BPH-15-005 Measurement of quarkonium production cross sections in pp collisions at $\sqrt{s} = 13\,\mathrm{TeV}$

—Supplemental material—
Dimuon invariant mass and lifetime distributions, numerical values of differential cross section, and correction factors for alternative polarization scenarios

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Abstract

Keywords: CMS, quarkonium, cross sections

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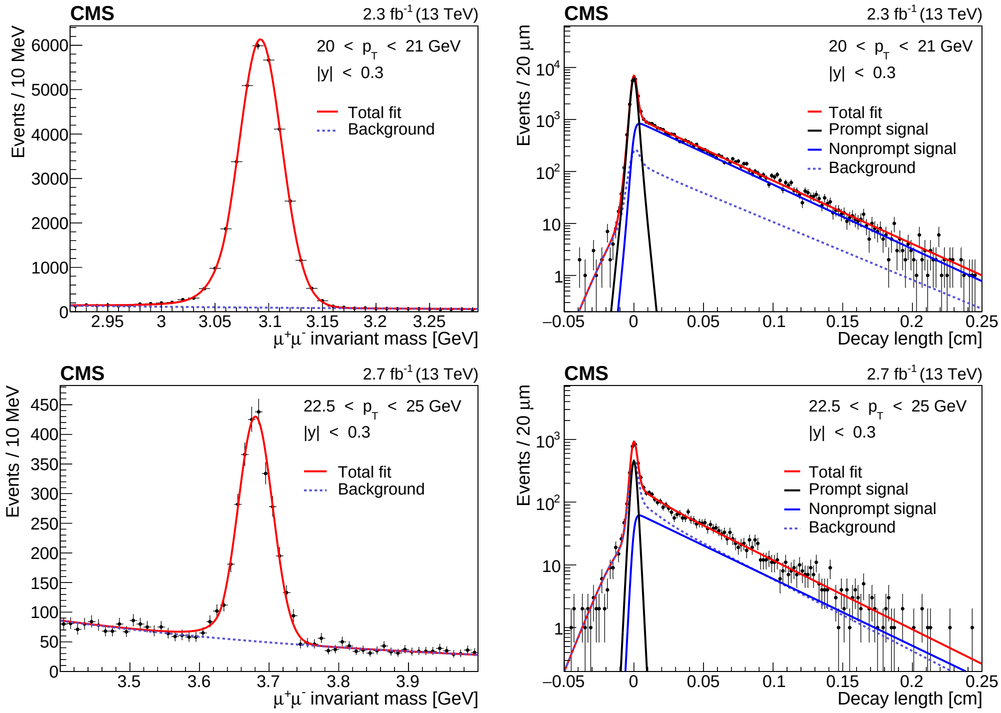

Figure 1: Examples of fits of the dimuon invariant mass (left) and decay length (right) distributions for J/ψ (upper row) and ψ(2S) (lower row) candidate events in the p_{T} and $|y|$ ranges given in the plots. The results from the total fit and from the various components included in the fit are shown.

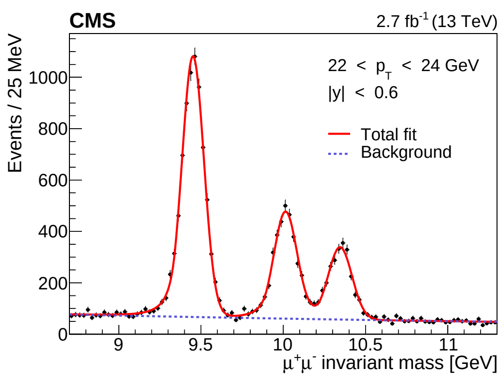

Figure 2: Examples of a fit of the dimuon invariant mass distribution for the Υ(nS) candidate events in the p_{T} and $|y|$ ranges given in the plot. The results from the total fit and for the background component are shown.

Table 1: Double-differential cross section times the dimuon branching fraction of the J/ψ meson for different ranges of p_T, in bins of $|y|$ and for the full $|y|$ range, for the unpolarized decay hypothesis, with their statistical and systematic uncertainties in percent. The average p_T value in each bin is also given. The global uncertainty in the integrated luminosity of 2.3% is not included in the systematic uncertainties.

		$\mathcal{B}\,d\sigma^2/dp_T dy$														
p_T	$\langle p_T \rangle$	$\lvert y\rvert < 0.3$			$0.3 < \lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 0.9$			$0.9 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	[GeV]	[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

Table 2: Double-differential cross section times the dimuon branching fraction of the ψ(2S) meson for different ranges of p_{T}, in bins of $|y|$ and for the full $|y|$ range, for the unpolarized decay hypothesis, with their statistical and systematic uncertainties in percent. The average p_{T} value in each bin is also given. The global uncertainty in the integrated luminosity of 2.3% is not included in the systematic uncertainties.

		$\mathcal{B}\,\mathrm{d}\sigma^2/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y$														
p_{T}	$\langle p_{\mathrm{T}} \rangle$	$\lvert y\rvert < 0.3$			$0.3 < \lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 0.9$			$0.9 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	[GeV]	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %
20–22	21.1	1.62E+00	3.3	5.4	1.65E+00	3.3	5.5	1.67E+00	3.2	5.0	1.58E+00	3.6	5.8	1.63E+00	1.6	5.8
22–25	23.7	9.46E-01	4.2	5.0	8.90E-01	4.4	5.0	1.03E+00	3.9	4.6	8.30E-01	4.8	5.3	9.19E-01	2.1	5.4
25–28	26.2	5.23E-01	5.6	5.0	5.12E-01	5.7	5.2	5.23E-01	5.3	4.4	4.89E-01	6.1	6.7	5.10E-01	2.8	6.8
28–30	28.7	3.45E-01	6.9	5.4	3.77E-01	6.3	5.6	3.08E-01	7.3	5.0	3.55E-01	6.8	6.7	3.45E-01	3.3	6.8
30–35	32.2	1.94E-01	6.4	6.1	2.04E-01	6.2	7.0	1.82E-01	6.6	6.2	1.46E-01	8.2	11	1.80E-01	3.3	11
35–40	37.2	9.68E-02	9.2	7.3	8.87E-02	9.1	8.1	8.42E-02	9.2	9.0	7.22E-02	11	12	8.46E-02	4.7	12
40–55	45.7	2.93E-02	9.3	7.5	2.87E-02	9.4	8.2	2.90E-02	9.6	9.1	2.63E-02	11	12	2.81E-02	4.8	12
55–75	62.5	4.75E-03	66	12	5.07E-03	21	15	4.82E-03	10	15	6.59E-03	18	17	4.97E-03	11	16
75–100	84.2	1.01E-03	48	18	1.20E-03	17	17	1.24E-03	23	18	8.81E-04	23	20	1.08E-03	6.6	20
100–130	111.0													2.85E-04	24	20

Table 3: Double-differential cross section times the dimuon branching fraction of the $\Upsilon(1S)$ meson for different ranges of p_T, in bins of $|y|$ and for the full $|y|$ range, for the unpolarized decay hypothesis, with their statistical and systematic uncertainties in percent. The average p_T value in each bin is also given. The global uncertainty in the integrated luminosity of 2.3% is not included in the systematic uncertainties.

		$\mathcal{B}\,d\sigma^2/dp_T dy$								
p_T	$\langle p_T \rangle$	$\lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	[GeV]	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %
20–22	20.9	5.76E+00	1.7	7.1	5.46E+00	1.7	7.8	5.62E+00	0.9	7.3
22–24	22.9	3.60E+00	1.6	6.0	3.77E+00	2.1	6.7	3.68E+00	1.1	6.3
24–26	25.0	2.50E+00	1.9	5.3	2.44E+00	2.1	6.1	2.47E+00	1.3	5.6
26–28	26.9	1.72E+00	2.2	4.8	1.75E+00	2.5	5.3	1.73E+00	1.5	4.9
28–30	29.0	1.19E+00	2.6	4.9	1.21E+00	3.1	5.2	1.20E+00	1.8	4.9
30–32	31.0	8.50E-01	3.5	4.9	8.62E-01	3.5	5.3	8.55E-01	2.1	5.1
32–34	33.0	6.43E-01	4.0	4.9	6.26E-01	4.1	5.0	6.36E-01	2.4	4.8
34–36	35.0	4.88E-01	4.2	4.7	4.55E-01	5.1	5.4	4.72E-01	2.8	5.3
36–38	37.0	3.52E-01	5.2	4.8	3.12E-01	6.0	6.1	3.32E-01	3.4	5.8
38–40	39.0	2.37E-01	6.1	5.0	2.65E-01	6.5	6.2	2.51E-01	3.9	6.0
40–43	41.4	2.17E-01	5.4	5.4	1.91E-01	5.7	5.1	2.04E-01	3.5	4.8
43–46	44.4	1.39E-01	6.0	5.5	1.17E-01	7.3	5.0	1.28E-01	4.3	4.9
46–50	47.9	7.87E-02	7.0	5.2	8.25E-02	7.0	5.1	8.07E-02	4.6	4.6
50–55	52.3	5.36E-02	7.4	5.0	4.96E-02	8.2	5.2	5.16E-02	5.2	4.7
55–60	57.3	3.72E-02	8.8	5.4	2.96E-02	11	5.6	3.33E-02	6.5	4.8
60–70	64.3	1.51E-02	10	5.2	1.72E-02	11	5.6	1.62E-02	6.8	5.1
70–100	80.5	3.83E-03	12	5.4	4.85E-03	12	5.6	4.32E-03	7.7	4.7
100–130	111.5							6.48E-04	20	4.7

Table 4: Double-differential cross section times the dimuon branching fraction of the $\Upsilon(2S)$ meson for different ranges of p_T, in bins of $|y|$ and for the full $|y|$ range, for the unpolarized decay hypothesis, with their statistical and systematic uncertainties in percent. The average p_T value in each bin is also given. The global uncertainty in the integrated luminosity of 2.3% is not included in the systematic uncertainties.

p_T	$\langle p_T \rangle$	$\mathcal{B}\, d\sigma^2/dp_T dy$								
		$\lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	[GeV]	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %
20–22	20.9	2.45E+00	2.6	6.1	2.30E+00	2.7	6.9	2.38E+00	1.4	6.4
22–24	22.9	1.55E+00	2.3	5.7	1.60E+00	3.3	7.1	1.57E+00	1.7	6.8
24–26	25.0	1.15E+00	2.7	5.2	1.16E+00	3.1	6.1	1.16E+00	1.9	5.8
26–28	26.9	7.54E-01	3.3	4.9	8.27E-01	3.7	5.9	7.89E-01	2.3	5.6
28–30	29.0	5.51E-01	3.7	5.0	5.39E-01	4.6	5.8	5.45E-01	2.7	5.5
30–32	31.0	4.02E-01	4.8	5.4	4.28E-01	5.2	6.5	4.14E-01	3.1	6.3
32–34	33.0	3.04E-01	5.8	6.0	3.31E-01	5.8	5.7	3.18E-01	3.6	5.5
34–36	35.0	2.36E-01	5.9	4.8	2.47E-01	7.6	6.2	2.41E-01	4.1	6.0
36–38	37.0	1.54E-01	7.2	4.7	1.61E-01	8.3	6.0	1.57E-01	5.0	5.6
38–40	39.0	1.28E-01	7.8	4.9	1.23E-01	9.4	5.8	1.26E-01	5.7	5.6
40–43	41.4	9.52E-02	7.6	5.2	1.03E-01	8.0	5.4	9.89E-02	5.0	5.1
43–46	44.4	6.83E-02	8.3	4.9	5.68E-02	11	5.0	6.19E-02	6.4	4.7
46–50	47.9	4.53E-02	9.1	4.8	3.32E-02	12	5.4	3.93E-02	6.9	5.0
50–55	52.3	2.81E-02	9.9	5.1	2.57E-02	12	5.4	2.68E-02	7.3	4.9
55–60	57.3	2.00E-02	11	5.5	1.77E-02	14	5.8	1.88E-02	8.6	5.1
60–70	64.3	8.99E-03	13	5.5	1.10E-02	13	6.3	9.96E-03	8.8	5.5
70–100	80.5	1.91E-03	19	6.3	2.24E-03	17	7.1	2.08E-03	12	5.9
100–130	111.5							5.79E-04	35	6.0

Table 5: Double-differential cross section times the dimuon branching fraction of the Υ(3S) meson for different ranges of p_T, in bins of $|y|$ and for the full $|y|$ range, for the unpolarized decay hypothesis, with their statistical and systematic uncertainties in percent. The average p_T value in each bin is also given. The global uncertainty in the integrated luminosity of 2.3% is not included in the systematic uncertainties.

p_T	$\langle p_T \rangle$	$\mathcal{B}\,d\sigma^2/dp_T dy$ $\lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	[GeV]	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %	[pb/GeV]	stat %	syst %
20–22	20.9	1.64E+00	3.3	7.3	1.55E+00	3.5	7.1	1.60E+00	1.8	6.7
22–24	22.9	1.08E+00	2.9	6.0	1.21E+00	4.0	6.5	1.13E+00	2.0	6.2
24–26	25.0	7.94E-01	3.4	6.2	7.81E-01	4.1	6.4	7.88E-01	2.4	6.1
26–28	26.9	5.72E-01	3.9	6.2	5.84E-01	4.8	6.6	5.79E-01	2.8	6.3
28–30	29.0	4.11E-01	4.5	5.8	3.79E-01	6.0	7.0	3.96E-01	3.3	6.8
30–32	31.0	2.93E-01	6.0	6.4	3.10E-01	6.6	7.3	3.01E-01	3.8	7.0
32–34	33.0	2.54E-01	6.9	6.1	2.13E-01	7.9	6.9	2.34E-01	4.3	6.8
34–36	35.0	1.82E-01	7.0	5.9	1.84E-01	9.7	8.1	1.82E-01	4.7	7.9
36–38	37.0	1.41E-01	7.9	5.8	1.27E-01	10	8.2	1.34E-01	5.4	8.0
38–40	39.0	1.16E-01	8.7	6.0	1.23E-01	11	8.0	1.19E-01	5.7	7.9
40–43	41.4	7.36E-02	9.4	6.4	7.23E-02	10	6.5	7.33E-02	6.1	6.1
43–46	44.4	4.46E-02	11	6.3	4.81E-02	13	6.0	4.59E-02	7.7	5.8
46–50	47.9	3.64E-02	11	6.8	2.84E-02	13	6.4	3.24E-02	7.7	6.0
50–55	52.3	2.22E-02	12	6.9	2.28E-02	13	7.2	2.24E-02	8.4	6.9
55–60	57.3	1.48E-02	14	8.1	1.35E-02	18	8.8	1.43E-02	11	8.3
60–70	64.3	6.34E-03	16	10	8.50E-03	17	11	7.36E-03	10	10
70–100	80.5	1.88E-03	17	13	2.10E-03	19	13	1.98E-03	12	13
100–130	111.5							2.30E-04	48	13

Table 6: Multiplicative scaling factors to obtain the J/ψ differential cross sections for different polarization scenarios ($\lambda_\theta^{\rm HX} = +1, k, -1$) from the unpolarized cross section measurements given in Table 1. The value of k is taken equal to +0.10, and corresponds to an average over $p_{\rm T}$ of the CMS measurement [1].

$p_{\rm T}$	$\lvert y\rvert < 0.3$			$0.3 < \lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 0.9$			$0.9 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	λ_θ=+1	λ_θ=k	λ_θ=−1	λ_θ=+1	λ_θ=k	λ_θ=−1	λ_θ=+1	λ_θ=k	λ_θ=−1	λ_θ=+1	λ_θ=k	λ_θ=−1	λ_θ=+1	λ_θ=k	λ_θ=−1
20–21	1.20	1.02	0.75	1.17	1.01	0.75	1.18	1.02	0.76	1.18	1.02	0.76	1.19	1.02	0.76
21–22	1.19	1.02	0.76	1.17	1.01	0.76	1.18	1.02	0.77	1.17	1.02	0.77	1.18	1.02	0.76
22–23	1.19	1.02	0.76	1.16	1.01	0.77	1.17	1.02	0.78	1.17	1.02	0.78	1.17	1.02	0.77
23–24	1.18	1.02	0.77	1.16	1.01	0.77	1.16	1.02	0.78	1.16	1.02	0.78	1.16	1.02	0.78
24–25	1.17	1.02	0.77	1.15	1.01	0.78	1.16	1.02	0.79	1.15	1.02	0.79	1.16	1.02	0.78
25–26	1.17	1.02	0.78	1.15	1.01	0.78	1.15	1.02	0.79	1.15	1.02	0.79	1.15	1.02	0.79
26–27	1.16	1.02	0.78	1.14	1.01	0.79	1.15	1.02	0.79	1.14	1.02	0.80	1.15	1.02	0.79
27–28	1.16	1.02	0.79	1.14	1.01	0.79	1.14	1.02	0.80	1.14	1.02	0.81	1.14	1.02	0.80
28–29	1.15	1.02	0.79	1.13	1.01	0.80	1.13	1.02	0.81	1.14	1.02	0.81	1.14	1.01	0.80
29–30	1.14	1.02	0.80	1.13	1.01	0.80	1.13	1.02	0.81	1.13	1.02	0.81	1.13	1.01	0.81
30–32	1.14	1.02	0.81	1.12	1.01	0.81	1.12	1.01	0.82	1.13	1.01	0.82	1.13	1.01	0.81
32–34	1.13	1.02	0.82	1.11	1.01	0.82	1.12	1.01	0.82	1.12	1.01	0.82	1.12	1.01	0.82
34–36	1.13	1.02	0.82	1.11	1.01	0.82	1.11	1.01	0.83	1.11	1.01	0.83	1.12	1.01	0.83
36–38	1.11	1.01	0.83	1.11	1.01	0.83	1.11	1.01	0.84	1.10	1.01	0.85	1.11	1.01	0.84
38–42	1.11	1.01	0.84	1.10	1.01	0.84	1.10	1.01	0.85	1.10	1.01	0.85	1.10	1.01	0.84
42–46	1.10	1.01	0.85	1.09	1.01	0.85	1.09	1.01	0.86	1.09	1.01	0.85	1.09	1.01	0.85
46–50	1.09	1.01	0.86	1.08	1.01	0.86	1.08	1.01	0.87	1.09	1.01	0.86	1.09	1.01	0.86
50–60	1.08	1.01	0.88	1.06	1.01	0.89	1.07	1.01	0.88	1.08	1.01	0.88	1.07	1.01	0.88
60–75	1.06	1.01	0.89	1.05	1.00	0.90	1.06	1.01	0.90	1.06	1.01	0.90	1.06	1.01	0.90
75–95	1.05	1.01	0.91	1.04	1.00	0.93	1.04	1.01	0.92	1.05	1.01	0.91	1.04	1.01	0.92
95–120	1.03	1.01	0.93	1.02	1.00	0.94	1.03	1.00	0.94	1.04	1.01	0.92	1.03	1.00	0.93
120–150													1.03	1.00	0.93

Table 7: Multiplicative scaling factors to obtain the ψ(2S) differential cross sections for different polarization scenarios ($\lambda_\theta^{\rm HX} = +1, k, -1$) from the unpolarized cross section measurements given in Table 1. The value of k is taken equal to +0.03, and corresponds to an average over $p_{\rm T}$ of the CMS measurement [1].

$p_{\rm T}$	$\lvert y\rvert < 0.3$			$0.3 < \lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 0.9$			$0.9 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	λ_θ=+1	λ_θ=k	λ_θ=−1	λ_θ=+1	λ_θ=k	λ_θ=−1	λ_θ=+1	λ_θ=k	λ_θ=−1	λ_θ=+1	λ_θ=k	λ_θ=−1	λ_θ=+1	λ_θ=k	λ_θ=−1
20–22	1.19	1.01	0.76	1.17	0.99	0.75	1.18	1.01	0.77	1.17	1.01	0.77	1.18	1.00	0.76
22–25	1.18	1.01	0.77	1.15	1.00	0.77	1.16	1.01	0.78	1.16	1.01	0.78	1.16	1.00	0.78
25–28	1.16	1.01	0.79	1.14	1.00	0.79	1.14	1.00	0.80	1.15	1.01	0.79	1.15	1.00	0.79
28–30	1.15	1.01	0.80	1.12	1.00	0.80	1.13	1.00	0.81	1.13	1.00	0.81	1.13	1.00	0.81
30–35	1.14	1.01	0.81	1.12	1.00	0.81	1.12	1.00	0.82	1.12	1.00	0.82	1.12	1.00	0.82
35–40	1.12	1.01	0.83	1.10	1.00	0.83	1.11	1.00	0.84	1.11	1.00	0.84	1.11	1.00	0.83
40–55	1.10	1.00	0.85	1.08	1.00	0.86	1.08	1.00	0.86	1.08	1.00	0.87	1.09	1.00	0.86
55–75	1.07	1.00	0.88	1.07	1.00	0.88	1.06	1.00	0.89	1.06	1.00	0.89	1.07	1.00	0.88
75–100	1.04	1.00	0.92	1.03	1.00	0.93	1.03	1.00	0.94	1.04	1.00	0.92	1.03	1.00	0.93
100–130													1.03	1.00	0.93

Table 8: Multiplicative scaling factors to obtain the $\Upsilon(1S)$ differential cross sections for different polarization scenarios ($\lambda_\theta^{HX} = +1, k, -1$) from the unpolarized cross section measurements given in Table 3. The parameter k corresponds to a linear interpolation of the CMS measured value of λ_θ^{HX} [2] as a function of p_T for $p_T < 50$ GeV. For $p_T > 50$ GeV, where no measurements of λ_θ^{HX} exist, k is taken as the average of all the measured values of λ_θ^{HX} for $p_T < 50$ GeV.

p_T	$\lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$
20–22	1.14	0.98	0.78	1.14	0.98	0.78	1.14	0.98	0.78
22–24	1.13	0.99	0.78	1.13	0.99	0.78	1.13	0.99	0.78
24–26	1.12	0.99	0.79	1.12	0.99	0.79	1.12	0.99	0.79
26–28	1.11	0.99	0.80	1.11	0.99	0.80	1.11	0.99	0.80
28–30	1.11	0.99	0.81	1.11	0.99	0.81	1.11	0.99	0.81
30–32	1.10	1.01	0.81	1.10	1.01	0.81	1.10	1.01	0.81
32–34	1.10	1.01	0.82	1.10	1.01	0.82	1.10	1.01	0.82
34–36	1.09	1.01	0.82	1.09	1.01	0.82	1.09	1.01	0.82
36–38	1.09	1.01	0.83	1.09	1.01	0.83	1.09	1.01	0.83
38–40	1.10	1.01	0.83	1.10	1.01	0.83	1.10	1.01	0.83
40–43	1.08	1.01	0.84	1.08	1.01	0.84	1.08	1.01	0.84
43–46	1.07	1.01	0.85	1.07	1.01	0.85	1.07	1.01	0.85
46–50	1.07	1.01	0.85	1.07	1.01	0.85	1.07	1.01	0.85
50–55	1.06	0.99	0.86	1.06	0.99	0.86	1.06	0.99	0.86
55–60	1.05	0.99	0.88	1.05	0.99	0.88	1.05	0.99	0.88
60–70	1.05	0.99	0.88	1.05	0.99	0.88	1.05	0.99	0.88
70–100	1.03	1.00	0.92	1.03	1.00	0.92	1.03	1.00	0.92
100–130							1.03	1.00	0.92

Table 9: Multiplicative scaling factors to obtain the $\Upsilon(2S)$ differential cross sections for different polarization scenarios ($\lambda_\theta^{HX} = +1, k, -1$) from the unpolarized cross section measurements given in Table 4. The parameter k corresponds to a linear interpolation of the CMS measured value of λ_θ^{HX} [2] as a function of p_T for $p_T < 50$ GeV. For $p_T > 50$ GeV, where no measurements of λ_θ^{HX} exist, k is taken as the average of all the measured values of λ_θ^{HX} for $p_T < 50$ GeV.

p_T	$\lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$
20–22	1.14	1.03	0.78	1.14	1.03	0.78	1.14	1.03	0.78
22–24	1.13	1.03	0.79	1.13	1.03	0.79	1.13	1.03	0.79
24–26	1.12	1.03	0.79	1.12	1.03	0.79	1.12	1.03	0.79
26–28	1.11	1.03	0.80	1.11	1.03	0.80	1.11	1.03	0.80
28–30	1.11	1.03	0.81	1.11	1.03	0.81	1.11	1.03	0.81
30–32	1.10	1.03	0.82	1.10	1.03	0.82	1.10	1.03	0.82
32–34	1.10	1.03	0.82	1.10	1.03	0.82	1.10	1.03	0.82
34–36	1.09	1.03	0.82	1.09	1.03	0.82	1.09	1.03	0.82
36–38	1.09	1.03	0.83	1.09	1.03	0.83	1.09	1.03	0.83
38–40	1.09	1.03	0.83	1.09	1.03	0.83	1.09	1.03	0.83
40–43	1.08	1.03	0.84	1.08	1.03	0.84	1.08	1.03	0.84
43–46	1.07	1.02	0.85	1.07	1.02	0.85	1.07	1.02	0.85
46–50	1.07	1.02	0.86	1.07	1.02	0.86	1.07	1.02	0.86
50–55	1.06	0.99	0.87	1.06	0.99	0.87	1.06	0.99	0.87
55–60	1.06	0.99	0.86	1.06	0.99	0.86	1.06	0.99	0.86
60–70	1.05	0.99	0.90	1.05	0.99	0.90	1.05	0.99	0.90
70–100	1.03	0.99	0.92	1.03	0.99	0.92	1.03	0.99	0.92
100–130							1.03	0.99	0.92

Table 10: Multiplicative scaling factors to obtain the Υ(3S) differential cross sections for different polarization scenarios ($\lambda_\theta^{\mathrm{HX}} = +1, k, -1$) from the unpolarized cross section measurements given in Table 5. The parameter k corresponds to a linear interpolation of the CMS measured value of $\lambda_\theta^{\mathrm{HX}}$ [2] as a function of p_{T} for $p_{\mathrm{T}} < 50\,\mathrm{GeV}$. For $p_{\mathrm{T}} > 50\,\mathrm{GeV}$, where no measurements of $\lambda_\theta^{\mathrm{HX}}$ exist, k is taken as the average of all the measured values of $\lambda_\theta^{\mathrm{HX}}$ for $p_{\mathrm{T}} < 50\,\mathrm{GeV}$, which are all consistent with a single value.

p_{T}	$\lvert y\rvert < 0.6$			$0.6 < \lvert y\rvert < 1.2$			$\lvert y\rvert < 1.2$		
[GeV]	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$	$\lambda_\theta = +1$	$\lambda_\theta = k$	$\lambda_\theta = -1$
20–22	1.13	1.03	0.78	1.13	1.03	0.78	1.13	1.03	0.78
22–24	1.13	1.02	0.79	1.13	1.02	0.79	1.13	1.02	0.79
24–26	1.12	1.02	0.79	1.12	1.02	0.79	1.12	1.02	0.79
26–28	1.11	1.02	0.80	1.11	1.02	0.80	1.11	1.02	0.80
28–30	1.11	1.02	0.81	1.11	1.02	0.81	1.11	1.02	0.81
30–32	1.10	1.03	0.82	1.10	1.03	0.82	1.10	1.03	0.82
32–34	1.10	1.03	0.82	1.10	1.03	0.82	1.10	1.03	0.82
34–36	1.09	1.03	0.83	1.09	1.03	0.83	1.09	1.03	0.83
36–38	1.09	1.03	0.83	1.09	1.03	0.83	1.09	1.03	0.83
38–40	1.09	1.03	0.84	1.09	1.03	0.84	1.09	1.03	0.84
40–43	1.08	1.03	0.84	1.08	1.03	0.84	1.08	1.03	0.84
43–46	1.07	1.02	0.85	1.07	1.02	0.85	1.07	1.02	0.85
46–50	1.06	1.02	0.86	1.06	1.02	0.86	1.06	1.02	0.86
50–55	1.06	0.99	0.87	1.06	0.99	0.87	1.06	0.99	0.87
55–60	1.06	0.99	0.87	1.06	0.99	0.87	1.06	0.99	0.87
60–70	1.05	0.99	0.89	1.05	0.99	0.89	1.05	0.99	0.89
70–100	1.03	0.99	0.92	1.03	0.99	0.92	1.03	0.99	0.92
100–130							1.03	0.99	0.92

Table 11: Ratios of the p_T differential cross sections times dimuon branching fractions of the prompt ψ(2S) to J/ψ, Υ(2S) to Υ(1S), and Υ(3S) to Υ(1S) mesons for $|y| < 1.2$, with their statistical and systematic uncertainties in percent.

p_T	ψ(2S) / J/ψ			p_T	Υ(2S)/ Υ(1S)			Υ(3S)/ Υ(1S)		
[GeV]		stat %	syst %	[GeV]		stat %	syst %		stat %	syst %
20–21	0.04	3	11	20–22	0.42	1.7	8.5	0.28	2.0	9.1
21–22	0.04	3	11	22–24	0.43	2.0	8.4	0.31	2.3	7.5
22–23	0.04	3	11	24–26	0.47	2.3	6.9	0.32	2.7	7.1
23–24	0.05	3	11	26–28	0.46	2.8	6.2	0.33	3.1	6.8
24–25	0.04	4	13	28–30	0.45	3.2	6.4	0.33	3.8	8.1
25–26	0.04	4	14	30–32	0.48	3.8	7.8	0.35	4.3	8.9
26–27	0.04	5	15	32–34	0.50	4.3	6.3	0.37	4.9	8.3
27–28	0.04	5	16	34–36	0.51	5.0	7.9	0.38	5.5	11
28–29	0.05	5	17	36–38	0.47	6.1	8.3	0.40	6.4	11
29–30	0.05	6	17	38–40	0.50	6.8	8.3	0.47	6.9	11
30–32	0.04	5	18	40–43	0.48	6.1	5.7	0.36	7.0	7.1
32–34	0.04	6	18	43–46	0.48	7.7	5.4	0.36	8.8	6.6
34–36	0.04	6	20	46–50	0.49	8.3	5.3	0.40	9.0	6.6
36–38	0.04	7	20	50–55	0.52	8.9	5.4	0.43	9.8	7.5
38–42	0.05	6	21	55–60	0.56	11	6.2	0.43	12	9.2
42–46	0.04	9	22	60–70	0.62	11	6.6	0.46	12	11
46–50	0.05	10	25	70–100	0.48	14	6.6	0.46	14	14
50–60	0.05	10	25	100–130	0.89	40	6.6	0.35	52	14
60–75	0.04	42	26							
75–95	0.05	10	29							
95–120	0.06	21	38							
120–150	0.07	71	38							

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