

7th International Conference on Chirality, Vorticity and Magnetic Field in Heavy-Ion Collisions

Vector meson polarization measurements in pp and Pb-Pb collisions with ALICE at the LHC

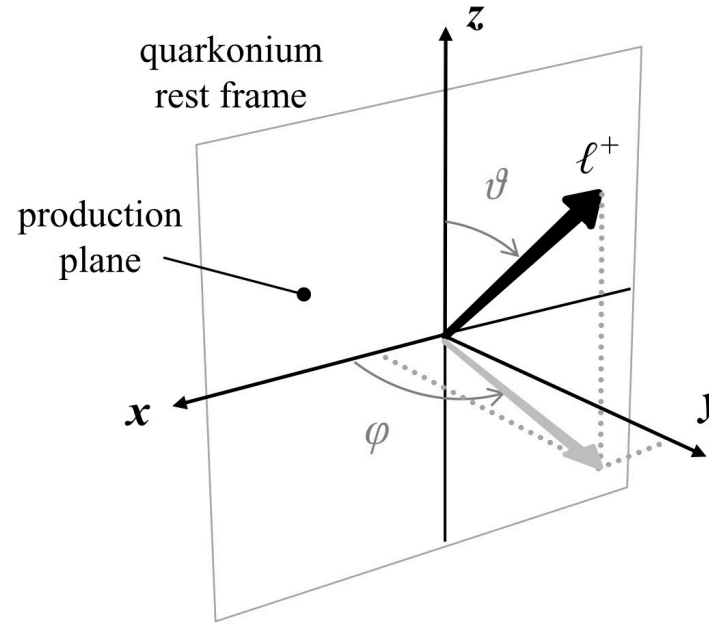
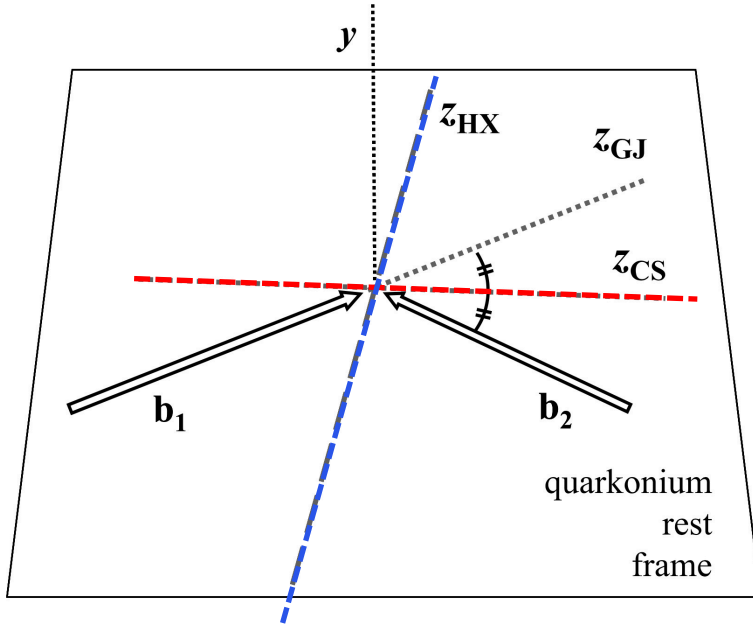
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Introduction



- **pp collisions:** Important to constrain quarkonium production mechanisms in hadronic collisions
- **AA collisions:** Polarization gives access to different time scales and mechanisms, like the early-produced magnetic field, angular momentum, and global polarization.

$$W(\cos \theta, \phi) \propto \frac{1}{3 + \lambda_\theta} \cdot (1 + \lambda_\theta \cos^2 \theta + \lambda_\phi \sin^2 \theta \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta \cos \phi)$$

$$\lambda_\theta \propto (3\rho_{00} - 1)/(1 - \rho_{00})$$

Polarization axis:

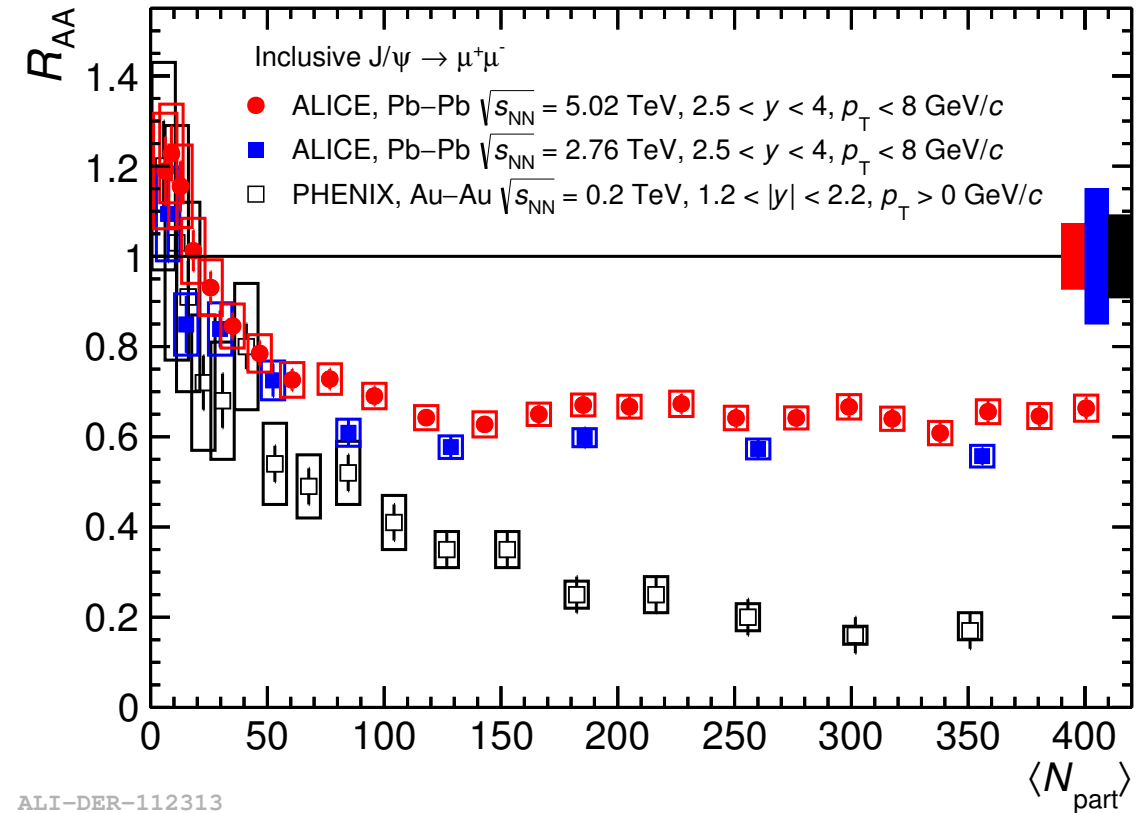
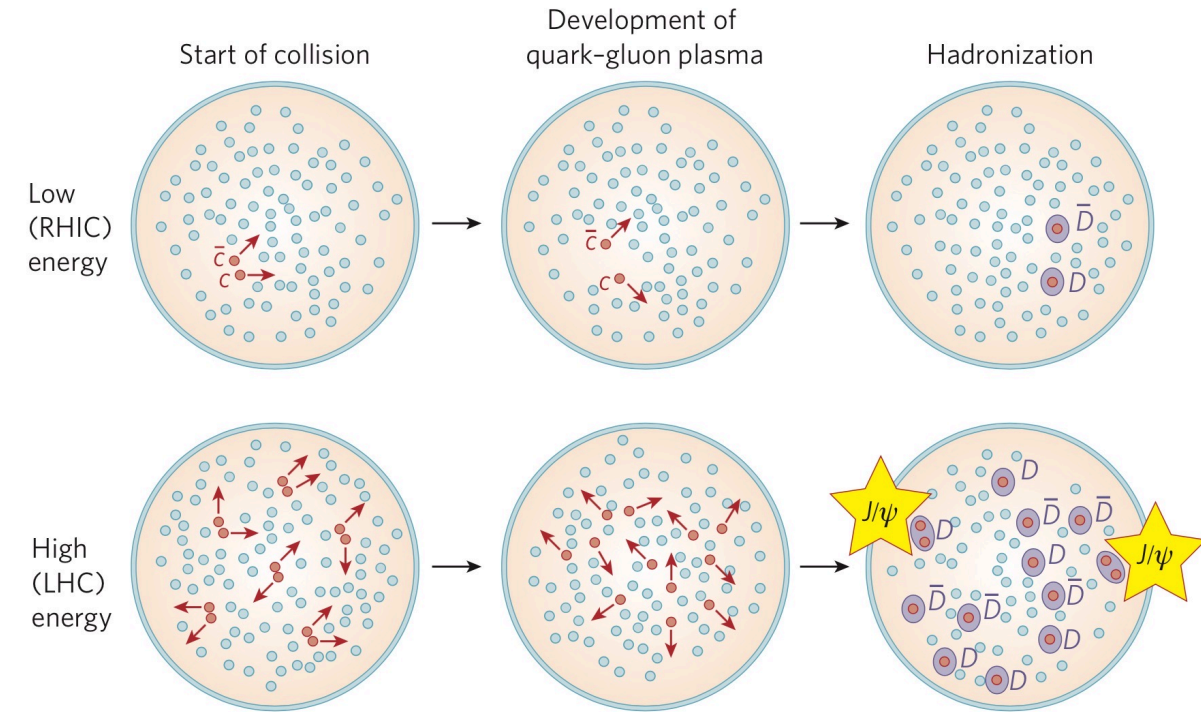
Helicity (HX): direction of vector meson in the collision center of mass frame

Collins-Soper (CS): the bisector of the angle between the beam and the opposite of the other beam, in the vector meson rest frame

Event Plane based frame(EP): axis orthogonal to the event plane in the collision center of mass frame

Quarkonium production in AA collisions

P. Braun-Munzinger, J. Stachel, Nature 448 (2007) 302



ALI-DER-112313

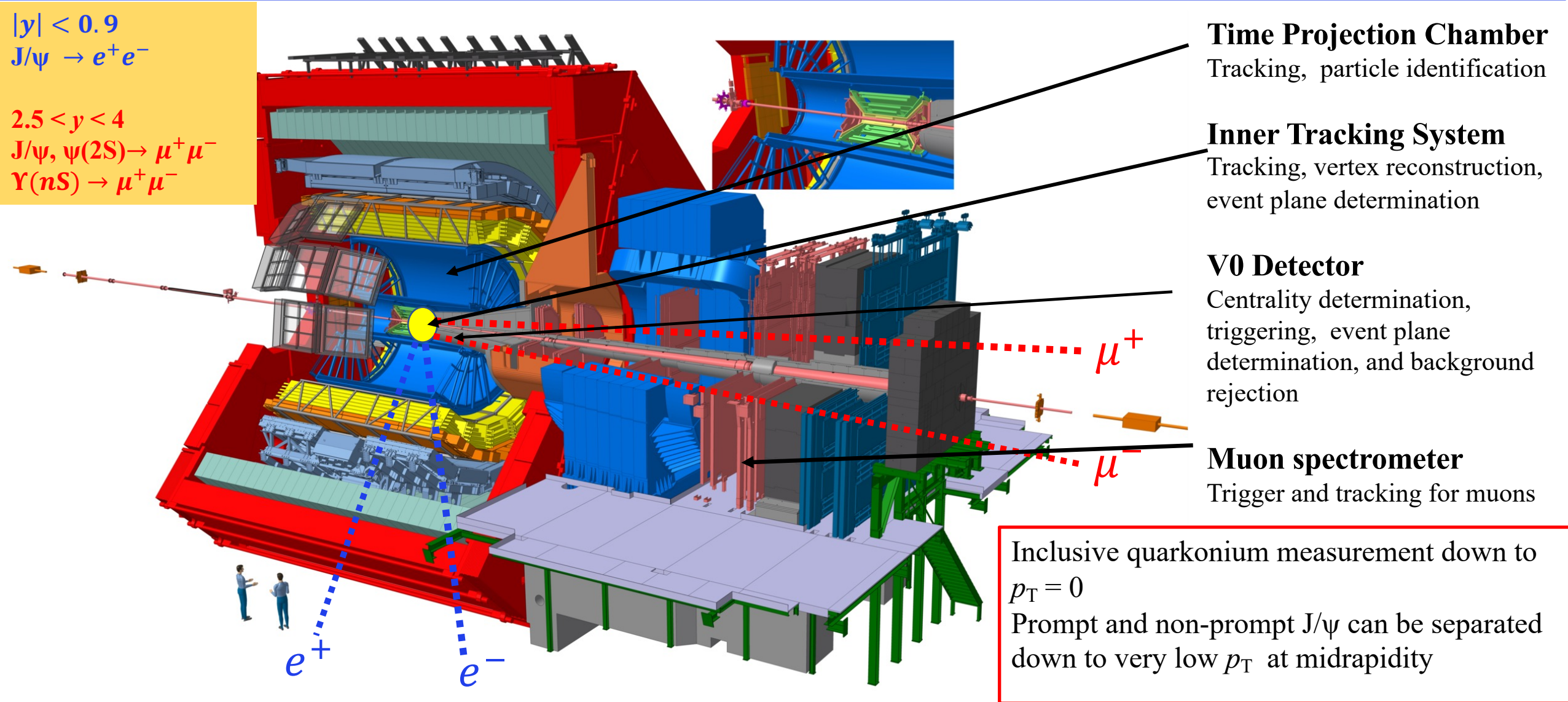
- Suppression of the direct charmonium due to colour screening and dissociation
- Charm quark (c and \bar{c}) production cross section at the LHC is larger compared to RHIC energies, and the (re-)generation contribution to the J/ψ is significantly higher than at RHIC

ALICE, PLB 766 (2017) 212 (ALICE)

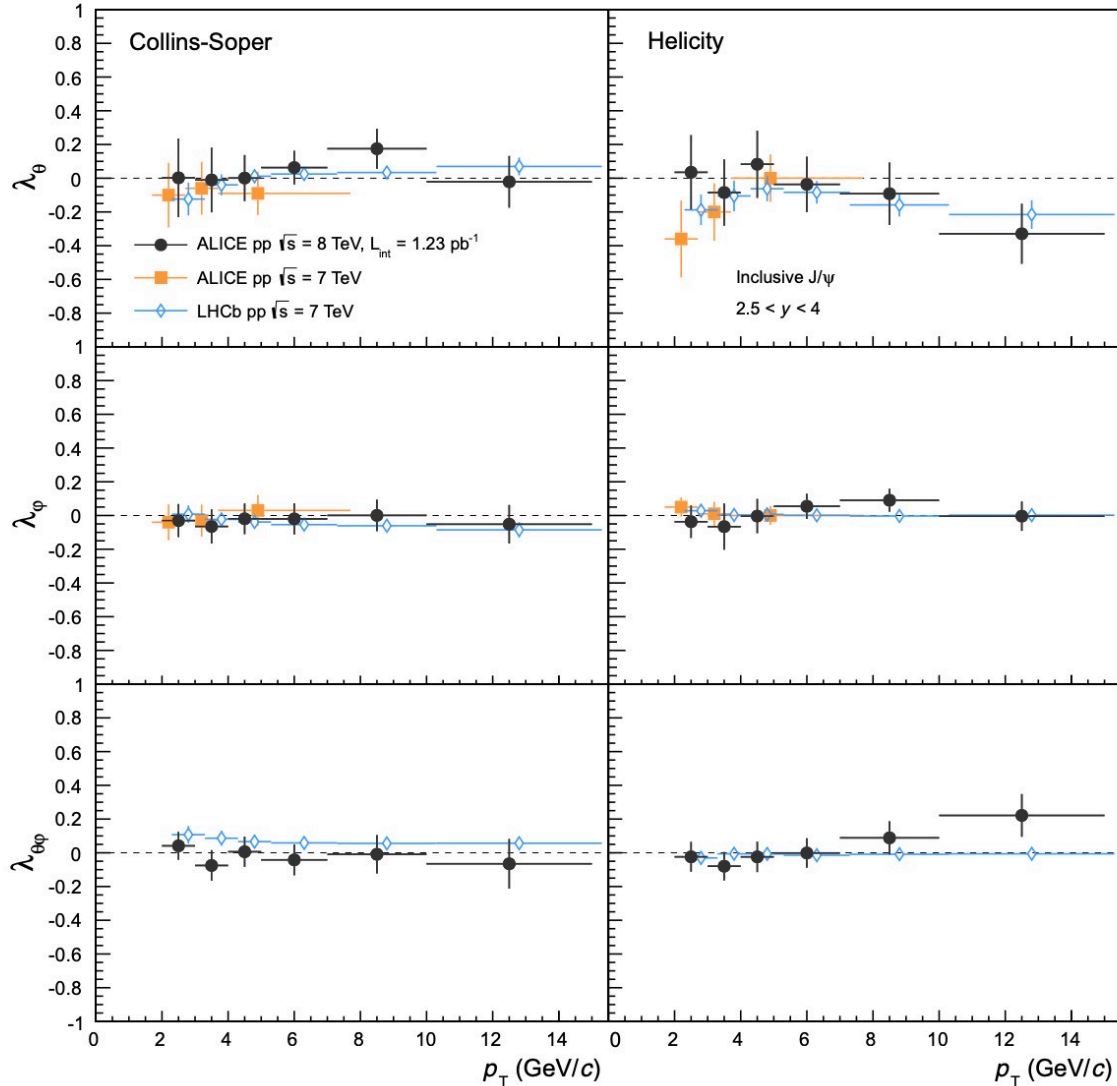
Quarkonium measurements with the ALICE detector (Run 2)

$|y| < 0.9$
 $J/\psi \rightarrow e^+e^-$

$2.5 < y < 4$
 $J/\psi, \psi(2S) \rightarrow \mu^+\mu^-$
 $\Upsilon(nS) \rightarrow \mu^+\mu^-$



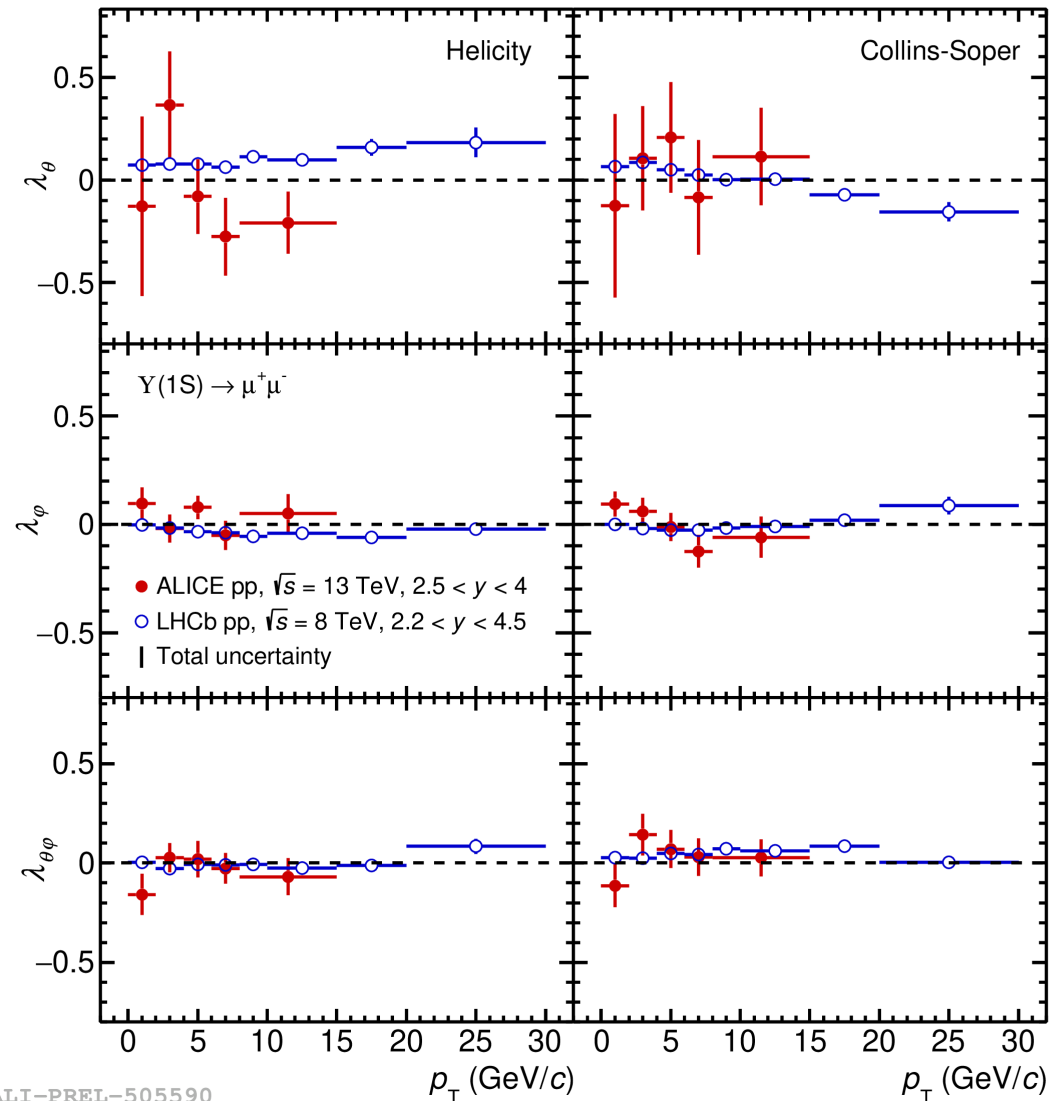
Charmonia polarization in pp collisions



- No strong J/ψ polarization is observed by ALICE at forward rapidity up to $p_T = 15$ GeV/c
- Results compatible within uncertainties with LHCb measurements at 7 TeV

ALICE, PRL 108 (2012) 082001
 ALICE, EPJC 78 (2018) 562
 LHCb, JHEP,12(2017) 110

Bottomonia polarization in pp collisions



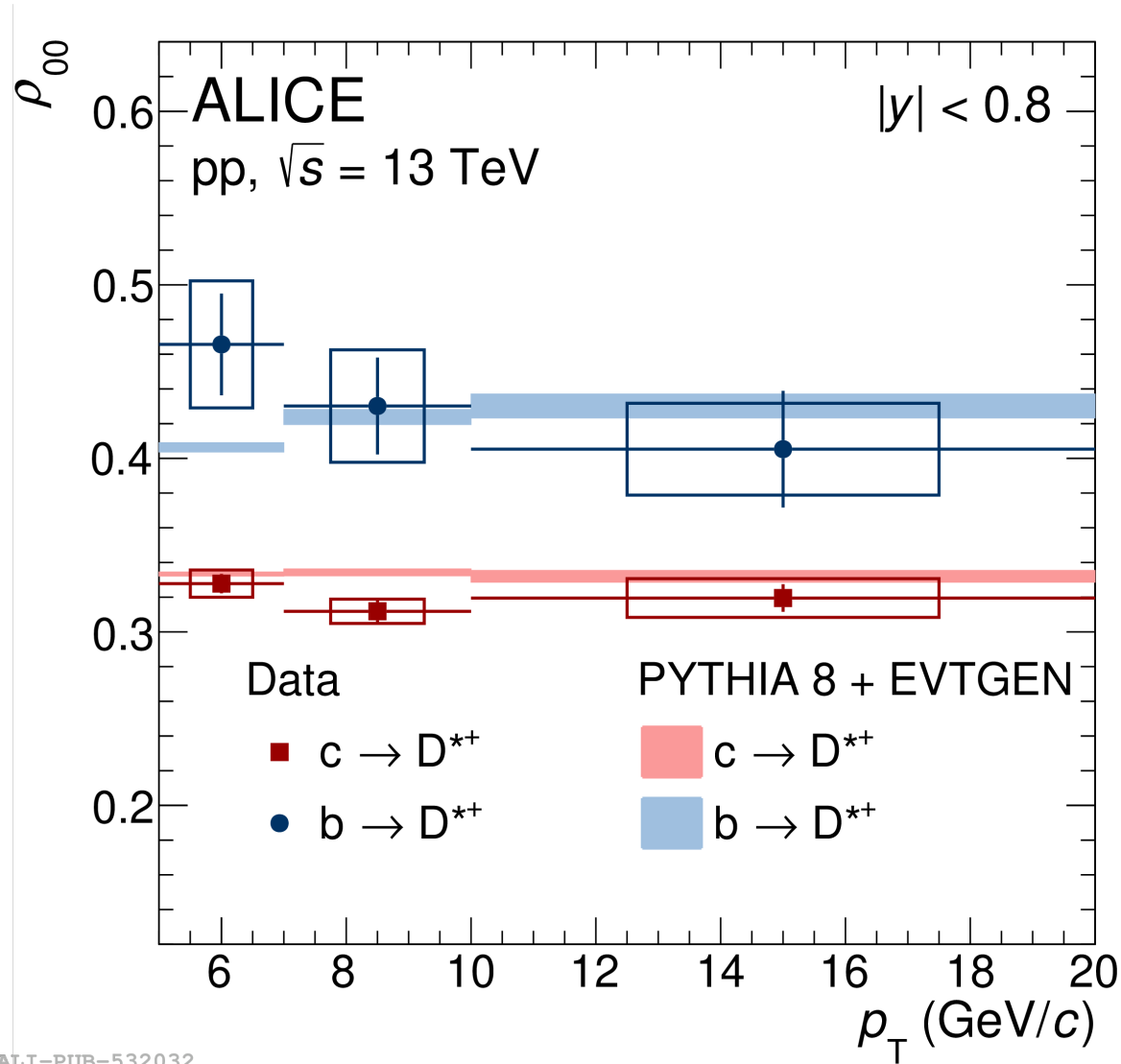
➤ $\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi}$ are compatible with zero in Helicity and Collins-Soper reference frames

➤ $\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi}$ evaluated down to zero p_T

➤ Results compatible within uncertainties with LHCb measurements at 8 TeV

LHCb: JHEP 12 (2017) 110

The prompt and non-prompt D^{*+} polarization



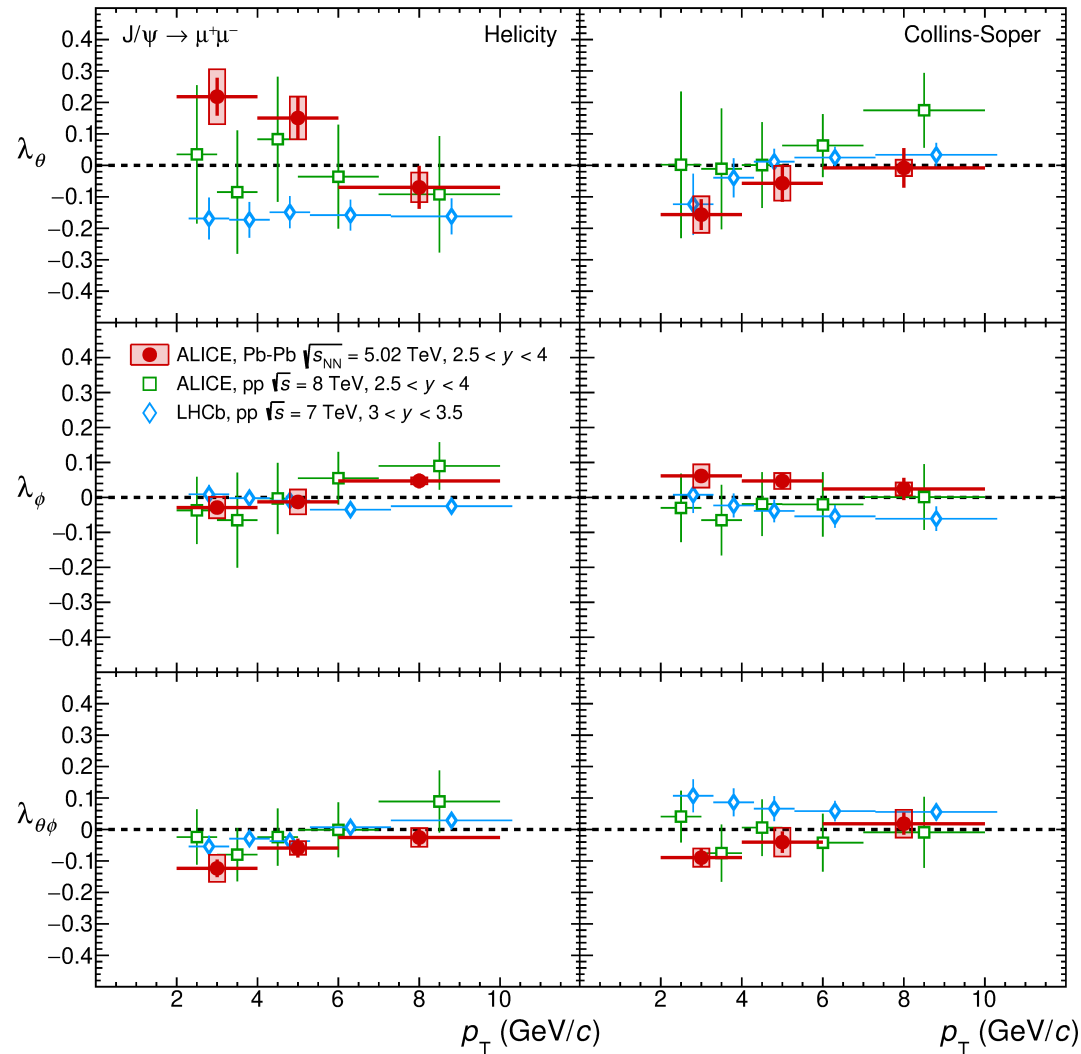
ALI-PUB-532032

- Measurement performed with respect to the helicity rest frame
- Prompt D^{*+} ρ_{00} compatible with 1/3 within uncertainties (no polarization)
- Non-prompt D^{*+} $\rho_{00} > 1/3$ due to the helicity conservation of the beauty hadrons decay
- The charm quarks are either produced unpolarised or their polarization is washed out during the hadronization process
- An important baseline for future spin alignment measurements of D^{*+} vector mesons in heavy-ion collisions

ALICE, arxiv:2212.06588, accepted by PLB

Polarization measurements in AA collisions

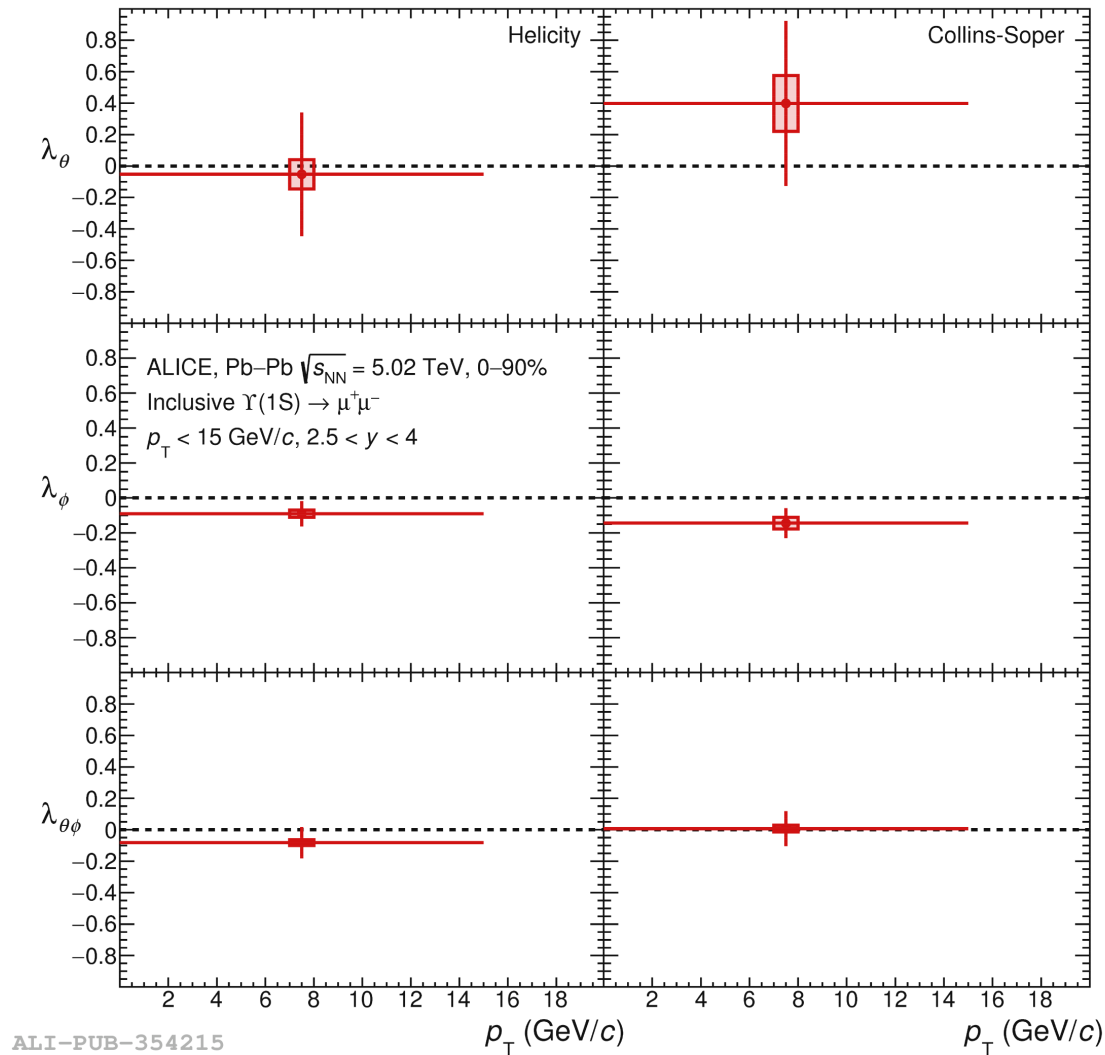
Charmonium polarization results in heavy-ion collisions



- $\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi}$ close to zero in Helicity and Collins-Soper reference frames
- Maximum deviation from zero is 2.1σ in the low p_T bin
- Comparable with ALICE results at 8 TeV in pp collisions within large uncertainties.

ALICE, *Phys.Lett.B* 815 (2021) 136146
LHCb, *JHEP* 12 (2017) 110

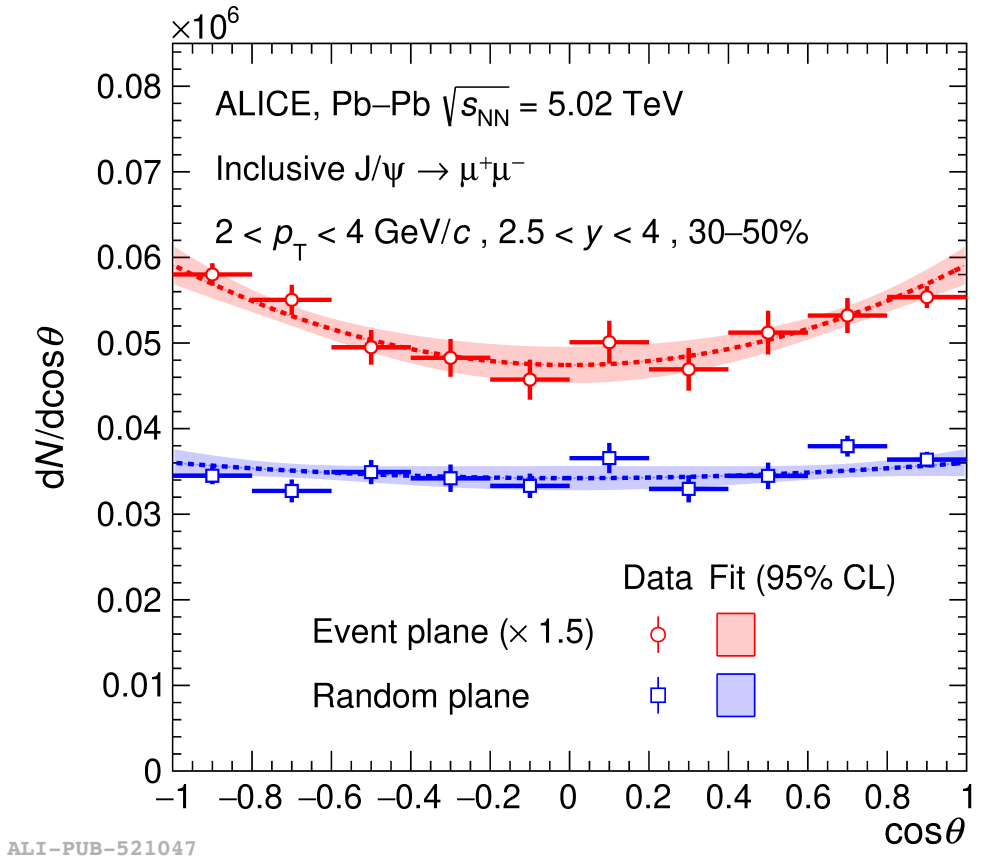
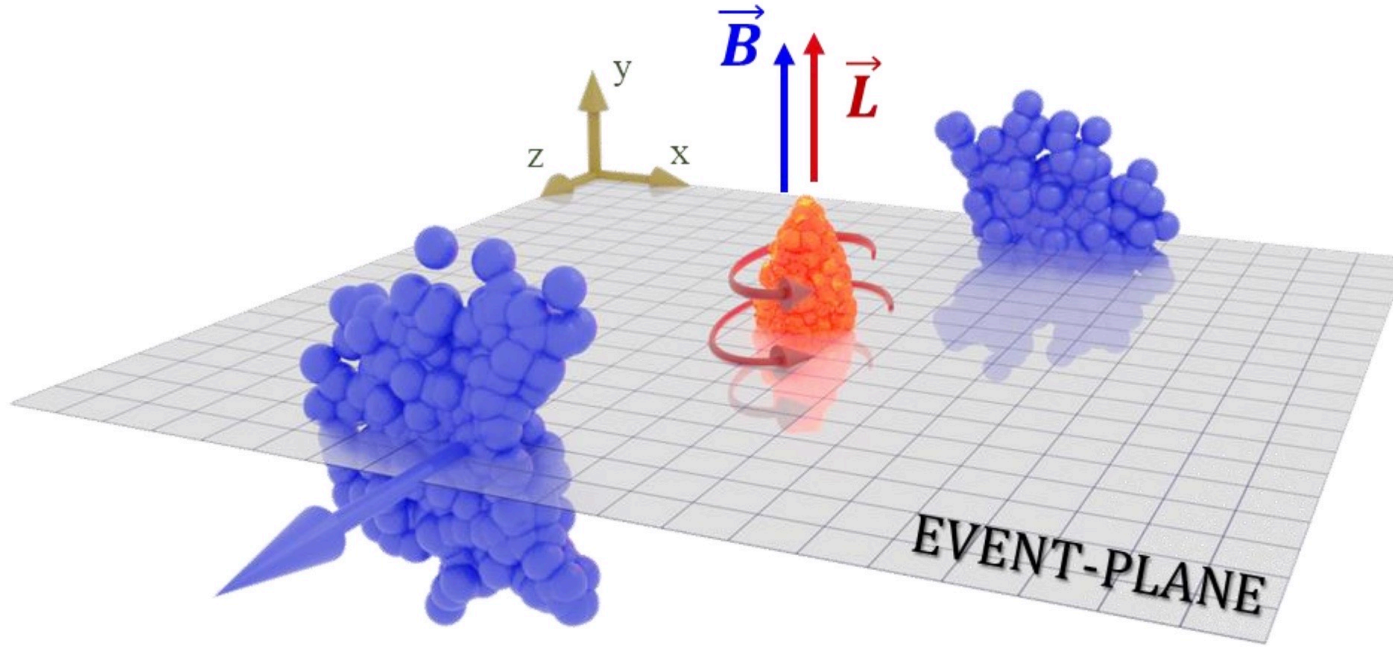
Bottomonia polarization results in heavy-ion collisions



- The $\Upsilon(1S)$ polarization was measured in Helicity and Collins-Soper reference frames
- $\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi}$ all compatible with zero but the measurement is still strongly limited by the statistics

ALICE, *Phys.Lett.B* 815 (2021) 136146

Quarkonium polarization wrt event plane

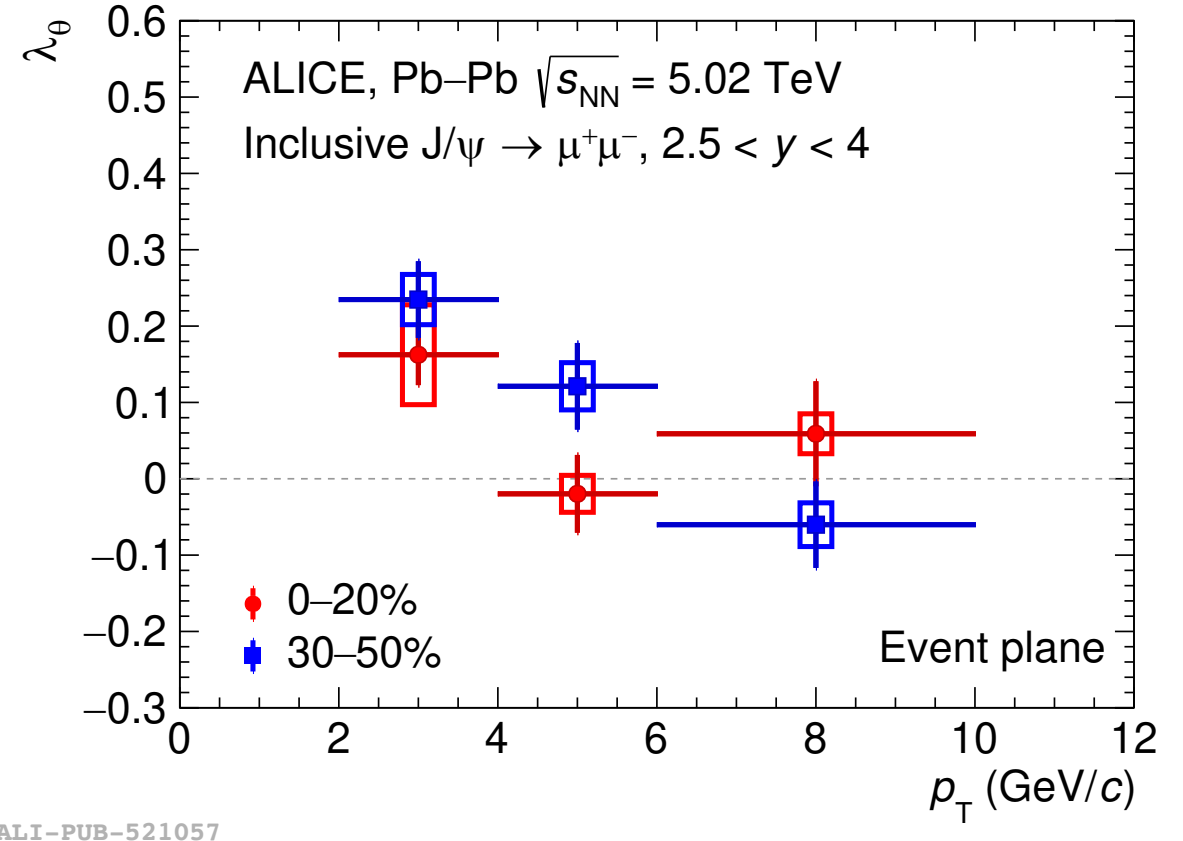
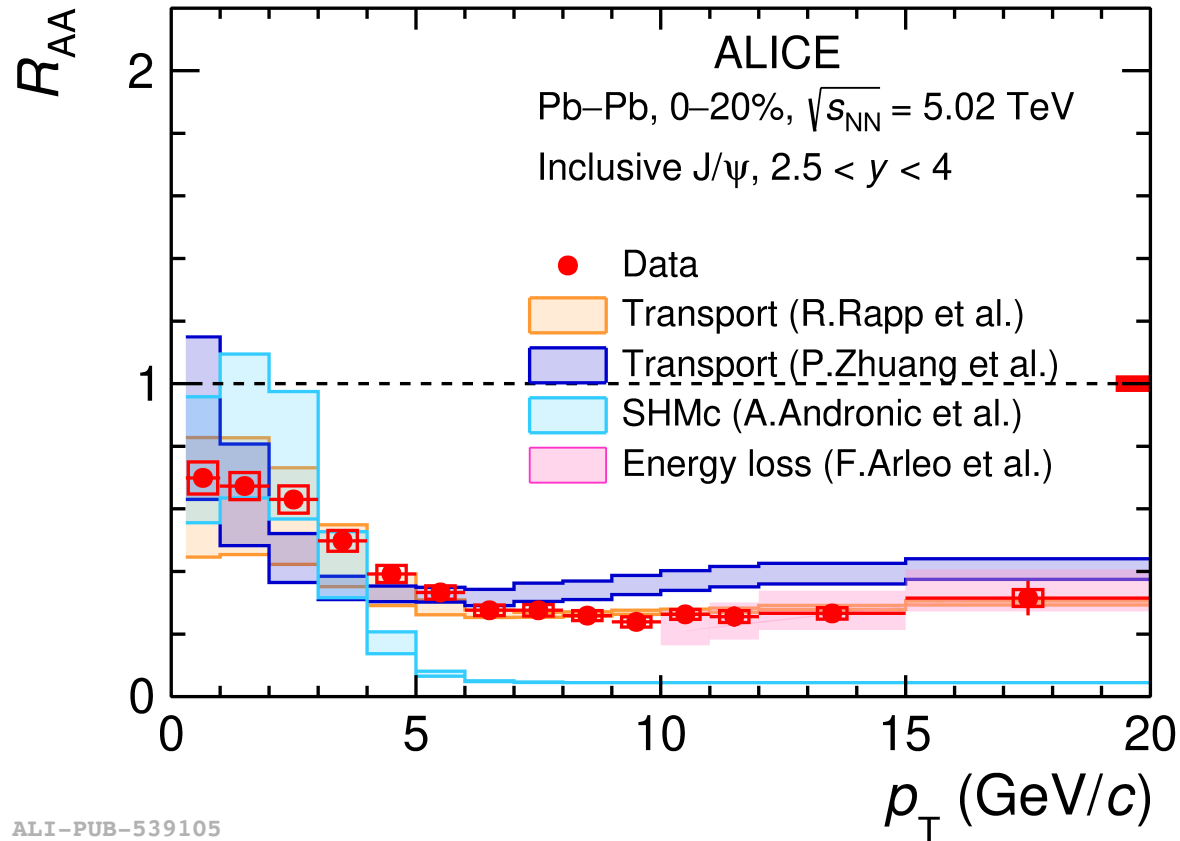


ALI-PUB-521047

Heavy quark pairs are produced in the earlier stage of AA collision and can experience both the short living **B** and the **L** of the rotating medium, J/ψ polarization w.r.t. an axis orthogonal to EP can be affected.

arXiv:2204.10171

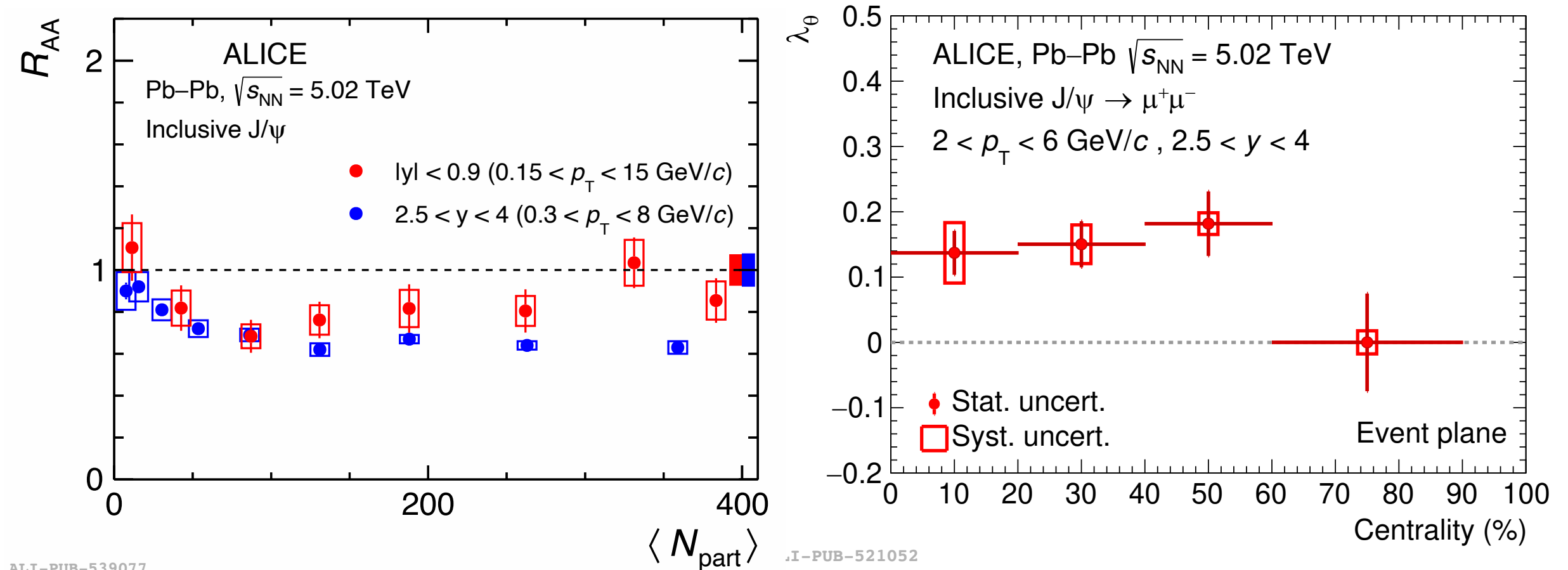
J/ψ polarization as a function of the p_T



- The λ_θ deviation reaches $\sim 3.9\sigma$ at low p_T ($2 < p_T < 4$ GeV/c) in 30-50%
- Is J/ψ global polarization inherited from polarized charm quarks via regeneration ?

arXiv:2204.10171
arXiv:2303.13361

J/ ψ polarization as a function of the centrality



- Significant polarization ($\sim 3.5\sigma$) observed in semicentral collisions (40-60%) in $2 < p_T < 6$ GeV/c
- Measuring the J/ ψ polarization at midrapidity can be expected from ALICE Run 3 via dielectron decays

arXiv:2204.10171
arXiv:2303.13361

Summary

➤ pp collisions:

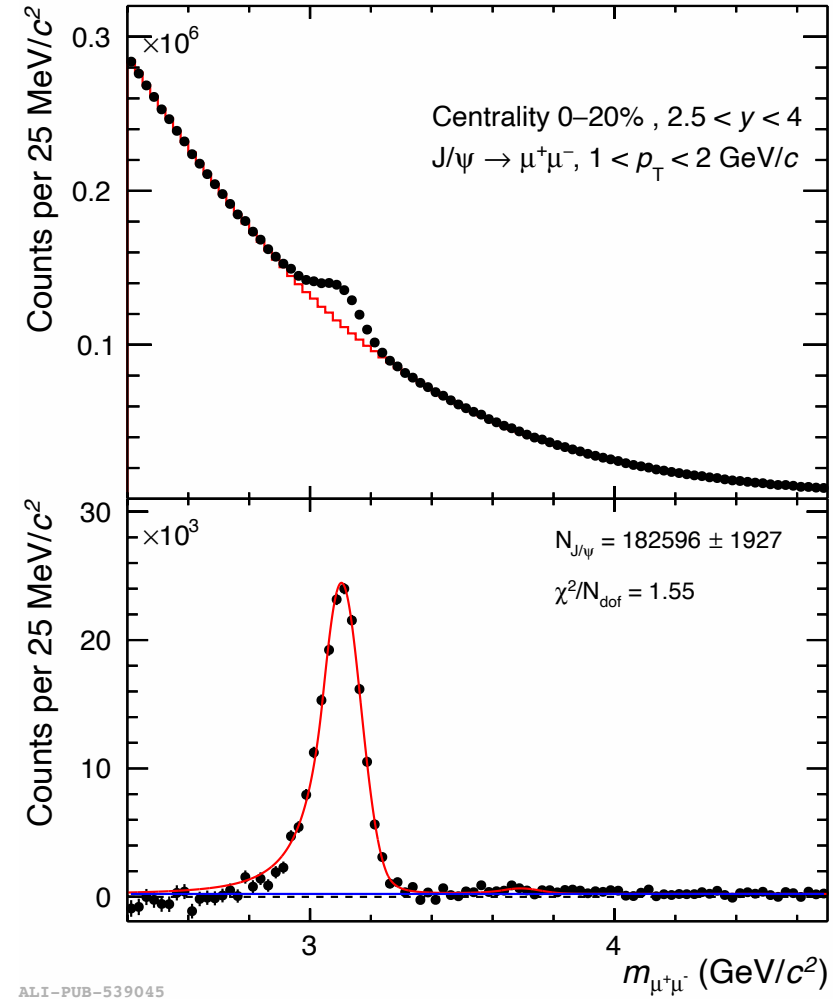
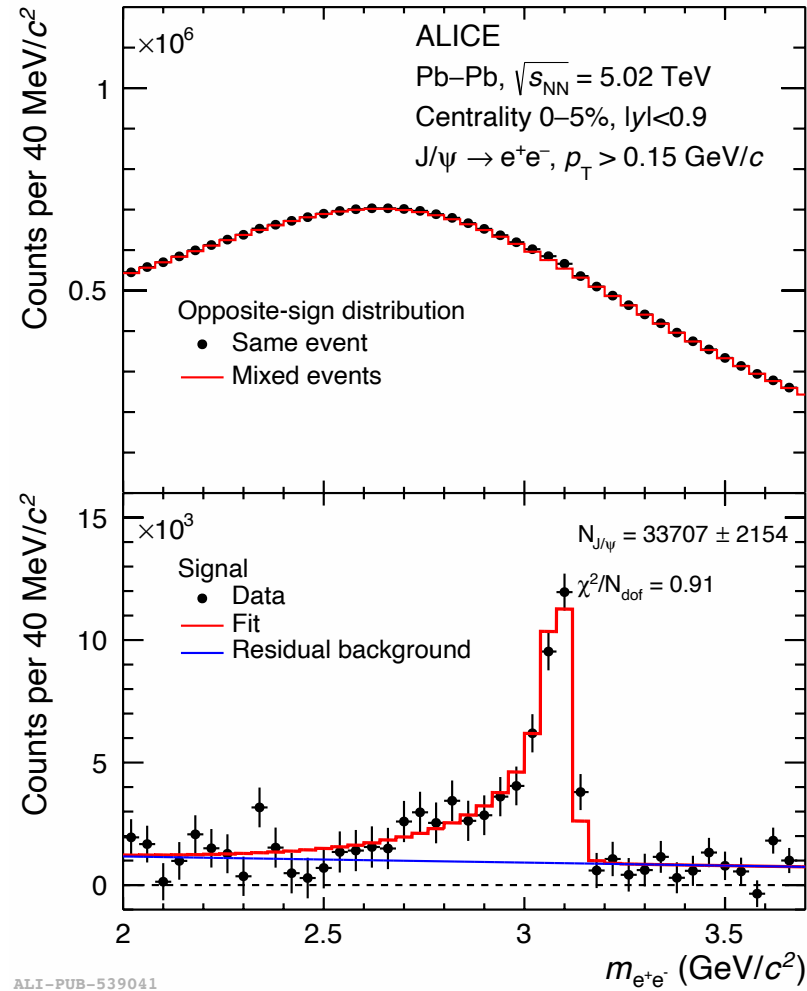
- J/ψ and $Y(1S)$ do not exhibit strong polarization in pp collisions
- Prompt D^{*+} ρ_{00} compatible with 1/3 within uncertainties (no polarization), non-prompt D^{*+} shows polarization due to the helicity conservation of beauty decay

➤ AA collisions

- J/ψ does not show strong polarization in Helicity and Collins-Soper reference frames
- Significant polarization ($\sim 3.9\sigma$) observed w.r.t the event plane, interpretation of results requires inputs from theoretical models

Thanks

J/ψ yield extraction in Pb–Pb collisions



arXiv:2303.13361

J/ψ are reconstructed via dielectron (left) and dimuon (right) decay channels at mid- and forward rapidity, respectively.