

BESIII



Charmonia production in e^+e^- annihilation at center-of-mass energies above 3.81 GeV

Olga Bakina

Joint Institute for Nuclear Research, Dubna
on behalf of the BESIII Collaboration

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The BESIII experiment

e^+e^- collisions in the τ -charm energy region, $L_{\text{peak}} = 1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

Data taking from 2009: the largest data sets at the J/ψ , $\psi(3686)$, and $\psi(3770)$ peaks; scan data at $\sqrt{s} = 2.00 - 4.95 \text{ GeV}$

Superconducting Solenoidal Magnet: 0.9/1.0 T

MDC

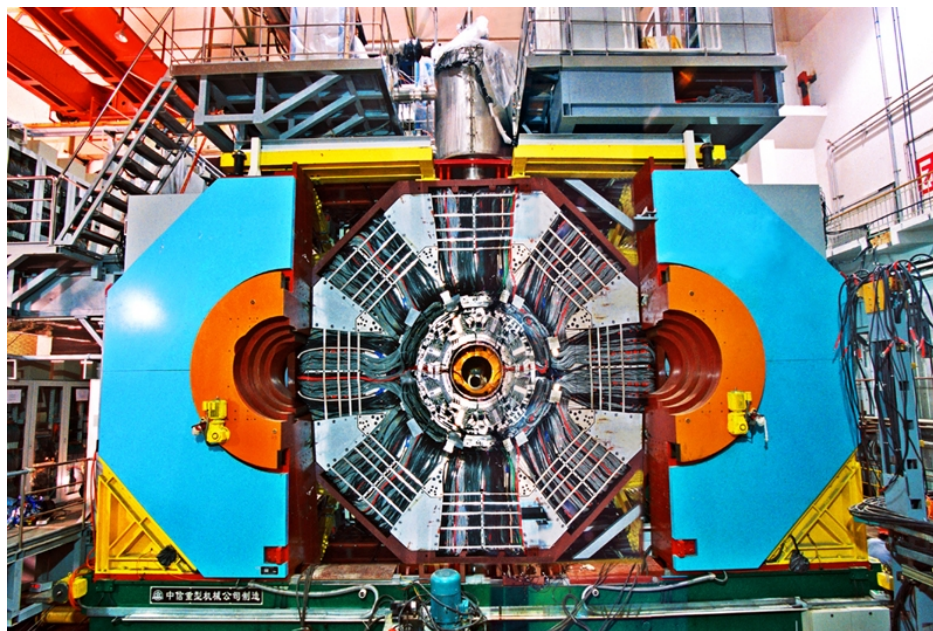
dE/dx : 6%

σ_p/p : 0.5% at 1 GeV/c

TOF

σ_T : 68 ps

110 ps (60 ps)



EMC

$\Delta E/E$: 2.5% (5%) at 1 GeV

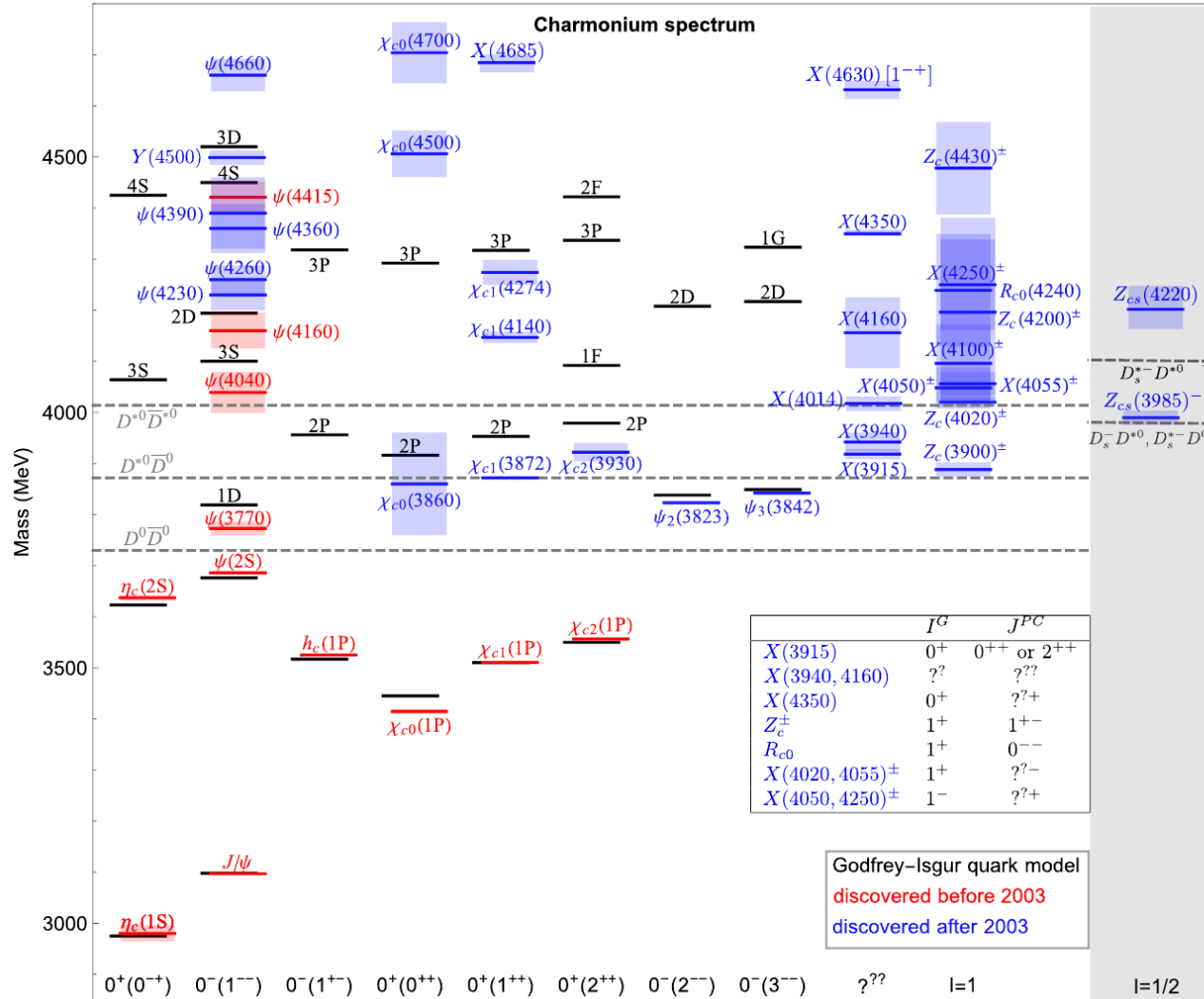
σ_z : 0.6 cm/ \sqrt{E}

MUC

$\sigma_{R\Phi}$: 2 cm

Figure: The BESIII detector at BEPCII.

Charmonium(-like) states



First observation of three charmonium-like states in $e^+e^- \rightarrow D_s^{*+}D_s^{*-}$

Data: $\mathcal{L} = 15.67 \text{ fb}^{-1}$, $\sqrt{s} = 4.226 - 4.951 \text{ GeV}$

Phys.Rev.Lett. 131 (2023) 15, 151903

Channel: $e^+e^- \rightarrow D_s^{*+}D_s^{*-}$, $D_s^{*\pm} \rightarrow \gamma D_s^\pm \rightarrow \gamma K^+K^-\pi^\pm$

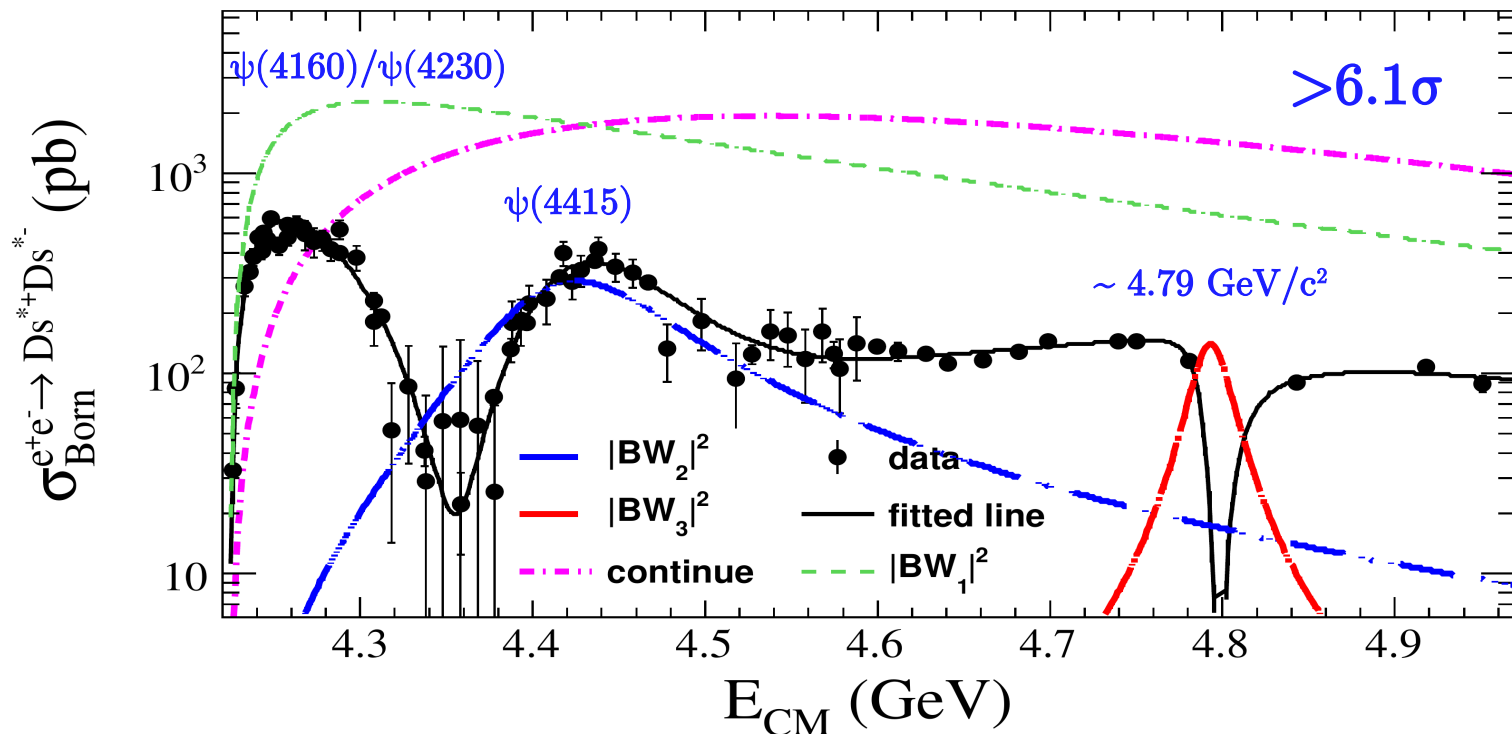


Figure: The fit result to the Born cross section line shape of $e^+e^- \rightarrow D_s^{*+}D_s^{*-}$.

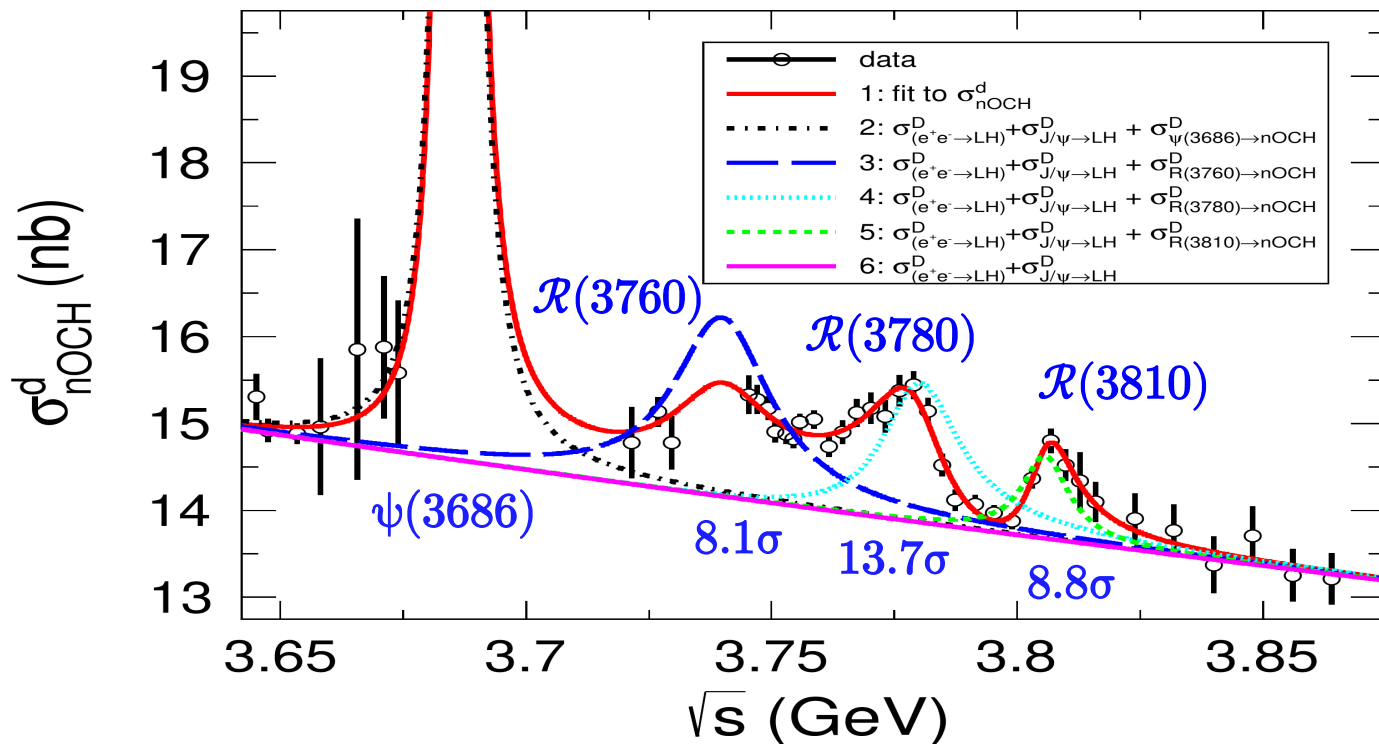
First observation of a three-resonance structure in $e^+e^- \rightarrow$ nonopen charm hadrons

Data: $\mathcal{L} = 75.5 \text{ pb}^{-1}$, $\sqrt{s} = 3.645 - 3.871 \text{ GeV}$

Phys.Rev.Lett. 132 (2024) 19, 191902

Channel: $e^+e^- \rightarrow$ nonopen charm hadrons

Figure: The dressed cross sections for $e^+e^- \rightarrow$ nonopen charm hadrons.



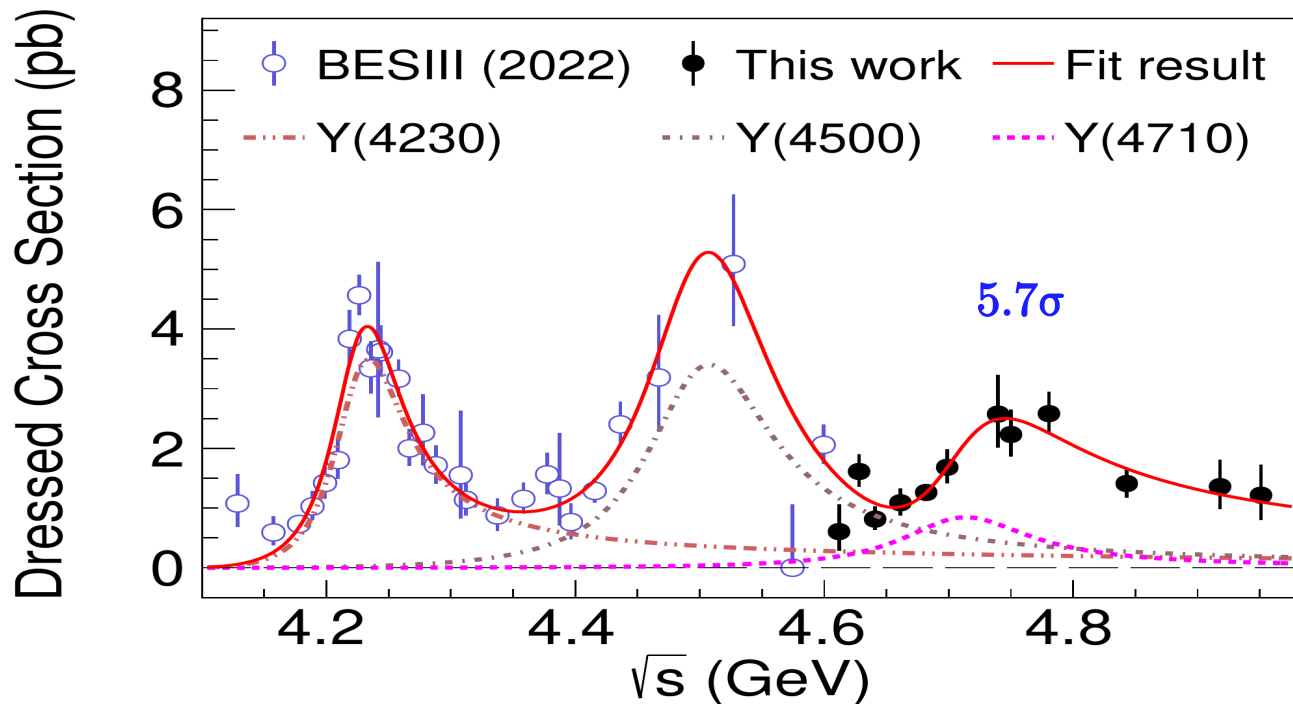
Observation of charmonium-like states in the process

$$e^+e^- \rightarrow K^+K^-J/\psi$$

Data: $\mathcal{L} = 5.85 \text{ fb}^{-1}$, $\sqrt{s} = 4.61 - 4.95 \text{ GeV}$

Phys.Rev.Lett. 131 (2023) 21, 211902

Channel: $e^+e^- \rightarrow K^+K^-J/\psi$, $J/\psi \rightarrow l^+l^-$ ($l = e, \mu$)



The suppression of the decay $Z_{cs}(3985)^+ \rightarrow K^+J/\psi$ supports the $Z_{cs}(3985)^{+(*)}$ and $Z_{cs}(4000)^{+(**)}$ as two different states.

(*) BESIII: $e^+e^- \rightarrow KZ_{cs}(3985)$,
 $Z_{cs}(3985)^+ \rightarrow (\bar{D}^0D_s^{*+} + \bar{D}^{*0}D_s^+)$
(**) LHCb: $B^+ \rightarrow K^+J/\psi\phi$,
 $Z_{cs}(4000)^+ \rightarrow K^+J/\psi$

Figure: Fit to the dressed cross section of $e^+e^- \rightarrow K^+K^-J/\psi$.

Observation of charmonium-like states in the processes $e^+e^- \rightarrow \omega\chi_{c1}$ and $\omega\chi_{c2}$

Data: $\mathcal{L} = 11.0 \text{ fb}^{-1}$, $\sqrt{s} = 4.308 - 4.951 \text{ GeV}$

Phys.Rev.Lett. 132 (2024) 16, 161901

Channel: $e^+e^- \rightarrow \omega\chi_{c1,2}$, $\chi_{c1,2} \rightarrow \gamma J/\psi$, $J/\psi \rightarrow l^+ l^-$ ($l = e, \mu$), $\omega \rightarrow \pi^+\pi^-\pi^0$, $\pi^0 \rightarrow \gamma\gamma$

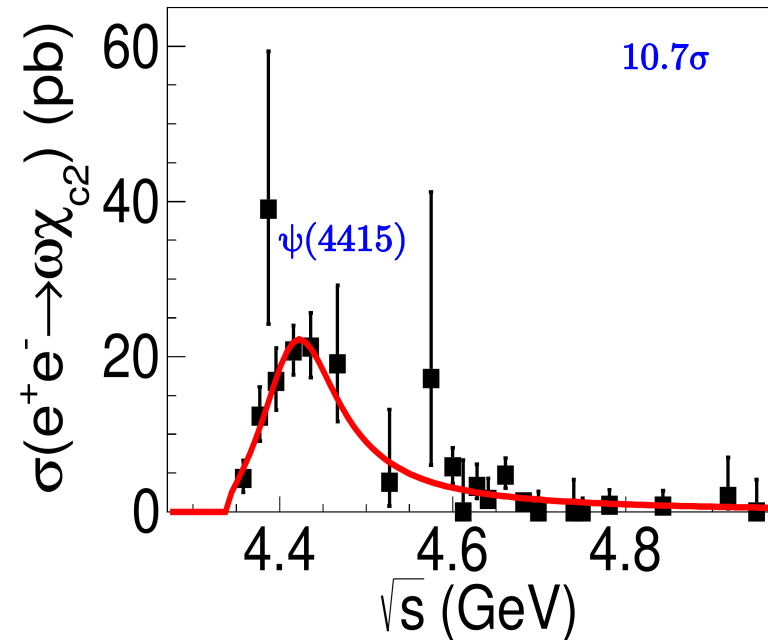
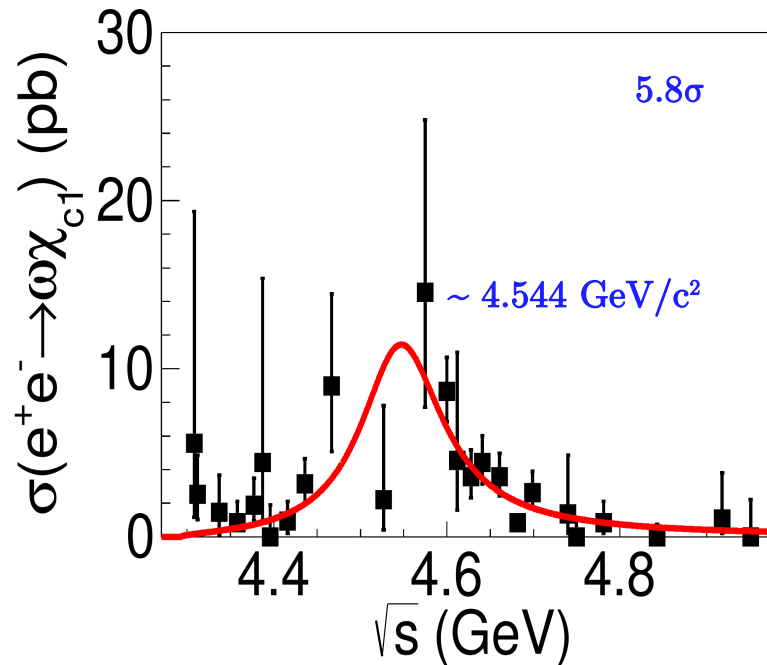


Figure: Fits to the dressed cross sections of $e^+e^- \rightarrow \omega\chi_{c1}$ and $e^+e^- \rightarrow \omega\chi_{c2}$ with one single resonance.

Prompt inclusive charmonium production

Goal:

- **Test the NRQCD factorization hypothesis:** the independence of Long Distance Matrix Elements (LDME) that describe the hadronization of the $c\bar{c}$ pair from the process (hadron-hadron collisions, electroproduction, or e^+e^- annihilation);
- **Clarify the contribution of the color octet channel** in the range of \sqrt{s} below the $J/\psi c\bar{c}$ threshold (~ 6 GeV): the color-octet LDMEs are non-zero if $\sigma > 10$ pb at $\sqrt{s} = 4.6 \sim 5.6$ GeV (Eur. Phys. J. C (2017) 77: 597);
- **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)

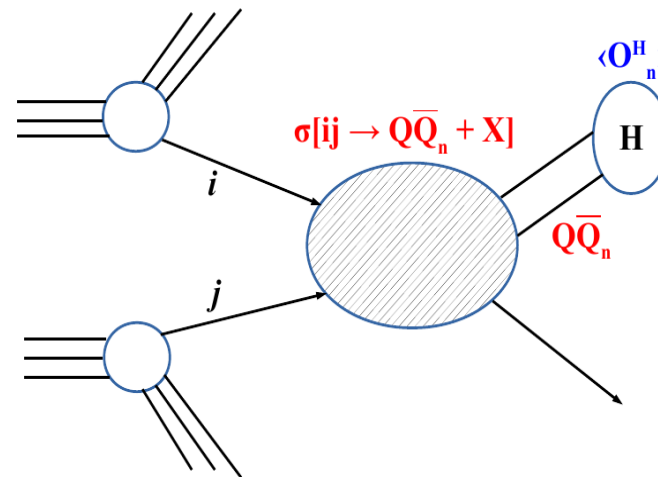


Figure: NRQCD factorization. The LDMEs $\langle O_n^H \rangle$ are determined from experimental data.

Prompt inclusive J/ψ and $\psi(3686)$ production (I)

Data: $\mathcal{L} = 22 \text{ fb}^{-1}$, $\sqrt{s} = 3.81 - 4.95 \text{ GeV}$

Channel: $J/\psi \rightarrow \mu^+\mu^-$, $\psi(3686) \rightarrow J/\psi \pi^+\pi^-$, $\chi_{cJ} \rightarrow \gamma J/\psi$, ($J = 1, 2$)

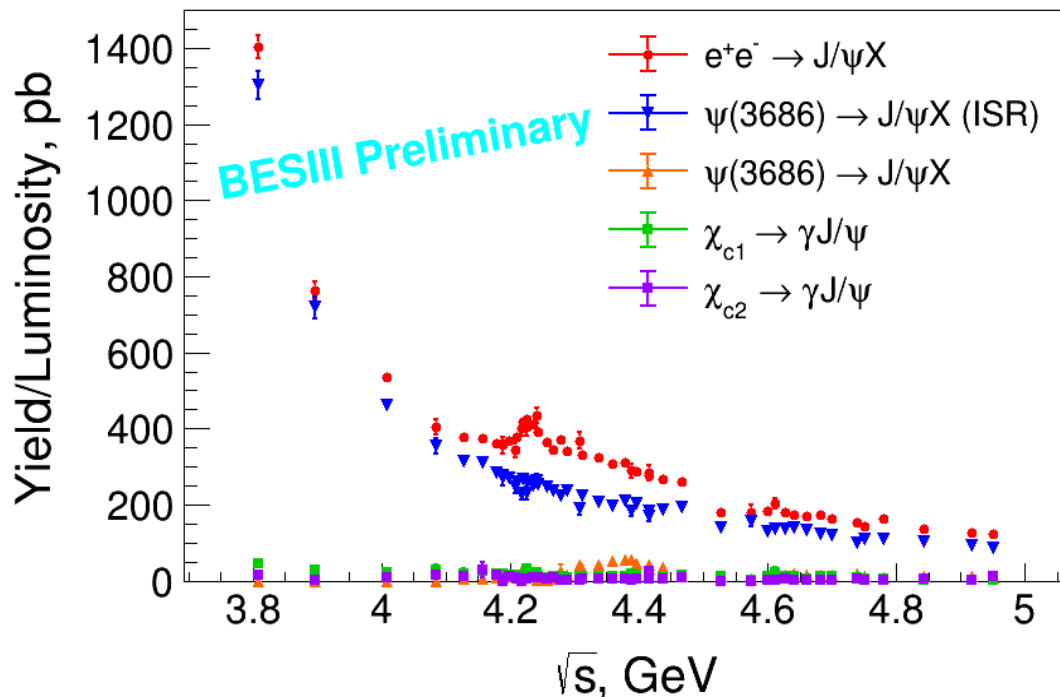


Figure: Yield of J/ψ from different sources normalized to corresponding luminosity.

Prompt inclusive J/ψ and $\psi(3686)$ production (II)

The preliminary result for the prompt inclusive production of

the J/ψ meson in the range
 $4.53 \sim 4.95$ GeV is
 $\sigma = 14.0 \pm 1.7_{\text{stat}}$ pb

the $\psi(3686)$ meson in the range
 $4.84 \sim 4.95$ GeV is
 $\sigma = 16.9 \pm 2.8_{\text{stat}}$ pb

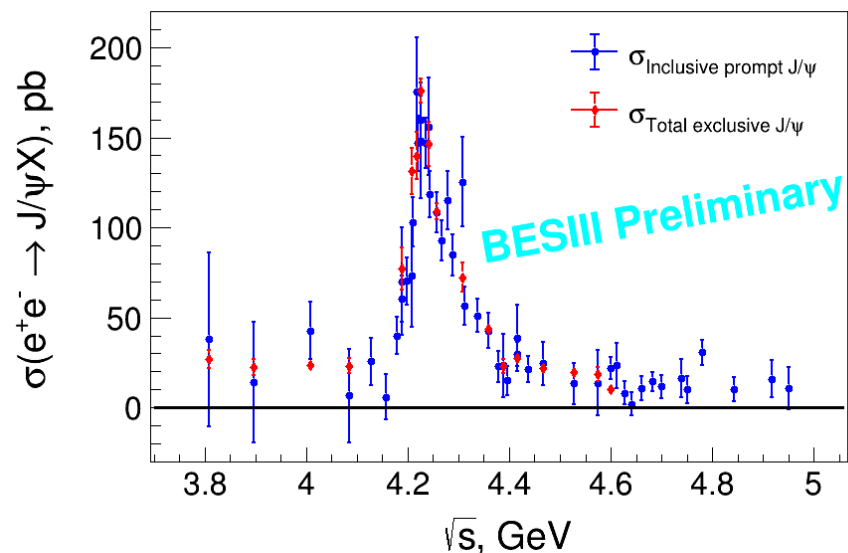


Figure: Prompt inclusive and total exclusive J/ψ cross sections.

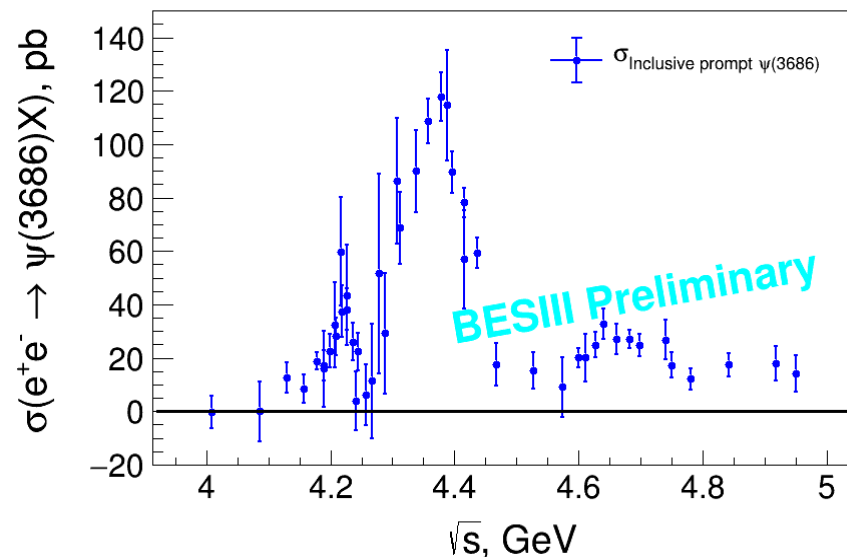


Figure: Prompt inclusive $\psi(3686)$ cross-sections.

Summary

- The charmonia production is a proven tool for verifying the basics of QCD;
- The BESIII experiment successfully applies e^+e^- annihilation data sets to search for new exotic charmonium-like states and study their properties;
- The prompt inclusive production of classical charmonia allows the BESIII experiment to test various theoretical models of the strong interaction at low energies, especially, NRQCD;
- The upcoming upgrade of the BEPCII will allow the BESIII experiment to explore charmonium-like states up to $\sqrt{s} = 5.6$ GeV.

Thank you for your attention!