Main Results from Belle II experiment

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On behalf of the Belle and Belle II collaborations

QCD@Work – Trani 17-21 June 2024
The SuperKEKB Collider

Asymmetric $e^+ (4 \text{ GeV})$ $e^- (7 \text{ GeV})$ collider working mainly at Y(4S) @ KEK laboratory, Tsukuba, Japan

Holds world luminosity record: $4.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ (2022)

Aims to exceed $10^{35}$ and to deliver multi ab$^{-1}$ data sample in the next few years

- Delivered 424 fb$^{-1}$ in Run1 (2019-22)
- Maintenance and upgrades during long shutdown 1
- Restarted collision (Run2) in Feb 2024.
• Excellent tracking performances
• 15 μm vertex resolution
• Hermetic detector: full event reconstruction to exploit kinematics constraint
• High photon efficiency (90% above 1.5 GeV momentum)
• Very good lepton ID: ε(μ) ~90% with 7% π mis-ID; ε(e) ~86% with 0.4% π mis-ID
• Kaon ID in full momentum range: ε(K) ~90% with 6% π mis-ID
Belle II and Belle data sample

In Run 1 Belle II has collected 364 fb\(^{-1}\) @ Y(4S) + 60 fb\(^{-1}\) at different c.m. energies. Equivalent to BaBar sample and about half the Belle sample.

Belle data can now be analyzed in Belle II framework. Many analyses use both samples.
\[ \sqrt{s} = m(\Upsilon(4S)) = 10.58 \text{GeV} \approx 2m_B \]

Kinematics constraint can be exploited to separate signals and backgrounds

\( B\bar{B} \) and \( q\bar{q} \) events have quite different event shapes which allow to distinguish between them

\[ s = m_{\Upsilon}^2 = 10.58 \text{GeV} \approx 2m_B \]

\[ s = (m_{\Upsilon} - m_B)^2 \]

\[ \Delta E = F_B^* - \sqrt{s/2} \]

\[ M_{bc} = \sqrt{(\sqrt{s}/2 - p_B^*)^2} \]

\[ \text{Expected } \Delta E \approx 0 \]

\[ \text{Expected } M_{bc} \approx m_B \]

\[ p(B) \approx 0.3 \text{ GeV/c} \]

\[ e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B} \]

\[ p(q) \approx 5 \text{ GeV/c} \]

\[ e^+e^- \rightarrow q\bar{q} \ (q \in \{u,d,s\}) \]
B factory basics/2

- One B meson can be used for tagging the flavour and the other as signal decay mode
- The new tag algorithm GFlaT, based on graph convolutional neural network (GNN) improves by 18% the efficiency with respect to the previous category based (CB) tag [arXiv:2402.17260]

\[ \varepsilon_{\text{tag}}(\text{CB}) = (31.7 \pm 0.5 \pm 0.4) \% \]
\[ \varepsilon_{\text{tag}}(\text{GFlaT}) = (37.40 \pm 0.43 \pm 0.36) \% \]

- Precise vertex reconstruction of both B meson decay allows to make time dependent analysis of CP asymmetries

\[ a_{\text{CPV}}(\Delta t) = \frac{\Gamma_{\bar{B} \to j}(\Delta t) - \Gamma_{\bar{B} \to f}(\Delta t)}{\Gamma_{\bar{B} \to j}(\Delta t) + \Gamma_{\bar{B} \to f}(\Delta t)} = S \sin(\Delta m_d \Delta t) - C \cos(\Delta m_d \Delta t) \]

- \( S \to \) indirect CP
- \( C = -A \to \) direct CP

19/06/2024
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Recent Belle II / Belle highlights

EW-radiative penguins:
- BR, $A_{CP}$ and $\Delta_{+0}$ of $B \to K^* \gamma$
- Search for $B^0 \to \gamma\gamma$
- $b \to d \ell\ell$
- Evidence of $B^+ \to K^+ \nu\bar{\nu}$

Semileptonic decays:
- $V_{ub}$ untagged $B \to \pi/\rho \ell \nu$
- Update of $B \to D^* \ell \nu$

b, c hadronic decays:
- BR of $B^- \to D^0 \rho^-$
- BR and $A_{CP}$ of $B^0 \to \pi^0\pi^0$
- BR of $\Xi^0_c \to \Xi^0\pi^0, \Xi^0\eta, \Xi^0\eta'$
- $\gamma$ angle Belle+Belle II determination

Low multiplicity and $\tau$
- $\sigma(e^+e^- \to \pi^+\pi^-\pi^0)$
- LFU in $\tau$ decays
- $\tau \to \mu\mu\mu$

Time dependent CPV:
- $B^0 \to \eta' K_S$
- $B^0 \to K_S \pi^0 \gamma$
- $B^0 \to J/\psi K_S$ using Gflat tag

Quarkonia and spectroscopy:
- $Y(10753)$ rediscovery
- Search $Y(10753) \to \omega \eta_b(1S)/\chi_{b0}(1P)$
- Energy dependence of $e^+e^- \to B^{(*)}\bar{B}^{(*)}$

Will briefly present the bold typed ones

Impressive result production rate in 2023-24:

29 published or accepted journal papers + 11 submitted and being reviewed (18 months! More than 2 paper per month on average!)

More than 15 new results targeting ICHEP 2024!
B hadronic decays
Branching fractions of $B^+ \rightarrow D^0 \rho(770)^+$

- $B^+ \rightarrow D^0 \rho^+$: test heavy-quark limit and factorisation models \cite{Nucl. Phys. B591, 313 (2000)}
- WA BF: $(1.35 \pm 0.18)\%$; driven by old CLEO measurement \cite{CLEO, PRD 50, 43 (1994)}
  - Very large $(14 \%)$ uncertainty
- Signal extracted from fit to $\Delta E$
- Challenge: separate $B \rightarrow D^0 \rho(\rightarrow \pi^+\pi^0)$ and non-resonant $B \rightarrow D^0 \pi^+\pi^0$ component
  - Fit performed in bins of helicity angle ($\cos \theta_\rho$)

$$\mathcal{B}(B^+ \rightarrow D^0 \rho^+) = (0.939 \pm 0.021 \pm 0.050) \%$$

2xbetter than previous world best
Systematically limited by $\pi^0$ efficiency accuracy
Result very useful to improve hadronic tag in missing energy channels
$B \rightarrow \pi^0\pi^0$

Previous result [PRD107 (2023) 112009] updated with full Run 1 statistics, new flavour tag (Gflat) and reduction of systematic uncertainties

- Bkg mostly from continuum and $B^+ \rightarrow \rho^+\pi^0$; $B^0 \rightarrow K_S\pi^0$
- Photons selected with BDT, continuum suppression trained on off-resonance data
- Extract signal by simultaneous fit to $\Delta E$, $M_{bc'}$, continuum variable, wrong tag probability

$\text{BR} = (1.26 \pm 0.20 \pm 0.11) \times 10^{-6}$
$A_{CP} = 0.06 \pm 0.30 \pm 0.06$

BR world best, $A_{CP}$ same as world best
Belle + Belle II determination of $\phi_3/\gamma$ angle

- SM benchmark: very reliably predicted ($10^{-7}$ relative)
- Tree level decays: no large BSM
- Access via interfering decays to same final state
- D decay strong phase from Cleo-c and BESIII

Several methods used:
- GLW $B^\pm \rightarrow D^0_{CP}K^{\pm}$ arXiv:2308.05048 [hep-ex]
  Use CP eigenstate of D meson
- ADS PRL 78 (1997) 3257
  Enhancement of CP violation by using doubly Cabibbo suppressed decays.
- BPGGSZ $D^0 \rightarrow K_S h^+ h^-$ JHEP 2022(2022), 63
  Different amplitude and strong phase in different region of Dalitz plot.
- GLS $D^0 \rightarrow K_S K\pi$ JHEP 09(2023)146

$r_B$ and $\delta_B$ are mode dependent
Belle + Belle II determination of $\phi_3/\gamma$ angle

<table>
<thead>
<tr>
<th>$B$ decay</th>
<th>$D$ decay</th>
<th>Method</th>
<th>Data set (Belle + Belle II) [fb$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^+ \rightarrow D h^+$</td>
<td>$D \rightarrow K_S^0 h^- h^+$</td>
<td>BPGGSZ</td>
<td>711 + 128</td>
</tr>
<tr>
<td>$B^+ \rightarrow D h^+$</td>
<td>$D \rightarrow K_S^0 \pi^- \pi^+ \pi^0$</td>
<td>BPGGSZ</td>
<td>711 + 0</td>
</tr>
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<td>$D \rightarrow K_S^0 \pi^- \pi^+ \pi^- \pi^0$</td>
<td>GLW</td>
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<tr>
<td>$B^+ \rightarrow D h^+$</td>
<td>$D \rightarrow K^+ \pi^-, K^+ \pi^- \pi^0$</td>
<td>ADS</td>
<td>711 + 0</td>
</tr>
<tr>
<td>$B^+ \rightarrow D h^+$</td>
<td>$D \rightarrow K_S^0 K^- \pi^+$</td>
<td>GLS</td>
<td>711 + 362</td>
</tr>
<tr>
<td>$B^+ \rightarrow D^* K^+$</td>
<td>$D \rightarrow K_S^0 \pi^- \pi^+$</td>
<td>BPGGSZ</td>
<td>605 + 0</td>
</tr>
<tr>
<td>$B^+ \rightarrow D^* K^+$</td>
<td>$D \rightarrow K_S^0 \pi^0, K_S^0 \phi, K_S^0 \omega$,</td>
<td>GLW</td>
<td>210+0</td>
</tr>
</tbody>
</table>

Result compatible with HFLAV WA: $\phi_3/\gamma \ (^\circ) = 66.2^{+3.4}_{-3.6}$

Valuable single experiment determination.

First combination of all Belle+ Belle II $\phi_3$ measurements:

Likelihood with 60 input observables, including 15 auxiliary inputs (D-decay), 16 free parameters

$\phi_3 = (78.6 \pm 7.3)^\circ$
Time dependent CP violation

\[ \Delta z = \beta \gamma c \Delta t \]

\[ \Delta t = t_{CP} - t_{tag} \]
A gluonic penguin: $B^0 \rightarrow \eta' K_S$

Two $\eta'$ decay modes are reconstructed:

$\eta' \rightarrow \eta\pi\pi$ ($\eta \rightarrow \gamma\gamma$) and $\eta' \rightarrow \rho\gamma$

Signal extracted via fit to $\Delta E$, $M_{bc}$ and continuum suppression BDT output

- Bkg $\Delta t$ shape from sidebands
- BKG asymmetry included in the fit
- Validation on control sample $B^+ \rightarrow \eta'K^+$

\[ S = 0.67 \pm 0.20 \pm 0.04 \]
\[ C = -0.19 \pm 0.08 \pm 0.03 \]

HFLAV: $S = 0.63 \pm 0.06$, $C = -0.05 \pm 0.04$

Precision comparable with Belle/BaBar
$B^0 \rightarrow K_S \pi^0 \gamma$

Expected to have small mixing induced CPV in SM, due to helicity suppression of $b \rightarrow s \gamma_R$

($b \rightarrow s \gamma_L$ and $\bar{b} \rightarrow s \gamma_R$) → Sensitive to NP

- B vertex with no prompt tracks reconstructed from $K_S \rightarrow \pi^+\pi^-$ with beam spot constraint
- Reconstructed separately for resonant channel $K^* \rightarrow K_S \pi^0$ and non resonant $K_S \pi^0$
- Signal extraction from combined fit to $\Delta E$ and $M_{bc}$

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![Graphs showing $\Delta E$ distributions for resonant and non-resonant channels](image-url)
$B^0 \rightarrow K_S \pi^0 \gamma$

Time dependent fit:

resonant

non resonant

World’s best result despite lower statistics, thanks to better acceptance and bkg suppression
B semileptonic decays
|V_{ub}| from B^0 \to \pi \ell \nu and B^+ \to \rho^0 \ell^+ \nu

Untagged reconstruction with full Run 1 statistics

- Build up BDT discriminator to suppress B \to X_c \ell \nu and continuum
- Require kinematical consistency of rest of event with B decay
- Require p_l^* (\pi) > 1 GeV and p_l^* (\rho) > 1.4 GeV

Extract signal yields by combined fit to \Delta E, M_{bc} in 13 bins (\pi mode) + 10 bins (\rho mode) of q^2 (defined as (p_B - p_{\pi,\rho})^2)

Consistent with WA

\[ B(B^0 \to \pi^+\ell\nu) = (1.516 \pm 0.042 \pm 0.059) \times 10^{-4} \]
\[ B(B^+ \to \rho^0\ell\nu) = (1.625 \pm 0.079 \pm 0.180) \times 10^{-4} \]

Leading systematic are the modelling of continuum and non-resonant B \to X_u \ell \nu decays
$|V_{ub}|$ from $B^0 \to \pi \ell \nu$ and $B^+ \to \rho^0 \ell^+ \nu$

$|V_{ub}|$ extracted by fitting $\text{BR}(q^2)$ assuming FF parametrization (BCL for $\pi$, BSZ for $\rho$) and lattice or light cone sum rules calculations (*).

$B^0 \to \pi^+ l^- \nu$ with LCQD

$B^0 \to \pi^+ l^- \nu$ with LCQD + LCSR

$B^+ \to \rho^0 l^+ \nu$ with LCSR

(*): References in the backup material
New LFU limits: $R(D^*)$  

\[
R(D^*) = \frac{B(B \rightarrow D^* \tau \nu)}{B(B \rightarrow D^* e \nu)}
\]

Extract $R(D^*)$ from 2D fit to missing mass squared and residual energy in ECL

\[
R(D^*) = 0.262 \pm 0.041 \text{(stat)} \pm 0.035 \text{(syst)}.
\]

- Result consistent both with SM and WA  
- Statistical error comparable to Belle. Systematics dominated by MC stat and PDF shapes  
- Analysis to be extended to full Run 1 dataset. $R(D)$ analysis also ongoing

19/06/20

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Electroweak and radiative penguins
Evidence for $B^+ \rightarrow K^+ \nu \nu$

- Reliable SM prediction, never observed before, possibly affected by NP (ALPs, dark scalars, $Z'$, leptoquarks...)
- Experimentally challenging for the 2 neutrinos in the final state
- Use two complementary B tag approach: low purity-high efficiency (0.8% - 8%) and its opposite (3.5% - 0.4%)

- Event selection by combining signal kaon, event topology, rest-of-event info in MVA classifiers
- Background from continuum, semileptonic $B$ decays, $B^+ \rightarrow K^+ n\bar{n}$, $B^+ \rightarrow K^+ K^0 \bar{K}^0$, pion fakes, $B \rightarrow X_c(\rightarrow K_L + X)$
- Signal efficiency and bkg estimation corrected and validated using a variety of control channels
- Closure test by measuring $BF(B^+ \rightarrow \pi^+ K^0)$
Evidence for $B^+ \rightarrow K^+ \nu \nu$

Perform binned maximum likelihood fit
- Inclusive tag: in bins of $q^2$ and classifier output
- Hadronic tag: in bins of classifier output

**ITA**

$$BF = (2.7 \pm 0.5 \pm 0.5) \times 10^{-5}$$

**HTA**

$$BF = (1.1^{+0.9+0.8}_{-0.8-0.5}) \times 10^{-5}$$

Combined: $BF = (2.3 \pm 0.5^{+0.5}_{-0.4}) \times 10^{-5}$

3.5 $\sigma$ excess, 2.7 $\sigma$ from SM

**Belle quotes only upper limits:** we calculated BF ourselves

Home cooked comparison

Belle quotes only upper limits: we calculated BF ourselves
A radiative penguin: $B^{(0,+)} \rightarrow K^{*(0,+)} \gamma$

- Reconstruct $K^* \rightarrow K^+ \pi^-, K_S^0 \pi^0, K^+ \pi^0, K_S^0 \pi^+$
- Classifiers to reject boosted photons from asymmetric $\pi^0 \rightarrow \gamma \gamma$ and $\eta \rightarrow \gamma \gamma$ decays, and continuum events
- Fit to $M_{bc}$ and $\Delta E$ to extract yields

$B[\bar{B}^0 \rightarrow K^{*0} \gamma] = (4.16 \pm 0.10 \pm 0.11) \times 10^{-5}$,
$B[B^+ \rightarrow K^{*+} \gamma] = (4.04 \pm 0.13 \pm 0.13) \times 10^{-5}$,
$\mathcal{A}_{CP}[\bar{B}^0 \rightarrow K^{*0} \gamma] = (-3.2 \pm 2.4 \pm 0.4)\%$,
$\mathcal{A}_{CP}[B^+ \rightarrow K^{*+} \gamma] = (-1.0 \pm 3.0 \pm 0.6)\%$,
$\Delta \mathcal{A}_{CP} = (2.2 \pm 3.8 \pm 0.7)\%$, and
$\Delta_{0+} = (5.1 \pm 2.0 \pm 1.5)\%$

- Consistent with WA and SM
- Similar sensitivity as Belle despite smaller sample (thanks mainly to improved $\Delta E$ resolution, $K^0_S$ efficiency and continuum suppression)
- Asymmetries statistically limited
Tau physics and low multiplicity
New LFU limits: $R_\mu$

- Signal side: $e$ or $\mu$
- Tag side: 1 charged hadron + ≥1 $\pi^0$
- Background suppression via NN
- 94% purity, 9.6% efficiency

$R_\mu$ obtained by binned ML fit to lepton momentum distribution.
Main systematics from PID (0.32%) and trigger (0.10%)

$R_\mu = 0.9675 \pm 0.0007$ (stat.) ± 0.0036 (sys.) and $|g_\mu/g_e|_\tau = 0.9974 \pm 0.0019$

- Most precise test of $\mu$-$e$ universality in $\tau$ decays
- Consistent with SM at 1.4$\sigma$
Limit on $\tau \to \mu\mu\mu$

**Signal side:** 3 muons

**Tag side:** up to 3 tracks
- Background reduction by BDT
- 2D signal region: $\varepsilon = 20.42\%$ x3 larger than Belle
- Expected Bckgr 0.5 events (estimated from sidebands) $\rightarrow 1$ event observed in signal region.

- **No significant excess found in 424 fb$^{-1}$ data sample**
- **Most stringent limit** on BR($t \to \mu\mu\mu$) at 90% CL: $1.9 \times 10^{-8}$

Better limit with smaller dataset thanks to the more inclusive tag technique (includes 3-prong vs only 1-prong)

<table>
<thead>
<tr>
<th></th>
<th>UL at 90% CL on $B(\tau \to 3\mu)$</th>
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<tbody>
<tr>
<td>Belle</td>
<td>$2.1 \times 10^{-8}$ ($\mathcal{L}_{\text{int}} = 782$ fb$^{-1}$)</td>
</tr>
<tr>
<td>BaBar</td>
<td>$3.3 \times 10^{-8}$ ($\mathcal{L}_{\text{int}} = 468$ fb$^{-1}$)</td>
</tr>
<tr>
<td>CMS</td>
<td>$2.9 \times 10^{-8}$ ($\mathcal{L}_{\text{int}} = 131$ fb$^{-1}$)</td>
</tr>
<tr>
<td>LHCb</td>
<td>$4.6 \times 10^{-8}$ ($\mathcal{L}_{\text{int}} = 2.0$ fb$^{-1}$)</td>
</tr>
<tr>
<td>Belle II</td>
<td>$1.9 \times 10^{-8}$ ($\mathcal{L}_{\text{int}} = 424$ fb$^{-1}$)</td>
</tr>
</tbody>
</table>
\[ \sigma \left( e^+e^- \rightarrow \pi^+ \pi^- \pi^0 \right) \]

Is the second largest contribution to HVP below 1 GeV.

HVP produces the largest uncertainty in the prediction of the muon \((g-2)\).

Measured at Belle II exploiting \(e^+e^- \rightarrow \pi^+ \pi^- \pi^0 \gamma_{ISR}\)

\(\rightarrow\) Scan the region \(0.7 < \sqrt{s} < 3.5\) GeV by \(\gamma_{ISR}\) reconstruction

- Used a 191 fb\(^{-1}\) sample
- Kinematic fit with beam momentum constraint to suppress background
- Signal efficiency from 9.2% (low energy) to 6.3% (high energy)
- Control samples to measure residual background
\[ \sigma \left( e^+ e^- \rightarrow \pi^+ \pi^- \pi^0 \right) \]

\( \pi^0 \) reconstruction efficiency measured from \( \omega \) resonance decays

\[ \varepsilon_{\pi^0} = \frac{N(\text{Full reconstruction of } \gamma_{ISR} \pi^+ \pi^- \pi^0)}{N(\text{Partial reconstruction of } \gamma_{ISR} \pi^+ \pi^-)} \]

1% accuracy reached
Main contribution to the systematics.
Not yet competitive with BaBar

Integrate over 3\( \pi \) cross section from 0.62 – 1.8 GeV (Preliminary):

\[ a_{\mu, 0.62-1.8}^{3\pi} \times 10^{10} = 48.91 \pm 0.23_{\text{stat.}} \pm 1.07_{\text{syst.}} \]

6.7% or 2.5\( \sigma \) higher than current global average, obtained from BABAR, CMD-2 and SND

\( \rightarrow \) Slightly smaller \( a_\mu \) anomaly

Leading systematics are \( \pi^0 \) efficiency and missing NNLO in generator
Quarkonium and spectroscopy
Rediscovery of $\Upsilon(10753)$

A new energy scan performed by Belle II to fill gaps in previous Belle scan, for a total integrated luminosity of 19 fb$^{-1}$

Observation of $\Upsilon(10753)$ in agreement with Belle results

$M(\Upsilon(10753)) = 10756.6 \pm 2.7 \pm 0.9 \text{ MeV}/c^2$

$\Gamma(\Upsilon(10753)) = 29.0 \pm 8.8 \pm 1.2 \text{ MeV}/c^2$

No signals of intermediate $Z'_b (10610/10650)$ resonances observed

arxiv:2401.12021
Search for $\text{Y}(10753) \rightarrow \omega \, \eta_{b}(1S)/\chi_{b0}(1P)$

$\text{Y}(10753)$ tetraquark interpretation predicts a strong transition to $\omega \, \eta_{b}(1S)$ compared to those into $\text{Y}\pi^{+}\pi^{-}$ [Chin. Phys. C 43, 123102 (2019)]

Reconstruct $\omega \rightarrow \pi^{+}\pi^{-}\pi^{0}$ and look for a peak in the recoil mass distribution

\[ \sigma(e^+e^- \rightarrow \omega \chi_{b0}(1S)) < 7.8 \text{ pb} \ (*) \]
\[ \sigma(e^+e^- \rightarrow \omega \eta_{b}(1S)) < 2.5 \text{ pb} \]

No significant signals observed $\rightarrow$ Tetraquark model is not supported

(*) obtained by averaging the result of this analysis with the previously published one

Phys. Rev. Lett. 130, 091902
Conclusions

Belle II and Belle hold a unique data sample from which a number of interesting measurement has been already performed in different fields, such as: Evidence for $B^+ \rightarrow K^+ \nu \nu$, test of $\mu$-e universality in $\tau$ decays, new limit on $\tau \rightarrow \mu\mu\mu$ decays, $|V_{ub}|$ exclusive measurement, $B \rightarrow \pi^0\pi^0$ decay.

Many more measurement are in progress.

Belle II has restarted collecting data for its Run 2, in close collaboration with the SuperKEKB team, aiming to significative increase of its data sample in the next few years.
SPARES
\[ \mathcal{B}(B^0 \to \pi^+\pi^-) = (5.83 \pm 0.22 \pm 0.17) \times 10^{-6} \]

world’s best

\[ \mathcal{B}(\pi^+\pi^0) = (5.10 \pm 0.29 \pm 0.32) \times 10^{-6} \]

\[ A_{CP}(\pi^+\pi^0) = -0.081 \pm 0.054 \pm 0.008 \]

- Compatible and competitive with WA
- Modes with \( \pi^0 \) limited by \( \pi^0 \) systematics: will be reduced with more data
Simultaneously extract signals in 2D grid of beam-constrained mass and energy difference for each bin of: 13 bins for mode, 10 bins for mode.

- Cross-feed signals are linked in two modes
- Dominant backgrounds are from $B \rightarrow X_c \ell \nu$ decays and continuum.
Form Factor parametrization and theory inputs for $|V_{ub}|$ extraction

<table>
<thead>
<tr>
<th></th>
<th>$B^0 \rightarrow \pi^+ l^- \bar{\nu}_l$</th>
<th>$B^- \rightarrow \rho^0 l^- \bar{\nu}_l$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form factor param.</strong></td>
<td>Bourrely-Caprini-Lellouch (BCL)</td>
<td>Bharucha-Straub-Zwicky (BSZ)</td>
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<td></td>
<td>LQCD + LCSR JHEP (2021) <strong>36</strong></td>
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</table>
The obtained cross sections at four energies are consistent with the Belle results.

$\sigma(e^+e^- \to B^*\bar{B}^*)$ increases rapidly above $B^*\bar{B}^*$ threshold

Similar phenomenon was observed near $D^*D^*$ threshold.

Possible interpretation: resonance or bound state ($B^*\bar{B}^*$ or $b\bar{b}$) near $B^*\bar{B}^*$ threshold

Inelastic channels [$\pi^+\pi^-\Upsilon(nS)$ and $\eta h_b(1P)$] could also be enhanced. Need more data to study these transitions.