ψ(2S)/J/ψ ratio at midrapidity in pp collisions at $\sqrt{s} = 13.6$ TeV with ALICE

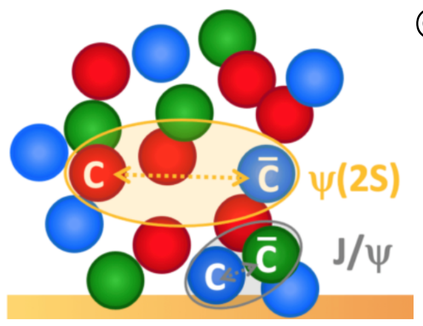
Pengzhong Lu for the ALICE Collaboration

University of Science and Technology of China (Hefei, China)

GSI Helmholtzzentrum für Schwerionenforschung (Darmstadt, Germany)

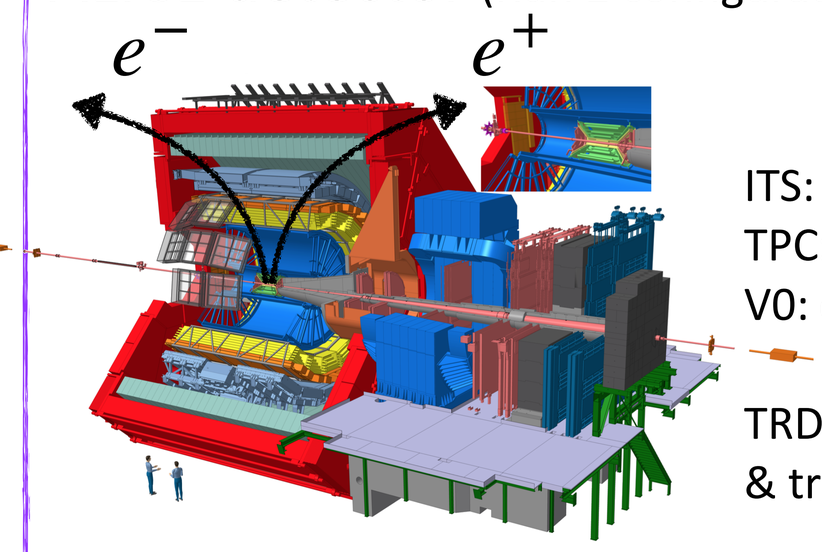
Email: pengzhong.lu@cern.ch

Motivation



- Charmonia: bound $c\bar{c}$ states
- In pp collisions:
  - ✓ Crucial for testing both perturbative and non-perturbative aspects of QCD
  - ✓ Provide a reference for investigating Quark Gluon Plasma (QGP) properties in A–A collisions and Cold Nuclear Matter (CNM) effects in p–A collisions[1]

ALICE detector (Run 2 configuration and Run 3 upgrade)



ITS: tracking & vertexing

TPC: tracking & PID

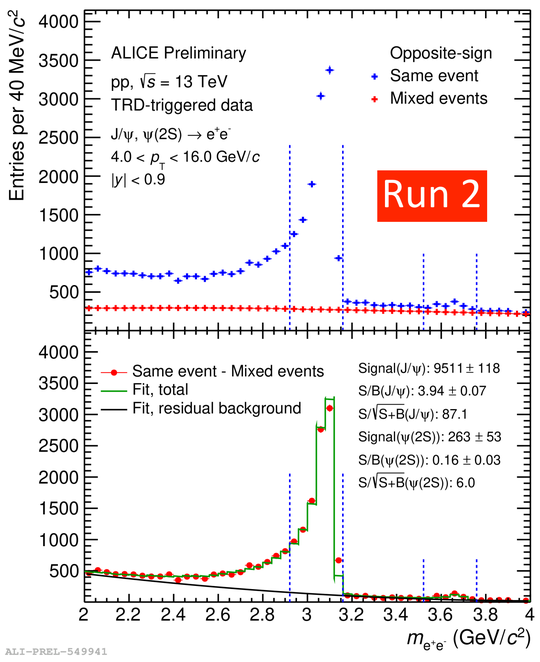
V0: event selection

TRD: electron identification & trigger

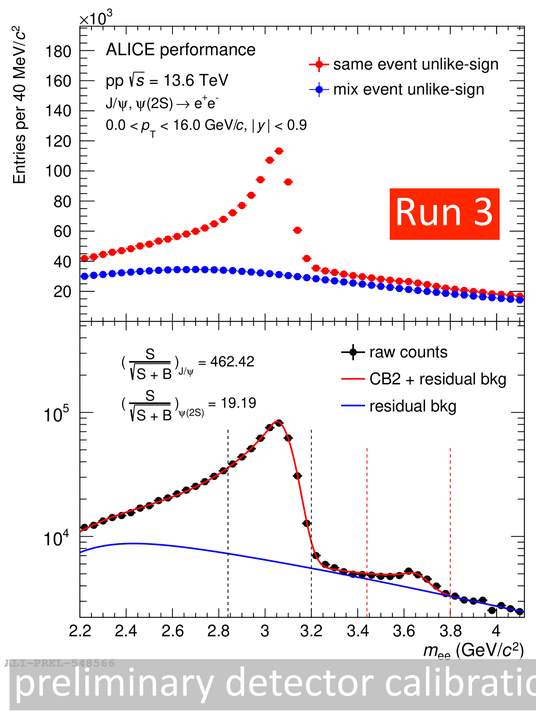
Due to the major upgrades installed in 2019-2021:

- ➡ 50x increase in readout rate[2,3]
- ➡ 3 to 6x improvement in pointing resolution[2,4]
- ➡ ITS inner barrel with 0.35% X_0 per layer[2,4]

J/ψ and ψ(2S) signal extraction



- Run 2: Clear J/ψ and ψ(2S) signals ($4 < p_{\mathrm{T}} < 6$ GeV/c) using the TRD triggered data
- Signal shape: MC templates
- Background: mixed-event technique + 2nd order polynomial for residual background



preliminary detector calibration

- Run 3: higher statistics, measurement dow to $p_{\mathrm{T}} = 0$ with minimum bias data
- Signal shapes are described by double Crystal Ball functions
- Background: mixed-event technique + 2nd order polynomial divided by an exponential for residual background

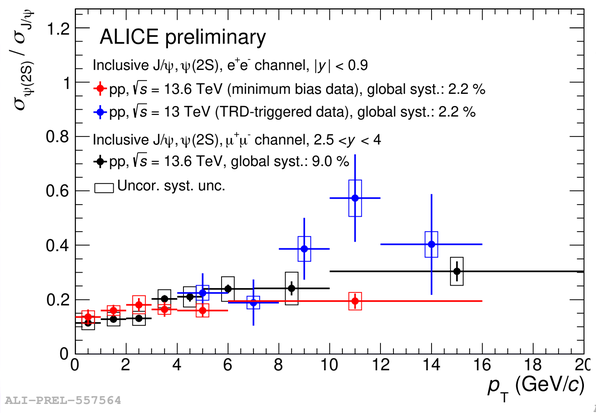
Yields ratio of ψ(2S) to J/ψ

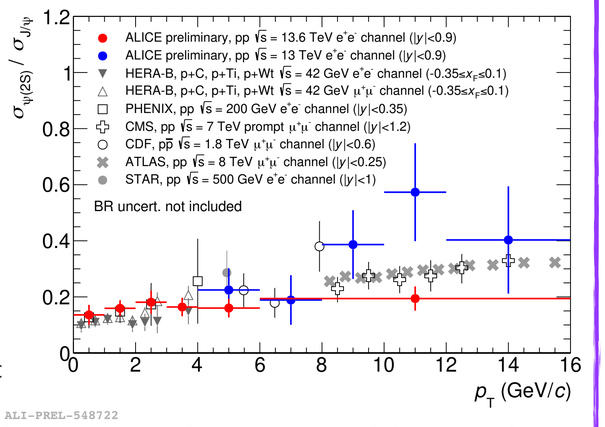
$$\frac{\sigma_{\psi(2S)}}{\sigma_{J/\psi}} = \frac{N_{\psi(2S)}}{N_{J/\psi}} \frac{(A \times \varepsilon)_{J/\psi}}{(A \times \varepsilon)_{\psi(2S)}} \frac{BR_{J/\psi \to ee}}{BR_{\psi(2S) \to ee}}$$

N: raw yields

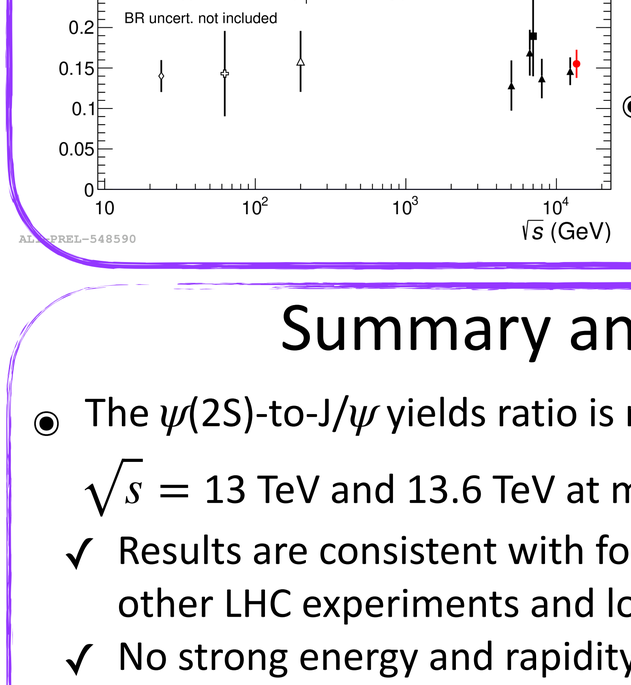
$A \times \varepsilon$: acceptance times efficiencies

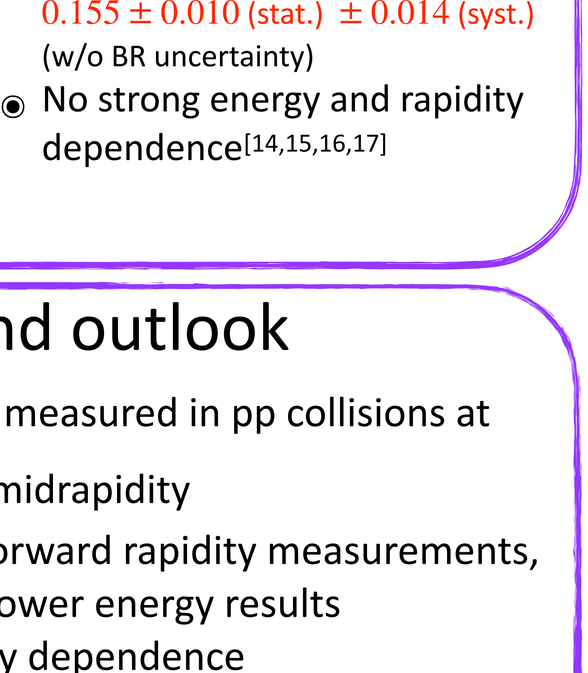
BR: branching ratio



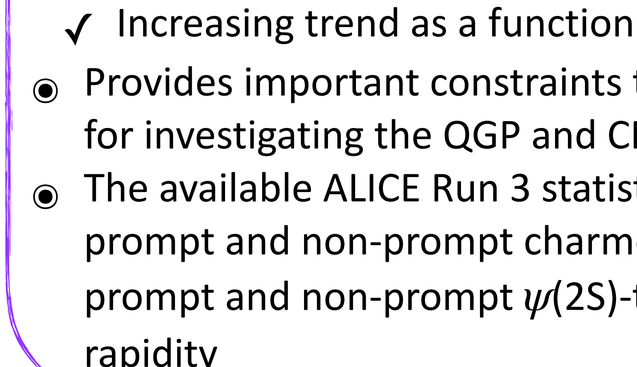


- Compatible results between mid (Run 2 and Run 3) and forward rapidity (Run 3)
- ALICE agrees with other experiments within uncertainties[5,6,7,8,9]. No strong energy dependence in the p_{T} dependence of the ratio
- Increasing trend as a function of p_{T}, which is also expected from models[10,11,12,13]





- NRQCD[11] which includes color-singlet and color-octet contributions can describe Run 2 measurements (left) within uncertainties, but tends to overestimate high-precision Run 3 data (right)
- ICEM[13] can reproduce the Run 3 measurements in the full p_{T} range (right)



- The p_{T} integrated yields ratio of ψ(2S) to J/ψ at 13.6 TeV: 0.155 ± 0.010 (stat.) ± 0.014 (syst.) (w/o BR uncertainty)
- No strong energy and rapidity dependence[14,15,16,17]

Summary and outlook

- The ψ(2S)-to-J/ψ yields ratio is measured in pp collisions at $\sqrt{s} = 13$ TeV and 13.6 TeV at midrapidity
  - ✓ Results are consistent with forward rapidity measurements, other LHC experiments and lower energy results
  - ✓ No strong energy and rapidity dependence
  - ✓ Increasing trend as a function of p_{T}
- Provides important constraints to QCD models and a reference for investigating the QGP and CNM
- The available ALICE Run 3 statistics will allow us to measure the prompt and non-prompt charmonia cross section as well as the prompt and non-prompt ψ(2S)-to-J/ψ ratio at mid and forward rapidity

[1] ALICE Collaboration, S. Acharya et al., Eur. Phys. J. C 83 (2023) 61.
[2] ALICE Collaboration: arXiv:2302.01238.
[3] ALICE TPC Collaboration: JINST 16 P03022 (2021).
[4] ALICE Collaboration: J. Phys. G 41 (2014) 087002.
[5] HERA-B Collaboration, I. Abt et al., Eur.Phys.J.C 49 (2007) 545-558.
[6] CMS Collaboration, S. Chatrchyan et al., JHEP 02 (2012) 011.
[7] CDF Collaboration, F. Abe et al., Phys.Rev.Lett. 79 (1997) 572-577.
[8] ATLAS Collaboration, G. Aad et al., Eur.Phys.J.C 76 (2016) 5, 283.
[9] STAR Collaboration, J. Adam et al., Phys. Rev. D 100 (2019) 052009.
[10] Y-Q. Ma et al., Phys.Rev.Lett. 106 (2011) 042002.
[11] M. Butenschoen et al., Phys.Rev.Lett. 106 (2011) 022003.
[12] Y-Q. Ma et al., Phys.Rev.D 94 (2016) 11, 114029.
[13] V.Cheung et al., PRD 98 (2018) 114029.
[14] LHCb Collaboration, R. Aaij et al., J. Phys. G 40 (2013) 045001.
[15] E705 Collaboration, L. Antoniazzi et al., Phys.Rev.Lett. 70 (1993) 383-386.
[16] PHENIX Collaboration, A. Adare et al., Phys. Rev. D 85 (2012) 092004.
[17] A.G. Clark et al., Nucl. Phys. B 142 (1978) 29.

LHCC poster session 27/11/2023