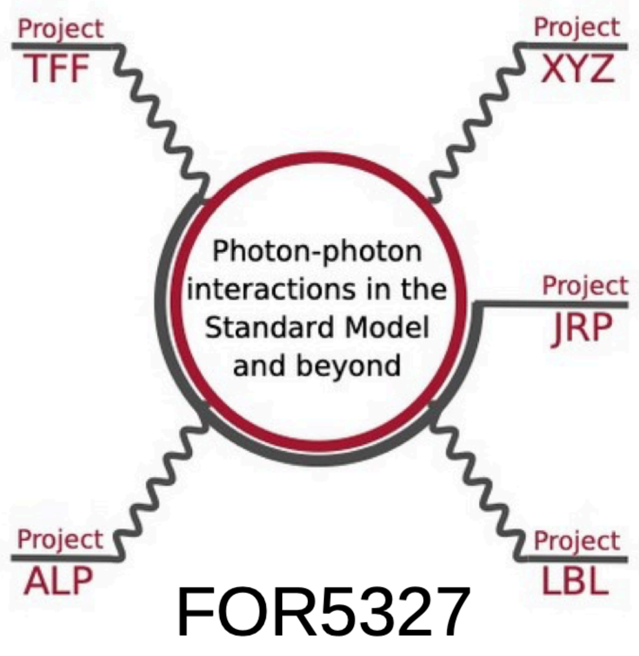
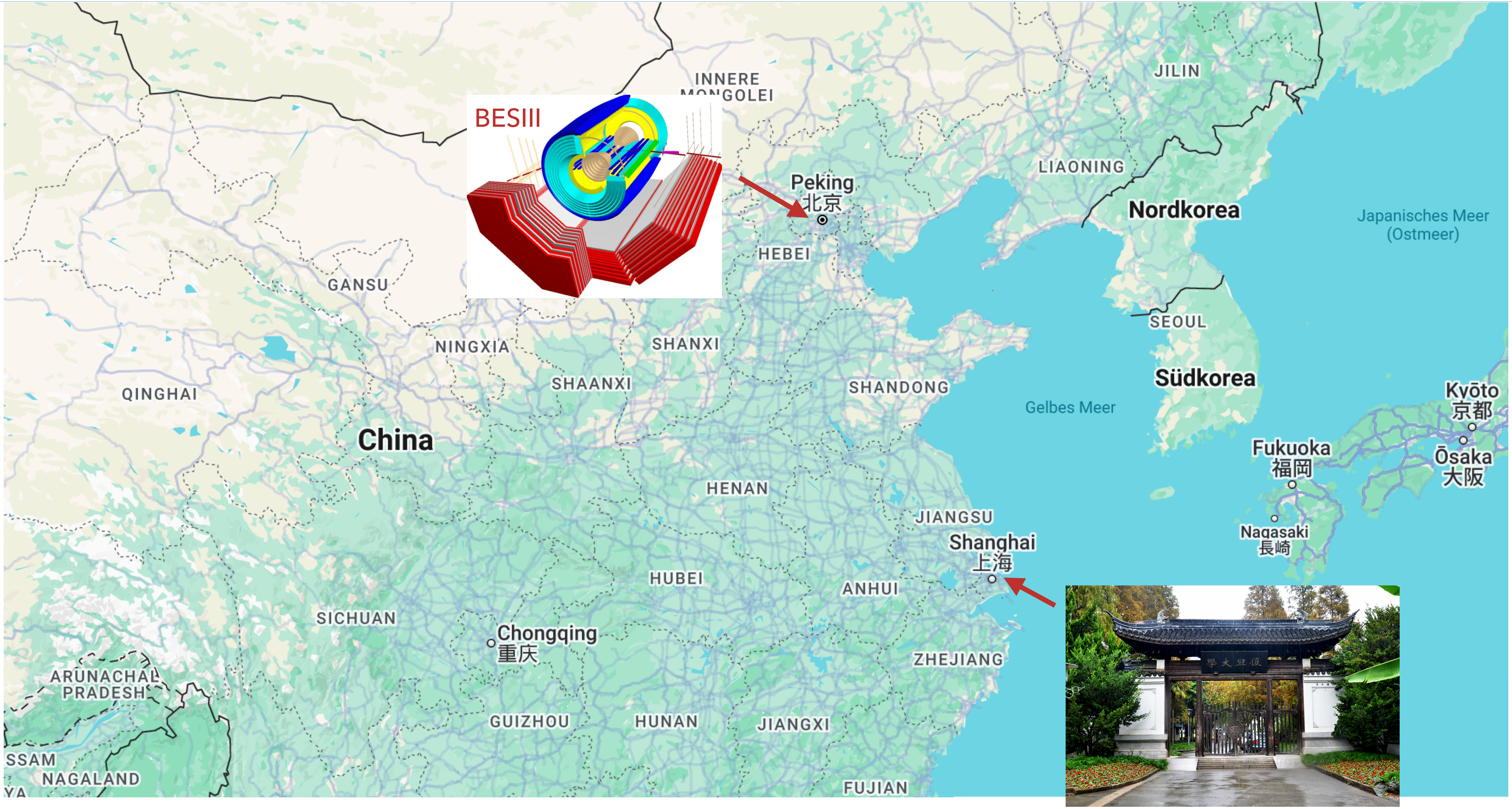
Porject XYZ-Experiment

Yuping Guo（郭玉萍）

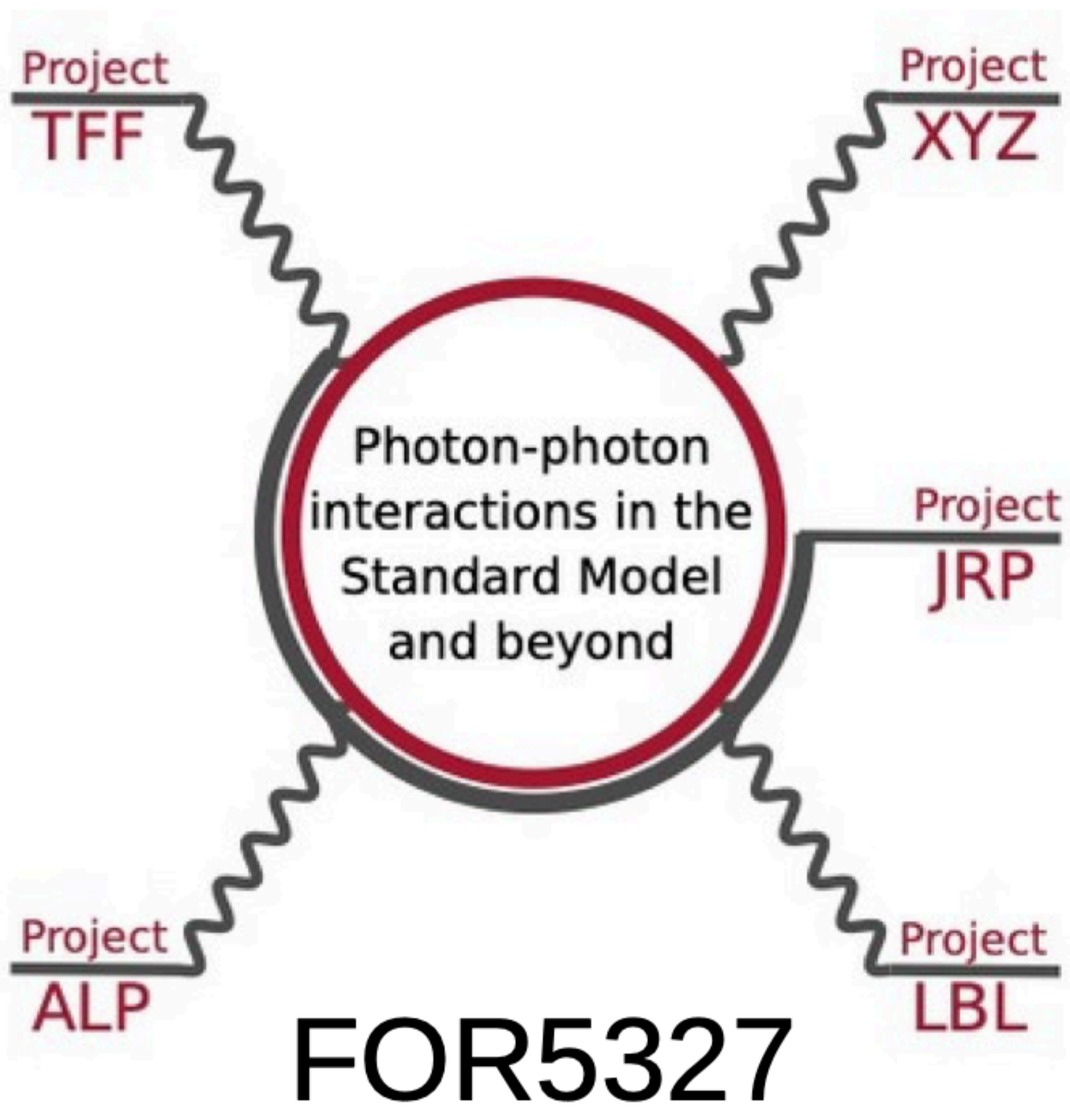


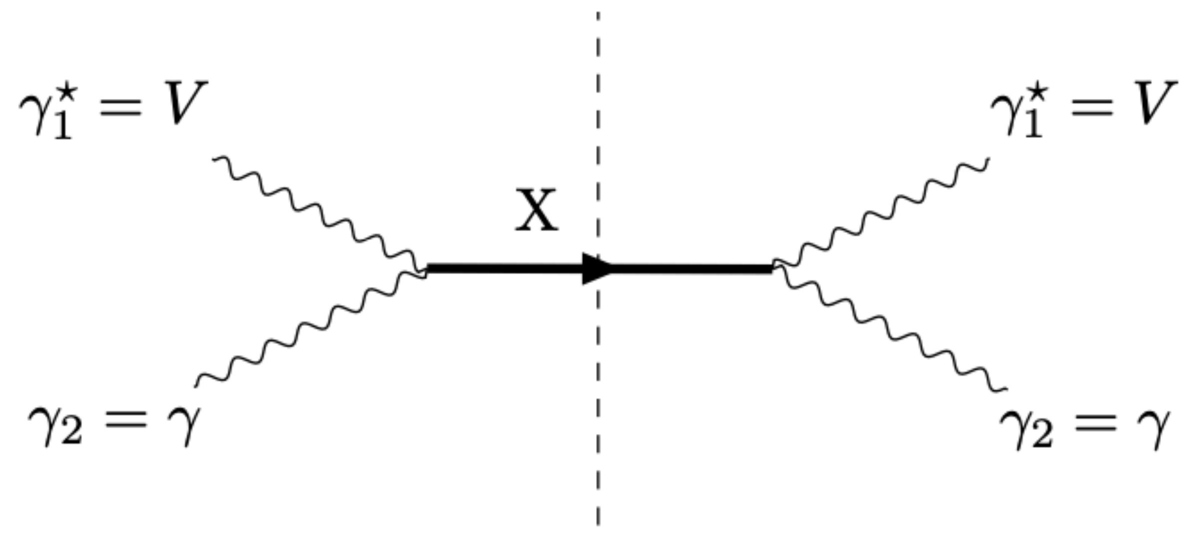
Worksho of Research unit FOR 5327

Jun 11-13 2025 St. Goar

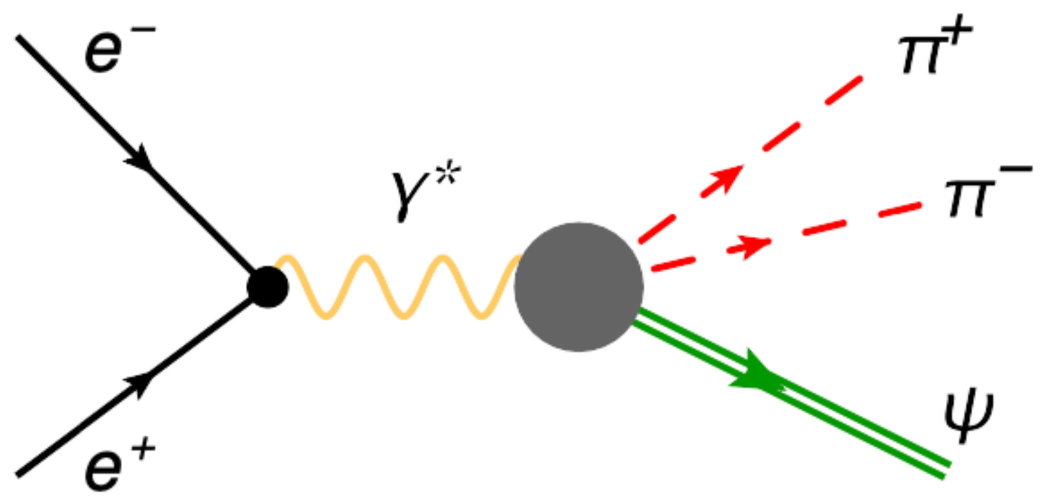

BESIII
INNERE
MONGOLEI
Peking
北京
HEBEI
JILIN
LIAONING
Nordkorea
Japanisches Meer
(Ostmeer)
SEOUL
Südkorea
GANSU
NINGXIA
SHANXI
SHAANXI
SHANDONG
Gelbes Meer
QINGHAI
China
Kyōto
京都
Ōsaka
大阪
Fukuoka
福岡
Nagasaki
長崎
HENAN
JIANGSU
Shanghai
上海
HUBEI
ANHUI
SICHUAN
Chongqing
重庆
ZHEJIANG
ARUNACHAL
PRADESH
GUIZHOU
HUNAN
JIANGXI
SSAM
NAGALAND
FUJIAN

Objectives

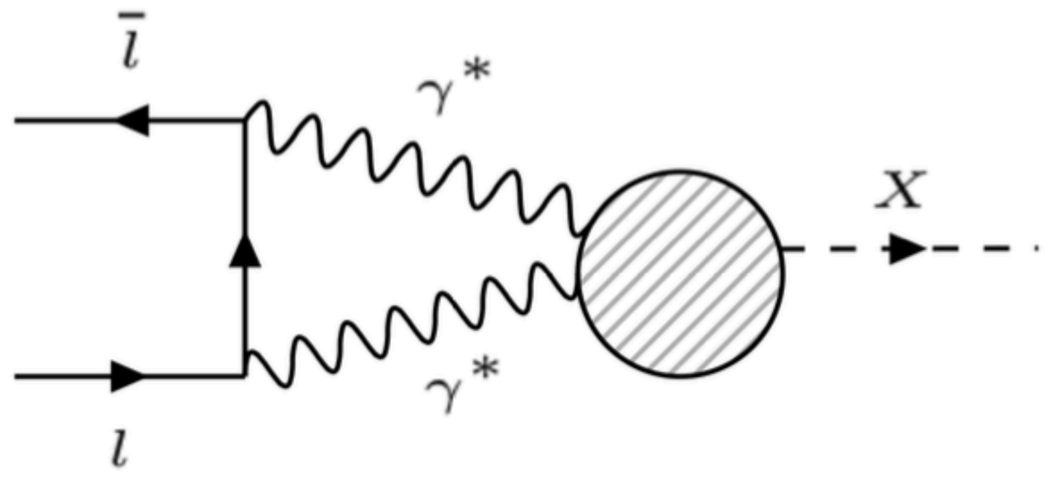




Direct production and/or decay of an exotic non-vector state (X)



e^+e^- production of an exotic vector state decaying into a vector quarkonium and light hadrons



Production of a non-vector quarkonium state in e^+e^- annihilation through a two-photon itermediate state

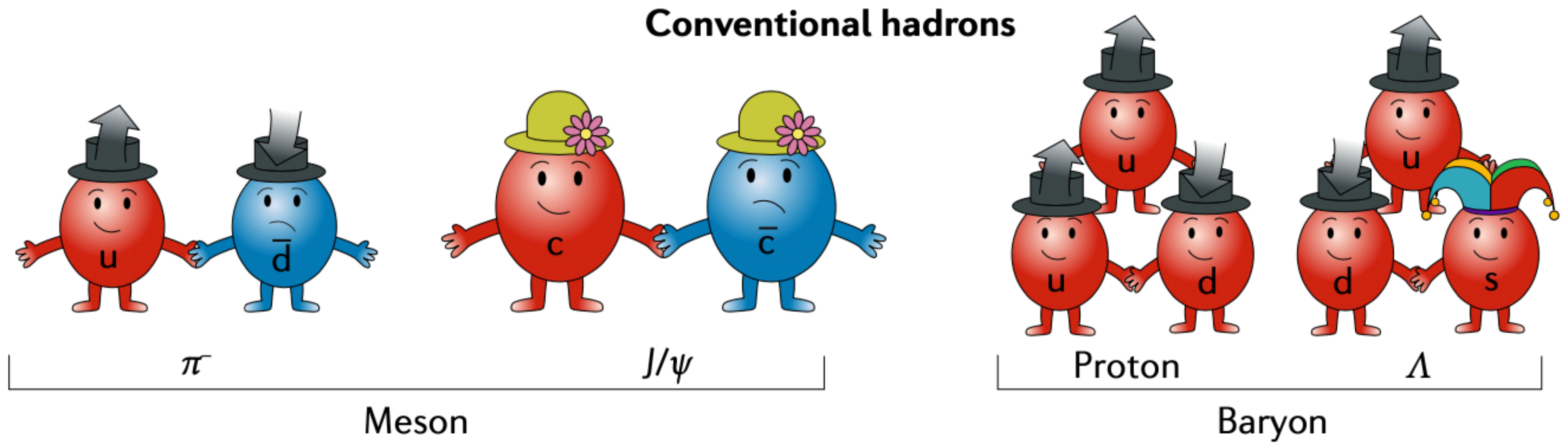
Objectives

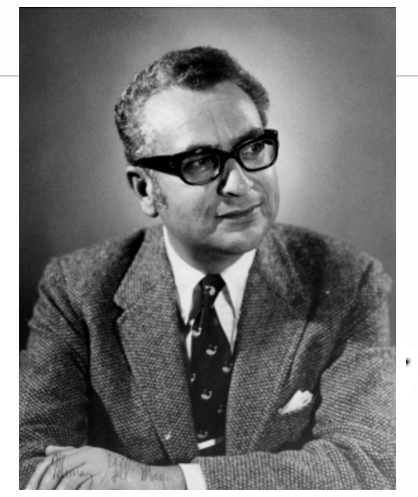
- 1. A study of XYZ charmonium-like states using a dispersive formlism
  - Analysis of the new data of $e^+e^- \to \pi\pi h_c$ at BESIII
  - PWA of the full BESIII $e^+e^- \to \pi\pi h_c$ data using dispersive techniques and determination of the spin and parity of the $Z_c(4020)$
  - PWA of the full BESIII data samples of the $e^+e^- \to \pi\pi(K\bar{K})J/\psi$ at cms energies of 4.23 and 4.26 GeV
- 2. Radiative transitions of vector charmina and bottomina using light-by-light sum rules
- 3. Production of non-vector resonances in e^+e^- annihilation via two-photon production
  - Energy scan around the χ_{c2} resonance and feasibililty studies for XYZ scans

Hadrons

- **Quark Model** [1964 by Gell-Mann and Zweig]

Lowest Configuration!





A SCHEMATIC MODEL OF BARYONS AND MESONS *

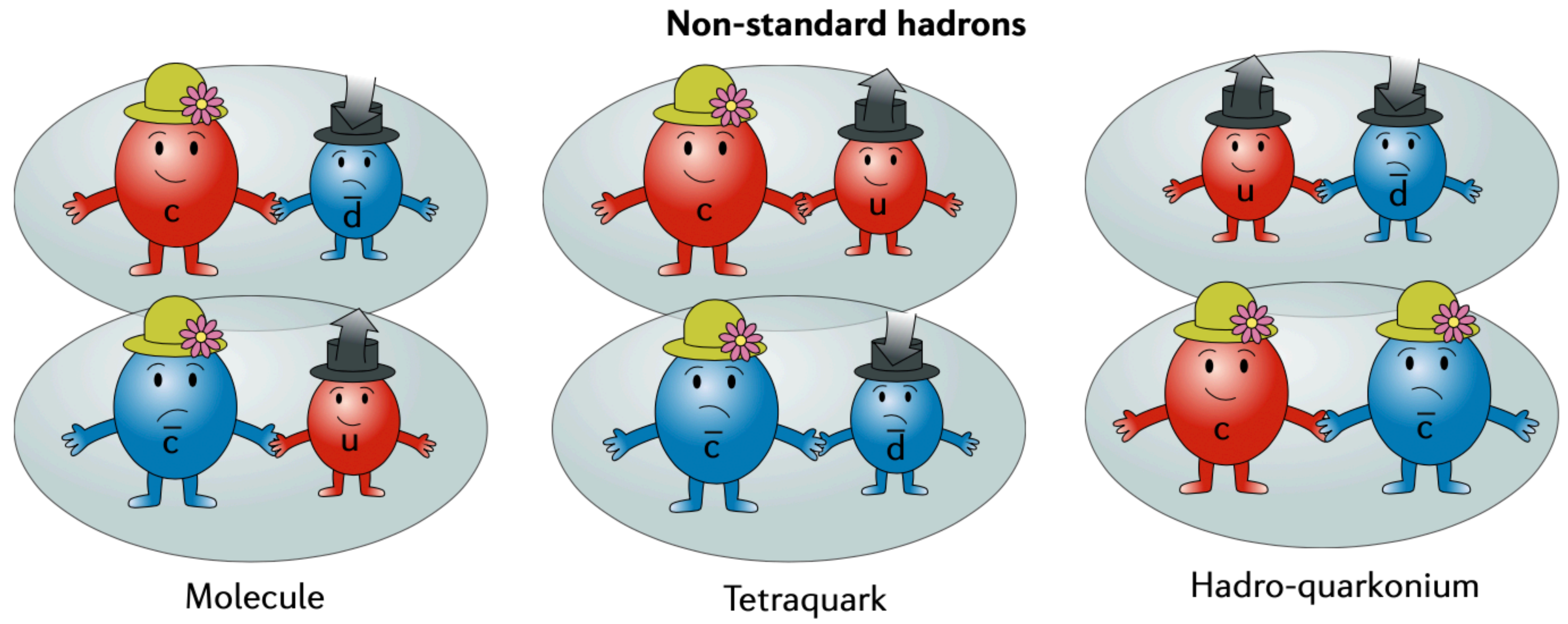
M. GELL-MANN

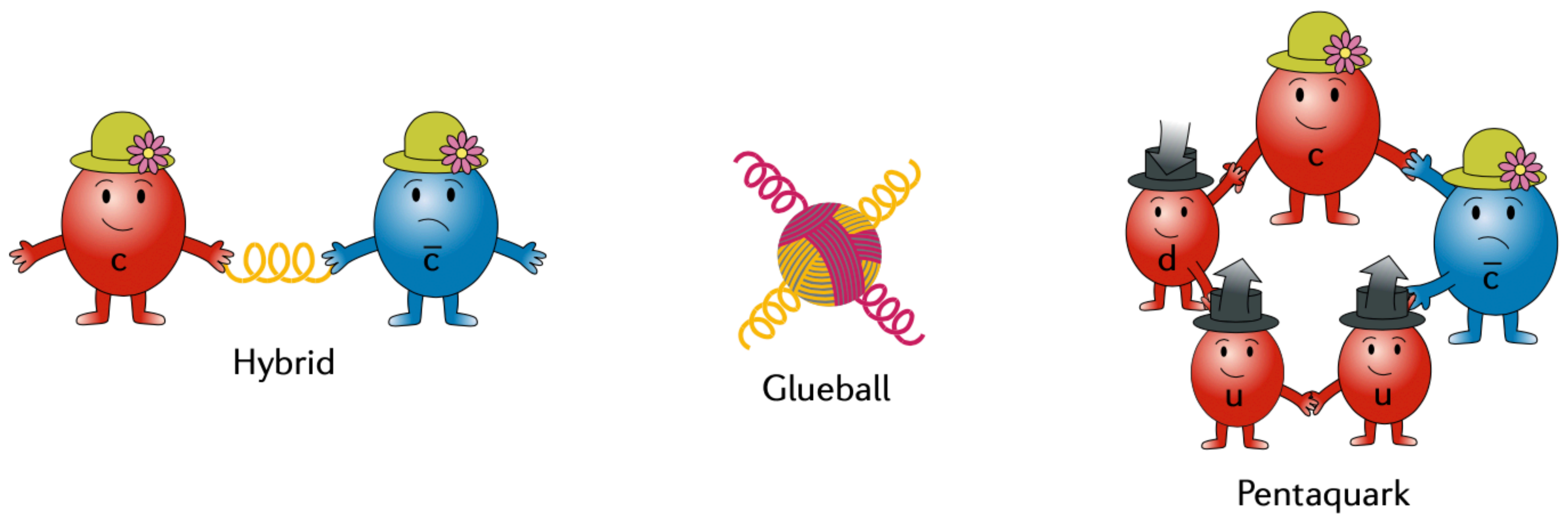
California Institute of Technology, Pasadena, California

Received 4 January 1964

anti-triplet as anti-quarks q̄. Baryons can now be constructed from quarks by using the combinations (q q q), (q q q q q̄), etc., while mesons are made out of (q q̄), (q q q̄ q̄), etc. It is assuming that the lowest baryon configuration (q q q) gives just the representations **1**, **8**, and **10** that have been observed, while the lowest meson configuration (q q̄) similarly gives just **1** and **8**.

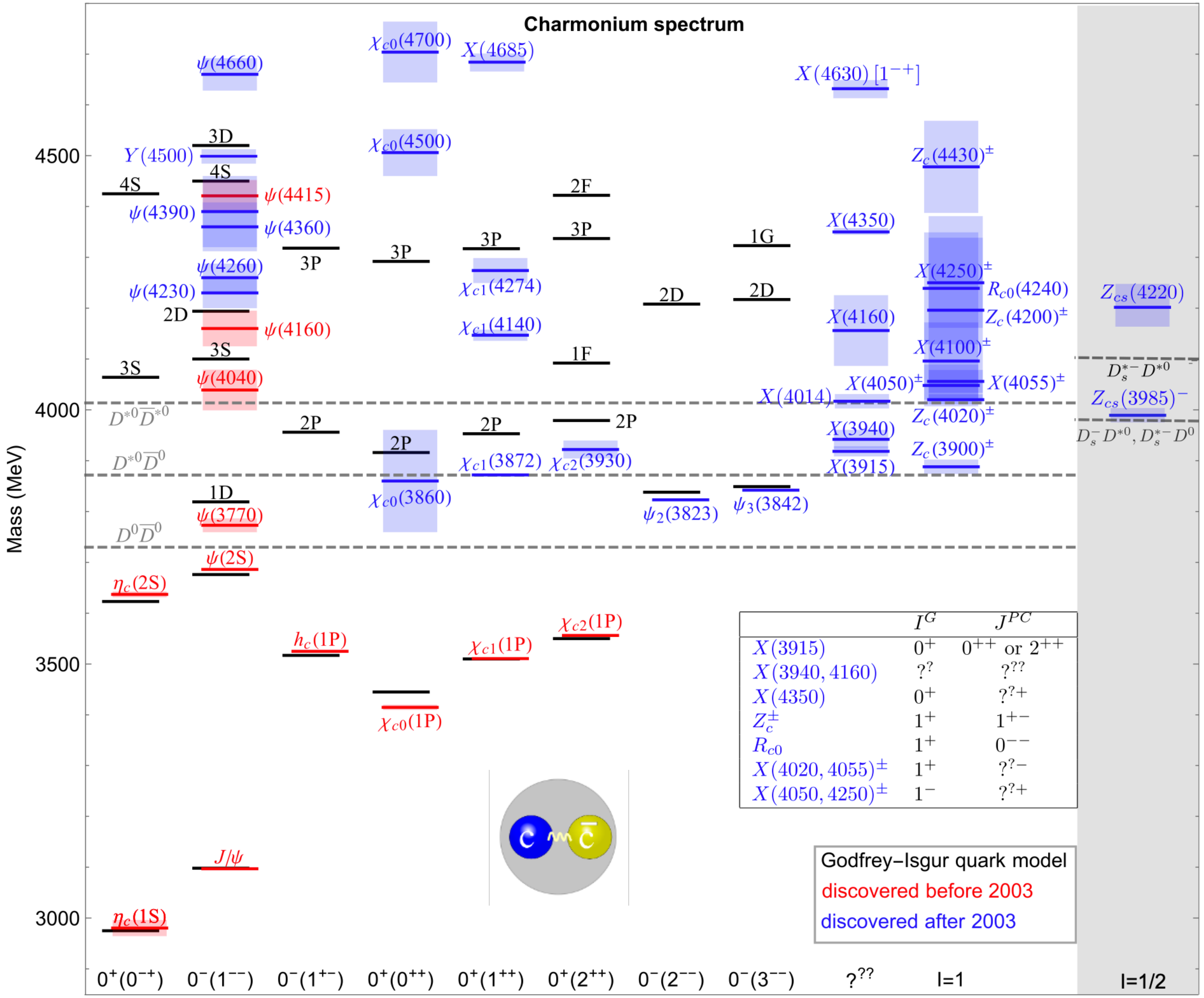
- **Exotic hadrons:**



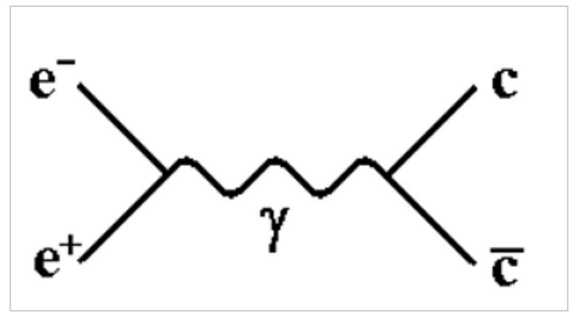


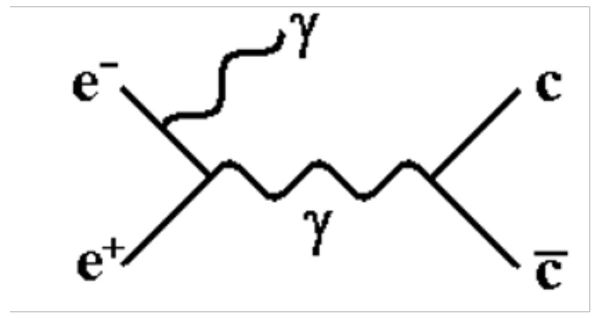
C. Z. Yuan, S. L. Olsen, Nature Reviews Physics 1, 480 (2019)

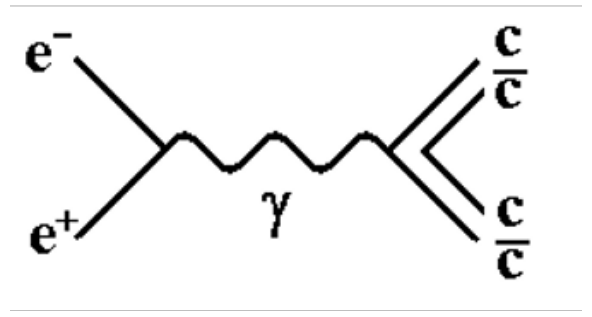
Charmonium Spectroscopy

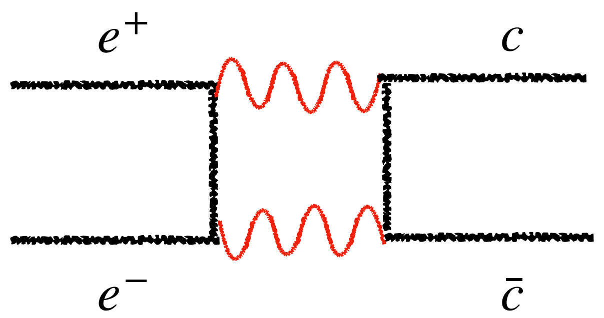


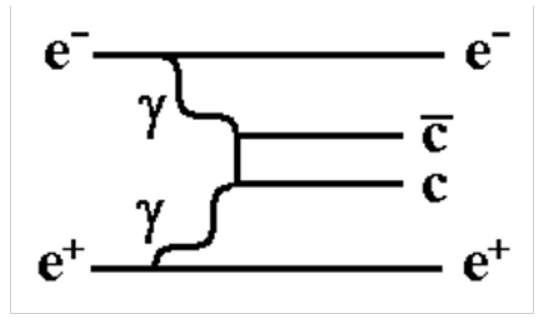
from F. K. Guo

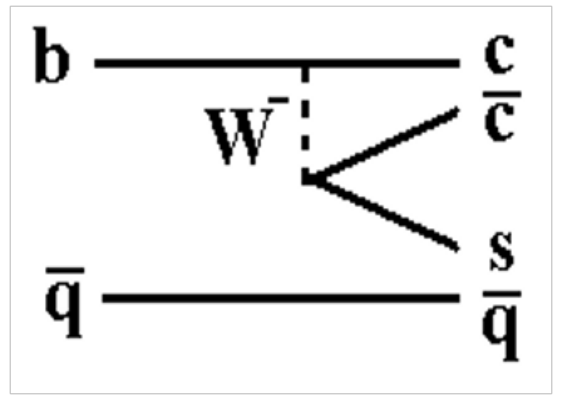


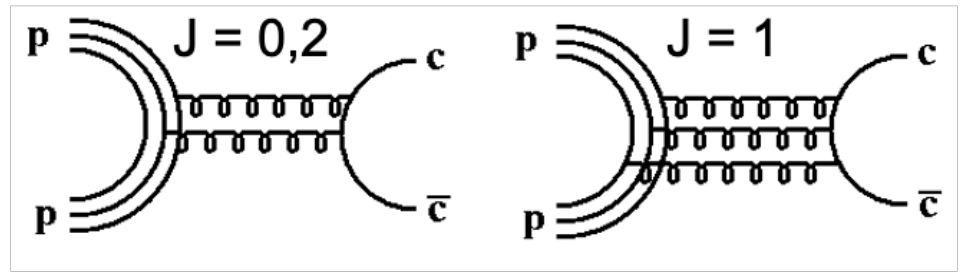












All quantum numbers

...

Beijing Electron Positron Collider II and BESIII

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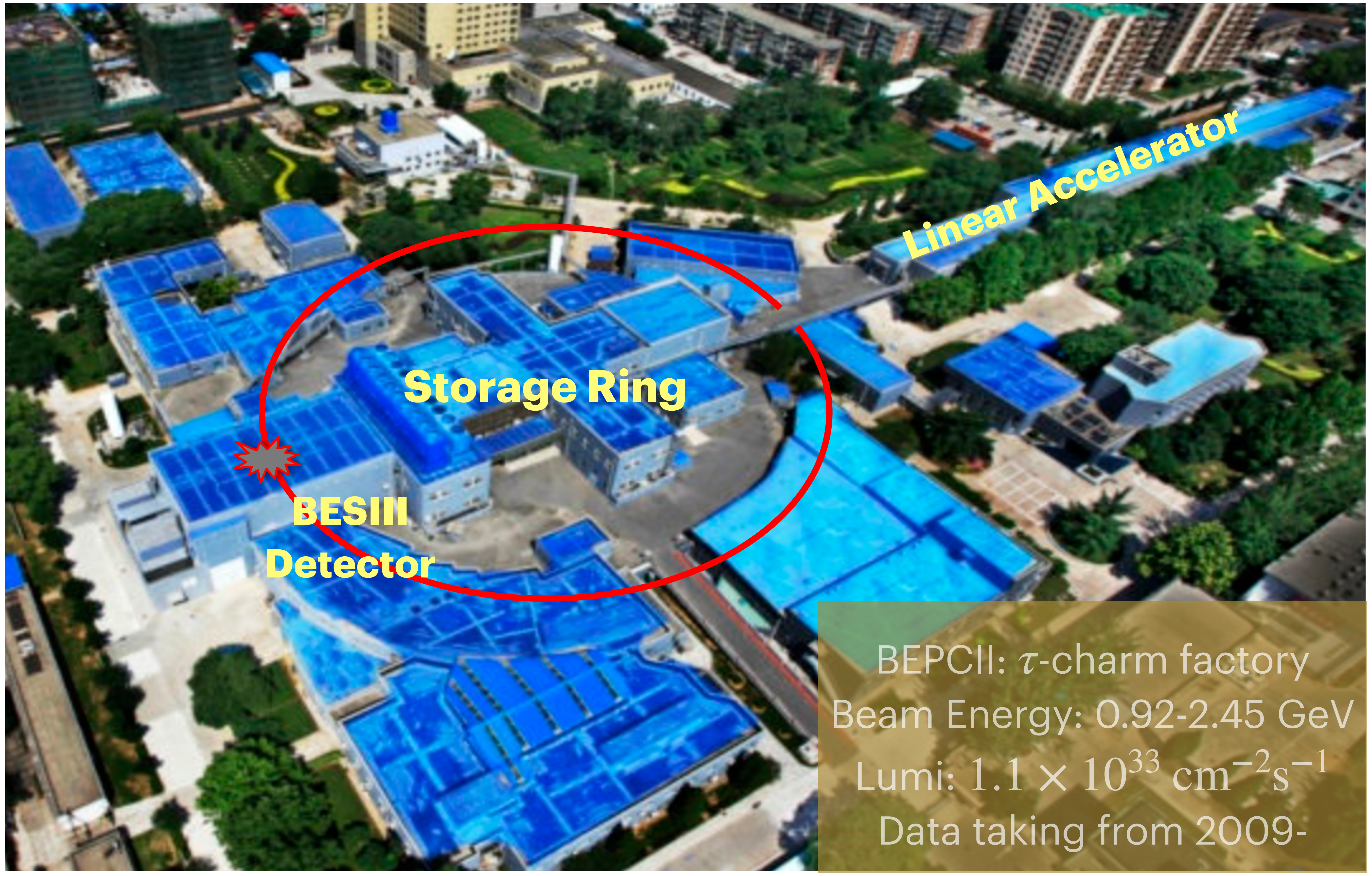


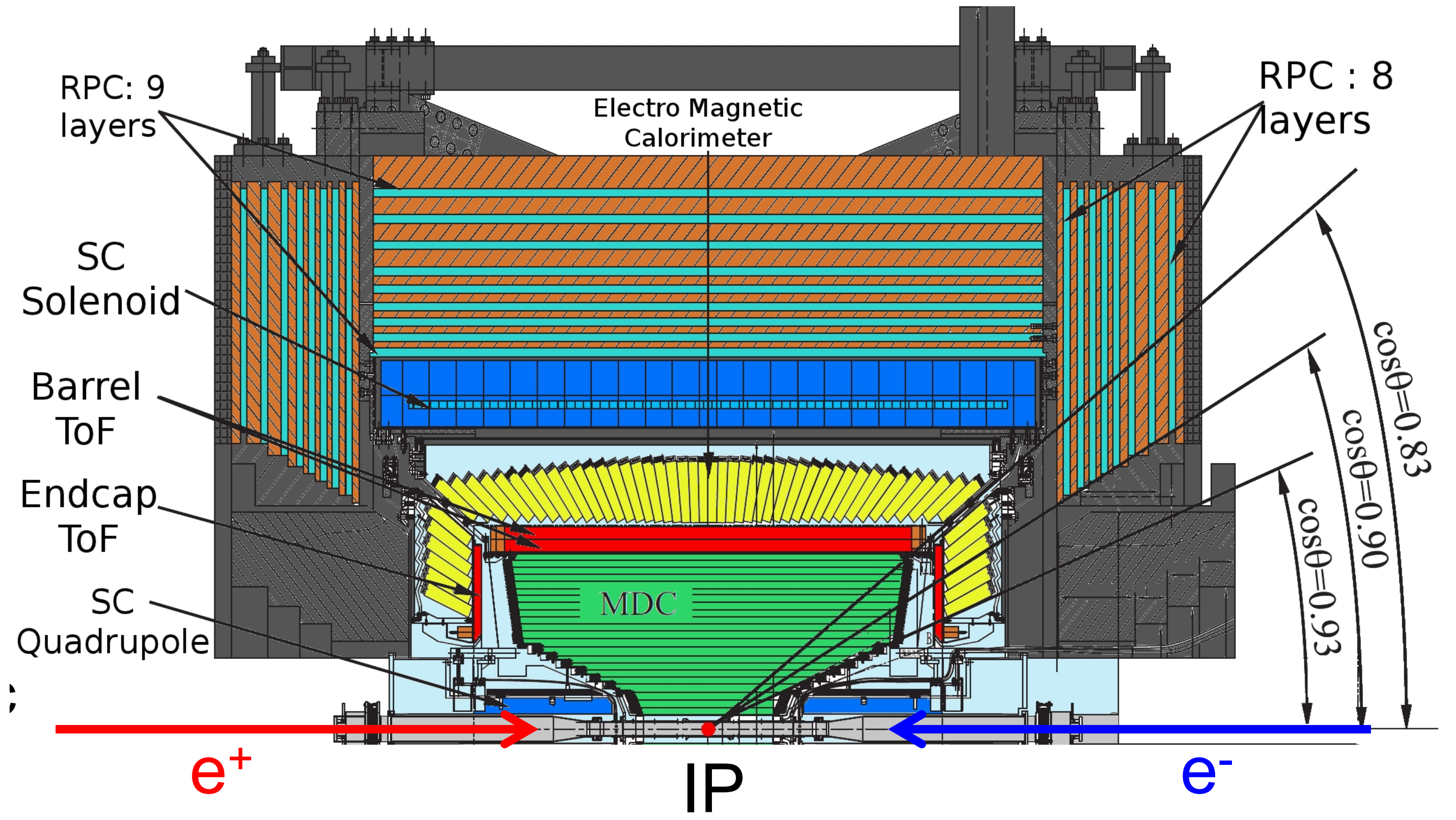
BEPCII: τ-charm factory

Beam Energy: 0.92-2.45 GeV

Lumi: $1.1 \times 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Data taking from 2009-

Solenoid Magnet: 0.9/1.0 T



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

TOF

σ_T :80 ps

110 ps (60 ps)

MDC

dE/dx: 6%

σ_p/p: 0.5% at 1GeV/c

EMC

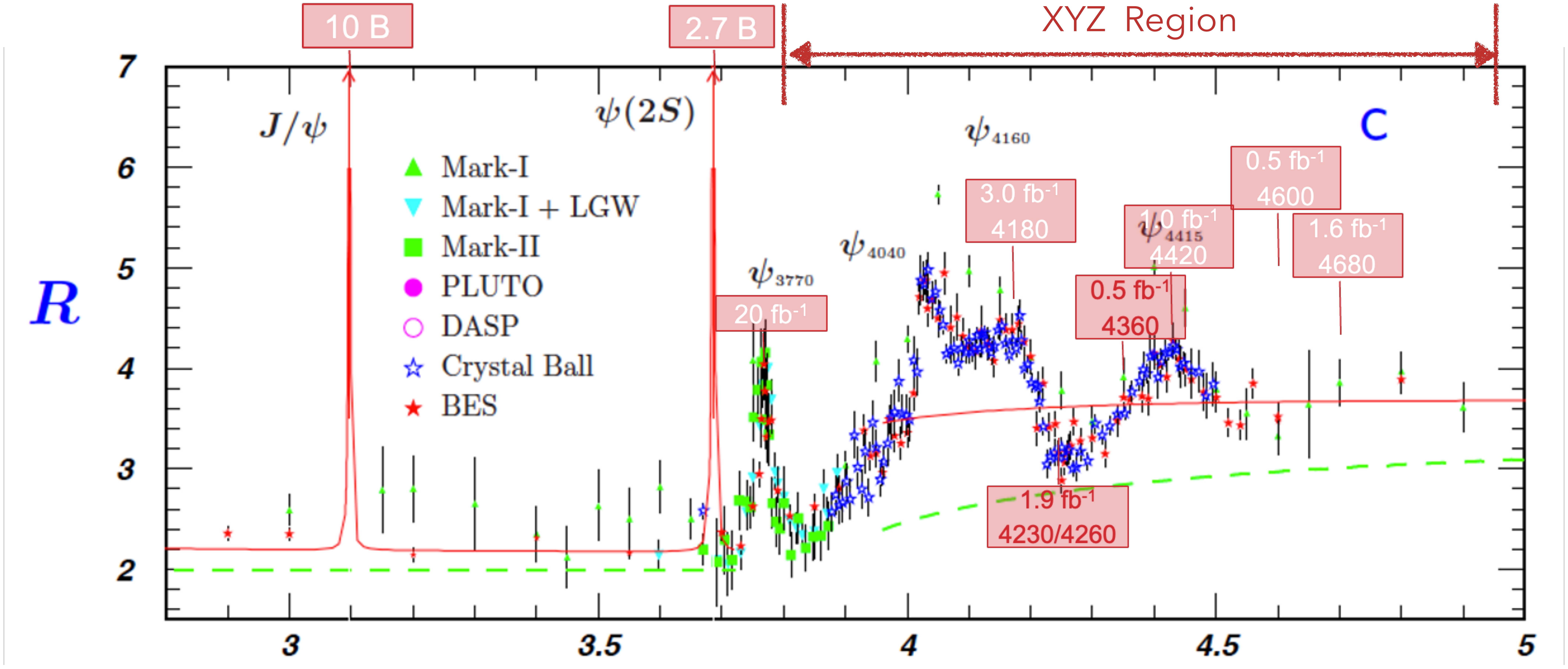
$\Delta E/E$: at 1GeV

2.5%

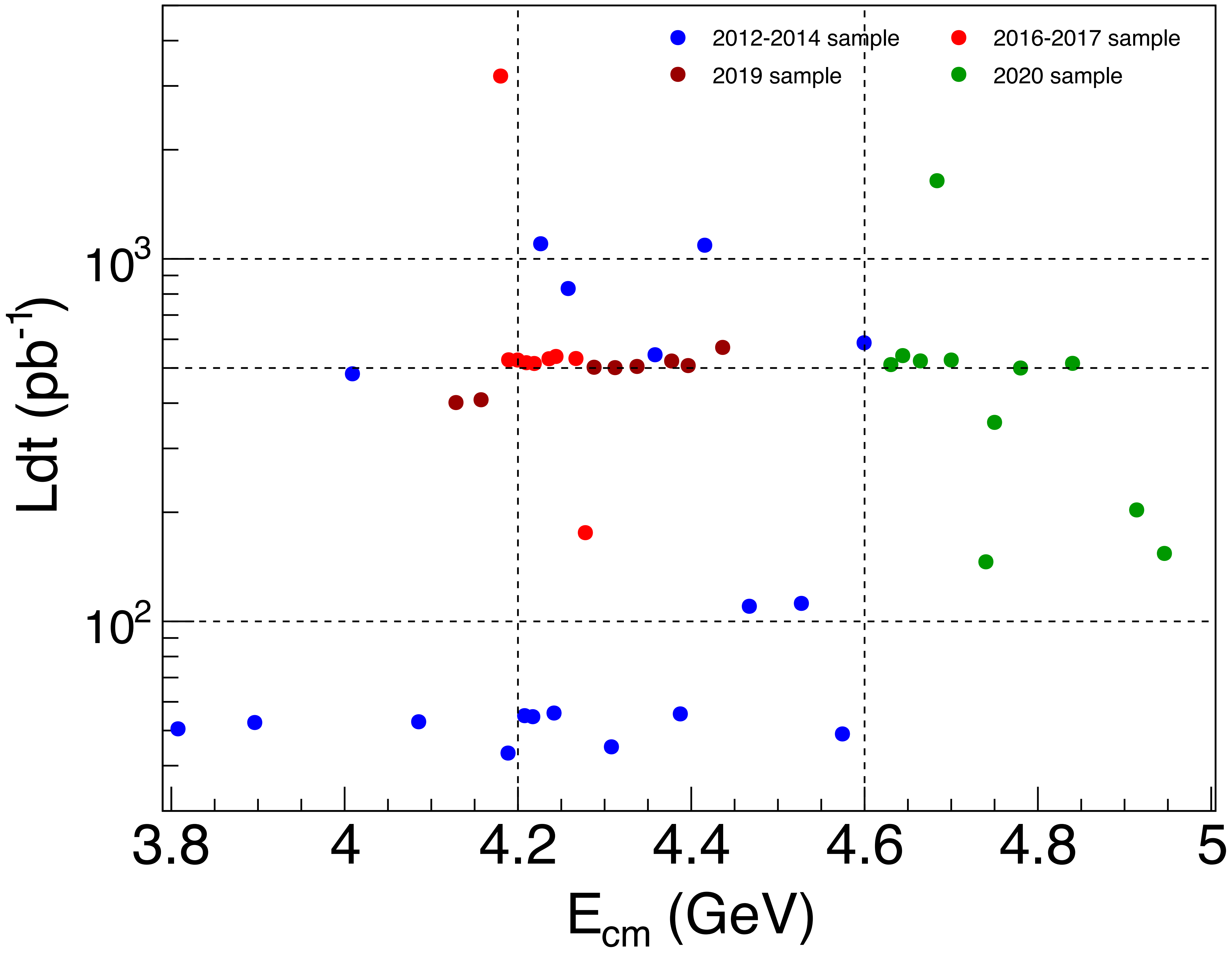
5.0%

σ_Z: 0.6 cm/$\sqrt{E}$

BESIII Data Samples

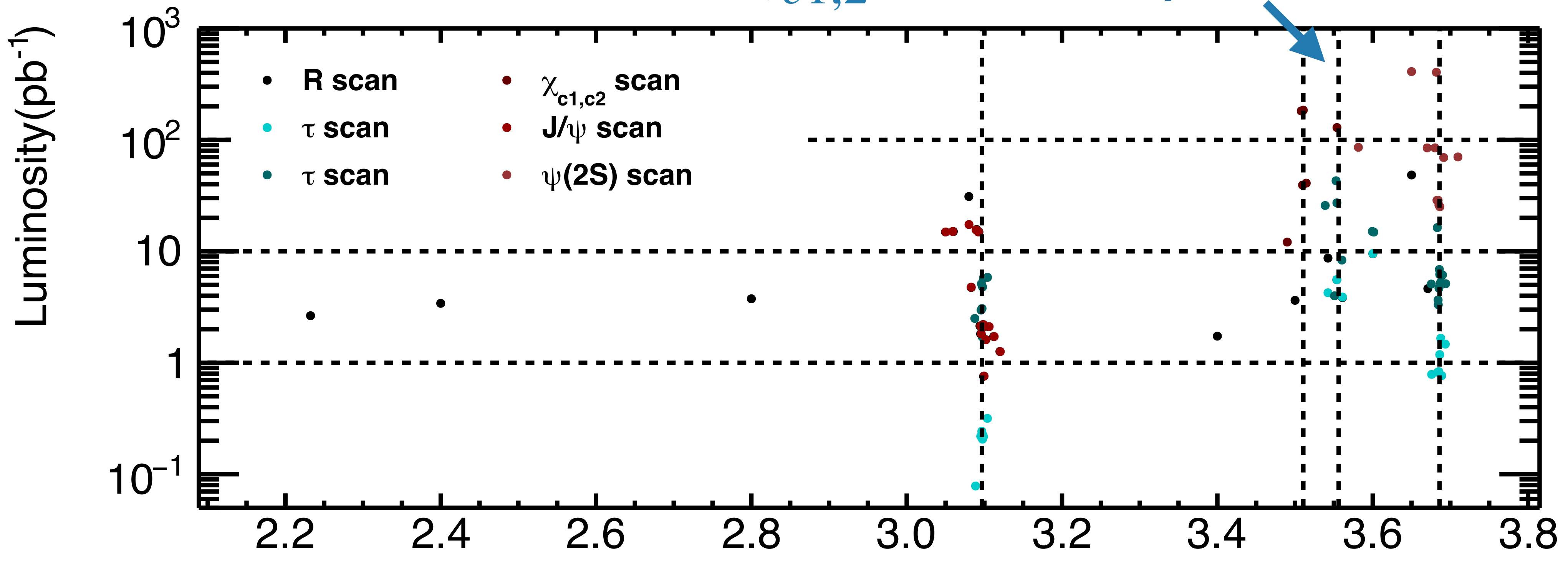


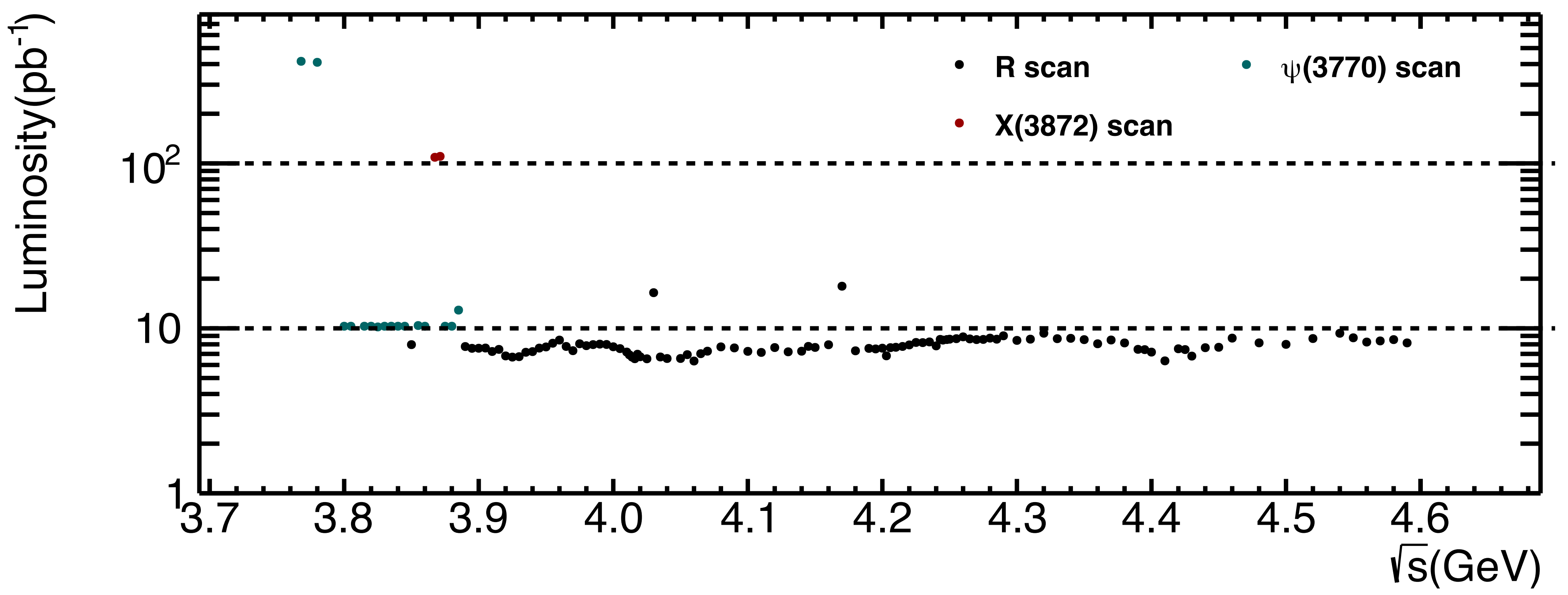
BESIII Data Samples



46 sample, ~22 fb^{-1}

$\chi_{c1,2}$ scan sample





+ Small scan sample, ~3.5 fb^{-1}

Can measure $\sigma[e^+e^- \to h_i]$ (CS) with high precision using direct e^+e^- annihilation data at BESIII

Charmonium Production at BESIII

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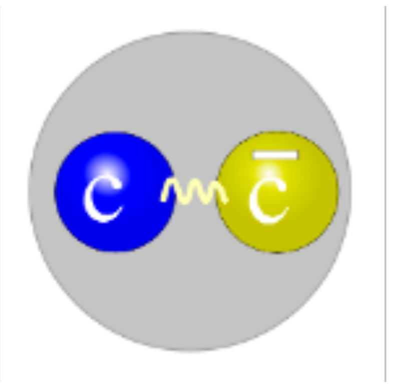
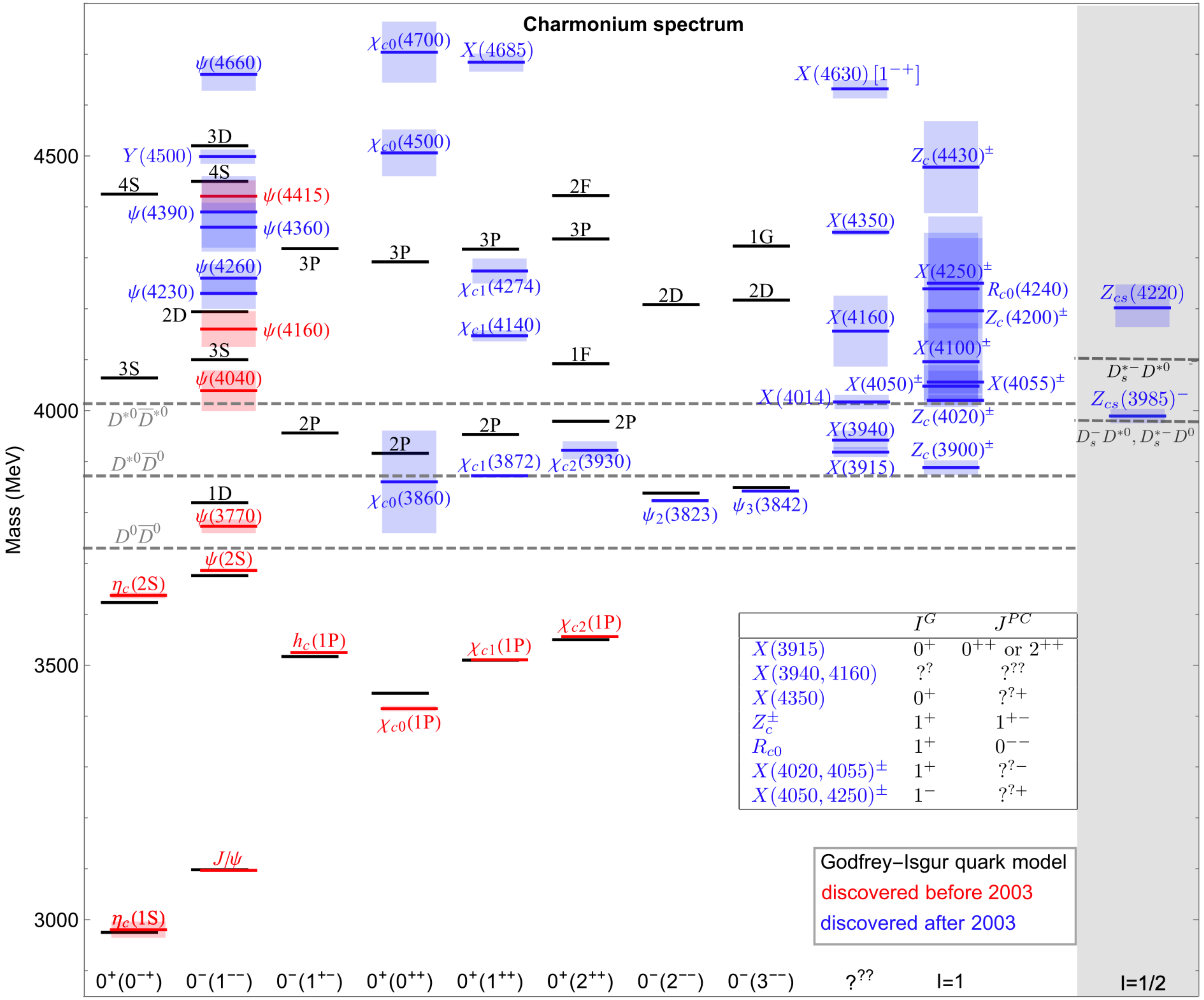
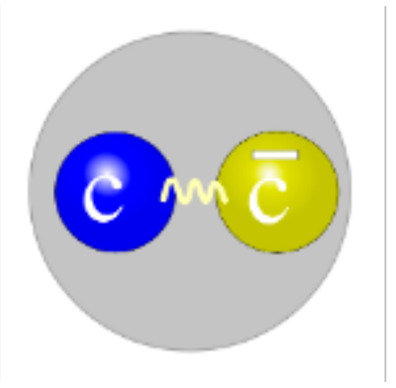


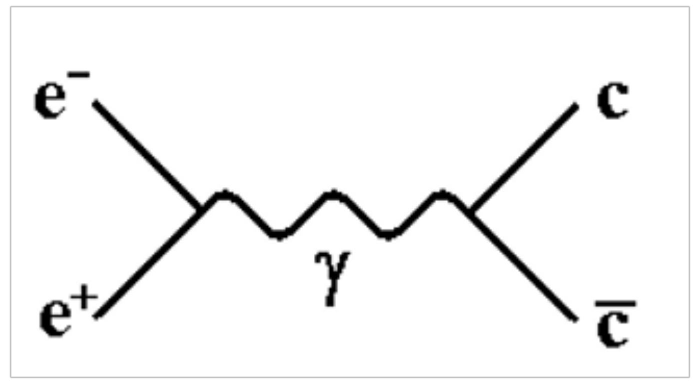


	I^G	J^{PC}
$X(3915)$	0^+	0^{++} or 2^{++}
$X(3940, 4160)$	$?^?$	$?^{??}$
$X(4350)$	0^+	$?^{?+}$
$Z_c^\pm$	1^+	1^{+-}
R_{c0}	1^+	0^{--}
$X(4020, 4055)^\pm$	1^+	$?^{?-}$
$X(4050, 4250)^\pm$	1^-	$?^{?+}$

from F. K. Guo

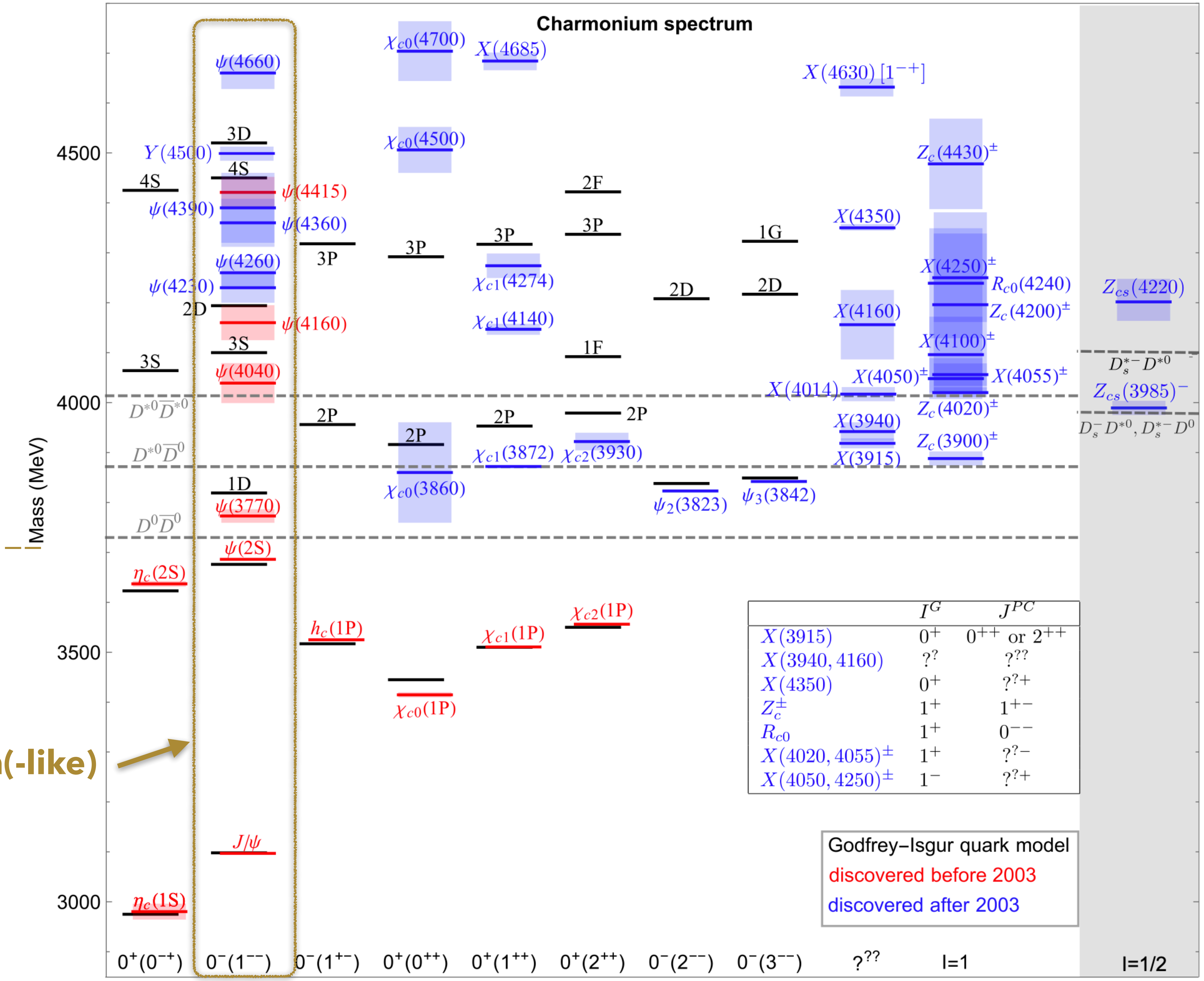
Charmonium Production at BESIII





$J^{PC} = 1^{--}$

Vector Charmonium(-like)



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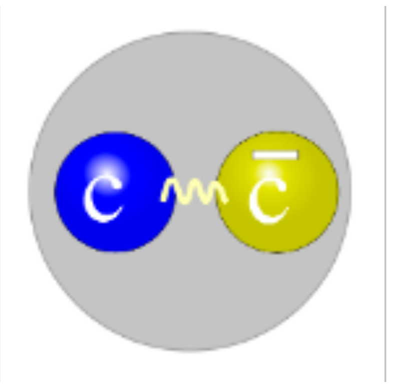
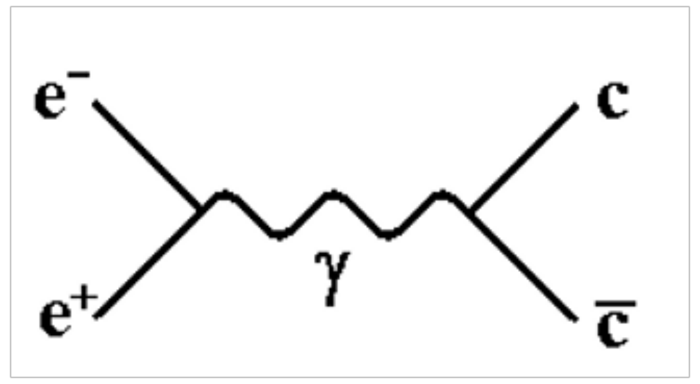
Charmonium Production at BESIII





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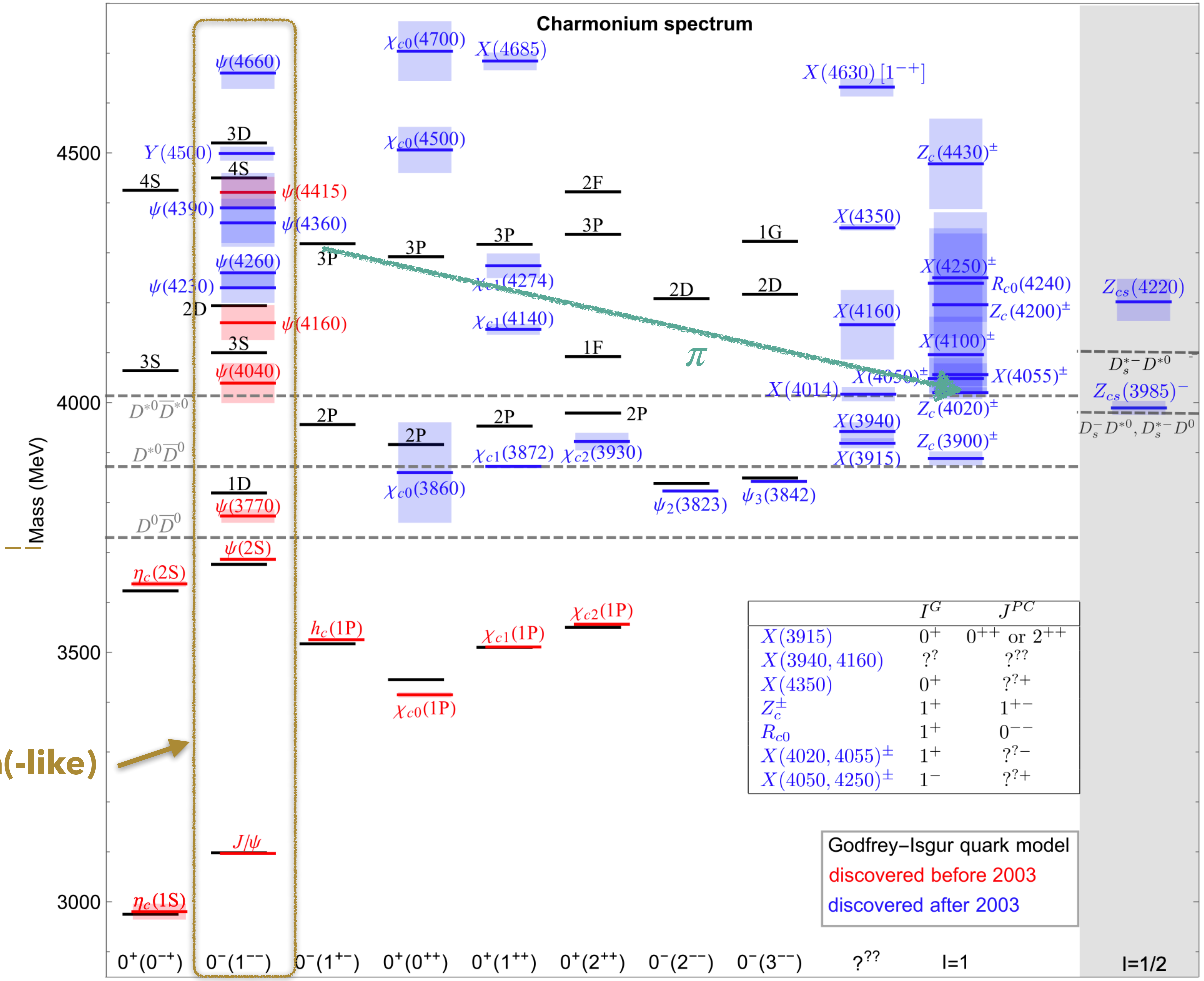

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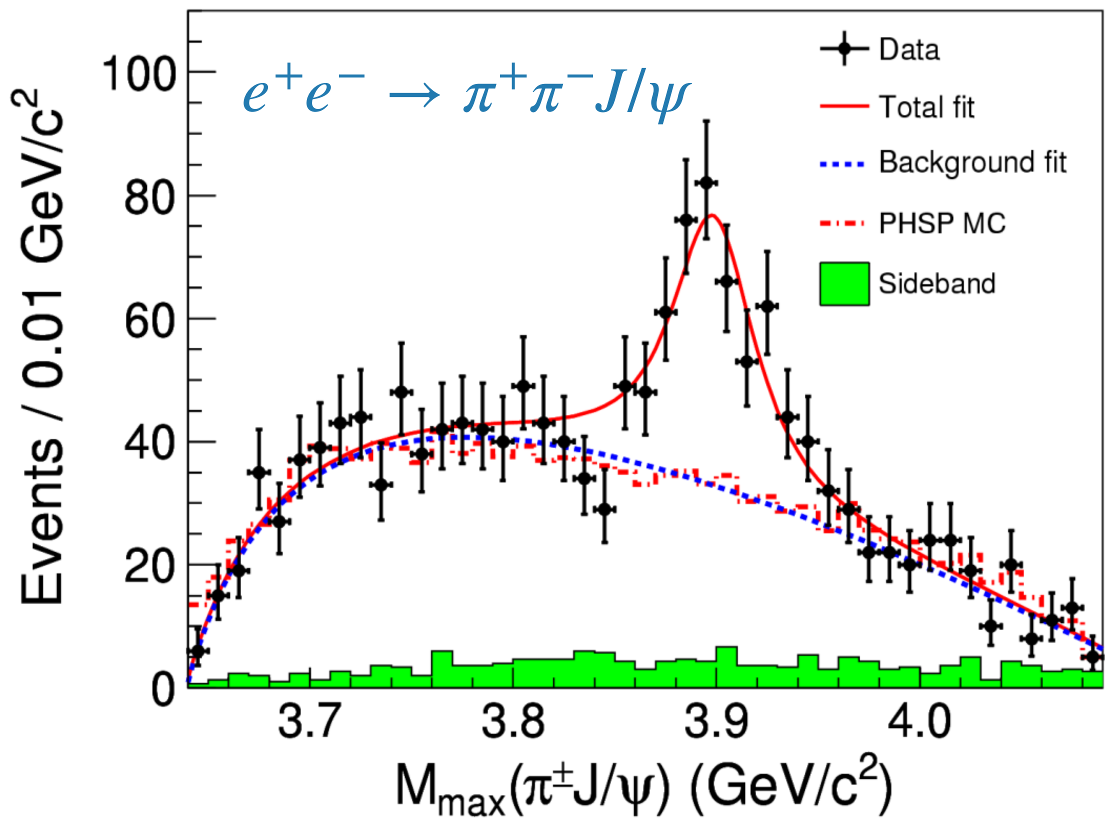
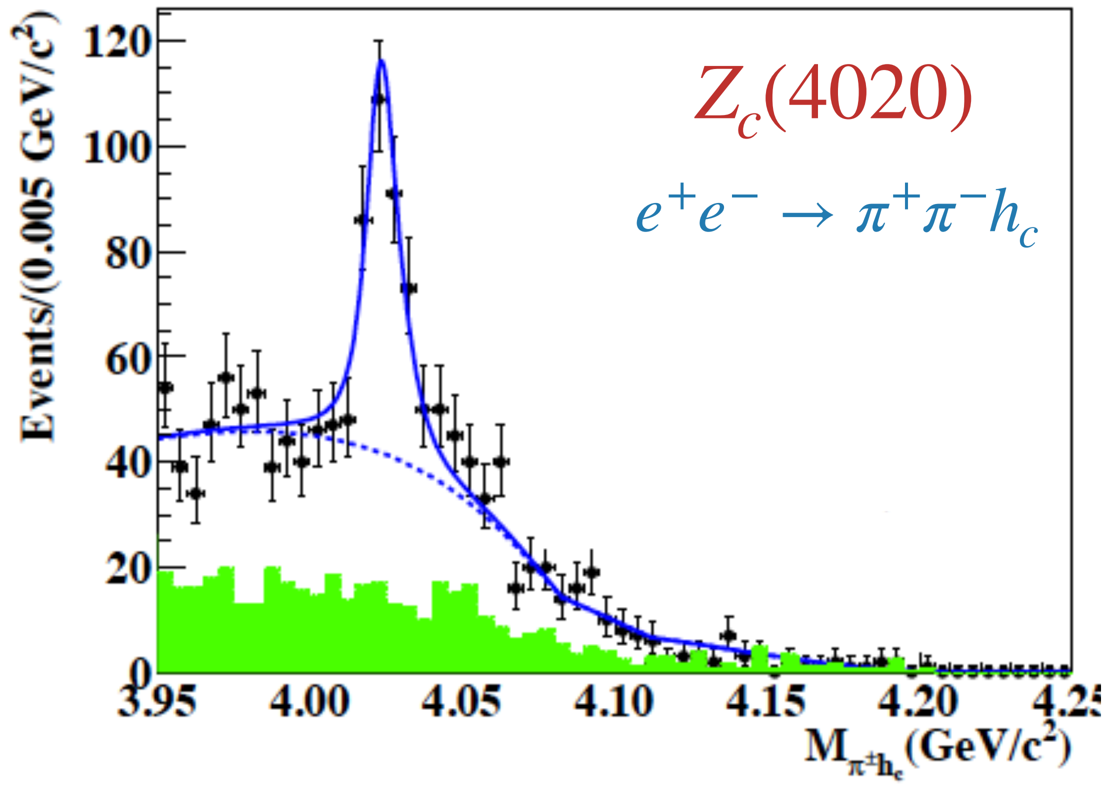
from F.K. Guo

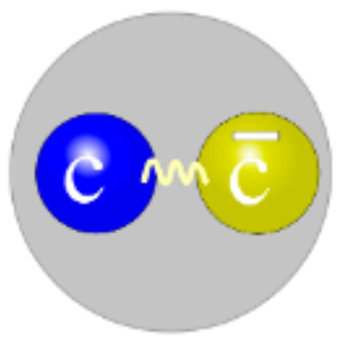
$Z_c(3900)/Z_c(3885)$

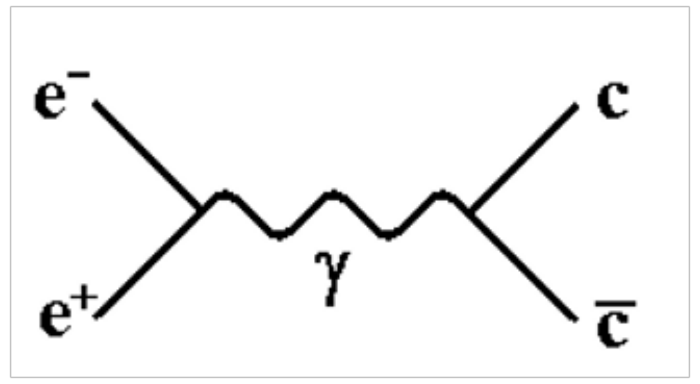




PRL110, 252001 (2013)
PRL111, 242001 (2013)

Charmonium Production at BESIII





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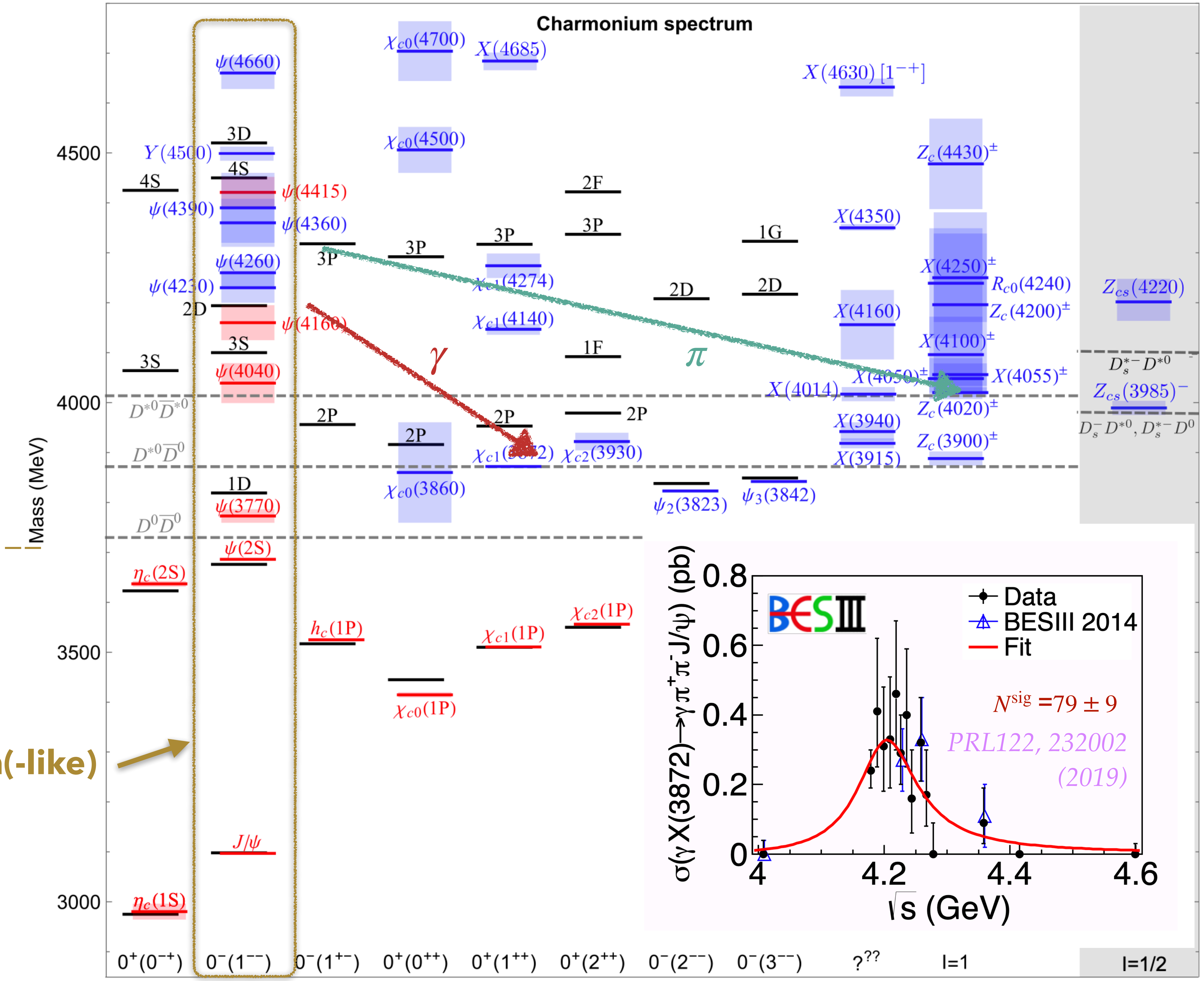

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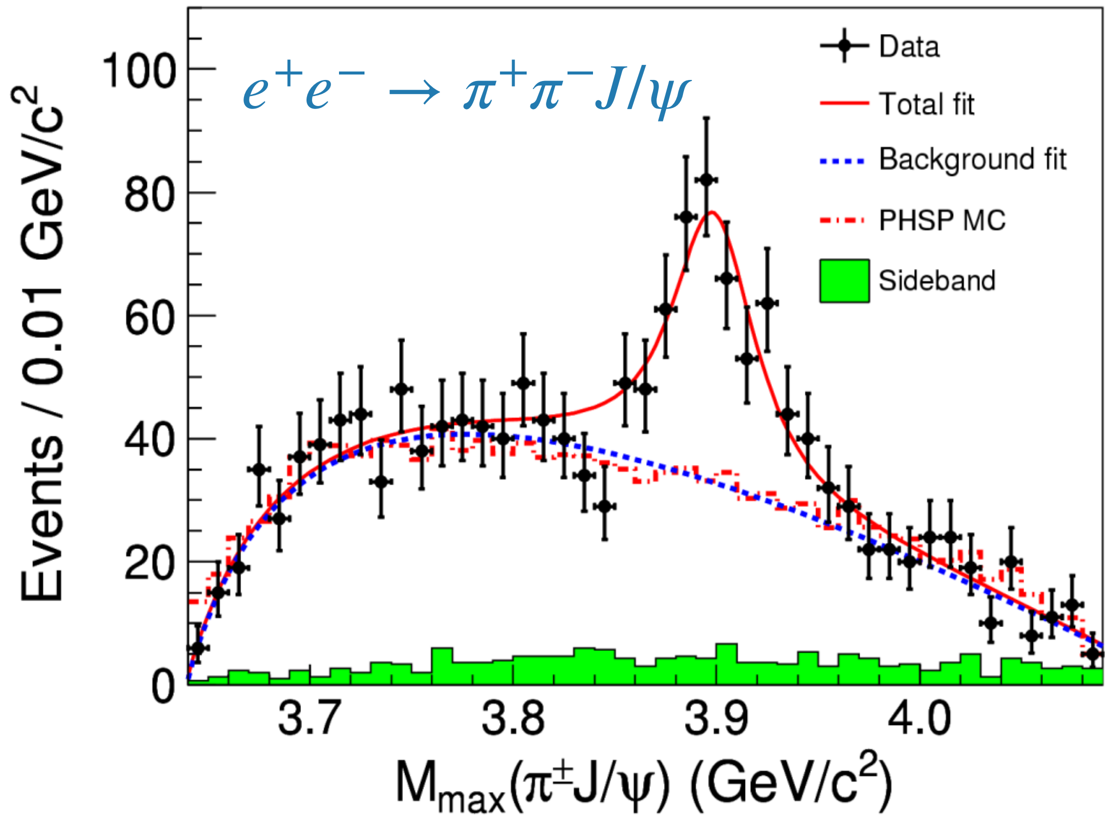

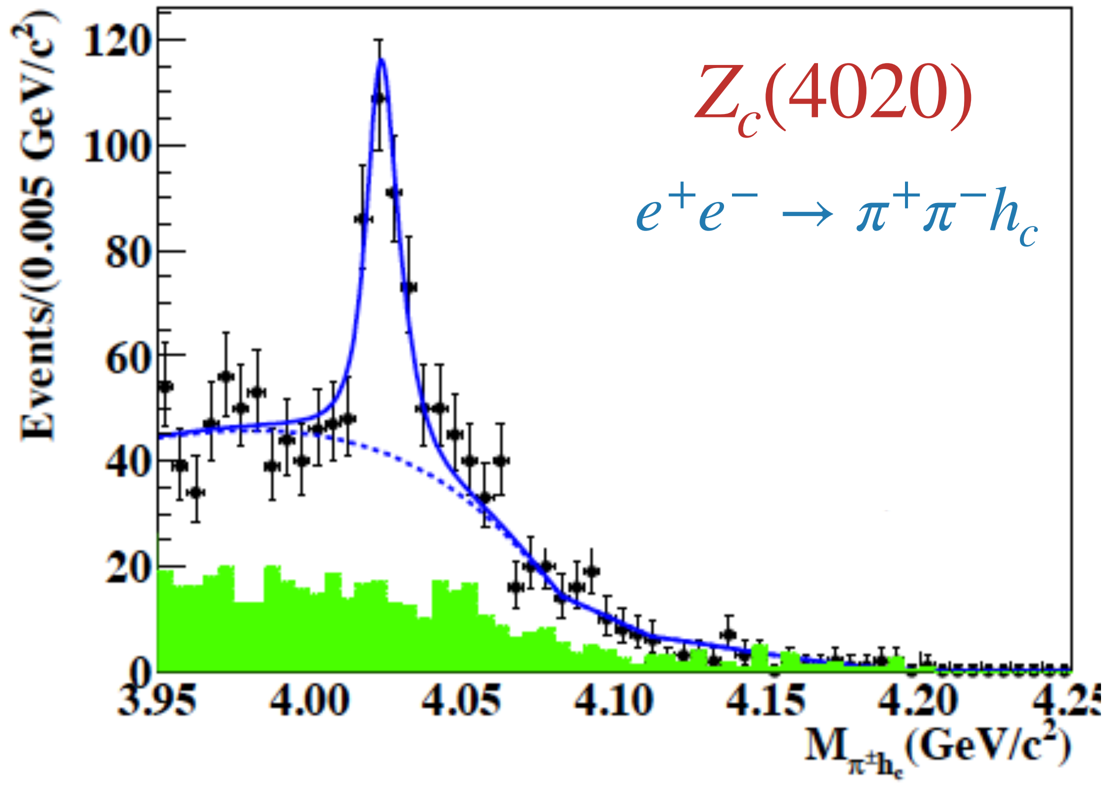

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PRL110, 252001 (2013)
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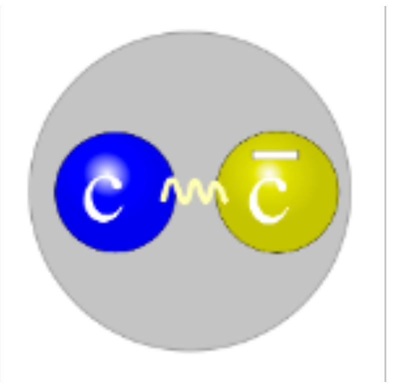

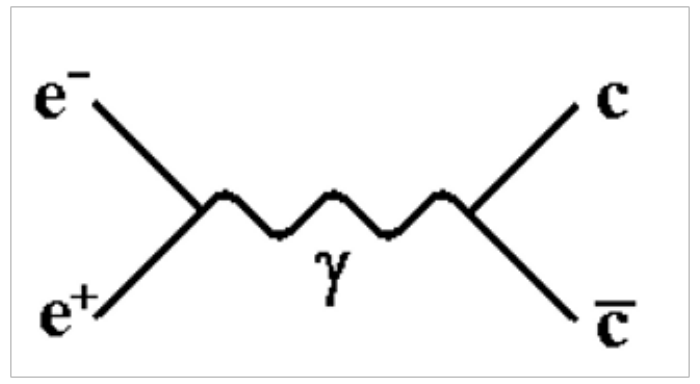

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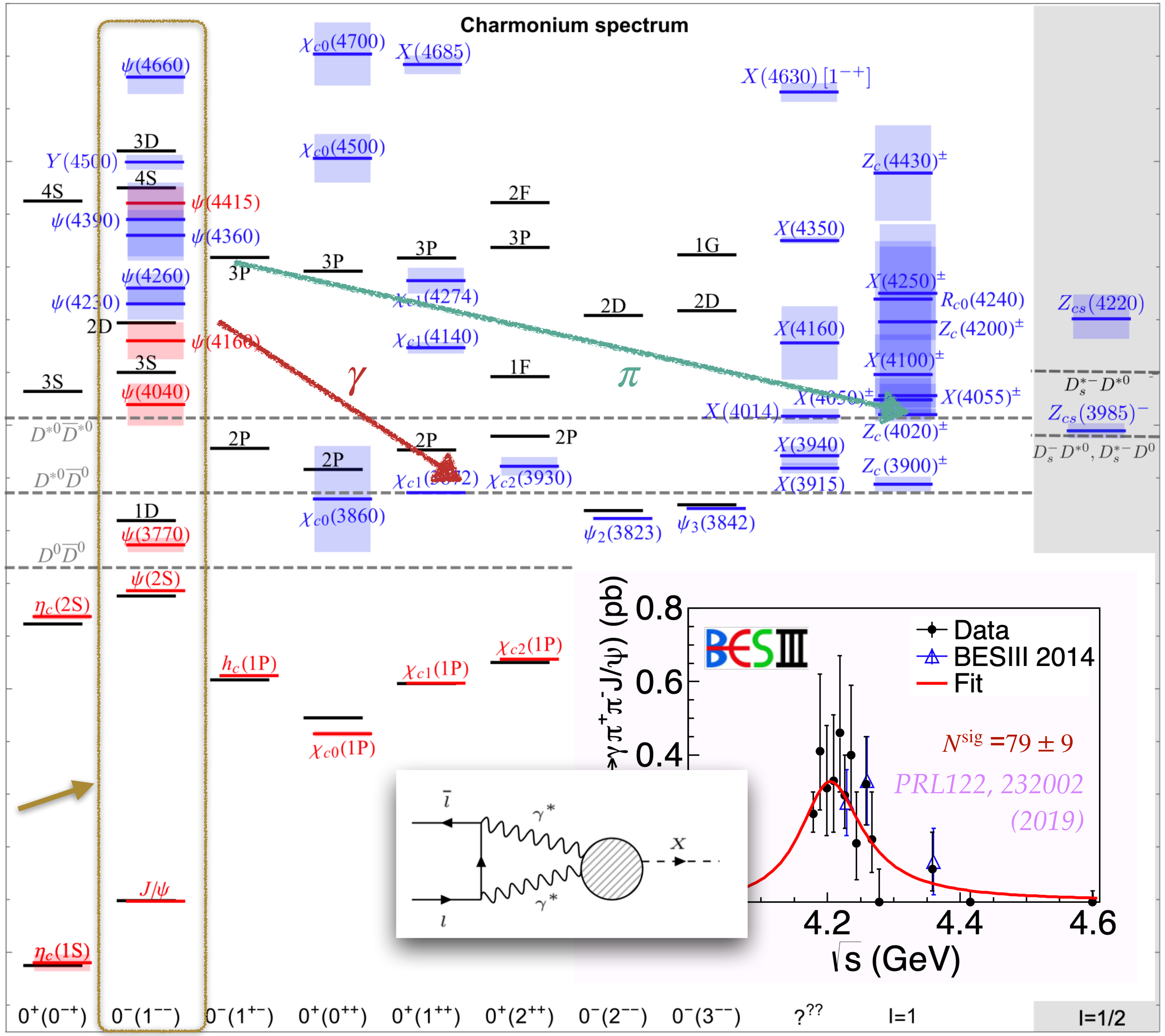

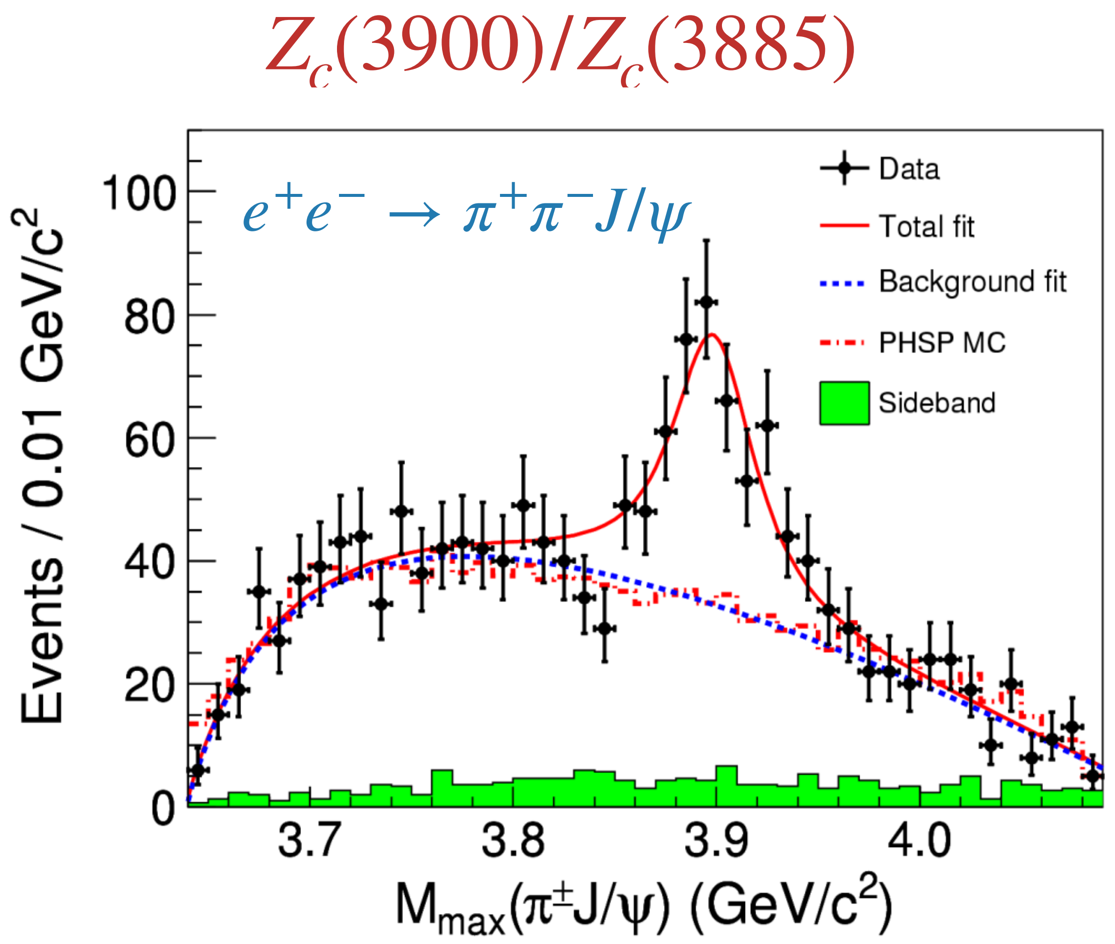

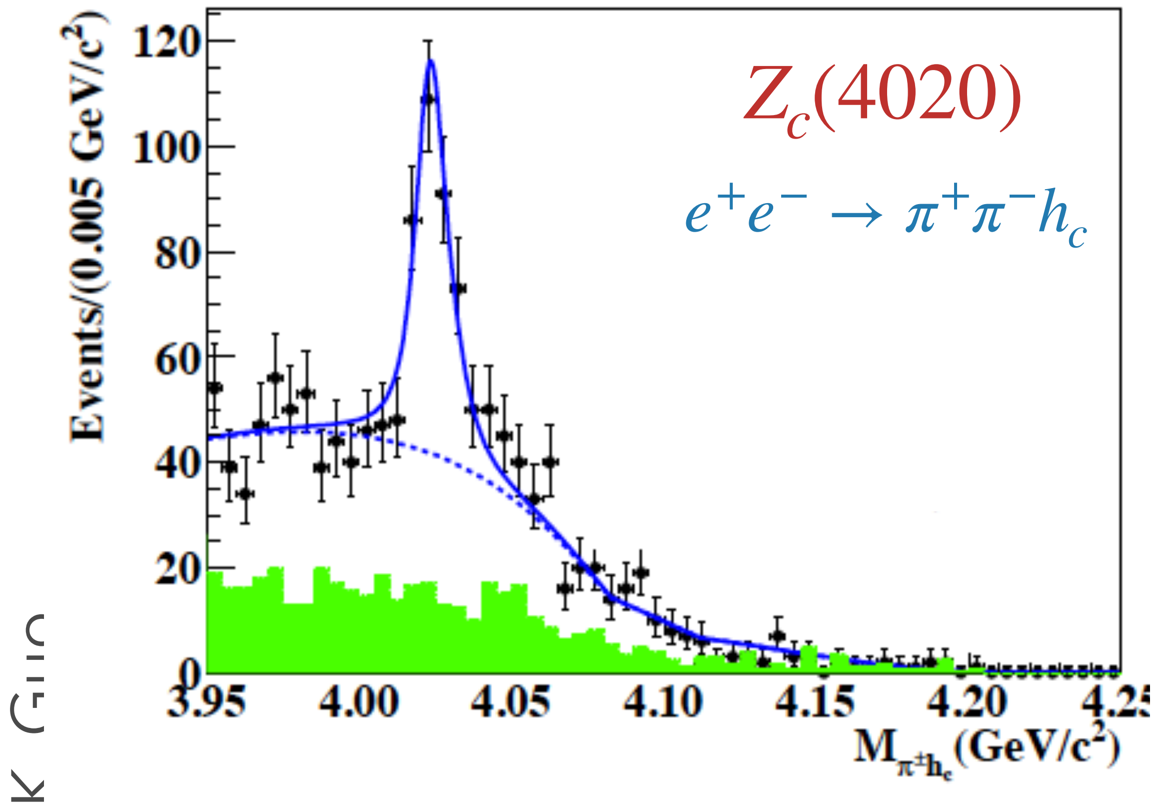

PRL110, 252001 (2013)
PRL111, 242001 (2013)

Objectives

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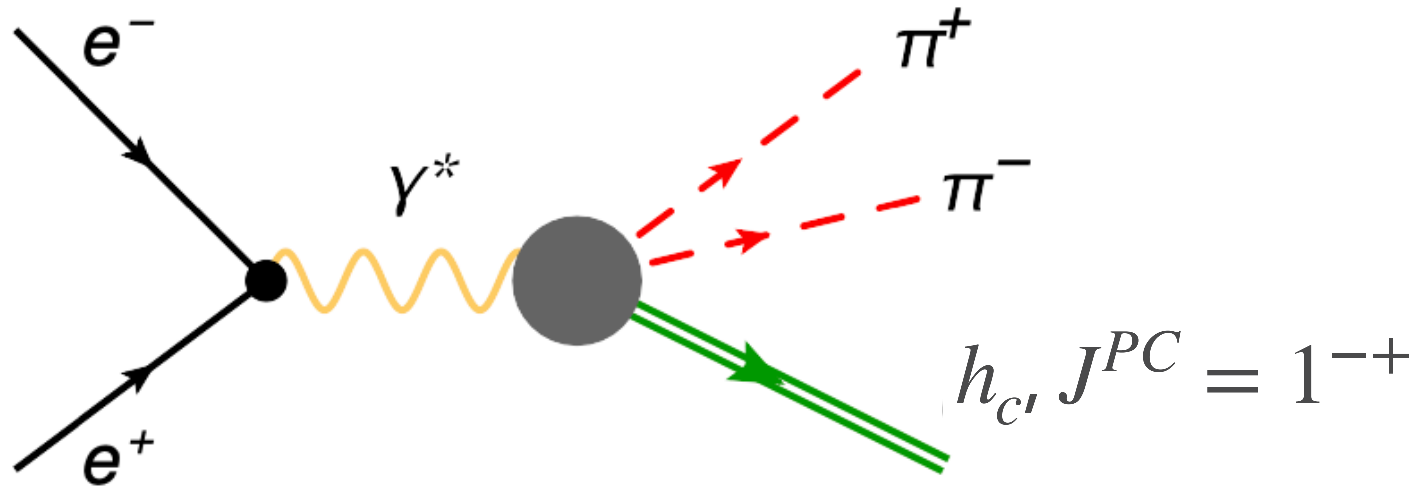
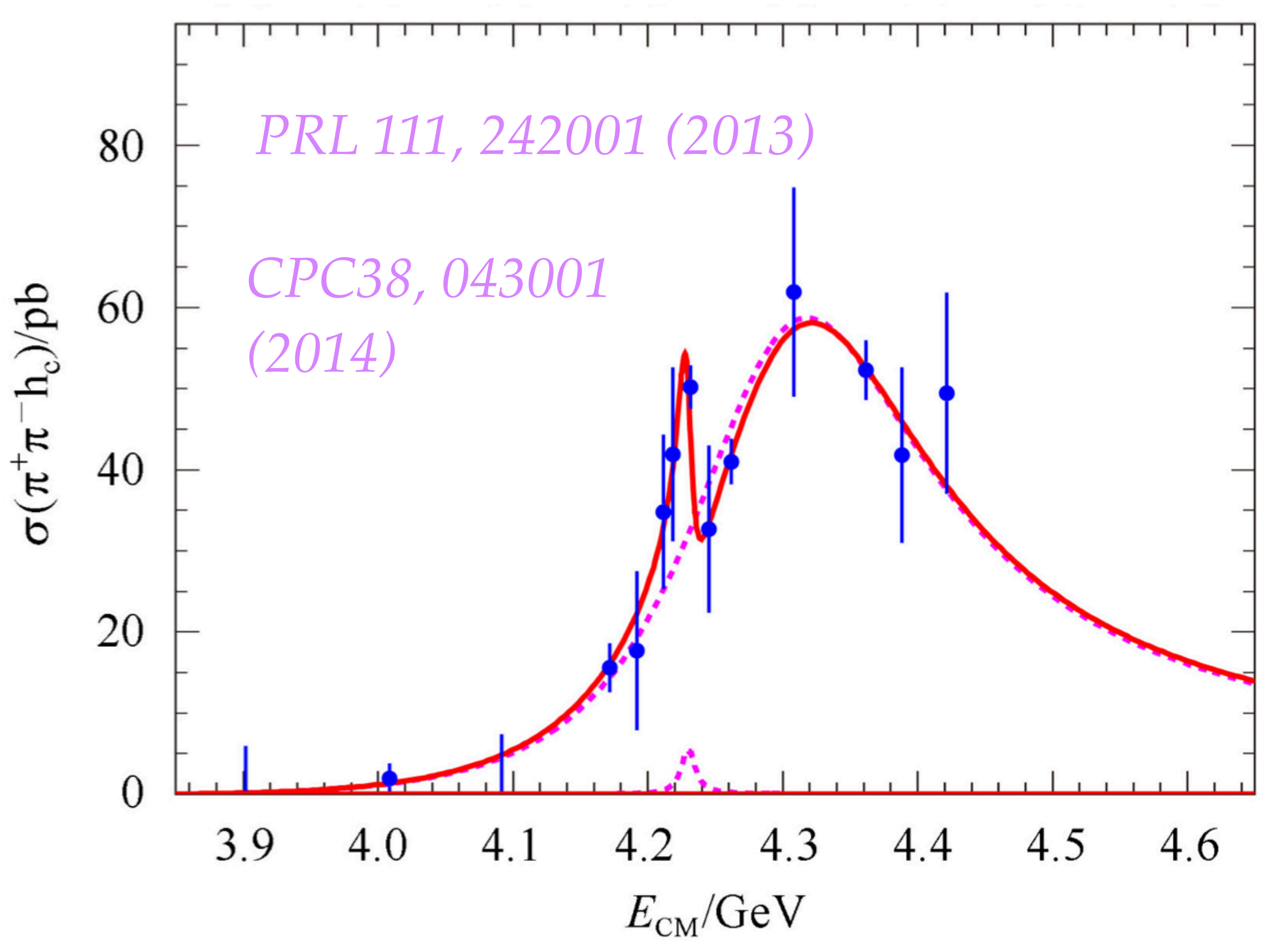


Analysis of New Data of $e^+e^- \to \pi^+\pi^-h_c$

- The $e^+e^- \to \pi^+\pi^-h_c$ process was observed by CLEO at $\sqrt{s}$=4.17 GeV $[10\sigma]$ *PRL107, 041803 (2011)*
- The process of $e^+e^- \to \pi^+\pi^-h_c$ was studied by BESIII at $\sqrt{s}$ from 3.9 to 4.42 GeV, a charged charmonium-like state, $Z_c(4020)$ was observed in the πh_c system *PRL 111, 242001 (2013)*
- The cross section of $e^+e^- \to \pi^+\pi^-h_c$ was measured by BESIII at $\sqrt{s}$ from 3.9 to 4.6 GeV, two resonant structures were observed *PRL118, 092002 (2017)*
- New data (27 data samples) between $\sqrt{s}$=4.18 to 4.95 GeV has been collected by BESIII



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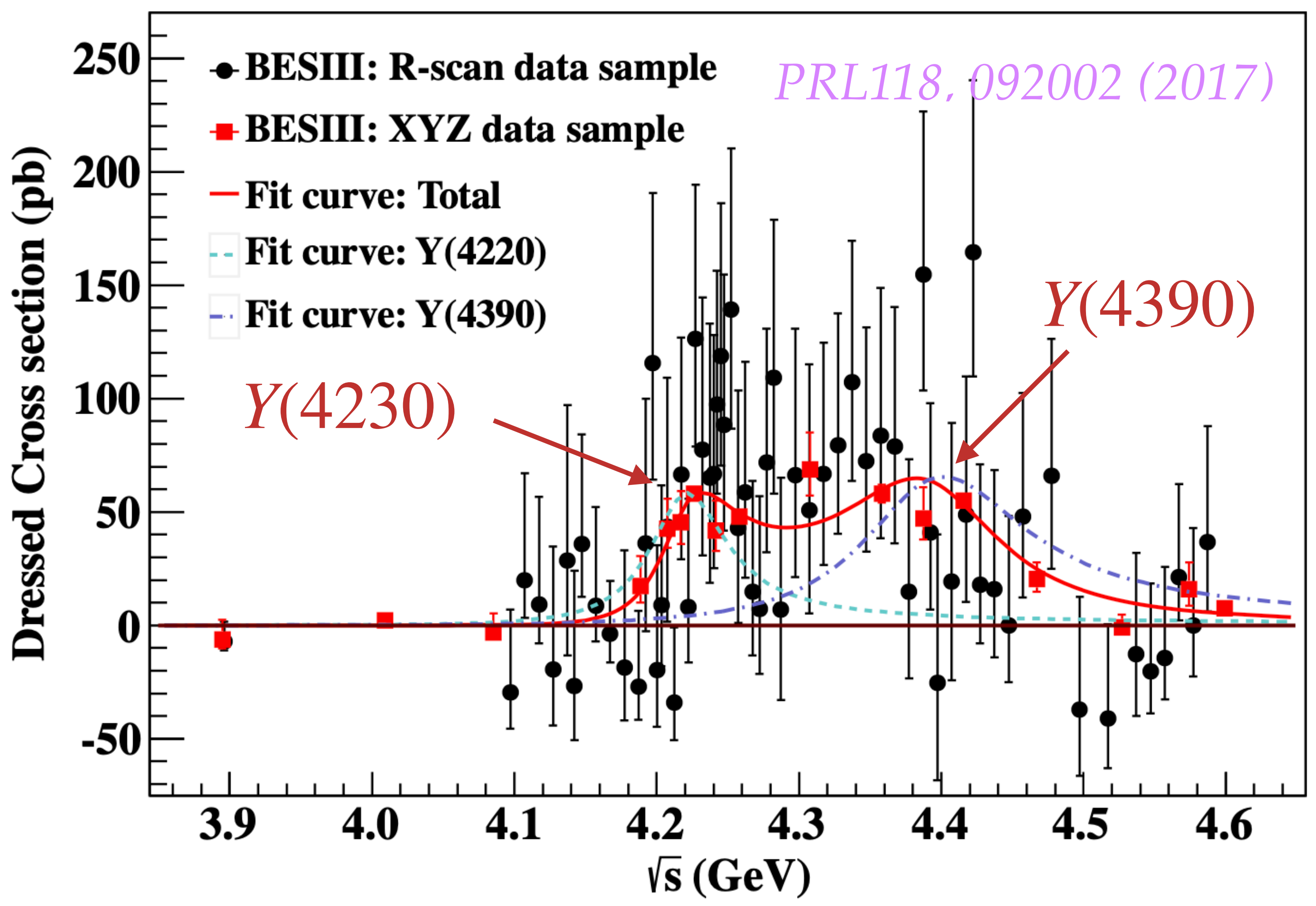

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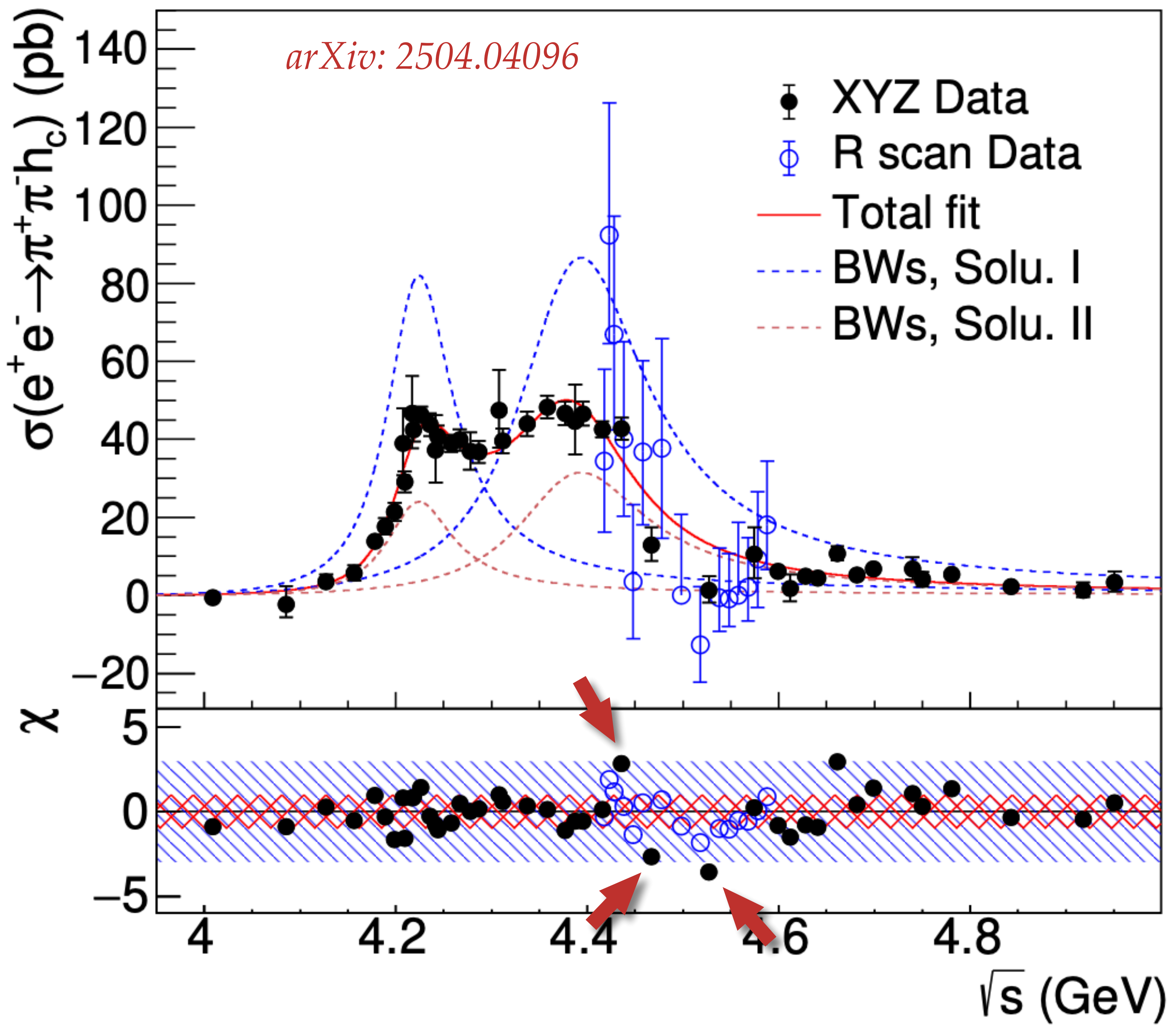
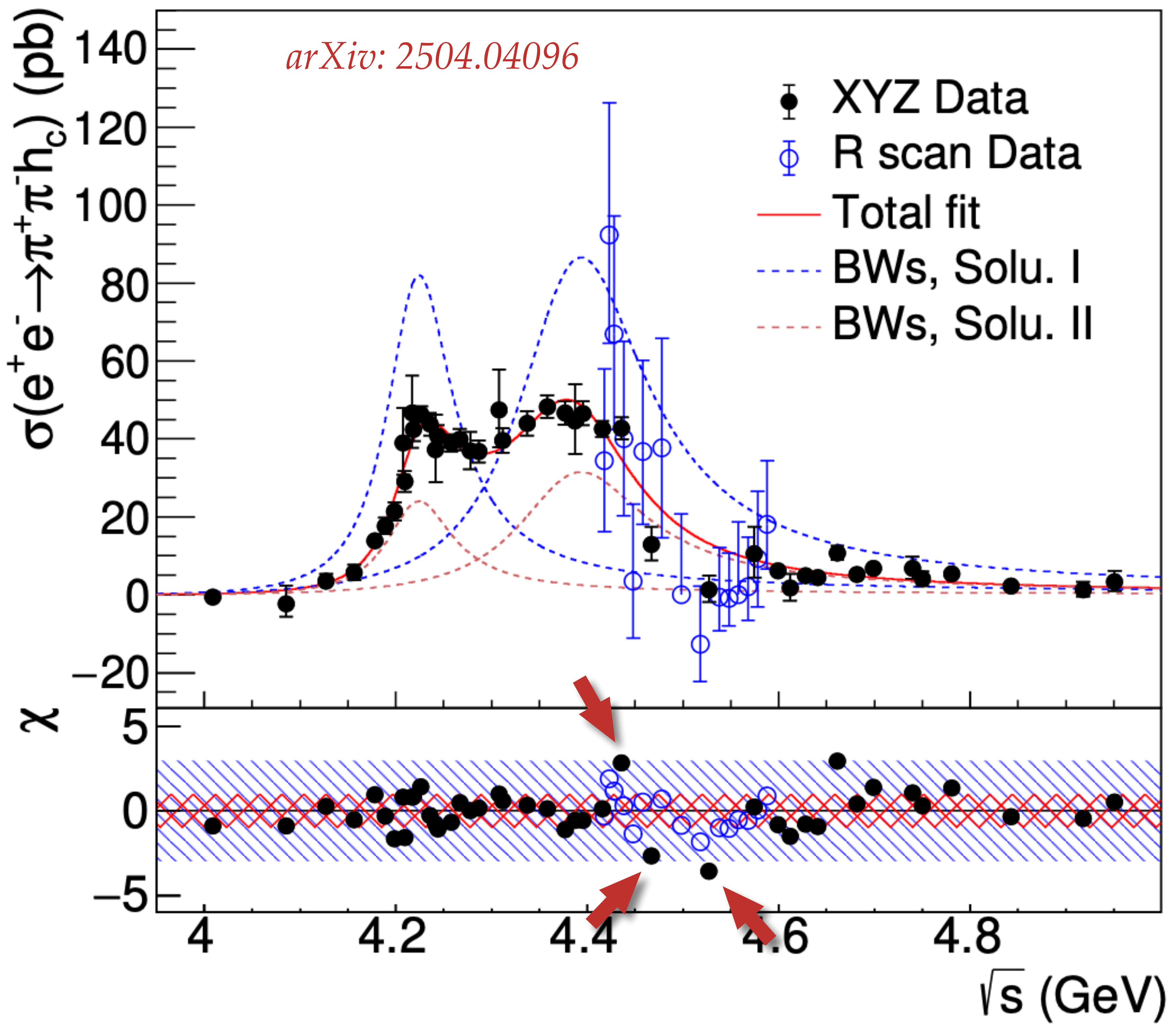
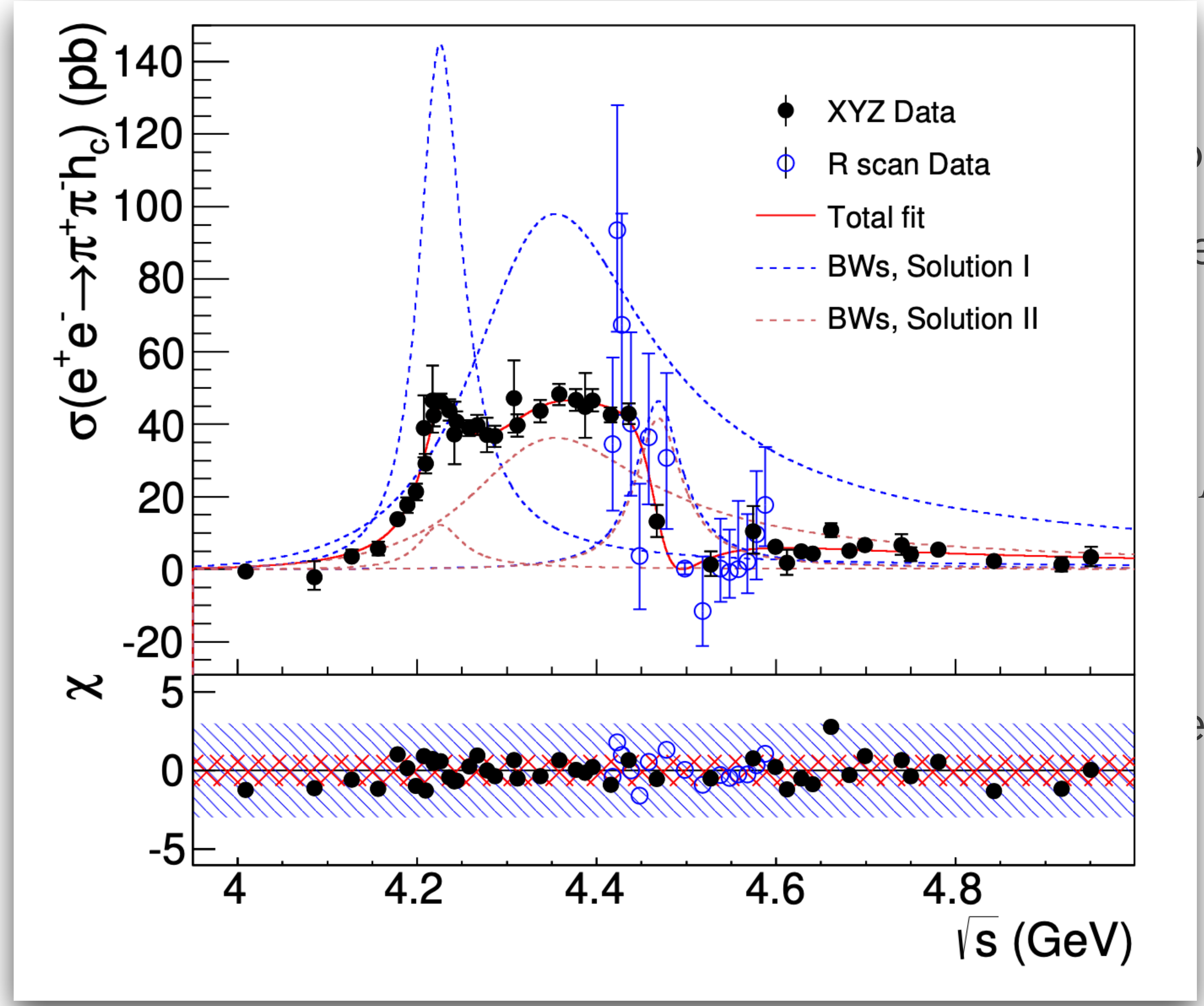
Analysis of New Data of $e^+e^- \to \pi^+\pi^- h_c$



- Test of resonance structures:
  - Starting with two coherent BWs, add one more BW, two more BWs, one more BW and a continuum term
  - Check significance of each addtional term
  - Baseline model: $\sigma^{\mathrm{dressed}} = |BW_1 + BW_2 e^{i\phi_2} + BW_3 e^{i\phi_3}|^2$
  - Significance of the third resonance: 5.4σ
  - Significance of addtional contribution smaller than 1σ

Analysis of New Data of $e^+e^- \to \pi^+\pi^- h_c$





ore BW, two

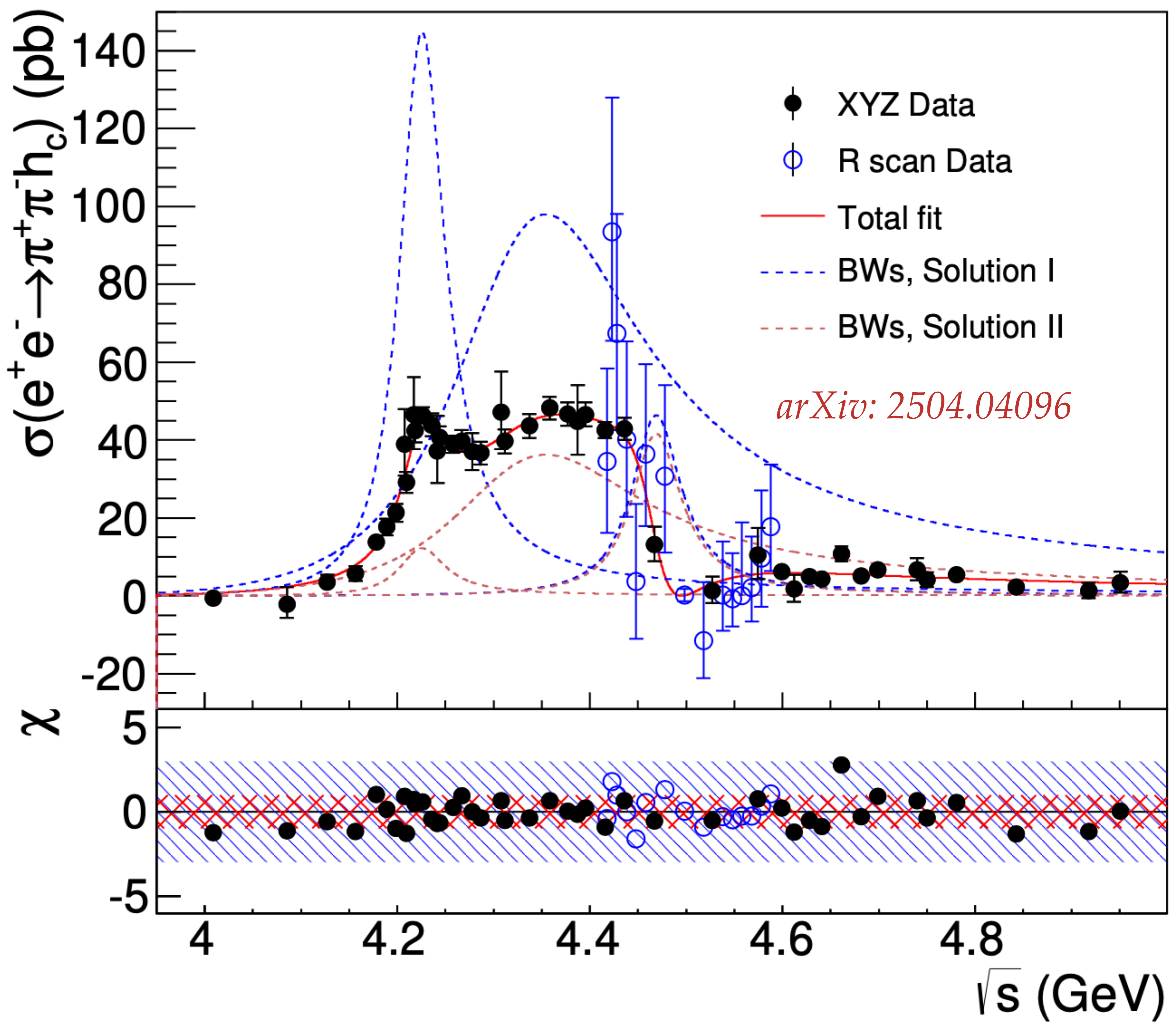
erm

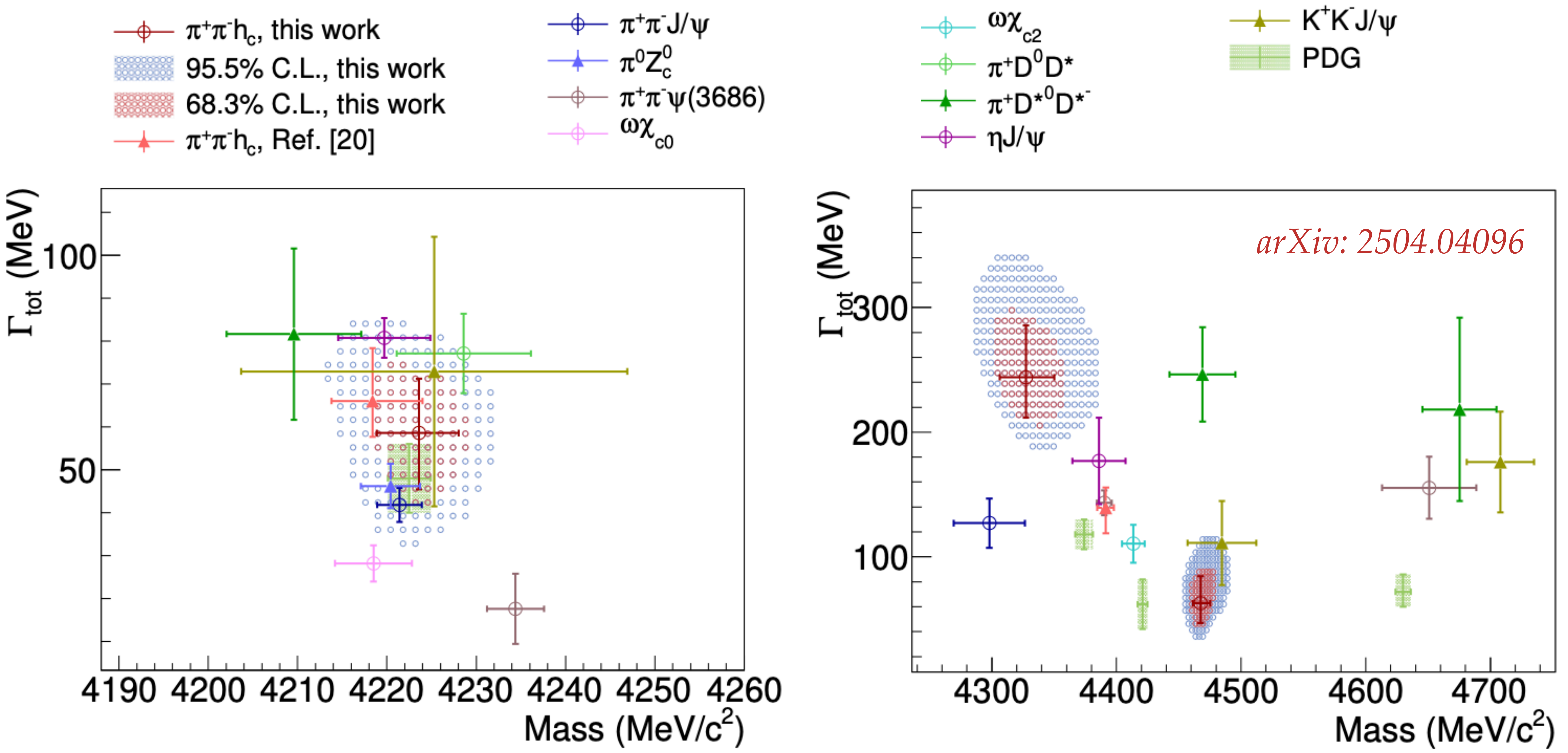
$BW_3 e^{i\phi_3}|^2$

er than 1σ

The cross section betweem 4.3 and 4.45 GeV exhibits a plateau-like shape and drops sharply around 4.5 GeV

Analysis of New Data of $e^+e^- \to \pi^+\pi^- h_c$

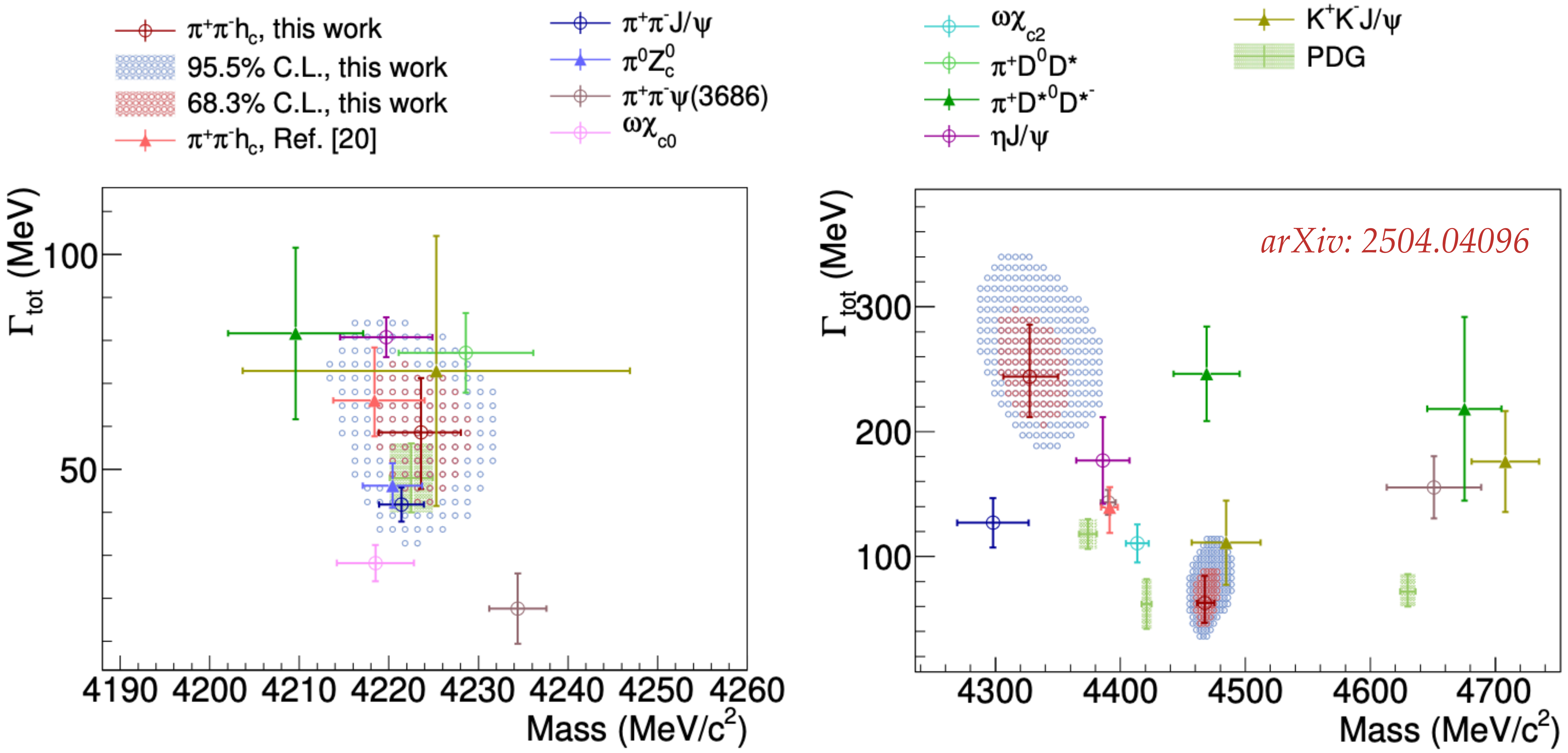




Resonance	Parameter	this measurement (3BW)	this measurement (2BW)	previous measurement
R_1	M (MeV/c^2)	$4223.6^{+3.6+2.6}_{-3.7-2.9}$	4219.7 ± 3.4	$4218.4 \pm 4.0 \pm 0.9$
	$\Gamma_{\rm tot}$ (MeV)	$58.5^{+10.8+6.7}_{-11.4-6.5}$	83.8 ± 5.5	$66.0 \pm 9.0 \pm 0.4$
R_2	M (MeV/c^2)	$4327.4^{+20.1+10.7}_{-18.8-9.3}$	4382.6 ± 6.0	$4391.6 \pm 6.3 \pm 1.0$
	$\Gamma_{\rm tot}$ (MeV)	$244.1^{+34.0+23.9}_{-27.1-18.0}$	163.1 ± 10.4	$139.5 \pm 16.1 \pm 0.6$
R_3	M (MeV/c^2)	$4467.4^{+7.2+3.2}_{-5.4-2.7}$	–	4421 ± 4
	$\Gamma_{\rm tot}$ (MeV)	$62.8^{+19.2+9.8}_{-14.4-6.6}$	–	62 ± 20 (from PDG)
	χ^2/ndf	41.9/70	78.5/66	–

Analysis of New Data of $e^+e^- \to \pi^+\pi^- h_c$

- Parameters of R_1 consistent with previous measurement and $\psi(4230)$
- Mass of R_2 consistent with $\psi(4360)$, but width much broader
- Parameters of R_3 consistent with $\psi(4500)$, and a hybrid state *PRD107, 054034 (2023)*
- No obvious resonance structure is found at around $\psi(4660)$
- In $S-D$ mixing scheme, $4S-3D$, $5S-4D$ states are located in this mass region, only three stuctures are observed in this mode *PRD99, 114003 (2019)*
- Mass of R_2/R_3 compatible with $\psi(3D)$ *PRD100, 074016 (2019)*



Resonance	Parameter	this measurement (3BW)	this measurement (2BW)	previous measurement
R_1	M (MeV/c^2)	$4223.6^{+3.6+2.6}_{-3.7-2.9}$	4219.7 ± 3.4	$4218.4 \pm 4.0 \pm 0.9$
	$\Gamma_{\rm tot}$ (MeV)	$58.5^{+10.8+6.7}_{-11.4-6.5}$	83.8 ± 5.5	$66.0 \pm 9.0 \pm 0.4$
R_2	M (MeV/c^2)	$4327.4^{+20.1+10.7}_{-18.8-9.3}$	4382.6 ± 6.0	$4391.6 \pm 6.3 \pm 1.0$
	$\Gamma_{\rm tot}$ (MeV)	$244.1^{+34.0+23.9}_{-27.1-18.0}$	163.1 ± 10.4	$139.5 \pm 16.1 \pm 0.6$
R_3	M (MeV/c^2)	$4467.4^{+7.2+3.2}_{-5.4-2.7}$	–	4421 ± 4
	$\Gamma_{\rm tot}$ (MeV)	$62.8^{+19.2+9.8}_{-14.4-6.6}$	–	62 ± 20 (from PDG)
	χ^2/ndf	41.9/70	78.5/66	–

Objectives

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- 1. A study of XYZ charmonium-like states using a dispersive formlism
  - Analysis of the new data of $e^+e^- \to \pi\pi h_c$ at BESIII
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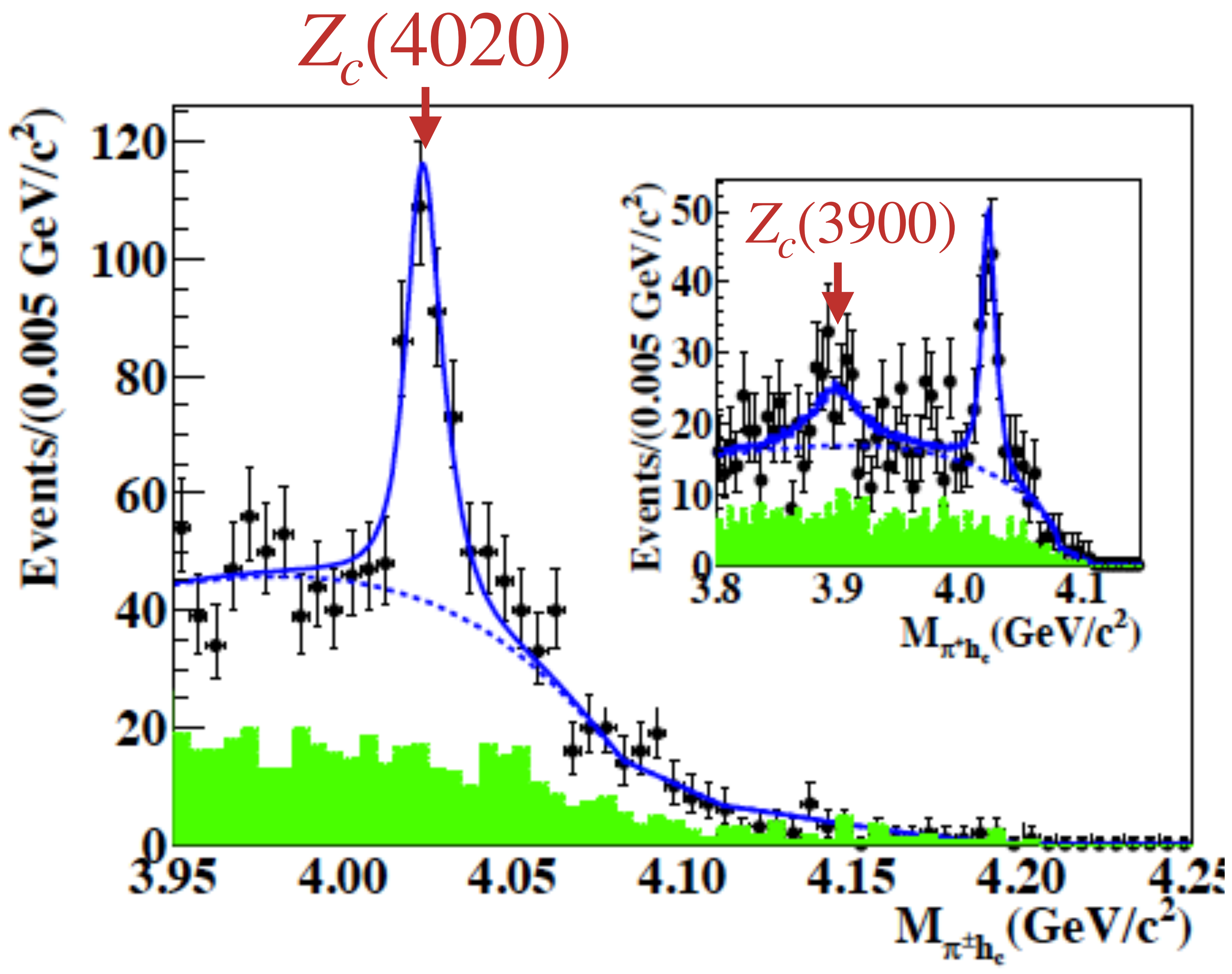
PWA of $e^+e^- \to \pi^+\pi^- h_c$

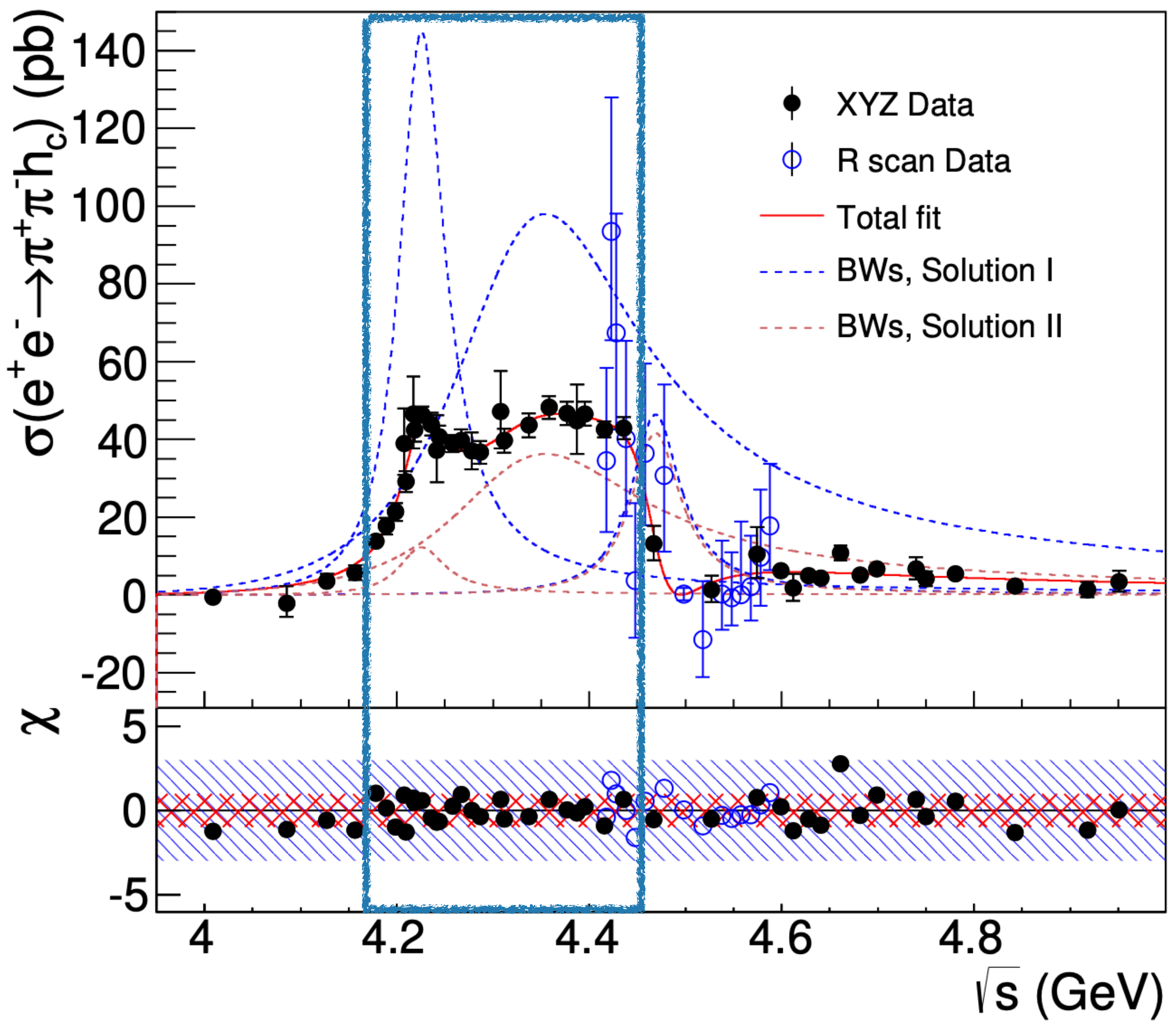
- In 2013, $Z_c(4020)$ was observed in $e^+e^- \to \pi Z_c(4020)(\to \pi h_c)$ process *PRL 111, 242001 (2013)*
- A search for $Z_c(3900)$ in the same decay channel showed a statistical significance of 2.1σ
- Three data samples: 4230, 4260, 4360, with a integrated luminosity of 2.46 fb^{-1}



- Mass and width of $Z_c(4020)$ determined from fit to $M(\pi h_c)$
  - M= 4022.9±0.8±2.7 MeV/c^2
  - Γ=7.9±2.7±2.6 MeV
- Quantum number of $Z_c(4020)$ not determined

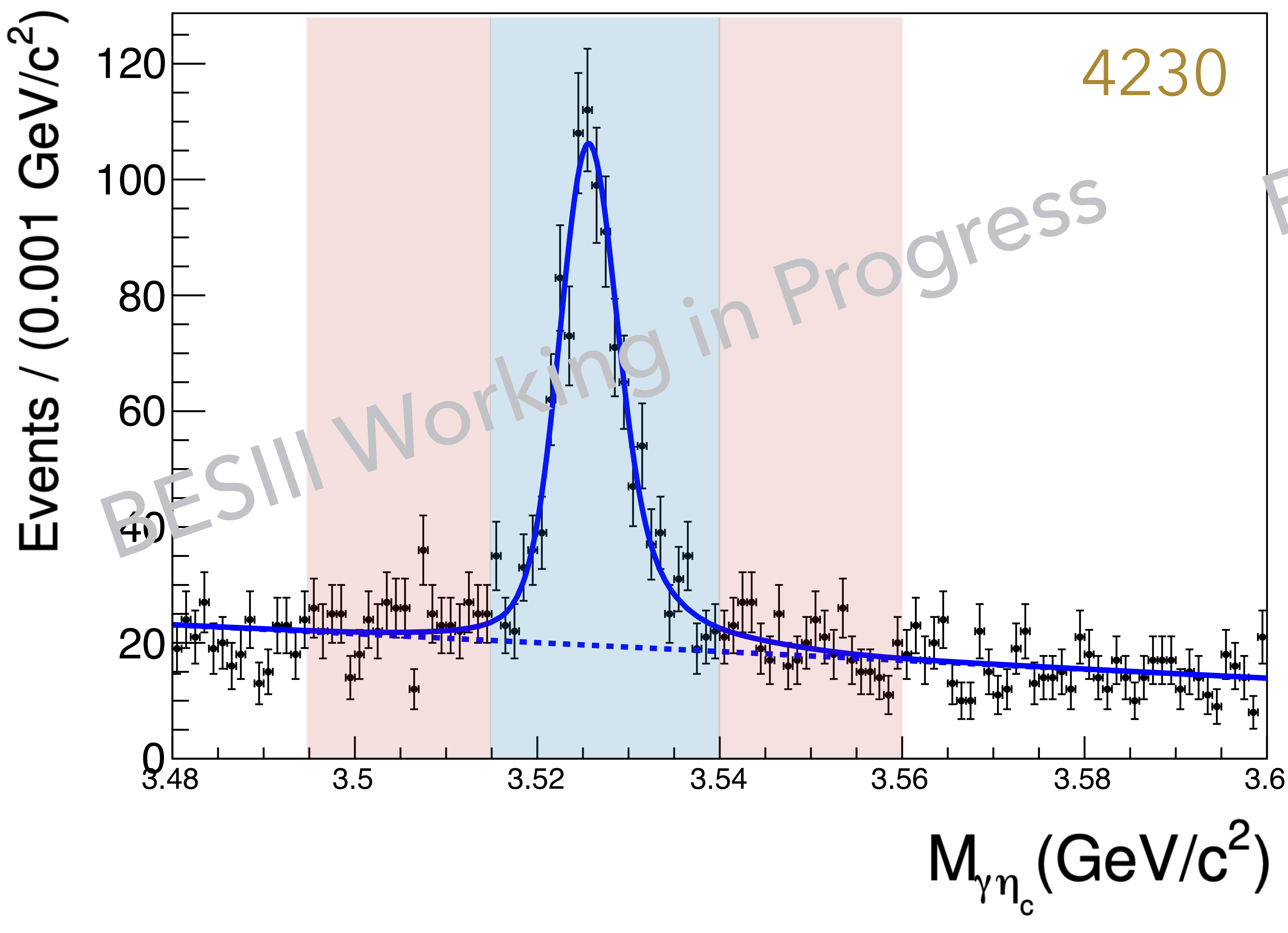
Data Samples for PWA

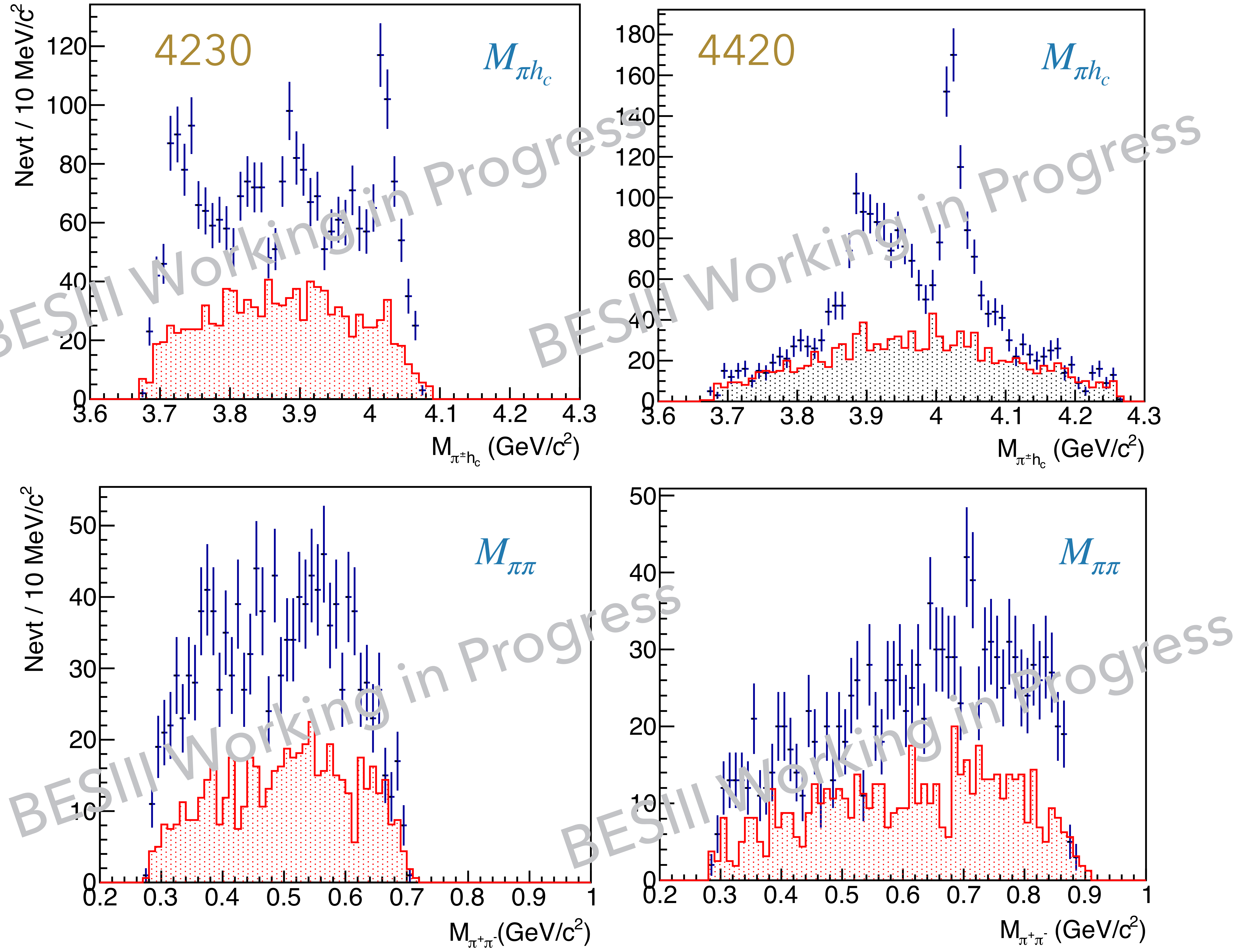
data point	$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})	N_{h_c}	σ^{dressed}
4180	4.178	3192	698 ± 41	13.8 ± 0.8 ± 0.8 ± 1.3
4190	4.189	570	158 ± 19	17.7 ± 2.1 ± 1.6 ± 1.7
4200	4.199	526	178 ± 19	21.3 ± 2.3 ± 2.8 ± 2.1
4210	4.209	517	234 ± 21	29.1 ± 2.7 ± 1.6 ± 2.8
4220	4.219	515	342 ± 24	42.4 ± 2.9 ± 2.3 ± 4.1
4230	4.226	1101	847 ± 38	46.3 ± 2.1 ± 2.5 ± 4.5
4237	4.236	530	393 ± 26	43.8 ± 2.9 ± 2.4 ± 4.3
4246	4.244	538	377 ± 26	40.7 ± 2.8 ± 2.2 ± 3.9
4260	4.258	828	569 ± 32	38.9 ± 2.2 ± 2.1 ± 3.8
4270	4.267	531	370 ± 26	39.8 ± 2.8 ± 2.2 ± 3.9
4280	4.278	176	111 ± 14	37.0 ± 4.7 ± 2.0 ± 3.6
4290	4.287	502	302 ± 24	36.8 ± 2.9 ± 2.0 ± 3.6
4315	4.311	501	328 ± 26	39.6 ± 3.1 ± 2.2 ± 3.8
4340	4.337	505	381 ± 27	44.0 ± 3.1 ± 2.4 ± 4.3
4360	4.358	544	472 ± 28	48.3 ± 2.9 ± 2.7 ± 4.7
4380	4.377	523	424 ± 27	46.7 ± 3.0 ± 2.6 ± 4.5
4400	4.395	508	411 ± 27	46.6 ± 3.1 ± 2.6 ± 4.5
4420	4.416	1091	831 ± 41	42.6 ± 2.1 ± 2.3 ± 4.1
4440	4.436	570	434 ± 29	42.8 ± 2.8 ± 2.4 ± 4.1



- 19 data samples from 4.18 to 4.44 GeV
- Purity of the sample:~70%

$e^+e^- \to \pi^+\pi^-h_c$ Signal from Data





PWA Formalism

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- A maximum likelihood fit to data, the negative log-likelihood funtion (NLL) defined as

$$-\ln = \sum_{i\in \mathrm{sigRG}} \ln P(x_i) - w_{\mathrm{bkg}} \sum_{j\in \mathrm{sidRG}} \ln P(x_j),$$

$P(x_i)$ is the probability to produce event i with a set of four-vector momentum $x_i = (p_{\pi^+}, p_{\pi^-}, p_\gamma, p_{\eta_c})$

- $P(x_i) = \dfrac{P(x_i)}{\mu_{\mathrm{MC}}} = \dfrac{(d\sigma/d\Phi)_i}{\mu_{\mathrm{MC}}}$, where μ_{MC} is the normalization factor calculated using a PHSP MC sample

- The decay cross section $\dfrac{d\sigma}{d\Phi}$ is written in two set of formalism: covariant tensor formalism and helicity formalism

B. S. Zou and D. V. Bugg, EPJA 16, 537-547 (2003)

PRD48, 1225(1993), PRD57, 431(1998)

PWA Formalism

- The decay cross section $\dfrac{d\sigma}{d\Phi}$:

  - $$\frac{d\sigma}{d\Phi} = \sum_{m_{\gamma^*},m_\gamma} \boxed{\psi_\mu(m_{\gamma^*})}\,\boxed{\gamma_{\mu''}(m_\gamma)}\,\boxed{A_{\mu\mu''}}\,\psi^*_\nu(m_{\gamma^*})\ \gamma^*_{\nu''}(m_\gamma)\ A^*_{\nu\nu''}$$

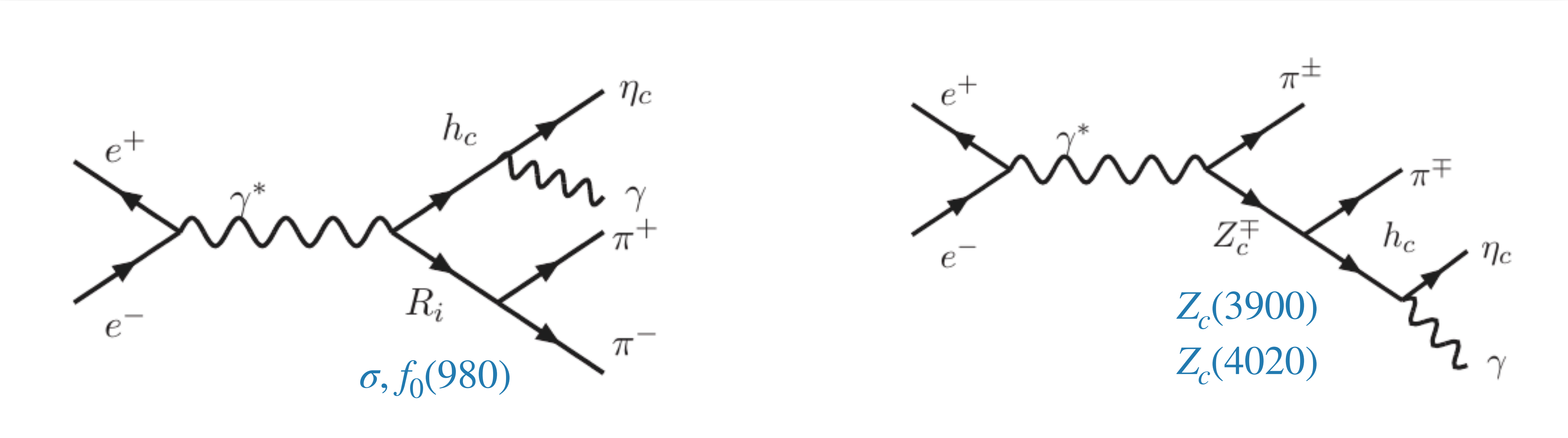
    Polarization vector of the vector meson, $m_{\gamma^*} = \pm 1$

    Polarization vector of the photon, $m_\gamma = \pm 1$

    Partial wave amplitudes

  - $$\frac{d\sigma}{d\Phi} = \sum_{\lambda^*,\lambda} |A(\lambda_{\gamma^*}, \lambda_\gamma)|^2$$

    $$A(\lambda_{\gamma^*}, \lambda_\gamma) = \sum_{i=1}^{n} g_i A_i(\lambda_{\gamma^*}, \lambda_\gamma),\ \lambda_{\gamma^*} = \pm 1,\ \lambda_\gamma = \pm 1$$



Propagator Models

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- $\sigma/f_0(500)$ [parameters fixed]:

$$BW(s) = \frac{1}{M^2 - s - iM\Gamma_{\rm tot}(s)},\ \Gamma_{\rm tot} = g_1\frac{\rho_{\pi\pi}(s)}{\rho_{\pi\pi}(M)} + g_2\frac{\rho_{4\pi}(s)}{\rho_{4\pi}(M)}$$

D. V. Bugg, PLB 572, 1-7 (2003)

BES: PLB 598, 149-158 (2004)

OR using Omnès formalism presented by Viktoriia Ermolina

- $f_0(980)$ [parameters fixed]: For data samples with $\sqrt{s}$>4.35 GeV

$$BW(s) = \frac{1}{M^2 - s - i(g_1\rho_{\pi\pi}(s) + g_2\rho_{K\bar{K}}(s))}$$

BES: PLB607, 243-253 (2005)

- $Z_c(3900)/Z_c(4020)$:

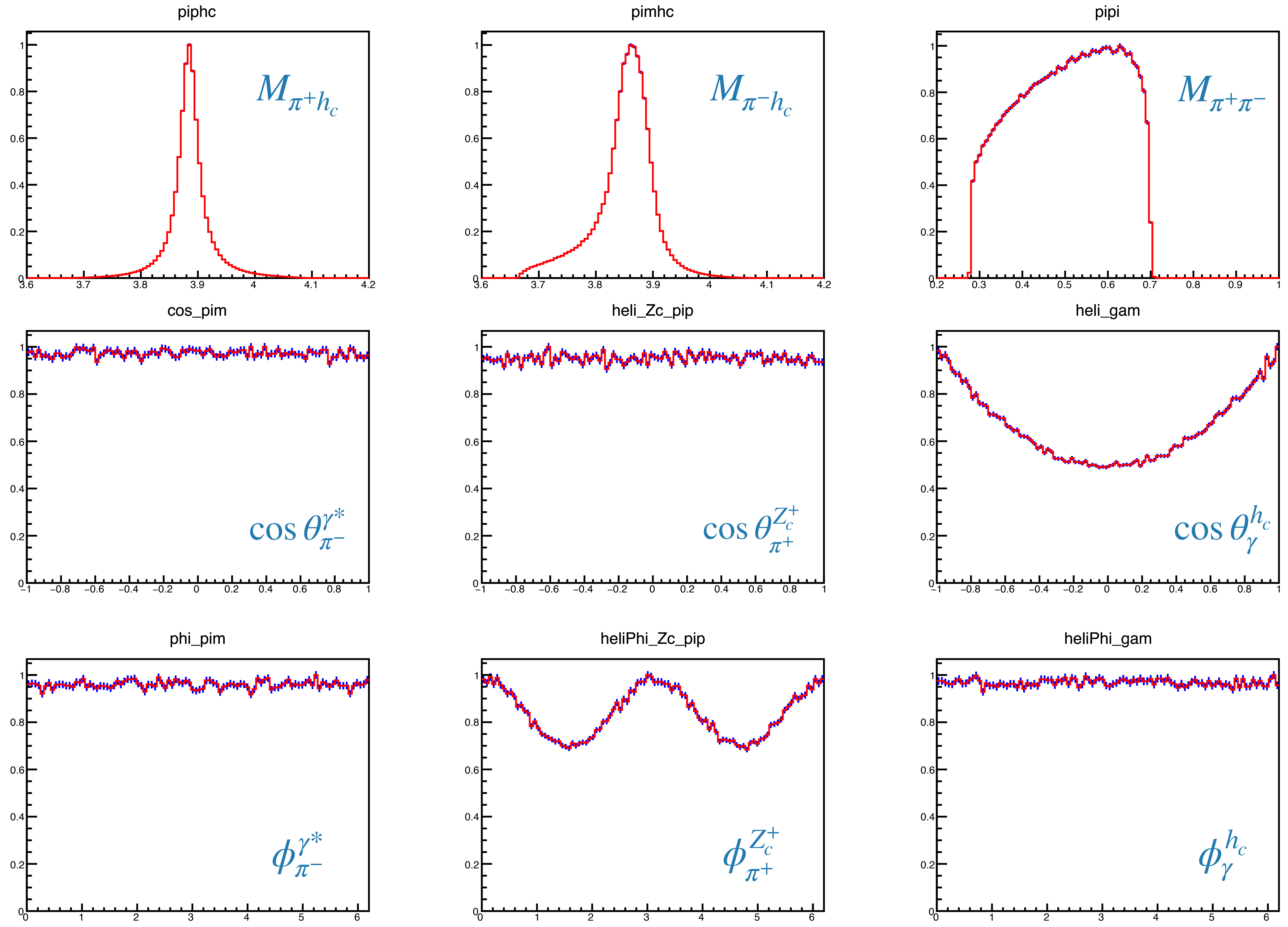
$$BW(s) = \frac{1}{M^2 - s - iM\Gamma_{\rm tot}}$$

  - Parameters of $Z_c(3900)$ fixed to BESIII PWA result; determine the mass and width of $Z_c(4020)$ combing all data samples above 4.20 GeV

BESIII, PWA of $\pi^+\pi^- J/\psi$, arXiv:2505.13222

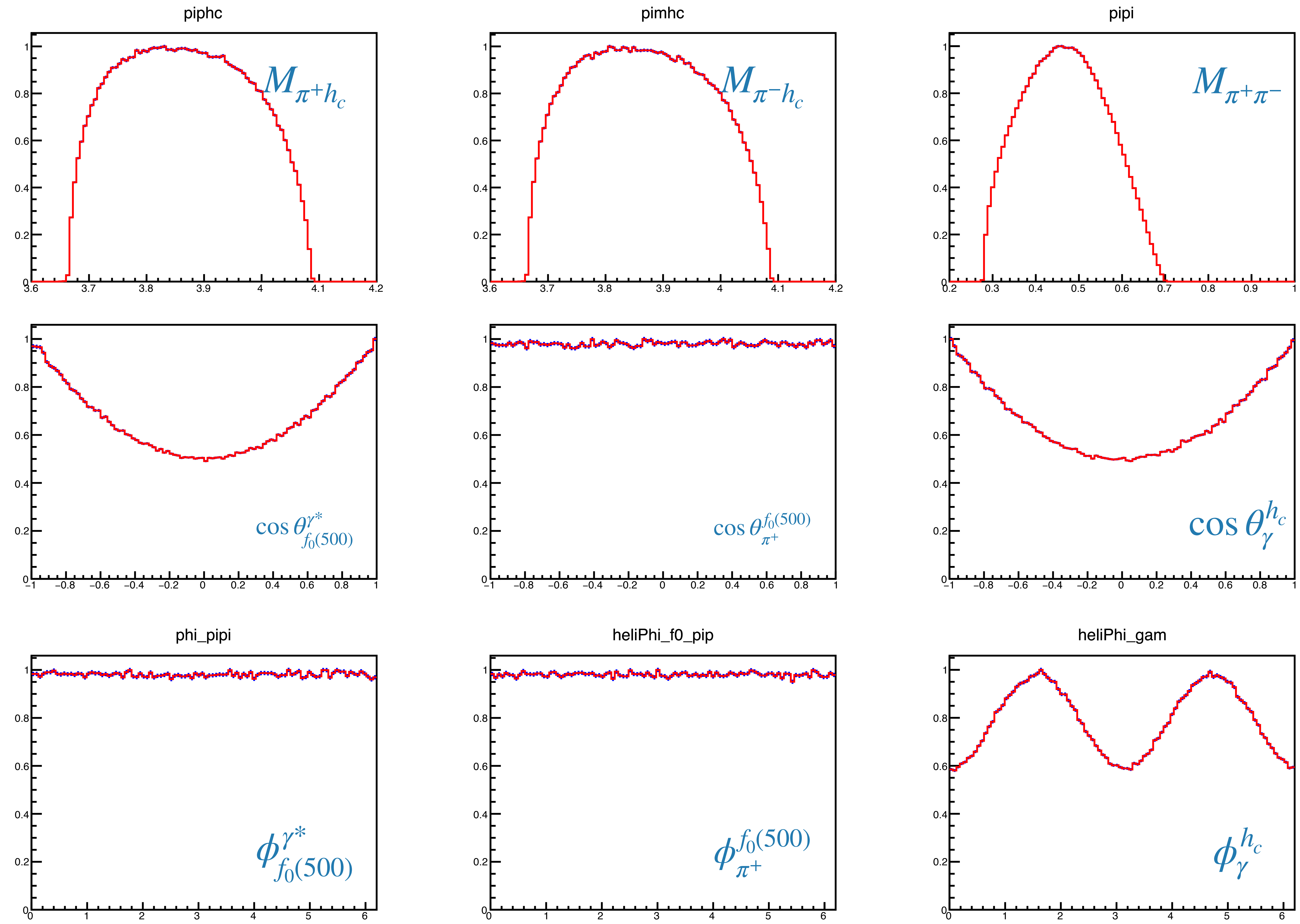
Consistency Check of the Formalism

$1^{--} \to \pi^- Z_c^+,\ Z_c^+ \to \pi^+ h_c,$
$h_c \to \gamma \eta_c$ with J^P of Z_c set to 1^+



Consistency Check of the Formalism

$1^{--} \to f_0(500)h_c, f_0(500) \to \pi^+\pi^-,$
$h_c \to \gamma\eta_c$



Mass and Width of $Z_c(4020)$

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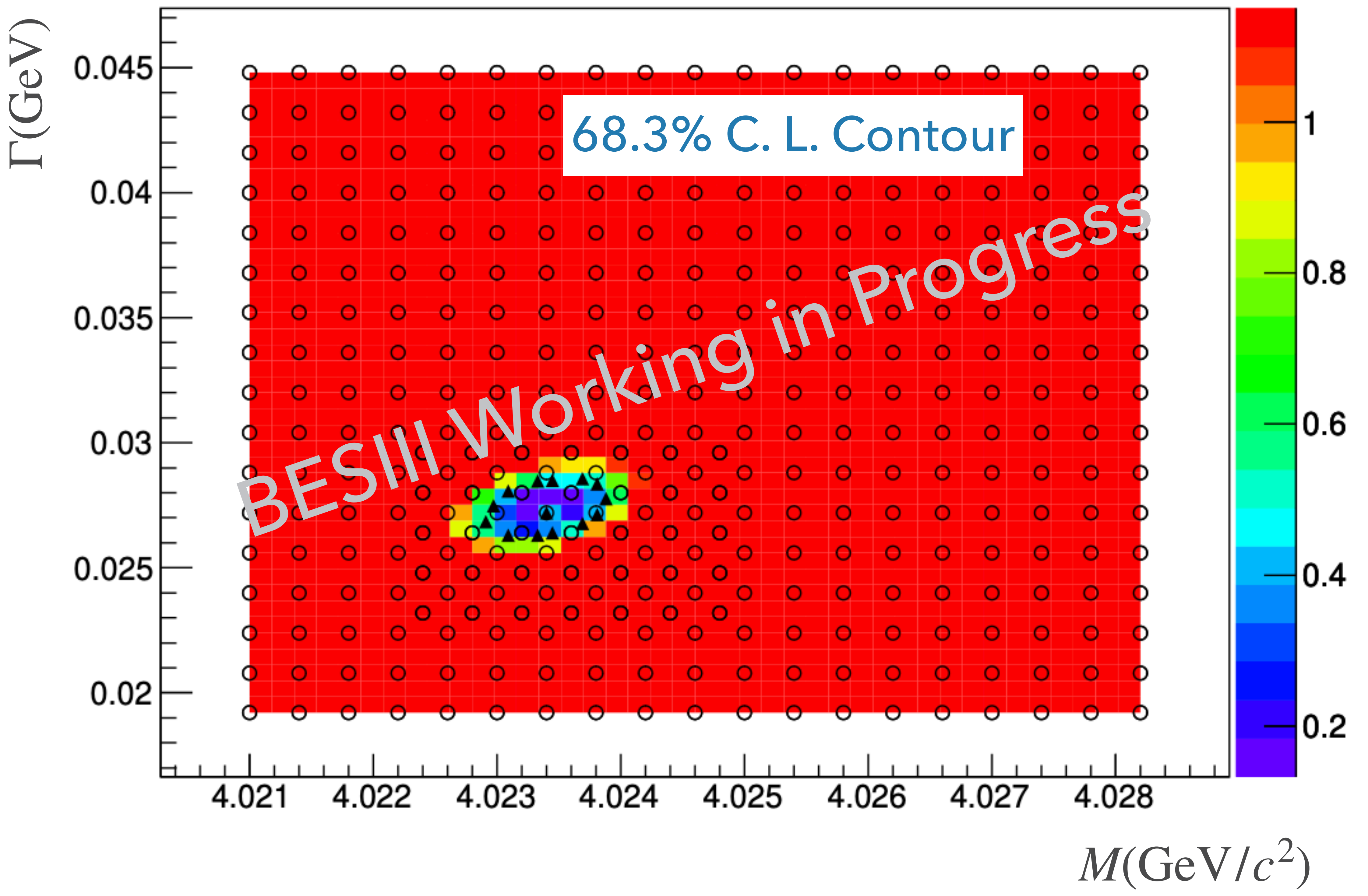

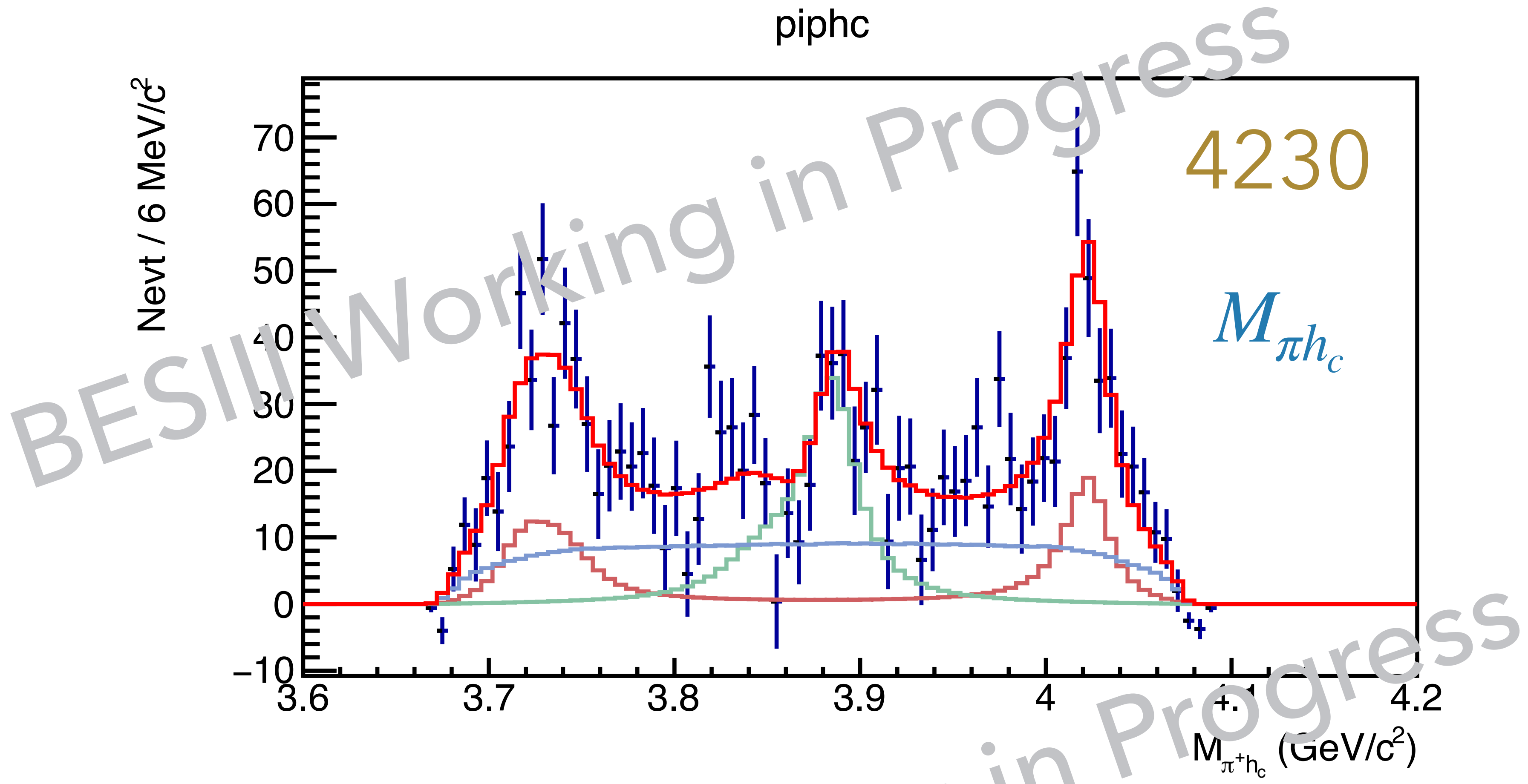

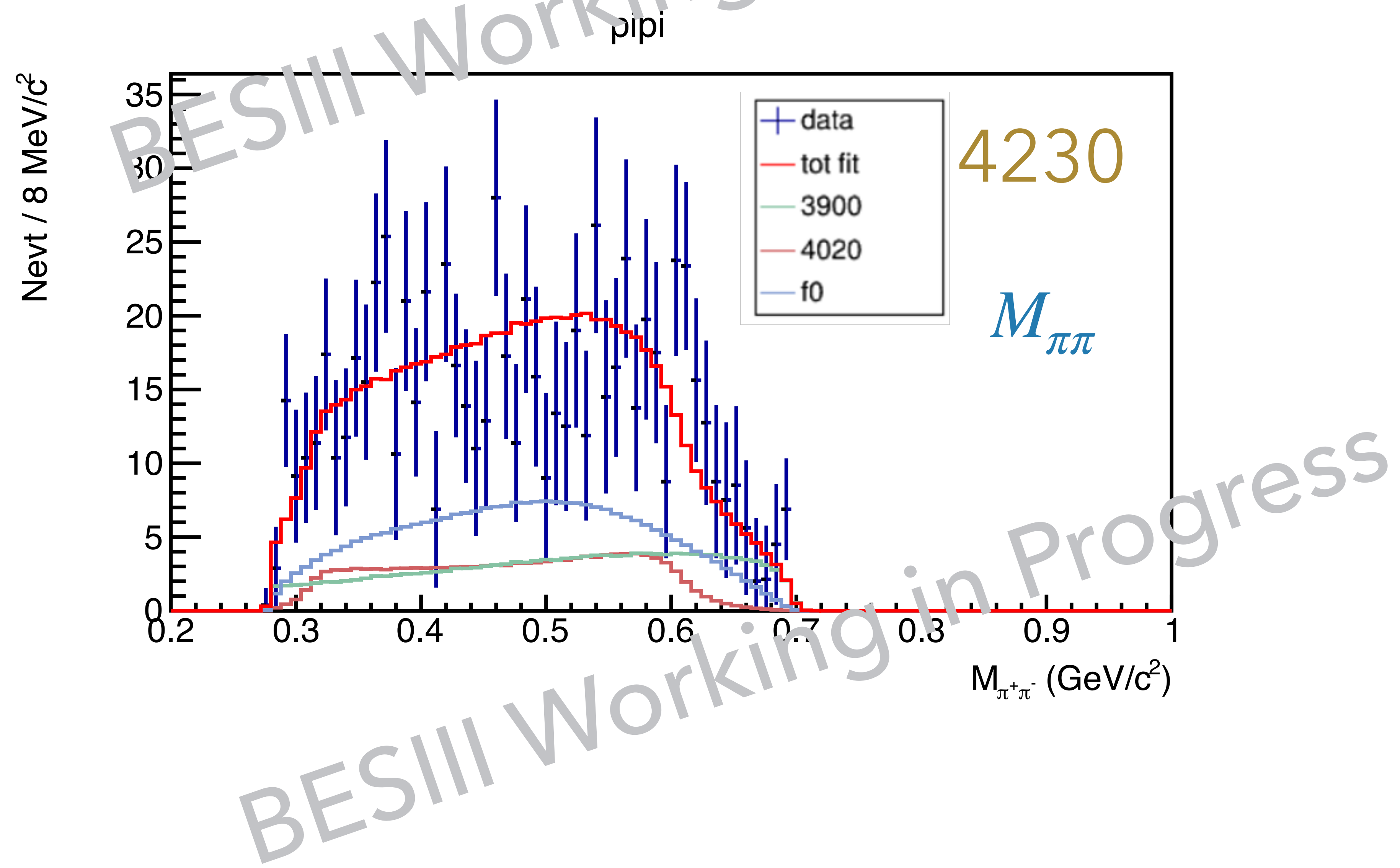

- M= 4022.9±0.8±2.7 MeV/c^2
- Γ=7.9±2.7±2.6 MeV

$\Rightarrow$

- M= 4023.4±0.5 MeV/c^2
- Γ=27.1±1.1 MeV

Quantum Number of $Z_c(4020)$

- From $e^+e^- \rightarrow \pi^+\pi^- h_c$ channel

$J^P_{Z_c(4020)}$	$-log(L)_{Z_c(4020)}$	$\Delta(-log(L))$ (over 1^+)
1^+	66417.5	0
1^-	66579.4	-161.9
2^+	66731.2	-313.7
2^-	66848.3	-430.8

Quantum Number of $Z_c(4020)$

- From $e^+e^- \to \pi^+\pi^- h_c$ channel

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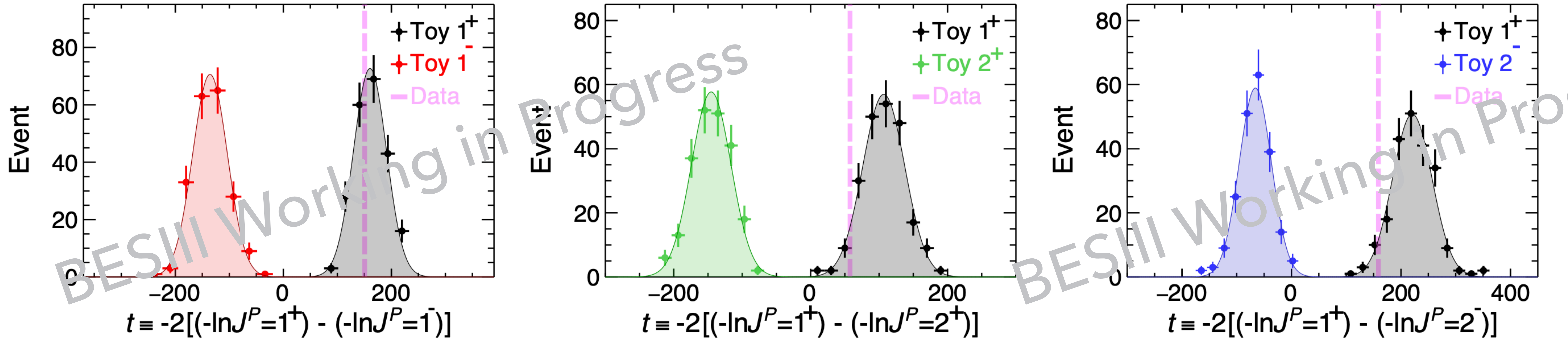
1^+	66417.5	0
1^-	66579.4	-161.9
2^+	66731.2	-313.7
2^-	66848.3	-430.8

- From a coupled-channel analysis of $e^+e^- \to \pi^+\pi^- J/\psi$, $e^+e^- \to \pi^+\pi^- h_c$, and $e^+e^- \to \pi^+ D^{*0} D^{*-}$ using 4400 and 4420 data samples



1^+ over other hypotheses $> 5\sigma$

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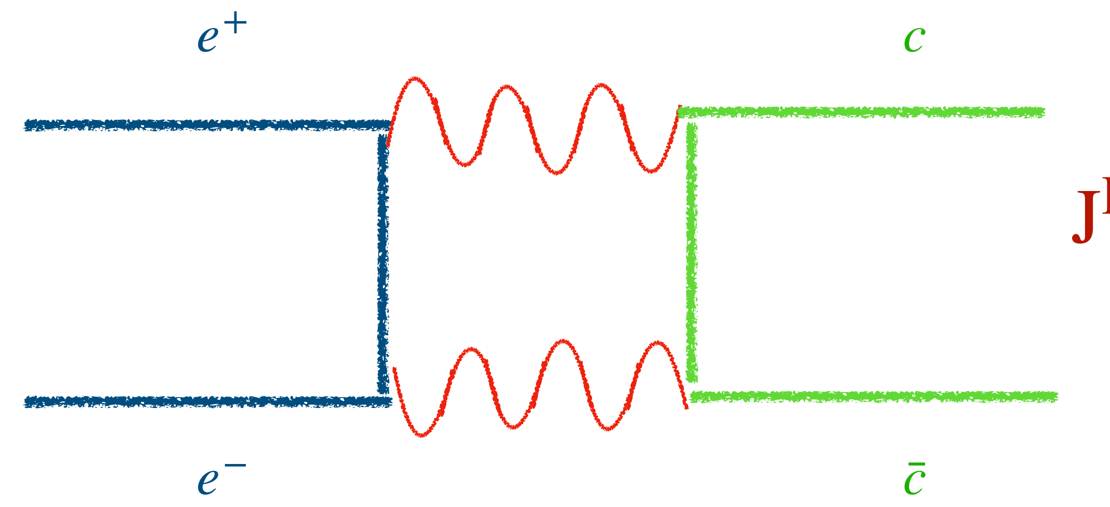
Direct Production of C-even State

- Direct production of C-even states go through a process with two virtual photons or neutral current
- The production rate is proportional to the electronic witdh of the state (Γ_{ee})
- For χ_{c1} state:

1. Unitarity limit: $\Gamma_{ee} > 0.04$ eV *J. Laplan, J. H. Kühn, PLB78, 252 (1978)*
2. Vector Dominance Mpdel: $\Gamma_{ee} = 0.46$ eV; OR $\Gamma_{ee} \sim 0.1$ eV *A. Denig, F. K. Guo, C. Hanhart, A. V. Nefediev, PLB736, 221 (2014)*
3. Non-Relativistic QCD: $\Gamma_{ee} \sim 0.1$ eV; $0.33^{+0.37}_{-0.01}$ eV *Y. Jia, Q. C. Pan, arXiv:2411.18560*
4. An updated analysis of 1, with interference with background process taken into accout: $\Gamma_{ee} = 0.43$ eV *H. Czyż, J. H. Kühn, S. Tracz,PRD94, 034033 (2016)*

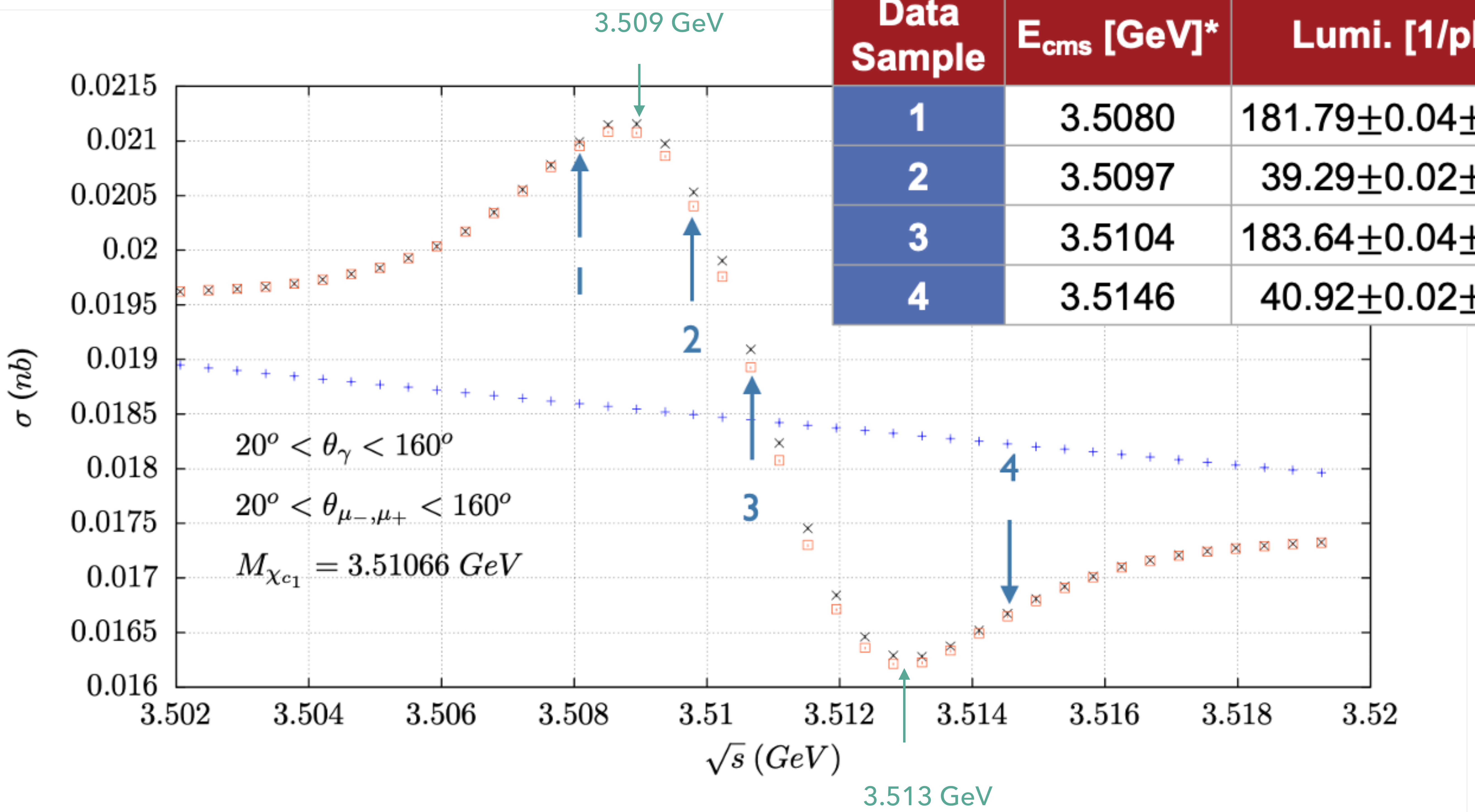
- For χ_{c2} state:

3. NRQCD: $\Gamma_{ee} \sim 0.1$ eV; $0.13^{+0.15}_{-0.01}$ eV *N. Kivel, M. Vanderhaeghen, JHEP02, 032 (2016)* *Y. Jia, Q. C. Pan, arXiv:2411.18560*
4. $\Gamma_{ee} = 4.2$ eV *H. Czyż, J. H. Kühn, S. Tracz,PRD94, 034033 (2016)*



$J^{PC} = 1^{++}$
2^{++}

χ_{c1} Scan Data Samples



Data Sample	E_{cms} [GeV]*	Lumi. [1/pb]
1	3.5080	181.79±0.04±1.04
2	3.5097	39.29±0.02±0.22
3	3.5104	183.64±0.04±1.05
4	3.5146	40.92±0.02±0.23

*E_{cms} and beam energy spread measured by BEMS

Uncertainty of E_{cms}: ±0.05 MeV ; Beam energy spread: (736 ± 27) keV

Analysis Strategy

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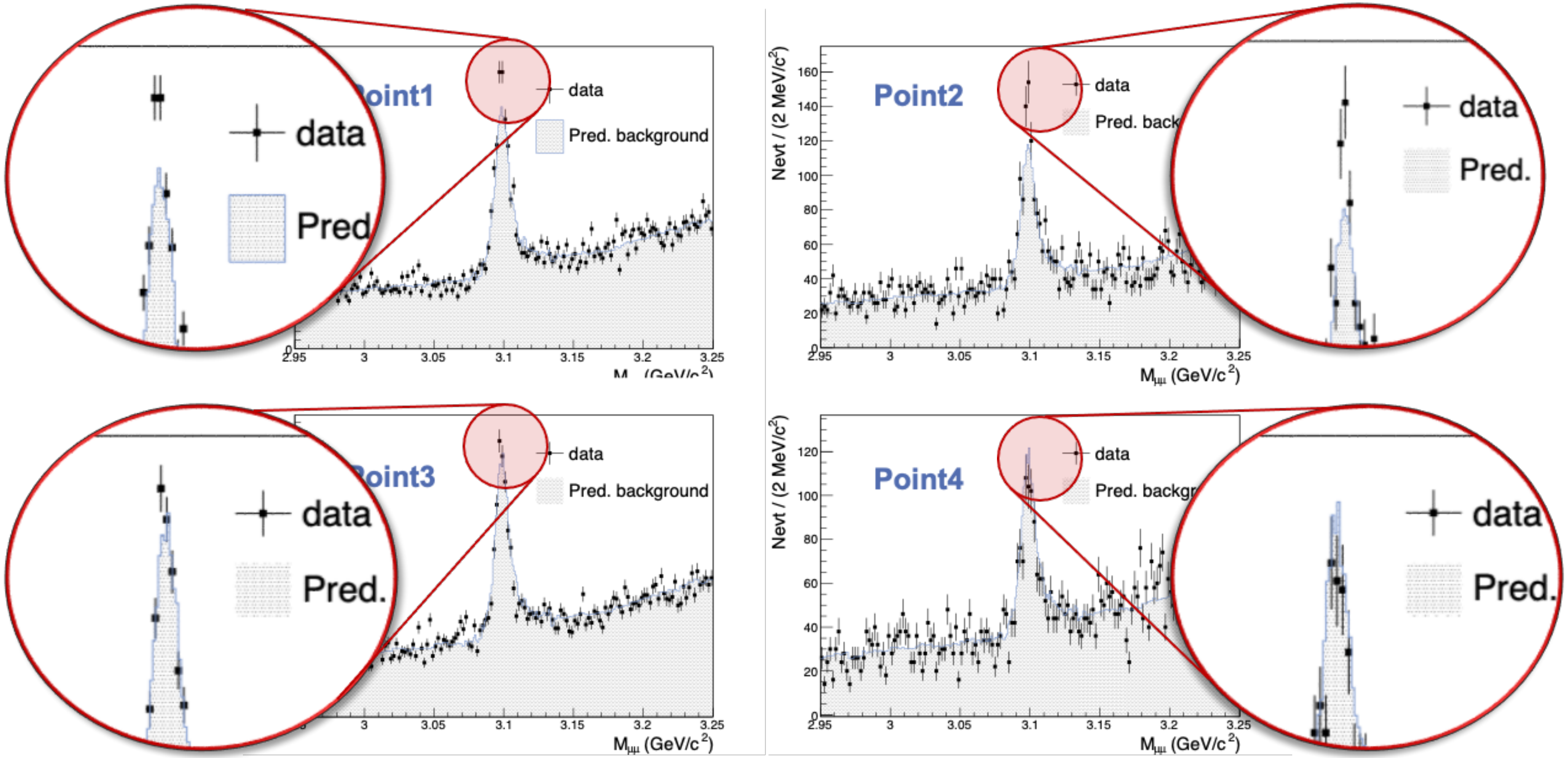
- Signal process: $e^+e^- \to \chi_{c1}, \chi_{c1} \to \gamma J/\psi$ (Br: 34%), $J/\psi \to \mu^+\mu^-$ (Br: 6%)
- Irreducible background process: ISR production of $(J/\psi + \mu^+\mu^-)$
- Validate the description of the ISR background simulated with PHOKHARA generator by using
  - High statistics data samples at $\psi(3770)$ and at $\sqrt{s} = 4.178$ GeV, ~3 fb^{-1} each
  - Off-peak data samples at $\sqrt{s} = 3.581$ and 3.670 GeV, ~85 pb^{-1} each

Validated and 2D Correction Applied

- Check $e^+e^- \to \chi_{c1}$ signal by searching for excess (reduction) of events beyond ISR background
- Study of interference pattern by combing the four data samples
  - No interference: excess of events at 3rd point (χ_{c1} nominal mass)
  - With interference (*if as predicted by PRD94, 034033 (2016)*): excess of events at 1st and 2nd points, reduction at 4th point

$M(\mu^+\mu^-)$ at χ_{c1} Scan Data Samples



PRL129, 122001 (2022)

Determination of $\Gamma_{ee}(\chi_{c1})$

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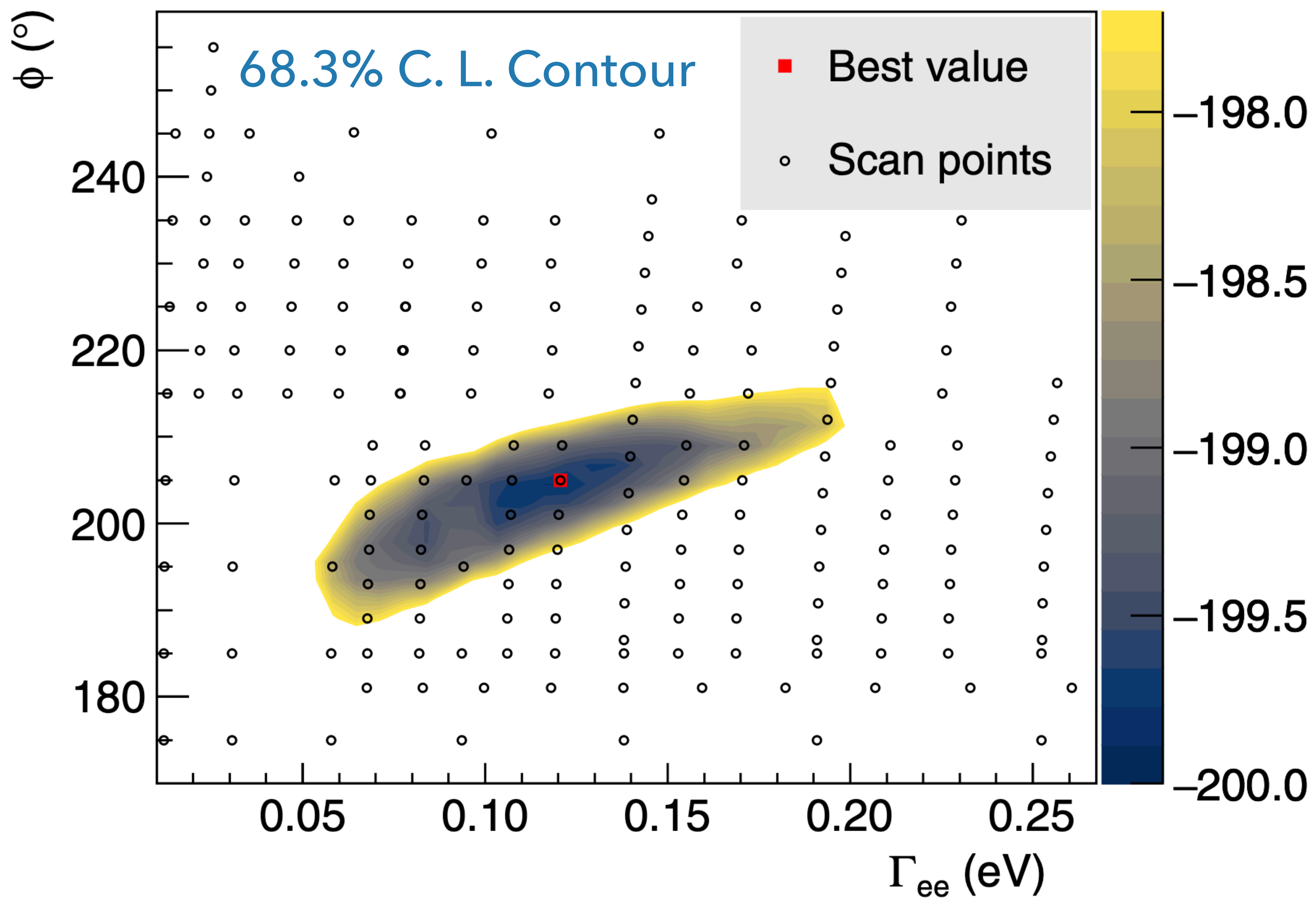
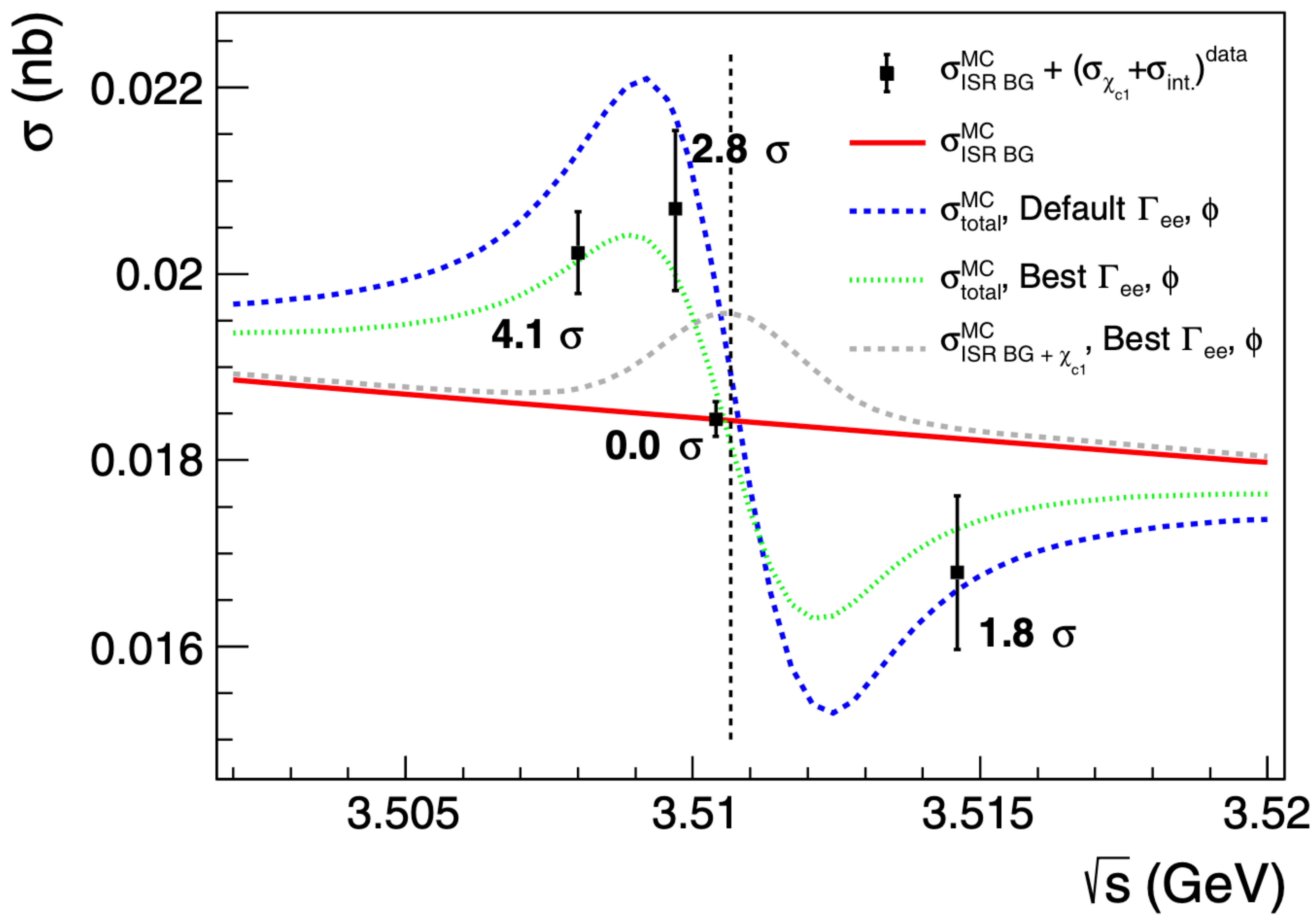
PRL129, 122001 (2022)



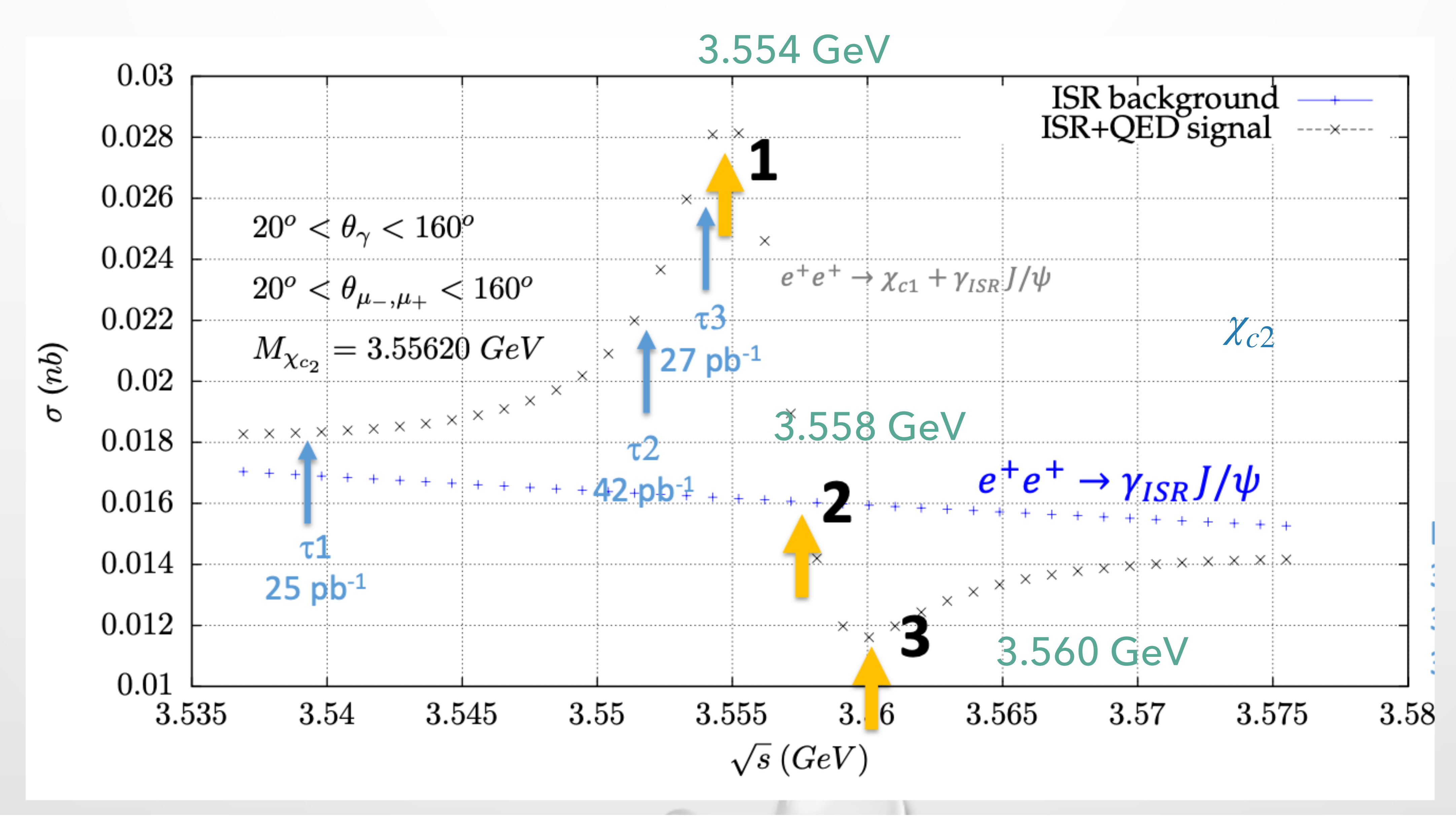


$\Gamma_{ee} = (0.12^{+0.13}_{-0.08})$ eV

Combined significance: 5.1σ

Scan Around χ_{c2}

- In 2024, ~120 pb^{-1} at $\sqrt{s} = 3.554$ GeV was taken
  - If the $\Gamma_{ee}(\chi_{c2})$ is 4.2 eV $\Rightarrow$ significance of signal $>5\sigma$



H. Czyż, J. H. Kühn, S. Tracz,PRD94, 034033 (2016)

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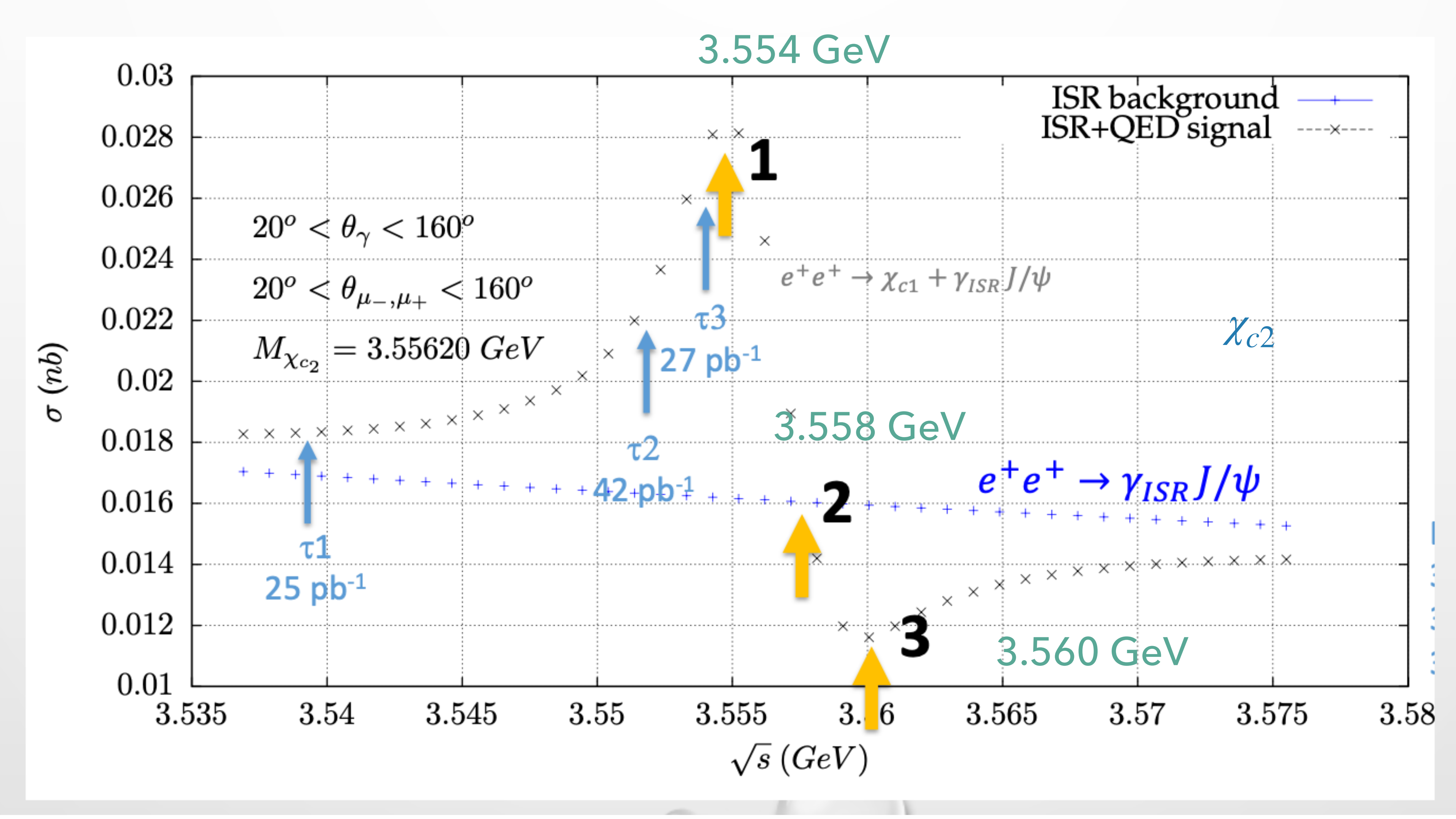

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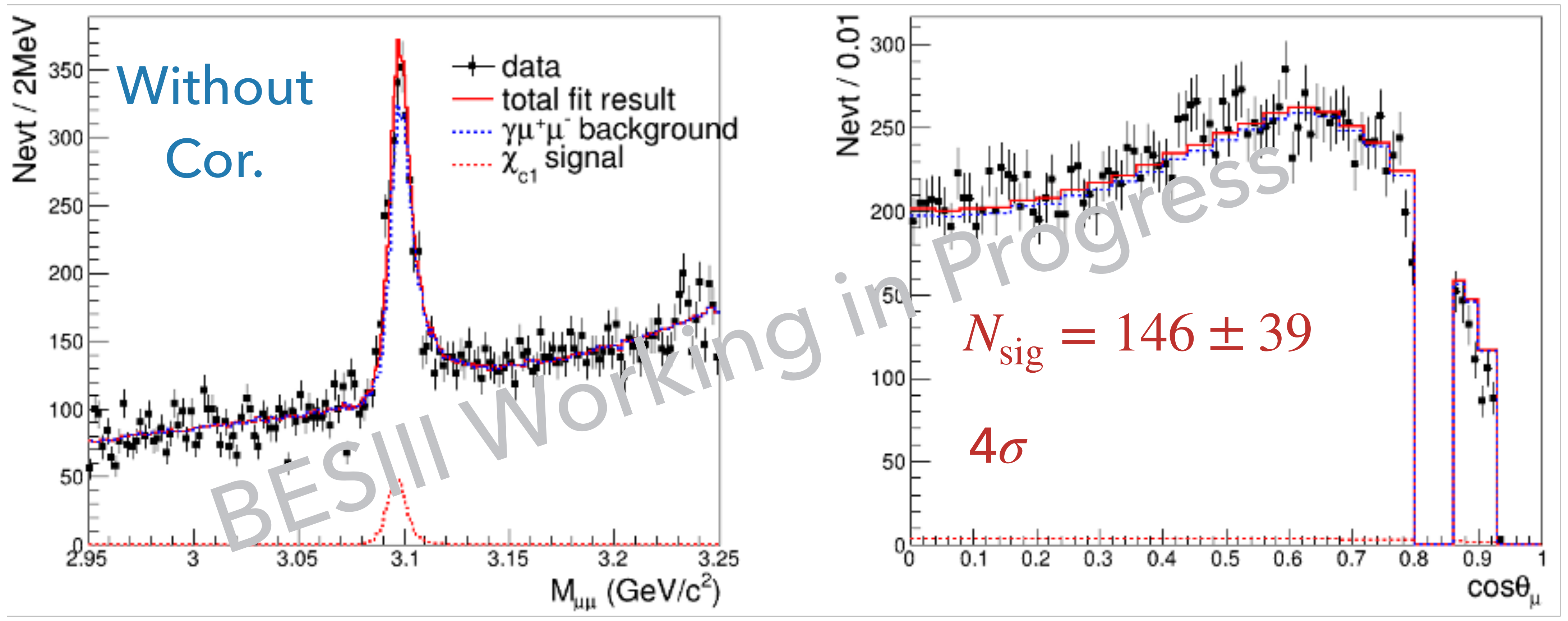
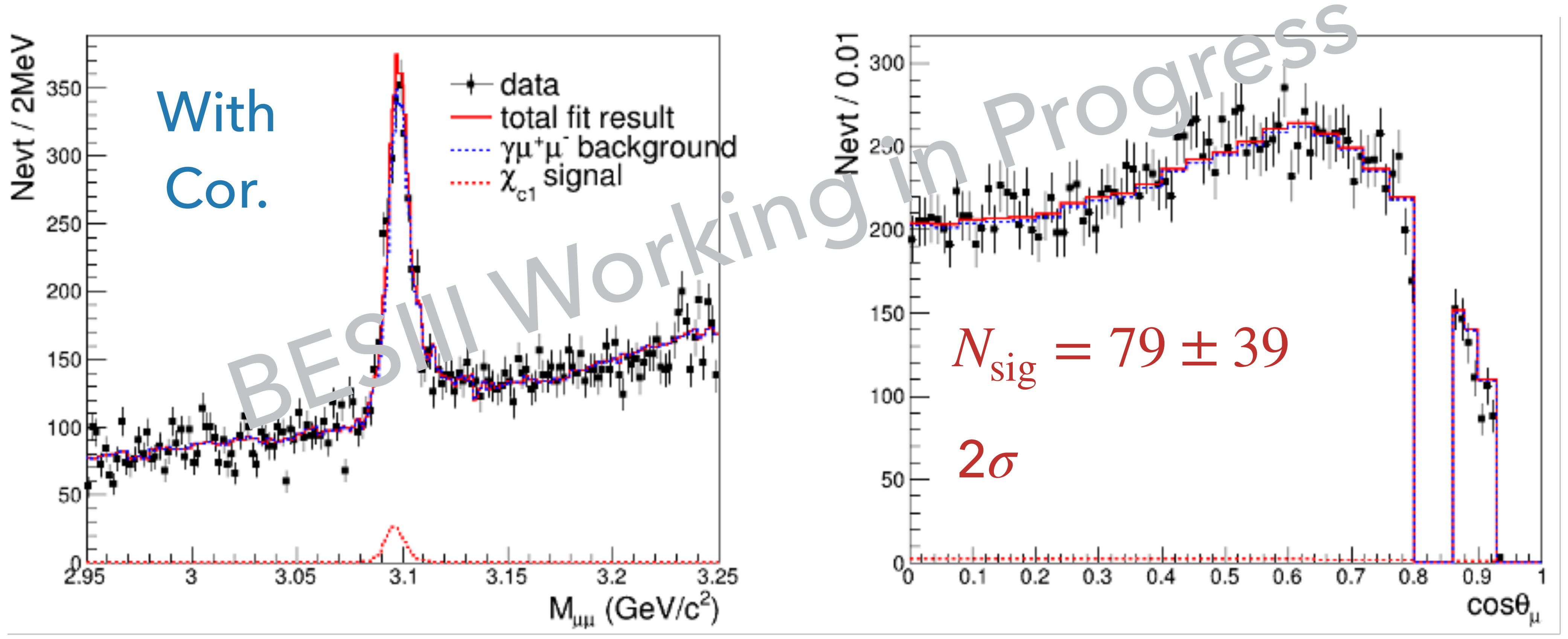
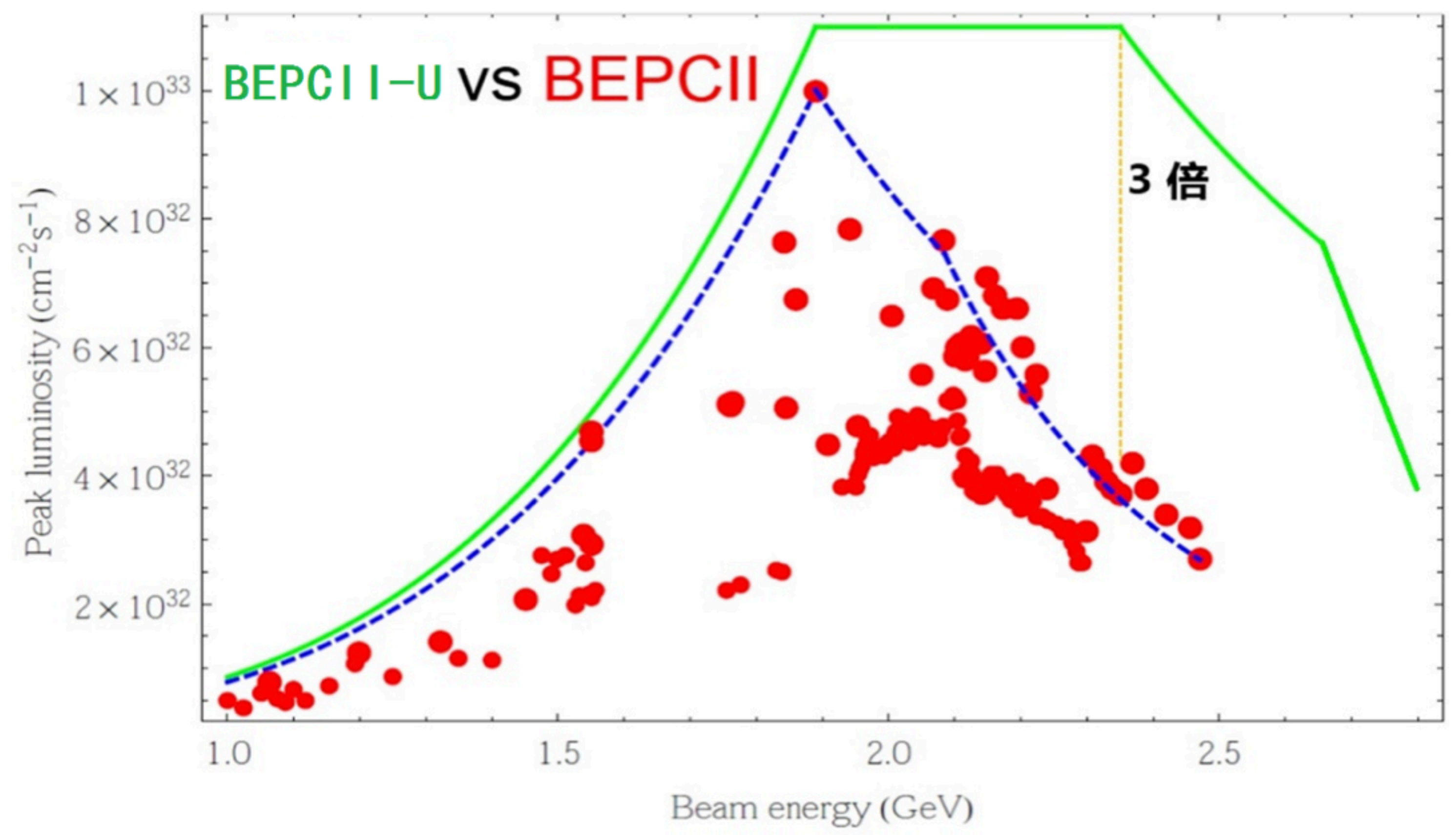




Scan Around χ_{c2}

Run plan 2025–2026

No dedicated synchrotron runs any more:
9–10 months of physics running for us per year!



- **~~Jan~~ Mar 2025 – Jul 2025** (round 18)
  Recover machine operation, scrub vacuum,
  collect sufficient quantity of tracks
  to commission, align and calibrate C
  Stay on ψ' peak
- **2025/26** (round 19) — allocation nc
  BEPCII-U: demonstrate operation at
  Run at 4680 MeV — start collecting
  Scans around $X(3872)$ and χ_{c2} (about one month each)

Energy (GeV)	Luminosity (pb^{-1})	Days
3.554	600	16
3.558	200	6
3.560	300	8

Slide from W. Gradl, 2025 BESIII Spring Workshop

SP Report | W. Gradl | 7

Summary and Outlook

- 1. A study of XYZ charmonium-like states using a dispersive formlism
  - Analysis of the new data of $e^+e^- \to \pi\pi h_c$ at BESIII *arXiv: 2504.04096*
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    part of χ_{c2} data has been taken

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Thank you!

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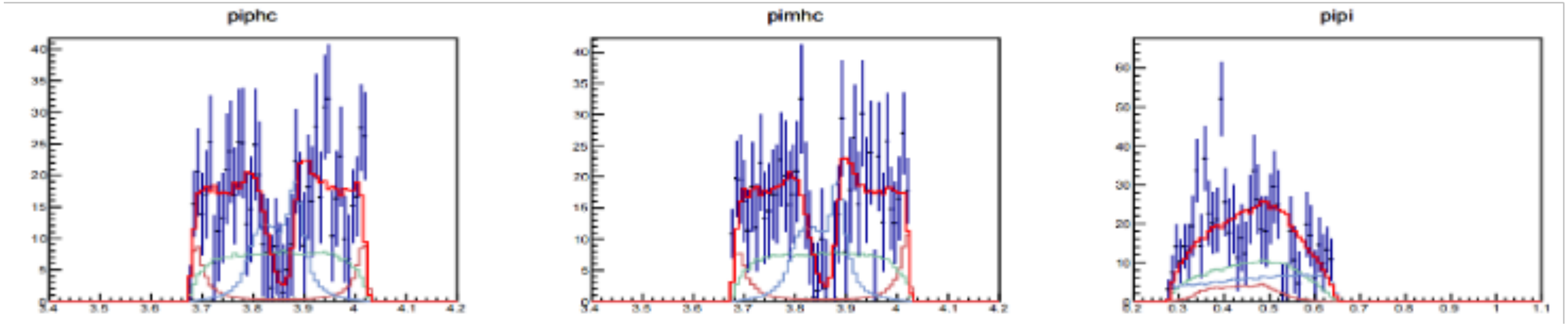
2.4 Time schedule

Project	2022 2023 2024 2025	2026 2027 2028 2029
XYZ-1	PWA of ee $\to \pi\pi h_c$ Determination of spin/parity of $Z_c(4020)$ PWA of ee $\to \pi\pi(KK)\, J/\psi$ at c.m. energies 4.23 and 4.26 GeV	PWA of full data samples of ee $\to \pi\pi(KK)\, J/\psi$, $\pi\pi\, \psi(2S)$ below 4.6 GeV & Extension to ee $\to \pi\pi\Upsilon(nS)$
XYZ-2	Radiative transitions of conventional charmonia and bottomonia	Radiative transitions of exotics
XYZ-3	χ_{c2} scan Data taking and data analysis Feasibility study for $\chi_{c1}(3872)$ scan in $\gamma J/\psi$ channel	$\chi_{c1}(3872)$ scan in $\gamma J/\psi$ channel Data taking and data analysis Feasibility study for $f_1(1285)$ production via ISR



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