Study of prompt J/ψ production in e^+e^- annihilation at center-of-mass energies from 3.810 GeV to 4.600 GeV

Olga BAKINA

On behalf of BESIII-JINR group
Joint Institute for Nuclear Research, Dubna, Russia

Charmonium group meeting
10 April 2019

Inclusive prompt J/ψ production ($e^+e^-\to J/\psi_{prompt}X$)

- Prompt = Total – $\{\psi'\to J/\psi\}$ – $\{\chi_{c1,2}\to J/\psi\}$ – $\{e^+e^-\to\gamma_{ISR}J/\psi(\psi')\}$
- Goal:
  - Test NRQCD (in particular, the universality of the NRQCD LDMEs)
  - NRQCD prediction: the color-octet LDMEs are non-zero if $\sigma>10$ pb at $\sqrt{s}$ = 4.6 ~ 5.6 GeV (arXiv:1409.2293v2 [hep-ph] 4 Aug 2016)
  - Test if unknown channels/states exist
- Data only available at $\sqrt{s}$ = 10.6 GeV:

  ✔ 2.5 ± 0.3 pb (BaBar)

  ✔ 1.5 ± 0.2 pb (Belle)

  ✔ 1.9 ± 0.2 pb (CLEO)

Data

- 20 energy points of the XYZ data (2011-2014), ~5 fb^{-1}
- 9 energy points of the XYZ data (2016-2017), ~7 fb^{-1}
- All the data and corresponding MC samples are reconstructed and simulated using BOSS 7.0.3

Energy measurement (Data 2011-2014): M. Ablikim et al. "Measurement of the center-of-mass energies at BESIII via the di-muon process", arXiv:1510.08654 [hep-ex] 29 Oct 2015

Luminosity (Data 2011-2014, 2017) and energy measurement (Data 2017): BESIII DocDB-doc-720-v13, https://docbes3.ihep.ac.cn/cgi-bin/DocDB/ShowDocument?docid=720

$$\sigma_{e^+e^-\to J/\psi_{prompt}X} = \frac{1}{\mathcal{L}} \times \left(Y_{J/\psi X} - Y_{\psi'_{ISR}\to J/\psi X} - Y_{\psi'\to J/\psi X} - Y_{\chi_c\to\gamma J/\psi}\right)$$

$$Y_{J/\psi X} = \frac{N^{obs}_{J/\psi X} - \mathcal{R}^{bg}_{J/\psi_{ISR}} \times N^{obs}_{J/\psi_{ISR}}}{\bar{\epsilon}_{J/\psi X} \times \mathcal{B}_{J/\psi\to\mu^+\mu^-}}$$

- $N^{obs}_{J/\psi X}$ – the observed number of $e^+e^- \to J/\psi X$ events
- $N^{obs}_{J/\psi_{ISR}}$ – the observed number of specially selected $e^+e^- \to (\gamma_{ISR})J/\psi$ events
- $\mathcal{R}^{bg}_{J/\psi_{ISR}}$ – the ratio of J/ψ_{ISR} selection efficiency in the nominal selection and in special ISR selection (~2% accroding to KKMC)
- $\bar{\epsilon}_{J/\psi X}$ – the reconstruction efficiency of J/ψ
- $\mathcal{B}_{J/\psi\to\mu^+\mu^-}$ – the branching fraction of $J/\psi \to \mu^+\mu^-$

Selection criteria for $J/\psi X$ and $(\gamma_{ISR})J/\psi$

Track configuration for $e^+e^- \to J/\psi X \to \mu^+\mu^- X$:

- exactly one positive and one negative reconstructed charged tracks and at least two photons (suppression of ~98% $e^+e^- \to (\gamma_{ISR})J/\psi$ events)
- exactly two positive and two negative reconstructed charged tracks and at least two photons (suppression of ~50% $e^+e^- \to (\gamma_{ISR})\psi'$ events)
- exactly two positive and two negative reconstructed charged tracks, less than two photons while the charged tracks do not form the ψ' signal via the $J/\psi\pi^+\pi^-$ final state
- other configurations with more than one positive or more than one negative reconstructed charged tracks

Track configuration for $e^+e^- \to (\gamma_{ISR})J/\psi \to (\gamma_{ISR})\mu^+\mu^-$:

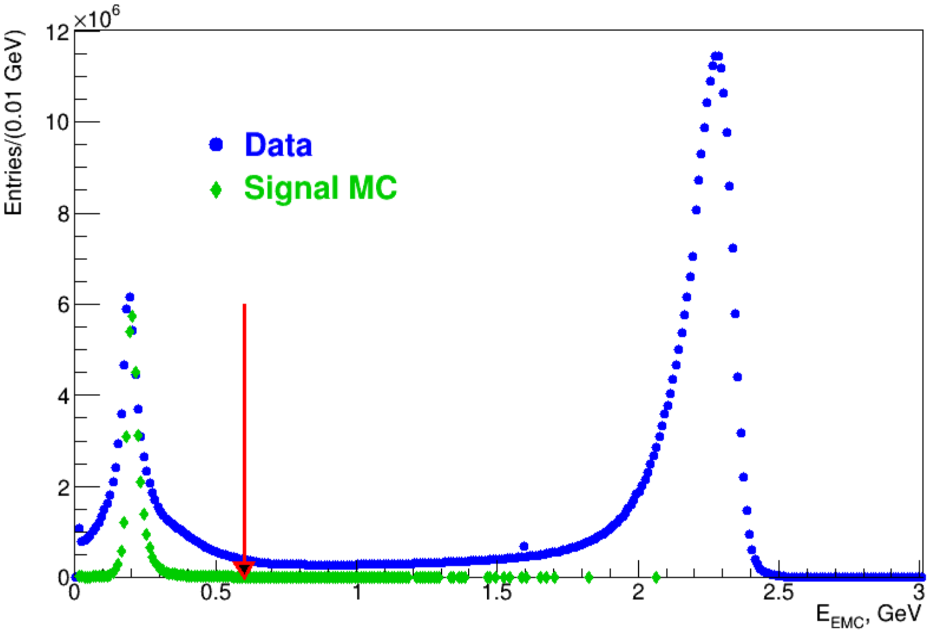
- exactly one positive and one negative reconstructed charged tracks and less than two photons

Charged tracks criteria:

- $\cos(\Theta) < 0.93$ (for each charged track);
- $r < 1$ cm, $|z| < 10$ cm (for each charged track);
- Eemc < 0.6 GeV (muons from J/ψ decay identification)
- 2.8 GeV < $M_{\mu^+\mu^-}$ < 3.4 GeV (mass window for J/ψ);

Photons criteria:

- EMC: $0 \leq t \leq 700$ ns;
- E > 25 MeV (barrel), E > 50 MeV (end-cups);
- The angle between the neutral track and the nearest charged track > 20°;



$$\sigma_{e^+e^-\to J/\psi_{prompt}X} = \frac{1}{\mathcal{L}} \times \left(Y_{J/\psi X} - Y_{\psi'_{ISR}\to J/\psi X} - Y_{\psi'\to J/\psi X} - Y_{\chi_c\to\gamma J/\psi}\right)$$

$$Y_{\psi'\to J/\psi X} = \frac{N^{obs}_{\psi' X} \times \tilde{\mathcal{B}}_{\psi'\to J/\psi X}}{\bar{\epsilon}_{\psi' X} \times \mathcal{B}_{\psi'\to J/\psi\pi^+\pi^-} \times \mathcal{B}_{J/\psi\to\mu^+\mu^-}}$$

$$Y_{\psi'_{ISR}\to J/\psi X} = \frac{N^{obs}_{\psi'_{ISR}} \times (1-\epsilon_{\psi'_{ISR}}) \times \tilde{\mathcal{B}}_{\psi'\to J/\psi X}}{\epsilon_{\psi'_{ISR}} \times \mathcal{B}_{\psi'\to J/\psi\pi^+\pi^-} \times \mathcal{B}_{J/\psi\to\mu^+\mu^-}}$$

- $N^{obs}_{\psi' X}$ – the observed number of $e^+e^- \to \psi' X$ events
- $\bar{\epsilon}_{\psi' X}$ – the reconstruction efficiency of ψ'
- $N^{obs}_{\psi'_{ISR}}$ – the observed number of $e^+e^- \to (\gamma_{ISR})\psi'$ events
- $\epsilon_{\psi'_{ISR}}$ – the reconstruction efficiency of ψ'_{ISR}
- $\mathcal{B}_{\psi'\to J/\psi\pi^+\pi^-}$ – the branching fraction of $\psi' \to J/\psi\pi^+\pi^-$
- $\tilde{\mathcal{B}}_{\psi'\to J/\psi X}$ – the branching fraction of $\psi' \to J/\psi X$ except $\psi' \to \gamma\chi_{c1,2} \to \gamma(\gamma J/\psi)$ decays

$$\tilde{\mathcal{B}}_{\psi'\to J/\psi X} = \mathcal{B}_{\psi'\to J/\psi X} - \mathcal{B}_{\psi'\to\gamma\chi_{c1}} \times \mathcal{B}_{\chi_{c1}\to\gamma J/\psi} - \mathcal{B}_{\psi'\to\gamma\chi_{c2}} \times \mathcal{B}_{\chi_{c2}\to\gamma J/\psi}$$

Selection criteria for $\psi'X$ and $(\gamma_{ISR})\psi'$

Track configuration for $e^+e^- \to \psi'X \to J/\psi\pi^+\pi^-X$:

- exactly two positive and two negative reconstructed charged tracks and at least two photons (suppression of ~50% $e^+e^- \to (\gamma_{ISR})\psi'$ events)
- more than two positive or more than two negative reconstructed charged tracks

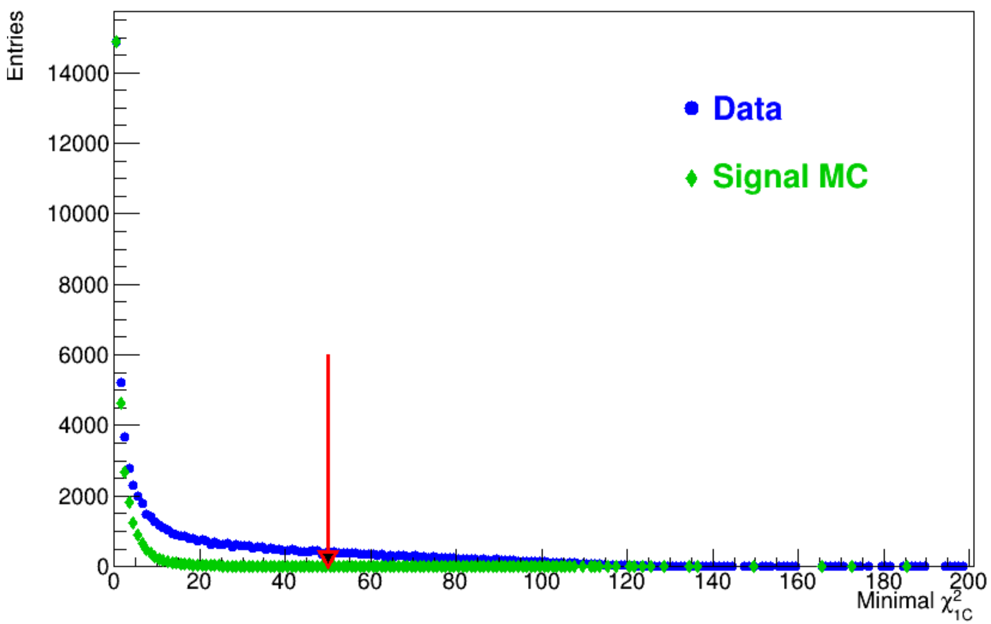
Track configuration for $e^+e^- \to (\gamma_{ISR})\psi' \to (\gamma_{ISR})J/\psi\pi^+\pi^-$:

- exactly two positive and two negative reconstructed charged tracks and less than two photons

Additionally, 1C kinematic fit to the J/ψ mass:

- 3.0 GeV < $M\mu^+\mu^-$ < 3.2 GeV;
- $\mu^+\mu^-$ combination with minimal χ^2;
- $\chi^2_{min} < 50$;

All other charged track pairs are considered as $\pi^+\pi^-$ without any particle identification.



$$\sigma_{e^+e^-\to J/\psi_{prompt}X} = \frac{1}{\mathcal{L}} \times \left(Y_{J/\psi X} - Y_{\psi'_{ISR}\to J/\psi X} - Y_{\psi'\to J/\psi X} - Y_{\chi_c\to\gamma J/\psi}\right)$$

$$Y_{\chi_c\to\gamma J/\psi} = \frac{N^{obs}_{\chi_c X}}{\epsilon_{\chi_c X} \times \mathcal{B}_{J/\psi\to\mu^+\mu^-}}$$

- $N^{obs}_{\chi_c X}$ – the observed number of $e^+e^- \to \chi_c X$ events
- $\epsilon_{\chi_c X}$ – the reconstruction efficiency of χ_c

Selection criteria for $\chi_c X$

Track configuration for $e^+e^- \to \chi_{c1,2}X \to \gamma J/\psi X$

(according to J/ψ selection criteria described above):

- exactly one positive and one negative reconstructed charged tracks and at least two photons
- exactly two positive and two negative reconstructed charged tracks and at least two photons
- exactly two positive and two negative reconstructed charged tracks, exactly one photon while the charged tracks do not form the ψ' signal via the $J/\psi\pi^+\pi^-$ final state
- other configurations with more than one positive or more than one negative reconstructed charged tracks and at least one photon

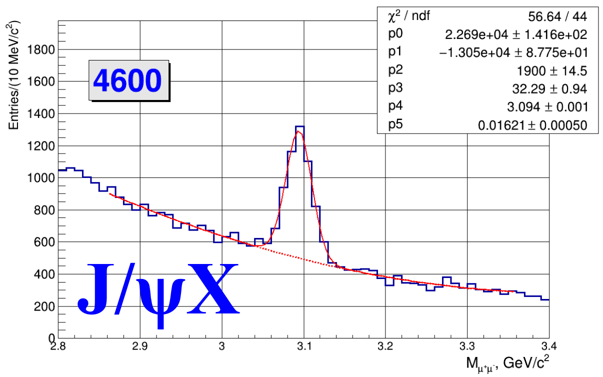
Additionally, 1C kinematic fit to the J/ψ mass:

- 3.0 GeV $< M_{\mu^+\mu^-} < 3.2$ GeV;
- $\mu^+\mu^-$ combination with minimal χ^2;
- $\chi^2_{min} < 50$;

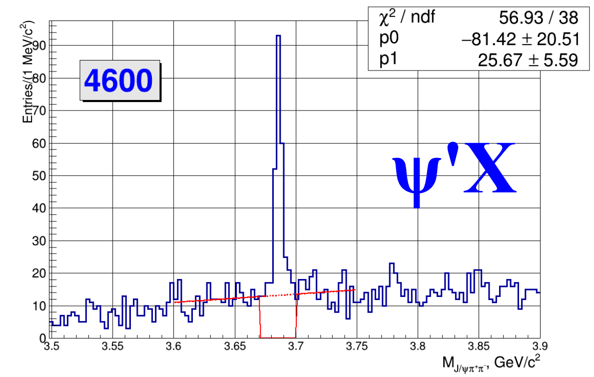
At least two photons for 2-track events and at least one photon for other events:

- EMC: $0 \leq t \leq 700$ ns;
- $E > 25$ MeV (barrel), $E > 50$ MeV (end-cups);
- The angle between the neutral track and the nearest charged track $> 20^\circ$;

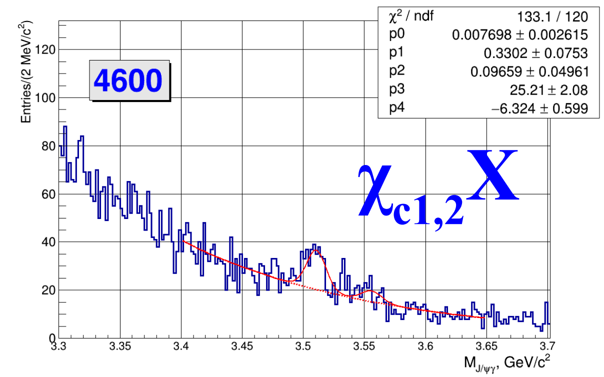
Observed number of events



Fit a normalized Gaussian function (signal) and a quadratic polynomial (background) to the data

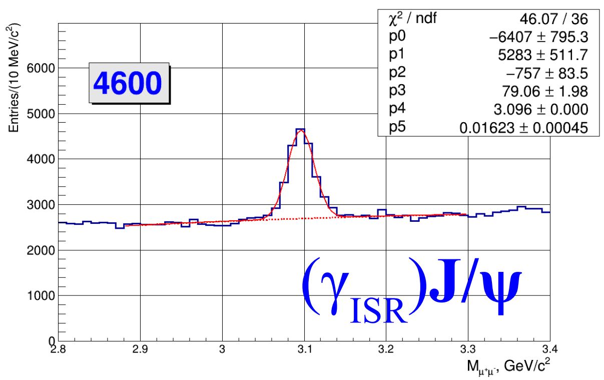


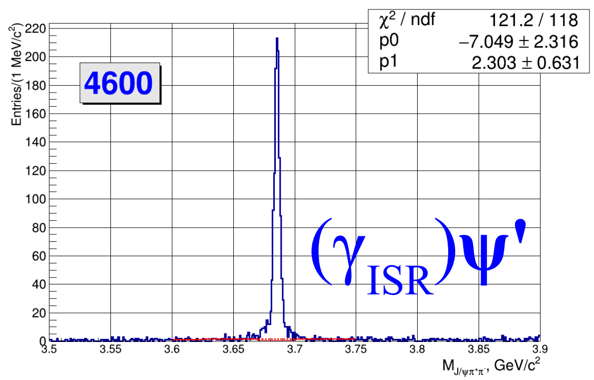
Background is fitted by a line



Fit two Breit-Wigner convoluted with Gaussian functions (signal) and an exponential function (background) to the data

Masses and widths of $\chi c_{1,2}$ are fixed parameters.



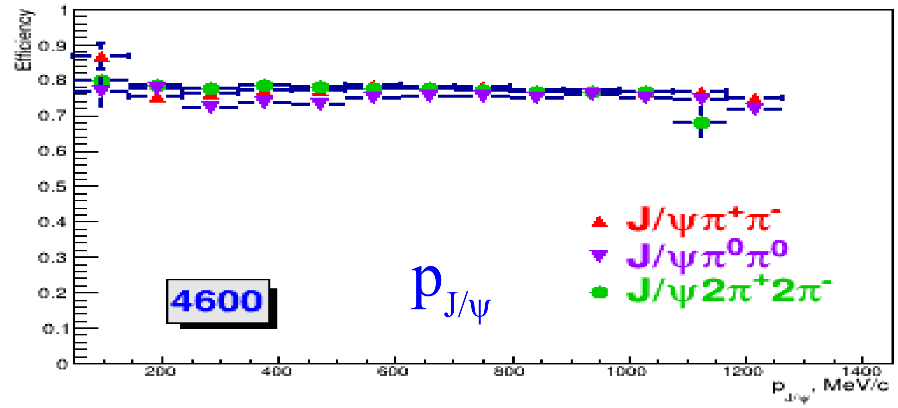


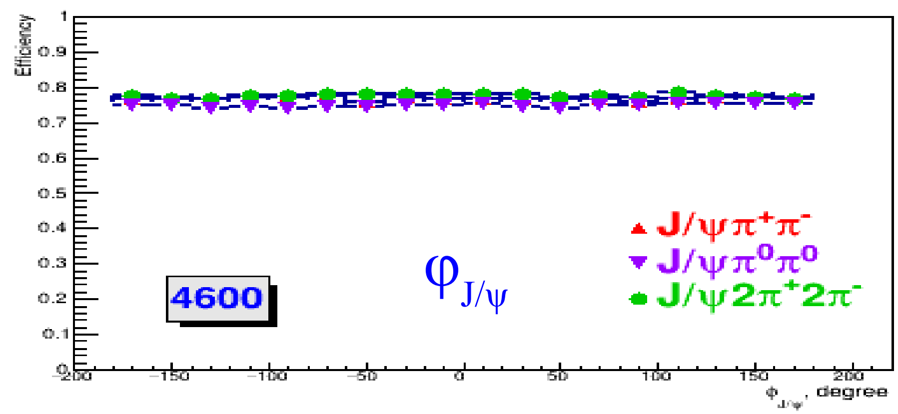
$$\sigma_{J/\psi_{prompt}X} = \frac{1}{586.9\ pb^{-1}} \times \left(\frac{3229 - 0.019 \times 7906}{\bar{\epsilon}_{J/\psi X} \times 0.05961} - \frac{1288 \times (1-\epsilon_{\psi'_{ISR}}) \times 0.5625}{\epsilon_{\psi'_{ISR}} \times 0.3467 \times 0.05961} - \frac{203 \times 0.5625}{\bar{\epsilon}_{\psi' X} \times 0.3467 \times 0.05961} - \frac{163}{\epsilon_{\chi_{c1} X} \times 0.05961} - \frac{47}{\epsilon_{\chi_{c2} X} \times 0.05961}\right)$$

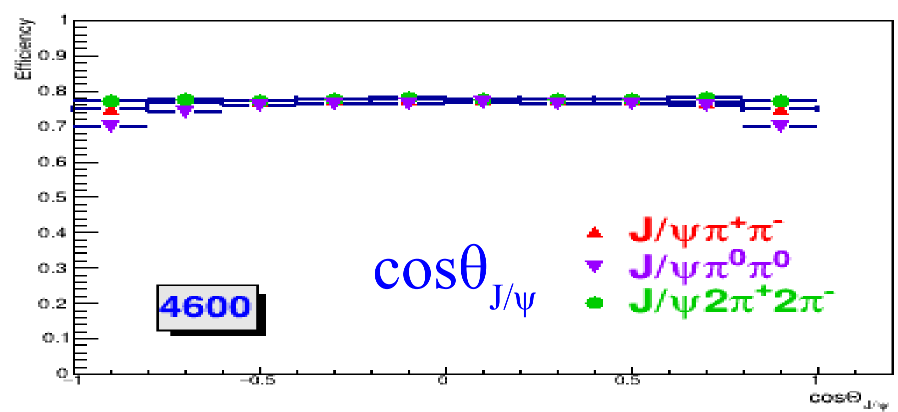
Efficiency

- To estimate efficiency we need to produce inclusive Monte Carlo samples of unknown composition.
- We assumed that efficiency mainly depends on topology of events (track multiplicity).
- Thus we decided to produce appropriate Monte Carlo samples as a mixture of major exclusive channels with typical topologies.
- Weights for the mixture we obtain from track multiplicity of the real data.

Momentum and angular dependence of J/ψ efficiency



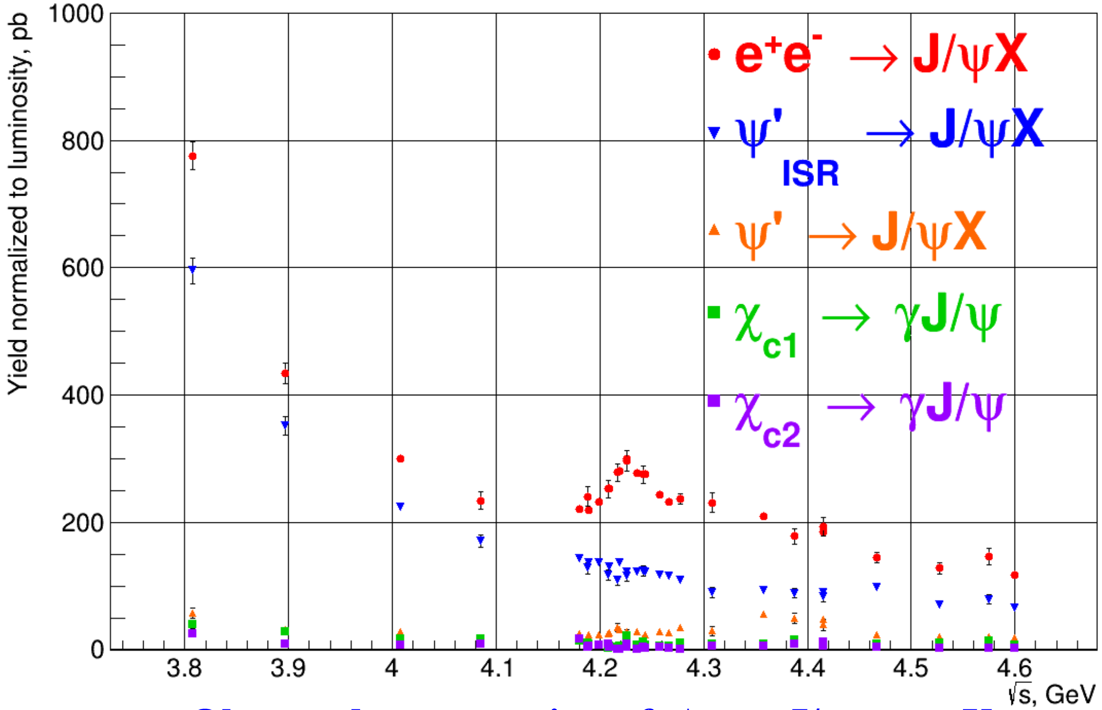




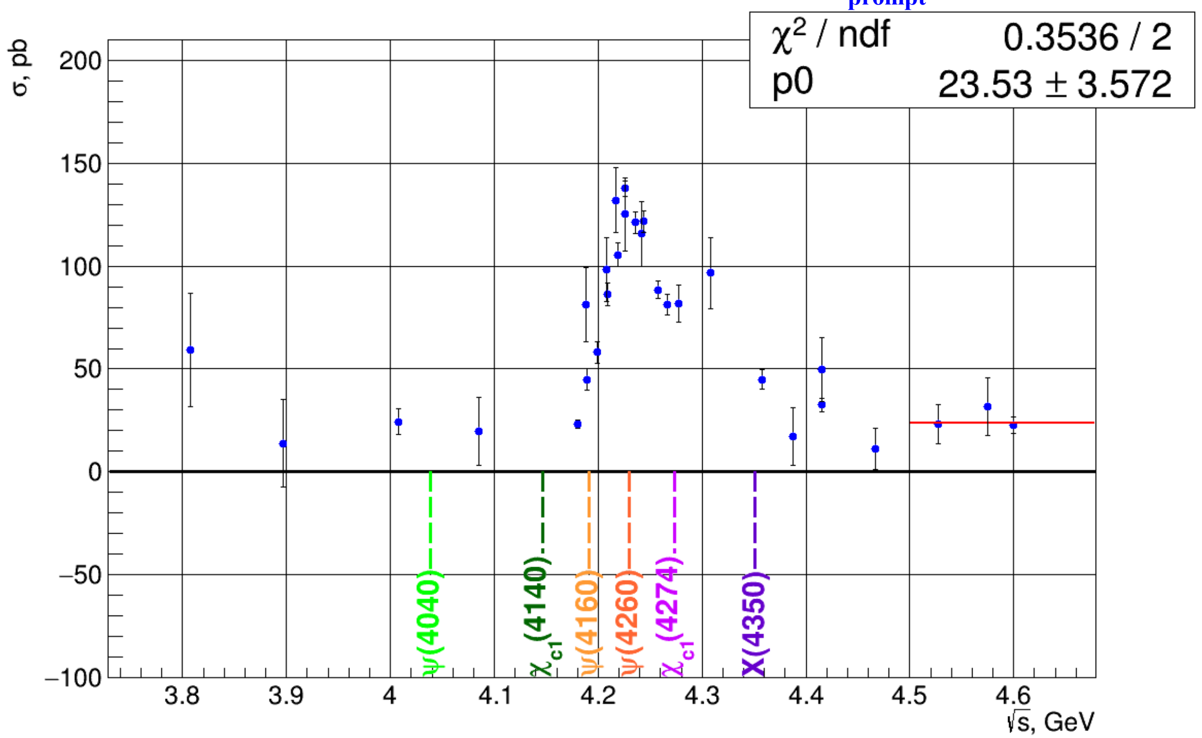
Monte Carlo

- **J/ψ: mix of the major exclusive channels weighted with multiplicity**
  - **MC samples (PHSP, each energy point):** $J/\psi\pi^+\pi^-$, $J/\psi\pi^0\pi^0$, $J/\psi 2\pi^+2\pi^-$, where $J/\psi \to \mu^+\mu^-$
- **ψ': mix of the major exclusive channels weighted with multiplicity**
  - **MC samples (PHSP, each energy point):** $\psi'\pi^+\pi^-$, $\psi'\pi^0\pi^0$, where $\psi' \to J/\psi\pi^+\pi^-$ and $J/\psi \to \mu^+\mu^-$
- **ψ'_{ISR}: one exclusive channel**
  - **MC samples (KKMC, each energy point):** $(\gamma_{ISR})\psi'$, where $\psi' \to J/\psi\pi^+\pi^-$ and $J/\psi \to \mu^+\mu^-$
- **$\chi_{c1,2}$: one exclusive three-particle channel**
  - **MC samples (PHSP, each energy point):** $\chi_{c1,2}2\gamma$, where $\chi_{c1,2} \to J/\psi\gamma$ and $J/\psi \to \mu^+\mu^-$

Yield of J/ψ from different sources normalized to corresponding luminosity



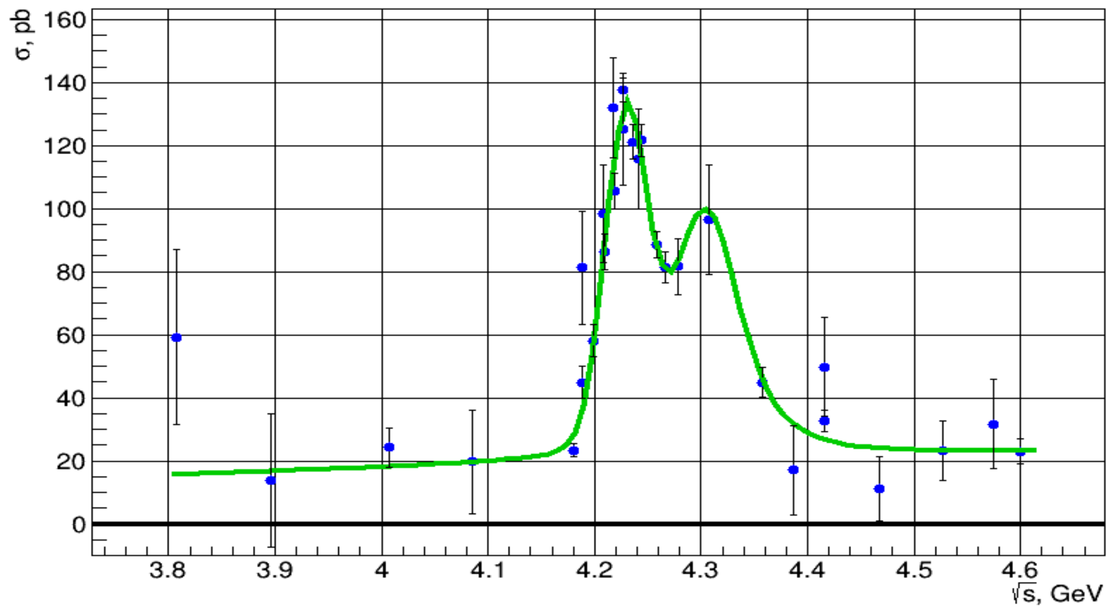
Observed cross-section of $e^+e^- \to J/\psi_{prompt} + X$



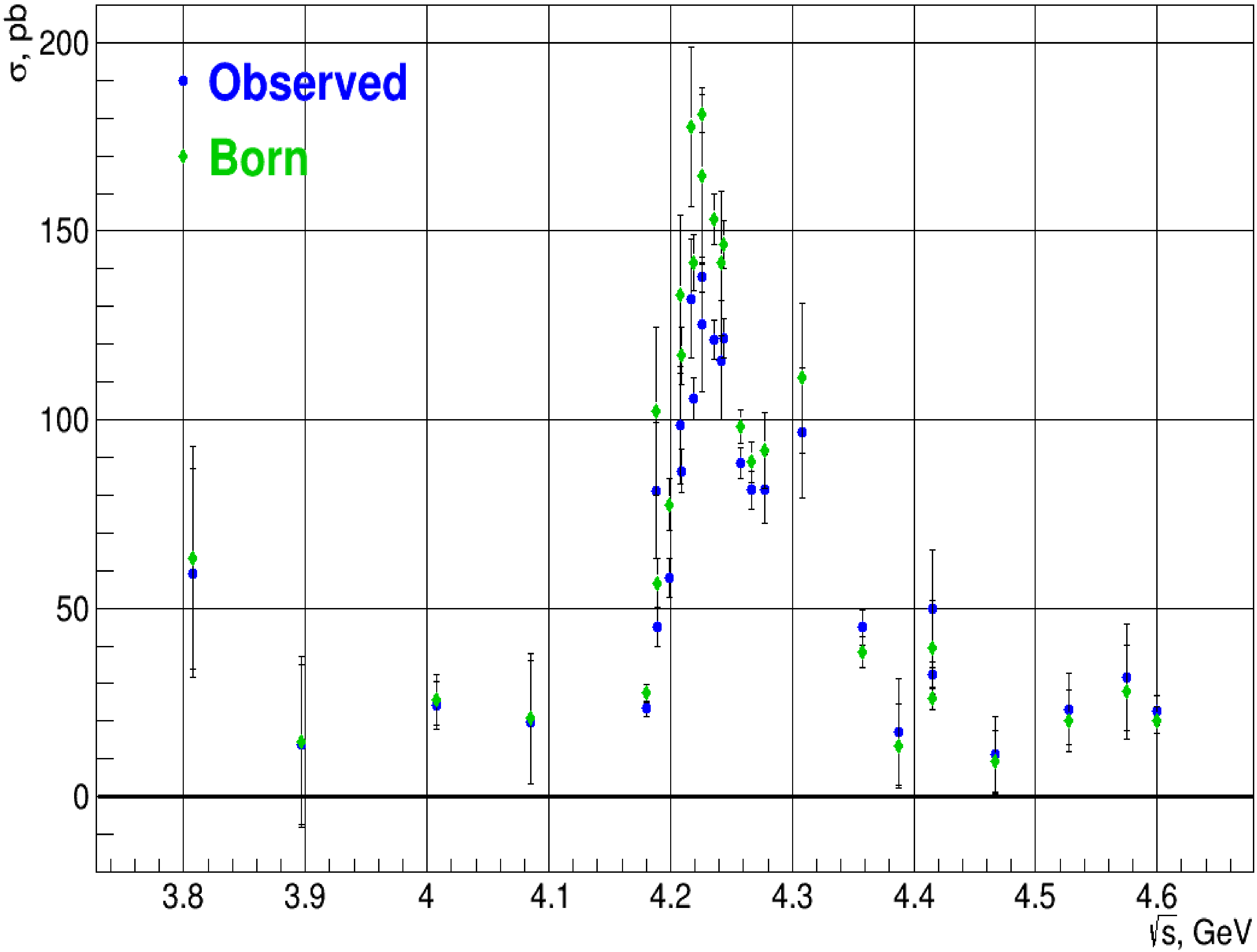
Deconvolution to Born cross-section

$$\sigma^{obs} = (1+\delta) * \sigma_{fit}^{Born} = \int \sigma_{fit}^{Born}(s(1-x))F(x,s)dx$$

The cross-section line shape for iteration process is obtained by fitting two Breit-Wigner convoluted with a gaussian functions for resonances and const*√(√s - $M_{J/\psi}$) for continuum to the measured cross-section



Observed and Born cross-section of $e^+e^- \to J/\psi_{prompt} + X$



Study of systematics

Tracking:

- Due to the discrepancy between MC and data is 1% for charged track reconstructed efficiency and 1% for photon reconstructed efficiency we performed the following variations of reconstructed efficiencies to obtain systematic errors of tracking:

$\varepsilon_{J/\psi}$: **2%** variation

$\varepsilon_{\psi'} = \varepsilon_{J/\psi} * \varepsilon_{\pi\pi} = \varepsilon_{J/\psi} * (\varepsilon_{\pi})^2$: **2%** variation

$\varepsilon_{\chi c1,2} = \varepsilon_{J/\psi} * \varepsilon_{\gamma}$: **1%** variation

- Errors of charged tracking were summed linearly, errors of photon tracking were also summed linearly, then resulting contributions were summed quadratically.

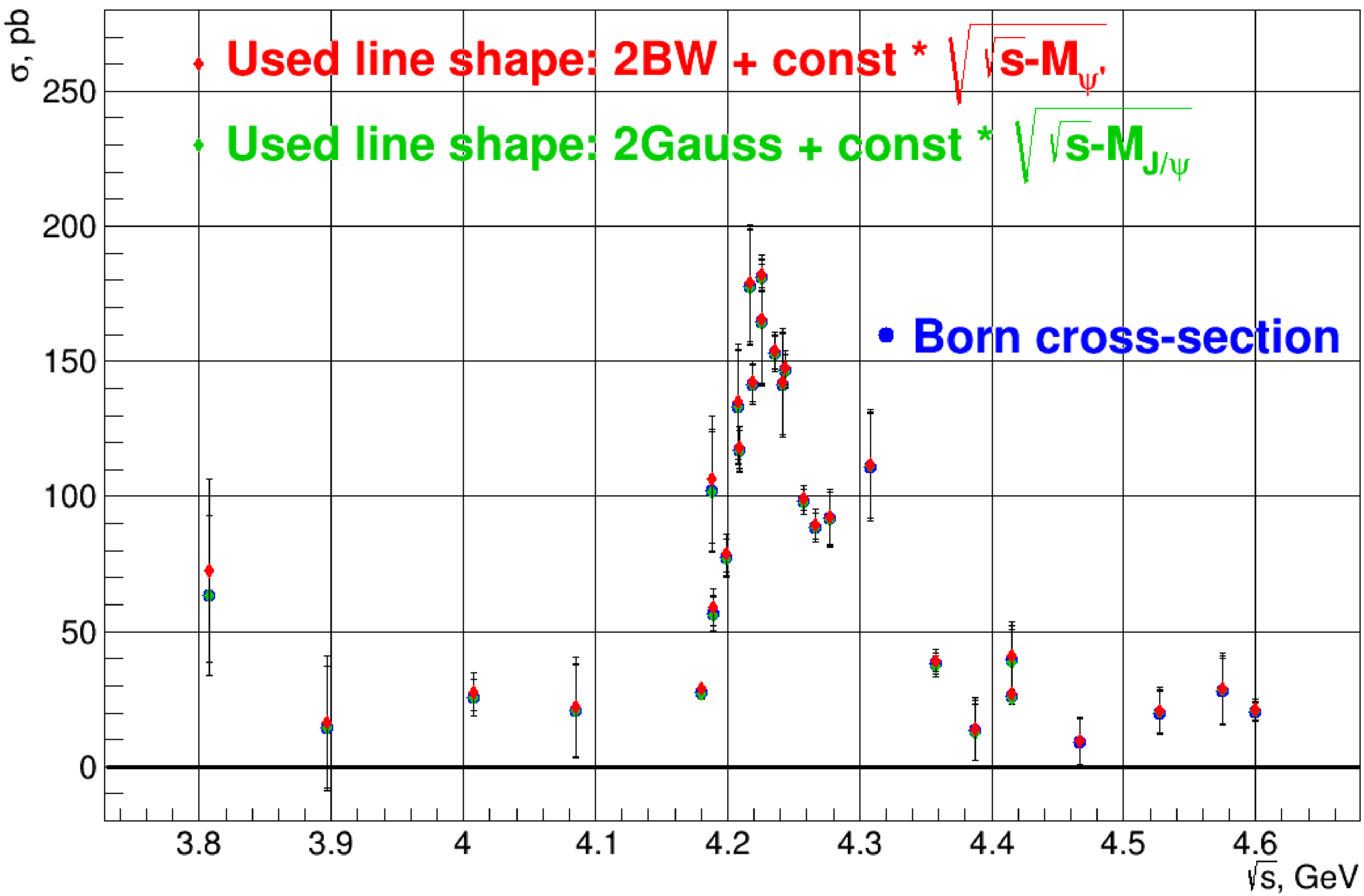
E_{emc} cut & $N_{J/\psi}$ fit:

- To decrease statistical fluctuations we combined the data into 3 groups (3810-4180, 4190-4310, 4360-4600) and we obtained relative systematic errors of the following sources:
  - E_{emc} cut: the value was varied as 0.5 GeV
  - $N_{J/\psi}$: fit a cubic polynomial to the data for background
- Using relative systematic errors we obtained absolute systematic errors for each energy point in the corresponding group

Luminosity: total errors of luminosity measurement were took into account to obtain systematic error for each energy point (Ref.: BESIII DocDB-doc-720-v13, https://docbes3.ihep.ac.cn/cgi-bin/DocDB/ShowDocument?docid=720)

Branching fractions: errors of branching fractions of all charmonia decays used in the analysis were took into account to obtain systematic error for each energy point (Ref.: Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018))

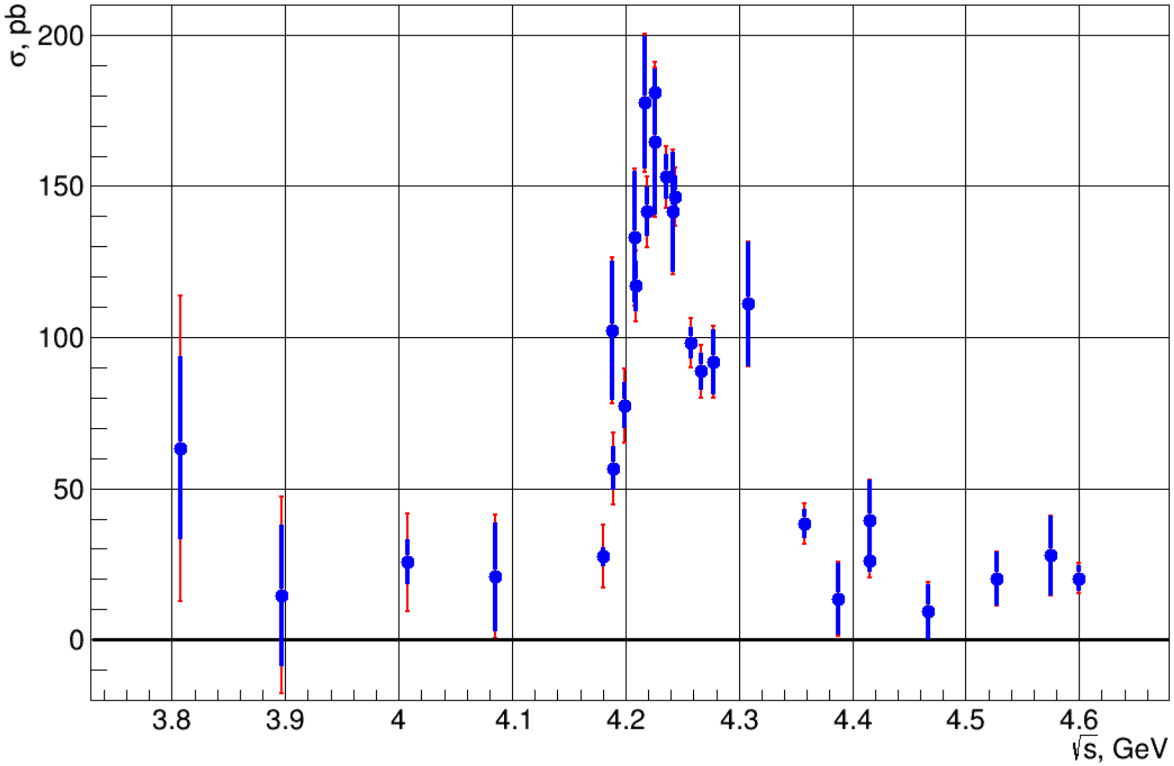
Study of systematics: Deconvolution to Born cross-section procedure

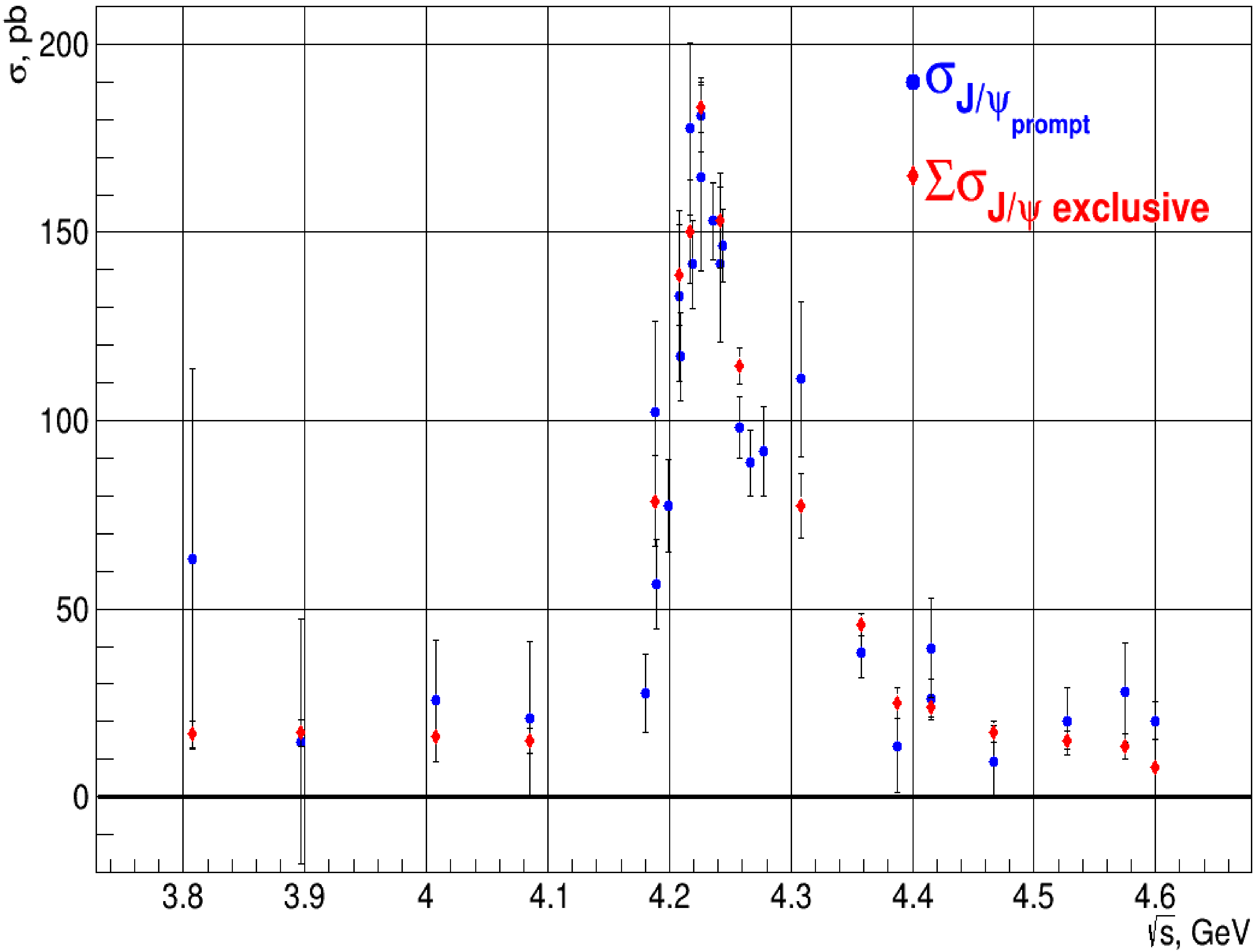


Contributions to systematic error (4600)

- Track and photon reconstruction: 15.8%
- EMC enegry cut: 1.1%
- Fit to dimuon invariant mass: 0.6%
- Total: 17.2%
- The procedure of deconvolution to Born cross-section: 4.4%
- Luminosity: 0.7%
- Branching fractions: 5.1%

Born cross-section with statistical and total errors




σ, pb
200
150
100
50
0
3.8
3.9
4
4.1
4.2
4.3
4.4
4.5
4.6
√s, GeV
$\sigma_{J/\psi_{prompt}}$
$\Sigma\sigma_{J/\psi\ exclusive}$

Conclusion

- New XYZ data (2016-2017) was included in the analysis
- The analysis was performed using BOSS 7.0.3
- The result is reasonable consistent with the total exclusive cross-section
- The result for the prompt J/ψ production in the range above 4.5 GeV is

$$\sigma = 20.8 \pm 3.2 \pm 3.8 \text{ pb}$$

- This value is one of the main results of the performed studies and could be used for tests of J/ψ production models (NRQCD)
- The memo is almost ready

Thank you for attention!

Backup slides

The observed and Born cross-section

ID	E_{cms}, MeV	$\mathcal{L}_{int}, pb^{-1}$	σ^{obs}	$(1+\delta)$	σ^{Born}
3810	3.80765	50.54	$59.30 \pm 27.62 \pm 37.38$	0.935	$63.40 \pm 29.52 \pm 40.99$
3900	3.89624	52.61	$13.82 \pm 21.30 \pm 22.01$	0.941	$14.68 \pm 22.63 \pm 23.44$
4009	4.00762	482.0	$24.27 \pm 6.27 \pm 13.74$	0.947	$25.63 \pm 6.62 \pm 14.67$
4090	4.08545	52.86	$19.72 \pm 16.36 \pm 10.38$	0.948	$20.81 \pm 17.26 \pm 11.05$
4180	4.180	3160.0	$23.36 \pm 2.06 \pm 8.58$	0.849	$27.50 \pm 2.43 \pm 10.21$
4190	4.18859	43.33	$81.25 \pm 17.84 \pm 6.61$	0.795	$102.25 \pm 22.45 \pm 9.26$
4190	4.18899	526.7	$44.93 \pm 5.11 \pm 7.74$	0.792	$56.71 \pm 6.44 \pm 10.01$
4200	4.19903	526.0	$58.18 \pm 5.19 \pm 7.46$	0.751	$77.42 \pm 6.91 \pm 10.07$
4210	4.20773	54.95	$98.45 \pm 15.56 \pm 5.99$	0.739	$133.20 \pm 21.05 \pm 8.27$
4210	4.20925	517.1	$86.40 \pm 5.63 \pm 6.51$	0.739	$116.96 \pm 7.63 \pm 8.92$
4220	4.21713	54.60	$132.02 \pm 15.80 \pm 6.11$	0.743	$177.61 \pm 21.26 \pm 8.33$
4220	4.21884	514.6	$105.55 \pm 5.53 \pm 6.69$	0.746	$141.56 \pm 7.42 \pm 9.03$
4230	4.22626	44.54	$125.19 \pm 17.81 \pm 5.93$	0.761	$164.59 \pm 23.41 \pm 7.87$
4230	4.22626	1056.4	$137.73 \pm 3.77 \pm 6.44$	0.761	$181.08 \pm 4.96 \pm 8.54$
4237	4.23582	530.3	$121.22 \pm 5.29 \pm 6.02$	0.792	$153.02 \pm 6.68 \pm 7.67$
4245	4.24166	55.88	$115.77 \pm 15.75 \pm 5.93$	0.819	$141.43 \pm 19.24 \pm 7.33$
4246	4.24393	538.1	$121.63 \pm 5.17 \pm 5.92$	0.83	$146.51 \pm 6.23 \pm 7.25$
4260	4.25797	828.4	$88.52 \pm 4.11 \pm 5.96$	0.903	$98.07 \pm 4.56 \pm 6.72$
4270	4.2668	531.1	$81.31 \pm 4.97 \pm 6.03$	0.917	$88.71 \pm 5.43 \pm 6.66$
4280	4.27774	175.7	$81.60 \pm 8.95 \pm 5.69$	0.889	$91.81 \pm 10.07 \pm 6.45$
4310	4.30789	45.08	$96.60 \pm 17.32 \pm 4.82$	0.870	$110.98 \pm 19.90 \pm 5.63$
4360	4.35826	543.9	$44.93 \pm 4.75 \pm 6.10$	1.175	$38.24 \pm 4.04 \pm 5.28$
4390	4.3874	55.57	$17.12 \pm 14.06 \pm 6.12$	1.262	$13.57 \pm 11.15 \pm 4.92$
4420	4.41558	46.80	$49.73 \pm 15.64 \pm 4.93$	1.255	$39.64 \pm 12.47 \pm 4.16$
4420	4.41558	1043.9	$32.55 \pm 3.37 \pm 5.86$	1.255	$25.95 \pm 2.68 \pm 4.75$
4470	4.46706	111.09	$11.24 \pm 10.12 \pm 5.98$	1.209	$9.30 \pm 8.37 \pm 4.96$
4530	4.52714	112.12	$23.30 \pm 9.49 \pm 4.14$	1.164	$20.01 \pm 8.15 \pm 3.66$
4575	4.5745	48.93	$31.71 \pm 14.23 \pm 4.49$	1.139	$27.85 \pm 12.50 \pm 4.13$
4600	4.59953	586.9	$22.93 \pm 4.01 \pm 3.80$	1.128	$20.33 \pm 3.55 \pm 3.49$

Cross-section of exclusive processes with J/ψ

ID	$\pi^+\pi^- J/\psi$	$\pi^0\pi^0 J/\psi$	$K^+K^- J/\psi$	$K^0K^0 J/\psi$	$\eta J/\psi$	$\eta' J/\psi$
3810	$16.7 \pm 3.3 \pm 1$	–	–	–	–	–
3900	$17.1 \pm 3.4 \pm 1$	–	–	–	–	–
4009	$16 \pm 1.1 \pm 1$	–	–	–	–	–
4090	$15 \pm 3.1 \pm 0.9$	–	–	–	–	–
4190	$15.5 \pm 3.8 \pm 0.9$	$9 \pm 3.3 \pm 0.6$	–	–	$50.8 \pm 10.2 \pm 2.1$	–
4210	$53.4 \pm 5.4 \pm 3.1$	$22.7 \pm 4.6 \pm 1.5$	–	–	$57.8 \pm 9.6 \pm 3.2$	–
4220	$60.3 \pm 5.7 \pm 3.5$	$27.4 \pm 4.9 \pm 1.8$	–	–	$57.7 \pm 9.7 \pm 3$	–
4230	$85.1 \pm 1.5 \pm 4.9$	$35.4 \pm 1.3 \pm 2.2$	$5.27 \pm 0.63 \pm 0.75$	$1.6 \pm 0.5 \pm 0.3$	$47 \pm 2 \pm 2.2$	$3.7 \pm 0.7 \pm 0.3$
4245	$84.4 \pm 6.3 \pm 4.9$	$40.3 \pm 5.8 \pm 2.7$	–	–	$24.8 \pm 6.5 \pm 2$	–
4260	$59.5 \pm 1.4 \pm 3.4$	$28.3 \pm 1.3 \pm 1.8$	$3.08 \pm 0.47 \pm 0.4$	$1.2 \pm 0.4 \pm 0.2$	$15.7 \pm 1.4 \pm 0.9$	$3.9 \pm 0.8 \pm 0.3$
4310	$52 \pm 5.7 \pm 3$	$24.1 \pm 4.9 \pm 1.6$	–	–	–	–
4360	$25.4 \pm 1.2 \pm 1.5$	$13.8 \pm 1.1 \pm 0.9$	–	–	$5.6 \pm 1.2 \pm 0.6$	–
4390	$20 \pm 3.2 \pm 1.2$	$4.7 \pm 1.9 \pm 0.3$	–	–	–	–
4420	$12.1 \pm 0.6 \pm 0.7$	$2.7 \pm 1.9 \pm 0.2$	$0.97 \pm 0.22 \pm 0.14$	–	$7.5 \pm 0.9 \pm 0.6$	–
4470	$13.3 \pm 2.1 \pm 0.8$	–	$3.8 \pm 1.3 \pm 0.5$	–	–	–
4530	$10.6 \pm 1.9 \pm 0.6$	–	$4.3 \pm 1.4 \pm 0.7$	–	–	–
4575	$13.4 \pm 3.2 \pm 0.8$	–	–	–	–	–
4600	$6.4 \pm 0.7 \pm 0.4$	–	$1.42 \pm 0.33 \pm 0.2$	–	–	–

arXiv:1611.01317v1 [hep-ex] 4 Nov 2016

arXiv:1506.06018v2 [hep-ex] 1 Aug 2015

arXiv:1802.01216v1 [hep-ex] 4 Feb 2018

arXiv:1503.06644v1 [hep-ex] 23 Mar 2015

arXiv:1605.03256v1 [hep-ex] 11 May 2016

The XYZ data

ID	$\sqrt{s}, MeV$	Run number	$\mathcal{L}_{int}, pb^{-1}$	Year
3810	$3807.65 \pm 0.10 \pm 0.58$	$33490 - 33556$	$50.54 \pm 0.03 \pm 0.49$	2013
3900	$3896.24 \pm 0.11 \pm 0.72$	$33572 - 33657$	$52.61 \pm 0.03 \pm 0.51$	2013
4009	$4007.62 \pm 0.05 \pm 0.66$	$23463 - 24141$	$482.0 \pm 0.1 \pm 4.7$	2011
4090	$4085.45 \pm 0.14 \pm 0.66$	$33659 - 33719$	$52.86 \pm 0.03 \pm 0.35$	2013
4180	$4180.xx \pm 0.xx \pm 0.xx$	$43716 - 47066$	$3160.xx \pm 0.xx \pm 0.xx$	2016
4190	$4188.59 \pm 0.15 \pm 0.68$	$30372 - 30437$	$43.33 \pm 0.03 \pm 0.29$	2013
4190	$4188.99 \pm 0.06 \pm 0.41$	$47543 - 48170$	$526.7 \pm 0.1 \pm 2.2$	2017
4200	$4199.03 \pm 0.05 \pm 0.41$	$48172 - 48713$	$526.0 \pm 0.1 \pm 2.1$	2017
4210	$4207.73 \pm 0.14 \pm 0.61$	$31983 - 32045$	$54.95 \pm 0.03 \pm 0.36$	2013
4210	$4209.25 \pm 0.06 \pm 0.42$	$48714 - 49239$	$517.1 \pm 0.1 \pm 1.8$	2017
4220	$4217.13 \pm 0.14 \pm 0.67$	$32046 - 32140$	$54.60 \pm 0.03 \pm 0.36$	2013
4220	$4218.84 \pm 0.05 \pm 0.40$	$49270 - 49787$	$514.6 \pm 0.1 \pm 1.8$	2017
4230	$4226.26 \pm 0.04 \pm 0.65$	$30438 - 30491$	$44.54 \pm 0.03 \pm 0.29$	2013
4230	$4226.26 \pm 0.04 \pm 0.65$	$32239 - 33484$	$1056.4 \pm 0.1 \pm 7.0$	2013
4237	$4235.82 \pm 0.05 \pm 0.38$	$49788 - 50254$	$530.3 \pm 0.1 \pm 2.7$	2017
4245	$4241.66 \pm 0.12 \pm 0.73$	$32141 - 32226$	$55.88 \pm 0.03 \pm 0.37$	2013
4246	$4243.93 \pm 0.05 \pm 0.38$	$50255 - 50793$	$538.1 \pm 0.1 \pm 2.6$	2017
4260	$4257.97 \pm 0.04 \pm 0.66$	$29677 - 30367, 31561 - 31981$	$828.4 \pm 0.1 \pm 5.5$	2013
4270	$4266.80 \pm 0.06 \pm 0.40$	$50796 - 51302$	$531.1 \pm 0.1 \pm 3.1$	2017
4280	$4277.74 \pm 0.11 \pm 0.57$	$51305 - 51498$	$175.7 \pm 0.1 \pm 1.0$	2017
4310	$4307.89 \pm 0.17 \pm 0.63$	$30492 - 30557$	$45.08 \pm 0.03 \pm 0.30$	2013
4360	$4358.26 \pm 0.05 \pm 0.62$	$30616 - 31279$	$543.9 \pm 0.1 \pm 3.6$	2013
4390	$4387.40 \pm 0.17 \pm 0.65$	$31281 - 31325$	$55.57 \pm 0.04 \pm 0.37$	2013
4420	$4415.58 \pm 0.04 \pm 0.72$	$31327 - 31390$	$46.80 \pm 0.03 \pm 0.31$	2013
4420	$4415.58 \pm 0.04 \pm 0.72$	$36773 - 38140$	$1043.9 \pm 0.1 \pm 6.9$	2014
4470	$4467.06 \pm 0.11 \pm 0.73$	$36245 - 36393$	$111.09 \pm 0.04 \pm 0.73$	2014
4530	$4527.14 \pm 0.11 \pm 0.72$	$36398 - 36588$	$112.12 \pm 0.04 \pm 0.74$	2014
4575	$4574.50 \pm 0.18 \pm 0.70$	$36603 - 36699$	$48.93 \pm 0.03 \pm 0.32$	2014
4600	$4599.53 \pm 0.07 \pm 0.74$	$35227 - 36213$	$586.9 \pm 0.1 \pm 3.9$	2014

Observed number of events

ID	$N^{obs}_{e^+e^-\to J/\psi X}$	$N^{obs}_{e^+e^-\to(\gamma_{ISR})J/\psi}$	$\mathcal{R}^{bg}_{J/\psi_{ISR}}$, %	$N^{obs}_{e^+e^-\to\psi' X}$	$N^{obs}_{e^+e^-\to(\gamma_{ISR})\psi'}$	$N^{obs}_{e^+e^-\to\chi_{c1} X}$	$N^{obs}_{e^+e^-\to\chi_{c2} X}$
3810	1858 ± 49	2121 ± 91	1.8	55 ± 8	1128 ± 34	68 ± 11	40 ± 9
3900	1087 ± 40	1719 ± 80	1.9	31 ± 6	675 ± 26	51 ± 10	16 ± 7
4009	6988 ± 113	14172 ± 253	2.5	257 ± 17	3853 ± 63	291 ± 26	119 ± 19
4090	593 ± 33	1332 ± 77	2.1	18 ± 5	323 ± 18	34 ± 9	16 ± 7
4180	33077 ± 248	70181 ± 547	2.1	1481 ± 43	15402 ± 127	1537 ± 68	1750 ± 71
4190	496 ± 30	969 ± 62	2.2	14 ± 5	196 ± 14	17 ± 7	7 ± 6
4190	5447 ± 101	11119 ± 227	2.1	231 ± 17	2453 ± 51	153 ± 25	93 ± 22
4200	5803 ± 105	12030 ± 237	2.1	239 ± 18	2441 ± 50	138 ± 23	126 ± 22
4210	657 ± 34	1330 ± 72	1.9	26 ± 6	233 ± 16	5 ± 7	18 ± 8
4210	6164 ± 113	11083 ± 234	2.5	253 ± 18	2209 ± 48	117 ± 23	77 ± 21
4220	718 ± 34	1188 ± 67	1.9	36 ± 7	214 ± 15	7 ± 7	1 ± 7
4220	6803 ± 108	10887 ± 221	2.6	307 ± 21	2301 ± 49	101 ± 25	18 ± 21
4230	621 ± 32	949 ± 62	2.0	22 ± 6	184 ± 14	34 ± 8	13 ± 6
4230	14927 ± 157	22203 ± 308	2.0	593 ± 30	4600 ± 70	266 ± 36	156 ± 32
4237	6942 ± 110	11167 ± 216	2.1	290 ± 21	2246 ± 48	124 ± 25	1 ± 20
4245	724 ± 35	1143 ± 68	1.9	20 ± 5	248 ± 16	25 ± 9	9 ± 7
4246	6992 ± 109	10785 ± 214	2.1	240 ± 22	2262 ± 49	136 ± 25	39 ± 19
4260	9650 ± 132	17363 ± 272	2.6	448 ± 38	3296 ± 59	178 ± 32	111 ± 26
4270	5837 ± 102	10937 ± 215	2.0	272 ± 31	2131 ± 47	118 ± 21	46 ± 17
4280	1965 ± 61	3240 ± 120	2.5	114 ± 18	640 ± 26	64 ± 14	5 ± 10
4310	493 ± 32	967 ± 61	2.1	26 ± 7	142 ± 12	15 ± 7	8 ± 6
4360	5361 ± 101	9818 ± 207	1.9	586 ± 28	1803 ± 43	182 ± 28	111 ± 21
4390	467 ± 31	937 ± 63	1.8	53 ± 9	173 ± 13	29 ± 8	15 ± 6
4420	426 ± 30	848 ± 57	2.0	35 ± 7	134 ± 12	15 ± 7	20 ± 7
4420	9143 ± 138	18089 ± 277	2.0	979 ± 36	3254 ± 58	329 ± 33	216 ± 29
4470	762 ± 44	1909 ± 90	2.0	48 ± 9	363 ± 19	34 ± 10	18 ± 9
4530	683 ± 43	1931 ± 97	2.0	43 ± 8	264 ± 17	43 ± 11	11 ± 8
4575	335 ± 28	593 ± 55	1.9	19 ± 6	130 ± 12	23 ± 7	3 ± 5
4600	3229 ± 94	7906 ± 198	1.9	203 ± 19	1288 ± 37	163 ± 29	47 ± 19

MC-based estimated efficiency

ID	$\bar{\epsilon}_{e^+e^-\to J/\psi X}$, %	$\bar{\epsilon}_{e^+e^-\to\psi' X}$, %	$\epsilon_{e^+e^-\to(\gamma_{ISR})\psi'}$, %	$\epsilon_{e^+e^-\to\chi_{c1}X}$, %	$\epsilon_{e^+e^-\to\chi_{c2}X}$, %
3810	77.85 ± 0.10	51.76 ± 0.83	50.52 ± 0.13	56.67 ± 0.13	54.09 ± 0.13
3900	77.44 ± 0.09	51.86 ± 0.84	49.88 ± 0.13	56.86 ± 0.13	54.40 ± 0.13
4009	76.97 ± 0.09	51.99 ± 0.85	49.33 ± 0.13	59.97 ± 0.13	55.15 ± 0.13
4090	76.55 ± 0.10	52.44 ± 0.13	49.31 ± 0.13	60.67 ± 0.13	56.44 ± 0.13
4180	75.90 ± 0.09	51.63 ± 0.11	48.11 ± 0.13	60.35 ± 0.13	57.24 ± 0.13
4190	76.36 ± 0.09	52.62 ± 0.11	49.13 ± 0.13	60.76 ± 0.13	57.93 ± 0.13
4190	75.99 ± 0.09	51.35 ± 0.11	48.04 ± 0.13	60.23 ± 0.13	57.60 ± 0.13
4200	76.29 ± 0.09	51.98 ± 0.10	48.19 ± 0.13	60.44 ± 0.13	57.72 ± 0.13
4210	76.50 ± 0.08	52.97 ± 0.10	49.51 ± 0.13	60.51 ± 0.13	57.84 ± 0.13
4210	75.50 ± 0.09	50.77 ± 0.10	47.26 ± 0.13	59.85 ± 0.13	57.36 ± 0.13
4220	76.62 ± 0.08	52.72 ± 0.10	49.59 ± 0.13	60.39 ± 0.13	58.05 ± 0.13
4220	75.80 ± 0.08	50.98 ± 0.10	47.13 ± 0.13	59.96 ± 0.13	57.58 ± 0.13
4230	76.52 ± 0.08	52.60 ± 0.10	49.17 ± 0.13	60.42 ± 0.13	57.98 ± 0.13
4237	76.37 ± 0.08	52.24 ± 0.10	48.69 ± 0.13	60.16 ± 0.13	58.03 ± 0.13
4245	76.62 ± 0.08	53.00 ± 0.11	49.35 ± 0.13	60.41 ± 0.13	58.10 ± 0.13
4246	76.40 ± 0.08	52.04 ± 0.10	48.40 ± 0.13	60.08 ± 0.13	57.90 ± 0.13
4260	76.35 ± 0.08	52.45 ± 0.10	48.00 ± 0.13	60.07 ± 0.13	58.06 ± 0.13
4270	76.40 ± 0.08	52.29 ± 0.10	48.57 ± 0.13	59.82 ± 0.13	57.97 ± 0.13
4280	75.90 ± 0.08	51.47 ± 0.10	47.47 ± 0.13	59.67 ± 0.13	57.76 ± 0.13
4310	76.30 ± 0.08	52.75 ± 0.10	48.79 ± 0.13	59.72 ± 0.13	57.86 ± 0.13
4360	76.21 ± 0.08	52.87 ± 0.09	49.06 ± 0.13	59.19 ± 0.13	57.64 ± 0.13
4390	76.15 ± 0.08	52.91 ± 0.09	48.77 ± 0.13	58.92 ± 0.13	57.51 ± 0.13
4420	76.06 ± 0.08	52.76 ± 0.09	48.63 ± 0.13	58.94 ± 0.13	57.26 ± 0.13
4470	75.60 ± 0.08	52.13 ± 0.10	47.83 ± 0.13	58.82 ± 0.13	56.87 ± 0.13
4530	75.24 ± 0.09	52.13 ± 0.09	47.53 ± 0.13	58.57 ± 0.13	56.33 ± 0.13
4575	75.78 ± 0.08	52.38 ± 0.10	47.80 ± 0.13	58.33 ± 0.13	56.22 ± 0.13
4600	75.32 ± 0.09	52.54 ± 0.09	47.70 ± 0.13	58.31 ± 0.13	56.20 ± 0.13

Efficiency of J/ψ reconstruction

ID	$\epsilon_{J/\psi\pi^0\pi^0}$, %	N_{2track}	$\epsilon_{J/\psi\pi^+\pi^-}$, %	N_{4track}	$\epsilon_{J/\psi 2\pi^+2\pi^-}$, %	N_{6track}	$\bar{\epsilon}_{e^+e^-\to J/\psi X}$, %
3810	77.80 ± 0.11	1269	78.17 ± 0.11	176	78.13 ± 0.11	0	77.85 ± 0.10
3900	77.32 ± 0.11	735	78.21 ± 0.11	119	79.34 ± 0.10	0	77.44 ± 0.09
4009	76.79 ± 0.11	4461	77.94 ± 0.11	860	76.51 ± 0.11	13	76.97 ± 0.09
4090	76.38 ± 0.11	405	77.75 ± 0.11	57	76.71 ± 0.11	3	76.55 ± 0.10
4180	75.58 ± 0.11	20018	77.13 ± 0.11	5070	76.89 ± 0.11	240	75.90 ± 0.09
4190	76.02 ± 0.11	296	77.70 ± 0.11	71	77.37 ± 0.11	6	76.36 ± 0.09
4190	75.67 ± 0.11	3160	77.26 ± 0.11	740	76.97 ± 0.11	48	75.99 ± 0.09
4200	75.85 ± 0.11	3306	77.52 ± 0.11	1131	77.26 ± 0.11	50	76.29 ± 0.09
4210	75.95 ± 0.11	362	77.73 ± 0.11	156	77.62 ± 0.11	8	76.50 ± 0.08
4210	75.10 ± 0.11	3372	76.66 ± 0.11	1182	75.10 ± 0.11	51	75.50 ± 0.09
4220	76.00 ± 0.11	366	77.82 ± 0.11	180	77.67 ± 0.11	10	76.62 ± 0.08
4220	75.23 ± 0.11	3581	76.94 ± 0.11	1709	76.71 ± 0.11	80	75.80 ± 0.08
4230	75.92 ± 0.11	7682	77.59 ± 0.11	4111	77.61 ± 0.11	191	76.52 ± 0.08
4237	75.73 ± 0.11	3613	77.57 ± 0.11	1894	77.45 ± 0.11	65	76.37 ± 0.08
4245	75.96 ± 0.11	354	77.74 ± 0.11	205	77.82 ± 0.11	2	76.62 ± 0.08
4246	75.77 ± 0.11	3552	77.58 ± 0.11	1809	77.59 ± 0.11	77	76.40 ± 0.08
4260	75.73 ± 0.11	4922	77.60 ± 0.11	2318	77.64 ± 0.11	147	76.35 ± 0.08
4270	75.74 ± 0.11	2914	77.63 ± 0.11	1484	77.57 ± 0.11	98	76.40 ± 0.08
4280	75.29 ± 0.11	990	77.09 ± 0.11	490	77.13 ± 0.11	24	75.90 ± 0.08
4310	75.64 ± 0.11	256	77.52 ± 0.11	130	77.69 ± 0.11	8	76.30 ± 0.08
4360	75.42 ± 0.11	2496	77.46 ± 0.11	1195	78.03 ± 0.11	274	76.21 ± 0.08
4390	75.37 ± 0.11	252	77.41 ± 0.11	123	77.83 ± 0.11	25	76.15 ± 0.08
4420	75.28 ± 0.11	4438	77.35 ± 0.11	2078	77.93 ± 0.11	420	76.06 ± 0.08
4470	75.00 ± 0.11	405	77.01 ± 0.11	154	77.67 ± 0.11	14	75.60 ± 0.08
4530	74.86 ± 0.11	417	76.96 ± 0.11	70	77.55 ± 0.11	17	75.24 ± 0.09
4575	74.78 ± 0.11	121	76.96 ± 0.11	84	77.63 ± 0.11	12	75.78 ± 0.08
4600	74.67 ± 0.11	1708	76.88 ± 0.11	636	77.54 ± 0.11	54	75.32 ± 0.09

Efficiency of ψ' reconstruction

ID	$\epsilon_{\psi'\pi^0\pi^0}$, %	N_{4track}	$\epsilon_{\psi'\pi^+\pi^-}$, %	N_{6track}	$\bar{\epsilon}_{e^+e^-\to\psi' X}$, %
4090	52.44 ± 0.13	15	48.86 ± 0.13	0	52.44 ± 0.13
4180	52.08 ± 0.13	1277	49.83 ± 0.13	317	51.63 ± 0.11
4190	53.04 ± 0.13	16	50.94 ± 0.13	4	52.62 ± 0.11
4190	51.77 ± 0.13	200	49.63 ± 0.13	49	51.35 ± 0.11
4200	52.52 ± 0.13	210	50.17 ± 0.13	63	51.98 ± 0.10
4210	53.37 ± 0.13	23	51.63 ± 0.13	7	52.97 ± 0.10
4210	51.22 ± 0.13	218	49.31 ± 0.13	68	50.77 ± 0.10
4220	53.27 ± 0.13	25	51.59 ± 0.13	12	52.72 ± 0.10
4220	51.50 ± 0.13	241	49.67 ± 0.13	96	50.98 ± 0.10
4230	53.11 ± 0.13	489	51.43 ± 0.13	217	52.60 ± 0.10
4237	52.65 ± 0.13	272	50.85 ± 0.13	81	52.24 ± 0.10
4245	53.24 ± 0.13	14	51.88 ± 0.13	3	53.00 ± 0.11
4246	52.45 ± 0.13	261	50.86 ± 0.13	91	52.04 ± 0.10
4260	52.90 ± 0.13	400	51.40 ± 0.13	170	52.45 ± 0.10
4270	52.77 ± 0.13	259	51.18 ± 0.13	113	52.29 ± 0.10
4280	51.84 ± 0.13	101	50.23 ± 0.13	30	51.47 ± 0.10
4310	53.20 ± 0.13	24	51.77 ± 0.13	11	52.75 ± 0.10
4360	53.46 ± 0.13	291	52.31 ± 0.13	308	52.87 ± 0.09
4390	53.32 ± 0.13	37	52.37 ± 0.13	28	52.91 ± 0.09
4420	53.12 ± 0.13	581	52.34 ± 0.13	502	52.76 ± 0.09
4470	52.50 ± 0.13	39	51.42 ± 0.13	20	52.13 ± 0.10
4530	52.38 ± 0.13	30	51.86 ± 0.13	27	52.13 ± 0.09
4575	52.49 ± 0.13	19	52.18 ± 0.13	10	52.38 ± 0.10
4600	52.67 ± 0.13	226	52.32 ± 0.13	130	52.54 ± 0.09

Study of systematics : Tracking

ID	$\mathcal{L}_{int}, pb^{-1}$	σ^{obs}	$\Delta_{\sigma(\epsilon_{J/\psi})}, pb$	$\Delta_{\sigma(\epsilon_{\psi' ISR})}, pb$	$\Delta_{\sigma(\epsilon_{\psi'})}, pb$	$\Delta_{\sigma(\epsilon_{\chi_{c1}})}, pb$	$\Delta_{\sigma(\epsilon_{\chi_{c2}})}, pb$
3810	50.54	59.30 ± 27.62	10.97	24.06	1.14	0.40	0.25
3900	52.61	13.82 ± 21.30	6.71	14.01	0.62	0.29	0.10
4009	481.96	24.27 ± 6.27	3.87	8.82	0.56	0.17	0.08
4090	52.86	19.72 ± 16.36	2.93	6.74	0.35	0.18	0.09
4180	$3160.xx$	23.36 ± 2.06	2.19	5.52	0.49	0.14	0.16
4190	43.33	81.25 ± 17.84	0.84	5.02	0.33	0.11	0.05
4190	526.70	44.93 ± 5.11	1.64	5.28	0.47	0.08	0.05
4200	526.00	58.18 ± 5.19	1.36	5.24	0.48	0.07	0.07
4210	54.95	98.45 ± 15.56	0.34	4.66	0.49	0.02	0.10
4210	517.10	86.40 ± 5.63	0.60	4.92	0.52	0.06	0.04
4220	54.60	132.02 ± 15.80	0.51	4.30	0.68	0.03	0.01
4220	514.60	105.55 ± 5.53	0.32	5.17	0.64	0.06	0.01
4230	44.54	125.19 ± 17.81	0.26	4.57	0.50	0.21	0.09
4230	1056.37	137.73 ± 3.77	0.38	4.82	0.58	0.07	0.04
4237	530.30	121.22 ± 5.29	0.12	4.74	0.57	0.07	0.00
4245	55.88	115.77 ± 15.75	0.10	4.89	0.37	0.13	0.05
4246	538.10	121.63 ± 5.17	0.14	4.73	0.47	0.07	0.02
4260	828.36	88.52 ± 4.11	0.40	4.51	0.56	0.06	0.04
4270	531.10	81.31 ± 4.97	0.56	4.50	0.53	0.06	0.03
4280	175.70	81.60 ± 8.95	0.35	4.18	0.69	0.10	0.01
4310	45.08	96.60 ± 17.32	0.21	3.52	0.59	0.09	0.05
4360	543.94	44.93 ± 4.75	0.91	3.68	1.11	0.09	0.06
4390	55.57	17.12 ± 14.06	1.35	3.47	0.98	0.15	0.08
4420	46.80	49.73 ± 15.64	0.57	3.21	0.78	0.09	0.13
4420	1043.86	32.55 ± 3.37	1.05	3.49	0.97	0.09	0.06
4470	111.09	11.24 ± 10.12	1.56	3.73	0.46	0.09	0.05
4530	112.12	23.30 ± 9.49	0.82	2.70	0.40	0.11	0.03
4575	48.93	31.71 ± 14.23	0.81	3.02	0.40	0.14	0.02
4600	586.89	22.93 ± 4.01	0.74	2.51	0.36	0.08	0.02

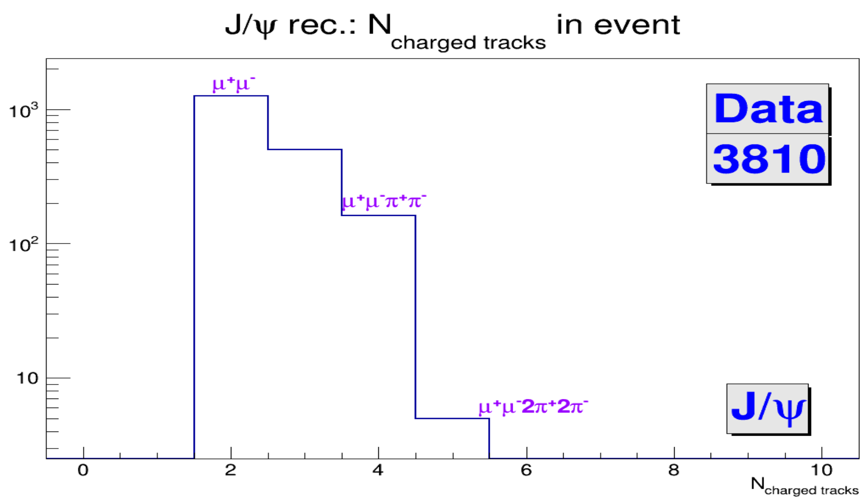
Study of systematics : E_{emc} cut, $N_{J/\psi}$ fit

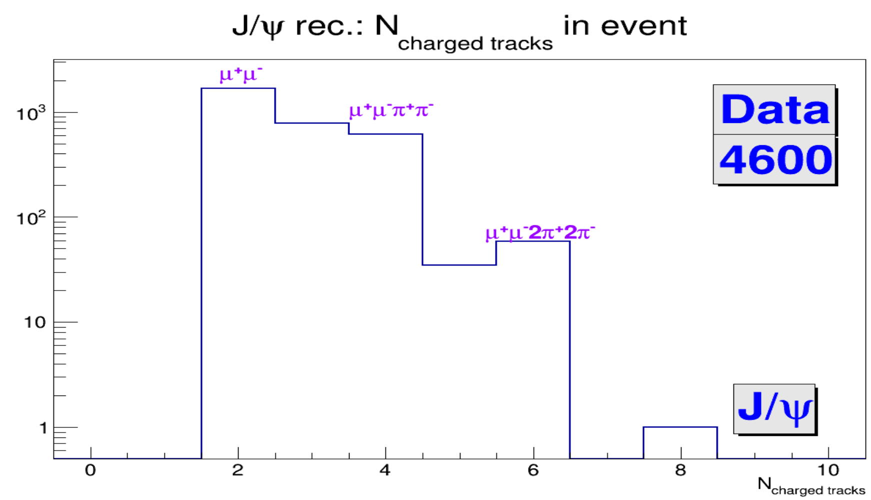
ID	$\mathcal{L}_{int}, pb^{-1}$	σ^{obs}	$\Delta_{\sigma(E_{emc})}, pb$	$\Delta_{\sigma(N_{J/\psi})}, pb$	$\Delta_{\sigma(ISRcor.)}, pb$
3810	50.54	59.30 ± 27.62	2.06	0.85	9.14
3900	52.61	13.82 ± 21.30	0.48	0.20	1.57
4009	482.0	24.27 ± 6.27	0.84	0.35	2.09
4090	52.86	19.72 ± 16.36	0.68	0.28	1.45
4180	3160.0	23.36 ± 2.06	0.81	0.33	1.50
4190	43.33	81.25 ± 17.84	0.83	0.14	4.06
4190	526.7	44.93 ± 5.11	0.46	0.08	2.21
4200	526.0	58.18 ± 5.19	0.60	0.10	1.68
4210	54.95	98.45 ± 15.56	1.01	0.17	1.67
4210	517.1	86.40 ± 5.63	0.89	0.15	1.34
4220	54.60	132.02 ± 15.80	1.36	0.23	1.37
4220	514.6	105.55 ± 5.53	1.08	0.19	1.02
4230	44.54	125.19 ± 17.81	1.29	0.22	1.01
4230	1056.4	137.73 ± 3.77	1.41	0.24	1.11
4237	530.3	121.22 ± 5.29	1.25	0.21	1.03
4245	55.88	115.77 ± 15.75	1.19	0.20	1.15
4246	538.1	121.63 ± 5.17	1.25	0.21	1.29
4260	828.4	88.52 ± 4.11	0.91	0.16	1.26
4270	531.1	81.31 ± 4.97	0.84	0.14	1.04
4280	175.7	81.60 ± 8.95	0.84	0.14	0.72
4310	45.08	96.60 ± 17.32	0.99	0.17	1.02
4360	543.9	44.93 ± 4.75	0.51	0.26	0.96
4390	55.57	17.12 ± 14.06	0.20	0.10	0.83
4420	46.80	49.73 ± 15.64	0.57	0.29	1.38
4420	1043.9	32.55 ± 3.37	0.37	0.19	0.90
4470	111.09	11.24 ± 10.12	0.13	0.07	0.38
4530	112.12	23.30 ± 9.49	0.27	0.14	0.87
4575	48.93	31.71 ± 14.23	0.36	0.19	1.22
4600	586.9	22.93 ± 4.01	0.26	0.13	0.89

Study of systematics : Luminosity, BF

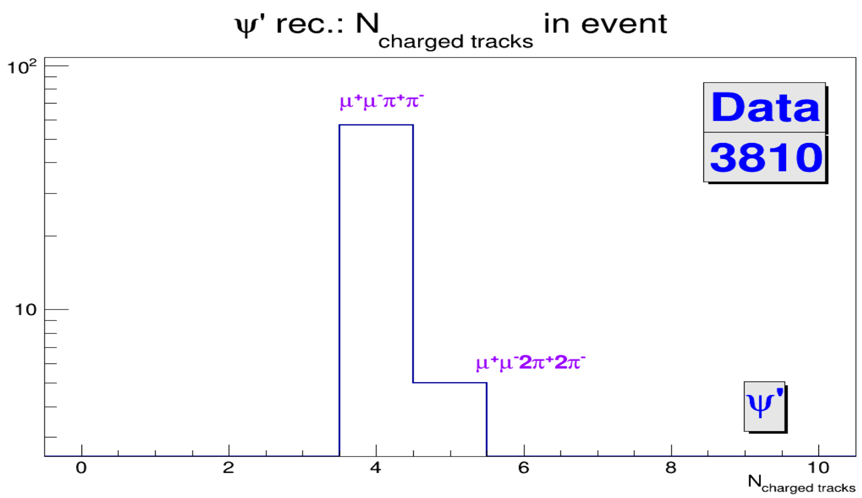
ID	$\mathcal{L}_{int}, pb^{-1}$	σ^{obs}	$\Delta_{\sigma(\mathcal{L}_{int})}, pb$	$\Delta_{\sigma(\mathcal{B}_{J/\psi\to\mu^+\mu^-})}, pb$	$\Delta_{\sigma(\mathcal{B}_{\psi'\to J/\psi\pi^+\pi^-})}, pb$	$\Delta_{\sigma(\tilde{\mathcal{B}}_{\psi'\to J/\psi X})}, pb$
3810	50.54	59.30 ± 27.62	0.58	0.33	5.64	7.14
3900	52.61	13.82 ± 21.30	0.13	0.08	3.31	4.19
4009	481.96	24.27 ± 6.27	0.24	0.13	2.18	2.76
4090	52.86	19.72 ± 16.36	0.13	0.11	1.63	2.06
4180	$3160.xx$	23.36 ± 2.06	–	0.13	1.45	1.84
4190	43.33	81.25 ± 17.84	0.55	0.45	1.25	1.58
4190	526.70	44.93 ± 5.11	0.19	0.25	1.39	1.76
4200	526.00	58.18 ± 5.19	0.23	0.32	1.38	1.75
4210	54.95	98.45 ± 15.56	0.65	0.55	1.23	1.56
4210	517.10	86.40 ± 5.63	0.30	0.48	1.35	1.71
4220	54.60	132.02 ± 15.80	0.87	0.73	1.23	1.56
4220	514.60	105.55 ± 5.53	0.37	0.58	1.46	1.85
4230	44.54	125.19 ± 17.81	0.82	0.69	1.22	1.55
4230	1056.37	137.73 ± 3.77	0.91	0.76	1.31	1.66
4237	530.30	121.22 ± 5.29	0.62	0.67	1.3	1.64
4245	55.88	115.77 ± 15.75	0.77	0.64	1.23	1.56
4246	538.10	121.63 ± 5.17	0.59	0.67	1.26	1.59
4260	828.36	88.52 ± 4.11	0.59	0.49	1.26	1.59
4270	531.10	81.31 ± 4.97	0.47	0.45	1.23	1.56
4280	175.70	81.60 ± 8.95	0.47	0.45	1.25	1.58
4310	45.08	96.60 ± 17.32	0.65	0.53	1.04	1.31
4360	543.94	44.93 ± 4.75	0.30	0.25	1.29	1.63
4390	55.57	17.12 ± 14.06	0.11	0.09	1.19	1.51
4420	46.80	49.73 ± 15.64	0.33	0.28	1.05	1.33
4420	1043.86	32.55 ± 3.37	0.22	0.18	1.19	1.51
4470	111.09	11.24 ± 10.12	0.07	0.06	1.04	1.31
4530	112.12	23.30 ± 9.49	0.15	0.13	0.79	1.00
4575	48.93	31.71 ± 14.23	0.21	0.18	0.86	1.09
4600	586.89	22.93 ± 4.01	0.15	0.13	0.72	0.91

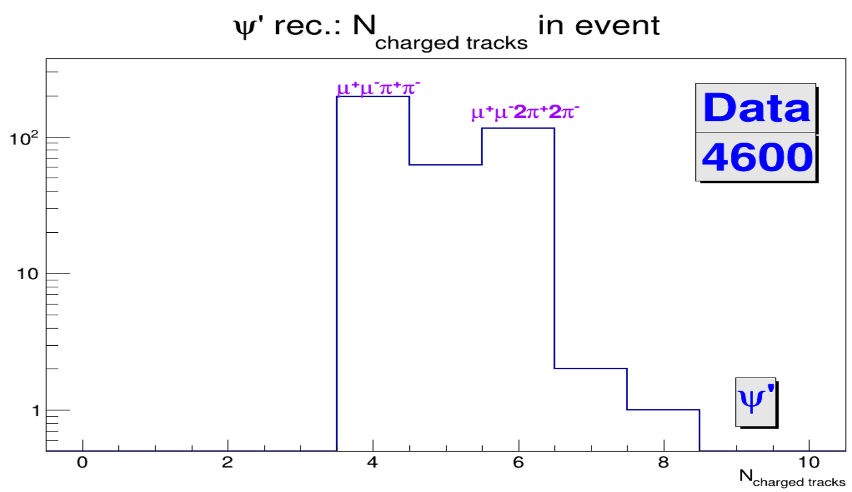
Multiplicity of charged tracks for selected J/ψ and ψ'

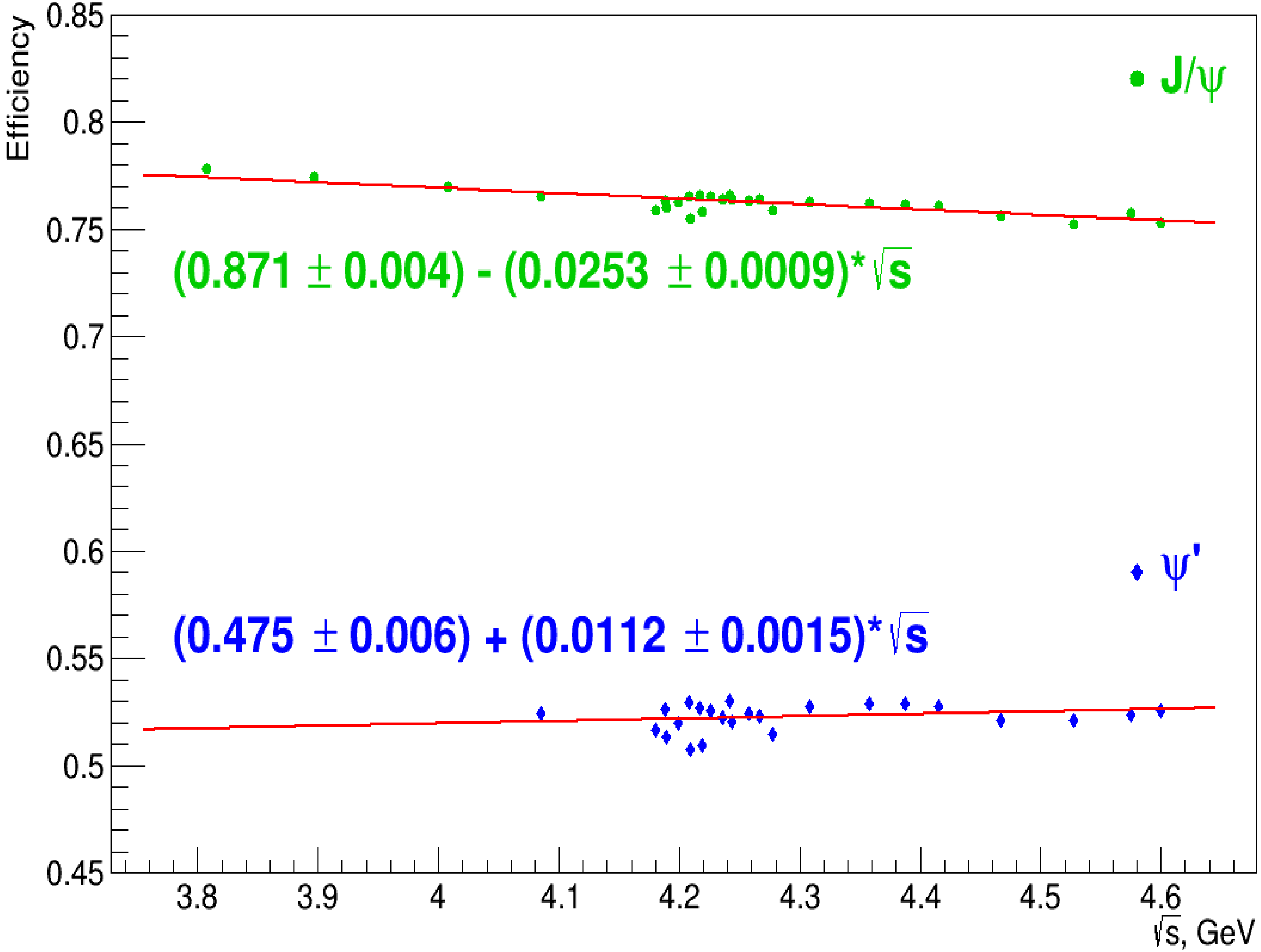




Logarithmic scale

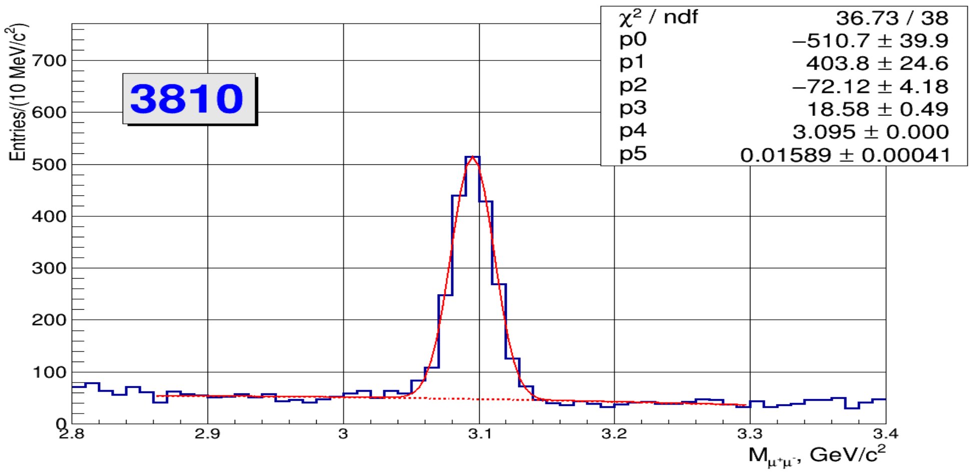


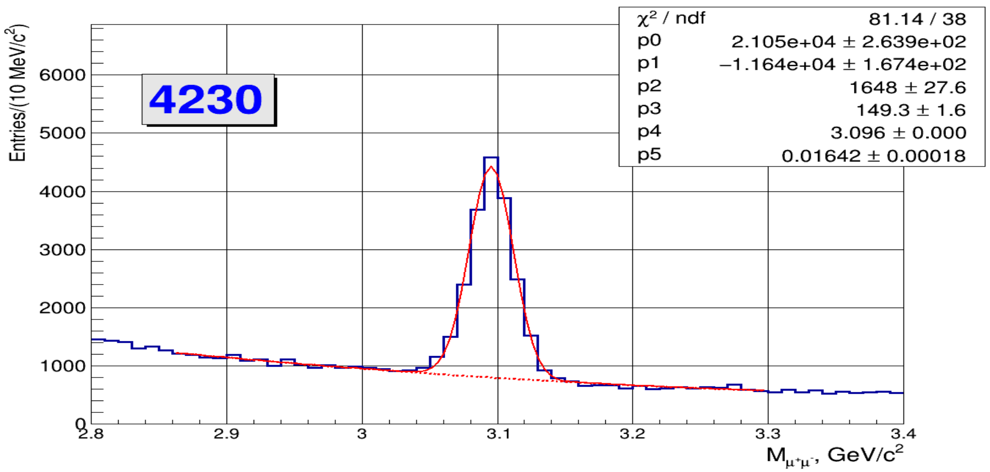



Efficiency
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
3.8
3.9
4
4.1
4.2
4.3
4.4
4.5
4.6
√s, GeV
J/ψ
ψ'
(0.871 ± 0.004) - (0.0253 ± 0.0009)* √s
(0.475 ± 0.006) + (0.0112 ± 0.0015)* √s

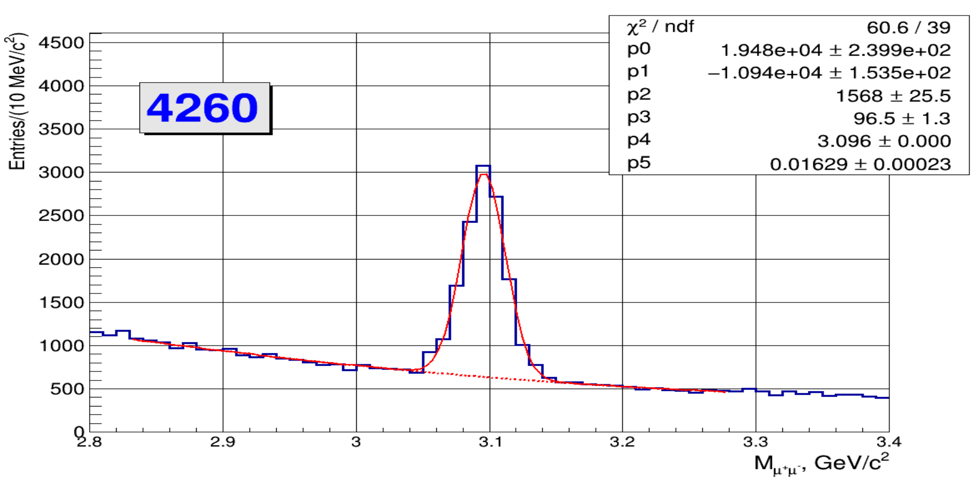
B12

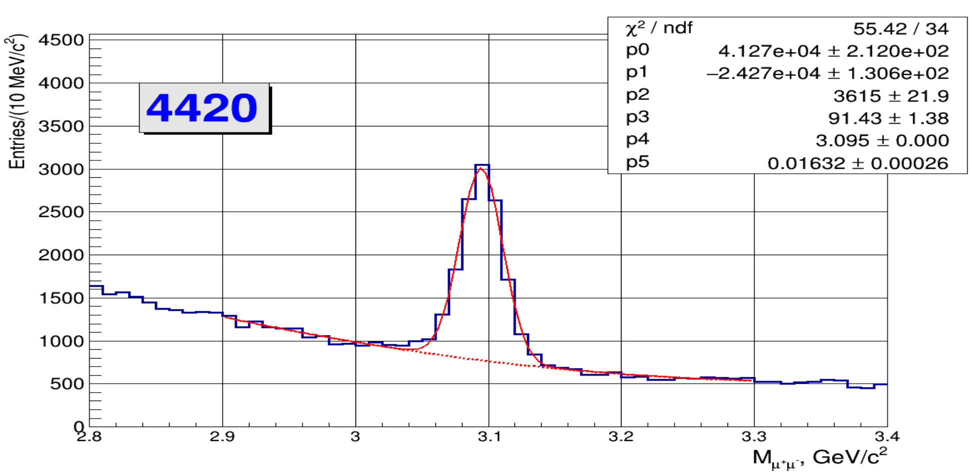
Observed number of J/ψX events



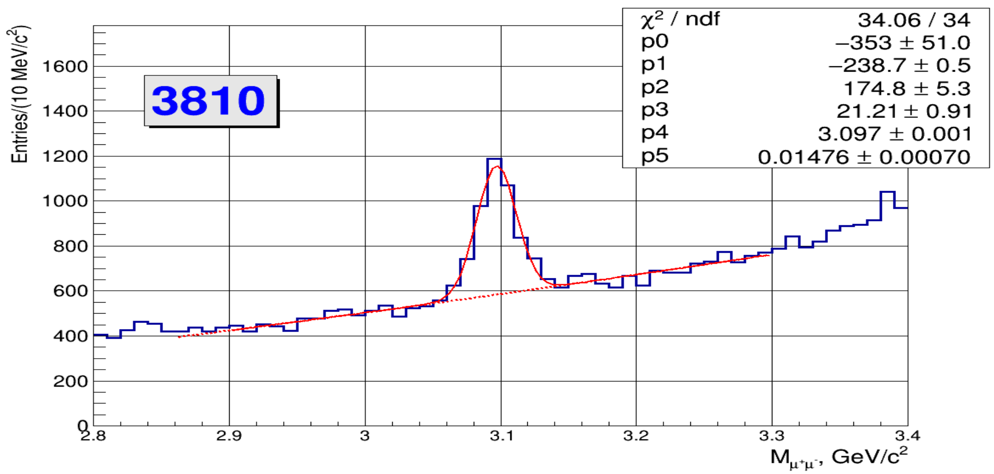


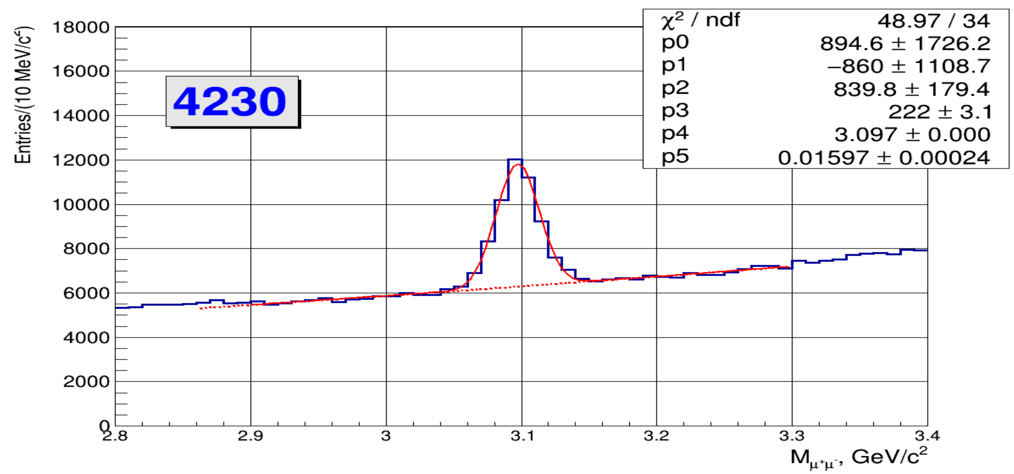
Fit a normalized Gaussian function (signal) and a quadratic polynomial (background) to the data



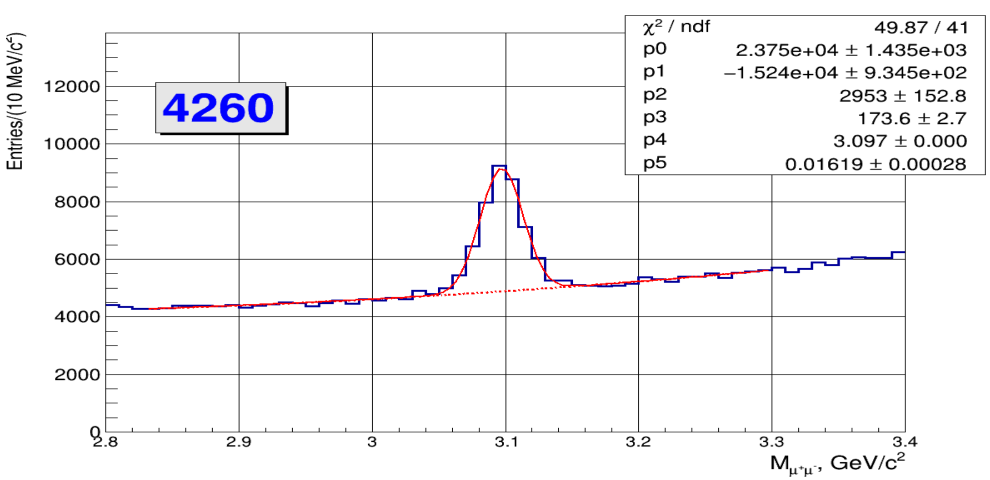


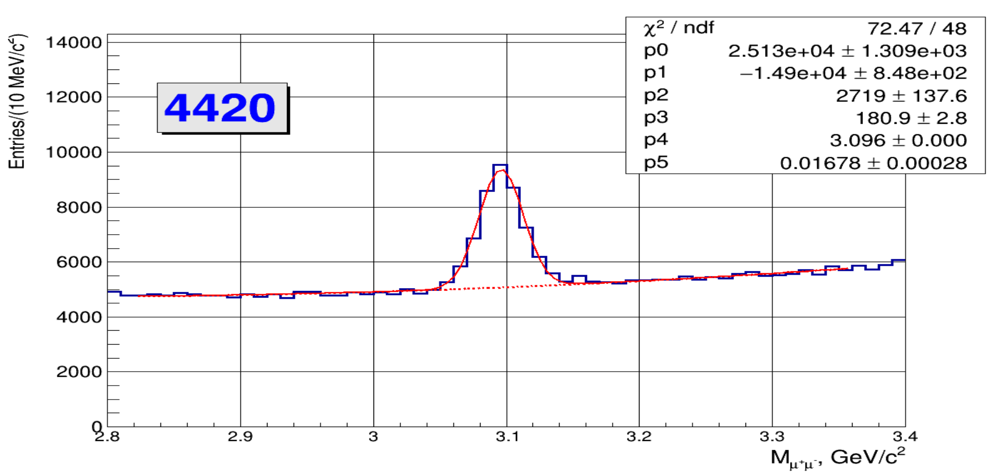
Observed number of $(\gamma_{ISR})J/\psi$ events



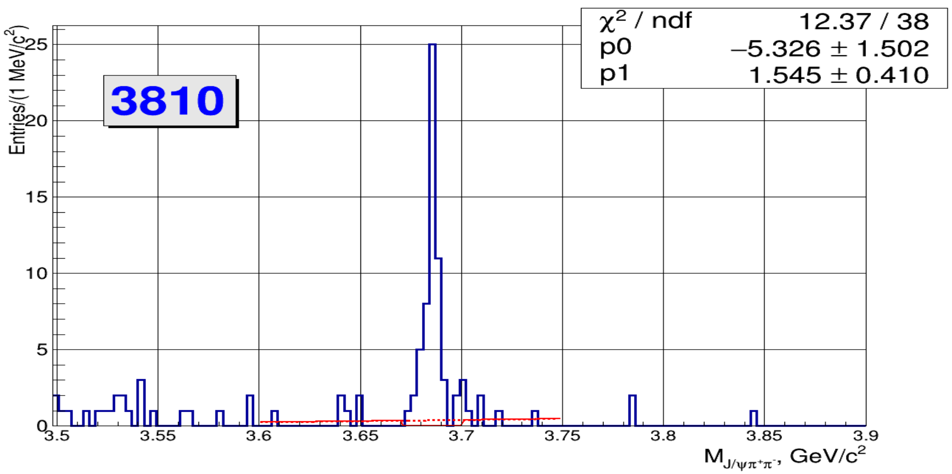


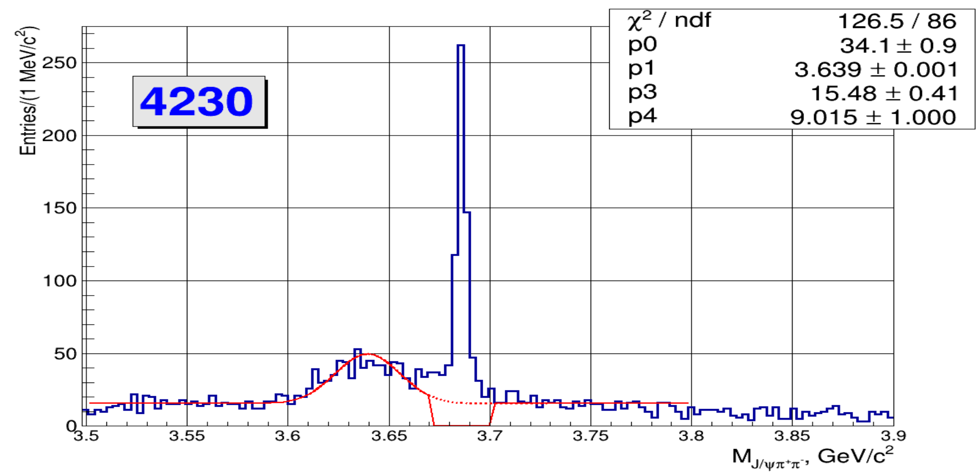
Fit a normalized Gaussian function (signal) and a quadratic polynomial (background) to the data



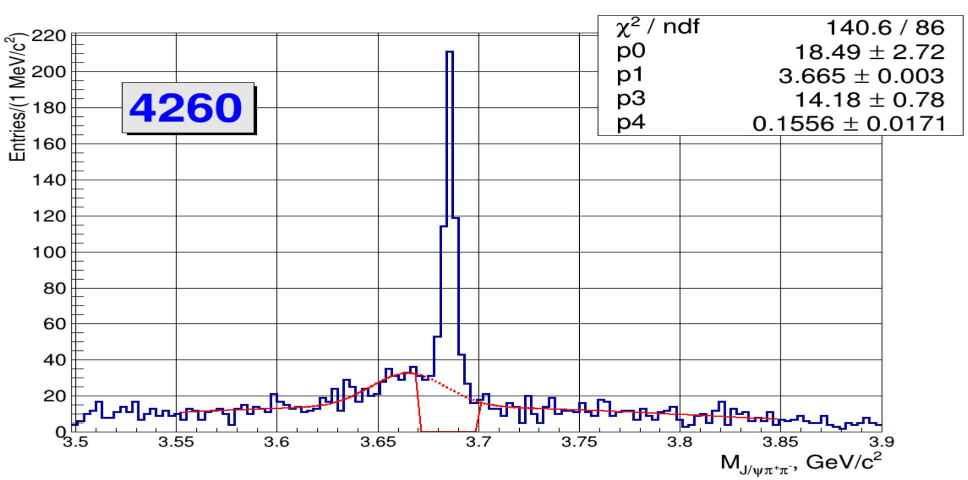


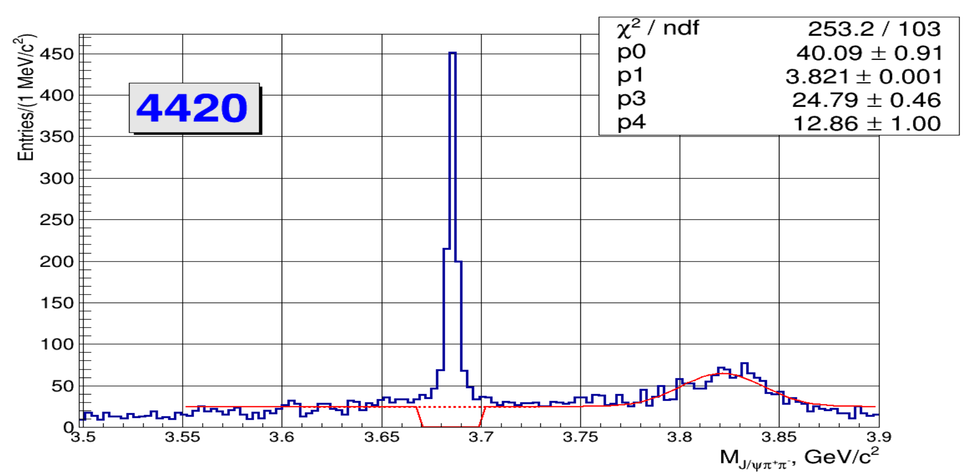
Observed number of ψ'X events



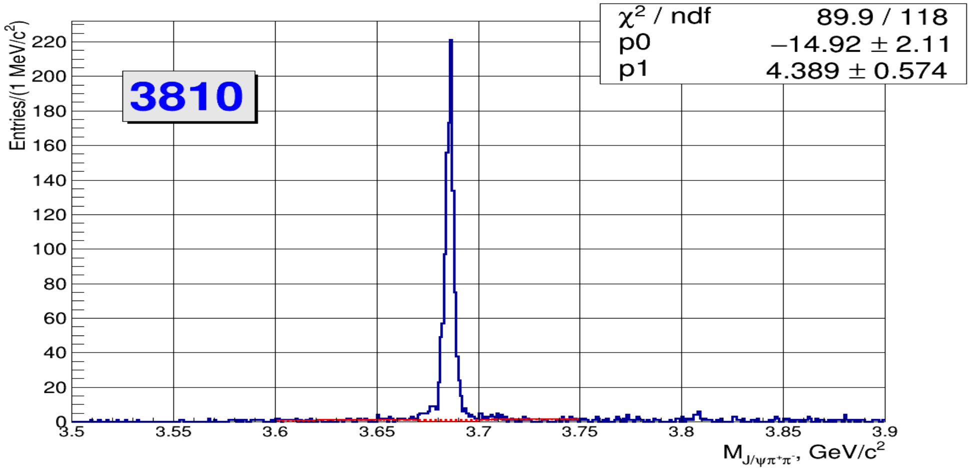


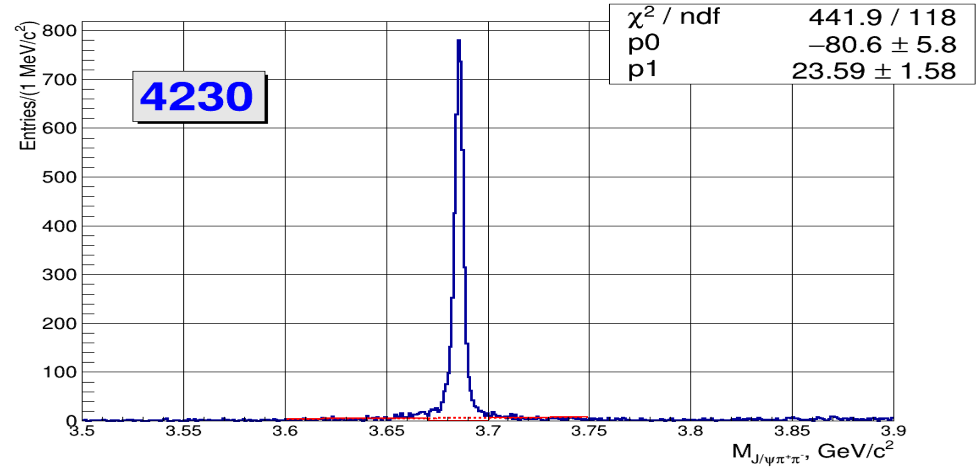
Background is fitted by a double Gaussian function
(by a line for other points)



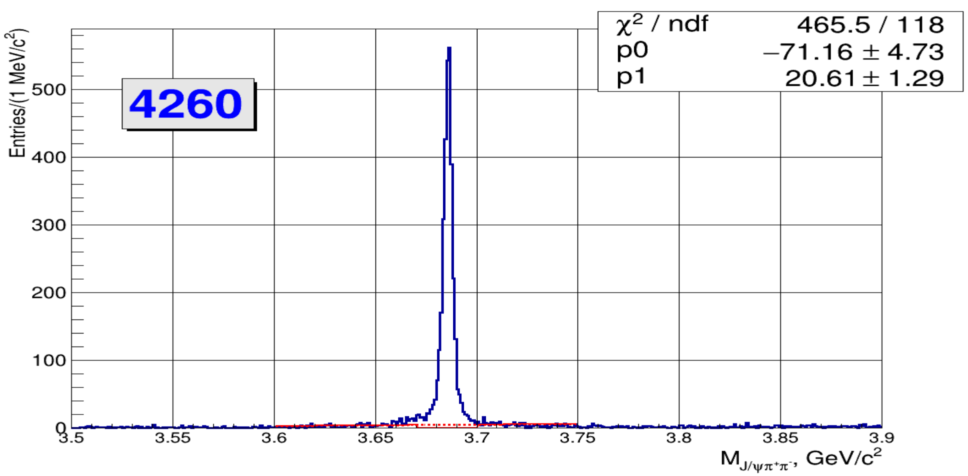


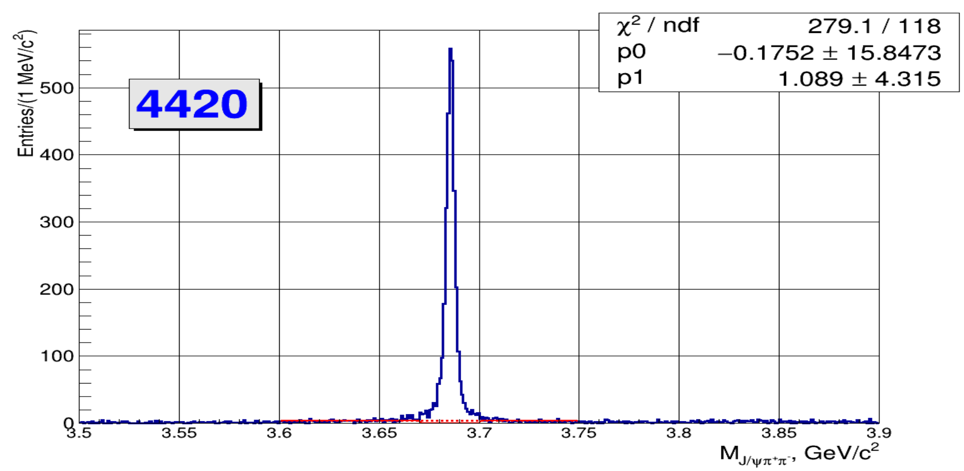
Observed number of $(\gamma_{ISR})\psi'$ events



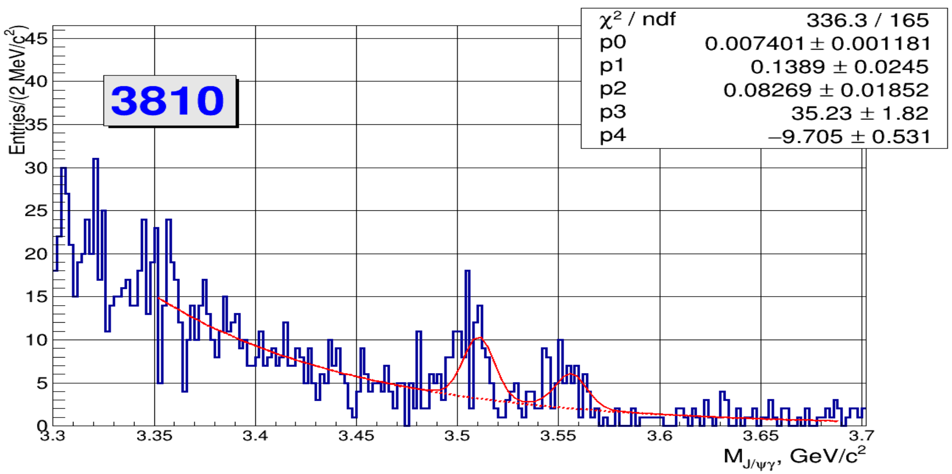


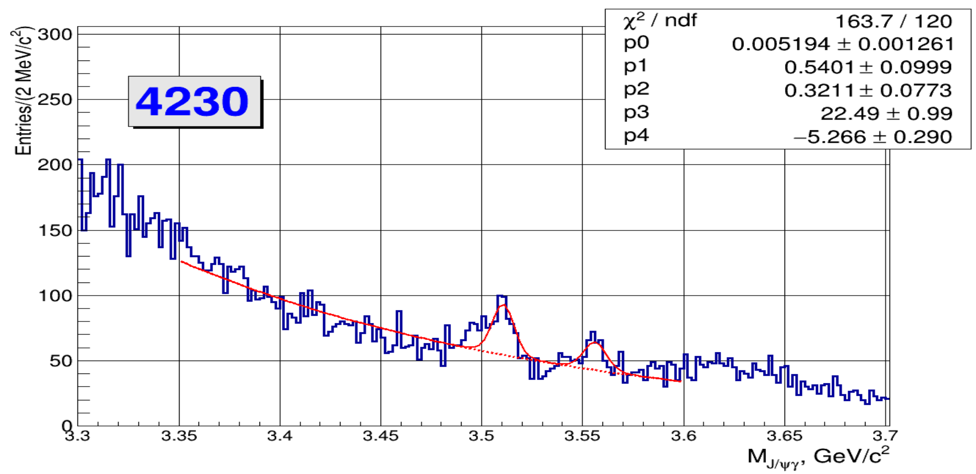
Background is fitted by a line





Observed number of $\chi_{c1,2}$X events





Fit two Breit-Wigner convoluted with Gaussian functions (signal) and an exponential function (background) to the data

Masses and widths of $\chi_{c1,2}$ are fixed parameters.