Spectroscopy at BESIII

Status and Highlights

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Outline

- BESIII Experiment
- Preamble… The XYZ Exotic States
- Understanding the $\chi_{c1}(3872)$
- Rediscovering the $Z_c(3900)$
- Glueballs (?) with Radiative J/ψ Decays
- Summary

BESIII Experiment

BESIII (BEijing Spectrometer III) is an experiment located at the BEPCII (Beijing Electron Positron Collider II) at IHEP (Institute of High Energy Physics)

Being **BEPCII** an **e^+e^- collider**, with a beam energy spread of [0.8, 2.0] MeV, BESIII can profit from **direct production** of **vector states** ($J^{PC} = 1^{--}$)

The **statistics of the ψ(nS)** decays allows to probe and study with **high precision** also the **non-vector** states

BESIII has also **unique opportunities** with datasets **above 3.8 GeV**

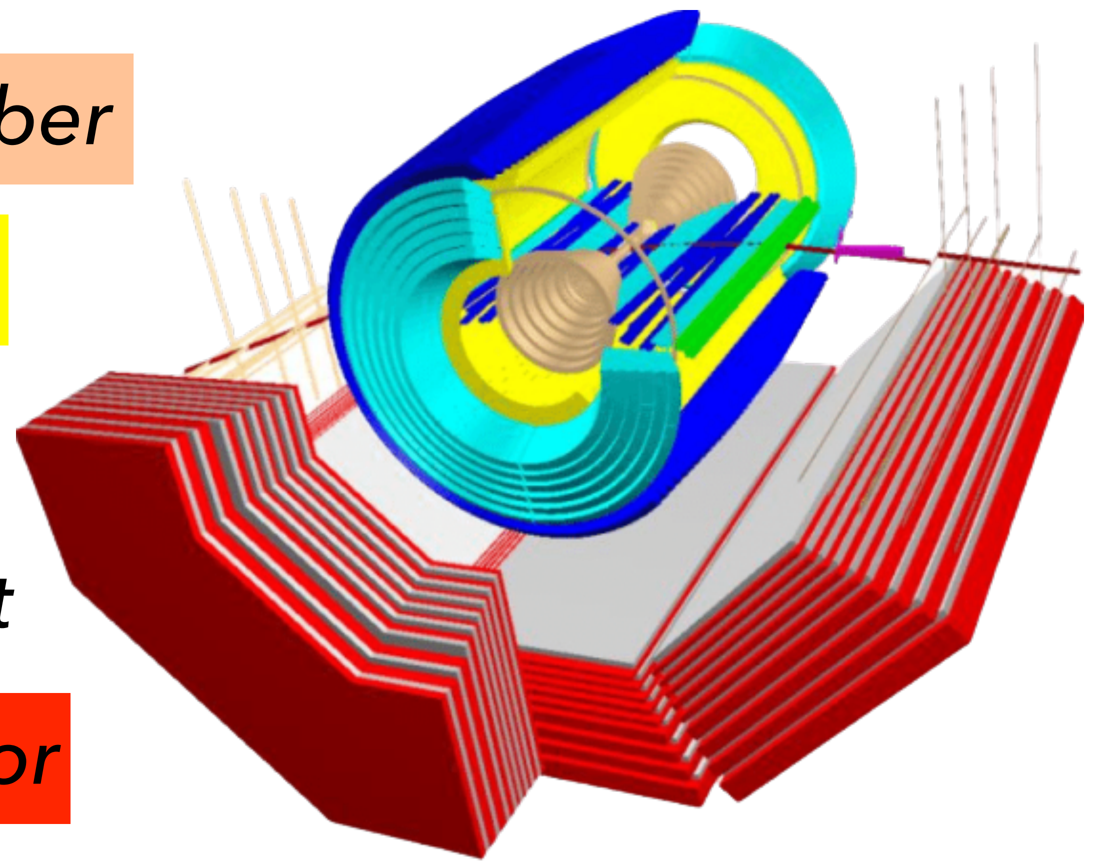
Multi-layer Drift Chamber

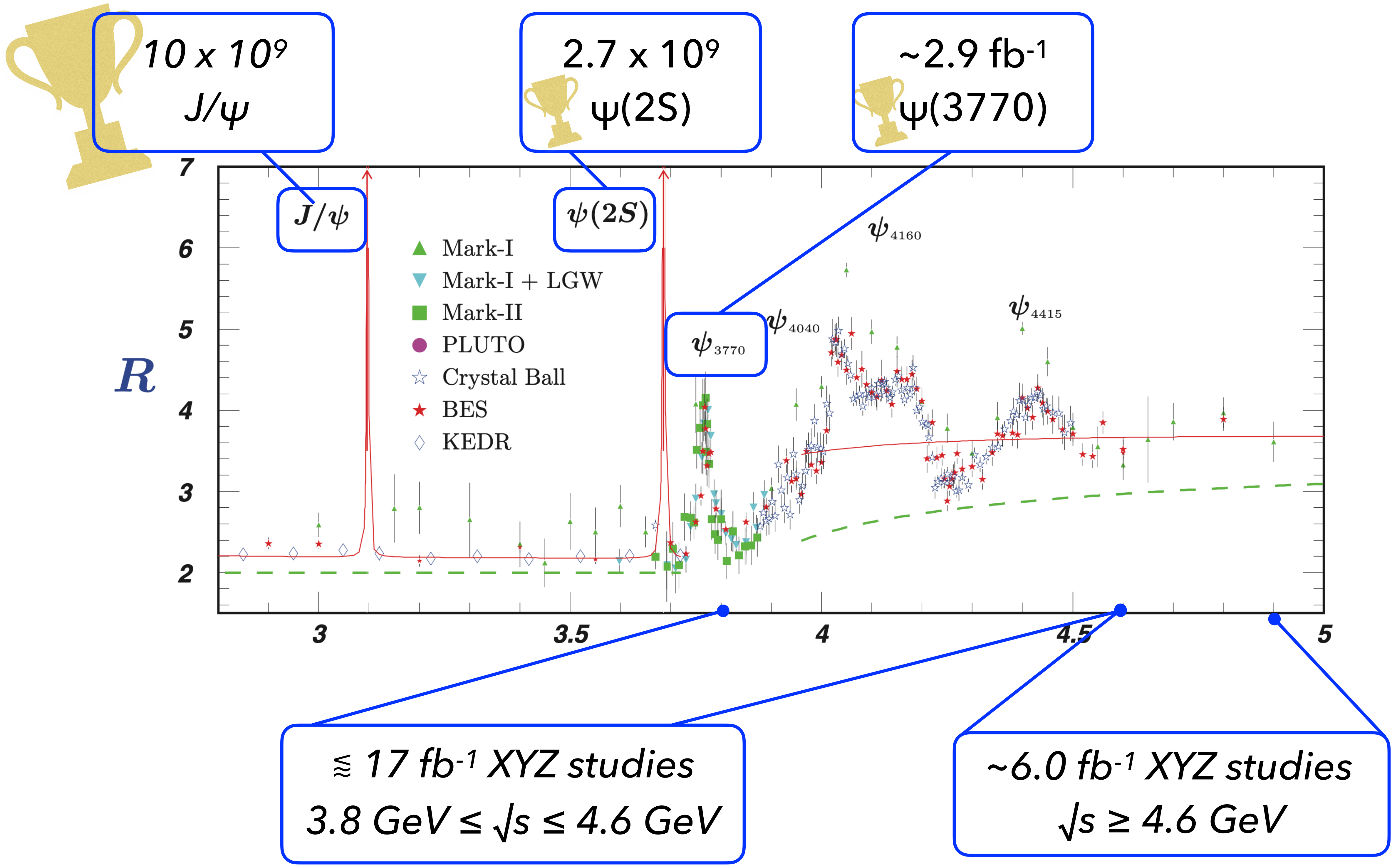
Time of Flight Detector

EM Calorimeter

1T Solenoidal Magnet

Muon Detector





τ-charm factory 2.0 GeV ≤ $\sqrt{s}$ ≤ 4.9 GeV

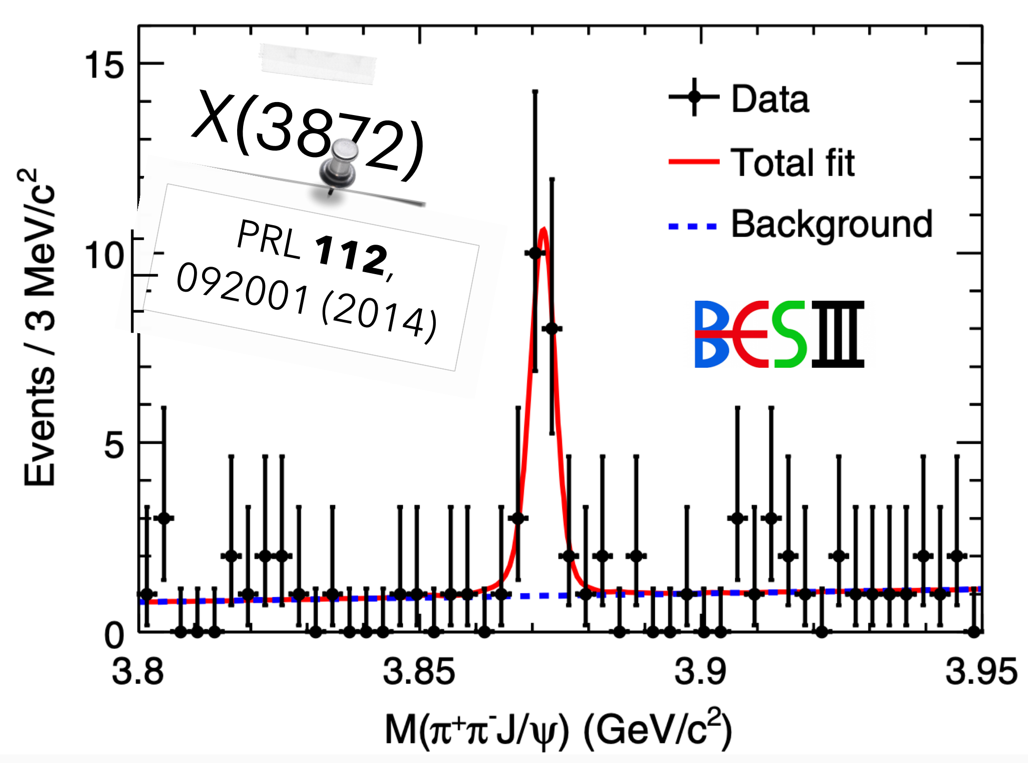
with an instantaneous luminosity of 10^{33} $cm^{-2}s^{-1}$ @ $\sqrt{s}$ = 3.77 GeV

Charmonium-like XYZ States

$c\bar{c}$ spectrum features **supernumerary states**

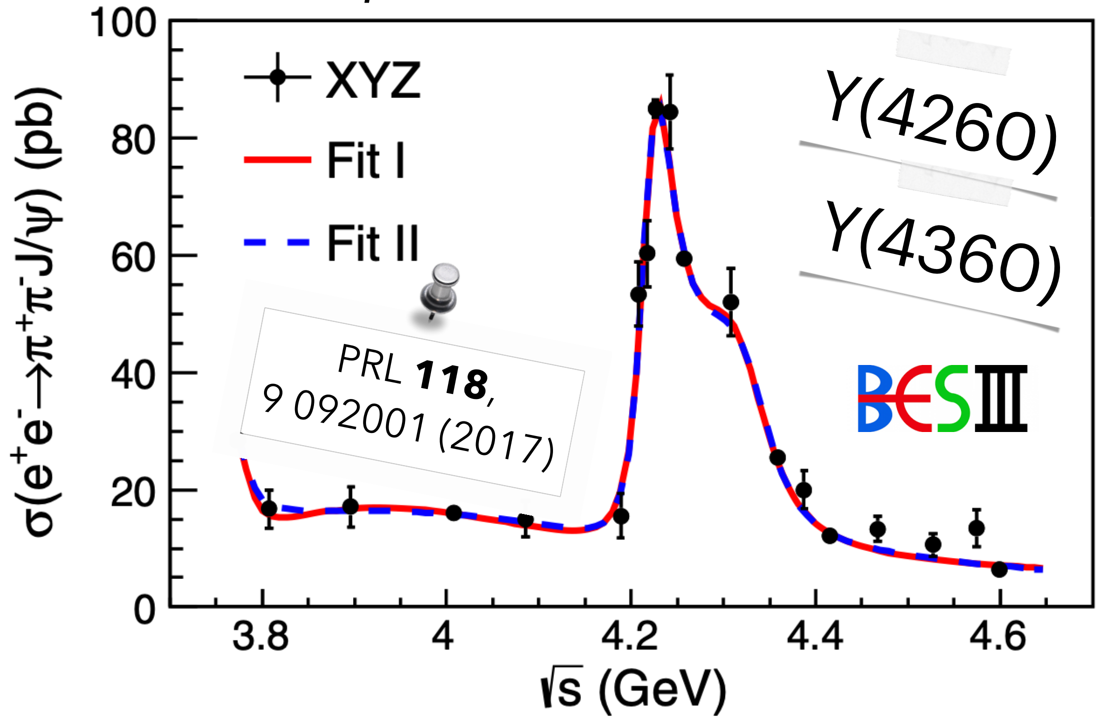
Exotic states **don't fit** potential model **predictions**, show strong **couplings to hidden charm** states, and exhibit a **non-zero charge**

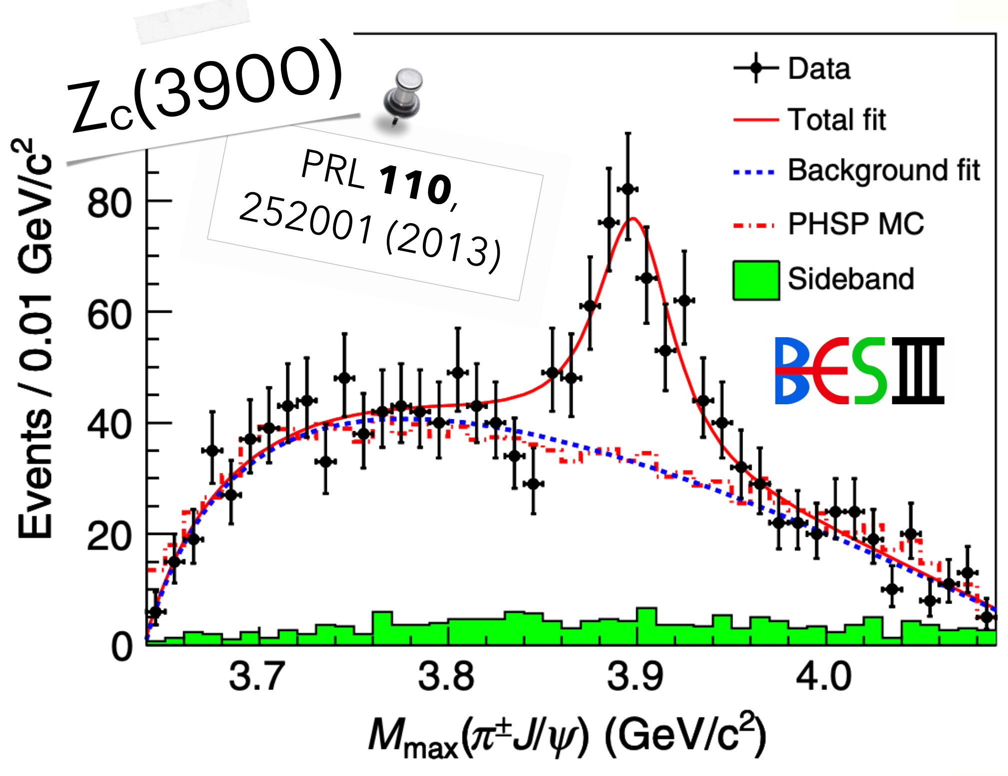
The **nature** of these exotic states is **not** yet **clear**



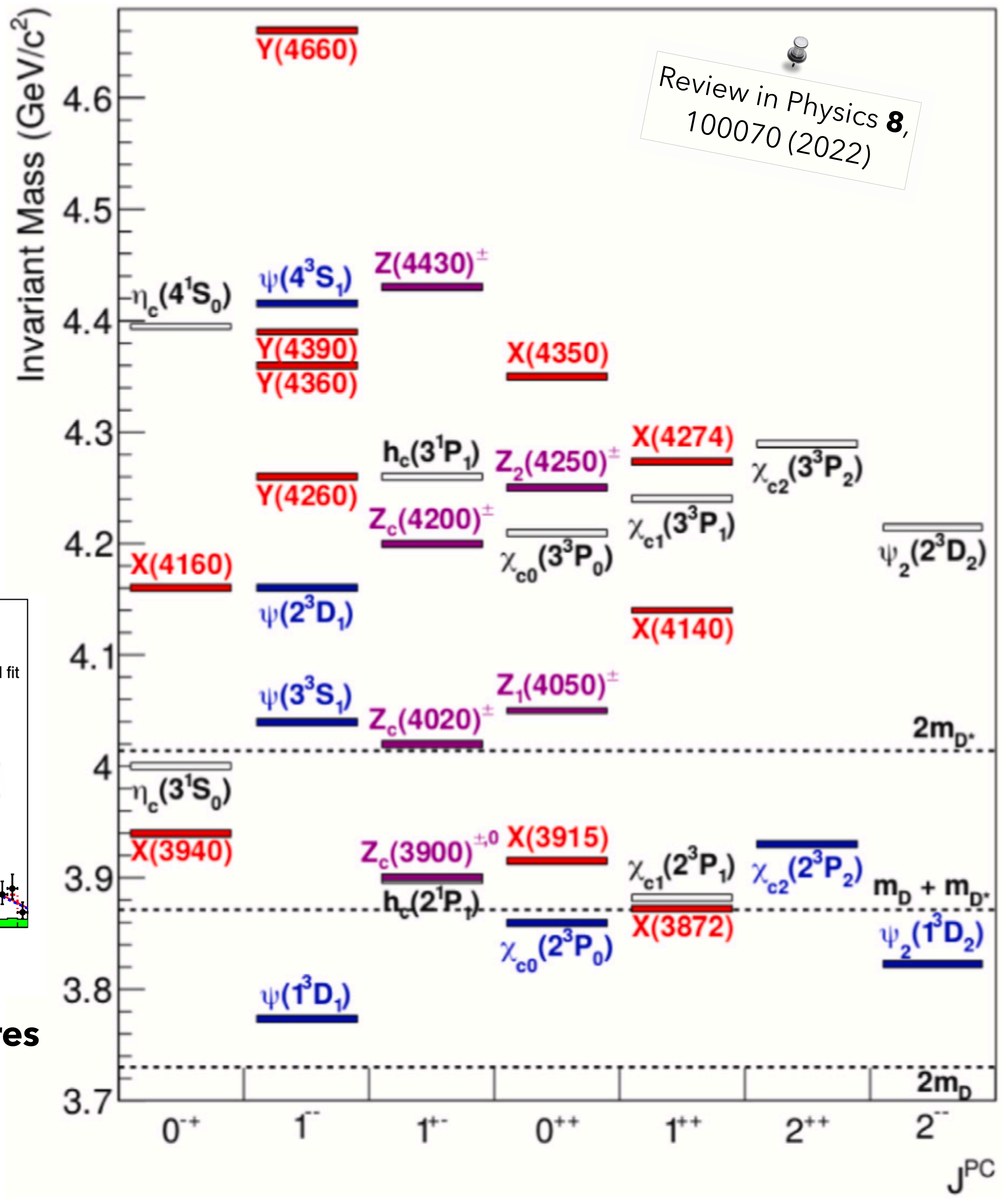
X: **Neither *Y* nor *Z***

Y (or ψ): **Vector resonances**





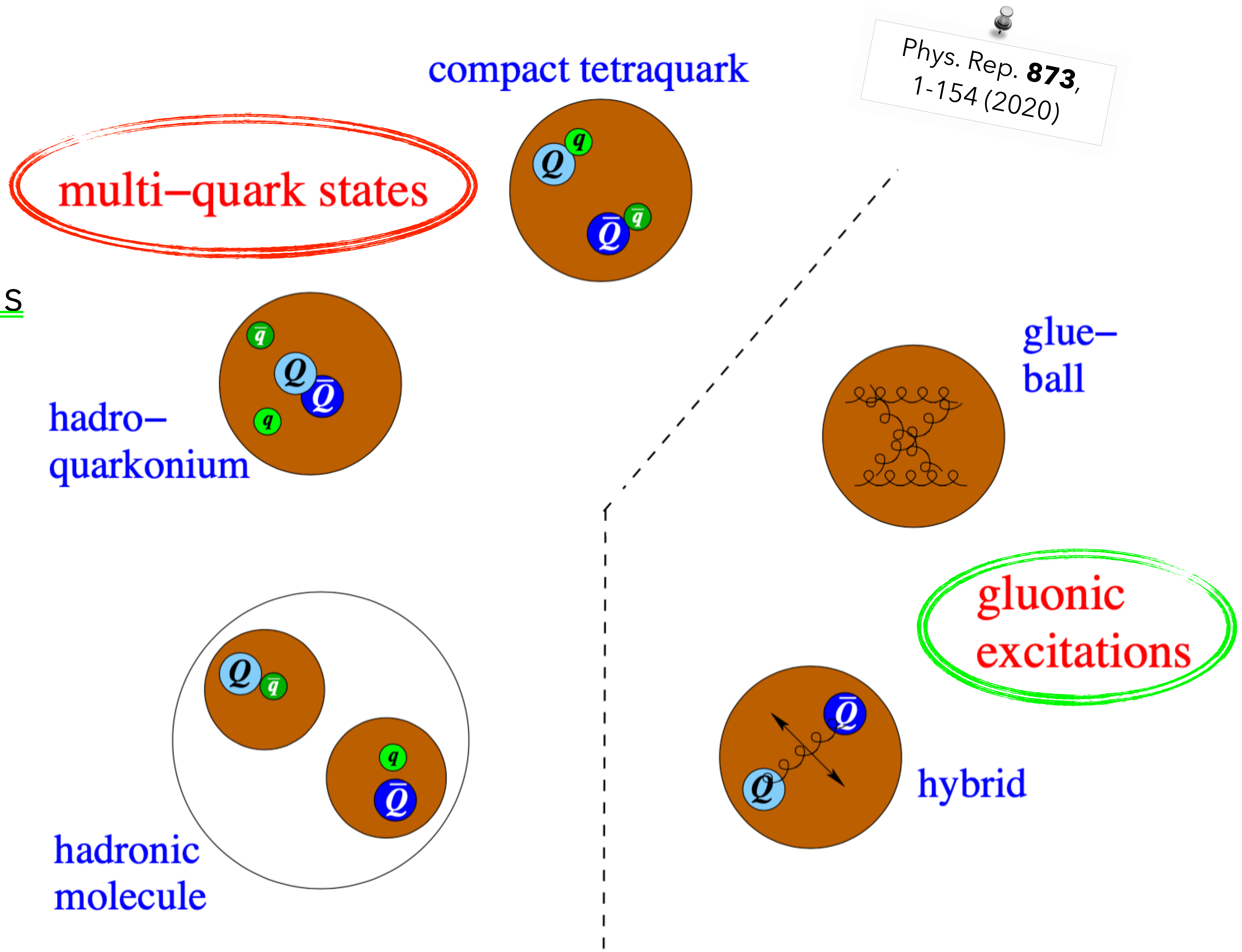
Z (or T_{XX}): **Charged structures**



Exotic States

Assuming a novel physical origin, **exotic hadrons** can be grouped into **two families following their valence content** with respect to the standard meson-baryon picture:

- they might contain additional (or only) valence gluons
- they can be multi-quark states



Some are **close to open-flavour thresholds**, which might induce kinematic **enhancements**[1, 2]

They **could** emerge as **interference effects** of various standard quarkonia

[1] Phys. Lett. B **598**, 8-14 (2004)
[2] Int. J. Mod. Phys. E **25**, 07 1642010 (2016)

X(3872)/χ_{c1}(3872)

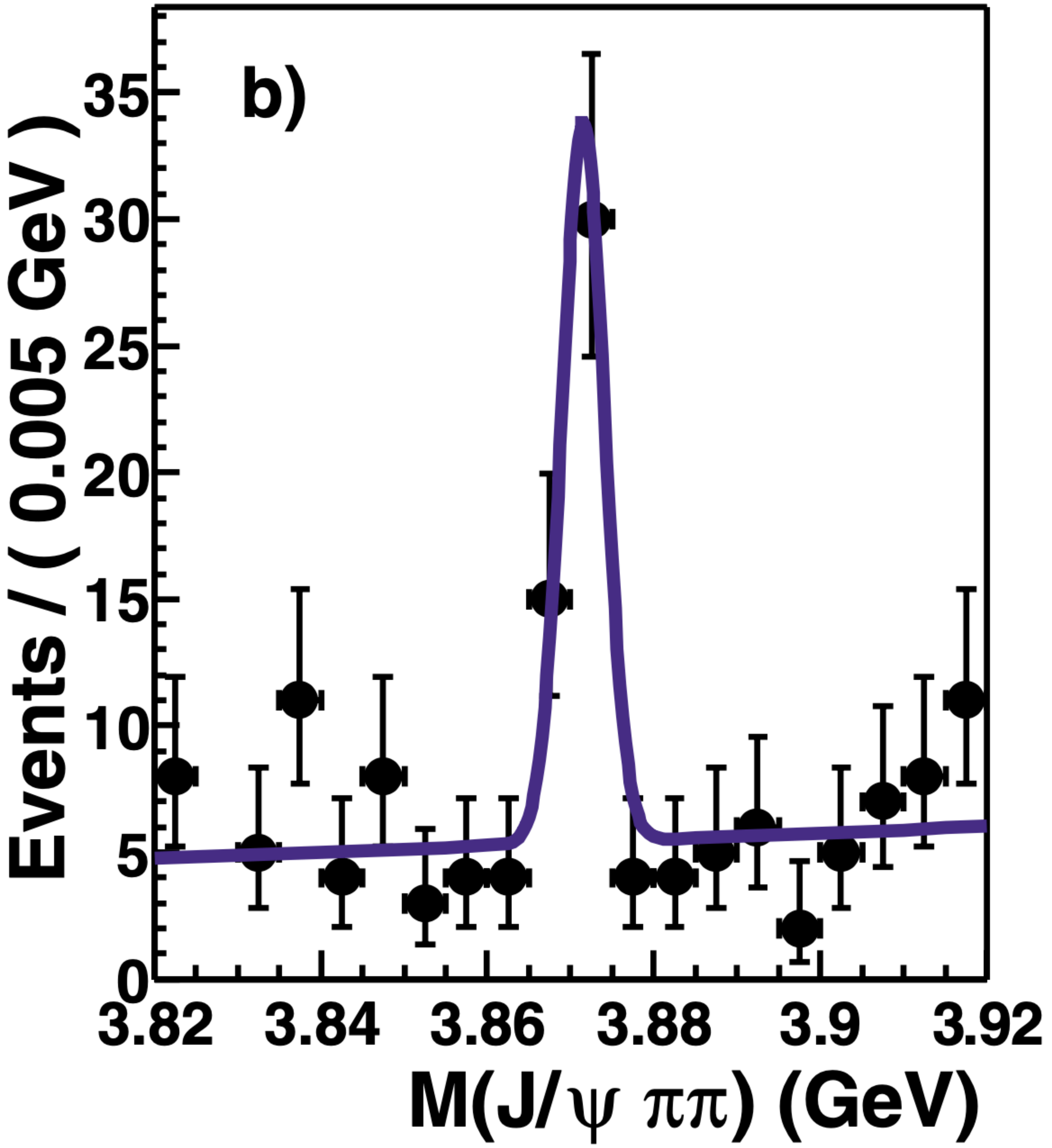
The **mass** lies **near** the **$D^0\bar{D}^{0*}$ threshold** ($M_{X(3872)}$ - $E_{Threshold} \lesssim \delta$), suggesting a possible molecular nature

The **loosely bound molecular nature** can explain the relatively **small width** (~1 MeV/c^2)[3]

Though, the relatively **large branching fraction** for the radiative transition **to hidden charm mesons** suggests an **admixture** of a conventional charmonium and a $D^0\bar{D}^{0*}$ molecule

BESIII is at the forefront of the X(3872) studies, thanks to its direct production mode(s) and clean leptonic environment

The BESIII collaboration found, in 2014[4], evidence for the Y(4230) → γX(3872) decay



[3] Phys. Lett. B **590**, 209–215 (2004)
[4] Phys. Rev. Lett. E **112**, 092001 (2014)

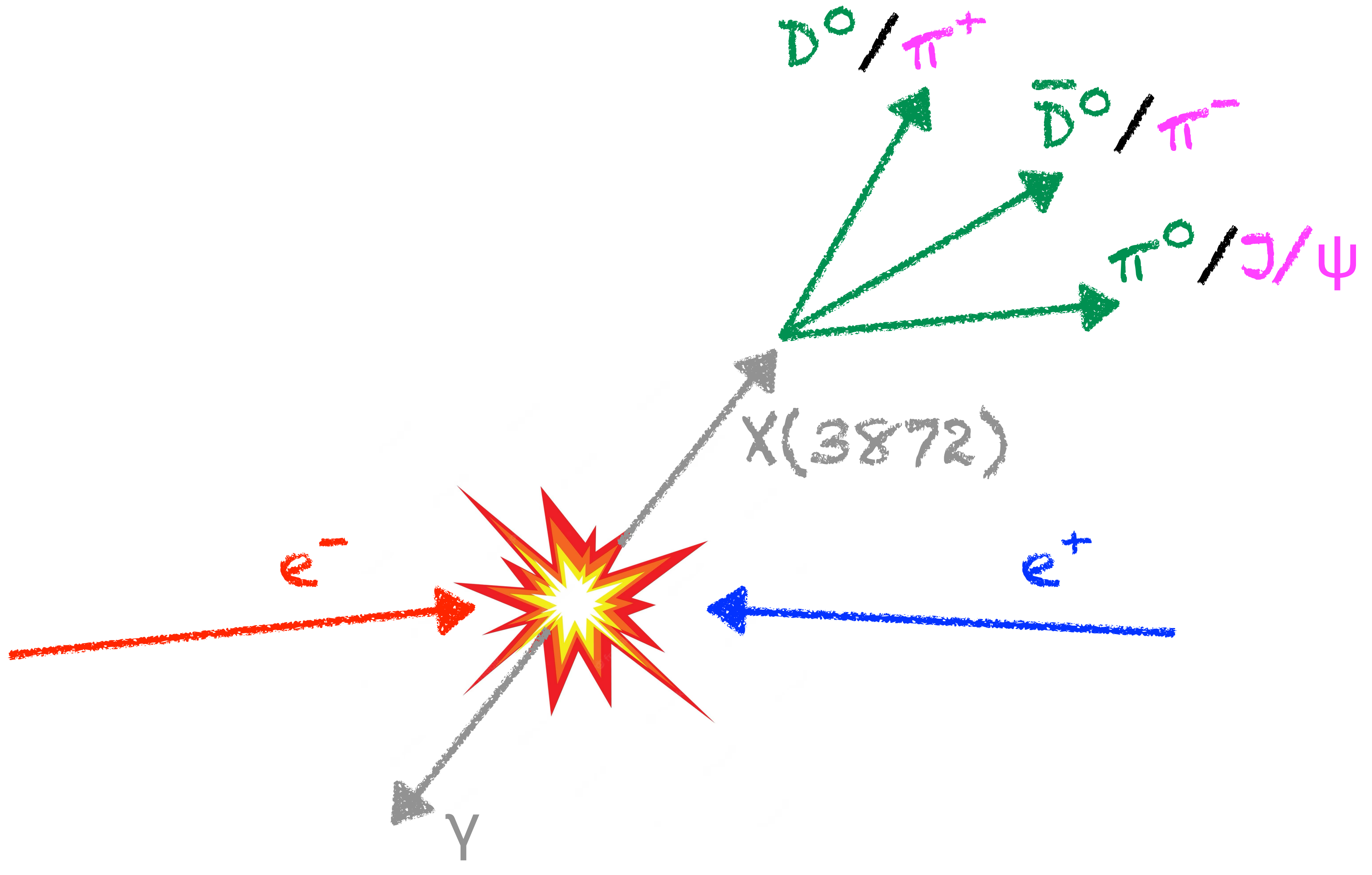
A coupled-channel analysis of the X(3872) line-shape with BESIII data

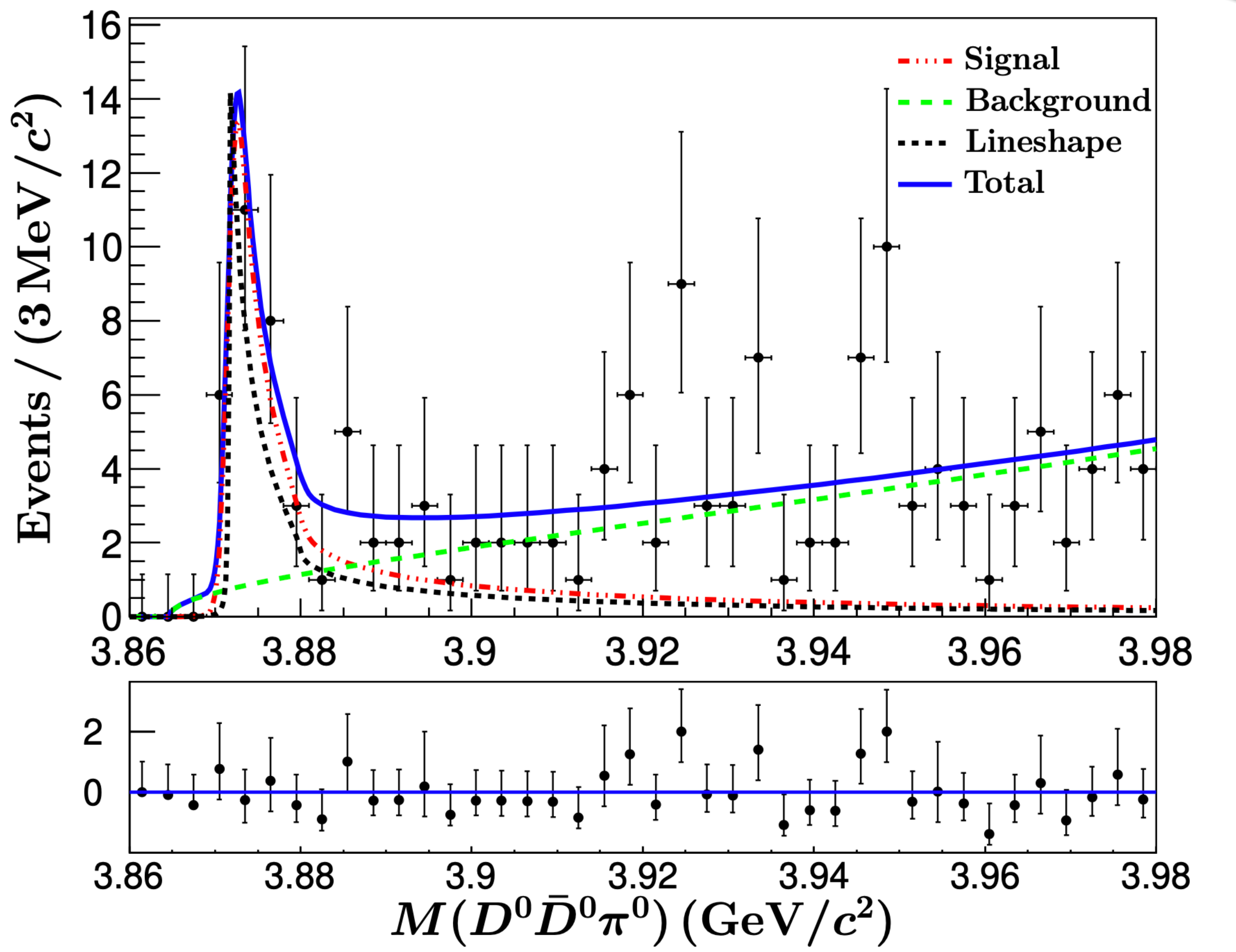
Phys. Rev. Lett. **132**, 151903 (2024)

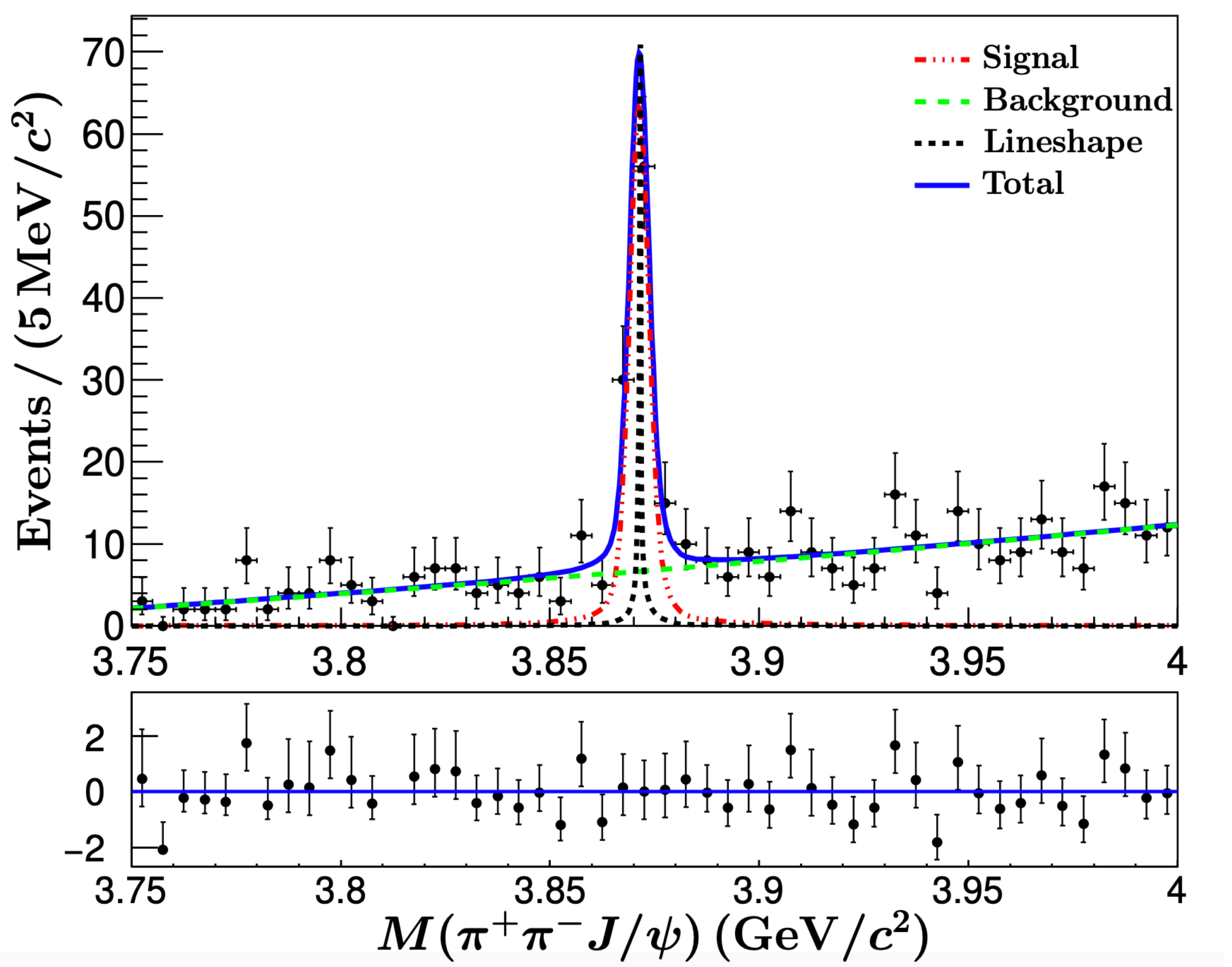
Using 11 energy points @$\sqrt{s}$ = **[4.178, 4.278] GeV**

Study of the **X(3872)** production **line-shape**

Simultaneous fit to the invariant masses of the two X(3872) decay channels ($D^0\bar{D}^0\pi^0$ e $\pi^+\pi^- J/\psi$)







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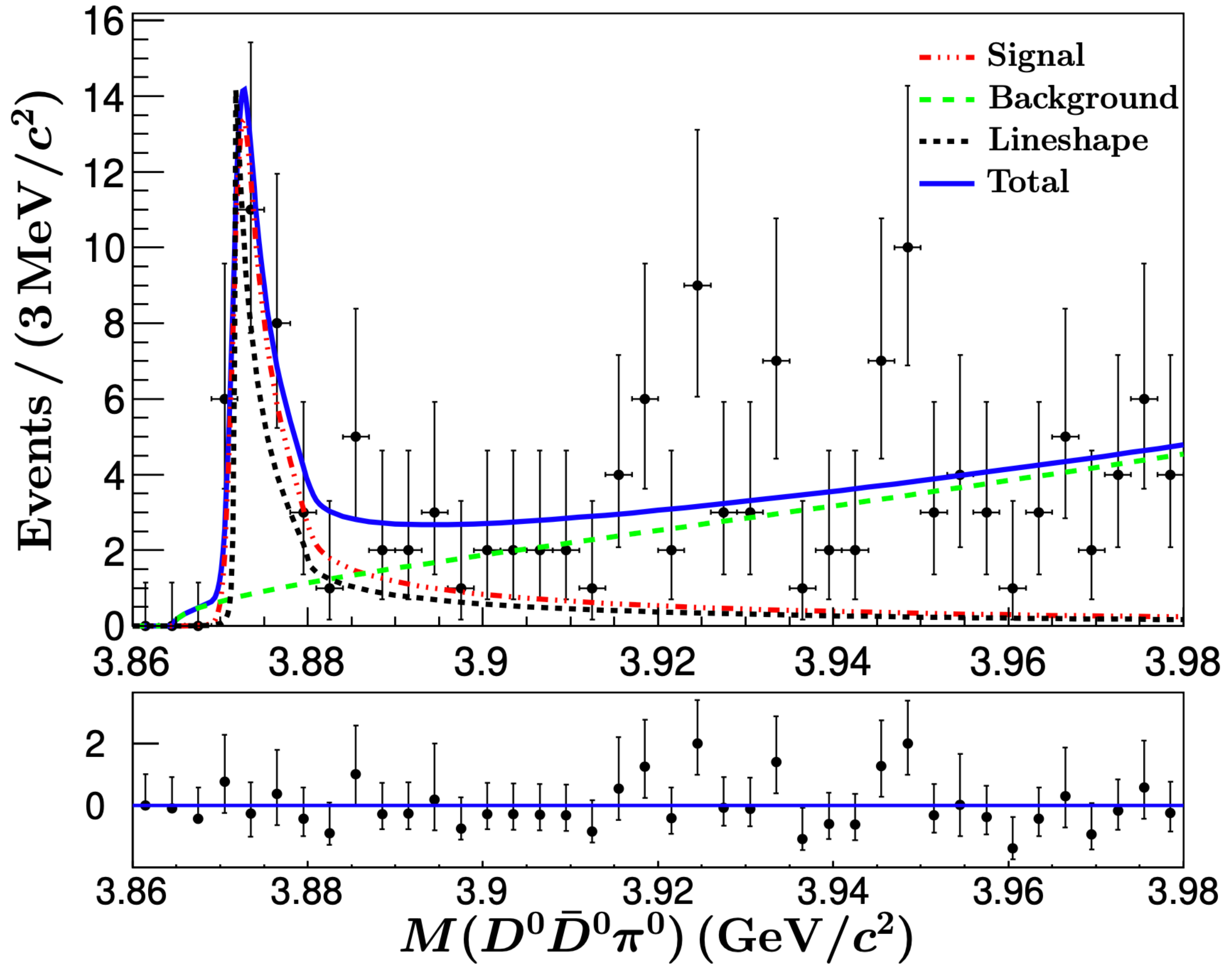
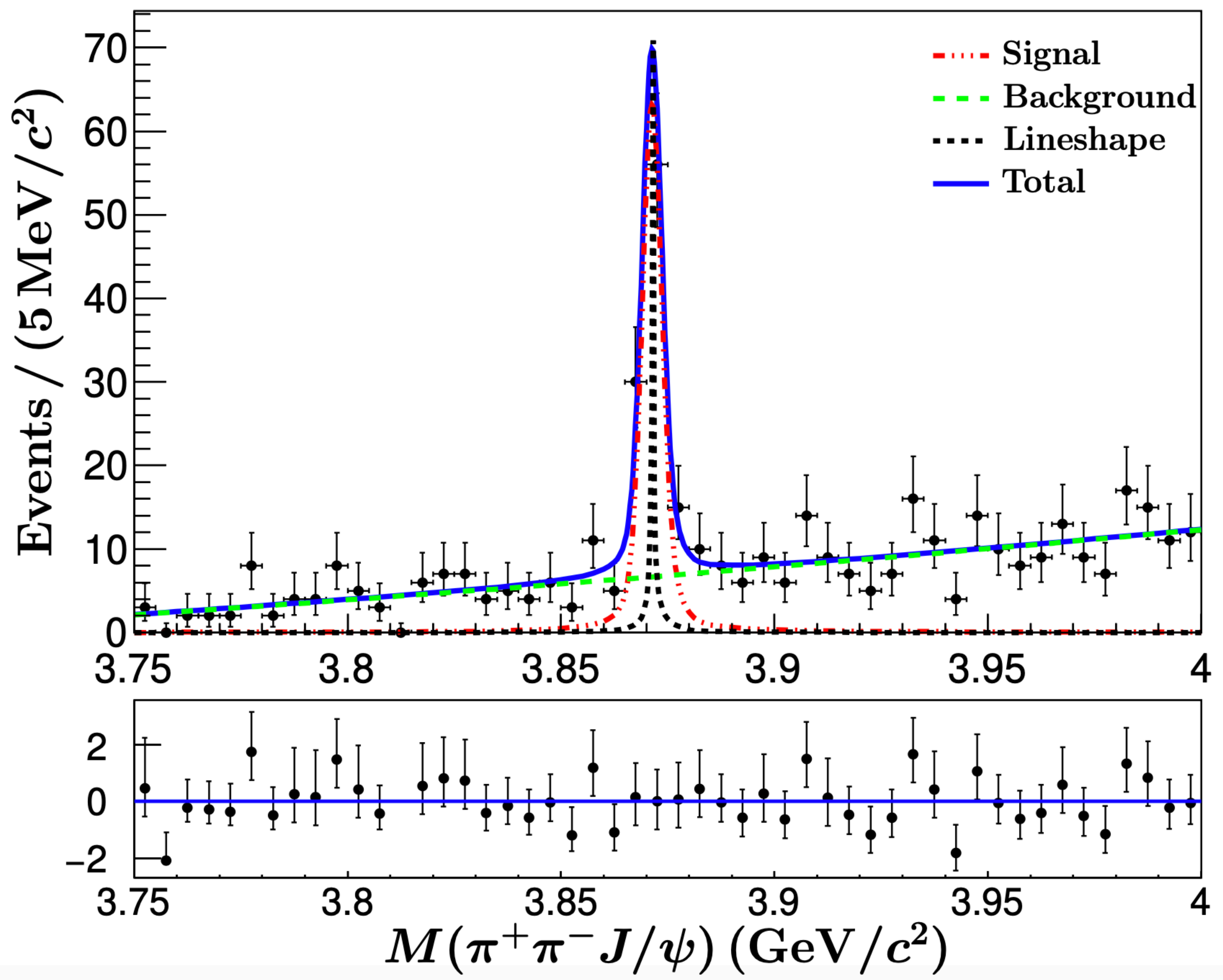
$$\frac{d\mathrm{Br}(D^0\bar{D}^0\pi^0)}{dE} = \mathcal{B}\frac{\mathrm{Br}(D^{*0}\to D^0\pi^0)\times g \times k_{\mathrm{eff}}(E)}{|D(E)|^2}$$

$$\frac{d\mathrm{Br}(\pi^+\pi^- J/\psi)}{dE} = \mathcal{B}\frac{\Gamma_{\pi^+\pi^- J/\psi}}{|D(E)|^2}$$

$$D(E) = E - E_X + \frac{1}{2}g\left[(\kappa_{\mathrm{eff}}(E) + ik_{\mathrm{eff}}(E)) + (\kappa^c_{\mathrm{eff}}(E) + ik^c_{\mathrm{eff}}(E))\right] + \frac{i}{2}\Gamma_0$$





[5] Phys. Rev. D **81**, 094028 (2010)

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$\mathcal{B}$ → Encapsulates X(3872) production terms

g → X(3872) - $D^*\bar{D}$ effective coupling constant

$\kappa_{\mathrm{eff}} + ik_{\mathrm{eff}}$ terms → Self-energy term, i.e., parametrisation of the coupling to the $D^*\bar{D}$ channels

Γ_0 → Amplitude of all decay channels, but $D^*\bar{D}$

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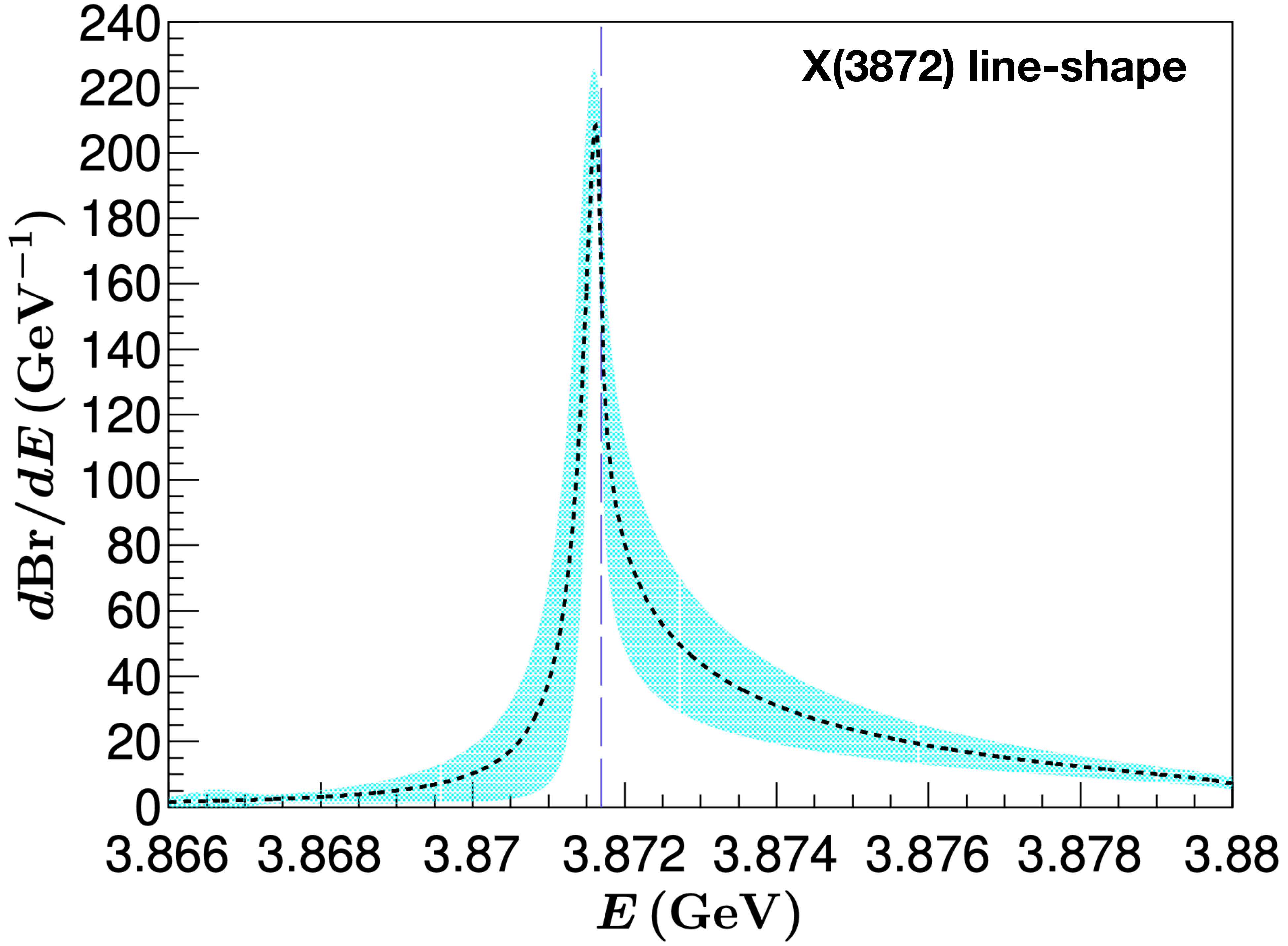

Parameters	g	Γ_0 (MeV)	M_X (MeV)
Fit results	0.16 ± 0.10	2.67 ± 1.77	3871.63 ± 0.13
Sum$_{\text{(Sys. Uncert.)}}$	$+1.12$ -0.11	$+8.01$ -0.82	$+0.06$ -0.05

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$$\left(-\sqrt{-2\left(E - E_R + \frac{i\Gamma_{D^{*0}}}{2}\right)} + \text{cost}\right)$$

Self-energy term, i.e., parametrisation of the coupling to the $D^*\bar{D}$ channels

Amplitude of all decay channels, but $D^*\bar{D}$

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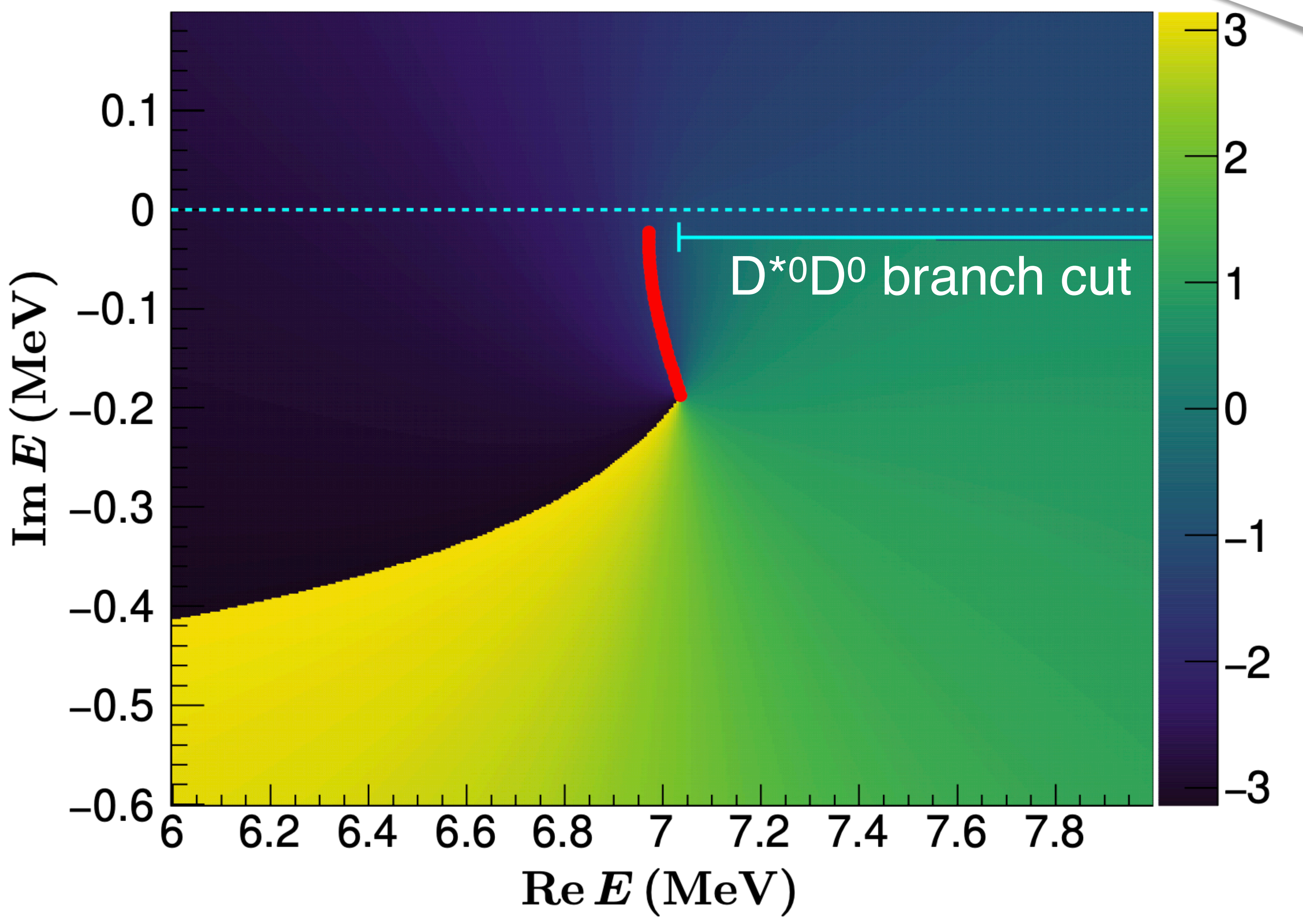
The $D^*\bar{D}$ term of the parametrisation identifies two Riemann sheets

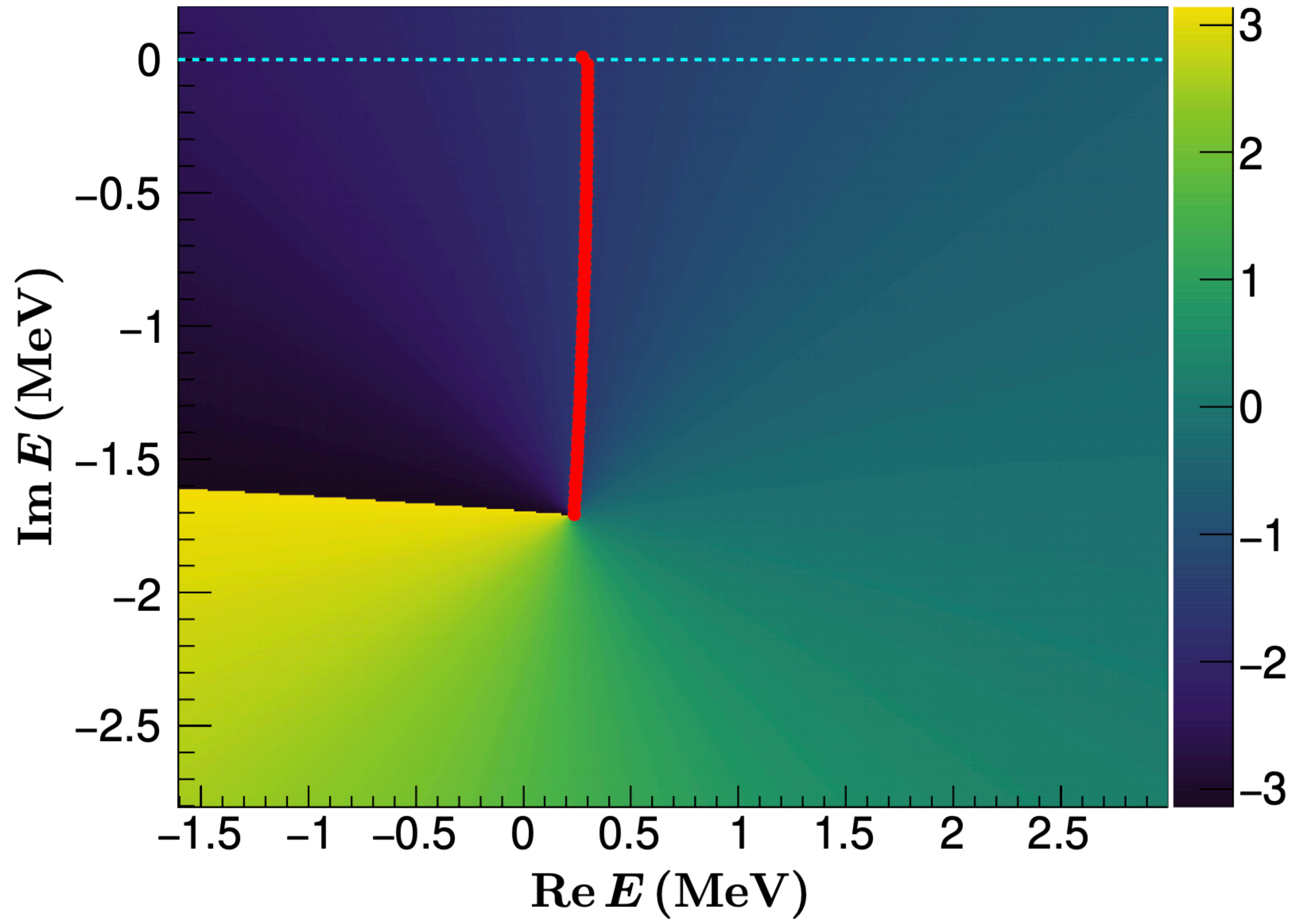
$$\mathrm{I}: \quad -g\sqrt{-2\left(E - E_R + \frac{i\Gamma_{D^{*0}}}{2}\right)} + i\Gamma_0$$

$$\mathrm{II}: \quad +g\sqrt{-2\left(E - E_R + \frac{i\Gamma_{D^{*0}}}{2}\right)} + i\Gamma_0$$

"***Switching off***" Γ_0, all the decay channels, but the $D^*\bar{D}$, disappear, showing that the E_I pole is the nearest to the $D^{*0}\bar{D}^0$ threshold

$E_I = (7.04 \pm 0.15^{+0.07}_{-0.08}) + i(-0.19 \pm 0.08^{+0.14}_{-0.19})$ MeV





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$$D(k) = \frac{1}{a} - ik + \frac{r_e}{2}k^2 + \mathcal{O}(k^3)$$

$$a = -\frac{2(1-Z)}{(2-Z)}\frac{1}{\gamma} + \mathcal{O}(\beta^{-1})$$

$$r_e = -\frac{Z}{1-Z}\frac{1}{\gamma} + \mathcal{O}(\beta^{-1})$$

BONUS

Effective Range Expansion parameters are also estimated (a and r_e found to be negative) and a **Z = 0.18**$^{+0.20}_{-0.23}$ is found (with big uncertainties!), suggesting a **similar compositeness to the deuteron**

"This is qualitatively different from a bona fide loosely bound molecule, for which Z = 0 and $r_0 > 0$"

PHYS. REV. D **105**, L031503 (2022)

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PHYS. REV. D **105**, L031503 (2022)

PS Calculating compositeness from Ref. [6]
$\bar{X}_A = 0.88 \pm 0.14$

[6] Eur. Phys. J. A **57:101** (2021)

The Charged Z_c States

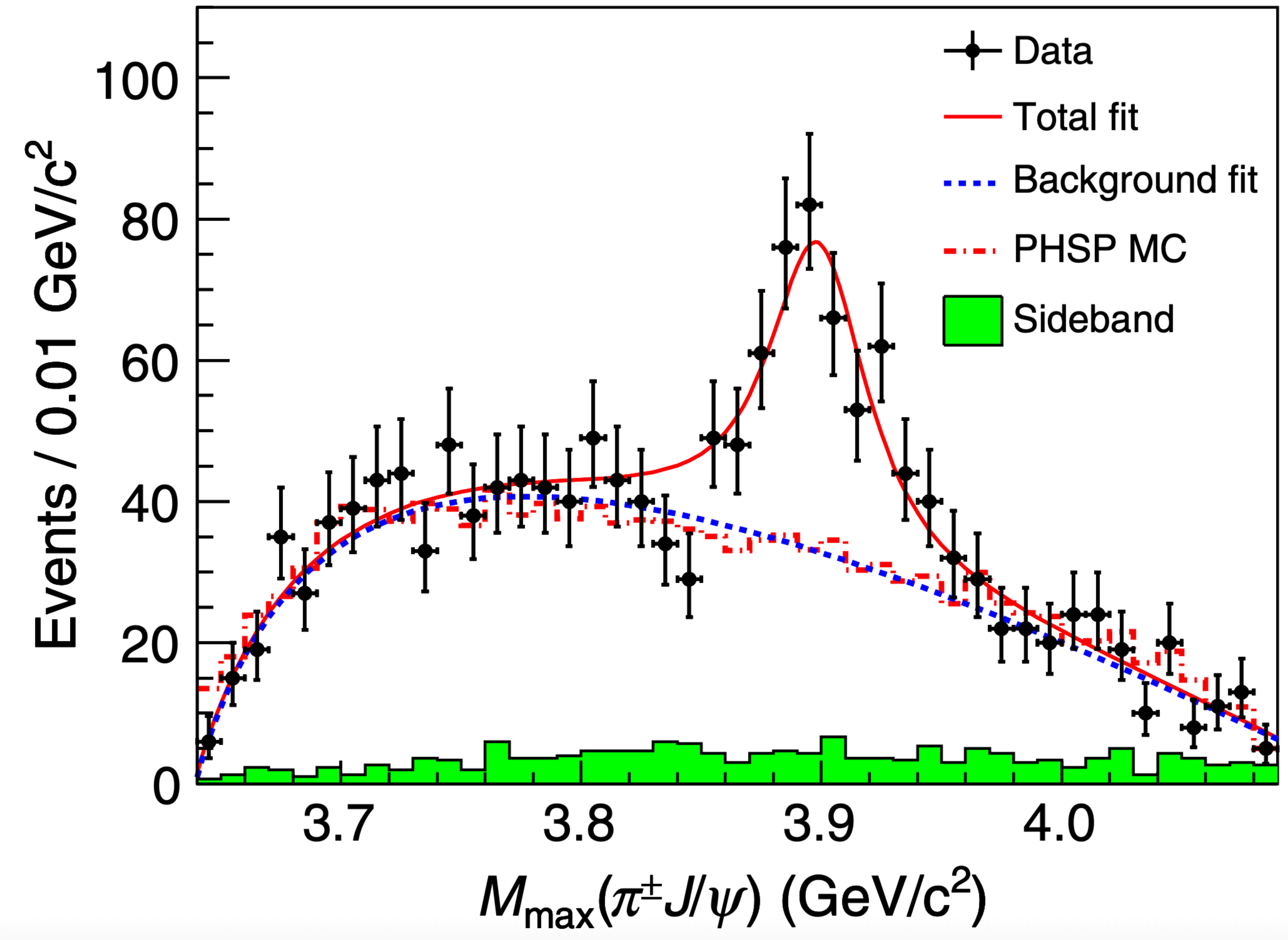
Charged structures seem to hint at a completely **exotic nature**, as they require a minimum quark content of at least four

Z_c(3900) ($T_{\bar{c}c1}$(3900)) has been **observed** in the invariant mass distribution of (**$\pi J/\psi$**) by the BESIII[7] and Belle[8] experiments and confirmed by the CLEO-c[9] collaboration

Strongly **correlated** with the **ψ(4230)**[10]

Z_c(3900) spin-parity $J^{P(C)}$ (I^G) = 1^{++} (1^+) spin-parity of was established by BESIII in an amplitude analysis[11]

Its **mass** is **close** to the **$D^*\bar{D}$ threshold**, which is also its dominant decay mode[12]



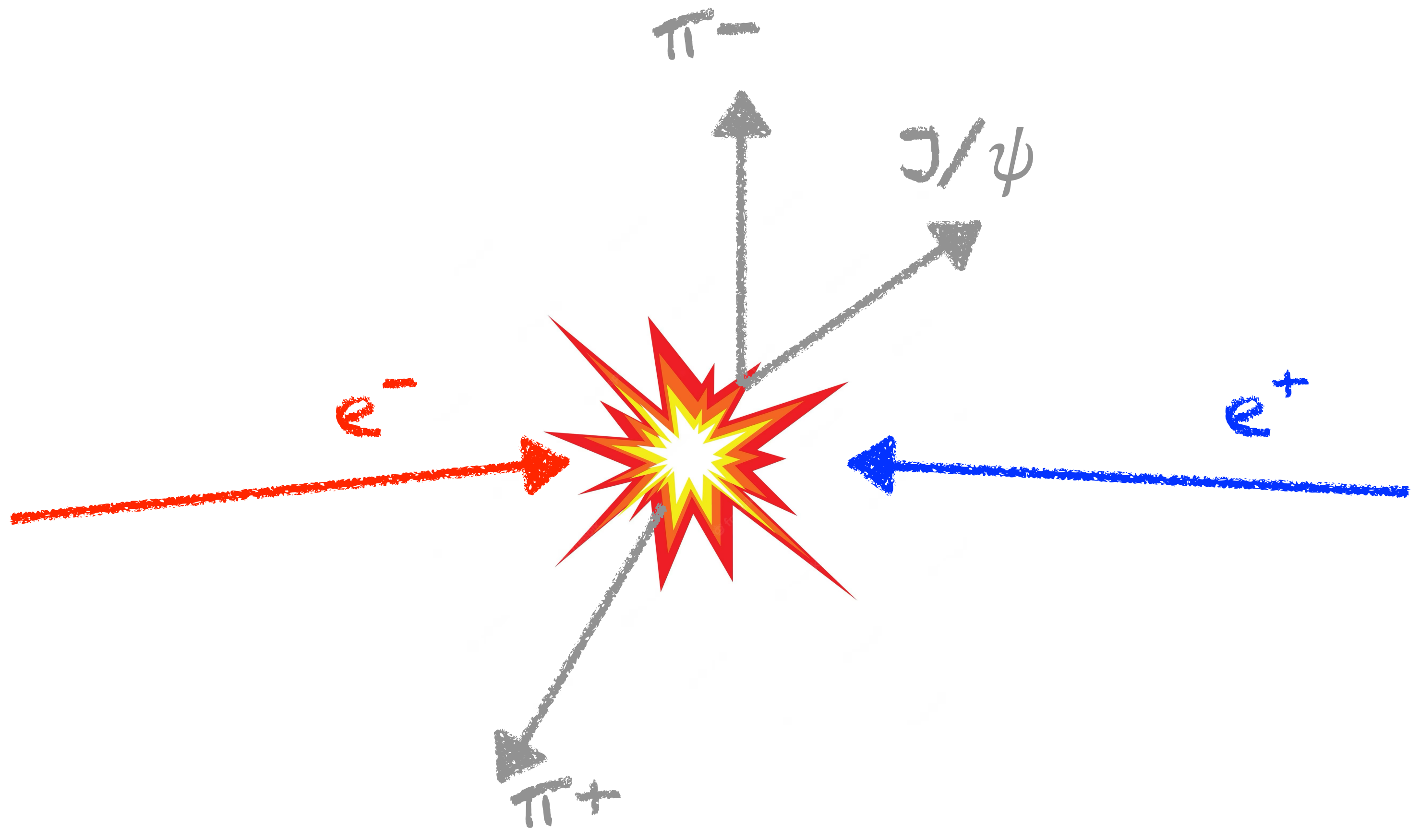
[7] Phys. Rev. Lett. **110** 252001 (2013)
[8] Phys. Rev. Lett. **110** 252002 (2013)
[9] Phys. Lett. B **727** (2013) 366
[10] Phys. Rev. D **102**, 012009 (2020)
[11] Phys. Rev. Lett. **119**, 072001 (2017)
[12] Phys. Rev. Lett. **112**, 022001 (2014)

PWA onto $e^+e^- \to \pi^+\pi^- J/\psi$

Phys. Rev. D **112**, 092013 (2025)

Using 17 energy points @$\sqrt{s}$ **= [4.127, 4.358] GeV**

Partial Wave Analysis (**PWA**) of the **$e^+e^- \to \pi^+\pi^- J/\psi$ channel** with a double objective (1) **cross sections** of $(\pi^+\pi^-)/(\pi J/\psi)$ **subprocesses** and (2) **$(M, \Gamma)_{Z_c}$**



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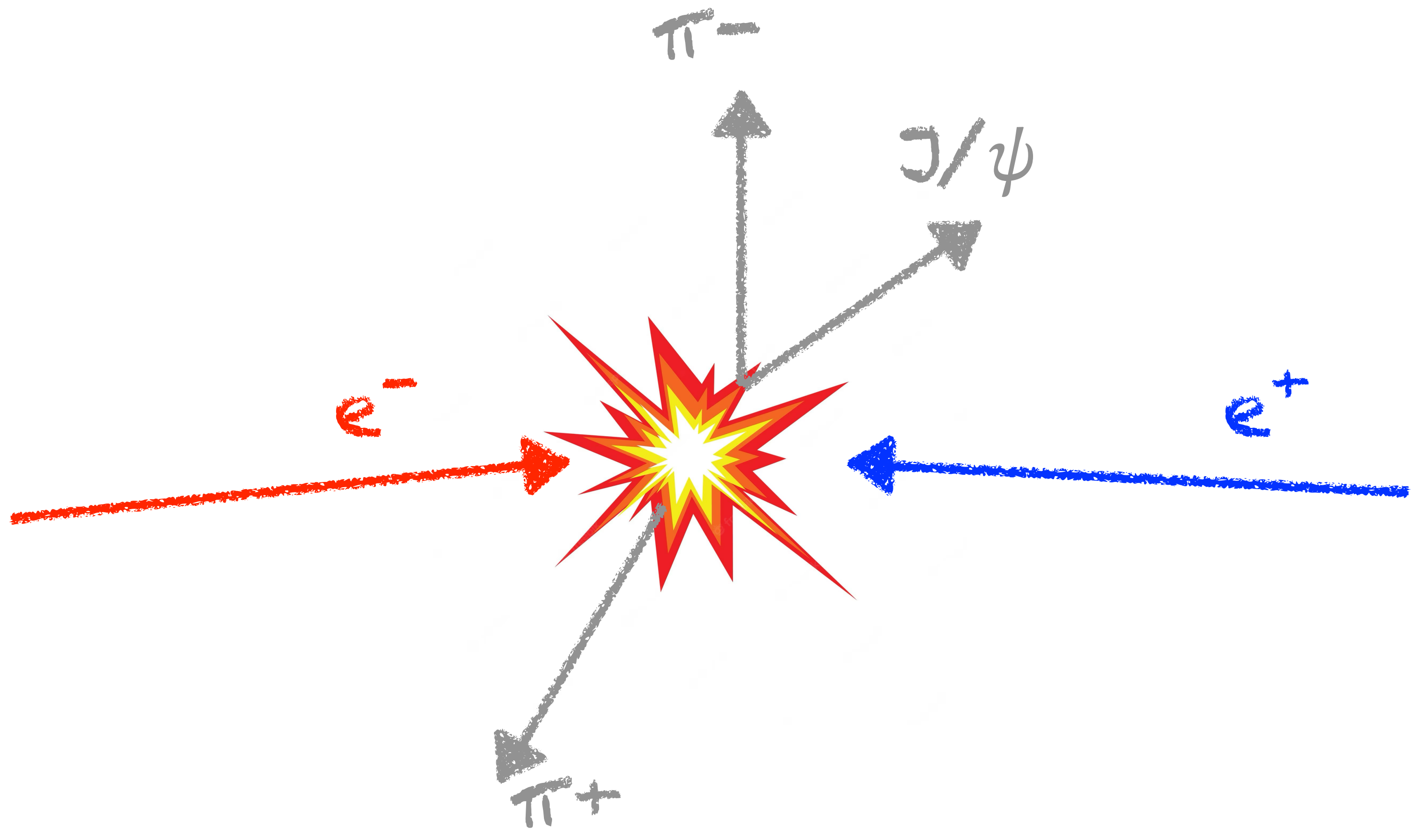
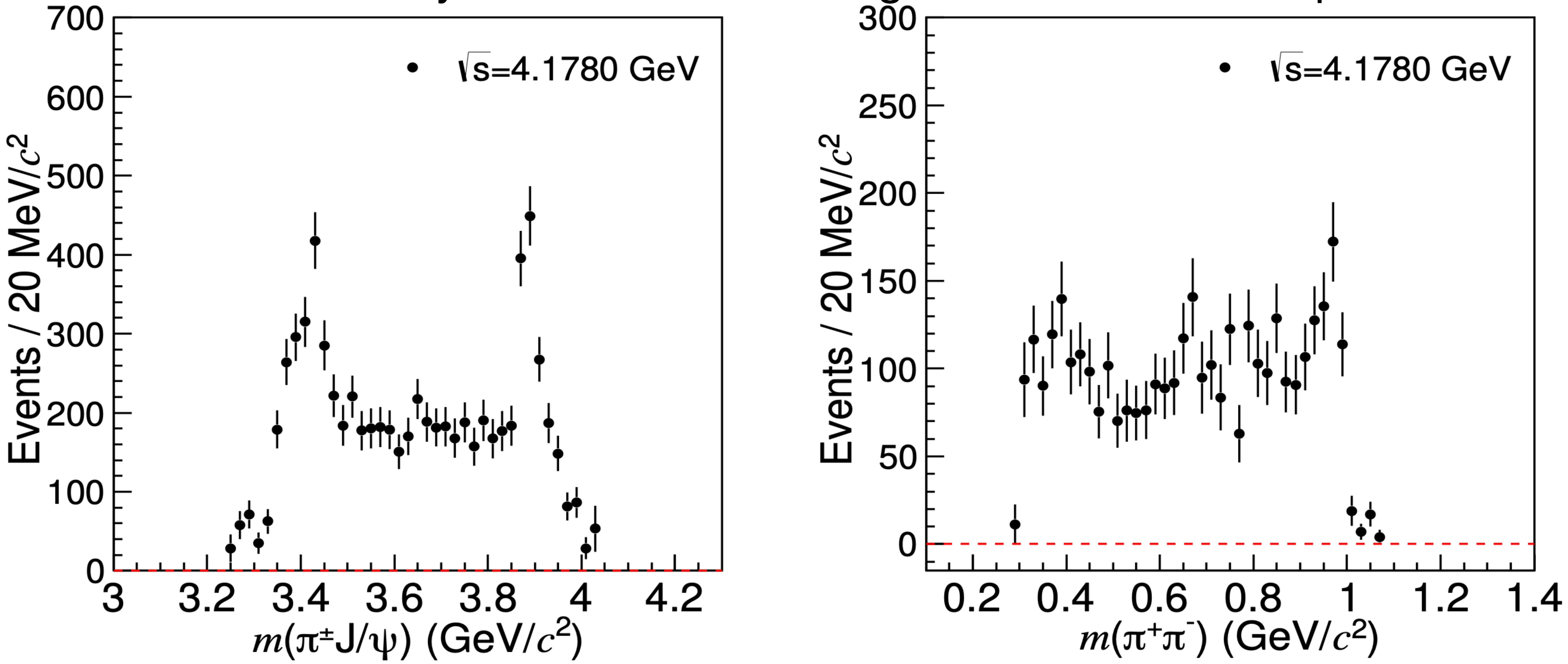


Efficiency corrected and background* subtracted spectra



[*] Estimated from J/ψ sidebands

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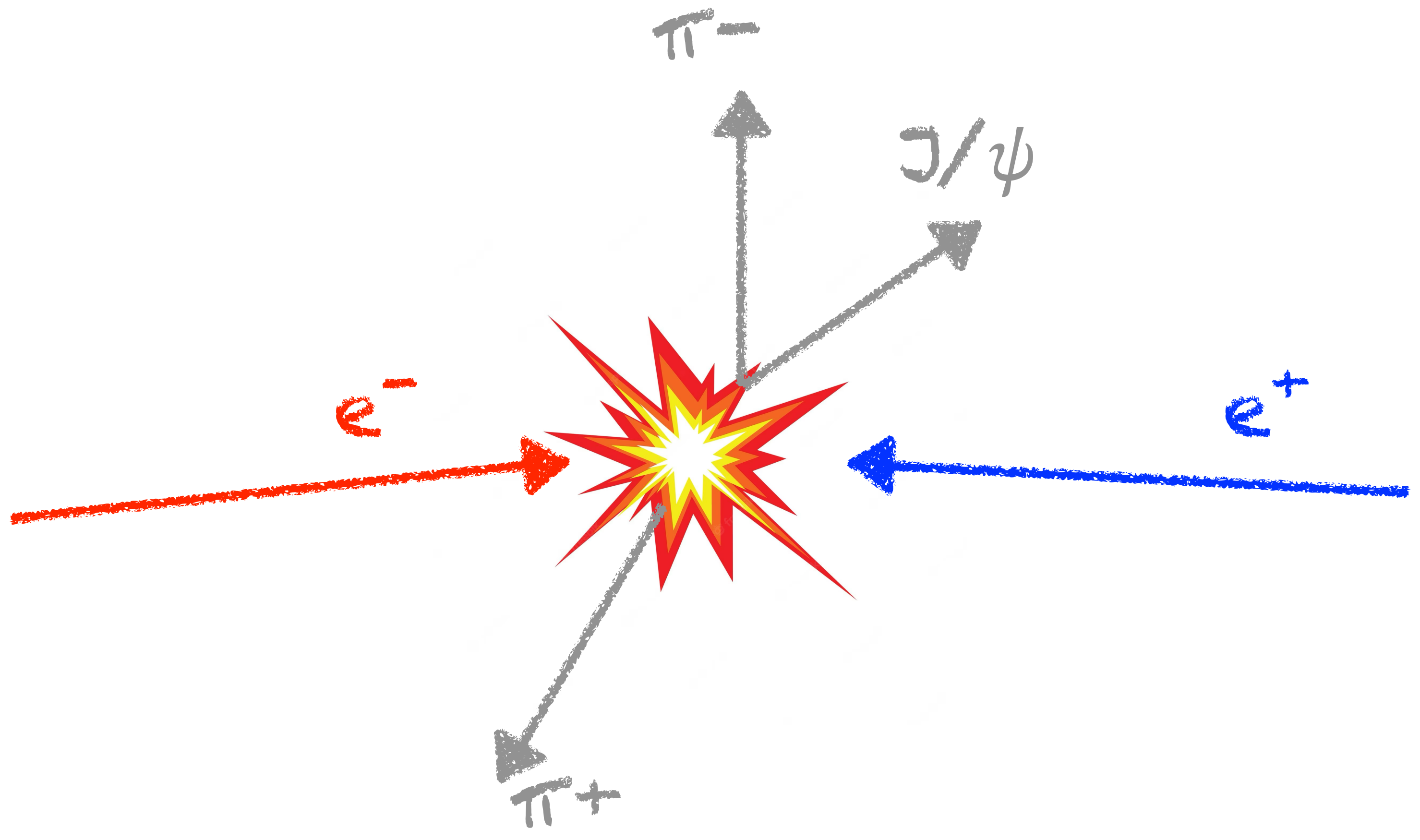
The parametrisation follows **two approaches**, given the f_2**(1270)**$^{(L,\,S)\,=\,(1,\,0)}$ and Z_c**(3900)** as **Breit-Wigners**:

- the f_0**(980)** is described by a **Flatté**, and the f_0**(500)** and f_0**(1370)** by **Breit-Wigners**
- the **$(\pi^+\pi^-)_{S\text{-Wave}}$** is modelled with the **K-matrix** method

(No PHSP and Z_c(4020))



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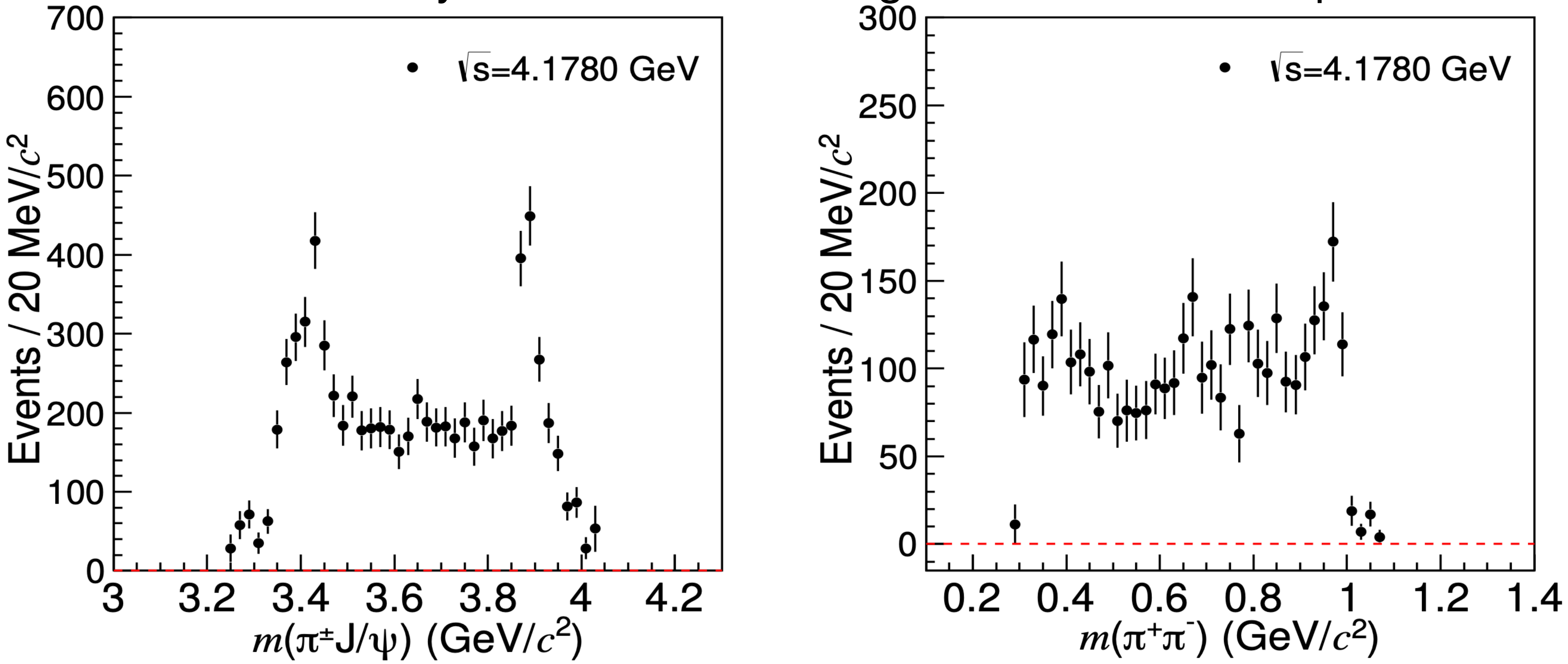

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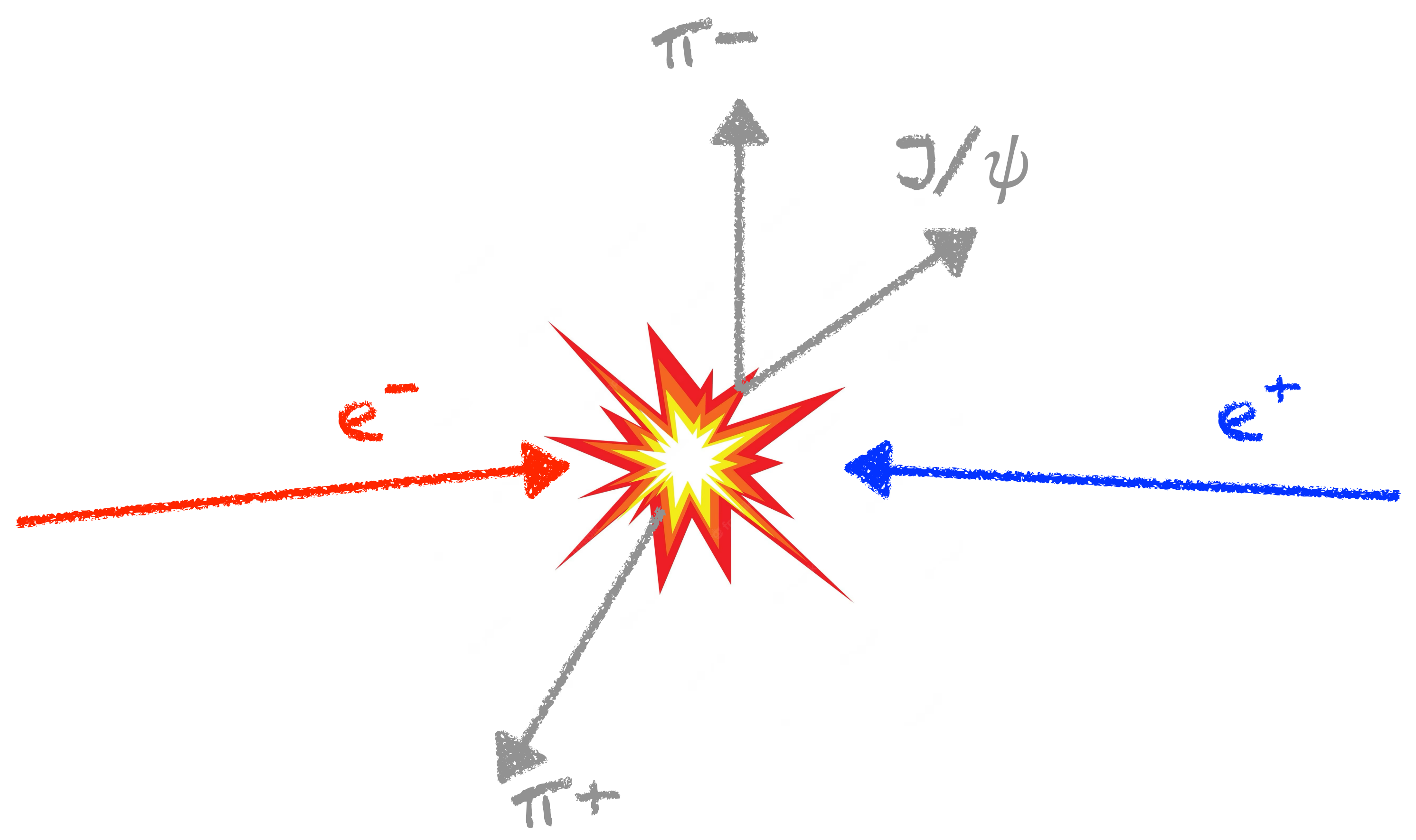

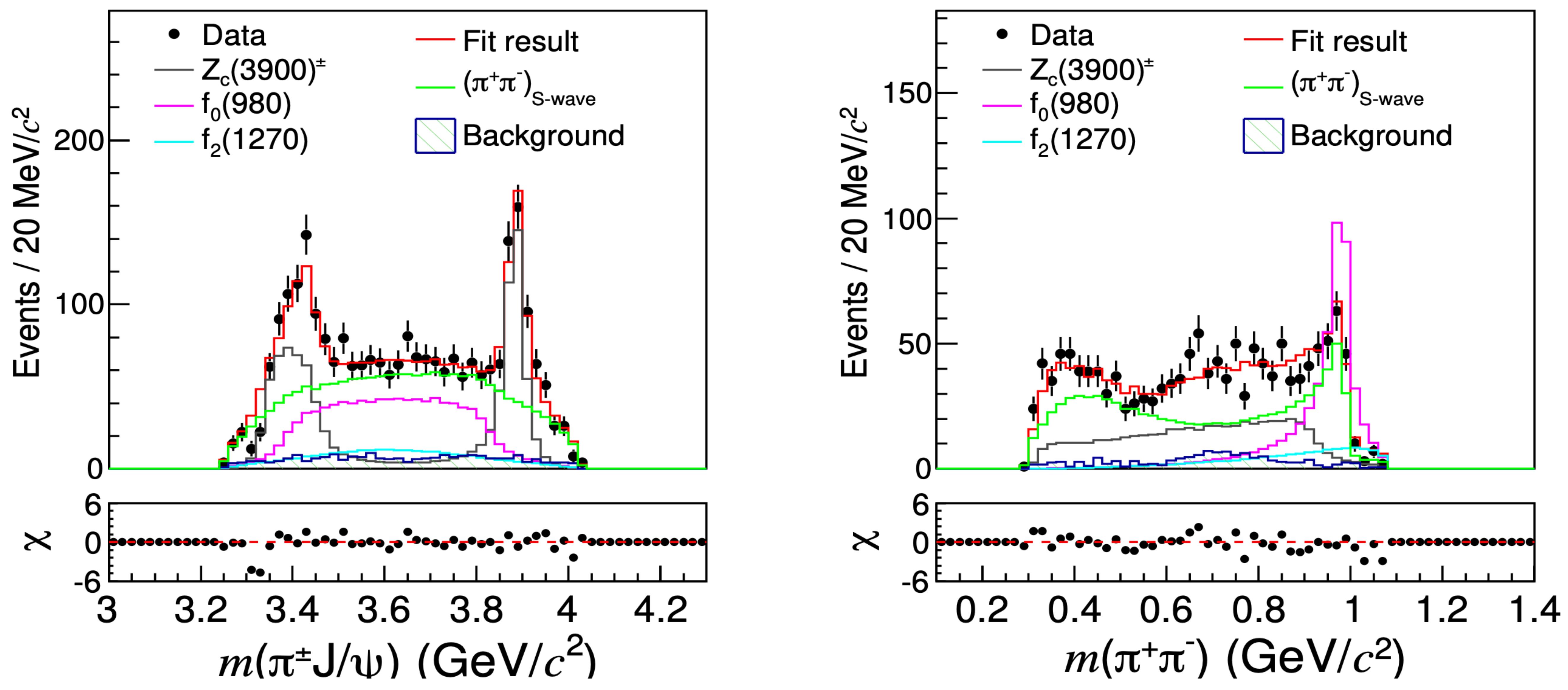

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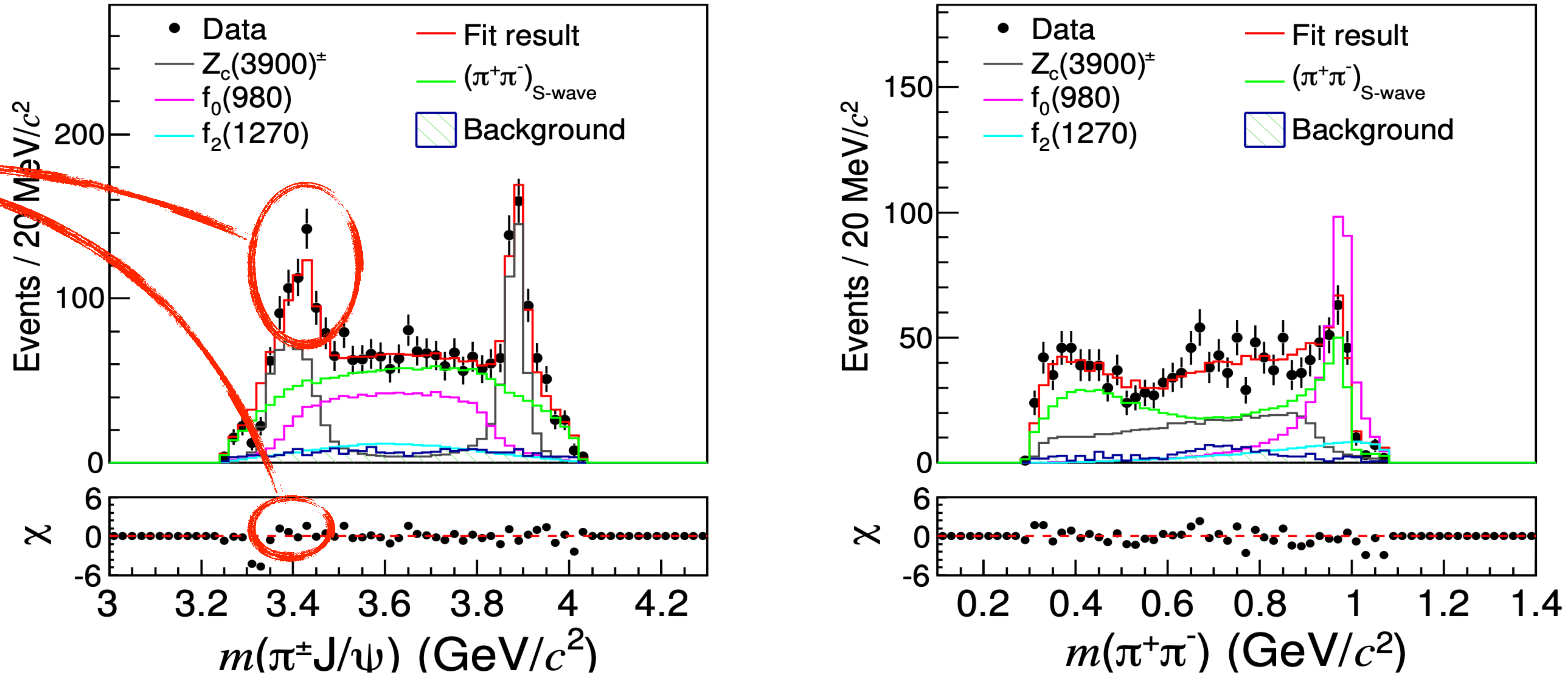
Small discrepancy around the mass region around of 3.4 GeV/c^2, where one expect the $Z_c(3900)$ reflection



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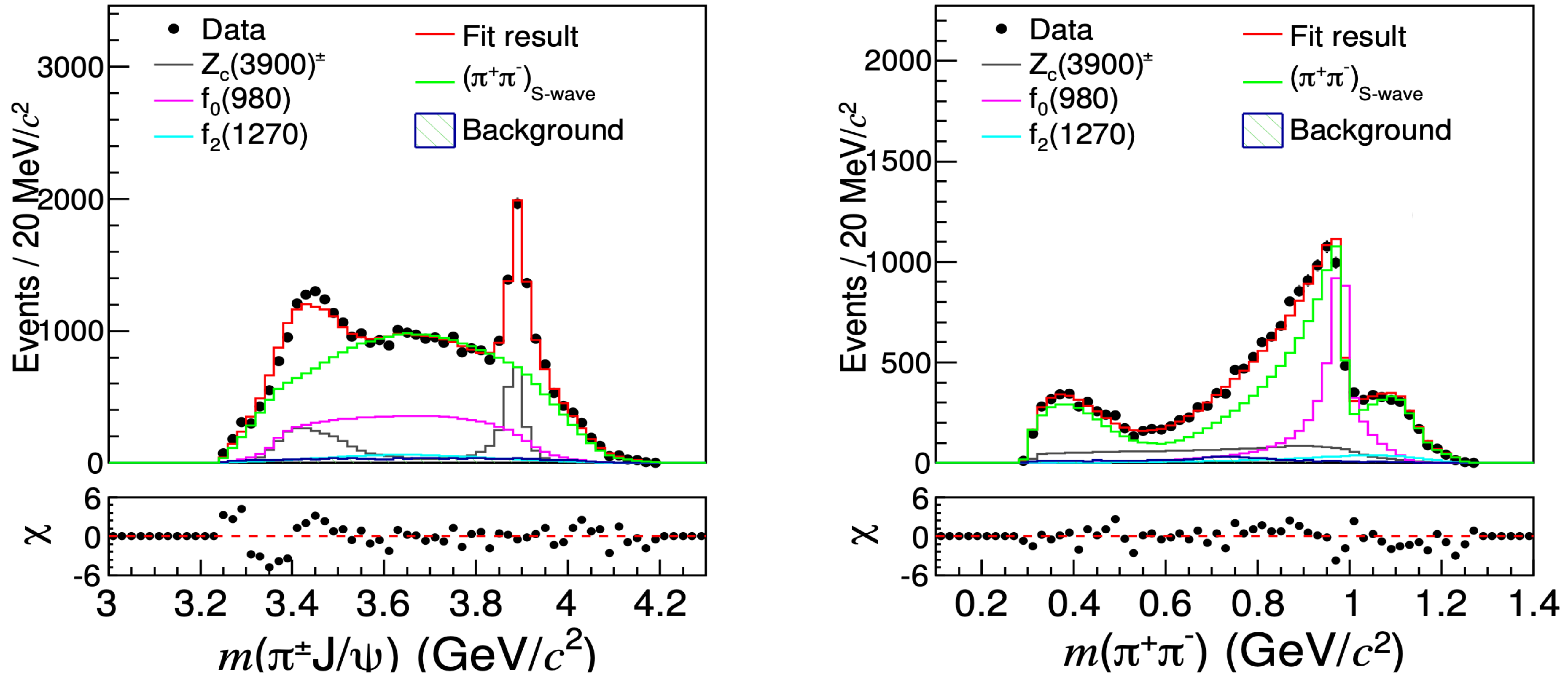
Fitting results for all data samples



PWA onto $e^+e^- \to \pi^+\pi^- J/\psi$

Phys. Rev. D **112**, 092013 (2025)

Using 17 energy points @$\sqrt{s}$ **= [4.127, 4.358] GeV**

Partial Wave Analysis (**PWA**) of the **$e^+e^- \to \pi^+\pi^- J/\psi$ channel** with a double objective (1) **cross sections** of $(\pi^+\pi^-)/(\pi J/\psi)$ **subprocesses** and (2) **$(M, \Gamma)_{Z_c}$**

The parametrisation follows **two approaches**, given the f_2**(1270)** and Z_c**(3900)** as **Breit-Wigners**:

- the f_0**(980)** is described by a **Flatté**, and the f_0**(500)** and f_0**(1370)** by **Breit-Wigners**
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Four simultaneous fits to four adjacent energy points are used to obtain the parameters of $Z_c(3900)^\pm$

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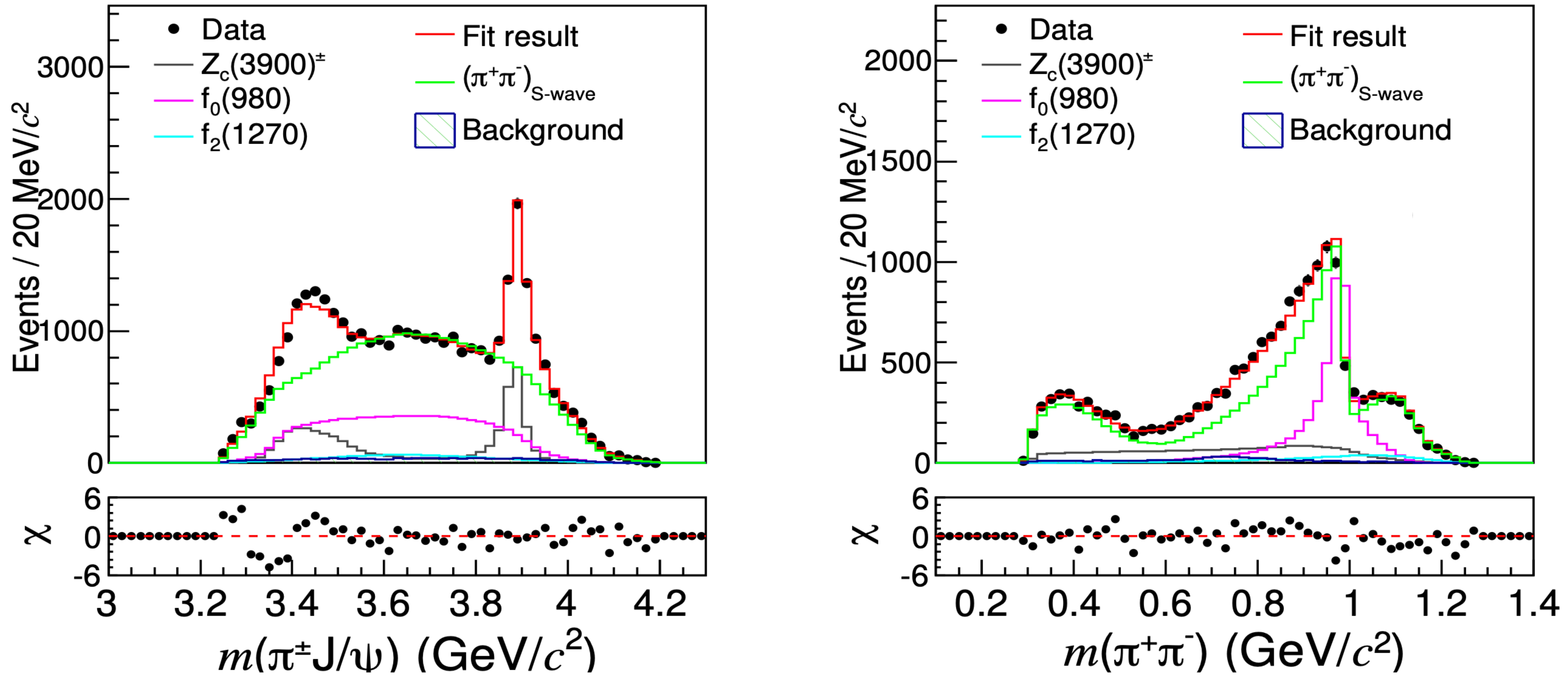

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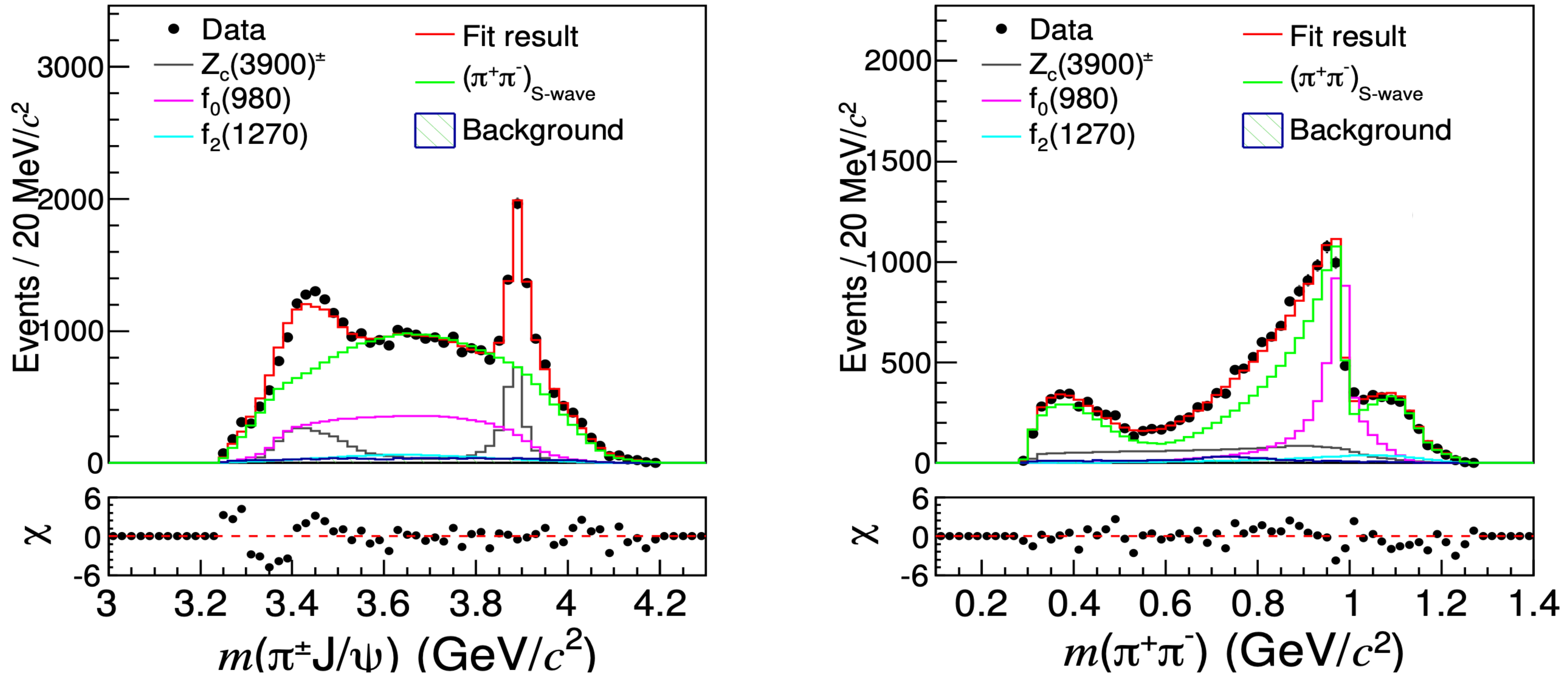
Sample	M (MeV/c^2)	Γ (MeV)
$4.1567 - 4.1989$	3883.5 ± 1.6	38.6 ± 3.6
$4.2091 - 4.2357$	3884.0 ± 1.0	37.8 ± 1.6
$4.2438 - 4.2776$	3884.9 ± 1.8	34.2 ± 3.3
$4.2866 - 4.3583$	3890.0 ± 2.3	36.1 ± 4.2
Average	$3884.6 \pm 0.7 \pm 3.3$	$37.2 \pm 1.3 \pm 6.6$

Fitting results for all data samples



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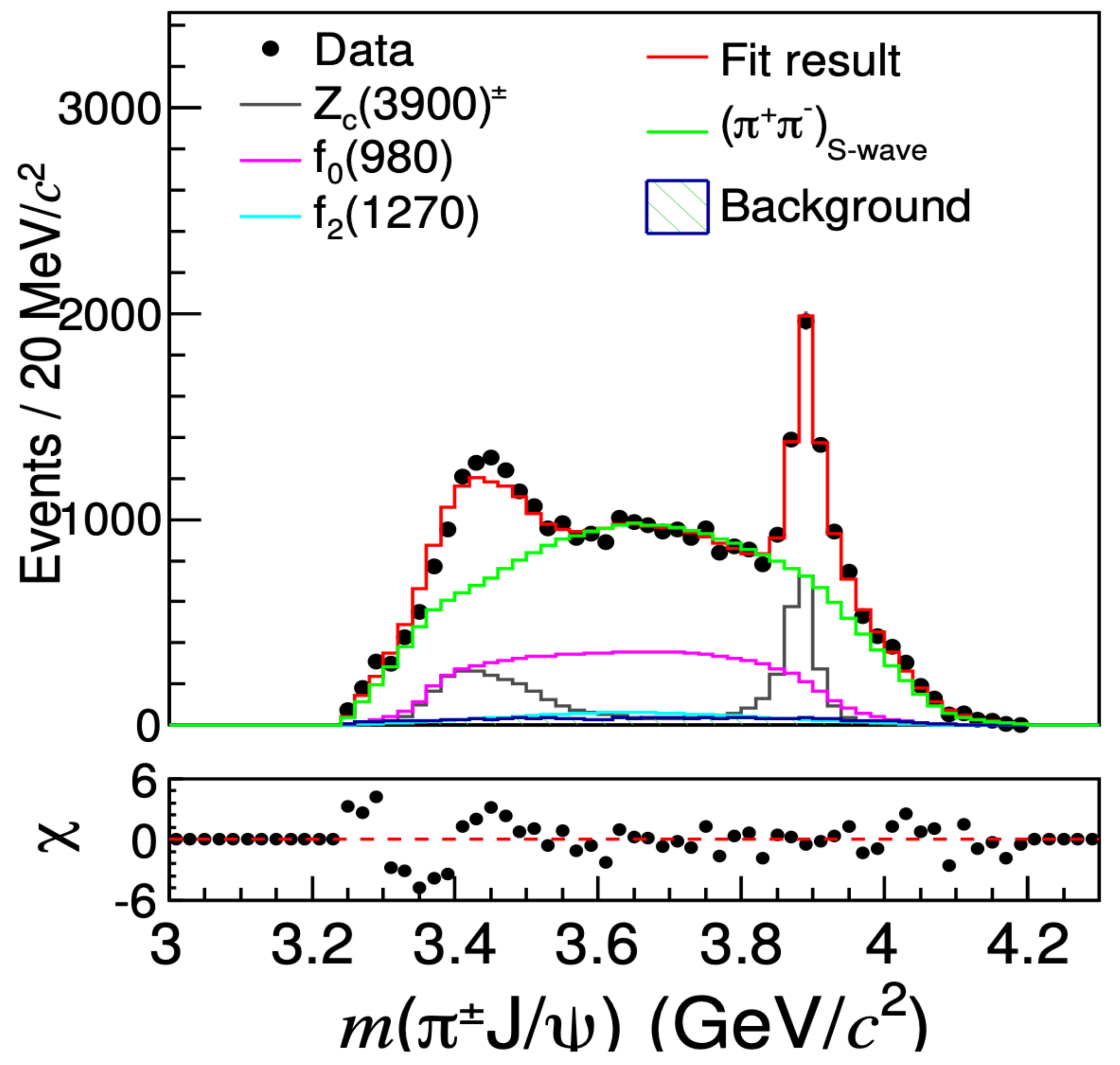
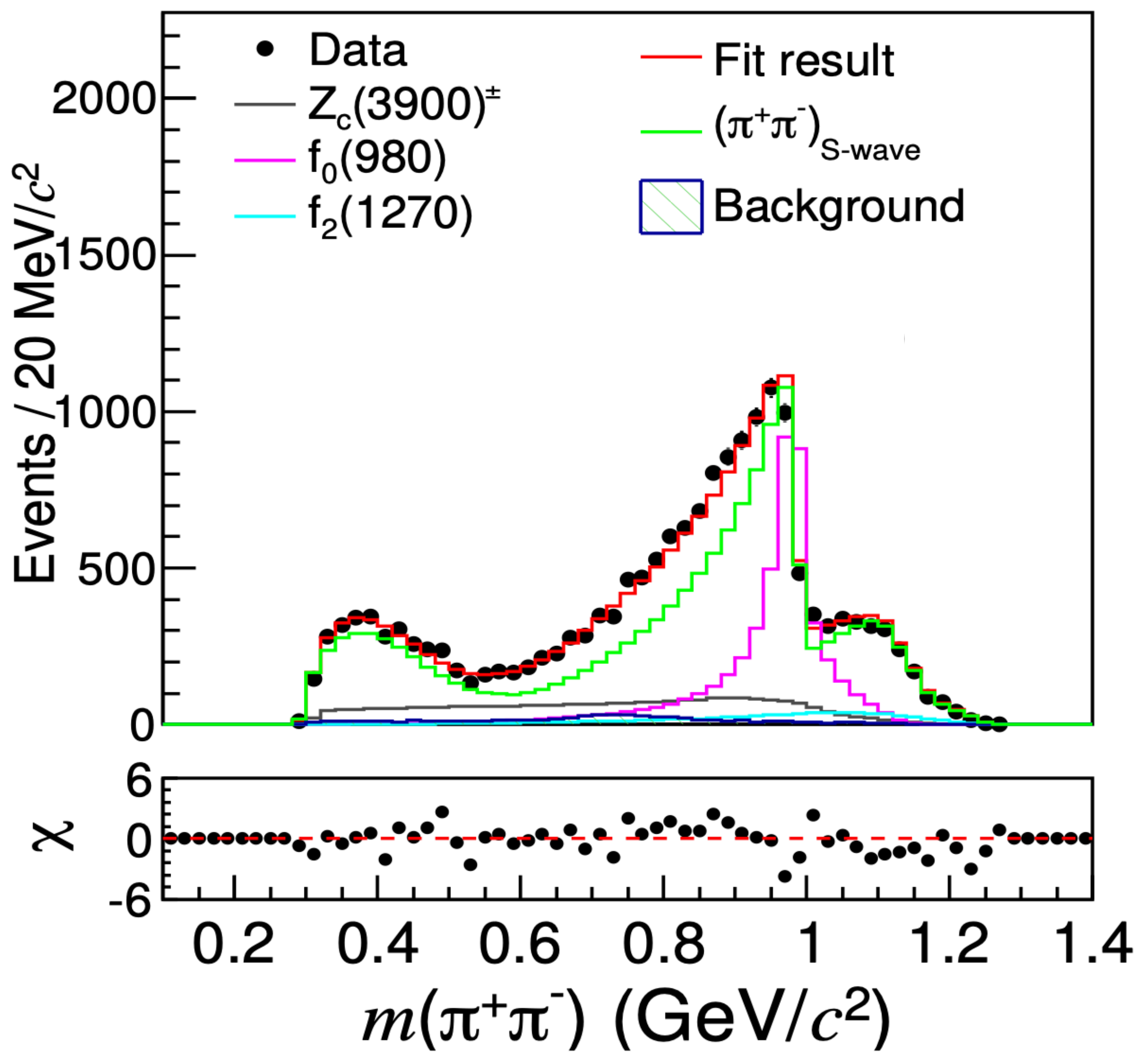
Systematic uncertainty

Fitting results for all data samples





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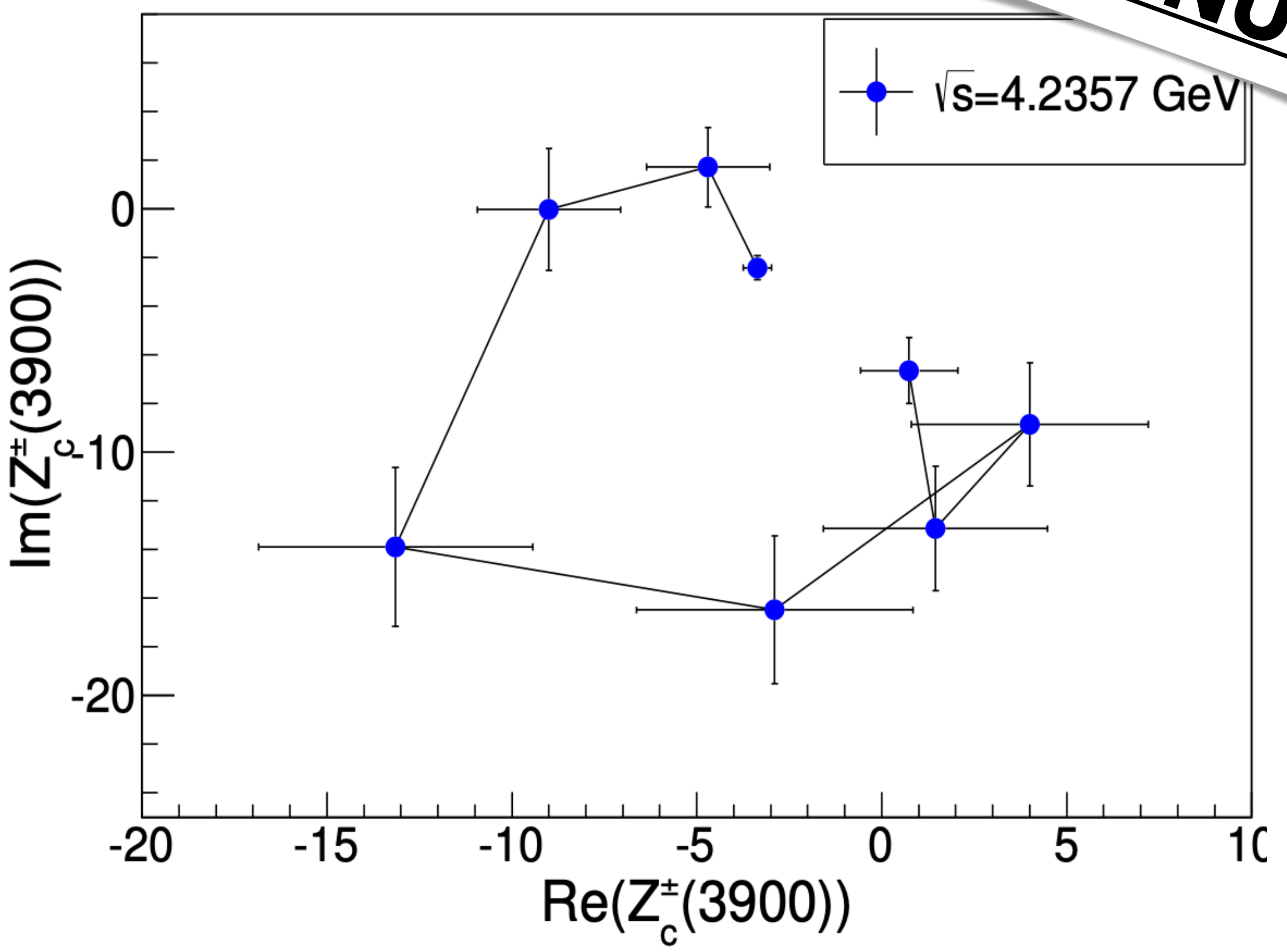
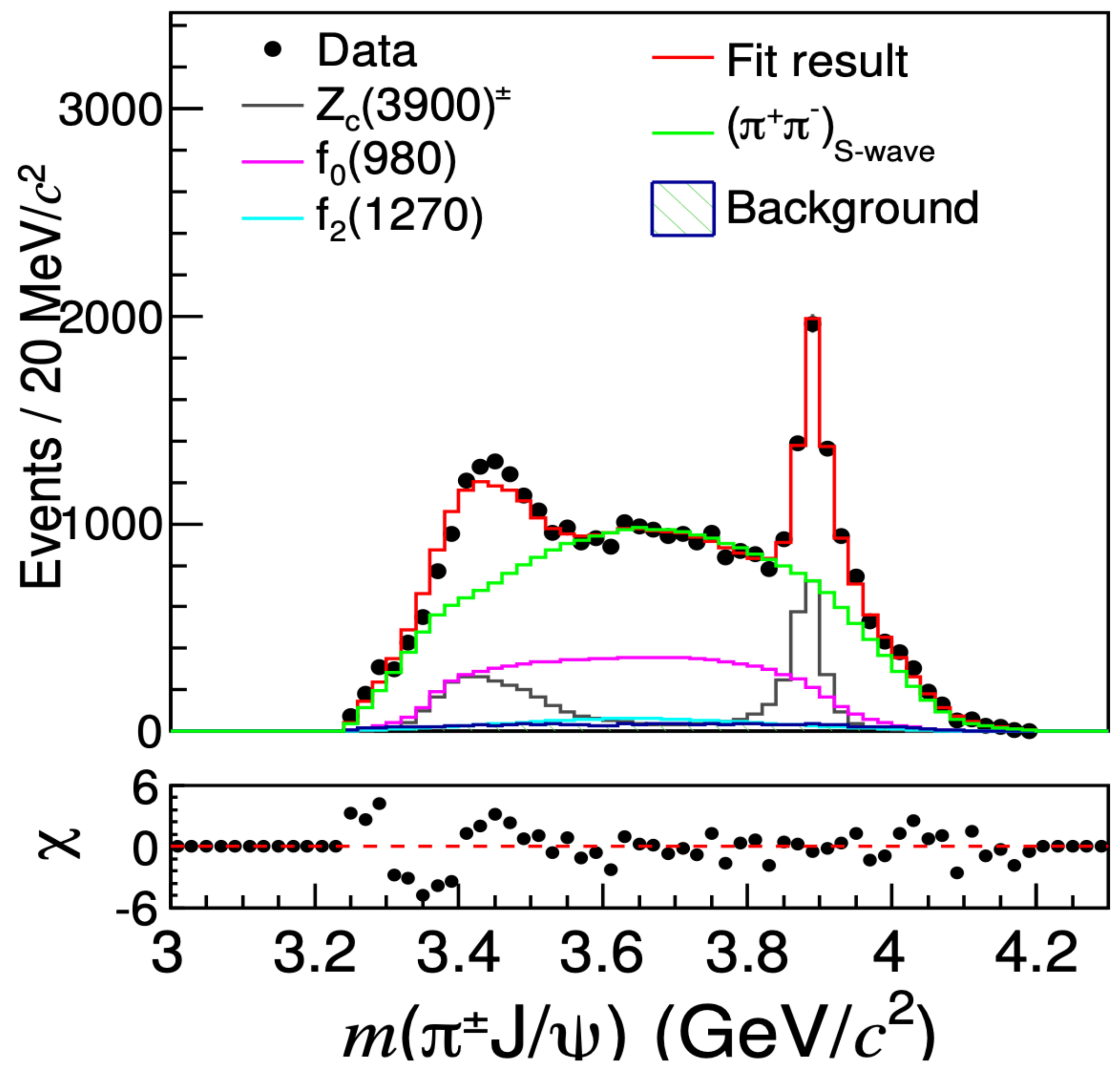
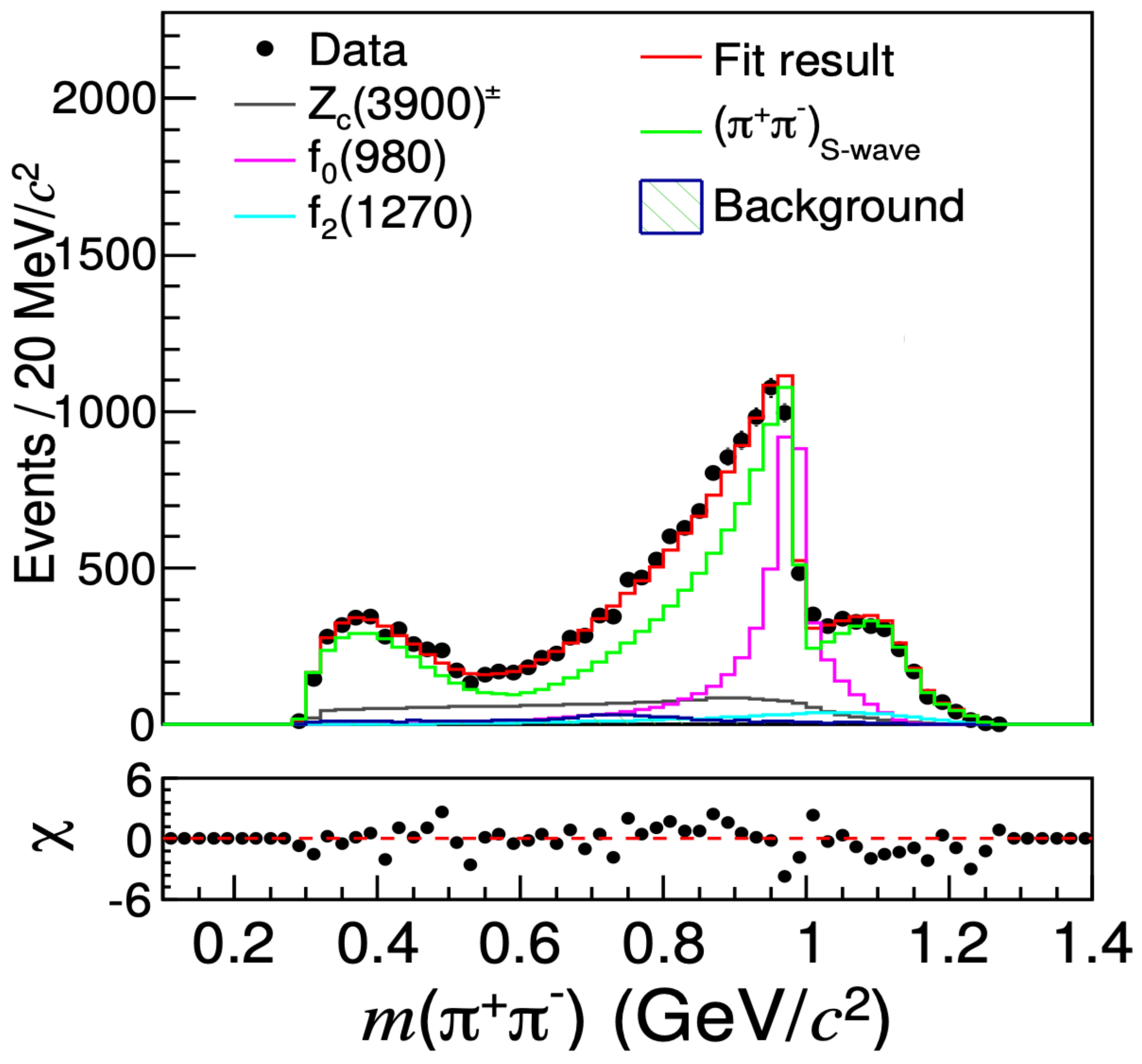
Argand plots: **uncertainties** are **large**, **but** the **features of a resonance** are evident

BONUS



Fitting results for all data samples





PWA onto $e^+e^- \to \pi^+\pi^- J/\psi$

Phys. Rev. D **112**, 092013 (2025)

Using 17 energy points @$\sqrt{s}$ **= [4.127, 4.358] GeV**

Partial Wave Analysis (**PWA**) of the $\boldsymbol{e^+e^- \to \pi^+\pi^- J/\psi}$ **channel** with a double objective (1) **cross sections** of $(\pi^+\pi^-)/(\pi J/\psi)$ **subprocesses** and (2) (**M, Γ**)$_{Z_c}$

Based on the **dressed** $\boldsymbol{e^+e^- \to \pi^+\pi^- J/\psi}$ cross section from Ref. [13] and the fit fraction from this PWA

[13] Phys. Rev. D **106**, 072001 (2022)

PWA onto $e^+e^- \to \pi^+\pi^- J/\psi$

Phys. Rev. D **112**, 092013 (2025)

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The **parametrisation** of the cross sections is based on **two** possible **BW-like resonances** and **a 2-body PHSP** term:

- Model I → $|BW_1 + BW_2|$ → $[\pi^\pm Z_c(3900)]$ subprocess
- Model II → $|BW_1 + PHSP|$ → $[\pi^\pm Z_c(3900)]$ subprocess
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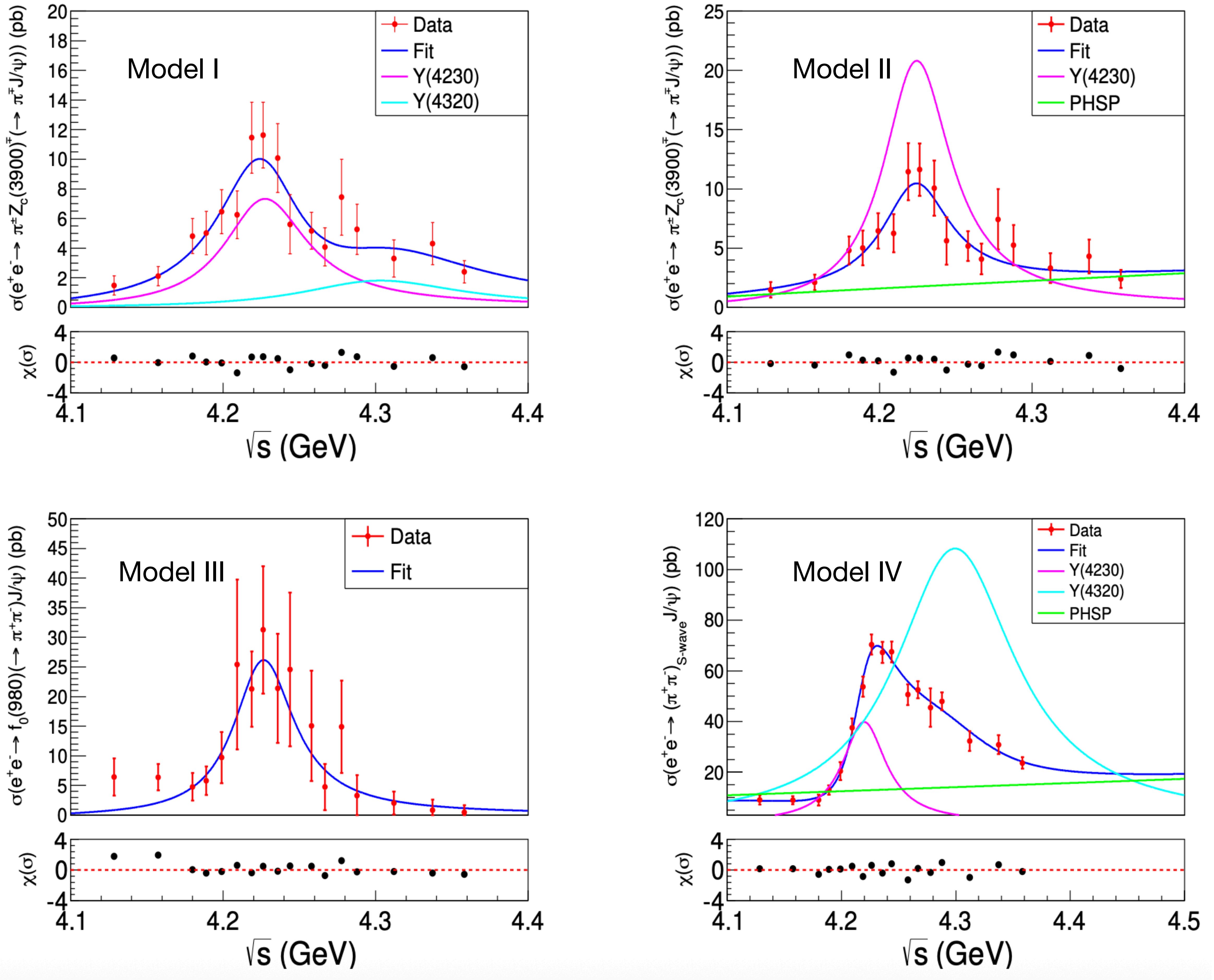
- Model IV → $|PHSP + BW_1 + BW_2|$ → $[(\pi^+\pi^-)_{S\text{-wave}}\, J/\psi]$ subprocess



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Phys. Rev. D **112**, 092013 (2025)

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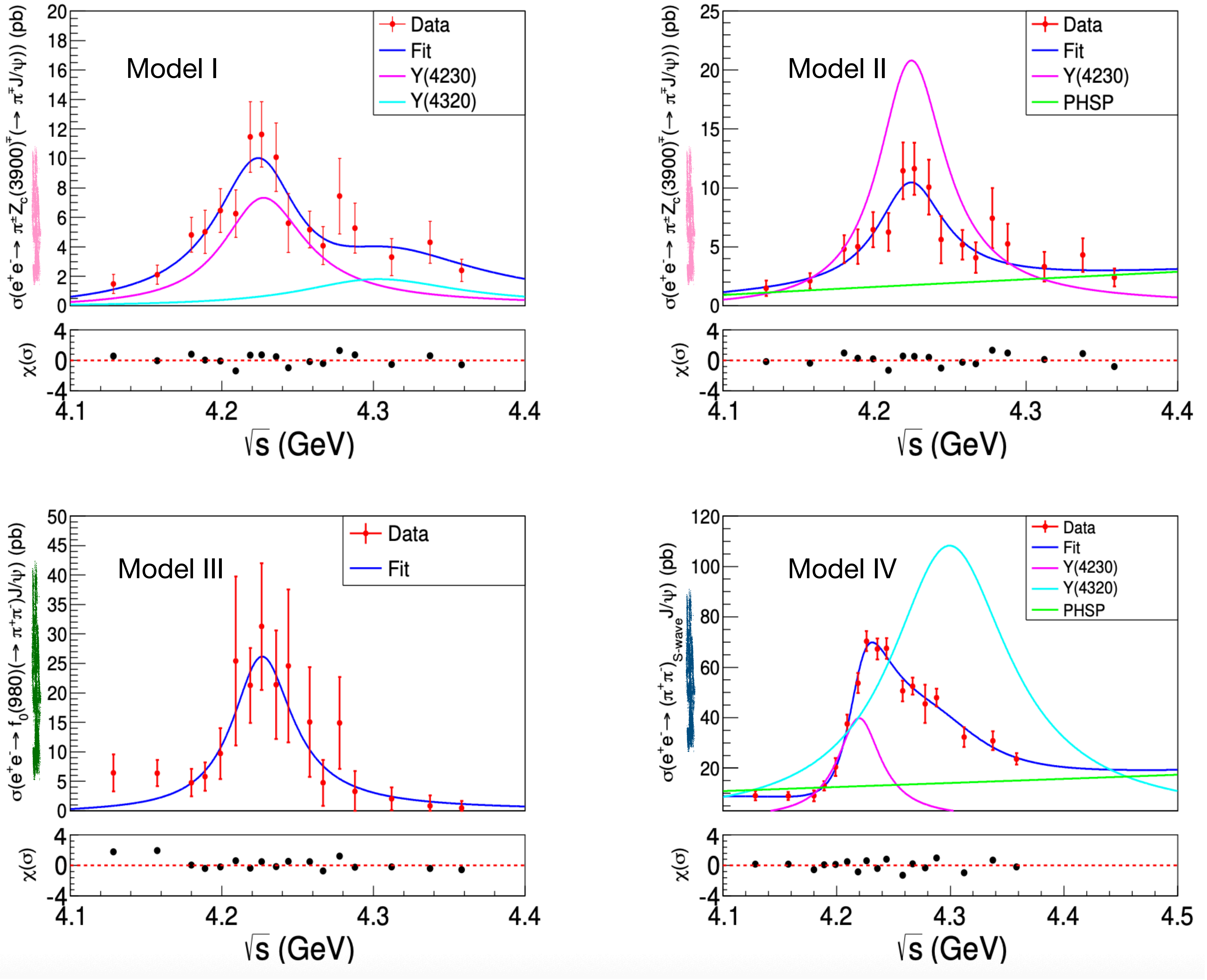

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PWA onto $e^+e^- \to \pi^+\pi^- J/\psi$

Phys. Rev. D **112**, 092013 (2025)

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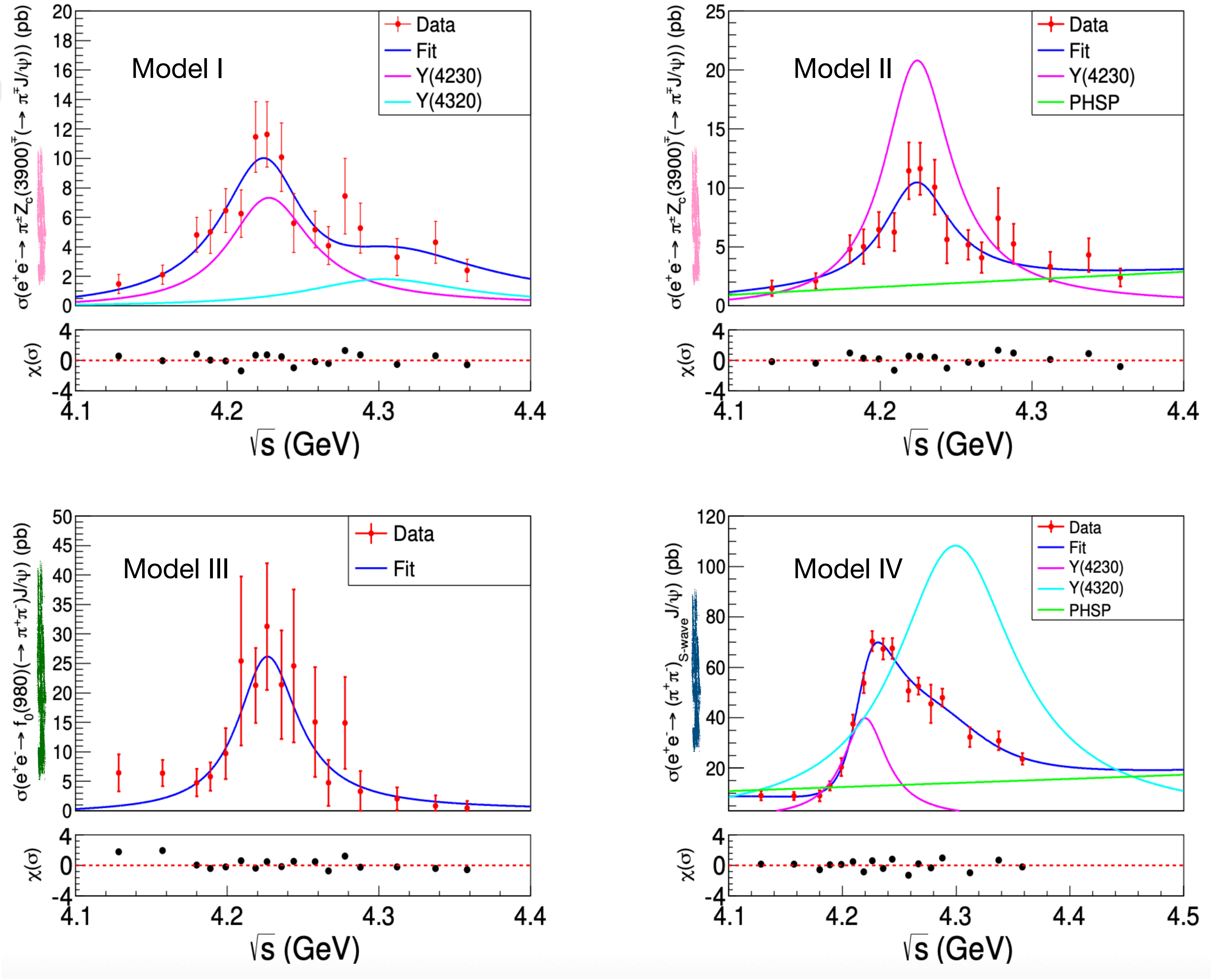


(a) Dominant contribution to the $e^+e^- \to \pi^+\pi^- J/\psi$ cross section comes from the $(\pi^+\pi^-)_{S\text{-wave}}\, J/\psi$ subprocess

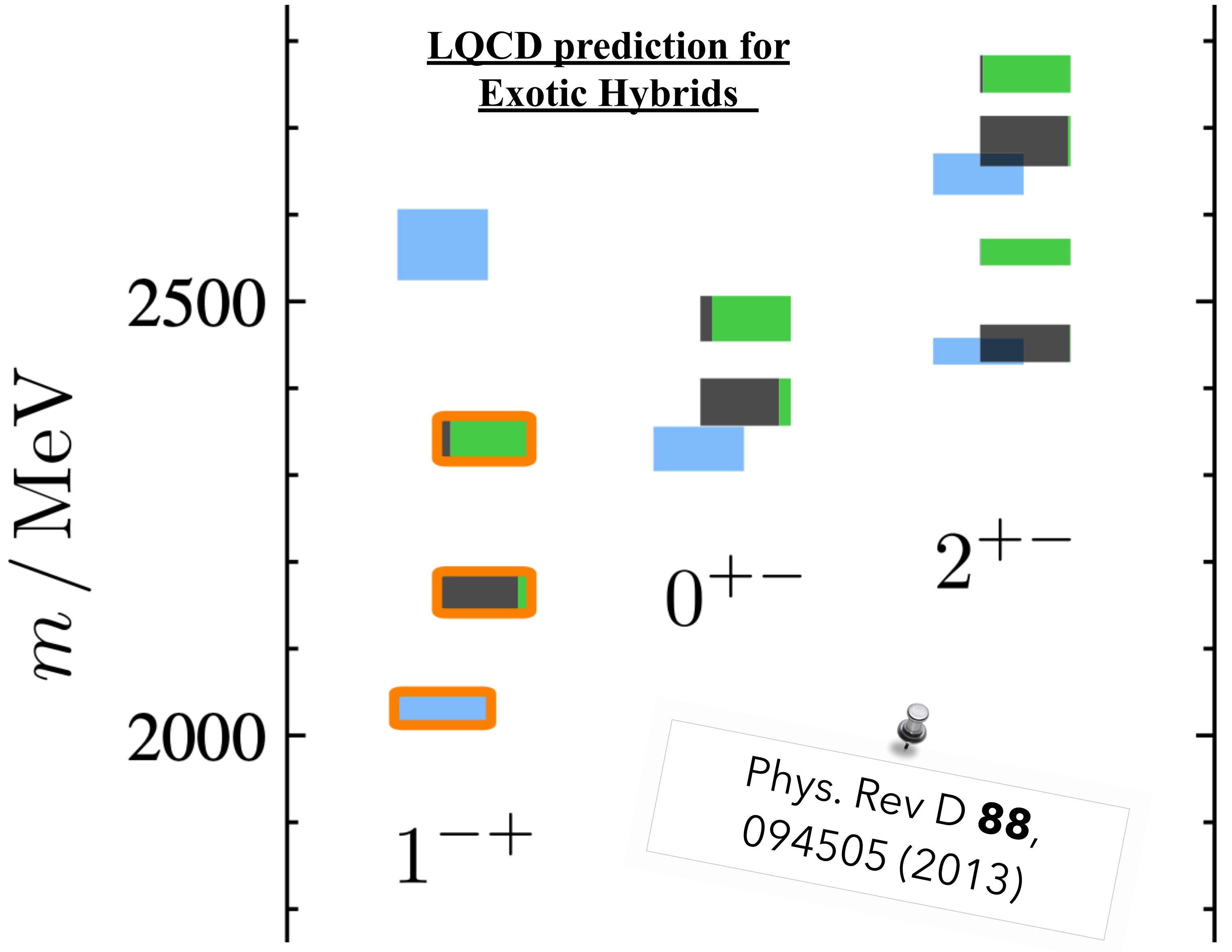
(b) The Y(4220) and Y(4320) resonances appear to be having different cross sections and final states

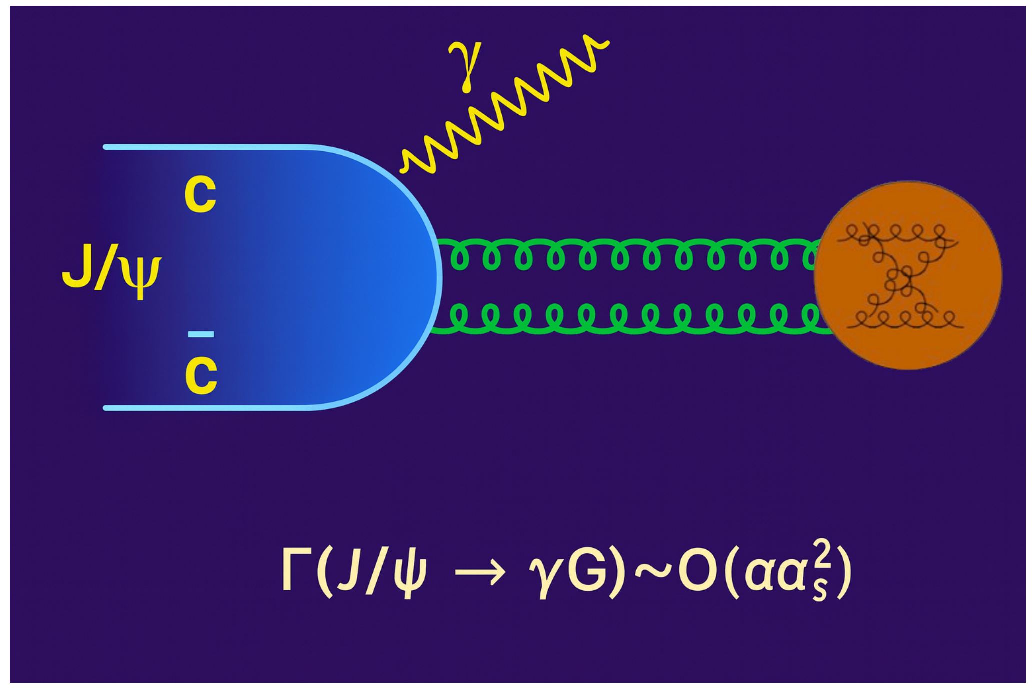
(c) The $f_0(980)\, J/\psi$ subprocess is described by the Y(4220) resonance

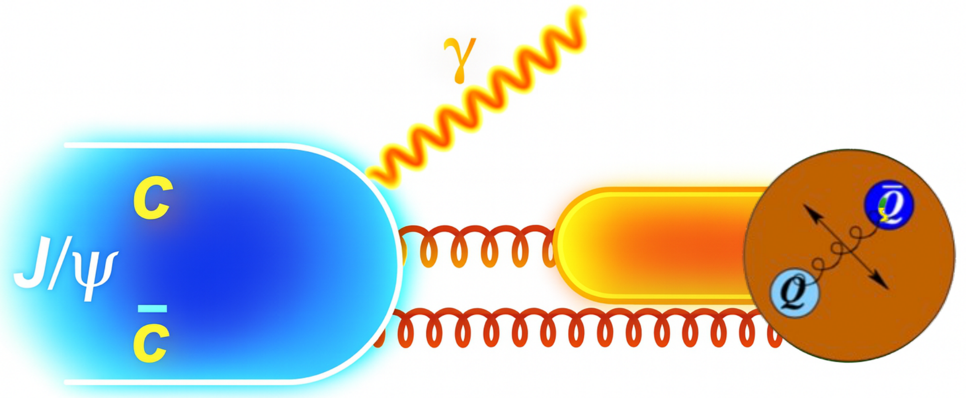
Glueballs (?) with Radiative J/ψ Decays

Vector charmonia radiative decays are the ideal laboratory for glueballs and hybrids hadron studies

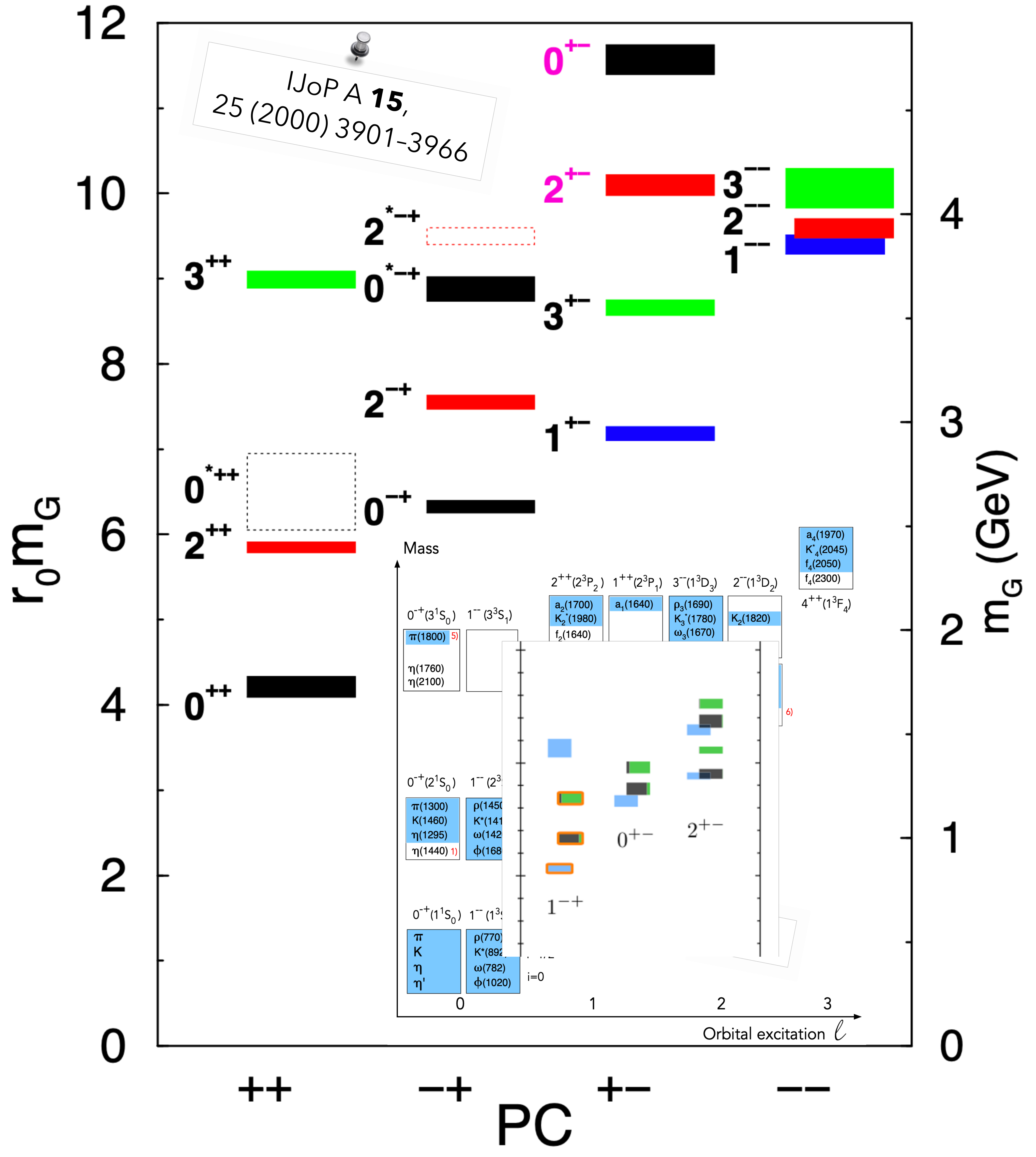
Following pQCD, glueballs and hybrids are expected to have a larger yield compared to mesons







Γ(J/ψ → γH) ~ O(αα³s)



Partial Wave Analyses on J/ψ Decays

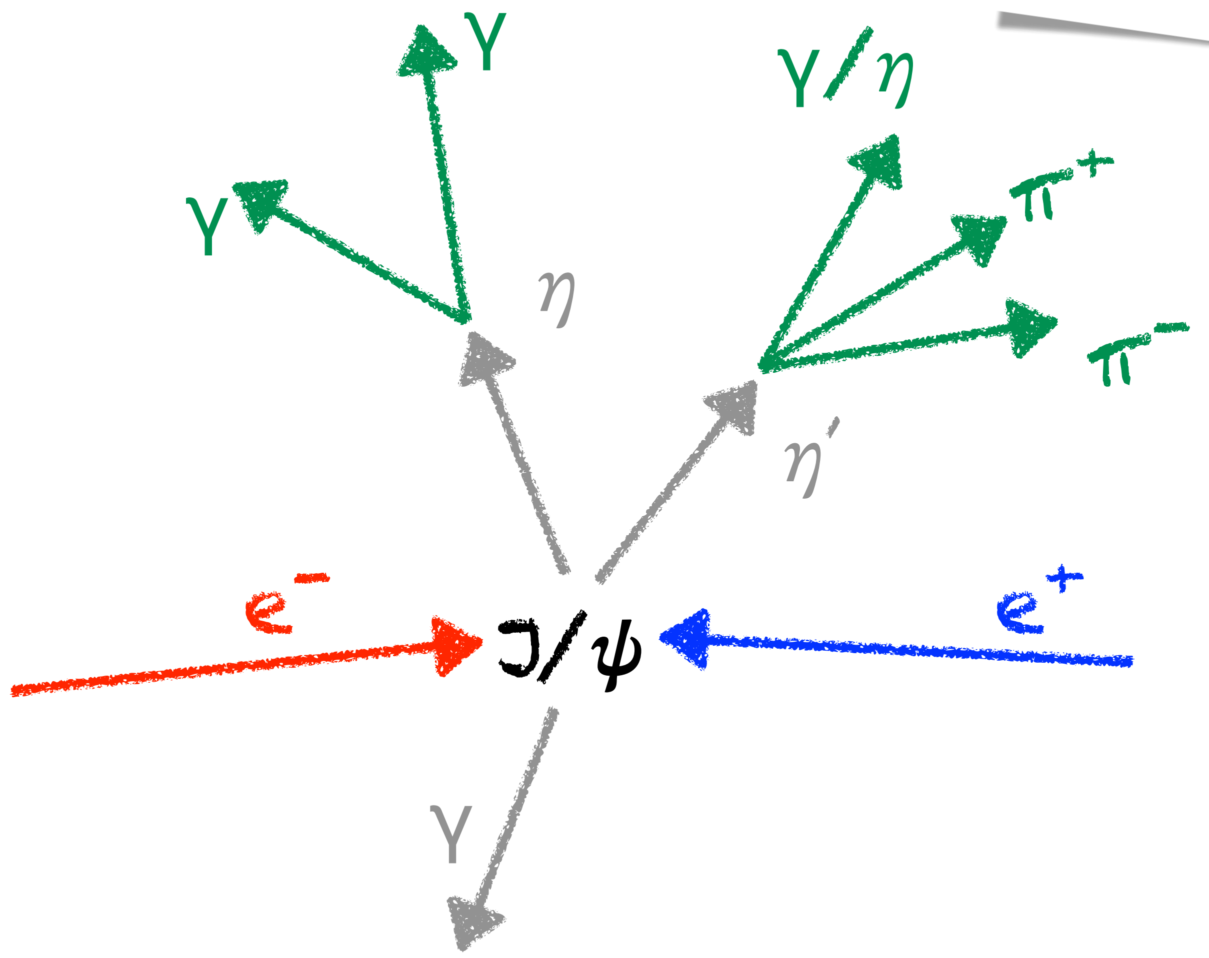
Using the 10 billion J/ψ data set

Via the **isobar model**[14], the total **amplitude** of the radiative **J/ψ decay** is parameterised as a sum of sequential quasi-two-body processes

Study of the J/$\psi \to \gamma\eta\eta'$ decay, reconstructing the η'

from its $\gamma\pi^+\pi^-$ & $\eta(\to\gamma\gamma)\pi^+\pi^-$ main decays

Phys. Rev. Lett. **129**, 192002 (2022) *et al.*



Study of the J/$\psi \to \gamma K_S^0 K_S^0 \eta'$ decay, reconstructing the η'

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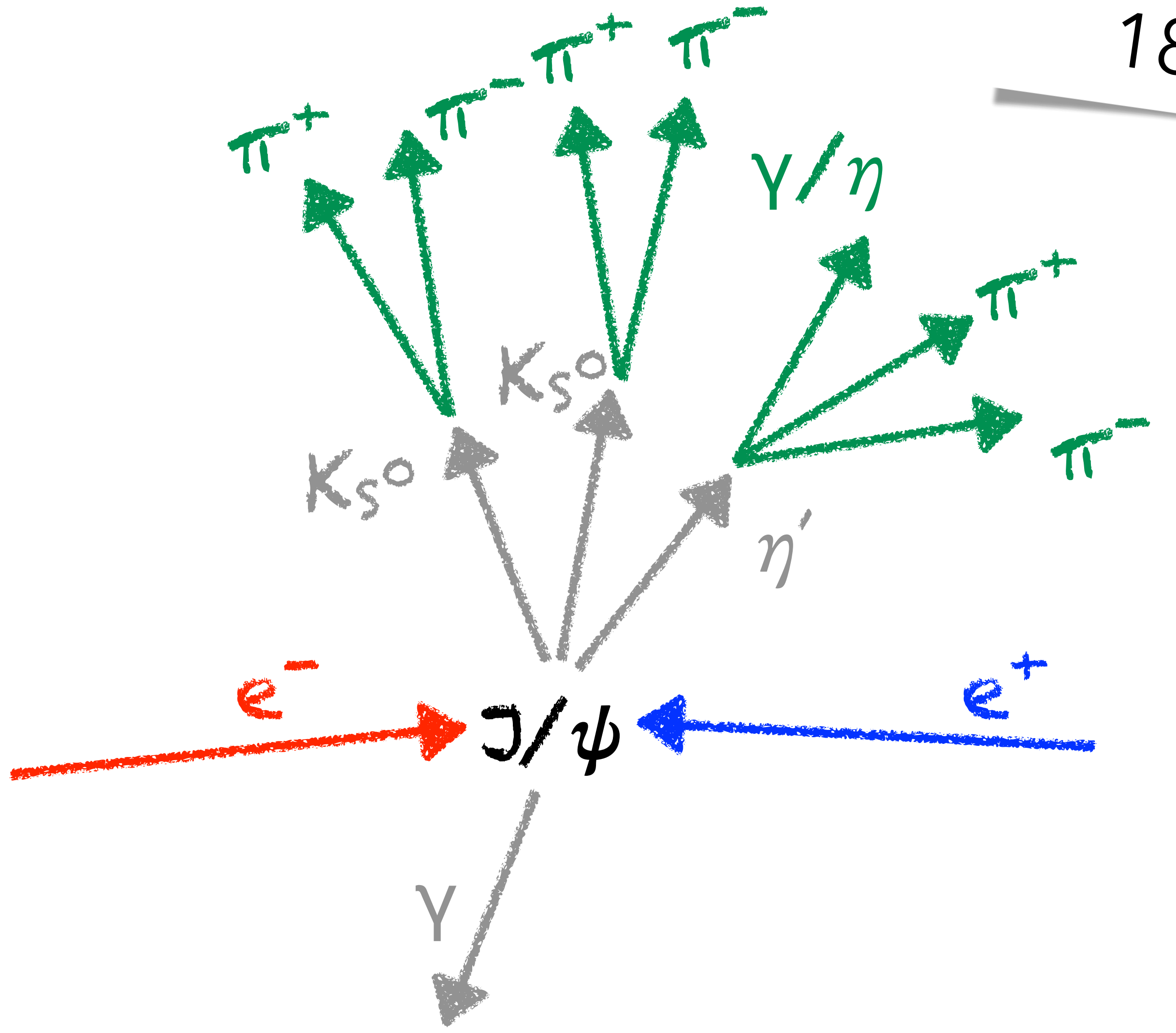
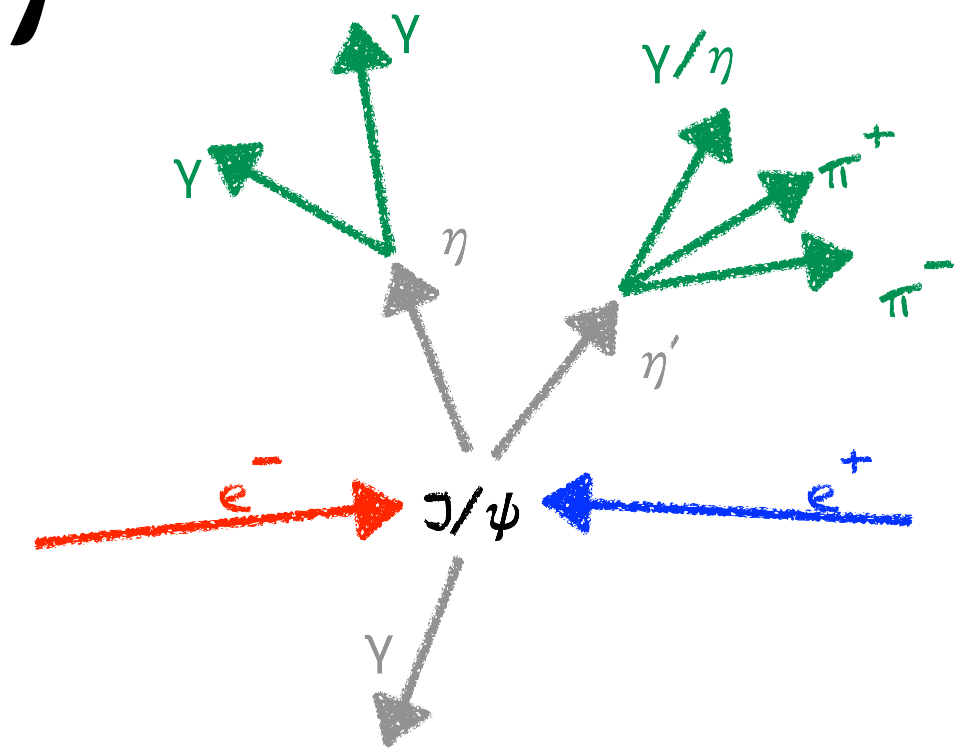
Phys. Rev. Lett. **132**, 181901 (2024)

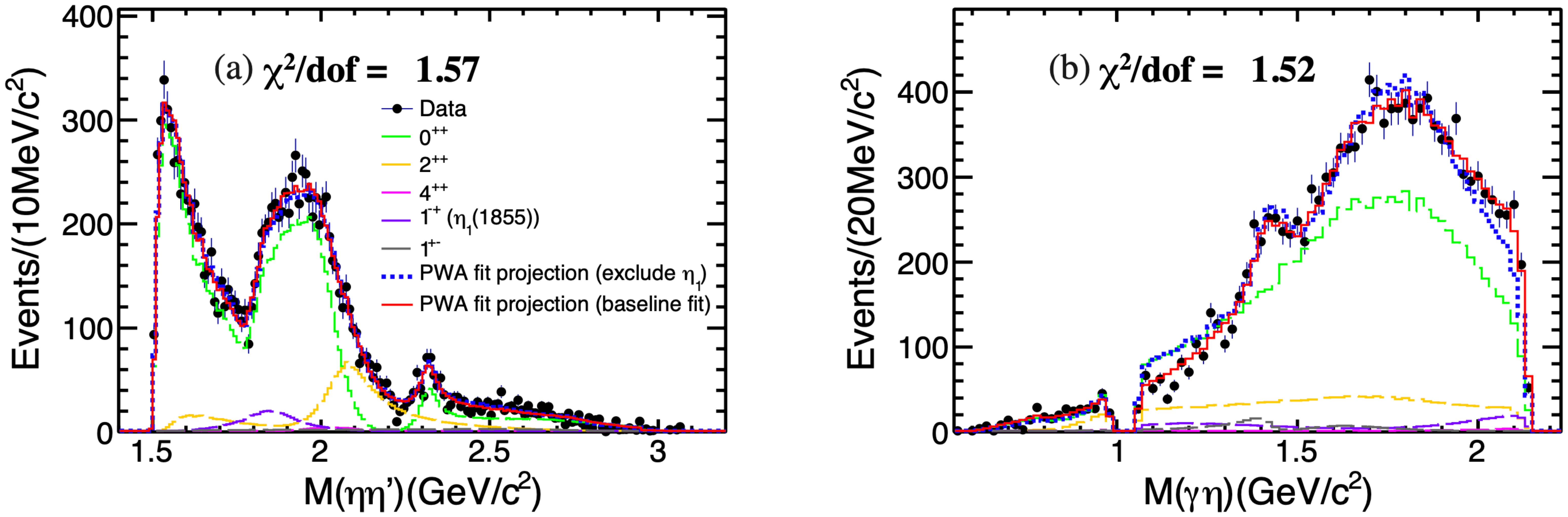


[14] Eur. Phys. J. A **16**, 537 (2003)

Partial Wave Analyses on J/ψ Decays

$J/\psi \to \gamma\eta\eta'$





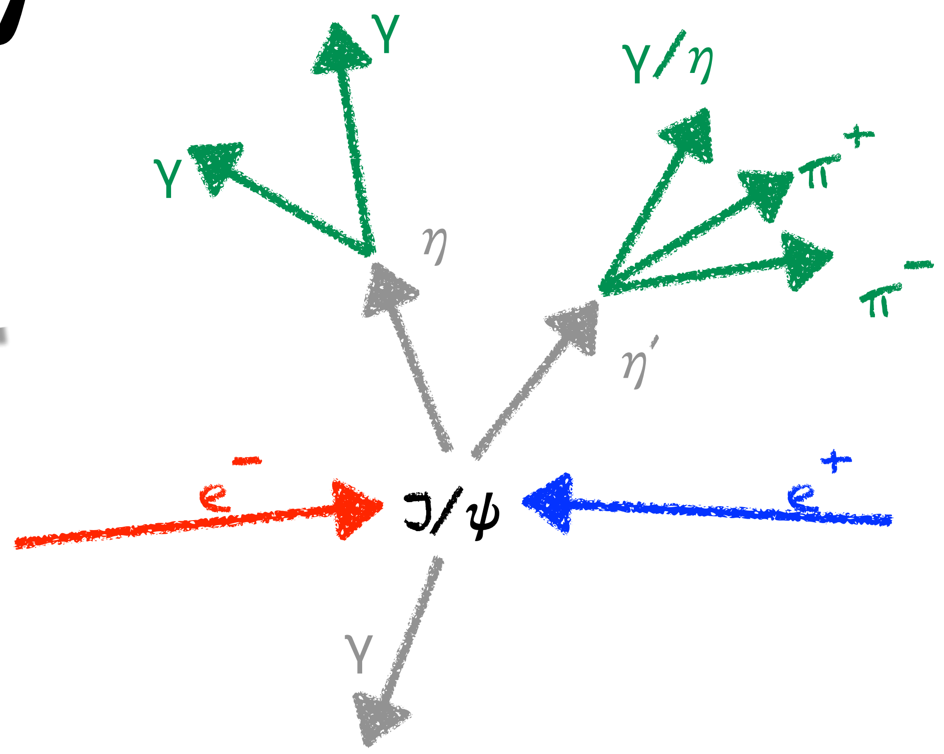
Decay mode	Resonance	M (MeV/c^2)	Γ (MeV)	$M_{\rm PDG}$ (MeV/c^2)	$\Gamma_{\rm PDG}$ (MeV)	B.F. ($\times 10^{-5}$)	Sig.
$J/\psi \to \gamma X \to \gamma\eta\eta'$	$f_0(1500)$	1506	112	1506	112	$1.81\pm0.11^{+0.19}_{-0.13}$	$\gg 30\sigma$
	$f_0(1810)$	1795	95	1795	95	$0.11\pm0.01^{+0.04}_{-0.03}$	11.1σ
	$f_0(2020)$	$2010\pm6^{+6}_{-4}$	$203\pm9^{+13}_{-11}$	1992	442	$2.28\pm0.12^{+0.29}_{-0.20}$	24.6σ
	$f_0(2330)$	$2312\pm7^{+7}_{-3}$	$65\pm10^{+3}_{-12}$	2314	144	$0.10\pm0.02^{+0.01}_{-0.02}$	13.2σ
	$\eta_1(1855)$	$1855\pm9^{+6}_{-1}$	$188\pm18^{+3}_{-8}$	-	-	$0.27\pm0.04^{+0.02}_{-0.04}$	21.4σ
	$f_2(1565)$	1542	122	1542	122	$0.32\pm0.05^{+0.12}_{-0.02}$	8.7σ
	$f_2(2010)$	$2062\pm6^{+10}_{-7}$	$165\pm17^{+10}_{-5}$	2011	202	$0.71\pm0.06^{+0.10}_{-0.06}$	13.4σ
	$f_4(2050)$	2018	237	2018	237	$0.06\pm0.01^{+0.03}_{-0.01}$	4.6σ
	0^{++} PHSP	-	-	-	-	$1.44\pm0.15^{+0.10}_{-0.20}$	15.7σ
$J/\psi \to \eta' X \to \gamma\eta\eta'$	$h_1(1415)$	1416	90	1416	90	$0.08\pm0.01^{+0.01}_{-0.02}$	10.2σ
	$h_1(1595)$	1584	384	1584	384	$0.16\pm0.02^{+0.03}_{-0.01}$	9.9σ

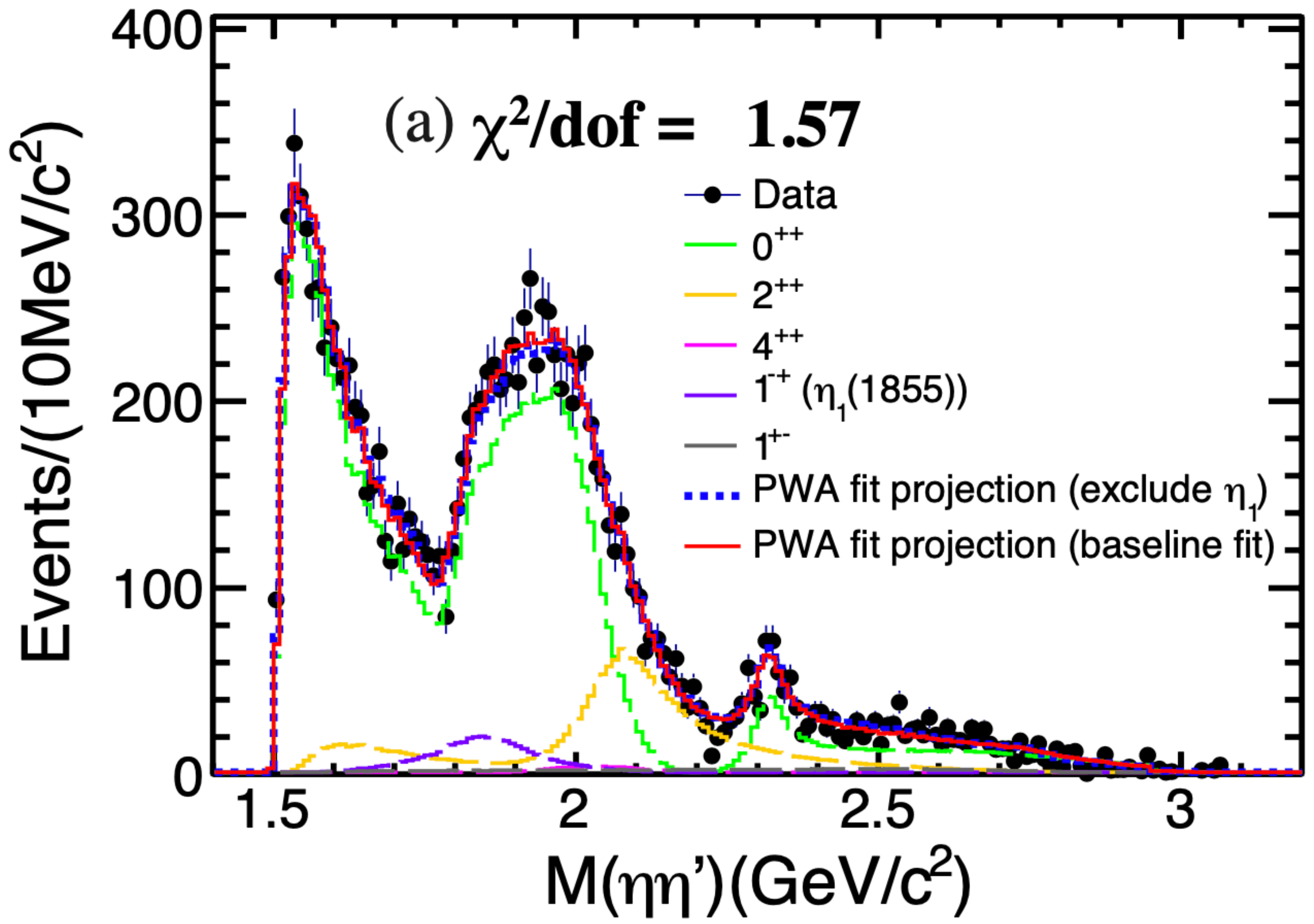
Phys. Rev. Lett. **129**, 192002 (2022)
Phys. Rev. D **106**, 072012 (2022)
Phys. Rev. D **107**, 079901 (2023)

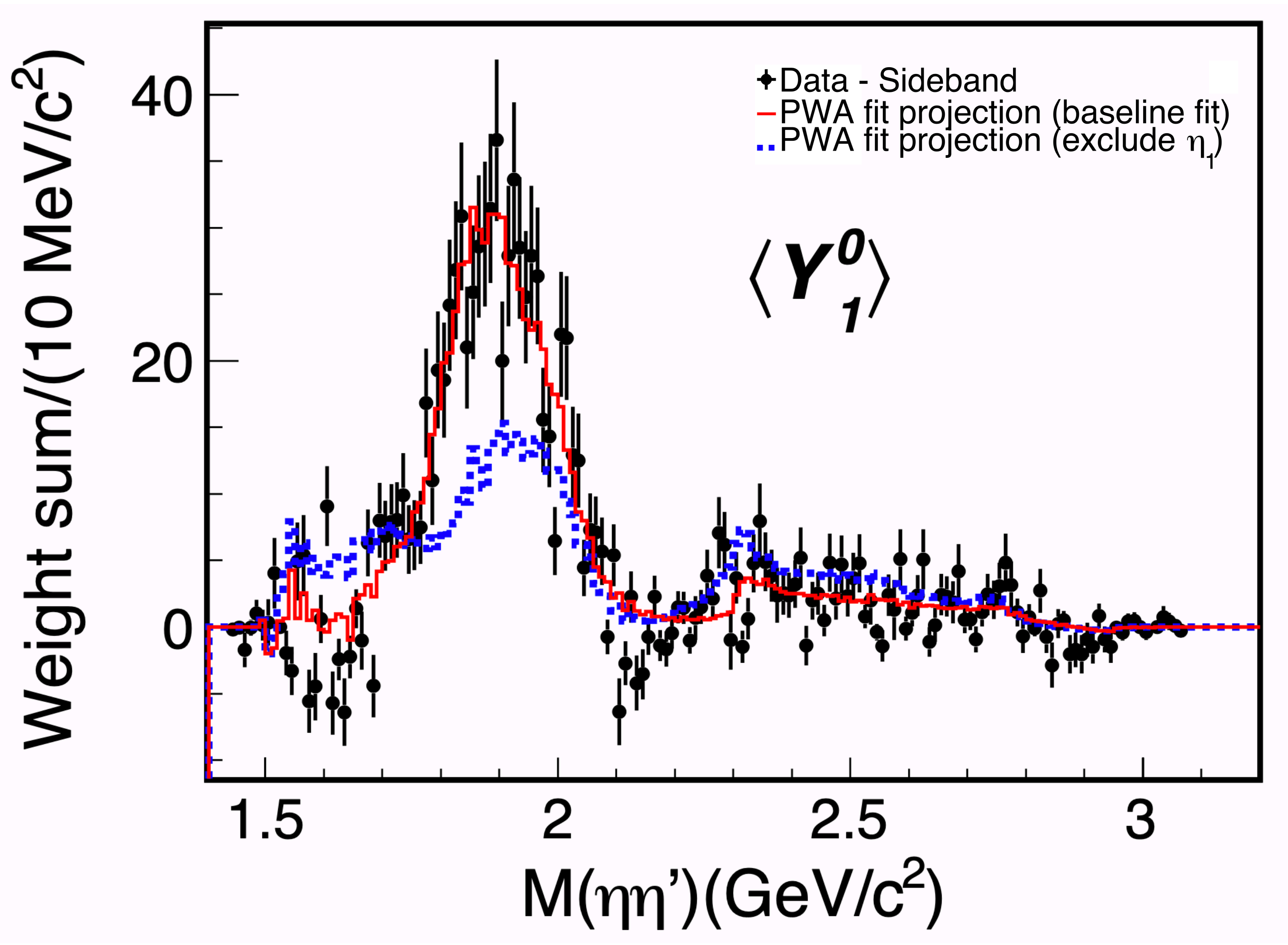
Partial Wave Analyses on J/ψ Decays

$J/\psi \to \gamma\eta\eta'$

Phys. Rev. Lett. **129**, 192002 (2022) et al.







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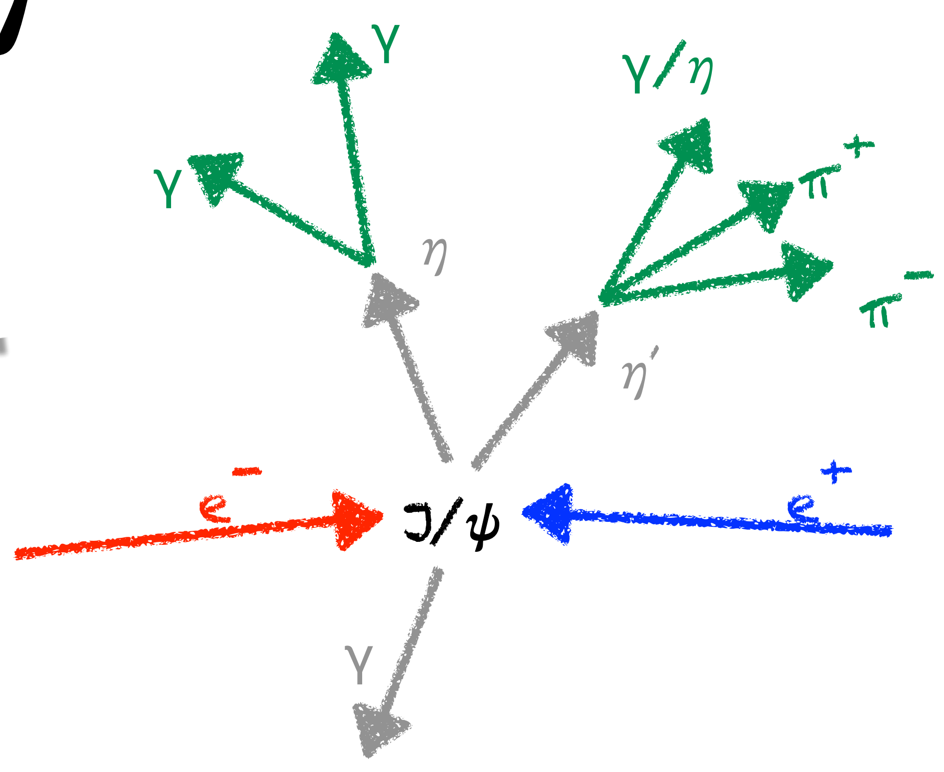
An ***exotic* isoscalar** state $J^{PC} = 1^{-+}$, whose parameters are **consistent** with **LQCD calculations** for the 1^{-+} hybrid[15]

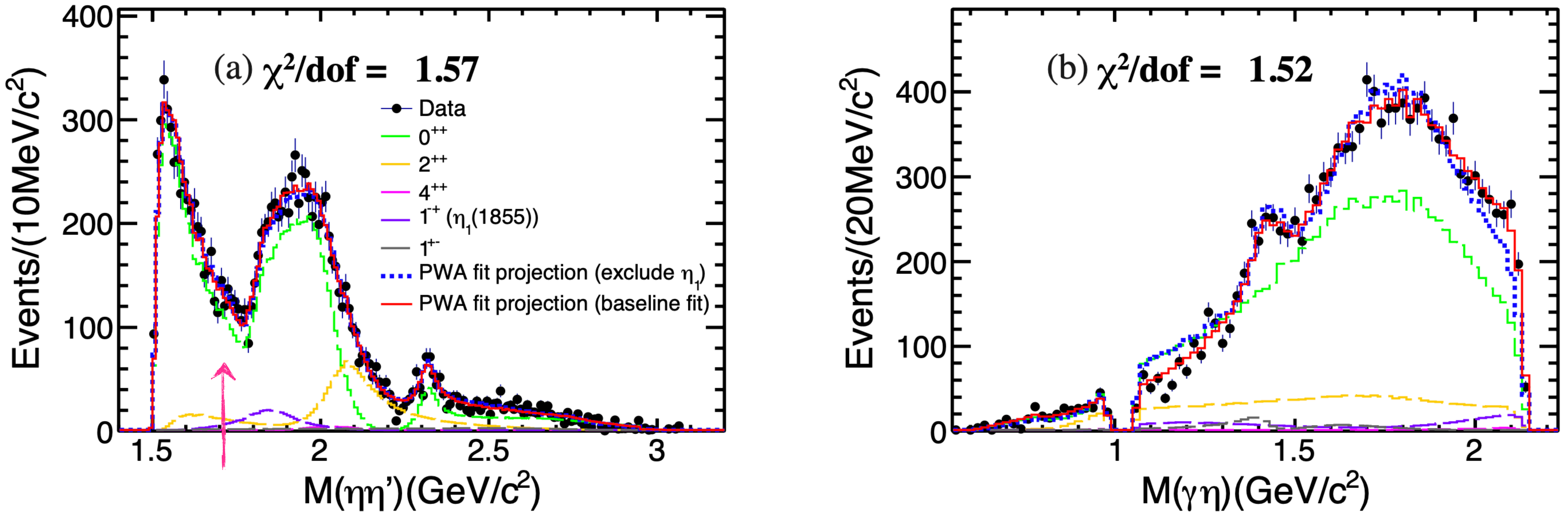
[15] Phys. Rev. D **88**, 094505 (2013)

Partial Wave Analyses on J/ψ Decays

$J/\psi \to \gamma\eta\eta'$

Phys. Rev. Lett. **129**, 192002 (2022) et al.





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$$\frac{\mathcal{B}(f_0(1500)\to\eta\eta')}{\mathcal{B}(f_0(1500)\to\pi\pi)} = (1.66\,^{+0.42}_{-0.40})\times 10^{-1}$$

Consistent with PDG

The **absence of f_0(1710)** signal allows to set an U.L. (@ 90% C.L.)

$$\frac{\mathcal{B}(f_0(1710)\to\eta\eta')}{\mathcal{B}(f_0(1710)\to\pi\pi)} = 1.61\times 10^{-3}$$

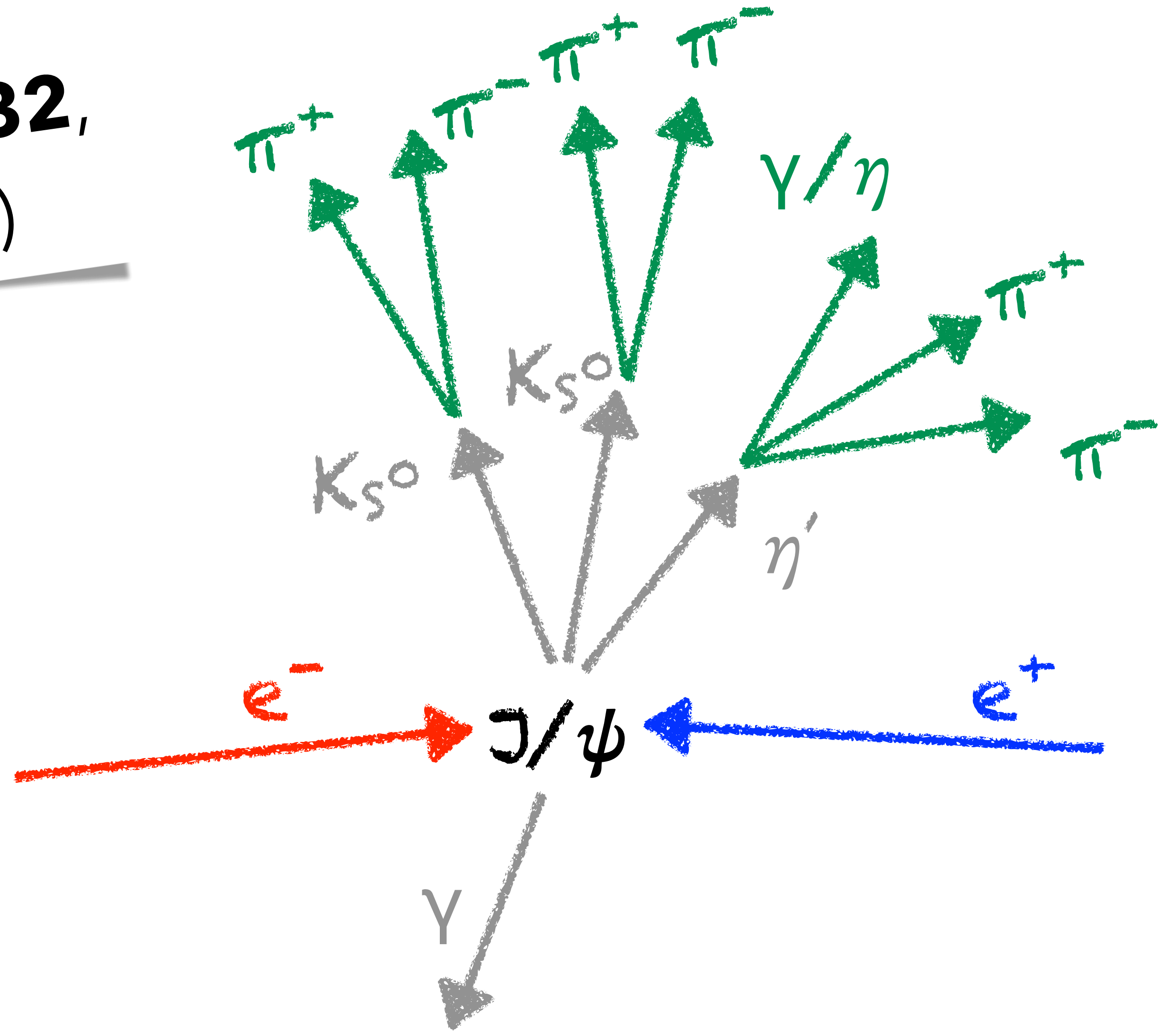
which **supports** to the hypothesis that the **f_0(1710) overlaps with** the ground state scalar (**0^{++}**) **glueball**[16]

[16] Phys. Rev. D **92**, 114035 (2015)

Partial Wave Analyses on J/ψ Decays

$J/\psi \to \gamma K_S^0 K_S^0 \eta'$

Phys. Rev. Lett. **132**, 181901 (2024)



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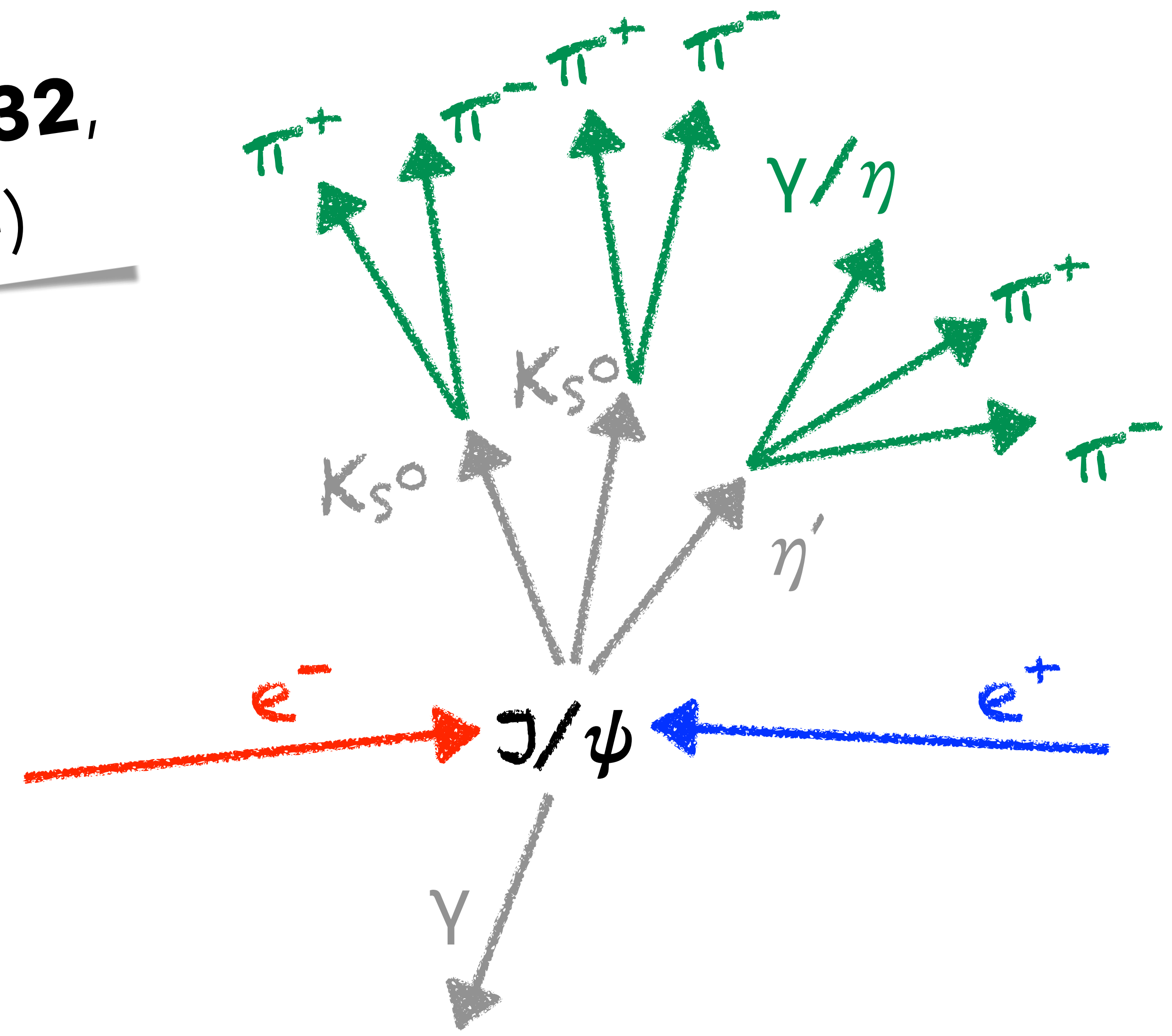
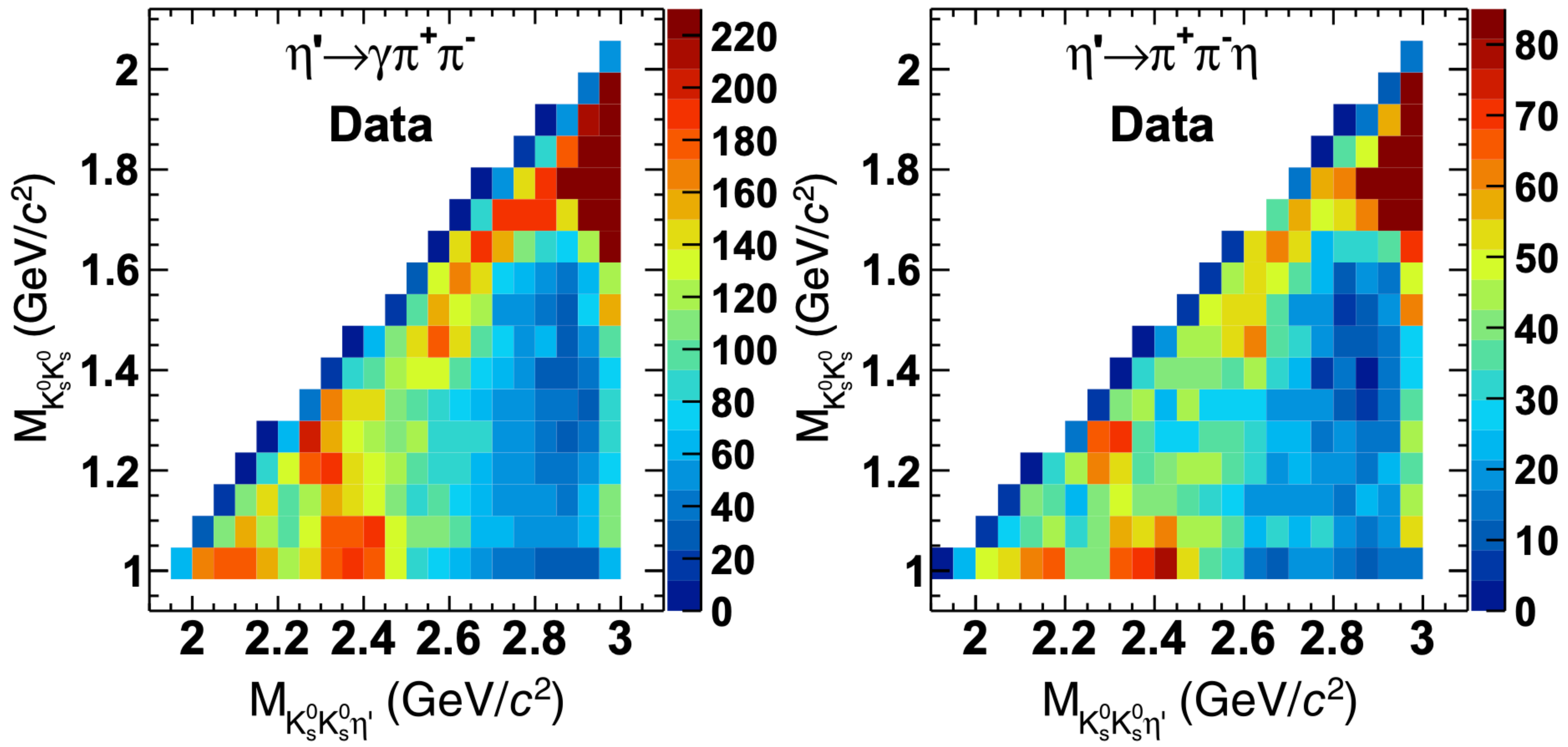
$J/\psi \to \gamma K_S{}^0 K_S{}^0 \eta'$

Phys. Rev. Lett. **132**, 181901 (2024)





Partial Wave Analyses on J/ψ Decays

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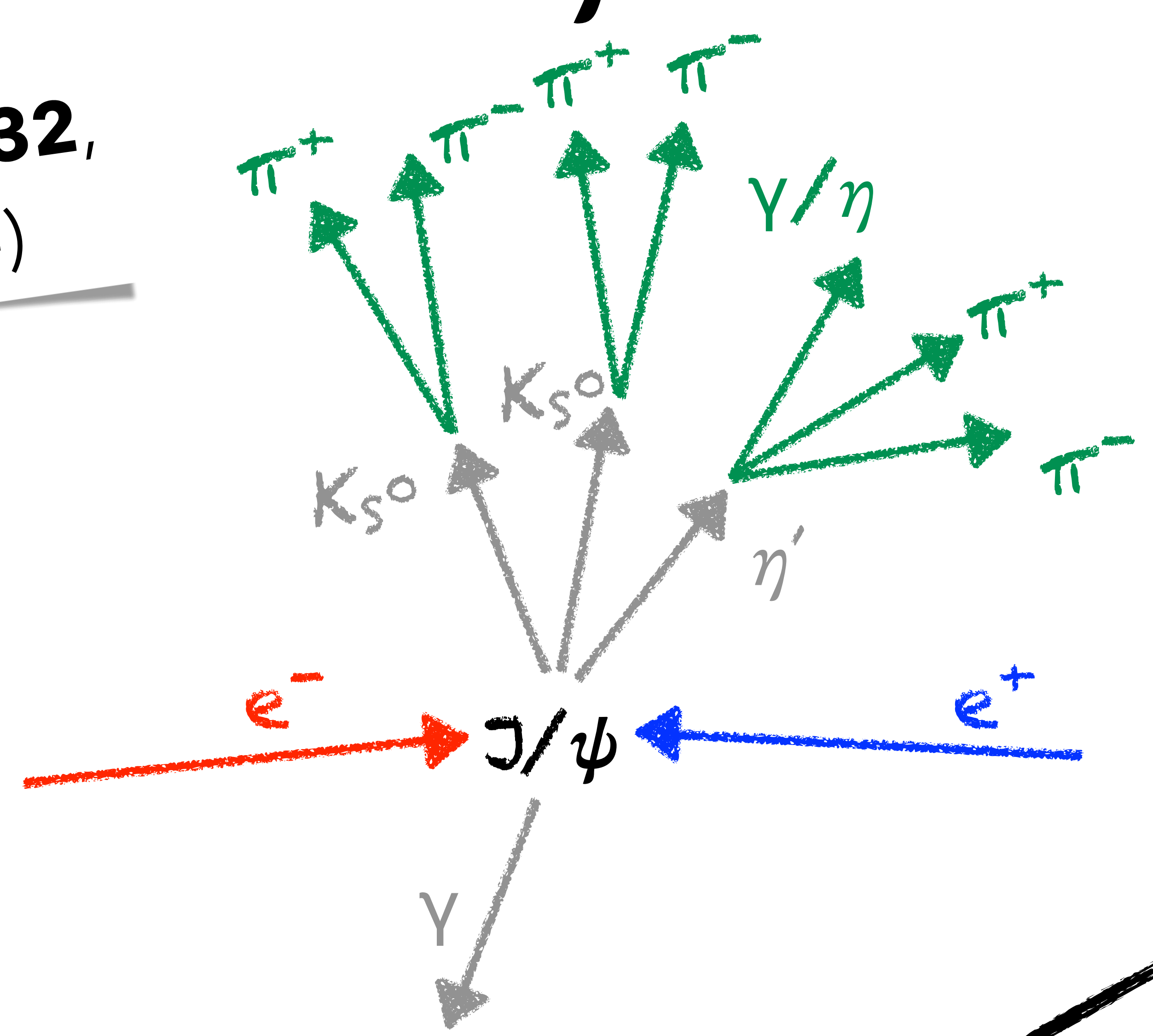

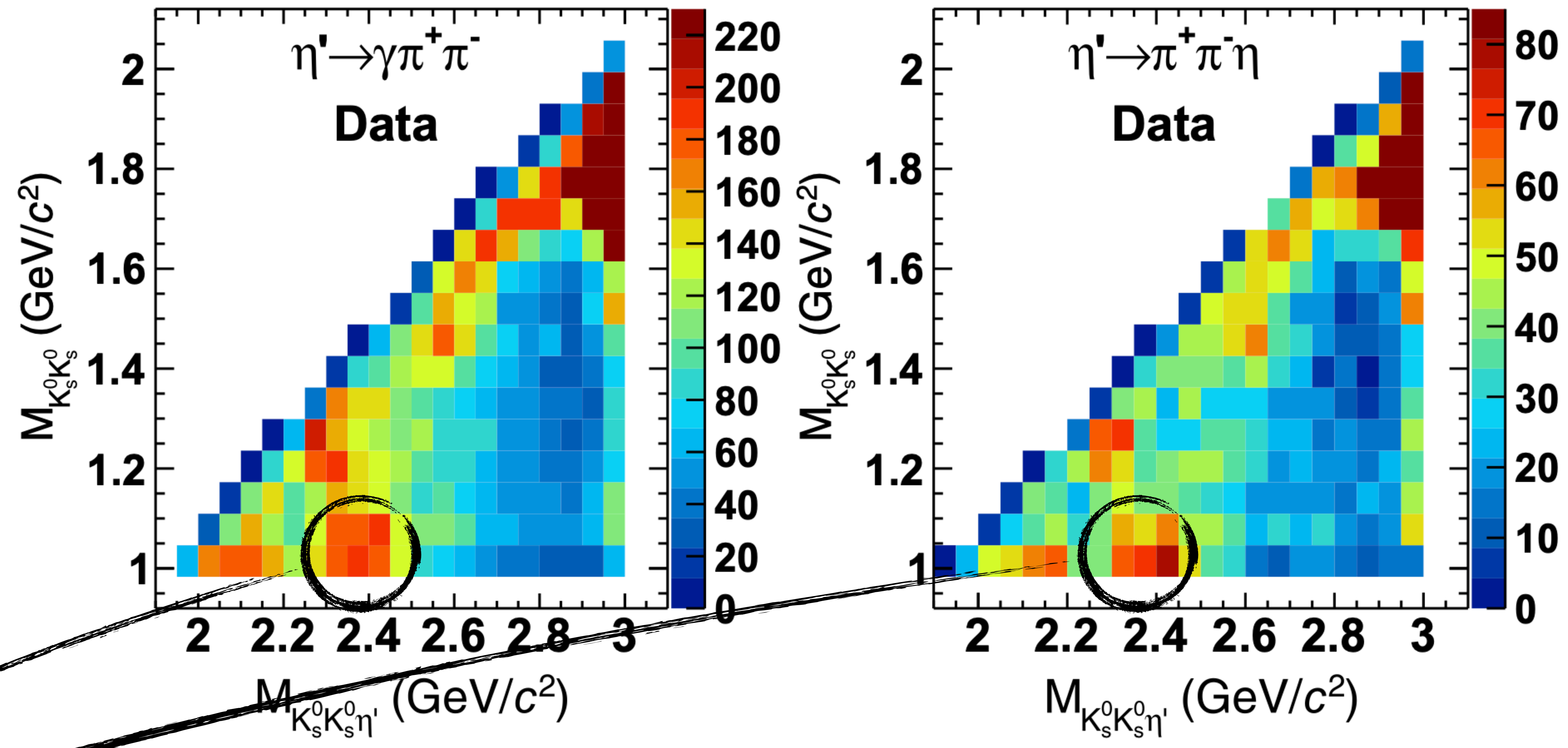

Enhancement near the $K_S{}^0K_S{}^0$ mass threshold in connection with the structure round 2.4 GeV/c^2

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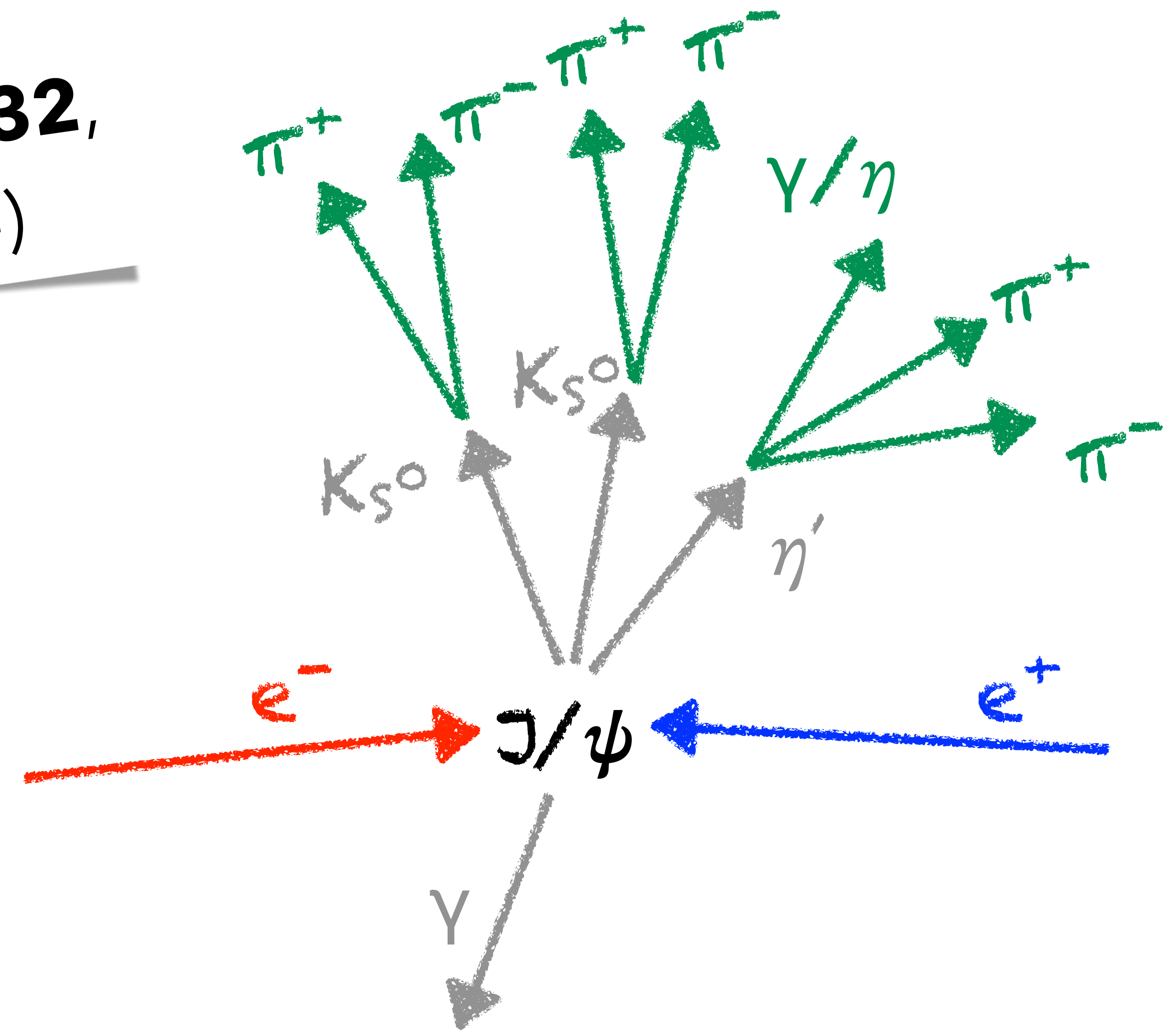

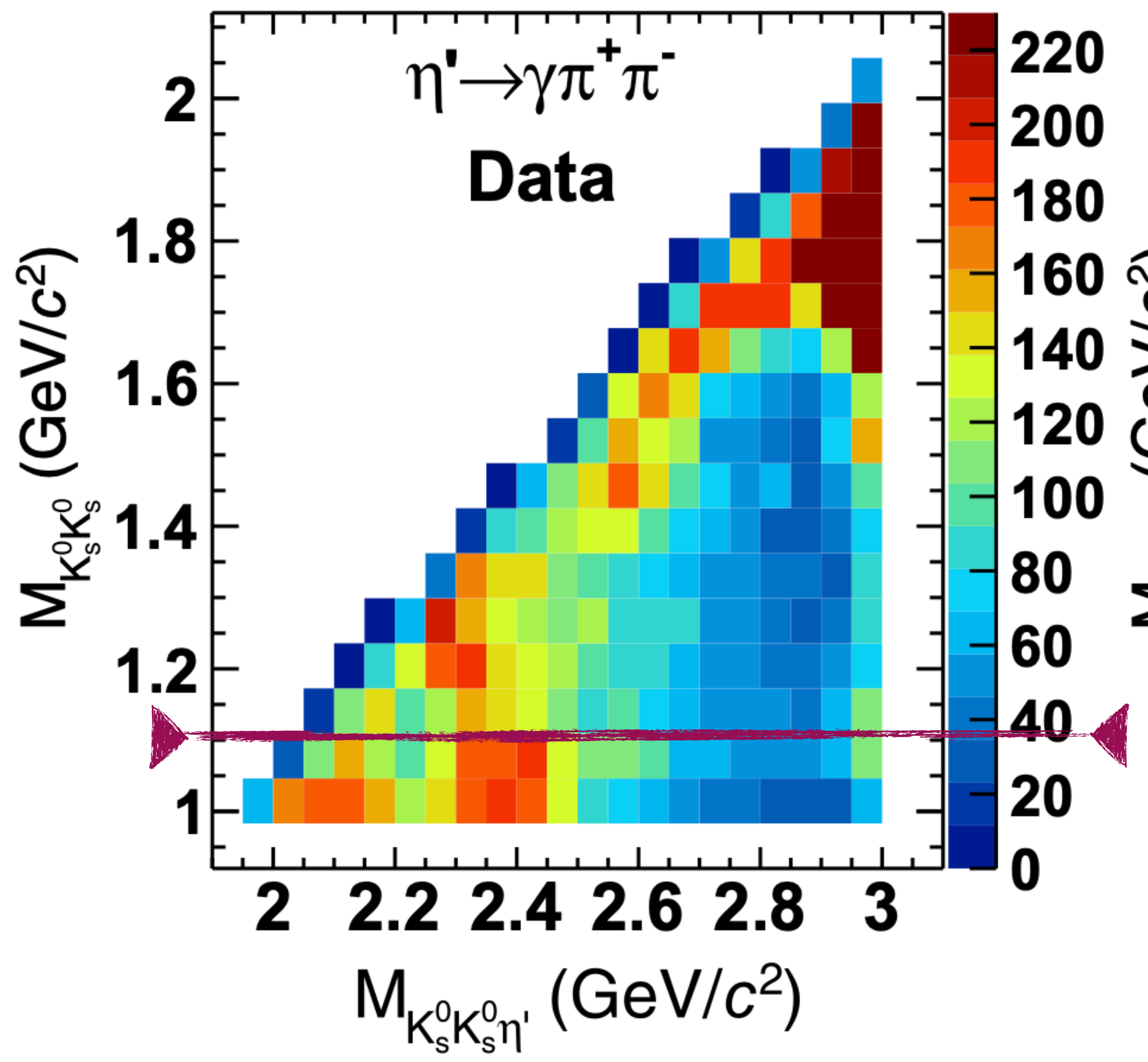

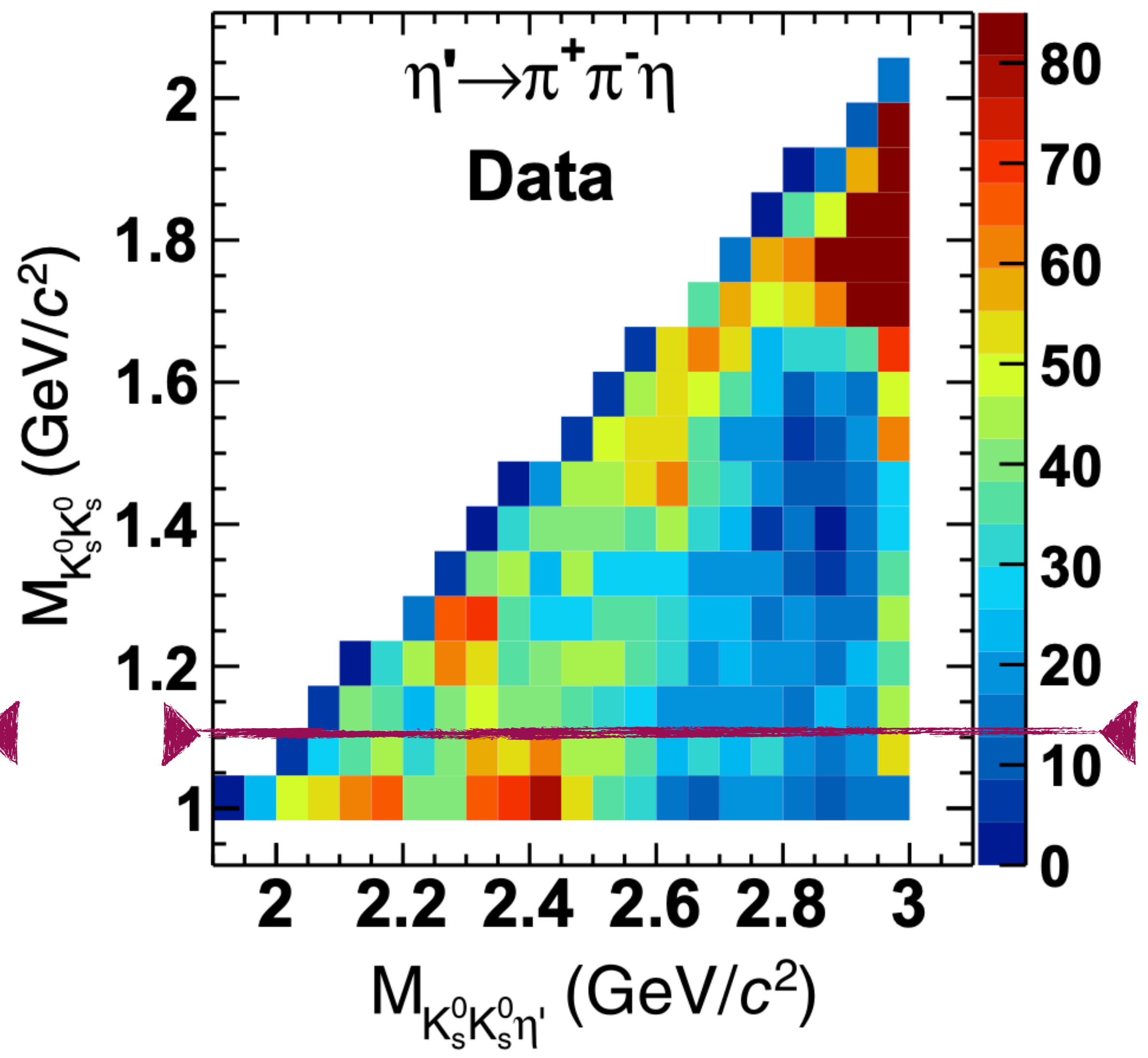

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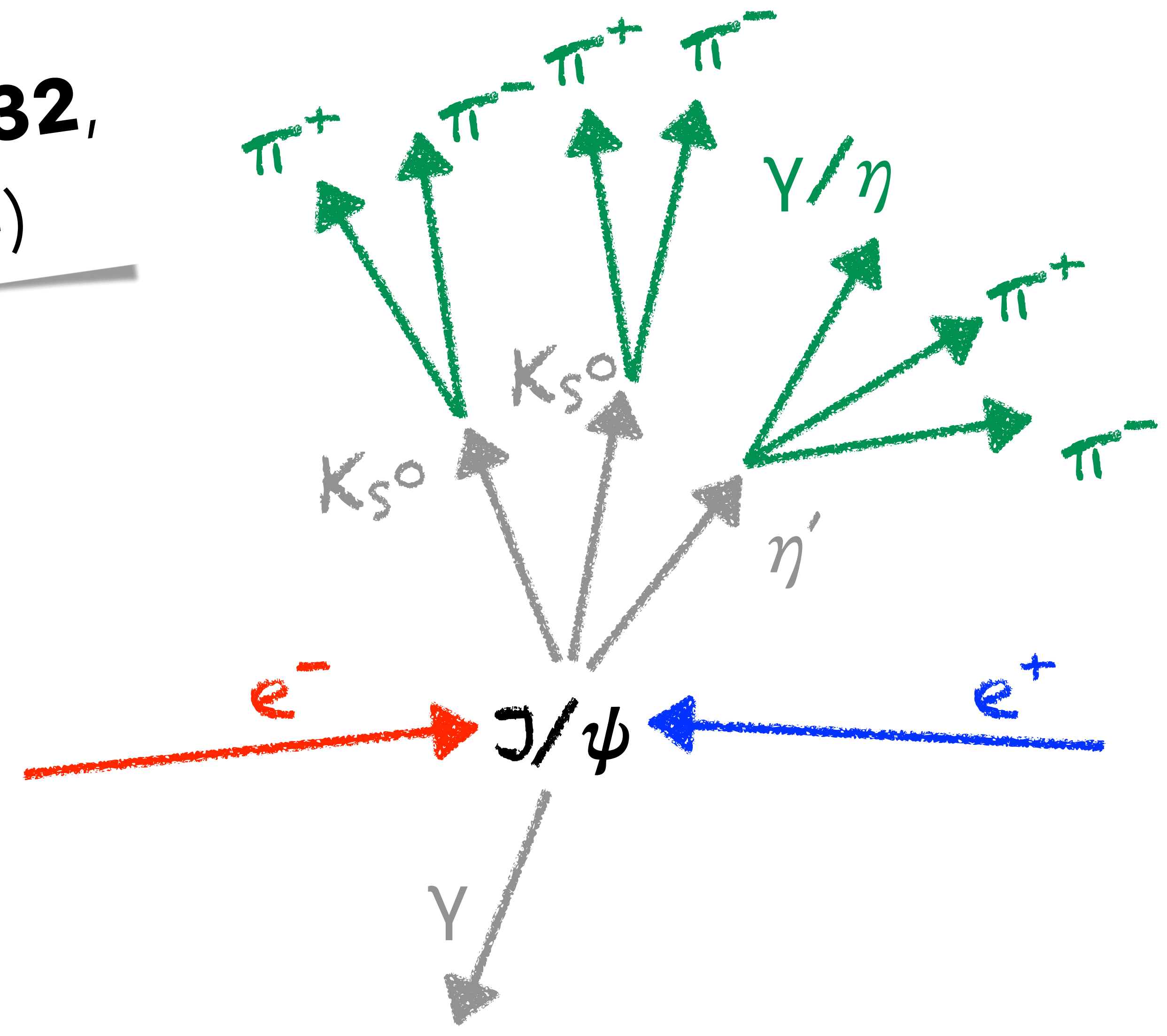

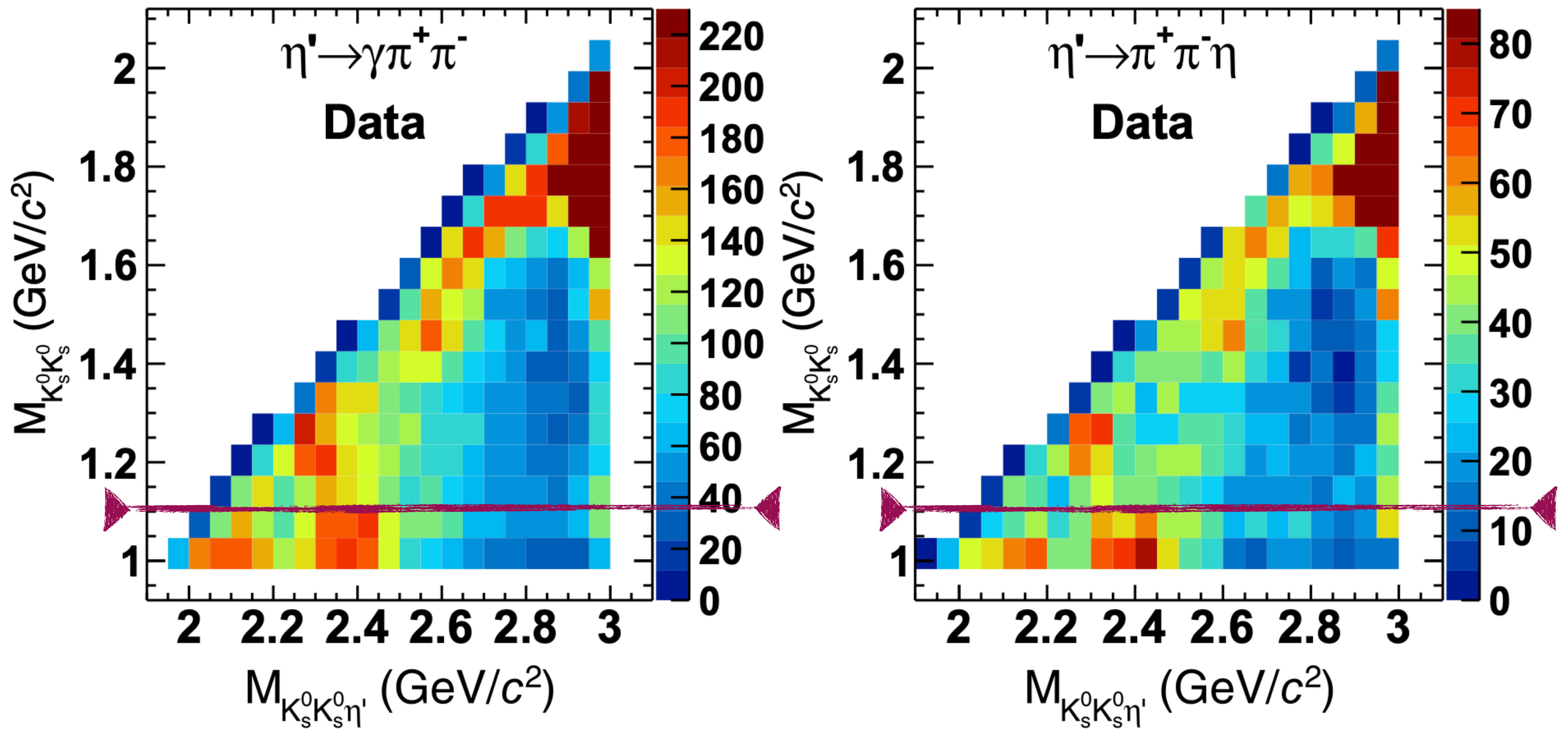

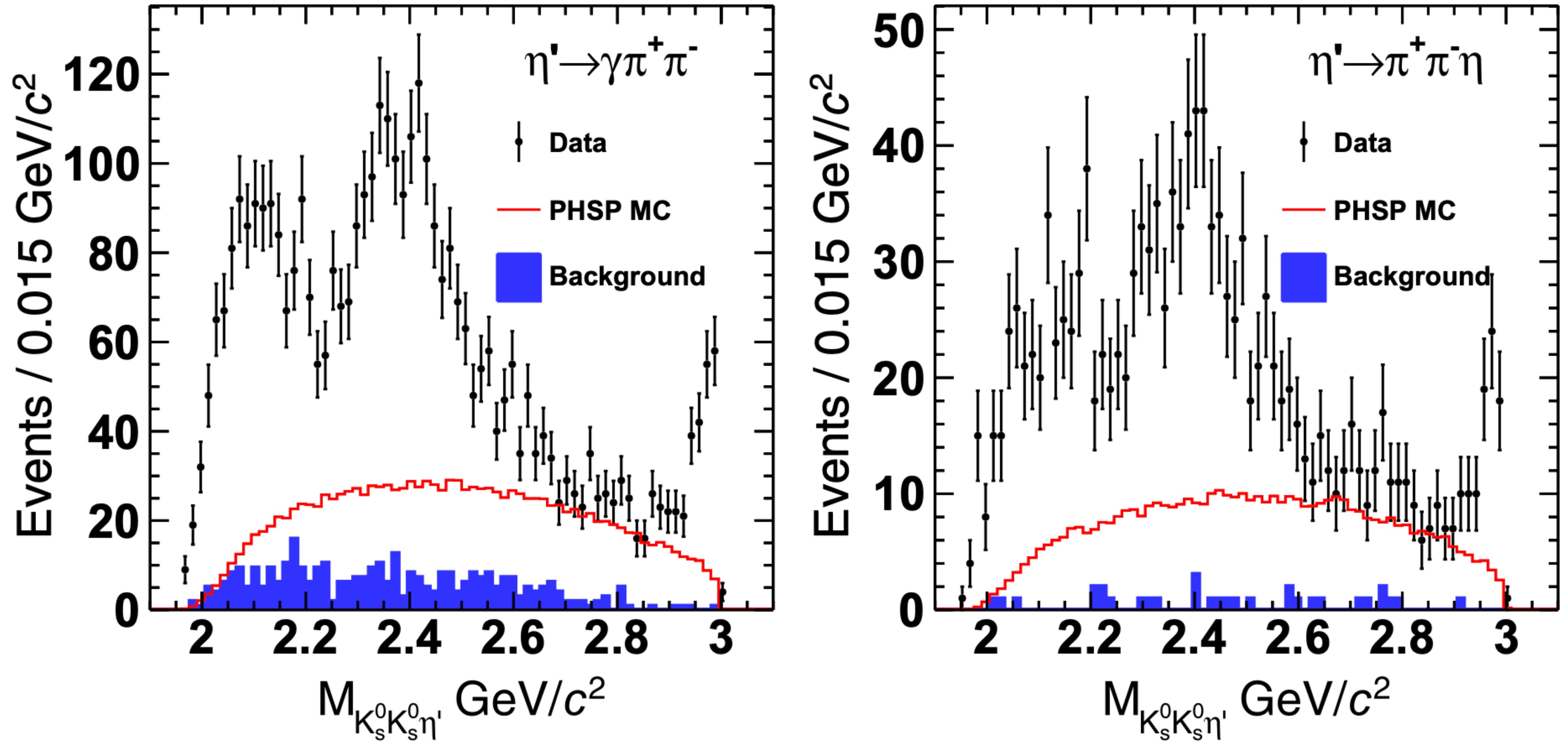

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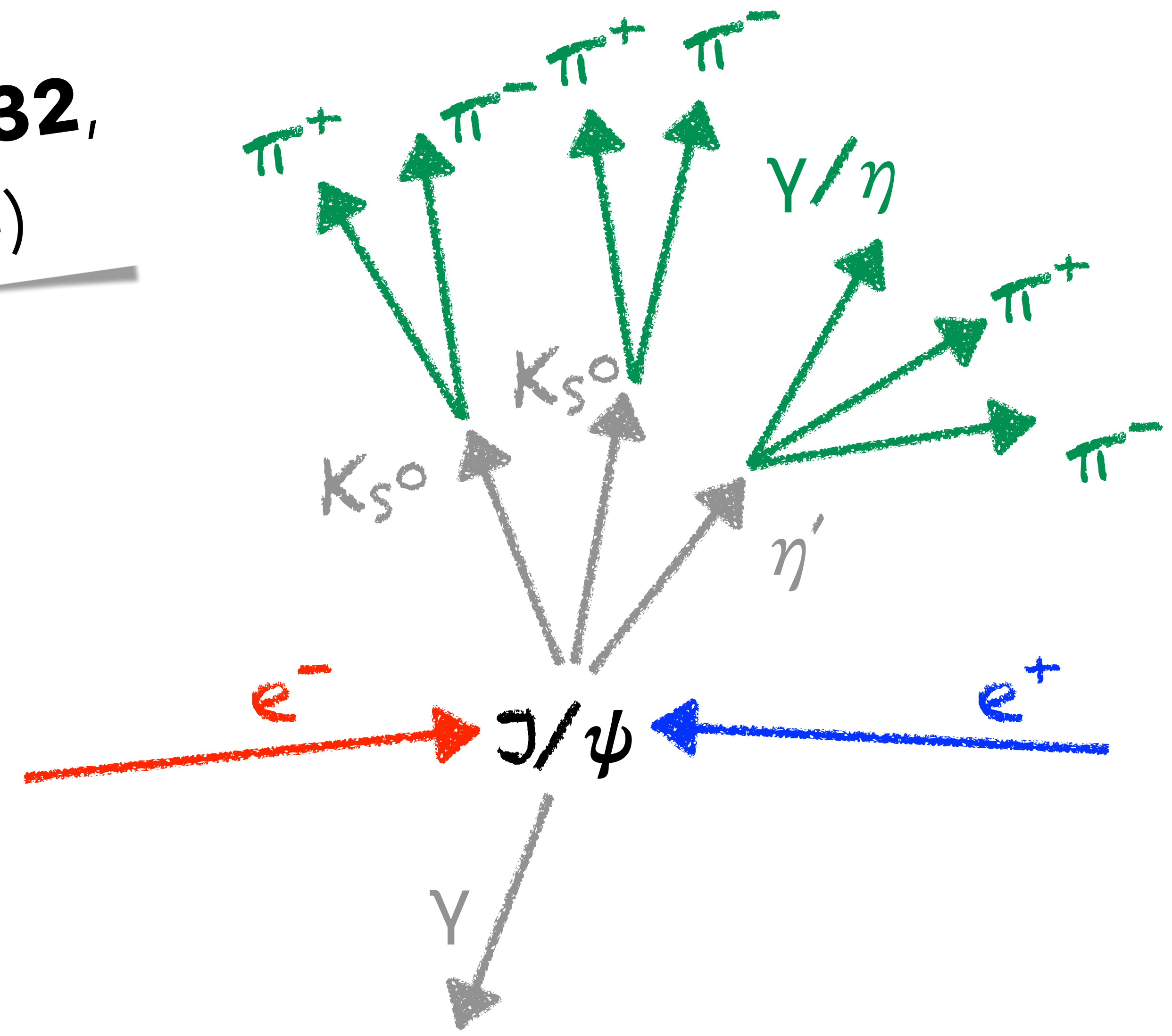
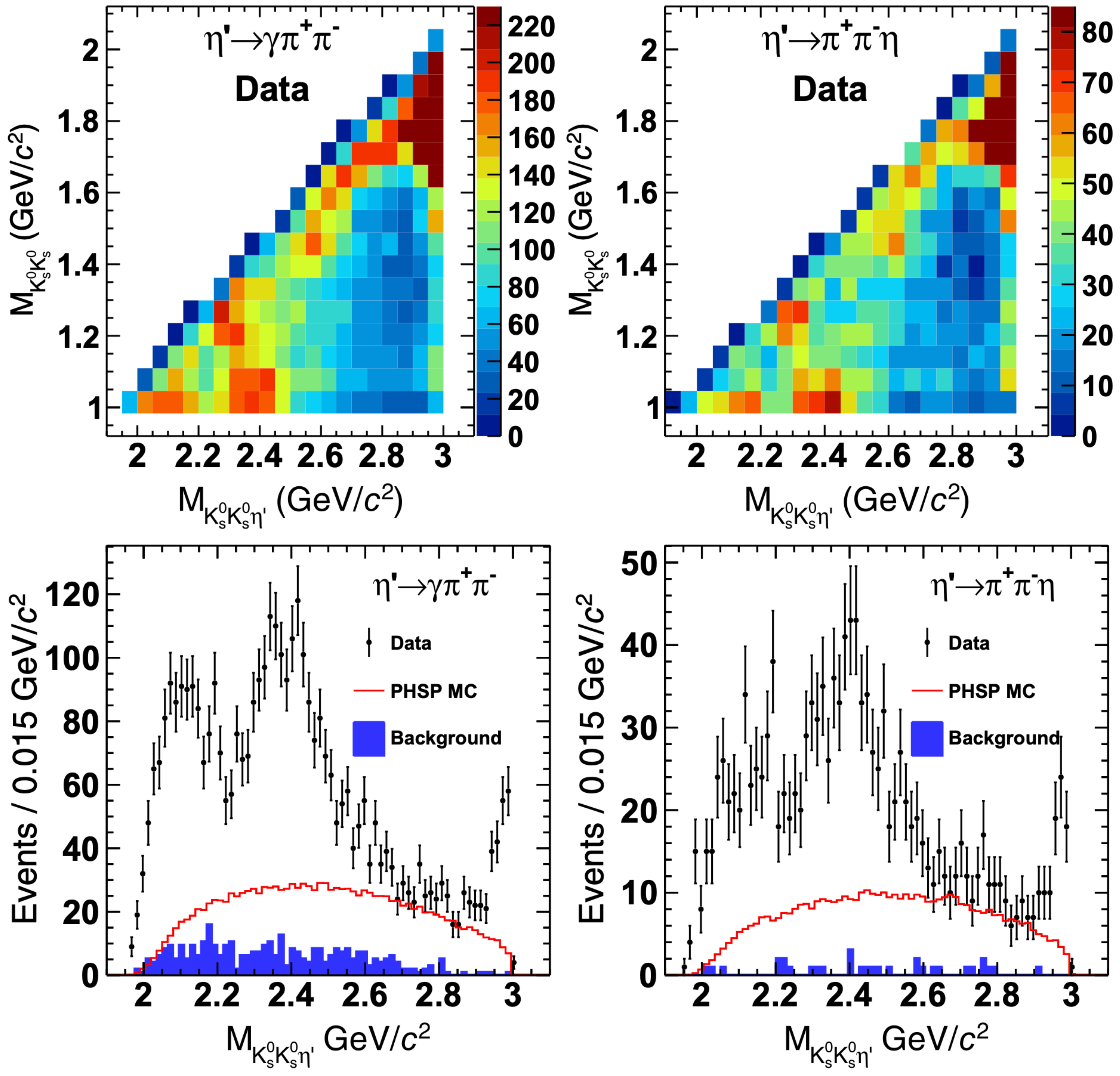


The parametrisation for the PWA:

- The [$f_0(980) \rightarrow K_S{}^0 K_S{}^0$] η' is described via the **X(1835)**, **X(2370)**, and the **η_c** resonances **and** a **broad X(2800)** ($J^{PC} = 0^{-+}$) structure, and **non-resonant** $(\mathbf{K_S{}^0 K_S{}^0})_{\mathbf{S/D\text{-}wave}}$
- Except for the **$f_0(980)$**, described by a **Flatté**, the **other states** are described by **BW**



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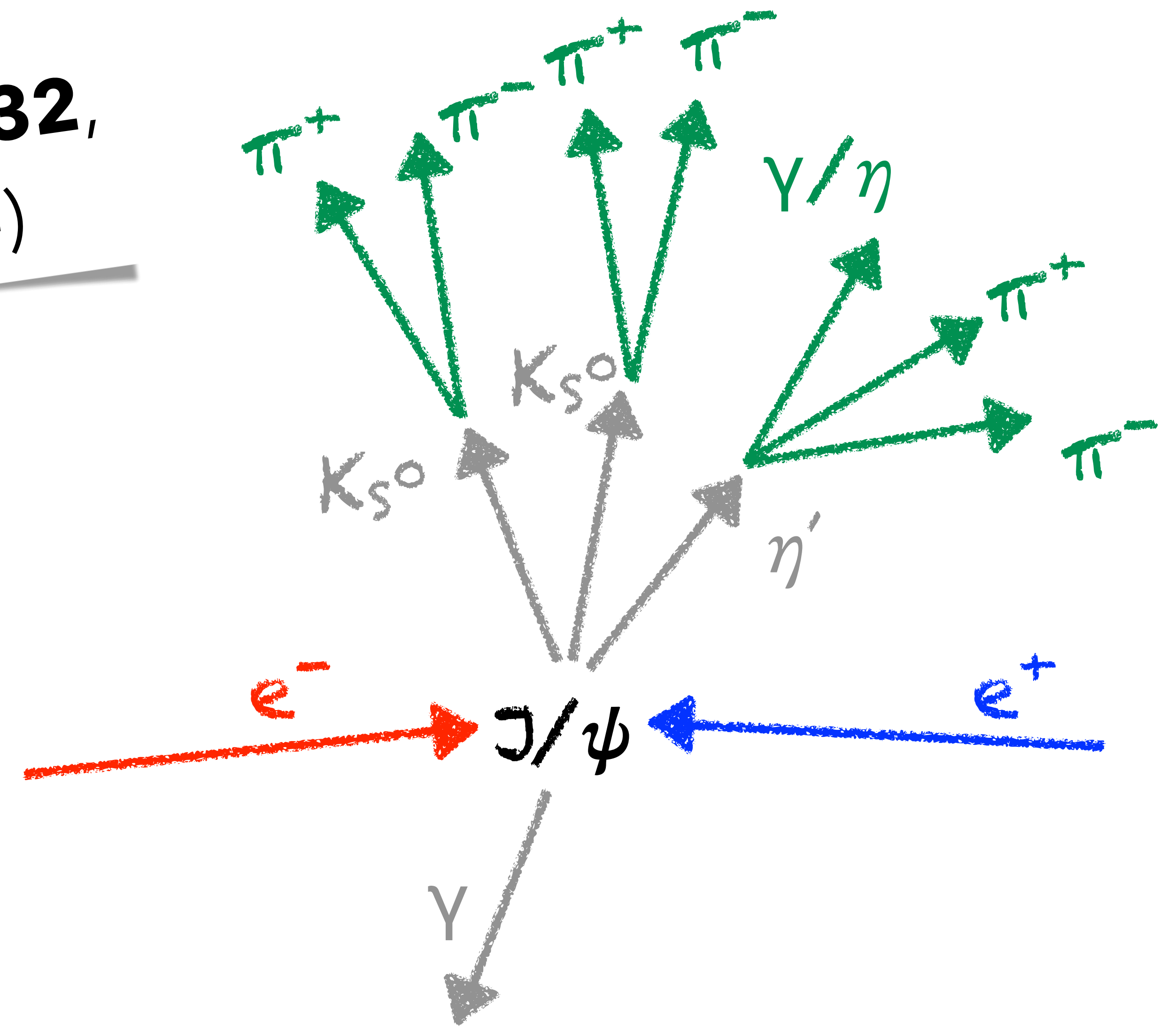

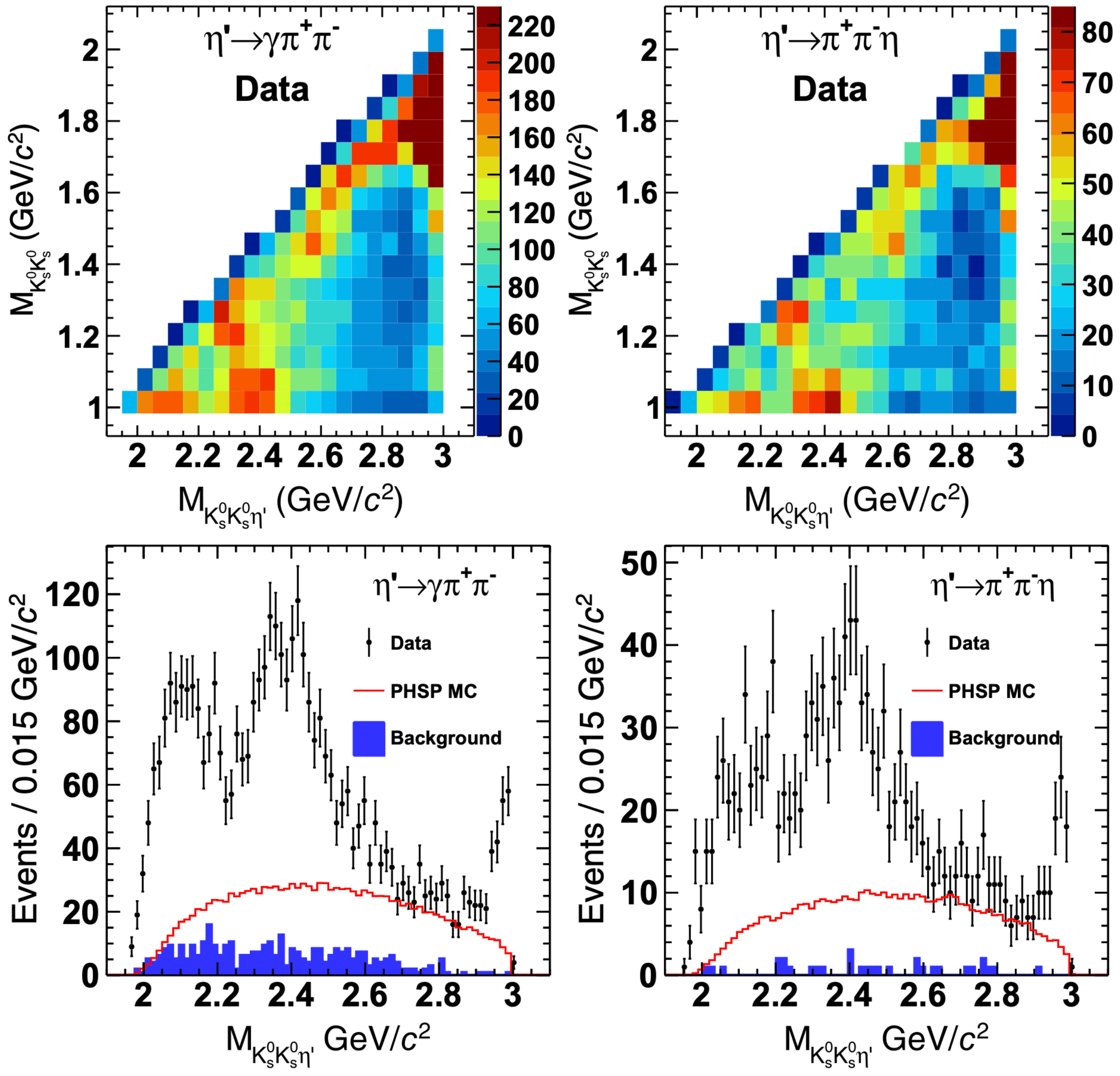

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X(2800) needed to effectively describe the X(2600) contribution (found @4.2σ) and the η_c line shape (changing its modelization decreases drastically the X(2800) significance)

Partial Wave Analyses on J/ψ Decays

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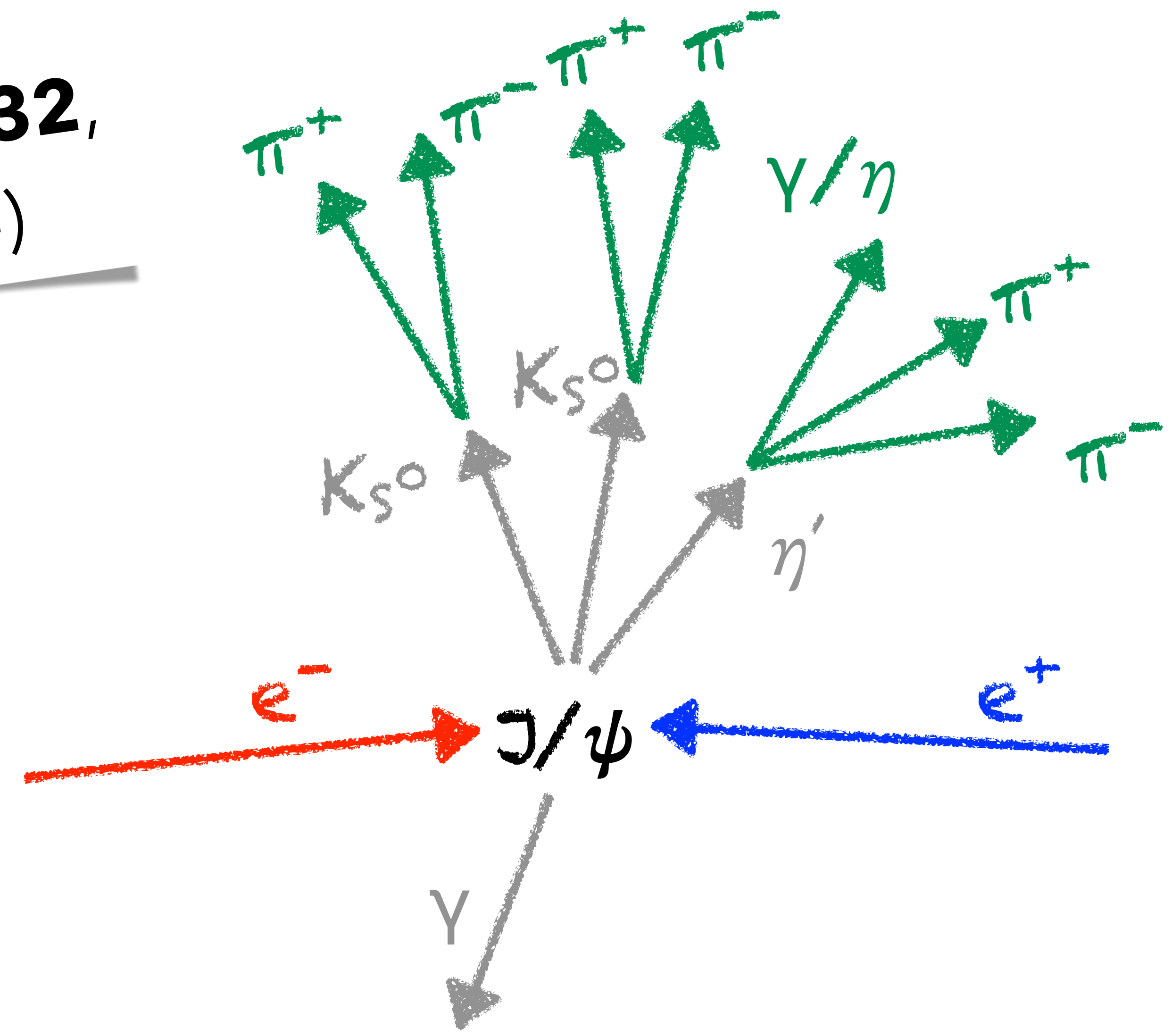

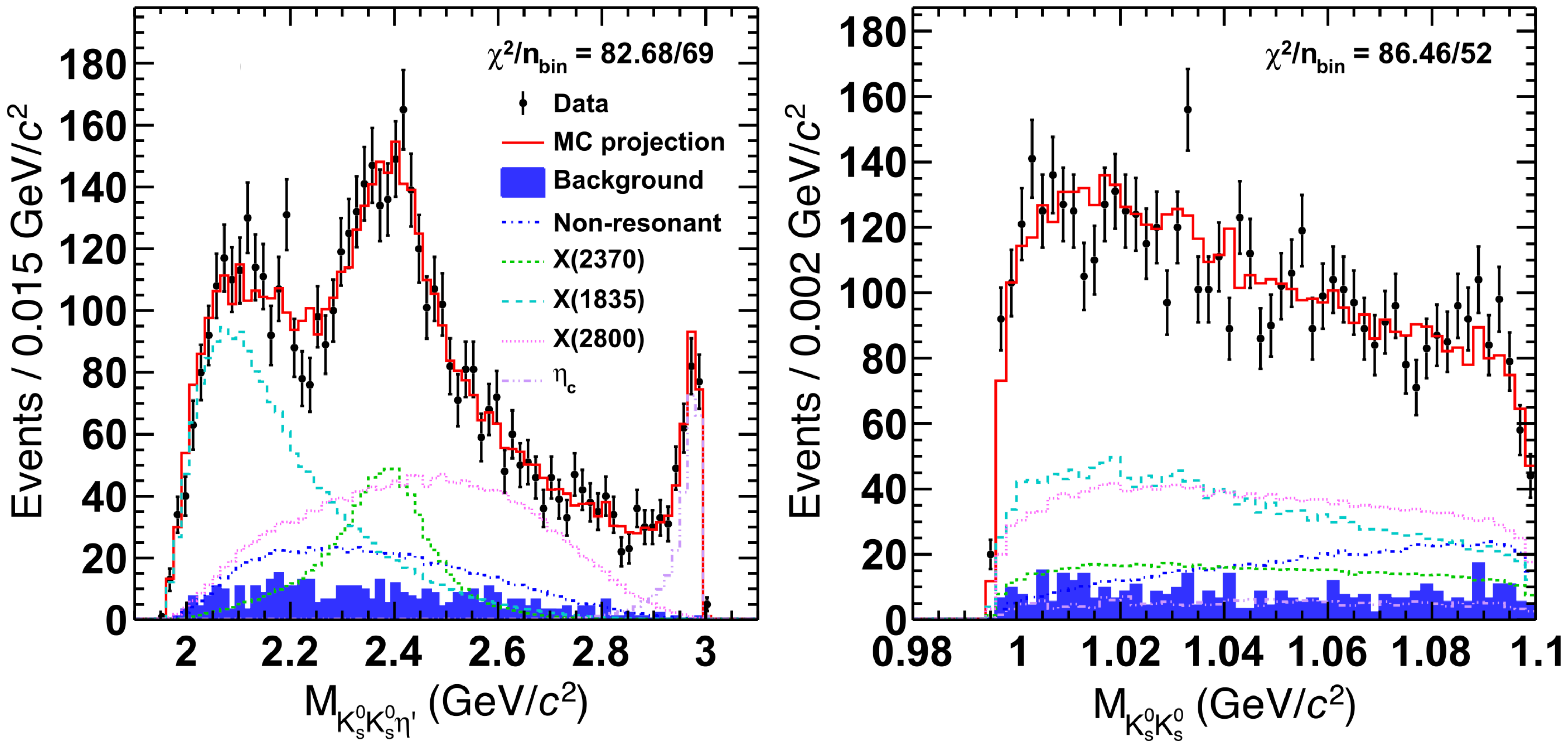

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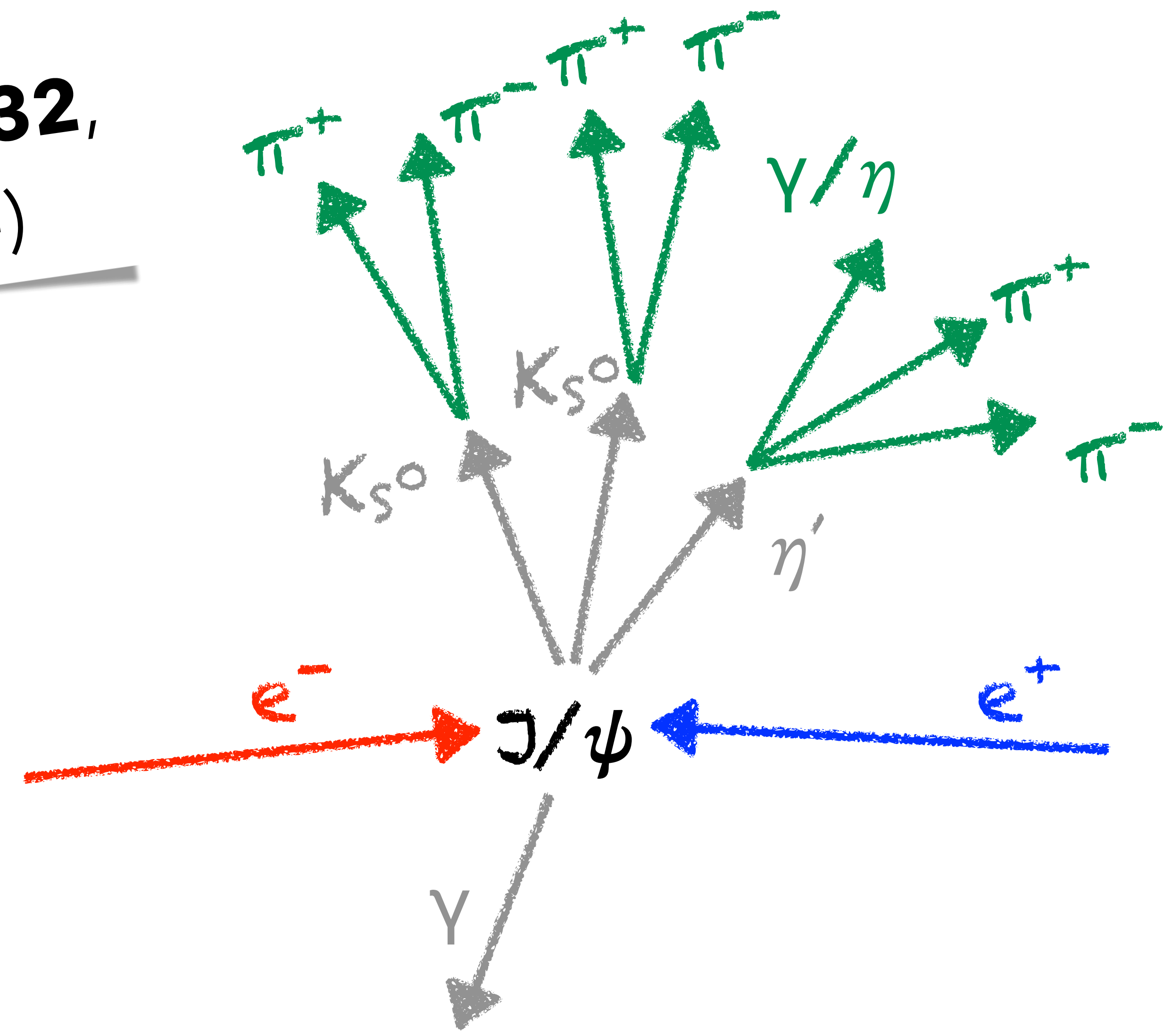

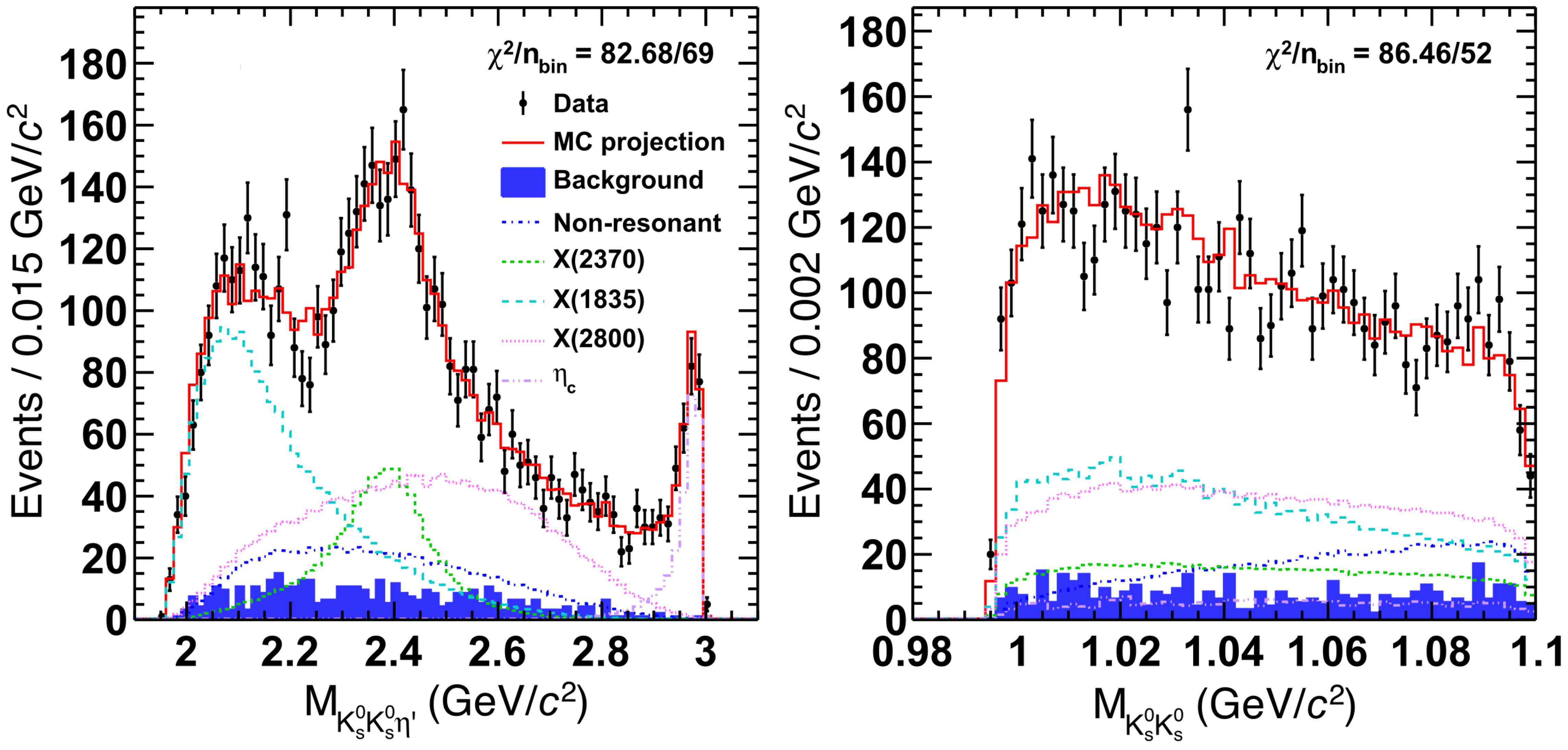

state	J^{PC}	Decay mode	Mass (MeV/c^2)	Width (MeV/c^2)	Significance
X(2370)	0^{-+}	$f_0(980)\eta'$	2395^{+11}_{-11}	188^{+18}_{-17}	14.9σ
X(1835)	0^{-+}	$f_0(980)\eta'$	1844	192	22.0σ
X(2800)	0^{-+}	$f_0(980)\eta'$	2799^{+52}_{-48}	660^{+180}_{-116}	16.4σ
η_c	0^{-+}	$f_0(980)\eta'$	2983.9	32.0	$> 20.0\sigma$
PHSP	0^{-+}	$\eta'(K_S^0 K_S^0)_{S-wave}$	− − −	− − −	9.0σ
		$\eta'(K_S^0 K_S^0)_{D-wave}$	− − −	− − −	16.3σ

The [$f_0(980) \rightarrow K_S{}^0 K_S{}^0$] η' is described via the **X(1835)**, **X(2370)**, and the **η_c** resonances **and** a **broad X(2800)** ($J^{PC} = 0^{-+}$) structure, and **non-resonant $(K_S{}^0 K_S{}^0)_{S/D\text{-wave}}$**

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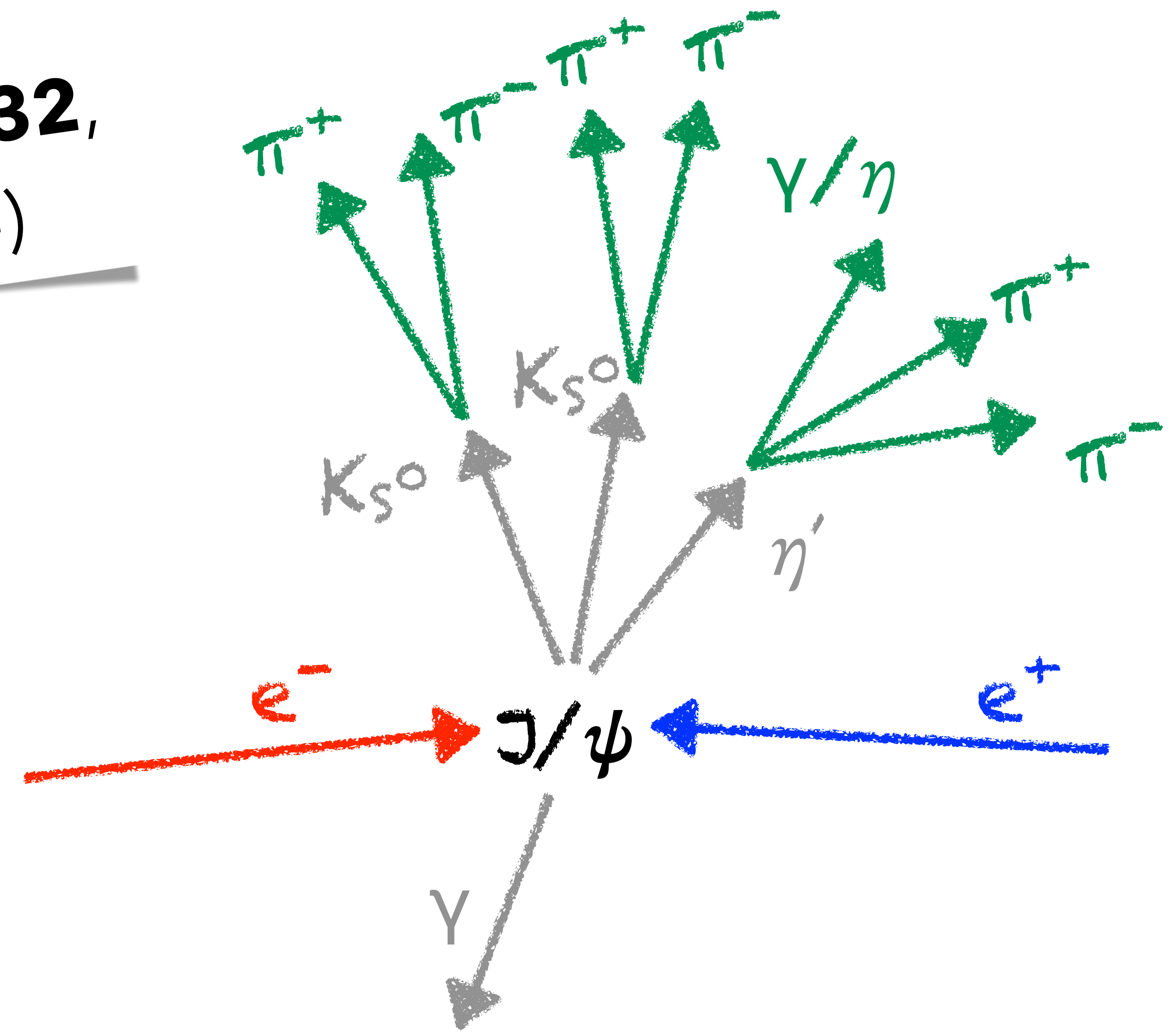

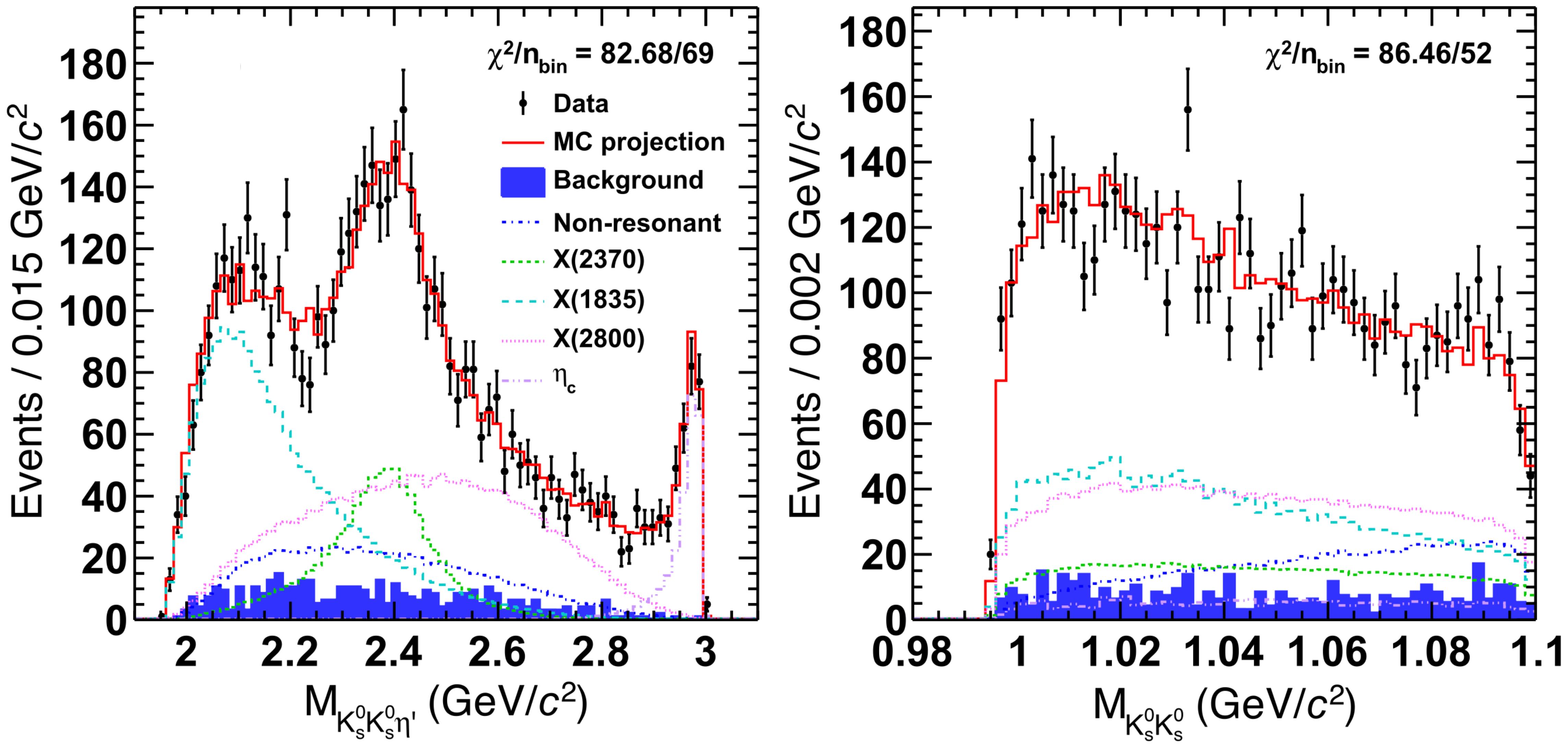

The $M_{X(2370)}$ is in agreement with the LQCD mass prediction[17] of the lightest pseudoscalar glueball, 2395 ± 14 MeV/c^2

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		$\eta'(K_S^0 K_S^0)_{D-wave}$	− − −	− − −	16.3σ

[17] Phys. Rev. D **100**, 054511 (2019)

Summary

BESIII started taking data in '08, and since then it has been **exploring and shedding light** on the **charmonium spectrum** and **the XYZ states**

Datasets above the **$D\bar{D}$ threshold** can shed new light on charmonium decays and hint at possible **connections** between **XYZ states and** conventional **charmonia**

Thanks to its **tuneable centre-of-mass energy** in the charmonium range and **leptonic beams**, **BESIII** can be **competitive** even with smaller datasets

Finally, **new data sets** are currently being taken and analysed

With the inner tracker and accelerator upgrades, exciting times wait ahead… thanks to high-energy high-statistics data sets (for XYZ searches and charmed baryon studies)

Thank you for the attention!

Backup Slides

BESIII Collaboration

~ 700 members
From 93 institutions
in 16 countries

Europe (19)

Germany(6): Bochum University, GSI Darmstadt, Helmholtz Institute Mainz, Johannes Gutenberg University of Mainz, Universitaet Giessen, University of Münster
Italy(3): Ferrara University, INFN, University of Turin,
Netherlands(1): KVI/University of Groningen
Russia(3): Budker Institute of Nuclear Physics, Dubna JINR, Lebedev Physical Institute
Sweden(1): Uppsala University
Turkey (1): Turkish Accelerator Center Particle Factory Group
UK(3): University of Manchester, University of Oxford, University of Bristol
Poland(1): National Centre for Nuclear Research

Pakistan(2)

Institute of Business Administration (IBA), Karachi
University of the Punjab

India(1)

Indian Institute of Technology madras

Mongolia(1)

Institute of Physics and Technology

Korea(1)

Chung-Ang University

Thailand(1)

Suranaree University of Technology

USA(3)

Carnegie Mellon University
Indiana University
University of Hawaii

Chile(2)

University of Tarapaca
University of La Serena

China (63)

Beihang University, Central China Normal University, Central South University, Chengdu University of Technology, China Center of Advanced Science and Technology, China University of Geosciences, Fudan University, Guangxi Normal University, Guangxi University, Guangxi University of Science and Technology, Hangzhou Normal University, Hebei University, Henan University, Henan Normal University, Henan University of Science and Technology, Henan University of Technology, , Hengyang Normal University, Huangshan College, Hunan University, Hunan Normal University, Inner Mongolia University, Institute of High Energy Physics, Institute of Modern Physics, Jiangsu Ocean University, Jilin University, Lanzhou University, Liaoning Normal University, Liaoning University, Longyan University, Nanjing Normal University, Nanjing University, Nankai University, North China Electric Power University, Peking University, Qufu Normal University, Renmin University of China, Shaanxi Normal University, Shanxi University, Shanxi Normal University, Sichuan University, Shandong Management University, Shandong Normal University, Shandong University, Shandong University of Technology, Shanghai Jiao Tong University, Soochow University, South China Normal University, Southeast University, Southwest University of Science and Technology, Sun Yat-sen University, Tsinghua University, University of Chinese Academy of Sciences, University of Jinan, University of Science and Technology of China, University of Science and Technology Liaoning, University of South China, Wuhan University, Xi'an Jiaotong University, Xinyang Normal University, Yantai University, Yunnan University, Zhejiang University, Zhengzhou University

BESIII Experiment

BESIII (BEijing Spectrometer III) is an experiment located at the BEPCII (Beijing Electron Positron Collider II) at IHEP (Institute of High Energy Physics)

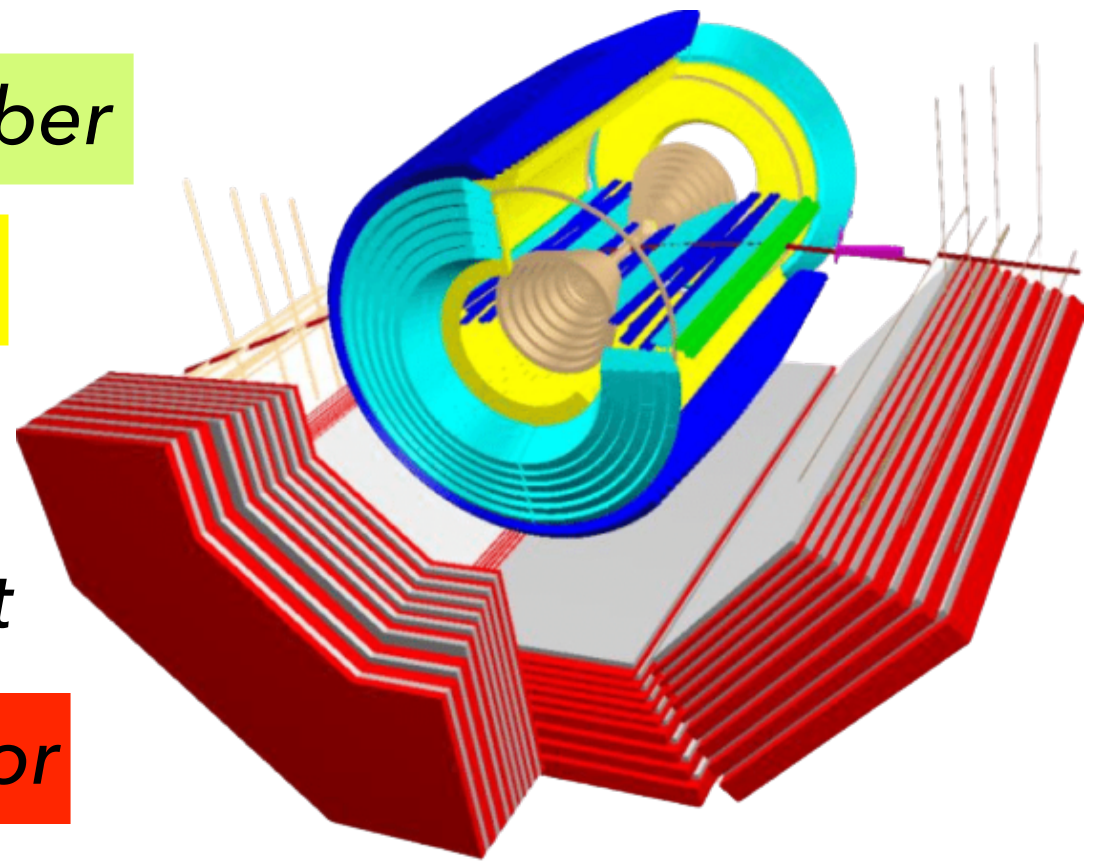
Multi-layer Drift Chamber

Time of Flight Detector

EM Calorimeter

1T Solenoidal Magnet

Muon Detector



τ-charm factory 2.0 GeV ≤ $\sqrt{s}$ ≤ 4.9 GeV

with a 10^{33} $cm^{-2}s^{-1}$ designed luminosity @ $\sqrt{s}$ = 3.77 GeV

MDC		
Single wire $\sigma_{r\phi}$ (1 GeV)	130	μm
σ_z (1 GeV)	~2	mm
σ_p/p (1 GeV)	0.5	%
$\sigma_{dE/dx}$ (1 GeV)	6	%

EMC		
σ_E/E (1 GeV)	2.5	%
Position resolution (1 GeV)	0.6	cm

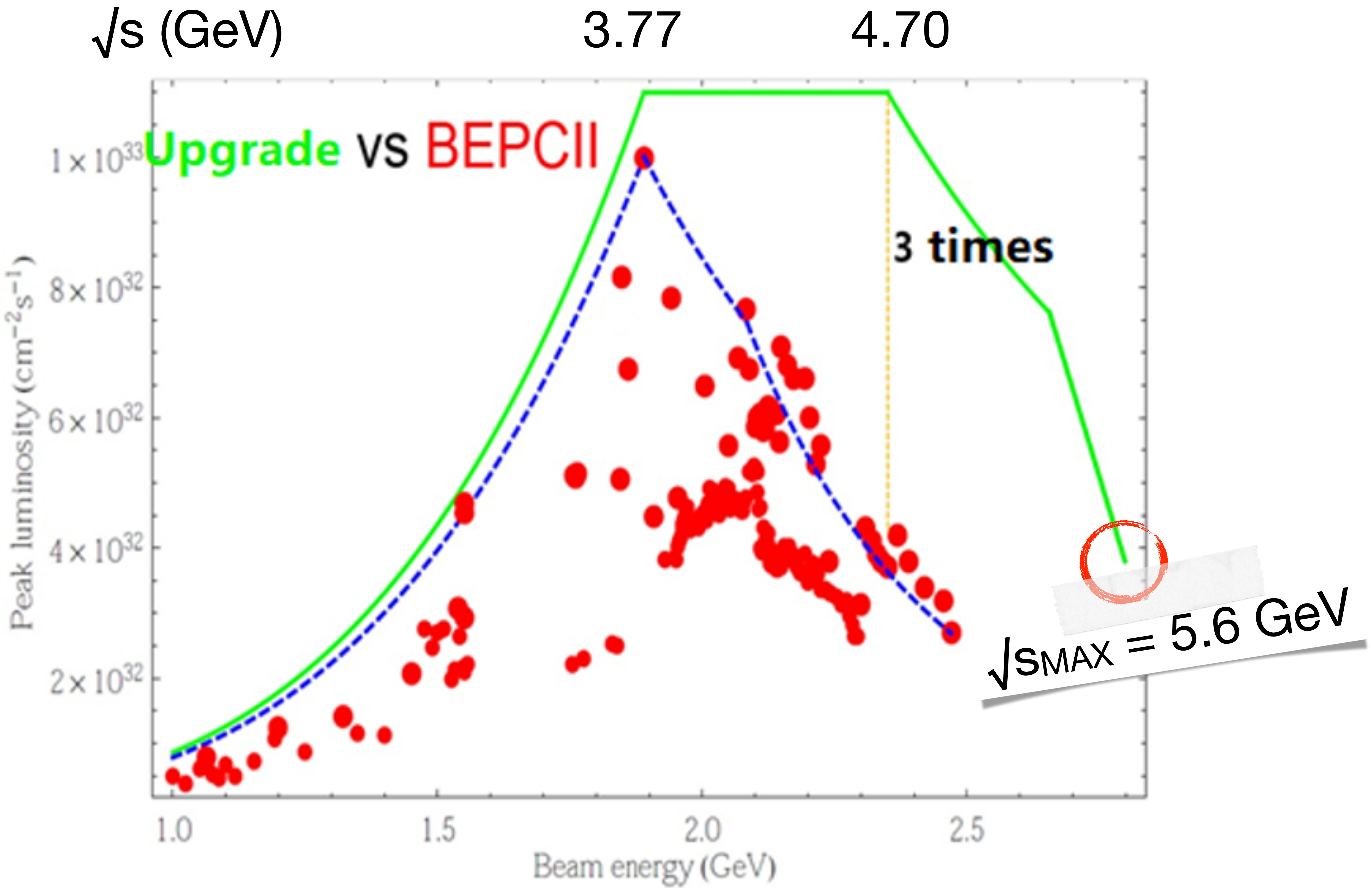
TOF		
σ_T		
Barrel (1 GeV/c muons)	100	ps
End cap (0.8 GeV/c pions)	65	ps

Muon Identifier		
No. of layers (barrel/end cap)	9/8	
Cut-off momentum	0.4	GeV/c

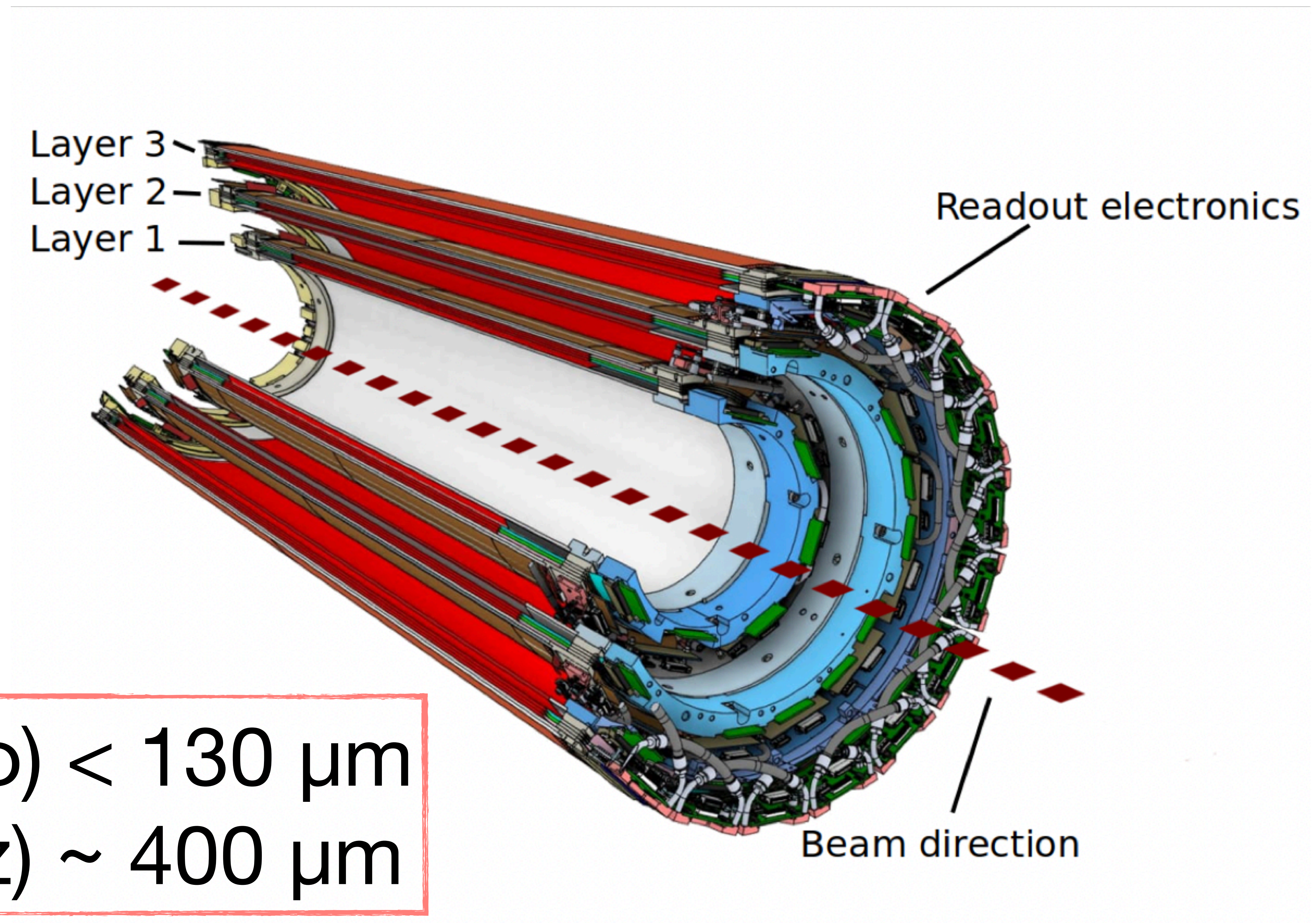
Solenoid field	1.0	T
$\Delta\Omega/4\pi$	93	%

Upgrading the BESIII Experiment

Energy & Luminosity



CGEM-IT



$\delta(\phi) < 130\ \mu m$
$\delta(z) \sim 400\ \mu m$

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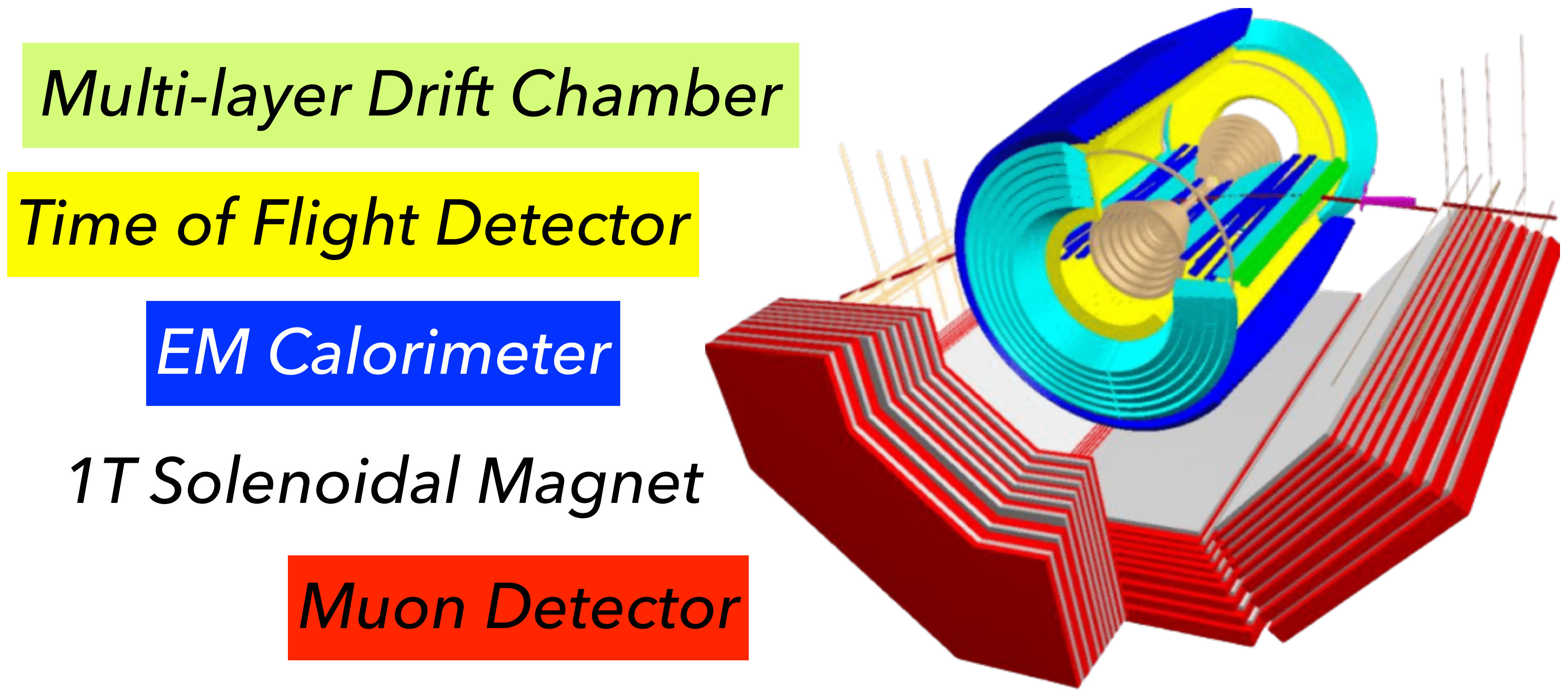

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with a 10^{33} $cm^{-2}s^{-1}$ designed luminosity

@ $\sqrt{s}$ = 3.77 GeV

Data sets

2009: 106M $\psi(2S)$
225M J/ψ
2010: 975 pb^{-1} at $\psi(3770)$
2011: 2.9 fb^{-1} *(total)* at $\psi(3770)$
482 pb^{-1} at 4.01 GeV
2012: 0.45B *(total)* $\psi(2S)$
1.3B *(total)* J/ψ
2013: 1092 pb^{-1} at 4.23 GeV
826 pb^{-1} at 4.26 GeV
540 pb^{-1} at 4.36 GeV
10×50 pb^{-1} scan 3.81 — 4.42 GeV
2014: 1029 pb^{-1} at 4.42 GeV
110 pb^{-1} at 4.47 GeV
110 pb^{-1} at 4.53 GeV
48 pb^{-1} at 4.575 GeV
567 pb^{-1} at 4.6 GeV
0.8 fb^{-1} R-scan 3.85 — 4.59 GeV
2015: R-scan 2 — 3 GeV + 2.175 GeV
2016: ~3fb^{-1} at 4.18 GeV (for D_s)
2017: 7×500 pb^{-1} scan 4.19 — 4.27 GeV
2018: more J/ψ *(and tuning new RF cavity)*
2019: 10B *(total)* J/ψ
8×500 pb^{-1} scan 4.13, 4.16, 4.29 — 4.44 GeV
2020: 3.8 fb^{-1} scan 4.61 - 4.7 GeV
2021: 2 fb^{-1} scan 4.74 - 4.946 GeV
3.0B (total) $\psi(2S)$
2022: 410 pb^{-1} at 3.65 GeV
404 pb^{-1} at 3.68 GeV
2024: 692 pb^{-1} scan 3.78 - 3.554 GeV

The New $\omega X(3872)$ Production Mode

Using 9 energy points @$\sqrt{s}$ = **[4.661 4.951] GeV**

Study of the $\sigma^{Born}(e^+e^- \to \omega\pi^+\pi^- J/\psi)$

Fit to $M(\pi^+\pi^- J/\psi)$ to estimate the X(3872) mass and its production cross-section

If the **X(3872) contains** a component of the spin-triplet state χ_{c1}**(2P)**, the **process** $e^+e^- \to \omega X(3872)$ should **exist**, as BESIII observed the $e^+e^- \to \omega\chi_{cJ}(1P)$ transitions[I]

Phys. Rev. Lett. **130**, 151904 (2023)

[I] Phys. Rev. Lett. **114**, 092003 (2015)

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Phys. Rev. Lett. **130**, 151904 (2023)

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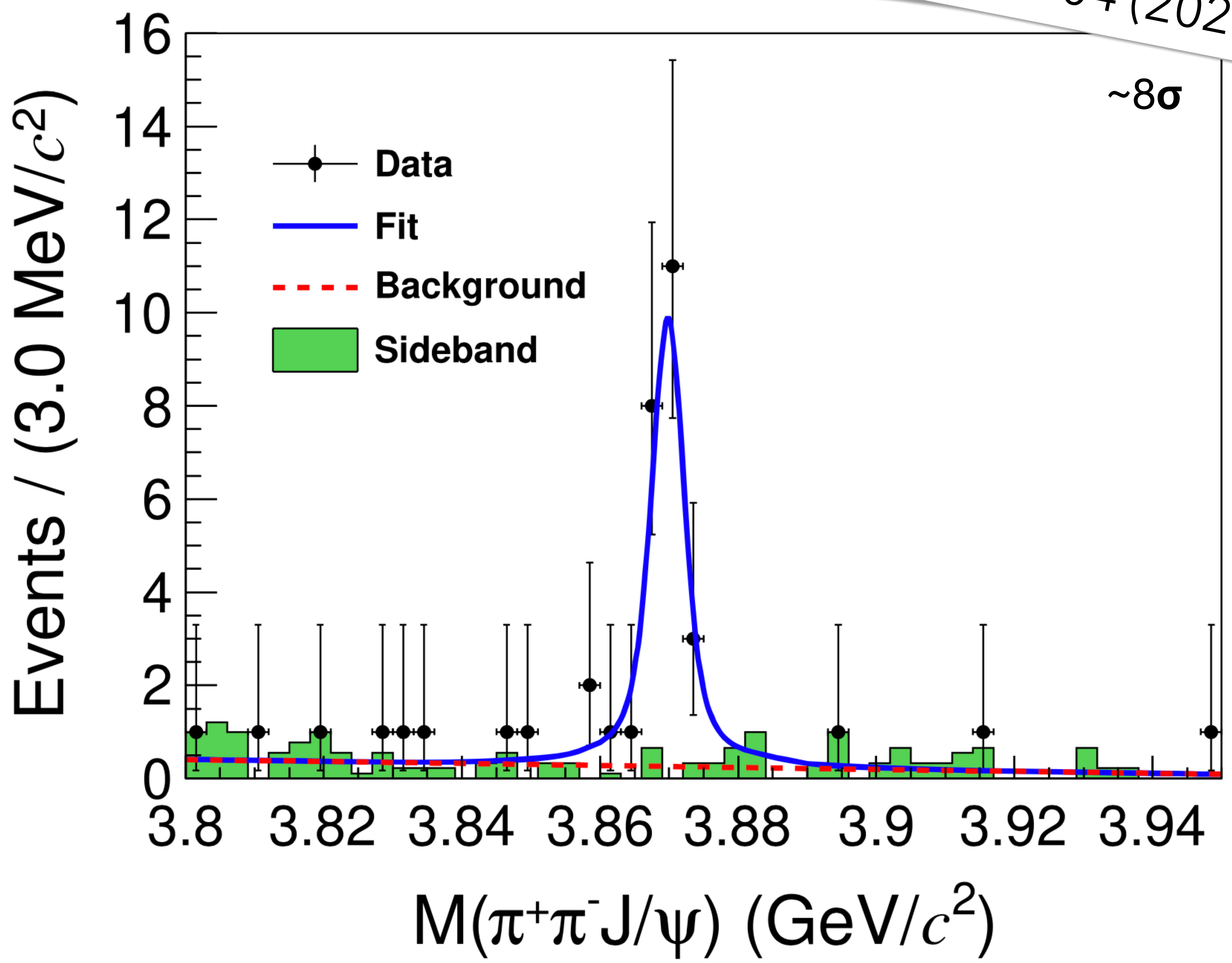

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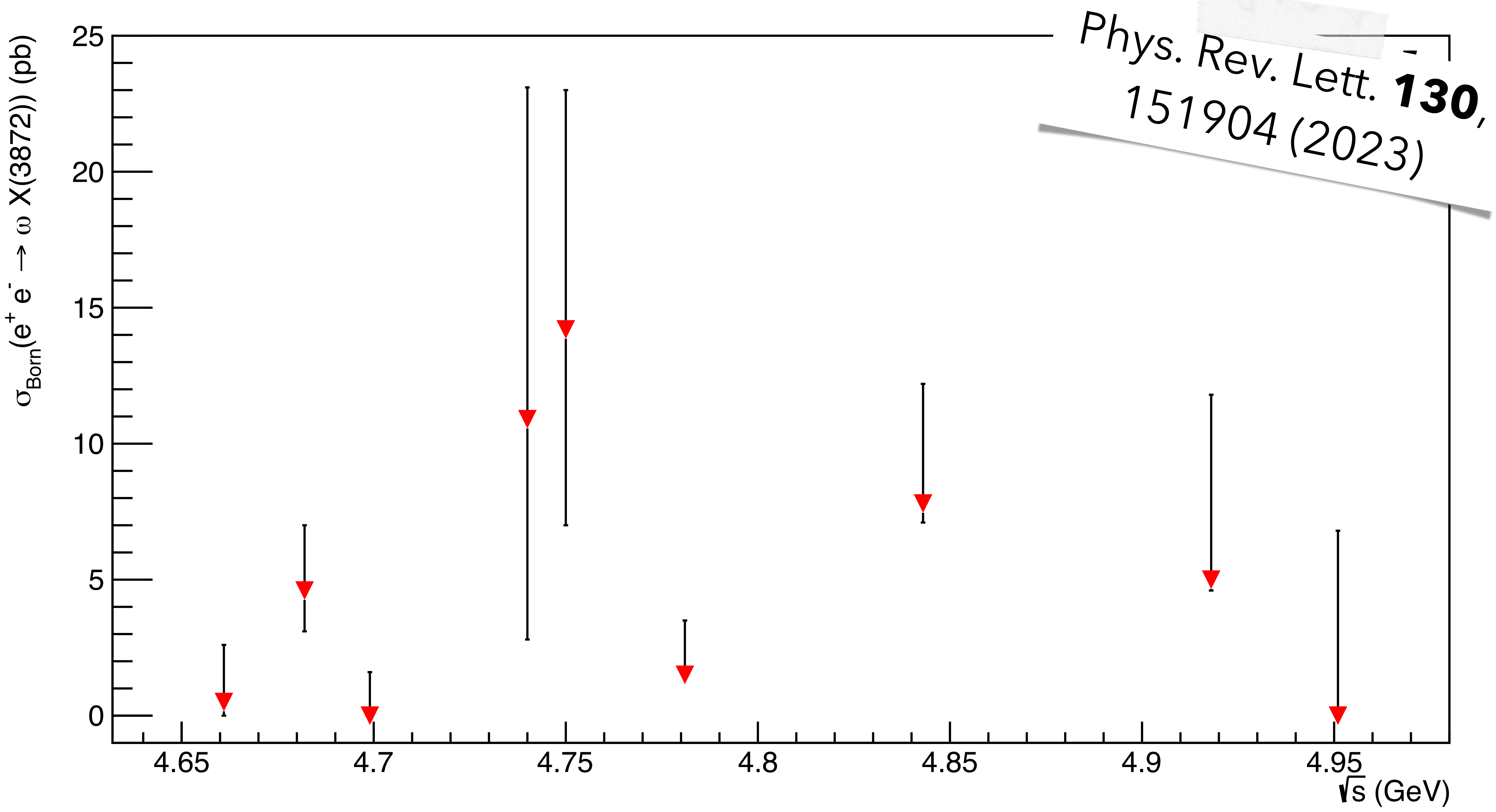

The **line-shape** suggests that the ***ωX(3872)*** production mode may derive from some **nontrivial structures** decays

[I] Phys. Rev. Lett. **114**, 092003 (2015)