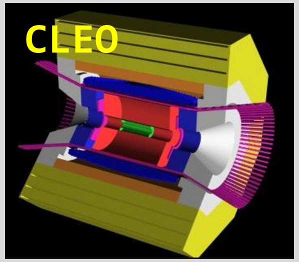
12th particle physics workshop of China

Study of $\Upsilon(1S,2S,3S)$ decays

Jia Sen

Beihang University

Data samples of Υ(1S) and Υ(2S)

	Υ(1S)	Υ(2S)
	21.2×10^6 ($1.06fb^{-1}$)	9.32×10^6 ($1.31fb^{-1}$)
BABAR	-	98.6×10^6 ($13.6fb^{-1}$)
BELLE	102×10^6 ($5.7fb^{-1}$)	158×10^6 ($24.9fb^{-1}$)

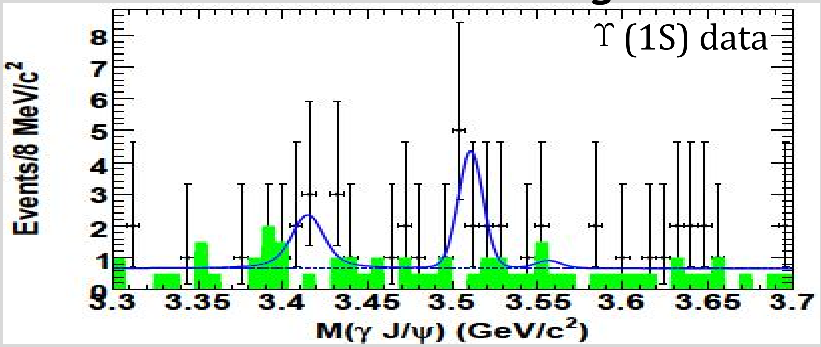
Belle experiment has collected the largest data samples of Υ(1S,2S) in the world!

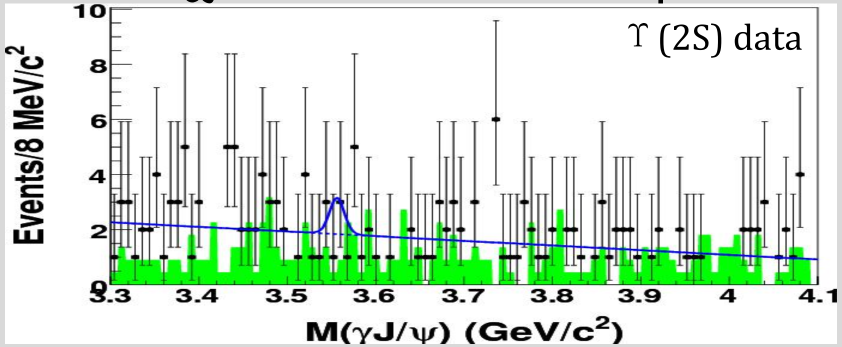
Outline

- Charmonium(-like) productions in $\Upsilon(1S)$ and $\Upsilon(2S)$ radiative decays
- Double-charmonium productions in $\Upsilon(1S,2S)$ exclusive decays
- $\Upsilon(1S,2S)$ decays into light hadrons
- Hadronic transitions of $\Upsilon(2S)$ to $(\eta, \pi^0)\Upsilon(1S)$
- Search for an H-Dibaryon in $\Upsilon(1S,2S)$ Decays
- $\Upsilon(1S)$ inclusive decays into J/ψ or $\psi(2S)$
- XYZ states in $\Upsilon(1S)$ inclusive decays
- Study of $\chi_{bJ}(1P)$ Properties in the Radiative $\Upsilon(2S)$ Decays
- $\Upsilon(1S,2S,3S)$ physics at Belle II
- Conclusion and Summary
- Acknowledgement

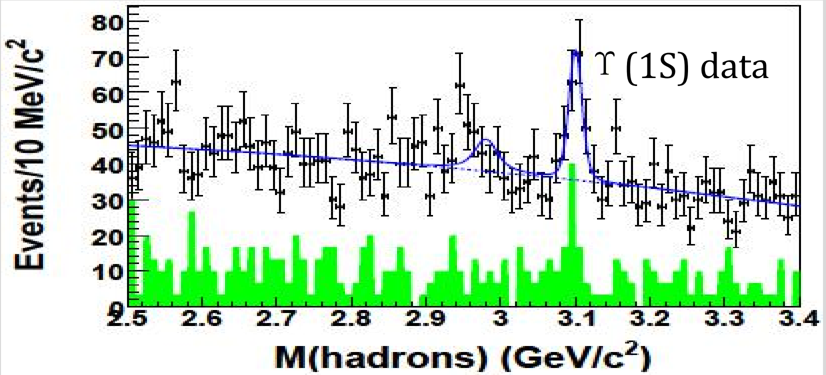
Charmonium(-like) productions in $\Upsilon(1S)$ and $\Upsilon(2S)$ radiative decays

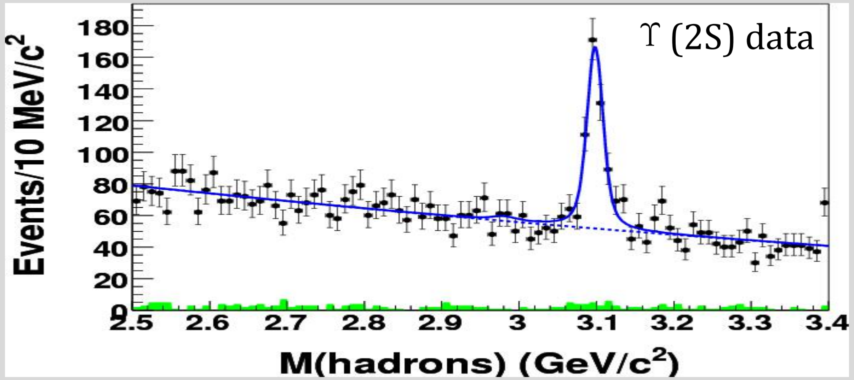
We search for χ_{cJ} in the $\gamma J/\psi$ mode. None of the χ_{cJ} production is significant unfortunately. Moreover,there are no structures at higher masses, where excited χ_{cJ} states would be expected[1].





To study the $\gamma\eta_c$ mode, the ηc candidates are reconstructed from the $K^+\pi^-$+c.c., $\pi^+\pi^-K^+K^-$, $2(K^+K^-)$,$2(\pi^+\pi^-)$ and $3(\pi^+\pi^-)$ channels[2]. The accumulation of events within the η_c mass region is small.

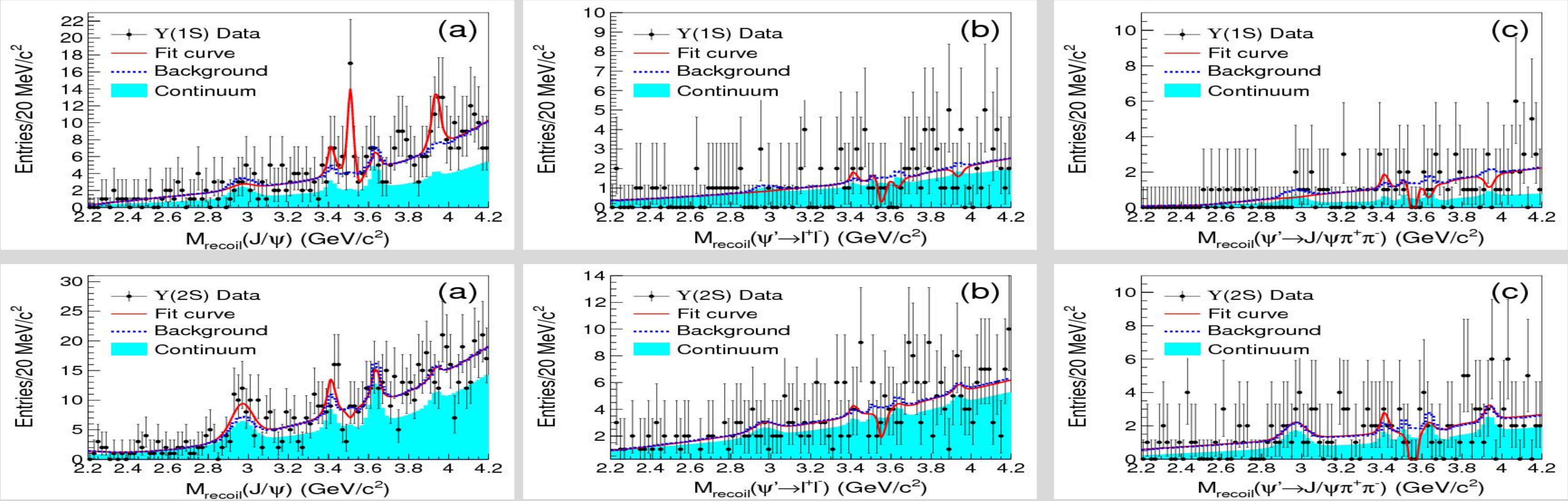




In addition, we search for several charmonium-like states. Only a small number of candidates are observed in the $\pi^+\pi^-J/\psi$ mode, while no X(3872) or X(3915) signal is observed in the $\pi^+\pi^-\pi^0J/\psi$ mode. We also search for the Y(4140) and X(4350)(only in $\Upsilon(2S)$ data), there is no candidate event in the signal region.

Double-charmonium productions in ϒ(1S,2S) exclusive decays

Search for ϒ(1S,2S) exclusive decays into a **J/ψ** or **ψ'** plus one of the η_c, χ_{cJ}, $\eta_c(2S)$, X(3940) and X(4160) states.

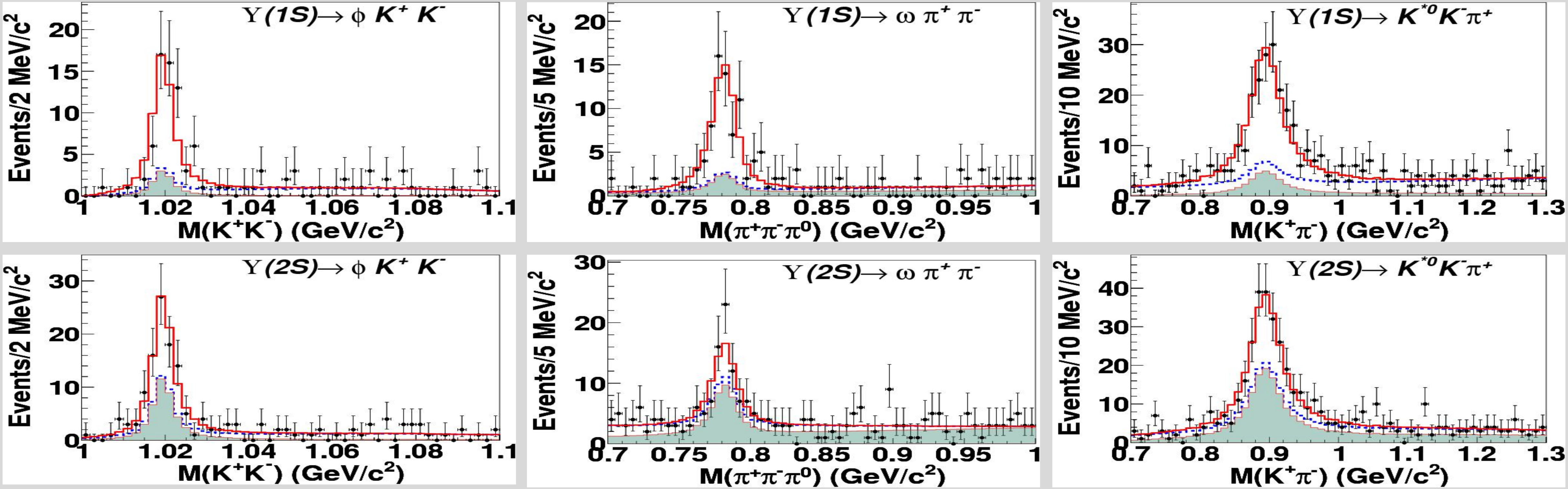


The evidence is found for ϒ(1S) → **J/ψ** χ_{c1} for the first time, and the branching fraction is measured to be (3.90 ± 1.21(stat.) ± 0.23(syst.))×10−6 with a signal significance of 4.6 σ [3]. While No other > 3σ signals are observed. The measurements are found to be consistent with the theoretical calculations[4,5].

ϒ(1S,2S) decays into light hadrons

An energy conservation variable, $X_T = \sum_h E_h / \sqrt{s}$ is introduced, where E_h is the energy of the final-state hadron h in the e^+e^- center-of-mass frame. Then for signals X_T should be around 1.

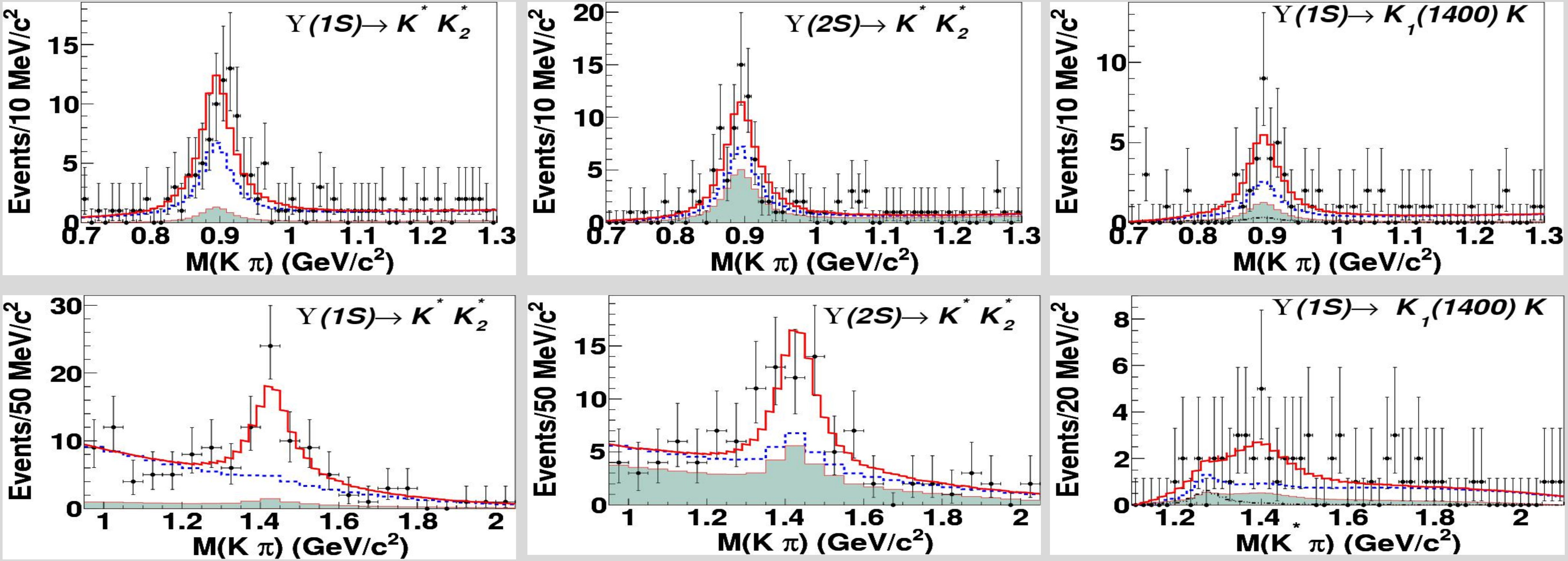
The K^+K^-, $\pi^+\pi^-\pi^0$, and $K^+\pi^-$ invariant mass distributions are shown in below plots for ϒ(1S,2S) to ϕK^+K^-, $\omega\pi^+\pi^-$, and $K^*(892)^0K^-\pi^+$ final states.



Clear φ, ω and $K^*(892)^0$ are evident[6].

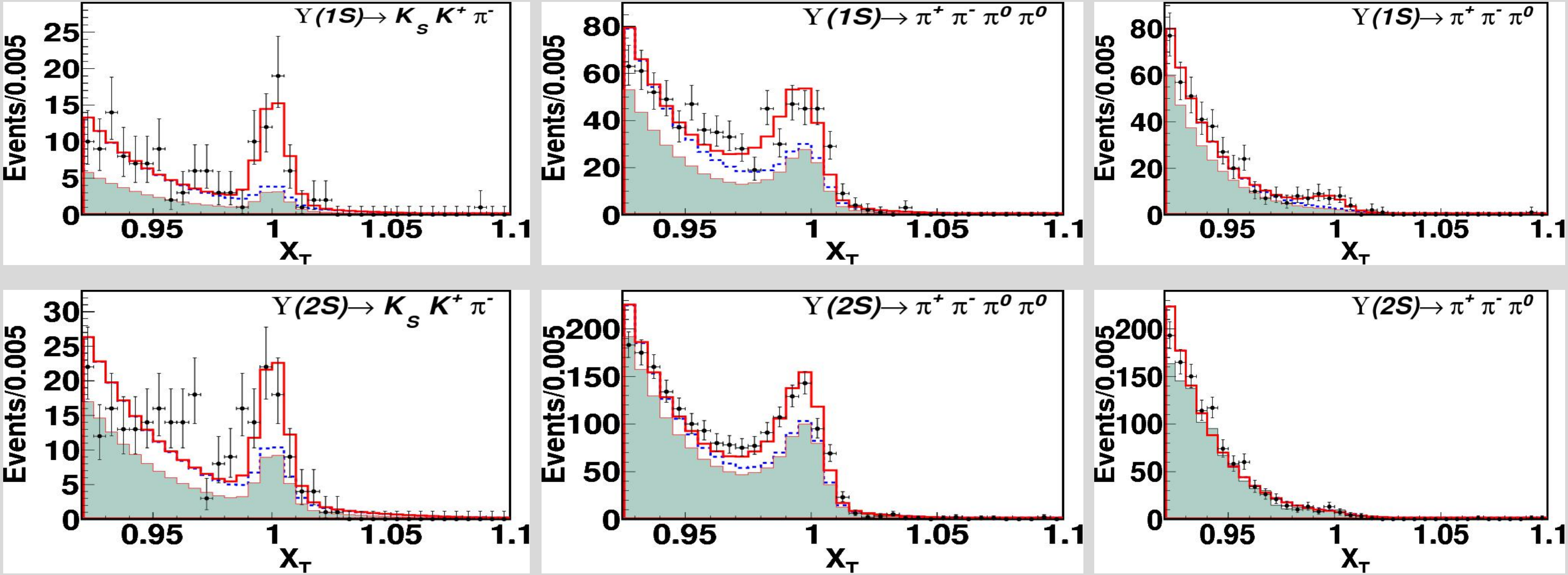
Υ(1S,2S) decays into light hadrons

Then the two-body intermediate vector-tensor(VT) and axial-vector-pseudoscaler(AP) processes are searched. Only in the VT $K^*(892)^0 \bar{K}^*_2(1430)^0$ mode, is there signal observed in Υ(1S) decay and evidence found in Υ(2S) decay; Among the AP modes only evidence is found for $\Upsilon(1S) \rightarrow K_1(1400)^+K^-$[6].



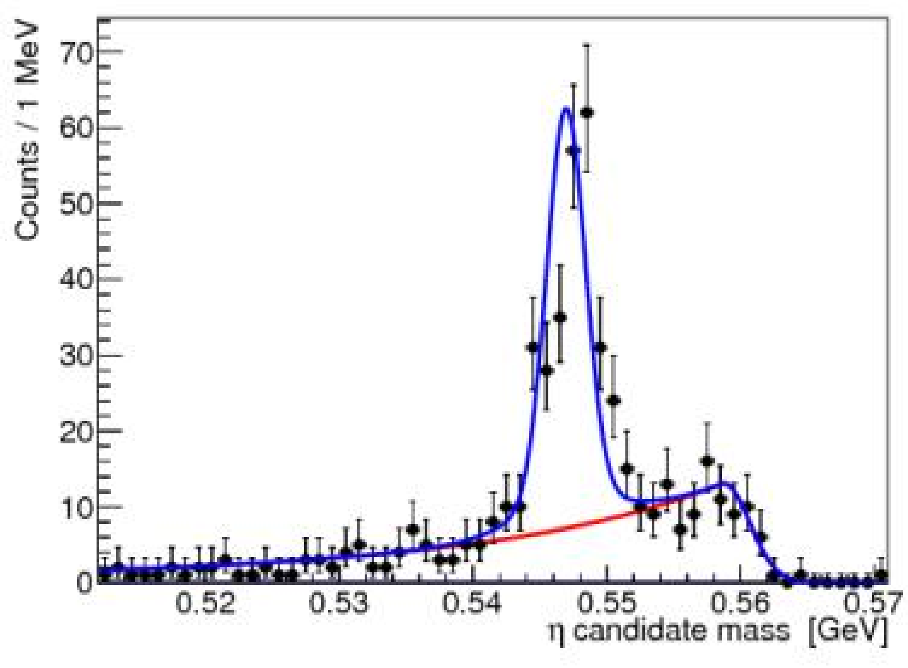
Υ(1S,2S) decays into light hadrons

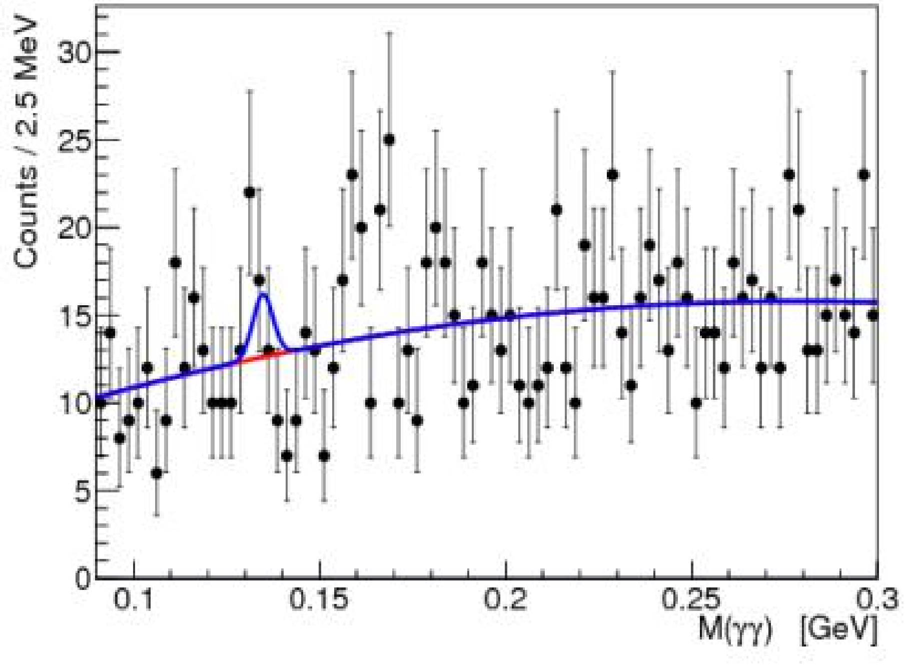
Some other light hadron final states, $K^0_S K^+ \pi^-$+ c.c., $\pi^+\pi^-\pi^0\pi^0$, and $\pi^+\pi^-\pi^0$, are also searched in Υ(1S/2S) exclusive decays. Distinct signals are first observed in $\Upsilon(1S) \rightarrow K^0_S K^+ \pi^-$+ c.c. and $\Upsilon(1S,2S) \rightarrow \pi^+\pi^-\pi^0\pi^0$, and evidence is found for $\Upsilon(1S) \rightarrow \pi^+\pi^-\pi^0$ and $\Upsilon(2S) \rightarrow K^0_S K^+ \pi^-$+ c.c.[7].



Hadronic transitions of $\Upsilon(2S)$ to $(\eta,\pi^0)\Upsilon(1S)$

The fitted signal yield results in $\mathcal{R}_{\eta,\pi^+\pi^-}=(1.99\pm0.14\pm0.11)\times10^{-3}$ which is about 14% below the value in Ref.[8] and 40% less than that predicted by scaling from the $\psi(2S)\to\eta J/\psi$ branching fraction[9]. A new measurement of $\mathcal{B}(\Upsilon(2S)\to\eta\Upsilon(1S))$ is obtained to be $(3.57\pm0.25(\text{stat.})\pm0.21(\text{syst.}))\times10^{-4}$, which is higher by about two standard deviations and more precise than those obtained by BABAR[10] and CLEO[11]. No clear evidence for a π^0 signal is found in either of the $\Upsilon(1S)\to l^+l^-$ mode. Thus an upper limit for the $\mathcal{R}_{\pi^0,\pi^+\pi^-}$ is determined to be $<2.3\times10^{-4}$ which is a factor of four more stringent than that by CLEO[11], and results in the upper limit of $\mathcal{B}(\Upsilon(2S)\to\pi^0\Upsilon(1S))<4.1\times10^{-5}$(90% C.L.)[12].





[8] M. Voloshin, Charmonium, Prog. Part. Nucl. Phys. 61, 455 (2008).

[9] Y.-P. Kuang, QCD multipole expansion and hadronic transitions in heavy quarkonium systems, Front. Phys. China 1 (2006) 19.

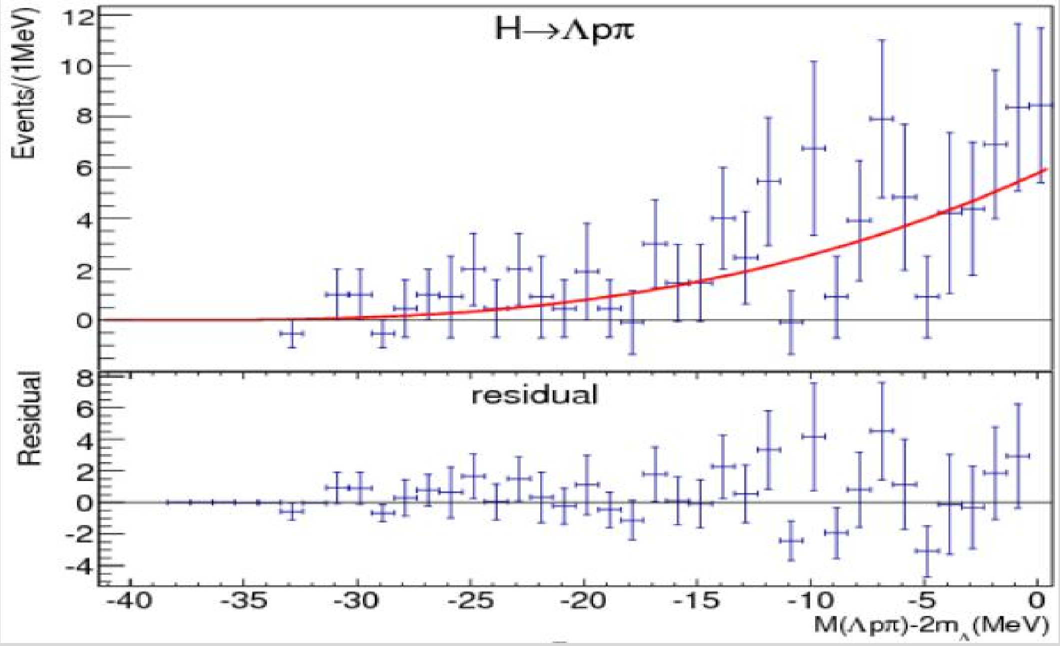
[10] J. P. Lees, et al., Study of $\Upsilon(3S, 2S)\to\eta\Upsilon(1S)$ and $\Upsilon(3S, 2S)\to\pi^+\pi^-\Upsilon(1S)$ hadronic transitions, Phys. Rev. D 84 (2011) 092003.

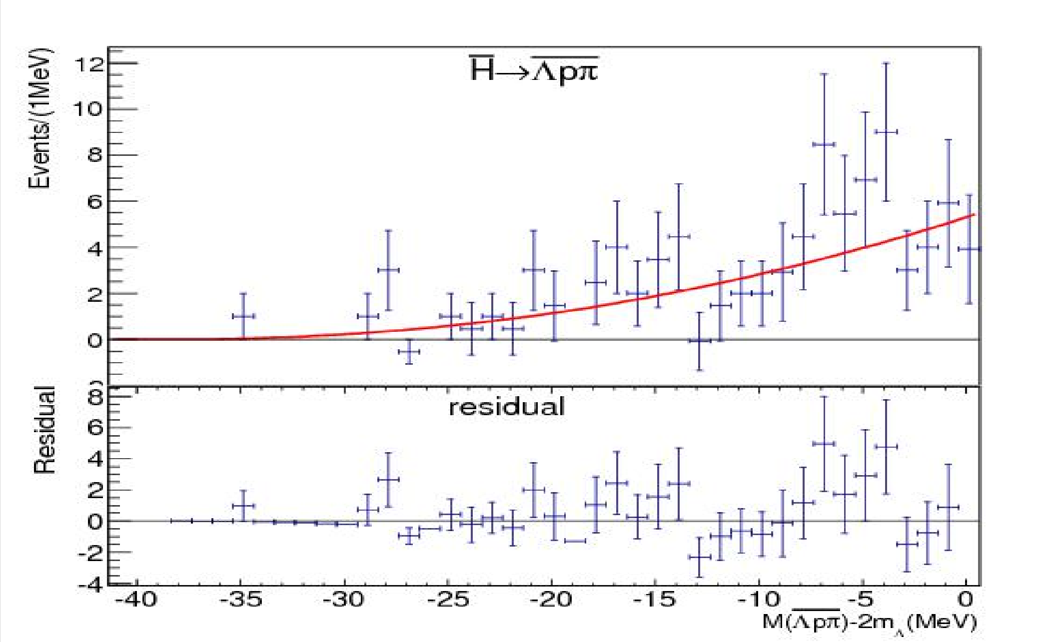
[11] Q. He, et al., Observation of $\Upsilon(2S)\to\eta\Upsilon(1S)$ and search for related transitions, Phys. Rev. Lett. 101 (2008) 192001.

Search for an H-Dibaryon in Υ(1S,2S) Decays

H dibaryon[13]: a doubly strange, six-quark structure (**uudds**s) with quantum numbers I =0 and $J^{PC}=0^{++}$ and a mass that is ≈ 80 MeV below the $2m_\Lambda$ threshold.

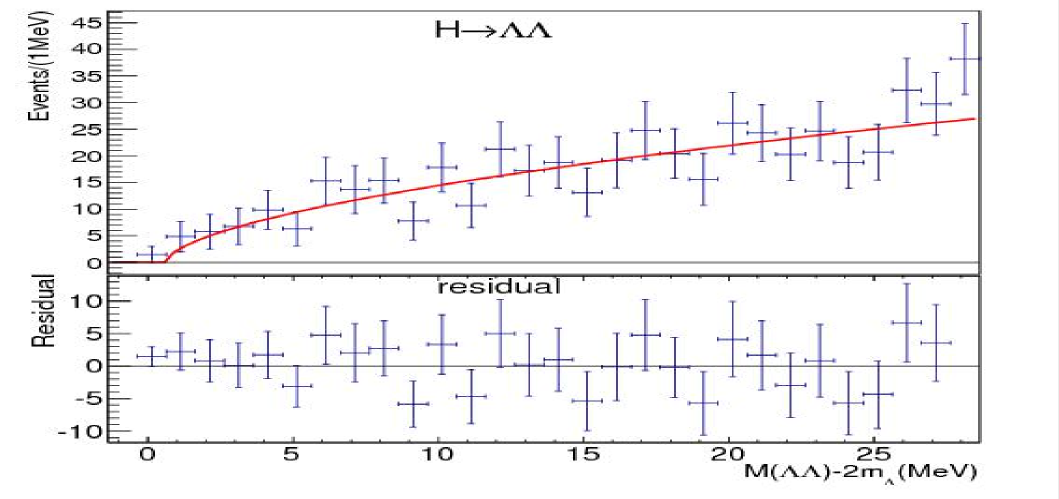
Here we report results of a search for H-dibaryon production in the inclusive processes Υ(1S, 2S)→H X; H → $\Lambda p \pi^-$ and $\Lambda\Lambda$. The resulting continuum-subtracted $M(\Lambda p \pi^-)$($M(\bar{\Lambda}\bar{p}\pi^+)$) distribution for the combined Υ(1S) and Υ(2S) samples, shown in the below plots, has no evident H →$\Lambda p \pi^-$ ($\bar{H}$ → $\bar{\Lambda}\bar{p}\pi^+$) signal. The curve in the figure is the result of a fit using an ARGUS-like threshold function to model the background ; fit residuals are also shown[14].

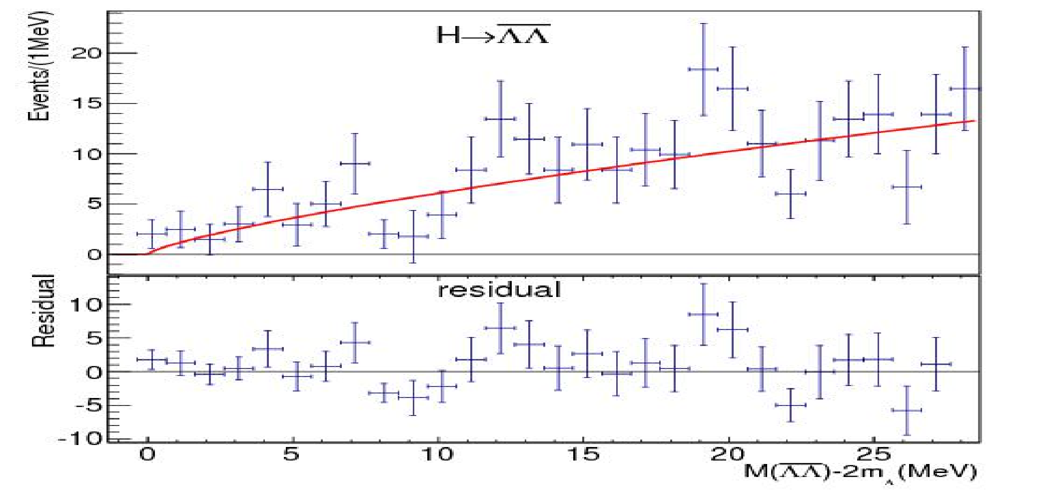




Search for an H-Dibaryon in Υ(1S,2S) Decays

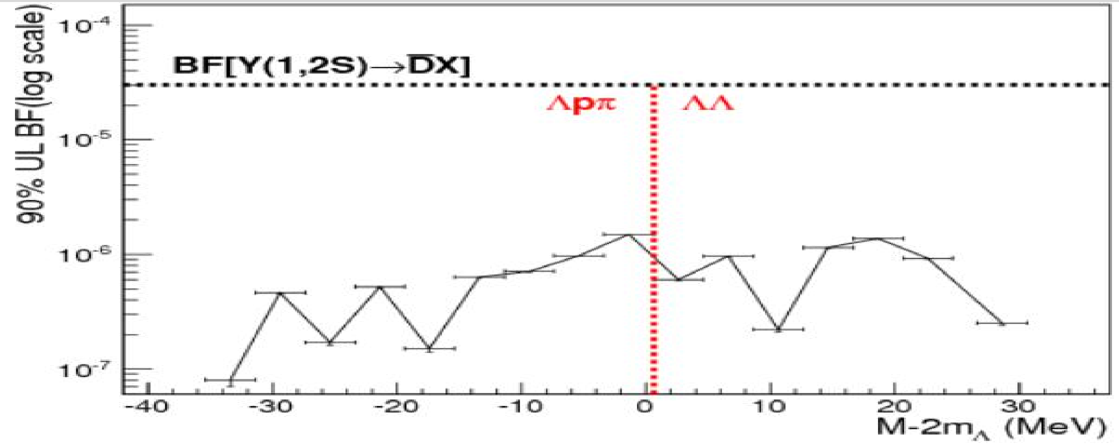
The continuum-subtracted M($\Lambda\Lambda$) (M($\bar{\Lambda}\bar{\Lambda}$)) distribution for events is shown in the below plots where there is no any other evident signal for H $\to\Lambda\Lambda$ ($\bar{\text{H}}\to\bar{\Lambda}\bar{\Lambda}$)[14].





90% CL upper limits on the braching fractions are obtained.

$$B(\Upsilon(1S,2S)\to H\ X)\bullet B(H\to f_i) < \frac{1}{2N_{\Upsilon}(B_{\Lambda\to p\pi^-})^i}\frac{N_i^{UL}(M_H)}{\varepsilon_i}$$



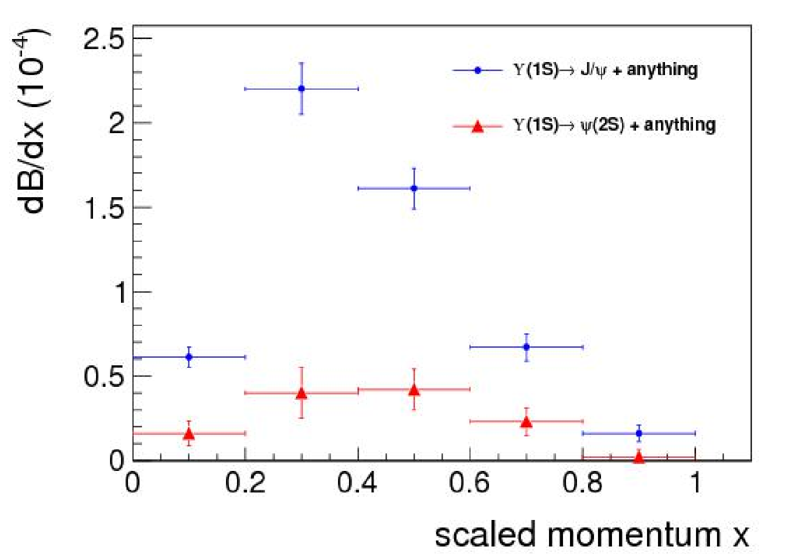
$\Upsilon(1S)$ inclusive decays into J/ψ or $\psi(2S)$

We divide the data samples into segments on the basis of the scaled momentum, x, that is defined as[15]:

$$x = p_{\psi}^{*} / (\frac{1}{2\sqrt{s}} \times (s - m_{\psi}^{2})), \quad \psi \text{ represents } J/\psi(\psi(2S))$$

x	$\Upsilon(1S) \to J/\psi$ + anything $N_{\rm fit}$	$\varepsilon(\%)$	$\sigma_{\rm syst}(\%)$	$\mathcal{B}(10^{-4})$	$\Upsilon(1S) \to \psi(2S)$ + anything $N_{\rm fit}$	$\varepsilon(\%)$	$\sigma_{\rm syst}(\%)$	$\mathcal{B}(10^{-4})$
(0.0, 0.2)	379.3±28.1	6.06	4.3	$0.61 \pm 0.05 \pm 0.03$	30.1±10.5	1.81	21.8	$0.16 \pm 0.06 \pm 0.04$
(0.2, 0.4)	1297.6±48.6	5.78	5.4	$2.20 \pm 0.08 \pm 0.12$	71.3±18.3	1.76	26.5	$0.40 \pm 0.10 \pm 0.11$
(0.4, 0.6)	904.6±41.6	5.51	5.6	$1.61 \pm 0.07 \pm 0.09$	71.5±15.4	1.68	18.6	$0.42 \pm 0.09 \pm 0.08$
(0.6, 0.8)	354.0±29.3	5.15	6.8	$0.67 \pm 0.06 \pm 0.05$	39.5±12.0	1.65	16.6	$0.23 \pm 0.07 \pm 0.04$
(0.8, 1.0)	54.2±13.4	3.36	7.6	$0.16 \pm 0.04 \pm 0.02$	2.5±5.7	1.40	78.4	$0.02 \pm 0.04 \pm 0.02$
Sum	2989.6±75.0	5.62	4.7	$\boxed{5.25 \pm 0.13 \pm 0.25}$	214.9±29.3	1.71	8.9	$\boxed{1.23 \pm 0.17 \pm 0.11}$

Differential branching fractions for $\Upsilon(1S)$ inclusive decays into the J/ψ and $\psi(2S)$ versus the scaled momentum x.



Our results have smaller central values and much better precision than the PDG averages[16]: $(6.5\pm0.7)\times10^{-4}$ and $(2.7\pm0.9)\times10^{-4}$.

[16] R. A. Briere, et al., (CLEO Collaboration), Phys. Rev. D 70, 072001 (2004).

XYZ states in $\Upsilon(1S)$ inclusive decays

- Distinct $J/\psi(\psi(2S))$ signals had been observed in $\Upsilon(1S)$ decays by CLEO[17] and Belle[18] Collaborations.

- Experimentally, most of XYZ states dominantly decay into the final states containing a charmonium and light hadrons[19].

- It is naturally to try to search for some XYZ states decaying into $J/\psi(\psi(2S))$ plus one or two $\pi^{\pm}/K^{\pm}$ mesons in $\Upsilon(1S)$ inclusive decays to supply for more information on the XYZ productions/decays.

- In our searches, 14 decay modes are considered: X(3872), Y(4260) in $\pi^+\pi^-J/\psi$; Y(4260), Y(4360),Y(4660) in $\pi^+\pi^-\psi(2S)$; Y(4260) in K^+K^-J/ψ; Y(4140), X(4350) in $\Phi J/\psi$ with $\Phi \to K^+K^-$, $Z_c(3900)^{\pm}$, $Z_c(3900)^{\pm}$, $Z_c(4330)^{\pm}$ in $\pi^{\pm}J/\psi$; $Z_c(4050)^{\pm}$, $Z_c(4430)^{\pm}$ in $\pi^{\pm}\psi(2S)$; $Z_{cs}^{\pm}$[20,21] with mass $(3.97\pm0,08)\,\mathrm{GeV}/c^2$ and width (24.9 ± 12.6) MeV in $K^{\pm}J/\psi$.

[17] R. A. Briere, et al., (CLEO Collaboration), Phys. Rev. D 70, 072001 (2004); [18] S. D. Yang, et al., (Belle Collaboration), Phys. Rev. D 90, 112008 (2014); [19] N. Brambilla, et al., Eur. Phys. J. C 74, 2981 (2014); [20] S. H. Lee, et al., J. Korean Phys. Soc. 55, 424 (2009); [21] J. M. Dias, et al., Phys. Rev. D 88, 096014 (2013).

XYZ states in $\Upsilon(1S)$ inclusive decays

No evident signal is found for any of XYZ and 90% C.L. upper limits are set on the product branching fractions[15].

State	$N_{\rm fit}$	$N_{\rm up}$	$\varepsilon(\%)$	$\sigma_{\rm syst}(\%)$	$\Sigma(\sigma)$	$\mathcal{B}_R$
$X(3872) \to \pi^+\pi^- J/\psi$	4.8±15.4	31.4	3.26	18.7	0.3	$< 9.5 \times 10^{-6}$
$Y(4260) \to \pi^+\pi^- J/\psi$	−31.1±88.9	134.6	3.50	35.6	–	$< 3.8 \times 10^{-5}$
$Y(4260) \to \pi^+\pi^- \psi(2S)$	6.7±29.4	56.9	0.71	35.0	0.2	$< 7.9 \times 10^{-5}$
$Y(4360) \to \pi^+\pi^- \psi(2S)$	−25.4±30.1	45.6	0.86	50.0	–	$< 5.2 \times 10^{-5}$
$Y(4660) \to \pi^+\pi^- \psi(2S)$	−55.0±26.2	23.1	1.06	40.7	–	$< 2.2 \times 10^{-5}$
$Y(4260) \to K^+K^- J/\psi$	−13.7±10.9	14.5	1.91	45.8	–	$< 7.5 \times 10^{-6}$
$Y(4140) \to \phi J/\psi$	−0.1±1.2	3.6	0.69	11.0	–	$< 5.2 \times 10^{-6}$
$X(4350) \to \phi J/\psi$	2.3±2.5	7.6	0.92	10.4	1.2	$< 8.1 \times 10^{-6}$
$Z_c(3900)^\pm \to \pi^\pm J/\psi$	−26.5±39.1	57.5	4.39	47.3	–	$< 1.3 \times 10^{-5}$
$Z_c(4200)^\pm \to \pi^\pm J/\psi$	−238.6±154.2	235.1	3.87	48.4	–	$< 6.0 \times 10^{-5}$
$Z_c(4430)^\pm \to \pi^\pm J/\psi$	94.2±71.4	195.8	3.97	34.4	1.2	$< 4.9 \times 10^{-5}$
$Z_c(4050)^\pm \to \pi^\pm \psi(2S)$	37.0±47.7	112.7	1.27	46.2	0.4	$< 8.8 \times 10^{-5}$
$Z_c(4430)^\pm \to \pi^\pm \psi(2S)$	23.2±42.4	92.0	1.35	47.1	0.1	$< 6.7 \times 10^{-5}$
$Z_{cs}^\pm \to K^\pm J/\psi$	−22.2±17.4	22.4	3.88	48.7	–	$< 5.7 \times 10^{-6}$

Study of $\chi_{bJ}(1P)$ Properties in the Radiative $\Upsilon(2S)$ Decays

We report a study of radiative decays of $\chi_{bJ}(1P)(J = 0, 1, 2)$ mesons into 74 hadronic final states comprising charged and neutral pions, kaons, protons; out of these, 41 modes are observed with at least 5 standard deviation significance. Our measurements not only improve the previous measurements by the CLEO Collaboration but also lead to first observations in many new modes[22].

Mode	$\chi_{b0}(1P)$ $\mathcal{B}$	σ	$\chi_{b1}(1P)$ $\mathcal{B}$	σ	$\chi_{b2}(1P)$ $\mathcal{B}$	σ
$2\pi^+2\pi^-$	$0.13 \pm 0.05 \pm 0.02$	3.0	$0.31 \pm 0.06 \pm 0.04$	6.8	$0.15 \pm 0.06 \pm 0.02$	3.1
$3\pi^+3\pi^-$	$0.67 \pm 0.08 \pm 0.06$	11.0	$1.84 \pm 0.12 \pm 0.16$	23.6	$0.96 \pm 0.10 \pm 0.10$	12.6
$4\pi^+4\pi^-$	$0.78 \pm 0.13 \pm 0.11$	8.5	$2.8 \pm 0.2 \pm 0.4$	22.5	$1.8 \pm 0.2 \pm 0.2$	14.6
$5\pi^+5\pi^-$	$0.53 \pm 0.14 \pm 0.10$	4.9	$1.5 \pm 0.2 \pm 0.3$	10.8	$1.7 \pm 0.2 \pm 0.3$	10.9
$\pi^+\pi^-K^+K^-$	$0.15 \pm 0.03 \pm 0.03$	8.1	$0.17 \pm 0.03 \pm 0.03$	8.6	$0.15 \pm 0.04 \pm 0.03$	6.3
$2\pi^+2\pi^-K^+K^-$	$0.53 \pm 0.08 \pm 0.05$	8.7	$1.20 \pm 0.11 \pm 0.10$	16.3	$0.8 \pm 0.10 \pm 0.08$	11.5
$3\pi^+3\pi^-K^+K^-$	$0.6 \pm 0.13 \pm 0.06$	5.8	$1.7 \pm 0.2 \pm 0.2$	13.7	$1.2 \pm 0.2 \pm 0.1$	9.8
$4\pi^+4\pi^-K^+K^-$	$1.2 \pm 0.2 \pm 0.2$	7.9	$1.6 \pm 0.2 \pm 0.2$	10.5	$1.6 \pm 0.2 \pm 0.2$	9.6
$\pi^+\pi^-2K^+2K^-$	$0.18 \pm 0.05 \pm 0.02$	5.4	$0.35 \pm 0.06 \pm 0.03$	8.6	$0.32 \pm 0.07 \pm 0.03$	7.4
$2\pi^+2\pi^-2K^+2K^-$	$0.33 \pm 0.12 \pm 0.03$	4.4	$0.60 \pm 0.12 \pm 0.06$	7.8	$0.56 \pm 0.12 \pm 0.06$	7.2
$3\pi^+3\pi^-2K^+2K^-$	$0.33 \pm 0.12 \pm 0.04$	3.8	$0.42 \pm 0.14 \pm 0.06$	4.5	$0.7 \pm 0.2 \pm 0.1$	6.2
$2\pi^+2\pi^-p\bar{p}$	< 0.2	0.9	$0.51 \pm 0.08 \pm 0.06$	10.2	$0.16 \pm 0.06 \pm 0.03$	3.5
$3\pi^+3\pi^-p\bar{p}$	$0.23 \pm 0.1 \pm 0.03$	3.1	$0.70 \pm 0.14 \pm 0.08$	7.8	$0.31 \pm 0.11 \pm 0.04$	3.6
$\pi^+\pi^-K^+K^-p\bar{p}$	$0.13 \pm 0.04 \pm 0.02$	4.2	$0.18 \pm 0.05 \pm 0.03$	5.7	$0.15 \pm 0.05 \pm 0.03$	3.7
$2\pi^+2\pi^-K^+K^-p\bar{p}$	$0.31 \pm 0.10 \pm 0.05$	4.5	$0.4 \pm 0.1 \pm 0.1$	6.3	$0.2 \pm 0.08 \pm 0.03$	3.4
$\pi^+\pi^-\pi^\pm K^\mp K_S^0$	< 0.1	0.0	$0.7 \pm 0.1 \pm 0.1$	12.9	$0.28 \pm 0.07 \pm 0.05$	5.0
$2\pi^+2\pi^-\pi^\pm K^\mp K_S^0$	< 0.4	2.2	$1.9 \pm 0.2 \pm 0.2$	13.9	$1.1 \pm 0.2 \pm 0.1$	8.5
$3\pi^+3\pi^-\pi^\pm K^\mp K_S^0$	< 0.7	2.1	$1.6 \pm 0.3 \pm 0.1$	8.9	$0.8 \pm 0.2 \pm 0.1$	4.3
$2\pi^+2\pi^-2K_S^0$	$0.2 \pm 0.08 \pm 0.04$	4.2	$0.28 \pm 0.08 \pm 0.03$	5.4	$0.29 \pm 0.09 \pm 0.03$	5.2
$3\pi^+3\pi^-2K_S^0$	< 0.6	2.2	$0.5 \pm 0.2 \pm 0.1$	5.0	$0.4 \pm 0.2 \pm 0.1$	3.8
$\pi^+\pi^-K^+K^-\pi^0$	< 0.2	0.7	$0.77 \pm 0.10 \pm 0.06$	10.7	$0.36 \pm 0.09 \pm 0.04$	5.2
$2\pi^+2\pi^-K^+K^-\pi^0$	$0.8 \pm 0.2 \pm 0.2$	4.5	$4.2 \pm 0.3 \pm 0.7$	18.3	$2.8 \pm 0.3 \pm 0.5$	11.8
$3\pi^+3\pi^-K^+K^-\pi^0$	$1.8 \pm 0.4 \pm 0.4$	5.2	$6 \pm 0.6 \pm 1.1$	14.5	$3.8 \pm 0.5 \pm 0.7$	9.0
$4\pi^+4\pi^-K^+K^-\pi^0$	< 1.7	1.4	$4 \pm 0.7 \pm 1.0$	7.8	$2.4 \pm 0.6 \pm 0.6$	4.4
$\pi^+\pi^-2K^+2K^-\pi^0$	$0.28 \pm 0.11 \pm 0.04$	3.2	$0.9 \pm 0.2 \pm 0.2$	7.9	$0.45 \pm 0.15 \pm 0.08$	3.9
$2\pi^+2\pi^-2K^+2K^-\pi^0$	$0.7 \pm 0.3 \pm 0.1$	3.2	$1.1 \pm 0.3 \pm 0.2$	5.0	$0.7 \pm 0.3 \pm 0.1$	3.5
$\pi^+\pi^-p\bar{p}\pi^0$	< 0.1	0.0	$0.24 \pm 0.07 \pm 0.04$	5.4	$0.14 \pm 0.06 \pm 0.02$	3.3
$\pi^+\pi^-K^+K^-p\bar{p}\pi^0$	< 0.5	2.8	$0.5 \pm 0.1 \pm 0.2$	5.5	$0.32 \pm 0.13 \pm 0.12$	3.3
$\pi^+\pi^-\pi^\pm K^\mp K_S^0\pi^0$	< 0.5	1.5	$2.2 \pm 0.3 \pm 0.2$	11.9	$1.2 \pm 0.2 \pm 0.2$	6.1
$2\pi^+2\pi^-\pi^\pm K^\mp K_S^0\pi^0$	$1.3 \pm 0.4 \pm 0.2$	3.8	$5.3 \pm 0.6 \pm 0.8$	12.1	$2.6 \pm 0.5 \pm 0.5$	6.1
$3\pi^+3\pi^-\pi^\pm K^\mp K_S^0\pi^0$	$2.4 \pm 0.7 \pm 0.5$	4.1	$4.6 \pm 0.8 \pm 1.0$	7.6	$2.9 \pm 0.7 \pm 0.6$	4.7
$2\pi^+2\pi^-2\pi^0$	$0.8 \pm 0.2 \pm 0.2$	3.9	$4.5 \pm 0.4 \pm 1$	16.9	$3.4 \pm 0.3 \pm 0.8$	12.5
$3\pi^+3\pi^-2\pi^0$	$3.6 \pm 0.6 \pm 0.5$	6.7	$16.8 \pm 0.9 \pm 2.3$	24.0	$9.7 \pm 0.9 \pm 1.5$	13.6
$4\pi^+4\pi^-2\pi^0$	$4.8 \pm 1 \pm 1.0$	5.3	$22.3 \pm 1.5 \pm 4.7$	19.6	$15.5 \pm 1.5 \pm 3.3$	13.3
$5\pi^+5\pi^-2\pi^0$	< 5.1	2.6	$10.8 \pm 1.6 \pm 2.4$	8.4	$11 \pm 1.9 \pm 2.5$	7.1
$\pi^+\pi^-K^+K^-2\pi^0$	$0.5 \pm 0.2 \pm 0.1$	3.3	$1.1 \pm 0.2 \pm 0.3$	7.0	$0.9 \pm 0.2 \pm 0.2$	5.4
$2\pi^+2\pi^-K^+K^-2\pi^0$	$1.7 \pm 0.5 \pm 0.4$	3.9	$4.9 \pm 0.6 \pm 1.1$	10.0	$3.5 \pm 0.6 \pm 0.8$	6.8
$3\pi^+3\pi^-K^+K^-2\pi^0$	$3.2 \pm 1 \pm 0.8$	3.6	$8.9 \pm 1.2 \pm 2.2$	9.4	$6.4 \pm 1.2 \pm 1.6$	6.3
$2\pi^+2\pi^-p\bar{p}2\pi^0$	< 1.8	2.7	$1.8 \pm 0.5 \pm 0.3$	5.0	$1.6 \pm 0.5 \pm 0.3$	4.4
$\pi^+\pi^-\pi^\pm K^\mp K_S^0 2\pi^0$	$2.0 \pm 0.5 \pm 0.3$	5.1	$3.6 \pm 0.5 \pm 0.4$	8.6	$1.7 \pm 0.5 \pm 0.2$	4.2
$2\pi^+2\pi^-\pi^\pm K^\mp K_S^0 2\pi^0$	$3.0 \pm 1.0 \pm 0.6$	3.5	$9 \pm 1.3 \pm 1.7$	9.1	$5.1 \pm 1.2 \pm 1.0$	5.1

Υ(1S,2S,3S) physics at Belle II

- Quarkonium and exotic physics questions will be addressed with extended run periods at Υ(nS) (n=1~6) and fine energy scans in intermediate regions[23].
- Data taken at the Υ(3S)[23]
  - 200fb^{-1}, 600M Υ(3S) event (~7×BABAR)
  - Golden channels: Υ(3S) decays including Υ(1D), Υ(2D) , η_b(1S,2S,3S), χ_{bJ}(1P,2P,3P), h_b(1P,2P,3P); Hadronic ($\pi\pi$, π^0, η) decays; Radiative transitions, etc.
  - Search for invisible decays of the light Higgs A^0, $\Upsilon(3S) \to \gamma A^0$, $A^0 \to$ invisible.
  - Model with a Dark sector (dark photons, light fermionic dark matter).
- Invisible decays of Υ(1S) can be used to probe new physics(NP) or to measure $\Upsilon(1S) \to \nu\bar{\nu}$ [23]:
  - Low mass dark matter particles however might play a role in the decays of Υ(1S), having $\Upsilon(1S) \to$ invisible if kinematic allowed[24].
  - New mediators (Z',A^0,h^0) or SUSY particles might enhance $\Upsilon(1S) \to \nu\bar{\nu}(\gamma)$[25].
  - In absence of new physics enhancement, Belle II should be able to observe the standard model(SM) $\Upsilon(1S) \to \nu\bar{\nu}$.

Conclusion and Summary

- Several studies on Υ(1S,2S) decays have been performed including Υ(1S,2S) decays into Charmonium or light hadrons, Υ(2S) hadronic transitions, searching for an H-Dibaryon and XYZ states in Υ(1S,2S) Decays and χ_{bJ}(1P) Properties in the Radiative Υ(2S) Decays.

- Our results are consistent with calculations using theoretical models and more precise than that by other experiments. And we provide more precise results in searching for new physics containing H-Dibaryon and XYZ states.

- It is anticipated that in the end of 2017 of data taking as many as 100 million Υ(3S) mesons will be produced on resonance, for searches of radiative Υ transitions to DM. With a total of 200fb^{-1}, 600M Υ(3S) events, we will study in a wide range of areas in quarkonium and exotic physics. In addition, more golden model await us is going to be research.

Acknowledgement

[1] C. P. Shen, et al., Search for charmonium and charmoniumlike states in Υ(1S) radiative decays, Phys. Rev. D 82 (2010) 051504.

[2] X. L. Wang, et al., Search for charmonium and charmoniumlike states in Υ(2S) radiative decays, Phys. Rev. D 84 (2011) 071107.

[3] S. D. Yang, et al., Evidence of $\Upsilon(1S) \to J/\psi + \chi_{c1}$ and search for double-charmonium production in Υ(1S) and Υ(2S) decays, Phys. Rev. D 90 (2014) 112008.

[4] Y. Jia, Exclusive double charmonium production from Υ decay, Phys. Rev. D 76 (2007) 074007.

[5] J. Xu, et al., Exclusive decay of Υ into $J/\psi + \chi_{c0,1,2}$, Phys. Rev. D 87 (2013) 094004.

[6] C. P. Shen, et al., Observation of exclusive Υ(1S) and Υ(2S) decays into light hadrons, Phys. Rev. D 86 (2012) 031102.

[7] C. P. Shen, et al., Measurement of exclusive Υ(1S) and Υ(2S) decays into vector-pseudoscalar final states, Phys. Rev. D 88(2013) 011102.

[12] U. Tamponi, et al., Study of the hadronic transitions $\Upsilon(2S) \to (\eta, \pi^0)\Upsilon(1S)$ at Belle, Phys. Rev. D 87 (2013) 011104.

[14] B.H. Kim, et al., Search for an H-dibaryon with mass near $2m_\Lambda$ in Υ(1S) and Υ(2S) decays, Phys.Rev.Lett. 110 (2013) 222002.

[15] C. P. Shen, et al., Search for XYZ states in Υ(1S) inclusive decays, Phys. Rev. D 93 (2016) 112013.

[22] A. Abdesselam, et al., Study of χ_{bJ}(1P) Properties in the Radiative Υ(2S) decay, arXiv:1606.01276.

[23] The Physics Prospects for Belle II, The Belle II collaboration and B2TiP theory community.

Thanks for your attention !