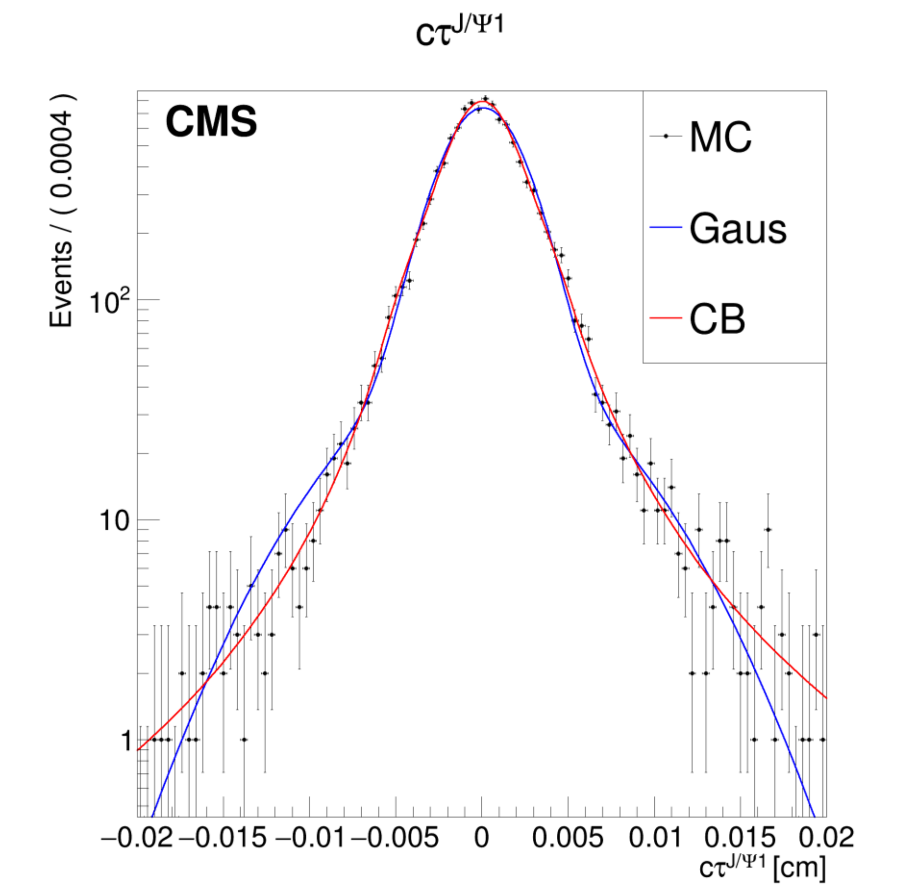
Fitting details

- 1. $c\tau$ p.d.f. for prompt $J/\psi J/\psi$ component
- AN2021_003_v4: The PR term is, effectively, the lifetime resolution function. ⋯ the sum of only two gaussians functions already provides a sufficiently-good description⋯
- AN2015_323_v12: For the case of the $J/\psi(1S)$ we found that the resolution is better modeled by the sum of two gaussians
- AN2014_003_v16: ⋯distribution of the prompt component ⋯ is equivalent to the resolution function ⋯ (two gaussians)
- (7 TeV): A double gaussian resolution function is used for the signal $c\tau$ PDF shapes ⋯

Fitting details

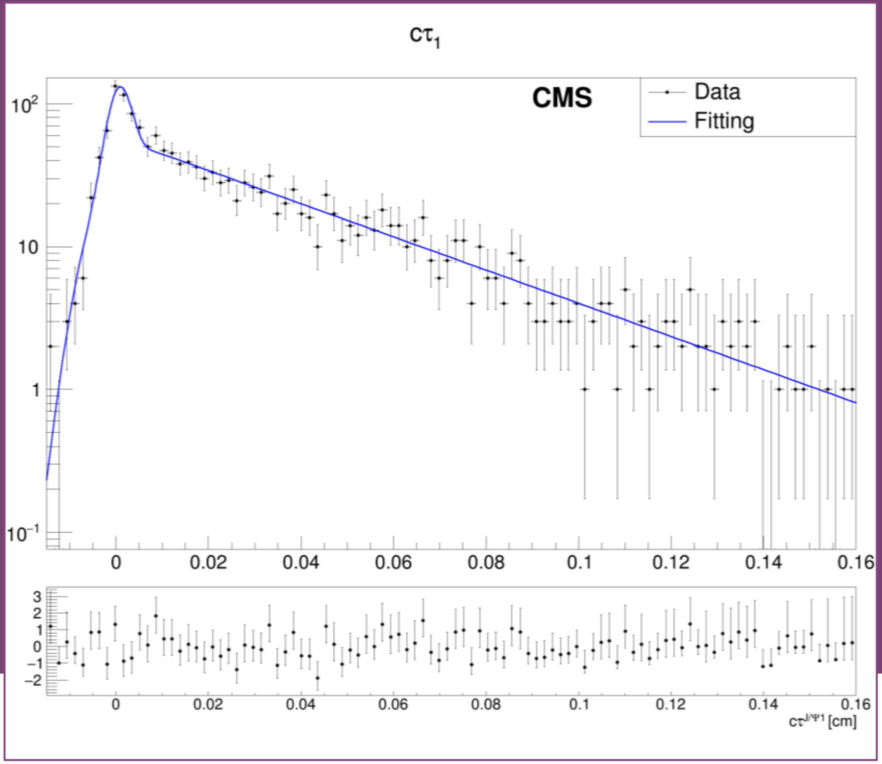
- 1. $c\tau$ p.d.f. for prompt $J/\psi J/\psi$ component



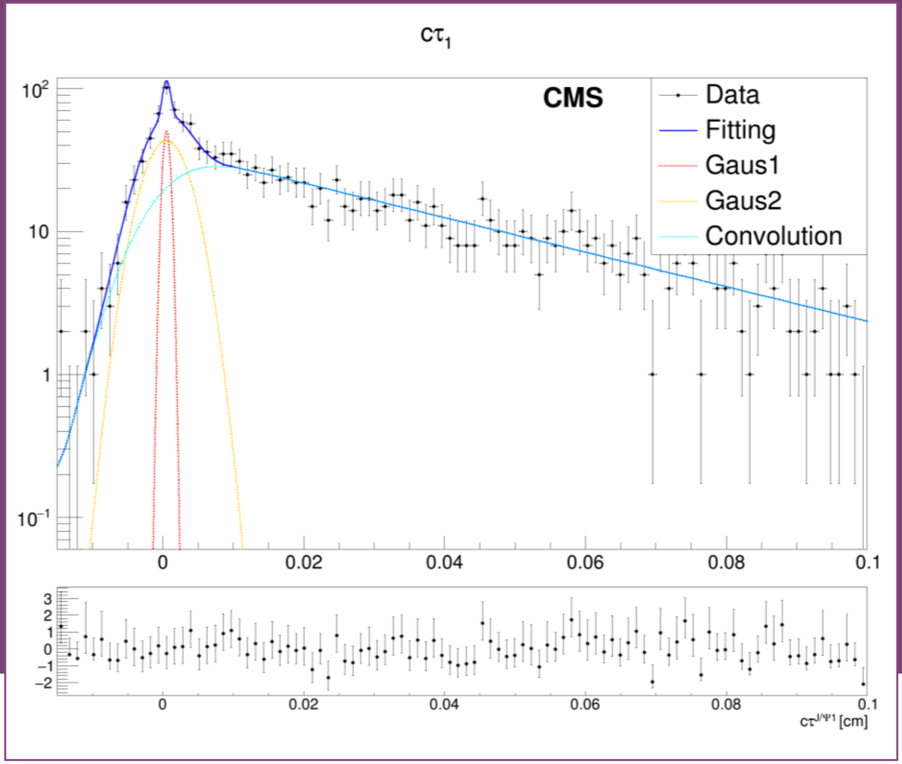
- Propose to use a sum of two gaussians

Fitting details

- 1. $c\tau$ p.d.f. for prompt $J/\psi J/\psi$ component
  - $c\tau$ p.d.f. for combinatorial background (J/ψ side)



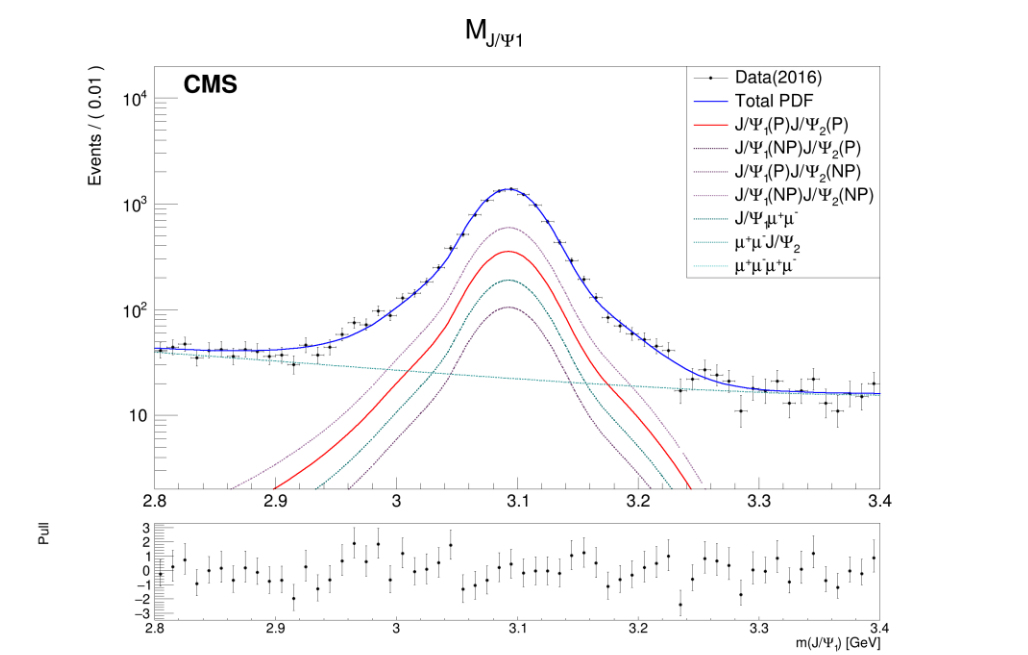
Another gaussian embedded



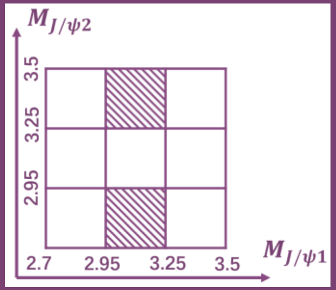
Fitting details

- 2. Mass p.d.f. for combinatorial component
  - AN2021_003_v4: ⋯ shape parameters of ⋯ functions must change with p_T in a smooth way (float)
  - AN2015_323_v12/AN2014_003_v16: (No detail found, may be float)
  - (7 TeV): Fix

	Fix	Float
P+P	2670 ± 60	2690 ± 60
P+NP	760 ± 30	800 ± 40
NP+NP	4310 ± 90	4510 ± 100
$J\mu\mu$	1570 ± 40	1440 ± 50
$\mu\mu\mu\mu$	100 ± 20	50 ± 20



Fitting procedure



- Mix SPS and DPS samples into the prompt sample (8K:4K)
- 1D fit to the prompt sample on the $c\tau_1$ dimension to acquire the **shape1** (double gaussian)
- 1D fit to the non-prompt sample on the $c\tau_1$ dimension to acquire the **shape2** (convolution of an exponent and a gaussian)
- Side band cut to the data sample to acquire the combinatorial background ($J/\psi_1\mu^+\mu^-$)
- 1D fit to the $J/\psi_1\mu^+\mu^-$ on the $c\tau_1$ dimension to acquire the **shape3** (merging of two gaussians and a convolution)
- 1D fit to the $J/\psi_1\mu^+\mu^-$ on the $c\tau_2$ dimension to acquire the **shape4** (convolution of an exponent and a gaussian)
- **Final fitting**

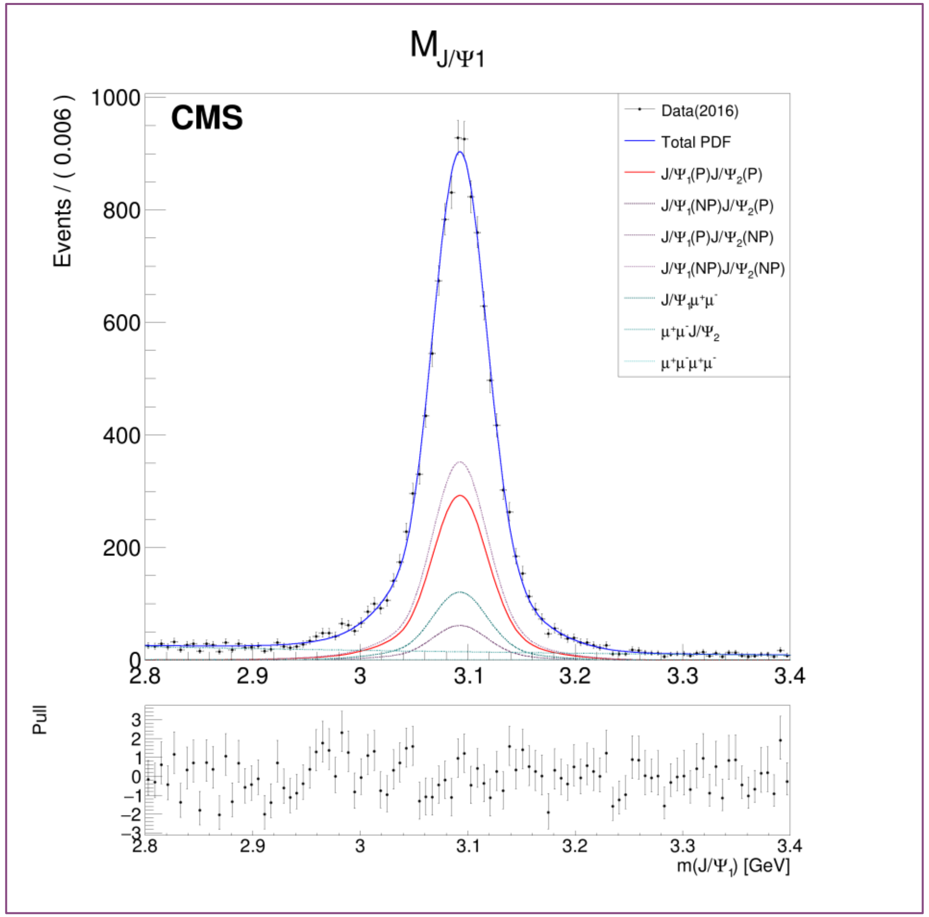
Final fitting

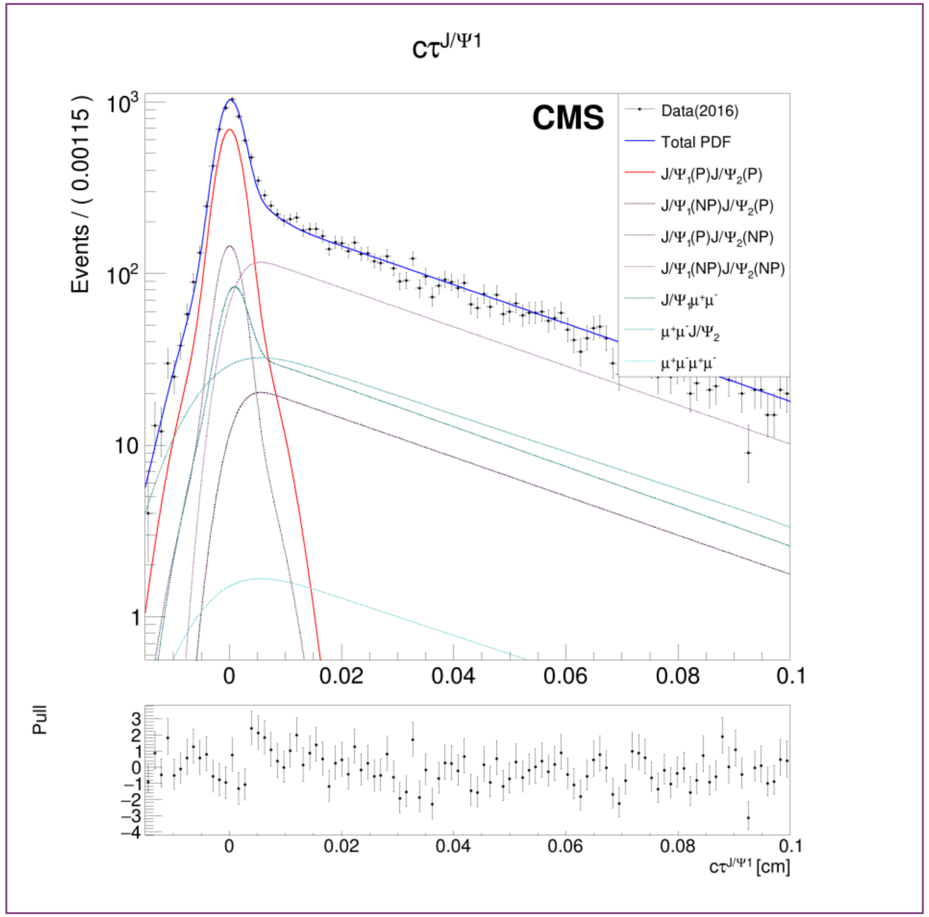
Components		$M_{J/\psi 1}$	$M_{J/\psi 2}$	$c\tau_1$	$c\tau_2$	N
$J/\psi_1 J/\psi_2$	P+P	Double CB	Double CB	Shape1	Shape1	$N_{JJ(PP)}$
	NP+P			Shape2	Shape1	$N_{JJ(PNP)}$
	P+NP			Shape1	Shape2	
	NP+NP			Shape2	Shape2	$N_{JJ(NPNP)}$
$J/\psi_1 \mu^+\mu^-$		Double CB	Cheb	Shape3	Shape4	$N_{J\mu\mu}$
$\mu^+\mu^- J/\psi_2$		Cheb	Double CB	Shape4	Shape3	
$\mu^+\mu^-\mu^+\mu^-$		Cheb	Cheb	Shape4	Shape4	$N_{\mu\mu\mu\mu}$

- **The functions that share the same name listed in the table also share the same set of parameters** (because of the smearing between two J/ψs)
- **The parameters for the shape1/2/3/4 are fixed from the previous fitting**
- **The parameters for the double CB and Chebyshev are float**
- **All the heights are float**

Fitting validation

- 1. Data + MC + generated samples





Fitting validation

- 1. Data + Pure MC + generated samples

		0	1	2	3	4	5
J/ψ_1 J/ψ_2	SPS	-	1000	-	1000	-	-
	DPS	-	-	500	500	-	-
	P+NP	-	-	-	-	500	-
	B decay	-	-	-	-	-	2000
$J/\psi\mu^+\mu^-$		-	-	-	-	-	-
$\mu^+\mu^-\mu^+\mu^-$		-	-	-	-	-	-

J/ψ_1 J/ψ_2	P+P	2650 ± 60	3660 ± 70	3080 ± 60	4090 ± 70	2630 ± 60	2650 ± 60
	NP+P	780 ± 30	770 ± 30	800 ± 30	790 ± 30	1290 ± 40	780 ± 40
	NP+NP	4420 ± 100	4410 ± 100	4390 ± 100	4390 ± 100	4290 ± 100	6220 ± 110
$J/\psi\mu^+\mu^-$		1500 ± 50	1510 ± 50	1520 ± 50	1520 ± 50	1510 ± 50	1500 ± 50
$\mu^+\mu^-\mu^+\mu^-$		80 ± 20	80 ± 20	80 ± 20	80 ± 30	80 ± 20	90 ± 20

Fitting validation

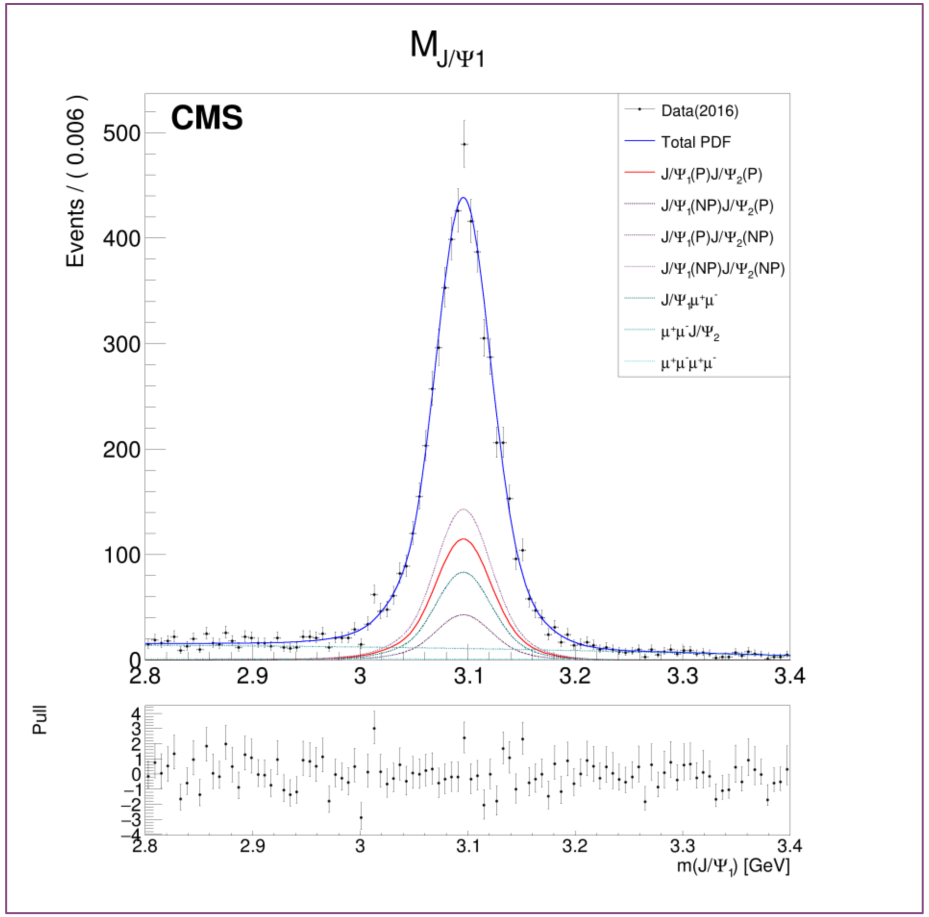
- 1. Data + Pure MC + generated samples

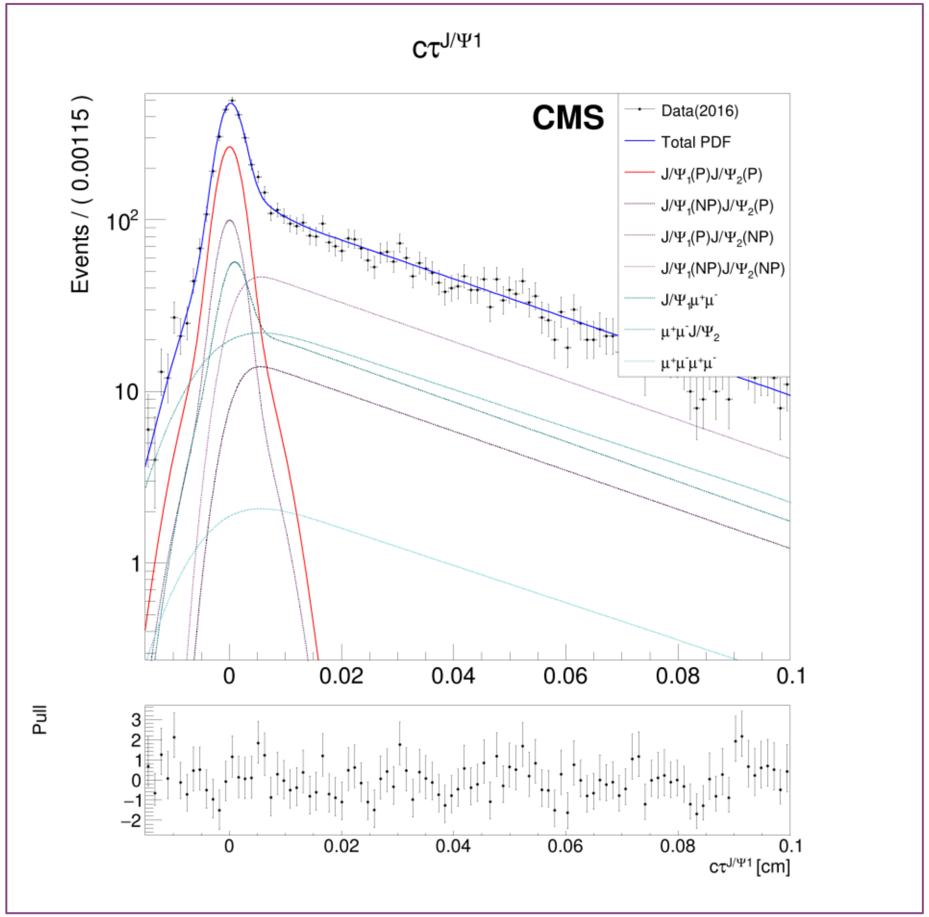
		0	6	7	8	9	10
J/ψ_1 J/ψ_2	SPS	-	-	-	1000	1000	1000
	DPS	-	-	-	500	500	500
	P+NP	-	-	-	500	-	500
	B decay	-	-	-	2000	-	2000
$J/\psi\mu^+\mu^-$		-	1000	-	-	1000	1000
$\mu^+\mu^-\mu^+\mu^-$		-	-	100	-	100	100

J/ψ_1 J/ψ_2	P+P	2650 ± 60	2630 ± 60	2640 ± 60	4080 ± 70	4070 ± 70	4050 ± 70
	NP+P	780 ± 30	780 ± 40	770 ± 30	1300 ± 40	790 ± 40	1300 ± 40
	NP+NP	4420 ± 100	4360 ± 110	4390 ± 100	6180 ± 110	4340 ± 100	6120 ± 120
$J/\psi\mu^+\mu^-$		1500 ± 50	2540 ± 60	1530 ± 50	1520 ± 50	2560 ± 60	2560 ± 60
$\mu^+\mu^-\mu^+\mu^-$		80 ± 20	70 ± 30	180 ± 30	100 ± 20	180 ± 30	190 ± 30

Fitting validation

- 2. Pure MC + generated samples





Fitting validation

- 2. Pure MC + generated samples

		1	2	3	4	5
J/ψ_1 J/ψ_2	SPS	1000	2000	1000	2000	1000
	DPS	500	500	1000	1000	500
	P+NP	500	500	500	500	1000
	B decay	2000	2000	2000	2000	2000
$J/\psi\mu^+\mu^-$		1000	1000	1000	1000	1000
$\mu^+\mu^-\mu^+\mu^-$		100	100	100	100	100

J/ψ_1 J/ψ_2	P+P	1410 ± 40	2400 ± 50	1860 ± 50	2850 ± 60	1470 ± 50
	NP+P	530 ± 30	520 ± 30	550 ± 30	540 ± 30	1020 ± 30
	NP+NP	1760 ± 60	1760 ± 60	1760 ± 60	1760 ± 60	1780 ± 70
$J/\psi\mu^+\mu^-$		1030 ± 40	1040 ± 30	1030 ± 40	1040 ± 30	1000 ± 40
$\mu^+\mu^-\mu^+\mu^-$		100 ± 20	100 ± 20	100 ± 20	100 ± 20	100 ± 20

Fitting validation

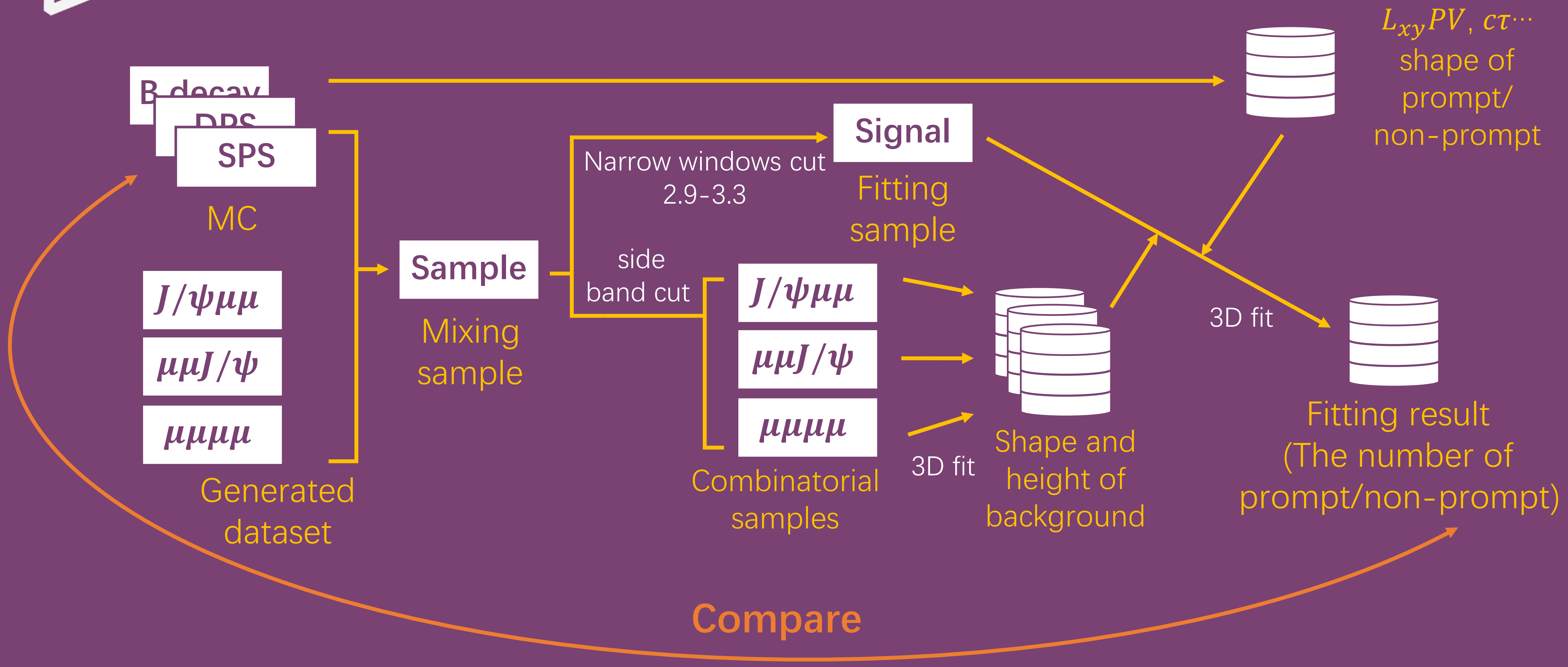
- 2. Pure MC + generated samples

		6	7	8	9	10
J/ψ_1 J/ψ_2	SPS	1000	1000	1000	2000	2000
	DPS	500	500	500	1000	1000
	P+NP	500	500	500	1000	500
	B decay	4000	2000	2000	4000	2000
$J/\psi\mu^+\mu^-$		1000	2000	1000	1000	2000
$\mu^+\mu^-\mu^+\mu^-$		100	100	200	200	200

J/ψ_1 J/ψ_2	P+P	1420 ± 40	1430 ± 40	1410 ± 40	2900 ± 60	2860 ± 60
	NP+P	520 ± 30	530 ± 30	530 ± 30	1020 ± 30	540 ± 30
	NP+NP	3510 ± 80	1860 ± 70	1760 ± 60	3520 ± 80	1850 ± 70
$J/\psi\mu^+\mu^-$		1060 ± 40	1960 ± 40	1030 ± 30	1040 ± 40	1970 ± 40
$\mu^+\mu^-\mu^+\mu^-$		100 ± 20	130 ± 30	190 ± 20	110 ± 20	230 ± 30

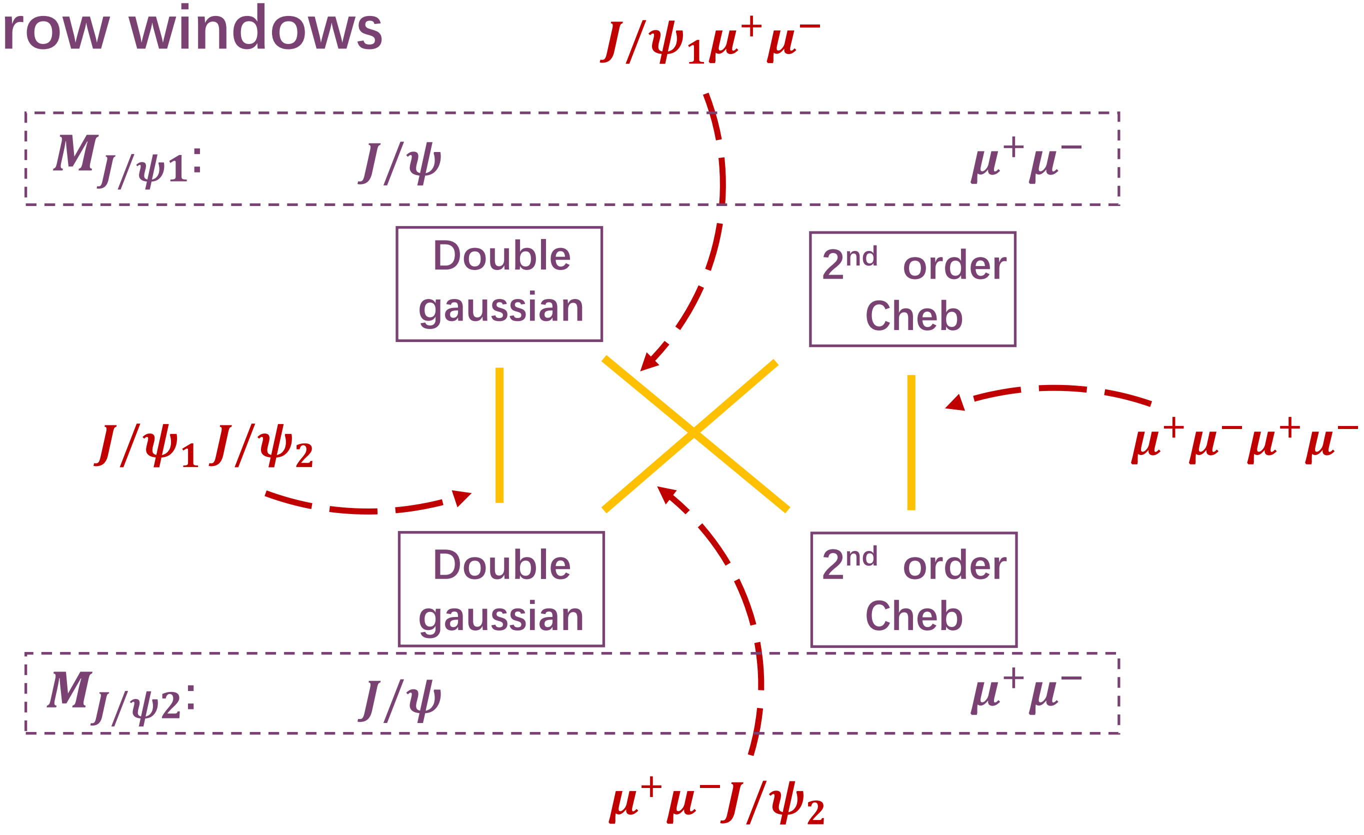
Back Up

Study of the combinatorial background



Fitting to the artificial sample

- The side band can be noticed in the “narrow” mass windows: directly fit in the narrow windows

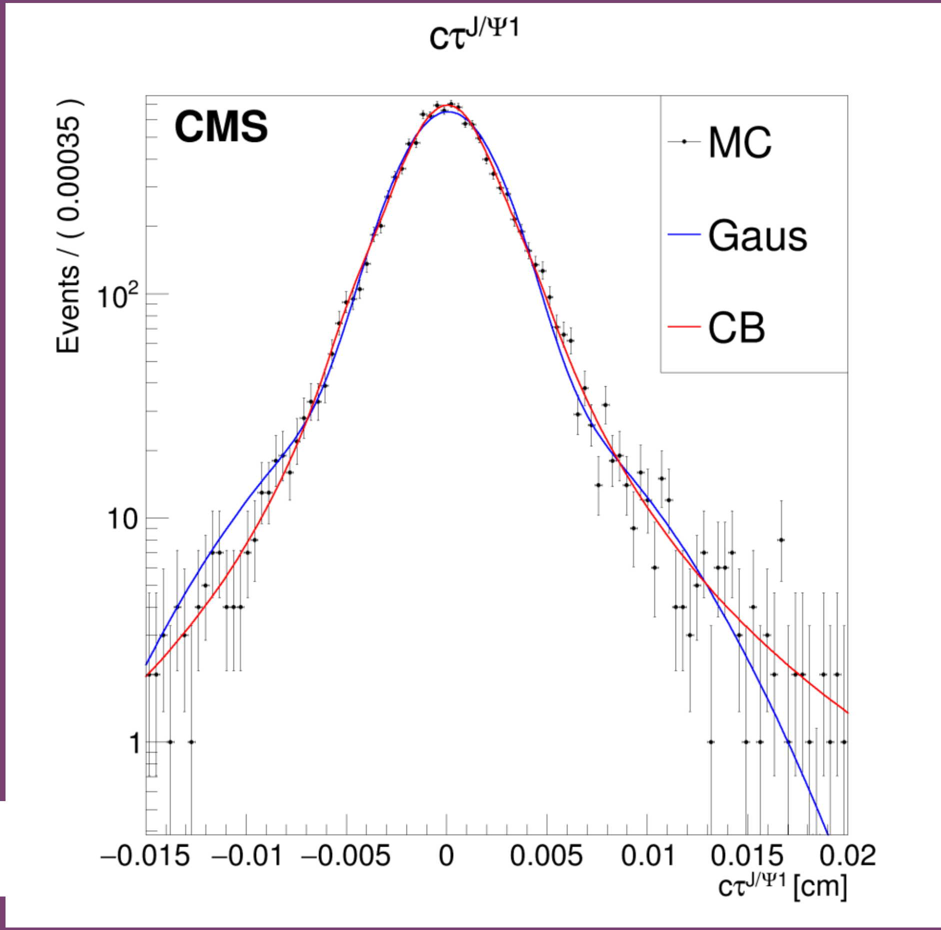


11.17

- The shape parameters of mass dimensions are left to float
- The distributions of lifetime dimensions of the combinatorial background are determined by the sub-range dataset

Fitting details

- 1. $c\tau$ p.d.f. for prompt $J/\psi J/\psi$ component
  - Double Gaussian or double CB



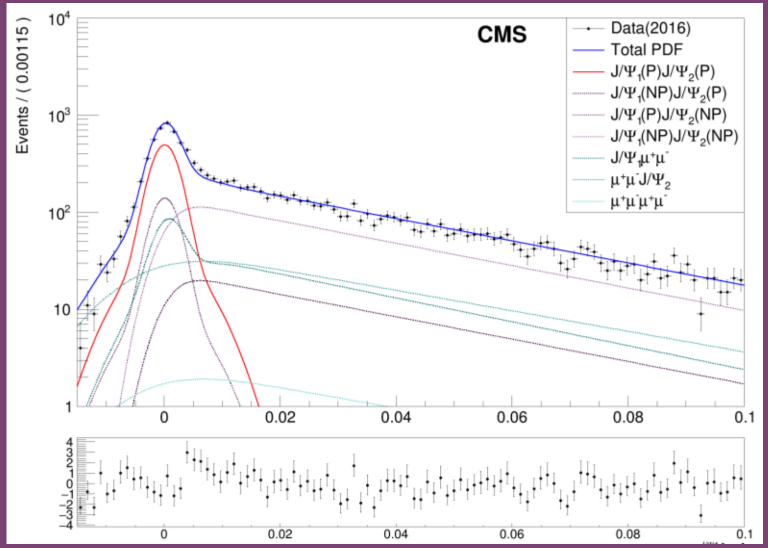
	Gaus	CB
NLL	-50983	-51031
Chi^2/ndf	1.68/4	0.91/7

Fitting details

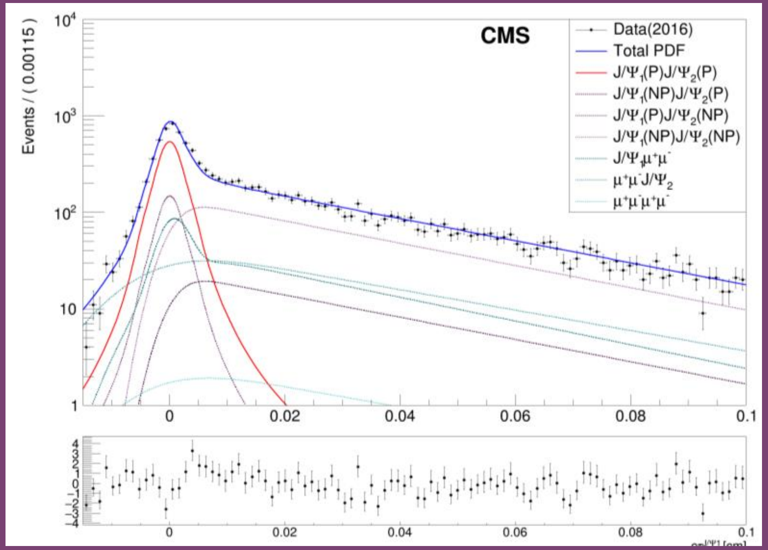
- 1. $c\tau$ p.d.f. for prompt $J/\psi J/\psi$ component
  - Double Gaussian or double CB

	Gaus	CB
NLL	-195865	-195872
Chi^2/ndf	1.24/4	1.24/4

P+P	2670 ± 60	2700 ± 60
P+NP	760 ± 30	740 ± 30
NP+NP	4310 ± 90	4300 ± 90
$J\mu\mu$	1570 ± 40	1570 ± 40
$\mu\mu\mu\mu$	100 ± 20	100 ± 20



Gaus



CB

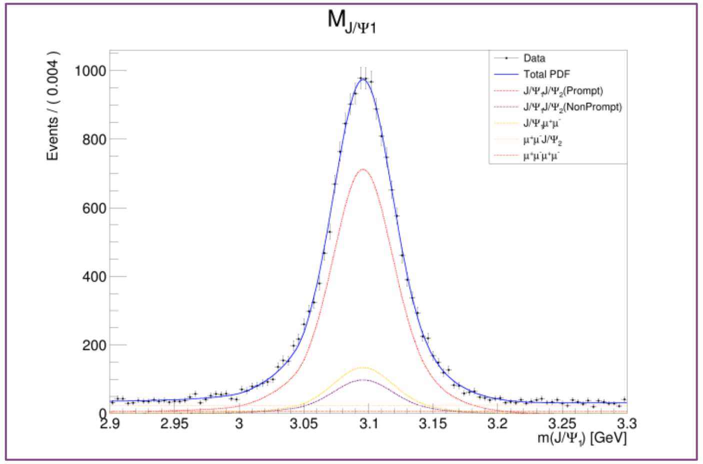
$c\tau_1$

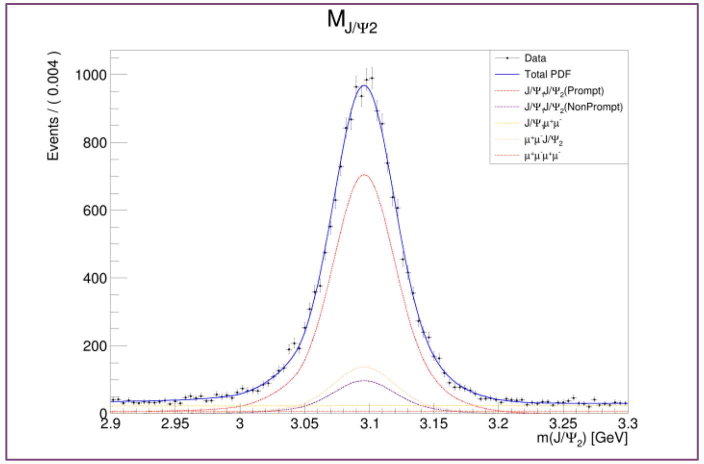
Fitting validation

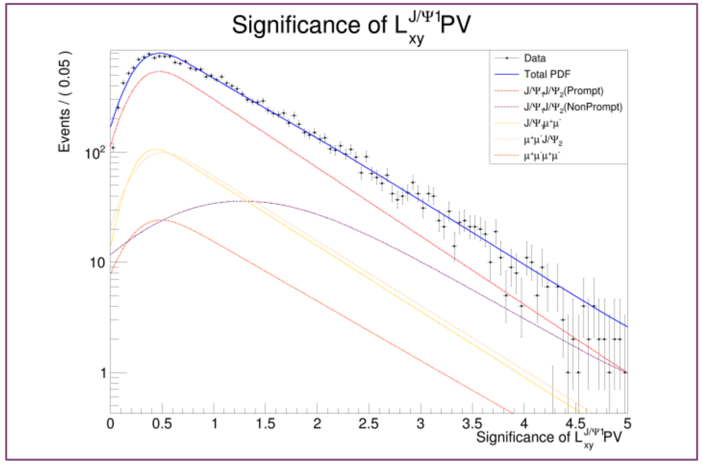
2022.11.10-12.1

- 1. A previous trial
  - 8K SPS + 4K DPS + 2K B decay + 5K $J/\psi_1\mu^+\mu^-$ + 5K $\mu^+\mu^-J/\psi_2$ + 2K $\mu^+\mu^-\mu^+\mu^-$

MC　　　　　　　　　　Generated







$J/\psi_1J/\psi_2$(P)	$J/\psi_1J/\psi_2$(NP)	$J/\psi_1\mu^+\mu^-$	$\mu^+\mu^-J/\psi_2$	$\mu^+\mu^-\mu^+\mu^-$
12600 ± 200	1700 ± 400	4700 ± 200	4820 ± 190	2500 ± 200

Fitting validation

- 2. Append MC samples to the dataset

	0	1	2	3	4	5
SPS	-	2000	-	-	2000	2000
DPS	-	-	1000	-	1000	1000
B decay	-	-	-	2000	-	2000

		0	1	2	3	4	5
$J/\psi_1 J/\psi_2$	P+P	2630 ± 60	4640 ± 70	3520 ± 70	2630 ± 60	5530 ± 80	5530 ± 80
	NP+P / P+NP	750 ± 30	730 ± 30	790 ± 30	750 ± 30	770 ± 30	770 ± 40
	NP+NP	4280 ± 90	4240 ± 90	4250 ± 90	6070 ± 100	4230 ± 90	6040 ± 100
$J/\psi_1 \mu^+\mu^-$ / $\mu^+\mu^- J/\psi_2$		1600 ± 40	1620 ± 40	1620 ± 40	1600 ± 40	1630 ± 40	1630 ± 40
$\mu^+\mu^-\mu^+\mu^-$		110 ± 30	120 ± 30	110 ± 30	120 ± 30	120 ± 30	130 ± 30

Fitting validation

- 3. Append generated samples to the dataset

		0	1	2	3	4	5	6	7	8
J/ψ_1 J/ψ_2	P+P	-	2000	-	-	-	-	1000	1000	1000
	P+NP	-	-	500	-	-	-	500	-	500
	NP+NP	-	-	-	2000	-	-	2000	-	2000
$J/\psi\mu^+\mu^-$		-	-	-	-	1000	-	-	1000	1000
$\mu^+\mu^-\mu^+\mu^-$		-	-	-	-	-	100	-	100	100

J/ψ_1 J/ψ_2	P+P	2630 ± 60	4670 ± 70	2620 ± 60	2630 ± 60	2630 ± 60	2630 ± 60	3630 ± 70	3630 ± 70	3620 ± 70
	NP+P / P+NP	750 ± 30	740 ± 30	1260 ± 40	760 ± 40	730 ± 30	750 ± 30	1230 ± 40	740 ± 30	1230 ± 40
	NP+NP	4280 ± 90	4270 ± 90	4260 ± 90	6270 ± 100	4270 ± 90	4270 ± 90	6300 ± 100	4270 ± 90	6220 ± 110
$J/\psi_1\mu^+\mu^-$ / $\mu^+\mu^-J/\psi_2$		1600 ± 40	1590 ± 40	1600 ± 40	1590 ± 50	2620 ± 50	1580 ± 40	1600 ± 50	2600 ± 60	2630 ± 50
$\mu^+\mu^-\mu^+\mu^-$		110 ± 30	110 ± 20	110 ± 30	110 ± 30	100 ± 30	250 ± 30	120 ± 30	240 ± 30	260 ± 30