Recent measurements of $|V_{xb}|$ from Belle (II)

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(for the Belle & Belle II Collaboration)

10 Feb 2023 @ KEK Flavor Factories Workshop

Content

Measurements covered in this talk:

Exclusive |V$_{cb}$|:

- Untagged $B \to D\ell\nu$
- Had. tagged $B^0 \to D^*\ell\nu$
- Had. tagged $B \to D^*\ell\nu$ and shapes of key kinematic variables

Inclusive |V$_{cb}$|:

- q^2 moments in $B \to X_c\ell\nu$ decays

Exclusive |V$_{ub}$|:

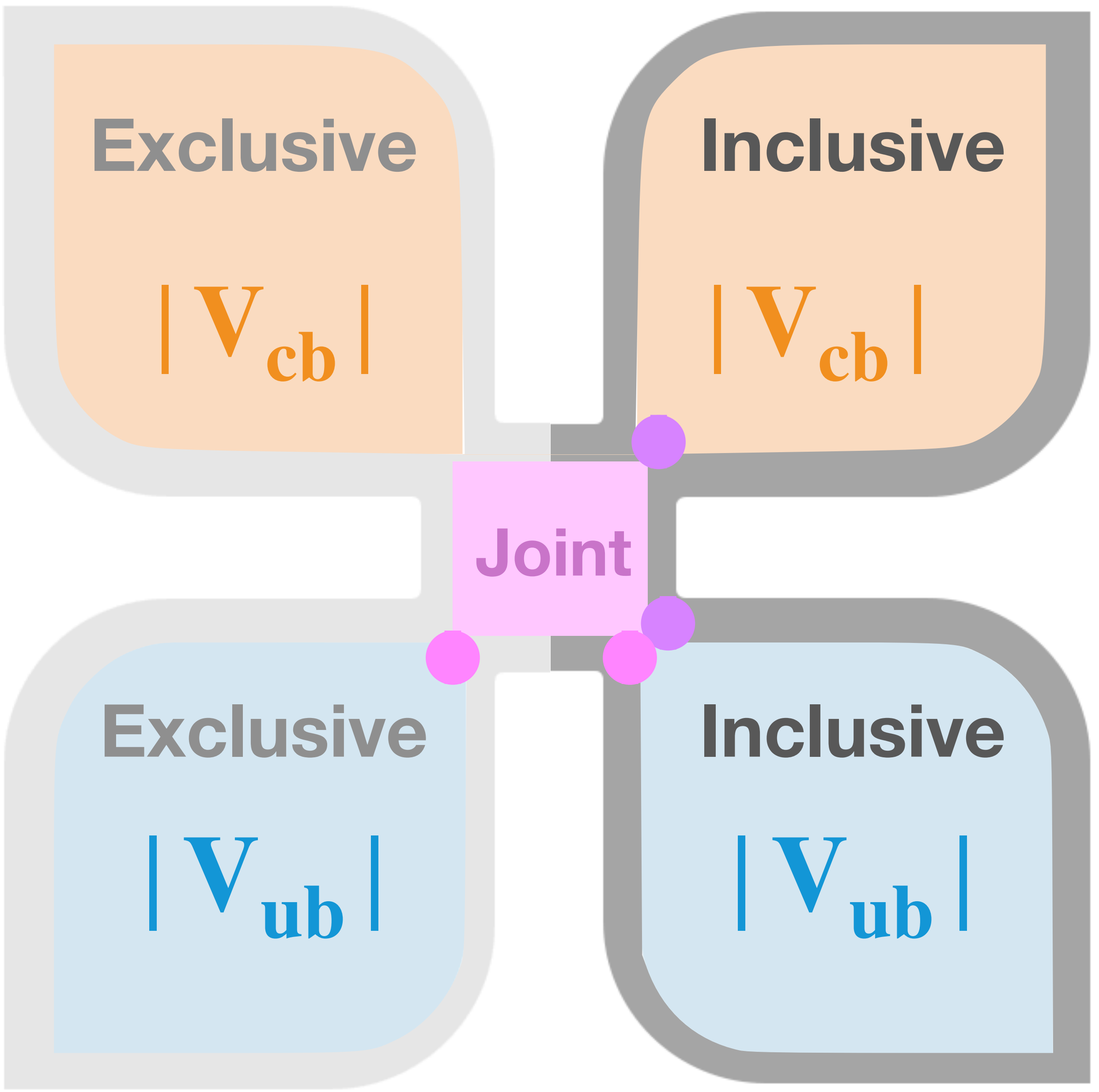
- Untagged $B^0 \to \pi^-\ell\nu$

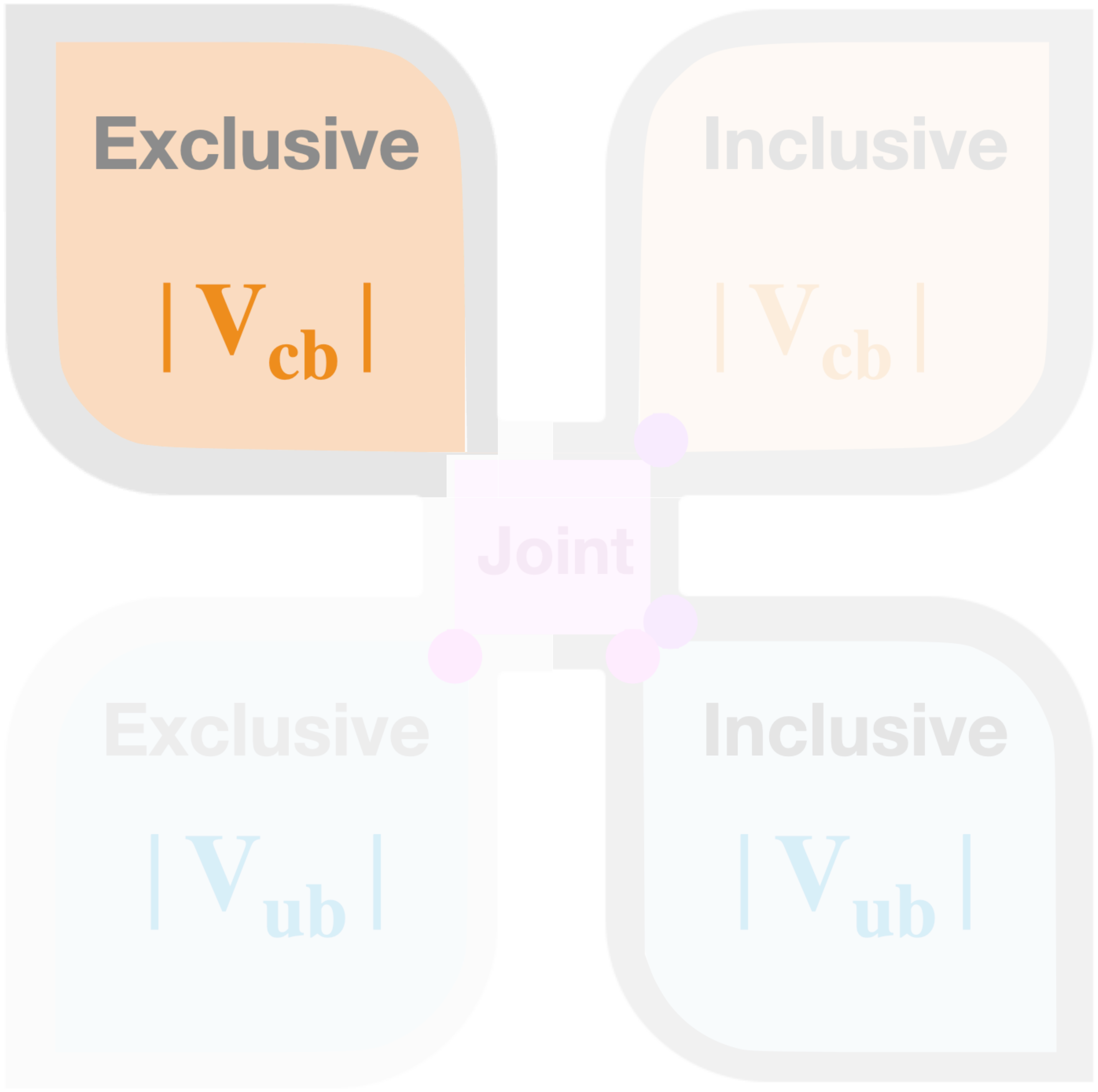
Inclusive |V$_{ub}$|:

- Partial & differential branching fractions of $B \to X_u\ell\nu$

Combined measurements:

- Excl. |V$_{ub}$| / incl. |V$_{ub}$|
- Incl. |V$_{ub}$| / incl. |V$_{cb}$|

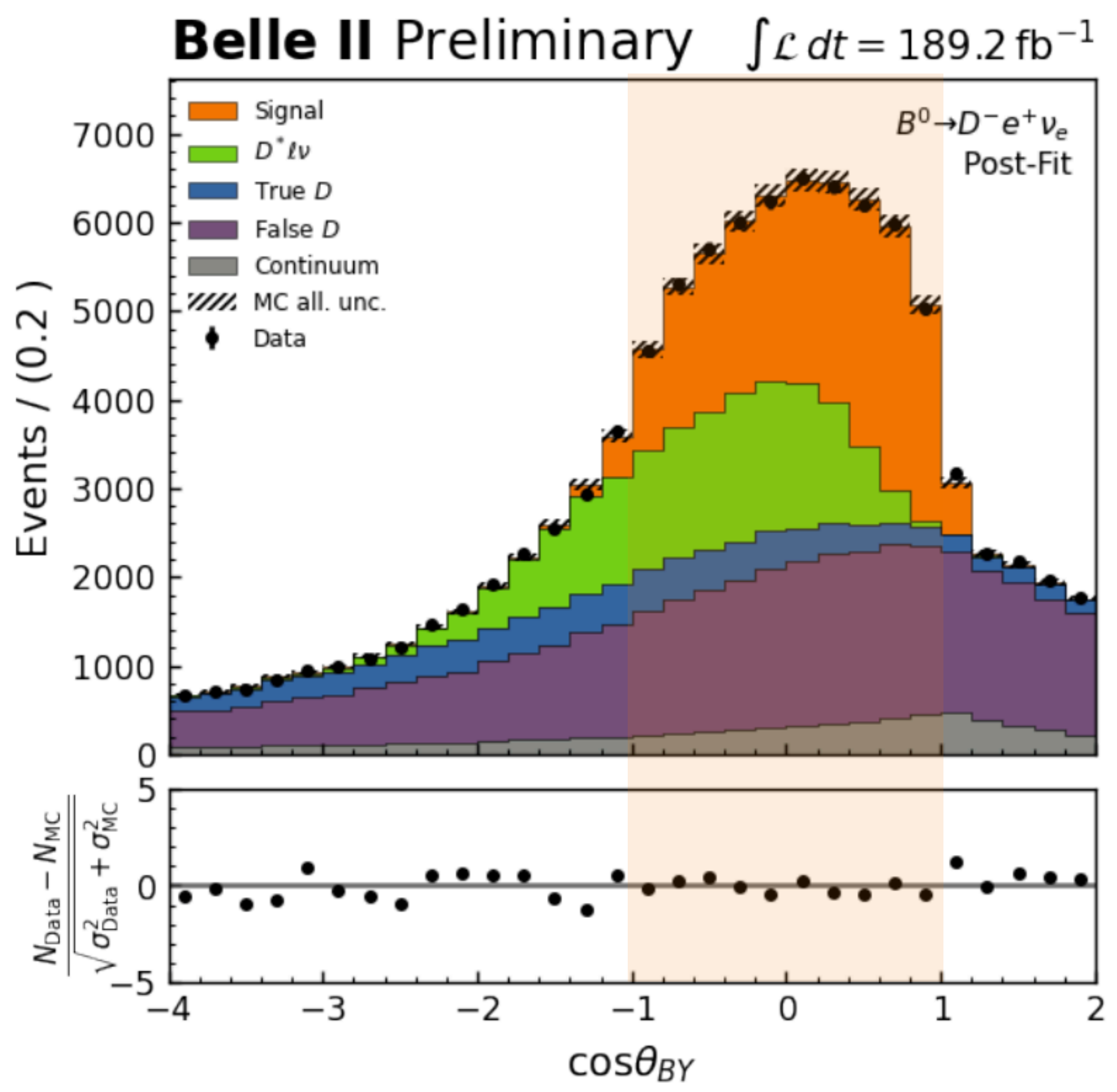



Exclusive
$|V_{cb}|$
Inclusive
$|V_{cb}|$
Joint
Exclusive
$|V_{ub}|$
Inclusive
$|V_{ub}|$

$|V_{cb}|$ in $B \to D\ell\nu$ with Belle II data

arXiv: 2210.13143

- Data set of 189.3 fb^{-1} for $B^{\pm,0}, \ell = e, \mu$
- Untagged analysis strategy, both $\mathrm{B\bar{B}}$ events included (high efficiency)
- Extract signal in $\mathbf{cos}\theta_{\mathbf{B,Y=D}\ell}$ separately for 10 bins of recoil variable $w = (p_B \cdot p_D)/(m_B \cdot m_D)$
- Based on w spectrum, extracted $\eta_{\mathrm{EW}}|\mathbf{V_{cb}}|$ with Boyd-Grinstein-Lebed (**BGL)** expansion including LQCD constraints (FNAL/MILC, HPQCD)



$$\cos\theta_{BY} = \frac{2\,E_B^* E_Y^* - m_B^2 - m_Y^2}{2 p_B^* p_Y^*}$$

|V$_{cb}$| in $B \to D\ell\nu$ with Belle II data

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- Data set of 189.3 fb^{-1} for $B^{\pm,0}$, $\ell = e, \mu$
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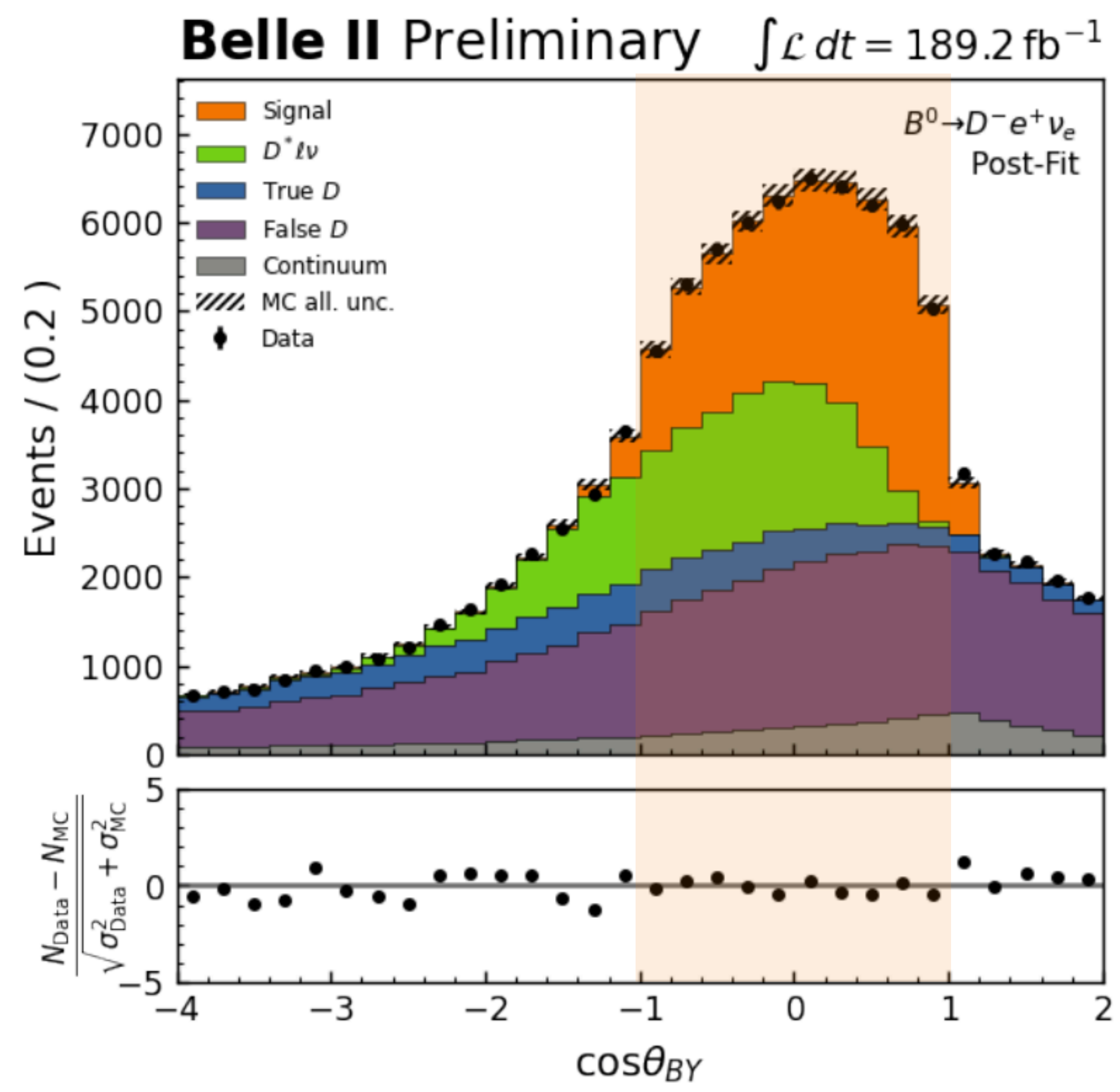

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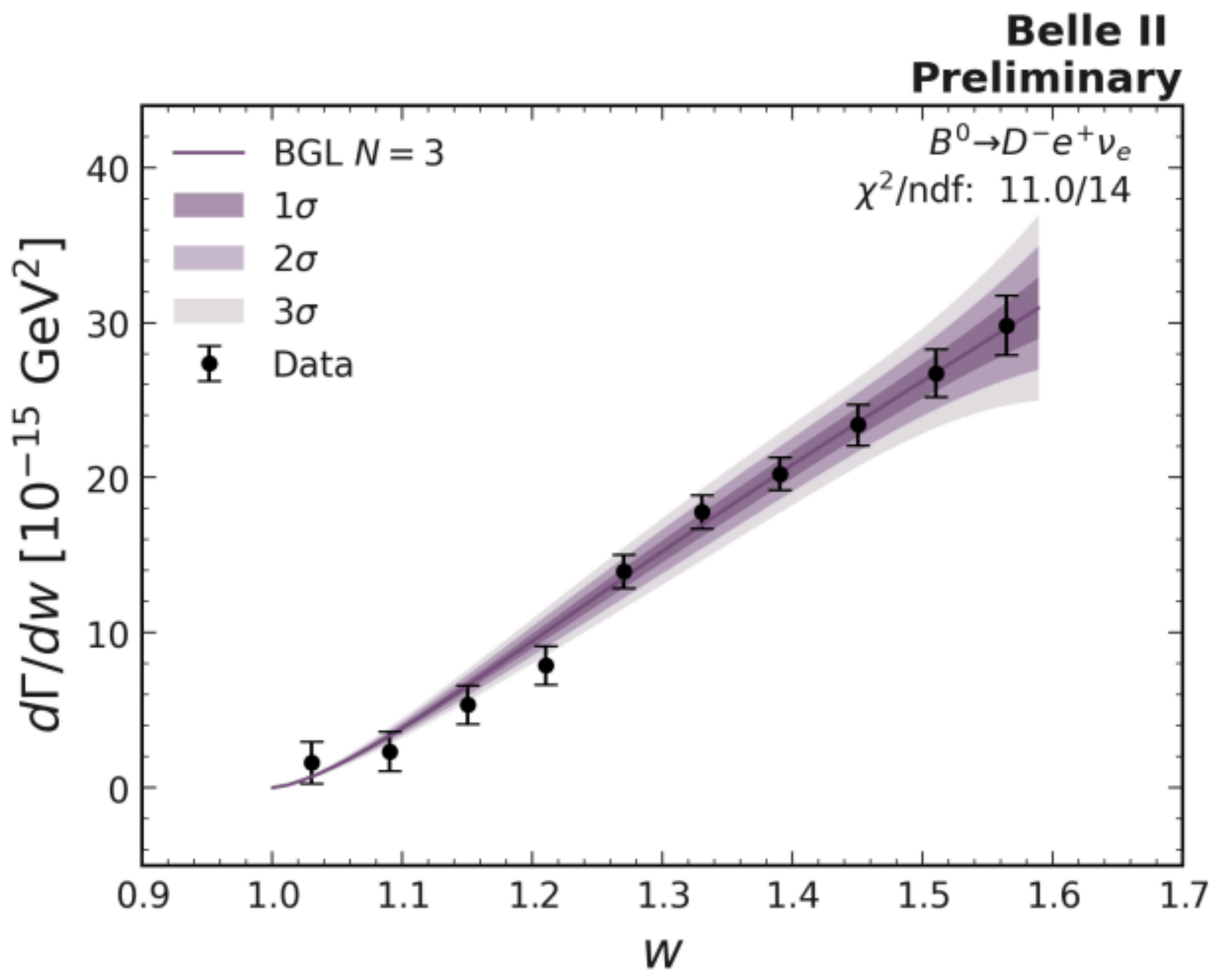
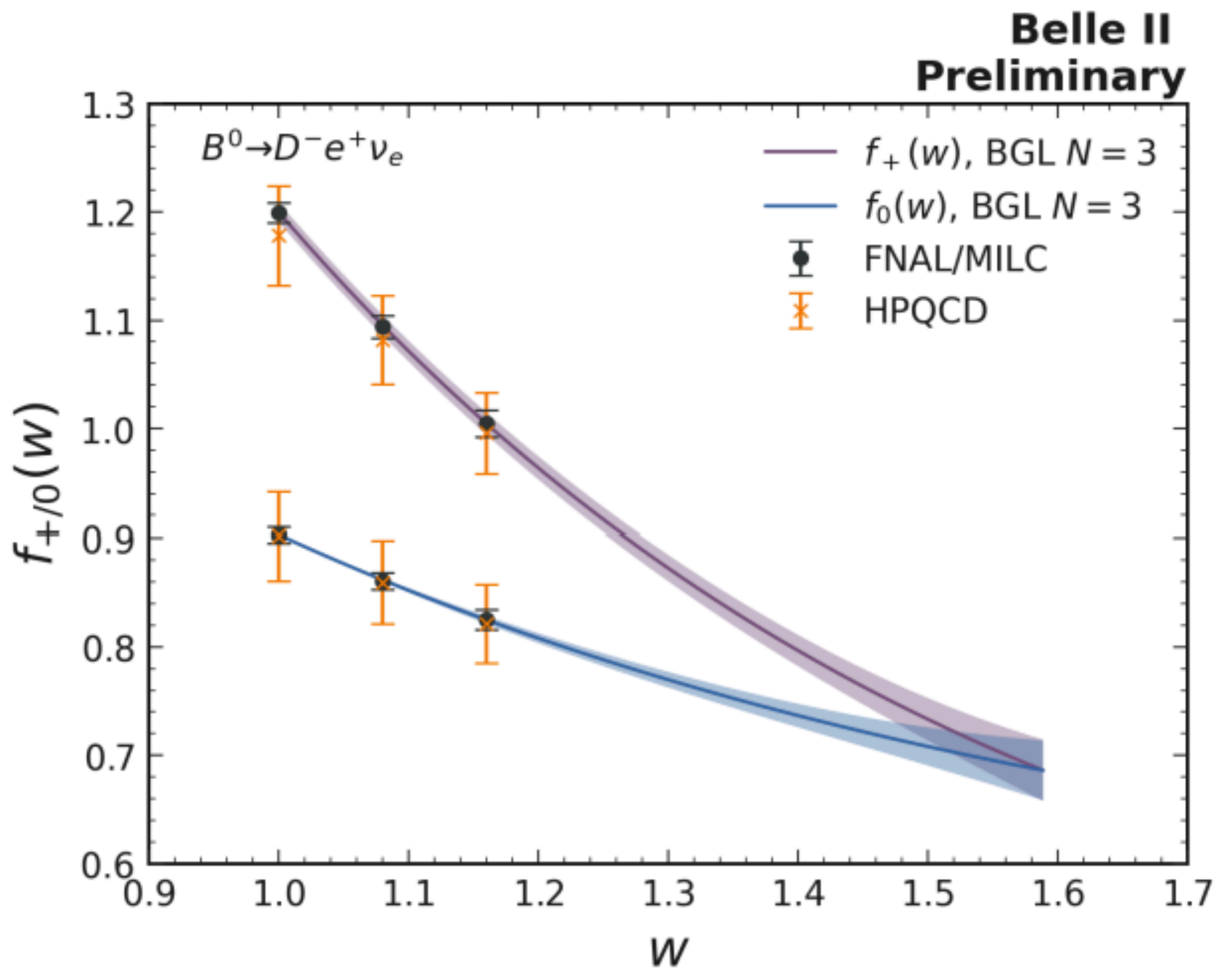


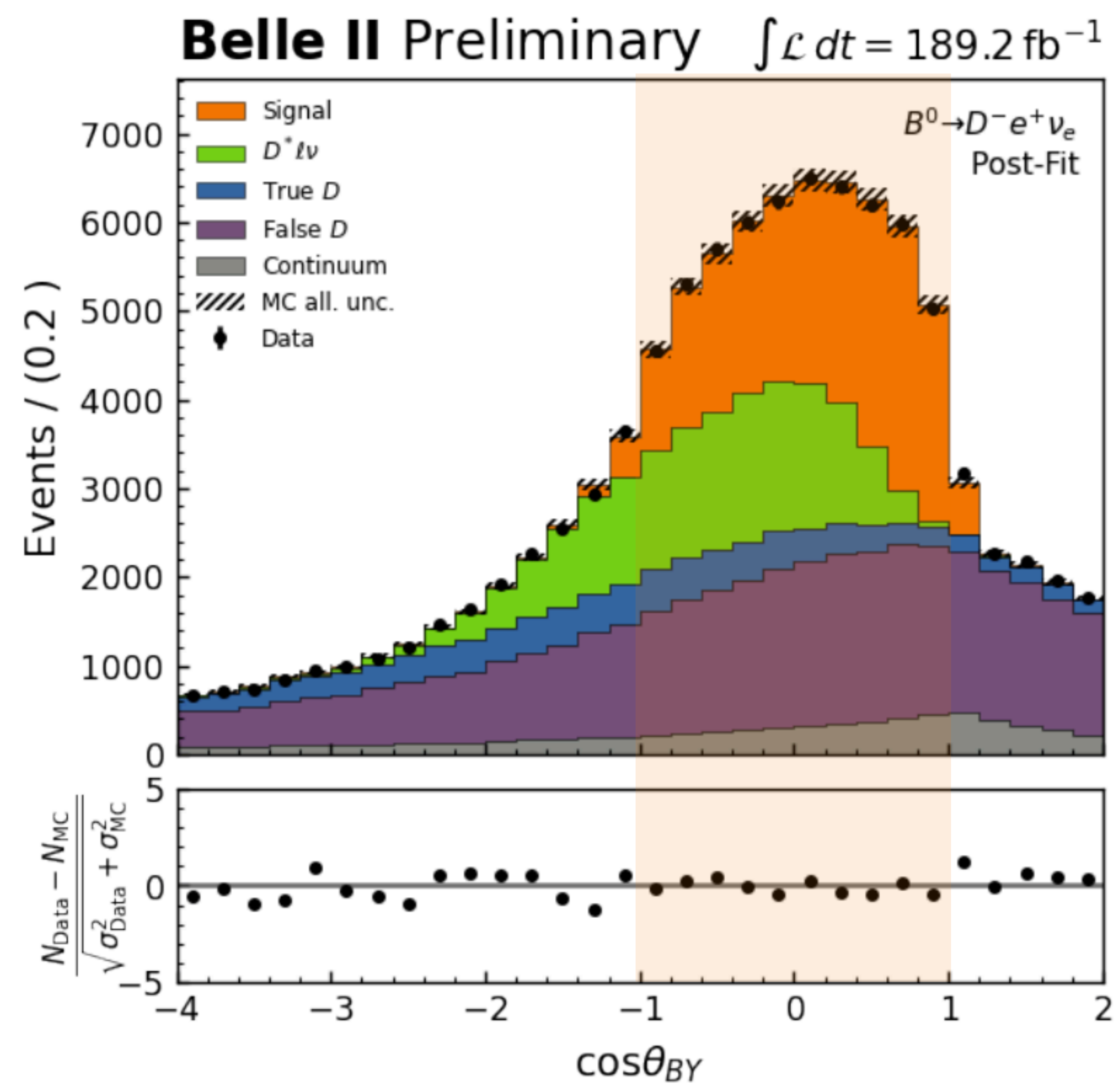


Weighted average of four modes: $\eta_{\mathrm{EW}}|V_{cb}| = (38.53 \pm 1.15) \times 10^{-3}$

$|V_{cb}|$ in $B \to D\ell\nu$ with Belle II data

arXiv: 2210.13143

- Data set of 189.3 fb^{-1} for $B^{\pm,0}$, $\ell = e, \mu$
- Untagged analysis strategy, both $\mathrm{B}\bar{\mathrm{B}}$ events included (high efficiency)
- Extract signal in $\cos\theta_{\mathrm{B,Y=D}\ell}$ separately for 10 bins of recoil variable $w = (p_B \cdot p_D)/(m_B \cdot m_D)$
- Based on w spectrum, extracted $\eta_{\mathrm{EW}}|\mathbf{V_{cb}}|$ with Boyd-Grinstein-Lebed (**BGL)** expansion including LQCD constraints (FNAL/MILC, HPQCD)



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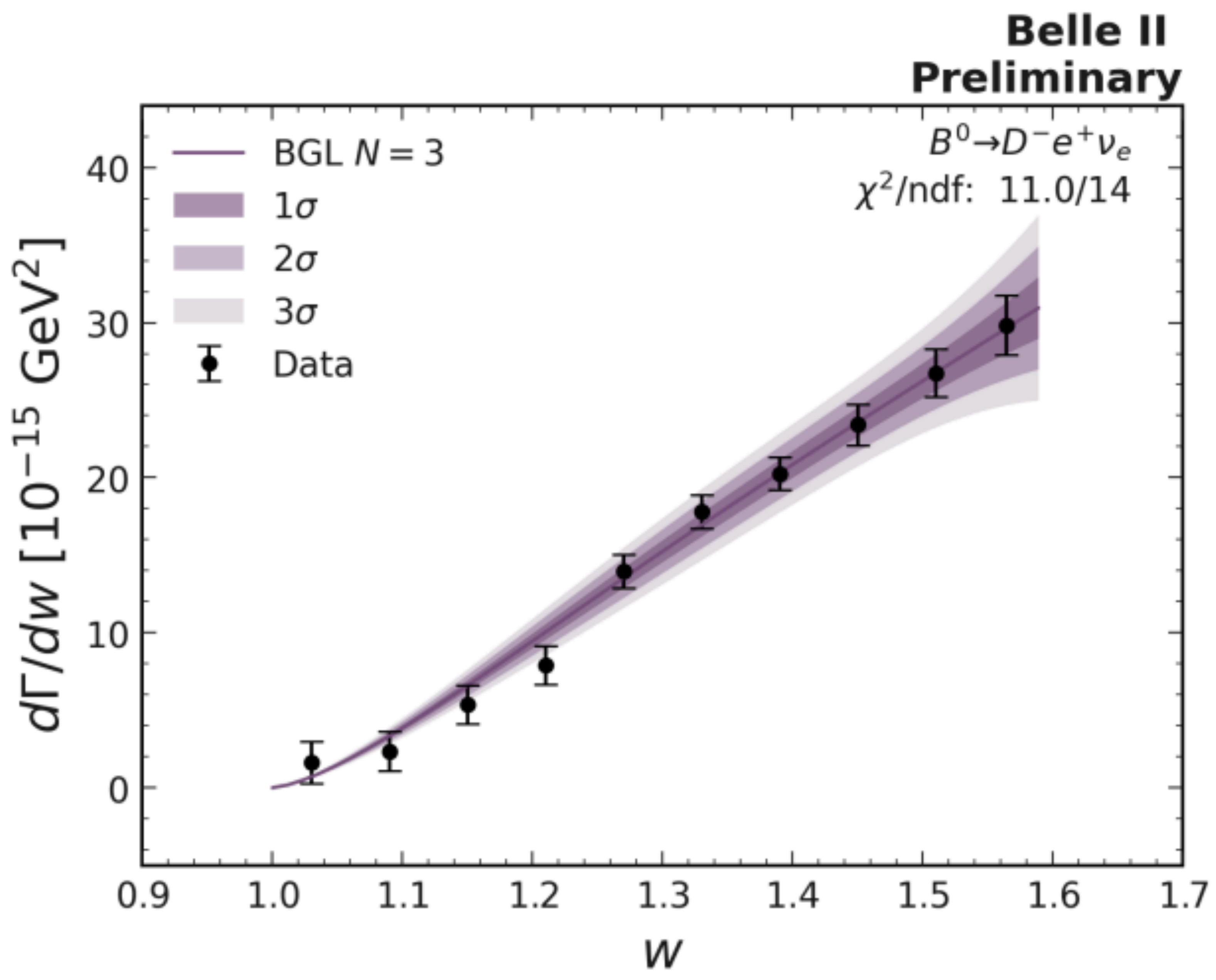
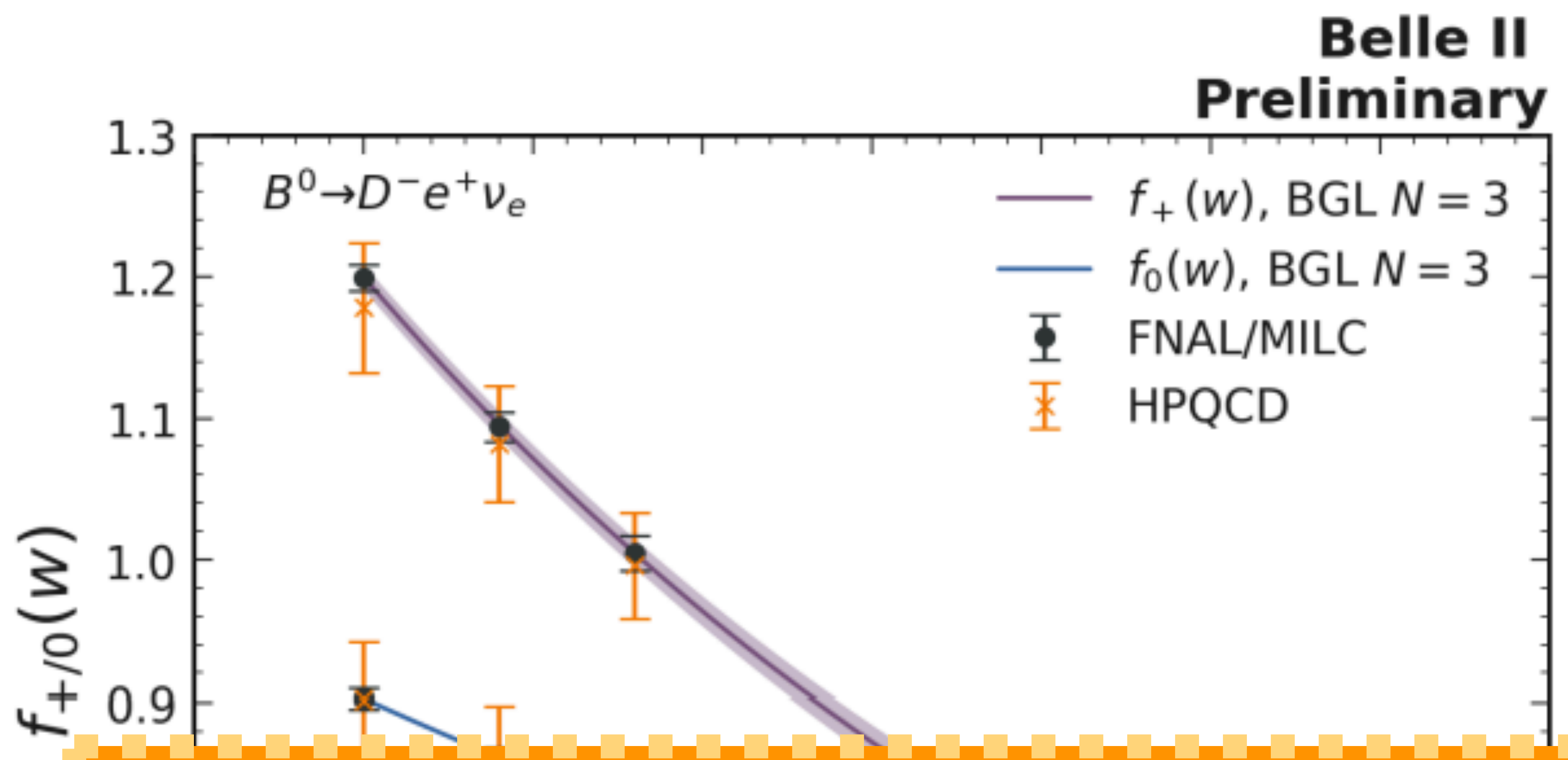




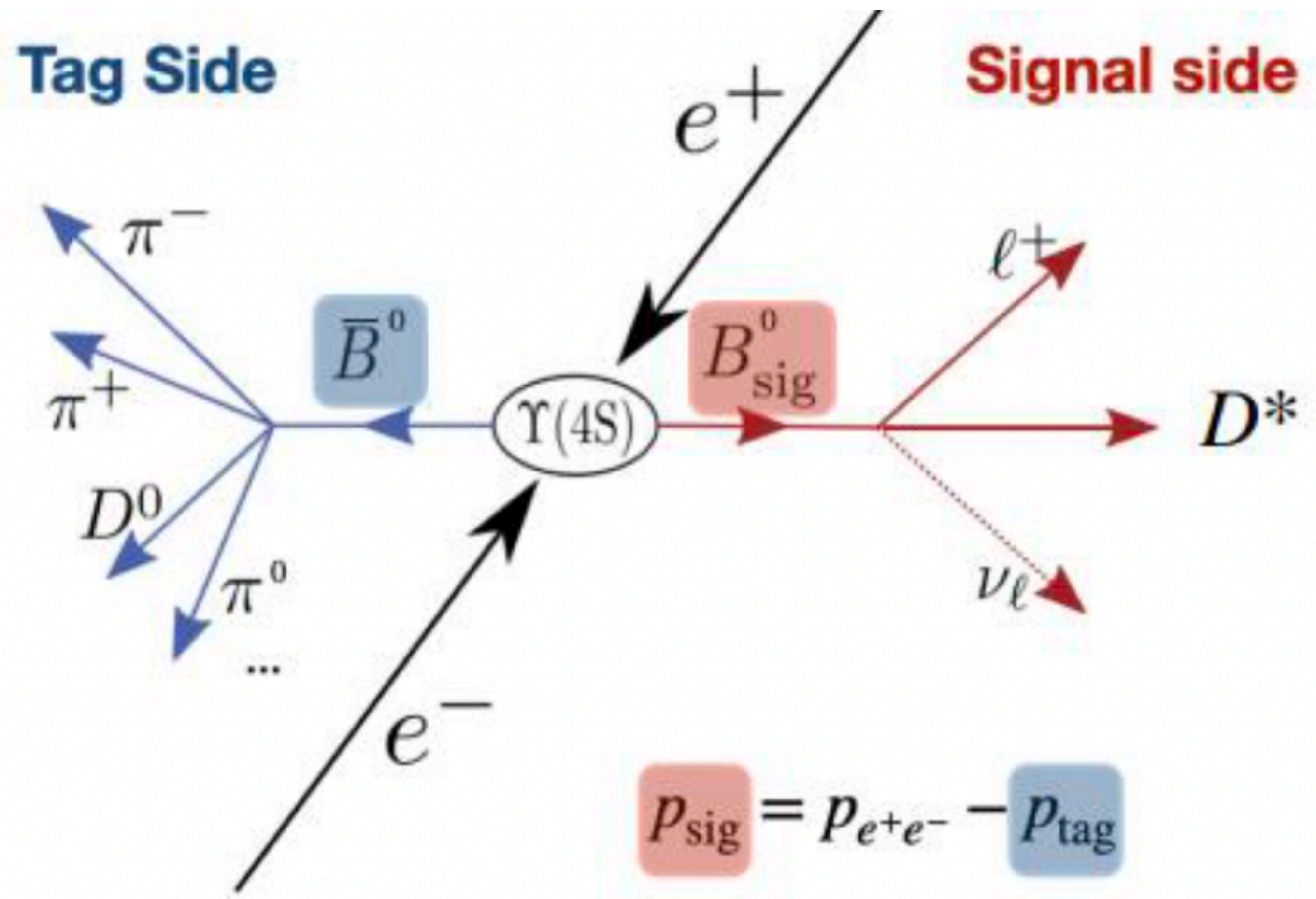
coming soon…

Untagged $B^0 \to D^*\ell\nu$ from Belle II: $|V_{cb}|$, 4 kin. variables & A_{FB}

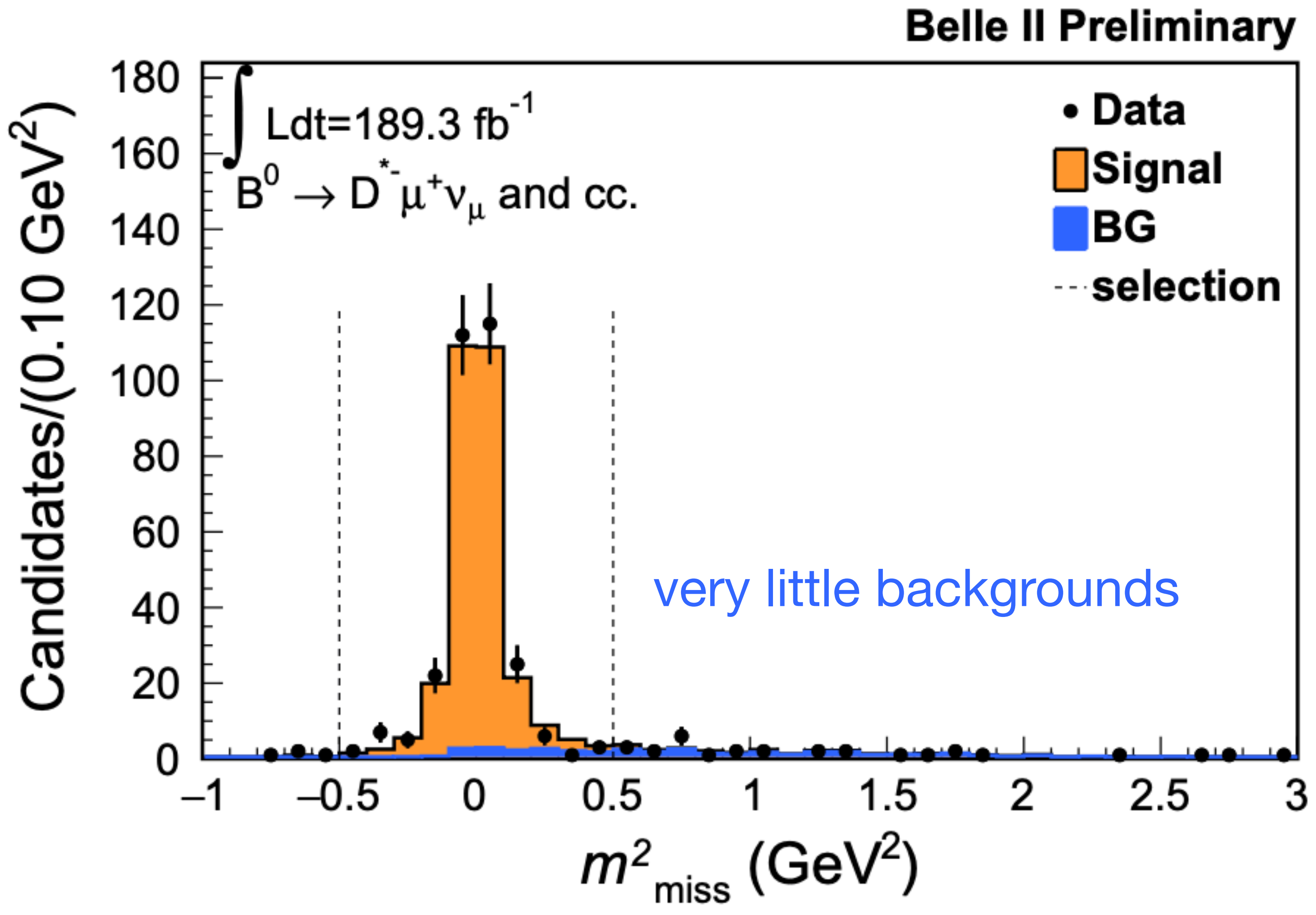
Weighted average of four modes: $\eta_{\mathrm{EW}}|V_{cb}| = (38.53 \pm 1.15) \times 10^{-3}$

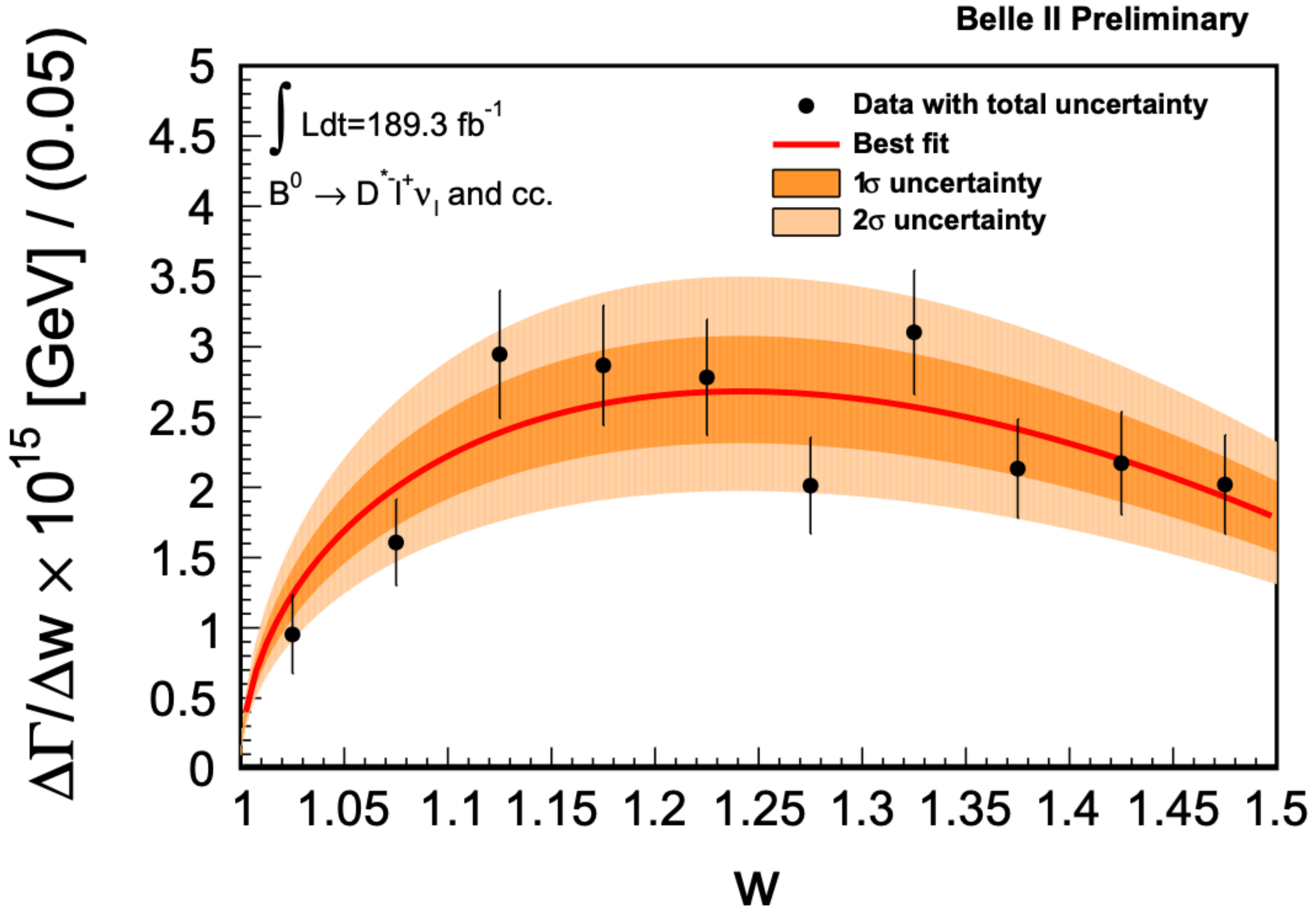
$|V_{cb}|$ in $B^0 \to D^* \ell \nu$ with Belle II data

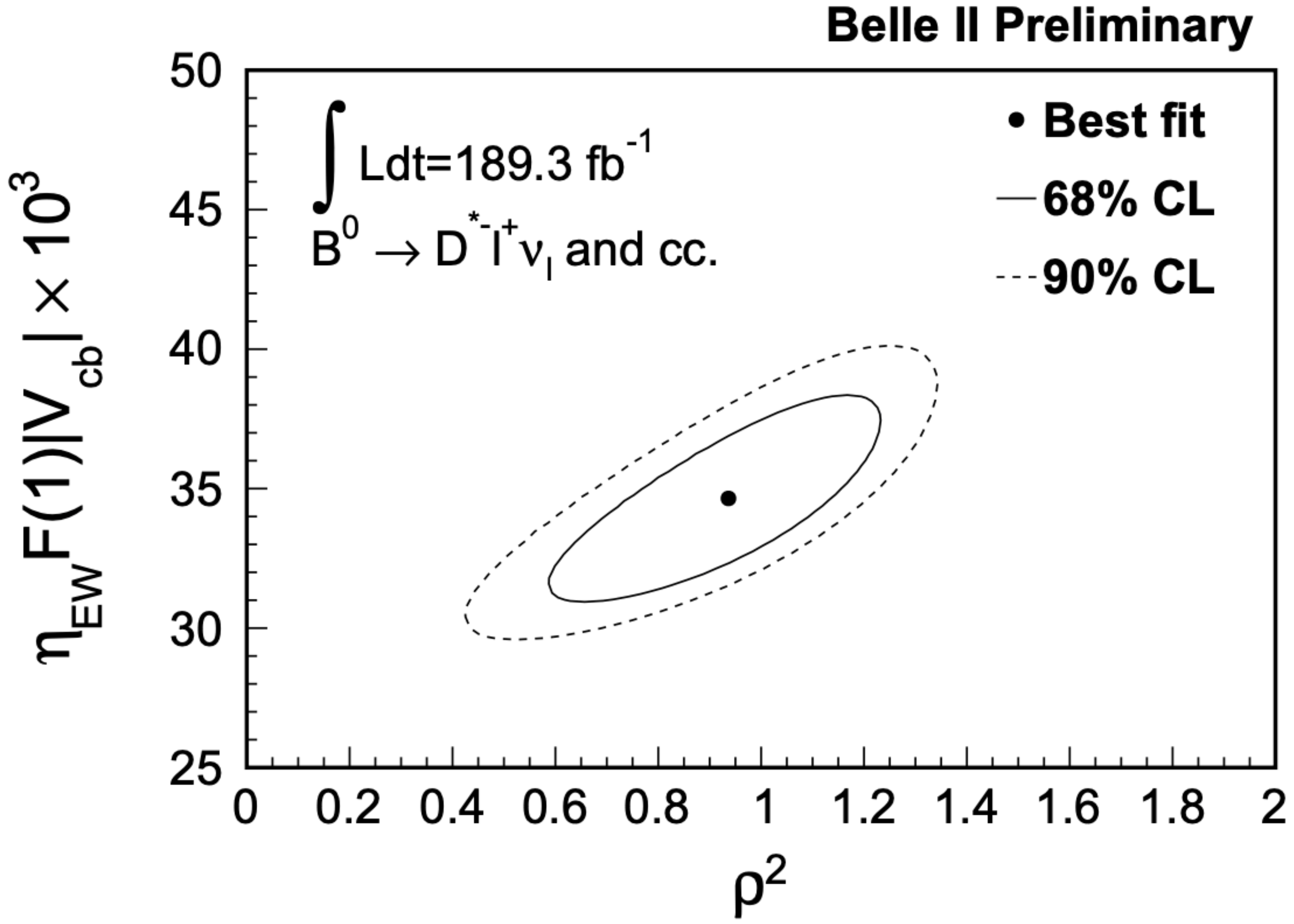
- Data set of 189.3 fb^{-1} for $\ell = e, \mu$
- One of $\mathrm{B\bar{B}}$ events fully reconstructed from hadronic decays (high purity)
- Background subtracted in $M^2_{\text{miss}} = (p_{\text{sig}} - p_{\text{D}*} - p_\ell)^2 \approx 0$
- Extracted $|\mathbf{V_{cb}}|$ with Caprini-Lellouch-Neubert (**CLN**) expansion of decay form factor



arXiv: 2301.04716







CLN: $\eta_{EW} F(1)|V_{cb}| \times 10^3 = 34.6 \pm 1.8 \ \text{(stat)} \pm 1.7 \ \text{(syst)}$

$\rho^2 = 0.94 \pm 0.18 \ \text{(stat)} \pm 0.11 \ \text{(syst)}$

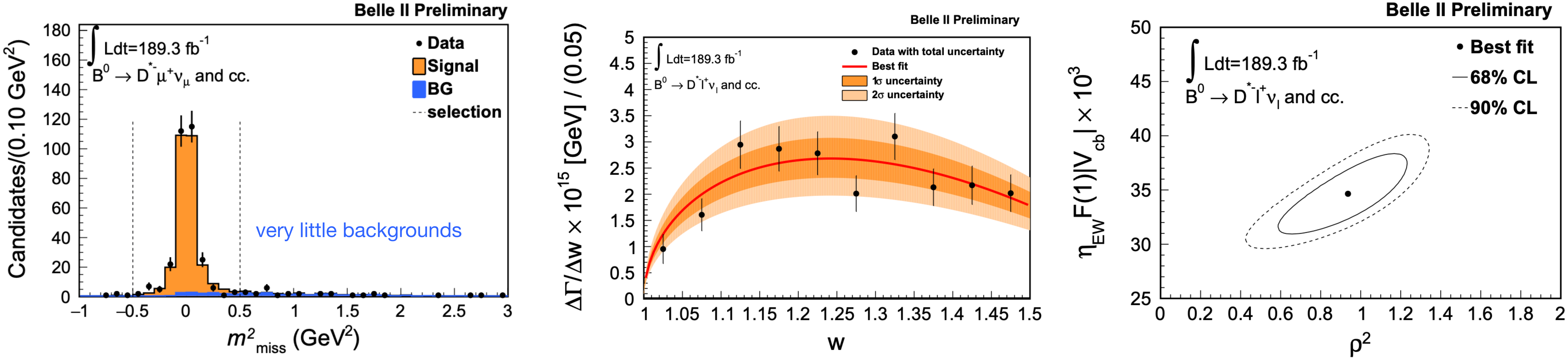
$|V_{cb}|$ in $B^0 \to D^*\ell\nu$ with Belle II data

arXiv: 2301.04716

- Data set of 189.3 fb^{-1} for $\ell = e, \mu$
- One of $\mathrm{B\bar{B}}$ events fully reconstructed from hadronic decays (high purity)
- Background subtracted in $M^2_{\mathrm{miss}} = (p_{\mathrm{sig}} - p_{\mathrm{D*}} - p_\ell)^2 \approx 0$
- Extracted $|\mathbf{V_{cb}}|$ with Caprini-Lellouch-Neubert (**CLN**) expansion of decay form factor

coming soon…

Had. tagged $B^0 \to D^*\ell\nu$ from Belle II: all angular variables ($S_3, S_5, ..$) & A_{FB}



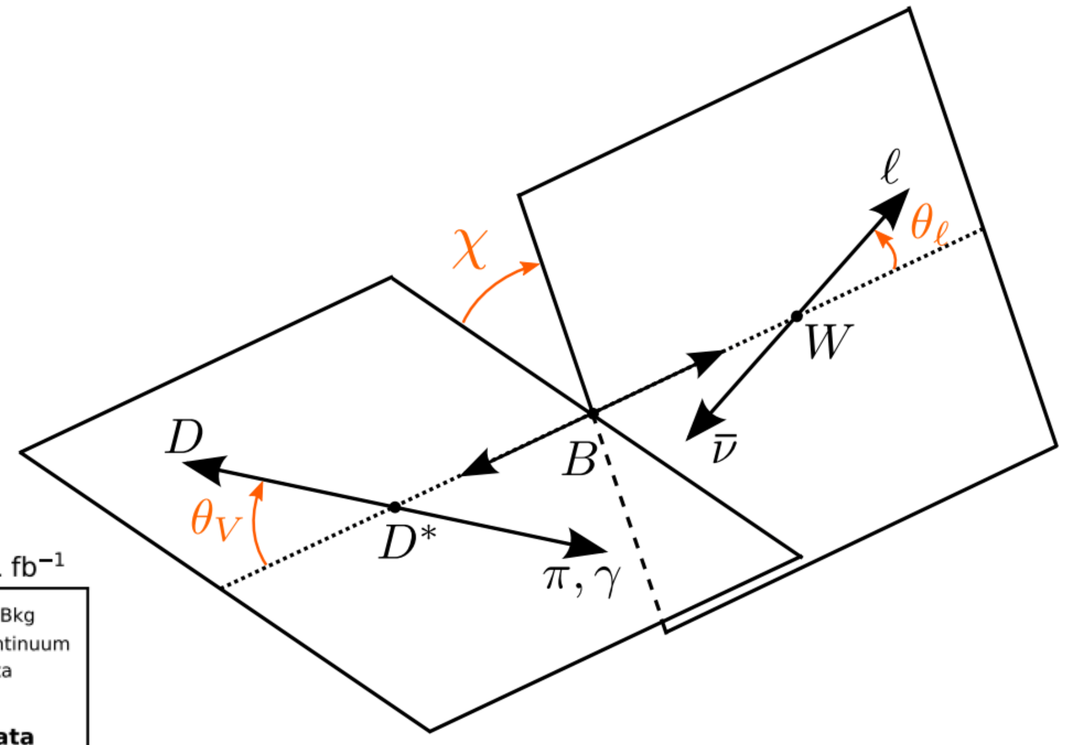
CLN: $\eta_{EW} F(1)|V_{cb}| \times 10^3 = 34.6 \pm 1.8 \;(\mathrm{stat}) \pm 1.7 \;(\mathrm{syst})$

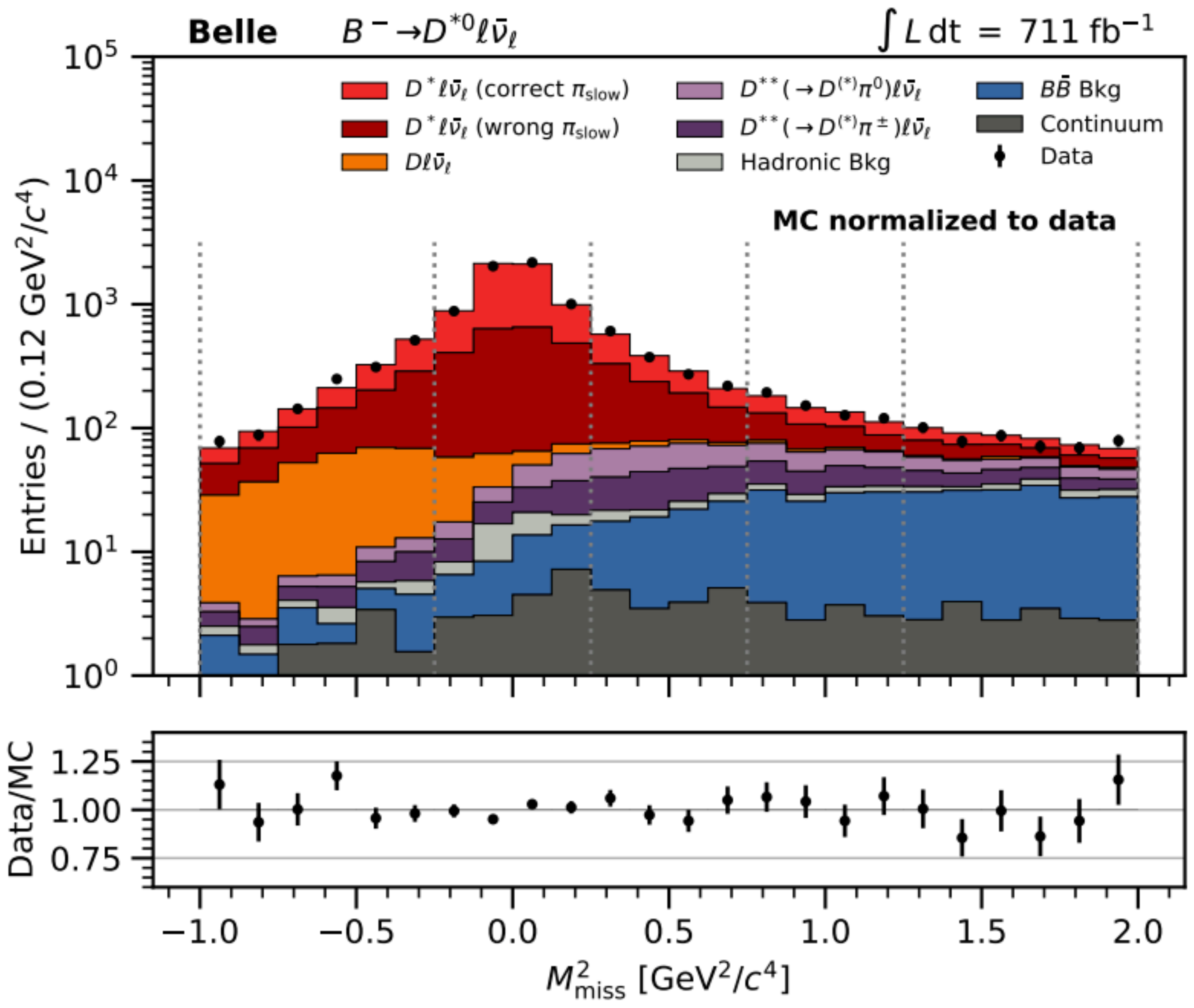
$\rho^2 = 0.94 \pm 0.18 \;(\mathrm{stat}) \pm 0.11 \;(\mathrm{syst})$

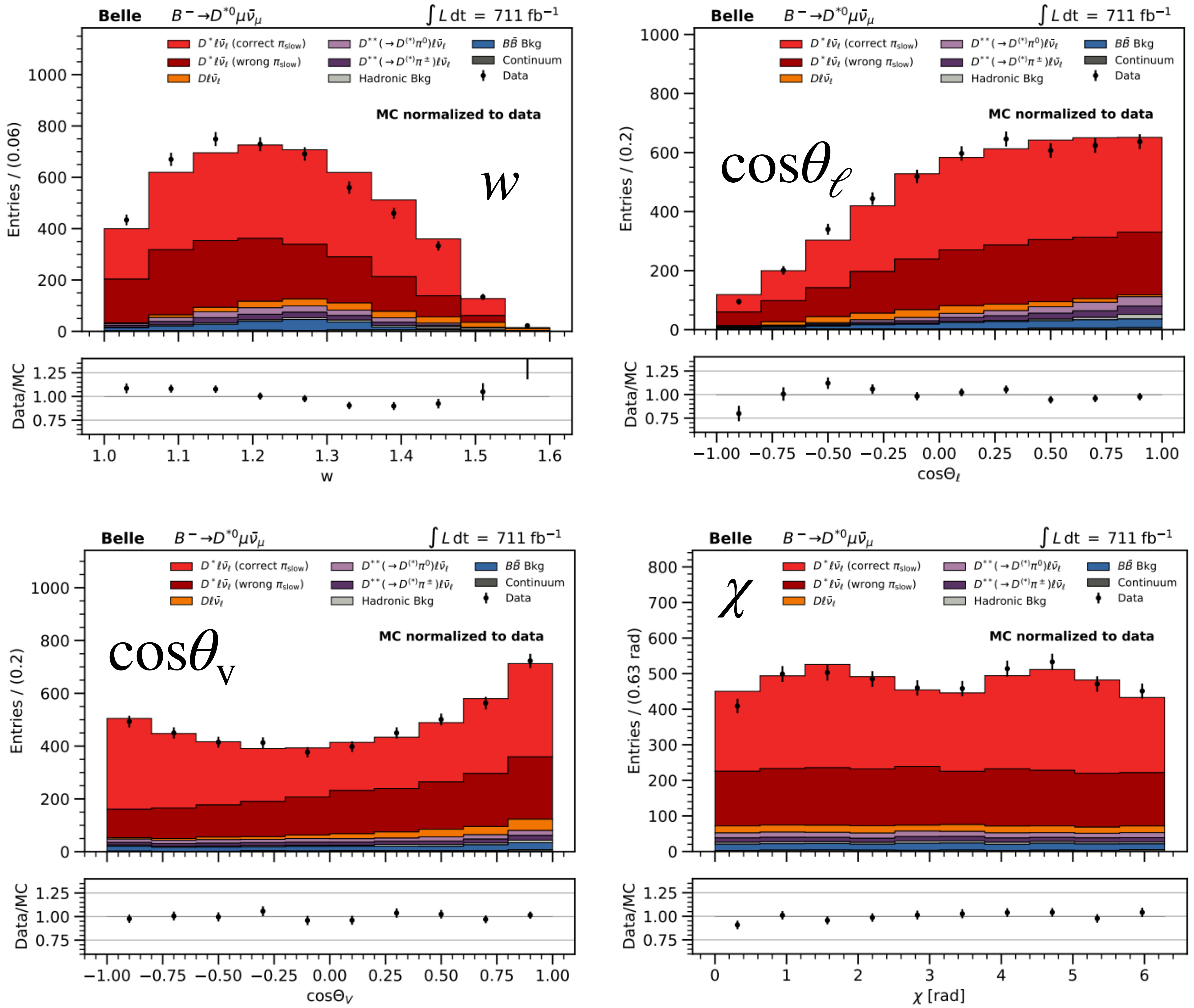
$|V_{cb}|$ & Differential Shapes of $B \to D^* \ell \nu$

arXiv: 2301.07529

- Full Belle data set of 711 fb^{-1} for $B^{\pm,0}, \ell = e, \mu$
- **Hadronic tagging** using Belle II tool (Full Event Interpretation)
- Background subtracted via fitting M^2_{miss} for bins of $w, \cos\theta_\ell, \cos\theta_v, \chi$ in **each decay mode independently**







ends up to **160** fits

fit stability & consistency were fully checked and compatible with expected uniform behavior

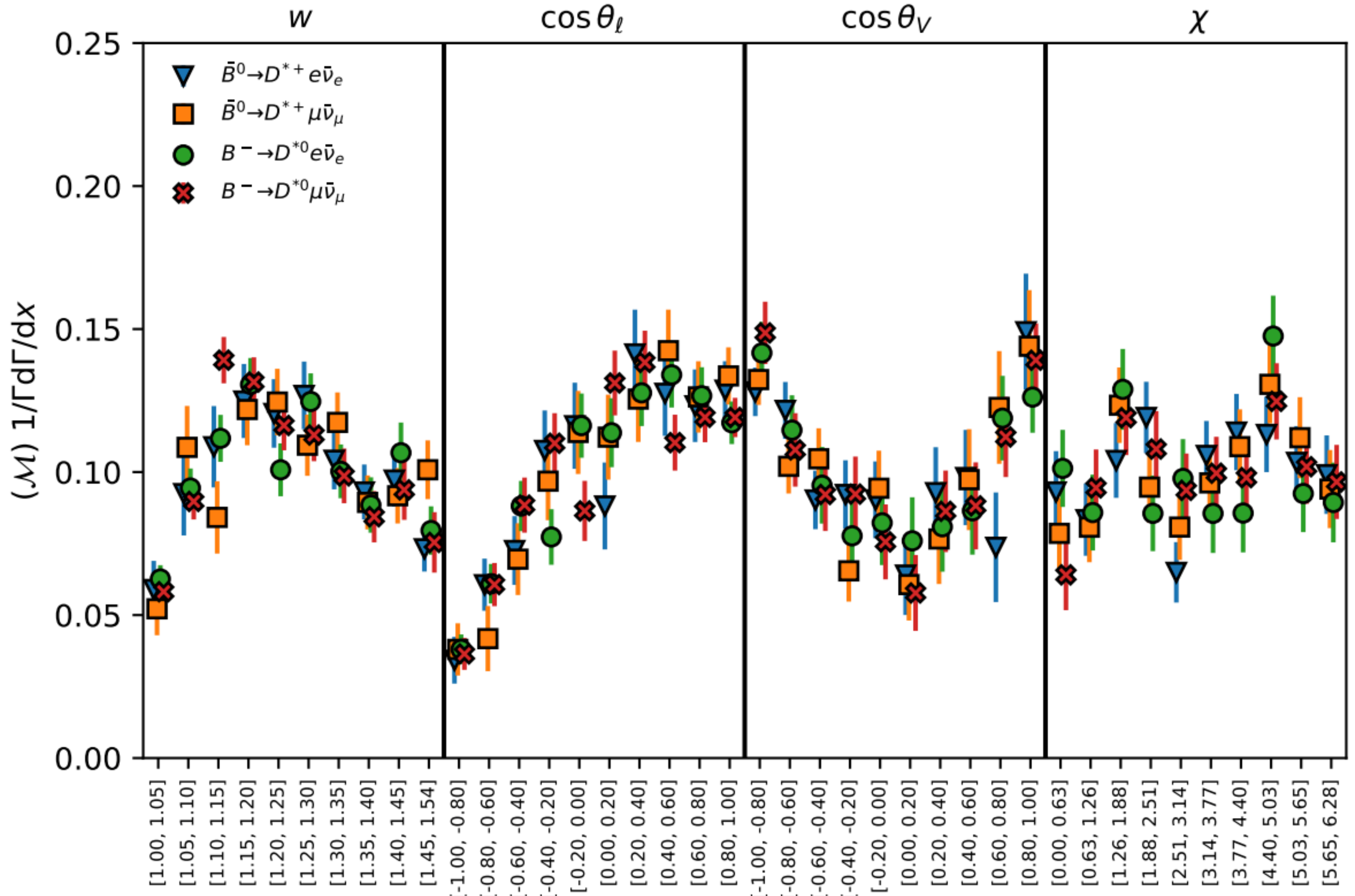
$|V_{cb}|$ & Differential Shapes of $B \to D^* \ell \nu$

arXiv: 2301.07529

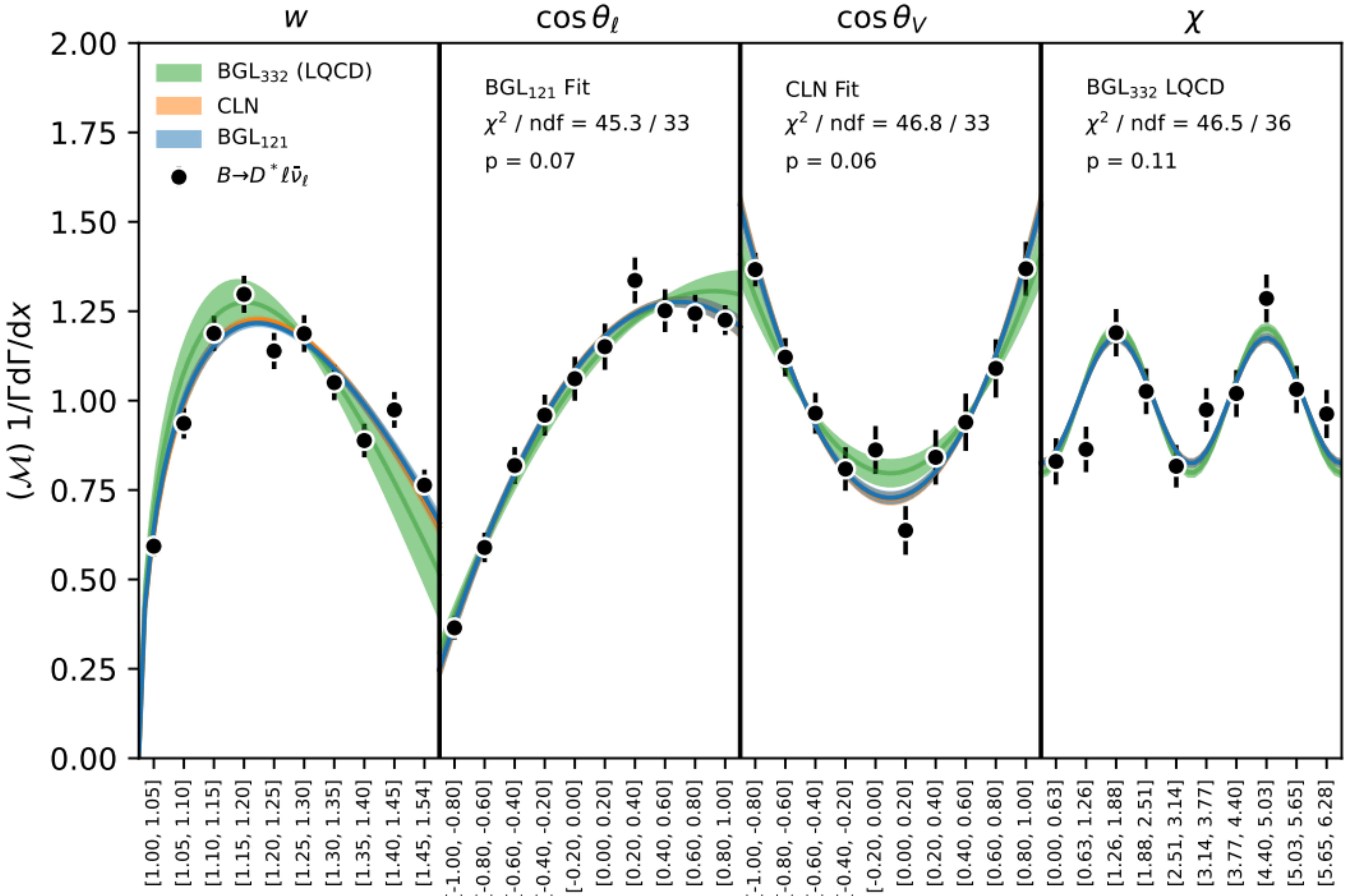
- Signal **shapes** corrected for resolution, reco. efficiency and acceptance effects
- Combined **all kinematic shapes** to extract **$|V_{cb}|$** in **BGL/CLN** with external constraints on **branching fractions** (HFLAV) and **LQCD results** (FNAL/MILC)

$$\chi^2 = \left(\frac{\Delta\vec{\Gamma}^{\mathrm{m}}}{\Gamma^{\mathrm{m}}} - \frac{\Delta\vec{\Gamma}^{\mathrm{p}}(\vec{x})}{\Gamma^{\mathrm{p}}(\vec{x})}\right) C_{\mathrm{exp}}^{-1} \left(\frac{\Delta\vec{\Gamma}^{\mathrm{m}}}{\Gamma^{\mathrm{m}}} - \frac{\Delta\vec{\Gamma}^{\mathrm{p}}(\vec{x})}{\Gamma^{\mathrm{p}}(\vec{x})}\right)^T$$
$$+ \left(\Gamma^{\mathrm{ext}} - \Gamma^{\mathrm{p}}(\vec{x})\right)^2 / \sigma(\Gamma^{\mathrm{ext}})^2$$
$$+ (h_X - h_X^{\mathrm{LQCD}}) C_{\mathrm{LQCD}}^{-1} (h_X - h_X^{\mathrm{LQCD}})$$

Corrected Shapes



Fitted Shapes



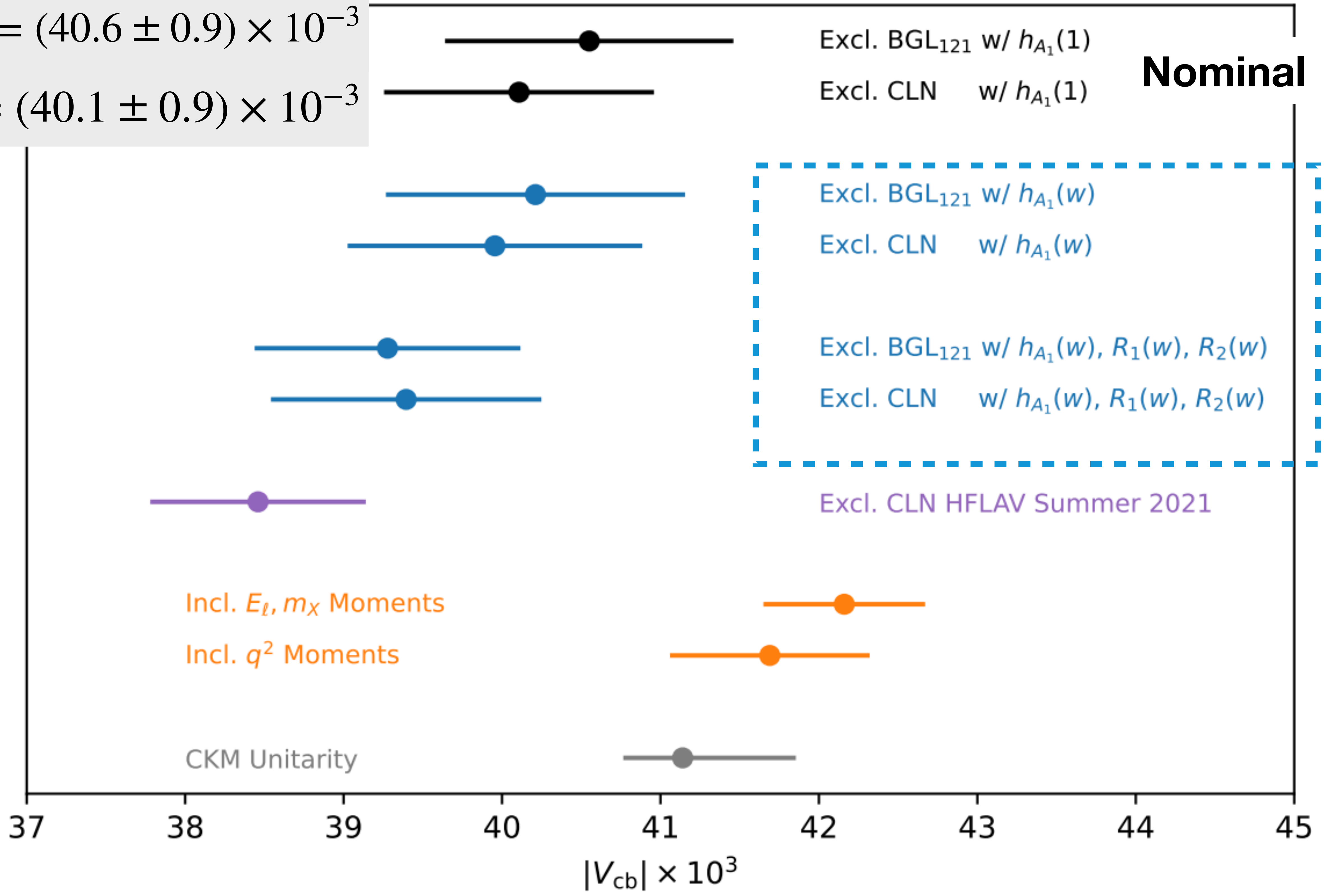
$|V_{cb}|$ & Differential Shapes of $B \to D^* \ell \nu$

arXiv: 2301.07529

- In $|V_{cb}|$ extraction, tested different BGL truncations, **LQCD constraining scenario** (at or beyond zero-recoil)

$$|V_{cb}|_{\mathrm{BGL}_{121}} = (40.6 \pm 0.9) \times 10^{-3}$$

$$|V_{cb}|_{\mathrm{CLN}} = (40.1 \pm 0.9) \times 10^{-3}$$



|Vcb| & Differential Shapes of $B \to D^* \ell \nu$

BELLE

arXiv: 2301.07529

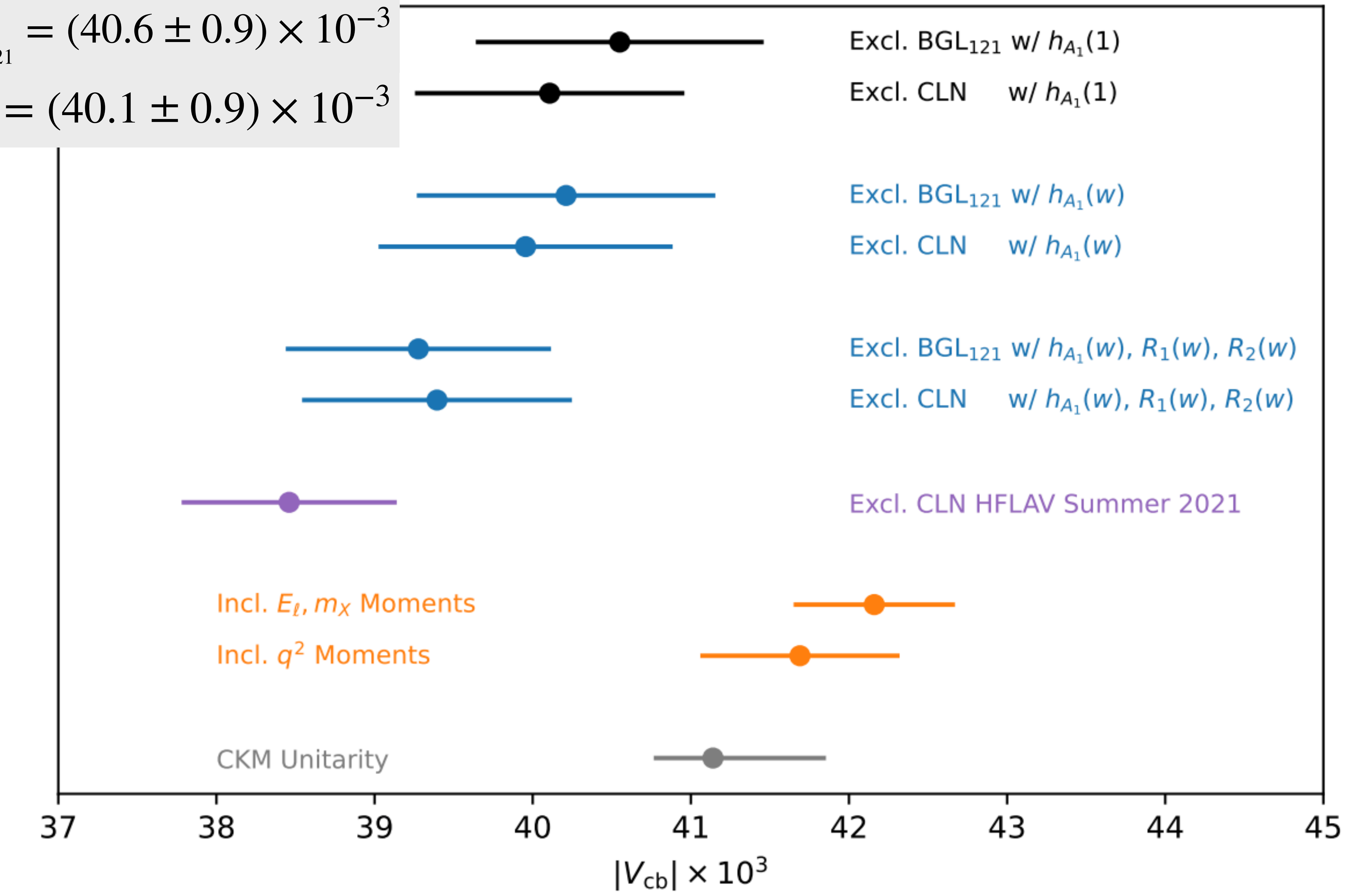
- In $|V_{cb}|$ extraction, tested different BGL truncations, LQCD constraining scenario (at or beyond zero-recoil)
- **Forward-backward asymmetry $\mathbf{A_{FB}}$** and **D* longitudinal polarization fraction $\mathbf{F_L^{D^*}}$** and their differences between e, μ also derived. **No significant LFUV found.**

$$A_{\rm FB} = \frac{\int_0^1 \mathrm{d}\cos_\ell \, \mathrm{d}\Gamma/\mathrm{d}\cos_\ell - \int_{-1}^0 \mathrm{d}\cos_\ell \, \mathrm{d}\Gamma/\mathrm{d}\cos_\ell}{\int_0^1 \mathrm{d}\cos_\ell \, \mathrm{d}\Gamma/\mathrm{d}\cos_\ell + \int_{-1}^0 \mathrm{d}\cos_\ell \, \mathrm{d}\Gamma/\mathrm{d}\cos_\ell}$$

	$\Delta A_{\rm FB}$
$\bar{B}^0 \to D^{*+} \ell \bar{\nu}_\ell$	$0.062 \pm 0.044 \pm 0.011$
$B^- \to D^{*0} \ell \bar{\nu}_\ell$	$-0.003 \pm 0.033 \pm 0.009$
$B \to D^* \ell \bar{\nu}_\ell$	$0.022 \pm 0.026 \pm 0.007$

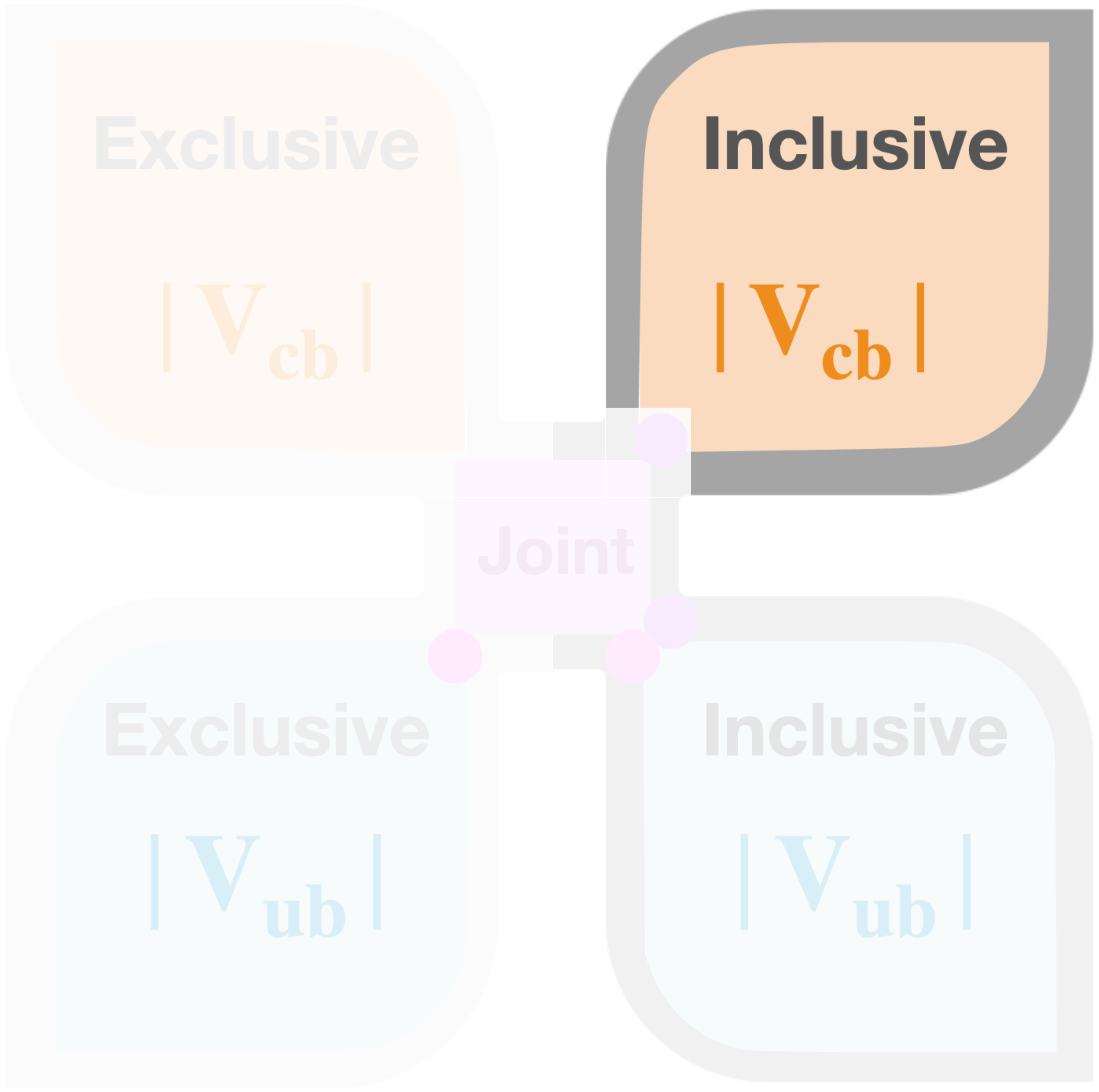
$$|V_{cb}|_{\mathrm{BGL}_{121}} = (40.6 \pm 0.9) \times 10^{-3}$$

$$|V_{cb}|_{\mathrm{CLN}} = (40.1 \pm 0.9) \times 10^{-3}$$



$$\frac{1}{\Gamma}\frac{\mathrm{d}\Gamma}{\mathrm{d}\cos\theta_V} = \frac{3}{2}\left(F_L \cos^2\theta_V + \frac{1-F_L}{2}\sin^2\theta_V\right)$$

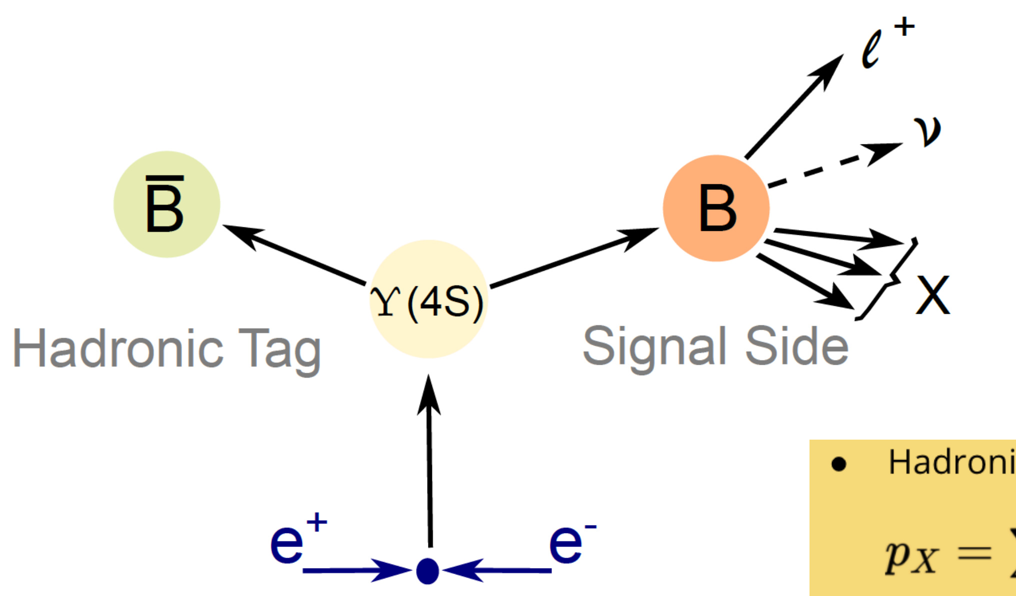
	$\Delta F_L^{D^*}$
$\bar{B}^0 \to D^{*+} \ell \bar{\nu}_\ell$	$0.032 \pm 0.033 \pm 0.010$
$B^- \to D^{*0} \ell \bar{\nu}_\ell$	$0.025 \pm 0.035 \pm 0.010$
$B \to D^* \ell \bar{\nu}_\ell$	$0.034 \pm 0.024 \pm 0.007$


Exclusive
|V_cb|
Inclusive
|V_cb|
Joint
Exclusive
|V_ub|
Inclusive
|V_ub|

q^2 Moments of Inclusive $B \to X_c \ell \nu$ Decays

PRD 104 , 112011 (2021)

- Full Belle data set of **711 fb^{-1}** for $\ell = e, \mu$
- **Hadronic tagging** with Neural Networks (~ 0.2-0.3% efficiency)
- Background suppressed in hadronic mass M_X and converted to signal prob. on q^2



Can fully assign each final state particle to either the tag or signal side

Allows to reconstruct X

- Hadronic system X:

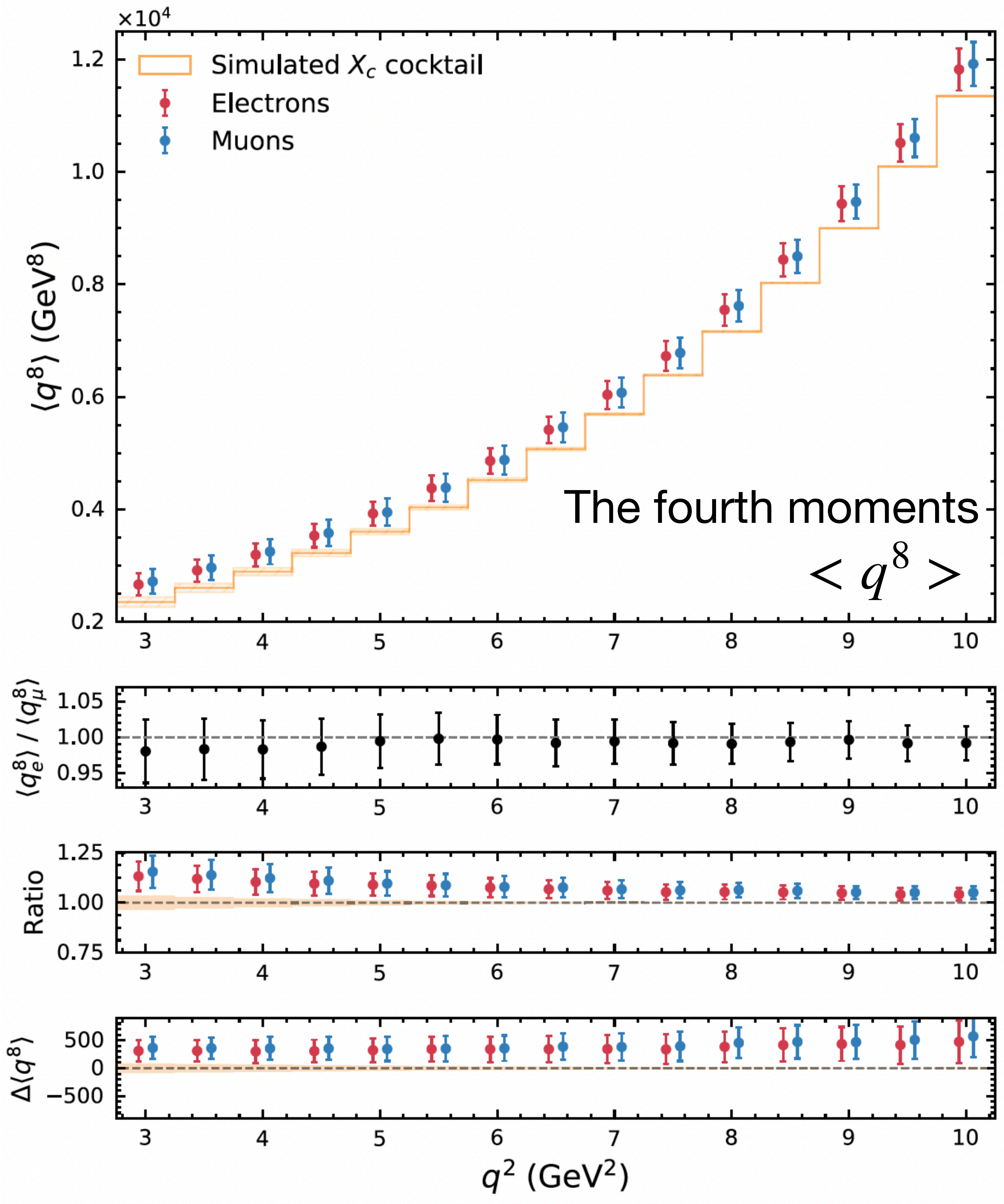
$$p_X = \sum_i \left(\sqrt{m_\pi^2 + |\mathbf{p_i}|^2}, \mathbf{p_i}\right) + \sum_i (E_i, \mathbf{k_i})$$

- Missing mass squared:

$$MM^2 = (P_{\Upsilon(4S)} - P_{\rm tag} - P_X - P_\ell)^2$$

- Leptonic system:

$$q^2 = (P_B - P_X)^2 = (P_\ell + P_\nu)^2$$



← Extract |V$_{cb}$|

← LFUV test

← Mea. / Sim.

← Mea. - Sim.

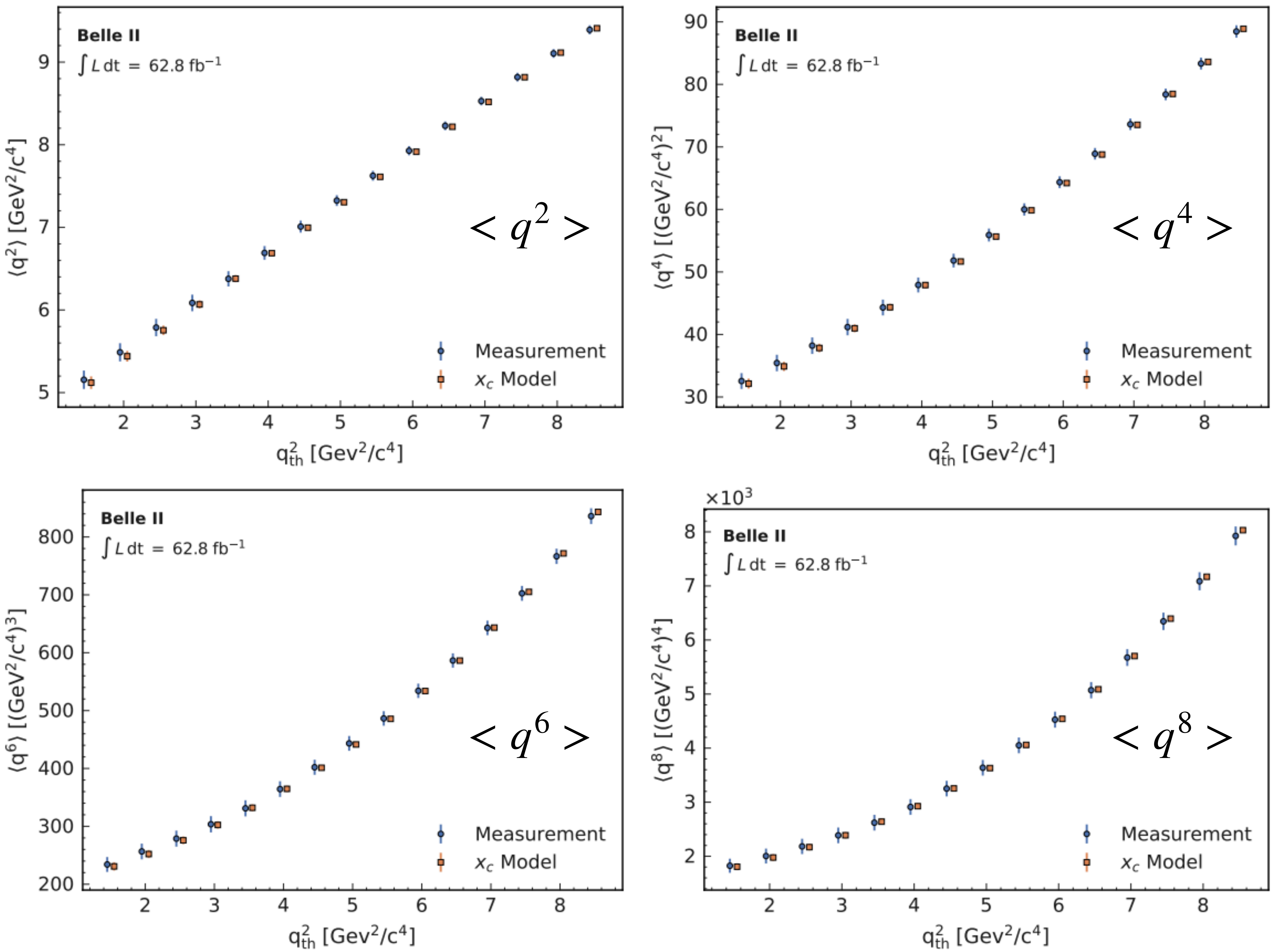
- **First to fourth moments (m=1~4)** measured at a progression of cuts on q^2
- Spectra corrected for linear distortions, eff. & acc. & residual bias

$$\langle q^{2m} \rangle = \frac{C_{\rm cal} \cdot C_{\rm acc}}{\sum_i^{\rm events} w(q_i^2)} \times \sum_i^{\rm events} w(q_i^2) \cdot q_{{\rm cal}\, i}^{2m}$$

q^2 Moments of Inclusive $B \to X_c \ell \nu$ Decays

arXiv: 2205.06372

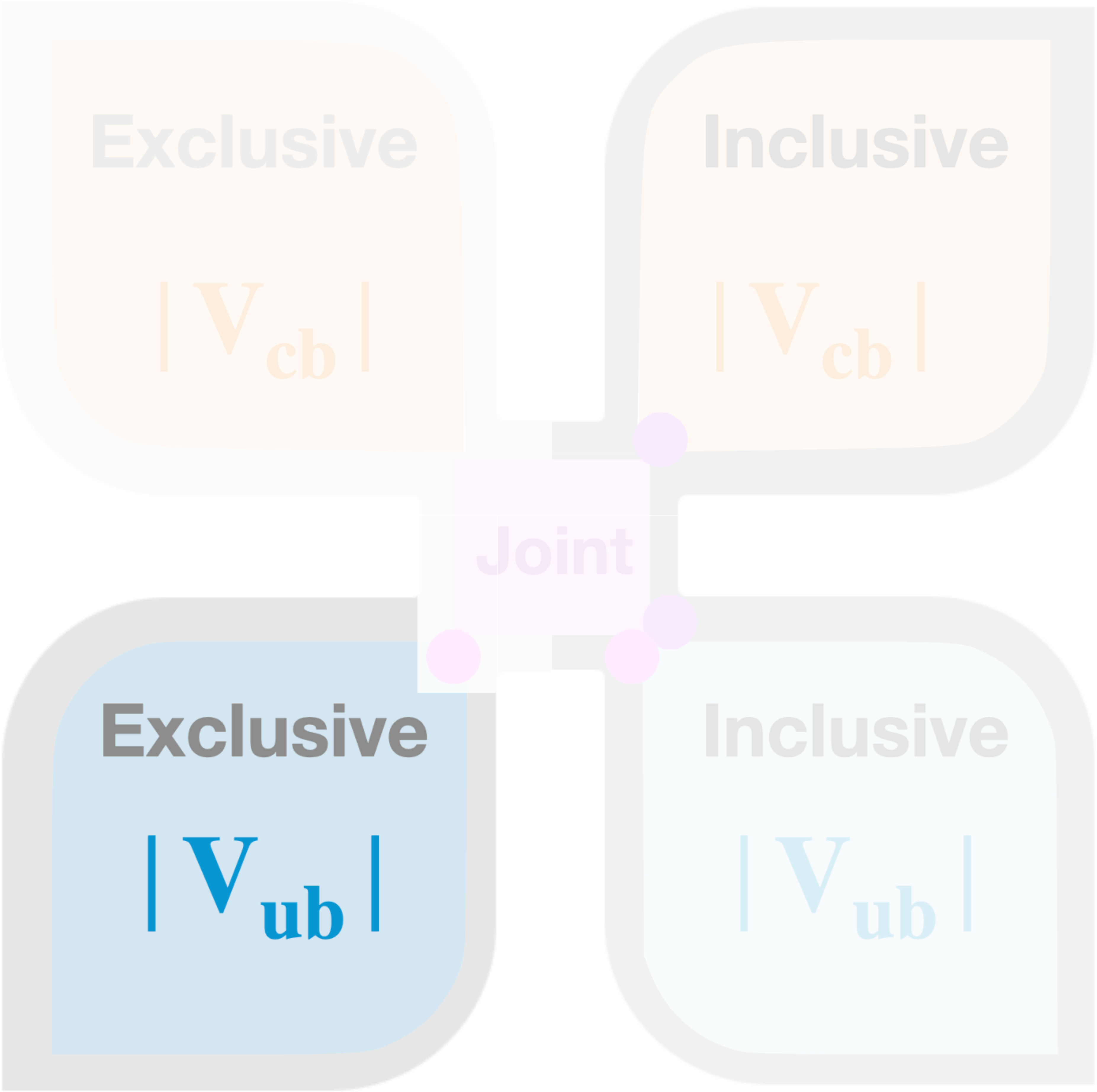
- Belle II data set of **62.8 fb^{-1}** for $\ell = e, \mu$
- Applied similar analysis strategy as in Belle



A side remark on |V$_{cb}$| determination

- Belle & Belle II $< q^{2m} >$ results are used in novel approach to extract |V$_{cb}$| [JHEP 10 (2022) 068]
- Benefit from reduced number of non-perturbative matrix elements
- Obtained consistent |V$_{cb}$| with previous results using M_X, E_ℓ^B moments

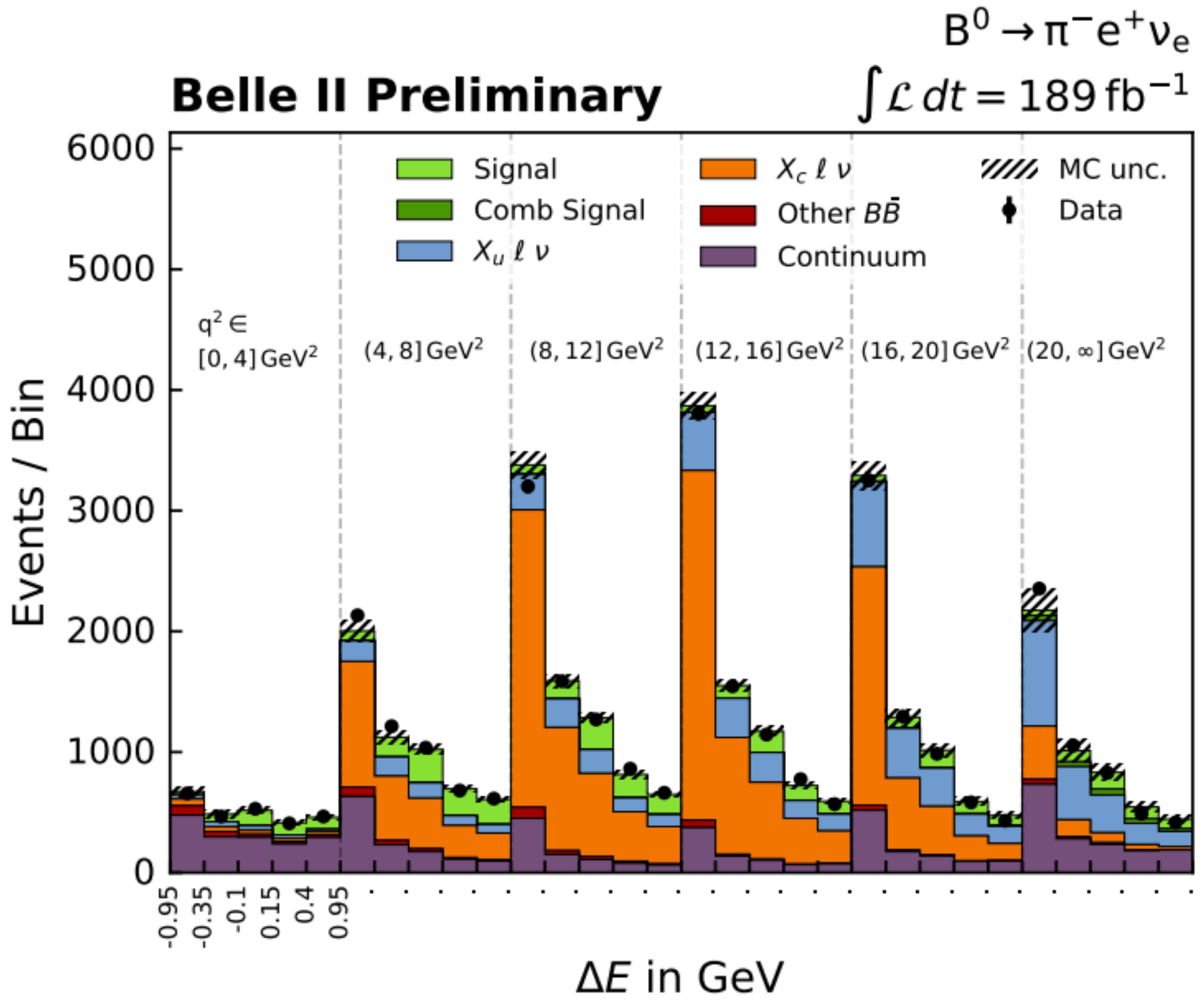
$$|V_{cb}| = (41.69 \pm 0.63) \times 10^{-3}$$


Exclusive
|Vcb|
Inclusive
|Vcb|
Joint
Exclusive
|Vub|
Inclusive
|Vub|

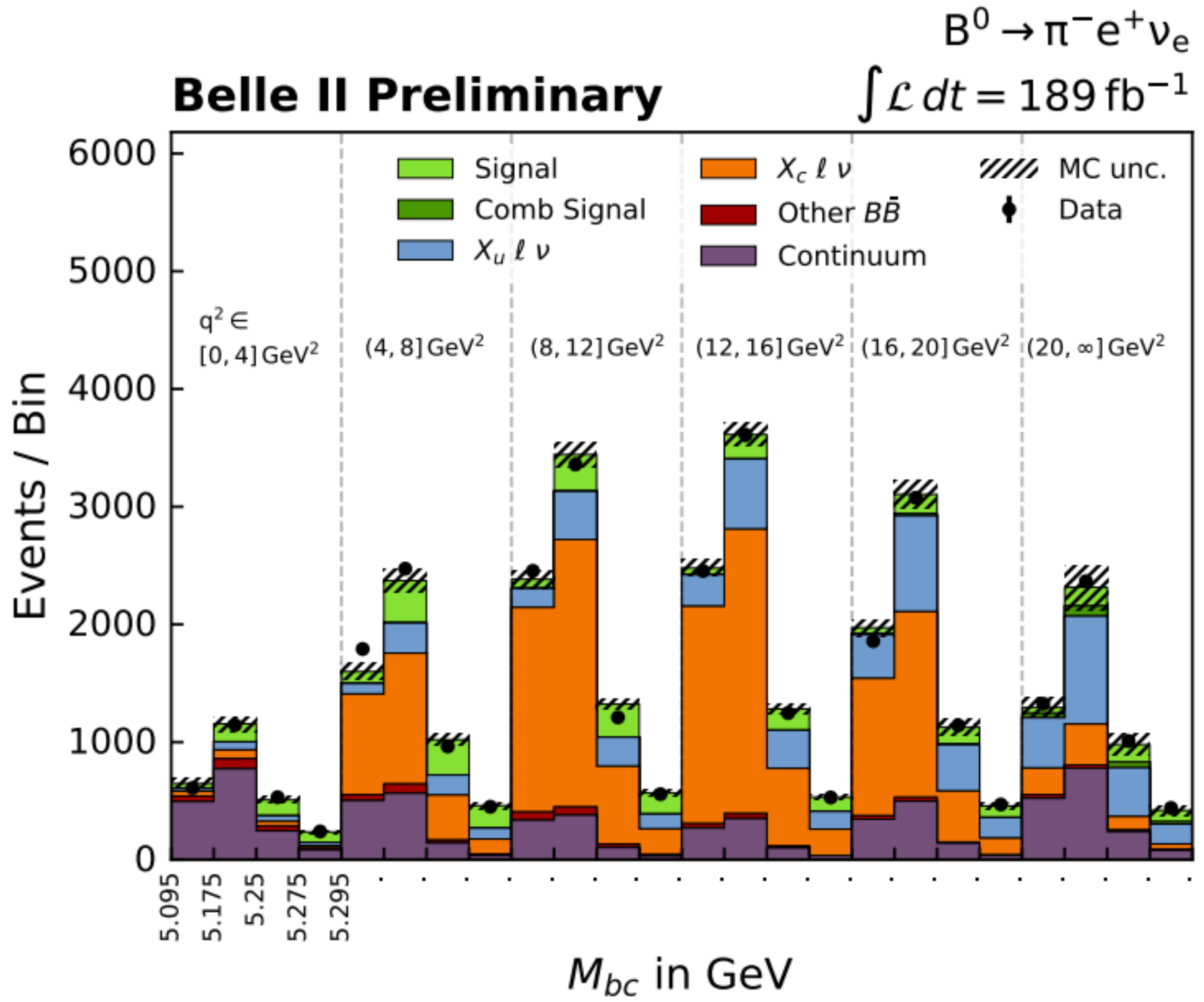
|Vub| in $B^0 \to \pi^- \ell^+ \nu$ with Belle II data

arXiv: 2210.04224

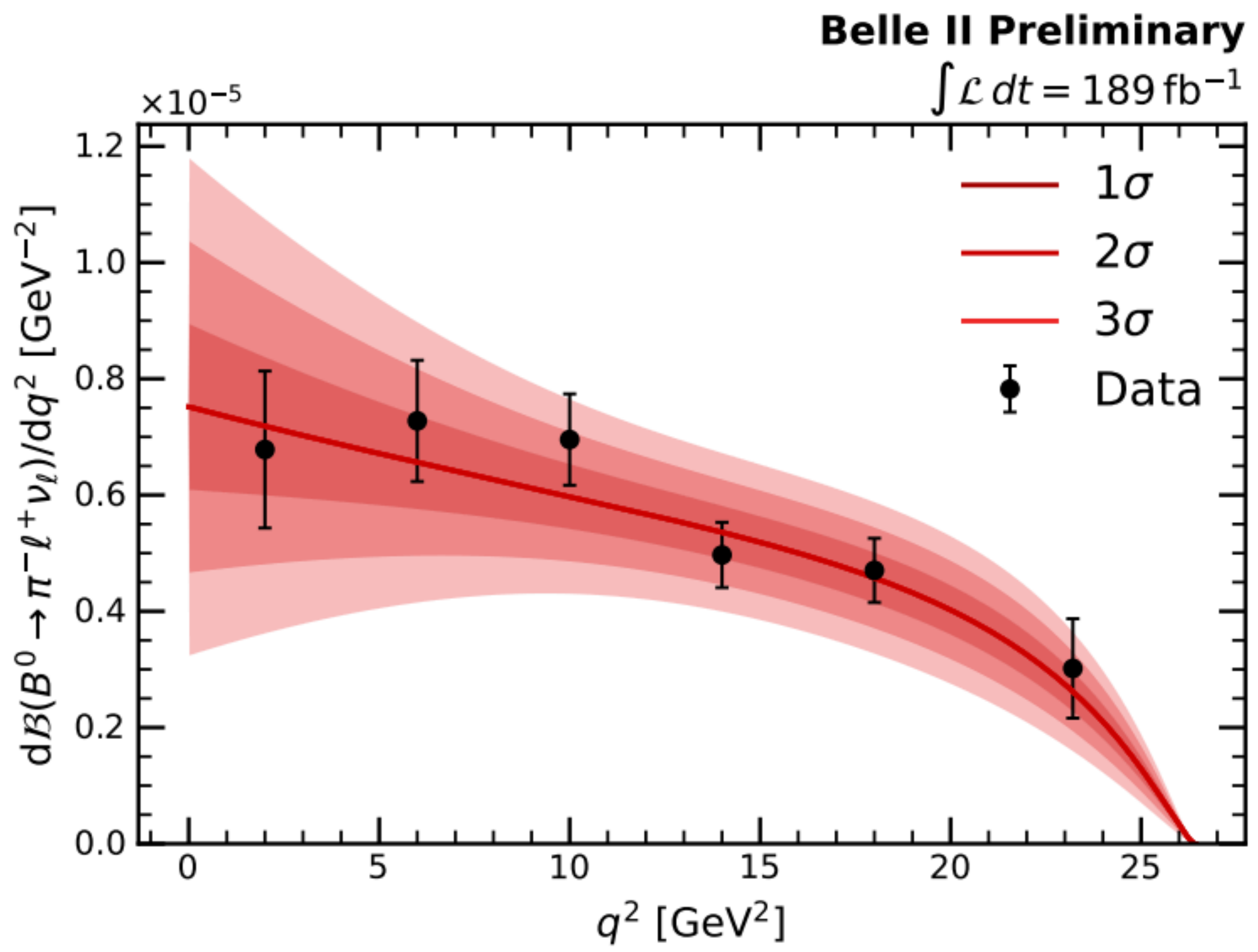
- Data set of 189.3 fb-1 with untagged analysis strategy
- Extract signal in beam-constrained mass M_{bc} and energy difference ΔE for each bin of q^2
- $|\mathbf{V_{ub}}|$ fitted with BCL expansion including LQCD constraints (FNAL/MILC)



$$\Delta E = E_B^* - E_{\text{beam}}^* = E_B^* - \frac{\sqrt{s}}{2}$$



$$M_{bc} = \sqrt{E_{\text{beam}}^{*2} - |\vec{p}_B^{\,*}|^2} = \sqrt{\left(\frac{\sqrt{s}}{2}\right)^2 - |\vec{p}_B^{\,*}|^2}$$



$$\mathcal{B} = (1.426 \pm 0.12_{\text{stat}} \pm 0.056_{\text{syst}} \pm 0.125_{\text{theo}}) \times 10^{-4}$$

$$|V_{ub}| = (3.55 \pm 0.12_{\text{stat}} \pm 0.13_{\text{syst}} \pm 0.17_{\text{theo}}) \times 10^{-3}$$

$|V_{ub}|$ in $B^0 \to \pi^- \ell^+ \nu$ with Belle II data

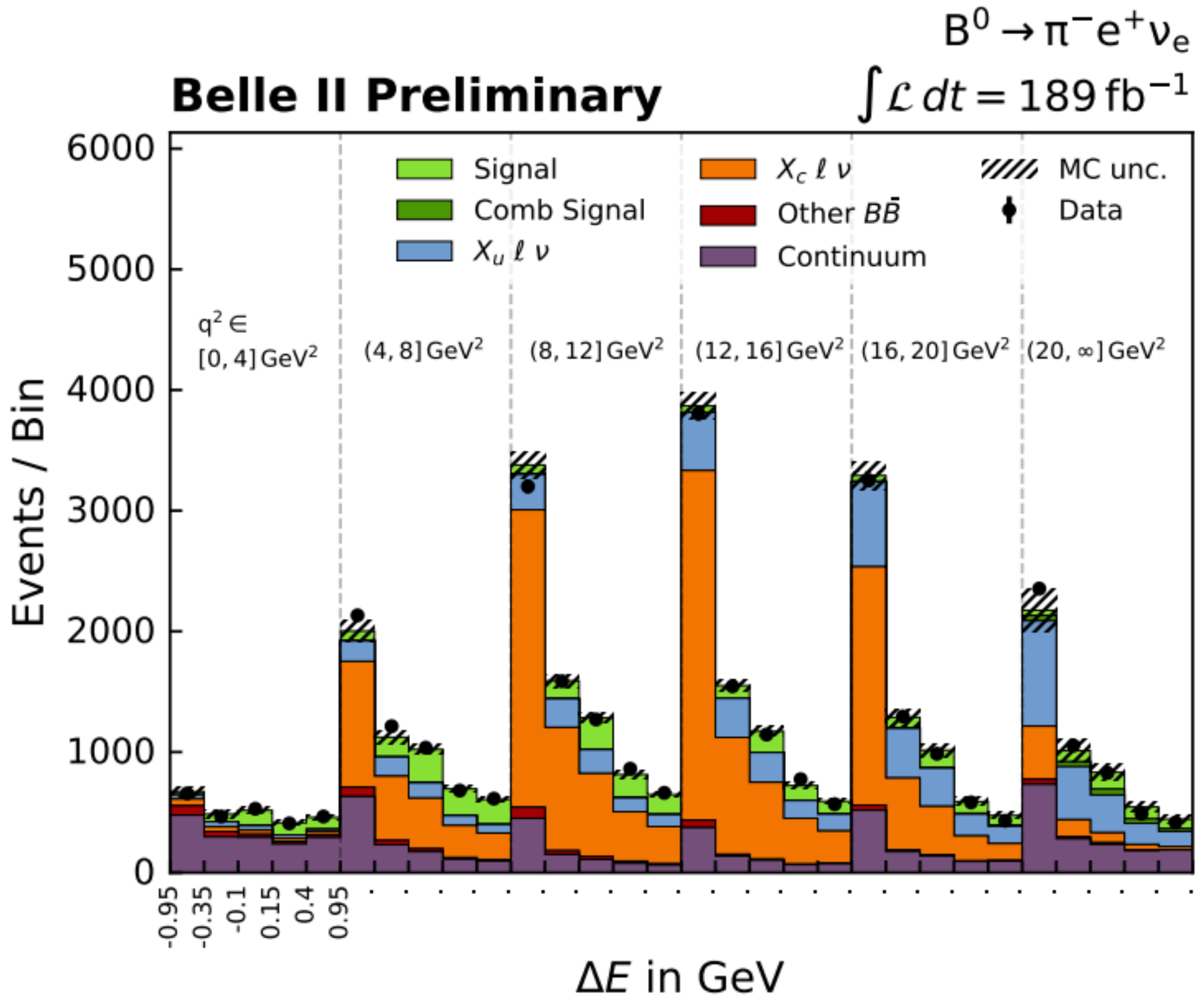
arXiv: 2210.04224

- Data set of 189.3 fb-1 with untagged analysis strategy
- Extract signal in beam-constrained mass M_{bc} and energy difference ΔE for eac

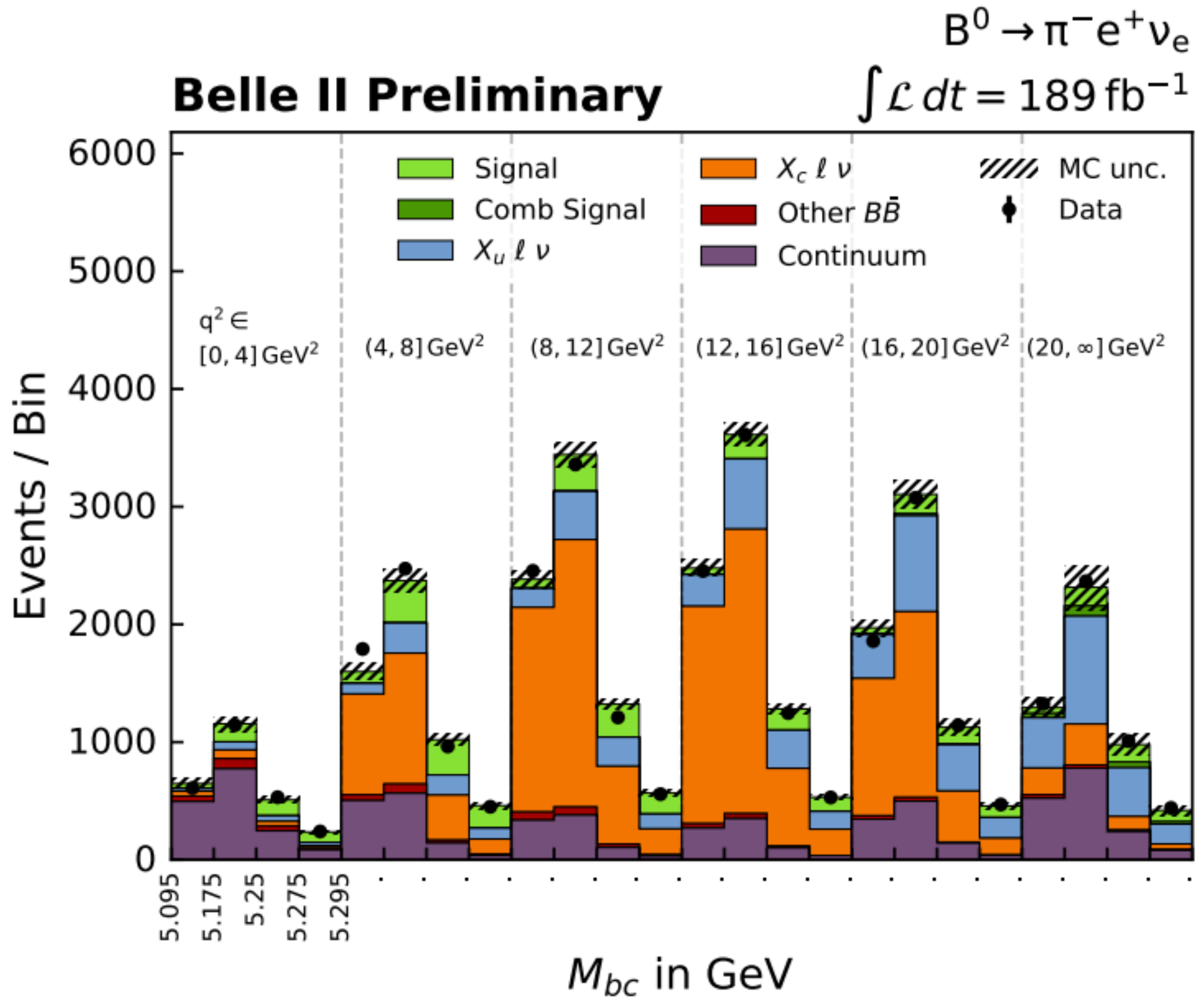
coming soon…

Untagged / Had. tagged $B \to (\pi, \rho)\ell\nu$

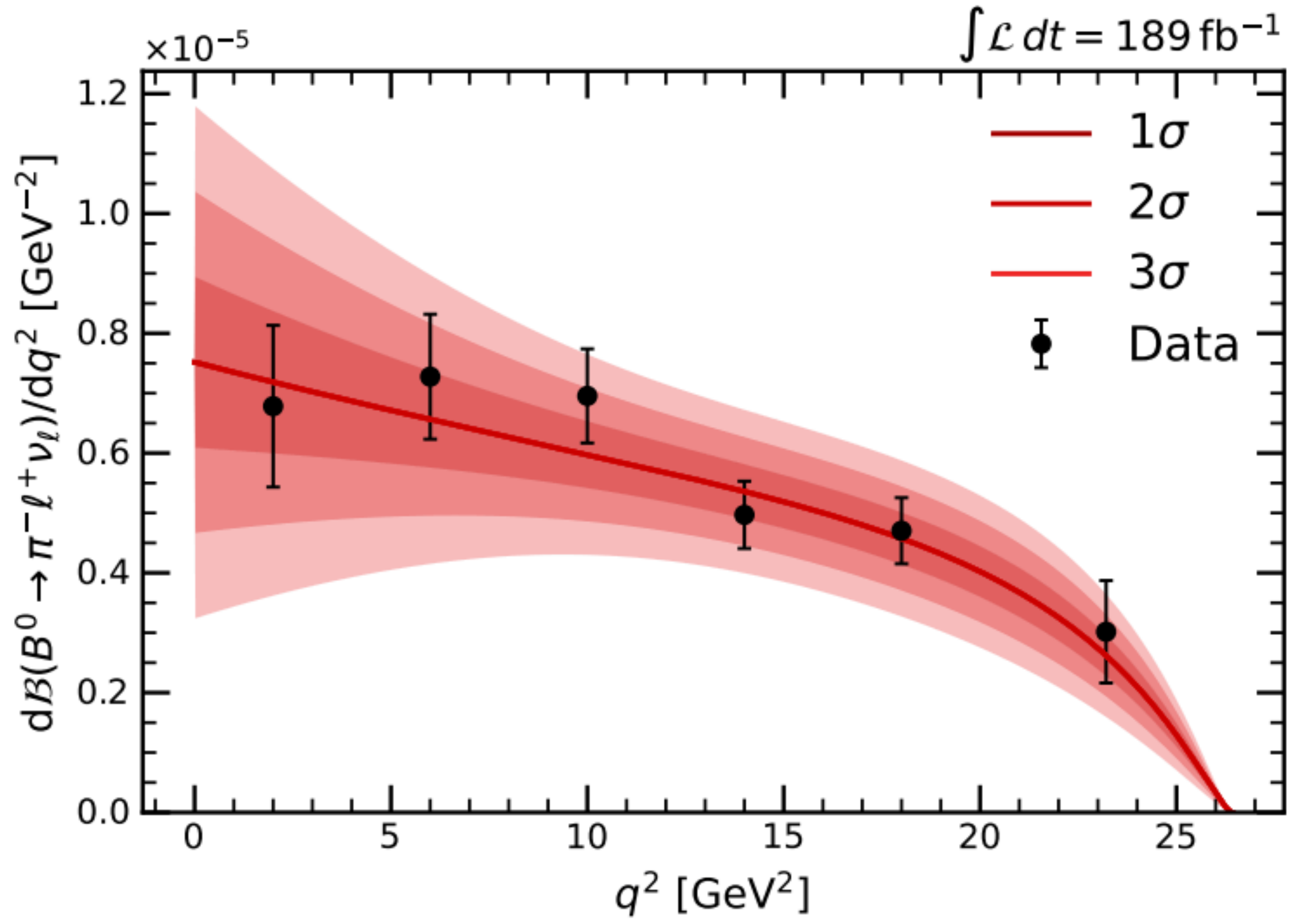
- $|\mathbf{V_{ub}}|$ fitted with BCL expansion including LQCD constraints (FNAL/MILC)



$$\Delta E = E_B^* - E_{\text{beam}}^* = E_B^* - \frac{\sqrt{s}}{2}$$



$$M_{bc} = \sqrt{E_{\text{beam}}^{*2} - |\vec{p}_B^{\,*}|^2} = \sqrt{\left(\frac{\sqrt{s}}{2}\right)^2 - |\vec{p}_B^{\,*}|^2}$$



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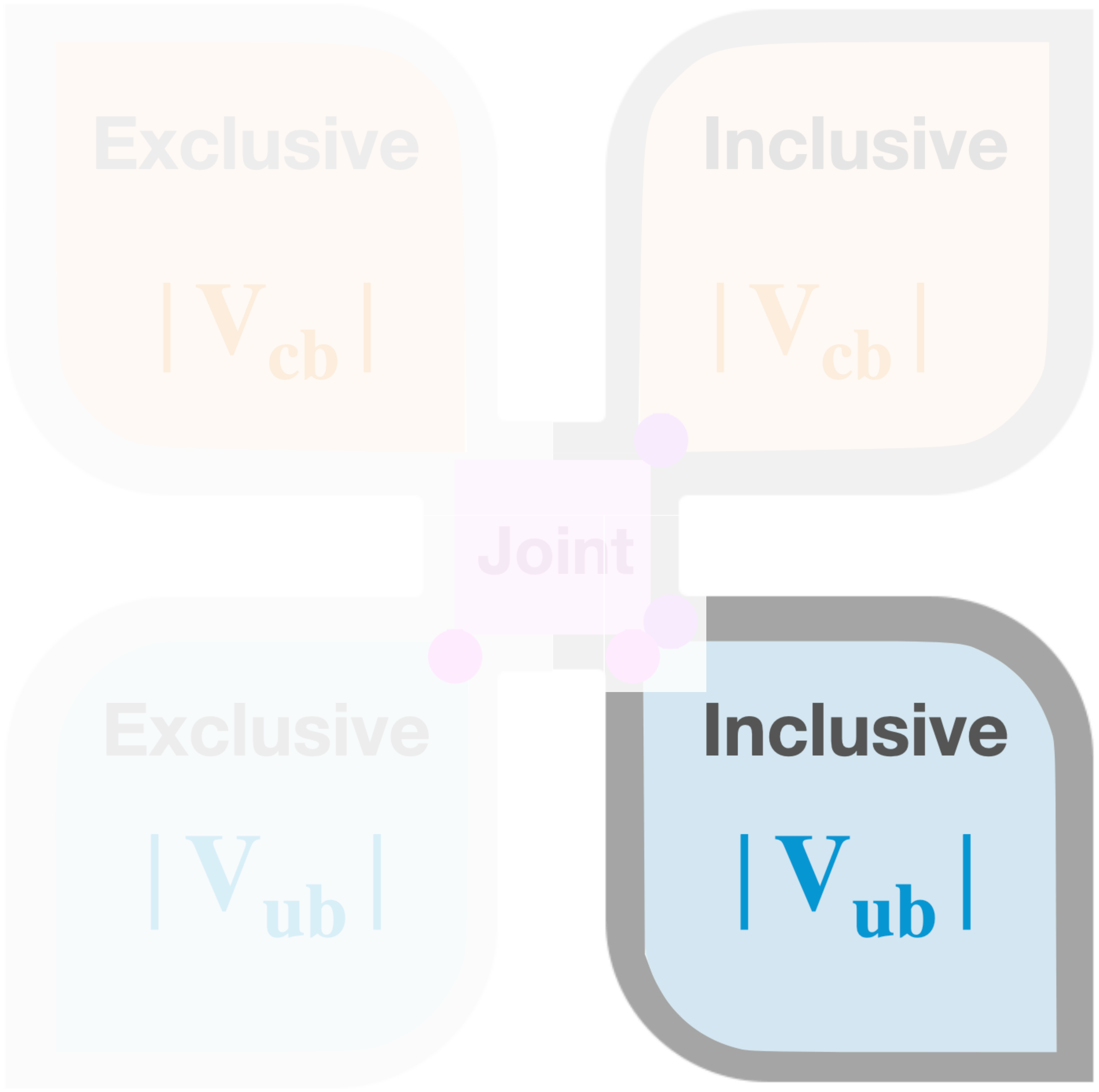
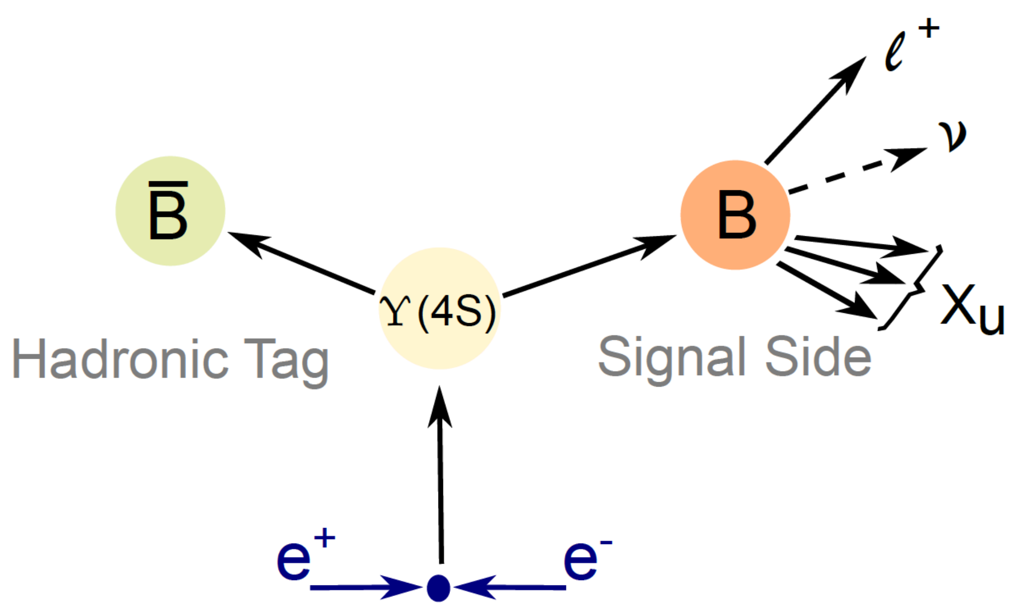
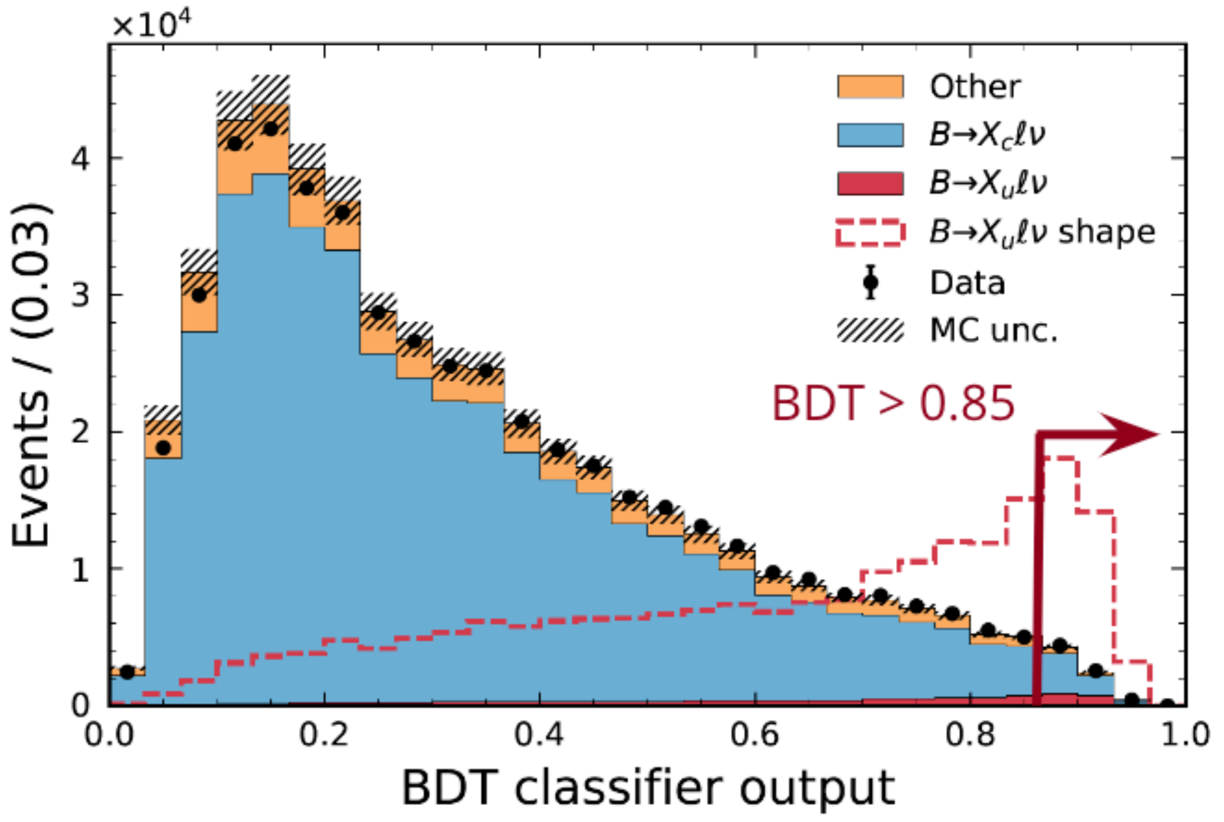

Exclusive
|Vcb|
Inclusive
|Vcb|
Joint
Exclusive
|Vub|
Inclusive
|Vub|

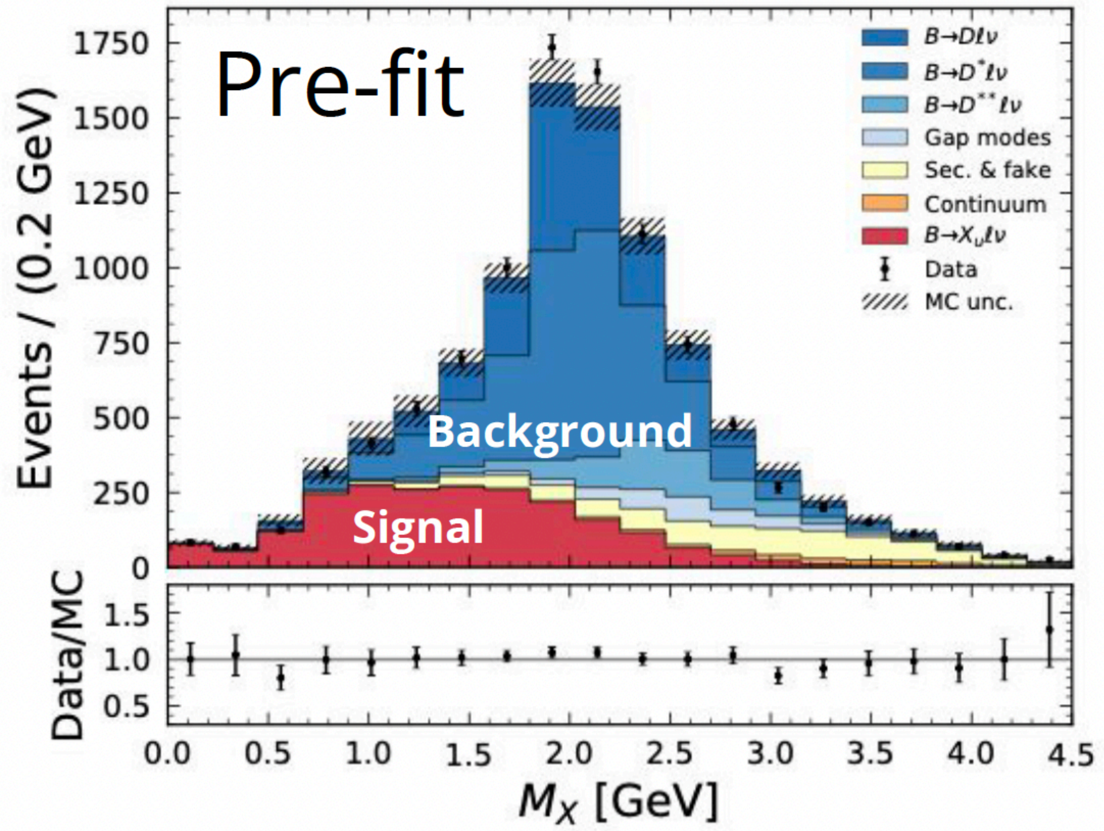
Partial Branching Fractions of Inclusive $B \to X_u \ell \nu$

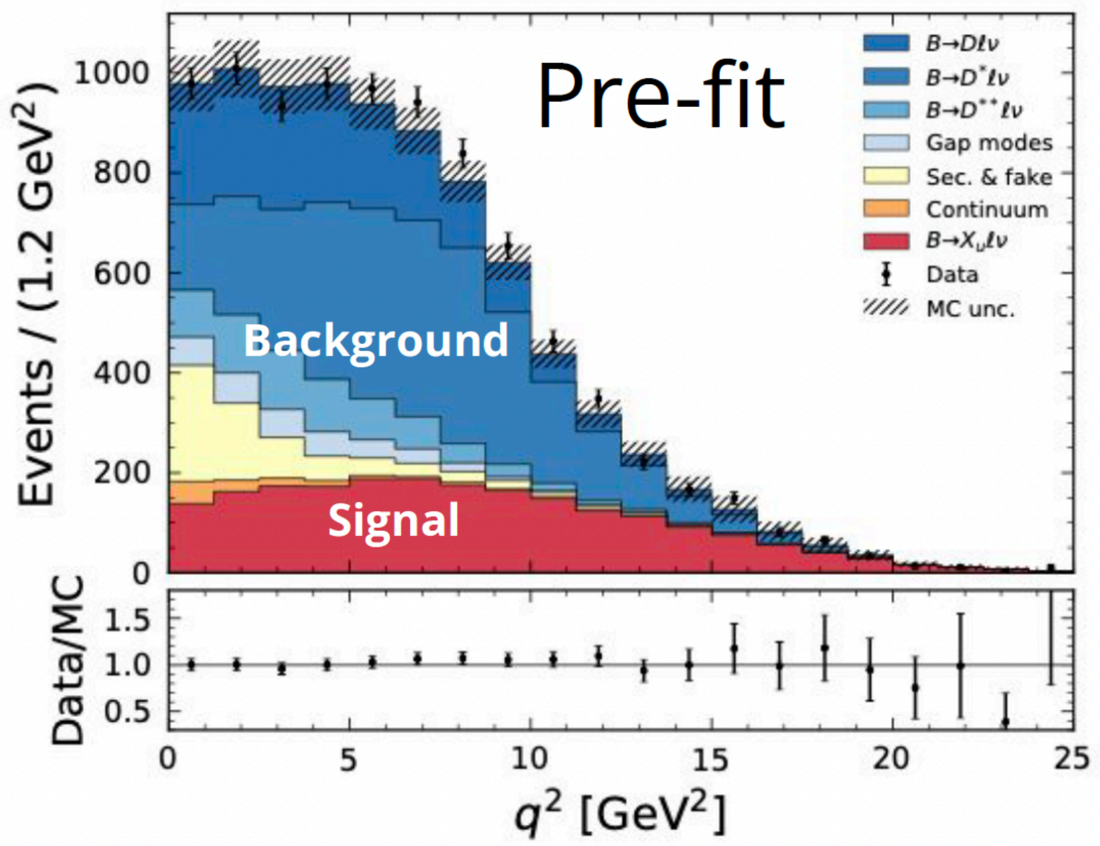
PRD 104 , 012008 (2021)

- **Full Belle** dataset with **Hadronic tagging**
- Use **machine learning (BDT)** to suppress backgrounds with 11 training features, e.g. MM^2,$\#K^{\pm}$, $\#K_S$, etc.









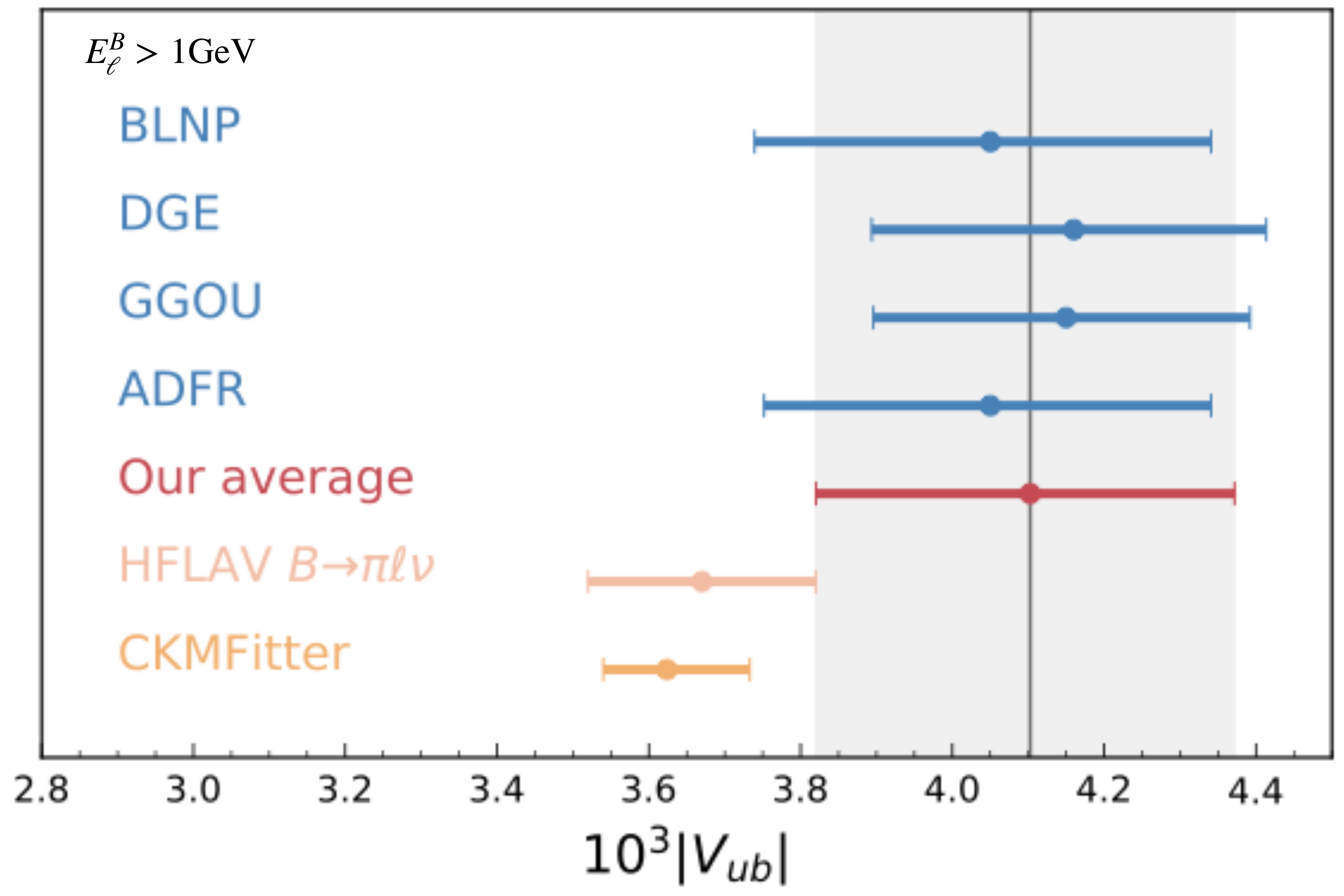
- Extract signal using binned likelihood in **3 phase space (PS) regions:**
  - $E_\ell^B > 1$ **GeV** (covers 86% of available signal PS)
  - $E_\ell^B > 1$ **GeV,** $M_X < 1.7$ **GeV** (56%)
  - $E_\ell^B > 1$ **GeV,** $M_X < 1.7$ **GeV,** $q^2 > 8$ **GeV**^{2} (31%)

→ Fit either E_ℓ^B , M_X , q^2 or 2D ($M_X : q^2$)

- Partial BF and inclusive $|V_{ub}|$ derived in each PS

$$\Delta\mathscr{B}(E_\ell^B > 1\mathrm{GeV}) = (1.59 \pm 0.07 \pm 0.16) \times 10^{-3}$$

$$|V_{ub}| = \sqrt{\frac{\Delta\mathscr{B}(B \to X_u \ell \nu)}{\tau_B \cdot \Delta\Gamma(B \to X_u \ell \nu)}}$$



Arithmetic avr. $|V_{ub}|$ based on various theo. decay rate:

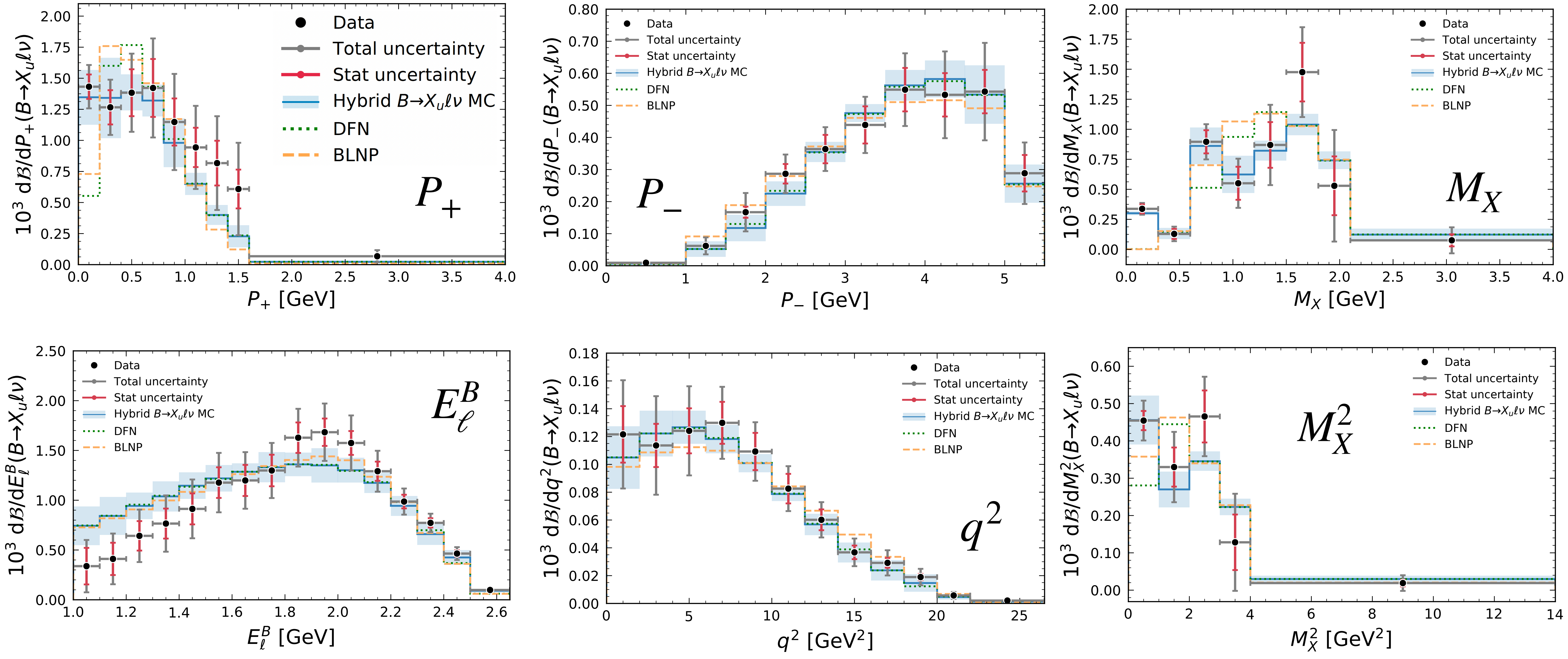
($4.10 \pm 0.09_{stat} \pm 0.22_{sys} \pm 0.15_{theo}$) x 10^{-3}

compatible with excl. and CKM expectation within 1.3σ and 1.6σ , respectively

First Measurement of Differential Spectra of $B \to X_u \ell \nu$

PRL 127, 261801 (2021)

- Inherit **same analysis strategy** in the partial BF measurement [PRD 104 , 012008 (2021)]
- Additional selections on $|E_{miss} - P_{miss}| < 0.1$ GeV & $M_X < 2.4$ GeV to **improve resolution** and reduce background shape uncertainty
- Background subtraction done via M_X fit, further corrected for efficiency & acceptance effects (phase space: $E_\ell^B > 1\mathrm{GeV}$)
- Full experimental covariance, spectra moments, migration matrices etc. available on HepData



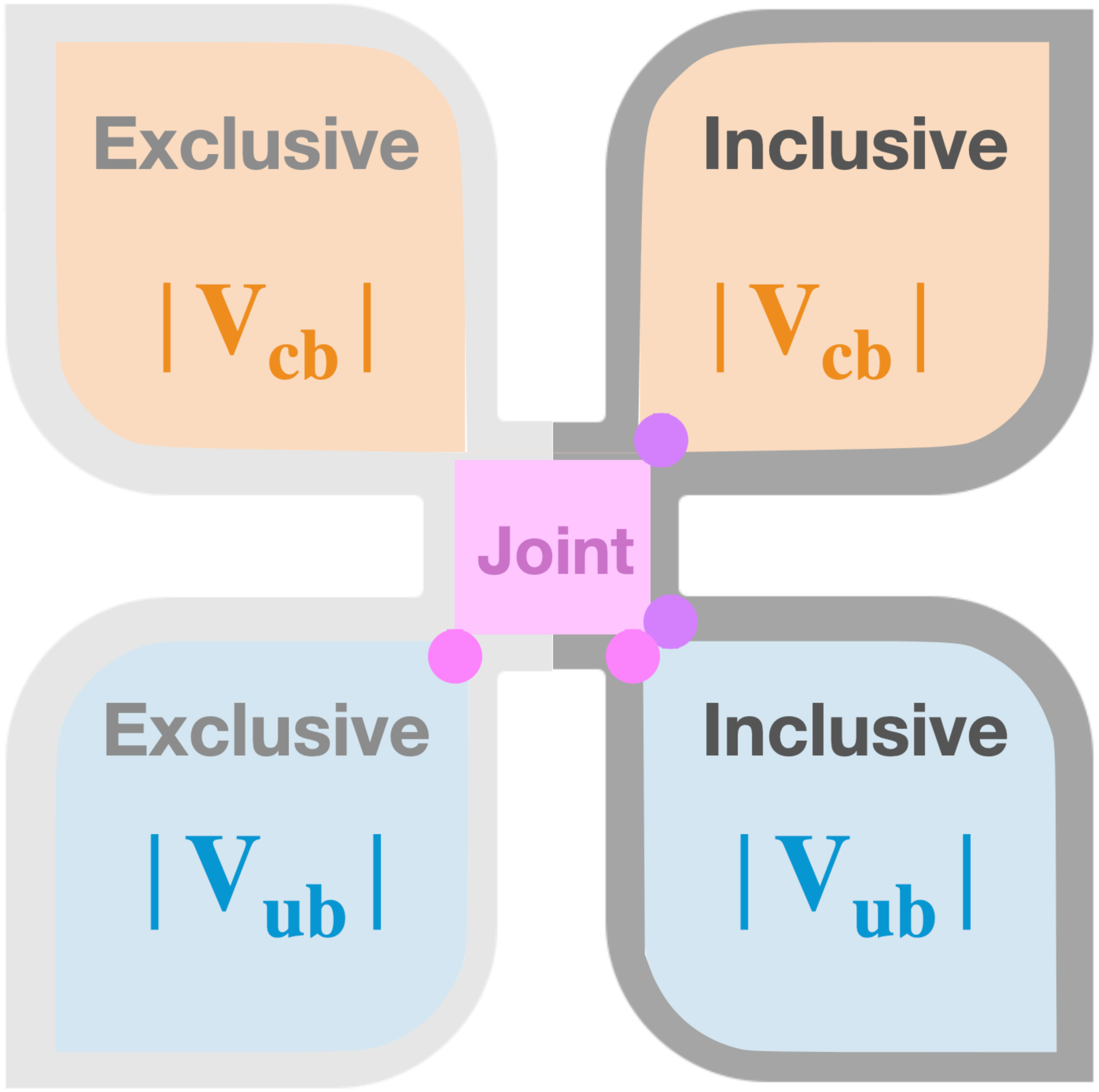
All MC shapes are normalised to 1.59 x 10^{-3} [Belle, PRD 104 , 012008 (2021)]

What can we gain for incl. $|V_{ub}|$?

Direct & more model-independent extraction

Normalization ⇒ Kin. shapes + Normalization

- Allows direct extraction of coefficients for non-perturbative shape functions in a global fit and $|V_{ub}|$
- Uncertainty can be further shrinked by including other inclusive B decays, e.g B→ $X_s\gamma$, B→ $X_c\ell\nu$ as the shape function in LO is universal
- Methods proposed by NNVub, SIMBA


Exclusive
$|V_{cb}|$
Inclusive
$|V_{cb}|$
Joint
Exclusive
$|V_{ub}|$
Inclusive
$|V_{ub}|$

First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

New

BELLE

Preliminary

- Inherit **same analysis strategy** in the partial BF measurement [PRD 104 , 012008 (2021)]
- Additional selections on thrust of X in c.m.s to **increase significance** of $B \to \pi \ell \nu$
- Extract signal in $\mathbf{q^2} : \mathbf{N}_{\pi^\pm}$ for $B \to \pi \ell \nu$ and $B \to X_u \ell \nu$ simultaneously

First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

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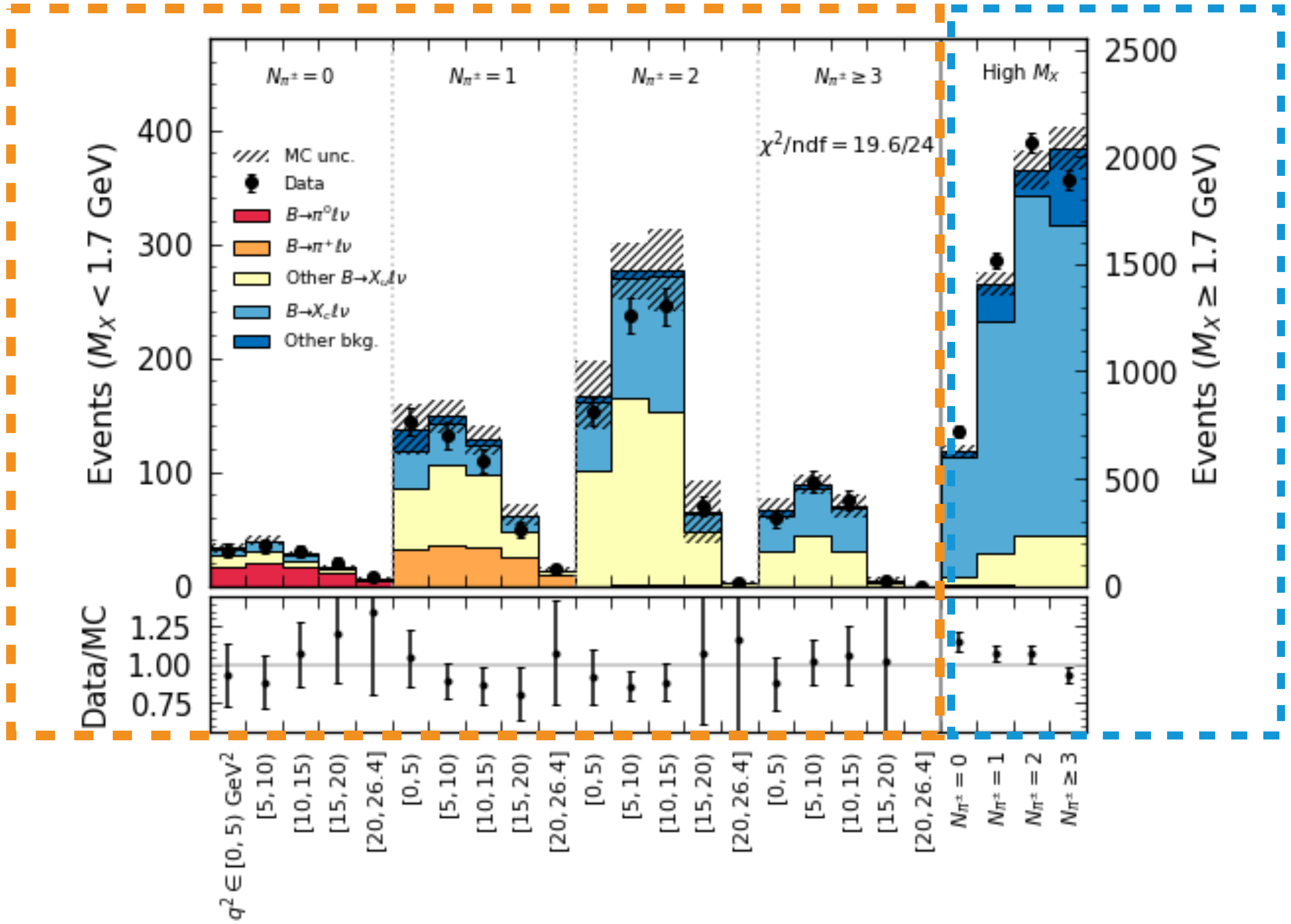
Flattened 2D Spectrum (pre-fit)

Low M_X



High M_X

First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

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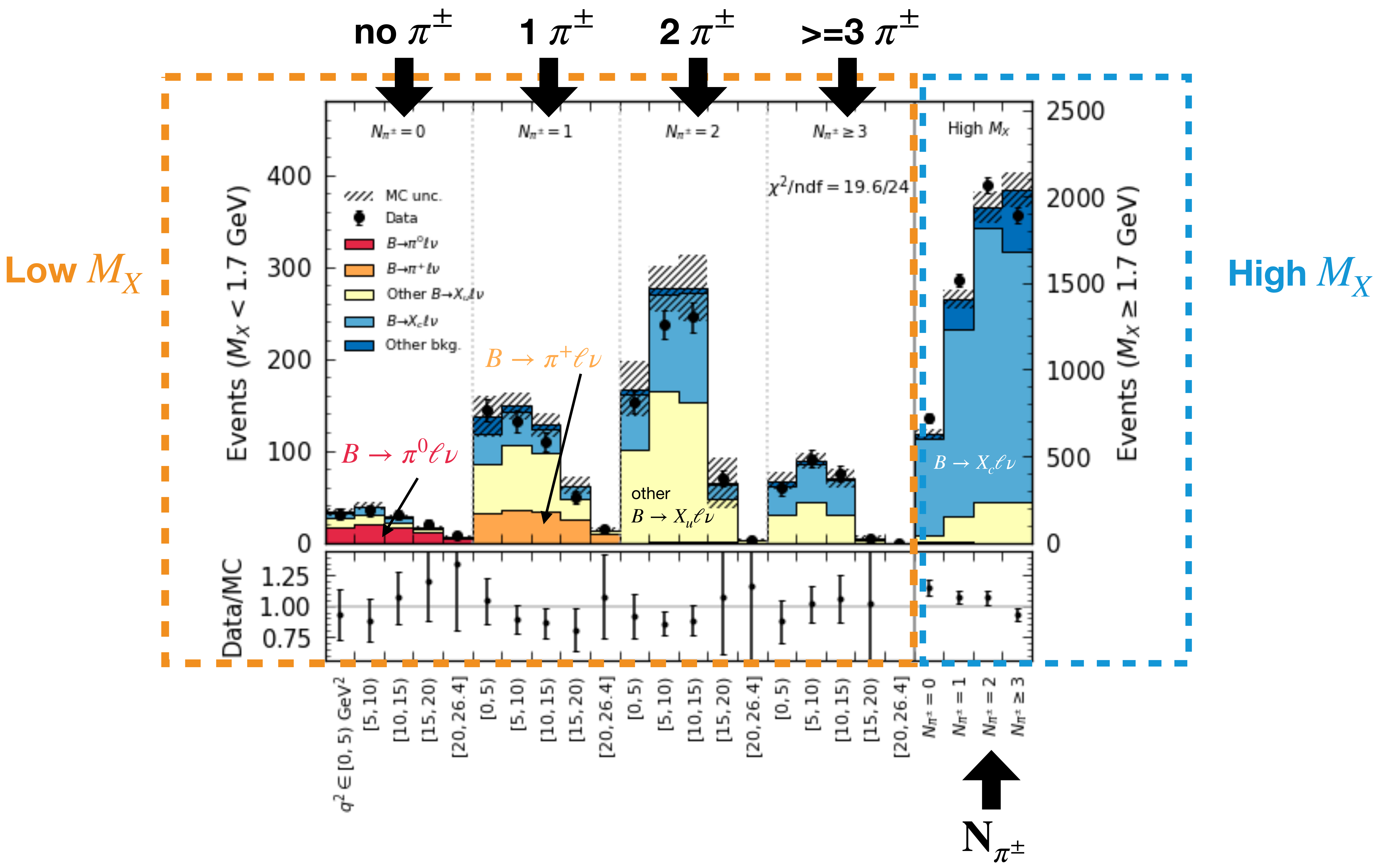

First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$ New

BELLE

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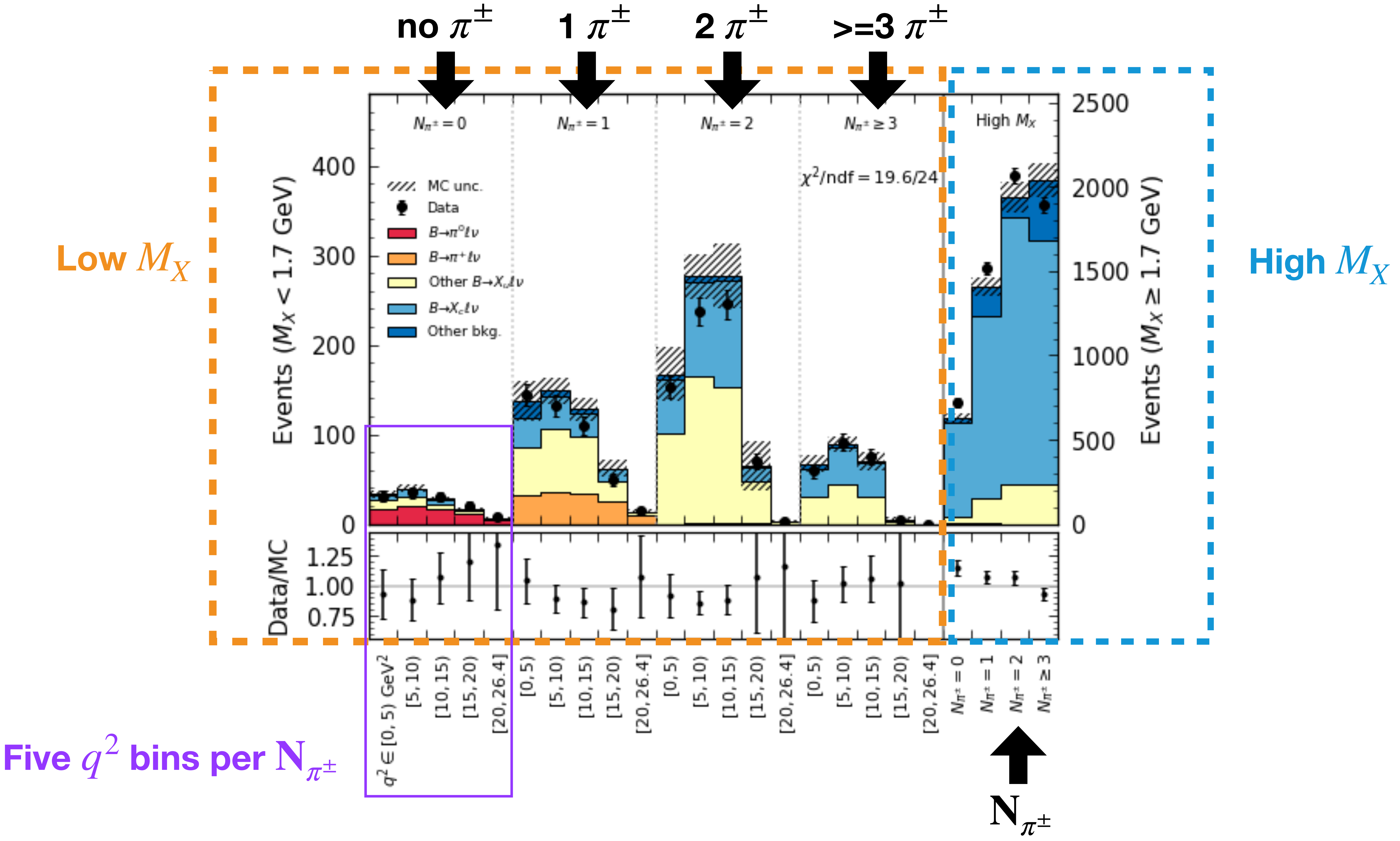
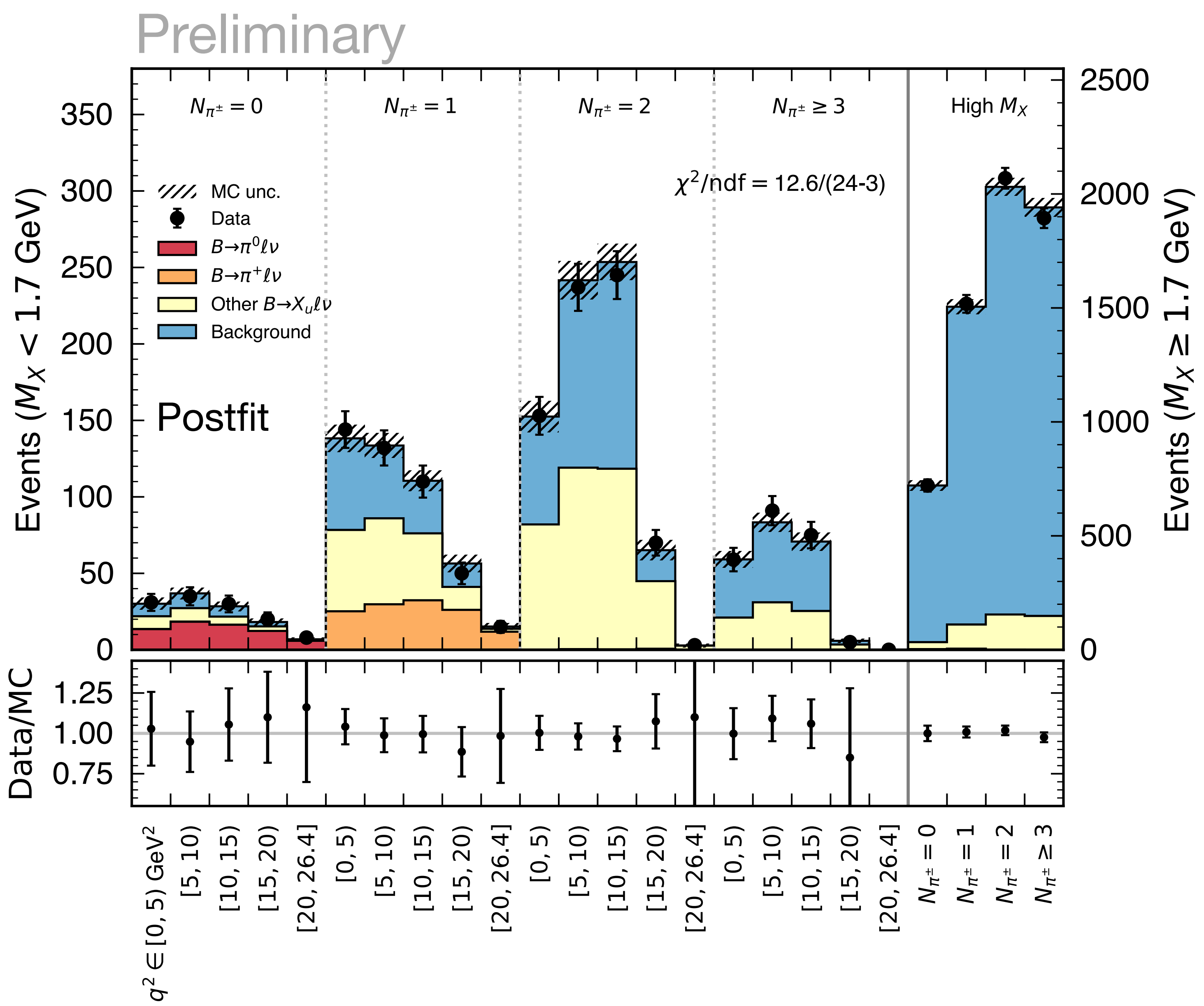


First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

Preliminary

- Fitter corporates experimental observation of templates' **normalisations** and $B \to \pi \ell \nu$ **form factor**
- Systematic uncertainties included via Nuisance parameters for both of additives and multiplicative impacts
- Dominant syst. are non-resonant $B \to X_u \ell \nu$ modelling, fragmentation and reconstruction efficiency (stat. limits $B \to \pi \ell \nu$)

$$-2\log\mathscr{L} = -2\log\prod_i \text{Poisson}\left(\eta_{\text{obs}}, \eta_{\text{pred}} \cdot (1+\epsilon\cdot\theta)\right) + \theta\rho_\theta^{-1}\theta^T + \chi^2_{\text{FF}}$$



Normalizations can be linked with isospin relation, or floating separately

$B \to \pi^0 \ell \nu$

$B \to \pi^+ \ell \nu$

other $B \to X_u \ell \nu$

all background

First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

New

BELLE

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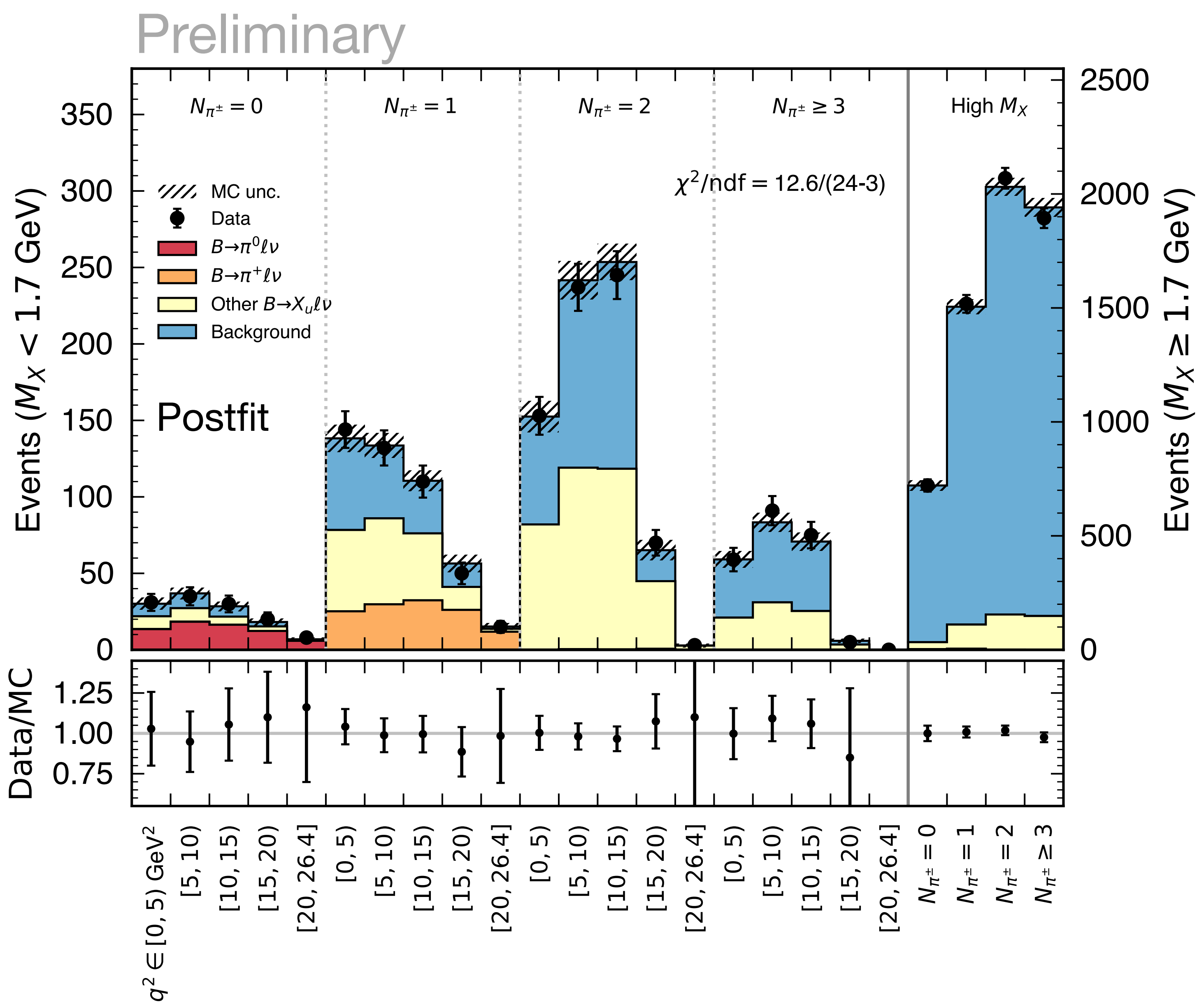
Constraints on BCL parameters , input taken from LQCD / LQCD+exp fits in FLAG Review 2021

Differential decay rates

Acceptance & reco. efficiency

Forward-folding q^2



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$B \to \pi^+ \ell \nu$
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all background

Shape described by BCL para.

First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

New

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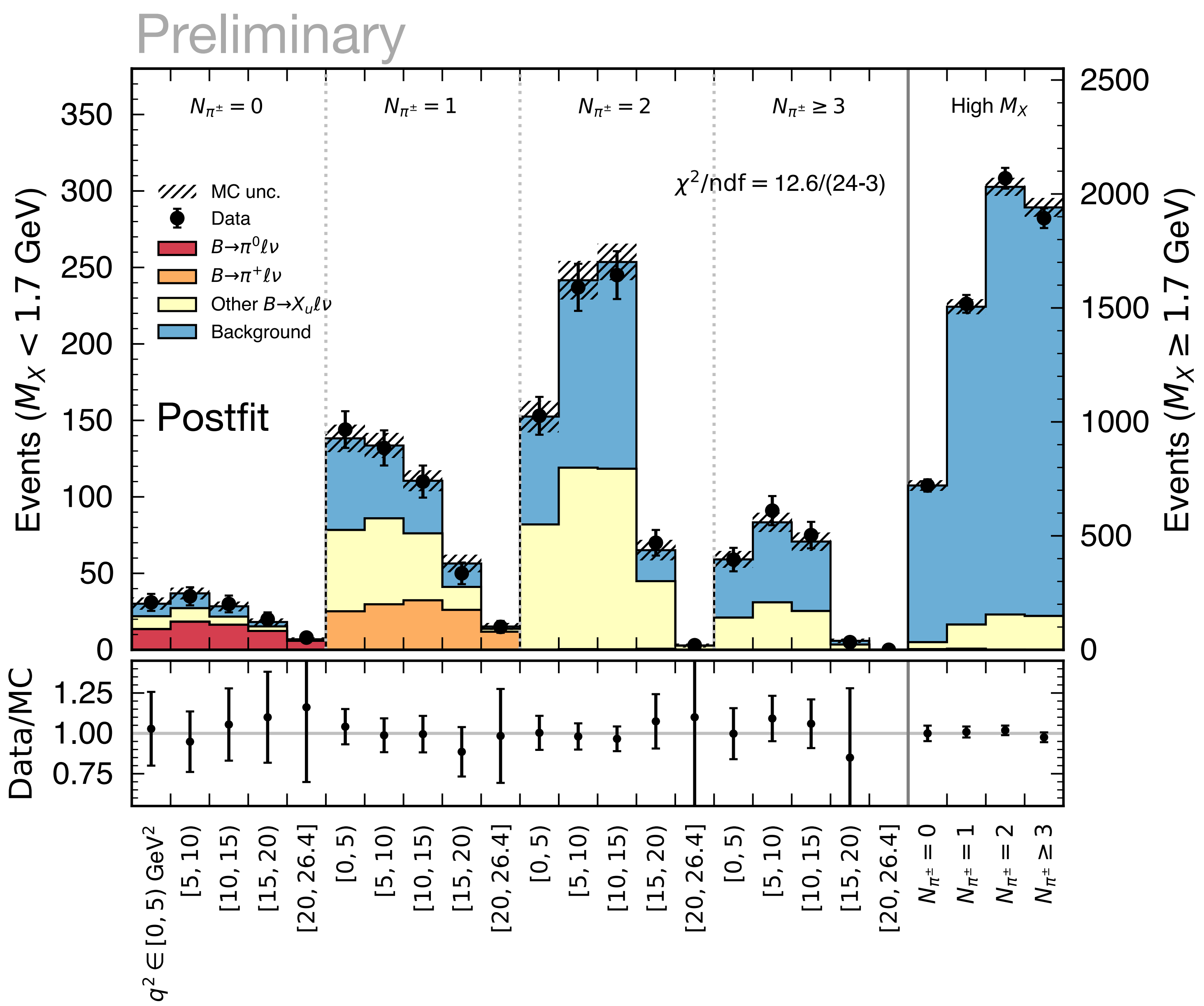

Normalizations can be linked with isospin relation, or floating separately

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$B \to \pi^+ \ell \nu$

other $B \to X_u \ell \nu$

all background

Shape described by BCL para.

$$\mathscr{B}(B \to X_u \ell \nu) = \mathscr{B}(B \to \pi^0 \ell \nu) + \mathscr{B}(B \to \pi^+ \ell \nu) + \mathscr{B}(B \to X_u^{\text{other}} \ell \nu)$$

$$\Delta \mathscr{B}(B \to X_u \ell \nu) = \mathscr{B}(B \to X_u \ell \nu) \cdot \epsilon_{\Delta \text{PS:E}_\ell^{\text{B}} > 1\text{GeV}}$$

$$|V_{ub}| = \sqrt{\frac{\mathscr{B}}{\tau_B \cdot \Gamma}}$$

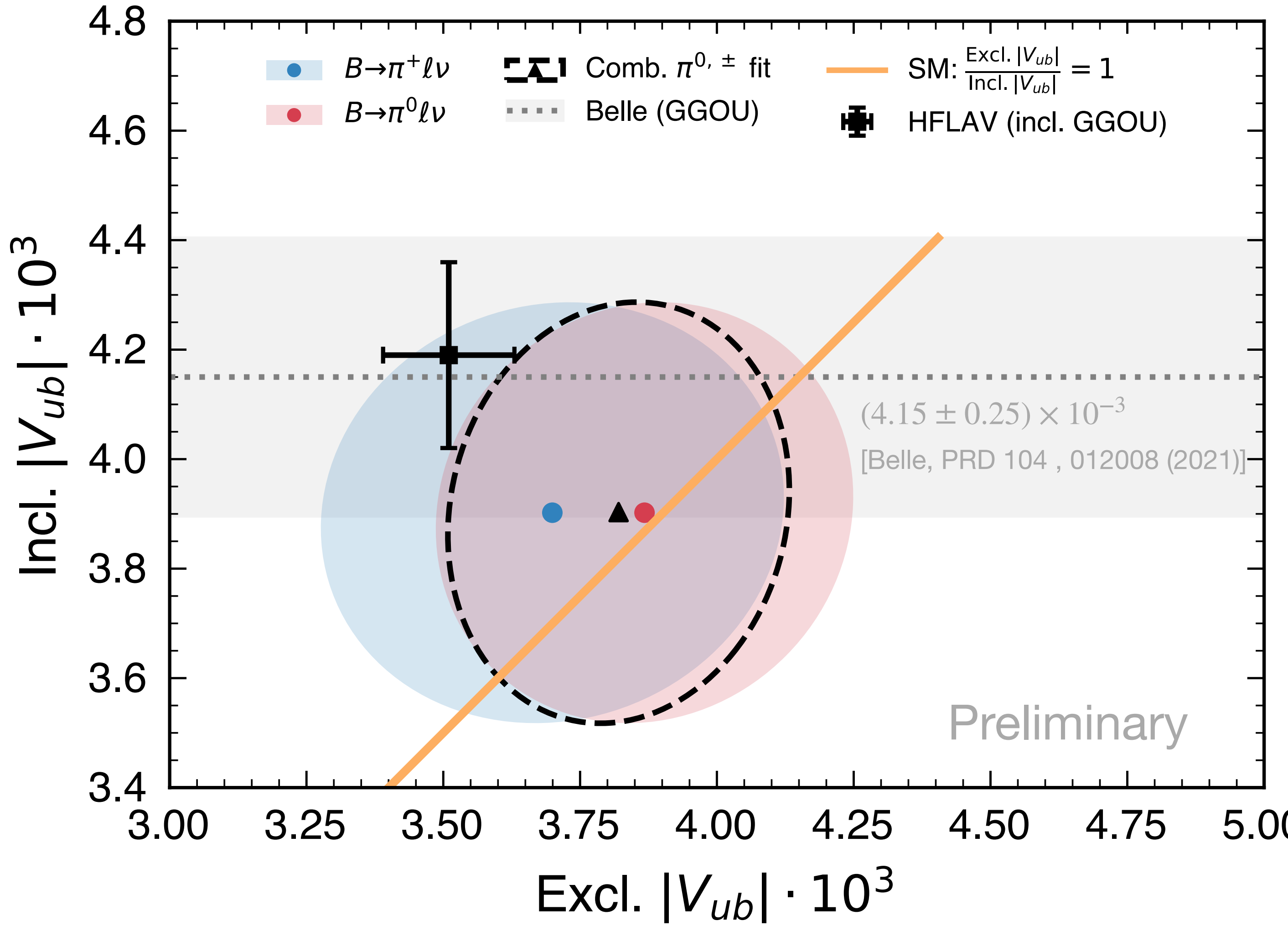
With fit results, derive three branching fractions, $B \to \pi \ell \nu$ decay rate, and hence exclusive and inclusive $|V_{ub}|$

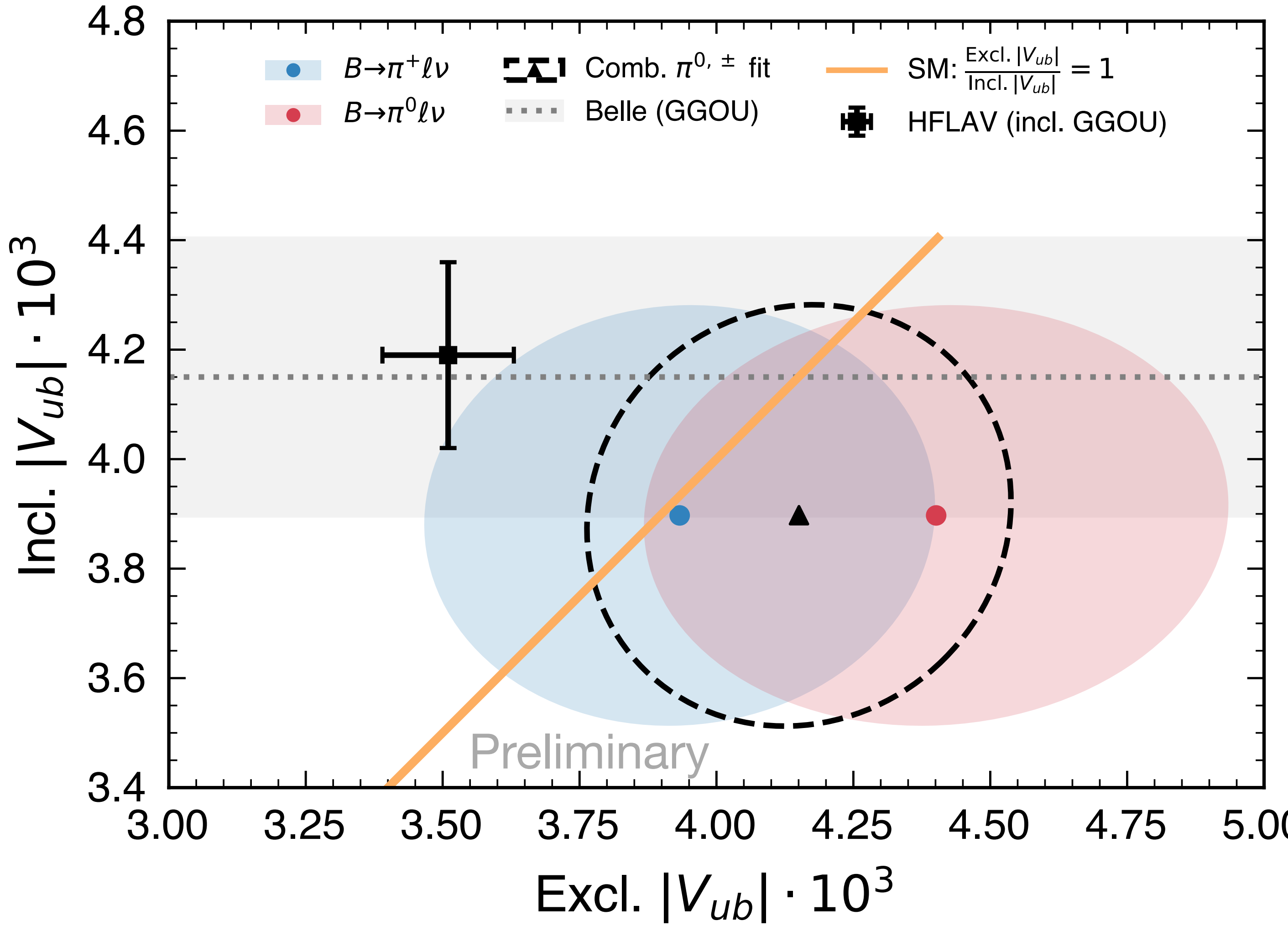
First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

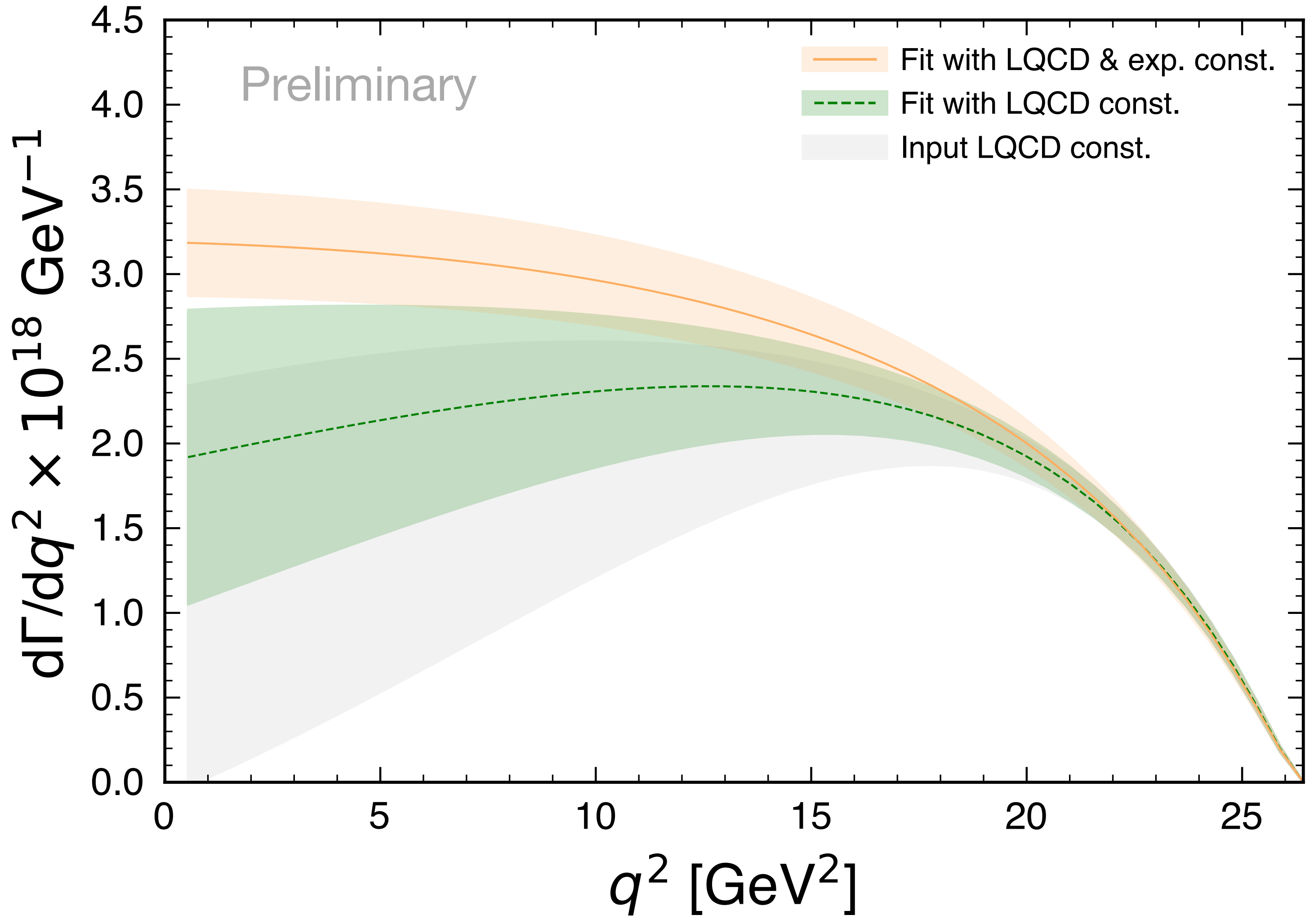
New

Preliminary

- Various fit scenarios applied:
  - **Combined** or separate $B \to \pi^+ \ell \nu$, $B \to \pi^0 \ell \nu$
  - Input BCL constraint: **LQCD + exp.** or **only LQCD**







$|V_{ub}|$ in **combined** scenario with **LQCD+exp** const.:

Excl. $(3.78 \pm 0.23_{\text{stat}} \pm 0.16_{\text{syst}} \pm 0.14_{\text{theo}}) \times 10^{-3}$

Incl. $(3.90 \pm 0.20_{\text{stat}} \pm 0.32_{\text{syst}} \pm 0.09_{\text{theo}}) \times 10^{-3}$

Ratio 0.97 ± 0.12

Correlation 0.10

Weighted average of excl. & incl.

$(3.85 \pm 0.26) \times 10^{-3}$

CKM global fit (w/o $|V_{ub}|$): $(3.64 \pm 0.07) \times 10^{-3}$, **compatible within 0.8σ**

First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

New

BELLE

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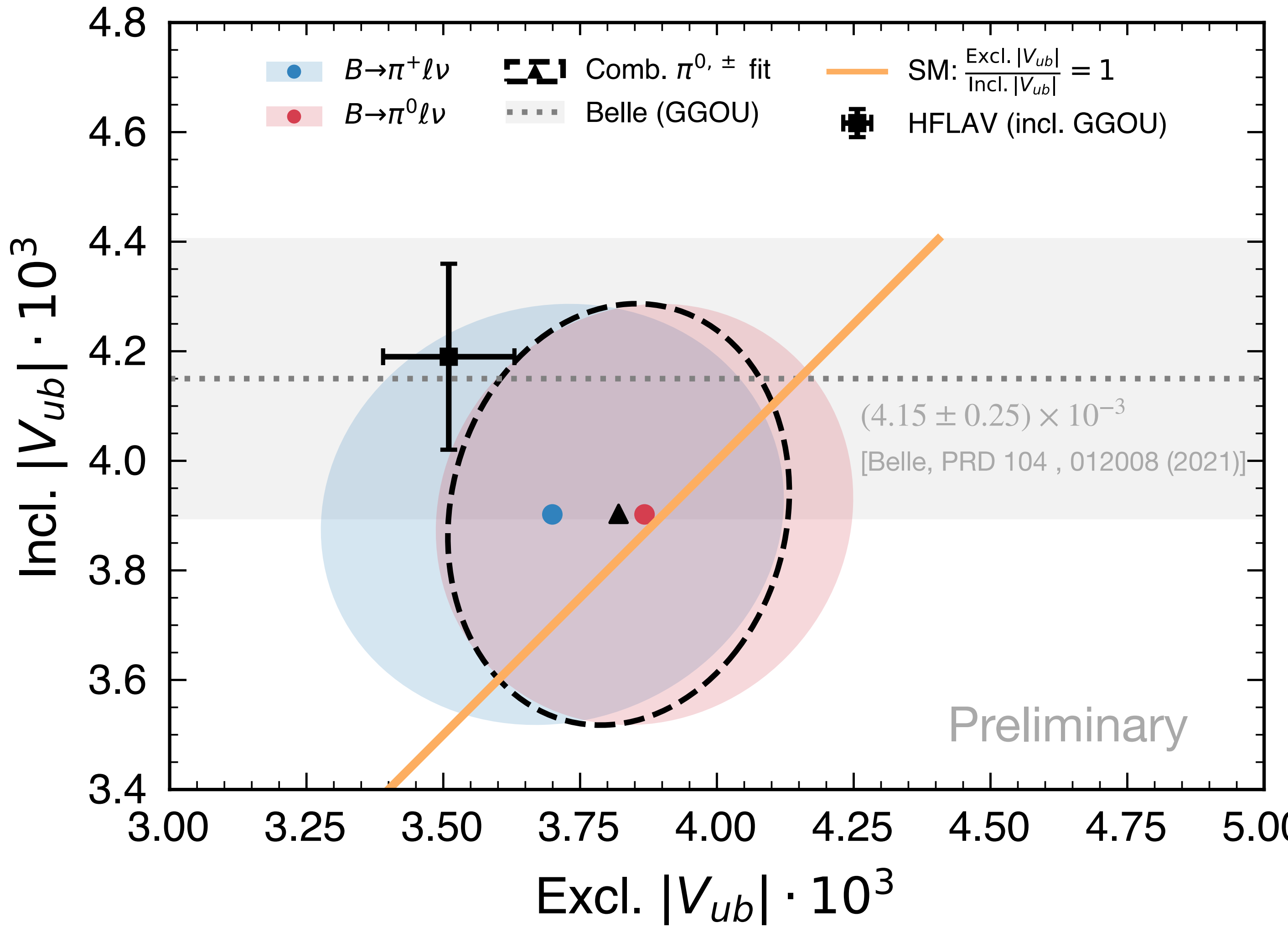
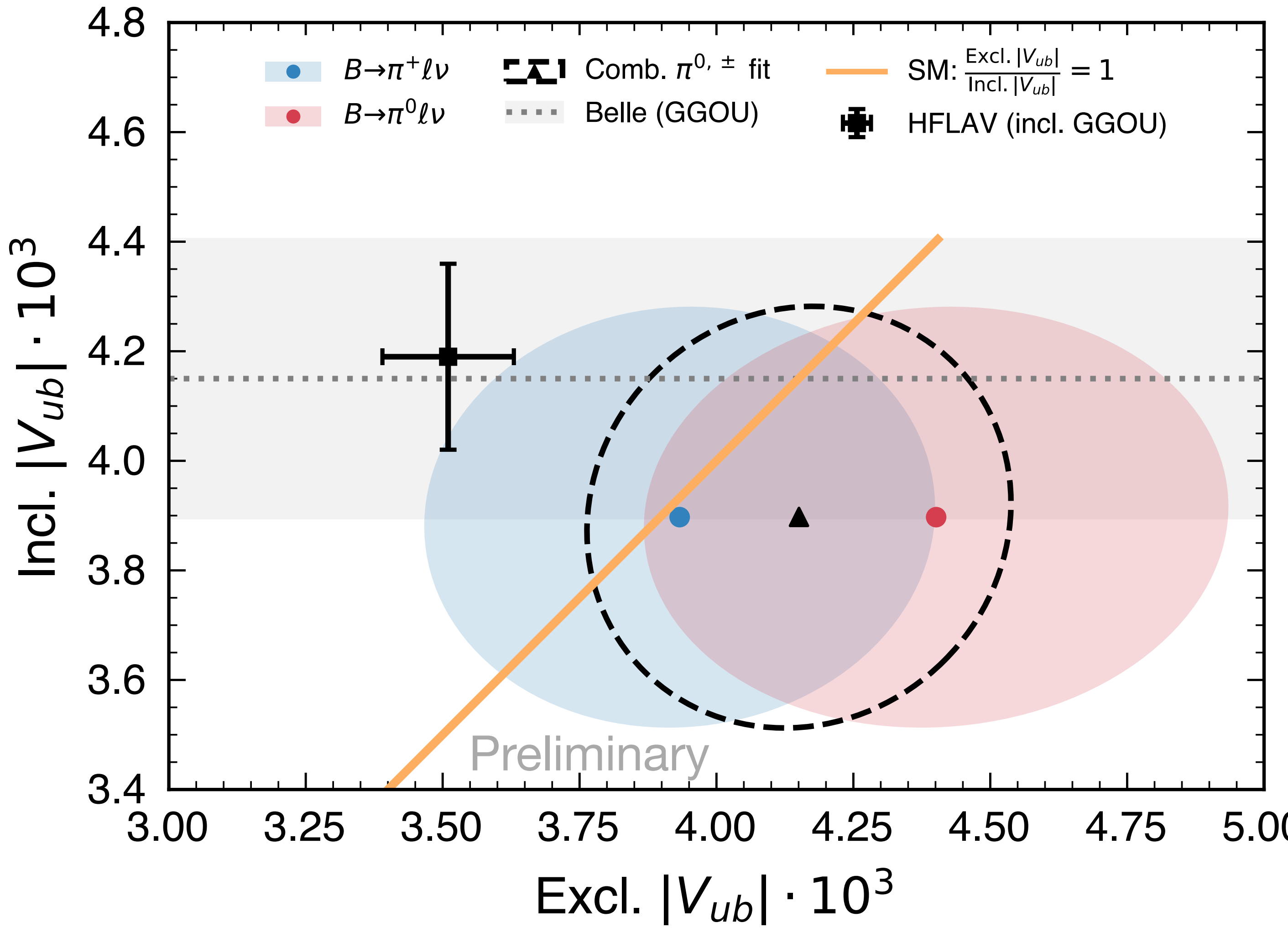
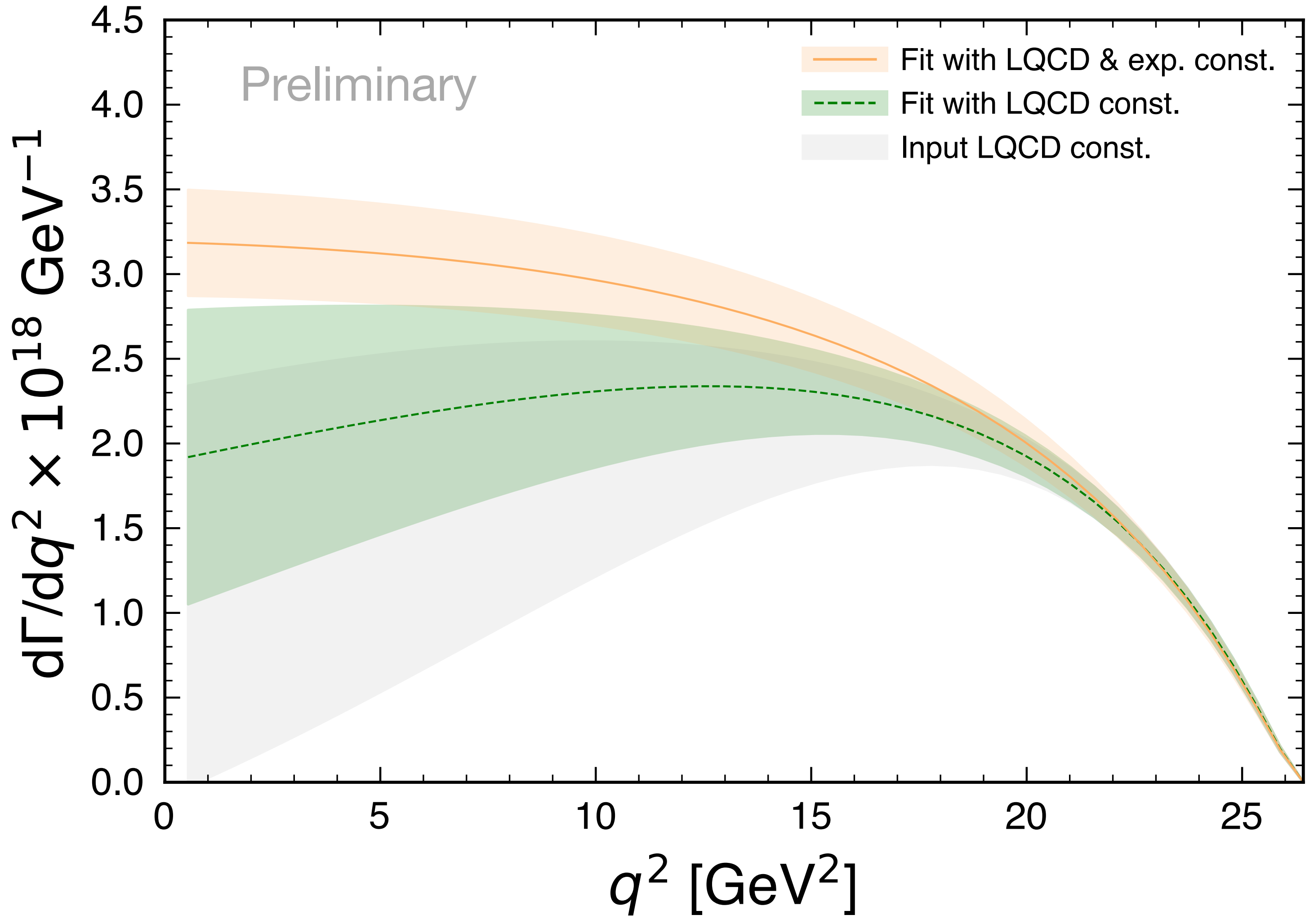
Preliminary







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Is Vub puzzle solved?

🧐 Not yet,

unless the uncertainty in both channels can be reduced

Ratio of Inclusive $\Delta\mathcal{B}(B \to X_u \ell \nu)$ and $\Delta\mathcal{B}(B \to X_c \ell \nu)$

Preliminary

- Full Belle data set with **Hadronic tagging** using Belle II tool (Full Event Interpretation)
- **Modified $B \to X_c \ell \nu$ modeling** using sideband data
- $B \to X_u \ell \nu$ yields extracted in $q^2 : p_\ell^B$; $B \to X_c \ell \nu$ yields obtained by subtracting other contributions in total $B \to X \ell \nu$
- Measured partial phase space region of $p_\ell^B > 1\,\mathrm{GeV}$, $\epsilon_\Delta^u = 86\,\%$, $\epsilon_\Delta^c = 79\,\%$

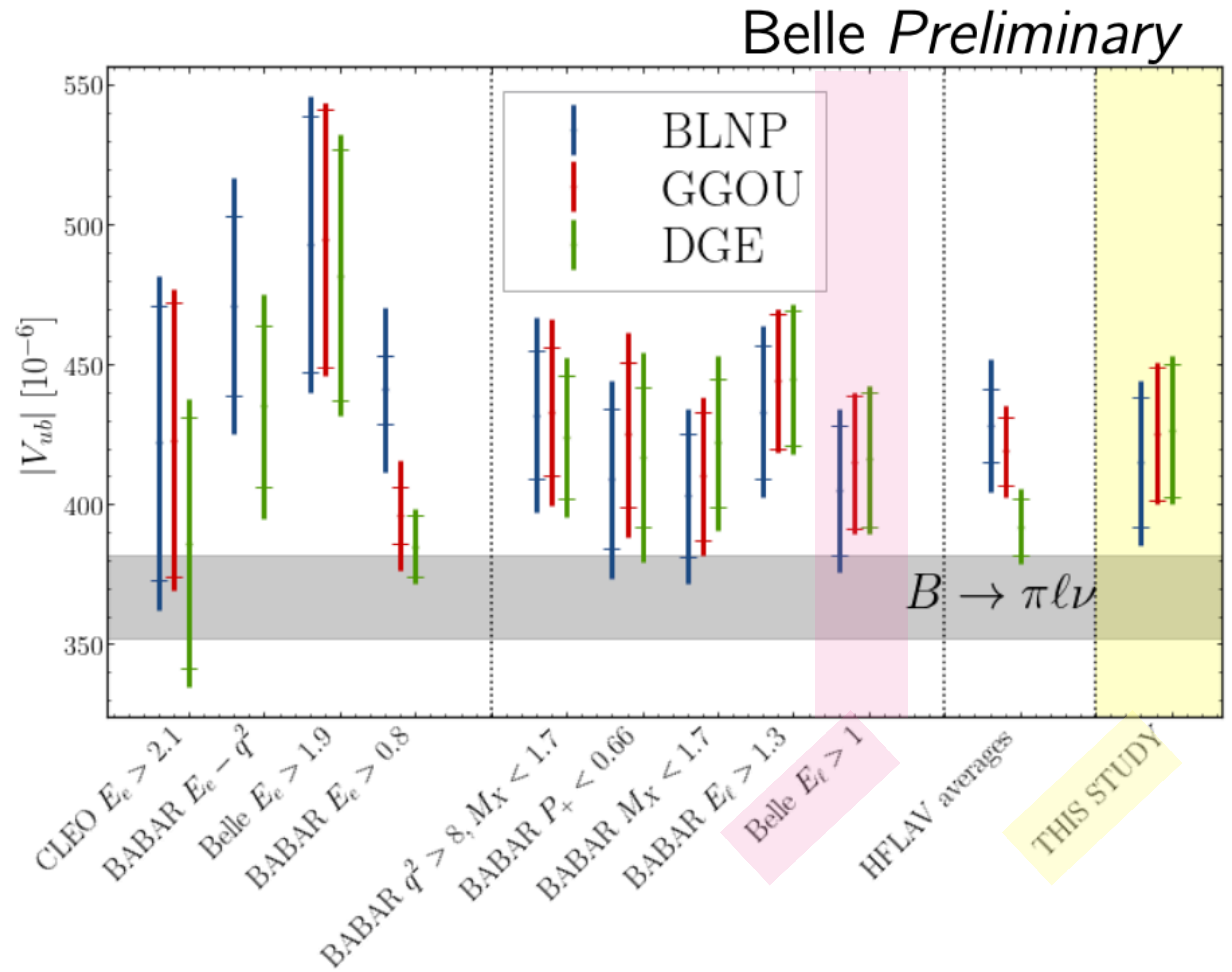
Preliminary

$$\frac{\Delta\mathcal{B}(B \to X_u \ell \nu)}{\Delta\mathcal{B}(B \to X_c \ell \nu)} = 1.95(1 \pm 8.4\%_{\mathrm{stat}} \pm 7.2\%_{\mathrm{syst}}) \times 10^{-2}$$

Based on this, one could try the following two quick and naive conversions

$$|V_{ub}| = \sqrt{\frac{1}{\tau_B \Delta\Gamma(B \to X_u \ell \nu)} \frac{\Delta\mathcal{B}(B \to X_u \ell \nu)}{\Delta\mathcal{B}(B \to X_c \ell \nu)} \boxed{\Delta\mathcal{B}(B \to X_c \ell \nu)}}$$

WA: (8.55 ± 0.13)%



Consistent with recent Belle result PRD 104 , 012008 (2021)

Ratio of Inclusive $\Delta\mathcal{B}(B \to X_u \ell \nu)$ and $\Delta\mathcal{B}(B \to X_c \ell \nu)$

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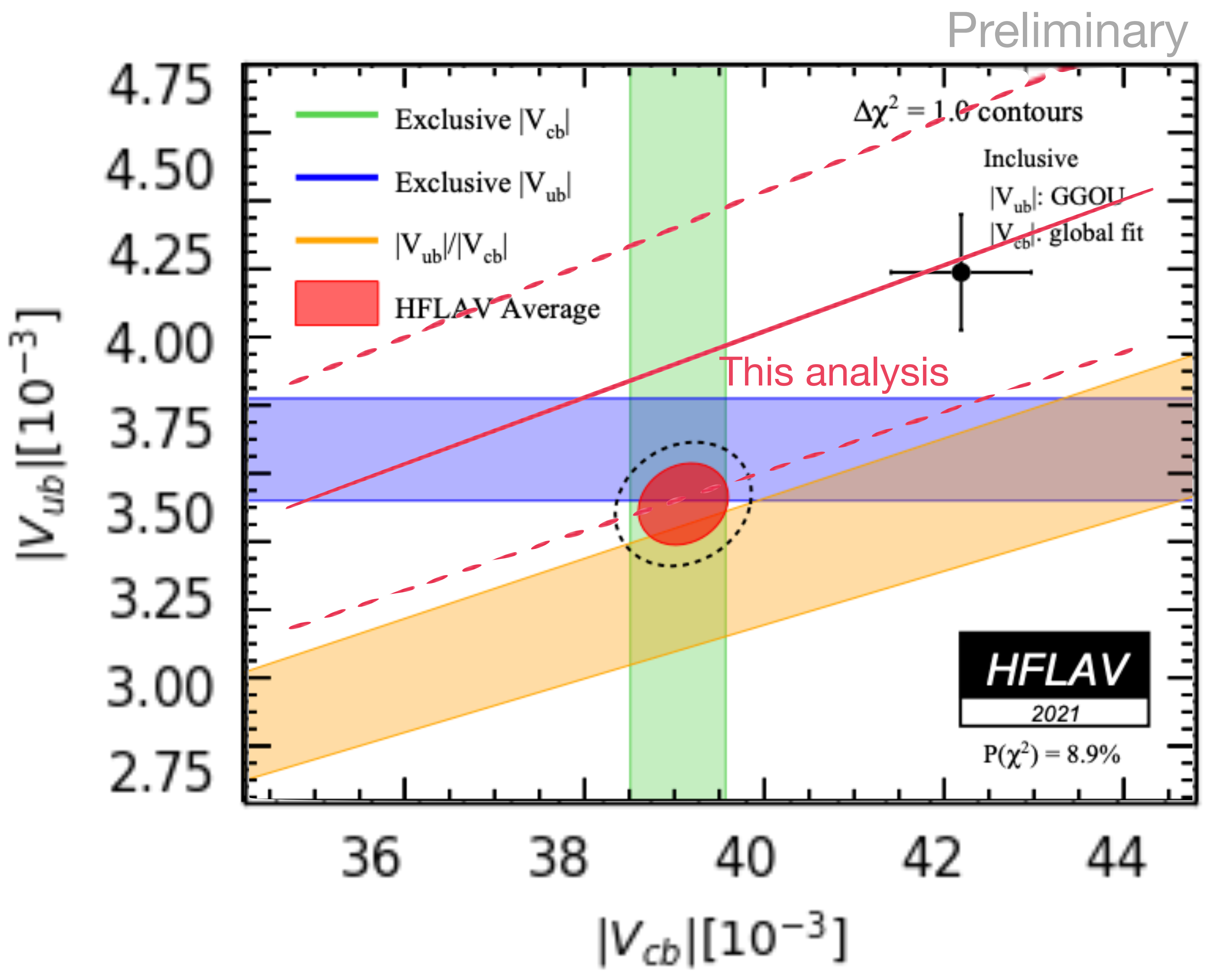
WA: (8.55 ± 0.13)%

$$\frac{|V_{ub}|}{|V_{cb}|} = \sqrt{\frac{\Delta\mathcal{B}(B \to X_u \ell \nu)}{\Delta\mathcal{B}(B \to X_c \ell \nu)} \frac{\Delta\Gamma(B \to X_c \ell \nu)}{\Delta\Gamma(B \to X_u \ell \nu)}}$$

Theo. input: $\Delta\Gamma^{\mathrm{GGOU}}(B \to X_u \ell \nu) = 58.5 \pm 2.7\,\mathrm{ps}^{-1}$

$\Delta\Gamma^{\mathrm{Kin}}(B \to X_c \ell \nu) = 29.9 \pm 1.2\,\mathrm{ps}^{-1}$



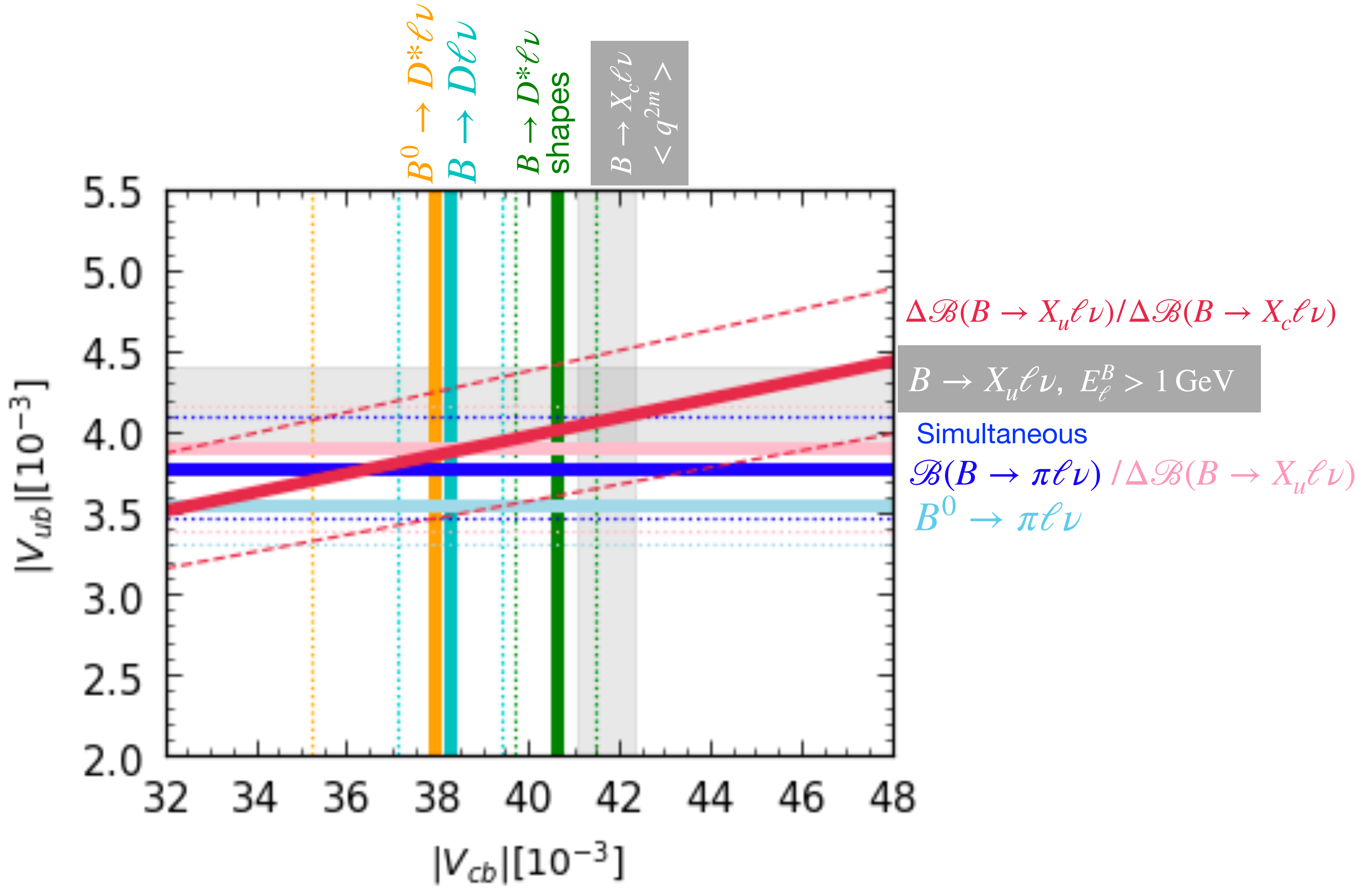
Summary

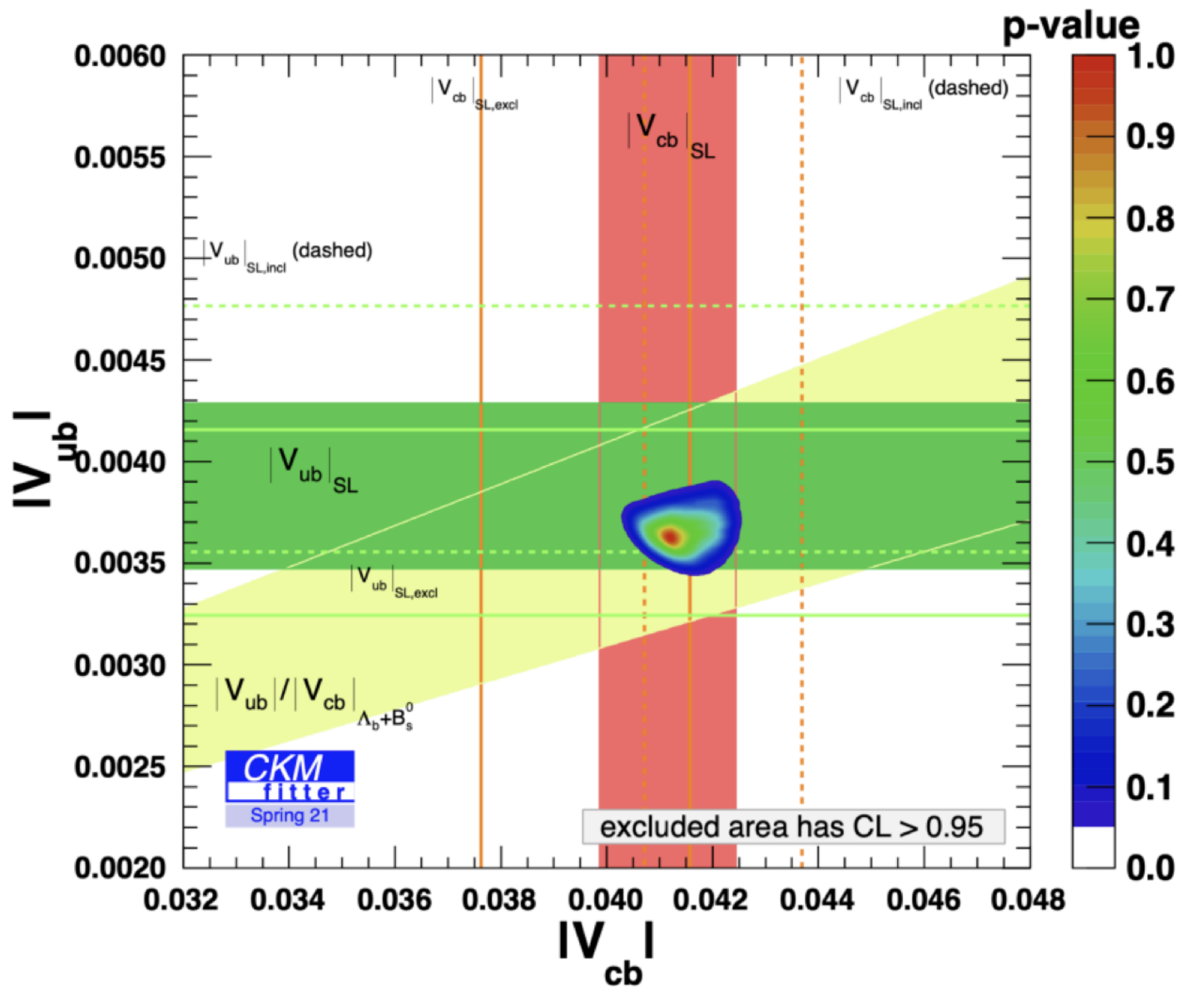
- Several new results on $|V_{xb}|$ measured recently at Belle and Belle II

- These new results will be very helpful to examine the long-standing $|V_{xb}|$ puzzle

- Continuous efforts from **experiment** and **theory** are still needed

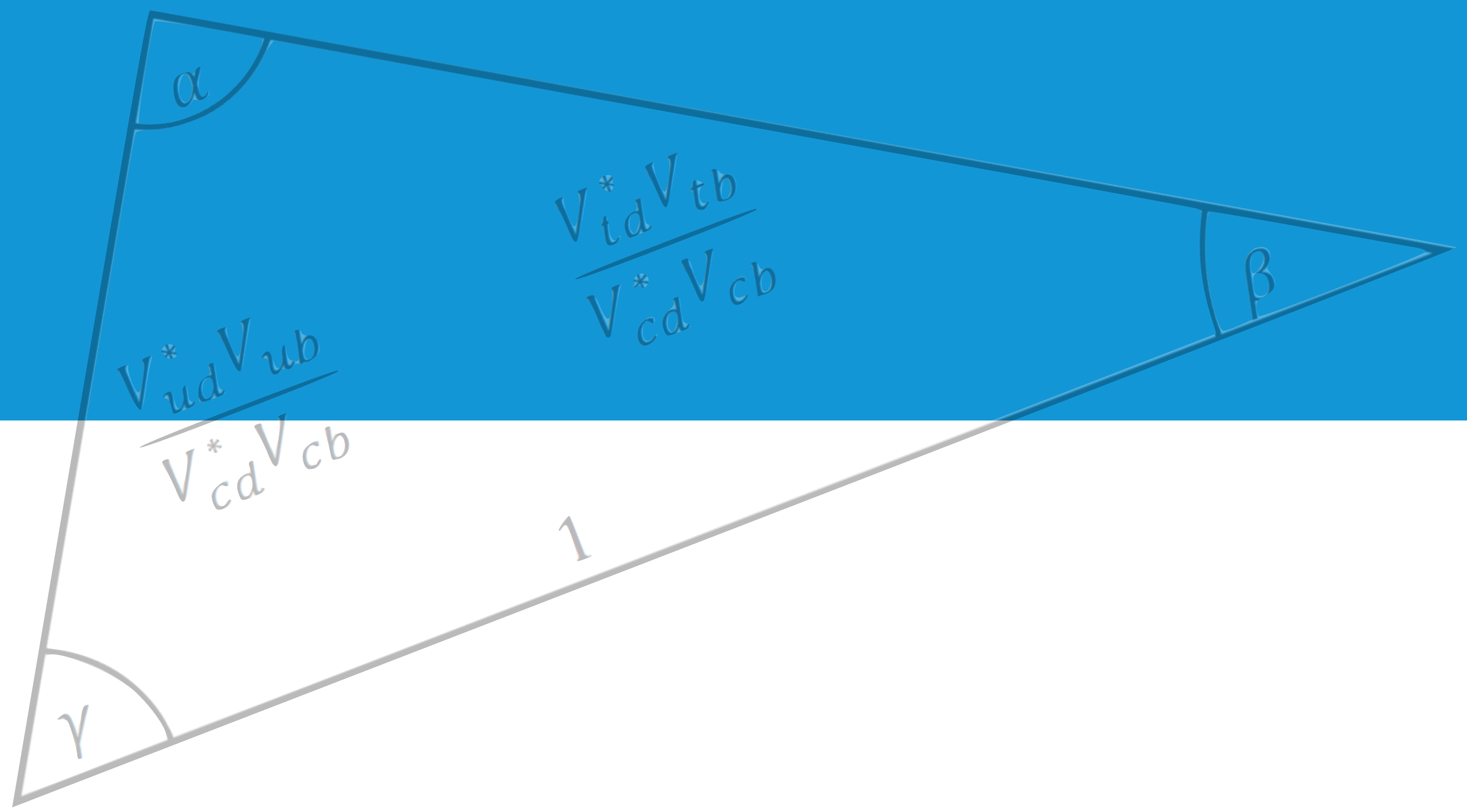
- Beyond these important results, the accumulated knowledge on MC modeling, analysis techniques, etc. will be beneficial for future measurements by e.g. **Belle II** or **LHCb**





THANK YOU

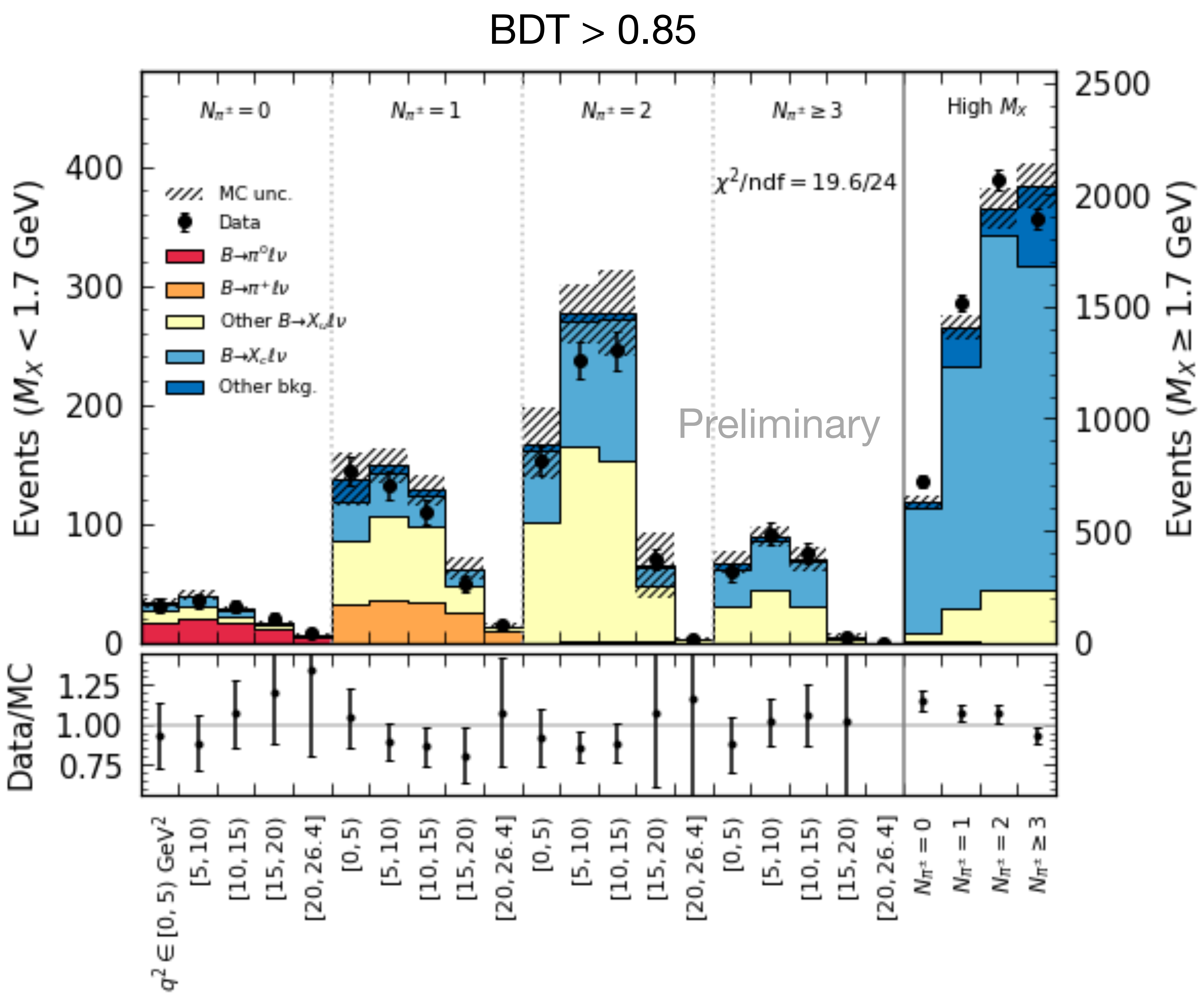
THANK YOU

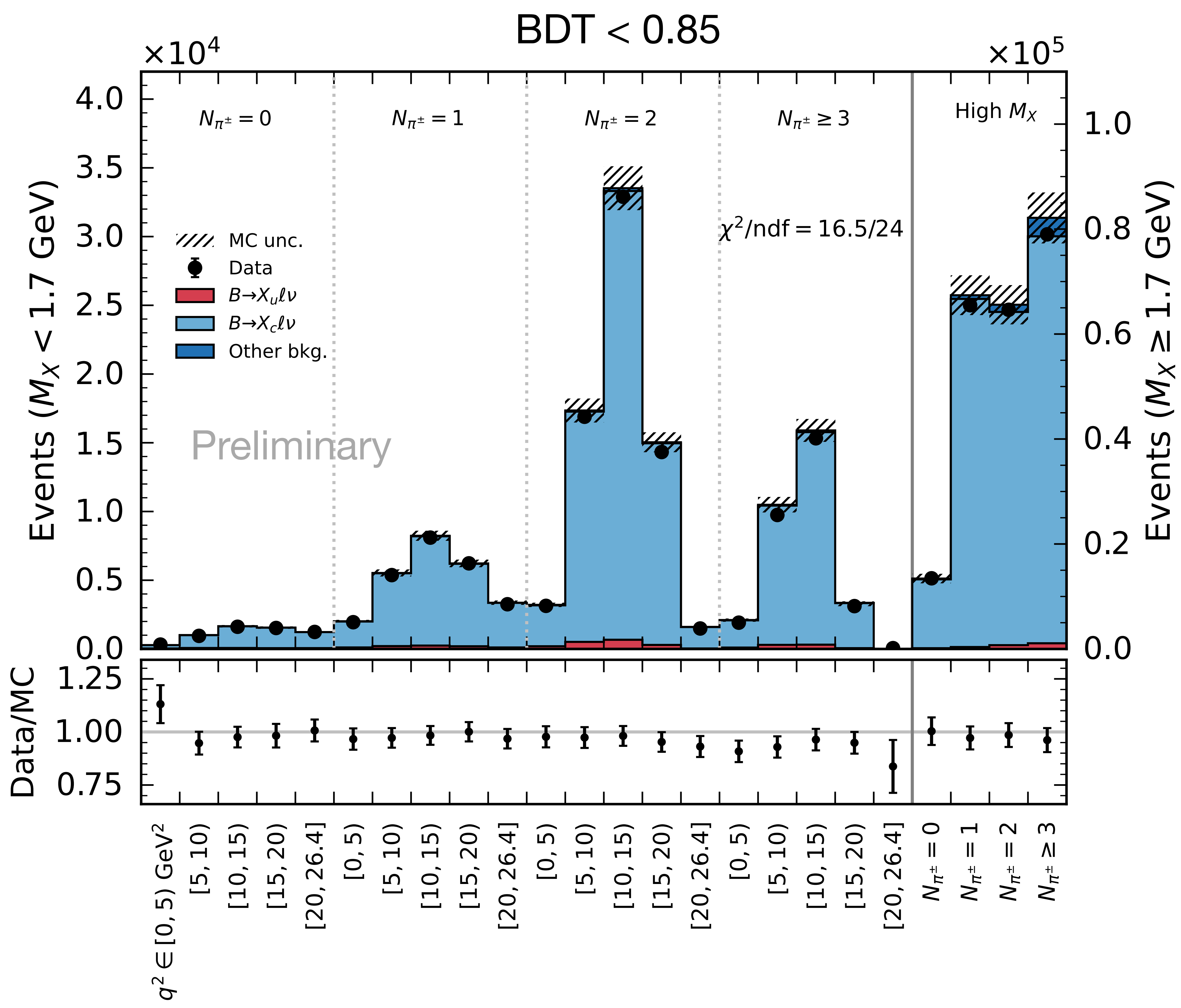


Backup: First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

Preliminary

- Prefit distributions





Backup: First Simultaneous Determination of Incl. & Excl. $|V_{ub}|$

Preliminary

Decay rate as a function of q^2 with fitted BCL para.