Tetraquark-based analysis and predictions of the cross sections and distributions for the processes $e^+e^- \to \Upsilon(1S)(\pi^+\pi^-, K^+K^-, \eta\pi^0)$ near $\Upsilon(5S)$

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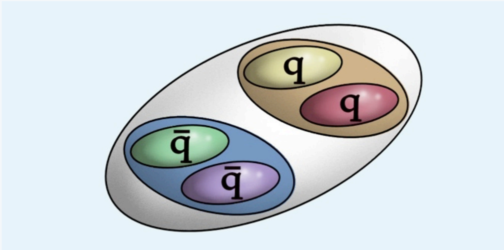
Ahmed Ali, Christian Hambrock and S.M., Phys. Rev. Lett. 106, 092002 (2011)

1. What are tetraquarks?

- A tetraquark consists of a colored diquark and a colored antidiquark. which are strongly bounded by QCD forces.



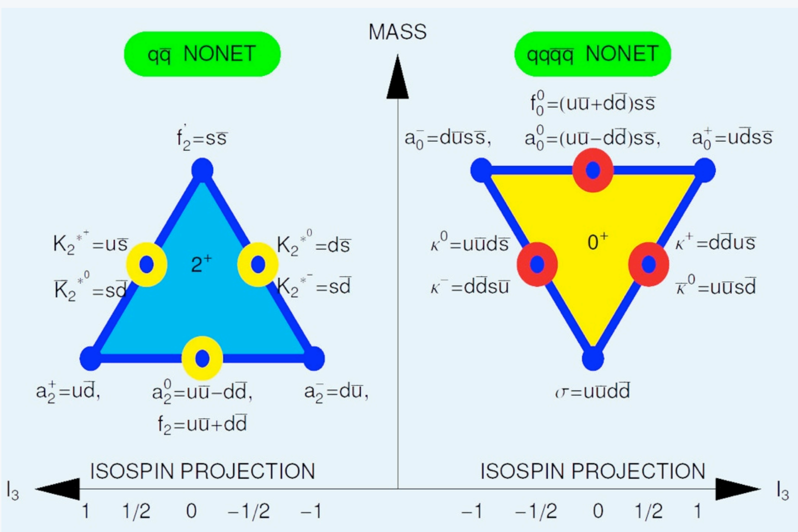
cf. A hadronic molecule is a bound state of uncolored mesons, weekly bounded by pion exchanges.

- Two possible diquarks: *Jaffe (05)*

$|qq;\ \bar{3}_c(A)\ \bar{3}_f(A)\ 0_s^+(A)\rangle$ *"good" diquark*

$|qq;\ \bar{3}_c(A)\ 6_f(S)\ 1_s^+(S)\rangle$ *"bad" diquark*

- The light-scalar nonet fits the tetraquark picture. *Maiani et al. (04)*



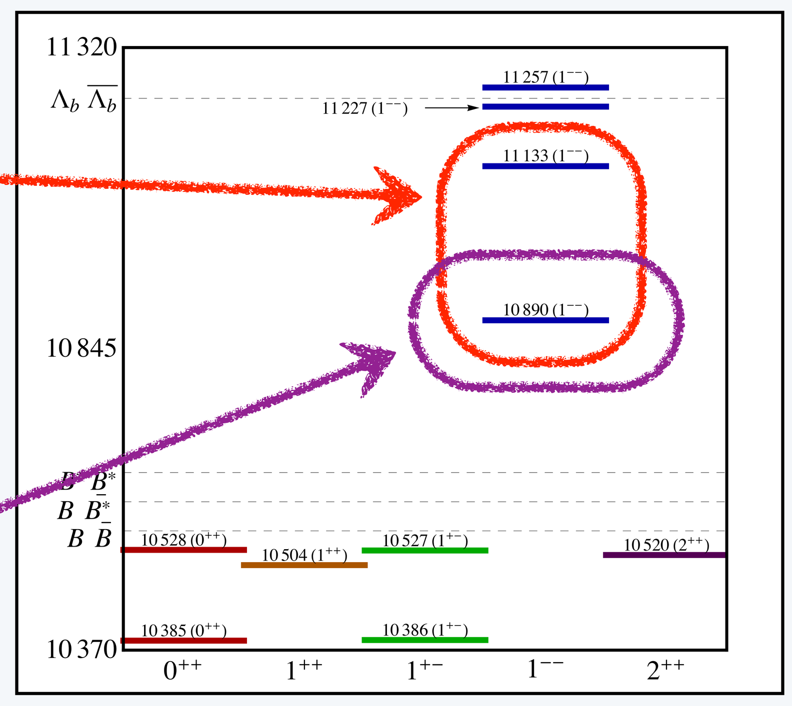
- Some of exotic charmonium-like states, e.g., X(3872) and Y(4260), could be interpreted as tetraquarks. *Maiani et al. (05)*

2. $[bq][\bar{b}\bar{q}]$ tetraquarks *Ali et al. (10)*

- Mass spectra have been calculated with the constituent diquark Hamiltonian:

$$H = 2m_{[bq]} + H_{SS}^{(qq)} + H_{SS}^{(q\bar{q})} + H_{SL} + H_{LL}$$

- The diquark mass has been estimated by identifying $Y_b(10890)$ as the lightest 1^{--} state, or by scaling up the diquark mass determined from charmonium-like states, yielding $m_{[bq]} \sim 5.3$ GeV.
- The 1^{--} states can be produced in e^+e^- annihilations, in the range of the BaBar and Belle energies.



- There are two almost degenerate states with $\Delta M \sim O(1)$ MeV. *mixture of $Y_{[bu]}$ and $Y_{[bd]}$*

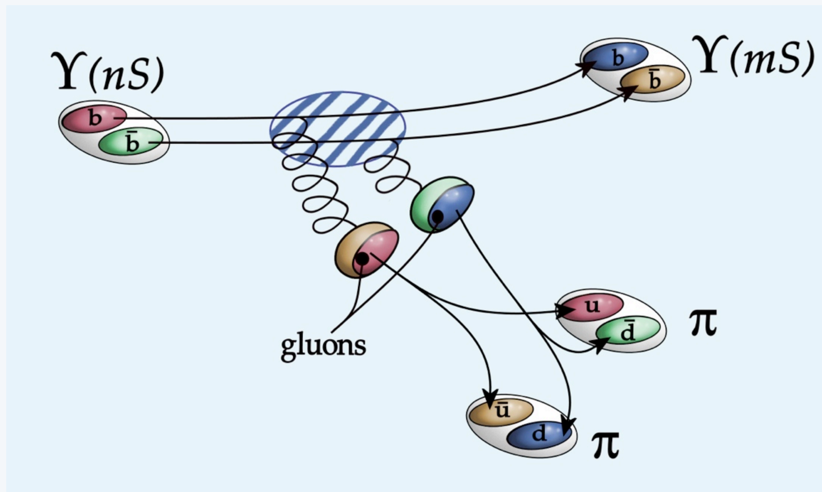
3. Tetraquark interpretation of $Y_b(10890)$

- Belle observed anomalously huge cross sections for $e^+e^- \to \Upsilon(5S) \to \Upsilon(nS)\pi^+\pi^- (n=1,2,3)$.

Process	$\Gamma_{e^+e^-}$	$\Gamma_{\Upsilon(1S)\pi^+\pi^-}$
$\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$	0.612 keV	0.0060 MeV
$\Upsilon(3S) \to \Upsilon(1S)\pi^+\pi^-$	0.443 keV	0.0009 MeV
$\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-$	0.272 keV	0.0019 MeV
$\Upsilon(5S) \to \Upsilon(1S)\pi^+\pi^-$	0.31 keV	0.59 MeV

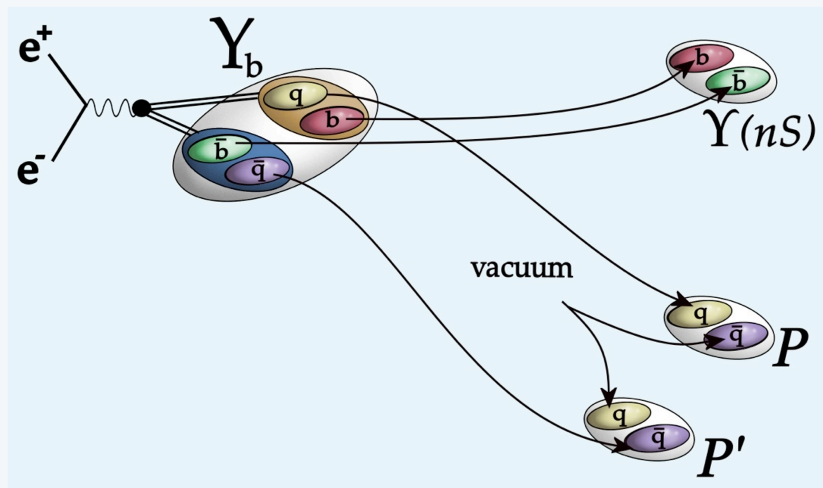
Chen et al. [Belle] (08)

Larger by two-orders of magnitude!



⇨ There may exist exotic **tetraquark states $Y_b(10890)$** near $\Upsilon(5S)$.

- $\Upsilon(nS) \to \Upsilon(mS)\pi^+\pi^-$ is Zweig forbidden, while $Y_b(10890) \to \Upsilon(mS)\pi^+\pi^-$ is Zweig allowed, which naturally explains huge cross sections. *Ali, Hambrock, Aslam (10)*

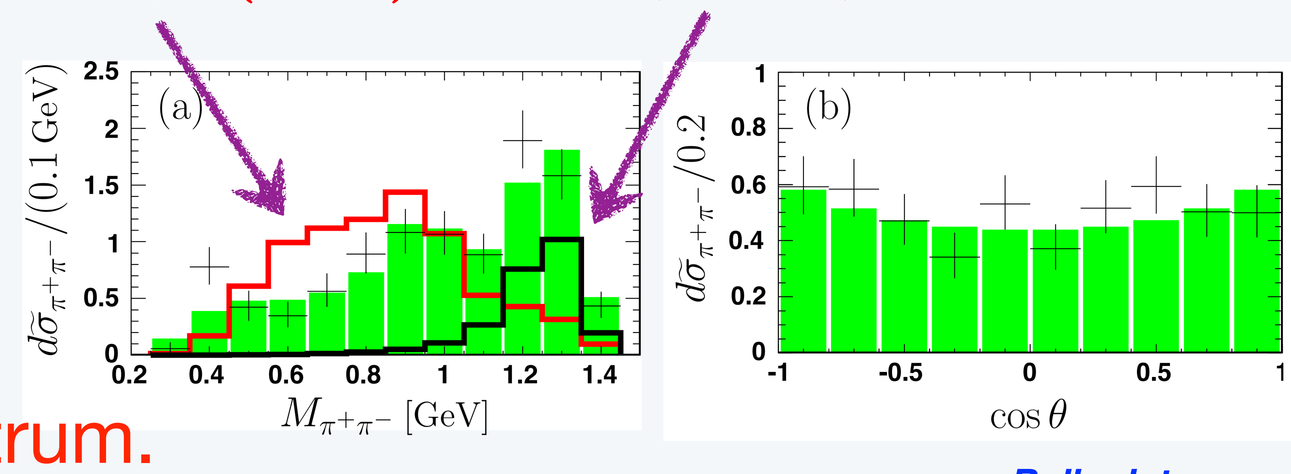


- Our estimate of the production rate is $\Gamma(Y_b \to e^+e^-) \sim O(10)$ eV. *Ali, Hambrock, S.M. (11)*
- The dominant decay modes of Y_b are $Y_b \to B^{(*)}B^{(*)}$, which are however hard to be observed due to large $\sigma(e^+e^- \to \Upsilon(5S) \to B^{(*)}B^{(*)})$.

4. Fit results and predictions

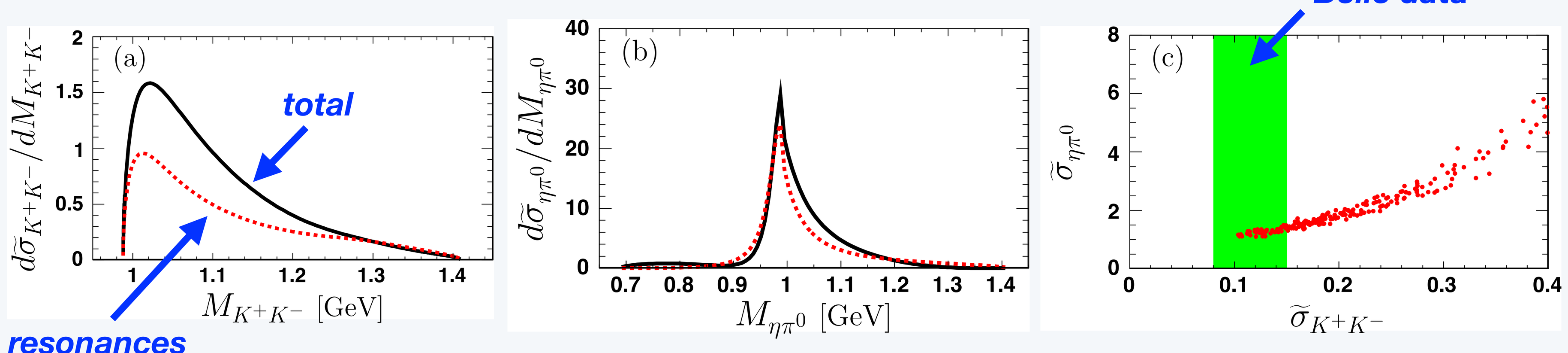
- We fit the $\Upsilon(1S)\pi^+\pi^-$ data, taking into account resonant contributions in the dipion system with the Flatté model, in addition to nonresonant contribution.

$\chi^2/\text{d.o.f.} = 21.5/15$



⇨ Resonance dominance in the dipion invariant-mass spectrum.

- Using the fitted parameters, we make predictions for $e^+e^- \to Y_b \to \Upsilon(1S)K^+K^-$ and $\Upsilon(1S)\eta\pi^0$, which are dominated by $f_0(980)+a_0(980)$ and $a_0(980)$, respectively.



Cross sections are normalized by the measured $\sigma(\Upsilon(1S)\pi^+\pi^-)$.