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HISKP

$Z_b(10610)$ and $Z_b(10650)$ from experimental line shapes

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Theoretical Aspects of Hadron Spectroscopy and Phenomenology

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in collaboration with

E. Epelbaum, A.A. Filin, C. Hanhart, R.V. Mizuk, A.V. Nefediev, S. Ropertz, Q.Wang and J.-L.Wynen

PRD 98, 074023 (2018), PRD 99, 094013 (2019) and arXiv: 2012.05034 [hep-ph]

Plan

— $Z_b(10610)$ and $Z_b(10650)$ from decays:

$$\Upsilon(10860) \to \pi Z_b^{(\prime)} \to \pi B^{(*)} \bar{B}^*$$
$$\Upsilon(10860) \to \pi Z_b^{(\prime)} \to \pi \pi h_b(mP)$$

Q. Wang, VB, A. A. Filin, C. Hanhart, A.V. Nefediev, and J.-L. Wynen PRD 98, 074023 (2018)

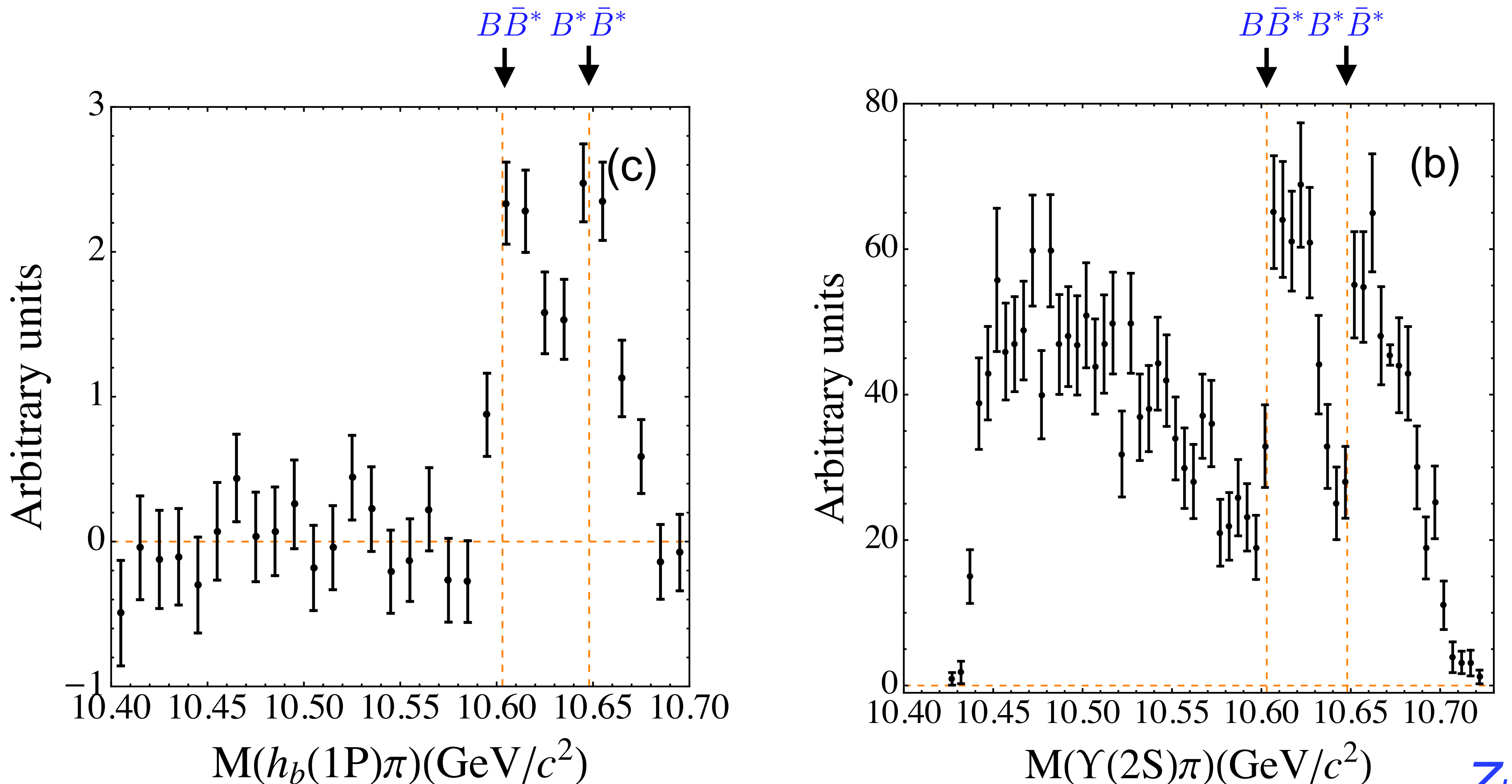
— Predictions for their spin partner states and line shapes

VB, E. Epelbaum, A. A. Filin, C. Hanhart, A.V. Nefediev, and Q. Wang PRD 99, 094013 (2019)

— Insights into the nature of the $Z_b(10610)$ and $Z_b(10650)$
from $\Upsilon(10860) \to \Upsilon(nS)\, \pi^+\pi^-$ (n=1,2,3)

VB, E. Epelbaum, A. A. Filin, C. Hanhart, R.V. Mizuk, A.V. Nefediev and S. Ropertz arXiv: 2012.05034 [hep-ph]

$Z_b(10610)$ and $Z_b(10650)$ from $\Upsilon(10860)$ decays at Belle



Peaks near BB* and B*B* thresholds in various channels:

$B\bar{B}^*,\ B^*\bar{B}^*$

$\pi^\pm h_b(mP),\ \pi^\pm\Upsilon(nS)$

Charged modes $\Longrightarrow$ $Z_b^{(\prime)}$ must be made of ≥4 quarks

- PDG: $M_{Z_b} = 10607.2 \pm 2.0$ MeV, $\Gamma_{Z_b} = 18.4 \pm 2.4$ MeV
  $M_{Z_b'} = 10652.2 \pm 1.5$ MeV, $\Gamma_{Z_b'} = 11.5 \pm 2.2$ MeV

Bondar et al. PRL108, 122001(2012)
Garmash et al.PRL116, 212001(2016)
PRD91, 072003 (2015)

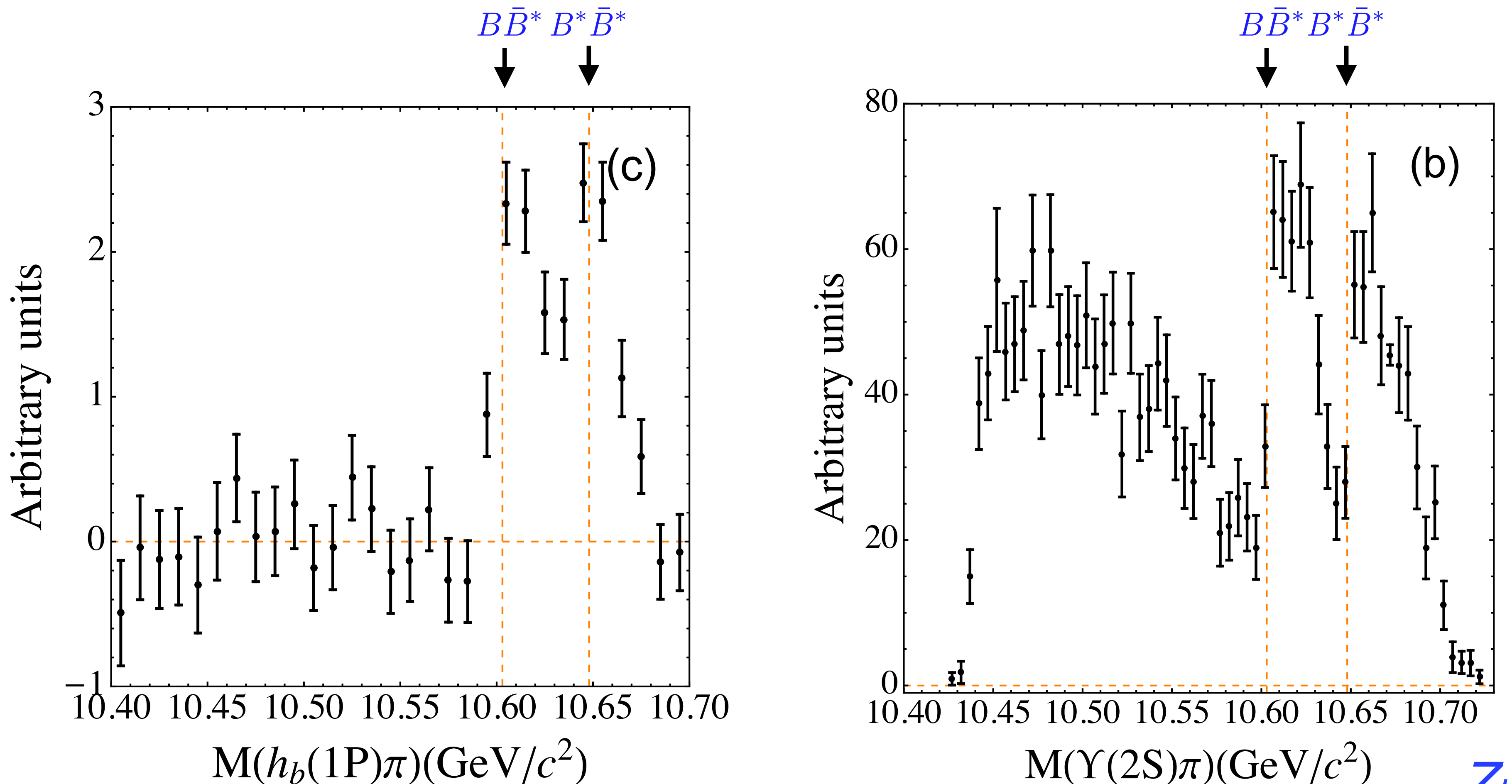
- dominant decays to open flavour channels

- $\underbrace{\mathrm{Br}[\Upsilon(10860) \to \pi\pi h_b(mP)]}_{\text{Heavy quark spin flip}} \simeq \underbrace{\mathrm{Br}[\Upsilon(10860) \to \pi\pi\Upsilon(nS)]}_{\text{No spin flip}}$

$\Longrightarrow$ a strong hint for a large molecular component in $Z_b(10610)/Z_b(10650)$

Bondar et al. PRD 84, 054010 (2011)

$Z_b(10610)$ and $Z_b(10650)$ from $\Upsilon(10860)$ decays by Belle



Peaks near BB* and B*B*

thresholds in various channels:

$B\bar{B}^*, \; B^*\bar{B}^*$

$\pi^\pm h_b(mP), \; \pi^\pm \Upsilon(nS)$

Charged modes $\Longrightarrow$

$Z_b^{(\prime)}$ must be made of ≥4 quarks

- PDG: $$M_{Z_b} = 10607.2 \pm 2.0 \text{ MeV}, \quad \Gamma_{Z_b} = 18.4 \pm 2.4 \text{ MeV}$$ $$M_{Z_b'} = 10652.2 \pm 1.5 \text{ MeV}, \quad \Gamma_{Z_b'} = 11.5 \pm 2.2 \text{ MeV}$$

Bondar et al. PRL108, 122001(2012)
Garmash et al. PRL116, 212001(2016)
PRD91, 072003 (2015)

- Exp. analysis is made using a sum of Breit-Wigner amplitudes:

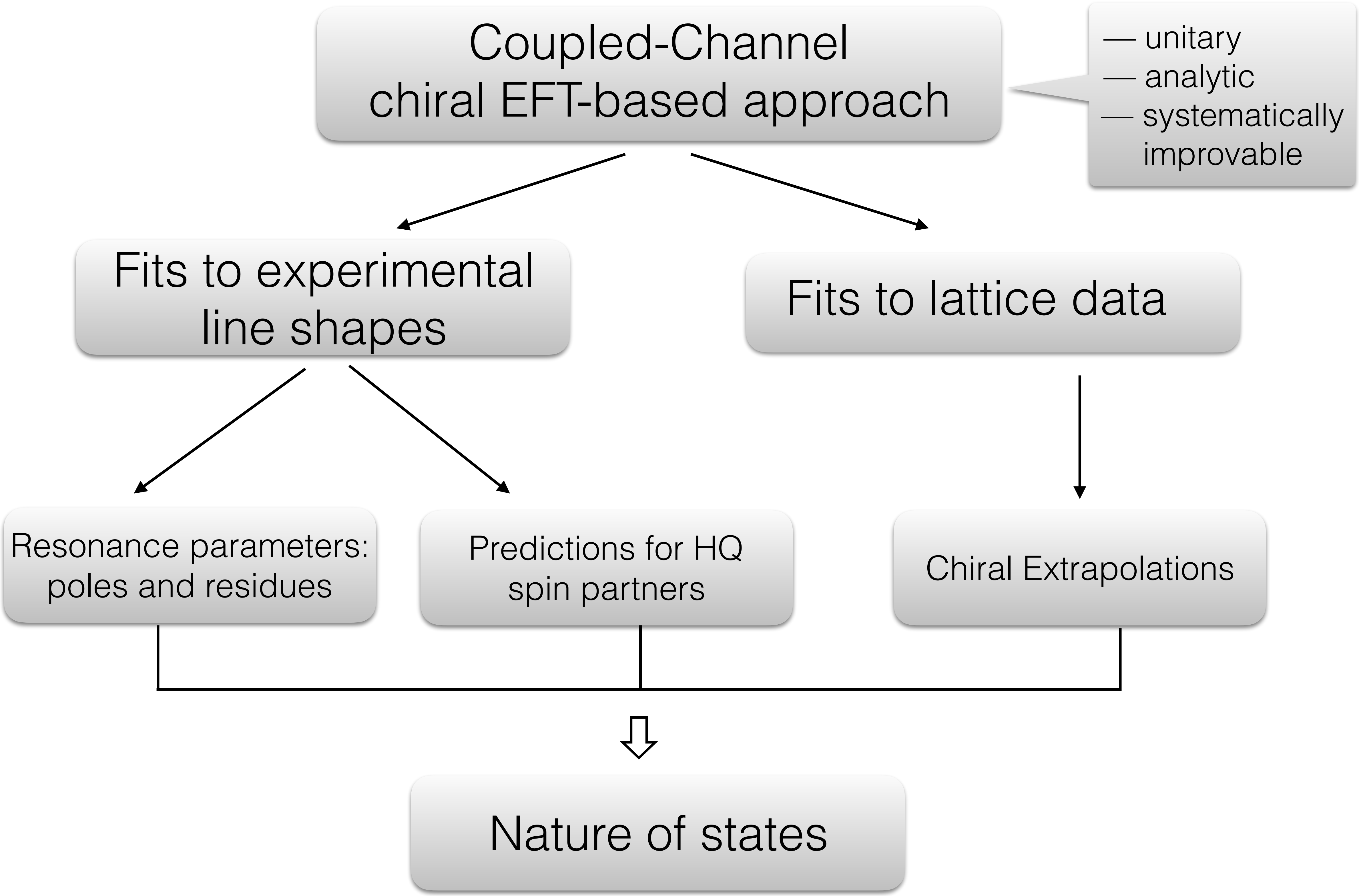
— does not account for threshold behavior

— naive coherent sum violates unitarity

— reaction dependent, no fits of all data simultaneously

How to improve?

Roadmap for analysing near-threshold states



Chiral EFT approach at low energies

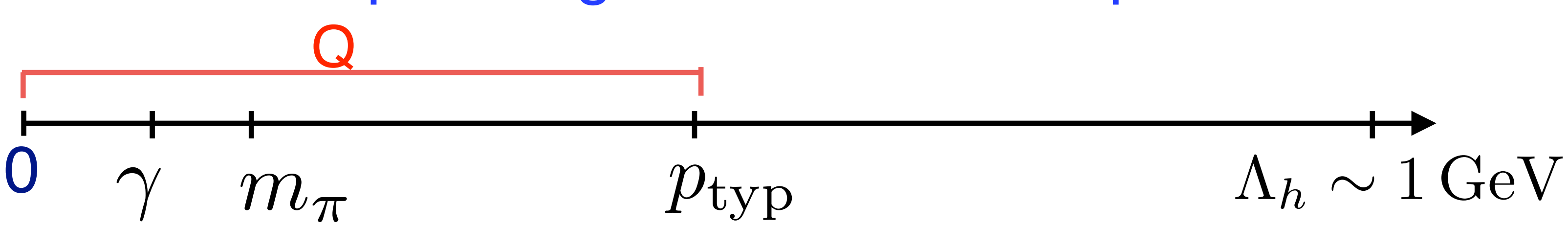
- Similar to nuclear EFT ⇒ deuteron as proton-neutron bound state, …

review: Epelbaum, Hammer, Meißner

- Elastic coupled-channel $B^{(*)}B^* \to B^{(*)}B^*$ potential to a given order in Q/Λ_h

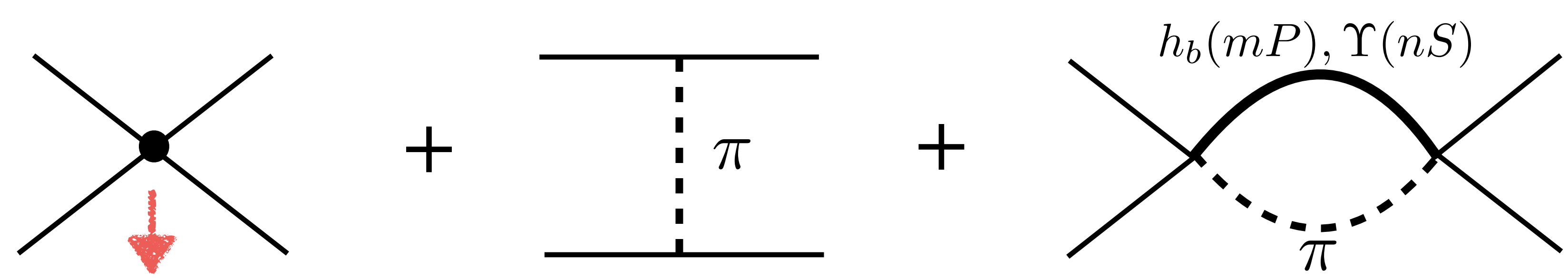
Weinberg power counting: Weinberg (1991)

☛ typical soft scale Q is quite large because of coupled-channels



$p_{\rm typ} = \sqrt{m\,\delta} \simeq 500\ \mathrm{MeV}, \qquad \delta = E^{\rm thr}_{B^*B^*} - E^{\rm thr}_{BB^*} = m_* - m \approx 45\ \mathrm{MeV}$ ~ range of validity

☛ $V^{\rm eff}_{\rm LO} =$



HQSS: 2 S-S wave LECs at O(Q⁰)
1 S-D wave LEC at O(Q²)

Long range: OPE

Imaginary part
from inelastic channels

- Amplitudes: non-perturbative solutions of coupled-channel integral equations

Formalism for line shapes $\Upsilon(10860) \to \pi Z_b^{(\prime)} \to \pi\alpha$

- Input: experimental distributions for

$$\Upsilon(10860) \to \pi Z_b^{(\prime)} \to \pi\alpha \qquad \alpha = BB^*, \quad B^*B^*, \quad h_b(1P)\pi, \quad h_b(2P)\pi$$

and branching fractions for $\alpha = B\bar{B}^*,\ B^*\bar{B}^*,\ h_b(1P)\pi,\ h_b(2P)\pi,\ \Upsilon(1S)\pi,\ \Upsilon(2S)\pi,\ \Upsilon(3S)\pi$

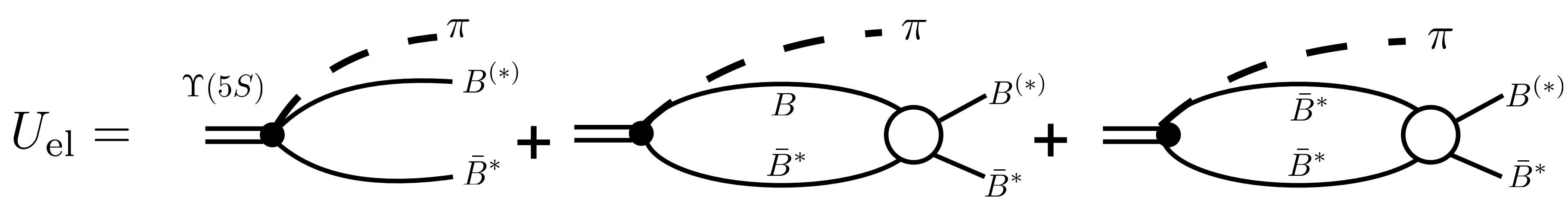
Belle: Bondar et al. (2012), Garmash et al. (2016)

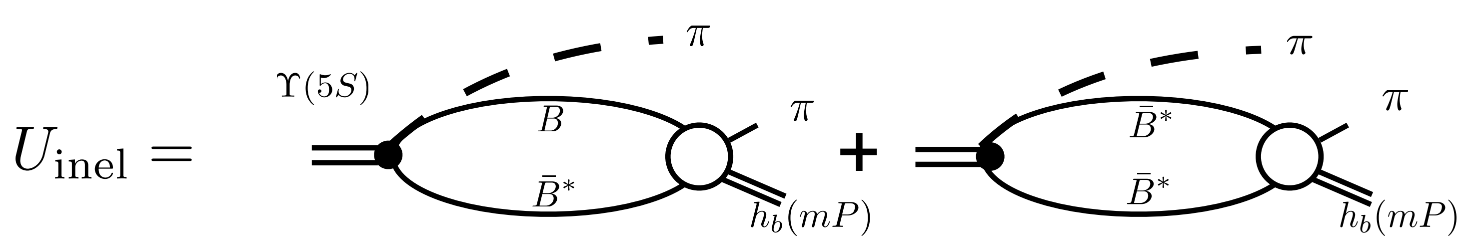
- $\Upsilon(mS)\pi\pi$ distributions not yet included: involve strong $\pi\pi$ FSI (come to this later!)

— Recent calculations for $\Upsilon(3S) \to \Upsilon(1S)\pi\pi,\ \Upsilon(4S) \to \Upsilon(1S, 2S)\pi\pi$

Chen et al. (2016-2017)

Production amplitudes for the events dominated by the Zb's poles:

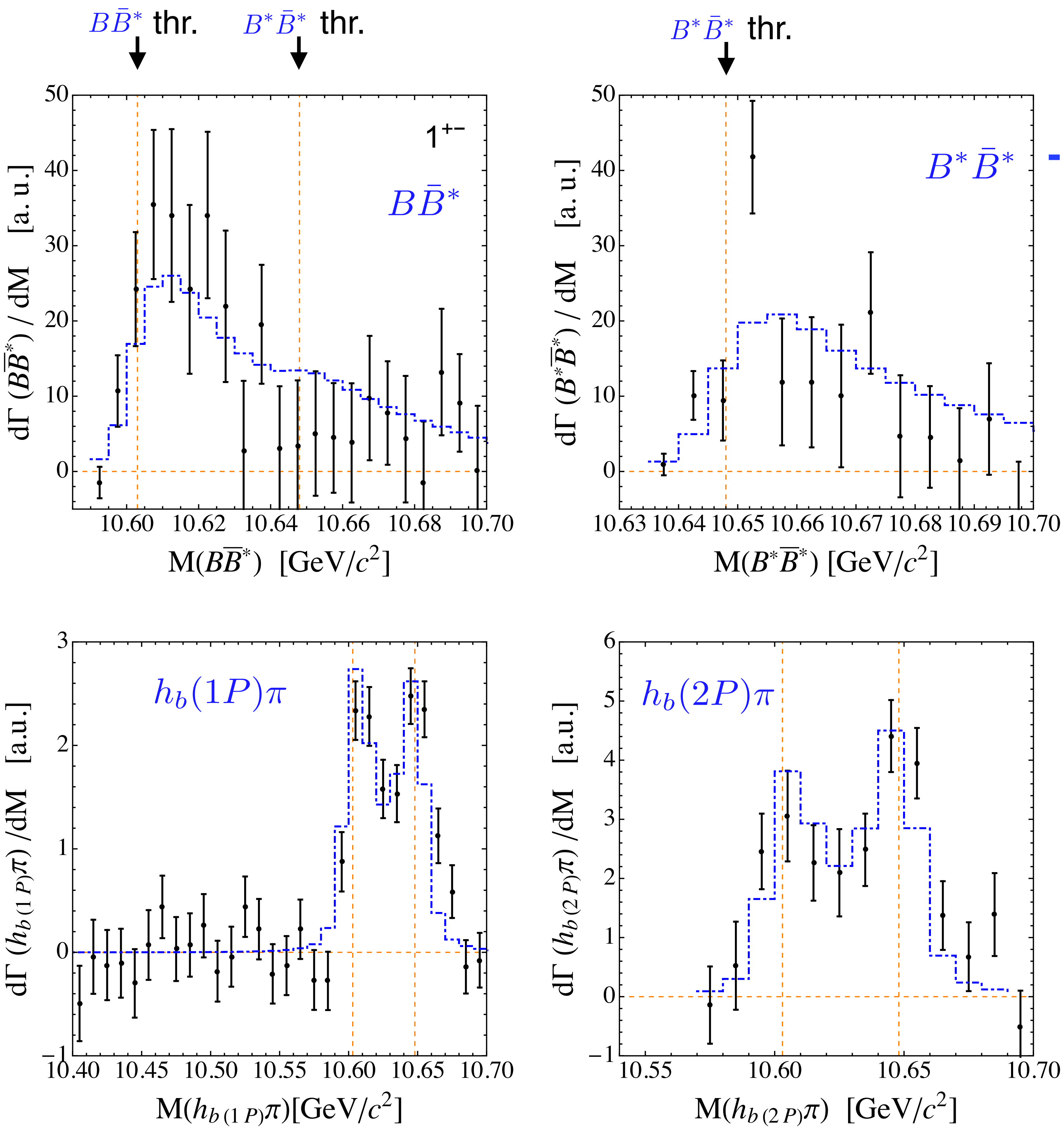




☛ Inelastic source $\Upsilon(5S) \to h_b(nP)\pi\pi$ requires flip in the HQ spin $\Longrightarrow$ suppressed by HQSS

Results: pionless theory at LO

our work:
PRD 98, 074023 (2018)



$$\chi^2 \equiv \frac{\chi^2}{\mathrm{dof.}}$$

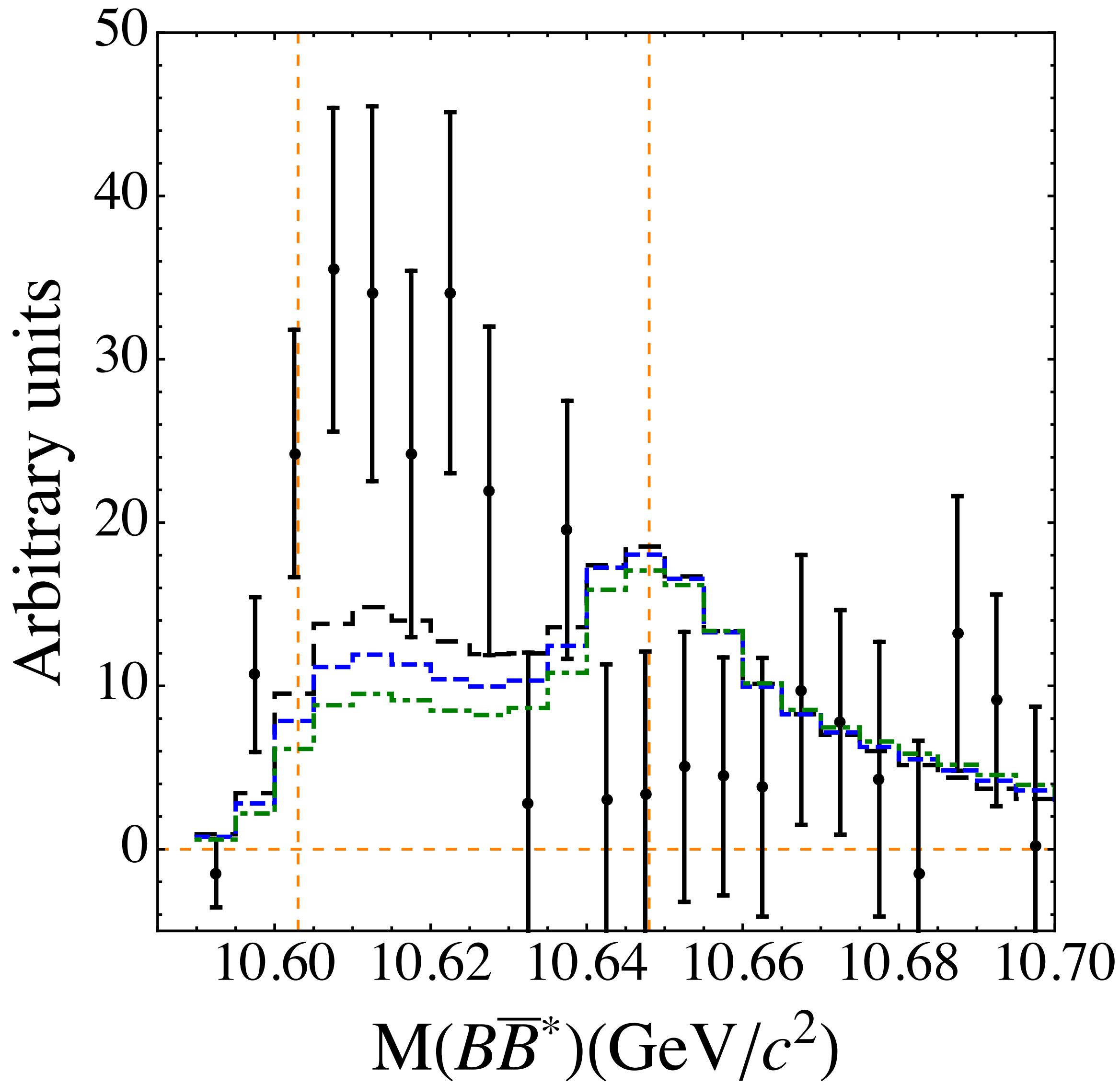
πless: LO CT's χ^2=1.29

— HQSS is preserved in the potentials

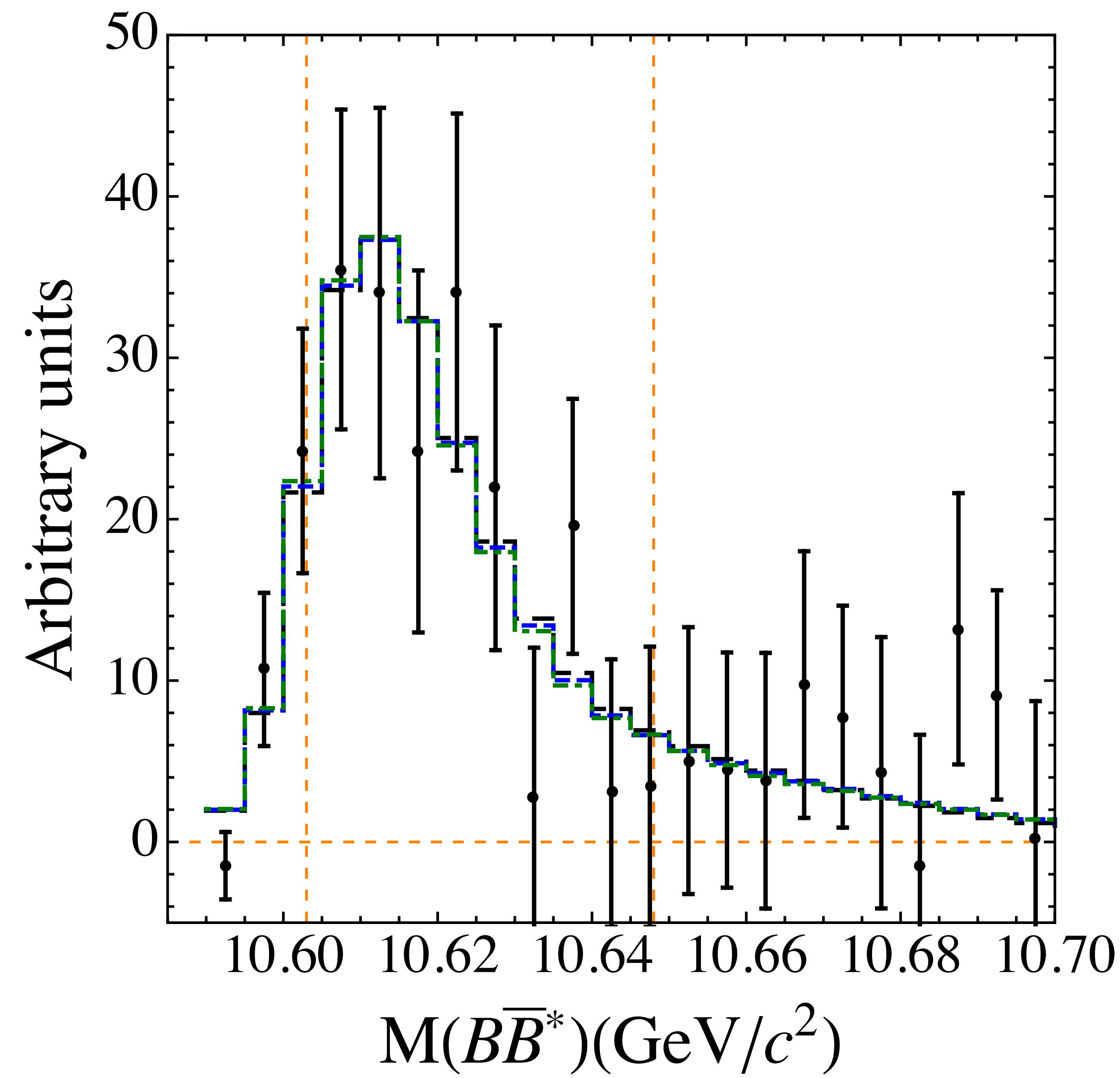
— consistent with the parameterisation by Guo et al. PRD 93, 074031 (2016)

Inclusion of OPE : regulator dependence

we use sharp cutoff $\Lambda \in [0.8 \text{ GeV}, 1.3 \text{ GeV}]$



without the SD contact term

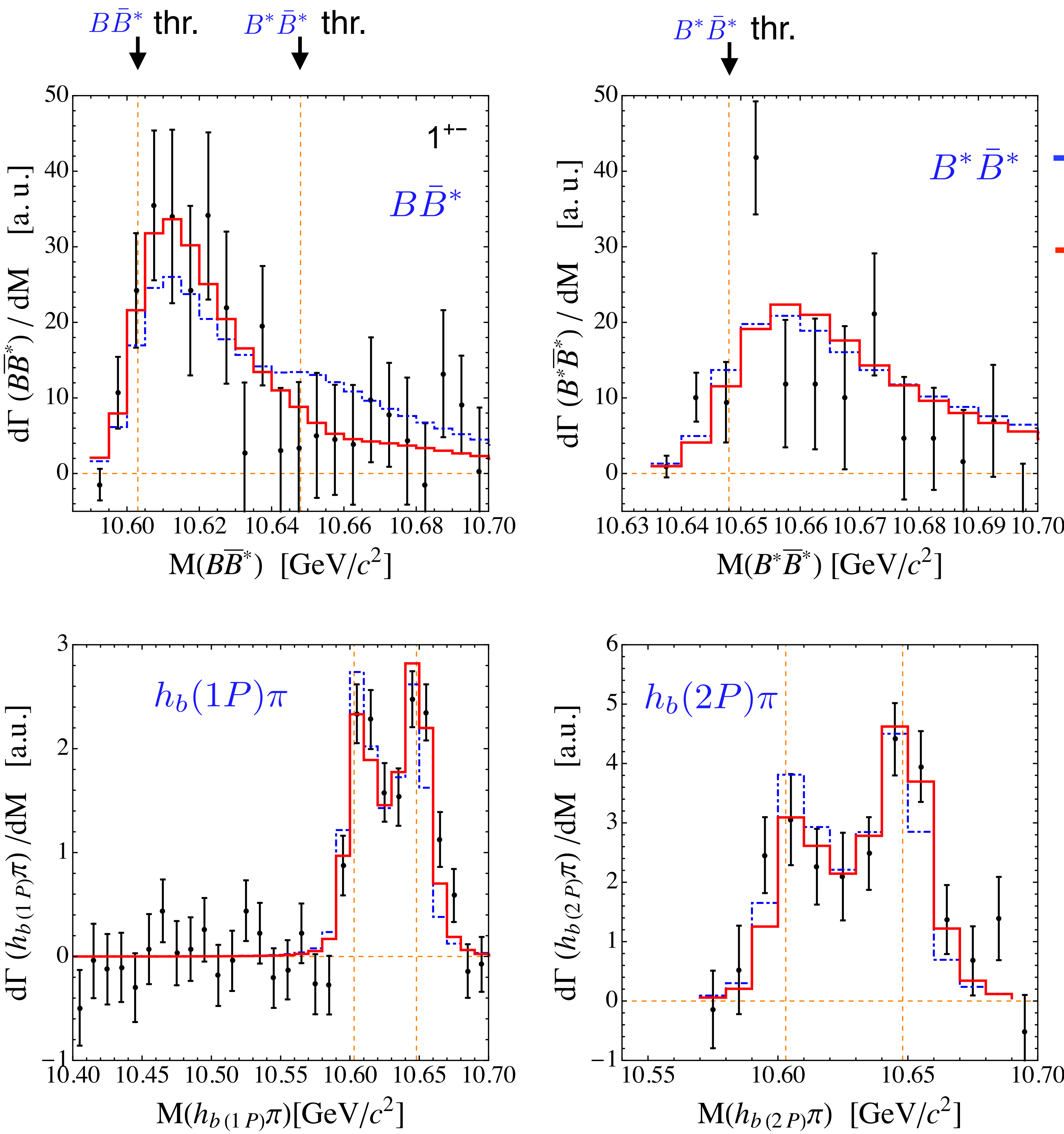


with the SD contact term

- Cutoff independence require S-wave-to-D-wave contact term to appear together with OPE

Results: LO contact terms (CT's) + OPE

our work: PRD 98, 074023 (2018)



$$\chi^2 \equiv \frac{\chi^2}{\text{dof.}}$$

πless: LO CT's χ^2=1.29

πful 1: LO CT's + OPE χ^2=0.95

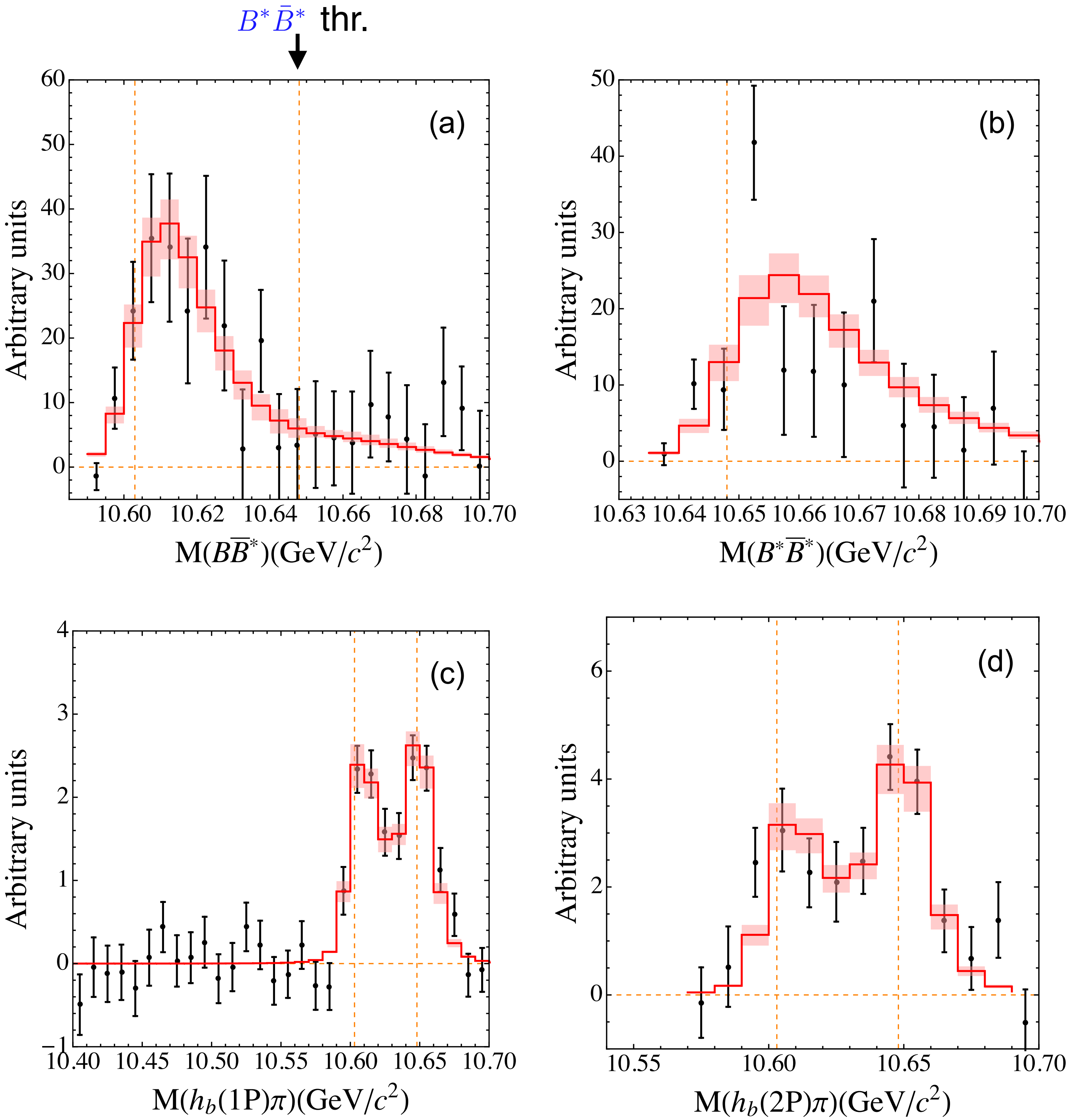
- S-wave central OPE is weak

- S-wave-to-D-wave tensor forces from OPE are important

our work: JHEP 1706, 158 (2017)

Residual effect from OPE results in a quantitative improvement of the fit

Final remarks



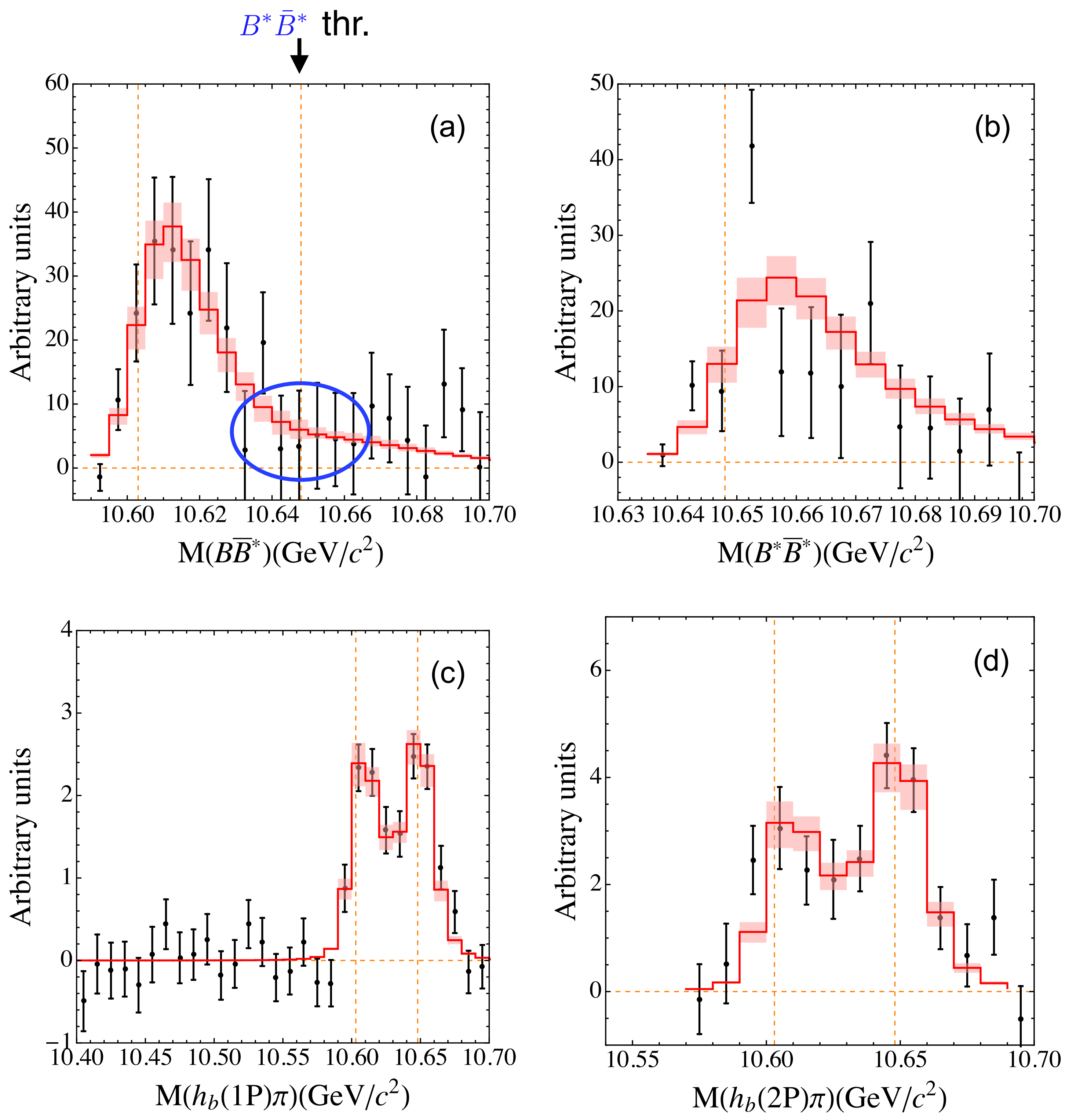
— All LECs are extracted from the best fit including 1σ errors

— Visible effect from OPE

— Natural suppression of higher-order terms

— Data are consistent with HQSS respecting interactions

Final remarks



— All LECs are extracted from the best fit including 1σ errors

— Visible effect from OPE

— Natural suppression of higher-order terms

— Data are consistent with HQSS respecting interactions

— Data: no pronounced coupled-channel structure around B*B* threshold.

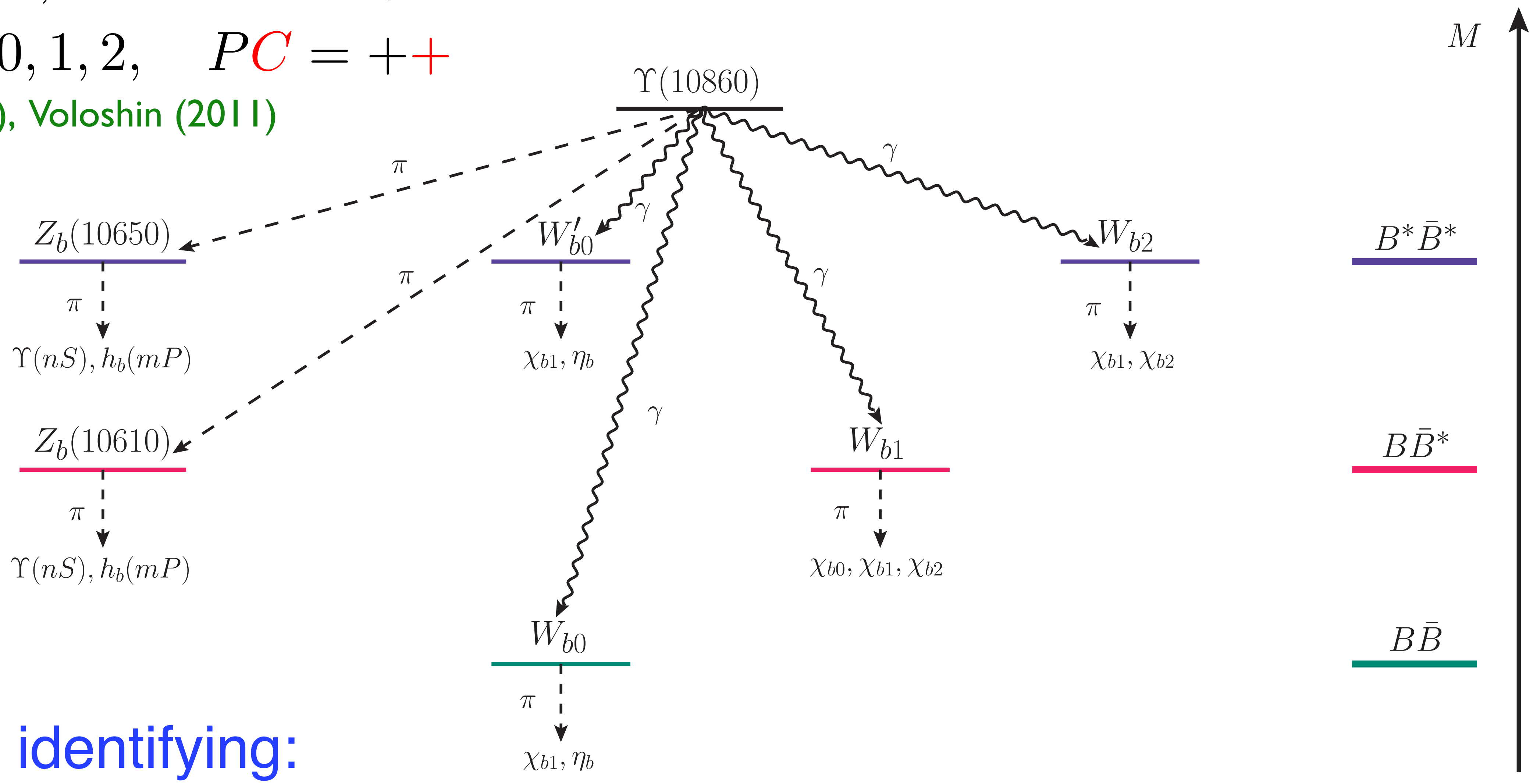
$Z_b(10650) \to B\bar{B}^*$ is suppressed

Applications: spin partners of $Z_b(10610)/Z_b(10650)$

$Z_b^{(\prime)}:\quad J=1,\quad PC=+-$

$W_{bJ}:\quad J=0,1,2,\quad PC=++$

Bondar et al. (2011), Voloshin (2011)



Difficulties in identifying:

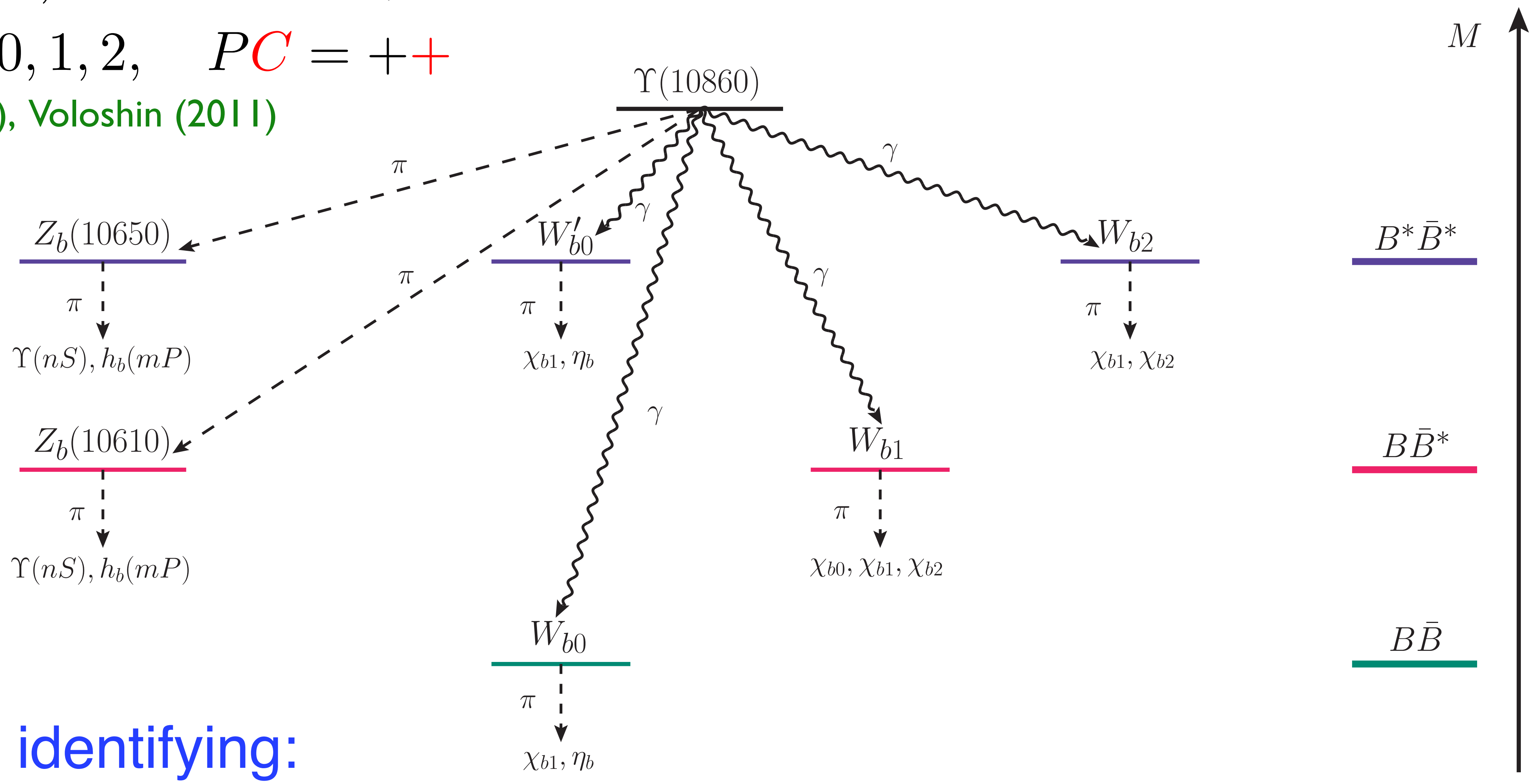
$\Upsilon(10860) \to \gamma W_{bJ} \to \text{final state}$	α=1/137 penalty
$\Upsilon(10860) \to \pi\pi W_{b0} \to \text{final state}$	very limited phase space
$\Upsilon(10860) \not\to \pi\pi W_{b1},\ \pi\pi W_{b0}',\ \pi\pi W_{b2}$	not possible
$\Upsilon(11020) \to \pi\pi W_{bJ} \to \text{final state}$	very limited phase space

Applications: spin partners of $Z_b(10610)/Z_b(10650)$

$$Z_b^{(\prime)}: \quad J=1, \quad PC=+-$$

$$W_{bJ}: \quad J=0,1,2, \quad PC=++$$

Bondar et al. (2011), Voloshin (2011)



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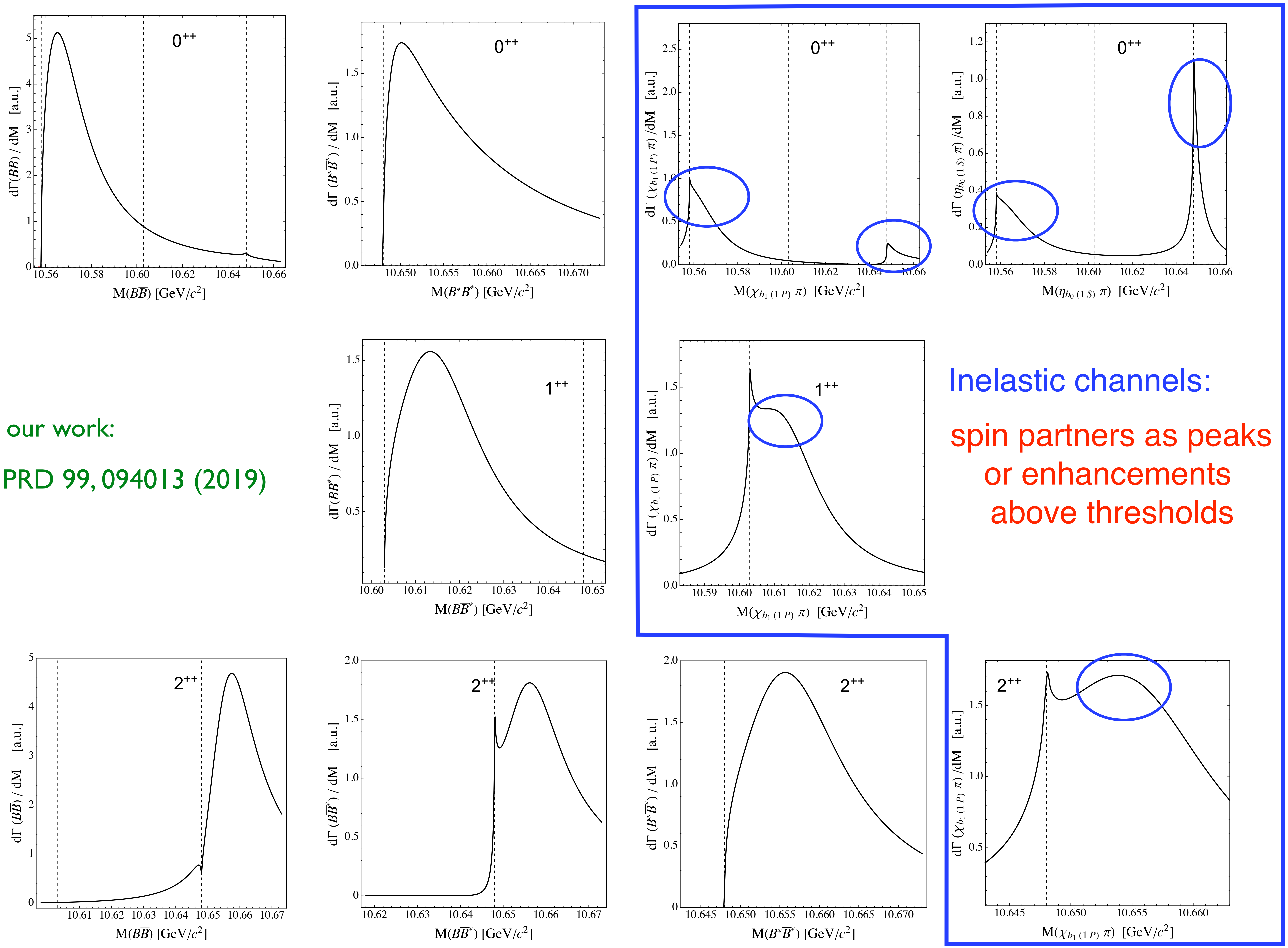
$\Upsilon(10860) \not\to \pi\pi W_{b1},\ \pi\pi W'_{b0},\ \pi\pi W_{b2}$	not possible
$\Upsilon(11020) \to \pi\pi W_{bJ} \to \text{final state}$	very limited phase space

Good news: large statistics by BELLE II!

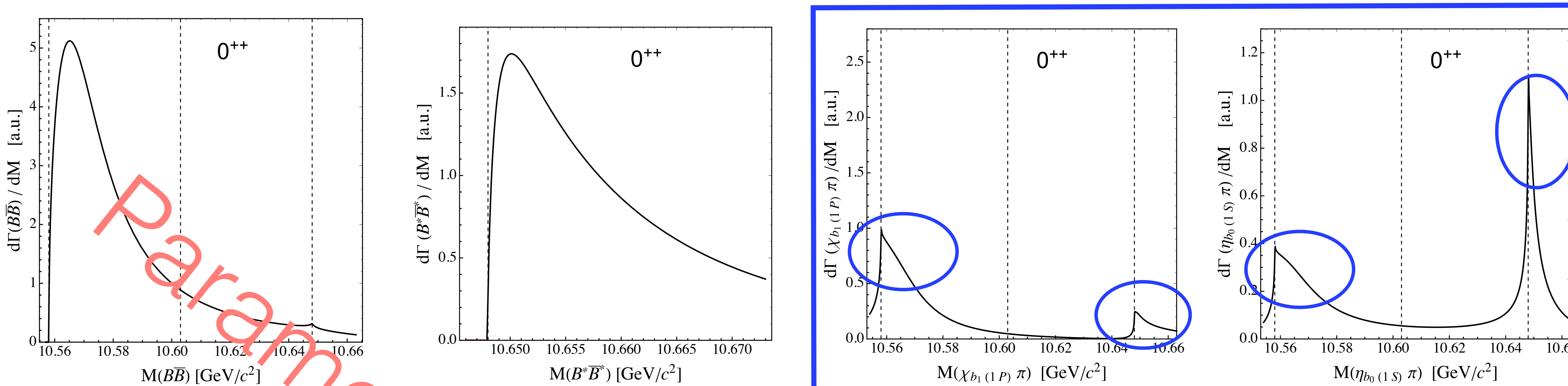
Line shapes for spin partners in $\Upsilon(10860) \to \gamma W_{bJ} \to$ final state



our work:

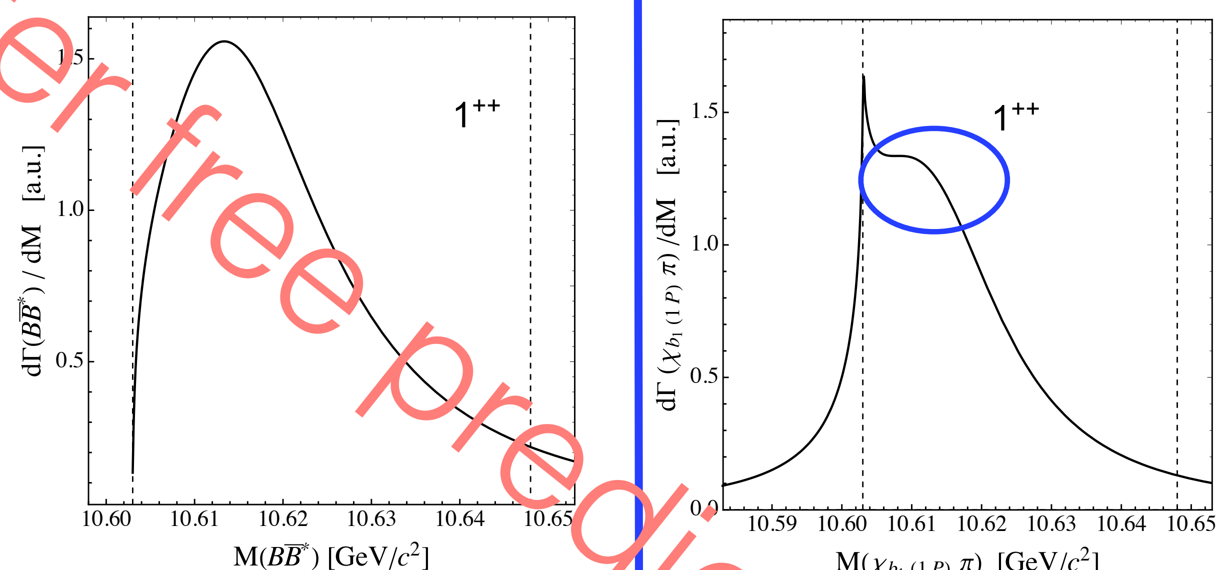
PRD 99, 094013 (2019)

Line shapes for spin partners in $\Upsilon(10860) \to \gamma W_{bJ} \to$ final state



our work:

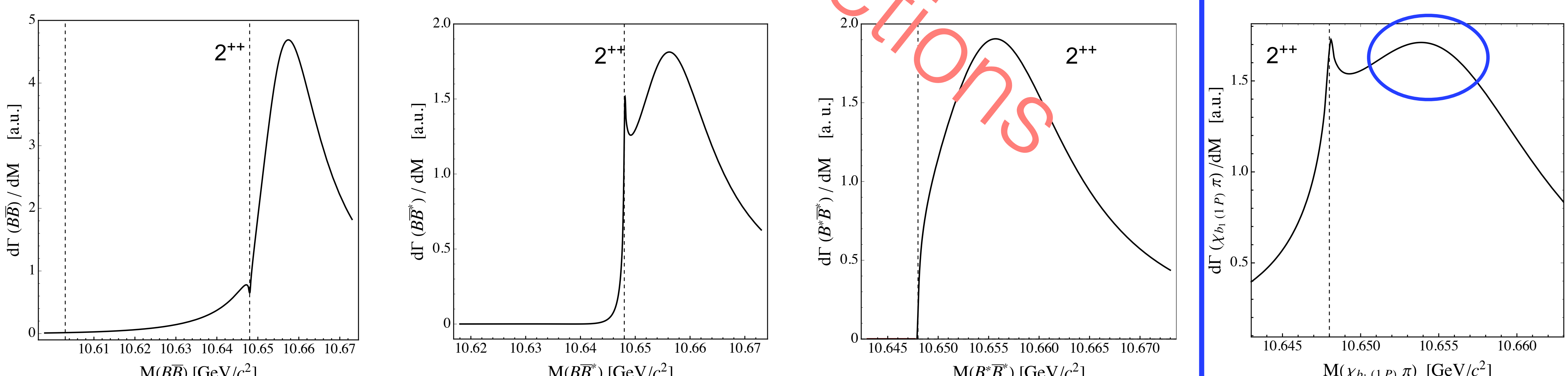
PRD 99, 094013 (2019)



Inelastic channels:

spin partners as peaks or enhancements above thresholds

Parameter free predictions



Pole positions and residues

our work: PRD 99, 094013 (2019)

J^{PC}	State	Threshold	E_B w.r.t. threshold, [MeV]	Residue at pole
1^{+-}	Z_b	$B\bar{B}^*$	$(-2.3 \pm 0.5) - i(1.1 \pm 0.1)$	$(-1.2 \pm 0.2) + i(0.3 \pm 0.2)$
1^{+-}	Z_b'	$B^*\bar{B}^*$	$(1.8 \pm 2.0) - i(13.6 \pm 3.1)$	$(1.5 \pm 0.2) - i(0.6 \pm 0.3)$
0^{++}	W_{b0}	$B\bar{B}$	$(2.3 \pm 4.2) - i(16.0 \pm 2.6)$	$(1.7 \pm 0.6) - i(1.7 \pm 0.5)$
0^{++}	W_{b0}'	$B^*\bar{B}^*$	$(-1.3 \pm 0.4) - i(1.7 \pm 0.5)$	$(-0.9 \pm 0.3) - i(0.3 \pm 0.2)$
1^{++}	W_{b1}	$B\bar{B}^*$	$(10.2 \pm 2.5) - i(15.3 \pm 3.2)$	$(1.3 \pm 0.2) - i(0.4 \pm 0.2)$
2^{++}	W_{b2}	$B^*\bar{B}^*$	$(7.4 \pm 2.8) - i(9.9 \pm 2.2)$	$(0.7 \pm 0.1) - i(0.3 \pm 0.1)$

All Z_b's and W_{bJ}'s are:

- virtual states in a scheme with just $O(Q^0)$ contact interactions
- resonances in a scheme when OPE is included

Conclusion: Z_b's and W_{bJ}'s are consistent with molecular scenario

Insights into the nature of the Zb and Zb'
from $\Upsilon(10860) \to \Upsilon(nS)\ \pi^+\pi^-$ (n=1,2,3)

arXiv: hep-ph 2012.05034 10.12.2020

VB, E.Epelbaum, A.A.Filin, C.Hanhart, R.V. Mizuk, A.Nefediev, and S. Ropertz

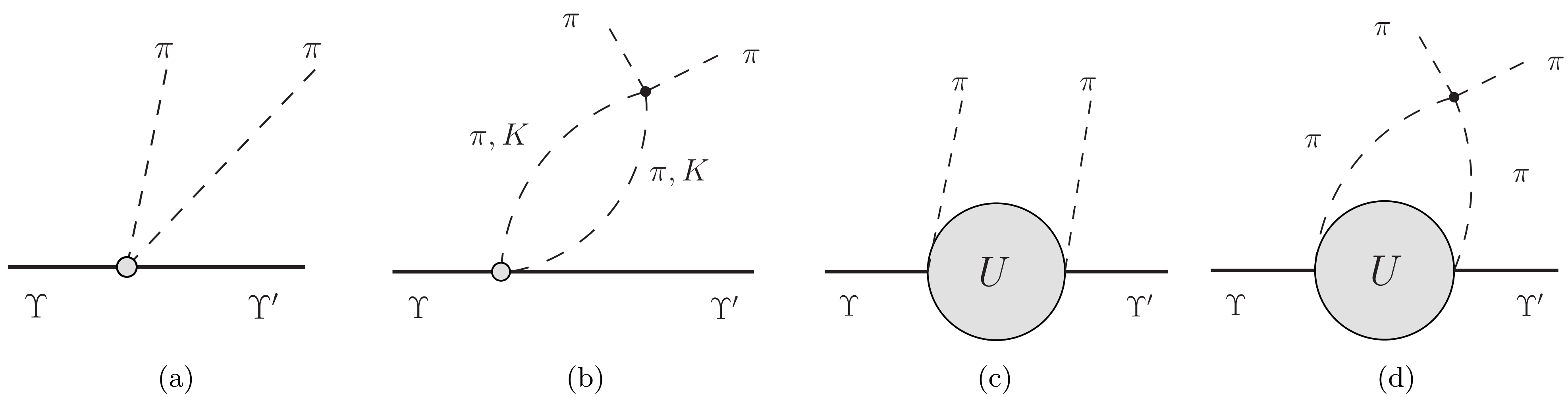
$\Upsilon(10860) \to \Upsilon(nS)\ \pi^+\pi^-$: Goals

VB, E. Epelbaum, A.A.Filin, C.Hanhart, R.V. Mizuk, A.Nefediev, and S. Ropertz hep-ph 2012.05034

— High-statistic data by Belle

— A significant nonresonant contribution from the $\pi\pi$ system ⇒ Dalitz plot analysis

- Production: contact (a-b) and coupled-channel via B-meson loops (c-d) formulated above



Employ U from a simple but realistic contact scheme

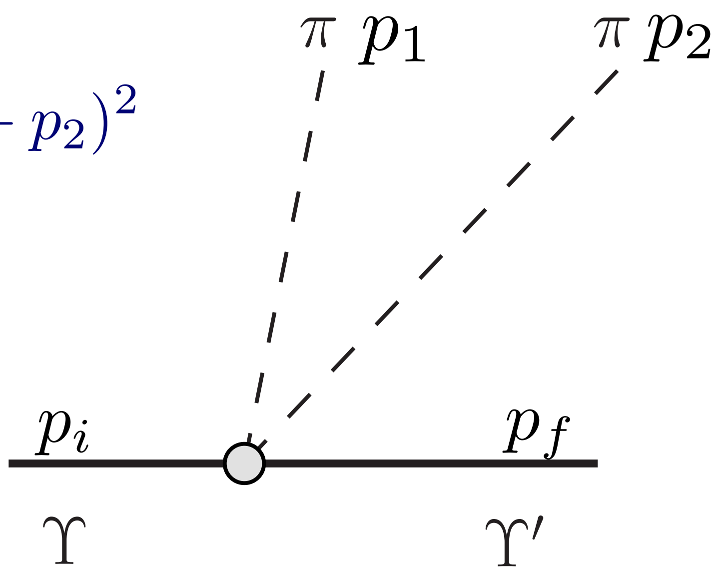
- Dispersive approach to account for the $\pi\pi$-KK final-state interaction (FSI),

  KK component is especially important for $\Upsilon(1S)$

- Dalitz plot analysis of Belle data

- Check consistency with previous results

Kinematics for $\Upsilon(10860) \to \pi^+\pi^-\Upsilon(nS)$



Mandelstam variables: $s = (p_1 + p_2)^2, \quad t = (p_f + p_1)^2, \quad u = (p_f + p_2)^2$

$$s + t + u = m_i^2 + m_f^2 + 2m_\pi^2$$

$$p_i^2 = m_i^2, \quad p_f^2 = m_f^2, \quad p_1^2 = p_2^2 = m_\pi^2$$

Kinematical relations:

$$t(s,z) = \frac{1}{2}(m_i^2 + m_f^2 + 2m_\pi^2 - s) + \frac{1}{2}k(s)z$$

$$u(s,z) = \frac{1}{2}(m_i^2 + m_f^2 + 2m_\pi^2 - s) - \frac{1}{2}k(s)z$$

$$z \equiv \cos\theta = \hat{\vec{p}}_1 \cdot \hat{\vec{p}}_f$$

helicity angle

$$k(s) = \frac{1}{s}\sqrt{\lambda(s, m_i^2, m_f^2)\,\lambda(s, m_\pi^2, m_\pi^2)}$$

λ - Källen triangle function

Production amplitude:

$$\boxed{M^{\text{full}} = M(s,t,u)\;\boldsymbol{\varepsilon}_{\Upsilon(10860)} \cdot \boldsymbol{\varepsilon}^*_{\Upsilon(nS)}}$$

Double differential production rate:

$$\boxed{\frac{d^2\mathrm{Br}}{ds\,dt} = \mathcal{N}\,|M(s,t,u)|^2}$$

$\mathcal{N}$ - overall normalization

Dispersion relations for $\pi\pi$-KK FSI

S-wave projection: $$M_0(s) = \frac{1}{2}\int_{-1}^{+1} dz\, M(s,t,u) \equiv M_0^L + M_0^R$$

Left-hand cut piece

Right-hand cut piece with FSI

Dispersive reconstruction of $\hat{M}_0^R(s)$ via $\hat{M}_0^L(s)$

$$\hat{M}_0(s) = \hat{M}_0^L(s) + \frac{\hat{\Omega}_0(s)}{\pi}\int_{4m_\pi^2}^{\infty} ds' \frac{\hat{\Omega}_0^{-1}(s')\hat{T}(s')\hat{\sigma}(s')\hat{M}_0^L(s')}{s'-s-i0}$$

$\pi\pi$-KK scattering amplitude: $$\hat{T}(s) = \begin{pmatrix} T_{\pi\pi\to\pi\pi} & T_{\pi\pi\to K\bar{K}} \\ T_{K\bar{K}\to\pi\pi} & T_{K\bar{K}\to K\bar{K}} \end{pmatrix} = \begin{pmatrix} \frac{\eta e^{2i\delta}-1}{2i\sigma_\pi} & g e^{i\psi} \\ g e^{i\psi} & \frac{\eta e^{2i(\psi-\delta)}-1}{2i\sigma_K} \end{pmatrix}$$

R. Garcia-Martin et al.,PRD83, 074004 (2011), I. Caprini et al., EPJC72, 1860 (2012), P. Buettiker et al., EPJC33, 409 (2004), L.Y.Dai et al., PRD90, 036004 (2014).

multichannel Omnès function: $$\hat{\Omega}_0(s) = \frac{1}{\pi}\int_{4m_\pi^2}^{\infty} ds' \frac{\hat{T}^*(s')\hat{\sigma}(s)\hat{\Omega}_0(s')}{s'-s-i0}$$

$$\hat{\sigma}(s) = \mathrm{diag}\{\sigma_\pi, \sigma_K\}$$

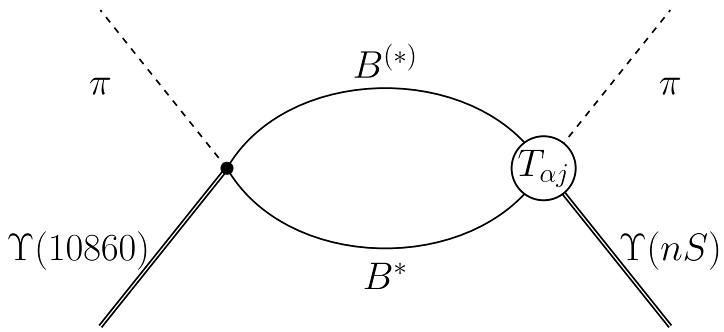
$$\sigma_P(s) = \sqrt{1 - s_P^{\mathrm{th}}/s}$$

$$P = \pi, K$$

Production via $\pi\pi$ mode: $$\hat{M}_0^L = \left([M_0^L]_{\pi\pi}, 0\right)^T$$

Left-hand cut production amplitude

$$M^L(t,u) =$$



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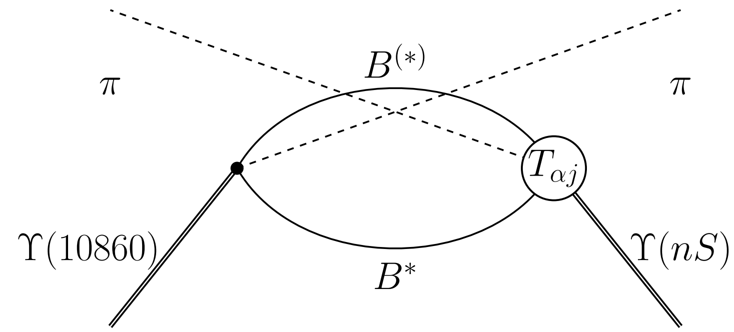


☛ $Z_b(10610)/Z_b(10650)$ are poles in the coupled-channel amplitudes

$$M^L(t,u) = U(t) + U(u) = -\frac{1}{\pi}\int_{(m_\pi+m_{\Upsilon(1S)})^2}^{\infty} d\mu^2\, \mathrm{Im}\, U(\mu^2)\left(\frac{1}{t-\mu^2}+\frac{1}{u-\mu^2}\right) \xrightarrow{\text{S-wave}} M_0^L(s)$$

$$M^L_{0,\mathrm{stable}}(s;\mu) = \frac{1}{2}\int dz\left(\frac{1}{t-\mu^2}+\frac{1}{u-\mu^2}\right) \equiv \left(-\frac{2}{\sigma_\pi(s)}\right)\frac{\mathrm{Disc}\, C_0(s)}{2\pi i}$$

$$C_0(s,\mu) \equiv C_0(m_i^2, s, m_f^2, \mu^2, m_\pi^2, m_\pi^2)$$

—standard scalar loop function

— Take care about anomalous thresholds

- $C_0(s,\mu)$ is an analytic function of μ only if anomalous contributions (AC) are included from the brach point of the Logarithm

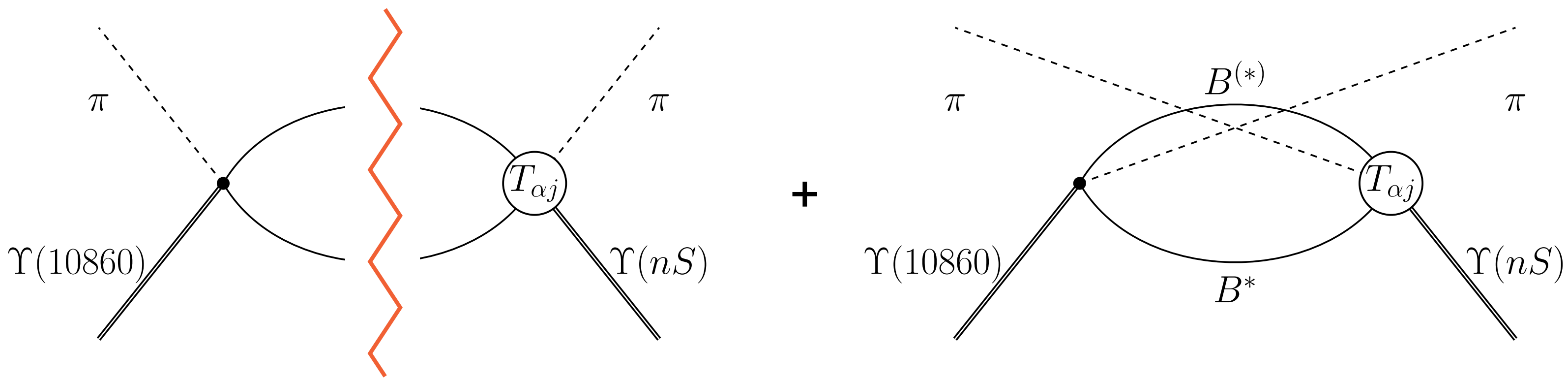
AC emerges if $\mu^2 < \mu^2_{\mathrm{crit}} \equiv \frac{1}{2}(m_f^2 + m_i^2) - m_\pi^2$

For Υ(3S): $\mu_{\mathrm{crit}} = 10.6097\,\mathrm{GeV}$

very close to $Z_b(10610)$ pole

Left-hand cut production amplitude

$M^L(t,u) =$



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$C_0(s,\mu) \equiv C_0(m_i^2, s, m_f^2, \mu^2, m_\pi^2, m_\pi^2)$ — standard scalar loop function

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AC emerges if $\mu^2 < \mu^2_{\mathrm{crit}} \equiv \frac{1}{2}(m_f^2 + m_i^2) - m_\pi^2$ For ϒ(3S): $\mu_{\mathrm{crit}} = 10.6097\,\mathrm{GeV}$ very close to $Z_b(10610)$ pole

— $\mathrm{Im}\, M_0^L(s)$: Leading contribution is from the $B^{(*)}\bar{B}^*$ cuts, these states can be on shell subleading one— from inelastic channels

Subtractions and matching to chiral contact amplitudes

$$\hat{M}_0(s) = \hat{M}_0^L(s) + \frac{\hat{\Omega}_0(s)}{\pi} \int_{4m_\pi^2}^{\infty} ds' \frac{\hat{\Omega}_0^{-1}(s') \hat{T}(s') \hat{\sigma}(s') \hat{M}_0^L(s')}{s' - s - i0}$$

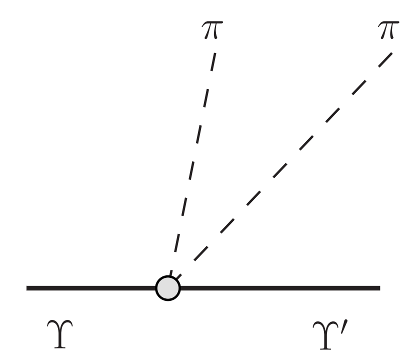
— Dispersive Integral is convergent but details of $\pi\pi$ at large s are known badly

$\Longrightarrow$ 2 subtractions with real coefficients

— matching to chiral expansion

$$\mathcal{L}_{\Upsilon\Upsilon'\Phi\Phi} = \frac{c_1}{2} \langle J^\dagger J' \rangle \langle u_\mu u^\mu \rangle + \frac{c_2}{2} \langle J^\dagger J' \rangle \langle u_\mu u_\nu \rangle v^\mu v^\nu + \text{h.c.}$$

$$J = \boldsymbol{\Upsilon} \cdot \boldsymbol{\sigma} + \eta_b$$



$$u_\mu = i \left(u^\dagger \partial_\mu u - u \partial_\mu u^\dagger \right) \qquad u = \exp\left(\frac{i\Phi}{\sqrt{2} f} \right)$$

$$\Phi = \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta_8 & \pi^+ & K^+ \\ \pi^- & -\frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta_8 & K^0 \\ K^- & \bar{K}^0 & -\frac{2}{\sqrt{6}}\eta_8 \end{pmatrix}$$

$$\Longrightarrow \quad \boxed{\hat{M}_0^\chi(s) = \left(M_0^{\chi,\pi\pi}(s), \frac{2}{\sqrt{3}} M_0^{\chi,KK}(s) \right)^T}$$

$$\boxed{M_0^{\chi,PP}(s) = -\frac{2}{f_P^2} \sqrt{m_\Upsilon m_{\Upsilon'}} \left\{ c_1 \left(s - 2m_P^2 \right) + \frac{c_2}{2} \left[s + q^2 \left(1 - \frac{\sigma_P^2(s)}{3} \right) \right] \right\}}$$

Chen et al. PRD93, 034030 (2016), PRD95, 034022 (2017)

Final results for $M(s,t,u)$

$$M(s,t,u) = \underbrace{M^L(t,u)}_{\substack{\text{coupled-channel} \\ \text{production amplitude,} \\ \text{contains all partial waves}}} + \hat{\Omega}_0(s)\left(\underbrace{\hat{M}_0^{\chi,\pi\pi}(s)}_{\substack{\text{chiral contact} \\ \text{term}}} + \underbrace{\hat{\tilde{I}}_0^{(2)}(s)}_{\substack{\text{dispersive} \\ \text{integral}}}\right) + \underbrace{\Omega_2(s)M_2^{\chi,\pi\pi}(s)}_{\text{D-wave contribution}}P_2(z)$$

$$\hat{\tilde{I}}_0^{(2)}(s) = \frac{s^2}{\pi}\int_{4m_\pi^2}^{\infty}\frac{ds'}{s'^2}\frac{\hat{\Omega}_0^{-1}(s')\hat{T}(s')\hat{\sigma}(s')\mathrm{Re}M_s^L(s')}{s'-s-i0} + \frac{i}{\pi}\int_{4m_\pi^2}^{\infty}ds'\frac{\hat{\Omega}_0^{-1}(s')\hat{T}(s')\hat{\sigma}(s')\mathrm{Im}M_s^L(s')}{s'-s-i0} + \hat{I}_0^{\mathrm{anom}}(s)$$

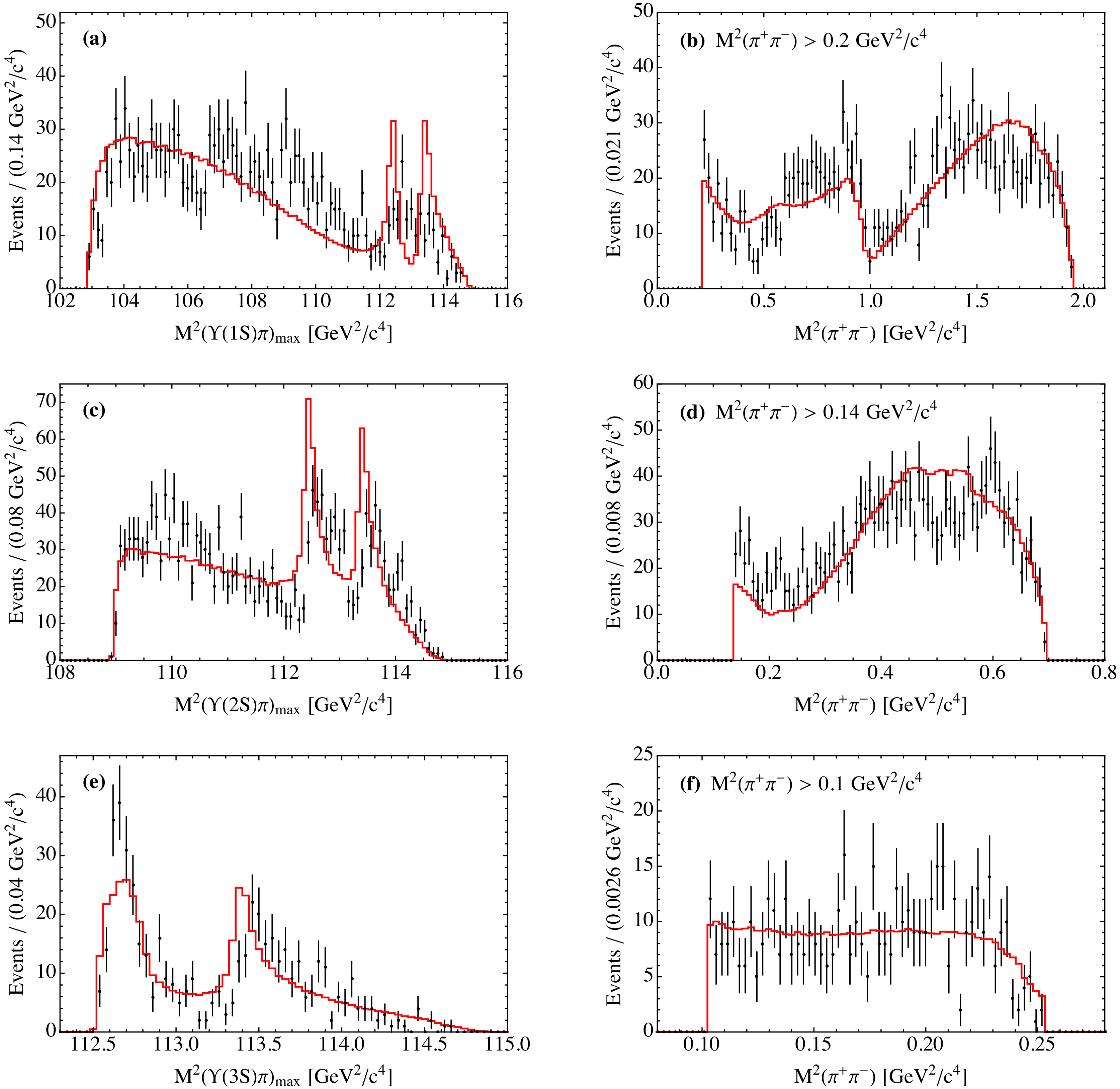
- All the parameters from a coupled-channel approach in $M^L(t,u)$ fixed from data to the decays

  $\Upsilon(10860) \to \pi Z_b^{(\prime)} \to \pi B^{(*)}\bar{B}^*$ and $\Upsilon(10860) \to \pi Z_b^{(\prime)} \to \pi\pi h_b(mP)$

- Correct for efficiency and resolution in $M(\pi\Upsilon(nS))^2$, add coherent experimental background and make maximum likelihood fits to Dalitz plot

- Parameters in the fits: overall normalization $\mathcal{N}$ and chiral LECs c1 and c2

Results for $M(\pi\Upsilon(nS))^2$ and $M(\pi\pi)^2$ projections



$\Upsilon(1S)$ and $\Upsilon(2S)$

☛ $\pi\pi$-KK FSI very important

Key contribution to:

— right shoulder in $M(\pi\pi)^2$

— left shoulder in $M(\pi\Upsilon(nS))^2$ n=1,2

— dip region ~1 GeV in $M(\pi\pi)^2$

$\Upsilon(3S)$

☛ Completely dominated by $M^L(t,u)$ = $U(t)+U(u)$

☛ $\pi\pi$ FSI is not important

☛ Very reasonable overall description

☛ Peaks of the Z_b's, consistent with $B^{(*)}B^*$ and $\pi\pi h_b(mP)$, are not exactly in accord with $\pi\Upsilon$(nS)

Summary

- Line shapes in *c* and *b*-sectors can be systematically analysed within an EFT approach consistent with chiral and heavy quark symmetries, analyticity and unitarity

- We analyse the line shapes $\Upsilon(10860) \to \pi Z_b^{(\prime)} \to \pi\alpha \implies$ poles and residues of the $Z_b^{(\prime)}$

- Line shapes for spin partners of $Z_b^{(\prime)}$ states and their poles are predicted parameter free
$\implies$ W_{bJ} can be searched for at Belle II

—A similar analysis of the LHCb P_c states from $\Lambda_b \to K\, P_c \to K\, J/\Psi\, p$

Talk by Meng-Lin Du on Thursday

- The Dalitz plot analysis of $\Upsilon(10860) \to \pi Z_b^{(\prime)} \to \pi\pi\Upsilon(nS)$ including $\pi\pi$-KK FSI yields very reasonable results with all parameters from $Z_b^{(\prime)}$ fixed

$\implies$ Strong evidence that the line shapes relevant for $Z_b^{(\prime)}$ states can be understood within a molecular scenario!

Next step: A combined analysis of all channels within the same framework