Recent physics results from Belle II including $B^+ \to K^+\nu\bar{\nu}$

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Overview

- Quick intro. to Belle II

Part I *B decays*

- Test of LFU at Belle II
  - ✓ Exclusive $R(D^{(*)})$ — arXiv:2401.02840 *submitted to* PRD
  - ✓ Inclusive $R(X_{\tau/\ell})$ — arXiv:2311.07248 *submitted to* PRL
- $B^+ \to K^+ \nu \bar{\nu}$ — arXiv:2311.14647 PRD *accepted*

Part II *charm baryons*

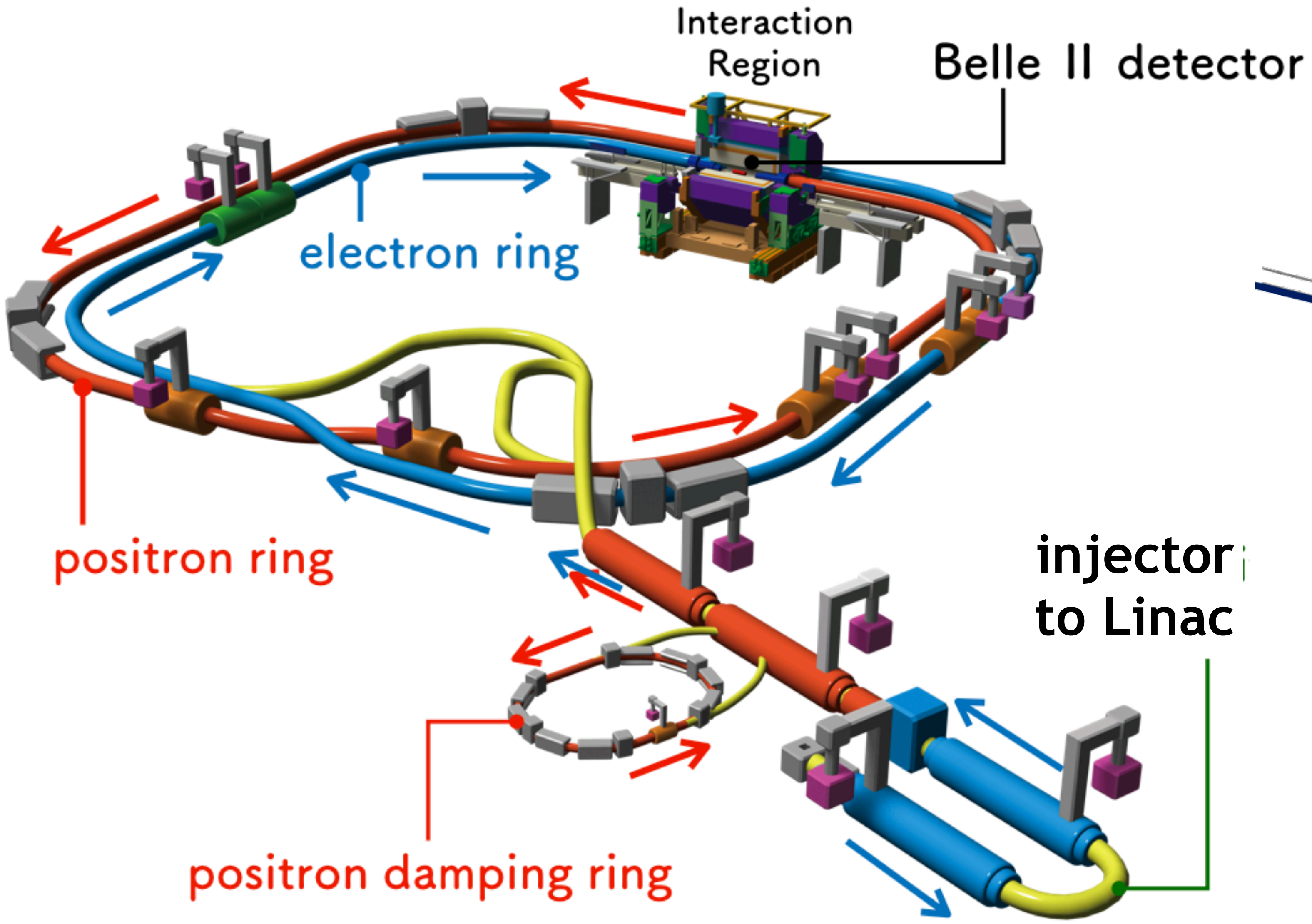
- $\Xi_c^0 \to \Xi^0 h^0 \ (h^0 = \pi^0, \eta, \eta')$ — in *preparation for* JHEP

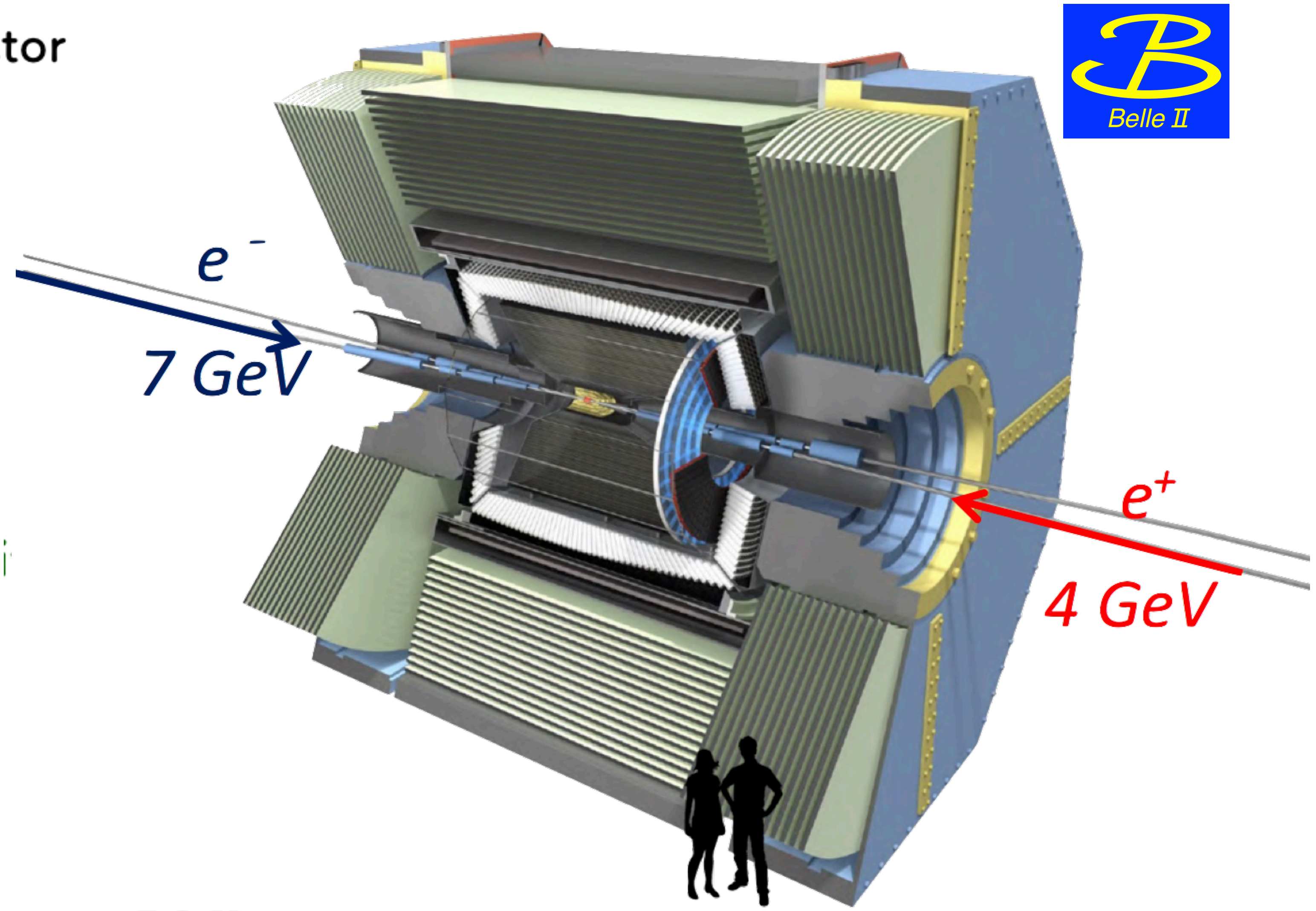
Part III *Energy scan for bottomonia*

- new results on $\Upsilon(10753)$ — arXiv:2401.12021, JHEP *submitted*; arXiv:2312.13043, PRD *accepted*
- Closing

SuperKEKB

Belle II





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

$$\sqrt{s} = 10.58\text{ GeV} = m_{\Upsilon(4S)}c^2$$

We also have data taken off-resonance as well as energy scan around $\Upsilon(5S)$

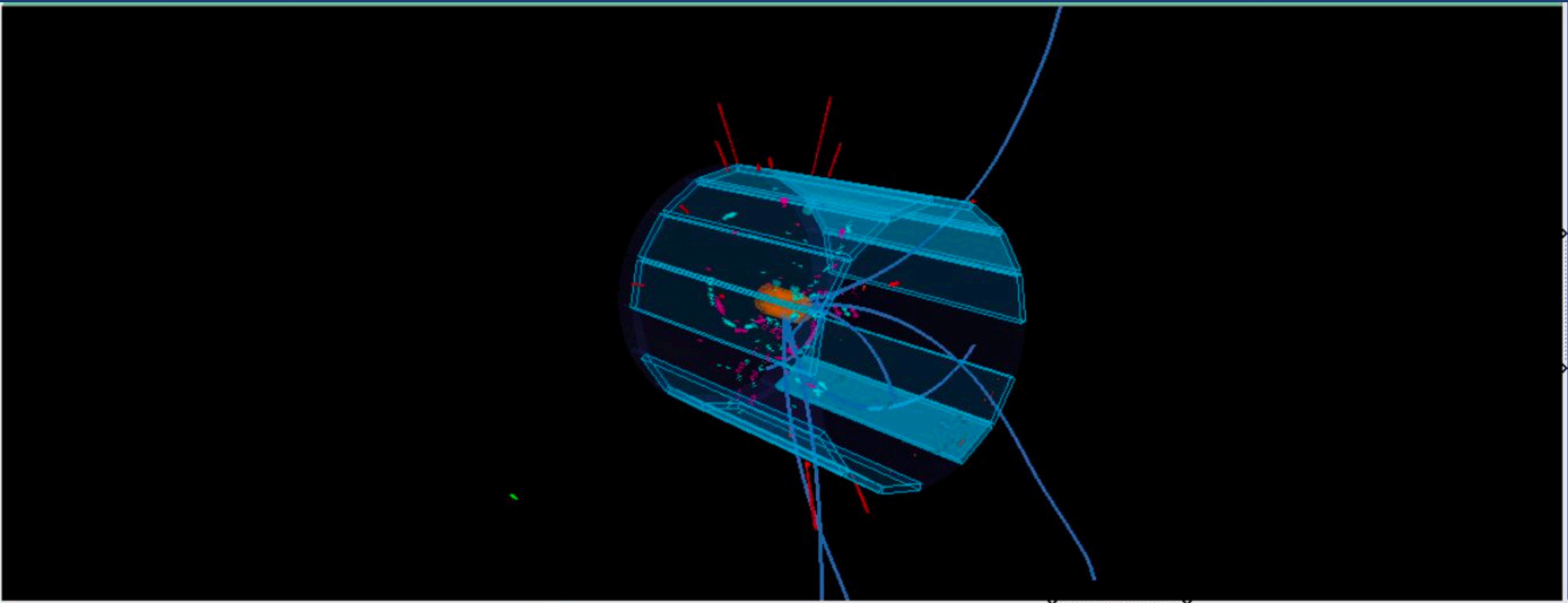
- $\mathcal{B}(\Upsilon(4S) \to B\bar{B}) > 96\%$, with $p_B^{CM} \sim 0.35$ GeV/c
- nothing else but $B\bar{B}$ in the final state

  $\therefore$ if we know $(E, \vec{p})$ of one B, the other B is also constrained

See Appendix, p.35-37.

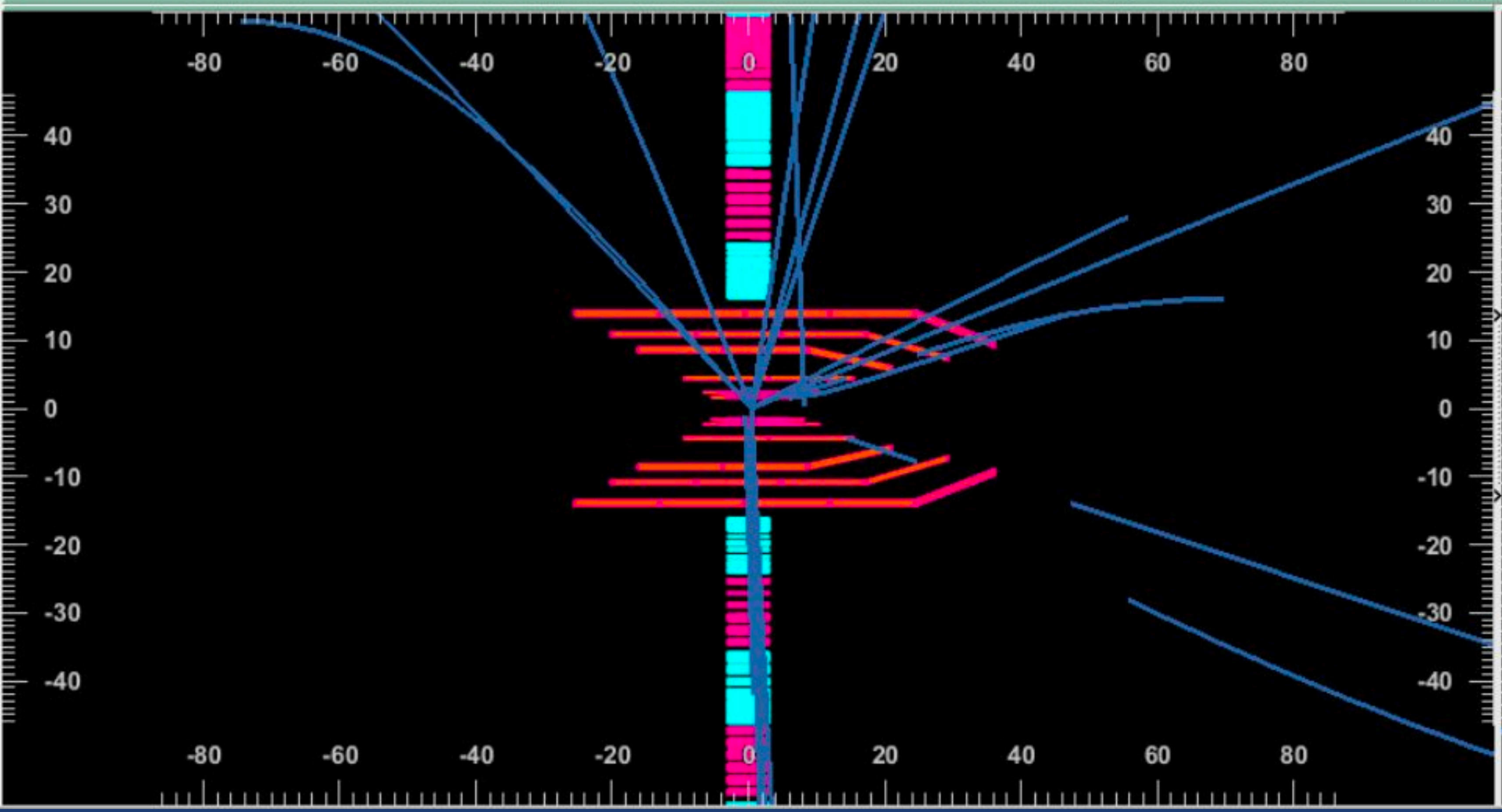
"B-tagging"

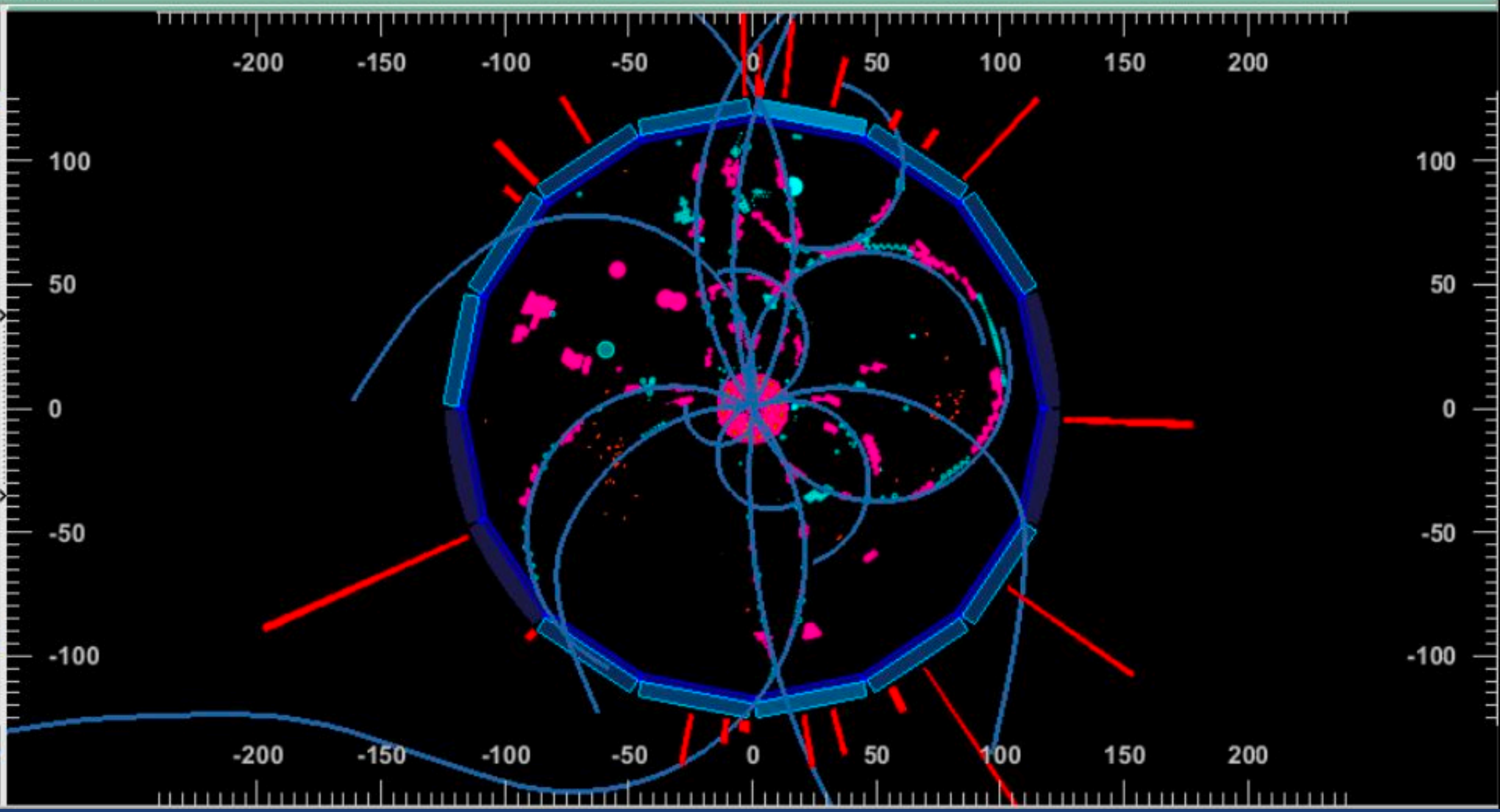
unique to e^+e^- B-factory

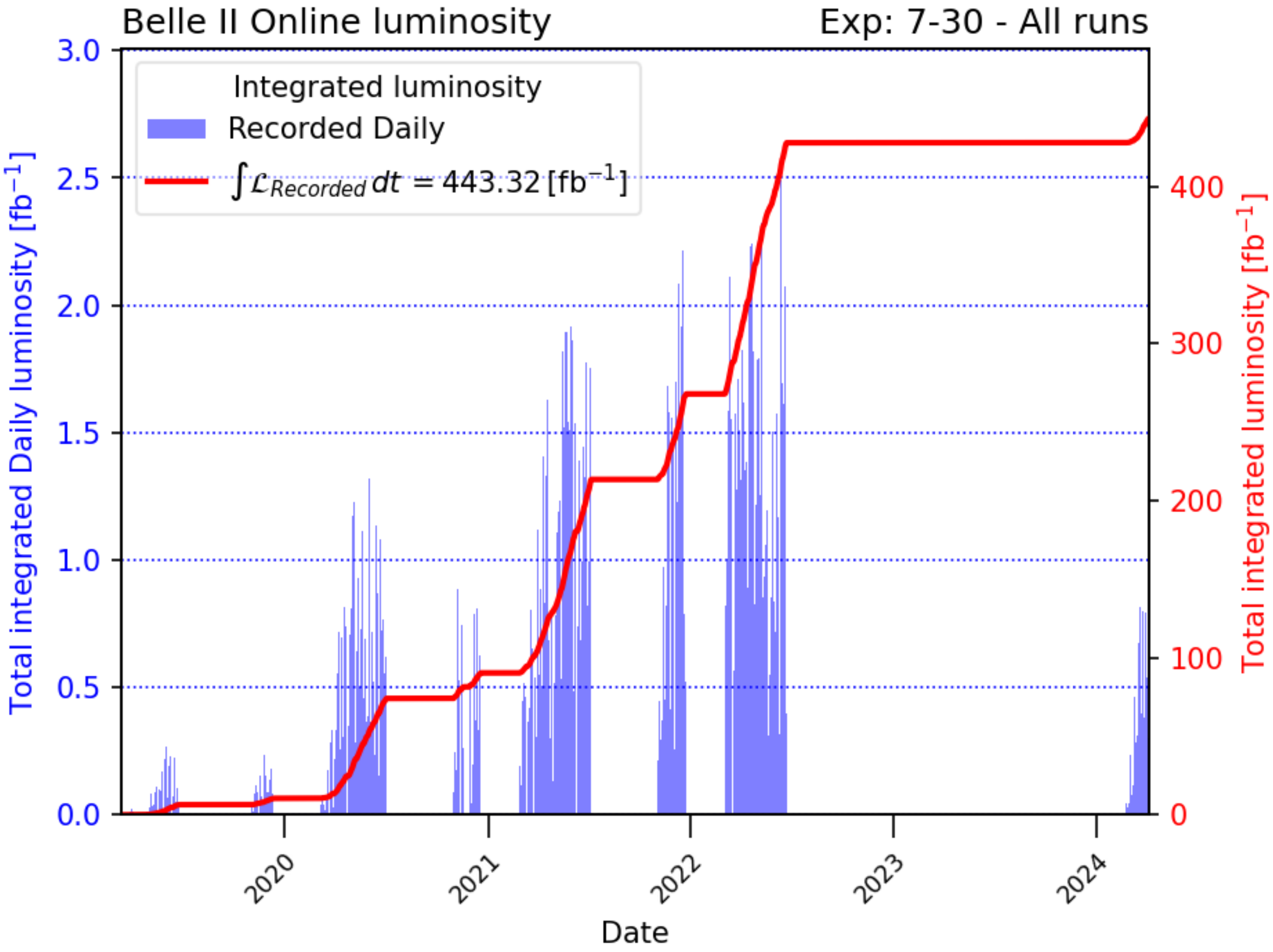


Belle II

First Collisions of Run 2
20th February 2024







Updated on 2024/04/04 06:07 JST

Belle (1999-2010)
Luminosity

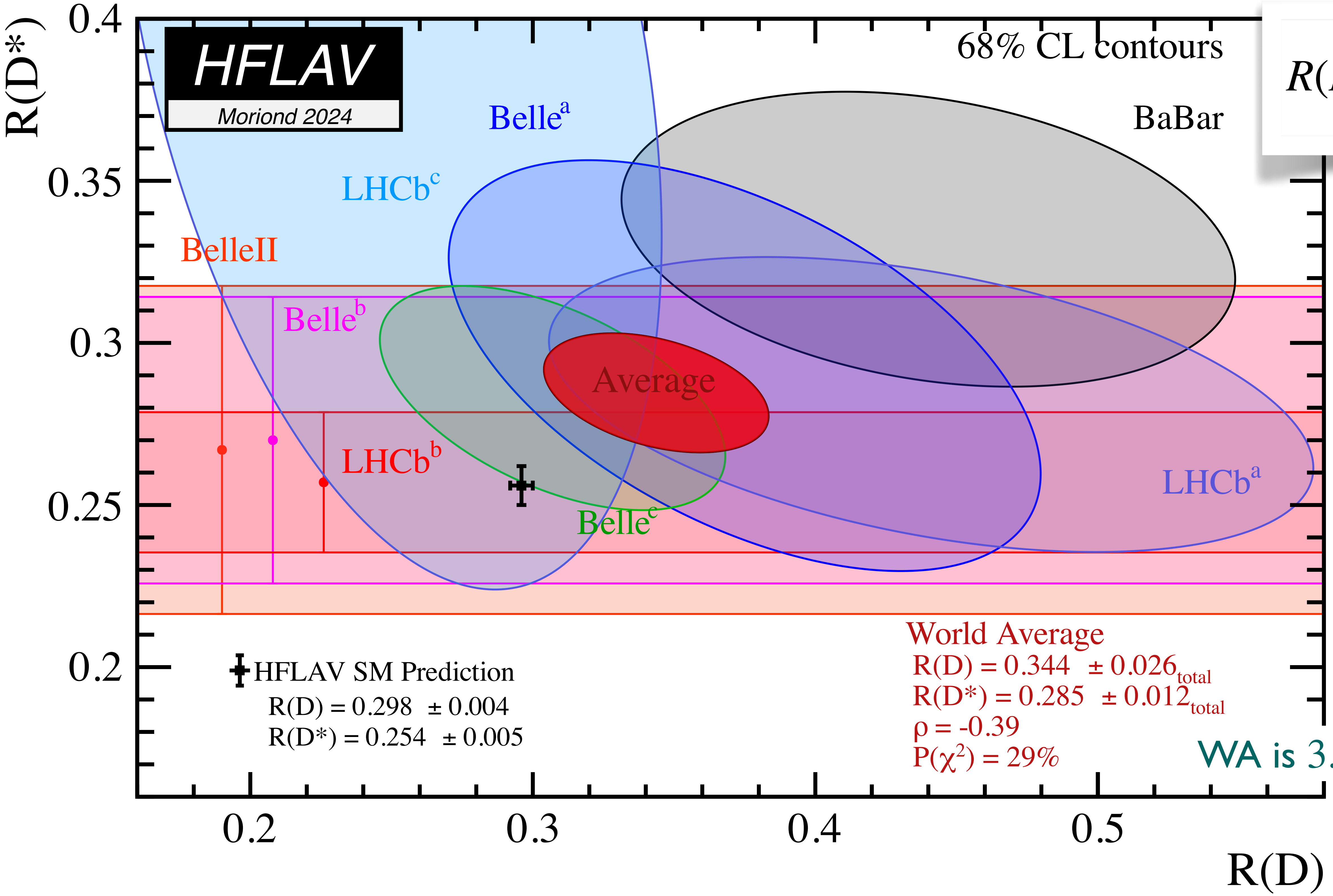
- $\int \mathscr{L}_{\text{total}} = 1039\ \text{fb}^{-1}$

  $980\ \text{fb}^{-1}$ for Ξ_c^0

- $\int \mathscr{L}_{\Upsilon(4S)} = 711\ \text{fb}^{-1}$

Part I *B decays*

LFU test via $R(D)$ vs. $R(D^*)$



$$R(D^*) \equiv \frac{\mathscr{B}(B \to D^*\tau^+\nu)}{\mathscr{B}(B \to D^*\ell^+\nu)}$$

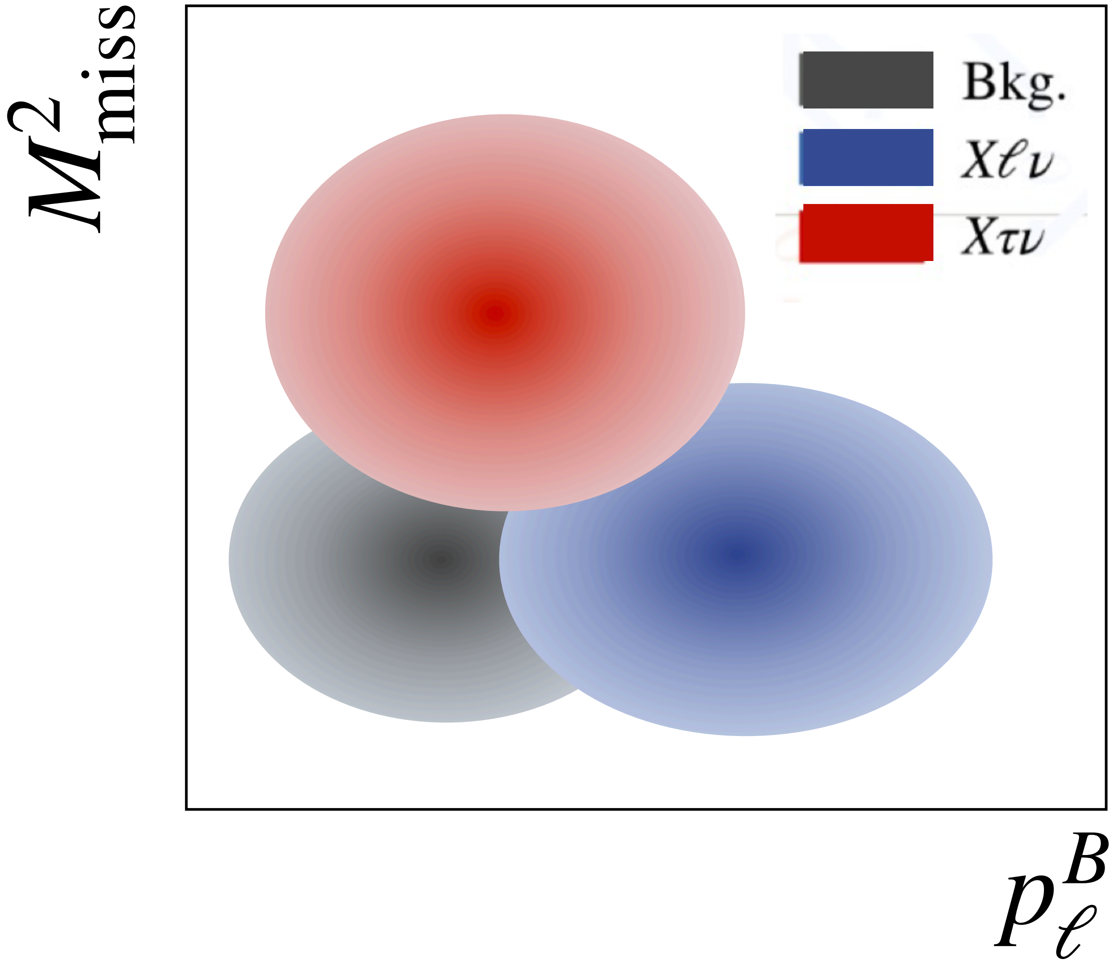
WA is 3.17σ from SM.

For details of the Belle II $R(D^*)$ measurement, see Appendix, p.38-40.

Inclusive LFU test w/ $R(X_{\tau/\ell})$

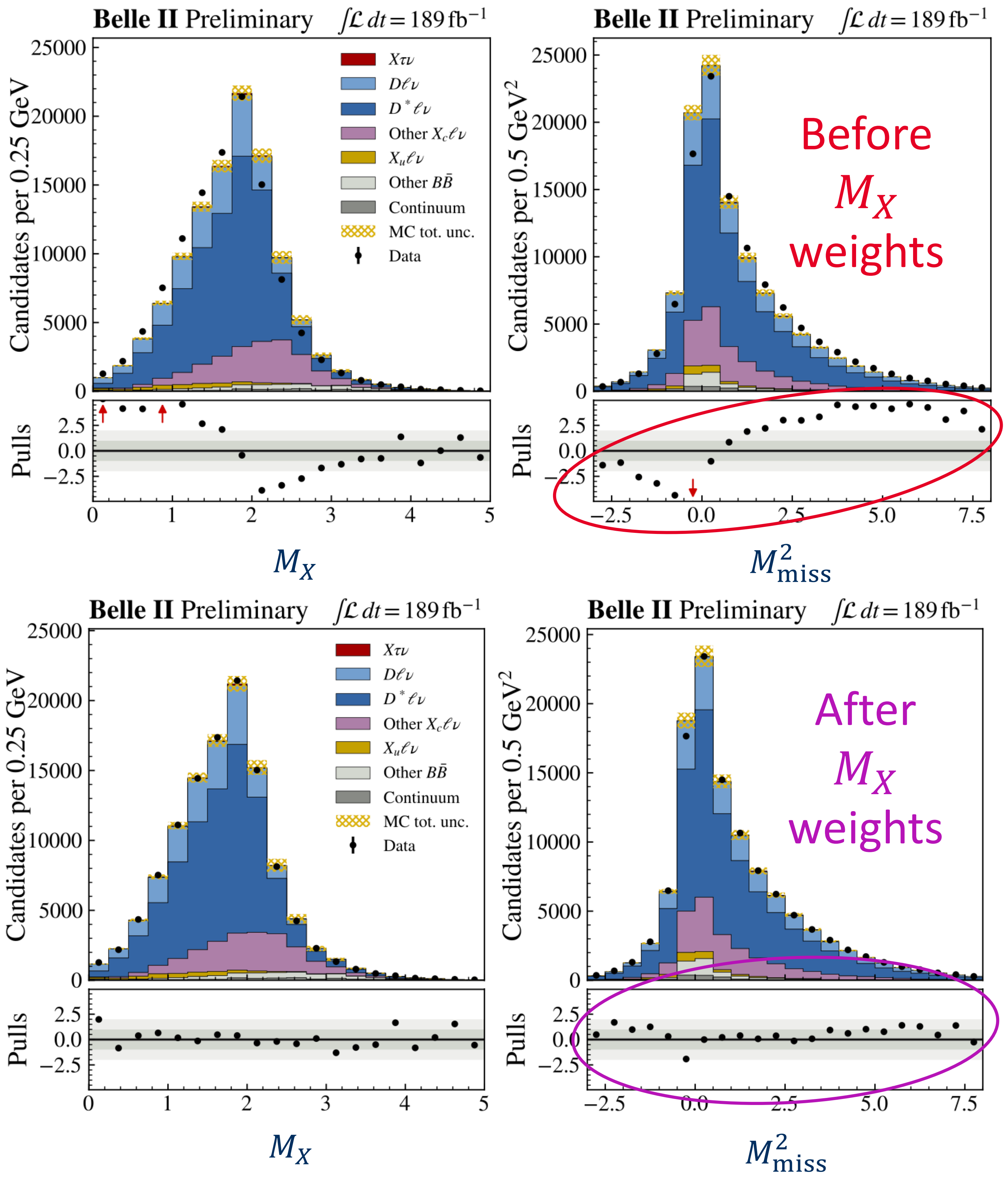
$$R(X_{\tau/\ell}) = \frac{\mathcal{B}(B \to X\tau\nu)}{\mathcal{B}(B \to X\ell\nu)}$$

- Why measure $R(X_{\tau/\ell})$?
  - different systematics from $R(D^{(*)})$
  - hence, a complementary test of LFU
- Procedure
  - use $\tau \to \ell\nu_\tau\bar{\nu}_\ell$ modes
  - select events with $B_{\text{tag}} + \ell$, with remaining particles attributed to X
  - distinguish signal from background by using M^2_{miss} and p^B_ℓ
  - background mostly from $b \to c \to \ell$; some continuum and fake leptons



arXiv:2311.07248
submitted to PRL

$R(X_{\tau/\ell})$, event distributions



- for reliable template shapes for fitting
  - make detailed adjustments to MC (FF's, B and D BF's)
  - corrections by comparing MC to data in control region: low q^2, low M^2_{miss}, high M_X
  - e.g. adjust M_X in $p_\ell > 1.4$ GeV sideband; using these weights also improves modeling in M^2_{miss} and q^2

Main sources of systematic uncertainty:

MC stat	± 5.7 %
Bkg shape	± 5.5 %
M_X modeling	± 7.1 %
$B \to X_c \ell\nu$ BFs	± 7.7 %
$B \to X_c \ell\nu$ FFs	± 7.9 %

arXiv:2311.07248
submitted to PRL

$R(X_{\tau/\ell})$ Results

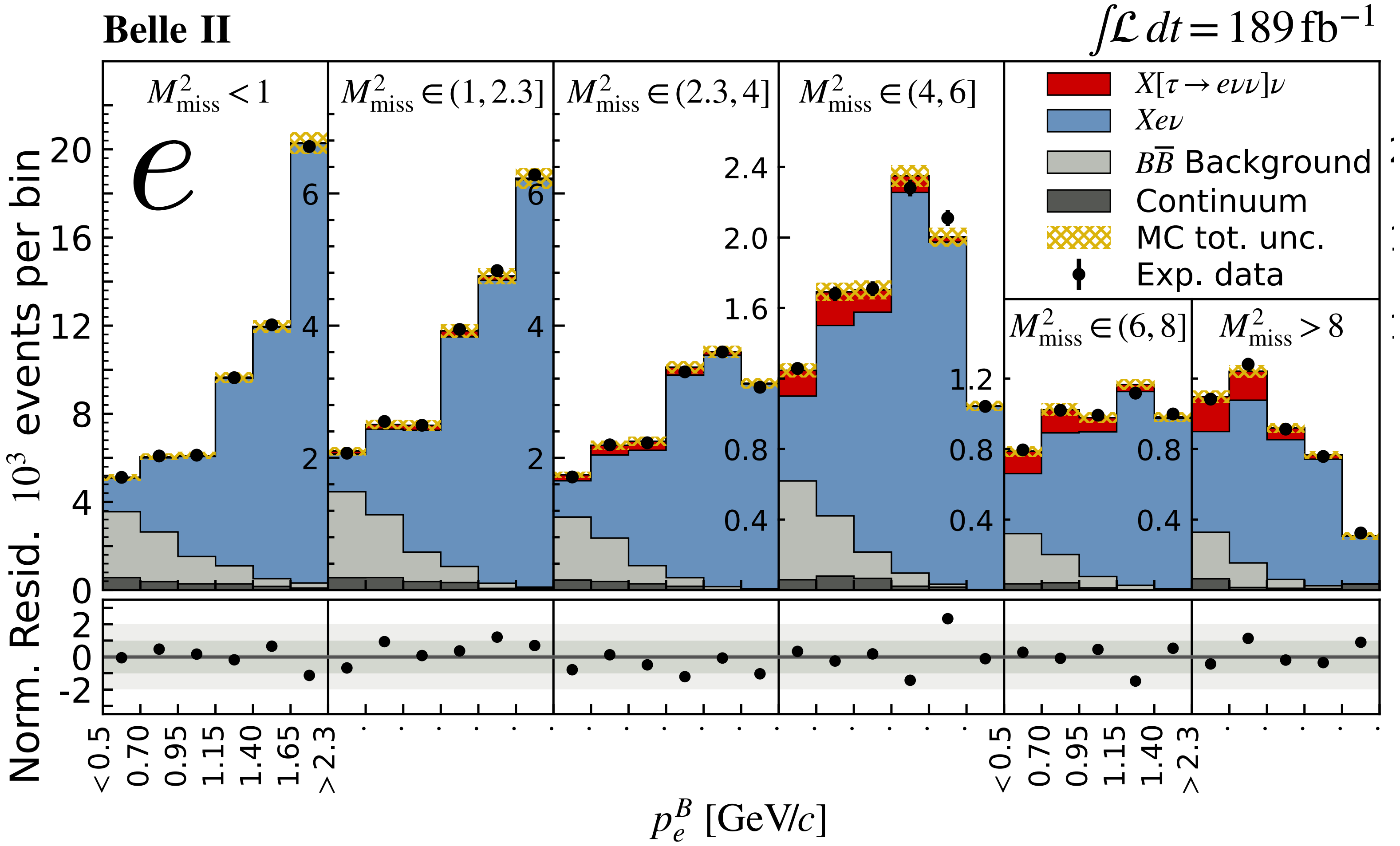
$$R(X_{\tau/\ell}) = 0.228 \pm 0.016 \pm 0.036$$

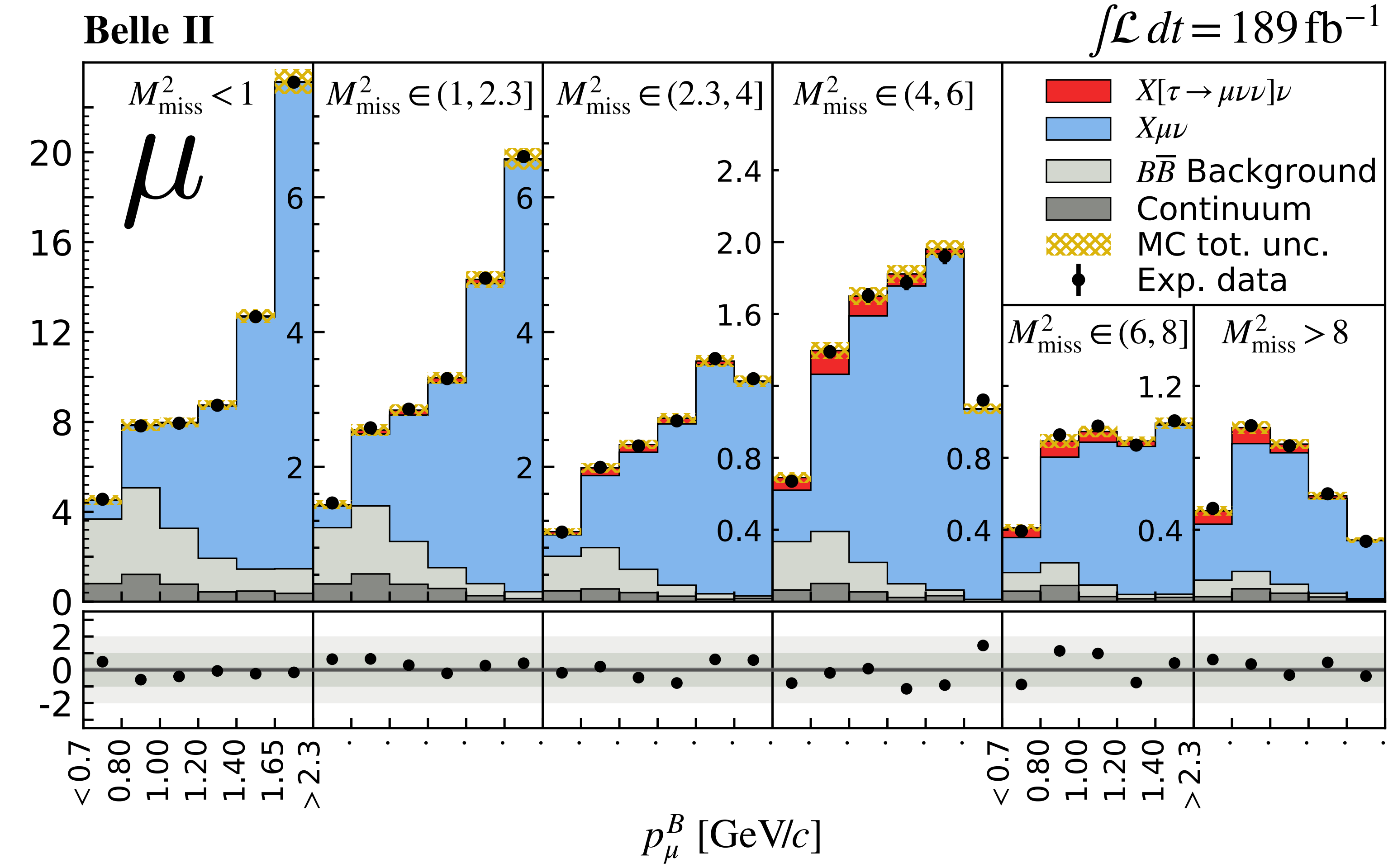
$$R(X_{\tau/e}) = 0.232 \pm 0.020 \pm 0.037$$

$$R(X_{\tau/\mu}) = 0.222 \pm 0.027 \pm 0.050$$

Consistent with SM: 0.223 ± 0.005

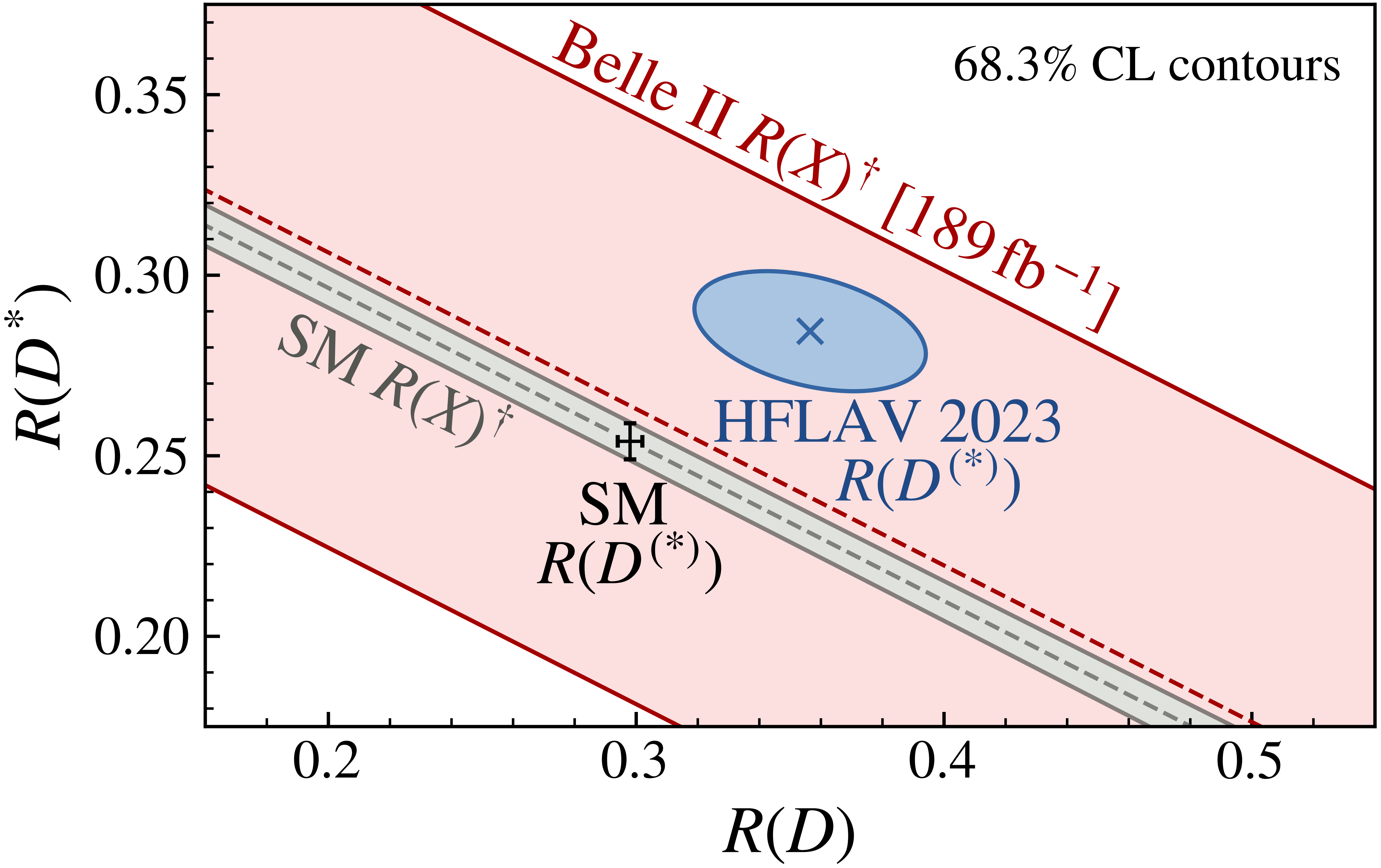
M. Freytsis et al. PRD 92, 054018 (2015)
M. Rahimi, K. K. Vos, JHEP 2022, 7 (2022)
Z. Ligeti et al. PRD 105, 073009 (2022)





$R(X_{\tau/\ell})$, compared with $R(D^{(*)})$

$\dagger$ = with expected SM contributions of $D^{**}_{\text{(gap)}}, X_u$ removed

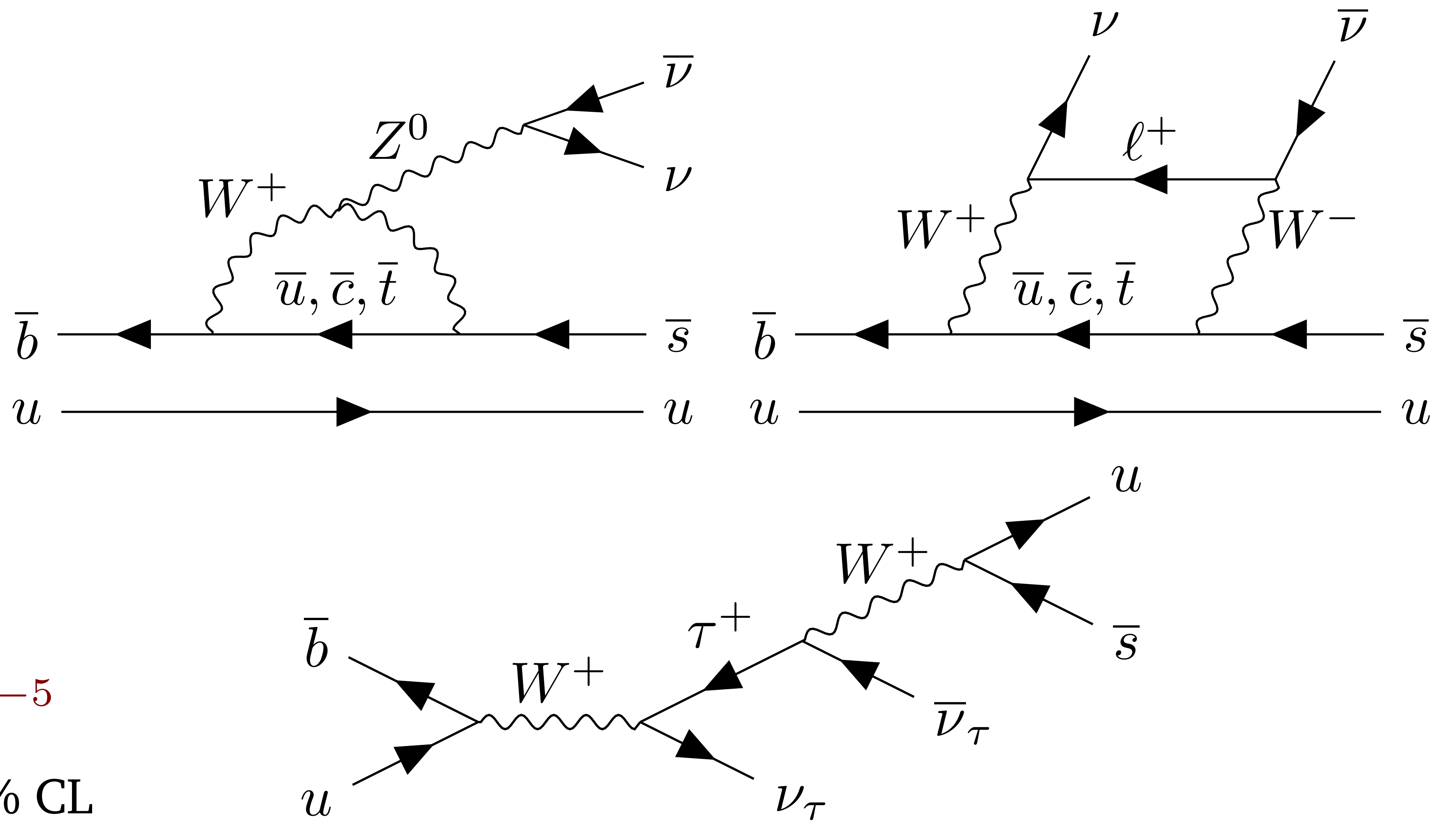


Search for $B^+ \to K^+\nu\bar{\nu}$ at Belle II

- In the SM,
  - $\mathscr{B}(B^+ \to K^+\nu\bar{\nu}) = (5.58 \pm 0.37) \times 10^{-6}$ [4]

[4] W. G. Parrott et al. PRD 107, 014511 (2023)
incl. long-distance contribution from $B \to \tau\nu$)

- sensitive to new physics BSM, e.g.
  - leptoquarks,
  - axions,
  - DM particles, etc.

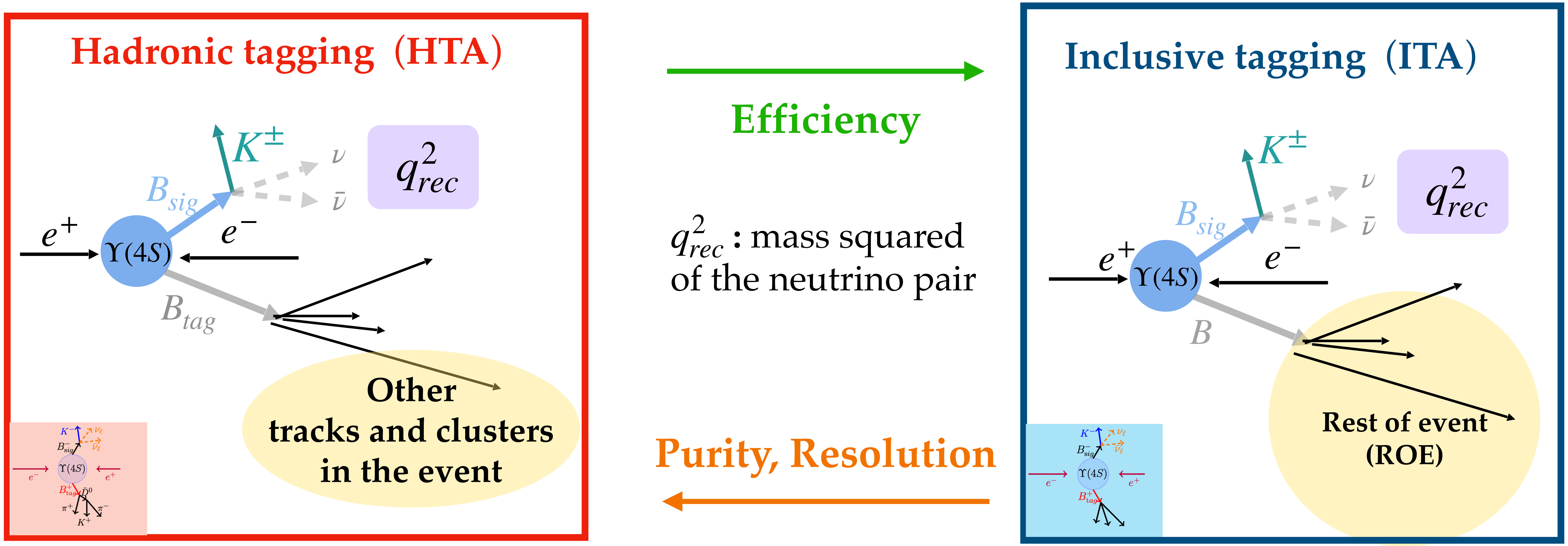


PRL 127, 181802 (2021)

$$\mathcal{B}(B^+ \to K^+\nu\bar{\nu}) = (1.9^{+1.3+0.8}_{-1.3-0.7}) \times 10^{-5}$$

$$< 4.1 \times 10^{-5}$$ @ 90% CL

Two ways of tagging



q^2_{rec} : mass squared of the neutrino pair

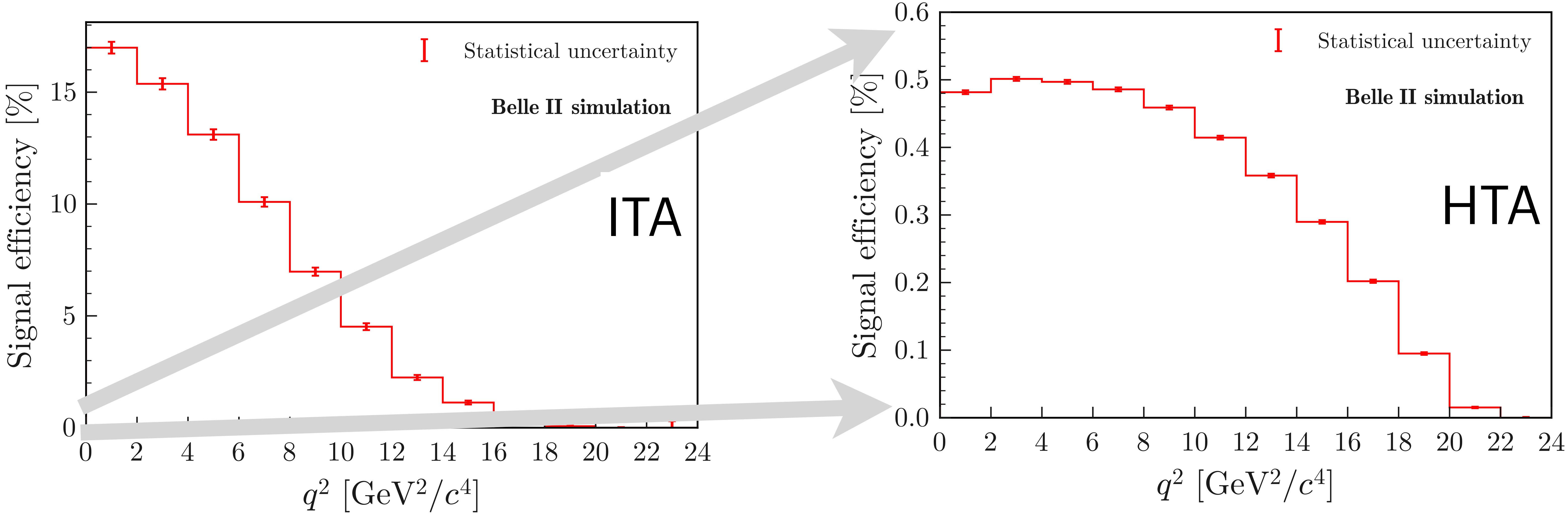
- Features of HTA
  - uses full decay chain information of of B_{tag}
  - high high purity, very low efficiency
  - uses BDT for signal extraction ($\mathrm{BDT_h}$)
- Features of ITA
  - exploits inclusive properties of B_{tag}
  - high efficiency, low purity
  - BDTs in two stages ($\mathrm{BDT_1}$ mostly for $q\bar{q}$; $\mathrm{BDT_2}$ for final signal extraction)

arXiv:2311.14647
PRD *accepted*

Signal efficiency (ITA vs. HTA)

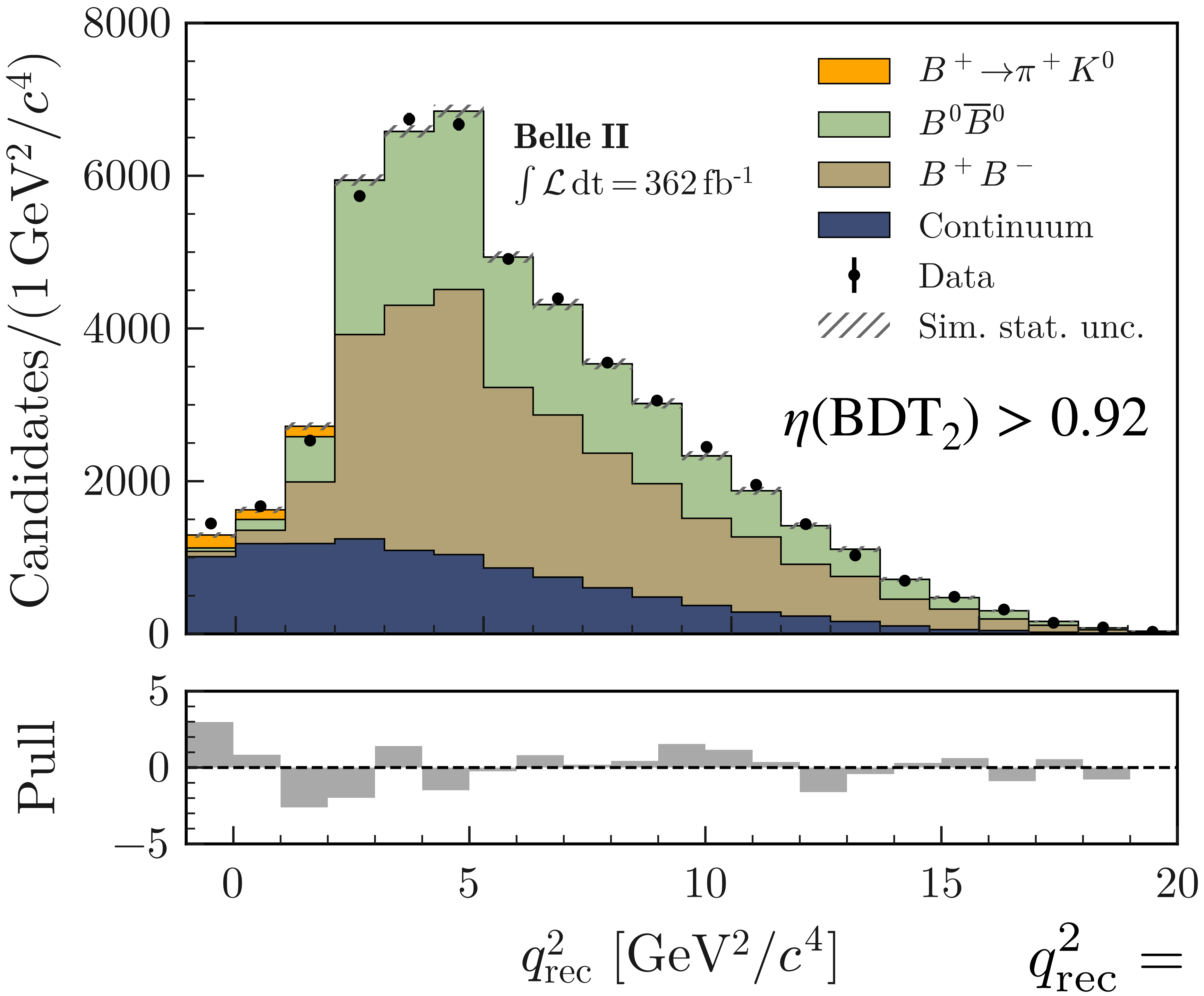
after multi-variate analysis for ROE with BDT

for BDT efficiency validation,
see p. 42 in the Appendix



$$q^2 = M(\nu\bar{\nu})^2$$

Closure test (ITA)



- Pion ID instead of kaon ID
- Different q^2_{rec} bin boundaries
- Only on-resonance data used for fit
- Only normalization systematics included

Result:

- $\mathscr{B}(B^+ \to \pi^+ K^0) = (2.5 \pm 0.5) \times 10^{-5}$

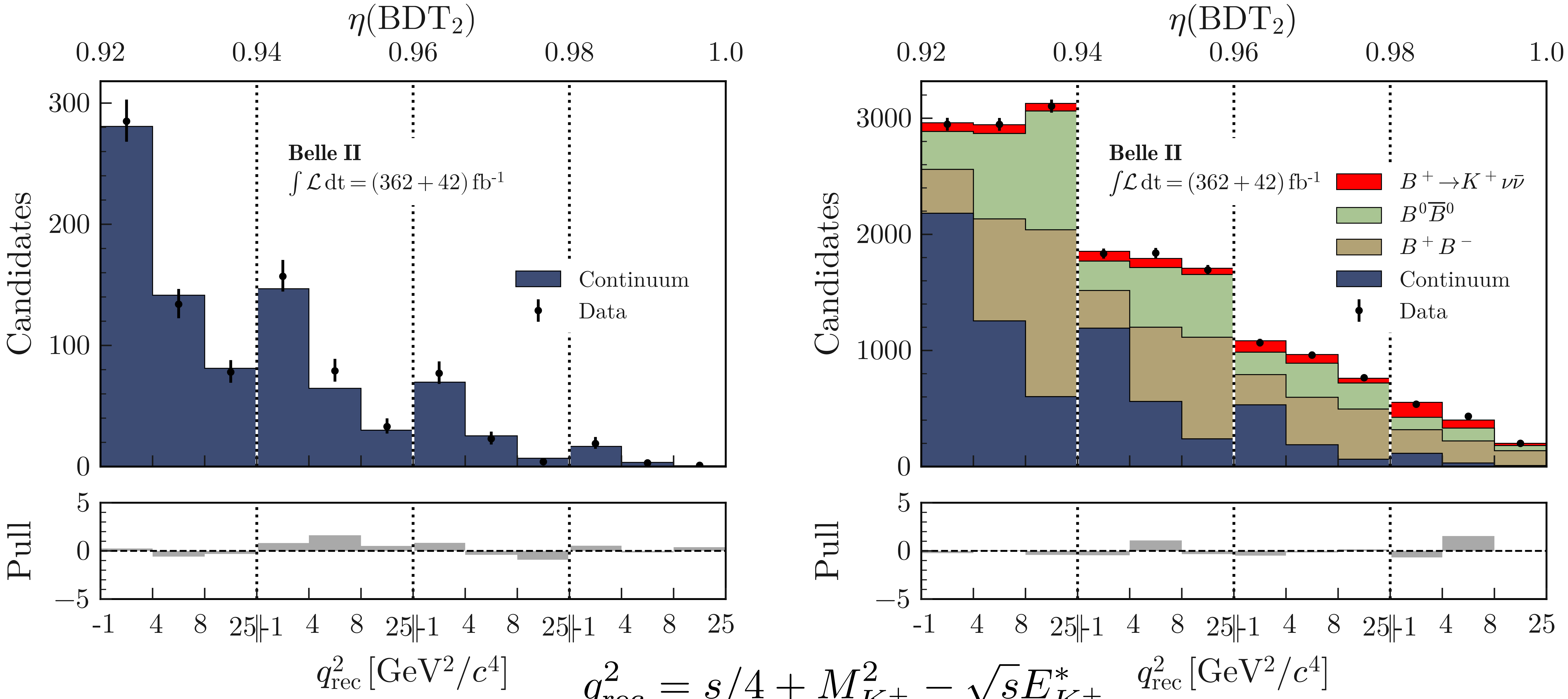
Consistent with PDG:

$\mathscr{B}(B^+ \to \pi^+ K^0) = (2.3 \pm 0.08) \times 10^{-5}$

$$q^2_{\mathrm{rec}} = s/4 + M^2_{\pi^+} - \sqrt{s}E^*_{\pi^+}$$

Assume B is at rest in the $\Upsilon(4S)$ rest-frame ($c = 1$)

$B^+ \to K^+\nu\bar{\nu}$ result (ITA)

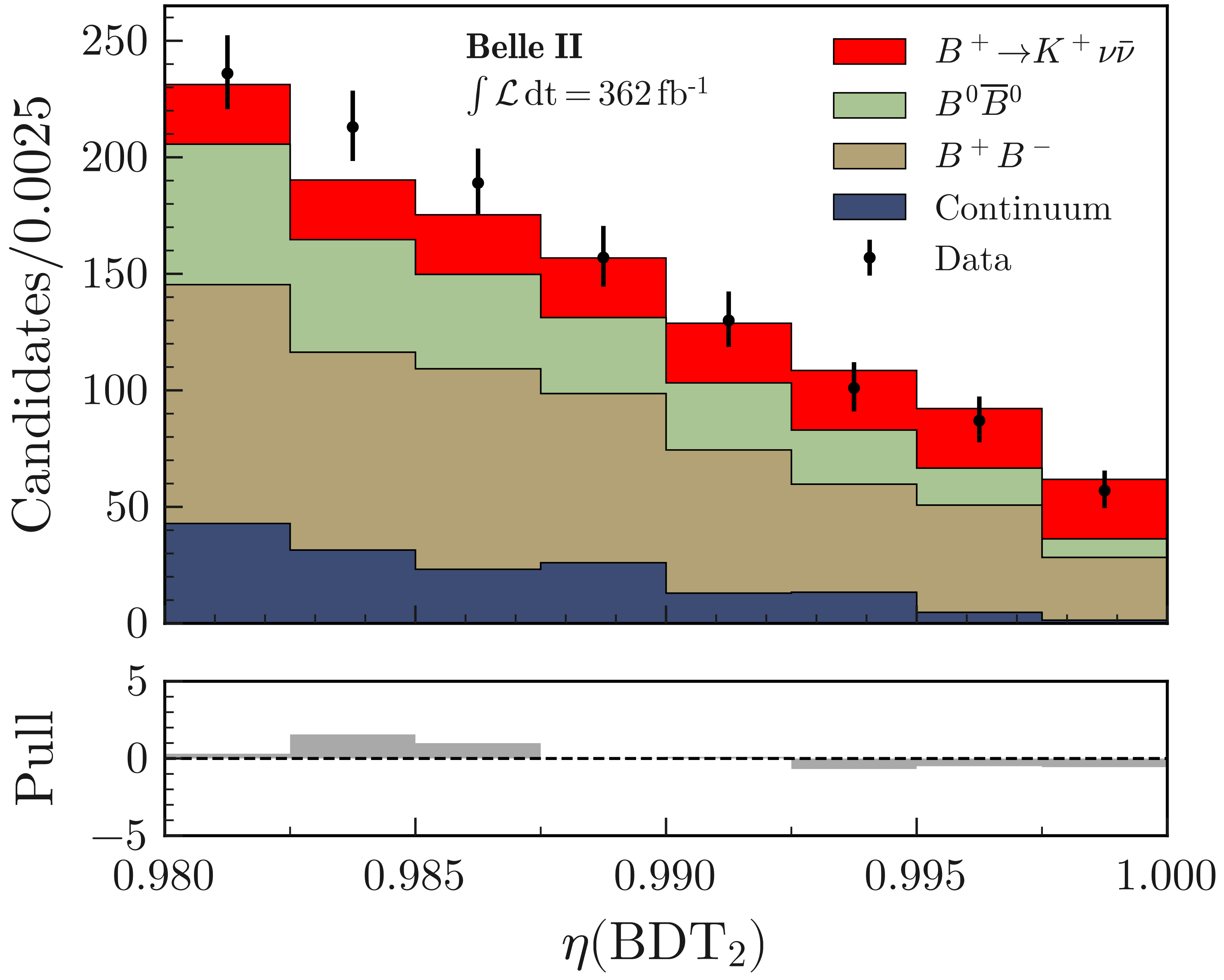


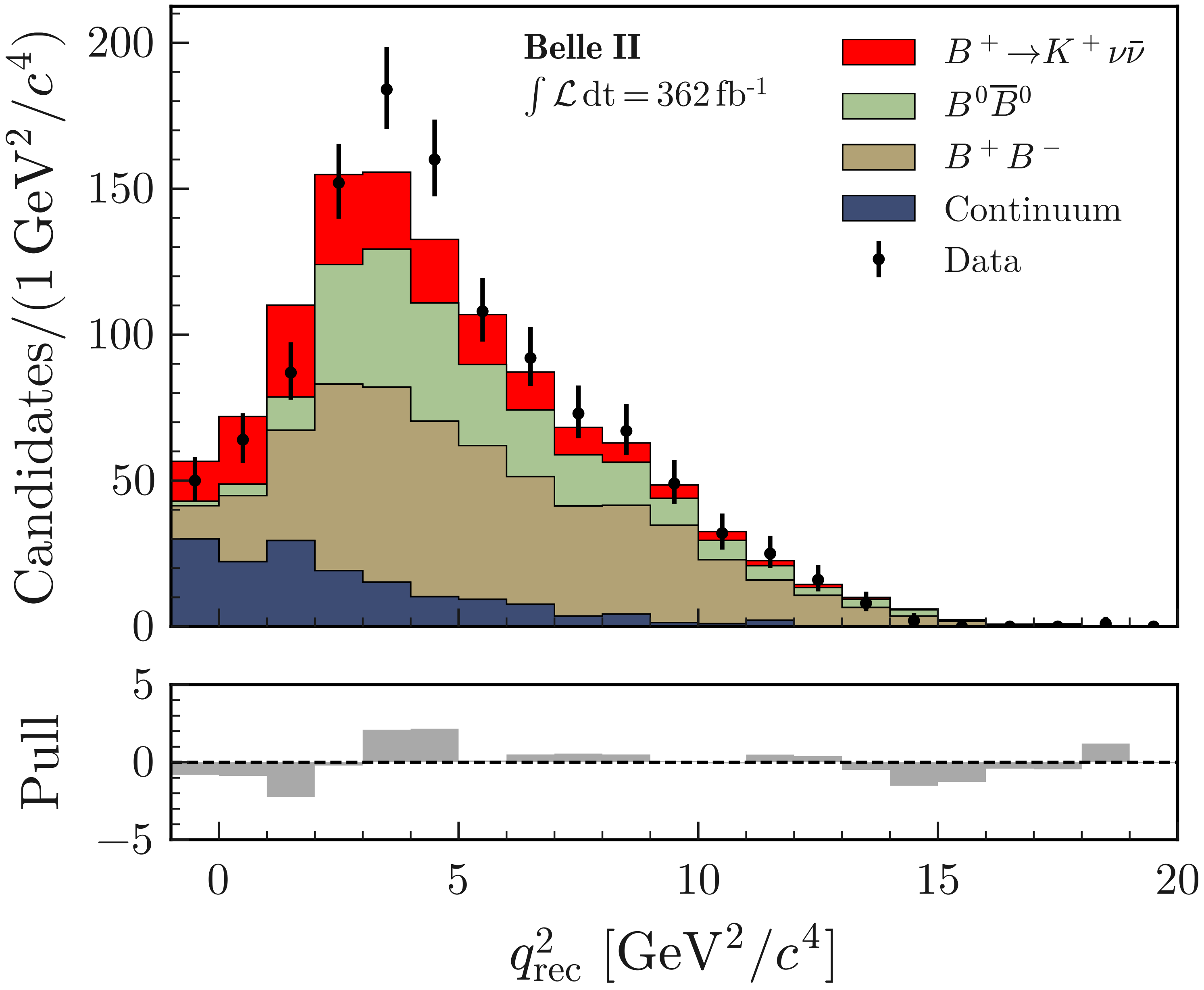
$$q^2_{\mathrm{rec}} = s/4 + M^2_{K^+} - \sqrt{s}E^*_{K^+}$$

$$\mathscr{B}(B^+ \to K^+\nu\bar{\nu})_{\mathrm{ITA}} = (2.7 \pm 0.5 \pm 0.5) \times 10^{-5}$$

$B^+ \to K^+\nu\bar{\nu}$ post-fit distributions (ITA)

$$\eta(\mathrm{BDT}_2) > 0.98$$

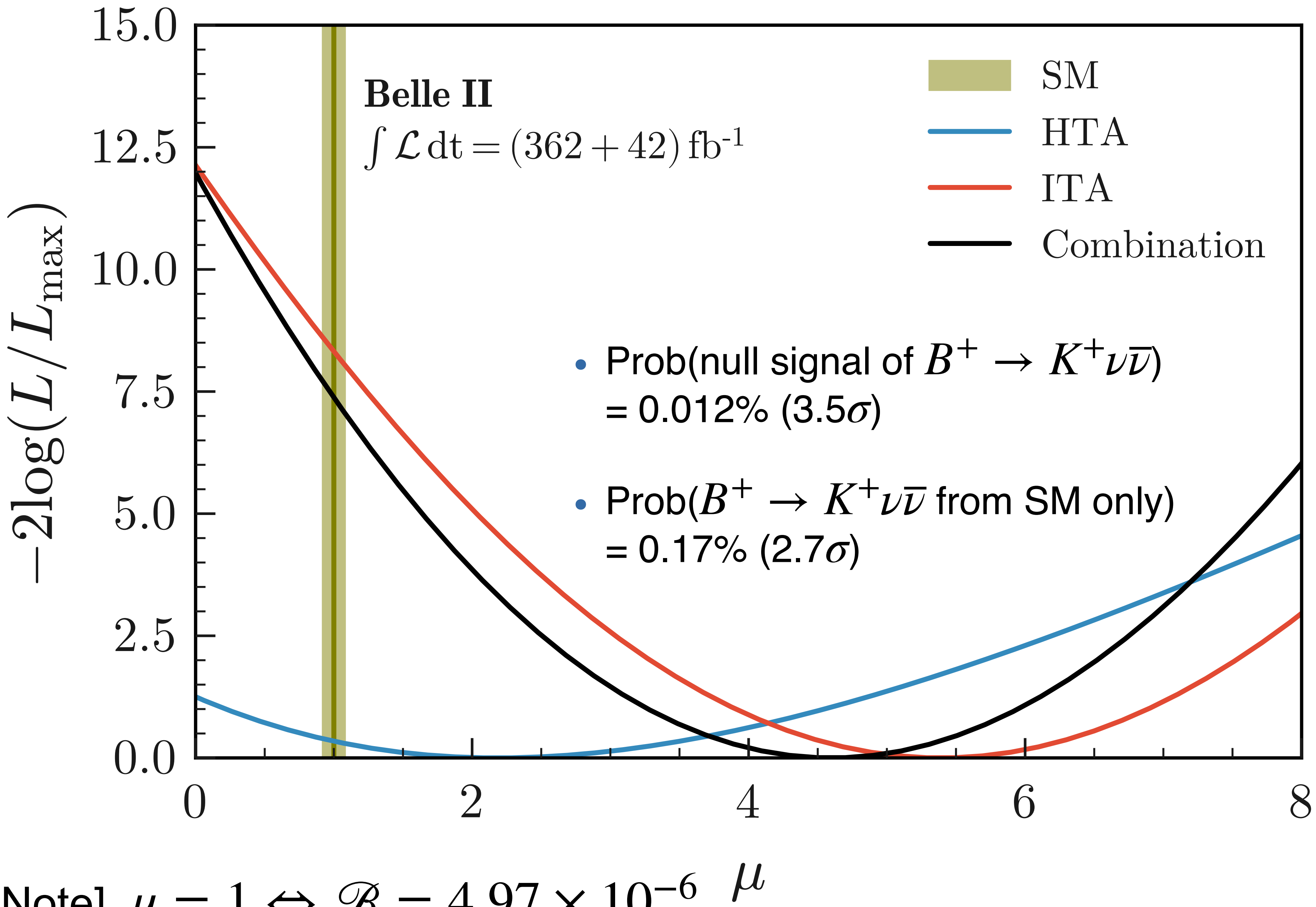




$$q^2_{\mathrm{rec}} = s/4 + M^2_{K^+} - \sqrt{s}E^*_{K^+}$$

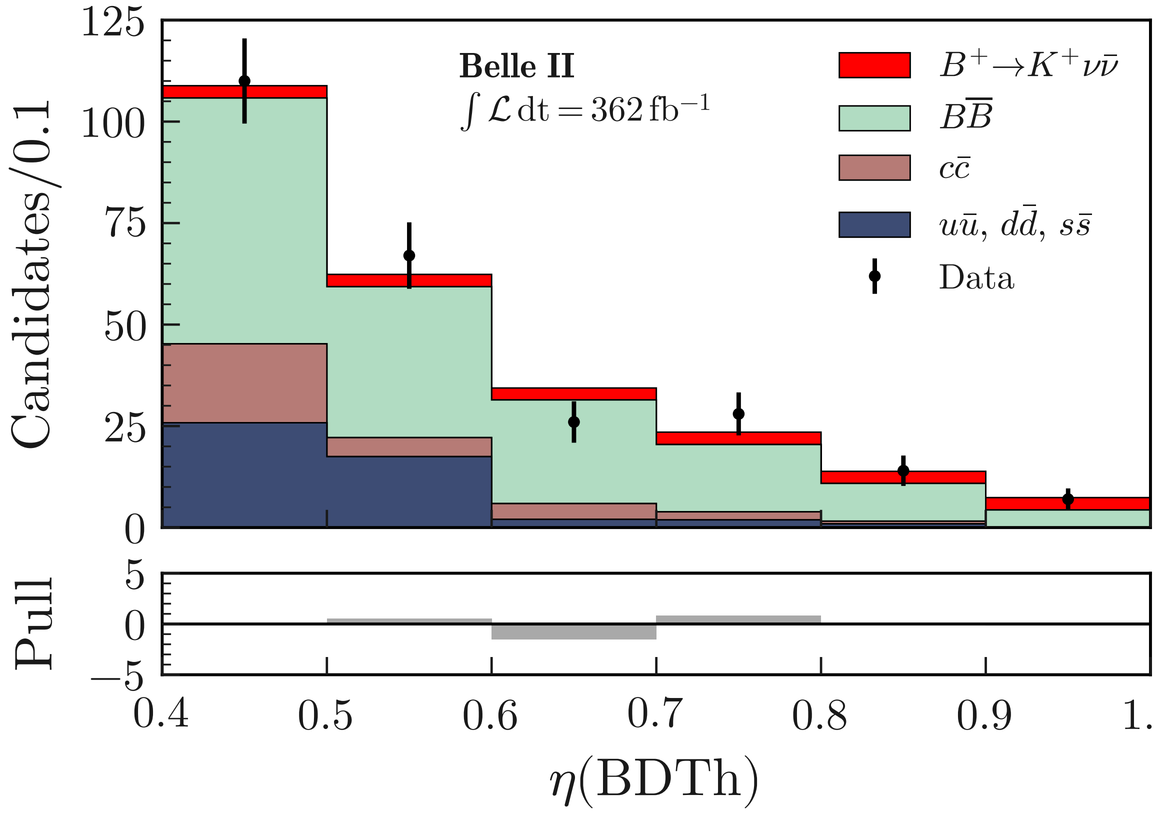
arXiv:2311.14647
PRD *accepted*

$B^+ \to K^+\nu\bar{\nu}$ (combined)



- Prob(null signal of $B^+ \to K^+\nu\bar{\nu}$) = 0.012% (3.5σ)
- Prob($B^+ \to K^+\nu\bar{\nu}$ from SM only) = 0.17% (2.7σ)

[Note] $\mu = 1 \Leftrightarrow \mathscr{B} = 4.97 \times 10^{-6}$
(SM value not incl. $B \to \tau\nu$)



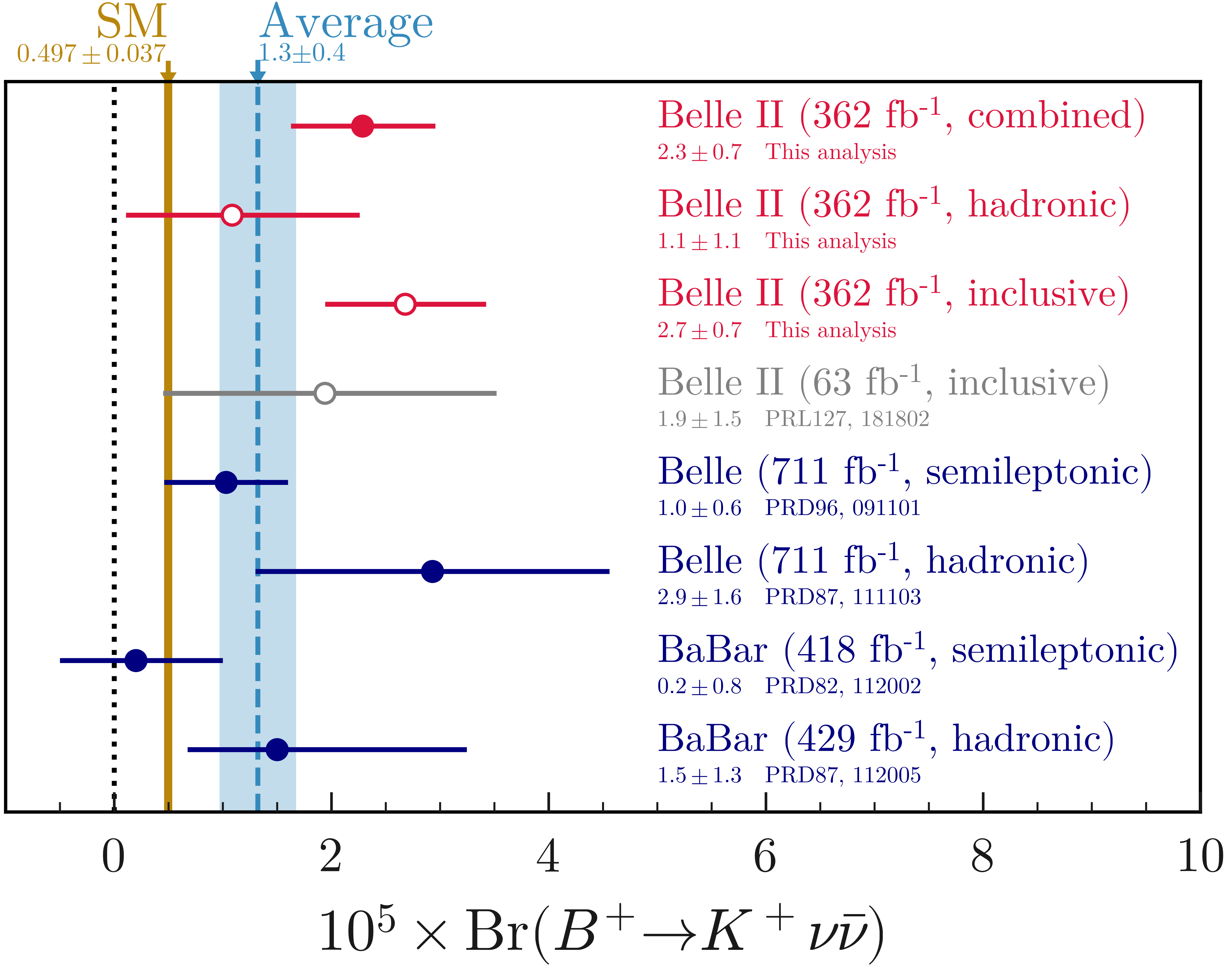
$$\mathscr{B}(B^+ \to K^+\nu\bar{\nu})_{\mathrm{HTA}} = (1.1^{+0.9+0.8}_{-0.8-0.5}) \times 10^{-5}$$

$$\mathscr{B}(B^+ \to K^+\nu\bar{\nu})_{\mathrm{ITA}} = (2.7 \pm 0.5 \pm 0.5) \times 10^{-5}$$

$$\mathscr{B}(B^+ \to K^+\nu\bar{\nu})_{\mathrm{comb}} = (2.3 \pm 0.5^{+0.5}_{-0.4}) \times 10^{-5}$$

arXiv:2311.14647
PRD *accepted*

$\mathcal{B}(B^+ \to K^+\nu\bar{\nu})$ global picture



Part II *Charm baryon*

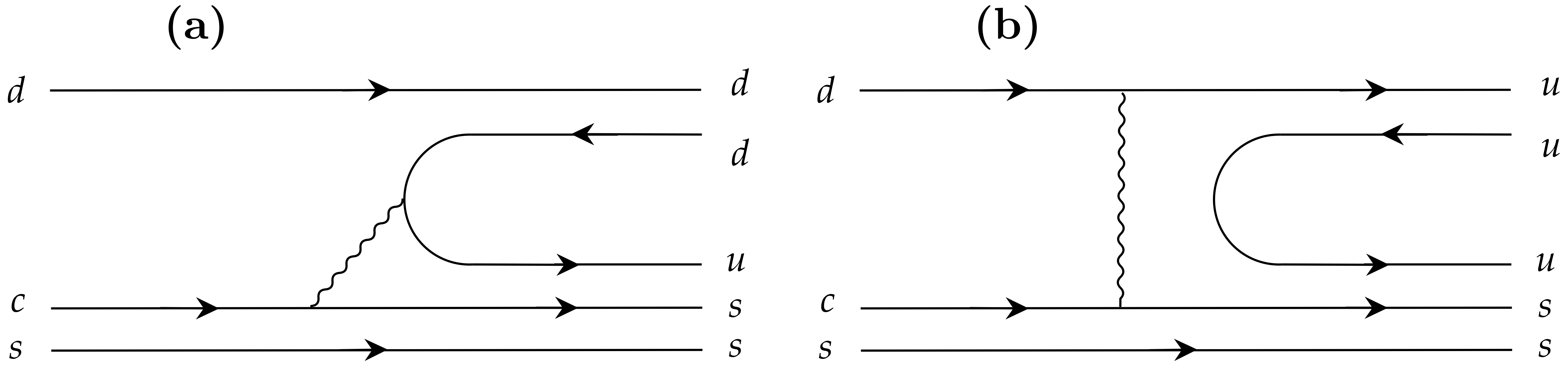
Charm baryon decays $\Xi_c^0 \to \Xi^0 h^0$

$(h^0 = \pi^0, \eta, \eta')$

- Sensitive to (a) W-emission, and (b) W-exchange diagrams
  - difficulties for theoretical predictions

Theory predictions vary in wide ranges for both BF and α
See Appendix, p.43

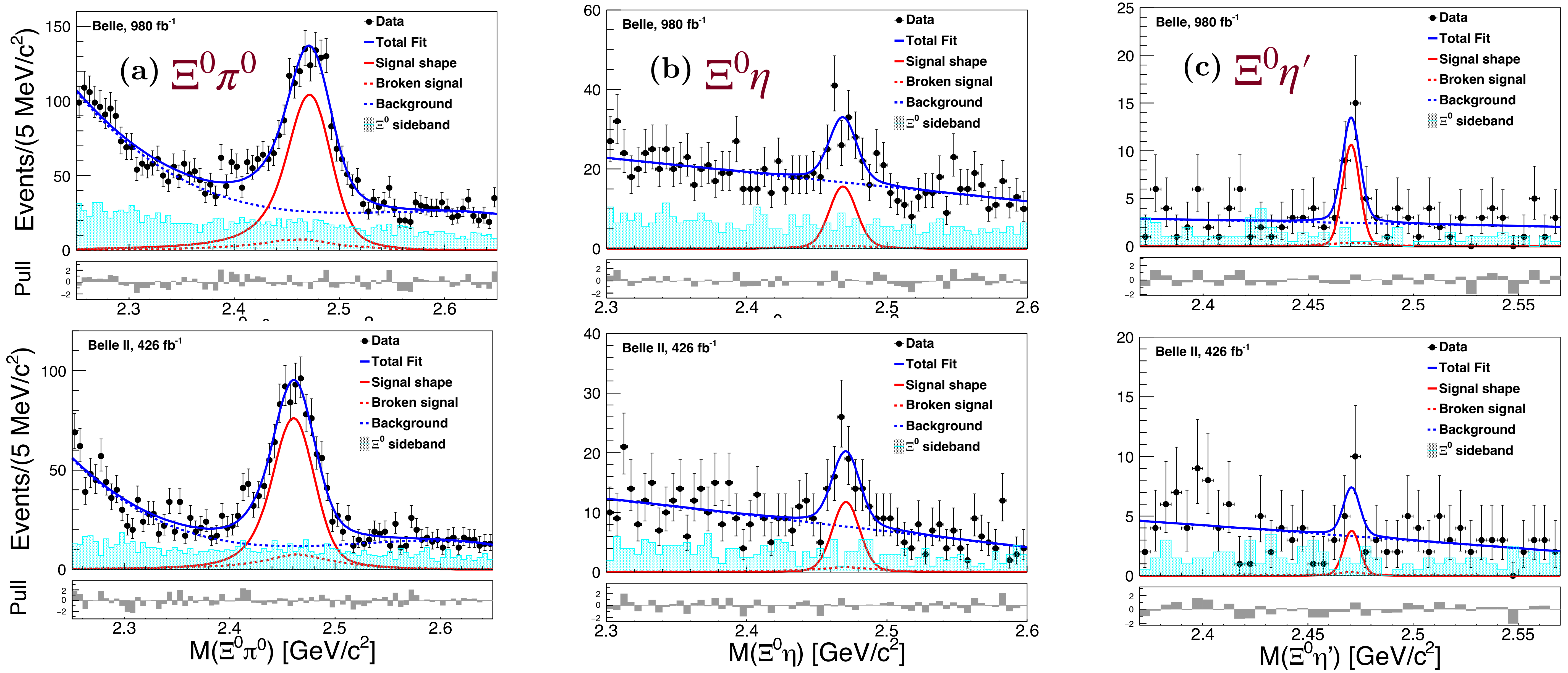
- measures BF and decay asymmetry parameter α
  - in a combined data set of Belle (980/fb) + Belle II (426/fb)



$$\frac{dN}{d\cos\theta_{\Xi^0}} \propto 1 + \alpha(\Xi_c^0 \to \Xi^0 h^0)\alpha(\Xi^0 \to \Lambda\pi^0)\cos\theta_{\Xi^0}$$

in *preparation for* JHEP

$\mathscr{B}(\Xi_c^0 \to \Xi^0 h^0)$ branching fractions



Belle

Belle II

Results	Belle	Belle II	Combined
$\mathcal{B}(\Xi_c^0 \to \Xi^0\pi^0)/\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$	$0.47 \pm 0.02 \pm 0.03$	$0.51 \pm 0.03 \pm 0.05$	$0.48 \pm 0.02 \pm 0.03$
$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta)/\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$	$0.10 \pm 0.02 \pm 0.01$	$0.14 \pm 0.02 \pm 0.02$	$0.11 \pm 0.01 \pm 0.01$
$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta')/\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$	$0.12 \pm 0.03 \pm 0.01$	$0.06 \pm 0.03 \pm 0.01$	$0.08 \pm 0.02 \pm 0.01$

$$\mathcal{B}(\Xi_c^0 \to \Xi_0\pi^0) = (6.9 \pm 0.3 \pm 0.5 \pm 1.5) \times 10^{-3}$$

$$\mathcal{B}(\Xi_c^0 \to \Xi_0\eta) = (1.6 \pm 0.2 \pm 0.2 \pm 0.4) \times 10^{-3}$$

$$\mathcal{B}(\Xi_c^0 \to \Xi_0\eta') = (1.2 \pm 0.3 \pm 0.1 \pm 0.3) \times 10^{-3}$$

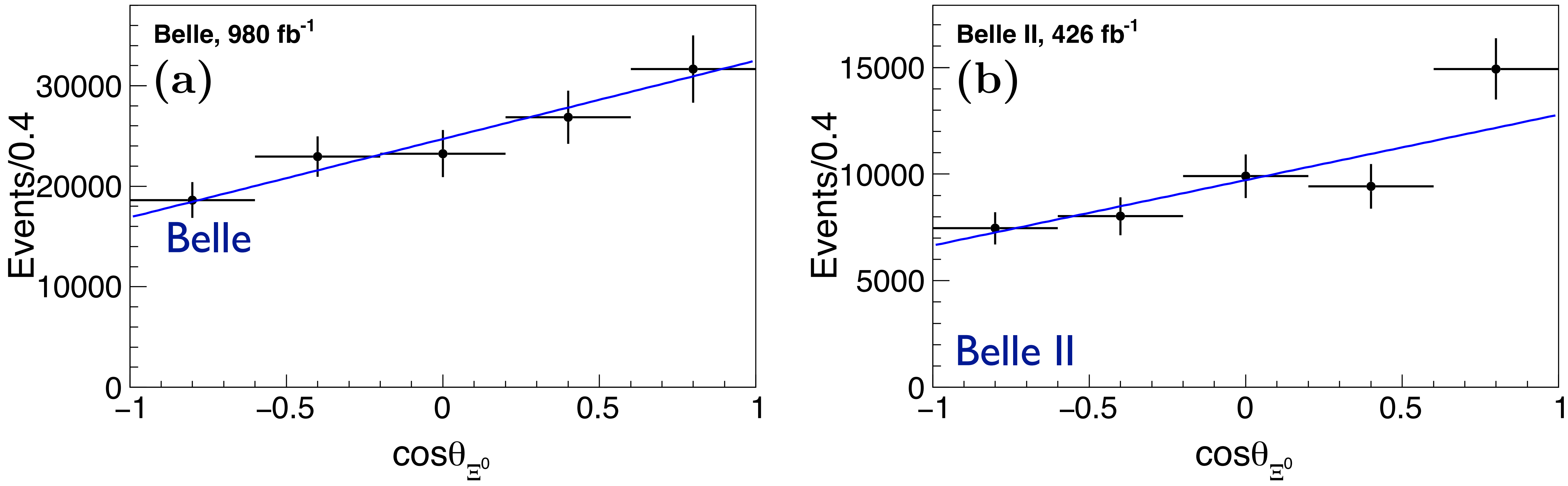
Belle II precision is comparable
to Belle with ~1/2 luminosity

consistent w/ Zhong et al. [JHEP (2023)]
based on SU(3)$_F$-breaking model

in *preparation for* JHEP

$\alpha(\Xi_c^0 \to \Xi^0\pi^0)$ decay asymmetry

$$\frac{dN}{d\cos\theta_{\Xi^0}} \propto 1 + \alpha(\Xi_c^0 \to \Xi^0 h^0)\alpha(\Xi^0 \to \Lambda\pi^0)\cos\theta_{\Xi^0}$$



$$\alpha(\Xi_c^0 \to \Xi^0\pi^0)\alpha(\Xi^0 \to \Lambda\pi^0) = 0.32 \pm 0.05(\text{stat})$$

by simultaneous fits to
Belle & Belle II data sets

using $\alpha(\Xi^0 \to \Lambda\pi^0) = -0.349 \pm 0.009$ (PDG),

$$\alpha(\Xi_c^0 \to \Xi^0\pi^0) = -0.90 \pm 0.15 \pm 0.23$$

consistent w/ Pole model, CA,
and SU(3)$_F$ approaches

Part III ***Energy Scan for Bottomoia***

arXiv:2401.12021
JHEP *submitted*

Energy scan for $\Upsilon(10753)$

$\Upsilon(10753)$

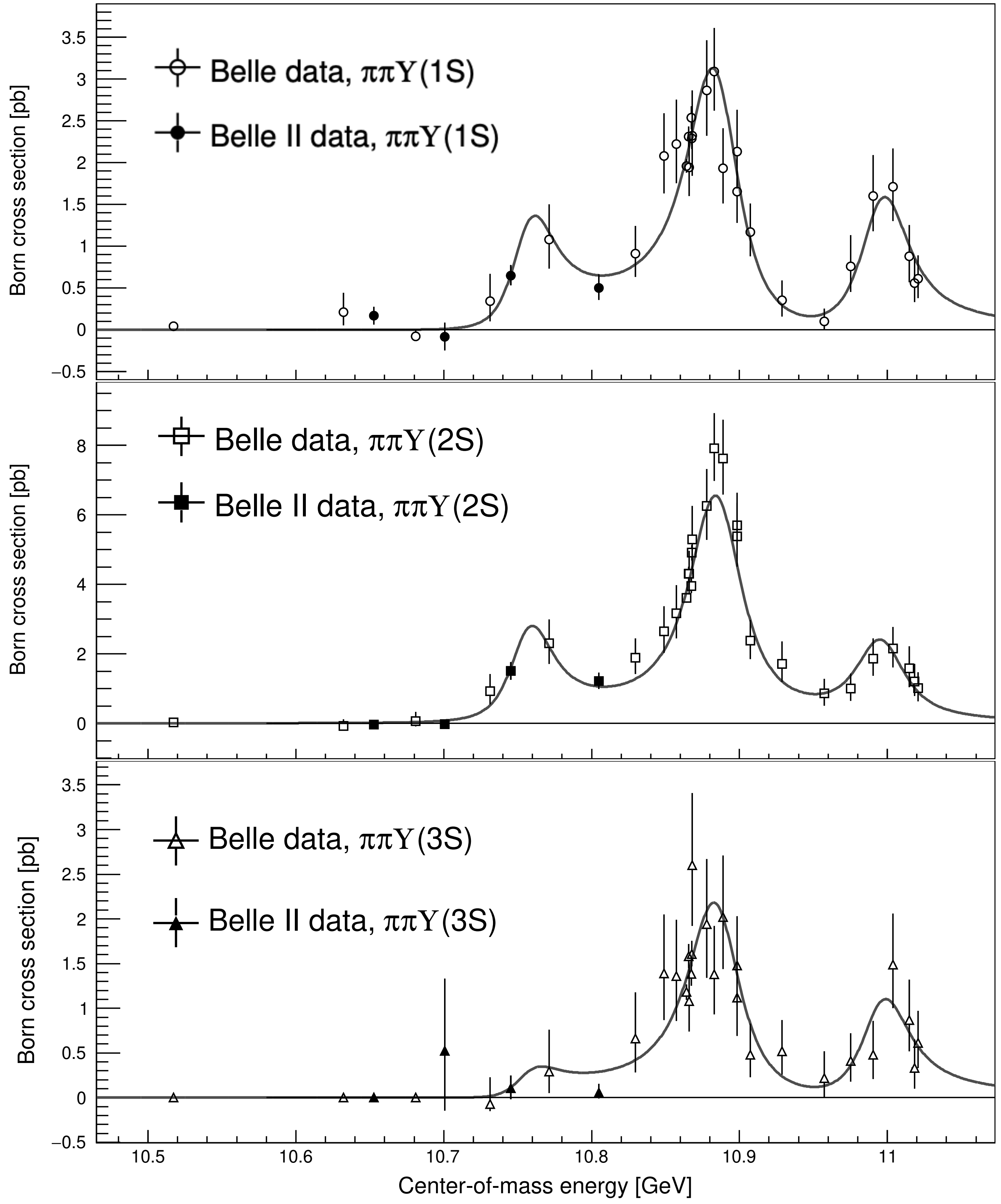
- first observed by Belle, [JHEP 10 (2019) 220] with 5.2σ
- in the energy dependence of $e^+e^- \to \Upsilon(nS)\pi^+\pi^-$
- ∃ several competing interpretations

Belle II result

- arxiv:2401.12021
- $e^+e^- \to \Upsilon(nS)\pi^+\pi^-$ with $\Upsilon(nS) \to \mu^+\mu^-$
- confirms Belle results of $\Upsilon(10753)$

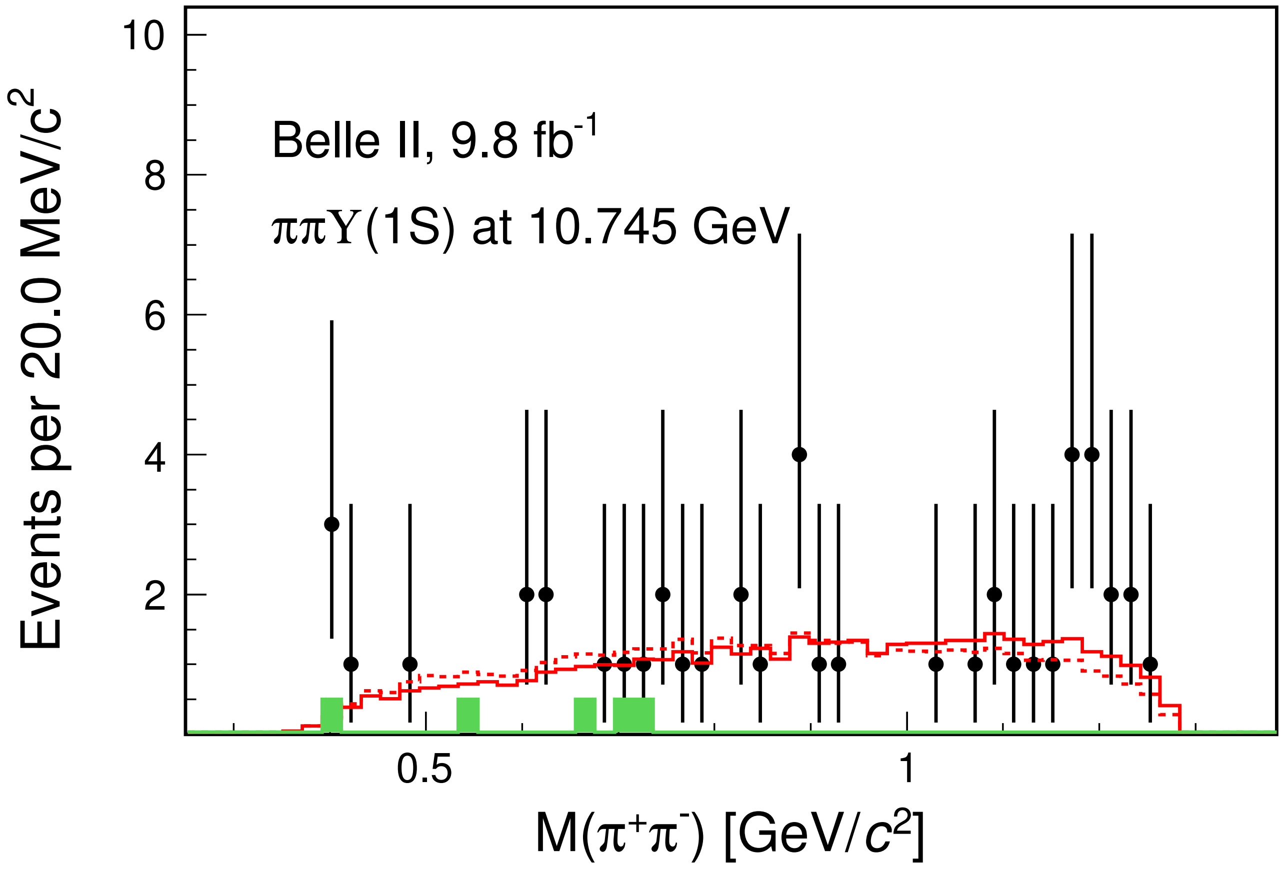
	$\mathcal{R}^{\Upsilon(10753)}_{\sigma(1S/2S)}$	$\mathcal{R}^{\Upsilon(10753)}_{\sigma(3S/2S)}$
Ratio	$0.46^{+0.15}_{-0.12}$	$0.10^{+0.05}_{-0.04}$

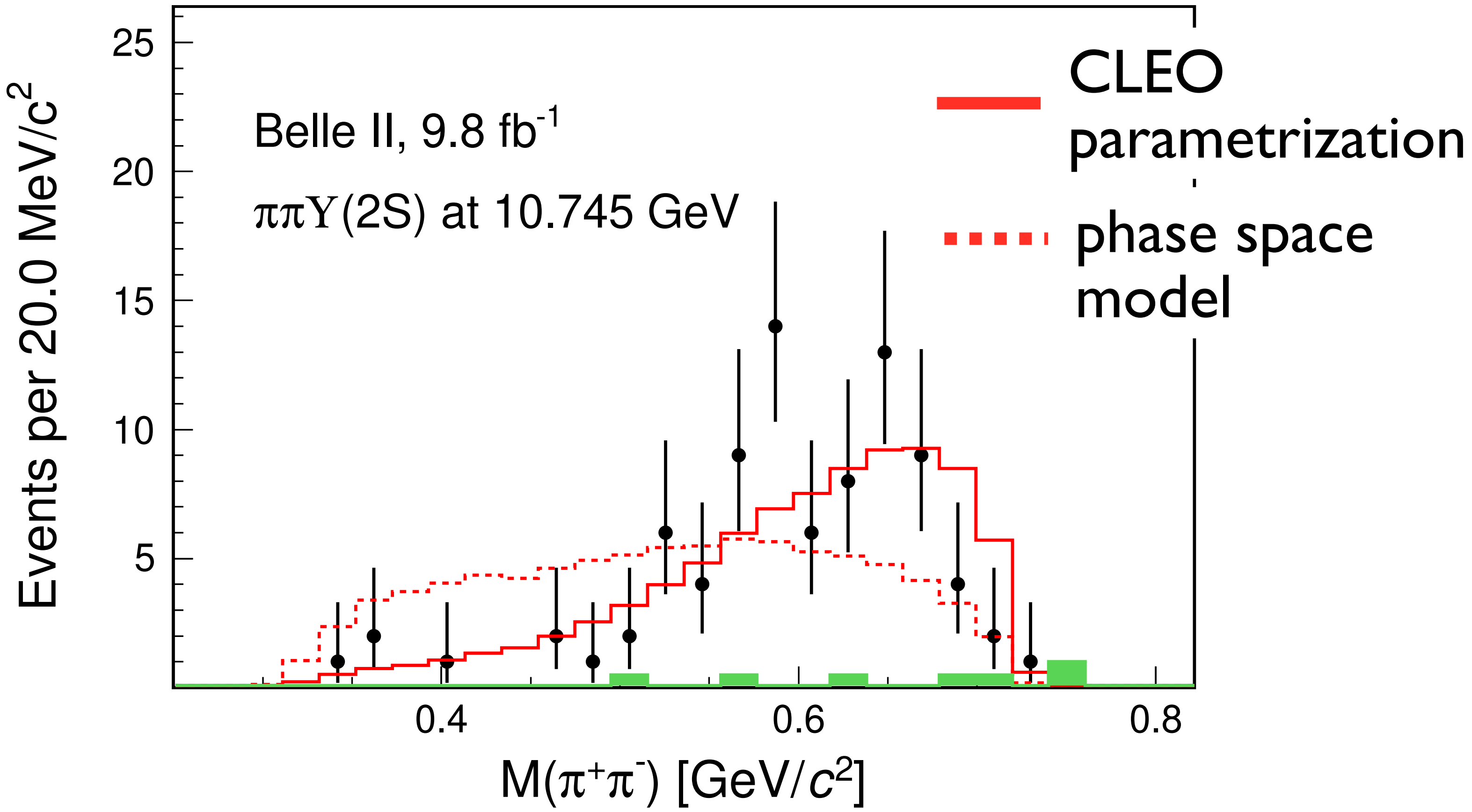
small



arXiv:2401.12021
JHEP *submitted*

Energy scan for $\Upsilon(10753)$

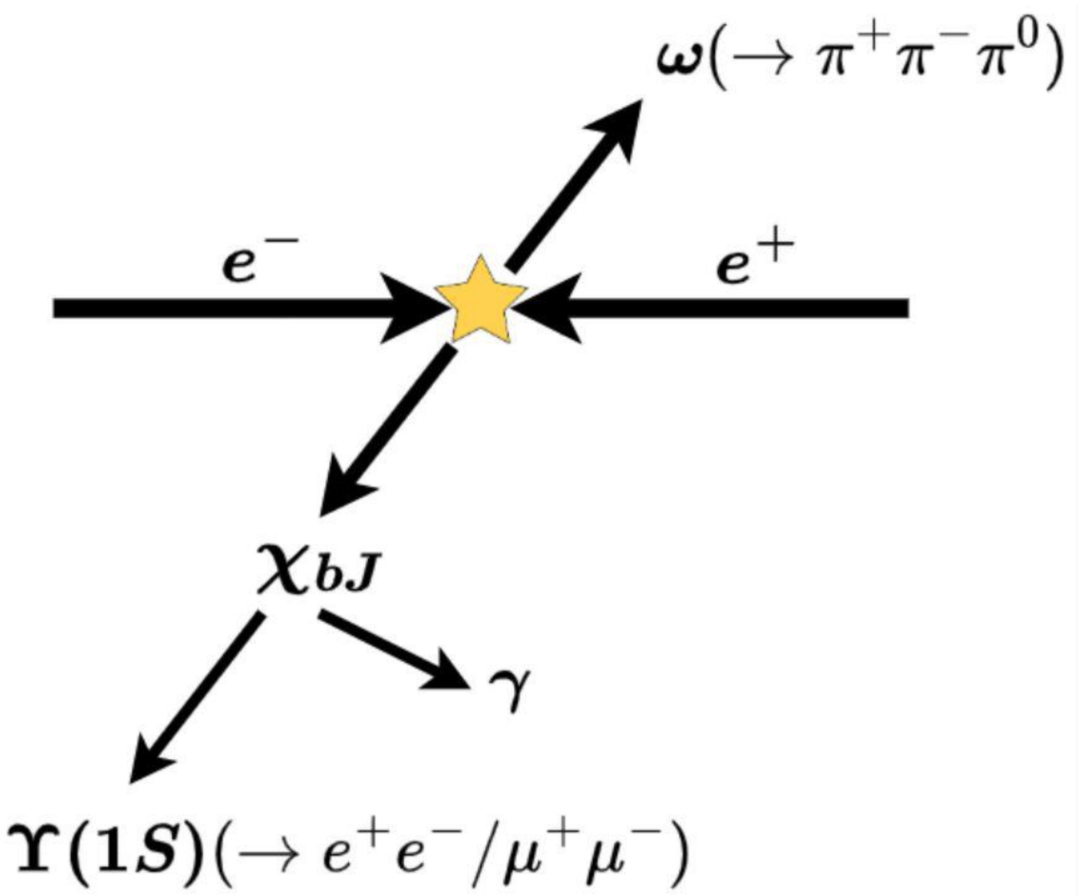


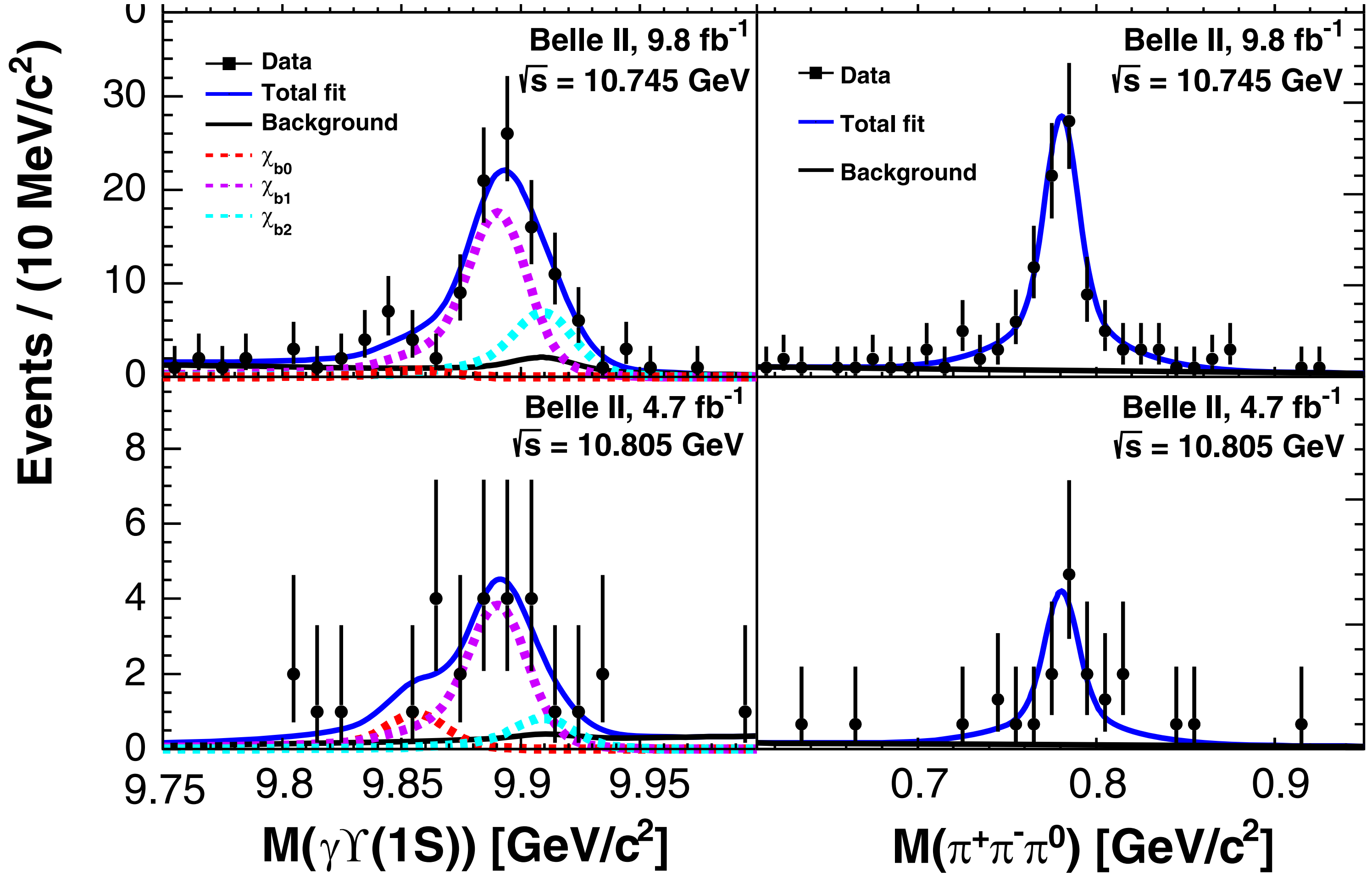


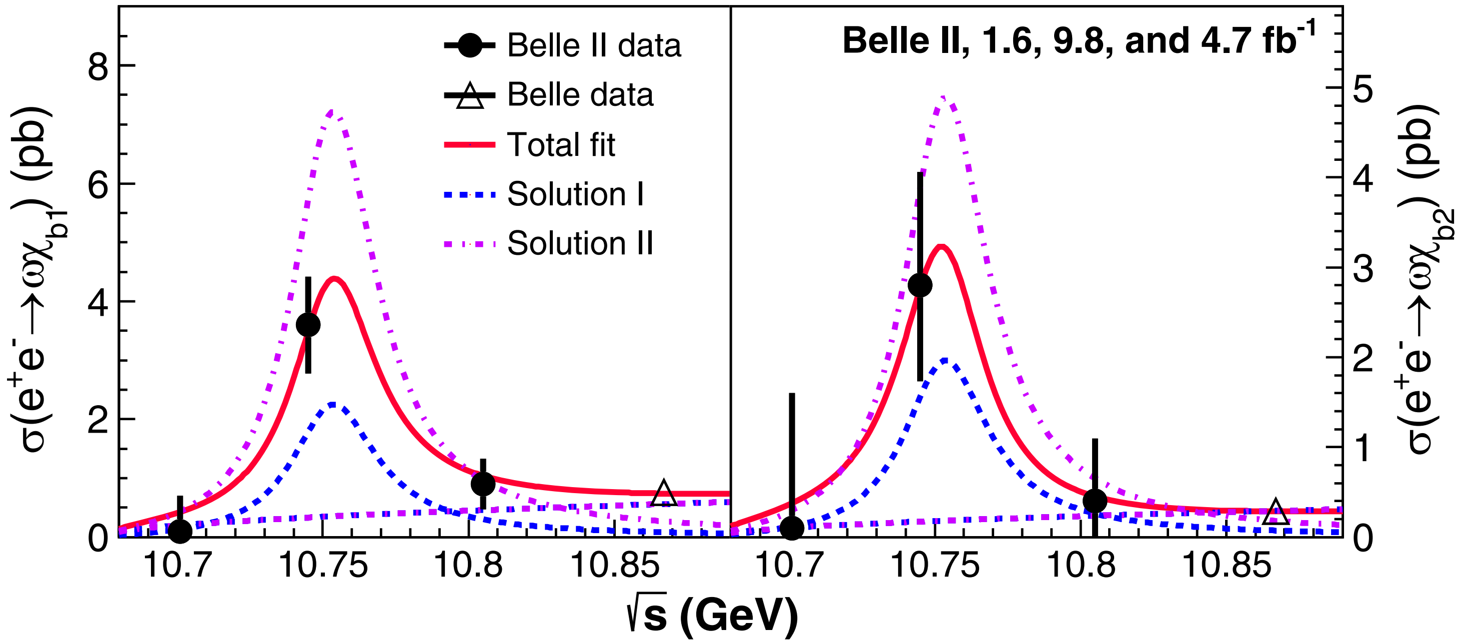
dipion mass distribution

- similar to both phase-space model and $\Upsilon(2S) \to \pi^+\pi^-\Upsilon(1S)$ for $\pi^+\pi^-\Upsilon(1S)$
- but similar to $\Upsilon(2S) \to \pi^+\pi^-\Upsilon(1S)$ only for $\pi^+\pi^-\Upsilon(2S)$

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





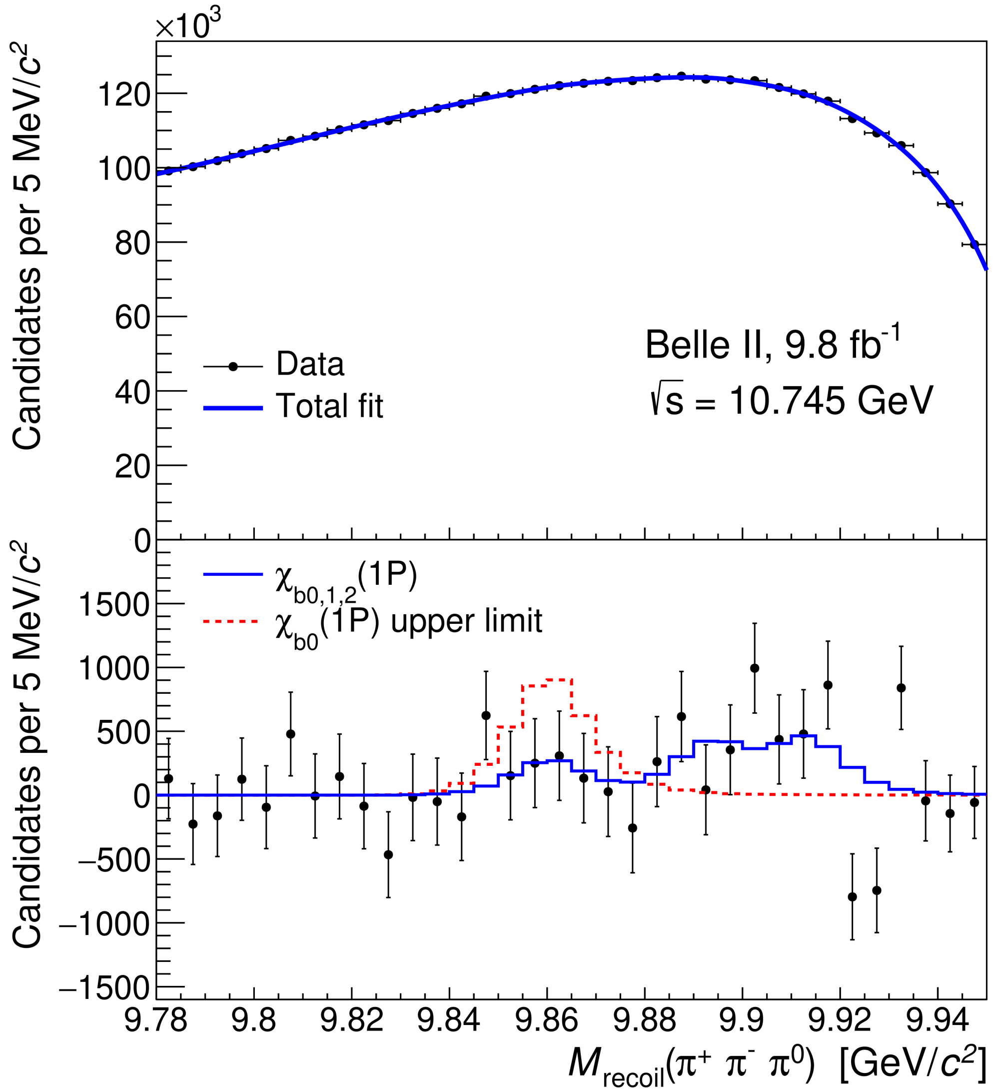


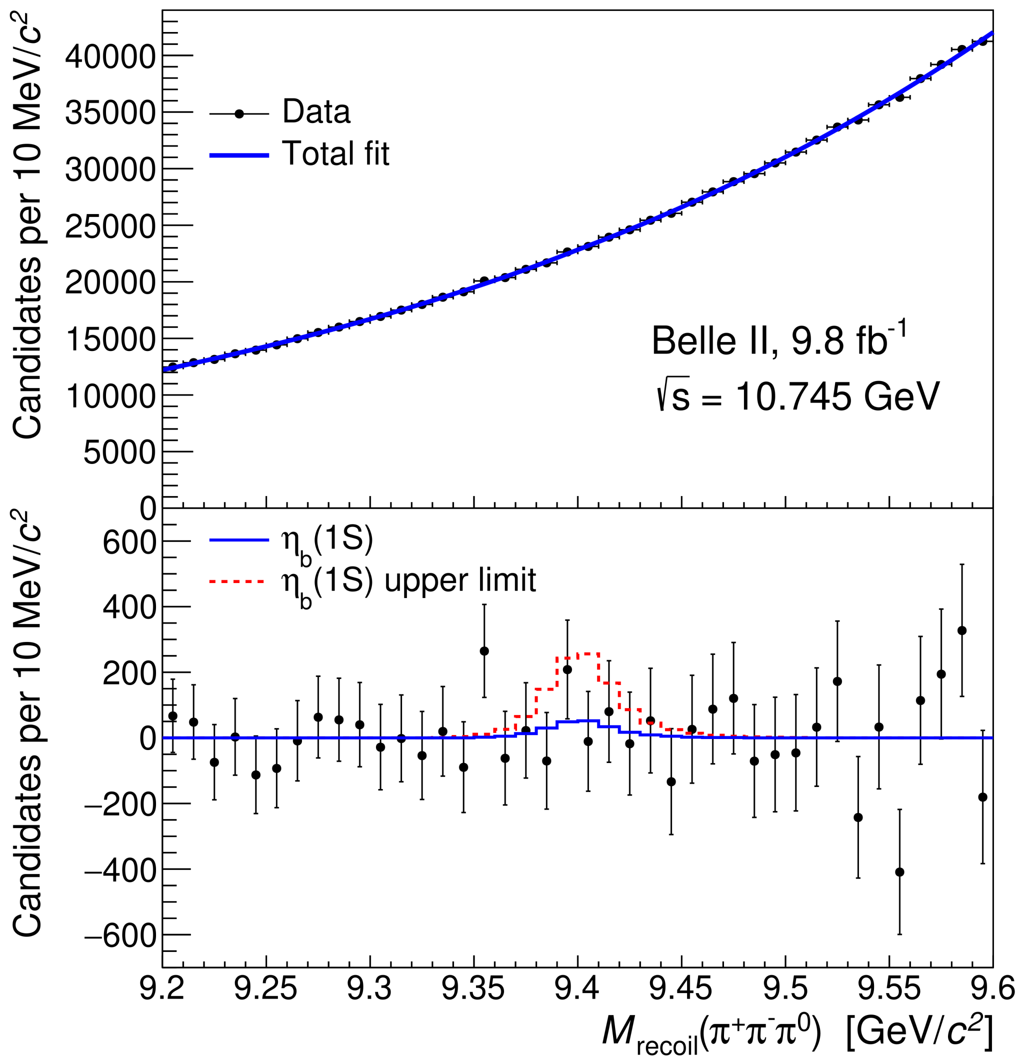
- cross section shows a peak at $\Upsilon(10753)$, hence a confirmation and a new decay channel
- the ratio $\chi_{b1}\omega/\pi\pi\Upsilon(nS)$ ~ one order of magnitude higher at $\Upsilon(10753)$ than at $\Upsilon(5S)$

arXiv:2312.13043
PRD *accepted*

$\Upsilon(10753) \to \chi_{b0}\omega$ and $\eta_b\omega$

- Tetraquark interpretation of this state predicts enhancement of $\Upsilon(10753) \to \eta_b(1S)\omega$ $$\frac{\Gamma(\omega\eta_b)}{\Gamma(\Upsilon\pi^+\pi^-)} \sim 30$$
- we measure η_b indirectly by using recoil mass $M_{\rm recoil}(\omega) = \sqrt{(E_{\rm cm} - E_\omega)^2 - p_\omega^2}$





$$\sigma_{\rm B}(e^+e^- \to \eta_b(1S)\omega) < 2.5\,{\rm pb},$$
$$\sigma_{\rm B}(e^+e^- \to \chi_{b0}(1P)\omega) < 8.7\,{\rm pb}.$$

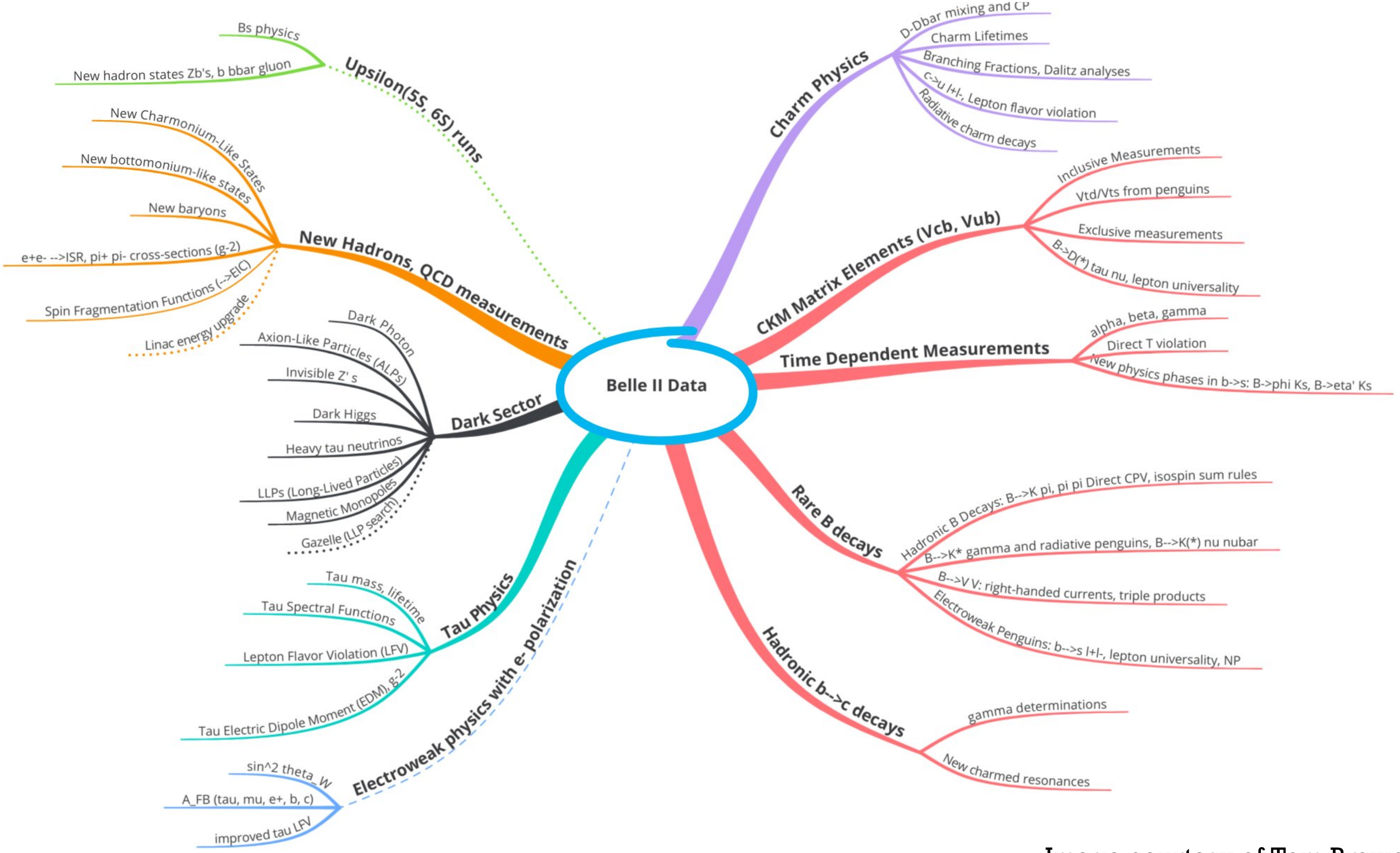
Summary

- Belle II has collected over $0.4\ \mathrm{ab}^{-1}$ data sample in its first 3 years of operation before LS1, and started Run 2 data taking in Feb. this year.
- With the data set of ~1/2 the size of Belle, the physics precision of Belle II results are comparable or better in many analyses.
- Recent Belle II physics highlights include first evidence for $B^+ \to K^+\nu\bar{\nu}$, and inclusive test of LFU with $B \to X\tau\nu$.
- In addition, we have presented interesting new results in charm baryons and bottomonium spectroscopy.
- Run 2 is underway with the goal of collecting a several ab^{-1} data in the next few years.

Thank you!

Appendices

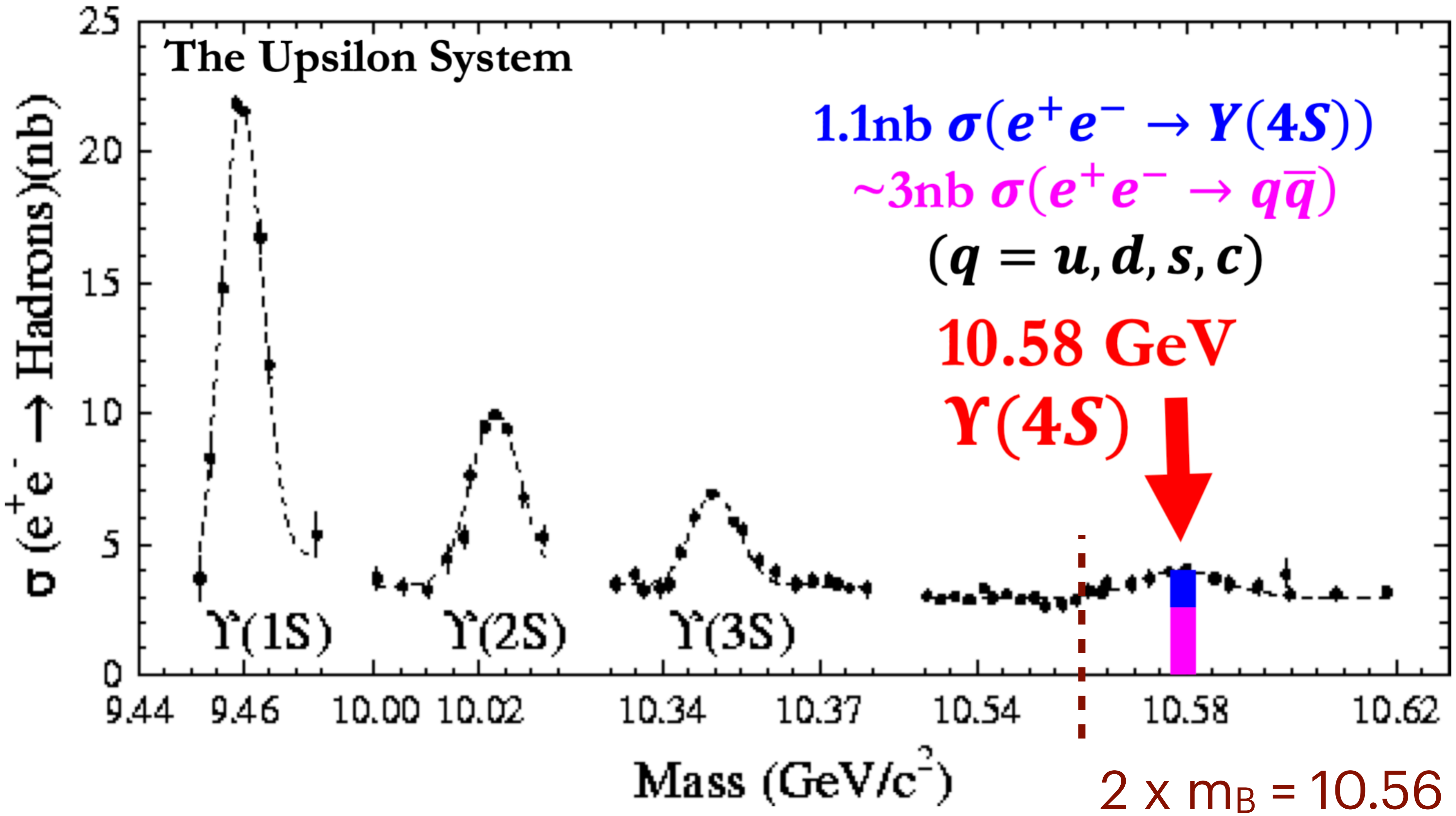
Belle II Physics Mind-map



- 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), g-2
  - Electroweak physics with e- polarization
    - sin^2 theta_W
    - A_FB (tau, mu, e+, b, c)
    - improved tau LFV
  - Charm Physics
    - D-Dbar mixing and CP
    - 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, NP
  - Hadronic b-->c decays
    - gamma determinations
    - New charmed resonances

Image courtesy of Tom Browder

$e^+e^- \to \Upsilon(4S)$ as a B-factory



1.1nb $\sigma(e^+e^- \to \Upsilon(4S))$

~3nb $\sigma(e^+e^- \to q\bar{q})$

$(q = u, d, s, c)$

10.58 GeV

$\Upsilon(4S)$

2 x m_B = 10.56 GeV

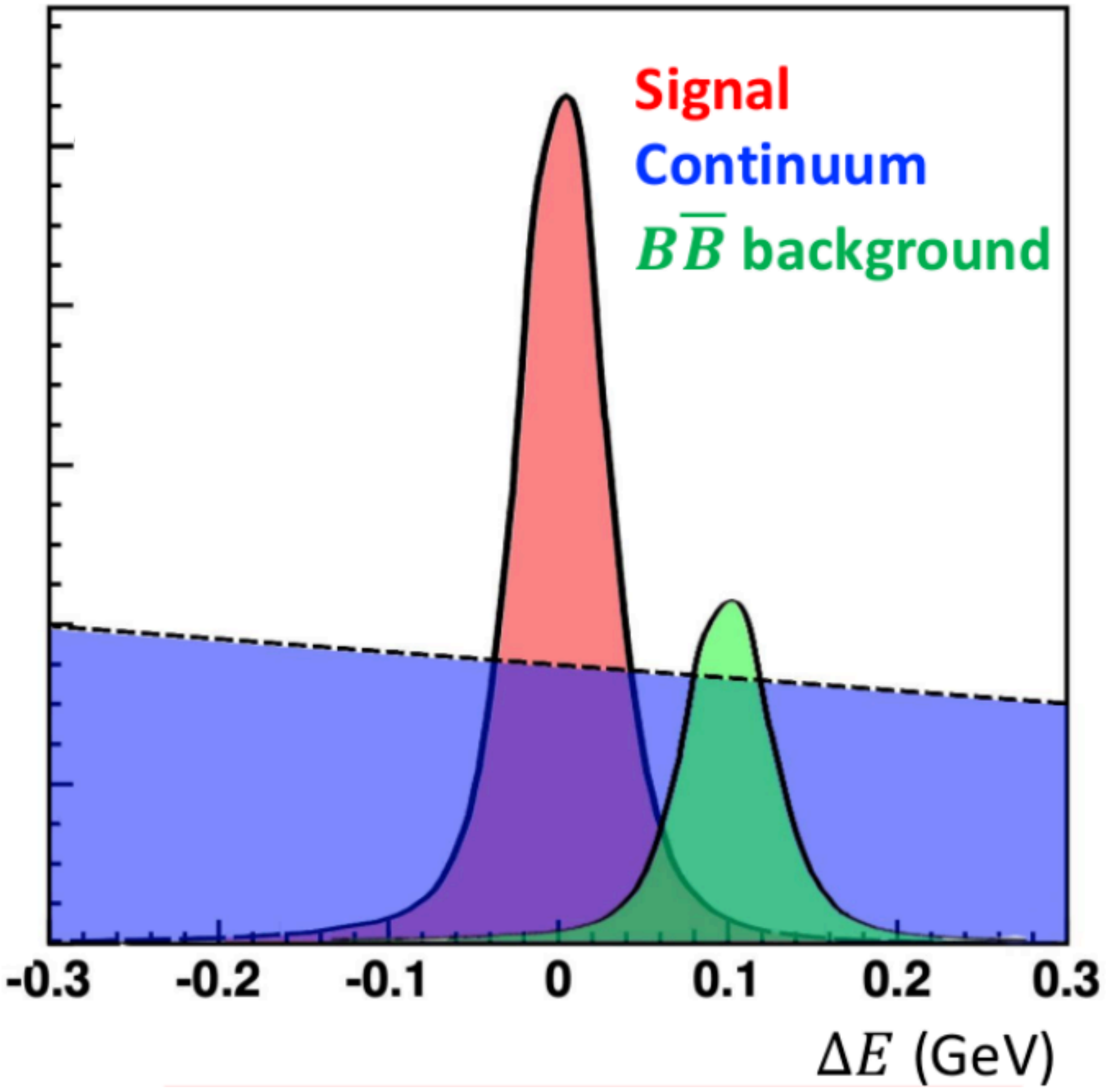
- $\mathcal{B}(\Upsilon(4S) \to B\bar{B}) > 96\%$, with $p_B^{CM} \sim 0.35$ GeV/c
- nothing else but $B\bar{B}$ in the final state

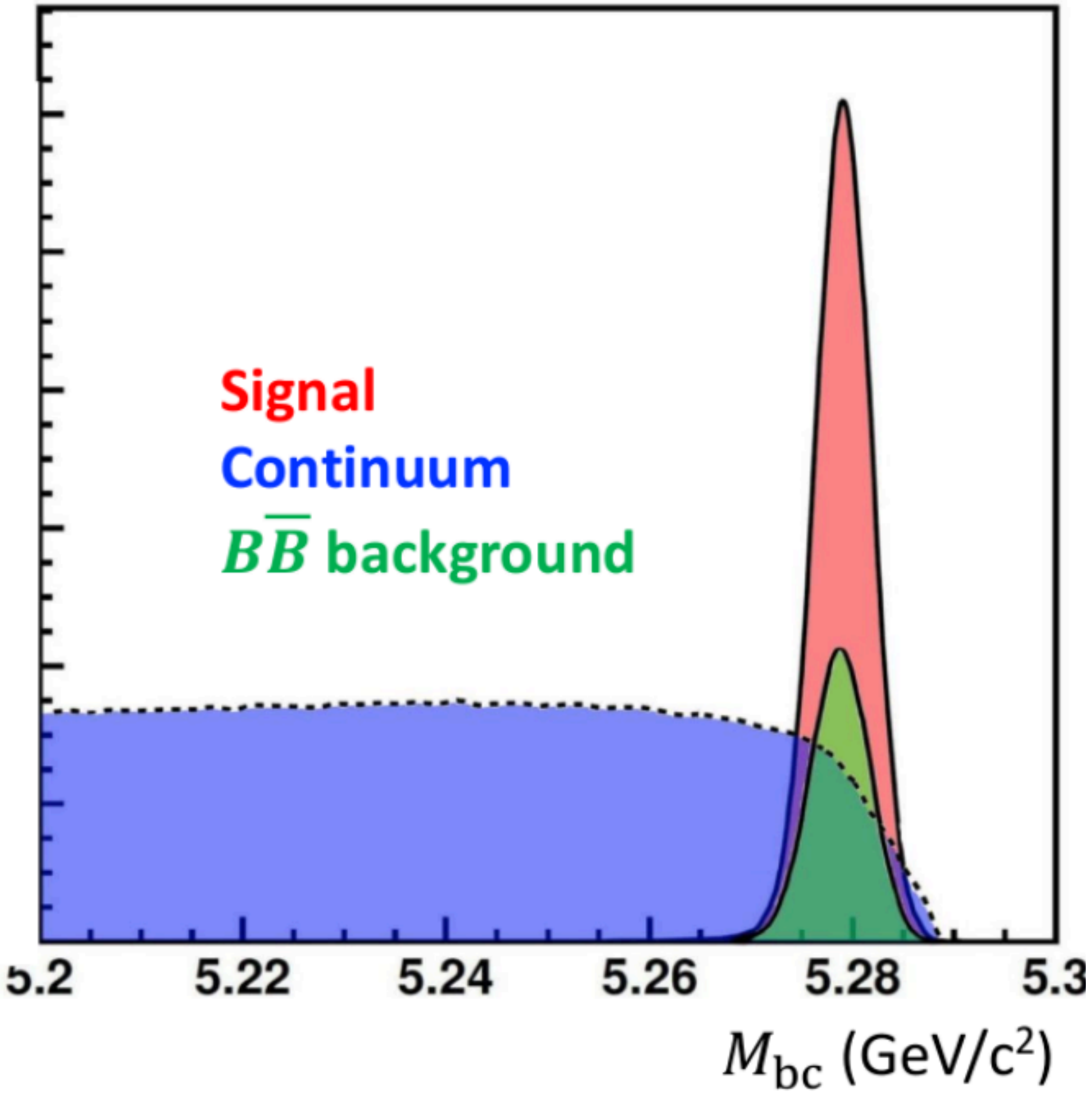
  $\therefore$ if we know $(E, \vec{p})$ of one B, the other B is also constrained

Key variables of *B* decays

$$\Delta E = E_B^* - \sqrt{s}/2$$

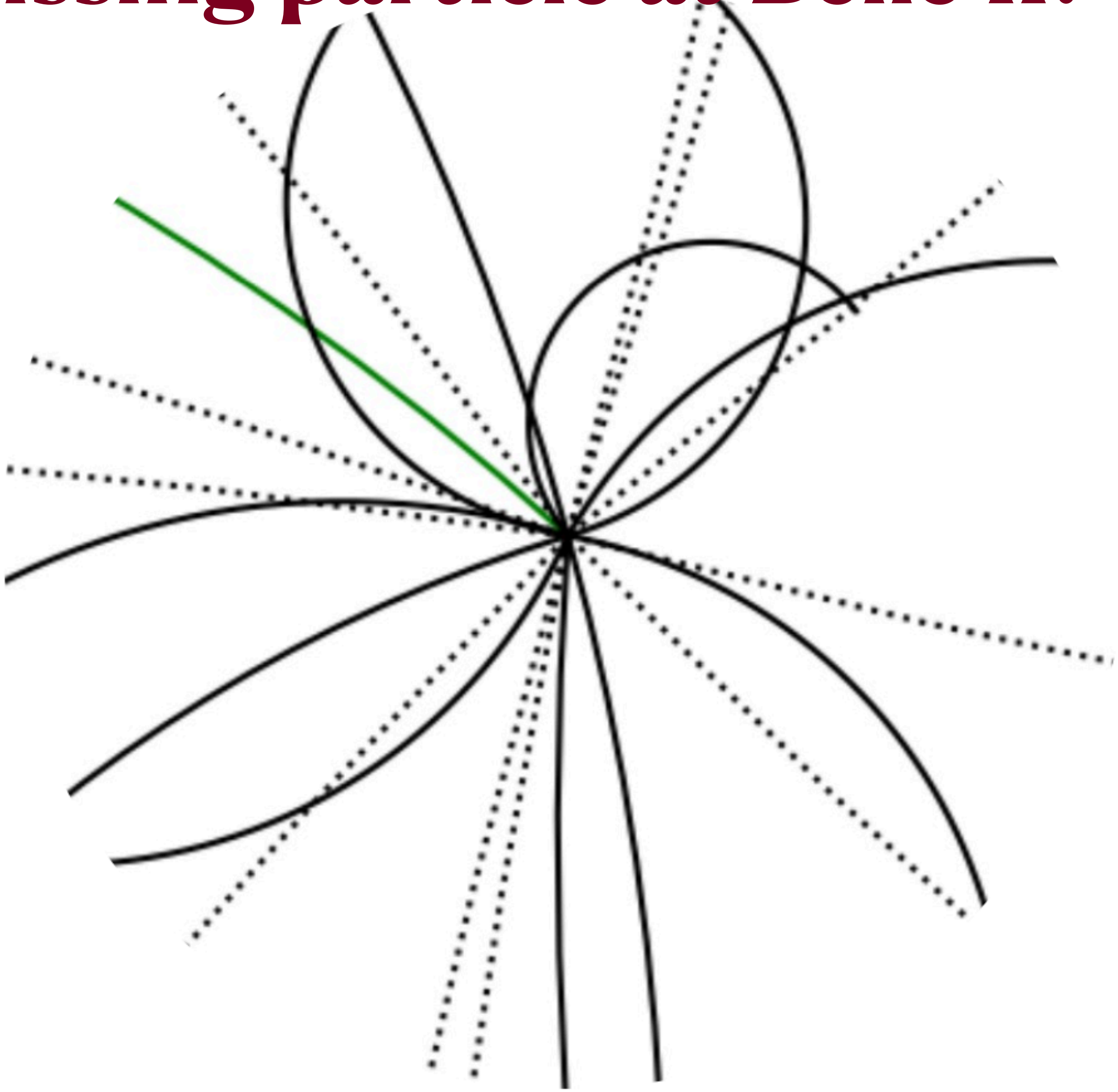
$$M_{bc} = \sqrt{(\sqrt{s}/2)^2 - \vec{p}_B^{*2}}$$





How to handle a missing particle at Belle II?

- $e^+e^- \to \Upsilon(4S) \to B\overline{B}$
  - only two B mesons in the final state
  - Since the initial state is clearly determined, fully accounting one B (B_{tag}) makes it possible to constrain the accompanying B (B_{sig})
  - Having a single missing particle (e.g. ν) is usually as clean as getting all particles measured
  - The price to pay is a big drop of efficiency ($< \mathcal{O}(1\%)$)



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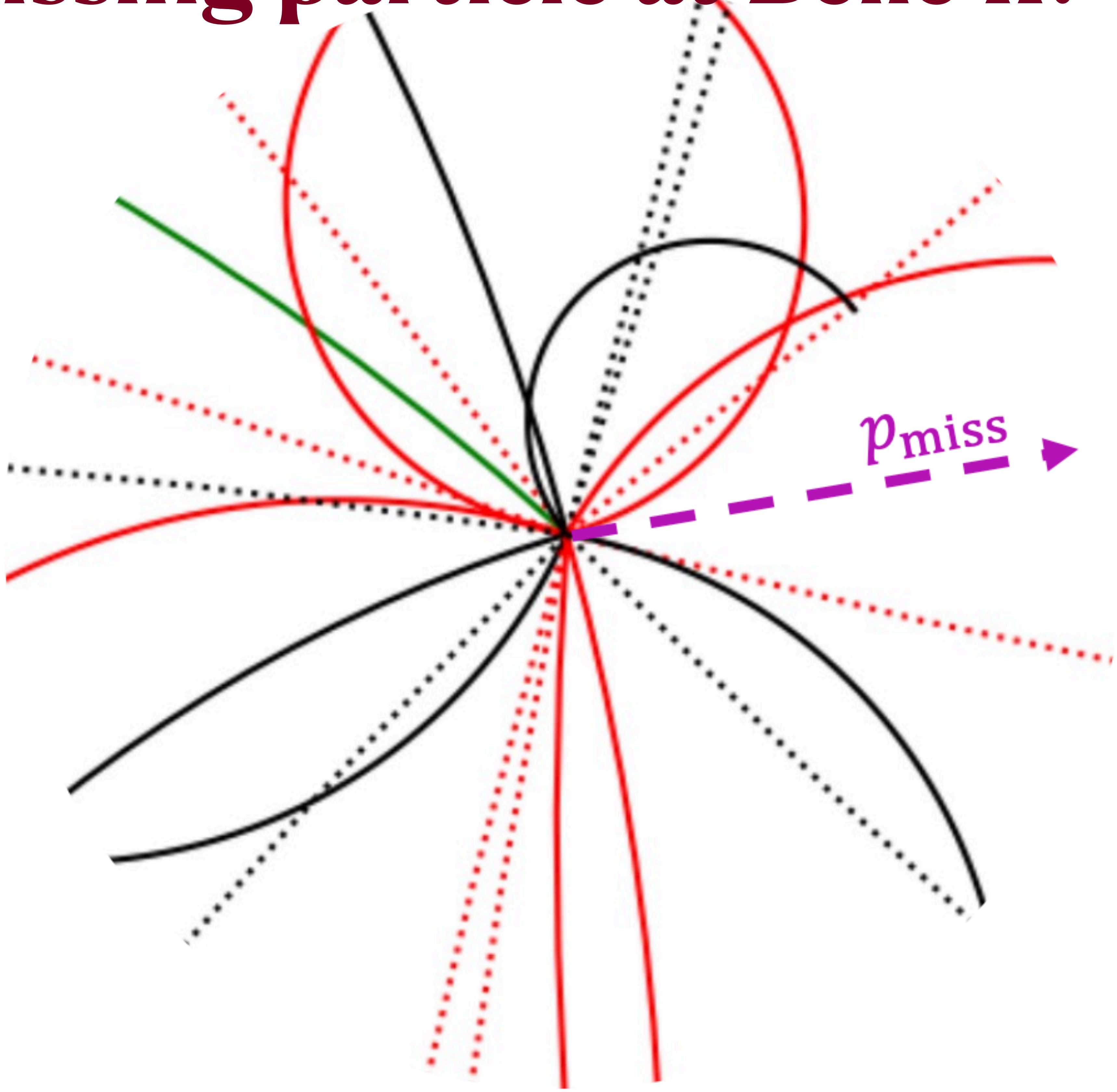
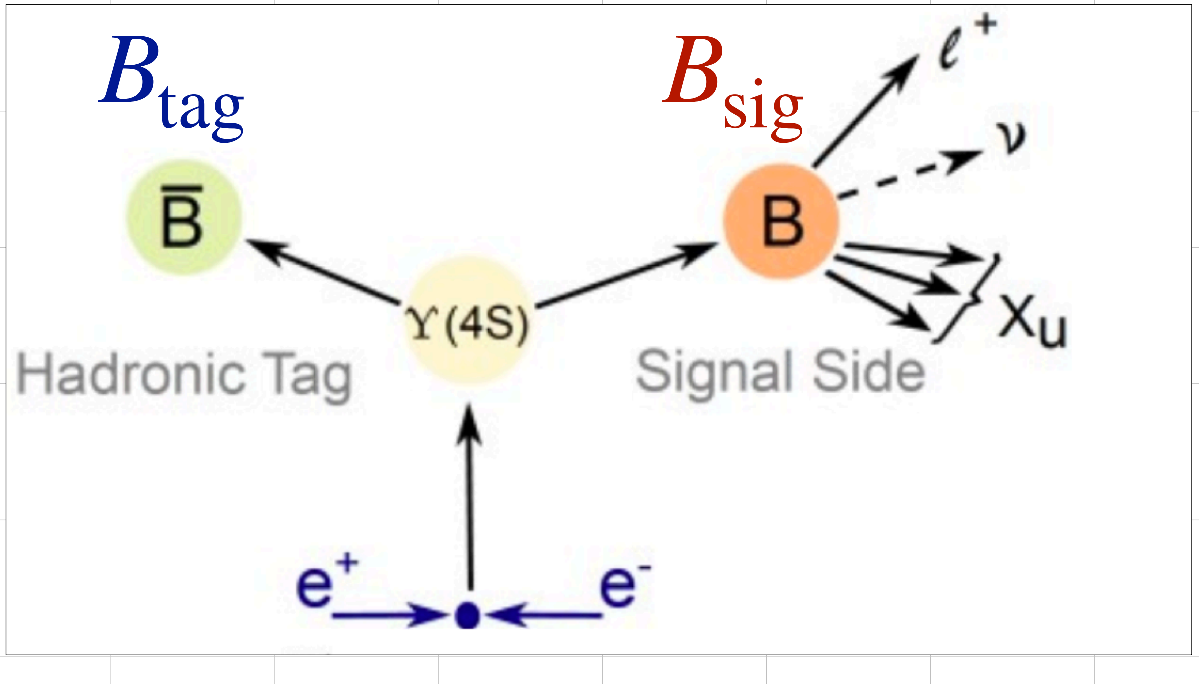


Full Event Interpretation (FEI)

- FEI algorithm to reconstruct B_{tag}
  - uses ~200 BDT's to reconstruct $\mathcal{O}(10^4)$ different B decay chains
  - assign signal probability of being correct B_{tag}



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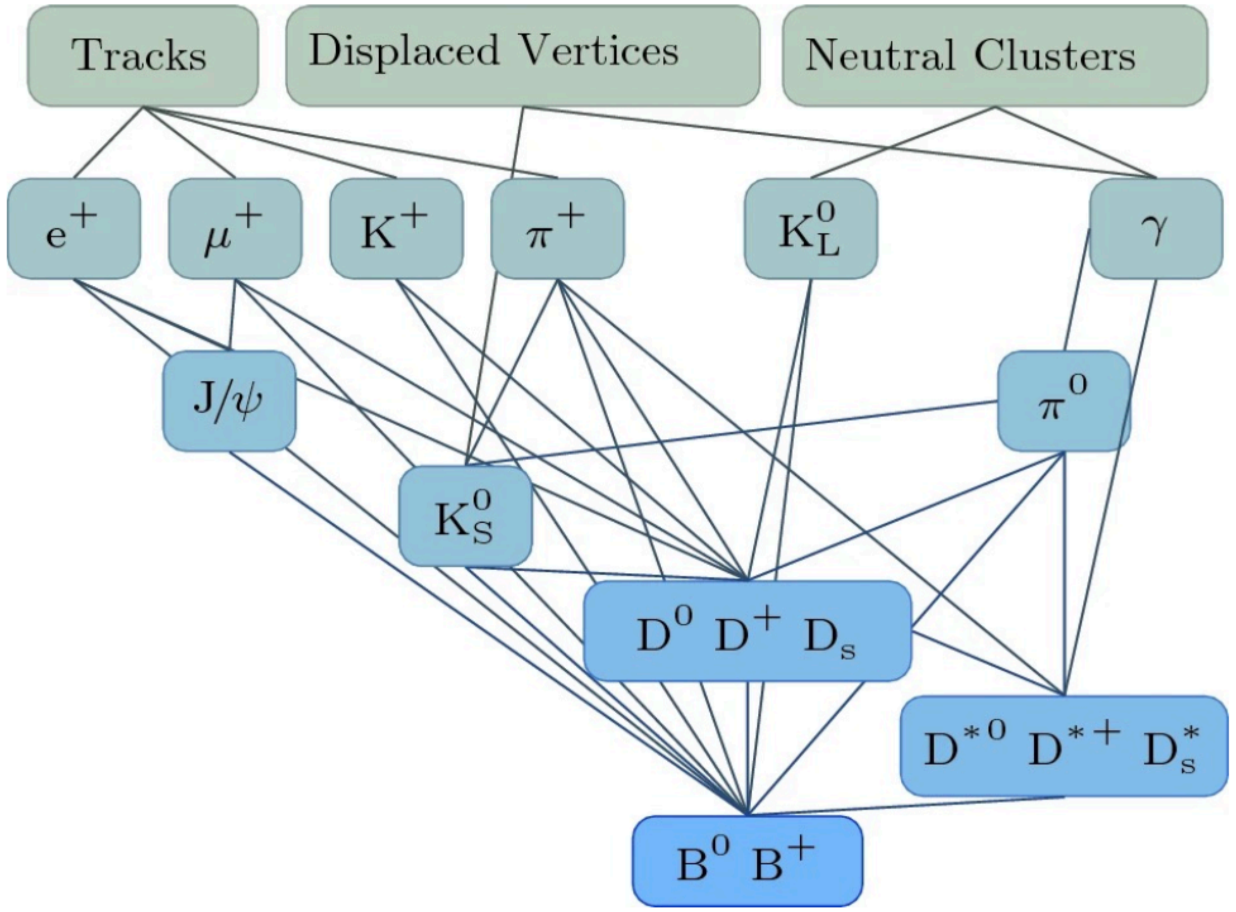
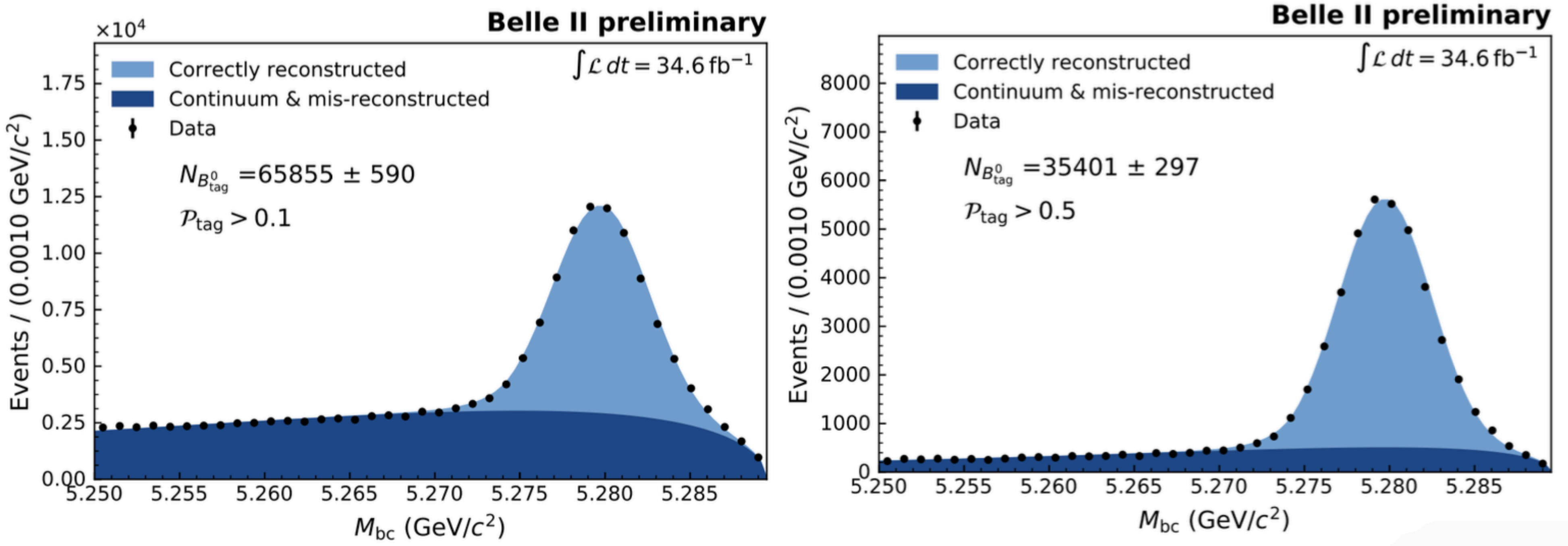


arXiv:2008.060965

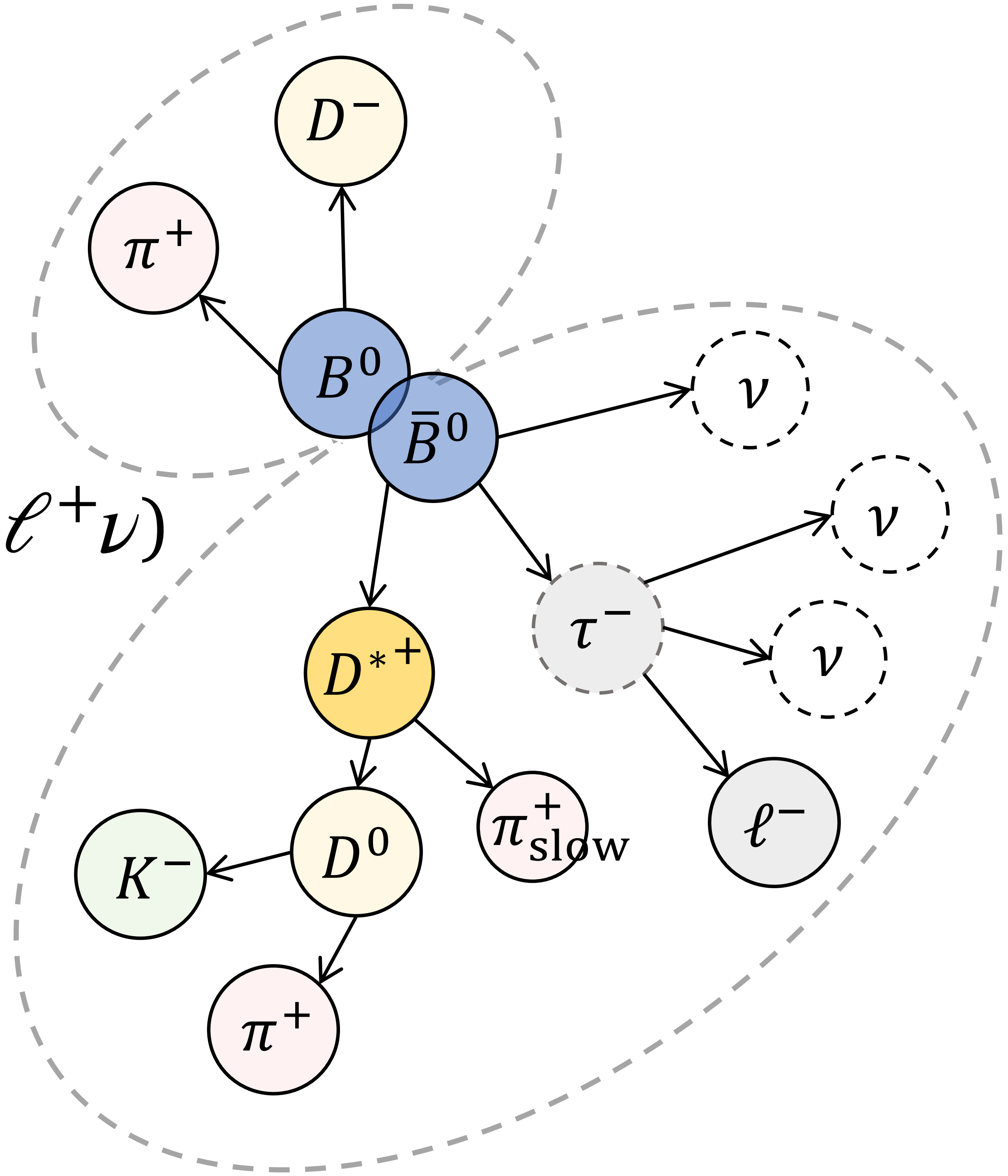


arXiv:2401.02840
PRD *submitted*

$R(D^*)$ from Belle II

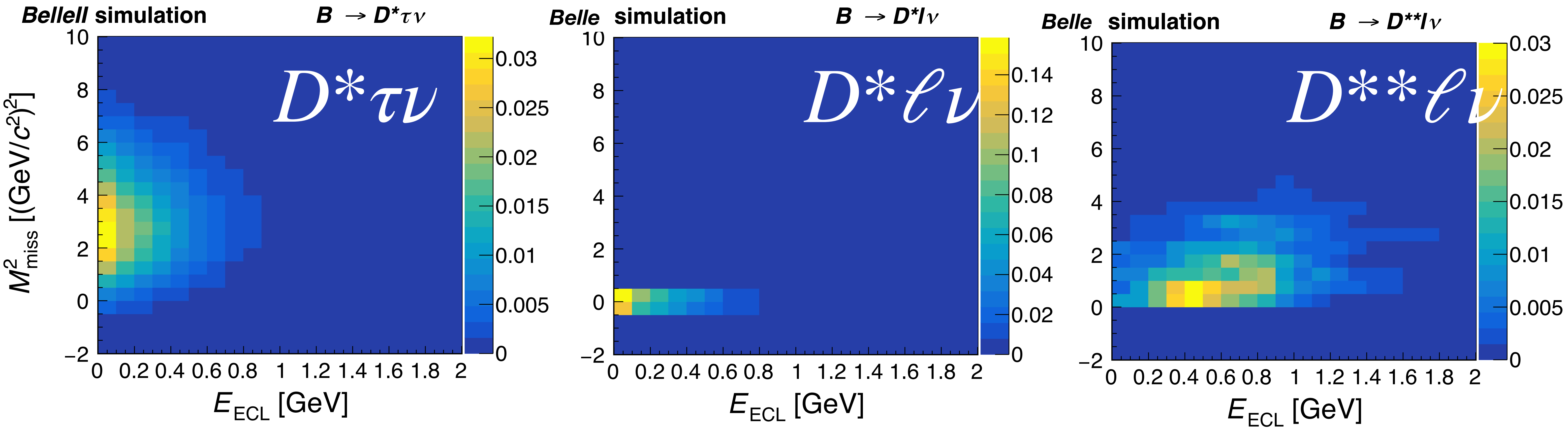
$$R(D^*) \equiv \frac{\mathscr{B}(B \to D^*\tau^+\nu)}{\mathscr{B}(B \to D^*\ell^+\nu)}$$

- First $R(D^*)$ result from Belle II
- Analysis features
  - Use hadronic B-tagging with FEI (slide 34)
  - leptonic τ decays, $\tau^+ \to \ell^+\nu_\ell\bar{\nu}_\tau$
  - three D^* modes: $D^{*+} \to D^0\pi^+$, $D^+\pi^0$ and $D^{*0} \to D^0\pi^0$
- Signal ($B \to D^*\tau^+\nu$) & Normalization ($B \to D^*\ell^+\nu$)
  - extracted simultaneously
  - by fitting 2D $(M^2_{\text{miss}}, E_{\text{ECL}})$



arXiv:2401.02840
PRD *submitted*

$R(D^*)$ from Belle II



- Signal ($B \to D^*\tau^+\nu$) & Normalization ($B \to D^*\ell^+\nu$)
  - extracted simultaneously
  - by fitting 2D $(M^2_{\rm miss}, E_{\rm ECL})$

$$M^2_{\rm miss} \equiv (p_{e^+e^-} - p_{B_{\rm tag}} - p_{D^*} - p_\ell)^2$$

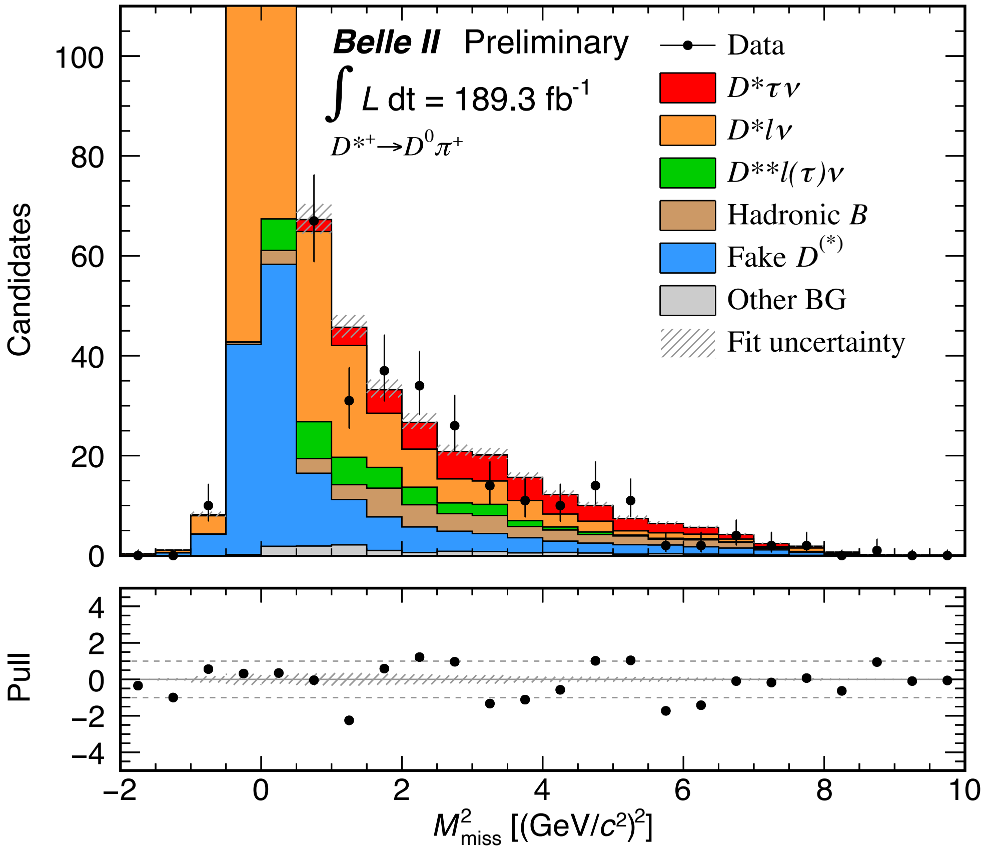
$E_{\rm ECL}$ = extra energy (unmatched) in the EM calorimeter

arXiv:2401.02840
PRD *submitted*

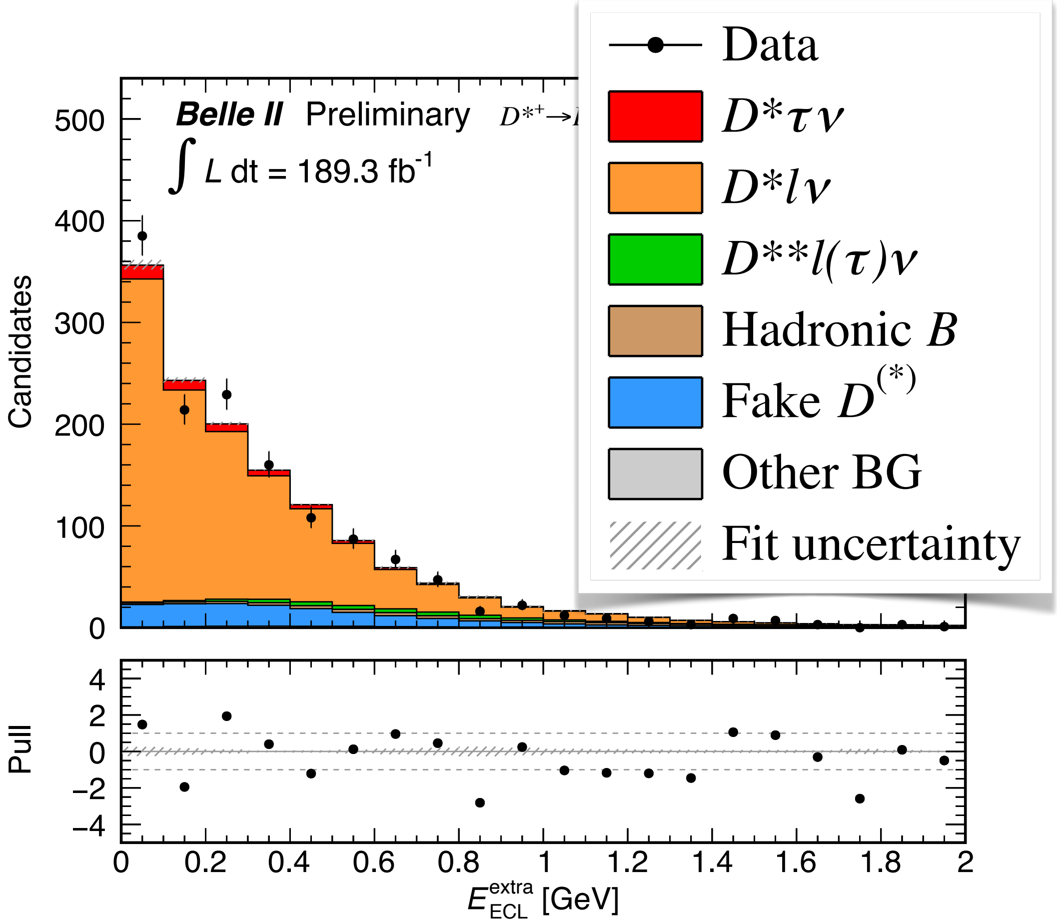
$R(D^*)$ from Belle II

- Fit projections for the sub-mode $D^{*+} \to D^0\pi^+$

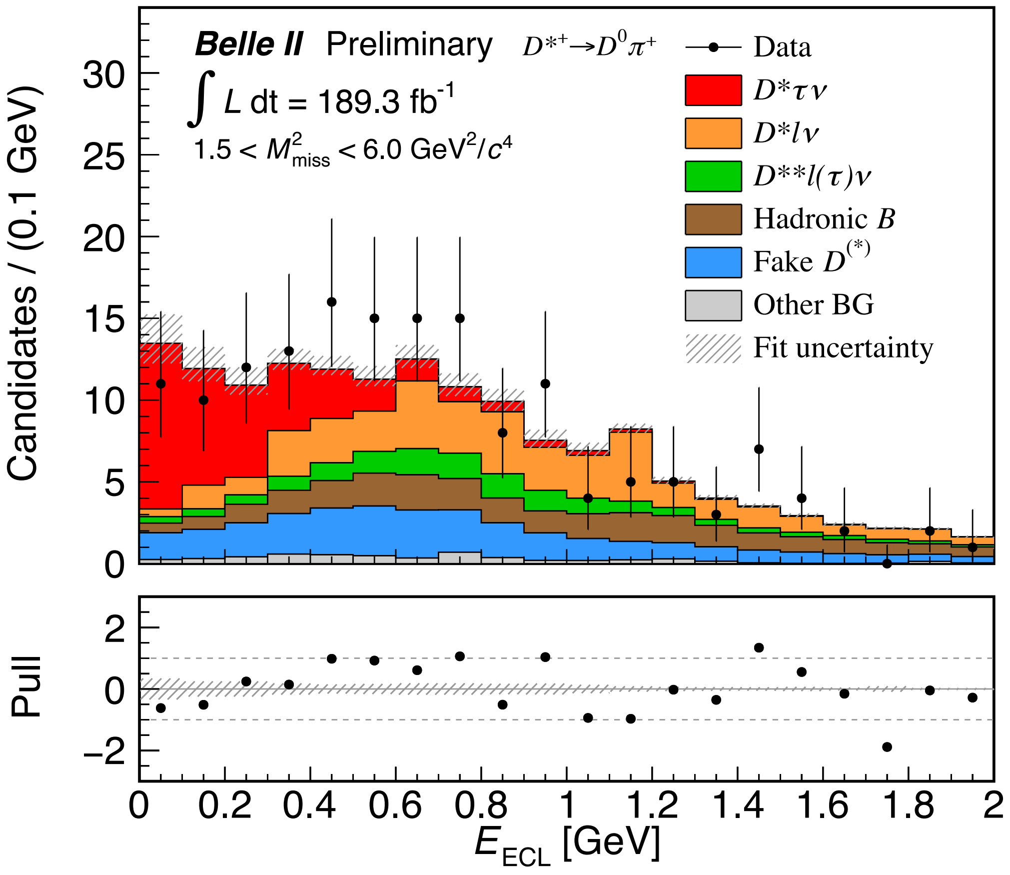
$\mathscr{L}_{\rm int} = 189\ {\rm fb}^{-1}$



$M^2_{\rm miss}$ (peak-bin yield ~O(600))



$E_{\rm ECL}$ for entire $M^2_{\rm miss}$ region



$E_{\rm ECL}$ for signal-enhanced region
$1.5 < M^2_{\rm miss} < 6.0\ {\rm GeV}^2$

$$R(D^*) = 0.262^{+0.041}_{-0.039}{}^{+0.035}_{-0.032}$$

- Systematics
  - dominant sources: $E_{\rm ECL}$ PDF shape, MC statistics

arXiv:2311.14647
PRD *accepted*

some corrections & validations

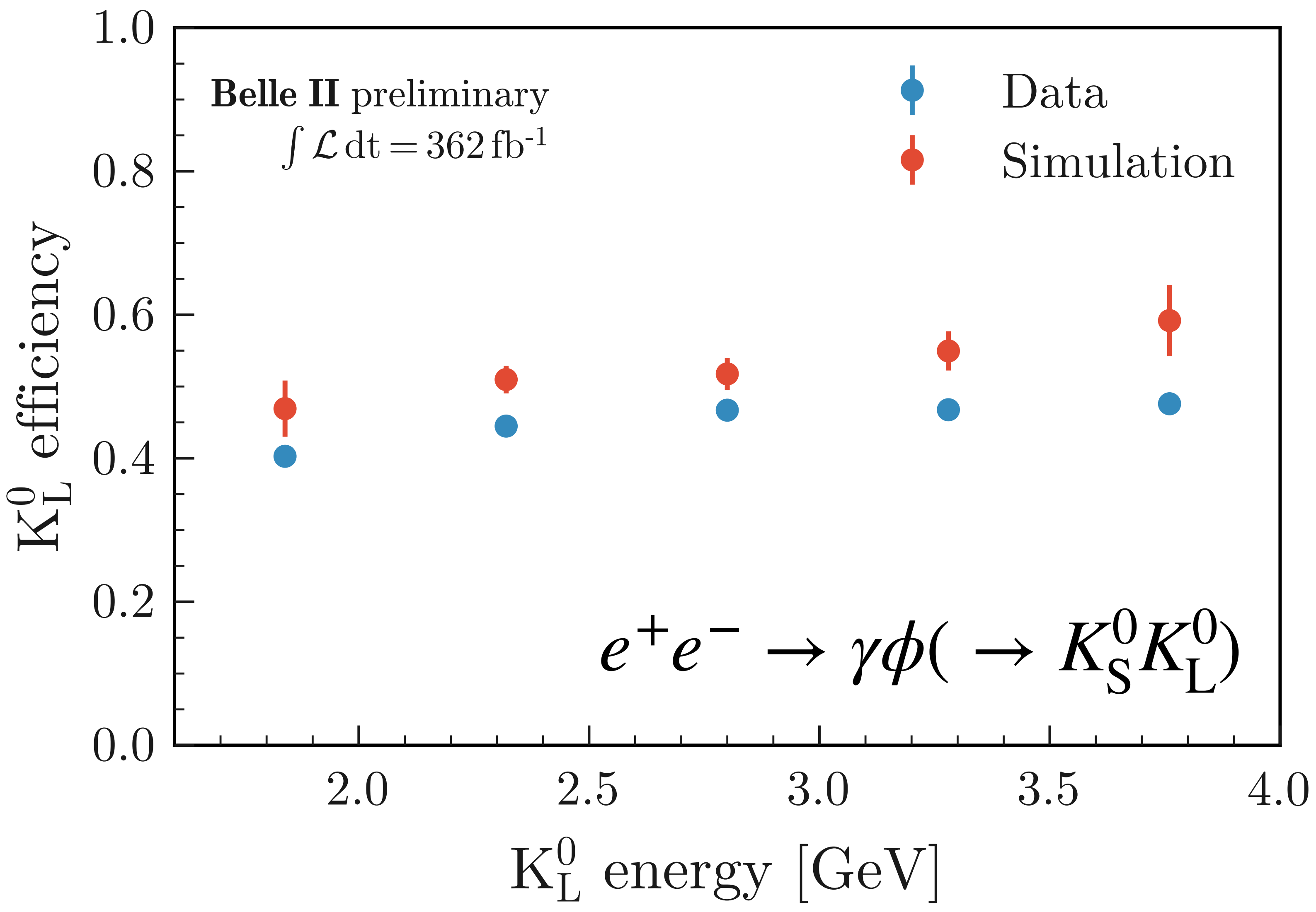


FIG. 4. Efficiency of reconstructing an energy deposit in the ECL matched to the K^0_L direction as a function of the K^0_L energy for data and simulation selected with the ITA analysis.

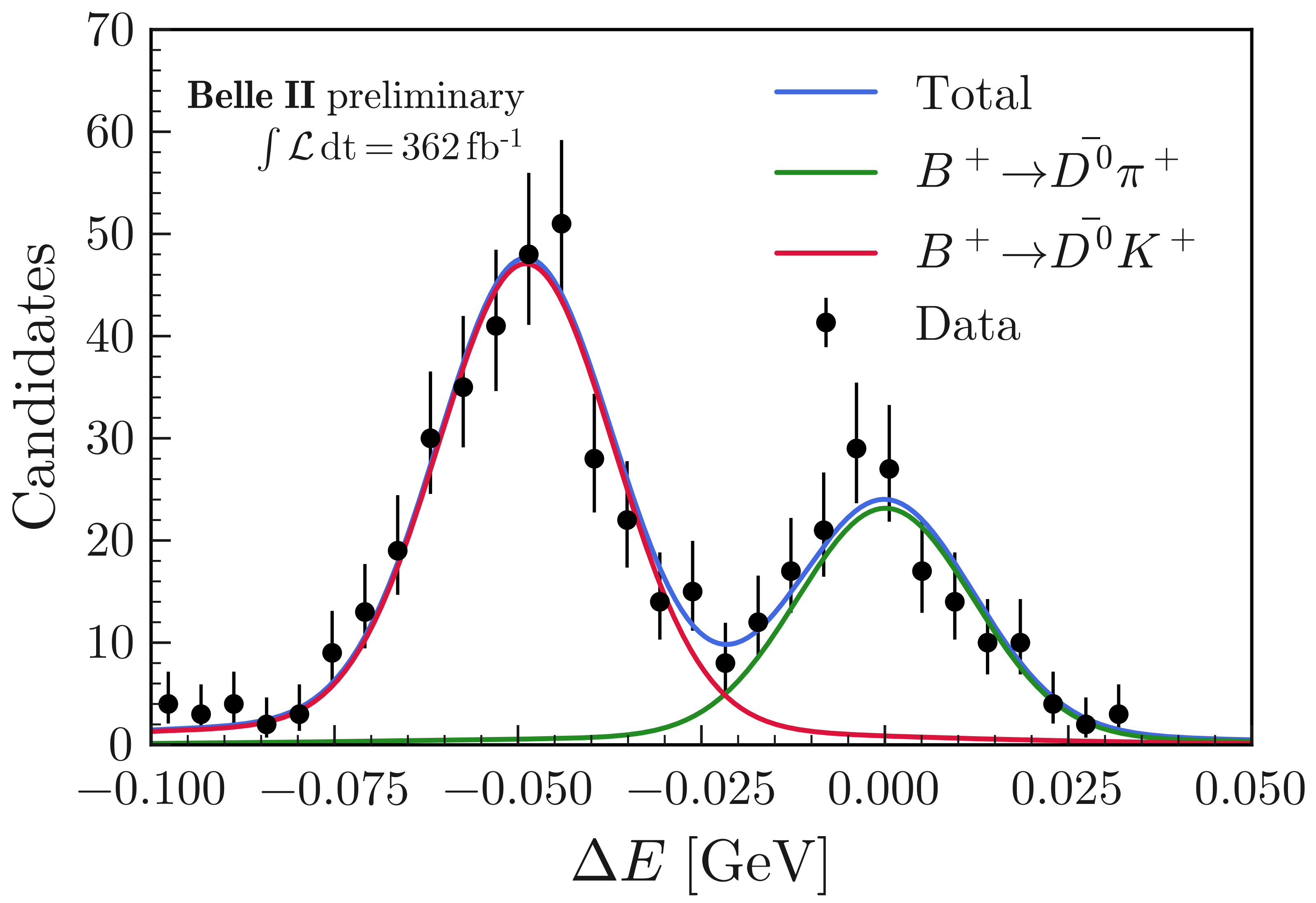
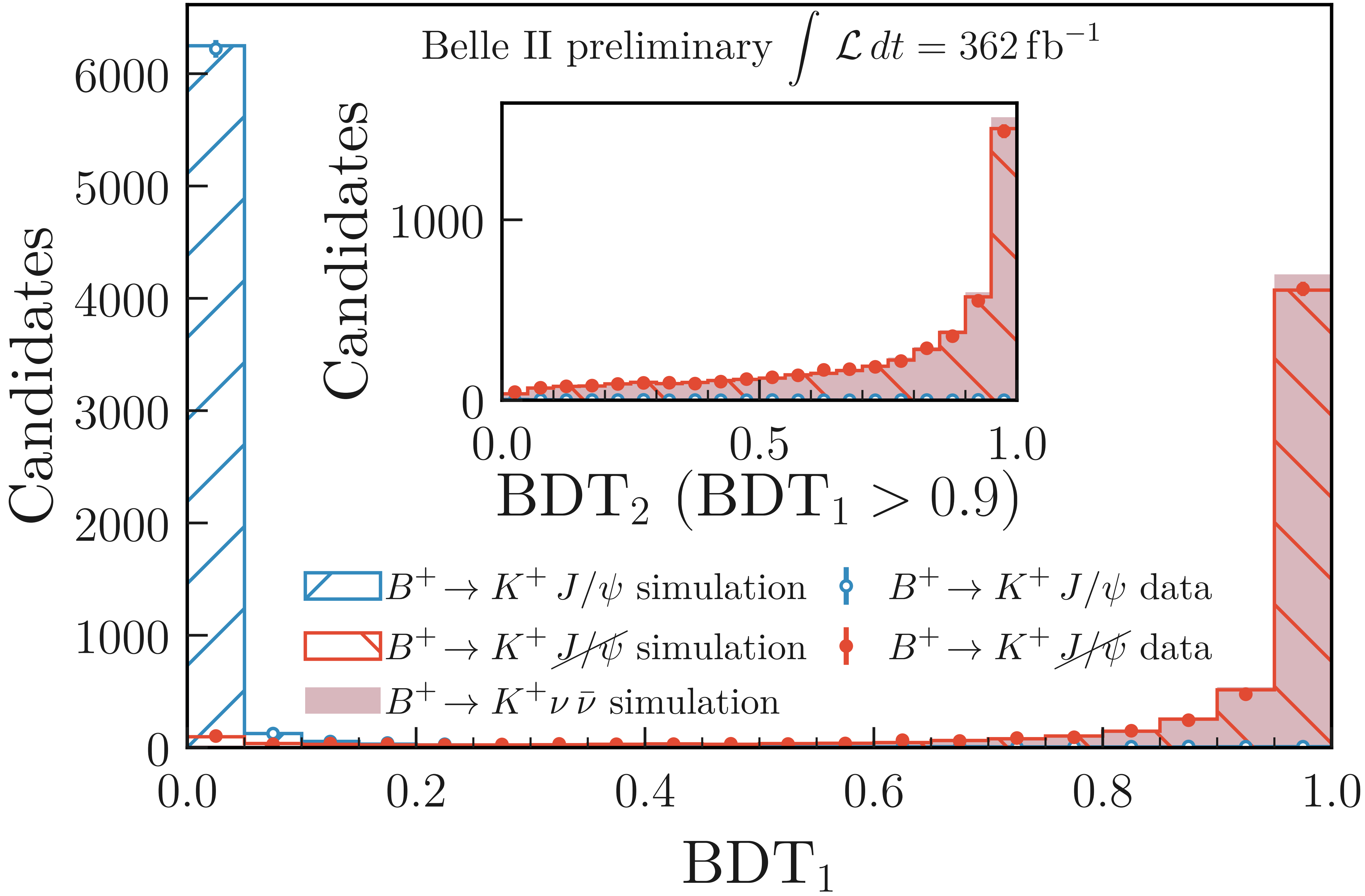


FIG. 22. Distribution of ΔE in data obtained for $B^+ \to (K^+, \pi^+)D^0$ decays reconstructed as $B^+ \to K^+\nu\bar{\nu}$ events with the daughters from the D^0 decays removed.

The relative abundance $\overline{D}^0K^+$ to $\overline{D}^0\pi^+$ for data vs. MC is found to be consistent w/ expectation with 1.03 ± 0.09

Signal efficiency validation (ITA)



in *preparation for* JHEP

Charm baryon decays $\Xi_c^0 \to \Xi^0 h^0$

$(h^0 = \pi^0, \eta, \eta')$

Table 1. Theoretical predictions for the branching fractions and decay asymmetry parameters for $\Xi_c^0 \to \Xi^0 h^0$ decays. Branching fractions are given in units of 10^{-3}.

Reference	Model	$\mathcal{B}(\Xi_c^0 \to \Xi^0\pi^0)$	$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta)$	$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta')$	$\alpha(\Xi_c^0 \to \Xi^0\pi^0)$
Körner, Krämer [5]	quark	0.5	3.2	11.6	0.92
Xu, Kamal [7]	pole	7.7	-	-	0.92
Cheng, Tseng [8]	pole	3.8	-	-	-0.78
Cheng, Tseng [8]	CA	17.1	-	-	0.54
Żenczykowski [9]	pole	6.9	1.0	9.0	0.21
Ivanov *et al.* [6]	quark	0.5	3.7	4.1	0.94
Sharma, Verma [11]	CA	-	-	-	-0.8
Geng *et al.* [12]	$\mathrm{SU}(3)_\mathrm{F}$	4.3 ± 0.9	$1.7^{+1.0}_{-1.7}$	$8.6^{+11.0}_{-6.3}$	-
Geng *et al.* [13]	$\mathrm{SU}(3)_\mathrm{F}$	7.6 ± 1.0	10.3 ± 2.0	9.1 ± 4.1	$-1.00^{+0.07}_{-0.00}$
Zhao *et al.* [14]	$\mathrm{SU}(3)_\mathrm{F}$	4.7 ± 0.9	8.3 ± 2.3	7.2 ± 1.9	-
Zou *et al.* [10]	pole	18.2	26.7	-	-0.77
Huang *et al.* [15]	$\mathrm{SU}(3)_\mathrm{F}$	2.56 ± 0.93	-	-	-0.23 ± 0.60
Hsiao *et al.* [16]	$\mathrm{SU}(3)_\mathrm{F}$	6.0 ± 1.2	$4.2^{+1.6}_{-1.3}$	-	-
Hsiao *et al.* [16]	$\mathrm{SU}(3)_\mathrm{F}$-breaking	3.6 ± 1.2	7.3 ± 3.2	-	-
Zhong *et al.* [17]	$\mathrm{SU}(3)_\mathrm{F}$	$1.13^{+0.59}_{-0.49}$	1.56 ± 1.92	$0.683^{+3.272}_{-3.268}$	$0.50^{+0.37}_{-0.35}$
Zhong *et al.* [17]	$\mathrm{SU}(3)_\mathrm{F}$-breaking	$7.74^{+2.52}_{-2.32}$	$2.43^{+2.79}_{-2.90}$	$1.63^{+5.09}_{-5.14}$	$-0.29^{+0.20}_{-0.17}$
Xing *et al.* [18]	$\mathrm{SU}(3)_\mathrm{F}$	1.30 ± 0.51	-	-	-0.28 ± 0.18