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Double Jpsi



	Phase space	Single Jpsi cross section	Double Jpsi cross section	Effective cross section
CMS group	Jpsi: $pt > 20 \text{ GeV}$, $ y < 1.2$, Muon: $pt > 4 \text{ GeV}$, $ y < 1.4$	4061.2pb	0.80pb DPS fraction: ?, <10%	?
Our measure	Jpsi: $pt > 20 \text{ GeV}$, $ y < 1.2$, Muon: $pt > 3.5 \text{ GeV}$, $ y < 1.4$	13171.8pb	$1.39 \pm 0.22 \text{ pb}$ DPS fraction: ? <10%	?
CMS group	Jpsi: $pt > 10 \text{ GeV}$, $ y < 1.2$ Muon: $pt > 4 \text{ GeV}$, $ y < 1.4$	110030.02pb	23.11pb DPS fraction: 0.59	0.44mb
Our measurement	Jpsi: $pt > 10 \text{ GeV}$, $ y < 1.2$ Muon: $pt > 3.5 \text{ GeV}$, $ y < 1.4$	80510pb	30.8pb DPS fraction: 0.64	0.164mb



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Phase space: J_{ψ} : $p_t > 20 \text{ GeV}$, $|y| < 1.2$,
Muon: $p_t > 4 \text{ GeV}$, $|y| < 1.4$

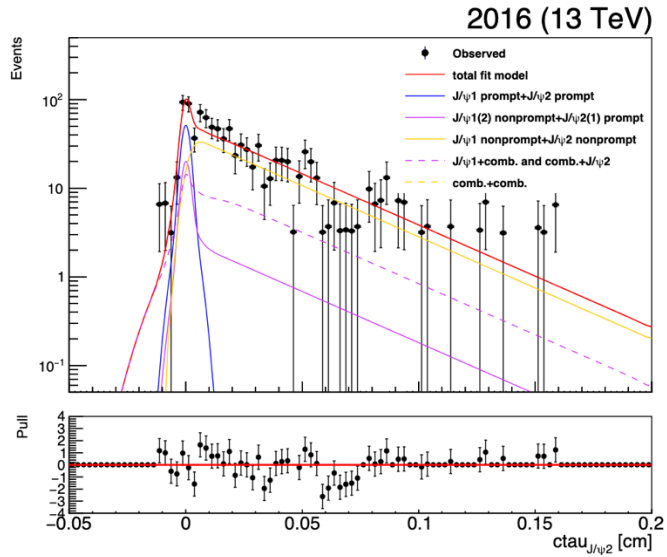
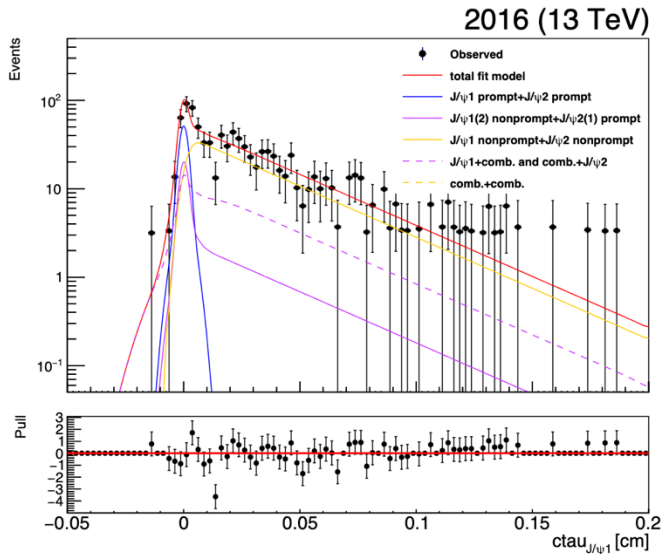
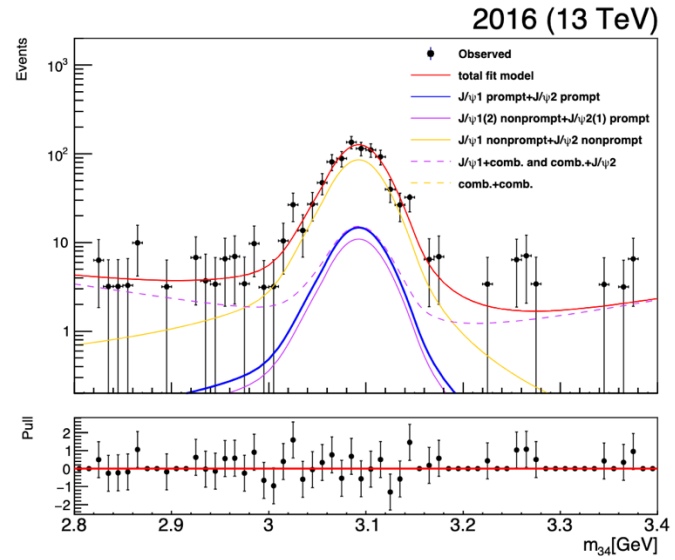
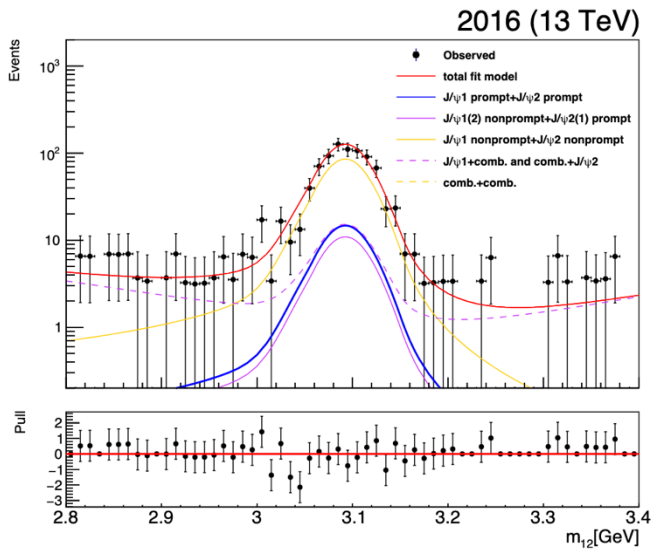


- Use other CMS single Jpsi result to calculate effective cross section
- Phase space: Jpsi: $p_T > 20 \text{ GeV}$, $|y| < 1.2$, Muon: $p_T > 4 \text{ GeV}$, $|y| < 1.4$

p_T [GeV]	$\langle p_T \rangle$ [GeV]	$B d\sigma^2/dp_T dy$														
		$ y < 0.3$			$0.3 < y < 0.6$			$0.6 < y < 0.9$			$0.9 < y < 1.2$			$ y < 1.2$		
		[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %
20-21	20.5	4.68E+01	1.7	5.3	4.63E+01	1.3	4.6	4.47E+01	1.2	4.5	4.51E+01	1.3	4.6	4.58E+01	0.7	4.6
21-22	21.5	3.52E+01	1.3	5.4	3.65E+01	1.2	4.8	3.52E+01	1.2	4.6	3.42E+01	1.3	4.8	3.53E+01	0.6	4.8
22-23	22.5	2.72E+01	1.4	5.2	2.80E+01	1.3	4.5	2.75E+01	1.3	4.4	2.69E+01	1.3	4.6	2.74E+01	0.7	4.6
23-24	23.5	2.14E+01	1.5	5.0	2.25E+01	1.4	4.5	2.18E+01	1.4	4.3	2.12E+01	1.5	4.4	2.18E+01	0.7	4.5
24-25	24.5	1.80E+01	1.6	5.0	1.81E+01	1.5	4.5	1.76E+01	1.5	4.3	1.66E+01	1.6	4.5	1.76E+01	0.8	4.5
25-26	25.5	1.46E+01	1.8	5.0	1.50E+01	1.7	4.5	1.38E+01	1.7	4.3	1.39E+01	1.8	4.5	1.43E+01	0.9	4.5
26-27	26.5	1.21E+01	1.9	5.1	1.22E+01	1.8	4.4	1.13E+01	1.9	4.3	1.11E+01	1.9	4.5	1.17E+01	0.9	4.5
27-28	27.5	1.00E+01	2.1	5.0	1.00E+01	2.0	4.4	9.76E+00	2.0	4.3	9.17E+00	2.1	4.5	9.75E+00	1.0	4.5
28-29	28.5	8.14E+00	2.3	5.1	8.31E+00	2.2	4.5	7.88E+00	2.2	4.3	7.67E+00	2.3	4.5	7.99E+00	1.1	4.5
29-30	29.5	6.68E+00	2.5	5.2	6.92E+00	2.4	4.5	6.78E+00	2.4	4.4	6.39E+00	2.5	4.6	6.70E+00	1.2	4.5
30-32	31.0	5.47E+00	1.9	5.2	5.44E+00	1.9	4.5	5.03E+00	1.9	4.3	4.91E+00	2.0	4.6	5.20E+00	1.0	4.6
32-34	33.0	3.84E+00	2.3	5.4	3.84E+00	2.2	4.6	3.72E+00	2.2	4.4	3.50E+00	2.3	4.8	3.72E+00	1.1	4.7
34-36	35.0	2.78E+00	2.7	5.7	2.84E+00	2.5	4.9	2.76E+00	2.5	4.9	2.62E+00	2.7	5.1	2.75E+00	1.3	5.0
36-38	37.0	2.12E+00	3.1	6.2	2.03E+00	2.9	5.4	2.02E+00	3.0	5.3	1.85E+00	3.1	5.6	2.00E+00	1.5	5.5
38-42	39.8	1.45E+00	2.6	6.4	1.40E+00	2.5	5.7	1.39E+00	2.5	5.6	1.33E+00	2.6	5.9	1.39E+00	1.3	5.8
42-46	43.8	8.33E-01	3.3	6.9	8.33E-01	3.2	6.1	7.74E-01	3.3	5.9	7.47E-01	3.4	6.5	7.96E-01	1.7	6.2
46-50	47.8	5.34E-01	4.2	7.0	5.48E-01	4.0	6.1	4.96E-01	4.2	6.1	4.54E-01	4.5	6.7	5.08E-01	2.1	6.3
50-60	54.2	2.79E-01	3.7	7.8	2.74E-01	3.5	7.1	2.49E-01	3.7	7.1	2.14E-01	4.1	7.7	2.54E-01	1.9	7.2
60-75	66.0	8.96E-02	5.4	8.0	9.05E-02	5.0	6.9	8.23E-02	5.6	6.9	6.64E-02	6.2	8.2	8.28E-02	2.7	7.3
75-95	82.7	2.54E-02	9.0	7.7	2.62E-02	8.5	6.4	2.37E-02	8.7	6.4	2.03E-02	9.6	7.6	2.39E-02	4.4	6.3
95-120	104.7	8.37E-03	15	8.3	8.56E-03	15	8.2	7.16E-03	15	7.3	5.61E-03	19	9.1	7.42E-03	7.7	7.9
120-150	131.1													1.53E-03	17	7.9

$$45.8 + 35.3 + 27.4 + 21.8 + 17.6 + 14.3 + 11.7 + 9.75 + 7.99 + 6.70 + 5.20 * 2 + 3.72 * 2 + 2.75 * 2 + 2.00 * 2 + 1.39 * 4 + 0.796 * 4 + 0.508 * 4 + 0.254 * 10 + 0.0828 * 15 + 0.0239 * 15 + 0.00742 * 25 + 0.00153 * 30 = 240.8279 \text{ pb}$$

$$240.8279 \text{ pb} / 0.0593 = 4061.2 \text{ pb}$$



Phase space: J/ψ : $pt > 20 \text{ GeV}$, $|y| < 1.2$
 Muon: $pt > 4 \text{ GeV}$, $|y| < 1.4$

Double J/ψ cross section : 0.80 pb



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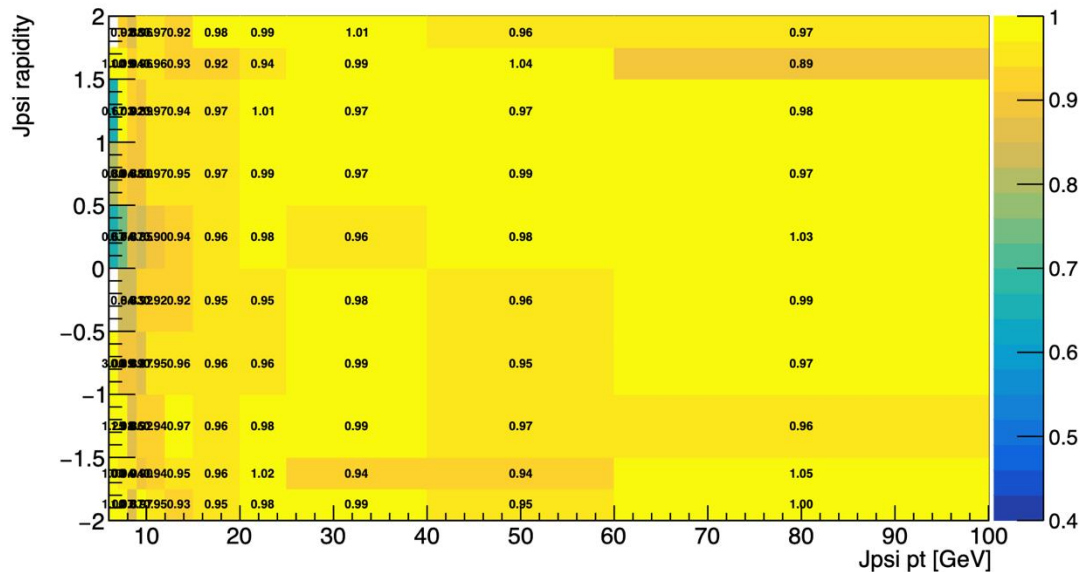
Phase space: Jpsi: $p_t > 20 \text{ GeV}$, $|y| < 2$
Muon: $p_t > 3.5 \text{ GeV}$, $|y| < 2.4$



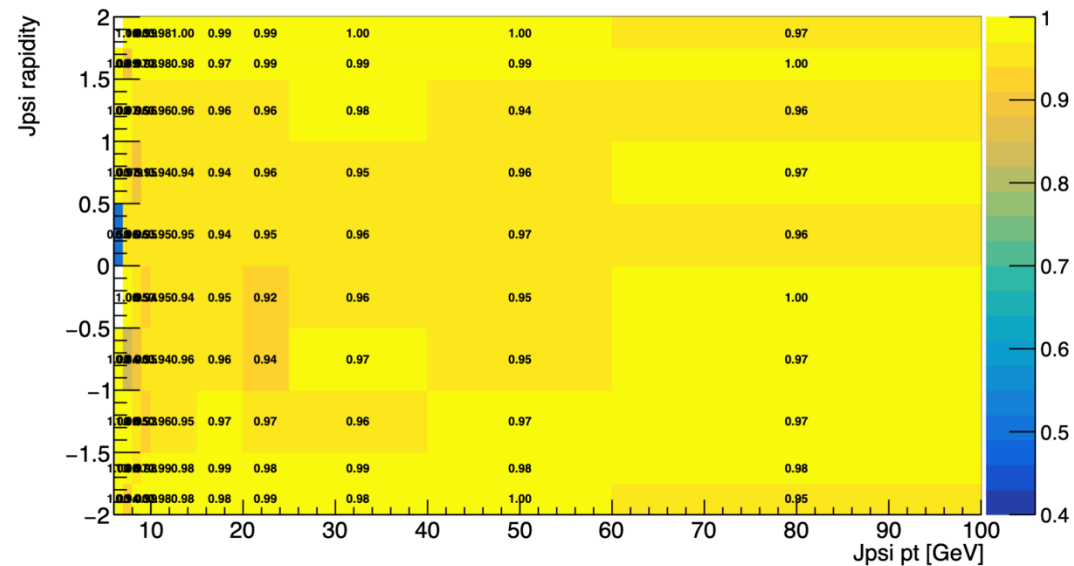
Efficiencies



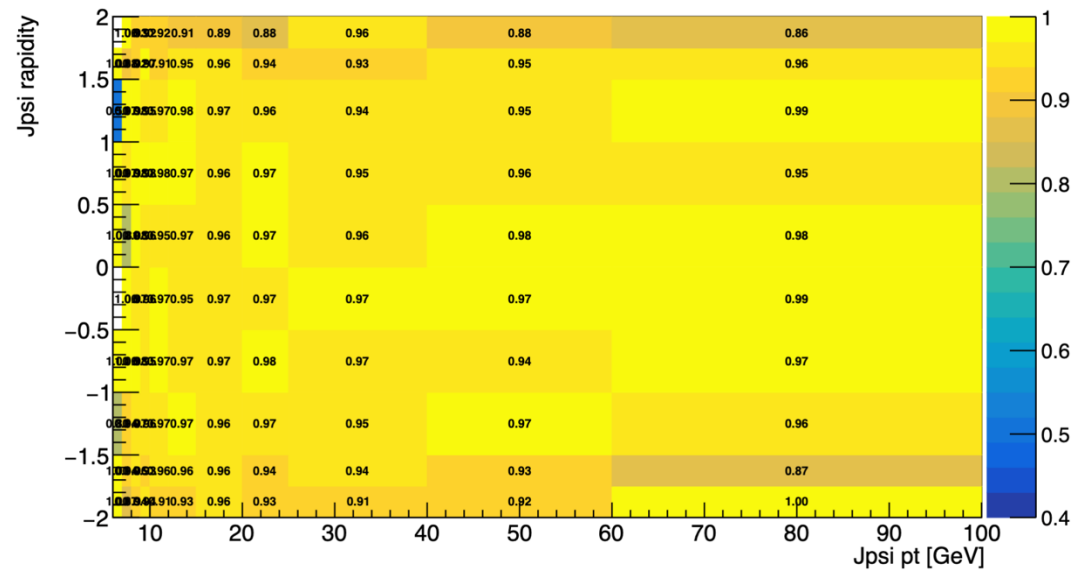
reconstruct probability



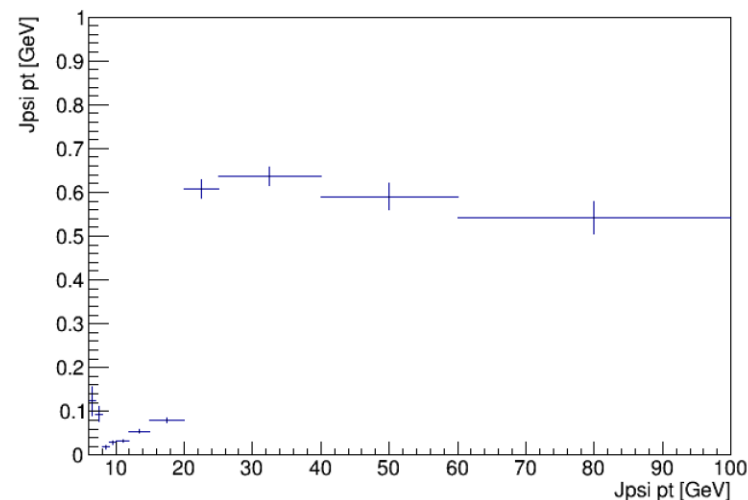
selection probability



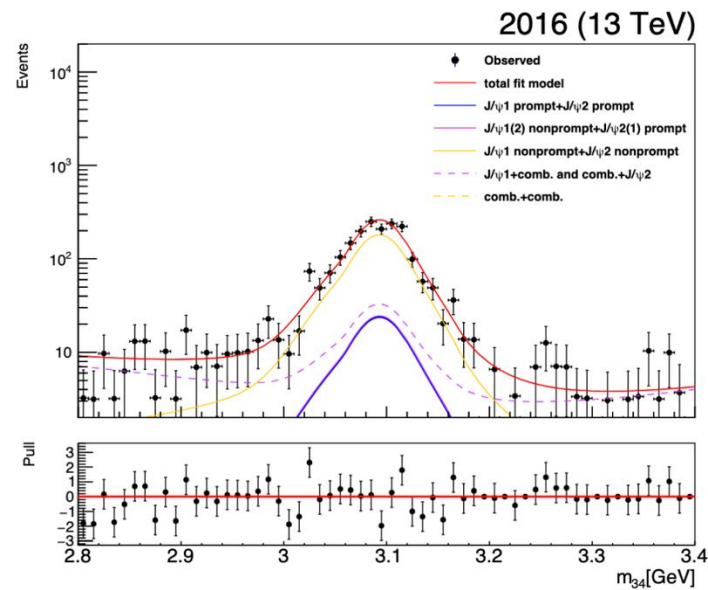
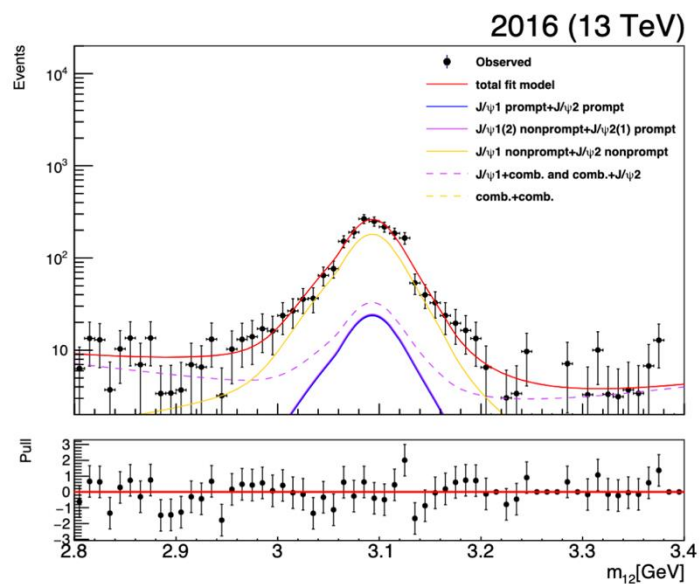
vertex probability



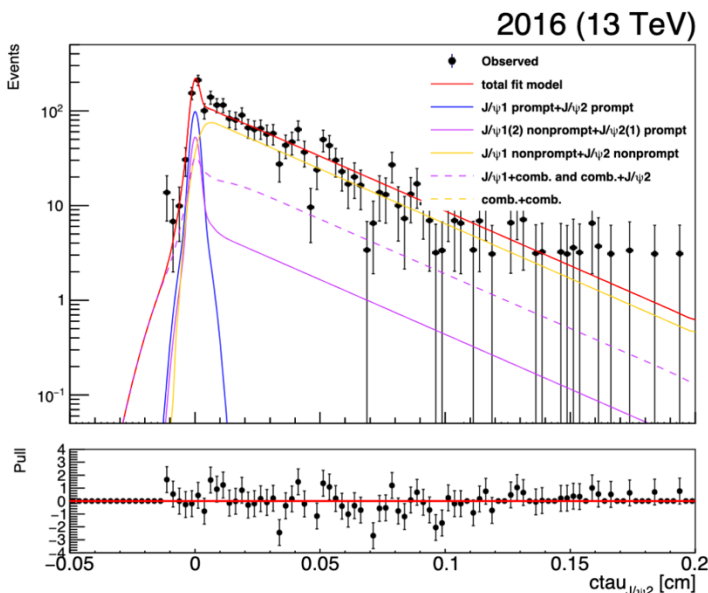
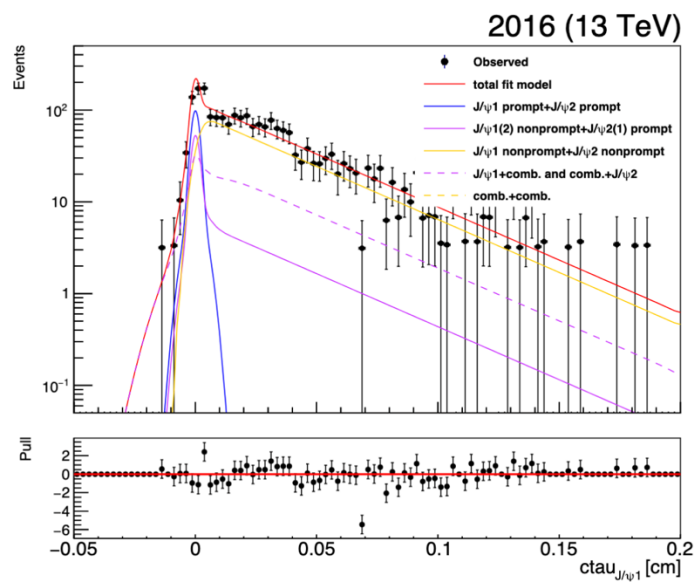
pass HLT probability



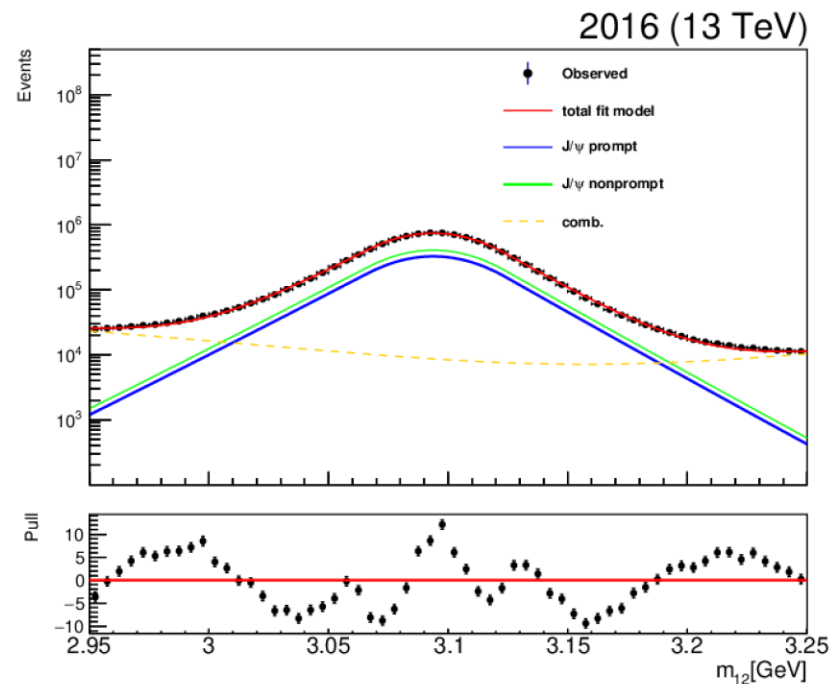
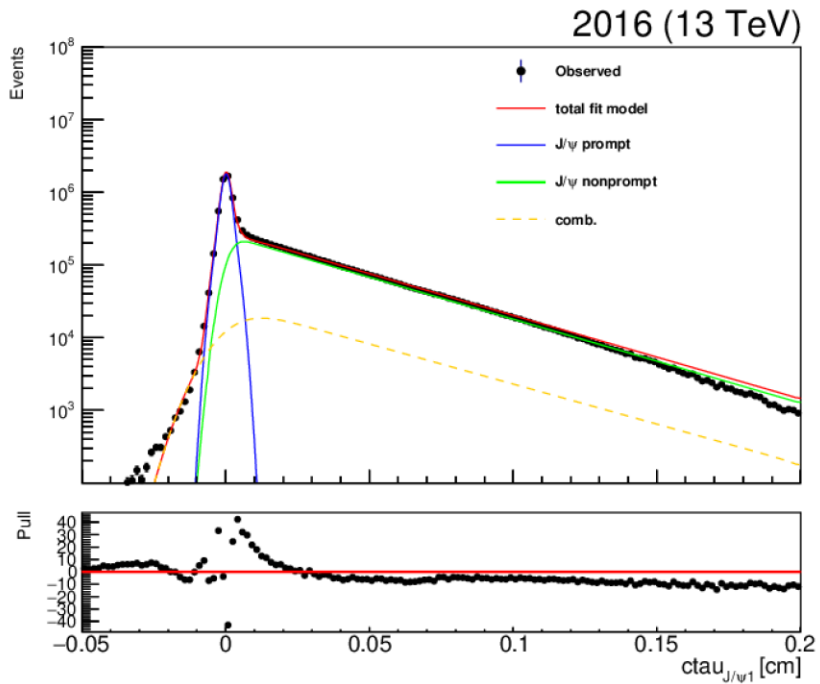
HLT_Dimuon20_Jpsi



- Phase space: Jpsi: $pt > 20 \text{ GeV}$, $|y| < 2$
- Muon: $pt > 3.5 \text{ GeV}$, $|y| < 2.4$



- Double Jpsi cross section : $1.39 \pm 0.22 \text{ pb}$

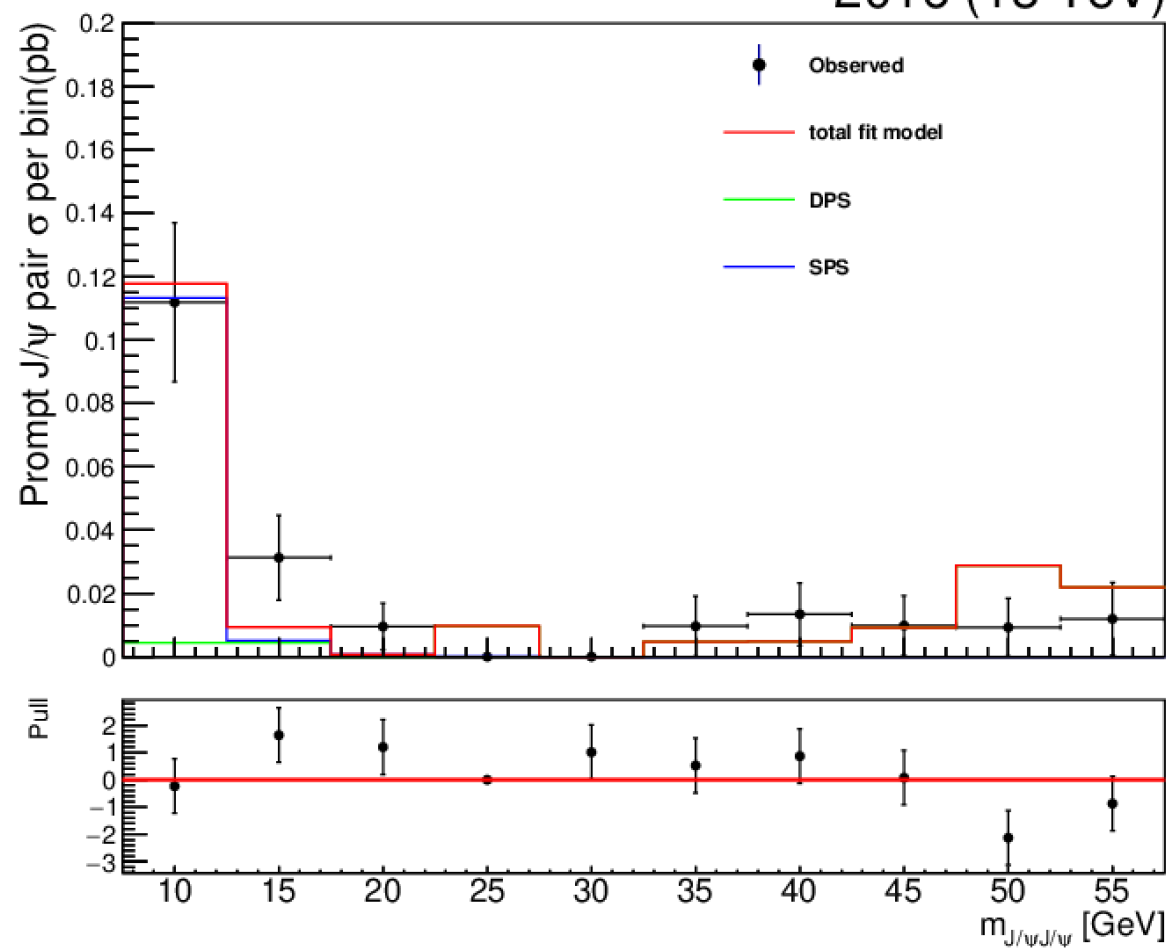


cross section: 13171.8pb

- Phase space: Jpsi: $pt > 20 \text{ GeV}$, $|y| < 2$
- Muon: $pt > 3.5 \text{ GeV}$, $|y| < 2.4$

$$\bullet \sigma_{eff} = \frac{\sigma_{J/\psi}^2}{2\sigma_{DPS \rightarrow J\psi J\psi}} = \frac{(13171.8 \text{ pb})^2}{2 * (1.39 * 0.59) \text{ pb}} = 0.15 \text{ mb}$$

2016 (13 TeV)





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Phase space: Jpsi: $p_t > 10 \text{ GeV}$, $|y| < 1.2$
Muon: $p_t > 4 \text{ GeV}$, $|y| < 1.4$

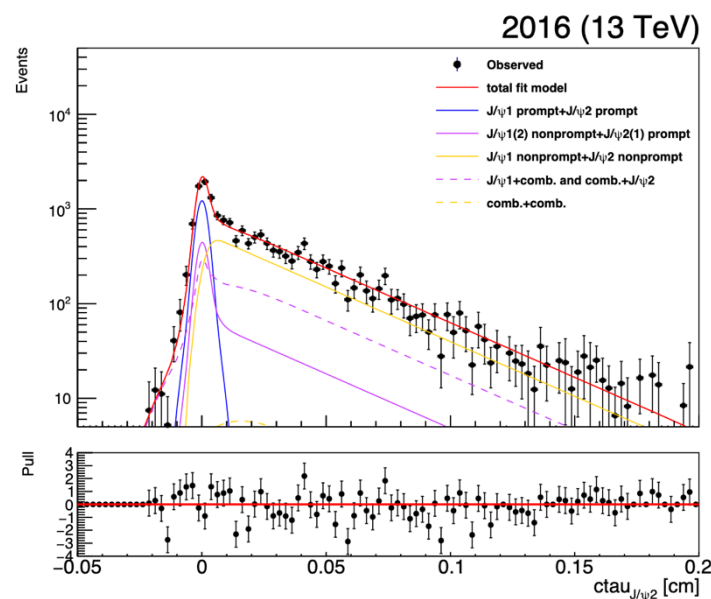
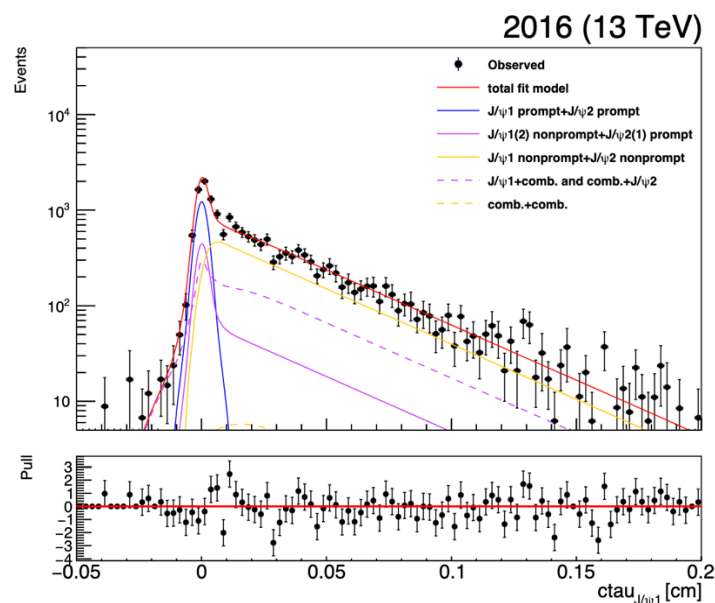
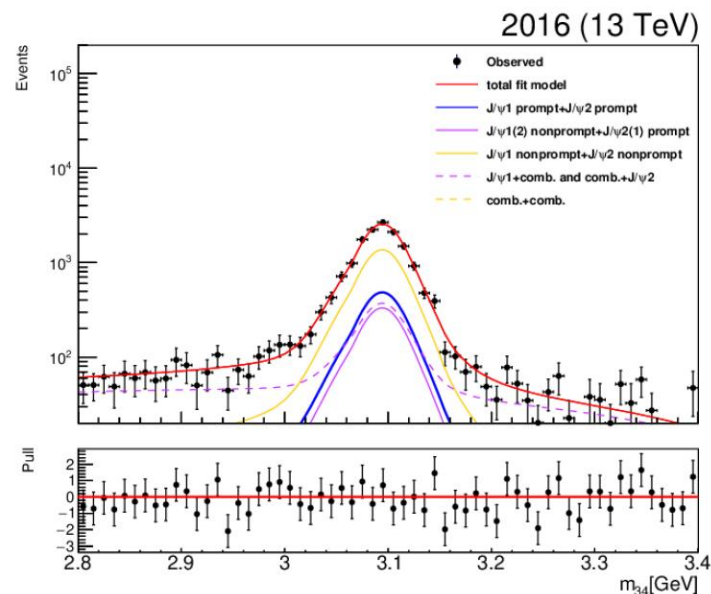
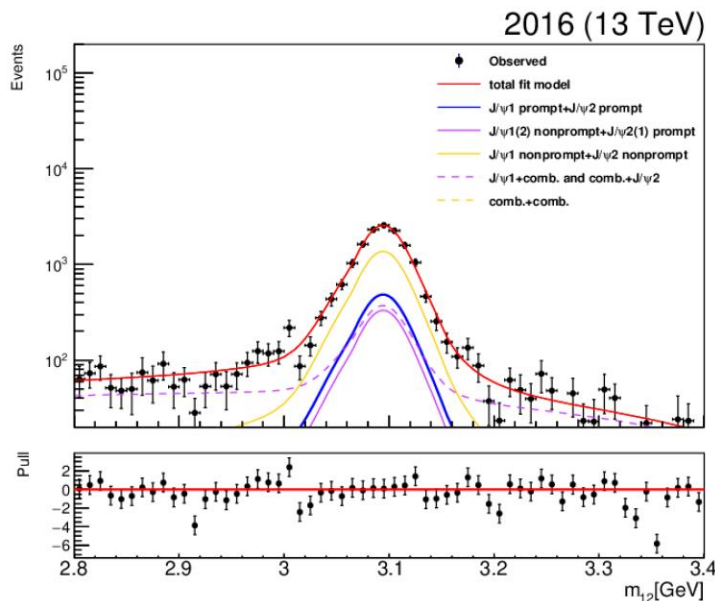
Table 18: J/ψ cross sections

p_T	$\langle p_T \rangle$	$\langle \mathcal{A} \rangle$	$\langle \epsilon \rangle$	$\langle \frac{1}{\mathcal{A}\epsilon} \rangle$	$\sigma \times BR[pb]$
$ y < 1.2$					
10-11	10.50	0.23	0.46	10.395 ± 0.019	2421.93 ± 26.97
11-12	11.49	0.29	0.56	6.308 ± 0.007	1293.31 ± 14.88
12-13	12.48	0.35	0.60	4.887 ± 0.005	822.42 ± 10.14
13-14	13.48	0.39	0.61	4.238 ± 0.004	562.05 ± 7.67
14-15	14.48	0.43	0.66	3.502 ± 0.003	384.42 ± 5.71
15-16	15.48	0.47	0.67	3.185 ± 0.003	246.73 ± 4.22
16-18	17.09	0.25	0.57	7.872 ± 0.010	168.58 ± 1.71
18-20	18.99	0.42	0.67	3.628 ± 0.002	87.22 ± 0.81
20-22	20.96	0.56	0.71	2.502 ± 0.001	48.87 ± 0.49
22-26	23.77	0.66	0.73	2.095 ± 0.001	24.01 ± 0.21
26-30	27.79	0.71	0.73	1.933 ± 0.001	10.51 ± 0.13
30-38	33.26	0.76	0.73	1.816 ± 0.001	4.11 ± 0.06
38-54	43.78	0.81	0.72	1.725 ± 0.003	0.86 ± 0.02
$1.2 < y < 1.8$					
16-18	17.02	0.29	0.53	6.803 ± 0.010	151.68 ± 2.14
18-20	18.97	0.47	0.62	3.482 ± 0.003	77.83 ± 1.07
20-22	20.95	0.61	0.64	2.586 ± 0.002	41.32 ± 0.65
22-26	23.72	0.70	0.65	2.247 ± 0.002	20.77 ± 0.30
26-30	27.78	0.74	0.65	2.108 ± 0.002	8.68 ± 0.19
30-38	33.11	0.79	0.63	2.057 ± 0.003	3.07 ± 0.07
38-54	43.39	0.83	0.60	2.089 ± 0.008	0.59 ± 0.02

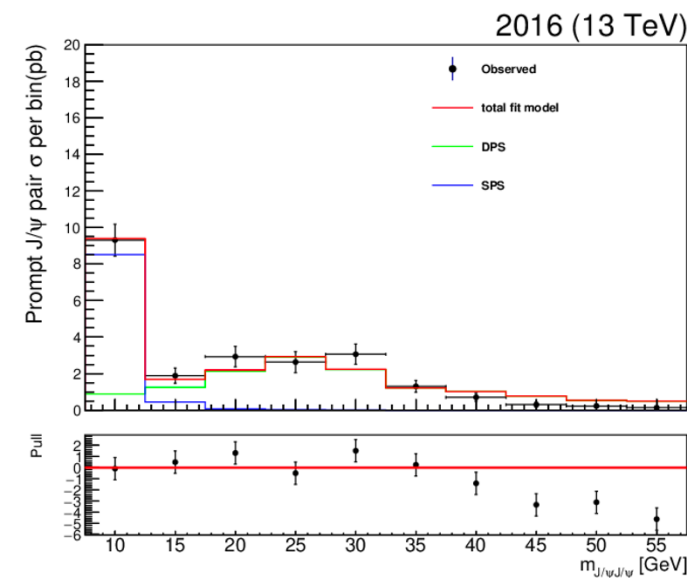
$$2421.9 + 1293.3 + 822.4 + 562.0 + 384.4 + 246.7 + 168.6 \cdot 2 + 87.22 \cdot 2 + 48.9 \cdot 2 + 24.0 \cdot 4 + 10.5 \cdot 4 + 4.11 \cdot 8 + 0.86 \cdot 16 = 6524.7800 \text{ pb}$$

$$6524.8 \text{ pb} / 0.0593 = 110030.02 \text{ pb}$$

$$\bullet \sigma_{eff} = \frac{\sigma_{J/\psi}^2}{2\sigma_{DPS \rightarrow J\psi J\psi}} = \frac{(110030.02 \text{ pb})^2}{2 \cdot (23.11 \cdot 0.59) \text{ pb}} = 0.44 \text{ mb}$$



Phase space: Jpsi: $p_t > 10 \text{ GeV}$, $|y| < 1.2$
 Muon: $p_t > 4 \text{ GeV}$, $|y| < 1.4$



Double Jpsi cross section : 23.11 pb
 DPS fraction: 0.59



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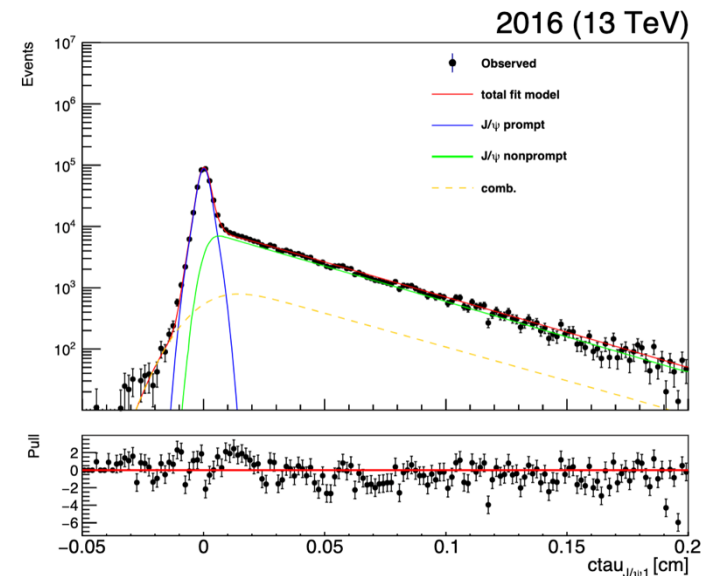
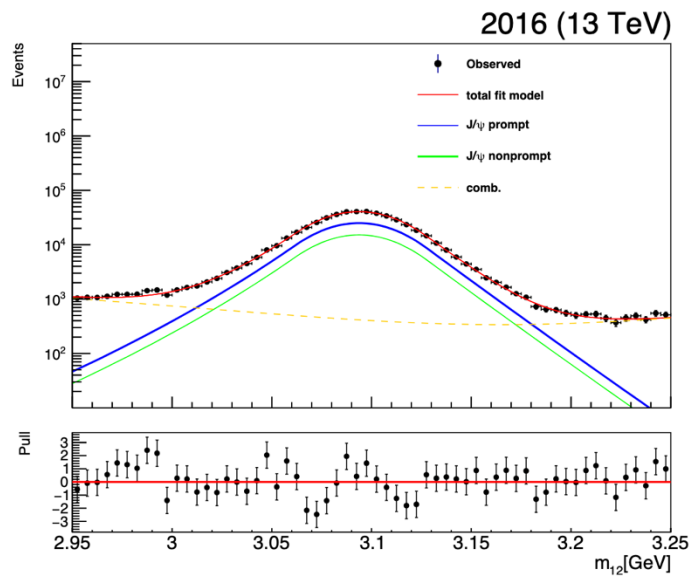
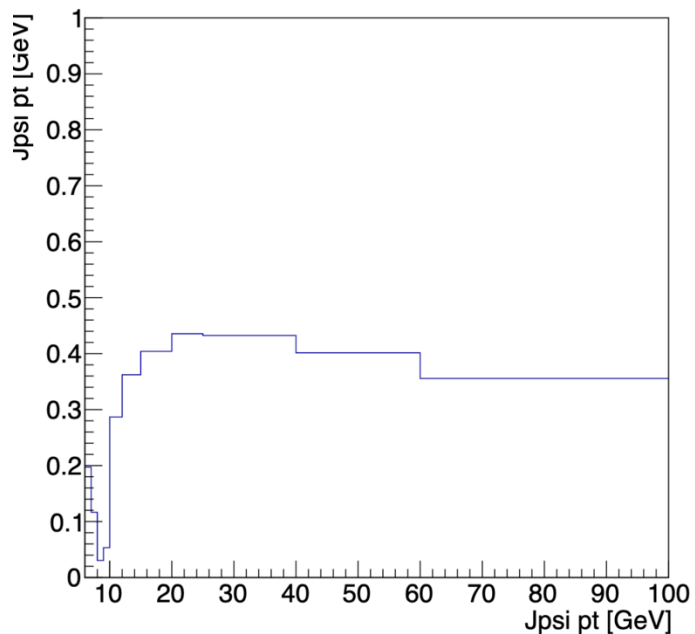


Phase space: $J\psi$: $p_t > 10 \text{ GeV}$, $|y| < 1.2$
Muon: $p_t > 3.5 \text{ GeV}$, $|\eta| < 1.4$

- Phase space: Jpsi: $pt > 10\text{GeV}$, $|y| < 1.2$
- Muon: $pt > 3.5\text{GeV}$, $|\eta| < 1.4$

HLT_Dimuon10_Jpsi_Barrel_v

pass HLT probability



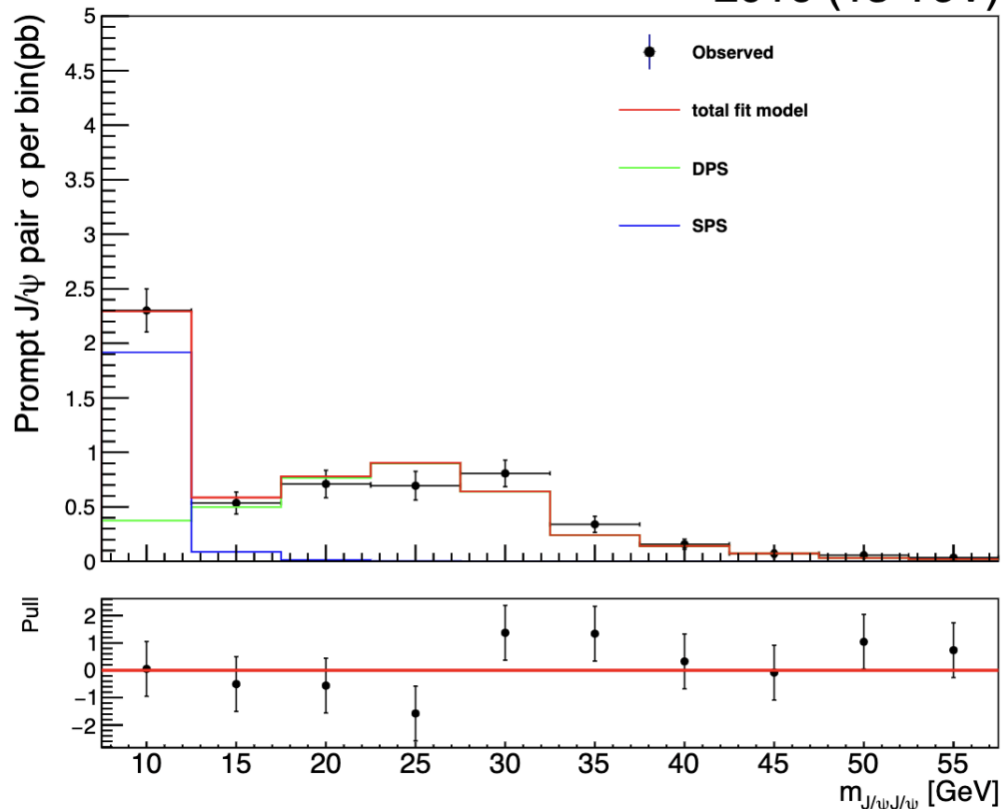
$$\frac{(308772/528646) * 6.78e+07}{5.819/fb * 0.0593} = 114849\text{pb}$$



Double Jpsi DPS



2016 (13 TeV)



$$\text{effective CS} = \frac{(114849\text{pb})^2}{2*18.56\text{pb}} = 0.355\text{mb}$$

$$\text{DPS} = 29\text{pb} * 0.64 = 18.56\text{pb}$$



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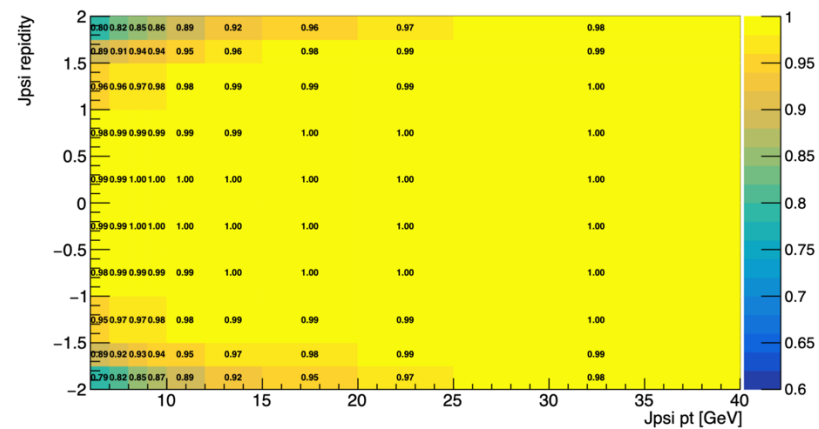
Phase space: J_{ψ} : $p_t > 10 \text{ GeV}$, $|y| < 1.2$
Muon: $p_t > 3.5 \text{ GeV}$, $|\eta| < 1.4$



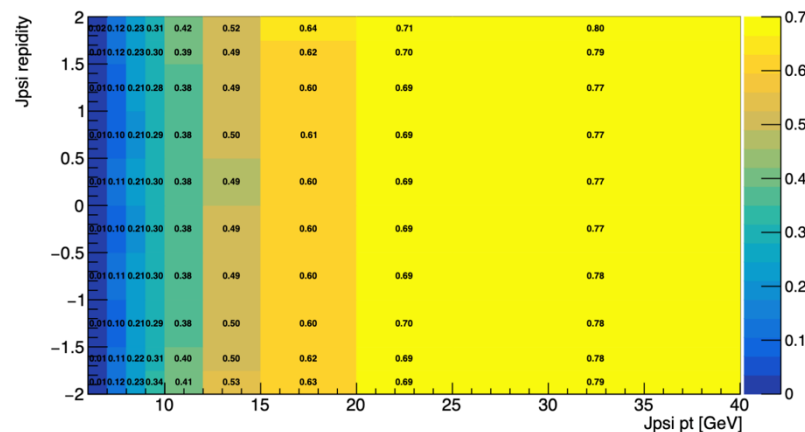
Single Acc and eff (old)



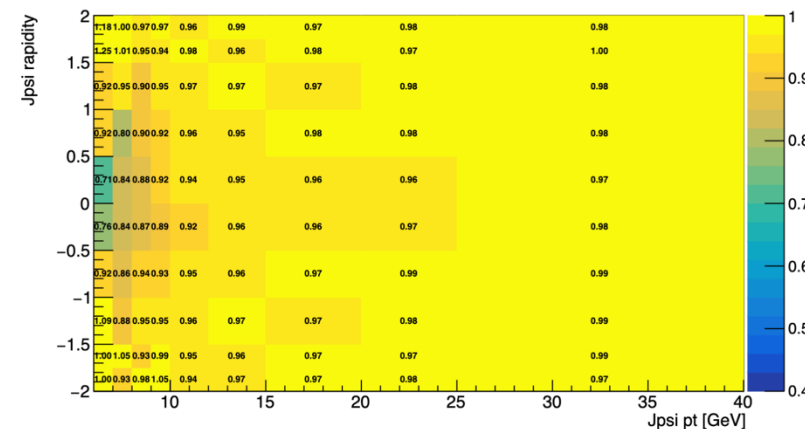
acceptance eta probability



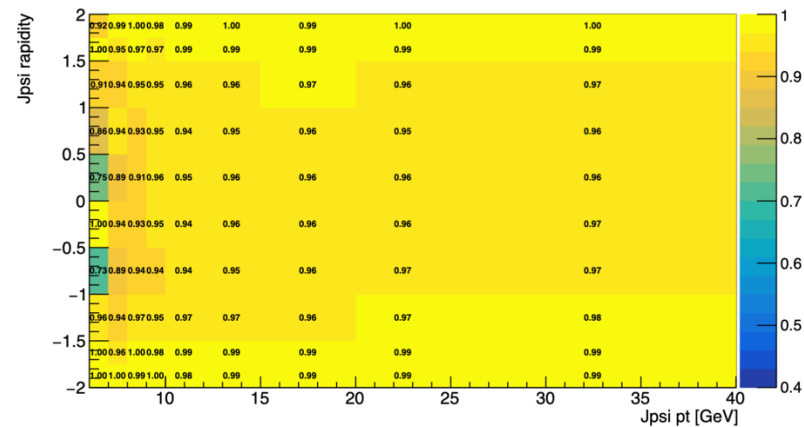
acceptance pt probability



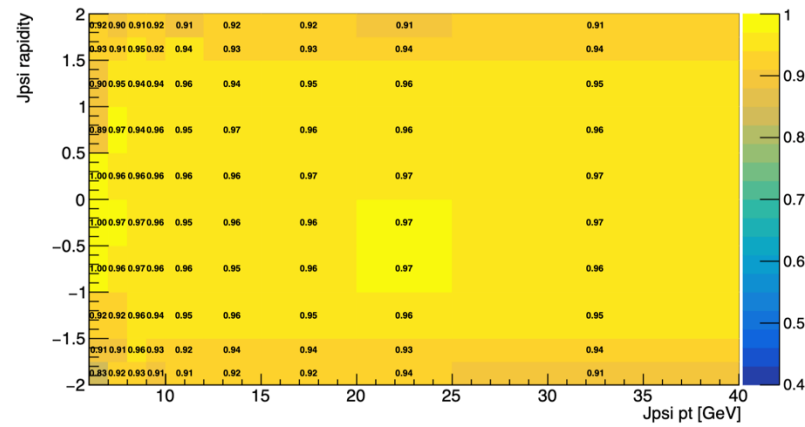
reconstruct probability



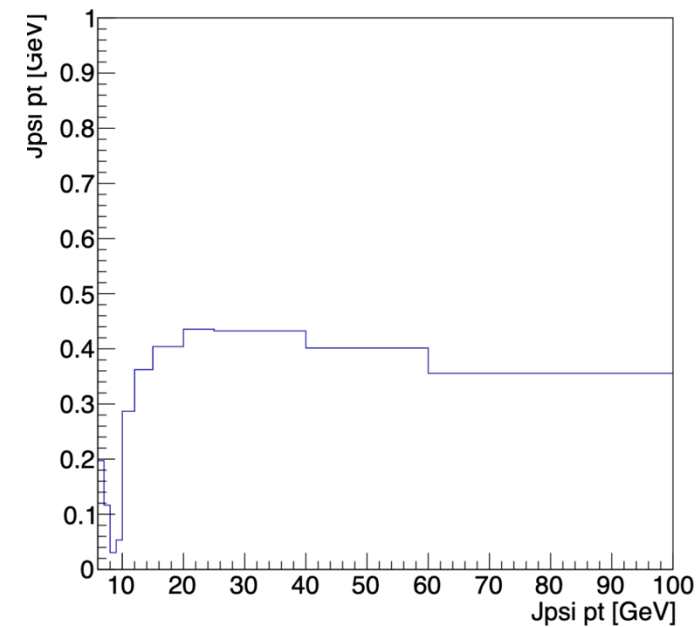
selection probability



vertex probability



pass HLT probability

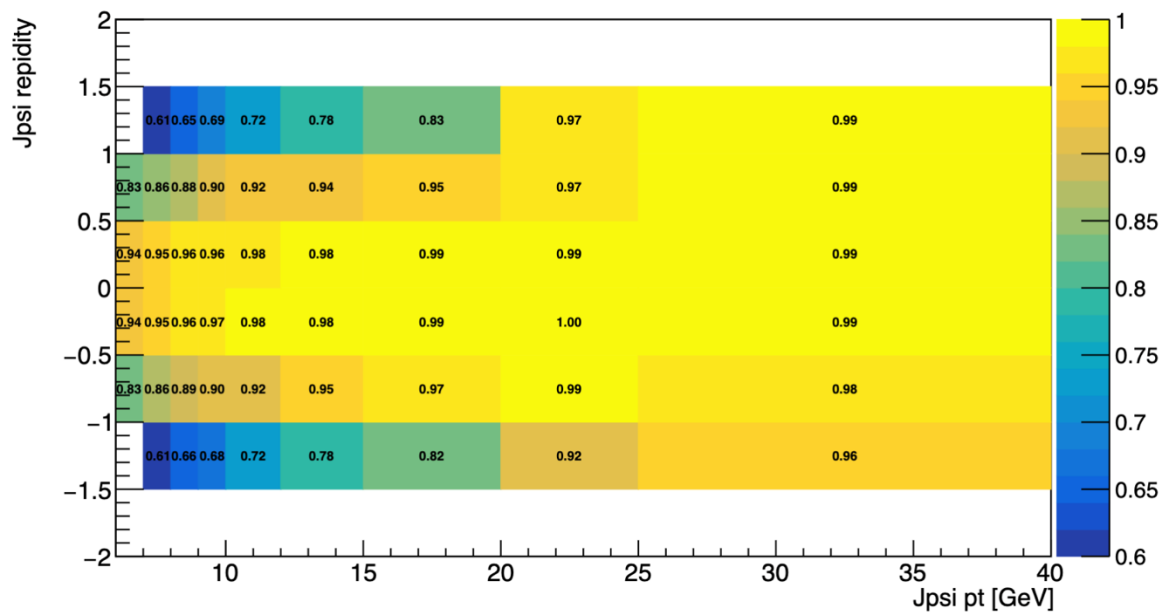




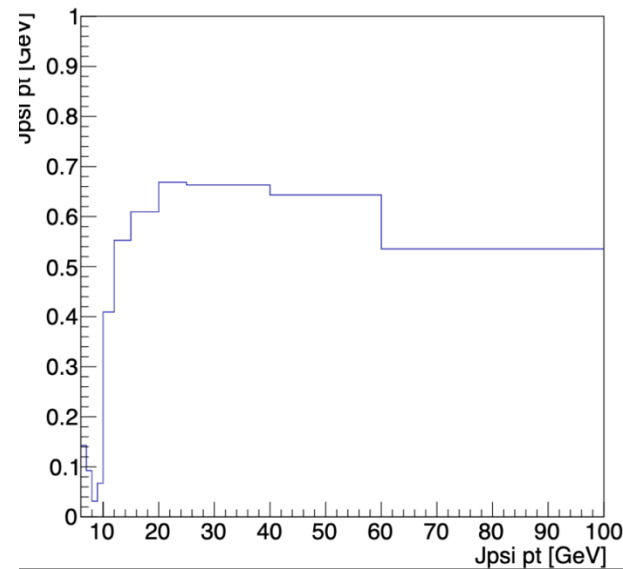
Single Acc and eff (new)

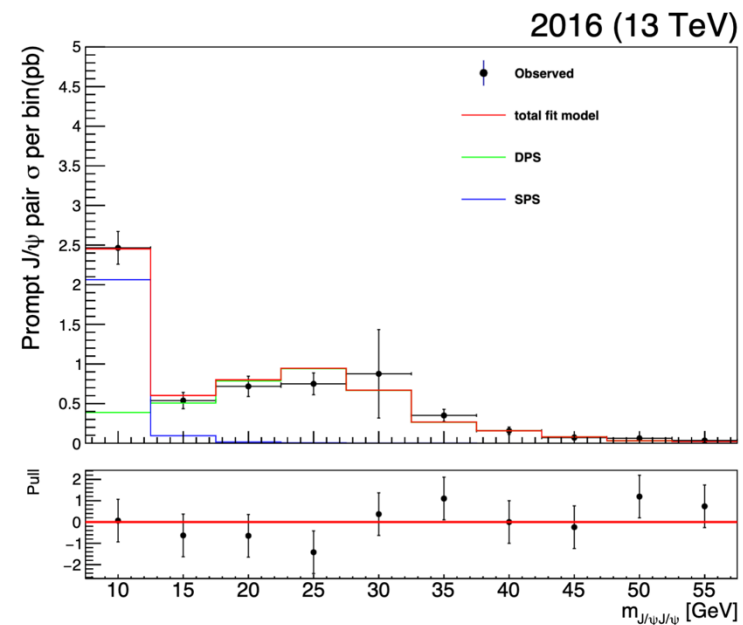
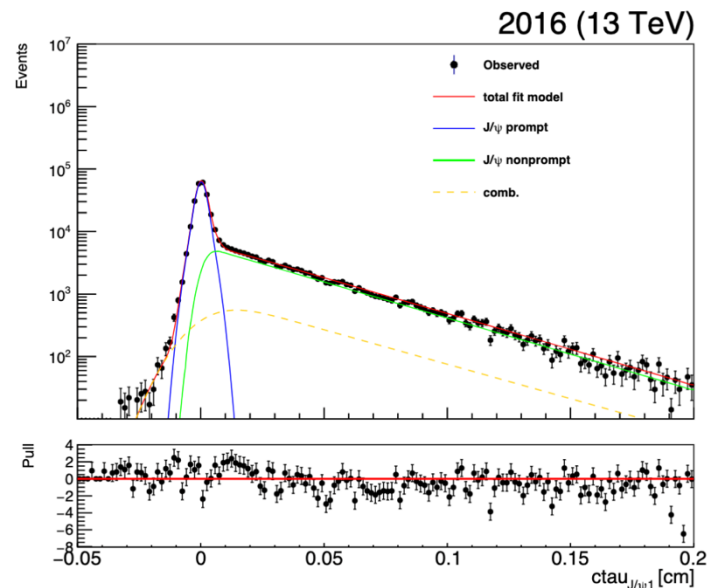
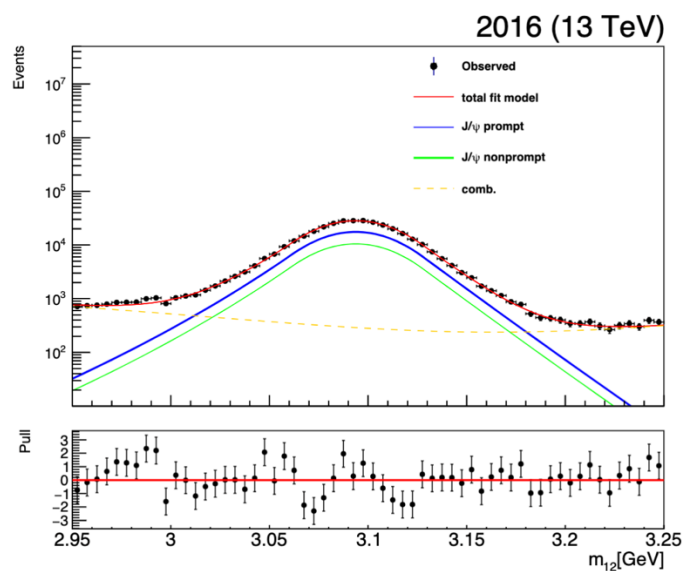


acceptance eta probability



pass HLT probability





$$\frac{(216733/379152) * 4.86e+07}{5.819/fb * 0.0593} = 80510 \text{ pb}$$

$$\text{DPS} = 30.8 \text{ pb} * 0.64 = 19.7 \text{ pb}$$

$$\text{effective CS} = \frac{(80510 \text{ pb})^2}{2 * 19.7 \text{ pb}} = 0.164 \text{ mb}$$