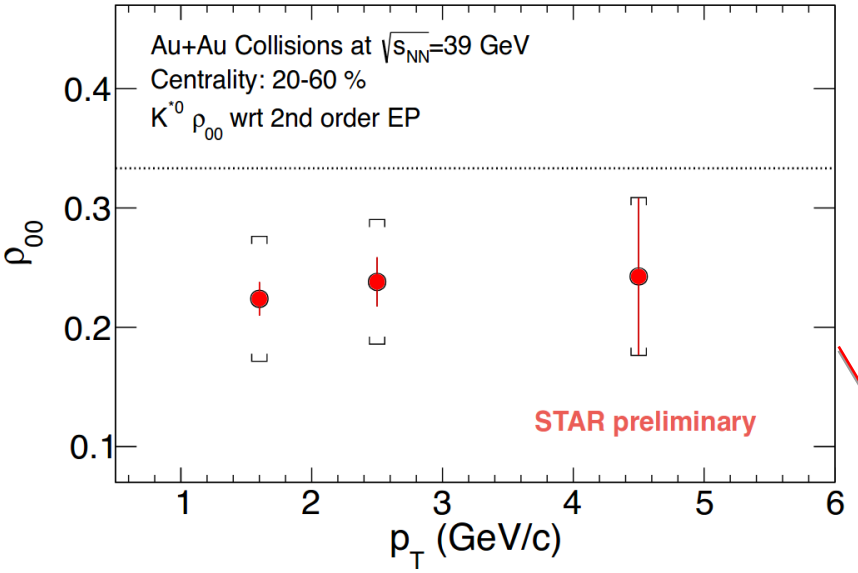


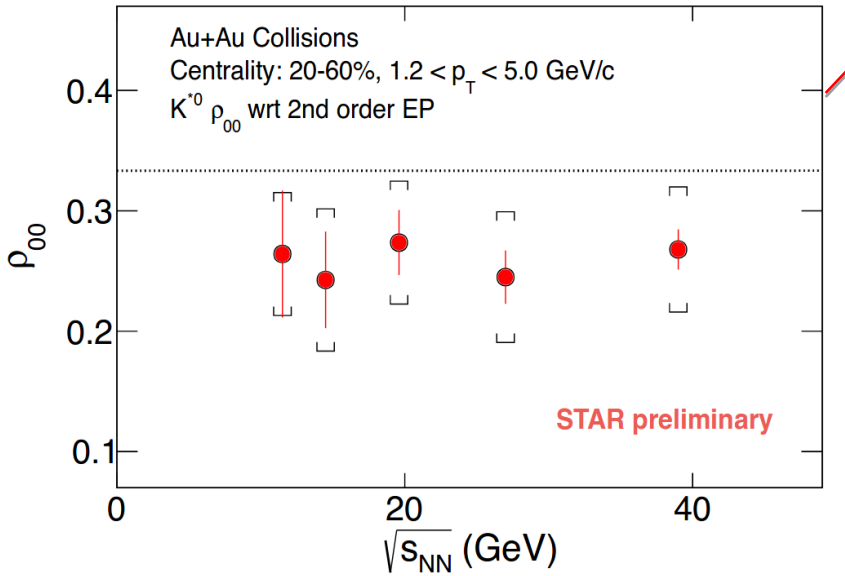


No spin alignment within uncertainty

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

Recent STAR measurements (QM2018)

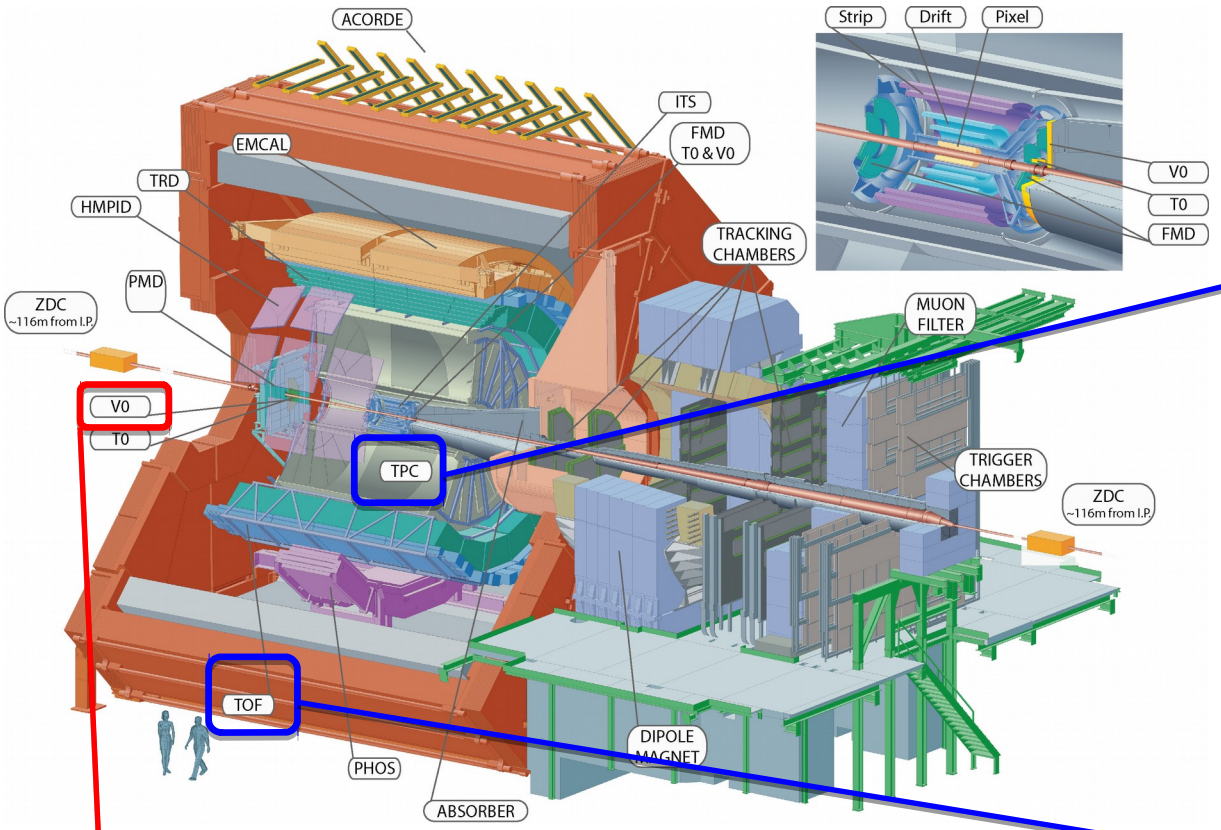


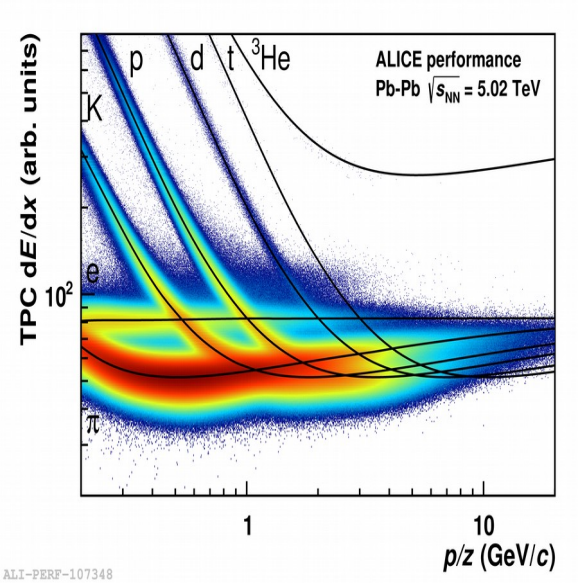


Hint of spin alignment

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

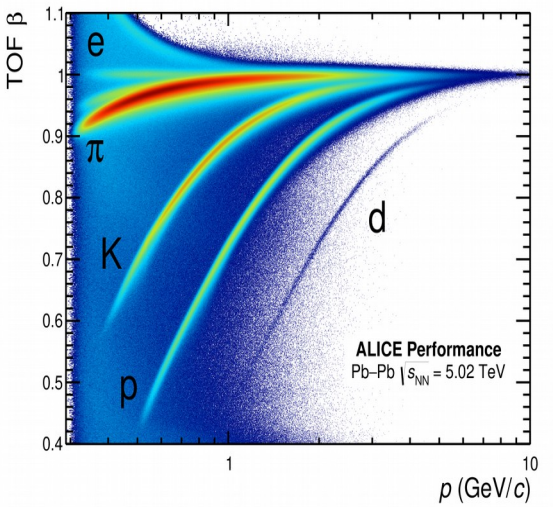
ALICE detector





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

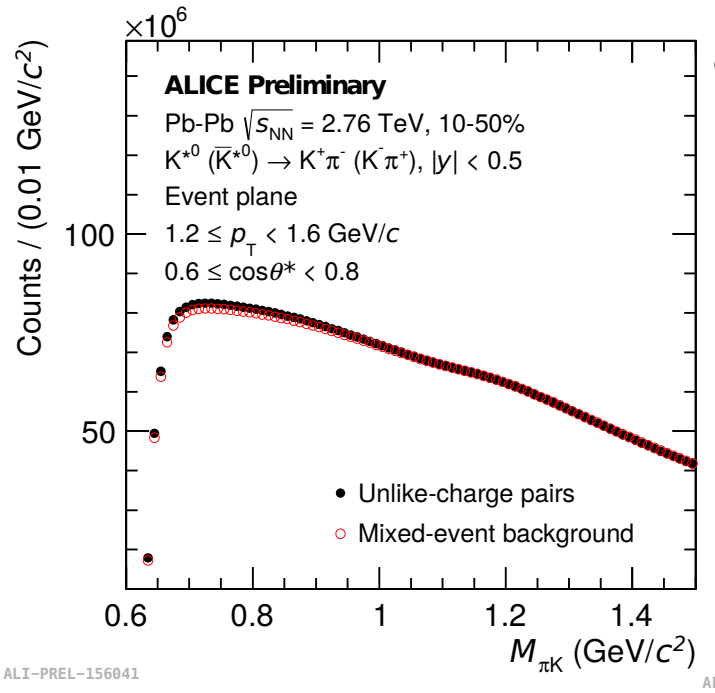
Collision system and energy	pp at 13 TeV, Minimum bias
Rapidity	$\|y\| < 0.5$
No. of events	~ 43 M
Hadrons	K^{*0}
Background	Mixed event technique
Efficiency x acceptance	Corrected
Quantization axis	Normal to production plane

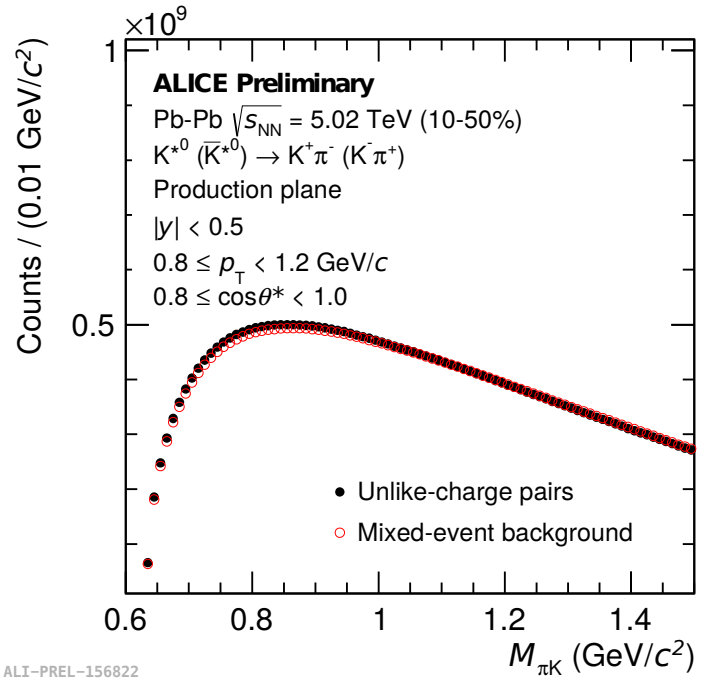
Heavy-ion collisions

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 event technique
Efficiency x acceptance	Corrected
Quantization axis	Normal to production plane and event plane

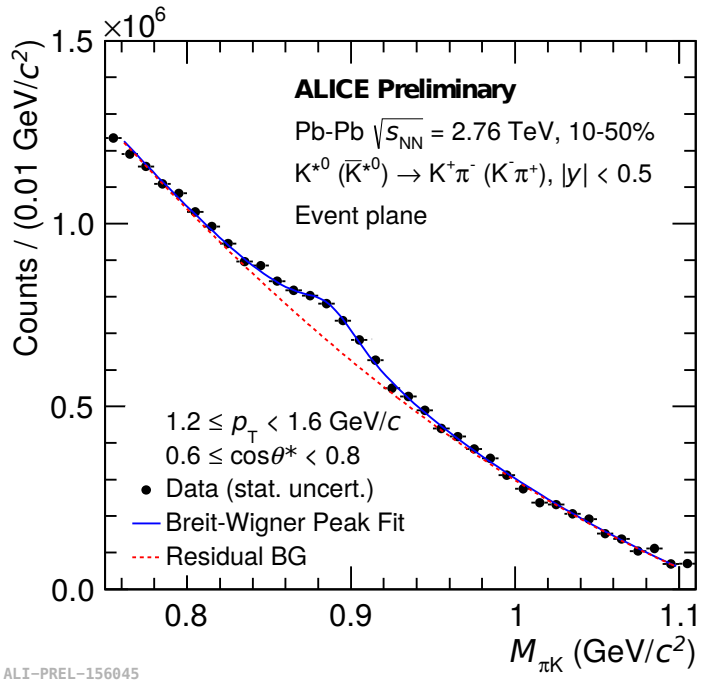
Goal: Measure $dN/d\cos\theta^*$ vs. $\cos\theta^*$ and extract ρ_{00} value as a function of p_T and centrality for K^{*0}

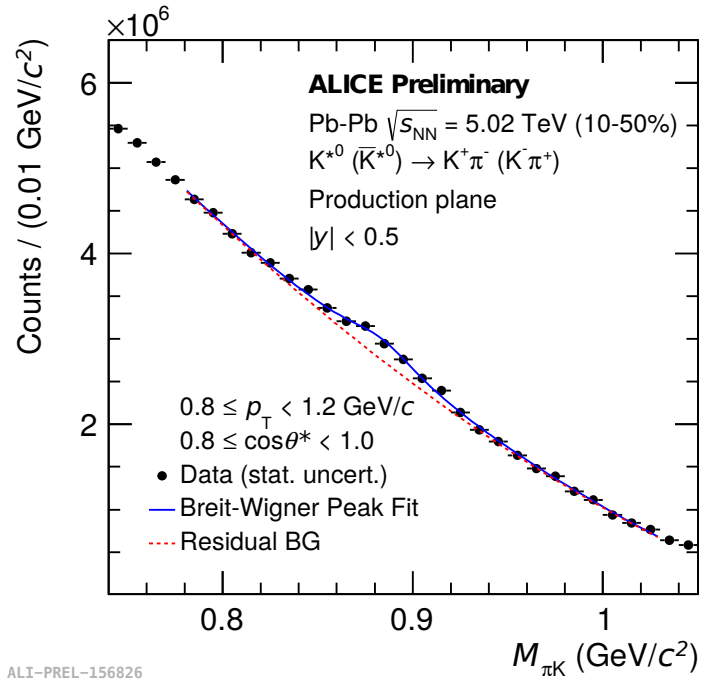
Invariant mass reconstruction of K^{*0} vector meson





Same event (signal+bkground) and mixed event (bkground) distributions

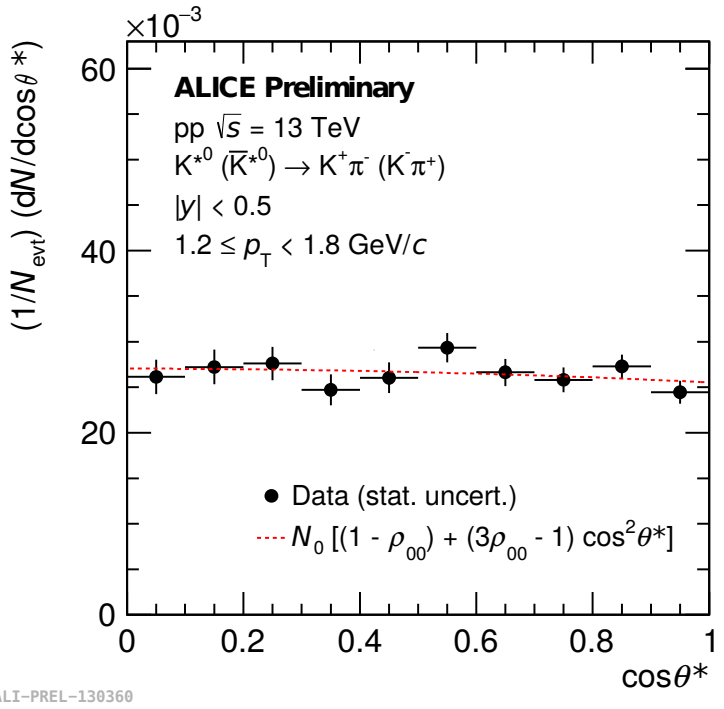


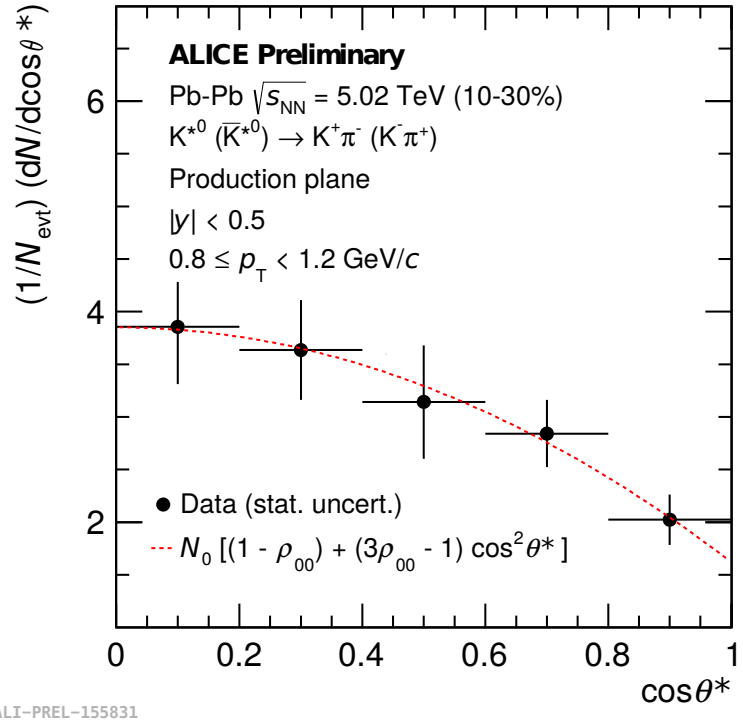


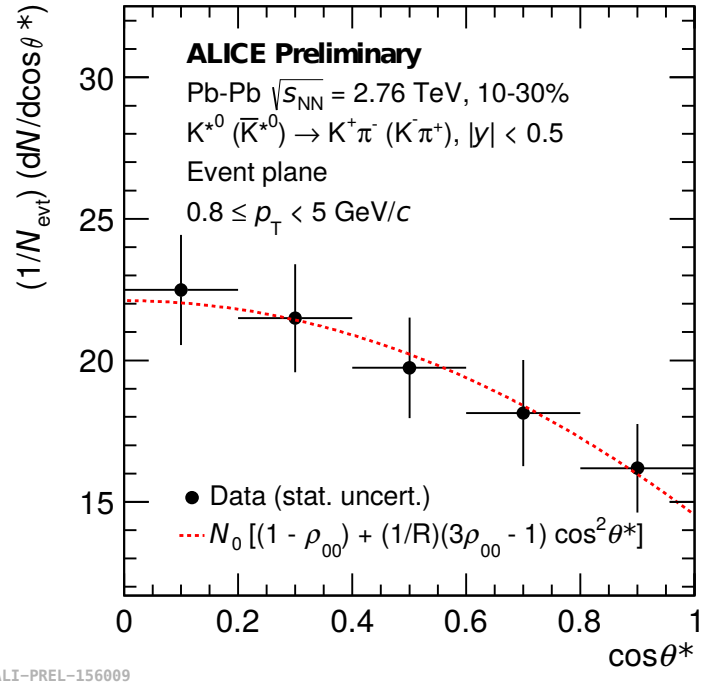
Same event distribution after mixed event background subtraction

Yield is the area under Breit-Wigner distribution

Angular distribution







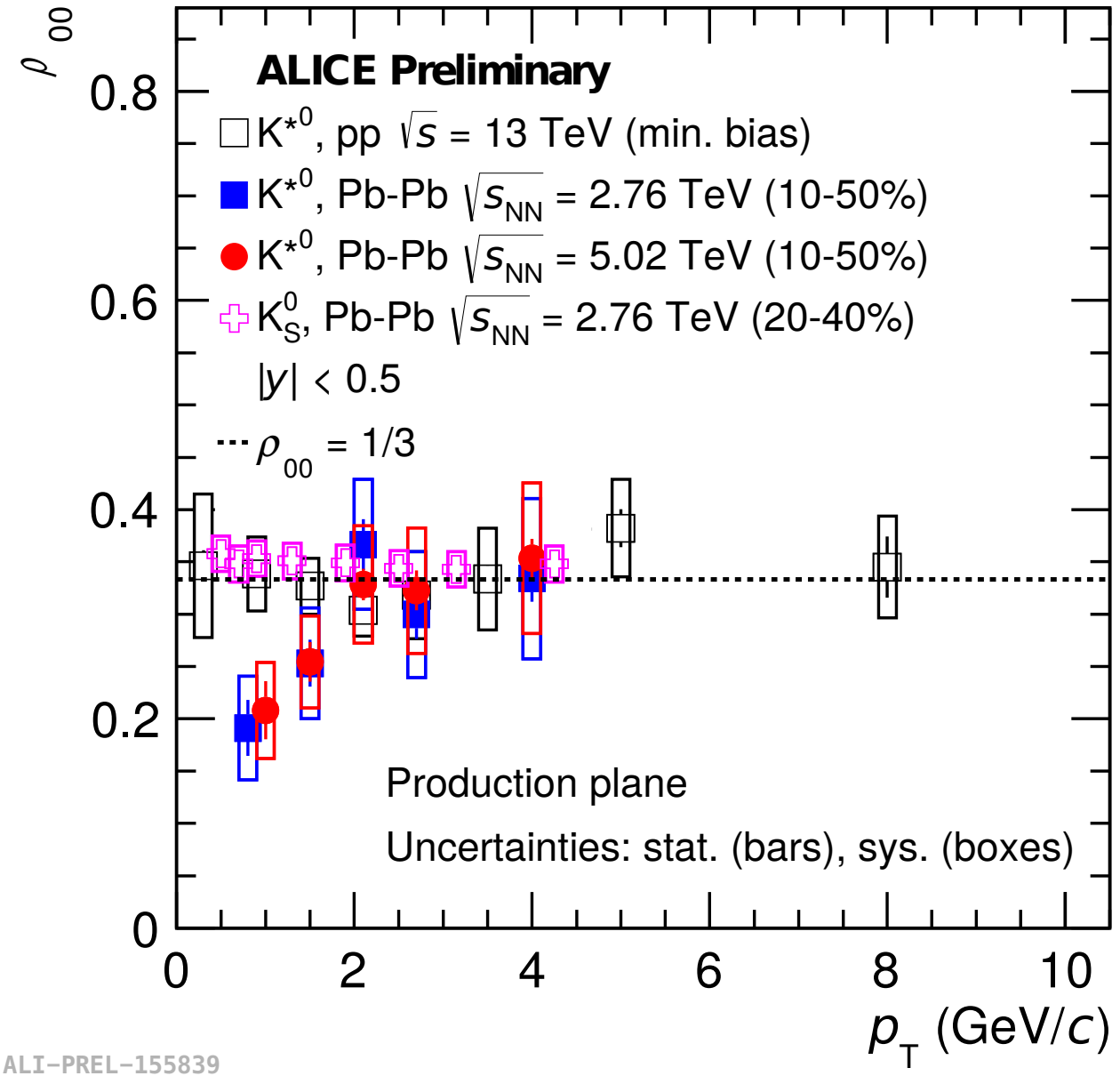
Two parameters (N_0 and ρ_{00}) fit to cosθ* distributions measured in different p_T bins

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

R=1 for production plane measurement

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

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



- ✔ 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 $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV
- ✔ No spin alignment is observed for spin 0 hadron K^0_S

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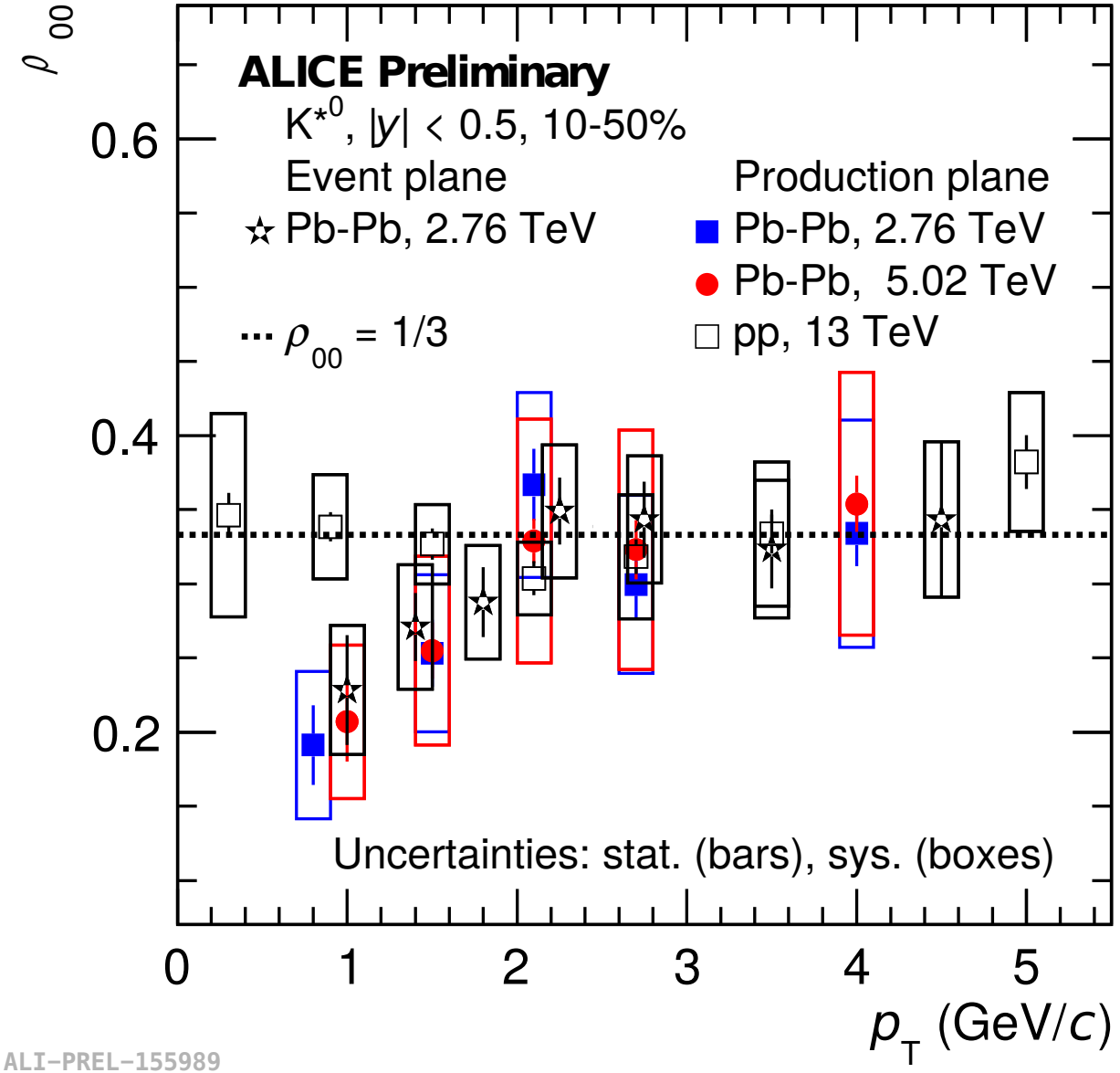
Spin density matrix element (ρ_{00}) vs. p_T : Event plane



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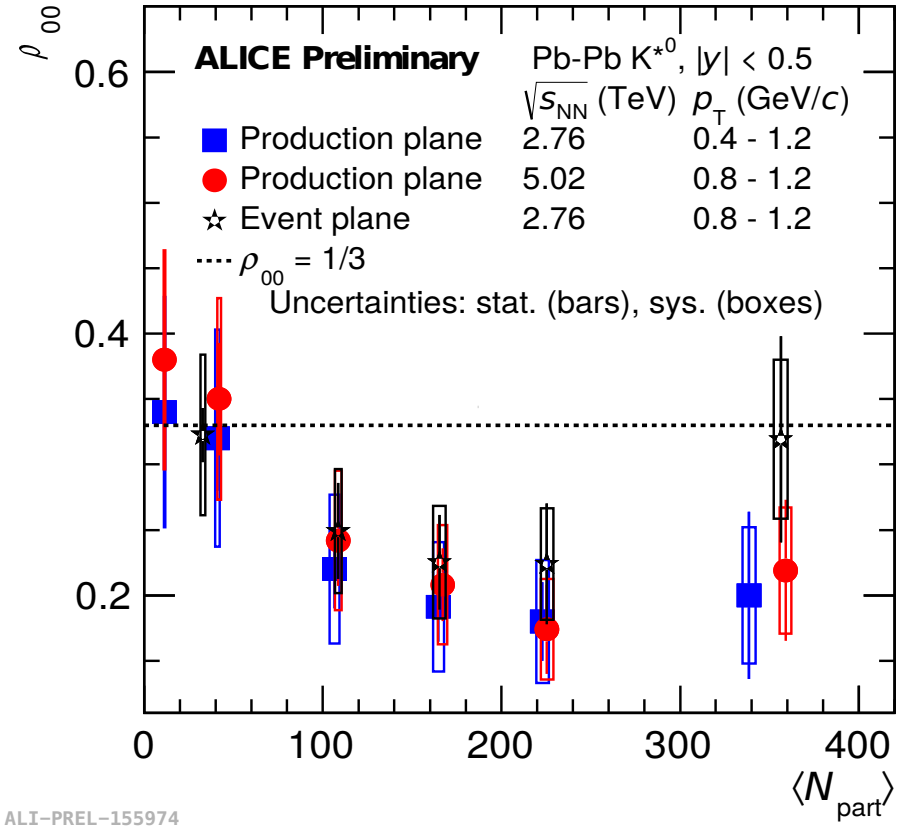
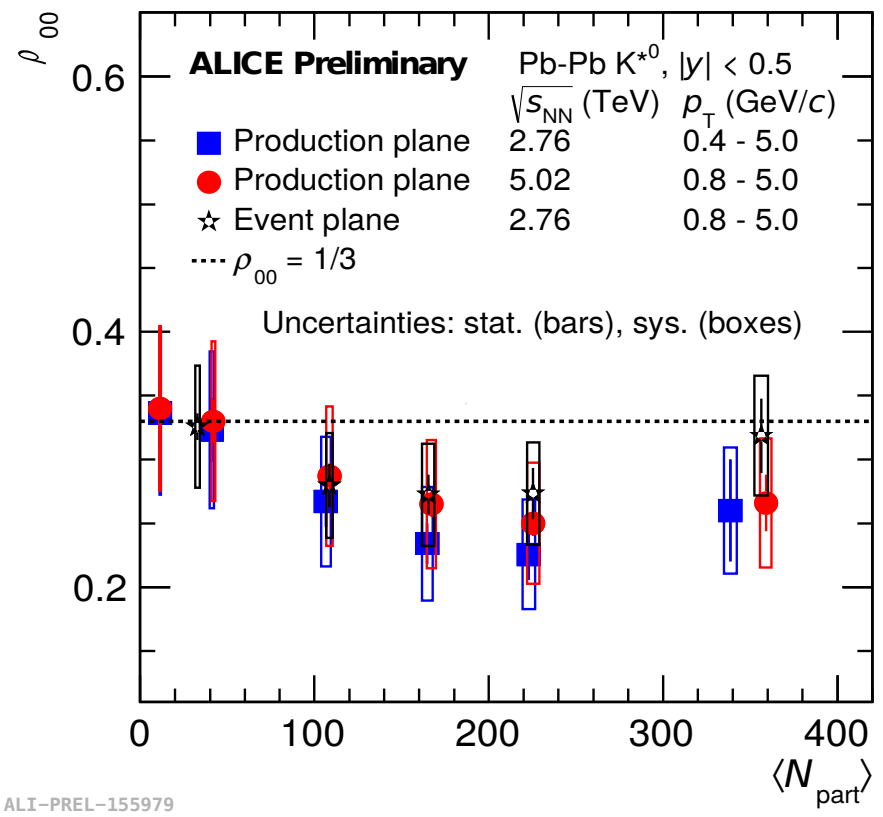
- ✔ ρ_{00} < 1/3 in Pb-Pb collisions for p_T < 2 GeV/c for both event plane and production plane measurements
- ✔ Within statistical and systematic uncertainties ρ_{00} values are similar in both production and event plane method

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

Low p_T



Integrated p_T



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

Summary

- ✔ ρ_{00} ~ 1/3 : Spin alignment is **not** observed in proton-proton collisions at 13 TeV
- ✔ ρ_{00} ~ 1/3 (within systematic errors) : Spin alignment is **not** observed for K^0_S (spin 0) w.r.t. production plane in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
- ✔ ρ_{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
- ✔ ρ_{00} consistent with 1/3 for p_T > 2 GeV/*c* in Pb-Pb collisions at $\sqrt{s_{NN}}$ =2.76 and 5.02 TeV
- ✔ ρ_{00} shows centrality dependence and maximum deviation for mid-central collisions in both event and production plane
- ✔ ρ_{00} values are similar at $\sqrt{s_{NN}}$ = 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

THANK YOU

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