Inclusive J/ψ pair production cross section measurement

Muhammad Ahmad[1], Gerry Bauer[1], Zhen Hu[1], Ozgun Kara[3], Hongbo Liao[2], Zhengchen liang[1], Jinfeng Liu[1], Kai Yi[1,4], Taozhe Yu[2], Yuan Yuan[1], Shunliang Zhang[1,5]

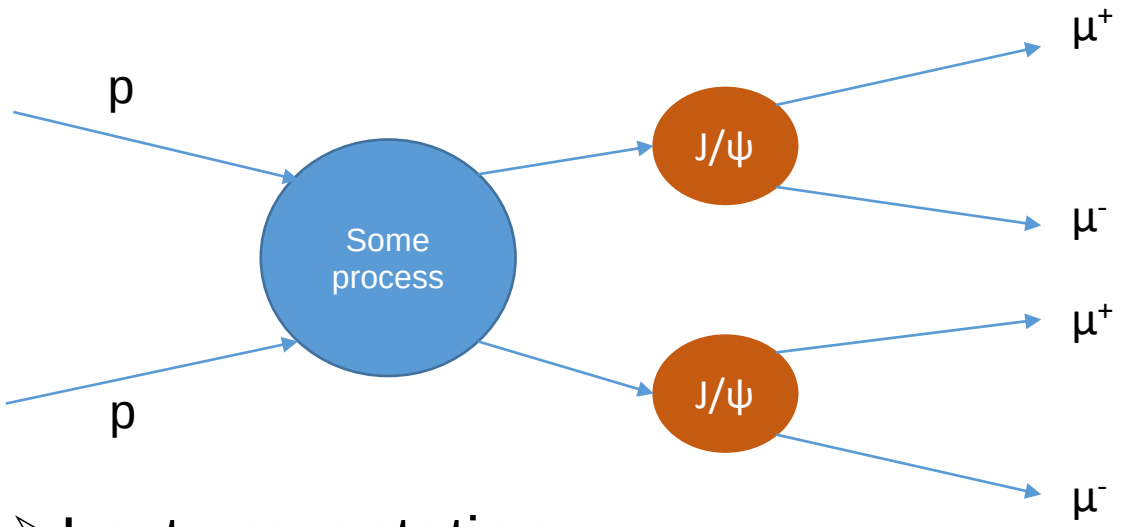
P&P meeting

2022.9.22

1.Tsinghua University, China
2.Institute of High Energy Physics, China
3.Cukurova University, Turkey
4.Nanjing Normal University, China

Introduction

- Measure the inclusive J/ψ pair production cross section using all Run2 data in CMS



$$\sigma_{fid} = \frac{N_{events}}{\varepsilon \mathcal{L} \mathcal{B}^2(J/\psi \to \mu^+\mu^-)}$$

$$\varepsilon = acceptance \times Eff_{\mu_{RECO}} \times Eff_{\mu_{ID}} \times Eff_{\mu^+\mu^-} \times Eff_{HLT} \times Eff_{\mu^+\mu^-\mu^+\mu^-}$$

- Last presentation
  - We calculated the acceptance and a list of reconstructed efficiencies
  - We do closure test for the acceptance and efficiencies
- This presentation
  - Study the variable which can distinguish prompt and non-prompt J/ψ
  - Make the strategy to extract the prompt J/ψ pair

Object and event selection

➢Trigger

HLT_Dimuon0_Jpsi_Muon

➢Muon

- Standard Soft muon ID
- pT(muon)>=3.5GeV
- |η(muon)|<=2.4
- Do the match with Gen muon
  - DeltaR(Gen muon, RECO muon)<0.03

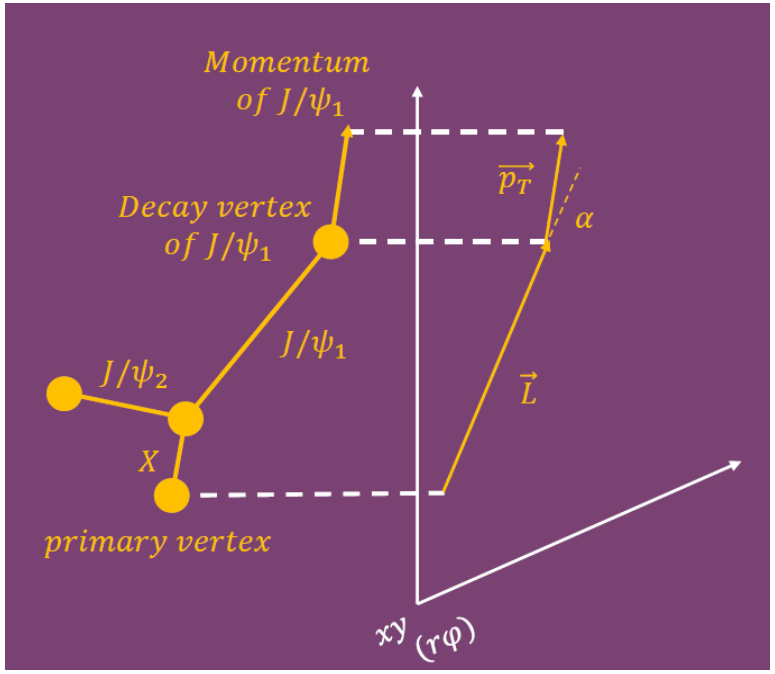
➢J/ψ

- The J/ψ was reconstructed by two opposite sign muon
- The vertex probability of the 2 muons associated to the J/ψ is greater than 0.5%
- 2.95<m(dimuon)<3.25GeV

➢J/ψ Pair

- The vertex probability of the 4 muons is greater than 1%
- J/ψ1(muon12) and J/ψ2(muon34) do not share a common muon

Variable to distinguish prompt and non-prompt J/ψ



The L_{xy} is calculated as $L_{xy}(J/\psi) = \vec{L} \cdot \vec{p}_T(J/\psi)/|p_T(J/\psi)|$

- $\vec{L}$ is the vector from the primary vertex to the J/ψ decay vertex in the $r-\phi$ plane
- $\vec{p}_T(J/\psi)$ is the transverse momentum vector

To reduce the dependence on J/ψ transverse momentum bin size and placement, a new variable $c\tau$, called pseudoproper decay time, is used instead of L_{xy} :

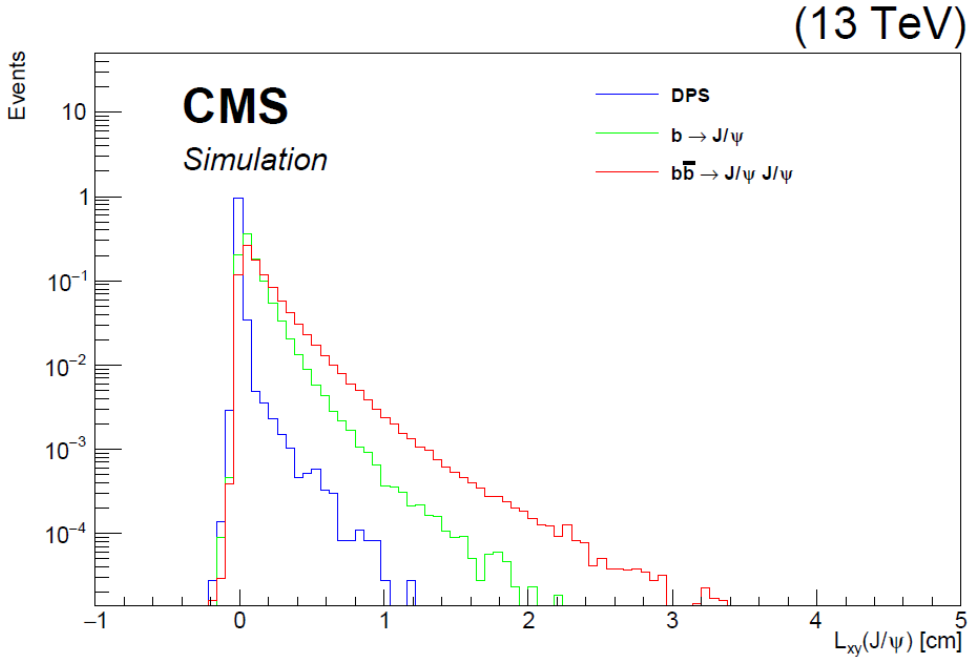
$$c\tau = L_{xy}(J/\psi) \cdot M(J/\psi)/p_T(J/\psi)$$

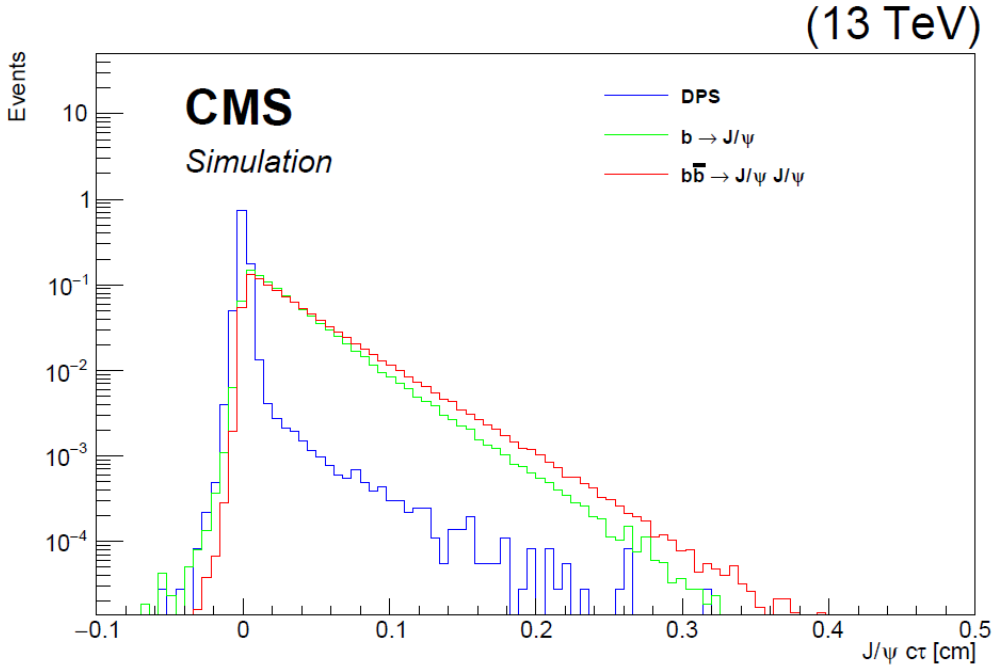
- L_{xy} or $c\tau$ can be the variable to distinguish prompt and non-prompt J/ψ
- Using the official sample B meson ->J/ψ+x and private DPS and $b\bar{b}$ -> J/ψ J/ψ + X sample to compare J/ψ L_{xy} and $c\tau$ distribution:

Prompt/Non-prompt sample		Sample
Non-prompt sample	B meson -> J/ψ + X	/BsToJPsiPhi_JPsiToMuMu_PhiToKK_SoftQCDnonD_TuneCP5_13TeV-pythia8-evtgen/RunIISummer20UL18RECO-106X_upgrade2018_realistic_v11_L1v1-v2/AODSIM
	bbbar -> J/ψ J/ψ + X	/Pythia8_BBartoJJ/jinfeng-MC2018_SKIM_JinfengLiu_bDecay-2c13f6522fd88ab3fbb3f545dbe011e8/USER
Prompt sample	DPS	/Pythia8_DPStoJJ/jiayis-MC2018_SKIM_JinfengLiu_v2-1631c8025908d8822669ac074a24ab90/USER

Variable distribution without Four mu vertex cut

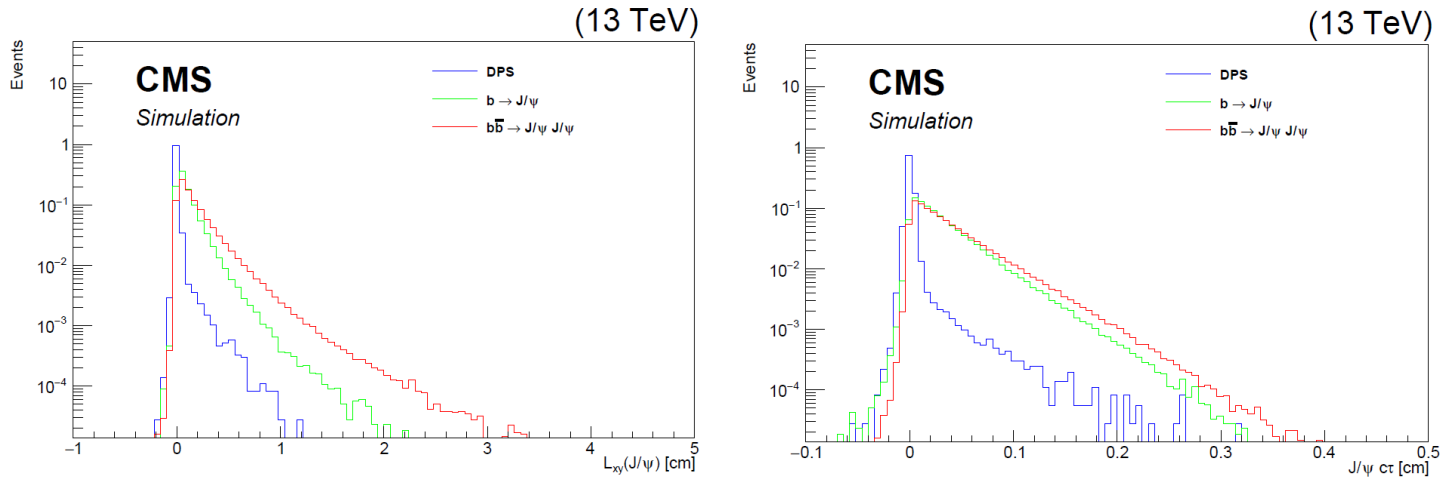
No Four muon vertex cut



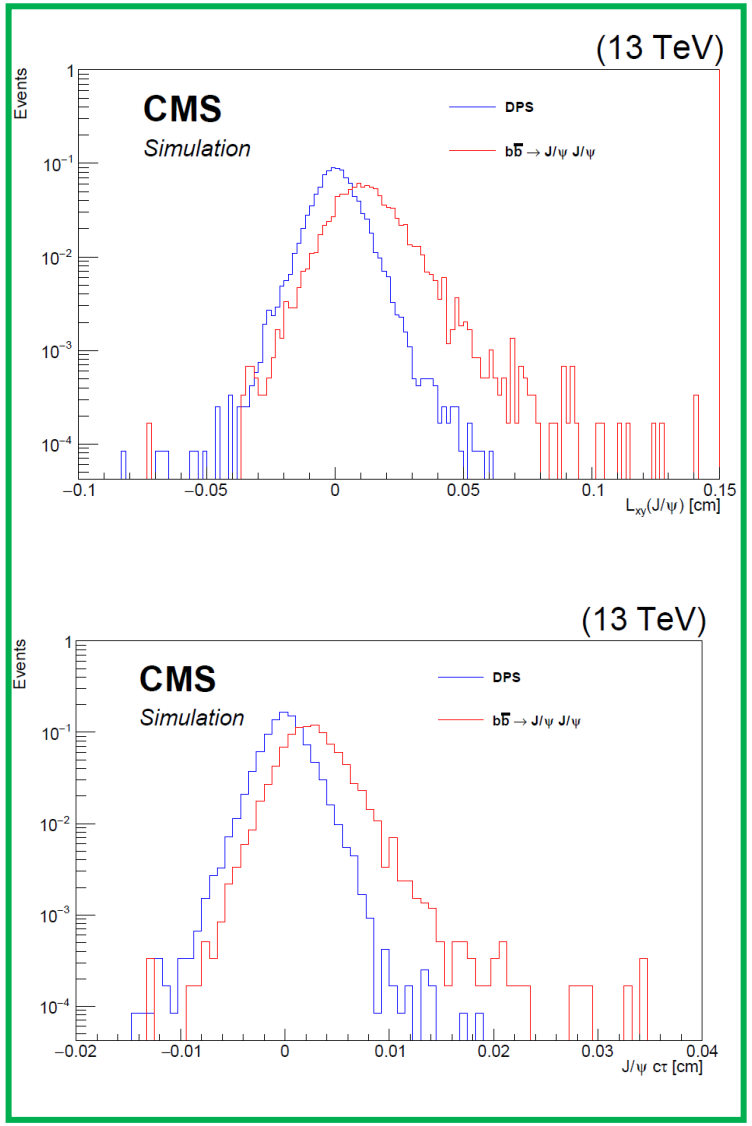


- We plot L_{xy} or $c\tau$ distribution without the four muon vertex cut
  - All sample event number normalize to 1
  - Non-prompt sample's tail is longer than prompt sample's
- The official B meson ->J/ψ+x sample have a similar distribution with private $b\bar{b}$ -> J/ψ J/ψ + X sample, that validities our private sample

Variable distribution with Four mu vertex cut



Add Four muon vertex probability cut



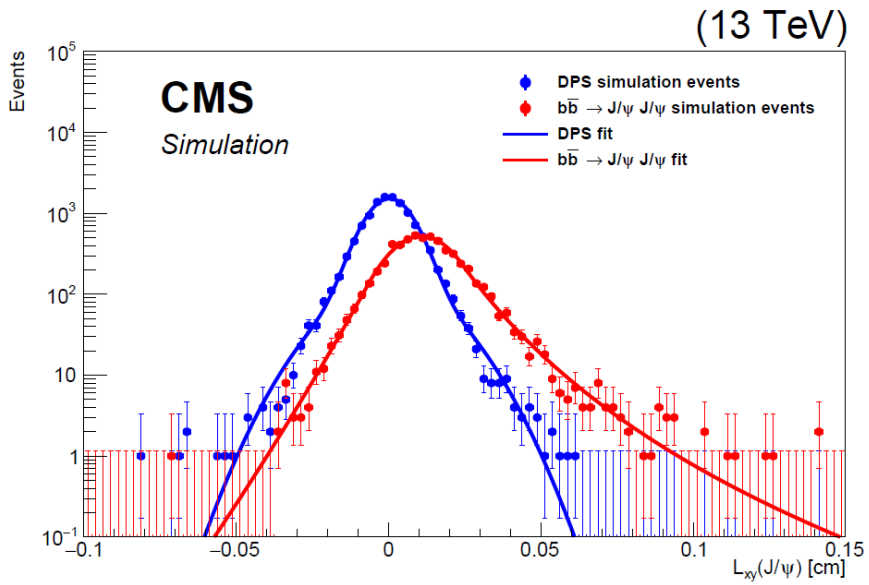
- Show the L_{xy} or $c\tau$ distribution applied the four mu vertex cut
  - The B ->J/ψ+x event disappear
  - Long distance component highly depressed by the vertex requirement
- The prompt and non-prompt distribution are different
  - The mean value are different
  - Prompt shape is symmetry around 0
  - Non-prompt shape have a little “tail”

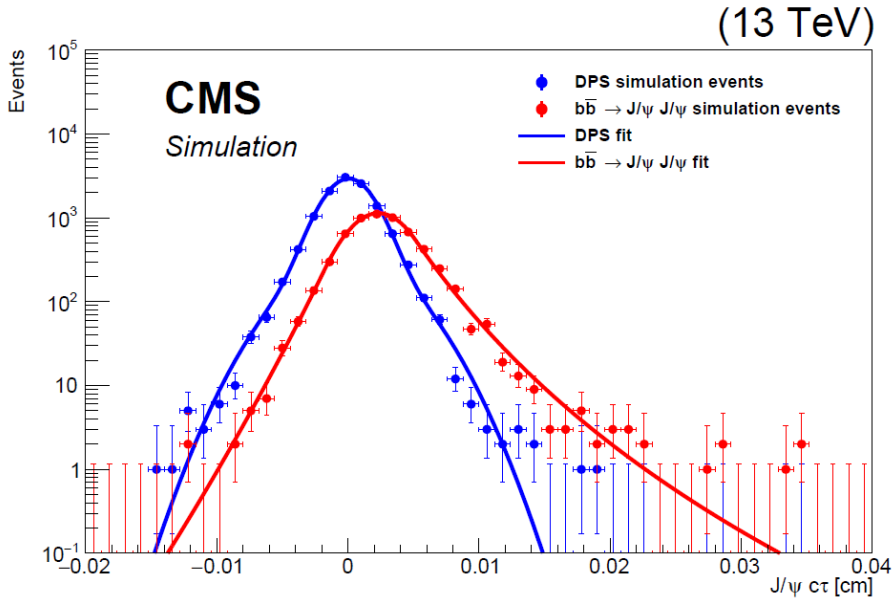
Fit the prompt and non-prompt Double J/ψ

- Using double Gauss function to fit prompt sample
  - The two gauss function mean are same and width are different

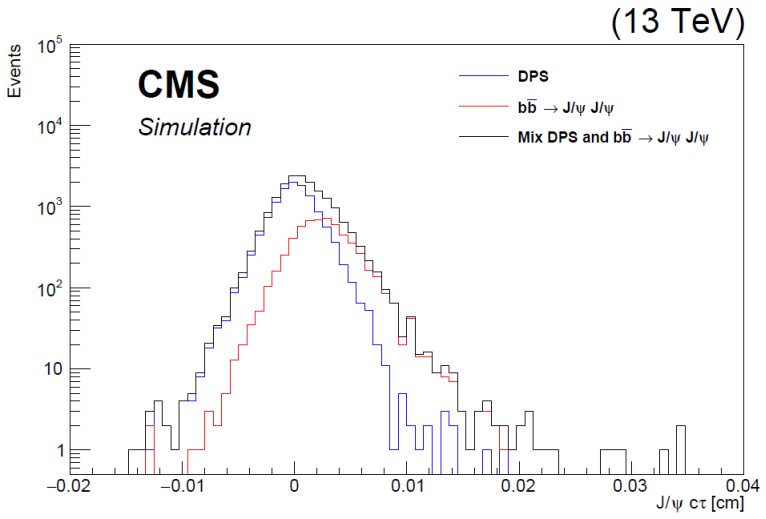
- Using double-sided Crystal Ball (DSCB) function to fit non-prompt sample

$$f_S(x;\vec{\theta}) = \begin{cases} \left(\frac{n_L}{|\alpha_L|}\right)^{n_L} \exp\left(\frac{-|\alpha_L|^2}{2}\right)\left(\frac{n_L}{|\alpha_L|} - |\alpha_L| - \frac{x-\mu}{\sigma}\right)^{-n_L}, & \text{for } \frac{x-\mu}{\sigma} \leq -\alpha_L \\ \exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right), & \text{for } -\alpha_L < \frac{x-\mu}{\sigma} < \alpha_R \\ \left(\frac{n_R}{|\alpha_R|}\right)^{n_R} \exp\left(\frac{-|\alpha_R|^2}{2}\right)\left(\frac{n_R}{|\alpha_R|} - |\alpha_R| + \frac{x-\mu}{\sigma}\right)^{-n_R}, & \text{for } \frac{x-\mu}{\sigma} \geq \alpha_R, \end{cases}$$

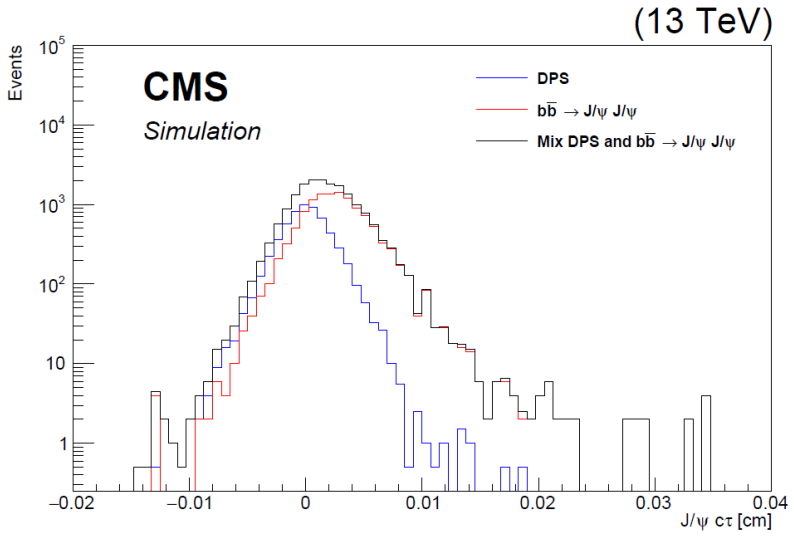




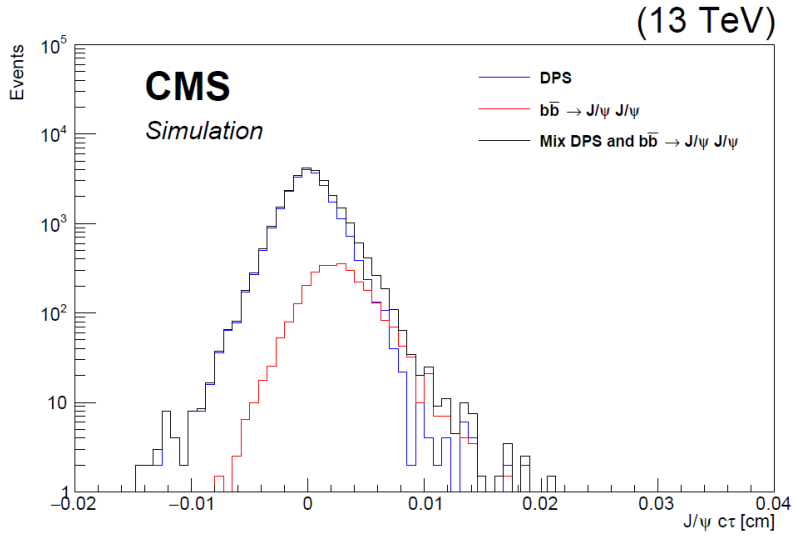
Closure test (1)



DPS + $b\bar{b}$ → J/ψ J/ψ



0.5*DPS + 2* $b\bar{b}$ → J/ψ J/ψ

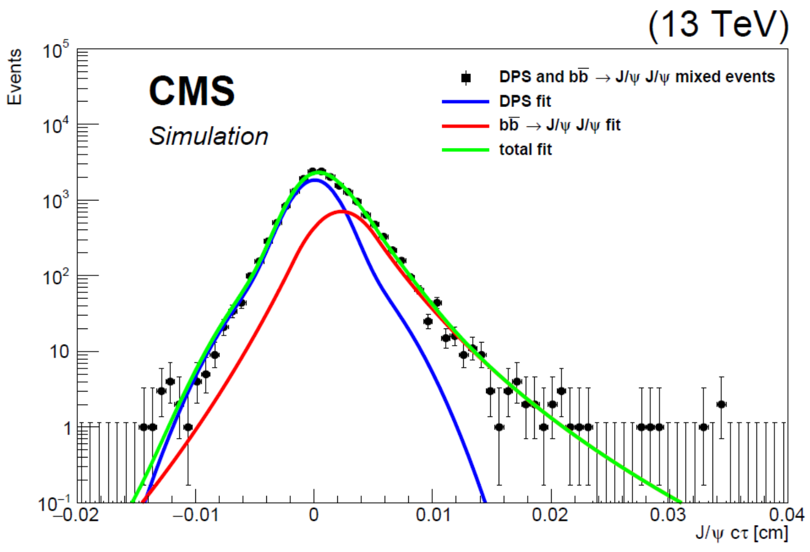


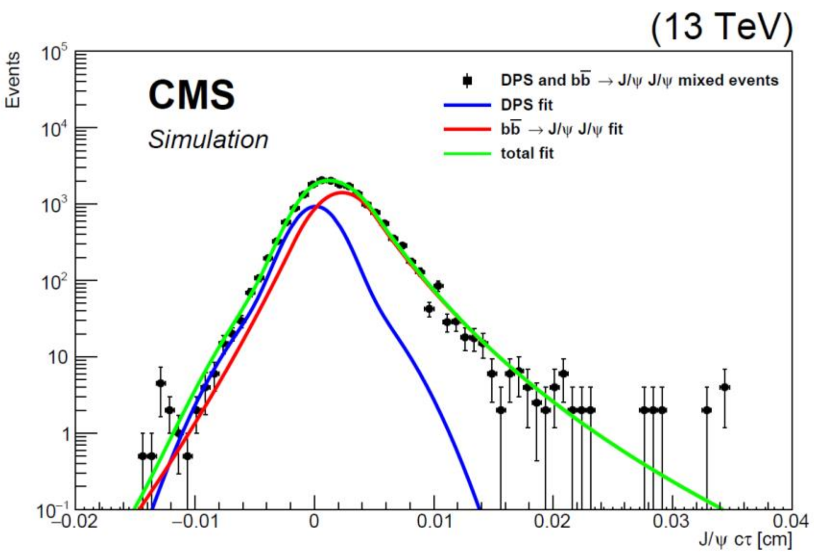
2*DPS + 0.5* $b\bar{b}$ → J/ψ J/ψ

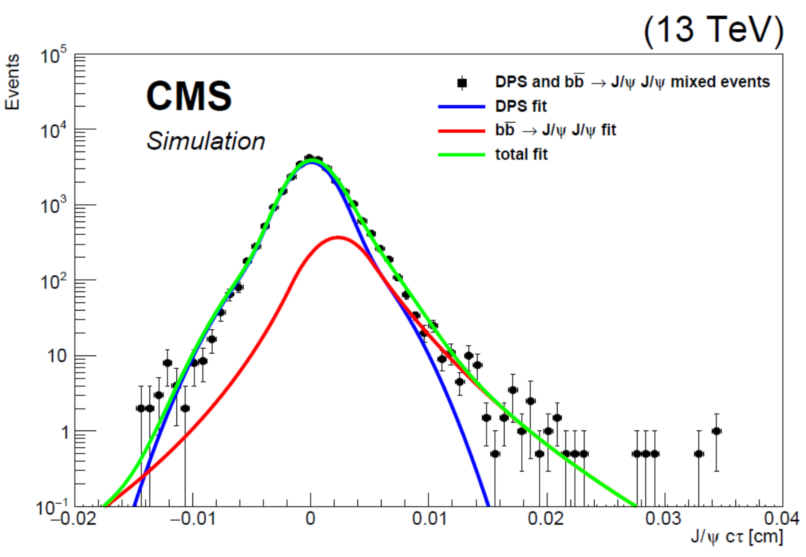
	DPS	$b\bar{b}$-> J/ψ J/ψ	total	DPS fraction
DPS + $b\bar{b}$-> J/ψ J/ψ	11970	5955	17925	0.668
0.5*DPS + 2*$b\bar{b}$-> J/ψ J/ψ	5985	11910	17895	0.334
2*DPS + 0.5*$b\bar{b}$-> J/ψ J/ψ	23940	2977.5	26917.5	0.889

- We mix the DPS and $b\bar{b}$-> J/ψ J/ψ histogram in some fraction to do closure test.
- We will use the function to fit mixed histogram to see if we can extract the DPS sample

Closure test (2)







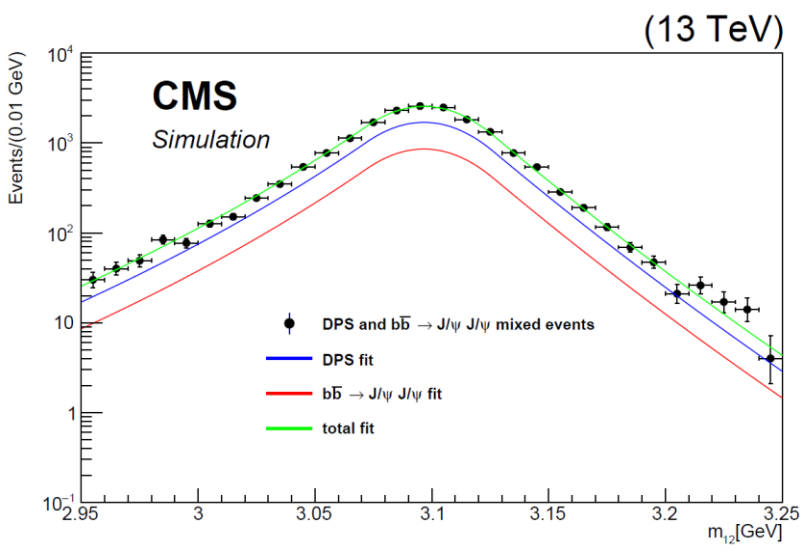
	total	DPS fraction	DPS number
DPS + $b\bar{b}$-> J/ψ J/ψ	17925	0.67 ± 0.01	12000.9 ±178.4
0.5*DPS + 2*$b\bar{b}$-> J/ψ J/ψ	17895	0.34 ± 0.01	6073.5±197.5
2*DPS + 0.5*$b\bar{b}$-> J/ψ J/ψ	26917.5	0.88 ± 0.03	23812±792

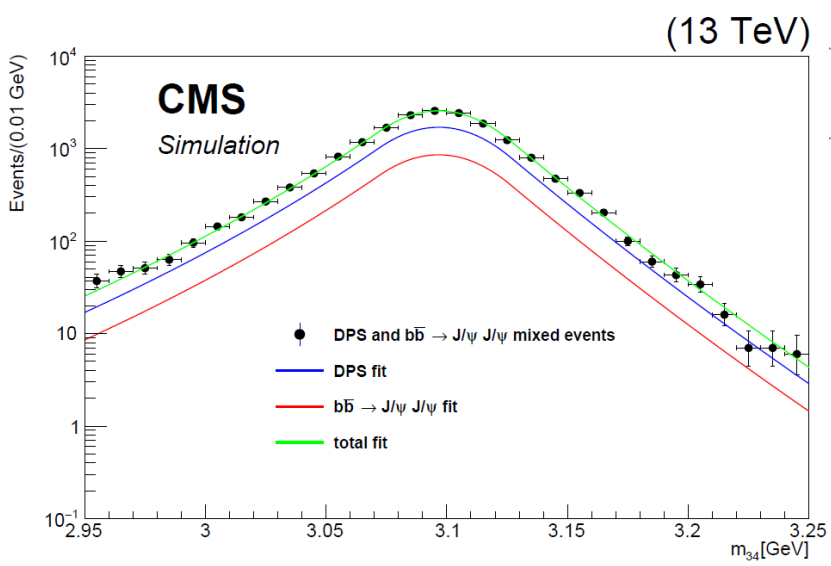
- We fix some parameters to fit the mixed histograms
  - Prompt sample: mean and width
  - Non-prompt sample: mean, width and alpha
- The DPS shape and number of events satisfy our expected

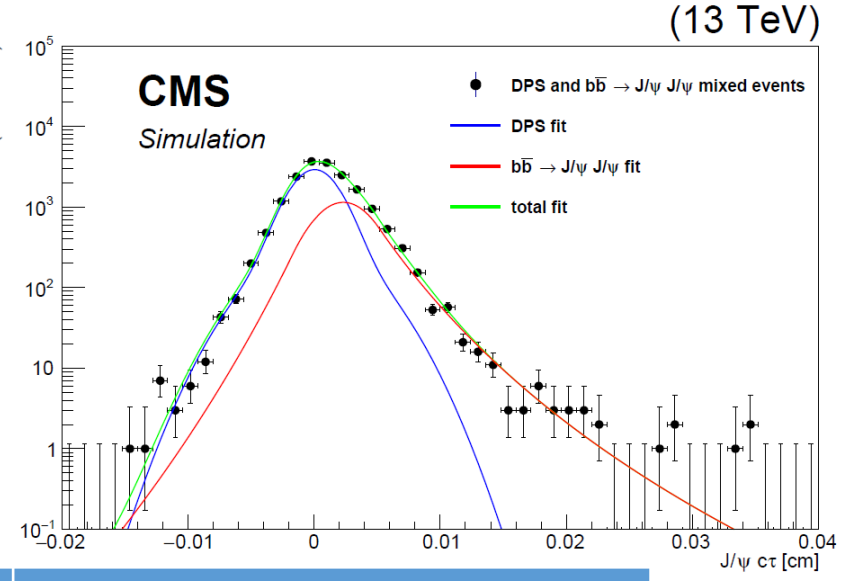
3D Fit closure test

- We will use 3D fit(invariant mass of J/ψ1 and J/ψ2, $c\tau$) to extract prompt J/ψ pair events in our analysis
  - The J/ψ1, J/ψ2 mass dimension can distinguish J/ψ and combinatorial background
  - The $c\tau$ dimension can distinguish prompt and non-prompt J/ψ

- In this 3D closure test, we just fix the DPS and $b\bar{b}$-> J/ψ J/ψ sample to see if we can extract prompt J/ψ events in the third dimension $c\tau$
  - We use double-sided Crystal Ball (DSCB) function to fit J/ψ1, J/ψ2 mass







	total	DPS fraction	DPS number
DPS + $b\bar{b}$-> J/ψ J/ψ	17925	0.66± 0.01	11916.4 ±178.1

Summary

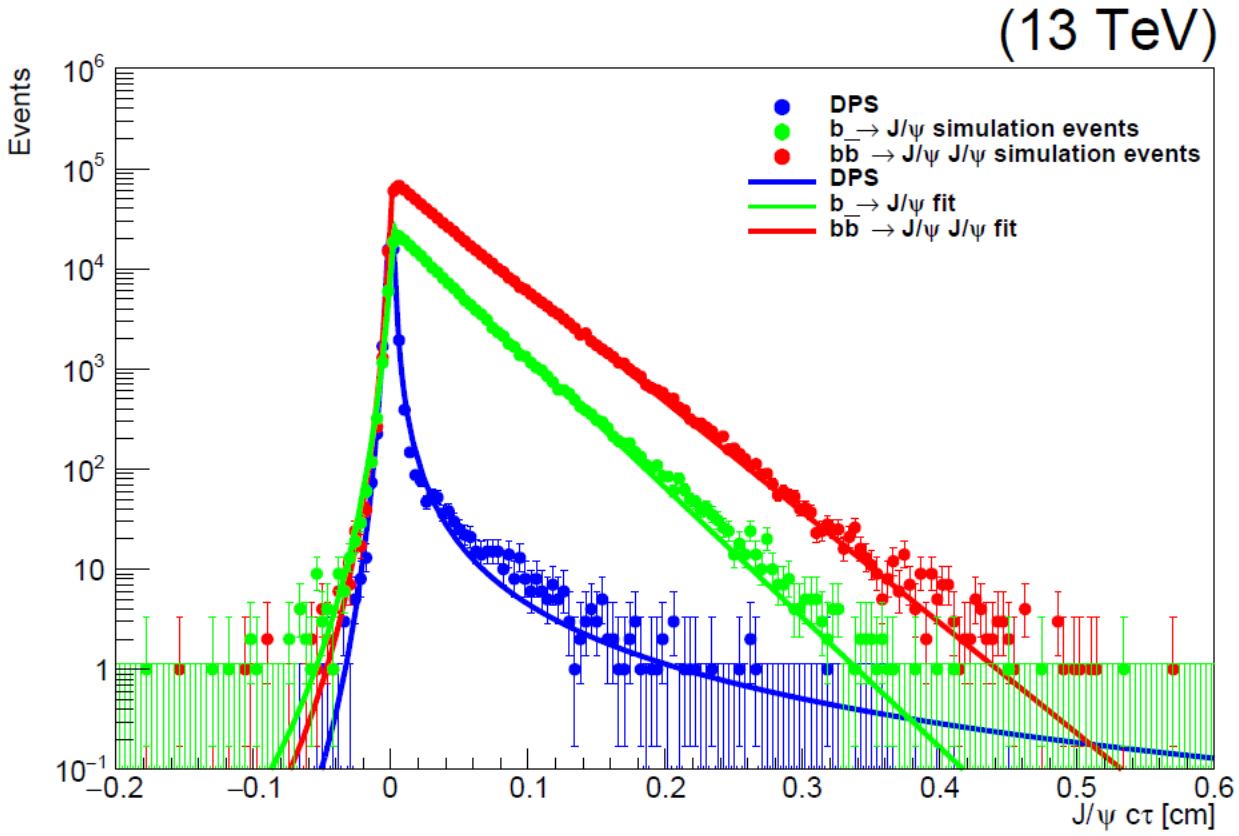
- L_{xy} or $c\tau$ can be the variable to distinguish prompt and non-prompt J/ψ
- Fit the L_{xy} and $c\tau$ distribution of prompt and non-prompt J/ψ
- Use 1D and 3D fit to do the closure test

➢Next step

- Using the data to do 3D fit to extract prompt J/ψ

backup

Ctau fit without four muon vertex cut



- B meson ->J/ψ+x and $b\bar{b}$-> J/ψ J/ψ use the function to fit

double-sided Crystal Ball (DSCB) function and exponential function convolution