FPCP 2011, May 23, 2011

Observation of the h_b's … and beyond from Belle's $\Upsilon(5S)$ data

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BELLE Collaboration

Puzzles of $\Upsilon(5S)$ decays

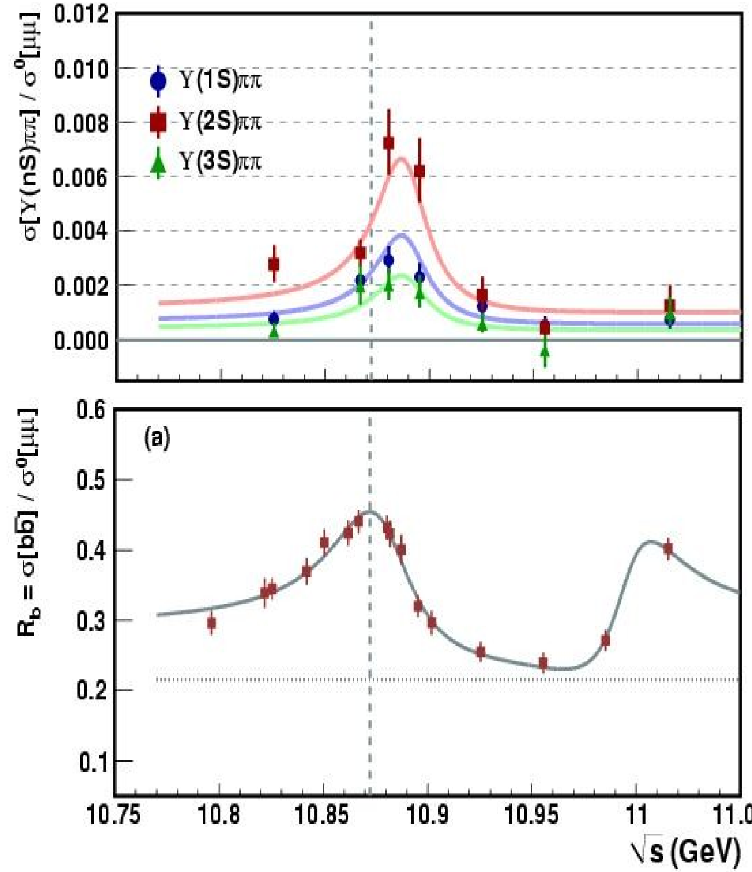
Anomalous production of $\Upsilon(nS)\pi^+\pi^-$ with 21.7 fb^{-1}

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

PRD82,091106R(2010)



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

Simonov JETP Lett 87,147(2008)

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

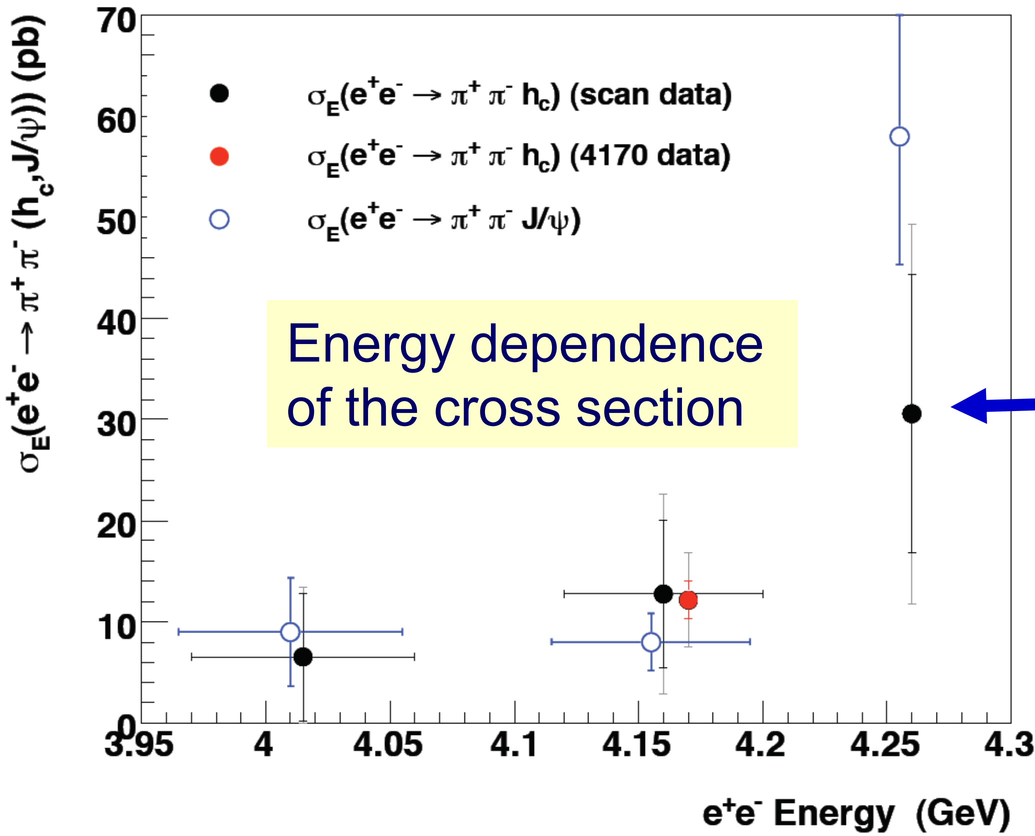
Dedicated energy scan $\Rightarrow$
shapes of R_b and $\sigma(\Upsilon\pi\pi)$ different (2σ)

$\Upsilon(5S)$ is very interesting and not yet understood
Finally Belle recorded 121.4fb^{-1} data set at $\Upsilon(5S)$

Motivation

Observation of $e^+e^- \rightarrow \pi^+\pi^- h_c$ by CLEO   arXiv:1104.2025

Ryan Mitchell @ CHARM2010



FPCP, J.Rosner, May 25

Enhancement of $\sigma(h_c\, \pi^+\pi^-)$ @ Y(4260)

⇓

$\sigma(h_b\, \pi^+\pi^-)$ is enhanced @ Y_b?

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

Introduction to $h_b(nP)$

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

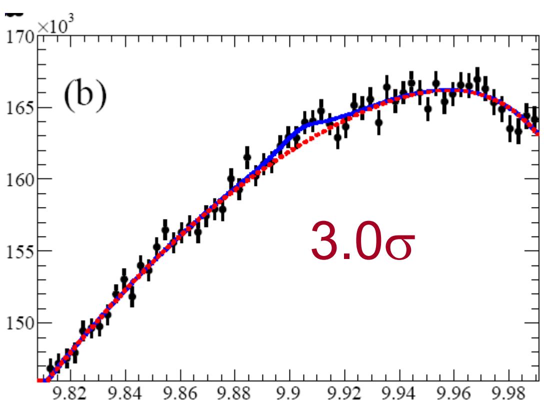
Expected mass (CoG of χ_{bJ})
$\approx (M\chi_{b0} + 3\ M\chi_{b1} + 5\ M\chi_{b2}) / 9$
$\Delta M_{HF} \Rightarrow$ test of hyperfine interaction

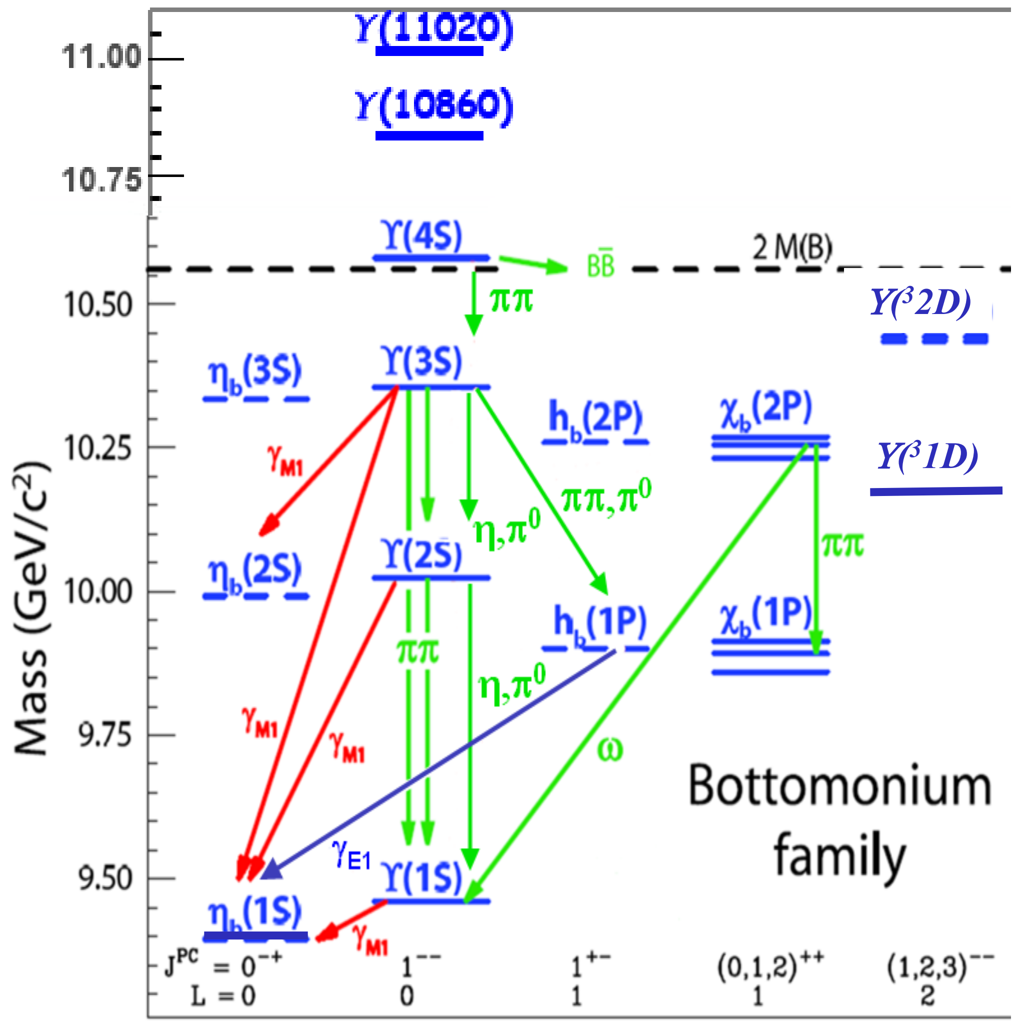
For h_c $\Delta M_{HF} = -0.12 \pm 0.30$,
expect smaller deviation for $h_b(nP)$.

arXiv:1102.4565

Evidence from BaBar

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





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

Upper limit from CLEO, J.Rosner, May 25

Method : missing mass technique

Search for signal $\Upsilon(5S) \to h_b(nP)\ \pi+\pi-$

$P_{\Upsilon(5S)}$ is given by
c.m. energy and boost
accelerator information

$P_{\pi+\pi-}$ is measured
reconstructed

$$M_{hb(nP)} = \sqrt{(P_{\Upsilon(5S)} - P_{\pi+\pi-})^2} \equiv MM(\pi+\pi-)$$

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

Simple selection :

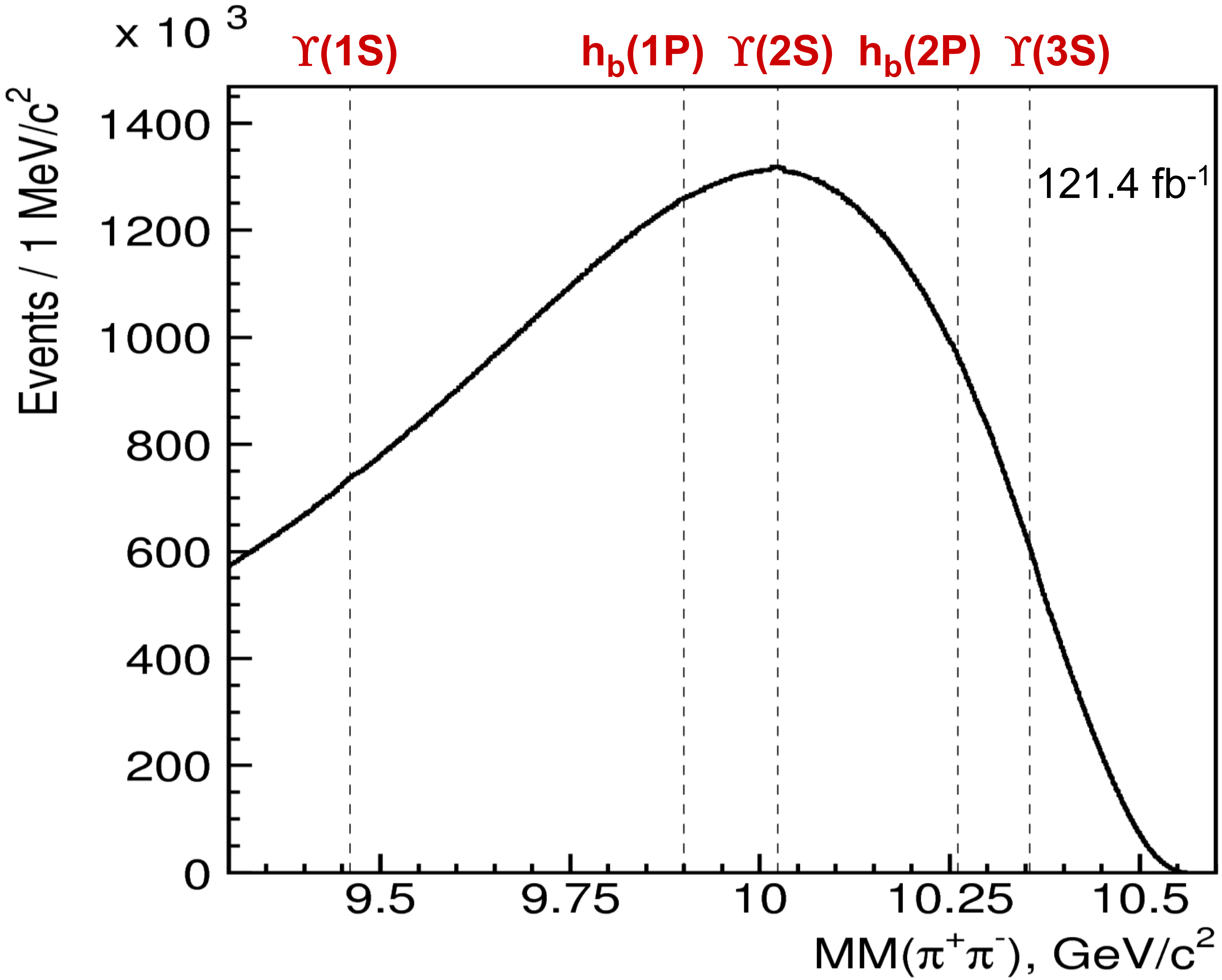
$\pi^+\pi^-$: good quality, positively identified

Continuum events have jet-like shape ⇒ cut on sphericity variable $R_2<0.3$

R_2 = ratio of Fox-Wolfram moments

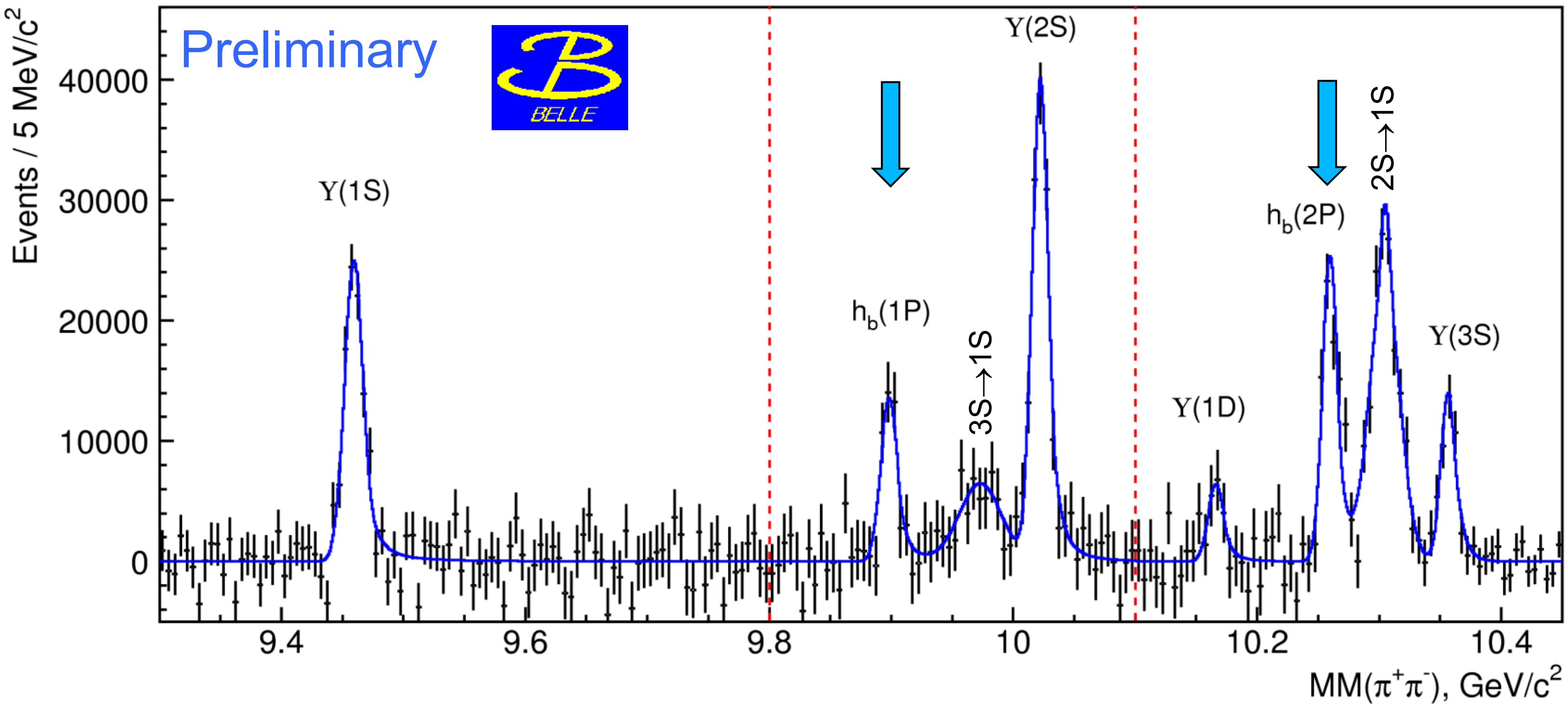
“blind analysis”

Raw $MM(\pi^+\pi^-)$ spectrum from $\Upsilon(5S)$



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

Mass measurements

Deviations from CoG of χ_{bJ} masses

$h_b(1P)$ 1.62 ± 1.52 MeV/c^2
$h_b(2P)$ $0.48\,^{+1.57}_{-1.22}$ MeV/c^2
} consistent with zero, as expected

Ratio of production rates

$$\frac{\Gamma[\Upsilon(5S) \to h_b(nP)\,\pi^+\pi^-]}{\Gamma[\Upsilon(5S) \to \Upsilon(2S)\,\pi^+\pi^-]} = \begin{cases} 0.407 \pm 0.079^{+0.043}_{-0.076} & \text{for } h_b(1P) \\ 0.78 \pm 0.09^{+0.22}_{-0.10} & \text{for } h_b(2P) \end{cases}$$

$S(h_b) = 0 \Rightarrow$ spin-flip
no spin-flip

Process with spin-flip of heavy quark is not suppressed

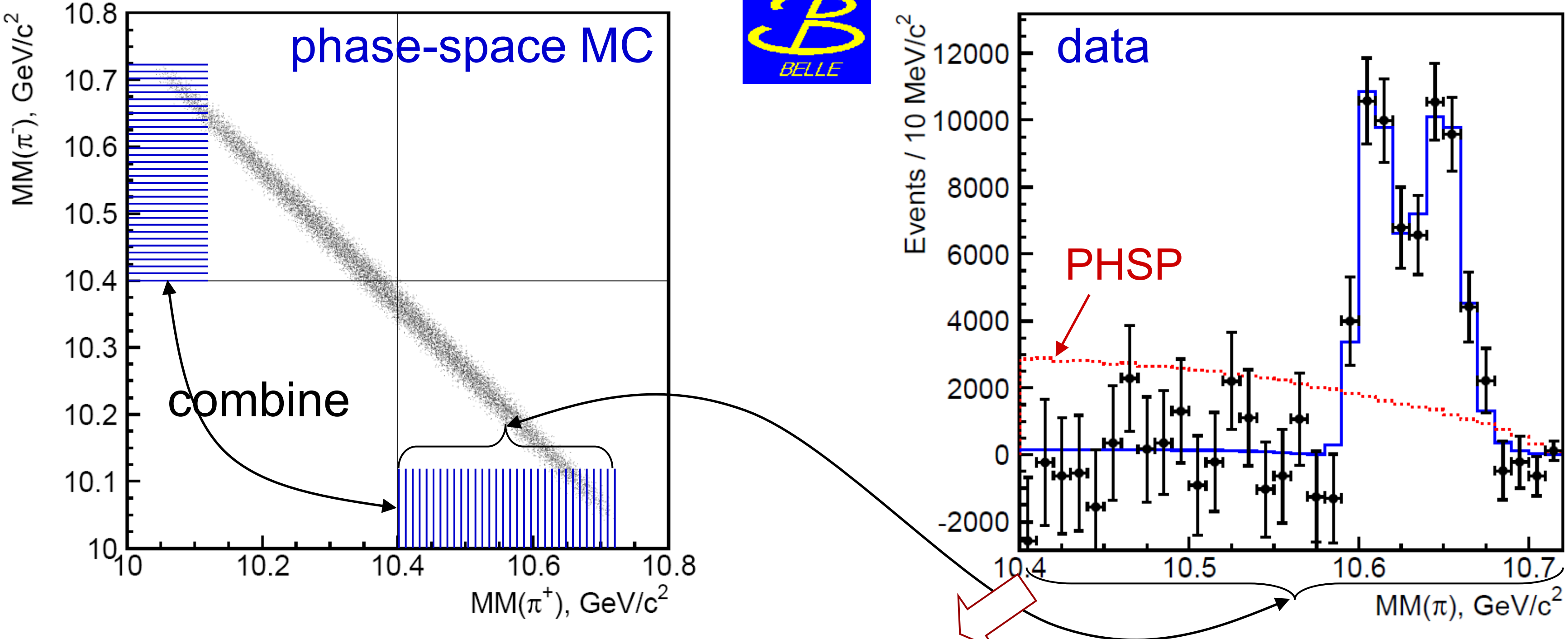
No h_b signal at Υ**(4S)**

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

This motivates us to study resonant substructure of this process

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 $MM(\pi)$***



Fit function $|BW(s,M_1,\Gamma_1) + ae^{i\phi}BW(s,M_2,\Gamma_2) + be^{i\psi}|^2 \,\frac{qp}{\sqrt{s}}$

[preliminary]

Results

$M_1 = 10605.1 \pm 2.2\,^{+3.0}_{-1.0}$ MeV/c² ~$B\bar{B}^*$ threshold

$\Gamma_1 = 11.4\,^{+4.5}_{-3.9}\,^{+2.1}_{-1.2}$ MeV $\quad a = 1.8\,^{+1.0}_{-0.7}\,^{+0.1}_{-0.5}$

$M_2 = 10654.5 \pm 2.5\,^{+1.0}_{-1.9}$ MeV/c² ~$B^*\bar{B}^*$ threshold

$\Gamma_2 = 20.9\,^{+5.4}_{-4.7}\,^{+2.1}_{-5.7}$ MeV $\quad \varphi = 188\,^{+44}_{-58}\,^{+4}_{-9}$ degree

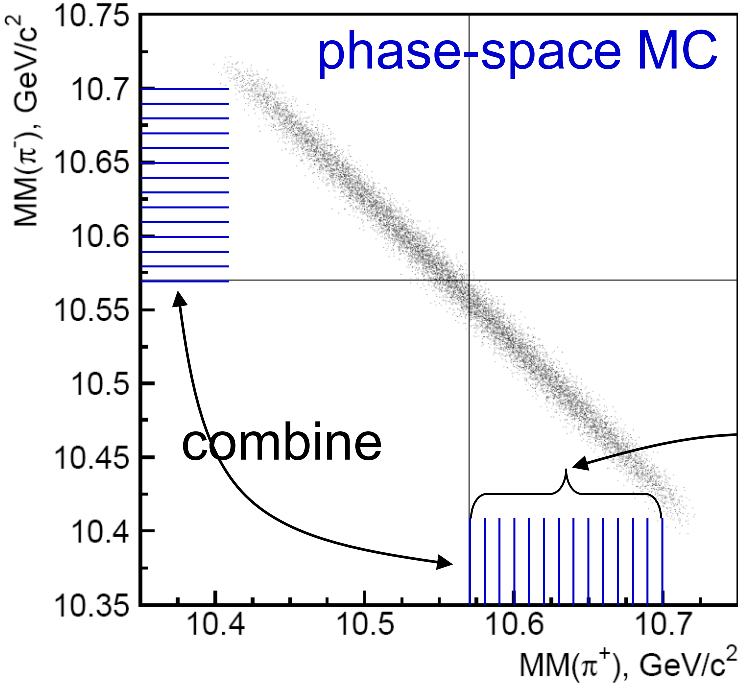
non-res.~0

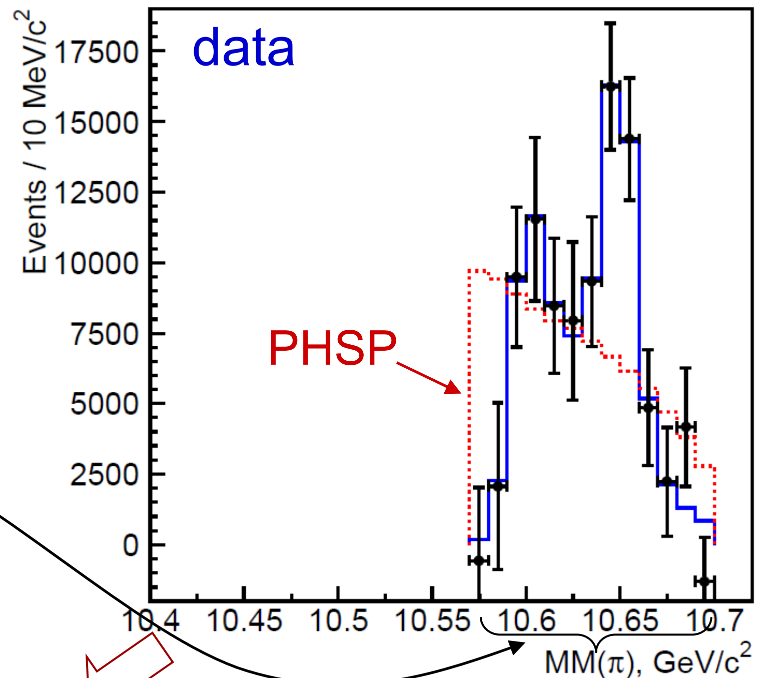
Significances

2 vs.1 : 7.4σ (6.6σ w/ syst)

2 vs.0 : 18σ (16σ w/ syst)

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





$h_b(1P)\pi^+\pi^-$		$h_b(2P)\pi^+\pi^-$
$M_1 = 10605.1 \pm 2.2\,^{+3.0}_{-1.0}$ MeV/c²		$10596 \pm 7\,^{+5}_{-2}$ MeV/c²
$\Gamma_1 = 11.4\,^{+4.5}_{-3.9}\,^{+2.1}_{-1.2}$ MeV	consistent	$16\,^{+16}_{-10}\,^{+13}_{-4}$ MeV
$M_2 = 10654.5 \pm 2.5\,^{+1.0}_{-1.9}$ MeV/c²		$10651 \pm 4 \pm 2$ MeV/c²
$\Gamma_2 = 20.9\,^{+5.4}_{-4.7}\,^{+2.1}_{-5.7}$ MeV		$12\,^{+11}_{-9}\,^{+8}_{-2}$ MeV
$a = 1.8\,^{+1.0}_{-0.7}\,^{+0.1}_{-0.5}$		$1.3\,^{+3.1}_{-1.1}\,^{+0.4}_{-0.7}$
$\varphi = 188\,^{+44}_{-58}\,^{+4}_{-9}$ degree		$255\,^{+56}_{-72}\,^{+12}_{-183}$ degree
non-res.~0		non-res.~0

[preliminary]

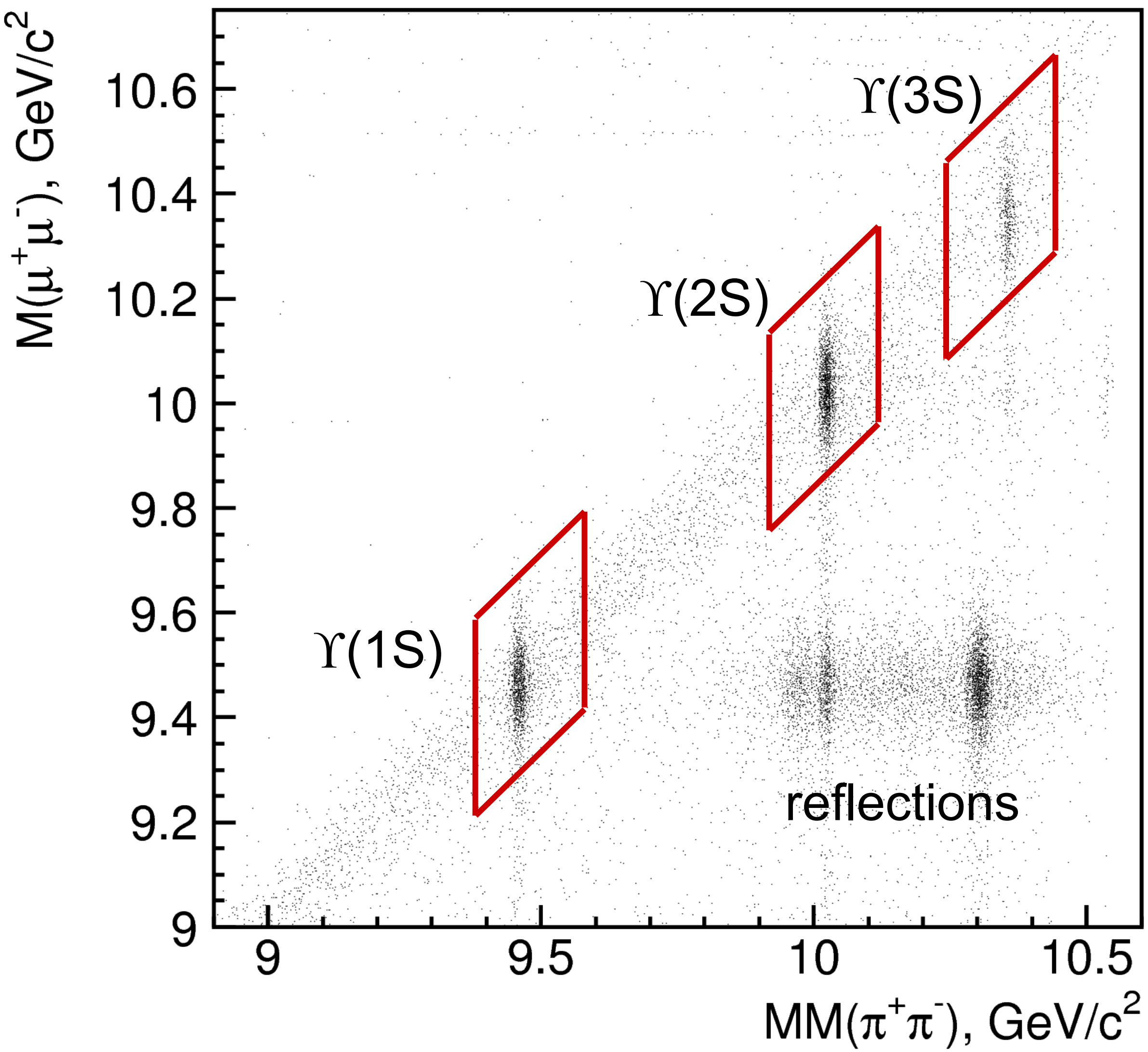
Significances

2 vs.1 : 2.7σ (1.9σ w/ syst)

2 vs.0 : 6.3σ (4.7σ w/ syst)

Exclusive Υ(5S) -> Υ(nS) $\pi^+\pi^-$

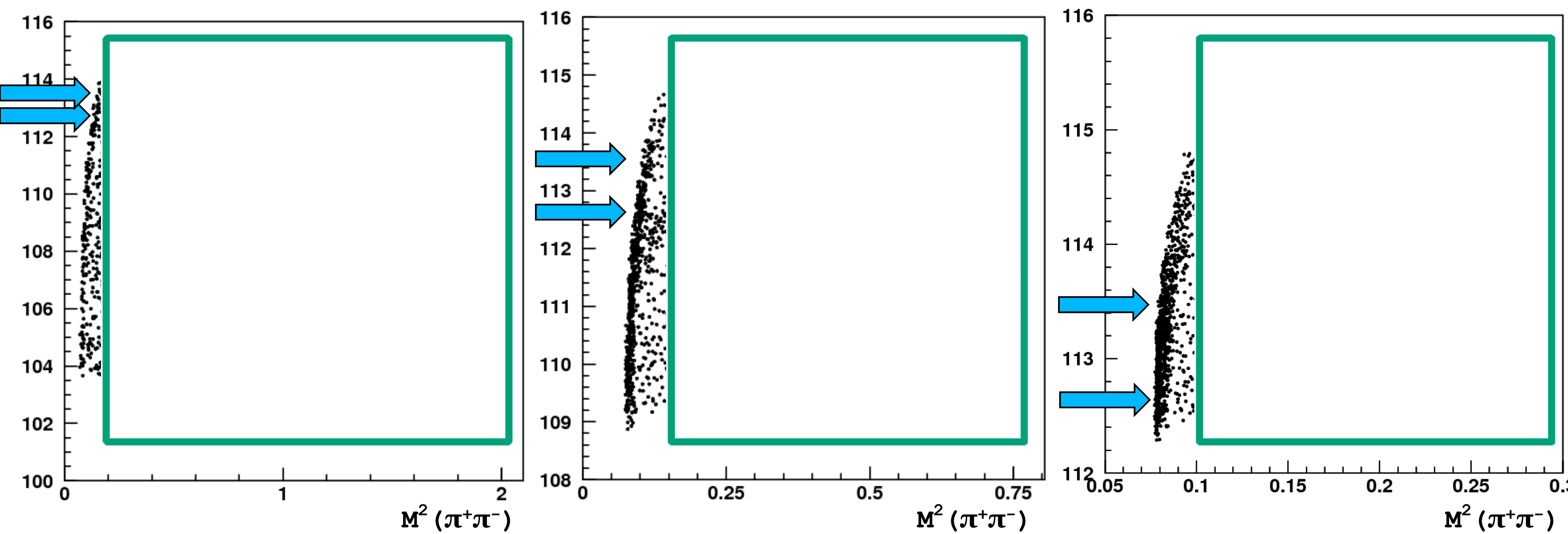
Υ(5S) → **Υ(nS)** π+π-
Υ(nS) → μ+μ-   (n = 1,2,3)



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

Dalitz distributions for events in Y(nS) signal regions.

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**



To exclude contamination from gamma conversions we require:

$M^2(\pi^+\pi^-) > 0.20$ GeV² **$M^2(\pi^+\pi^-) > 0.16$ GeV²** **$M^2(\pi^+\pi^-) > 0.10$ GeV²**

Fitting the Dalitz plots

Signal amplitude parameterization:

$S(s1,s2) = A(Z_{b1}) + A(Z_{b2}) + A(f_0(980)) + A(f_2(1275)) + A_{NR}$

$A_{NR} = C_1 + C_2 \cdot m^2(\pi\pi)$

Parameterization of the non-resonant amplitude is discussed in

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

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

and references therein.

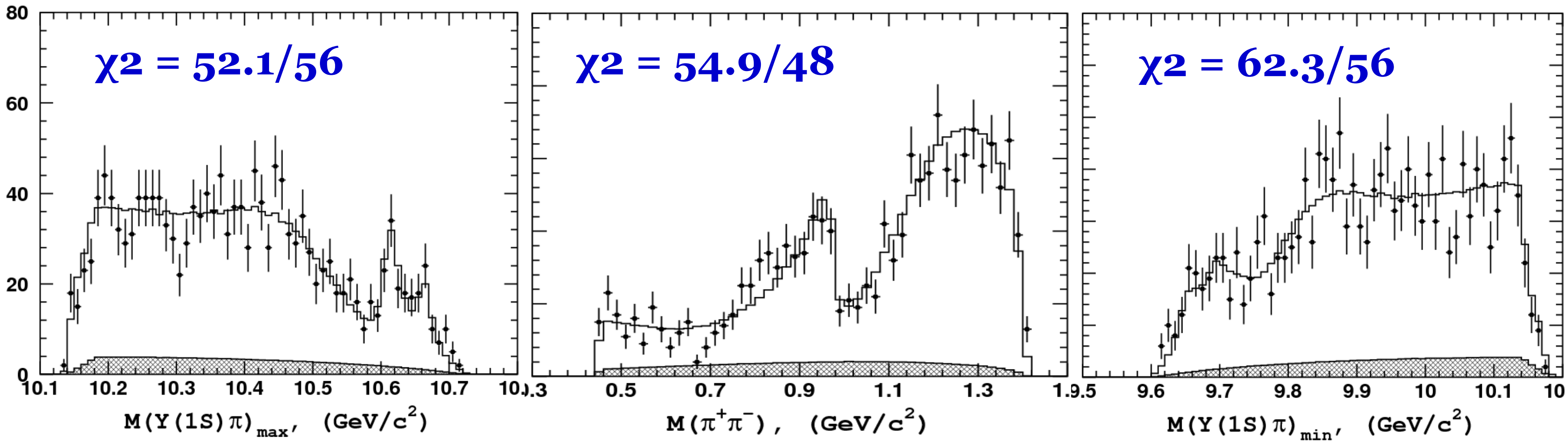
Z_b amplitudes are parameterized by Breit-Wigner functions and symmetrized with respect to interchange of the two pions π_1 and π_2:

$A(Z_b) = BW(s_1,M_Z,\Gamma_Z) + BW(s_2,M_Z,\Gamma_Z)$

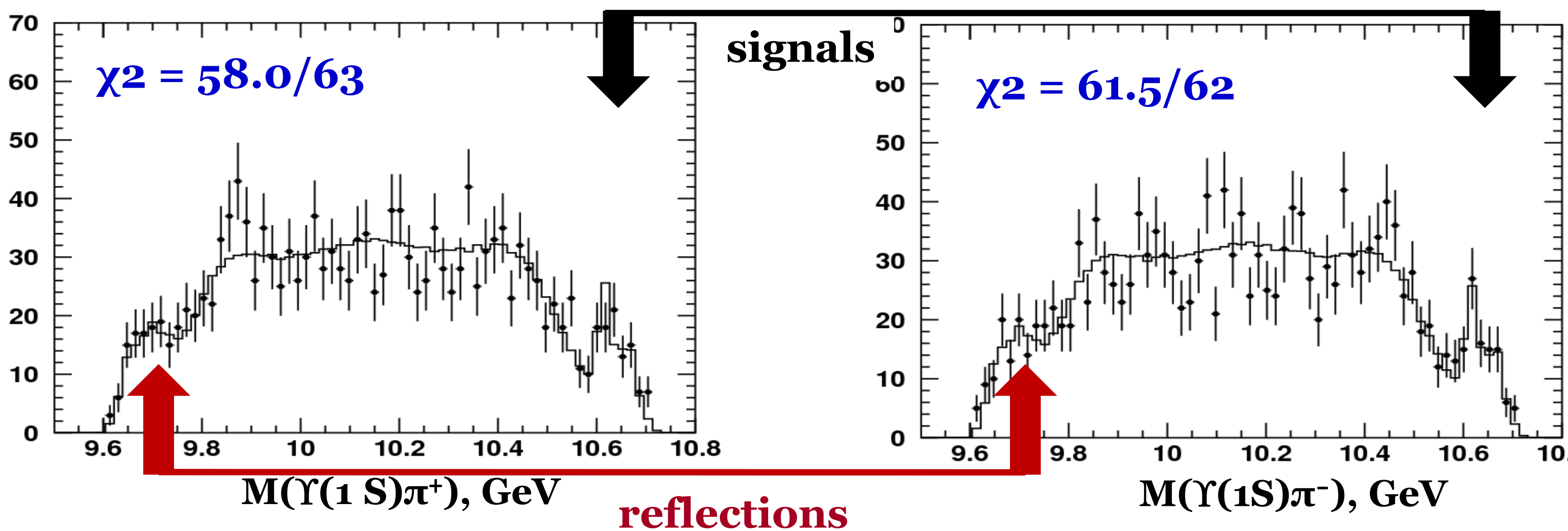
$A(f_0(980))$ – Flatte function with parameters m=950 MeV, $g_{\pi\pi}$=0.23 and g_{KK}=0.73 determined from the analysis of $B\to K\pi\pi$.

$A(f_2(1275))$ – Breit-Wigner function

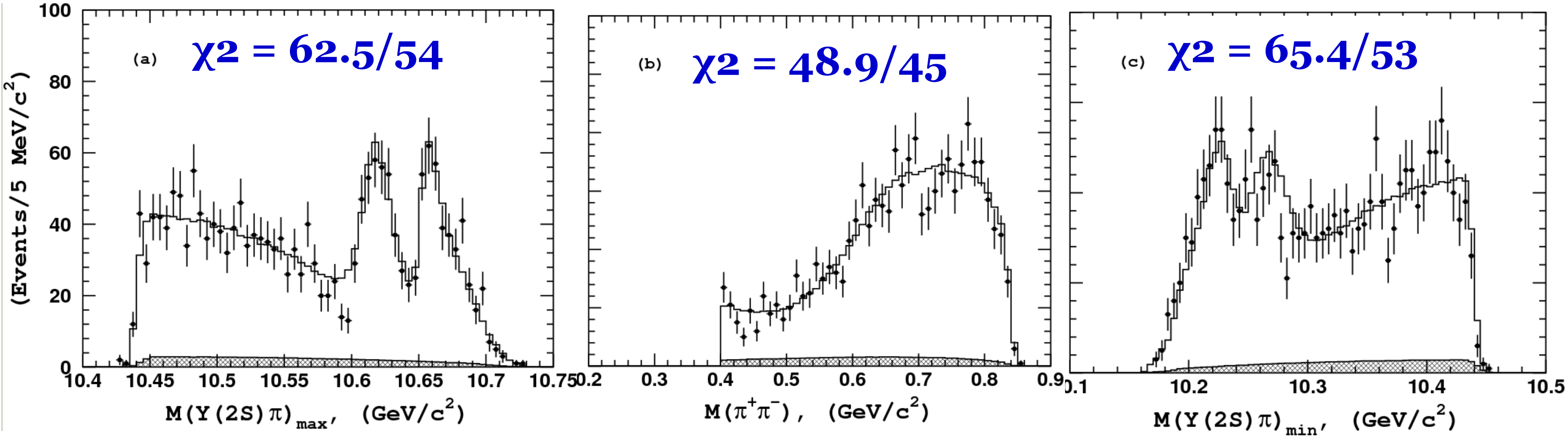
Results: $\Upsilon(1S)\pi^+\pi^-$



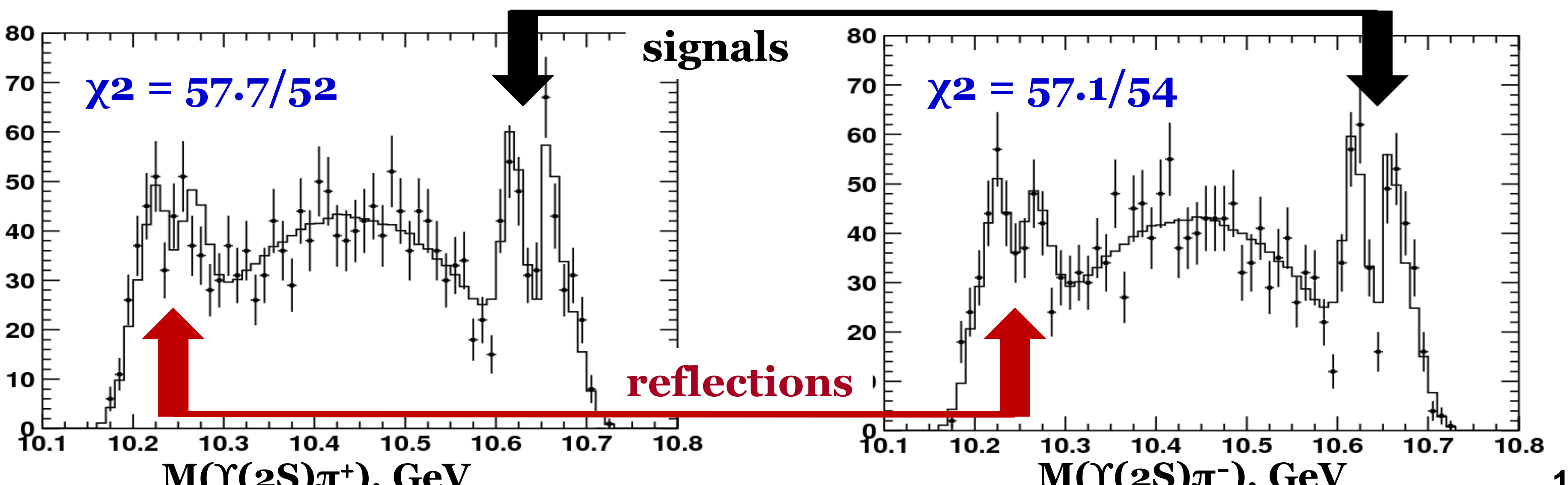
$M(\Upsilon(1S)\pi^+)$ and $M(\Upsilon(1S)\pi^-)$ projections:



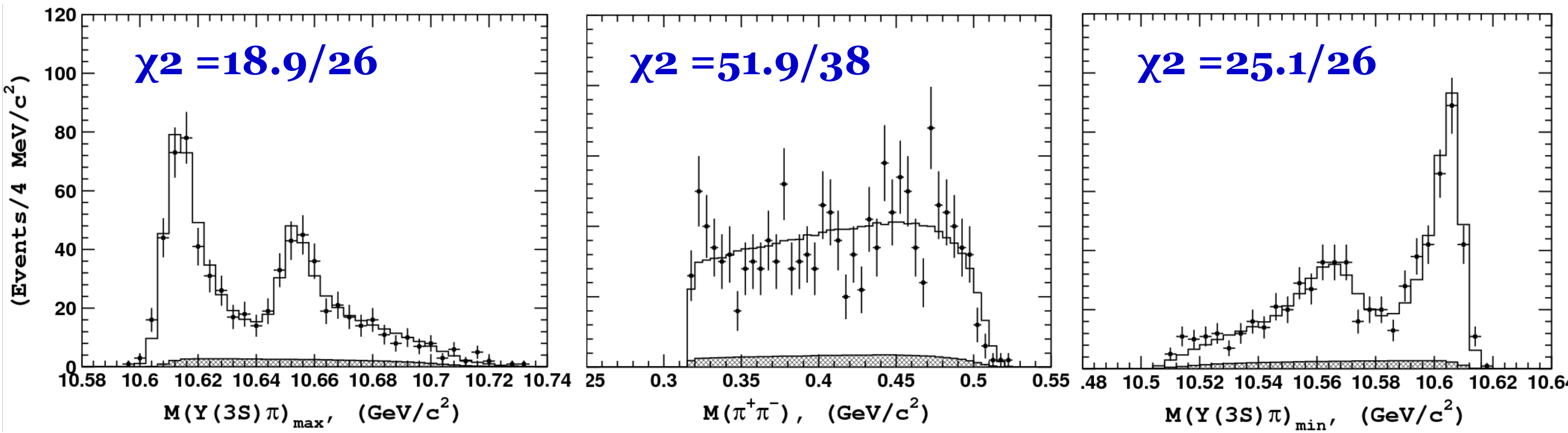
Results: ϒ(2S)π⁺π⁻



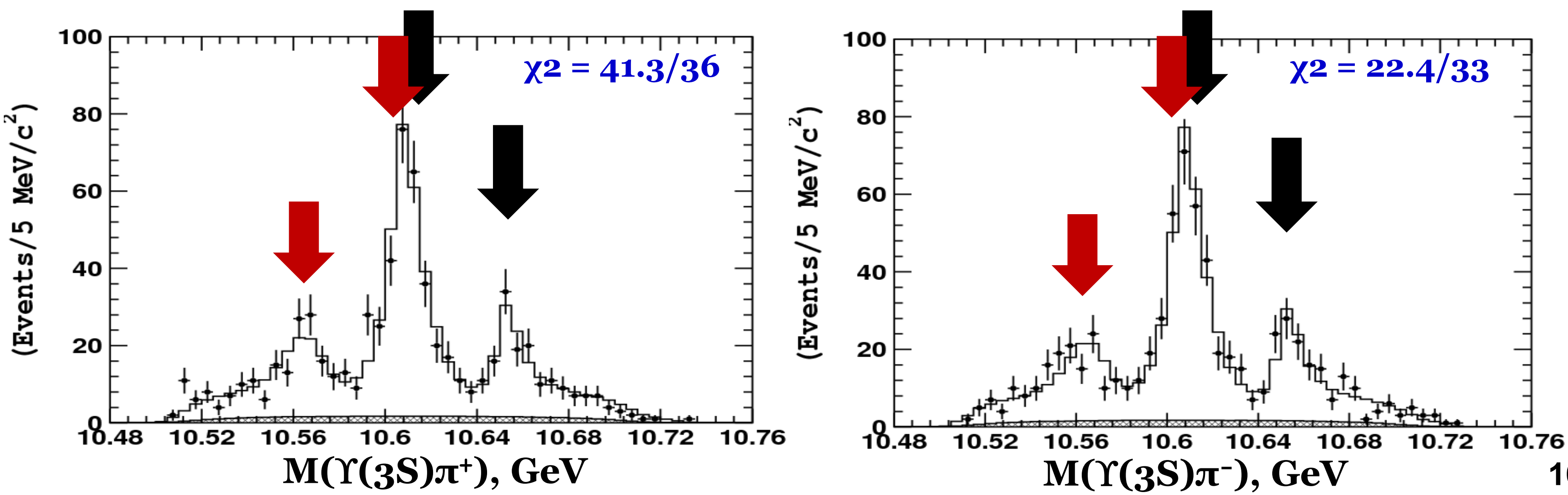
M(ϒ(2S)π⁺) and M(ϒ(2S)π⁻) projections:



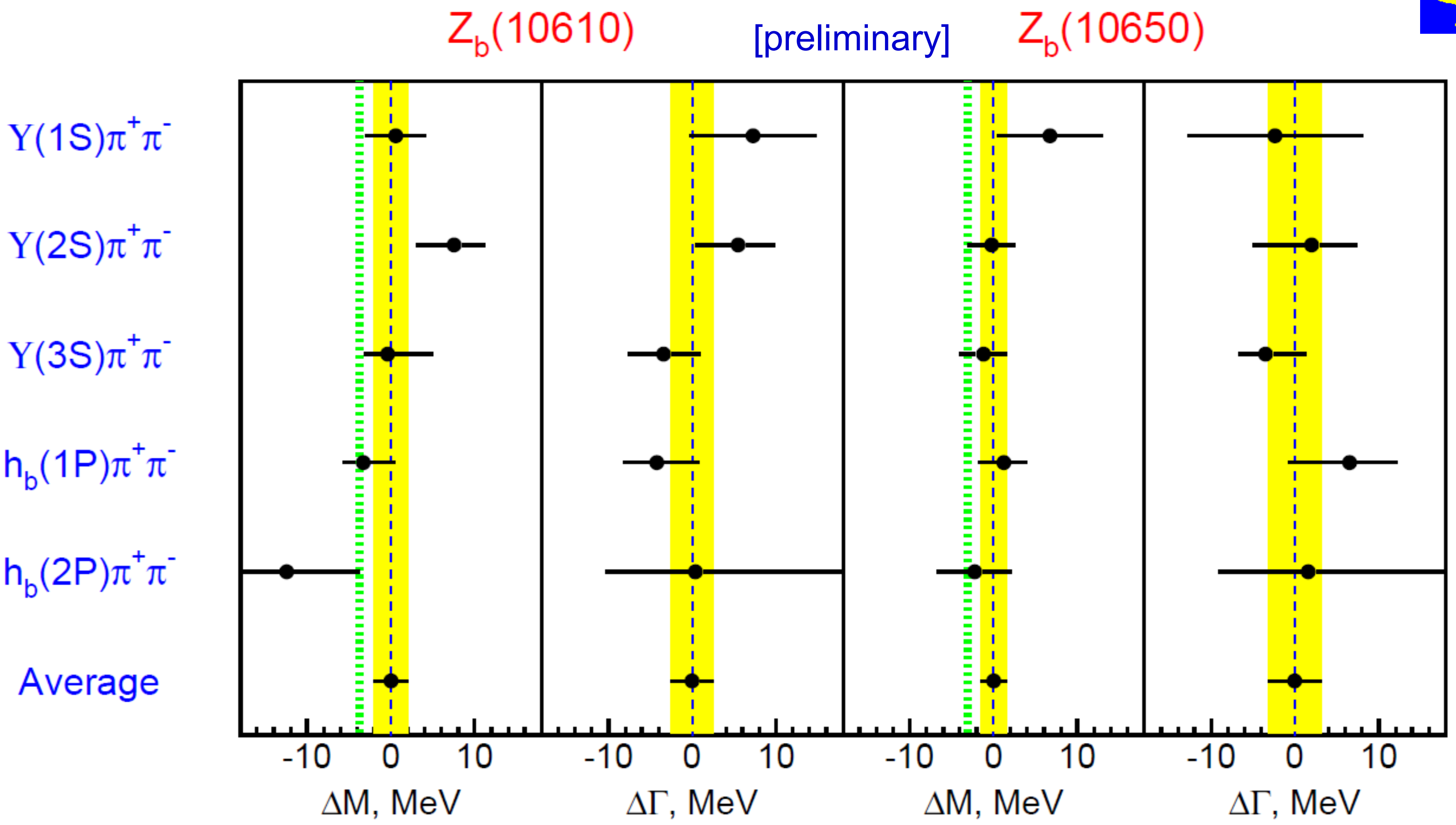
Results: $\Upsilon(3S)\pi^+\pi^-$



M(ϒ(3S)π⁺) and M(ϒ(3S)π⁻) projections:



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

Summary of parameters of charged Z_b states

[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	$22.9 \pm 7.3 \pm 2$	$21.1 \pm 4^{+2}_{-3}$	$12.2 \pm 1.7 \pm 4$	$11.4\,^{+4.5}_{-3.9}\,^{+2.1}_{-1.2}$	$16\,^{+16}_{-10}\,^{+13}_{-4}$
$M(Z_b(10650))$, 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	$12 \pm 10 \pm 3$	$16.4 \pm 3.6^{+4}_{-6}$	$10.9 \pm 2.6^{+4}_{-2}$	$20.9\,^{+5.4}_{-4.7}\,^{+2.1}_{-5.7}$	$12\,^{+11}_{-9}\,^{+8}_{-2}$
Rel. amplitude	$0.59 \pm 0.19^{+0.09}_{-0.03}$	$0.91 \pm 0.11^{+0.04}_{-0.03}$	$0.73 \pm 0.10^{+0.15}_{-0.05}$	$1.8\,^{+1.0}_{-0.7}\,^{+0.1}_{-0.5}$	$1.3\,^{+3.1}_{-1.1}\,^{+0.4}_{-0.7}$
Rel. phase, degrees	$53 \pm 61^{+5}_{-50}$	$-20 \pm 18^{+14}_{-9}$	$6 \pm 24^{+23}_{-59}$	$188\,^{+44}_{-58}\,^{+4}_{-9}$	$255\,^{+56}_{-72}\,^{+12}_{-183}$

Masses, widths, relative amplitudes are consistent

Relative phases are swapped for Υ and h_b final states $\Leftarrow$ 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

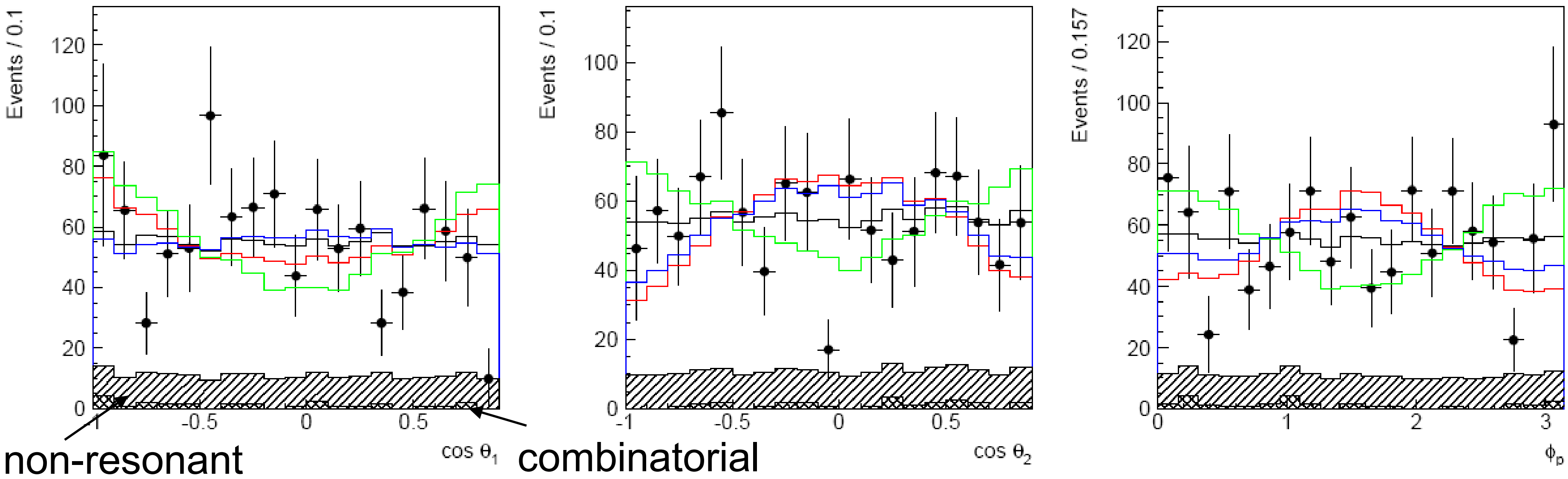
Γ=14.4 ± 3.2 MeV

Angular analyses

Consider **1D** projections on $\angle(\pi_i, e^+)$, $\angle(\pi_1, \pi_2)$, $\angle[\text{plane}(\pi_1, e^+), \text{plane}(\pi_1, \pi_2)]$

[preliminary]

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

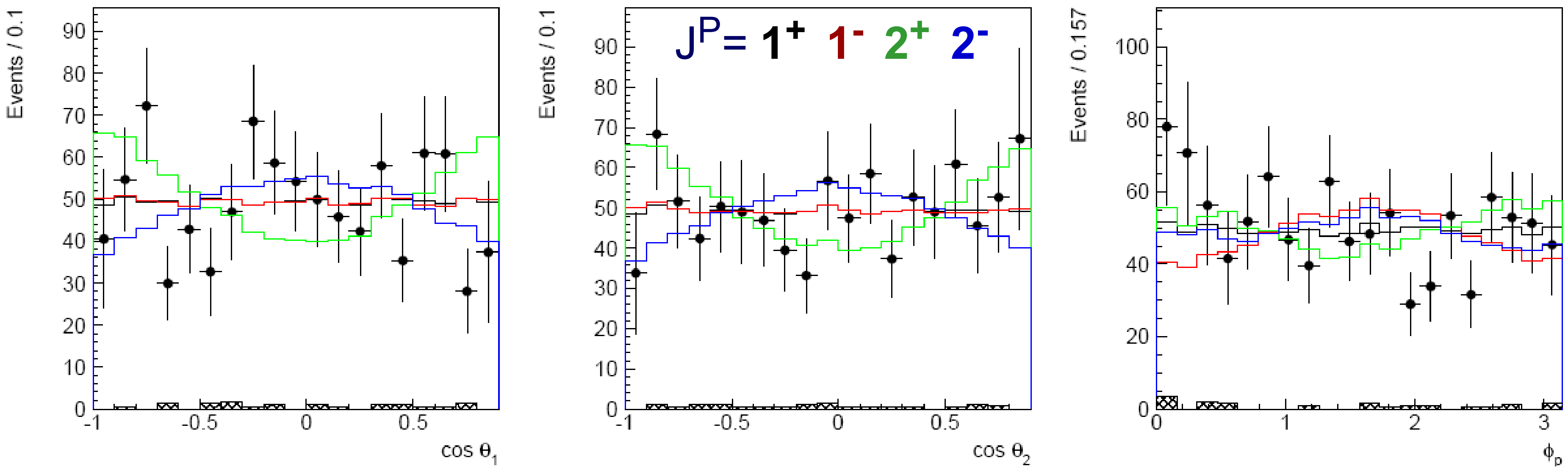


Color coding: J^P= **1^+** 1^- 2^+ 2^- ($0^\pm$ is forbidden by parity conservation)

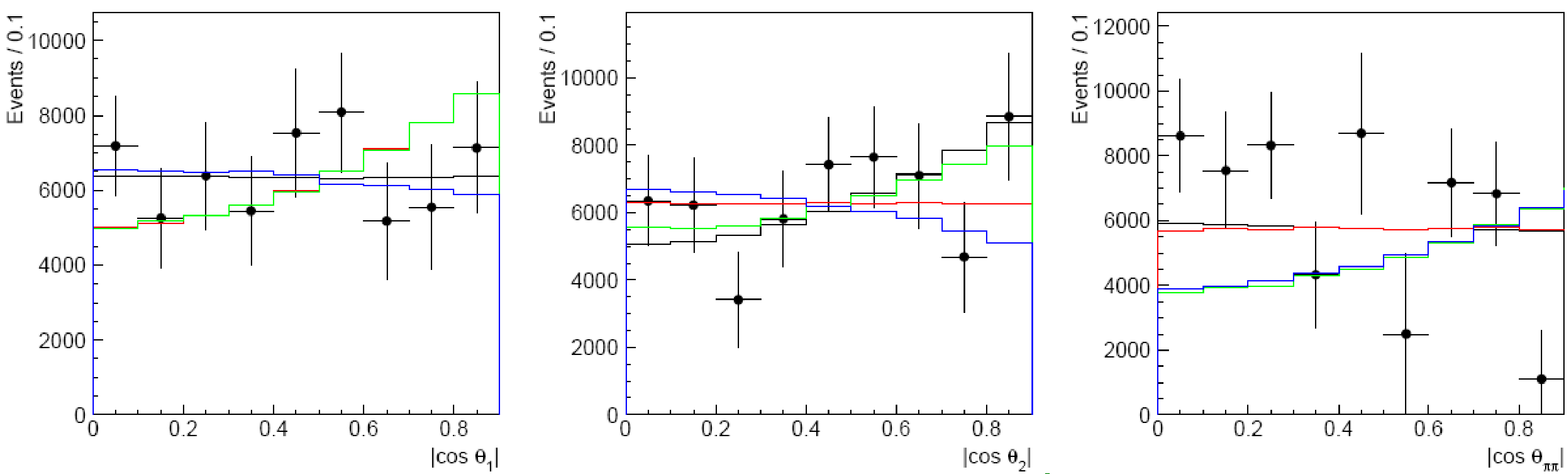
Best discrimination: $\cos\theta_2$ for 1^- and 2^- ; $\cos\theta_1$ for 2^+

Example : $\Upsilon(5S) \to Z_b^+(10610)\,\pi^- \to [\Upsilon(3S)\pi^+]\,\pi^-$

[preliminary]



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^-

Summary of angular analyses

All angular distributions are consistent with $J^P=1^+$ for $Z_b(10610)$ & $Z_b(10650)$.

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	

[preliminary]

All other J^P with $J\leq 2$ are disfavored at typically 3σ level.

Summary of the Belle results

First observation of $h_b(1P)$ and $h_b(2P)$ **arXiv:1103.3419**

Masses consistent with CoG of χ_{bJ} states, as expected

First observation of two charged bottomonium-like resonances (new for FPCP)

$Z_b(10610)$ M = 10608.1 ± 1.7 MeV [preliminary]
Γ = 15.5± 2.4 MeV

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

Seen in 5 different final states, parameters are consistent

Masses are close to B*B and B*B* thresholds ⇒

Suggestive of S-wave molecules

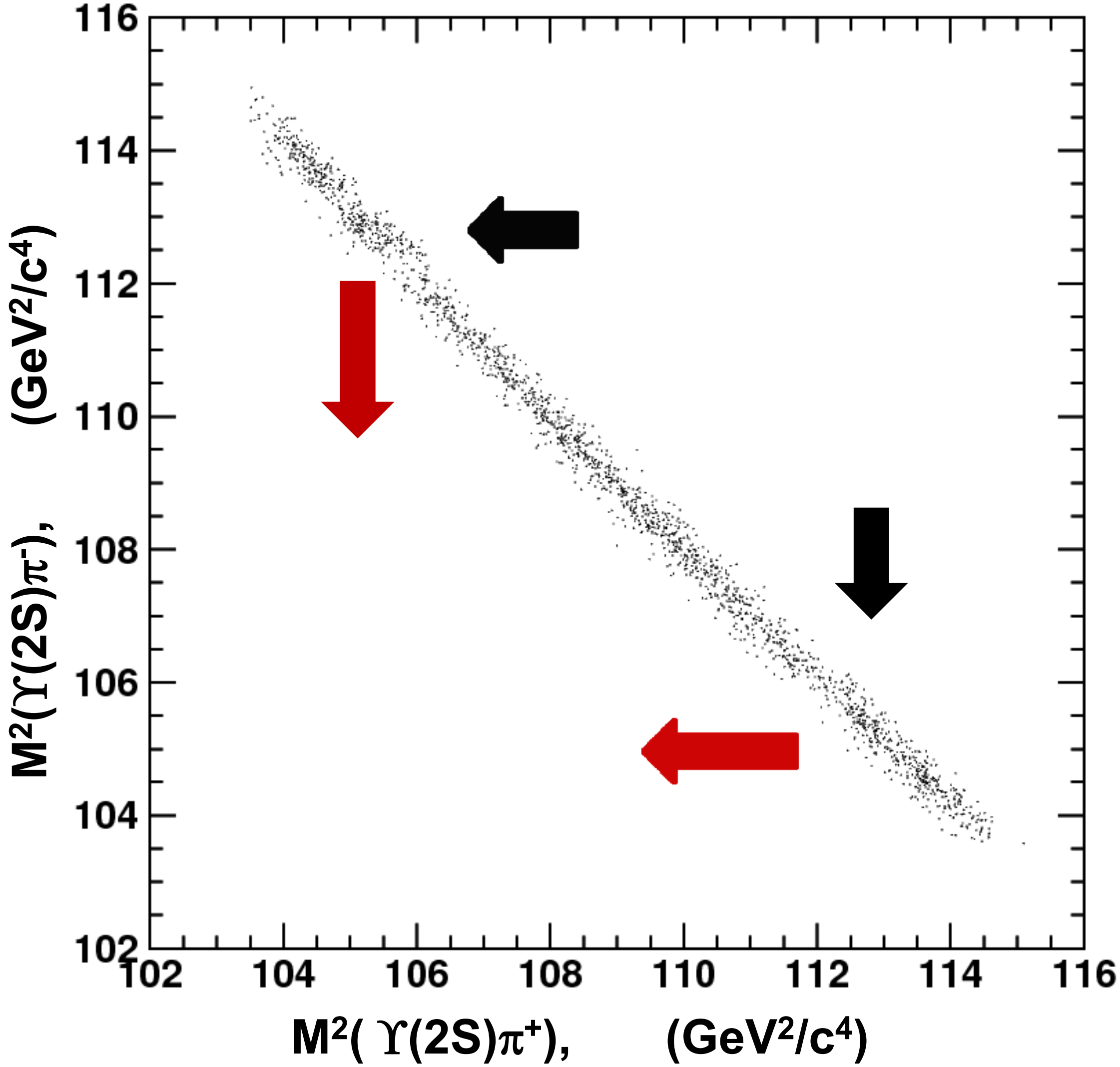
Expect $J^P=1^+$ – in agreement with data; other J^P are disfavored.

Amplitude ratio A[Z_b(10610)] / A[Z_b(10650)] ~1.

Relative phase ~0 for Υ and ~180 for h_b.

Explains why $h_b\pi\pi$ is unsuppressed relative to $\Upsilon\pi\pi$.

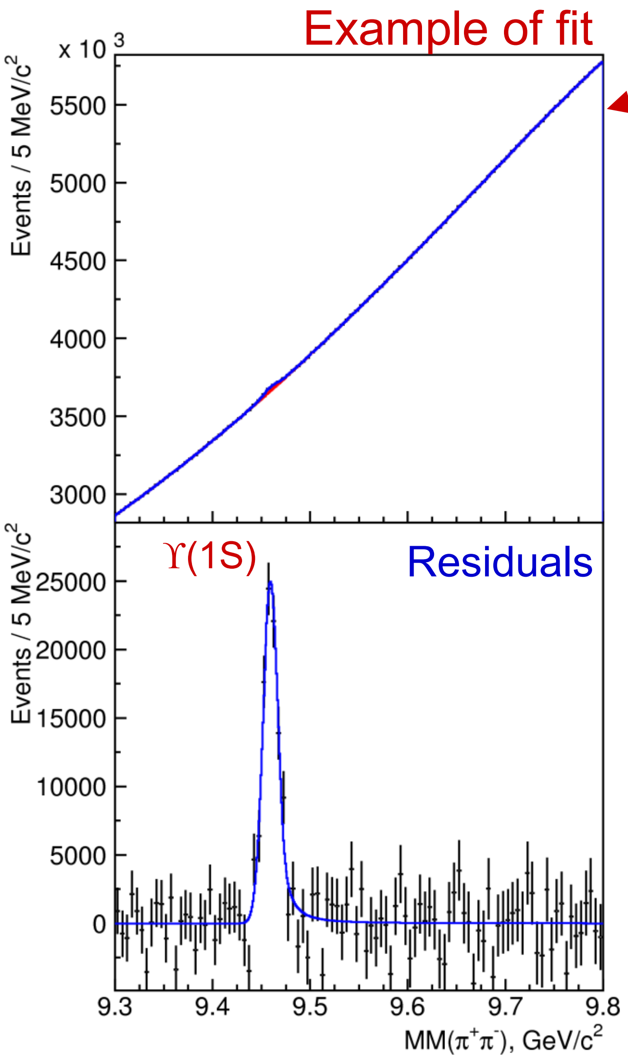
Dalitz Plot



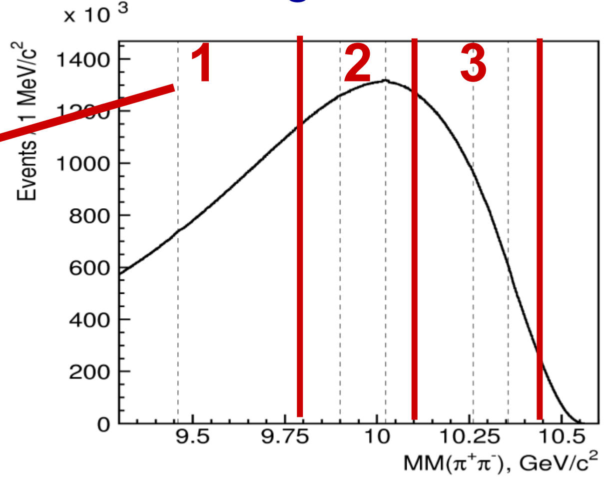
If there is a signal in the $\Upsilon\ \pi$ system

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

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



Three fit regions



BG: Chebyshev polynomial: max C.L. of fit

6th or 7th order

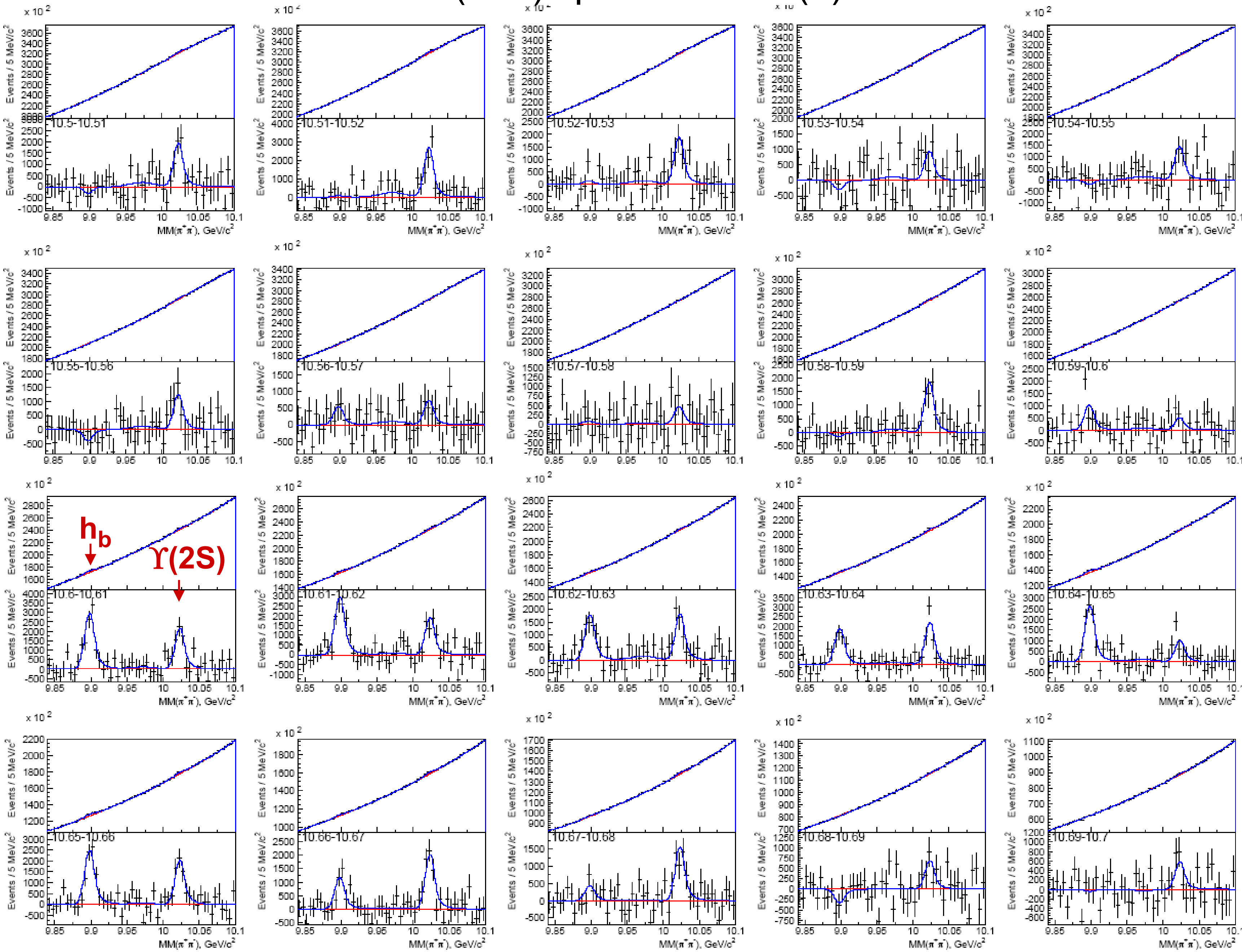
Signal: shape is fixed from $\mu^+\mu^-\pi^+\pi^-$ data

"Residuals" – subtract polynomial from data points

K_S contribution: subtract bin-by-bin

in region #3 only

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

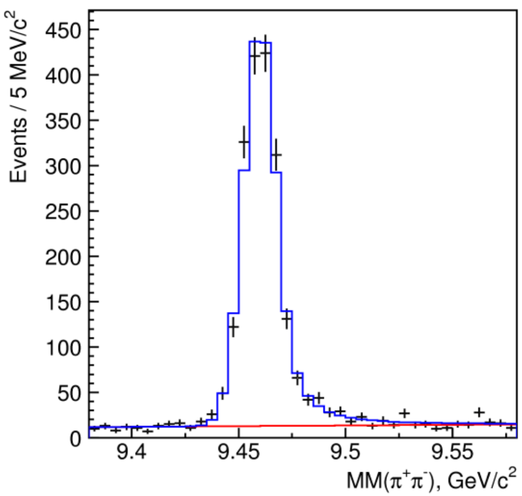


Calibration channels

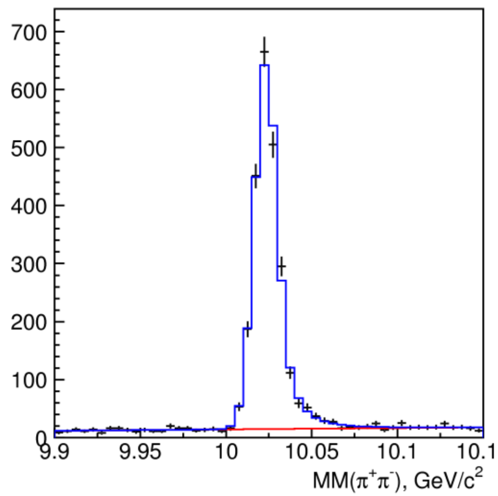
$\Upsilon(5S) \rightarrow \Upsilon(nS)\ \pi^+\pi^-$

$\Upsilon(nS) \rightarrow \mu^+\mu^-$ (n = 1,2,3)

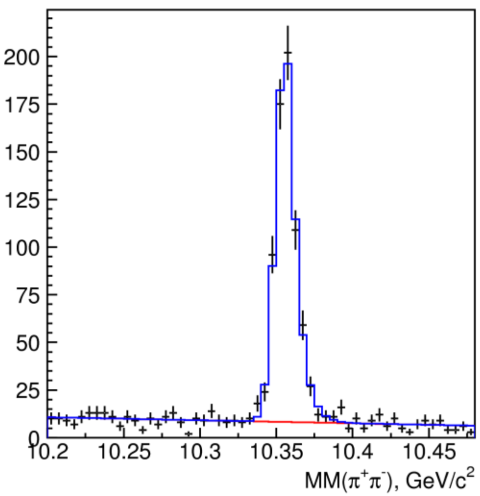
$\Upsilon(5S) \rightarrow \Upsilon(1S)\ \pi\pi$

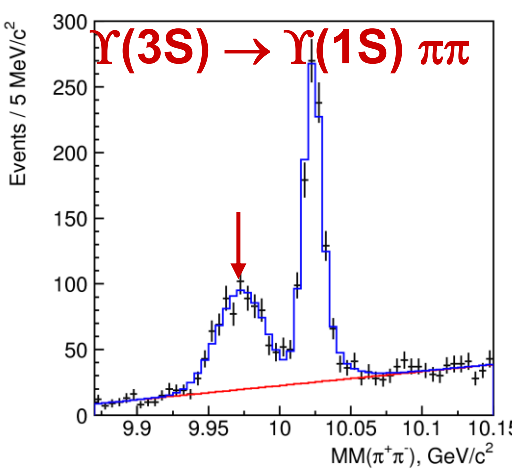


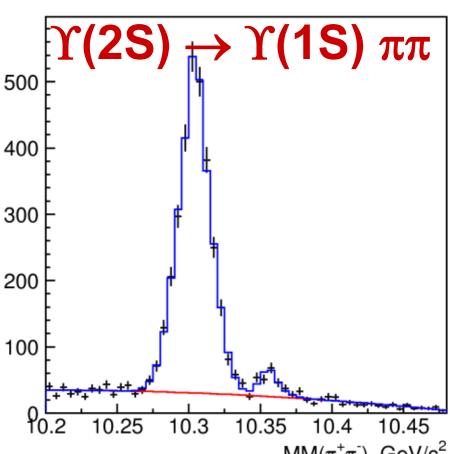
$\Upsilon(5S) \rightarrow \Upsilon(2S)\ \pi\pi$



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







$\Rightarrow$ **Shapes of signals**

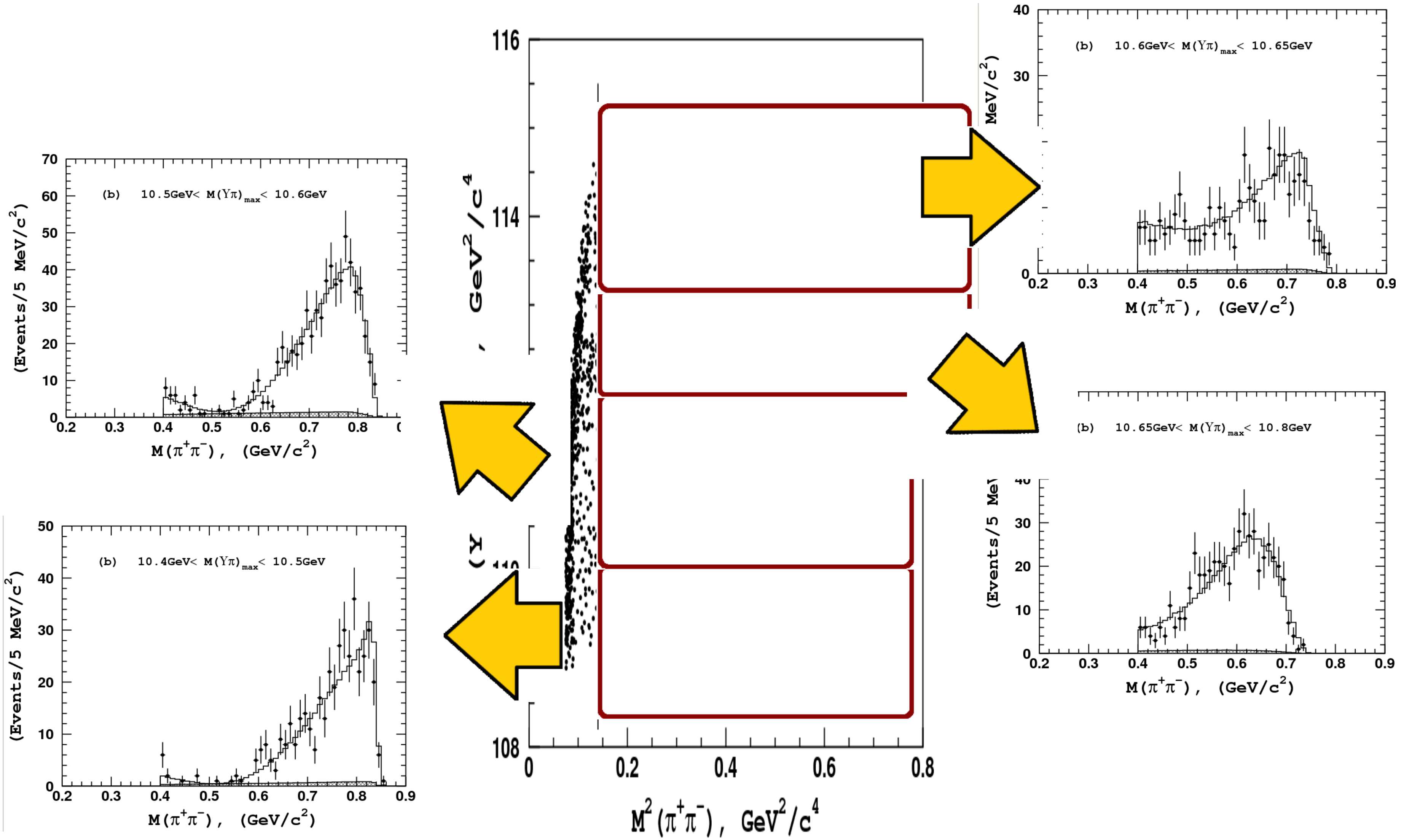
CrystalBall function

tail (8%) – ISR of soft γ

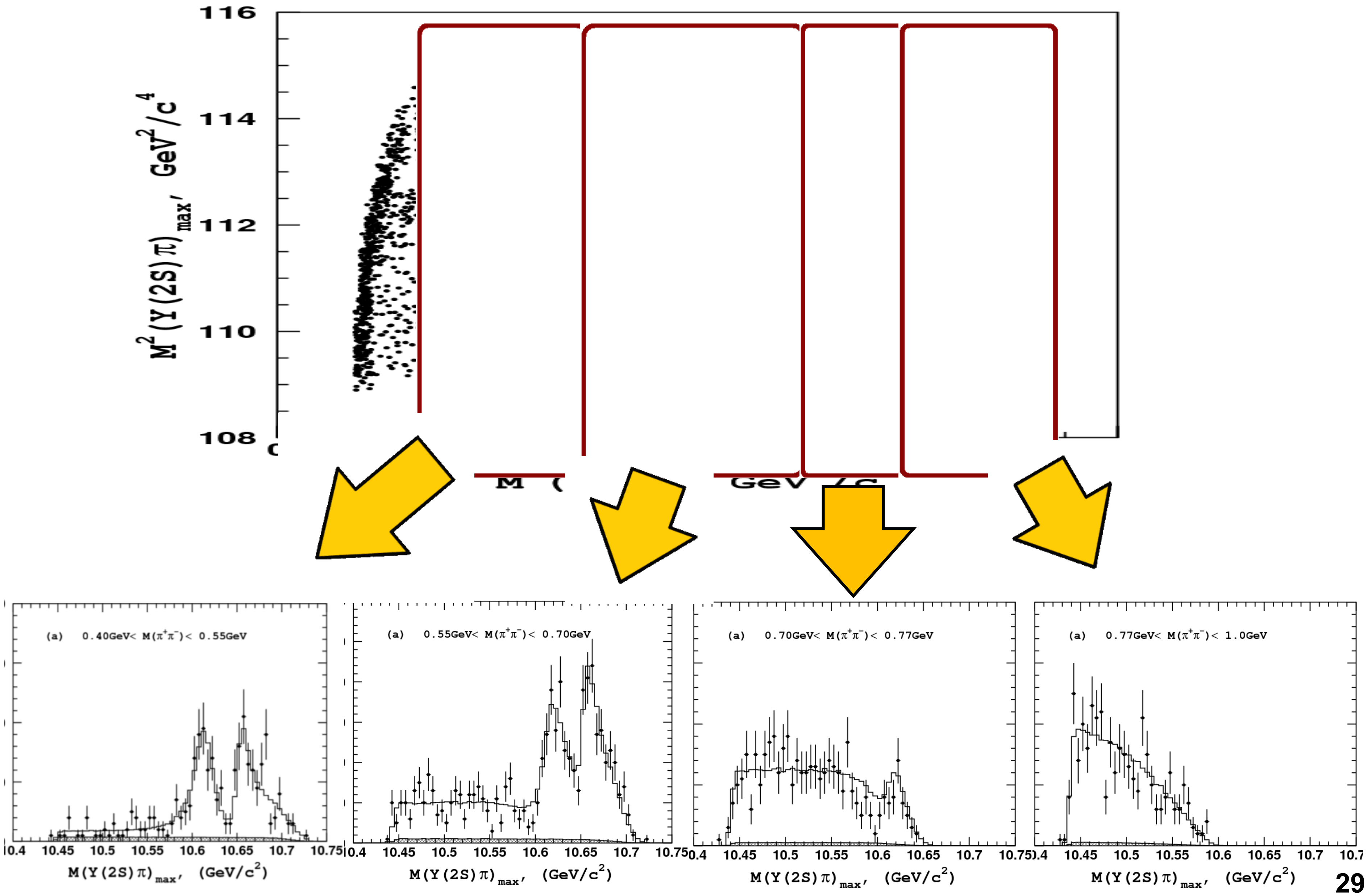
σ = 5.7 – 7.5 MeV

$\Rightarrow$ **Shapes of reflections**

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



Results: Υ(2S)π⁺π⁻



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

λ – beam direction

many thanks to A. Milstein (BINP)

1^+ isotropic

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

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

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

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

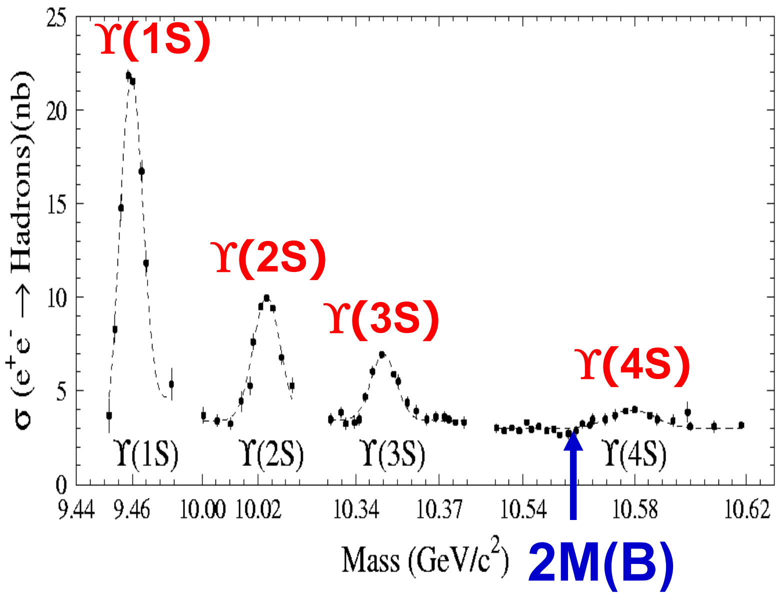
also formulae for h_b are available

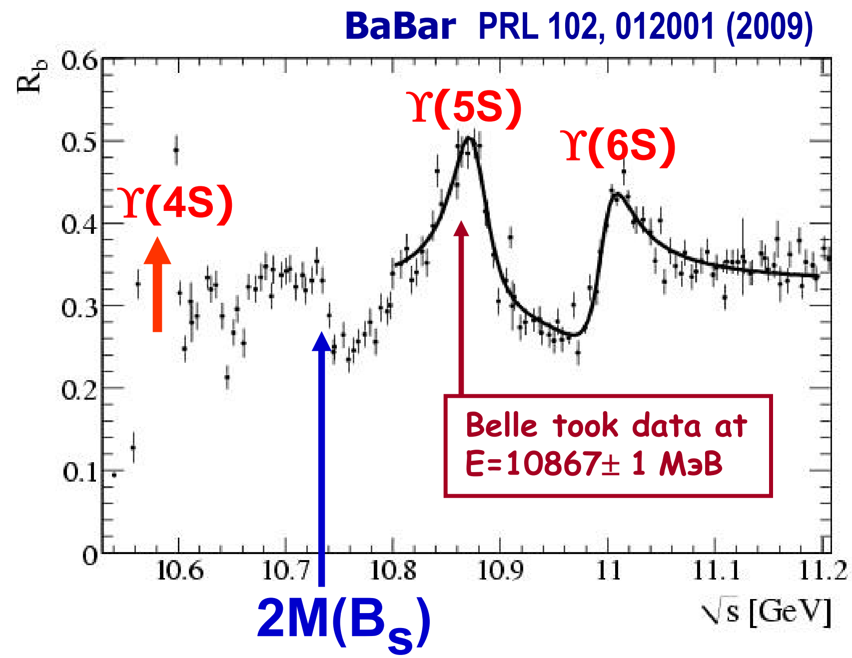
Consider 1D projections

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



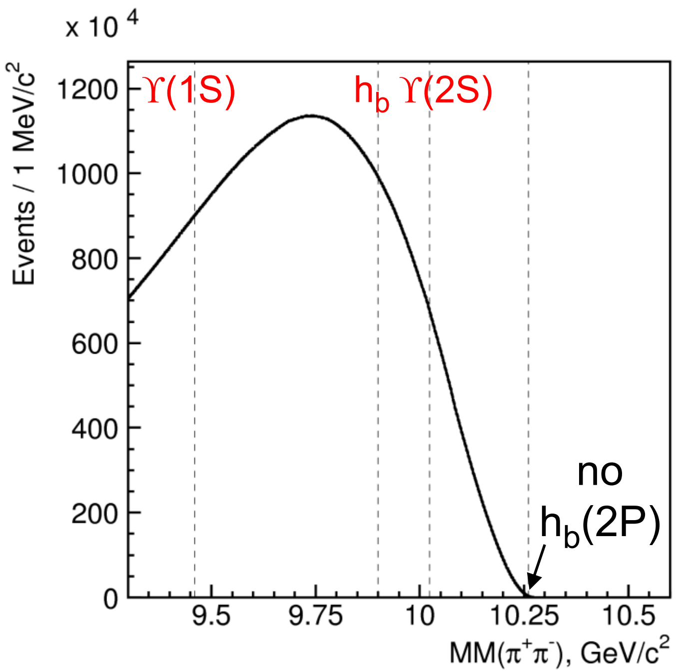


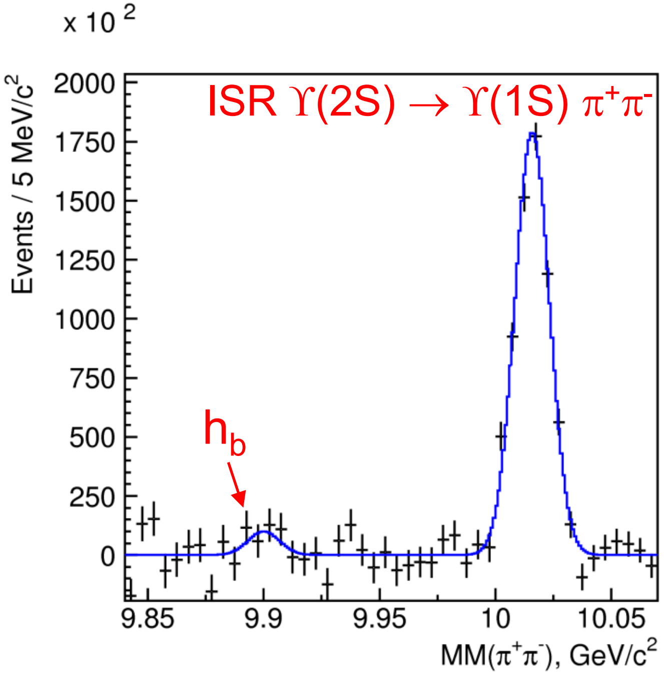
$e^+ e^-$ -> Υ(4S) -> $B\bar{B}$, where B is B^+ or B^0

$e^+ e^-$ -> $b\bar{b}$ (Υ(5S)) -> $B^{(*)}\bar{B}^{(*)}$, $B^{(*)}\bar{B}^{(*)}\pi$, $B\bar{B}\pi\pi$, $B_s^{(*)}\bar{B}_s^{(*)}$, Υ(1S) ππ , Υ X …

study

Search in Υ(4S) data



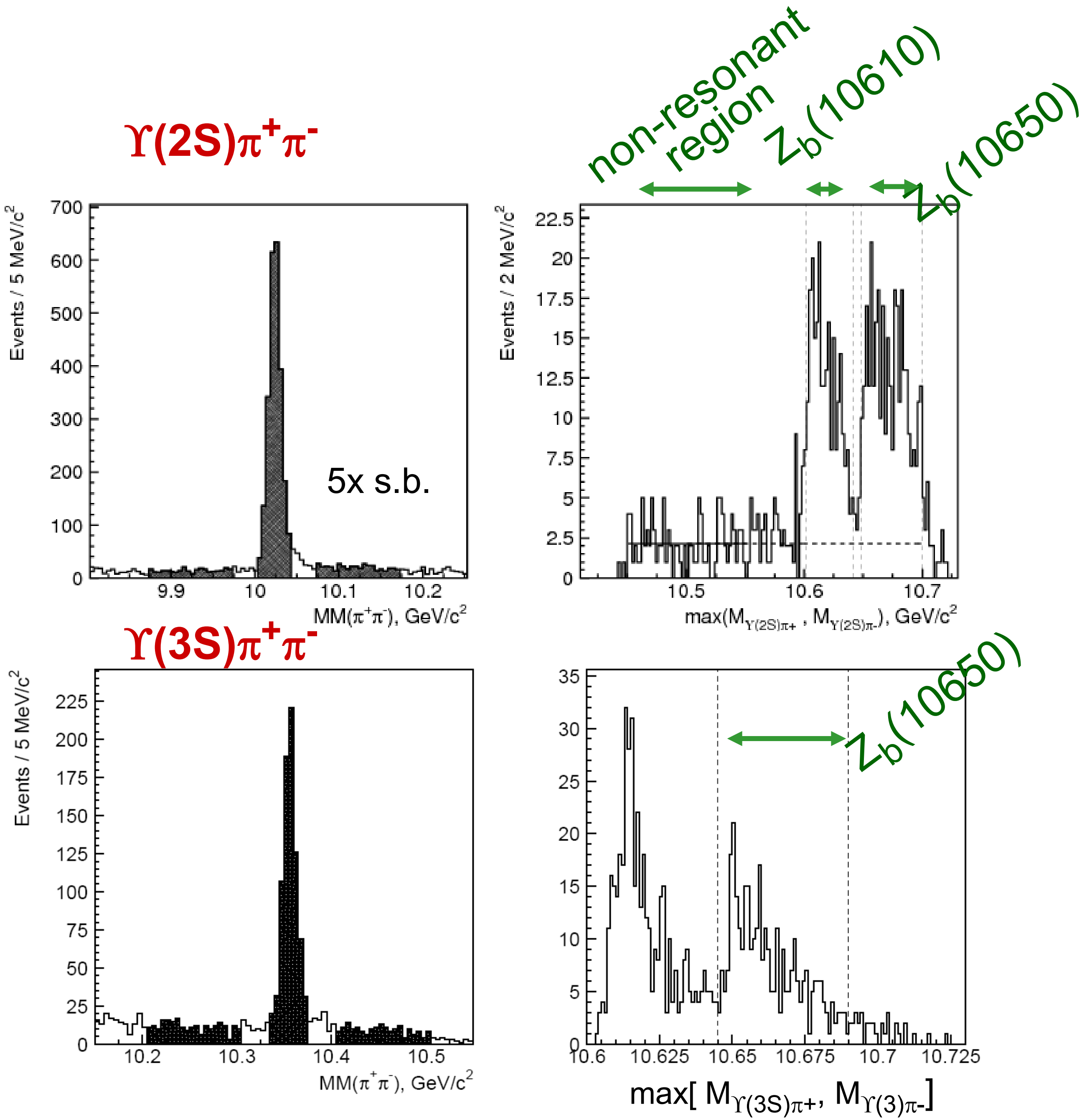


L = 711fb^{-1} [×6 Υ(5S) sample]

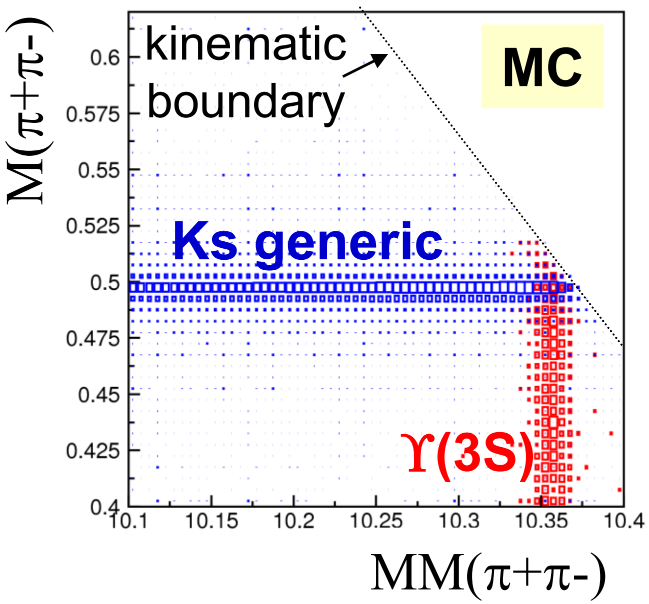
No significant signal of h_b(1P): $(34\pm20)\times10^3$ (1.7σ)

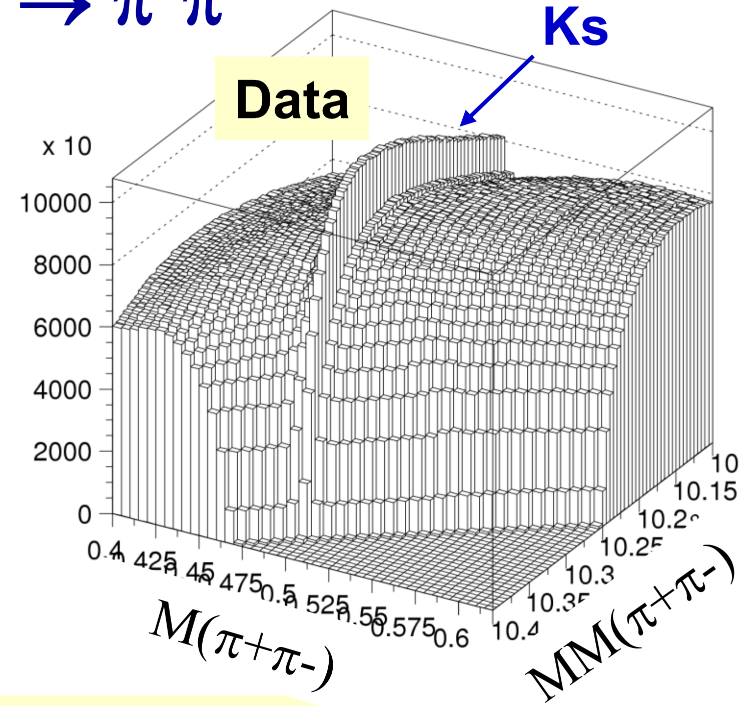
$$\frac{\sigma[e^+e^- \to h_b(1P)\,\pi^+\pi^-]\ @\ \Upsilon(4S)}{\sigma[e^+e^- \to h_b(1P)\,\pi^+\pi^-]\ @\ \Upsilon(5S)} < 0.28 \text{ at } 90\%\text{C.L.}$$

⇒ **Υ(4S) does not show anomalous properties**

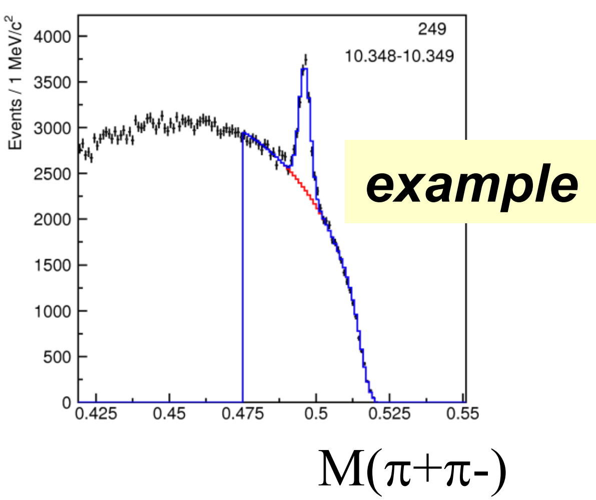

Υ(2S)π+π-
non-resonant region
Zb(10610)
Zb(10650)
Events / 5 MeV/c2
5x s.b.
MM(π+π-), GeV/c2
Events / 2 MeV/c2
max(MΥ(2S)π+ , MΥ(2S)π-), GeV/c2
Υ(3S)π+π-
Events / 5 MeV/c2
MM(π+π-), GeV/c2
Zb(10650)
max[MΥ(3S)π+, MΥ(3)π-]

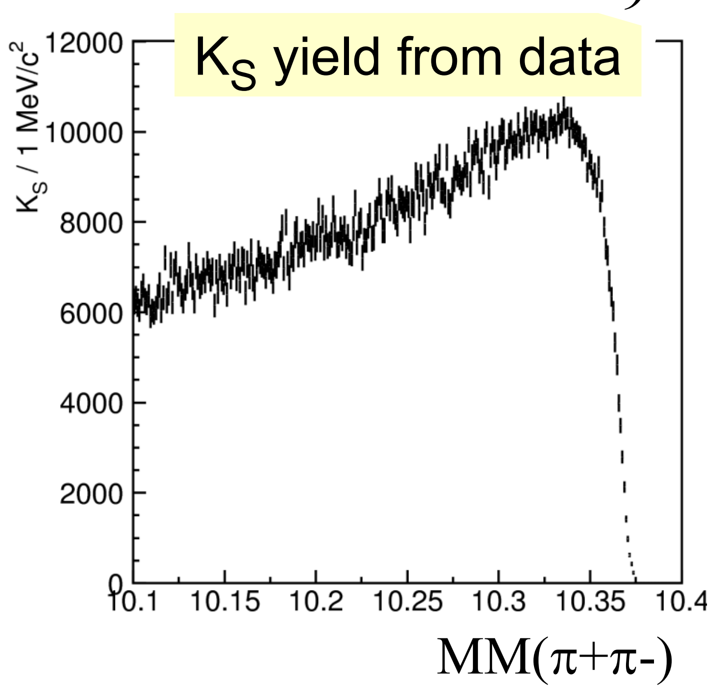
Reflection from $K_S \to \pi^+\pi^-$





Fit to $M(\pi^+\pi^-)$ in $MM(\pi^+\pi^-)$ bins ⇒





Systematics

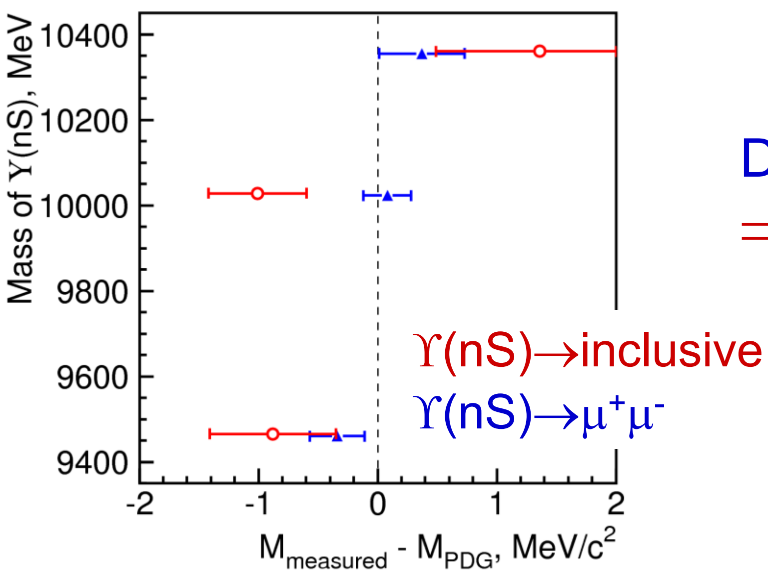
	Polynomial order	Fit range	Signal shape	Selection requirements
$N[h_b]$, 10^3	± 2.4	± 3.6	${}^{+1.2}_{-8.0}$	$-$
$M[h_b]$, MeV/c^2	$\pm .04$	$\pm .10$	${}^{+0.04}_{-0.20}$	${}^{+.20}_{-.30}$
$N[h_b(2P)]$, 10^3	± 2.2	± 2.6	${}^{+23.}_{-9.0}$	$-$
$M[h_b(2P)]$, MeV/c^2	$\pm .10$	$\pm .20$	${}^{+1.0}_{-0.0}$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

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

⇒ 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%
$Z_b(10610)$	15%	63%	7.2%