Status and Prospects of Belle II

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on behalf of the Belle II collaboration
Belle II Experiment

• Here at KEK Tsukuba campus
  – SuperKEKB accelerator
  – Belle II detector
SuperKEKB Accelerator

- **Highest luminosity collider**
  - \( \mathbf{L}_{\text{target}} = 6 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1} \)

- \( E_{\text{CM}} = 10.58 \text{GeV} \) on \( \Upsilon(4S) \)
  - Just above the \textit{BB} threshold to produce B meson pairs efficiently
  - Can go higher, \( \Upsilon(5S) \) up to 11.24GeV

- **Energy-asymmetric collisions**
  - 7.0GeV \( (e^-) \) x 4.0GeV \( (e^+) \)
  - To boost B mesons to measure time dependent CPV

- 50ab\(^{-1}\) will be accumulated around 2035
  - Containing \( 1 \times 10^{11} \) B mesons, \( 1.4 \times 10^{11} \) charm hadrons, and \( 0.9 \times 10^{11} \) \( \tau \)
  - Processes with cross sections of \( O(1)\text{ab or less} \) are reachable
Belle II Detector

• Significant detector improvements from Belle
  – Better and Larger Vertex Detector ➔ Time dependent CPV, especially with long lived Ks.
  – Two level trigger system ➔ dark sector searches etc.

  KLong and muon detector:
  Resistive Plate Chambers (barrel outer layers)
  Scintillator + WLSF + SiPM’s (end-caps, inner 2 barrel layers)

  EM Calorimeter:
  CsI(Tl), waveform sampling (barrel+ endcap)

  Particle Identification
  TOP detector system (barrel)
  Prox. focusing Aerogel RICH (fwd)

  Beryllium beam pipe
  2cm diameter

  Vertex Detector
  2 layers DEPFET + 4 layers DSSD

  Central Drift Chamber
  He(50%):C₂H₆(50%), small cells, long lever arm, fast electronics (Core element)

  electrons (7 GeV)

  positrons (4 GeV)
Luminosity and Dataset

- June 2022: Run1 operation stopped
  - World’s highest luminosity of \(4.7 \times 10^{34}\) cm\(^{-2}\)s\(^{-1}\)
  - 428 fb\(^{-1}\) data were accumulated so far
    - 362 fb\(^{-1}\) on resonance, 42 fb\(^{-1}\) off-resonance, 19 fb\(^{-1}\) energy scan
    - C.f. Belle collected 1040 fb\(^{-1}\)
Belle II Cons and Pros (vs. LHCb)

• Cons.
  – Statistics of b hadrons!! (cross section 1nb vs. 144μb)
    • We will only have $10^{11}$ B mesons with 50ab$^{-1}$ on Y(4S) and $5 \times 10^8$ $B_s$ with 5ab$^{-1}$ on Y(5S)
  – No large samples of $b$ baryons and $B_c$
    • Production of these hadrons are not yet established at $e^+e^-$ collisions around Y(nS).
  – Proper time resolution is worse and B meson is not so boosted.
    • Background suppression with B vertex displacement is not so easy
    • $B_s$ mixing ($\Delta m_s$) can not be measured (while $\Delta \Gamma_s$ can be measured).
Belle II Cons and Pros (vs. LHCb)

• Pros.
  – Smaller background cross section \((O(1)\text{nb vs. } O(10)\text{mb})\)
    • \(~3.4\text{nb for } \text{ee}\to qq, ~1.08\text{nb for } \text{ee}\to \Upsilon(4S)\to BB\)
  – Almost 100% trigger efficiency for BB events (11 charged + 5 photons in average).
    • Main triggers
      – 3-track || 2-track with opening angle || ECL energy sum >1GeV || ECL # of Clusters >=4
    • Absolute BF measurement possible.
  – Two level trigger system for low multiplicity events
    • Many dark sectors signature \((X+\text{missing})\) can be triggered
  – High hermeticity \(4\pi \times 94\%
    • High reconstruction efficiency of O(1)\sim O(10)\%.
    • Full reconstruction of B meson possible (tagging of the other B meson)
      – More than one missing neutrino modes \(\Rightarrow B\to D^*(\gamma)\tau\nu, B\to \tau\nu, B\to K^*(\gamma)\nu\nu, B\to \pi\tau, B\to \nu\nu\)
    • 4 momentum conservation usable \(\Rightarrow\) dark sector searches
  – Detection of electron
    • Detection efficiency of electron is almost the same as that of muon \(\Rightarrow\) test of LFU
    • Easy to recover bremsstrahlung photon
  – Detection of neutrals
    • reconstruction of \(\gamma, \pi^0\text{ and } Ks\) efficiently \(\Rightarrow\) sum-of-exclusive method for \(B\to Xs\ell^+\ell^-, B\to \pi^0\pi^0, B_{(s)}\to \gamma\gamma\)
    • Better energy resolution of hard \(\gamma\) \(\Rightarrow\) \(B\to K^*\gamma\) background to \(B\to \rho\gamma\) can be suppressed
Rich Physics Program

• Flavor physics
  – B
    • CKM Unitarity Triangle
    • Rare decays
    • Lepton Flavor Universality
    • etc
  – Charm
    • CPV
    • mixing
    • Lifetime
    • etc
  – \( \tau \)
    • Mass
    • Lifetime
    • CPV
    • EDM
    • etc
• QCD
  – Bottomonia, charmonia and exotic hadrons containing heavy quark
  – HVP with radiative return for muon g-2
  – fragmentation
  – etc
• EW
  – Weak mixing angle
  – etc
• Light new particle searches
  – Dark sector mediators
  – etc
• And more
Recent Highlights
CKM Matrix and Unitarity Triangle

• Unitarity condition of CKM Matrix
  – Product of $d$ and $b$ columns
  \[ V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0 \]
  \[ \frac{V_{ub}^* V_{ud}}{V_{cb}^* V_{cd}} + 1 + \frac{V_{tb}^* V_{td}}{V_{cb}^* V_{cd}} = 0 \]

• This draws triangle in complex plain
  – called unitarity triangle (UT)
  – Three angles ($\phi_1, \phi_2, \phi_3$) $\rightarrow$ CP violations
  – Three sides ($|V_{cb}|, |V_{ub}|, |V_{td}|$) $\rightarrow$ Amplitudes

• Test of UT is one of the most important missions at Belle II
  – All angles and sides can be measured only at Belle II

Current status
New Physics Reach with UT

- Search for new physics in $B^0$ mixing
  - Can reach to $O(1000)$ TeV new physics scale
New Physics Reach with UT

- Search for new physics in $B^0$ mixing
  - Can reach to $O(1000)$ TeV new physics scale
  - Improve $\varepsilon_K$ by precise measurement of $|V_{cb}|$
    - $O(10^5)$ TeV
UT Angle $\phi_1$

- Time dependent CPV in $b \to c\bar{c}s$ process

$$\frac{\Gamma(\bar{B}^0 \to f_{CP}; t) - \Gamma(B^0 \to f_{CP}; t)}{\Gamma(B^0 \to f_{CP}; t) + \Gamma(B^0 \to f_{CP}; t)} = S \cdot \sin(\Delta m_d \cdot t) - C \cdot \cos(\Delta m_d \cdot t)$$

$$S = -\xi_{CP} \sin 2\phi_1, \ C=0$$

- Requires proper time difference ($\Delta t$) and flavor tagging information
  - Vertex resolution improved with pixel detector
  - Flavor tagging efficiency improved by 18% with Graph Neural Net
    - (31.68 ± 0.45 ± 0.41) % (old)
    - $\to$ (37.40 ± 0.43 ± 0.34) % (GNN)
Measurement of $\sin 2\phi_1$ in $B \rightarrow J/\psi \, K_s$

- Time dependent CPV in $B \rightarrow J/\psi \, K_s$
  - $S = \sin 2\phi_1 = 0.724 \pm 0.035 \pm 0.014$
  - $C = 0.035 \pm 0.026 \pm 0.012$
- Consistent with current World Average

$HFLAV: S = 0.695 \pm 0.019 \, C = 0.000 \pm 0.020$
$LHCb: \quad S = 0.716 \pm 0.015 \, C = 0.012 \pm 0.012$

$\sin(2\beta) \equiv \sin(2\phi_1)$
Measurement of $\phi_3$

- Utilize an interference between $b\to c$ and $b\to u$, such as $B^+\to D^0K^+$
  - The amplitude ratio is around 0.1
- $D^0$ and $\bar{D}^0$ interfere when decaying to common final states
  - $D\to K^+K^-, Ks\pi^+\pi^-, KsK^{\pm}\pi^{\mp}$
  - Measurement of Direct CPVs and BF ratios
- LHCb gives the best $\phi_3$ results with combination
  - $\phi_3=(63.8\pm3.6)^{\circ}$
  - LHCb-CONF-2022-003
- Combining Belle and Belle II analyses
  - $\phi_3=(78.6\pm7.3)^{\circ}$
- With a several ab$^{-1}$, Belle II can give the competitive result

\begin{tabular}{|c|c|c|c|}
\hline
\textbf{$B$ decay} & \textbf{$D$ decay} & \textbf{Method} & \textbf{Data set (Belle + Belle II)[fb$^{-1}$]} \\
\hline
$B^+\to Dh^+$ & $D\to K^0\pi^+\pi^-$ & BPGSZ & 711 + 128 \\
$B^+\to Dh^+$ & $D\to K^0\pi^+\pi^+$ & BPGSZ & 711 + 0 \\
$B^+\to Dh^+$ & $D\to K^0\pi^+\pi^+$ & GLW & 711 + 189 \\
$B^+\to Dh^+$ & $D\to K^0\pi^+\pi^+$ & ADS & 711 + 0 \\
$B^+\to Dh^+$ & $D\to K^0\pi^+\pi^+$ & GLS & 711 + 362 \\
$B^+\to D^+K^+$ & $D\to K^0\pi^+\pi^+$ & BPGSZ & 605 + 0 \\
$B^+\to D^+K^+$ & $D\to K^0\pi^+\pi^+$ & GLW & 210 + 0 \\
\hline
\end{tabular}

- $\phi_3=(78.6\pm7.3)^{\circ}$

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Preliminary
\[ |V_{cb}| \]

- Measure with semileptonic decays
  - \( b \rightarrow c \ell \nu \)
  - Two techniques: exclusive and inclusive
    - About \( 3\sigma \) difference between exclusive and inclusive measurements
    - Theory \& Experiment \& Lattice QCD?

\[ \text{Diagram showing the decay process} \]
$|V_{cb}|$ in Angular analysis of $B \rightarrow D^* \ell \nu$

- Measure 4D differential decay rate

$$\frac{d^4\Gamma}{d\omega d \cos \theta_{\ell} d \cos \theta_{\ell'}} \propto |V_{cb}|^2 A(w, \cos \theta_{\ell}, \cos \theta_{\ell'}, \chi)$$

- Using BGL and CLN parameterizations with Lattice QCD input at zero recoil $w=1$

  $|V_{cb}|_{\text{BGL}} = (40.57 \pm 0.31 \pm 0.95 \pm 0.58) \times 10^{-3}$

  $|V_{cb}|_{\text{CLN}} = (40.13 \pm 0.27 \pm 0.93 \pm 0.58) \times 10^{-3}$

  - Consistent with WA

  WA values [HFLAV 2021]

  $|V_{cb}|_{\text{excl}} = (39.10 \pm 0.50) \times 10^{-3}$

  - Slightly better agreement with inclusive measurement
Lepton Flavor Universality in B Decays
Lepton Flavor Universality

- SM respects LFU

\[
R(D^{(*)}) = \frac{\mathcal{B}(B \to D^{(*)} \tau \nu_\tau)}{\mathcal{B}(B \to D^{(*)} \ell \nu_\ell)}
\]

\[
R(X) = \frac{\mathcal{B}(B \to X \tau \nu_\tau)}{\mathcal{B}(B \to X \ell \nu_\ell)}
\]

- Deviation from unity for the Ratio only comes from lepton masses

- While new physics such as leptoquark can differ the Ratio from the SM prediction

- Current WA is about 3σ to 4σ deviated from the SM predictions
First Measurement of $R(D^*)$ at Belle II

- **Signal side**
  - Three $D^*$ channels, $D^{*+} \rightarrow D^0 \pi^+/D^{0+}\pi^0$, $D^{*0} \rightarrow D^0 \pi^0$
  - Two leptonic $\tau$ decays, $\tau \rightarrow e\nu\nu$, $\tau \rightarrow \mu\nu\nu$

- **Tag side**
  - Hadronic decays

- **Results**
  \[
  R(D^*) = 0.267 \pm 0.041 \text{ (stat.)} \pm 0.028 \text{ (syst.)}
  \]

- Consistent with both SM and WA

Preliminary $189 \text{ fb}^{-1}$
Measurement of $R(X)$

- First measurement of $R(X)$ at B factory
  - Complementary to exclusive $R(D^{(*)})$

  \[
  R(X) = \frac{\mathcal{B}(B \to X \tau \nu_\tau)}{\mathcal{B}(B \to X \ell \nu_\ell)}
  \]

- Reconstruction
  - Signal $\tau \to e\nu\nu$, $\tau \to \mu\nu\nu$
  - Hadronic tagging

- Use missing mass squared and lepton momentum to isolate signal from $B \to X \ell \nu$ background
  - Template fitting performed

- Result

  \[
  R(X) = 0.228 \pm 0.016 \text{(stat.)} \pm 0.036 \text{(syst.)}
  \]

  - Consistent with SM prediction
  - Major systematics
    - MC statistics, PDF shape, BF of $B \to D^{**} \ell \nu$

Preliminary

$189 fb^{-1}$
Rare B Decays
Time Dependent CPV in $B \rightarrow \eta' K_s$

- $b \rightarrow sqq$ process dominated by QCD penguin
- If measured $S$ is deviated from $\sin^2 \phi_1$, it might be a new physics signal
- Reconstruction
  - $\eta' \rightarrow \eta(\gamma \gamma) \pi^+ \pi^-$
  - $\eta' \rightarrow \rho(\pi^+ \pi^-) \gamma$
- Result
  \[
  S = 0.67 \pm 0.10 \pm 0.04 \\
  C = -0.19 \pm 0.08 \pm 0.03 \\
  \]

  HFLAV: $S = 0.63 \pm 0.06 \quad C = -0.05 \pm 0.04$
  - Consistent with $\sin^2 \phi_1$ and WA
Time Dependent CPV in $B \to K^* \gamma$

- Photon in $b \to s \gamma$ process is predominantly left-handed in SM
- New physics enchases the right-handed photons
- Time dependent CPV in $B \to K^{*0} \gamma$ is sensitive to the photon polarization
- $S^\sim$ in SM while larger value for NP
  \[ S_{K^*(K^0_S \pi^0)}^{SM} = (-2.3 \pm 1.6)\%
  \]
- Reconstruction
  - $B \to (Ks\pi^0)\gamma$
  - Vertex is determined from long lived $K_s$ decaying to $\pi^+\pi^-$ using beam spot constraint
- Result
  - $S = 0.00^{+0.27}_{-0.26} \pm 0.03$
  - $C = 0.10 \pm 0.13 \pm 0.03$
    - HFLAV: $S = -0.16 + 0.22$ $C = -0.04 + 0.14$
  - Consistent with the SM prediction
  - Most precise to date!
$B^+ \rightarrow K^+ \nu \bar{\nu}$

- FCNC process with no charm loop $\leftrightarrow b \rightarrow s l^+ l^-$
- Precise SM prediction
  - $B(B^+ \rightarrow K^+ \nu \bar{\nu}) = (5.58 \pm 0.37) \times 10^{-6}$
- Sensitive to New physics
  - Axion, ALPs, dark scalar, $Z'$, LQ
- Experimentally challenging
  - Only Kaon in the final state $\rightarrow$ Huge backgrounds
  - Analysis performed with $63\,fb^{-1}$
  - Update with $362\,fb^{-1}$

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PRD 107, 014511 (2023)
PRD 107, 119903 (2023)
**B⁺ → K⁺ νν Analysis Methods**

- **Hadronic tagging analysis (HTA)**
  - The other B meson reconstructed with hadronic decays
  - BDT to suppress backgrounds
  - Efficiency 0.4%
  - High purity S/N=7%

- **Inclusive tagging analysis (ITA)**
  - Highest momentum kaon candidate is selected as signal candidate.
  - Charged and neutral particles are collected as rest of events.
  - Two consecutive BDTs are used (BDT₁, BDT₂) to suppress backgrounds
  - High efficiency of 8%
  - Purity S/N=0.8%

- BDT distributions are transformed by flattening the signal component and then are fitted (with \( q^2 \) for ITA) to extract signal
**B⁺→K⁺νν Result**

- First evidence for B⁺→K⁺νν

**HTA and ITA combined**

\[
\mu = 4.7 \pm 1.0\text{(stat)} \pm 0.9\text{(syst)} \\
\mathcal{B}(B^+ \to K^+\nu\bar{\nu}) = [2.4 \pm 0.5\text{(stat)}^{+0.5}_{-0.4}\text{(syst)}] \times 10^{-5}
\]

- 3.6σ from null
- 2.8σ from SM prediction
- When taking the combination, common events are removed from ITA sample (~2% of the total)

**HTA**

\[
\mu = 2.2 \pm 2.3\text{(stat)}^{+1.6}_{-0.7}\text{(syst)} \\
\mathcal{B}(B^+ \to K^+\nu\bar{\nu}) = [1.1^{+0.9}_{-0.8}\text{(stat)}^{+0.8}_{-0.5}\text{(syst)}] \times 10^{-5}
\]

**ITA**

\[
\mu = 5.6 \pm 1.1\text{(stat)}^{+1.1}_{-0.9}\text{(syst)} \\
\mathcal{B}(B^+ \to K^+\nu\bar{\nu}) = 2.8 \pm 0.5\text{(stat)} \pm 0.5\text{(syst)} \times 10^{-5}
\]
FCNC process with $b \to d$ transition

- Isospin violation large?

\[ a_1^0 = \frac{c_2^2}{c_1^2} \left[ \frac{\Gamma(B^0 \to \bar{V}^0 \gamma) - \Gamma(B^- \to V^- \gamma)}{\Gamma(B^0 \to V^0 \gamma) + \Gamma(B^- \to V^- \gamma)} \right] \]

- WA $A_I = (30^{+16}_{-13})\%$

- $\bar{a}_I^{SM}(\rho \gamma) = (5.2 \pm 2.8)\%$

Analysis

- Combination of Belle (711 fb$^{-1}$) and Belle II (362 fb$^{-1}$)
- $B^0 \to \rho^0 \gamma, \ B^+ \to \rho^+ \gamma$
- Large $B \to K^* \gamma$ background is suppressed using PID and $\Delta E$

Results

- $A_I$ is consistent with both SM and WA
- Most precise results to date

\[
BR(\rho^+ \gamma) = (12.87^{+2.02}_{-1.92}^{+1.00}_{-1.17}) \times 10^{-7} \\
BR(\rho^0 \gamma) = (7.45^{+1.33}_{-1.27}^{+1.00}_{-0.80}) \times 10^{-7} \\
A_I = (14.2^{+11.0}_{-11.7}^{+8.9}_{-9.1})\% \\
A_{CP} = (-8.4^{+15.2}_{-15.3}^{+1.3}_{-1.4})\% 
\]
Cham, $\tau$ and Dark Sector
Charm Hadron Lifetime

- Good vertex resolution allows precise measurement of charm hadron lifetime
- Measurements of lifetime improve the understanding of QCD in charm hadron decays

\[ 
\Gamma(D) = \frac{1}{2m_D} \sum_X \int \left( \frac{2\pi}{\mathcal{L}} \right)^4 \mathcal{L} \left( p_D - p_X \right) X(p_X) |\mathcal{H}_{\text{eff}}(D(p_D))|^2, \\
\rightarrow \frac{1}{2m_D} \Im(D|T|D) \text{ where } T = i \int d^4x T \left\{ \mathcal{H}_{\text{eff}}(x), \mathcal{H}_{\text{eff}}(0) \right\} \\
\rightarrow \Gamma_3 + \Gamma_5 \frac{\mathcal{O}_5}{m_c^2} + \Gamma_6 \frac{\mathcal{O}_6}{m_c^3} + \ldots + 16\pi^2 \left( \frac{\mathcal{O}_6}{m_c^2} + \frac{\mathcal{O}_7}{m_c^3} + \ldots \right) 
\]

- Except for \( \Omega_c \), Belle II has made the world’s best precision
  - For \( \Omega_c \), Belle II confirms longer lifetime measured by LHCb
**τ mass**

- Fundamental parameter of the SM
- Crucial for LFU test in τ decays
- Use pseudo-mass technique with $\tau \rightarrow 3\pi\nu$
  \[ M_{\min} = \sqrt{M_{3\pi}^2 + 2(\sqrt{s}/2 - E_{3\pi}^+)(E_{3\pi}^+ - p_{3\pi}^+)} \leq m_\tau. \]
- Result
  \[ m_\tau = 1777.09 \pm 0.08 \pm 0.11 \text{ MeV} \]
  - Dominant uncertainties
    - Beam energy
    - Momentum scale

\[
\left( \frac{g_\mu}{g_e} \right)_\tau = \sqrt{R_\mu \frac{f(m_\mu^2/m_\tau^2)}{f(m_\tau^2/m_\tau^2)}},
\]

\[
R_\mu = \frac{B[\tau^- \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau]}{B[\tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau]}
\]

\[ f(x) = 1 - 8x + 8x^3 - x^4 - 12x^2 \ln x \]
Dark Sector

- $Z'$ in $L_\mu - L_\tau$
  - Gauging the difference of $\mu$ and $\tau$ numbers
  - Might couple to dark sector particles
  - Can explain muon $g-2$ anomaly

- Search for $\text{ee} \rightarrow \mu \mu Z'$ with $Z' \rightarrow \mu \mu$ and invisible decays
  - $Z' \rightarrow \mu \mu$ similar limit with Belle and Babar
    - Exclude almost all region of $M_{Z'} > 2m_\mu$ explaining muon $g-2$
  - Fully invisible $Z'$
    - First exclusion explaining muon $g-2$, $0.8 < M_{Z'} < 4.5$GeV

Preliminary to be submitted to PRD
Near Future Prospects

- June 2022 – Jan 2024: Long Shutdown 1 for SuperKEKB and Belle II upgrades
  - New collimators to reduce beam induced backgrounds which limit beam current
    - → can go higher luminosity
  - Two-layer pixel detector was installed
    - → better vertex resolution under higher beam induced background
  - TOP PMT replacement → better Kaon ID
- Jan 2024: SuperKEKB operation resumed
  - Plan to accumulate more data than Belle in run2
Future Prospects on Physics

- Summarized in Physics Book
  - [https://doi.org/10.1093/ptep/ptz106](https://doi.org/10.1093/ptep/ptz106)
- One example on UT measurements
  - Uncertainty of Sides: \( \sim 1\% \) for \( |V_{cb}| \) and \( |V_{ub}| \)
  - Uncertainty of Angles: 0.2\( \text{deg} \), 0.6\( \text{deg} \), 1.5\( \text{deg} \) for \( \phi_1 \), \( \phi_2 \) and \( \phi_3 \)
  - Should consider
    - \( \phi_1 \): Penguin pollution
    - \( \phi_2 \): isospin breaking effect

Current status

Around 2035

See deviation?
Summary

• Belle II at SuperKEKB has rich physics program
• With a data corresponding to a half of Belle data, world leading and unique physics results are presented

• SuperKEKB operation will resume in Jan 2024
• Belle II will collect more data than Belle in Run2

• Stay tuned
backup
Comparison of $B \rightarrow K \nu \nu$

Privately produced comparison

- **Belle II (362 fb$^{-1}$, Combined)**: $2.4 \pm 0.7$ This analysis, preliminary
- **Belle II (362 fb$^{-1}$, Hadronic)**: $1.1 \pm 1.1$ This analysis, preliminary
- **Belle II (362 fb$^{-1}$, Inclusive)**: $2.8 \pm 0.7$ This analysis, preliminary
- **Belle II (63 fb$^{-1}$, Inclusive)**: $1.9 \pm 1.5$ PRL127, 181802
- **Belle (711 fb$^{-1}$, Semileptonic)(*)**: $1.0 \pm 0.6$ PRD96, 091101
- **Belle (711 fb$^{-1}$, Hadronic)(*)**: $3.9 \pm 1.6$ PRD87, 111103
- **Babar (418 fb$^{-1}$, Combined)**: $0.8 \pm 0.6$ PRD87, 112005
- **Babar (418 fb$^{-1}$, Semileptonic)**: $0.2 \pm 0.8$ PRD87, 112005
- **Babar (429 fb$^{-1}$, Hadronic)**: $1.5 \pm 1.3$ PRD87, 112005