Study of properties of $\Upsilon(10753)$ on Belle II experiment

第七届强子谱与强子结构会议

殷俊昊
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35 new hadrons found at Belle
Mass [GeV/c²]
11.0
10.0
9.0
5.0
4.0
3.0
2.0
1.0
2005
2010
2015
2020
Z_b(10650)^+
Z_b(10610)^+
Z_b(10610)^0
h_b(2P)
h_b(1P)
η_b(2S)
ϒ(10753)
ψ(4660)
Zc(4430)^+
ψ(4360)
X(4350)
Zc(4250)^+
Zc(4050)+
Zc(3900)^+
Zc(4200)^+
ψ_2(3823)
X*(3860)
χ_c0(3915)
X(3940)
χ_c1(3872)
X(4160)
η_c(2S)
χ_c2(2P)
D*(3350)
Ξc(3080)^0
Ξc(3080)^+
Ξc(2970)^+
Σc(2800)^0
Σc(2800)^++
Σc(2800)^+
D_0*(2300)
Λc(2910)^+
Ω*−(2012)
Σ*+(1430)
Σ*−(1430)
bb̄ (qq̄)
bq̄
cc̄(qq̄)
cc̄cc̄
cq̄
cq̄qq̄
bqq
cqq
cc̄qqq


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Zb(10650)+
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χc0(3915)
X(3940)
X(4160)
Zc(3900)+
ψ2(3823)
X*(3860)
χc1(3872)
ηc(2S)
χc2(2P)
D*(3350)
Ξc(3080)0
Ξc(3080)+
Ξc(2970)+
Σc(2800)0
Σc(2800)++
Σc(2800)+
Λc(2910)+
D0*(2300)
Ω*−(2012)
Σ*+(1430)
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bb̄(qq̄)
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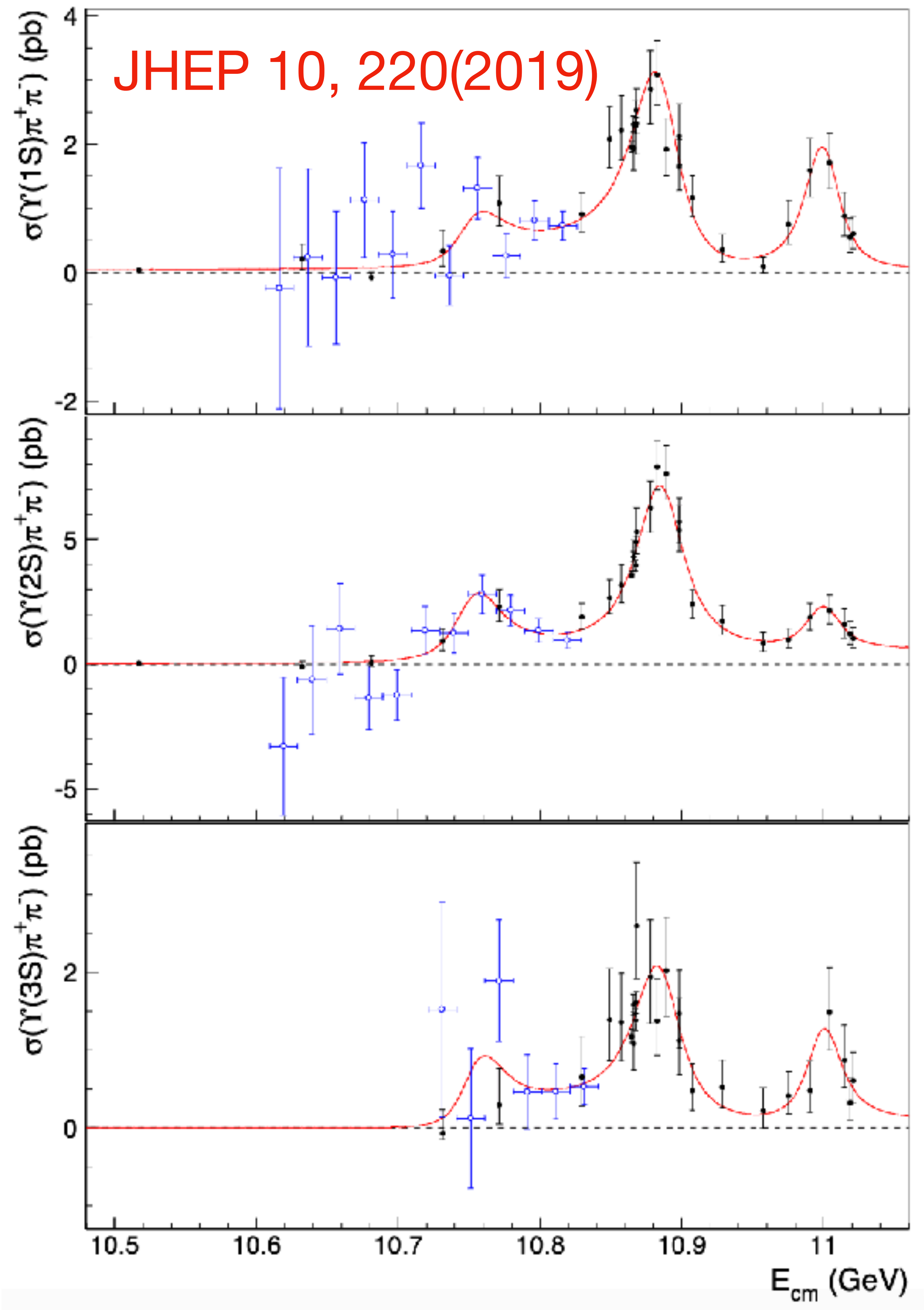
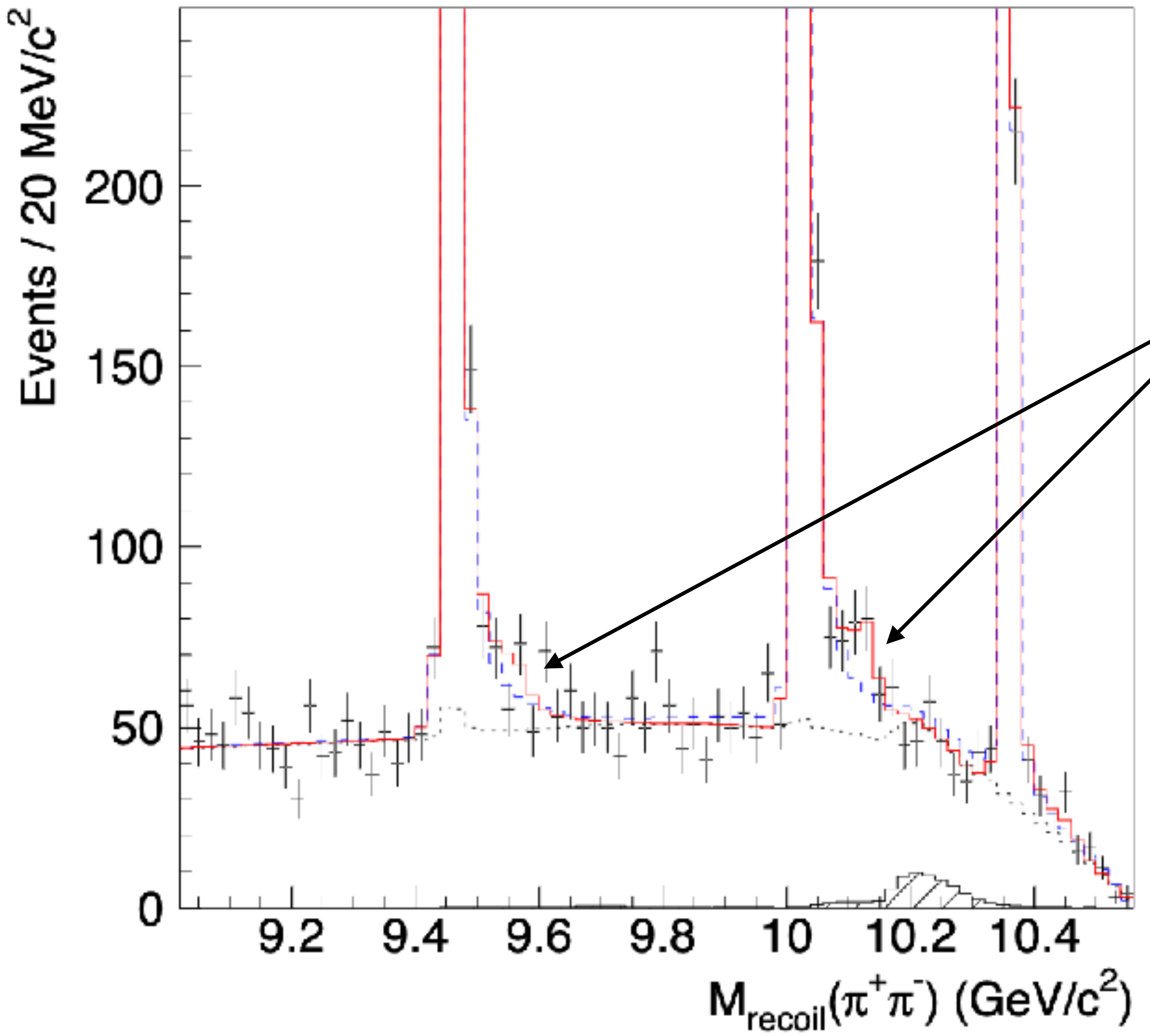
cc̄(qq̄)
cc̄cc̄
cq̄
cq̄qq̄
bqq
cqq
cc̄qq

$\Upsilon(10753)$ — discovery and studies



- The $\Upsilon(10753)$ was firstly observed in the process of $e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-(n = 1,2,3)$ by Belle.

- Simultaneous fit to cross sections and $M_{\rm recoil}(\pi\pi)$

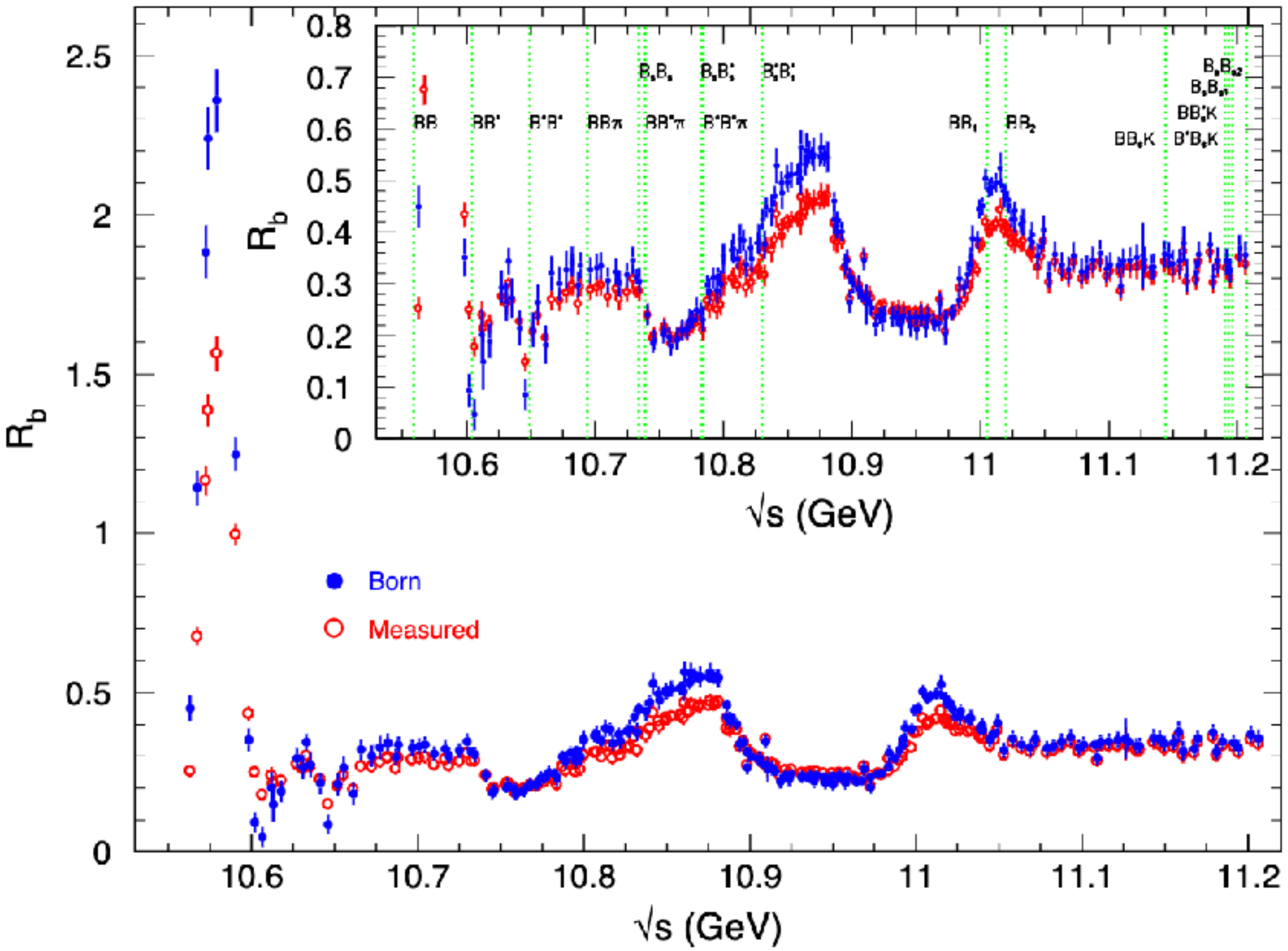


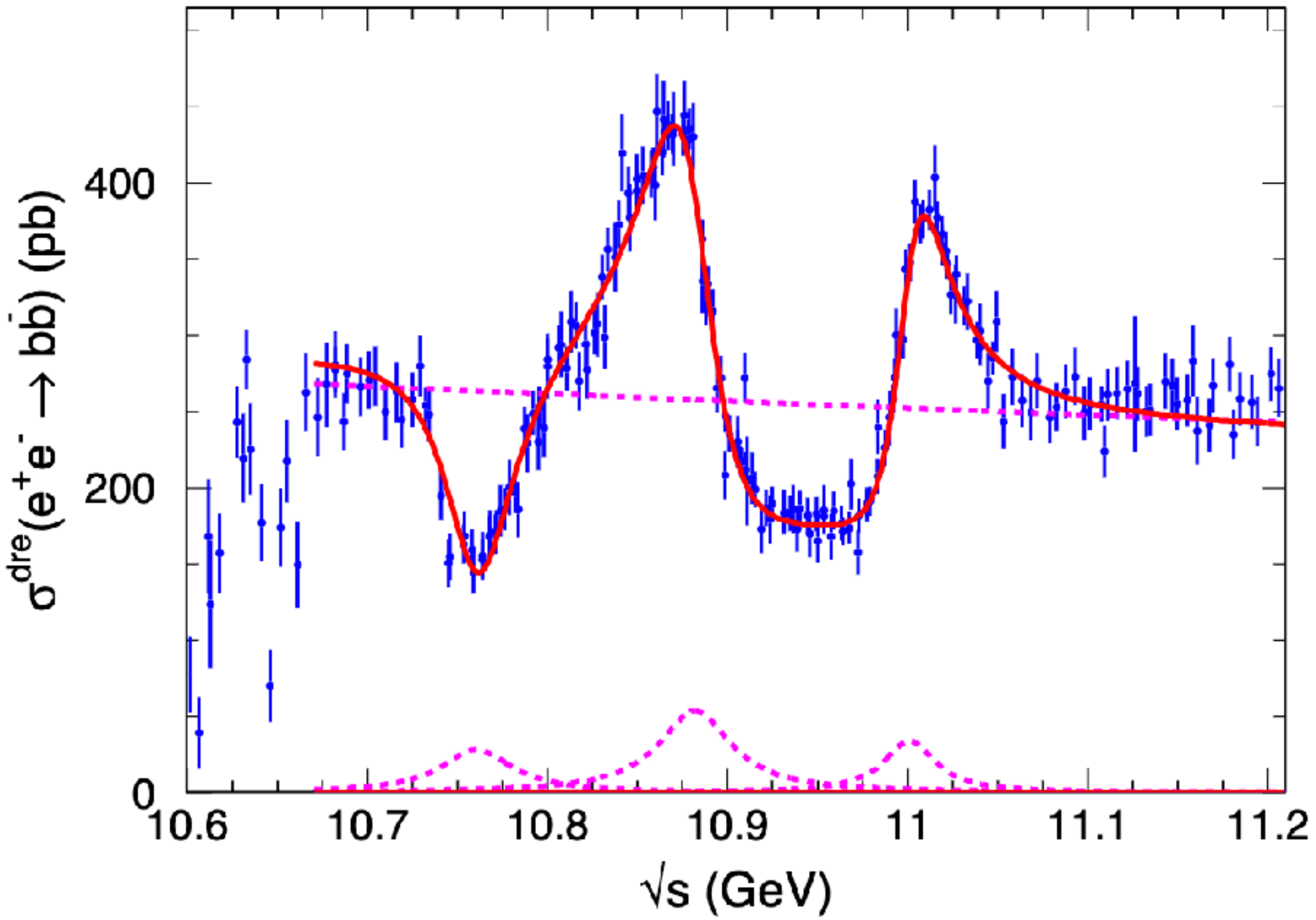
Existence of $\Upsilon(10753)$

Computed as blue dots in left plot

$M = (10752.7 \pm 5.9^{+0.7}_{-1.1})\ {\rm MeV}/c^2$

$\Gamma = (35.5^{+17.6}_{-11.3}\ {}^{+3.9}_{-3.3})\ {\rm MeV}$





$M = (10761 \pm 2)\ \mathrm{MeV}/c^2$

$\Gamma = (48.5 \pm 3.0)\ \mathrm{MeV}$

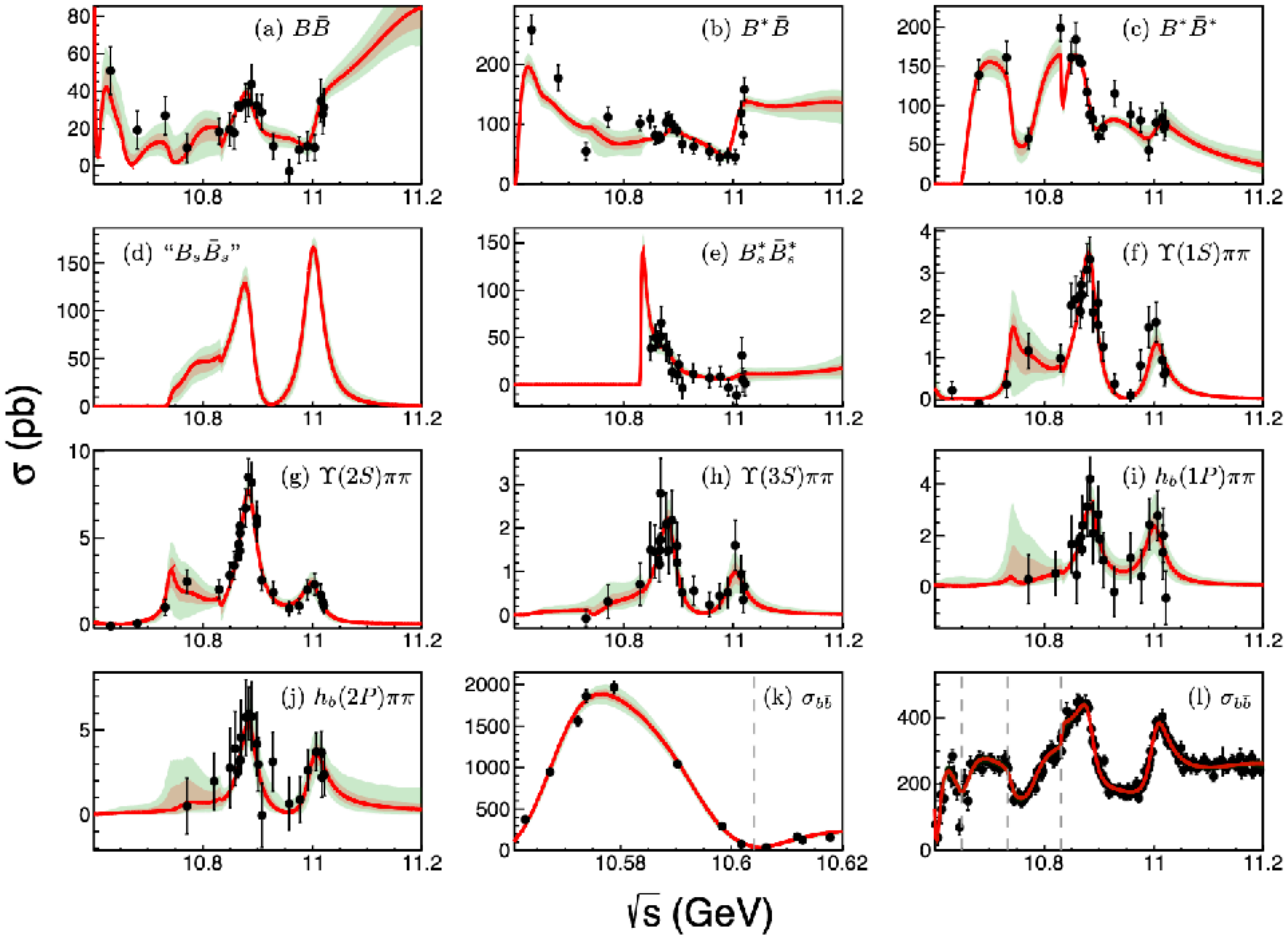
- A dip in the R_b distribution near $10.75\ \mathrm{GeV}$
- Fit to dressed cross section of $b\bar{b}$ with three BWs.

“The results from these fits may change dramatically by including more information on each exclusive mode. ”

K-matrix Analysis of e^+e^- Annihilation in the Bottomonium Region

N. Hüsken,[1,2] R.E. Mitchell,[1] and E.S. Swanson[3]

Phys.Rev.D 106 (2022) 9, 094013



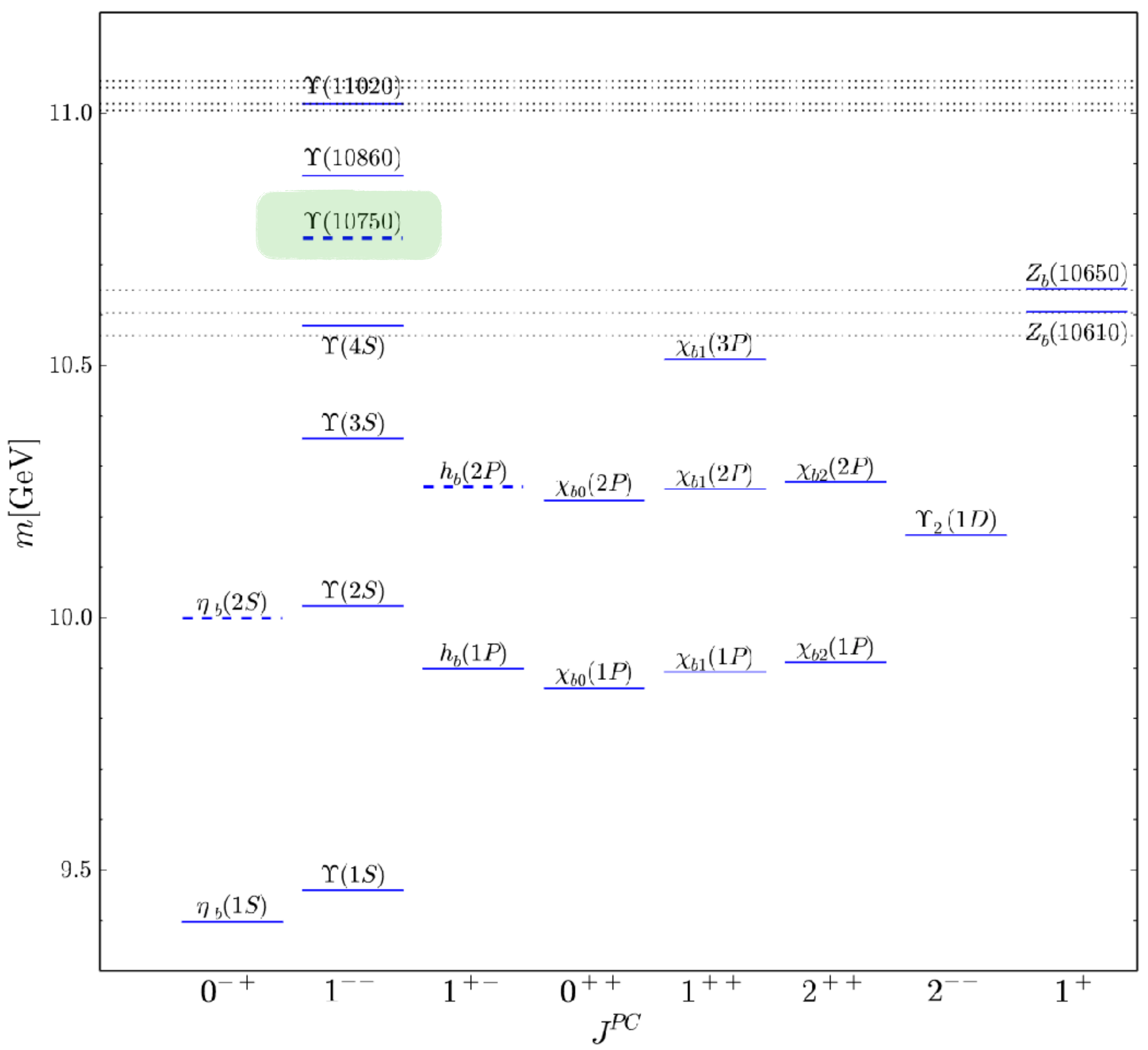
Strong evidence for $\Upsilon(10753)$ with significance $>10\sigma$

Pole locations varies with models.

state	RPP	our estimate	GM	ARM	NR	bbg	SOEF	LGT
1^3S_1	9460		9465	9444	9454	9445	9502	9419.1(4)
2^3S_1	10023		10003	10029	10010	10002	10015	9981(4)
3^3S_1	10355		10354	10374	10344	10339	10349	10384(12)
4^3S_1	10579	(10590 - 10610)	10635	10641	10614	10610	10607	
5^3S_1	10885	(10878 - 10884)	10878	10865	10849	10848	10818	
6^3S_1	11000	(11000 - 11008)	11102	11065	11064	11064	10995	
1^3D_1			10138	10156	10146	10148	10117	10191(9)
2^3D_1			10441	10453	10432	10435	10414	10718(33)
3^3D_1			10698	10697	10679	10684	10653	
$\Upsilon(10750)$	10753	(10630 - 10780)						
hybrid						11093		10952(33)

TABLE IV. Experimental and Theoretical Vector Bottomonium Masses (MeV).

Coupled channel analysis of high energy scan data using the K-matrix formalism shows four poles: $\Upsilon(4S)$, $\Upsilon(10753)$, $\Upsilon(5S)$, $\Upsilon(6S)$.



Bottomonium?

Phys. Rev. D 101, 014020 (2020)

Phys. Lett. B 803, 135340 (2020)

Eur. Phys. J. C 80, 59 (2020)

Phys. Rev. D 102, 014036 (2020)

Prog. Part. Nucl. Phys. 117, 103845 (2021)

Phys. Rev. D 104, 034036 (2021)

Phys. Rev. D 105, 074007 (2022)

etc…

Hybrid?

Phys. Rept. 873, 1 (2020)

Phys. Rev. D 104, 034019 (2021)

etc…

Tetraquark?

Phys. Lett. B 802, 135217 (2020)

Chin. Phys. C 43, 123102 (2019)

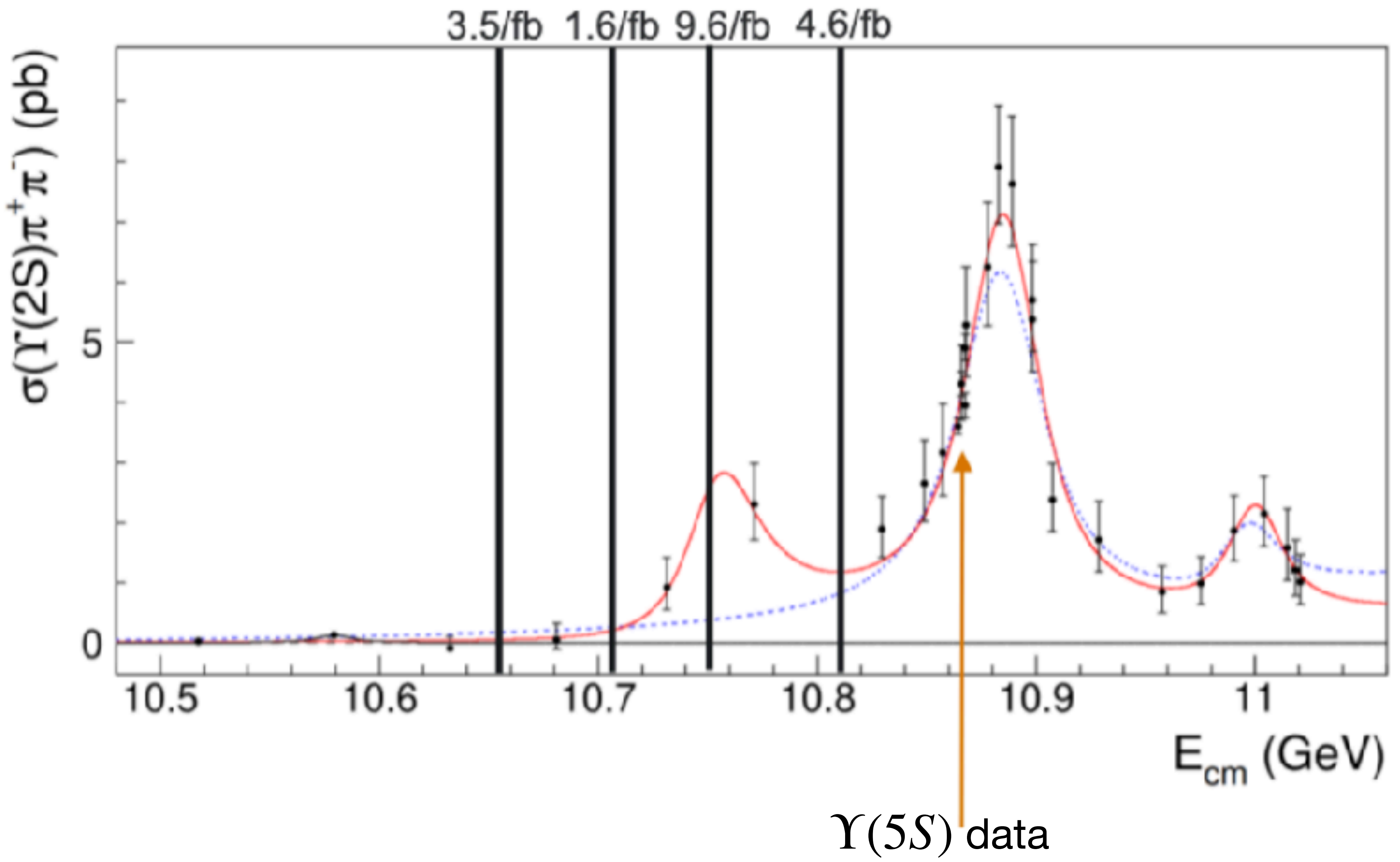
Phys. Rev. D 103, 074507 (2021)

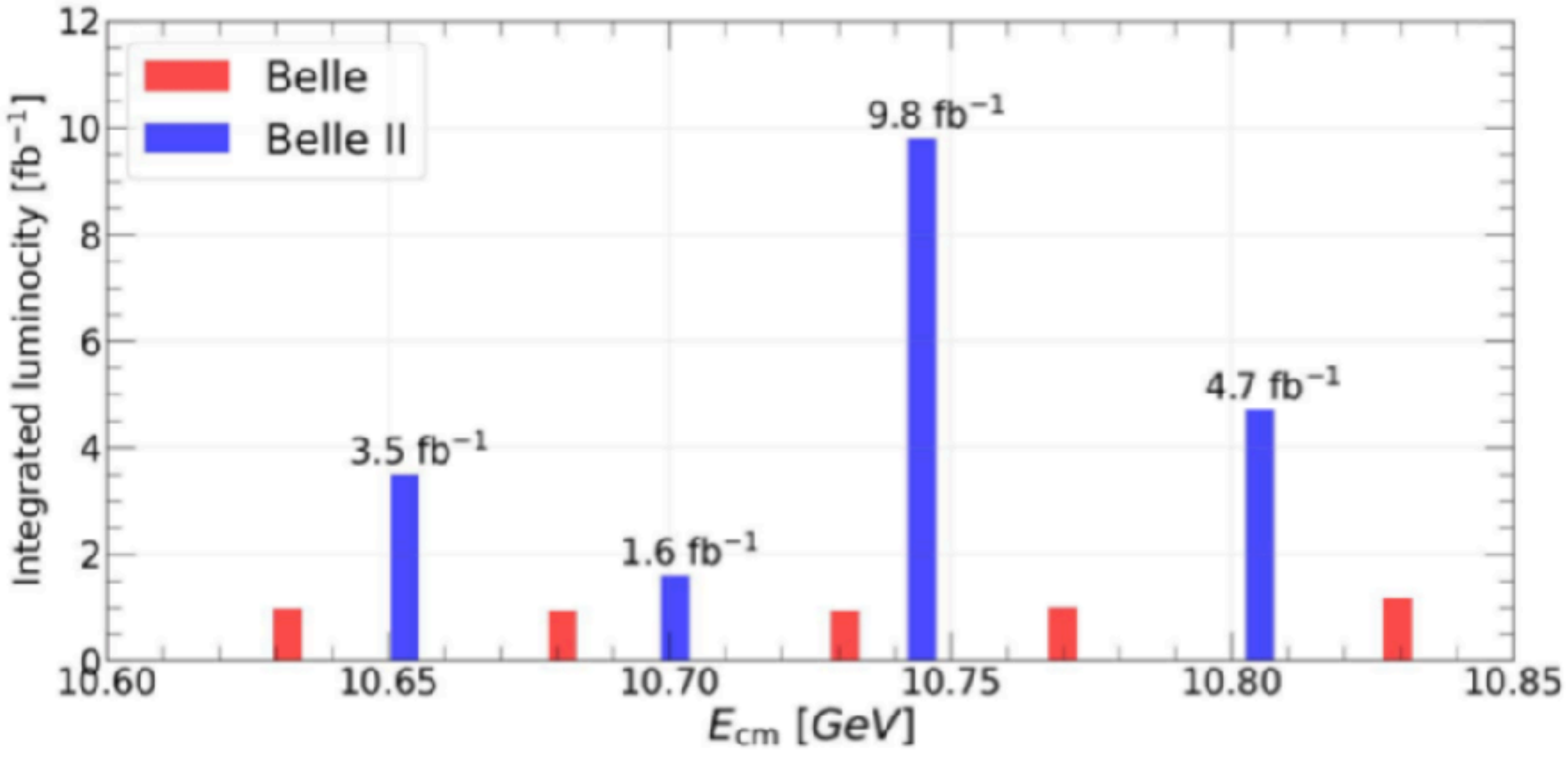
Phys. Rev. D 107, 094515 (2023)

etc…

Unique data

- Largest bottomonium data sample
- In Nov. 2021, Belle II collected ~20/fb of unique scan data at energies near 10.75 GeV
  - Fill the gaps in Belle Scan data
  - Physics goal is to understand the nature of $\Upsilon(10753)$



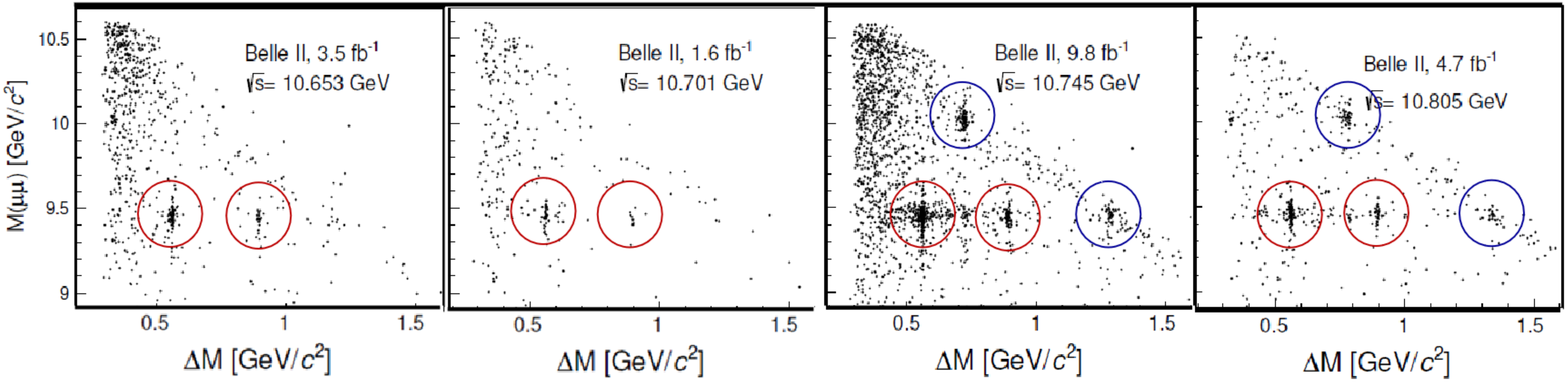


Confirmation of $\Upsilon(10753)$ on Belle II

- Full reconstruction of $\pi^+\pi^-\Upsilon(nS), n = 1,2,3$, where $\Upsilon(nS) \to \mu^+\mu^-$.

$\Delta M = M(\pi\pi\mu\mu) - M(\mu\mu)$

Belle-II preliminary, arxiv:2401.12021



ISR $\Upsilon(2S, 3S) \to \Upsilon(1S)\pi^+\pi^-$

Signal $e^+e^- \to [\Upsilon(nS) \to \mu^+\mu^-]\pi^+\pi^-$

Fit with three coherent BW, convoluting a Gaussian modeling energy spread:

$$\sigma \propto |\sum_{i}^{3} \frac{\sqrt{12\pi\Gamma_i\mathscr{B}_i}}{s - M_i + iM_i\Gamma_i} \cdot \sqrt{\frac{f(\sqrt{s})}{f(M_i)}} e^{i\phi_i}|^2 \otimes G(0,\delta E)$$

All parameters are free, except $\delta E = 0.0056\ \mathrm{GeV}$

Parameters of $\Upsilon(10753)$:

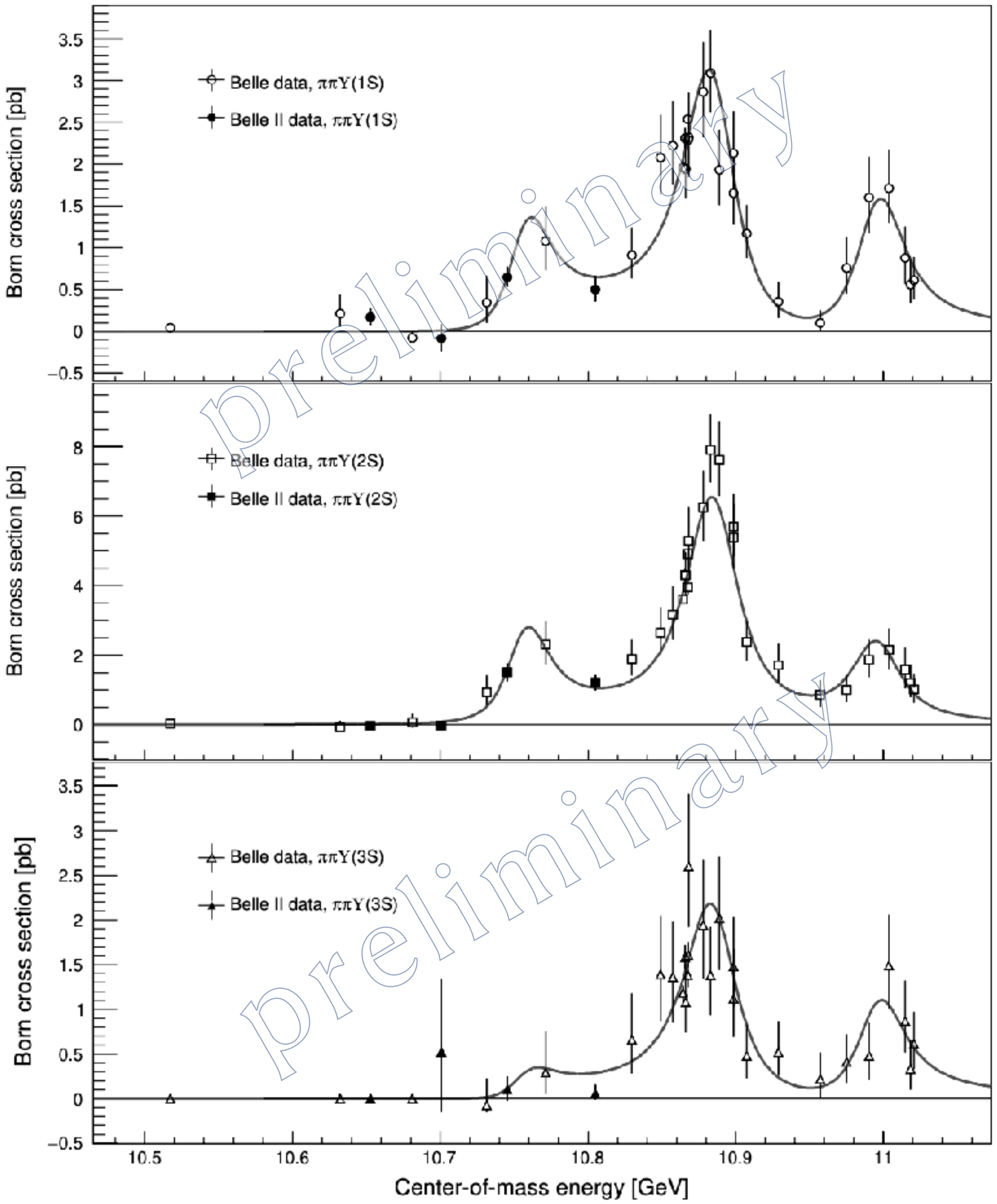
$$M = 10756.6 \pm 2.7_{(stat.)} \pm 0.8_{(syst.)}\ \mathrm{MeV}/c^2$$

$$\Gamma = 29.0 \pm 8.8_{(stat.)} \pm 1.2_{(syst.)}\ \mathrm{MeV}$$

Agree with previous Belle measurement.

Improve uncertainties ~2 times smaller

resonance	mass (MeV/c^2)	width (MeV)
$\Upsilon(5S)$	10884.7 ± 1.2	38.7 ± 3.7
$\Upsilon(6S)$	10995.5 ± 4.2	34.6 ± 8.6

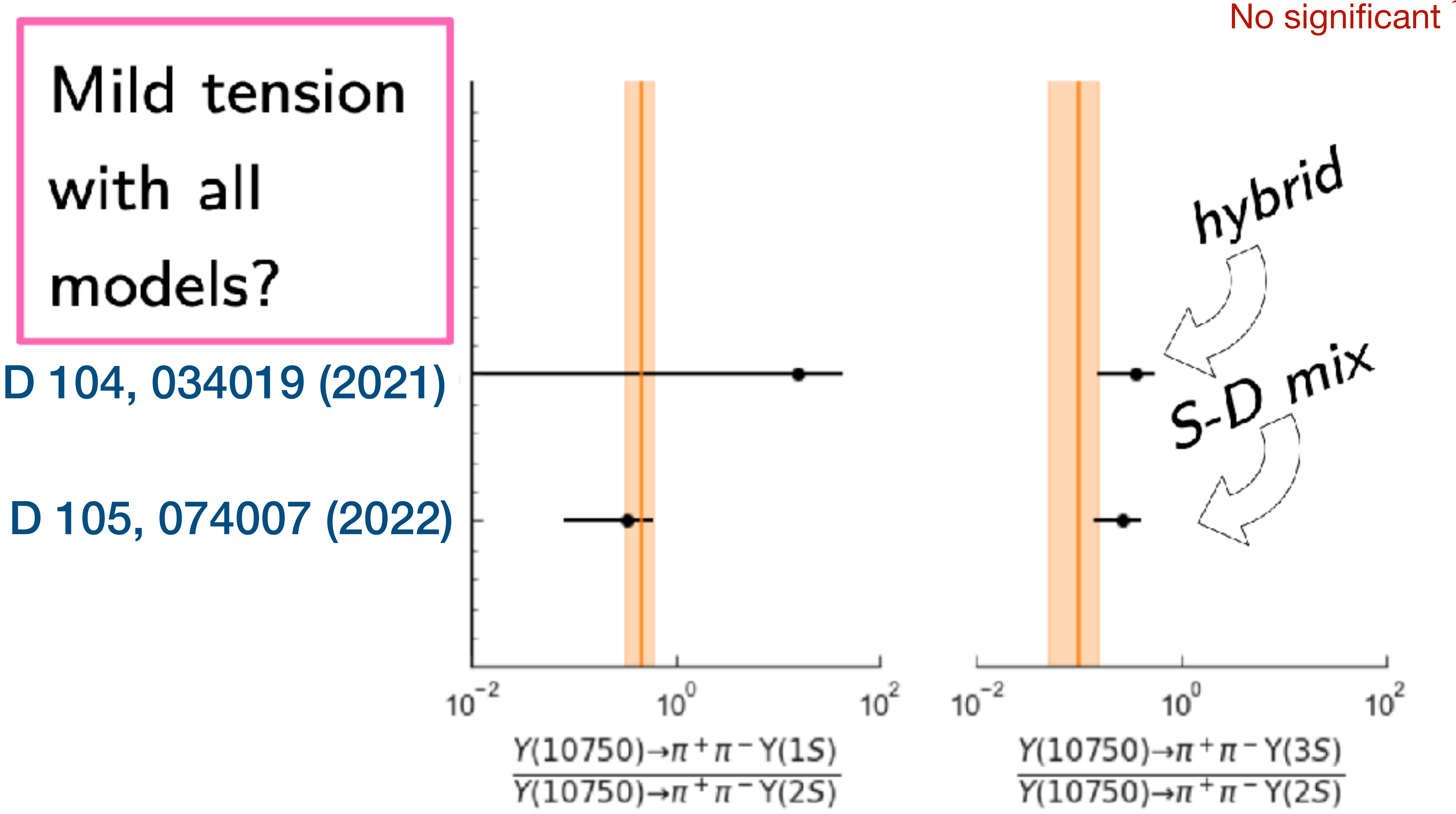


Relative ratios

Relative ratios of the Born cross section at the resonance peak.

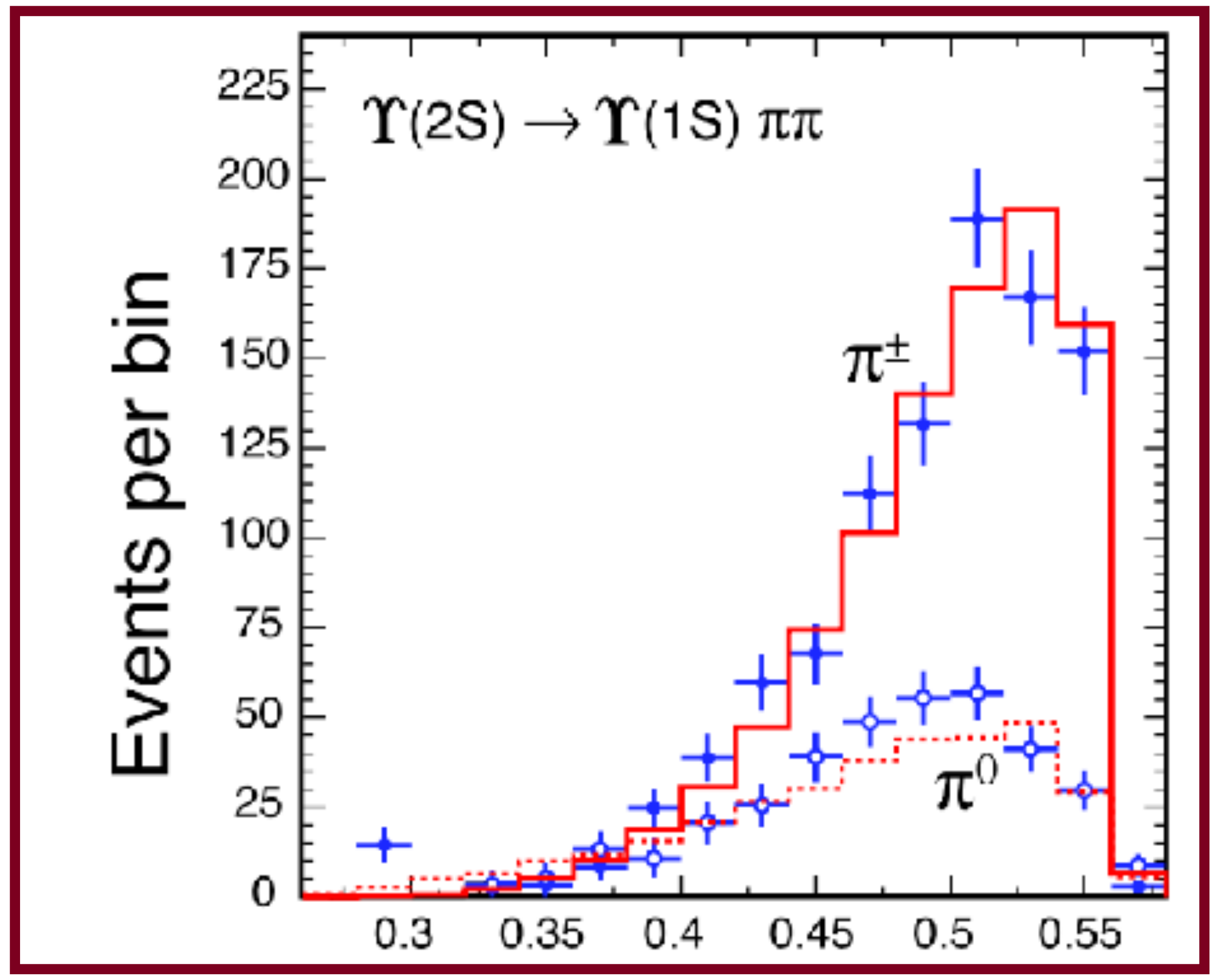
	$\mathcal{R}^{\Upsilon(10753)}_{\sigma(1S/2S)}$	$\mathcal{R}^{\Upsilon(10753)}_{\sigma(3S/2S)}$	$\mathcal{R}^{\Upsilon(5S)}_{\sigma(1S/2S)}$	$\mathcal{R}^{\Upsilon(5S)}_{\sigma(3S/2S)}$	$\mathcal{R}^{\Upsilon(6S)}_{\sigma(1S/2S)}$	$\mathcal{R}^{\Upsilon(6S)}_{\sigma(3S/2S)}$
Ratios	$0.46^{+0.15}_{-0.12}$	$0.10^{+0.05}_{-0.04}$	$0.45^{+0.04}_{-0.04}$	$0.32^{+0.04}_{-0.03}$	$0.64^{+0.23}_{-0.13}$	$0.41^{+0.16}_{-0.12}$

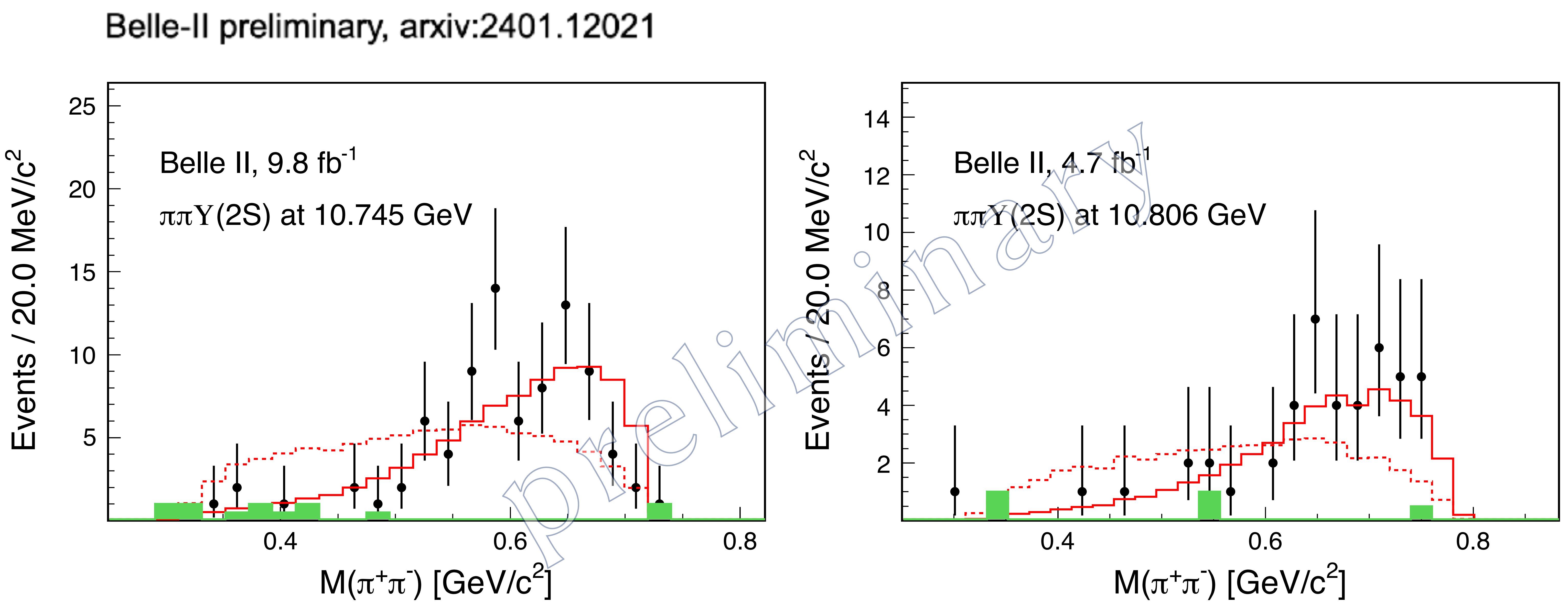
No significant $\Upsilon(10753) \to \pi\pi\Upsilon(3S)$



Castella. *et. al.* Phys. Rev. D 104, 034019 (2021)

Bai. *et. al.*Phys. Rev. D 105, 074007 (2022)



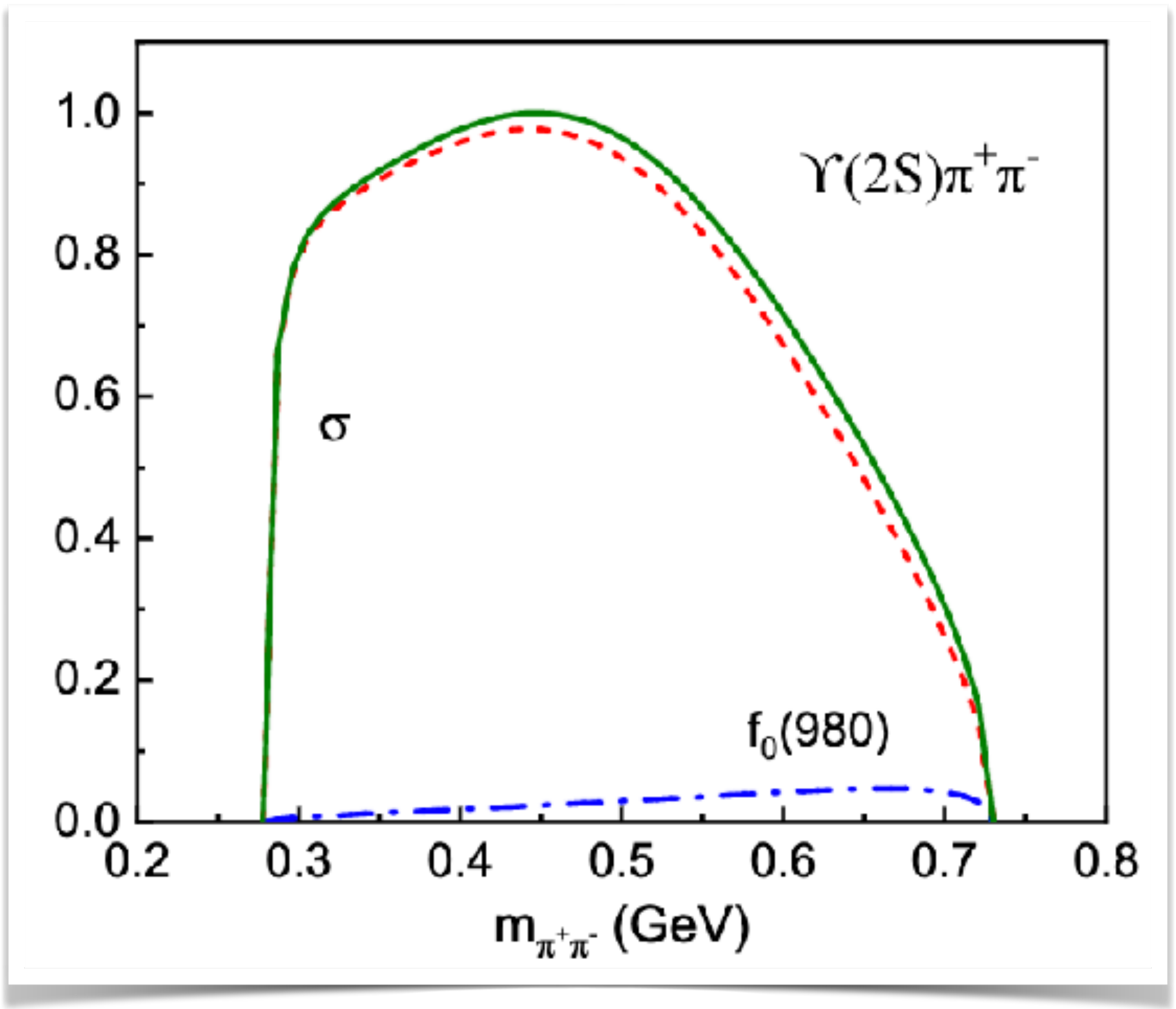


- The $M(\pi^+\pi^-)$ distribution is very similar with that from $\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$
- Use CLEO parameterization:

$$\mathscr{M} \propto \mathscr{A}(q^2 - 2M_\pi^2) + \mathscr{B}E_1E_2 + \mathscr{C}[(\epsilon' \cdot q_1)(\epsilon \cdot q_2) + (\epsilon' \cdot q_2)(\epsilon \cdot q_1)]$$

The $\mathscr{C}$ term could be ignored because of spin flip should be very small.

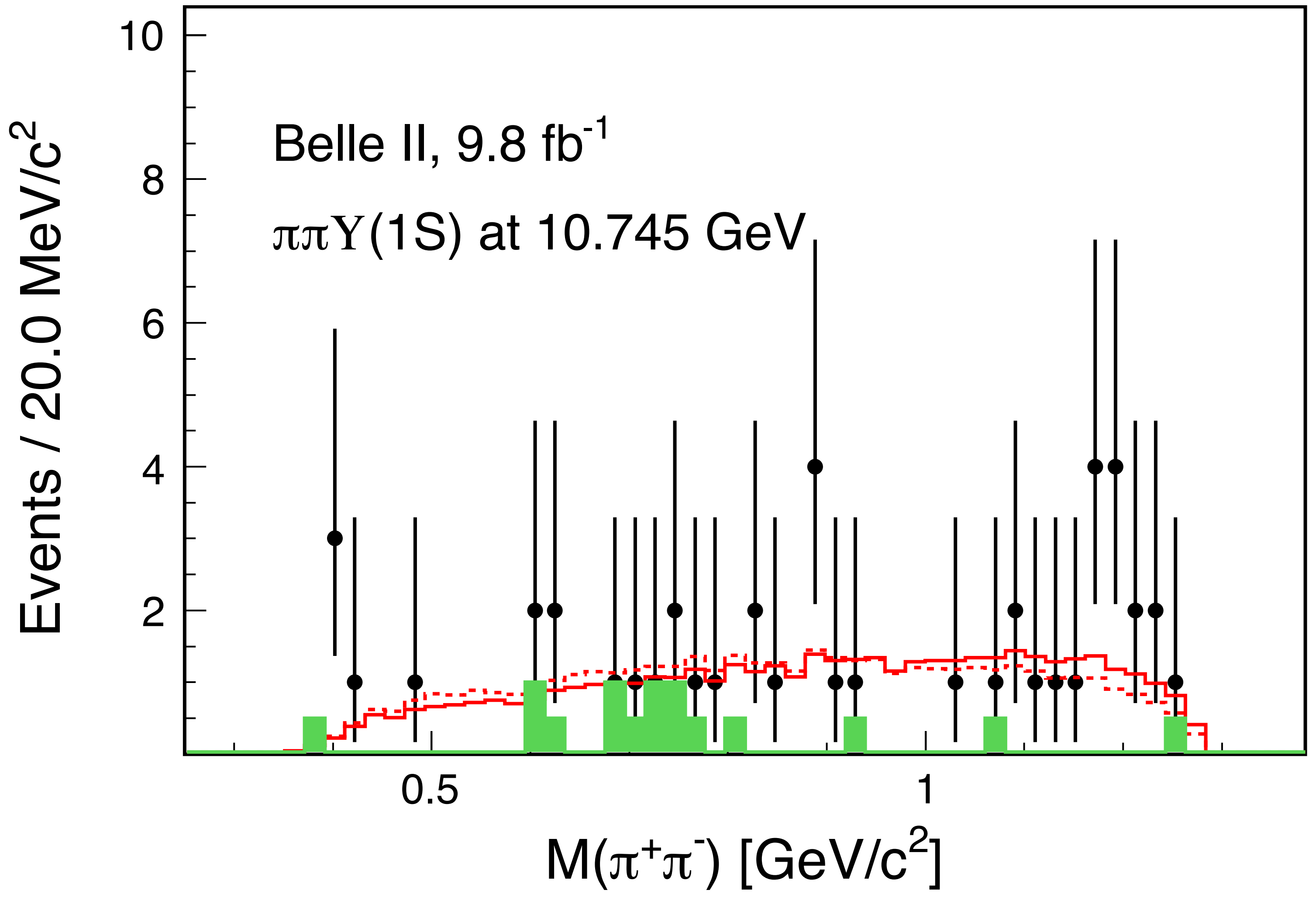
We fix $\mathscr{A} = 1$, and $\mathscr{B}$ is fitted to be $(1.1 \pm 0.3) + (4.7 \pm 1.5)i$

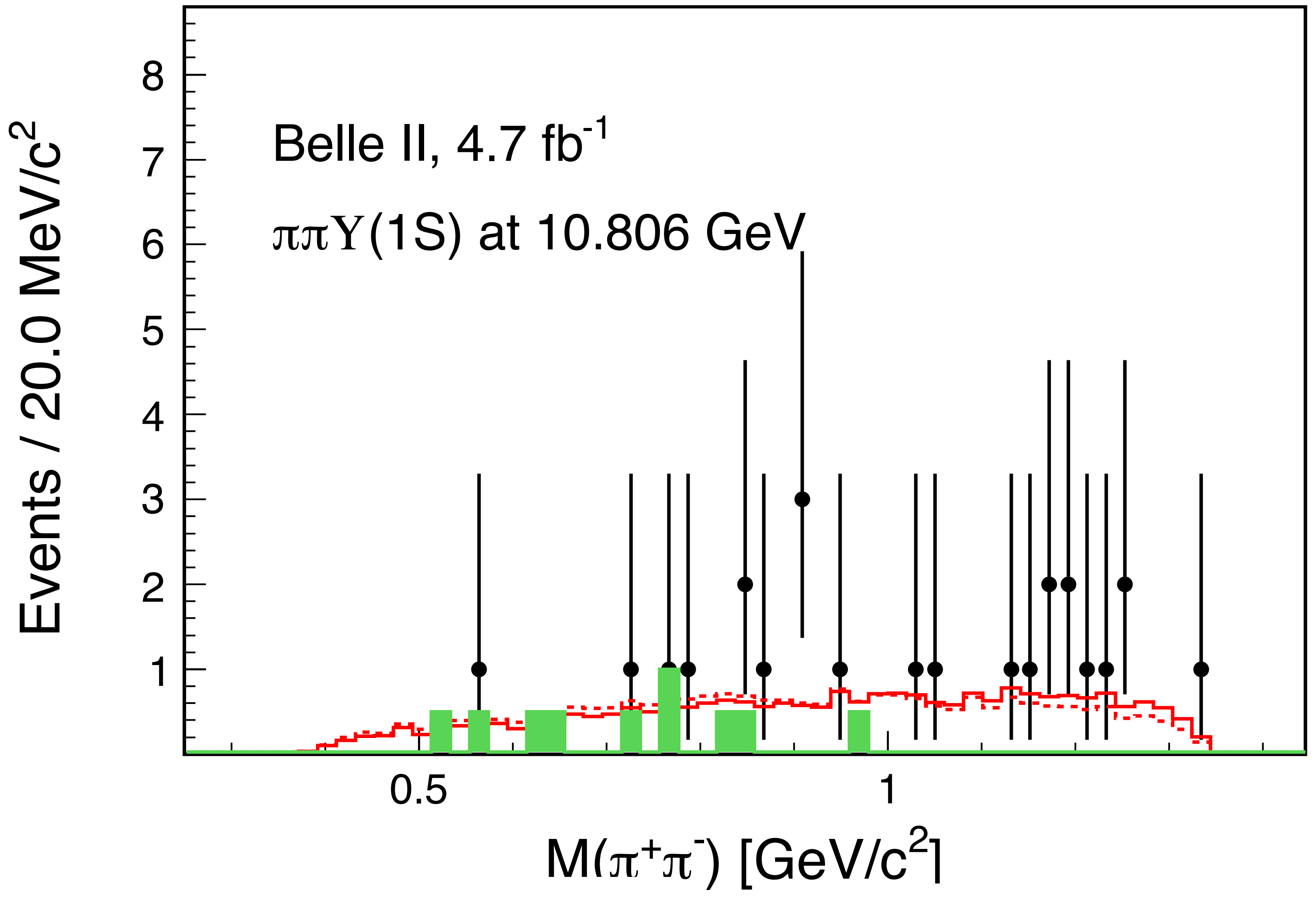


Bai. *et. al.*
Phys. Rev. D 105, 074007 (2022)

S-D mix

In the case of $\Upsilon(10753) \to \pi\pi\Upsilon(1S)$

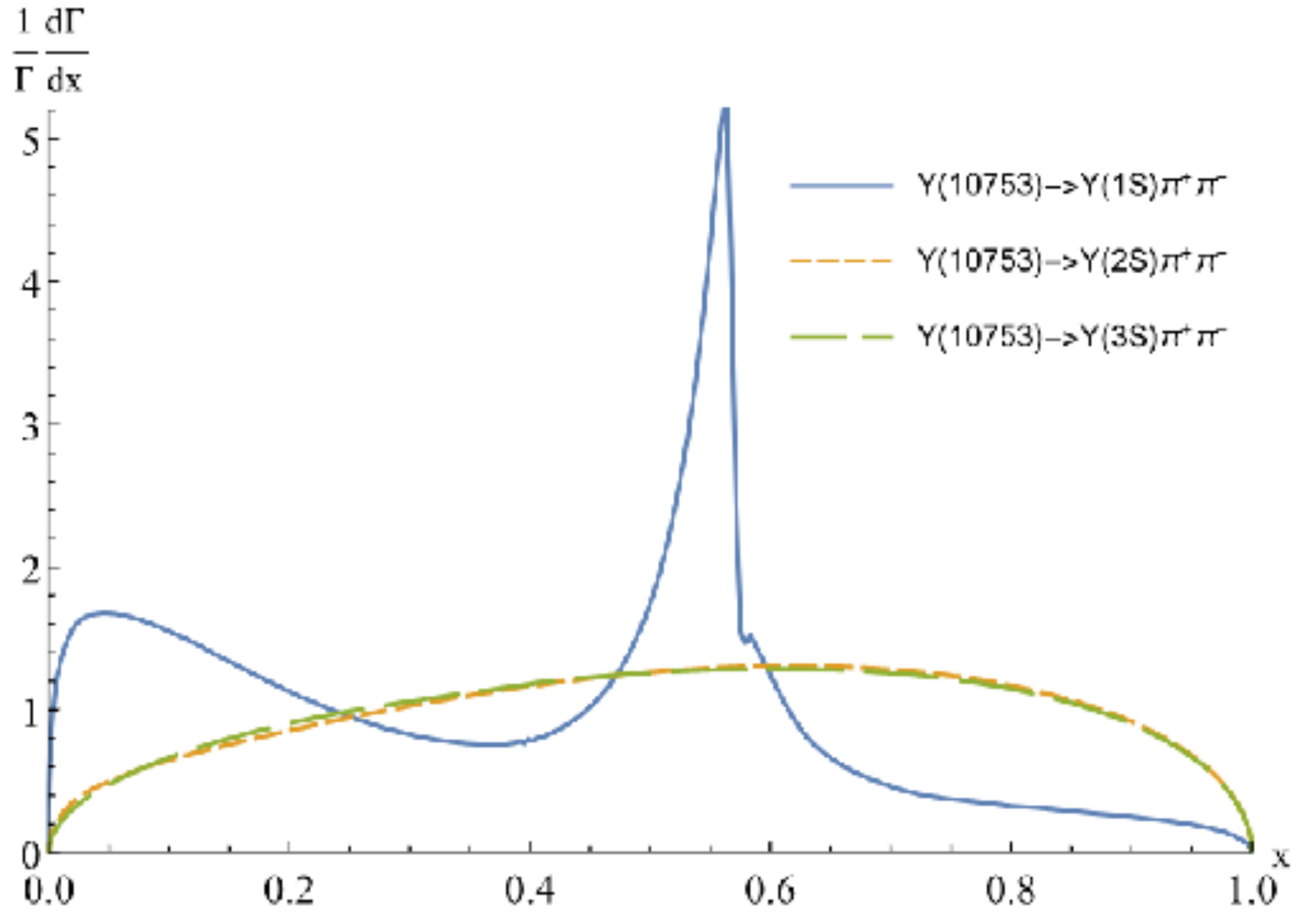




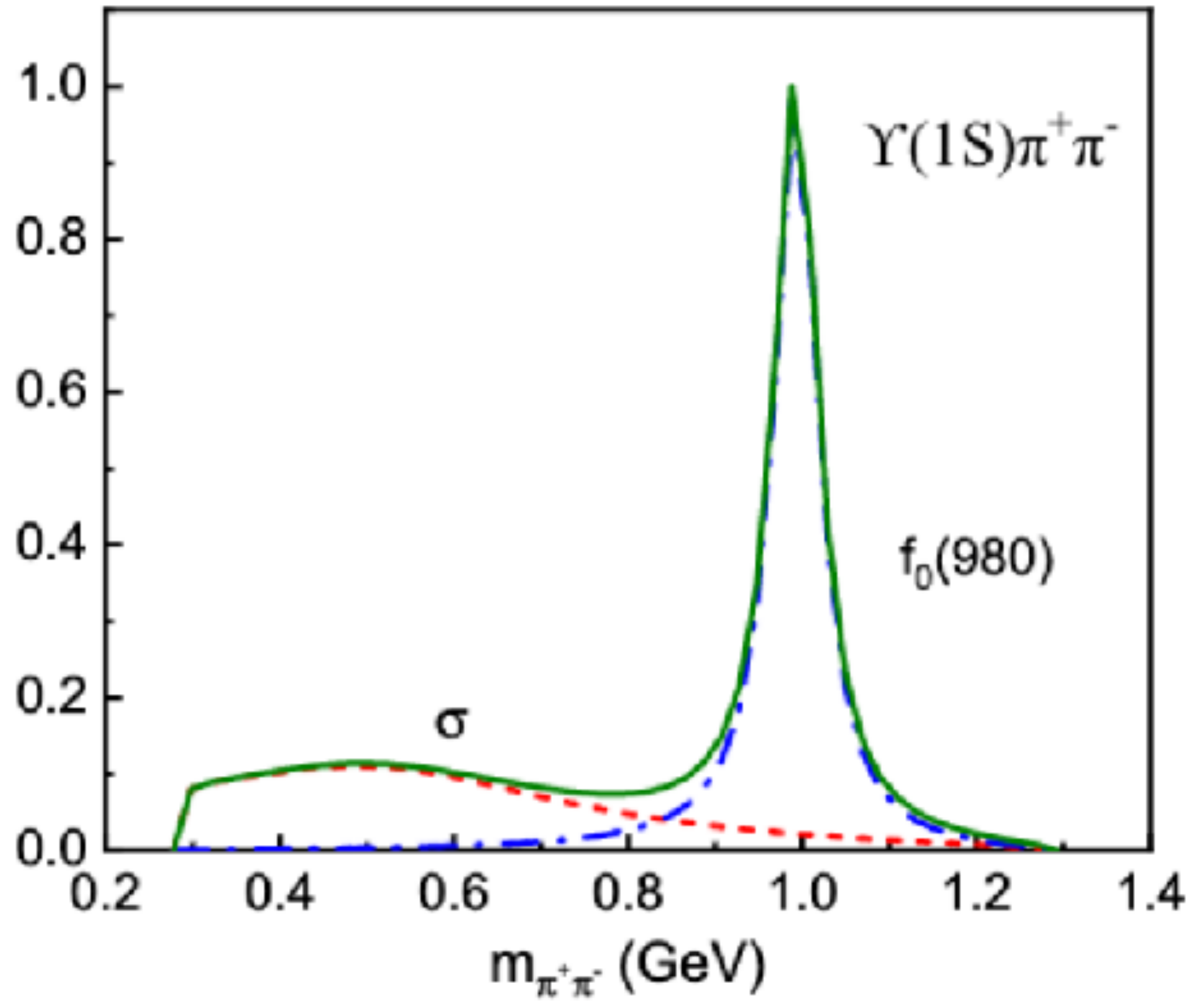
Castella. *et. al.*
Phys. Rev. D 104, 034019 (2021)

Bai. *et. al.*
Phys. Rev. D 105, 074007 (2022)

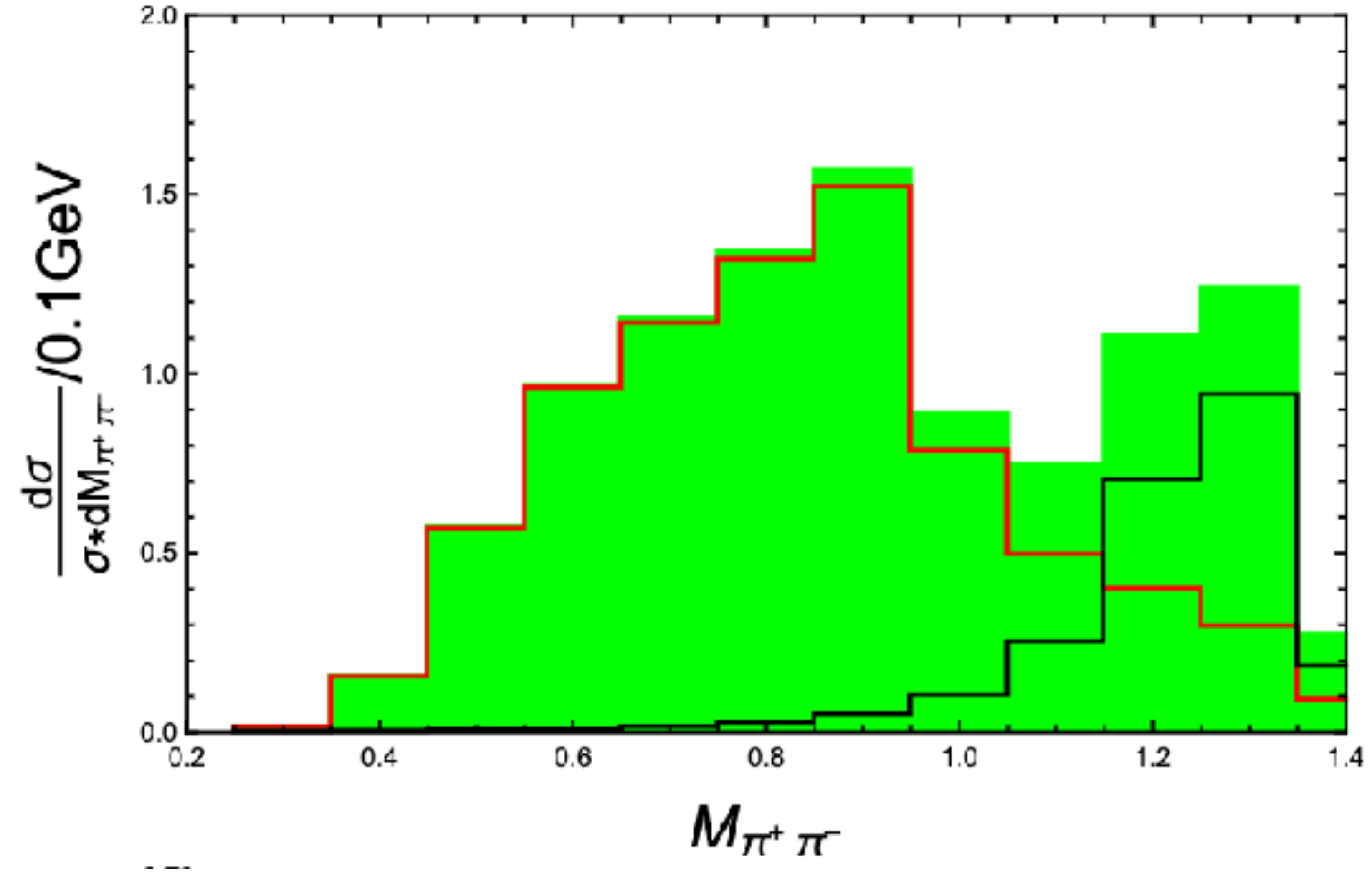
Maiani. *et. al.*
Phys. Rev. D 105, 074007 (2022)



Hybrid



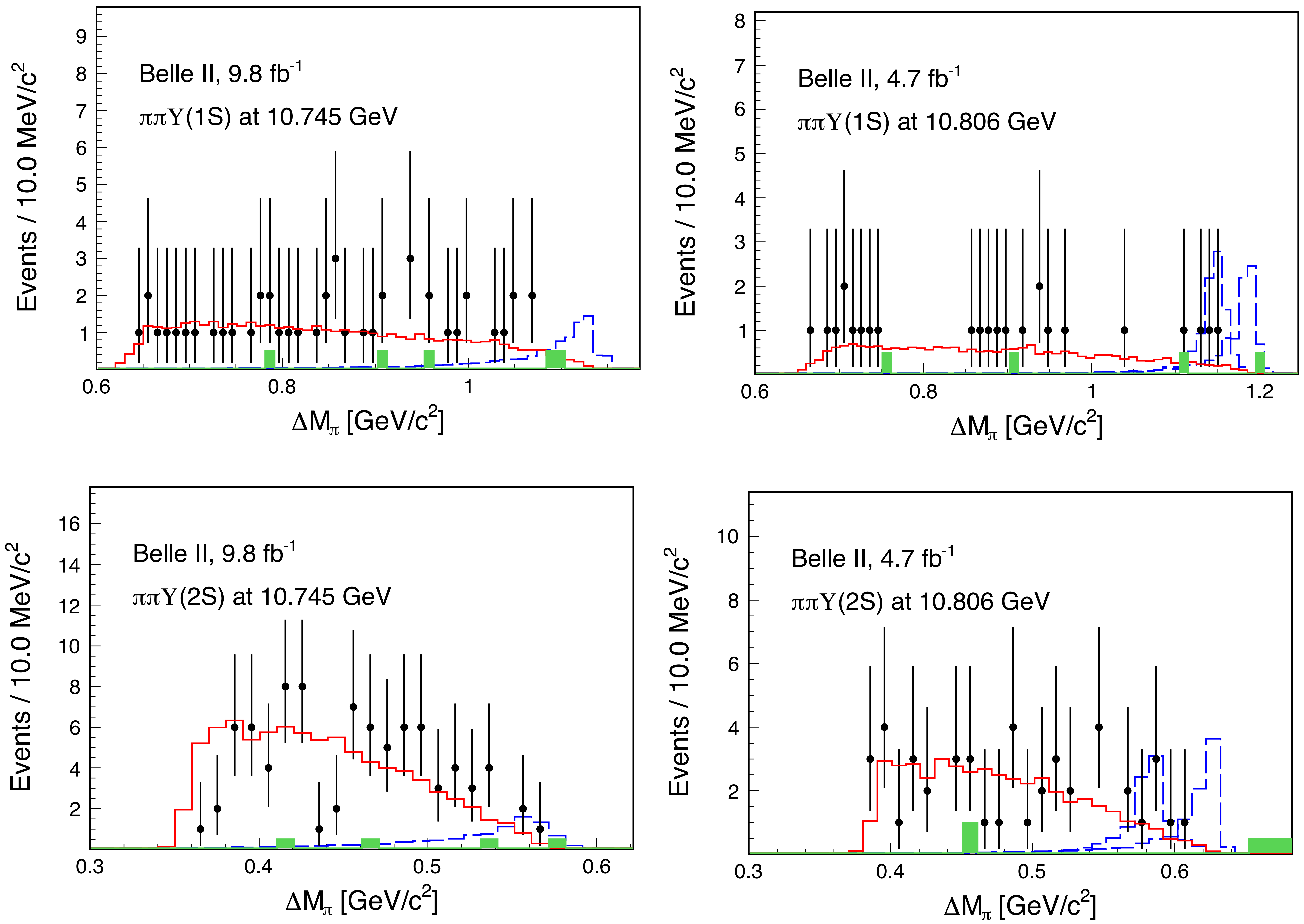
S-D mix



Tetraquark

Intermediate state — $\Upsilon(10753) \rightarrow \pi Z_b$

Belle-II preliminary, arxiv:2401.12021

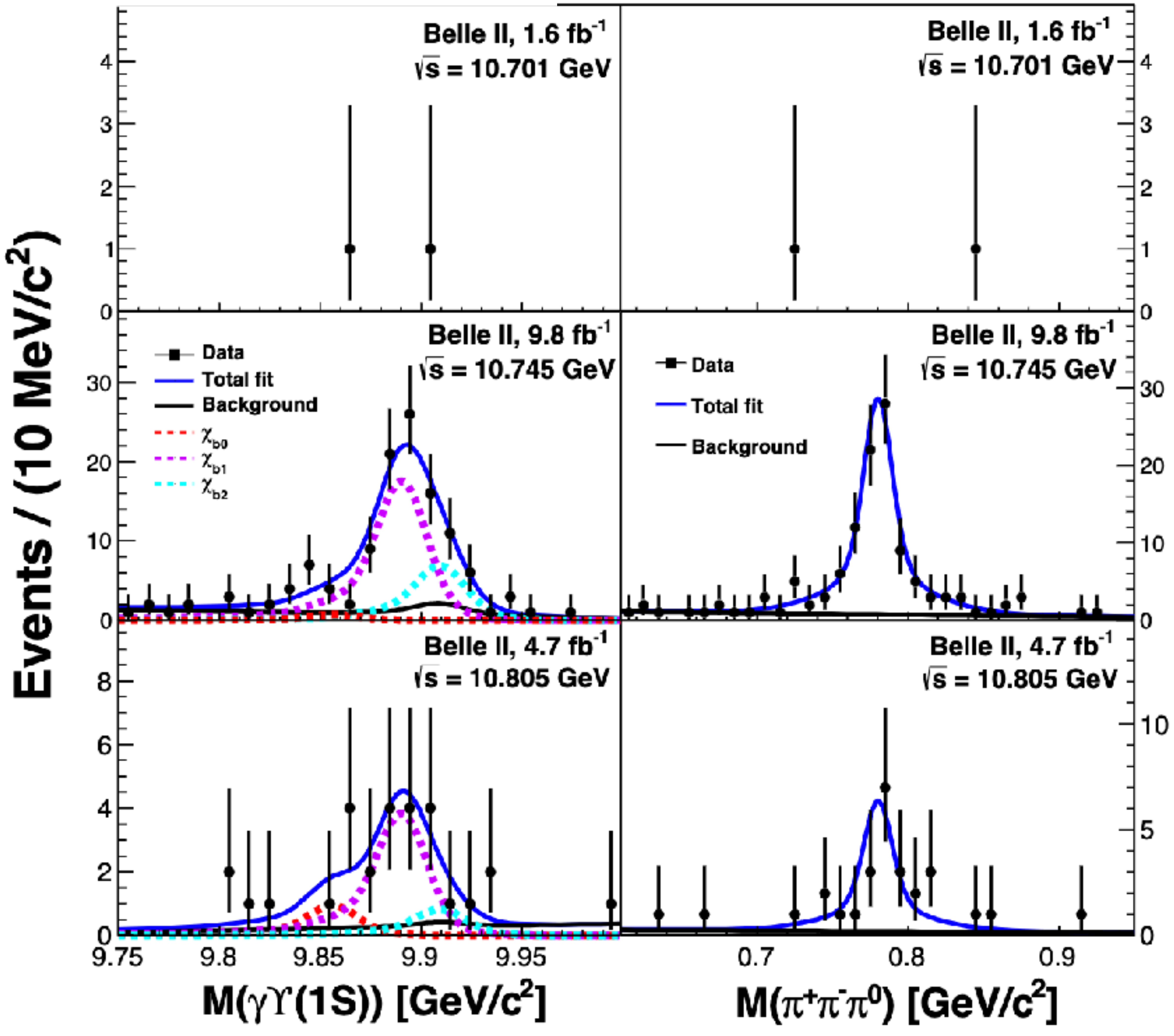


- No Evidence of $Z_b(10610/10650)$.
- Upper limits estimated at 90 % C.L. using Bayesian method.

Mode	$N_{Z_{b1}}$	$N^{UL}_{Z_{b1}}$	$\sigma_{Z_{b1}}$ (pb)	$\sigma^{UL}_{Z_{b1}}$ (pb)	$N^{UL}_{Z_{b2}}$	$N_{Z_{b2}}$	$\sigma_{Z_{b2}}$ (pb)	$\sigma^{UL}_{Z_{b2}}$ (pb)
10.745 GeV								
$\pi\Upsilon(1S)$	$0.0^{+1.6}_{-0.0}$	< 4.9	$0.00^{+0.04}_{-0.00}$	< 0.13	–	–	–	
$\pi\Upsilon(2S)$	$5.8^{+5.9}_{-4.6}$	< 13.8	$0.06^{+0.06}_{-0.05}$	< 0.14	–	–	–	
10.805 GeV								
$\pi\Upsilon(1S)$	$2.5^{+2.4}_{-1.6}$	< 5.2	$0.21^{+0.20}_{-0.13}$	< 0.43	$0.0^{+0.7}_{-0.0}$	< 5.8	$0.00^{+0.03}_{-0.00}$	< 0.28
$\pi\Upsilon(2S)$	$5.2^{+3.8}_{-3.0}$	< 12.3	$0.15^{+0.11}_{-0.09}$	< 0.35	$0.0^{+0.8}_{-0.0}$	< 6.0	$0.00^{+0.04}_{-0.00}$	< 0.30

Observation of $\Upsilon(10753) \to \omega\chi_{bJ}$

[PRL 130, 091902 (2023)]

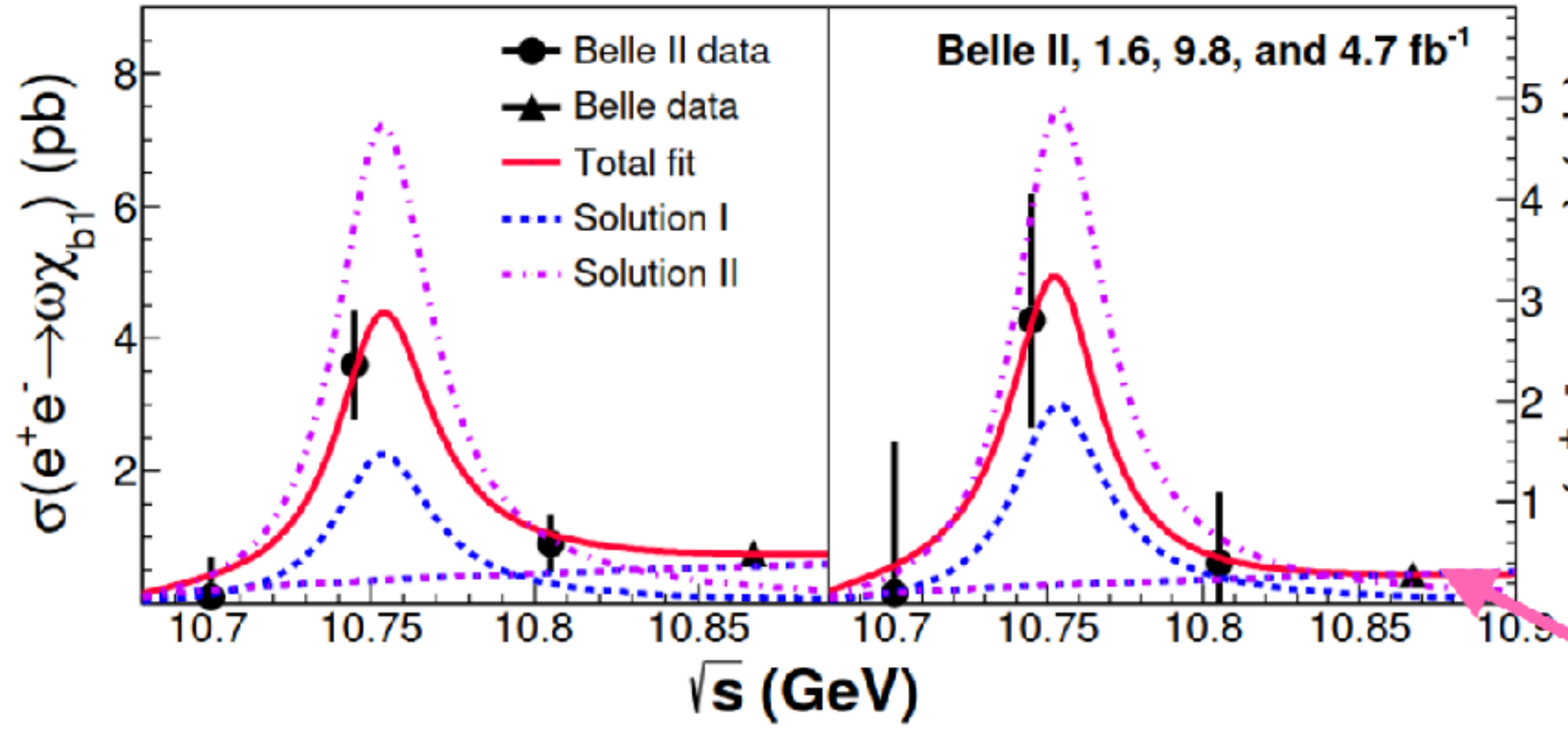


- Reconstruct $\omega \to \pi^+\pi^-\pi^0, \chi_{bJ} \to \gamma\Upsilon(1S)$
- Clear $\omega\chi_{bJ}$ signals at $\sqrt{s} = 10.745$ and 10.805 GeV
- 2D fit to $M(\pi^+\pi^-\pi^0)$ vs. $M(\gamma\Upsilon(1S))$

Channel	$\sqrt{s}$ (GeV)	N^{sig}	$\sigma^{(UL)}_{Born}$ (pb)
$\omega\chi_{b1}$	10.745	$68.9^{+13.7}_{-13.5}$	$3.6^{+0.7}_{-0.7} \pm 0.4$
$\omega\chi_{b2}$		$27.6^{+11.6}_{-10.0}$	$2.8^{+1.2}_{-1.0} \pm 0.5$
$\omega\chi_{b1}$	10.805	$15.0^{+6.8}_{-6.2}$	1.6 @90% C.L.
$\omega\chi_{b2}$		$3.3^{+5.3}_{-3.8}$	1.5 @90% C.L.

- The total χ_{bJ} signal significances are 11.5σ and 5.2σ at $\sqrt{s}$= 10.745 and 10.805 GeV

[PRL 130, 091902 (2023)]



At $\sqrt{s} = 10.867$ GeV:

$\sigma_{\text{Born}}(e^+e^- \to \omega\chi_{b1}) = (0.76 \pm 0.11 \pm 0.11)$ pb

$\sigma_{\text{Born}}(e^+e^- \to \omega\chi_{b1}) = (0.29 \pm 0.11 \pm 0.08)$ pb

[PRL 113, 142001(2014)]

What we thought was $\Upsilon(5S) \to \omega\chi_{bj}(1P)$ is probably just the tail of the $\Upsilon(10750)$!

$\sigma[ee \to \omega\chi_{b0}(1P)] < 11.3\ pb\ @\ 10.750\ GeV$

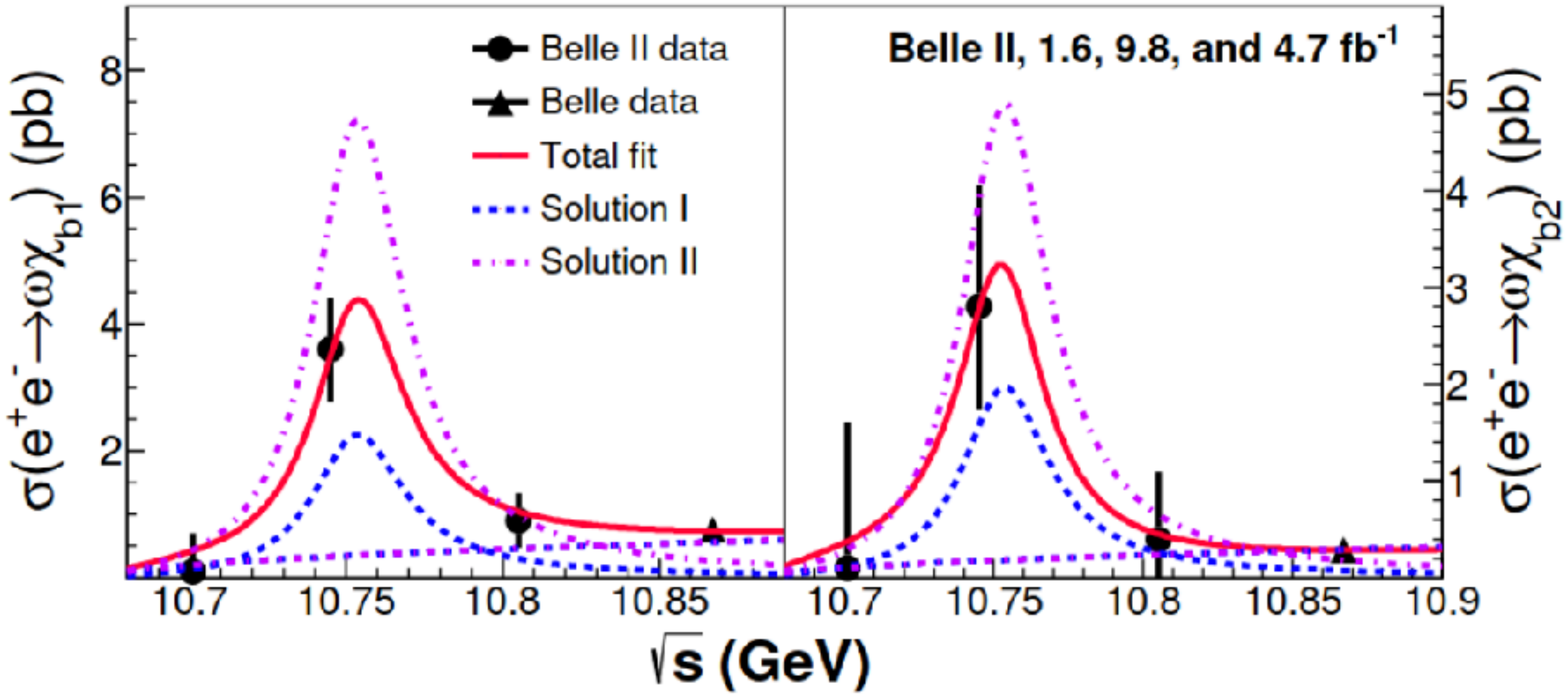
Two solutions (constr. or destr. interference):

$$\Gamma_{ee} \times B[\Upsilon(10750) \to \omega\chi_{b1}(1P)] = \begin{array}{l}(0.63 \pm 0.39 \pm 0.20)\,eV \\ (2.01 \pm 0.38 \pm 0.76)\,eV\end{array}$$

$$\Gamma_{ee} \times B[\Upsilon(10750) \to \omega\chi_{b2}(1P)] = \begin{array}{l}(0.53 \pm 0.40 \pm 0.15)\,eV \\ (1.32 \pm 0.44 \pm 0.53)\,eV\end{array}$$

Combined analysis with Belle data coming soon

[PRL 130, 091902 (2023)]



$$\sigma[ee \to \omega \chi_{b0}(1P)] < 11.3\, pb\, @\, 10.750\, GeV$$

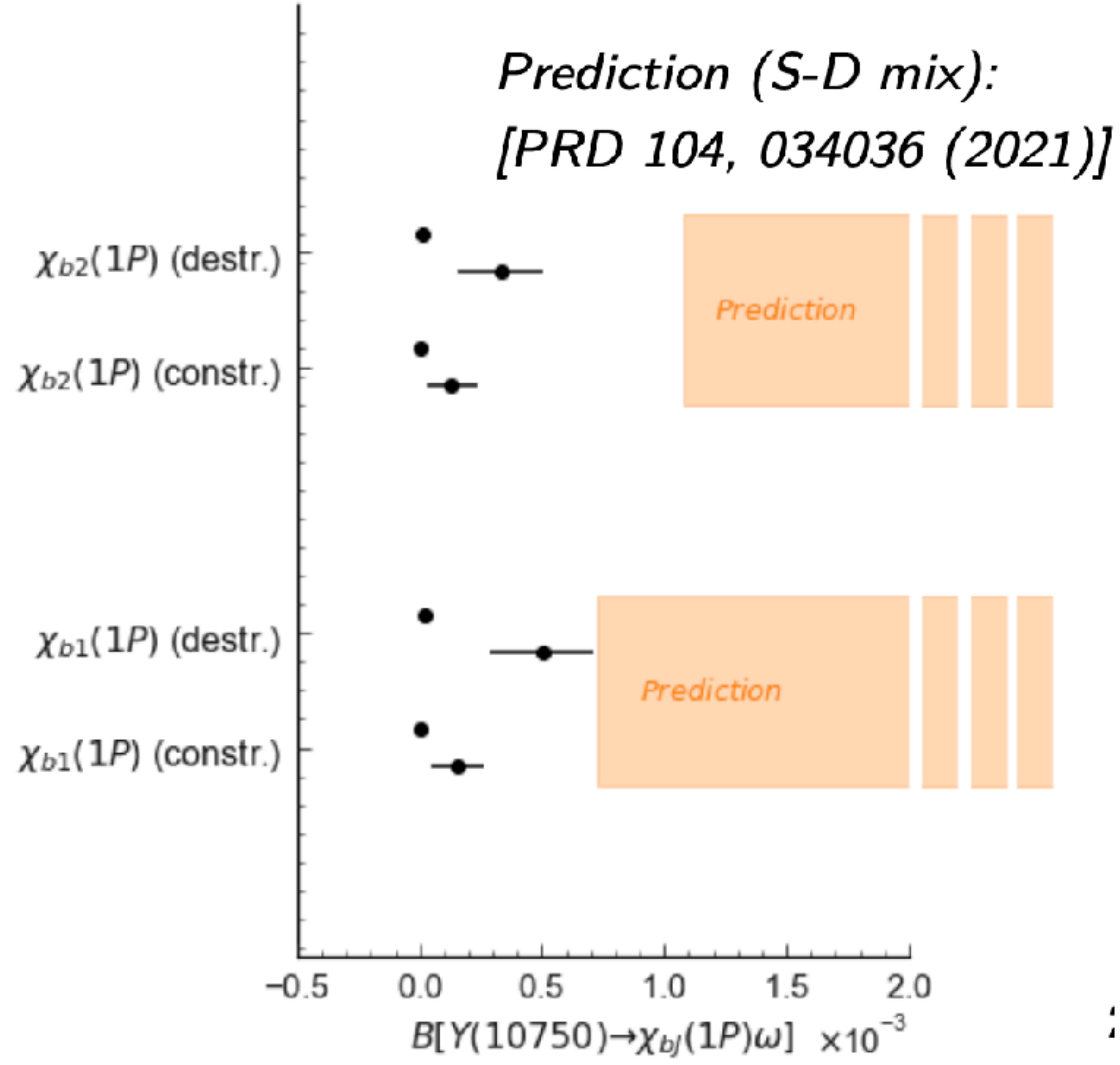
Two solutions (constr. or destr. interference):

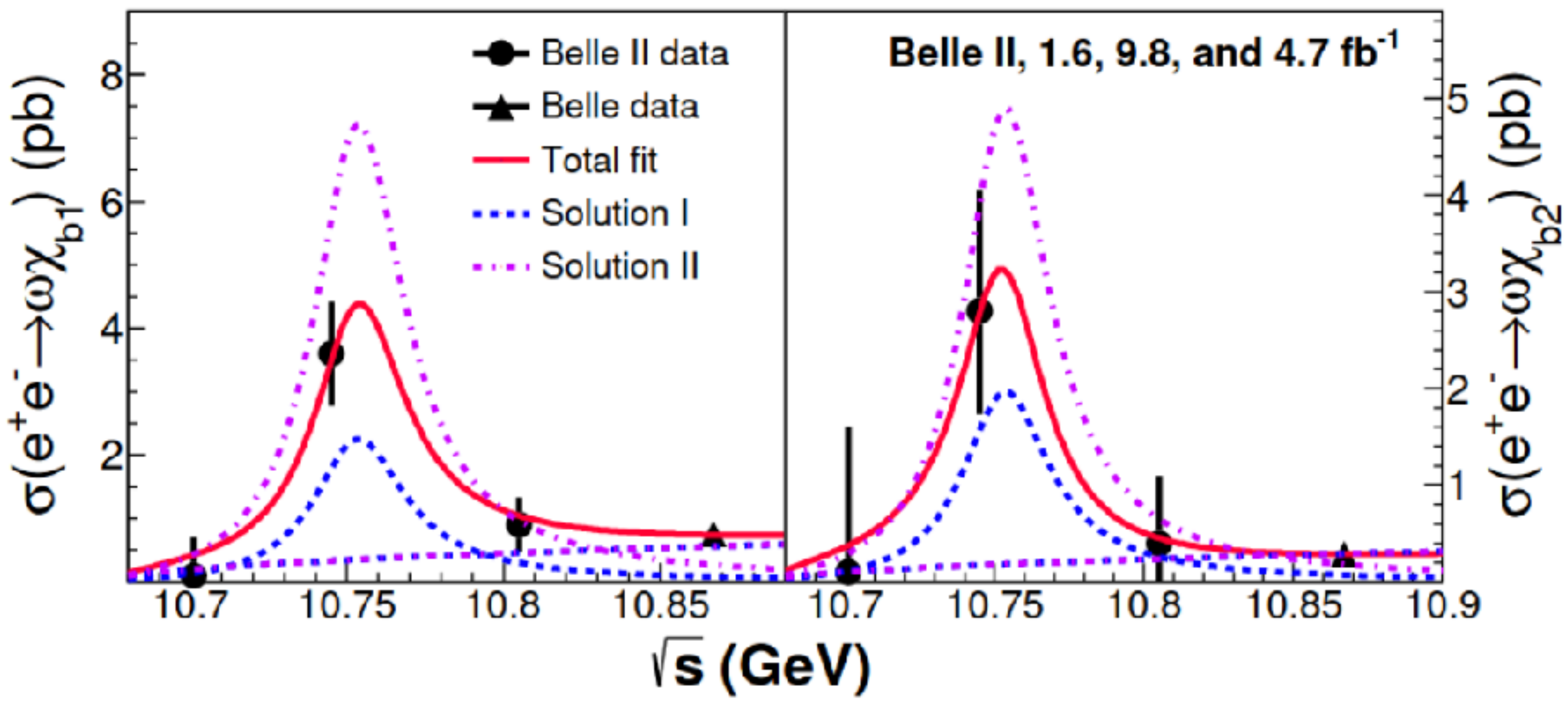
$$\Gamma_{ee} \times B[Y(10750) \to \omega \chi_{b1}(1P)] = \begin{matrix} (0.63 \pm 0.39 \pm 0.20)\, eV \\ (2.01 \pm 0.38 \pm 0.76)\, eV \end{matrix}$$

$$\Gamma_{ee} \times B[Y(10750) \to \omega \chi_{b2}(1P)] = \begin{matrix} (0.53 \pm 0.40 \pm 0.15)\, eV \\ (1.32 \pm 0.44 \pm 0.53)\, eV \end{matrix}$$

[PRL 130, 091902 (2023)]

Disagreement with *S*-*D* model?





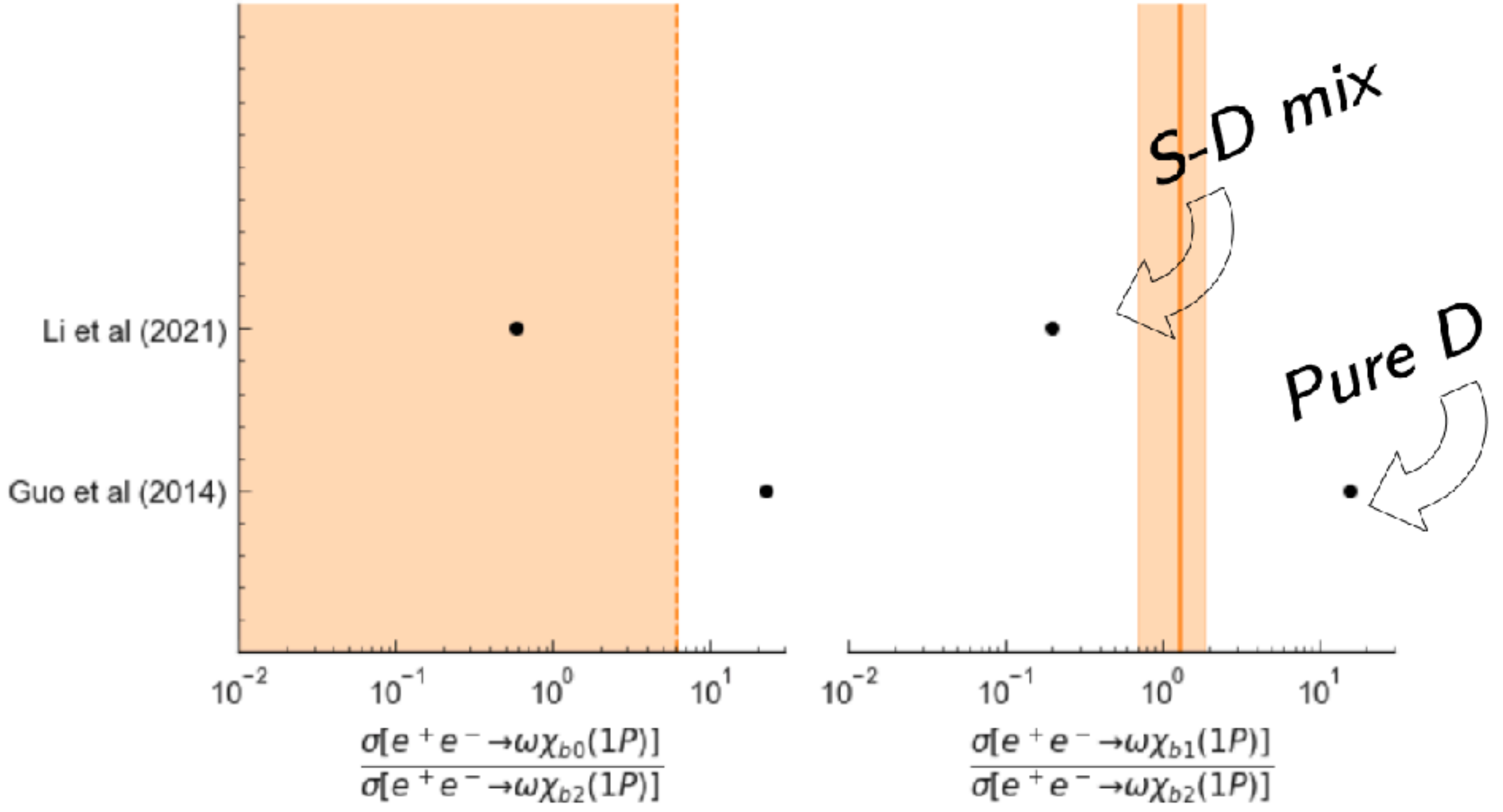
[PRL 130, 091902 (2023)]

Disagreement with both pure D and S-D mixed predictions?

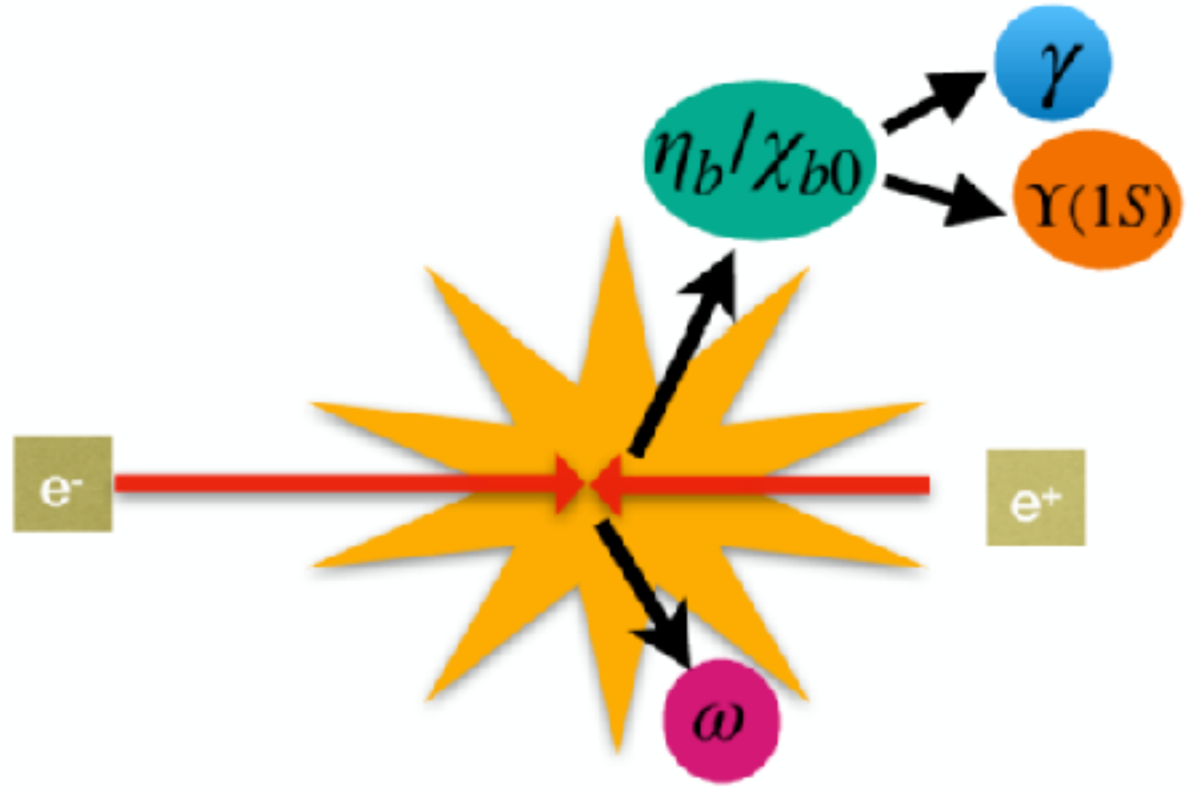
Measured ratios:

$$\frac{B[Y(10750)\to\omega\chi_{b1}(1P)]}{B[Y(10750)\to\omega\chi_{b2}(1P)]}=1.3\pm0.6$$

$$\frac{B[Y(10750)\to\omega\chi_{b0}(1P)]}{B[Y(10750)\to\omega\chi_{b2}(1P)]}<7 \quad \textit{(private extrapolation)}$$

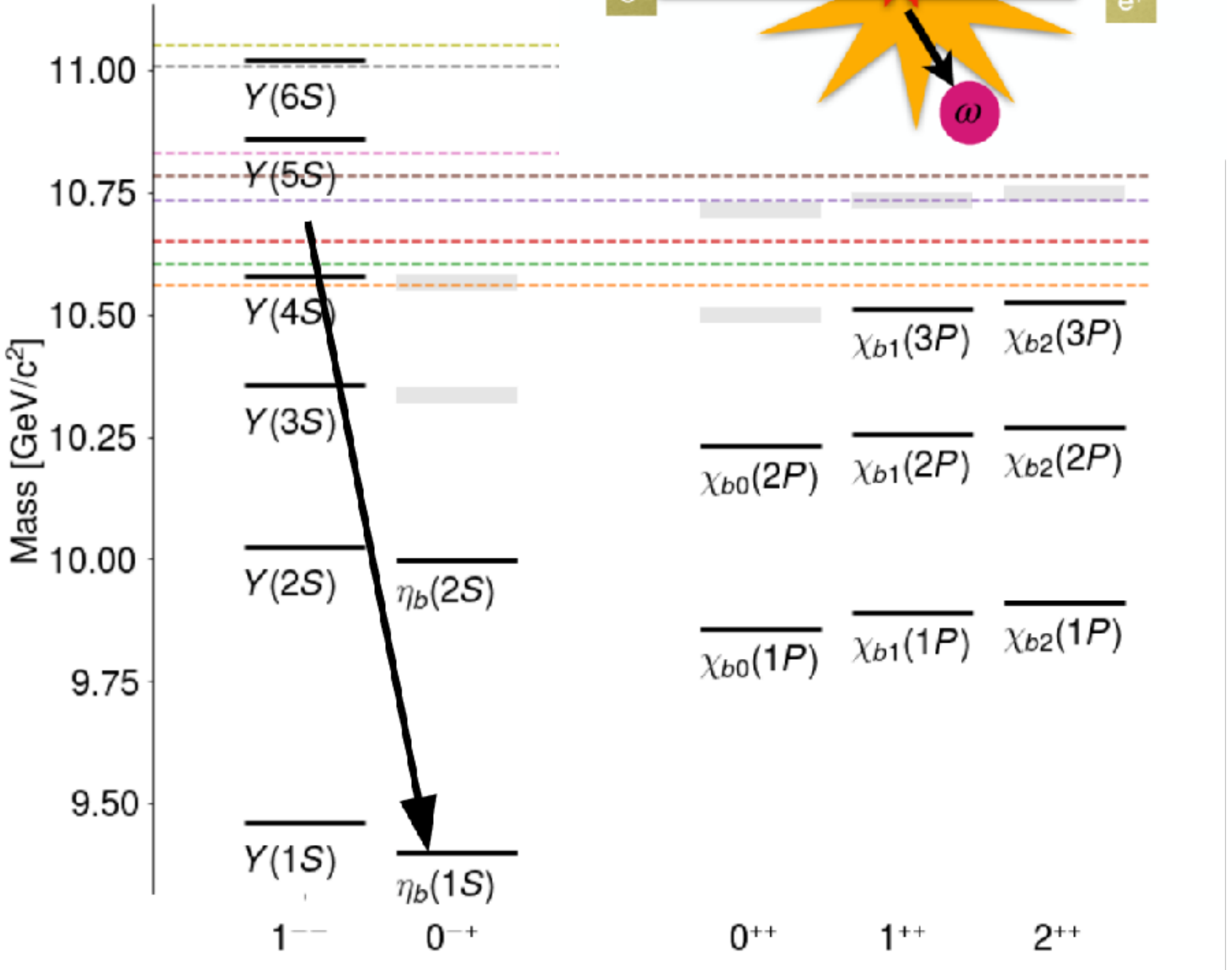


Search for $\Upsilon(10753) \to \omega\eta_b,\ \omega\chi_{b0}$



[Wang, Chin. Phys. C 43, 123102 (2019)]

Mode	$\mathcal{B}(4q)$ (%)	$\mathcal{B}(b\bar{b})$ (%)
$B\overline{B}$	$39.3^{+38.7}_{-22.9}$	21.3
$B\overline{B}^*$	~ 0.2	14.3
$B^*\overline{B}^*$	$52.3^{+54.9}_{-31.7}$	64.1
$B_s\overline{B}_s$	-	0.3
$\omega\eta_b$	$7.9^{+14.0}_{-5.0}$	-
$f_0(1370)\Upsilon$	$0.2^{+0.6}_{-0.2}$	-
$\omega\Upsilon$	~ 0	-

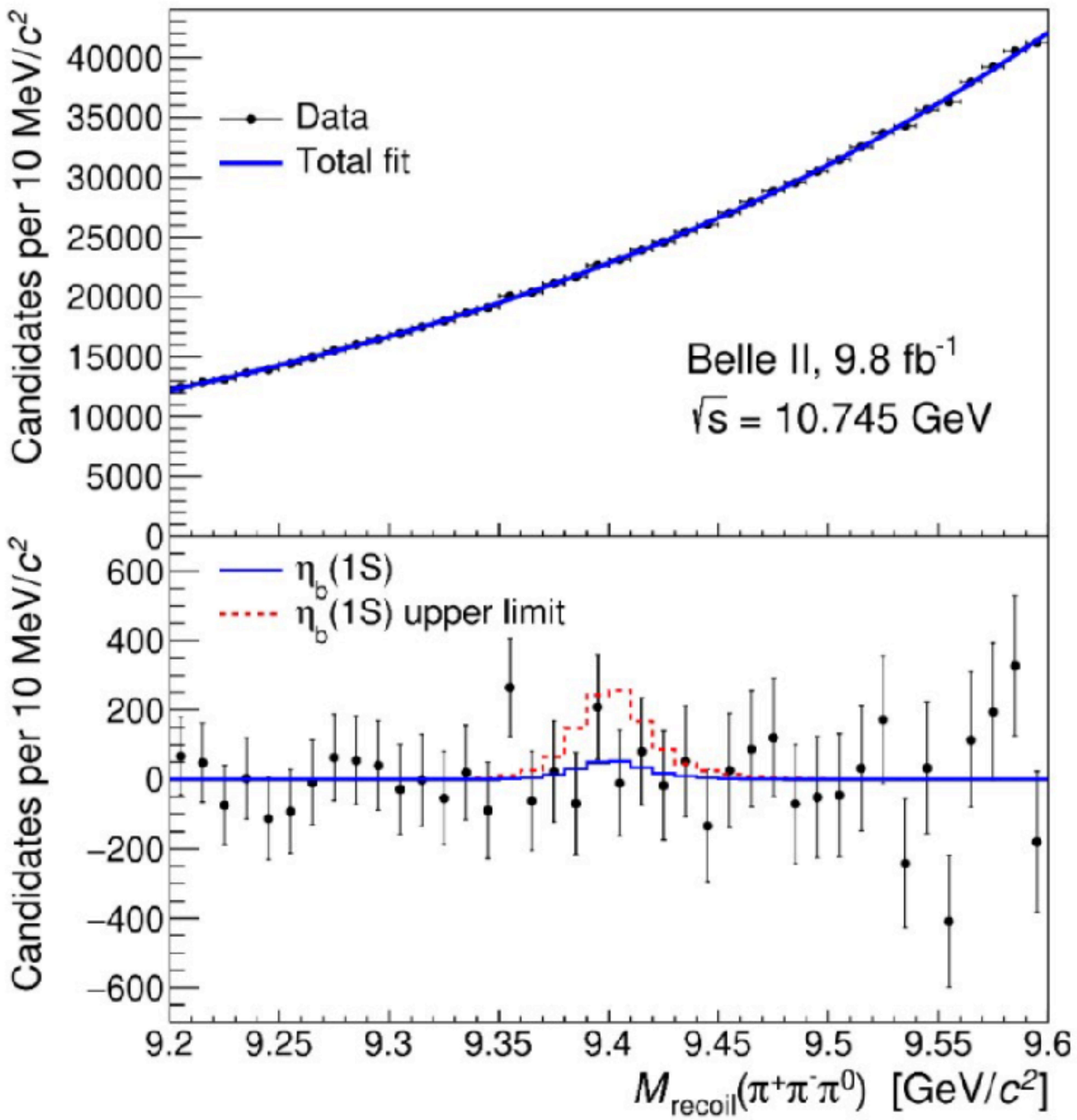


Strategy:

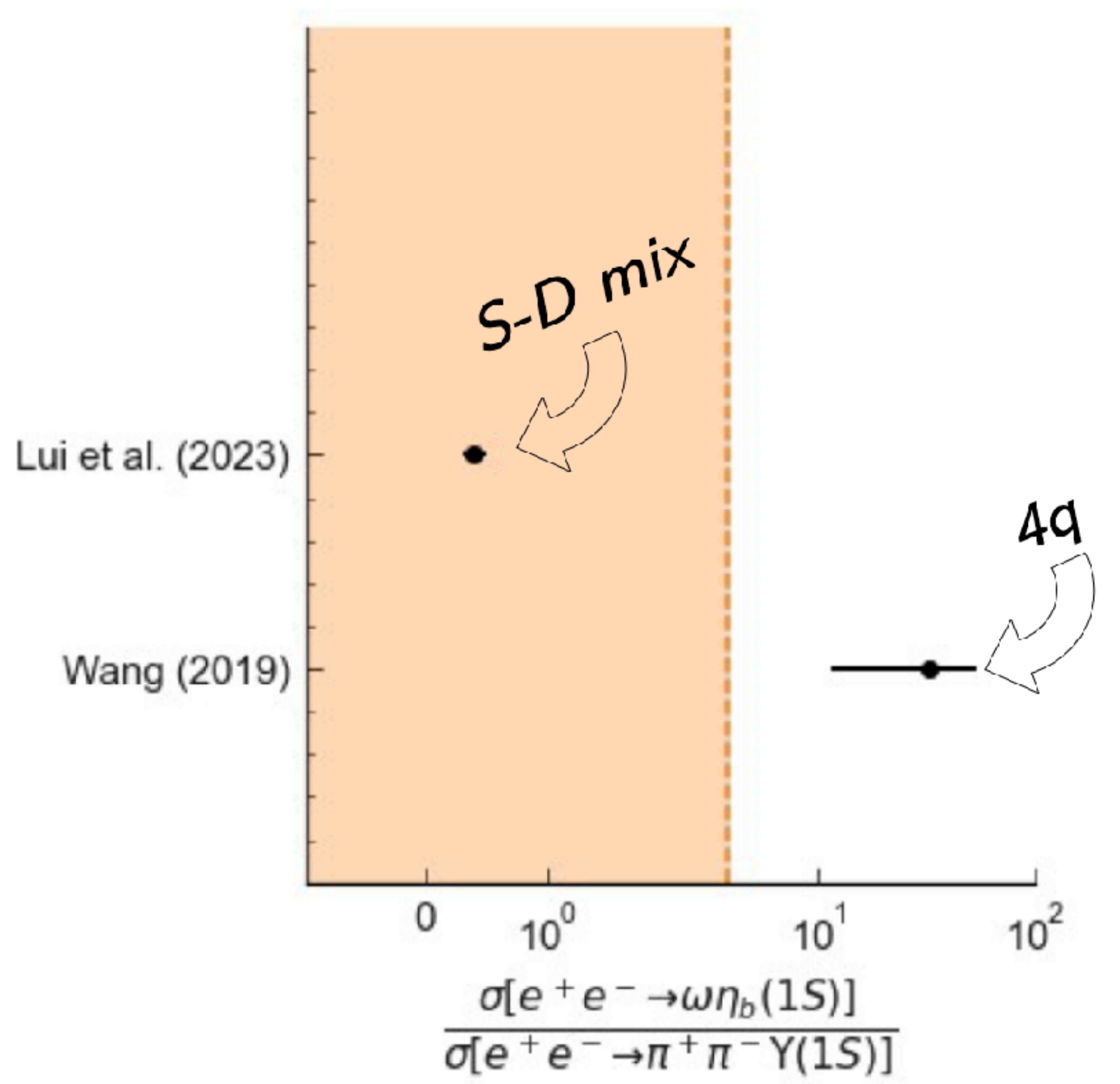
- → Reconstruct ω
- → Measure its recoil mass

No convenient reconstruction decay channels for $\eta_b(1S)$

[arxiv:2312.13043]



Compatible with S-D mixed

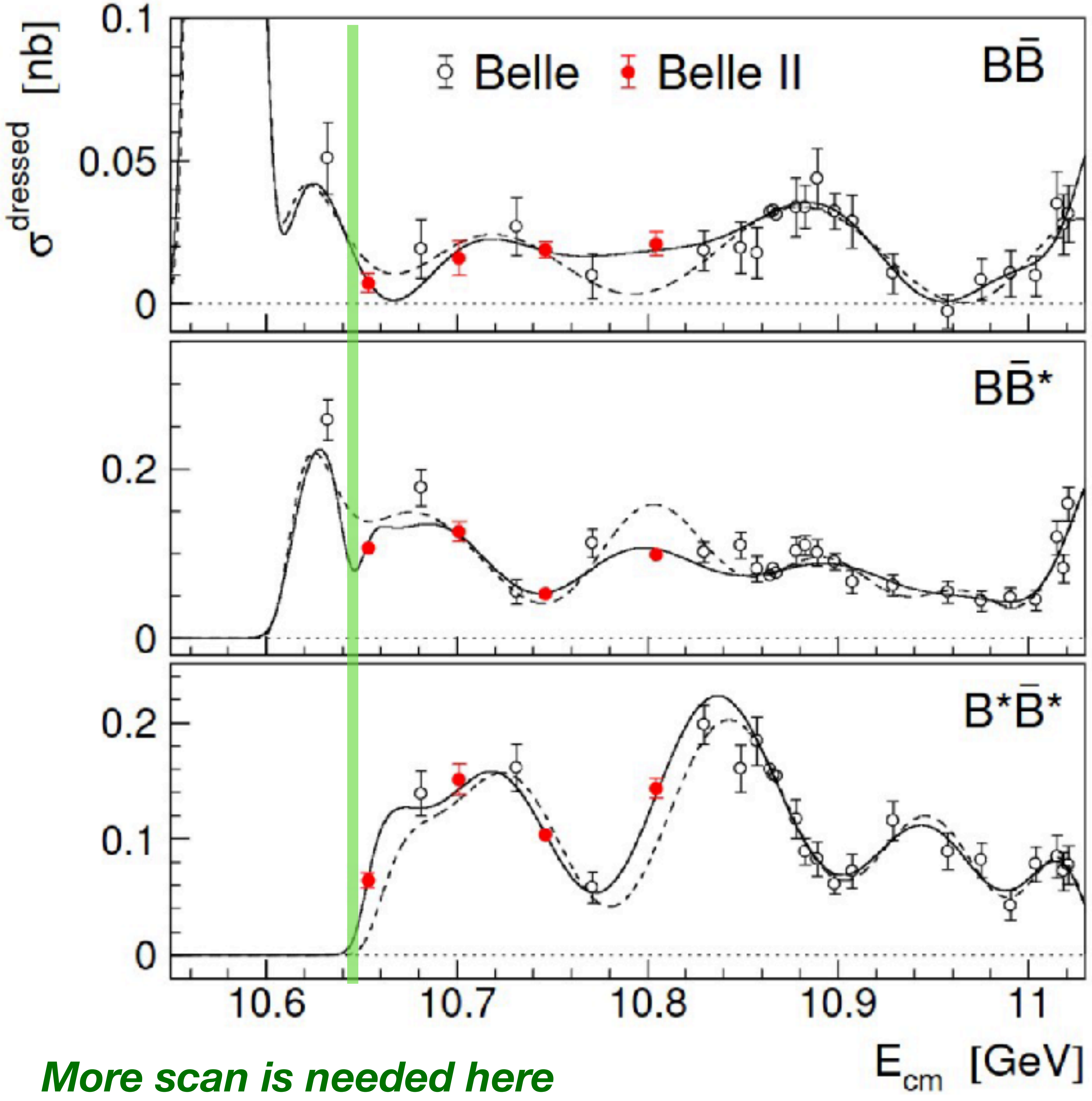


No evidence of ω transition to $\eta_b(1S)$!

$$\sigma_B(e^+e^- \to \eta_b(1S)\omega) < 2.5\,\text{pb}$$

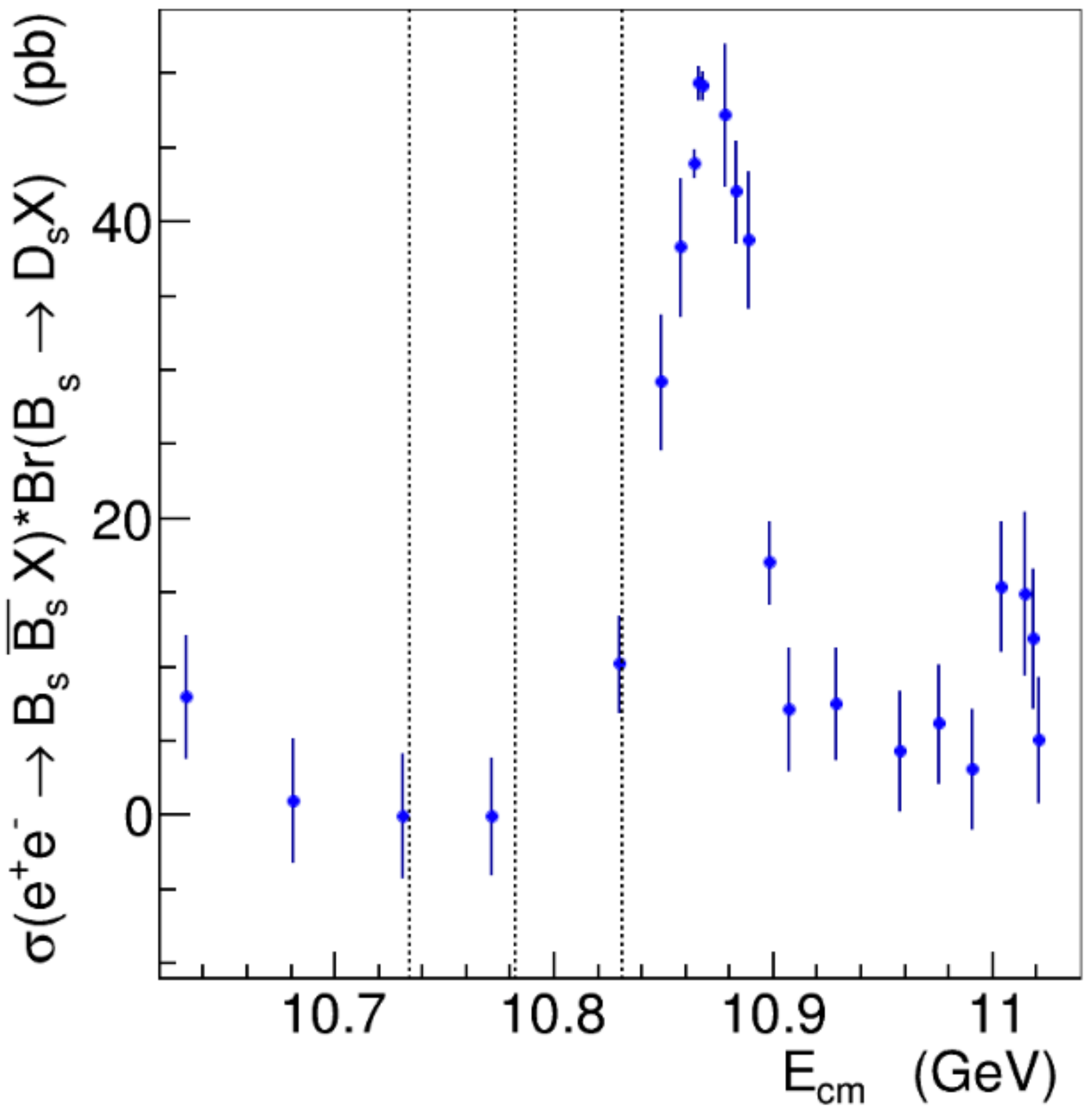
Measurement of $e^+e^- \to B^{(*)}\bar{B}^{(*)}$, $B_s^{(*)}\bar{B}_s^{(*)}$

arXiv: 2104.08371 *[Belle II Preliminary]*



More scan is needed here

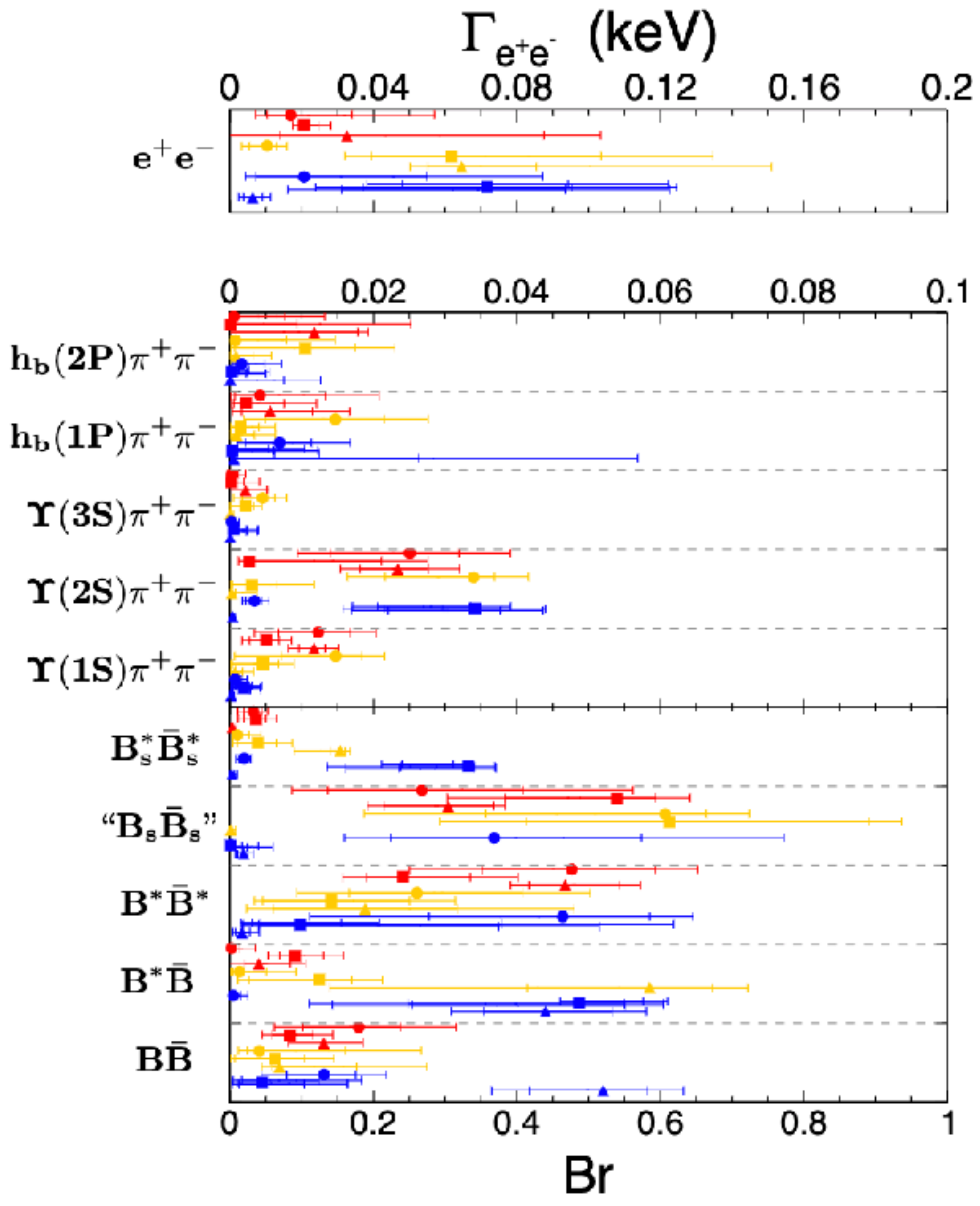
[JHEP 08 2023, 131 (2023)]



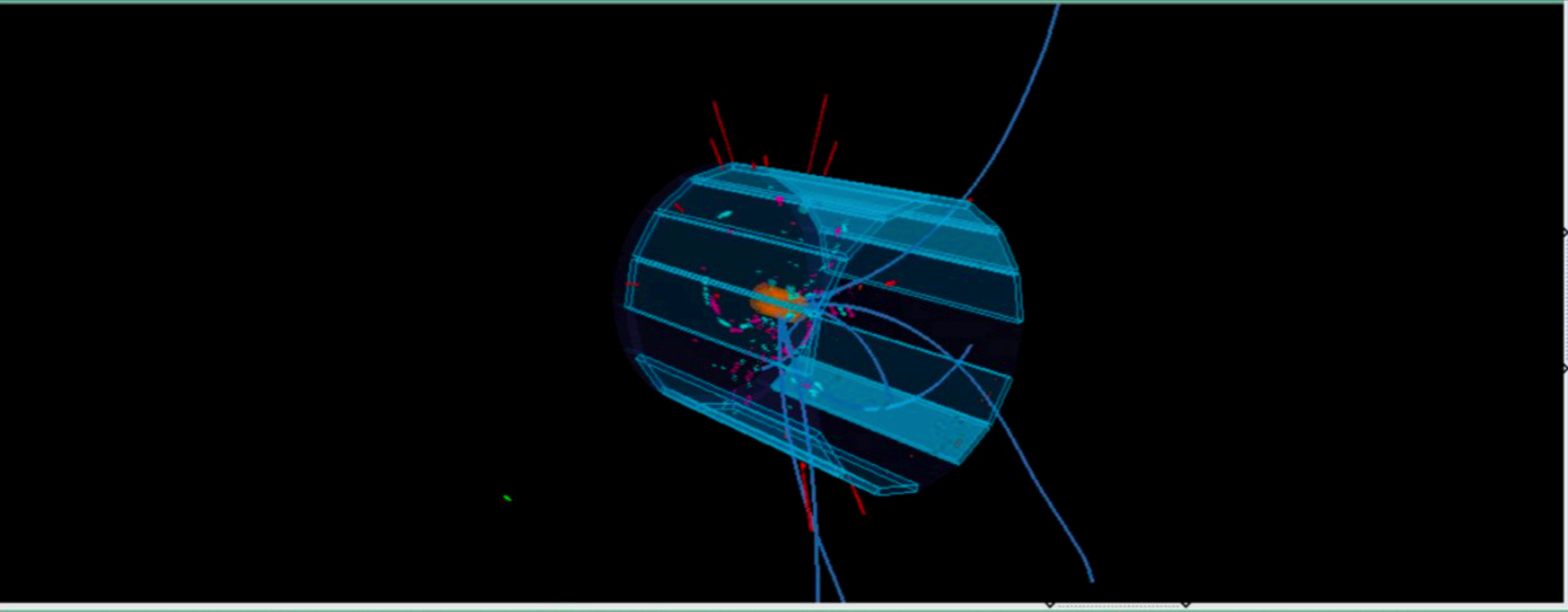
$\Upsilon(10753) \to B_s\bar{B}_s$ ***is small***

Summary

- Suggestive of a conventional bottomonium state
- More analyses are ongoing:
  - $\Upsilon(10753) \to K^+K^-\Upsilon(nS)$
  - $\Upsilon(10753) \to \eta(\eta')\Upsilon(nS)$
  - $\Upsilon(10753) \to \gamma\chi_{bJ}$
  - …
- Up to 79% branching fraction is missing[1]. Where are they?
- Belle II has collected 424/fb data, including ~380/fb $\Upsilon(4S)$.
  - More results other than $\Upsilon(10753)$ will come out.
- Long shutdown has finished, is accumulating more data.
  - More data, more new results



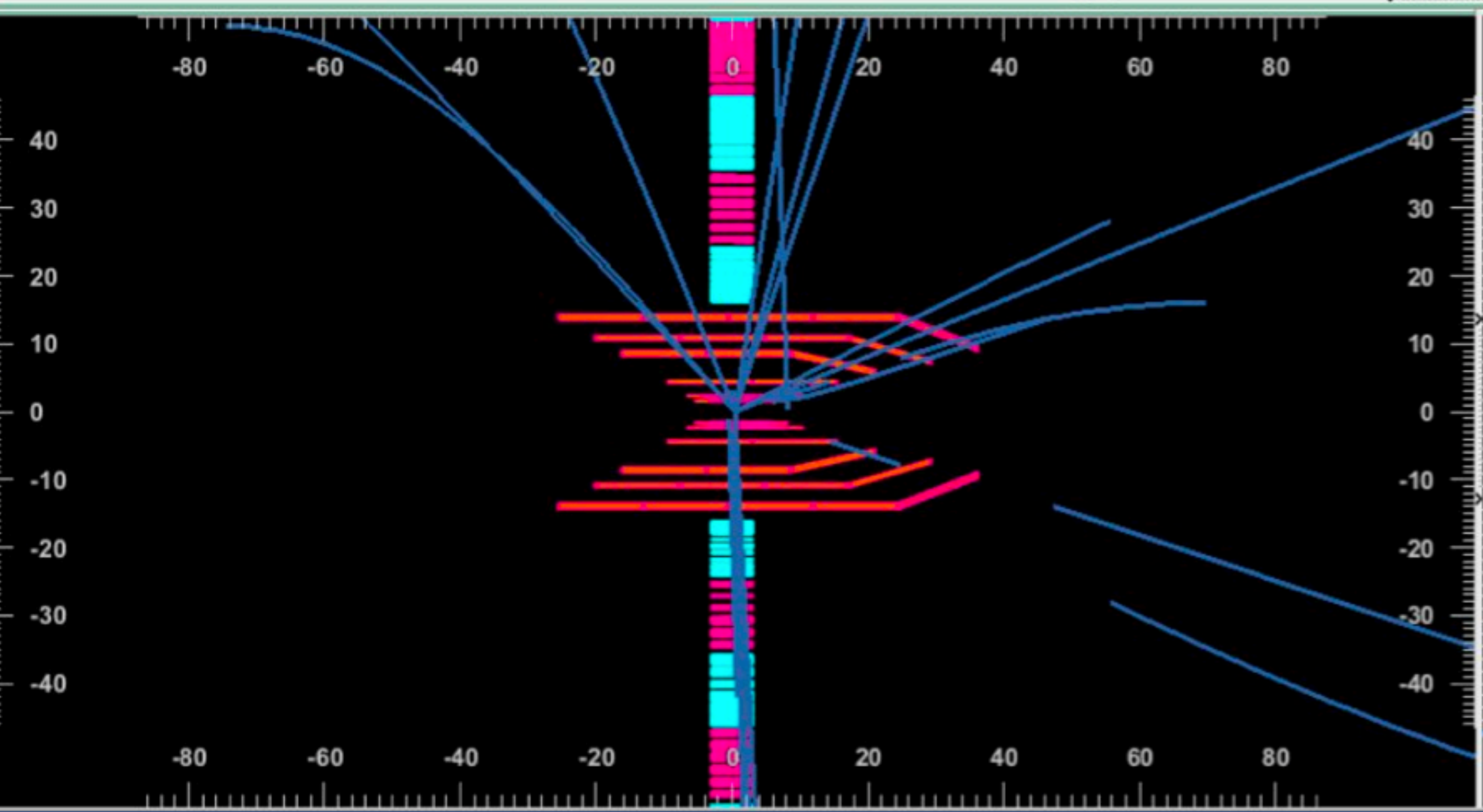
[1]Phys.Rev.D 106 (2022) 9, 094013

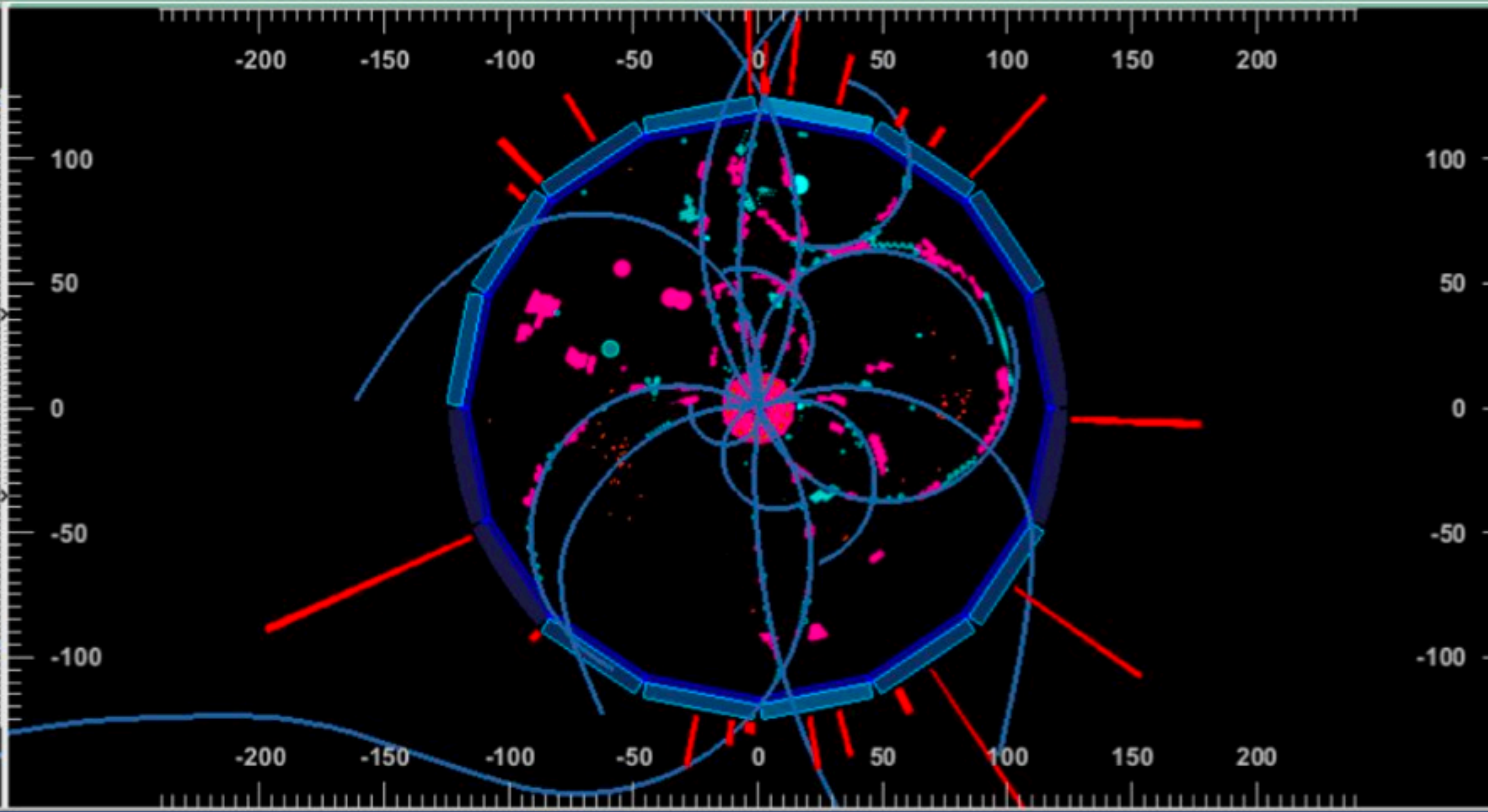


Belle II

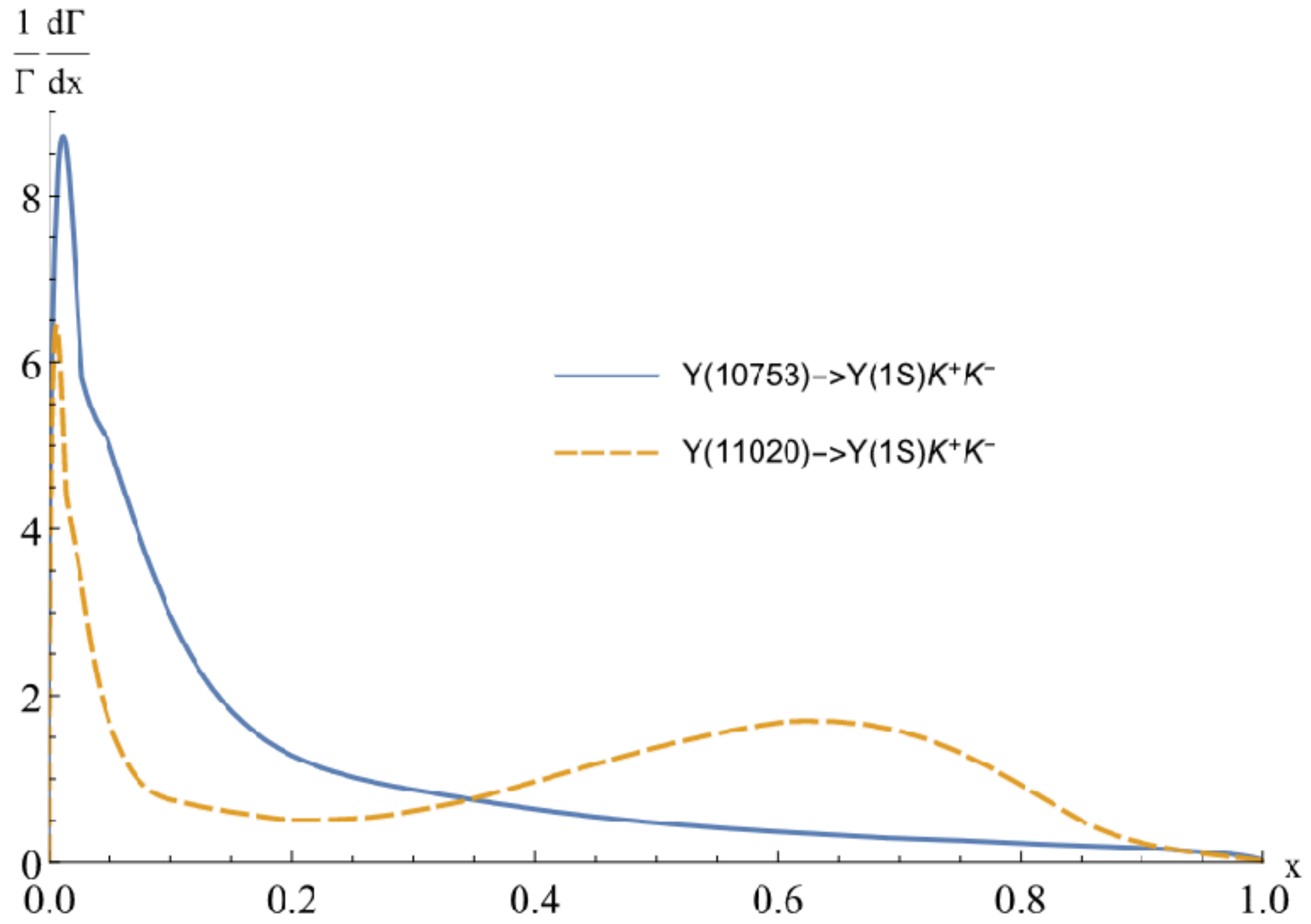
First Collisions of Run 2

20th February 2024



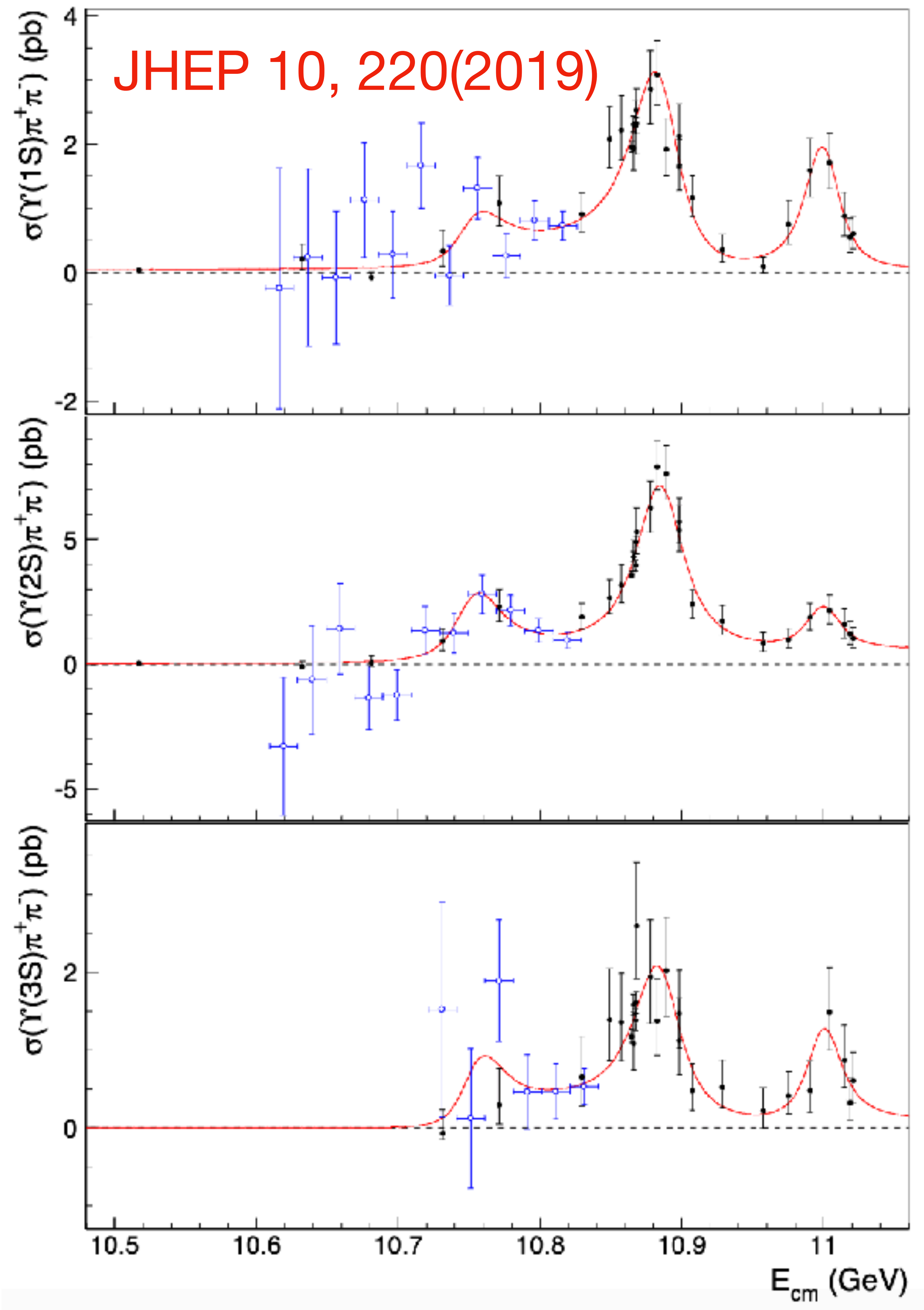


BACK UP



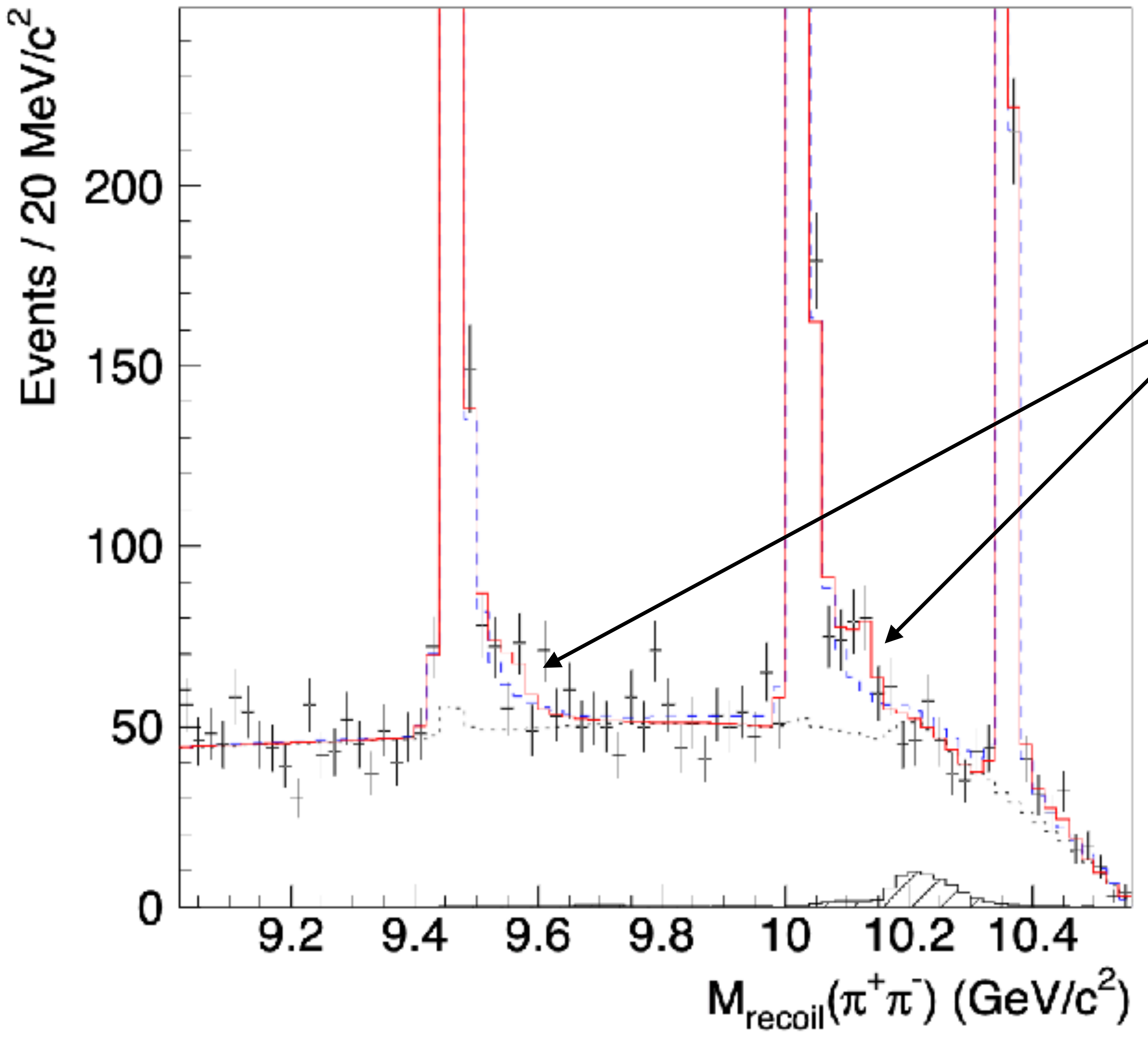
$\frac{1}{\Gamma}\frac{d\Gamma}{dx}$
Υ(10753)->Υ(1S)K^+K^-
Υ(11020)->Υ(1S)K^+K^-
x
0
2
4
6
8
0.0
0.2
0.4
0.6
0.8
1.0

$\Upsilon(10753)$ — discovery and studies



- The $\Upsilon(10753)$ was firstly observed in the process of $e^+e^- \to \Upsilon(nS)\pi^+\pi^-(n = 1,2,3)$ by Belle.

- Simultaneous fit to cross sections and $M_{\mathrm{recoil}}(\pi\pi)$

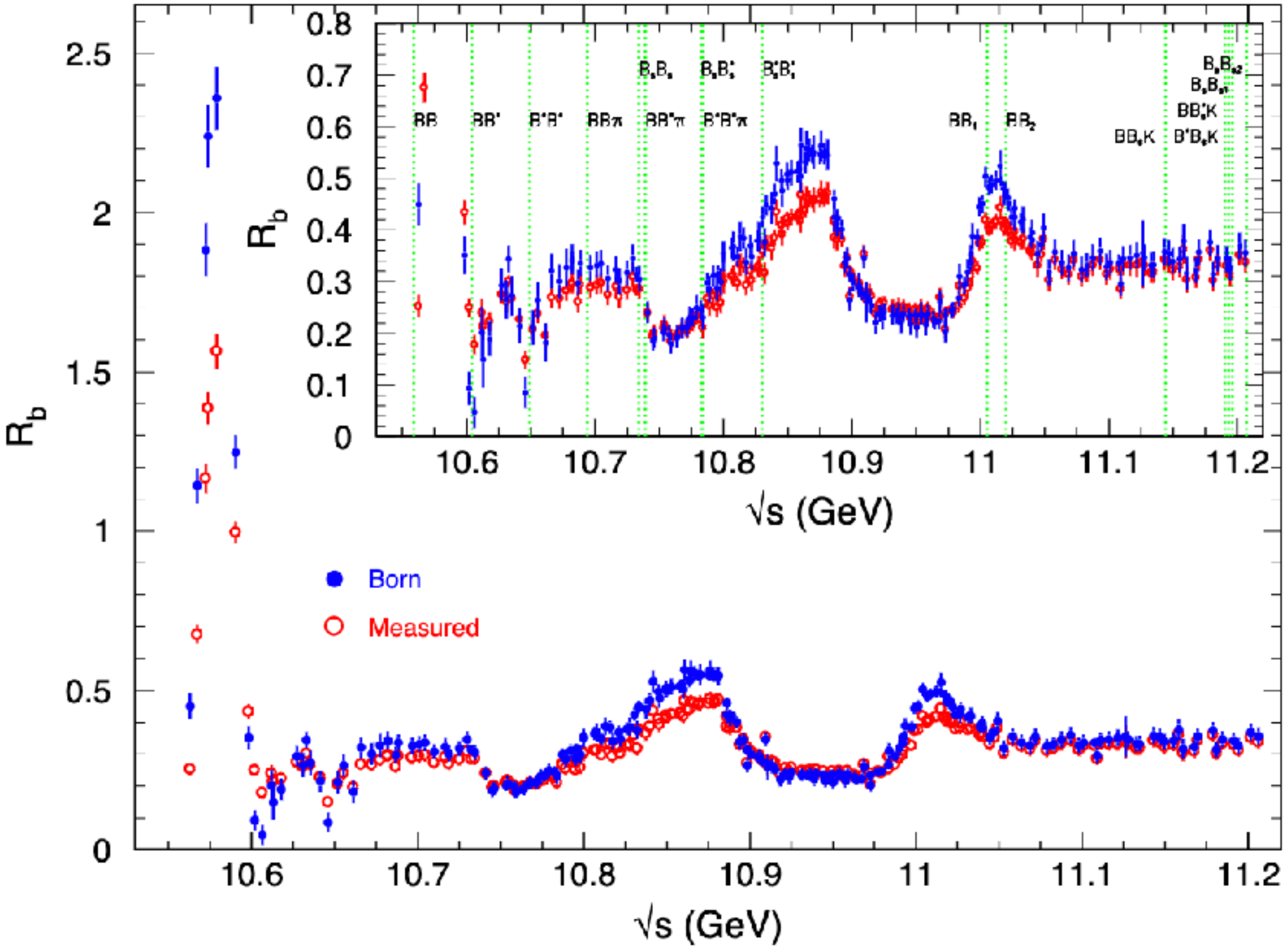


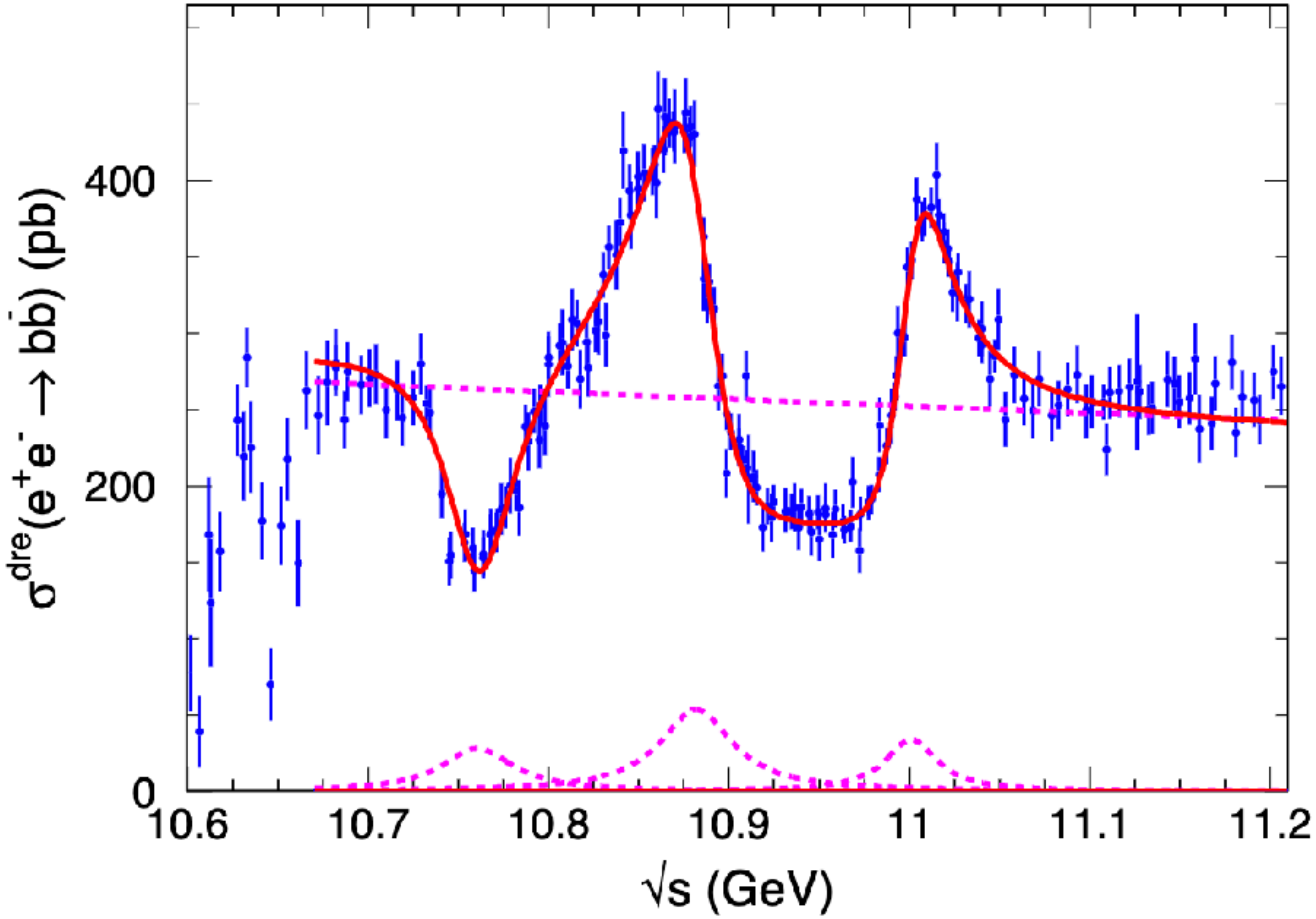
Existence of $\Upsilon(10753)$

Computed as blue dots in left plot

$M = (10752.7 \pm 5.9^{+0.7}_{-1.1})\ \mathrm{MeV}/c^2$

$\Gamma = (35.5^{+17.6}_{-11.3}\ {}^{+3.9}_{-3.3})\ \mathrm{MeV}$





$M = (10761 \pm 2)\ \mathrm{MeV}/c^2$

$\Gamma = (48.5 \pm 3.0)\ \mathrm{MeV}$

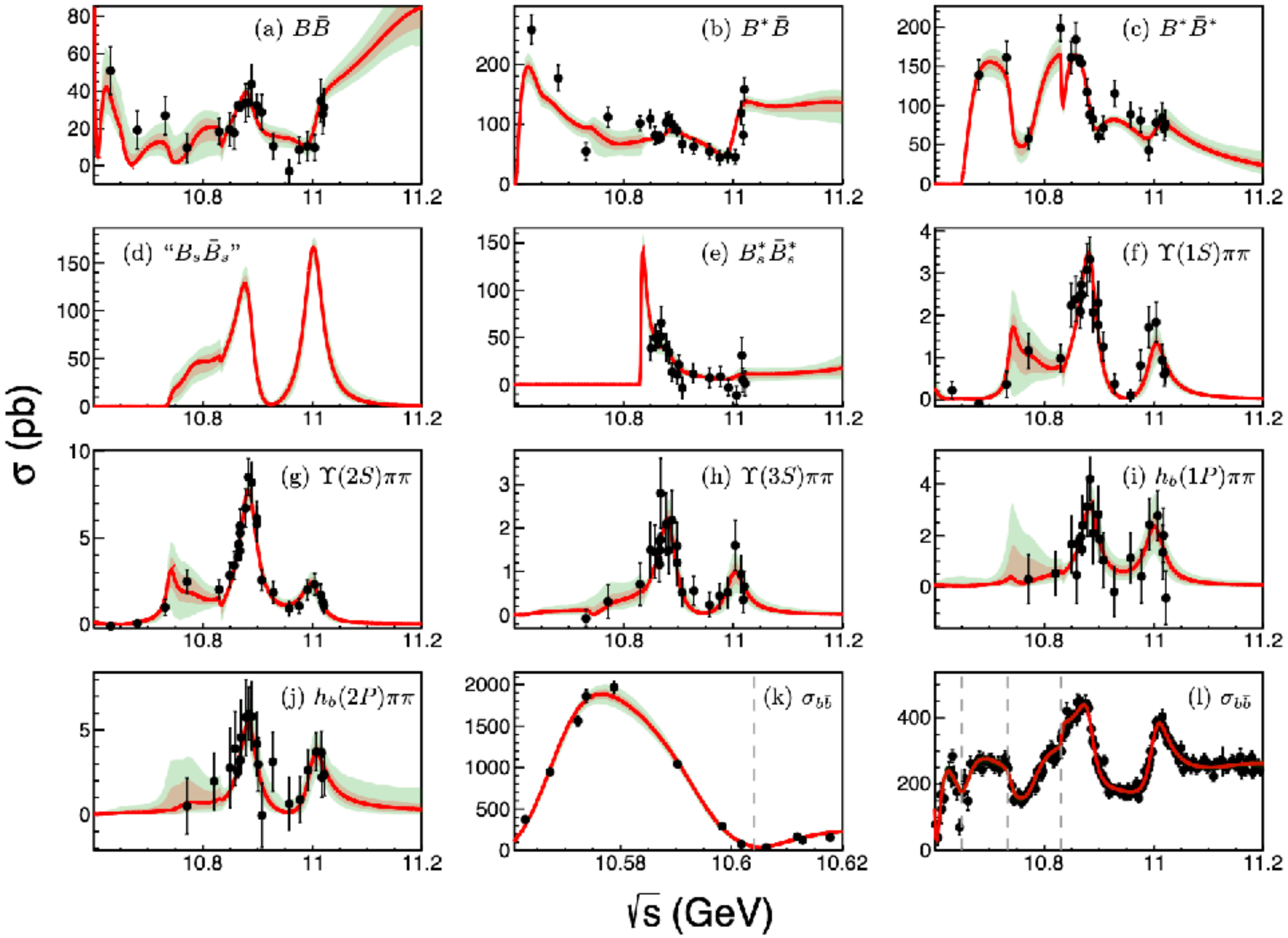
- A dip in the R_b distribution near $10.75\ \mathrm{GeV}$
- Fit to dressed cross section of $b\bar{b}$ with three BWs.

"The results from these fits may change dramatically by including more information on each exclusive mode. "

K-matrix Analysis of e^+e^- Annihilation in the Bottomonium Region

N. Hüsken,[1,2] R.E. Mitchell,[1] and E.S. Swanson[3]

Phys.Rev.D 106 (2022) 9, 094013

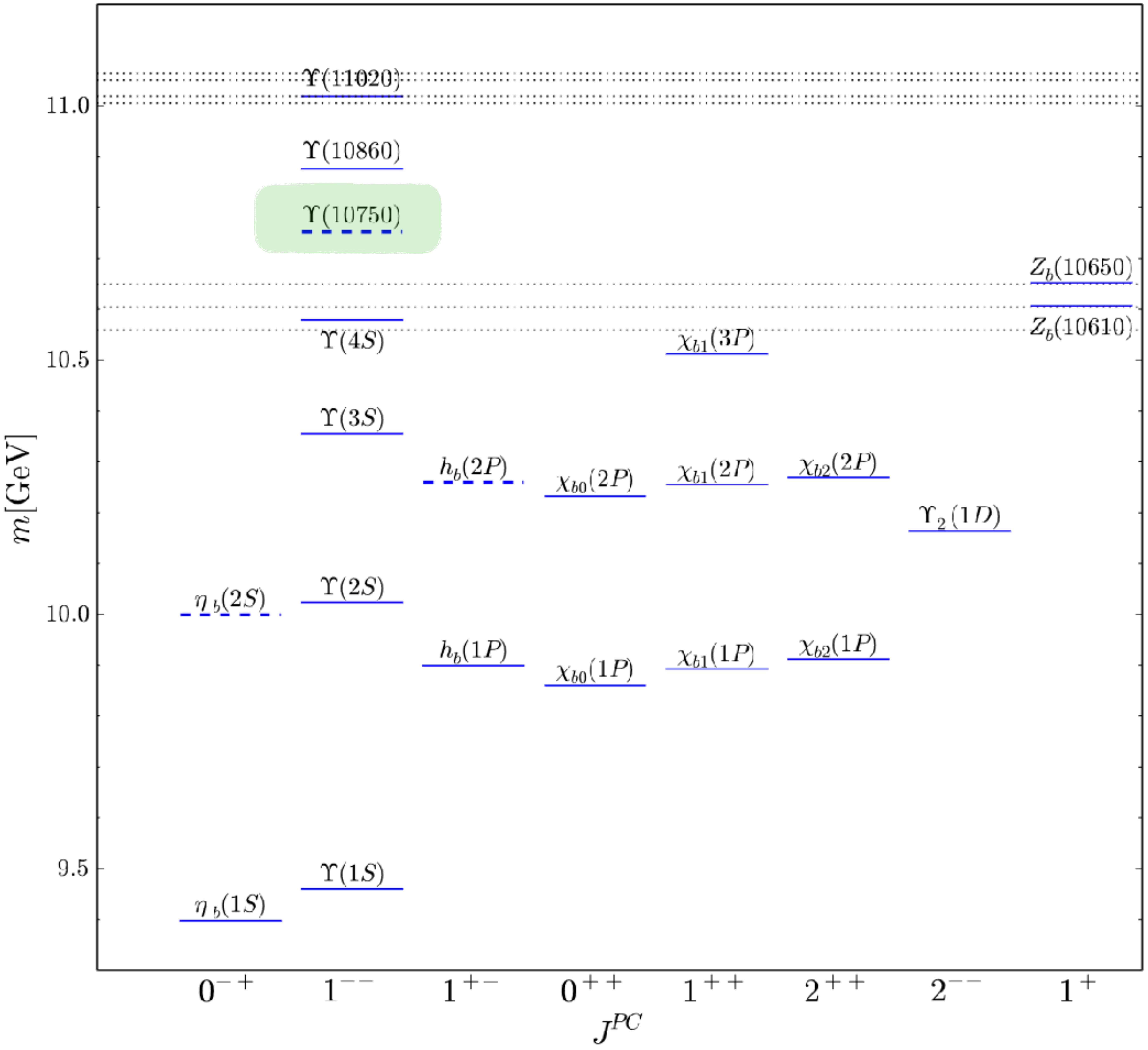


Strong evidence for $\Upsilon(10753)$ with significance $>10\sigma$

Pole locations varies with models.

state	RPP	our estimate	GM	ARM	NR	bbg	SOEF	LGT
1^3S_1	9460		9465	9444	9454	9445	9502	9419.1(4)
2^3S_1	10023		10003	10029	10010	10002	10015	9981(4)
3^3S_1	10355		10354	10374	10344	10339	10349	10384(12)
4^3S_1	10579	(10590 - 10610)	10635	10641	10614	10610	10607	
5^3S_1	10885	(10878 - 10884)	10878	10865	10849	10848	10818	
6^3S_1	11000	(11000 - 11008)	11102	11065	11064	11064	10995	
1^3D_1			10138	10156	10146	10148	10117	10191(9)
2^3D_1			10441	10453	10432	10435	10414	10718(33)
3^3D_1			10698	10697	10679	10684	10653	
$\Upsilon(10750)$	10753	(10630 - 10780)						
hybrid						11093		10952(33)

TABLE IV. Experimental and Theoretical Vector Bottomonium Masses (MeV).



Bottomonium?

Phys. Rev. D 101, 014020 (2020)

Phys. Lett. B 803, 135340 (2020)

Eur. Phys. J. C 80, 59 (2020)

Phys. Rev. D 102, 014036 (2020)

Prog. Part. Nucl. Phys. 117, 103845 (2021)

Phys. Rev. D 104, 034036 (2021)

Phys. Rev. D 105, 074007 (2022)

etc…

Hybrid?

Phys. Rept. 873, 1 (2020)

Phys. Rev. D 104, 034019 (2021)

etc…

Tetraquark?

Phys. Lett. B 802, 135217 (2020)

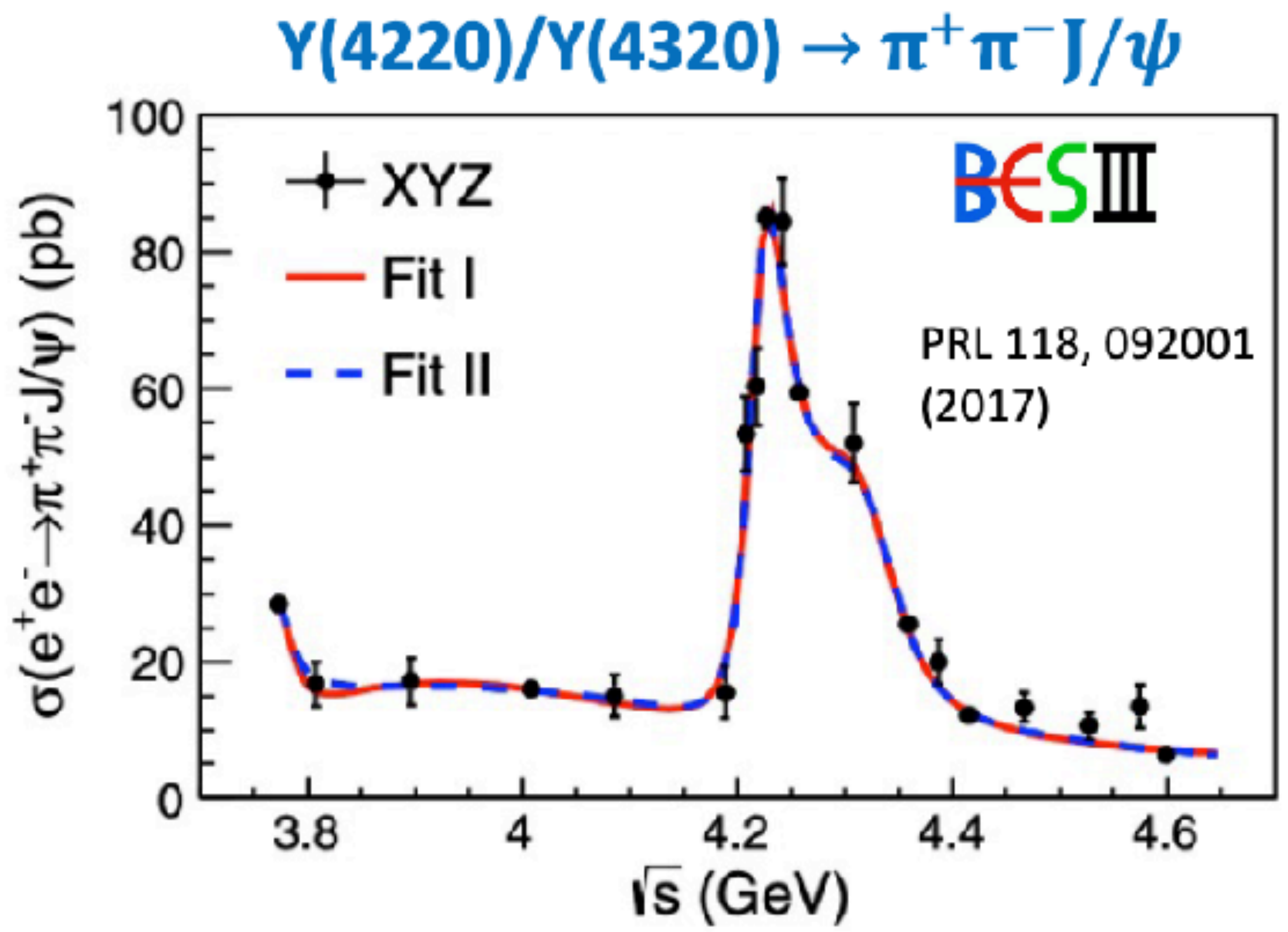
Chin. Phys. C 43, 123102 (2019)

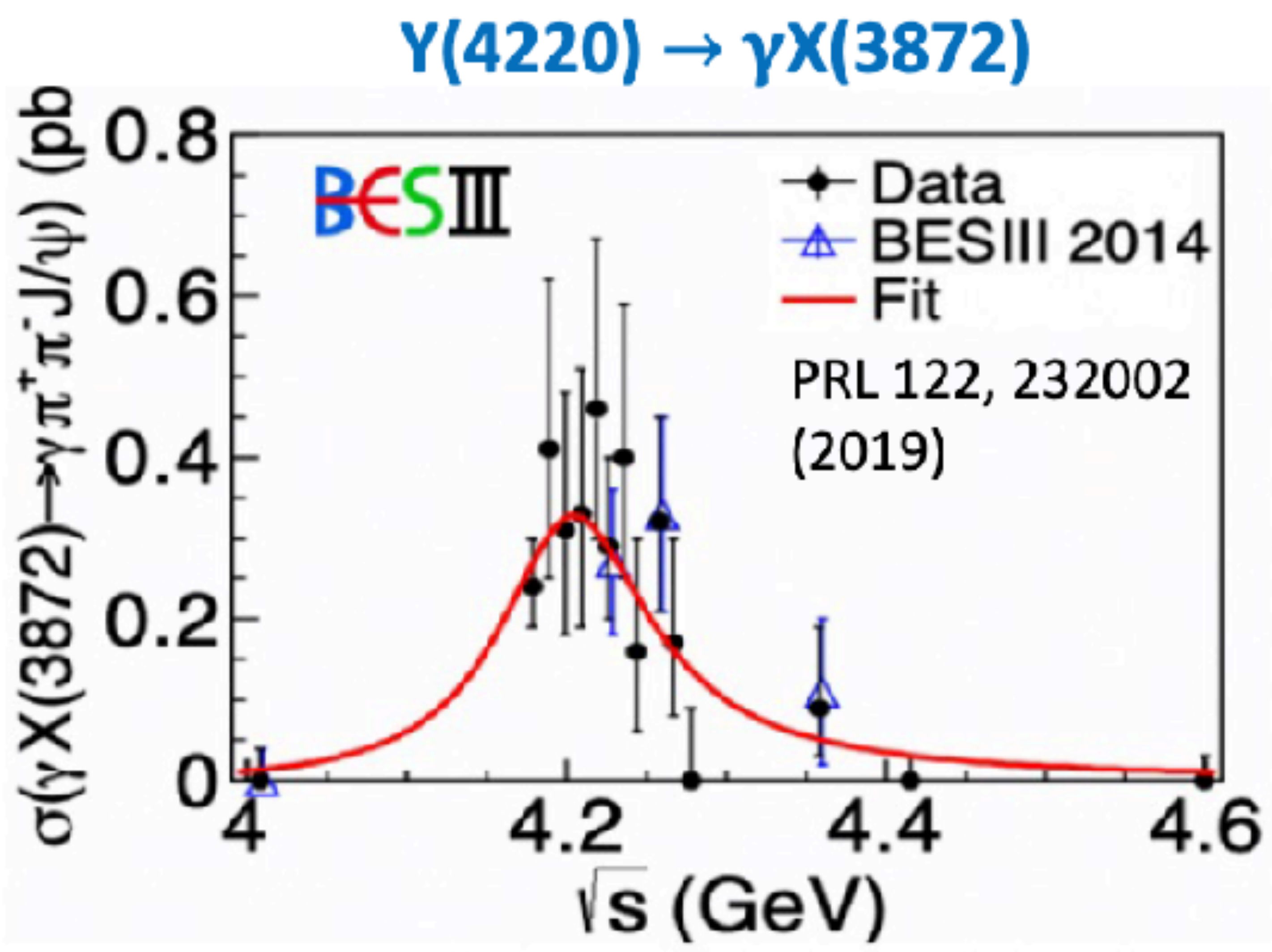
Phys. Rev. D 103, 074507 (2021)

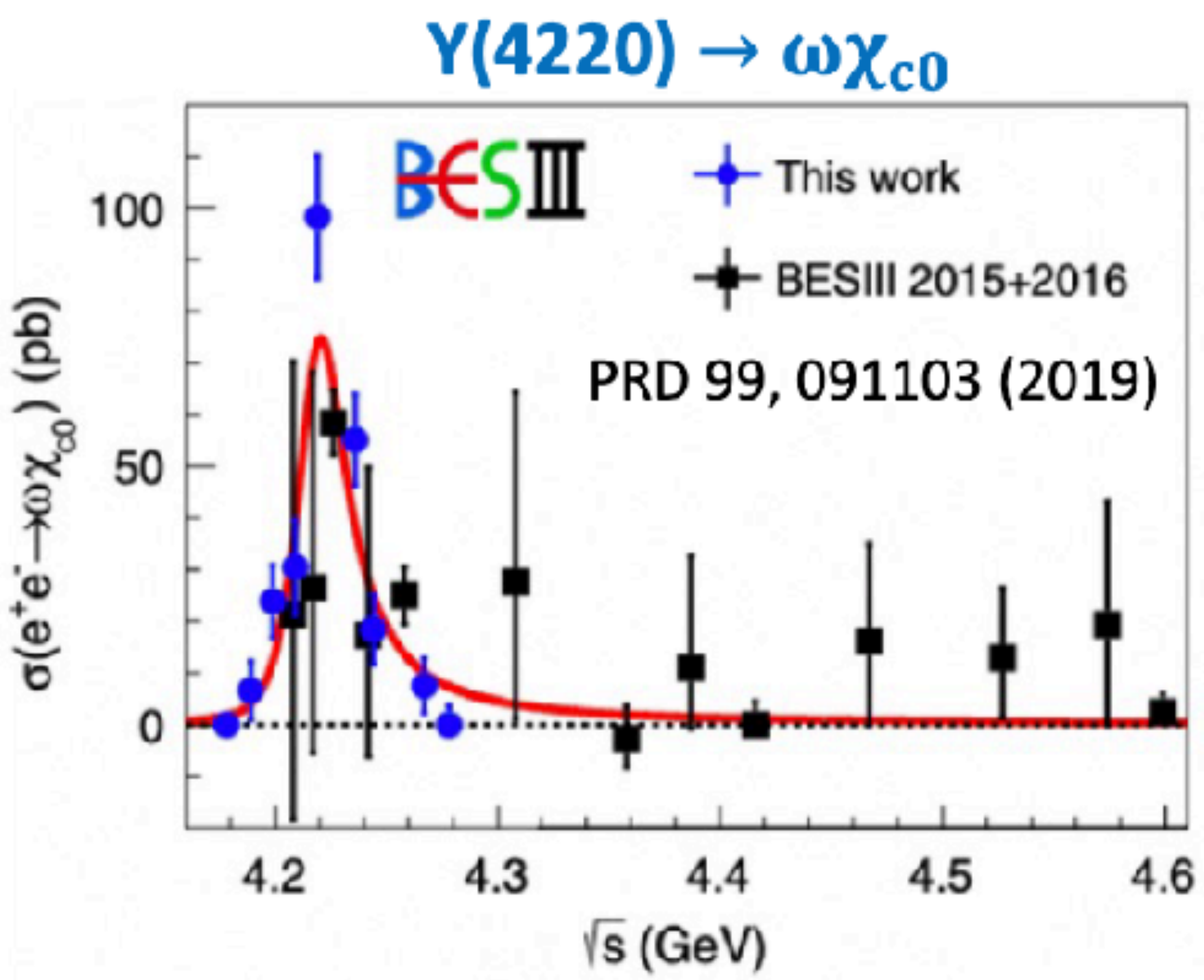
Phys. Rev. D 107, 094515 (2023)

etc…

Two close peaks observed in the cross sections for $e^+e^- \to \pi^+\pi^- J/\psi$ by BESIII and $e^+e^- \to \pi^+\pi^- \Upsilon(nS)$ by Belle. May suggest similar nature.

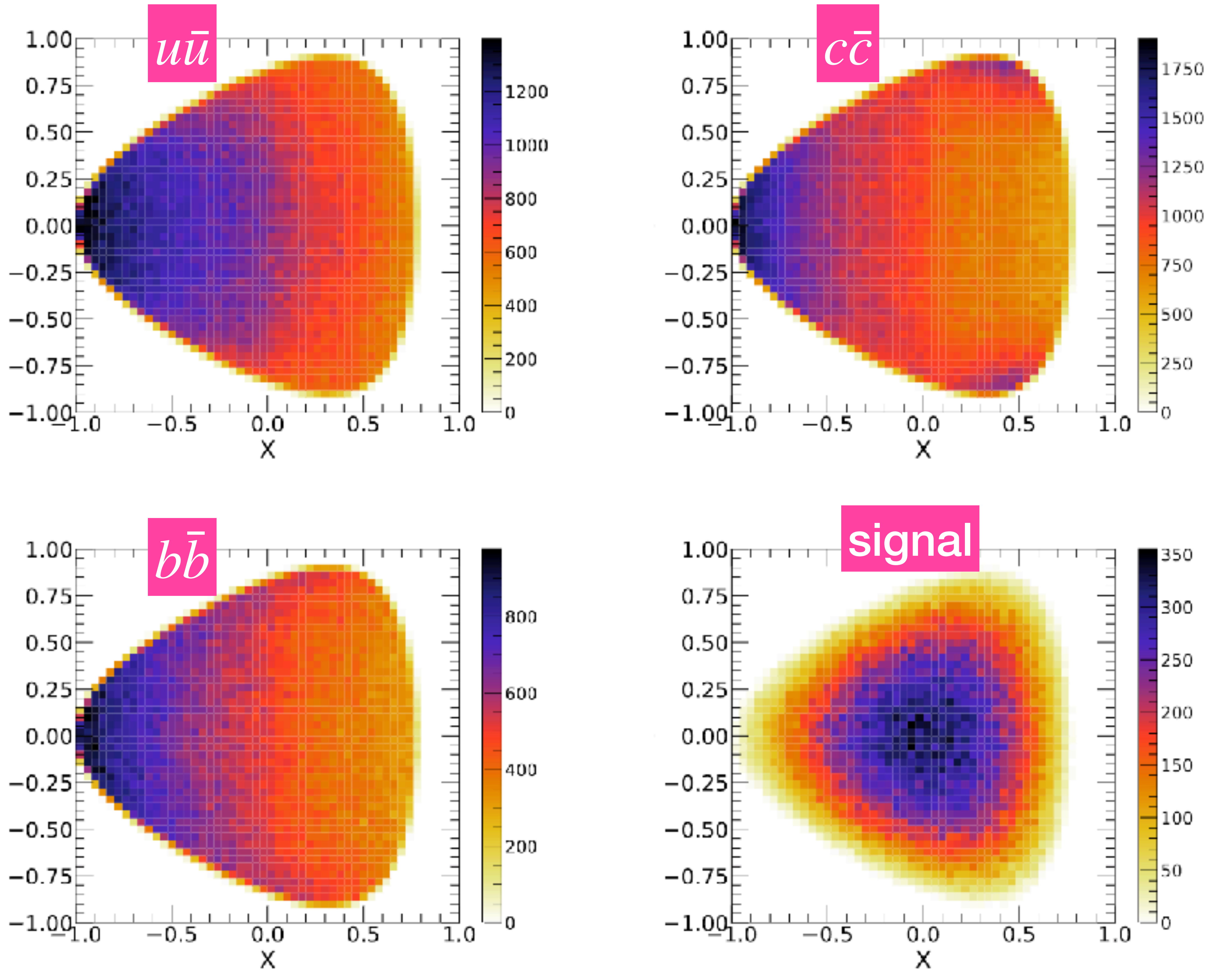


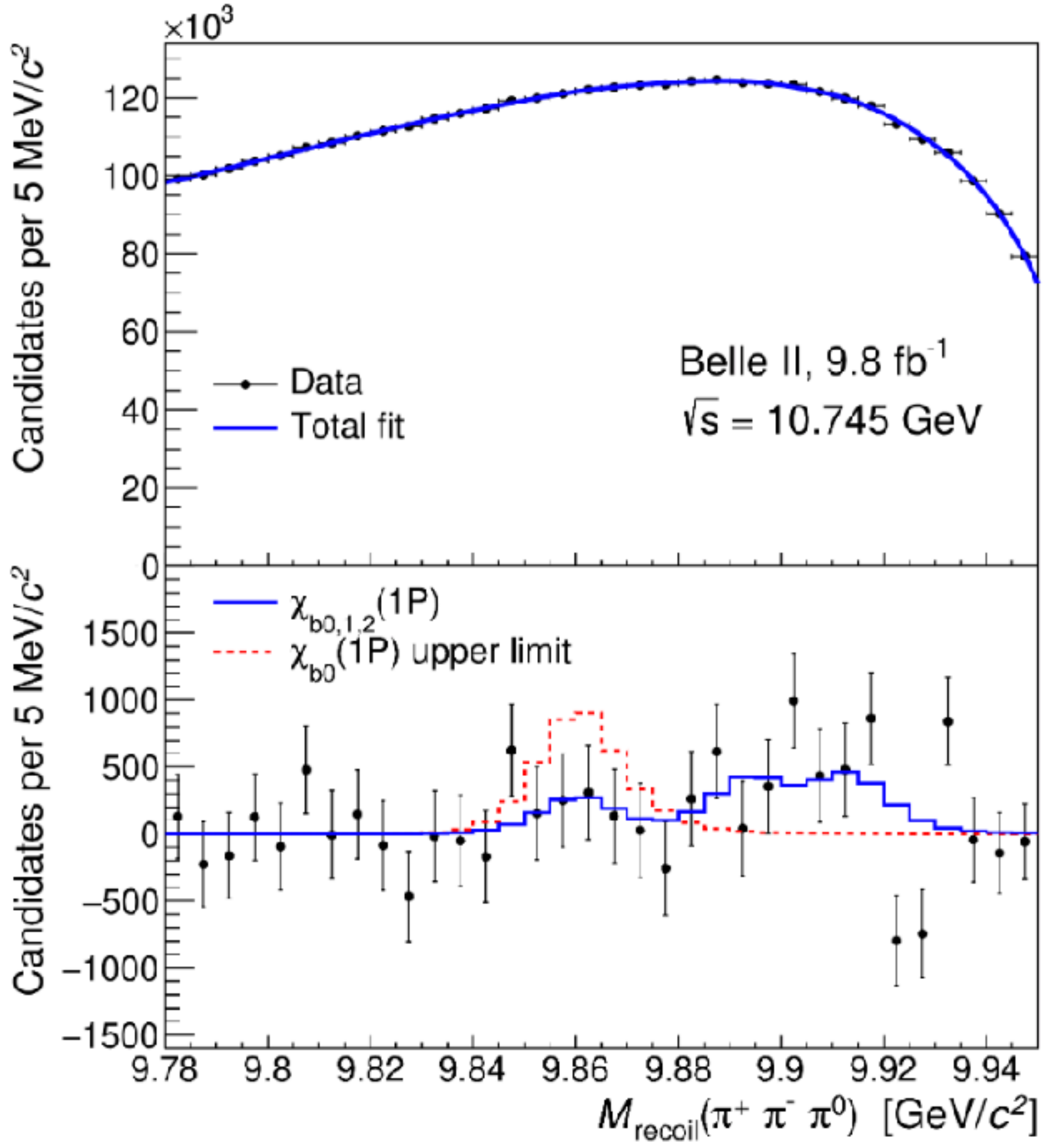




- $Y(4230) \to \gamma X(3872)$ and $Y(4230) \to \omega\chi_{c0}$ were observed by BESIII.
  - Expect the $\Upsilon(10753)$ state to decay into $X_b\gamma$.
  - Should be more easily to be found in $\omega\Upsilon(1S)$ than $\pi\pi\Upsilon(1S)$ *[Eur.Phys.J.C 74 (2014) 9, 3063]*

Suppress background with ω-Dalitz plot.

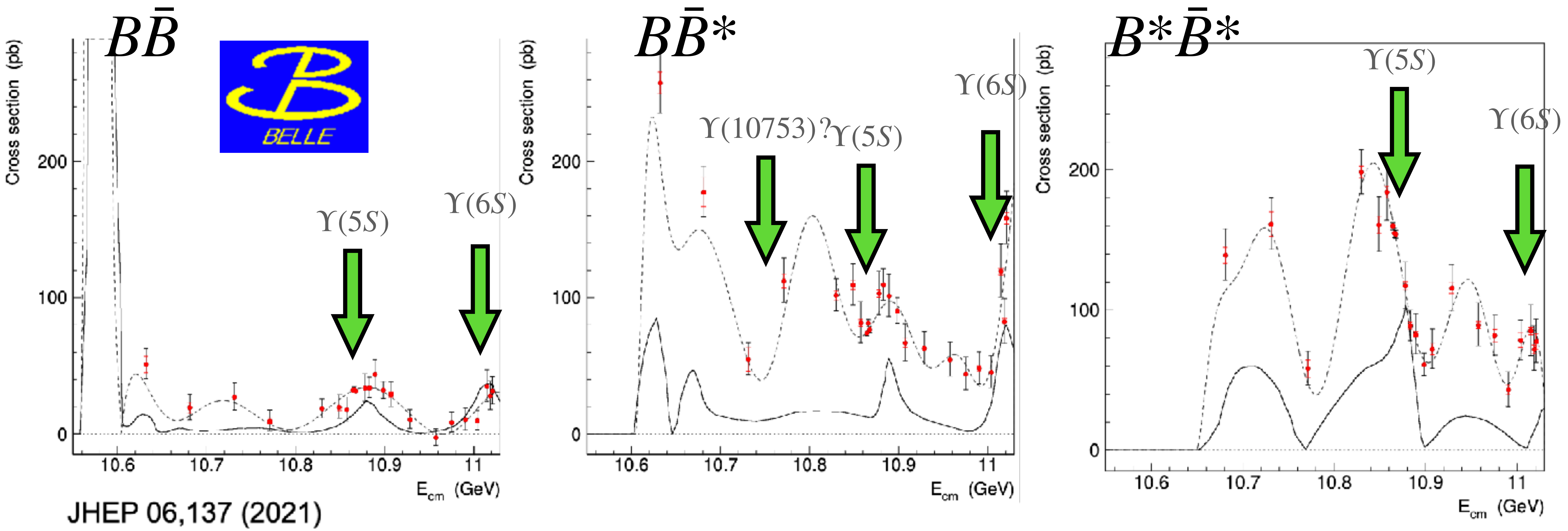




Signal yields: $(1.2 \pm 1.4 \pm 0.9) \times 10^3$ ==> $\sigma_{\text{Born}} = (2.6 \pm 3.1 \pm 2.0)$ pb

$\sigma^{\text{up}}_{\text{Born}} < 8.7$ pb, comparable to the UL obtained before (11.3 pb)

Measurement of $e^+e^- \to B^{(*)}\bar{B}^{(*)}$



JHEP 06,137 (2021)

- Coupled channel analysis of high energy scan data using the K-matrix formalism shows four poles: $\Upsilon(4S)$, $\Upsilon(10753)$, $\Upsilon(5S)$, $\Upsilon(6S)$.
- Need more data to fill the gaps.

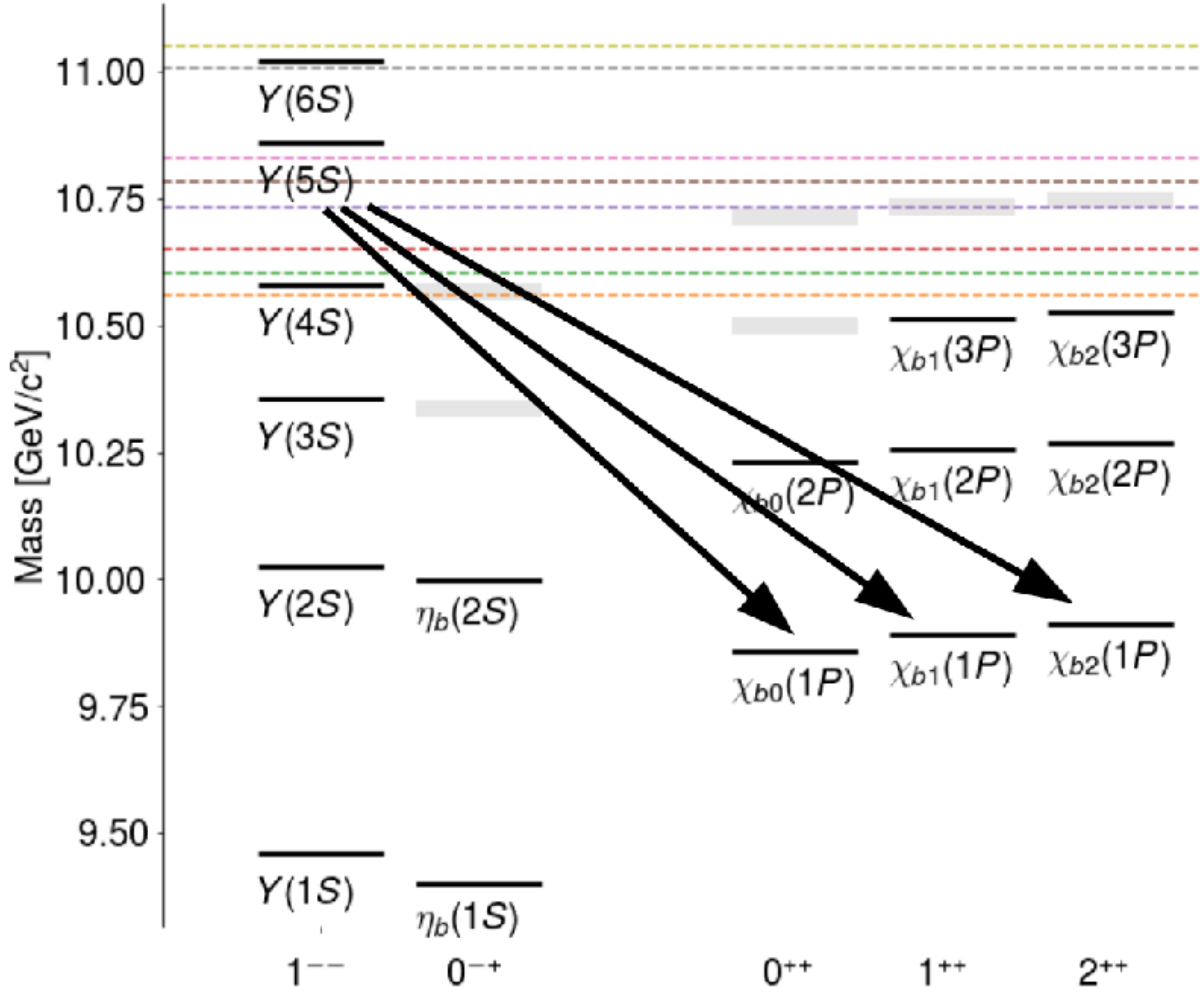
$\Upsilon(10753) \to \omega\chi_{bJ}$

Y(10750) → ω χ_b in the conventional quarkonium model (S-D mixing state)

[Y.S. Li, et al., PRD 104, 034036 (2021)]

$$\mathcal{B}[\Upsilon(10753) \to \chi_{b0}\omega] = (0.73\text{–}6.94) \times 10^{-3},$$
$$\mathcal{B}[\Upsilon(10753) \to \chi_{b1}\omega] = (0.25\text{–}2.16) \times 10^{-3},$$
$$\mathcal{B}[\Upsilon(10753) \to \chi_{b2}\omega] = (1.08\text{–}11.5) \times 10^{-3}.$$

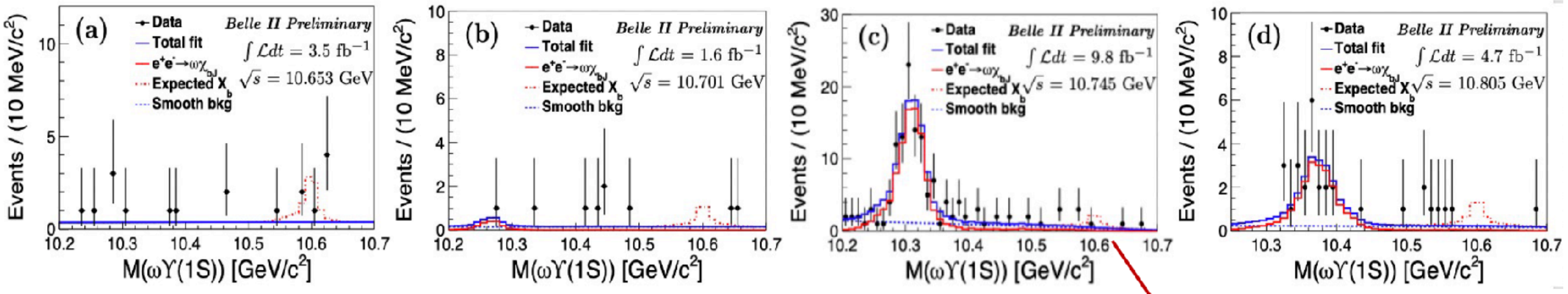
$$R_{12} = \frac{\mathcal{B}[\Upsilon(10753) \to \chi_{b1}\omega]}{\mathcal{B}[\Upsilon(10753) \to \chi_{b2}\omega]} = (0.18\text{–}0.22)$$
$$R_{02} = \frac{\mathcal{B}[\Upsilon(10753) \to \chi_{b0}\omega]}{\mathcal{B}[\Upsilon(10753) \to \chi_{b2}\omega]} = (0.55\text{–}0.63)$$



Sizable branching fractions

Search for $X_b \to \omega\Upsilon(1S)$ in $e^+e^- \to \gamma\omega\Upsilon(1S)$

[PRL 130, 091902 (2023)]



From simulated events with $m(X_b) = 10.6$ GeV/c^2
The yield is fixed at the upper limit at 90% C.L.

- No significant X_b signal is observed.
- The peaks are the reflections of $e^+e^- \to \omega\chi_{bJ}$.

Upper limits at 90% C.L. on $\sigma_B(e^+e^- \to \gamma X_b) \cdot \mathcal{B}(X_b \to \omega\Upsilon(1S))$ (pb)	$\sqrt{s}$ (GeV)	10.653	10.701	10.745	10.805
	$m(X_b) = 10.6$ GeV/c^2	0.45	0.33	0.10	0.14
	$m(X_b) = (10.45, 10.65)$ GeV/c^2	(0.14, 0.54)	(0.25, 0.84)	(0.06, 0.14)	(0.08, 0.36)