$\Upsilon(1S)$ polarization in pp collisions at $\sqrt{s} = 13$ TeV with ALICE

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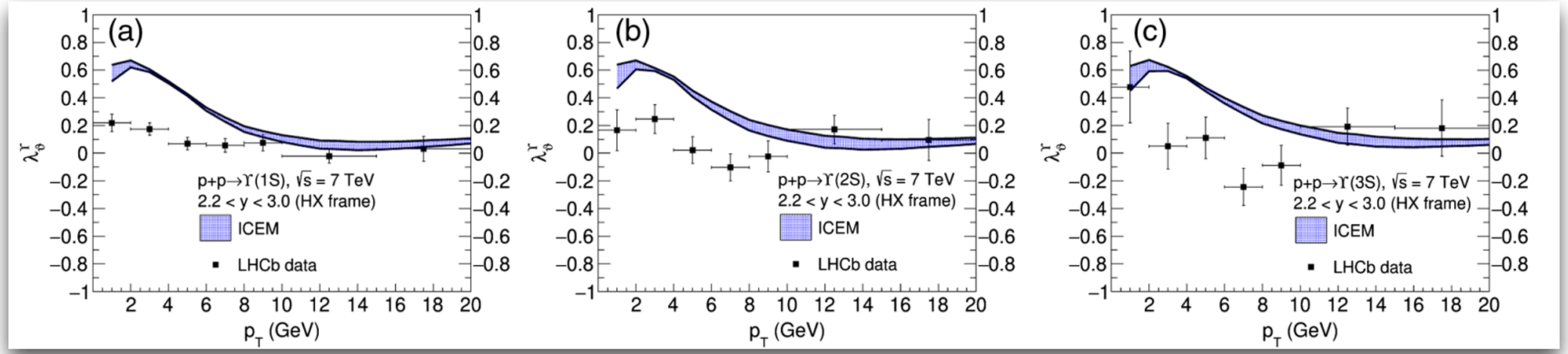
1. Motivation

Quarkonium polarization in pp collisions: constrains quarkonium production mechanisms

- Theoretically
  - ☑ **NLO calculations** [1] ==> small polarization for $\Upsilon(1S)$ and $\Upsilon(2S)$ states, but a strong transverse polarization for $\Upsilon(3S)$ at high p_T
  - ☑ **ICEM** (k_T-factorization approach) [2] ==> no significant differences in polarizations among the $\Upsilon(nS)$ states
- Existing $\Upsilon(nS)$ polarization measurements at the LHC in pp collisions
  - ☑ **CMS** measurements in pp collisions at $\sqrt{s} = 7$ TeV [3] ==> no significant polarization
  - ☑ **LHCb** measurements in pp collisions at $\sqrt{s} = 7$ and 8 TeV [4] ==> no large transverse or longitudinal polarization



[1] Phys. Rev. Lett. **112** (2014) 3, 032001; [2] Phys. Rev. D **99** (2019) 3, 034007; [3] Phys. Rev. Lett. **110** (2013) 8, 081802; [4] JHEP **12** (2017) 110

2. Analysis strategy (I)

$\Upsilon(1S)$ is measured based on the data from pp collisions at $\sqrt{s} = 13$ TeV

- Candidate selection: opposite-charge muon pairs formed with **muon tracks** satisfying selection criteria (see Ref. [5])
- Analysis procedure:

[5] Phys. Lett. B **738** (2014) 361-372

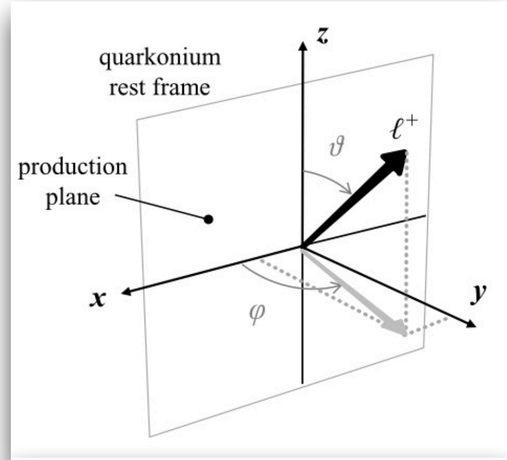
i. **Signal extraction**: number of $\Upsilon(1S)$ obtained by fitting the $\mu^+\mu^-$ invariant mass distribution

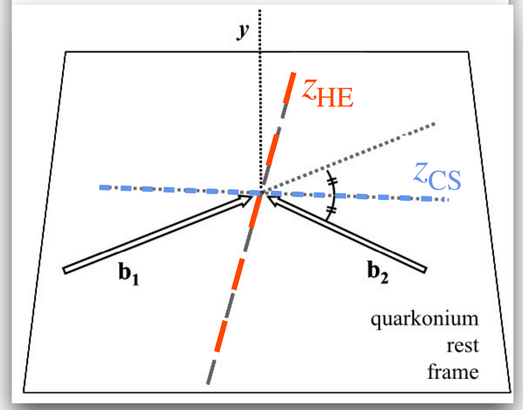
ii. $A \times \varepsilon$ **correction**: number of $\Upsilon(1S)$ corrected with the $A \times \varepsilon$ obtained with a MC simulation

iii. **Polarization parameters determination**: fit to the $A \times \varepsilon$-corrected $\Upsilon(1S)$ angular distributions

GOAL: obtain λ_θ , λ_φ and $\lambda_{\theta\varphi}$

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





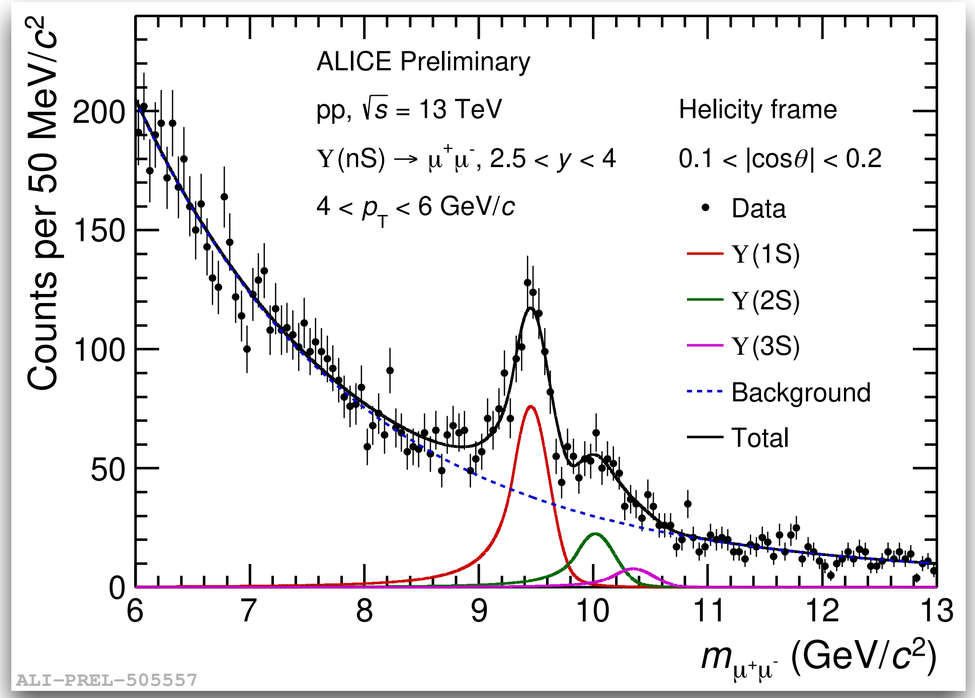
- Reference frames:

i. Helicity (HE): the direction of quarkonium in the center-of-mass frame

ii. Collins-Soper (CS): the bisector of the angle between one beam and the opposite of the other beam in the quarkonium rest frame

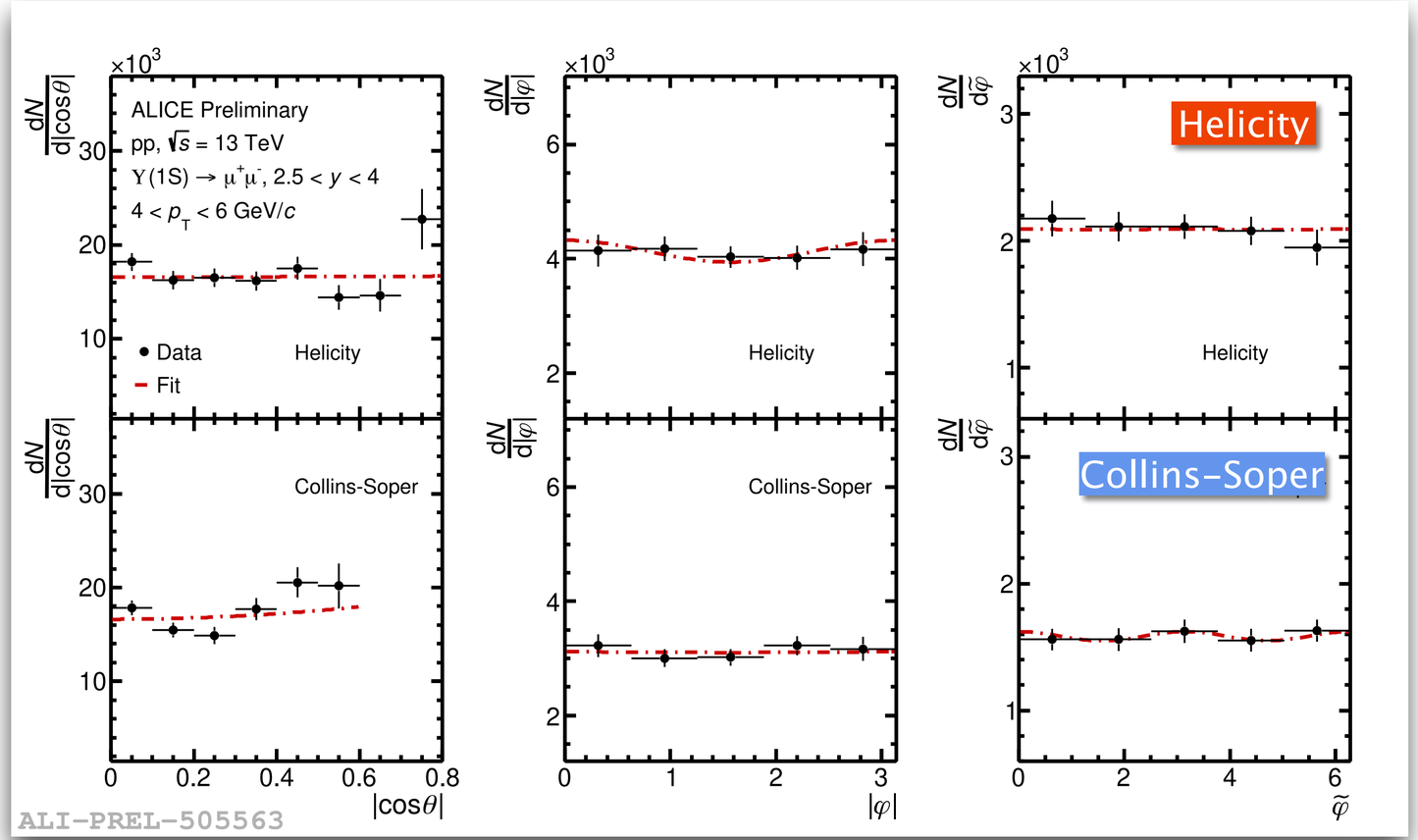
2. Analysis strategy (II)

- Signal extraction
  - ☑ **Raw** number of $\Upsilon(1S)$ obtained by fitting the dimuon invariant mass distribution



- Acceptance x efficiency correction
  - ☑ **Corrected** number of $\Upsilon(1S)$ evaluation based on a MC simulation

- Polarization parameters determination
  - ☑ λ_θ , λ_φ and $\lambda_{\theta\varphi}$ extracted via fitting the $A \times \varepsilon$-corrected $\Upsilon(1S)$ angular distributions in both frames simultaneously



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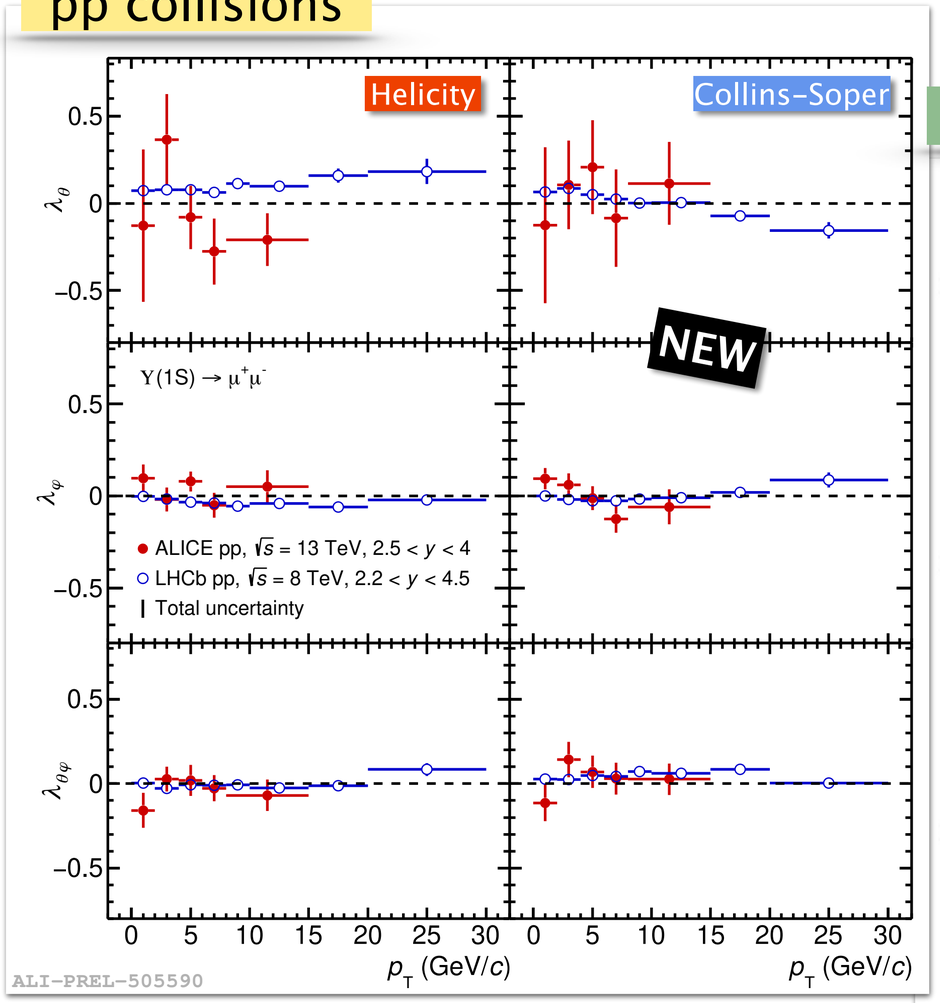
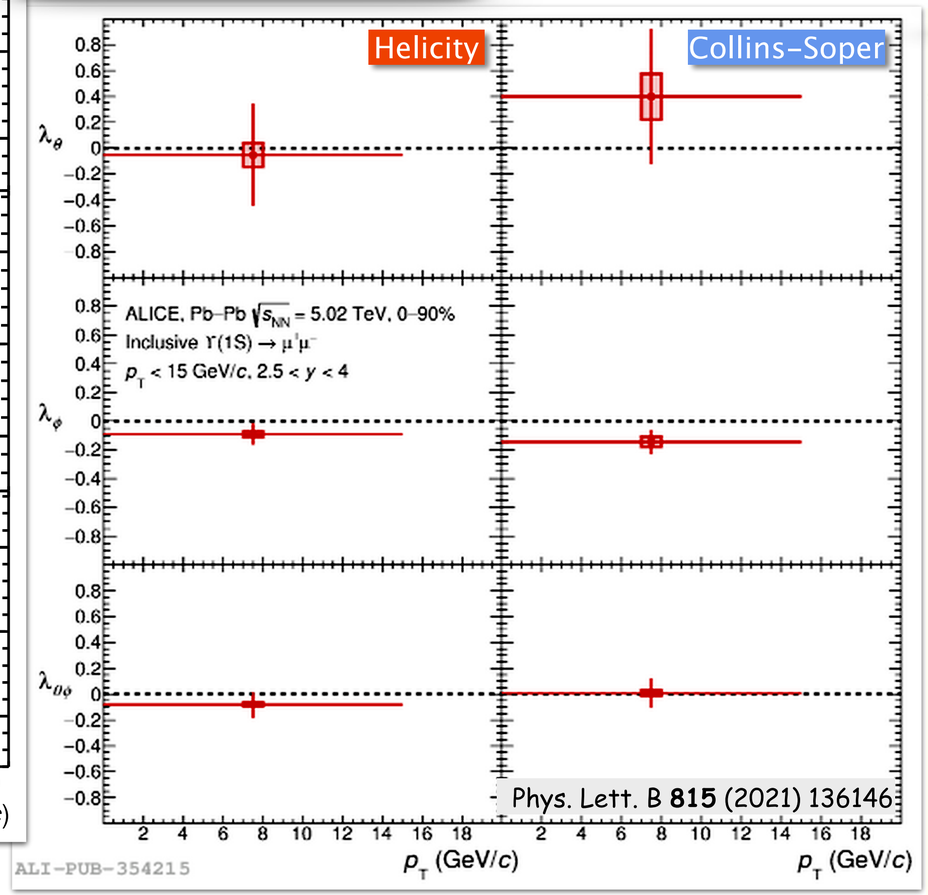
3. Results and summary

pp collisions

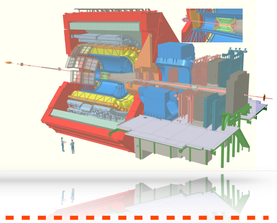


Pb—Pb collisions



Summary

- First **ALICE** $\Upsilon(1S)$ measurement in pp collisions
  - ☑ λ_θ , λ_φ and $\lambda_{\theta\varphi}$ consistent with zero within uncertainties in both **HE** and **CS** frames, compatible with **Pb—Pb** results
- Good agreement with **LHCb** in a similar rapidity range
- Also no polarization observed for the J/Ψ in pp collisions within uncertainties



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