Meson Classification Based on Effective Theory— X(3872) and Zb(10610)&Zb(10650) as examples

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Outline

- Introduction
- X(3872) and Zb
- Conclusion

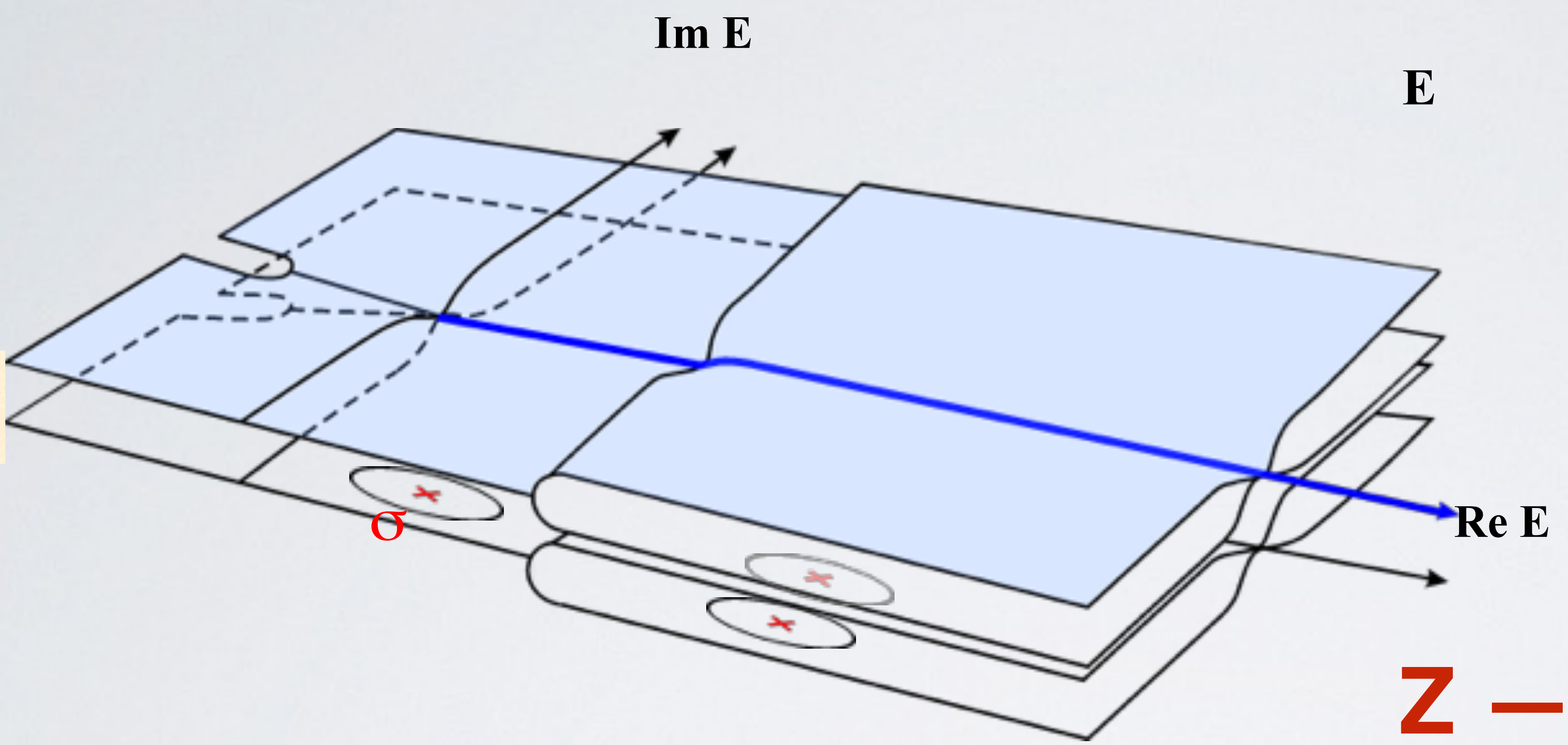
Introduction

1, How to distinguish particle to be an elementary or a molecule particle ?

2, What are the new hadron states ?
Four quark state, Molecule, Glueball, Hybrid, qbar q meson

3, How to search the new hadron states ?
BES e+e-
Belle e+e-\gamma, B decay
BaBar e+e-\gamma, B decay
JLab GlueX \gamma P
LHC B decay

Elementary state vs Molecule



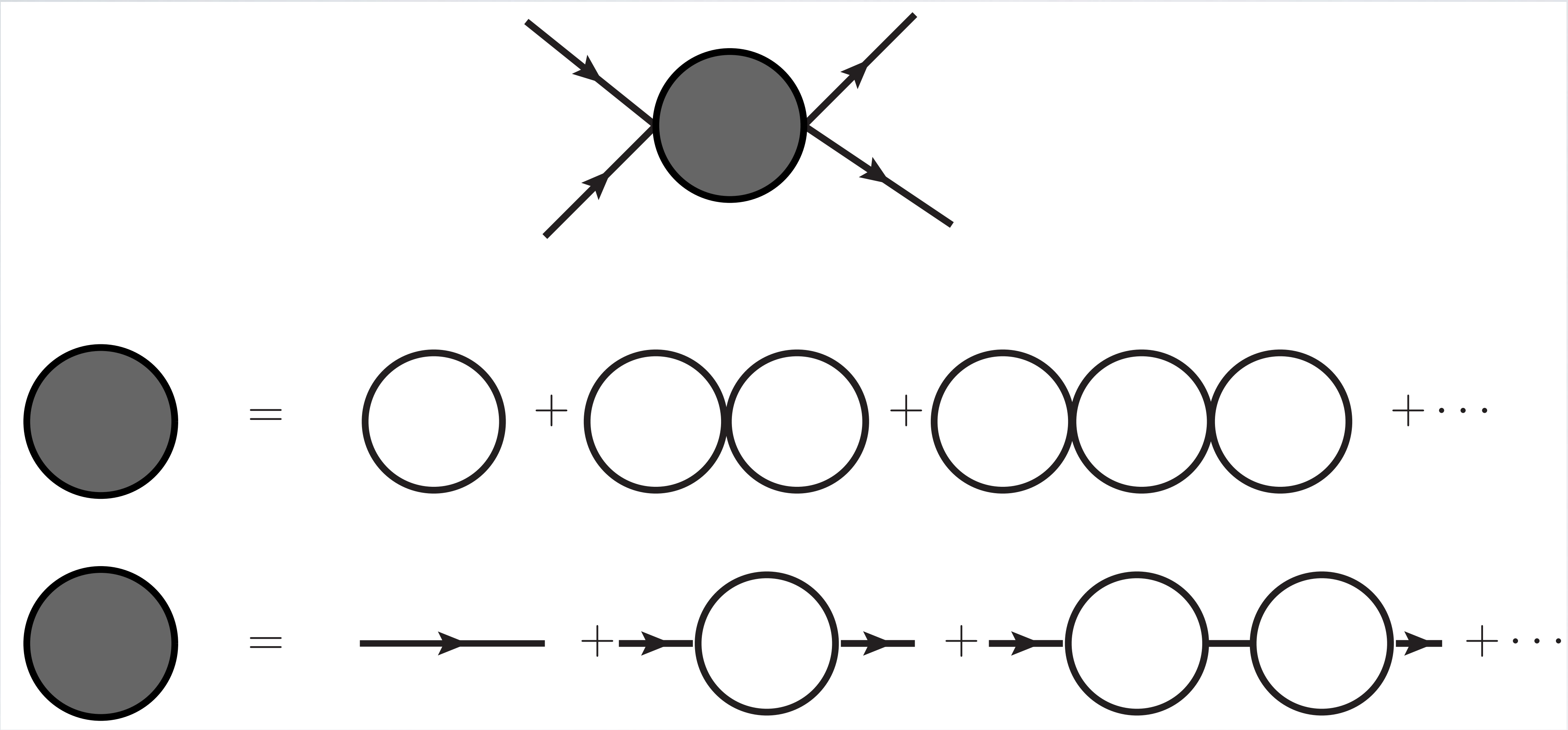
From Michael R Pennington

Renormalization Constant Z

Z —> 0 Molecule
Z —>1 Elementary State

Weinberg 1963,1964
Morgan 1992
Hanhart, Kalashnikova et al 2004,2007
Meng, Sanz-Cillero, Yao, Shi, Zheng 2014

Elementary state vs Molecule

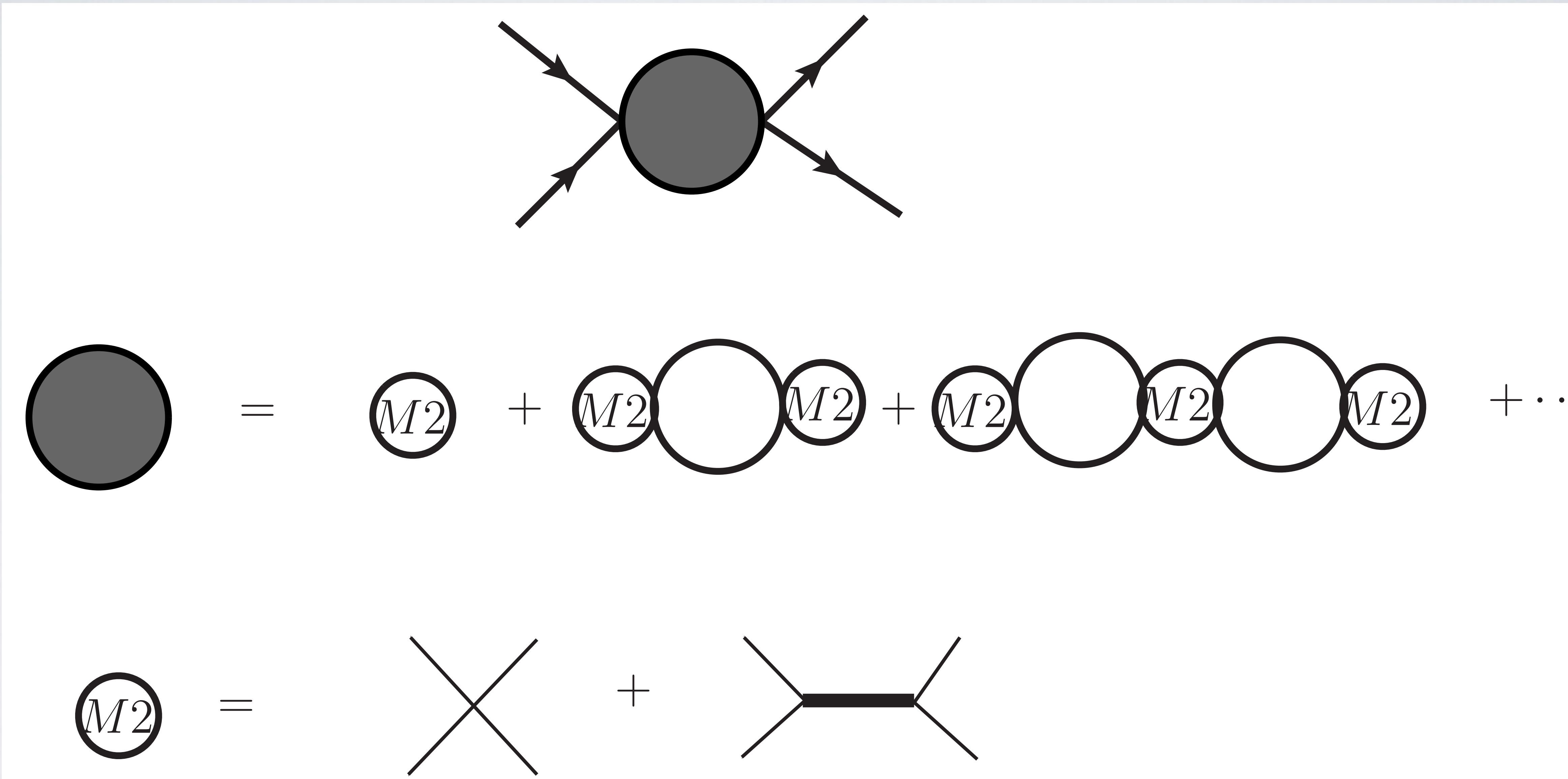


Molecule

Elementary

Or both ?

Elementary state & Molecule



X(3872) 1^{++}

B

$\downarrow$

$DD^*, J/\psi\pi\pi, J/\psi\pi\pi\pi$

arxiv:1411.3106

Zb(10610) 1^{+-}

&

Zb(10650)

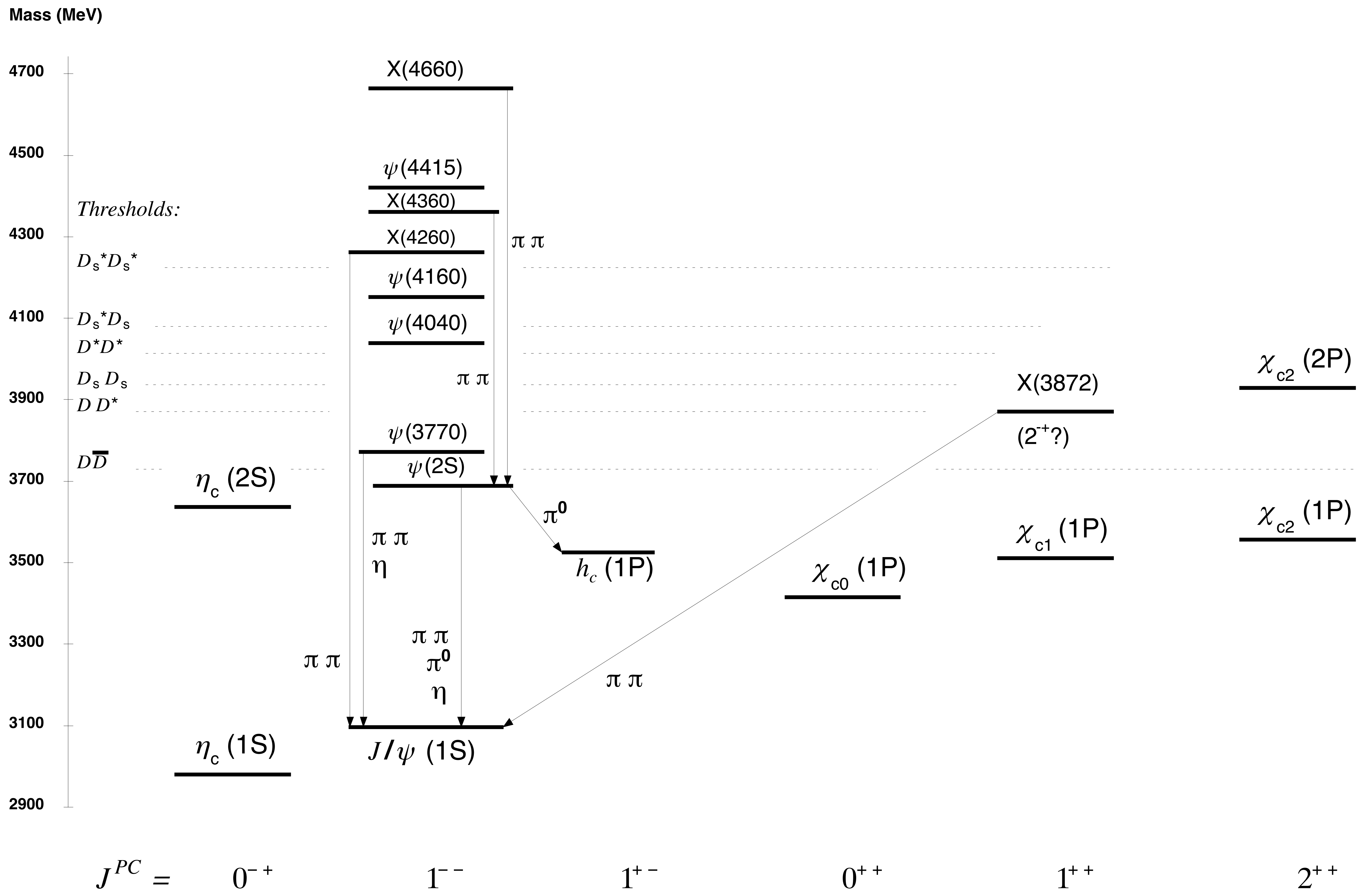
$\Upsilon(5S)$

$\downarrow$

$\Upsilon(nS)\pi(n=1,2,3),\ h_b(mP)\pi(m=1,2)$

$BB^*,\ B^*B^*$

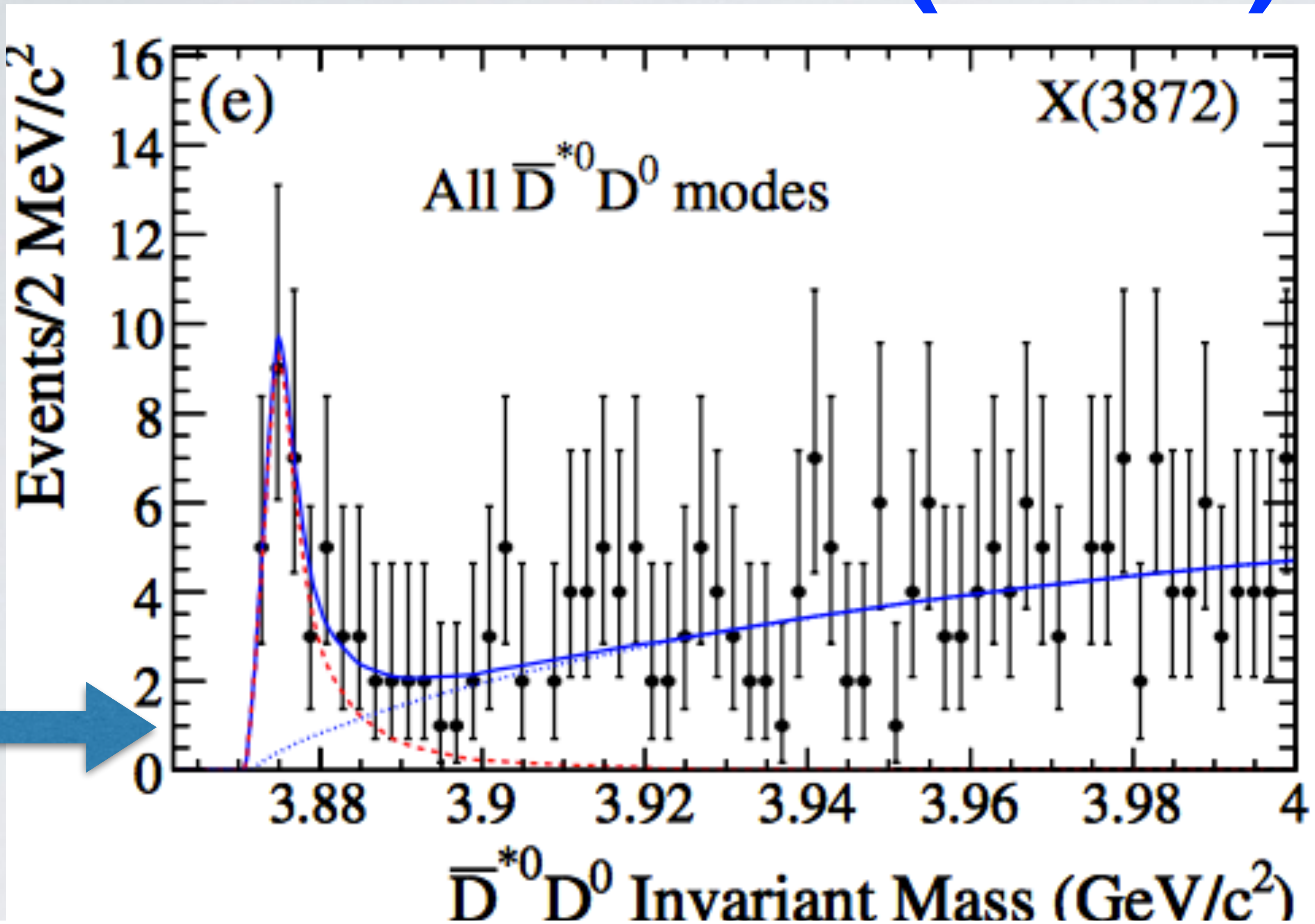
In preparation

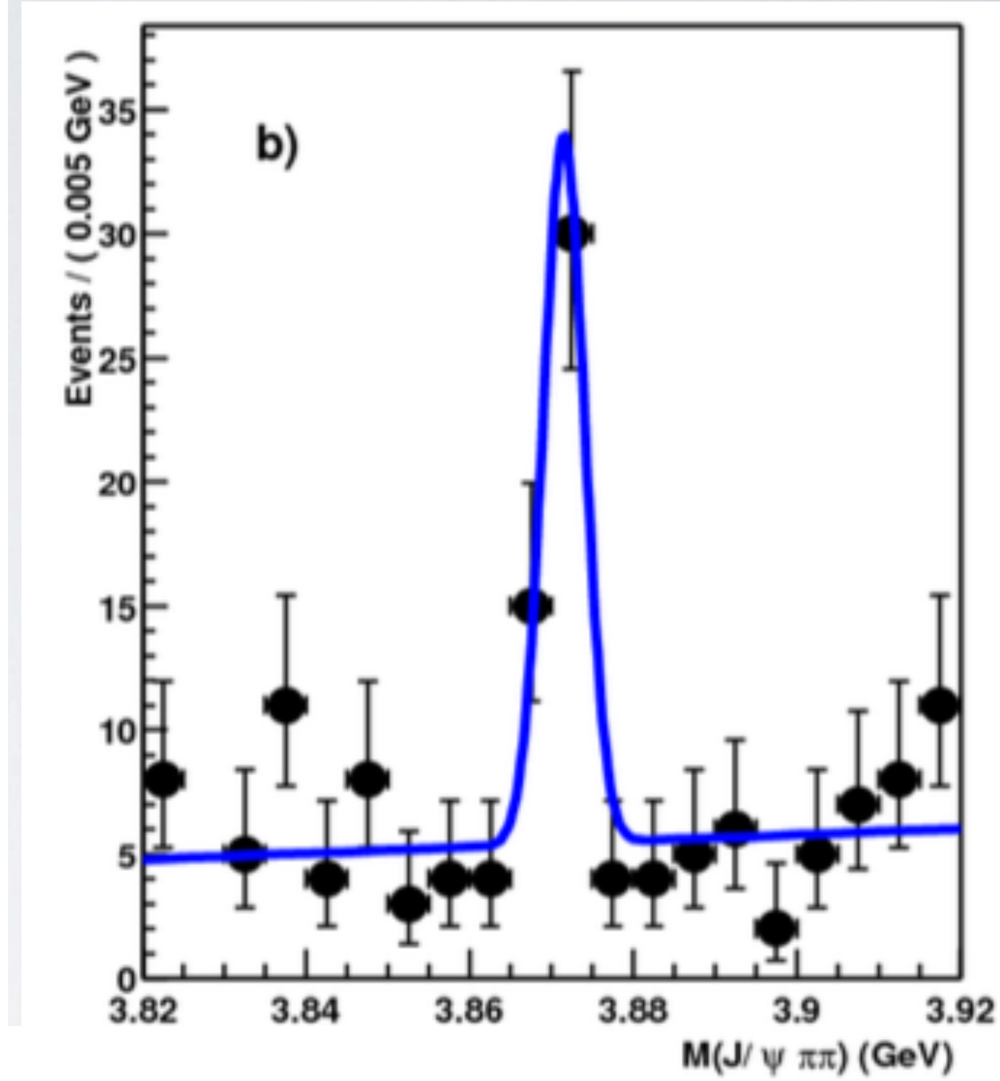


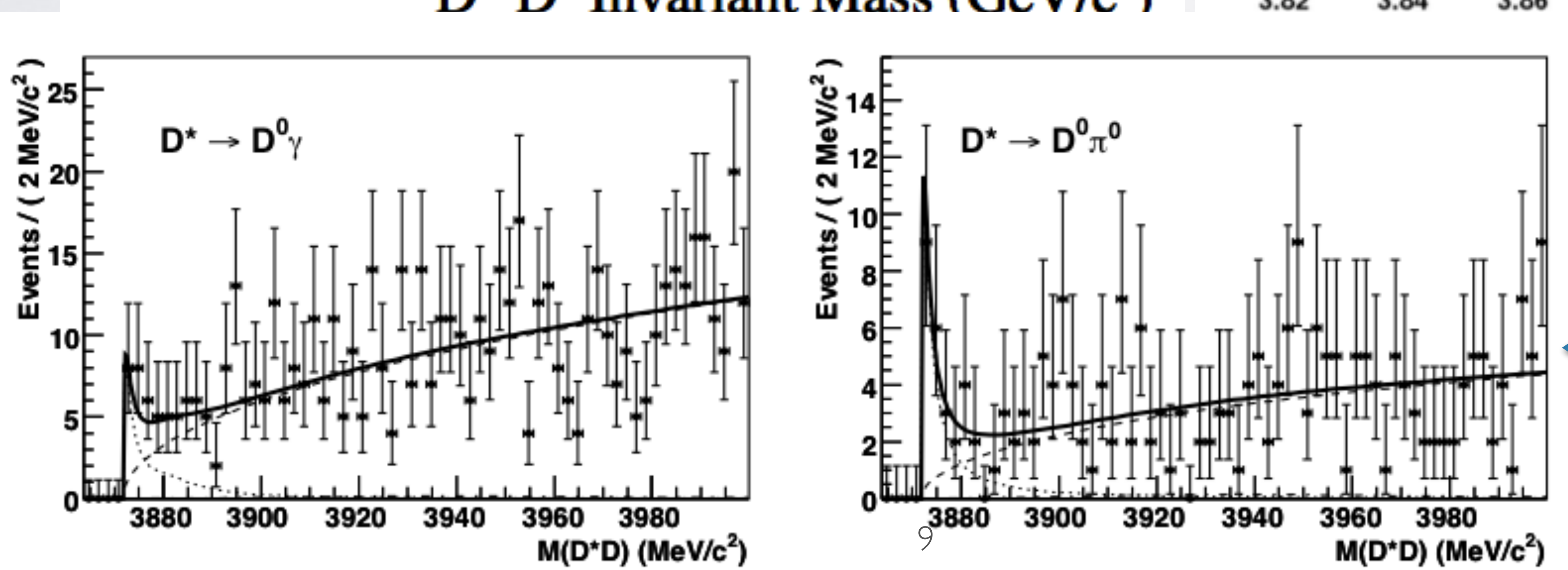
From PDG2014

X(3872)

BaBar



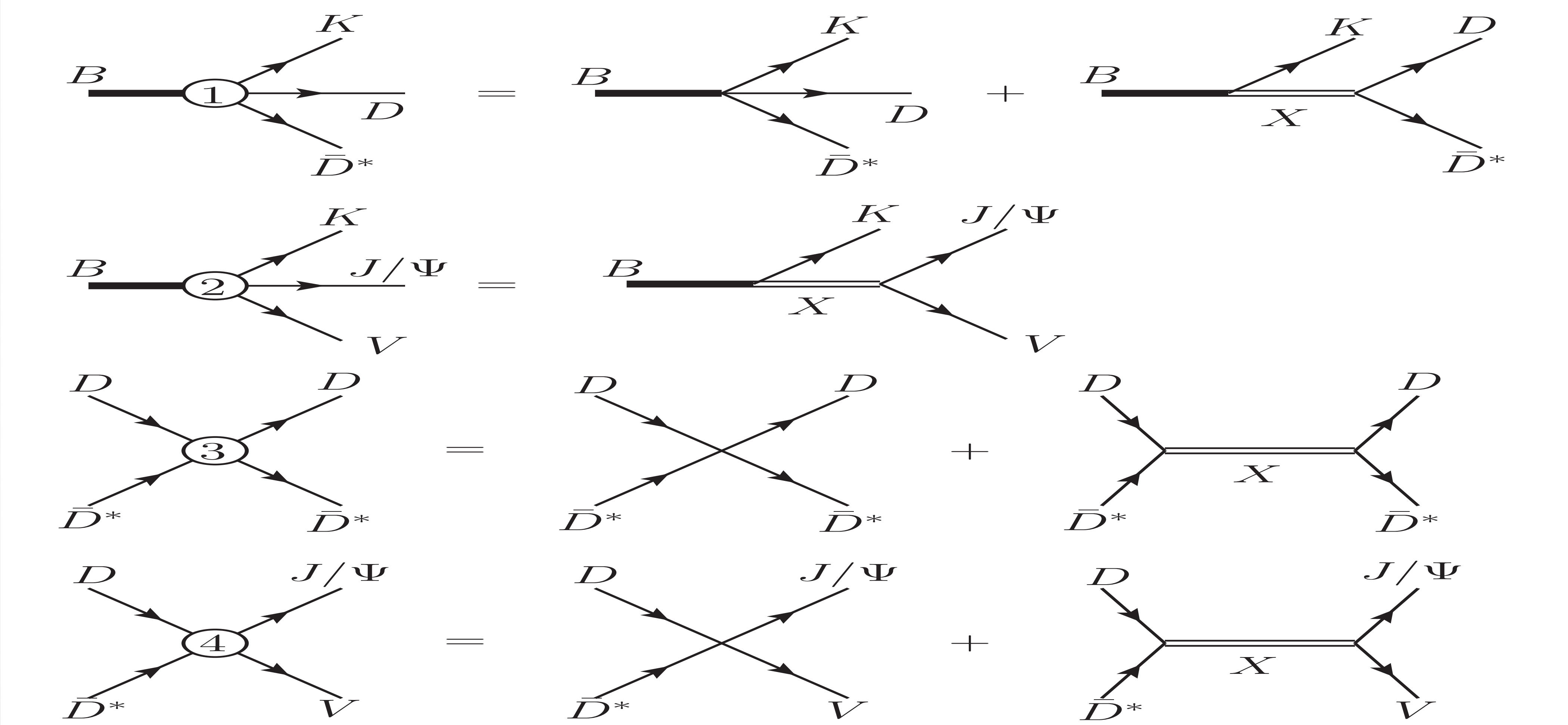


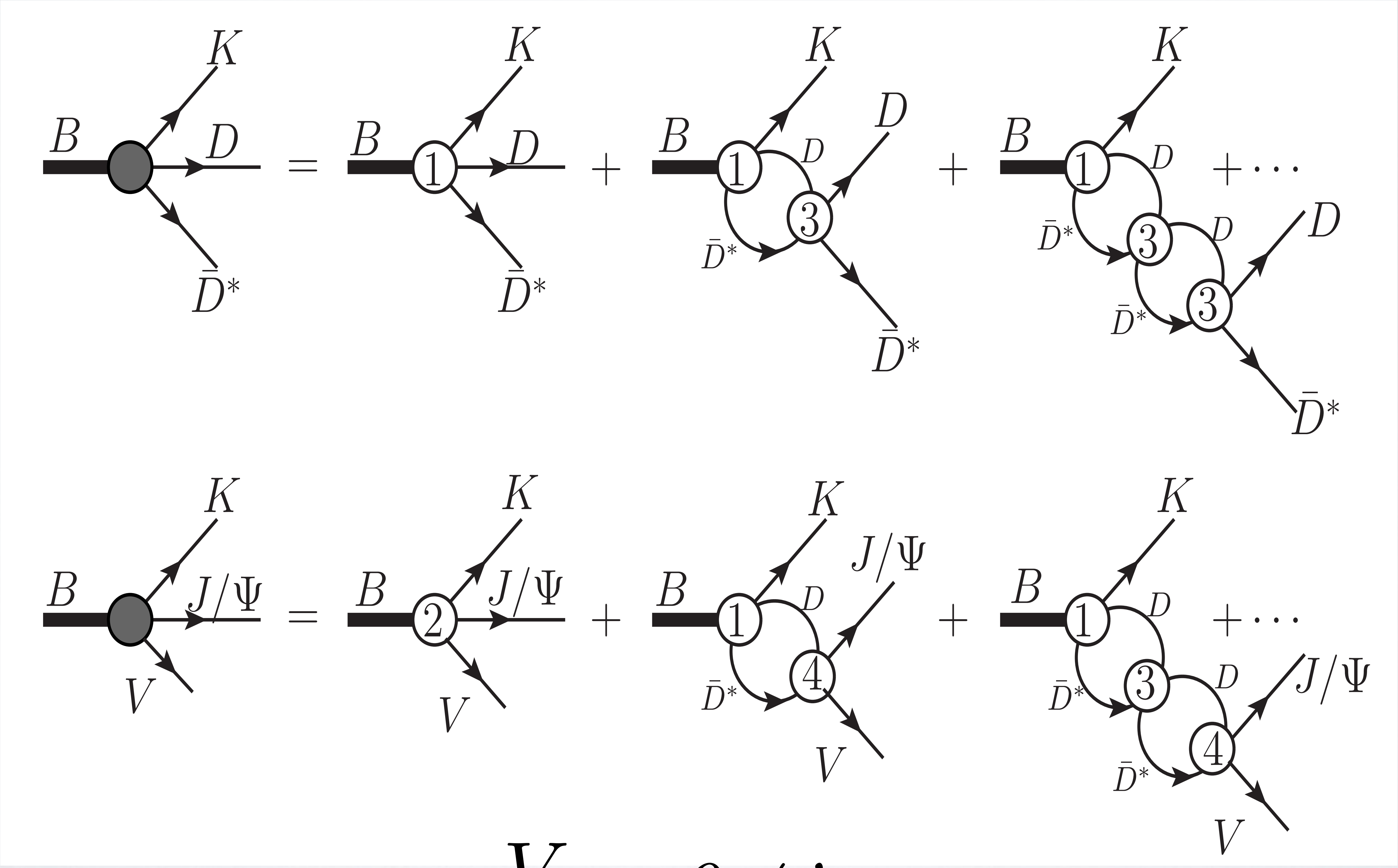


Belle

$$
\begin{aligned}
\mathcal{L}_{D\bar{D}^*} &= \lambda_1(\bar{D}^{*\mu} D \bar{D}^{*\mu} D + \bar{D} D^{*\mu} \bar{D} D^{*\mu}) + \lambda_2(\bar{D}^{*\mu} D \bar{D} D^{*\mu}) \,, \\
\mathcal{L}_{XD\bar{D}^*} &= g_1 X^\mu (\bar{D} D^*_\mu - \bar{D}^*_\mu D), \\
\mathcal{L}_{BXK} &= i g_2 X^\mu \left(\overline{B} \partial_\mu K + \text{h.c.}\right) , \\
\mathcal{L}_{BKD\bar{D}^*} &= i g_3 (\bar{D} D^*_\mu - \bar{D}^*_\mu D) \left(\overline{B} \partial^\mu K + \text{h.c.}\right) ,
\end{aligned}
$$

$$
\begin{aligned}
\mathcal{L}_{X\Psi V} &= i g_4 X^\mu \Psi^\nu \partial^\alpha V^\beta \epsilon_{\mu\nu\alpha\beta} \,, \\
\mathcal{L}_{\Psi V D\bar{D}^*} &= i g_5 (\bar{D} D^{*\mu} - \bar{D}^{*\mu} D) \Psi^\nu \partial^\alpha V^\beta \epsilon_{\mu\nu\alpha\beta} \,,
\end{aligned}
$$





$$V = \rho,\ \omega$$

$$\mathcal{M}_{D^0\bar{D}^{*0}} = -\frac{(g_3 + \frac{g_1 g_2}{s-M_X^2}) p_K^\mu \epsilon_{D^*}^\nu}{1-(i\lambda_2 + i\frac{g_1^2}{s-M_X^2})\hat{\Pi}_T(s)} P_{T\mu\nu}(p) + \frac{(g_3 + \frac{g_1 g_2}{M_X^2}) p_K^\mu \epsilon_{D^*}^\nu}{1-(i\lambda_2 + i\frac{g_1^2}{M_X^2})\hat{\Pi}_L(s)} P_{L\mu\nu}(p)$$

$$\int \frac{d^D k}{(2\pi)^D} \frac{g_{\mu\nu} - \frac{k_\mu k_\nu}{m_{D^{*0}}^2}}{(k^2 - m_{D^{*0}}^2)((p-k)^2 - m_{D^0}^2)} = P_{T\mu\nu}(p)\Pi_{T_{D^0\bar{D}^{*0}}}(s) + P_{L\mu\nu}(p)\Pi_{L_{D^0\bar{D}^{*0}}}(s)$$

$$s - M_X^2 \Rightarrow s - M_X^2 + iM_X(\Gamma_{J/\Psi\pi\pi}(s) + \Gamma_{J/\Psi\pi\pi\pi}(s) + \Gamma_0),$$

$$\Gamma_{J/\Psi\pi\pi}(s) = g_4^2 \int_{2m_\pi}^{\sqrt{s}-m_{J/\Psi}} \frac{dm}{2\pi} \frac{k(m)(\frac{s\cdot k(m)^2}{m_{J/\Psi}^2} + 2m_{J/\Psi}^2 + 2s - 6\sqrt{s}k(m) + k(m)^2)\Gamma_\rho}{4\pi s((m-m_\rho)^2 + \Gamma_\rho^2/4)},$$

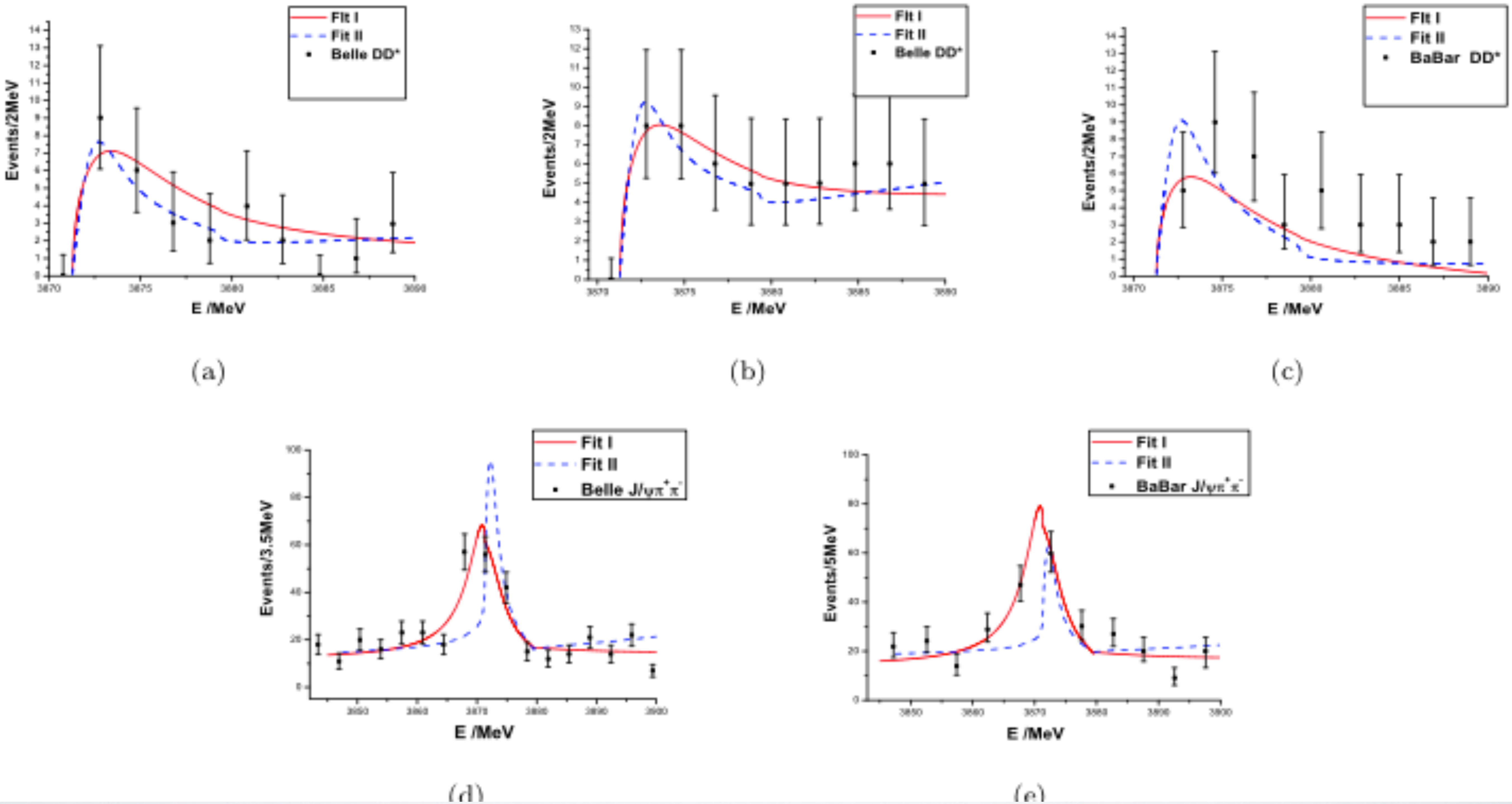
$$\Gamma_{J/\Psi\pi\pi\pi}(s) = g_4'^2 \int_{3m_\pi}^{\sqrt{s}-m_{J/\Psi}} \frac{dm}{2\pi} \frac{k(m)(\frac{s\cdot k(m)^2}{m_{J/\Psi}^2} + 2m_{J/\Psi}^2 + 2s - 6\sqrt{s}k(m) + k(m)^2)\Gamma_\omega}{4\pi s((m-m_\omega)^2 + \Gamma_\omega^2/4)},$$

$$k(m) = \sqrt{\frac{(s-(m+m_{J/\Psi})^2)(s-(m-m_{J/\Psi})^2)}{4s}}$$

$$\mathcal{M}_{J/\Psi V} = \frac{p_K^\mu \epsilon_\Psi^\nu p_V^\alpha \epsilon_V^\beta \epsilon_{\rho\nu\alpha\beta}(g_2 g_4(1 - i\lambda_2 \hat{\Pi}_T) + i g_1 g_2 g_5 \hat{\Pi}_T + i g_3 g_5 (s - M_X^2)\hat{\Pi}_T + i g_1 g_3 g_4 \hat{\Pi}_T)}{(s - M_X^2)(1 - i\lambda_2 \hat{\Pi}_T) - i g_1^2 \hat{\Pi}_T} P^\rho_{T\mu}(p)$$

$$+ i\, g_3 p_K^\mu \hat{\Pi}_L \epsilon_\Psi^\nu p_V^\alpha \epsilon_V^\beta \epsilon_{\rho\nu\alpha\beta} \frac{i g_5 - \frac{i g_1 g_4}{M_X^2}}{1 - (i\lambda_2 - \frac{i g_1^2}{M_X^2})\hat{\Pi}_L} P^\rho_{L\mu}(p) - \frac{i g_2 p_K^\mu (g_4 + \frac{i g_1 g_5 \hat{\Pi}_L}{1 - i\lambda_2 \hat{\Pi}_L}) \epsilon_\Psi^\nu p_V^\alpha \epsilon_V^\beta \epsilon_{\rho\nu\alpha\beta}}{M_X^2 + \frac{i g_1^2 \hat{\Pi}_L}{1 - i\lambda_2 \hat{\Pi}_L}} P^\rho_{L\mu}(p)$$

$$s - M_X^2 \Rightarrow s - M_X^2 + i M_X (\Gamma_{J/\Psi\pi\pi}(s) + \Gamma_{J/\Psi\pi\pi\pi}(s) + \Gamma_0),$$



(a) (b) (c) (d) (e)

Fit I Elementary State Two poles

Fit II Molecule One pole

arxiv:1411.3106

	Fit I	Fit II
	$\chi^2/dof = 47.1/(60-17)$	$\chi^2/dof = 83.3/(60-12)$
λ_2	–	552.7 ± 1.1
c_0	–	$(1.70 \pm 0.01) \times 10^{-4}$
g_1 (MeV)	1977 ± 908	–
g_2/g_3 (MeV)	196 ± 52	–
g_4	0.27 ± 0.08	–
g_4'	0.44 ± 0.11	–
g_5 (MeV^{-1})	0.016 ± 0.014	1.0 (fixed)
M_X(MeV)	3870.3 ± 0.5	–
Γ_0(MeV)	4.3 ± 1.5	–
$N_{11} \cdot g_3^2 (10^{-3}\text{MeV}^{-3})$	9.2 ± 5.0	159 ± 55
$N_{12} \cdot g_3^2 (10^{-3}\text{MeV}^{-3})$	8.1 ± 4.0	181 ± 53
$N_{13} \cdot g_3^2 (10^{-3}\text{MeV}^{-3})$	9.1 ± 4.7	143 ± 48
$N_{21} \cdot g_3^2\ (10^{-5}\text{MeV}^{-4})$	4.7 ± 1.3	63 ± 35
$N_{22} \cdot g_3^2\ (10^{-5}\text{MeV}^{-4})$	3.9 ± 1.1	116 ± 33
$c_{11} \times 10^5$	3.4 ± 1.7	3.6 ± 1.4
$c_{12} \times 10^5$	1.9 ± 1.0	0.4 ± 0.2
$c_{13} \times 10^5$	1.6 ± 1.2	1.1 ± 1.0
c_{21}	15.5 ± 2.1	15.1 ± 2.0
c_{22}	13.1 ± 1.5	12.6 ± 1.4

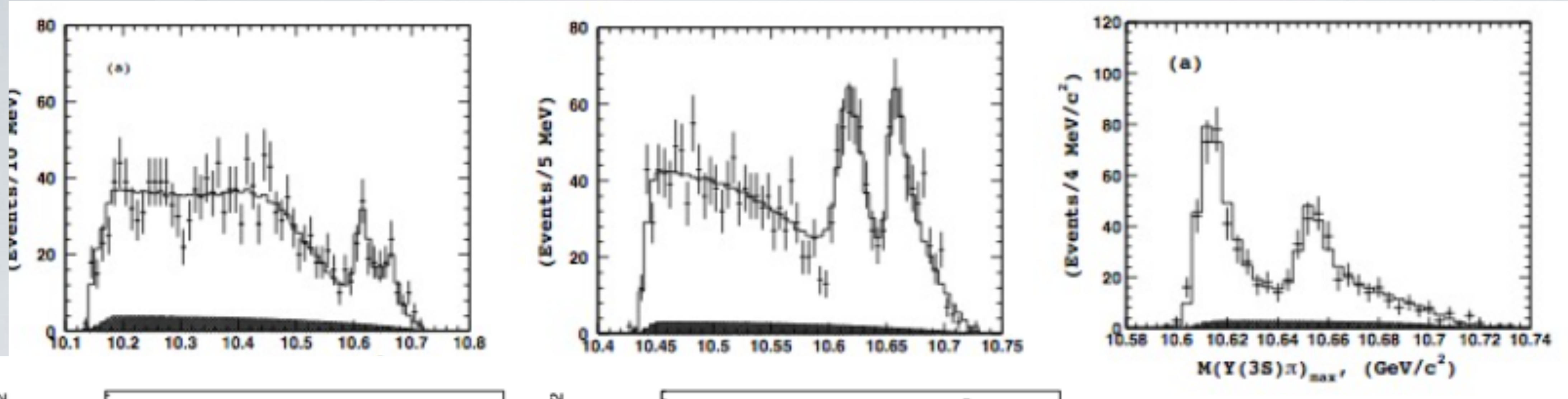
	sheet I	sheet II	sheet III	sheet IV
$\rho_{D^0 D^{*0}}(s)$	+	-	-	+
$\rho_{D^+ D^{*-}}(s)$	+	+	-	-

Sheet	Fit I	Fit II
I	3871.1-3.3i	–
II	3870.5-3.7i	3871.7-0.9i
III	3869.0-4.0i	–
IV	3869.8-3.5i	–

$$M^{1st}_{X(3872)} = (3871.2 \pm 0.7)\,\mathrm{MeV}, \qquad \Gamma^{1st}_{X(3872)} = (6.5 \pm 1.2)\,\mathrm{MeV}.$$

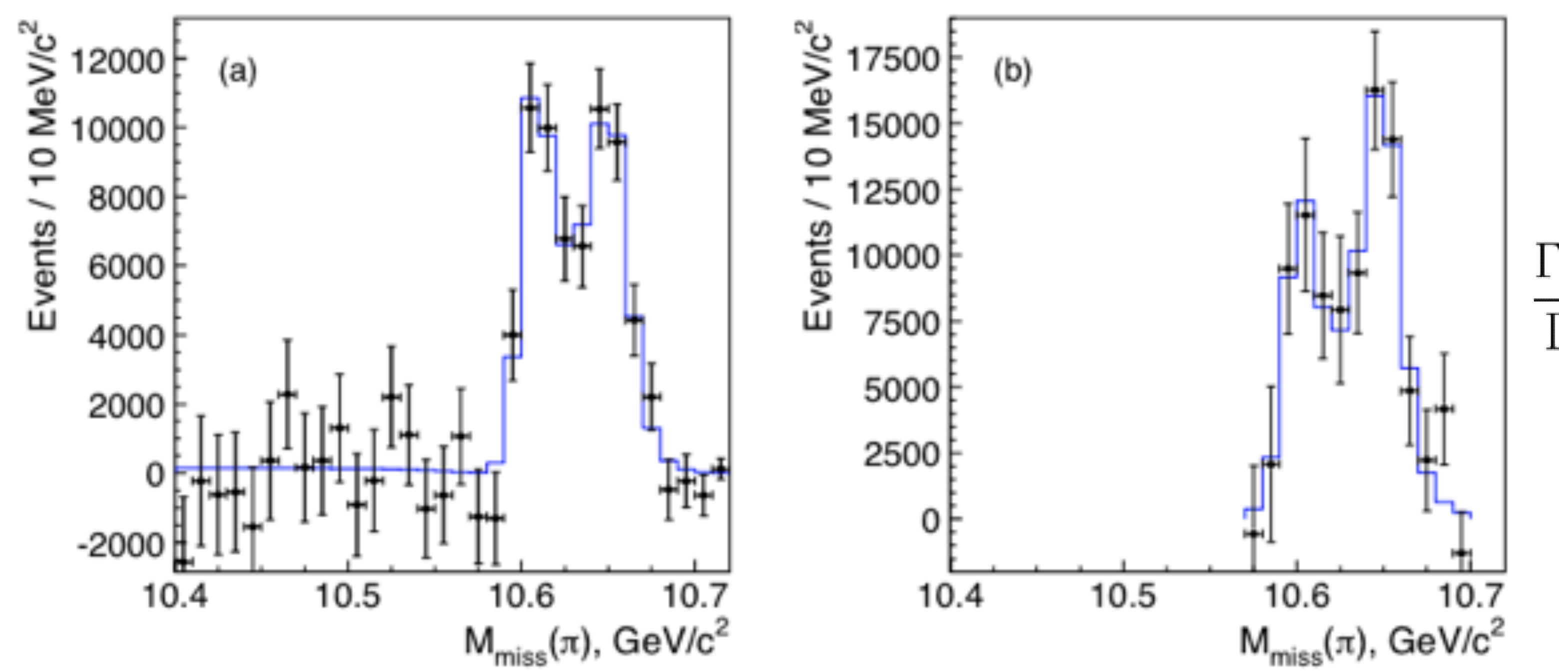
$$M^{2nd}_{X(3872)} = (3870.5 \pm 0.2)\,\mathrm{MeV}, \qquad \Gamma^{2nd}_{X(3872)} = (7.9 \pm 1.6)\,\mathrm{MeV}.$$

Zb(10610) and Zb(10650)



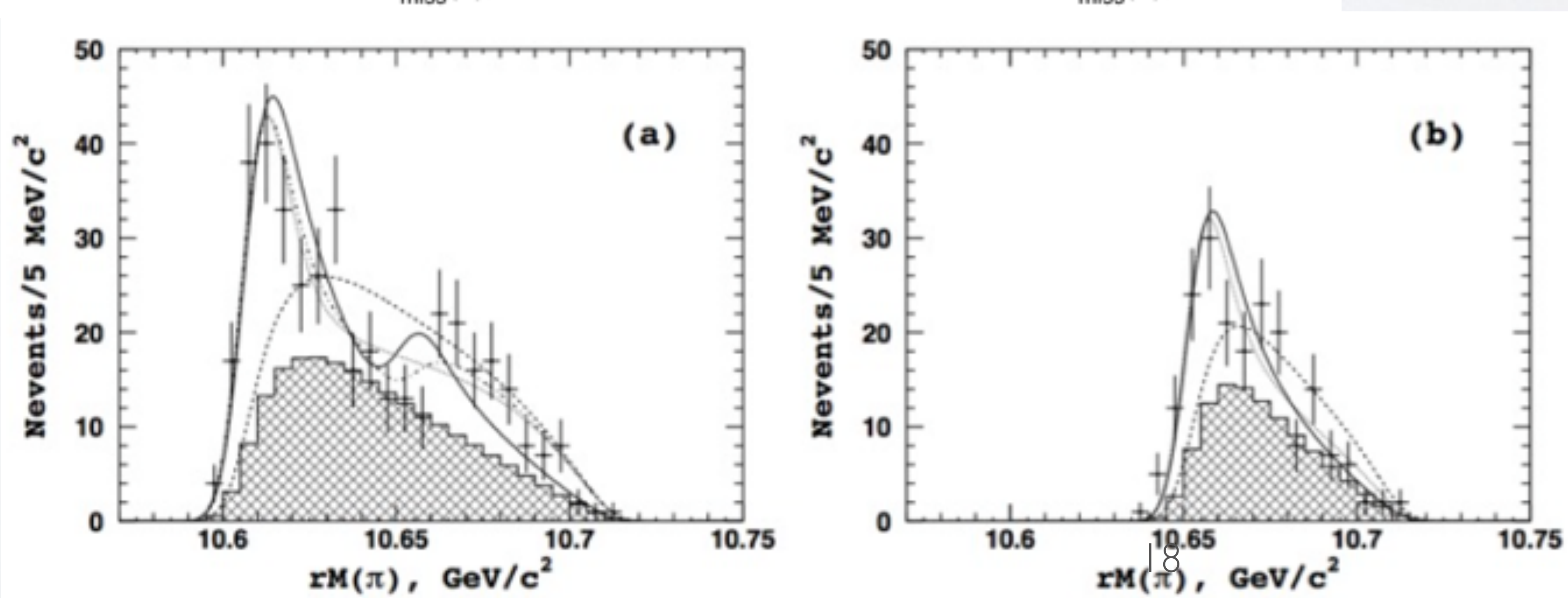
$\Upsilon(nS)\pi\pi$

n=1,2,3



$$\frac{\Gamma[\Upsilon(5S) \to h_b(nP)\,\pi^+\pi^-]}{\Gamma[\Upsilon(5S) \to \Upsilon(2S)\,\pi^+\pi^-]} = \begin{cases} 0.45 \pm 0.08^{+0.07}_{-0.12} & \text{for } h_b(1P) \\ 0.77 \pm 0.08^{+0.22}_{-0.17} & \text{for } h_b(2P) \end{cases}$$

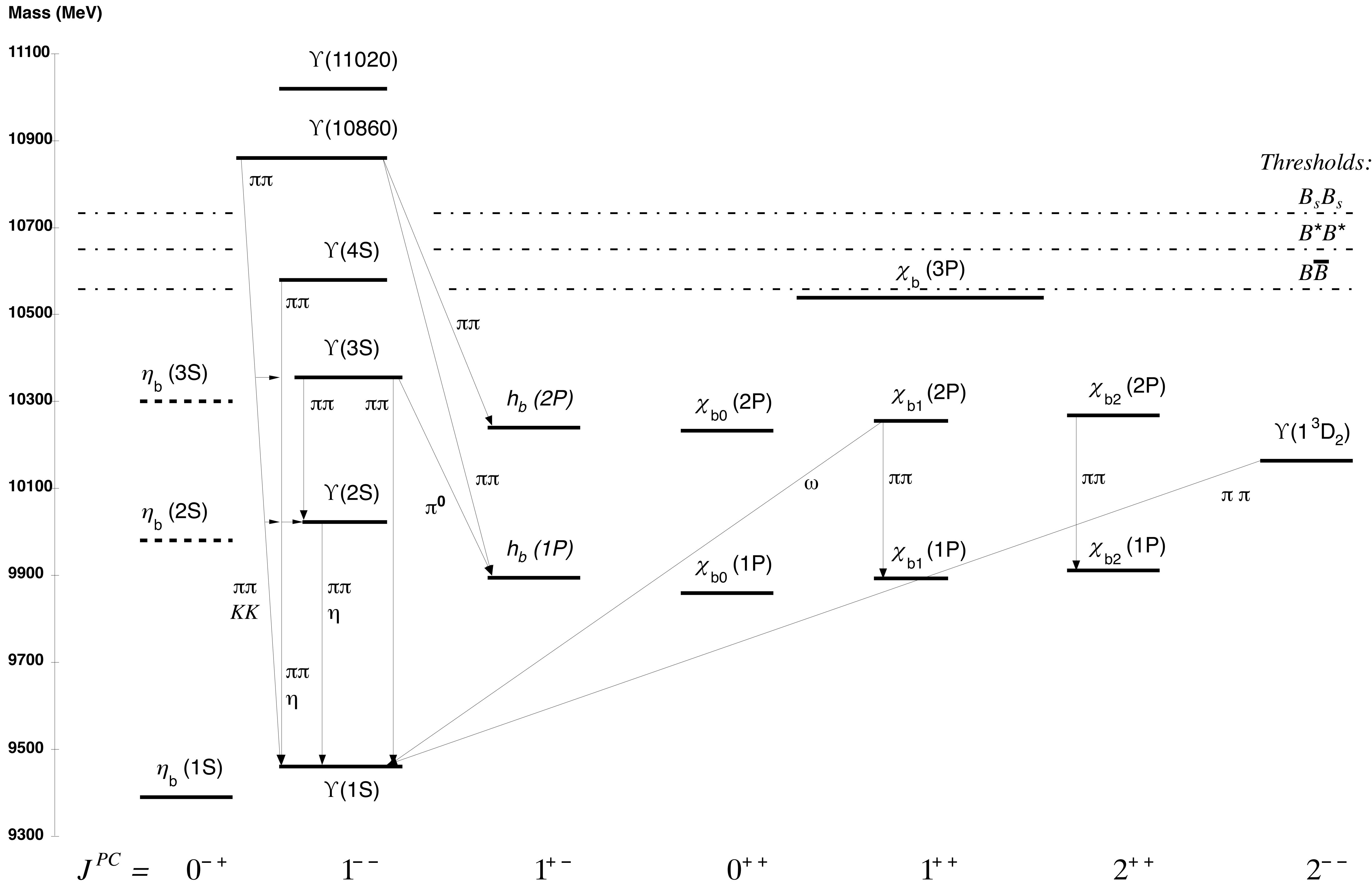
no flip   spin-flip



$BB^*\pi$

and

$B^*B^*\pi$



From PDG2014

- Many Evidences point to a molecule Zb state

M. B. Voloshin

$$Z_b(10610) \sim (B^* \bar{B} - \bar{B}^* B) \sim \frac{1}{\sqrt{2}} \left(0_H^- \otimes 1_{SLB}^- + 1_H^- \otimes 0_{SLB}^- \right) \ ,$$

$$Z_b(10650) \sim B^* \bar{B}^* \sim \frac{1}{\sqrt{2}} \left(0_H^- \otimes 1_{SLB}^- - 1_H^- \otimes 0_{SLB}^- \right) \ ,$$

T. Mehen

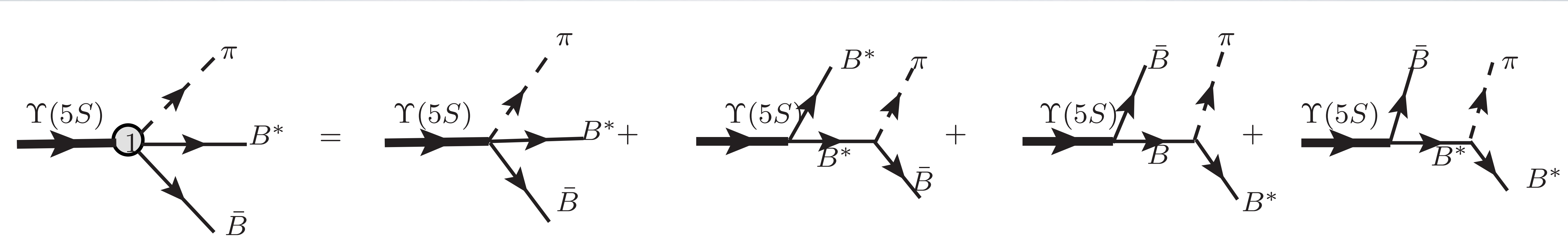
$$Z^{Ai} = \frac{1}{\sqrt{2}}(V_a^i \tau_{ab}^A \bar{P}_b - P_a \tau_{ab}^A \bar{V}_b^i), \quad Z'^{Ai} = \frac{i}{\sqrt{2}} \epsilon^{ijk} V_a^j \tau_{ab}^A \bar{V}_b^k,$$

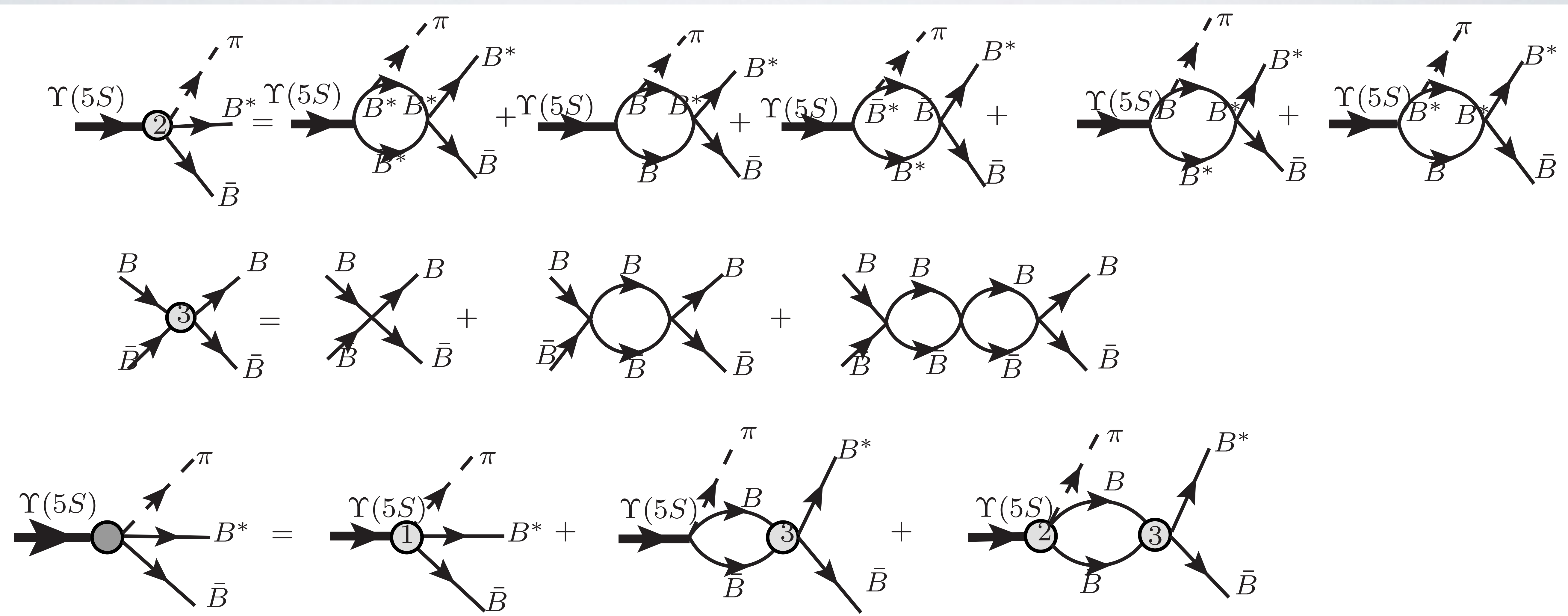
$$
\begin{aligned}
\mathcal{L} = & \, g_\pi Tr[\bar{H}_a^\dagger \sigma^i \bar{H}_b] A_{ab}^i - g_\pi Tr[\bar{H}_a^\dagger \sigma^i \bar{H}_b] A_{ab}^i \\
& + \frac{1}{2} g_{\pi\Upsilon,n} Tr[\Upsilon_n^\dagger H_a \bar{H}_b] A_{ab}^0 + \frac{1}{2} g_{\Upsilon,n} Tr[\Upsilon_n^\dagger H_a \sigma^j \overleftrightarrow{\partial}_j i \bar{H}_a] + H.c. \\
& + \frac{1}{2} g_{\pi\chi,n} Tr[\chi_{n,i}^\dagger H_a \sigma^j \bar{H}_b] \epsilon_{ijk} A_{ab}^k + \frac{i}{2} g_{\chi,n} Tr[\chi_{n,i}^\dagger H_a \sigma^i \bar{H}_a] + H.c. \\
& + \frac{1}{4} g'_{\pi\Upsilon,n} Tr[(\Upsilon \sigma^i + \sigma^i \Upsilon) \bar{H}_a^\dagger \sigma^i H_a^\dagger] A^0 + H.c..
\end{aligned}
$$

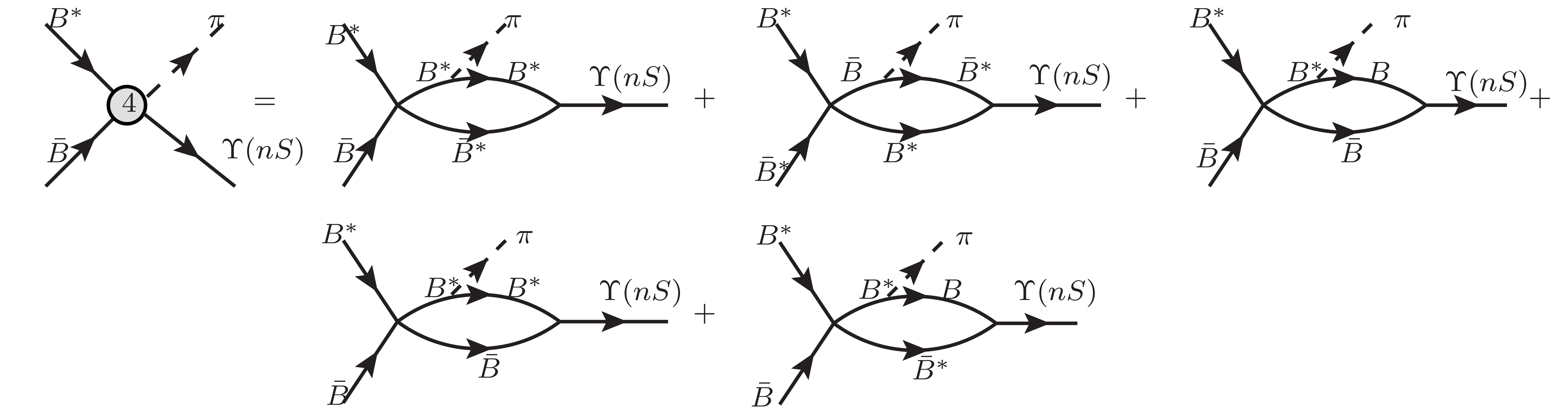
$$
H_a = P_a + V_a^i \sigma^i, \;\; \bar{H}_a = \bar{P}_a - \bar{V}_a^i \sigma^i
$$

$$
\Upsilon_n = \sigma^i \Upsilon^i + \eta_b, \;\; \chi_n^i = \sigma_l (\chi_{b2}^{il} + \frac{1}{\sqrt{2}} \epsilon^{ilm} \chi_{b1}^m + \frac{1}{\sqrt{3}} \delta^{il} \chi_{b0}) + h_b^i.
$$

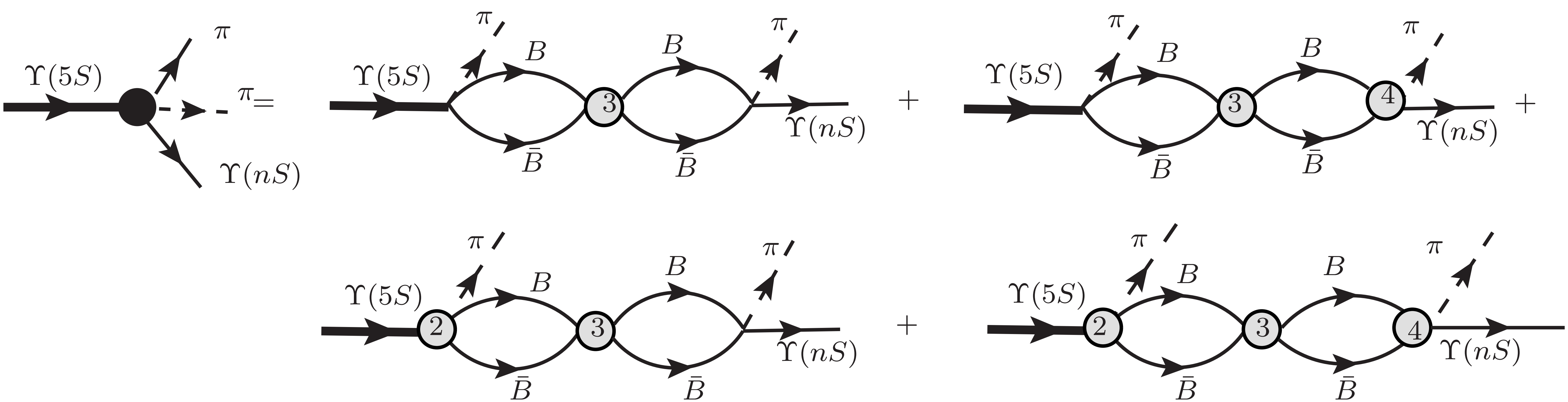
$$
Z^{Ai} = \frac{1}{\sqrt{2}} (V_a^i \tau_{ab}^A \bar{P}_b - P_a \tau_{ab}^A \bar{V}_b^i), \;\; Z'^{Ai} = \frac{i}{\sqrt{2}} \epsilon^{ijk} V_a^j \tau_{ab}^A \bar{V}_b^k.
$$


$\Upsilon(5S)$
π
B^*
$\bar{B}$
1
=
+
$\Upsilon(5S)$ π B^* $\bar{B}$
$\Upsilon(5S)$ B^* π B^* $\bar{B}$
$\Upsilon(5S)$ $\bar{B}$ π B B^*
$\Upsilon(5S)$ $\bar{B}$ π B^* B^*

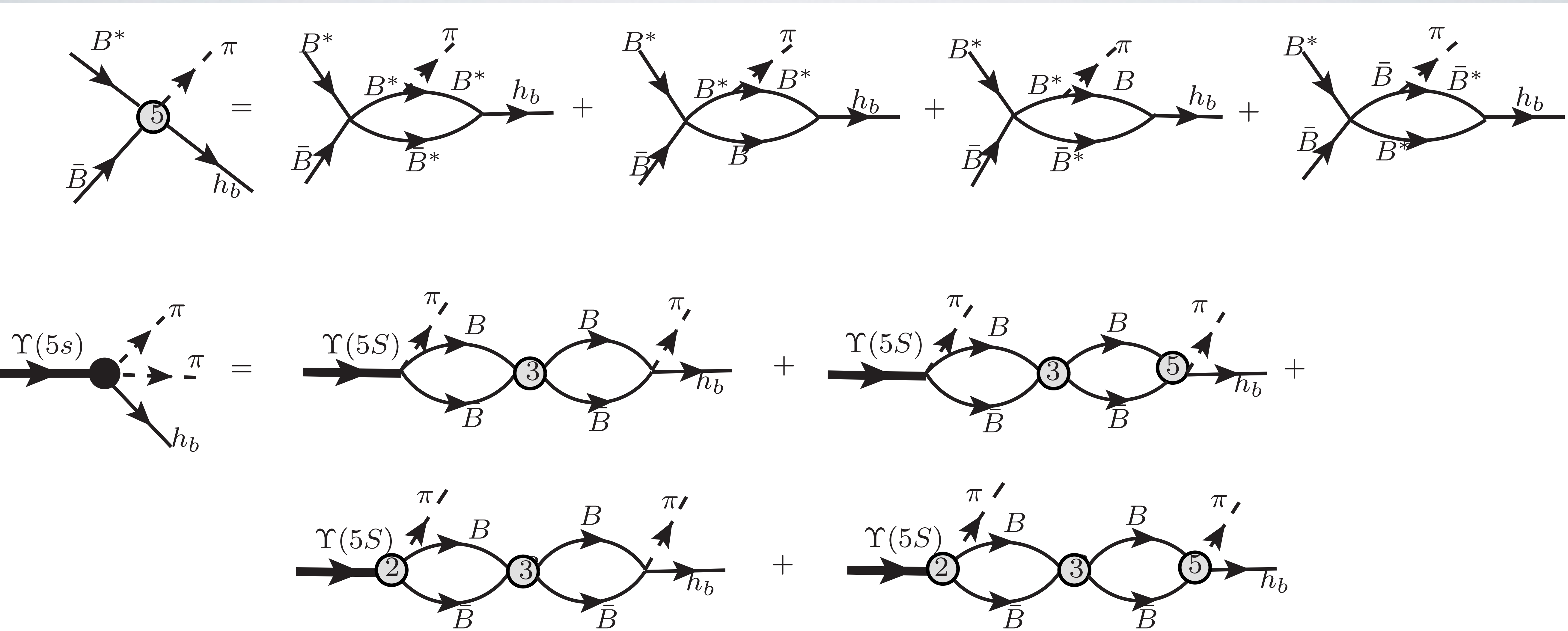

$\Upsilon(5S)$ 2 π B^* $\bar{B}$
=
+
$\Upsilon(5S)$ π B^* B^* B^* B^* $\bar{B}$
$\Upsilon(5S)$ π B B^* B^* B $\bar{B}$
$\Upsilon(5S)$ π $\bar{B}^*$ $\bar{B}$ B^* B^* $\bar{B}$
$\Upsilon(5S)$ π B B^* B^* B^* $\bar{B}$
$\Upsilon(5S)$ π B^* B^* B^* B $\bar{B}$
3
B B $\bar{B}$ $\bar{B}$
B B $\bar{B}$ $\bar{B}$
B B B $\bar{B}$ $\bar{B}$ $\bar{B}$
B B B B $\bar{B}$ $\bar{B}$ $\bar{B}$ $\bar{B}$
$\Upsilon(5S)$ π B^* $\bar{B}$
$\Upsilon(5S)$ 1 π B^* $\bar{B}$
$\Upsilon(5S)$ π B $\bar{B}$ 3 B^* $\bar{B}$
$\Upsilon(5S)$ 2 π B $\bar{B}$ 3 B^* $\bar{B}$



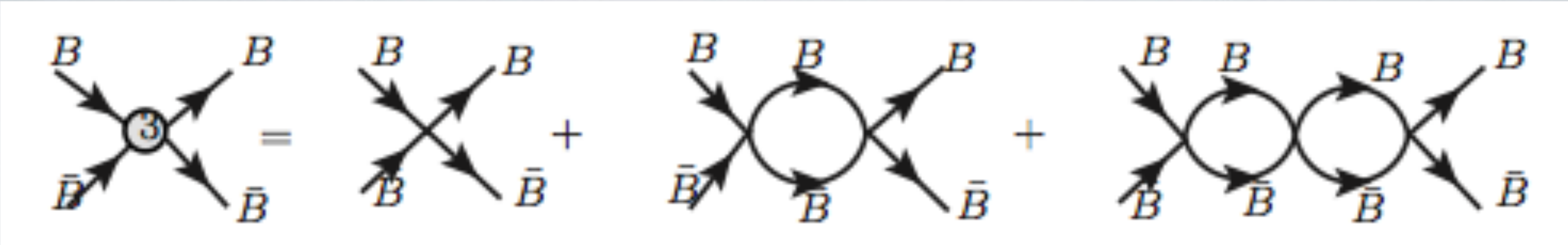
B^*
π
4
$\bar{B}$
$\Upsilon(nS)$
=
$\bar{B}^*$
+
B



$\Upsilon(5S)$
π
=
$\Upsilon(nS)$
B
$\bar{B}$
2
3
4
+



B^*
π
5
$\bar{B}$
h_b
=
B^*
π
B^*
B^*
h_b
$\bar{B}$
$\bar{B}^*$
+
B^*
π
B^*
B^*
h_b
$\bar{B}$
$\bar{B}$
+
B^*
π
B^*
B
h_b
$\bar{B}$
$\bar{B}^*$
+
B^*
π
$\bar{B}$
$\bar{B}^*$
h_b
$\bar{B}$
B^*
$\Upsilon(5s)$
π
π
h_b
=
$\Upsilon(5S)$
π
B
3
B
π
h_b
$\bar{B}$
$\bar{B}$
+
$\Upsilon(5S)$
π
B
3
B
5
π
h_b
$\bar{B}$
$\bar{B}$
+
$\Upsilon(5S)$
2
π
B
3
B
π
h_b
$\bar{B}$
$\bar{B}$
+
$\Upsilon(5S)$
2
π
B
3
B
5
π
h_b
$\bar{B}$
$\bar{B}$



$$T_Z = -C_Z + C_Z\Sigma_Z C_Z - C_Z\Sigma_Z C_Z \Sigma_Z C_Z + \cdots$$
$$= -(1 + T_Z \Sigma_Z) C_Z.$$

$$T_Z^{-1} = -C_Z^{-1} - \Sigma_Z(E),$$

$$C_Z = \begin{pmatrix} C_+ & C_- \\ C_- & C_+ \end{pmatrix} = \begin{pmatrix} C_{11} + C_{10} & C_{11} - C_{10} \\ C_{11} - C_{10} & C_{11} + C_{10} \end{pmatrix}$$

$$C_{10} = \frac{2\pi}{M}\frac{1}{-\Lambda + \gamma_{10}},$$
$$C_{11} = \frac{2\pi}{M}\frac{1}{-\Lambda + \gamma_{11}}.$$

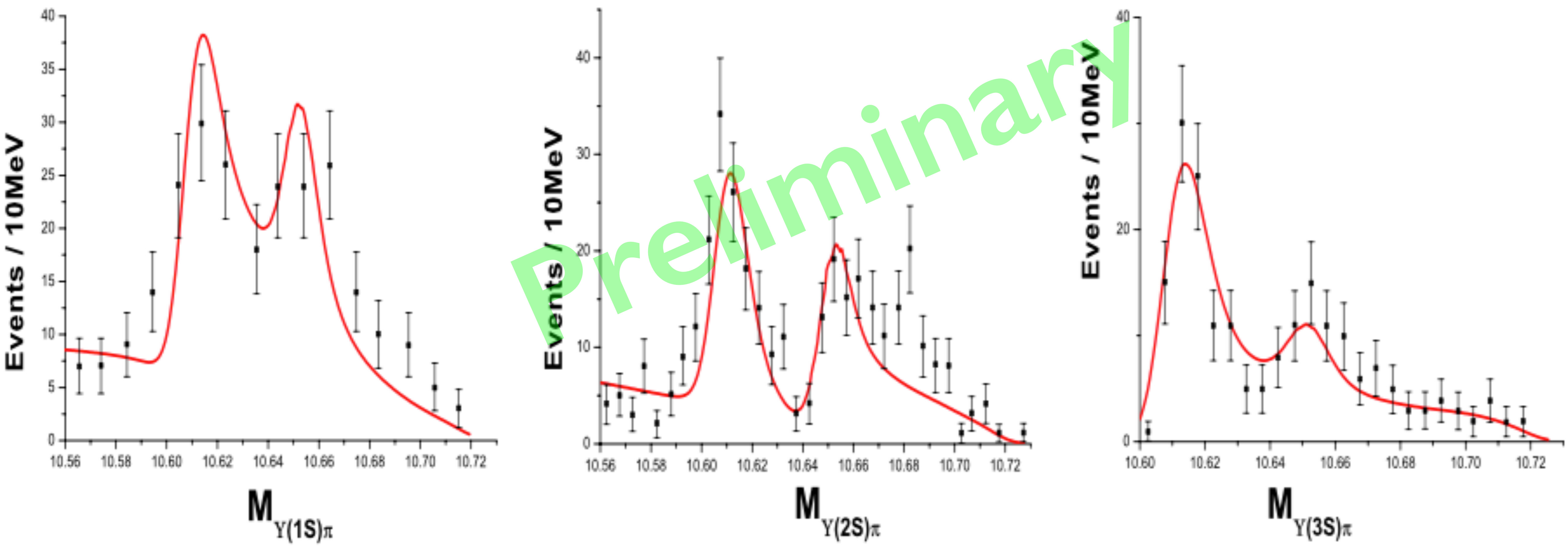
$$\Sigma_Z(E) = \begin{pmatrix} \Sigma_{B^*B^*}(E) & 0 \\ 0 & \Sigma_{B^*B}(E) \end{pmatrix}$$
$$= \frac{M}{4\pi}\begin{pmatrix} \Lambda - \sqrt{M(2\Delta - E) - i\epsilon} & 0 \\ 0 & \Lambda - \sqrt{M(\Delta - E) - i\epsilon} \end{pmatrix}$$

$$T_Z = \frac{4\pi}{M} \begin{pmatrix} \frac{\Delta_1 - \gamma_+}{(\gamma_+ - \Delta_1)(\gamma_+ - \Delta_2) - \gamma_-^2} & \frac{\gamma_-}{(\gamma_+ - \Delta_1)(\gamma_+ - \Delta_2) - \gamma_-^2} \\ \frac{\gamma_-}{(\gamma_+ - \Delta_1)(\gamma_+ - \Delta_2) - \gamma_-^2} & \frac{\Delta_2 - \gamma_+}{(\gamma_+ - \Delta_1)(\gamma_+ - \Delta_2) - \gamma_-^2} \end{pmatrix}$$

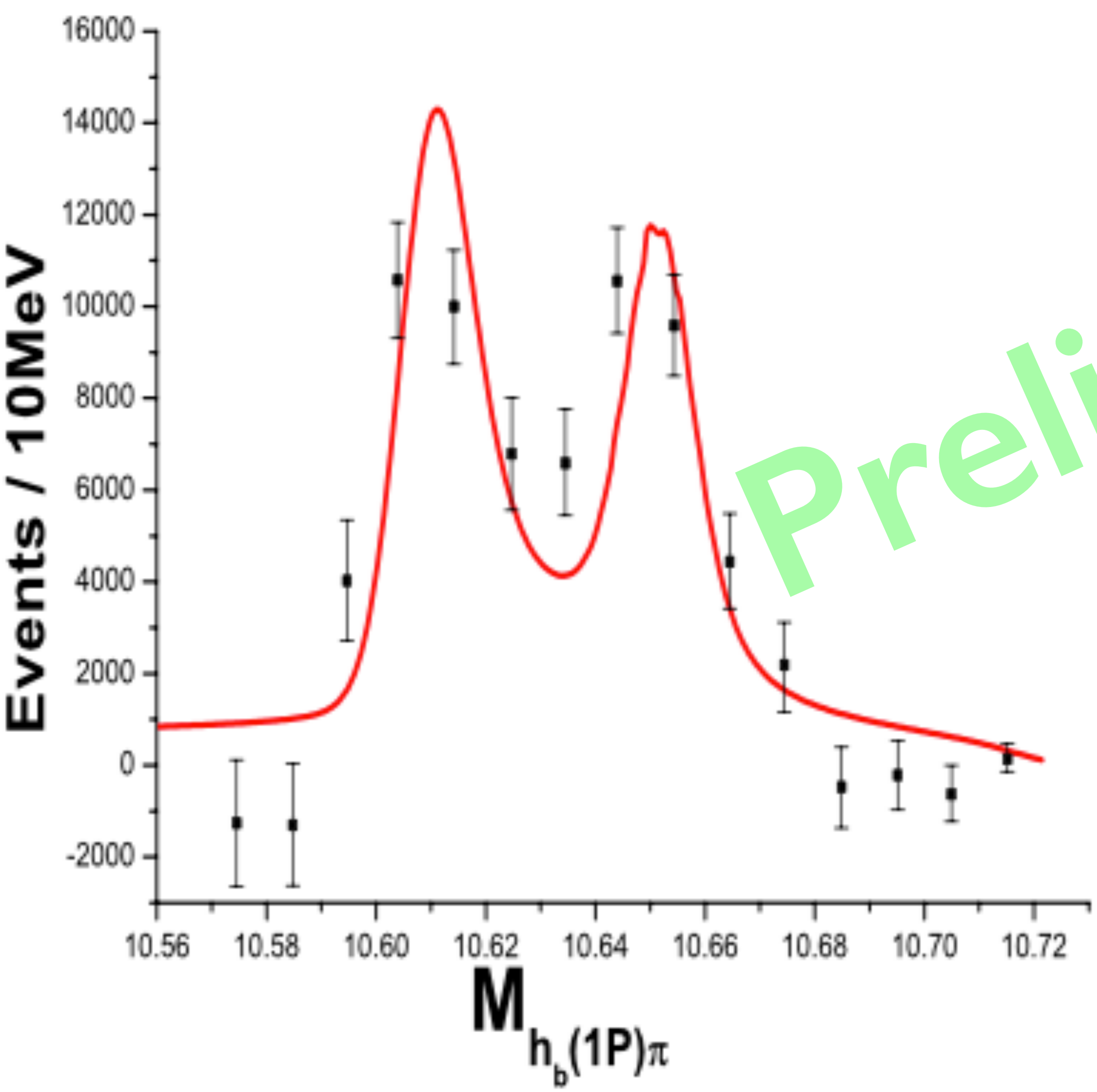
$$\Delta_1 = \sqrt{M(\Delta - E) - i\epsilon} \quad \Delta_2 = \sqrt{M(2\Delta - E) - i\epsilon}$$

$$\gamma_\pm = (\gamma_{11} \pm \gamma_{10})/2$$

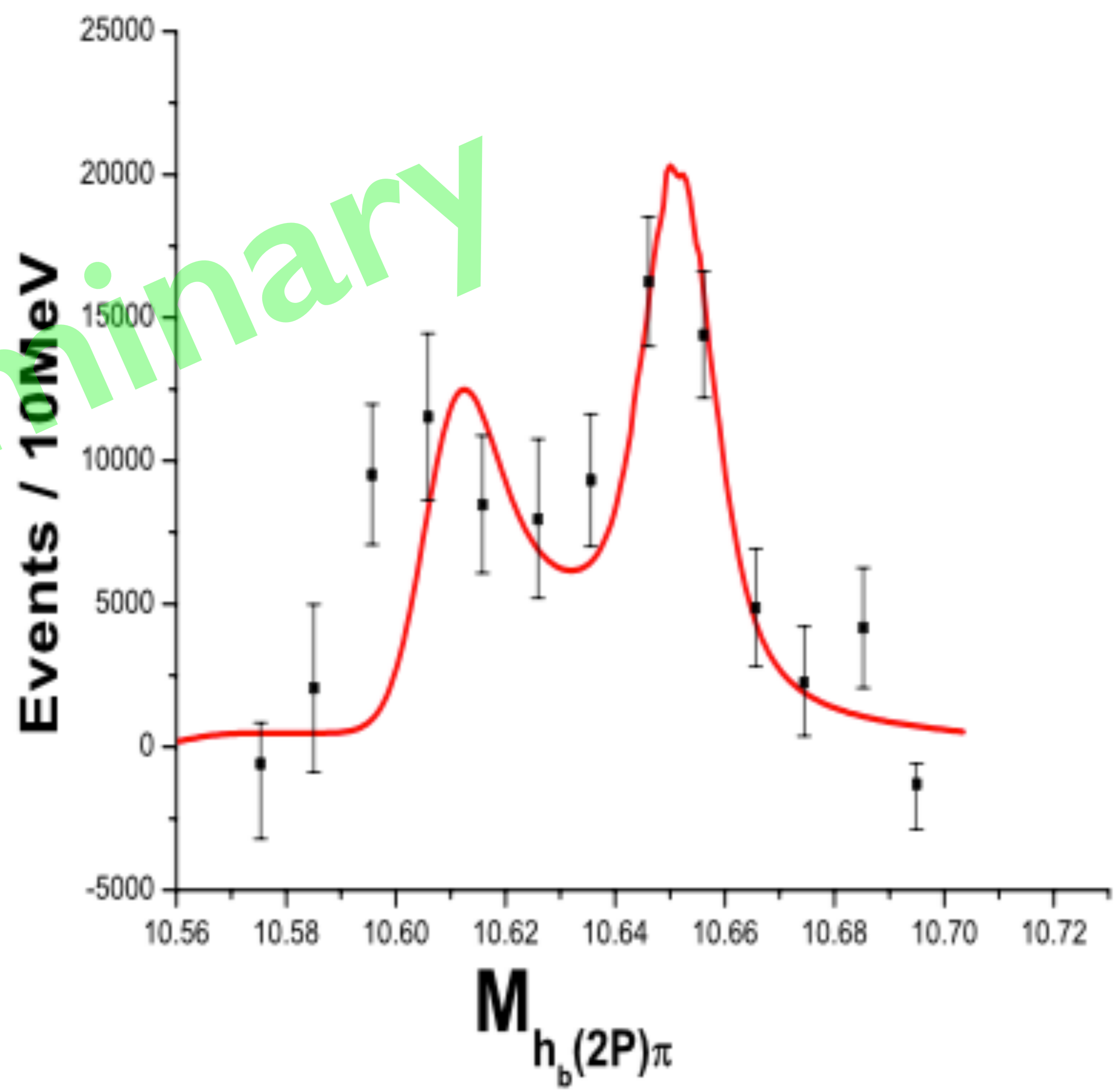
$$\Delta = m_{B^*} - m_B$$


Events / 10MeV
$M_{\Upsilon(1S)\pi}$
Events / 10MeV
$M_{\Upsilon(2S)\pi}$
Events / 10MeV
$M_{\Upsilon(3S)\pi}$
Preliminary

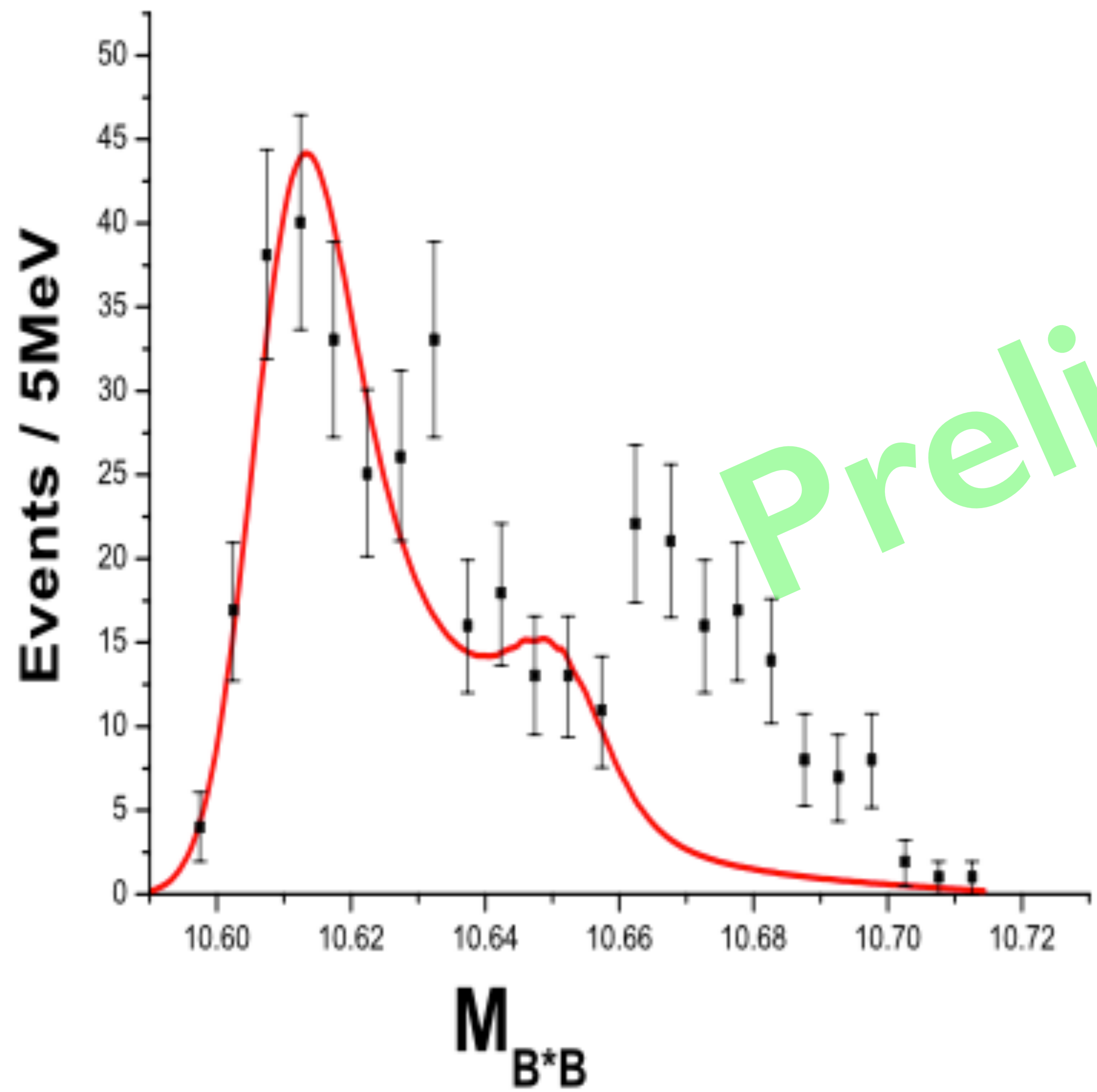
(a) (b) (c)


Events / 10MeV
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
10.56
10.58
10.60
10.62
10.64
10.66
10.68
10.70
10.72
M h_b(1P)π

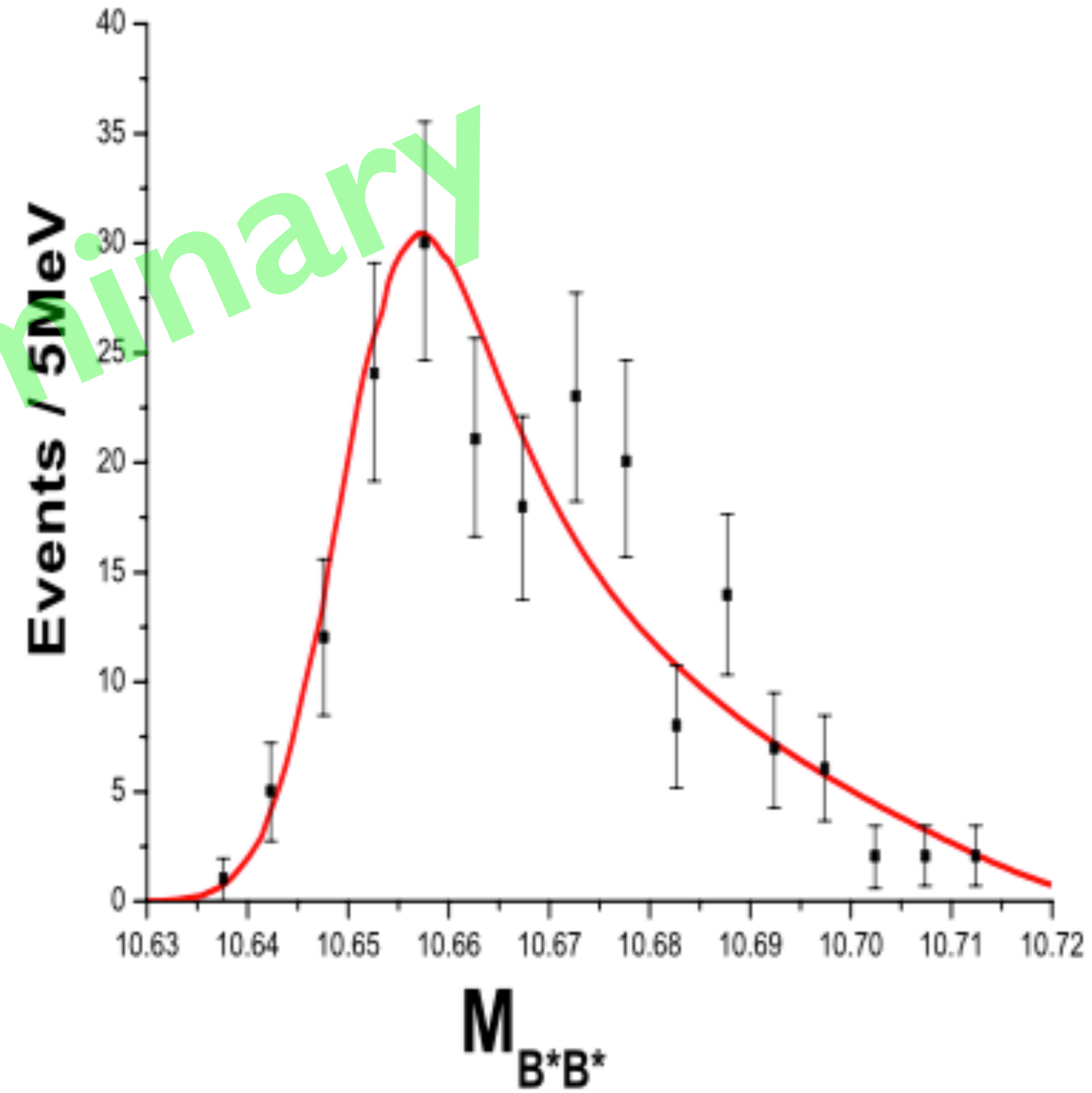
(d)


Events / 10MeV
25000
20000
15000
10000
5000
0
-5000
10.56
10.58
10.60
10.62
10.64
10.66
10.68
10.70
10.72
M h_b(2P)π
Preliminary

(e)


Events / 5MeV
50
45
40
35
30
25
20
15
10
5
0
10.60
10.62
10.64
10.66
10.68
10.70
10.72
M_{B^*B}
Preliminary

(f)


Events / 5MeV
40
35
30
25
20
15
10
5
0
10.63
10.64
10.65
10.66
10.67
10.68
10.69
10.70
10.71
10.72
$M_{B^*B^*}$

(g)

$\mathrm{Re}[\gamma_+] = -143 \pm 3$ MeV	$\mathrm{Im}[\gamma_+] = -138 \pm 2$ MeV
$\mathrm{Re}[\gamma_-] = -222 \pm 3$ MeV	$\mathrm{Im}[\gamma_-] = 10.2 \pm 1.8$ MeV
$g_{\pi\Upsilon,1} = 0.017 \pm 0.005\ \mathrm{GeV}^{-\frac{3}{2}}$	$g_{\pi\Upsilon,2} = 0.235 \pm 0.023\ \mathrm{GeV}^{-\frac{3}{2}}$
$g_{\pi\Upsilon,3} = 0.510 \pm 0.063\ \mathrm{GeV}^{-\frac{3}{2}}$	$g_{\pi\Upsilon,5} = 3.408 \pm 0.216\ \mathrm{GeV}^{-\frac{3}{2}}$
$g_{\Upsilon,1} = 0.022 \pm 0.004\ \mathrm{GeV}^{-\frac{3}{2}}$	$g_{\Upsilon,2} = -0.150 \pm 0.071\ \mathrm{GeV}^{-\frac{3}{2}}$
$g_{\Upsilon,3} = 0.654 \pm 0.321\ \mathrm{GeV}^{-\frac{3}{2}}$	$g_{\Upsilon,5} = -0.112\ \mathrm{GeV}^{-\frac{3}{2}}$ (fixed)
$g_{\sigma,1} = 0.367 \pm 0.028$	$g_{f_0,1} = 1.526 \pm 0.610$
$g_{\sigma,2} = 0.957 \pm 0.141$	$g_{\sigma,3} = 0.514 \pm 0.021$
$g_{\pi\chi,1} = -0.784 \pm 0.039\ \mathrm{GeV}^{-\frac{3}{2}}$	$g_{\chi,1} = -0.258 \pm 0.031\ \mathrm{GeV}^{-\frac{1}{2}}$
$g_{\pi\chi,2} = -1.172 \pm 0.280\ \mathrm{GeV}^{-\frac{3}{2}}$	$g_{\chi,2} = -0.445 \pm 0.133\ \mathrm{GeV}^{-\frac{1}{2}}$

Channel	our model	PDG [24]
$\mathrm{BR}(\Upsilon(1S)\pi\pi)$	$(3.4 \pm 2.1) \times 10^{-3}$	$(5.3 \pm 0.6) \times 10^{-3}$
$\mathrm{BR}(\Upsilon(2S)\pi\pi)$	$(1.3 \pm 0.5) \times 10^{-2}$	$(7.8 \pm 1.3) \times 10^{-3}$
$\mathrm{BR}(\Upsilon(3S)\pi\pi)$	$(2.5 \pm 2.2) \times 10^{-3}$	$(4.8^{+1.9}_{-1.7}) \times 10^{-3}$
$\mathrm{BR}(h_b(1P)\pi\pi)$	$(6.5 \pm 2.4) \times 10^{-3}$	$(3.5^{+1.0}_{-1.3}) \times 10^{-3}$
$\mathrm{BR}(h_b(2P)\pi\pi)$	$(7.6 \pm 6.6) \times 10^{-3}$	$(6.0^{+2.1}_{-1.8}) \times 10^{-3}$
$\mathrm{BR}(B\bar{B}^*\pi + \bar{B}B^*\pi)$	$(11.6 \pm 2.1)\%$	$(7.3 \pm 2.3)\%$
$\mathrm{BR}(B^*\bar{B}^*\pi)$	$(2.4 \pm 0.4)\%$	$(1.0 \pm 1.4)\%$

Preliminary

$$\Gamma_{Z_b\to\Upsilon(1S)\pi} : \Gamma_{Z_b\to\Upsilon(2S)\pi} : \Gamma_{Z_b\to\Upsilon(3S)\pi} = 0.10 : 2.76 : 1 \ ,$$

$$\Gamma_{Z_b'\to\Upsilon(1S)\pi} : \Gamma_{Z_b'\to\Upsilon(2S)\pi} : \Gamma_{Z_b'\to\Upsilon(3S)\pi} = 0.07 : 1.95 : 1 \ ,$$

$$\Gamma_{Z_b\to h_b(1P)\pi} : \Gamma_{Z_b\to h_b(2P)\pi} = 4.2 \ ,$$

$$\Gamma_{Z_b'\to h_b(1P)\pi} : \Gamma_{Z_b'\to h_b(2P)\pi} = 3.4 \ .$$

$$T_Z = \frac{4\pi}{M} \begin{pmatrix} \frac{\Delta_1 - \gamma_+}{(\gamma_+ - \Delta_1)(\gamma_+ - \Delta_2) - \gamma_-^2} & \frac{\gamma_-}{(\gamma_+ - \Delta_1)(\gamma_+ - \Delta_2) - \gamma_-^2} \\ \frac{\gamma_-}{(\gamma_+ - \Delta_1)(\gamma_+ - \Delta_2) - \gamma_-^2} & \frac{\Delta_2 - \gamma_+}{(\gamma_+ - \Delta_1)(\gamma_+ - \Delta_2) - \gamma_-^2} \end{pmatrix}$$

$$\Delta_1 = \sqrt{M(\Delta - E) - i\epsilon} \qquad \Delta_2 = \sqrt{M(2\Delta - E) - i\epsilon}$$

$$\gamma_\pm = (\gamma_{11} \pm \gamma_{10})/2$$

$$\Delta = m_{B^*} - m_B$$

	sheet I	sheet II	sheet III	sheet IV
Δ_1	+	-	-	+
Δ_2	+	+	-	-

Preliminary

	$Z_b(B\bar{B}^*)$	$Z_b'(B^*\bar{B}^*)$
Sheet I	10595.3-14.7i	10649.2-0.65i
Sheet II	–	10655.5-10.2i
Sheet III	–	–
Sheet IV	10608.7-4.4i	–

Conclusion:

X(3872) is more like an elementary particle, which cannot be a pure molecule state.

Zb(10610) and Zb(10650)' are bound states of BB* and B*B*


Thank You