Recent results from Belle

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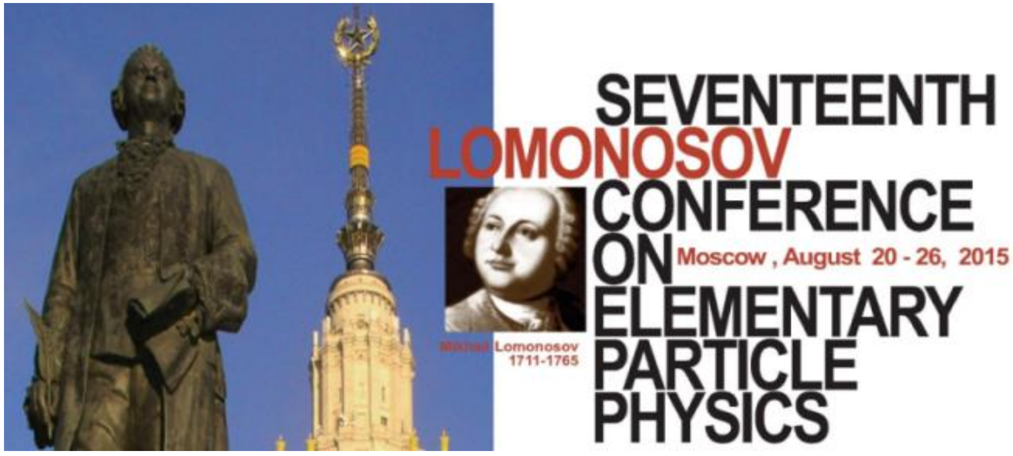
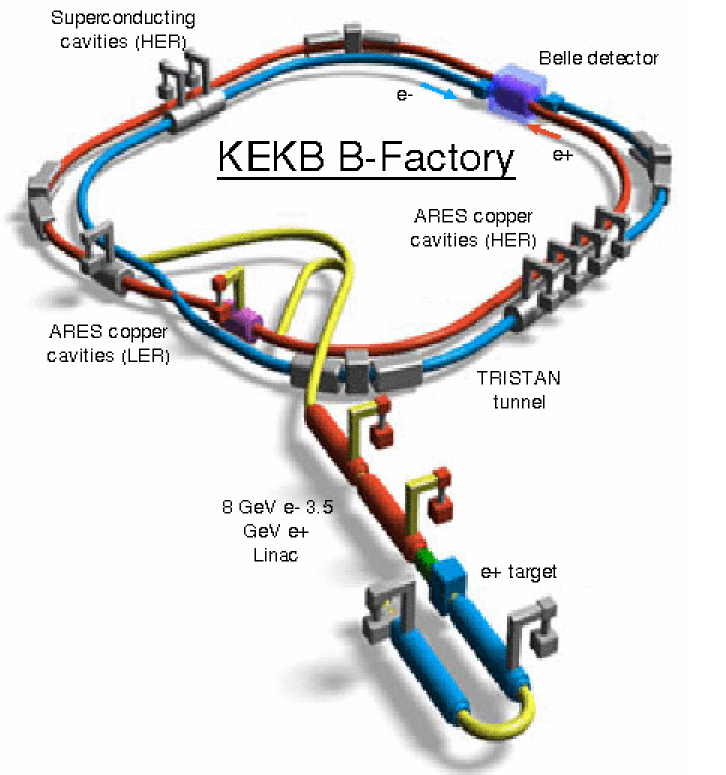
on behalf of Belle collaboration

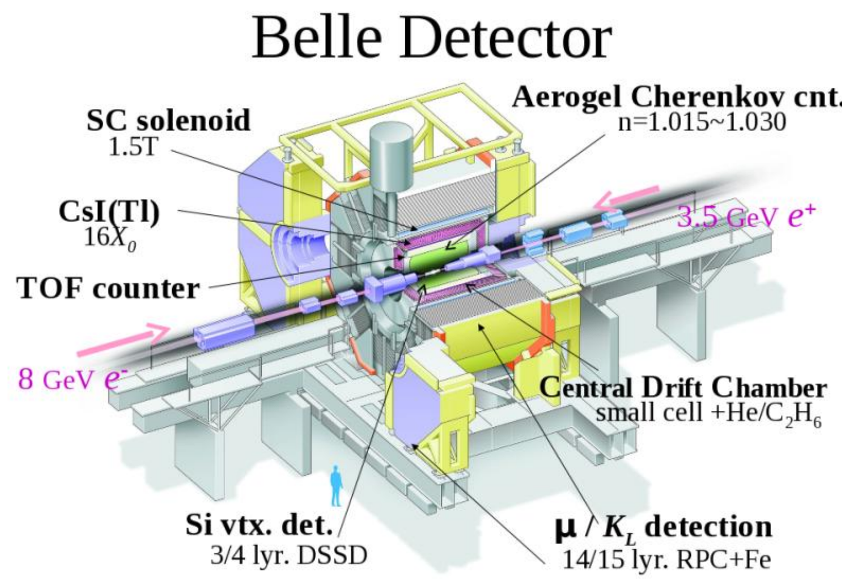
Outline:

- **Study of bottomonia and exotic $Z_b^{\pm}$**
- **Search for New Physics in $B \to D^{(*)} \tau \nu$**
- **Search for dark photon and dark Higgs**

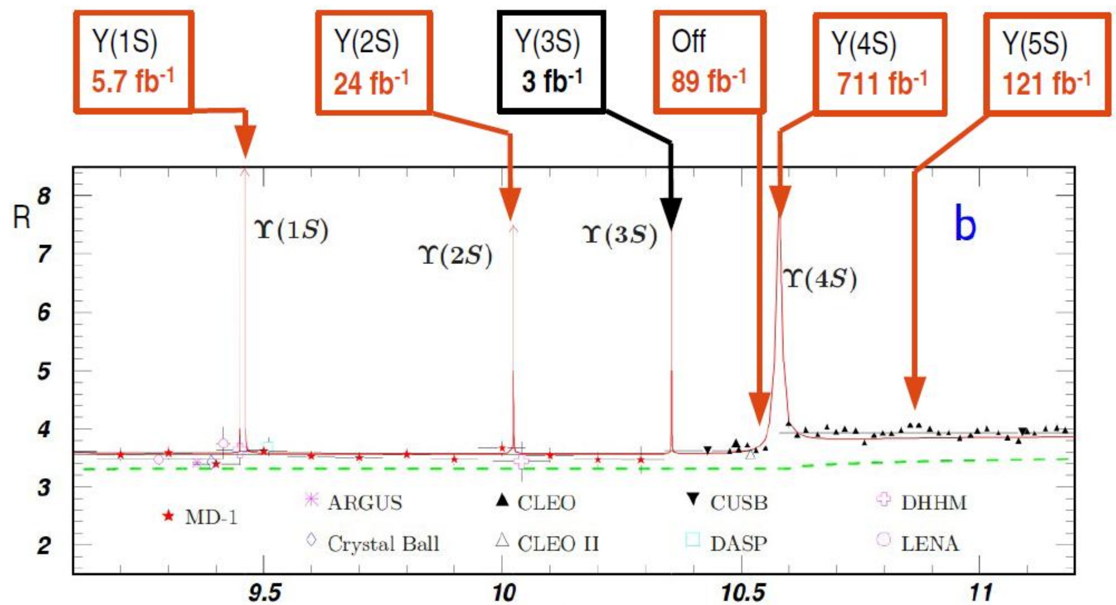


Belle experiment





- $E_{e^-} = 8$ **GeV**, $E_{e^+} = 3.5$ **GeV**
- **Peak luminosity:** $L = 2.11 \times 10^{34}$ $\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- **Integrated luminosity:** $\int Ldt \simeq 1$ ab^{-1}



Study of $\sigma(e^+e^- \to \Upsilon(nS)\pi^+\pi^-)$ and $\sigma(e^+e^- \to b\bar{b})$ in the region of $\Upsilon(5S)$ and $\Upsilon(6S)$ resonances

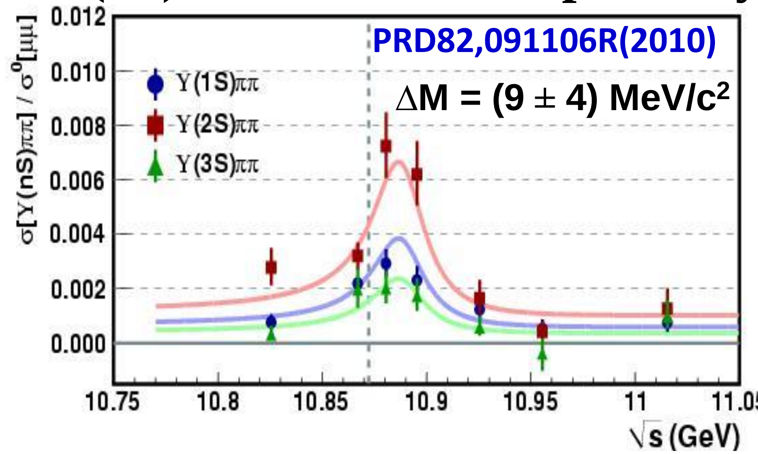
Anomalous $\Upsilon(5S) \to \Upsilon(nS)\pi^+\pi^-$ rates were previously observed at Belle.

$R_{\Upsilon\pi\pi} = \sigma(e^+e^- \to \Upsilon(nS)\pi^+\pi^-)/\sigma_{\mu\mu}$ and $R_b = \sigma(e^+e^- \to b\bar{b})/\sigma_{\mu\mu}$ were measured in the region of $\Upsilon(5S)$ and $\Upsilon(6S)$. Mass and width of $\Upsilon(5S)$ were measured precisely.

PRL100,112001(2008)

	Γ(MeV)
$\Upsilon(5S) \to \Upsilon(1S)\pi^+\pi^-$	$0.59 \pm 0.04 \pm 0.09$
$\Upsilon(5S) \to \Upsilon(2S)\pi^+\pi^-$	$0.85 \pm 0.07 \pm 0.16$
$\Upsilon(5S) \to \Upsilon(3S)\pi^+\pi^-$	$0.52^{+0.20}_{-0.17} \pm 0.10$
$\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$	0.0060
$\Upsilon(3S) \to \Upsilon(1S)\pi^+\pi^-$	0.0009
$\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-$	0.0019

10^2



(1) Rescattering $\Upsilon(5S) \to BB\pi\pi \to \Upsilon(nS)\pi\pi$

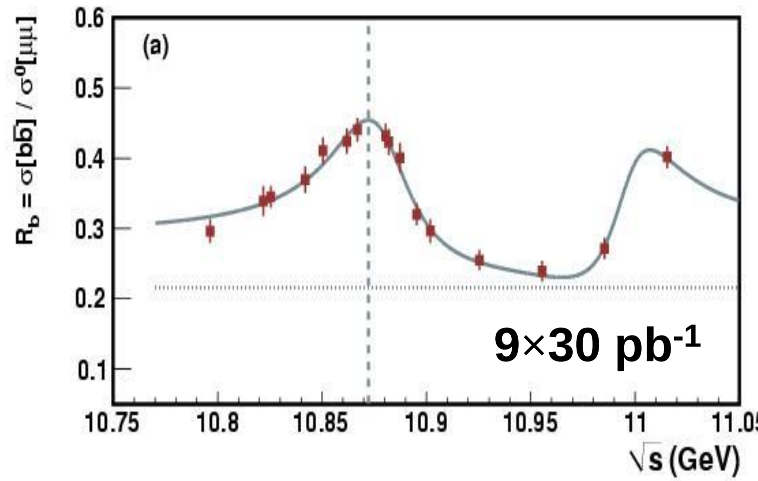
Simonov JETP Lett 87,147(2008);
Meng et al. Phys.Rev.D78:034022,2008

(2) Exotic resonance Y_b near $\Upsilon(5S)$ analogue of Y(4260) resonance with anomalous $\Gamma(J/\psi\ \pi^+\pi^-)$

Hou et al., Phys.Rev.D74:017504,2006
Ali et al. Phys.Rev.Lett.104:162001,2010

(3) Tetraquarks

Karliner et al. arXiv:0802.0649v2;
N. Brambilla et al, Eur.Phys.J. C71 (2011) 1534



Study of $\sigma(e^+e^-\to\Upsilon(nS)\pi^+\pi^-)$ and $\sigma(e^+e^-\to b\bar{b})$ in the region of $\Upsilon(5S)$ and $\Upsilon(6S)$ resonances

New

hep-ex :1501.0113?

Data: 61 points / 50 pb^{-1}; 5 MeV step

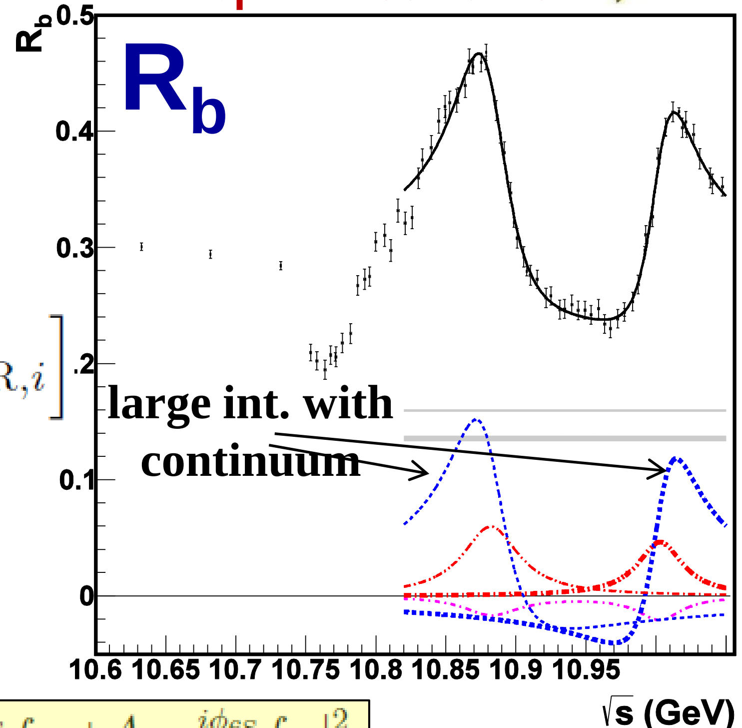
Selections: ≥5 IP tracks, ≥2 ECL clusters)
ECL energy: (0.1−0.8) √s, total energy > 0.5√s

Efficiency: (70−74)%

$$N_i = \mathcal{L}_i \times \left[\sigma_{b\bar{b},i}\epsilon_{b\bar{b},i} + \sigma_{q\bar{q},i}\epsilon_{q\bar{q},i} + \sum \sigma_{\mathrm{ISR},i}\epsilon_{\mathrm{ISR},i}\right]$$

subtracted from cont. point (10.52 GeV)

rad. return to Υ(1÷3S)



R_b: w/ rad. return to Υ(1÷3S)

R'_b: w/o rad. return to Υ(1÷3S)

Fit of R_b/R'_b:

$$|A_{\mathrm{nr}}|^2 + |A_{\mathrm{r}} + A_{5S}e^{i\phi_{5S}} f_{5S} + A_{6S}e^{i\phi_{6S}} f_{6S}|^2$$

	M_{5S} (MeV/c^2)	Γ_{5S} (MeV)	M_{6S} (MeV/c^2)	Γ_{6S} (MeV)
R_b	$10881.9 \pm 1.0 \pm 1.2$	$49.8 \pm 1.9\,^{+2.1}_{-2.8}$	$11002.9 \pm 1.1\,^{+0.8}_{-0.9}$	$38.5^{+1.6}_{-1.5}\,^{+1.3}_{-2.4}$
R'_b	$10881.8^{+1.0}_{-1.1} \pm 1.2$	$48.5^{+1.9}_{-1.8}\,^{+2.0}_{-2.8}$	$11003.0 \pm 1.1\,^{+0.9}_{-1.0}$	$39.3^{+1.7}_{-1.6}\,^{+1.3}_{-2.4}$

Uncontrollable systematic error of the resonance masses and widths due to large contribution from continuum with unknown shape

Study of $\sigma(e^+e^-\to\Upsilon(nS)\pi^+\pi^-)$ and $\sigma(e^+e^-\to b\bar{b})$ in the region of $\Upsilon(5S)$ and $\Upsilon(6S)$ resonances

hep-ex :1501.01137

Data: (16+6) points / 1 fb^{-1}

Full reconstruction of $\Upsilon(nS)[\to\mu^+\mu^-]\pi^+\pi^-$

Efficiency: (15 ÷ 45)%

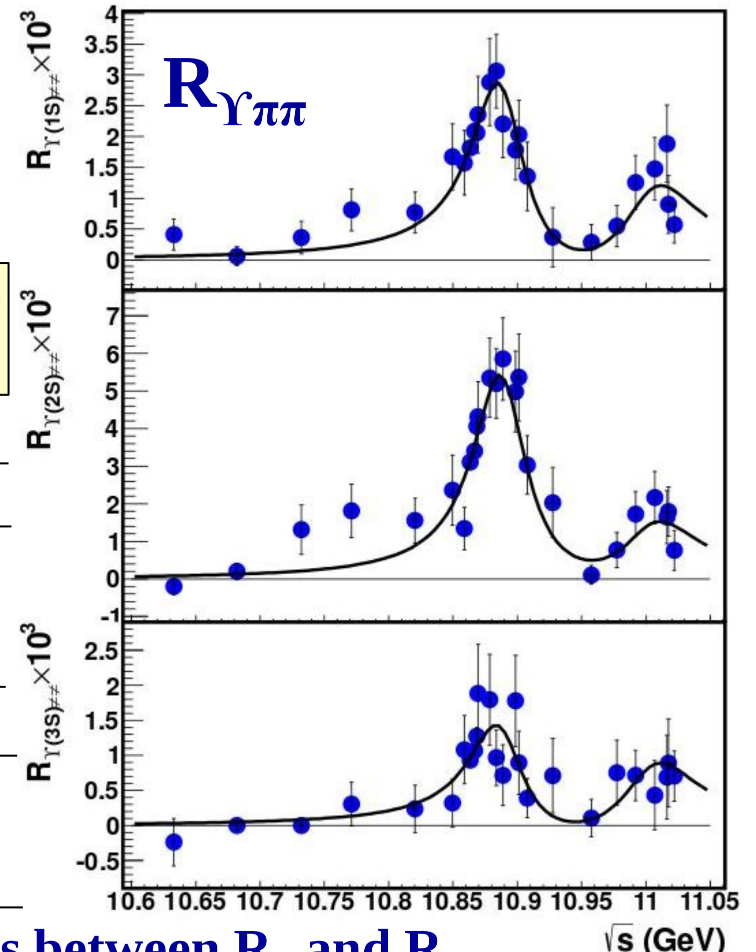
Fit of $R_{\Upsilon\pi\pi}$:

$$|A_{nr}|^2 + |A_r + A_{5S}e^{i\phi_{5S}} f_{5S} + A_{6S}e^{i\phi_{6S}} f_{6S}|^2$$

A_{nr}, A_r consistent with zero, fixed at zero

		M_{5S} (MeV/c^2)	Γ_{5S} (MeV)
ΔM=(9.3 ± 3.9) MeV/c^2	R'_b	$10881.8^{+1.0}_{-1.1} \pm 1.2$	$48.5^{+1.9}_{-1.8}{}^{+2.0}_{-2.8}$
	$R_{\Upsilon\pi\pi}$	$10891.1 \pm 3.2^{+0.6}_{-1.5}$	$53.7^{+7.1}_{-5.6}{}^{+0.9}_{-5.4}$

		M_{6S} (MeV/c^2)	Γ_{6S} (MeV)
ΔM=(15.5±11.1) MeV/c^2	R'_b	$11003.0 \pm 1.1^{+0.9}_{-1.0}$	$39.3^{+1.7}_{-1.6}{}^{+1.3}_{-2.4}$
	$R_{\Upsilon\pi\pi}$	$10987.5^{+6.4}_{-2.5}{}^{+9.0}_{-2.1}$	$61^{+9}_{-19}{}^{+2}_{-20}$



No significant difference in $\Upsilon(5S)$ parameters between R_b and $R_{\Upsilon\pi\pi}$
$R_{\Upsilon\pi\pi}$ is preferable for measuring masses and widths of $\Upsilon(5S,6S)$

Study of $\sigma(e^+e^-\to h_b(nP)\pi^+\pi^-)$ (n=1,2) in the region of $\Upsilon(5S)$ and $\Upsilon(6S)$ resonances

Data: 121.4 fb^{-1} @$\Upsilon(5S)$ +19 points /1 fb^{-1}

Selections: inclusive reconstruction in

$$M_{\rm miss}(\pi^+\pi^-) = \sqrt{(E_{\rm c.m.} - E^*_{\pi^+\pi^-})^2 - p^{*2}_{\pi^+\pi^-}}$$

$$10.59\,{\rm GeV}/c^2 < M_{\rm miss}(\pi) < 10.67\,{\rm GeV}/c^2$$

fit of $h_b(nP)$ signals in $M_{miss}(\pi^+\pi^-)$

Cross section:

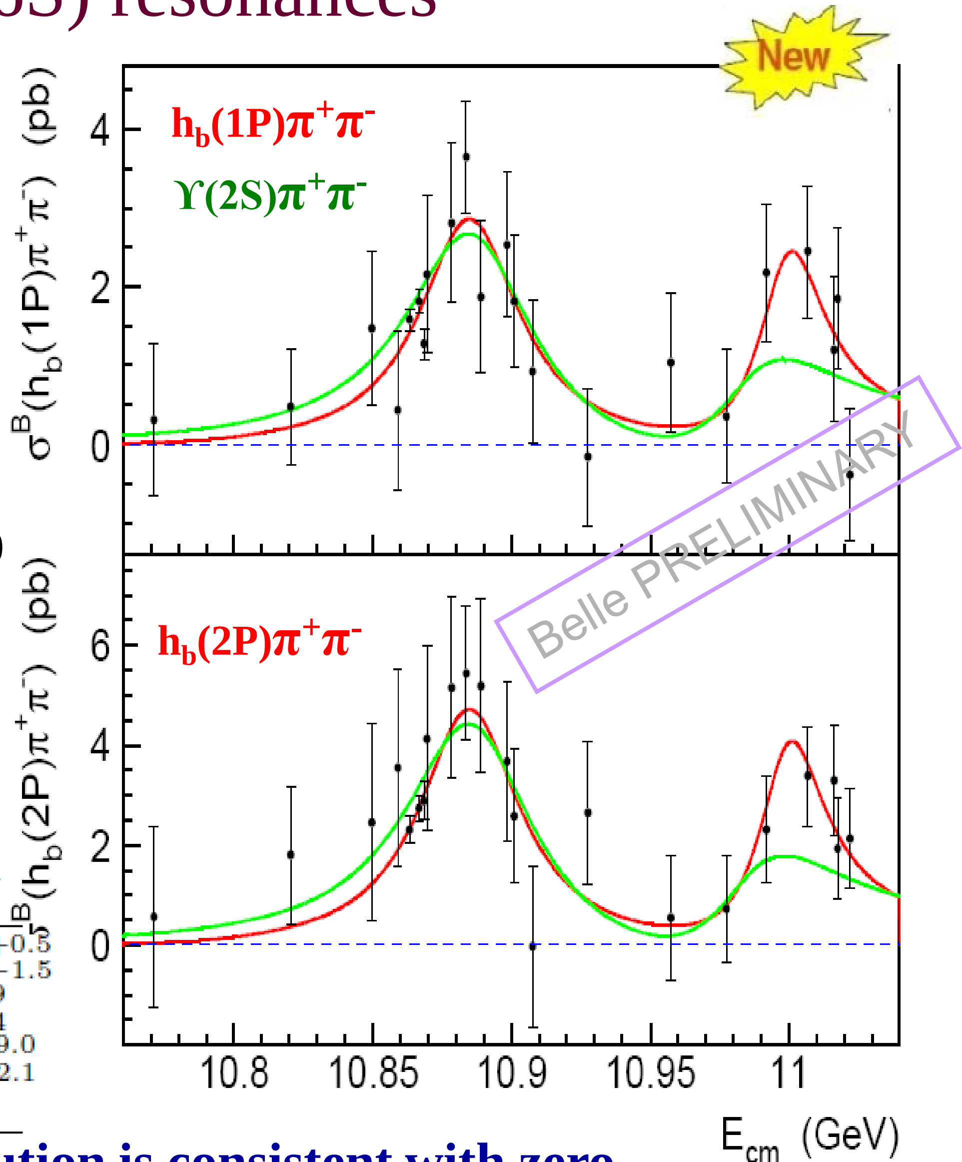
$$\sigma^B(e^+e^- \to h_b(nP)\pi^+\pi^-) = \frac{N(\text{ISR corr.})}{L\,\epsilon\,|1-\Pi|^2}$$

Fit of $\sigma^B(e^+e^-\to h_b(nP)\pi^+\pi^-)$:

$$A_n\, p(s)\, |BW(s, M_5, \Gamma_5) + a\, e^{i\phi} BW(s, M_6, \Gamma_6) + b\, e^{i\delta}|^2$$

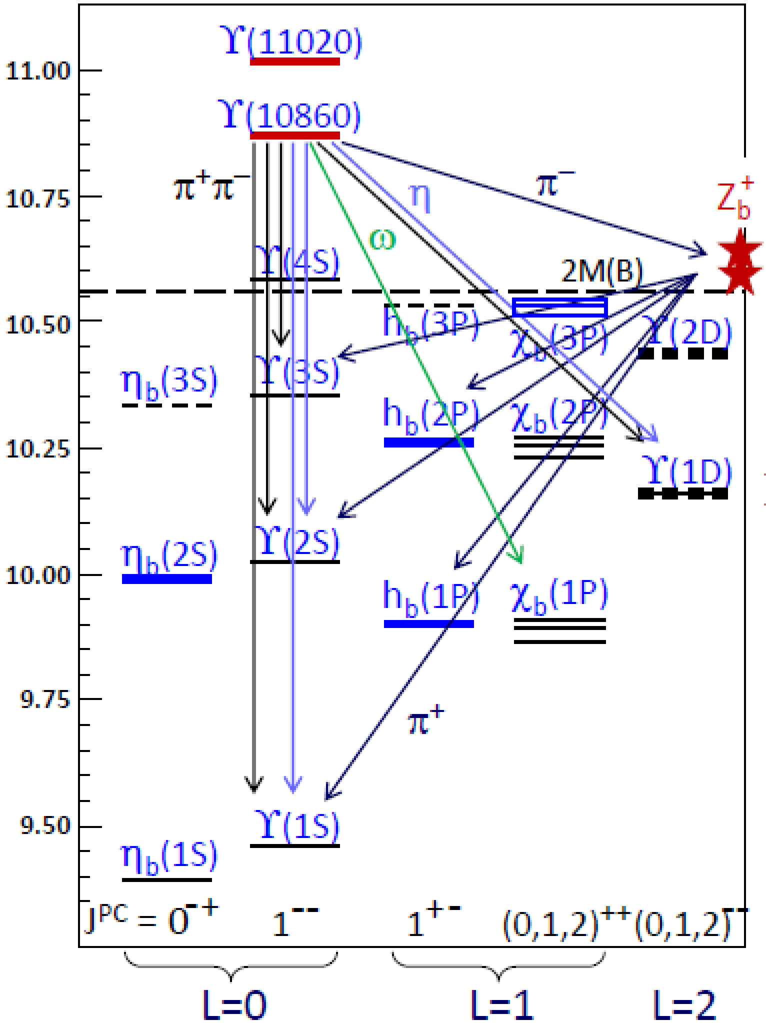
phase space factor takes into account dynamics with Z_b states

	$h_b(nP)\pi^+\pi^-$	$\Upsilon(nS)\pi^+\pi^-$
M_5, MeV/c^2	$10884.7^{+3.2+8.6}_{-2.9-0.6}$	$10891.1 \pm 3.2^{+0.5}_{-1.5}$
Γ_5, MeV	$44.2^{+11.9+2.2}_{-7.8\ -15.8}$	$53.7^{+7.1+0.9}_{-5.6-5.4}$
M_6, MeV/c^2	$10998.6 \pm 6.1^{+16.1}_{-1.1}$	$10987.5^{+6.4+9.0}_{-2.5-2.1}$
Γ_6, MeV	29^{+20+2}_{-12-7}	$61^{+9\ +2}_{-19-20}$



Non-resonant continuum contribution is consistent with zero
$\Upsilon(5S)$ and $\Upsilon(6S)$ parameters agree with those measured in $\sigma(e^+e^-\to\Upsilon(nS)\pi^+\pi^-)$

Anomalies in $\Upsilon(5S)\to b\bar{b}\pi^+\pi^-$ transitions



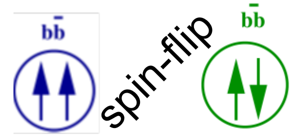
Belle: PRL100, 112001 (2008)

$\Gamma(\Upsilon(5S)\to\Upsilon(1S/2S/3S)\pi^+\pi^-)$ = 260/430/290 keV

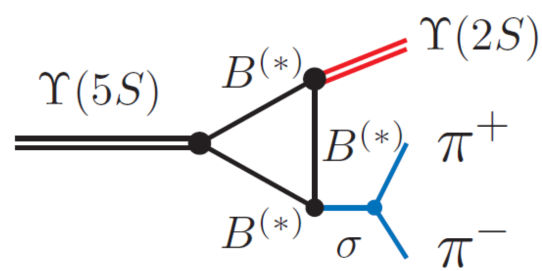
Belle: PRL108, 032001 (2012)

$\Gamma(\Upsilon(5S)\to h_b(1P/2P)\pi^+\pi^-)$ = 190/330 keV

$\Upsilon(5S)\to h_b(1P/2P)\pi^+\pi^-$ are not suppressed, although expect suppression $\sim\Lambda_{QCD}/m_b$ due to



Rescattering of on-shell $B^{(*)}\bar{B}^{(*)}$?



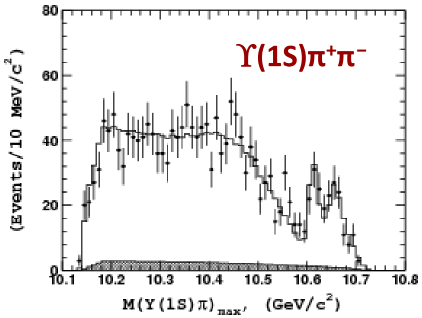
Study dynamics of $\Upsilon(5S)\to b\bar{b}\pi^+\pi^-$ transitions:

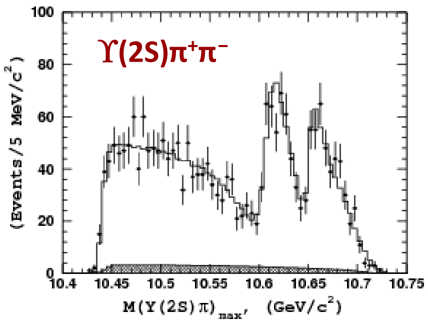
Belle: PRL108, 032001 (2012)

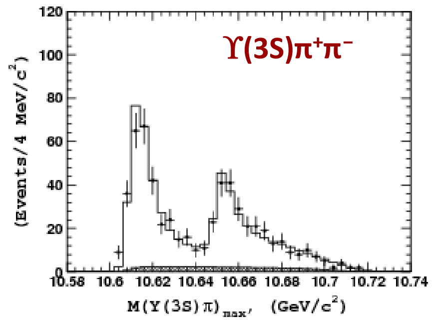
Two charged bottomoniumlike resonances, $Z_b(10610)$ and $Z_b(10650)$, were observed in five decay channels, $\Upsilon(nS)\pi^\pm$ (n = 1, 2, 3) and $h_b(mP)\pi^\pm$ (m = 1, 2)

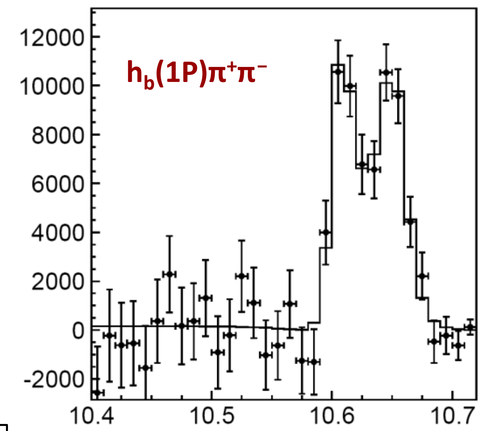
Study of $\Upsilon(5S)\to Z_b\pi$

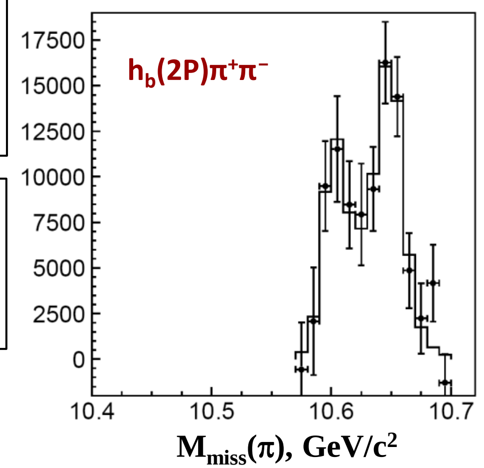
Similar production rates of $Z_b(10610)$ and $Z_b(10650)$ in five decay channels



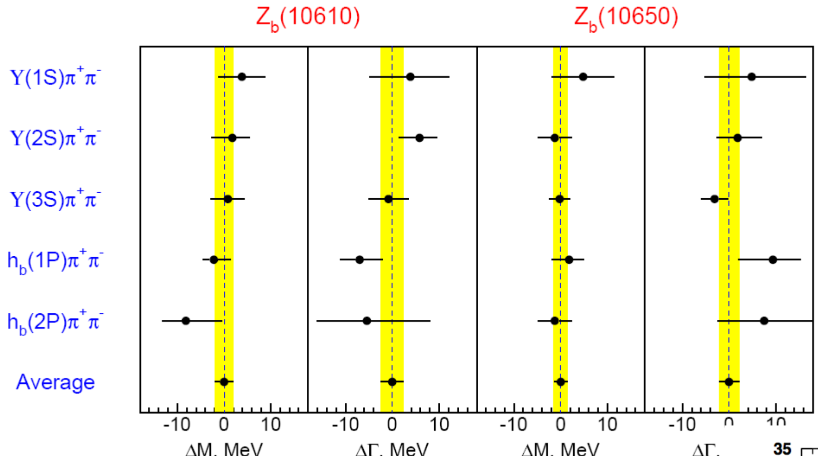








Average over 5 channels



Averages for $Z_b^{\pm}$:

$\langle M_1 \rangle = 10607.2\pm2.0$ MeV

$\langle \Gamma_1 \rangle = 18.4\pm2.4$ MeV

$\langle M_2 \rangle = 10652.2\pm1.5$ MeV

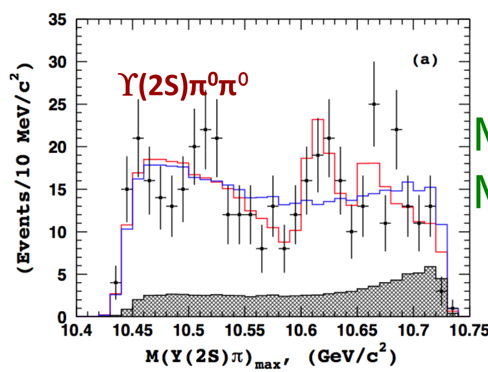
$\langle \Gamma_2 \rangle = 11.5 \pm 2.2$ MeV

Belle: PRD 88, 052016 (2013)

Z_b^0 Results:

$\langle M_1 \rangle = 10609\pm7\pm6$ MeV

consistent with $Z_b^{\pm}$

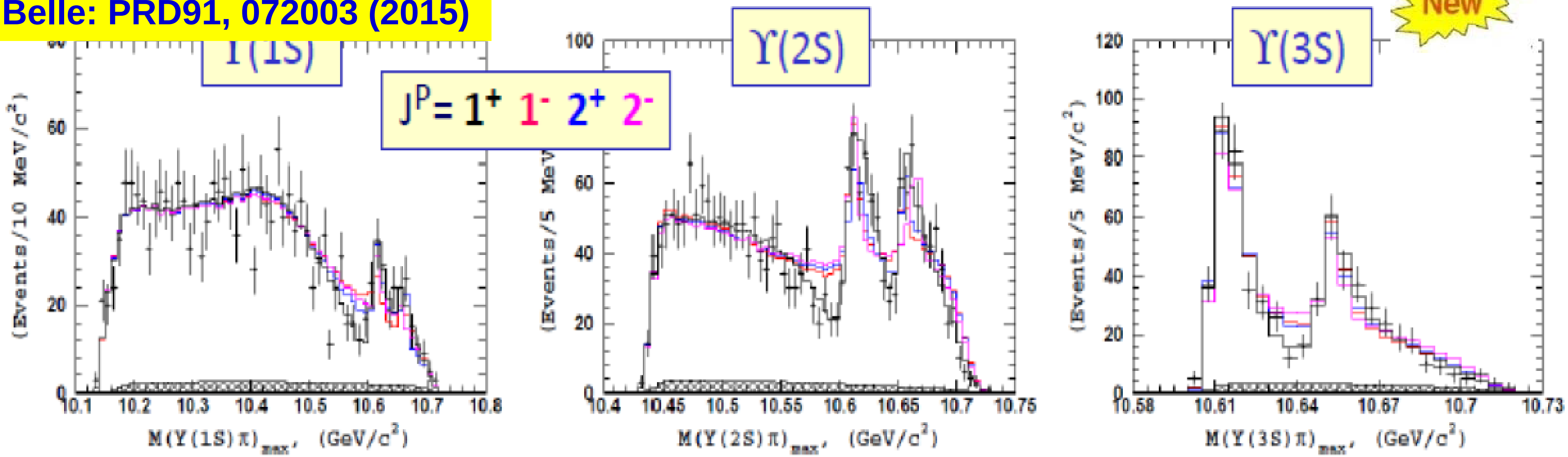


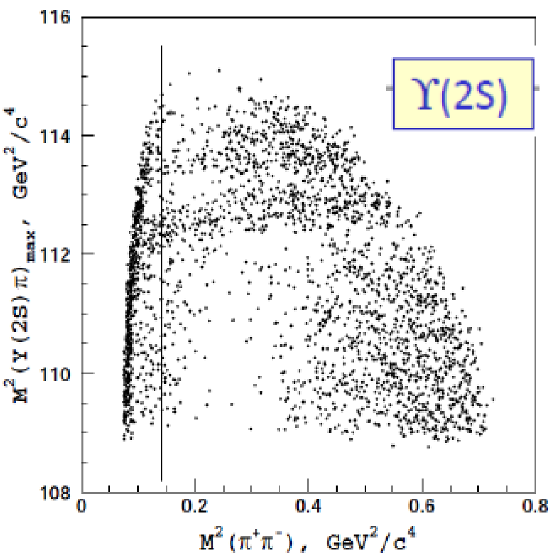
$M_1 - M_B - M_{B*} = (2.4 \pm 2.1)$ MeV/c^2

$M_2 - M_{B*} - M_{B*} = (1.8 \pm 1.8)$ MeV/c^2

Amplitude analysis of $e^+e^-\to\Upsilon(nS)\pi^+\pi^-$

Belle: PRD91, 072003 (2015)





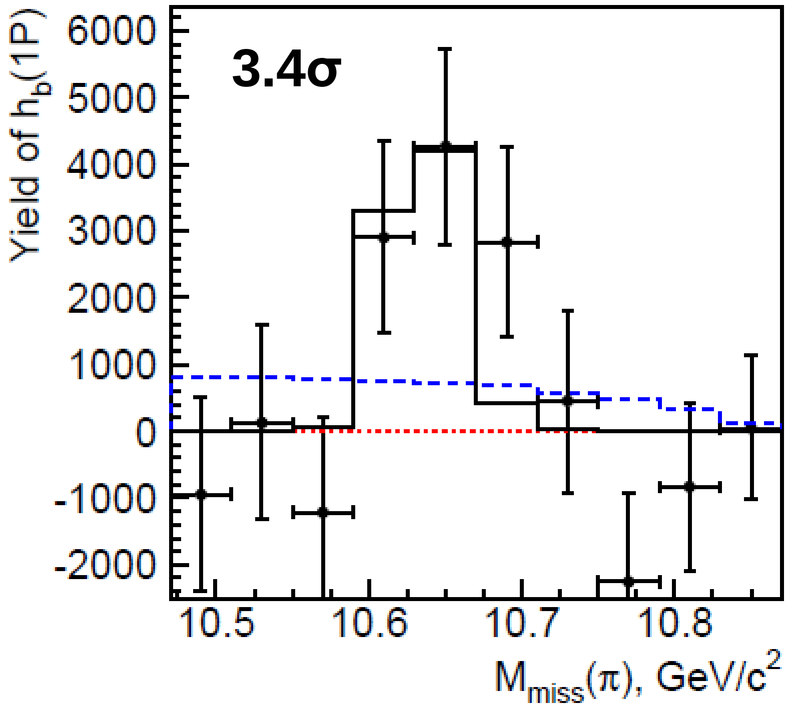
$\mathscr{L}_{fit}-\mathscr{L}_{nominal}$ for $\Upsilon(2S)\pi^+\pi^-$ ($\Upsilon(3S)\pi^+\pi^-$)

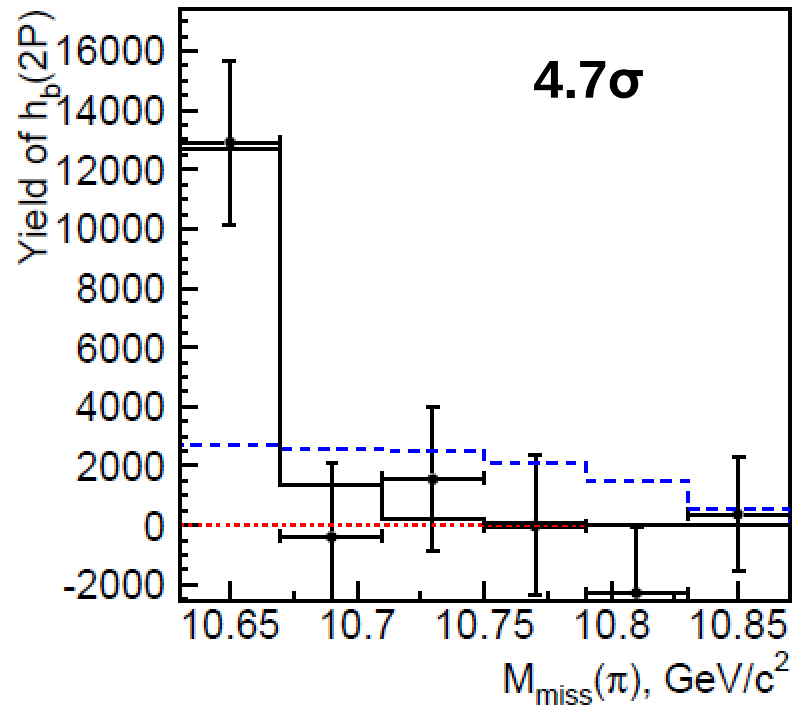
$Z_b(10650)$ / $Z_b(10610)$	1^+	1^-	2^+	2^-
1^+	0 (0)	60 (33)	42 (33)	77 (63)
1^-	226 (47)	264 (73)	224 (68)	277 (106)
2^+	205 (33)	235 (104)	207 (87)	223 (128)
2^-	289 (99)	319 (111)	321 (110)	304 (125)

Spin-parity of Zb(10610) and Zb(10650) is 1^+.
All other J^P<3 are excluded.

Evidence of $\Upsilon(6S) \to Z_b[\to h_b\pi]\pi$

New





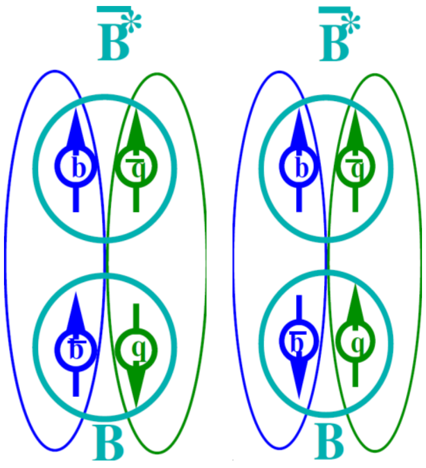
$M_{miss}(\pi^+\pi^-)$ was fitted in bins of $M_{miss}(\pi)$

With present statistics we cannot conclude if both Z_b(10610) and Z_b(10650) states are produced at Υ(6S), or only one of them.

Heavy quark spin structure in Z_b

A.B.,A.Garmash,A.Milstein,R.Mizuk,M.Voloshin PRD84 054010 (arXiv:1105.4473)

Wave function at large distance – molecule B(*)B*:



$$|Z_b'\rangle = \frac{1}{\sqrt{2}} 0^-_{b\bar{b}} \otimes 1^-_{Q\bar{q}} - \frac{1}{\sqrt{2}} 1^-_{b\bar{b}} \otimes 0^-_{Q\bar{q}}$$

$$|Z_b\rangle = \frac{1}{\sqrt{2}} 0^-_{b\bar{b}} \otimes 1^-_{Q\bar{q}} + \frac{1}{\sqrt{2}} 1^-_{b\bar{b}} \otimes 0^-_{Q\bar{q}}$$

Explains:

- Why $h_b\pi\pi$ is unsuppressed relative to $\Upsilon\pi\pi$
- Relative phase ~0 for Υ and ~180^0 for h_b
- Production rates of Z_b(10610) and Z_b(10650) are similar
- Widths of Z_b(10610) and Z_b(10650) are similar
- **Dominant decays to B(*)B***

Other Possible Explanations

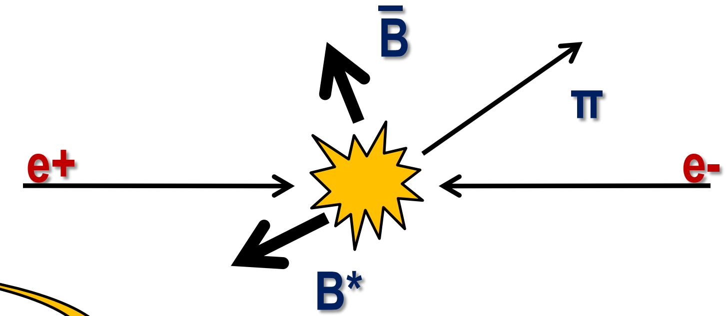
- Coupled channel resonances (I.V.Danilkin et al, arXiv:1106.1552)
- Cusp (D.Bugg Europhys.Lett.96 (2011),arXiv:1105.5492)
- Tetraquark (M.Karliner, H.Lipkin, arXiv:0802.0649)

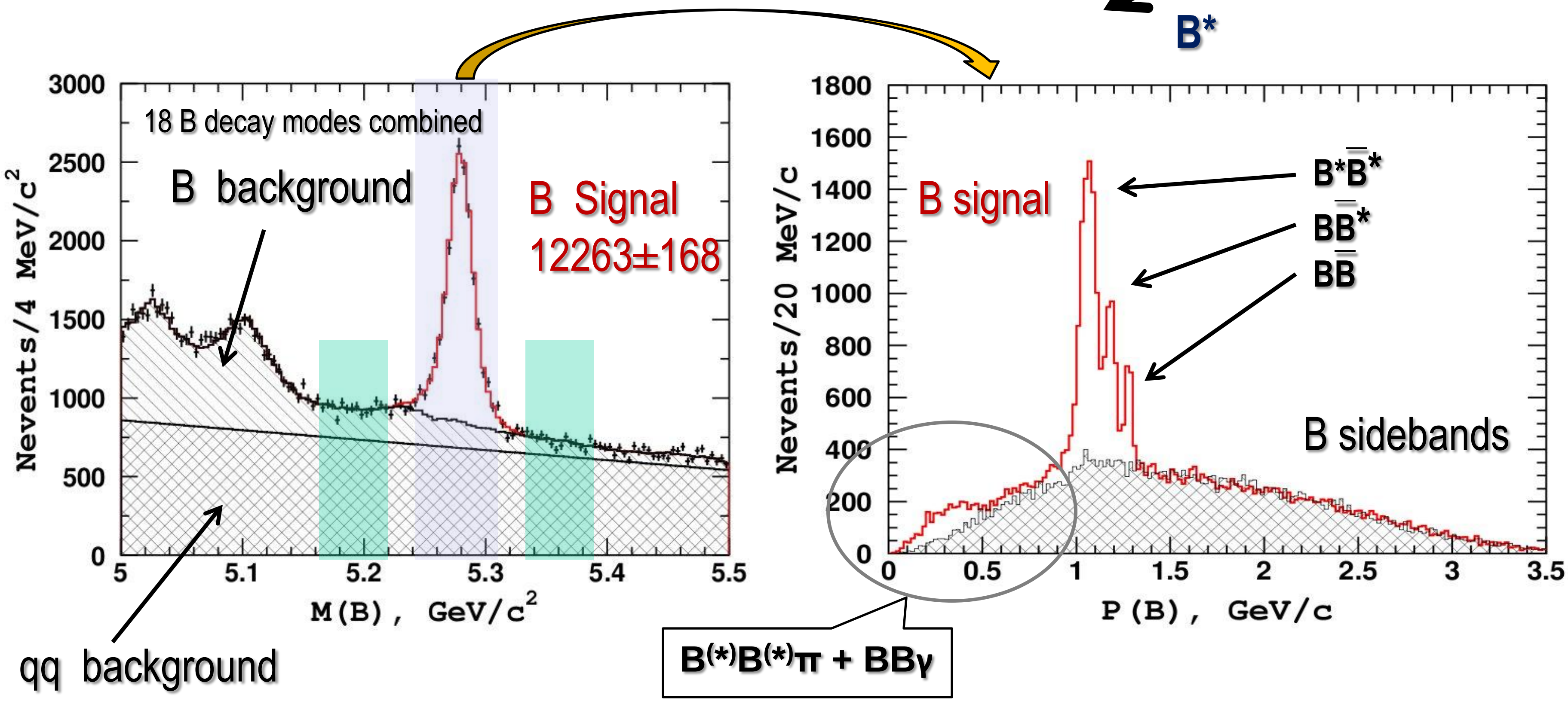
Study of $e^+e^- \to B^{(*)}\bar{B}^{(*)}\pi$ at $\Upsilon(5S)$

Masses of the observed Z_b resonances are close to the BB* and B*B* thresholds, respectively: branching fractions $Z_b \to B(*)B*$ might be large (dominant).

Analysis strategy:

- Full reconstruction of one B meson in eighteen modes: $B^+ \to J/\psi\, K^{(*)+}$, $D^{(*)0}\pi^+$; $B^0 \to J/\psi K^{(*)0}$, $D^{(*)-}\pi^+$

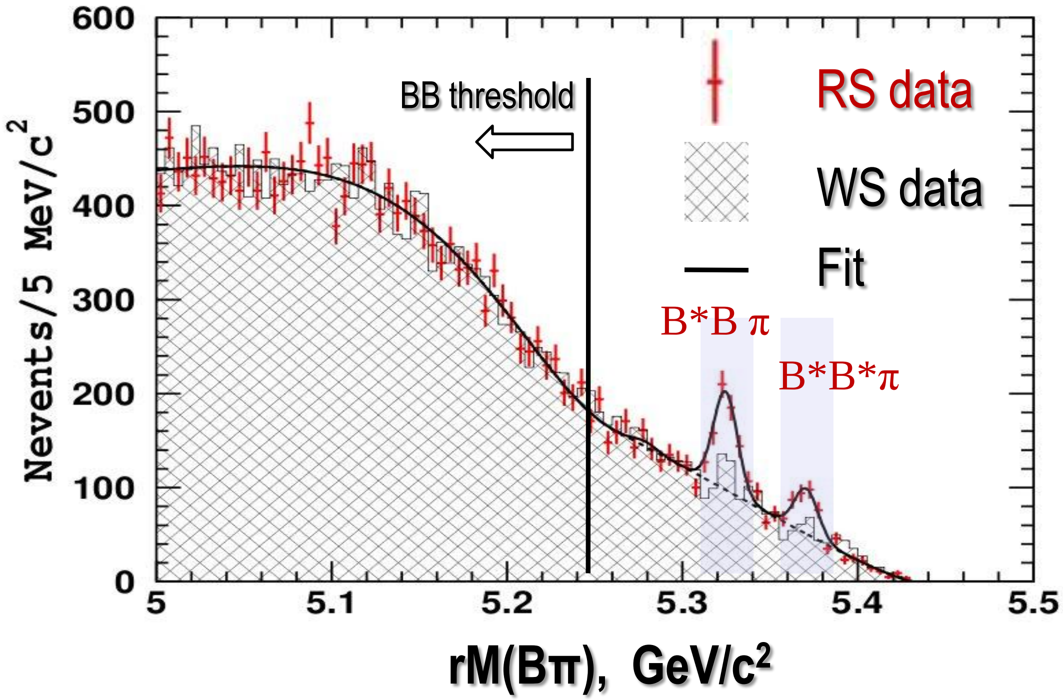


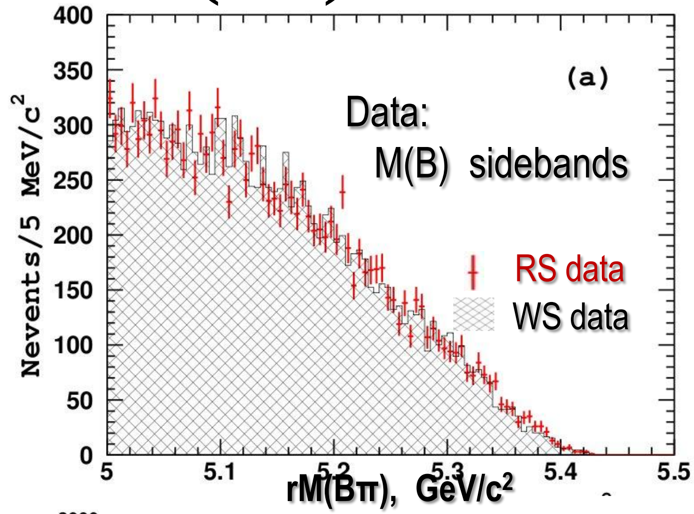


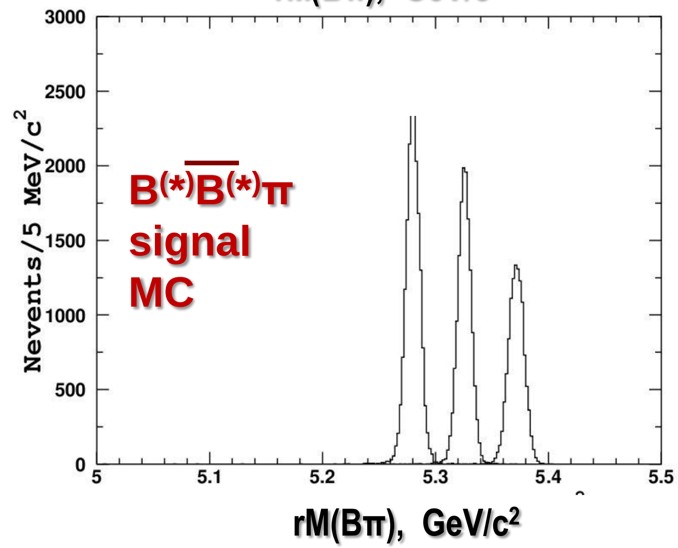
Study of $e^+e^- \to B^{(*)}\bar{B}^{(*)}\pi$ at $\Upsilon(5S)$

Analysis strategy:

- Combine a B candidate with a charged pion from the rest of the event → calculate recoil mass against the Bπ system







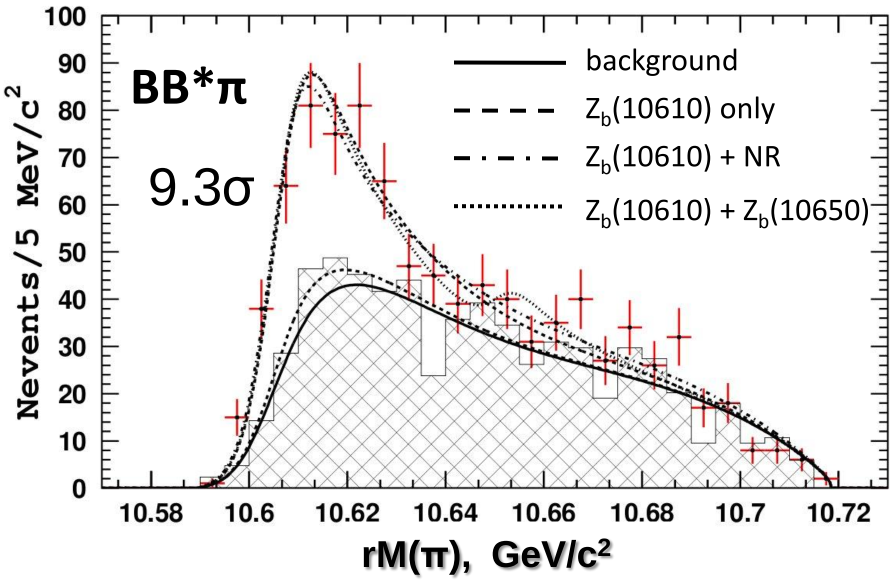
$N(B\bar{B}\pi)$ = 13 ± 25
$N(B\bar{B}^*\pi)$ = 357 ± 30
$N(B^*\bar{B}^*\pi)$ = 161 ± 21

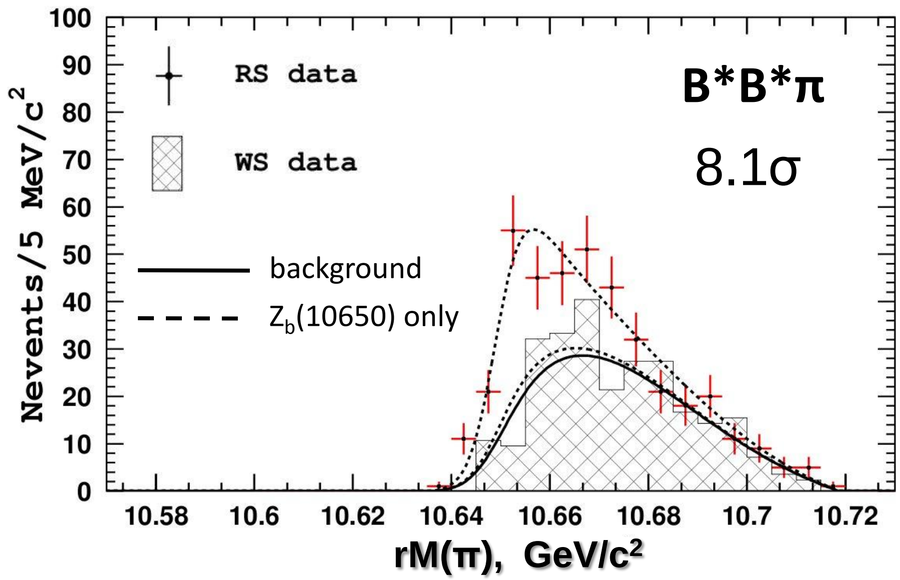
$\sigma(e^+e^- \to B\bar{B}\pi)$ $\sigma(e^+e^- \to B\bar{B}^*\pi)$ $\sigma(e^+e^- \to B^*\bar{B}^*\pi)$ were measured

New

Study of $e^+e^- \to B^{(*)}\bar{B}^{(*)}\pi$ at $\Upsilon(5S)$

Analysis strategy: For events from 3-body sig. region → recoil mass against primary $\pi^\pm$





BB*π and B*B*π data fits well to just $Z_b(10610)$ and $Z_b(10650)$ signal,

Channel	Fraction, % $Z_b(10610)$	Fraction, % $Z_b(10650)$
$\Upsilon(1S)\pi^+$	$0.60 \pm 0.06 \pm 0.16$	$0.17 \pm 0.02 \pm 0.06$
$\Upsilon(2S)\pi^+$	$4.05 \pm 0.40 \pm 0.79$	$1.38 \pm 0.16 \pm 0.43$
$\Upsilon(3S)\pi^+$	$2.40 \pm 0.24 \pm 0.55$	$1.62 \pm 0.19 \pm 0.47$
$h_b(1P)\pi^+$	$4.26 \pm 0.54 \pm 1.17$	$9.23 \pm 1.48 \pm 2.82$
$h_b(2P)\pi^+$	$6.08 \pm 0.65 \pm 2.22$	$17.0 \pm 2.4 \pm 4.6$
$B^+\bar{B}^{*0} + \bar{B}^0 B^{*+}$	$82.6 \pm 12.6 \pm 11.9$	–
$B^{*+}\bar{B}^{*0}$	–	$70.6 \pm 14.3 \pm 10.9$

Assuming Z_b decays are saturated by already observed channels

$B^{(*)}B^*$ channels dominate the Z_b decays

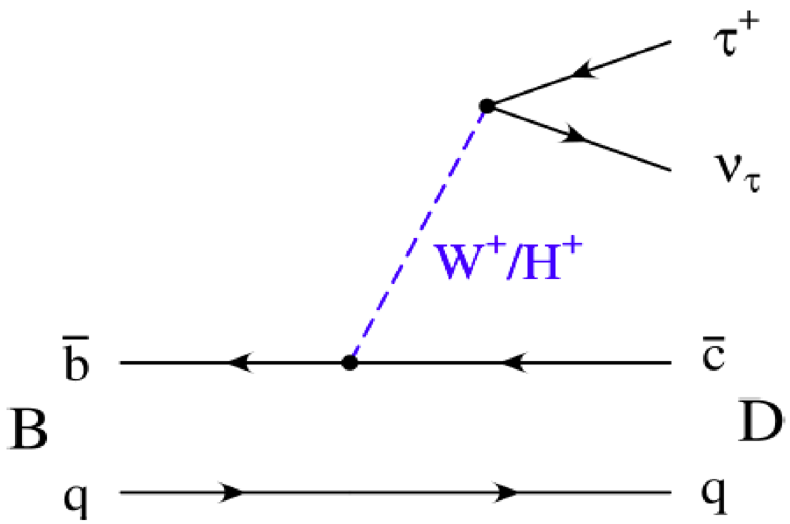
Summary on $Z_b(10610)$ and $Z_b(10650)$

- Z_b are very close to $B\bar{B}^*$ and $B^*\bar{B}^*$ thresholds
- Their quantum numbers are: $I^G, J^{PC} = 1^+, 1^{+(-)}$
- They are observed both in the hidden-bottom modes ($\Upsilon(1S/2S/3S)\pi$ and $h_b(1P/2P)\pi$) and in the open-bottom modes ($B\bar{B}^*$, $B^*\bar{B}^*$) at $\Upsilon(5S)$ resonance
- We found an evidence of $Z_b(10610)$ and $Z_b(10650)$ states in decays $\Upsilon(6S) \to Z_b[\to h_b(1P/2P)\pi]\pi$
- $B\bar{B}^*/B^*\bar{B}^*$ modes dominate in Z_b decays with the branching ratios 83%/71%
- Energy behaviour of $\sigma(e^+e^- \to \Upsilon(nS)\pi^+\pi^-)$ and $\sigma(e^+e^- \to h_b(nP)\pi^+\pi^-)$ are similar
- **Z_b properties agree well with $B^{(*)}\bar{B}^*$ molecular structure**

Search for New Physics in $B \to D^{(*)}\tau\nu$

Process with third generation quarks and leptons

In models with charged Higgs bosons their couplings are proportional to lepton mass, hence NP effects are enhanced for τ



New physics could change:

- Branching fraction
- Tau polarization
- Effect could be different for D and D^*

Confirm BaBar result: PRL **109** 101802 (2012), PRD **88** 072012 (2013)

Experimental challenge: 2 (hadronic τ decay) or 3 (leptonic τ decay) undetected neutrinos

$$R = \frac{\mathcal{B}(\bar{B} \to D\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D\ell^-\bar{\nu}_\ell)} \qquad R^* = \frac{\mathcal{B}(\bar{B} \to D^*\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^*\ell^-\bar{\nu}_\ell)}$$

$\ell^- = e^-$ or μ^-

Search for New Physics in $B \to D^{(*)}\tau\nu$

arXiv: 1507.03233 New

Statistics: **772×10^6 $B\bar{B}$ pairs** **Selections:**

B_{tag} is reconstructed using hadronic full reconstruction algorithm, which includes 1149 B final states (rec. efficiency 0.3% for B^+ and 0.2% for B^0). Additional requirements on the purity of B_{tag} sample preserves ≈85% of signal $B \to D^{(*)}\tau\nu$ decays

τ is reconstructed in the leptonic decays $\tau \to e\nu\nu$, $\mu\nu\nu$, so the signal and normalization modes have the same final particles → reduces systematic uncertainty of $R^{(*)}$

In the events with B_{tag} we select $D^{(*)}\ell$ ($D^+\ell^-$, $D^0\ell^-$, $D^{*+}\ell^-$, $D^{*0}\ell^-$), ℓ = e or μ among remaining tracks and clusters:

$D^+ \to K^-\pi^+\pi^+$, $K^0_S\pi^+$, $K^0_S\pi^+\pi^0$, $K^0_S\pi^+\pi^+\pi^-$; **$D^{*+} \to D^0\pi^+$, $D^+\pi^0$;**

$D^0 \to K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$, $K^-\pi^+\pi^0$, $K^0_S\pi^0$, $K^0_S\pi^+\pi^-$; **$D^{*0} \to D^0\pi^0$, $D^0\gamma$;**

$(-0.2 < M^2_{miss} < 8.0)$ GeV^2/c^4 **$M^2_{miss} = (P_{beam} - P_{B_{tag}} - P_{D^{(*)}} - P_\ell)^2/c^2$;**

$q^2 > 4$ GeV^2/c^4 **$q^2 = (P_B - P_{D^{(*)}})^2$;**

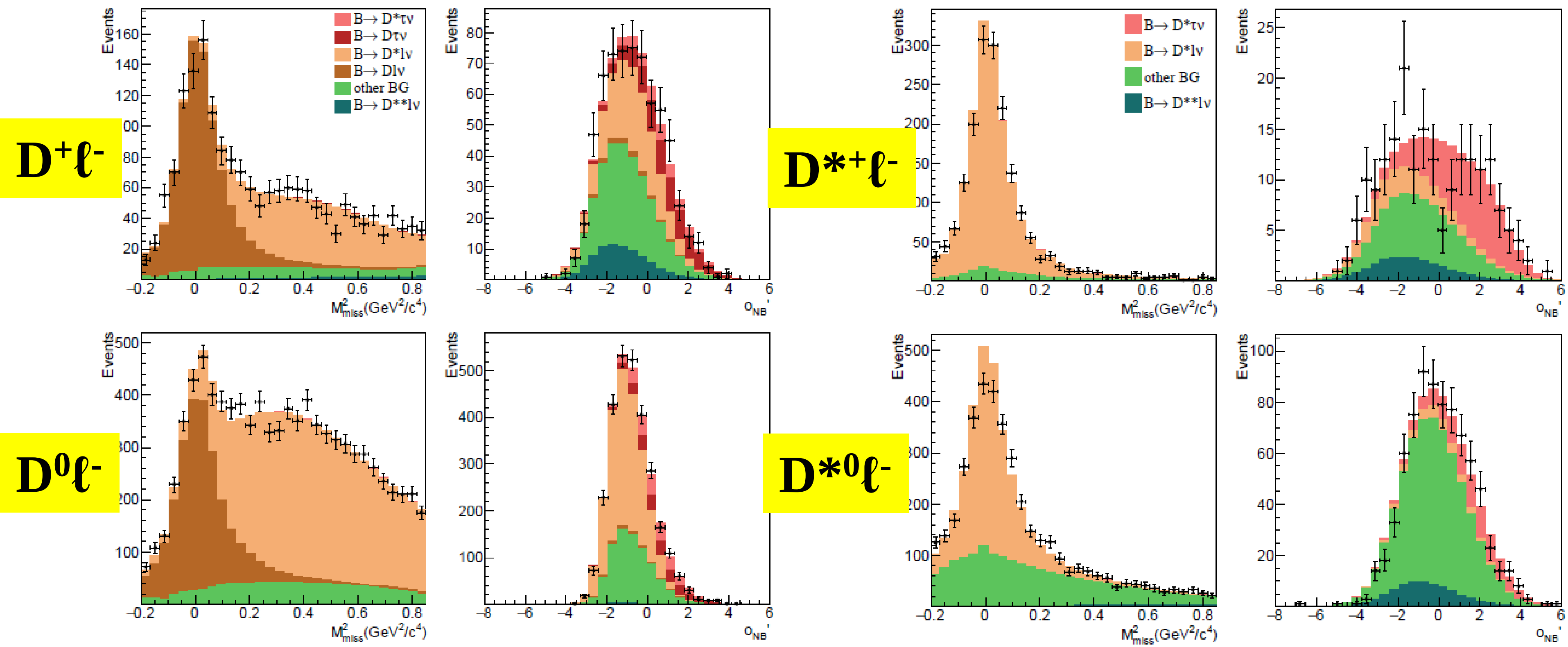
Search for New Physics in $B \to D^{(*)}\tau\nu$

M^2_{miss} range is split into two regions:

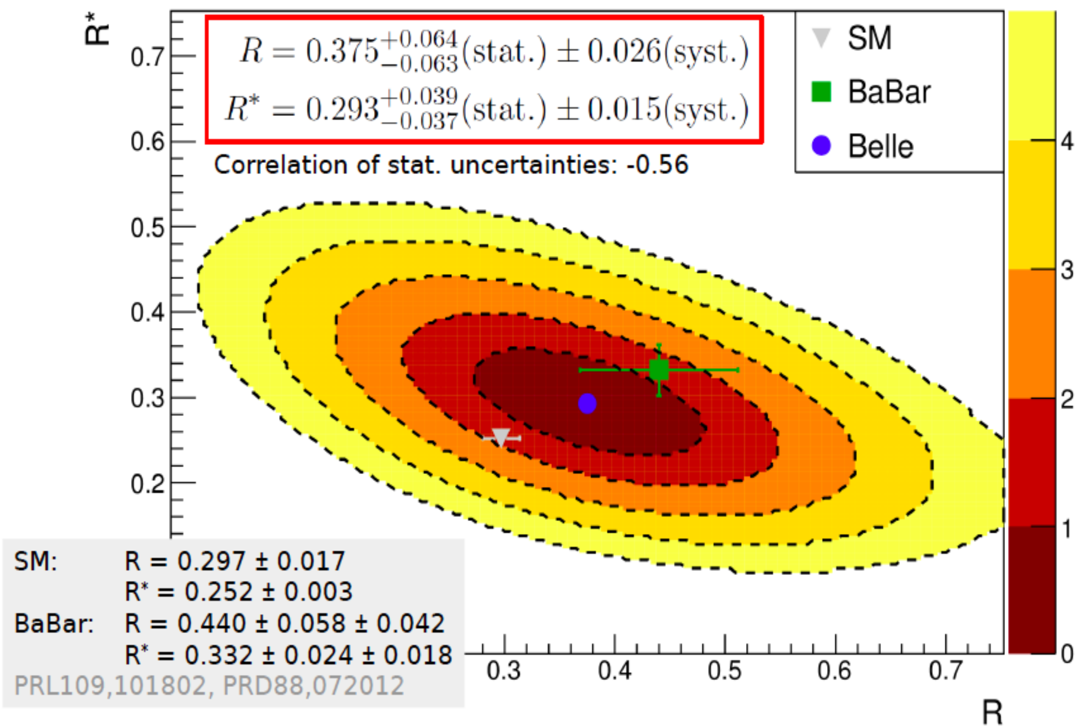
1) **$M^2_{miss} < 0.85\ GeV^2/c^4$:** populated by events of $B \to D^{(*)}e\nu$, $D^{(*)}\mu\nu$

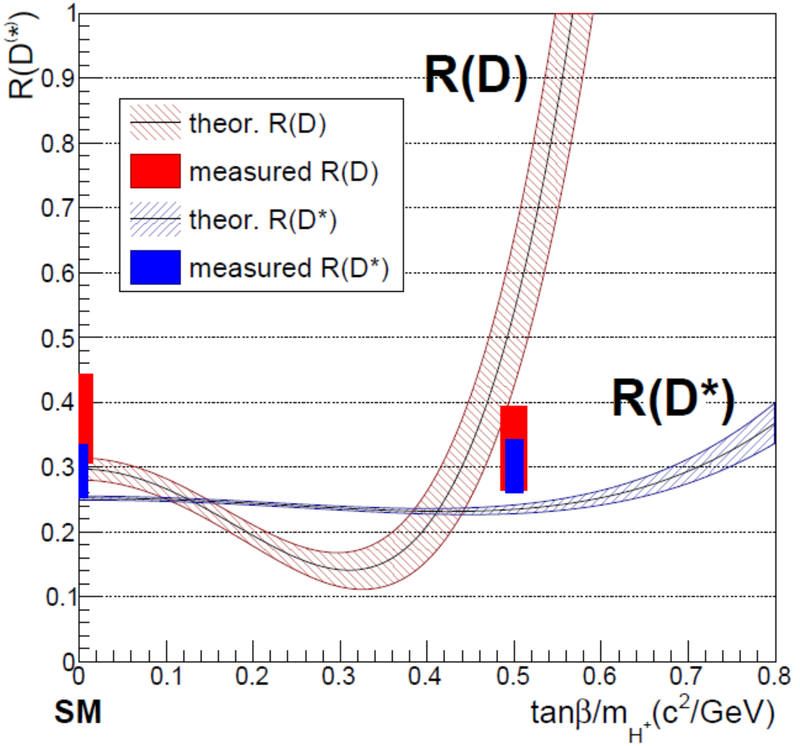
2) **$M^2_{miss} > 0.85\ GeV^2/c^4$:** enriched by $B \to D^{(*)}\tau\nu$ ($\tau \to e\nu\nu$, $\mu\nu\nu$)

To constrain $B \to D^{(*)}e\nu$, $D^{(*)}\mu\nu$ yields M^2_{miss} in fitted in the region **1)**, while neural-network output **O_{NB}** is fitted in region **2)**. $O'_{NB} = \frac{O_{NB} - O_{min}}{O_{max} - O_{NB}}$



Search for New Physics in $B \to D^{(*)} \tau \nu$





The fit was repeated with the PDF generated from 2HDM type II MC with $\tan\beta/M_{H\pm} = 0.5\ c^2/\text{GeV}$:

$R(D) = 0.329 \pm 0.060 \pm 0.022$; $R(D)_{2HDM} = 0.590 \pm 0.125$;

$R(D^*) = 0.301 \pm 0.039 \pm 0.015$; $R(D^*)_{2HDM} = 0.241 \pm 0.007$.

Belle result compatible with 2HDM type II model in the region around $\tan\beta/M_{H\pm} = 0.5\ c^2/\text{GeV}$

Search for dark photon and dark Higgs boson

New **Belle: PRL 114, 211801 (2015)**

Dark photon **A'** and dark Higgs boson **h'** are introduced in the Dark Sector Models, with kinetic mixing (ϵ) between **A'** and $\boldsymbol{\gamma_{SM}}$, and **A'** coupling to **h'** ($\boldsymbol{\alpha_D}$). One of the promising **A'** and **h'** production channels at $e^+ e^-$ colliders is **Higgs'-strahlung**:

$$e^+ e^- \rightarrow A' h'$$

B. Batell *et al*., Phys. Rev. D **79**, 115008 (2009)

a) $m_{h'} < m_{A'}$: $h' \rightarrow A'^* A'^*$

b) $m_{A'} < m_{h'} < 2m_{A'}$: $h' \rightarrow A' A'^*$

c) $m_{h'} > 2m_{A'}$: $h' \rightarrow A' A'$

At Belle we searched for $e^+ e^- \rightarrow A' h' [\rightarrow A' A']$, $A' \rightarrow e^+e^-, \mu^+\mu^-, \pi^+\pi^-$

in 10 exclusive final states: $3(e^+e^-)$, $3(\mu^+\mu^-)$, $3(\pi^+\pi^-)$, $2(e^+e^-)(\mu^+\mu^-)$, $2(e^+e)(\pi^+\pi^-)$, $2(\mu^+\mu^-)(e^+e^-)$, $2(\mu^+\mu^-)(\pi^+\pi^-)$, $2(\pi^+\pi^-)(e^+e^-)$, $2(\pi^+\pi^-)(\mu^+\mu^-)$, $(e^+e^-)(\mu^+\mu^-)(\pi^+\pi^-)$

$0.1 \text{ GeV}/c^2 < m_{A'} < 3.5 \text{ GeV}/c^2$ $\quad$ $0.2 \text{ GeV}/c^2 < m_{h'} < 10.5 \text{ GeV}/c^2$

in 3 inclusive final states: $2(e^+e^-)X$, $2(\mu^+\mu^-)X$, $(e^+e^-)(\mu^+\mu^-)X$

$1.1 \text{ GeV}/c^2 < m_{A'} < 3.5 \text{ GeV}/c^2$ $\quad$ $2.2 \text{ GeV}/c^2 < m_{h'} < 10.5 \text{ GeV}/c^2$

Search for dark photon and dark Higgs boson

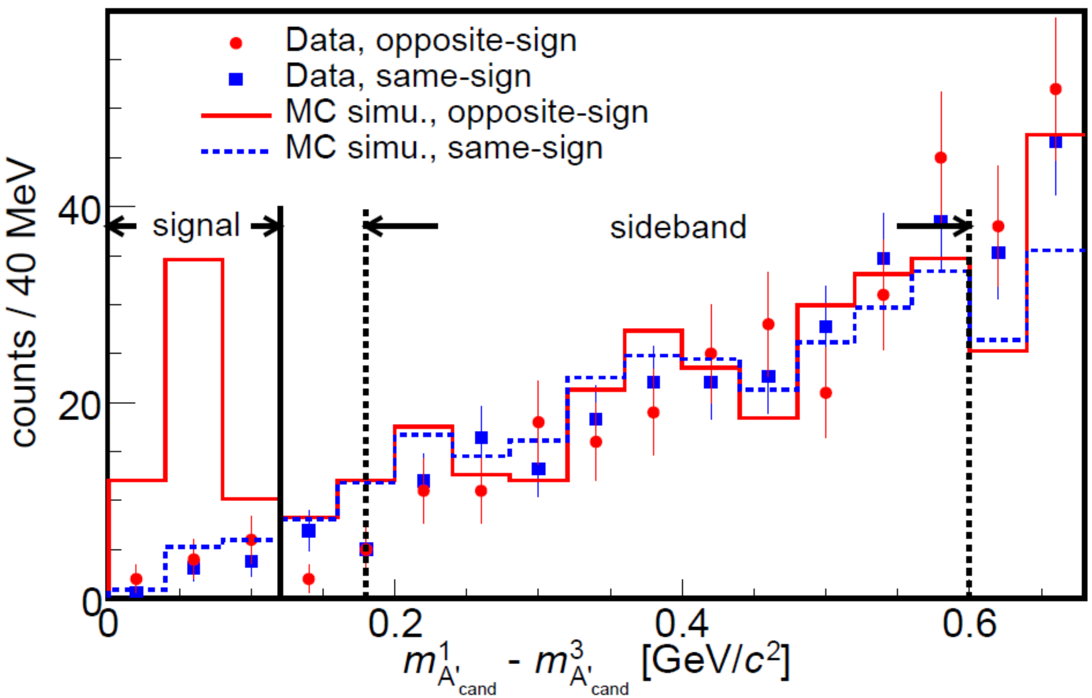
Data: 977 fb^{-1}

Selections:

- $m^1_{A'} > m^2_{A'} > m^3_{A'}$
- analysis in bins of $m^1_{A'}$
- divide $m^1_{A'}$ - $m^3_{A'}$ into signal and sideband regions
- same-sign events were used to evaluate background in the signal region

Efficiency: (20 ÷ 30)%

$$N_{\text{obs}} = \sigma_{\text{Born}}(1+\delta)|1-\Pi|^2 \mathcal{L}\mathcal{B}\varepsilon + N_{\text{bkg}}$$

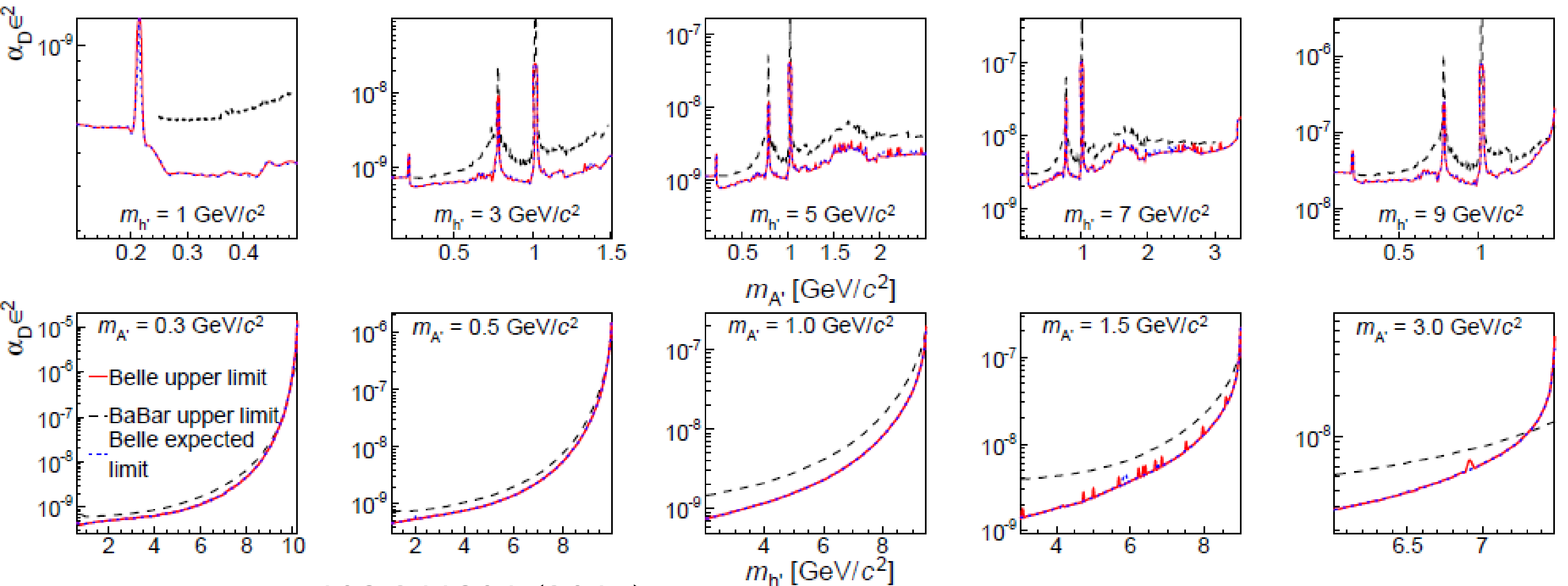


Number of observed events

Final state	Events	Final state	Events
$3(e^-e^+)$	1	$2(\mu^+\mu^-)(e^+e^-)$	1
$3(\mu^+\mu^-)$	2	$2(\mu^+\mu^-)(\pi^+\pi^-)$	1
$3(\pi^+\pi^-)$	147	$2(\pi^+\pi^-)(e^+e^-)$	5
$2(e^+e^-)(\mu^+\mu^-)$	7	$2(\pi^+\pi^-)(\mu^+\mu^-)$	6
$2(e^+e^-)(\pi^+\pi^-)$	2	$(e^+e^-)(\mu^+\mu^-)(\pi^+\pi^-)$	7
$2(e^+e^-)X$	572	$(e^+e^-)(\mu^+\mu^-)X$	30
$2(\mu^+\mu^-)X$	20		

Search for dark photon and dark Higgs boson

90%CL upper limits on the product $\alpha_D \times \epsilon^2$



BaBar: PRL 108 211801 (2014)

No significant signal is observed

Summary

- Cross sections of the reactions $e^+e^-\to\Upsilon(nS)\pi^+\pi^-$, $e^+e^-\to h_b(nP)\pi^+\pi^-$ and $e^+e^-\to b\bar{b}$ have been measured in the region of $\Upsilon(5S)$ and $\Upsilon(6S)$ resonances. Energy behaviour of the $\sigma(e^+e^-\to\Upsilon(nS)\pi^+\pi^-)$ and $\sigma(e^+e^-\to h_b(nP)\pi^+\pi^-)$ is similar. Masses and widths of $\Upsilon(5S,6S)$ were measured precisely, they agree with the previous measurements.

- We found an evidence of $\Upsilon(6S)\to Z_b[\to h_b\pi]\pi$.

- $B\bar{B}^*/B^*\bar{B}^*$ modes dominate in Z_b decays with the branching ratios 83%/71%, Z_b properties agree well with $B^{(*)}\bar{B}^*$ molecular structure.

- $B\to D^{(*)}\tau\nu$ have been studied at Belle , our result on R and R^* agrees with both SM expectation and BaBar result. It is also consistent with 2HDM type II model in the region around $\tan\beta/M_{H\pm} = 0.5\ c^2/\mathrm{GeV}$

- No significant signal was found for dark photon and dark Higgs, 90% CL upper limits on the product $\alpha_D \times\epsilon^2$ were obtained.