Study of charmonium(-like) states at the Belle experiment

> Changzheng YUAN (苑长征) (for part of the IHEP group)

> > IHEP, Beijing Apr. 8, 2009

Outline

- Introduction
- What have been achieved
 - $-e^+e^- \rightarrow \pi^+\pi^- J/\psi$

 - $-e^+e^- \rightarrow \phi \pi^+ \pi^-$
 - [discovery of the Y(4008)] $-e^+e^- \rightarrow \pi^+\pi^- \psi(2S)$ [discovery of the Y(4660)] [confirmation of the Y(2175)]
- Work in progress
 - $-e^+e^- \rightarrow \gamma \gamma J/\psi$

 - [search for new decay modes] $-e^+e^- \rightarrow K^+K^-\psi(2S)$ [search for new particles]
 - $-\Upsilon \rightarrow \gamma$ +charmonium [search for excited charmonia]
- Plan for the future

Onia and their properties

FORCES		System Ground triplet state 1 ³ S ₁			$(\pi \alpha)^2$	Number of states below dissociation energy			
binding	decay			Name	Г (MeV)	Mass (GeV)	(v/c)-	n ³ S ₁	all
POSITRONIUM									
EM	EM		e+e-	Ortho-	5 10 ⁻¹⁵	0.001	~0.0	2	8
QUARKONIUM									
	S		uu,dd	ρ	150.00	0.8	~1.0	0	0
S	T		SS	φ	4.40	1.0	~0.8	"1"	"2"
T R	R O	Е	cc	J /ψ	0.09	3.1	~0.25	2	8
O N	N G	M	bb	Y	0.05	9.5	~0.08	3	30
G	wea	ak	tt		(3000.0)	(360.)	<0.01	0	0



Quarkonium is the bound state of quark and anti-quark by the gluon.

Charmonium is charm anti-charm bound state!



R values/ excited ψ / Y particles



 e^{-}

4.7 GeV region is very limited. ISR data are free gift of B-factories!



Effective luminosity

One of the best ways of studying vectors below 5 GeV.

Even better than dedicated runs at each energy point.



$e^+e^- \rightarrow \psi(2S)$ as calibration signal

N ^{obs}	Lum (/fb)	Cross section (pb)
15,444	547.8	15.42±0.12±0.89



Belle: C.Z.Yuan & C.P. Shen et al., PRL99, 182004 (2007)

$e^+e^- \rightarrow \pi^+\pi^- J/\psi$ and $\pi^+\pi^-\psi(2S)$



Confirmed the Y(4260) and Y(4360), discovered two new structures: the Y(4008) and Y(4660) !

Citations > 120 in less than 2 years!

One of the hot topics in various international conferences and workshops!

C.Z. Yuan & C.P. Shen et al. PRL99, 182004 (2007) X.L.Wang & C.Z. Yuan et al., PRL99, 142002 (2007)

Strange version of the Y states?

C.P.Shen et al. arXiv:0808.0006



Agree with Babar's and BES's measurements
Width is larger than prev measurements → Y(2175) = excited φ remains a possibility
Y_s or excited ss state ?



🥝 Internet

From Belle home page:

discovery ofnew particles!

Charmonia? New spectroscopy?



What are they (+X(3872), Z(4430), XYZ(3930), ...)?

Charmonium? Hybrid? Tetraquark? Molecular? Hadro-charmonium?

Not all of them are charmonium states!

Analyses in progress

With ISR data:

- $e^+e^- \rightarrow \gamma \gamma J/\psi$

• $e^+e^- \rightarrow K^+K^-\psi(2S)$ [search for new particles] [new modes of Y decays]





The missing charmonium states



Still many charmonium states missing: Excited P-wave spin-triplet [only Z(3930) observed] Excited S-wave spin-singlet [only $\eta_c(2S)$ observed] And even more ...

Υ(nS) radiative decays



Calculations by K. T. Chao and his collaborators (Peking University): hep-ph/0701009.

process	$\Upsilon o \chi_{c2} \gamma$	$\Upsilon o \chi_{c1} \gamma$	$\Upsilon o \chi_{c0} \gamma$	$\Upsilon o \eta_c \gamma$
BR_{QCD}	5.1×10^{-6}	4.5×10^{-6}	4.0×10^{-6}	2.9×10^{-5}
$BR_{QCD+QED}$	5.6×10^{-6}	9.8×10^{-6}	3.2×10^{-6}	4.9×10^{-5}

BRs at O(10⁻⁶) are not small, N(Υ)~O(10⁸)

Calculations of $\Upsilon(nS) \rightarrow \gamma \chi_c(nP)$, $\gamma \eta_c(nS)$, and $\gamma X(3872)$ underway!

Υ(nS) data at Belle

	On Resonance (fb⁻¹)	Off Resonance (fb⁻¹)
Υ (1S)	5.7	1.7
Ƴ (2S)	6.7	0
Ƴ (3S)	2.9	0

Estimation:

- about 100M Y(1S) events
- about 50M Υ (2S) events
- about 10M Y(3S) events

Summary

- Belle supplies as a good place for charmonium study, an excellent extension of the BES charmonium physics
- New particles observed in Belle data by Chinese group
- More study underway in searching for new particles and new phenomena (ISR and bottomonium decays)
- JSPS support is important for a closer relationship between the experiment and physicists
- We are involved in SuperBelle project: contribute hardware and software, and share the data



Y(4260) in other experiments



$e^+e^- \rightarrow \pi^+\pi^-\psi(2S)$ via ISR at BaBar



BaBar: B. Aubert et al., PRL98, 212001 (2007)