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

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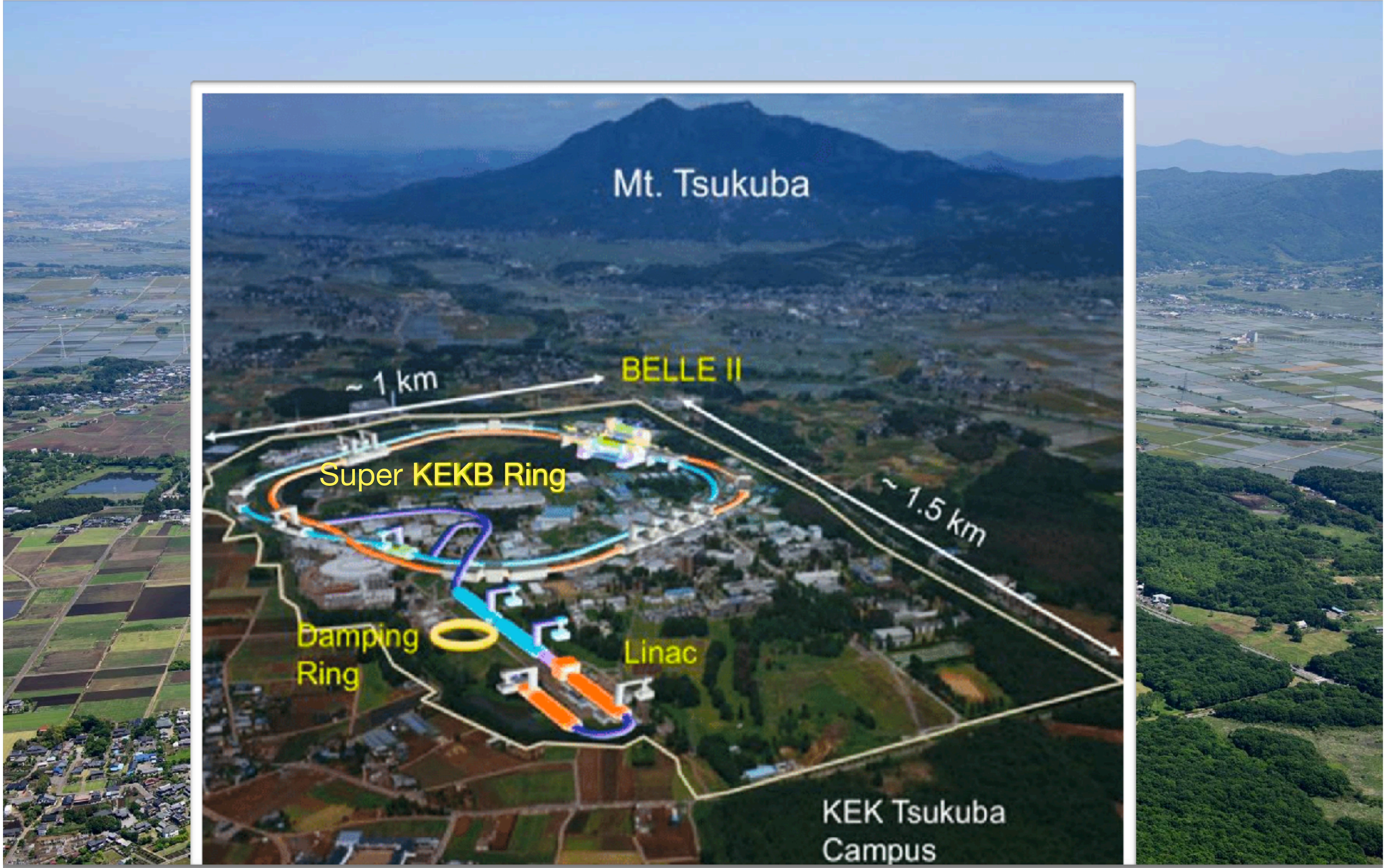
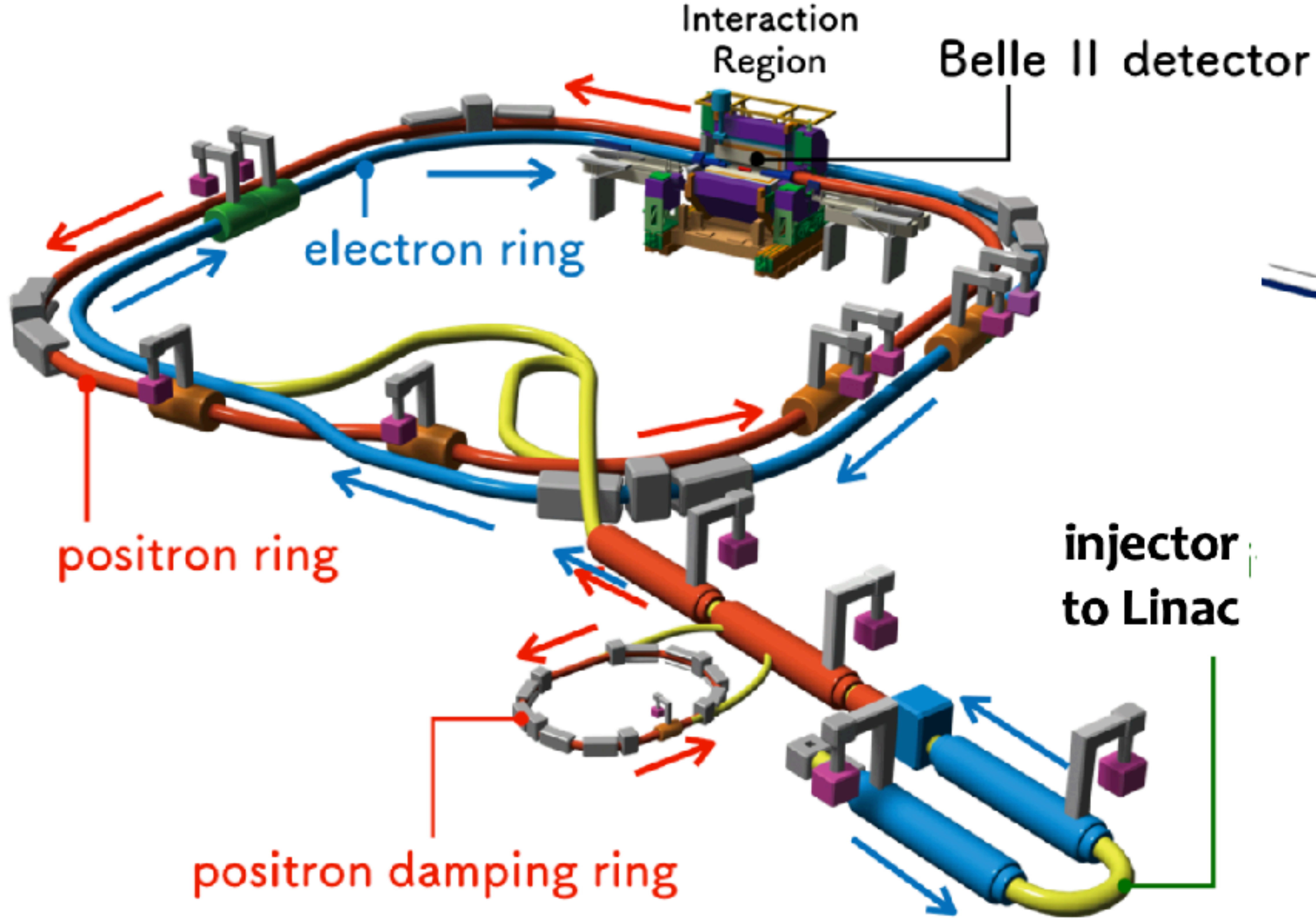
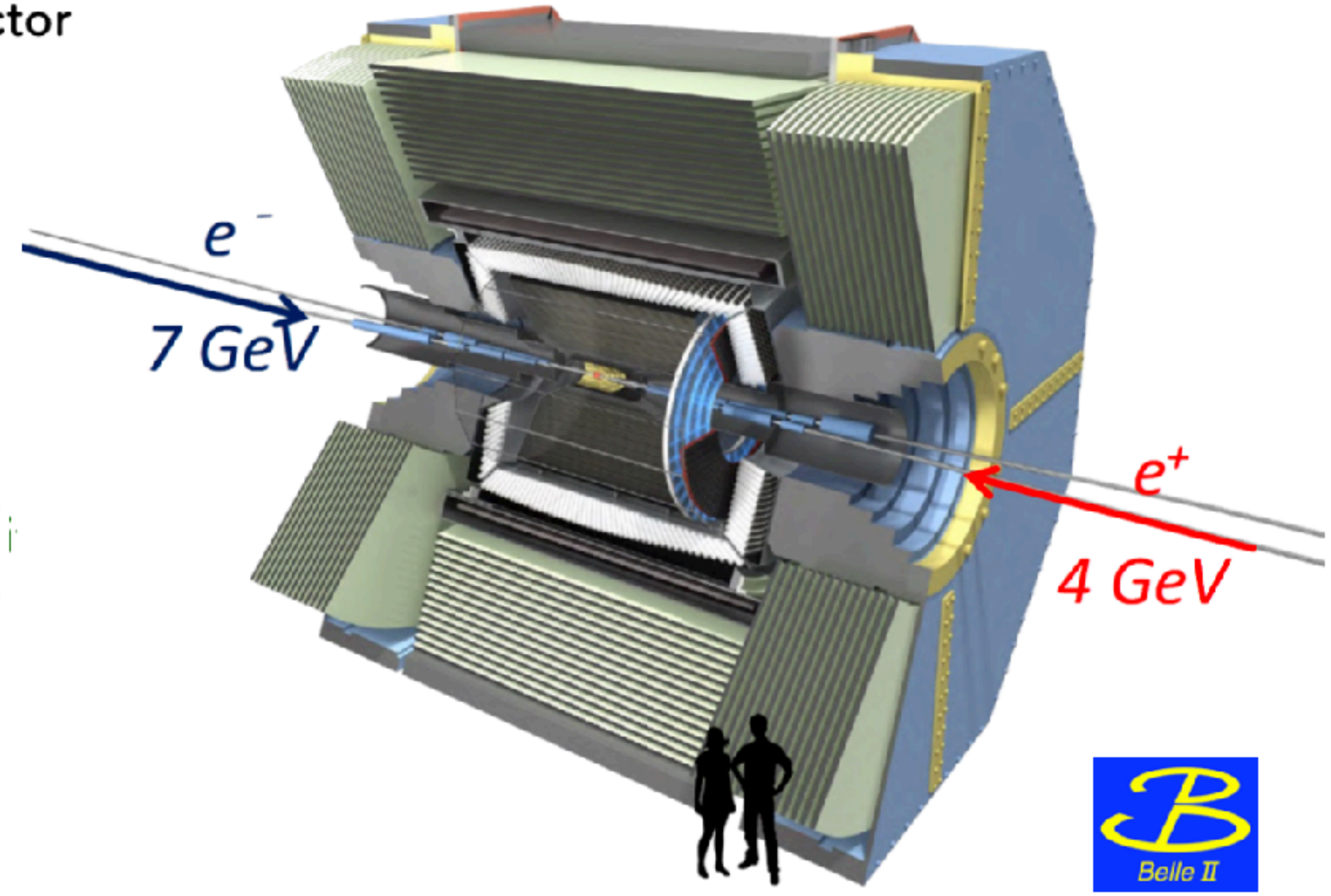
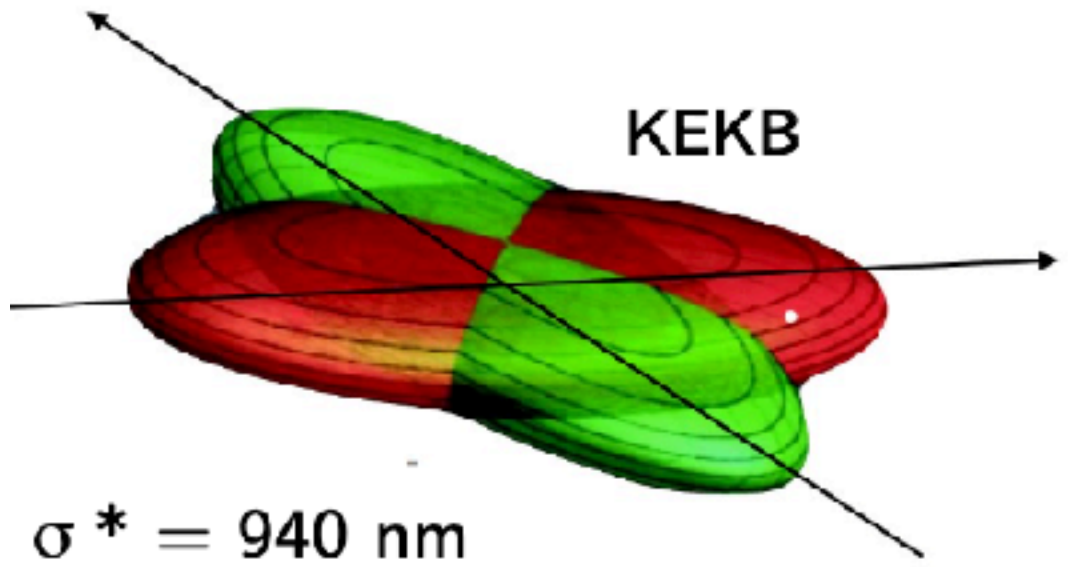
南开大学


Mt. Tsukuba
~ 1 km
BELLE II
Super KEKB Ring
~ 1.5 km
Damping
Ring
Linac
KEK Tsukuba
Campus

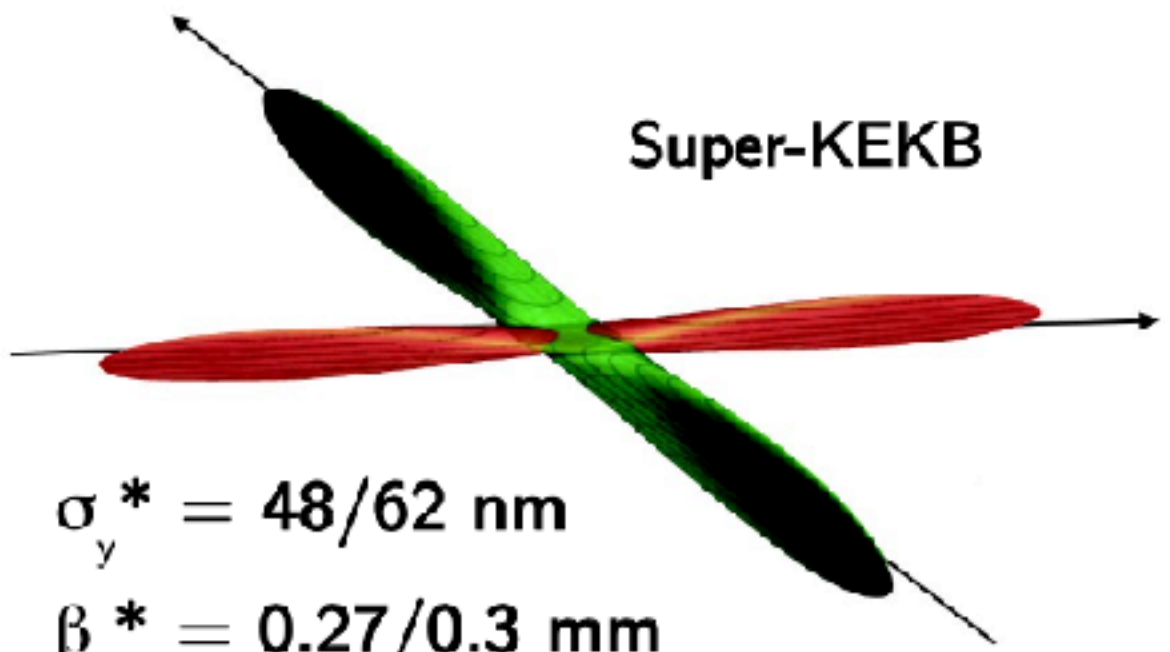
SuperKEKB $e^- \xrightarrow{7\text{ GeV}} (\star) \xleftarrow{4\text{ GeV}} e^+$ Belle II







$\sigma_y^* = 940$ nm
$\beta_y^* = 5.9$ mm
$\sigma_x^* = 147/170$ μm

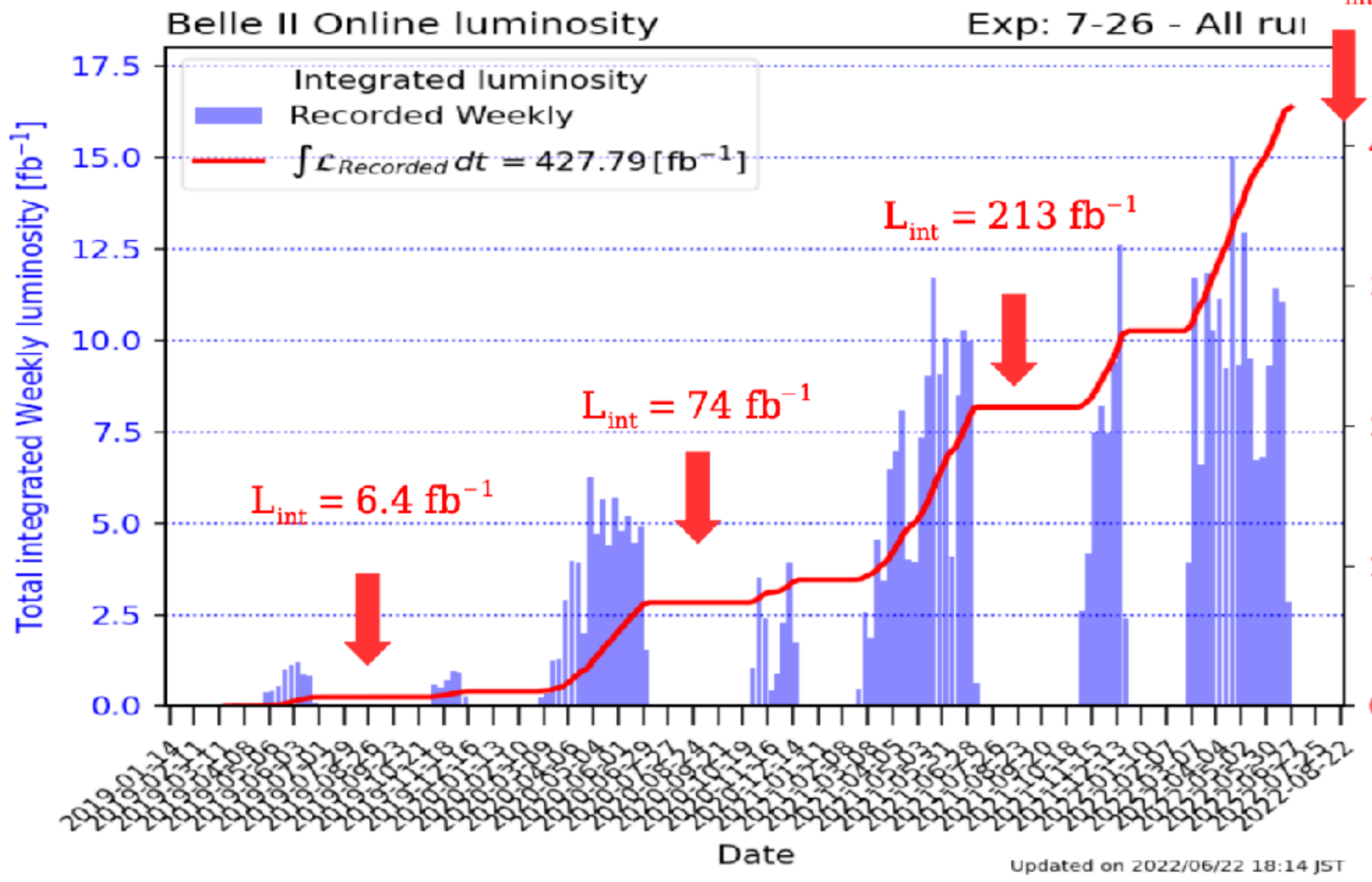


$\sigma_y^* = 48/62$ nm
$\beta_y^* = 0.27/0.3$ mm
$\sigma_x^* = 10.1/10.7$ μm

$$\mathcal{L}_{\mathrm{II}}^{\mathrm{peak}} \approx 30 \times \mathcal{L}_{\mathrm{I}}^{\mathrm{peak}}$$

$$\int^{\mathrm{goal}} \mathcal{L}_{\mathrm{II}}\, dt = 50\ \mathrm{ab}^{-1} \approx 50 \int \mathcal{L}_{\mathrm{I}}\, dt$$

Belle II RUN-I (2019-2022)



$5 \times 10^{34}/cm^2/s$
$\sim$ 1 BaBar/year

$\Rightarrow$ **$362\ fb^{-1}$ at the $\Upsilon(4S)$ resonance (rest off resonance, and scan)**

luminosity: $4.7\times10^{34}/cm^2/s$! $> 2\ fb^{-1}$ per day !

June, 2022

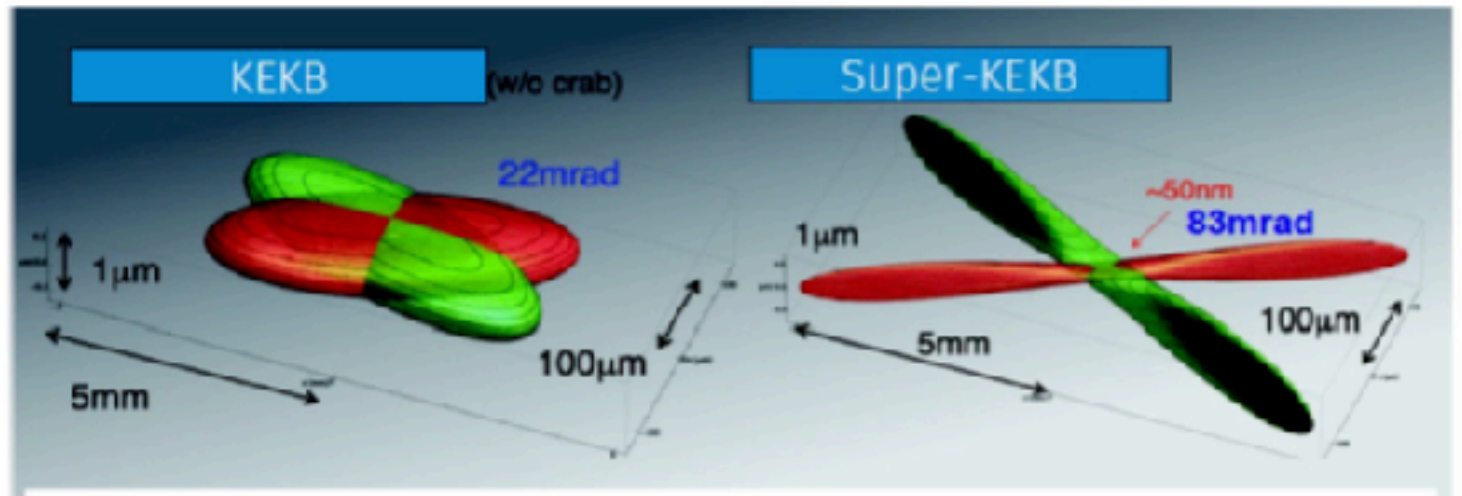
				06/07 23:59:36 - 06/08 23:59:36, 2022 JST				
$\mathcal{L}_{peak}$	$4.653 \times 10^{34}\ cm^{-2}s^{-1}$ @ 22:58:08 06/08	HER I_{peak}	1127 mA	n_b	2249	β^*_x / β^*_y	60 / 1	mm
int. $\mathcal{L}$/day	1253 / 1681 pb^{-1}	LER I_{peak}	1405 mA	n_b	2249	β^*_x / β^*_y	80 / 1	mm

record of KEKB/Belle

$2 \times 10^{34}/cm^2/s$; currents $> 1\ A$

record of PEPII/BaBar

$1 \times 10^{34}/cm^2/s$; currents $> 2\ A$



	E (GeV) LER/HER	β^*_y (mm) LER/HER	β^*_x (cm) LER/HER	φ (mrad)	I (A) LER/HER	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1×10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80×10^{34}

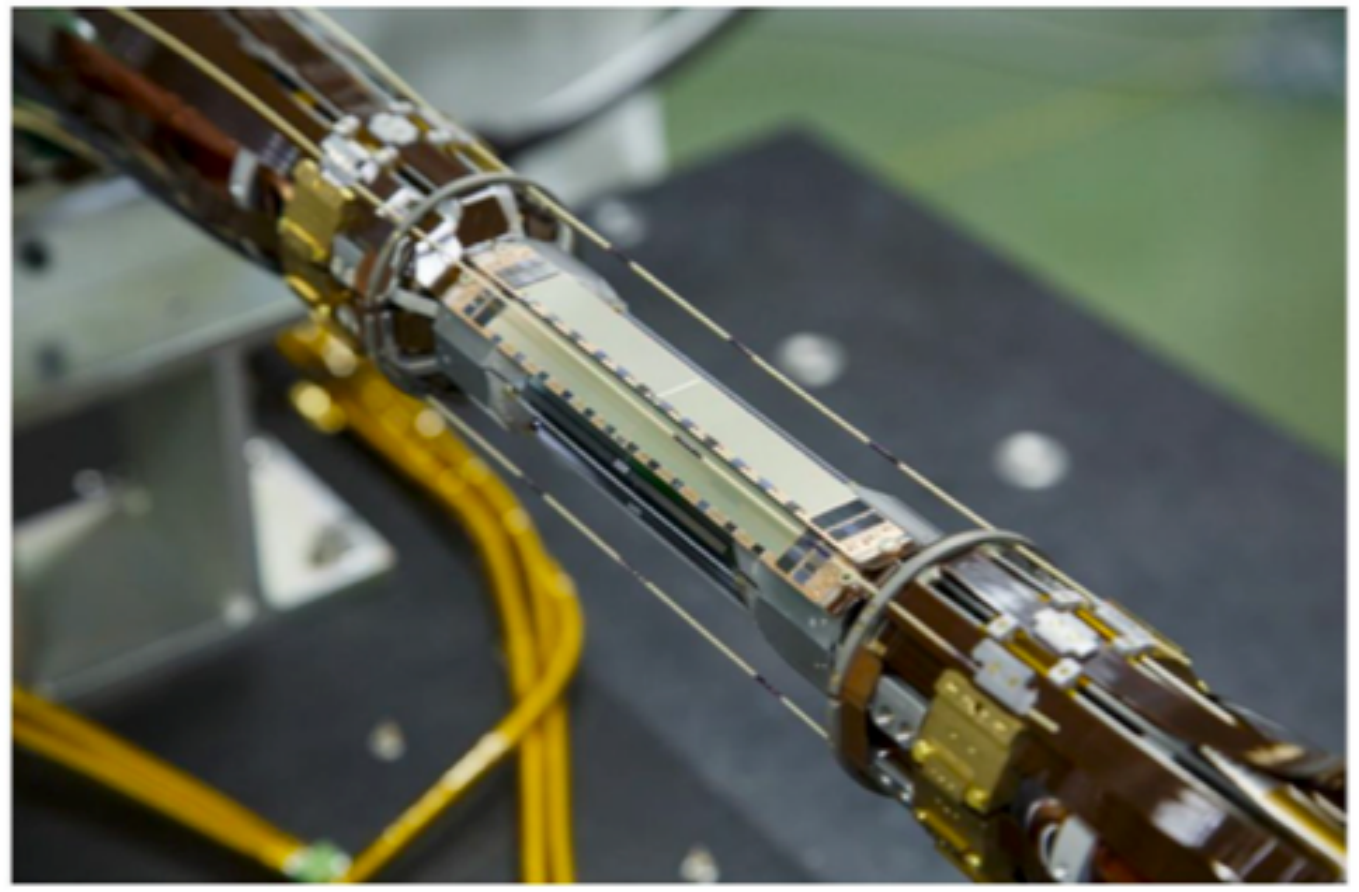
factor 20 factor 2-3

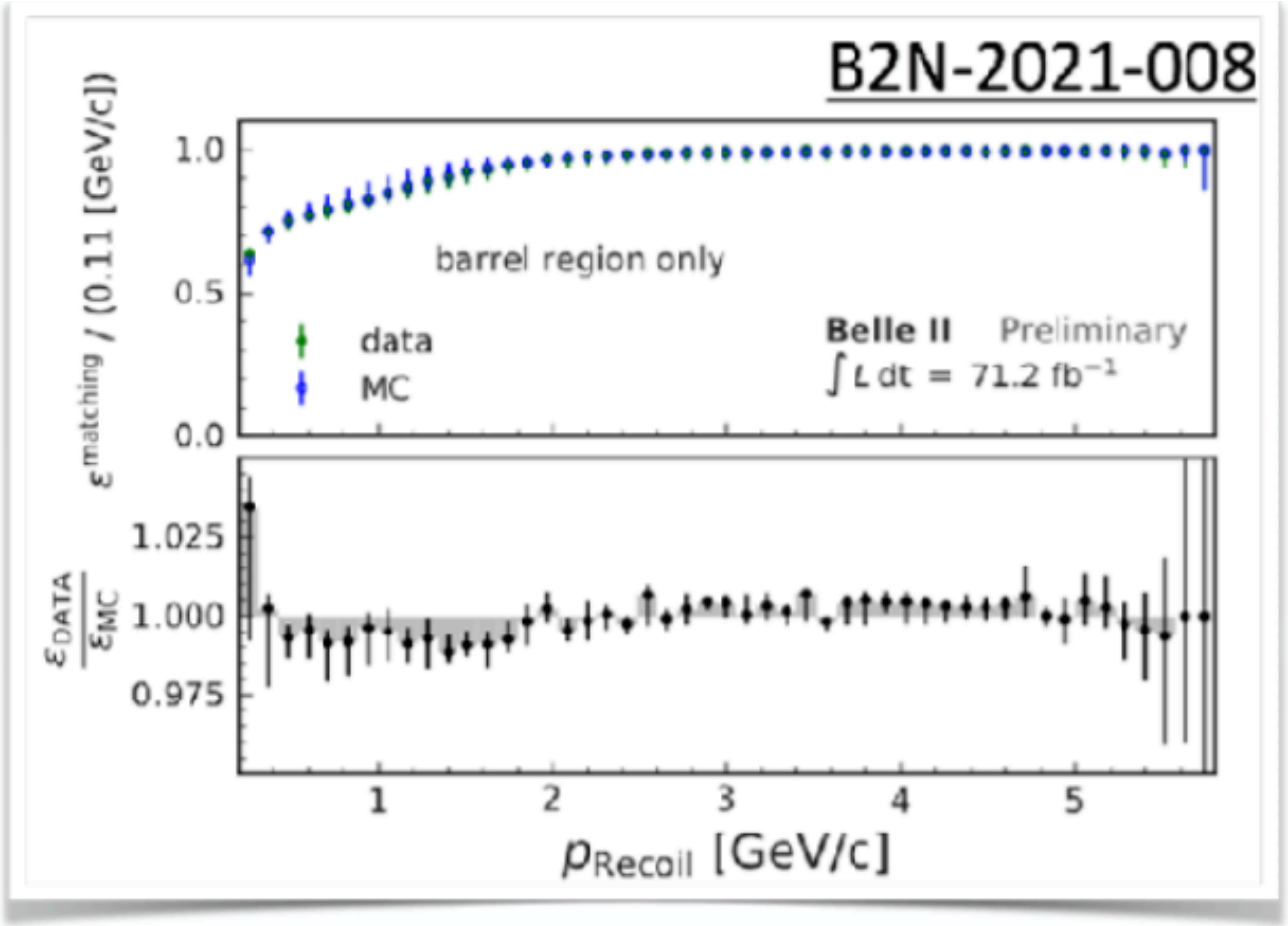
squeezing further β^*_y ($\rightarrow$ 0.6mm)
doubling (or more) the currents
$\Rightarrow L > 10^{35}/cm^2/s$ after LS1

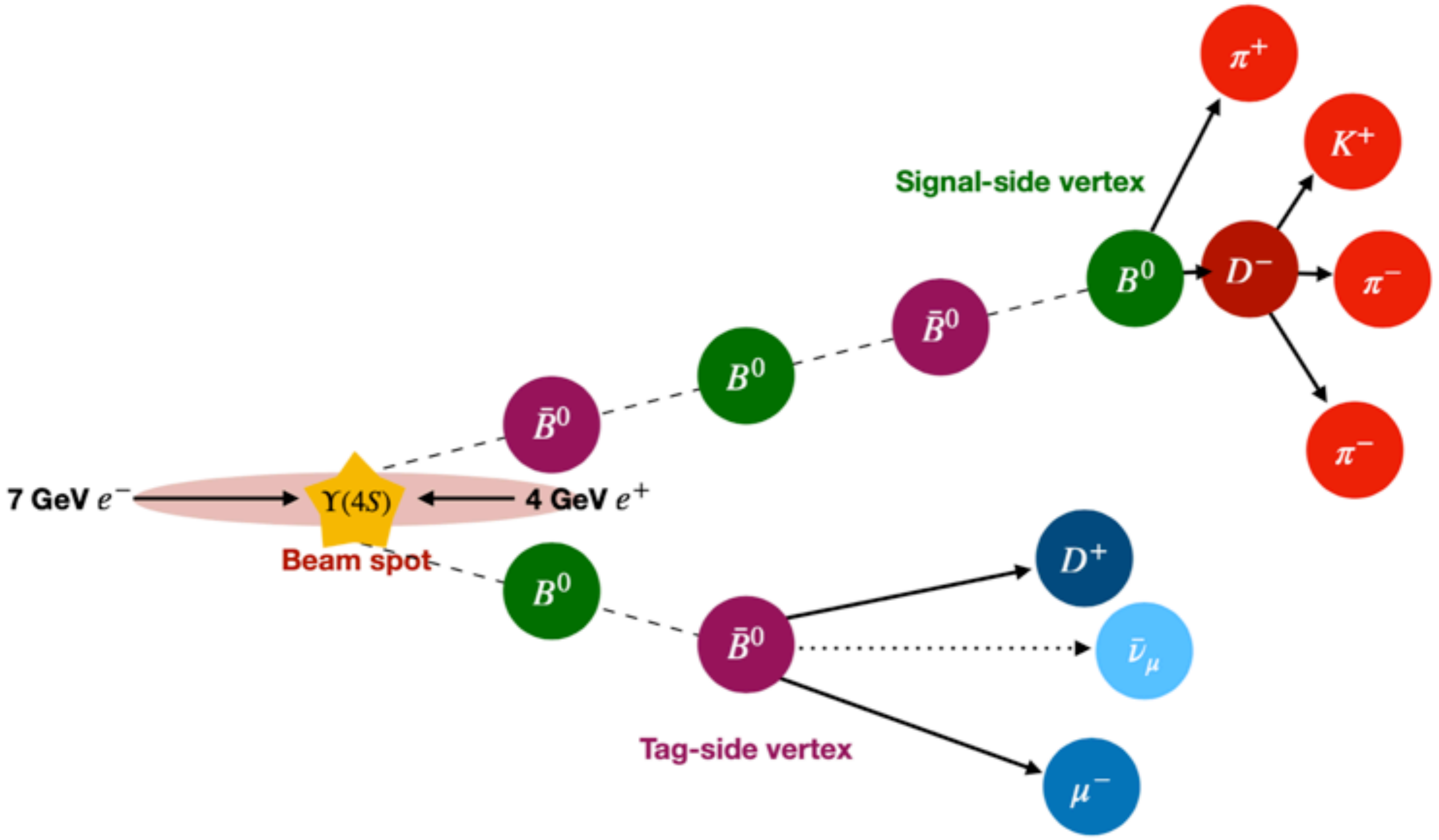
Belle II Data
Upsilon(5S, 6S) runs
Bs physics
New hadron states Zb's, b bbar gluon
New Hadrons, QCD measurements
New Charmonium-Like States
New bottomonium-like states
New baryons
e+e- -->ISR, pi+ pi- cross-sections (g-2)
Spin Fragmentation Functions (->EIC)
Linac energy upgrade
Dark Sector
Dark Photon
Axion-Like Particles (ALPs)
Invisible Z' s
Dark Higgs
Heavy tau neutrinos
LLPs (Long-Lived Particles)
Magnetic Monopoles
Gazelle (LLP search)
Tau Physics
Tau mass, lifetime
Tau Spectral Functions
Lepton Flavor Violation (LFV)
Tau Electric Dipole Moment (EDM),
Electroweak physics with e- polarization
sin^2 theta_W
A_LR (tau, mu, e+, b, c)
NC (Neutral Current) universality
improved tau LFV
Charm Physics
D-Dbar mixing and CPV
Charm Lifetimes
Branching Fractions, Dalitz analyses
C->u l+l-, Lepton flavor violation
Radiative charm decays
CKM Matrix Elements (Vcb, Vub)
Inclusive Measurements
Vtd/Vts from penguins
Exclusive measurements
B->D(*) tau nu, lepton universality
Time Dependent Measurements
alpha, beta, gamma
Direct T violation
New physics phases in b->s: B->phi Ks, B->eta' Ks
Rare B decays
Hadronic B Decays: B-->K pi, pi pi Direct CPV, isospin sum rules
B-->K* gamma and radiative penguins, B-->K(*) nu nubar
B-->V V: right-handed currents, triple products
Electroweak Penguins: b-->s l+l-, lepton universality, b-->s nu nubar
Hadronic b-->c decays
gamma determinations
New charmed resonances

Belle II advantages

- Excellent muon and electron identification
- High photon detection efficiency
- Good hermiticity: useful for modes with missing energy
- Good vertex and momentum resolution

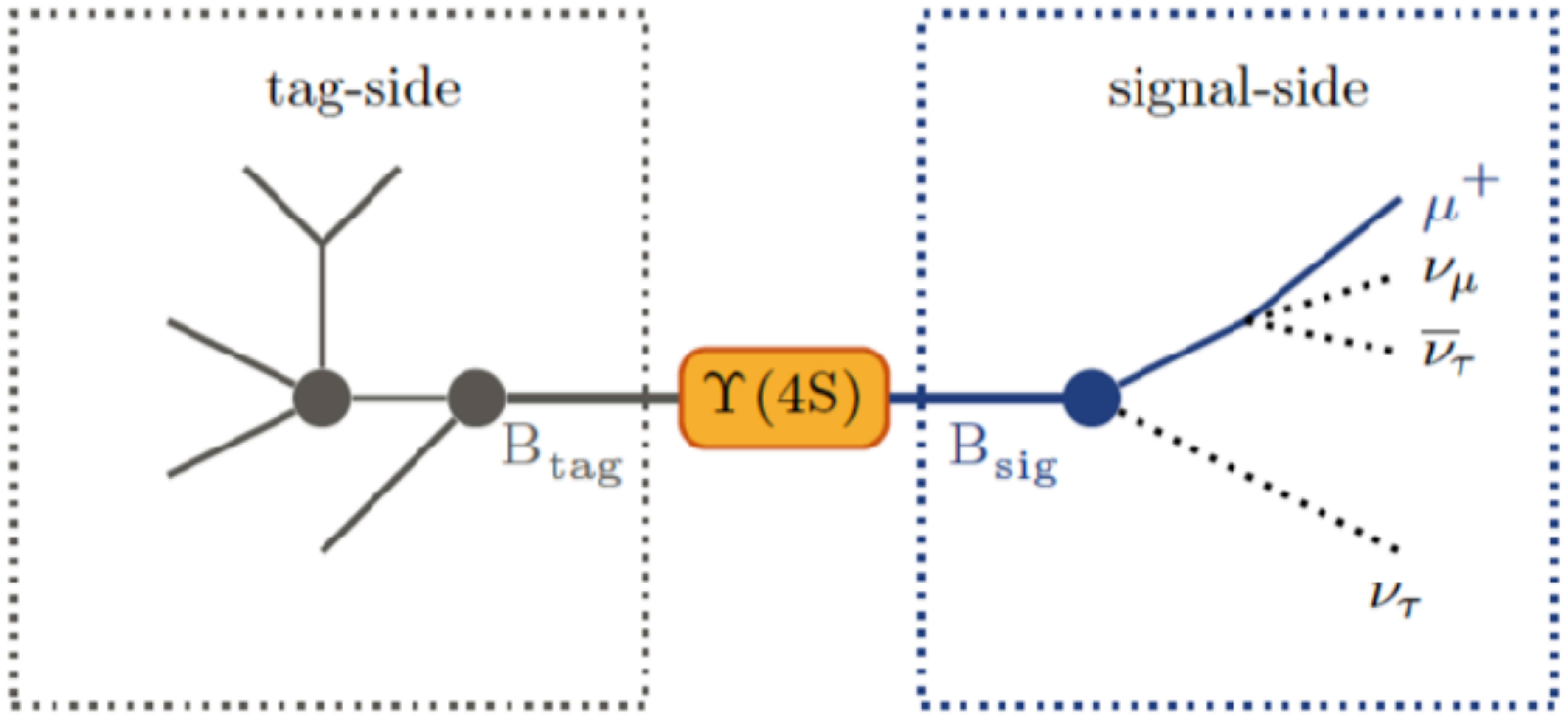


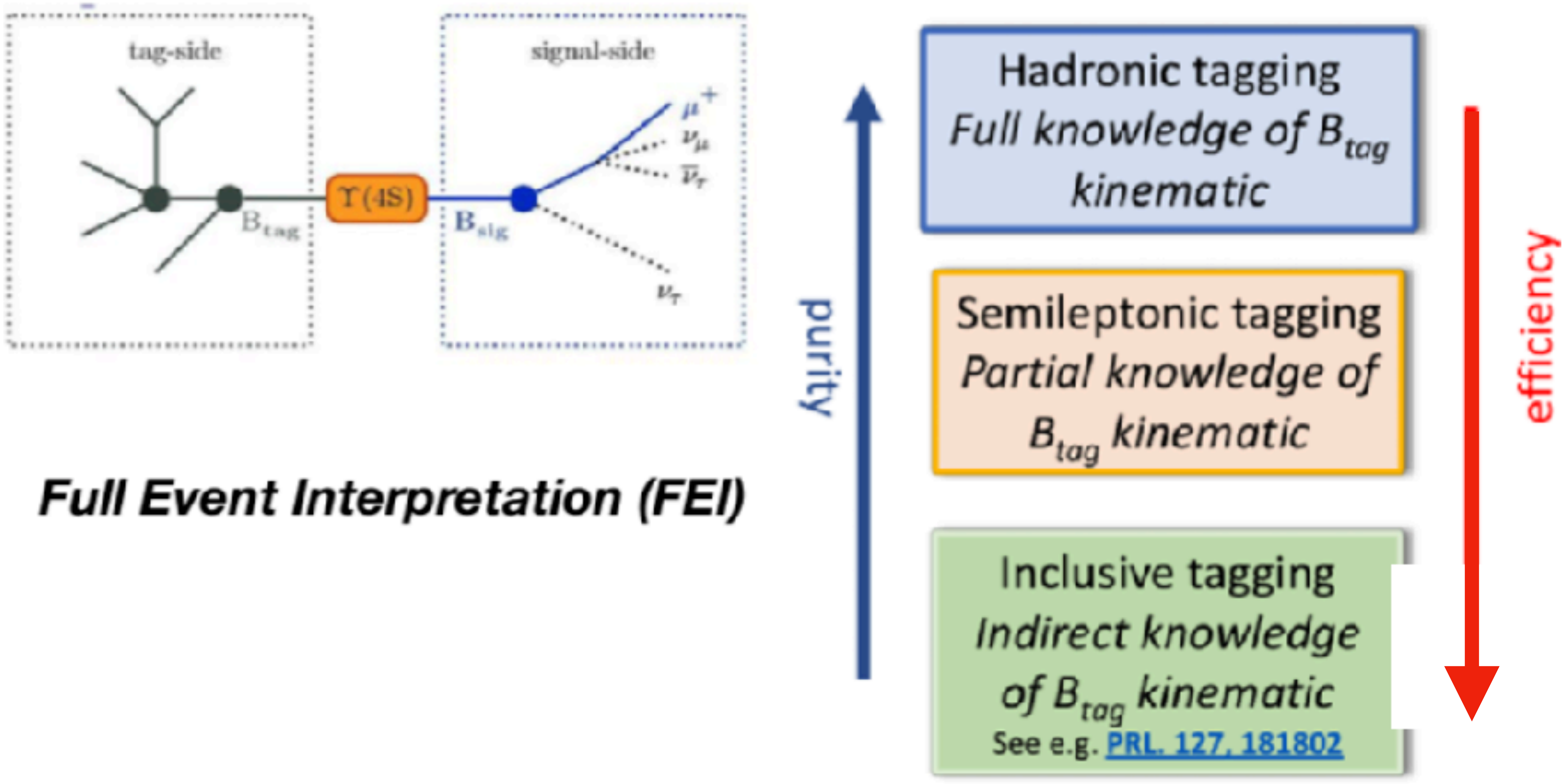


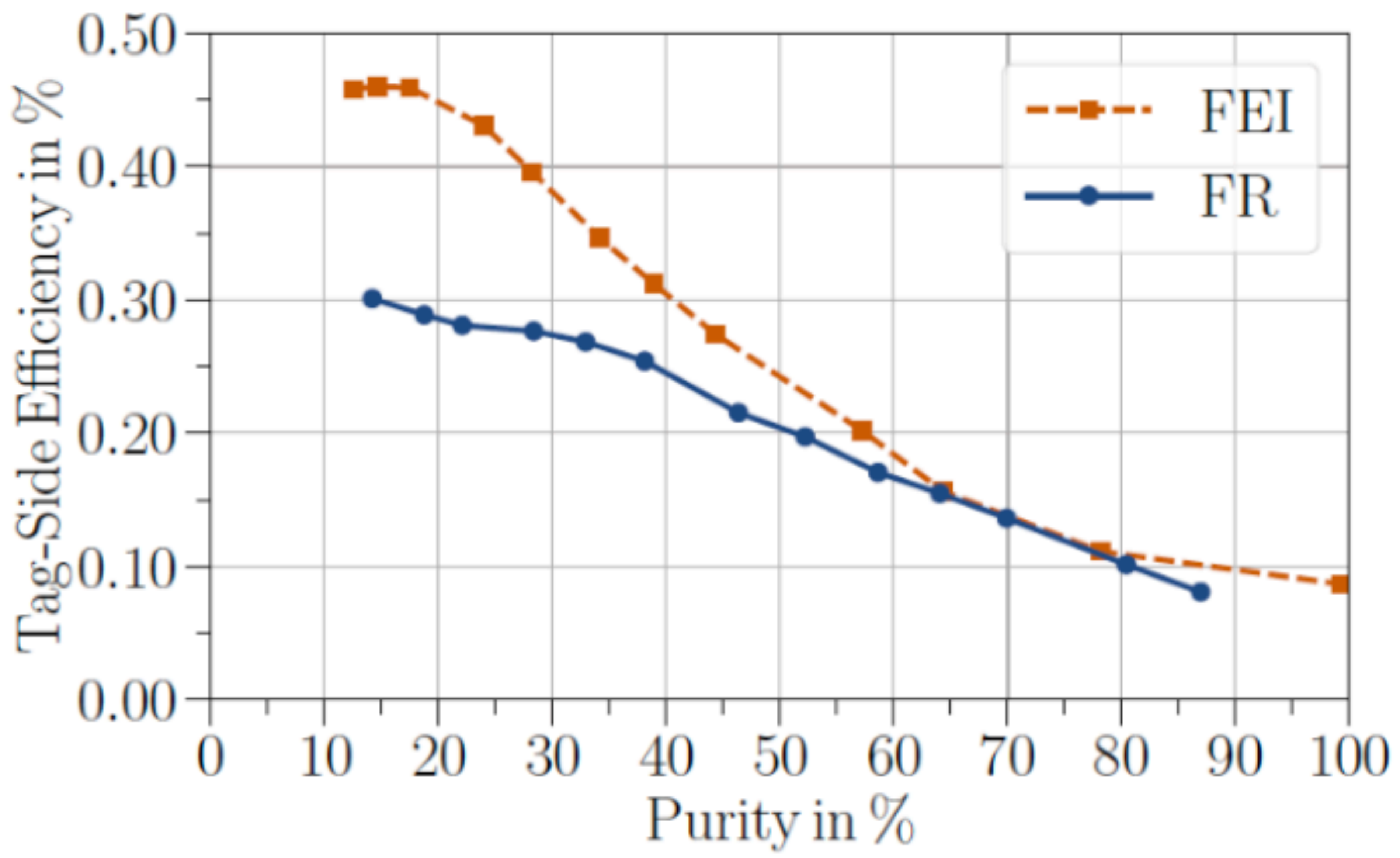


Full Event Interpretation (FEI)

- Reconstructs this B_{tag} in roughly 10 000 channels
- First reconstructing low-level particles $(K,\ \pi,\ldots)$, then intermediate D mesons and finally B mesons.
- Most-likely particle candidates are selected using pre-trained multivariate classifiers

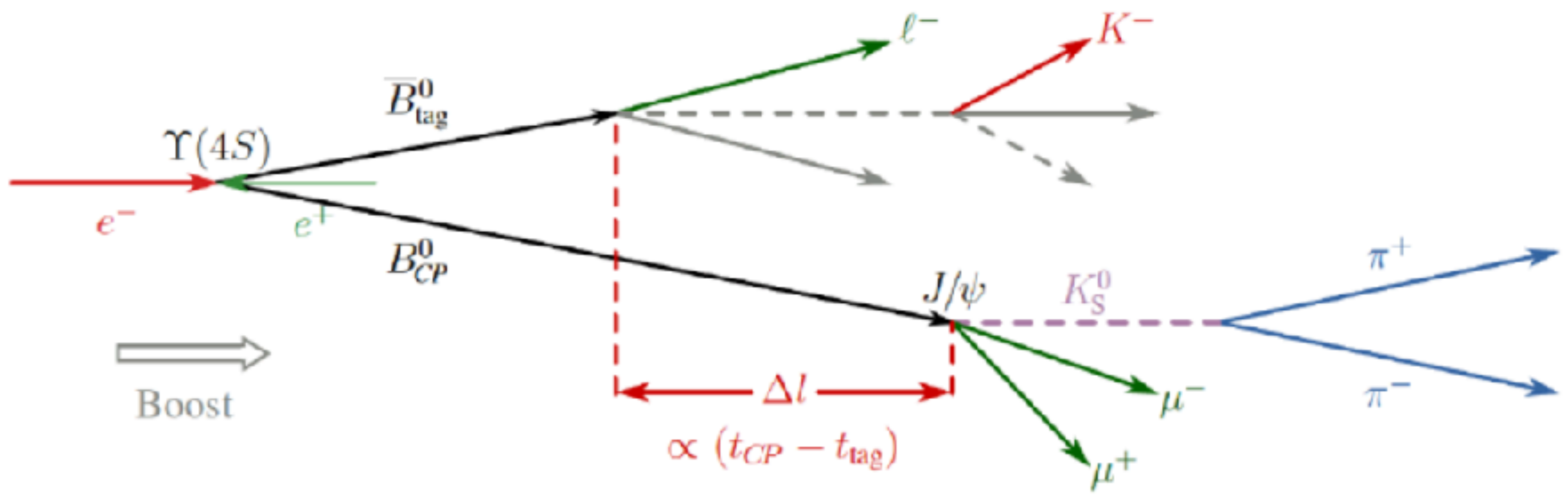


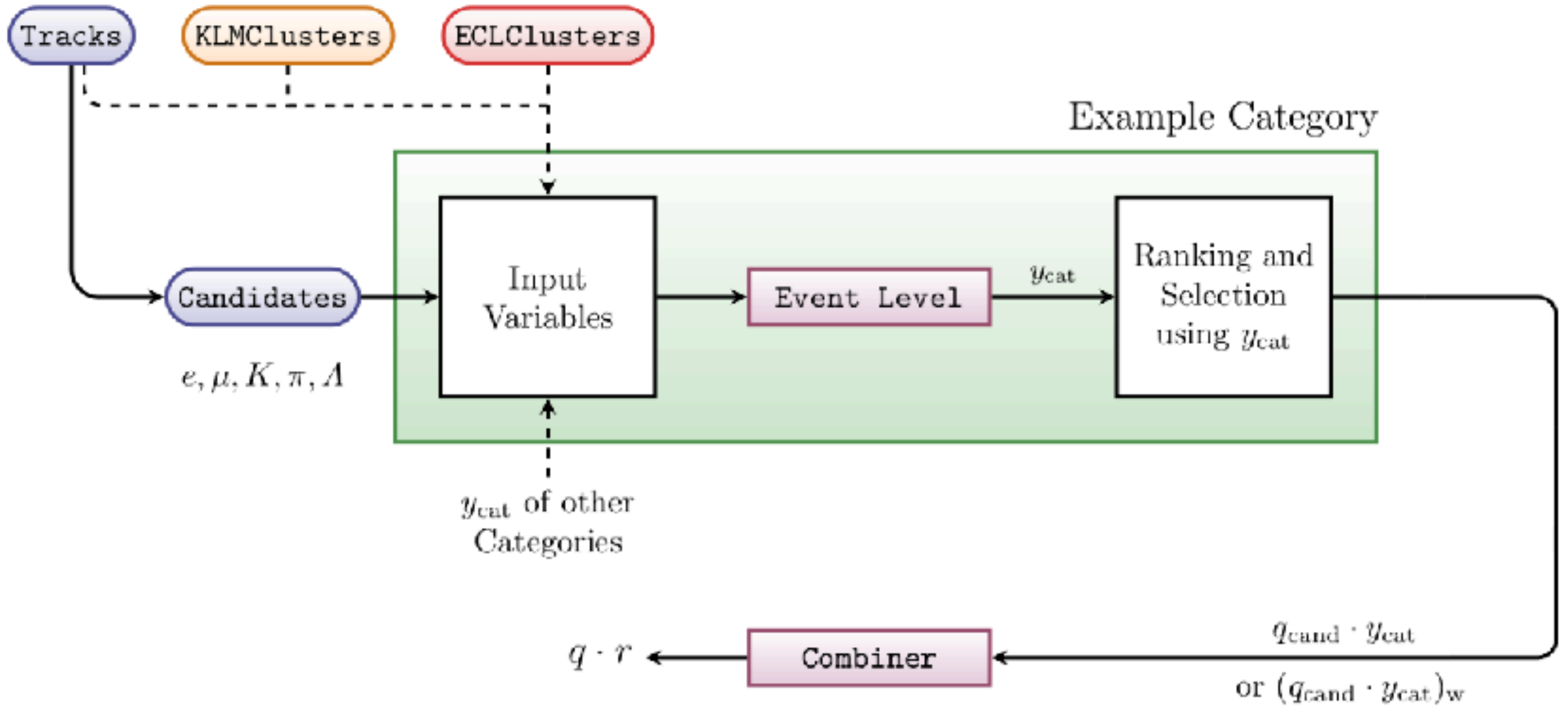




Flavor Tagger

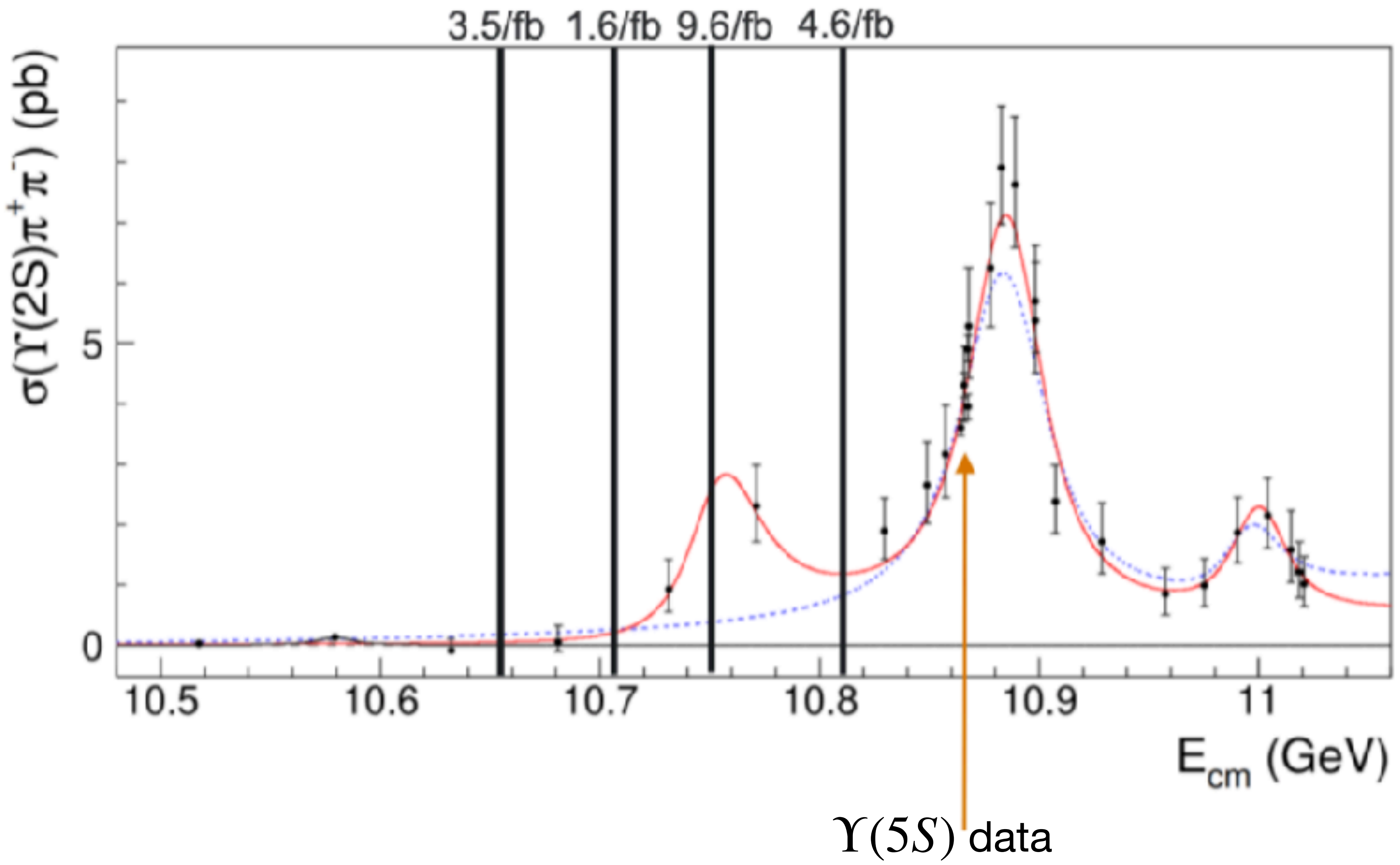
- Identify flavor of a particle, useful in TDCPV
- Inspired by the Flavor Tagging concept developed by Belle and BaBar.
- Proceeds in 2 levels: *EventLevel* and *CombinerLevel*. Each step relies on pre-trained multivariate methods.
- High efficiency: 37% in Belle II, 30% in Belle.

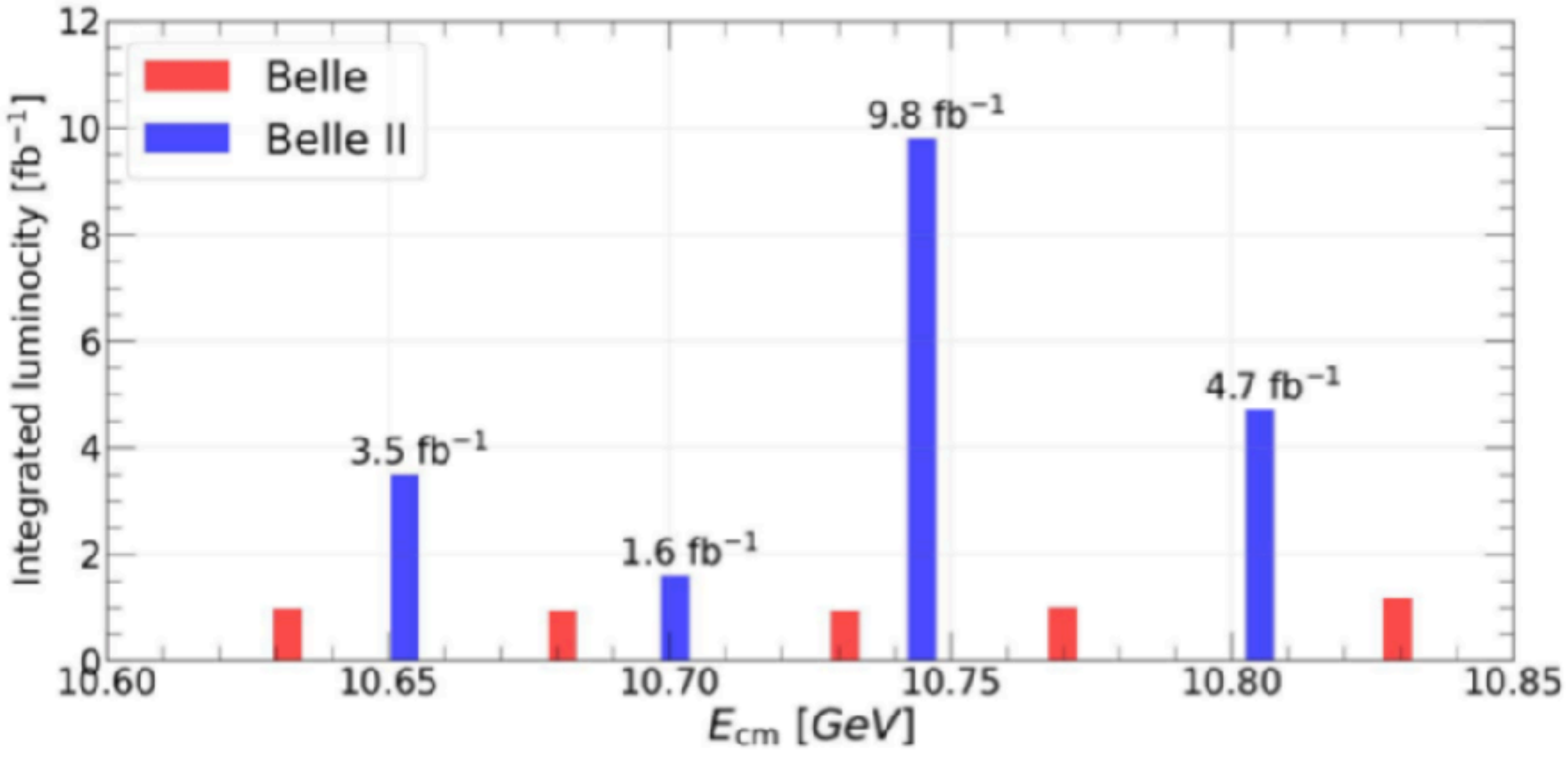




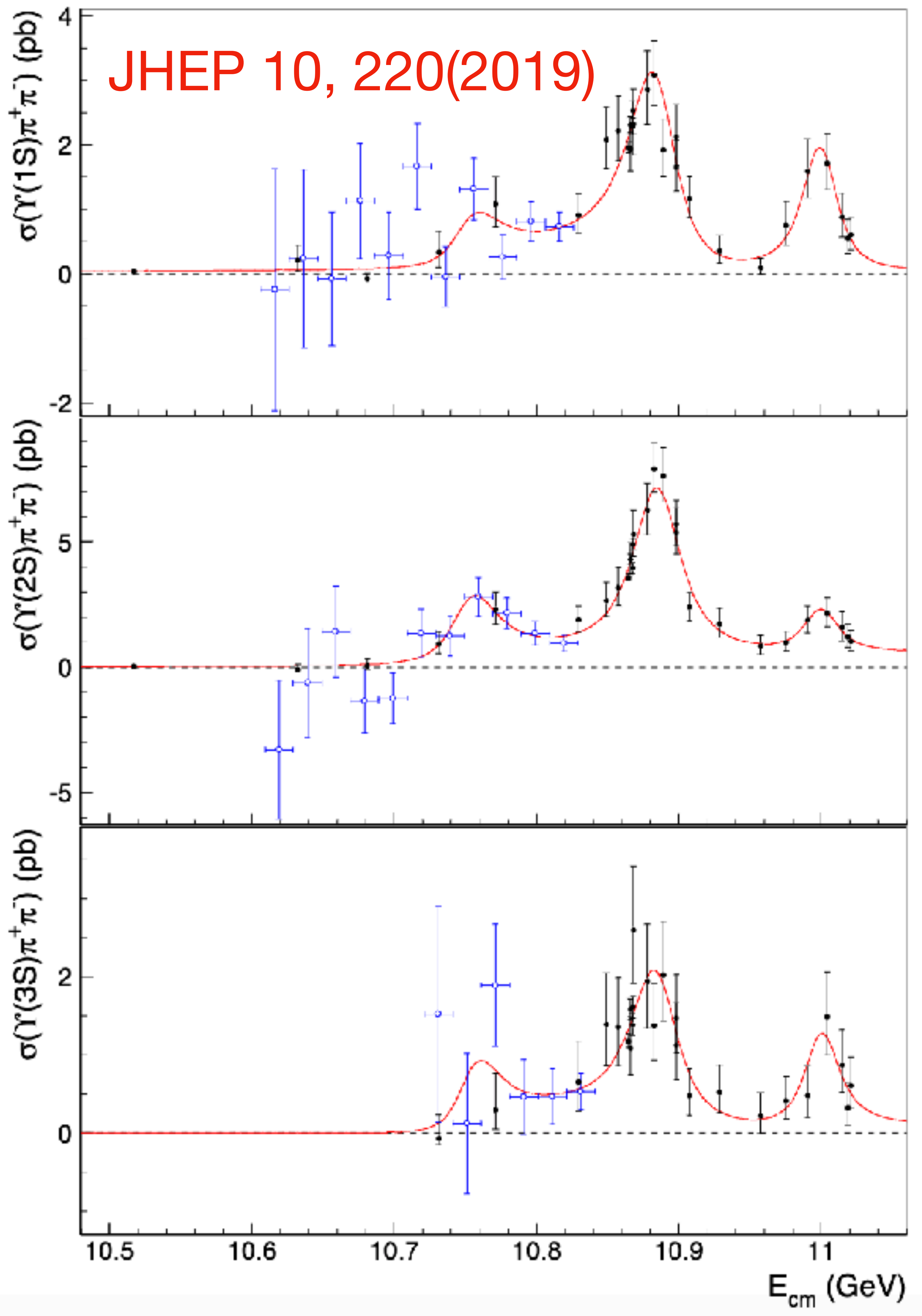
Unique data

- 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 $\Upsilon(10753)$



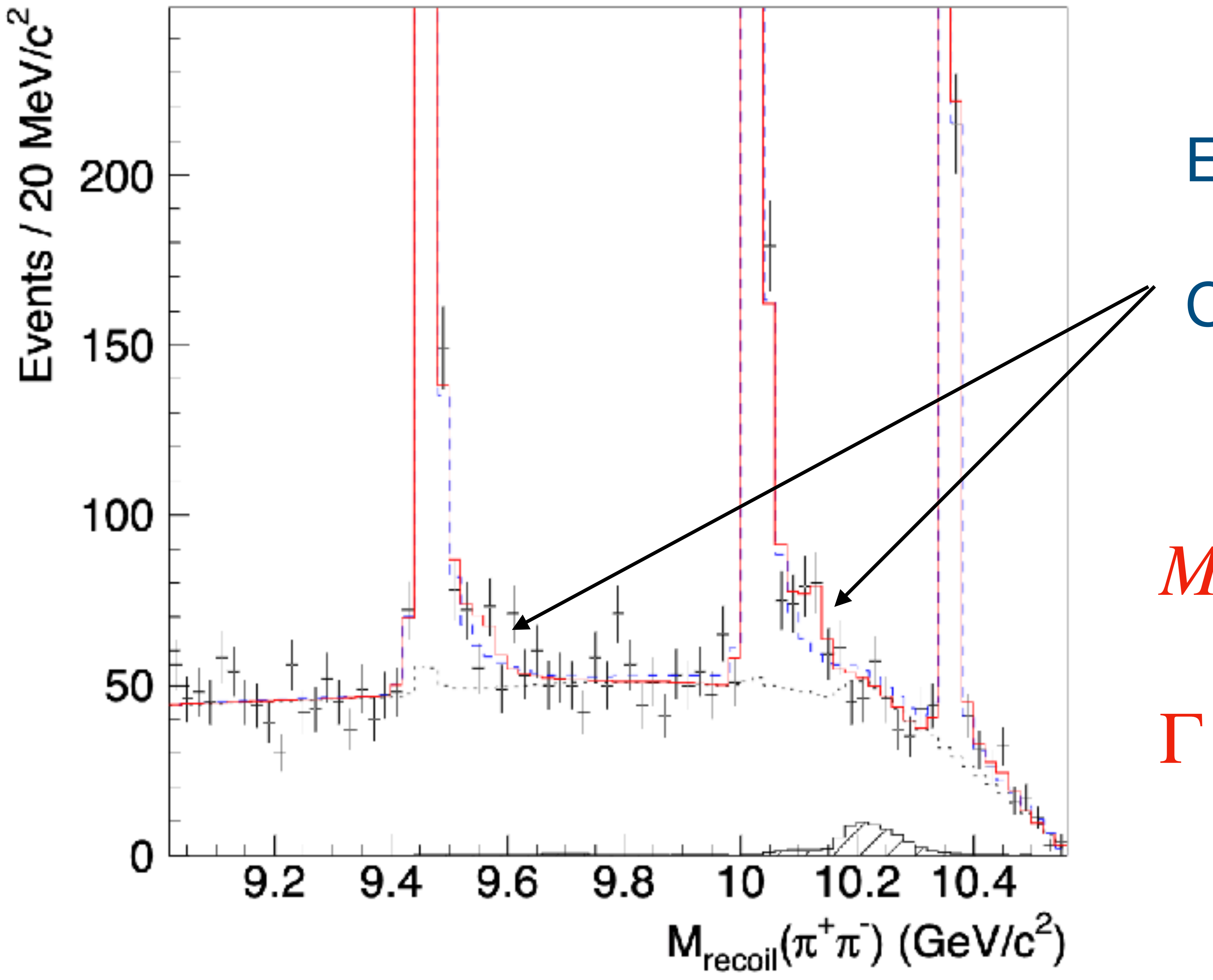


$\Upsilon(10753)$ — discovery and studies



- 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 $M_{\text{recoil}}(\pi\pi)$

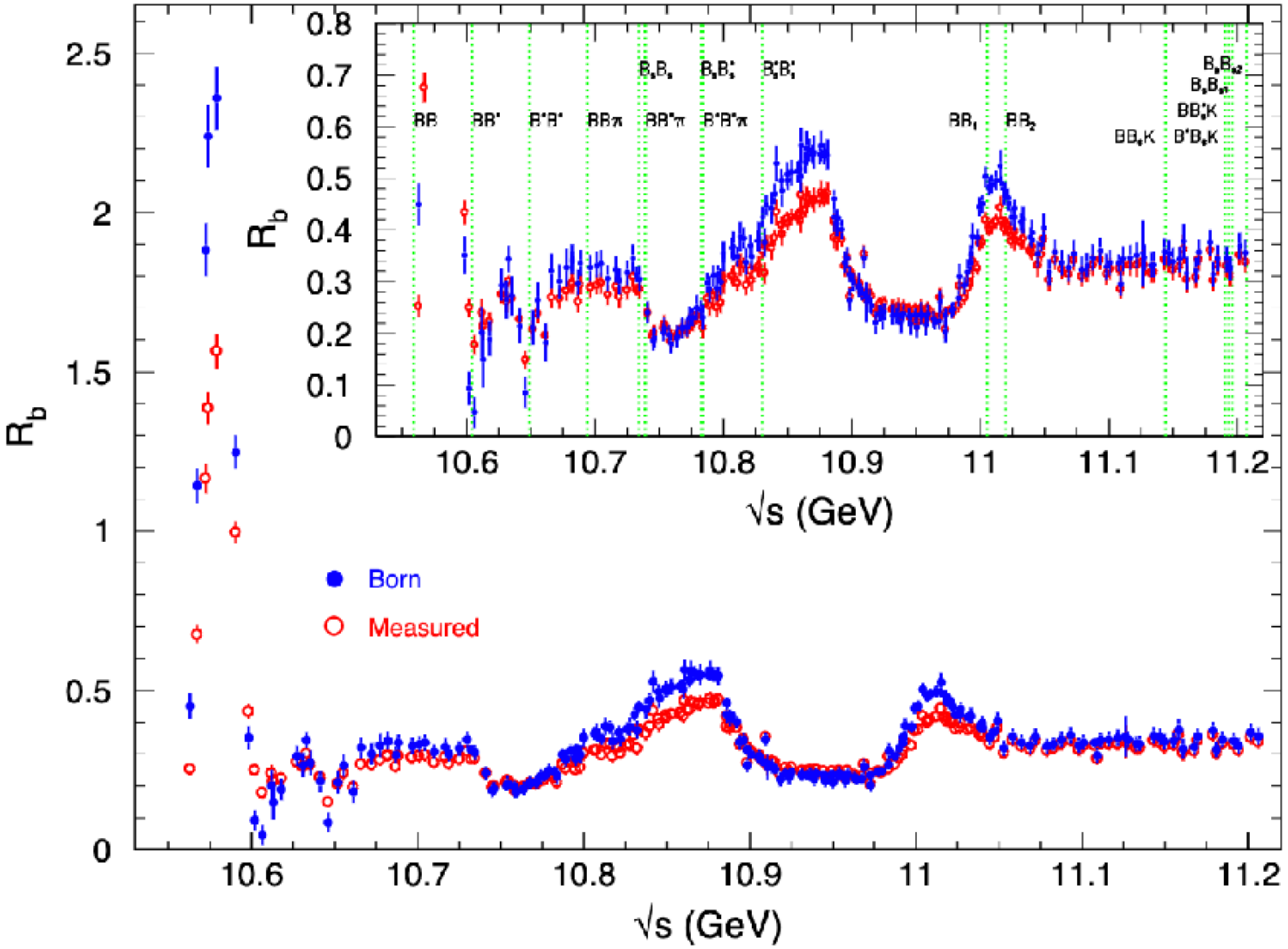


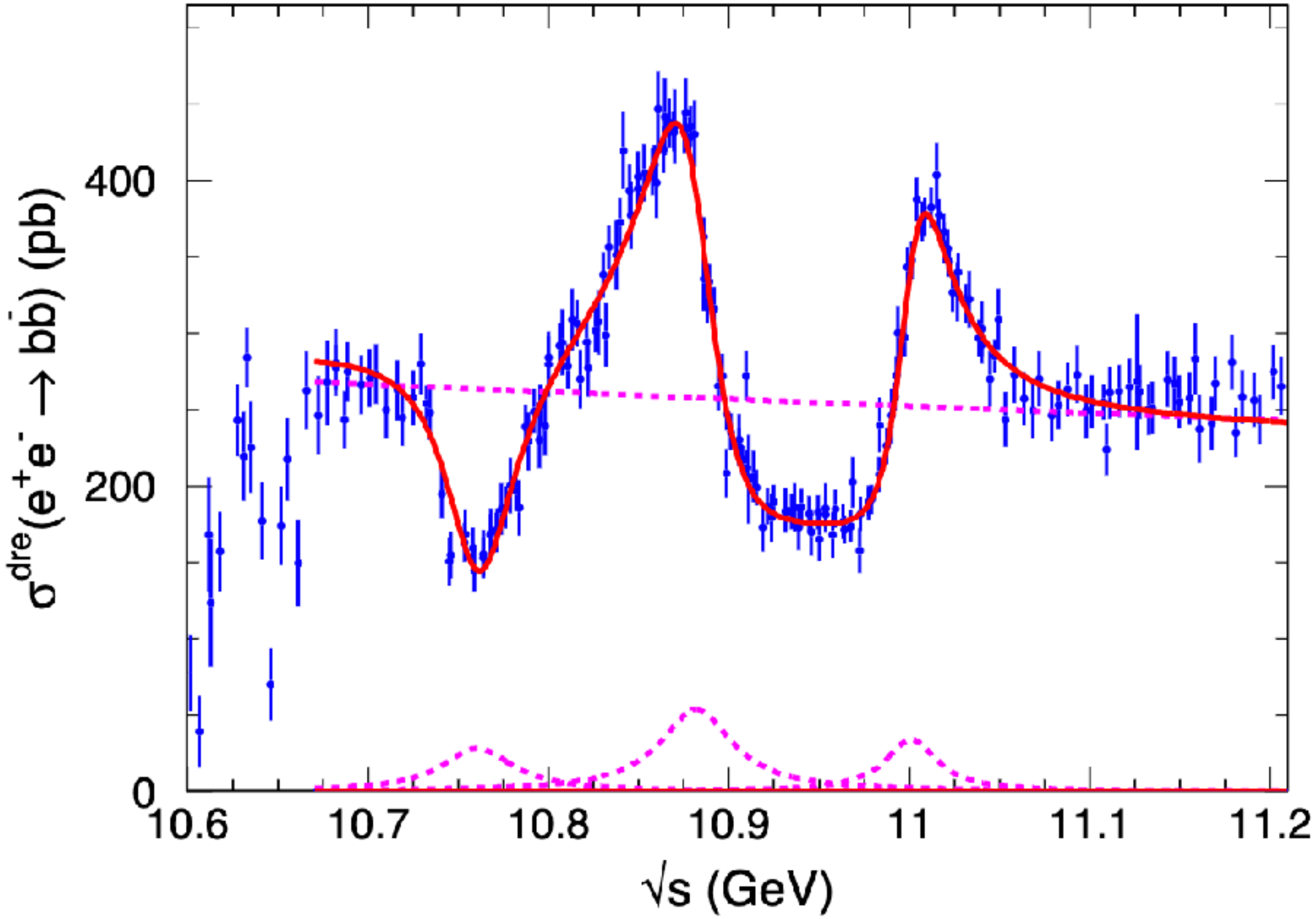
Existence of $\Upsilon(10753)$

Computed as blue dots in left plot

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

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





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

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

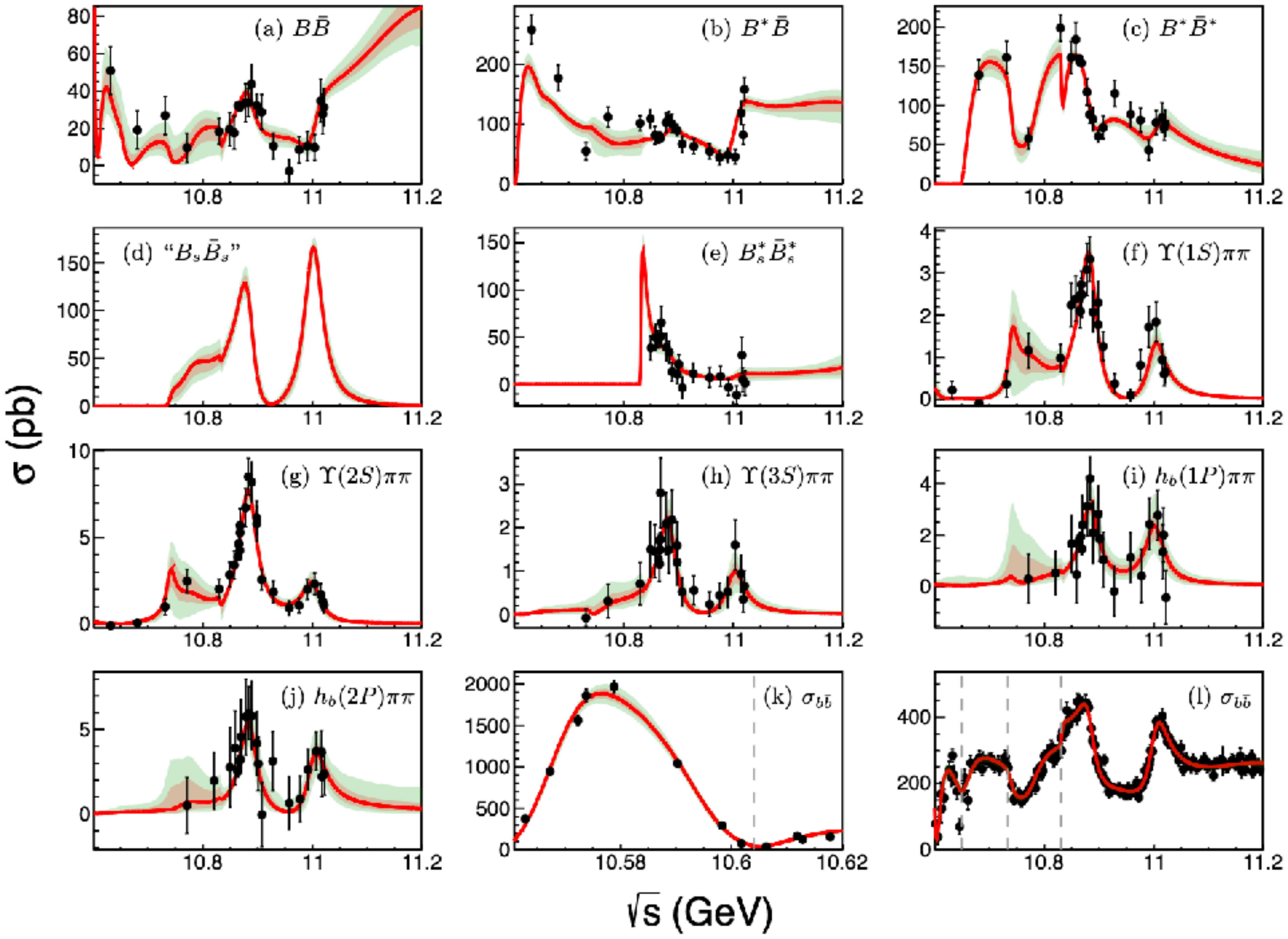
- A dip in the R_b distribution near $10.75\ \mathrm{GeV}$
- Fit to dressed cross section of $b\bar{b}$ with three BWs.

"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

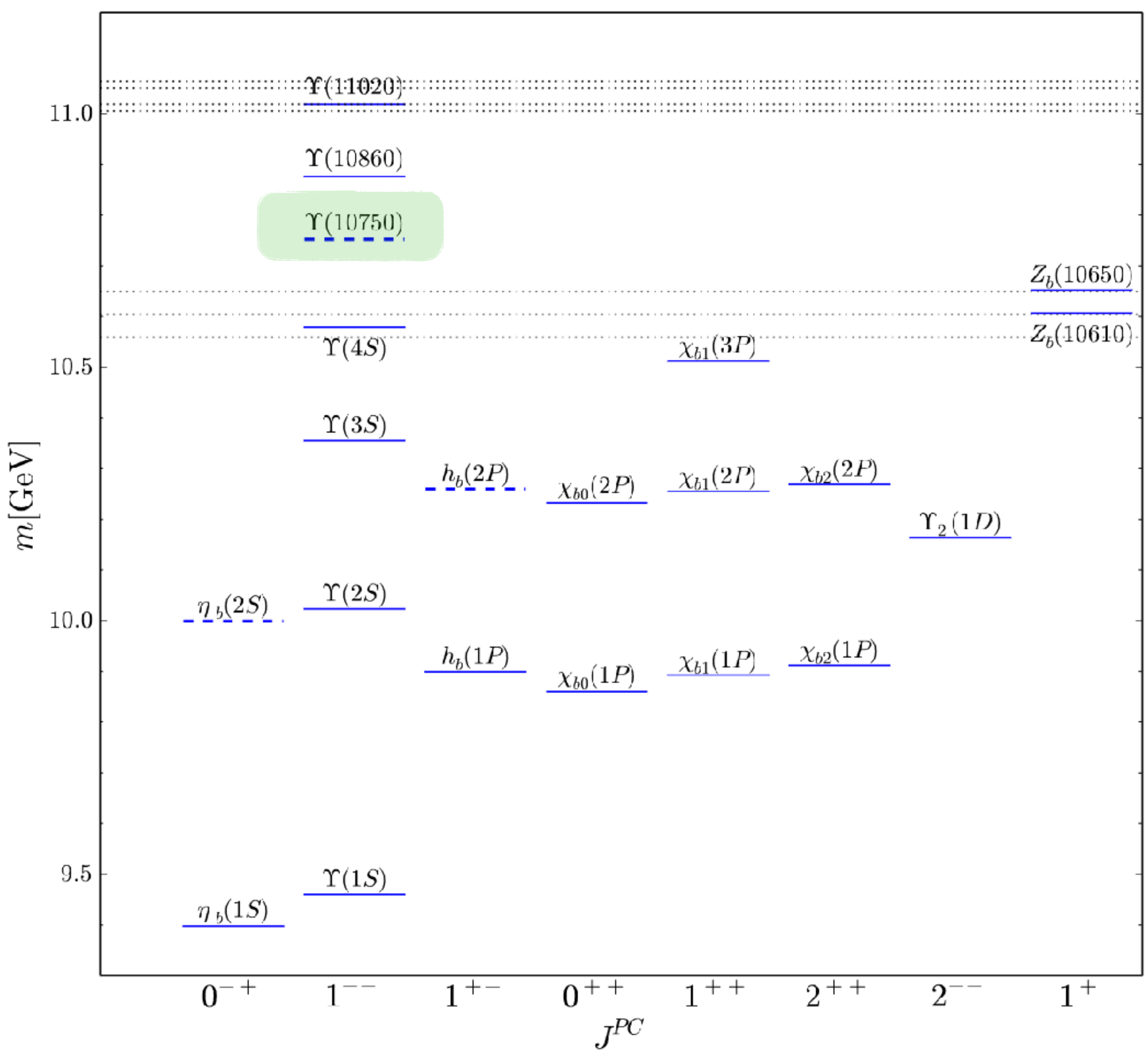


Strong evidence for $\Upsilon(10753)$ with significance $>10\sigma$

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)

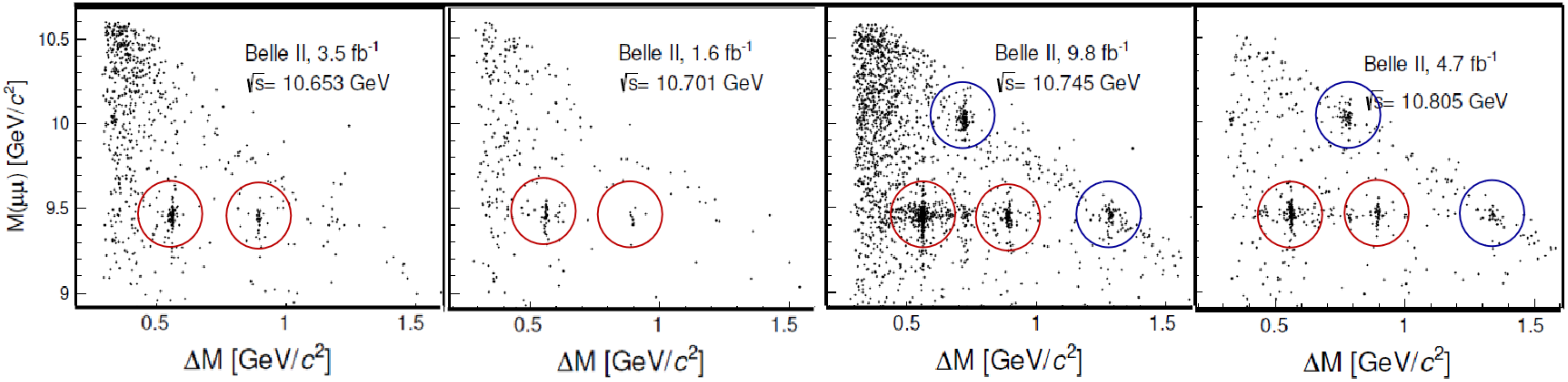
etc…

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

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

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

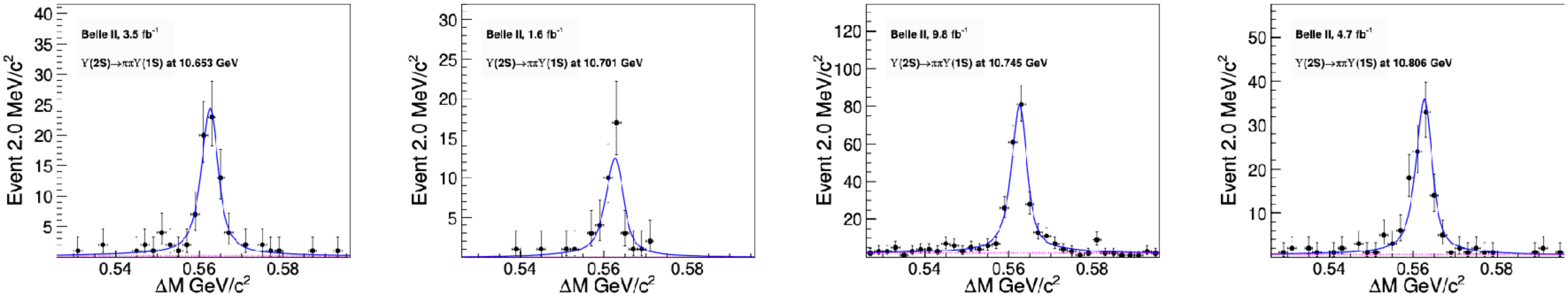
Belle-II preliminary, arxiv:2401.12021



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

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

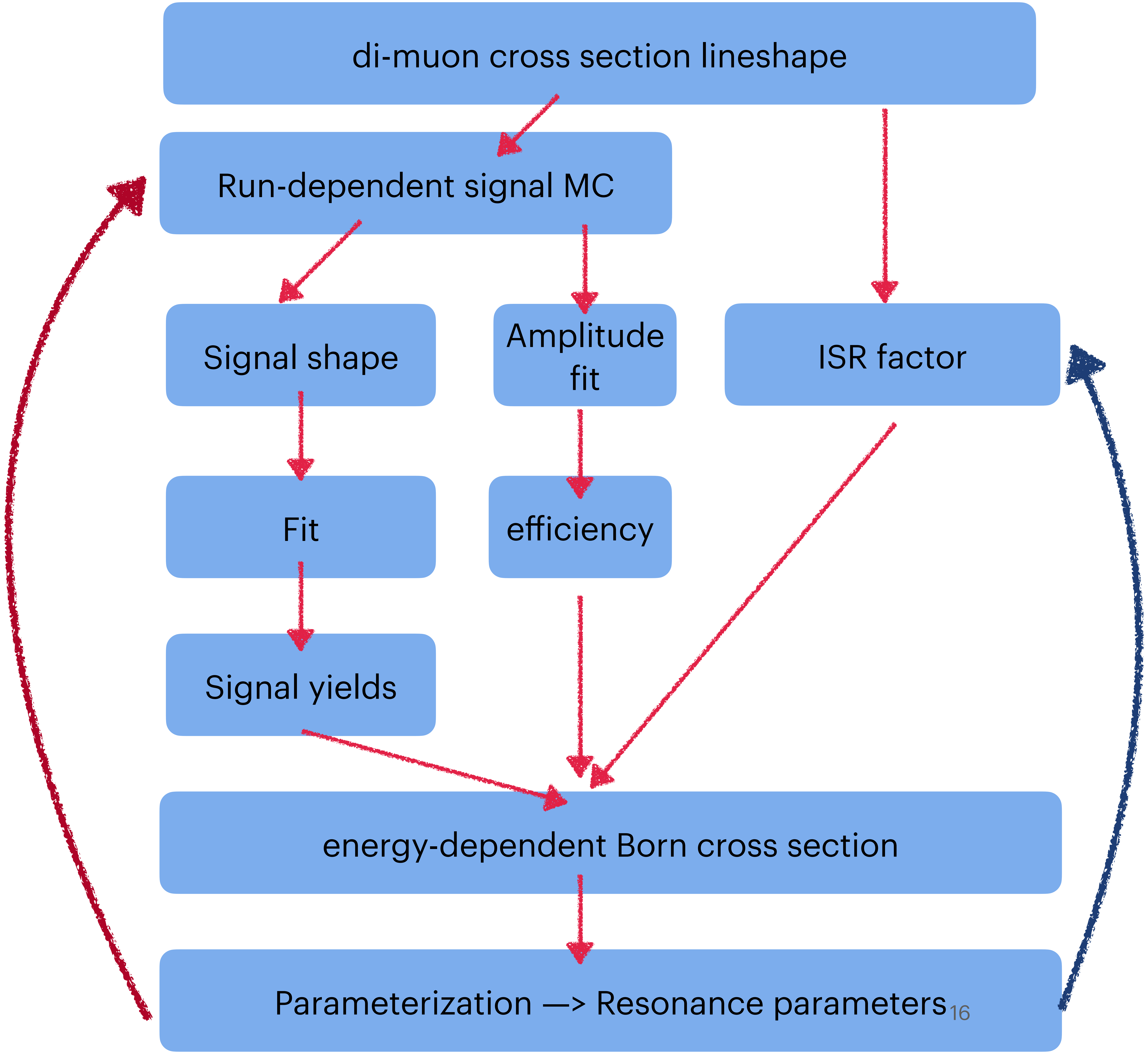
Validation by ISR events



E_{CM}	$N^{\rm fit}$	$N^{\rm peak}$	Lumi ($\rm pb^{-1}$)	ϵ (%)	$\sigma^{\rm obs}$ (pb)	$\sigma^{\rm expect}$ (pb)
10652.7 MeV	83.7 ± 10.2	9.5	3521	37.0	12.9 ± 1.8	14.9 ± 0.3
10700.8 MeV	45.0 ± 6.7	3.6	1632	37.7	15.2 ± 2.5	13.8 ± 0.2
10745.4 MeV	252.0 ± 18.1	28.4	9818	35.3	13.6 ± 1.1	12.9 ± 0.2
10804.8 MeV	114.5 ± 11.9	12.8	4690	40.9	13.0 ± 1.5	11.9 ± 0.2

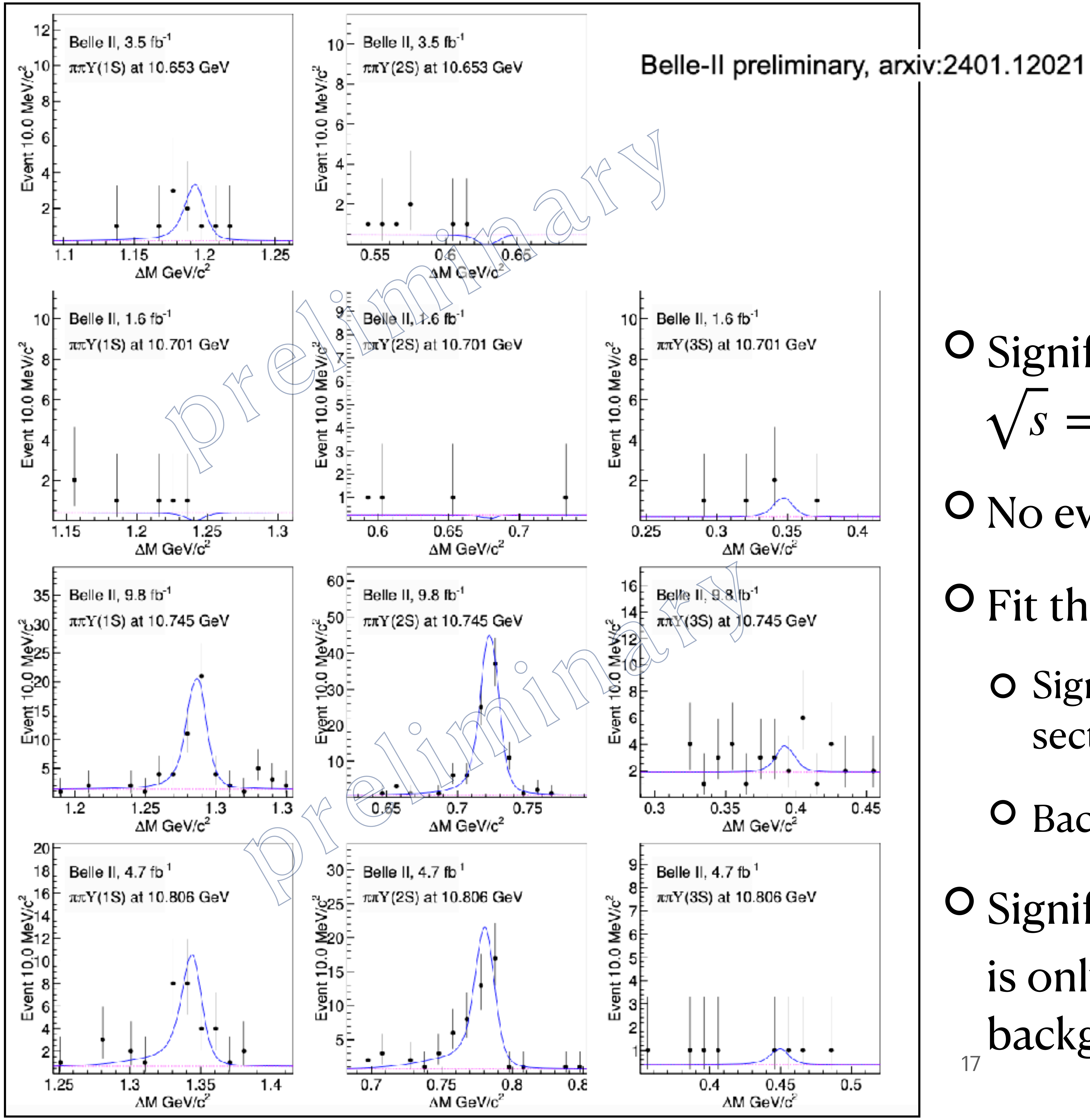
Signal yields & Cross sections

—Iterative approach



re-Weight

Until parameters are consistent with previous result



Signal yields

Fit results in the final loop

- Significant signals for $\Upsilon(1S,2S)\pi^+\pi^-$ at $\sqrt{s} = 10.745,\ 10.806$ GeV
- No evident signals for $\Upsilon(3S)\pi^+\pi^-$
- Fit the ΔM distribution with two components:
  - Signal: MC simulated shapes, re-weighted with cross-section dependence and amplitude fit result
  - Background: 1st-order polynomial
- Significance for $\Upsilon(1S)\pi^+\pi^-$ at $\sqrt{s} = 10.653$ GeV is only $1.7 \sim 2.3\sigma$, depending on different background assumptions.

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

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

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

Parameters of $\Upsilon(10753)$:

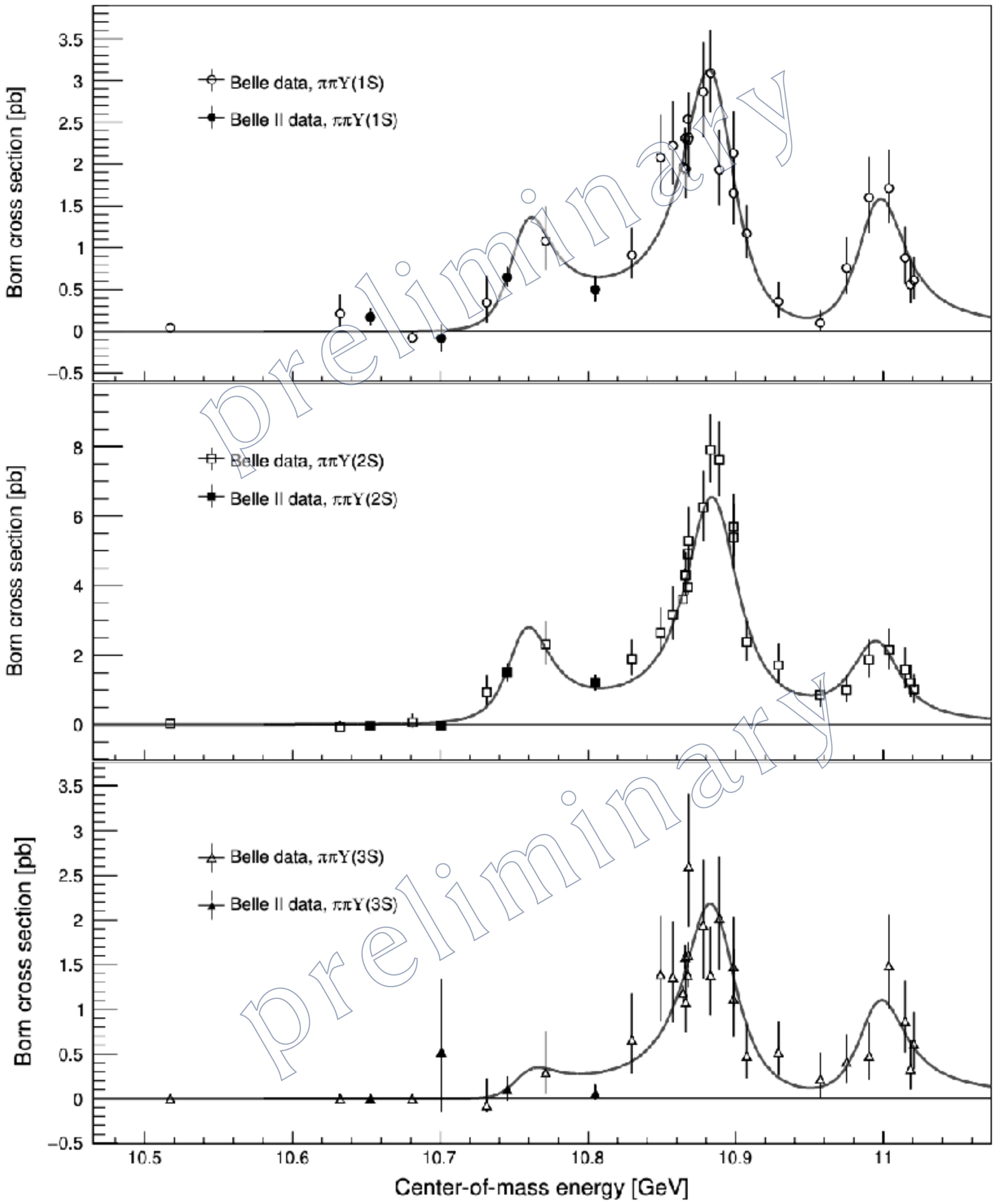
$M = 10756.3 \pm 2.7_{(stat.)} \pm 0.6_{(syst.)}$ MeV/c^2

$\Gamma = 29.7 \pm 8.5_{(stat.)} \pm 1.1_{(syst.)}$ 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.

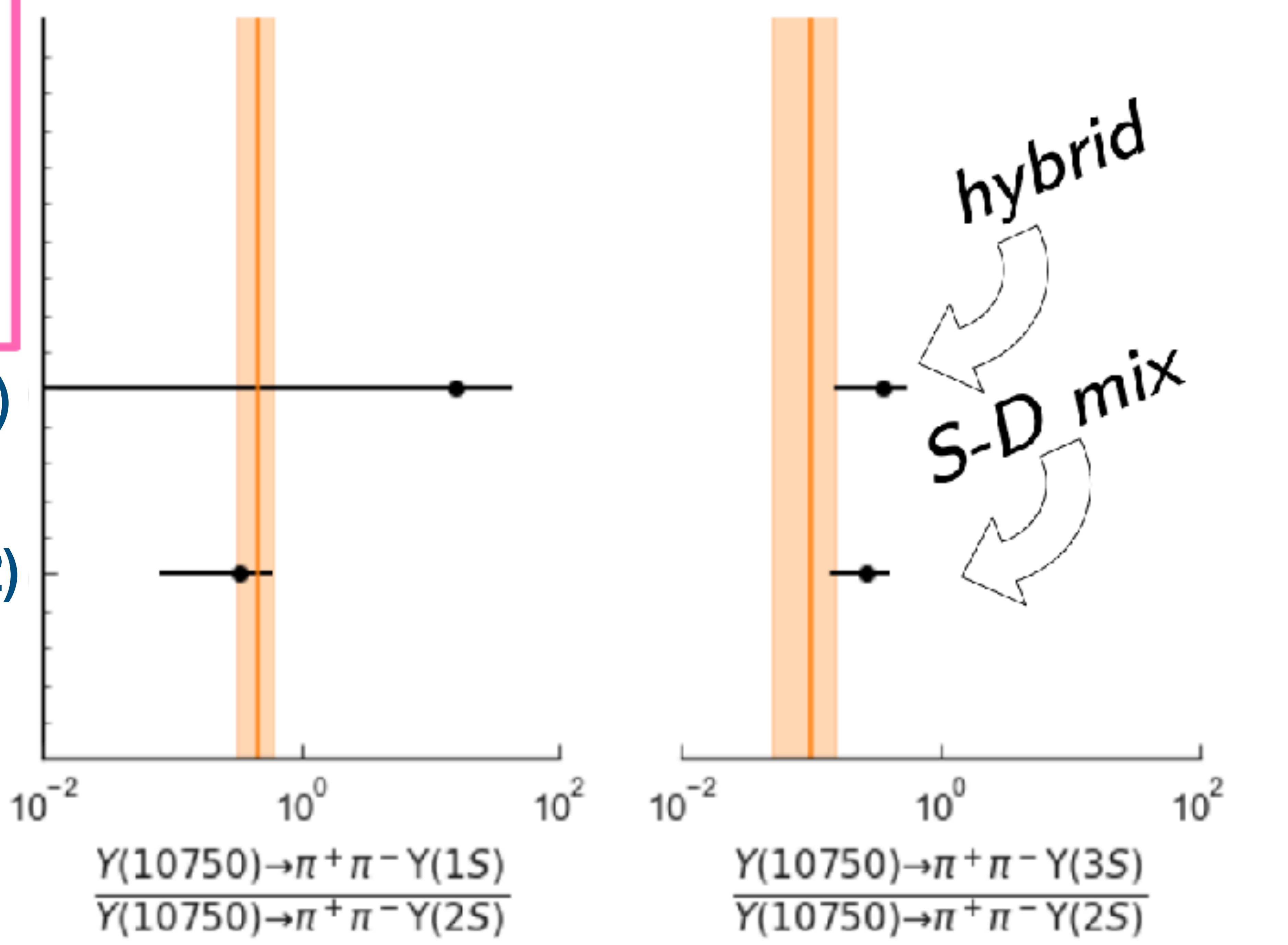
	$\mathcal{R}^{\Upsilon(10753)}_{\sigma(1S/2S)}$	$\mathcal{R}^{\Upsilon(10753)}_{\sigma(3S/2S)}$	$\mathcal{R}^{\Upsilon(5S)}_{\sigma(1S/2S)}$	$\mathcal{R}^{\Upsilon(5S)}_{\sigma(3S/2S)}$	$\mathcal{R}^{\Upsilon(6S)}_{\sigma(1S/2S)}$	$\mathcal{R}^{\Upsilon(6S)}_{\sigma(3S/2S)}$
Ratios	$0.46^{+0.15}_{-0.12}$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

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

Mild tension with all models?

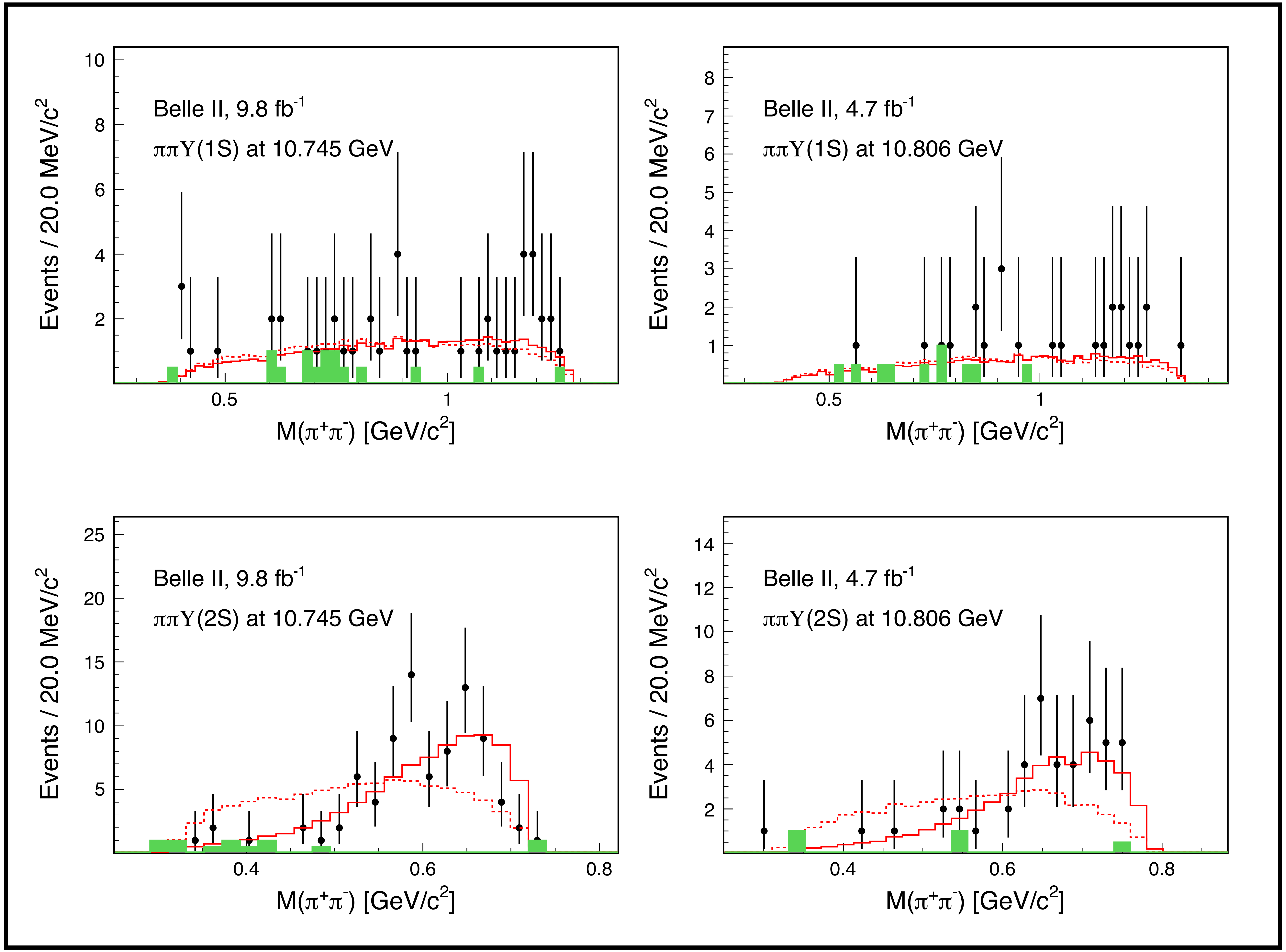
Castella. *et. al.* Phys. Rev. D 104, 034019 (2021)

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



Belle-II preliminary, arxiv:2401.12021

Intermediate state — $M(\pi\pi)$



Dots: events in signal region

Green: nearest sidebands, scaled with area

Red dashed: signal MC, simulated uniformly

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

Consistent with PHSP

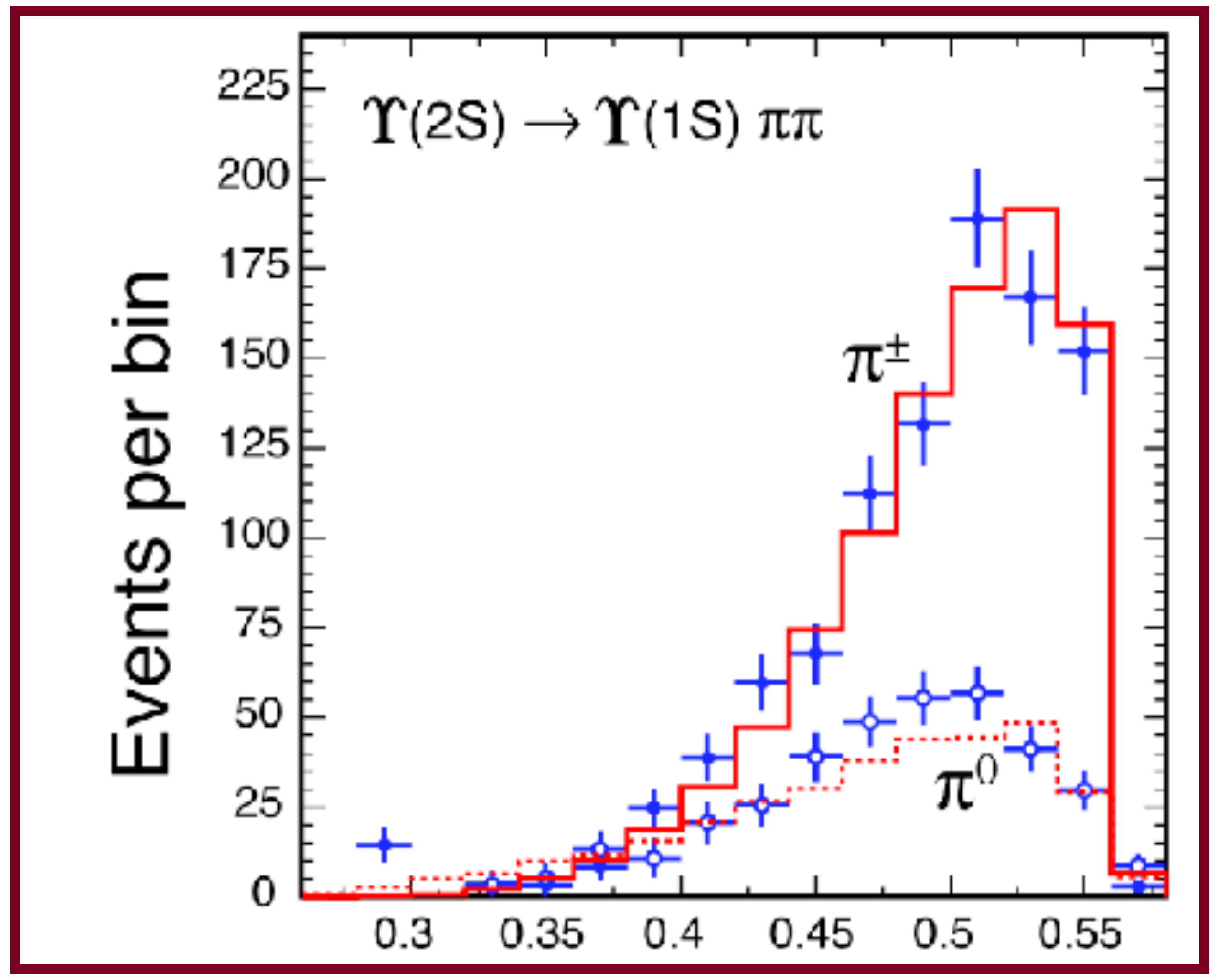
($\chi^2 = 0.98,\ 1.14$)

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

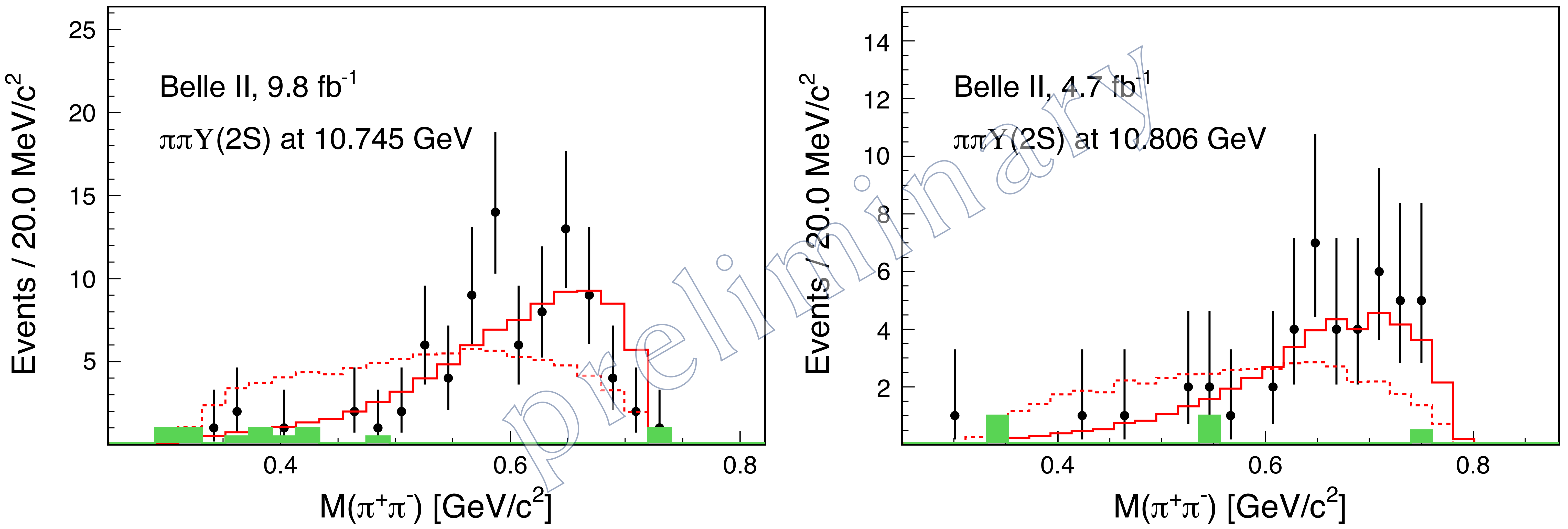
Not consistent with PHSP

$\chi^2 = 3.45,\ 2.43$

Phys.Rev.D 76 (2007) 072001



Belle-II preliminary, arxiv:2401.12021

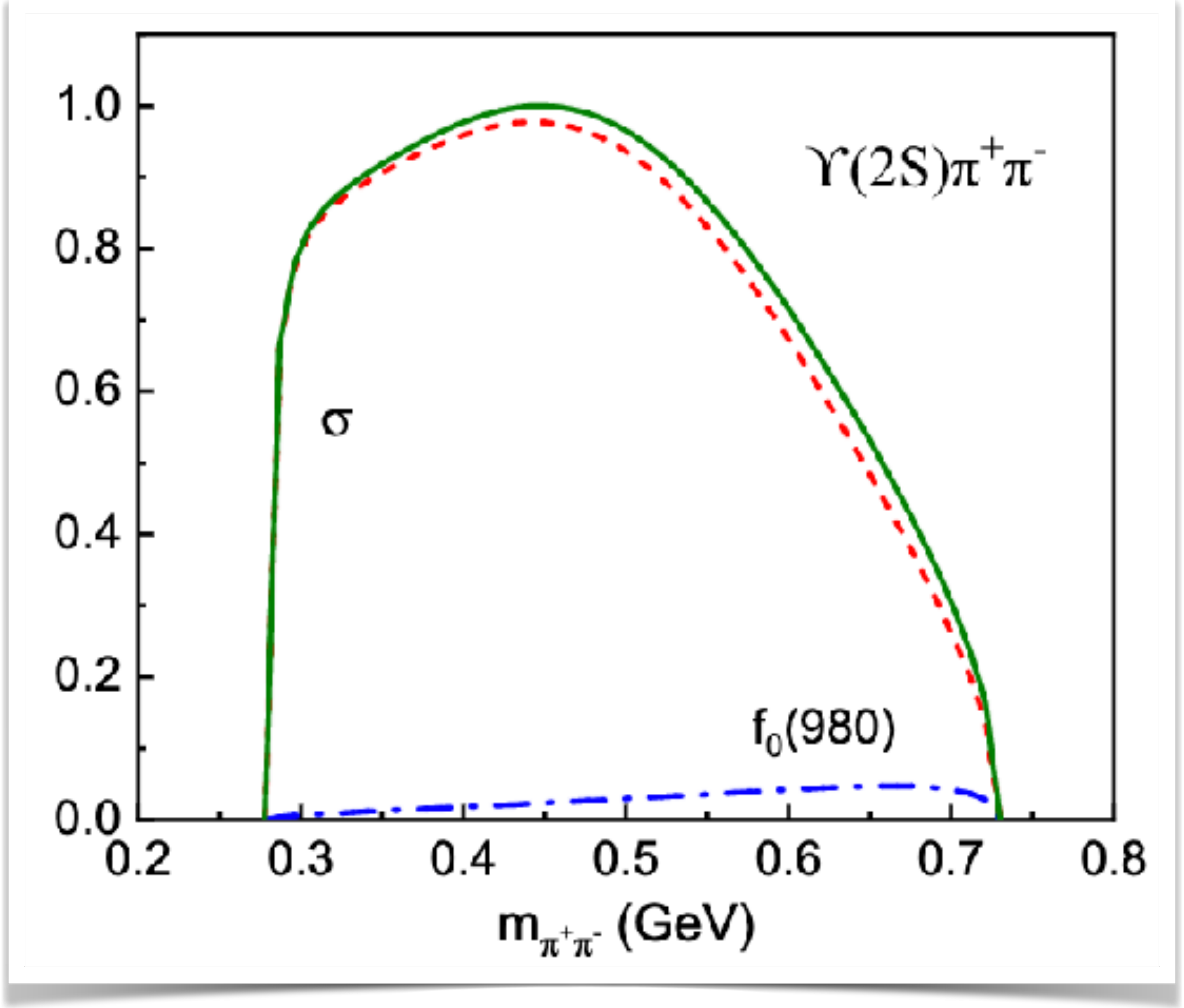


- The $M(\pi^+\pi^-)$ distribution is very similar with that from $\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$
- Use CLEO parameterization:

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

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

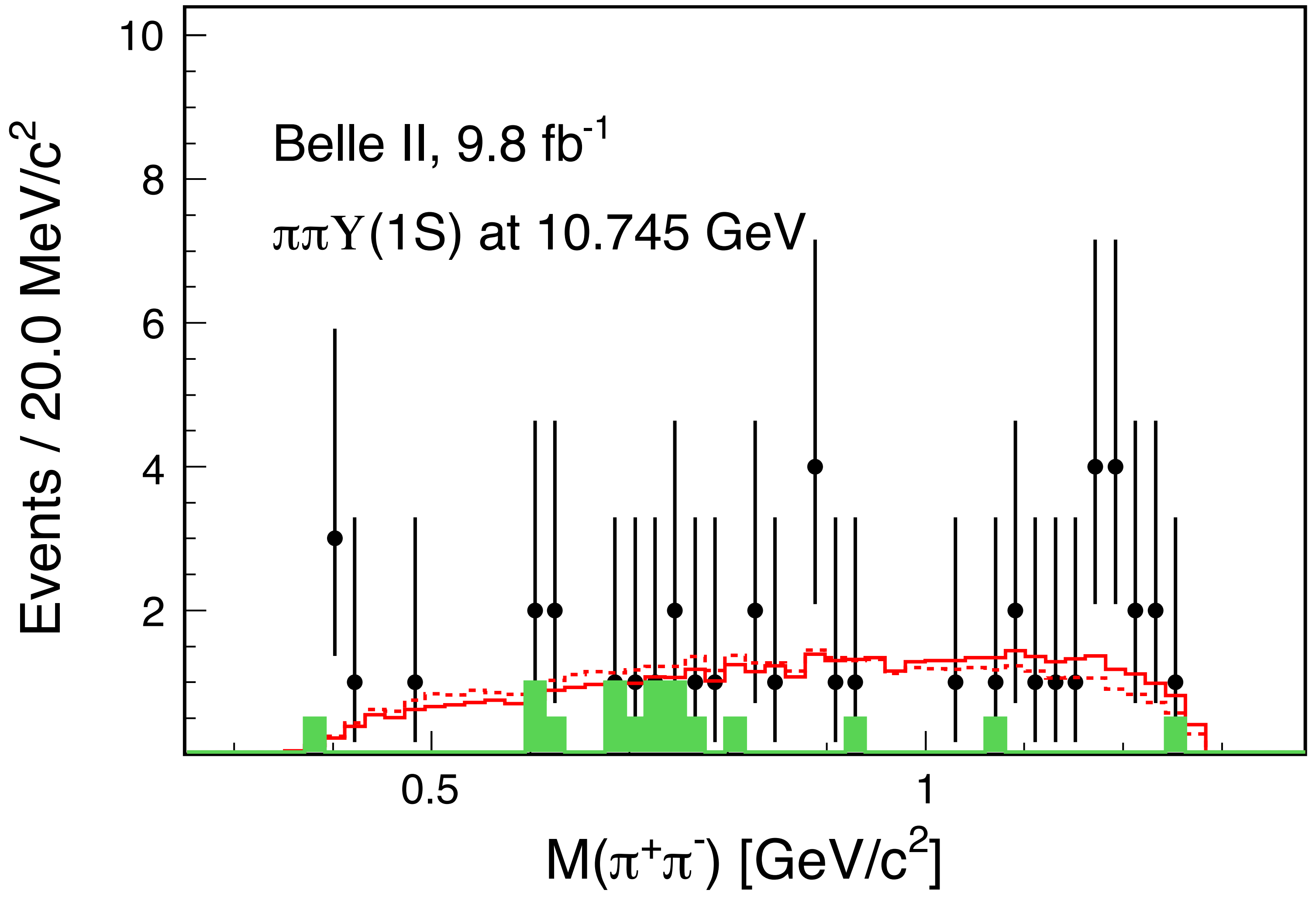
We fix $\mathscr{A} = 1$, and $\mathscr{B}$ is fitted to be $(1.1 \pm 0.3) + (4.7 \pm 1.5)i$

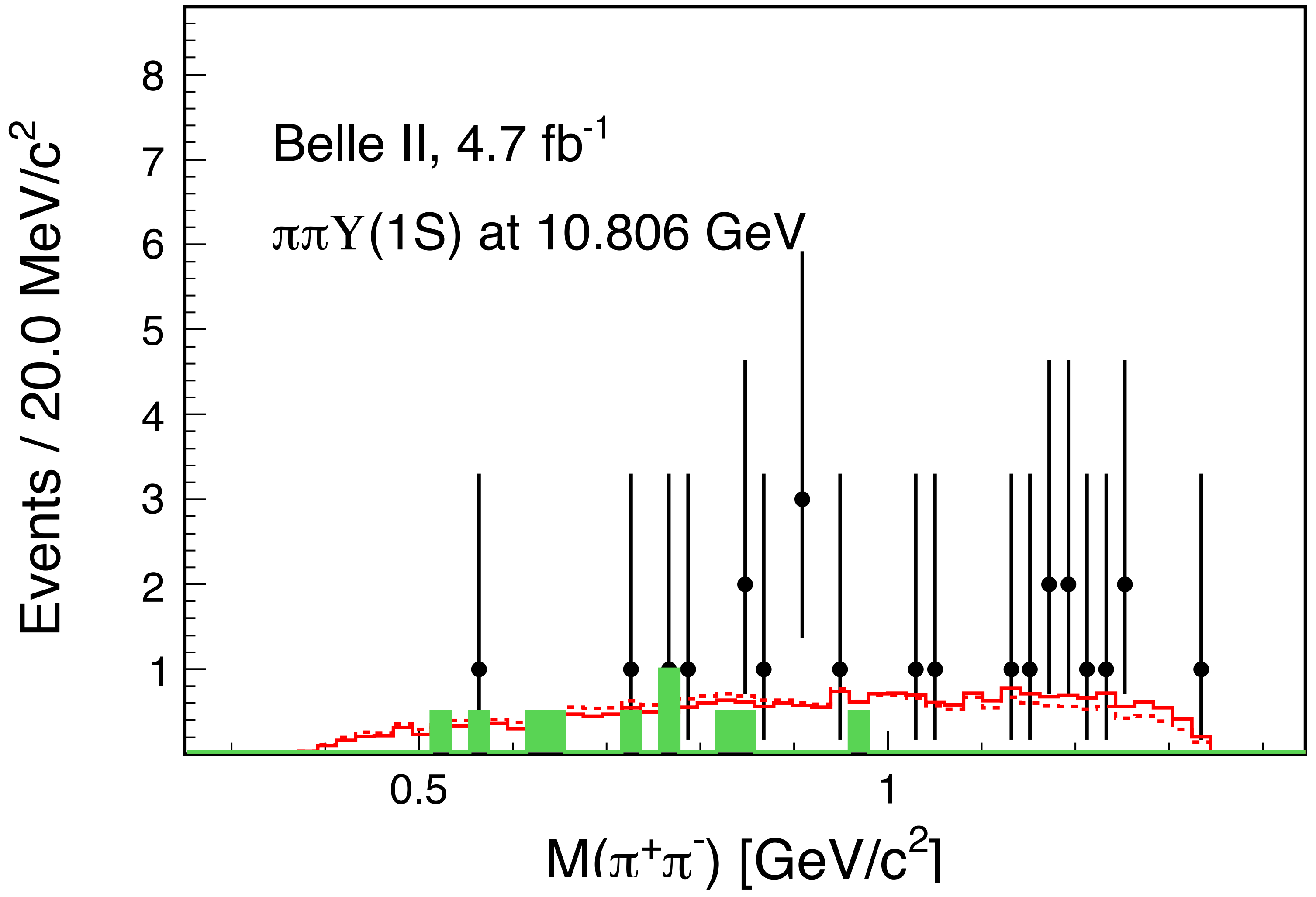


Bai. *et. al.*
Phys. Rev. D 105, 074007 (2022)

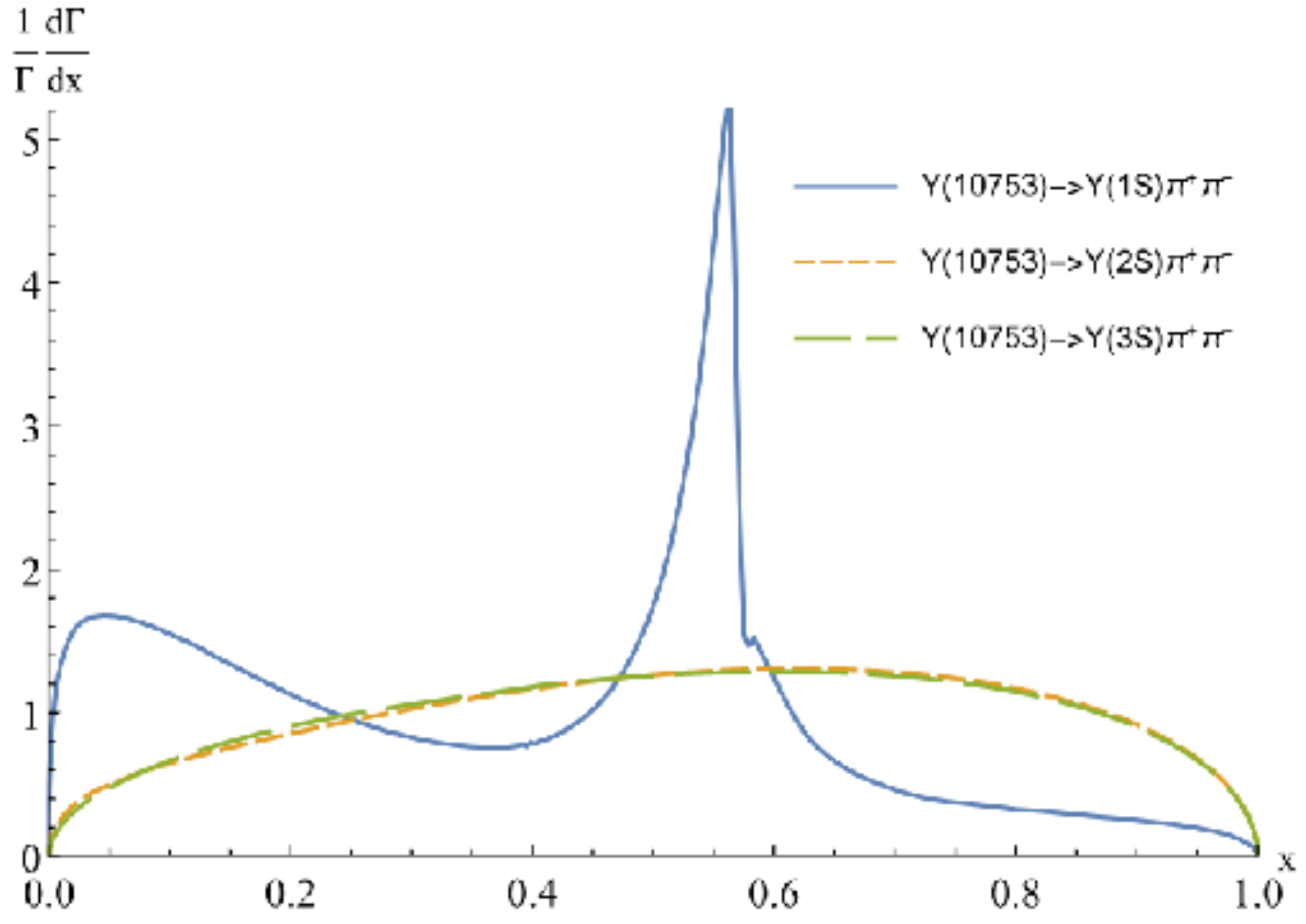
S-D mix

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



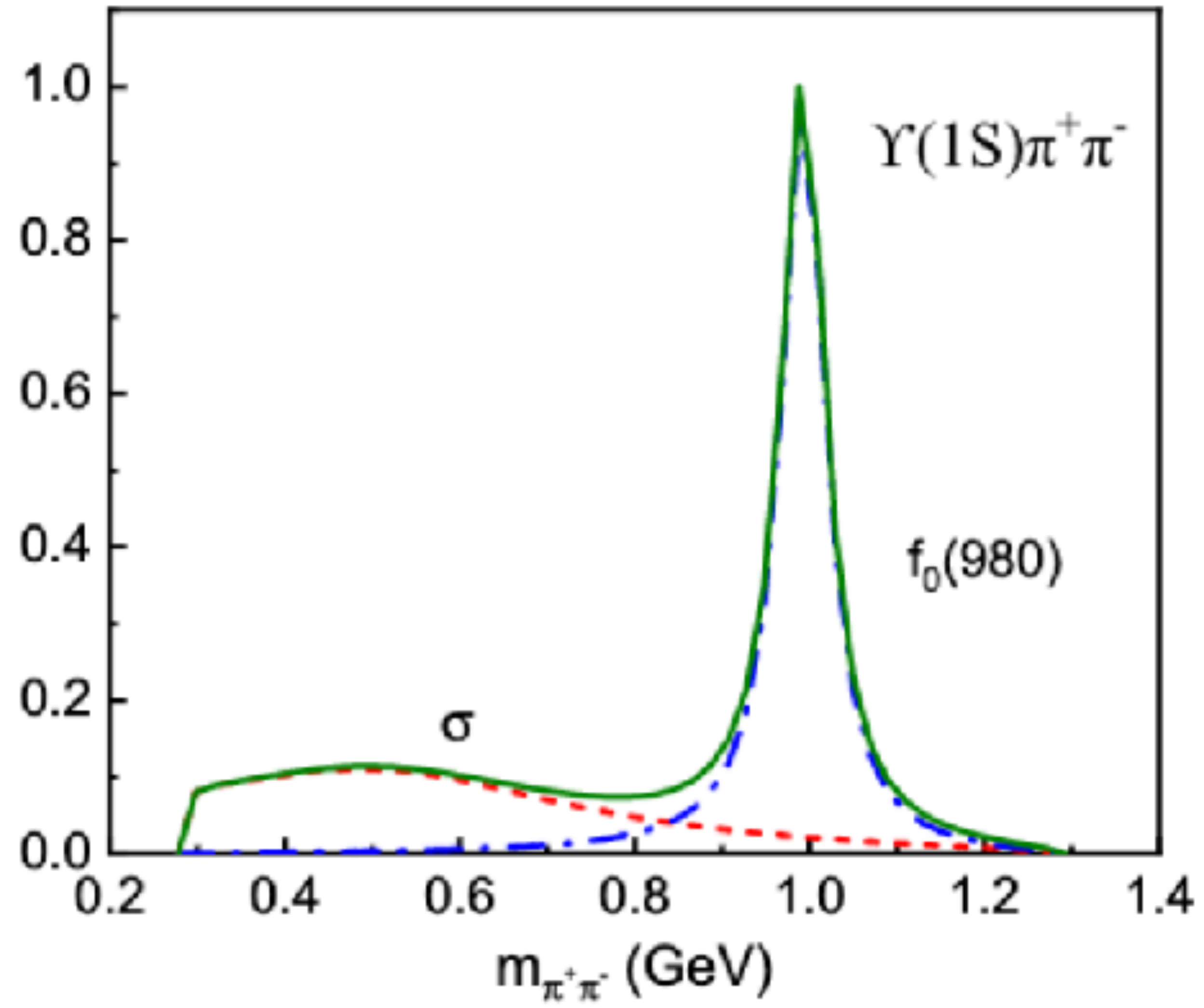


Castella. ***et. al.***
Phys. Rev. D 104, 034019 (2021)



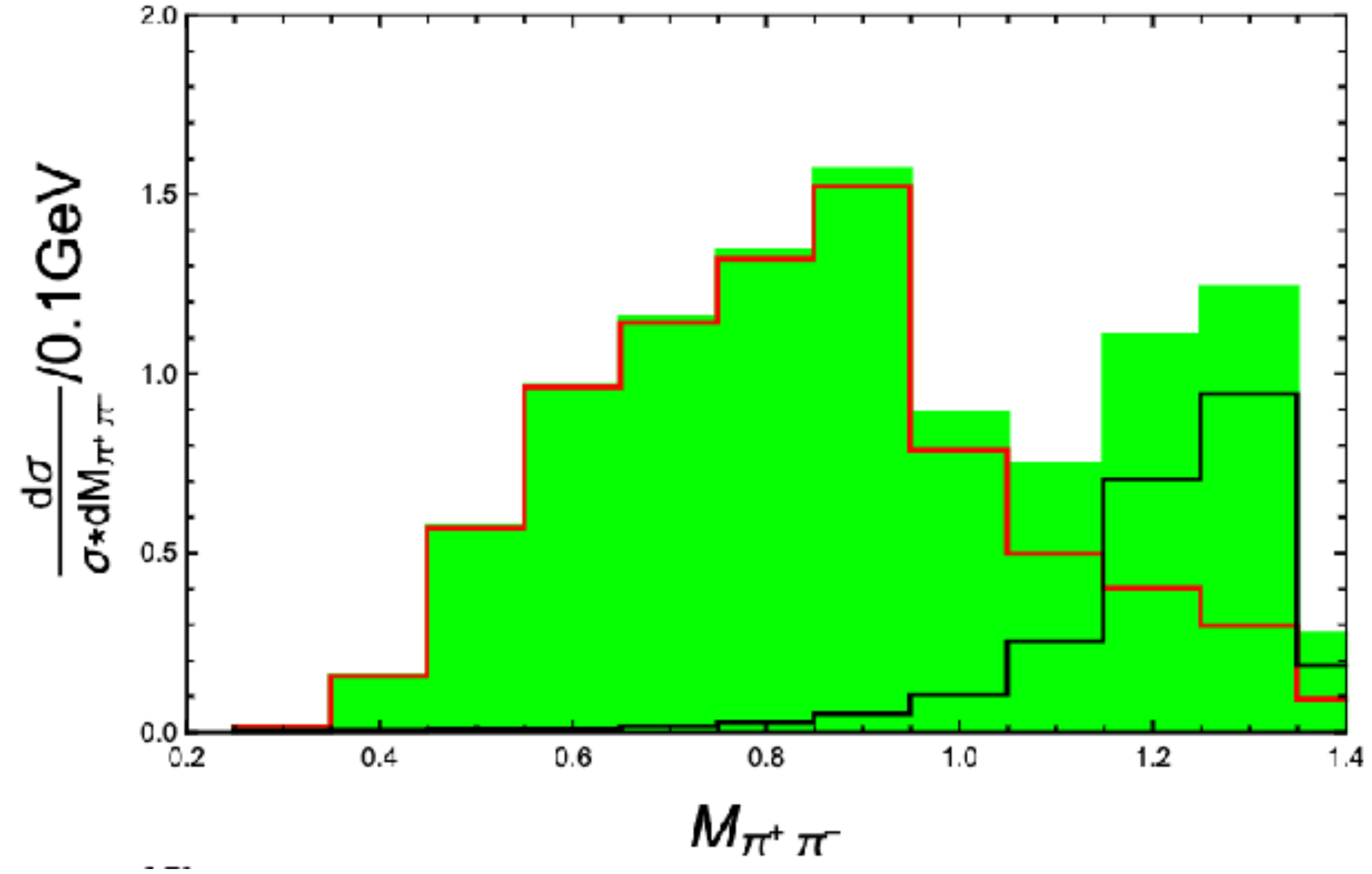
Hybrid

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



S-D mix

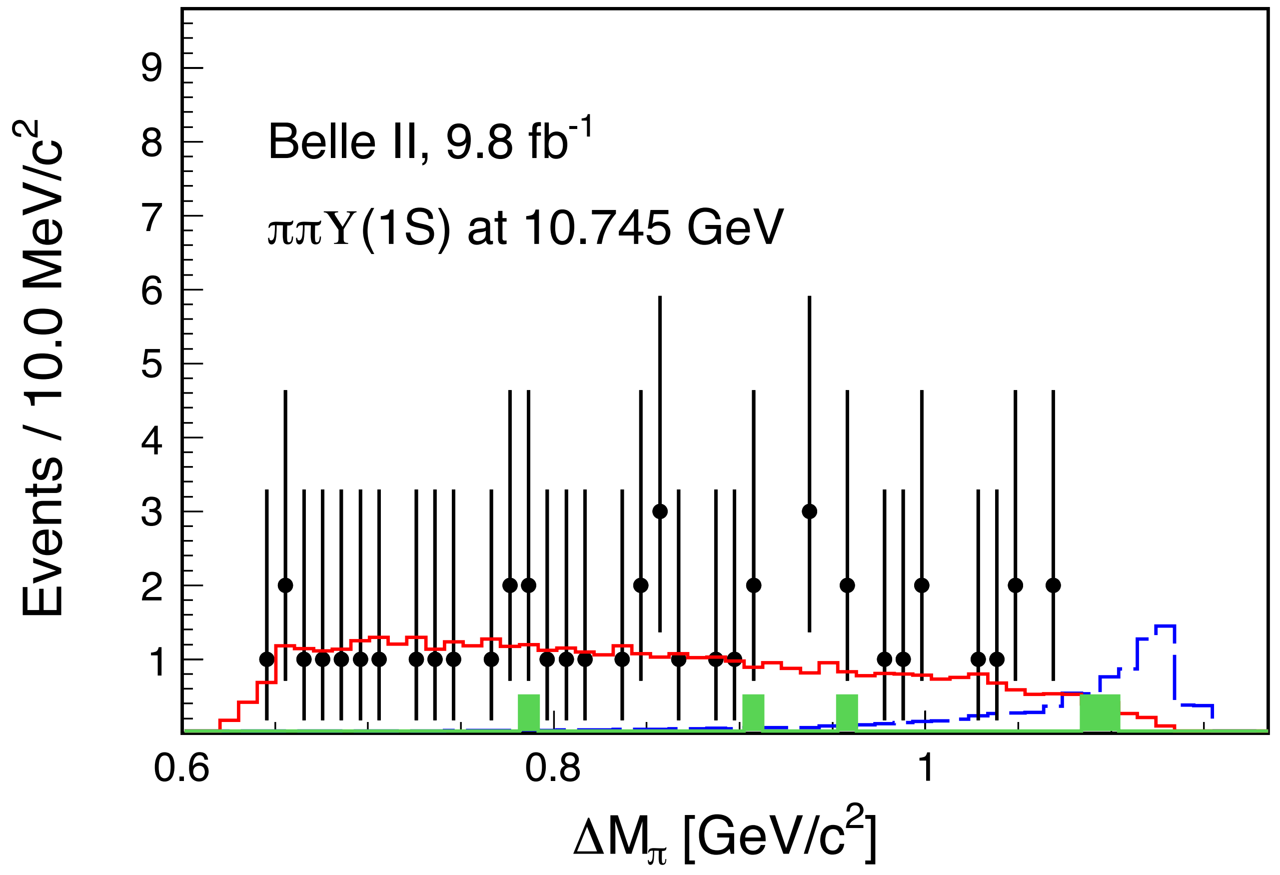
Maiani. ***et. al.***
Phys. Rev. D 105, 074007 (2022)

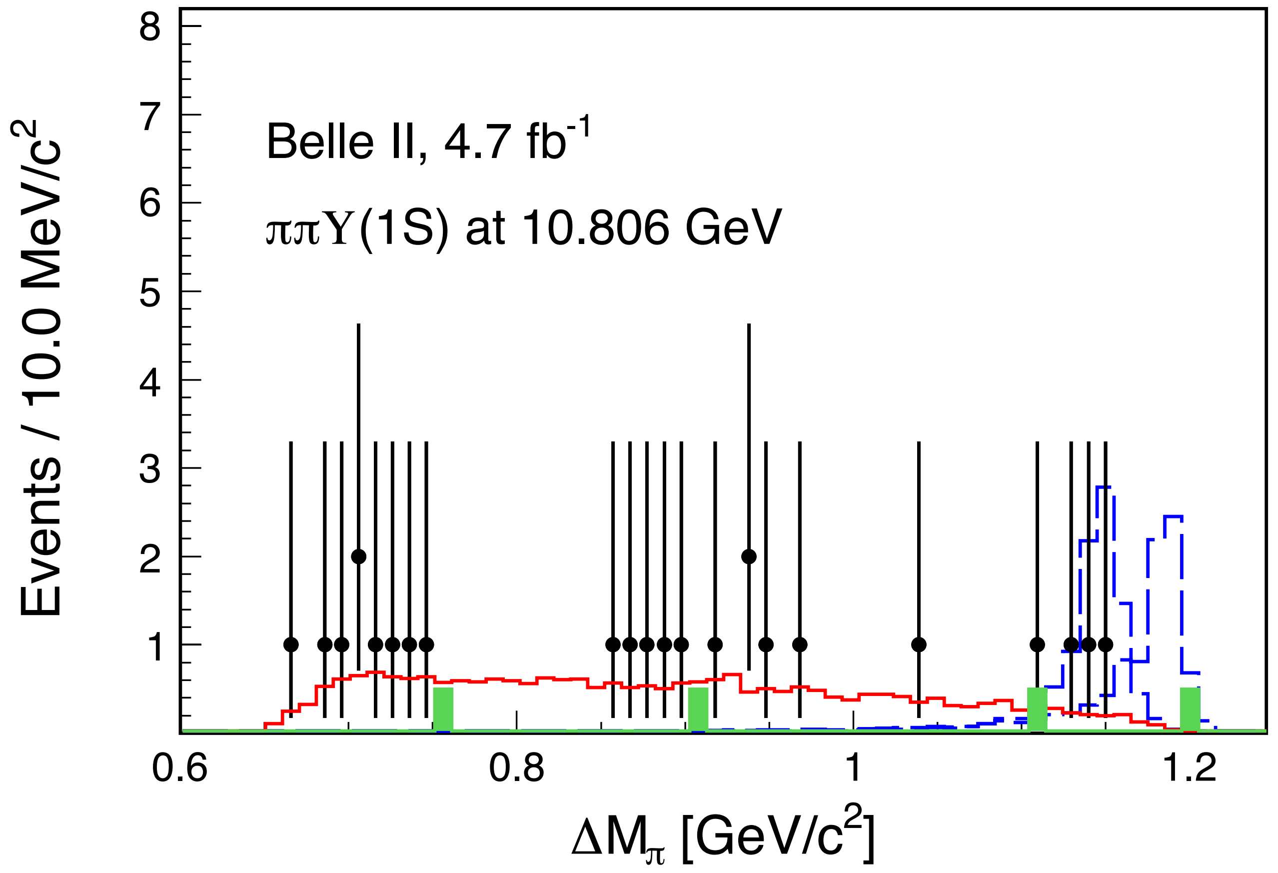


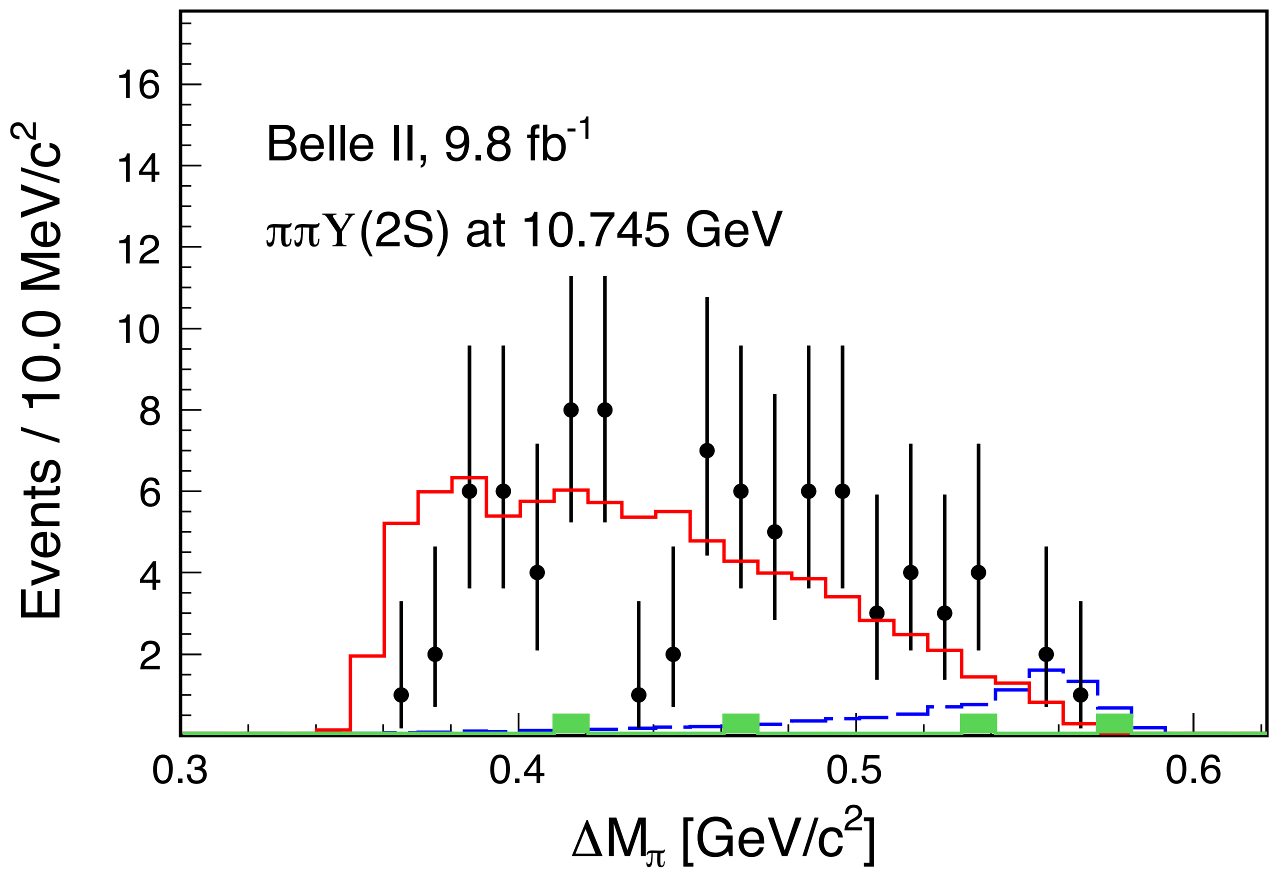
Tetraquark

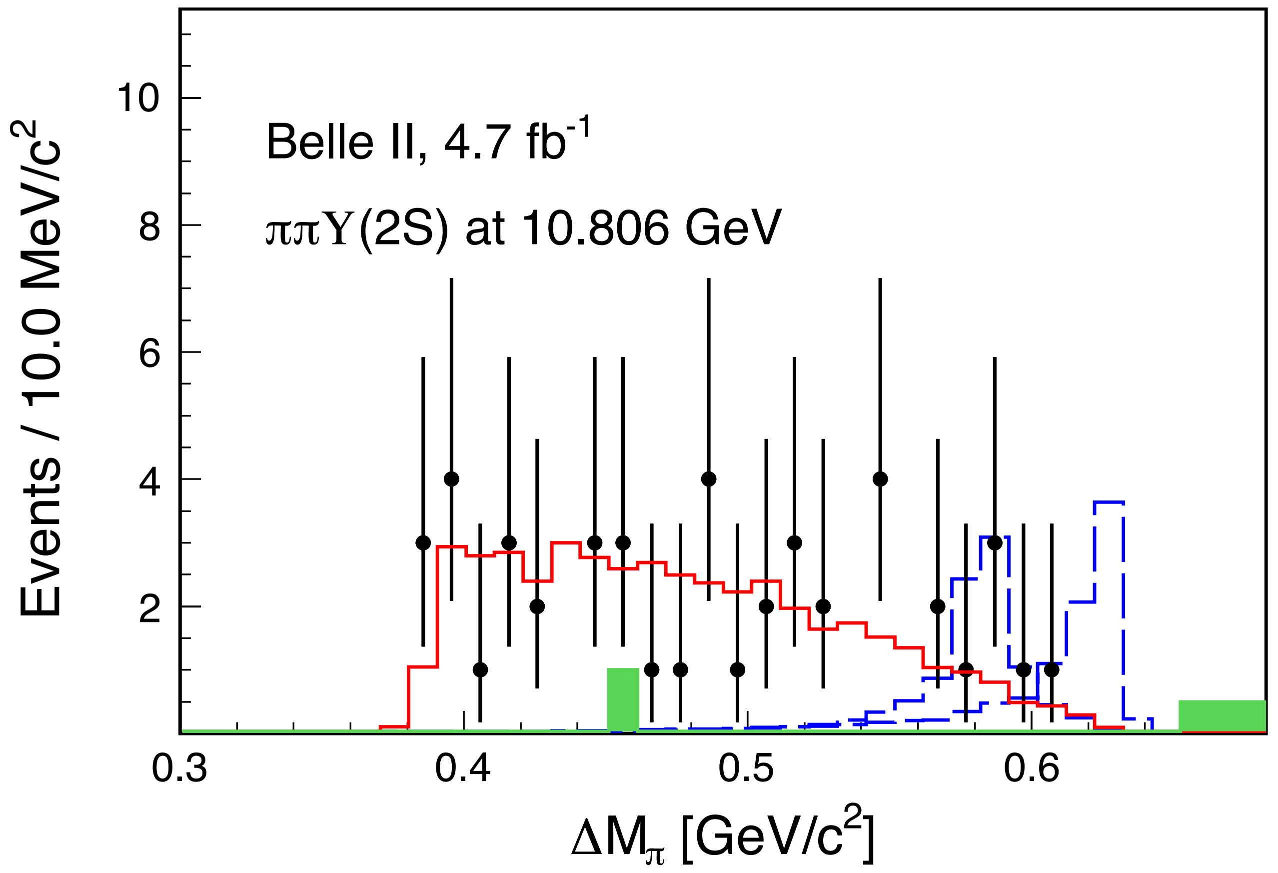
Intermediate state — $\Upsilon(10753) \to \pi Z_b$

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

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

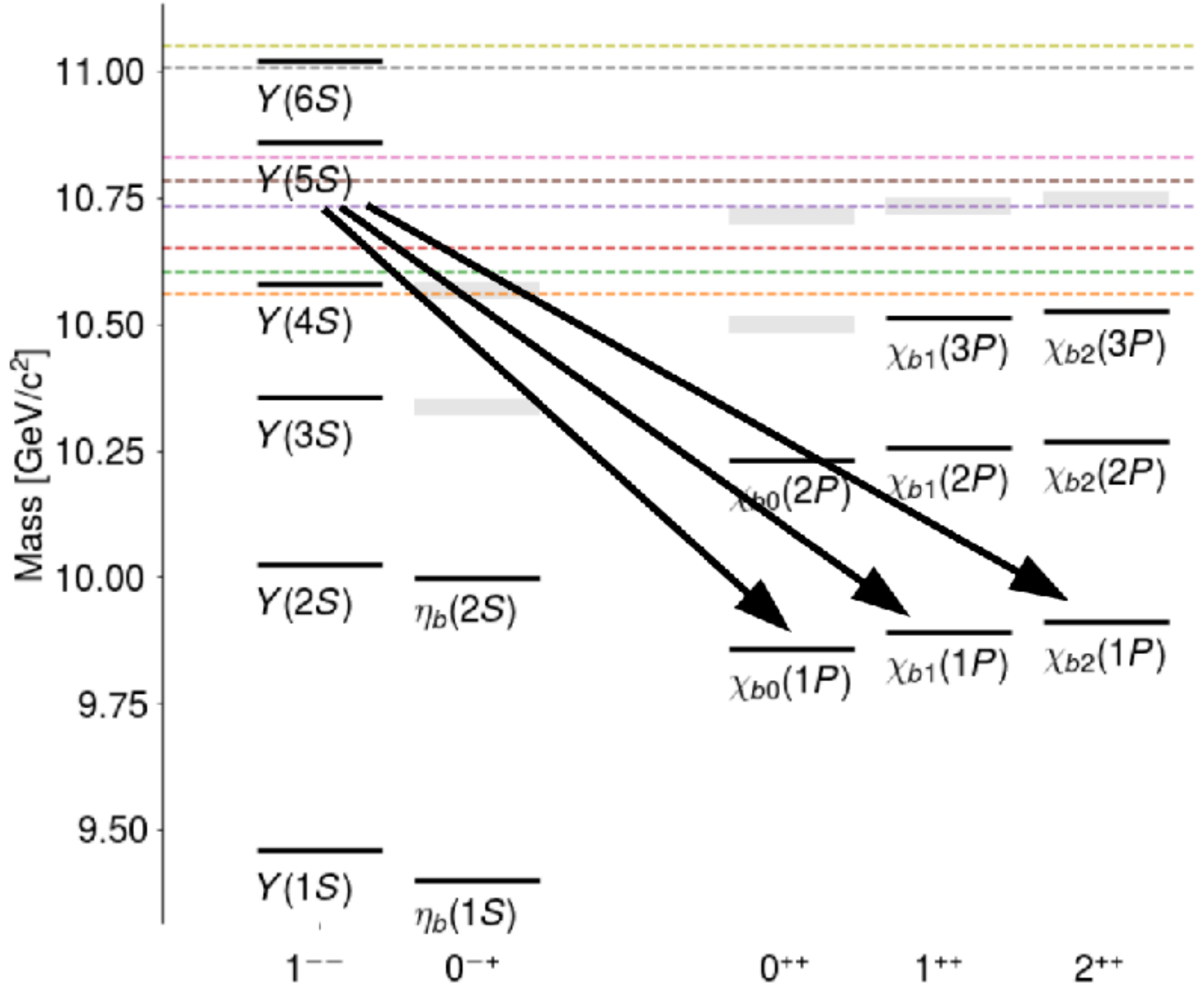
Y(10750) → ω χ_b in the conventional quarkonium model (S-D mixing state)

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

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

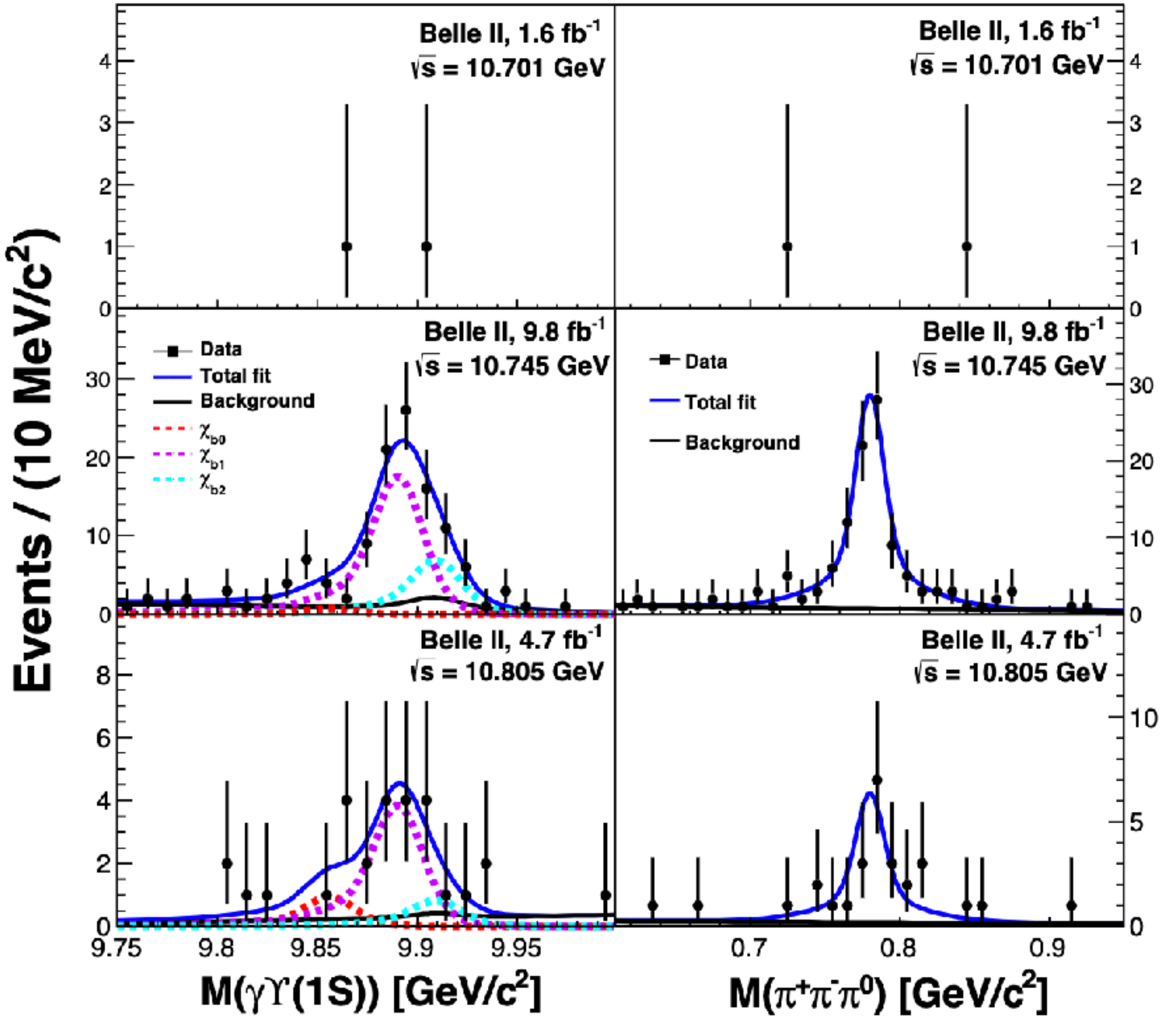
$$R_{12} = \frac{\mathcal{B}[\Upsilon(10753) \to \chi_{b1}\omega]}{\mathcal{B}[\Upsilon(10753) \to \chi_{b2}\omega]} = (0.18\text{–}0.22)$$
$$R_{02} = \frac{\mathcal{B}[\Upsilon(10753) \to \chi_{b0}\omega]}{\mathcal{B}[\Upsilon(10753) \to \chi_{b2}\omega]} = (0.55\text{–}0.63)$$

Sizable branching fractions



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

[PRL 130, 091902 (2023)]

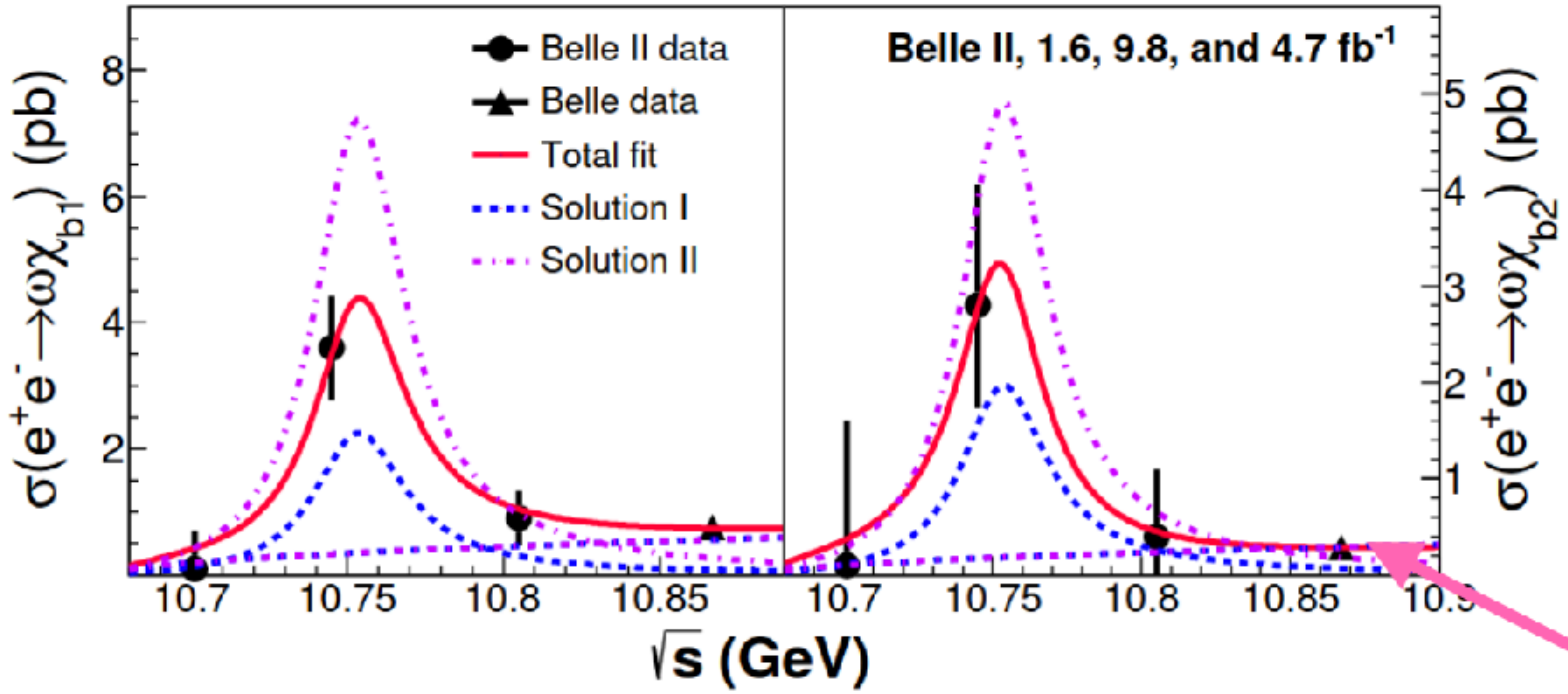


- Reconstruct $\omega \to \pi^+\pi^-\pi^0, \chi_{bJ} \to \gamma\Upsilon(1S)$
- Clear $\omega\chi_{bJ}$ signals at $\sqrt{s} = 10.745$ and 10.805 GeV
- 2D fit to $M(\pi^+\pi^-\pi^0)$ vs. $M(\gamma\Upsilon(1S))$

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)]



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

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)]

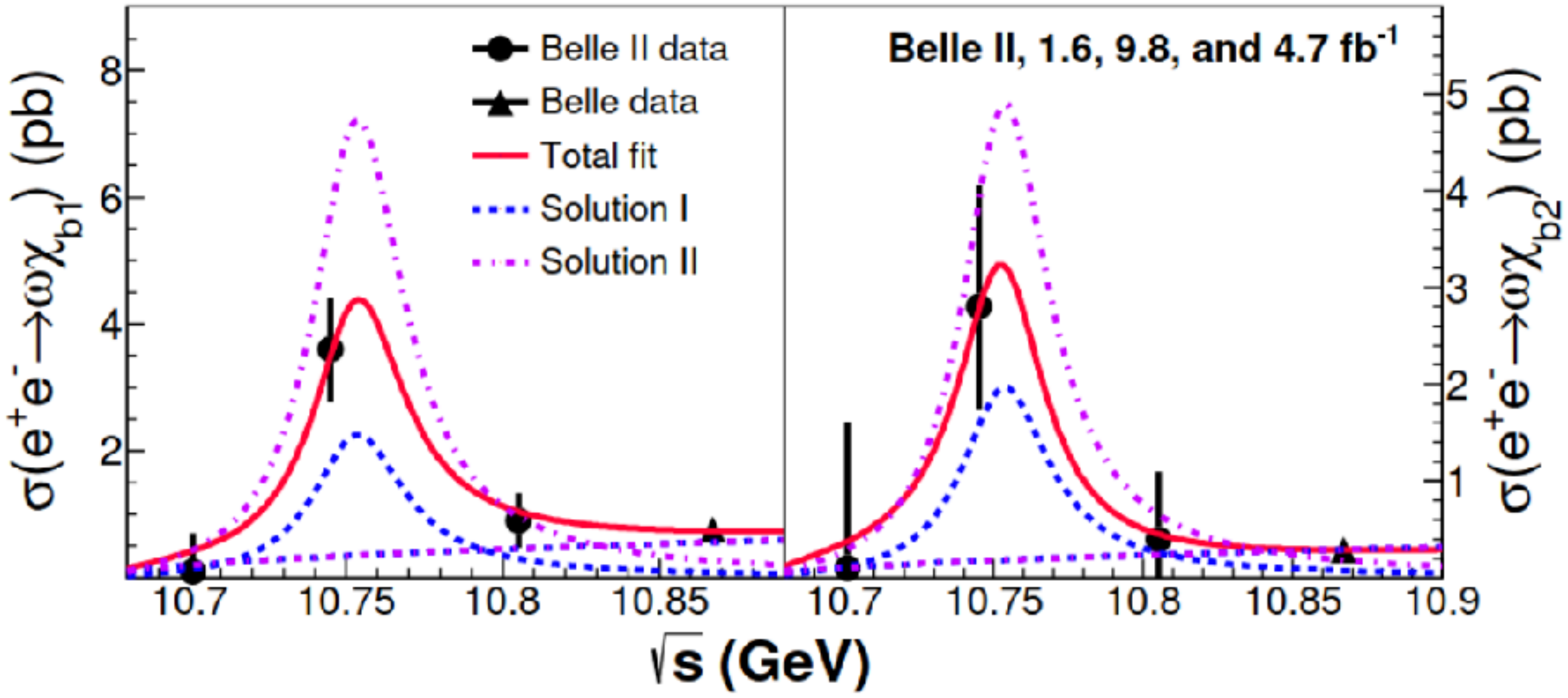
What we thought was $\Upsilon(5S) \to \omega\chi_{bj}(1P)$ is probably just the tail of the $\Upsilon(10750)$!

Two solutions (constr. or destr. interference):

$$\Gamma_{ee}\times B[\Upsilon(10750)\to\omega\chi_{b1}(1P)] = \begin{matrix}(0.63\pm0.39\pm0.20)\,eV\\(2.01\pm0.38\pm0.76)\,eV\end{matrix}$$

$$\Gamma_{ee}\times B[\Upsilon(10750)\to\omega\chi_{b2}(1P)] = \begin{matrix}(0.53\pm0.40\pm0.15)\,eV\\(1.32\pm0.44\pm0.53)\,eV\end{matrix}$$

[PRL 130, 091902 (2023)]



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

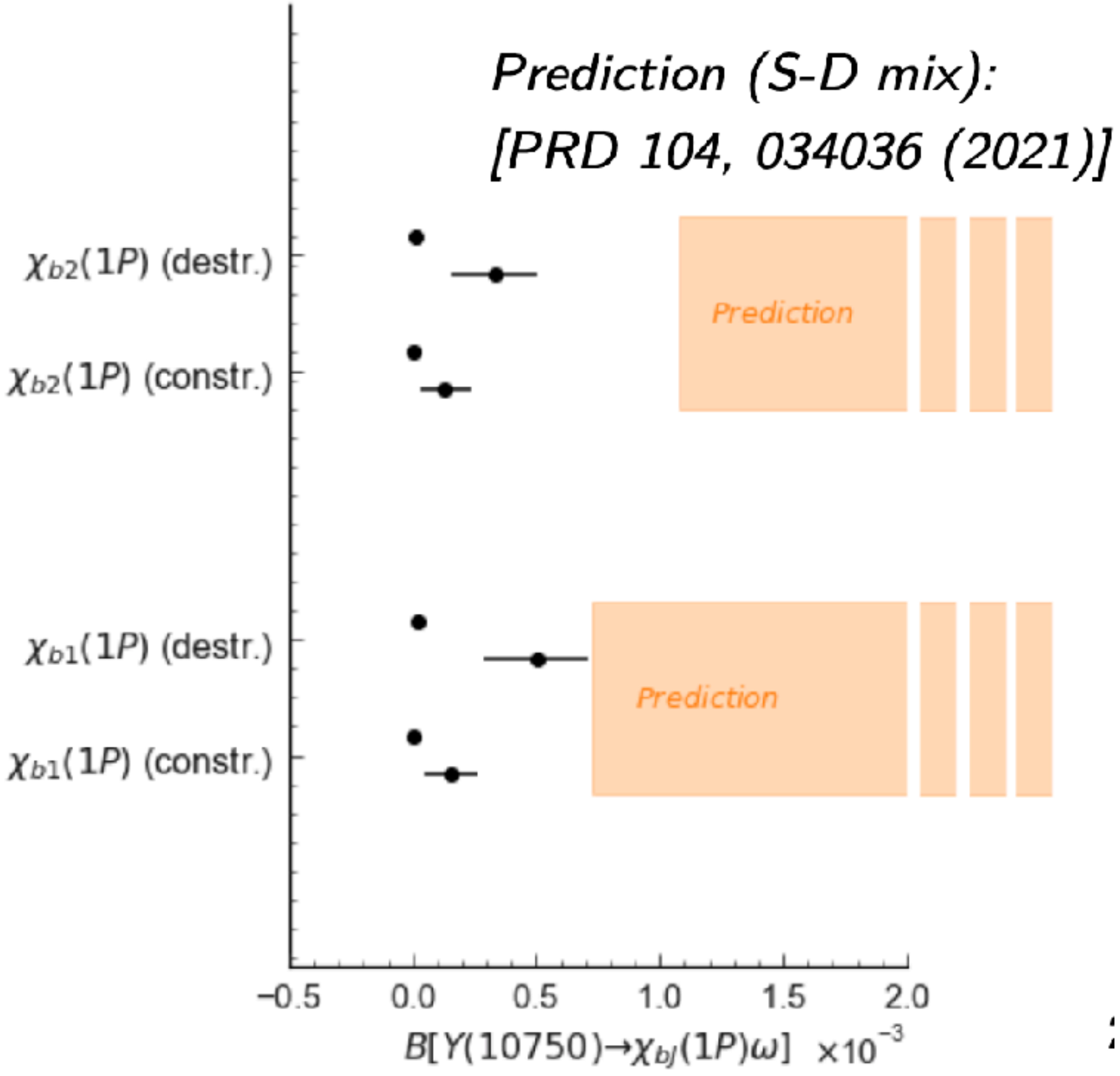
Two solutions (constr. or destr. interference):

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

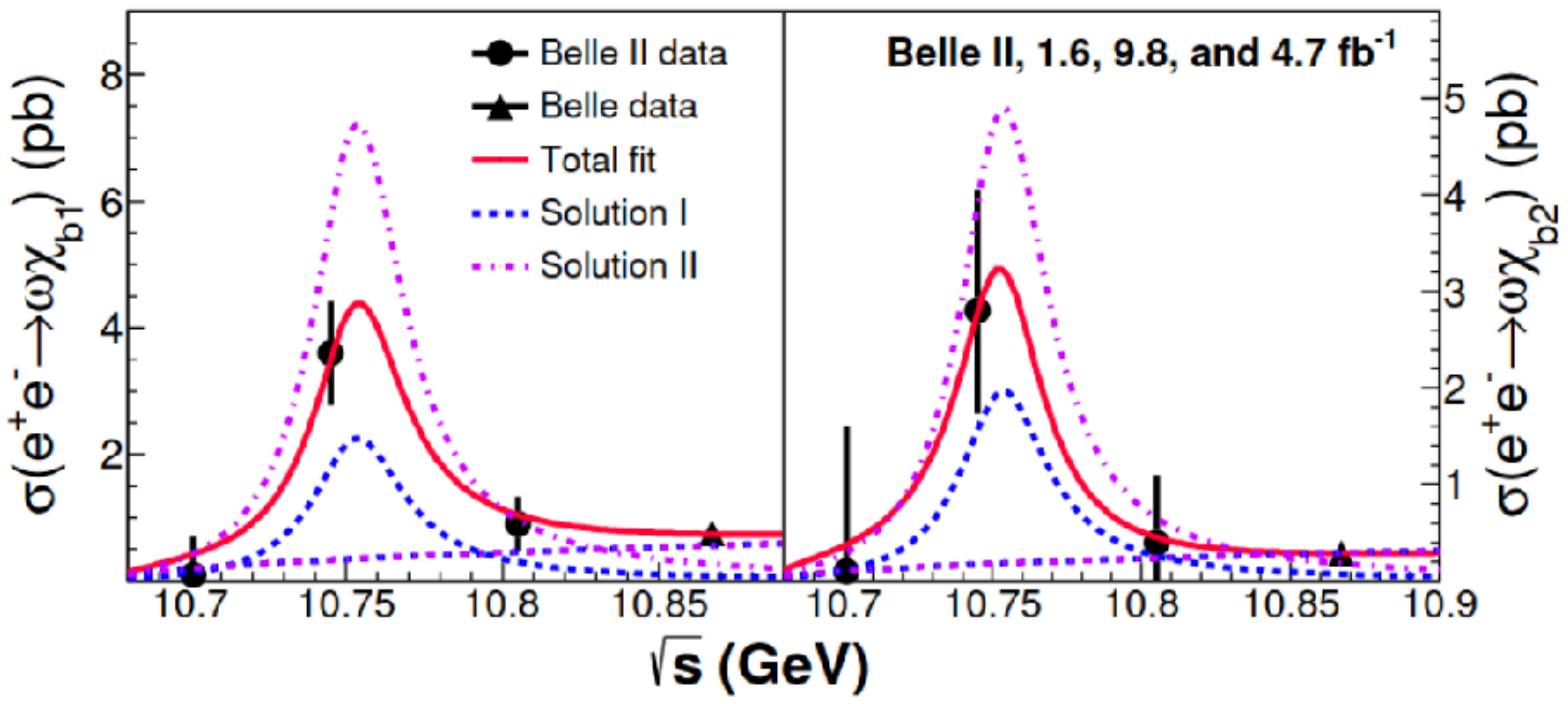
$$\Gamma_{ee} \times B[Y(10750) \to \omega\chi_{b2}(1P)] = \begin{matrix} (0.53 \pm 0.40 \pm 0.15)\, eV \\ (1.32 \pm 0.44 \pm 0.53)\, eV \end{matrix}$$

[PRL 130, 091902 (2023)]

Disagreement with *S-D* model?



[PRL 130, 091902 (2023)]



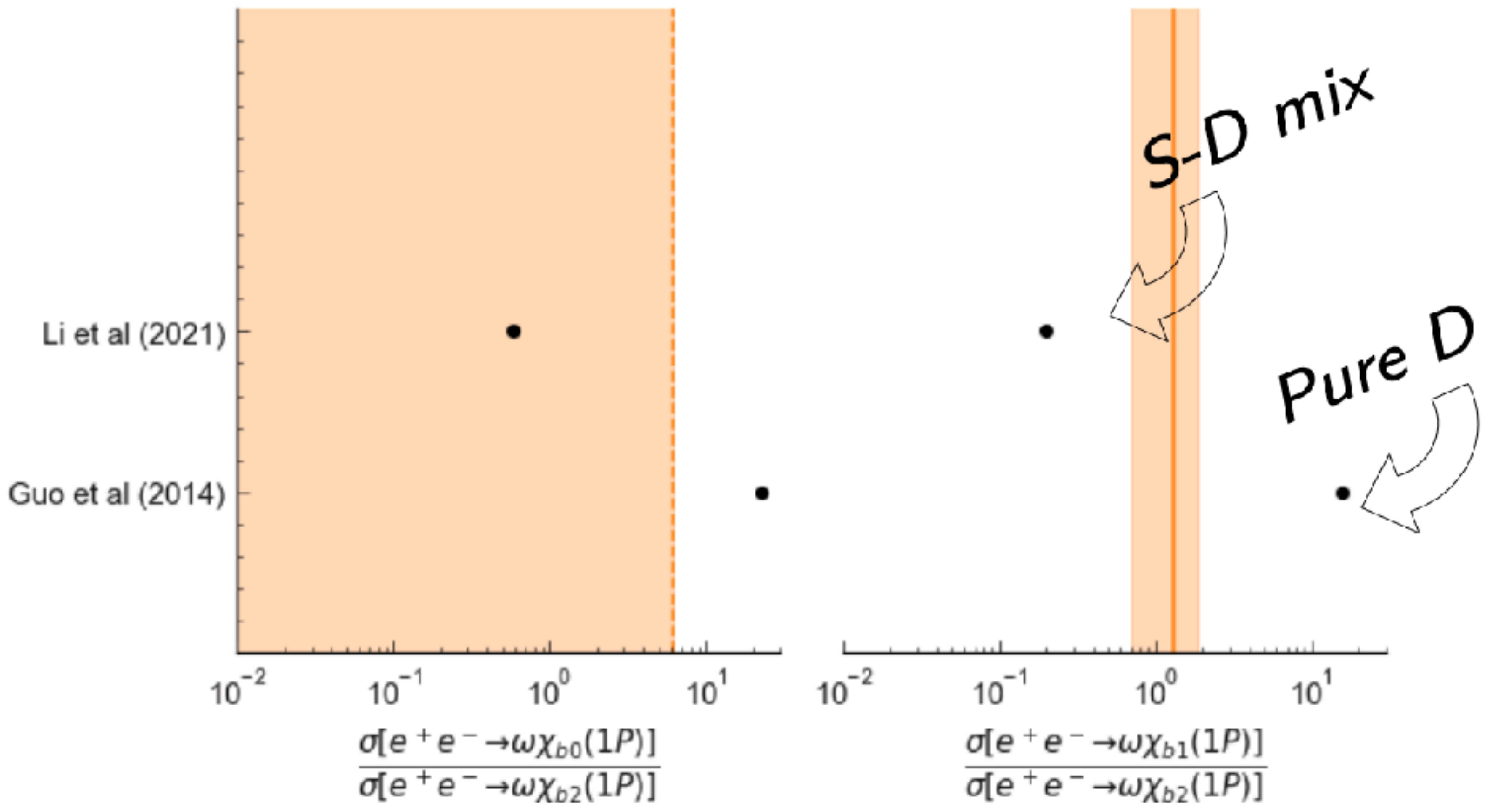
[PRL 130, 091902 (2023)]

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

Measured ratios:

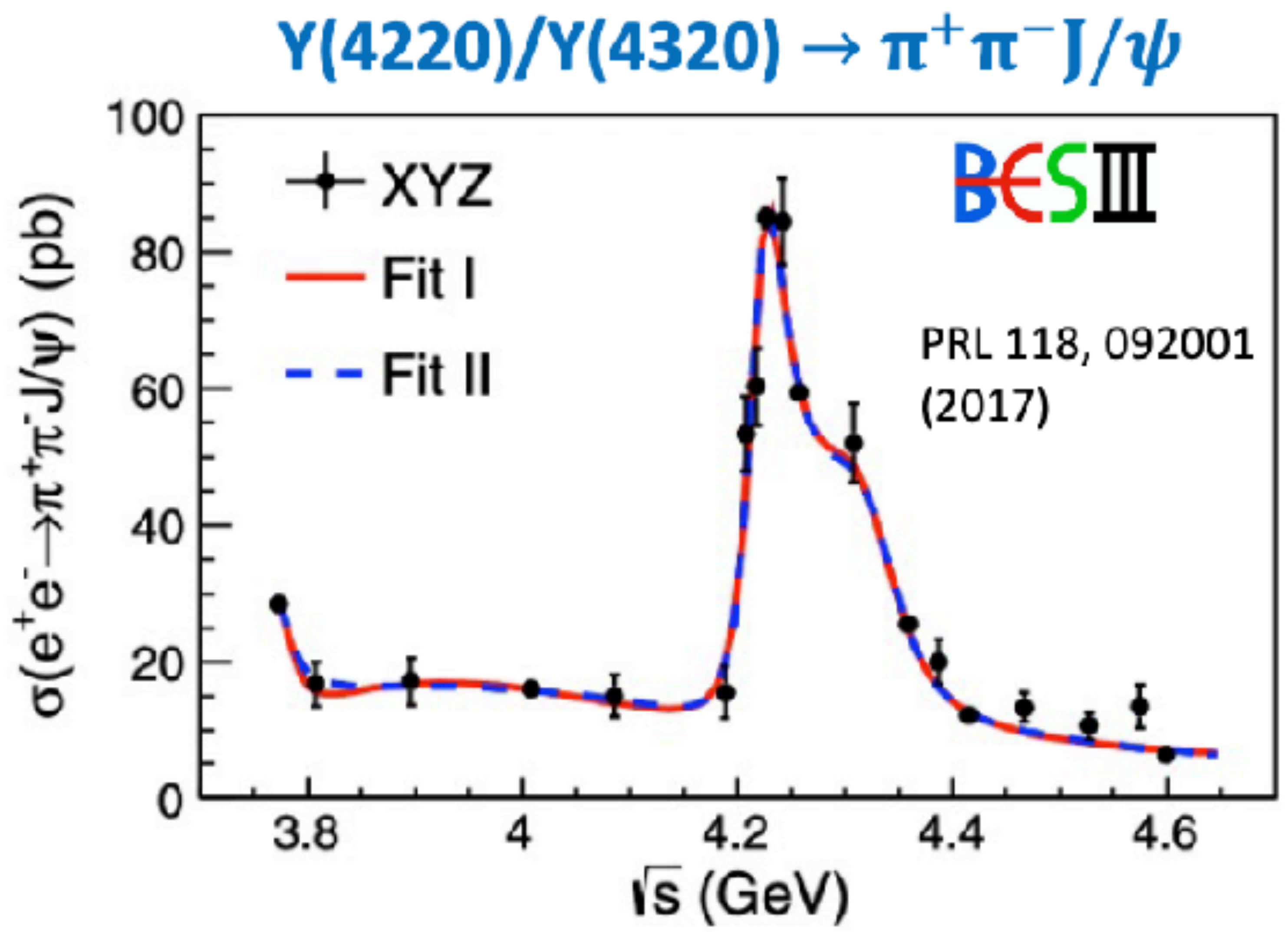
$$\frac{B[Y(10750)\to\omega\chi_{b1}(1P)]}{B[Y(10750)\to\omega\chi_{b2}(1P)]}=1.3\pm0.6$$

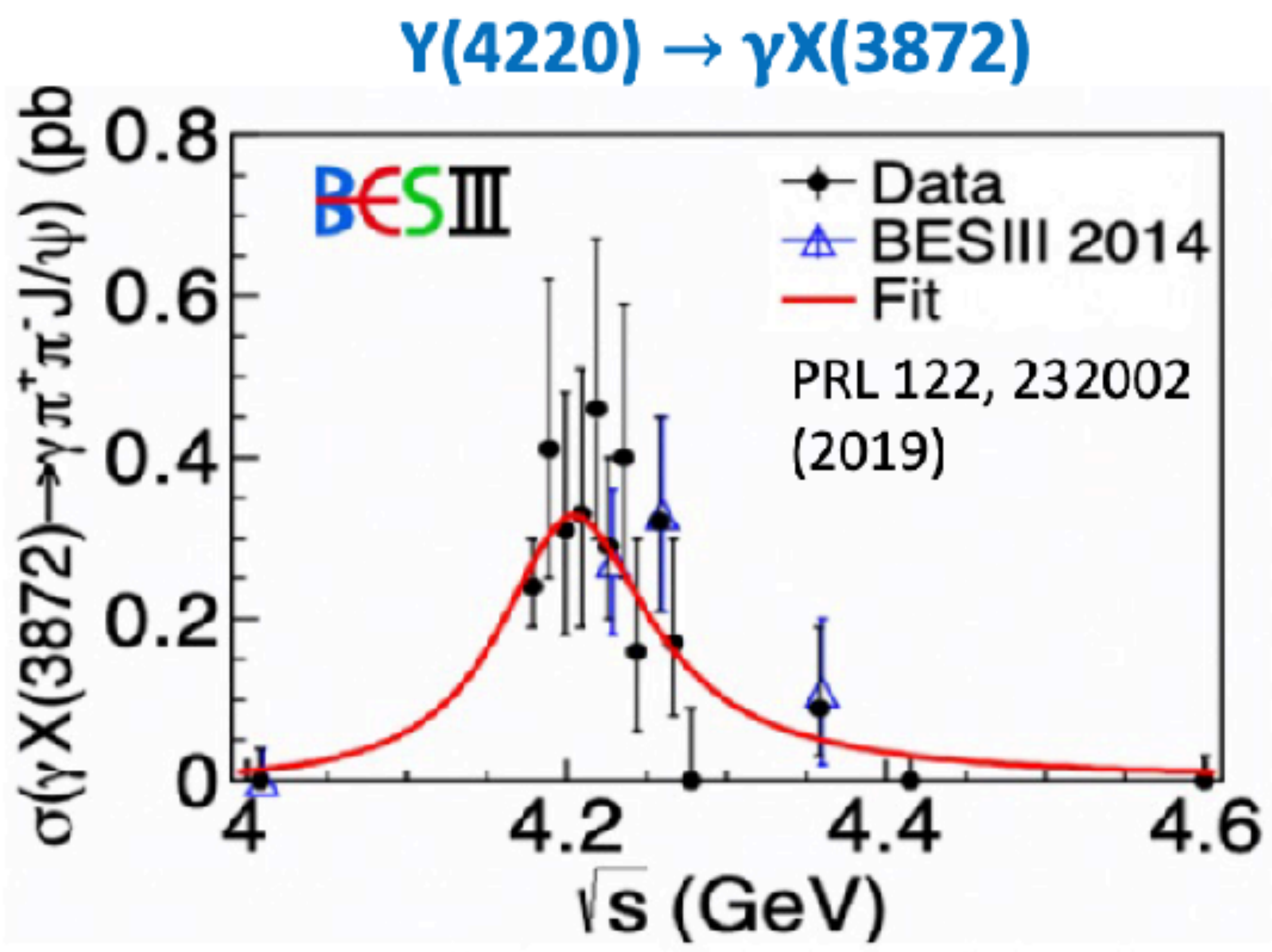
$$\frac{B[Y(10750)\to\omega\chi_{b0}(1P)]}{B[Y(10750)\to\omega\chi_{b2}(1P)]}<7$$ *(private extrapolation)*

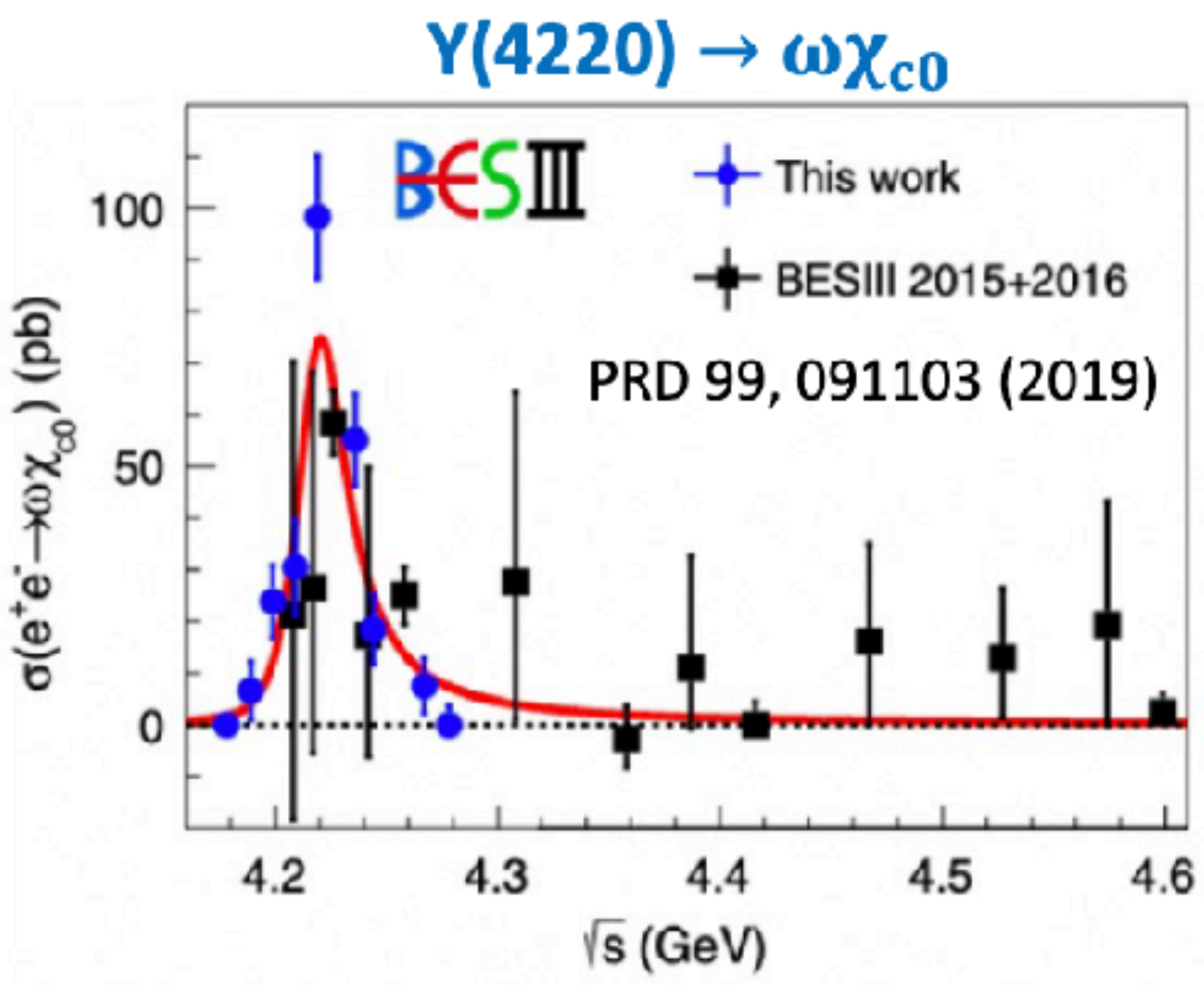


$Y(4230)$ ⟷ Analogy ⟷ $\Upsilon(10753)$

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.



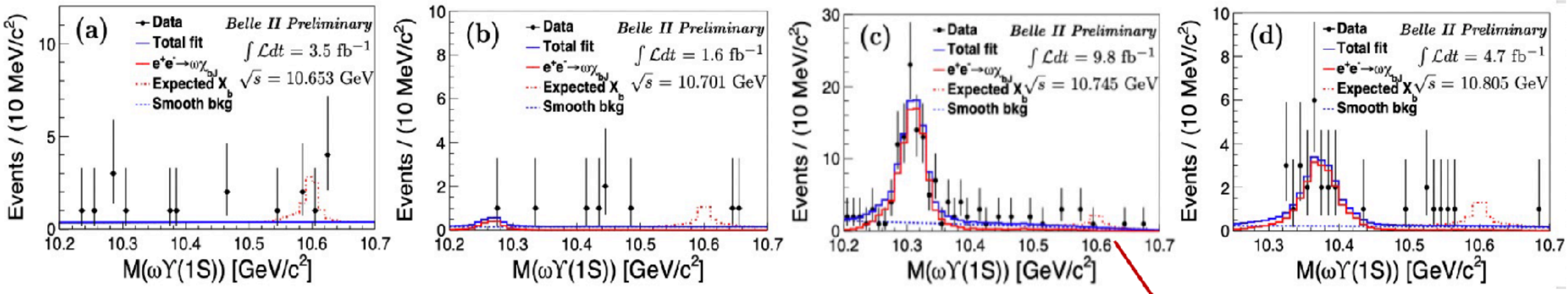




- $Y(4230) \to \gamma X(3872)$ and $Y(4230) \to \omega\chi_{c0}$ were observed by BESIII.
  - Expect the $\Upsilon(10753)$ state to decay into $X_b\gamma$.
  - Should be more easily to be found in $\omega\Upsilon(1S)$ than $\pi\pi\Upsilon(1S)$ *[Eur.Phys.J.C 74 (2014) 9, 3063]*

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.

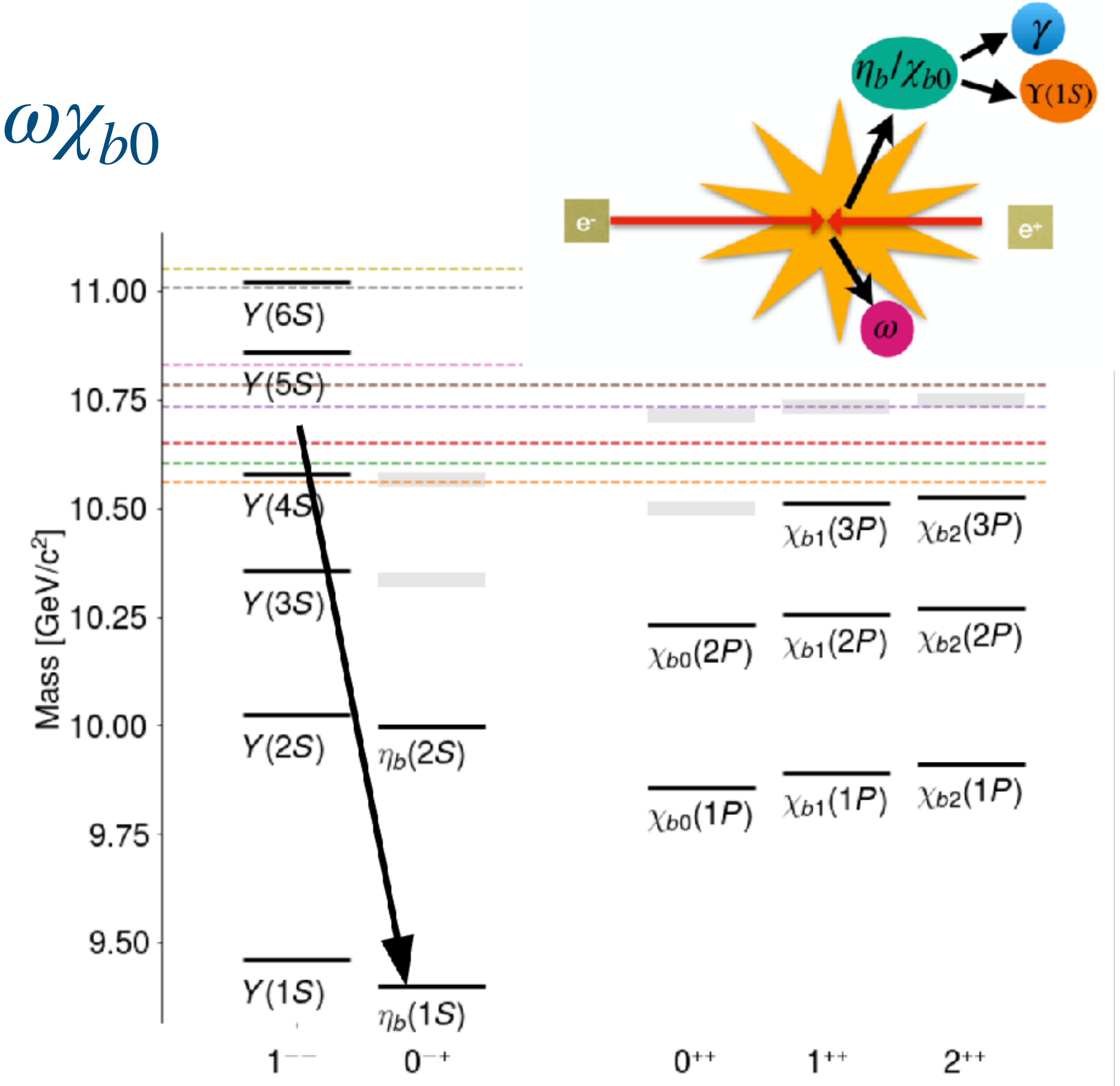
- No significant X_b signal is observed.
- The peaks are the reflections of $e^+e^- \to \omega\chi_{bJ}$.

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)

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	-



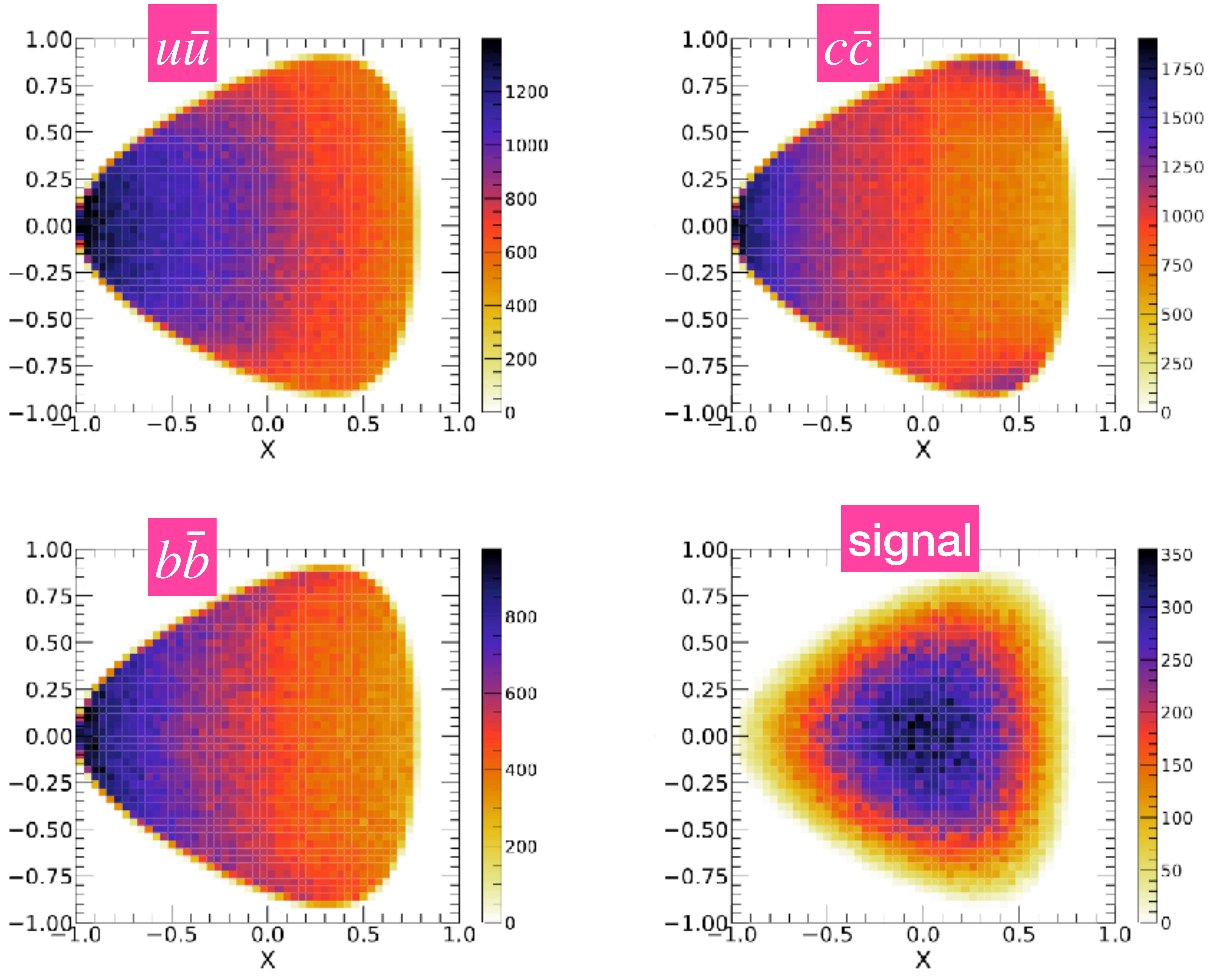
Strategy:

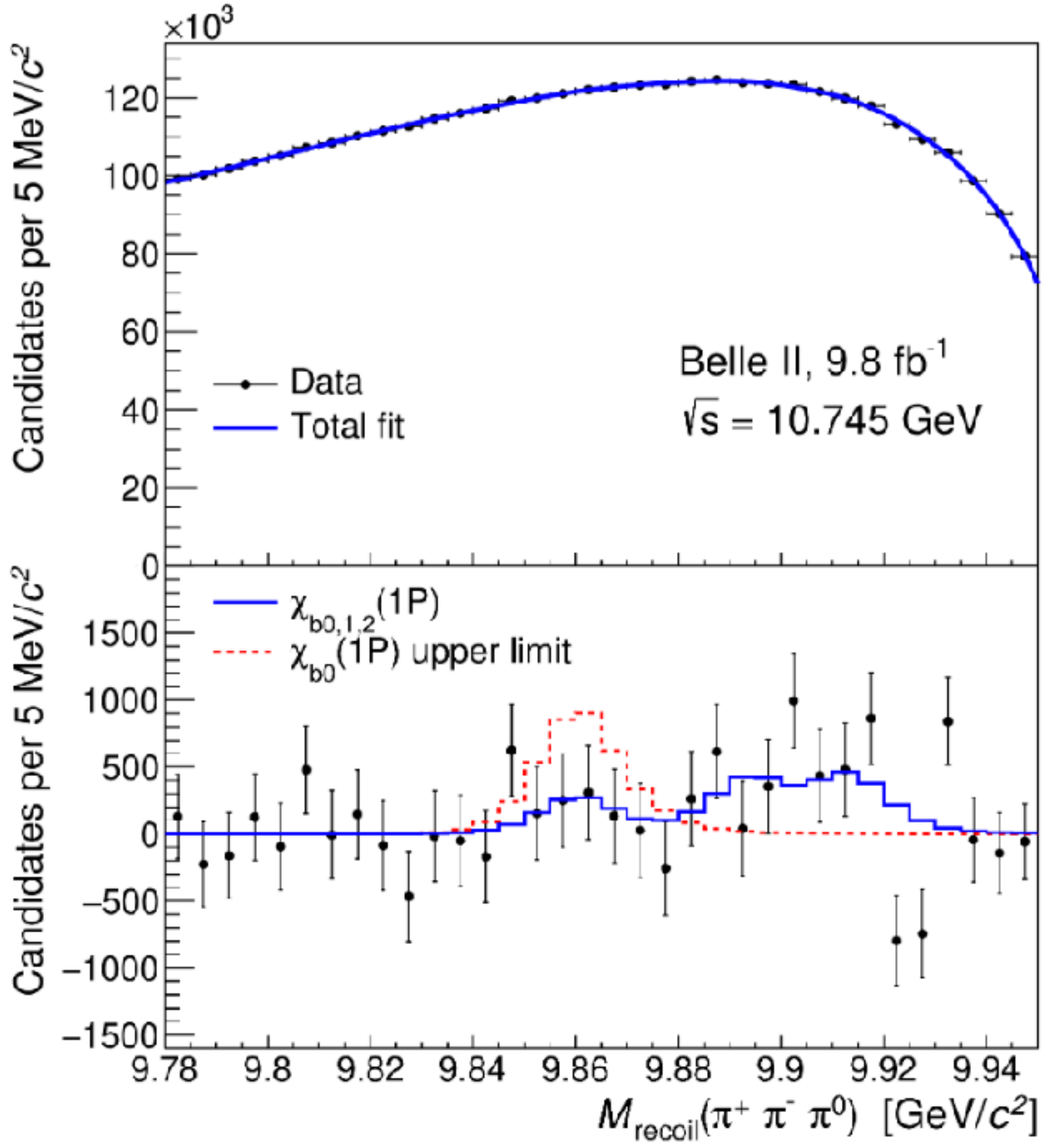
→ Reconstruct ω

→ Measure its recoil mass

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

Suppress background with ω-Dalitz plot.

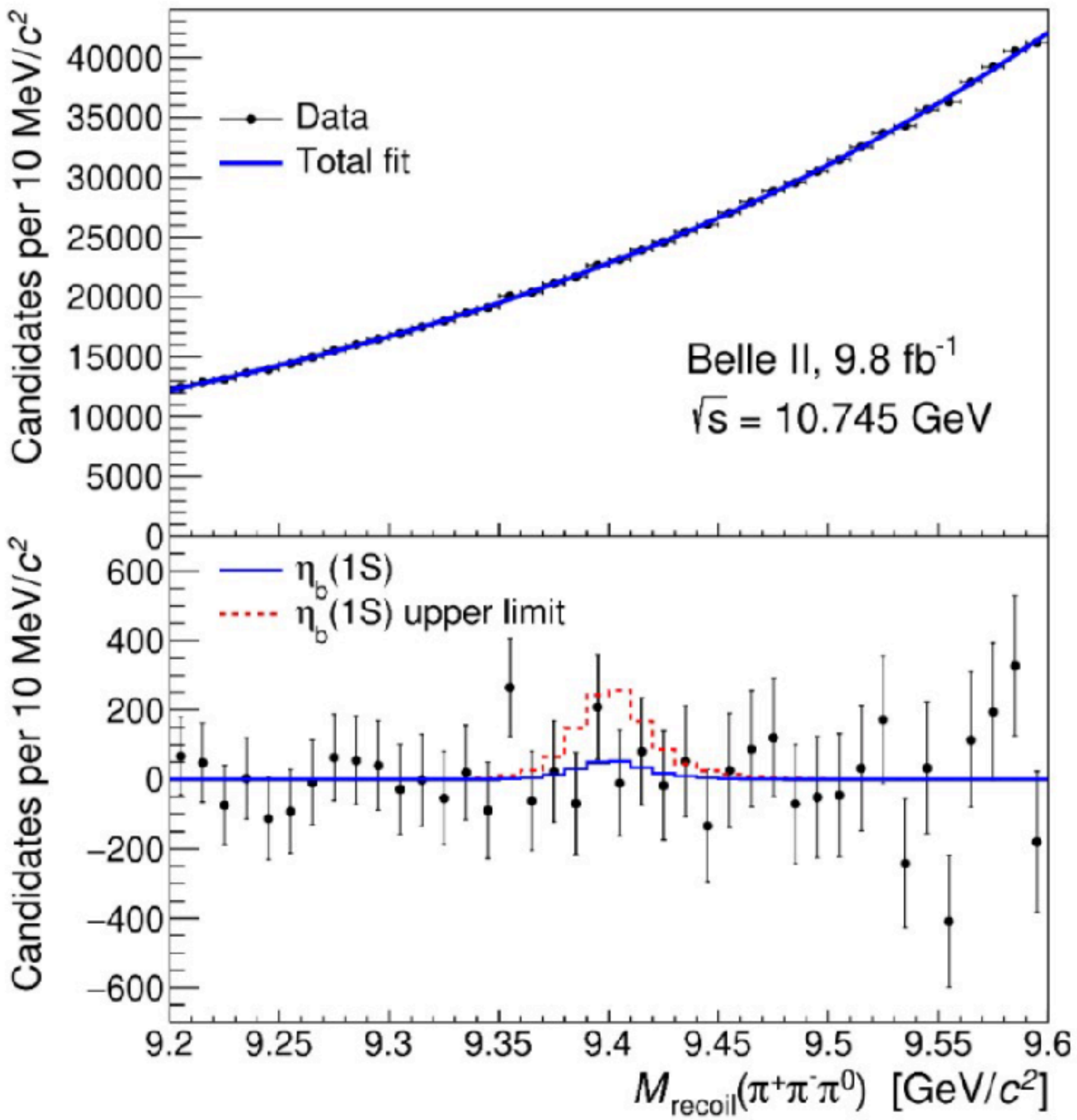




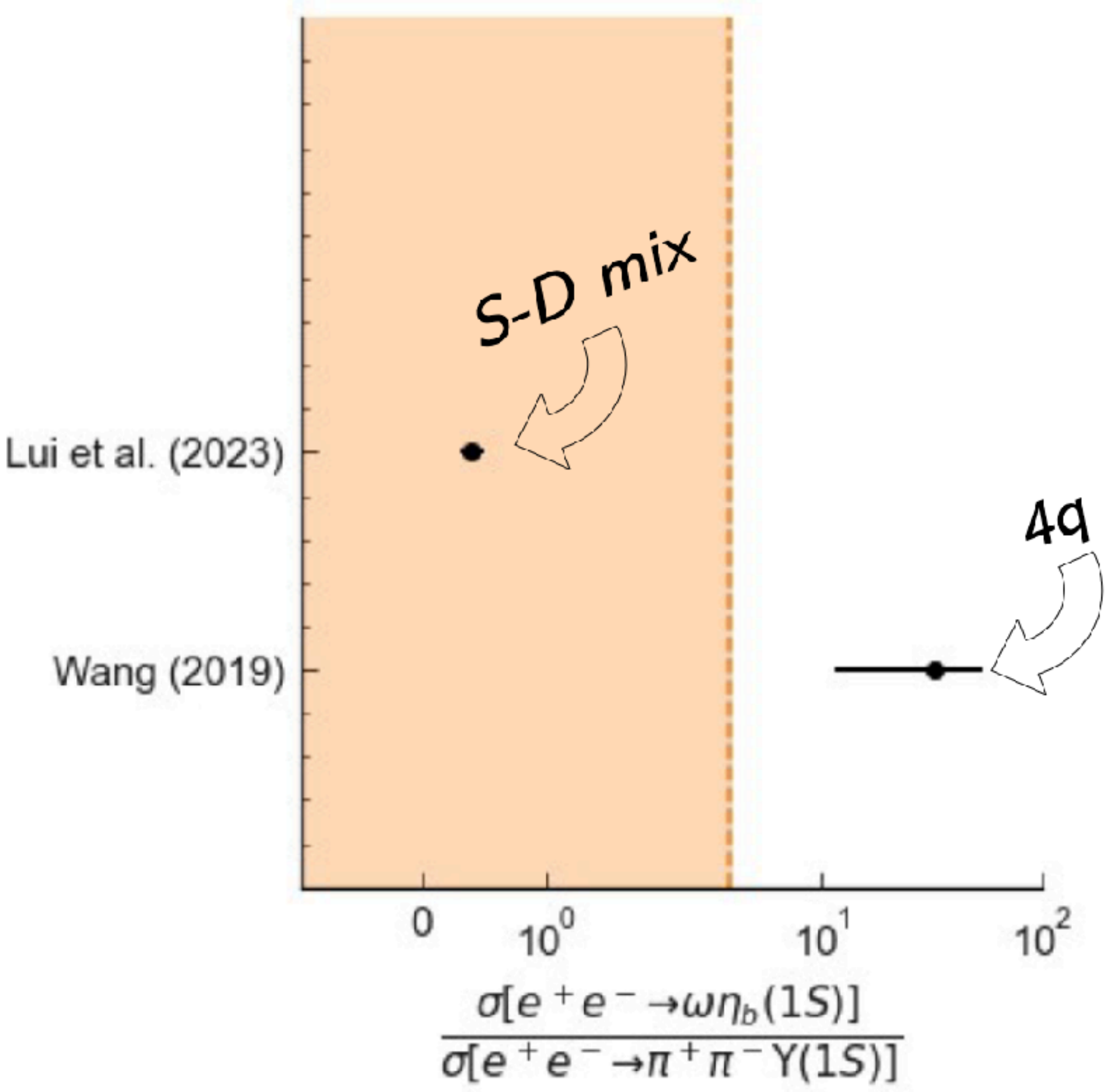
Signal yields: $(1.2 \pm 1.4 \pm 0.9) \times 10^3$ ==> $\sigma_{\text{Born}} = (2.6 \pm 3.1 \pm 2.0)$ pb

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

[arxiv:2312.13043]



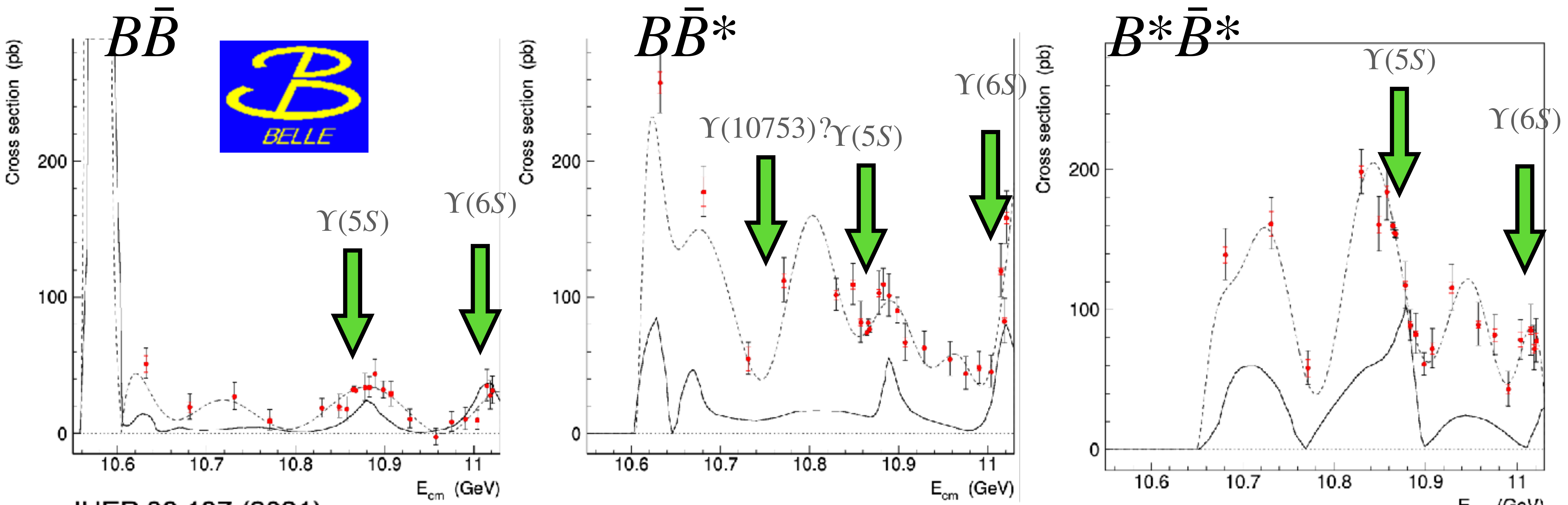
Compatible with S-D mixed



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

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

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



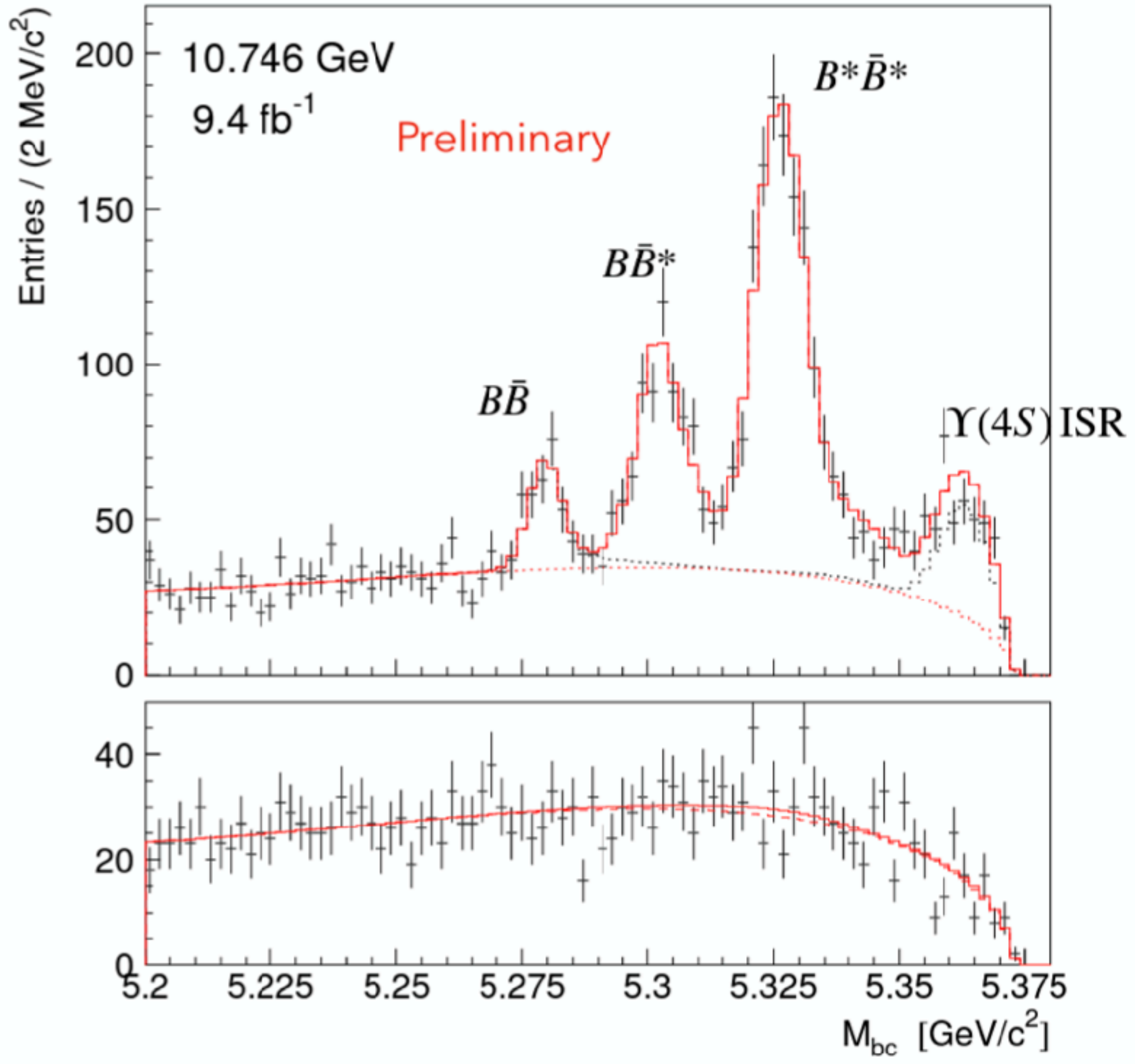
JHEP 06,137 (2021)

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

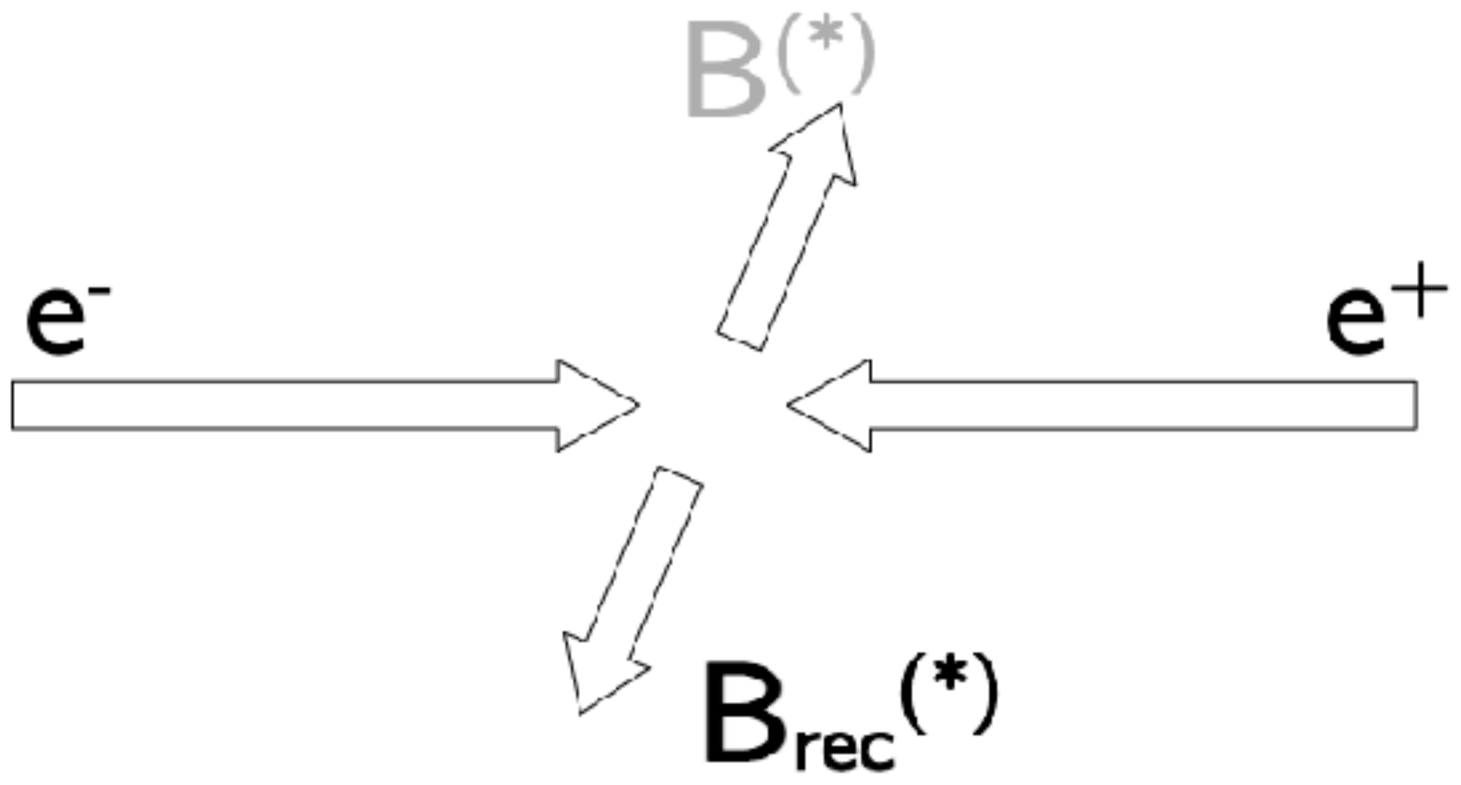
- Need more data to fill the gaps.

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

Update the measurements with Belle II energy scan data



arXiv: 2104.08371

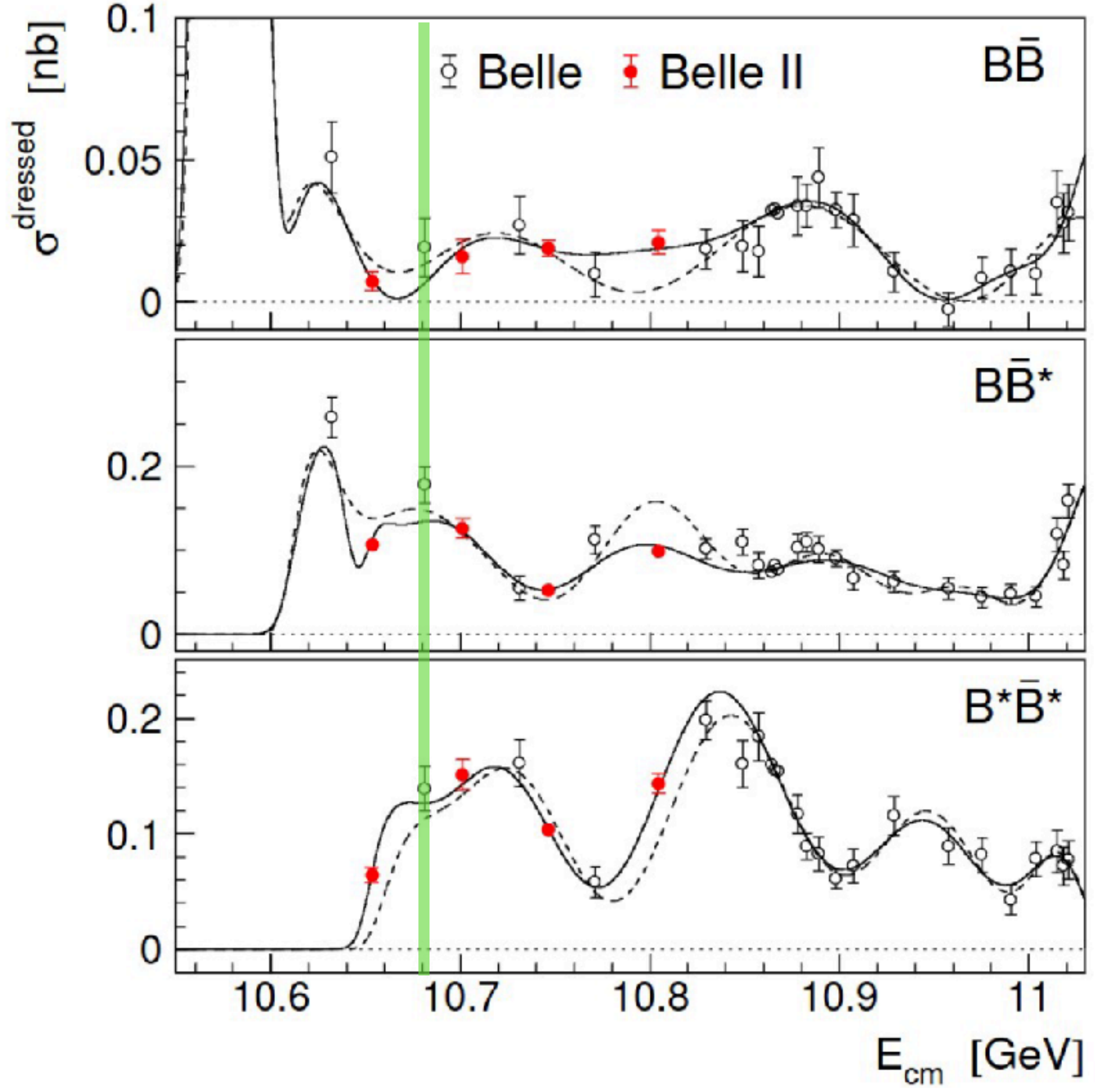


- Reconstruct B_{rec} with FEI
  - 16 channels
  - Ignore γ from $B^* \to B$
- Yield signals from simultaneous fit to M_{bc} (SR and SB)

Prominent features:

- → Sharp rise in B^*B^*
  - → first point only ~2 MeV above $B^{0*}B^{0*}$ threshold
  - → Indication of bound state?
- → Dip in B^*B at the B^*B^* threshold

arXiv: 2104.08371 [Belle II Preliminary]

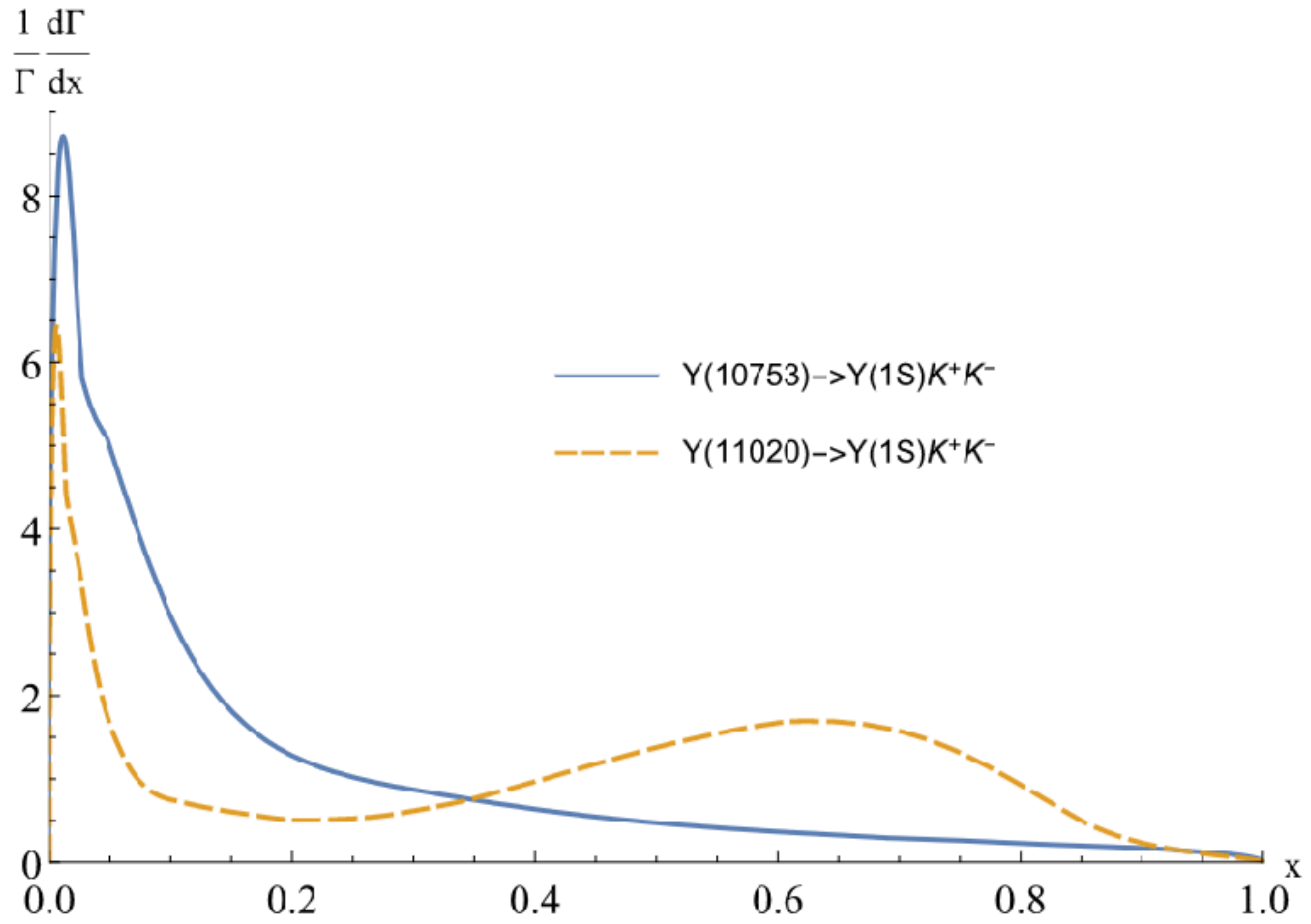


To verify the existence of a $B^*\bar{B}^*$ bound state near the threshold, a detailed scan must be performed in this energy region.

Summary

- Unique data in Belle II leads to unique results!
- More analyses are ongoing
  - $\Upsilon(10753) \to K^+K^-\Upsilon(nS)$
  - $\Upsilon(10753) \to \eta(\eta')\Upsilon(nS)$
  - $\Upsilon(10753) \to \gamma X_b,\ X_b \to \pi\pi\chi_{bJ}, \pi\pi\Upsilon(nS)$
  - etc…
- Belle II has collected 424/fb data, including ~380/fb $\Upsilon(4S)$ data.
  - More results other than $\Upsilon(10753)$ will come out.
- Long shutdown has finished, will accumulate more data.
  - More data, more new results

BACK UP



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