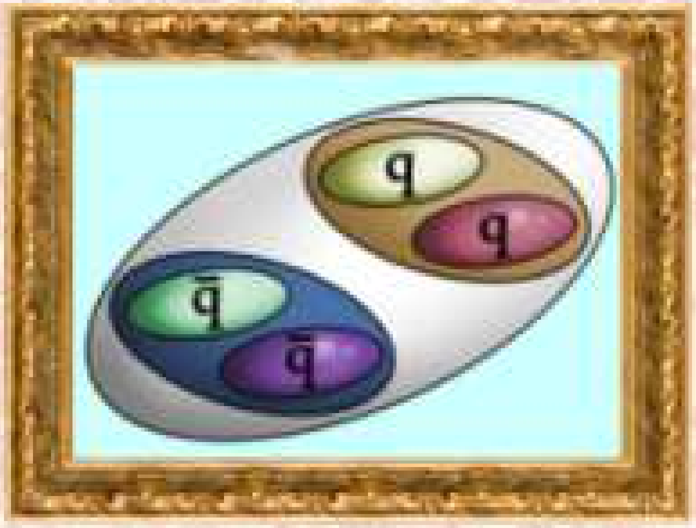
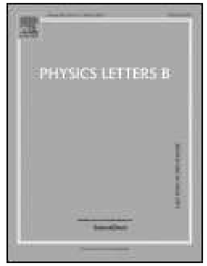


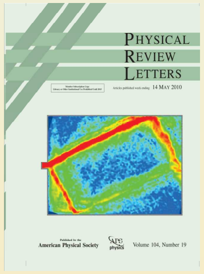
Tetraquark interpretation of $e^+e^- \rightarrow \Upsilon\pi^+\pi^-$ Belle data and $e^+e^- \rightarrow b\bar{b}$ BaBar data

Ahmed Ali (DESY)

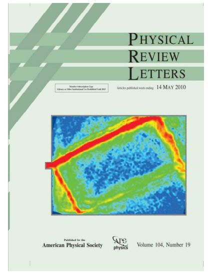
underlying work

A. Ali, C. Hambrock, I. Ahmed and M. J. Aslam,
"A case for hidden $b\bar{b}$ tetraquarks based on $e^+e^- \to b\bar{b}$ cross section between $\sqrt{s} = 10.54$ and 11.20 GeV,"
Phys. Lett. B **684** (2010) 28





A. Ali, C. Hambrock and M. J. Aslam,
"Tetraquark interpretation of the BELLE data on the anomalous $\Upsilon(1S)\pi^+\pi^-$ and $\Upsilon(2S)\pi^+\pi^-$ production near the $\Upsilon(5S)$ resonance," Phys. Rev. Lett. **104**, 162001 (2010)



A. Ali, C. Hambrock and S. Mishima
"Tetraquark-based analysis and testes in e^+e^- annihilation near the $\Upsilon(5S)$" DESY Report 10-076 (work in progress)

Overview

- Production and decays of $J^{PC} = 1^{--}$ $b\bar{b}$ tetraquarks
- tetraquarks in BaBar data!
- tetraquarks in Belle data!
- conclusion and outlook

states observed by Belle

Summary of new states observed by Belle. [arXiv:0910.3404 [hep-ex]]

State	M (MeV)	Γ (MeV)	J^{PC}	Decay Modes	Production Modes	Also observed by
$Y_s(2175)$	2175 ± 8	58 ± 26	1^{--}	$\phi f_0(980)$	e^+e^- (ISR) $J/\psi \to \eta Y_s(2175)$	BaBar, BESII
$X(3872)$	3871.4 ± 0.6	< 2.3	1^{++}	$\pi^+\pi^- J/\psi$, $\gamma J/\psi$,$D\bar{D}^*$	$B \to KX(3872)$, $p\bar{p}$	BaBar CDF, D0,
$X(3915)$	3914 ± 4	28^{+12}_{-14}	$0/2^{++}$	$\omega J/\psi$	$\gamma\gamma \to X(3915)$	
$Z(3930)$	3929 ± 5	29 ± 10	2^{++}	$D\bar{D}$	$\gamma\gamma \to Z(3940)$	
$X(3940)$	3942 ± 9	37 ± 17	$0^{?+}$	$D\bar{D}^*$ (not $D\bar{D}$ or $\omega J/\psi$)	$e^+e^- \to J/\psi X(3940)$	
$Y(3940)$	3943 ± 17	87 ± 34	$?^{?+}$	$\omega J/\psi$ (not $D\bar{D}^*$)	$B \to KY(3940)$	BaBar
$Y(4008)$	4008^{+82}_{-49}	226^{+97}_{-80}	1^{--}	$\pi^+\pi^- J/\psi$	e^+e^-(ISR)	
$X(4160)$	4156 ± 29	139^{+113}_{-65}	$0^{?+}$	$D^*\bar{D}^*$ (not $D\bar{D}$)	$e^+e^- \to J/\psi X(4160)$	
$Y(4260)$	4264 ± 12	83 ± 22	1^{--}	$\pi^+\pi^- J/\psi$	e^+e^-(ISR)	BaBar, CLEO
$Y(4350)$	4361 ± 13	74 ± 18	1^{--}	$\pi^+\pi^- \psi'$	e^+e^-(ISR)	BaBar
$X(4630)$	4634^{+9}_{-11}	92^{+41}_{-32}	1^{--}	$\Lambda_c^+\Lambda_c^-$	e^+e^-(ISR)	
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$Z(4050)$	4051^{+24}_{-23}	82^{+51}_{-29}	?	$\pi^\pm \chi_{c1}$	$B \to KZ^\pm(4050)$	
$Z(4250)$	4248^{+185}_{-45}	177^{+320}_{-72}	?	$\pi^\pm \chi_{c1}$	$B \to KZ^\pm(4250)$	
$Z(4430)$	4433 ± 5	45^{+35}_{-18}	?	$\pi^\pm \psi'$	$B \to KZ^\pm(4430)$	
$Y_b(10890)$	$10,890 \pm 3$	55 ± 9	1^{--}	$\pi^+\pi^- \Upsilon(1,2,3S)$	$e^+e^- \to Y_b$	

recent theoretical review: [Drenska et al., arXiv:1006.2741 [hep-ph]]

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our (hidden bottom) tetraquark candidate

hamiltonian

The previously defined states need to diagonalize the hamiltonian:

$$H = 2m_{\mathcal{Q}} + H_{SS}^{(qq)} + H_{SS}^{(q\bar{q})} + H_{SL} + H_{LL}$$

hamiltonian

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constituent mass

with

hamiltonian

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$$H = 2m_{\mathcal{Q}} + H_{SS}^{(qq)} + H_{SS}^{(q\bar{q})} + H_{SL} + H_{LL}$$

qq **spin coupling**

with

$$H_{SS}^{(qq)} = 2(\mathcal{K}_{bq})_{\bar{3}}[(\mathbf{S}_b \cdot \mathbf{S}_q) + (\mathbf{S}_{\bar{b}} \cdot \mathbf{S}_{\bar{q}})]$$

hamiltonian

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$q\bar{q}$ **spin coupling**

with

$$H_{SS}^{(qq)} = 2(\mathcal{K}_{bq})_{\bar{3}}[(\mathbf{S}_b \cdot \mathbf{S}_q) + (\mathbf{S}_{\bar{b}} \cdot \mathbf{S}_{\bar{q}})]$$

$$H_{SS}^{(q\bar{q})} = 2(\mathcal{K}_{b\bar{q}})(\mathbf{S}_b \cdot \mathbf{S}_{\bar{q}} + \mathbf{S}_{\bar{b}} \cdot \mathbf{S}_q) + 2\mathcal{K}_{b\bar{b}}(\mathbf{S}_b \cdot \mathbf{S}_{\bar{b}}) + 2\mathcal{K}_{q\bar{q}}(\mathbf{S}_q \cdot \mathbf{S}_{\bar{q}})$$

hamiltonian

The previously defined states need to diagonalize the hamiltonian:

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L S **coupling**

with

$$\begin{aligned} H_{SS}^{(qq)} &= 2(\mathcal{K}_{bq})_{\bar{3}}[(\mathbf{S}_b \cdot \mathbf{S}_q) + (\mathbf{S}_{\bar{b}} \cdot \mathbf{S}_{\bar{q}})] \\ H_{SS}^{(q\bar{q})} &= 2(\mathcal{K}_{b\bar{q}})(\mathbf{S}_b \cdot \mathbf{S}_{\bar{q}} + \mathbf{S}_{\bar{b}} \cdot \mathbf{S}_q) \\ &\quad +2\mathcal{K}_{b\bar{b}}(\mathbf{S}_b \cdot \mathbf{S}_{\bar{b}}) + 2\mathcal{K}_{q\bar{q}}(\mathbf{S}_q \cdot \mathbf{S}_{\bar{q}}) \\ H_{SL} &= 2A_{\mathcal{Q}}(\mathbf{S}_{\mathcal{Q}} \cdot \mathbf{L} + \mathbf{S}_{\bar{\mathcal{Q}}} \cdot \mathbf{L}) \end{aligned}$$

hamiltonian

The previously defined states need to diagonalize the hamiltonian:

$$H = 2m_{\mathcal{Q}} + H_{SS}^{(qq)} + H_{SS}^{(q\bar{q})} + H_{SL} + H_{LL}$$

$L\,L$ **coupling**

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$$H_{SL} = 2A_{\mathcal{Q}}(\mathbf{S}_{\mathcal{Q}} \cdot \mathbf{L} + \mathbf{S}_{\bar{\mathcal{Q}}} \cdot \mathbf{L})$$

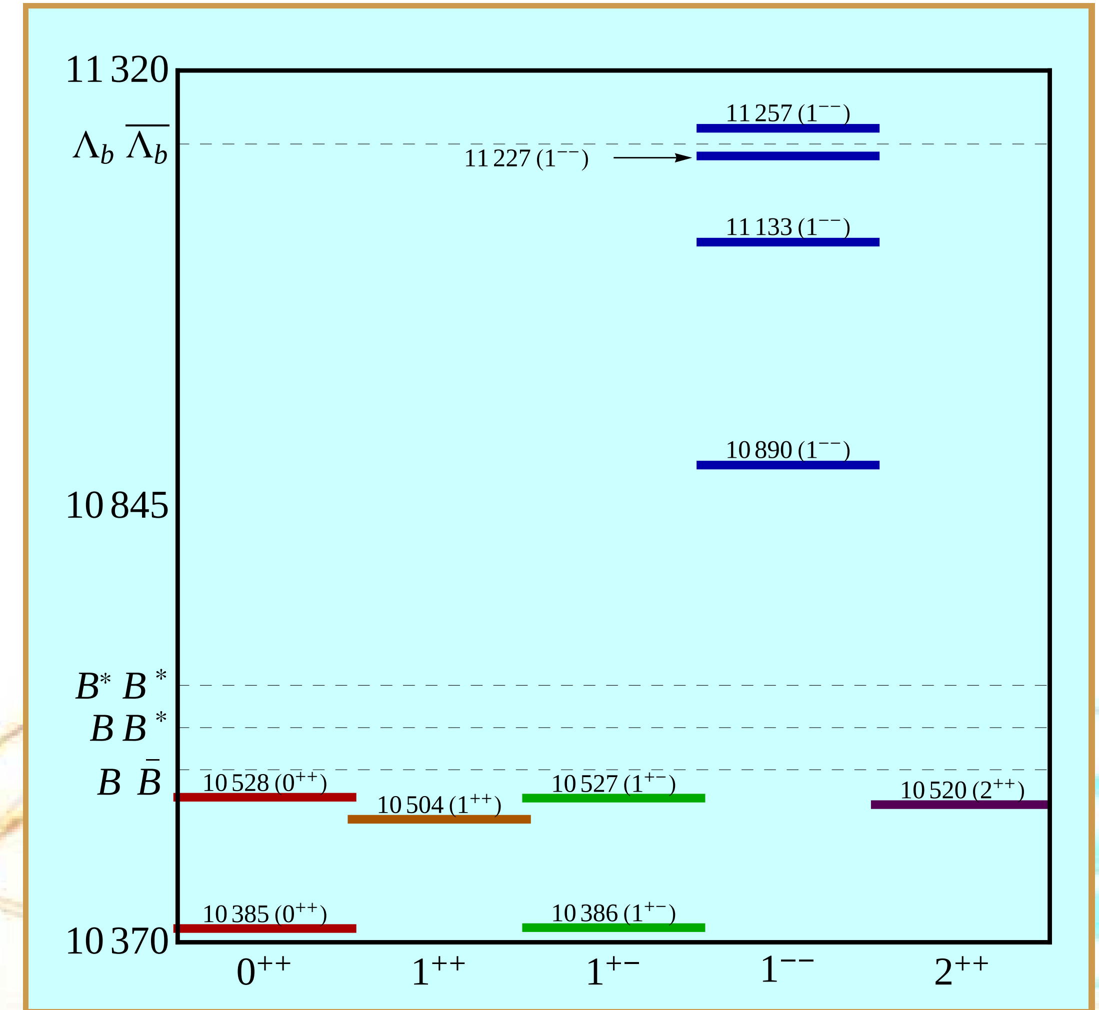
$$H_{LL} = B_{\mathcal{Q}}\frac{L_{\mathcal{Q}\bar{\mathcal{Q}}}(L_{\mathcal{Q}\bar{\mathcal{Q}}} + 1)}{2}$$

possible observable states

which states are accessible in todays experiments?

possible observable states

closer look at the light $[bq][\bar{b}\bar{q}]$ tetraquarks:



possible observable states

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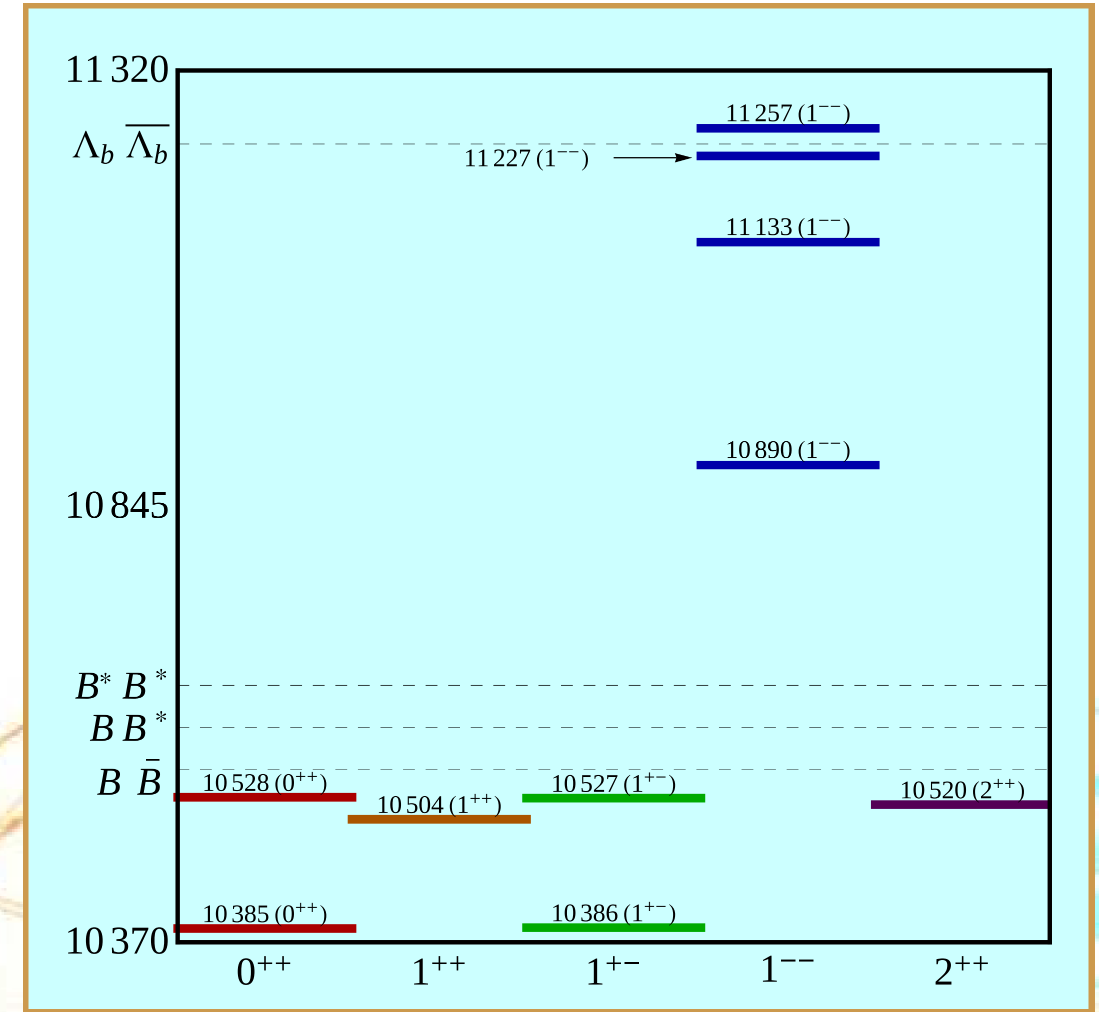
- The 1^{--} states, we call Y_b, have the right quantum numbers to be produced in e^+e^-annihilation.



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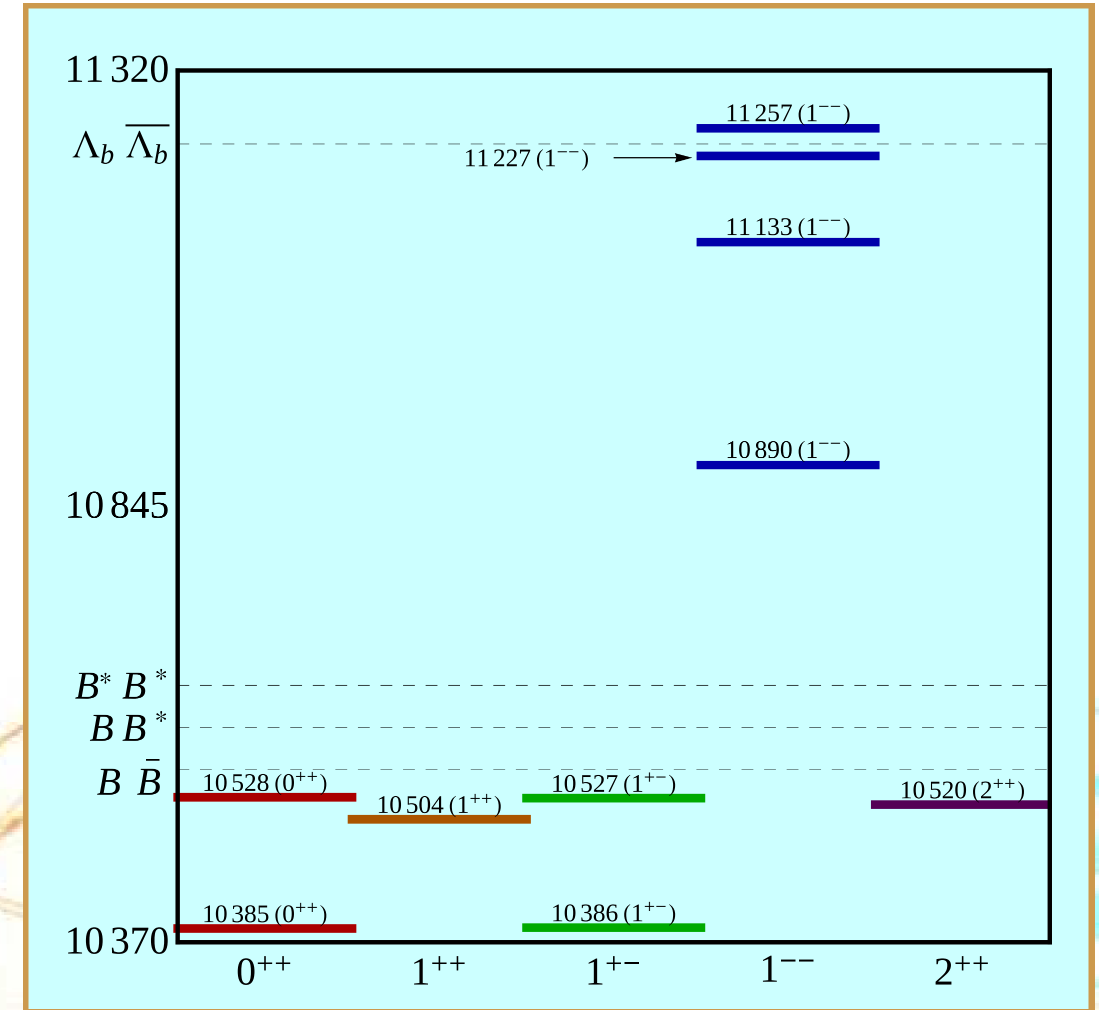
- Two of them are in the range of the BaBar and Belle center of mass energies.



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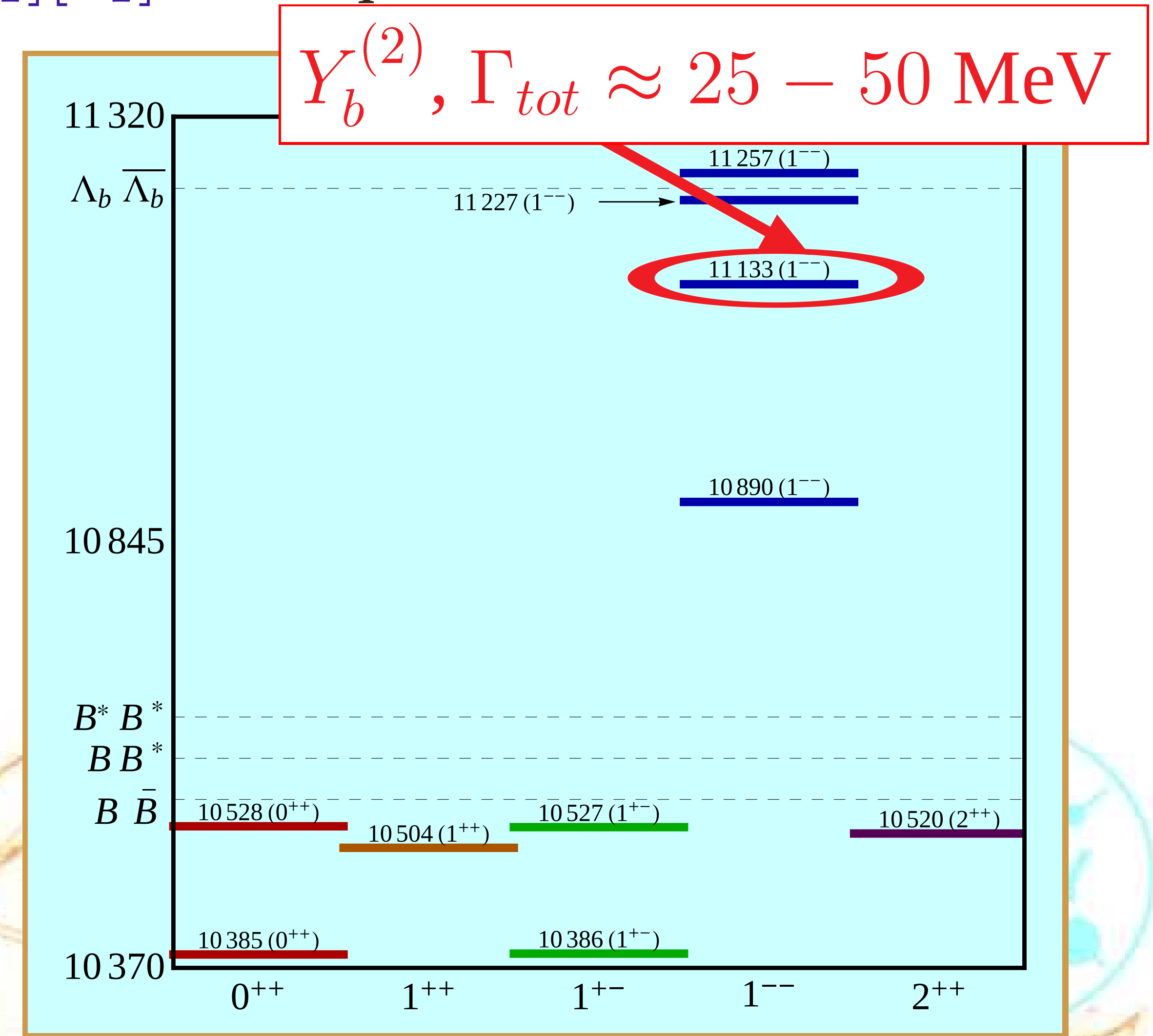

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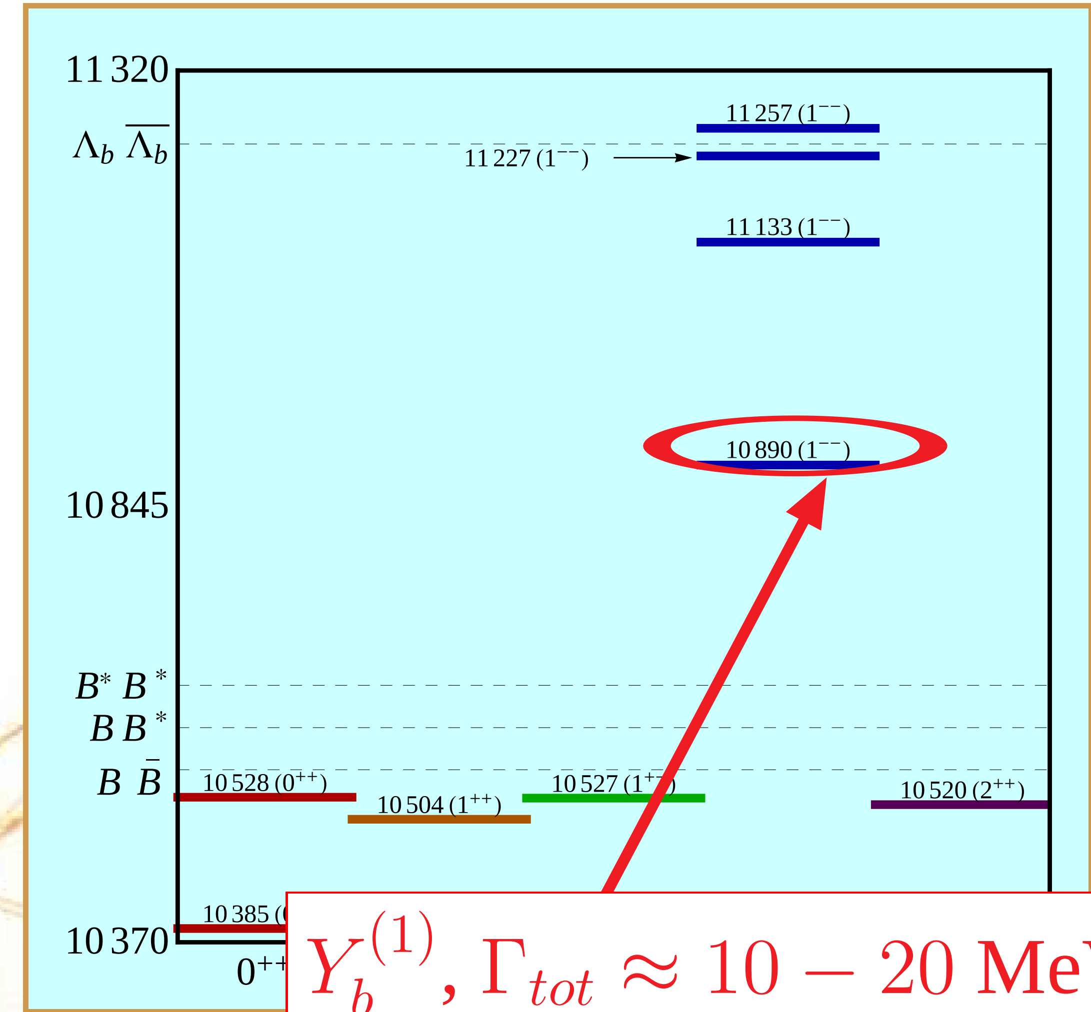

$Y_b^{(1)}, \Gamma_{tot} \approx 10 - 20$ MeV

isospin breaking

Y_b mass eigenstates

$$Y_{[b,l]} = \cos\theta\, Y_{[bu]} + \sin\theta\, Y_{[bd]},$$
$$Y_{[b,h]} = -\sin\theta\, Y_{[bu]} + \cos\theta\, Y_{bd]}.$$

with isospin mass breaking

$$M(Y_{[b,h]}) - M(Y_{[b,l]}) = (7 \pm 3)\ \cos(2\theta)\ \mathrm{MeV}.$$

and charge

$$Q_{Y_{[b,l]}} = \frac{1}{3}\cos\theta - \frac{2}{3}\sin\theta,$$
$$Q_{Y_{[b,h]}} = -\frac{1}{3}\sin\theta - \frac{2}{3}\cos\theta.$$

Υ_b production

- We have derived the Van Royen-Weisskopf formula for the electronic widths of the 1^{--} tetraquark, made up of point-like diquarks [A. Ali, C. Hambrock and S. Mishima] :

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$$\Gamma_{ee}(Y_{[b,l/h]}) = \frac{24\alpha^2 Q^2_{[b,l/h]}}{M^4_{Y_{[b,l/h]}}}\,\kappa^2 \left|R^{(1)}_{11}(0)\right|^2$$

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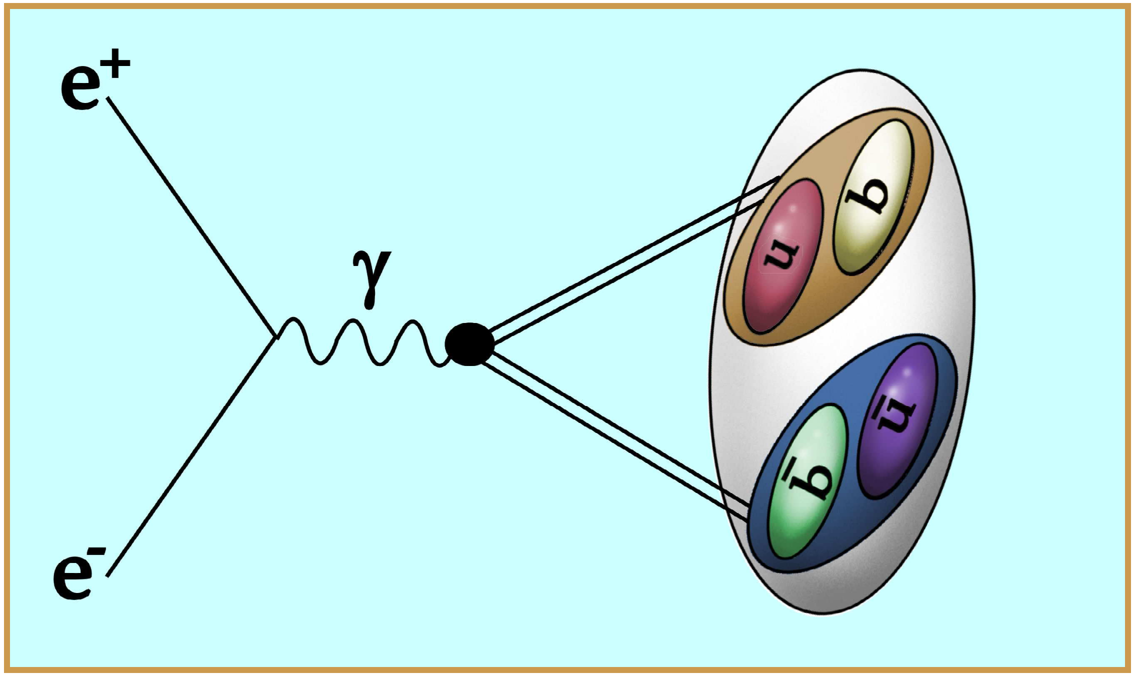

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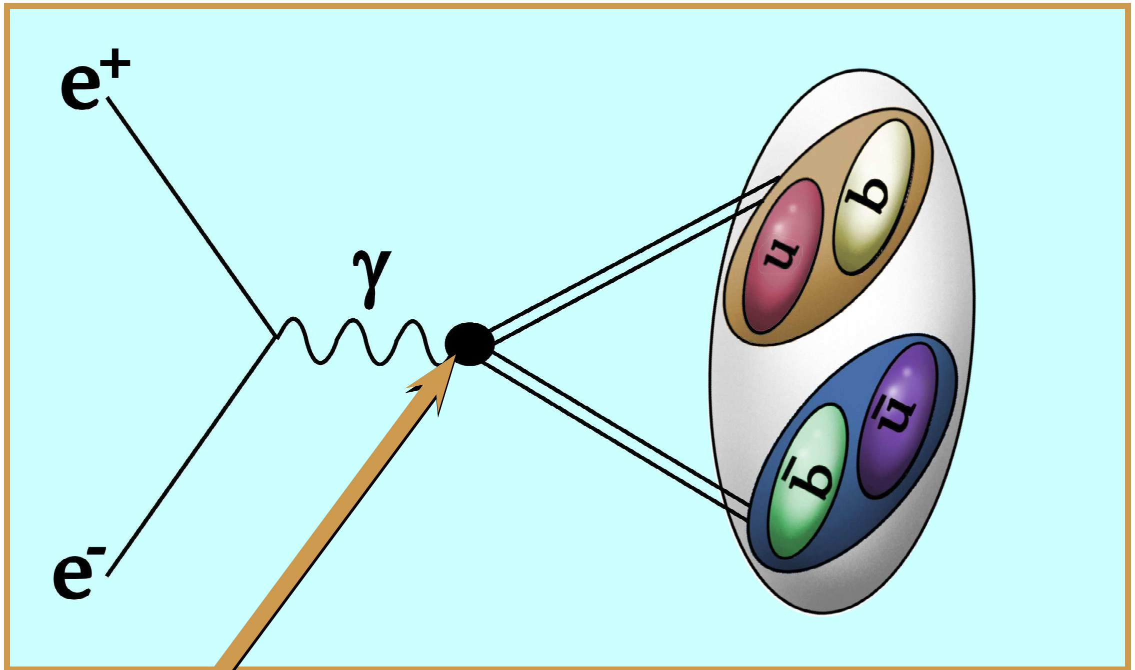

diquark charge

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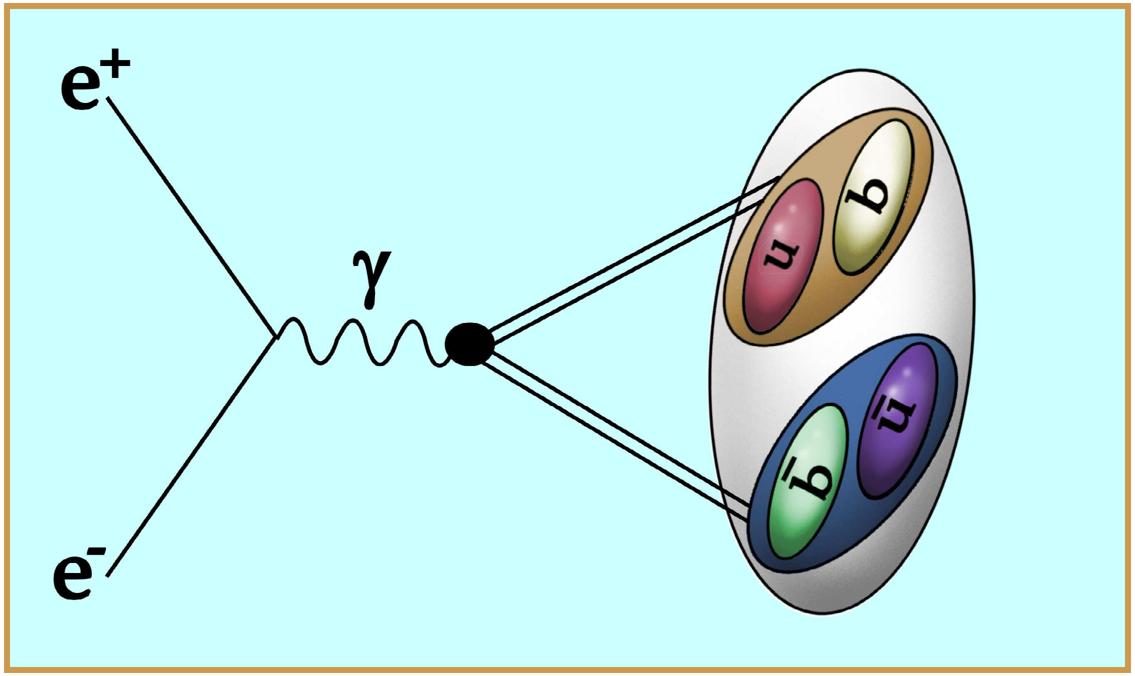

hadronic size parameter

$$\Gamma_{ee}(Y_{[b,l/h]}) = \frac{24\alpha^2 Q^2_{[b,l/h]}}{M^4_{Y_{[b,l/h]}}} \kappa^2 \left| R^{(1)}_{11}(0) \right|^2$$

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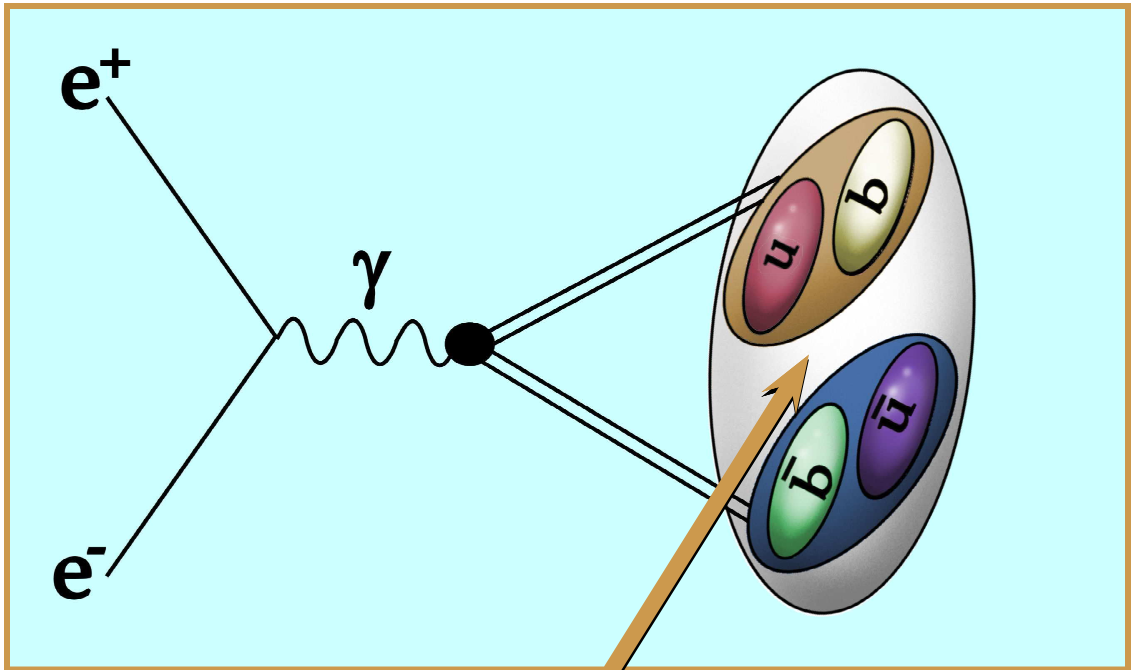

radial tetraquark wave function at origin

$$\Gamma_{ee}(Y_{[b,l/h]}) = \frac{24\alpha^2 Q^2_{[b,l/h]}}{M^4_{Y_{[b,l/h]}}} \kappa^2 \left| R^{(\;)}_{11}(0) \right|^2$$

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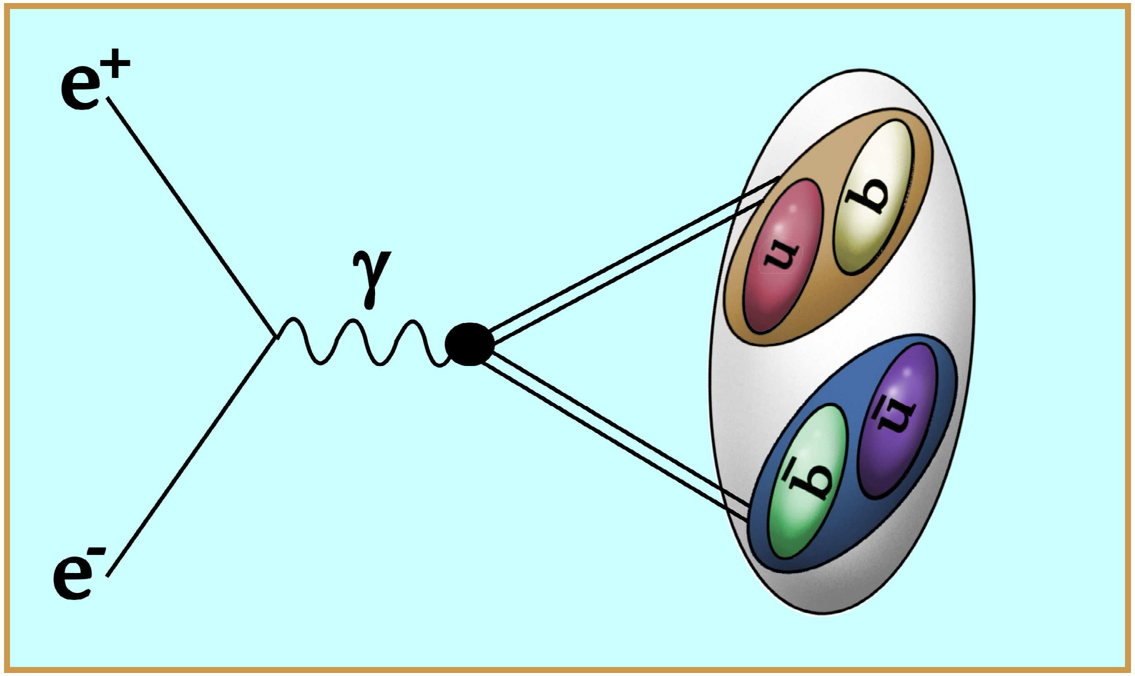

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- Production ratio: $R_{ee} = \frac{\Gamma_{Y_{[b,l]}}}{\Gamma_{Y_{[b,h]}}} = \left(\frac{1-2\tan\theta}{2+\tan\theta}\right)^2$ $(1/4 \leq R_{ee} \leq 4)$.

Y_b decay

Γ_{tot} is dominated by two-body decays ($B\bar{B}$, $B\bar{B}^*$, $B^*\bar{B}^*$):

Y_b decay

channel

$B\bar{B}$

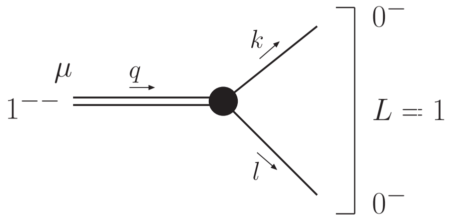
$B\bar{B}^*$

$B^*\bar{B}^*$

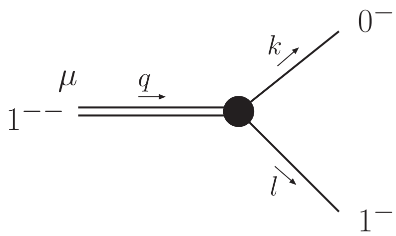
Y_b decay

channel | diagram

$B\bar{B}$



$B\bar{B}^*$



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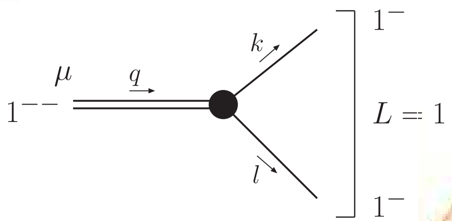
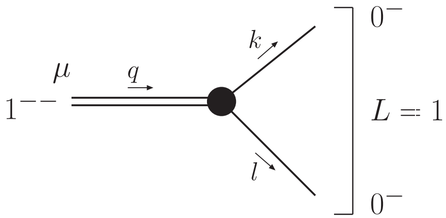


Y_b decay

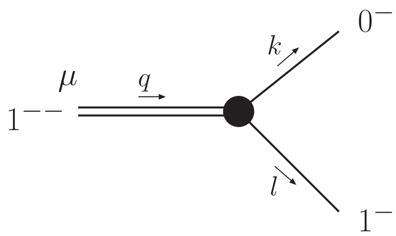
channel — diagram — vertex

$B\bar{B}$



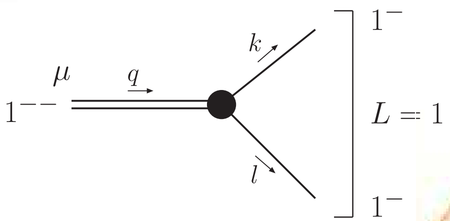
$\widehat{=} \, F(k^\mu - l^\mu)$

$B\bar{B}^*$



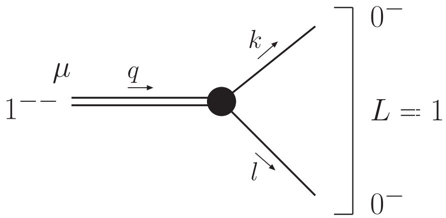
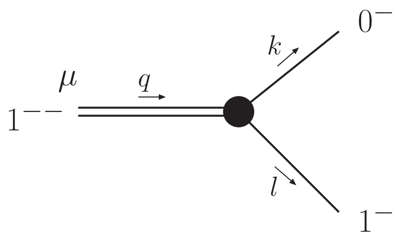
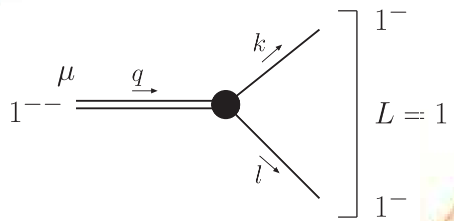
$\widehat{=} \, \frac{F}{M} \epsilon^{\mu\nu\rho\sigma} k_\rho l_\sigma$

$B^*\bar{B}^*$

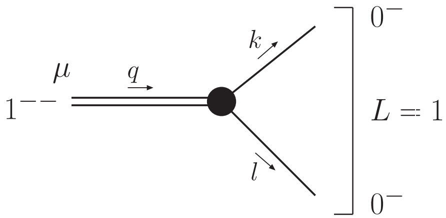
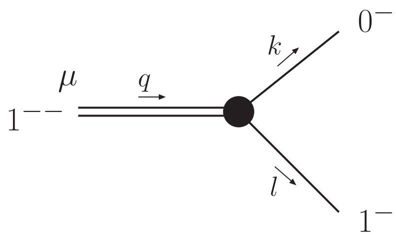
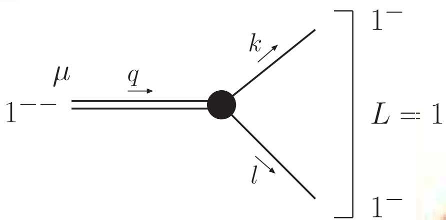


$$\widehat{=} \quad F(g^{\mu\rho}(q+l)^\nu - g^{\mu\nu}(k+q)^\rho + g^{\rho\nu}(q+k)^\mu)$$

Y_b decay

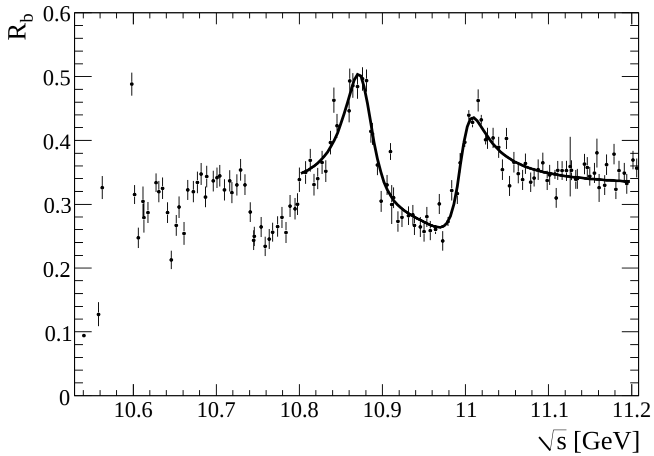
channel	diagram	vertex	width
$B\bar{B}$		$\widehat{=} F(k^\mu - l^\mu)$	$\Rightarrow \Gamma = \frac{F^2 \lvert\vec{k}\rvert^3}{2M^2\pi}$
$B\bar{B}^*$		$\widehat{=} \frac{F}{M}\epsilon^{\mu\nu\rho\sigma}k_\rho l_\sigma$	$\Rightarrow \Gamma = \frac{F^2 \lvert\vec{k}\rvert^3}{4M^2\pi}$
$B^*\bar{B}^*$		$\widehat{=} F(g^{\mu\rho}(q+l)^\nu - g^{\mu\nu}(k+q)^\rho + g^{\rho\nu}(q+k)^\mu)$	$\Rightarrow \Gamma = \frac{F^2 \lvert\vec{k}\rvert^3 (48\lvert\vec{k}\rvert^4 - 104 M^2 \lvert\vec{k}\rvert^2 + 27 M^4)}{2\pi (M^3 - 4\lvert\vec{k}\rvert^2 M)^2}$

Y_b decay

channel	diagram	vertex	width
$B\bar{B}$		$\widehat{=} F(k^\mu - l^\mu)$	$\Rightarrow \Gamma = \frac{F^2 \lvert\vec{k}\rvert^3}{2M^2\pi}$
$B\bar{B}^*$		$\widehat{=} \frac{F}{M}\epsilon^{\mu\nu\rho\sigma} k_\rho l_\sigma$	$\Rightarrow \Gamma = \frac{F^2 \lvert\vec{k}\rvert^3}{4M^2\pi}$
$B^*\bar{B}^*$		$\widehat{=} F(g^{\mu\rho}(q+l)^\nu - g^{\mu\nu}(k+q)^\rho + g^{\rho\nu}(q+k)^\mu)$	$\Rightarrow \Gamma = \frac{F^2 \lvert\vec{k}\rvert^3 (48\lvert\vec{k}\rvert^4 - 104M^2\lvert\vec{k}\rvert^2 + 27M^4)}{2\pi(M^3 - 4\lvert\vec{k}\rvert^2 M)^2}$

- The couplings F are estimated from the measured widths of the $\Upsilon(5S)$ decays ($\Gamma_{tot}(Y_b^{(1)}) \approx 10 - 20$ MeV, $\Gamma_{tot}(Y_b^{(2)}) \approx 25 - 50$ MeV, . . .)

BaBar fit

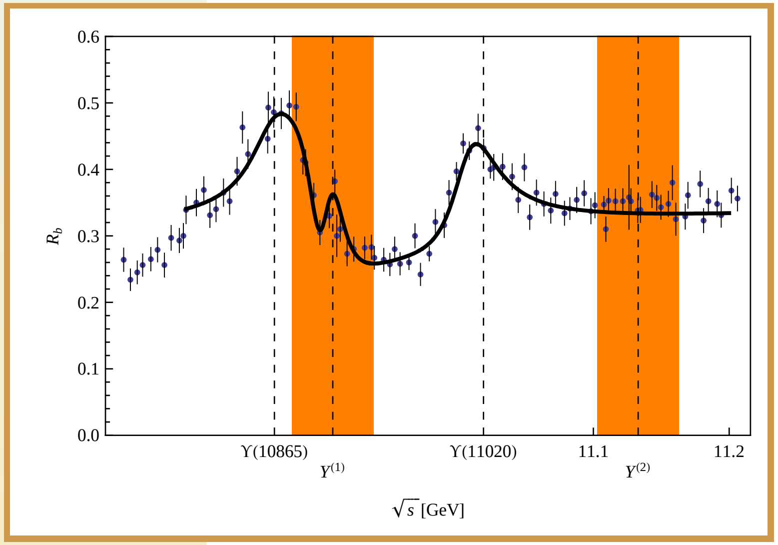


$$\sigma(e^+e^- \to b\bar{b}) =$$
$$|A_{nr}|^2 + |A_r + A_{10860}e^{i\phi_{10860}}$$
$$\times BW(M_{10860}, \Gamma_{10860}) + A_{11020}e^{i\phi_{11020}}$$
$$\times BW(M_{11020}, \Gamma_{11020})|^2$$

$\chi^2/\text{d.o.f.} \approx 2$

[Phys. Rev. Lett. **102**, 012001 (2009)]

BaBar fit



$\chi^2/\text{d.o.f.} = 88/67$

$$\sigma(e^+e^- \to b\bar{b}) =$$
$$|A_{nr}|^2 + |A_r + A_{10860}e^{i\phi_{10860}}$$
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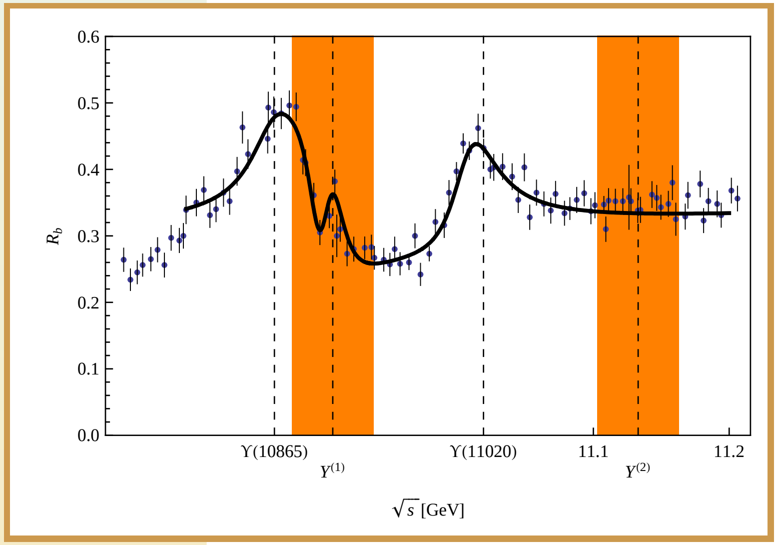
add $A_{Y_{[b,l]}} e^{i\phi_{Y_{[b,l]}}} BW(M_{Y_{[b,l]}}, \Gamma_{Y_{[b,l]}})$

and $A_{Y_{[b,h]}} e^{i\phi_{Y_{[b,h]}}} BW(M_{Y_{[b,h]}}, \Gamma_{Y_{[b,h]}})$

BaBar fit



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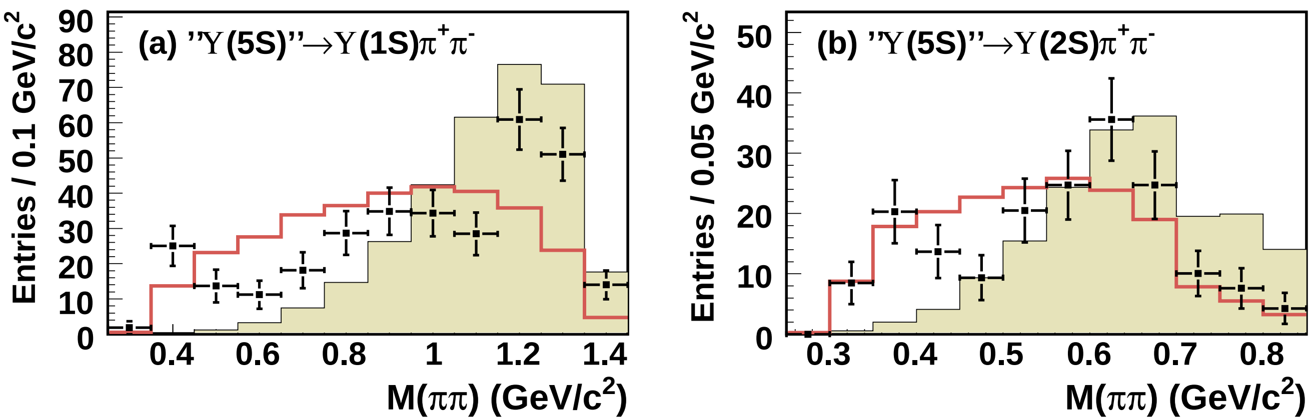
and $A_{Y_{[b,h]}} e^{i\phi_{Y_{[b,h]}}} BW(M_{Y_{[b,h]}}, \Gamma_{Y_{[b,h]}})$

	M [MeV]	Γ [MeV]	φ [rad.]
$\Upsilon(5S)$	10864 ± 5	46 ± 8	1.3 ± 0.3
$\Upsilon(6S)$	11007 ± 0.3	40 ± 2	0.88 ± 0.06
$Y_{[b,l]}$	$10900 - \Delta M/2 \pm 2$	28 ± 2	1.3 ± 0.2
$Y_{[b,h]}$	$10900 + \Delta M/2 \pm 2$	28 ± 2	1.9 ± 0.2

$\Delta M = 5.6 \pm 2.8$ MeV, $\Gamma_{ee}(Y_{[b,l]}) = 0.045 \pm 0.015$ keV, $\Gamma_{ee}(Y_{[b,h]}) = 0.04 \pm 0.015$ keV

enigmatic Belle data



Phys. Rev. Lett. **100**, 112001 (2008)

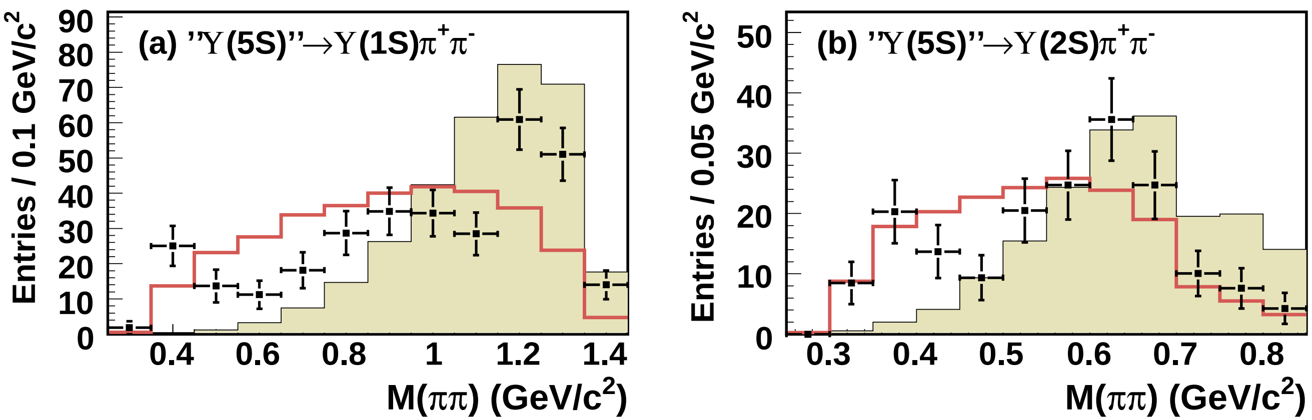
$$\Gamma(\Upsilon(2S) \to \Upsilon(1S)\pi\pi) \approx 0.0060 \text{ MeV}$$

$$\Gamma(\Upsilon(3S) \to \Upsilon(1S)\pi\pi) \approx 0.0009 \text{ MeV}$$

$$\Gamma(\Upsilon(4S) \to \Upsilon(1S)\pi\pi) \approx 0.0019 \text{ MeV}$$

$$\Gamma(\text{"}\Upsilon(5S)\text{"} \to \Upsilon(1S)\pi^+\pi^-) \approx 0.59 \text{ MeV}$$

enigmatic Belle data



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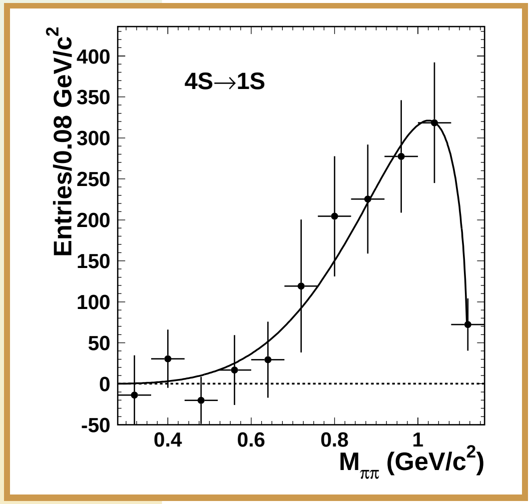
differs by two orders of magnitude!

why is the belle data puzzling?

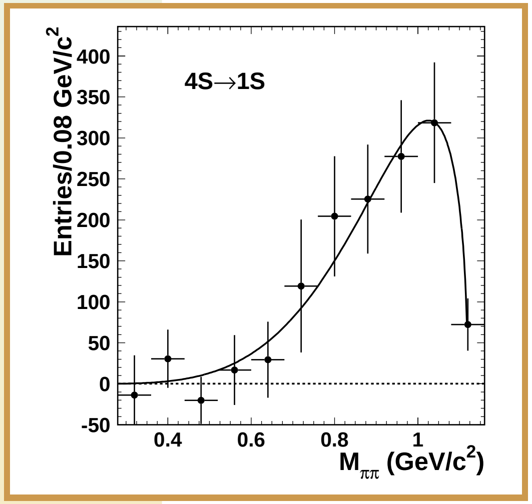
- typical $\Upsilon(nS) \to \Upsilon(1S)\pi\pi$ decays:



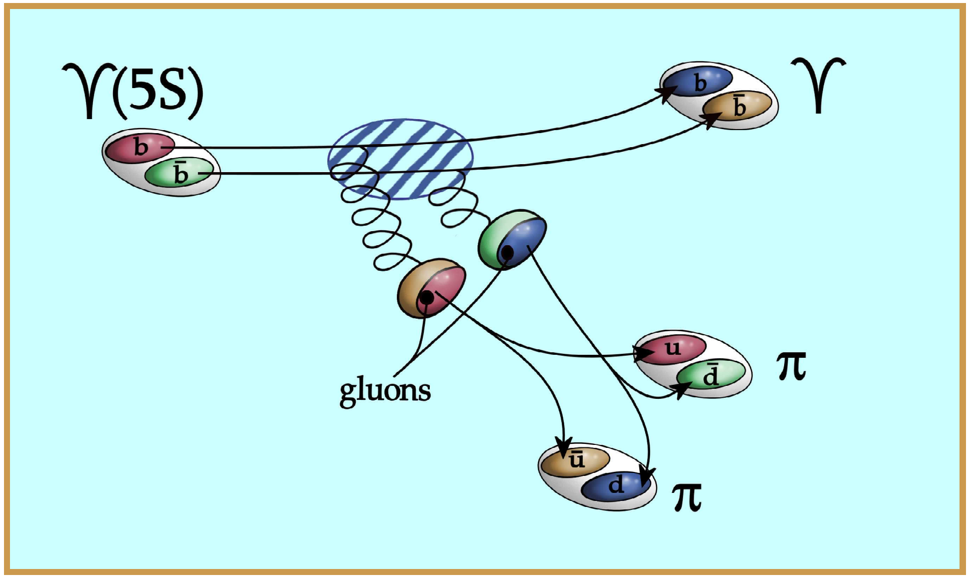
[Phys. Rev. D **79** (2009) 051103]

why is the belle data puzzling?

- typical $\Upsilon(nS) \to \Upsilon(1S)\pi\pi$ decays:



[Phys. Rev. D **79** (2009) 051103]



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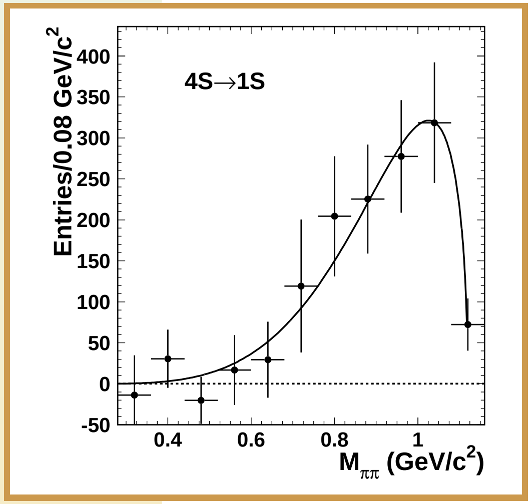
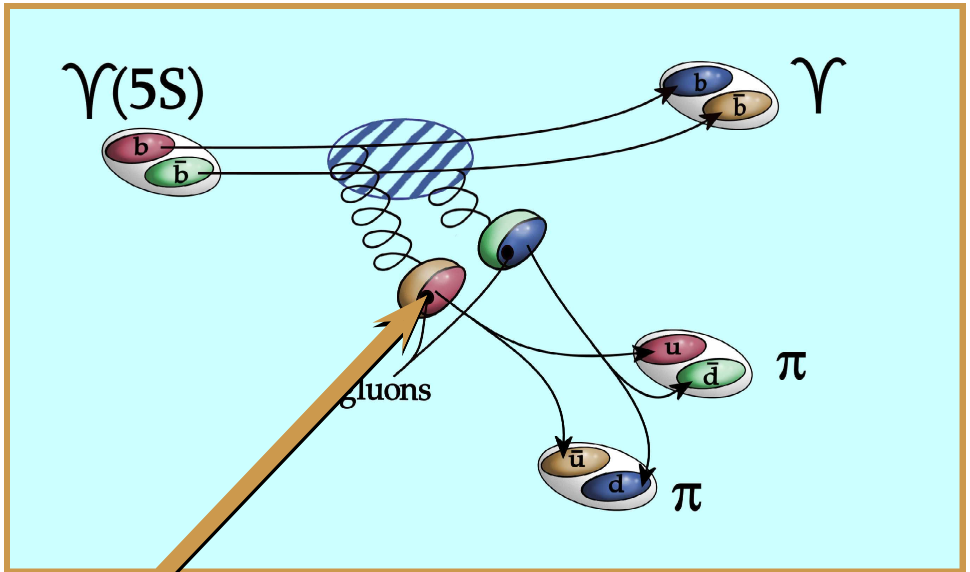


[Phys. Rev. D **79** (2009) 051103]

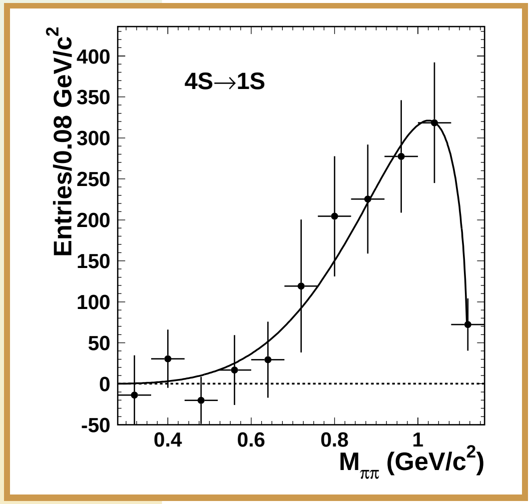


underlying process is

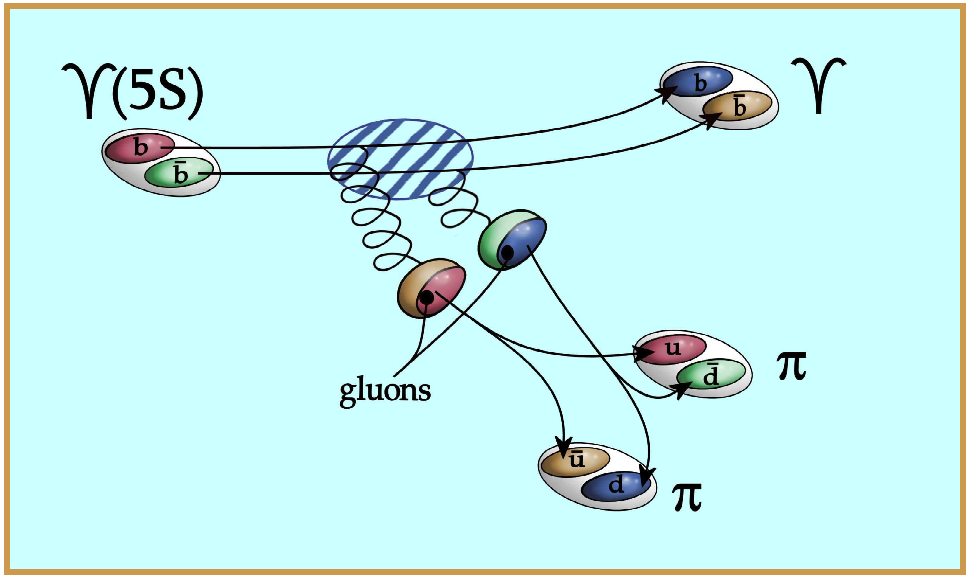
Zweig forbidden

why is the belle data puzzling?

- typical $\Upsilon(nS) \to \Upsilon(1S)\pi\pi$ decays:



[Phys. Rev. D **79** (2009) 051103]

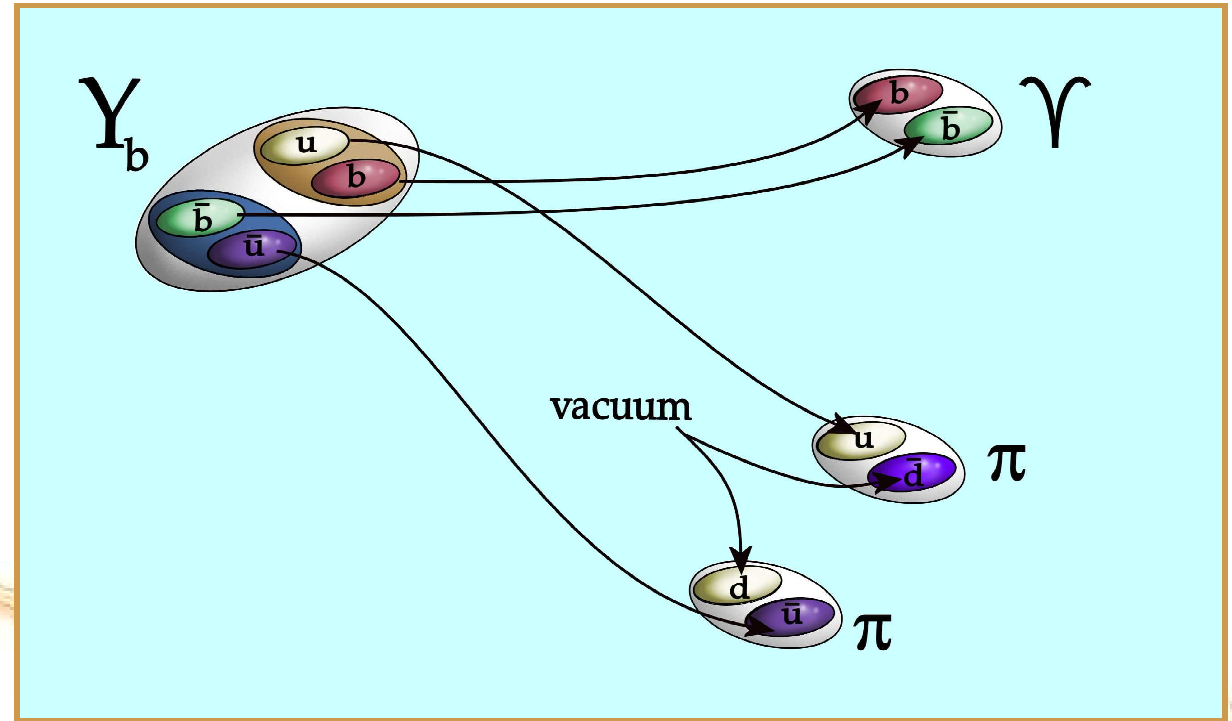


$$\mathcal{M}_{\mathbf{a}}^{\mu\nu} = g^{\mu\nu}\frac{F}{F_\pi^2}\Big[m_{\pi\pi}^2 - \beta(\Delta M)^2(1+\frac{2m_\pi^2}{m_{\pi\pi}^2})$$
$$+\frac{3}{2}\beta((\Delta M)^2 - m_{\pi\pi}^2)(1-\frac{4m_\pi^2}{m_{\pi\pi}^2})(cos^2\theta - \frac{1}{3})\Big]$$

[Phys. Rev. Lett. **35**, 1 (1975)]

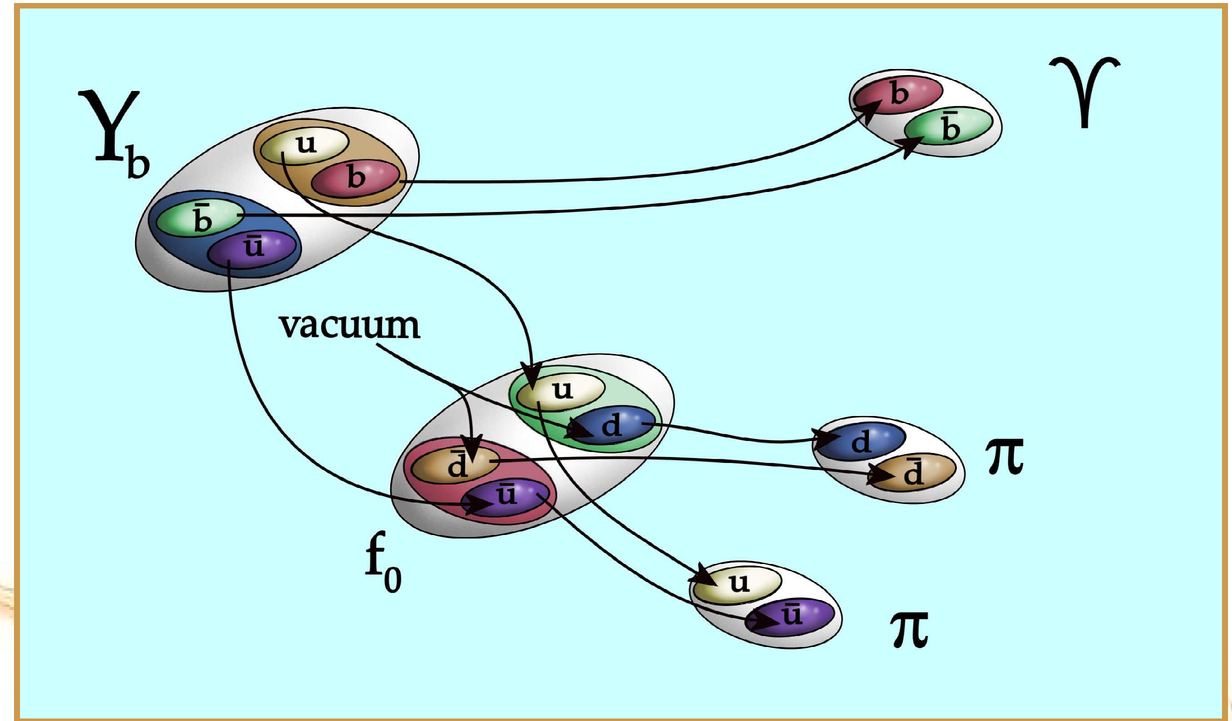
continuum contribution

- The tetraquark decay has a different Zweig allowed underlying process:

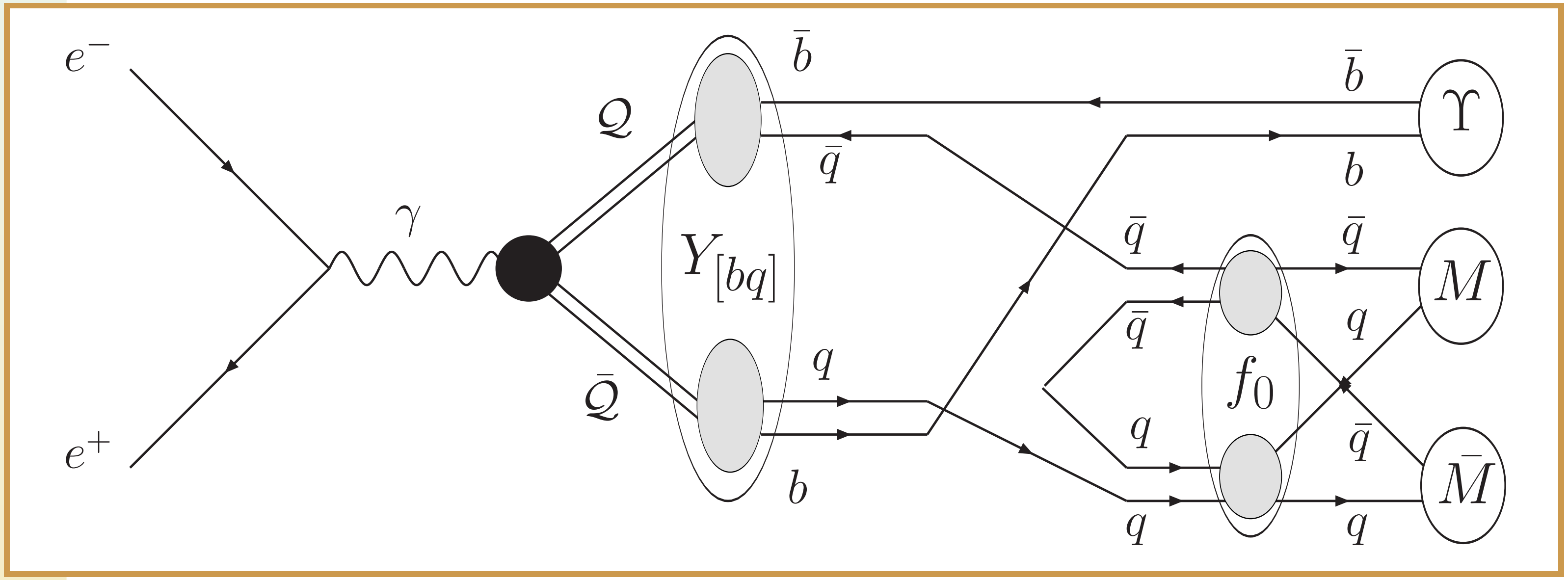


resonance contribution

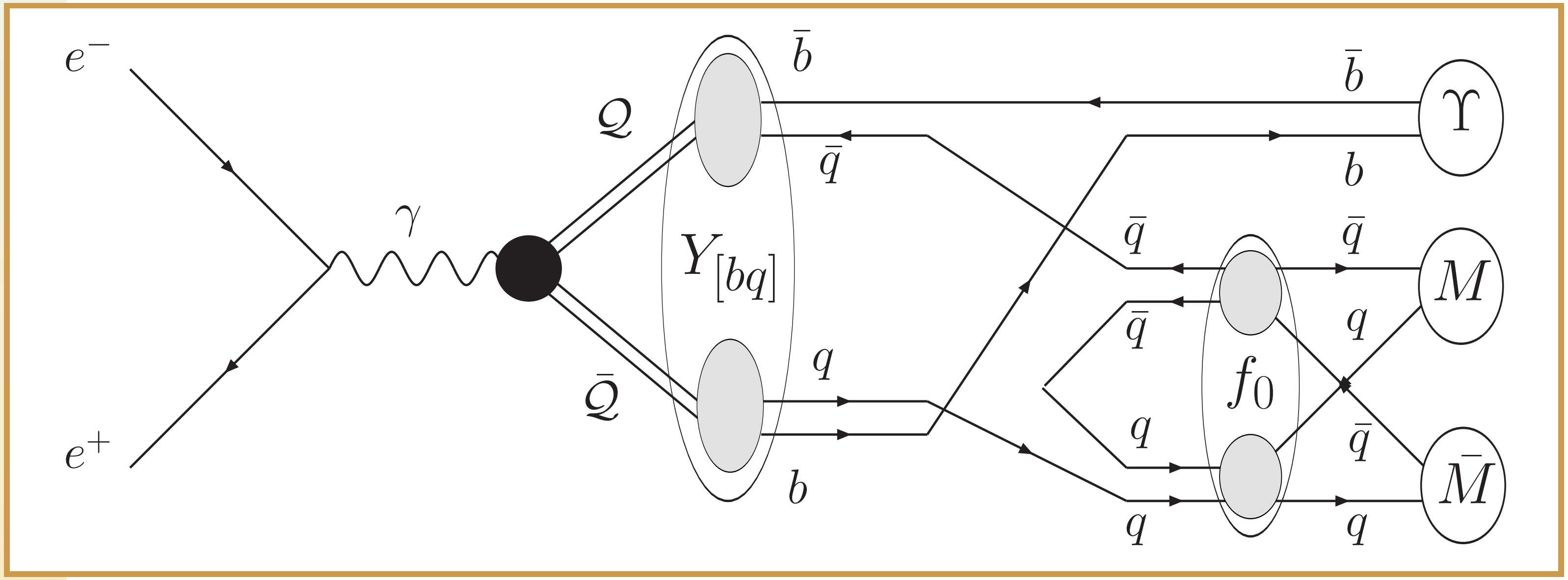
The tetraquark resonances can also account for Zweig allowed contributions in the decay process:



0^{++} resonance contribution

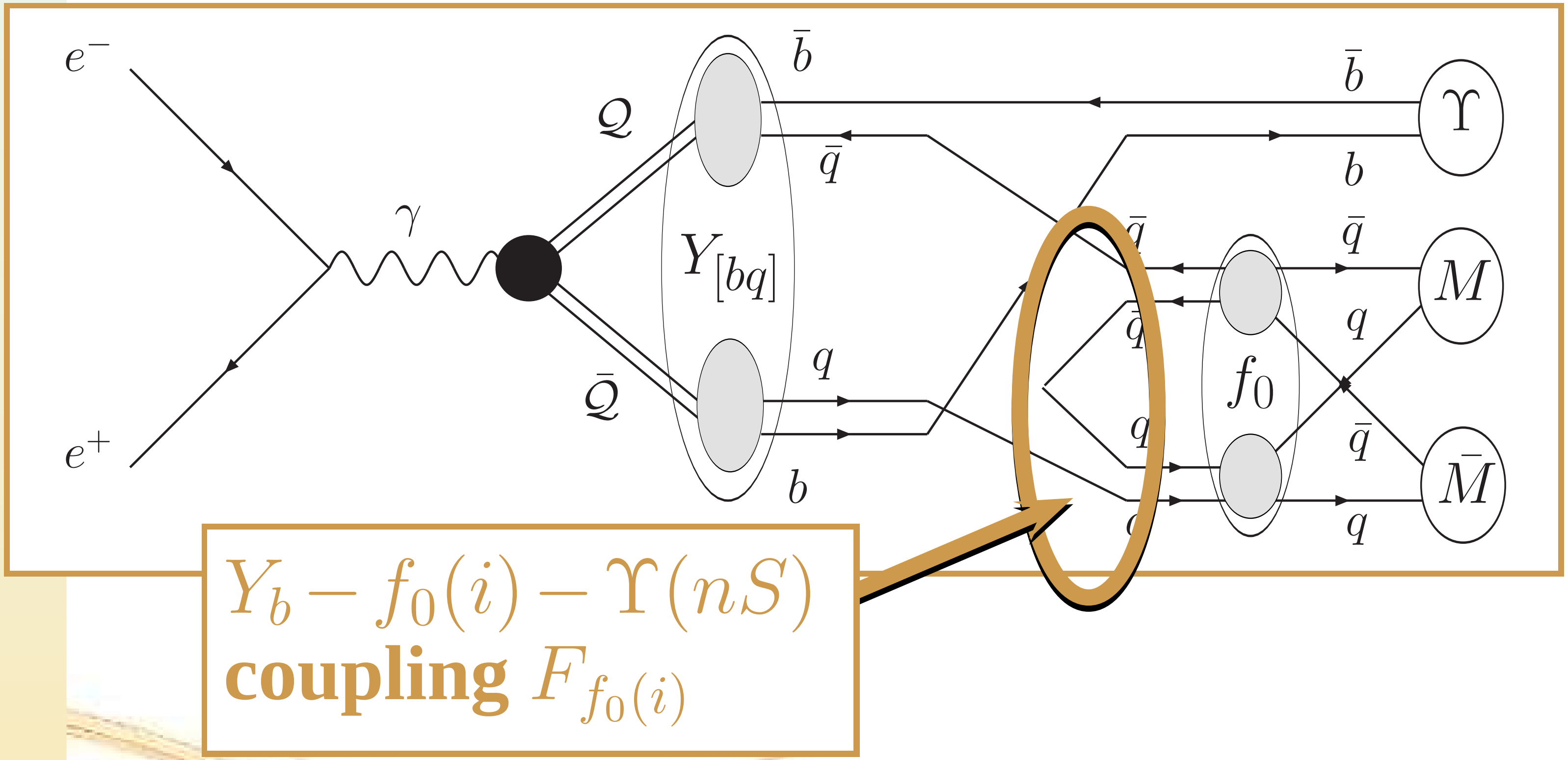


0^{++} resonance contribution



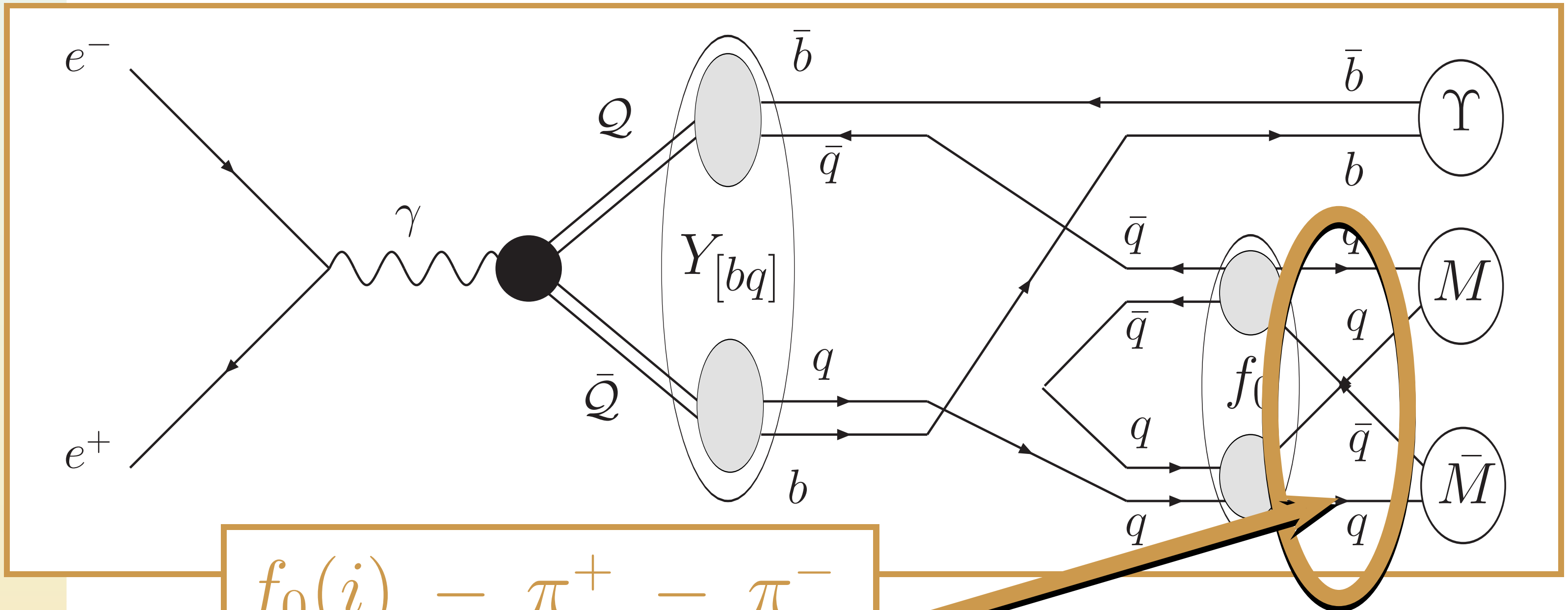
$$\mathcal{M}_{0^{++}\text{ resonance}} = \varepsilon^{Y}.\varepsilon^{\Upsilon} \sum_i \frac{a_{f_0(i)} e^{i\varphi_{f_0(i)}} (m_{\pi\pi}^2 - 2m_\pi^2)/2}{m_{\pi\pi}^2 - m_{f_0(i)}^2 + i m_{f_0(i)} \Gamma_{f_0(i)}(m_{\pi\pi})}$$

0^{++} resonance contribution



$$\mathcal{M}_{0^{++}\,\text{resonance}} = \varepsilon^{Y}.\varepsilon^{\Upsilon}\sum_i \frac{a_{f_0(i)}e^{i\varphi_{f_0(i)}}(m_{\pi\pi}^2 - 2m_\pi^2)/2}{m_{\pi\pi}^2 - m_{f_0(i)}^2 + i m_{f_0(i)}\Gamma_{f_0(i)}(m_{\pi\pi})}$$

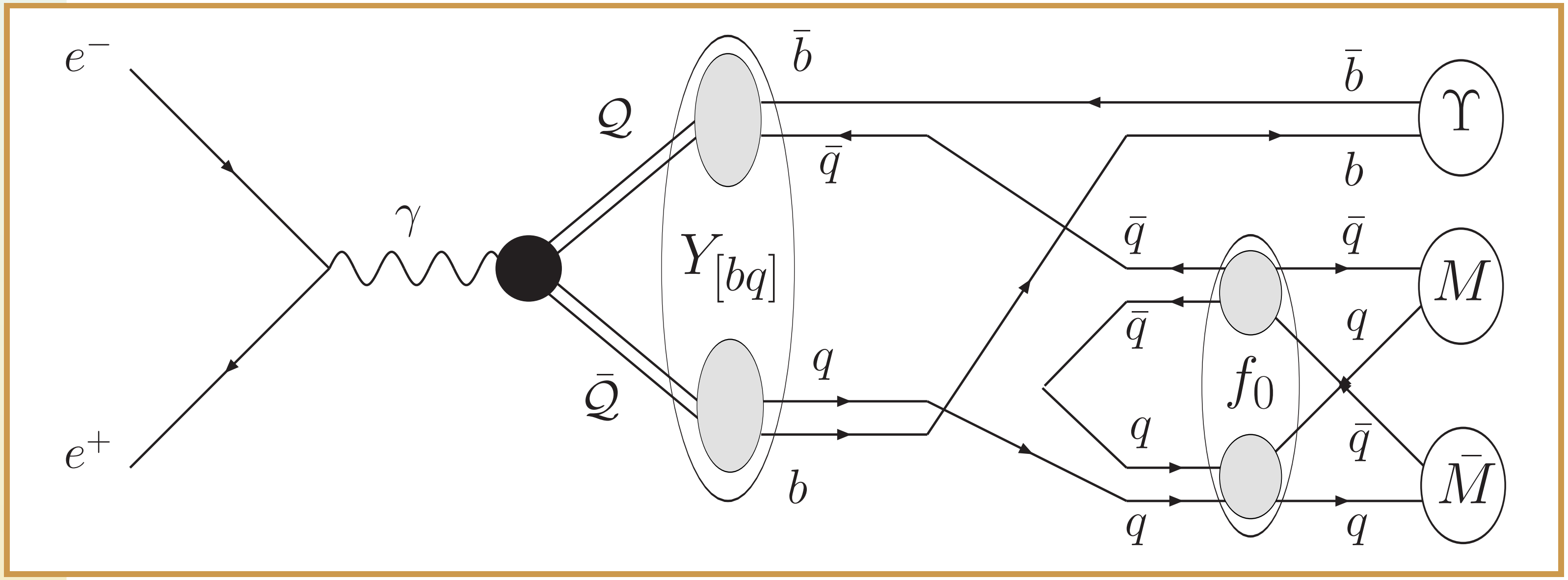
0^{++} resonance contribution



$f_0(i) - \pi^+ - \pi^-$
coupling $g_{f_0(i)\pi\pi}$

$$\mathcal{M}_{0^{++}\ \text{resonance}} = \varepsilon^{Y}.\varepsilon^{\Upsilon}\sum_i \frac{a_{f_0(i)}e^{i\varphi_{f_0(i)}}(m_{\pi\pi}^2-2m_\pi^2)/2}{m_{\pi\pi}^2-m_{f_0(i)}^2+im_{f_0(i)}\Gamma_{f_0(i)}(m_{\pi\pi})}$$

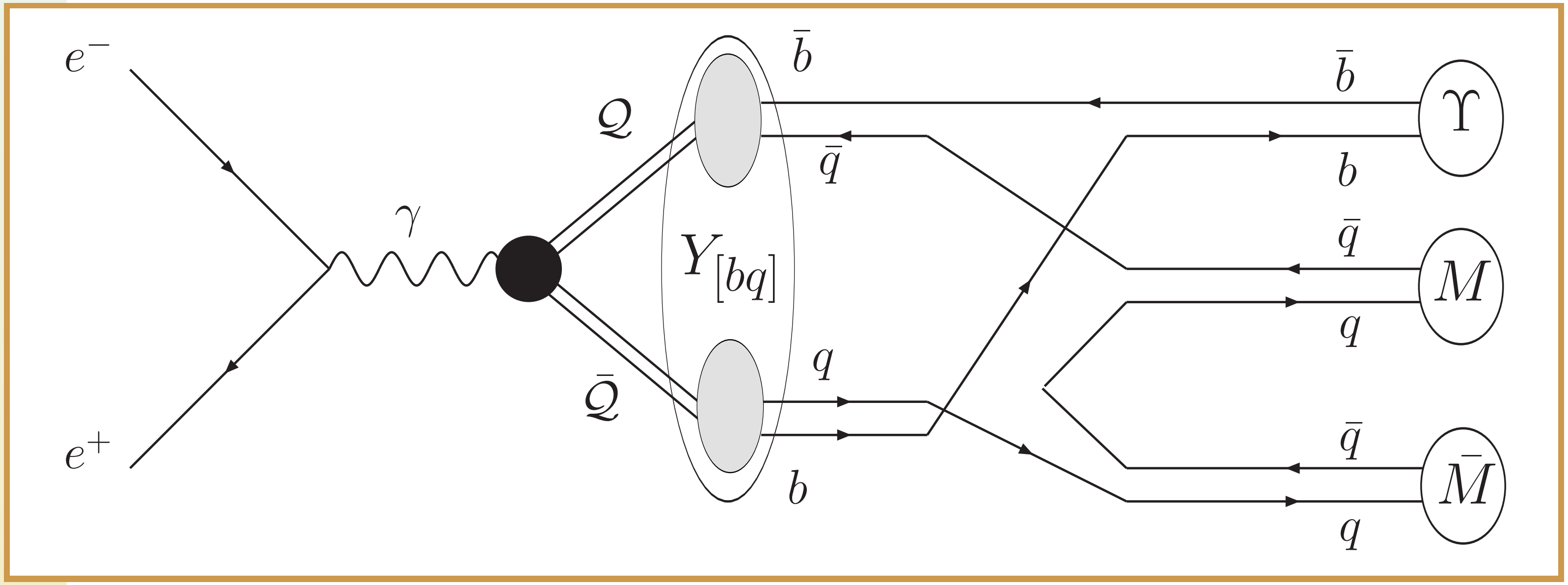
0^{++} resonance contribution



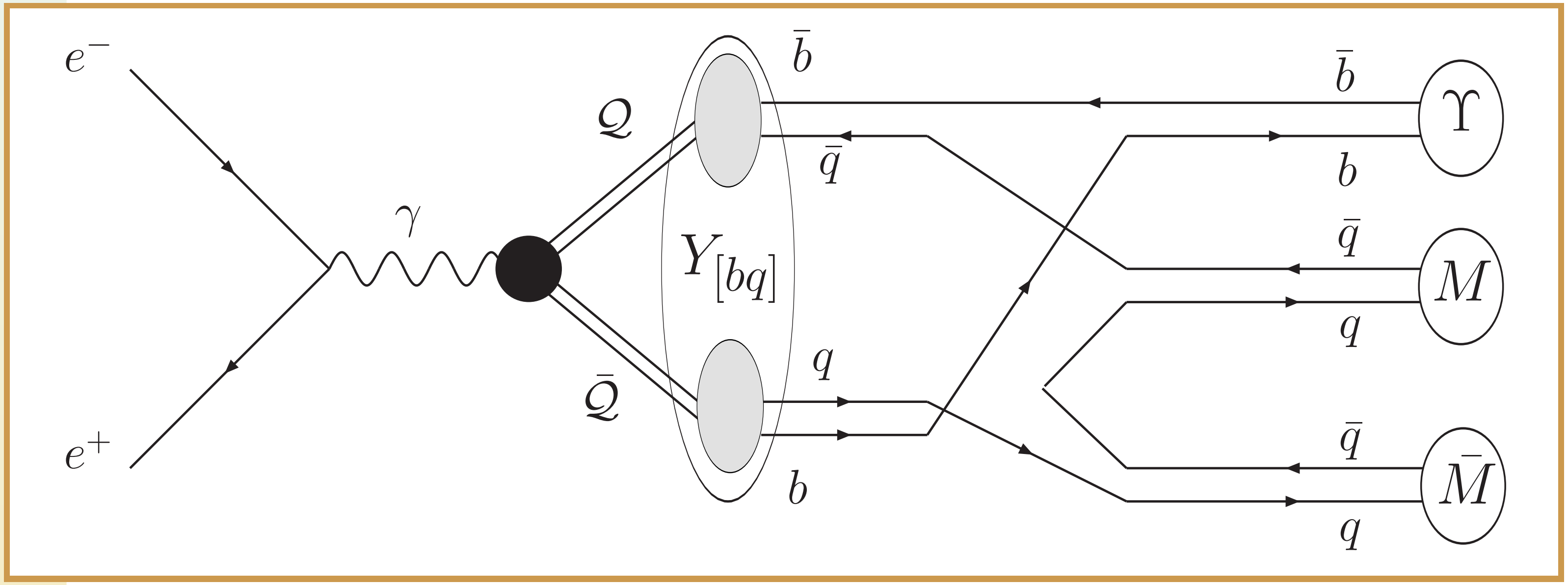
$$a_{f_0(i)} \propto F_{f_0(i)} \times g_{f_0(i)\pi\pi}$$

$$\mathcal{M}_{0^{++}\,\text{resonance}} = \varepsilon^{Y}.\varepsilon^{\Upsilon} \sum_i \frac{a_{f_0(i)} e^{i\varphi_{f_0(i)}} (m_{\pi\pi}^2 - 2m_\pi^2)/2}{m_{\pi\pi}^2 - m_{f_0(i)}^2 + i m_{f_0(i)} \Gamma_{f_0(i)}(m_{\pi\pi})}$$

continuum contribution

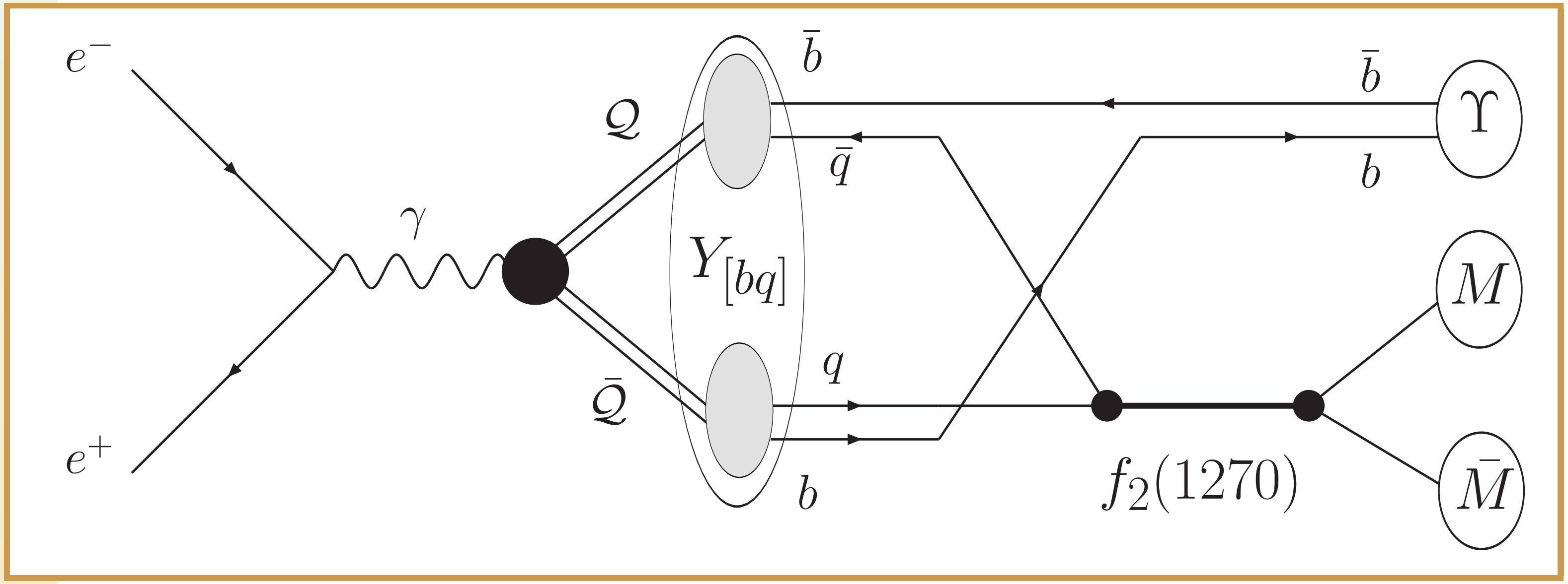


continuum contribution

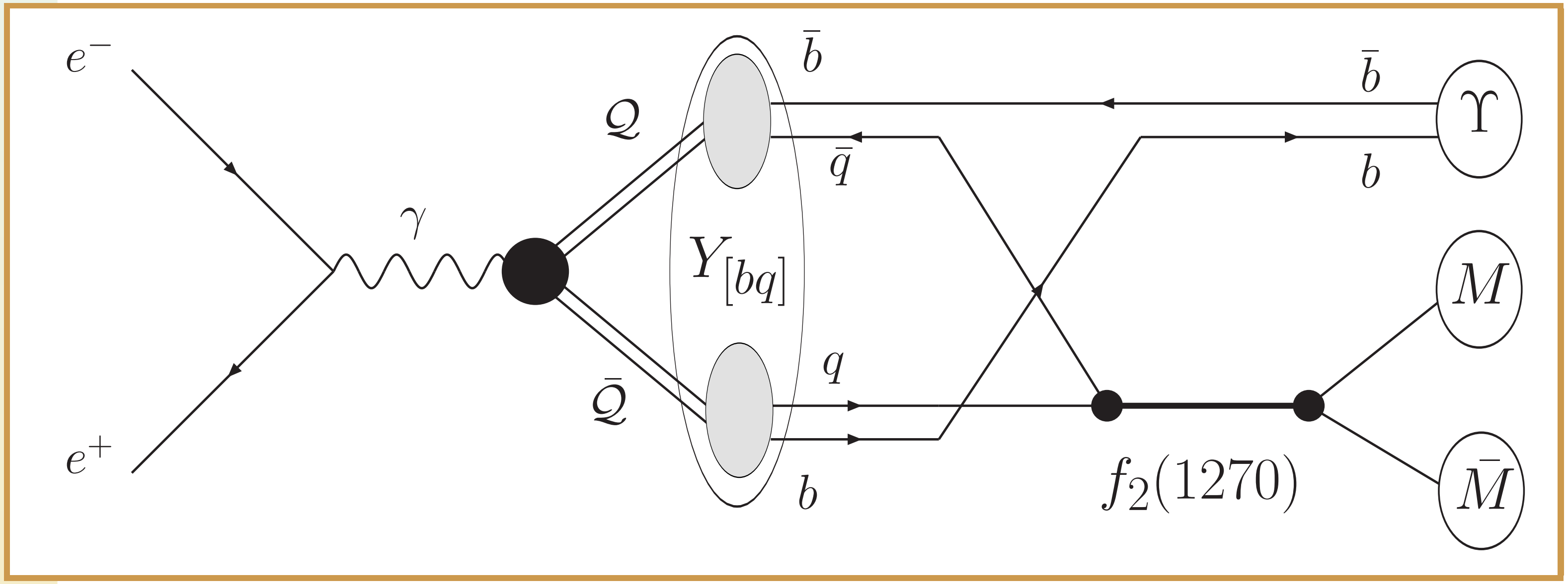


$$\mathcal{M}_{\text{continuum}} = \varepsilon^{Y}.\varepsilon^{\Upsilon}\frac{F}{F_\pi^2}\Big[m_{\pi\pi}^2 - \beta(\Delta M)^2(1+\frac{2m_\pi^2}{m_{\pi\pi}^2}) + \frac{3}{2}\beta((\Delta M)^2 - m_{\pi\pi}^2)\times(1-\frac{4m_\pi^2}{m_{\pi\pi}^2})(\cos^2\theta - \frac{1}{3})\Big]$$

D-wave 2^{++} contribution

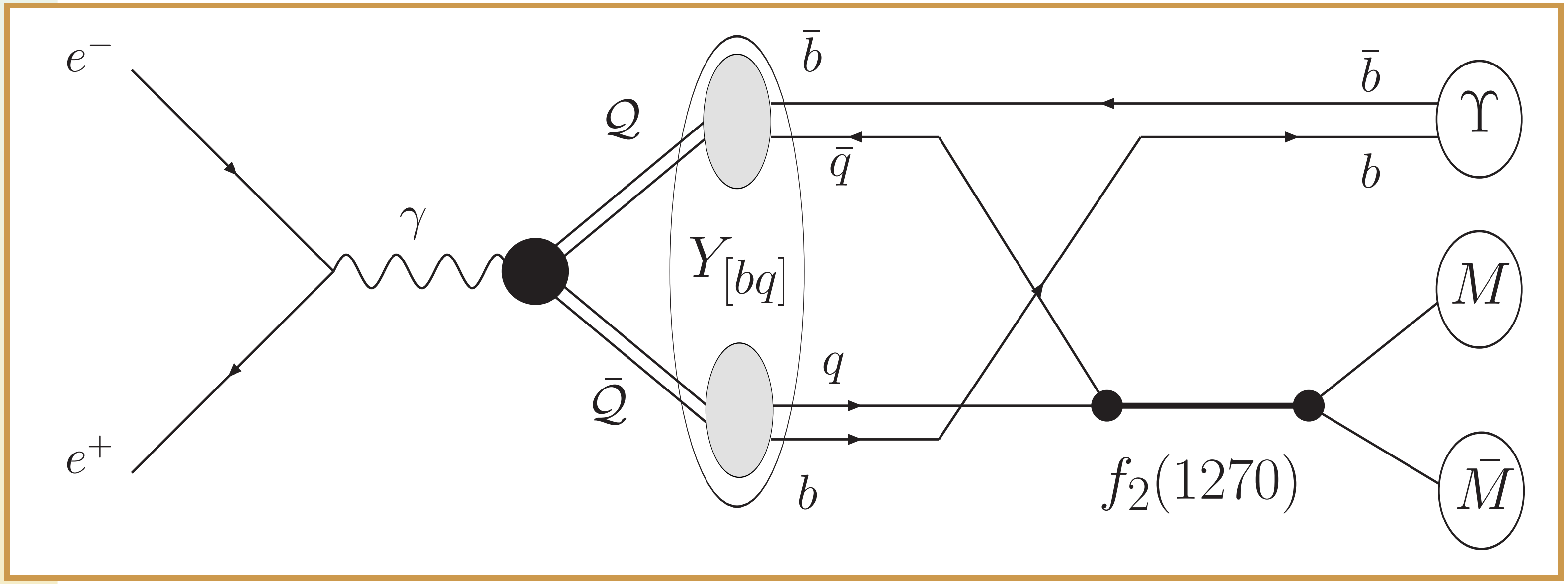


D-wave 2^{++} contribution



$$\mathcal{M}_{f_2(1270)} = \varepsilon^{Y}.\varepsilon^{\Upsilon} a_{f_2(1270)} e^{i\varphi_{f_2(1270)}} A_{f_2(1270)}$$

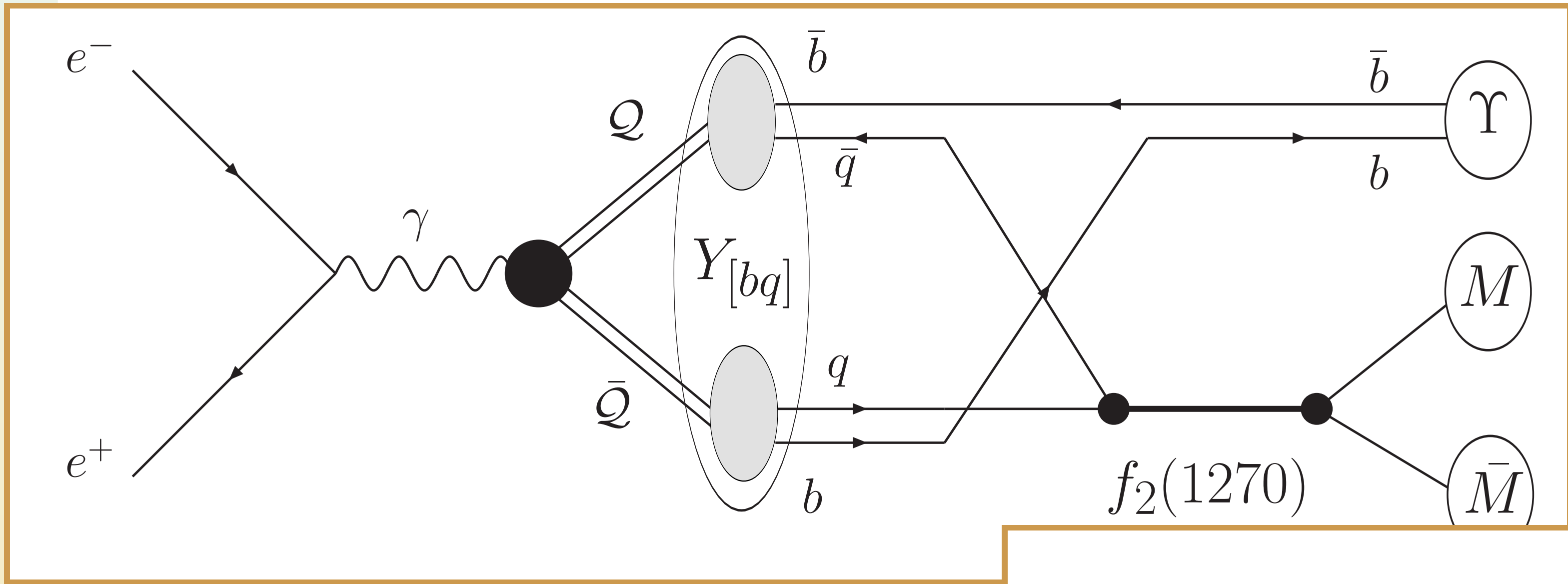
D-wave 2^{++} contribution



$$\mathcal{M}_{f_2(1270)} = \varepsilon^{Y}.\varepsilon^{\Upsilon} a_{f_2(1270)} e^{i\varphi_{f_2(1270)}} A_{f_2(1270)}$$

$$A_{f_2(1270)} = \frac{\sqrt{8\pi(2J+1)}}{\sqrt{m_{\pi\pi}}} Y_2^2 \frac{a_{f_2(1270)}\sqrt{m_{f_2(1270)}}}{m^2_{f_2(1270)} - m^2_{\pi\pi} - i m_{f_2(1270)}\Gamma_{f_2(1270)}}$$

D-wave 2^{++} contribution



spherical harmonics:

$$|Y_2^2| = \sqrt{\frac{15}{32\pi}}\sin^2\theta$$

$$\mathcal{M}_{f_2(1270)} = \varepsilon^{Y}.\varepsilon^{\Upsilon} a_{f_2(1270)} \ldots$$

$$A_{f_2(1270)} = \frac{\sqrt{8\pi(2J+1)}}{\sqrt{m_{\pi\pi}}} Y_2^2 \frac{a_{f_2(1270)}\sqrt{m_{f_2(1270)}}}{m^2_{f_2(1270)} - m^2_{\pi\pi} - i m_{f_2(1270)}\Gamma_{f_2(1270)}}$$

full amplitude

summing the single contributions leads to the full amplitude:

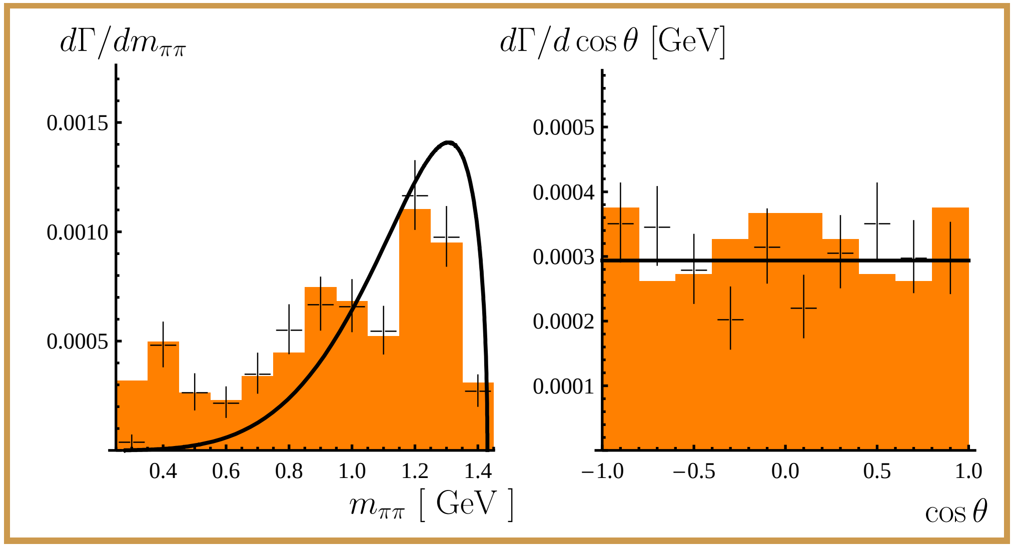
$$
\begin{aligned}
\mathcal{M} &= \varepsilon^{Y}.\varepsilon^{\Upsilon}\Big[\frac{F}{F_\pi^2}\Big[m_{\pi\pi}^2-\beta(\Delta M)^2(1+\frac{2m_\pi^2}{m_{\pi\pi}^2})\\
&\quad+\frac{3}{2}\beta((\Delta M)^2-m_{\pi\pi}^2)(1-\frac{4m_\pi^2}{m_{\pi\pi}^2})(\cos^2\theta-\frac{1}{3})\Big]\\
&\quad+\sum_i\frac{a_{f_0(i)}e^{i\varphi_{f_0(i)}}(m_{\pi\pi}^2-2m_\pi^2)/2}{m_{\pi\pi}^2-m_{f_0(i)}^2+im_{f_0(i)}\Gamma_{f_0(i)}(m_{\pi\pi})}\\
&\quad+a_{f_2(1270)}e^{i\varphi_{f_2(1270)}}A_{f_2(1270)}(m_{\pi\pi})\Big]
\end{aligned}
$$

differential partial decay width:

$$
d\Gamma=\frac{1}{(2\pi)^3}\frac{1}{32M_{Y_b}^3}\overline{|\mathcal{M}|^2}dm_{\Upsilon\pi}^2dm_{\pi\pi}^2
$$

fit to Belle data

Fit for $Y_b \to \Upsilon(1S)\pi^+\pi^-$ with $\chi^2/\text{d.o.f.} = \mathbf{5/5}$:

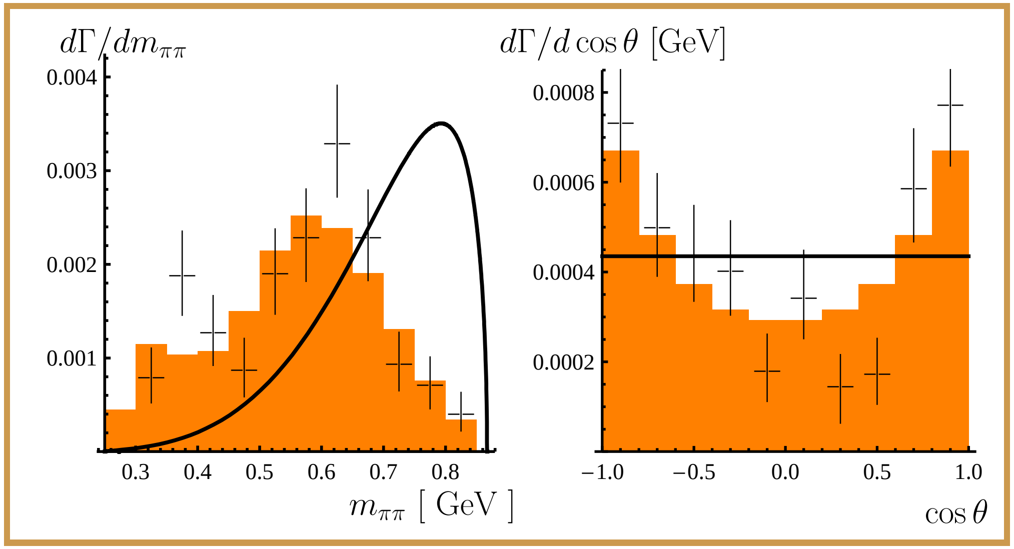


$F = 0.19 \pm 0.03$, $\beta = 0.54 \pm 0.12$, $a_{f_2(1270)} = 0.5 \pm 0.16$, $\varphi_{f_2(1270)} = 3.33 \pm 0.06$

	$a_{f_0(i)}$	$F_{f_0(i)}$	$\varphi_{f_0(i)}$ (rad.)
$f_0(600)$	3.6 ± 0.7	1.38 ± 0.27	1.14 ± 0.14
$f_0(980)$	0.47 ± 0.02	1.02 ± 0.04	4.12 ± 0.3

fit to Belle data

Fit for $Y_b \to \Upsilon(2S)\pi^+\pi^-$with $\chi^2/\text{d.o.f.} = \mathbf{9/8}$:



$F = 0.86 \pm 0.34$, $\beta = 0.7 \pm 0.3$

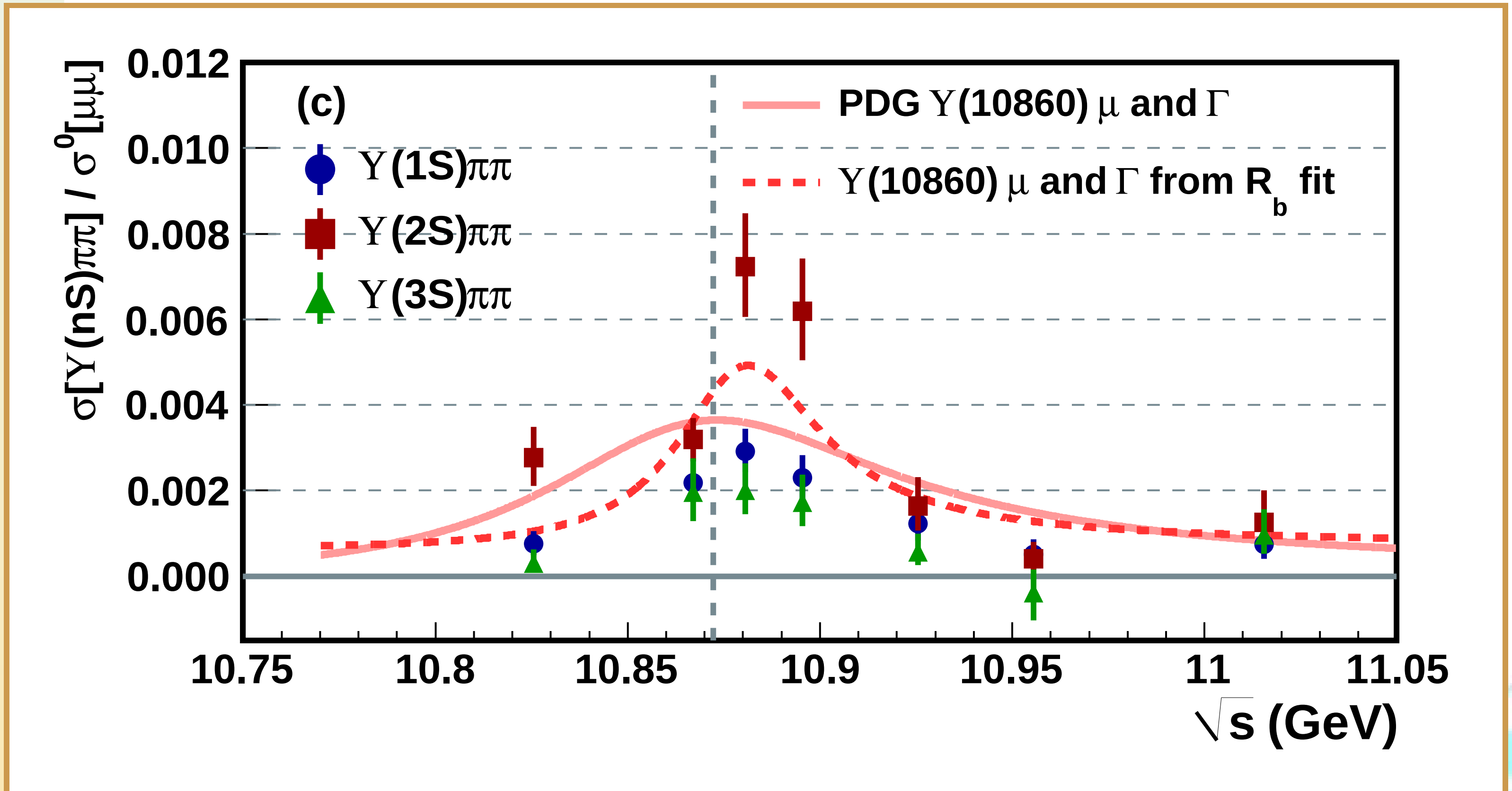
	$a_{f_0(i)}$	$F_{f_0(i)}$	$\varphi_{f_0(i)}$ (rad.)
$f_0(600)$	10.89 ± 2.4	4.19 ± 0.92	2.76 ± 0.22

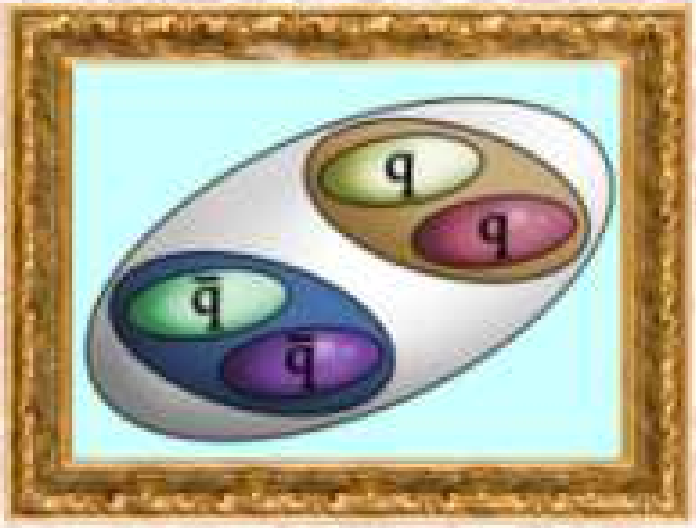
Summarizing:

- $\Upsilon(5S) \to \Upsilon(1S)\pi^+\pi^-,\ \Upsilon(2S)\pi^+\pi^-$ decays are Zweig forbidden .
- $Y_b \to \Upsilon(1S)\pi^+\pi^-,\ \Upsilon(2S)\pi^+\pi^-$ decays are Zweig allowed and can explain the large observed decay widths measured by Belle.
- The coupling to intermediate light quark resonances ($f_0(600)$, $f_0(980)$, $a_2(1270)$) can explain the shape of the invariant mass contribution (scalar meson dominance) .
- Crucial Tests:
  - Is there any sign of Y_b in Belle's R_b-scan?
  - Are the decays $Y_b \to \Upsilon(1S)K^+K^-(\Upsilon(1S)\eta\pi^0)$ dominated by the light tetraquarks $f_0(980)$ and $a_0(980)$?

new Belle data

fits under preparation





thank you!