Belle II highlights

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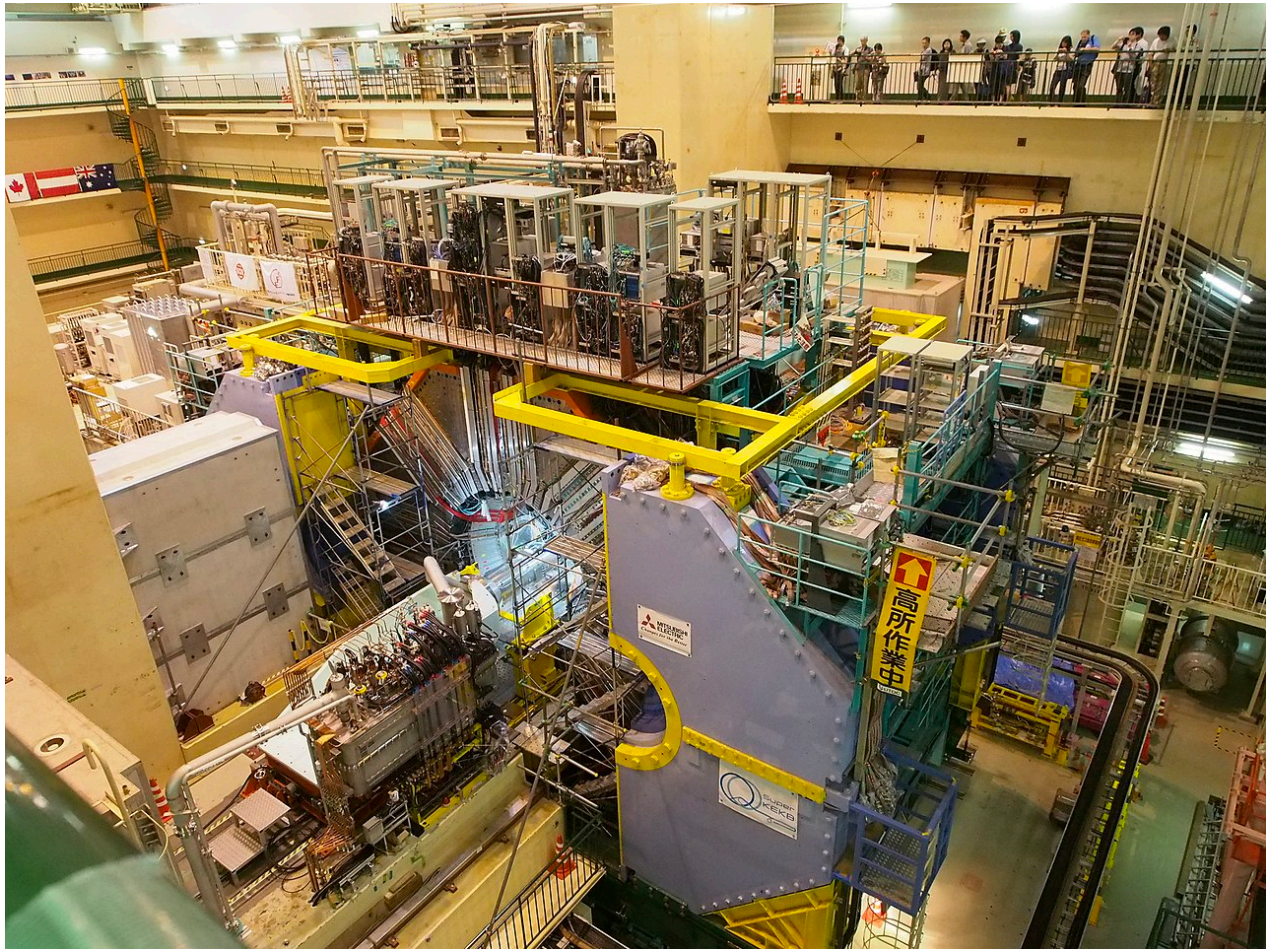
UniBo seminar, 05/04/23

Outline

- Belle II experiment at SuperKEKB
  - Historical introduction
  - Detector operations
  - B factory basics
- Recent Belle II highlights
  - CKM measurements
  - Lepton universality tests
  - Charm and tau physics



CP-violation and the CKM

Violation of *CP* invariance, *C* asymmetry, and baryon asymmetry of the universe

A. D. Sakharov

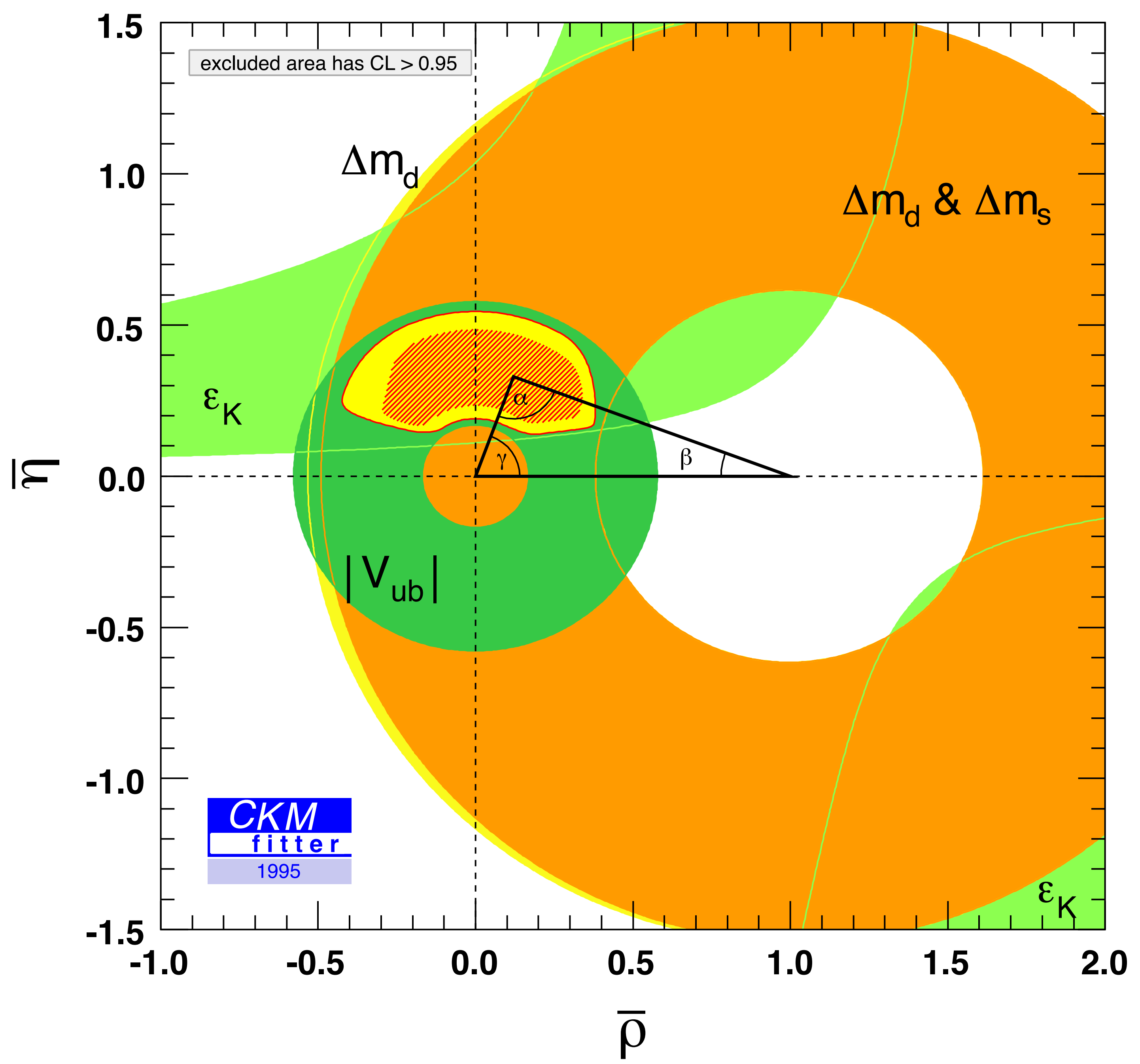
(Submitted 23 September 1966)
Pis'ma Zh. Eksp. Teor. Fiz. **5**, 32–35 (1967) [JETP Lett. **5**, 24–27 (1967).
Also S7, pp. 85–88]

Usp. Fiz. Nauk **161**, 61–64 (May 1991)

The theory of the expanding universe, which presupposes a superdense initial state of matter, apparently excludes the possibility of macroscopic separation of matter from antimatter; it must therefore be assumed that there are no antimatter bodies in nature, i.e., the universe is asymmetrical with respect to the number of particles and antiparticles (*C* asymmetry). In particular, the absence of antibaryons and the proposed absence of baryonic neutrinos implies a nonzero baryon charge (baryonic asymmetry). We wish to point out a possible explanation of *C* asymmetry in the hot model of the expanding universe (see Ref. 1) by making use of effects of *CP* invariance violation (see Ref. 2). To explain baryon asymmetry, we propose in addition an approximate character for the baryon conservation law.

According to our hypothesis, the occurrence of *C* asymmetry is the consequence of violation of *CP* invariance in the nonstationary expansion of the hot universe during the superdense stage, as manifest in the difference between the partial probabilities of the charge-conjugate reactions. This effect has not yet been observed experimentally, but its existence is theoretically undisputed (the first concrete example, Σ_+ and Σ_- decay, was pointed out by S. Okubo as early as 1958) and should, in our opinion, have much cosmological significance.

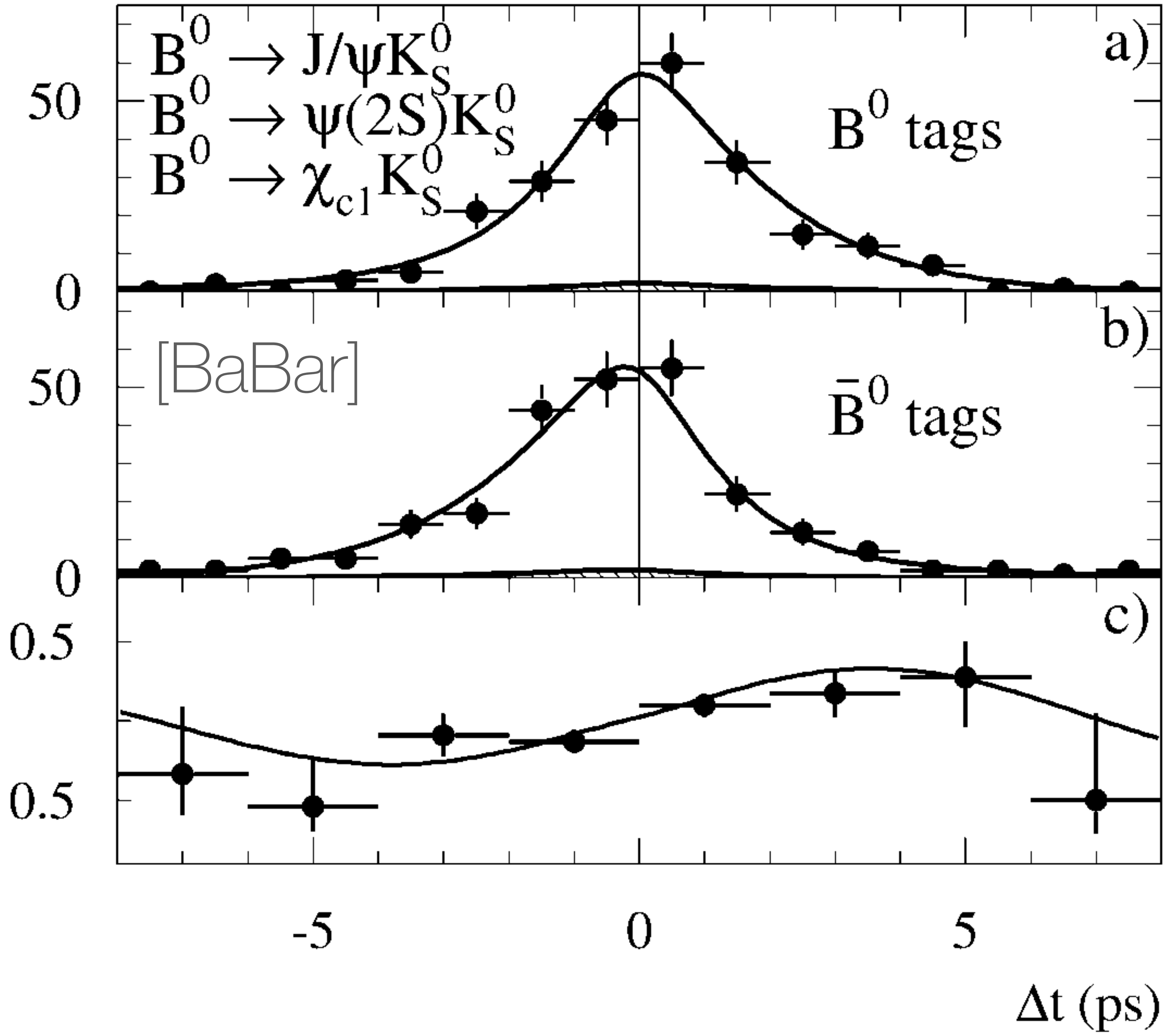
[1995]



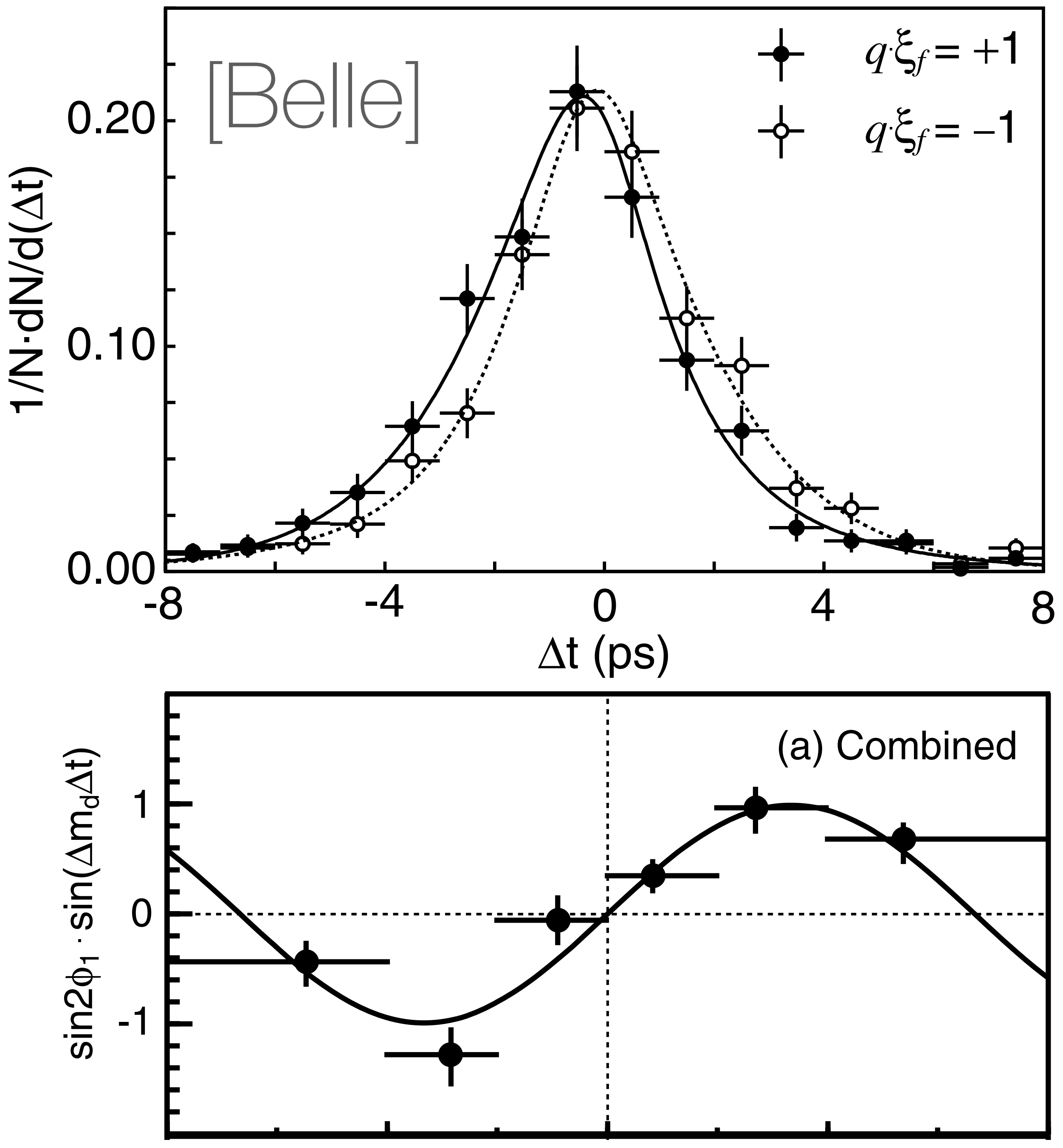
- Violation of charge-conjugation and parity-reversal (CP-violation) necessary ingredient to explain the imbalance between matter and antimatter in the universe
- Accommodated in the weak interactions of quarks via the Cabibbo-Kobayashi-Maskawa (CKM) unitary matrix, represented as a triangle in the complex plane

Asymmetric B-factories

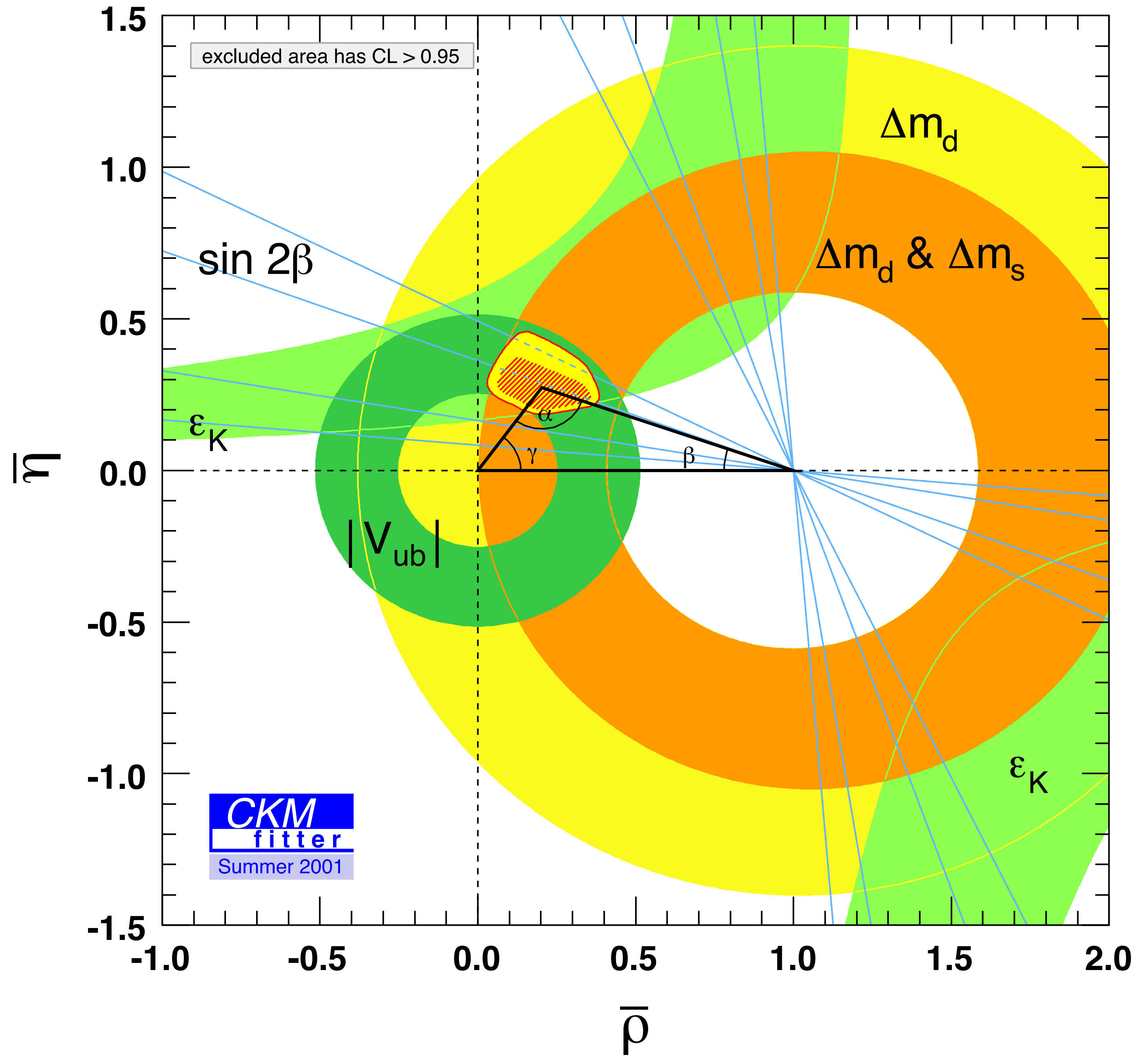
[PRL87. 091801 (2001)]



[PRL87. 091802 (2001)]



[2001]

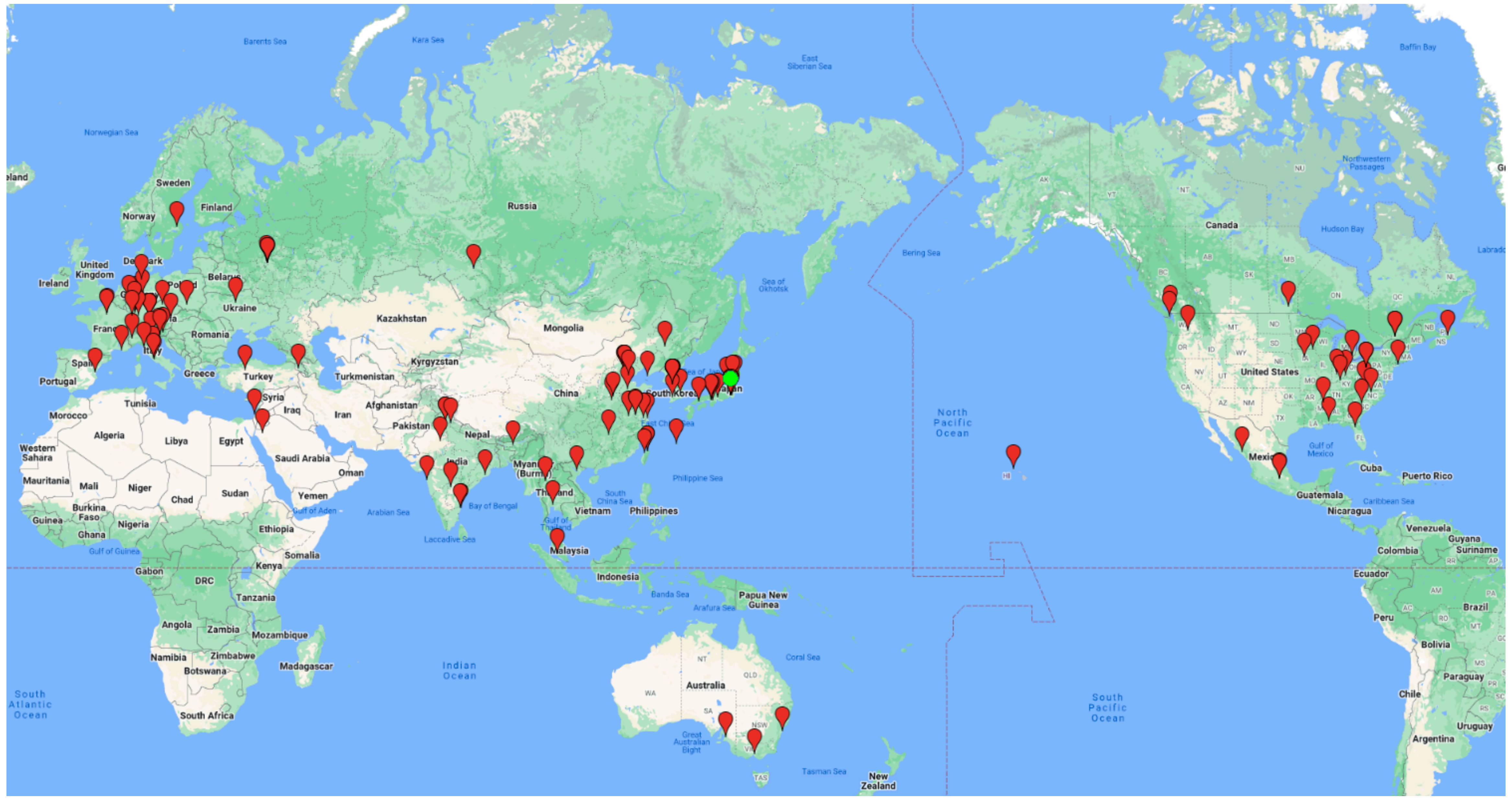


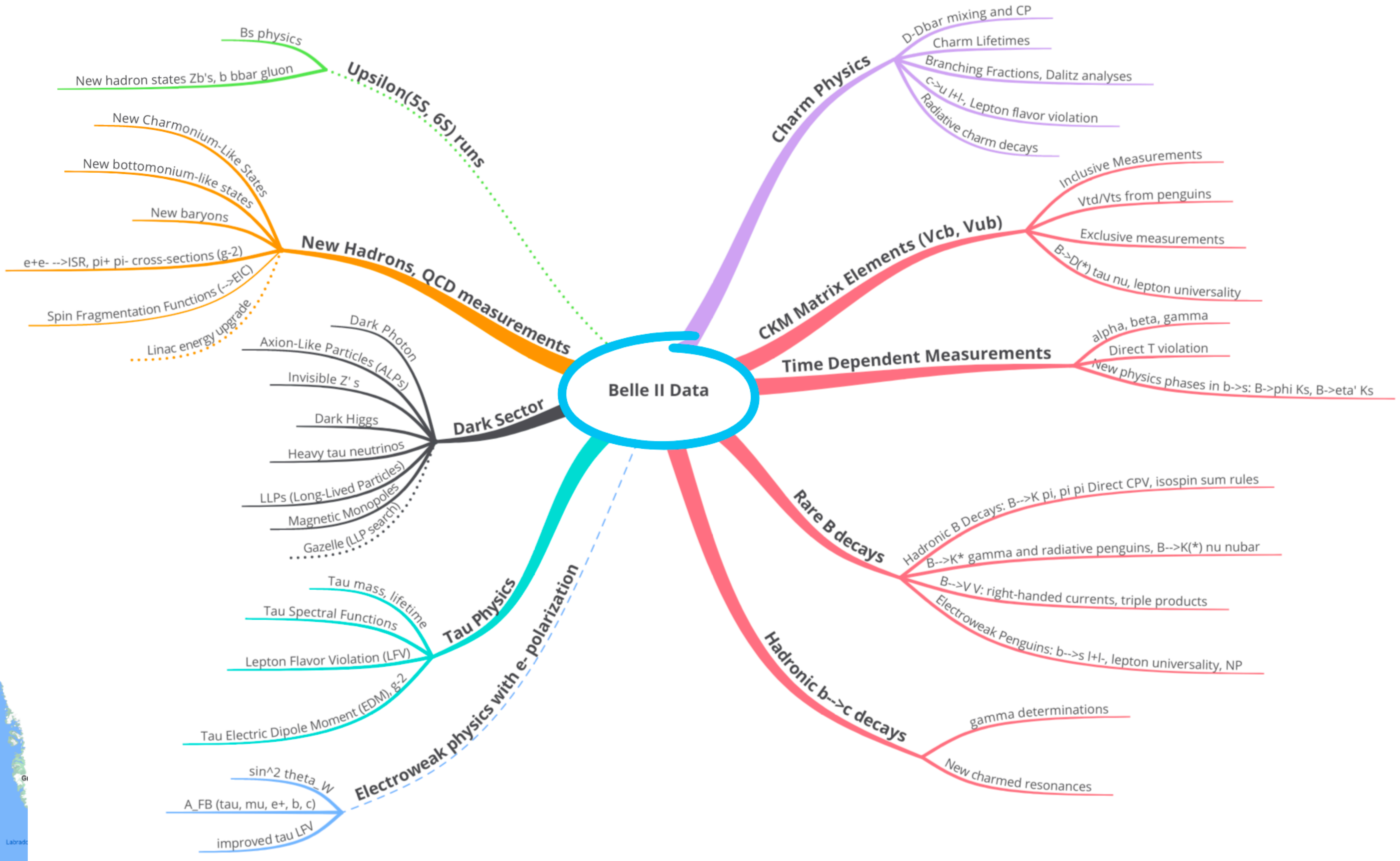
- Observation of CP-violation in the interference of $B^0 \to J/\psi K^0$ and $B^0 \to \overline{B}^0 \to J/\psi K^0$, constraining the UT angle β/ϕ_1
- Achievements summarized in the "The physics of the B-factories" book [arxiv.org:1406.6311]

"As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier." [https://www.nobelprize.org/prizes/physics/2008/press-release/]

Belle II

- Successor of Belle at the upgraded SuperKEKB high-luminosity collider
- Broad physics program building upon end expanding that of Belle
- World-wide effort of ~100 institutes and ~1000 collaborators

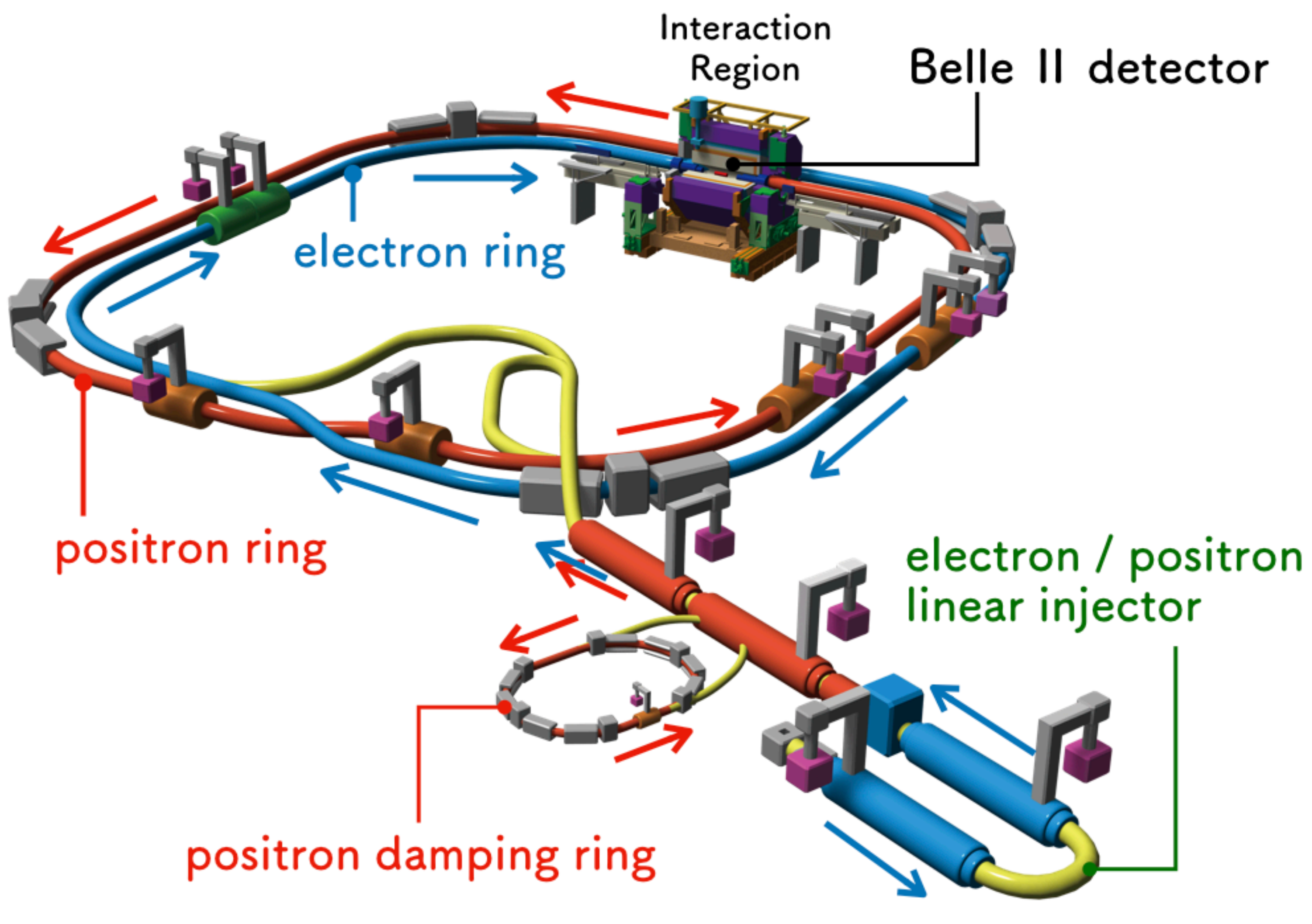




Physics Book [arxiv.org:1808.10567]
Snowmass Whitepaper [arxiv.org:2207.06307]

SuperKEKB

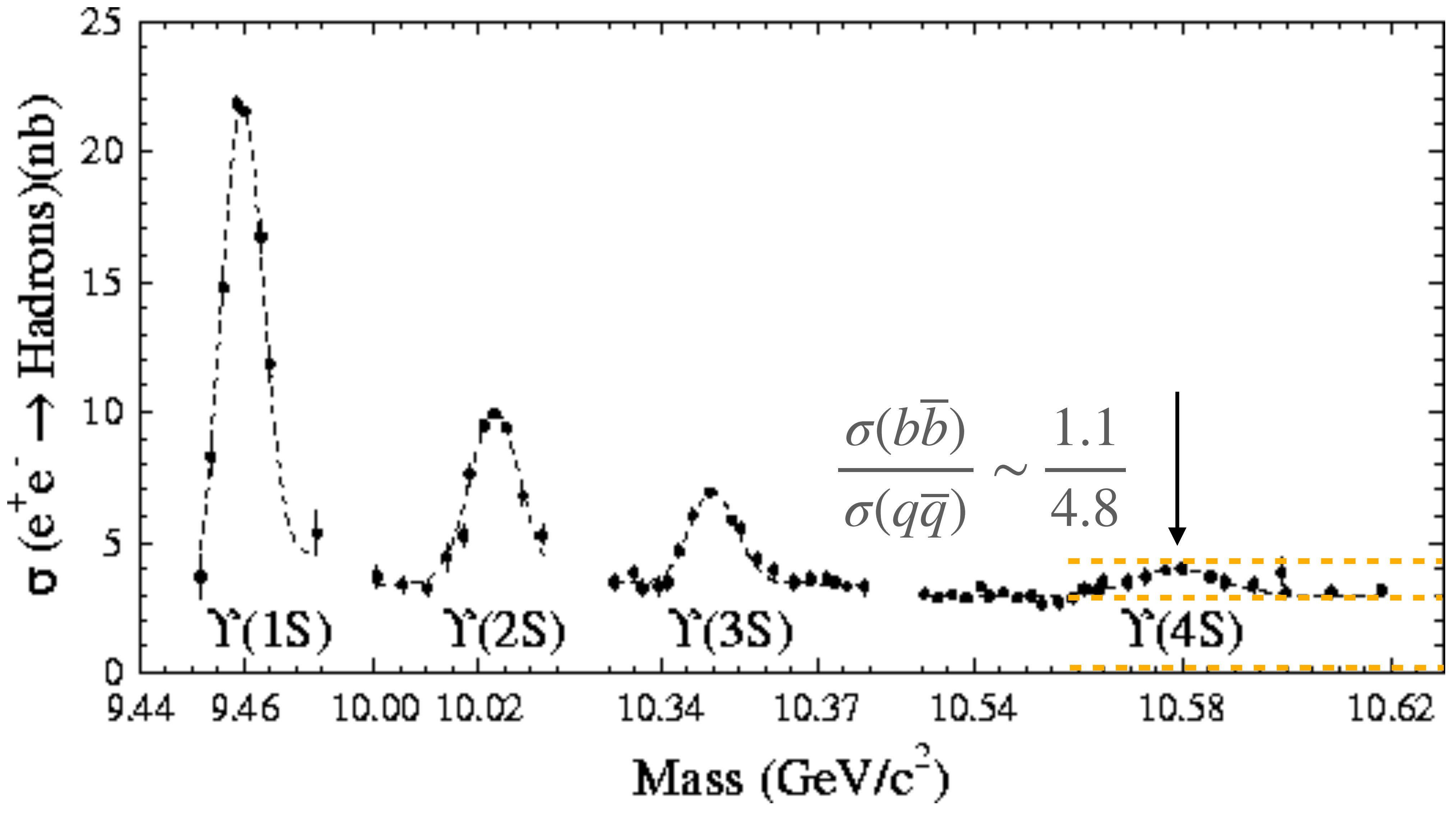
- Asymmetric e^+e^- accelerator operating in Tsukuba, Japan
  - Colliding 7 GeV electrons on 4 GeV positrons at Υ(4s) mass
  - 30x increase in luminosity wrt KEKB thanks to the new nano-beam scheme

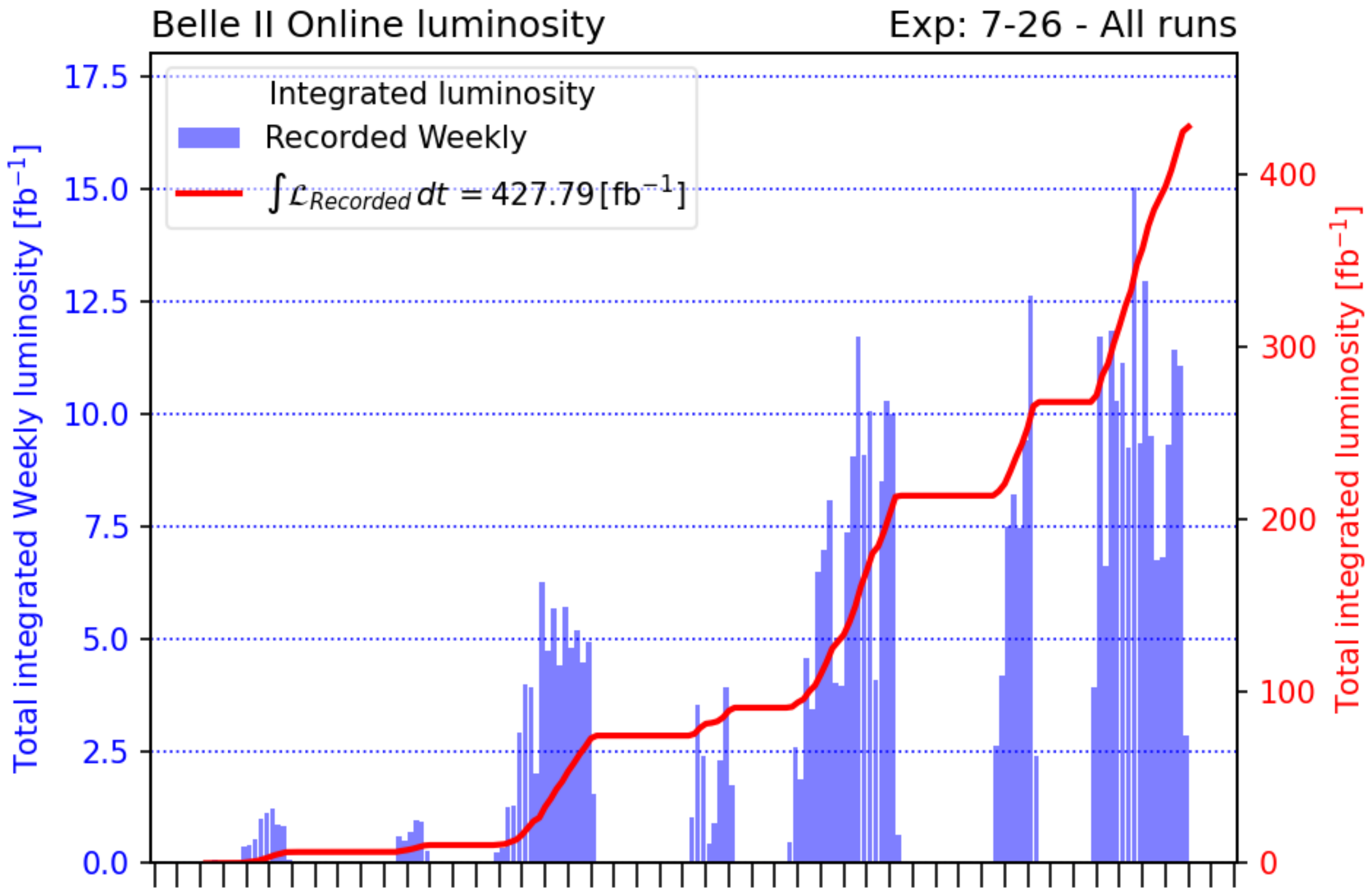


- Currently in LS1, resuming data-taking in winter
  - Installation of new 2-layered pixel detector
  - Replacement of beam pipe and aging detector components
  - Additional shielding and increased resilience against higher beam backgrounds

Operations

- Producing abundant sample of B, D and τ decays
  - Most ee->ll collisions discarded based on event multiplicity
  - 30 (now) / 600 (design) BB, DD per second along with 2-3x production of light quarks
- Several milestones reached so far
  - Achieved world's highest instantaneous luminosity (4.7x10^{34} cm^{-2}s^{-1})
  - Collected 362 fb^{-1} dataset at the Y(4s) in 2019-22, corresponding to 387M B$\bar{B}$ pairs
  - Recorded ~20fb^{-1} unique dataset above the Y(4s), and ~40fb^{-1} off-resonance

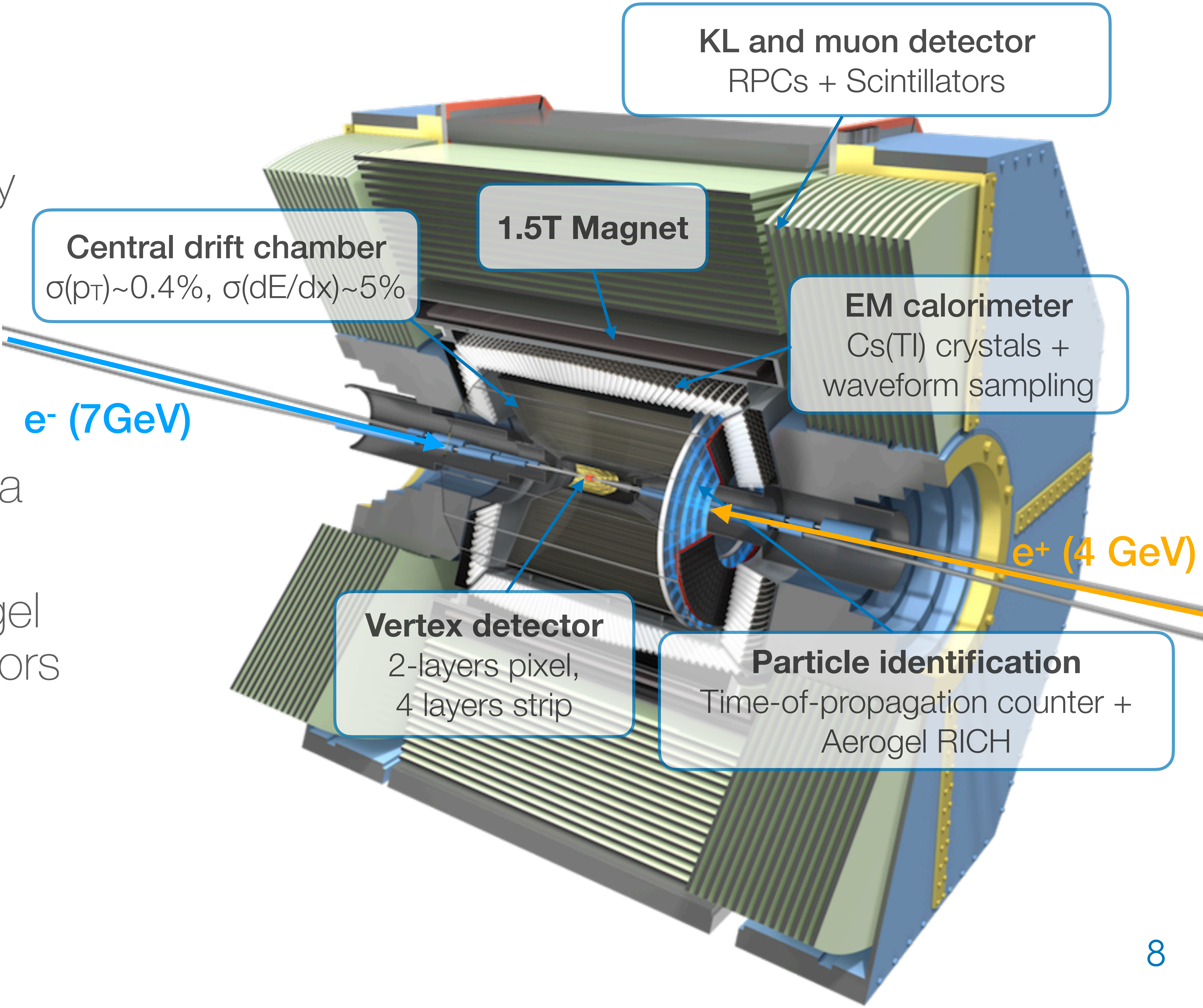




<— Jan. 2019 Jul. 2022 —>

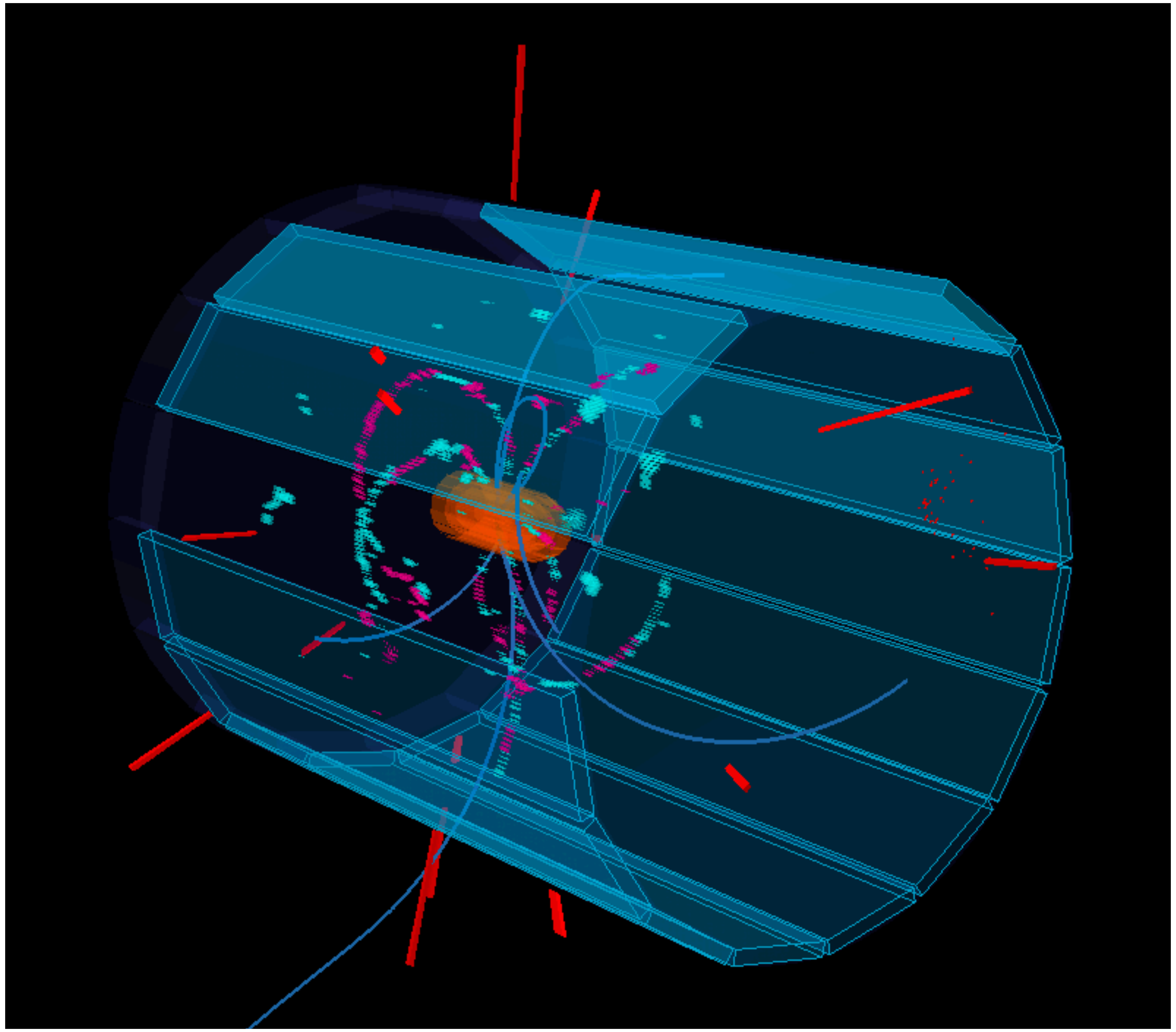
Detector

- Looks like old Belle, but effectively brand-new detector
  - 2-layer pixel and 4-layer strip silicon vertex detectors
  - Central drift chamber providing measurement of track momenta and dE/dx
  - Time-of-propagation and aerogel ring-imaging Cherenkov detectors
  - Upgraded electronics
- Only magnet, support structure, calorimeter crystals and muon detector barrel RPCs are reused

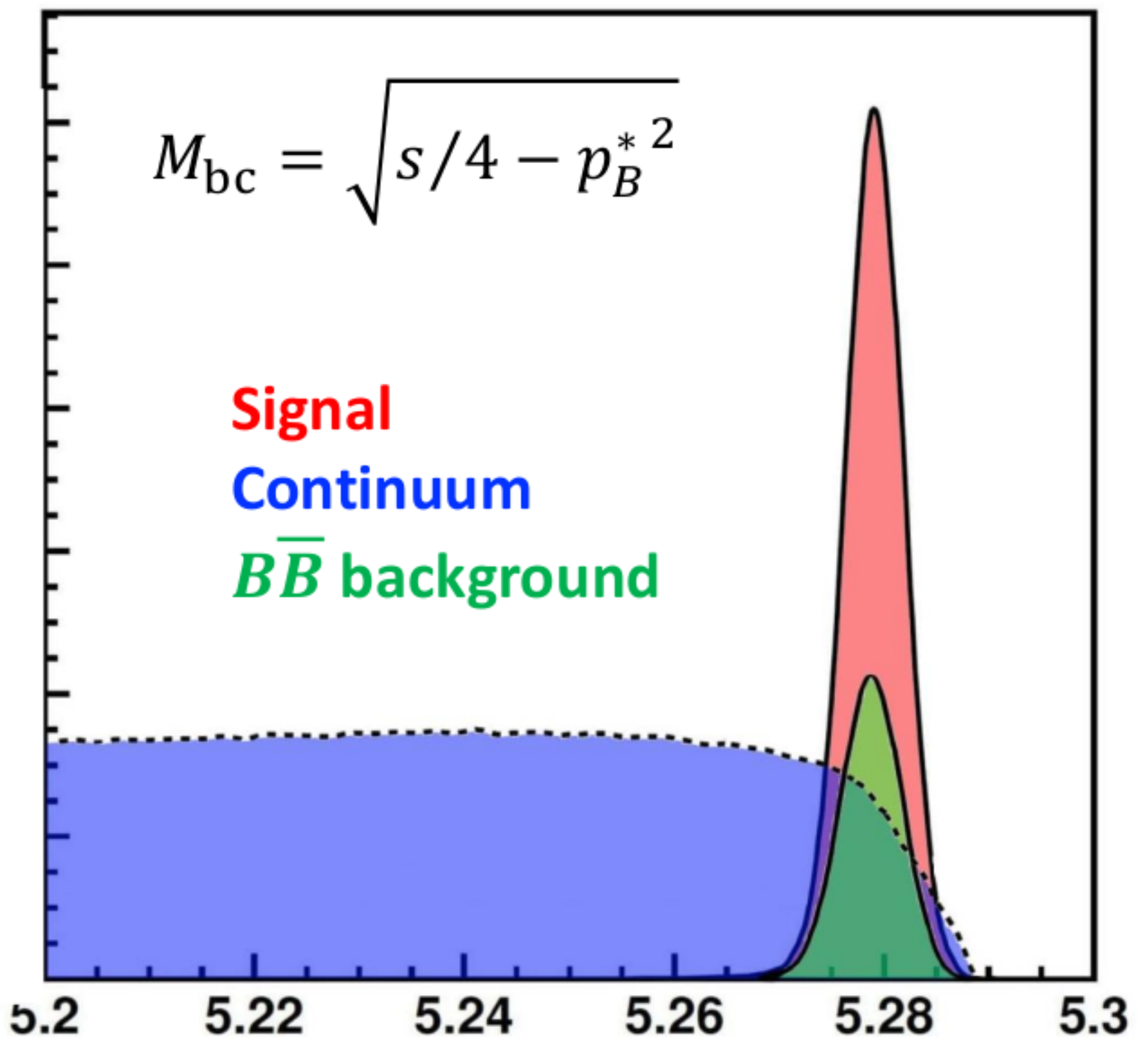


e+e- collisions

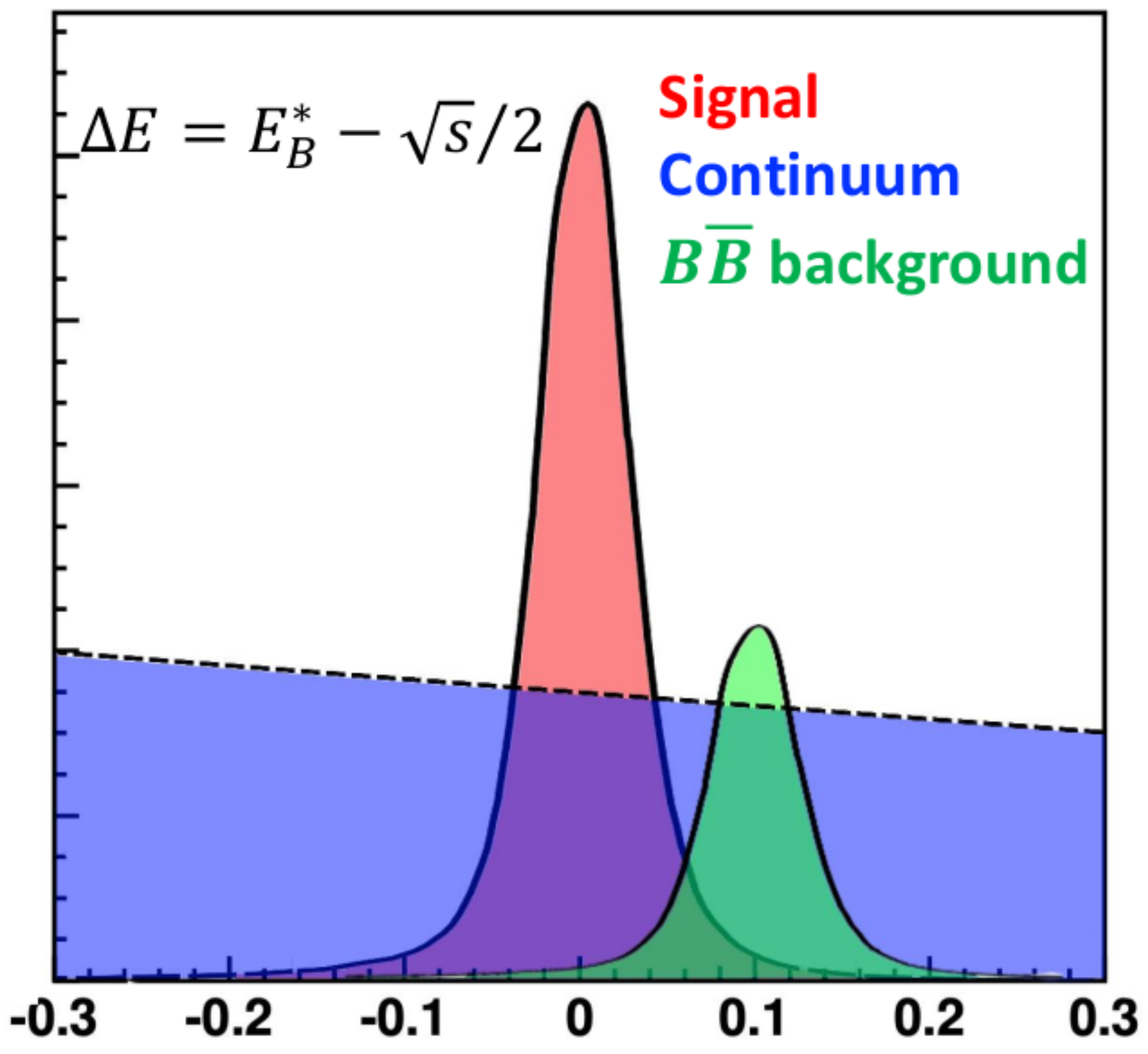
- Clean experimental environment, offering several advantages
  - Efficient reconstruction of neutrals and missing energy
  - Kinematic constraints from known initial energy at Y(4s)
  - Comparable performance for muons and electrons
  - Non biasing triggers for B and D physics
  - Low multiplicity triggers for single track, muon, photon



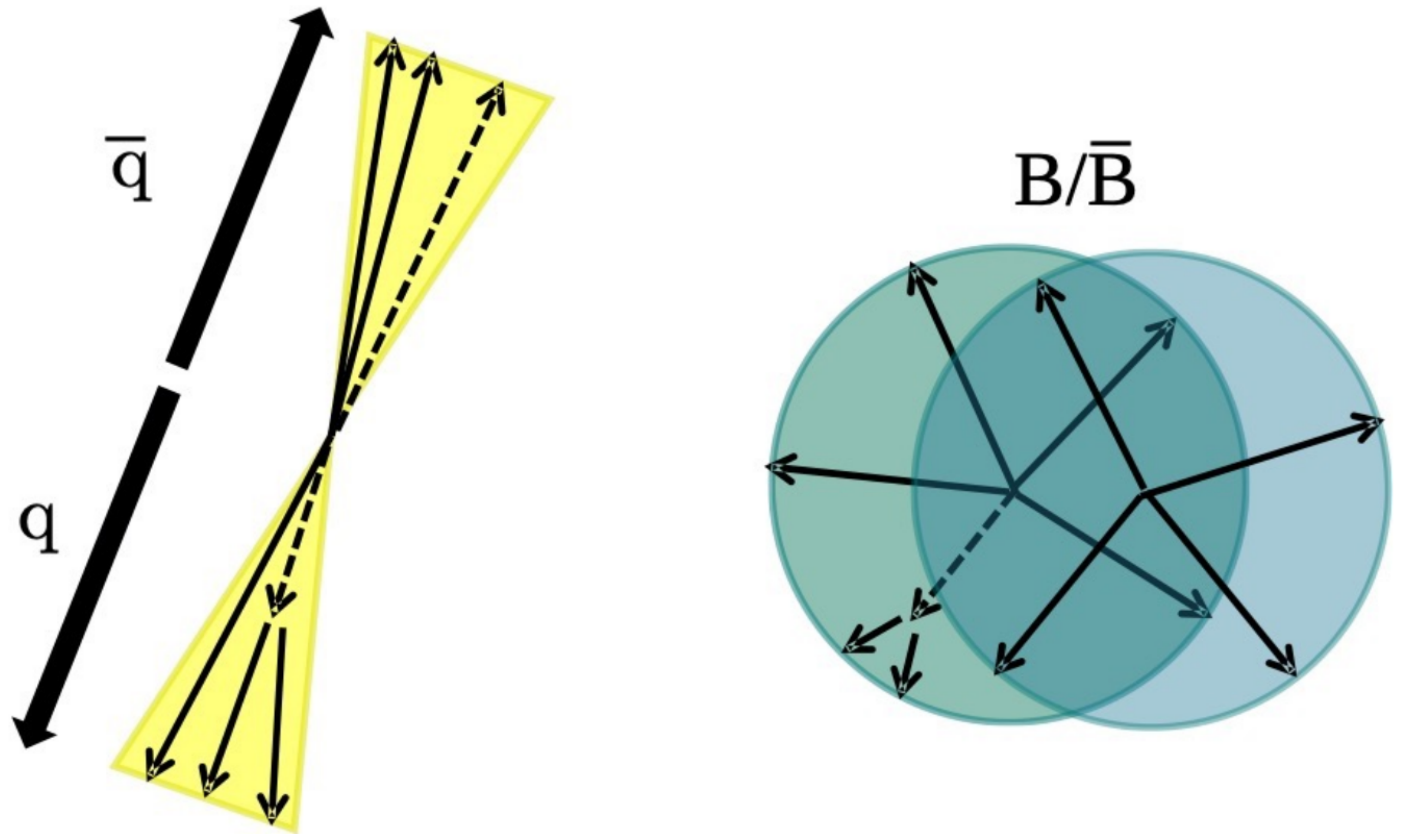
B-factory analysis 101



Beam-constrained mass [GeV/c^2]



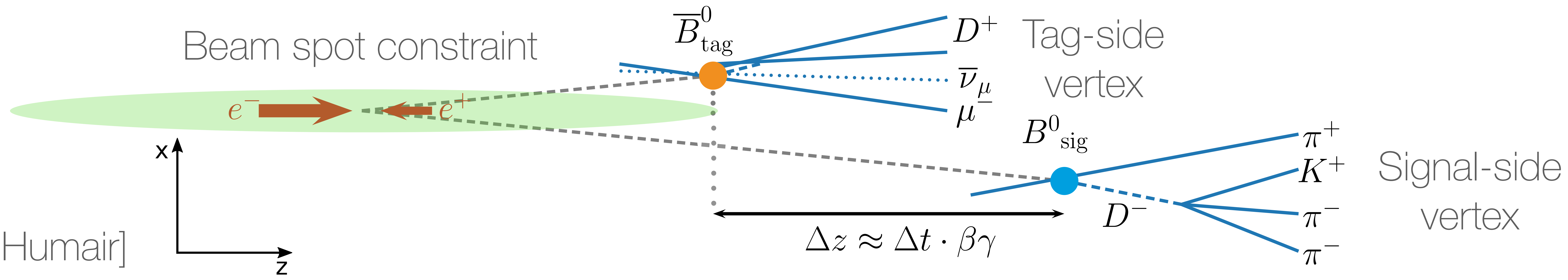
Energy difference [GeV]



Event shape

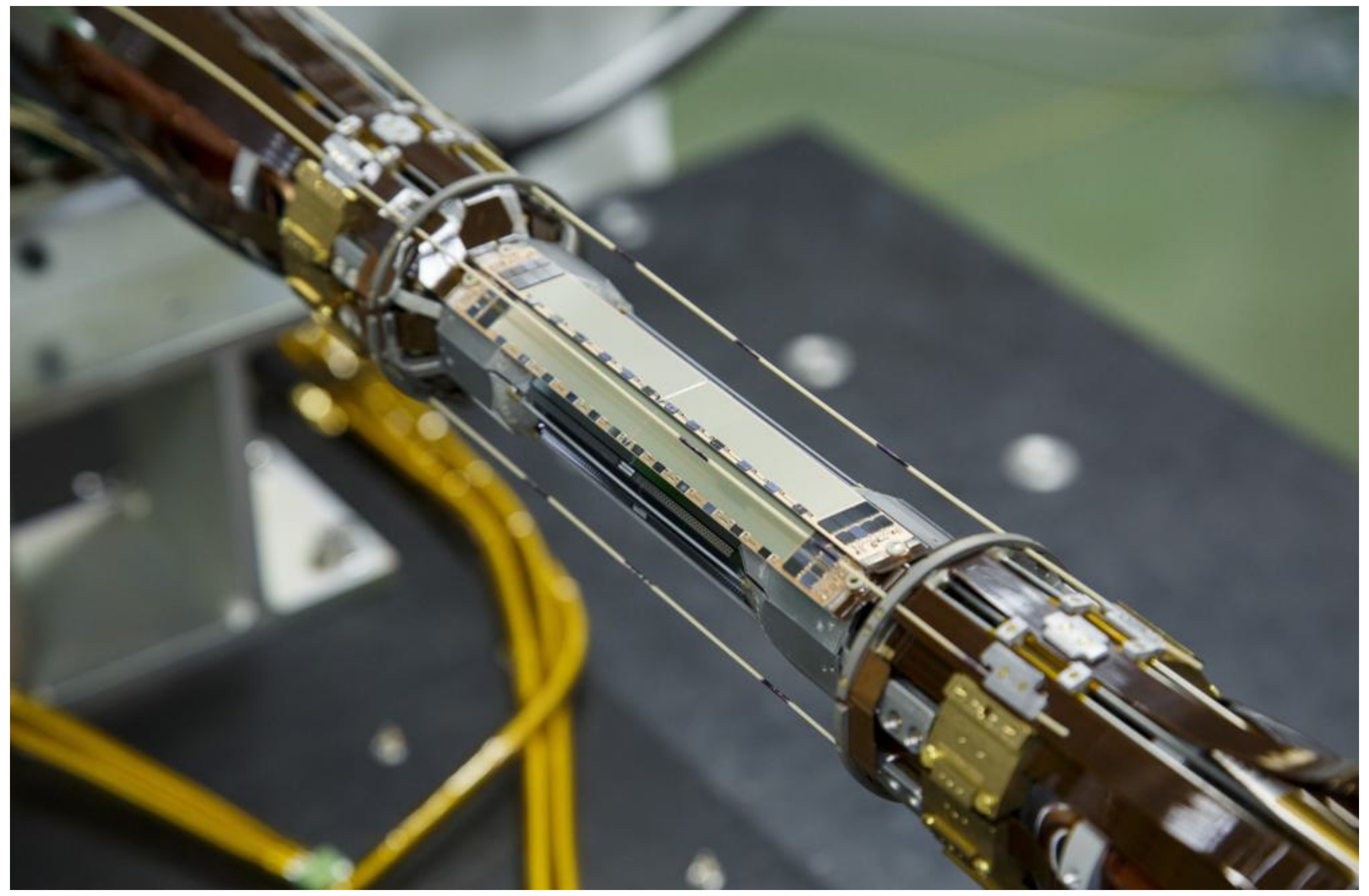
- High resolution (~2-10 MeV) high-level analysis variables (M_{bc}, ΔE), separating signal from backgrounds, using the knowledge of beam energy
- Several event shape variables exploiting the correlations in e^+e^- collision, usually combined into continuum-suppression classifier

Time measurement



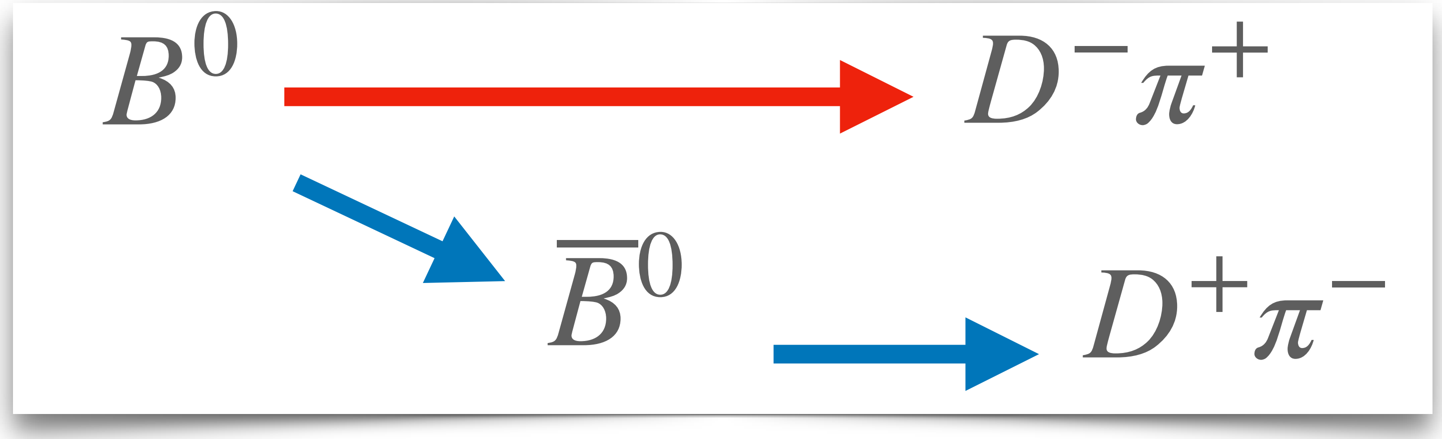
[Credits: T. Humair]

- Measuring the time difference Δt of coherently produced $B\overline{B}$ pairs from the decay of a Υ(4S), boosted along z
- Improved vertex resolution from pixel in spite of lower boost
  - Belle: βγ=0.43, Δz≈200μm —> Belle II: βγ=0.29, Δz≈130μm
- Enhanced Δt resolution from the beam spot profile in combination with the new nano-beam scheme
- Highly efficient category-based flavor tagger (ε_{tag}~30%)

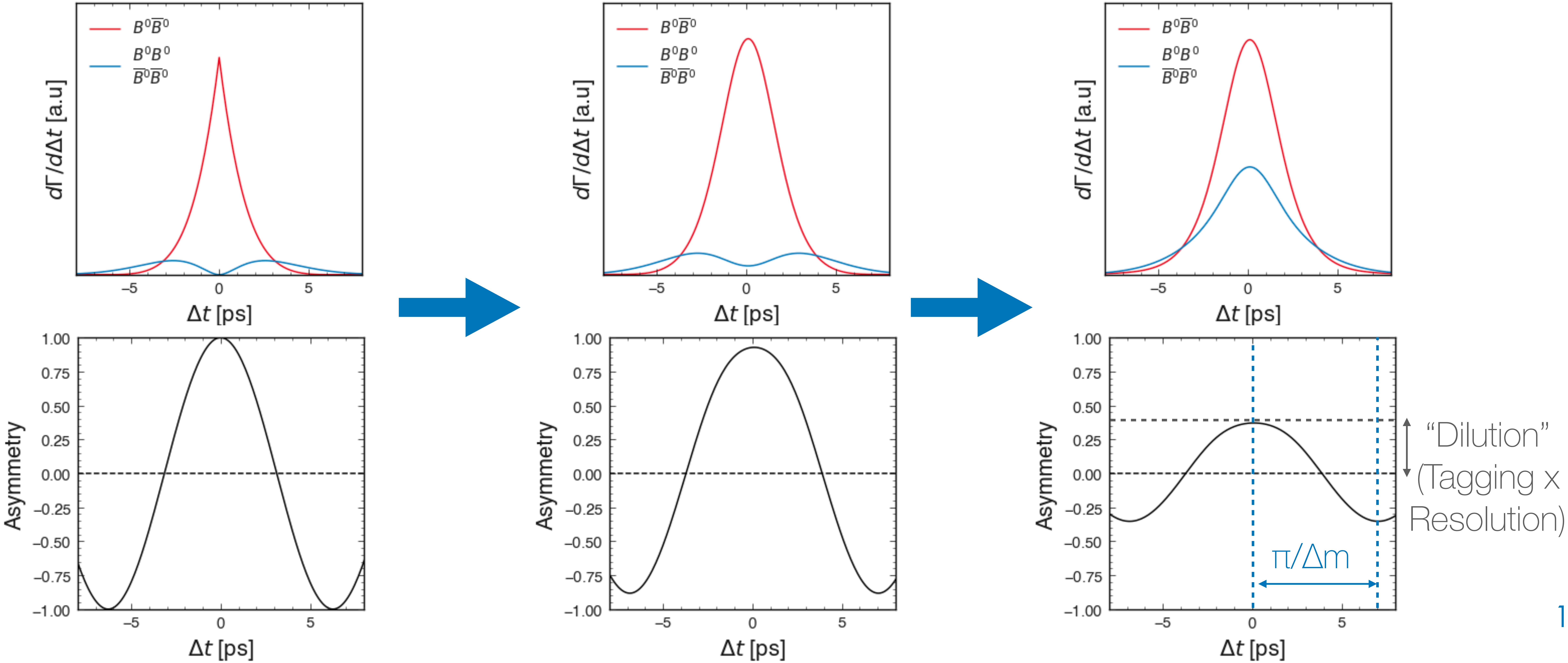


Pixel detector radius ≈ 1.4 cm

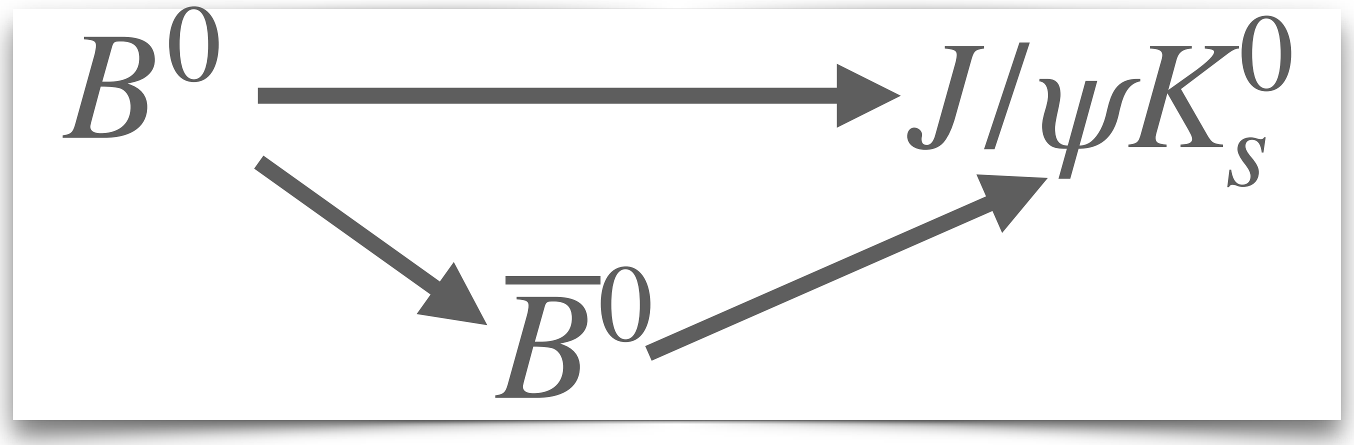
Δt resolution and flavor tagging



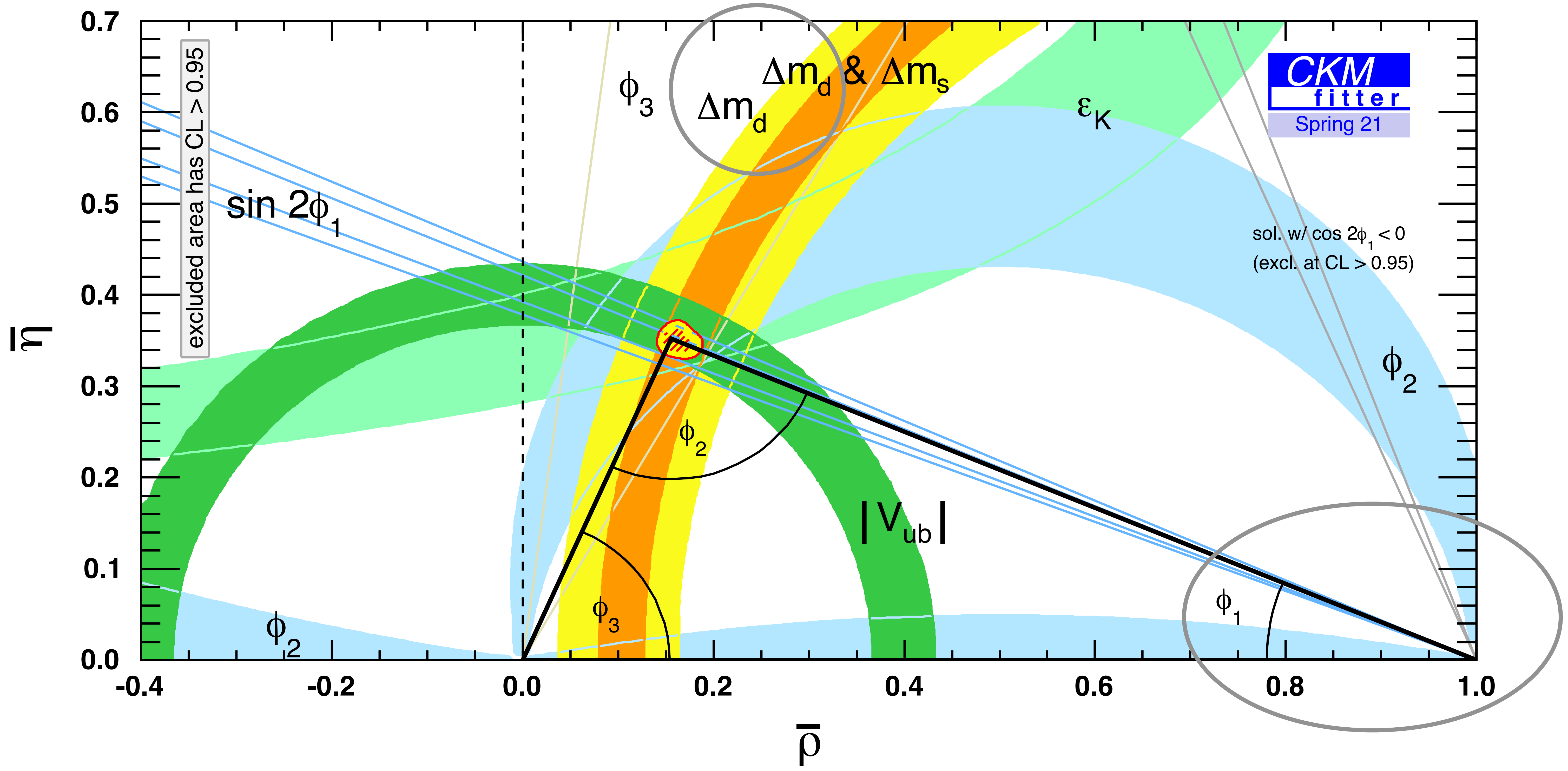
Δm ~ 0.5 ps^{-1} | Resolution ~ 1ps | Mistag ~ 30%



Δt resolution and flavor tagging



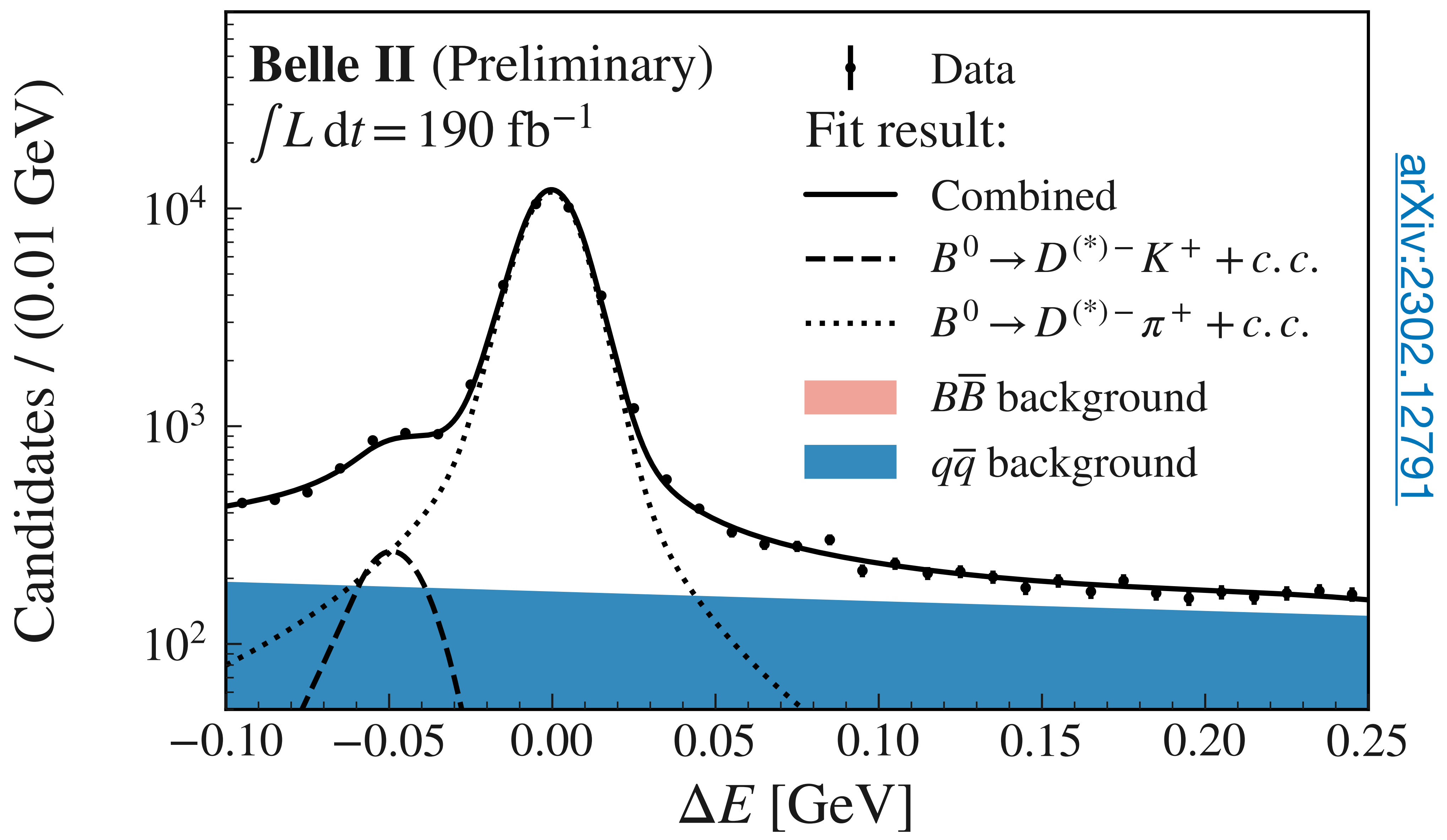
Mixing with flavor
specific B^0 decays



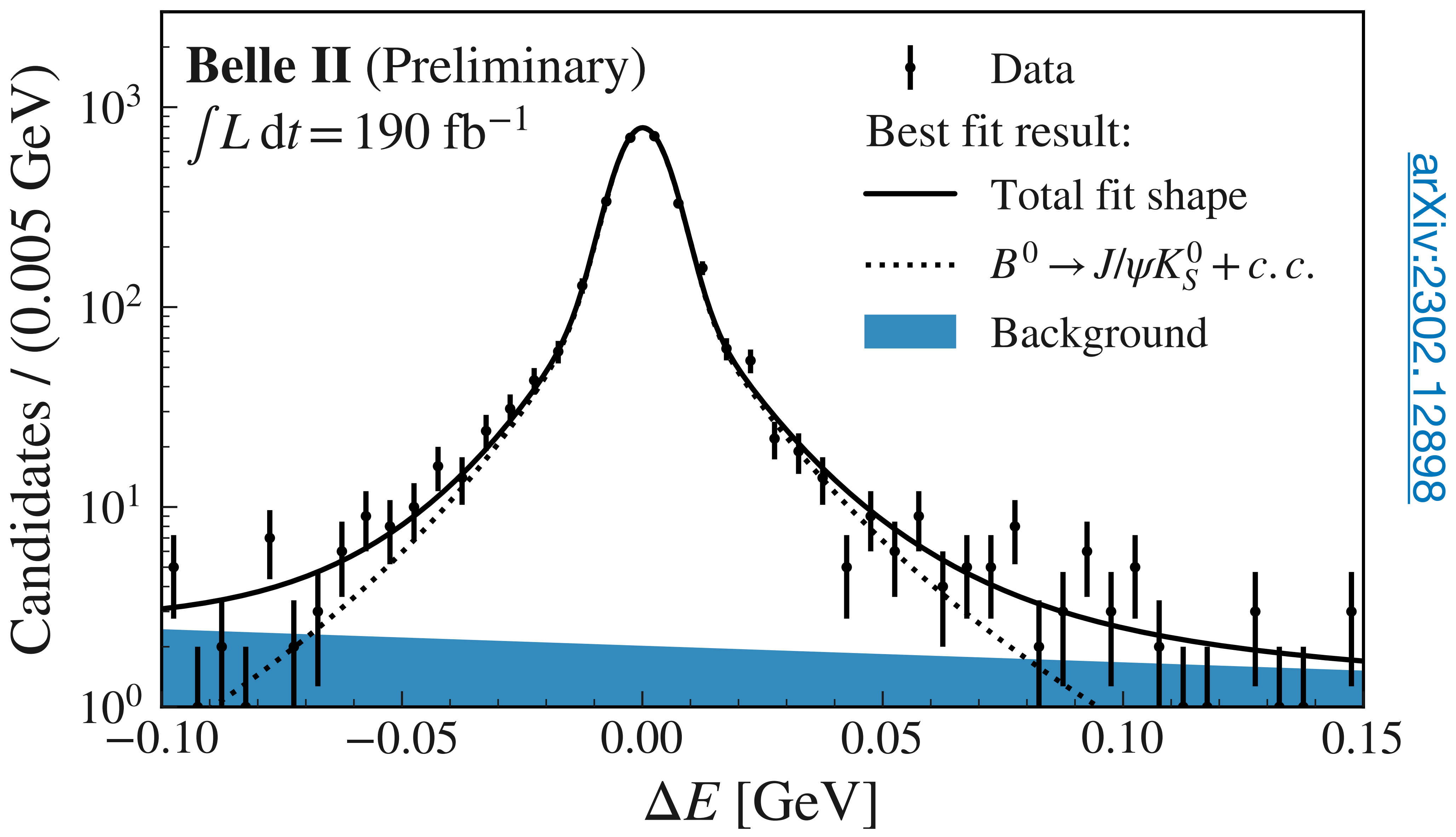
Interference b/w mixing and
decay in b->ccs transitions

Δm and sin2ϕ₁

~33k B->D(*)π



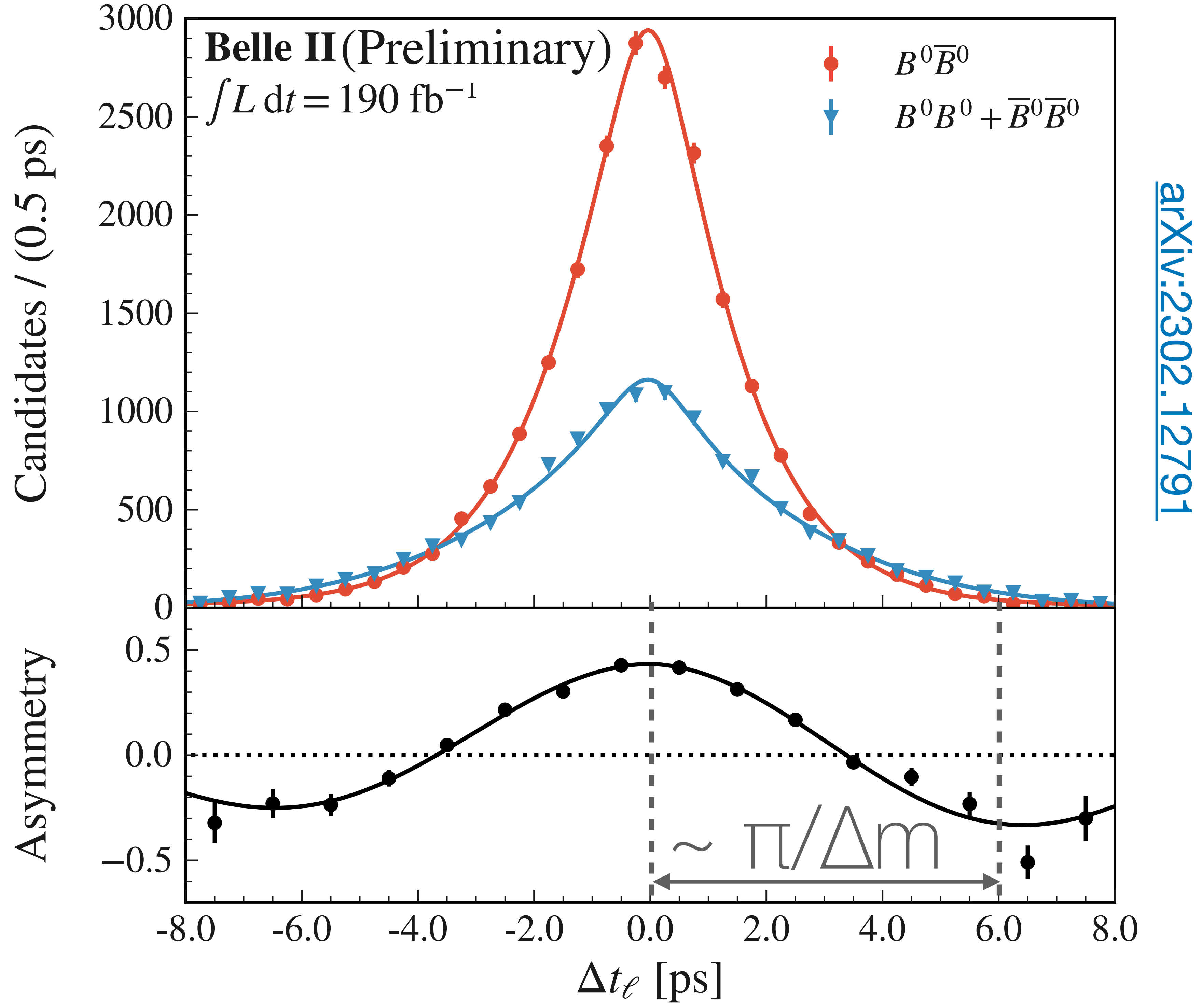
~2.8k B->J/ψKs



- High-yield, low-background modes used for benchmark measurements of time-dependent observables
- Main challenge: accurate understanding of vertex resolution (Δt resolution ~1 ps) and flavor tagging (ε_{tag}~30%)

Δm and sin2φ₁

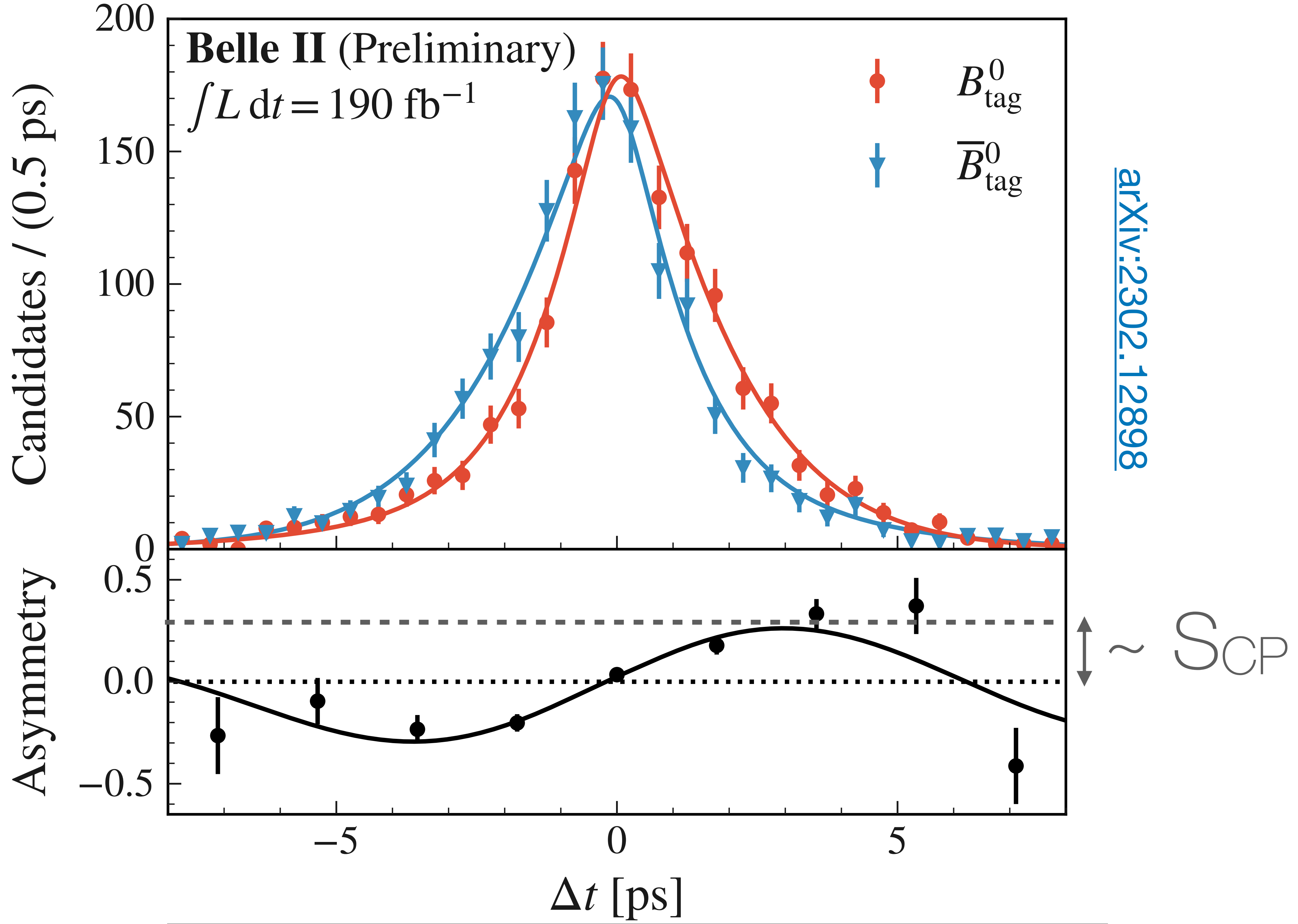
~33k B->D(*)π



$$\tau_{B^0} = (1.499 \pm 0.013 \pm 0.008)\ \mathrm{ps}$$
$$\Delta m_d = (0.516 \pm 0.008 \pm 0.005)\ \mathrm{ps}^{-1}$$

WA: τ =1.519±0.004 ps, Δm= 0.5065±0.0019 ps^{-1}

~2.8k B->J/ψK$_S$



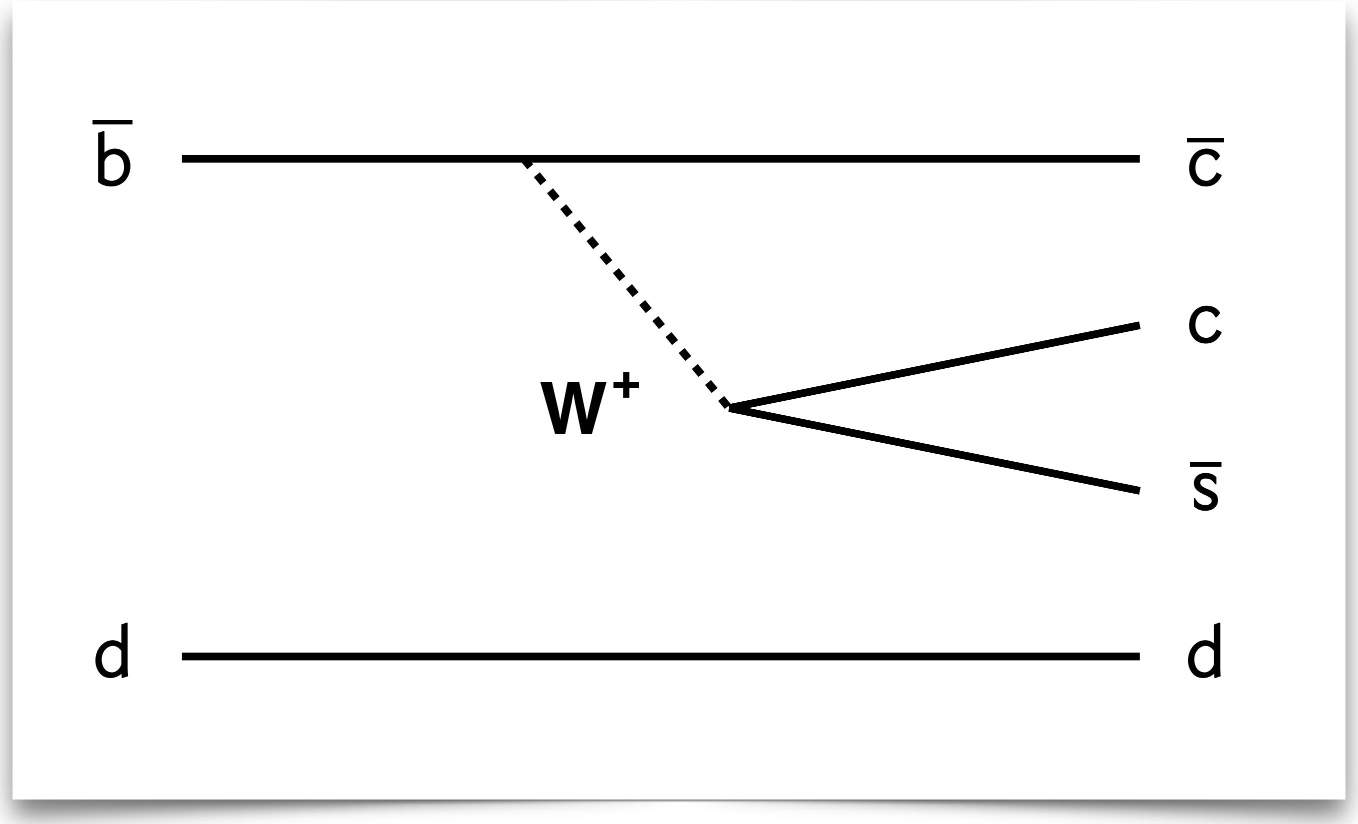
$$S_{CP} = 0.720 \pm 0.062(\mathrm{stat}) \pm 0.016(\mathrm{syst})$$
$$A_{CP} = 0.094 \pm 0.044(\mathrm{stat})^{+0.042}_{-0.017}(\mathrm{syst})$$

WA: S = 0.699±0.017, A = 0.005±0.015

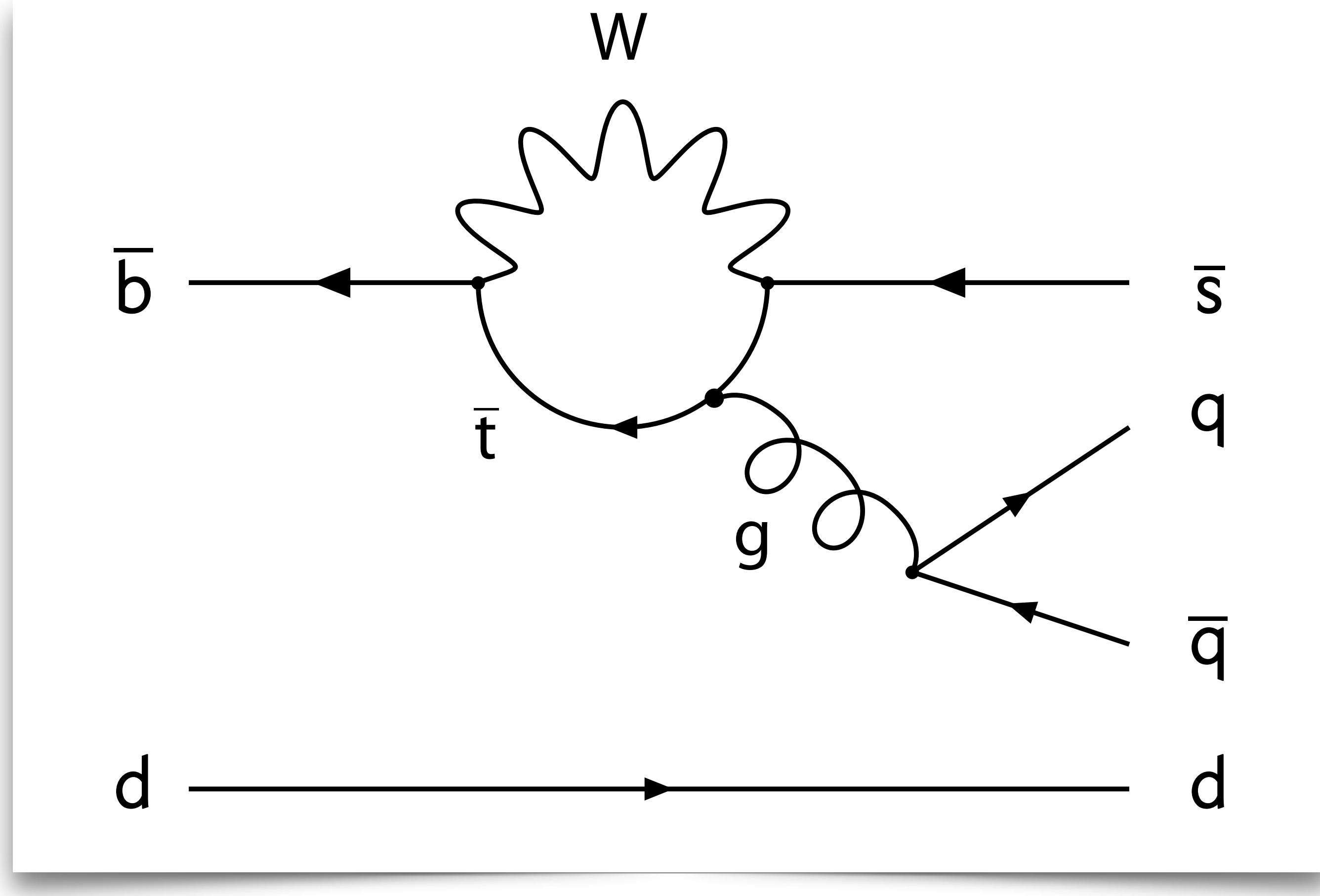
$\sin 2\phi_1$ with penguins

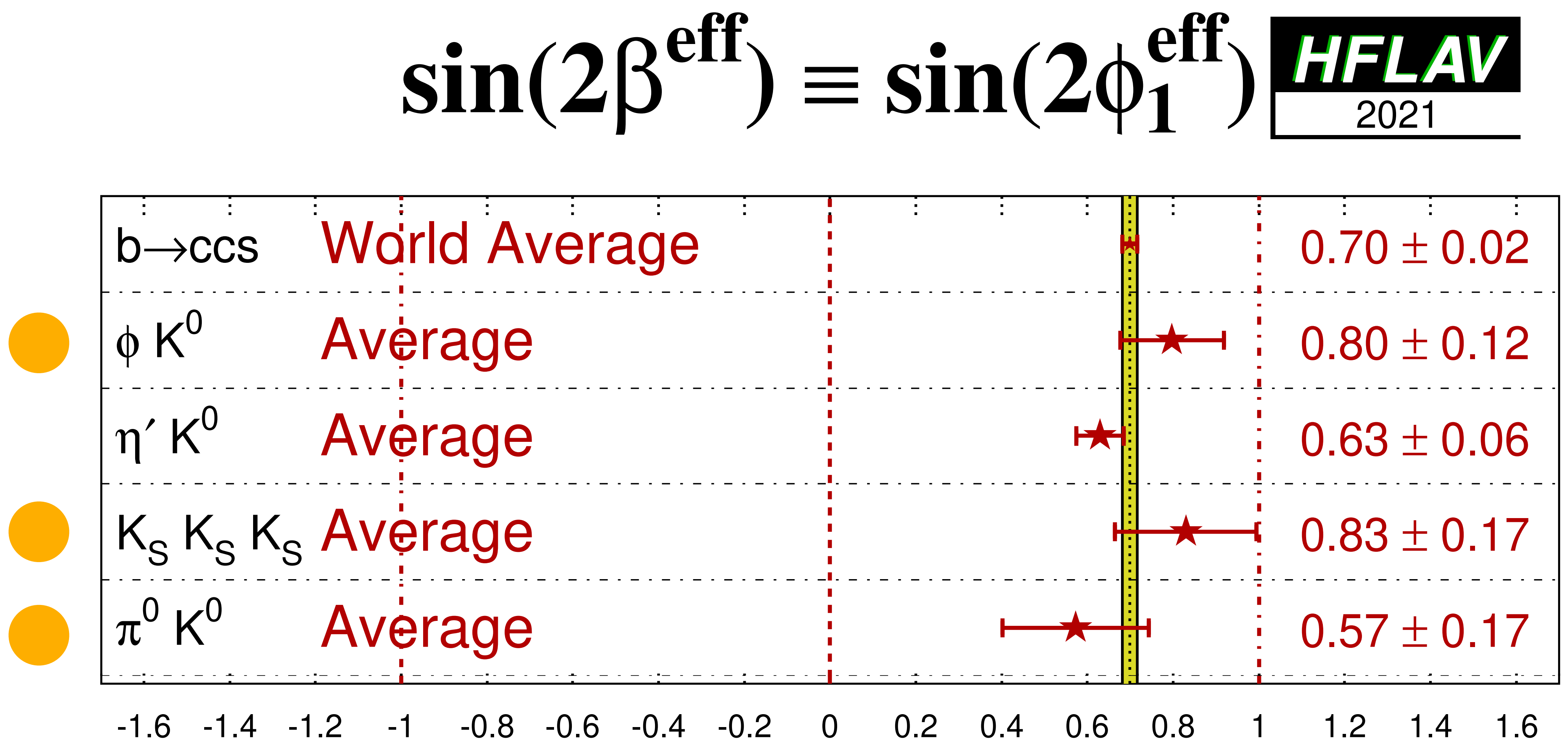
- Measurements of $\sin 2\phi_1$ in b->qqs transitions can be used as a probe of generic BSM physics
    - Clean theory prediction (~few %)
    - Loop-suppressed, potentially affected by competing BSM amplitudes
- Experimentally challenging, due to
    - Small BF (~10^{-6}) and neutrals in the final state (K_S, π^0)
    - Sophisticated analysis techniques (tagging and Δt resolution)

b->ccs



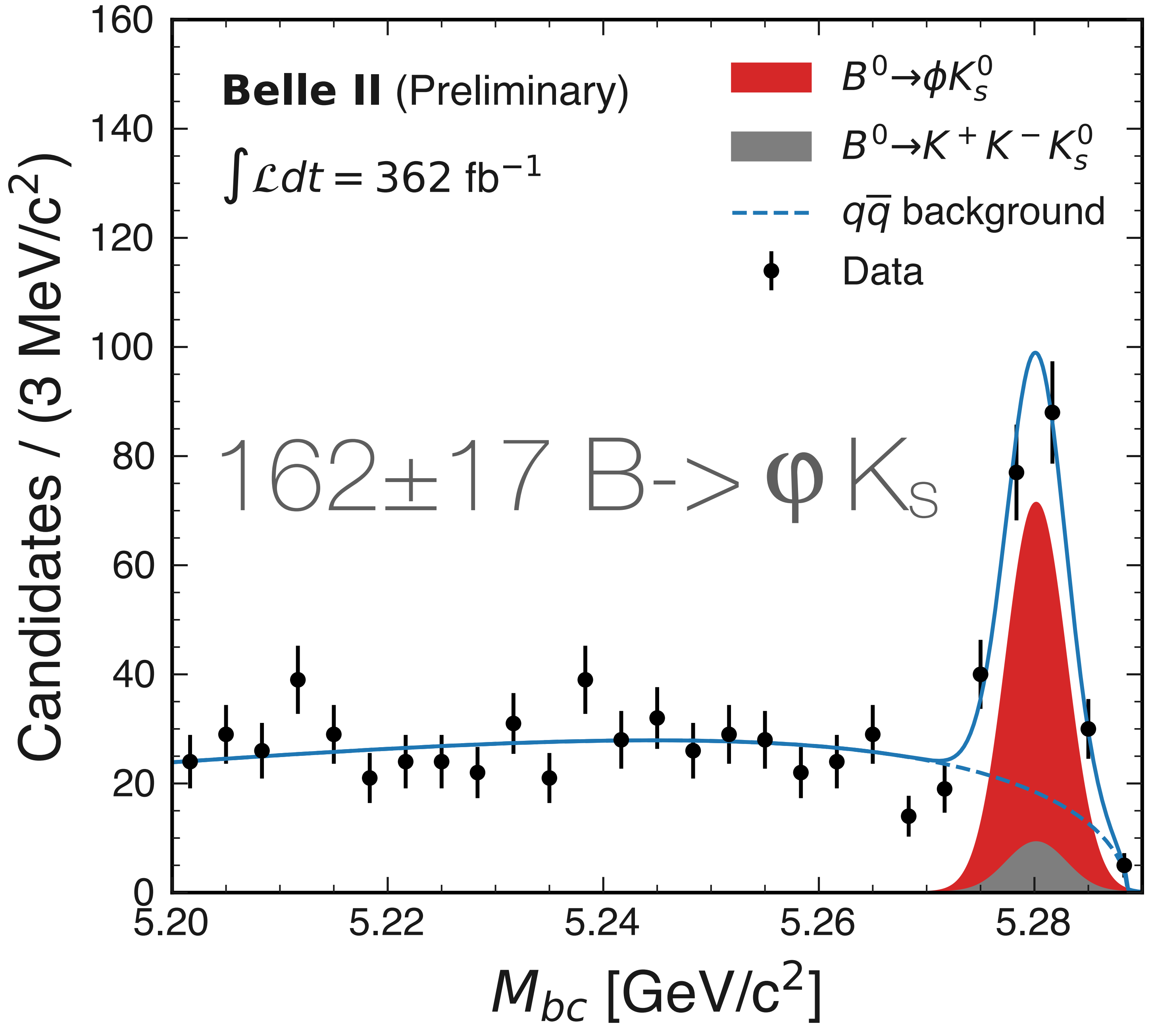
b->qqs



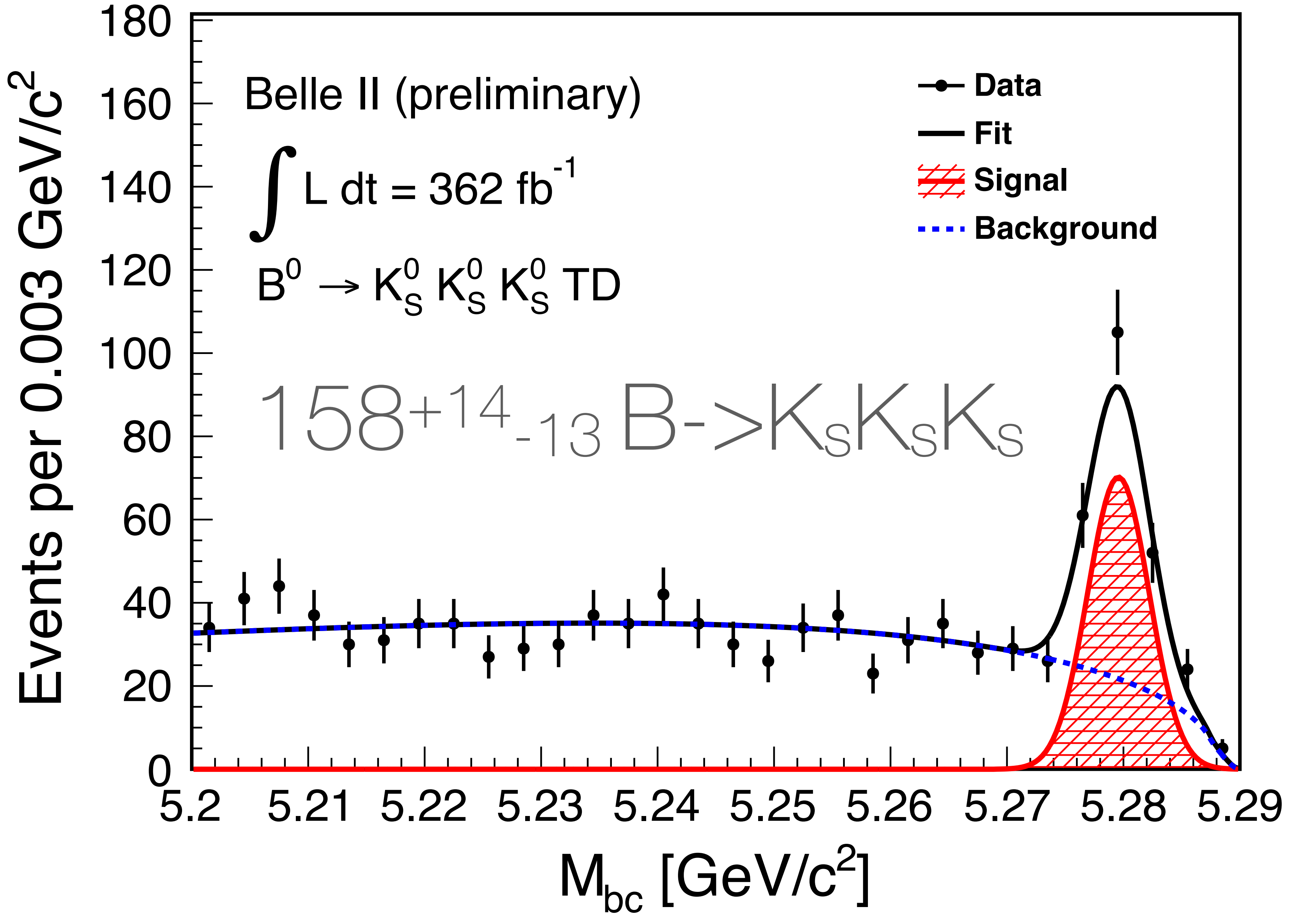


$\sin 2\phi_1$ with penguins

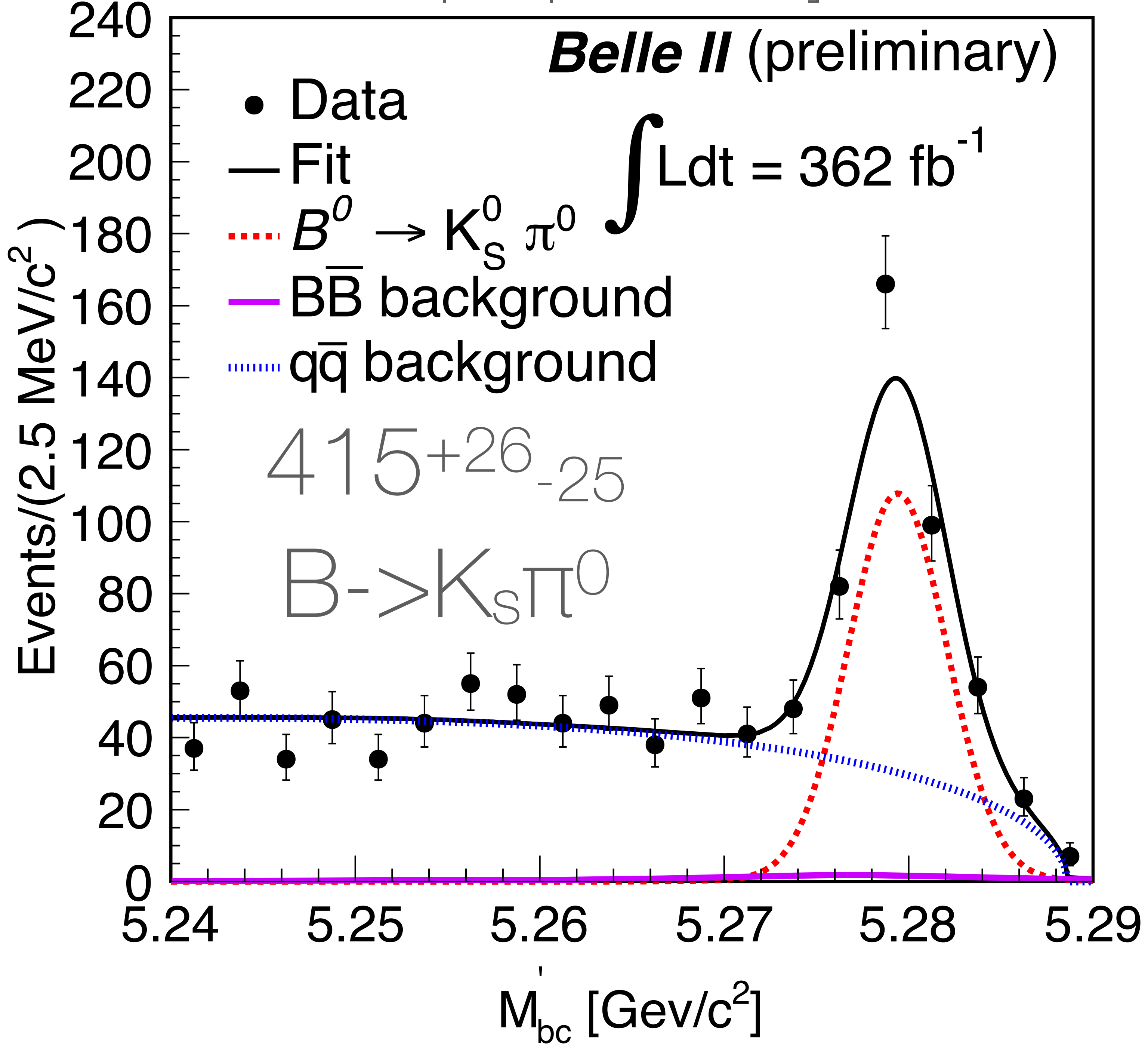
[BELLE2-PUB-2023-004, in preparation]



[BELLE2-PUB-2023-002, in preparation]



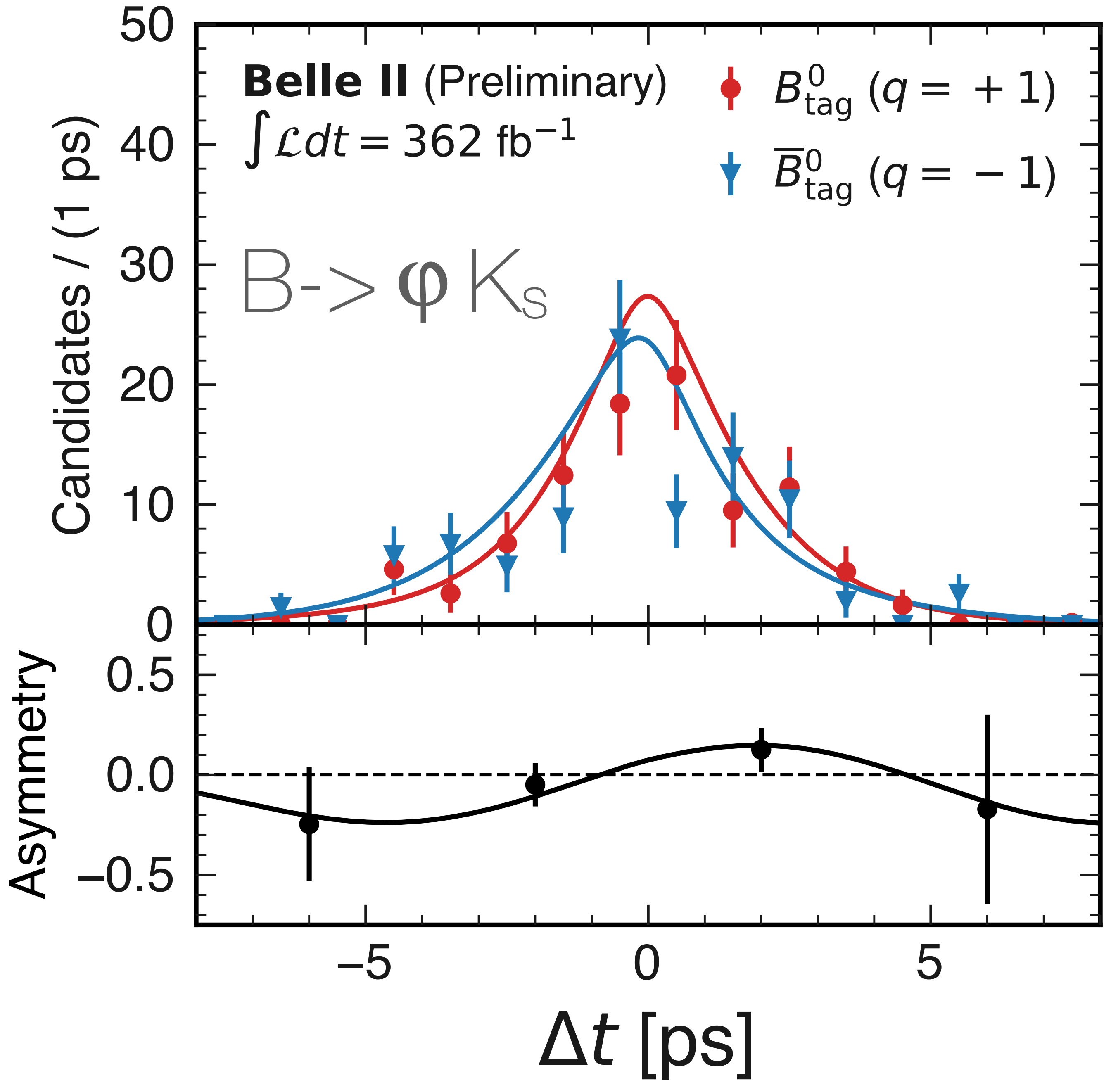
[BELLE2-PUB-2023-005, in preparation]



- Dilution from non-resonant decays with opposite CP modeled in cosθ (B-> φK_S)
- Decay vertex reconstruction relying on the K_S trajectory and profile of the interaction point (B->$K_SK_SK_S$ and B->$K_S\pi^0$)

sin2ϕ₁ with penguins

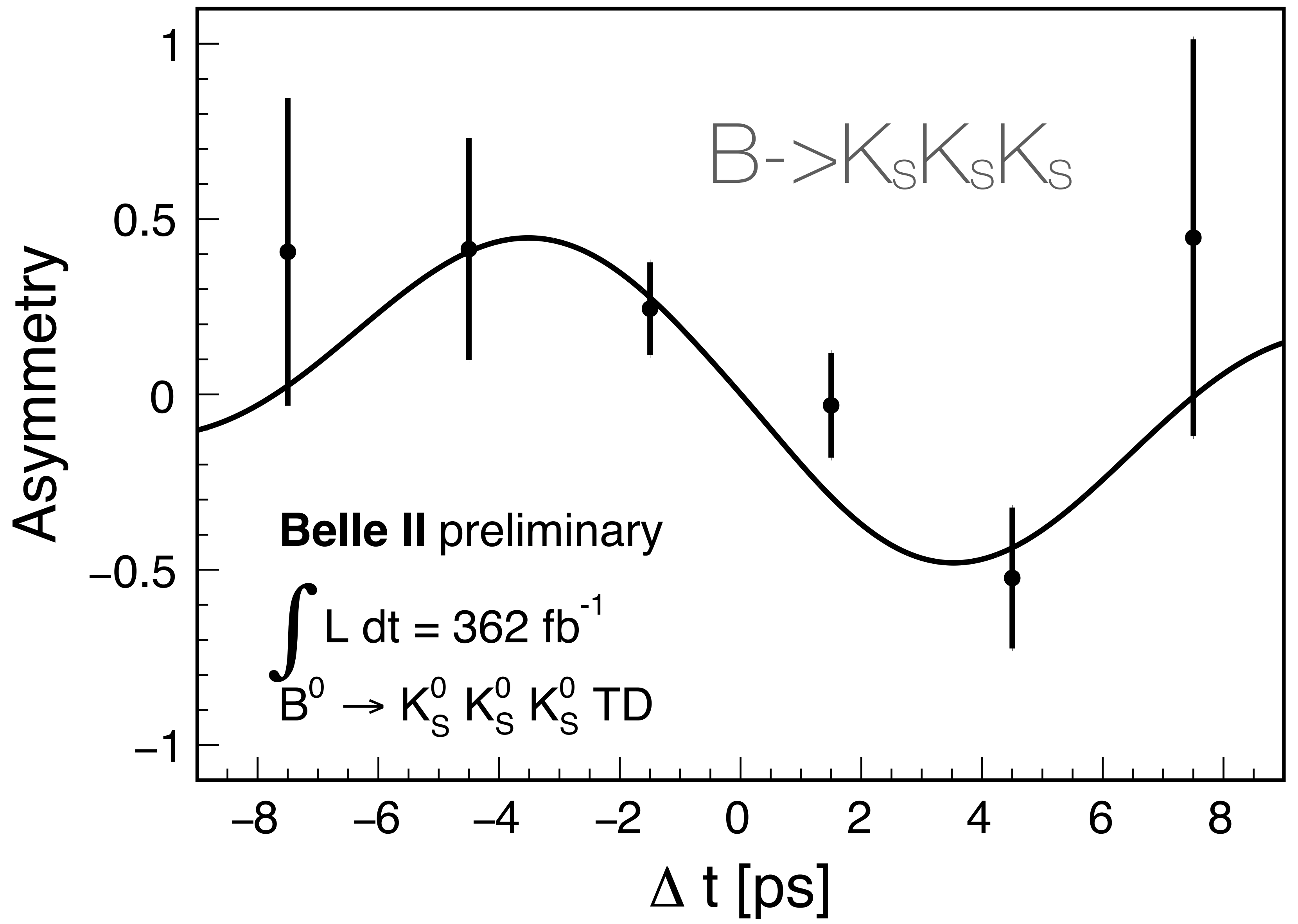
[BELLE2-PUB-2023-004, in preparation]



$$A_{CP} = 0.31 \pm 0.20^{+0.05}_{-0.06}$$
$$S_{CP} = 0.54 \pm 0.26^{+0.06}_{-0.08}$$

WA: S = $0.74^{+0.11}_{-0.13}$, A = -0.01±0.14

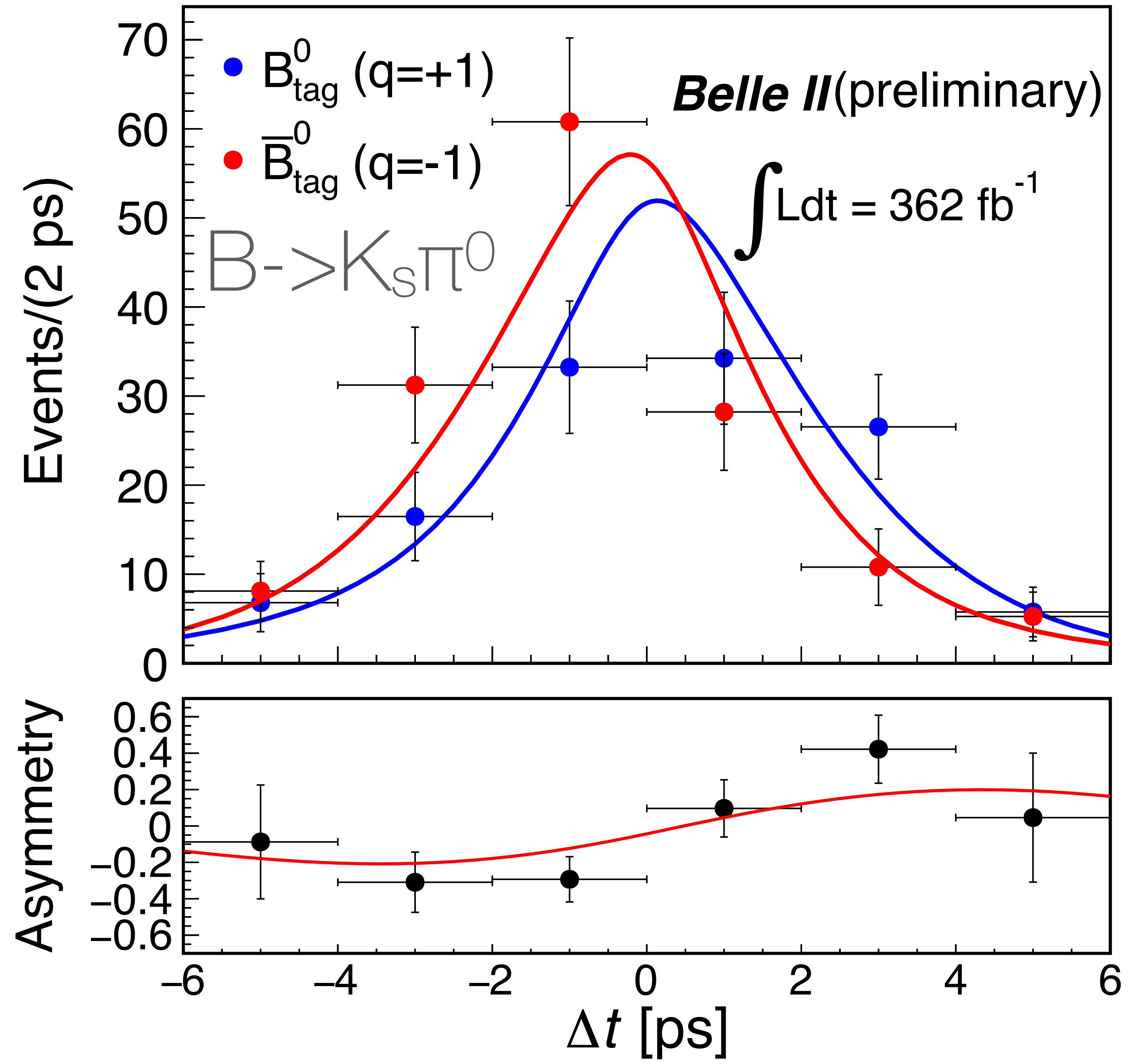
[BELLE2-PUB-2023-002, in preparation]



$$A_{CP} = 0.07^{+0.15}_{-0.20} \pm 0.02$$
$$S_{CP} = -1.37^{+0.35}_{-0.45} \pm 0.03$$

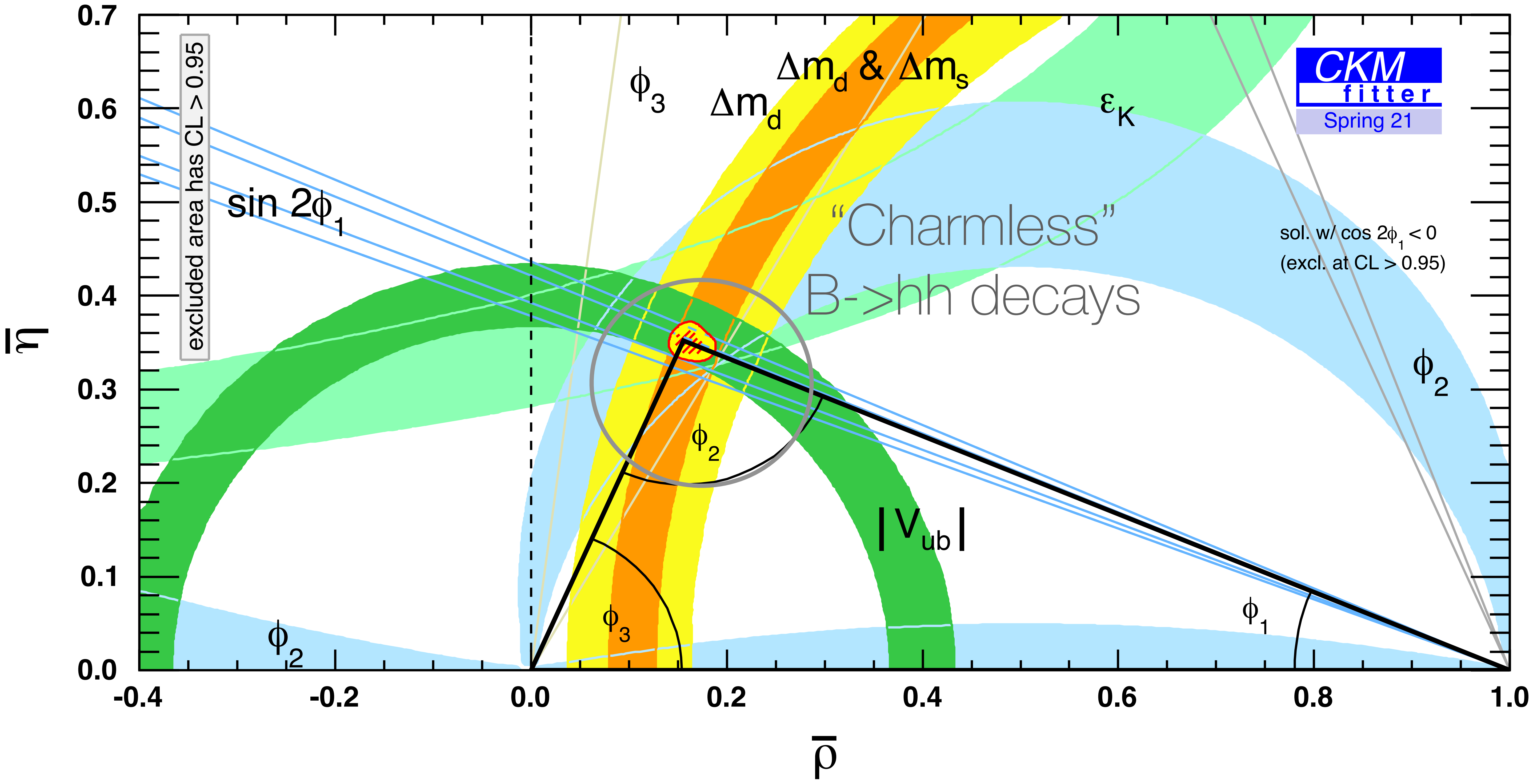
WA: S = -0.83±0.17, A = 0.15±0.12

[BELLE2-PUB-2023-005, in preparation]



$$A_{CP} = 0.04 \pm 0.15 \pm 0.05$$
$$S_{CP} = 0.75^{+0.20}_{-0.23} \pm 0.04$$

WA: S = 0.57±0.17, A = -0.01±0.10



CKM
fitter
Spring 21
sin 2ϕ1
excluded area has CL > 0.95
ϕ3
Δmd
Δmd & Δms
εK
"Charmless"
B->hh decays
sol. w/ cos 2ϕ1 < 0
(excl. at CL > 0.95)
ϕ2
|Vub|
ϕ1
η̄
ρ̄

Kπ isospin sum rule and ϕ_2

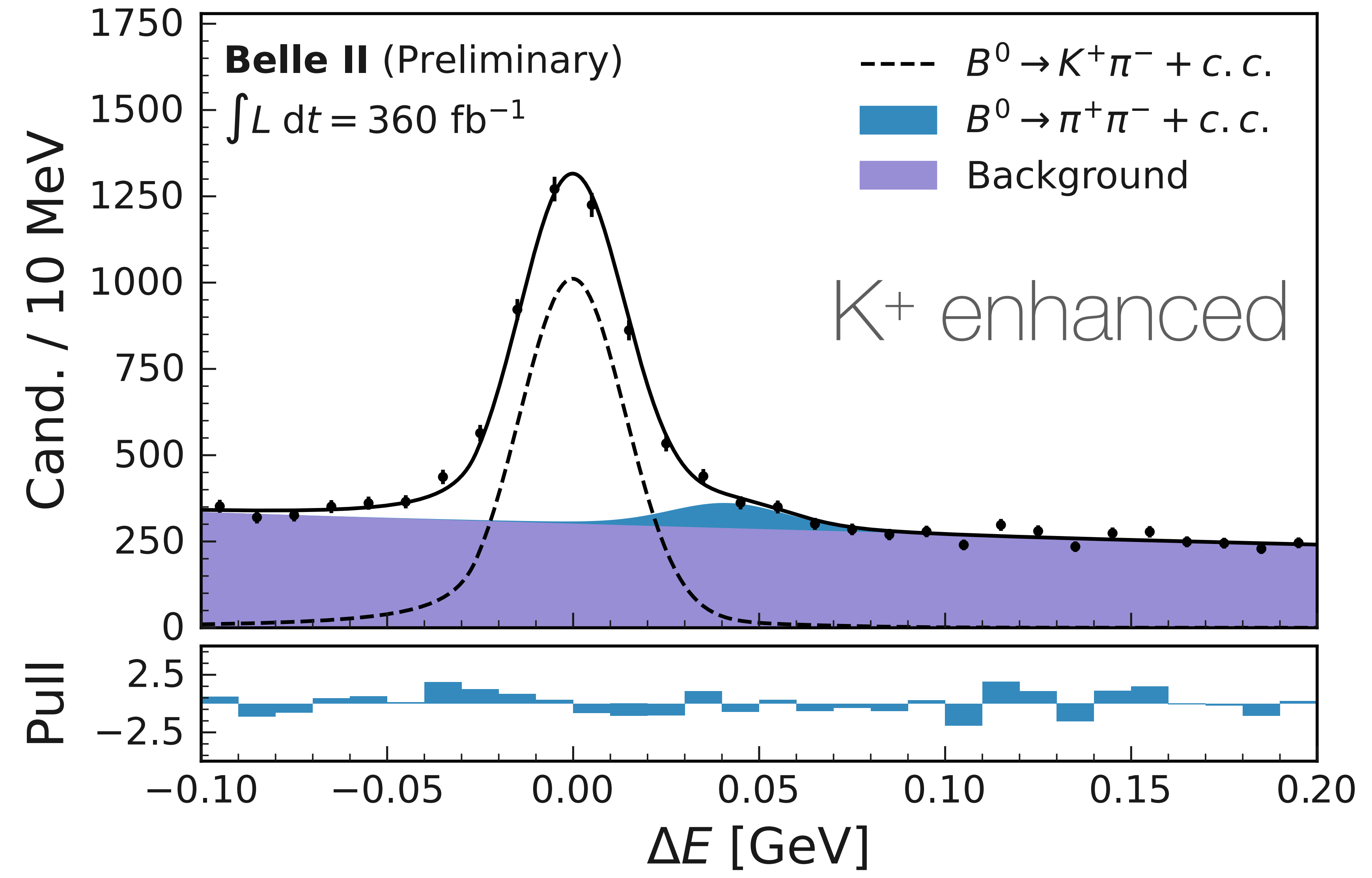
[BELLE2-PUB-2023-009, in preparation]

WA: -0.13±0.11

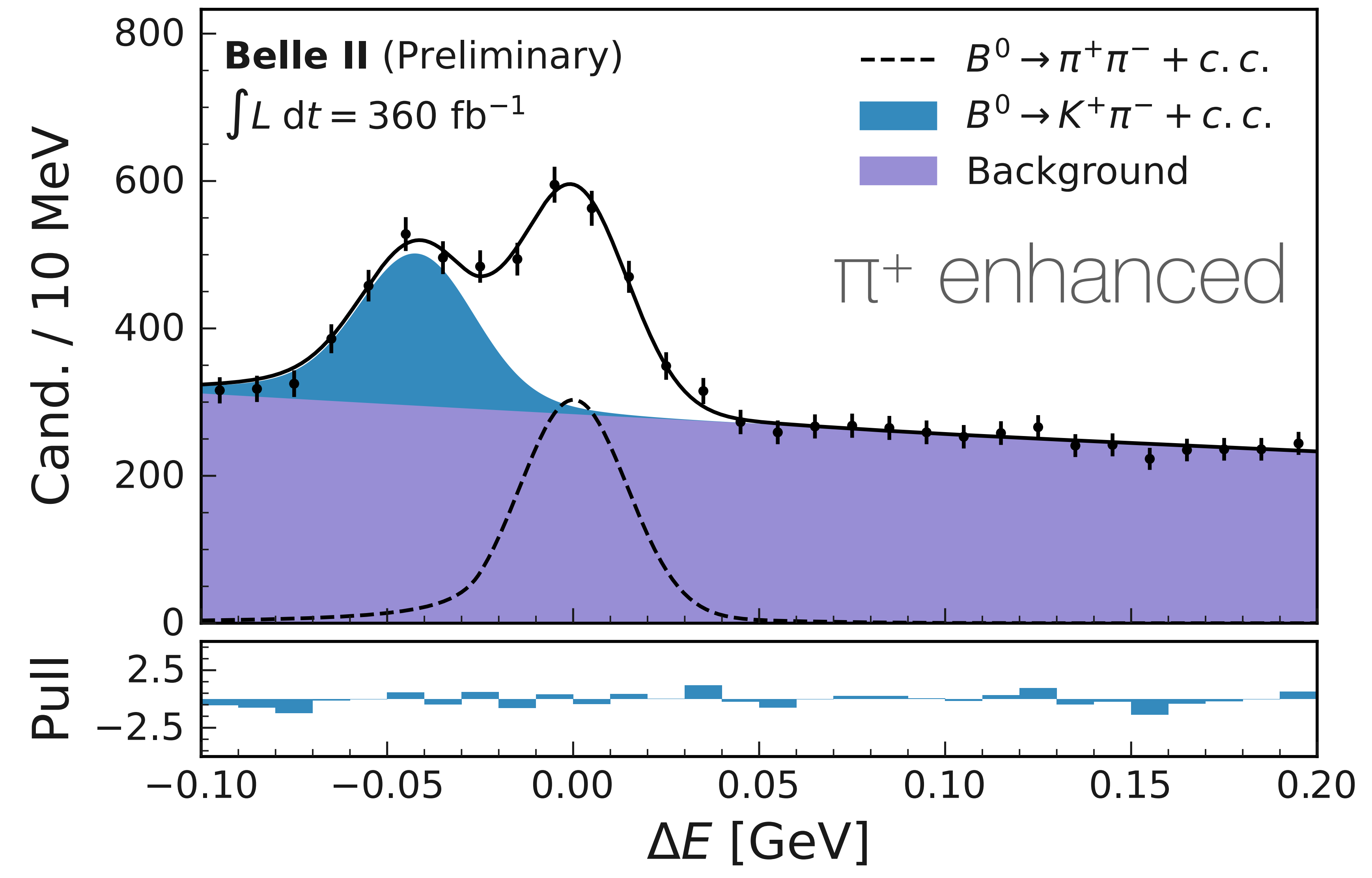
$$I_{K\pi} = \boxed{\mathcal{A}_{CP}^{K^+\pi^-}} + \mathcal{A}_{CP}^{K^0\pi^+} \frac{\mathcal{B}_{K^0\pi^+}}{\boxed{\mathcal{B}_{K^+\pi^-}}} \frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{CP}^{K^+\pi^0} \frac{\mathcal{B}_{K^+\pi^0}}{\boxed{\mathcal{B}_{K^+\pi^-}}} \frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{CP}^{K^0\pi^0} \frac{\mathcal{B}_{K^0\pi^0}}{\boxed{\mathcal{B}_{K^+\pi^-}}}$$

$$\mathcal{A}_{CP}^{K^+\pi^-} = -0.072 \pm 0.019 \pm 0.007$$

$$\mathcal{B}_{K^+\pi^-} = (20.67 \pm 0.37 \pm 0.62) \times 10^{-6}$$



- Null test of SM with O(1%) theoretical uncertainty
- Experimentally limited by knowledge of $K_S\pi^0$
- B->ππ modes providing inputs for determination of ϕ_2 from time-dependent analysis of $B^0 \to \pi^+\pi^-$
- Belle II is able to access all final states



Kπ isospin sum rule and ϕ_2

[BELLE2-PUB-2023-009, in preparation]

WA: -0.13±0.11

$$I_{K\pi} = \mathcal{A}_{CP}^{K^+\pi^-} + \mathcal{A}_{CP}^{K^0\pi^+}\frac{\mathcal{B}_{K^0\pi^+}}{\mathcal{B}_{K^+\pi^-}}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{CP}^{K^+\pi^0}\frac{\mathcal{B}_{K^+\pi^0}}{\mathcal{B}_{K^+\pi^-}}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{CP}^{K^0\pi^0}\frac{\mathcal{B}_{K^0\pi^0}}{\mathcal{B}_{K^+\pi^-}}$$

$$\mathcal{A}_{CP}^{K^+\pi^0} = 0.013 \pm 0.027 \pm 0.005$$

$$\mathcal{B}_{K^+\pi^0} = (14.21 \pm 0.38 \pm 0.85) \times 10^{-6}$$

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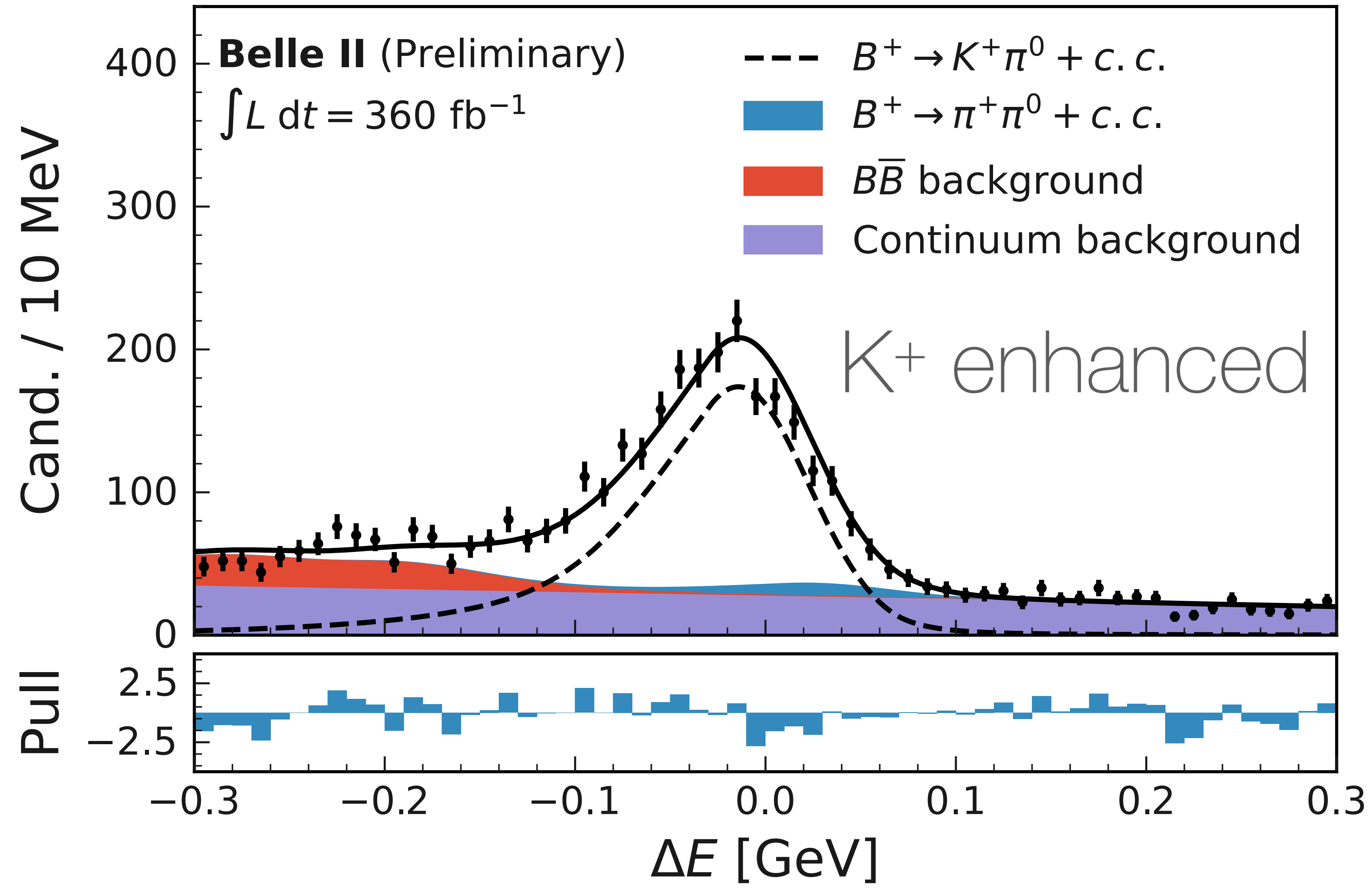
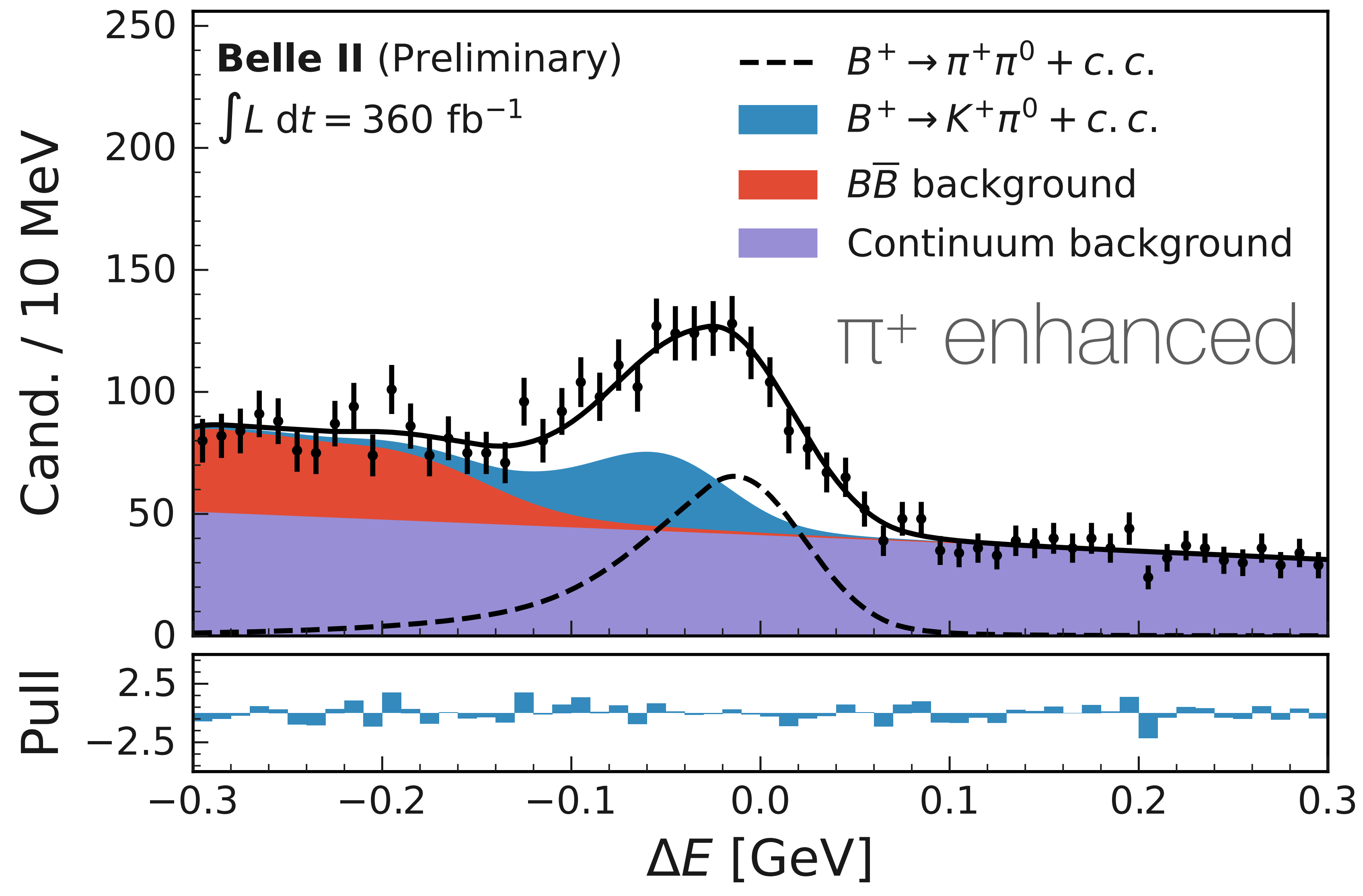




Kπ isospin sum rule and ϕ_2

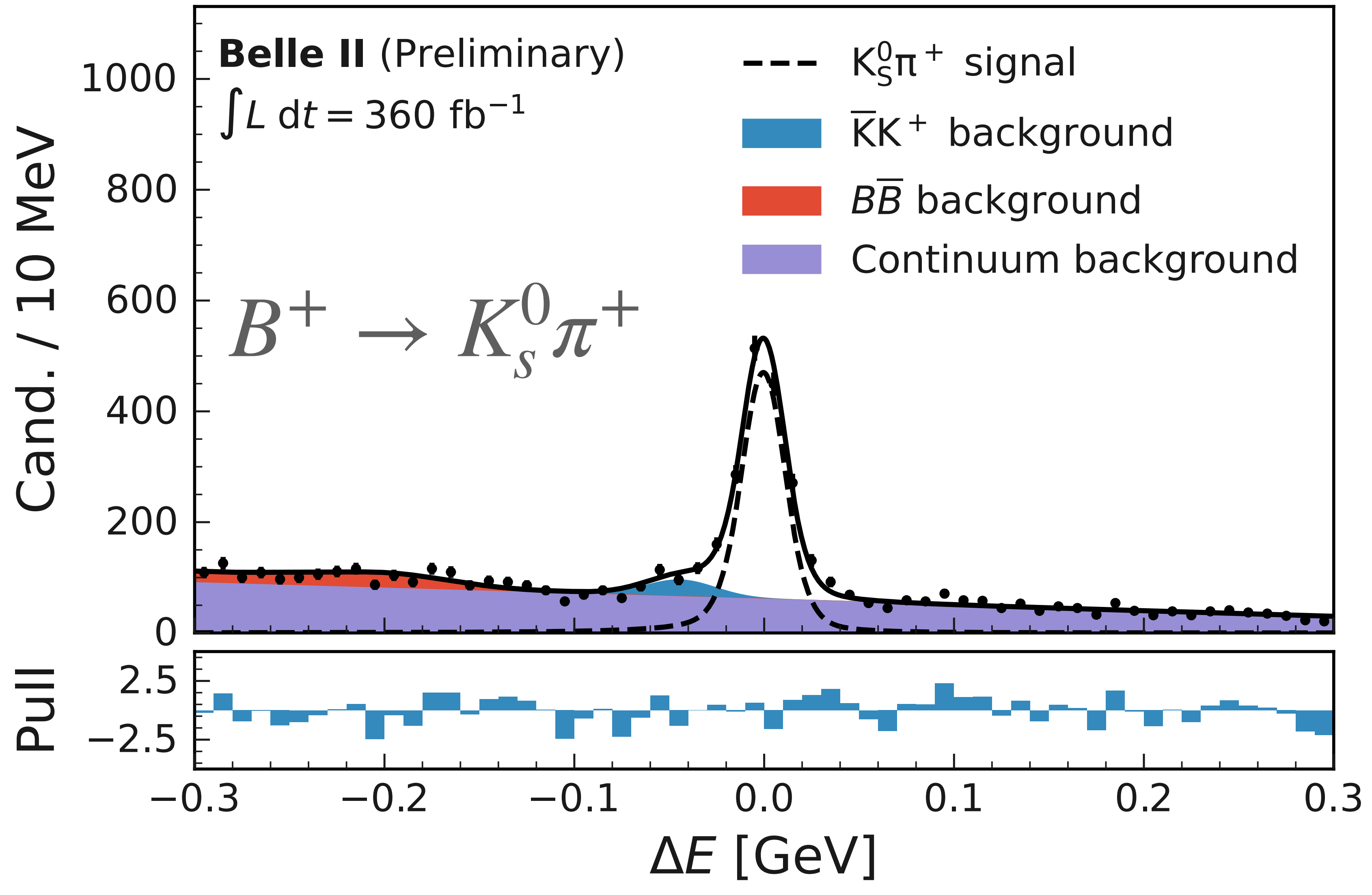
[BELLE2-PUB-2023-009, in preparation]

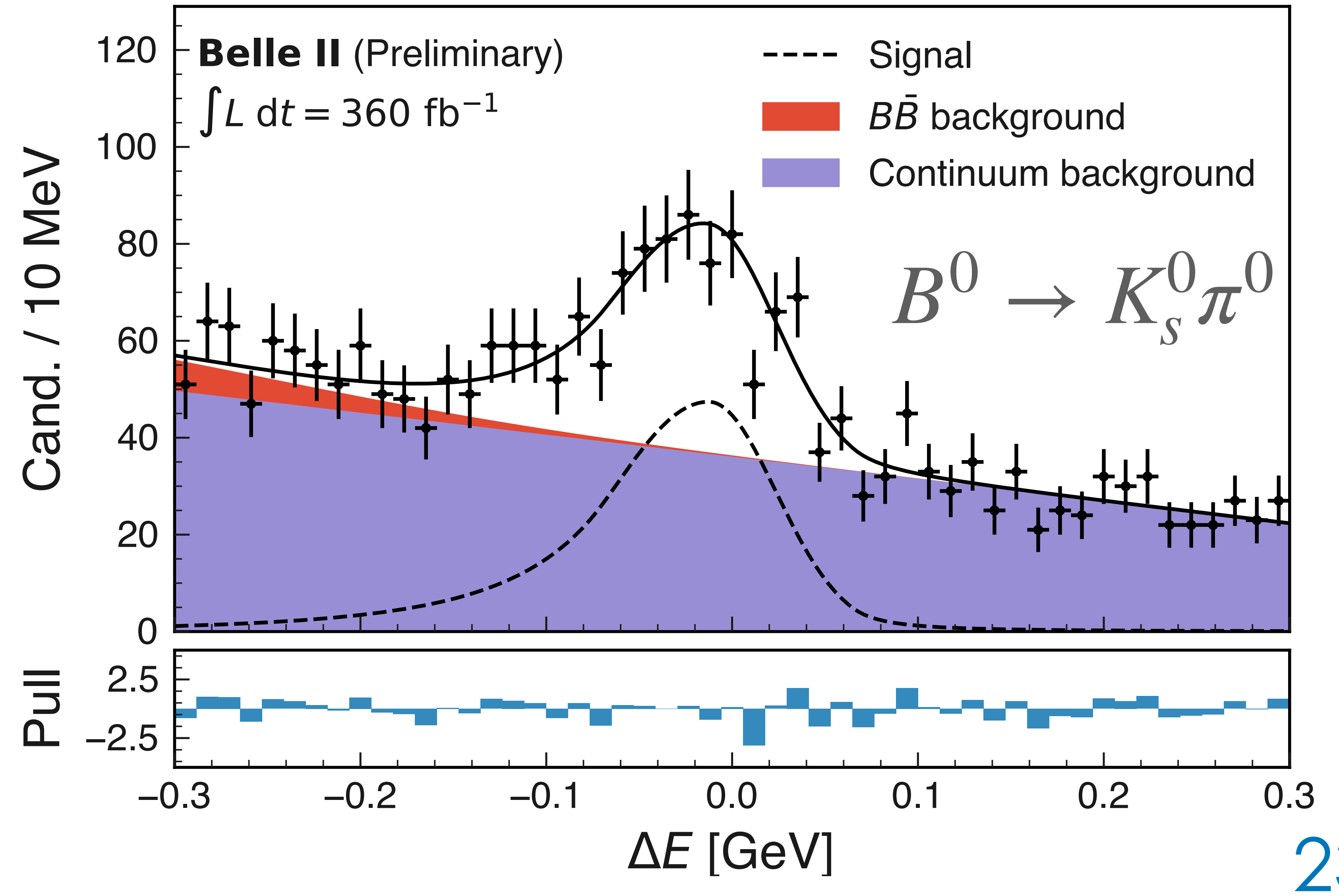
WA: -0.13±0.11

$$I_{K\pi} = \mathcal{A}_{CP}^{K^+\pi^-} + \mathcal{A}_{CP}^{K^0\pi^+}\frac{\mathcal{B}_{K^0\pi^+}}{\mathcal{B}_{K^+\pi^-}}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{CP}^{K^+\pi^0}\frac{\mathcal{B}_{K^+\pi^0}}{\mathcal{B}_{K^+\pi^-}}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{CP}^{K^0\pi^0}\frac{\mathcal{B}_{K^0\pi^0}}{\mathcal{B}_{K^+\pi^-}}$$

$$\mathcal{A}_{CP}^{K^0\pi^+} = 0.046 \pm 0.029 \pm 0.007$$
$$\mathcal{B}_{K^0\pi^+} = (24.4 \pm 0.71 \pm 0.86) \times 10^{-6}$$

$$\mathcal{A}_{CP}^{K^0\pi^0} = -0.06 \pm 0.15 \pm 0.05$$
$$\mathcal{B}_{K^0\pi^0} = (10.16 \pm 0.65 \pm 0.65) \times 10^{-6}$$





- Null test of SM with O(1%) theoretical uncertainty
- Experimentally limited by knowledge of $K_S\pi^0$
- B->ππ modes providing inputs for determination of ϕ_2 from time-dependent analysis of $B^0 \to \pi^+\pi^-$
- Belle II is able to access all final states

Kπ isospin sum rule and ϕ_2

WA: -0.13±0.11

$$I_{K\pi} = -0.03 \pm 0.13 \pm 0.05$$

[BELLE2-PUB-2023-009, in preparation]

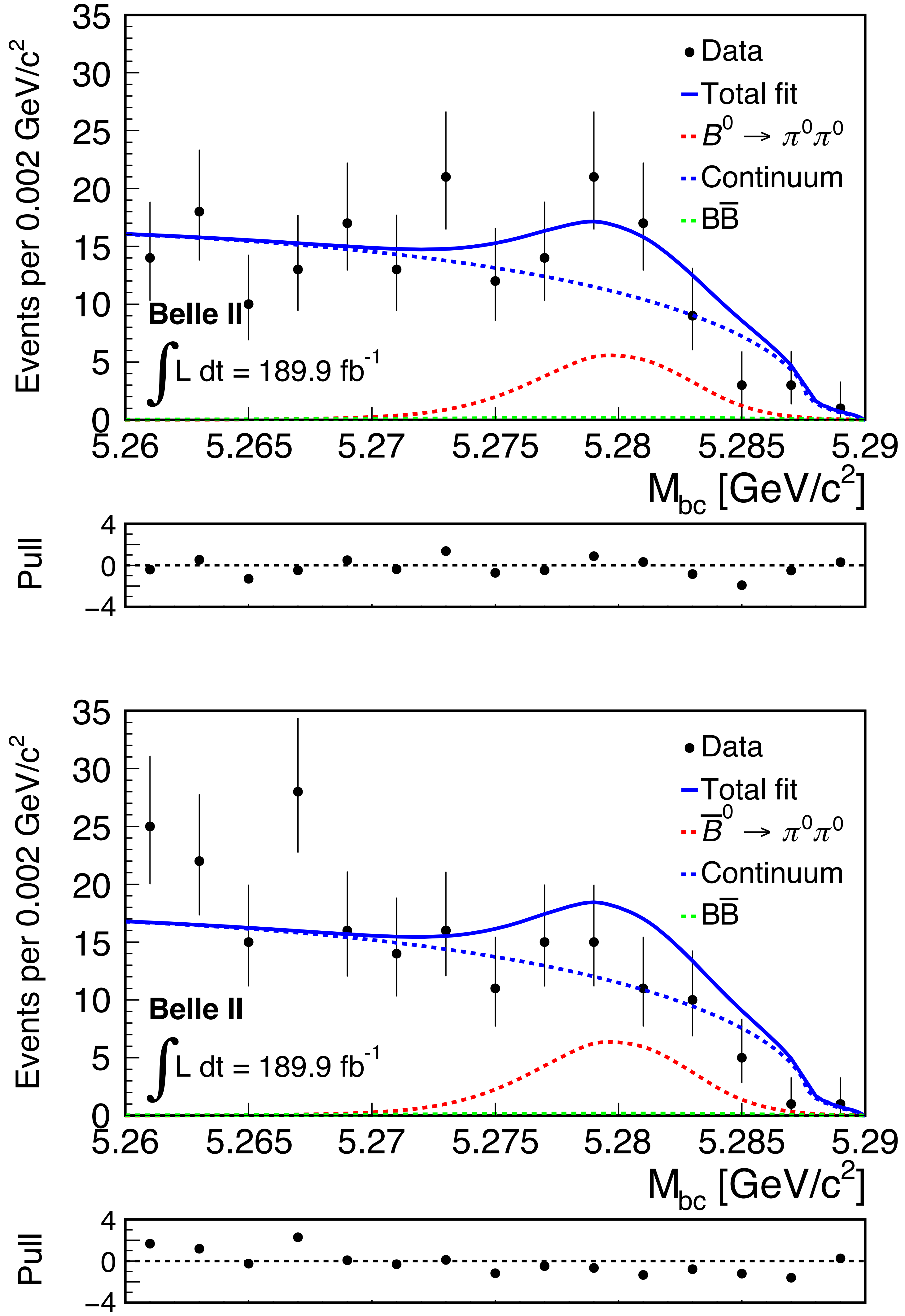
$$\mathcal{B}(B^0 \to \pi^0\pi^0) = (1.38 \pm 0.27 \pm 0.22) \times 10^{-6}$$

$$\mathcal{A}(B^0 \to \pi^0\pi^0) = 0.14 \pm 0.46 \pm 0.07$$

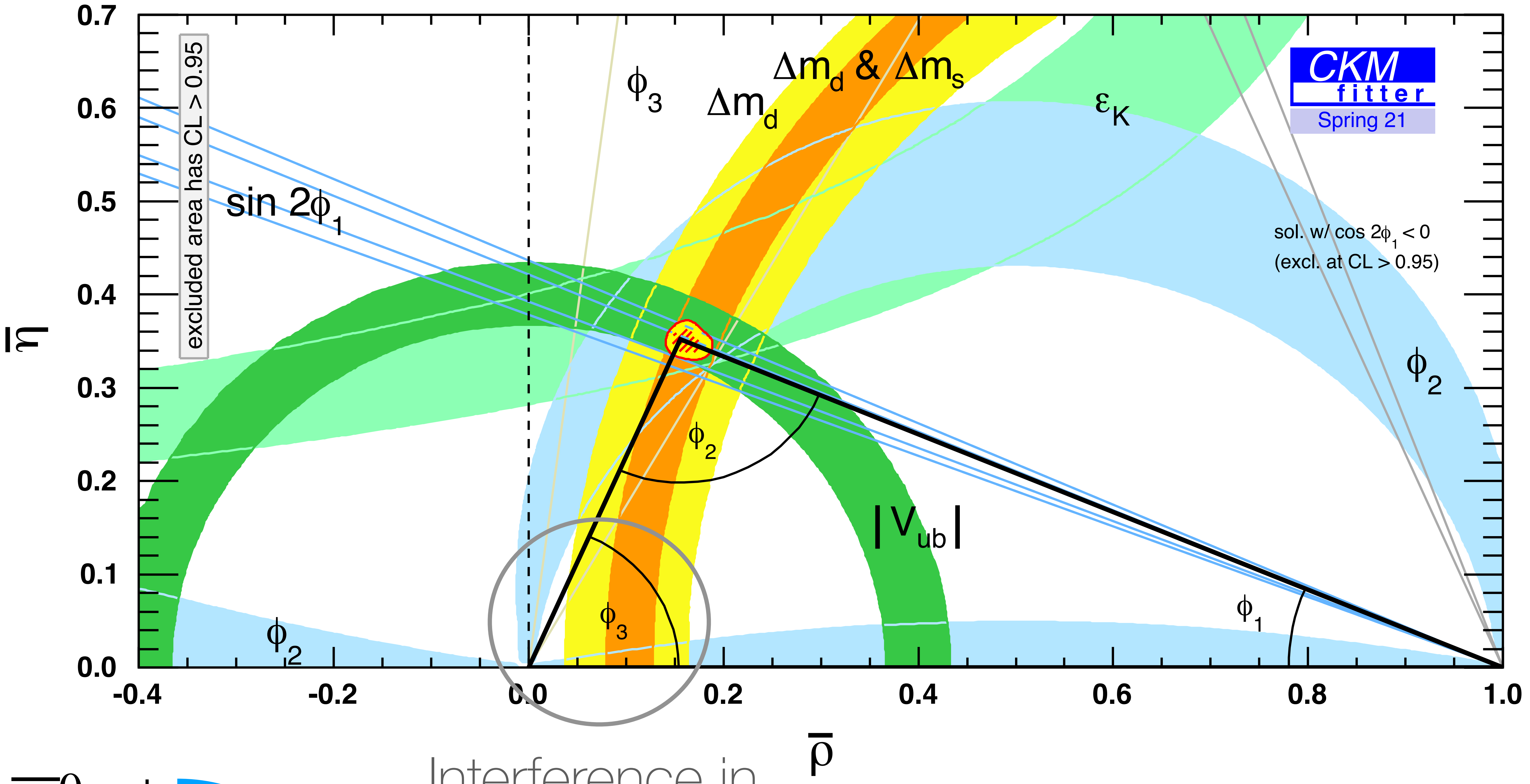
arXiv:2303.08354

- Null test of SM with O(1%) theoretical uncertainty
- Experimentally limited by knowledge of $K_S\pi^0$
- B->ππ modes providing inputs for determination of ϕ_2 from time-dependent analysis of $B^0\text{->}\pi^+\pi^-$
- Belle II is able to access all final states

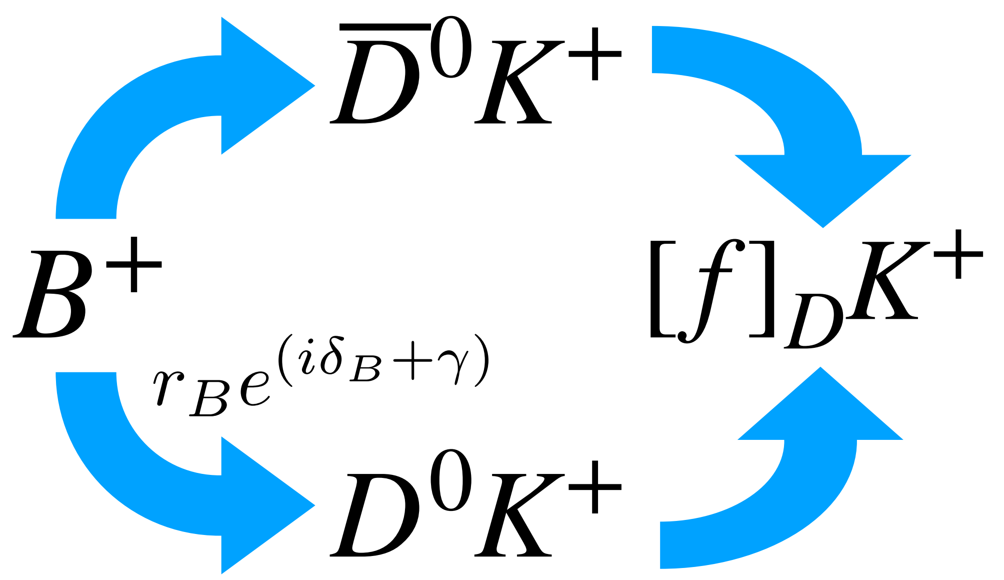
$B^0 \to \pi^0\pi^0$



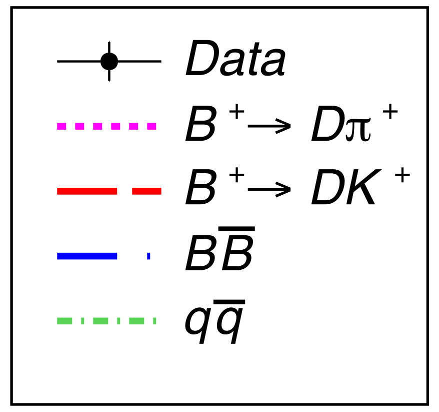
arXiv:2303.08354



Interference in
B±->DK± decays

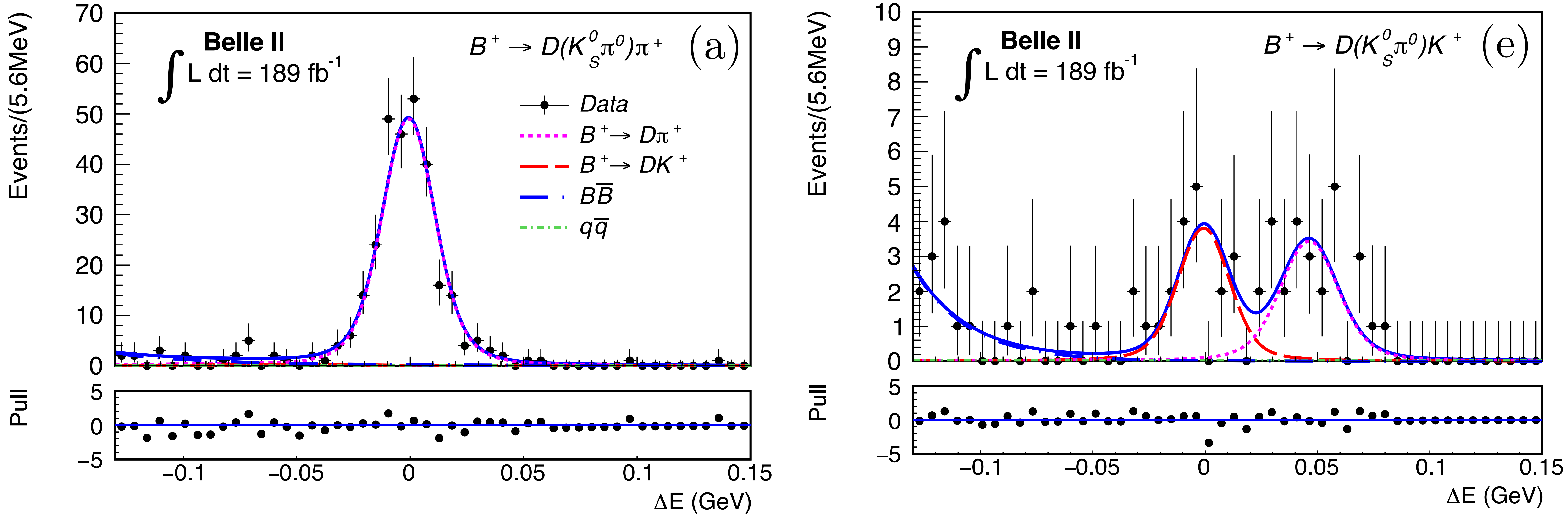


GLW determination of ϕ_3



Belle (772M BB) + Belle II (198M BB)

[BELLE2-PAPER in preparation]



$$\mathcal{R}_{CP+} = 1.164 \pm 0.081 \pm 0.036,$$
$$\mathcal{R}_{CP-} = 1.151 \pm 0.074 \pm 0.019,$$
$$\mathcal{A}_{CP+} = (+12.5 \pm 5.8 \pm 1.4)\%,$$
$$\mathcal{A}_{CP-} = (-16.7 \pm 5.7 \pm 0.6)\%.$$

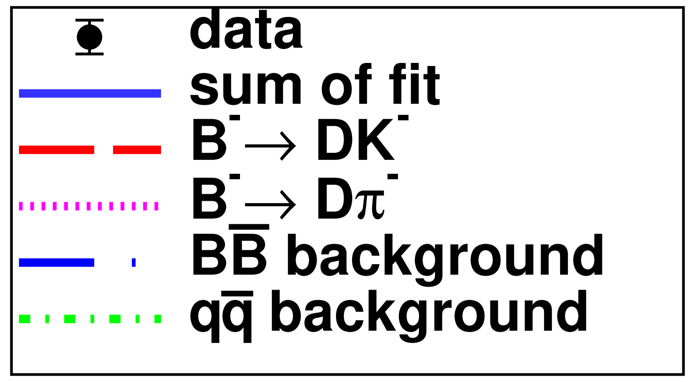
- $B^{\pm} \to D^0 K^{\pm}$ with $D^0 \to K^+K^-, K_S^0\pi^0$ (CP eigenstates) and $K\pi$ (flavor specific)
- Used to extract ϕ_3 together with hadronic parameters

$$\mathcal{R}_{CP\pm} \equiv \frac{\mathcal{B}(B^- \to D_{CP\pm}K^-) + \mathcal{B}(B^+ \to D_{CP\pm}K^+)}{\mathcal{B}(B^- \to D_{\rm flav}K^-) + \mathcal{B}(B^+ \to D_{\rm flav}K^+)}$$

$$\mathcal{A}_{CP\pm} \equiv \frac{\mathcal{B}(B^- \to D_{CP\pm}K^-) - \mathcal{B}(B^+ \to D_{CP\pm}K^+)}{\mathcal{B}(B^- \to D_{CP\pm}K^-) + \mathcal{B}(B^+ \to D_{CP\pm}K^+)},$$

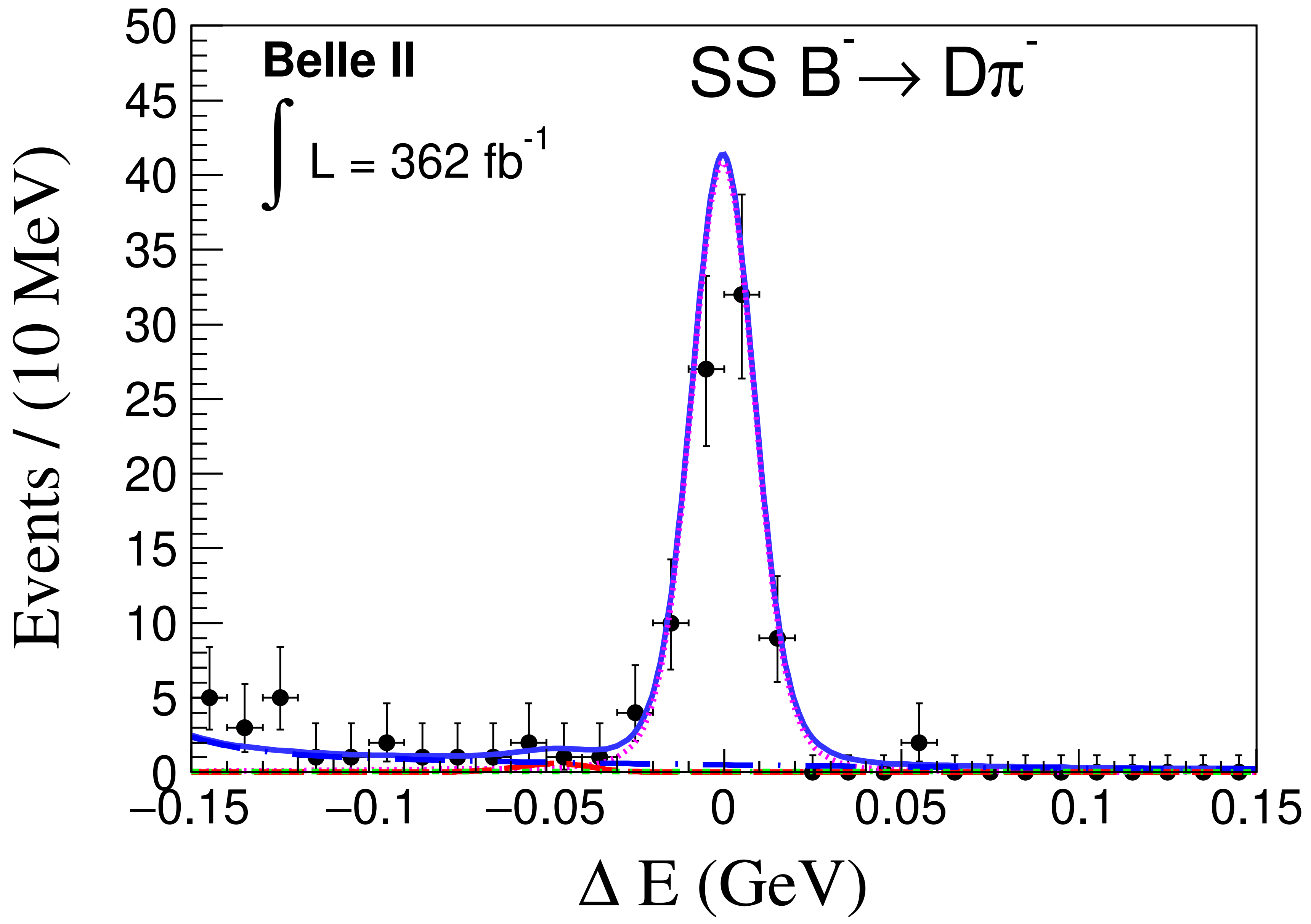
2 ratios of BRs and 2 asymmetries

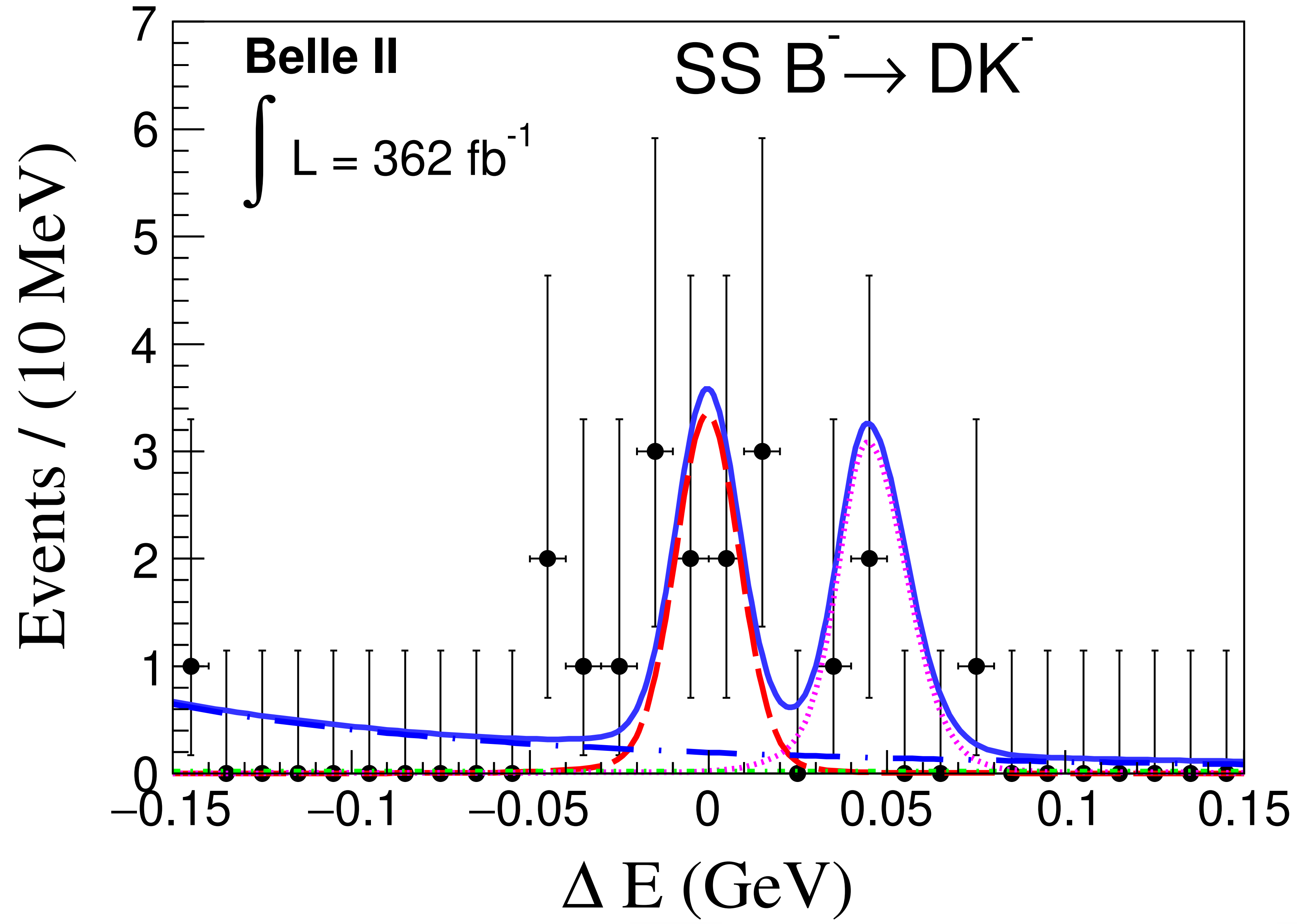
GLS determination of ϕ3



Belle (772M BB) + Belle II (387M BB) in K* region

[BELLE2-PAPER in preparation]





$$
\begin{aligned}
A_{\rm SS}^{DK} &= 0.055 \pm 0.119 \pm 0.020,\\
A_{\rm OS}^{DK} &= 0.231 \pm 0.184 \pm 0.014,\\
A_{\rm SS}^{D\Pi} &= 0.046 \pm 0.029 \pm 0.016,\\
A_{\rm OS}^{D\Pi} &= 0.009 \pm 0.046 \pm 0.009,\\
R_{\rm SS}^{DK/D\pi} &= 0.093 \pm 0.012 \pm 0.005,\\
R_{\rm OS}^{DK/D\pi} &= 0.103 \pm 0.020 \pm 0.006,\\
R_{\rm SS/OS}^{D\pi} &= 2.412 \pm 0.132 \pm 0.019.
\end{aligned}
$$

- $B^{\pm} \to D^0 h^{\pm}$ with $D^0 \to K_S^0 K^{\pm}\pi^{\mp}$, split into 8 categories of (SS,OS) x (DK,Dπ) x (+,-)
- Used to constrain ϕ3 from the knowledge of D^0 decay dynamics (CLEO)

$$
\mathcal{A}_m^{Dh} \equiv \frac{N_m^{Dh^-} - N_m^{Dh^+}}{N_m^{Dh^-} + N_m^{Dh^+}}
$$

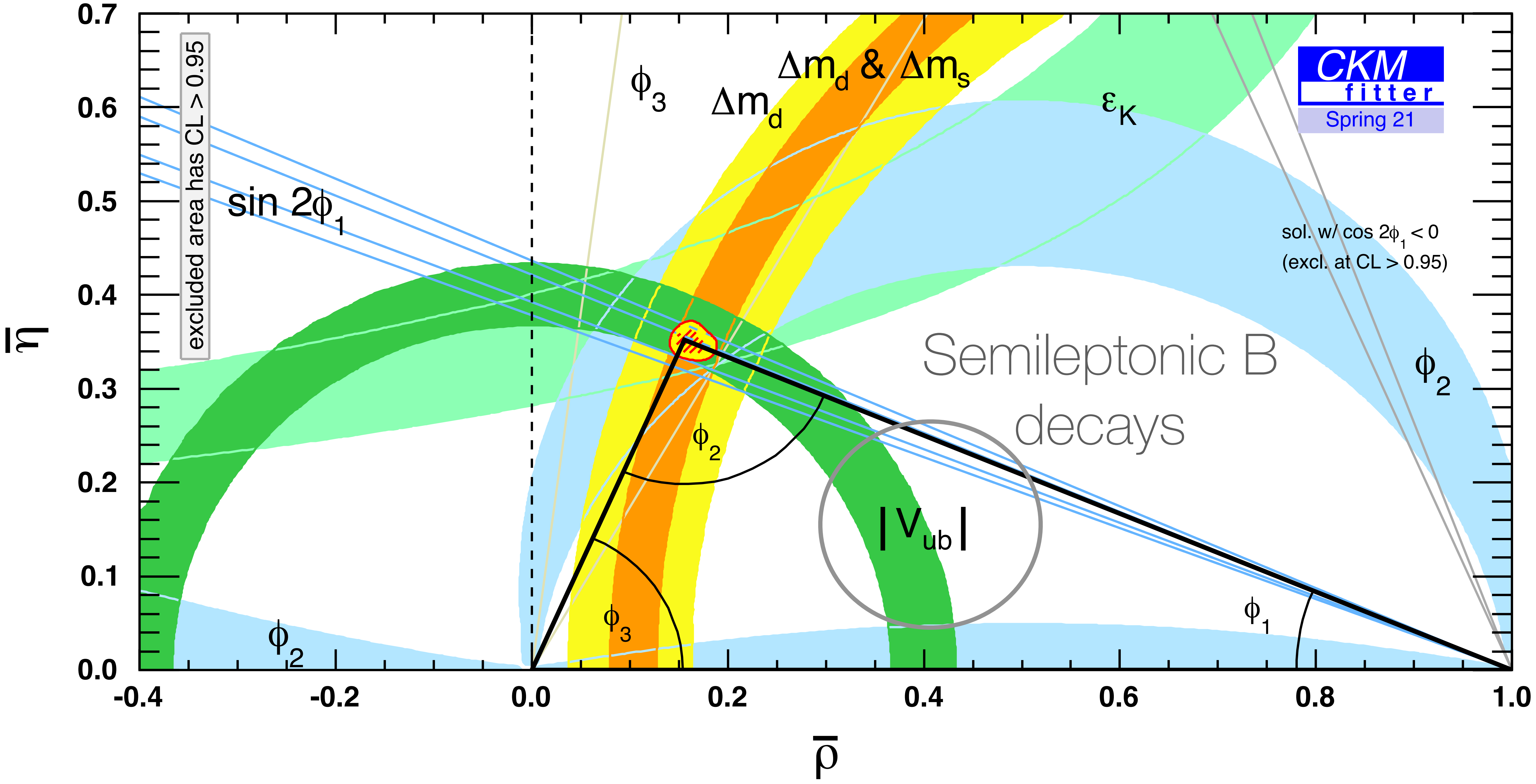
with $h = \pi, K, \quad m = \rm SS, OS,$

4 asymmetries

$$
\mathcal{R}_m^{DK/D\pi} \equiv \frac{N_m^{DK^-} + N_m^{DK^+}}{N_m^{D\pi^-} + N_m^{D\pi^+}}
$$

$$
\mathcal{R}_{\rm SS/OS}^{D\pi} \equiv \frac{N_{\rm SS}^{D\pi^-} + N_{\rm SS}^{D\pi^+}}{N_{\rm OS}^{D\pi^-} + N_{\rm OS}^{D\pi^+}}.
$$

3 ratios of BRs

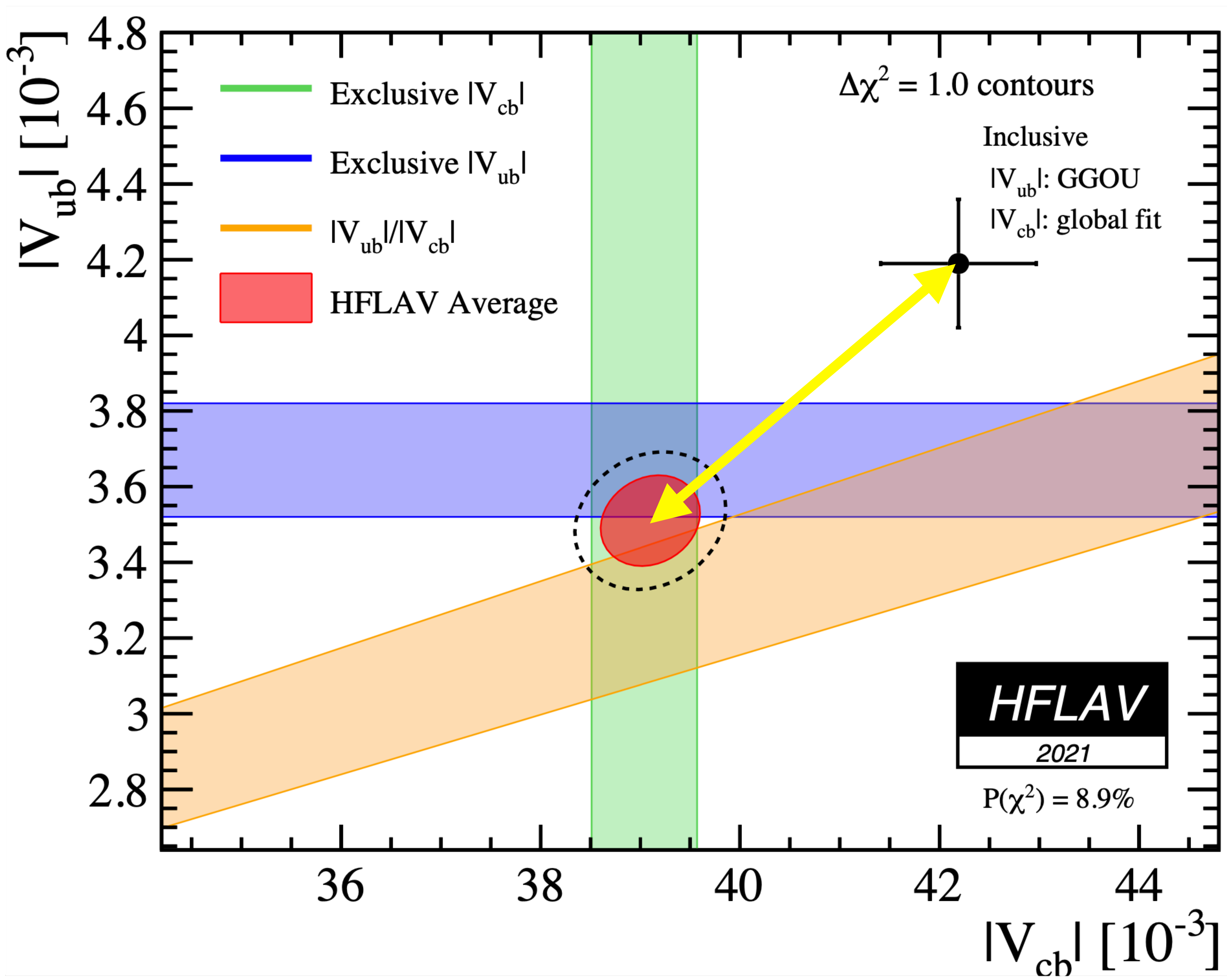


CKM fitter
Spring 21
excluded area has CL > 0.95
sin 2φ1
φ3
Δmd
Δmd & Δms
εK
sol. w/ cos 2φ1 < 0
(excl. at CL > 0.95)
Semileptonic B decays
φ2
|Vub|
φ1
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
η̄
ρ̄

Vub vs. Vcb

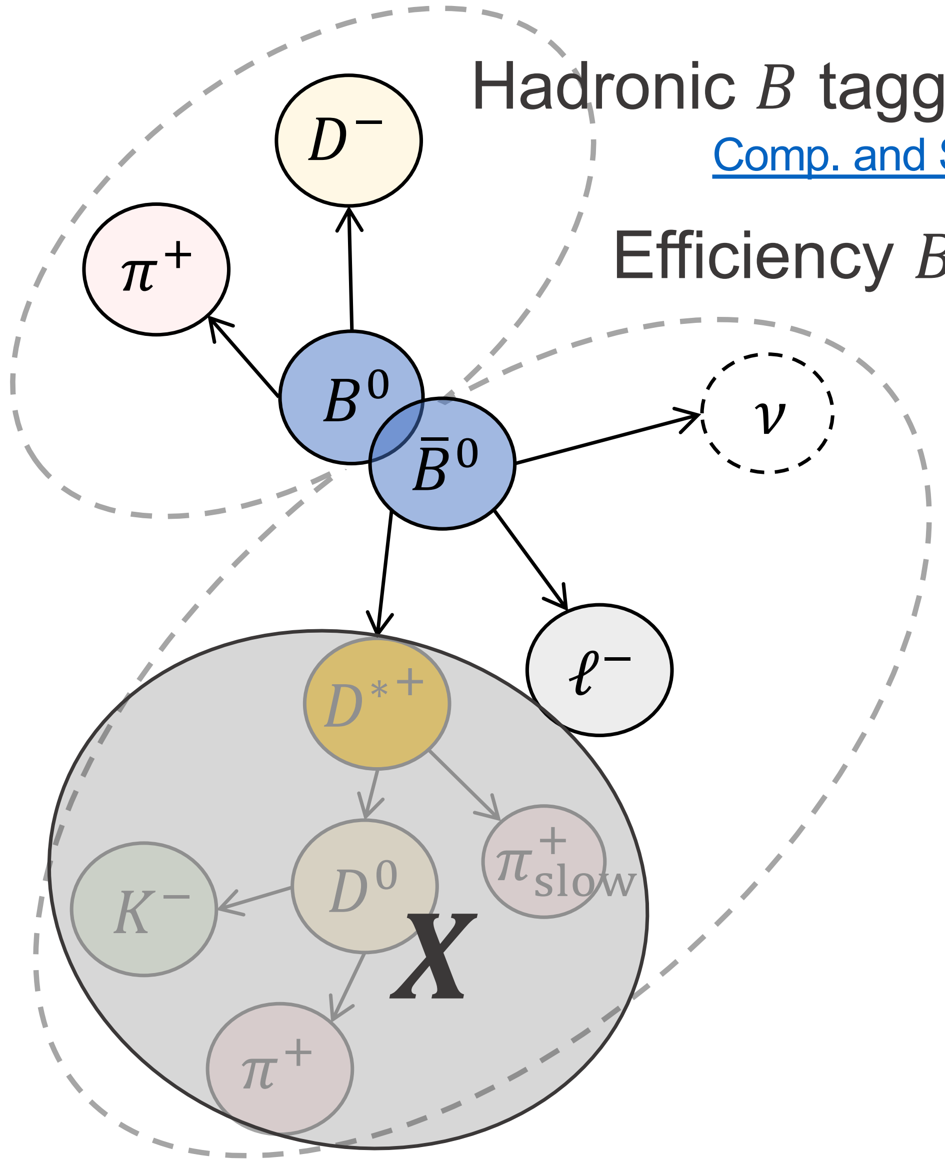
- ~3σ discrepancy between the inclusive and exclusive determination of |Vub| and |Vcb|
- Limiting the global constraining power of UT fits
- Important inputs for BF prediction of ultra-rare decays, e.g. K->πνν

[Credits: K. Kojima]

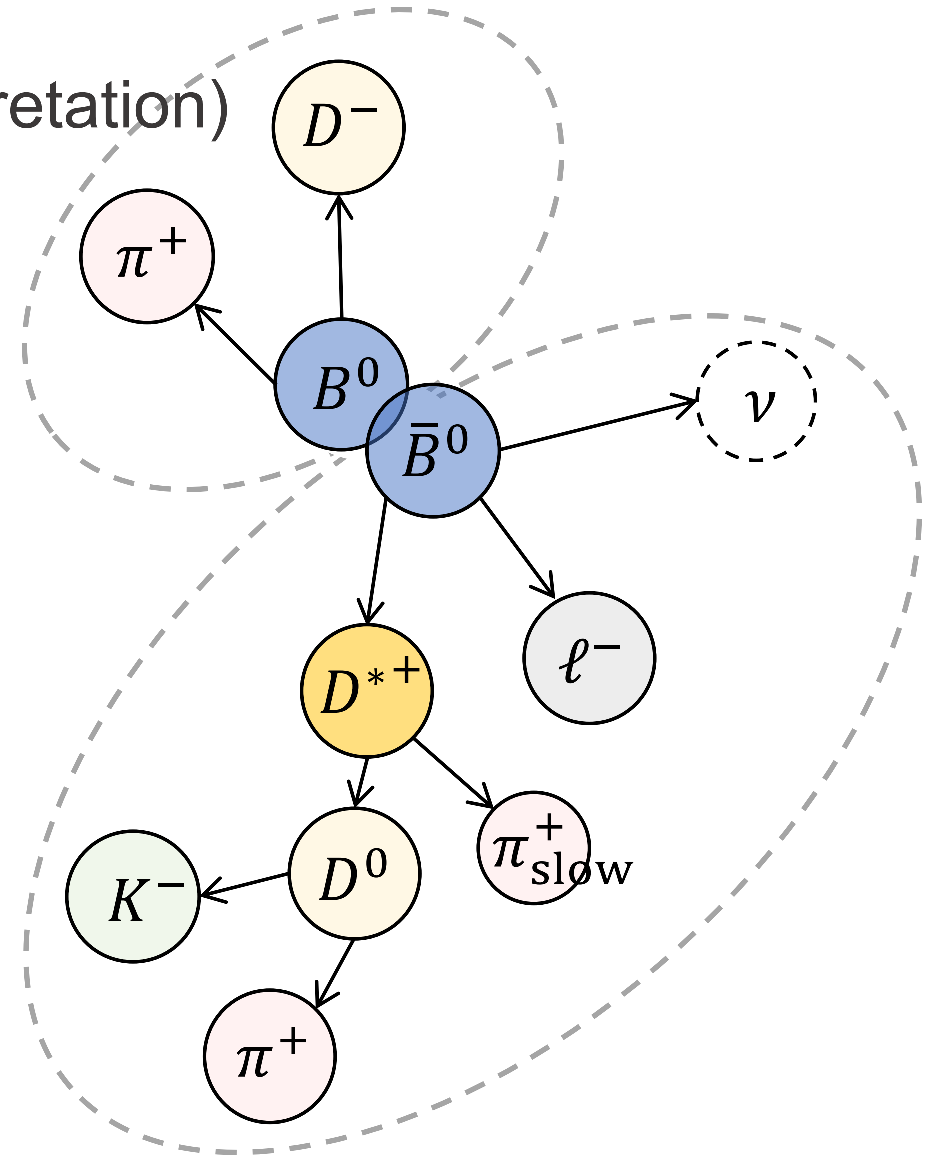


Hadronic B tagging (Full Event Interpretation)
Comp. and Soft. For Big Sci. **3**, 6 (2019)

Efficiency B^0: 0.27%, B^+: 0.35%
arXiv:2008.06096



1. **Inclusive signal B modes**



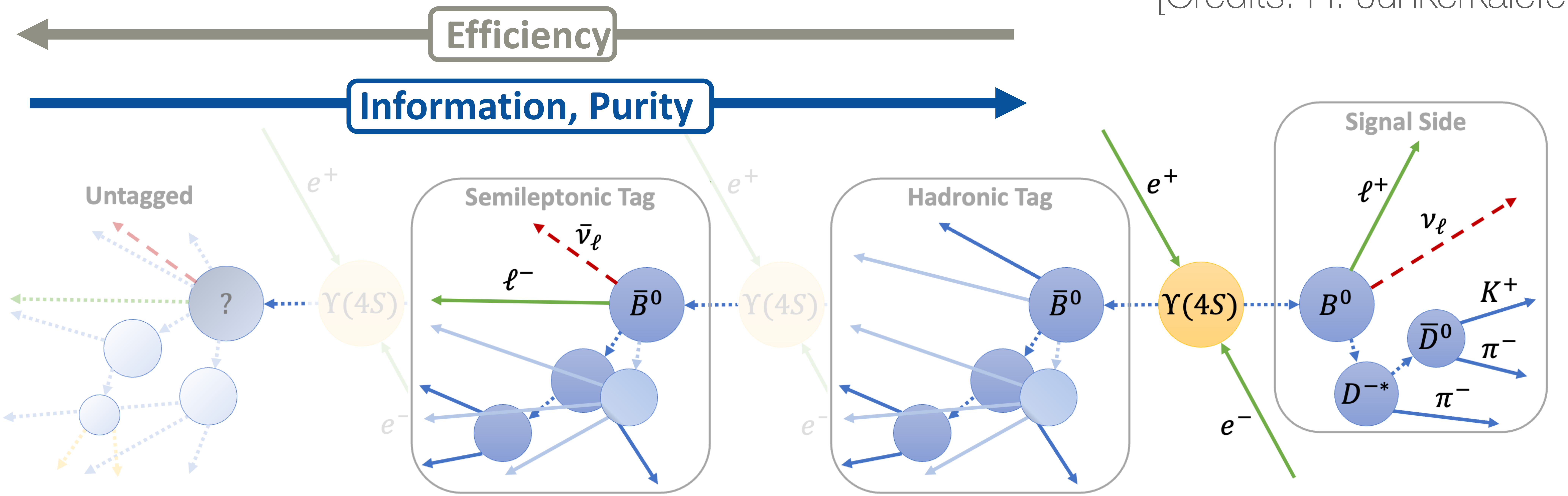
2. **Exclusive signal B modes**

	Experiment	**Theory**
Exclusive $\|V_{cb}\|$	B → Dlν, D*lν (low backgrounds)	Lattice QCD, light cone sum rules
Inclusive $\|V_{cb}\|$	B → Xlν (higher background)	Operator product expansion

[Credits: C. Schwanda]

Tagging

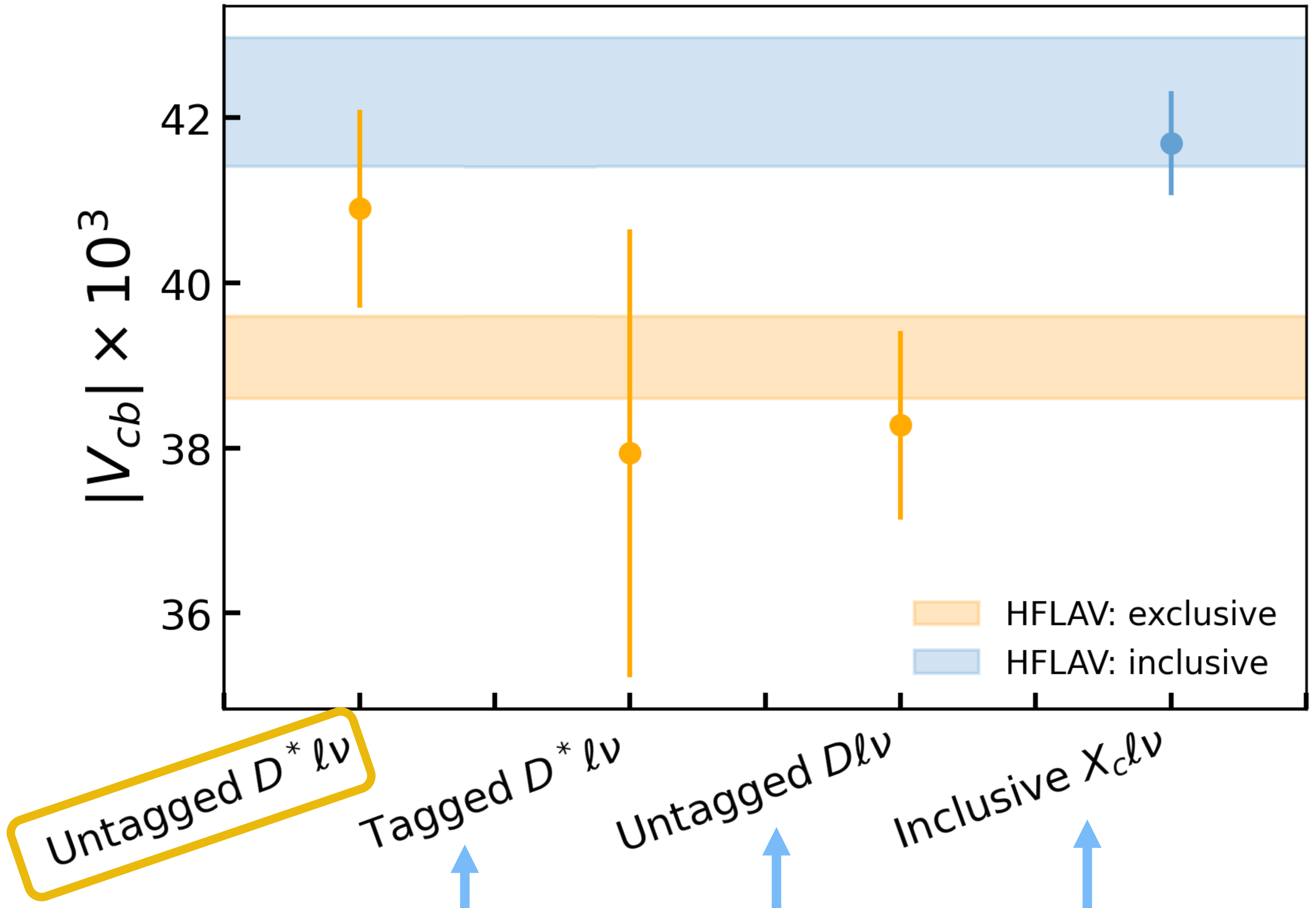
[Credits: H. Junkerkalefeld]

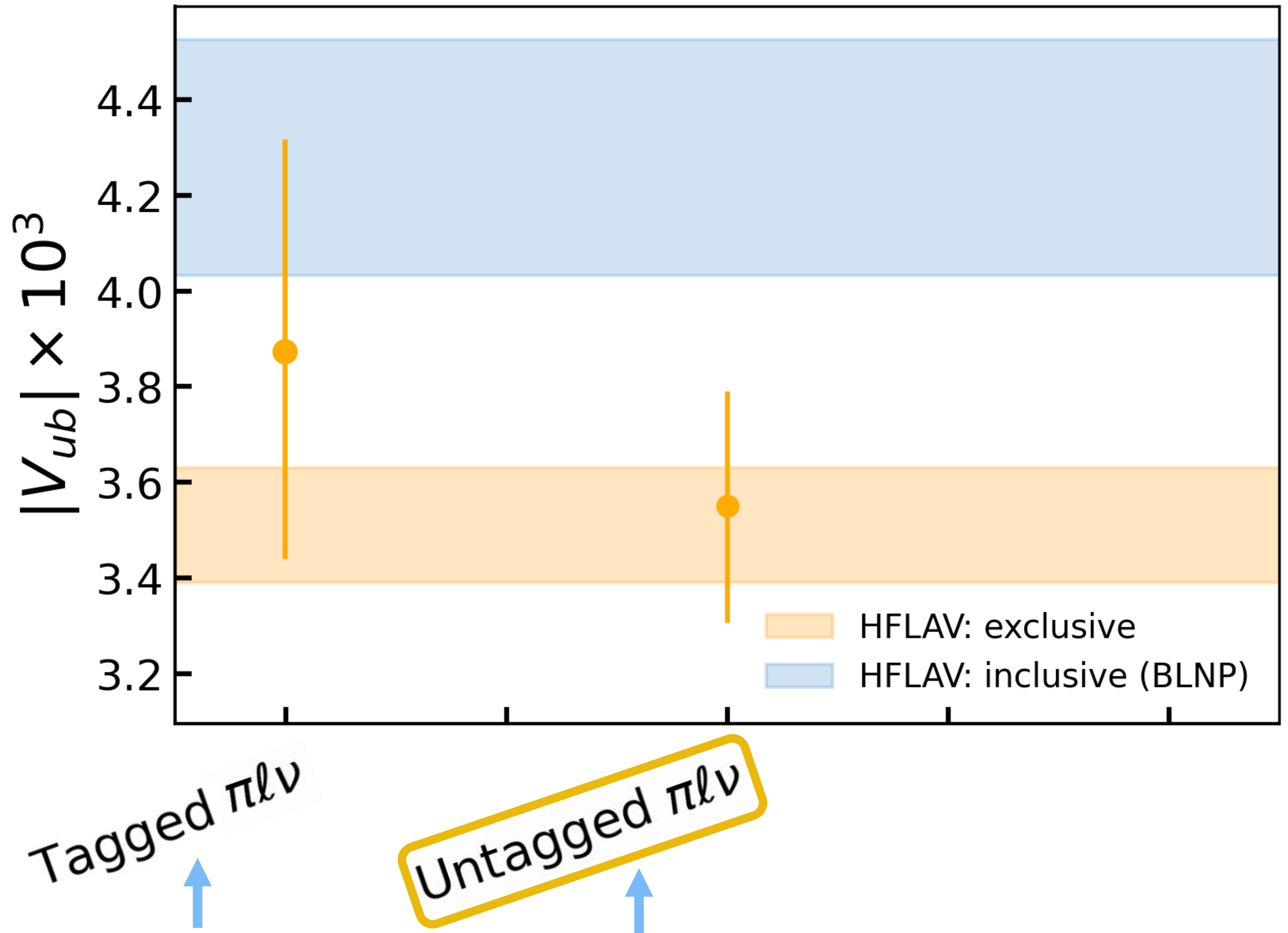


$\epsilon = \mathcal{O}(100\%)$	$\epsilon = \mathcal{O}(1\%)$	$\epsilon = \mathcal{O}(0.1\%)$
Only approximate kinematical information	Rough knowledge of B_{tag} kinematics (missing $\boldsymbol{\nu}$)	**Exact** knowledge of B_{tag} kinematics

Recent Belle II results

[Credits: C. Lyu and H. Junkerkalefeld]





arXiv:2210.13143

arXiv:2206.08102

arXiv:2301.04716

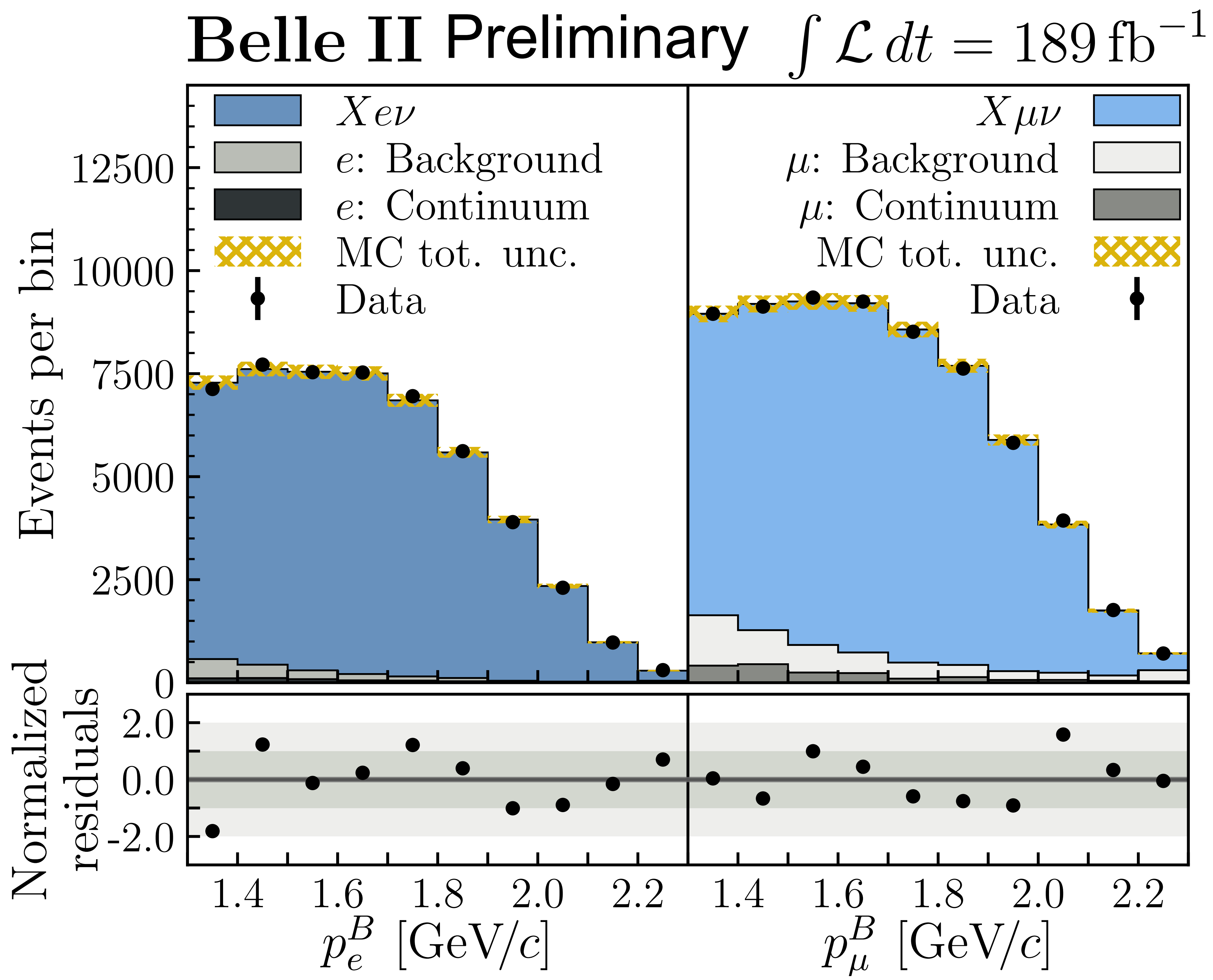
arXiv:2210.04224

Novel $|V_{cb}|$ extraction method[1]
based on measured q^2 moments
by Belle[2] & Belle II[3]

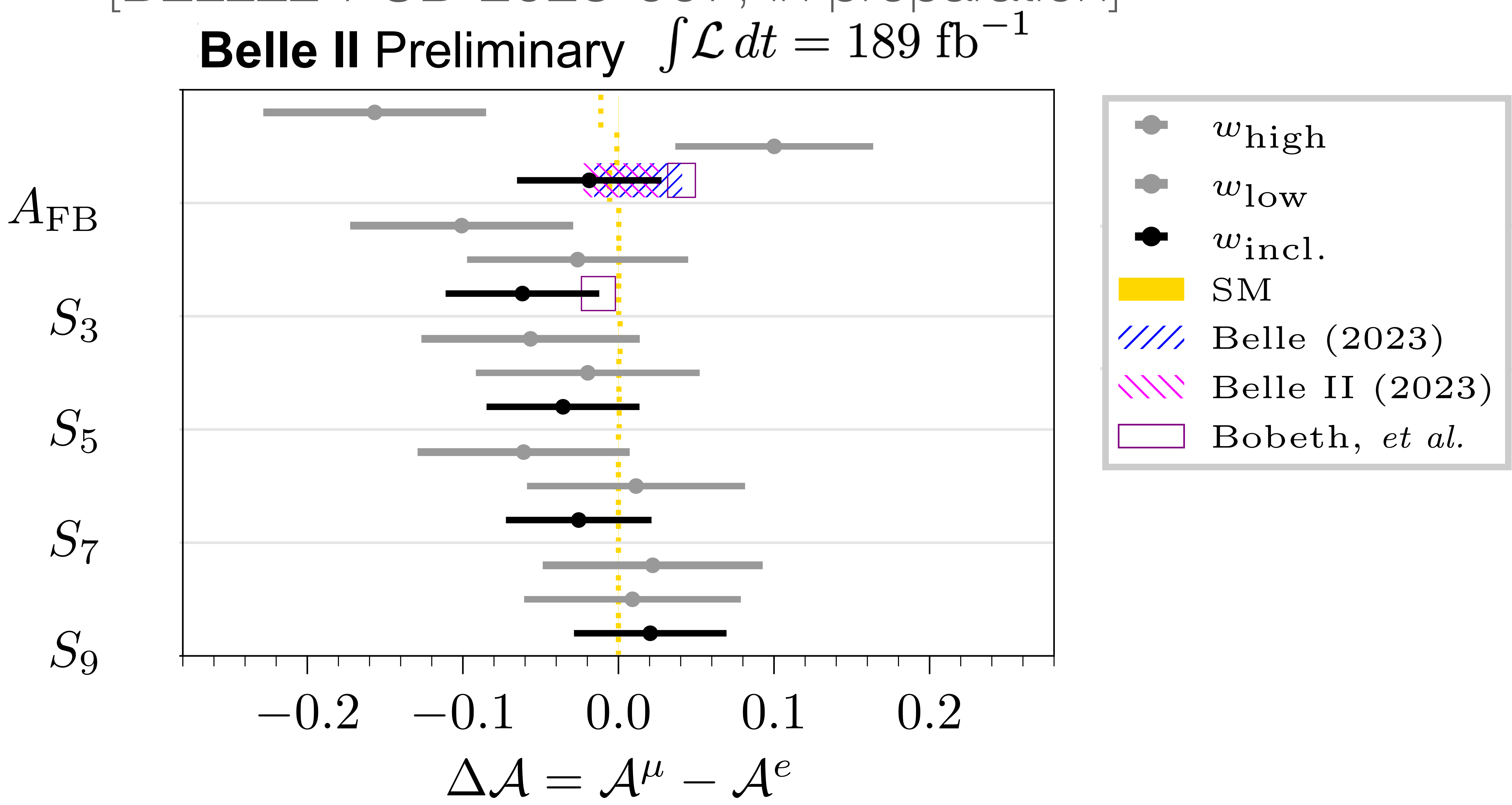
[1] = JHEP **10** 068 (2022), [2] = Phys. Rev. D **104**, 112011,
[3] = arXiv:2205.06372

Lepton universality tests

[arXiv:2301.08266]



[BELLE2-PUB-2023-007, in preparation]



- First inclusive measurement of light-lepton universality ratio with B->Xlv (l=e,μ)

Preliminary

$$R(X_{e/\mu}) = \mathbf{1.033 \pm 0.010^{stat} \pm 0.019^{syst}}$$

[arXiv:2301.08266]

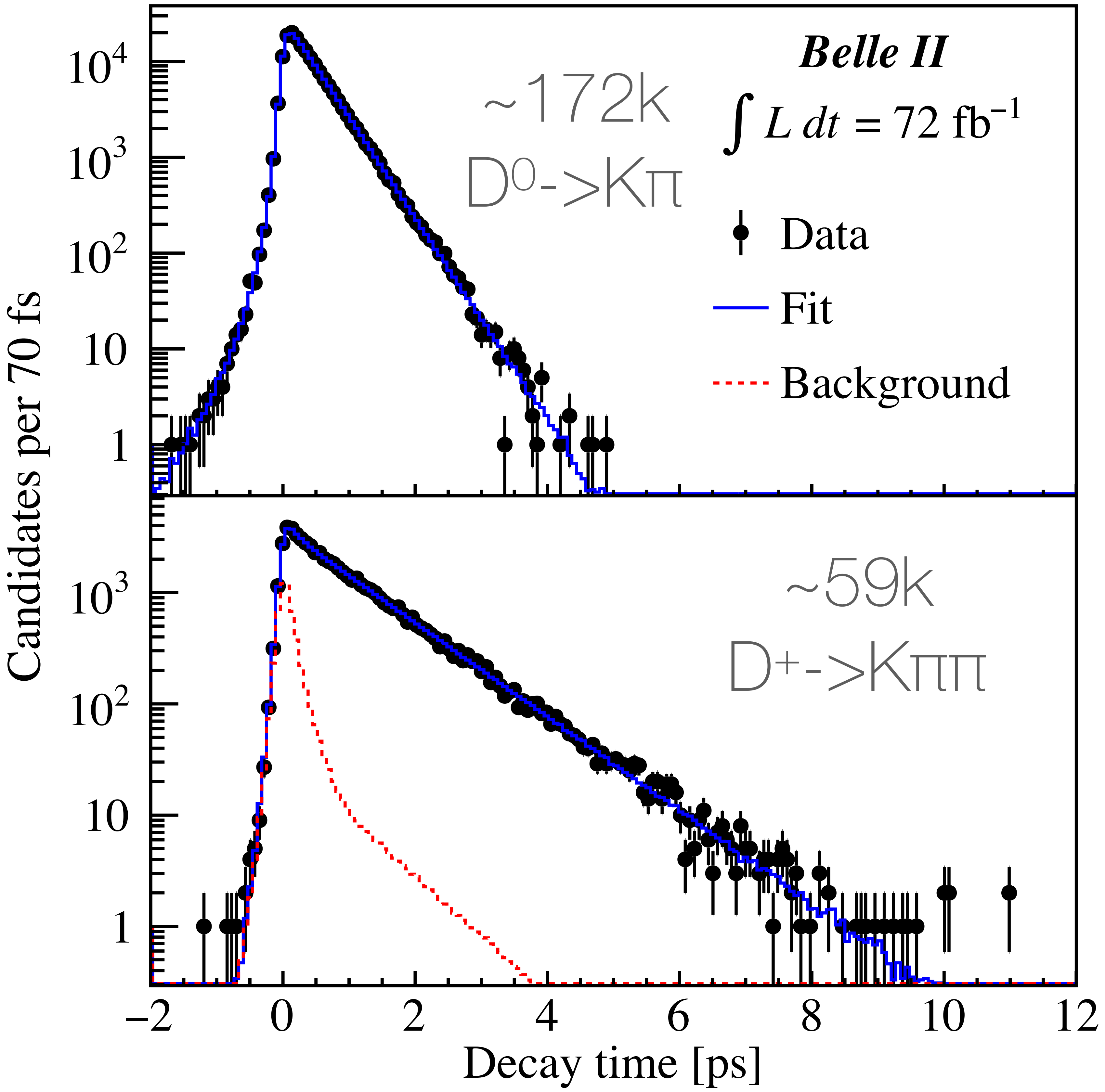
- Complete set of five angular asymmetries with had-tag B->D*lv (l=e,μ)

Charm lifetimes

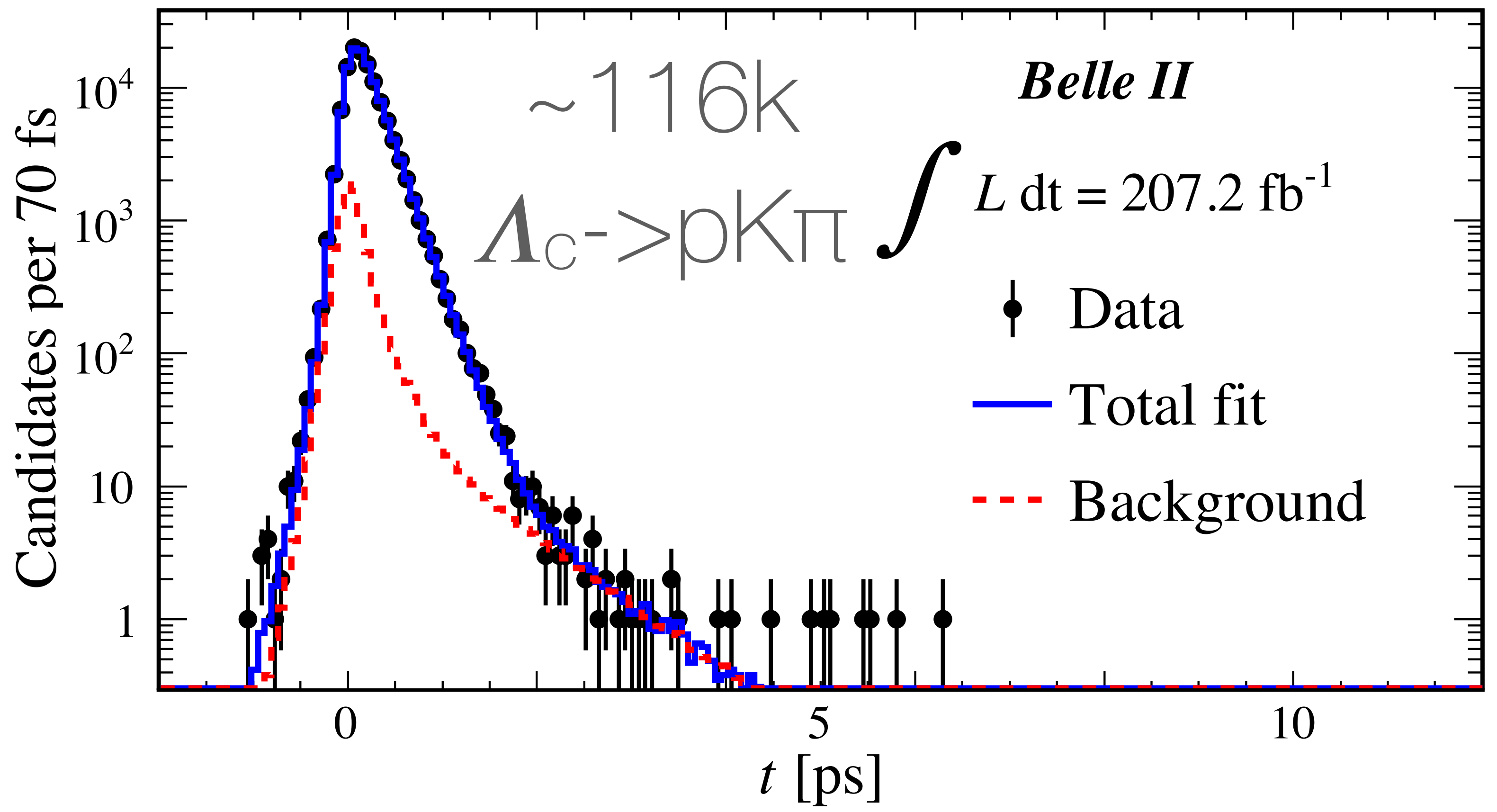
- Rich program of charm lifetimes measurements
- Already world's leading determinations using only partial dataset
- Important input for HQE predictions and lifetime hierarchy

$$\tau(\Xi_c^0) < \tau(\Lambda_c^+) < \tau(\Omega_c^0) < \tau(\Xi_c^+)$$

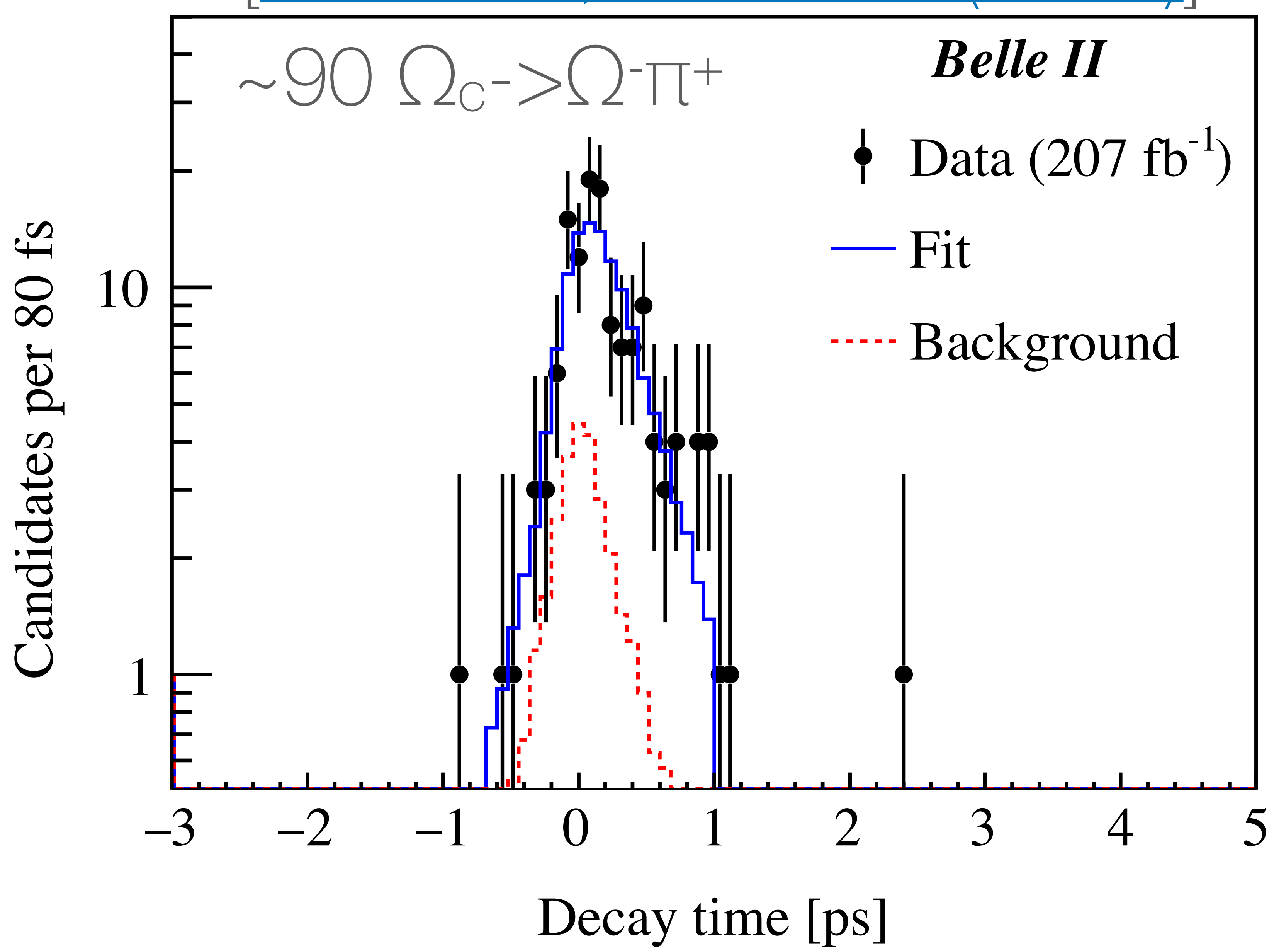
[PRL 127 21801(2021)]



[PRL 130, 071802 (2023)]



[PRD 107, L031103 (2023)]



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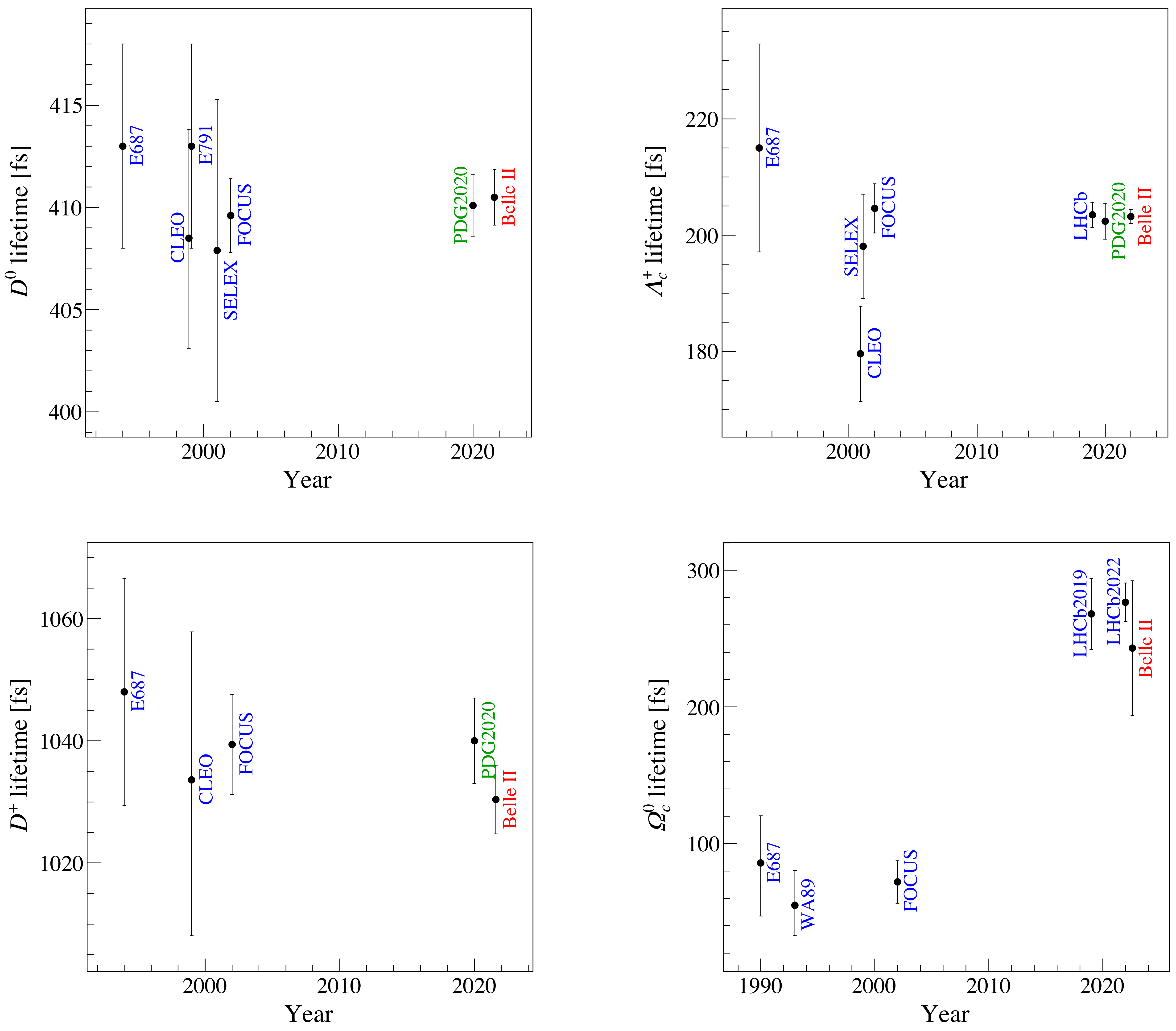
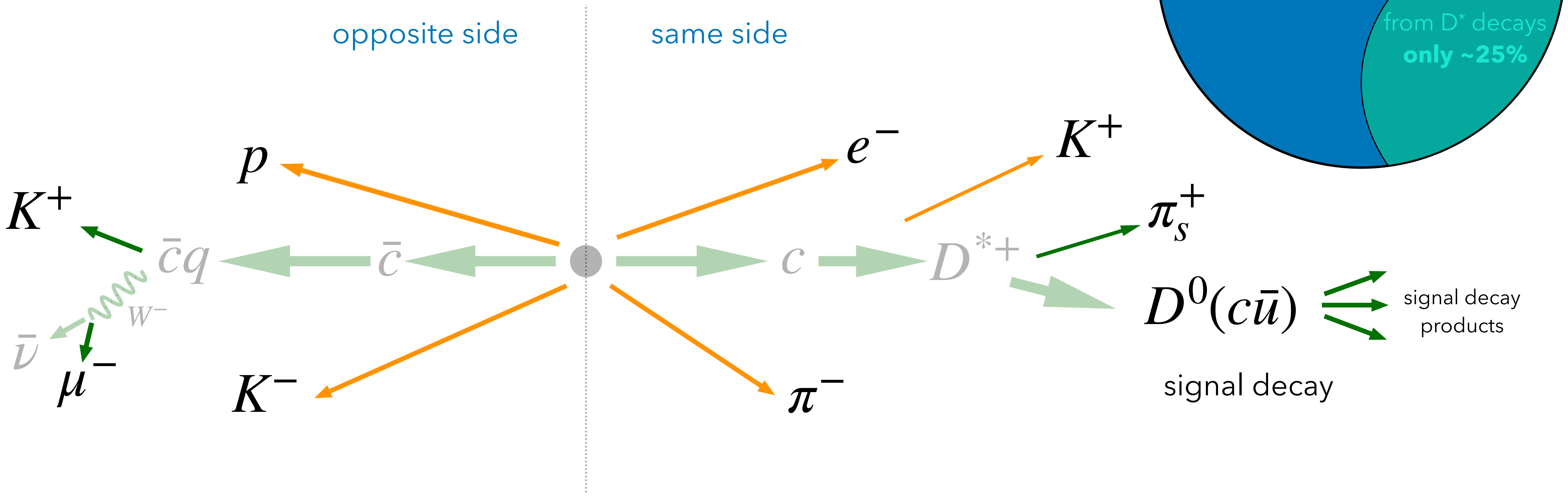
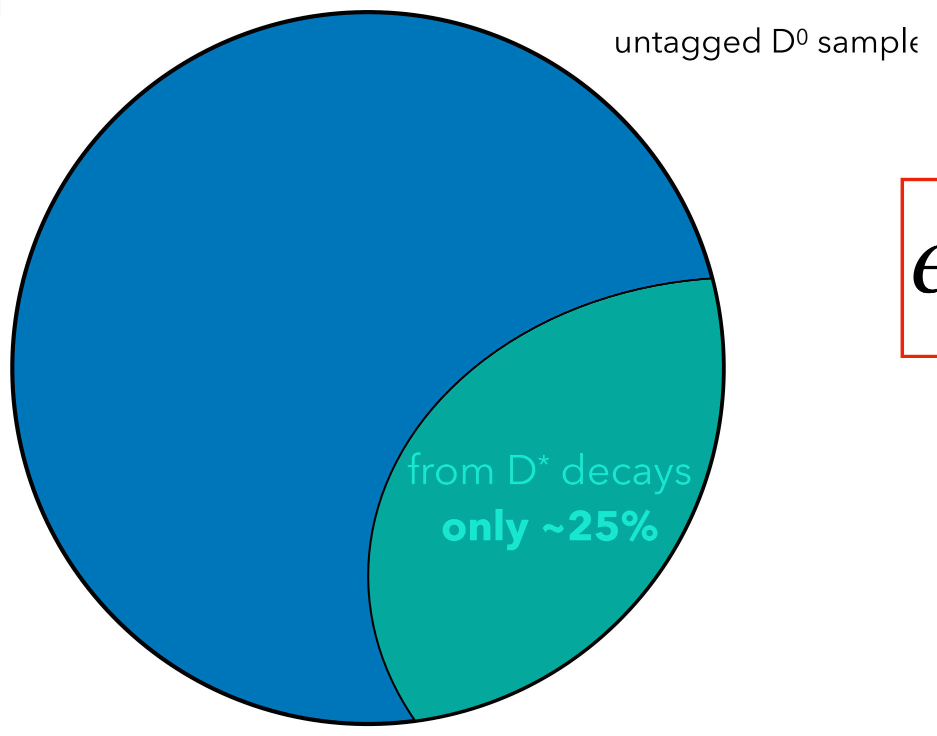


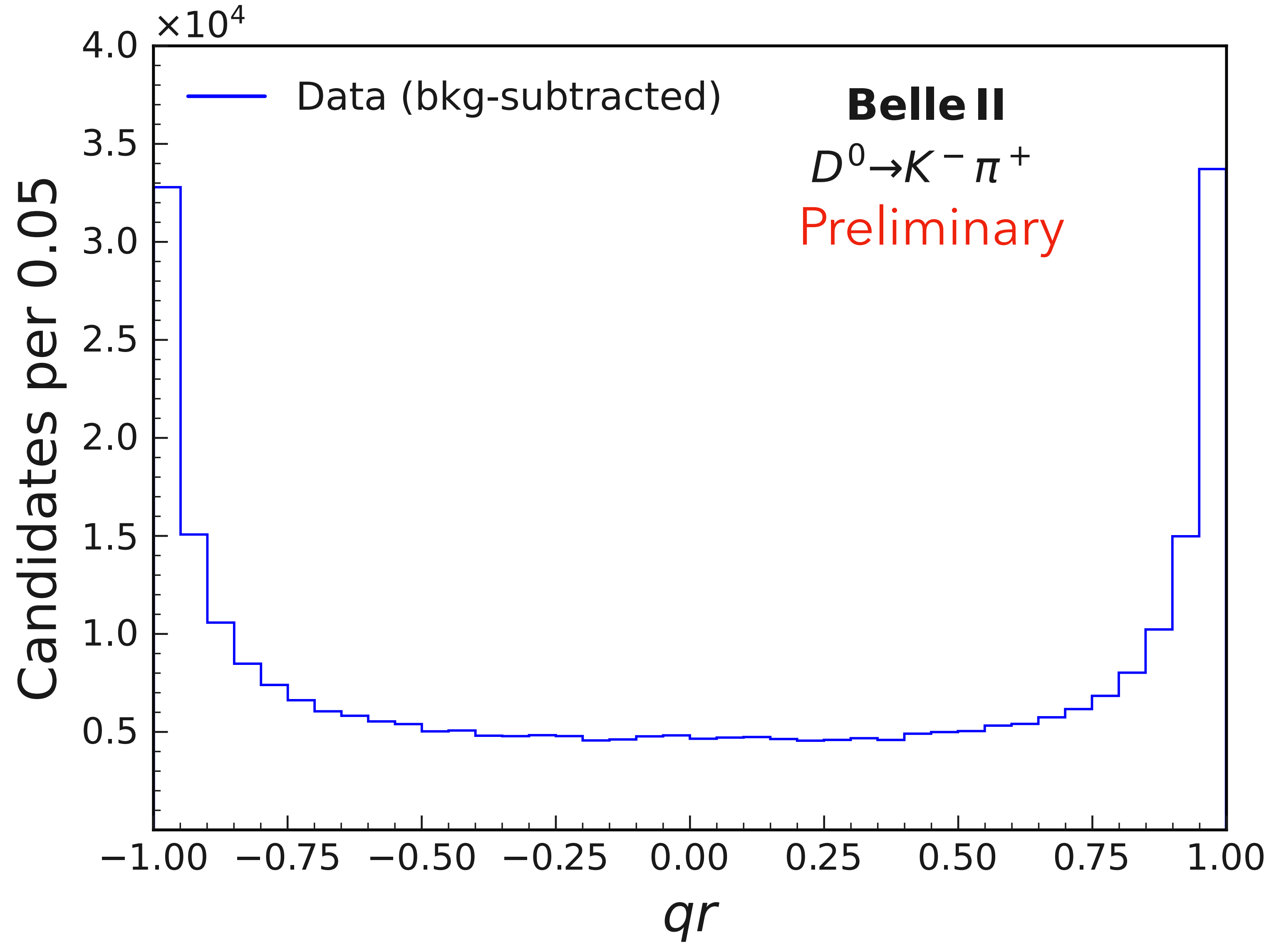
Charm flavor tagger



[Credits: M. Bertemes]



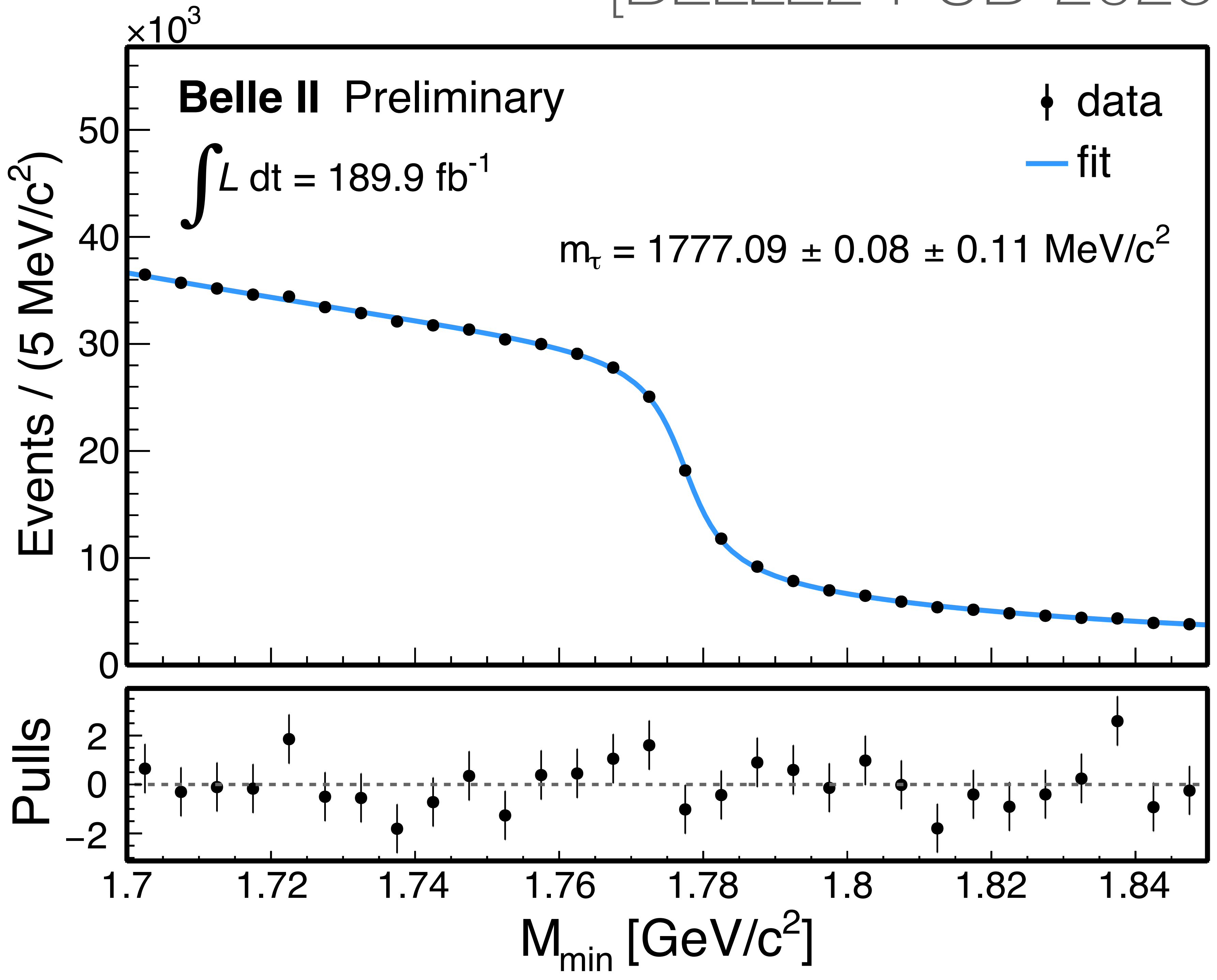
$$\epsilon_{\mathrm{tag}}^{\mathrm{eff}} = (47.91 \pm 0.07(\mathrm{stat.}) \pm 0.51(\mathrm{syst.}))\,\%$$

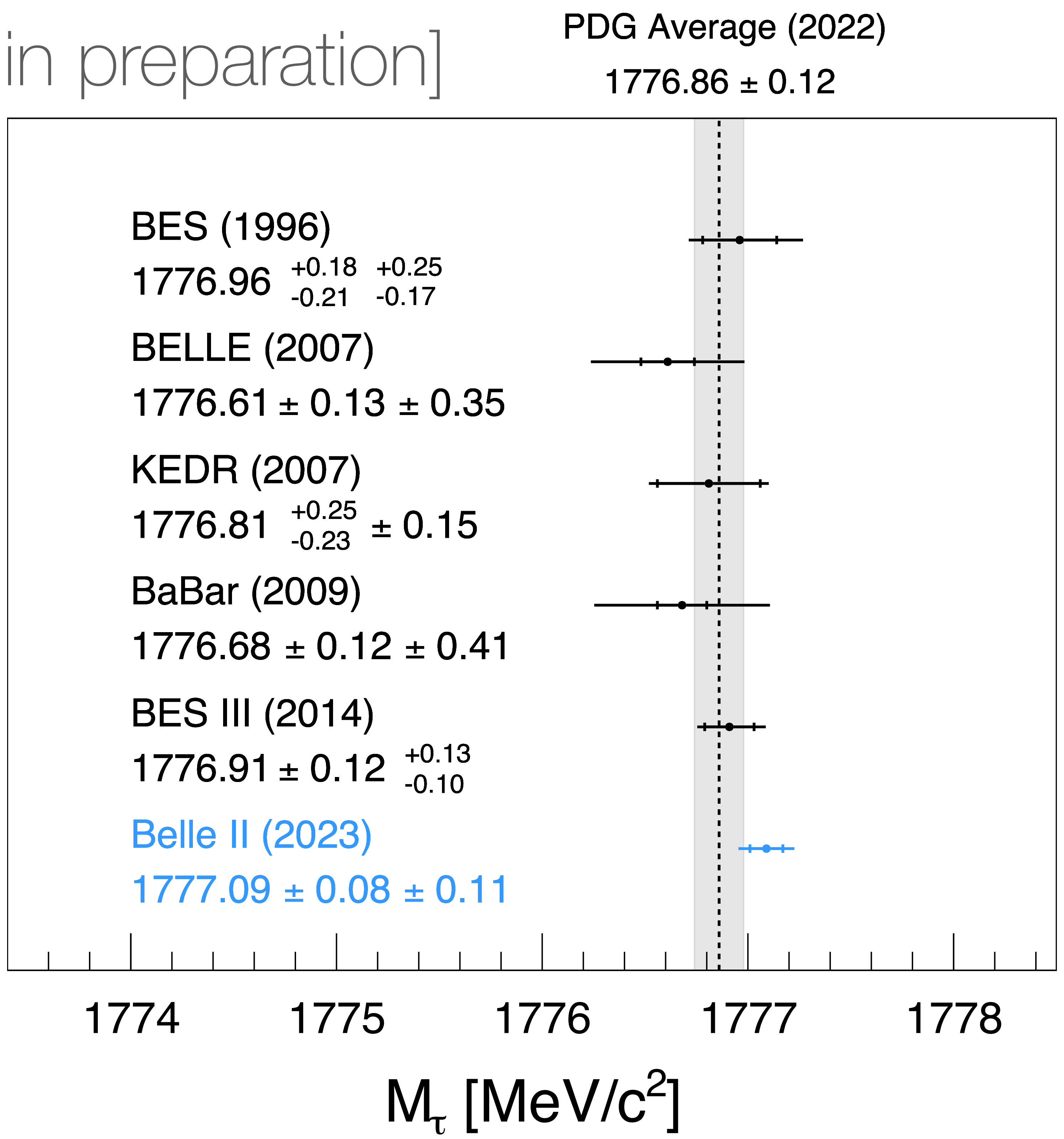


- New flavor-tagging algorithm recovering D^0 candidates not tagged by traditional approach reconstructing $D^{*+} \to D^0\pi^+$ decay chain
- Exploiting charm pair production and charge correlation between signal D flavor and the tracks in the rest of the events
- Effective tagging efficiency calibrated in data with flavor-specific decays, roughly doubling the size of tagged D^0 sample

Tau mass

[BELLE2-PUB-2023-001, in preparation]





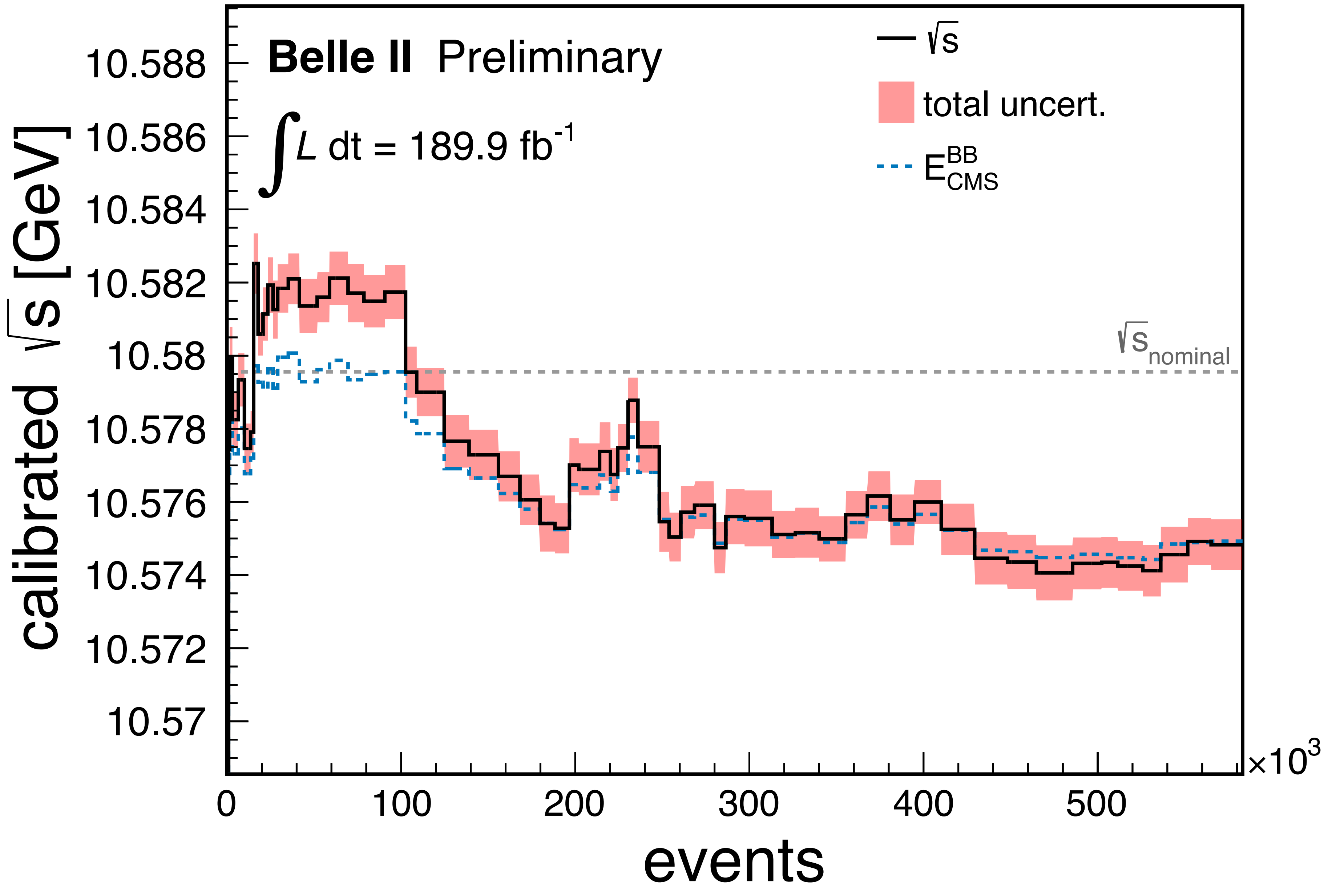
$$M_{\min} = \sqrt{M_{3\pi}^2 + 2(\sqrt{s}/2 - E_{3\pi}^*)(E_{3\pi}^* - P_{3\pi}^*)} \leq m_\tau$$

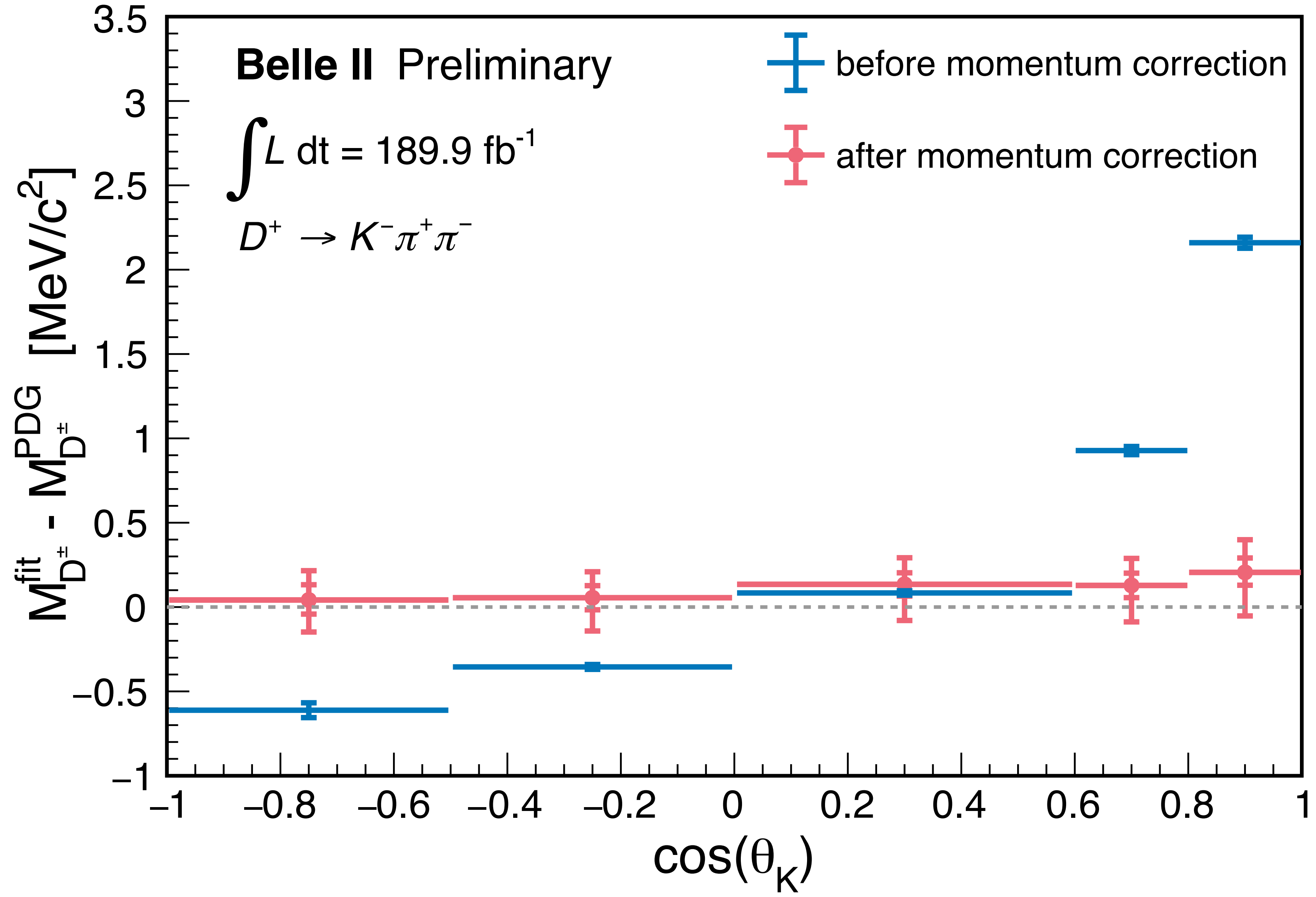
- New world's best determination (~10 keV precision!), reconstructing tag $\tau^\pm \to \pi^\pm(\pi^0)\nu$, $l\nu\nu$ and signal $\tau \to 3\pi\nu$ using the M_{min} method
- Kinematic edge at m_τ, smeared due to detector resolution and tails from ISR

Tau mass

[BELLE2-PUB-2023-001, in preparation]

Source	Uncertainty [MeV/c^2]
Knowledge of the colliding beams:	
Beam energy correction	0.07
Boost vector	$\leq$ 0.01
Reconstruction of charged particles:	
Charged particle momentum correction	0.06
Detector misalignment	0.03
Fitting procedure:	
Estimator bias	0.03
Choice of the fit function	0.02
Mass dependence of the bias	$\leq$ 0.01
Imperfections of the simulation:	
Detector material budget	0.03
Modeling of ISR and FSR	0.02
Momentum resolution	$\leq$ 0.01
Neutral particle reconstruction efficiency	$\leq$ 0.01
Tracking efficiency correction	$\leq$ 0.01
Trigger efficiency	$\leq$ 0.01
Background processes	$\leq$ 0.01
Total	0.11





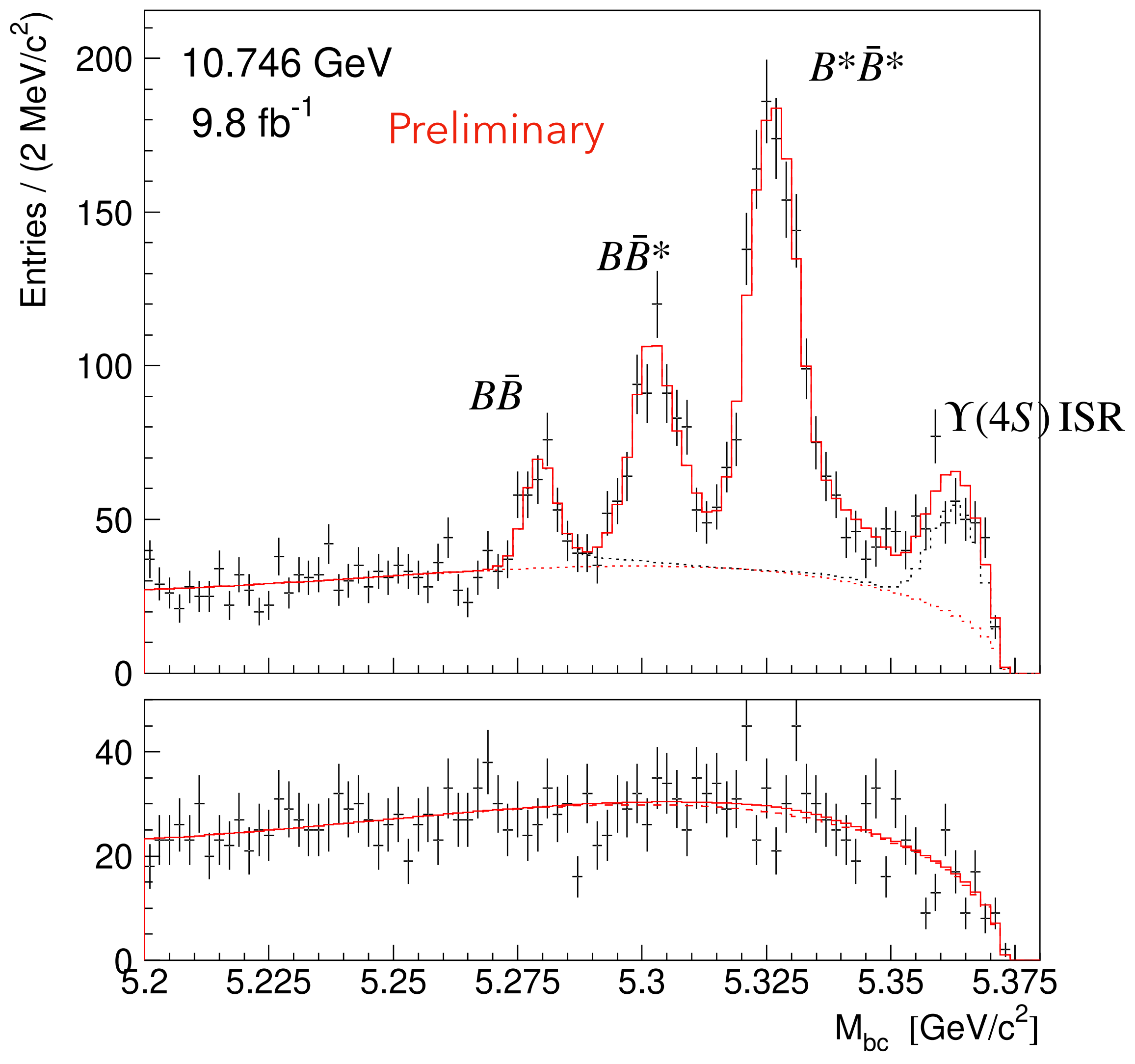
$$M_{\min} = \sqrt{M^2_{3\pi} + 2(\sqrt{s}/2 - E^*_{3\pi})(E^*_{3\pi} - P^*_{3\pi})} \leq m_\tau$$

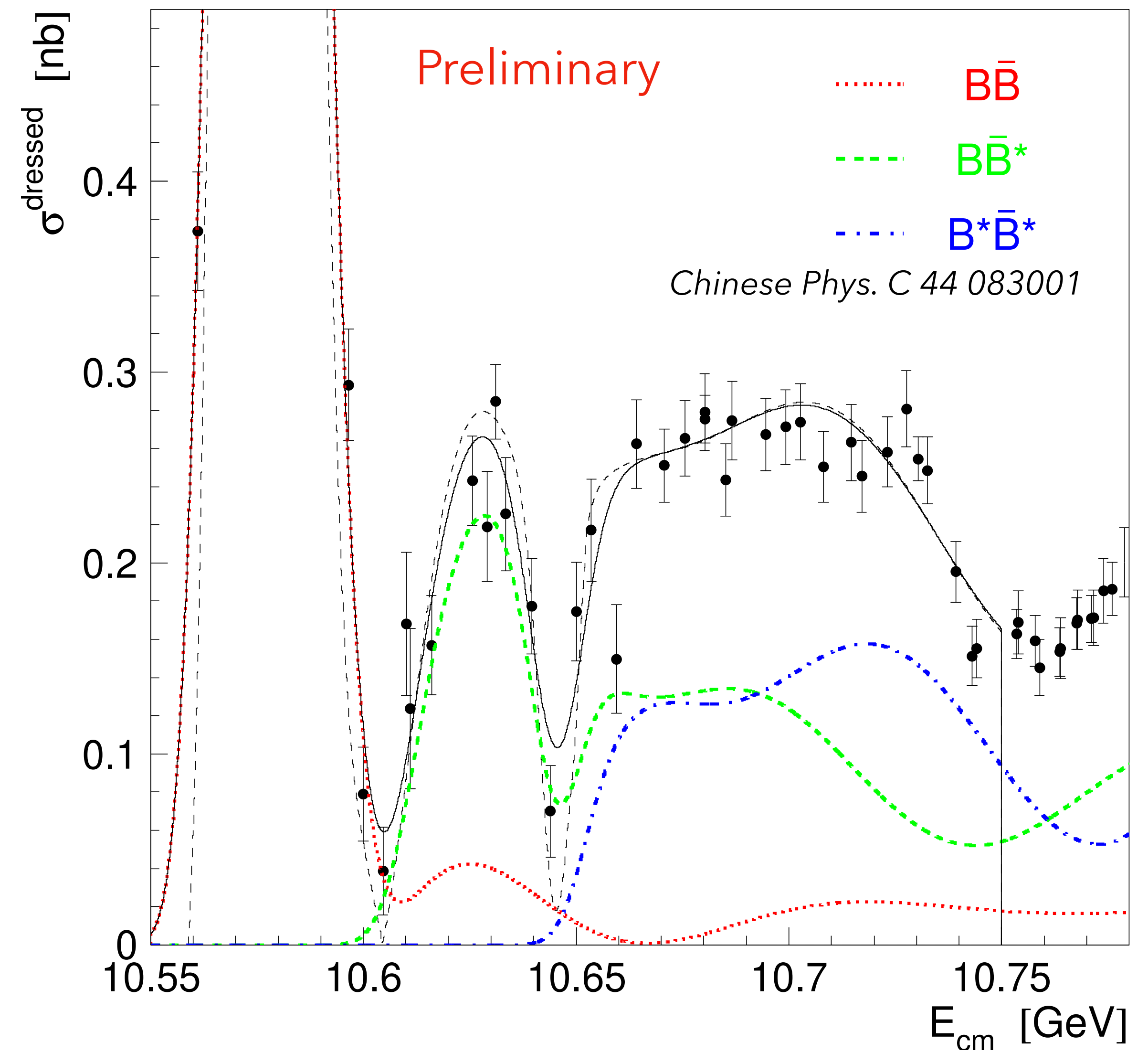
- Requires precise knowledge of beam energy and track momentum scale
- Benchmark for precision capabilities of Belle II

Miscellanea

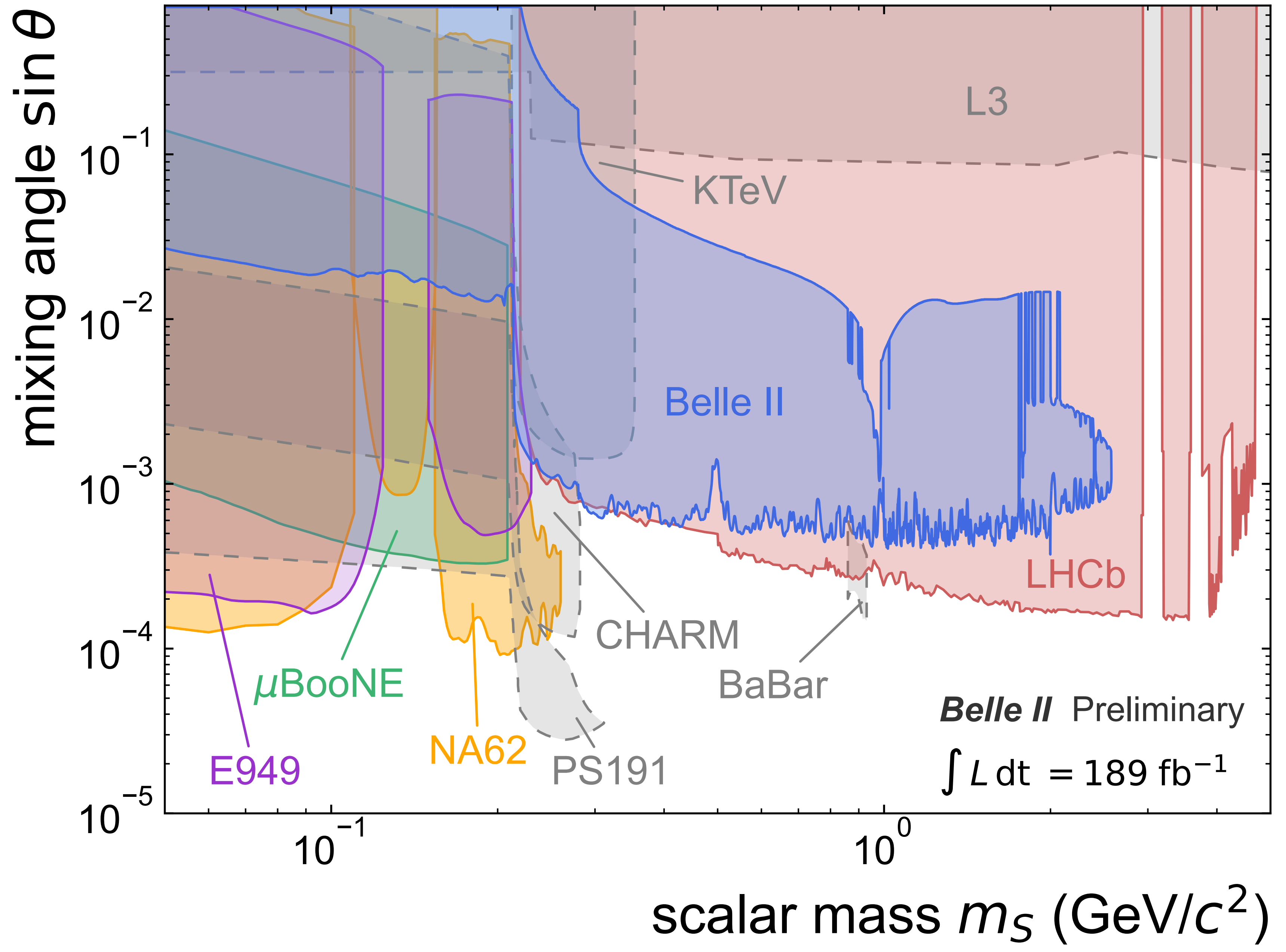
- Rich quarkonium physics program
  - Unique dataset near E_{cm}~10.75 GeV
- Complementary sensitivity to dark sector searches in light mass ranges
- EW penguin and radiative decays
  - Benefit from ~equal e,μ reconstruction and excellent capabilities with neutrals
  - Still limited by size of dataset

[e+e- -> B(*)B(*) x-sections]





[First LLP search at Belle II]



Full list of recent results (<1yr)

ICHEP 2022 [~half pre-LS1 dataset]

- |Vcb| from untagged B->Dlν decays [arxiv:2210.13143]
- |Vub| from untagged B->πlν decays [arxiv:2210.04224]
- BF(B->ρlν) from tagged decays [arxiv:2211.15270]
- LFU test in inclusive B->Xlν [arxiv:2301.08266]
- Photon energy spectrum in inclusive B->$X_s\gamma$ [arxiv:2210.10220]
- Measurement of sin2ϕ_1 [arxiv:2302.12898]
- CPV in B->$K_SK_SK_S$ [arxiv:2209.09547]
- BF and fL in B->ρρ [arxiv.org:2208.03554]
- BF and A_{CP} in B^+->$h^+\pi^0$ [arxiv:2209.05154]
- BF and A_{CP} in B->$\pi^0\pi^0$ [arxiv:2303.08354]
- Search for τ->lα (invisible) [arxiv:2212.03634]
- Observation of $e^+e^- \to \omega\chi_b$ at 10.75 GeV [arxiv:2208.13189]
- BF, isospin asymmetry and LFU in B->J/ψK [arxiv:2207.11275]
- Search for Z'->invisible [arxiv:2212.03066]
- Search for Z', S, ALP -> *ττ, μμττ* [in preparation]
- Ω_c lifetime [arxiv:2208.08573]

Moriond 2023 [~full pre-LS1 dataset]

[in preparation]

- Charm flavor tagger
- CPV in B->ϕK_S
- CPV in B->$K_S\pi^0$
- CPV in B->$K_SK_SK_S$
- |Vcb| with B->D*lν untagged
- LFU test in angular asymmetries with B->D*lν
- BF and A_{CP} in B->Kπ and B->ππ
- τ lepton mass
- LLP search in b->s transitions
- BF and CP asymmetries in B->DK GLS
- BF and CP asymmetries in B->DK GLW
- LFU in angular asymmetries in had-tag B->D*lν
- Energy dependence of ee->BB,B*B,B*B* x-sections
- BF in B->D(*)KK_S decays
- Search for τ->lϕ

Summary

- New flavor physics experiment offering complementarity and redundancy to measurements at *pp* colliders
- Clean experimental environment and unique access to final states with K^0, π^0, γ, ν
- ~30 new results in the past 9 months and restarting data taking soon