Υ(nS,n≠4) Decays at B-Factories

on behalf of:

BELLE

Physics in Collisions, Kobe, 31/8/2009

Outline

Y(2,3S) transitions to parabottomonia

Y(1S), χ_b (1,2P) inclusive decays to open charm

Y(1S) decays to charmonia

χ_b (1,2P) exclusive decays to light hadrons

Y(5S) exclusive decays

Y(nS) radiative decays to light Higgs

Y(1S) decays to DM

LF violation in Y(nS) decays

Data samples

Non-Υ(4S) Data taken in 2008-9

BABAR:

- Jan-Feb 2008: 120 M Υ(3S) decays
- March 2008: 100 M Υ(2S) decays
- March 2008: 3.3 fb^{-1} scan from 10.54 to 11.2 GeV

BELLE:

- June 2008: 100 M Υ(1S) decays
- Sep-Nov 2008: 28 fb^{-1} at Υ(5S) peak
- Dec. 2008: 46 M Υ(2S) decays
- Apr-Jun 2009: 50 fb^{-1} at Υ(5S) peak

Overall summary on Υ(1,2,3,5S) samples (units 10^6 or fb^{-1}) :

	CLEO-III	BABAR_ISR(a)	BABAR	BELLE_ISR(b)	BELLE
1S	20	6.80	[19+5]	11.8	100[9]
2S	9	5.95	100	10.4	46
3S	6	10.0	120	17.4	11
5S	0.5/fb		3.3/fb		100/fb

(a) from 347.5/fb at Υ(4S)

(b) from 604.5/fb at Υ(4S)

* []= ππ tagged Υ(2,3S) decays

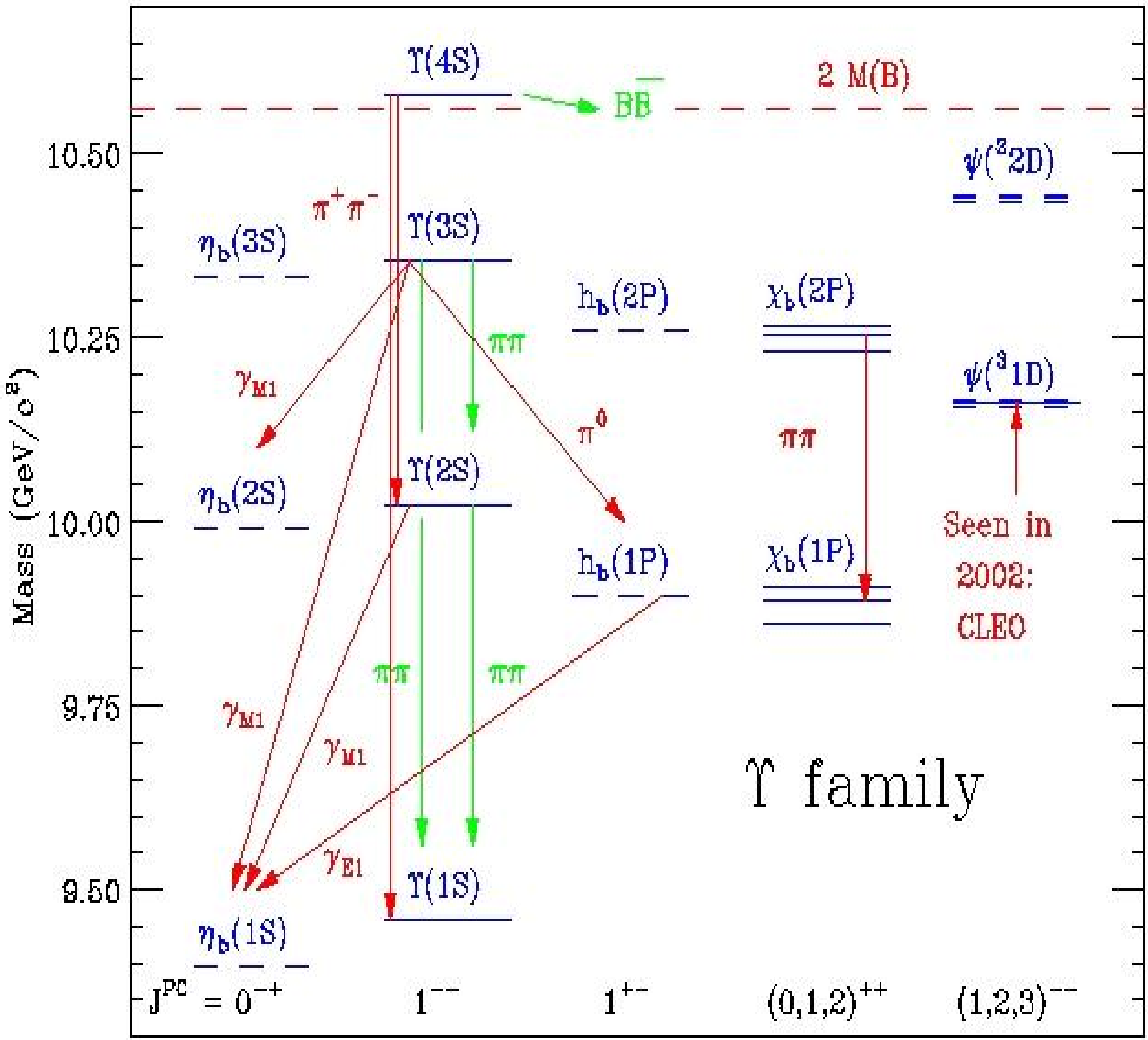
Bottomonium

What can B-factories do for bottomonium?

Action Items:

- find missing states below open bottom threshold:
  - 5 parabottomonia (in S,P wave)
  - Y(1,2D) states
- find bottomonium analogues of most recent charmonium discoveries:
  - X(3872)
  - Y(4260)

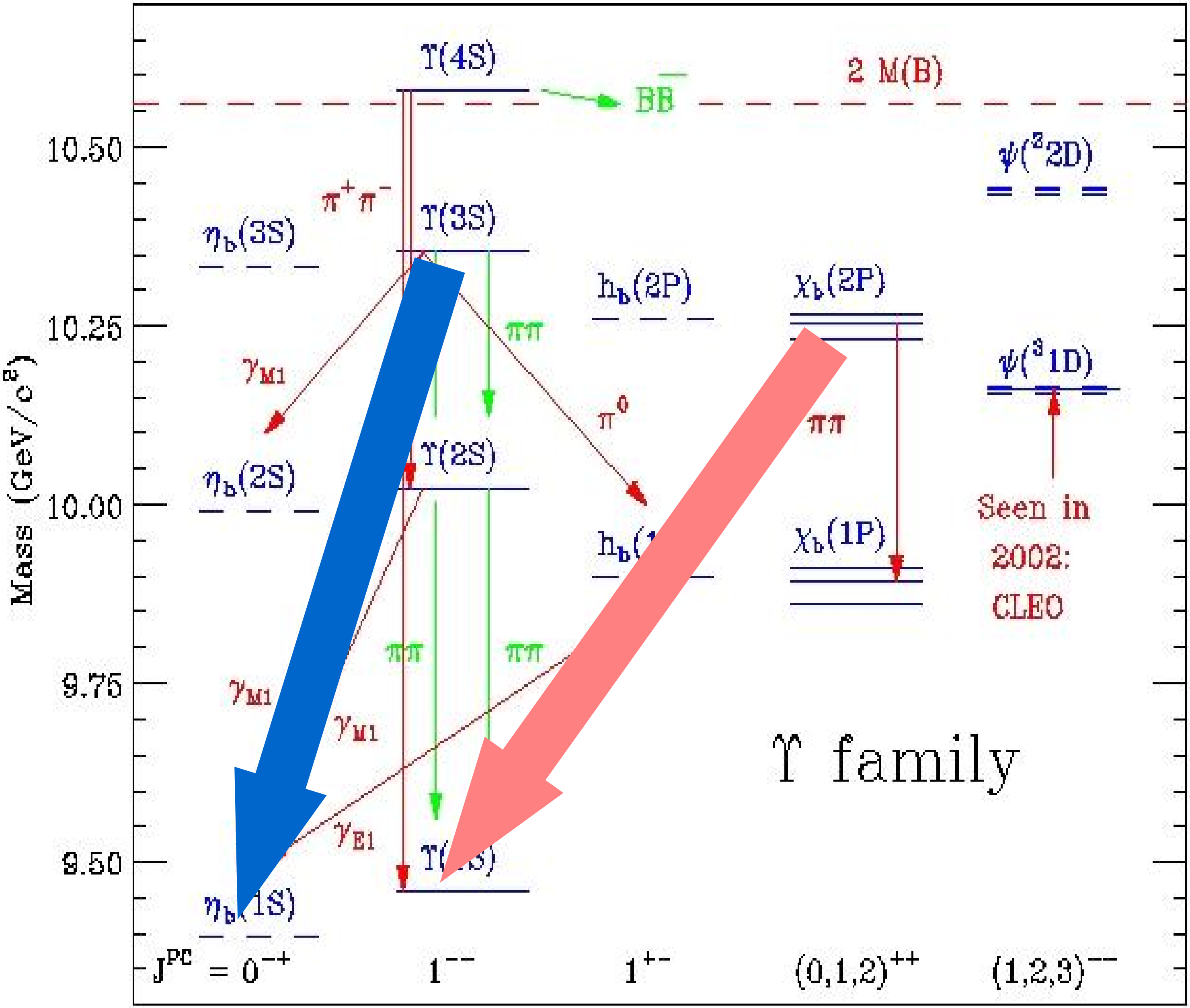
(see CZ Yuan talk tomorrow)



η_b(1S) searches in Y(3S) decays

Peak hunting between 890 and 950 MeV in the single photon inclusive spectrum at Y(3S) peak.

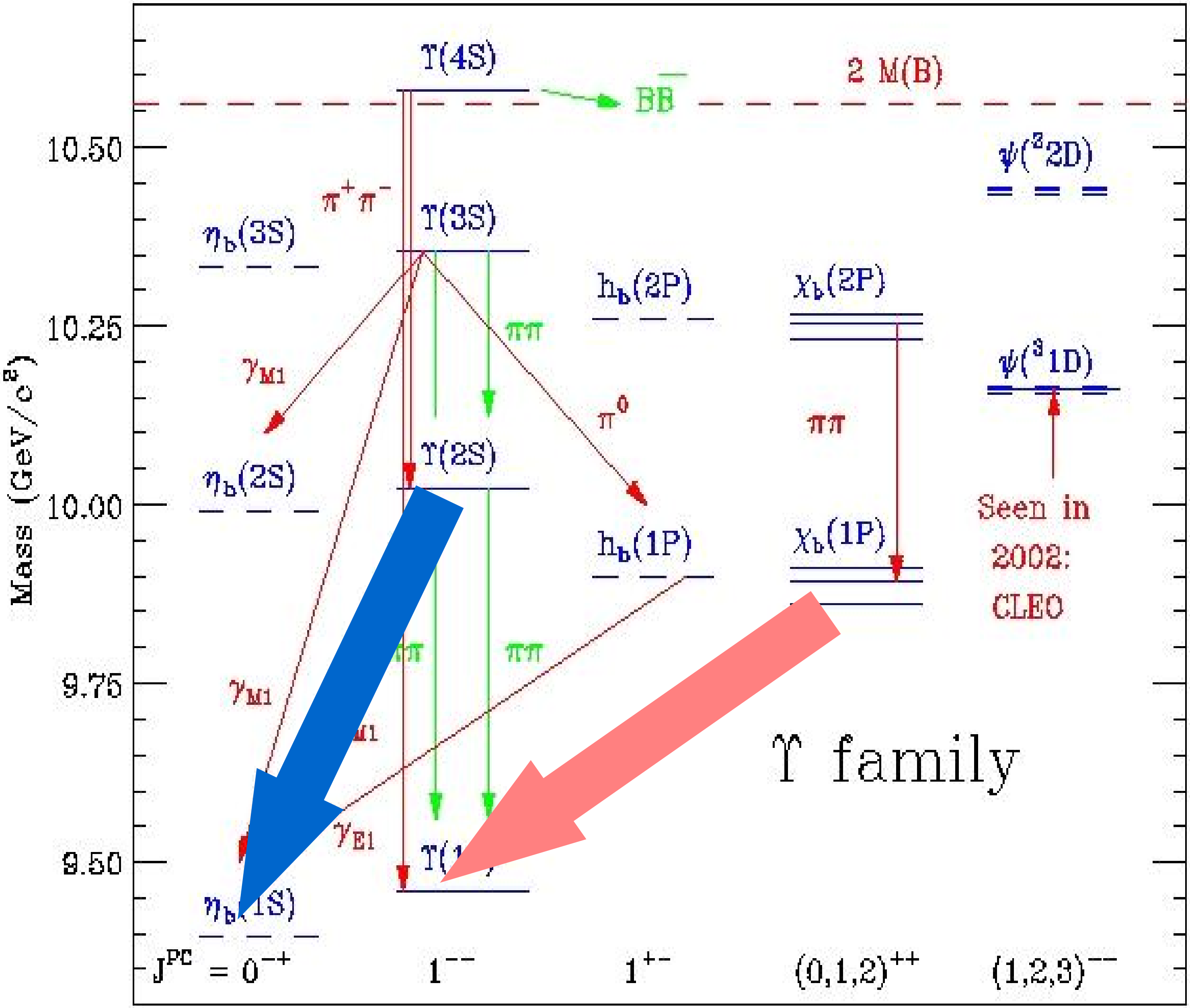
Challenge: huge background from single photons from continuum and other Y(nS) transitions



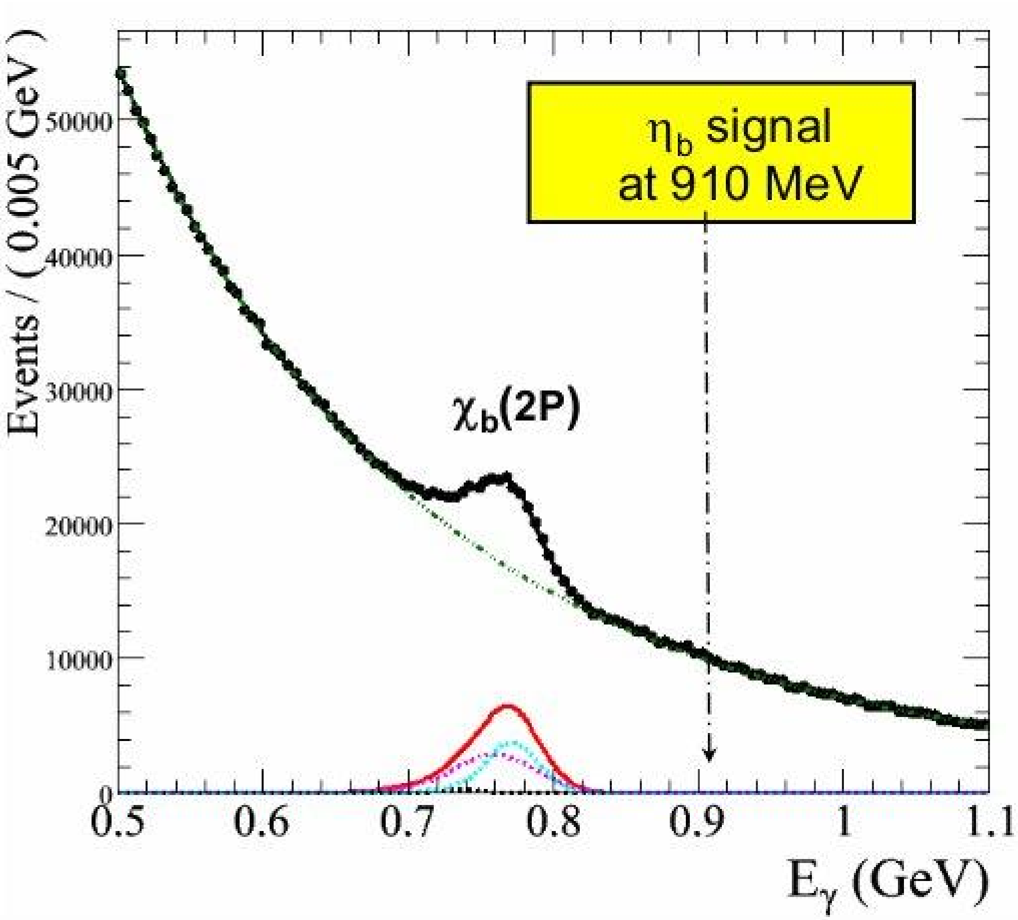
$\eta_b(1S)$ searches in Y(2S) decays

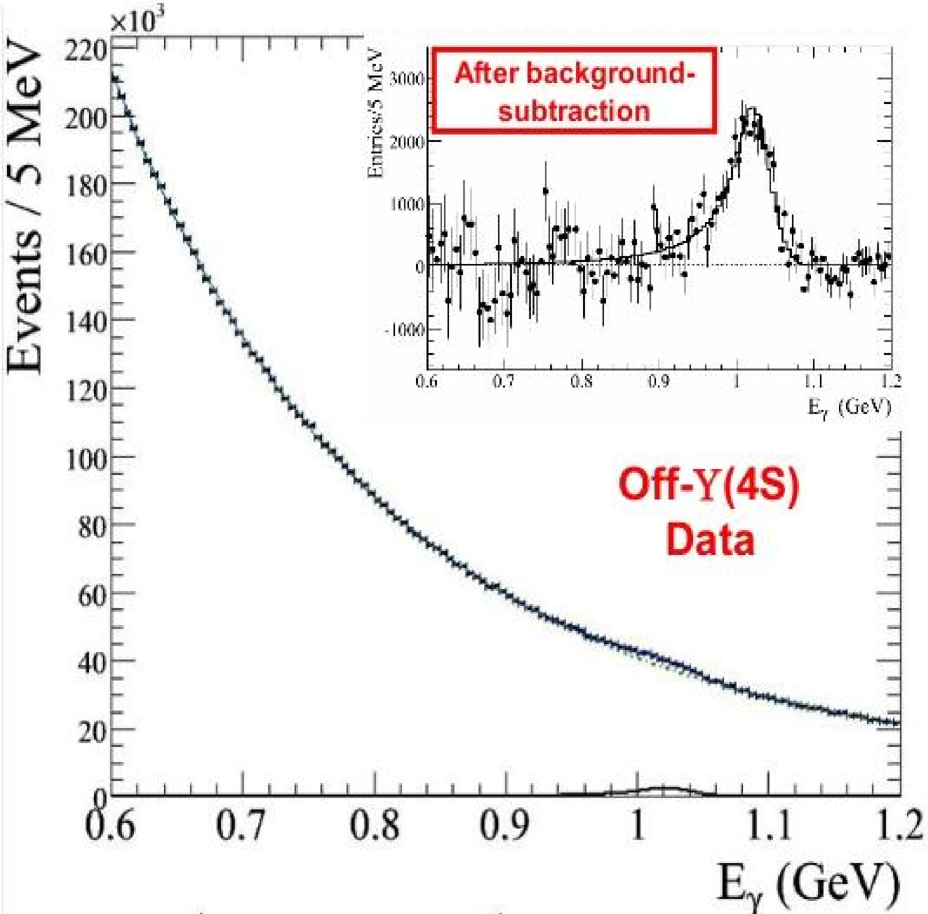
Peak hunting between 560 and 620 MeV in the single photon inclusive spectrum at Y(2S) peak.

Challenge: huge background from single photons from continuum and other Y(nS) transitions



Inclusive photon spectrum at Υ(3S)





Non peaking background fitted with 4 parameter function: $A\left(C + e^{-\alpha E_\gamma - \beta E_\gamma^2}\right)$

Peaking backgrounds:

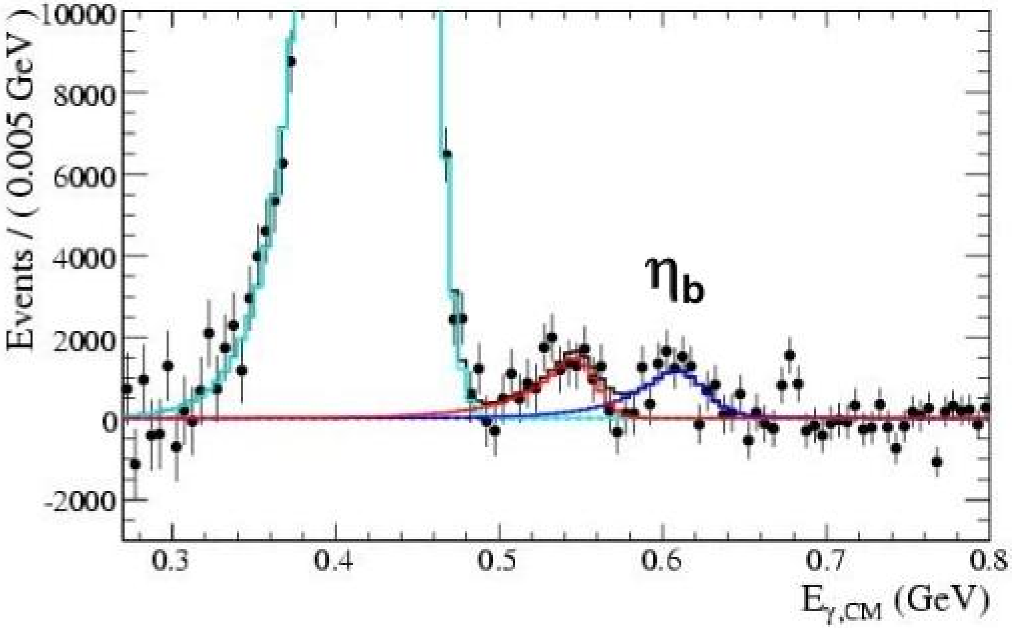
- on resonance: from Doppler broadened peaks from $\chi_{b1,2}$(2P) $\rightarrow\gamma$ Υ(1S) (764-777 MeV)
- Modeled with resolution function (from MC): Signal PDF: Crystal Ball Fcn ⊗ BreitWigner

- on continuum: from ISR formation of Υ(1S): $e^+e^- \rightarrow \gamma_{ISR} + \Upsilon(1S)$ (E=850 MeV at 3S)
- studied using 44 fb^{-1} at 10.54 GeV

BaBar results on $\Upsilon(2,3S) \to \gamma \eta_b(1S)$

$\Upsilon(2S) \to \gamma \eta_b$

[14.5 fb^{-1} = 100 M Y(2S), Mar.2008]



ArXiV:0903.1124

$$E_\gamma = 610.5^{+4.5}_{-4.3} \pm 1.8 \text{ MeV}$$

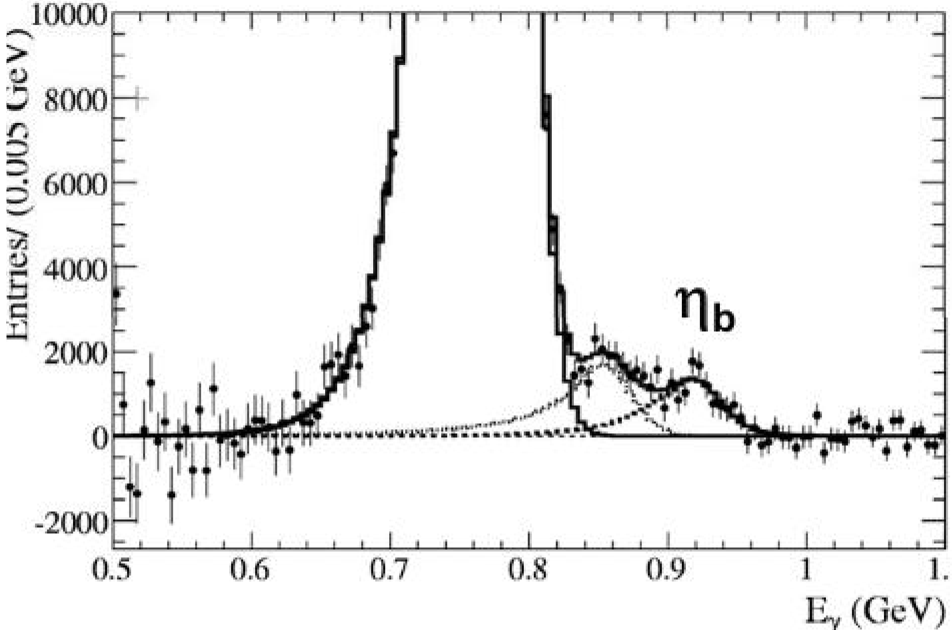
$$M(\eta_b) = 9392.9^{+4.6}_{-4.8} \pm 1.8 \text{ MeV}/c^2$$

$$M(\Upsilon(1S)) - M(\eta_b) = 67.4^{+4.8}_{-4.5} \pm 1.9 \text{ MeV}/c^2$$

$$B(\Upsilon(2S) \to \gamma\, \eta_b) = [4.2^{+1.1}_{-1.0} \pm 0.9] \times 10^{-4}$$

$\Upsilon(3S) \to \gamma \eta_b$

[30.2 fb^{-1} = 120 M Y(3S), Jan-Feb.2008]



PRL 101,071801(2008)

$$E_\gamma = 921.2^{+2.1}_{-2.8} \pm 2.4 \text{ MeV}$$

$$M(\eta_b) = 9388.9^{+3.1}_{-2.3} \pm 2.7 \text{ MeV}/c^2$$

$$M(\Upsilon(1S)) - M(\eta_b) = 71.4^{+2.3}_{-3.1} \pm 2.7 \text{ MeV}/c^2$$

$$B(\Upsilon(3S) \to \gamma\, \eta_b) = [4.8 \pm 0.5 \pm 1.2] \times 10^{-4}$$

Theory predictions

NRQCD:
NLL calculation of δM_{hf} :

δM_{hf}=39±10(th)±9($\delta\alpha_S$) MeV/c^2

Kniehl et al., PRL 92(2004),242001

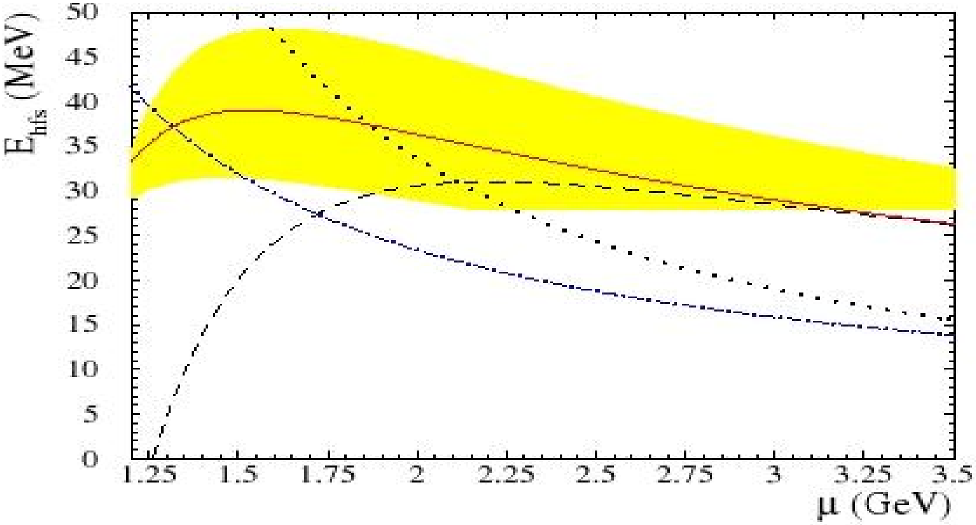


FIG. 1: HFS of 1S bottomonium as a function of the renormalization scale μ in the LO (dotted line), NLO (dashed line), LL (dot-dashed line), and NLL (solid line) approximations. For the NLL result, the band reflects the errors due to $\alpha_s(M_Z) = 0.118 \pm 0.003$.

Lattice QCD (δM_{hf} at LO)

M(Y1S)-M(η_b)=61±14 MeV/c^2

(th. error dominated by QCD radiative corrections)

Gray et al, PRD72(2005),094507

Experiment: (BABAR from Y3S)

$$E_{hfs}^{exp} = 71.4 \pm 2.7\,(\mathrm{syst})\,^{+2.3}_{-3.1}\,(\mathrm{stat})\ \mathrm{MeV}$$

Rel.Quark Model, LO pQCD:

δM_{hf}=60 MeV/c^2

Godfrey,Isgur, PRD32(1985),189

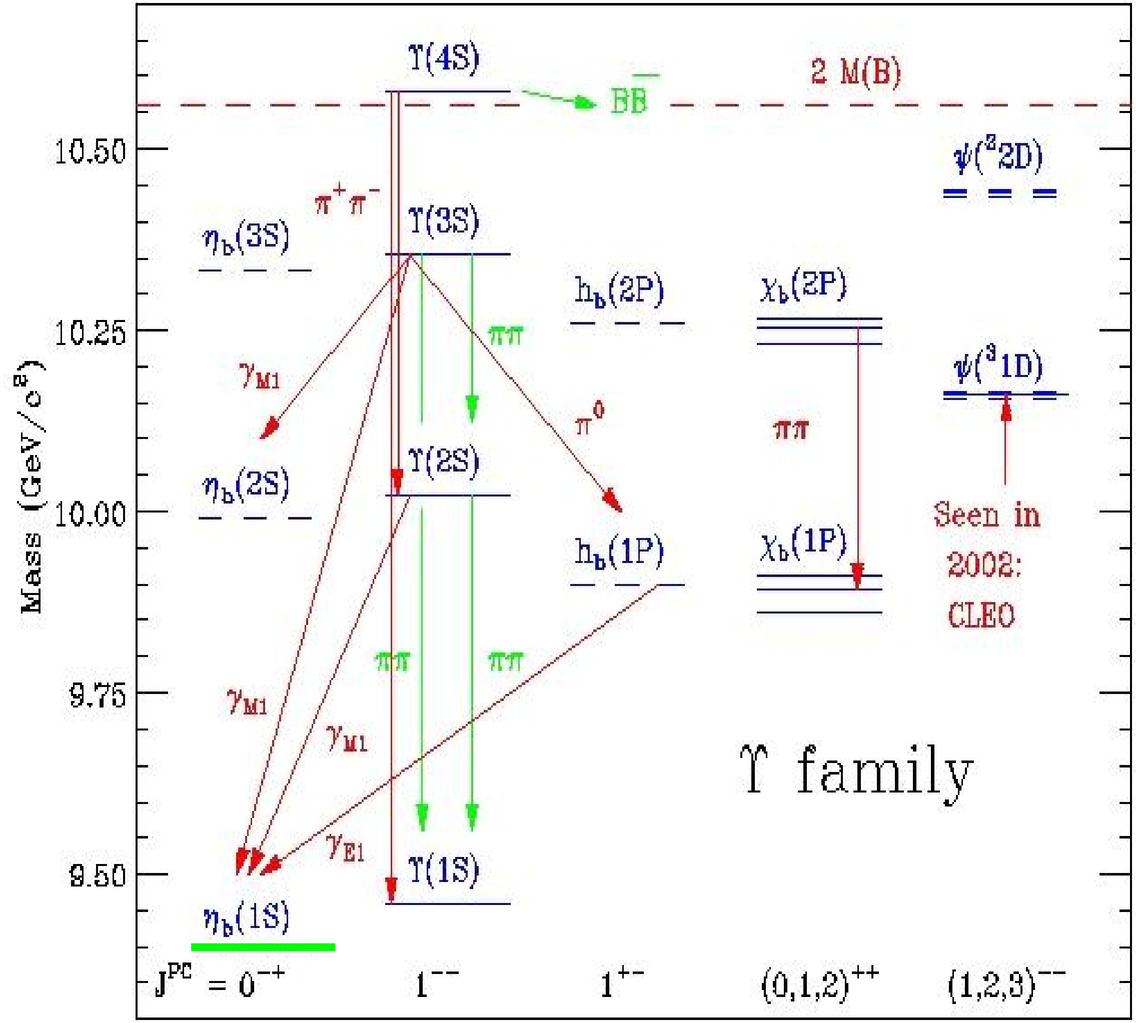
Further searches

The remaining 4 S=0 states:

- Search for $\eta_b(2S)$ from Y(3S)
- $Y(3S)\rightarrow\pi\, h_b(1P)\rightarrow\gamma\eta_b(1S)$
- $\eta_b(3S)$: exclusive modes?
- $h_b(2P)$: decays from Y(5,6S)?

Y(1D) states

Narrow states at thresholds?



Y(1,2,3S) decays : searches for

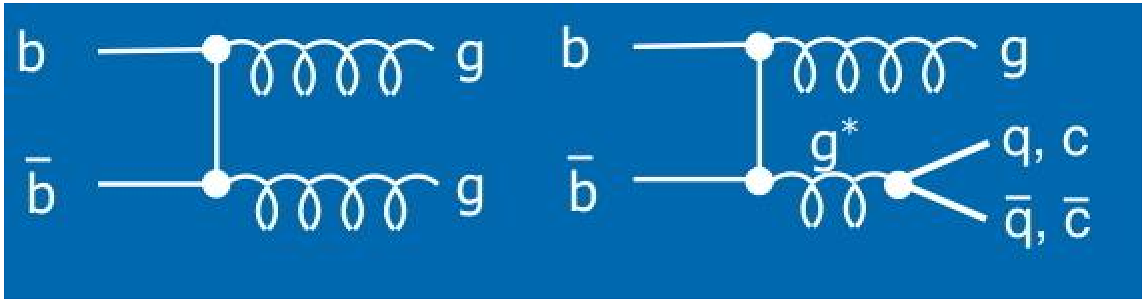
charmonia *[CLEO:PRD70(2004)072001]*

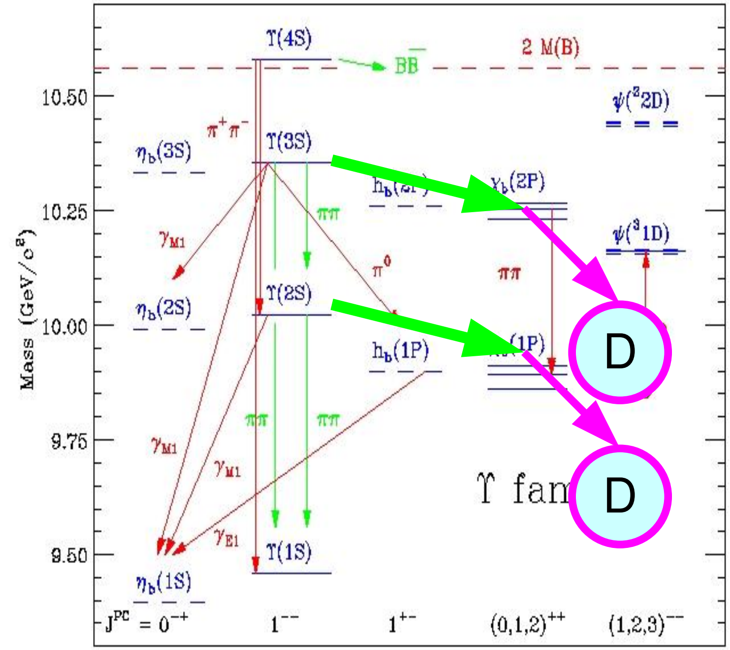
inclusive charm *[Cleo: PRD78:092007,2008,Babar: note 2234]*

exclusive decays *[Cleo: PRD78:091103,2008]*

nuclei *[CLEO:PRD75(2007)012009]*

Inclusive decay to charm mesons





Continuum e+e- → qq; charm favored by Q^2 term in Q

In Y(1S) → ggg → $D^{*\pm X}$ +X: severe charm suppression

[Argus: BR(Y(1S) → $D^{*\pm}$ + X)< 1.9%] *Z. Phys. C 55, 25 (1992)*

Early QCD calculations (Barbieri et al.) pointed out that :

$\chi_{b0,2}$: *dominant gg term suppresses charm*

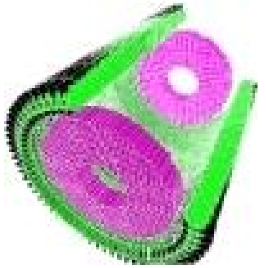
χ_{b1}: *dominant gqq term should favor flavor blindness*

NRQCD prediction:

R_j = $B(\chi_{bJ} \to gg,gqq \to ccX)/B(\chi_{bJ} \to gg,gqq)$ = 5, 23, 8%

Bodwin et al, PRD 51,1125(1995),PRD 55,5853E (1997),PRD 76,054001(2007)

Inclusive decay to charm mesons



Photon tagged inclusive $\chi_b(1,2P) \rightarrow D^0 + X$

If a D^0 is reconstructed in one of 3 decay modes:

$D^0 \rightarrow K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^-\pi^+\pi^+$ (BR=25%)

search for E1 peaks in photon spectrum, due to $Y(2,3S) \rightarrow \gamma\chi_b(1,2P)$ transition.

Cut on D momentum spectrum: $p(D^0) > 2.5$ GeV

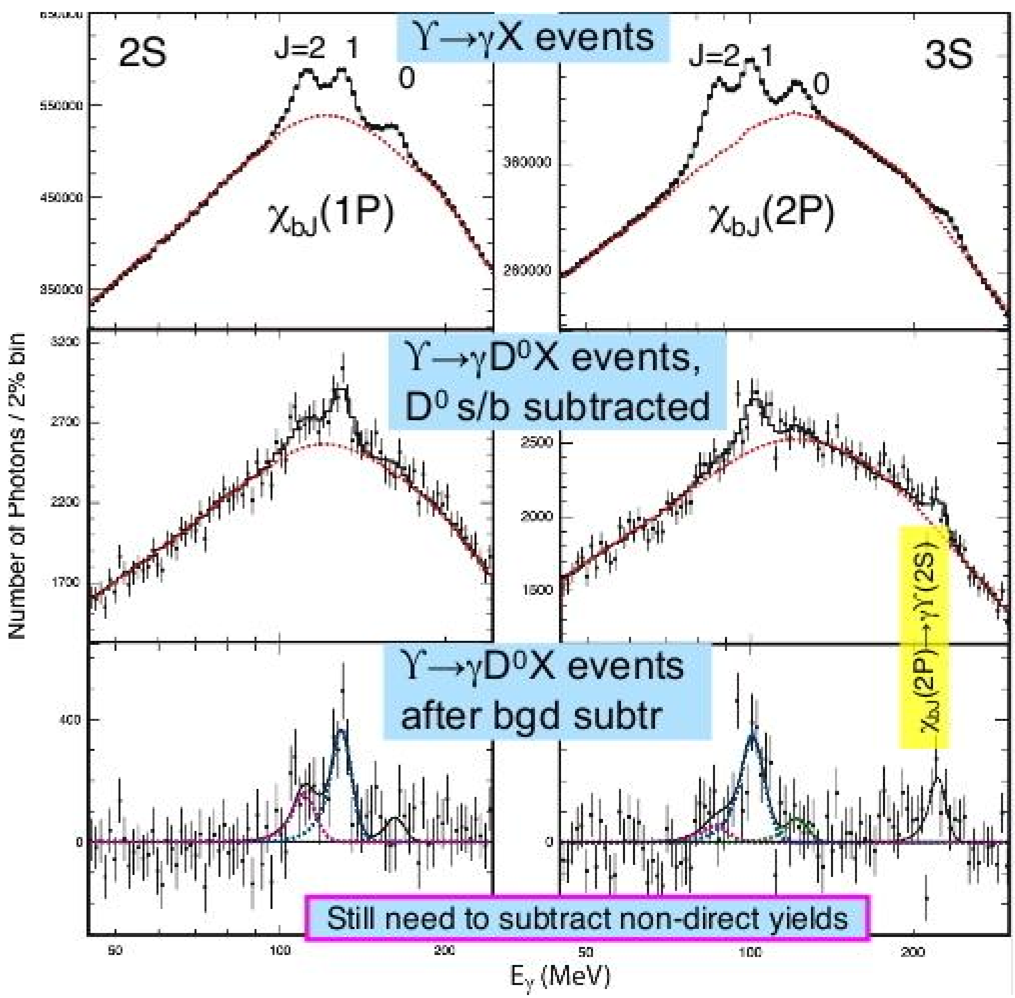
Possible contaminations from:

$Y(2,3S) \rightarrow D^0\pi^0 + X$

(veto γ from π^0's)

$Y(1S) \rightarrow D^0 + X$

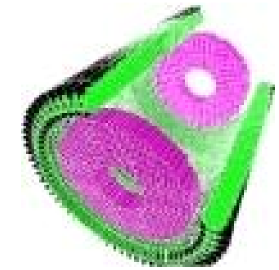
(subtracted from Y(1S) data)



CLEO-III *Phys.Rev.D78:092007,2008*

Inclusive decay to charm mesons

CLEO-III
Phys.Rev.D78:092007,2008



State	$\mathcal{B}(\chi_{bJ}(nP) \to gg, q\bar{q}g \to D^0X)$ (%)	90% CL UL (%)
$\chi_{b0}(1P)$	$5.6 \pm 3.6 \pm 0.5$	< 10.4
$\chi_{b1}(1P)$	$12.6 \pm 1.9 \pm 1.1$	
$\chi_{b2}(1P)$	$5.4 \pm 1.9 \pm 0.5$	< 7.9
$\chi_{b0}(2P)$	$4.1 \pm 3.0 \pm 0.4$	< 8.2
$\chi_{b1}(2P)$	$8.8 \pm 1.5 \pm 0.8$	
$\chi_{b2}(2P)$	$0.2 \pm 1.4 \pm 0.1$	< 2.4

State	R_j measurement	UL(90%CL)	NRQCD
$\chi_{b0}(1P)$	9.6±6.2±6.2±0.8	(<17.9)	6.3
$\chi_{b1}(1P)$	24.8±3.8±2.2±3.6		23.7
$\chi_{b2}(1P)$	9.8±3.5±0.9±0.9	(<14.6)	10.8
$\chi_{b0}(2P)$	8.7±6.4±0.9±0.7	(<17.7)	4.9
$\chi_{b1}(2P)$	25.3±4.3±2.5±2.4		22.1
$\chi_{b2}(2P)$	0.4±3.5±0.4±0.1	(<6.1)	7.4

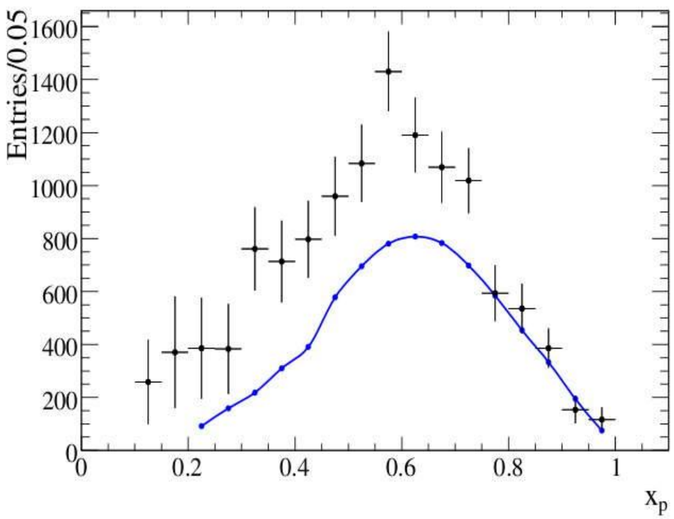
Good agreement with NRQCD predictions, at first order , for the χ_{bJ}(1,2P) states: what about Y(1S)?

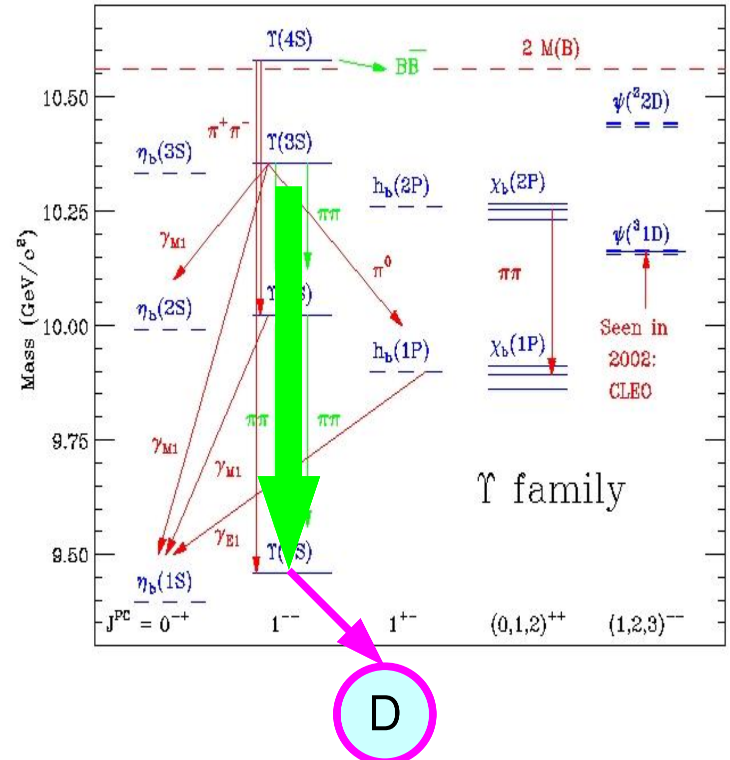
Inclusive decay to charm mesons

Babar: preliminary result

Dipion tagged inclusive $\Upsilon(1S) \rightarrow D^{*\pm} + X$ momentum spectrum

$D^* \rightarrow D^0 \pi$, $D^0 \rightarrow K\pi$

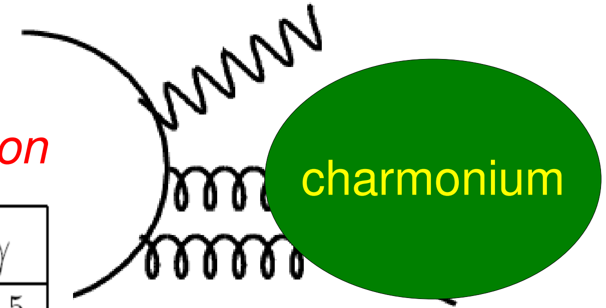




$$\mathcal{B}[\Upsilon(1S) \rightarrow D^{*\pm} + X] = \frac{N_{Sig}}{k_{DCS} \times \mathcal{B}_{decay} \times N_{\Upsilon(1S)}} =$$

$$(2.59 \pm 0.13(stat) \pm 0.15(syst))\% \qquad (6)$$

Υ(1s) decays to hidden charm



a) Radiative decay to charmonium: *BELLE results expected soon*

process	$\Upsilon \to \chi_{c2}\gamma$	$\Upsilon \to \chi_{c1}\gamma$	$\Upsilon \to \chi_{c0}\gamma$	$\Upsilon \to \eta_c\gamma$
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}

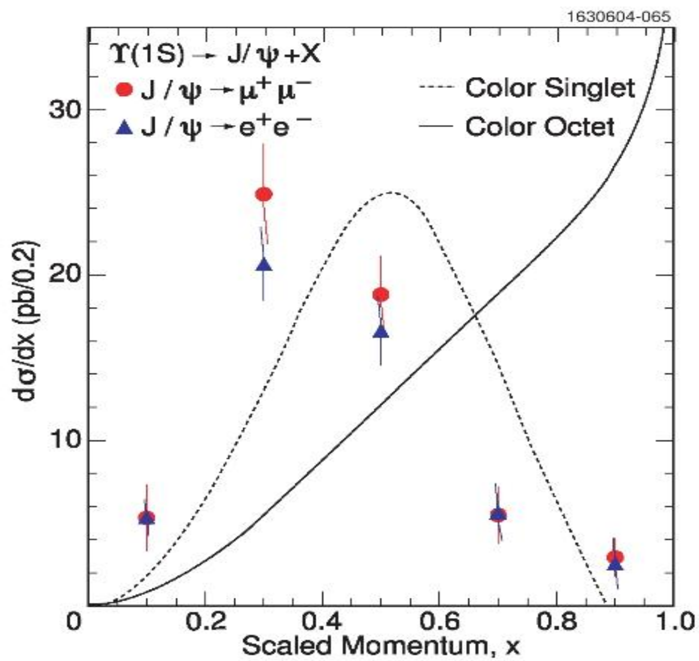
K. T. Chao et al., hep-ph/0701009.

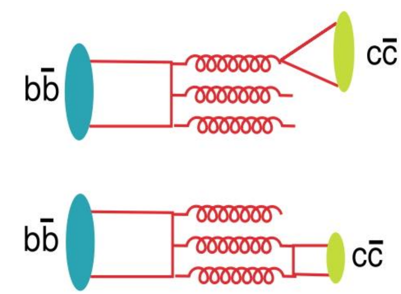
b) Strong decay to charmonium+X

CLEO result: PRD70(2004) 72001

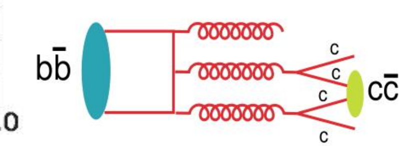
$B(\Upsilon(1S) \to J/\psi+X) = (6.4\pm0.4\pm0.6)10^{-4}$

f	B(f+X)/B(J/ψ+X)	Feeddown to J/ψ
ψ'	0.41±0.11±0.08	0.24±0.06±0.05
χ_{c1}	0.35±0.08±0.06	0.11±0.03±0.02
χ_{c2}	0.52±0.12±0.09	0.10±0.02±0.02





(a) Color-Octet Diagrams



(b) Color-Singlet Diagram

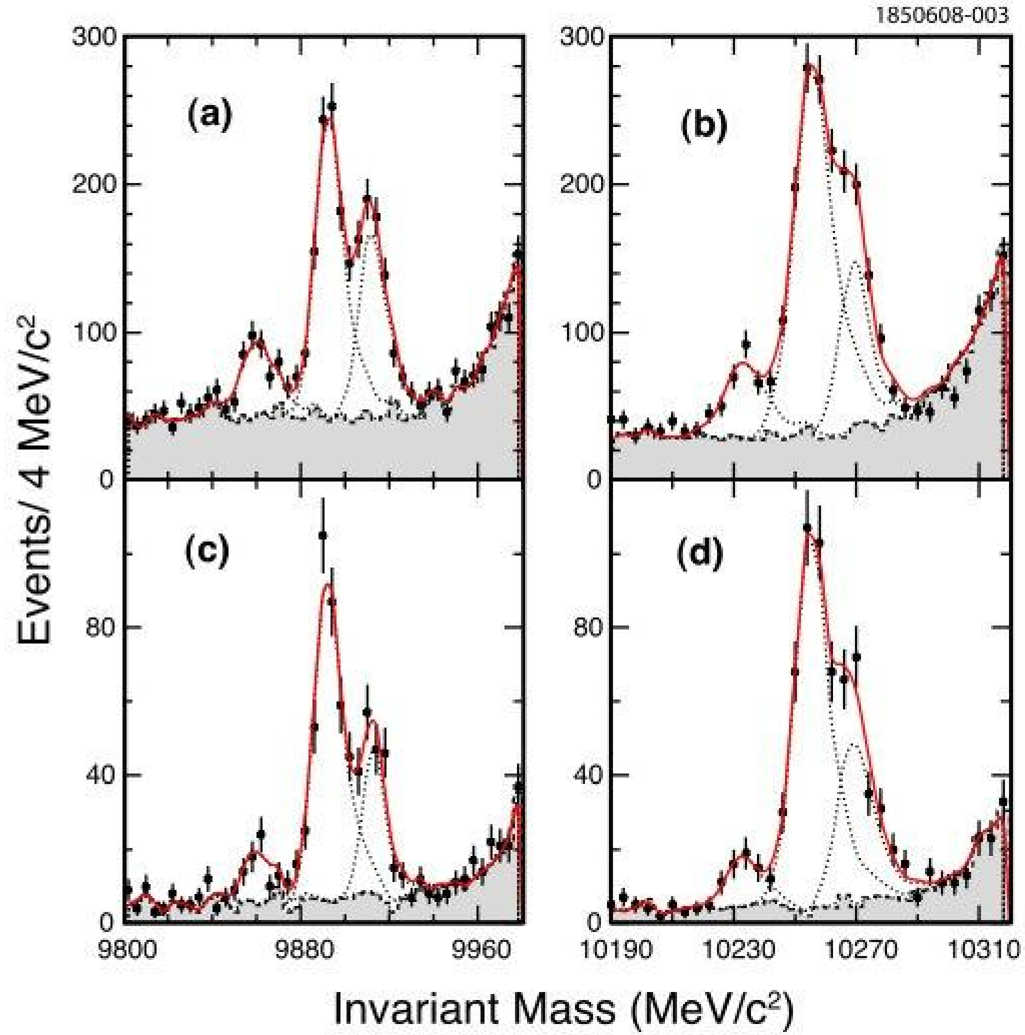
Soft momentum spectrum challenges NRQCD expectations

Large contribution from higher excitations : direct J/ψ = ψ'

Exclusive modes

CLEO-III *Phys.Rev.D78:091103,2008*

$\Upsilon(2S) \to \gamma \chi_b(1P)$ $\Upsilon(3S) \to \gamma \chi_b(2P)$



Full reconstruction of 659 exclusive $\chi_b(1,2P)$ decay modes from $\Upsilon(2S,3S)$ radiative decays.

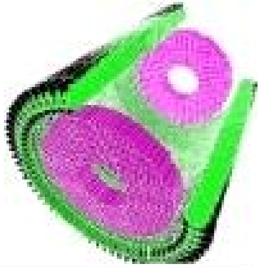
Only 14 decays modes detected with $>5\sigma$ significance

We might use them to tag exclusive $\Upsilon \to \gamma \eta_b$ transitions, BUT:

$BR(\Upsilon \to \gamma \eta_b) < 10^{-2}\, BR(\Upsilon \to \gamma \chi_b)$

Exclusive modes

CLEO-III *Phys.Rev.D78:091103,2008*



All Branching Ratios in 10^{-4} units

χ_b(nP)

	J=0		J=1		J=2	
	2S → 1P	3S → 2P	2S → 1P	3S → 2P	2S → 1P	3S → 2P
$2\pi 2K 1\pi^0$	< 0.6	< 0.2	$1.4 \pm 0.3 \pm 0.3$	$3.9 \pm 0.8 \pm 0.9$	$0.6 \pm 0.3 \pm 0.2$	< 1.4
$3\pi 1K 1K^0_S$	< 0.2	< 0.3	$0.9 \pm 0.3 \pm 0.2$	$1.4 \pm 0.5 \pm 0.3$	< 0.7	< 1.2
$3\pi 1K 1K^0_S 2\pi^0$	< 1.8	< 1.3	< 4.2	$9.7 \pm 3.0 \pm 2.6$	$3.8 \pm 1.4 \pm 1.0$	< 8.7
$4\pi 2\pi^0$	< 0.8	< 1.4	$5.5 \pm 0.9 \pm 1.4$	$7.4 \pm 1.6 \pm 1.9$	$2.5 \pm 0.8 \pm 0.6$	$5.1 \pm 1.6 \pm 1.3$
$4\pi 2K$	$0.4 \pm 0.2 \pm 0.1$	< 0.9	$1.0 \pm 0.3 \pm 0.2$	$1.2 \pm 0.4 \pm 0.3$	$0.8 \pm 0.2 \pm 0.2$	$1.2 \pm 0.4 \pm 0.3$
$4\pi 2K 1\pi^0$	< 1.0	< 1.3	$2.4 \pm 0.6 \pm 0.6$	$6.9 \pm 1.3 \pm 1.7$	$1.5 \pm 0.5 \pm 0.4$	$3.2 \pm 1.1 \pm 0.8$
$4\pi 2K 2\pi^0$	< 2.0	< 6.3	$5.9 \pm 1.4 \pm 1.7$	$12.1 \pm 2.9 \pm 3.3$	$2.8 \pm 1.1 \pm 0.7$	$6.2 \pm 2.3 \pm 1.7$
$5\pi 1K 1K^0_S 1\pi^0$	< 0.6	< 3.9	$6.4 \pm 1.6 \pm 1.6$	$8.5 \pm 2.3 \pm 2.2$	< 3.6	< 5.8
6π	< 0.3	< 0.4	$1.3 \pm 0.3 \pm 0.3$	$1.5 \pm 0.4 \pm 0.3$	$0.5 \pm 0.2 \pm 0.1$	$1.2 \pm 0.4 \pm 0.3$
$6\pi 2\pi^0$	< 2.2	< 7.2	$11.9 \pm 1.8 \pm 3.2$	$15.0 \pm 3.0 \pm 4.0$	$7.3 \pm 1.6 \pm 2.0$	$15.9 \pm 3.3 \pm 4.3$
$6\pi 2K$	$0.9 \pm 0.4 \pm 0.2$	< 0.9	$1.8 \pm 0.4 \pm 0.4$	$2.5 \pm 0.7 \pm 0.6$	< 0.6	$1.9 \pm 0.7 \pm 0.5$
$6\pi 2K 1\pi^0$	< 3.7	< 4.3	$5.2 \pm 1.1 \pm 1.4$	$7.7 \pm 1.7 \pm 2.1$	$2.6 \pm 0.8 \pm 0.7$	$5.5 \pm 1.6 \pm 1.5$
8π	< 0.3	< 1.0	$1.8 \pm 0.4 \pm 0.5$	$2.2 \pm 0.6 \pm 0.5$	$0.6 \pm 0.2 \pm 0.2$	$1.2 \pm 0.5 \pm 0.3$
$8\pi 2\pi^0$	< 7.7	< 3.8	$9.6 \pm 2.4 \pm 2.9$	$24.1 \pm 4.7 \pm 7.2$	$13.2 \pm 3.1 \pm 4.0$	$16.5 \pm 4.6 \pm 5.0$

Modes in RED are the only ones above 10^{-3}
Modes with Nπ^0 favored on ones with 0 π^0

Dominant modes have 8,10 π's
Sum of all BR's does not exceed 1%

More states in Y(5S)-Y(6S) region?

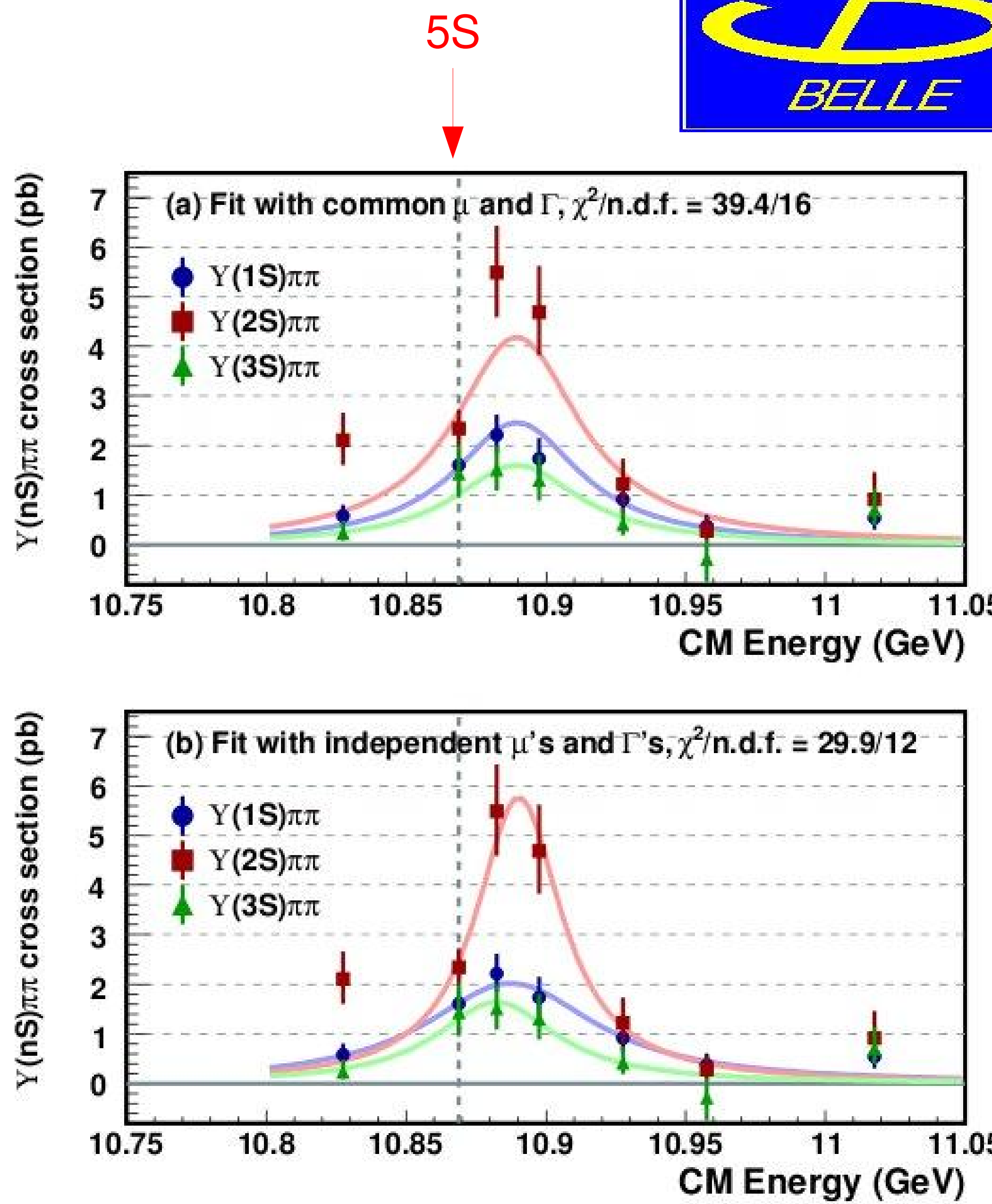
arXiv: 0808.2445

A large excess of Y(1,2S)ππ at 5S peak triggered a high luminosity study (6 points, 1fb^{-1} each) of the region 10.8-11.1.

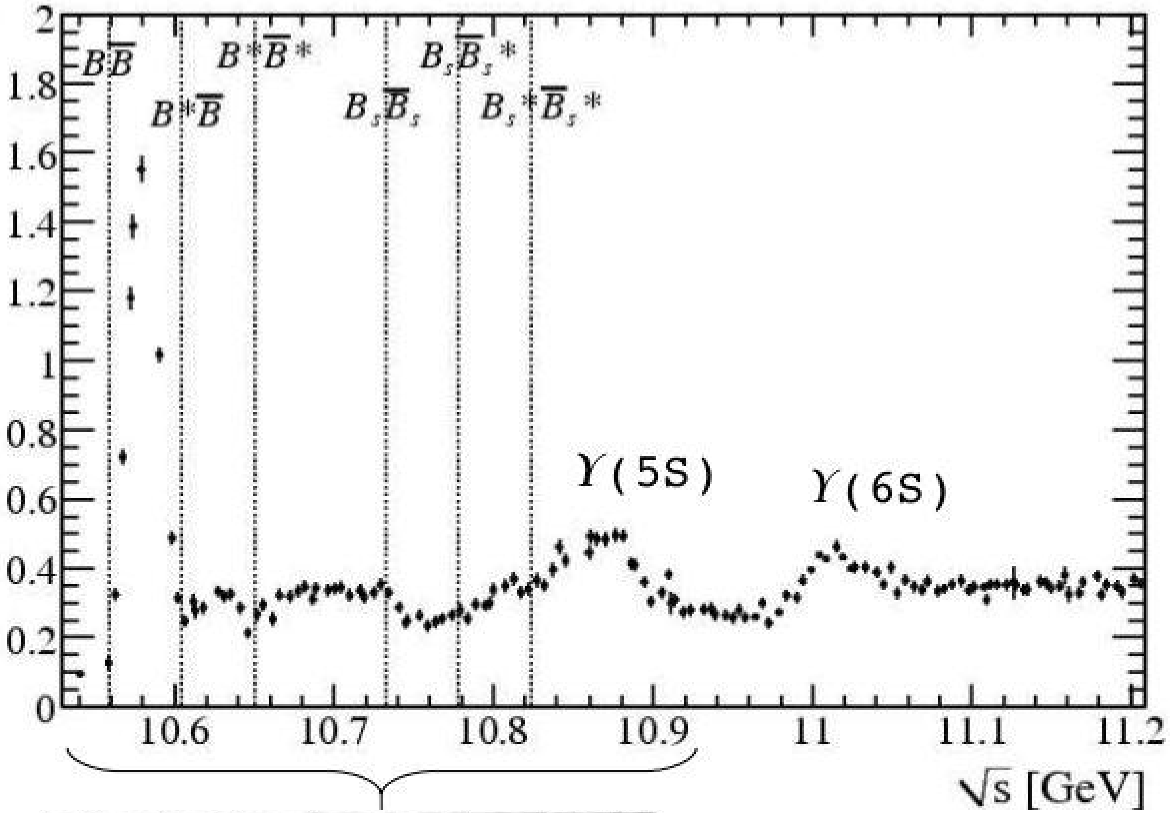
Yππ yields peak 25 MeV above 5S
is this a bottom partner of Y(4260)?

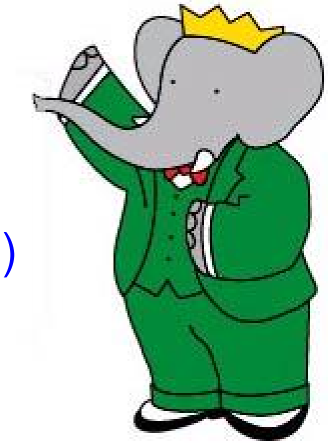
Fit with common μ and Γ			
Process	Peak σ (pb)	μ (MeV)	Γ (MeV)
$\Upsilon(1S)\pi\pi$	$2.46^{+0.27}_{-0.25} \pm 0.18$		
$\Upsilon(2S)\pi\pi$	$4.18^{+0.49}_{-0.46} \pm 0.55$	$10889.6 \pm 1.8 \pm 1.5$	$54.7^{+8.5}_{-7.2} \pm 2.5$
$\Upsilon(3S)\pi\pi$	$1.61^{+0.31}_{-0.28} \pm 0.21$		

Fit with separate μ's and Γ's			
Process	Peak σ (pb)	μ (MeV)	Γ (MeV)
$\Upsilon(1S)\pi\pi$	$2.03^{+0.27}_{-0.22} \pm 0.15$	$10887.4^{+4.1}_{-4.5} \pm 1.6$	$74^{+19}_{-14} \pm 3$
$\Upsilon(2S)\pi\pi$	$5.77^{+0.90}_{-0.80} \pm 0.67$	$10890.3^{+2.3}_{-1.9} \pm 1.4$	$37.0^{+7.9}_{-6.2} \pm 3.1$
$\Upsilon(3S)\pi\pi$	$1.65^{+0.36}_{-0.32} \pm 0.21$	$10882.3^{+7.2}_{-7.3} \pm 1.5$	$52^{+20}_{-14} \pm 1$



Fine scan of the Υ(5S)-Υ(6S) region



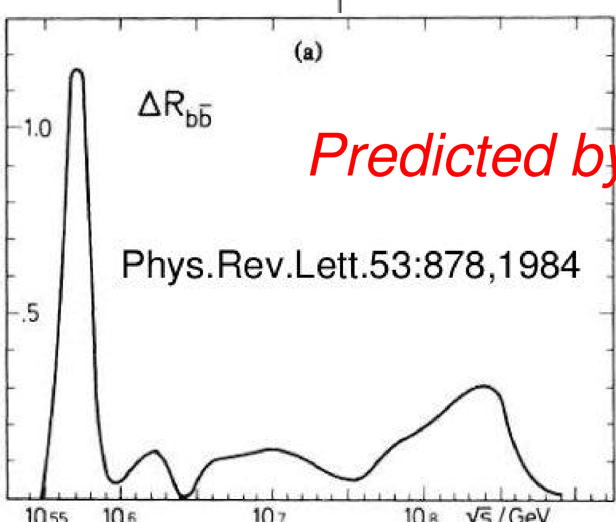


PRL102:012001 (2009)

Ldt 25 pb^{-1} per point,
E=10.54-11.2 ; dE=5 MeV
Total 3.3fb-1

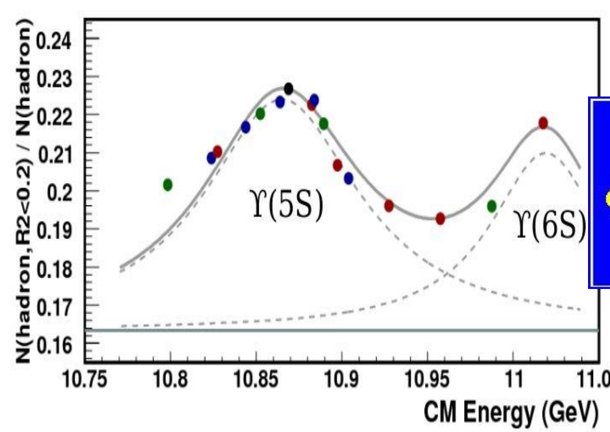
Rb=σ(bb)/σ(μμ)

5S and 6S widths to be redefined, compare w/ PDG



Predicted by Tornqvist in 1984!!

Phys.Rev.Lett.53:878,1984



BELLE

Υ(5S) Exclusive modes

ArXiv: 0905.2959

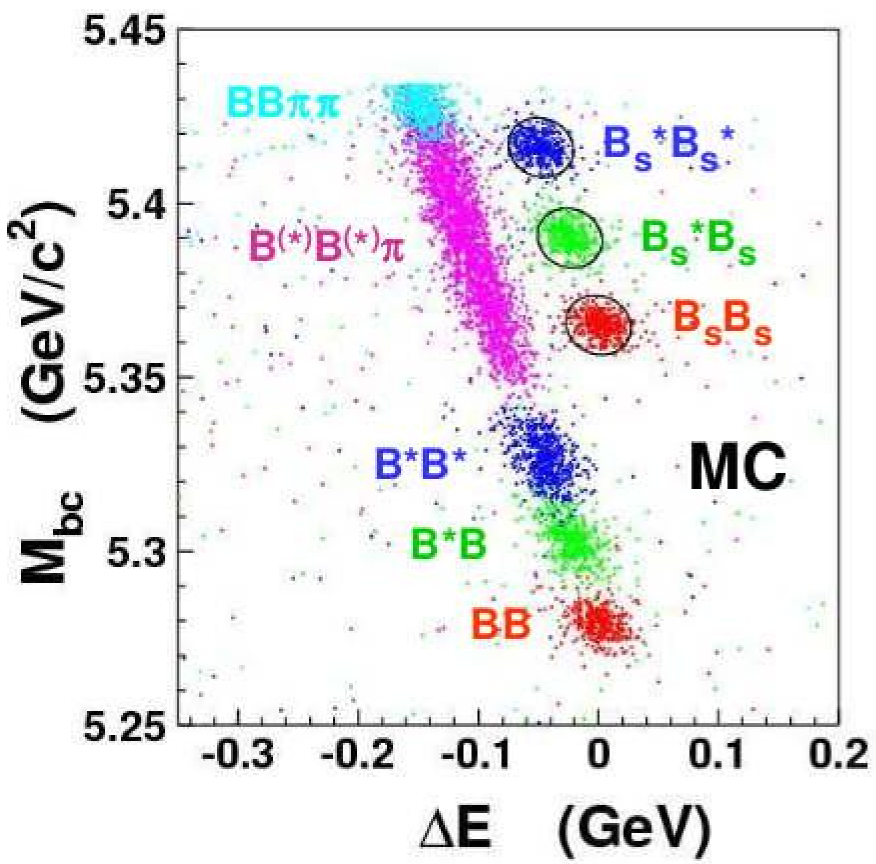
$e^+ e^- \to b\bar{b}\,(\Upsilon(5S)) \to B^{(*)}\bar{B}^{(*)},\ B^{(*)}\bar{B}^{(*)}\pi,\ B\bar{B}\pi\pi,\ B_s^{(*)}\bar{B}_s^{(*)},\ \Upsilon(1S)\,\pi\pi,\ \Upsilon X$ ...

where $B^* \to B\gamma$ and $B_s^* \to B_s\gamma$

CLEO: 2003: ~0.42 fb^{-1}
Belle: 2005 1.86 fb^{-1}, 2006 21.7 fb^{-1},
2008 ~28 fb^{-1}, 2009 ~50 fb^{-1}

B's reconstructed in 5 modes:

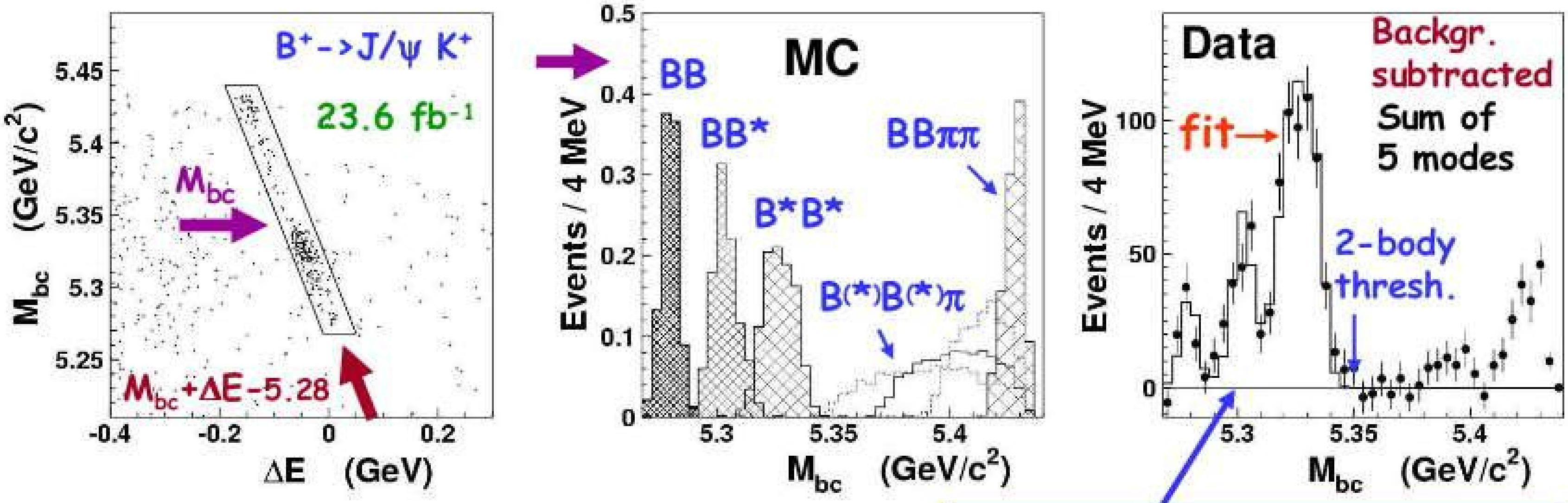
- $B^+ \to K^+ J/\psi$
- $B^+ \to D^0\pi^+; D^0 \to K\pi$
- $B^+ \to D^0\pi^+; D^0 \to K\,3\pi$
- $B^0 \to K^{*0} J/\psi$
- $B^0 \to D^-\pi^+; D^- \to K^+\pi^+\pi^-$



Reconstructed B meson:
M_{bc}, ΔE ; $\Delta X(rec) = M_{bc} + \Delta E - 5.28$

Y(5S) Exclusive modes

Results from 23.8 fb^{-1}
(7.1M BB pairs) of data
shown at EPS2009 Conference:



Simultaneous fit of 5 B modes in $M_{bc} < 5.35 GeV/c^2$ region

Channel fractions per *bb*-pair:

BB:	5.1 ±0.9 ±0.4 %
B*B:	$12.6^{+1.2}_{-1.1}$ ±1.0 %
B*B*:	$34.5^{+1.9}_{-1.8}$ ±2.7 %
B(*)B(*)π(π)	$16.5^{+1.6}_{-1.5}$ ±1.2 %

(3+4)body decay fractions largely exceed theory predictions, ranging from 0.03% (Simonov et al hep-ph:0805.4518) to 0.3% (L.Lellouch et al. NP B405,55(1993))

Searches for Υ(nS) decays beyond SM

Lepton Universality Violation ($\tau\tau/\mu\mu$)
[Babar:Proc.FPCP]

Light Higgs searches *[Babar:PRL103(2009)081803]*

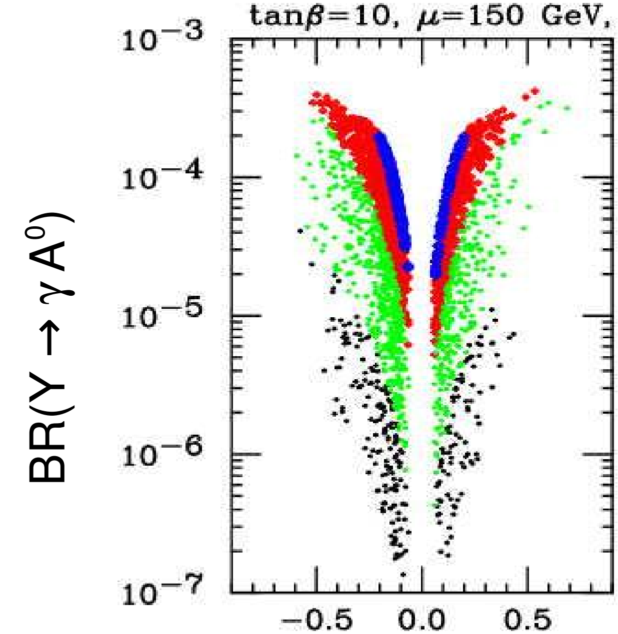
DM candidates *[Belle:PRL98(2007)132001]*
[Babar:ArXiV:0908.2840]

LFV ($e\tau$, $\mu\tau$) *[Babar:arXiv:0812.1021]*

Light CP-odd Higgs searches

Physics motivation: the existence of a light CP-odd higgs boson, expected in NMSSM framework, is not excluded by LEP limits. If H → A0 A0 is dominant decay, and if M(A0)<2M(B), LEP and Tevatron searches can miss the Higgs.

Decay channels: $A_0 \to \tau\tau$ would be the golden mode



$M_A<2M_\tau$

$2M_\tau< M_A<7.5$GeV

$7.5< M_A<8.8$GeV

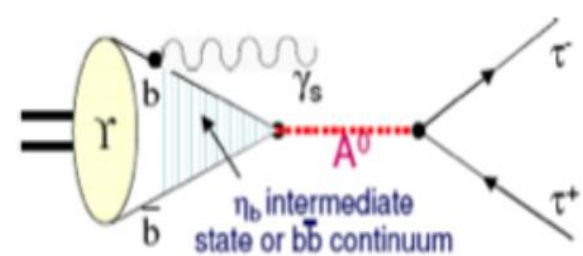
$8.8< M_A<9.3$GeV

Signatures:

- Indirect searches : lepton universality violation in Y(1,2,3S) decays
- Direct search in radiative transitions of Y(1,2,3S) resonance: large background from ISR process
- Search on dipion tagged sample of Y(1S) decays, produced from either Y2S) or Y(3S)

Decay modes for tau lepton:

with one $\tau \to$ 1 prong (=$e\nu\nu,\mu\nu\nu,\pi\nu,\rho\nu$,...) BR=85%
and the other $\tau \to e\nu\nu$ or $\mu\nu\nu$ BR=35.2%
(background from misidentified ρ's)

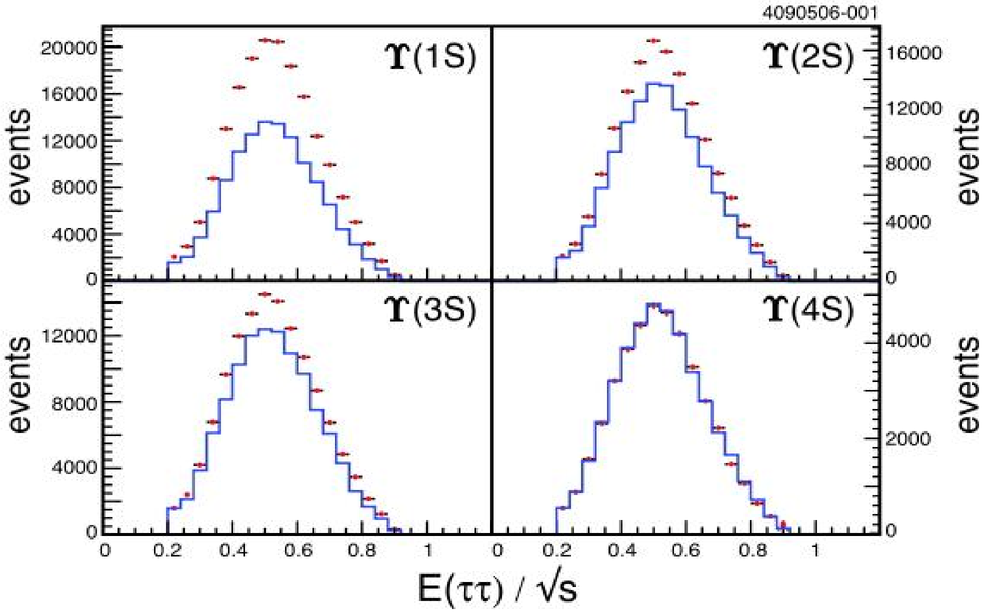


Lepton Universality Violation in Υ(nS) decays

CLEO: PRL98, 052002 (2007)

Directly measures the ratio $R_{\tau\tau} = BR(\Upsilon \to \tau\tau)/BR(\Upsilon \to \mu\mu)$ comparing resonant and continuum dilepton yields

	$\mathcal{R}^{\Upsilon}_{\tau\tau}$
Υ(1S)	$1.02 \pm 0.02 \pm 0.05$
Υ(2S)	$1.04 \pm 0.04 \pm 0.05$
Υ(3S)	$1.05 \pm 0.08 \pm 0.05$

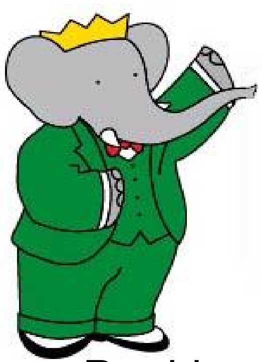


Superseded by new Babar result:
Υ(1S) tagged from Υ(3S) →Υ(1S)π+π−

$R_{\tau\tau}(1S)=(1.009\pm0.010 \pm0.020)$ Proc.FPCP2009

$\Upsilon(2,3S) \rightarrow \gamma A^0 \rightarrow \gamma\mu\mu$

arXiv:0905.4539

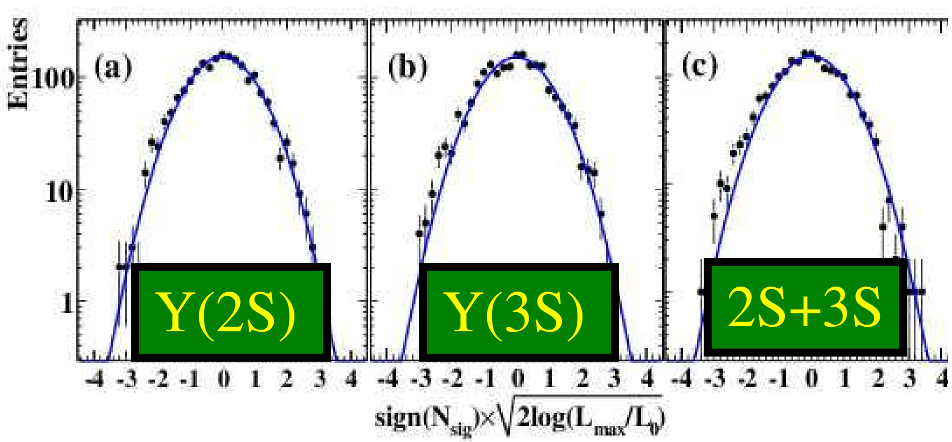


Search for a peak in M(μμ) in the range 0.212-9.3 GeV (~1500 independent bins)

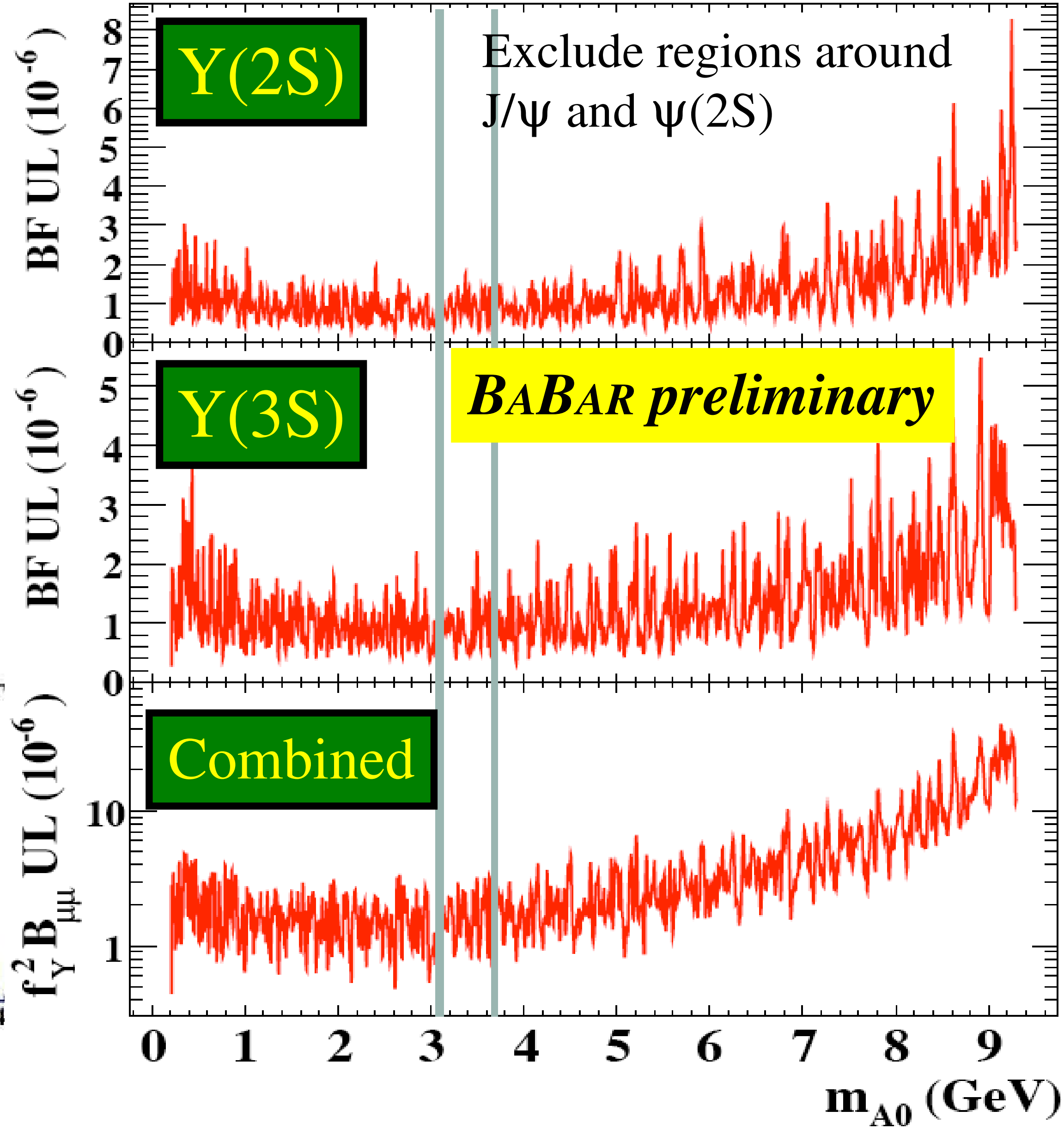
Smooth irreductible QED background from $e^+e^- \rightarrow \gamma\mu\mu$

Peaking background from ISR production of ρ,φ,J/ψ,ψ': in ρ region, tighter cuts on μ ID to reject pions.

No significant fluctuations observed.

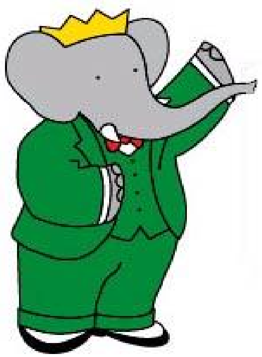


90% Limits on the HyperCP excess at 214 MeV lowered to $1.6*10^{-6}$



$\Upsilon(3S) \to \gamma A^0 \to \gamma\tau\tau$

arXiv:0906.2219

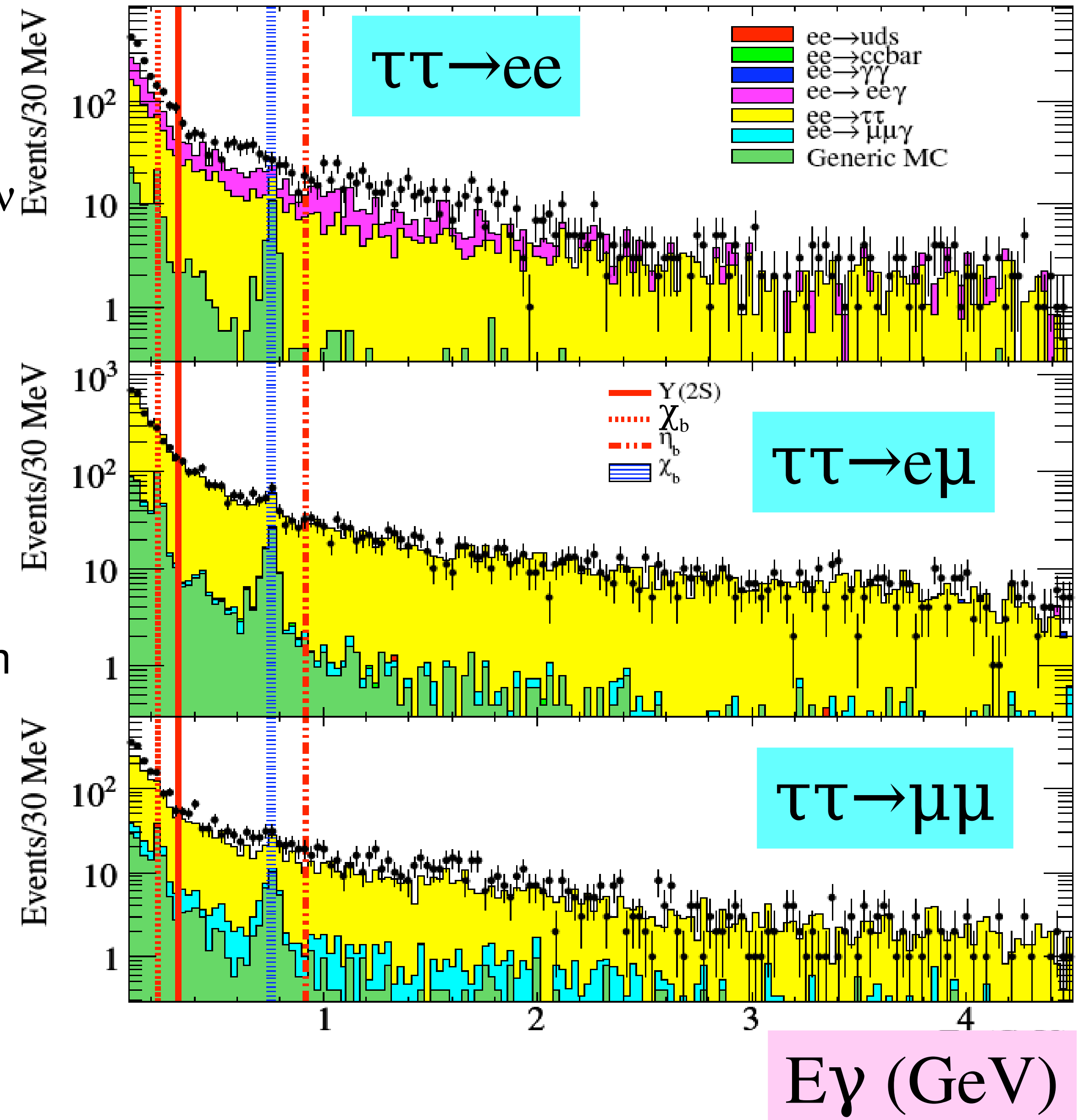


Search for a peak in the inclusive photon spectrum.
Sample: 122M $\Upsilon(3S)$'s

Decay modes: $\tau \to e\nu\nu$, $\mu\nu\nu$
($BR=0.35^2= 12\%$)
$M(\tau\tau)$ in the range
4.03-10.10 GeV

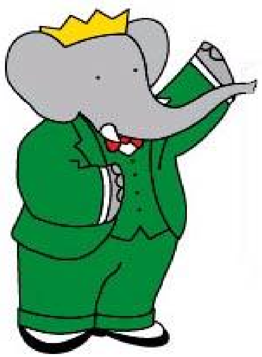
Smooth irreductible QED background from $e^+e^- \to \gamma\tau\tau$

Peaking background from bottomonium decay $\Upsilon(3S) \to \gamma\gamma\, \Upsilon(1S)$; $\Upsilon(1S) \to \tau\tau$, via E1 transitions through $\chi_b(1,2P)$ (the range 9.52-9.61 GeV is vetoed)



$\Upsilon(3S) \to \gamma A^0 \to \gamma\tau\tau$

arXiv:0906.2219



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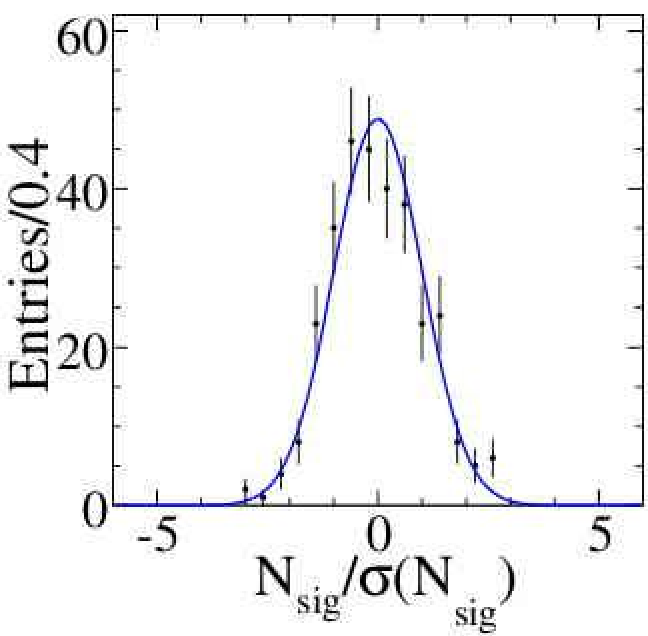
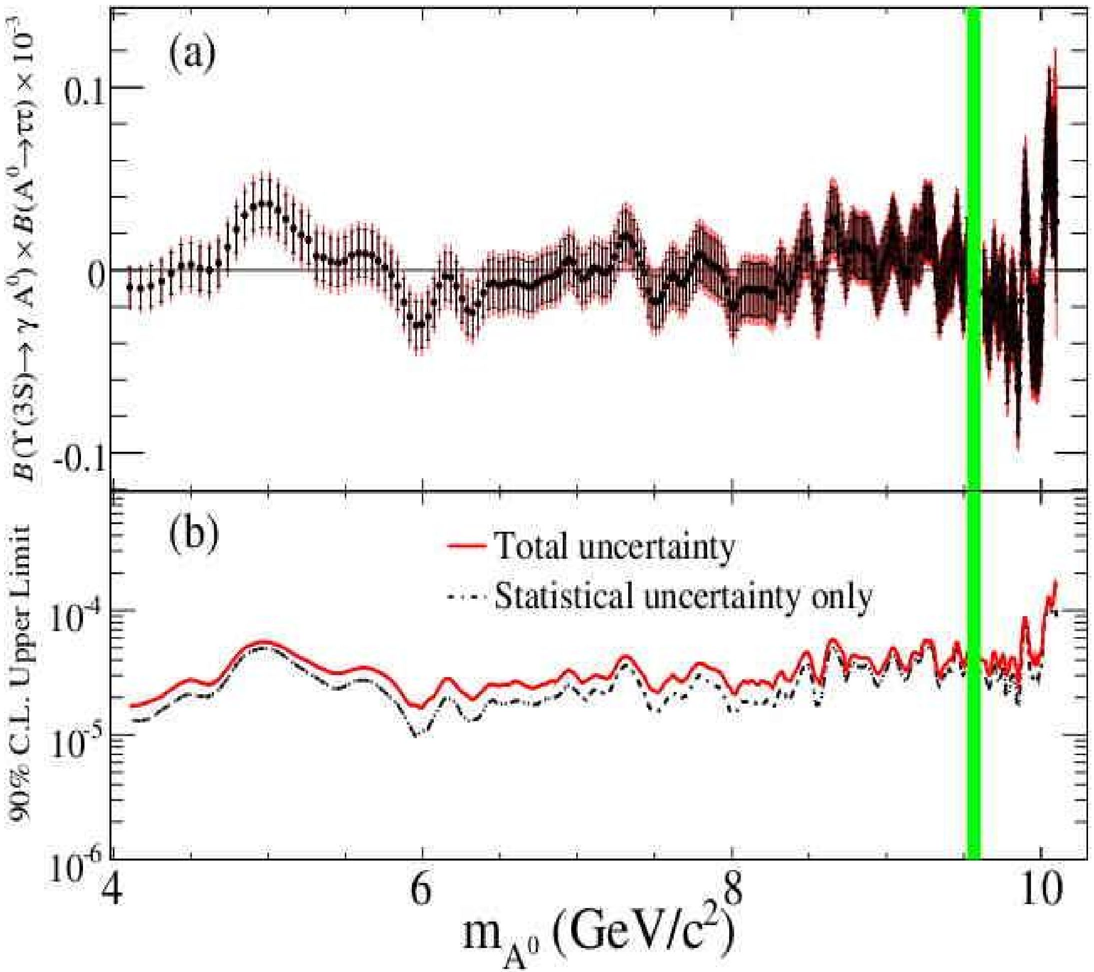
($BR=0.35^2= 12\%$)
$M(\tau\tau)$ in the range
4.03-10.10 GeV

No significant fluctuations observed.

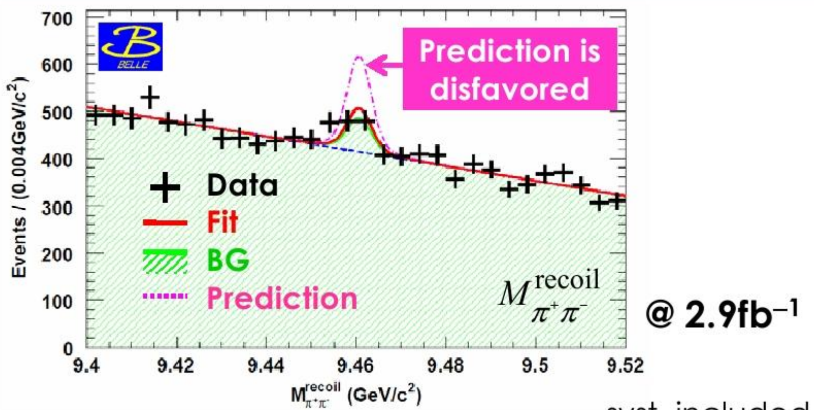




Dark matter searches in Υ(1S) decays

Belle: Υ(3S) → ππ + NOTHING

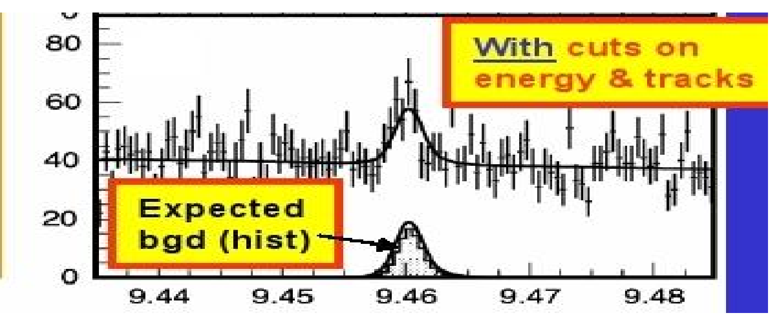
N_{sig} = 38 □ 39(stat) ⇔ 0 consistent

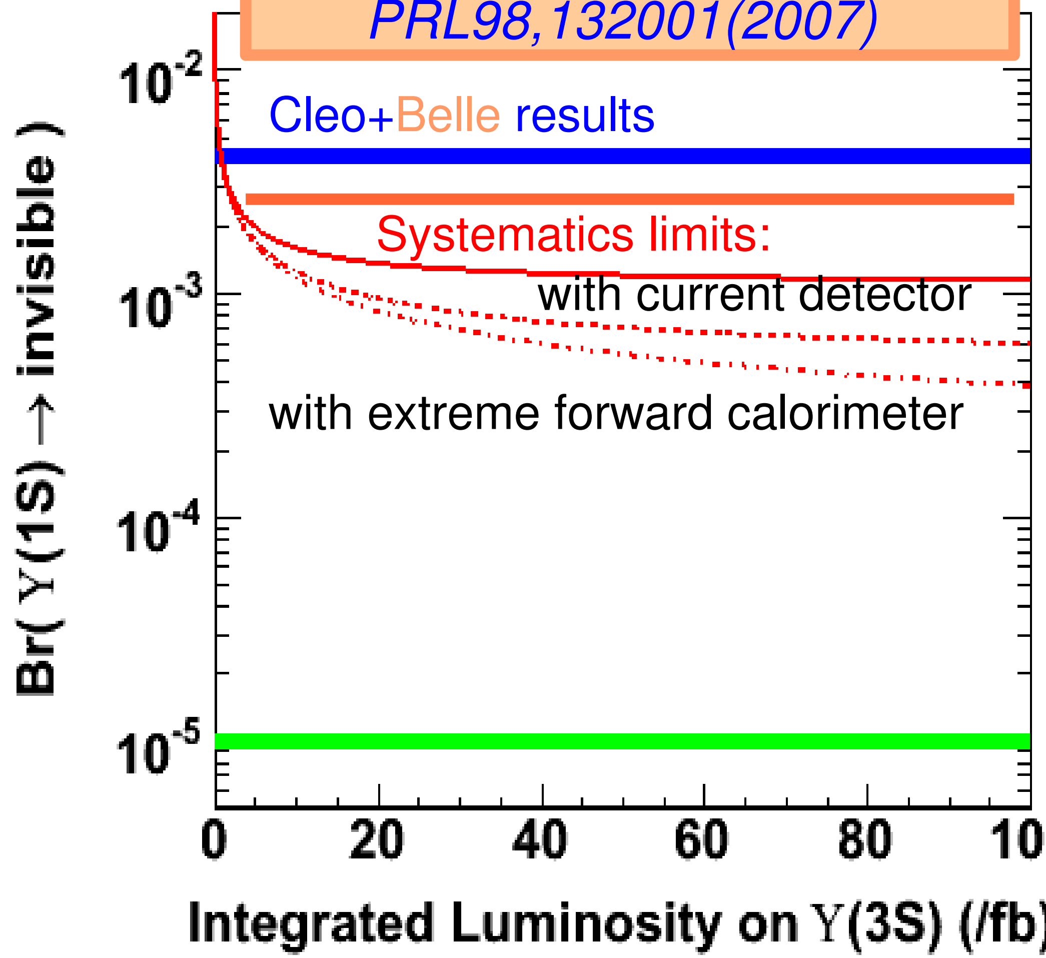


syst. included

Br(Υ(1S) → invisible) < 2.5 x 10^{-3} (@90%C.L.)

Cleo: Υ(2S) → ππ + NOTHING





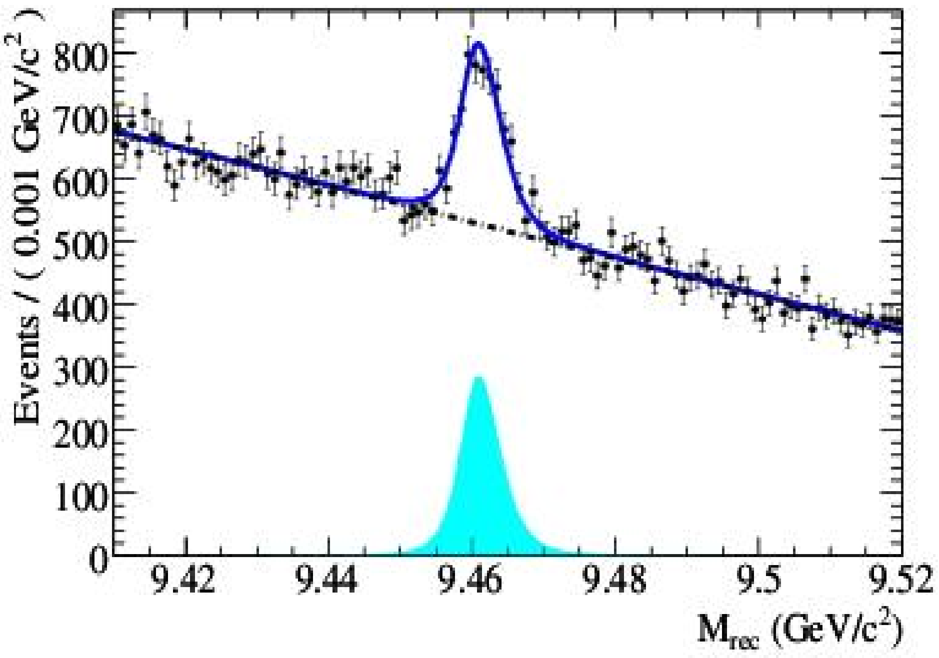
1.46 fb⁻¹, 6M Y(3S)

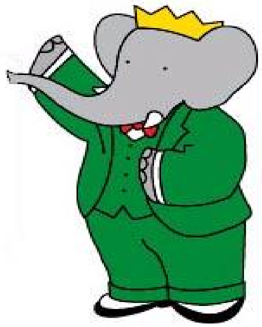
PRD75,031104(2007)

BR(Y(1S) → invisible) < 3.9*10^{-3} (90% CL)

Dark matter searches in Υ(nS) decays

Babar: Υ(3S) → ππ + NOTHING





From MC simulations:

Belle	Babar
50.3	1019 Υ(1S) → ee
77.3	1007 Υ(1S) → μμ
5.2	92 Υ(1S) → ττ
	3 Υ(1S) → hadrons
	2122 events tot exp.

Renormalized from analysis of 3 and 4 track events:

$133.2^{+19.7}_{-14.7}$	2451+/- 38	total exp
38+/-39	2326+/-105	total obs

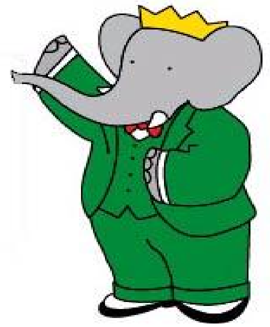
BR(Υ(1S) → invisible) < 3*10^{-4} (90% CL)

BABAR: 30 fb^{-1}. *91.4M Υ(3S)*

arXiv:0906.2219

LFV in Y(3S) decays

arXiv: 0812.1021



EFTs estimate that Y(nS) $\rightarrow$ eτ,$\mu\tau$ allows to search for new physics phenomena at scale $\Lambda^{(\ell\tau)}$:

$$\frac{\Gamma(\Upsilon(3S) \to \ell^{\pm}\tau^{\mp})}{\Gamma(\Upsilon(3S) \to \ell^{+}\ell^{-})} = \frac{1}{2q_b^2}\left(\frac{\alpha_N^{(\ell\tau)}}{\alpha}\right)^2 \left(\frac{M_{\Upsilon(3S)}}{\Lambda^{(\ell\tau)}}\right)^4 \quad (\ell = e, \mu)$$

Signal :

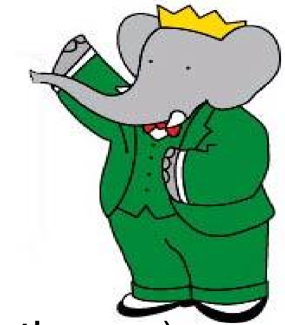
- leptonic eτ: Y(3S)$\rightarrow$eτ, $\tau\rightarrow\mu\nu\nu$
- hadronic eτ: Y(3S)$\rightarrow$eτ, $\tau\rightarrow\pi^0\pi^-\nu,\pi^0\pi^0\pi^-\nu$
- leptonic $\mu\tau$: Y(3S)$\rightarrow\mu\tau$, $\tau\rightarrow$e$\nu\nu$
- hadronic $\mu\tau$: Y(3S)$\rightarrow\mu\tau$, $\tau\rightarrow\pi^0\pi^-\nu,\pi^0\pi^0\pi^-\nu$

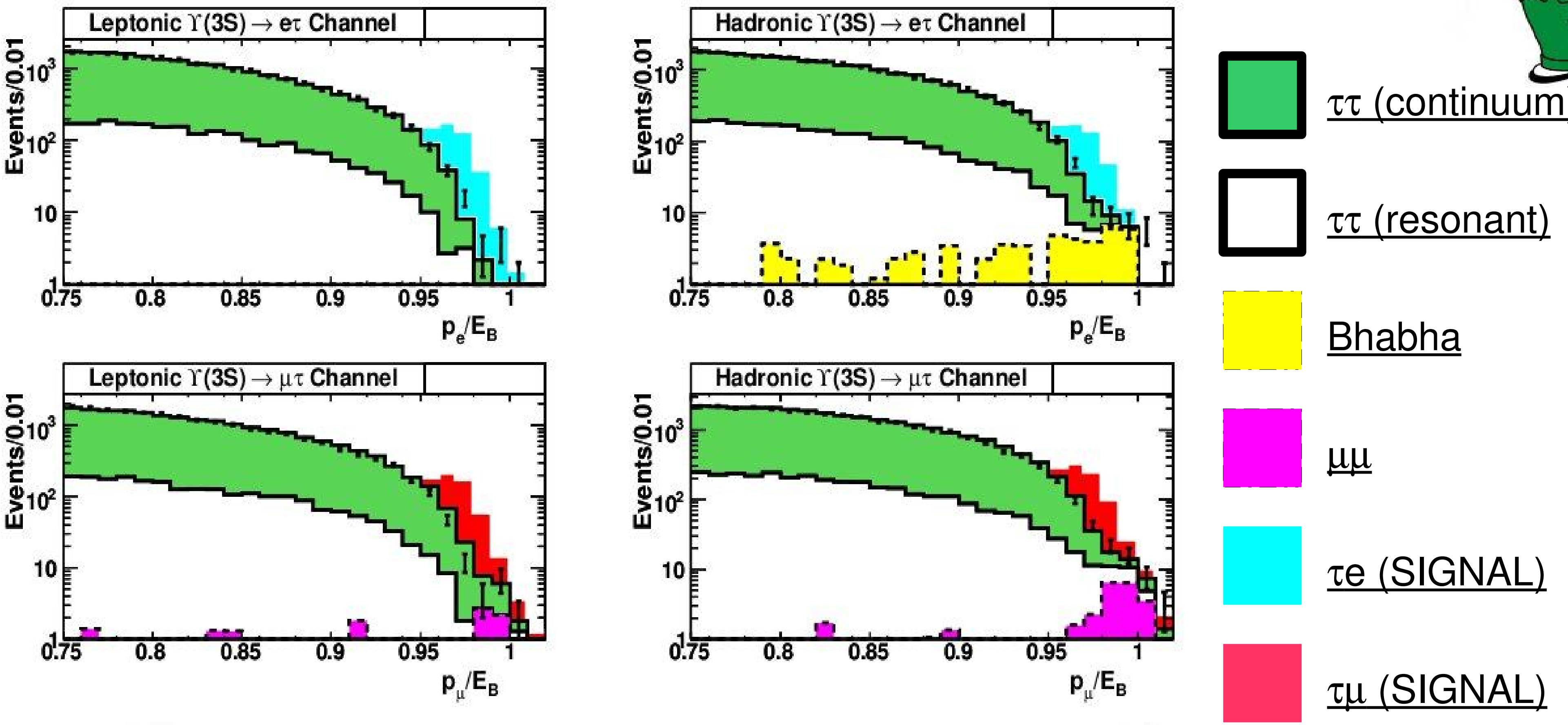
Backgrounds:

$\tau\tau$ (continuum and resonant), ee, $\mu\mu$

LFV in Y(3S) decays

arXiv: 0812.1021





	UL	MPV
$BF(\Upsilon(3S) \to e^{\pm}\tau^{\mp})$ $(\times 10^{-6})$	< 5.0	$2.2^{+1.9}_{-1.8}$
$BF(\Upsilon(3S) \to \mu^{\pm}\tau^{\mp})$ $(\times 10^{-6})$	< 4.1	$1.2^{+1.9}_{-1.9}$

Summary

In the last two years, the B-factories have provided a >10x increase in Y(1,2,3S) data samples (tagged, untagged), and a 100x increase in data samples above 4S

The long awaited ground state of parabottomonia ()has been discovered (BaBar), to be confirmed by Belle (and Cleo?)

Inclusive and Exclusive decays to open and hidden charm will provide checks on NRQCD... and may confirm also some of the new charmonia .

Exclusive decomposition of the 5S bb decay modes have been completed by Belle: an excess of 3-4 body events is observed.

New results on light Higgs and DM searches at Babar put more stringent constraints on BSM effects in Y(nS) decays

ありがとう
ございます。