Bottomonium results at Belle

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BINP

For Belle Collaboration

Hadron 2011, June 14, 2011

Puzzles of $\Upsilon(5S)$ decays

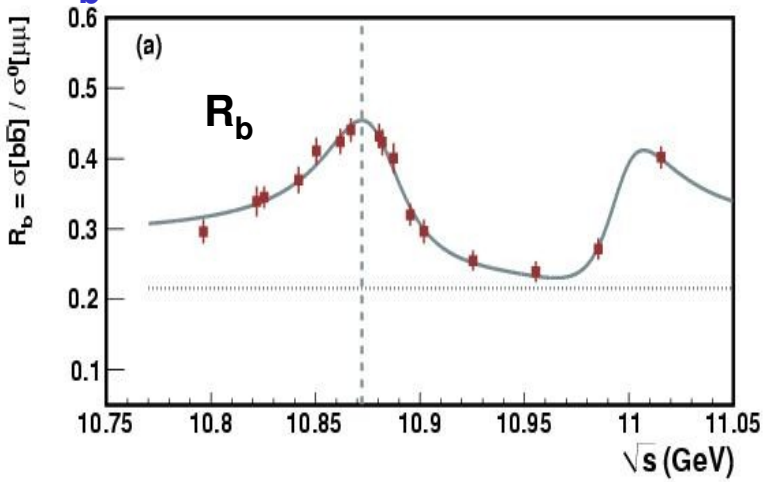
PRL100,112001(2008)

At 21.7 fb^{-1} Υ (5S) ->Υ(nS) $\pi^+\pi^-$ two orders of magnitude larger than in Υ (4S) decay

PRD82,091106R(2010)

	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

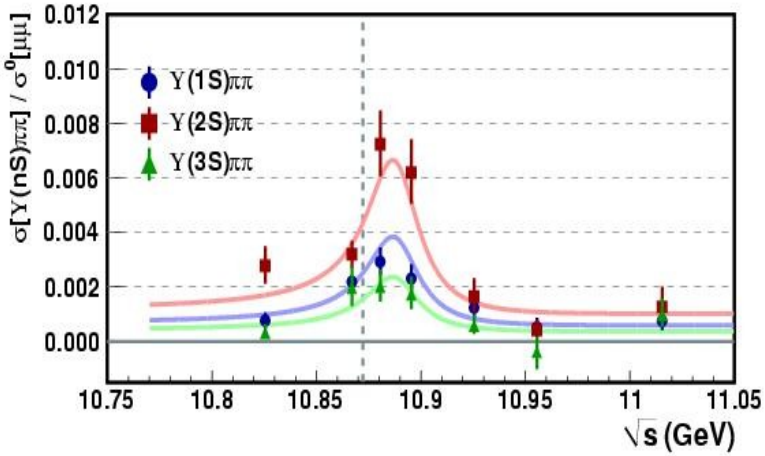
Dedicated energy scan ⇒
shapes of R_b and $\sigma(\Upsilon\pi\pi)$ different (2σ)



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

Simonov JETP Lett 87,147(2008)

-Exotic resonance Y_b near $\Upsilon(5S)$



$\Upsilon(5S)$ is very interesting and not yet understood

Finally Belle recorded 121.4fb^{-1} at $\Upsilon(5S)$

arXiv:1104.2025

Observation of $e^+e^- \to \pi^+\pi^- h_c$ by CLEO

⇒ Belle search for h_b in $\Upsilon(5S)$ data

Introduction to $h_b(nP)$

$(\bar{b}b)$: S=0 L=1 $J^{PC}=1^{+-}$

Expected mass (CoG of χ_{bJ})

$\approx (M\chi_{b0} + 3\,M\chi_{b1} + 5\,M\chi_{b2}) / 9$

$\Delta M_{HF} \Rightarrow$ test of hyperfine interaction

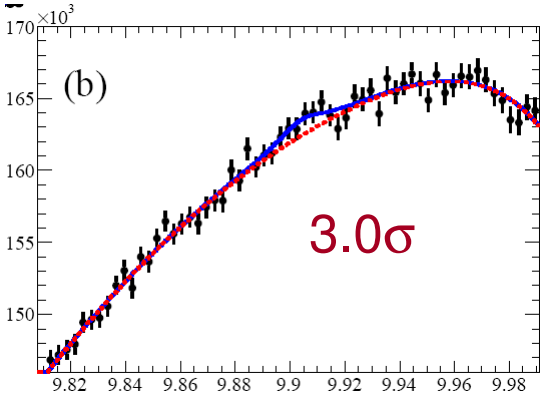
For h_c $\Delta M_{HF} = -0.12 \pm 0.30$,

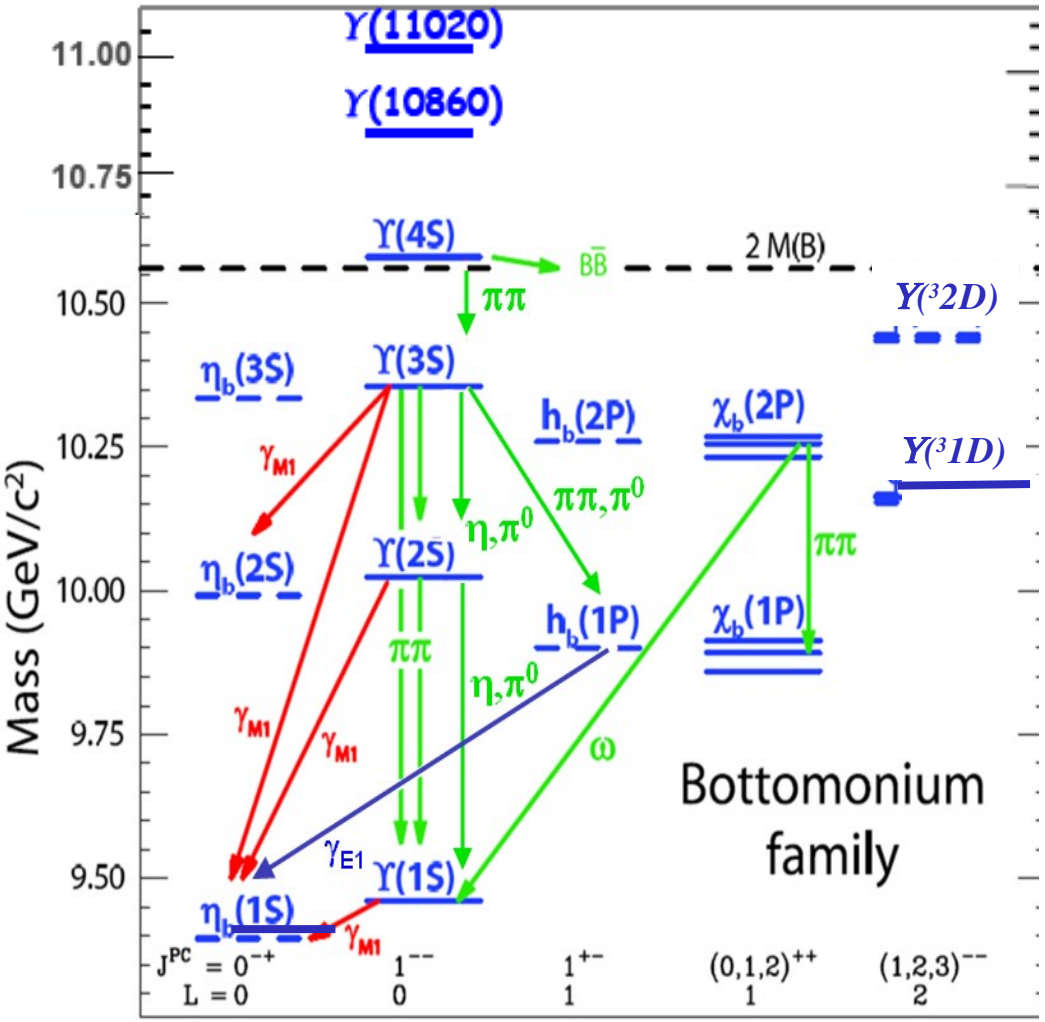
expect smaller deviation for $h_b(nP)$.

arXiv:1102.4565

Evidence from BaBar

$\Upsilon(3S) \rightarrow \pi^0 h_b(1P) \rightarrow \pi^0 \gamma \eta_b(1S)$

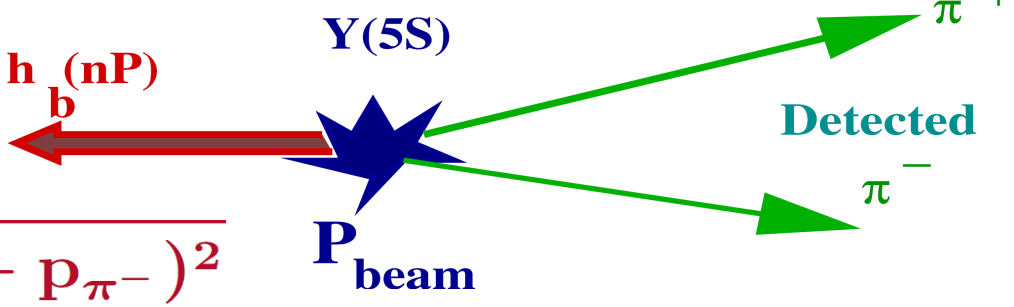




$B(\Upsilon(3S) \rightarrow \pi^0 h_b) \times B(h_b \rightarrow \gamma \eta_b) = (3.7 \pm 1.1 \pm 0.7) \times 10^{-4}$

h_b reconstruction

Missing mass to $\pi\pi$ system



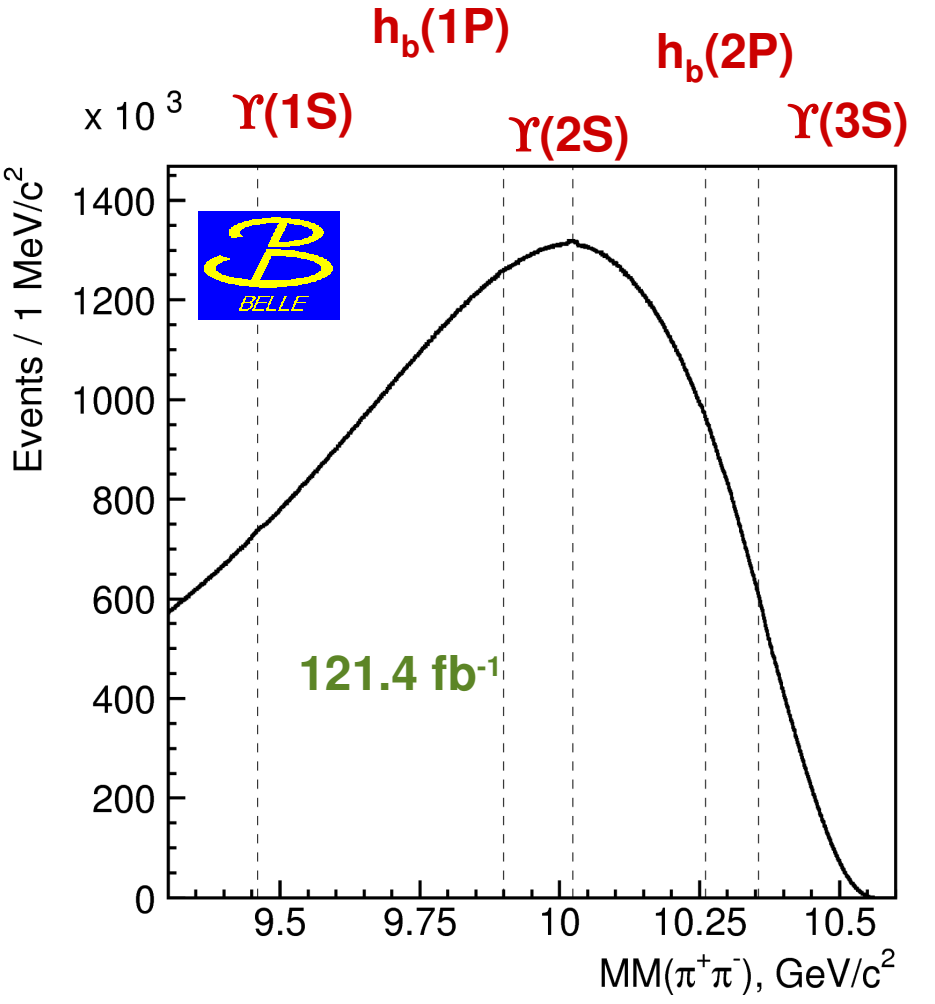
$$M_{miss} = \sqrt{P^2_{beam} - (p_{\pi+} + p_{\pi-})^2}$$

Simple selection :

$\pi^+\pi^-$: good quality, positively identified

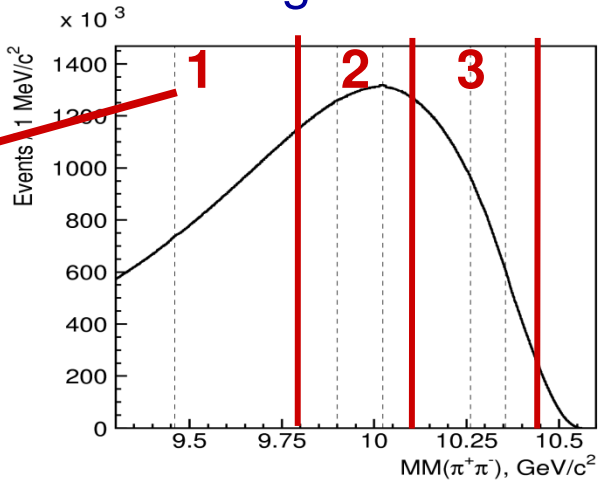
Suppression of continuum events
FW R2<0.3

⇒ Search for h_b(nP) peaks in MM($\pi^+\pi^-$) spectrum

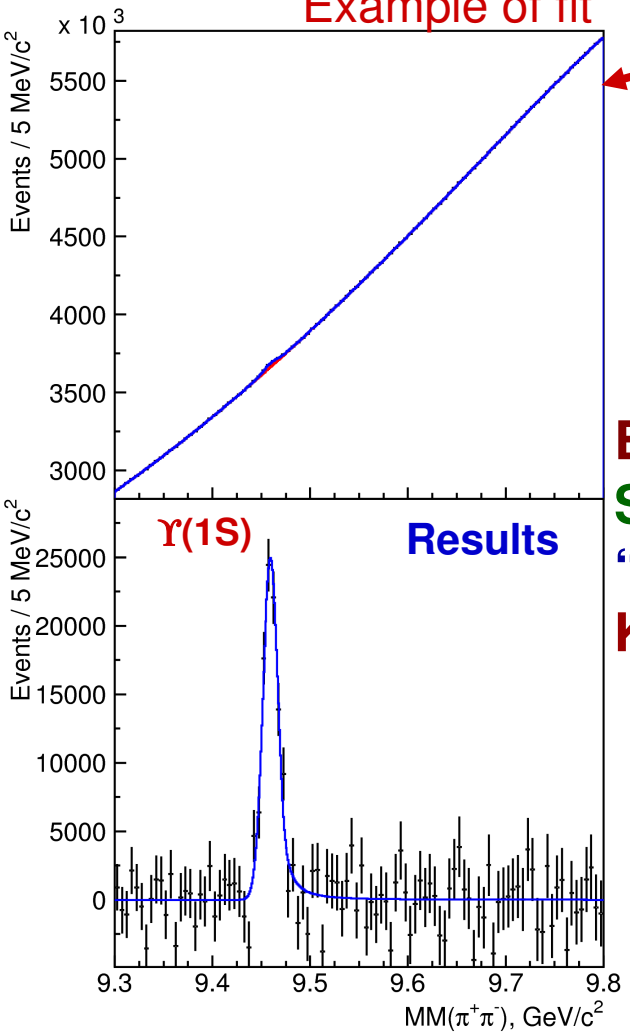


Description of fit to MM($\pi^+\pi^-$)

Three fit regions



Example of fit

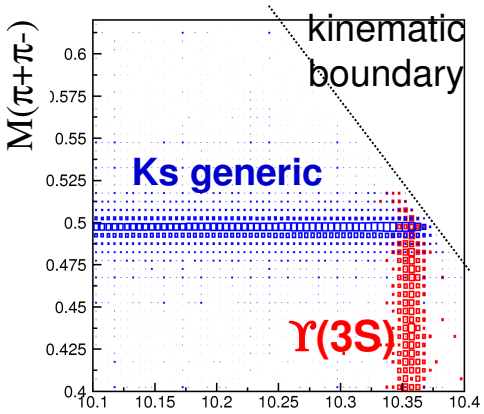


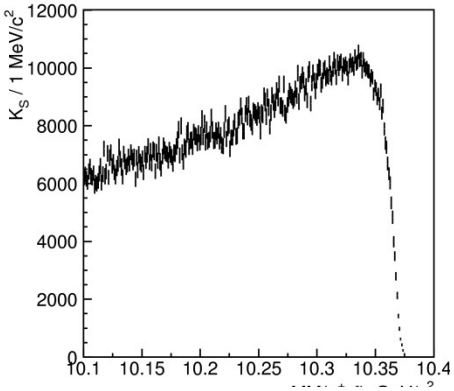
BG: Chebyshev polynomial 6th-7th order

Signal: shape is fixed from $\mu^+\mu^-\pi^+\pi^-$ data

"Results" – subtract polynomial from data points

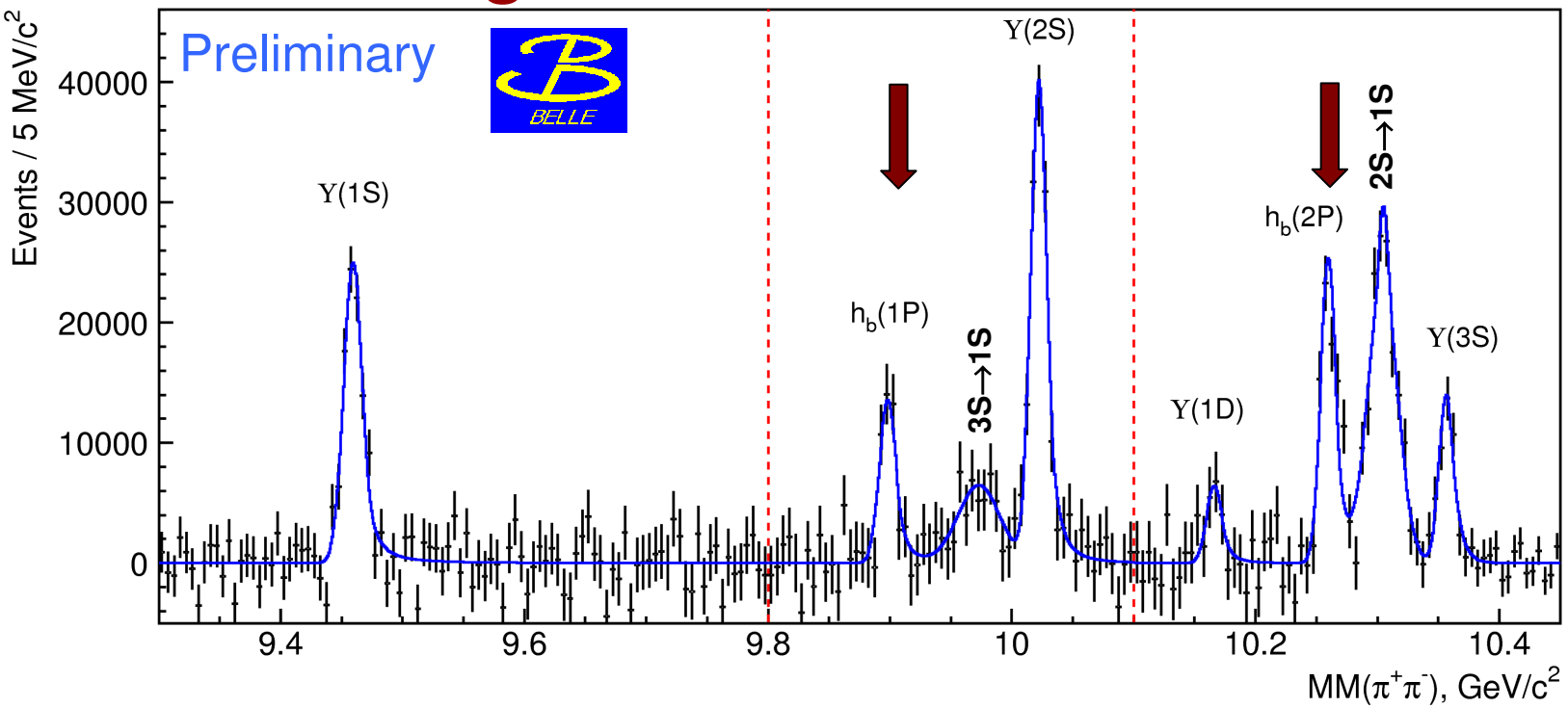
K_S contribution: subtract bin-by-bin in region #3





Background Subtracted Results

121.4 fb^{-1}



	Yield, 10^3	Mass, MeV/c^2	Signif.
$\Upsilon(1S)$	$105.2 \pm 5.8 \pm 3.0$	$9459.42 \pm 0.53 \pm 1.02$	$18.2\,\sigma$
$h_b(1P)$	$50.4 \pm 7.8^{+4.5}_{-9.1}$	$9898.25 \pm 1.06^{+1.03}_{-1.07}$	$6.2\,\sigma$
$3S \to 1S$	55 ± 19	9973.01	$2.9\,\sigma$
$\Upsilon(2S)$	$143.4 \pm 8.7 \pm 6.8$	$10022.25 \pm 0.41 \pm 1.01$	$16.6\,\sigma$
$\Upsilon(1D)$	22.1 ± 7.8	10166.2 ± 2.4	$2.4\,\sigma$
$h_b(2P)$	$84.4 \pm 6.8^{+23.}_{-10.}$	$10259.76 \pm 0.64^{+1.43}_{-1.03}$	$12.4\,\sigma$
$2S \to 1S$	$151.6 \pm 9.7^{+9.0}_{-20.}$	$10304.57 \pm 0.61 \pm 1.03$	$15.7\,\sigma$
$\Upsilon(3S)$	$44.9 \pm 5.1 \pm 5.1$	$10356.56 \pm 0.87 \pm 1.06$	$8.5\,\sigma$

arXiv:1103.3419

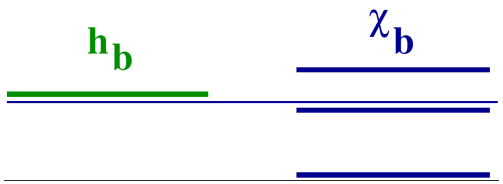
Significance w/systematics

h$_b$(1P) 5.5σ

h$_b$(2P) 11.2σ

h_b results

Deviations from CoG of χ_{bJ} masses consistent with zero.



$$\Delta M = 1.62 \pm 1.57\ \mathrm{MeV/c^2} : \mathrm{h_b(1P)}$$

$$\Delta M = 0.48^{+1.57}_{-1.22}\ \mathrm{MeV/c^2} : \mathrm{h_b(2P)}$$

Ratio of production rates

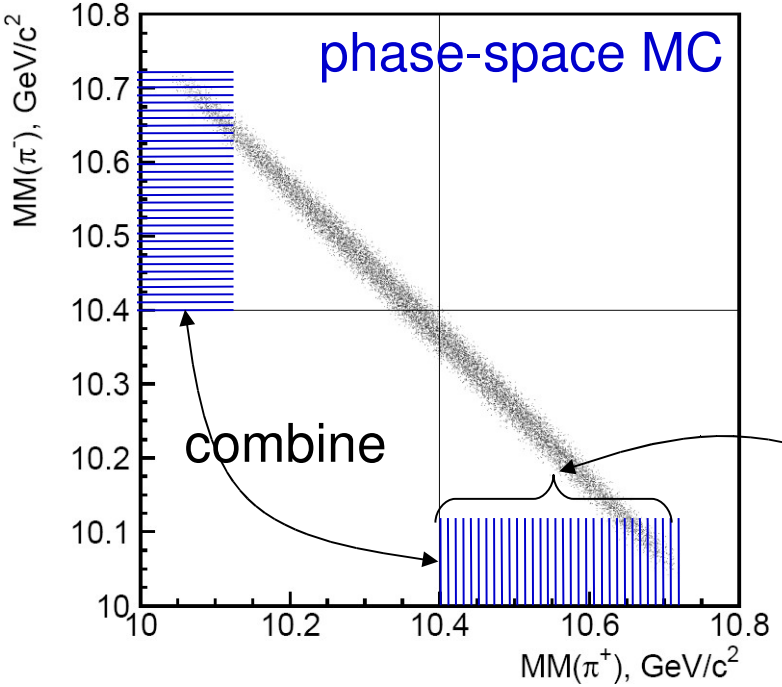
$$\frac{\Gamma(\Upsilon(5S) \to h_b(nP)\pi^+\pi^-)}{\Gamma(\Upsilon(5S) \to \Upsilon(2S)\pi^+\pi^-)} = \begin{cases} 0.407 \pm 0.079^{+0.043}_{-0.076} & : \mathrm{h_b(1P)} \\ 0.79 \pm 0.09^{+0.22}_{-0.10} & : \mathrm{h_b(2P)} \end{cases}$$

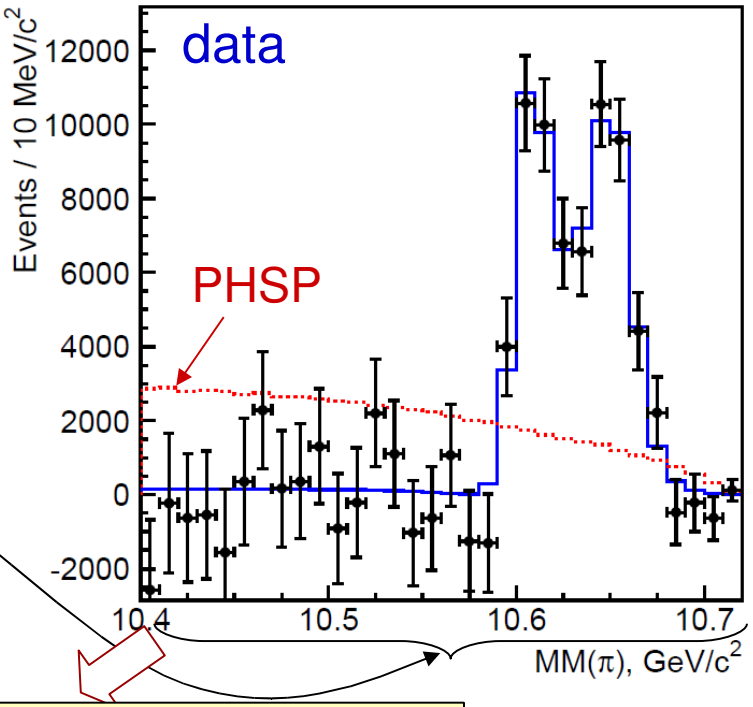
Process with spin-flip is not suppressed
No h_b signal at $\Upsilon(4S)$

- **Mechanism of $\Upsilon(5S) \to h_b(nP)\ \pi^+\pi^-$ decay is exotic!**

Resonant substructure of $\Upsilon(5S) \to h_b(1P)\pi^+\pi^-$

$P(h_b) = P_{\Upsilon(5S)} - P(\pi^+\pi^-) \Rightarrow$ **$M(h_b\pi^+) = MM(\pi^-)$** $\Rightarrow$ ***measure $\Upsilon(5S)\to h_b\pi\pi$ yield in bins of $MM(\pi)$***





$$|BW(s, M_1, \Gamma_1) + ae^{i\phi}BW(s, M_1, \Gamma_1) + be^{i\psi}|^2 \frac{qp}{\sqrt{s}}$$

[preliminary]

~ $B\bar{B}^*$threshold

M (MeV/c²)	Γ (MeV)	a	ϕ
$10605.1 \pm 2.2^{+3.0}_{-1.0}$	$11.4^{+4.5+2.1}_{-3.9-1.2}$	1	0
$10654.5 \pm 2.5^{+1.0}_{-1.9}$	$20.9^{+5.4+2.1}_{-4.7-5.7}$	$1.8^{+1.0+0.1}_{-0.7-0.5}$	188^{+44+4}_{-58-9}

~ $B^*\bar{B}^*$threshold

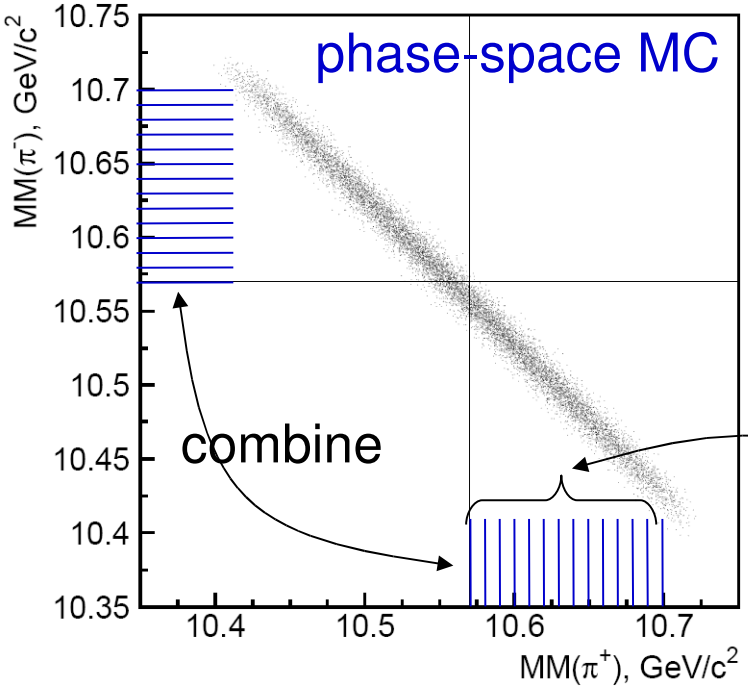
non-res.~0

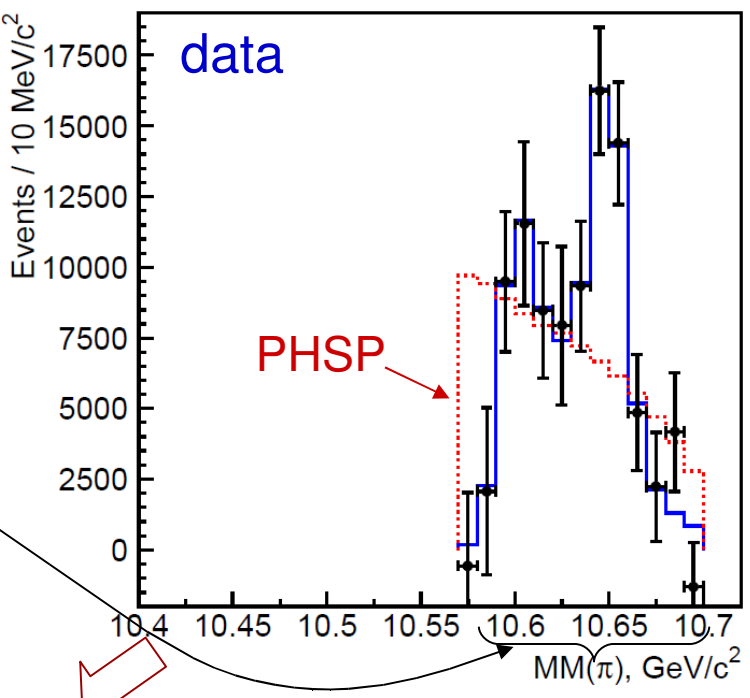
Significances

2 vs.1 : 7.4σ (6.6σ w/ syst)

2 vs.0 : 18σ (16σ w/ syst)

Resonant substructure of $\Upsilon(5S) \to h_b(2P)\pi^+\pi^-$





	$h_b(1P)\pi^+\pi^-$	$h_b(2P)\pi^+\pi^-$
M_1 (MeV/c²)	$10605.1 \pm 2.2^{+3.0}_{-1.0}$	$10596 \pm 7^{+5}_{-2}$
Γ_1 (MeV)	$11.4^{+4.5+2.1}_{-3.9-1.2}$	16^{+16+13}_{-10-4}
M_2 (MeV/c²)	$10654.5 \pm 2.5^{+1.0}_{-1.9}$	$10651 \pm 4 \pm 2$
Γ_2 (MeV)	$20.9^{+5.4+2.1}_{-4.7-5.7}$	12^{+11+8}_{-9-2}
a	$1.8^{+1.0+0.1}_{-0.7-0.5}$	$1.3^{+3.1+0.4}_{-1.1-0.7}$
ϕ (degree)	188^{+44+4}_{-58-9}	$255^{+56+12}_{-72-183}$
non − res	~ 0	~ 0

[preliminary]

Significances

2 vs.1 : 2.7σ (1.9σ w/ syst)

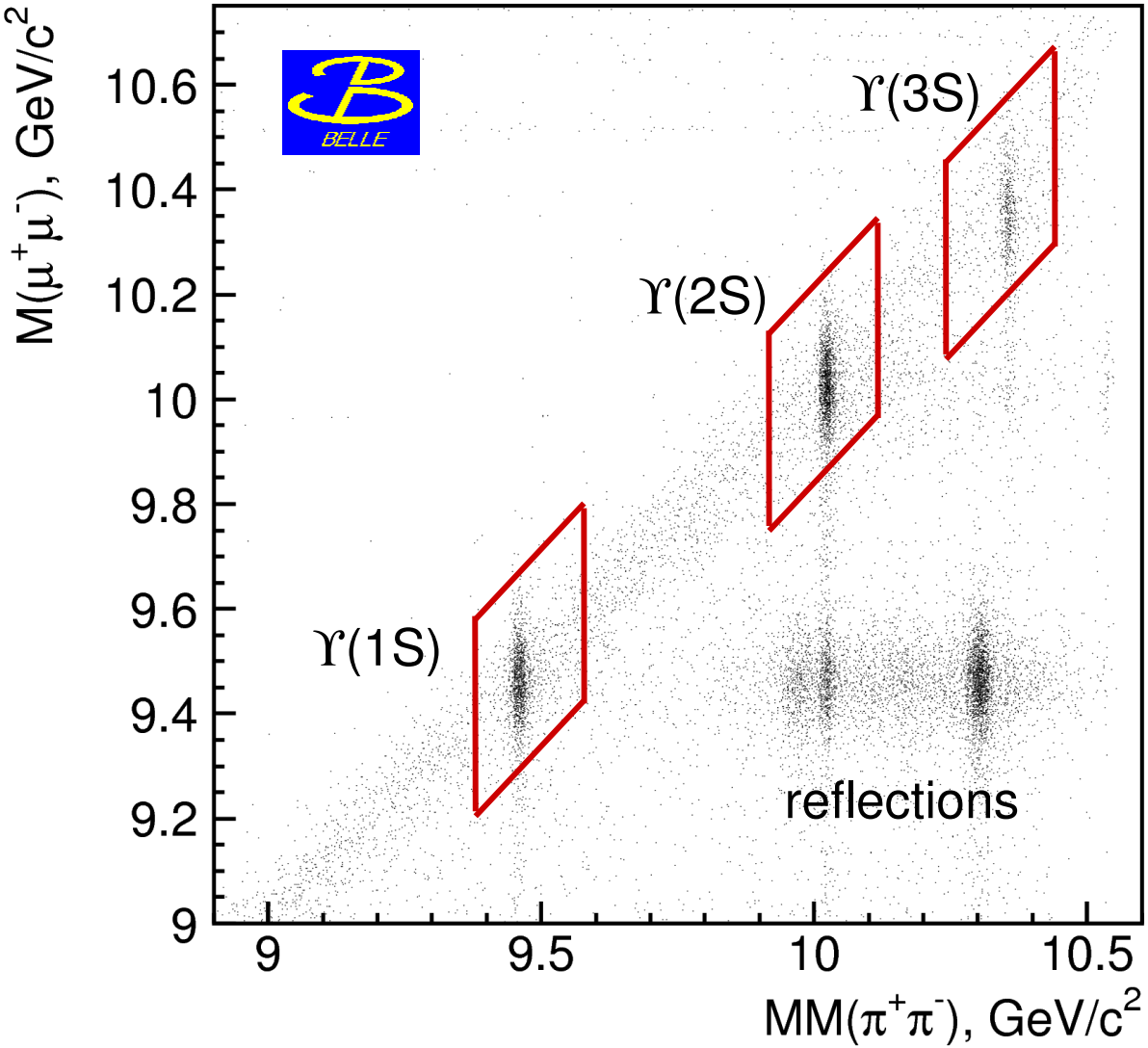
2 vs.0 : 6.3σ (4.7σ w/ syst)

Resonances parameters are consistent

Exclusive $\Upsilon(5S) \to \Upsilon(nS)\,\pi^+\pi^-$

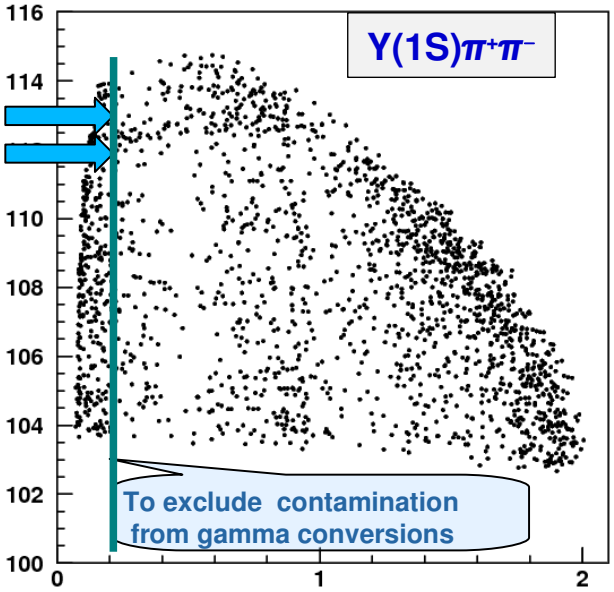
$\Upsilon(5S) \to \Upsilon(nS)\,\pi+\pi-$ (n = 1,2,3)

$\Upsilon(nS) \to \mu+\mu-$

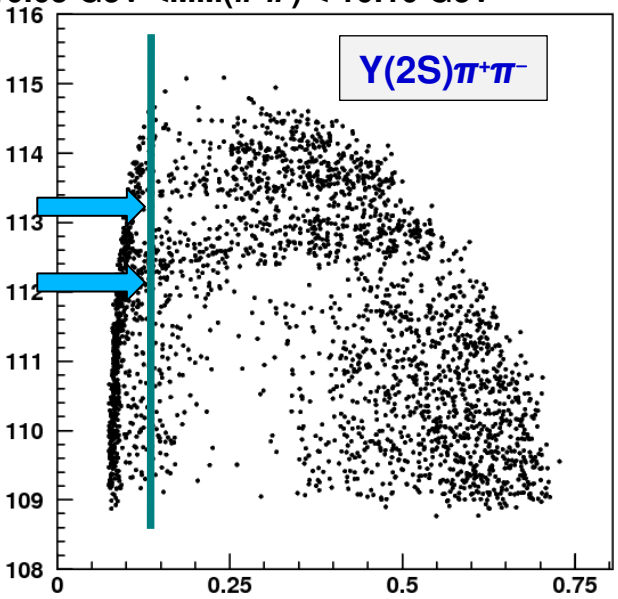


$\Upsilon(5S) \to \Upsilon(nS)\,\pi^+\pi^-$ Dalitz plots

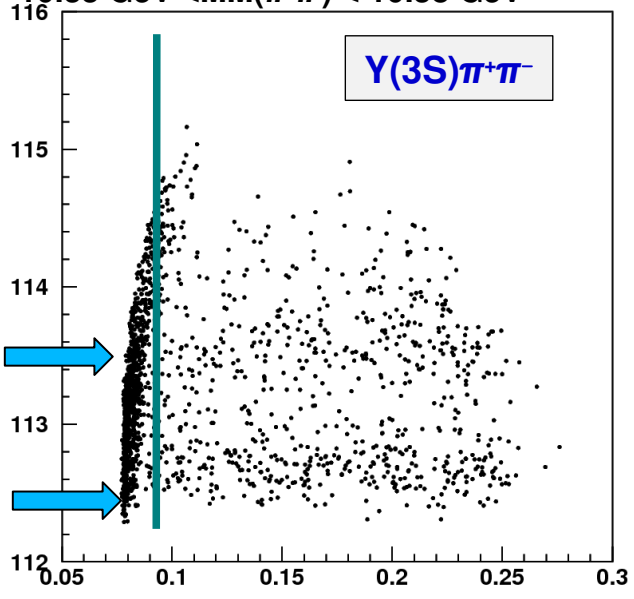
9.43 GeV <MM($\pi^+\pi^-$) < 9.48 GeV



10.05 GeV <MM($\pi^+\pi^-$) < 10.10 GeV



10.33 GeV <MM($\pi^+\pi^-$) < 10.38 GeV



$s_i \equiv M^2_{\pi_i \Upsilon}$ **Unbinned fit of DP with signal function:**

Flatte m=950 MeV/c²

D-wave Breit-Wigner

$$S(s_1, s_2) = |A_{Z_{b1}} + A_{Z_{b2}} + A_{NR} + A_{f_0(980)} + A_{f_2(1275)}|^2$$

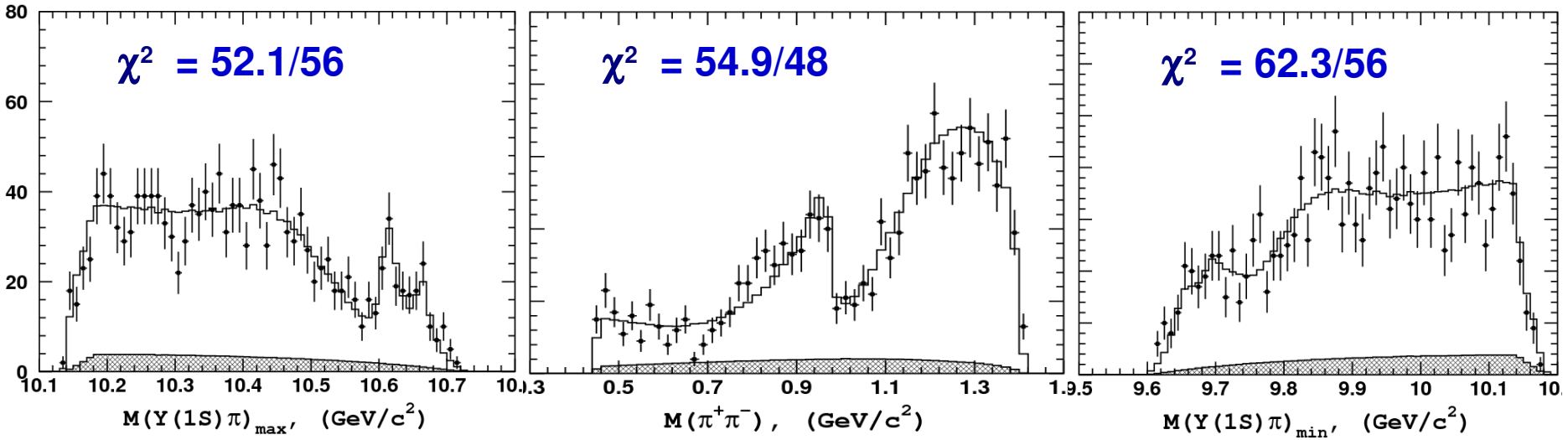
$$A_{Z_{bi}} = \frac{\sqrt{M_i \Gamma_i}}{M_i^2 - s_1 + iM_i\Gamma_i} + \frac{a_i e^{i\phi_i}\sqrt{M_i\Gamma_i}}{M_i^2 - s_2 + iM_i\Gamma_i}$$

$$A_{NR} = c_1 + c_2 m^2_{\pi\pi}$$

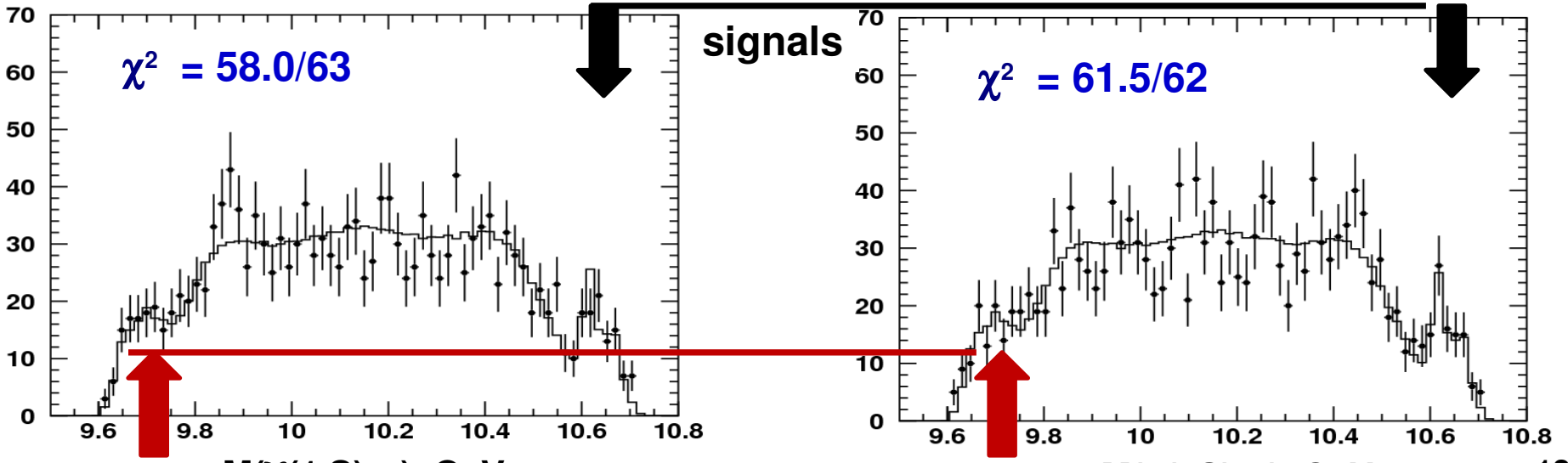
[1] M.B. Voloshin, Prog. Part. Nucl. Phys. 61:455, 2008.

[2] M.B. Voloshin, Phys. Rev. D74:054022, 2006.

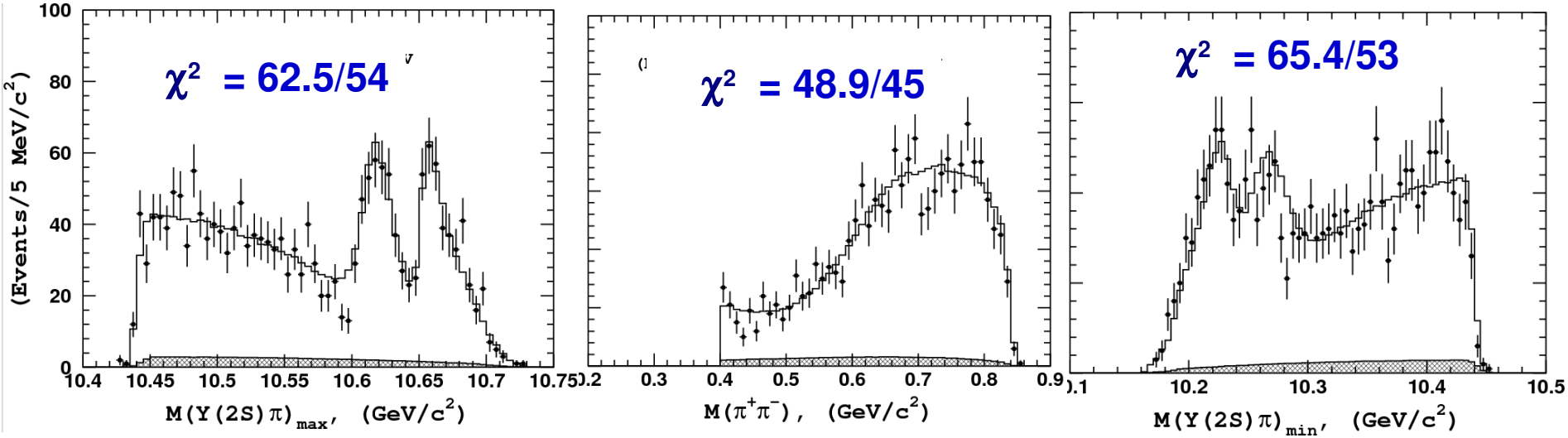
Results: $\Upsilon(1S)\pi^+\pi^-$



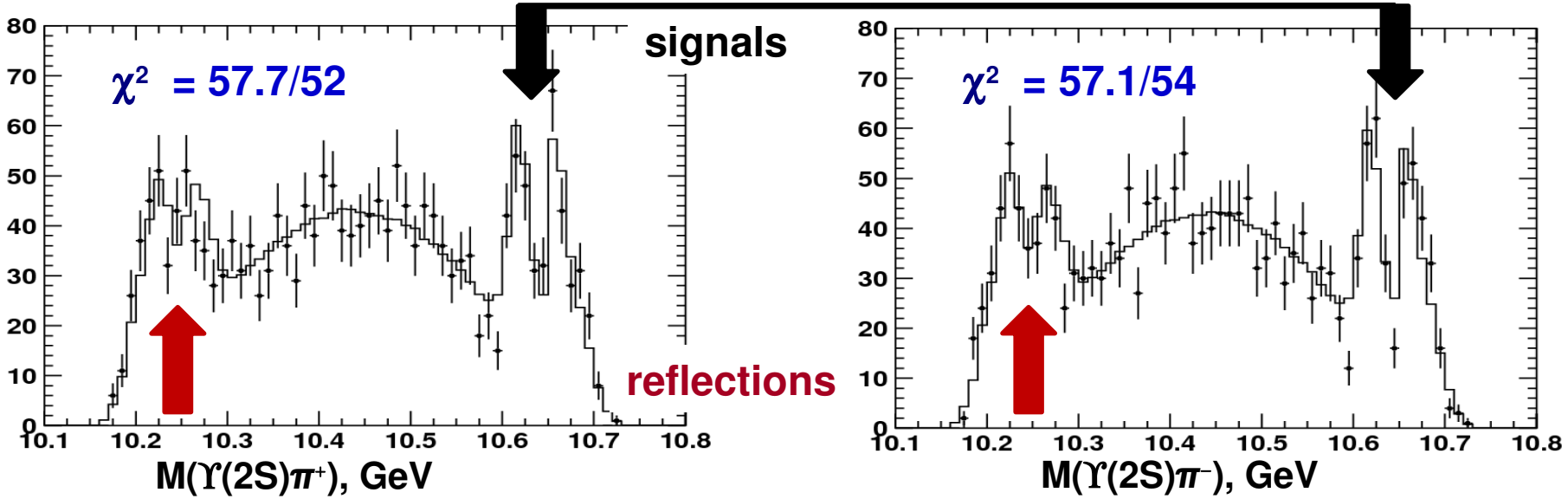
$M(\Upsilon(1S)\pi^+)$ and $M(\Upsilon(1S)\pi^-)$ projections:



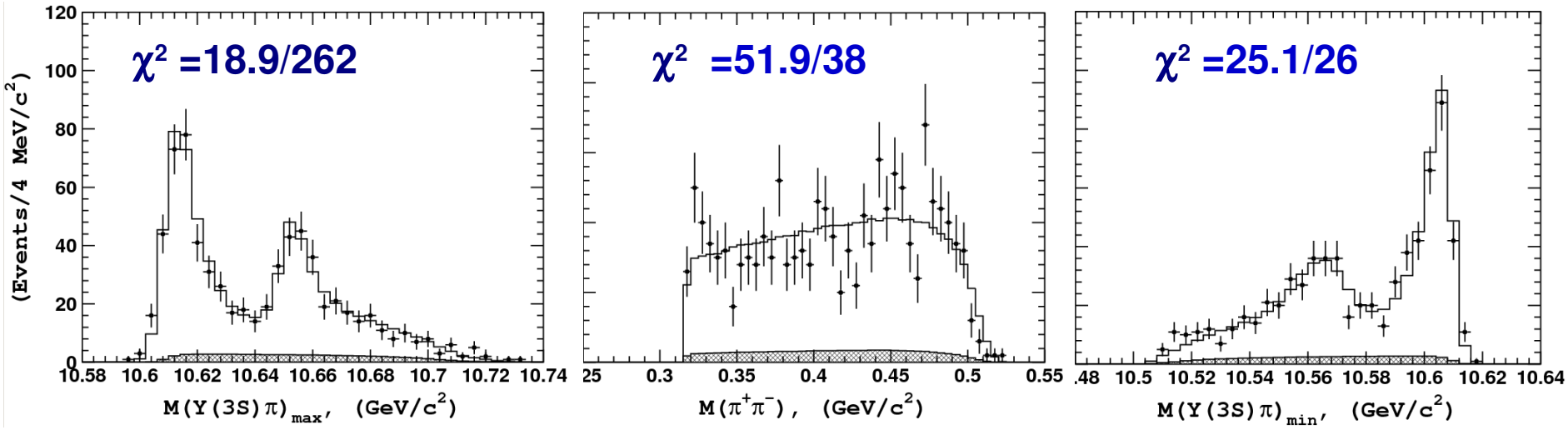
Results: $\Upsilon(2S)\pi^+\pi^-$



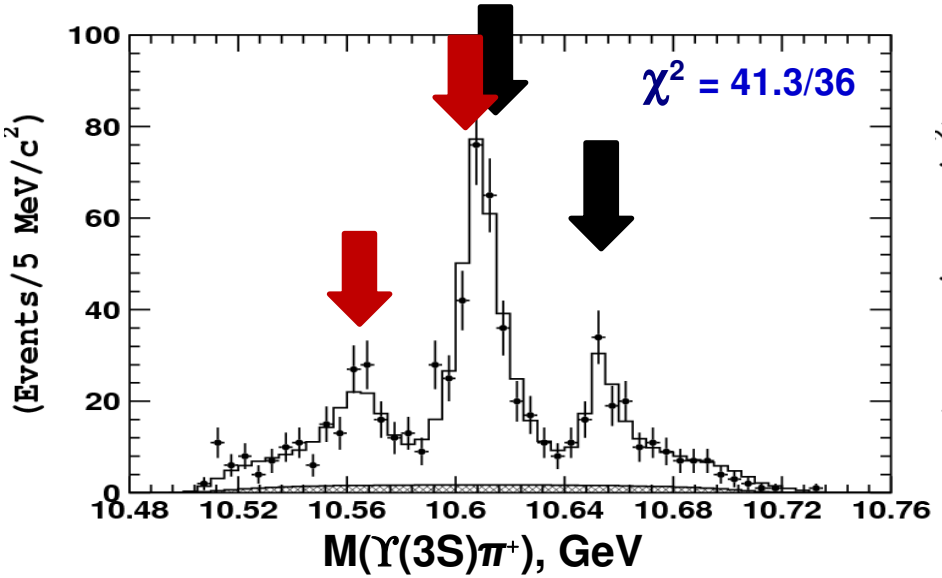
$M(\Upsilon(2S)\pi^+)$ and $M(\Upsilon(2S)\pi^-)$ projections:

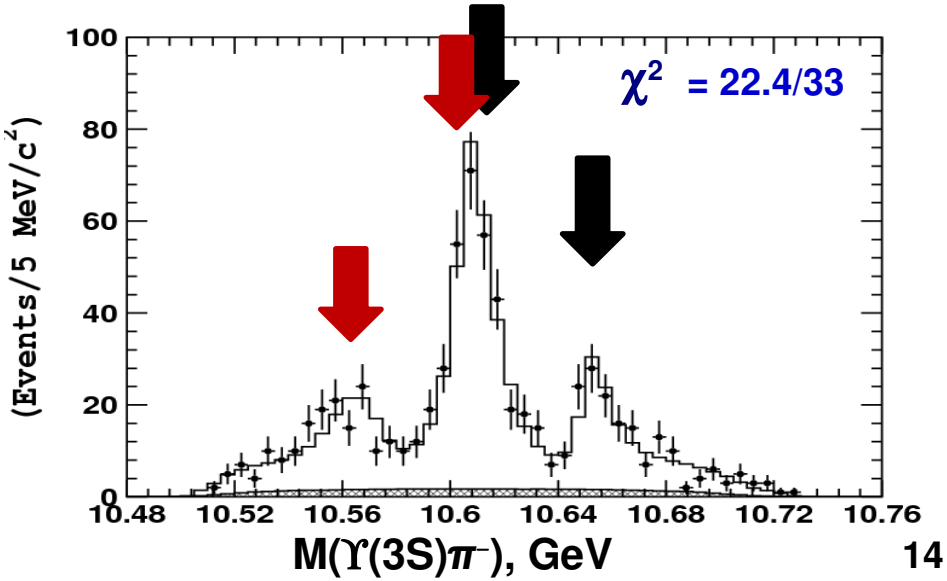


Results: $\Upsilon(3S)\pi^+\pi^-$



$M(\Upsilon(3S)\pi^+)$ and $M(\Upsilon(3S)\pi^-)$ projections:





Fit results

[preliminary]

Final state	$\Upsilon(1S)\pi^+\pi^-$	$\Upsilon(2S)\pi^+\pi^-$	$\Upsilon(3S)\pi^+\pi^-$	$h_b(1P)\pi^+\pi^-$	$h_b(2P)\pi^+\pi^-$
$M(Z_b(10610))$, MeV/c^2	$10609 \pm 3 \pm 2$	$10616 \pm 2^{+3}_{-4}$	$10608 \pm 2^{+5}_{-2}$	$10605.1 \pm 2.2^{+3.0}_{-1.0}$	$10596 \pm 7^{+5}_{-2}$
$\Gamma(Z_b(10610))$, MeV	$22.9 \pm 7.3 \pm 2$	$21.1 \pm 4^{+2}_{-3}$	$12.2 \pm 1.7 \pm 4$	$11.4^{+4.5\ +2.1}_{-3.9\ -1.2}$	$16^{+16\ +13}_{-10\ -4}$
$M(Z_b(10650))$, MeV/c^2	$10660 \pm 6 \pm 2$	$10653 \pm 2 \pm 2$	$10652 \pm 2 \pm 2$	$10654.5 \pm 2.5^{+1.0}_{-1.9}$	$10651 \pm 4 \pm 2$
$\Gamma(Z_b(10650))$, MeV	$12 \pm 10 \pm 3$	$16.4 \pm 3.6^{+4}_{-6}$	$10.9 \pm 2.6^{+4}_{-2}$	$20.9^{+5.4\ +2.1}_{-4.7\ -5.7}$	$12^{+11\ +8}_{-9\ -2}$
Rel. amplitude	$0.59 \pm 0.19^{+0.09}_{-0.03}$	$0.91 \pm 0.11^{+0.04}_{-0.03}$	$0.73 \pm 0.10^{+0.15}_{-0.05}$	$1.8^{+1.0\ +0.1}_{-0.7\ -0.5}$	$1.3^{+3.1\ +0.4}_{-1.1\ -0.7}$
Rel. phase, degrees	$53 \pm 61^{+5}_{-50}$	$-20 \pm 18^{+14}_{-9}$	$6 \pm 24^{+23}_{-59}$	$188^{+44\ +4}_{-58\ -9}$	$255^{+56\ +12}_{-72\ -183}$

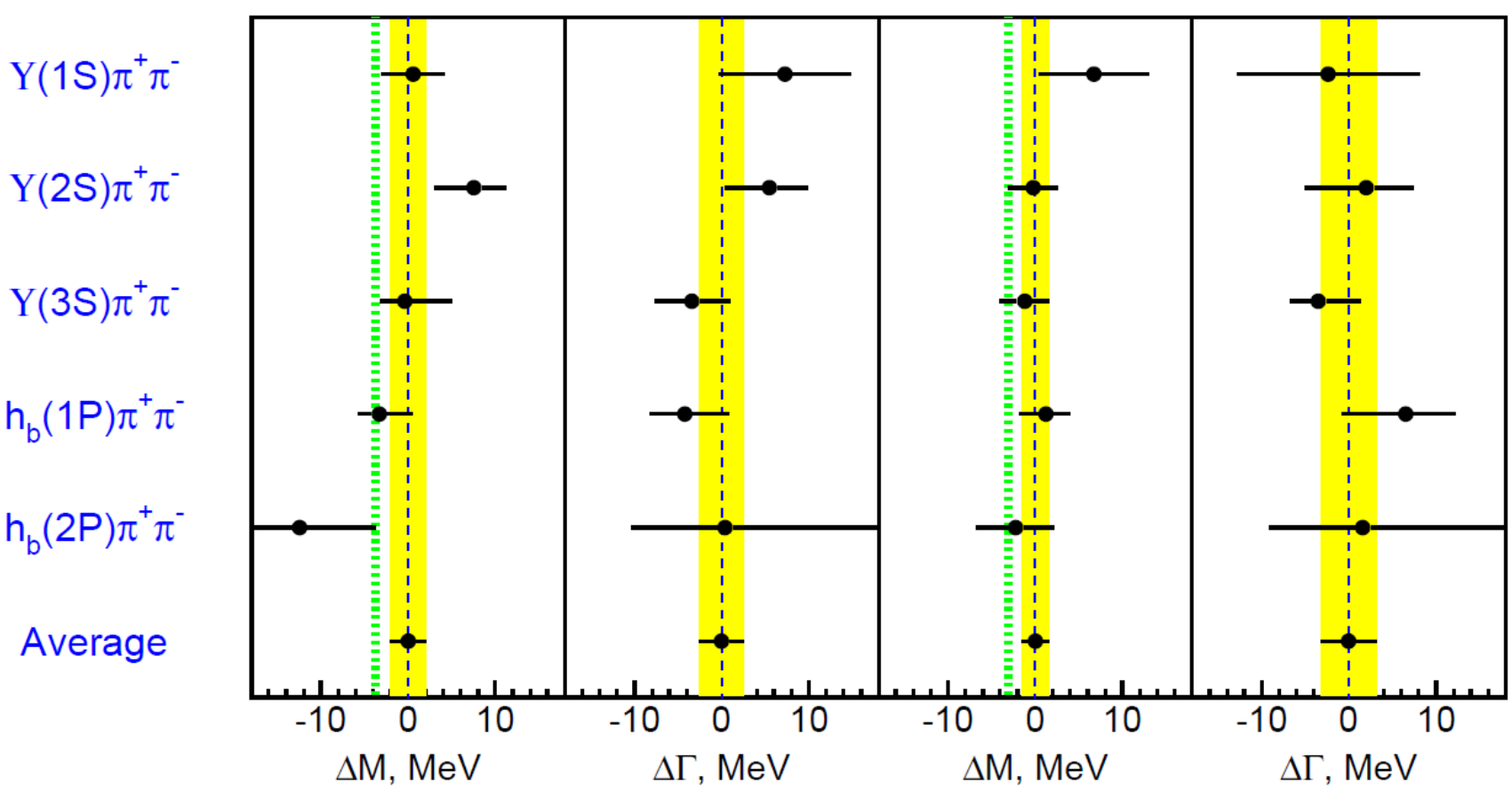
Masses, widths, relative amplitudes are consistent

Relative phases are swapped for Υ and h_b final states ⇐ expectation from a 'molecular' model

$Z_b(10610)$
M=10608.4±2.0 MeV
Γ=15.6±2.5 MeV

$Z_b(10650)$
M=10653.2±1.5 MeV
Γ=14.4 ± 3.2 MeV

Summary of parameters of charged Z_b states



$Z_b(10610)$

M=10608.4±2.0 MeV

Γ=15.6±2.5 MeV

$Z_b(10650)$

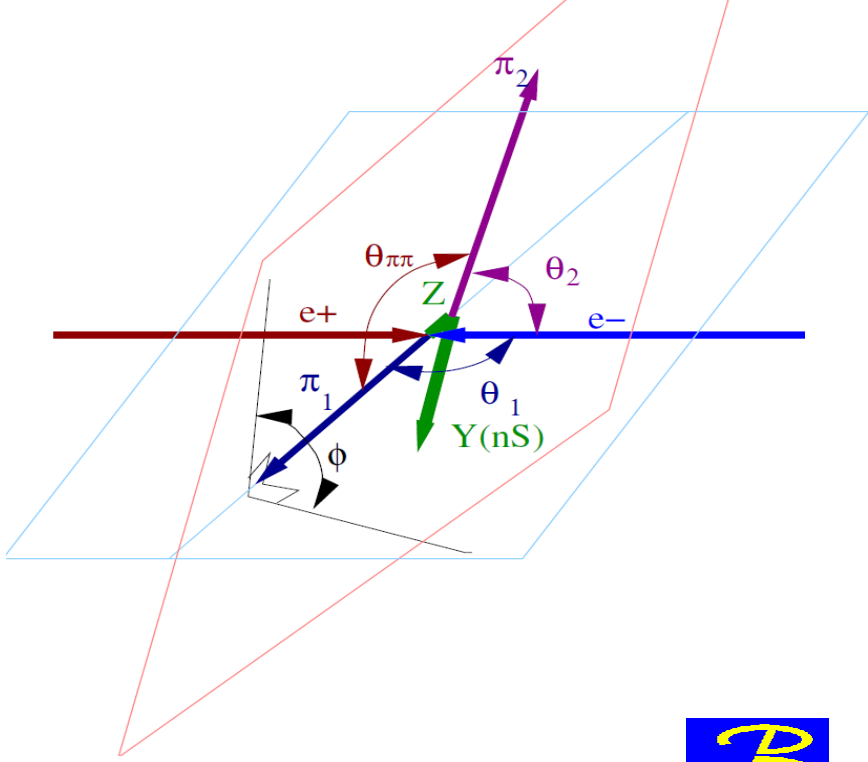
M=10653.2±1.5 MeV

Γ=14.4±3.2 MeV

Angular analysis

$\Theta_i = \angle(\pi_i, e^+)$, $\theta_{\pi\pi} = \angle(\pi_1, \pi_2)$,

$\phi = \angle[\text{plane}(\pi_1, e^+), \text{plane}(\pi_1, \pi_2)]$



$\Upsilon(5S) \to Z_b^+(10610)\,\pi^- \to [\Upsilon(2S)\pi^+]\,\pi^-$

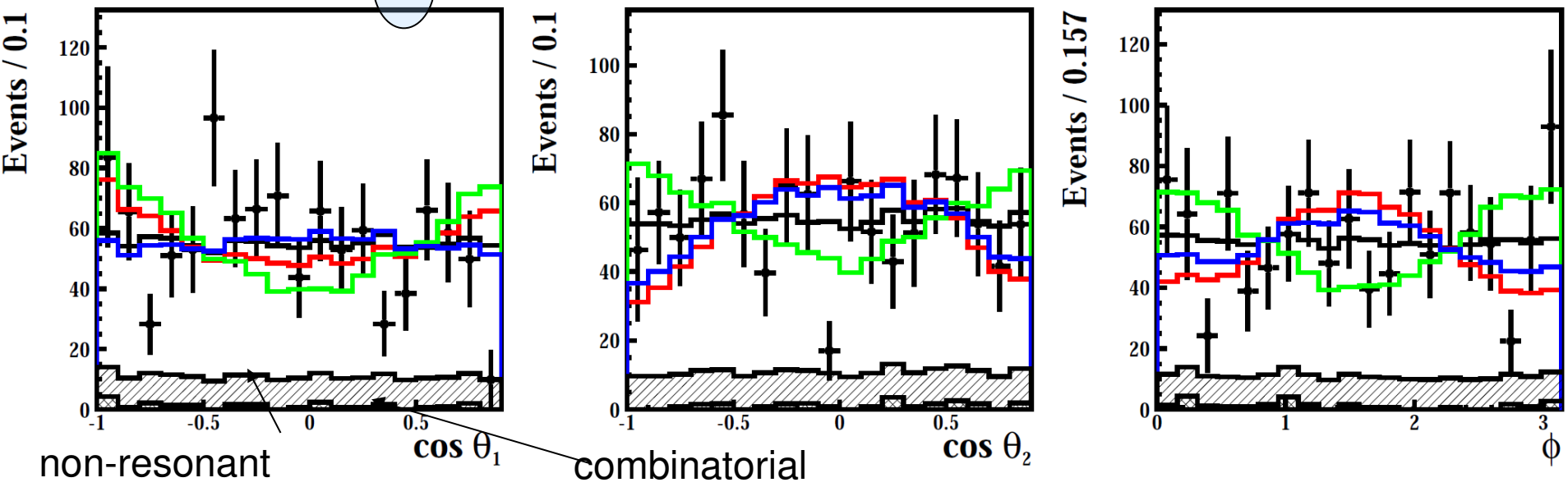
$\cos\theta_{\pi\pi}$ degraded by interference

Best discrimination:

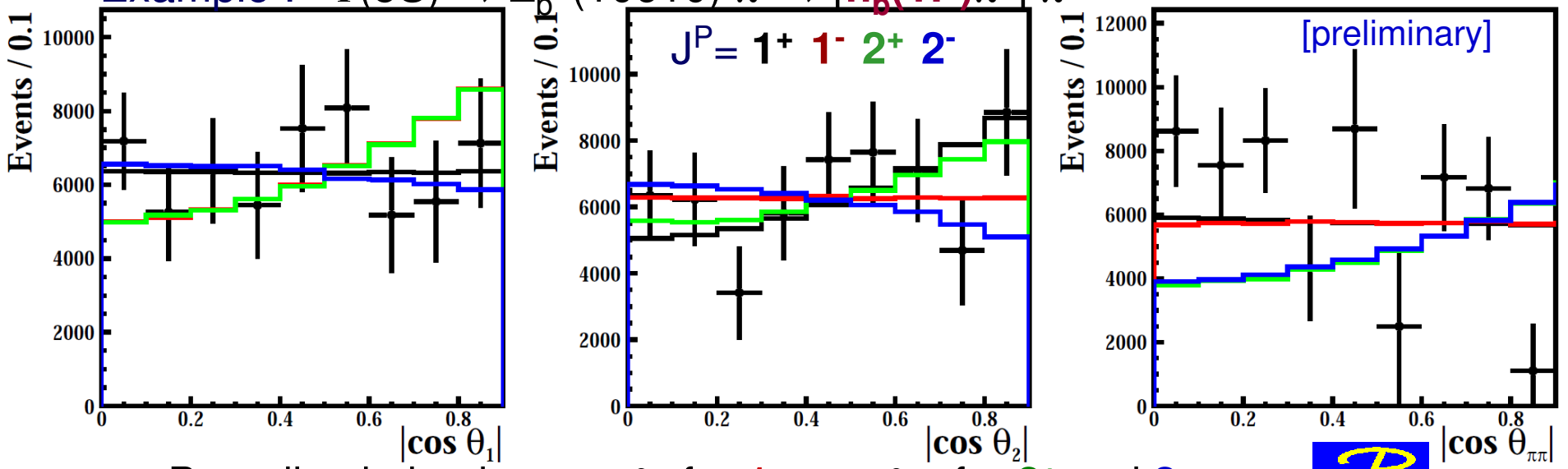
$\cos\theta_2$ for **1^-** and **2^-** ;

$\cos\theta_1$ for **2^+**

Color coding: $J^P =$ **1^+** **1^-** **2^+** **2^-** ($0^\pm$ is forbidden by parity conservation)



Example : $\Upsilon(5S) \to Z_b^+(10610)\,\pi^- \to [h_b(1P)\pi^+]\,\pi^-$



Best discrimination: $\cos\theta_2$ for 1^-; $\cos\theta_{\pi\pi}$ for 2^+ and 2^-

Confidence Levels of angular fits to $\Upsilon(5S) \to Z_b^+\,\pi^- \to [h_b(1P)\pi^+]\,\pi^-$ decay with hypothesis 1^+

	$\cos\theta_1$	$\cos\theta_2$	$\cos\theta_{\pi\pi}$
$Z_b(10610)$	84%	37%	1.1%
$Z_b(10650)$	15%	63%	7.2%

Probabilities at which different J^P hypotheses are disfavored compared to 1^+

J^P	$Z_b(10610)$			$Z_b(10650)$		
	$\Upsilon(2S)\pi^+\pi^-$	$\Upsilon(3S)\pi^+\pi^-$	$h_b(1P)\pi^+\pi^-$	$\Upsilon(2S)\pi^+\pi^-$	$\Upsilon(3S)\pi^+\pi^-$	$h_b(1P)\pi^+\pi^-$
1^-	3.6σ	0.3σ	0.3σ	3.7σ	2.6σ	2.7σ
2^+	4.3σ	3.5σ	4.3σ	4.4σ	2.7σ	2.1σ
2^-	2.7σ	2.8σ		2.9σ	2.6σ	

1+ assignment is favorable.

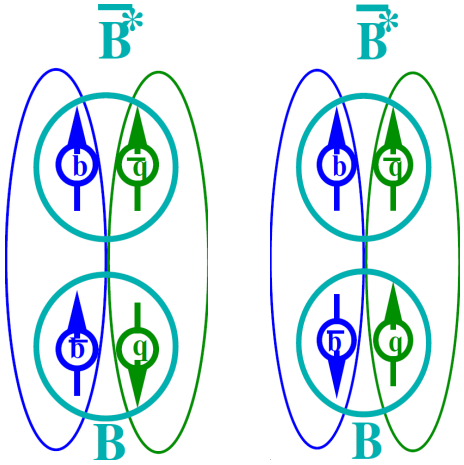
1-, 2+ ,2- are disfavored at typically 3σ level.

Possible nature of Z_b's

B*B and B*B* S-wave molecules

$$\left|Z_b'\right\rangle = \frac{1}{\sqrt{2}} 0^-_{bb} \otimes 1^-_{Qq} - \frac{1}{\sqrt{2}} 1^-_{bb} \otimes 0^-_{Qq}$$

$$\left|Z_b\right\rangle = \frac{1}{\sqrt{2}} 0^-_{bb} \otimes 1^-_{Qq} + \frac{1}{\sqrt{2}} 1^-_{bb} \otimes 0^-_{Qq}$$



Masses of Z_b are close to B*B(*) thresholds

- **Quantum number $J^P=1^+$**
- **Amplitude ratio A[Z_b(10610)] / A[Z_b(10650)] ~1**
- **Relative phase ~0 for Υ and ~180^0 for h_b.**
- **Explains why $h_b\pi\pi$ is unsuppressed relative to $\Upsilon\pi\pi$.**
- **Additional measurements in B*B and B*B* mode should be done**
- **Existence of other molecular states is predicted**

Summary

arXiv:1103.3419

-First observation of $h_b(1P)$ and $h_b(2P)$ in $\Upsilon(5S) \to \pi^+\pi^- h_b$

Masses consistent with CoG of χ_{bJ} states

-First observation of two charged bottomonium-like resonances in 5 different final states:

$h_b(1P)\pi^+\pi^-$, $h_b(2P)\pi^+\pi^-$, $\Upsilon(1S)\pi^+\pi^-$, $\Upsilon(2S)\pi^+\pi^-$, $\Upsilon(3S)\pi^+\pi^-$

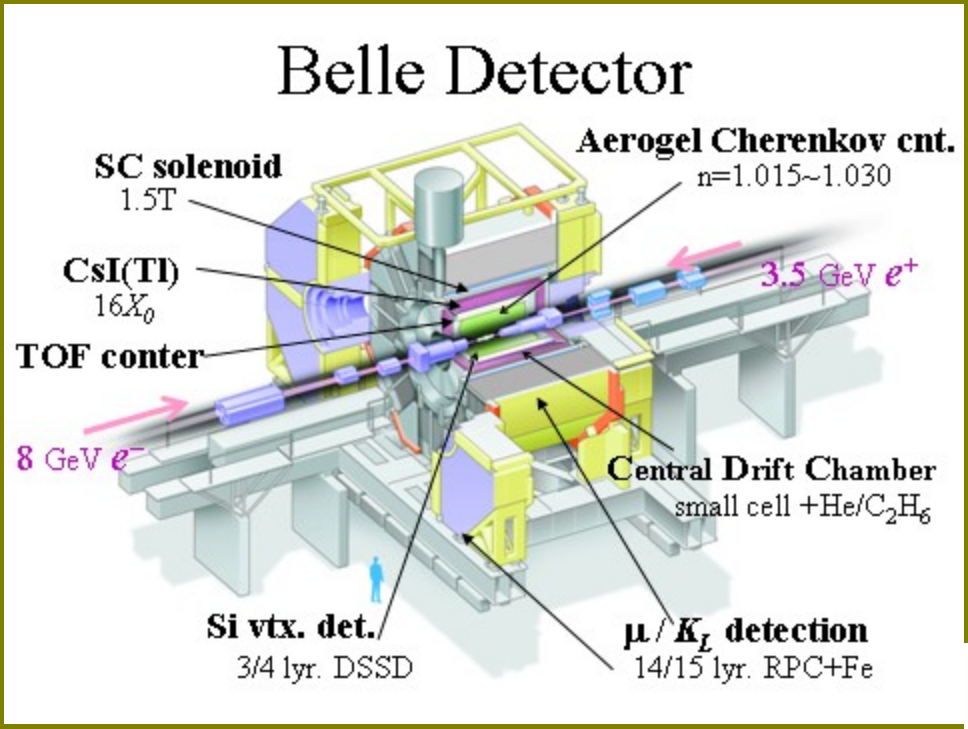
[preliminary]

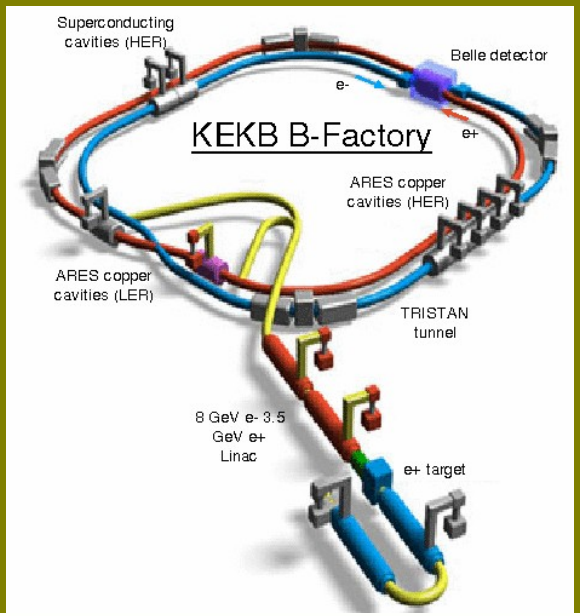
$Z_b(10610)$ **M = 10608.1 ± 1.7 MeV**
Γ = 15.5± 2.4 MeV

$Z_b(10650)$ **M = 10653.3 ± 1.5 MeV**
Γ = 14.0 ± 2.8 MeV

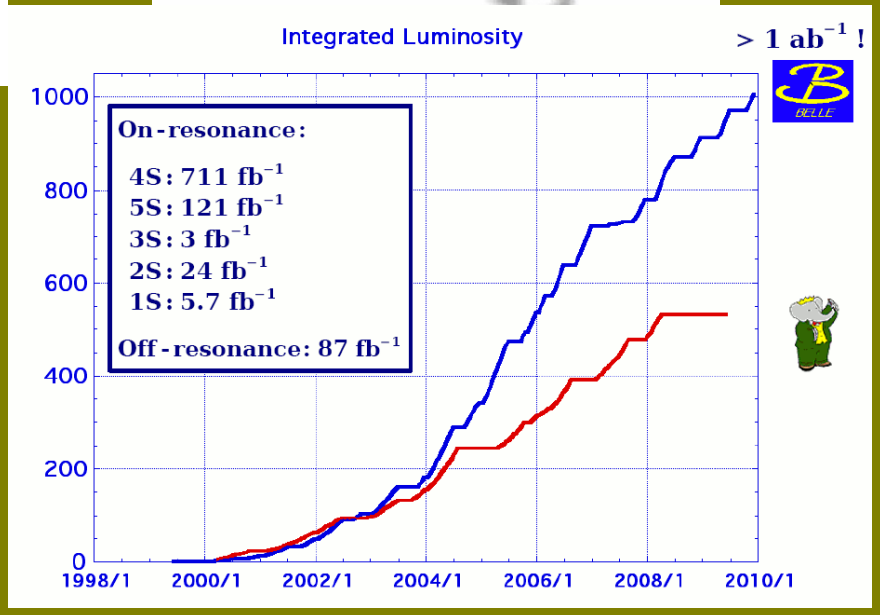
-Angular analysis favors :$J^P=1^+$; other J^P are disfavored.

-Z_b properties are consistent with the B*B and B*B* S-wave molecules .

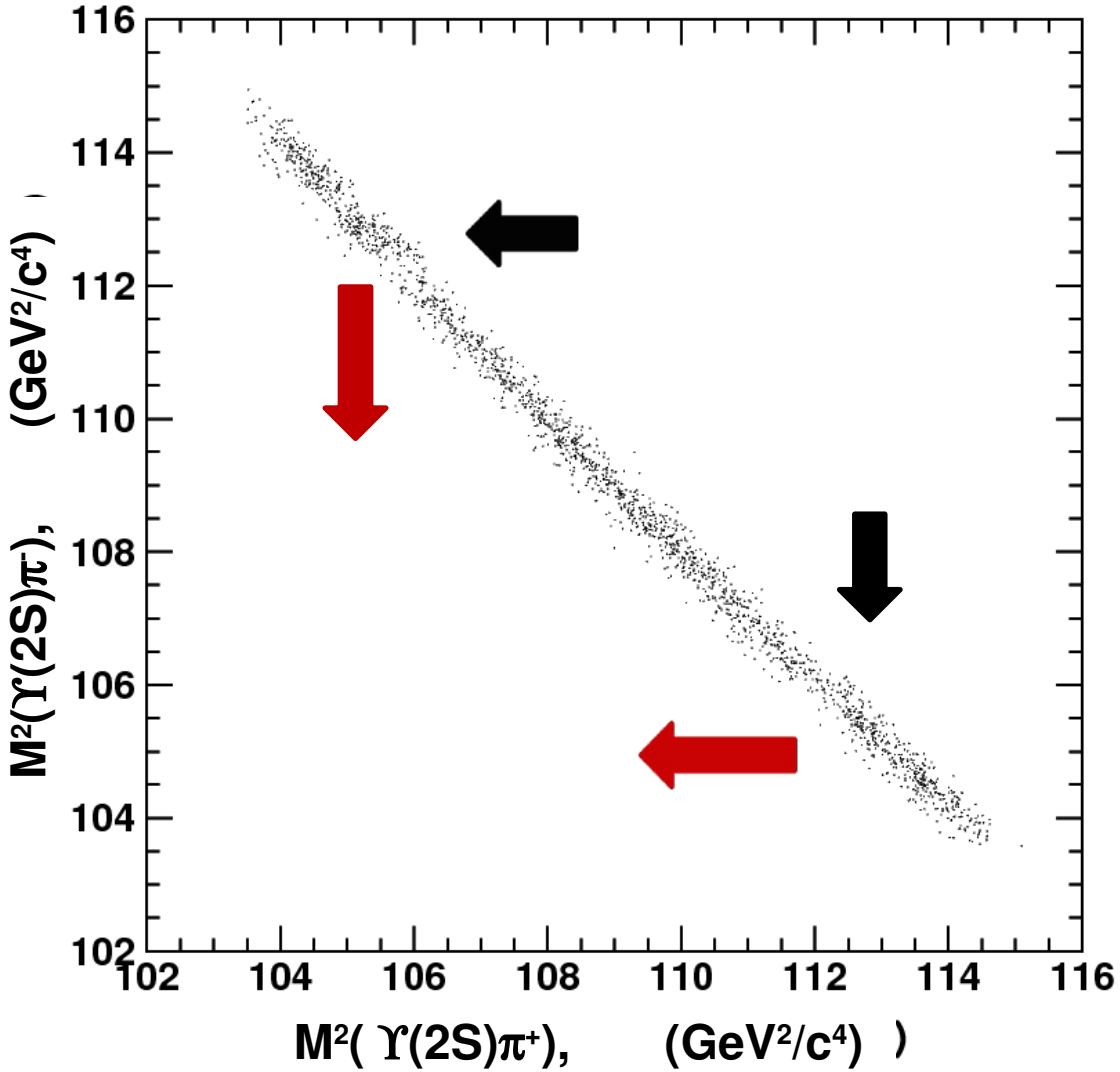




- 3.5 GeV e^+ × 8.0 GeV e^-.
- $\mathcal{L}_{\max} = 2.1 \times 10^{34} cm^{-2} s^{-1}$
- Continuous injection
  $\rightarrow 1.1\,\mathrm{fb}^{-1}/\mathrm{day}$.
- $\int \mathcal{L} dt \approx 1\,ab^{-1}$



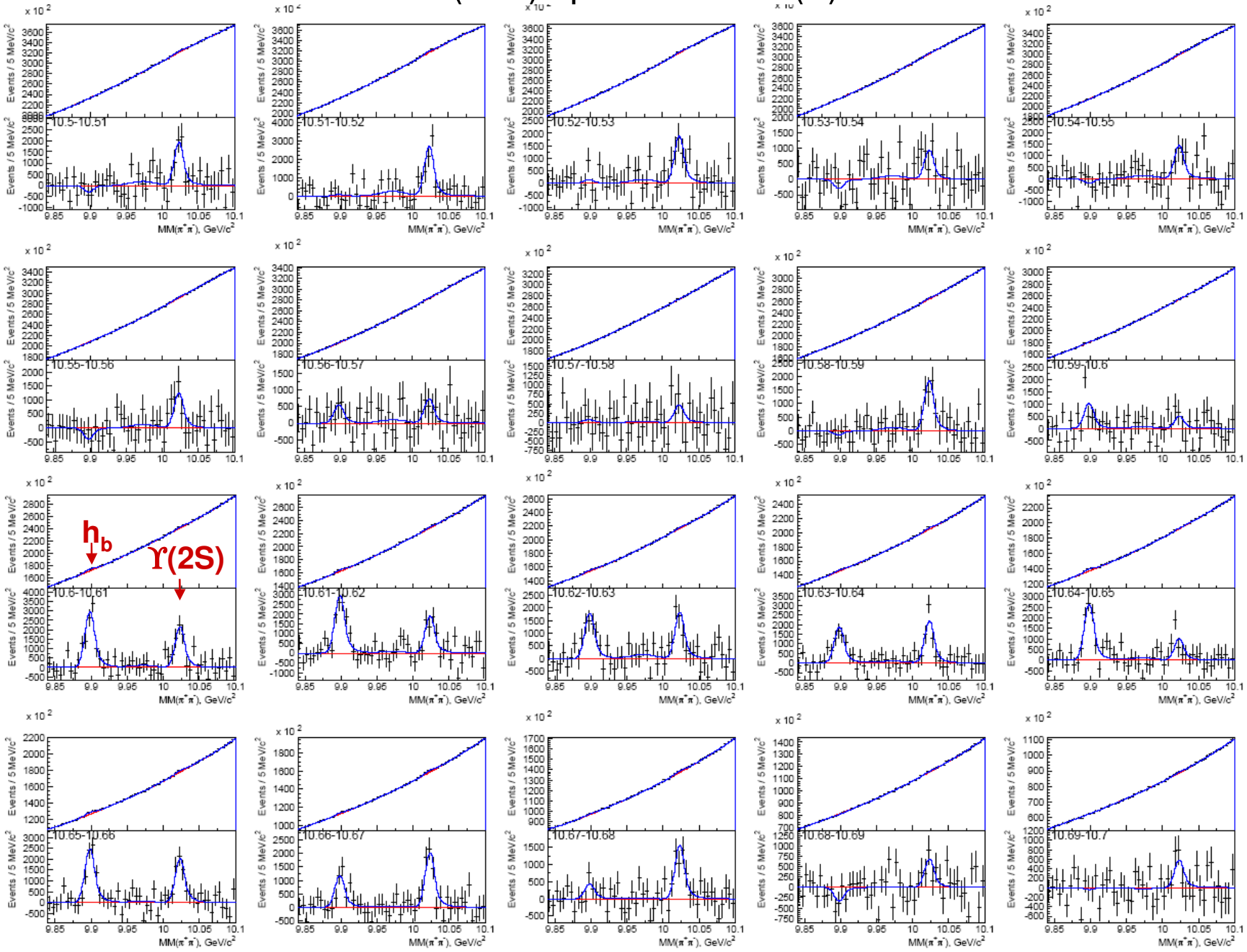
Dalitz Plot



If there is a signal in the $\Upsilon\,\pi$ system

It will also produce a signal like reflection on the other axis

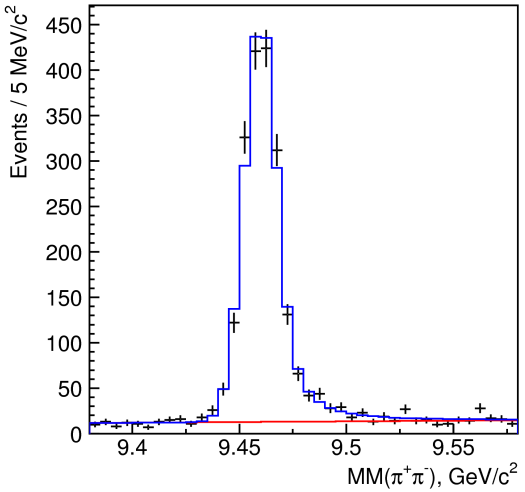
Fits to MM($\pi^+\pi^-$) spectra in MM(π) bins



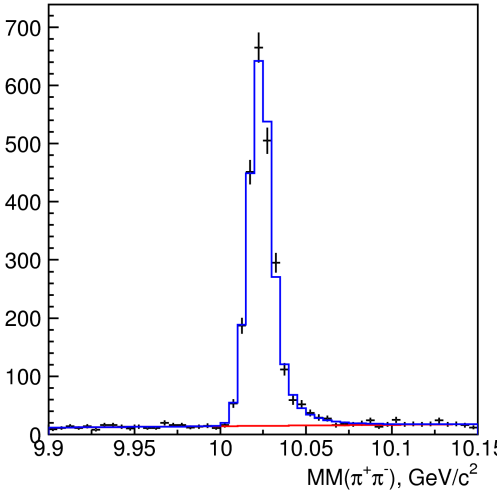
Calibration channels

$\Upsilon(5S) \to \Upsilon(nS)\ \pi^+\pi^-$
$\Upsilon(nS) \to \mu^+\mu^-$
(n = 1,2,3)

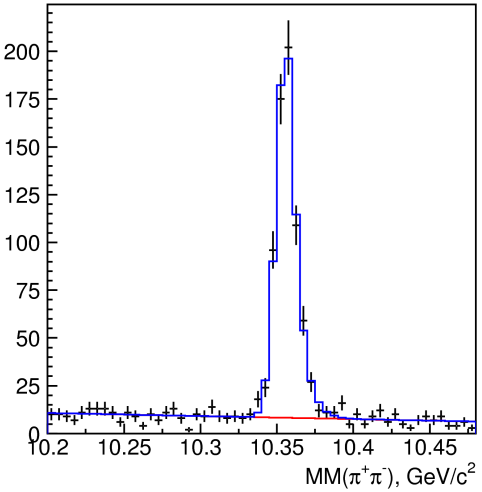
$\Upsilon(5S) \to \Upsilon(1S)\ \pi\pi$



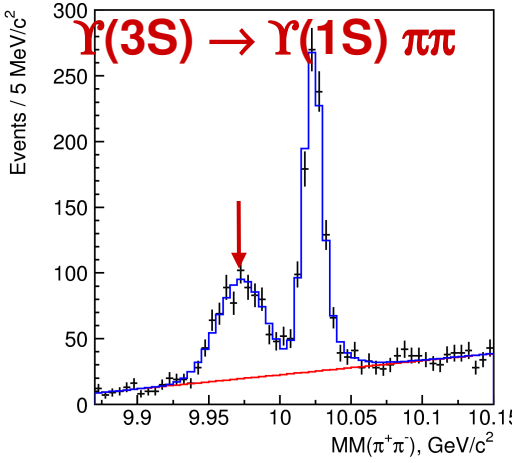
$\Upsilon(5S) \to \Upsilon(2S)\ \pi\pi$



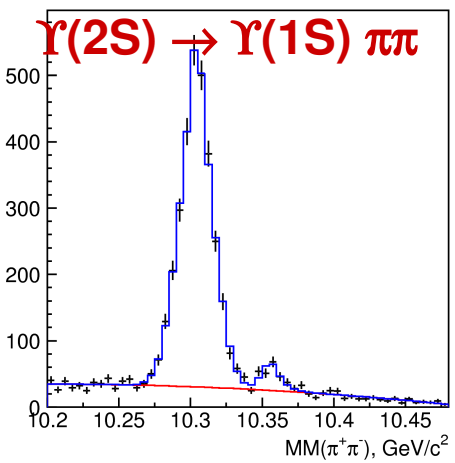
$\Upsilon(5S) \to \Upsilon(3S)\ \pi\pi$



$\Upsilon(3S) \to \Upsilon(1S)\ \pi\pi$



$\Upsilon(2S) \to \Upsilon(1S)\ \pi\pi$



⇒ Shapes of signals

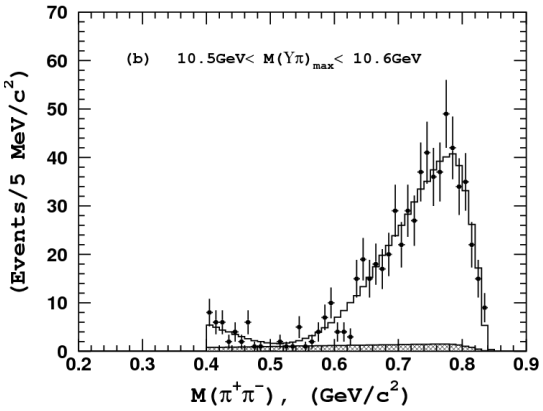
CrystalBall function

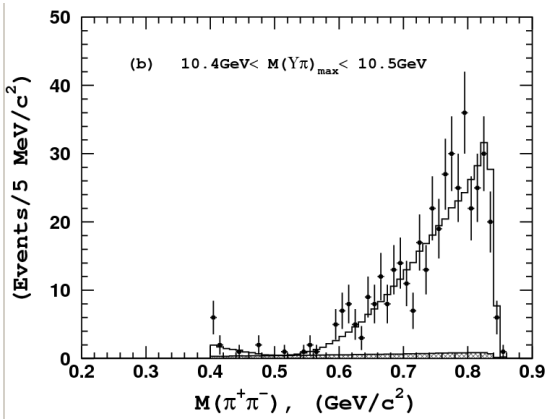
tail (8%) – ISR of soft γ

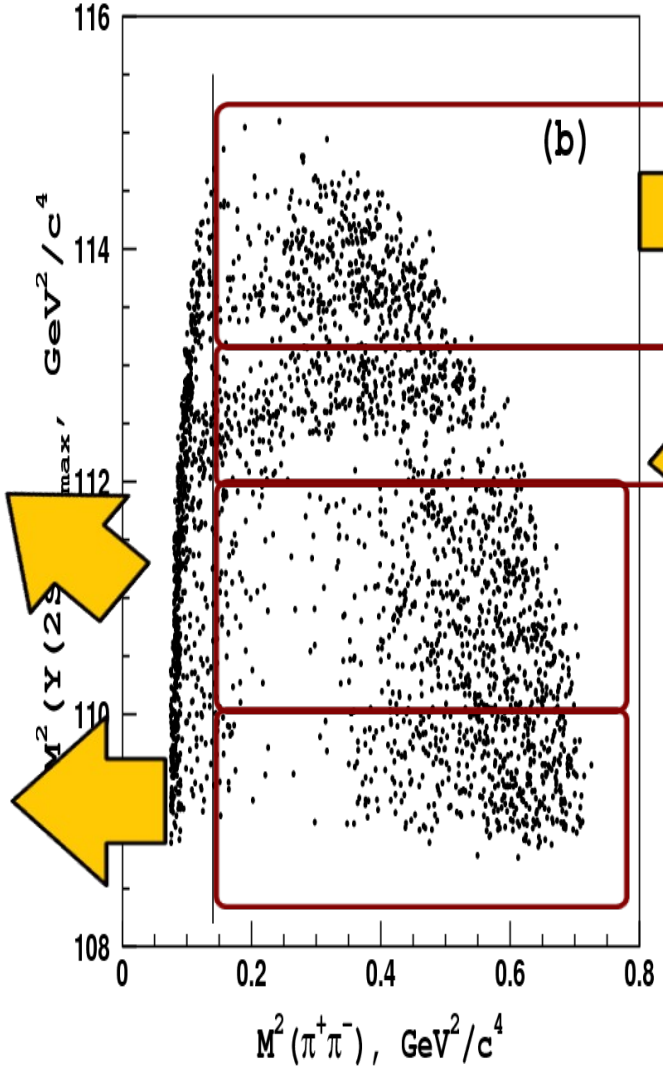
σ = 5.7 – 7.5 MeV

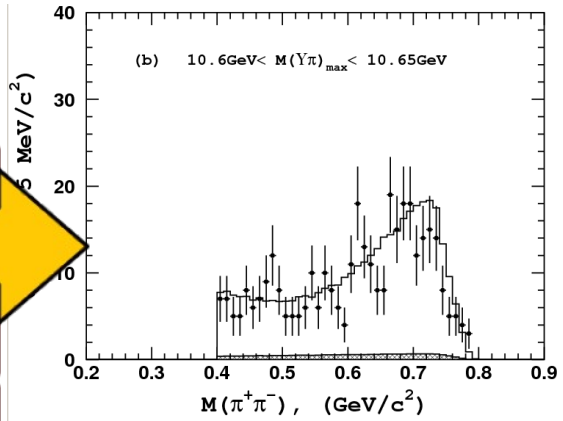
⇒ Shapes of reflections

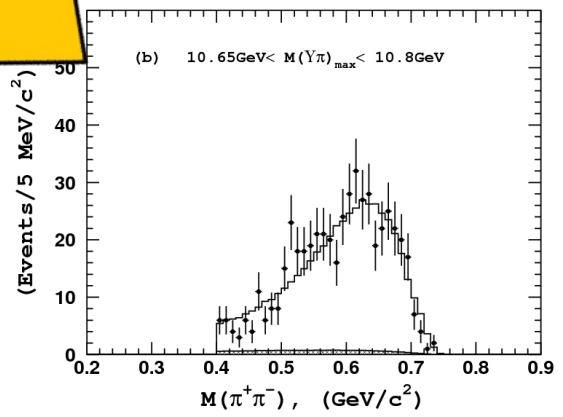
Results: $\Upsilon(2S)\pi^+\pi^-$



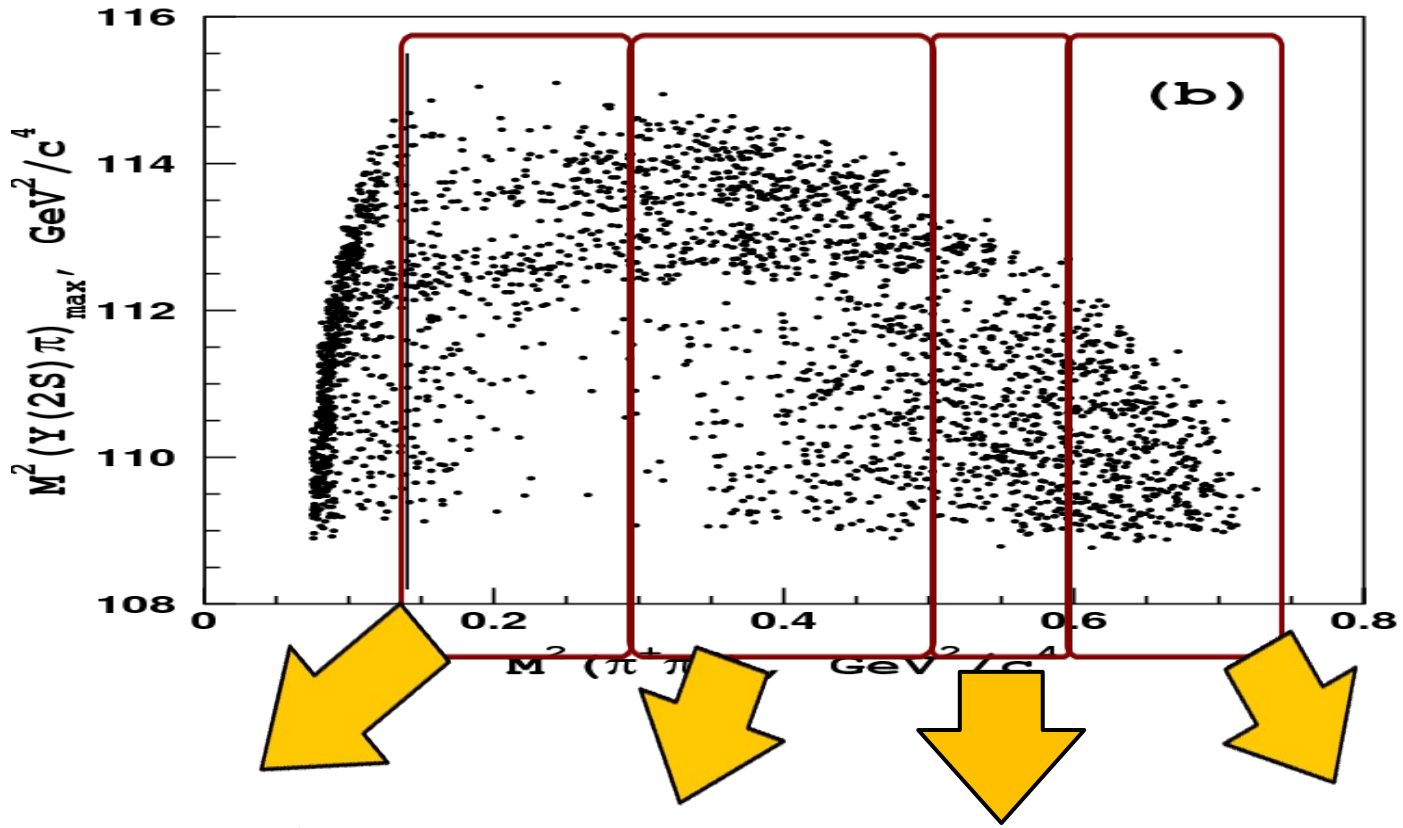


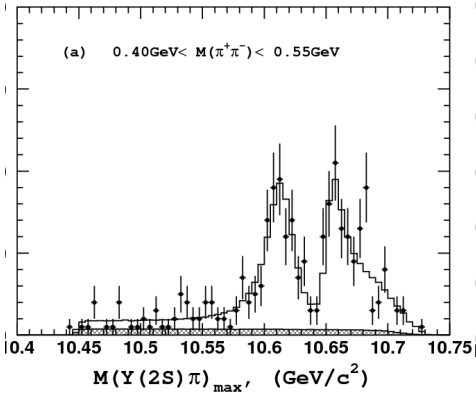


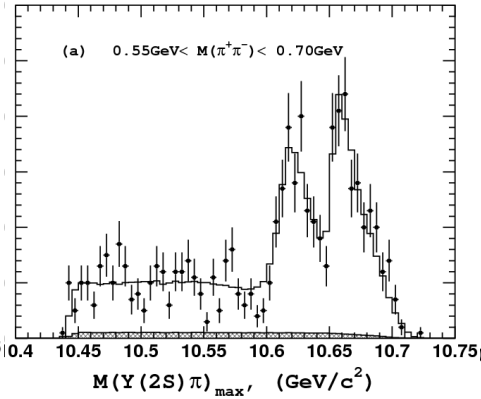


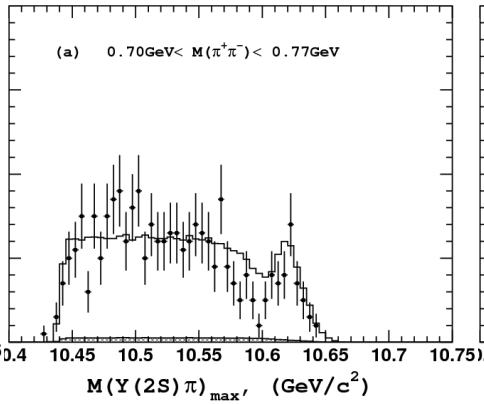


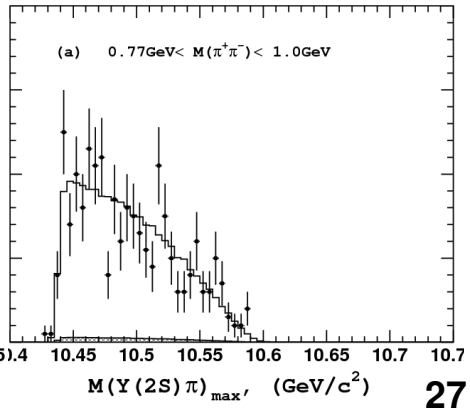
Results: $\Upsilon(2S)\pi^+\pi^-$











Expectations $\Upsilon(5S) \to Z_b \pi_1 \to [\Upsilon(2S)\, \pi_2]\, \pi_1$

1^+ isotropic

λ – *beam direction*

1^- $\overline{|M_{tot}|^2} \propto p_1^2[p_2^2 - (\lambda \boldsymbol{p}_2)^2] + 2(\boldsymbol{p}_1\boldsymbol{p}_2)(\lambda \boldsymbol{p}_1)(\lambda \boldsymbol{p}_2)$

2^+ $\overline{|M_{tot}|^2} \propto (\lambda[\boldsymbol{p}_1 \times \boldsymbol{p}_2])^2[2(\boldsymbol{p}_1\boldsymbol{p}_2)^2 - \frac{1}{2}p_1^2p_2^2] + \frac{1}{2}(p_1^2)^2(p_2^2)^2$

$+(\boldsymbol{p}_1\boldsymbol{p}_2)^2[2(\boldsymbol{p}_1\boldsymbol{p}_2)^2 - 2p_1^2p_2^2 + \frac{1}{2}(\lambda \boldsymbol{p}_1)^2p_2^2]\,.$

2^- $\overline{|M_{tot}|^2} \propto 6(\boldsymbol{p}_1\boldsymbol{p}_2)^2 + 17p_1^2p_2^2 - 9p_1^2(\lambda \boldsymbol{p}_2)^2 - 8p_2^2(\lambda \boldsymbol{p}_1)^2 + 12(\boldsymbol{p}_1\boldsymbol{p}_2)(\lambda \boldsymbol{p}_1)(\lambda \boldsymbol{p}_2)$

many thanks to A. Milstein (BINP)

neglect Z_b recoil motion ($\beta<0.02 \Rightarrow$ very good approximation)

also formulae for h_b are available

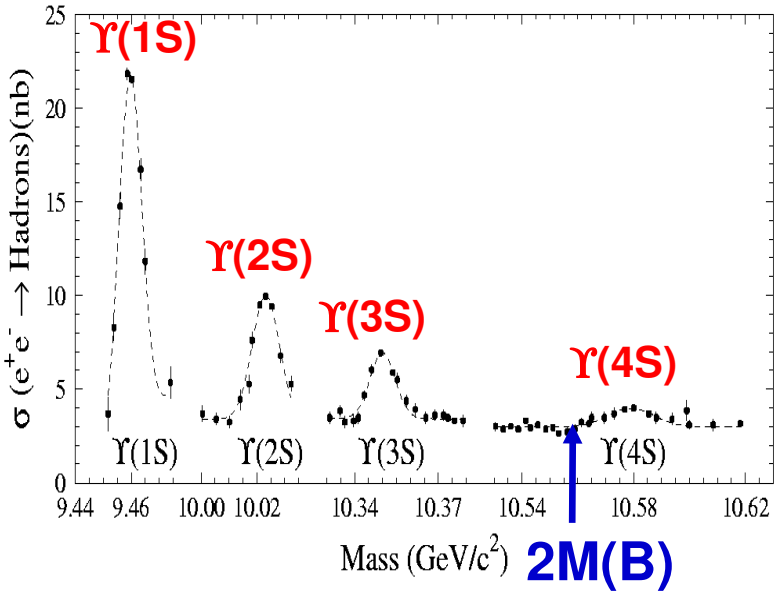
Consider 1D projections

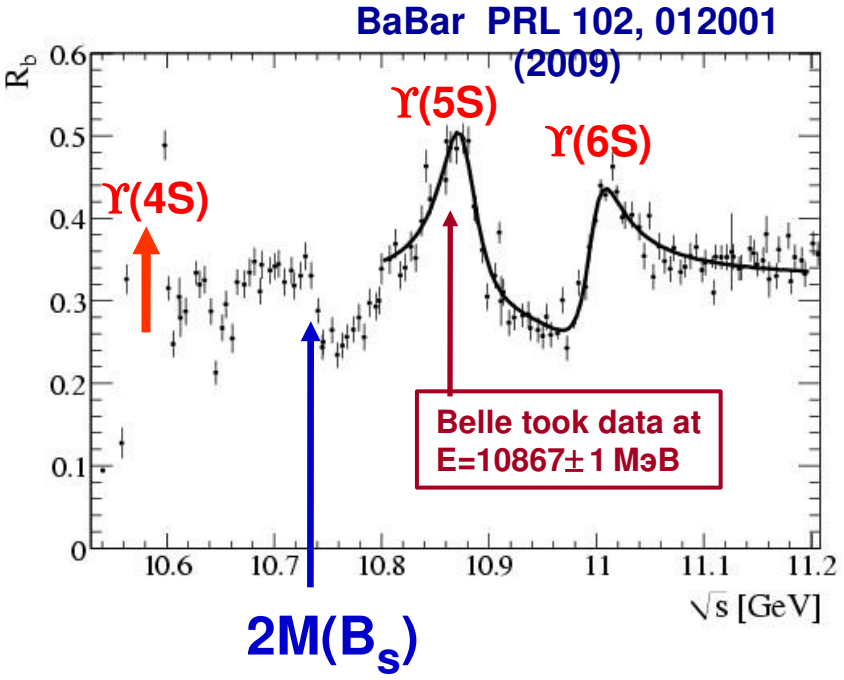
θ_1, θ_2 – polar angles of 1st and 2nd pions

φ_p – angle btw planes defined by (1) π_1 & Z axis, (2) π_1 & π_2 .

Interference terms vanish after integration over other angular variables
$\Rightarrow$ subtraction of non-resonant contribution is possible.

e^+e^- hadronic cross-section



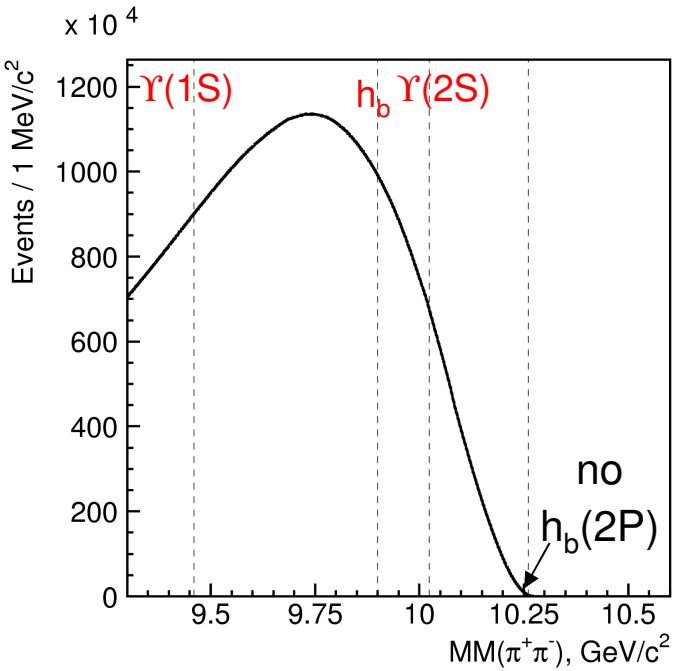


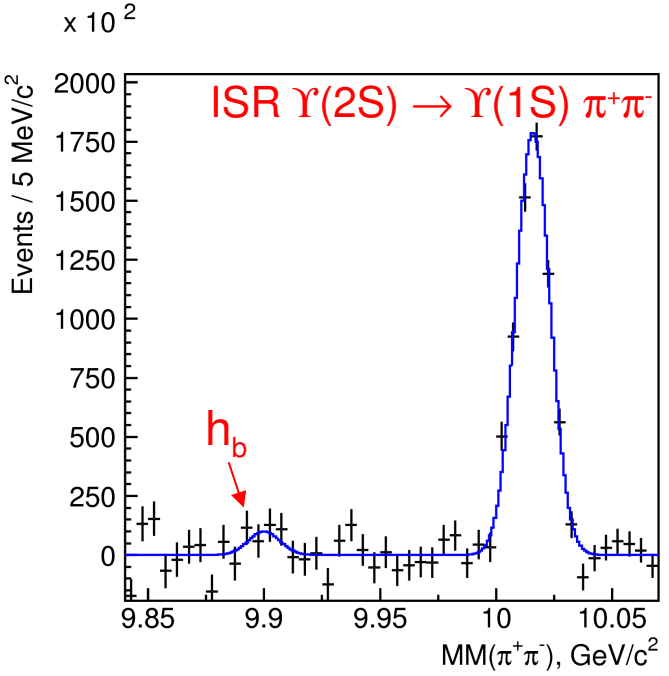
$e^+ e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$, where B is B^+ or B^0

$e^+ e^- \rightarrow b\bar{b}(\Upsilon(5S)) \rightarrow B^{(*)}\bar{B}^{(*)}$, $B^{(*)}\bar{B}^{(*)}\pi$, $B\bar{B}\pi\pi$, $B_s^{(*)}\bar{B}_s^{(*)}$, $\Upsilon(1S)\pi\pi$, ΥX …

study

Search in $\Upsilon(4S)$ data





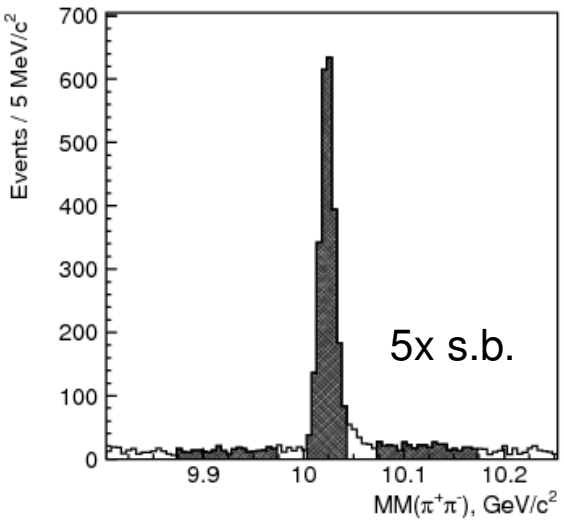
L = 711fb^{-1} [×6 $\Upsilon(5S)$ sample]

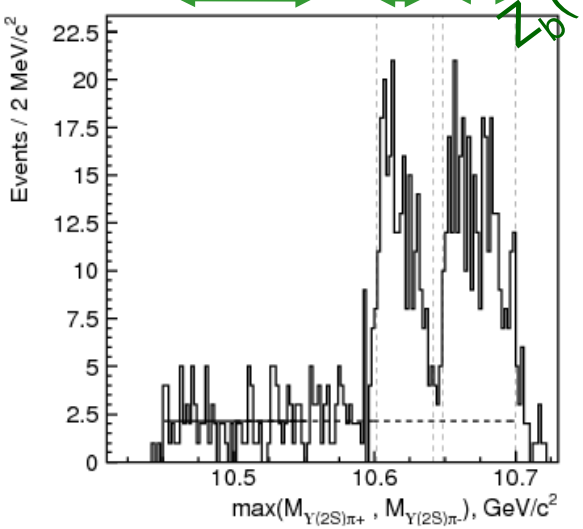
No significant signal of $h_b(1P)$: $(34\pm20)\times10^3$ (1.7σ)

$$\frac{\sigma[e^+e^- \to h_b(1P)\,\pi^+\pi^-]\ @\ \Upsilon(4S)}{\sigma[e^+e^- \to h_b(1P)\,\pi^+\pi^-]\ @\ \Upsilon(5S)} < 0.28 \text{ at } 90\%\text{C.L.}$$

⇒ $\Upsilon(4S)$ does not show anomalous properties

$\Upsilon(2S)\pi^+\pi^-$



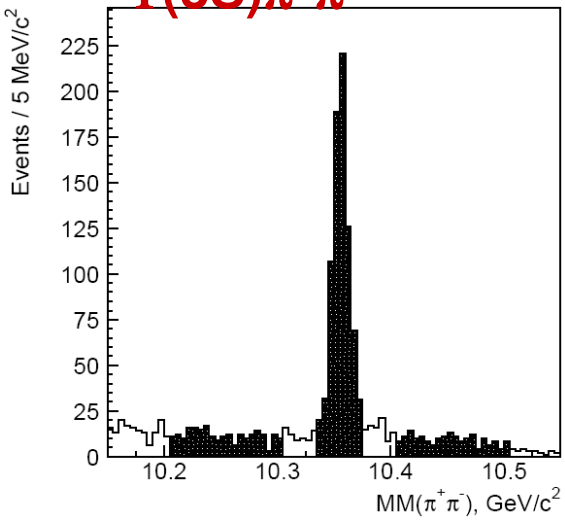


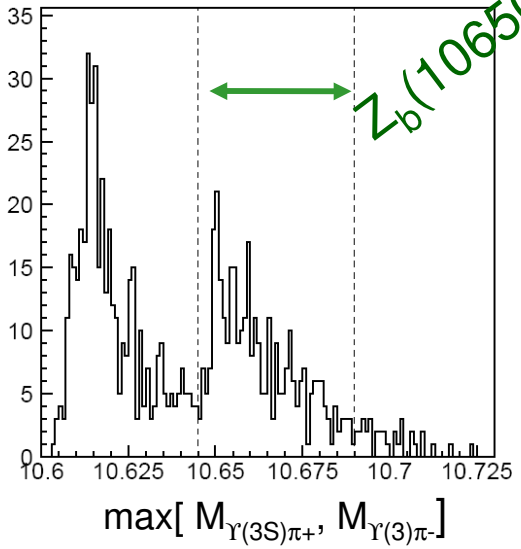
non-resonant region

$Z_b(10610)$

$Z_b(10650)$

$\Upsilon(3S)\pi^+\pi^-$





$Z_b(10650)$

Systematics

	Polynomial order	Fit range	Signal shape	Selection requirements
$N[h_b]$, 10^3	± 2.4	± 3.6	$^{+1.2}_{-8.0}$	–
$M[h_b]$, MeV/c^2	$\pm .04$	$\pm .10$	$^{+0.04}_{-0.20}$	$^{+.20}_{-.30}$
$N[h_b(2P)]$, 10^3	± 2.2	± 2.6	$^{+23.}_{-9.0}$	–
$M[h_b(2P)]$, MeV/c^2	$\pm .10$	$\pm .20$	$^{+1.0}_{-0.0}$	$\pm .08$

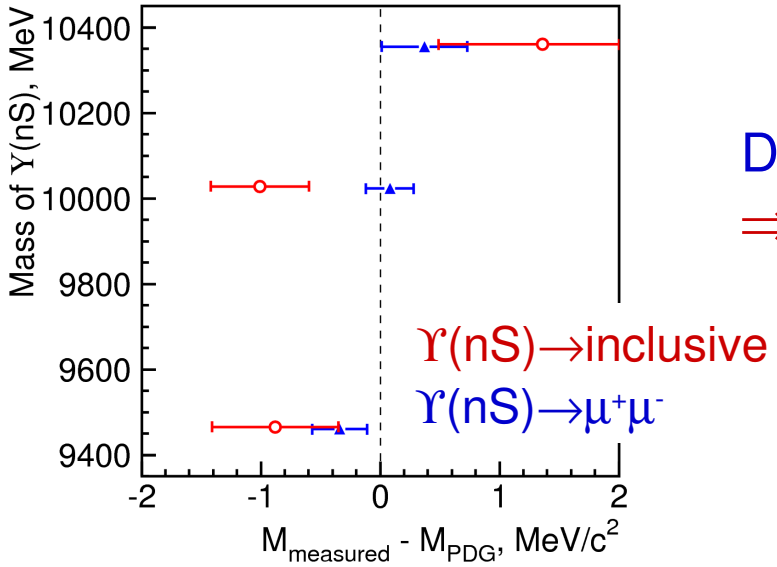
Results are stable

Significance w/ systematics

$h_b(1P)$ 5.5σ

$h_b(2P)$ 11.2σ

$M_{measured} - M_{PDG}$ for reference channels



Deviations of reference channels from PDG

$\Rightarrow$ additional uncertainty ± 1MeV

local variations of background shape?

Confidence Levels of angular fits to $\Upsilon(5S) \to Z_b^+ \pi^- \to [h_b(1P)\pi^+] \pi^-$ decay with hypothesis 1^+

	$\cos\theta_1$	$\cos\theta_2$	$\cos\theta_{\pi\pi}$
$Z_b(10610)$	84%	37%	1.1%
$Z_b(10650)$	15%	63%	7.2%