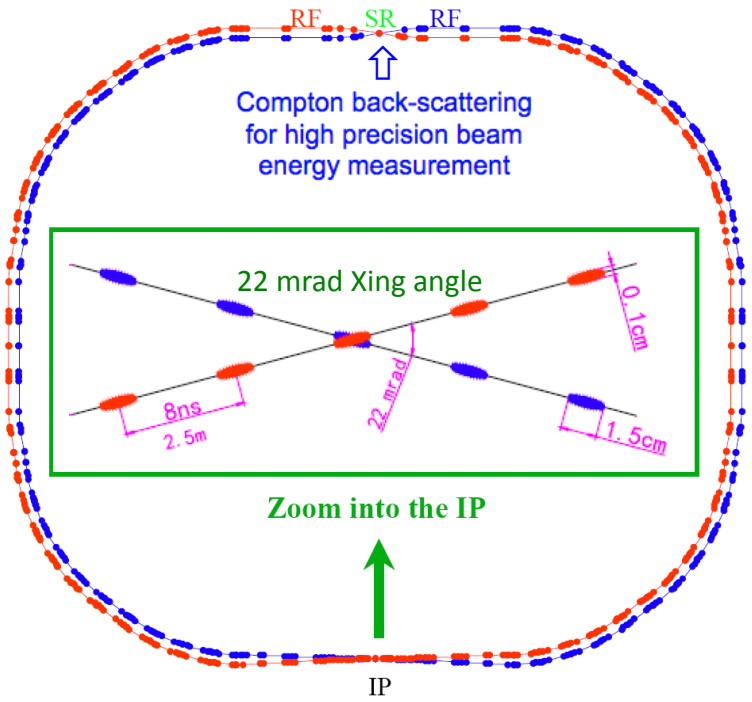
News from BES III

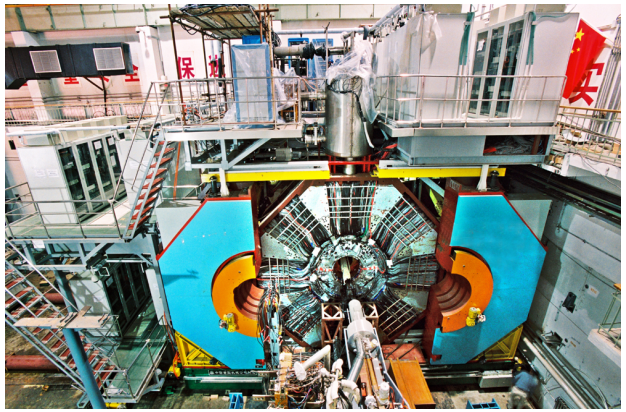
55th International Meeting on Nuclear Physics, Bormio Italy, Jan 22-27, 2017

Stephen Lars Olsen Institute for Basic Science Daejeon, KOREA

Institute of High Energy Physics
-- Beijing --

BEPCII storage rings





Beam energy: 1.0 − 2.3 GeV

Peak Luminosity:

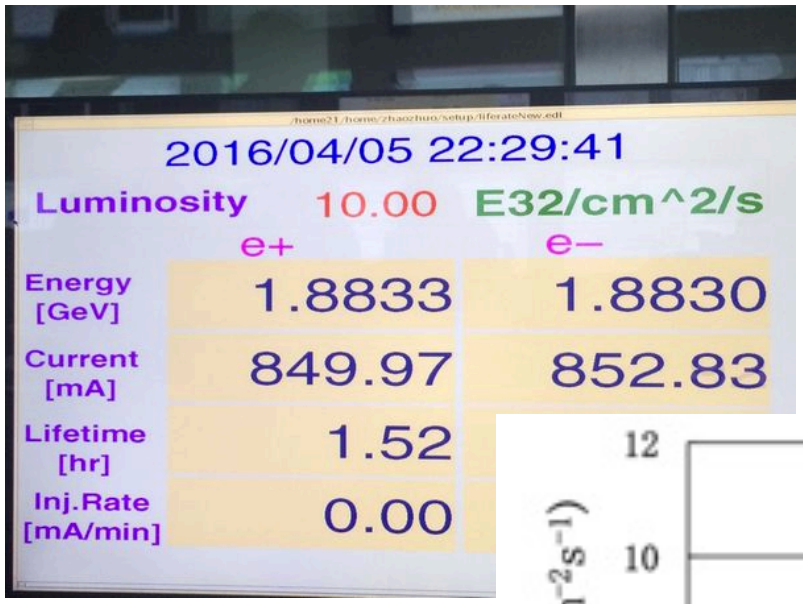
Design: 1×10^{33} $cm^{-2}s^{-1}$ ←*Achieved!*

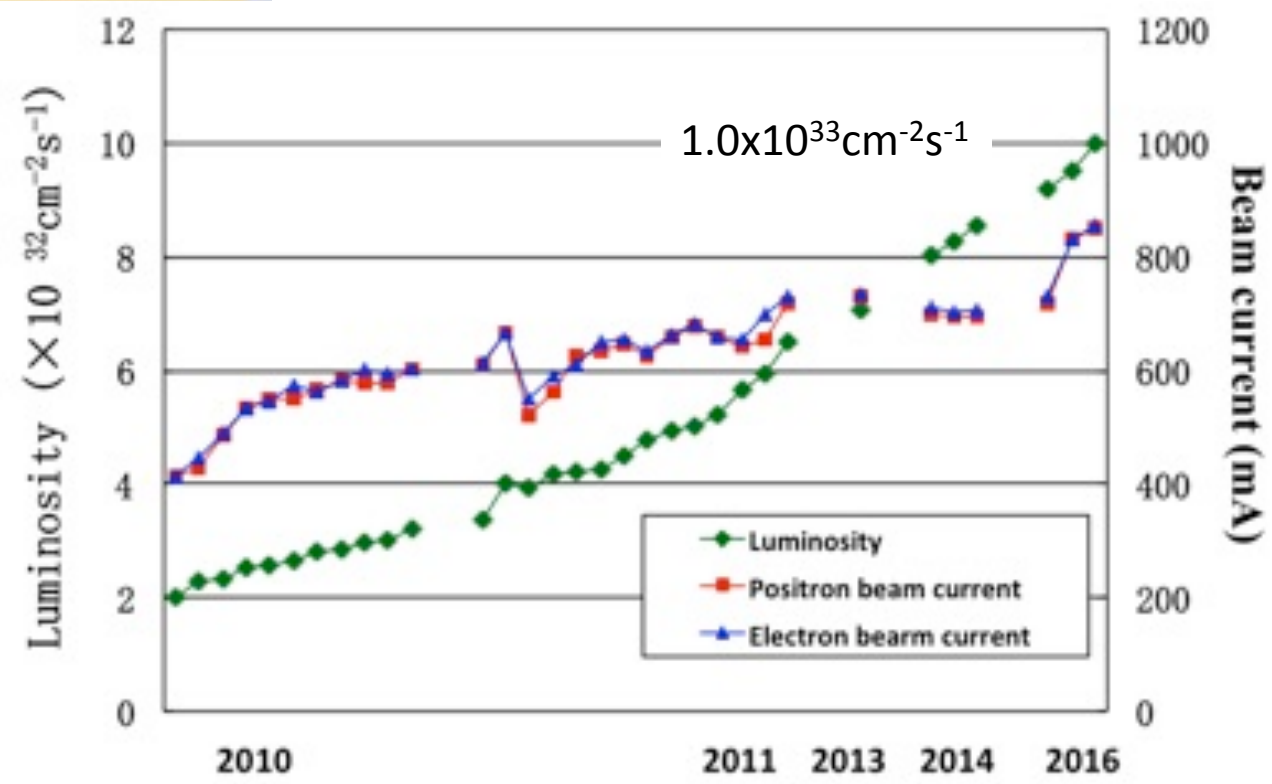
Beam energy measurement: Using Compton backscattering technique.

Accuracy: $\delta E_{beam}/E_{beam} \approx 5x10^{-5}$

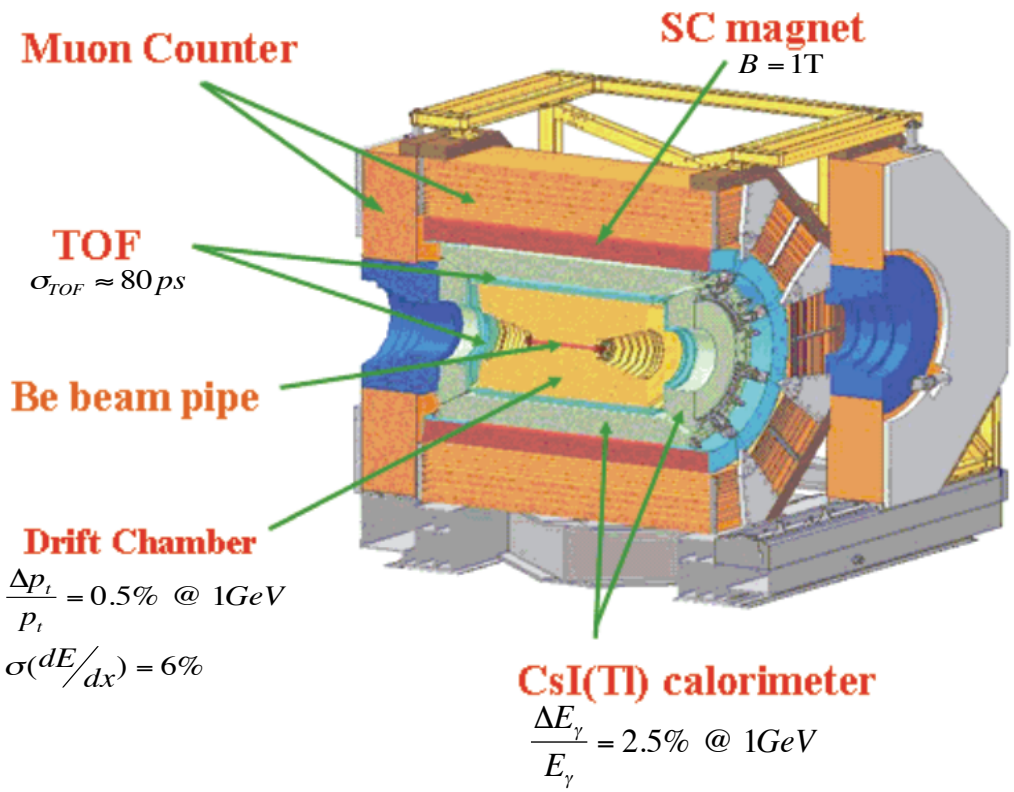
➔$\delta E_{beam} \approx 50$ KeV @$E_{beam} \approx m_{\tau}$

luminosity since startup

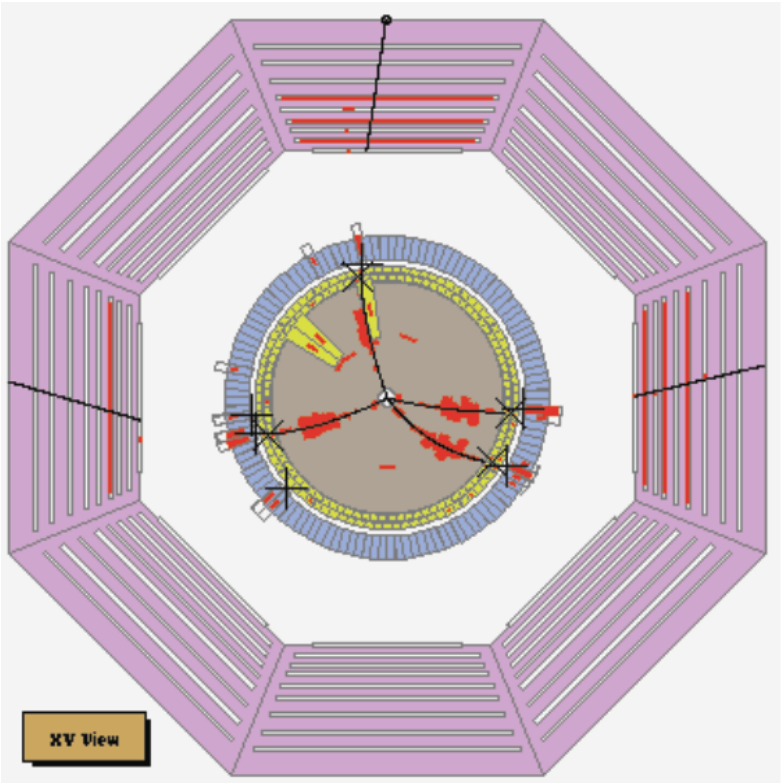




The BESIII Detector

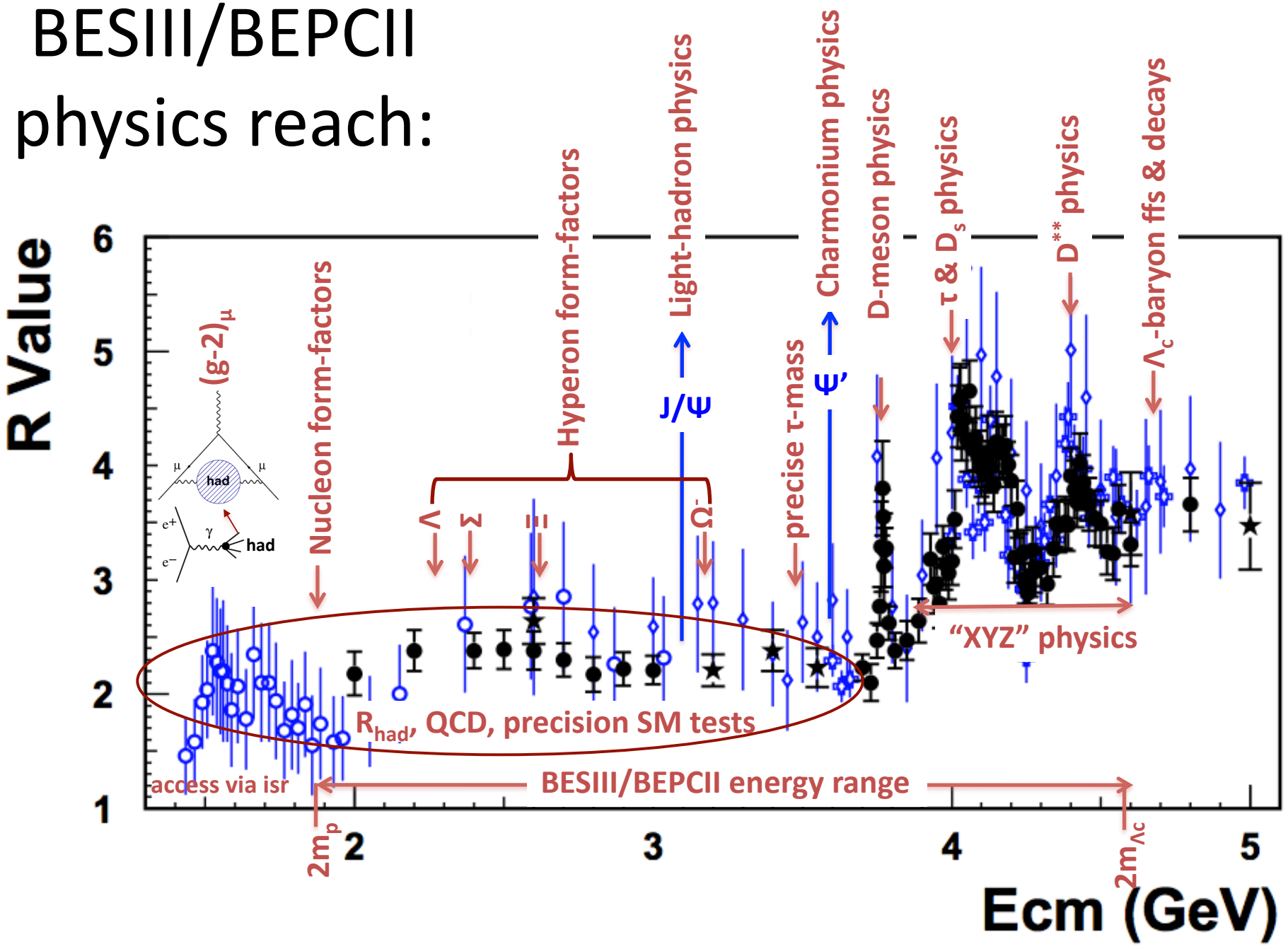


BESIII's 1st event



BESIII Collaboration

BESIII/BEPCII physics reach:



News from BESIII

Results from the BEPCII/BESIII Y(4260) factory

XYZ mesons & P_c Pentaquarks

Light quark sector

Neutral charmonium-like

Charged charmonium-like

Hidden-charm pentaquarks

b-quark sector

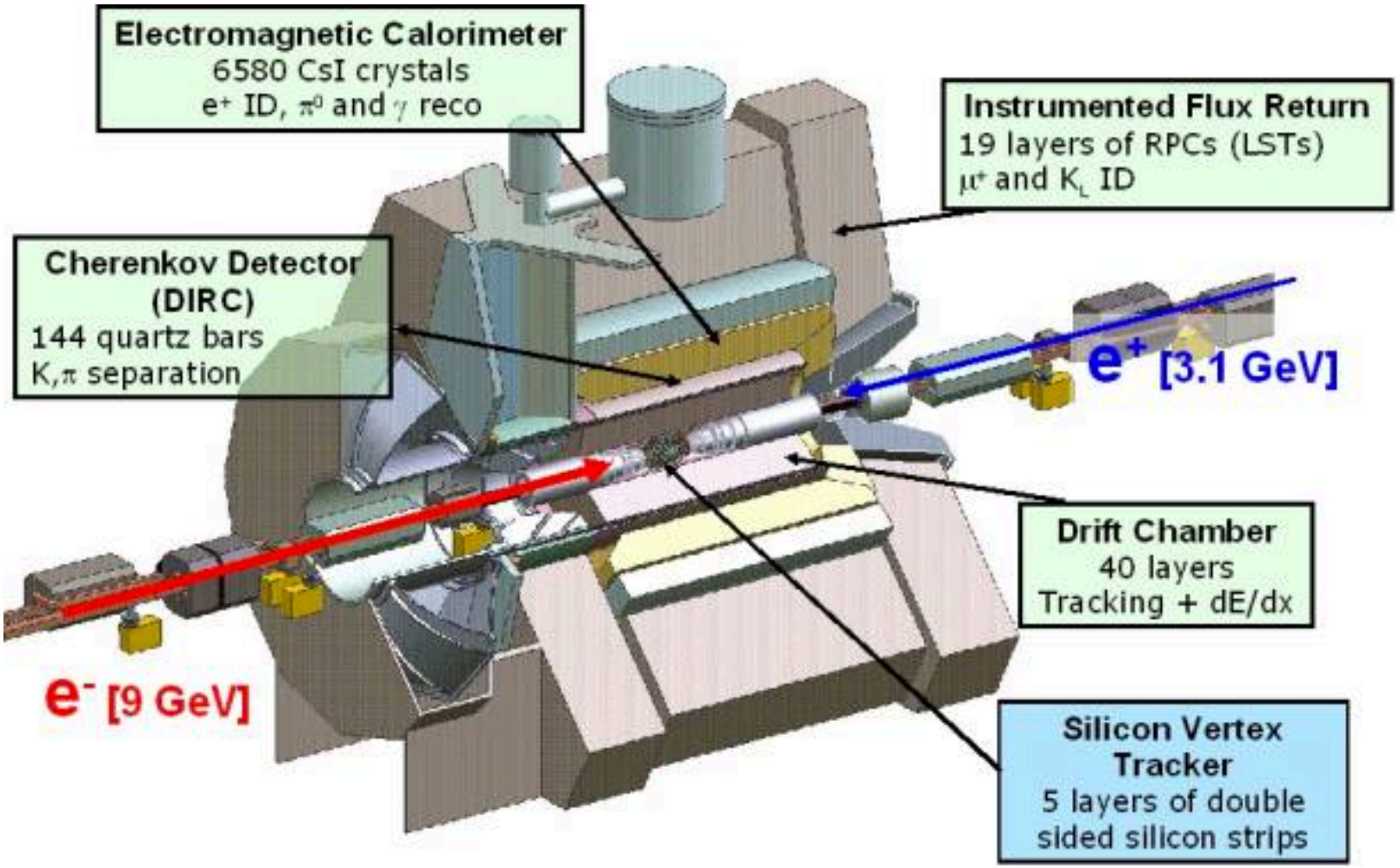
State	M (MeV)	Γ (MeV)	J^{PC}	Process (decay mode)	Experiment
$\pi_1(1400)$	1354±25	330 ± 25	1^{-+}	$\pi^- p \to (\eta\pi^-)p$	MPS, Compass
				$p\bar{p} \to \pi^0(\pi^0\eta)$	Xtal Barrel
$X(1835)$	$135.7^{+5.0}_{-3.2}0$	99 ± 50	0^{-+}	$J/\psi \to \gamma(p\bar{p})$	BESII, CLEOc, BESIII
				$J/\psi \to \gamma\,(\pi^+\pi^-\eta')$	BESII, BESIII
$X(3872)$	3871.68±0.17	< 1.2	1^{++}	$B \to K + (J/\psi\,\pi^+\pi^-)$	Belle, BaBar, LHCb
				$p\bar{p} \to (J/\psi\,\pi^+\pi^-) + ...$	CDF, D0
				$B \to K + (J/\psi\,\pi^+\pi^-\pi^0)$	Belle, BaBar
				$B \to K + (D^0\bar{D}^0\pi^0)$	Belle , BaBar
				$B \to K + (J/\psi\,\gamma)$	BaBar, Belle , LHCb
				$B \to K + (\psi'\,\gamma)$	BaBar, Belle , LHCb
				$pp \to (J/\psi\,\pi^+\pi^-) + ...$	LHCb, CMS
$X(3915)$	3917.4 ± 2.7	28^{+10}_{-9}	0^{++}	$B \to K + (J/\psi\,\omega)$	Belle , BaBar
				$e^+e^- \to e^+e^- + (J/\psi\,\omega)$	Belle , BaBar
$\chi_{c2}(2P)$	3927.2 ± 2.6	24±6	2^{++}	$e^+e^- \to e^+e^- + (D\bar{D})$	Belle , BaBar
$X(3940)$	3942^{+9}_{-8}	37^{+27}_{-17}	$0(?)^{-(?)+}$	$e^+e^- \to J/\psi + (D^*\bar{D})$	Belle
				$e^+e^- \to J/\psi + (...)$	Belle
$G(3900)$	3943 ± 21	52±11	1^{--}	$e^+e^- \to \gamma + (D\bar{D})$	BaBar, Belle
$Y(4008)$	4008^{+121}_{-49}	226±97	1^{--}	$e^+e^- \to \gamma + (J/\psi\,\pi^+\pi^-)$	Belle
$Y(4140)$	$4146.5^{+6.4}_{-5.3}$	$83^{+30}_{-25}9$	1^{++}	$B \to K + (J/\psi\,\phi)$	CDF, CMS, LHCb
$X(4160)$	4156^{+29}_{-25}	139^{+113}_{-65}	$0(?)^{-(?)+}$	$e^+e^- \to J/\psi + (D^*\bar{D})$	Belle
$Y(4260)$	4263^{+8}_{-9}	95±14	1^{--}	$e^+e^- \to \gamma + (J/\psi\,\pi^+\pi^-)$	BaBar, CLEO, Belle
				$e^+e^- \to (J/\psi\,\pi^+\pi^-)$	CLEO, BESIII
				$e^+e^- \to (J/\psi\,\pi^0\pi^0)$	CLEO, BESIII
$Y(4274)$	4273^{+19}_{-9}	56 ± 16	1^{++}	$B \to K + (J/\psi\,\phi)$	CDF, CMS, LHCb
$X(4350)$	$4350.6^{+4.6}_{-5.1}$	$13.3^{+18.4}_{-10.0}$	$0/2^{++}$	$e^+e^- \to e^+e^-\,(J/\psi\,\phi)$	Belle
$Y(4360)$	4361 ± 13	74±18	1^{--}	$e^+e^- \to \gamma + (\psi'\,\pi^+\pi^-)$	BaBar, Belle
$X(4630)$	$4634^{+\ 9}_{-11}$	92^{+41}_{-32}	1^{--}	$e^+e^- \to \gamma\,(\Lambda_c^+\Lambda_c^-)$	Belle
$Y(4660)$	4664±12	48±15	1^{--}	$e^+e^- \to \gamma + (\psi'\,\pi^+\pi^-)$	Belle
$Z_c^+(3900)$	3890 ± 3	33 ± 10	1^{+-}	$Y(4260) \to \pi^- + (J/\psi\,\pi^+)$	BESIII, Belle
				$Y(4260) \to \pi^- + (D\bar{D}^*)^+$	BESIII
$Z_c^+(4020)$	4024 ± 2	10 ± 3	$1(?)^{+(?)-}$	$Y(4260) \to \pi^- + (h_c\,\pi^+)$	BESIII
				$Y(4260) \to \pi^- + (D^*\bar{D}^*)^+$	BESIII
$Z_1^+(4050)$	4051^{+24}_{-43}	82^{+51}_{-55}	$?^{?+}$	$B \to K + (\chi_{c1}\,\pi^+)$	Belle, BaBar
$Z^+(4200)$	4196^{+35}_{-32}	370^{+99}_{-149}	1^{+-}	$B \to K + (J/\psi\,\pi^+)$	Belle, LHCb
$Z_2^+(4250)$	4248^{+185}_{-45}	177^{+321}_{-72}	$?^{?+}$	$B \to K + (\chi_{c1}\,\pi^+)$	Belle, BaBar
$Z^+(4430)$	4477 ± 20	181 ± 31	1^{+-}	$B \to K + (\psi'\,\pi^+)$	Belle, LHCb
				$B \to K + (J\psi\,\pi^+)$	Belle
$P_c^+(4380)$	4380 ± 30	205 ± 88	$(3/2)^-$	$\Lambda_b^+ \to K + (J/\psi\,p)$	LHCb
$P_c^+(4450)$	4449.8 ± 3.0	39 ± 20	$(5/2)^+$	$\Lambda_b^+ \to K + (J/\psi\,p)$	LHCb
$Y_b(10890)$	10888.4 ± 3.0	$30.7^{+8.9}_{-7.7}$	1^{--}	$e^+e^- \to (\Upsilon(nS)\,\pi^+\pi^-)$	Belle
$Z_b^+(10610)$	10607.2 ± 2.0	18.4 ± 2.4	1^{+-}	"$\Upsilon(5S)'' \to \pi^- + (\Upsilon(nS)\,\pi^+)$, $n = 1,2,3$	Belle
				"$\Upsilon(5S)'' \to \pi^- + (h_b(nP)\,\pi^+)$, $n = 1,2$	Belle
				"$\Upsilon(5S)'' \to \pi^- + (B\bar{B}^*)^+$, $n = 1,2$	Belle
$Z_b^0(10610)$	10609 ± 6		1^{+-}	"$\Upsilon(5S)'' \to \pi^0 + (\Upsilon(nS)\,\pi^0)$, $n = 1,2,3$	Belle
$Z_b^+(10650)$	10652.2 ± 1.5	11.5 ± 2.2	1^{+-}	"$\Upsilon(5S)'' \to \pi^- + (\Upsilon(nS)\,\pi^+)$, $n = 1,2,3$	Belle
				"$\Upsilon(5S)'' \to \pi^- + (h_b(nP)\,\pi^+)$, $n = 1,2$	Belle
				"$\Upsilon(5S)'' \to \pi^- + (B^*\bar{B}^*)^+$, $n = 1,2$	Belle

Y(4260)

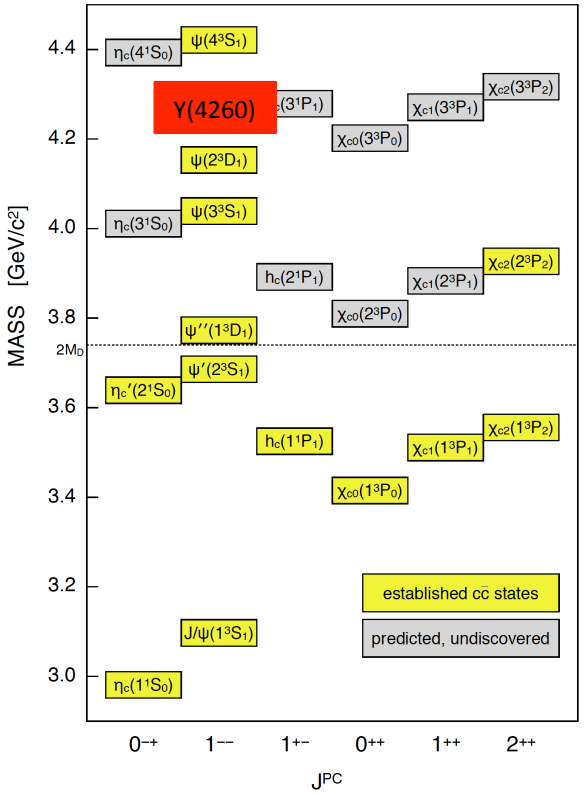
The Y(4260)

--discovered at Babar--

BaBar detector



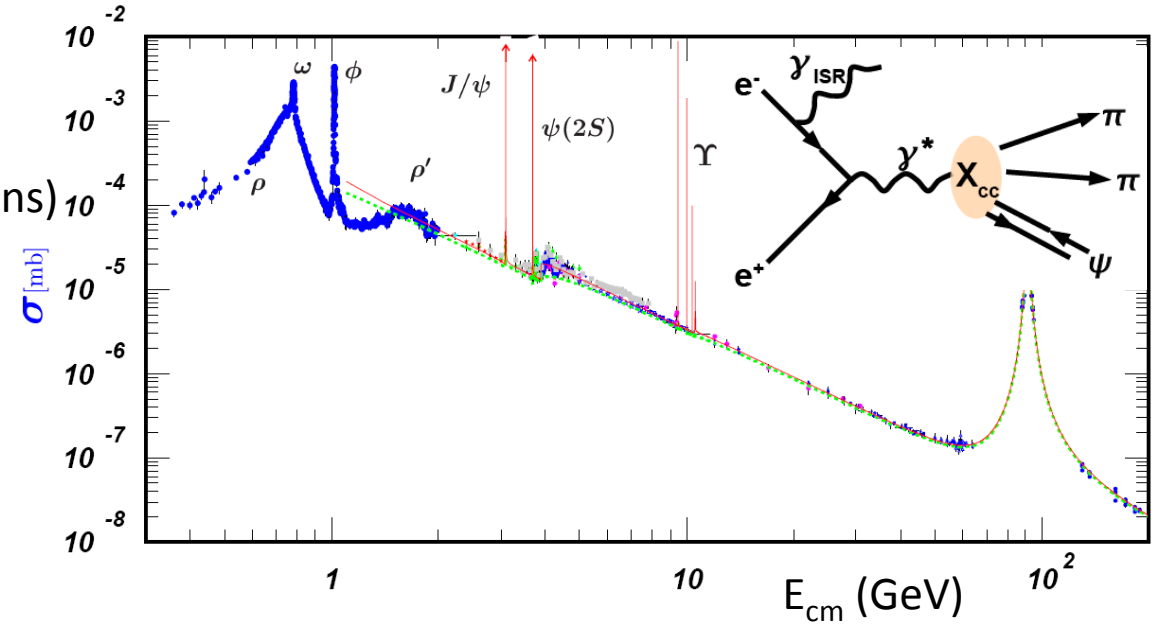
What is the Y(4260)?



All the $J^{PC} = 1^{--}$ charmonium states below M=4500 MeV have already been assigned

found by BaBar in $e^+e^- \rightarrow \gamma_{ISR}\pi^+\pi^- J/\psi$

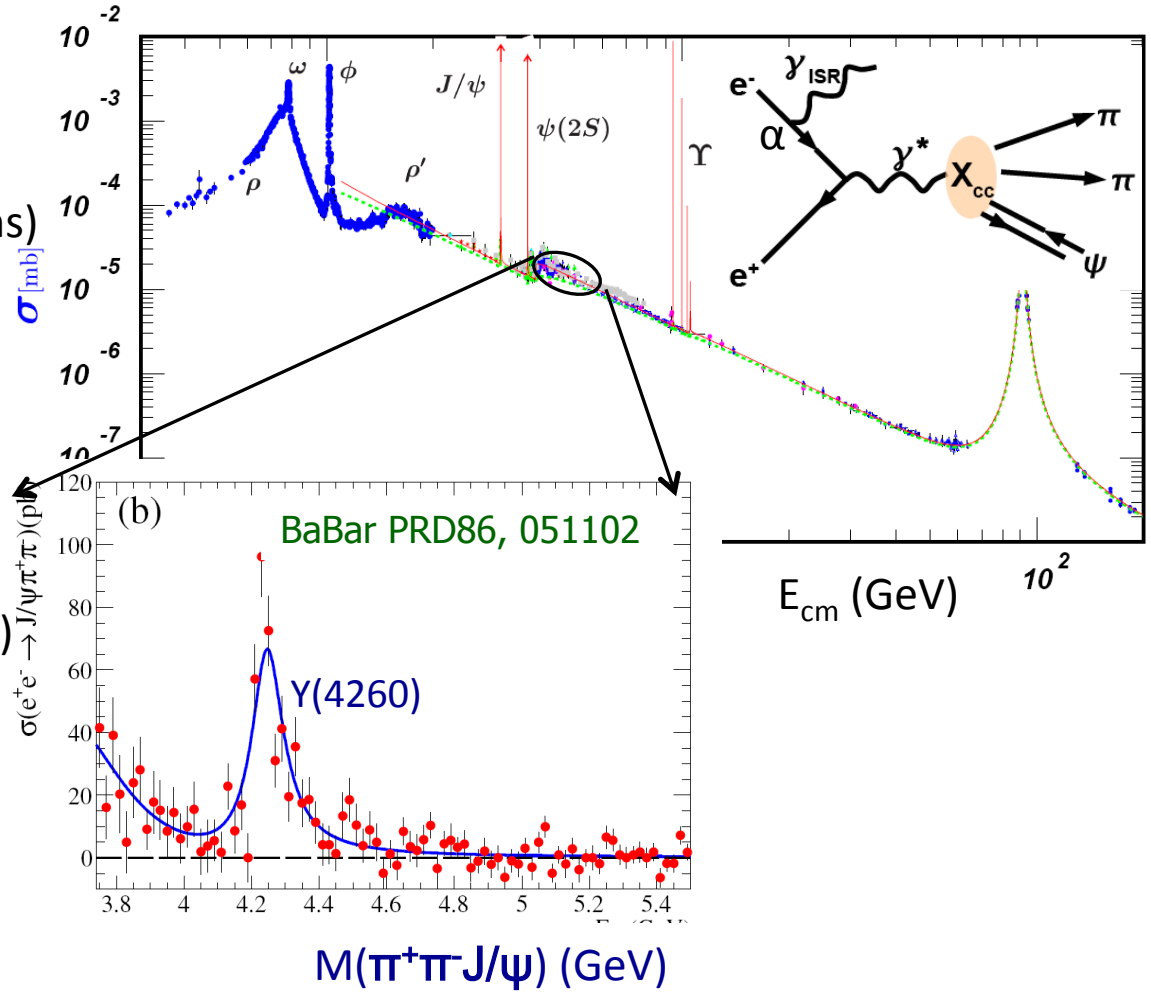
$\sigma(e^+e^- \rightarrow \text{hadrons})$



found by BaBar in $e^+e^- \rightarrow \gamma_{ISR}\pi^+\pi^- J/\psi$

$\sigma(e^+e^- \rightarrow \text{hadrons})$

$\sigma(e^+e^- \rightarrow \pi^+\pi^- J/\psi)$



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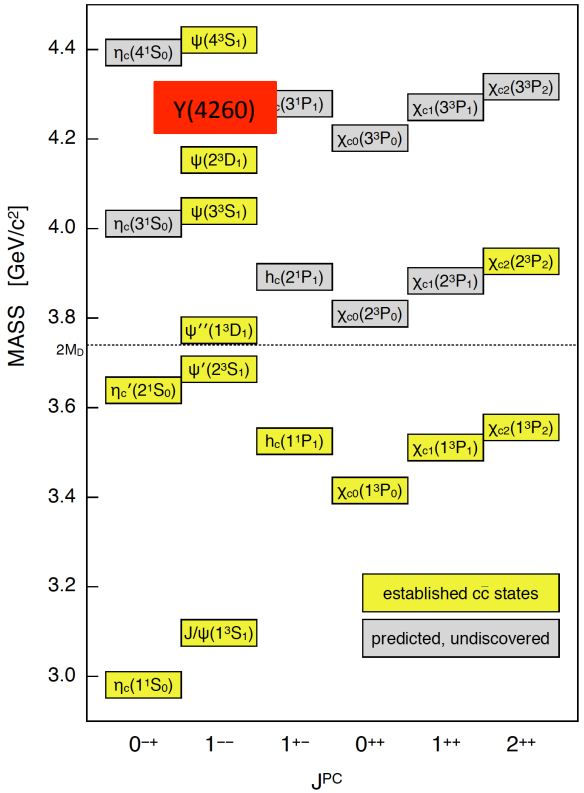
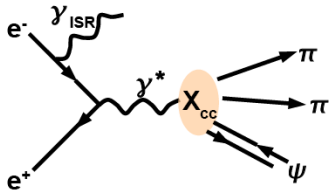
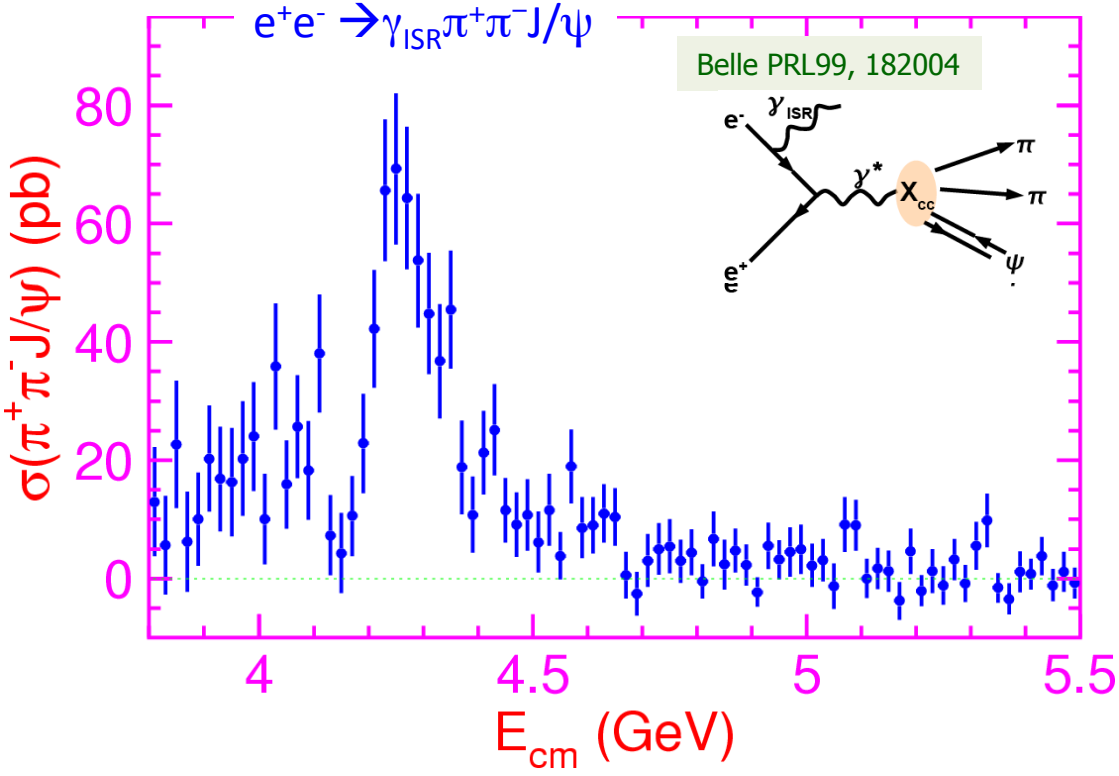




prod. mode ensures $J^{PC} = 1^{--}$

all the $J^{PC} = 1^{--}$ charmonium states below M=4500 MeV have already been assigned

Y(4260) → $\pi^+\pi^-$J/ψ confirmed by Belle



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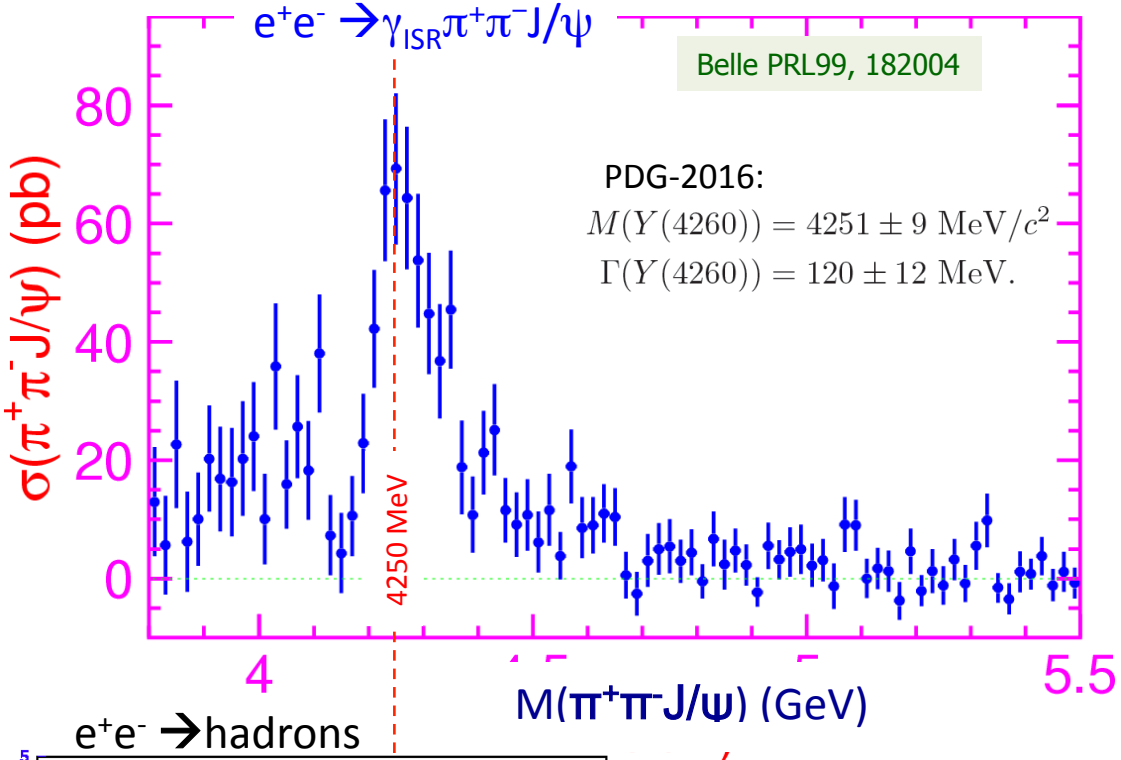
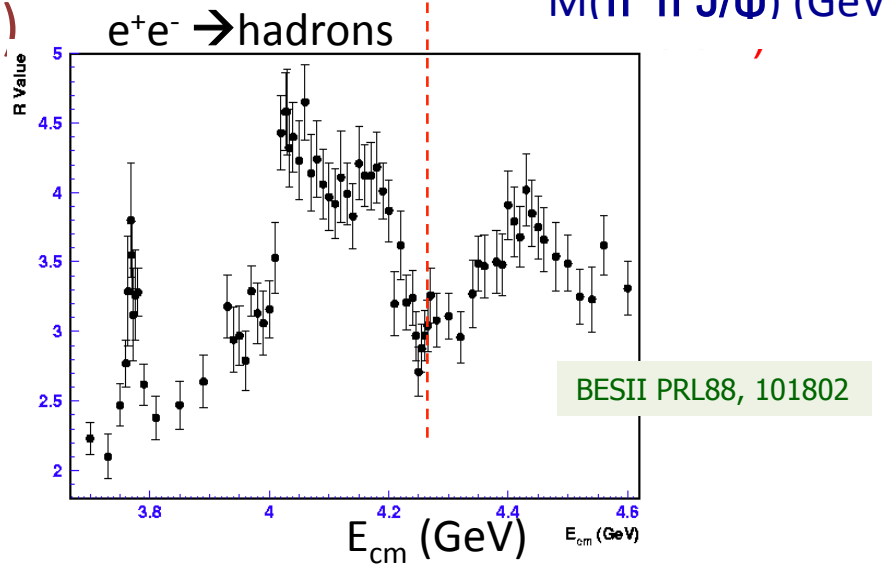


no sign of Y(4260) → $D^{(*)}\bar{D}^{(*)}$

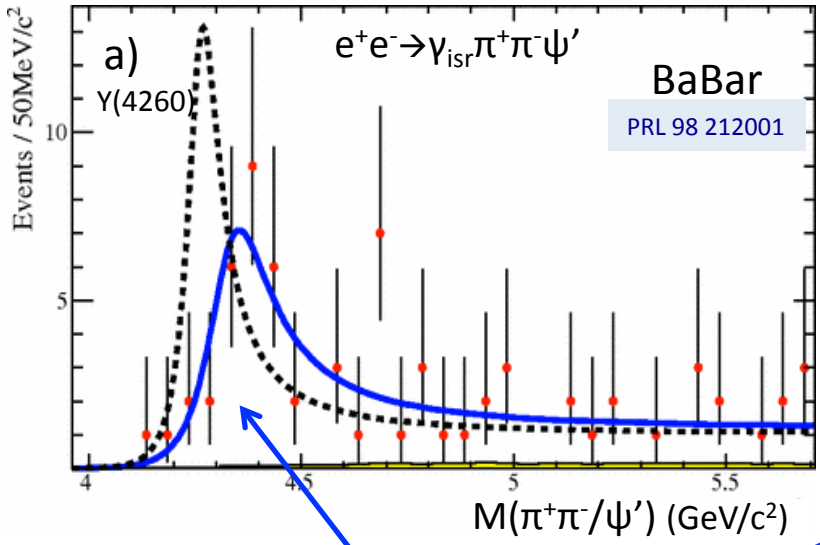
Y(4260) peak in σ ($\pi^+\pi^-$J/ψ)
occurs at a dip in σ($D^{(*)}\bar{D}^{(*)}$)

$\Gamma(\pi^+\pi^-J/\psi)$ is large, but
should be OZI suppressed if $c\bar{c}$



resonances in $e^+e^- \to \gamma_{ISR}\pi^+\pi^-\psi'$

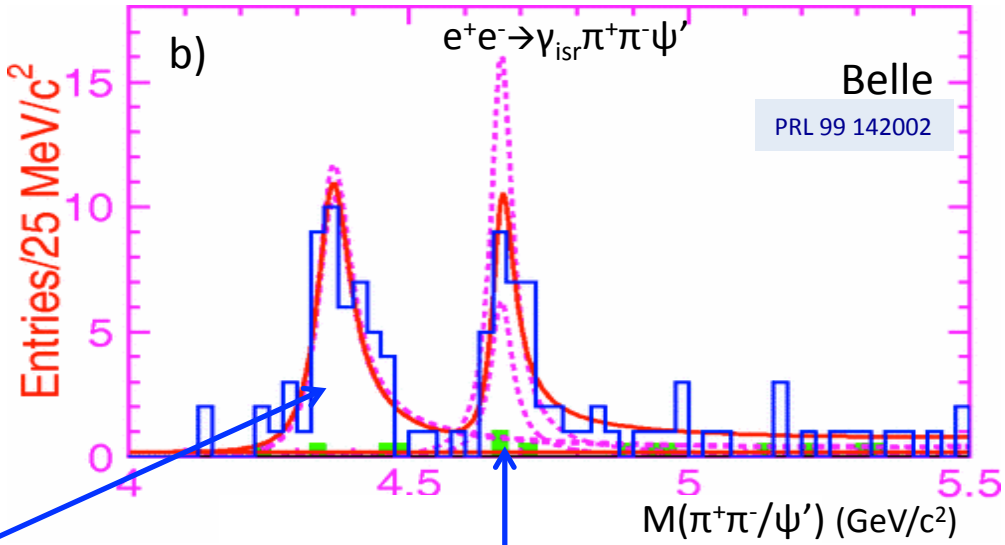
BaBar: another one in $\pi^+\pi^-\psi'$ (not the Y(4260))



PDG-2016:

$$M(Y(4360)) = 4346 \pm 6 \text{ MeV}/c^2$$
$$\Gamma(Y(4360)) = 102 \pm 12 \text{ MeV}.$$

Belle: confirms the Y(4360) & finds another @ 4660



PDG-2016:

$$M(Y(4660)) = 4643 \pm 9 \text{ MeV}/c^2$$
$$\Gamma(Y(4660)) = 72 \pm 11 \text{ MeV}.$$

BEPCII/BESIII

BEPCII and BESIII

Beam energy: 1.0 ~ 2.3 GeV

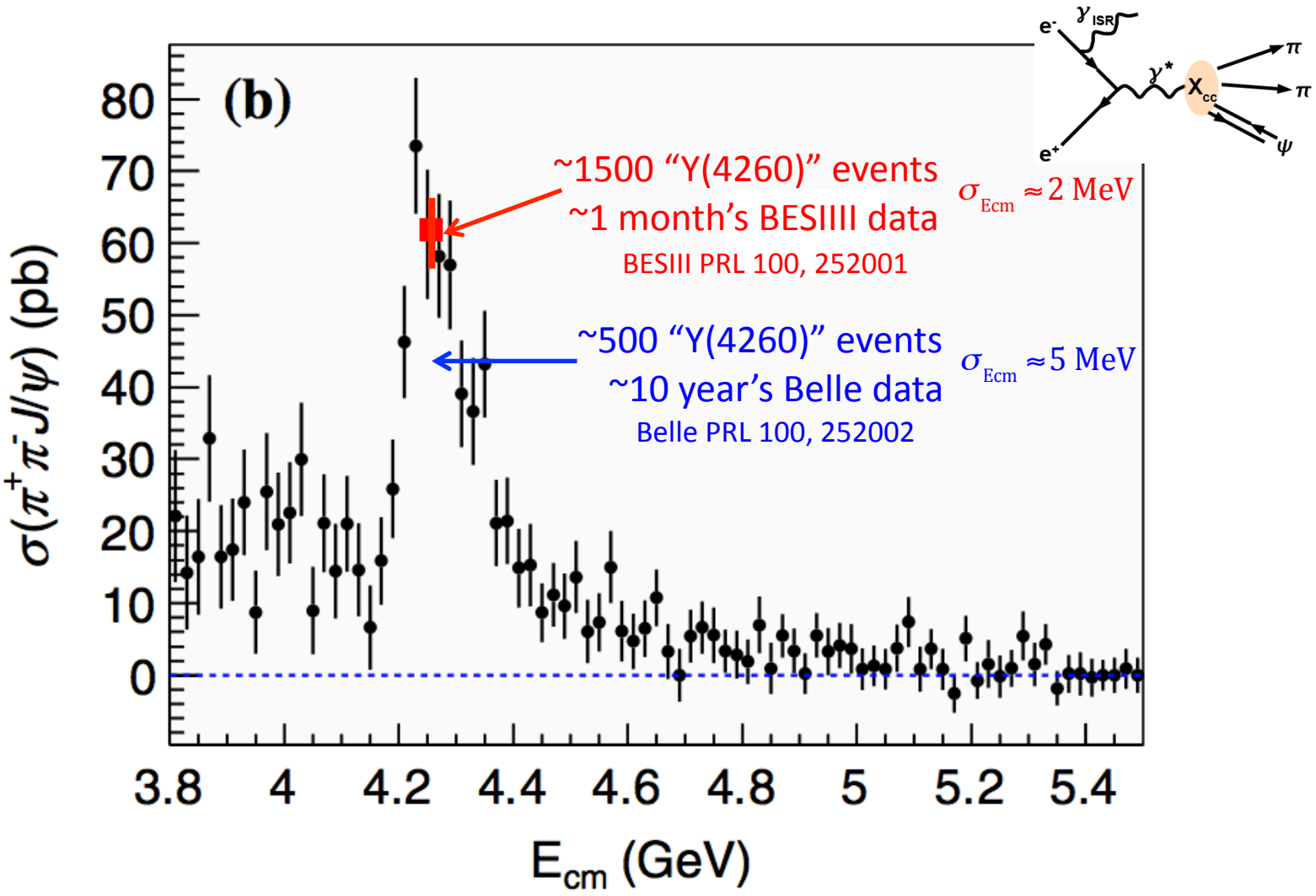
Luminosity: 1.0×10^{33} $cm^{-2}s^{-1}$
(reached in April 5th, 2016)

2004: BEPCII upgrade, BEPCIII construction

2008: test run

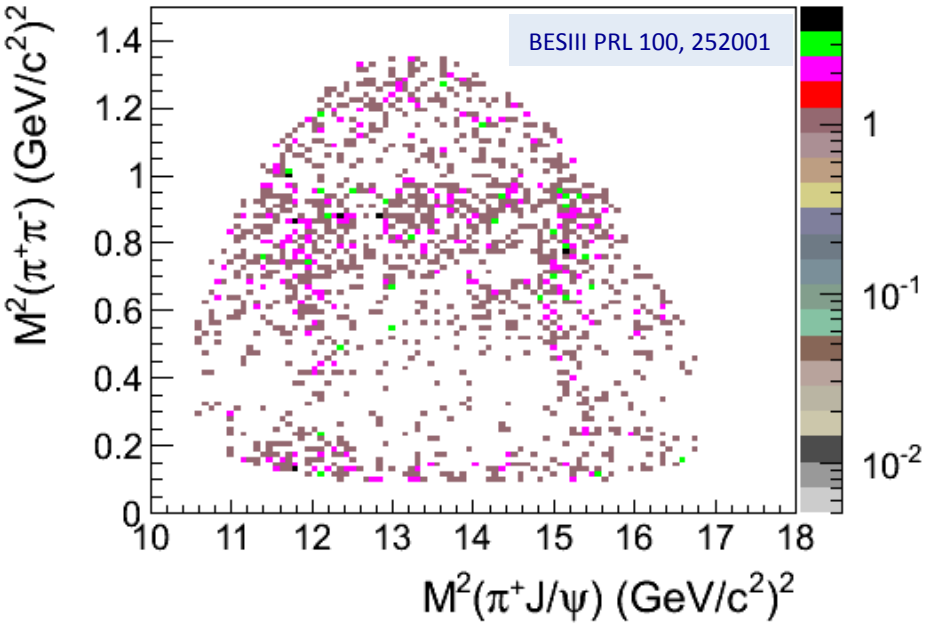
2009 ~ now: physics run

Y(4260) in BESIII & Belle

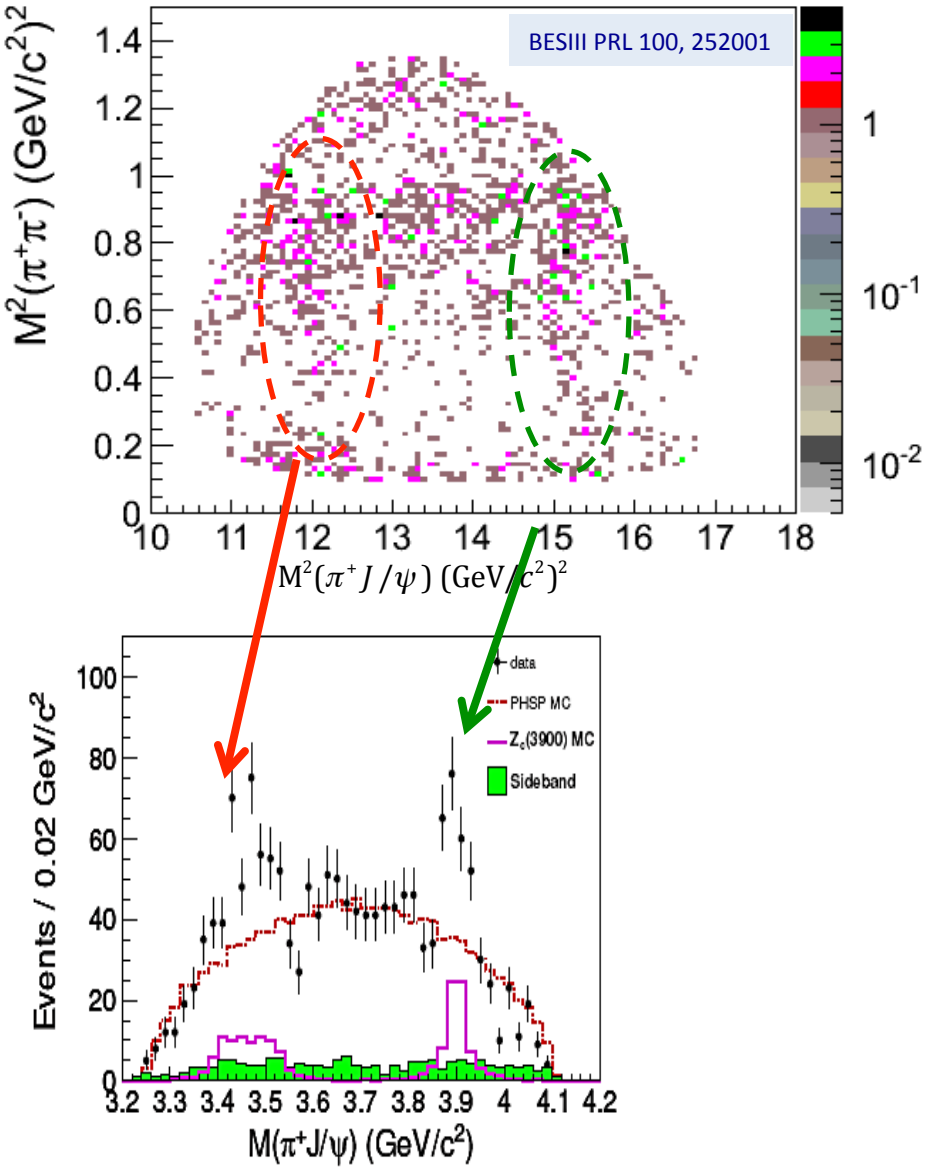


Other Y(4260) decay modes?

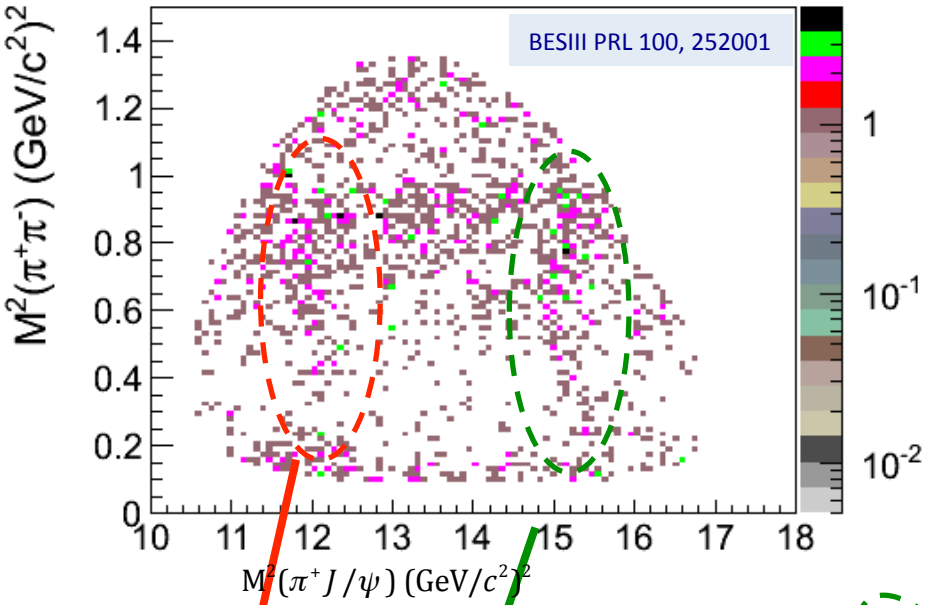
$e^+e^- \rightarrow \pi^+\pi^- J/\psi$ "Dalitz plot"

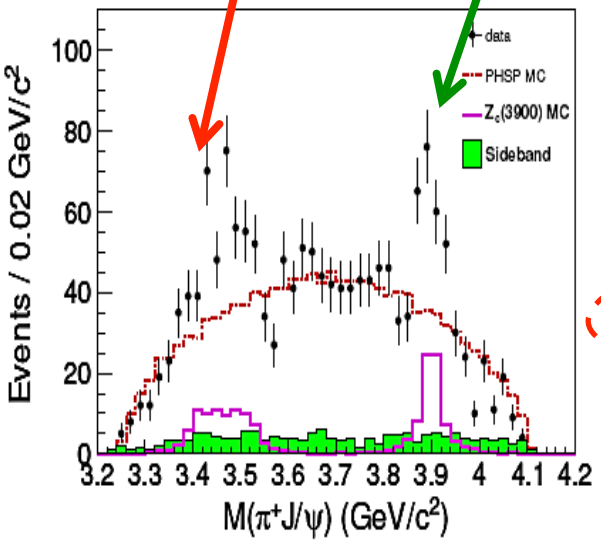


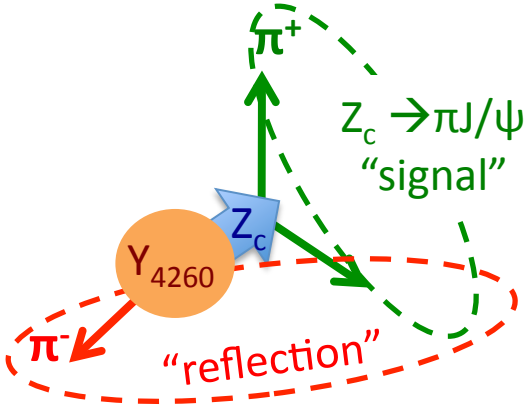
$e^+e^- \rightarrow \pi^+\pi^- J/\psi$ "Dalitz plot"



$e^+e^- \rightarrow \pi^+\pi^- J/\psi$ "Dalitz plot"

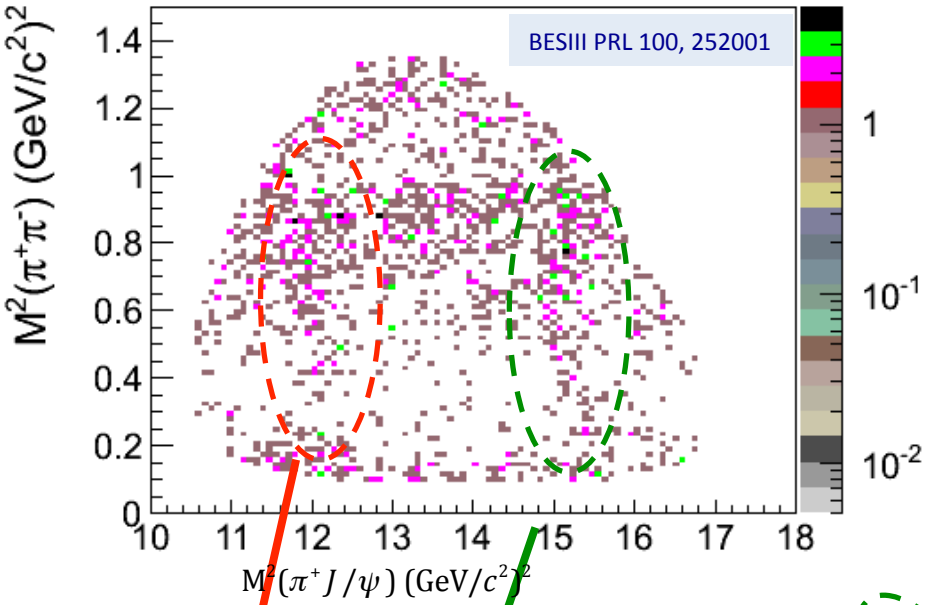


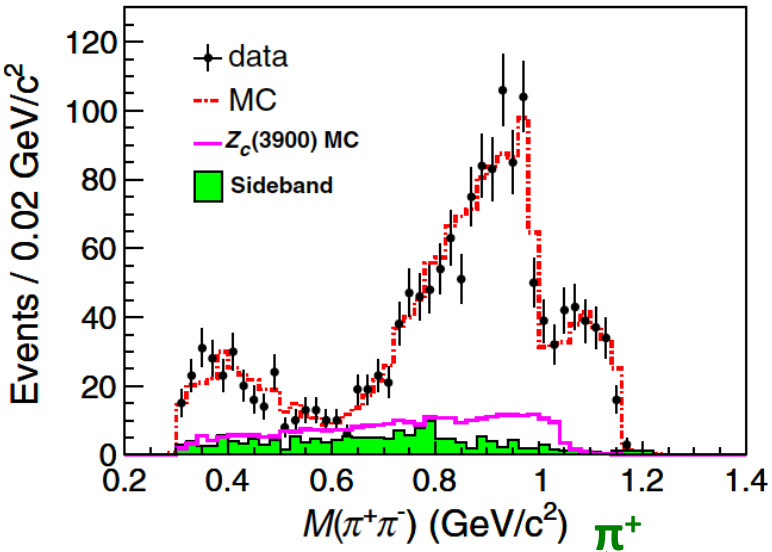


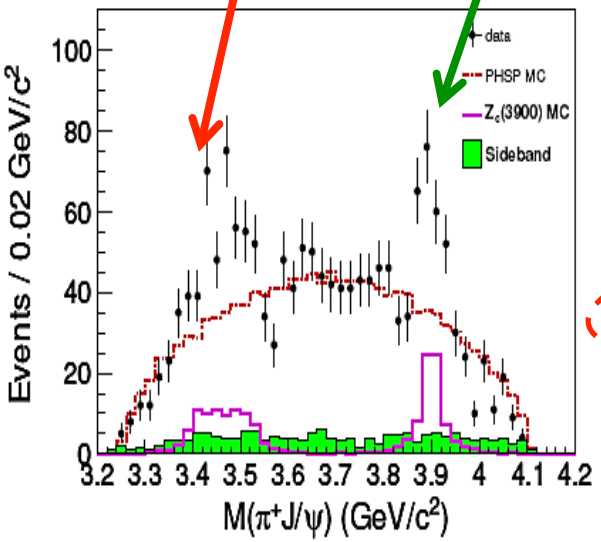


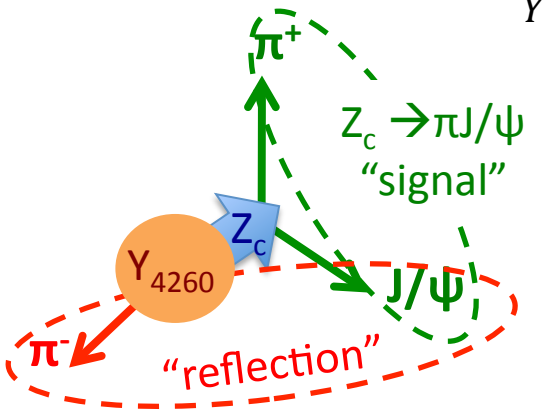
$$Y(4260) \rightarrow \pi^{\pm} Z_c^{\mp}(3900)$$
$$\hookrightarrow \pi^{\mp} J/\psi$$

$e^+e^- \rightarrow \pi^+\pi^- J/\psi$ "Dalitz plot"



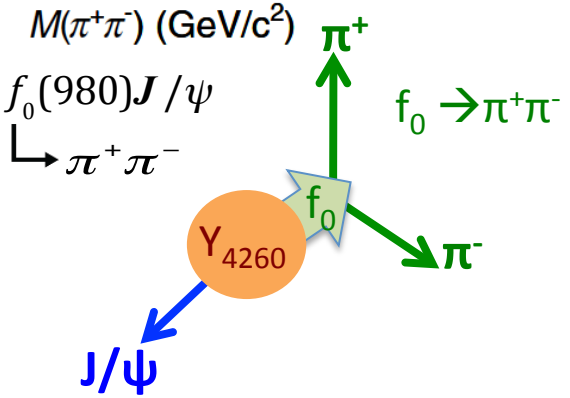




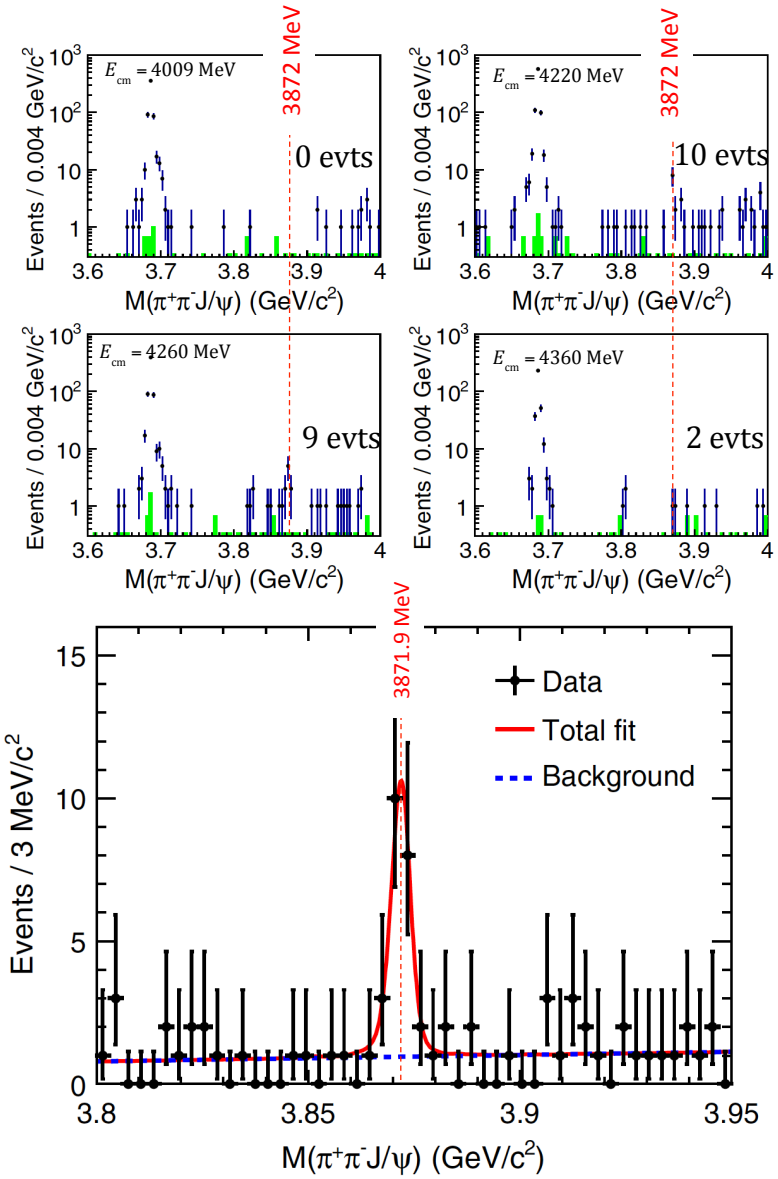


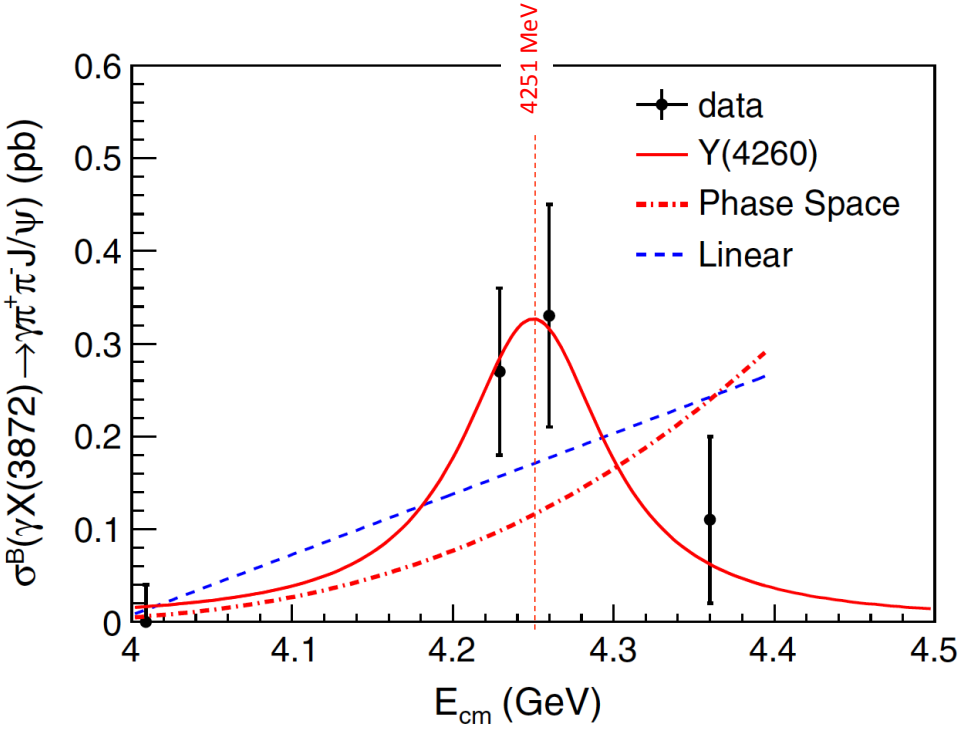
$Y(4260) \rightarrow \pi^{\pm} Z_c^{\mp}(3900)$
$\hookrightarrow \pi^{\mp} J/\psi$

$Y(4260) \rightarrow f_0(980) J/\psi$
$\hookrightarrow \pi^+\pi^-$



Radiative decays? Y(4260)→γ $\pi^+\pi^-$J/ψ?





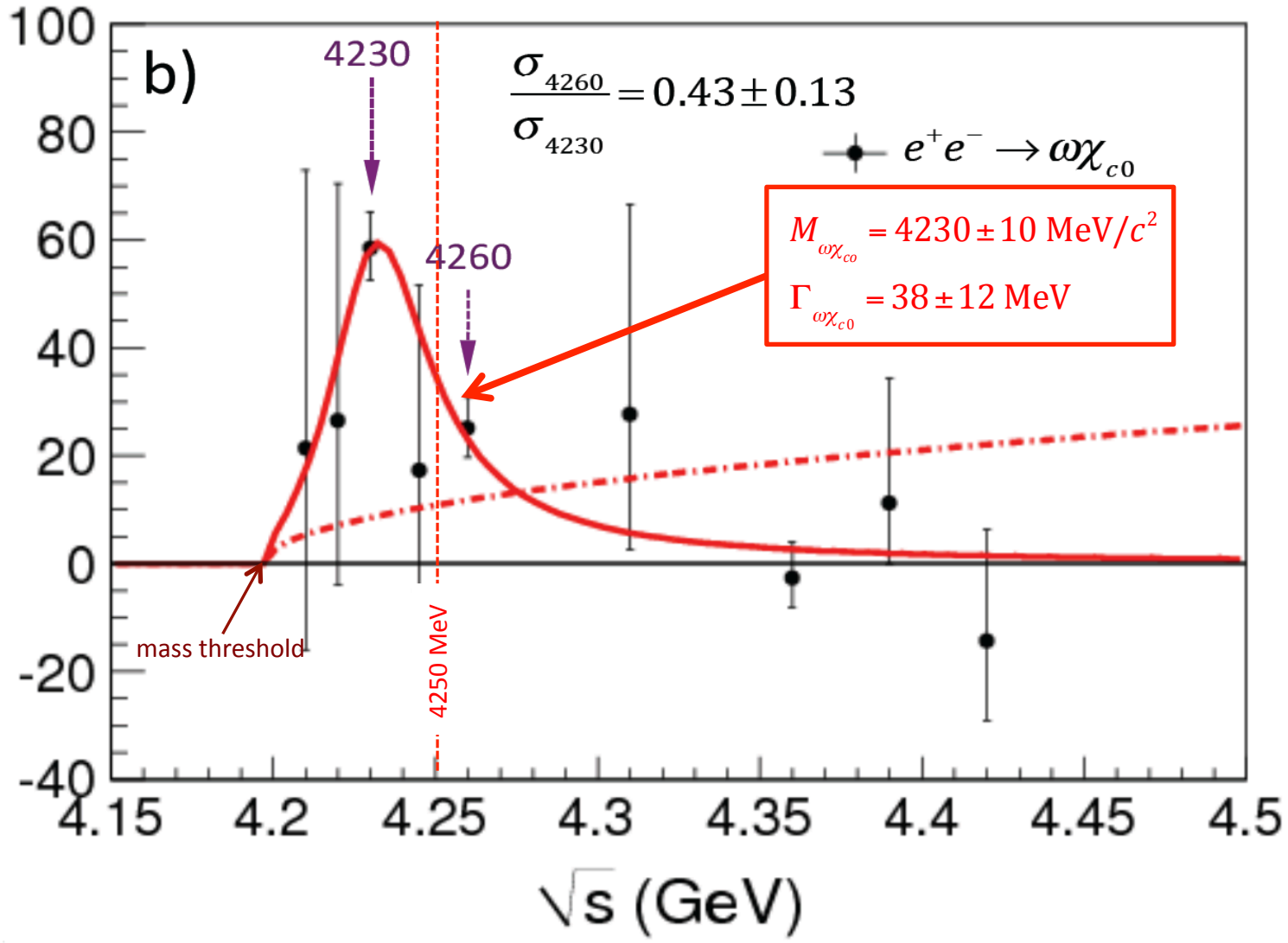
assuming $Bf(X_{3872}\to\pi^+\pi^-J/\psi)$=5%:

$$\frac{Bf(Y_{4260}\to\gamma X_{3872})}{Bf(Y_{4260}\to\pi^+\pi^- J/\psi)}\sim 0.1$$

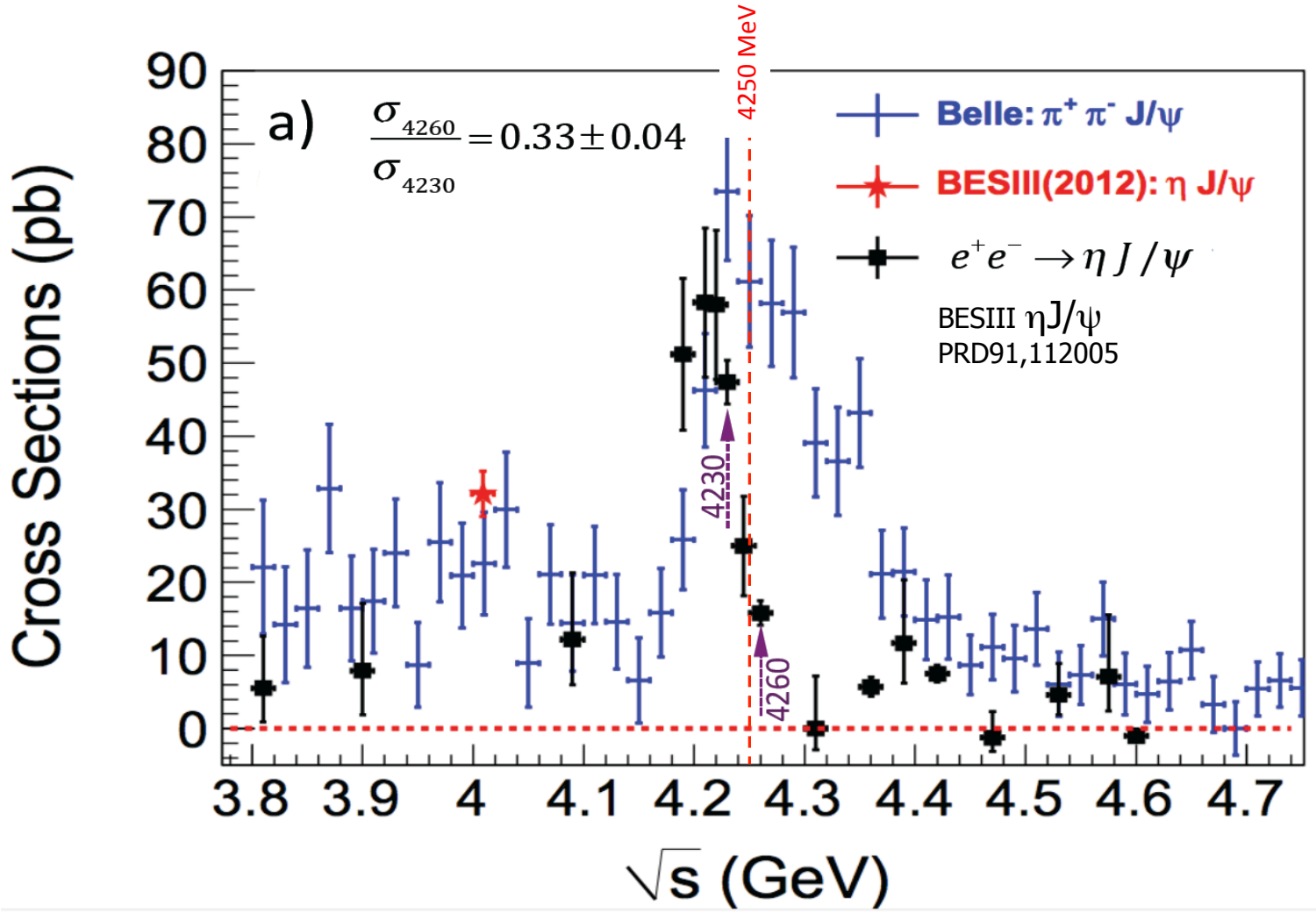
←not small!!

some commonality between X(3872) & Y(4260)?

Y(4260)→ωχ$_{c0}$??

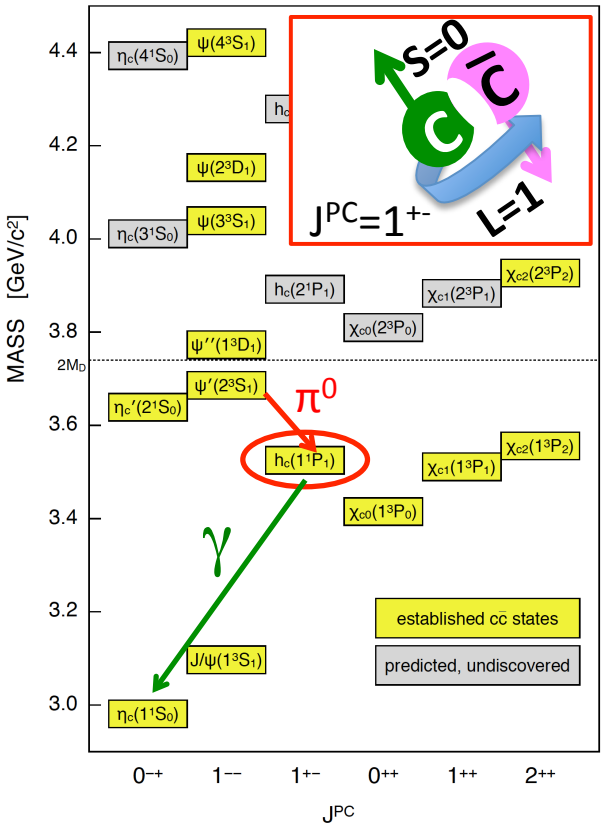

b)
4230
4260
$\frac{\sigma_{4260}}{\sigma_{4230}} = 0.43 \pm 0.13$
$e^+e^- \to \omega\chi_{c0}$
$M_{\omega\chi_{c0}} = 4230 \pm 10$ MeV/c^2
$\Gamma_{\omega\chi_{c0}} = 38 \pm 12$ MeV
mass threshold
4250 MeV
100
80
60
40
20
0
-20
-40
4.15
4.2
4.25
4.3
4.35
4.4
4.45
4.5
$\sqrt{s}$ (GeV)

Y(4260)→ηJ/ψ ?


a)
$\frac{\sigma_{4260}}{\sigma_{4230}} = 0.33 \pm 0.04$
4250 MeV
Belle: $\pi^+\pi^-$ J/ψ
BESIII(2012): η J/ψ
$e^+e^- \to \eta J/\psi$
BESIII ηJ/ψ
PRD91,112005
4230
4260
Cross Sections (pb)
$\sqrt{s}$ (GeV)
0
10
20
30
40
50
60
70
80
90
3.8
3.9
4
4.1
4.2
4.3
4.4
4.5
4.6
4.7

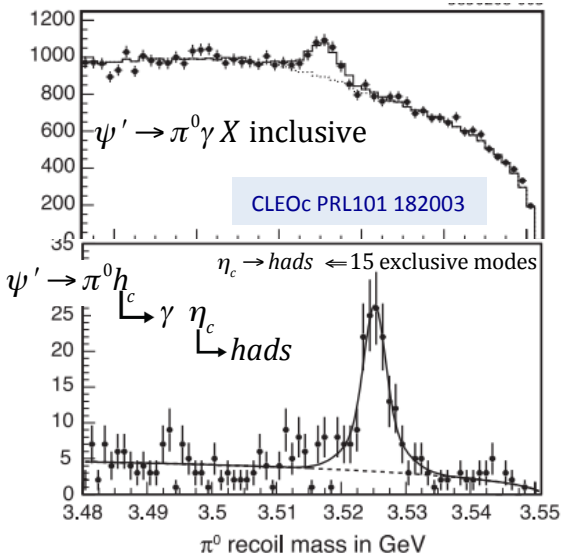
Y(4260)→$\pi^+\pi^- h_c$??

What is the h_c?

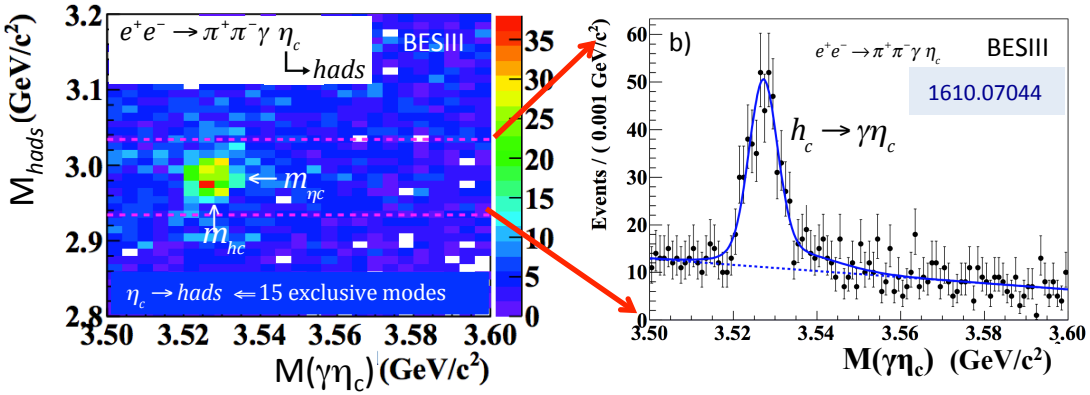


h_c history:

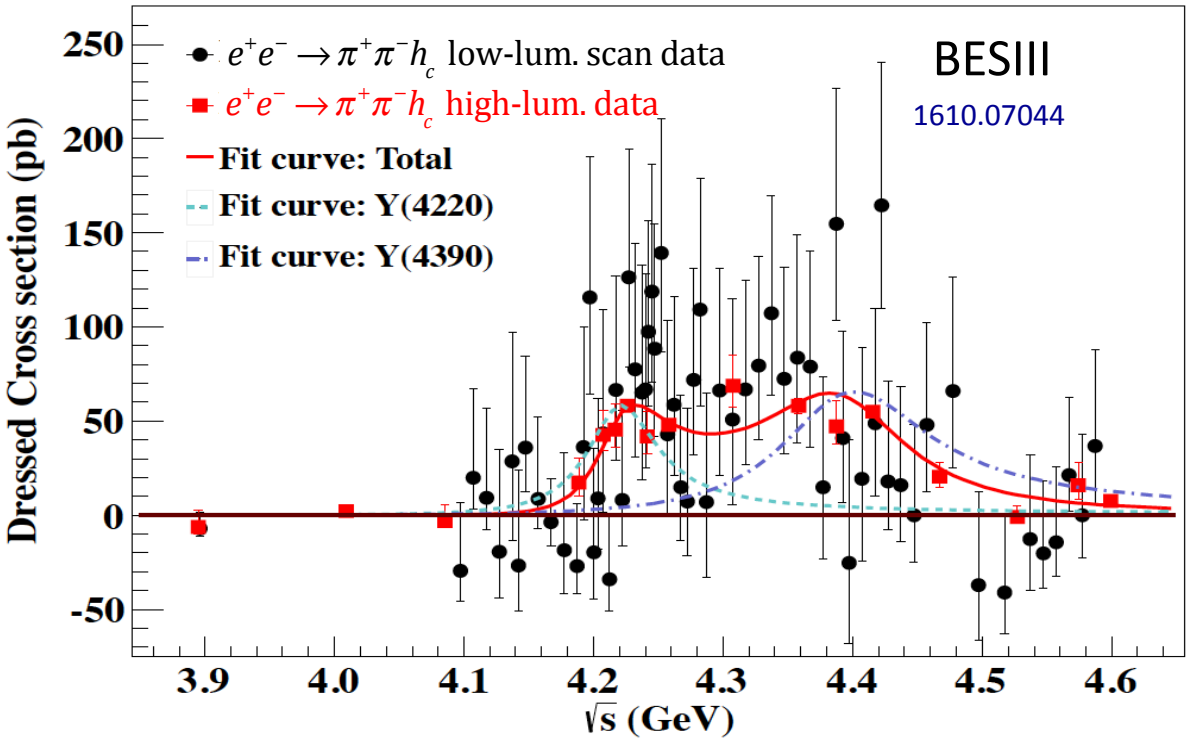
- 1974: existence predicted
- 2008: found by CLEOc



- 2013: exploited by BESIII

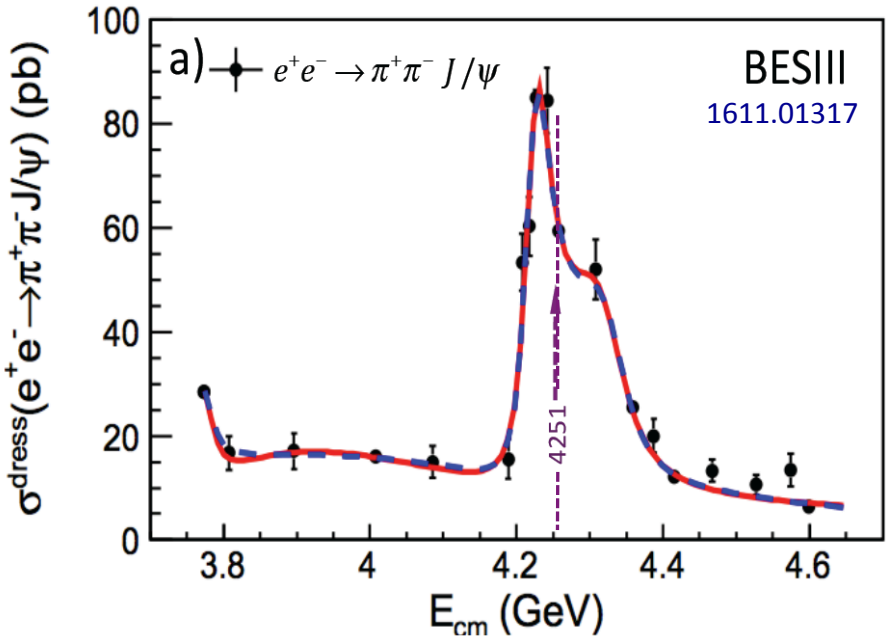


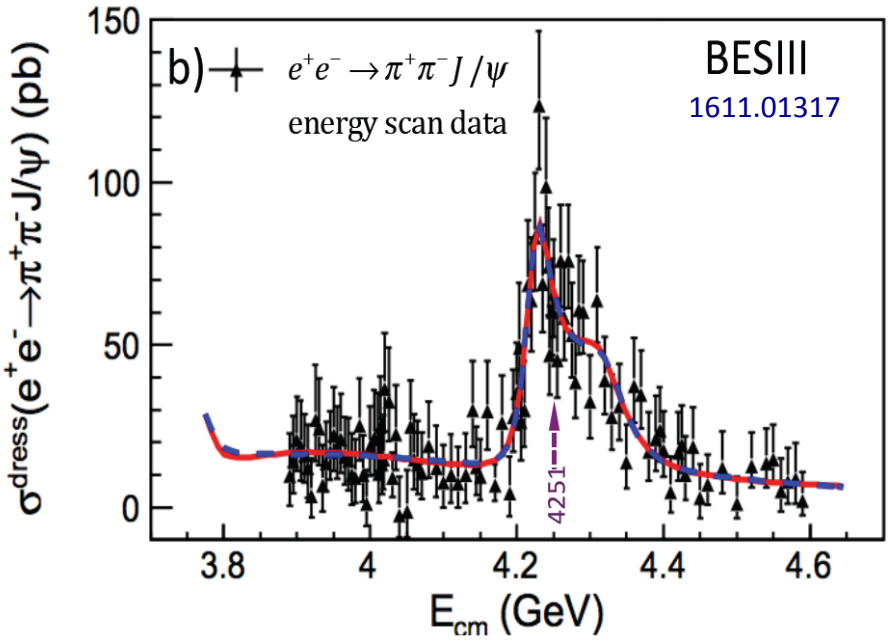
$e^+e^- \to \pi^+\pi^- h_c$



$$M_1 = 4218 \pm 4 \text{ MeV}/c^2 \qquad \Gamma_1 = 66 \pm 9 \text{ MeV}$$
$$M_2 = 4392 \pm 6 \text{ MeV}/c^2 \qquad \Gamma_2 = 140 \pm 16 \text{ MeV}$$

The Y(4260) is not a single BW resonance!



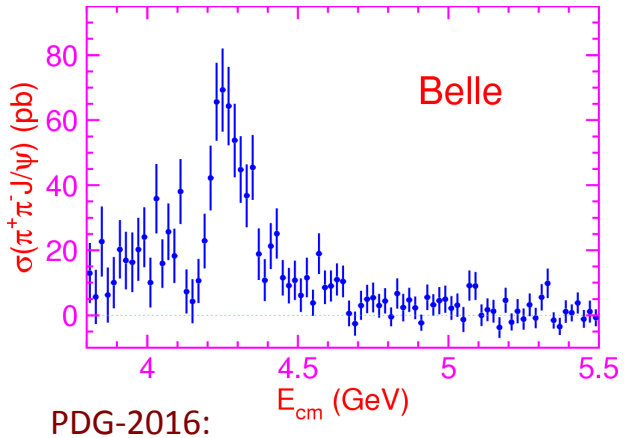


2 BW res. fit preferred over 1 BW res. fit by >7σ

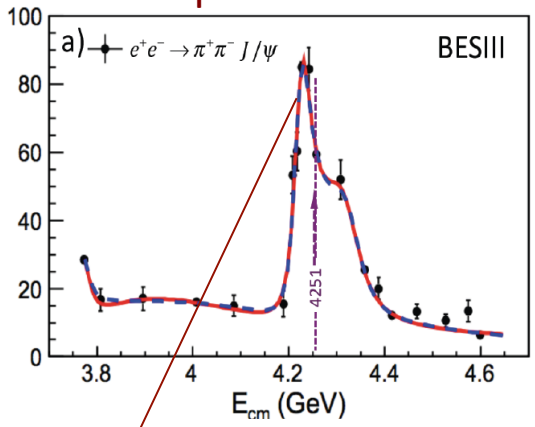
$$M_1 = 4220 \pm 4 \text{ MeV}/c^2 \qquad \Gamma_1 = 44 \pm 5 \text{ MeV}$$
$$M_2 = 4320 \pm 13 \text{ MeV}/c^2 \qquad \Gamma_2 = 101^{+27}_{-22} \text{ MeV}$$

Y(4260): mass → lower & width → narrower

pre-2017



post-2017



PDG-2016:

$M(Y(4260)) = 4251 \pm 9\ \mathrm{MeV}/c^2$ —-31 MeV→ $M_1 = 4220 \pm 4\ \mathrm{MeV}/c^2$

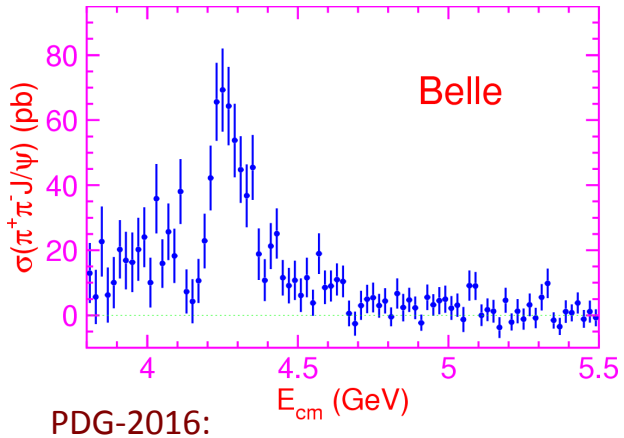
$\Gamma(Y(4260)) = 120 \pm 12\ \mathrm{MeV}.$ —×⅓→ $\Gamma_1 = 44 \pm 5\ \mathrm{MeV}$

Y(4220) decay modes:

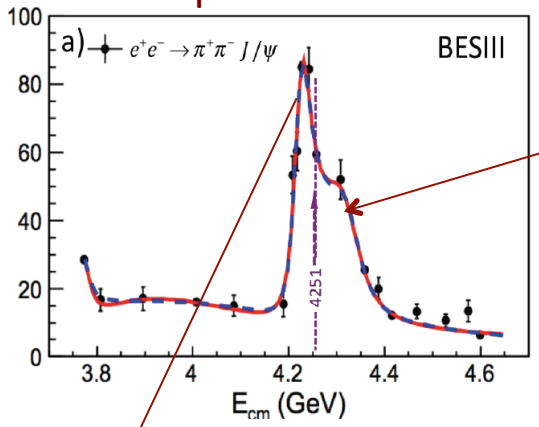
- $\pi^+\pi^- J/\psi$
  - $\pi Z_c(3900)$
  - $f_0(980)\ J/\psi$
- $\pi^+\pi^- h_c$
- $\omega\chi_{c0}$
- $\eta J/\psi$
- $\gamma X(3872)$
- $\pi D\bar{D}^*$

Y(4260): mass → lower & width → narrower

pre-2017



post-2017



what is the 2nd peak?

PDG-2016:

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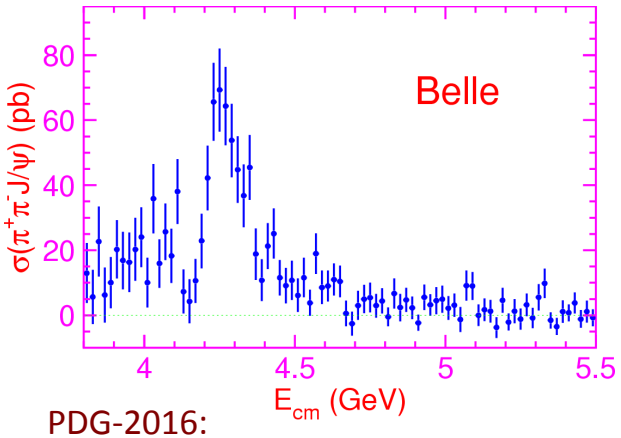
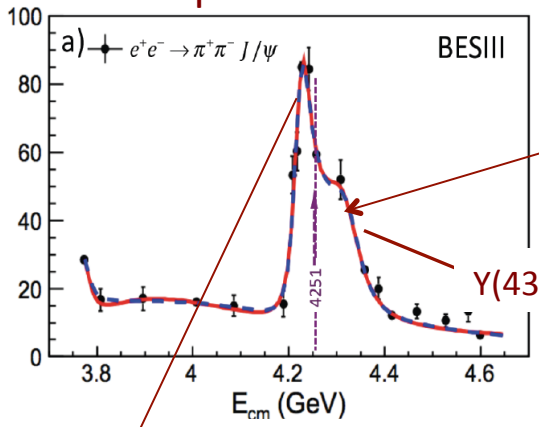
- $\eta J/\psi$
- $\gamma X(3872)$
- $\pi D\bar{D}^*$

Y(4260): mass → lower & width → narrower

pre-2017

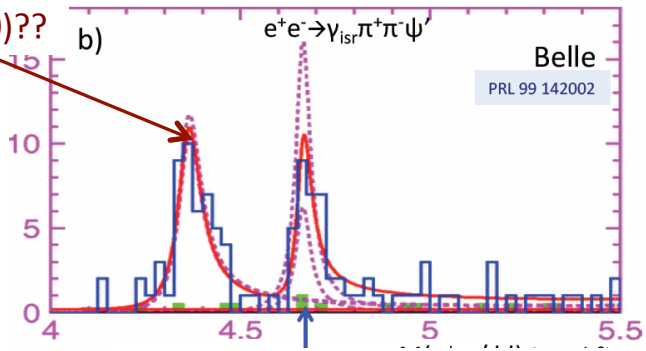


post-2017



what is the 2nd peak?

Y(4360)??



PDG-2016:

$M(Y(4260)) = 4251 \pm 9$ MeV/c^2 —-31 MeV→ $M_1 = 4220 \pm 4$ MeV/c^2

$\Gamma(Y(4260)) = 120 \pm 12$ MeV. —×⅓→ $\Gamma_1 = 44 \pm 5$ MeV

Y(4220) decay modes:

- $\pi^+\pi^- J/\psi$
  - $\pi Z_c(3900)$
  - $f_0(980)\, J/\psi$
- $\pi^+\pi^- h_c$
- $\omega\chi_{c0}$
- $\eta J/\psi$
- $\gamma X(3872)$
- $\pi D\bar{D}^*$

$M_2 = 4320 \pm 13$ MeV/c^2 —δM≈-1.8σ→ $M(Y(4360)) = 4346 \pm 6$ MeV/c^2

$\Gamma_2 = 101^{+27}_{-22}$ MeV —spot on→ $\Gamma(Y(4360)) = 102 \pm 12$ MeV.

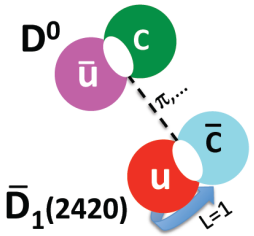
Y(4320) decay modes:

- $\pi^+\pi^- J/\psi$
- $\pi^+\pi^- \psi'$

What is the Y(4260)?

some proposed models

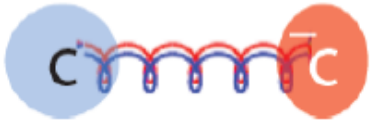
$D\bar{D}_1(2420)$ molecule



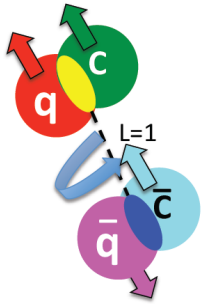
actually:

$$Y(4260) = \frac{1}{\sqrt{2}}\left[D\bar{D}_1(2420) \pm D_1(2420)\bar{D}\right]$$

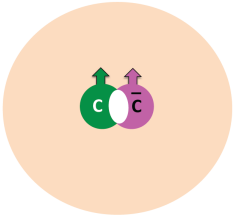
QCD $c\bar{c}$-gluon hybrid



QCD diquark-diantiquark "tetra-quark"



"hadrocharmonium"



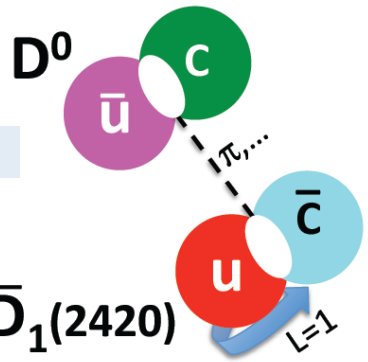
Models for the Y(4260) I

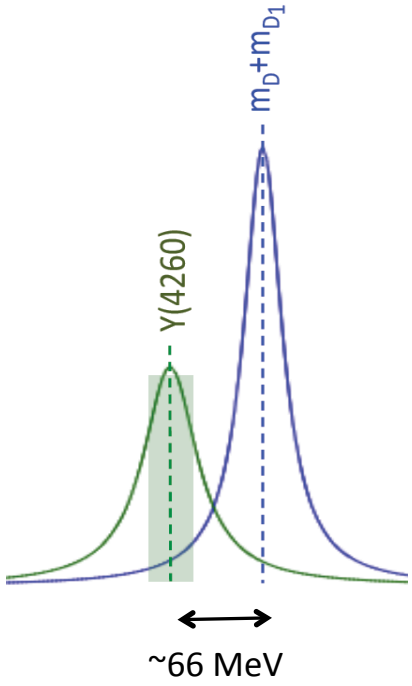
Molecule?

Ding PRD 79, 014001

Wang, Hanhart & Zhao PRL 111, 132002

Cleven, Wang, Guo, Hanhart, Meissner & Zhao PRD 90, 074039



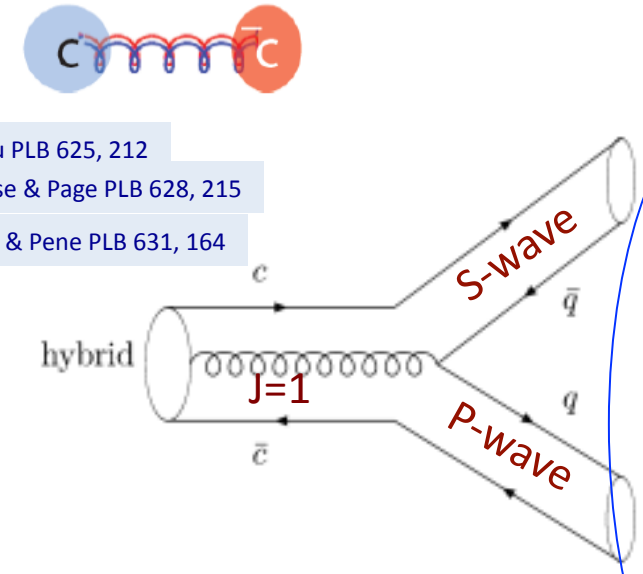


$D_1(2420)$ $J^P=1^+$
M=2421.4 ± 0.6 MeV Γ= 27.4 ± 2.5 MeV Decay: $D_1(2420) \rightarrow D^*\pi$ Y(4260) "B.E." ≈ 66 MeV

pre-2017: BE≈35 MeV

Models for the Y(4260) II

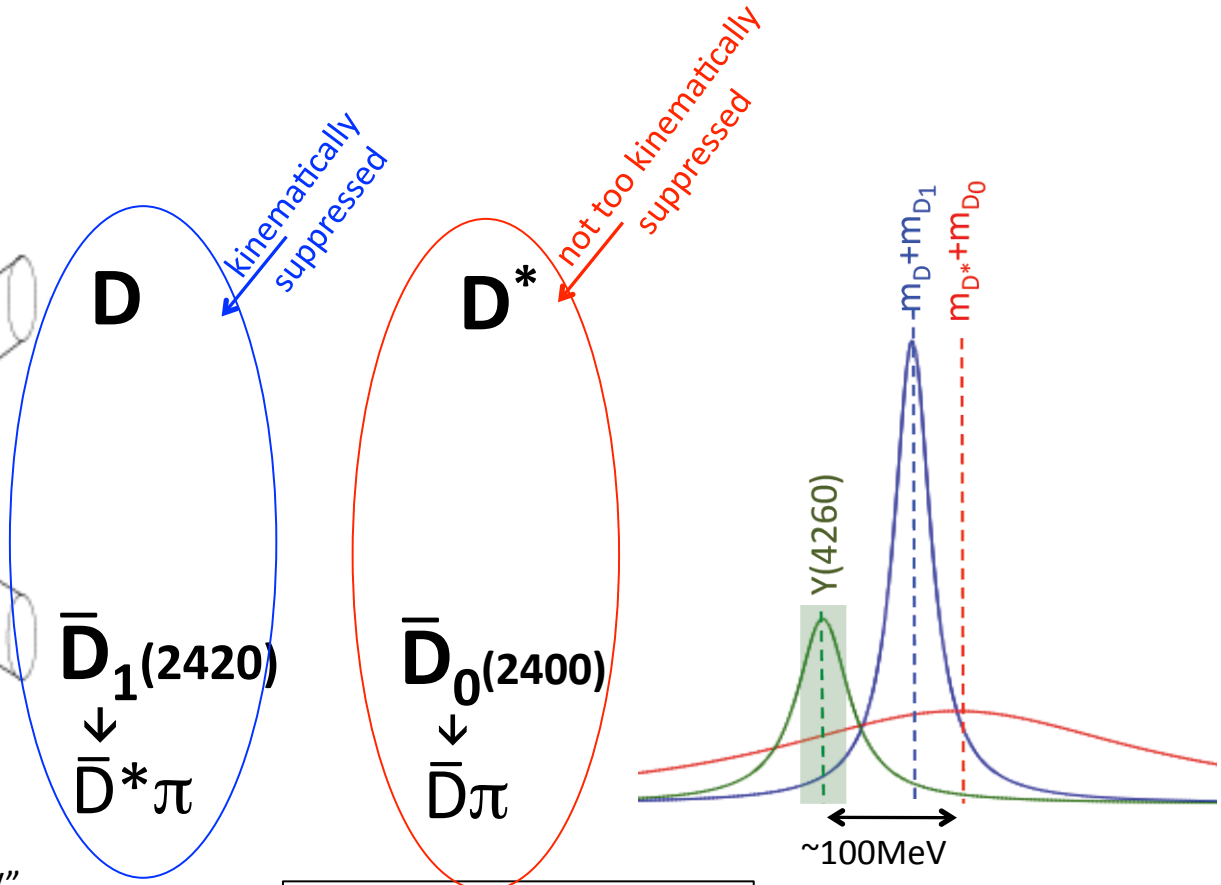
$c\bar{c}$-gluon hybrid?



Zhu PLB 625, 212

Close & Page PLB 628, 215

Kou & Pene PLB 631, 164



2012 LQCD calc. ($m_\pi \approx 400$ MeV):

"Lowest 1^{--} $c\bar{c}$-gluon hybrid: M=4285 ± 14 MeV"

pre-2017: too high by ~35 MeV
post-2017: too high by ~65 MeV

Had. Spectr. Collab. JHEP07, 126

very broad
hard to see

$D_0(2400)$ $J^P=0^+$

M=2318 ± 29 MeV

Γ= 267 ± 40 MeV

Decay: $D_0(2400) \rightarrow D\pi$

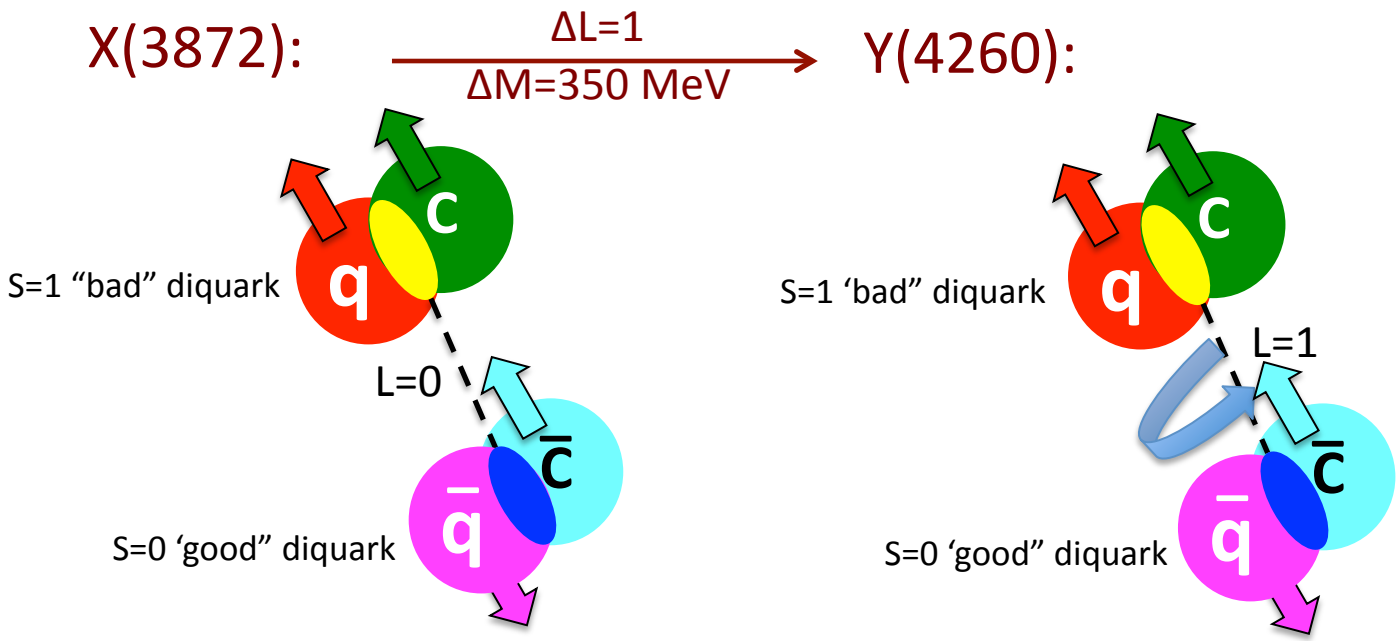
Y(4260) "B.E." ≈ 100 MeV

Models for the Y(4260) III

QCD tetraquark?

Maiani et al. PRD 89, 114010

L=1 excitation of the X(3872):



- naturally accounts for large Y(4260)→γX(3872) as an allowed E1 transition

- 350 MeV is a typical mass "penalty" for ΔL=1:

L=1	L=0	δM (MeV)
$D_1(2420)$	$D^*(2010)$	410
$D_{s1}(2460)$	$D_s(2110)$	350
$h_c(3525)$	J/ψ	430

Models for the Y(4260) IV

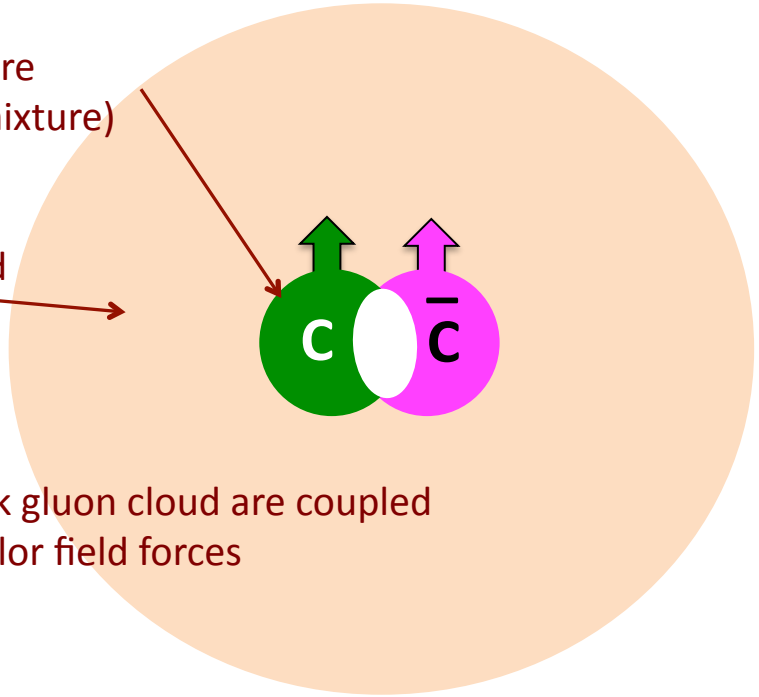
Hadrocharmonium?

Dubynskiy & Voloshin, PLB 666, 344

Li & Voloshin, Mod. Phys. Lett. A29, 1450060

color-singlet charmonium core
(for Y(4260) this a J/ψ + h_c mixture)

surrounding color-singlet cloud
of light quarks & gluons



charmonium core & light-quark gluon cloud are coupled
via Van-der-Waals–like color field forces

Y(4260) → J/ψ (or h_c)+ light-hadrons decays should be dominant,
--- decays to other charmonium states are suppressed

Testing Y(4260) models against data

- $D\bar{D}_1(2420)$ molecule:

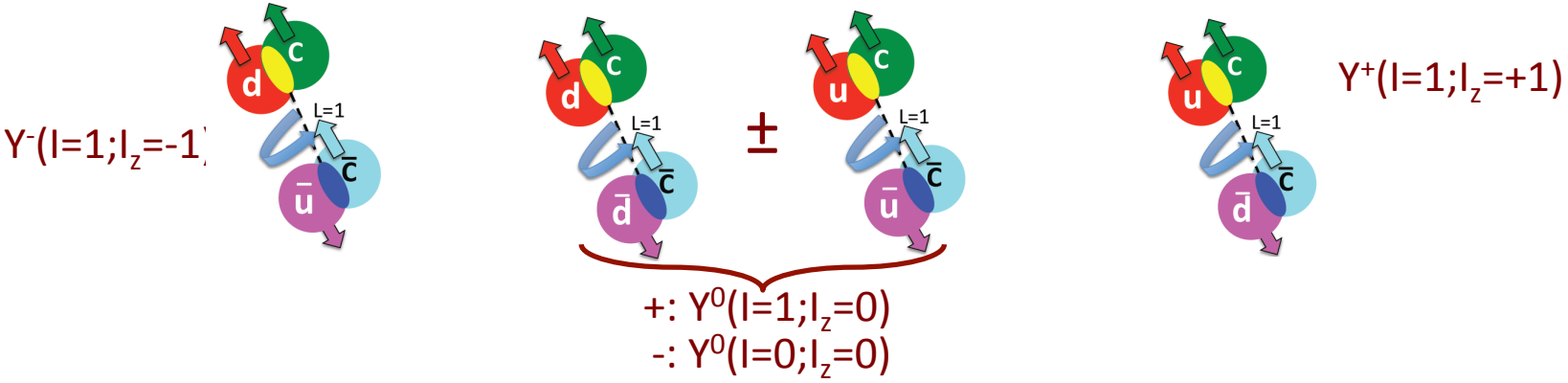
  expect a strong Y(4260) affinity for $D\bar{D}_1(2420)$-like final states

- $c\bar{c}$-gluon hybrid:

  expect a strong Y(4260) affinity for $D^*\bar{D}_0(2400)$-like final states

- QCD tetraquark models:

  expect partner states, including charged partners (likewise for the X(3872))



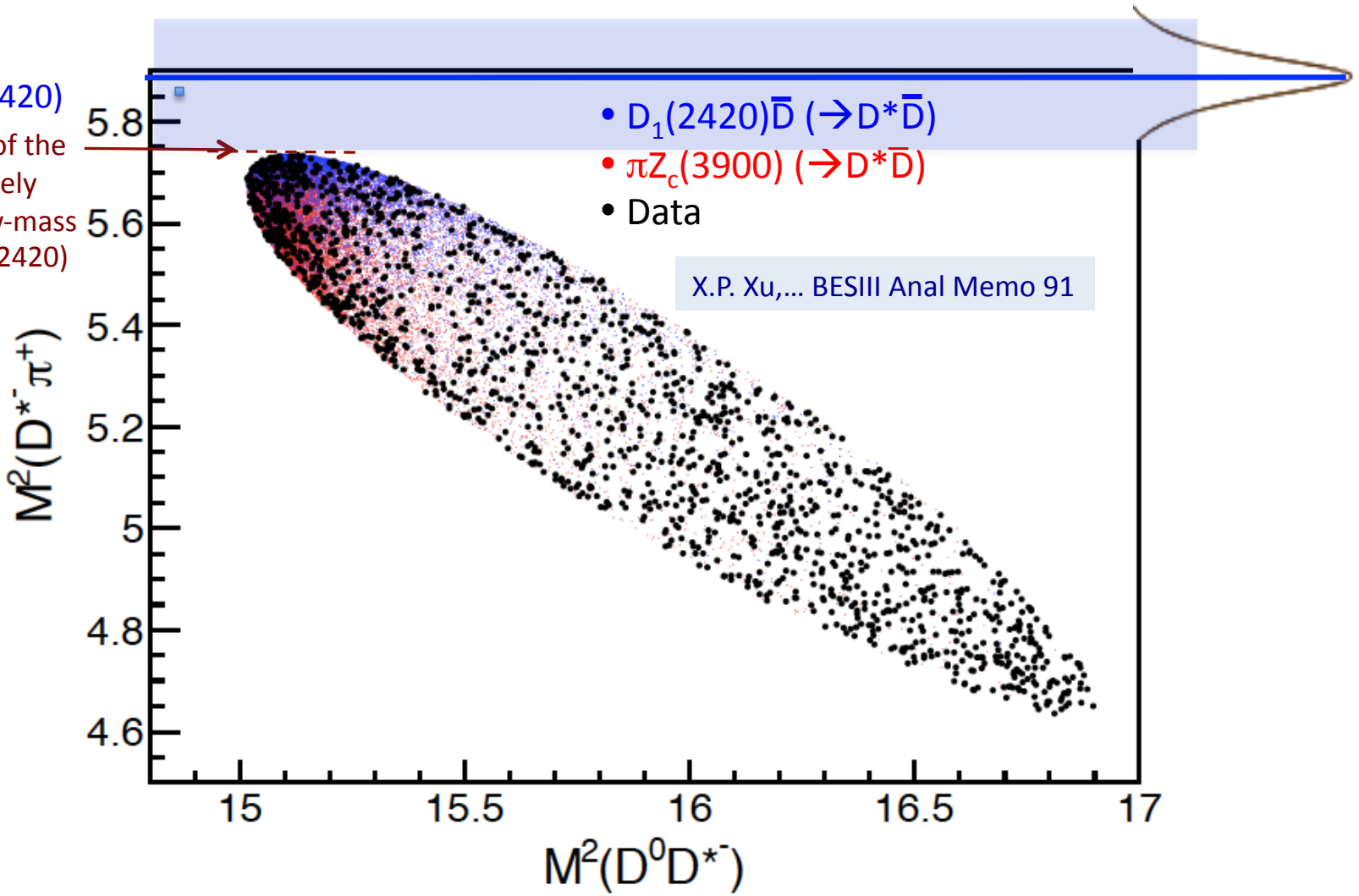
- hadrocharmonium model:

  expect $Bf(Y(4260)\rightarrow \pi\pi\, J/\psi) >> Bf(Y(4260)\rightarrow \omega\, \chi_{c0})$

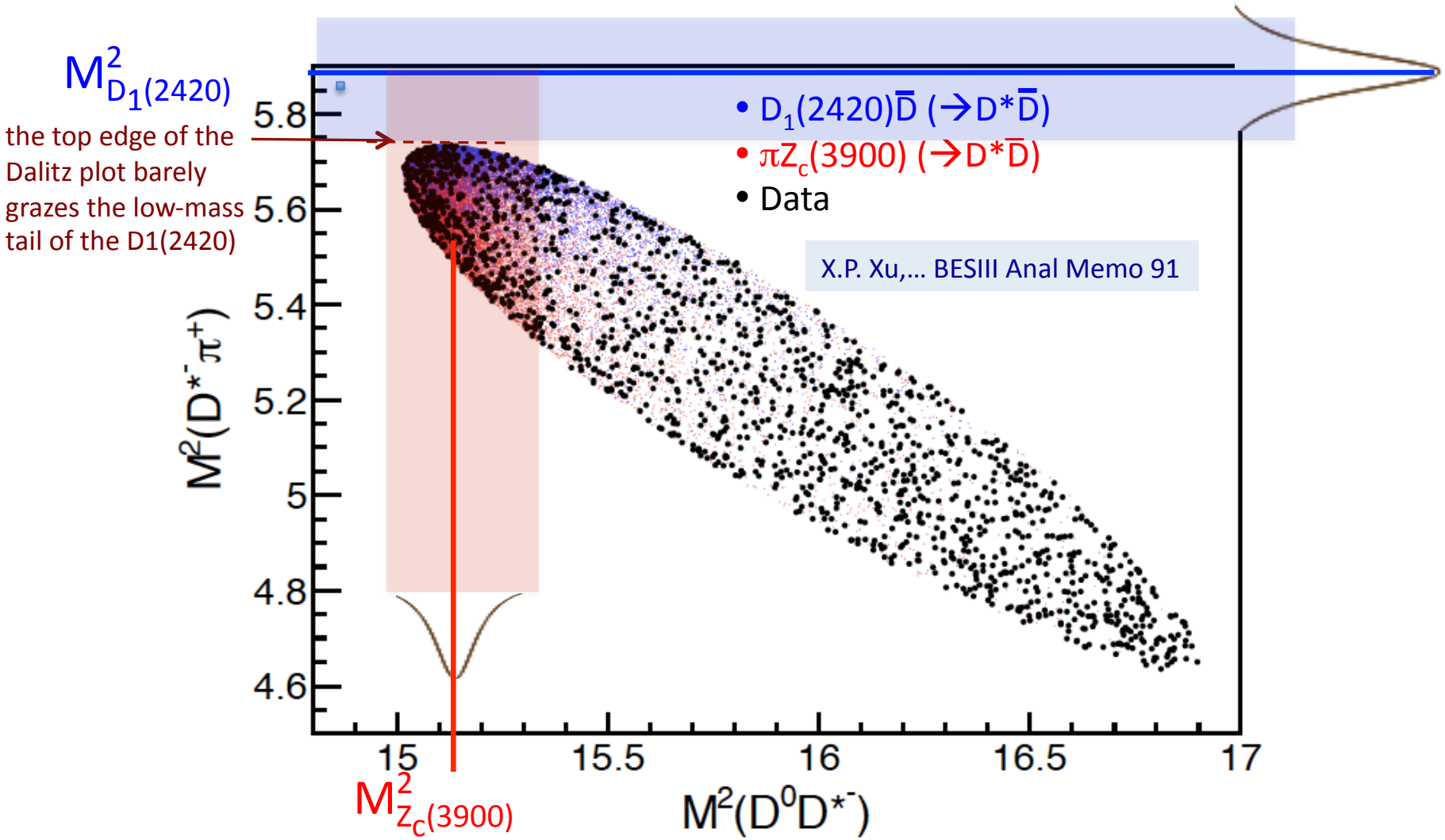
$e^+e^- \to \pi D\bar{D}^*$ @ E_{cm}=4260 MeV Dalitz plot

$M^2_{D_1(2420)}$

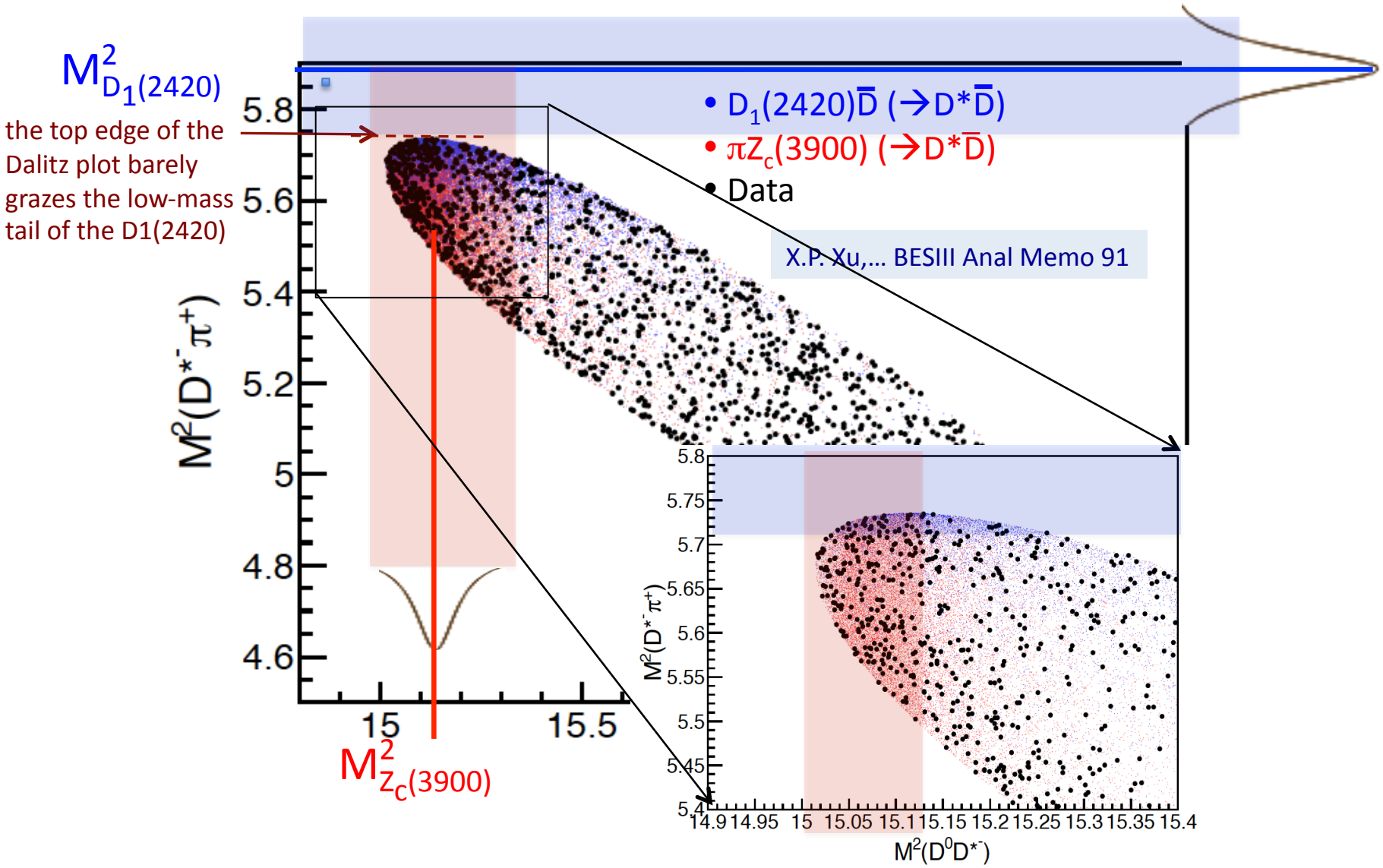
the top edge of the Dalitz plot barely grazes the low-mass tail of the D1(2420)



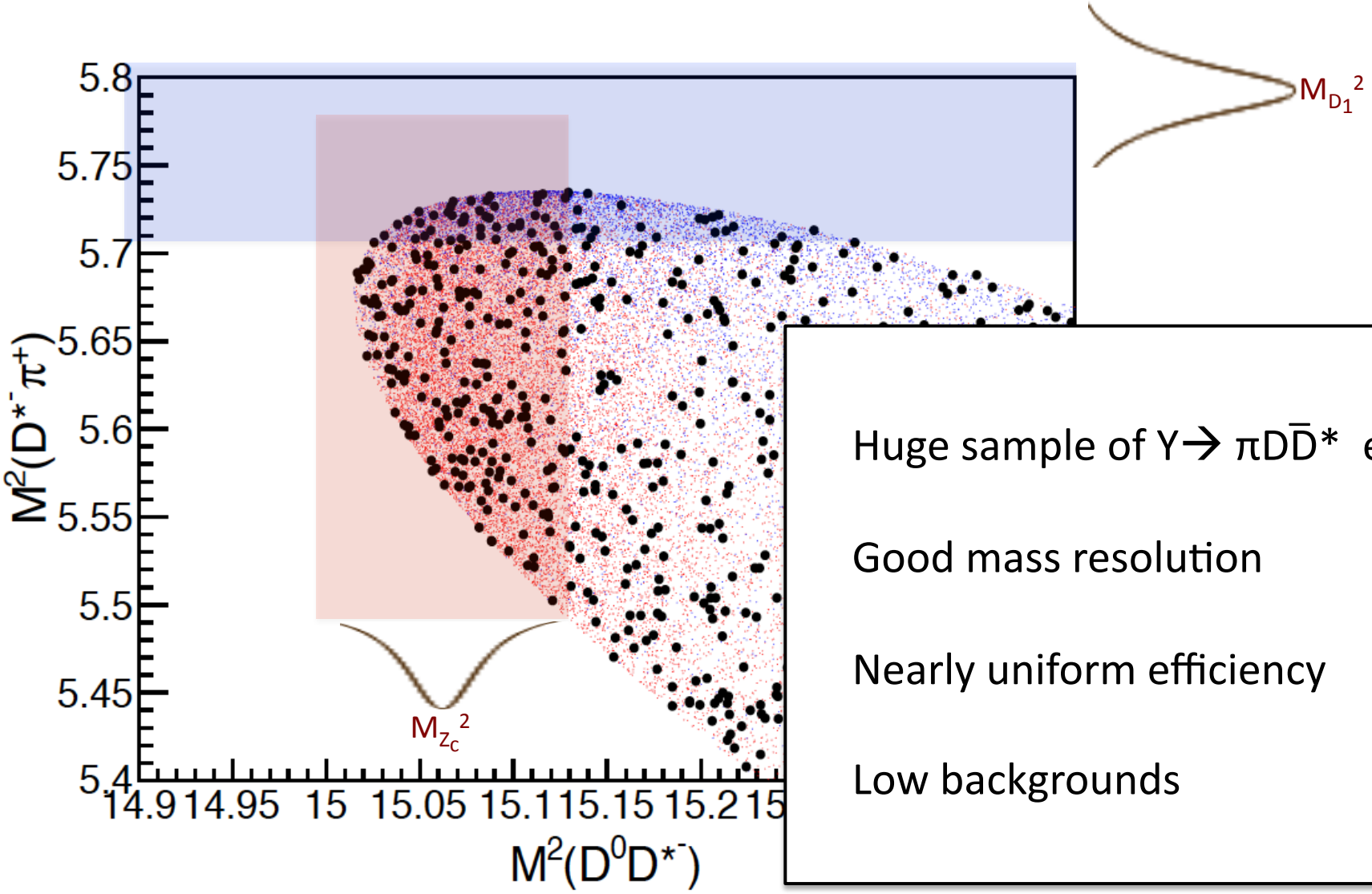
$e^+e^- \to \pi D\bar{D}^*$ @ E_{cm}=4260 MeV Dalitz plot



$e^+e^- \to \pi D\bar{D}^*$ @ E_{cm}=4260 MeV Dalitz plot



What s needed



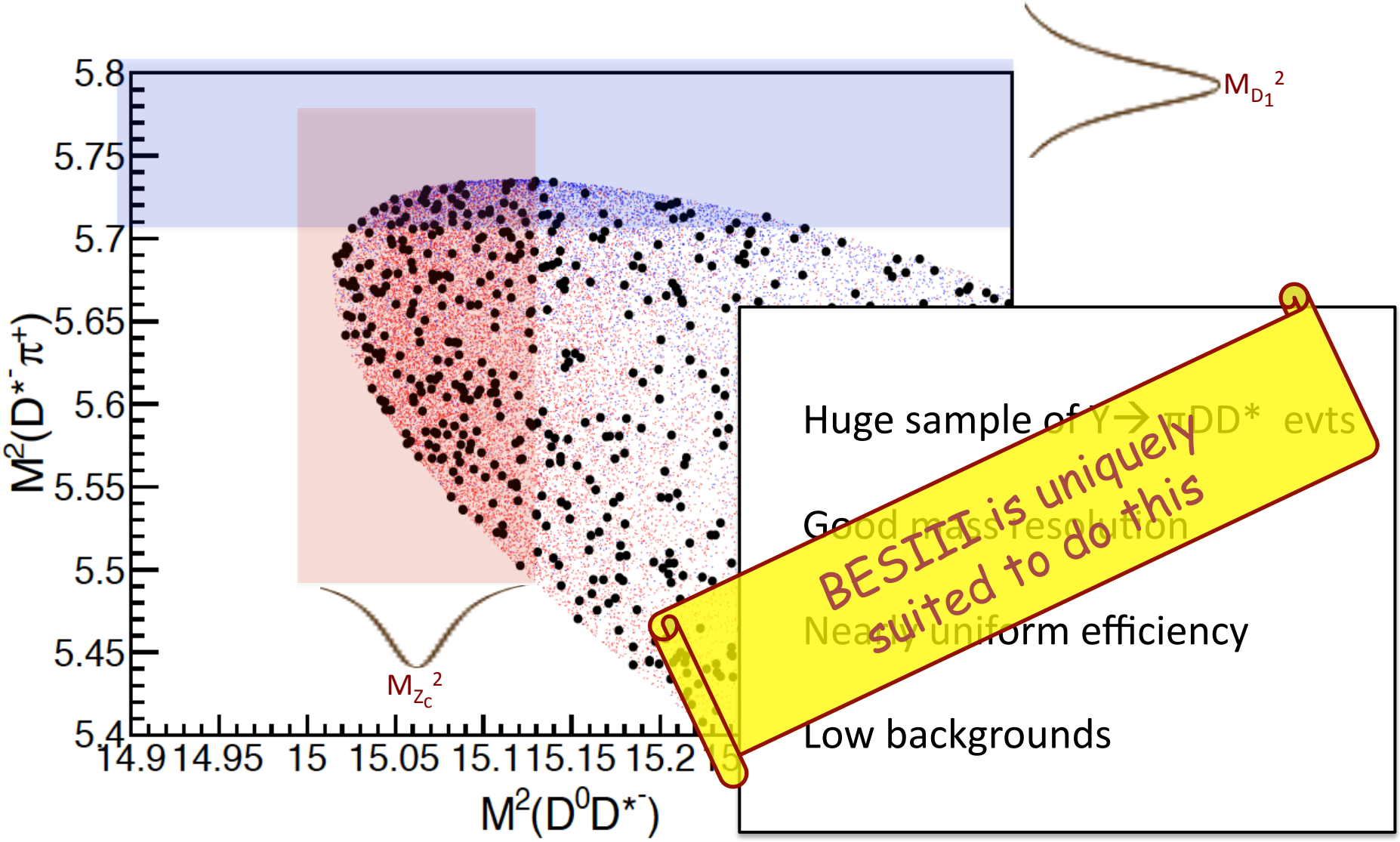
Huge sample of $\Upsilon \rightarrow \pi D\bar{D}^*$ evts

Good mass resolution

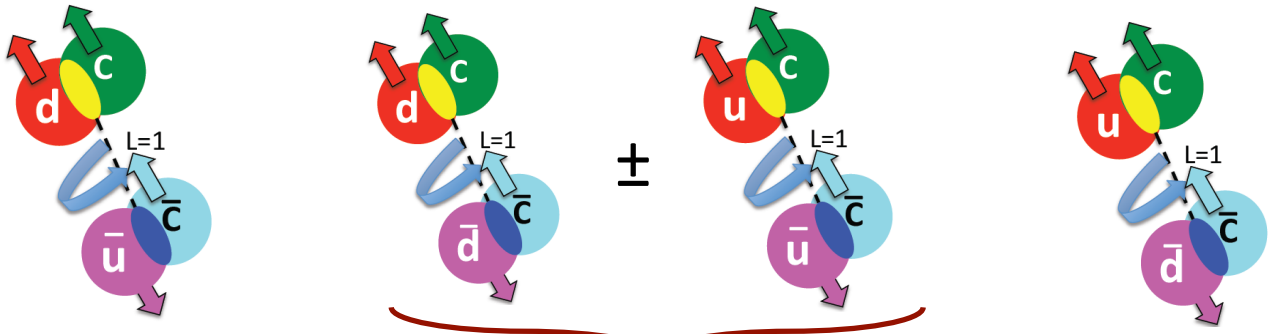
Nearly uniform efficiency

Low backgrounds

What s needed



Partner states?



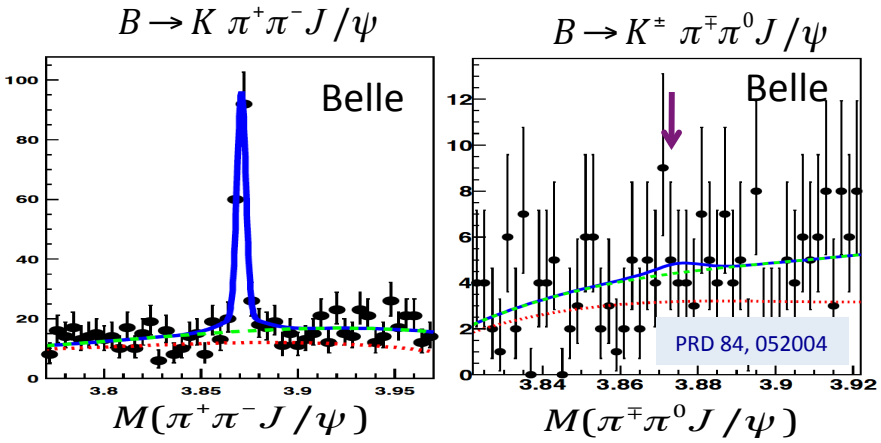
$Y^-(I=1;I_z=-1)$ $+: Y^0(I=1;I_z=0)$ $Y^+(I=1;I_z=+1)$

I=1, 1^{--} states have not been seen
—need to look at π J/ψ or πψ'—

$-: Y^0(I=0;I_z=0)$

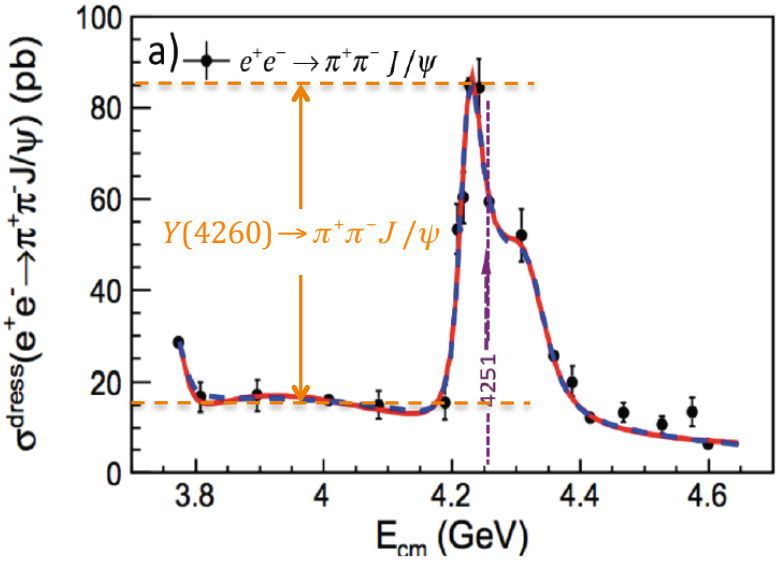
Y(4260)?

(same for X(3872). BaBar & Belle searches for B→K"$X^{\pm}$"; "$X^{\pm}$"→ $\rho^{\pm}$ J/ψ found nothing):

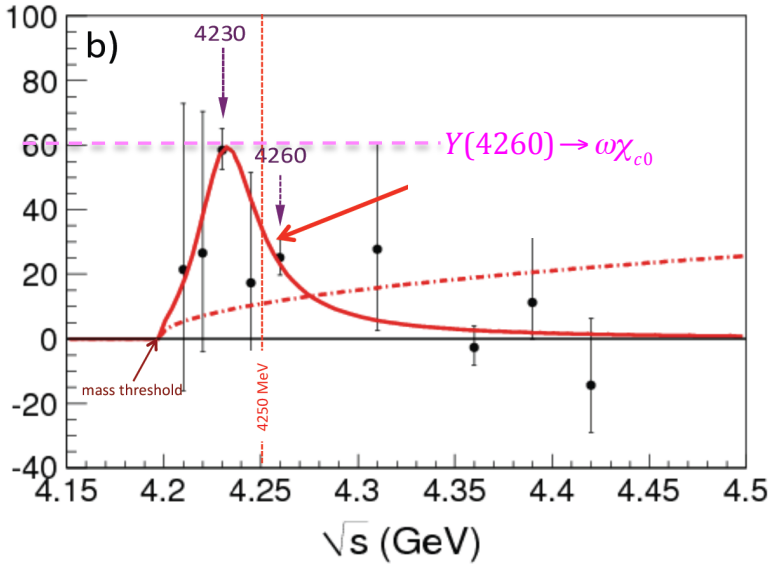


$Bf(Y(4260)\to\pi\pi J/\psi)$ *vs* $Bf(Y(4260)\to\omega\chi_{c0})$

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



$e^+e^- \to \omega\chi_{c0}$



$Bf(Y(4260)\to\pi^+\pi^- J/\psi) \approx Bf(Y(4260)\to\omega\chi_{c0})$ ⇐ within a factor of ~2

~~$Bf(Y(4260)\to\pi^+\pi^- J/\psi) \gg Bf(Y(4260)\to\omega\chi_{c0})$~~ ⇐ not the case

What is the Y(4260)?

The Y(4260) mass is lower and width narrower than previously thought

"Y(4260)" → Y(4220)?

If it is a $D\bar{D}_1(2420)$ molecule:

B.E. ≈ 66 MeV

"affinity" to $D\bar{D}_1(2420)$ should be high ← a quantitative test of this is in progress

If it is a $c\bar{c}$-gluon hybrid:

its mass is ~65 MeV below current ($m_\pi \approx 400$ MeV) LQCD predictions

"affinity" to $D\bar{D}_0(2400)$ should be high ← hard to identify; tests are in progress

If it is a QCD diquark–diantiquark tetraquark:

it should have Isospin- & $SU_F(3)$-multiplet partner states ← none seen (so far)

If it is hadrocharmonium:

decays to non-$J/\psi(h_c)$ charmonium states should be suppressed ← they aren't

BESIII is well suited to further investigate this intriguing puzzle ← a "Y(4260)" factory

Gong Xi Fa Cai

GRAZIE