J/ψ+ψ(2S) cross section measurement

Lekai Yao* on behalf of the CMS group in Tsinghua University
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Introduction

- Quarkonium is a tool for investigation of new phenomena in particle physics.
- The production mechanism of heavy quarkonia is a long-standing and intriguing problem in quantum chromodynamics (QCD).
- An effective field theory, non-relativistic QCD (NRQCD), provides the foundation for much of the current theoretical work. The NRQCD calculations depend on the colour-singlet (CS) and colour-octet (CO) matrix elements.
- Leading order (LO) calculations in the CS model underestimates the observed cross-section for single J/ψ production at high pT[1,2]. Next leading order(NLO) calculations narrow the gap between the CS predictions and the experimental data [3,4].
- To resolve this discrepancy the CO mechanism was introduced[5,6]. But the CO mechanism fails to describe polarization[7,8].
- The production mechanism of quakonium can be probed via the measurement of J/ψ+ψ(2S) cross section.

Data samples & Event selections

- The full CMS Run II Charmonium datasets except 2017B dataset have been utilized for this study. The integral luminosity is 135 fb^{-1}.
- Trigger:
  - HLT_Dimuon0_Jpsi_Muon for 2016 data
  - HLT_Dimuon0_Jpsi3p5_Muon2 for 2017 & 2018 data
- Main selections for 4μ:
  - Fire corresponding trigger in each year;
  - $p_T(\mu)$>=3.5 GeV; $|\eta(\mu)|$<=2.4;
  - $p_T(\mu^+\mu^-)$>=10 GeV; $m_1(\mu^+\mu^-)$ in [2.7,3.5] GeV; $m_2(\mu^+\mu^-)$ in [3.3,4.1] GeV;
  - $\mu^+\mu^-$ vertex probability > 0.005.
- Multiple candidates treatment:
  - Select best combination of same 4μ with

$$\chi_m^2 = \left(\frac{m_1(\mu^+\mu^-) - M_{J/\psi}}{\sigma_{m_1}}\right)^2 + \left(\frac{m_2(\mu^+\mu^-) - M_{\psi(2S)}}{\sigma_{m_2}}\right)^2$$

- MC samples are produced by Pythia8.

Acceptance & Efficiency

- Specific acceptance is required for μ to reach the sensitive detectors, and efficiency is introduced by event reconstruction and selection.
- To extract the number of events produced by proton-proton collisions, acceptance and efficiency corrections are essential.
- The acceptance and efficiency corrections are applied event-by-event according to the maps obtained from MC samples.

$$A_{total} = A_{\eta(\mu)}(J/\psi) * A_{\eta(\mu)}(\psi(2S)) * A_{p_T(\mu)}(J/\psi) * A_{p_T(\mu)}(\psi(2S))$$

$$\epsilon_{total} = \epsilon_{RECO}(J/\psi) * \epsilon_{RECO}(\psi(2S)) * \epsilon_{ID}(J/\psi) * \epsilon_{ID}(\psi(2S)) * \epsilon_{\mu^+\mu^-}(J/\psi) * \epsilon_{\mu^+\mu^-}(\psi(2S)) * \epsilon_{HLT}(J/\psi) * \epsilon_{HLT}(\psi(2S)) * \epsilon_{\mu^+\mu^-\mu^+\mu^-}(J/\psi) * \epsilon_{\mu^+\mu^-\mu^+\mu^-}(\psi(2S))$$

$$W = 1/(A_{total} * \epsilon_{total})$$

Prefit

- 2D fit to MC signal samples and sideband fit are used to fix several parameters.
- Components for 4D fit:

$$M(\psi(2S)) * M(J/\psi) * CT(p1) * CT(p2)$$
$$M(\psi(2S)) * M(J/\psi) * CT(p1) * CT(np2)$$
$$M(\psi(2S)) * M(J/\psi) * CT(np1) * CT(p2)$$
$$M(\psi(2S)) * M(J/\psi) * CT(np1) * CT(np2)$$
$$M(\psi(2S)) * M(J/\psi - comb) * CT(\psi(2S)) * CT(J/\psi - comb)$$
$$M(\psi(2S) - comb) * M(J/\psi) * CT(\psi(2S) - comb) * CT(J/\psi)$$
$$M(\psi(2S) - comb) * M(J/\psi - comb) * CT(\psi(2S) - comb) * CT(J/\psi - comb)$$

Side band fit:
(1)1D fit to cτ(J/ψ) in 1,2,3,7,8,9
(2)1D fit to cτ(J/ψ) in 1,4,7,3,6,9
(3)2D fit to cτ(J/ψ) and m(J/ψ) in 1-9

(4)1D fit to cτ(ψ(2S)) in 1,4,7,3,6,9
(5)1D fit to cτ(ψ(2S)) in 1,2,3,7,8,9
(6)2D fit to cτ(ψ(2S)) and m(ψ(2S)) in 1-9

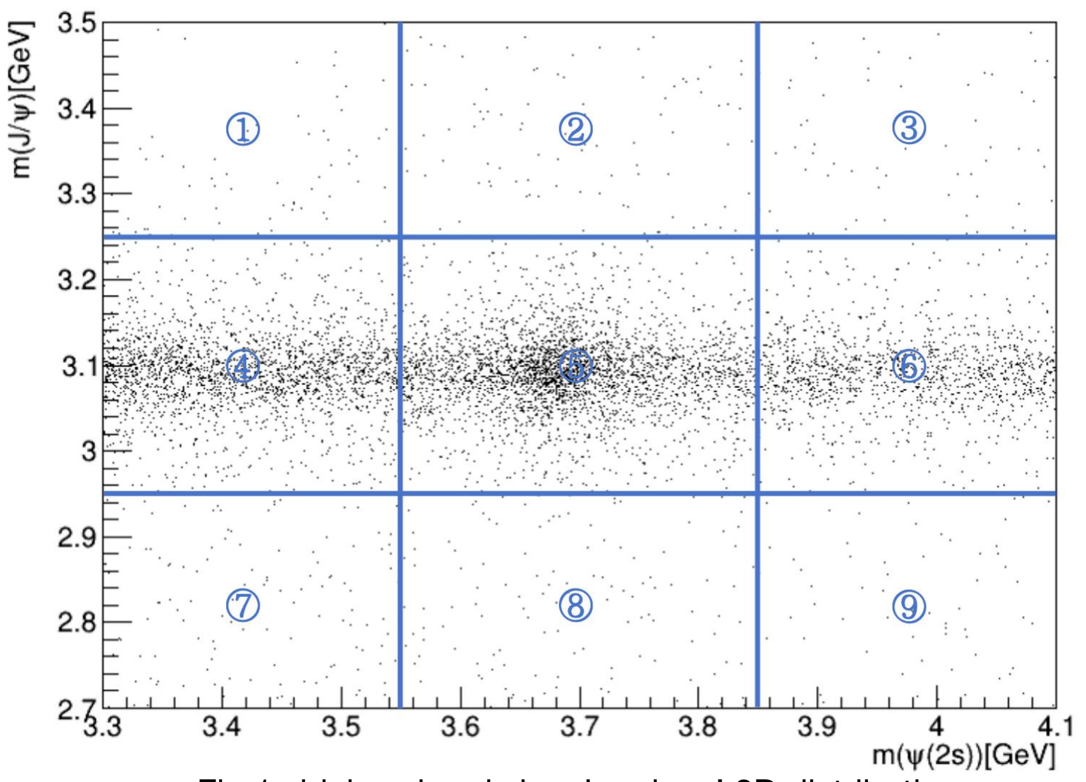

Fig.1 sideband and signal regions' 2D distribution

Fit result

- With some parameters fixed by prefit above, the 4D fit result with event-bu-event correction:

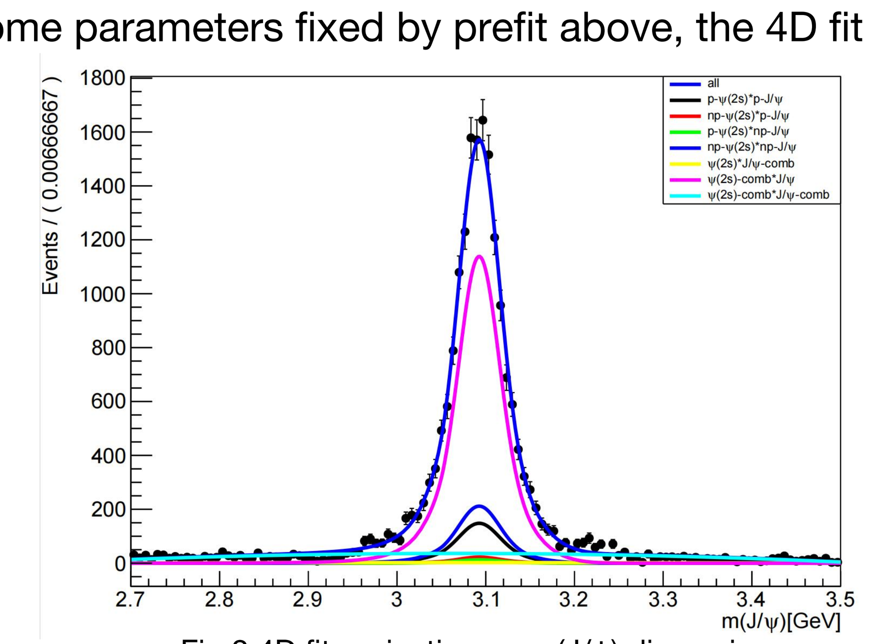

Fig.2 4D fit projection on m(J/ψ) dimension

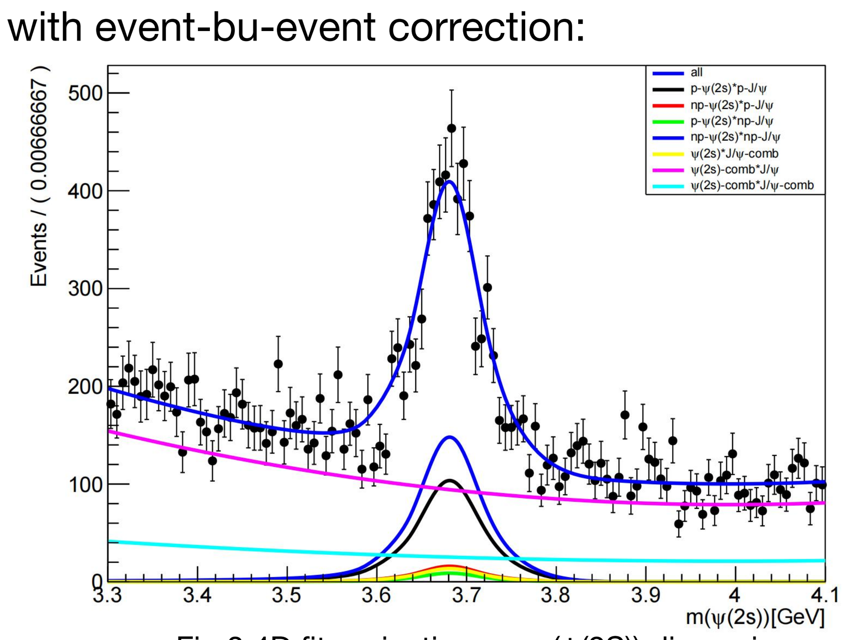

Fig.3 4D fit projection on m(ψ(2S)) dimension

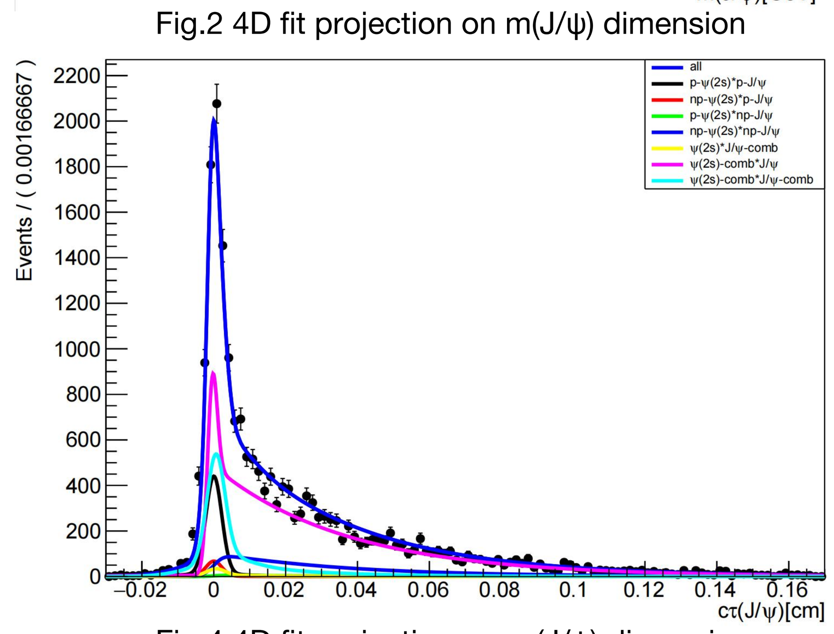

Fig.4 4D fit projection on cτ(J/ψ) dimension

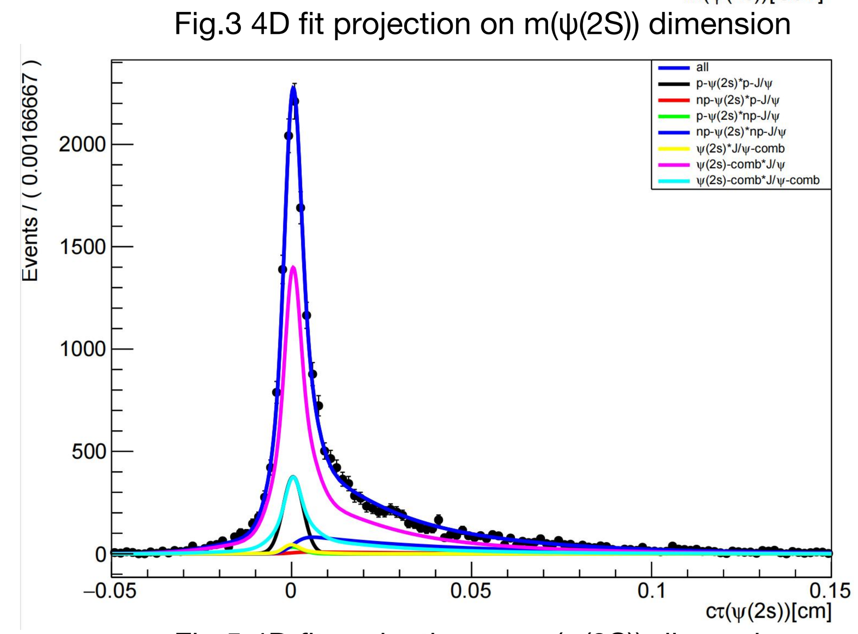

Fig.5 4D fit projection on cτ(ψ(2S)) dimension

Summary

We made a rough measurement of J/ψ+ψ(2S) inclusive cross section and differential cross section on m(J/ψ+ψ(2S)) using 135 fb^{-1} 13 TeV data.

The inclusive cross section $\sigma = 24.5 \pm 2.1$ pb.

Outlook:
- More accurate calculation of acceptance and efficiency;
- Detailed study about the systematic errors;
- Possibility to distinguish SPS and DPS components.

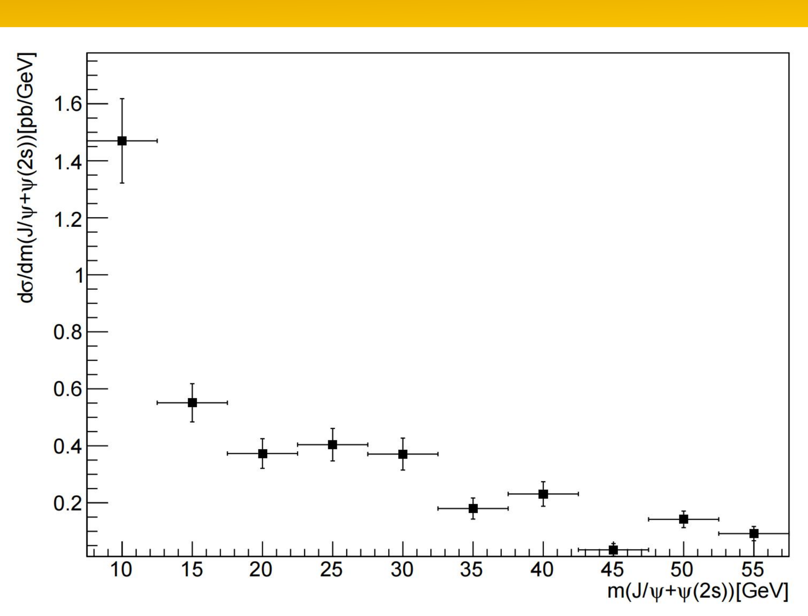

Fig.6 differential cross section on m(J/ψ+ψ(2S)), mass region is [7.5GeV,57.5GeV] with a width of 5 GeV

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*lekai.yao@cern.ch