The open charm cross section measurement at BESIII

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On behalf of the BESIII collaboration

Outline

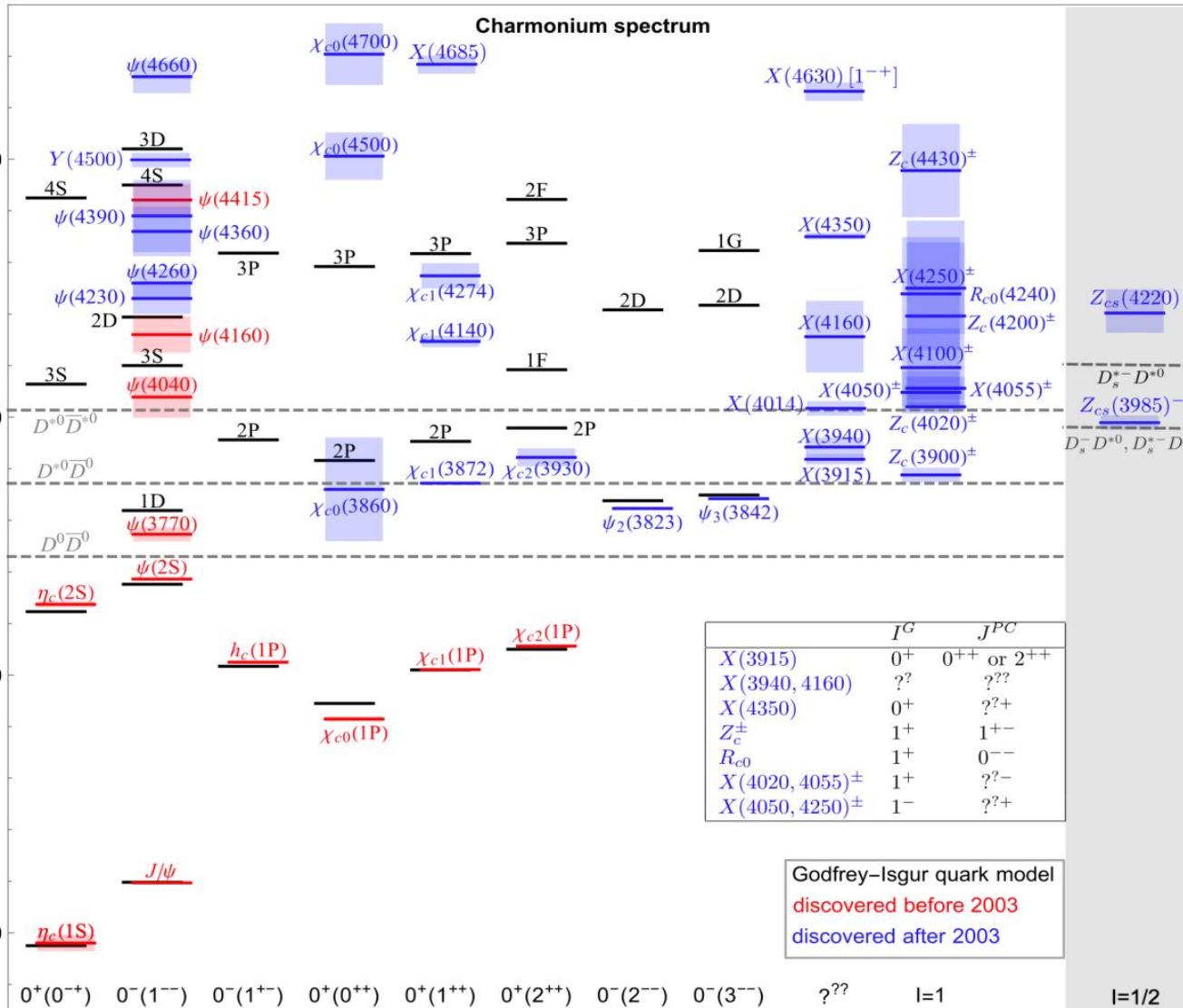# Introduction

A series of vector charmonium states above the charm meson threshold $\psi(4040)(3S)$, $\psi(4160)(1D)$, and $\psi(4415)(4S)$ are consistent with the potential model.
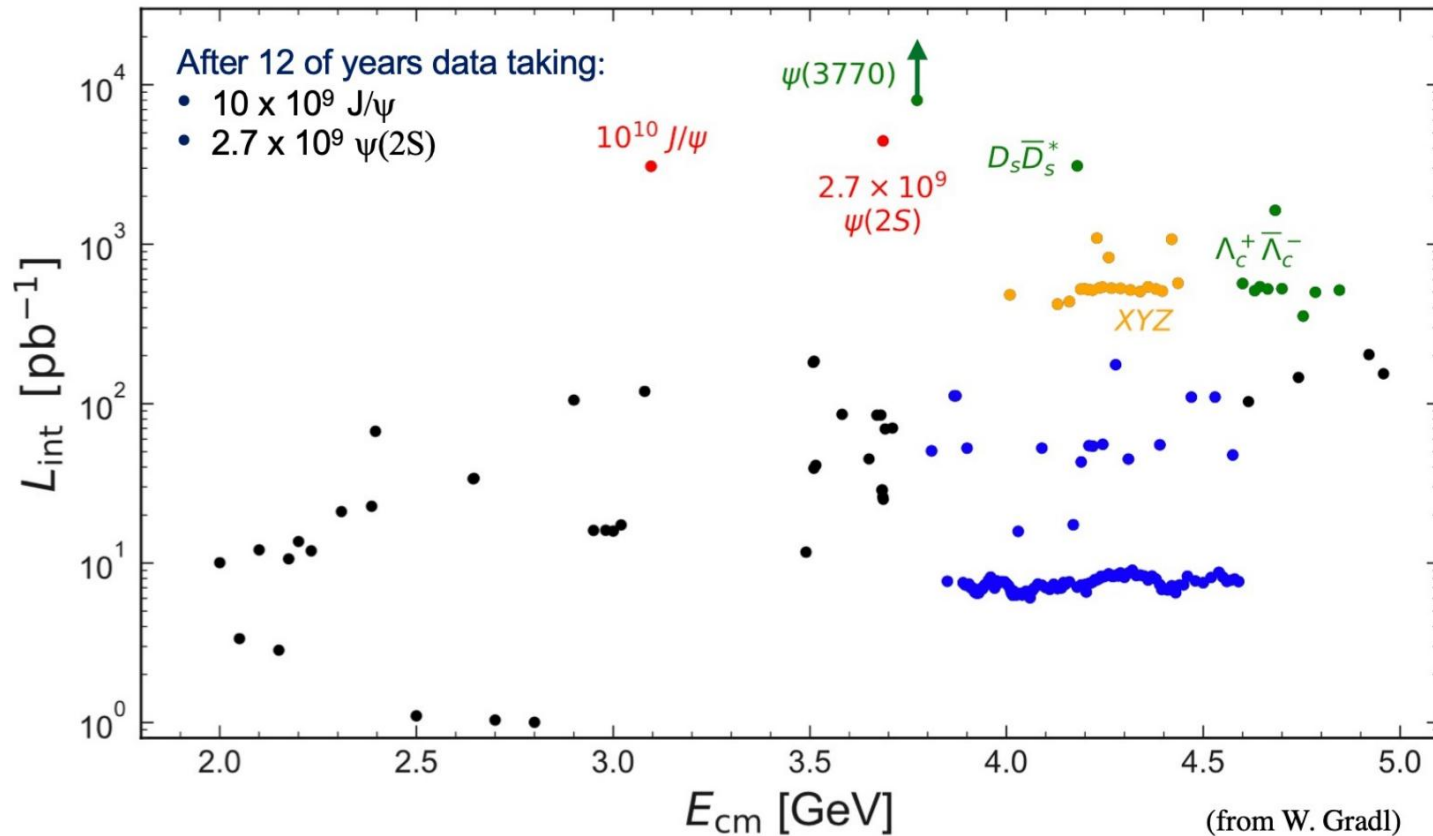
In the past two decades, unexpected vector charmonium-like resonance structures have been observed in hidden-charm final states, such as $Y(4230)$, $Y(4360)$ and $Y(4660)$.

Open charm process dominates at 4~5 GeV

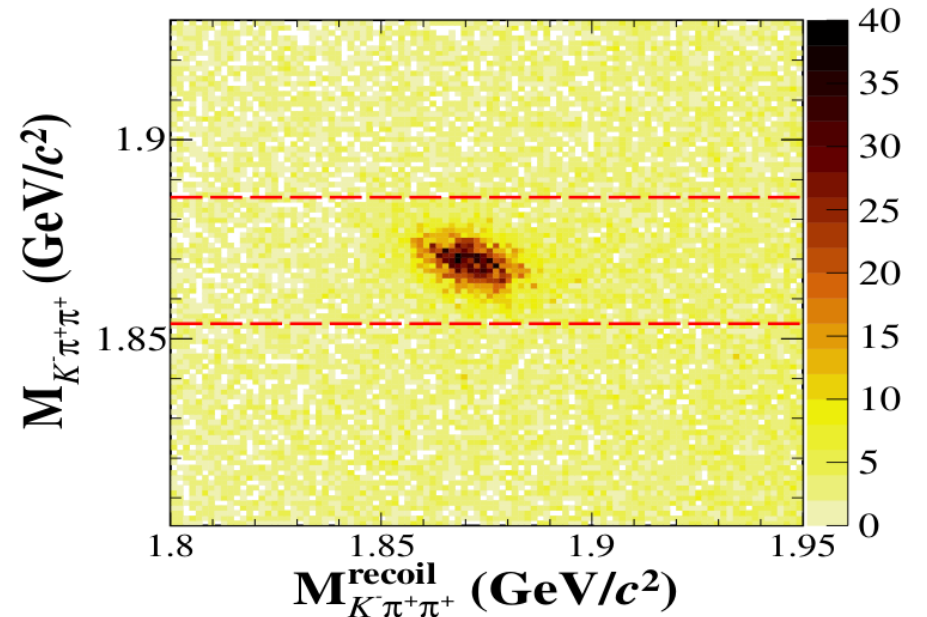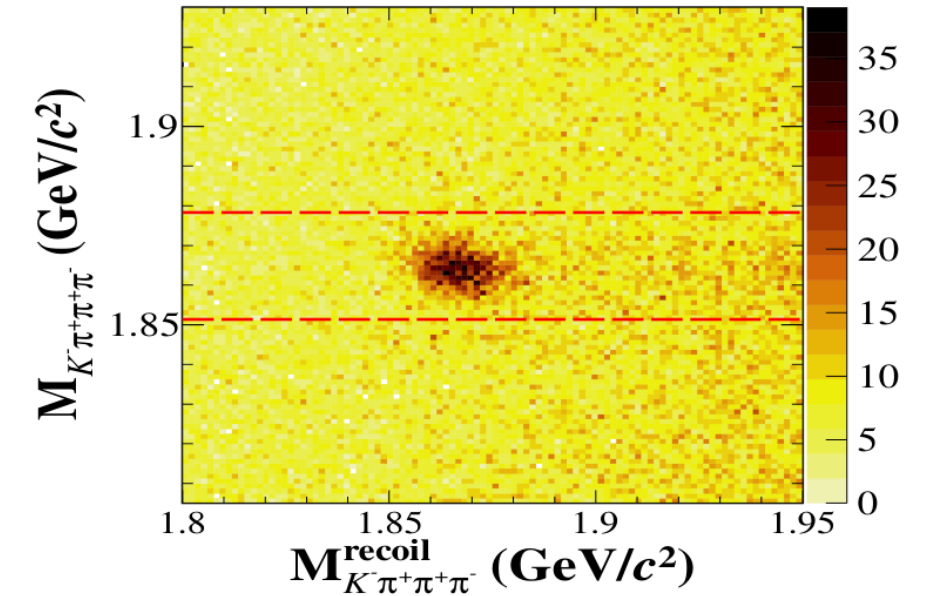Searching for more final states of charmonium-like decay above the open-charm threshold.

3

BESIII Data Samples

(from W. Gradl)

46 XYZ energy points 104 R-scan energy points corresponding in total to an integrated luminosity of 22.9 fb^{-1}

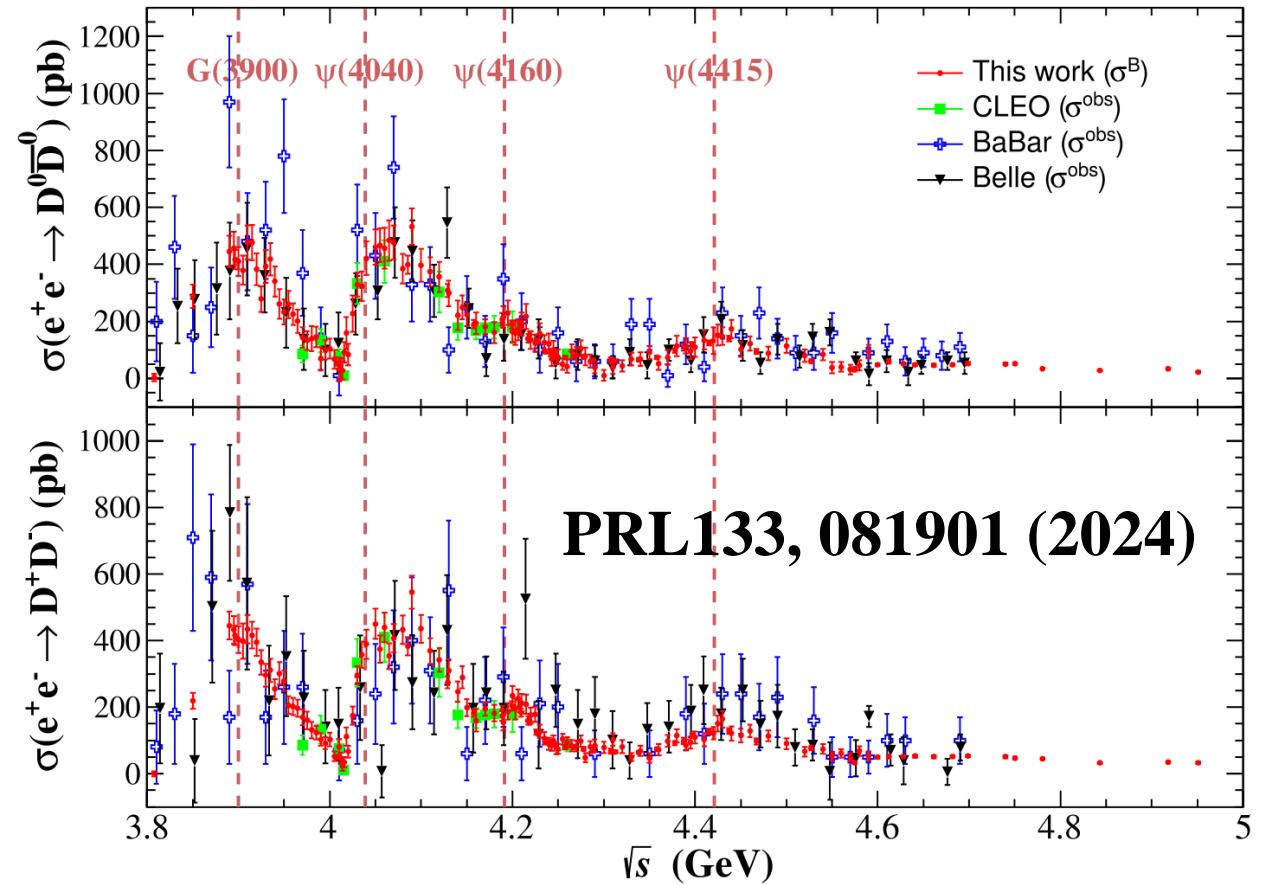# $e^+e^- \rightarrow D^0\overline{D}^0, D^+D^-$

- $\sqrt{S}$ from 3.80 to 4.95 GeV

- Integrated luminosity 20 fb^{-1}

- Single tag $D0$ ($D+$) is reconstructed

  via $K^-\pi^+\pi^+\pi^-(K^-\pi^+\pi^+)$ mode

- D-mass window cut

  - $|M_{K\pi\pi\pi} - M_{D^0}| < 14$ MeV/c^2
  - $|M_{K\pi\pi} - M_{D^+}| < 16$ MeV/c^2

MC Shape $\otimes$ Gaussian Function

Second-order Polynomial Function

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Second-order Polynomial Function

PRL133, 081901 (2024)
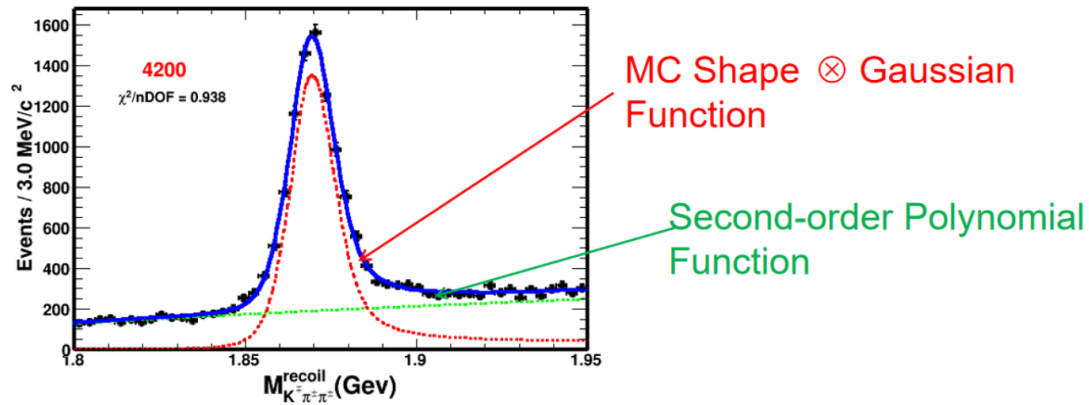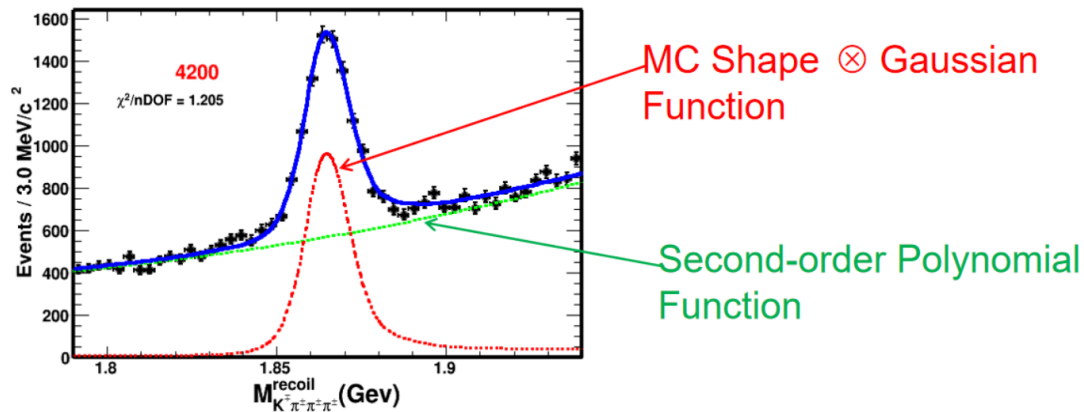
$$\sigma^B(s) = \frac{N_{\mathrm{obs}}}{2\mathcal{L}(1+\delta)\frac{1}{|1-\prod|^2}\epsilon\mathcal{B}}$$

Clear peaks of
G(3900), ψ(4040) , ψ(4160), ψ(4260), ψ(4415)
Consistent with previous measurements

The systematics is 7.0% (6.5%) for $D^0(D^+)$ mode
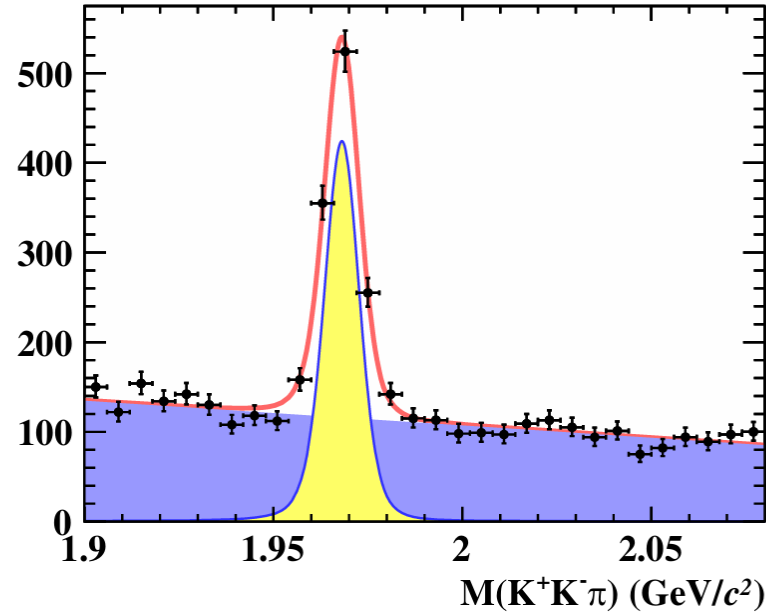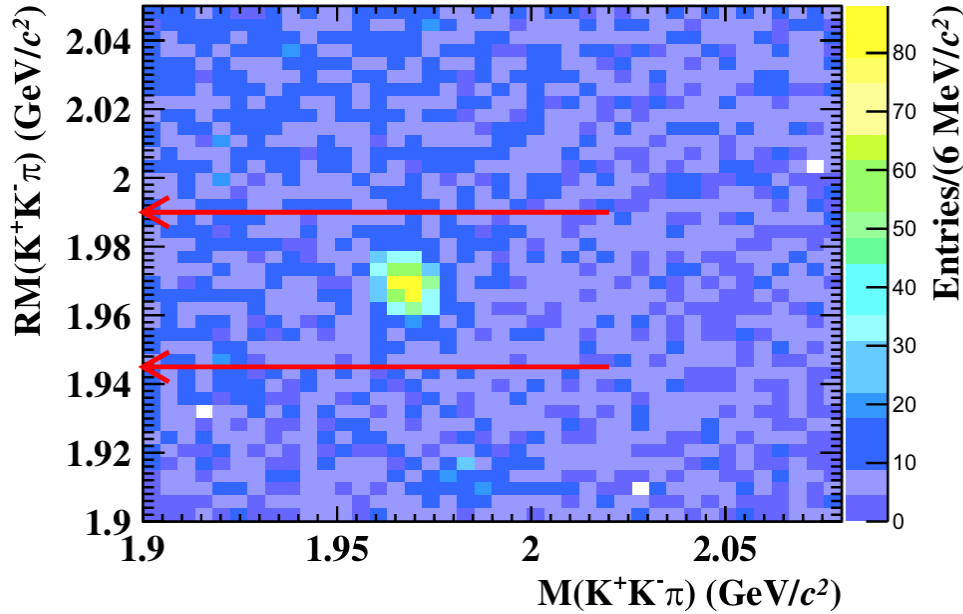
signal MC shape $\otimes$ Gaussian
1nd polynomial

$$\sigma_{\text{Born}} = \frac{N_{D_s}^{\text{fit}} - N_{D_s^{\pm} D_s^{\mp *}}}{2\mathcal{B}(D_s^{\pm} \rightarrow K^+ K^- \pi^{\pm})\epsilon(1+\delta)\frac{1}{|1-\Pi|^2}\mathcal{L}}$$

- $\sqrt{S}$ from 4.009 to 4.95 GeV

- Integrated luminosity 22.8 fb^{-1}

- Only single D_s^+ or D_s^- is reconstructed via $K^+ K^- \pi^{\pm}$ mode

- Recoil mass window cut

- Possible peaking background of $D_s^{\pm} D_s^{*\mp}$ is subtract

PRL 133, 261902 (2024)
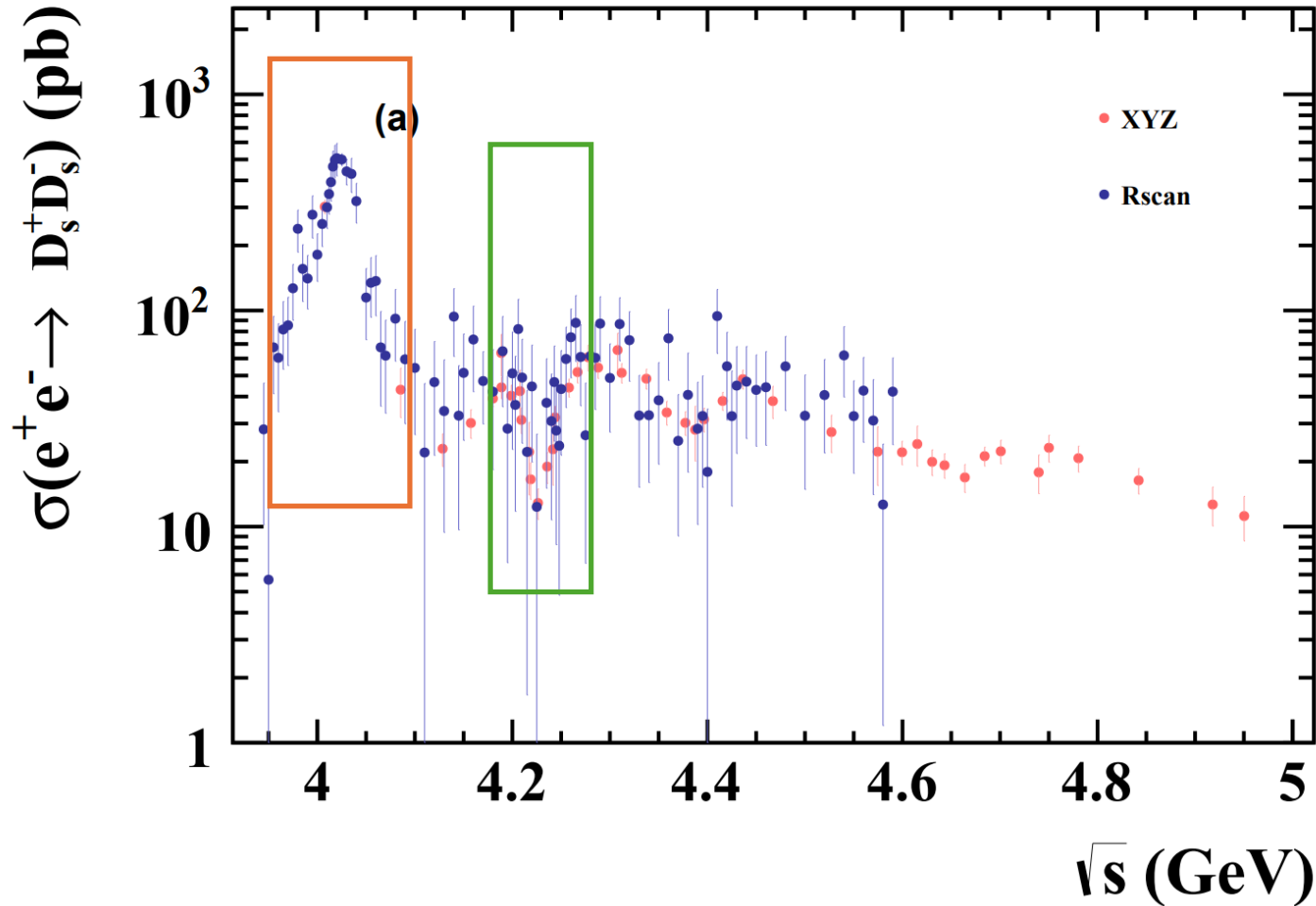
The width of ψ (4040) around 4.02 GeV is about 40 MeV, significantly smaller than the 80 ± 10 MeV listed by the PDG

A narrow dip observed around 4.23 GeV, which closely corresponds to the $D_s^{*+} D_s^{*-}$ threshold and the peak position of the ψ(4230).

Signal: MC shape $\otimes$ Gaussian
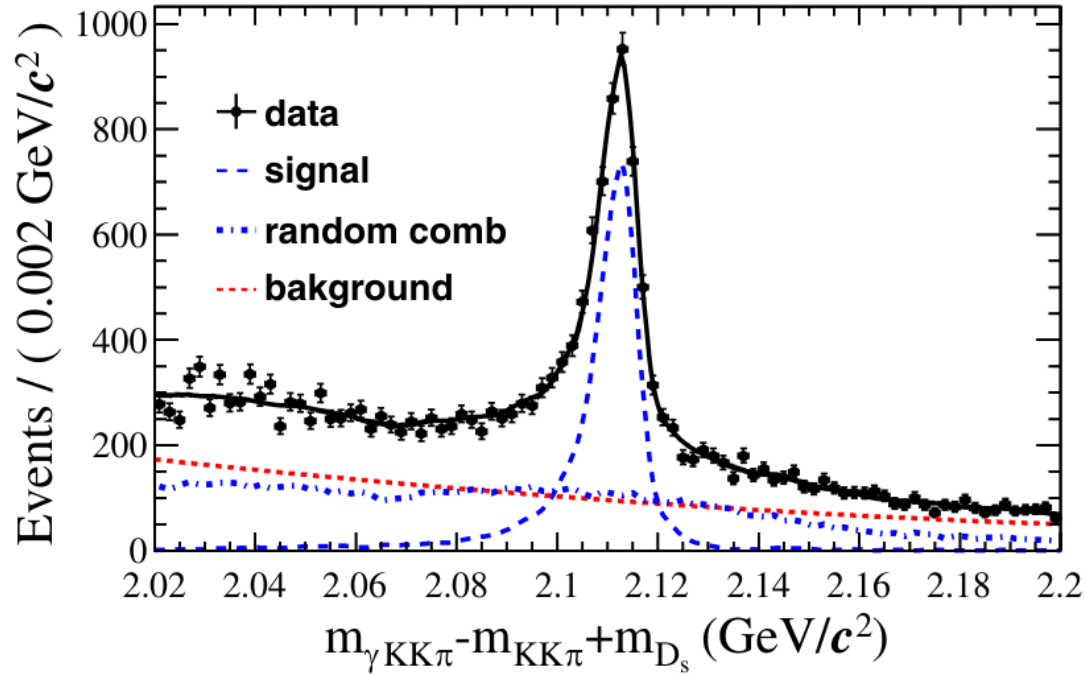Background: 1. Random combinations
        2. 2nd Chebyshev function

Systematic uncertainties vary from 26% to 6%
The large uncertainty at lower region due to
the calibration of energy

- $\sqrt{S}$ from 4.226 to 4.95 GeV

- Integrated luminosity 15.8 fb^{-1}
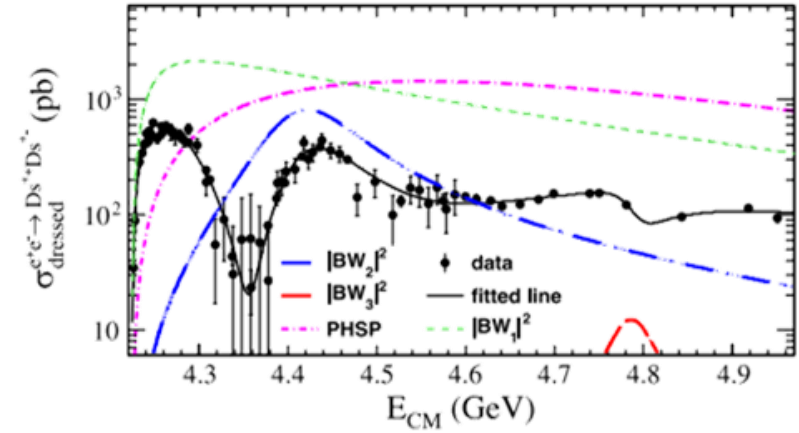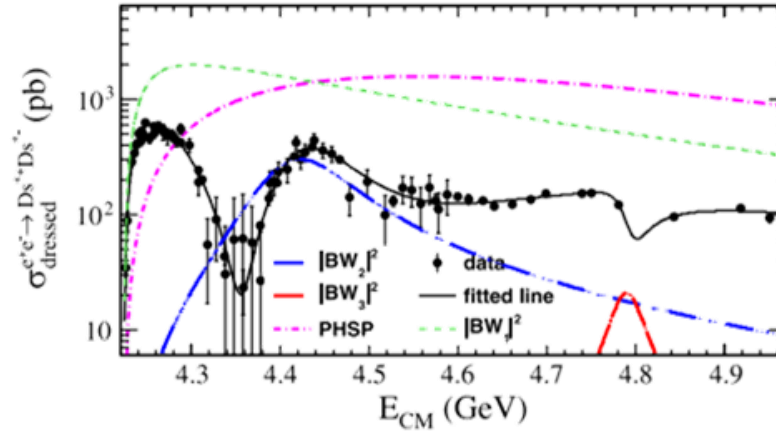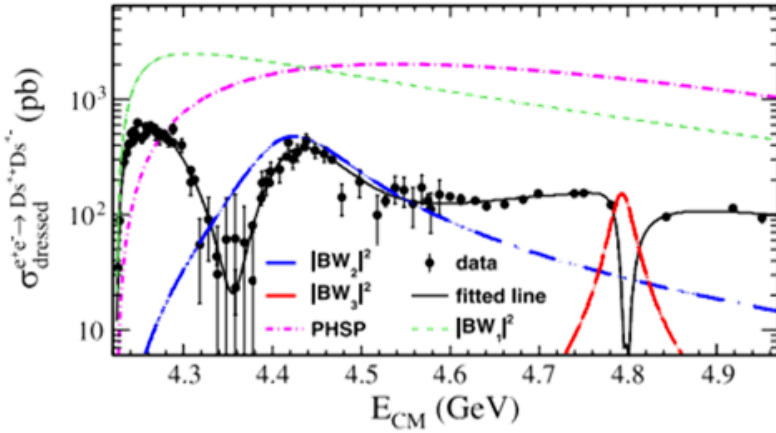
- Resconstruct D_s^{*+} or D_S^{*-} with
$$D_s^{*\pm} \rightarrow D_s^{\pm}\gamma, D_s^{\pm} \rightarrow K^+K^-\pi^{\pm}$$

- $\left|M_{miss} - m_{D_S^*}\right| < 5\sigma_{M_{miss}^{mc}}$

- Possible peaking background
$$e^+e^- \rightarrow D_s^{\pm}D_s^{*\mp}\gamma^{isr} \text{ is subtracted}$$

The significances of third structure exceed 5.9σ in all three results.

$$\sigma_{\text{dressed}} = \left| BW_1(E_{\text{c.m.}}) + \sum_{j=2}^{3} BW_j(E_{\text{c.m.}})e^{i\phi_j} + \frac{a_0\sqrt{\beta^3(E_{\text{c.m.}})}}{E_{\text{c.m.}}^n}e^{i\phi_0} \right|^2$$

In the nominal fit, only statistics are considered. Systematics of resonance parameters are large

	Result 1	Result 2	Result 3
M_1 (MeV/c^2)	4186.8 ± 8.7	4194.1 ± 6.8	4195.6 ± 6.5
Γ_1 (MeV)	55 ± 15	61.1 ± 8.5	61.7 ± 7.7
M_2 (MeV/c^2)	4414.6 ± 3.4	4411.9 ± 3.2	4411.1 ± 3.2
Γ_2 (MeV)	122.5 ± 7.5	120.2 ± 7.4	119.9 ± 7.3
M_3 (MeV/c^2)	4793.3 ± 6.7	4789.7 ± 8.7	4786.0 ± 9.4
Γ_3 (MeV)	27.1 ± 6.5	42 ± 75	60 ± 34

ψ(4415)

Sources	Fitting	R	$E_{\text{c.m.}}$	σ_{dressed}	Total
M_1 (MeV/c^2)	8.8	2.9	28.3	5.1	30
Γ_1 (MeV)	6.7	1.9	51	11.8	53
M_2 (MeV/c^2)	3.5	0.6	4.0	3.0	6.1
Γ_2 (MeV)	2.6	0.2	7.6	1.0	8.1
M_3 (MeV/c^2)	7.3	1.0	2.4	5.1	9.3
Γ_3 (MeV)	32.9	1.1	5.3	3.4	34

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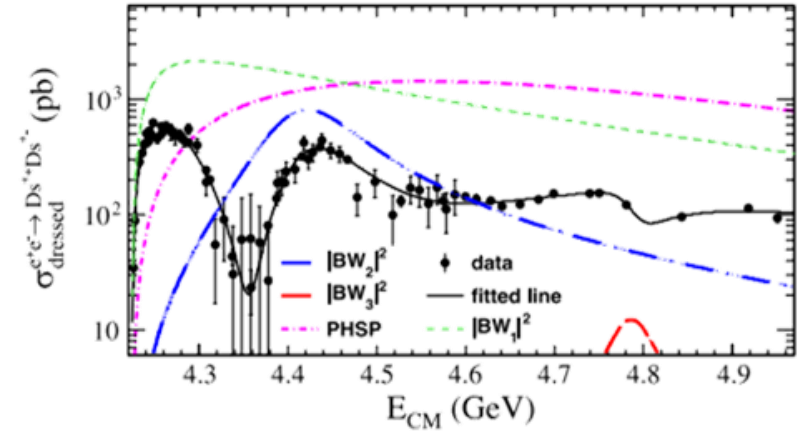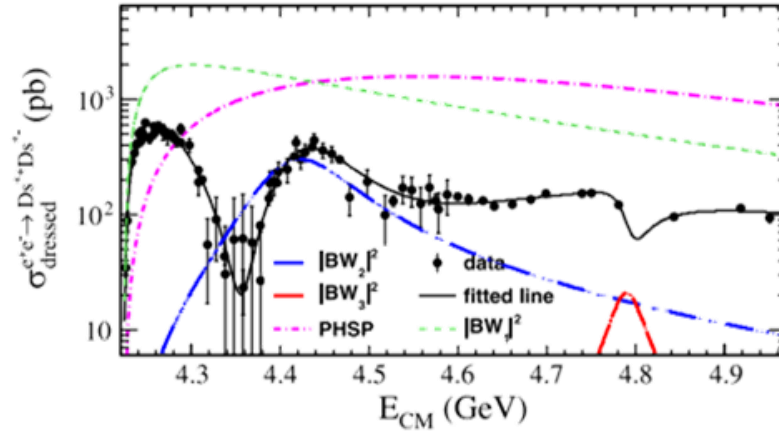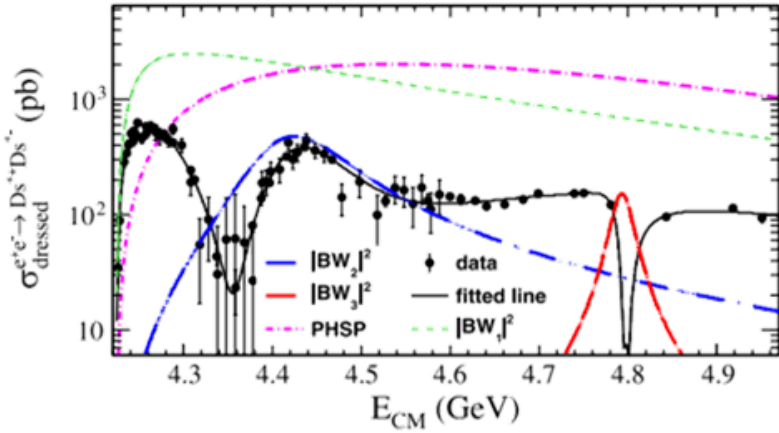
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11

Summary and Outlook

- Precision measurements of the cross sections of $e^+e^- \to D\bar{D}$, $D_s^+ D_s^-$, $D_s^{*+} D_s^{*-}$ are presented

- Observation of numerous intriguing structures, strong coupled-channel effects need to be considered

- Hard to fit the cross sections, need more comprehensive

- In the future, coupled channels analysis is desired to including open and hidden charm, as well as charmonium and charmoniumlike resonances.

- $e^+e^- \to D_s^{*\pm} D_s^{\mp}$, is on the road

$e^+e^- \rightarrow D^0\bar{D}^0$ and D^+D^-
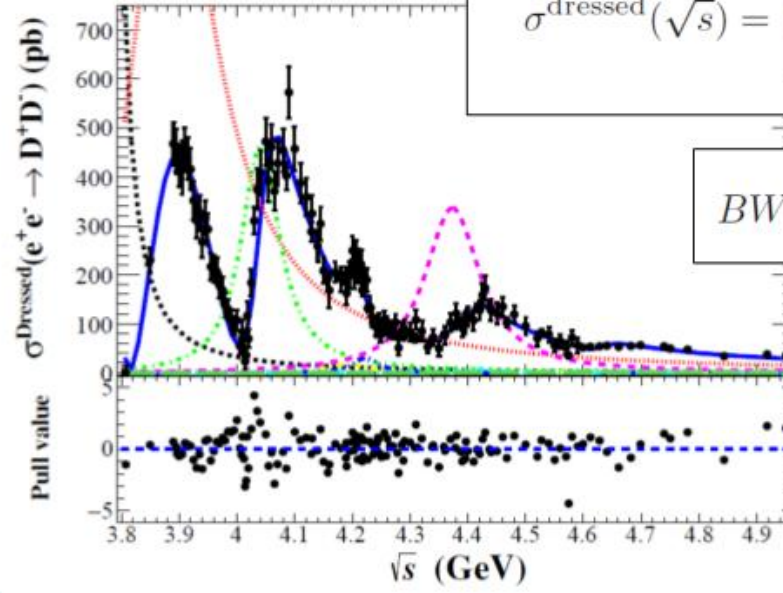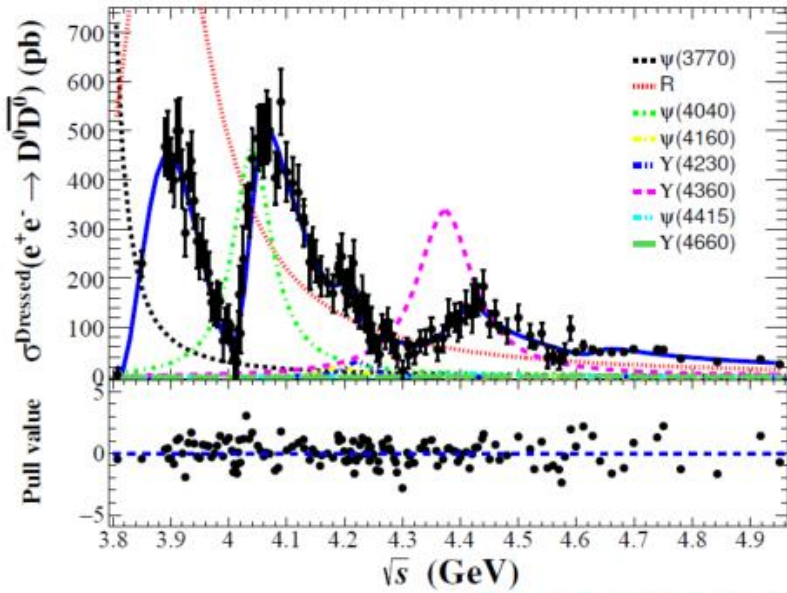
$$\sigma^{\text{dressed}}(\sqrt{s}) = \left| \sum_{i=1} e^{i\phi} BW_i(\sqrt{s}) \sqrt{\frac{P(\sqrt{s})}{P(M)}} \right|^2$$

$$BW(\sqrt{s}) = \frac{\sqrt{12\pi\Gamma_{ee}\mathcal{B}\Gamma}}{s - M^2 + iM\Gamma}$$

coupled channel effect?

$e^+e^- \rightarrow D\bar{D}$								
	$\psi(3770)$	R	$\psi(4040)$	$\psi(4160)$	$Y(4230)$	$Y(4360)$	$\psi(4415)$	$Y(4660)$
Mass (MeV/c^2)	3773.7 (fixed)	3872.5$\pm$14.2$\pm$3.0	4039 (fixed)	4191 (fixed)	4222.5 (fixed)	4374 (fixed)	4421 (fixed)	4630 (fixed)
Width (MeV/c^2)	87.6 (fixed)	179.7$\pm$14.1$\pm$7.0	80 (fixed)	70 (fixed)	48 (fixed)	118 (fixed)	62 (fixed)	72 (fixed)
$\Gamma_{ee}\mathcal{B}$ (eV)	95-106	202-292	41-44	1-2	1-2	50-144	0-2	0-1
S(σ)	10	> 20	13	7	11	11	4	8
χ^2/d.o.f = 346/275				p-value = 0.002				