

MENU 2026

The 17th International Conference on Meson-Nucleon Physics and the Structure of the Nucleon

Recent results from Belle II

Carnegie Mellon University

Oct 21, 2026

Renu
(On behalf of the Belle II collaboration)
Supported by DOE funding

**Carnegie
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Outline

- Belle II at SuperKEKB: physics program, detector and data sample
- **Time dependent CP violation:** Photon helicity in radiative B decays and the CKM angle ϕ_2
- **Semileptonic decays:** Lepton flavor universality and determination of $|V_{ub}|$
- **Electroweak penguin decays:** Searches for $B \rightarrow K\tau^+\tau^-$
- **Charm physics:** Hadron structure and CP violation
- Summary and outlook

Belle II physics program

Primarily a **B factory**; But not only B physics!

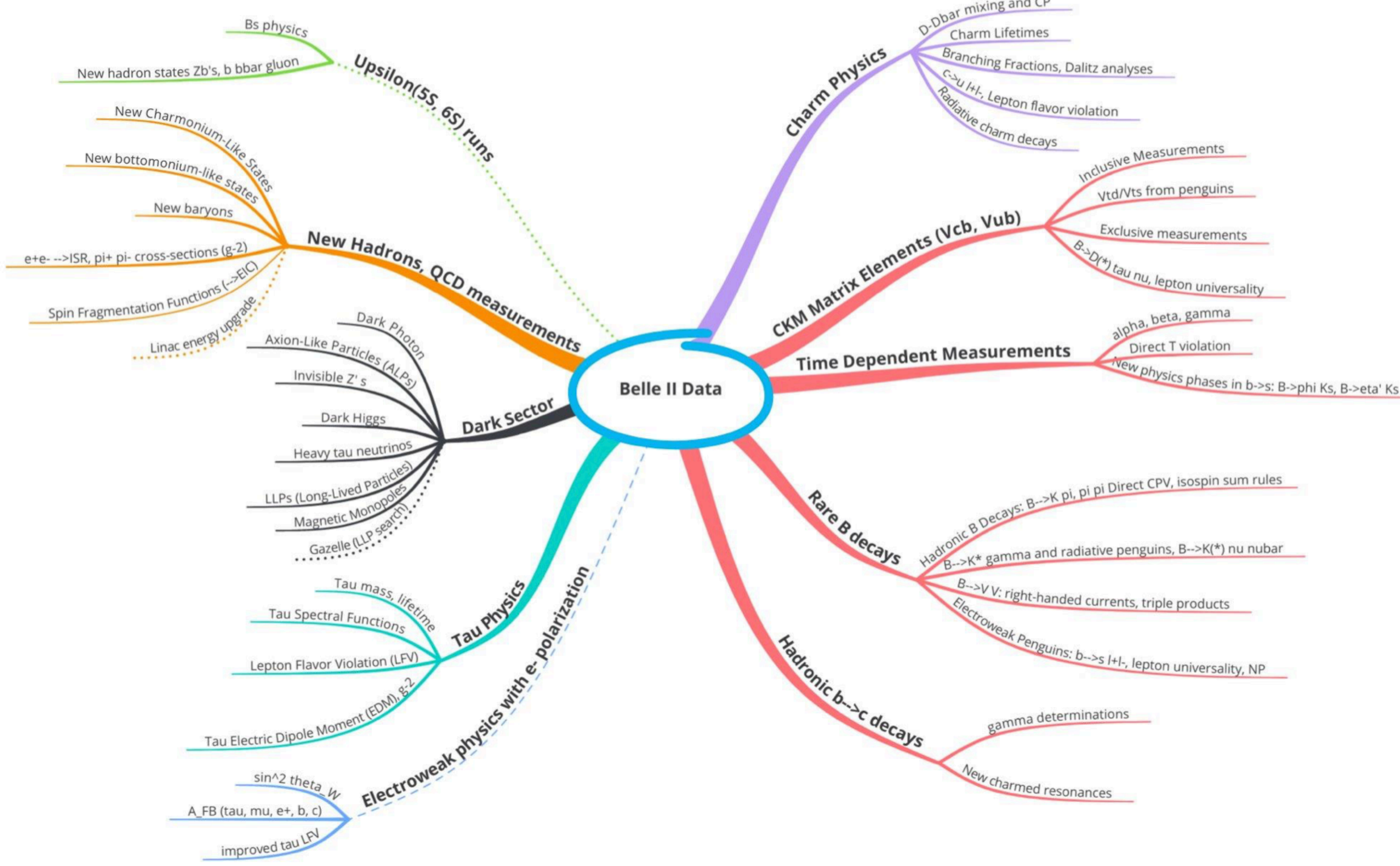
- Also **tau**, **charm** factories
- Clean background for **spectroscopy** and searching for **dark sector**

Various types of analyses:

- Well-suited for decays with missing energy and missing mass
- Lifetime, time-dependent measurement

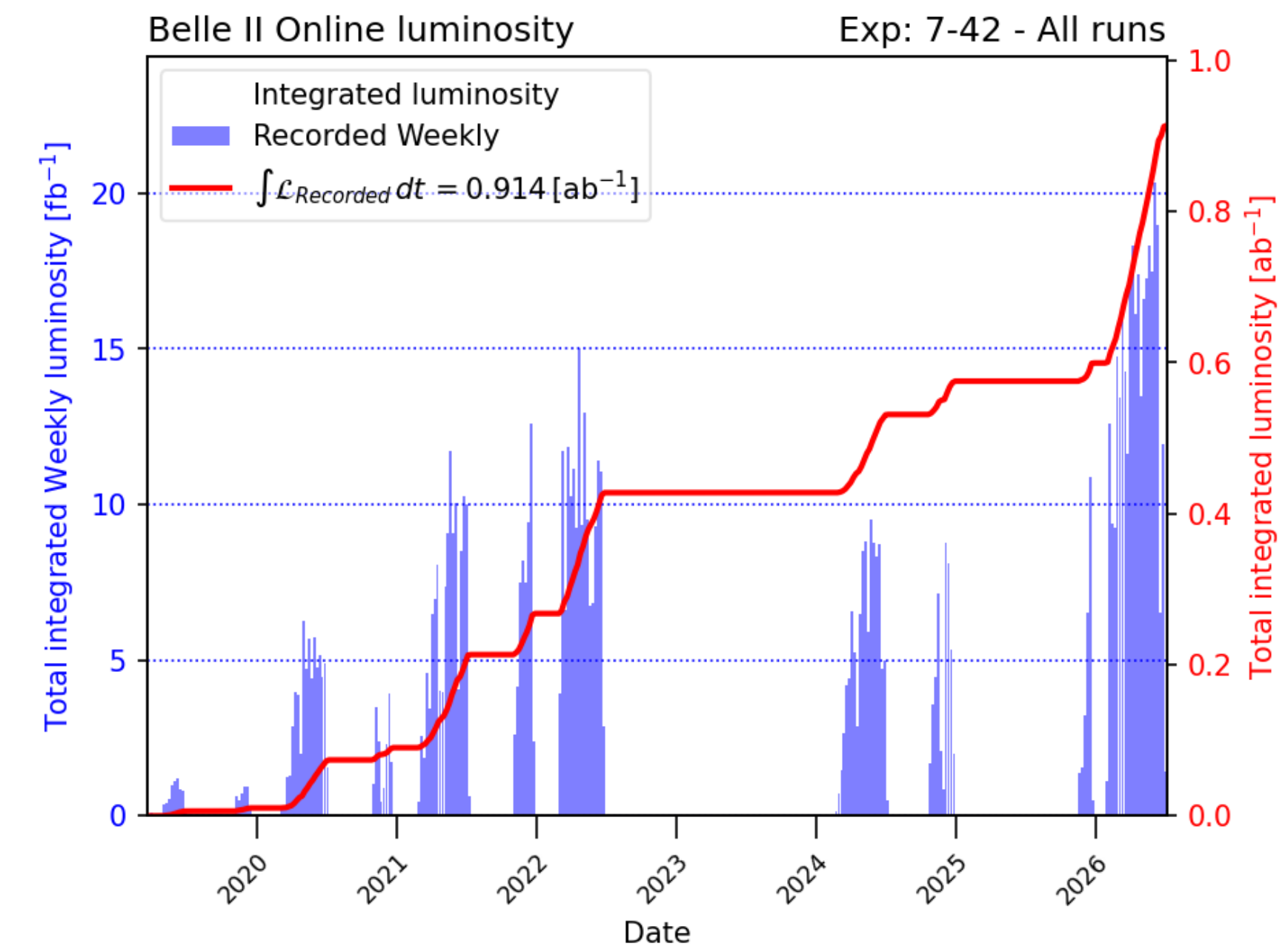
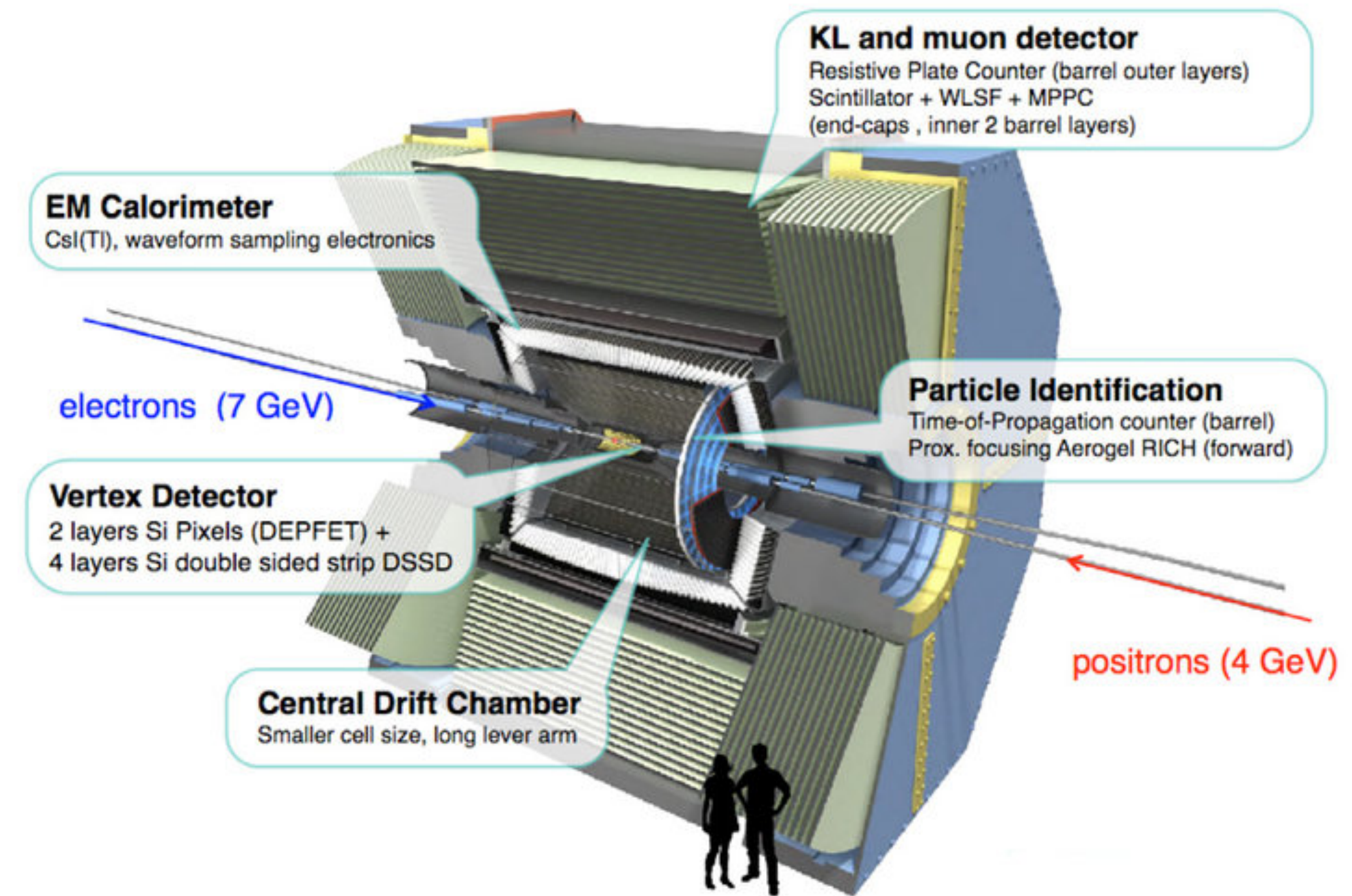
$e^+e^- \rightarrow$	Cross section [nb]
$\Upsilon(4S)$	1.05 ± 0.10
$c\bar{c}$	1.30
$s\bar{s}$	0.38
$u\bar{u}$	1.61
$d\bar{d}$	0.40
$\tau^+\tau^-(\gamma)$	0.919
$\mu^+\mu^-(\gamma)$	1.148
$e^+e^-(\gamma)$	300 ± 3

Diversified physics program



Data sample and detector

- **SuperKEKB**
 - Nanobeam scheme increases the instantaneous luminosity by factor 30 to collect multi-ab⁻¹ sample.
 - World-record instantaneous luminosity of $5.319 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ reached in June 2026
 - Target $6 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
- **Belle II detector**
 - Nearly hermetic coverage with precise vertexing and charged-particle tracking.
 - Excellent particle identification and efficient reconstruction of photons and neutral mesons.
 - Beam-background control is essential for operation at higher luminosity.
- **Data sample**
 - **Run 1** (2019 - 2022): 365 fb⁻¹ at $\Upsilon(4S)$ + 42 fb⁻¹ just below the $\Upsilon(4S)$ resonance for background studies.
 - **Run 2** (2024 - present): + ~549 fb⁻¹ at $\Upsilon(4S)$
 - **Combined $\Upsilon(4S)$ data:** ~914 fb⁻¹, exceeding Belle's $\Upsilon(4S)$ data.



B -physics at $\Upsilon(4S)$

Belle II operates at an e^+e^- collider running at the $\Upsilon(4S)$, which provides a clean environment to study B meson decays.

- **Advantages:**

- Low particle multiplicity supports efficient reconstruction of neutral particles.
- Known initial-state kinematics allow missing-momentum reconstruction for decays with neutrinos.
- Coherent $B^0\bar{B}^0$ production enables time-dependent CP studies.
- An inclusive trigger retains nearly all B decays.

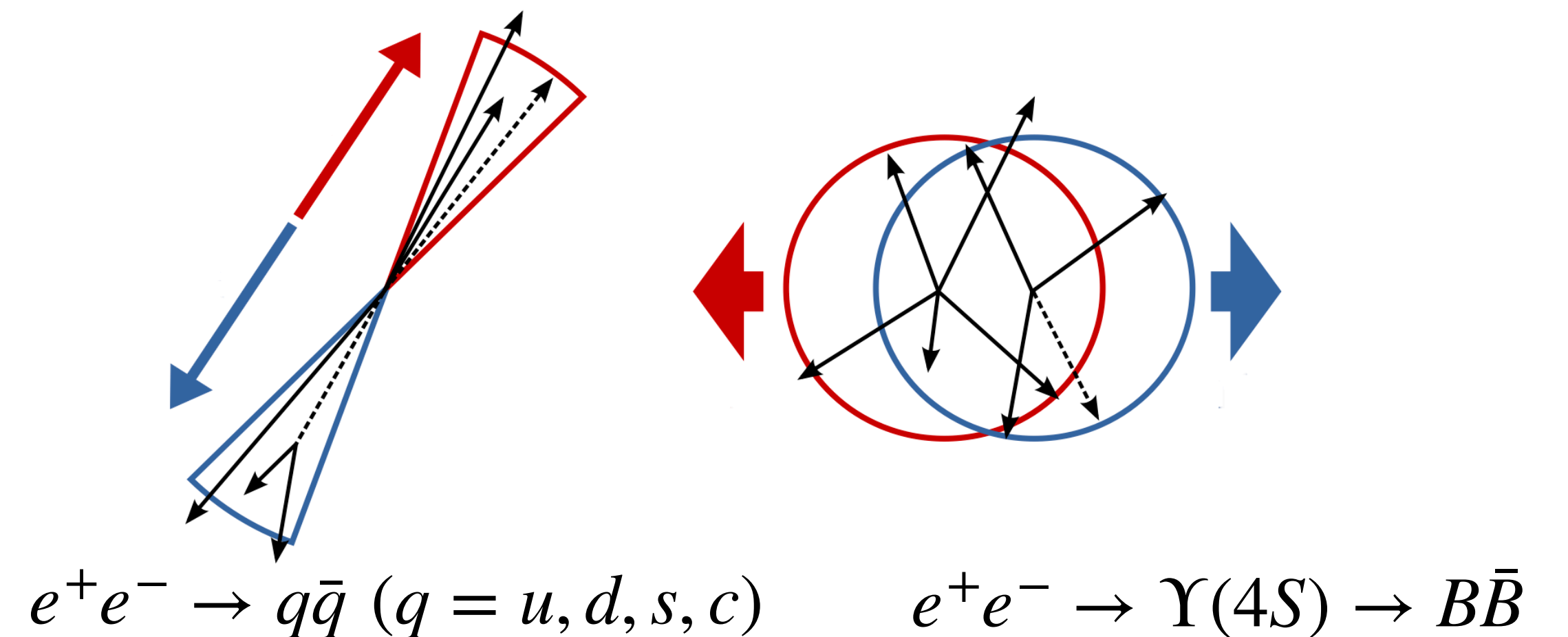
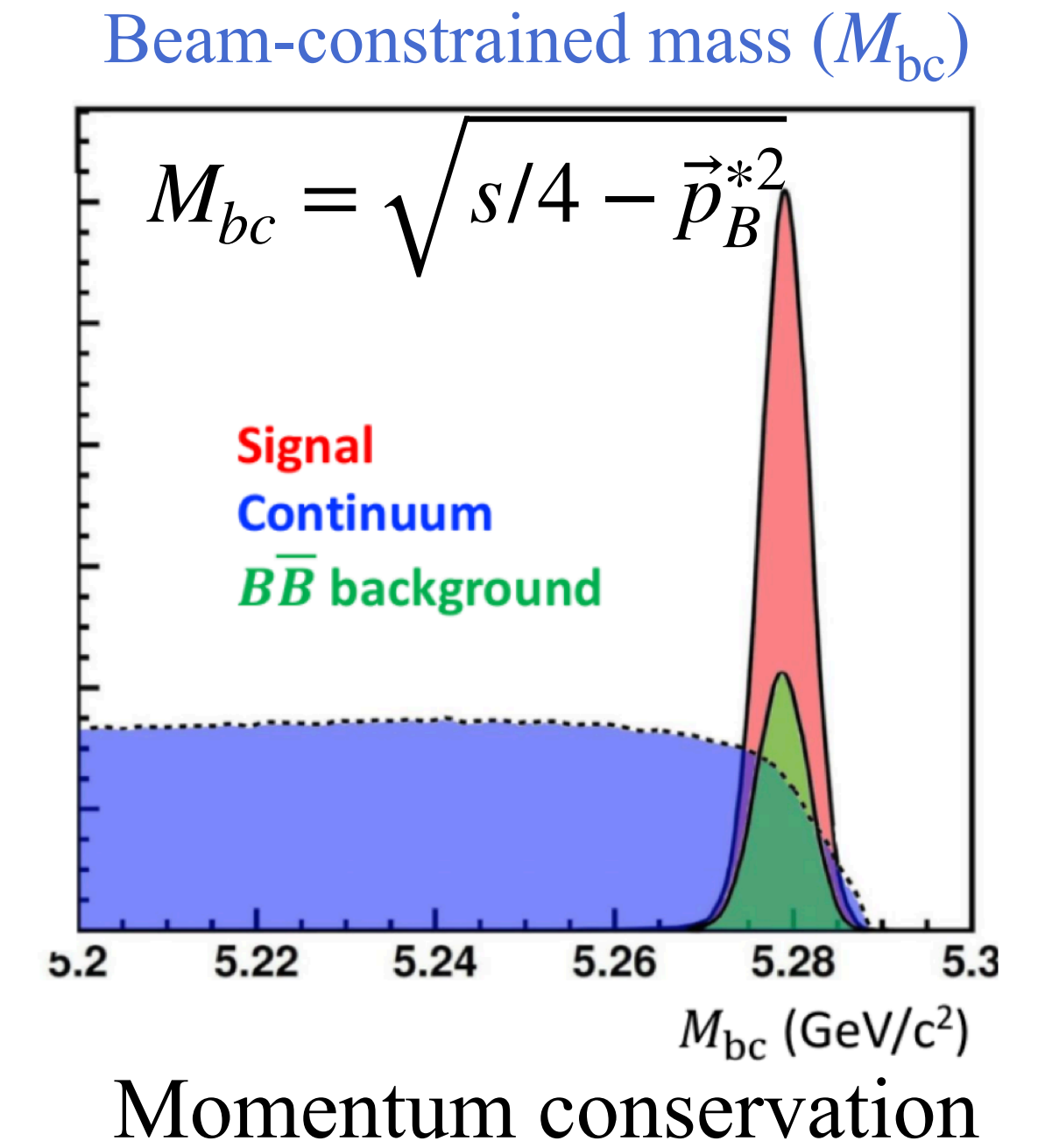
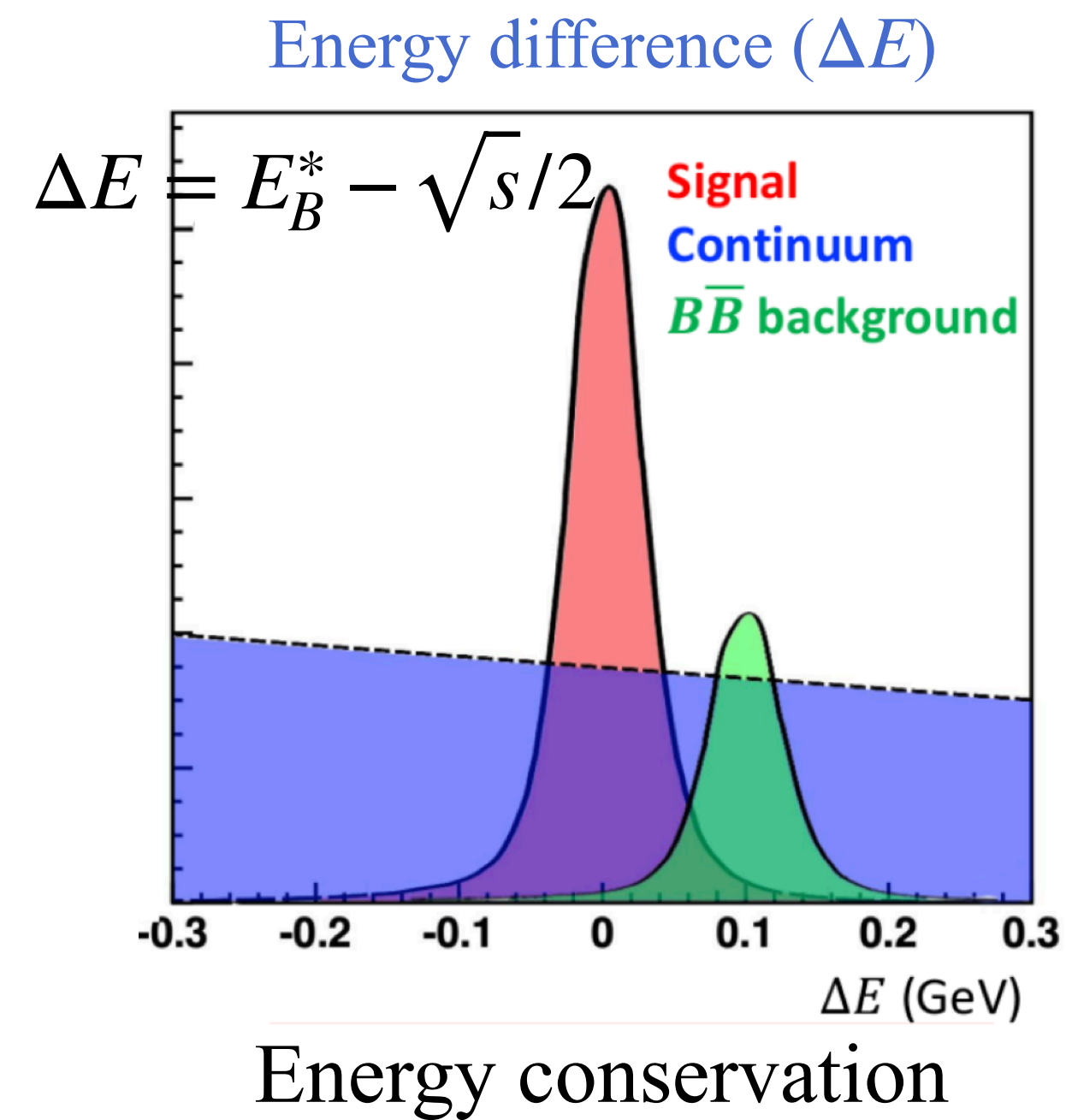
- **Disadvantages:**

- B production rates are much lower than at hadron colliders.
- At the $\Upsilon(4S)$, no B_s , B_c , or Λ_b are produced.

Today's talk highlights Belle II's strengths in studying decays with neutral particles and neutrinos.

Kinematics and Continuum Suppression

- **Collisions at the $\Upsilon(4S)$**
 - $\sqrt{s} = 10.58 \text{ GeV} \approx 2m_B$: $B\bar{B}$ pairs are produced nearly at rest in the center-of-mass frame.
 - Precisely known beam energy constrains B -candidate kinematics through ΔE and M_{bc} .
- **Continuum $q\bar{q}$ events:** back-to-back jets produce a jet-like topology.
- **$B\bar{B}$ events:** B mesons are nearly at rest in the c.m. frame, giving a more spherical event topology.
- **Multivariate classifiers** combine event-shape variables, such as thrust and Fox-Wolfram moments, to suppress continuum.

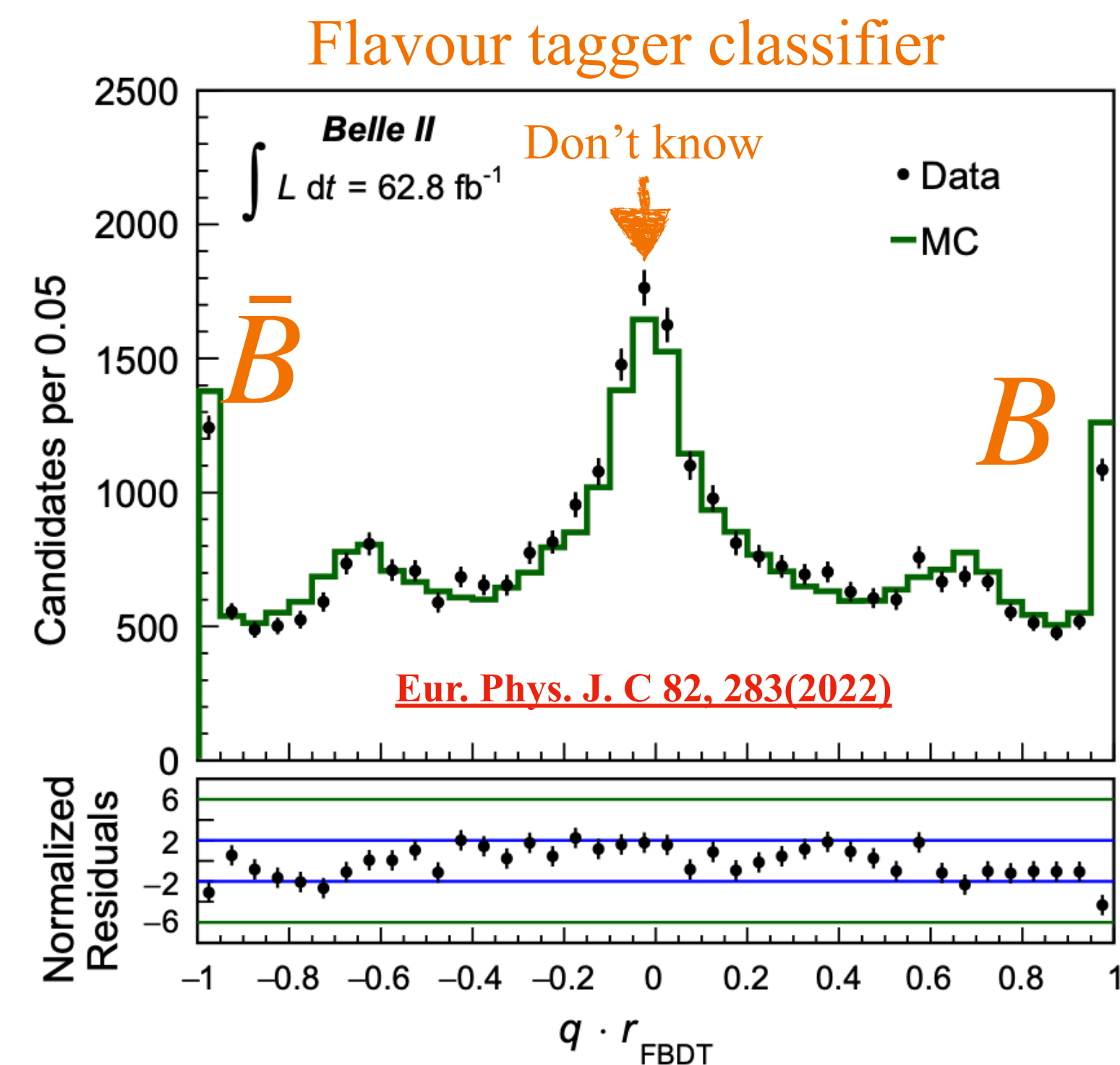
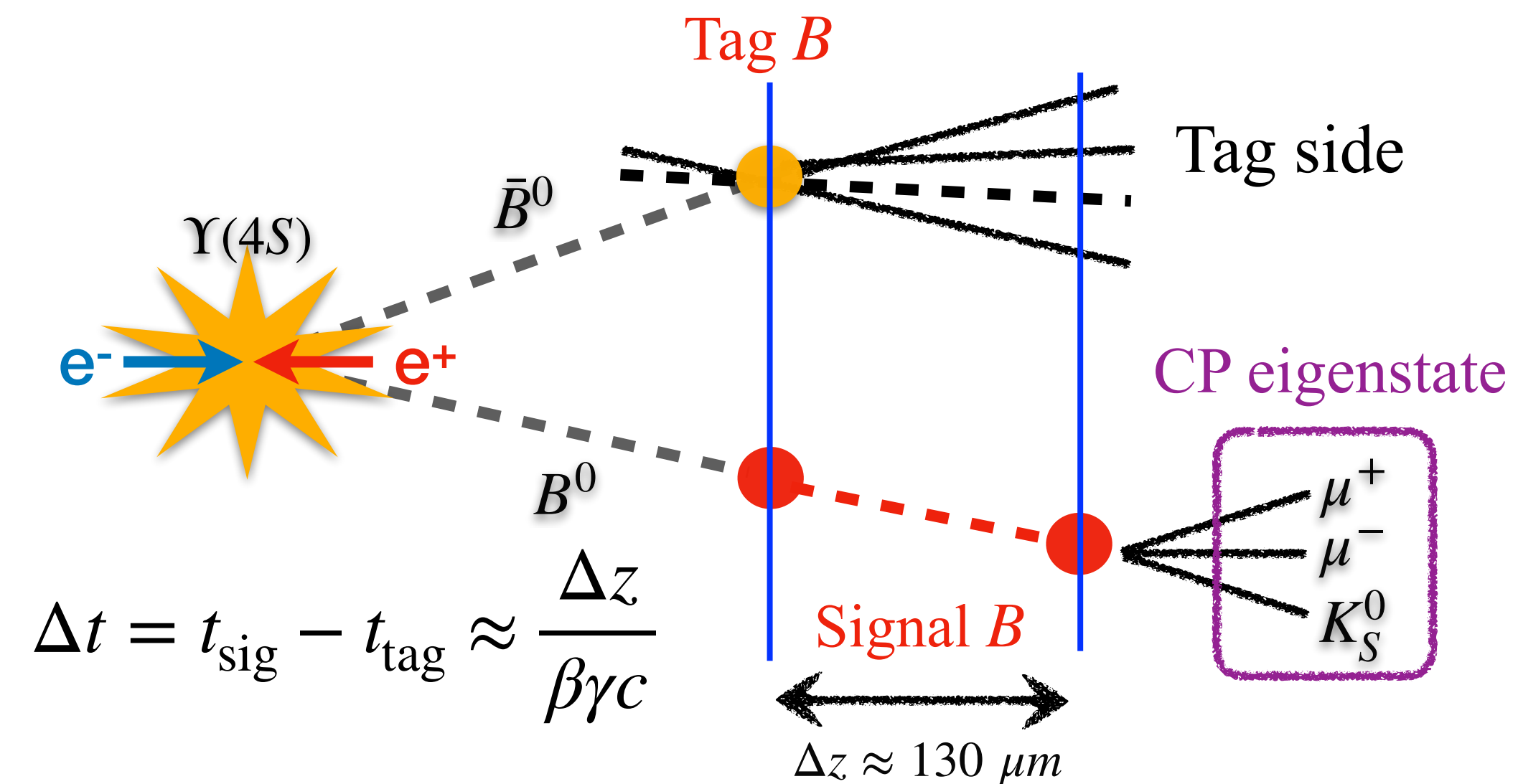


Time-dependent CP violation

Photon polarization and the CKM angle ϕ_2

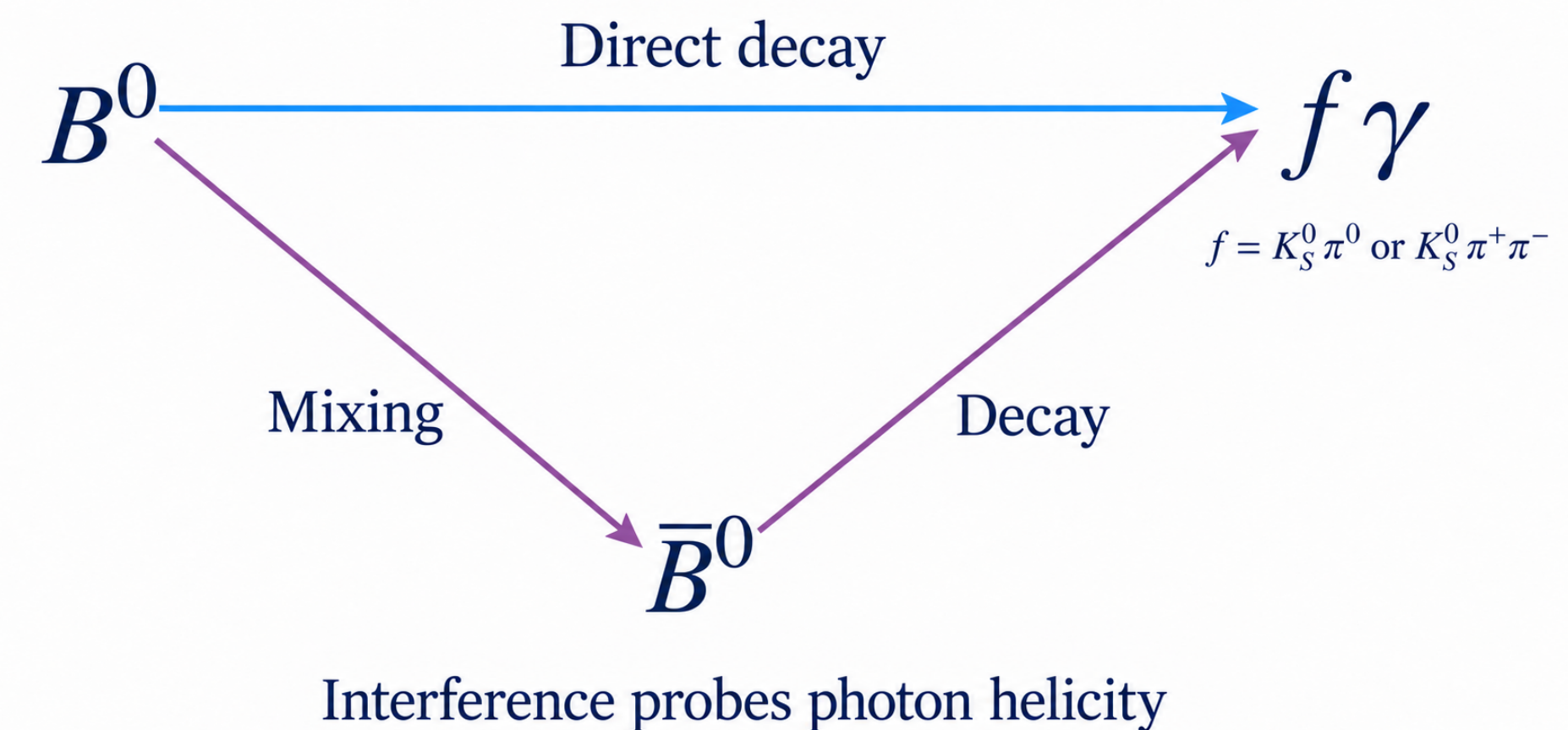
Time-dependent CP violation

- At the $\Upsilon(4S)$, neutral B mesons are produced as a quantum-correlated $B^0\bar{B}^0$ pair.
- Reconstruct the **signal B** in a final state accessible to both B^0 and $\bar{B}^0$.
- Identify the flavor of the **tag B** using its decay products.
- Asymmetric beam energies boost the $B\bar{B}$ system, allowing precise vertex reconstruction to determine the decay-time difference.
- Fit the flavor-dependent Δt distributions to extract the **mixing-induced CP parameter S** and **direct CP parameter C** .



Probing photon helicity with time-dependent CP violation

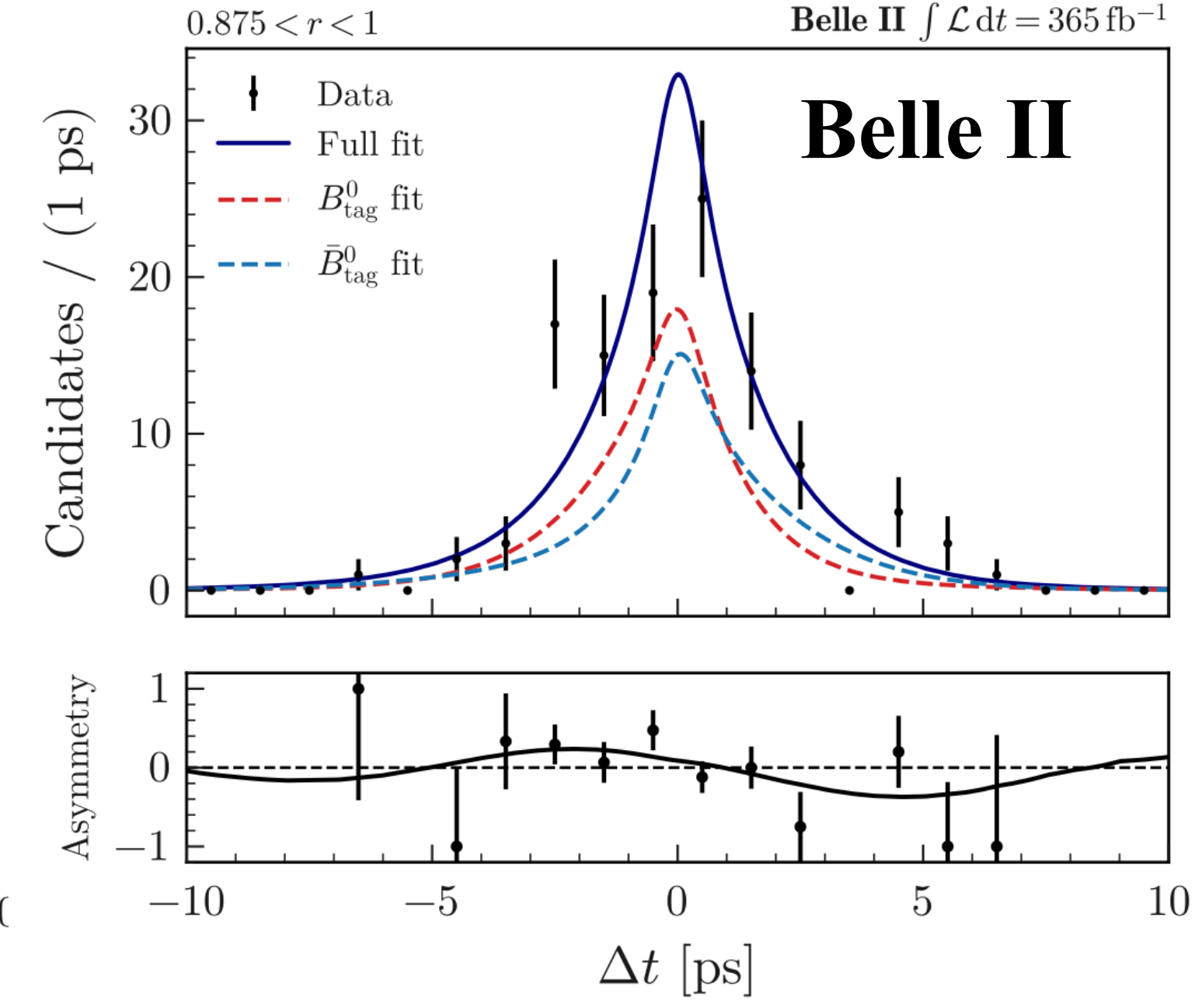
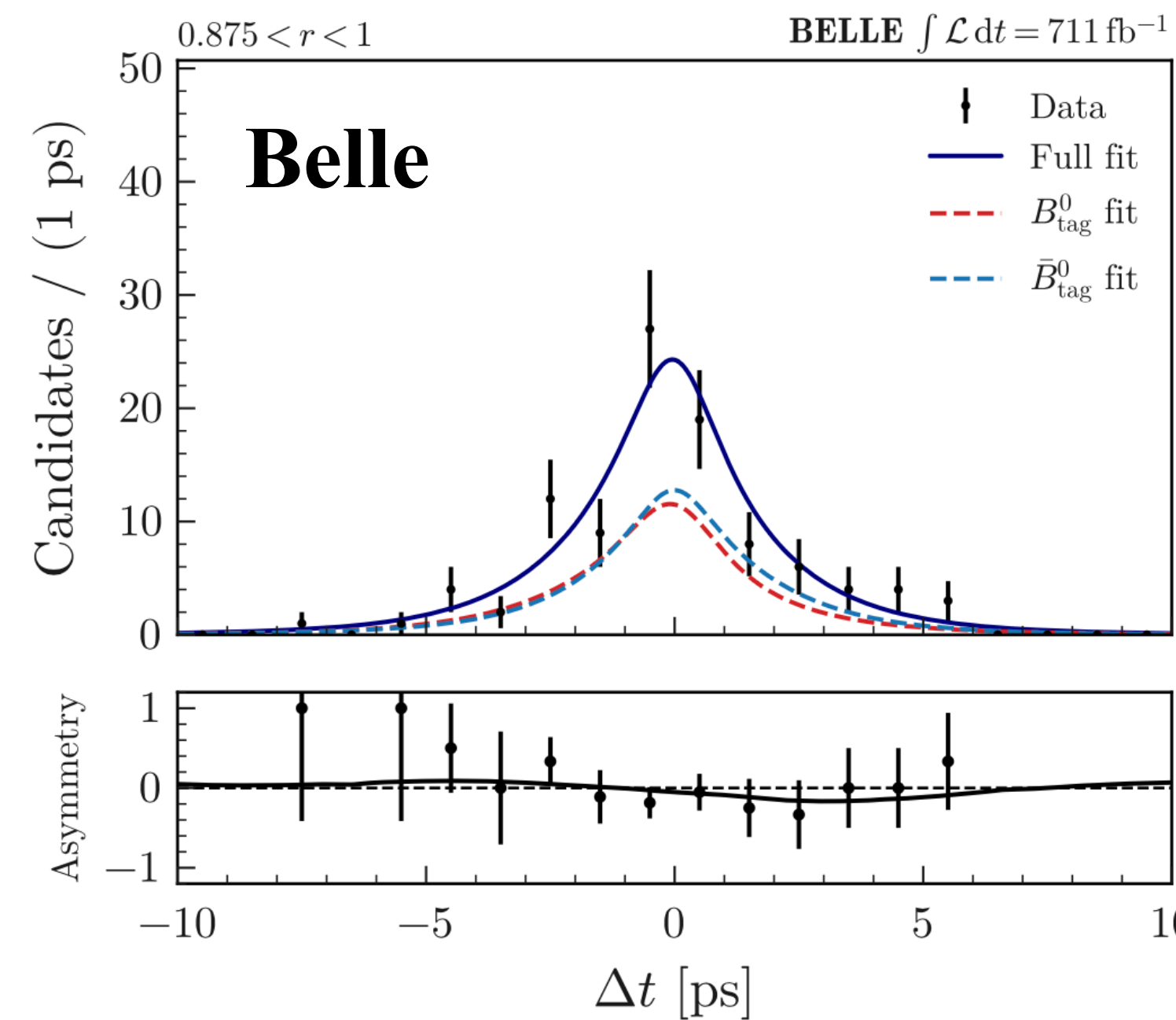
- Radiative $b \rightarrow s\gamma$ decays are sensitive to new physics.
- The **Standard Model** predicts predominantly **left-handed photons**
 - the right-handed amplitude suppressed by m_s/m_b , leading to small mixing-induced CP asymmetries.
- **New physics** could enhance the right-handed amplitude and produce a larger asymmetry.
- **Method:** measure the decay-time difference between the signal B and the flavor-tagged B meson.
- Belle and Belle II studied this through:
 - $B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma$
 - $B^0 \rightarrow K_S^0 \pi^0 \gamma$



Time-dependent CP violation in $B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma$

[arXiv:2510.01331v2](https://arxiv.org/abs/2510.01331v2)

- **Data:** Belle 711 fb⁻¹ + Belle II 365 fb⁻¹
- Decay proceeds through intermediate resonances: $B^0 \rightarrow K_{\text{res}} \gamma \rightarrow K_S^0 \pi^+ \pi^- \gamma$.
- Contributions such as $K^{*\pm} \pi^\mp$ are not CP eigenstates and dilute the sensitivity to $S_{K_S^0 \rho^0 \gamma}$.
- 3D unbinned maximum-likelihood fit to M_{bc} , ΔE , and Δt
 - extracts S and C .



$$S = -0.29 \pm 0.11_{\text{stat}} \pm 0.05_{\text{syst}}$$

$$C = -0.17 \pm 0.09_{\text{stat}} \pm 0.04_{\text{syst}}$$

Uncertainties are statistically dominated

Most precise determination of S in any $b \rightarrow s\gamma$ transition
 Improves uncertainty on S and C by at least a factor of 2 vs. previous measurements

[PRL.101.251601](https://arxiv.org/abs/2510.01331v2)

[PRD.93.052013](https://arxiv.org/abs/2510.01331v2)

Time-dependent CP violation in $B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma$

[arXiv:2510.01331v2](https://arxiv.org/abs/2510.01331v2)

- Two new observables, S^+ and S^- , defined in halves of the Dalitz plane
 - Provide further constraints on the photon polarization

[JHEP 09 \(2019\) 034](#)

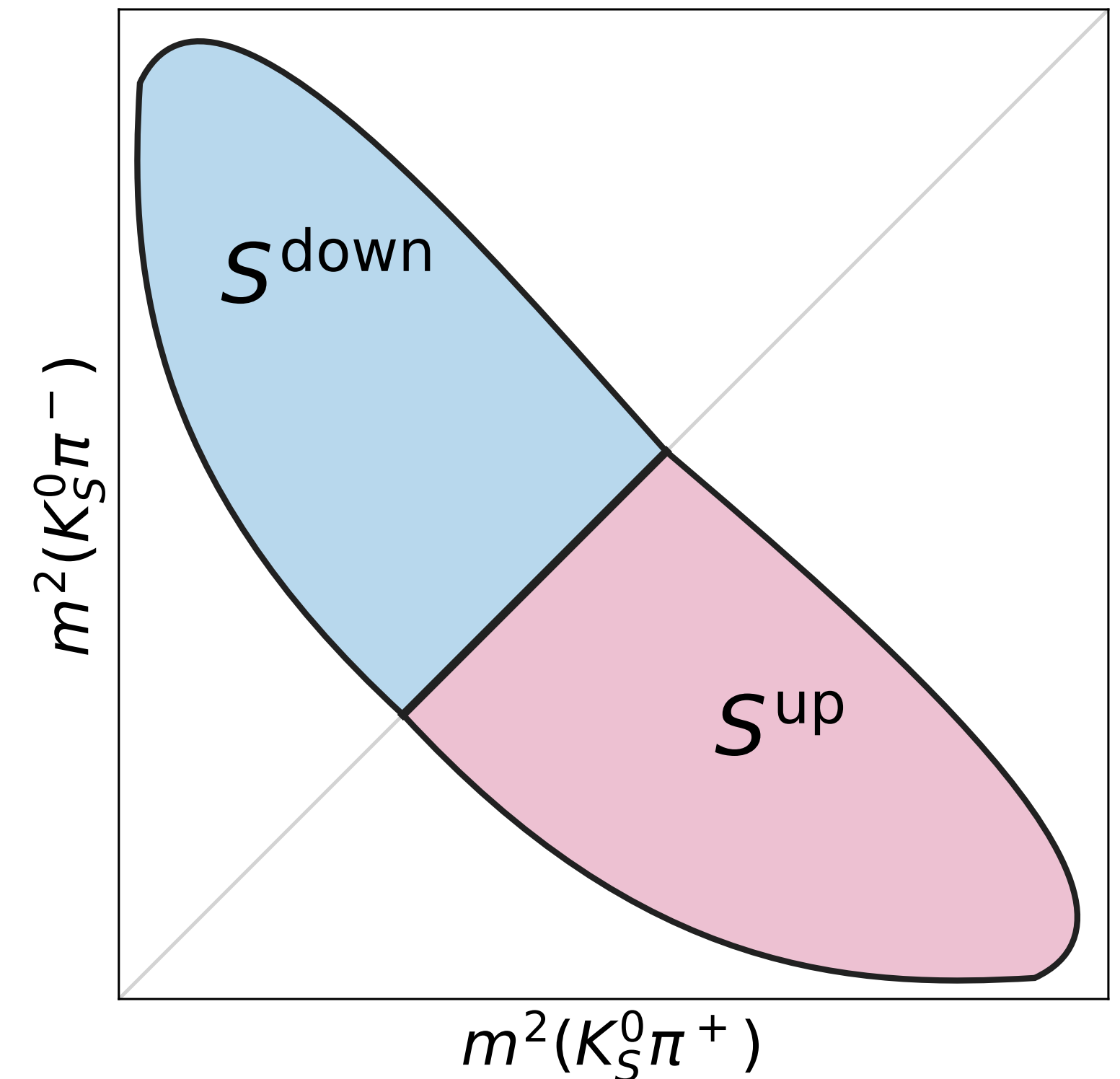
$$S^+ = S_{\text{up}} + S_{\text{down}}, \quad S^- = S_{\text{up}} - S_{\text{down}}.$$

- Uncertainties are statistically dominated.

$$S^+ = -0.57 \pm 0.23_{\text{stat}} \pm 0.10_{\text{syst}}$$

$$S^- = 0.31 \pm 0.24_{\text{stat}} \pm 0.05_{\text{syst}}$$

- First measurement of CP parameters S^+ and S^- .
- Further constrain new-physics models with enhanced right-handed currents in $B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma$ transition.



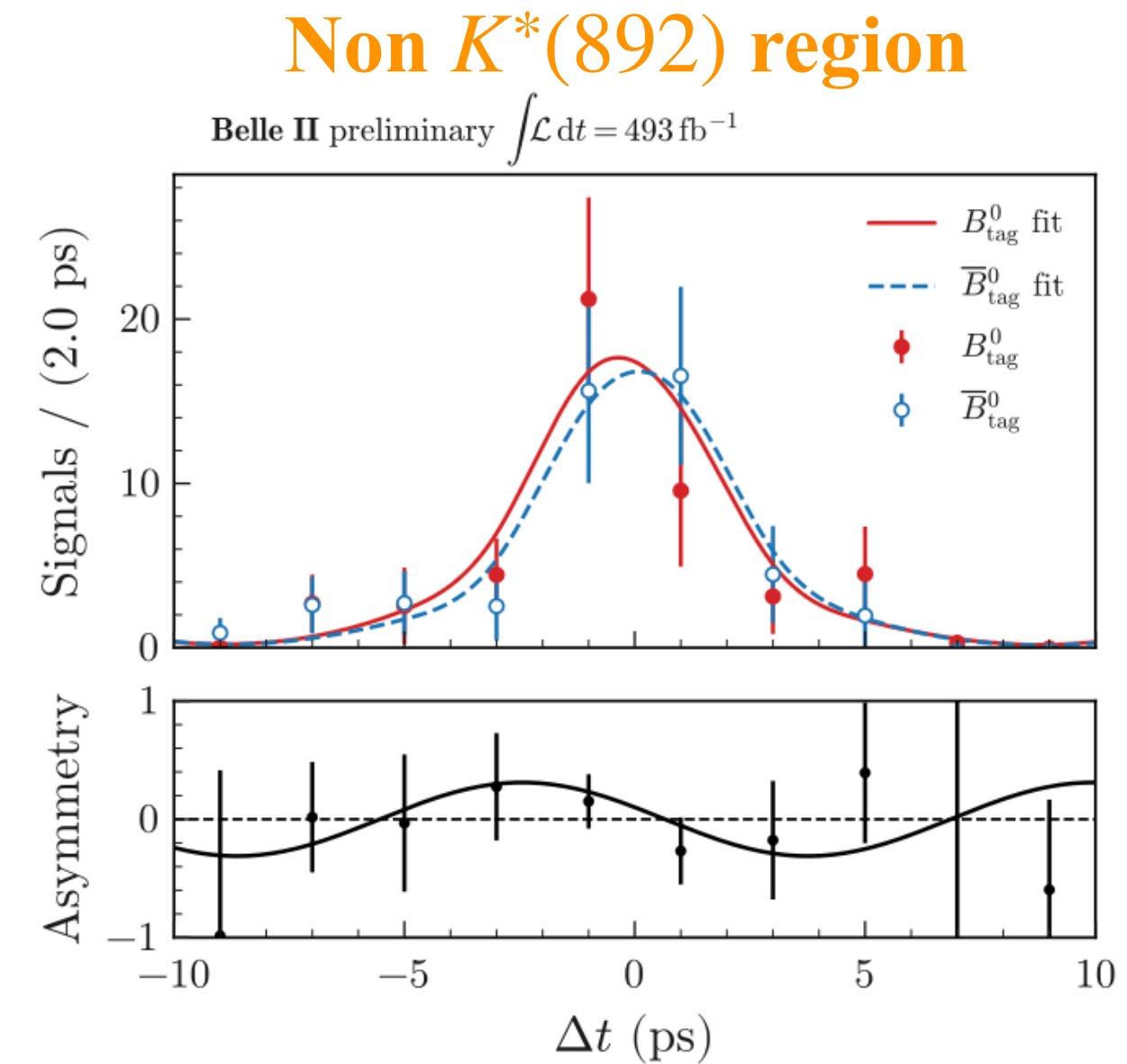
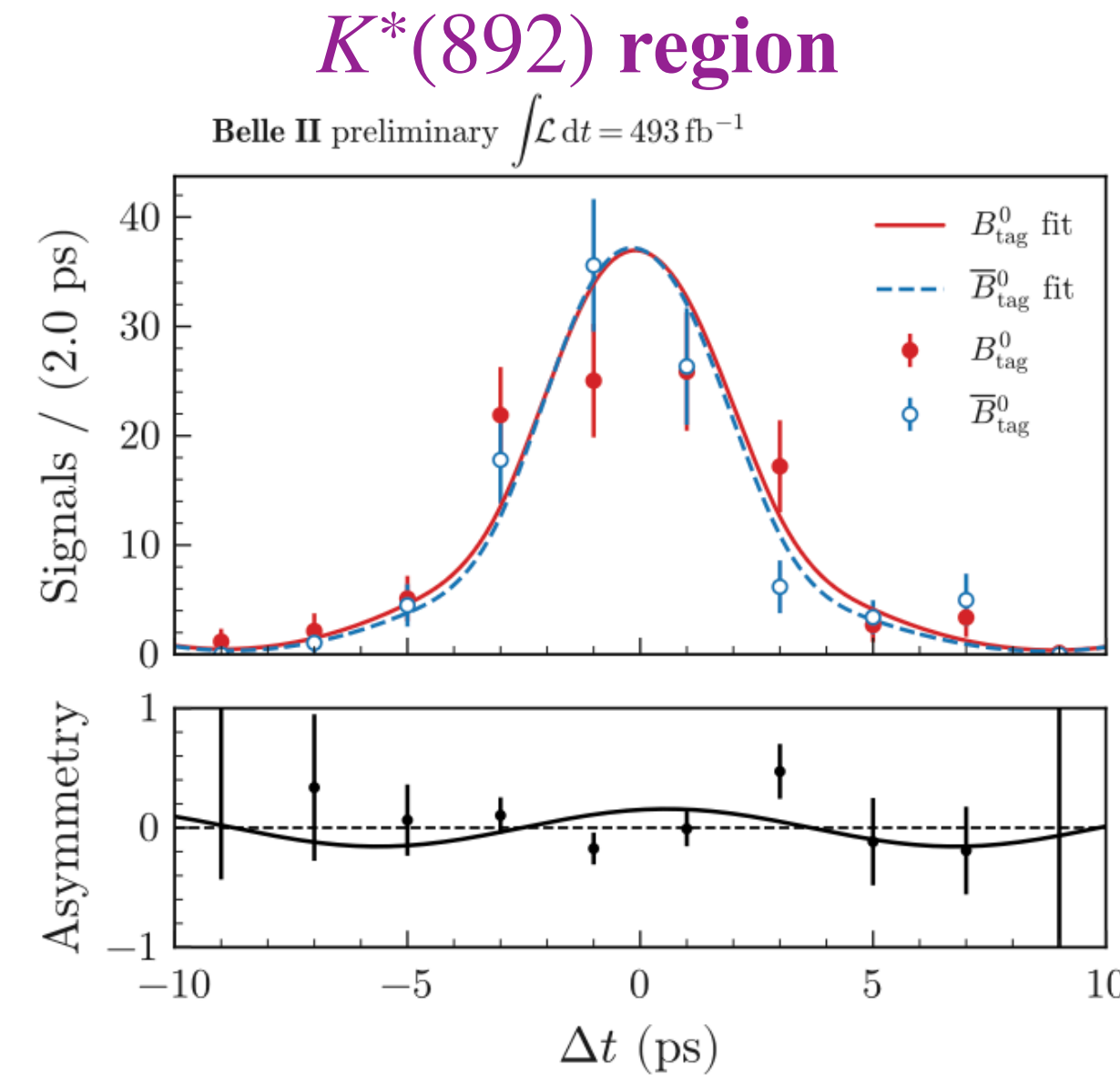
Divide the Dalitz plane into two halves,

- $m^2(K_S^0 \pi^+) > m^2(K_S^0 \pi^-)$: up
- $m^2(K_S^0 \pi^+) < m^2(K_S^0 \pi^-)$: down

Time-dependent CP violation in $B^0 \rightarrow K_S^0 \pi^0 \gamma$

[JHEP 09 2026, 216](#)

- **Data:** Belle 711 fb⁻¹ + Belle II 493 fb⁻¹
- Complementary channel with CP eigenstate final state.
- Measure S and C in $K^*(892)$ and **non- $K^*(892)$** regions.
- Simultaneous fit to time-dependent and time-integrated samples:
 - Extracts S and C .
 - Uses M_{bc} , ΔE , continuum suppression output.
 - Includes Δt for the time-dependent sample.



$$S_{K^*\gamma} = 0.09 \pm 0.16_{\text{stat}} \pm 0.02_{\text{syst}},$$

$$S_{\text{non-}K^*\gamma} = -0.32 \pm 0.33_{\text{stat}} \pm 0.09_{\text{syst}}$$

$$C_{K^*\gamma} = -0.09 \pm 0.08_{\text{stat}} \pm 0.04_{\text{syst}},$$

$$C_{\text{non-}K^*\gamma} = -0.07 \pm 0.17_{\text{stat}} \pm 0.08_{\text{syst}}$$

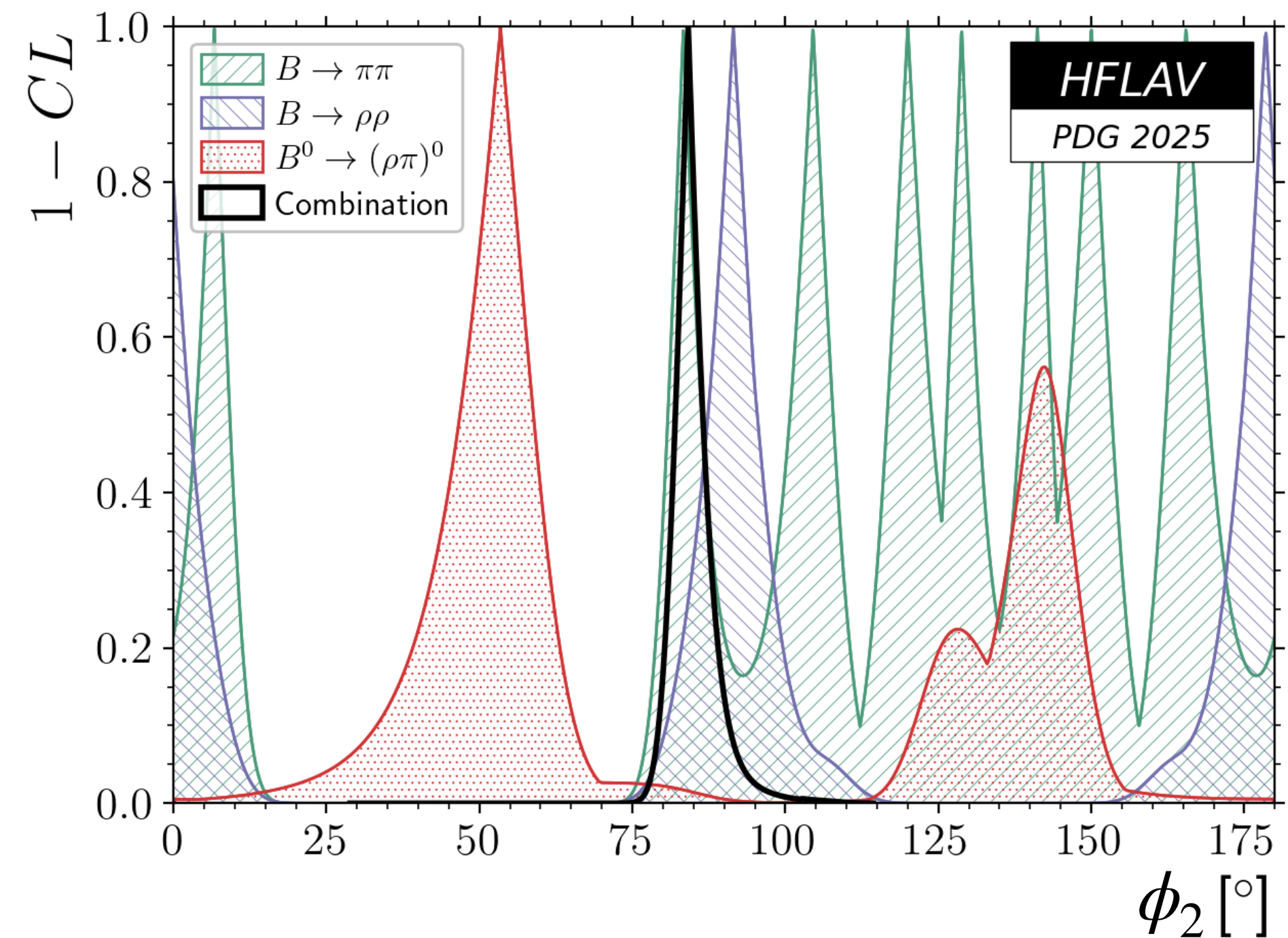
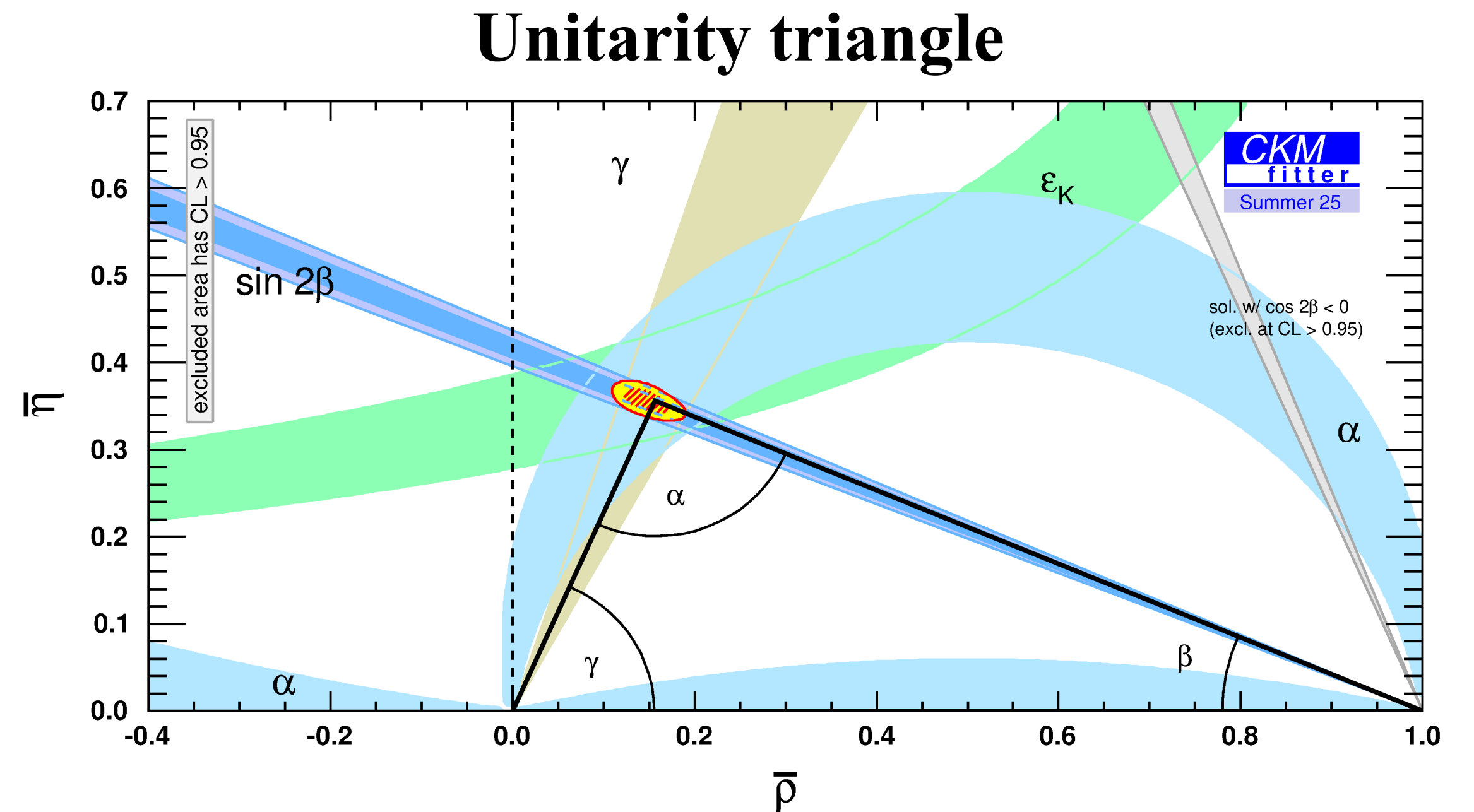
Uncertainties are statistically dominated.

Most precise S and C measurement to date in $K^*(892)$ region
 Results are consistent with SM - no evidence yet for right-handed photon (BSM)

$$\phi_2: B^0 \rightarrow \pi^0 \pi^0$$

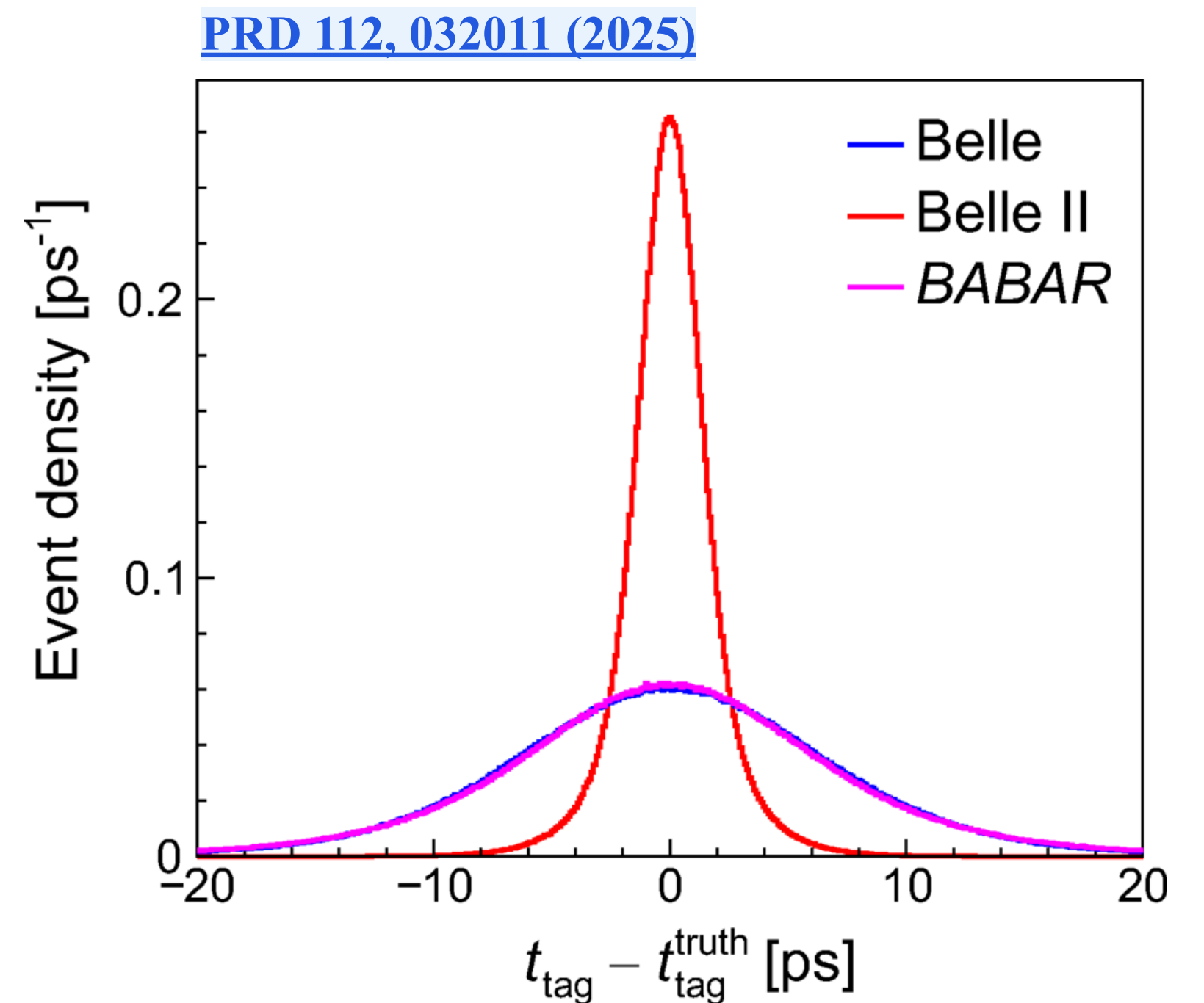
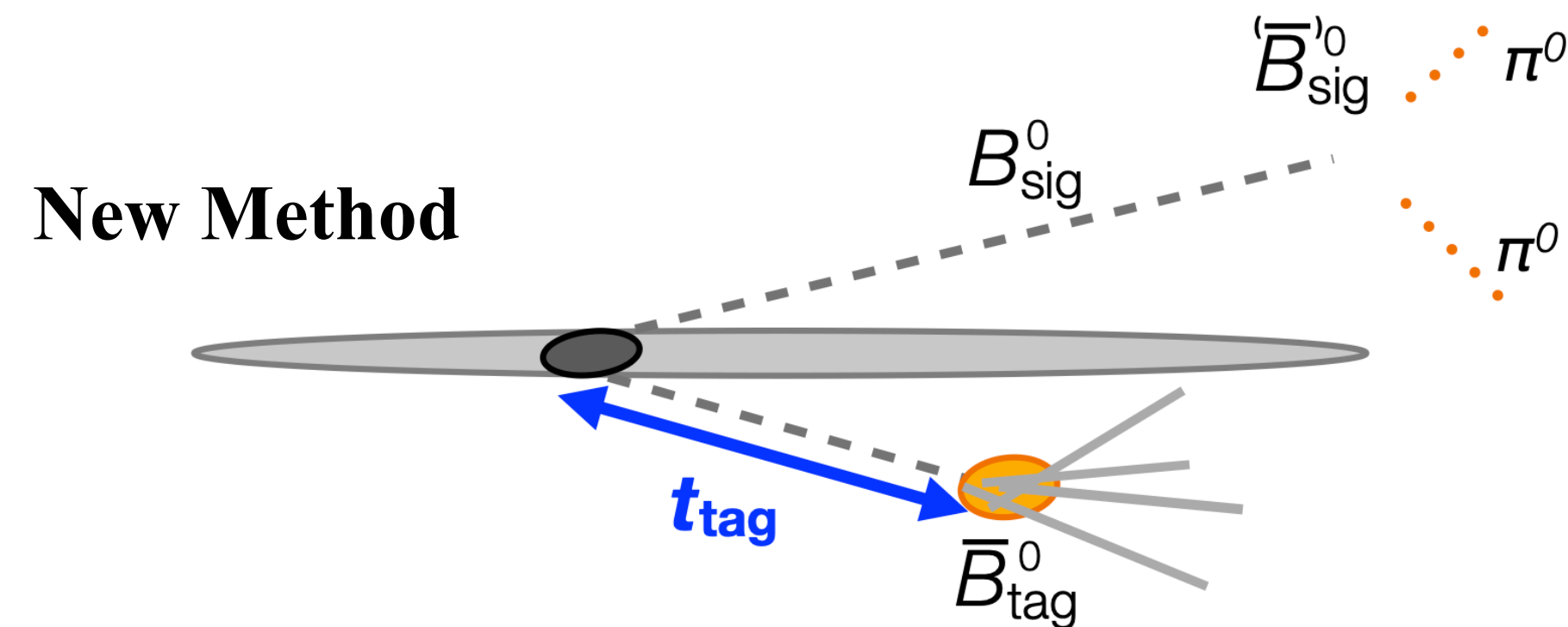
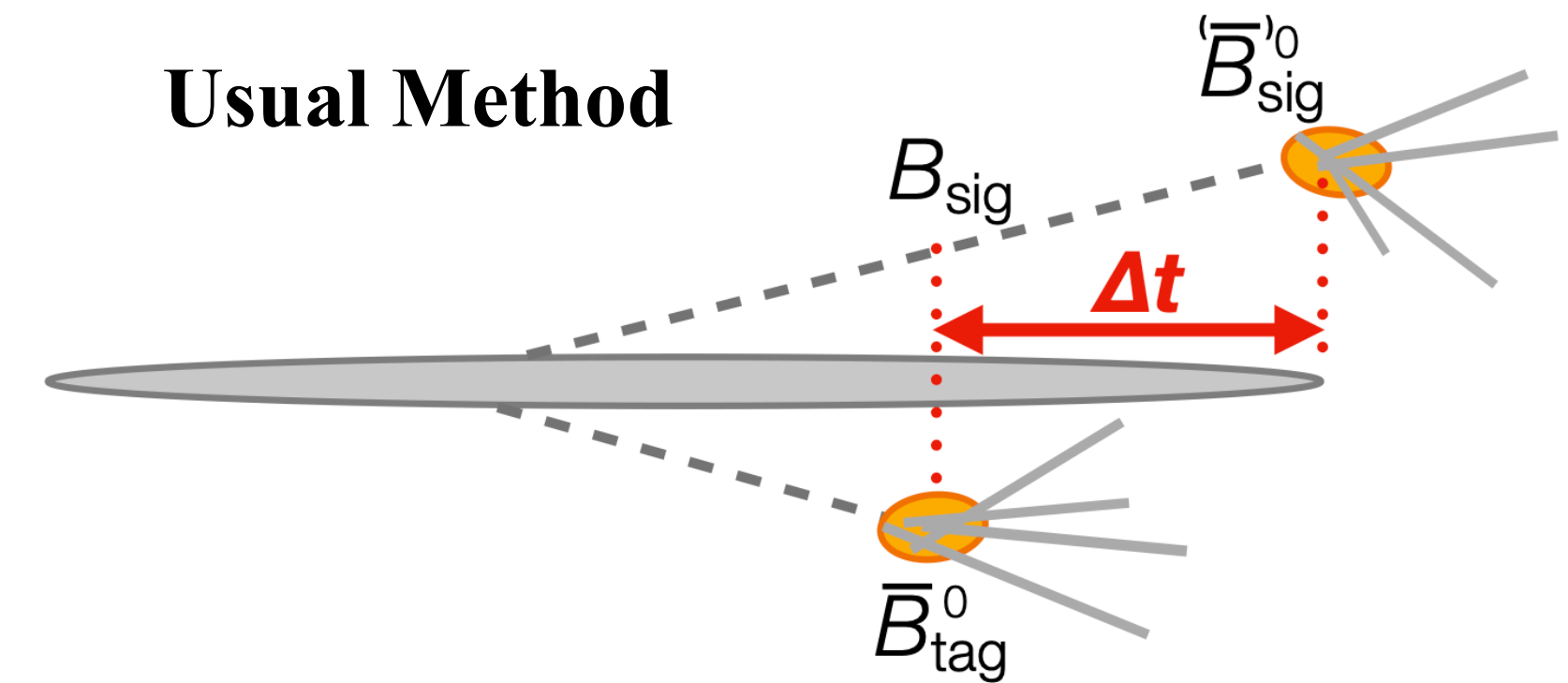
- ϕ_2 is the least precisely known angle of the unitarity triangle.
- CP asymmetries and decay rates in $B \rightarrow \pi\pi$, $\rho\rho$, and $\rho\pi$ constrain it through isospin relations.
- For $B \rightarrow \pi\pi$, a key missing input was time-dependent CP violation in $B^0 \rightarrow \pi^0 \pi^0$ decay.
- **Belle II has now made the first measurement**, improving the $B \rightarrow \pi\pi$ constraint on ϕ_2 .

$$\alpha, \beta, \gamma \rightarrow \phi_2, \phi_1, \phi_3$$



Time dependent measurement of $B^0 \rightarrow \pi^0 \pi^0$

- **Usual method:** measure the decay-time difference between the signal B and the flavor-tagged B meson.
- **No signal-side vertex for $B^0 \rightarrow \pi^0 \pi^0$** in the usual four-photon final state.
 - A $\pi^0 \rightarrow e^+ e^- \gamma$ decay provides charged tracks, allowing vertex reconstruction in only about 2% of events.
- **At Belle II:** the small collision region and pixel detector allow a precise measurement of the tag-side decay time, t_{tag} .
- The $B^0 \bar{B}^0$ pair from the $\Upsilon(4S)$ is quantum correlated, so the CP asymmetry influences the t_{tag} distribution.



$B^0 \rightarrow \pi^0 \pi^0$: results

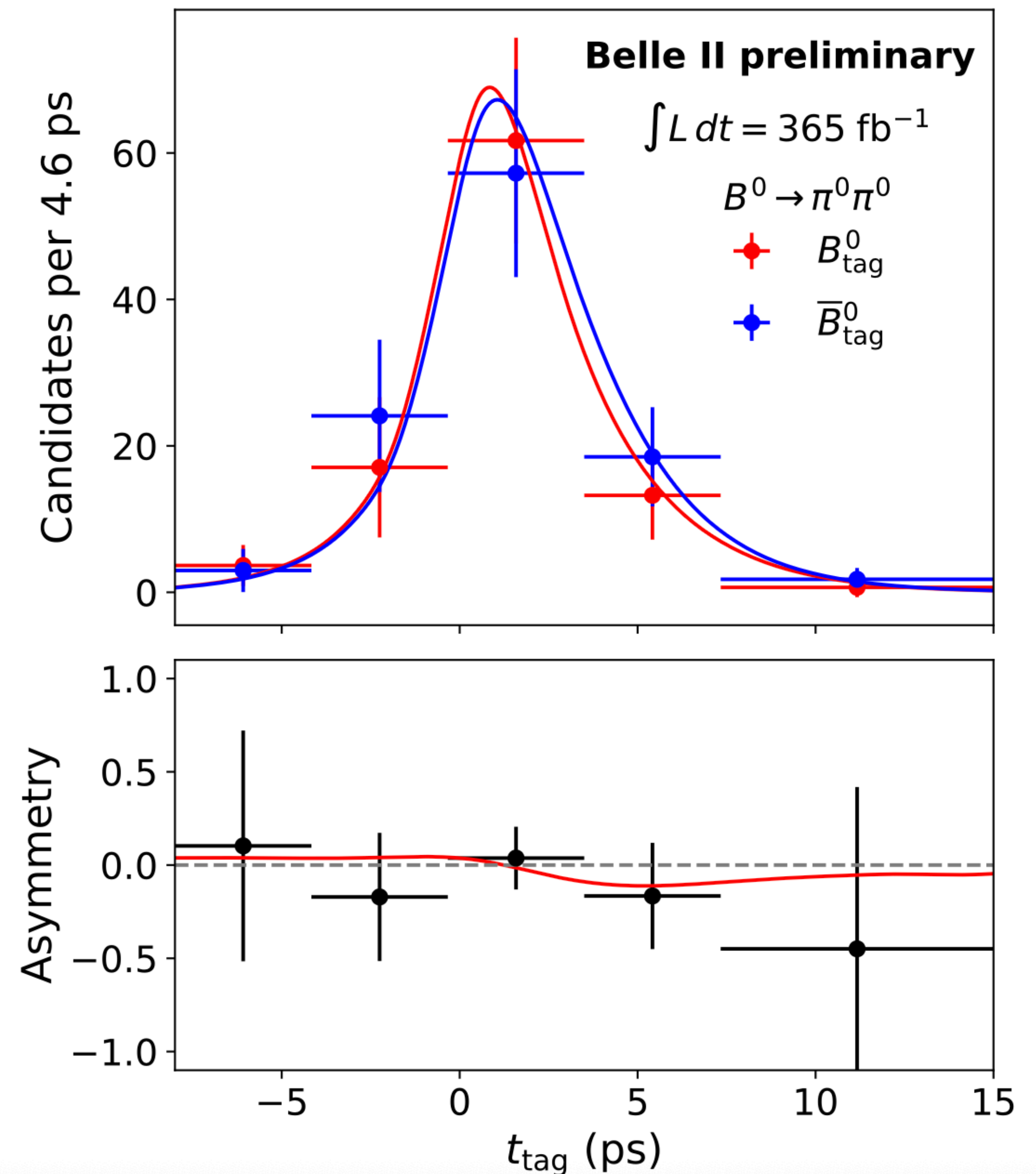
[arXiv:2606.20797](https://arxiv.org/abs/2606.20797)

- **Data:** Belle II 365 fb⁻¹
- Fit to M_{bc} , ΔE , wrong-flavor probability, continuum suppression variable, t_{tag} and $\sigma(t_{\text{tag}})$
- 171 ± 24 signal events

$$S_{\pi^0 \pi^0} = 0.61_{-0.79}^{+0.75} \text{ (stat)} \pm 0.11 \text{ (syst)}$$

$$C_{\pi^0 \pi^0} = 0.05 \pm 0.28 \text{ (stat)} \pm 0.07 \text{ (syst)}$$

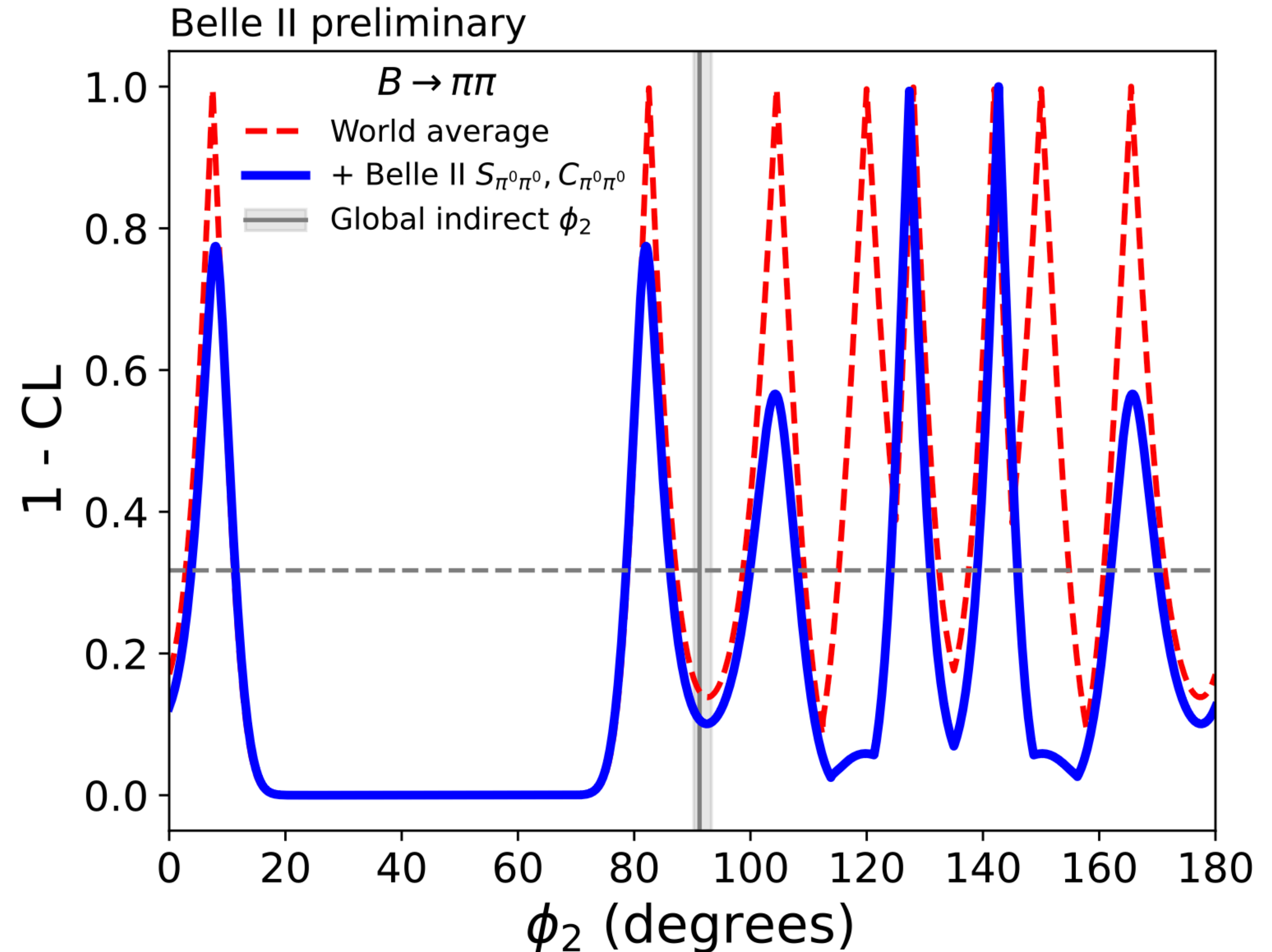
First measurement of mixing induced CP violation in the $B^0 \rightarrow \pi^0 \pi^0$ decay



$B^0 \rightarrow \pi^0 \pi^0$: impact and outlook

[arXiv:2606.20797](https://arxiv.org/abs/2606.20797)

- Clear impact on the measurement of ϕ_2 with just 0.37 ab^{-1}
- Control samples for the t_{tag} resolution model which is largest systematic uncertainty
- Significant improvement will be made with a large Belle II data sample



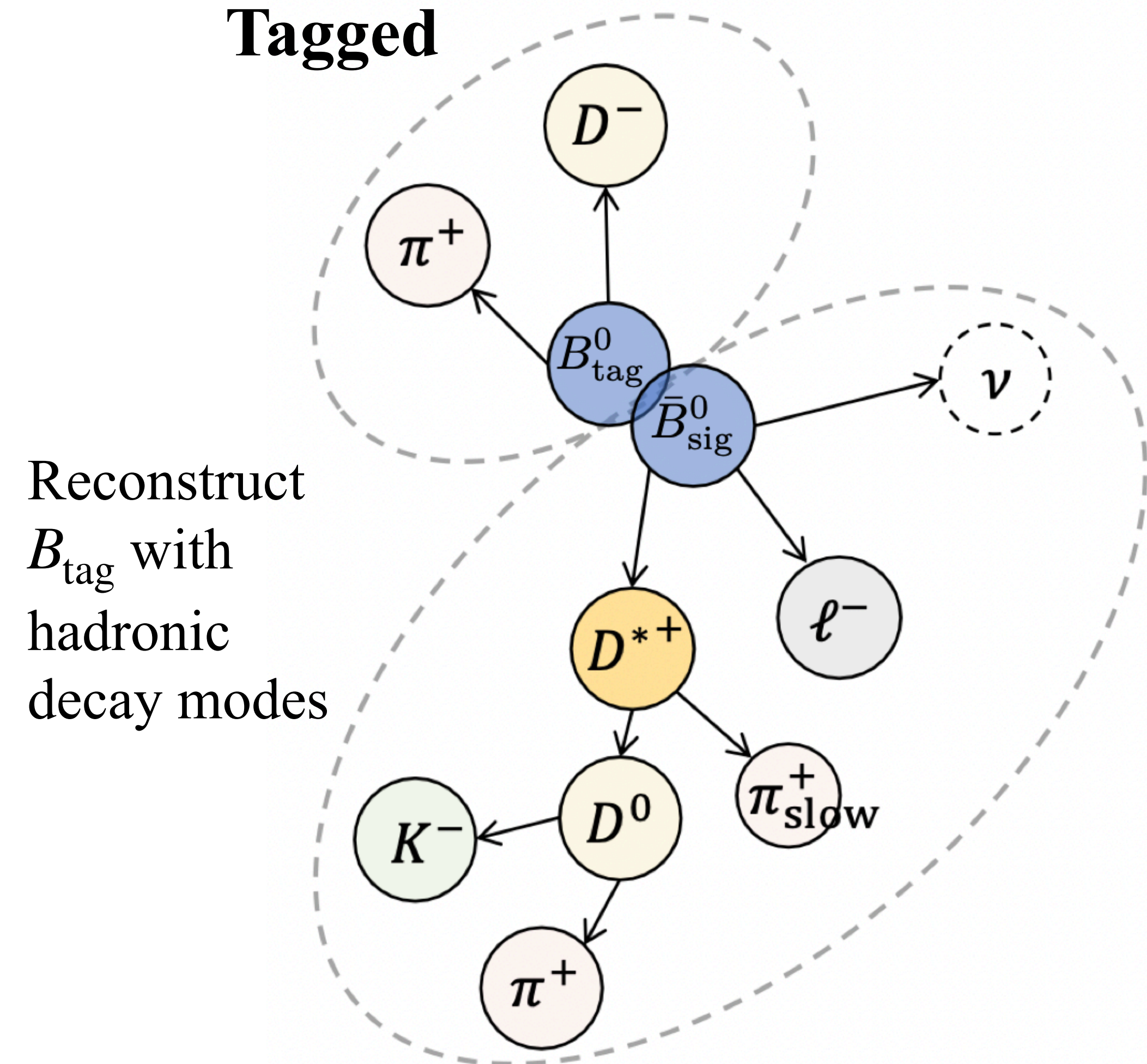
Lepton flavor universality (LFU)

$R(D)$ and $R(D^*)$

Hadronic B tagging for decays with missing energy

[Comput. Softw. Big Sci. 3 \(2019\) 6](#)

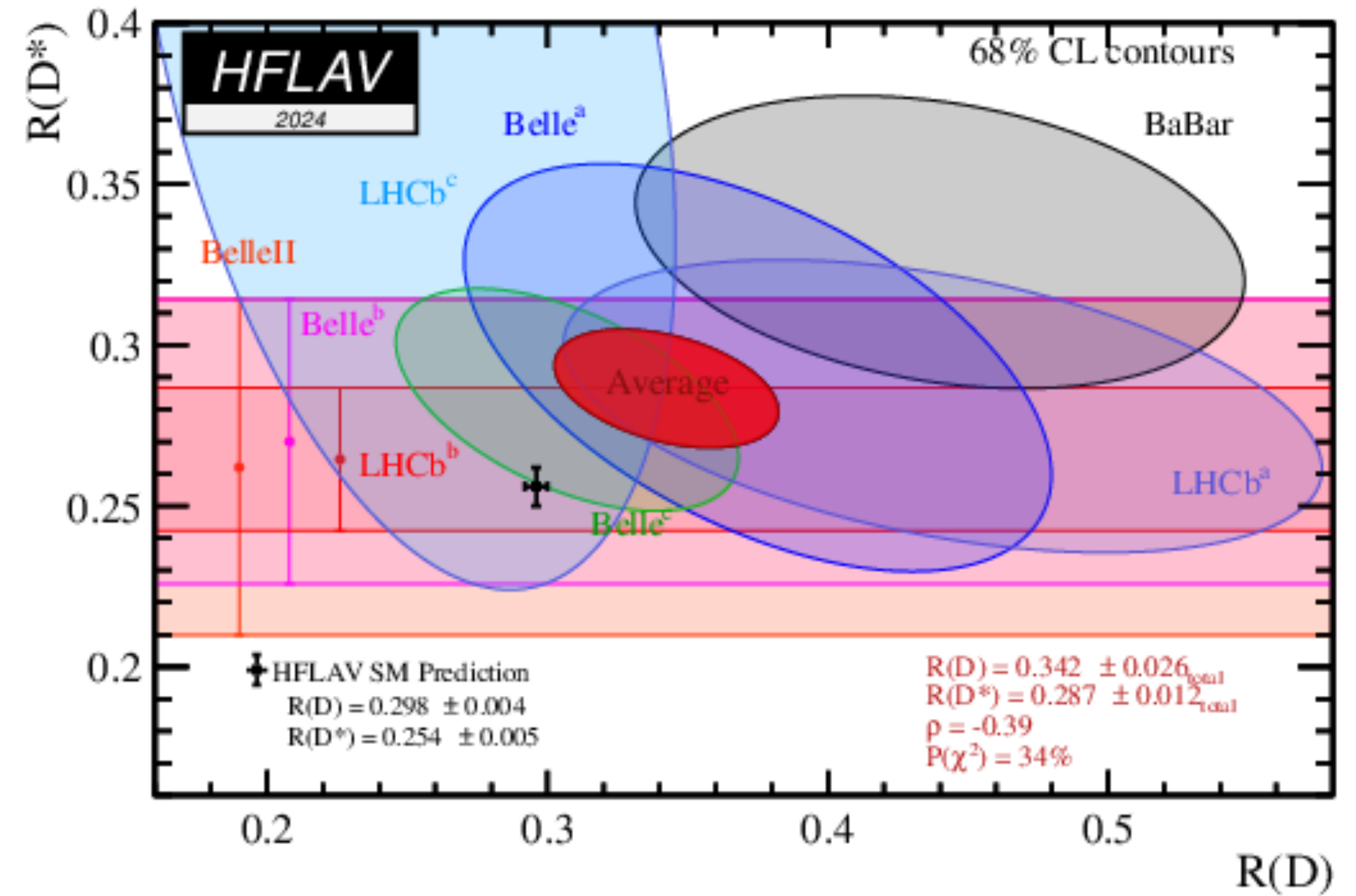
- Fully reconstruct tag B meson in hadronic decay modes.
 - $B \rightarrow D^{(*)0} m\pi^{\pm} n\pi^0$, where $m \geq 1$ $n \geq 0$
- Use tag B four-momentum and the known initial state to constrain the signal B .
- Assign the remaining particles to the signal decay and reconstruct the missing momentum.
- Machine learning algorithm used to boost efficiency as much as possible.
- Low tagging efficiency ($< 1\%$), but a powerful tool for studying decays with missing energy.



LFU in semi-leptonic B decays

- Semileptonic decays provide clean tests of lepton flavor universality (LFU).
- Ratios of decay rates reduce form-factor and experimental uncertainties:

$$R(D^{(*)}) = \frac{\mathcal{B}(B \rightarrow D^{(*)}\tau\nu_\tau)}{\mathcal{B}(B \rightarrow D^{(*)}\ell\nu_\ell)}, \quad \ell = e, \mu$$
- Long-standing tensions in $R(D^{(*)})$ motivate searches for new contributions, such as charged Higgs bosons or leptoquarks.
- New physics coupling mainly to the third generation could be difficult to detect in high- p_T searches.



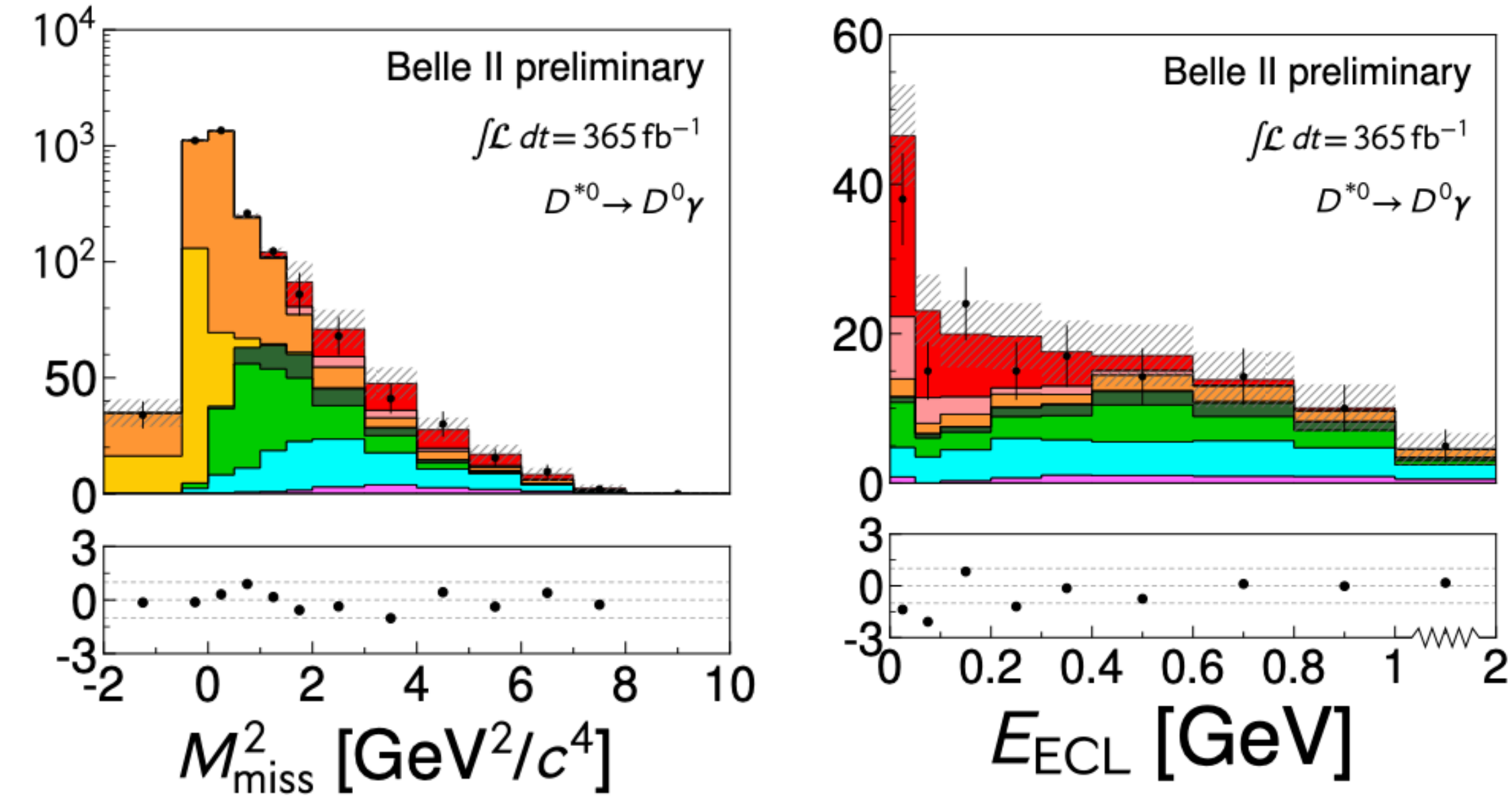
Additional rate and angular measurements are needed to clarify the situation.

LFU: $R(D)$ and $R(D^*)$

[arXiv:2609.21947](https://arxiv.org/abs/2609.21947)

- **Data:** Belle II 365 fb⁻¹
- Hadronic B tagging constrains the signal kinematics and enables reconstruction of:
 - M_{miss}^2 : broad for $B \rightarrow D^{(*)}\tau\nu_\tau$ but peaks near zero for $B \rightarrow D^{(*)}\ell\nu_\ell$ (normalization)
 - E_{ECL} : unassigned calorimeter energy; signal peaks near zero.
- Simultaneous 2D fit to M_{miss}^2 and E_{ECL} across five samples: $D^{*+}, D^{*0} \rightarrow D^0\pi^0, D^{*0} \rightarrow D^0\gamma, D^0$, and D^+
- **Systematics** – simulation sample size for templates, D^{**} model, (π^0, γ) efficiency

Fit projection for one of the five samples.



$$R(D^*) = 0.242 \pm 0.019_{\text{stat}} \pm 0.016_{\text{syst}}$$

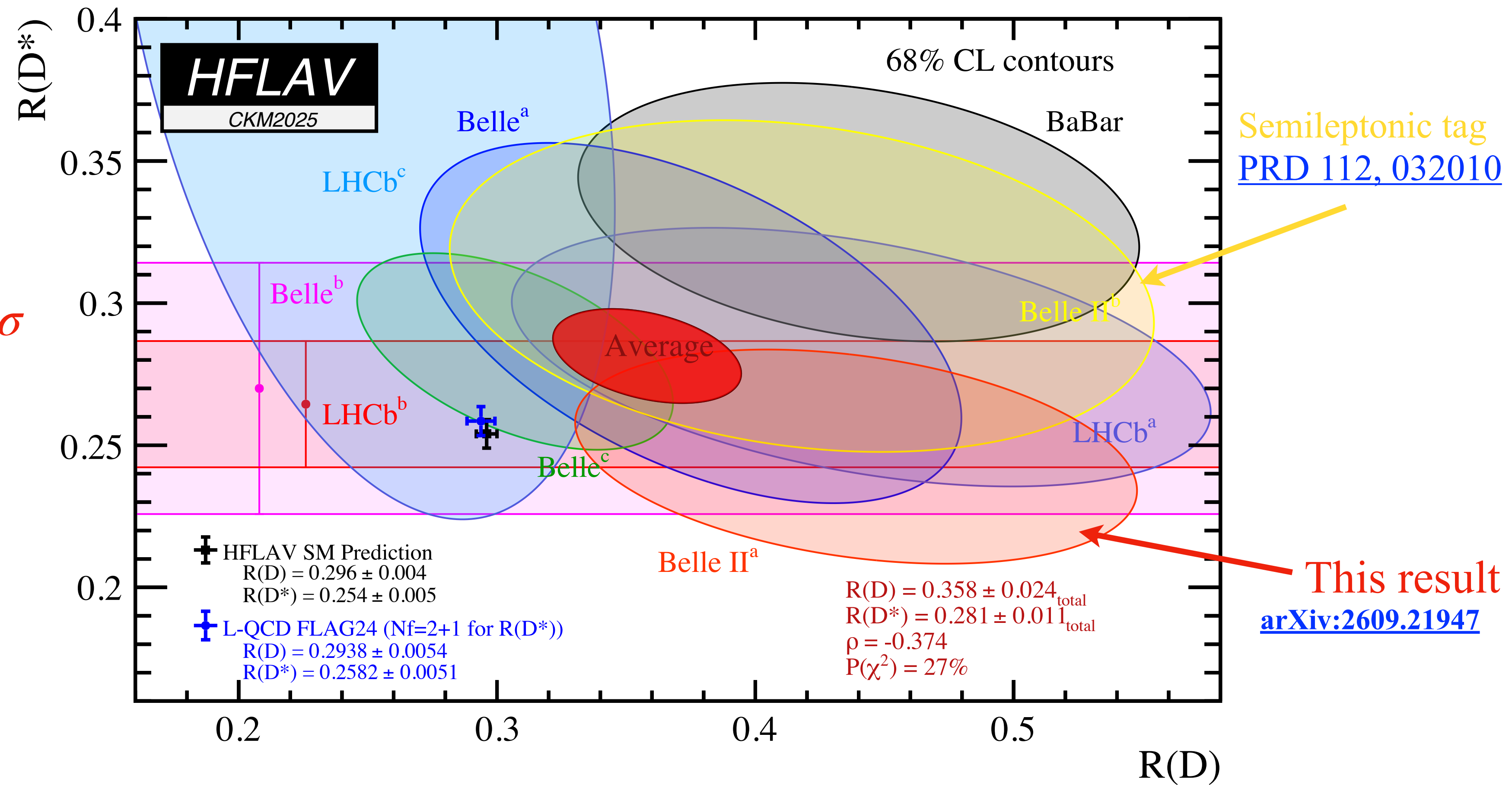
$$R(D) = 0.439 \pm 0.055_{\text{stat}} \pm 0.046_{\text{syst}}$$

Most precise determination of $R(D)$ and $R(D^*)$ to date
Consistent with Standard Model predictions and previous measurements

Comparison with other results

The world average differs from the SM prediction by 3.8σ

- $R(D)$ tension with SM 2.5σ
- $R(D^*)$ tension with SM 2.3σ



CKM matrix

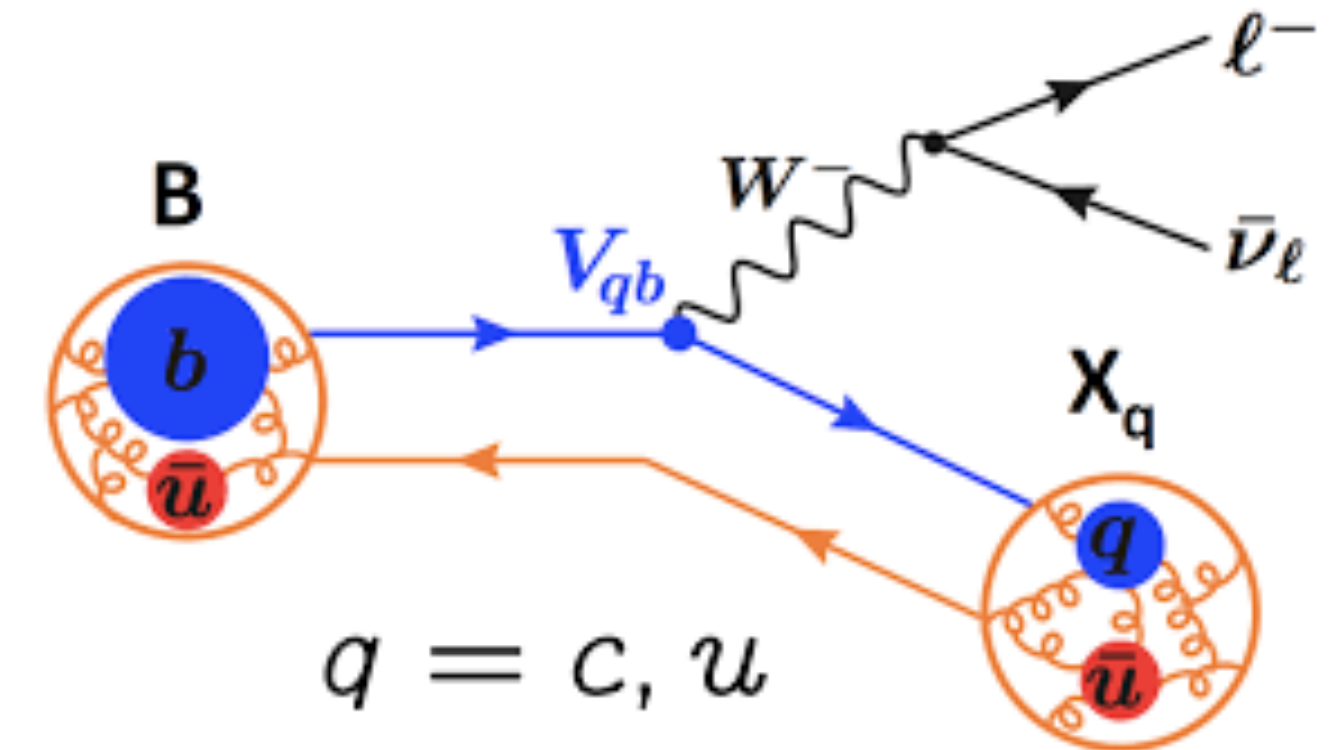
Determination of $|V_{ub}|$

Semi-leptonic B decays - CKM matrix

- Semi-leptonic B decays are studied to determine the CKM elements $|V_{cb}|$ and $|V_{ub}|$.
- $|V_{xb}|$ limit the global constraining power of unitarity triangle fits.
- The determination can be: **exclusive** (single final state) or **inclusive** (sensitive to all final states).

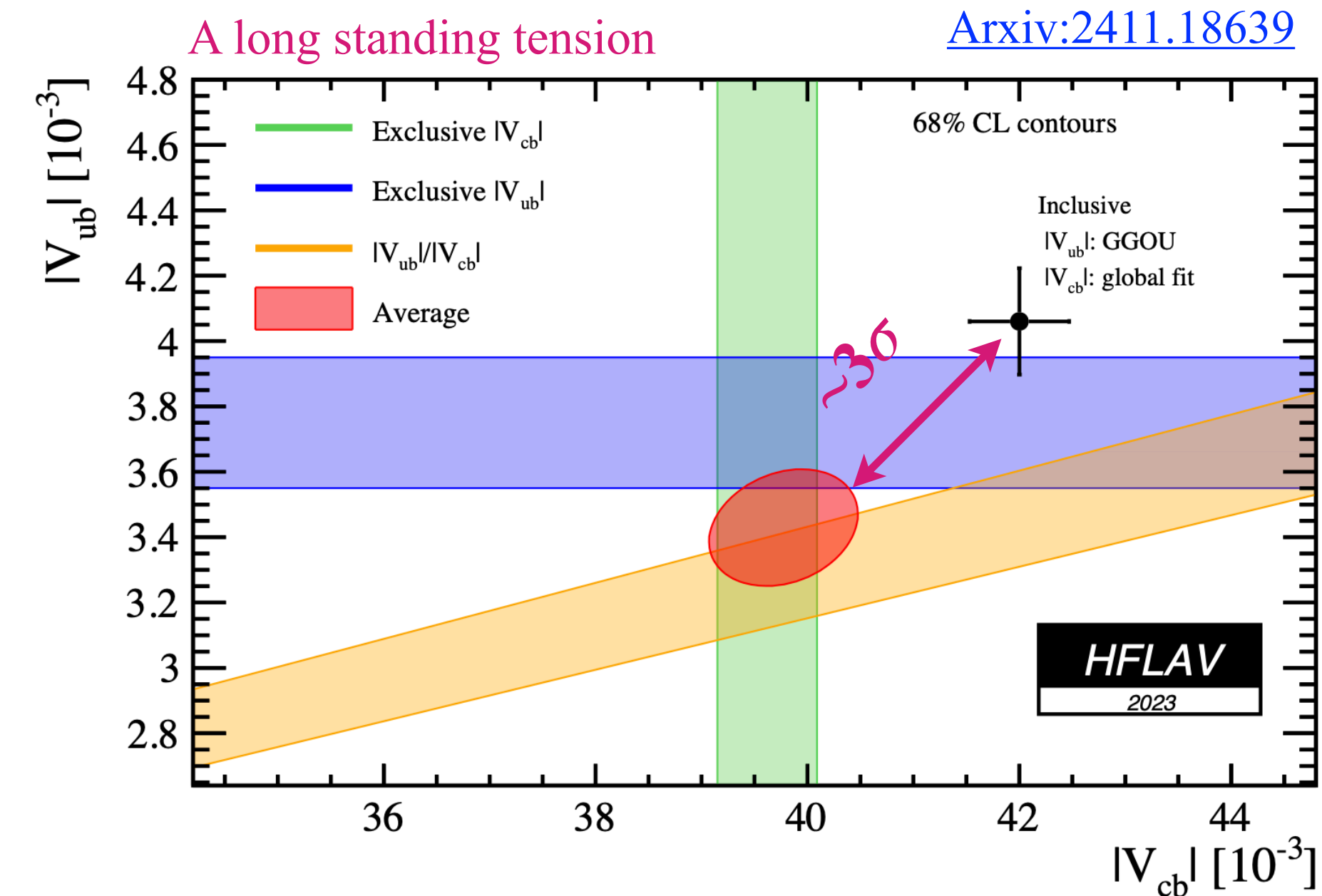
Experimentally clean
Theoretically challenging

Experimentally challenging
Theoretically clean



Experimental Status:

- Determinations of both $|V_{cb}|$ and $|V_{ub}|$ exhibit a discrepancy at the level of $\sim 3\sigma$ between **exclusive** and **inclusive**.
- The current **experimental focus** is on understanding the origin of this discrepancy, as this inconsistency limits the power of precision flavor physics.

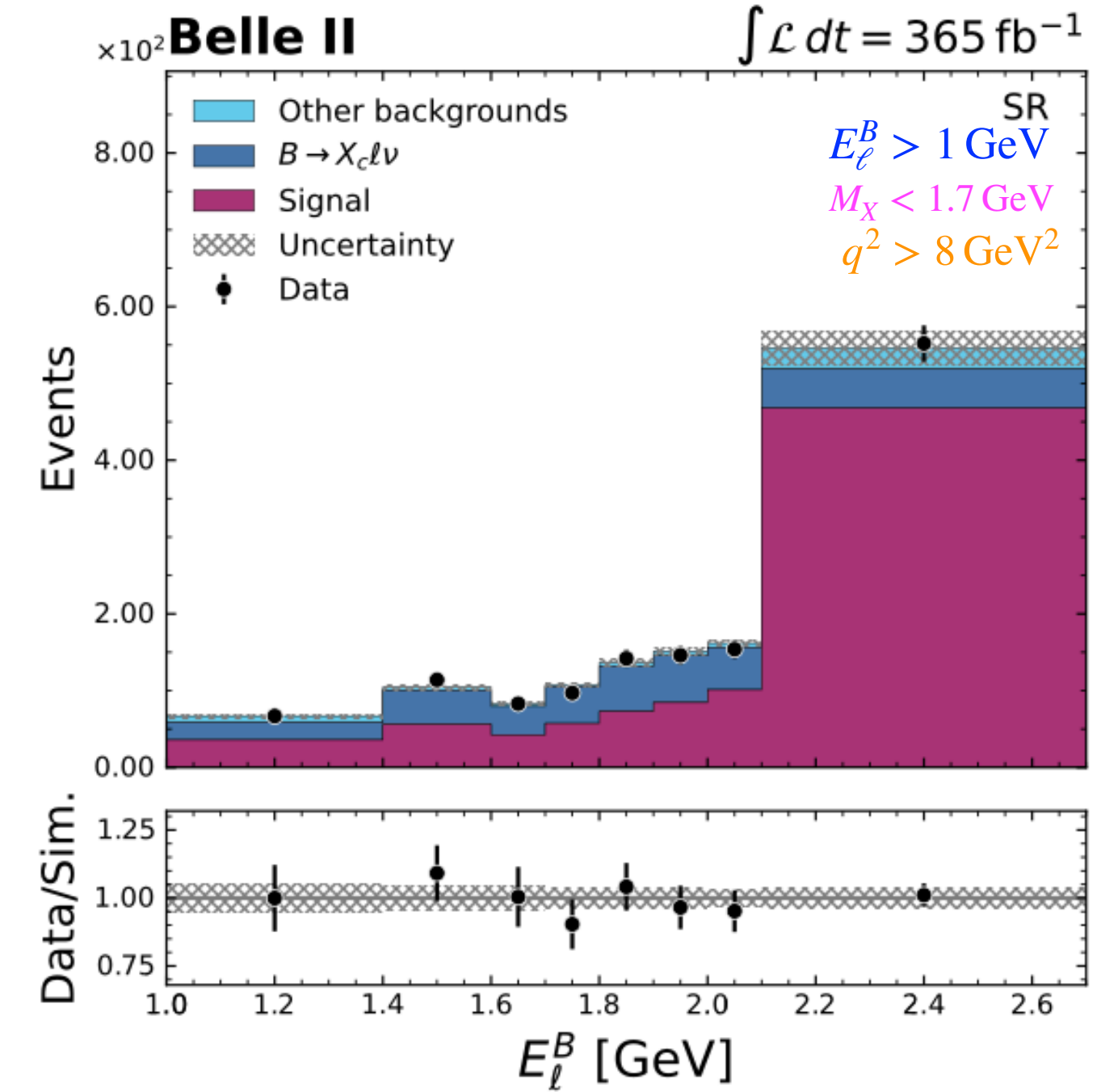
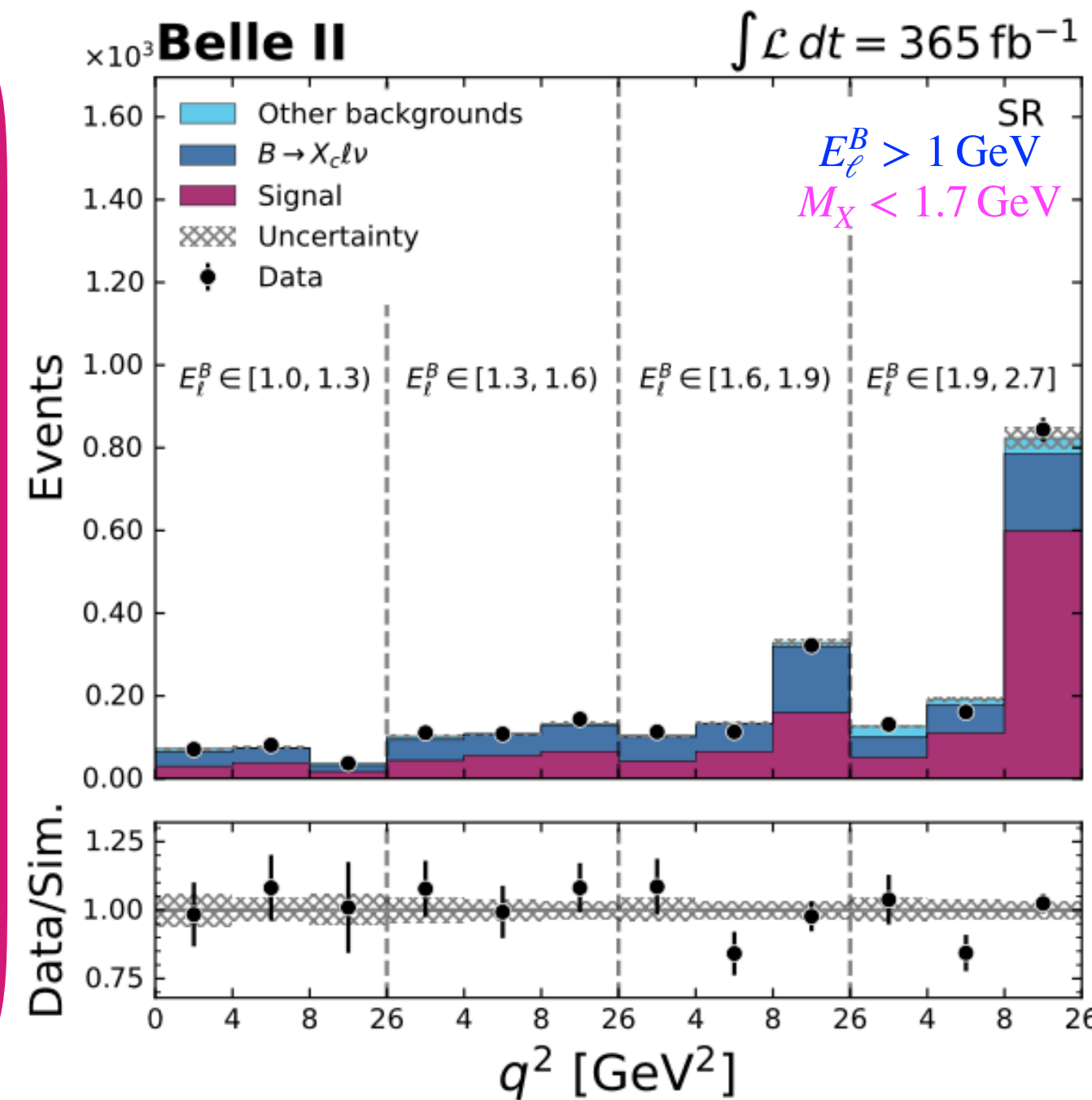
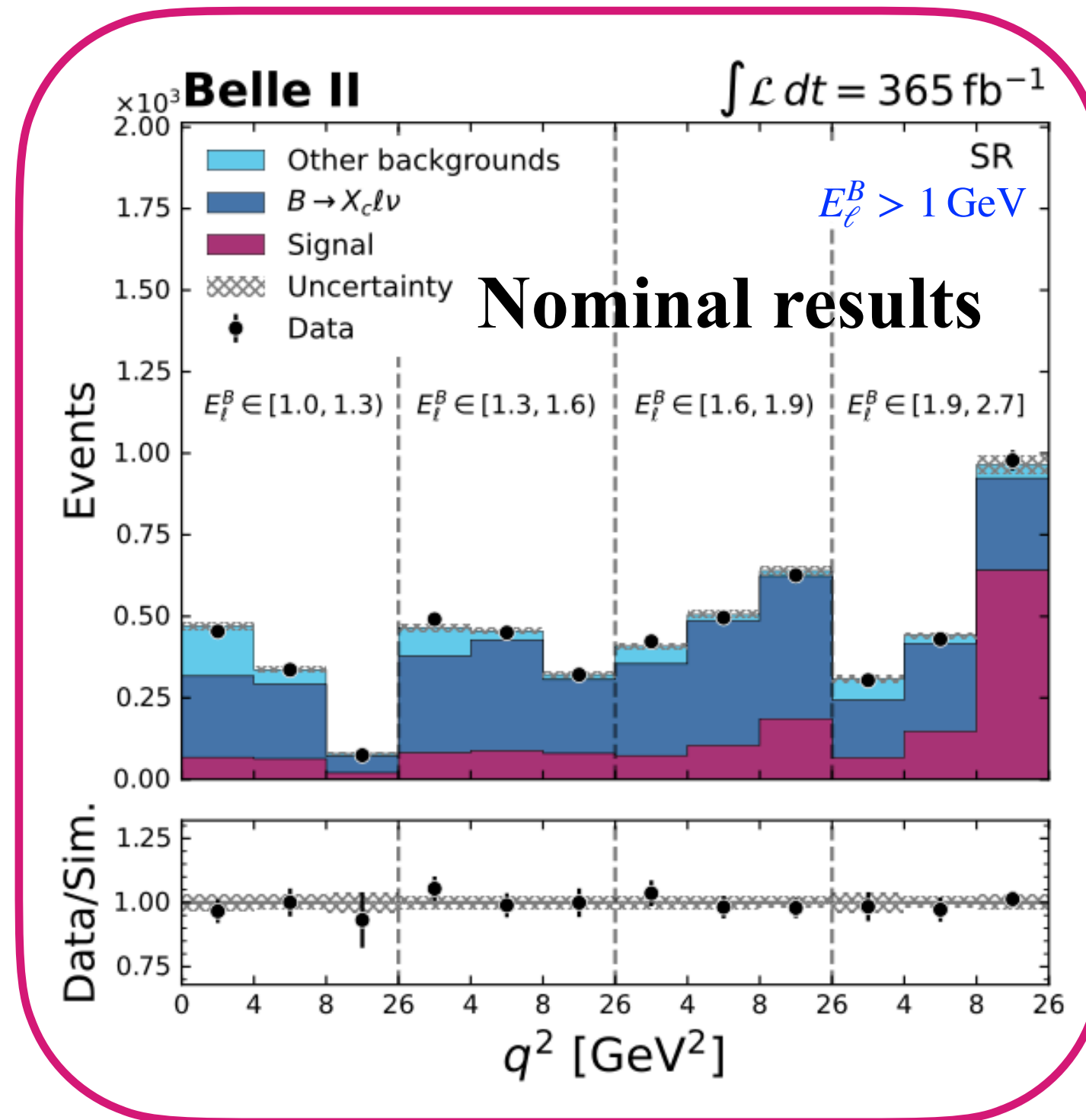


Inclusive $B \rightarrow X_u \ell \nu$

PRD 113, 032004

- **Data:** Belle II 365 fb^{-1} , using hadronic B tagging.
- **Main challenge:** $B \rightarrow X_c \ell \nu$ background is about 50 times larger.
- **Three phase-space regions:** $E_\ell^B > 1 \text{ GeV}$, adding $M_X < 1.7 \text{ GeV}$, then $q^2 > 8 \text{ GeV}^2$.
- Template fits to E_ℓ^B , q^2 in the first two regions and E_ℓ^B in the third; with a control region that constrains charm background.

$$q^2 = M_{\ell\nu}^2$$



Inclusive $B \rightarrow X_u \ell \nu$

[PRD 113, 032004](#)

- Determine $|V_{ub}|$ from measured partial branching fractions in 3 different phase space regions:

$$|V_{ub}| = \sqrt{\frac{\Delta\mathcal{B}(B \rightarrow X_u \ell \nu_\ell)}{\tau_B \cdot \Delta\Gamma(B \rightarrow X_u \ell \nu_\ell)}}$$

BLNP model:

[PRD72,073006](#)

DGE model:

[JHEP 01 \(2006\) 097](#)

GGOU model:

[JHEP 10 \(2007\) 058](#)

Nominal results: $|V_{ub}|$ in $E_\ell^B > 1\text{ GeV}$ with GGOU theoretical framework:

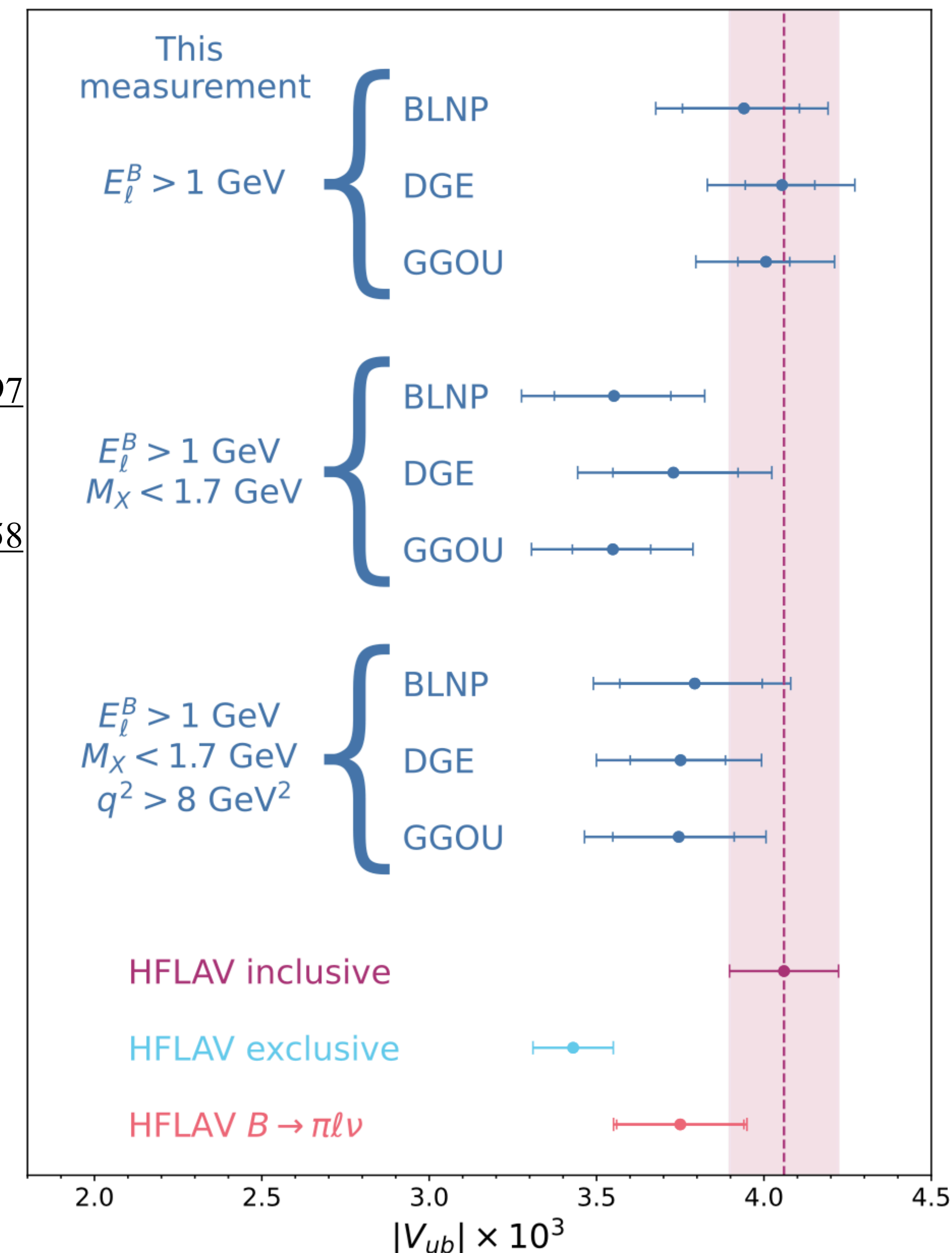
$$|V_{ub}| = (4.01 \pm 0.11_{\text{stat}} \pm 0.16_{\text{syst}+0.07_{\text{theory}}}) \times 10^{-3}$$

Covering 87% of phase space

- Main systematic uncertainty: modeling of the inclusive $B \rightarrow X_u \ell \nu$ spectrum.

Consistent with previous inclusive measurements

Belle II

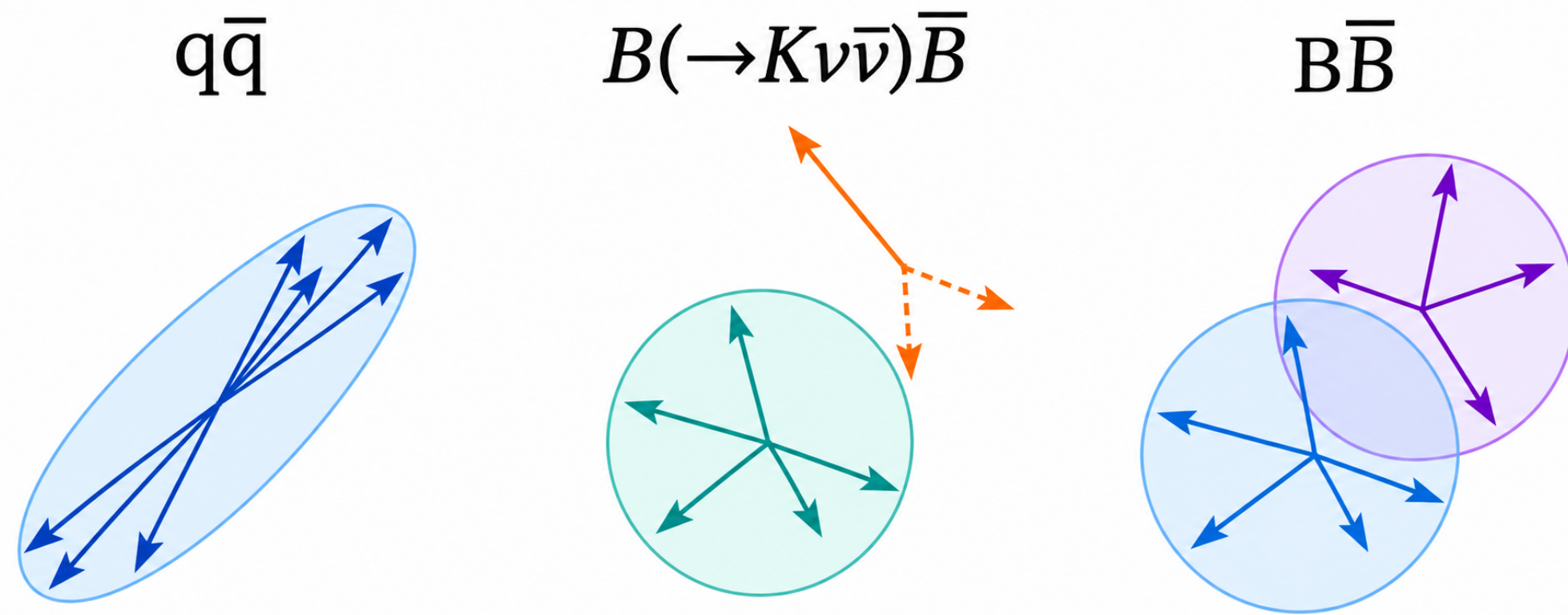


Electroweak penguin decays

Searches for $B^+ \rightarrow K^+ \nu \bar{\nu}$, $B \rightarrow K \tau^+ \tau^-$

$$B^+ \rightarrow K^+ \nu \bar{\nu}$$

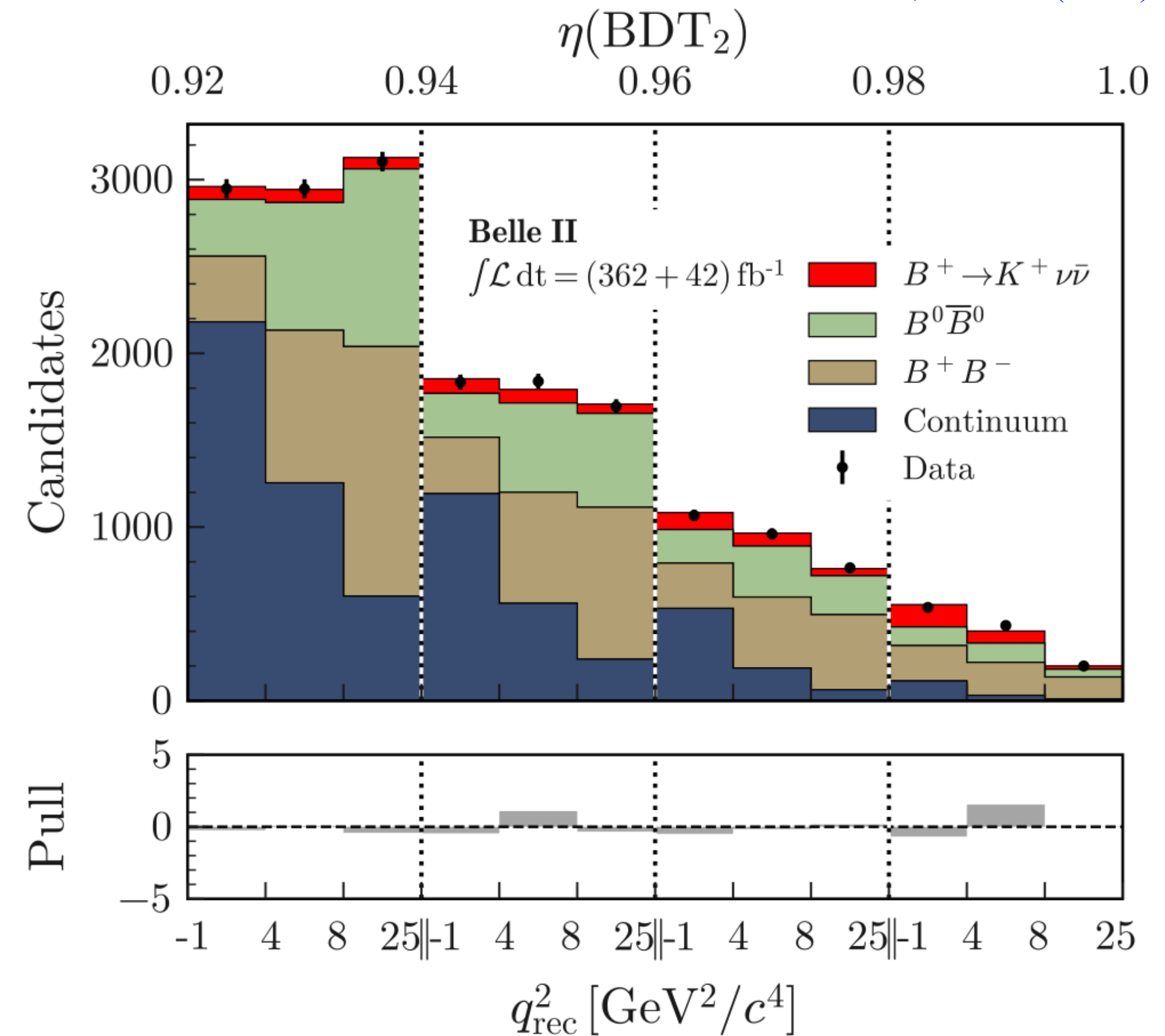
- Theoretically clean and third generation sensitive flavor changing neutral current $b \rightarrow s \ell \ell$ transition



- Inclusive tag developed that exploits topology: 8% efficiency
 - Results are cross checked and combined with the lower-efficiency hadronic-tag measurement.
- Fit to squared invariant mass of neutrinos (q^2) and classifier (η)

Inclusive + hadronic tag measurement:

$$\mathcal{B}(B^+ \rightarrow K^+ \nu \bar{\nu}) = 2.3 \pm 0.5 \text{ (stat)}_{-0.4}^{+0.5} \text{ (syst)} \times 10^{-5}$$



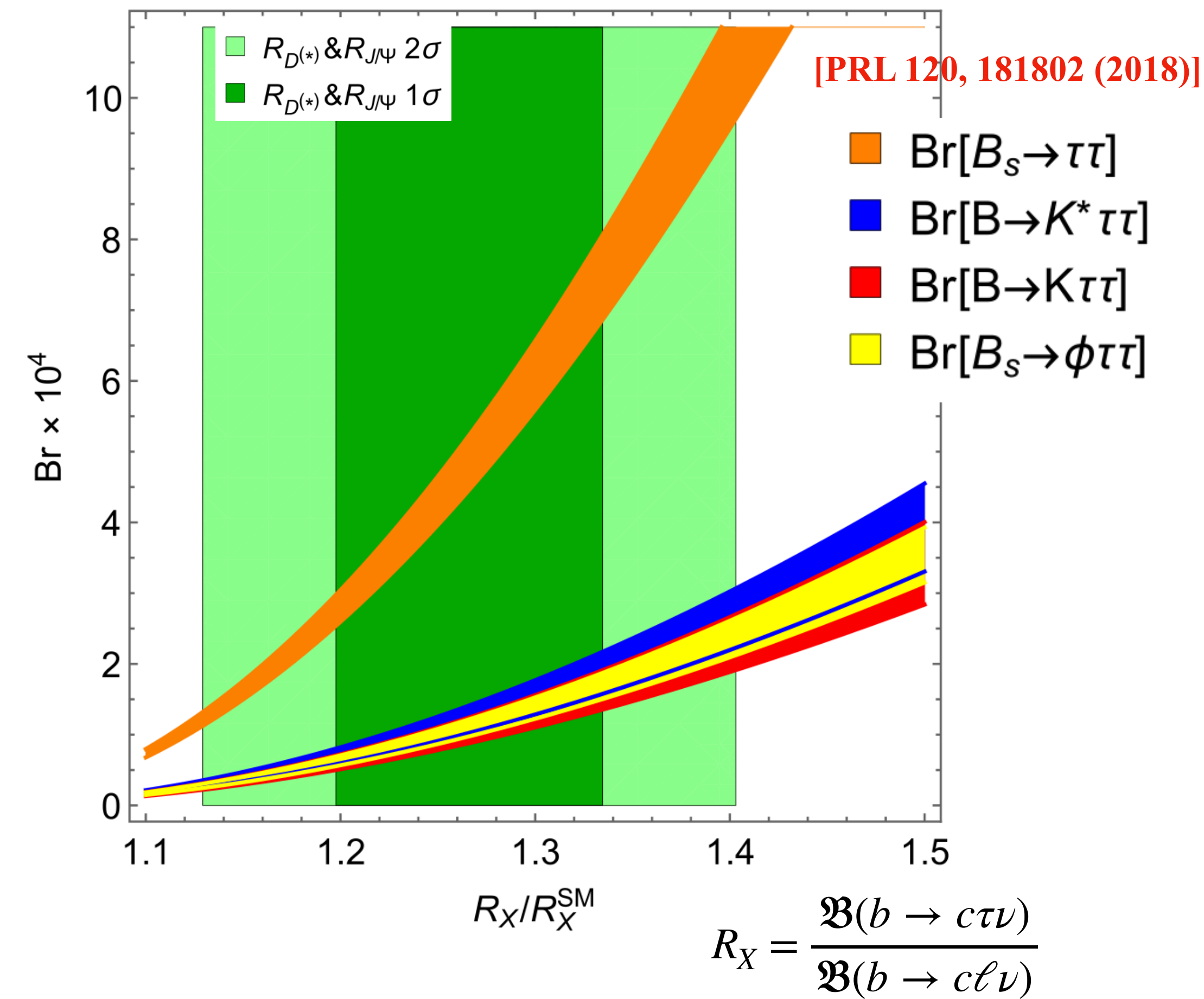
Evidence @ 3.5σ

**2.7σ Tension with SM
prediction of 0.6×10^{-5}**

$b \rightarrow s\tau^+\tau^-$ decays

- The $b \rightarrow s\tau^+\tau^-$ transition occurs only through loop and box diagrams in the SM, with branching fractions of order 10^{-7} .
- New particles, such as leptoquarks or Z' bosons, could enhance the rate and help explain flavor anomalies.
- These decays directly probe new physics coupling to third-generation leptons.
- Multiple neutrinos make reconstruction challenging; hadronic B tagging constrains the signal kinematics.
- **Tau reconstruction:**
 - leptonic decays for $B^+ \rightarrow K^+\tau^+\tau^-$,
 - single-prong leptonic and hadronic decays for $B^0 \rightarrow K_S^0\tau^+\tau^-$.

Prediction of $\mathfrak{B}(b \rightarrow s\tau\tau)$ as a function of R_X/R_X^{SM}

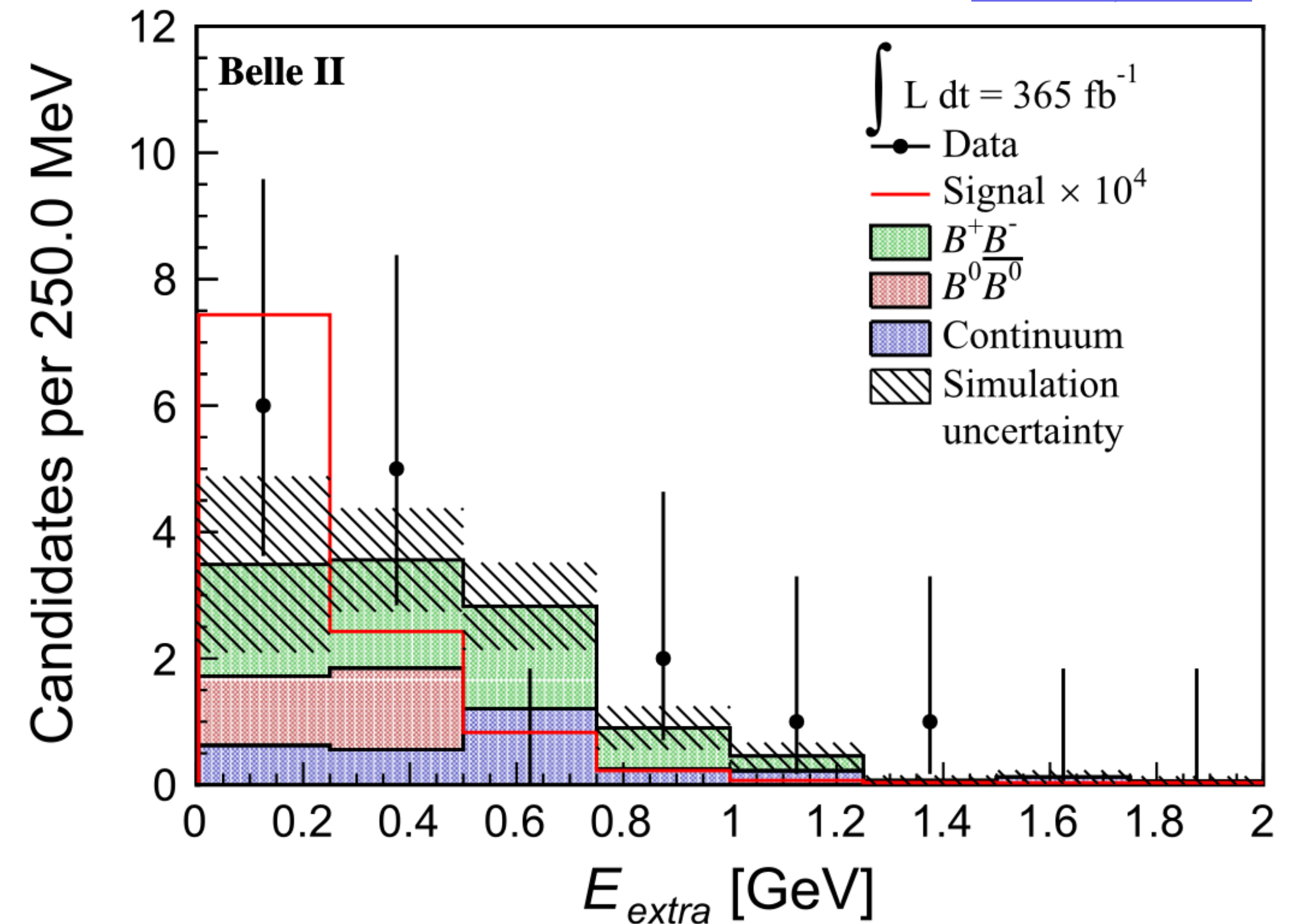


$$B^+ \rightarrow K^+ \tau^+ \tau^-$$

- Belle + Belle II data: $711 + 365 \text{ fb}^{-1} \approx 1.1 \text{ ab}^{-1}$.
- Hadronic B tagging with both τ leptons reconstructed through $\tau \rightarrow \ell \nu \nu$.
- E_{extra} : unassigned neutral calorimeter energy, peaks near zero for signal.
- Template fit to E_{extra}
- No significant signal observed.

$$\mathcal{B}(B^+ \rightarrow K^+ \tau^+ \tau^-) < 5.6 \times 10^{-4} \quad \text{at 90\% CL}$$

[PRL 137, 051805](#)



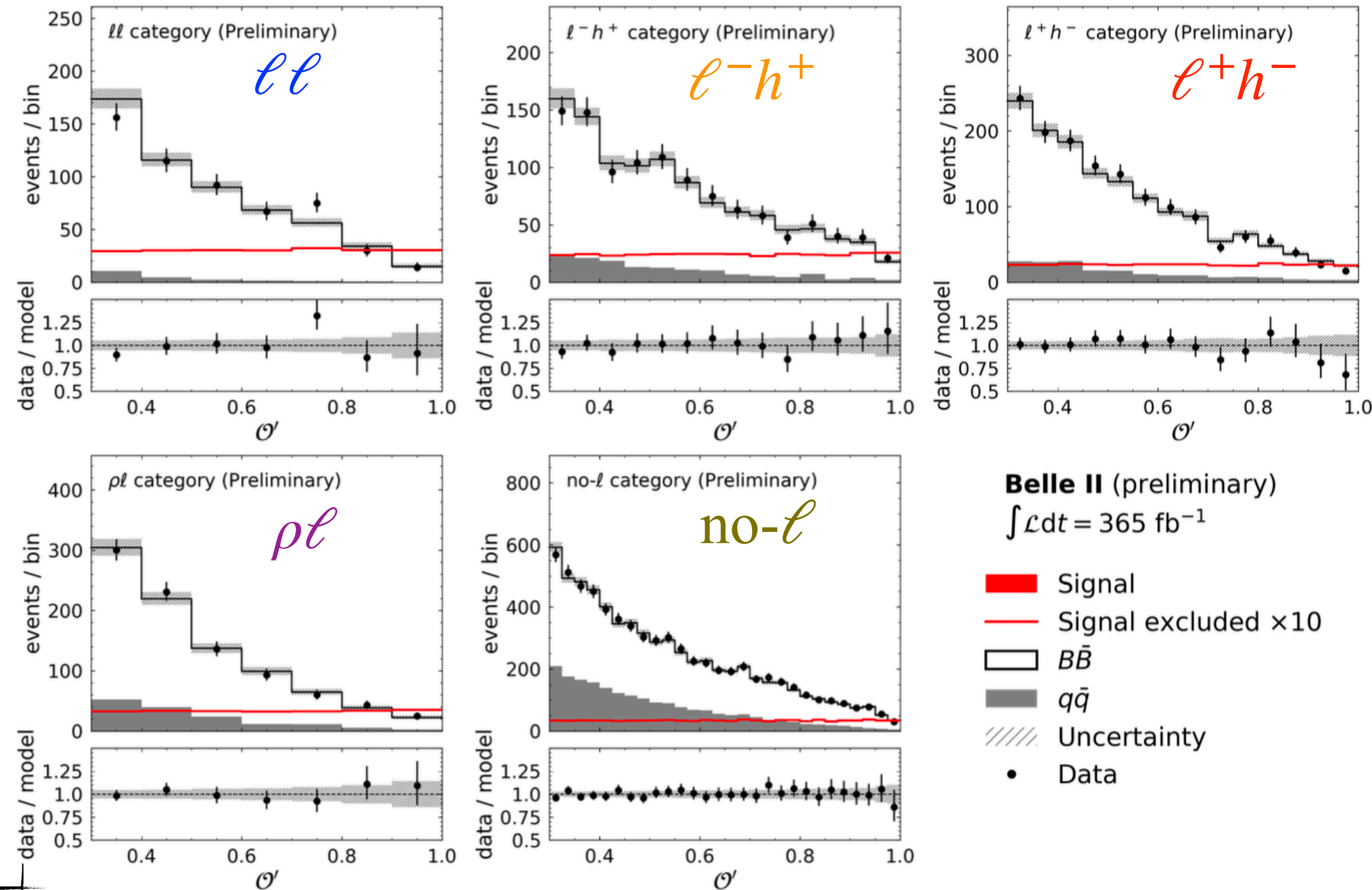
Most stringent limits to date

$$B^0 \rightarrow K_S^0 \tau^+ \tau^-$$

- Belle + Belle II data:
 $711 + 365 \text{ fb}^{-1} \approx 1.1 \text{ ab}^{-1}$
- Hadronic B tagging.
- Reconstruct single-prong τ decays in five categories: $\ell\ell$, ℓ^-h^+ , ℓ^+h^- , $\rho\ell$, and $\text{no-}\ell$, where $\ell = e, \mu$ and h denotes a charged hadron.
- Simultaneous binned template fit to the Multivariate classifier output ($\mathcal{O}'$) across all categories and both datasets.
- No significant signal observed.

Multivariate classifier output ($\mathcal{O}'$)

[arXiv:2607.25607](https://arxiv.org/abs/2607.25607)



$$\mathcal{B}(B^0 \rightarrow K_S^0 \tau^+ \tau^-) < 8.3 \times 10^{-4} \quad \text{at 90\% CL}$$

Most stringent limits to date

Charm physics

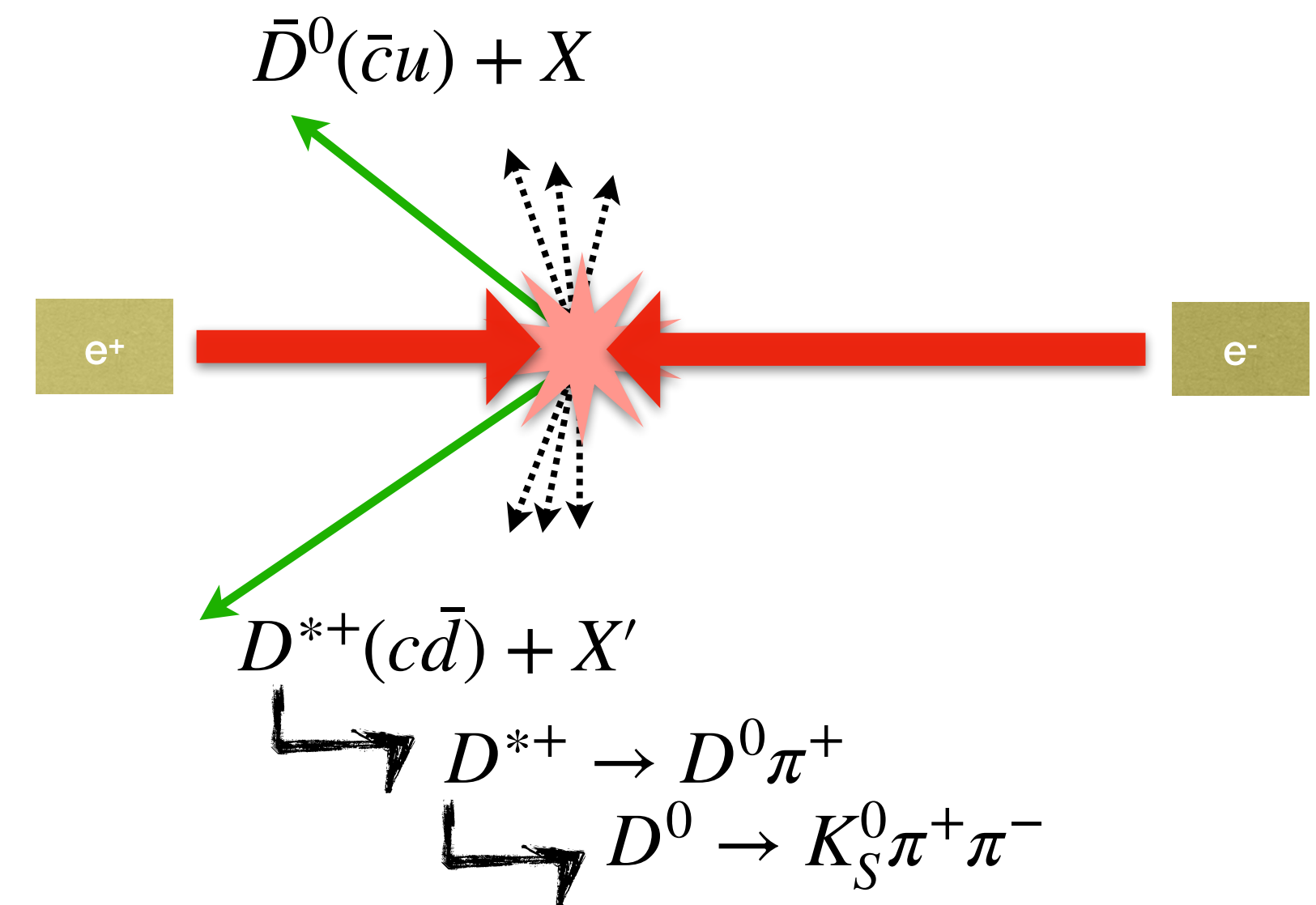
Nature of $D_{s0}^*(2317)^+$ and CP violation

Exploring charm

$$e^+e^- \rightarrow \text{two charm hadrons} + \text{fragmentation particles}$$

- Charm provides a unique setting to study weak decays of an up-type quark.
- Flavor tagging is essential for neutral- D CP violation and mixing measurements, using decays such as $D^{*+} \rightarrow D^0\pi^+$.
- Radiative transitions and baryon decays probe hadron structure, low-energy QCD, and diquark correlations.
- New decay channels, precise branching fractions, and resonant substructure help test theoretical models.
- Rare decays and CP violation provide complementary searches for new physics.

$$e^+e^- \rightarrow c\bar{c} \rightarrow D_{\text{tag}} X_{\text{frag}} D_{\text{sig}}$$

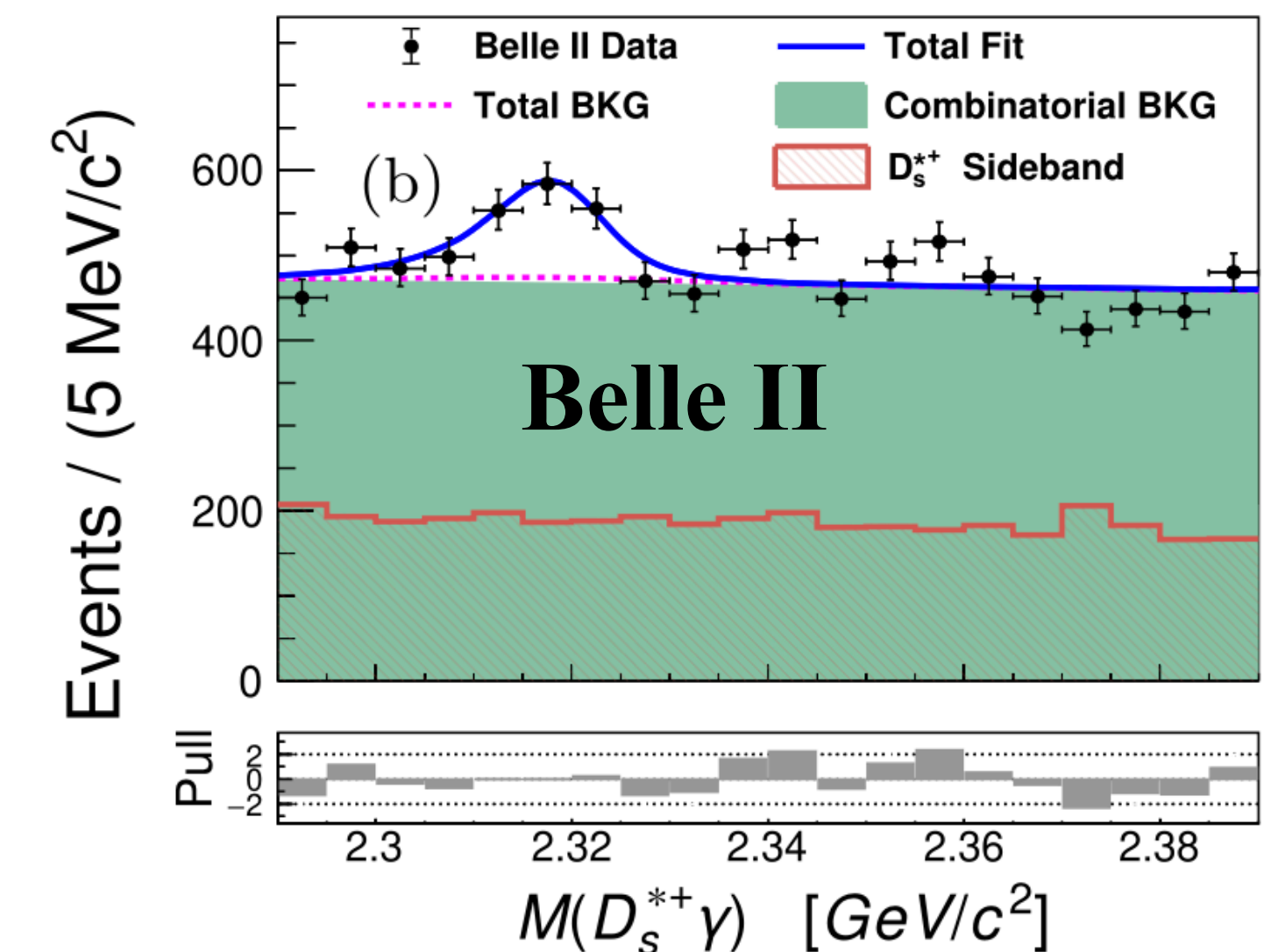
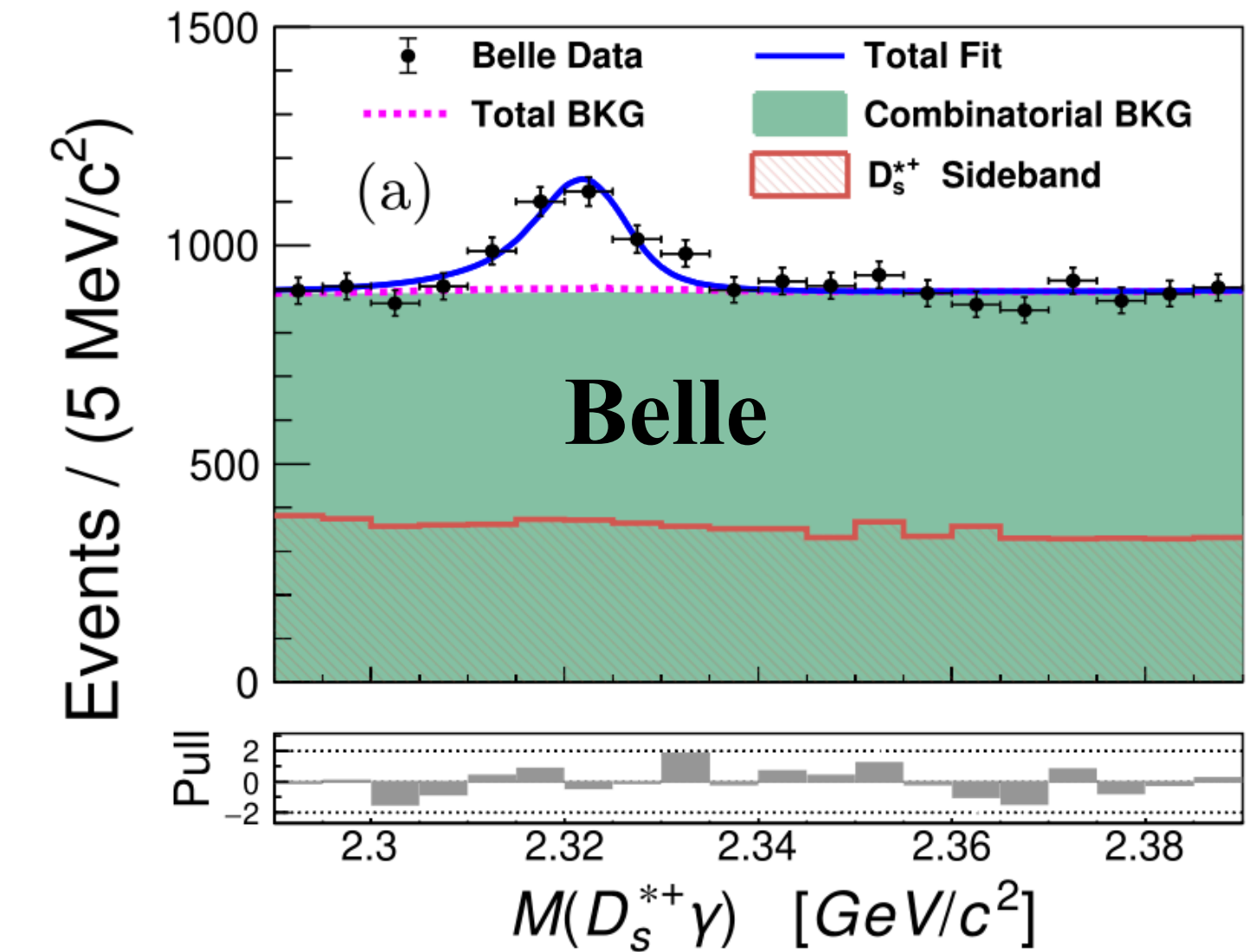


Today: selected highlights in hadron structure and charm CP violation.

First observation of $D_{s0}^*(2317)^+ \rightarrow D_s^{*+} \gamma$

[PRL 136, 241901](#)

- The nature of $D_{s0}^*(2317)^+$ remains **uncertain**;
 - Its mass is **lower than quark-model expectations**.
- Possible interpretations include a $c\bar{s}$ state, a DK molecule, a compact tetraquark, or a mixture.
- It lies below the DK threshold and decays through the isospin-violating channel $D_{s0}^*(2317)^+ \rightarrow D_s^{*+} \pi^0$.
- Measuring or constraining $\mathcal{B}(D_{s0}^*(2317)^+ \rightarrow D_s^{*+} \gamma)$ **helps distinguish these interpretations**.
- Unbinned maximum-likelihood fit to
 - $M(D_s^{*+} \gamma) = M(D_s^{*+} \gamma_1) - M(D_s^{*+} \gamma_2) + m(D_s^{*+})$
Removes effect from mass resolution of the D_s^{*+} .



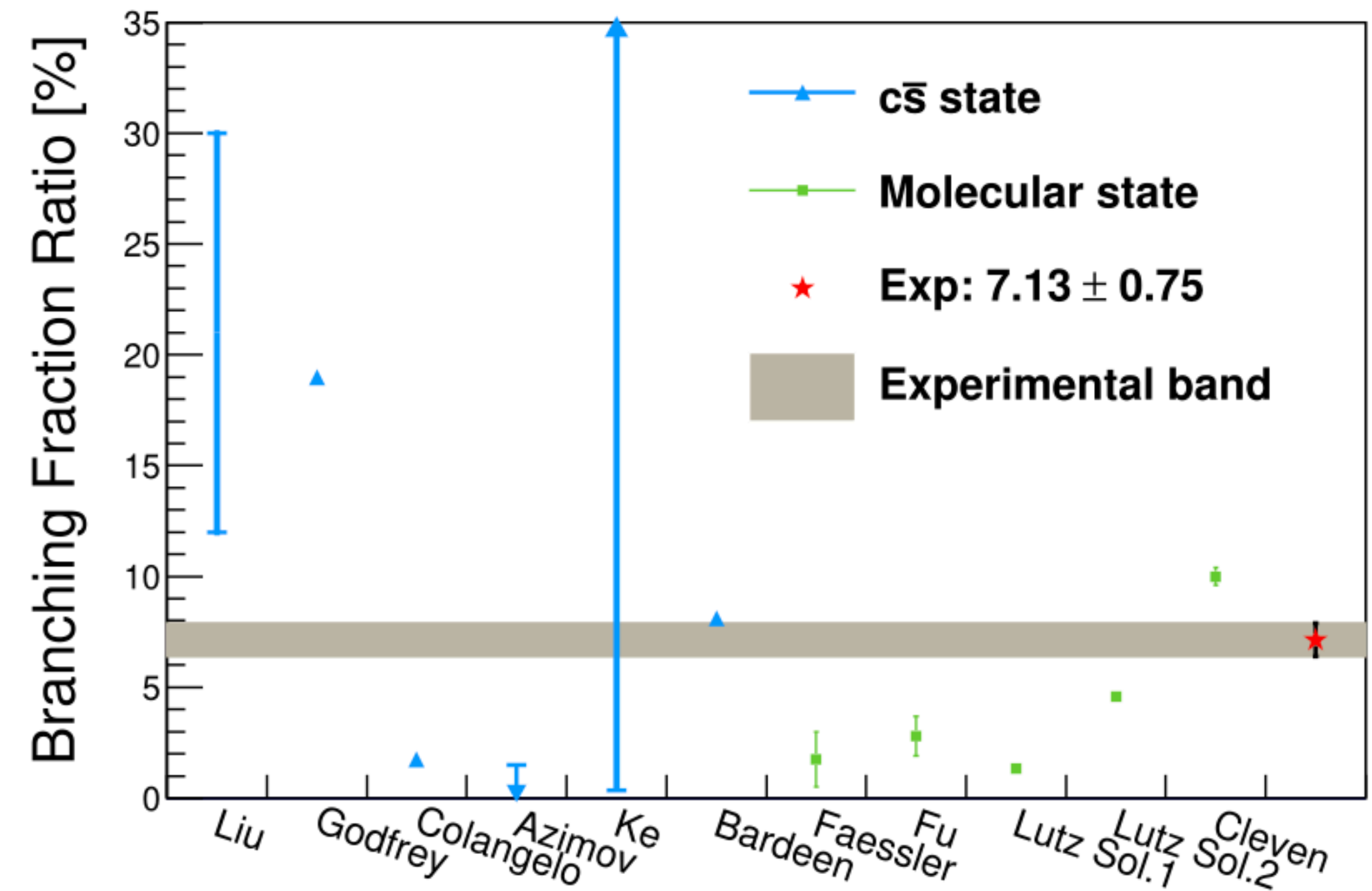
First observation of $D_{s0}^*(2317)^+ \rightarrow D_s^{*+} \gamma$

[PRL 136, 241901](#)

- Belle + Belle II data: $980.4 + 427.9 \text{ fb}^{-1}$
- Extract the branching fraction ratio, R :

$$R \equiv \frac{\mathcal{B}(D_{s0}^*(2317)^+ \rightarrow D_s^{*+} \gamma)}{\mathcal{B}(D_{s0}^*(2317)^+ \rightarrow D_s^+ \pi^0)} = (7.13 \pm 0.70_{\text{stat}} \pm 0.26_{\text{syst}}) \%$$

- Measured ratio generally **exceeds molecular-state** predictions but lies **below some quark-model predictions**.
- **Theoretical interpretation remains unclear**



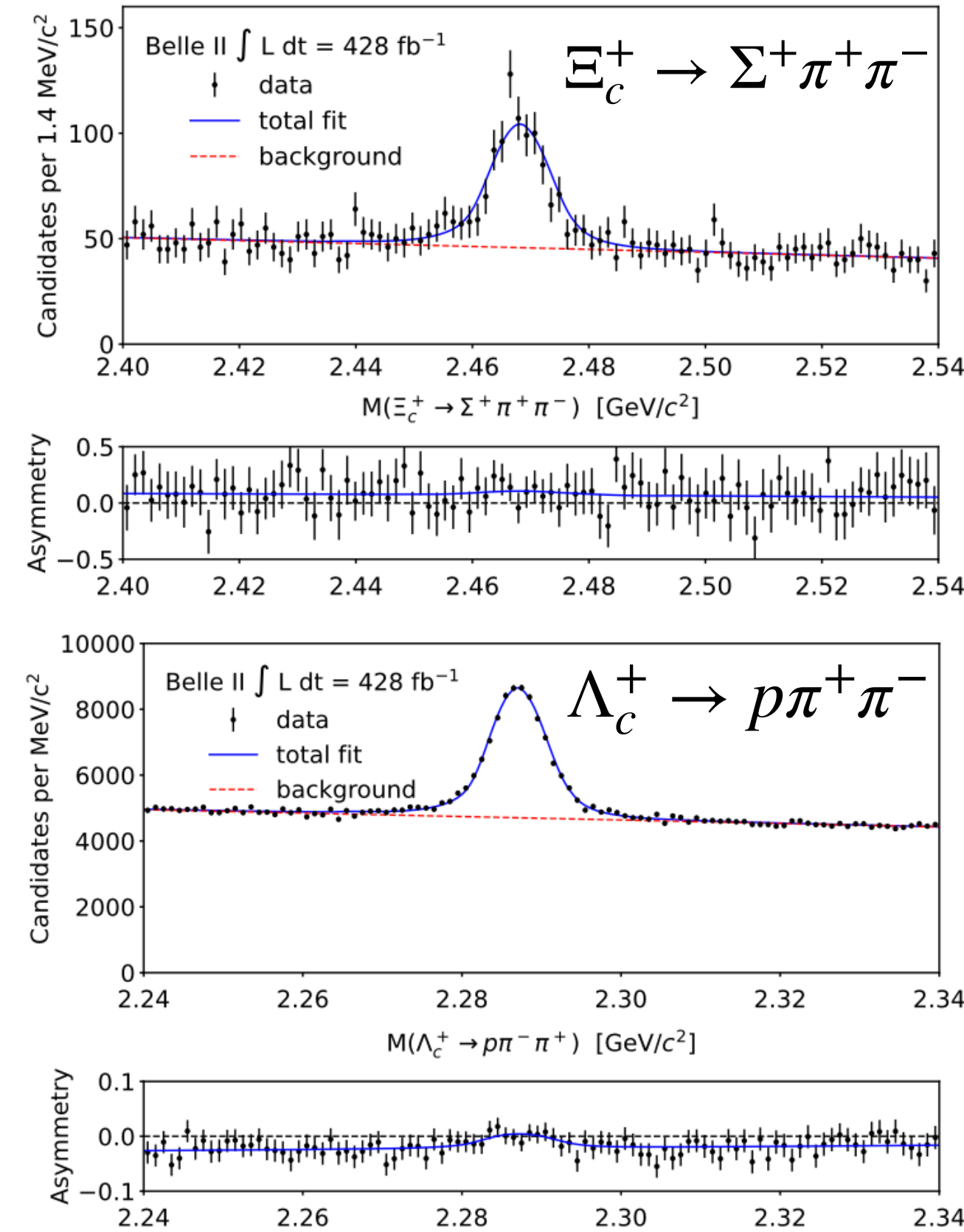
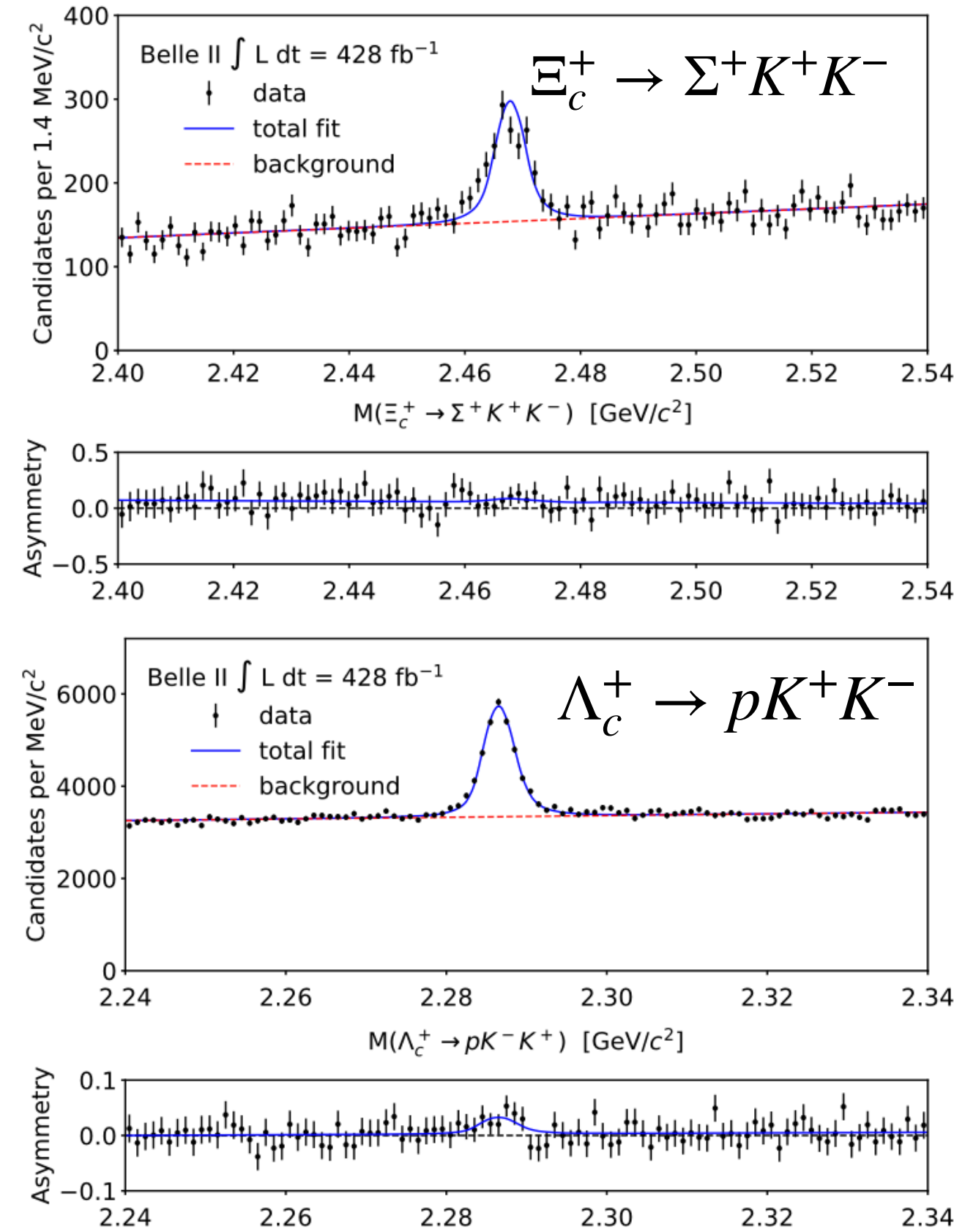
CP asymmetry in $\Xi_c^+ \rightarrow \Sigma^+ h^+ h^-$ and $\Lambda_c^+ \rightarrow p h^+ h^-$

[PRD 113, 032017](#)

- First measurements of individual CP asymmetries in $\Xi_c^+ \rightarrow \Sigma^+ h^+ h^-$ and $\Lambda_c^+ \rightarrow p h^+ h^-$, with $h = K, \pi$.
- Belle II data sample: 428 fb^{-1} .

$$\begin{aligned}
 A_{CP}(\Xi_c^+ \rightarrow \Sigma^+ K^+ K^-) &= (3.7 \pm 6.6 \pm 0.6) \% \\
 A_{CP}(\Xi_c^+ \rightarrow \Sigma^+ \pi^+ \pi^-) &= (9.5 \pm 6.8 \pm 0.5) \% \\
 A_{CP}(\Lambda_c^+ \rightarrow p K^+ K^-) &= (3.9 \pm 1.7 \pm 0.7) \% \\
 A_{CP}(\Lambda_c^+ \rightarrow p \pi^+ \pi^-) &= (0.3 \pm 1.0 \pm 0.2) \%
 \end{aligned}$$

- Uncertainties are statistically dominated.



CP summed figures

No significant CP violation observed

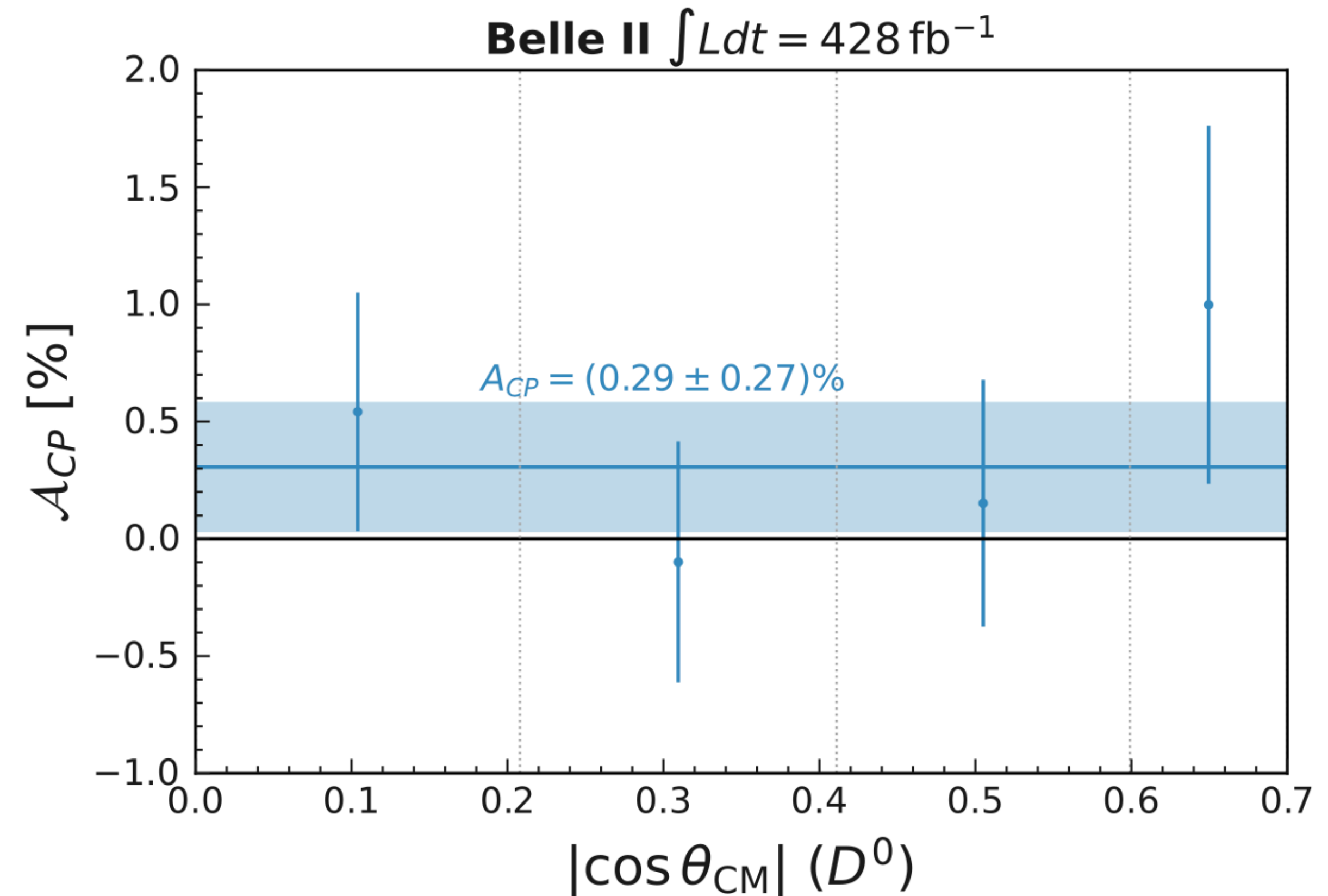
CP asymmetry in $D^0 \rightarrow \pi^+\pi^-\pi^0$

[PRD 113, 052006](#)

- Search for CP violation in a singly Cabibbo-suppressed charm decay.
- Belle II data sample: 428 fb^{-1} .
- D^{*+} tagged sample for $D^0 \rightarrow \pi^+\pi^-\pi^0$.
- Extract signal yields using a 2D fit to $m(D^0)$ and $\Delta m = m(D^*) - m(D^0)$.

$$A_{CP} = (0.29 \pm 0.27_{\text{stat}} \pm 0.13_{\text{syst}}) \%$$

- Most precise measurement with 34% better precision than the previous best result.

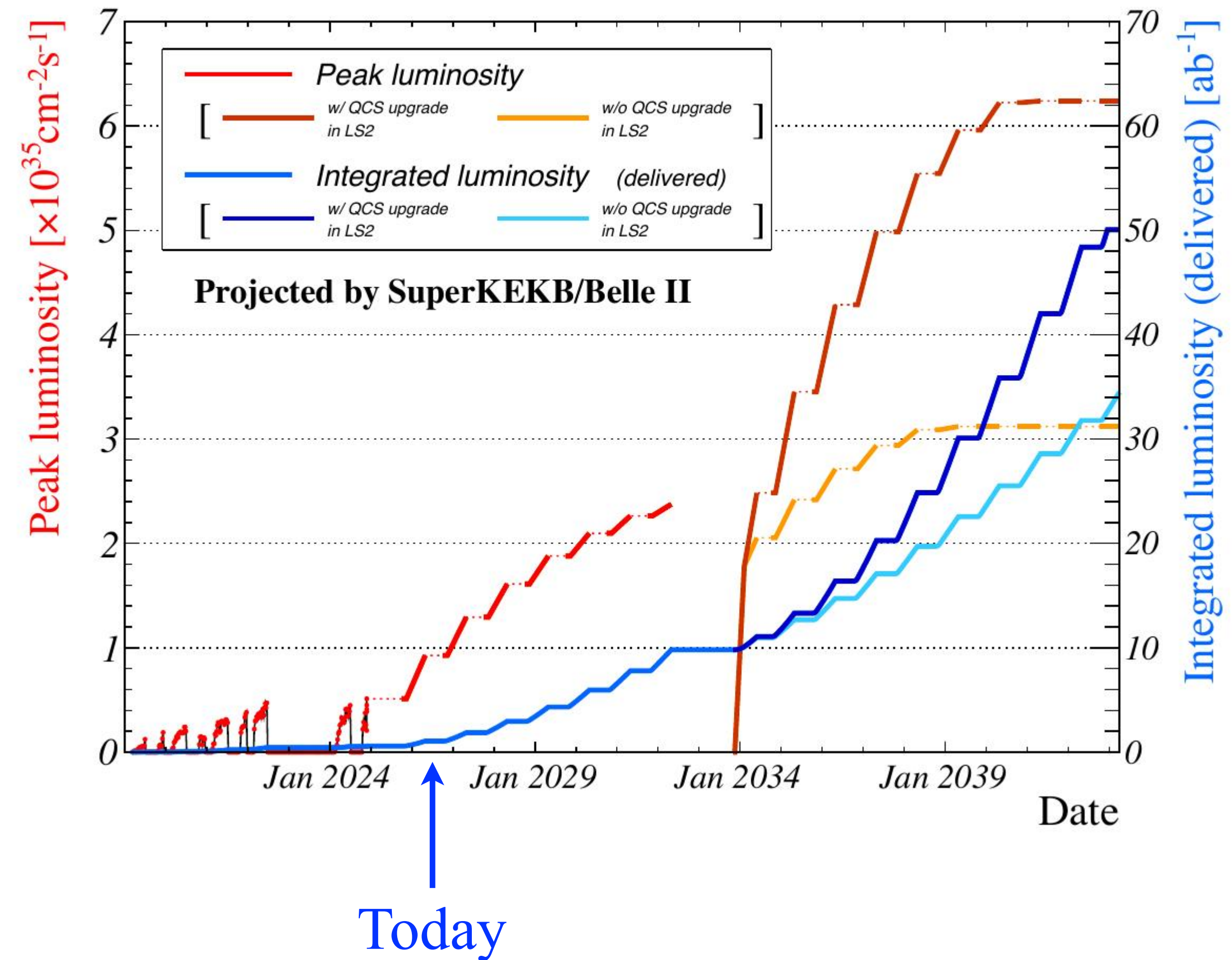


Consistent with no CP violation.

Future outlook

- The clean e^+e^- environment and efficient neutral reconstruction offer substantial scope for improved precision.
- About 2% of the target 50 ab^{-1} dataset has been collected; larger samples will enable more precise measurements and broader rare-decay searches.
- Combined Belle + Belle II analyses and refined techniques will further improve sensitivity.
- Planned accelerator and detector upgrades will support higher luminosity and improved performance.

Much more to come from Belle II!



Summary

- Belle II is delivering precise and unique measurements across a broad physics programme.
- Radiative B decays probe photon helicity through time-dependent CP violation.
- New CP measurements constrain the CKM angle ϕ_2 .
- Semileptonic decays test lepton flavor universality and determine $|V_{ub}|$.
- Electroweak penguin searches set stronger limits on $B \rightarrow K\tau^+\tau^-$.
- Charm measurements probe hadron structure and extend CP -violation searches.
- These measurements highlight the strengths of the clean e^+e^- environment, precise vertexing, and efficient neutral reconstruction.
- The results presented today represent only part of Belle II's physics programme.

Other highlights from Belle II

- A few examples from the broader physics programme, beyond the results covered today.
- **Hadronization**
 - [PRD 111, 052003](#)
- **Quarkonium and spectroscopy**
 - $e^+e^- \rightarrow \eta\Upsilon(2S), \eta\Upsilon(1S), \gamma X_b$ [PRD 113, L051102](#)
 - $e^+e^- \rightarrow \gamma\chi_{bJ} (J = 0,1,2)$ [PRD 113, 052009](#)
 - $e^+e^- \rightarrow \Upsilon_J(1D)\eta (J = 1,3)$ [arXiv:2607.04369](#)
 - $e^+e^- \rightarrow \pi^+\pi^-\Upsilon(1D)$ [JHEP 06 2026, 278](#)
 - $X(3872) \rightarrow \pi^0\chi_{c0}(1P)$ and $X(3915) \rightarrow \pi^0\chi_{c0}(1P)$ [arXiv:2606.24578](#)
- **Dark sector**
 - $B^0 \rightarrow \bar{D}^0 X_{\text{inv}}$ and $B^\pm \rightarrow h X_{\text{inv}} (h = \pi^\pm, K^\pm, D_s^\pm, p^\pm)$ [arXiv:2601.07104](#)
- **Electroweak penguins**
 - $B \rightarrow X_s \nu \bar{\nu}$ [PRL 136, 231801](#)
- **Hadronic B decays**
 - $B^+ \rightarrow \Sigma_c(2455)^{++} \bar{\Xi}_c^{\prime -}$ and $B^0 \rightarrow \Sigma_c(2455)^0 \bar{\Xi}_c^{\prime 0}$ [arXiv:2606.12905](#)
- **Tau physics**
 - $\tau^\pm \rightarrow \mu^\pm \gamma$ [arXiv:2608.23009](#)

Belle II's clean, low-multiplicity environment enables this broad physics program, from spectroscopy to searches for new particles.

Backup

$R(D)$ and $R(D^*)$

[arXiv:2609.21947](https://arxiv.org/abs/2609.21947)

