Bottomonium Physics at

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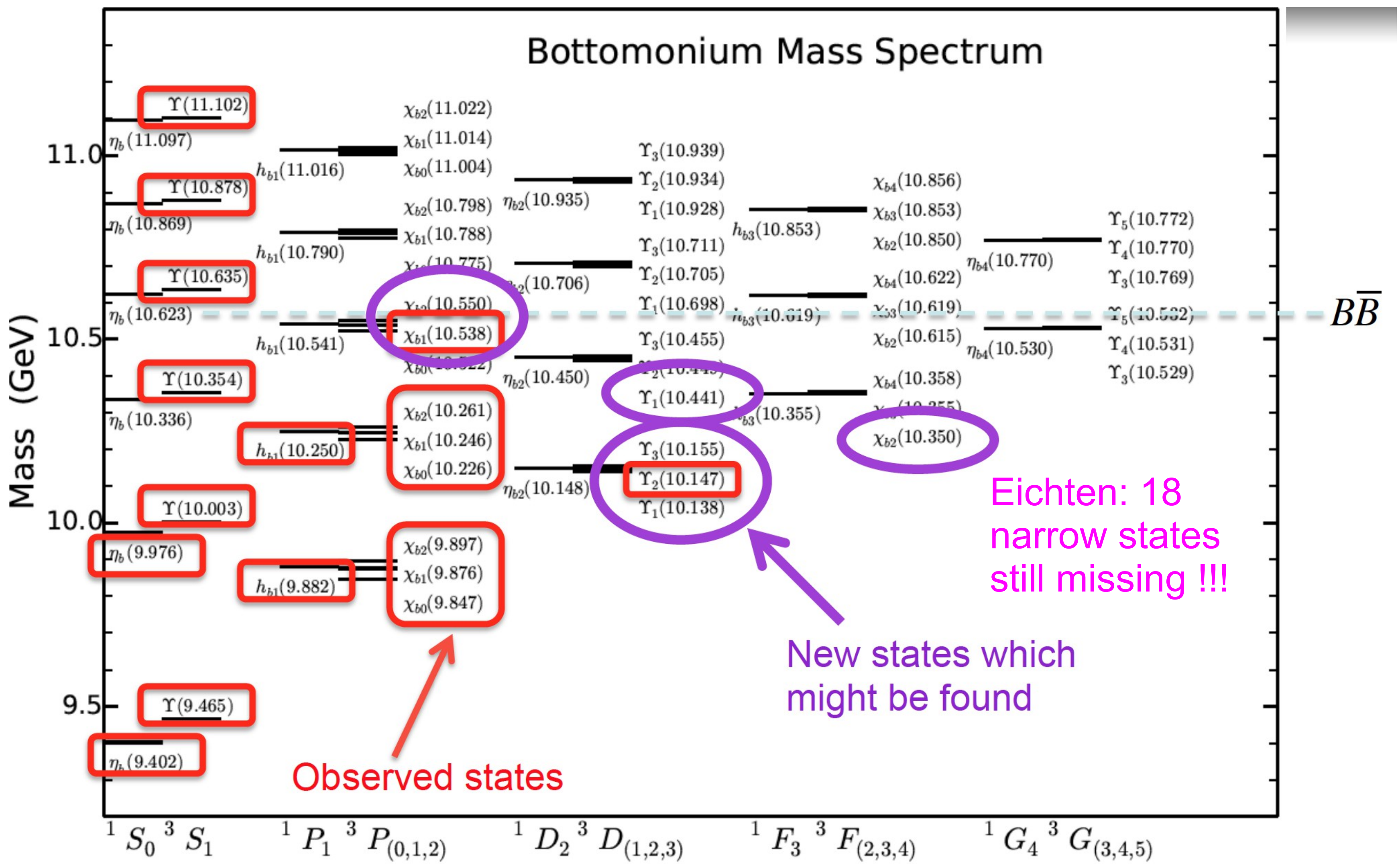


First question: where to run

Energy	Outcome	Lumi (fb^{-1})	Comments
ϒ(1S) On	N/A	60+	-No interest identified for Phase 2 -Low energy
ϒ(2S) On	N/A	200	-No interest identified for Phase 2
ϒ(1D) Scan	Particle discovery	10-20	-Accessible in B Factories?
ϒ(3S) On	Many topics	200+	-Known resonance -High luminosity requirement: Phase 3
ϒ(3S) Scan	Precision QED	~10	-Understanding of beam conditions needed
ϒ(2D) Scan	Particle discovery	10-20	-Unknown mass
ϒ(4S)+ Scan	Particle discovery?	10+?	-Energy to be determined
Y(6S) On	Particle discovery?	30+?	-Upper limit of machine energy
Single γ	New physics?	30+	-Special triggers required

Oggi parlero' di:
- grandezza e limiti della Y(6S) in phase II
- altre ragioni per fare Y(3S) in phase III

First question: where to run

Y(6S) Yb? Y(2D) Y(1D)

Experiment	Scans/Off. Res.	$\Upsilon(5S)$		$\Upsilon(4S)$		$\Upsilon(3S)$		$\Upsilon(2S)$		$\Upsilon(1S)$	
		10876 MeV		10580 MeV		10355 MeV		10023 MeV		9460 MeV	
	fb^{-1}	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6
CLEO	17.1	0.4	0.1	16	17.1	1.2	5	1.2	10	1.2	21
BaBar	54	R_b scan		433	471	30	122	14	99	–	
Belle	100	121	36	711	772	3	12	25	158	6	102

Prospects of a pilot run at Y(6S) in phase II
More physics with 1 Billion Y(3S) in phase III

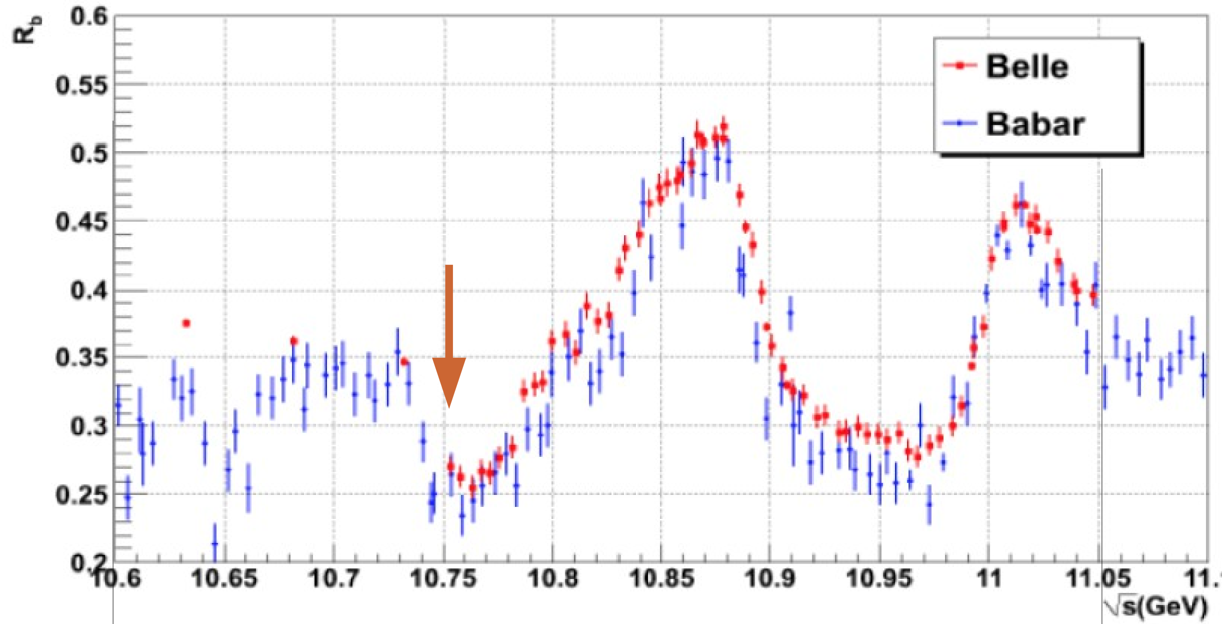
Boundary conditions

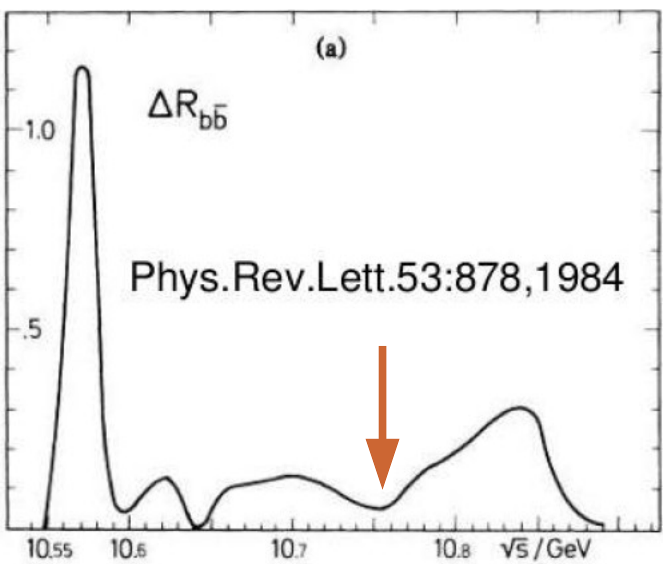
- Goals of Phase 2
  - Machine study for settings to reach high luminosity
  - Understand beam background for safe VXD installation
  - Establish conditions for stable machine operation
  - Reach target luminosity of ~1×10^{34} cm^{-2} s^{-1}
- Phase 2 Operating Conditions
  - ~4-5mos. of machine studies, ~1-2mos. physics
  - Energy spread assumed to be ~5MeV (similar to Belle)
  - Maximum possible energy 11.06 - 11.25 GeV
  - Stable operation close to $\Upsilon(4S)$ strongly preferred
  - Large uncertainty on Phase 2 luminosity (20±20 fb^{-1})
- Phase 3
  - Operate at nominal conditions ($1+\times10^{34}$ cm^{-2} s^{-1})
  - Some combination of $\Upsilon(4S)$ and other energies?

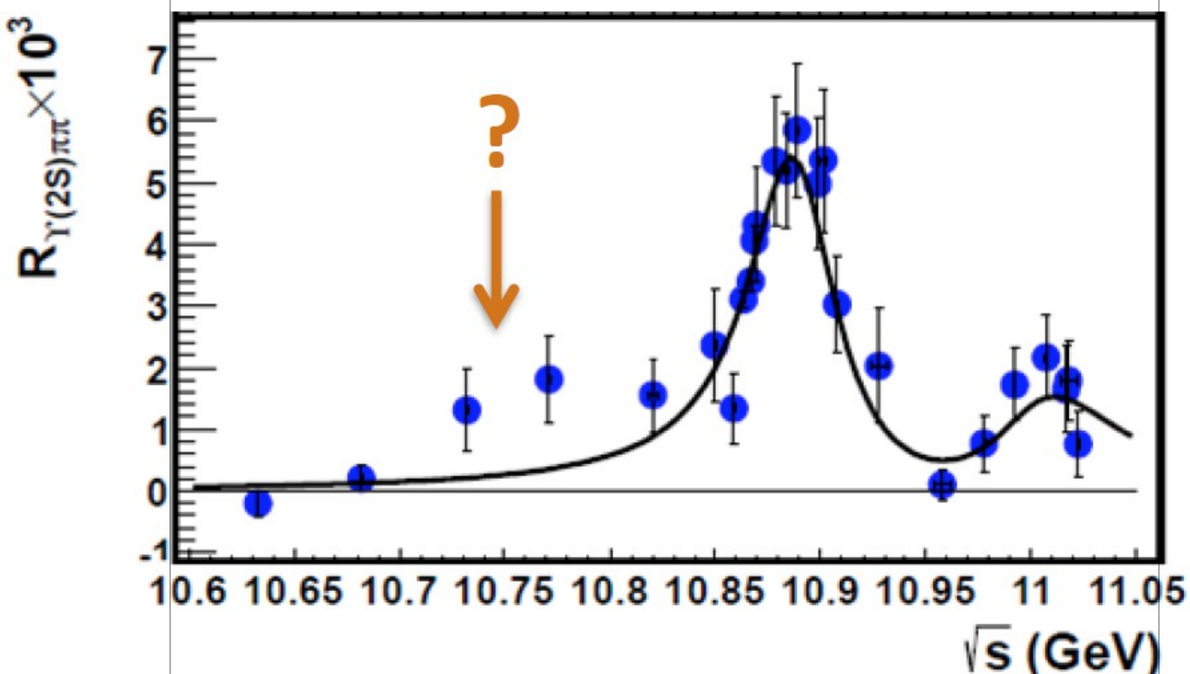
BELLE-I scans

- 61 points, 50/pb, 10.75-11.05 GeV
- 16 points, 1/fb, 10.63-11.02 GeV

Not just Rb analysis: also Υππ
Exclude Ali's peak at 10.91

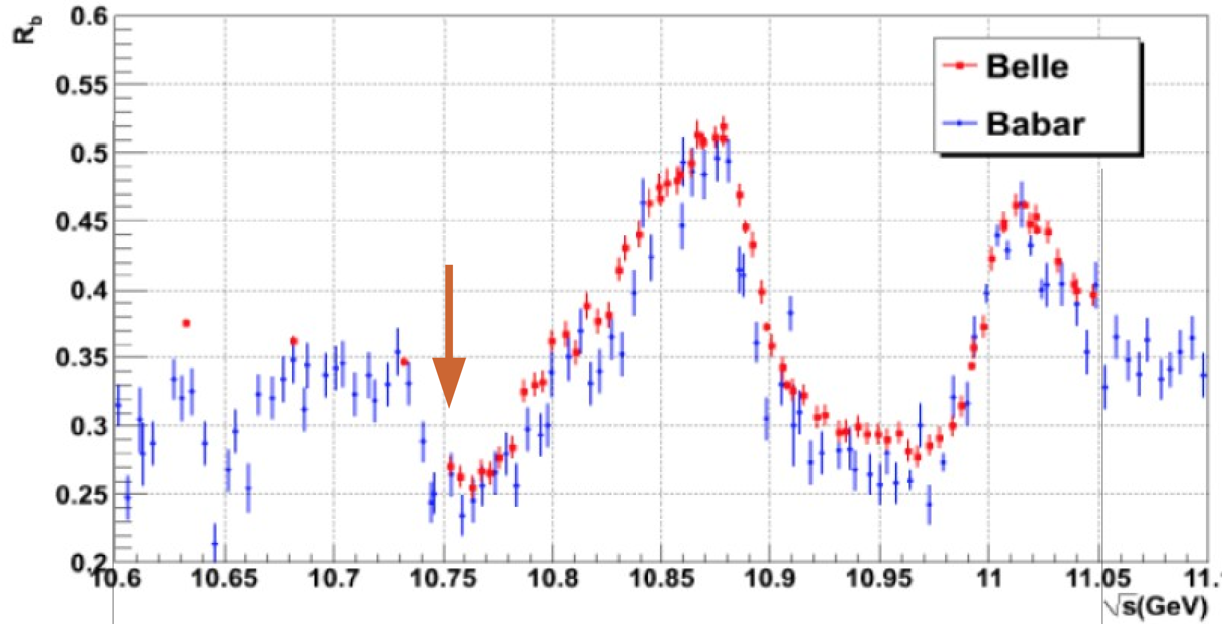


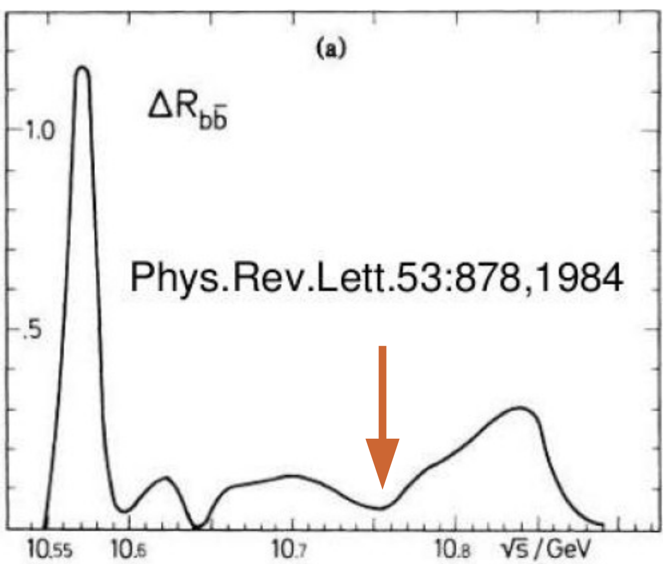


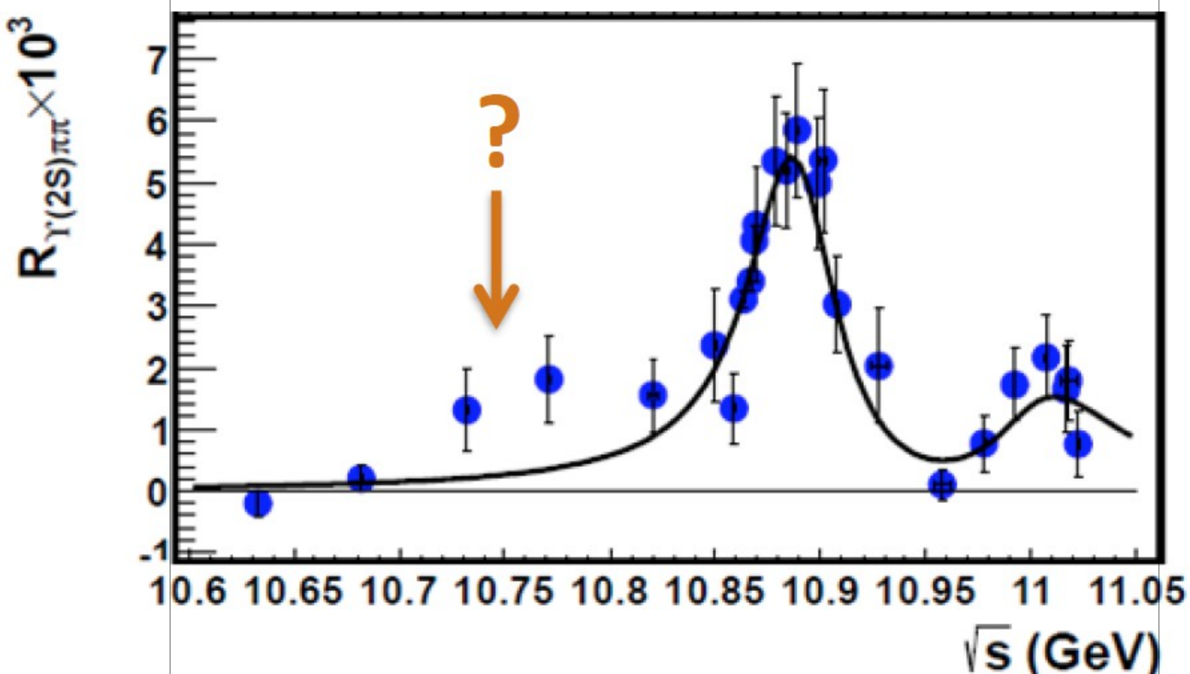


BELLE-II phase-2

We may think to take 10 fb^{-1} at 10.75 (where Rb collapses and R_{Υ} starts rising); *not a scan,* just stay there

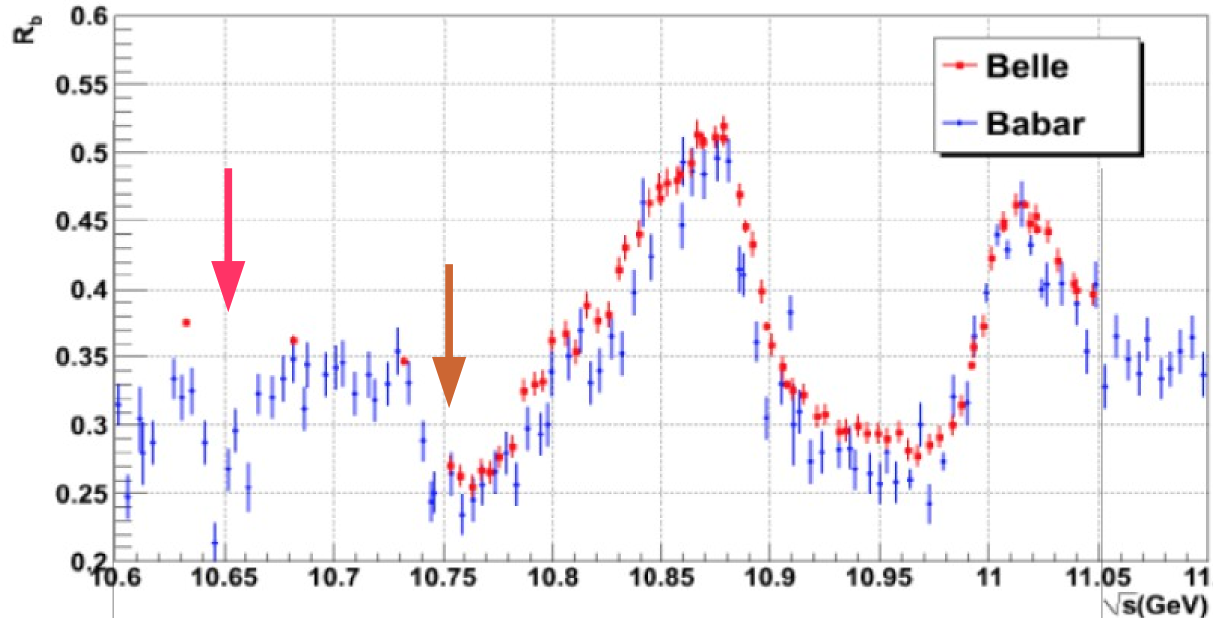


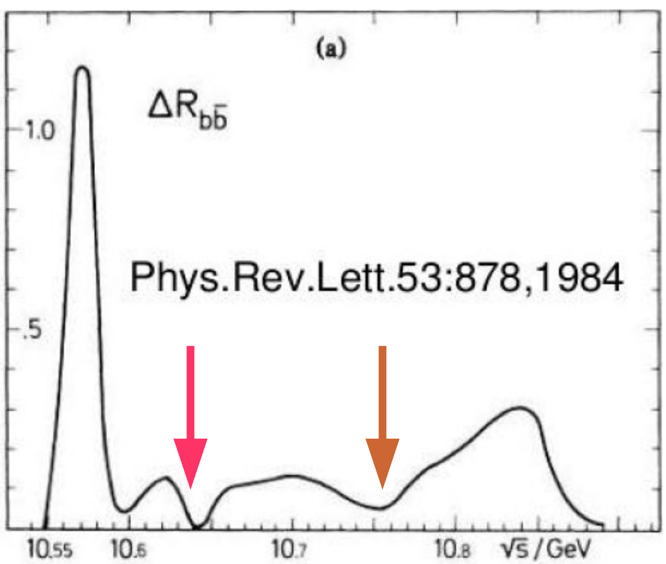


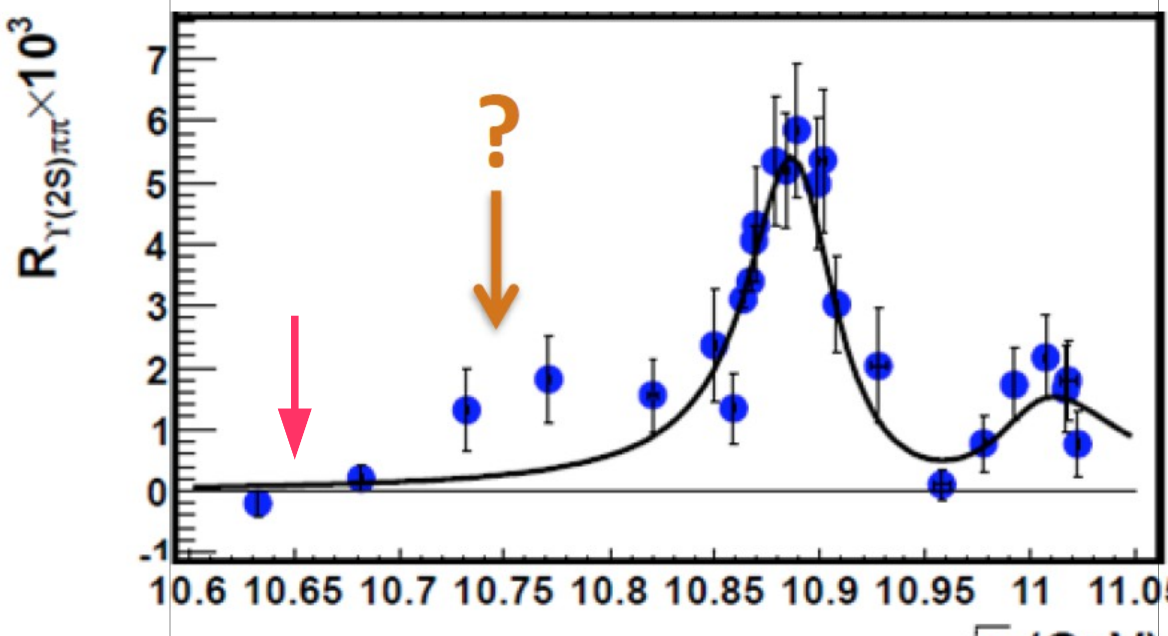


BELLE-II phase-2

We may think to take 10 fb^{-1} at 10.75 (where Rb collapses and R_{Υ} starts rising) ... and 10 fb^{-1} at 10.65 (where Rb shows a dip, just above the B*B* threshold)



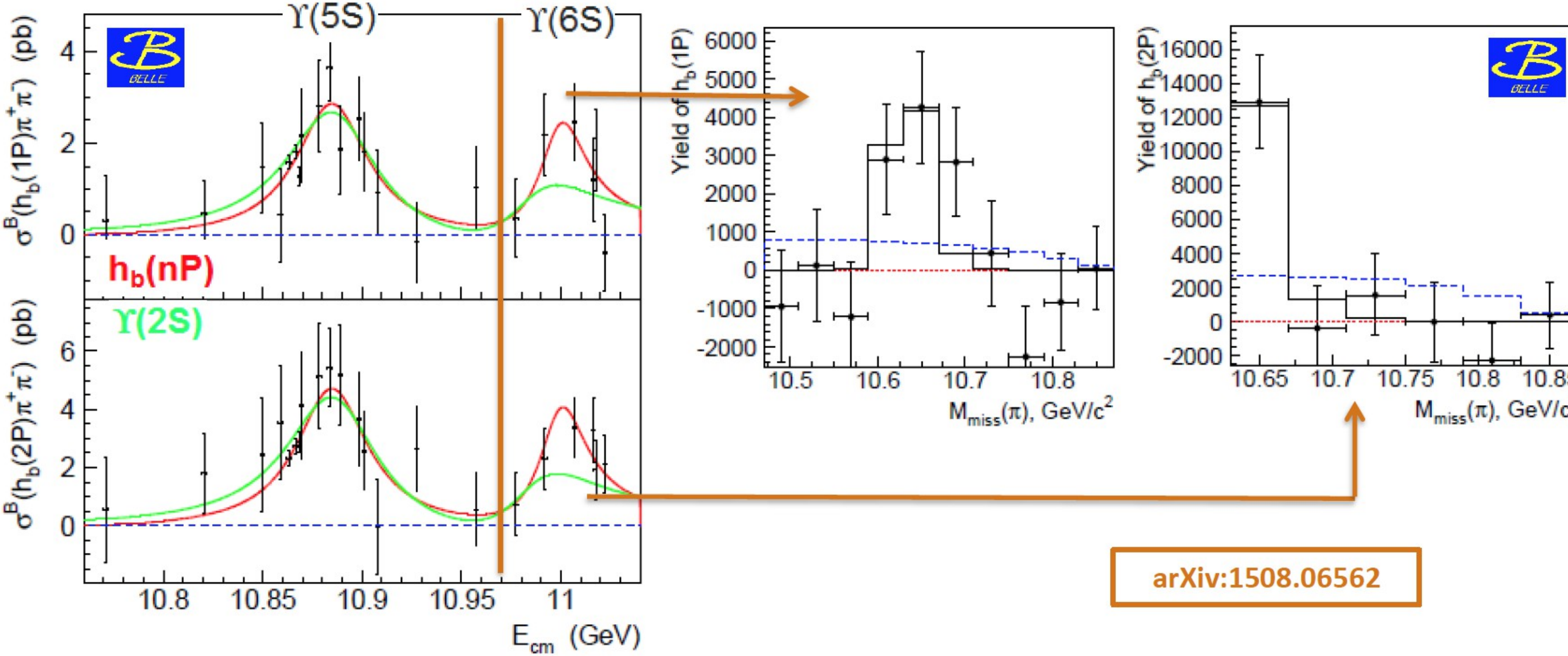




Study these channels: BB,B*B,B*B*,Υππ,Υη at 10.65,10.75

Y(6S) results in Belle-I

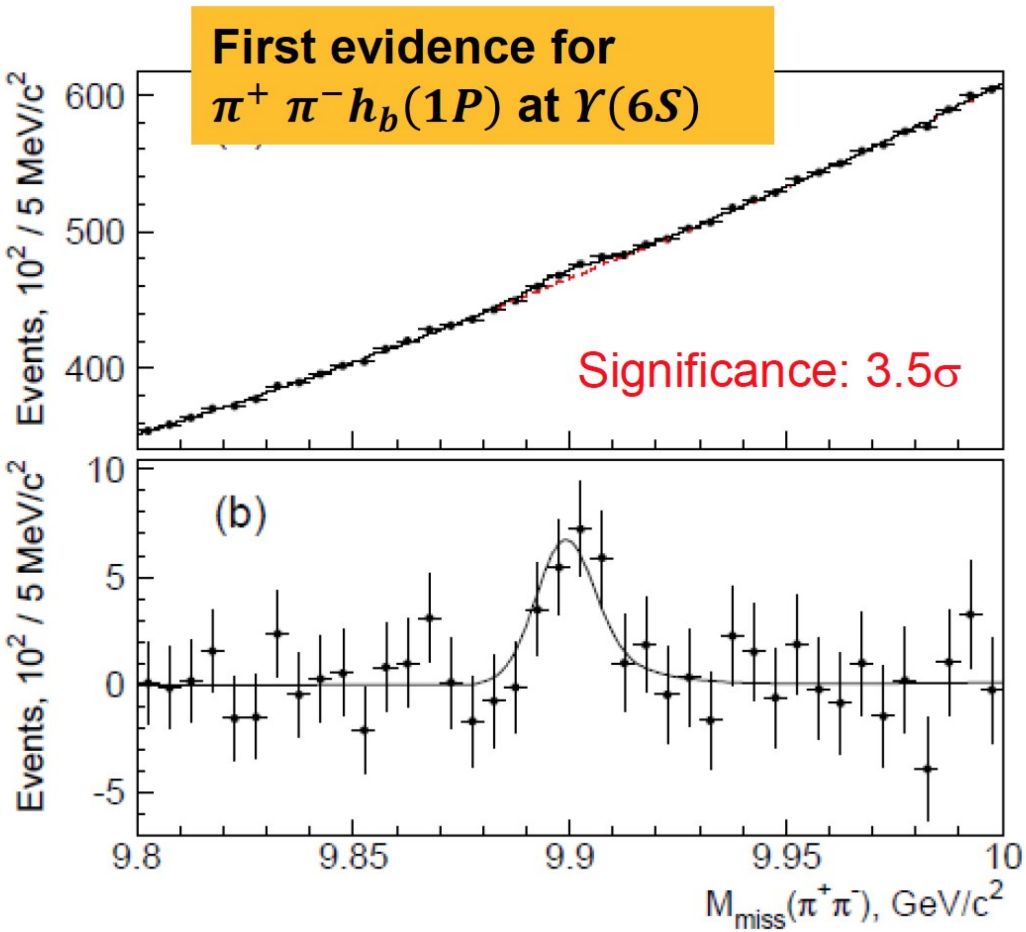
- Preliminary evidence for $\Upsilon(6S)\to\pi\pi h_b(nP)$, via $\pi Z_b^{\pm}(106XX)$ decay

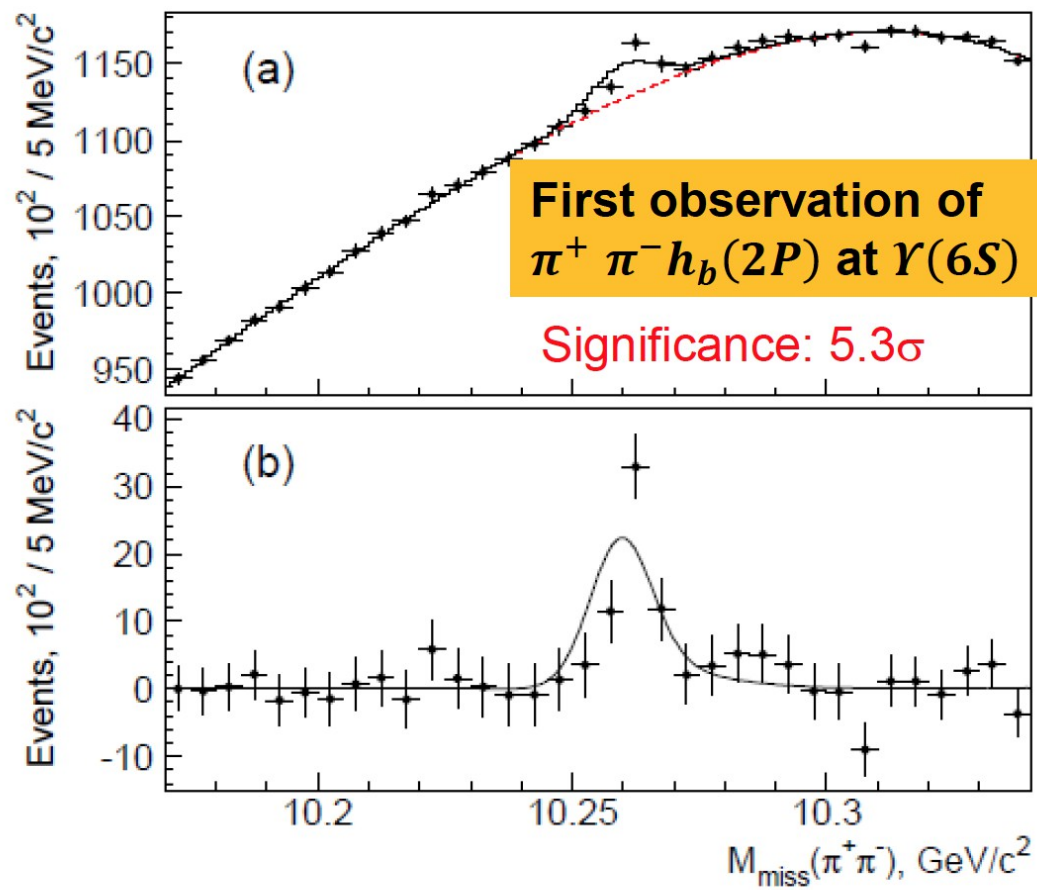


arXiv:1508.06562

- Resonance structure of $\Upsilon(6S)\to\pi\pi\Upsilon(pS)$ decays not fully studied

Υ(6S) results in Belle-I



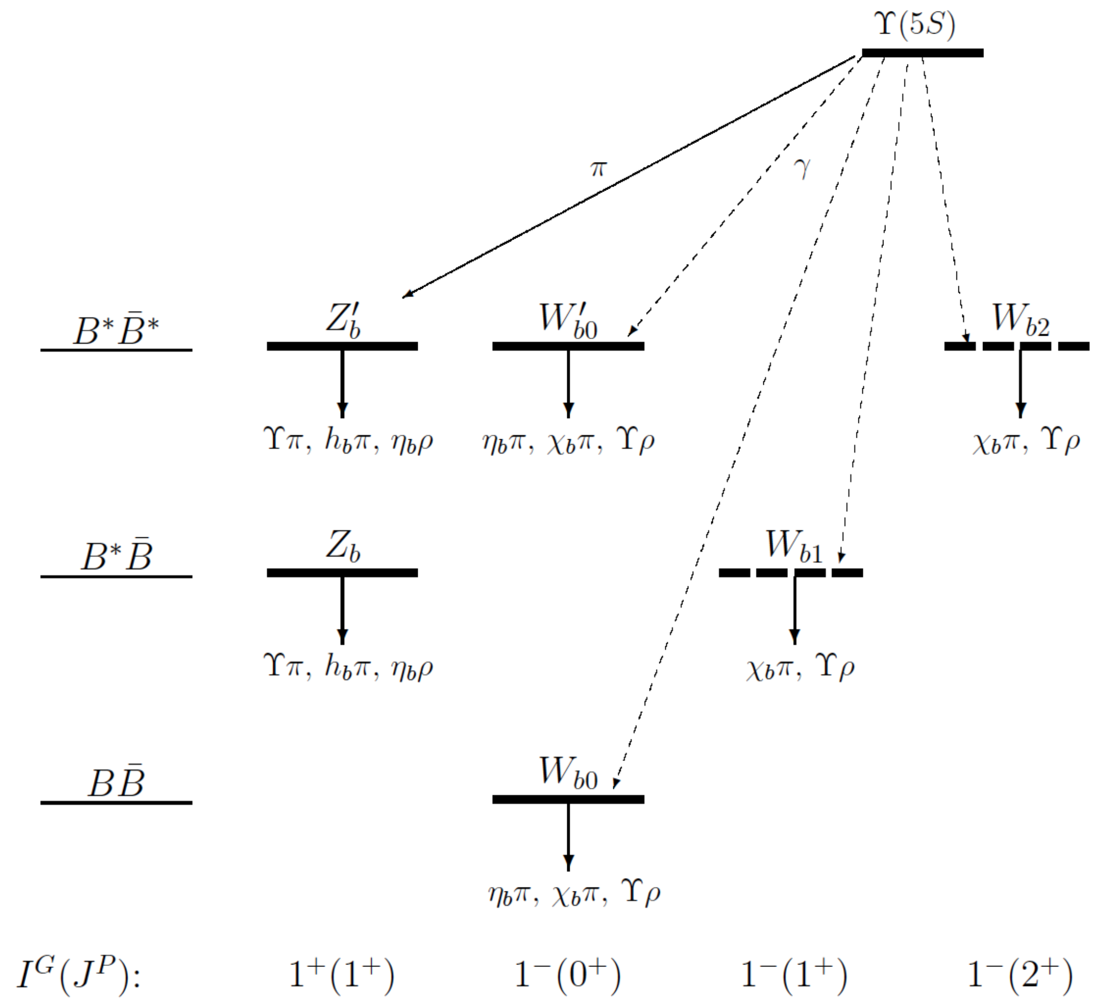


Significance figures include syst errors

Y(6S) prospects in Belle-II phase II

(Voloshin at B2TIP-2016)

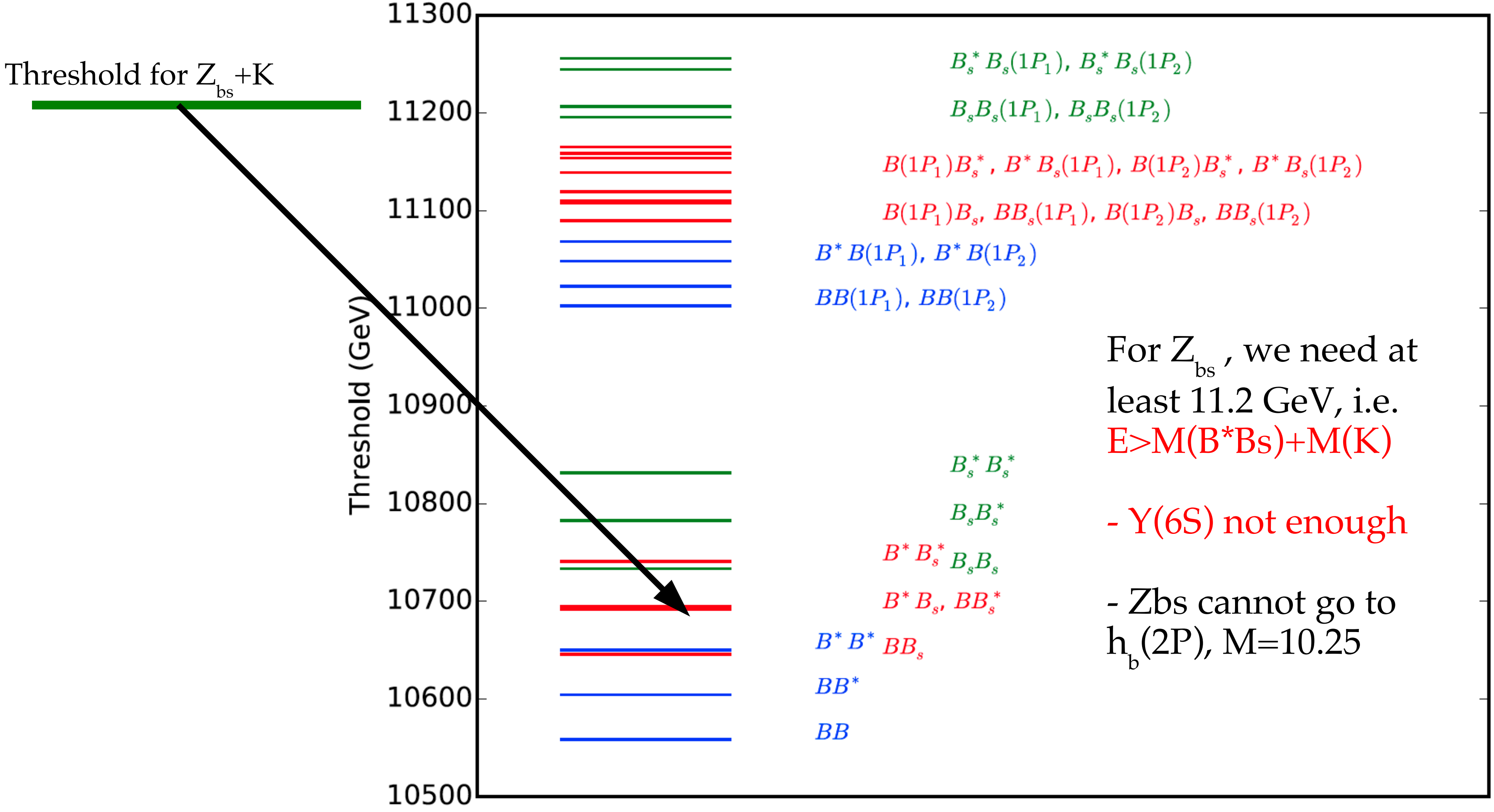
Voloshin has explored consequences of the molecular model to the spectrum of the Zb states: neutral partners (Wb) with J=0,1,2 are expected on the same energy range, and should be reachable from Y(5S) via radiative transitions.



- Important to find/exclude W_b states!
- Intriguing possibility: search for strange bottomonium molecules, $B_s^{(*)}\bar{B}^{(*)}$ with mass 10.700÷10.750 GeV in $e^+e^- \to Z_{bs}K$ around 10.4÷10.5 GeV.

?? probably meant 11.4-11.5

Z_{bs} searches in Belle-II



For Z_{bs} , we need at least 11.2 GeV, i.e.
E>M(B*Bs)+M(K)

- Y(6S) not enough

- Zbs cannot go to $h_b(2P)$, M=10.25

Υ(6S) prospects in Belle-II phase II

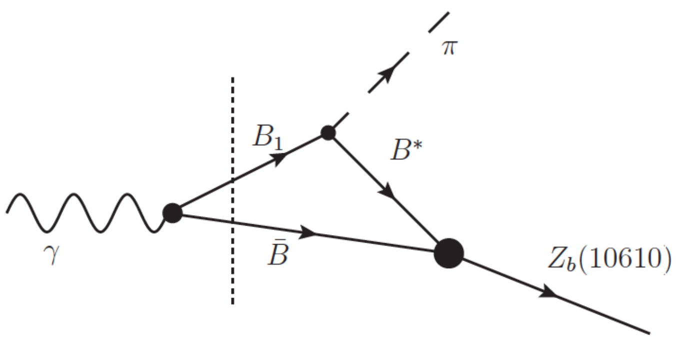
(Voloshin at B2TIP-2016)

- With current (limited) statistics at $\Upsilon(6S)$ ($\sim 11.00\,\text{GeV}$):

$$\left.\frac{\Upsilon(nS)\pi\pi}{h_b(kP)\pi\pi}\right|_{\Upsilon(6S)} \approx \left.\frac{\Upsilon(nS)\pi\pi|_{\text{through}Z_b}}{h_b(kP)\pi\pi}\right|_{\Upsilon(5S)}$$

  I.e. at $\Upsilon(6S)$ essentially no non-resonant background not associated with $Z_b^{(\prime)}$, unlike at $\Upsilon(5S)$. (The HQSS 'forbidden' channels $h_b(kP)\pi\pi$ go exclusively through the $Z_b^{(\prime)}$ within either peak.)

- 11006 MeV is the threshold for $B_1(5721)\bar{B}$. If the pair is produced near threshold, then a 'threshold triangle singularity' is possible with



$Z_b(10610)$ [not the $Z_b(10650)$].

Υ(6S) prospects in Belle-II phase II

If this is the mechanism, then

- The production of final states with bottomonium at $\Upsilon(6S)$ proceed through the $Z_b(10610)$ resonance with no non-resonant background.
- Only the $Z_b(10610)$ is present in the production channels, but not the $Z_b(10650)$.
- There should be a detectable production of $B_1(5721)\bar{B} + c.c.$ heavy meson pairs in the threshold region. In particular, this should contribute to the yield of the final channel $(B^*\bar{B} + c.c.)\,\pi$, but not $B^*\bar{B}^*\pi$.
- The sub dominant decay of the B_1 meson, $B_1 \to B\pi\pi$, may provide, through a similar mechanism, a gateway to the expected at the $B\bar{B}$ threshold resonance W_{b0} with $I^G(J^P) = 1^-(0^+)$.
- Additionally, there may be another similar bump at the c.m. energy around 11.06 GeV, near the threshold of $B_1\bar{B}^*$ and possibly $B_2\bar{B}^*$, where the production of channels with bottomonium may proceed through a mixture of the $Z_b(10610)$ and $Z_b(10650)$ resonances. (At present there is no appropriate data at e^+e^- energies above 11.02 GeV.)

Y(6S) prospects in Belle-II phase II

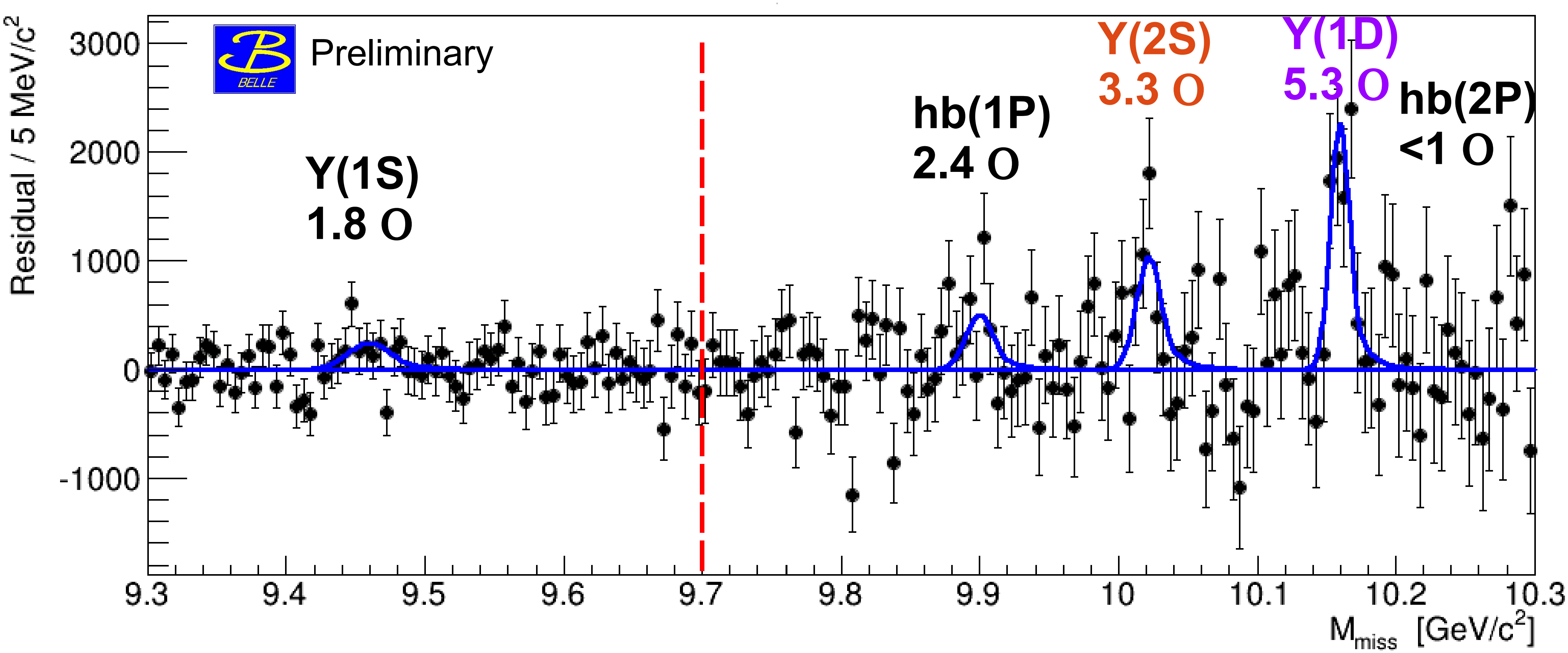
- Exotics at heavy thresholds — new nuclear physics
- Dominant correlations: molecular, hadro-quarkonium, di-diquark, mess?
- Forces in molecules. Guidance from spin. (HQSS OK in Z_b.)
- Unexpected LQSS?
- Expected new states (W_{bJ}, strange hidden-bottomonium). Requires venturing into higher energies, 11.5 GeV and above.
- $Z_b(10610)$ and $Z_b(10650)$ at $\Upsilon(6S)$ and beyond - can have interesting features.
- Hadro-bottomonium? Requires searching beyond 11 GeV.

$\Upsilon(5,6S)$ *eta meson transitions*

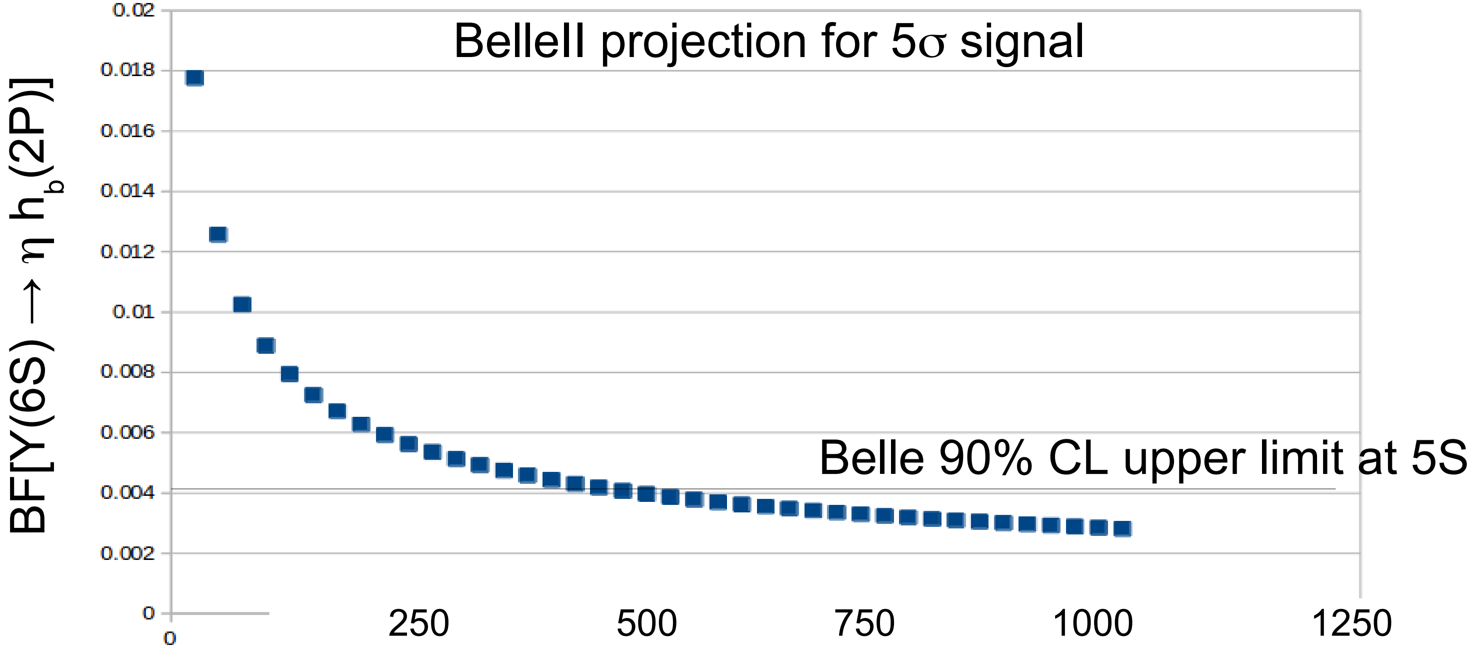
Assuming $\sigma(e^+e^- \to \Upsilon(5S)) = (0.340 \pm 0.016)$ nb

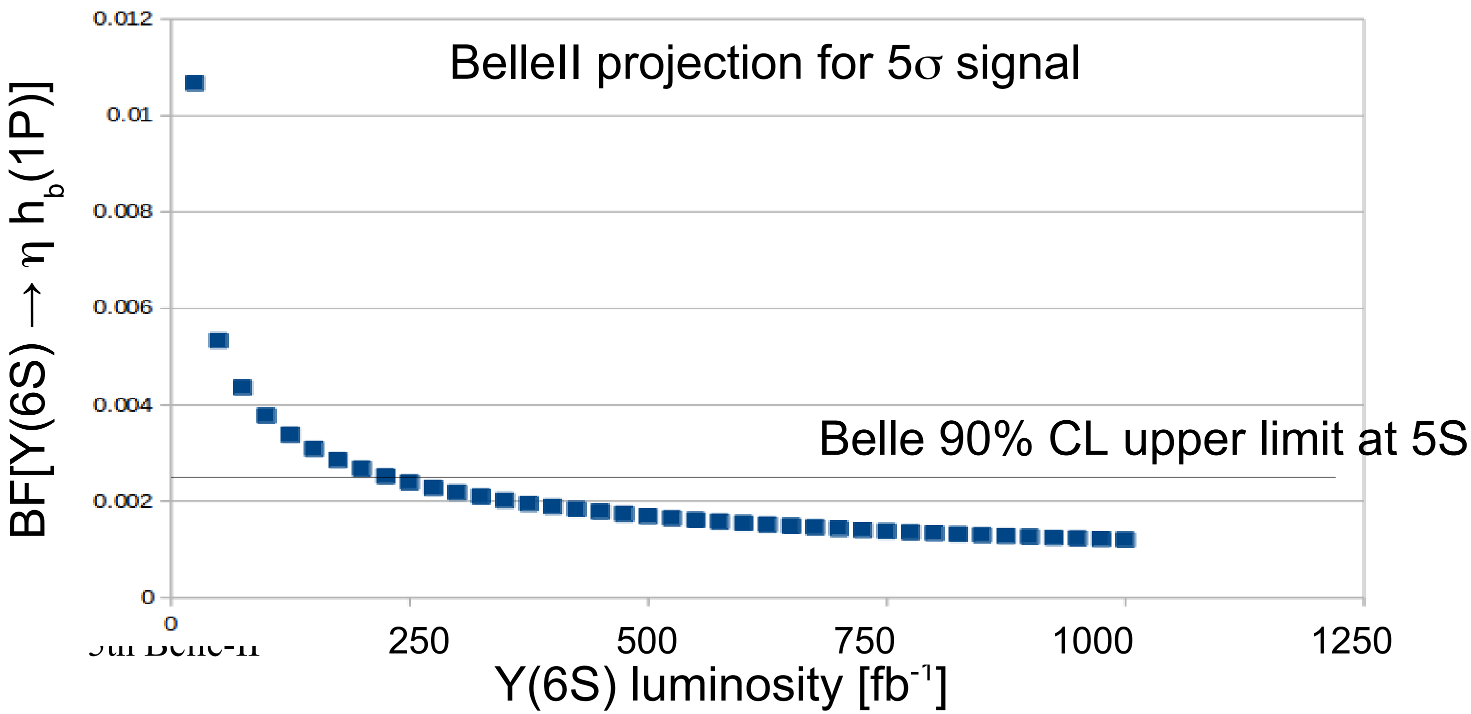
BF[Y(5S) → η Y(2S)]=(2.1 ± 0.7 ± 0.3) x 10^{-3}
BF[Y(5S) → η Y(1D)]=(2.8 ± 0.7 ± 0.4) x 10^{-3}
BF[Y(5S) → η h_b(1P)] < 3.3 x 10^{-3} (90% CL)
BF[Y(5S) → η h_b(2P)] < 3.7 x 10^{-3} (90% CL)

Questions: large eta transitions also from Y(6S)? Is hb(3P) reachable with eta transitions?

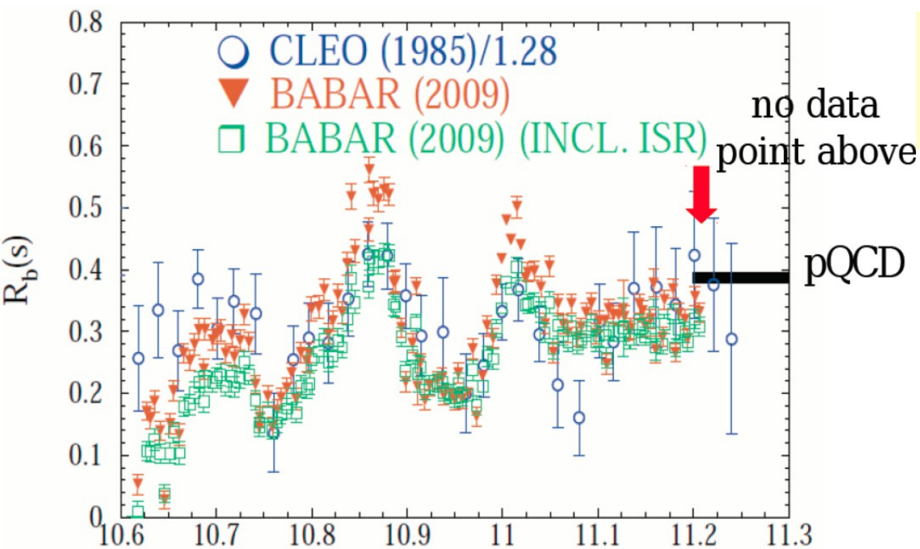


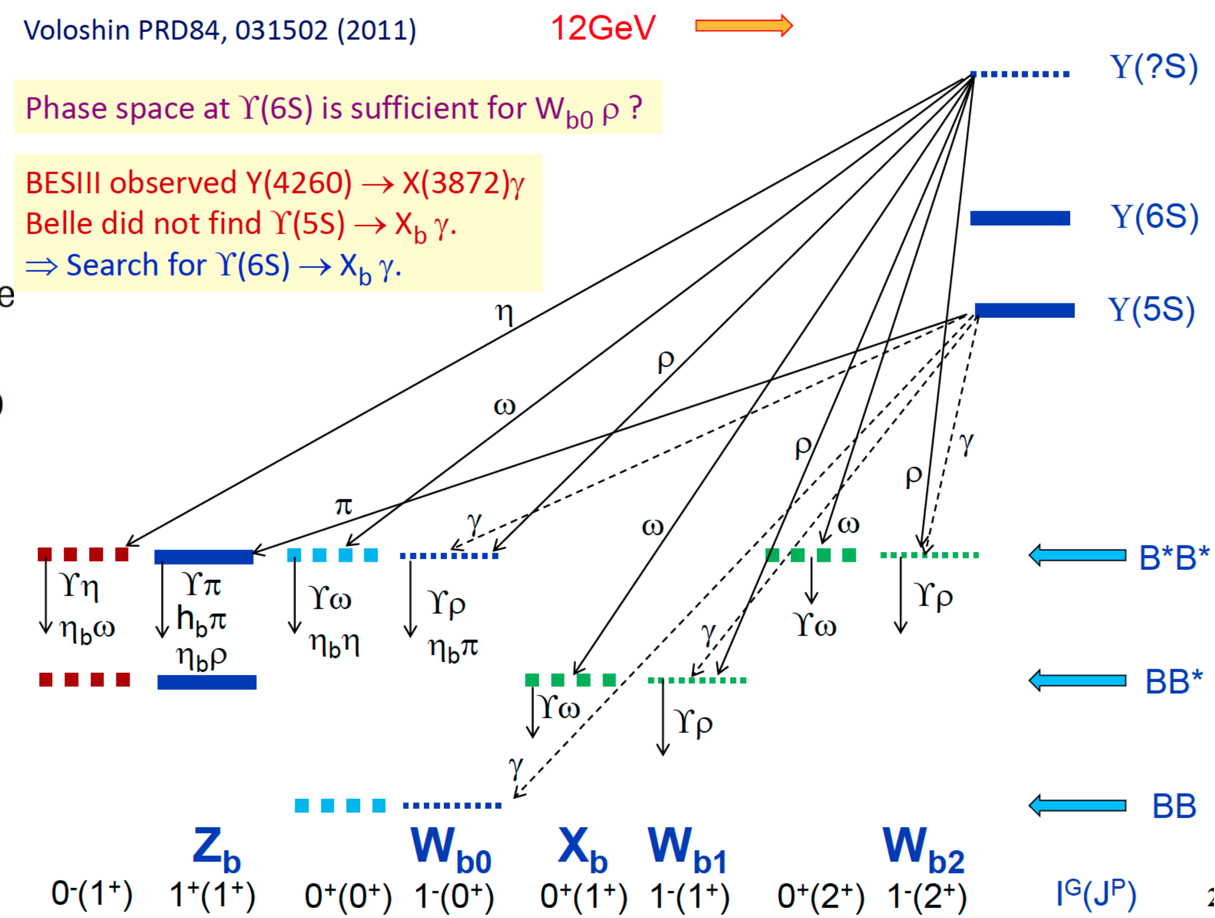
Y(6S) eta meson transitions

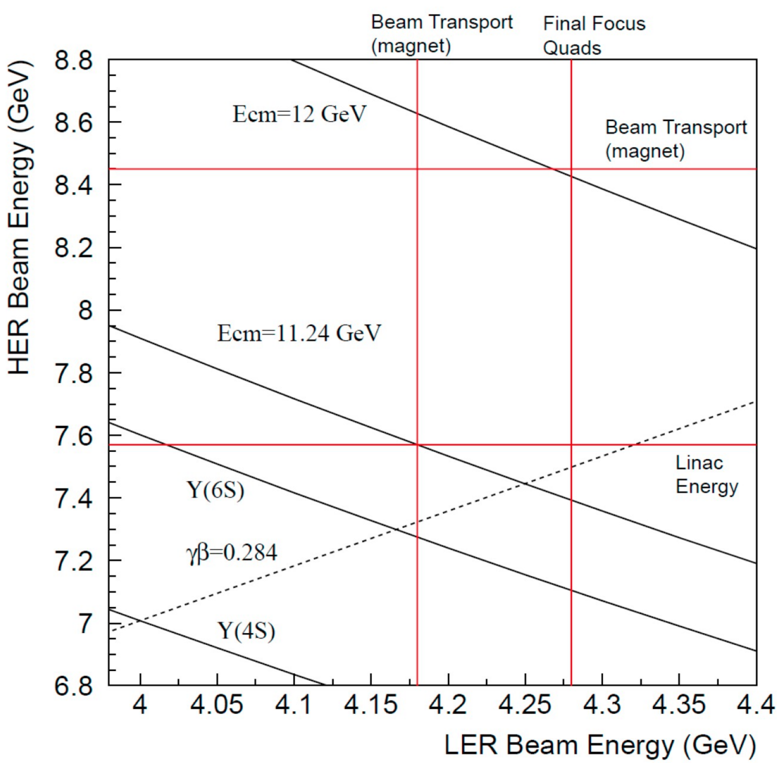




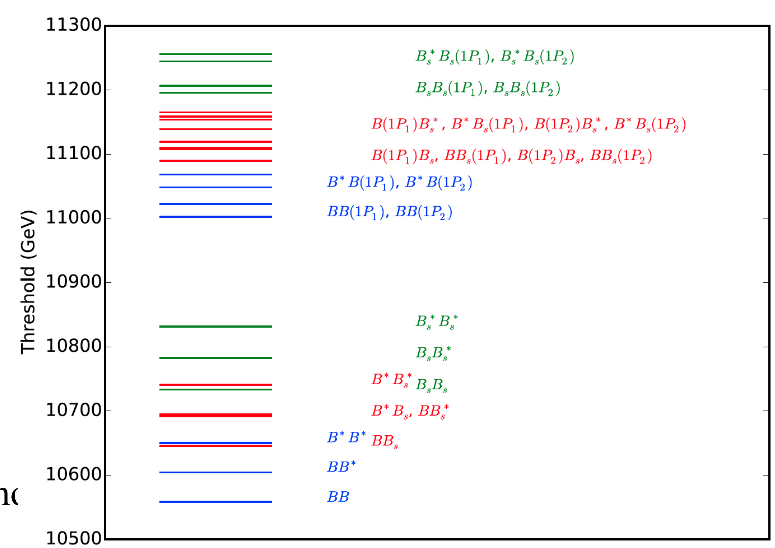
SuperKEK Limits







ıssa, Bottomc



BSM at Υ(3S): χ_{b0}(1,2P) coupling to Light Higgs

Godfrey-Logan @ B2TIP-2016

$\chi_{b0} \to \tau\tau$: s-channel H_{125} and H_{new}

Matrix element (alignment limit for H_{125}):

$$\mathcal{M}^H = \langle \ell^+\ell^- | \frac{im_\ell}{v} \bar{\ell}\ell | 0 \rangle \frac{i}{M^2_{\chi_{b0}} - M^2_{H_{125}}} \langle 0 | \frac{im_b}{v} \bar{b}b | \chi_{b0} \rangle$$
$$+ \langle \ell^+\ell^- | \frac{im_\ell \tan\beta}{v} \bar{\ell}\ell | 0 \rangle \frac{i}{M^2_{\chi_{b0}} - M^2_{H_{\text{new}}}} \langle 0 | \frac{im_b \tan\beta}{v} \bar{b}b | \chi_{b0} \rangle$$

Including H_{new} exchange the partial width becomes:

$$\Gamma^H(\chi_{b0} \to \tau\tau) = \frac{M_{\chi_{b0}}}{8\pi} \left[1 - \frac{4m_\tau^2}{M^2_{\chi_{b0}}}\right]^{3/2} \left(\frac{m_b m_\tau}{v^2 M^2_{H_{125}}}\right)^2 f^2_{\chi_{b0}}$$
$$\times \left[1 + \frac{M^2_{H_{125}} \tan^2\beta}{M^2_{\text{new}} - M^2_{\chi_{b0}}}\right]^2$$

The Higgs-mediated BRs are also multiplied by this factor:

$$\left.\begin{array}{l} \text{BR}^H(\chi_{b0}(1P) \to \tau\tau) = 3.1 \times 10^{-13} \\ \text{BR}^H(\chi_{b0}(2P) \to \tau\tau) = (1.9 \pm 0.5) \times 10^{-12} \end{array}\right\} \times \left[1 + \frac{M^2_{H_{125}} \tan^2\beta}{M^2_{\text{new}} - M^2_{\chi_{b0}}}\right]^2$$

Will only need $(M_{H_{125}}/M_{H_{\text{new}}}) \tan\beta \sim 30$ for $\mathcal{O}(100)$ signal events in $\Upsilon(3S) \to \gamma\chi_{b0}(2P) \to \gamma\tau\tau$

BSM at Υ(3S): χ_{b0}(1,2P) coupling to Light Higgs

SuperKEKB/Belle-II offers a new era in high-statistics studies of scalar bottomonium via radiative Υ decays $\Upsilon \to \gamma\chi_{b0}$:

- 250 fb^{-1} on $\Upsilon(3S) \to 5.9 \times 10^7\ \chi_{b0}(2P) + 2.7 \times 10^6\ \chi_{b0}(1P)$

- 250 fb^{-1} on $\Upsilon(2S) \to 6.2 \times 10^7\ \chi_{b0}(1P)$

χ_{b0} has the same spin and CP quantum numbers as the Higgs. Can its decays be used to probe (BSM) Higgs physics?

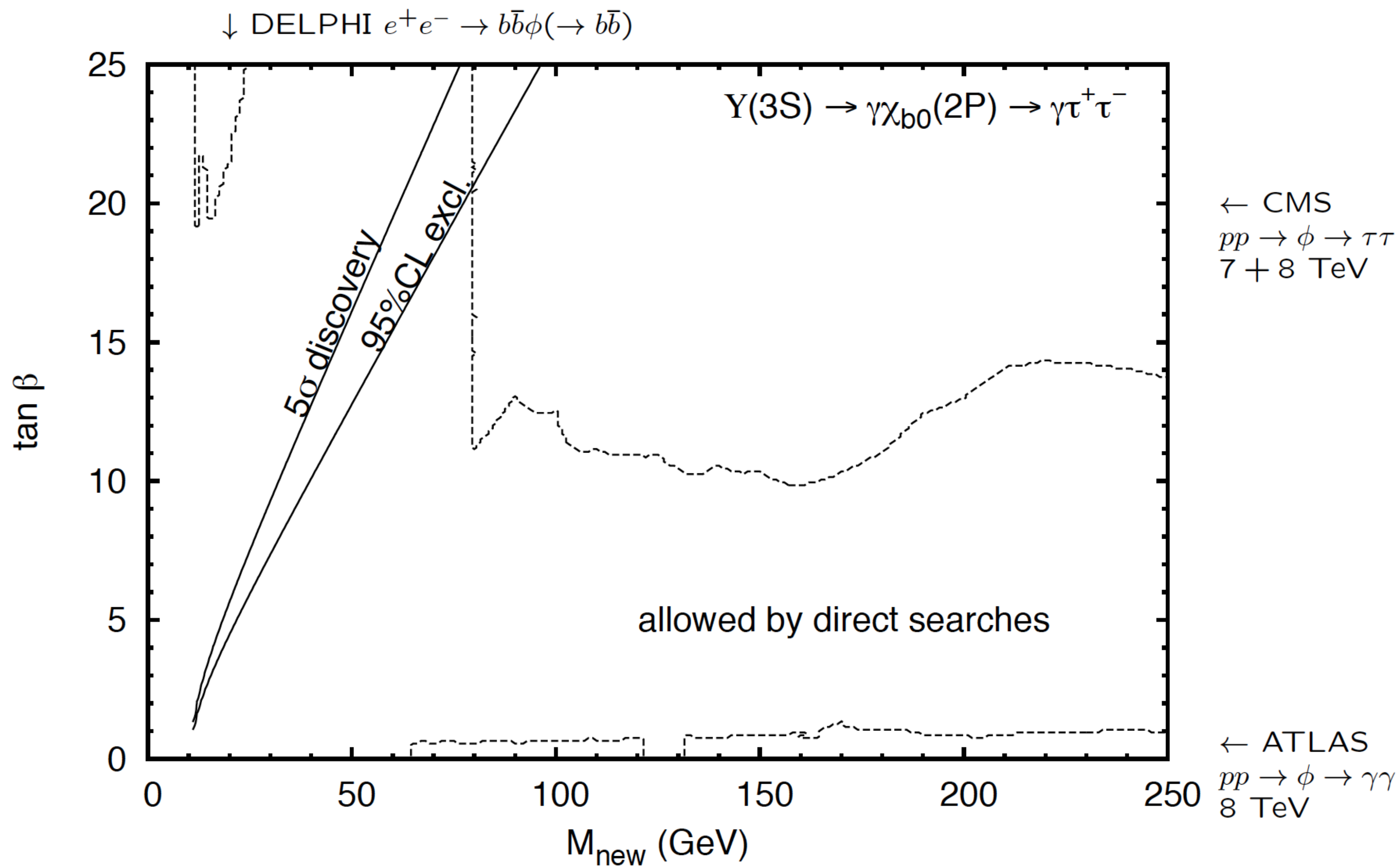
Precedents:
- $B^+ \to \tau^+\nu$ sensitive to s-channel charged Higgs Hou 1993
- $\eta_b \to \tau\tau$ sensitive to s-channel CP-odd Higgs Rashed et al 2010

$\to$ $\chi_{b0} \to \tau\tau$ should be sensitive to s-channel CP-even Higgs

Haber, Kane & Sterling, NPB 1979

BSM at $\Upsilon(3S)$: $\chi_{b0}(1,2P)$ coupling to Light Higgs

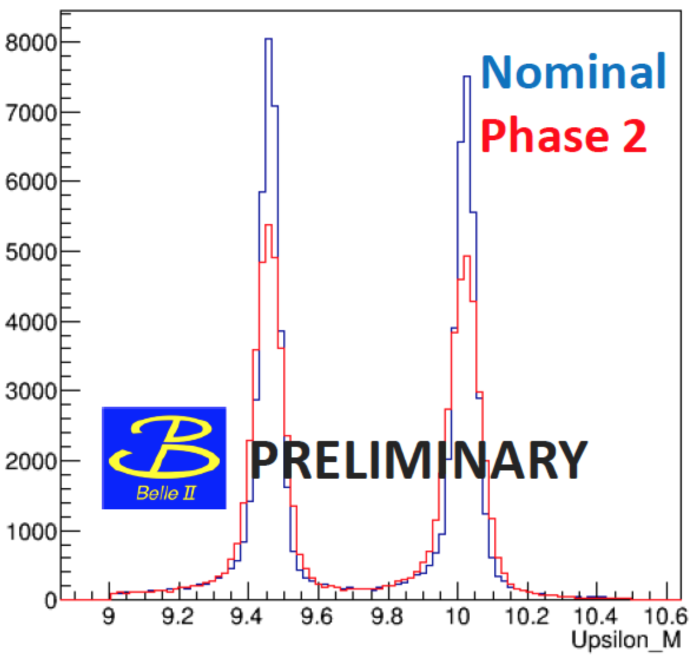
Results: $\Upsilon(3S)$



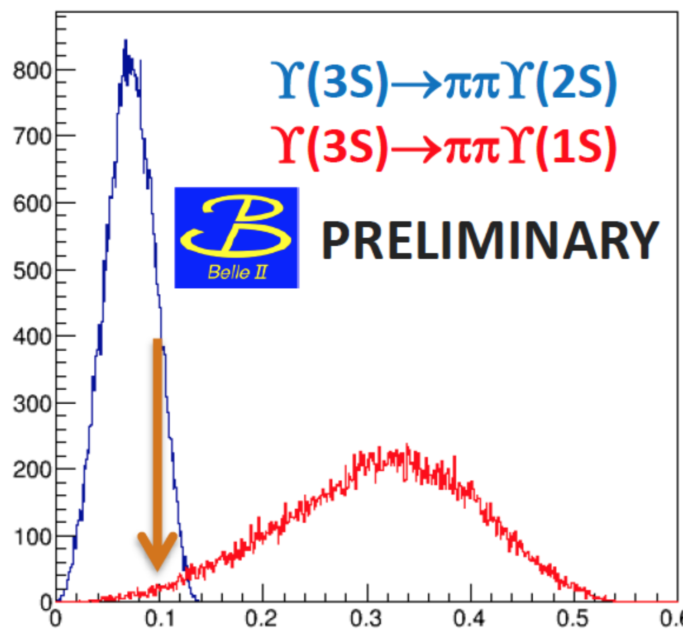
Direct search exclusions: HiggsBounds 4.2.0 S. Godfrey and H.E. Logan, 1510.04659

Phase II Tracking

- $\Upsilon(3S) \to \pi^+\pi^-\Upsilon(1S/2S) \to \mu^+\mu^-$ MC (50/50 split)
- Impact of lack of VXD: $\Upsilon(3S) \to \pi^+\pi^-\Upsilon(2S)$ not feasible
- $\Upsilon(nS) \to \mu\mu$ mass resolution affected as well

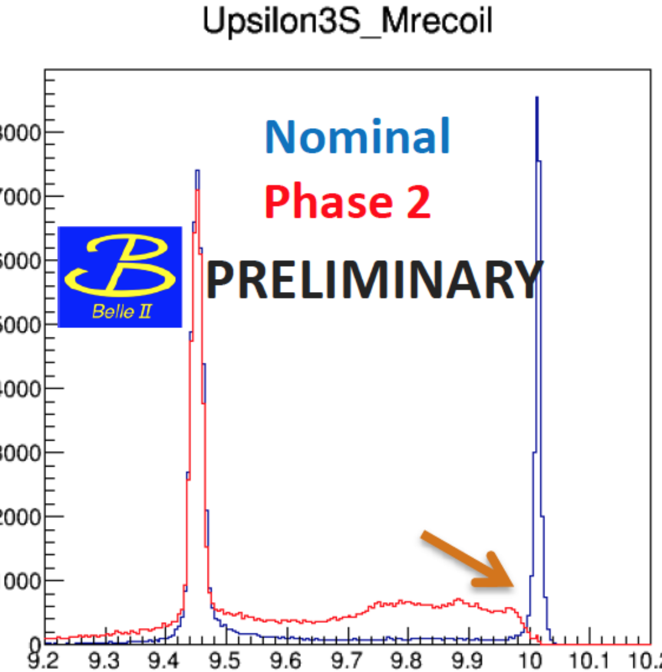


$m(\Upsilon(1S,2S) \to \mu\mu)$



$\Upsilon(3S) \to \pi\pi\ \Upsilon(pS)(\mu\mu)$

Minimum pion momentum



$M(\pi\pi)$ recoil mass

Dipion transitions: BELLE-II vs Babar

Babar: two analyses:

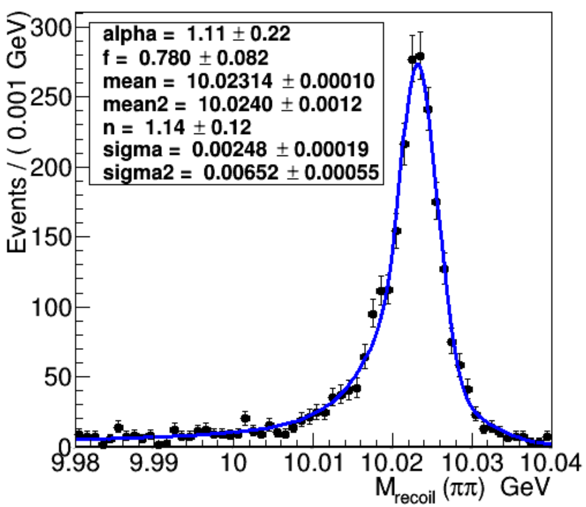
- **Aubert et al., PRD78, 112002 (2008)**

Using data from Y(4S): ISR exclusive decays

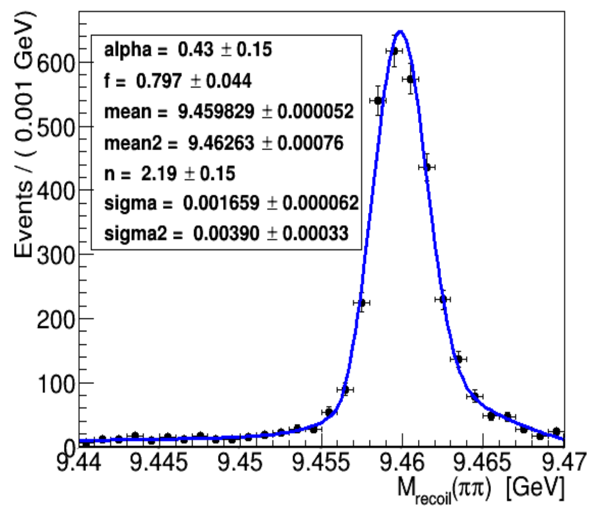
- **Lees et al, PRD84, 011104 (2011)**

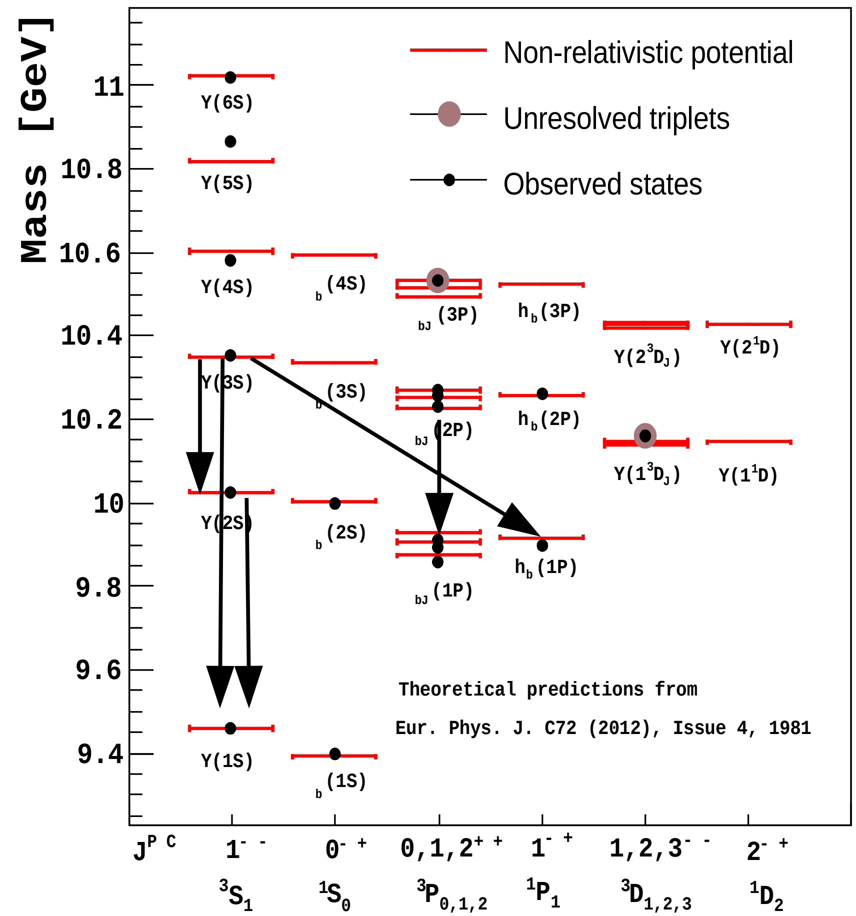
Inclusive dipion transitions from 108 M Y(3S)

Y(3S) → Y(2S) MC



Y(3S) → Y(1S) MC

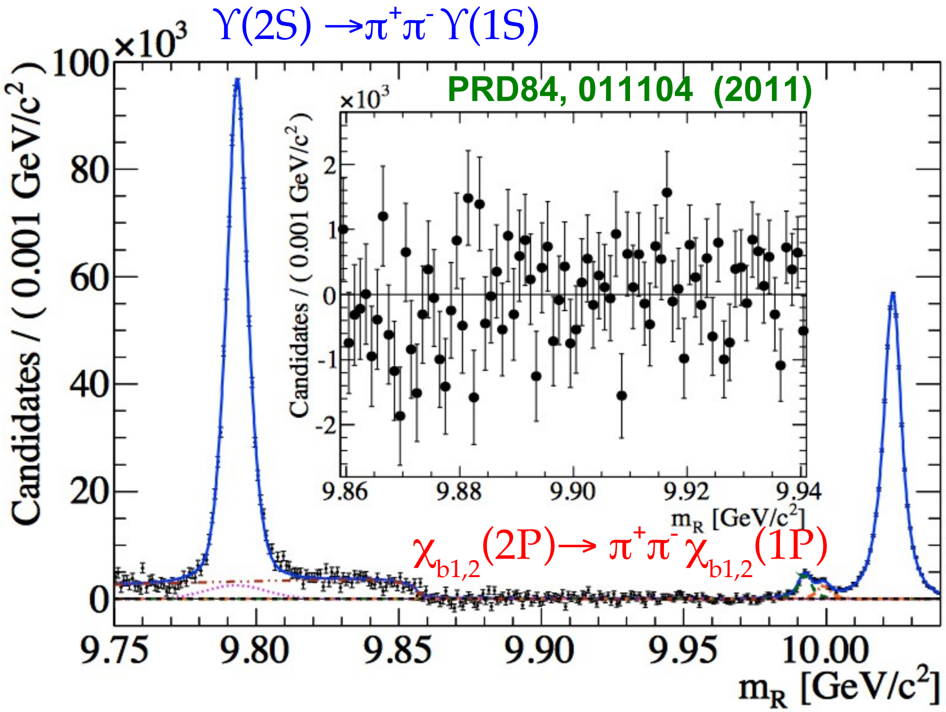


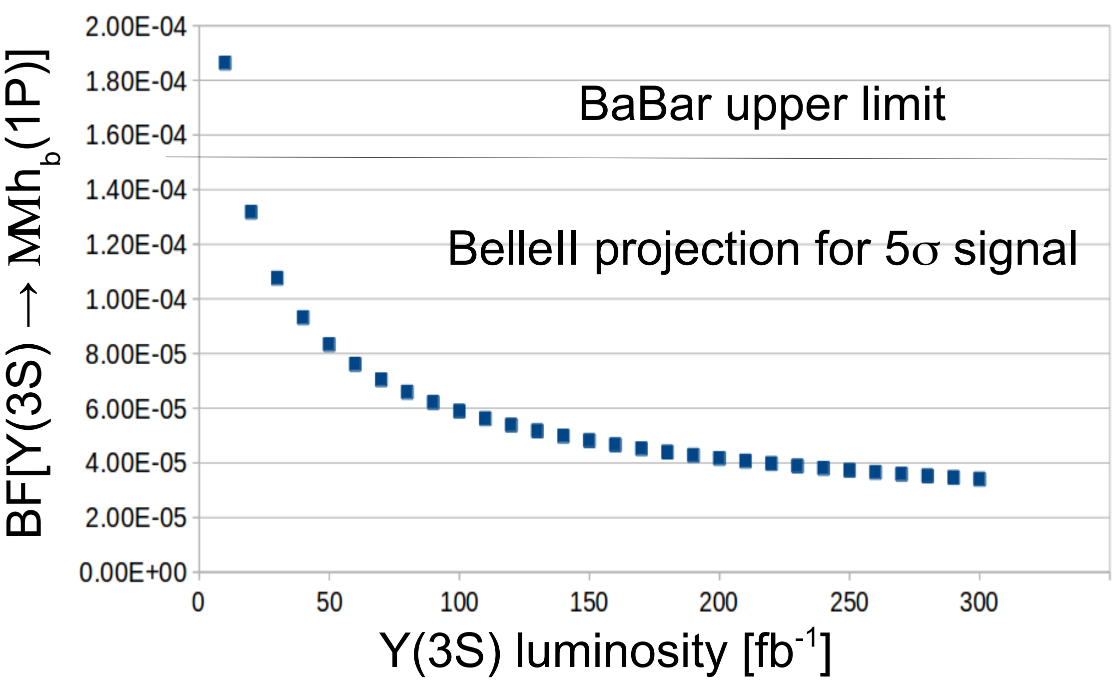


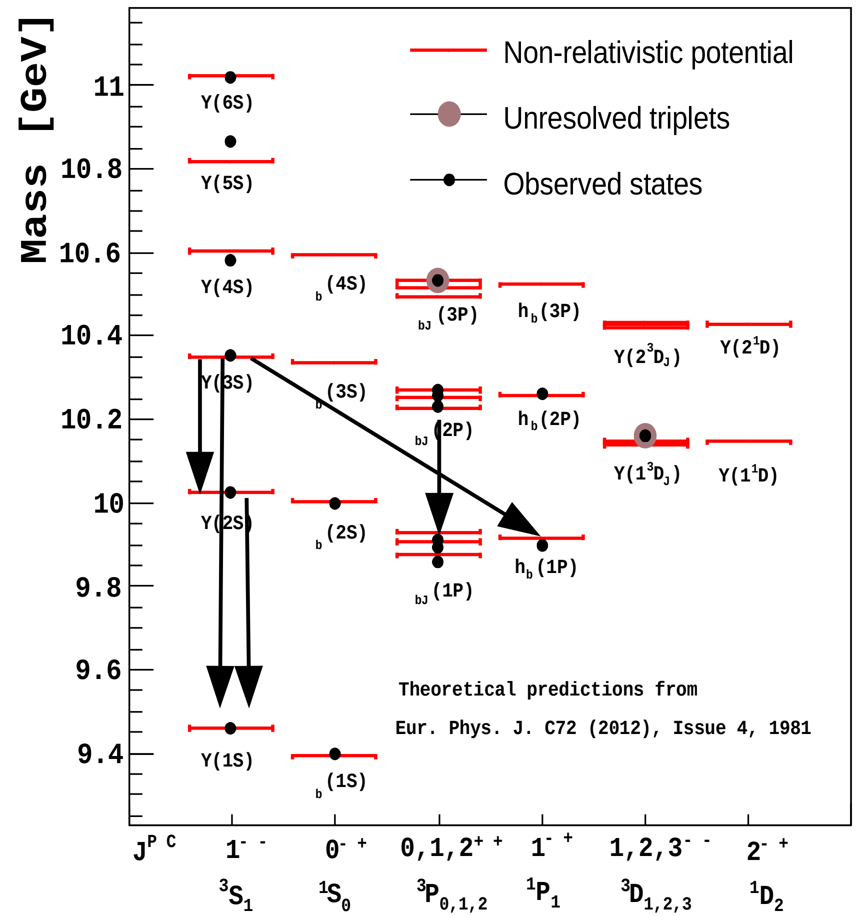
Better resolution and better efficiency

	BaBar σ	BaBar ε	BelleII σ	BelleII ε
Y(3S) → Y(2S)	~4 MeV	16.7 %	2.5 MeV	45%
Y(3S) → Y(1S)	< 4 MeV	41.8%	1.8 MeV	63%

$Y(3S)$ ^ $\pi\pi\, h_b(1P)$



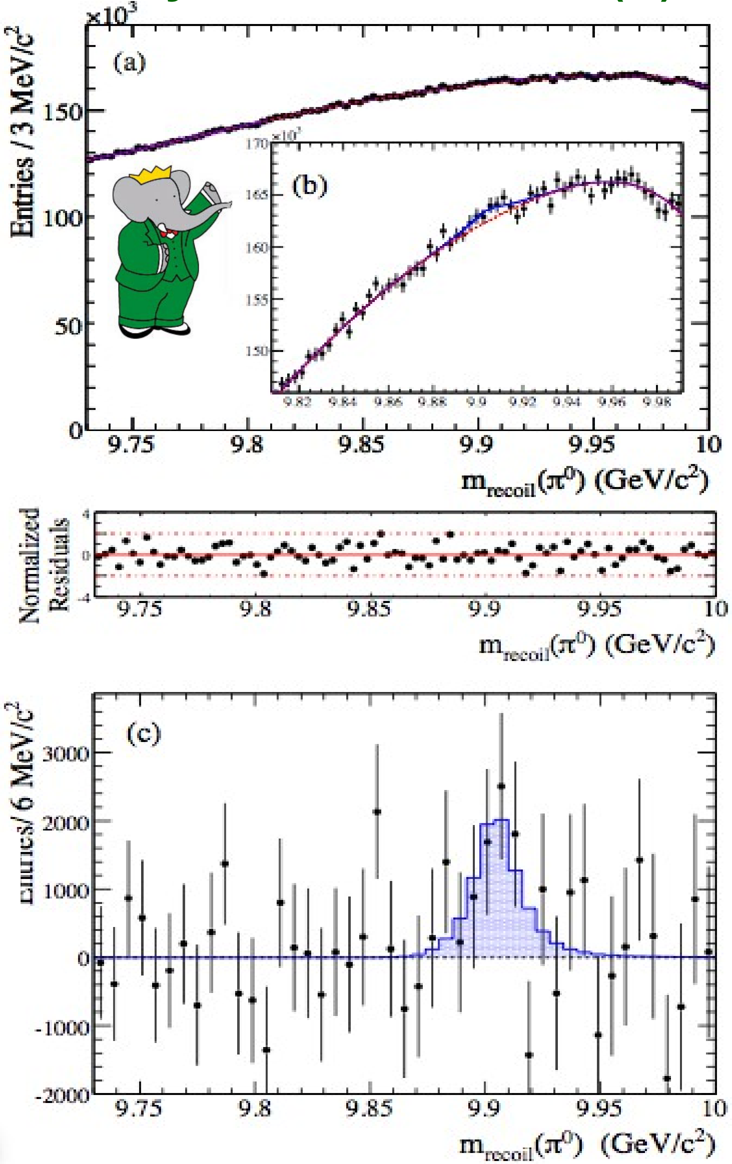




Great improvement thanks to better resolution

$Y(3S)$ single meson transitions

Phys.Rev.D 84 091101(R)

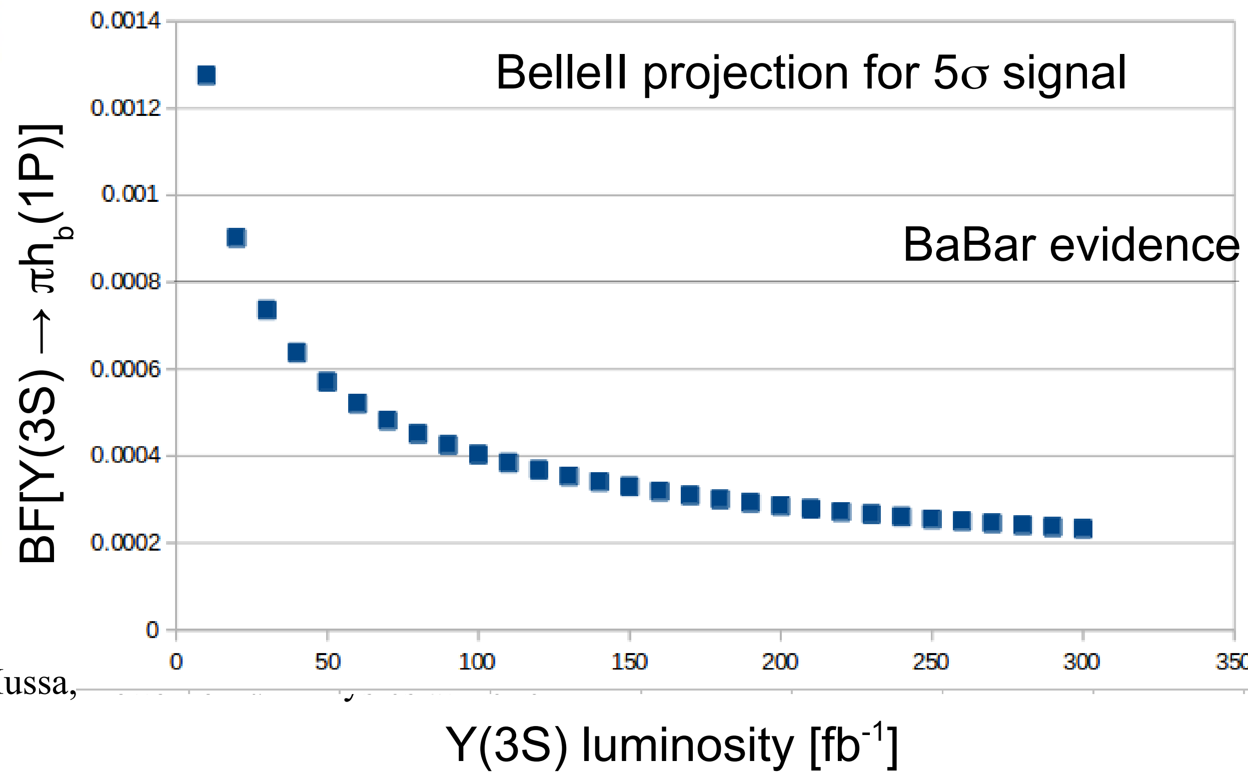


Controversial evidence of
$Y(3S) \rightarrow \pi^0\, h_b(1P) \rightarrow \gamma\, \pi^0\, \Gamma_b(1S)$

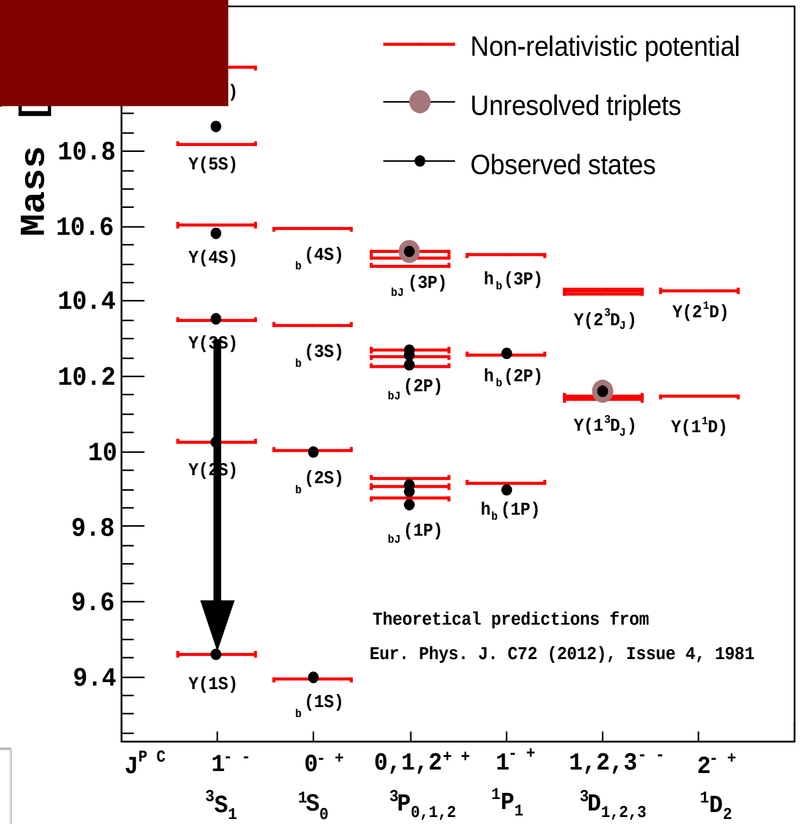
Isospin violating

$$\frac{B[Y(3S)\rightarrow\pi^0 h_b(1P)]}{B[Y(3S)\rightarrow\eta Y(1S)]} > 10$$

Isospin preserving



Y(3S) single meson transitions

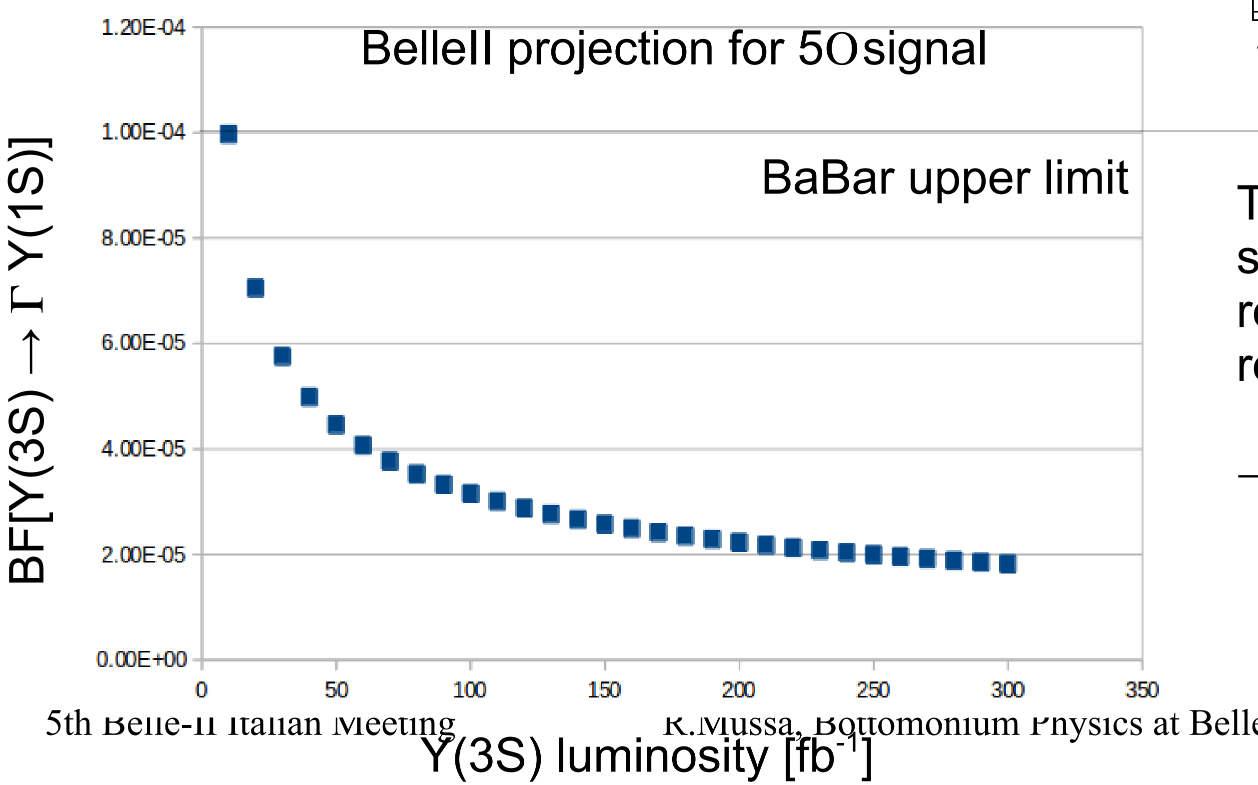


Testing QCD multipole expansion

Three transitions should be visible from Y(3S) but experimental limits, where available, are below theory expectations:

- B(Y(3S) → ηY(1S)) theory: 5-10× 10^{-4}

BaBar: <1x10^{-4}



The projection assumes a significant improvement of the reconstruction performances w/ respect to BaBar

→ compare Belle and BaBar on Y(2S) → Γ Y(1S)

Y(3S) single meson transitions

Testing QCD multipole expansion

Three transitions should be visible from Y(3S) but experimental limits, where available, are below theory expectations:

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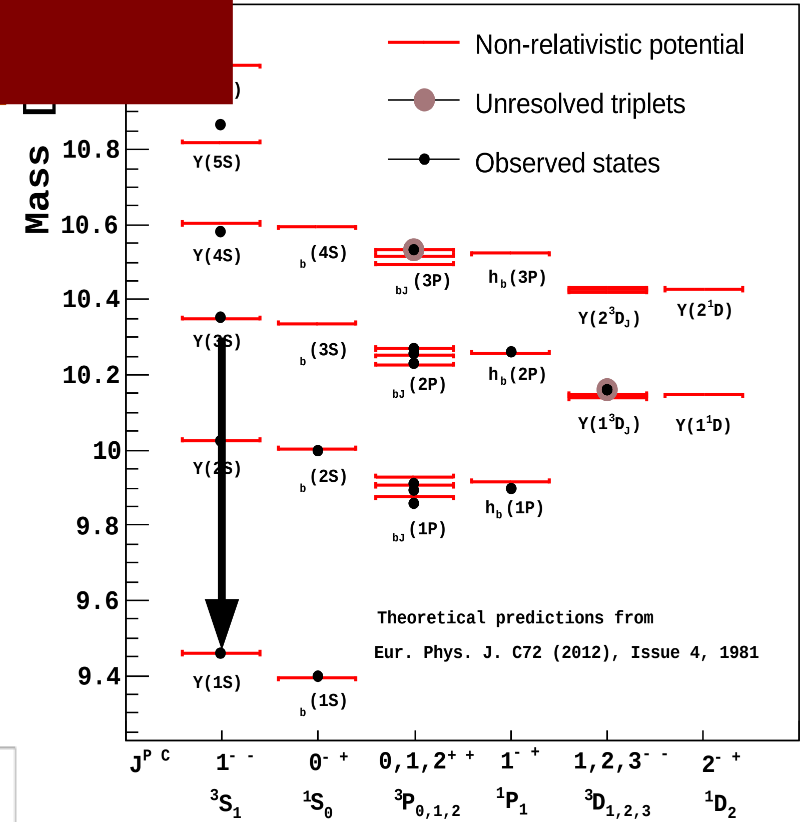
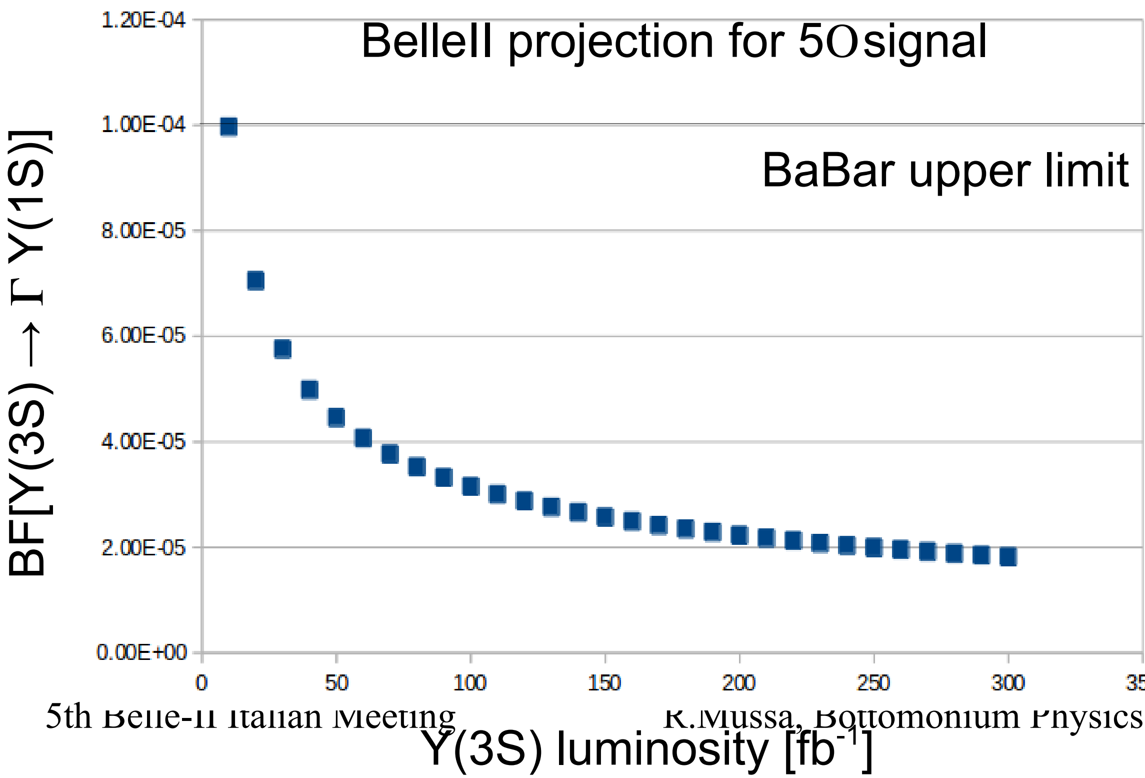




The projection assumes a significant improvement of the reconstruction performances w/ respect to BaBar

→ compare Belle and BaBar on Y(2S) → Γ Y(1S)

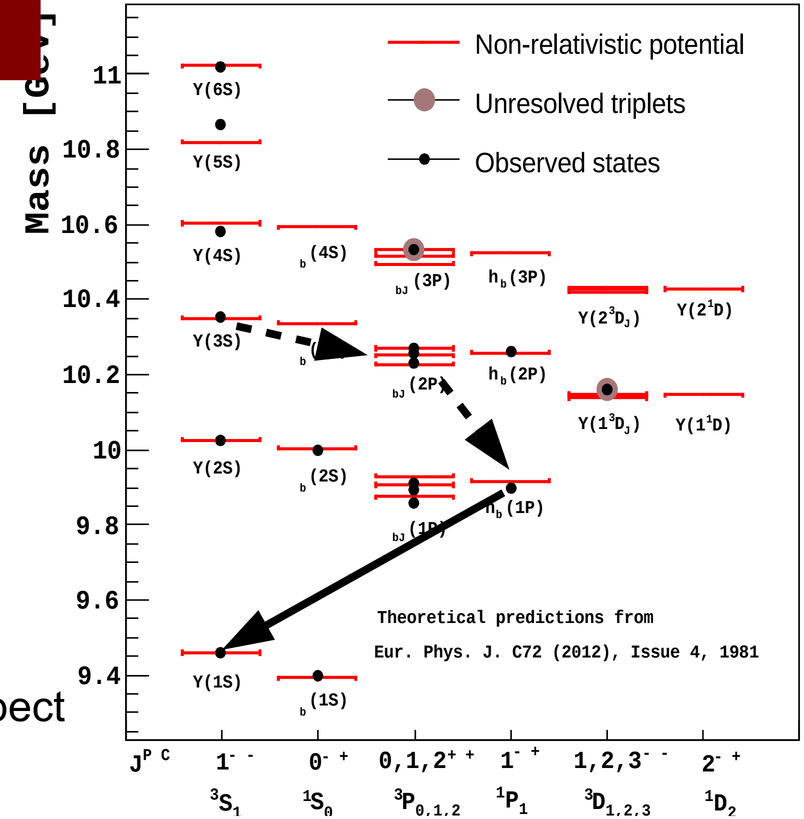
η transitions from Υ(3S)

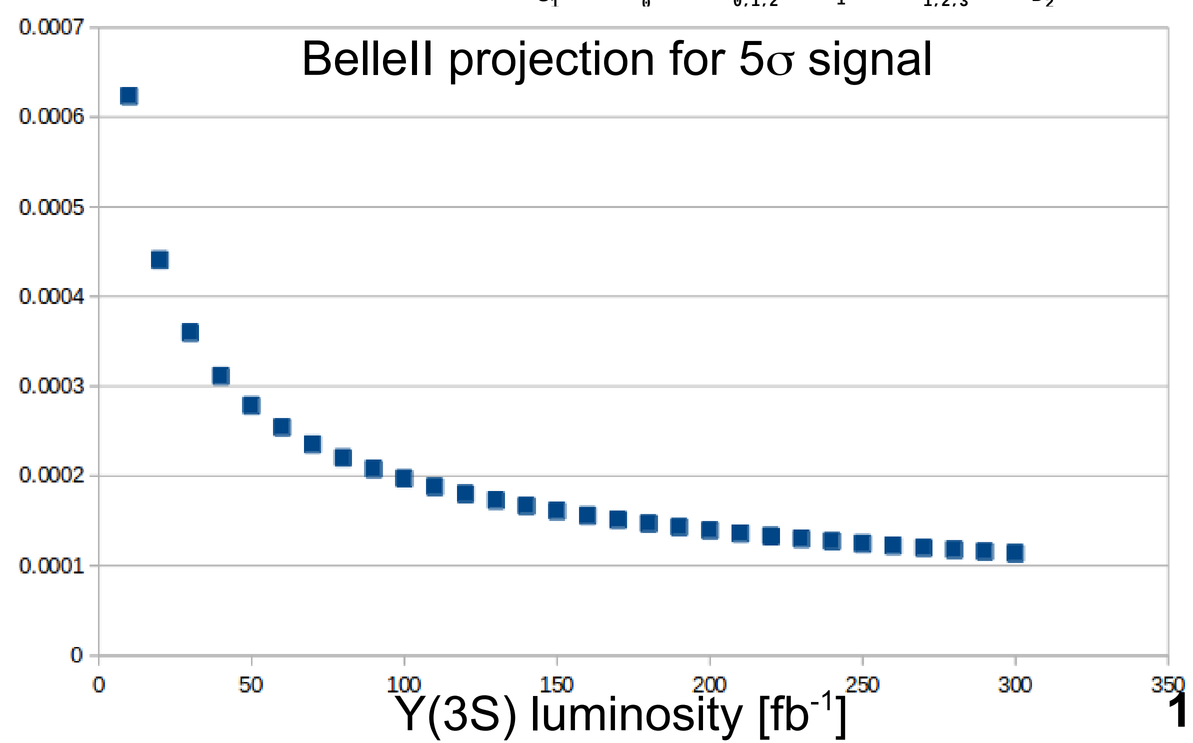
Testing QCD multipole expansion

Three transitions should be visible from Υ(3S) but experimental limits, where available, are below theory expectations:

- Υ(3S) ⟶ ηΥ(1S) theory: 5-10× 10^{-4}
BaBar: <1x10^{-4}

- Υ(1D) ⟶ ηΥ(1S) Voloshin: PLB 562, 68(2003)
QCD Axial Anomaly should enhance Υ(1D) → ηΥ(1S) with respect to Υ(1D) → ππΥ(1S)
→ no quantitative analysis
→ Υ(1D) reconstruction through radiative cascade:
High sensitivity to low energy backgrounds





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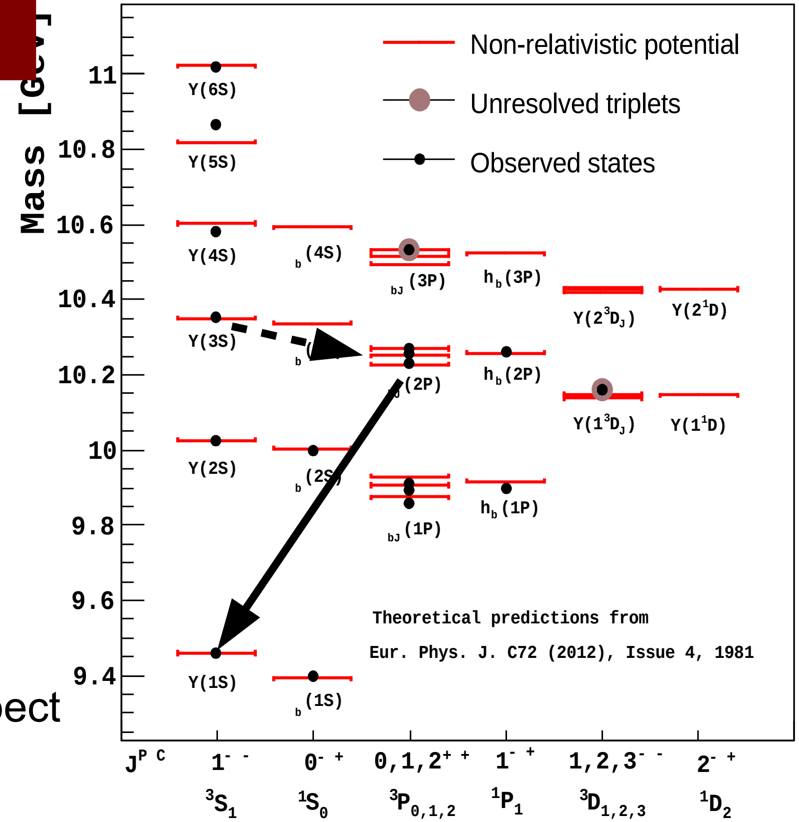


Voloshin: Mod.Phys.Lett. A19, 2895(2004)

- χ_{b0}(2P) ⟶ η η_b
→ BF of the order of few 10^{-3} (S-wave)
→ BelleII estimate ~40 M χ_{b0}(2P) → **~10000 reconstructed events**
→ full inclusive analysis, low energy photons: hard to estimate the backgrounds now...

Υ(3S) to Υ($1^3D_{1,2,3}$) states via 4-photon cascades

- Obtain event numbers by using Belle-BaBar cross section averages

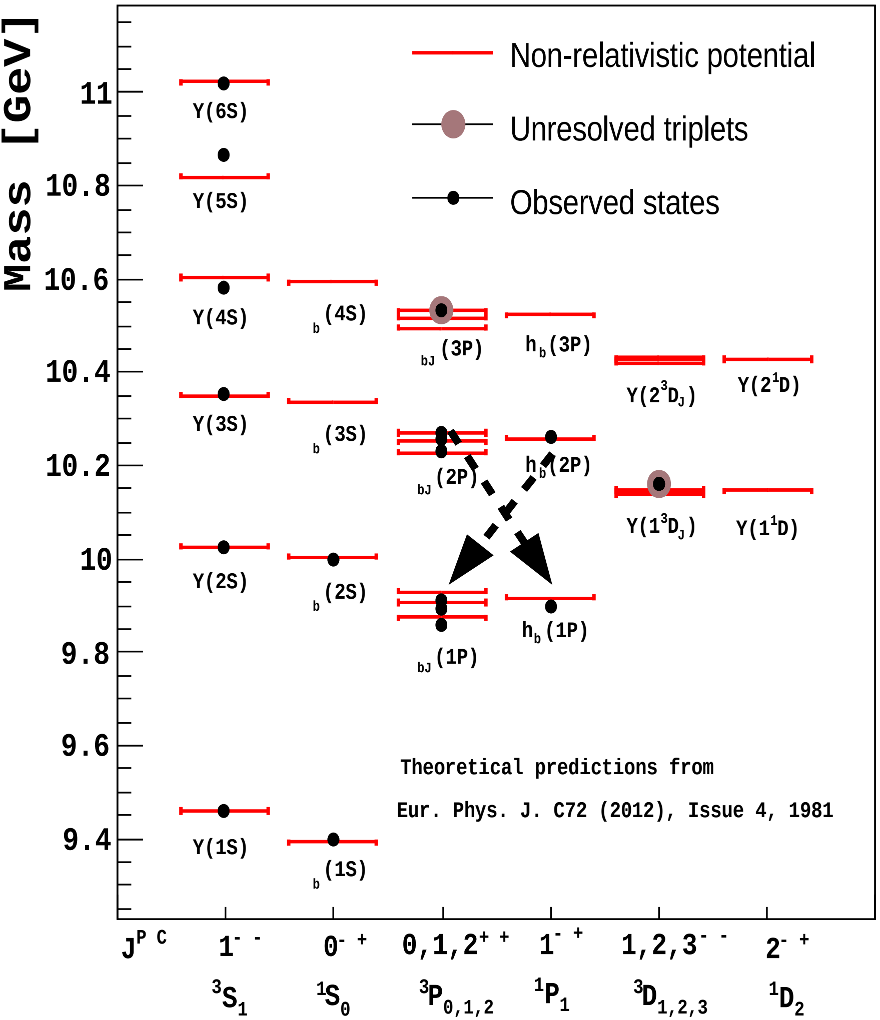
For $\Upsilon(3S)$ 250 fb^{-1} yields 10^9 $\Upsilon(3S)$ (about 7 times Belle-Babar)

Interested in Υ(3S) decay chains via unobserved 1D states

Parent	Decay chain	Combined BR	Events pp	Events e^+e^-
3^3S_1	$\xrightarrow{13.1\%} 2^3P_2\gamma(86.2) \xrightarrow{1.2\%} 1^3D_3\gamma(96.5) \xrightarrow{91.0\%} 1^3P_2\gamma(256.0) \xrightarrow{19.1\%} 1^3S_1\gamma(441.6) \xrightarrow{2.48\%} \mu^+\mu^-$	6.8×10^{-6}	2100	6800
	$\xrightarrow{13.1\%} 2^3P_2\gamma(86.2) \xrightarrow{0.2\%} 1^3D_2\gamma(104.4) \xrightarrow{22\%} 1^3P_2\gamma(248.4) \xrightarrow{19.1\%} 1^3S_1\gamma(441.6) \xrightarrow{2.48\%} \mu^+\mu^-$	2.7×10^{-7}	84	270
	$\xrightarrow{13.1\%} 2^3P_2\gamma(86.2) \xrightarrow{0.2\%} 1^3D_2\gamma(104.4) \xrightarrow{74.7\%} 1^3P_1\gamma(267.3) \xrightarrow{33.9\%} 1^3S_1\gamma(423.0) \xrightarrow{2.48\%} \mu^+\mu^-$	1.6×10^{-6}	500	1600
	$\xrightarrow{13.1\%} 2^3P_2\gamma(86.2) \xrightarrow{0.02\%} 1^3D_1\gamma(78.0) \xrightarrow{1.6\%} 1^3P_2\gamma(239.1) \xrightarrow{19.1\%} 1^3S_1\gamma(441.6) \xrightarrow{2.48\%} \mu^+\mu^-$	2.0×10^{-9}	0.6	2
	$\xrightarrow{13.1\%} 2^3P_2\gamma(86.2) \xrightarrow{0.02\%} 1^3D_1\gamma(78.0) \xrightarrow{28\%} 1^3P_1\gamma(258.0) \xrightarrow{33.9\%} 1^3S_1\gamma(423.0) \xrightarrow{2.48\%} \mu^+\mu^-$	6.2×10^{-8}	19	62
	$\xrightarrow{13.1\%} 2^3P_2\gamma(86.2) \xrightarrow{0.02\%} 1^3D_1\gamma(78.0) \xrightarrow{47.1\%} 1^3P_0\gamma(290.5) \xrightarrow{1.76\%} 1^3S_1\gamma(391.1) \xrightarrow{2.48\%} \mu^+\mu^-$	5.4×10^{-9}	2	5
	$\xrightarrow{13.1\%} 2^3P_2\gamma(86.2) \xrightarrow{0.02\%} 1^3D_1\gamma(78.0) \xrightarrow{0.00393\%} \mu^+\mu^-$	1.0×10^{-9}	0.3	1
	$\xrightarrow{12.6\%} 2^3P_1\gamma(99.3) \xrightarrow{1.9\%} 1^3D_2\gamma(91.3) \xrightarrow{22\%} 1^3P_2\gamma(248.4) \xrightarrow{19.1\%} 1^3S_1\gamma(441.6) \xrightarrow{2.48\%} \mu^+\mu^-$	2.5×10^{-6}	780	2500
	$\xrightarrow{12.6\%} 2^3P_1\gamma(99.3) \xrightarrow{1.9\%} 1^3D_2\gamma(91.3) \xrightarrow{74.7\%} 1^3P_1\gamma(267.3) \xrightarrow{33.9\%} 1^3S_1\gamma(423.0) \xrightarrow{2.48\%} \mu^+\mu^-$	1.5×10^{-5}	4650	15,000
	$\xrightarrow{12.6\%} 2^3P_1\gamma(99.3) \xrightarrow{0.80\%} 1^3D_1\gamma(100.8) \xrightarrow{1.6\%} 1^3P_2\gamma(239.1) \xrightarrow{19.1\%} 1^3S_1\gamma(441.6) \xrightarrow{2.48\%} \mu^+\mu^-$	7.6×10^{-8}	24	76
	$\xrightarrow{12.6\%} 2^3P_1\gamma(99.3) \xrightarrow{0.80\%} 1^3D_1\gamma(100.8) \xrightarrow{28\%} 1^3P_1\gamma(258.0) \xrightarrow{33.9\%} 1^3S_1\gamma(423.0) \xrightarrow{2.48\%} \mu^+\mu^-$	2.4×10^{-6}	740	2400
	$\xrightarrow{12.6\%} 2^3P_1\gamma(99.3) \xrightarrow{0.80\%} 1^3D_1\gamma(100.8) \xrightarrow{47.1\%} 1^3P_0\gamma(290.5) \xrightarrow{1.76\%} 1^3S_1\gamma(391.1) \xrightarrow{2.48\%} \mu^+\mu^-$	2.1×10^{-7}	65	210
	$\xrightarrow{5.9\%} 2^3P_0\gamma(122.0) \xrightarrow{0.4\%} 1^3D_1\gamma(78.0) \xrightarrow{1.6\%} 1^3P_2\gamma(239.1) \xrightarrow{19.1\%} 1^3S_1\gamma(441.6) \xrightarrow{2.48\%} \mu^+\mu^-$	1.8×10^{-8}	6	18
	$\xrightarrow{5.9\%} 2^3P_0\gamma(122.0) \xrightarrow{0.4\%} 1^3D_1\gamma(78.0) \xrightarrow{28\%} 1^3P_1\gamma(258.0) \xrightarrow{33.9\%} 1^3S_1\gamma(423.0) \xrightarrow{2.48\%} \mu^+\mu^-$	5.6×10^{-7}	170	560
	$\xrightarrow{5.9\%} 2^3P_0\gamma(122.0) \xrightarrow{0.4\%} 1^3D_1\gamma(78.0) \xrightarrow{47.1\%} 1^3P_0\gamma(290.5) \xrightarrow{1.76\%} 1^3S_1\gamma(391.1) \xrightarrow{2.48\%} \mu^+\mu^-$	4.8×10^{-8}	15	48
3^1S_0	$\xrightarrow{1.8\times10^{-6}} 2^3S_1\gamma(309.2) \xrightarrow{1.93\%} \mu^+\mu^-$	3.4×10^{-8}	5	NA
	$\xrightarrow{1.5\times10^{-5}} 1^3S_1\gamma(840.0) \xrightarrow{2.48\%} \mu^+\mu^-$	3.7×10^{-7}	52	NA

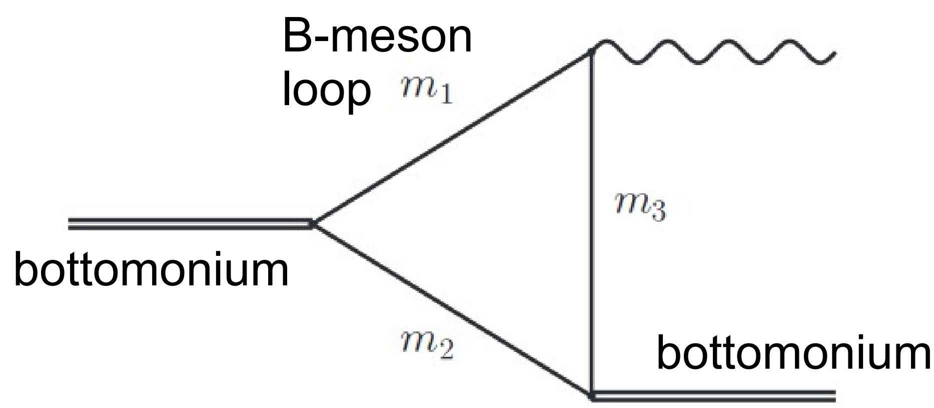
Problem : QED+beam backgrounds, to be estimated

Hindered M1 transitions from Υ(3S)



Spin triplet - spin singlet transitions
sensitive to heavy quark spin symmetry breaking

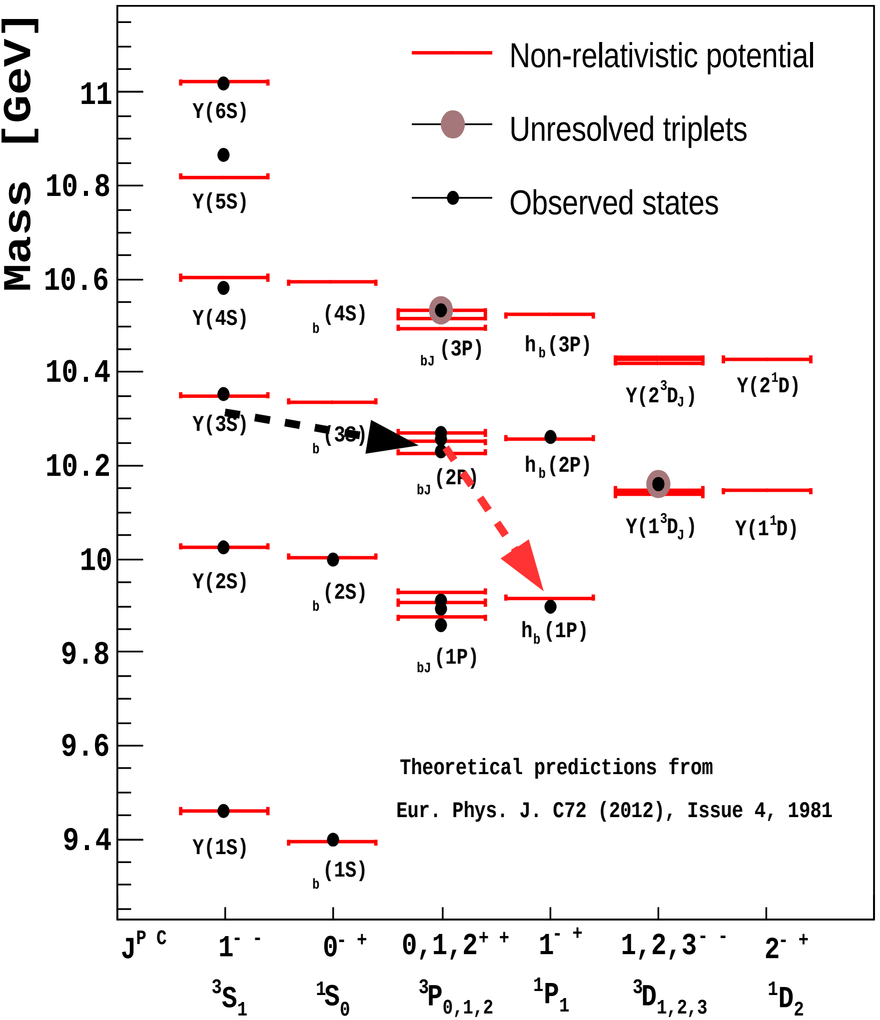
Very recent paper: arXiv:1604.00770

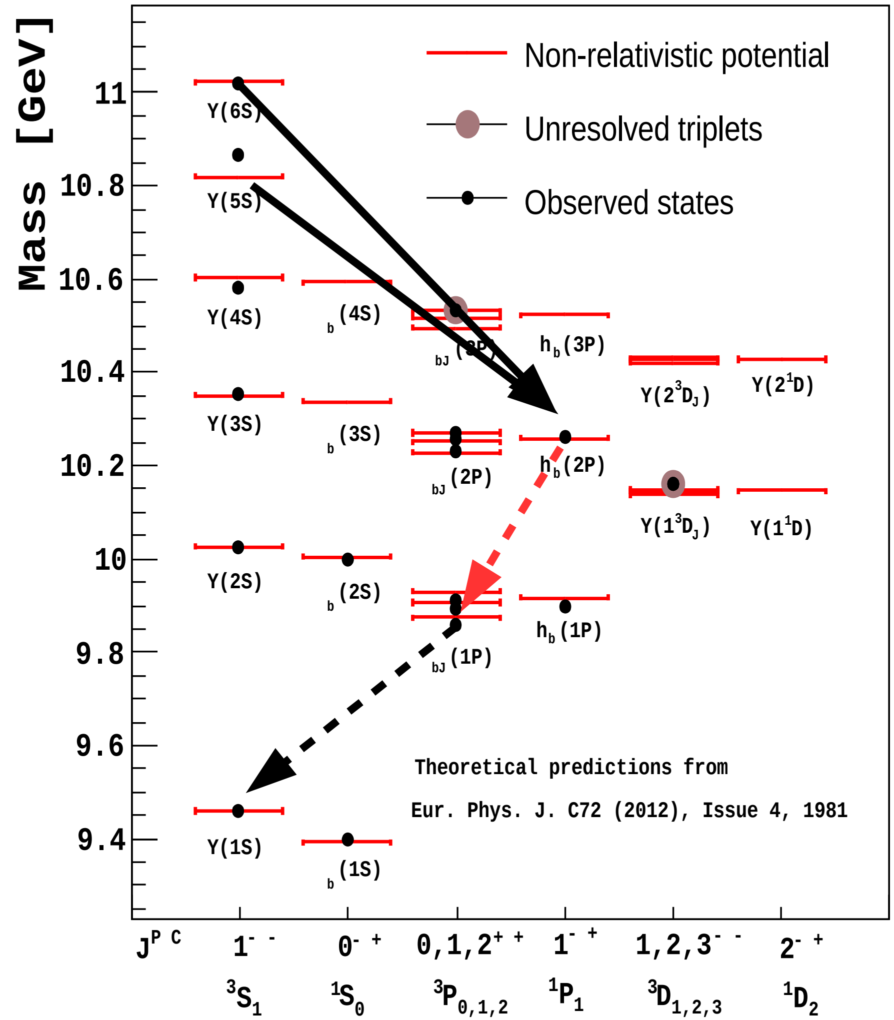


Components of the loop for different transitions

$\chi_{b0} \to h_b\gamma$	$[B^*, \bar{B}^*, B]$, $[B^*, \bar{B}^*, B^*]$, $[B, \bar{B}, B^*]$
$\chi_{b1} \to h_b\gamma$	$[B^*, \bar{B}, B^*]$, $[B, \bar{B}^*, B^*]$
$\chi_{b2} \to h_b\gamma$	$[B^*, \bar{B}^*, B]$, $[B^*, \bar{B}^*, B^*]$
$h_b \to \chi_{b0}\gamma$	$[B^*, \bar{B}, B]$, $[B, \bar{B}^*, B^*]$, $[B^*, \bar{B}^*, B^*]$
$h_b \to \chi_{b1}\gamma$	$[B^*, \bar{B}, B^*]$, $[B^*, \bar{B}^*, B]$
$h_b \to \chi_{b2}\gamma$	$[B, \bar{B}^*, B^*]$, $[B^*, \bar{B}^*, B^*]$

Hindered M1 transitions between P waves





Experimentally unexplored territory

$\chi_{bJ}(2P) \rightarrow \gamma h_b(2P)$
- → requires Υ(3S) data
- → High background (inclusive reconstruction)

$h_b(2P) \rightarrow \gamma \chi_{bJ}(1P)$
- → requires Υ(5,6S) data
- → Low background (exclusive reconstruction)

Antinuclei in Y(3S) decays

CLEO results :

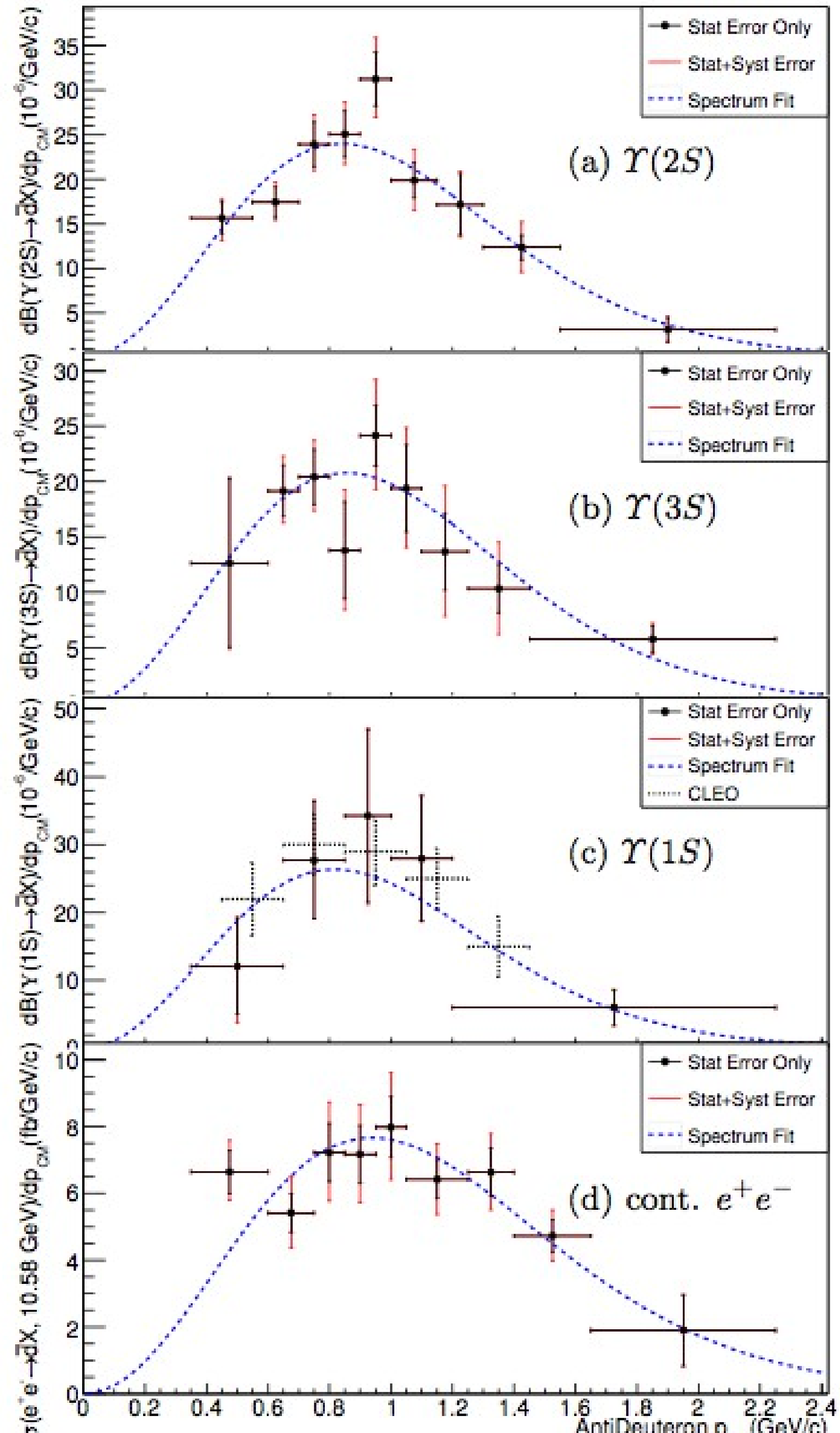
$$\mathcal{B}^{\,\mathrm{dir}}(\Upsilon(1S)\to \bar{d}X) = (3.36 \pm 0.23 \pm 0.25)\times 10^{-5}.$$

$$\mathcal{B}\,(\Upsilon(2S)\to \bar{d}+X) = (3.37 \pm 0.50 \pm 0.25)\times 10^{-5}.$$

BABAR results :

Resonance	Onpeak	# of Υ Decays	Offpeak
$\Upsilon(4S)$	$429\,\mathrm{fb}^{-1}$	463×10^{6}	$44.8\,\mathrm{fb}^{-1}$
$\Upsilon(3S)$	$28.5\,\mathrm{fb}^{-1}$	116×10^{6}	$2.63\,\mathrm{fb}^{-1}$
$\Upsilon(2S)$	$14.4\,\mathrm{fb}^{-1}$	98.3×10^{6}	$1.50\,\mathrm{fb}^{-1}$

Process	Rate
$\mathcal{B}(\Upsilon(3S)\to\bar{d}X)$	$(2.33\pm0.15^{+0.31}_{-0.28})\times10^{-5}$
$\mathcal{B}(\Upsilon(2S)\to\bar{d}X)$	$(2.64\pm0.11^{+0.26}_{-0.21})\times10^{-5}$
$\mathcal{B}(\Upsilon(1S)\to\bar{d}X)$	$(2.81\pm0.49^{+0.20}_{-0.24})\times10^{-5}$
$\sigma(e^+e^-\to\bar{d}X)$ $[\sqrt{s}\approx10.58\,\mathrm{GeV}]$	$(9.63\pm0.41^{+1.17}_{-1.01})$ fb
$\dfrac{\sigma(e^+e^-\to\bar{d}X)}{\sigma(e^+e^-\to\mathrm{Hadrons})}$	$(3.01\pm0.13^{+0.37}_{-0.31})\times10^{-6}$



With 0.8-1 Billion Y(3S) decays, we can *search for anti-tritium and He-3 production in bottomonium*

Conclusions

We may be able to do some valuable physics during phase-II run , without low momentum tracking , and no vertexing.
It's a gamble to predict how many papers we'll be able to write.

A pilot run on Y(6S) peak, even with only $20fb^{-1}$, will give us about the 10x data taken in Belle-I. IF machine people are willing to work so close to machine limits, this is the most interesting point, but many other thresholds open 50, 100, 200 MeV above

Coupled channels effects studies are feasible at 10.65 +10.75 GeV,

200-300 fb^{-1} at (and about) the Y(3S) will allow to publish >10 physics papers after the first year of data taking :

- BSM physics from 0++ states
- spectroscopy of D waves
- hindered radiative transitions
- antitritium in Y decays
- many eta transitions

Eichten 2008: rethinking at CCCM