$b \rightarrow s\nu\bar{\nu}$ at Belle II

Anomalies and Precision in the Belle II Era
September 6-8, 2021

Filippo Dattola, on behalf of the Belle II Collaboration
$b \rightarrow s\nu\bar{v}$ transitions
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In the Standard Model (SM):
$b \to s\nu\bar{\nu}$ transitions

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- flavour-changing neutral-current transitions (FCNCs);
- can occur only at the loop level, highly suppressed;
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\text{BR}(B \rightarrow K^{*} \nu \bar{\nu})_{SM} = (8.4 \pm 1.5) \times 10^{-6}
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[T. Blake, et al., Prog. Part. Nucl. Phys. 92, 50 (2017)]
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![Diagram](image)

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To constrain scenarios beyond the SM:

- Dark matter [PRD 98, 055003 (2018)];
- Leptoquarks [PRD 102, 015023 (2020)];
- Axions [PRD 101, 095006 (2020)].
$b \to s\nu\bar{\nu}$ transitions

Challenging measurements:
$b \to s \nu \bar{\nu}$ transitions

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Challenging measurements:

• decays with 2 neutrinos in the final state leaving no signature in the detector;

• can be measured at $B$ factories like Belle II because of the clean event environment and the well defined initial state.
Search for $B^+ \to K^+ \nu \bar{\nu}$ decays using an inclusive tagging method at Belle II

Previous searches for $B^+ \rightarrow K^+ \nu \bar{\nu}$
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$e^- \rightarrow \Upsilon(4S) \leftrightarrow e^+$

Hadronic reconstruction:
$B^\pm_{\text{tag}} \rightarrow \text{hadrons}$

OR
Semileptonic reconstruction:
$B^\pm_{\text{tag}} \rightarrow D^{(*)} l \nu_l$

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Previous searches for $B^+ \rightarrow K^+\nu\bar{\nu}$

The previous studies all adopted an explicit reconstruction of the $B_{\text{tag}}$ followed by the signal reconstruction.
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The previous studies all adopted an explicit reconstruction of the $B_{tag}$ followed by the signal reconstruction.

Low reconstruction efficiency because of the low tag-reconstruction efficiency:

- hadronic tagging $\epsilon_{sig} \cdot \epsilon_{tag} \sim 0.04\%$
- semileptonic tagging $\epsilon_{sig} \cdot \epsilon_{tag} \sim 0.2\%$

$e^- \to \Upsilon(4S) \leftarrow e^+$

- Hadronic reconstruction: $B_{tag}^\pm \to \text{hadrons}$
- OR
- Semileptonic reconstruction: $B_{tag}^\pm \to D^{(*)}\nu_l$
Previous searches for $B^+ \rightarrow K^+ \bar{\nu}\nu$

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Upper limits on the branching ratios were set:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Year</th>
<th>Observed limit on BR($B^+ \rightarrow K^+ \bar{\nu}\nu$)</th>
<th>Approach</th>
<th>Data [fb$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BABAR</td>
<td>2013</td>
<td>$&lt; 1.6 \times 10^{-5}$ [Phys.Rev.D87,112005]\</td>
<td>SL + Had tagging</td>
<td>429</td>
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<tr>
<td>Belle</td>
<td>2013</td>
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<tr>
<td>Belle</td>
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Luminosity and data sample at Belle II
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- Data used in the analysis collected in 2019-2020 (summer):
  - 63 fb$^{-1}$ of data collected at $\sqrt{s} \to \Upsilon(4S)$ resonance $\sim 68$ million $B\bar{B}$ pairs.
  - 9 fb$^{-1}$ of (off-resonance) data collected 60 MeV below the $\Upsilon(4S)$ resonance for background studies.
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- \(\sim 213\) fb$^{-1}$ of data collected before the summer 2021 shutdown.

Phase III data
The inclusive tagging
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The idea
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- Signal reconstructed as the highest $p_T$ track (correct match $\sim 80\%$)
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\[ e^− \rightarrow Υ(4S) \leftarrow e^+ \]

$B_{\text{sig}}^\pm$

Highest $p_T$ track
The inclusive tagging

The idea

- **Signal reconstructed as the highest** $p_T$ **track** (correct match $\sim 80\%$) **followed by** inclusive reconstruction of the **rest of the event** (ROE).

\[ e^- \rightarrow \Upsilon(4S) \leftarrow e^+ \]

\[ B_{\text{sig}}^\pm \]

[Diagram: Belle II plot showing distribution of $p_T(K^+)$ with categories such as $\tau\bar{\tau}$, Neutral B, Charged B, $c\bar{c}$, $s\bar{s}$, $u\bar{u}$, $d\bar{d}$, $B^+ \rightarrow K^+\nu\bar{\nu}$, and an annotation for Exp 8, Run 3123.]

**ROE:**

remaining tracks and clusters
The inclusive tagging

The idea

- **Signal reconstructed as the highest** $p_T$ track (**correct match ~ 80%**) followed by inclusive reconstruction of the rest of the event (ROE).

For most background events the ROE consists of a wrong/too large combination of charged tracks/photons, while for the signal some objects can be missing.
The inclusive tagging

The idea

- **Signal reconstructed as the highest** $p_T$ **track** (correct match $\sim 80\%$) **followed by inclusive reconstruction of the rest of the event (ROE).**

- **Higher signal efficiency** (up to $\epsilon_{\text{sig}} \sim 4\%$ in the signal region) but larger background contributions from generic B decays and continuum ($u\bar{u}, d\bar{d}, c\bar{c}, s\bar{s}$).

\[ e^- \rightarrow \Upsilon(4S) \leftarrow e^+ \]

\[ B^\pm_{\text{sig}} \]

ROE: remaining tracks and clusters

For most background events the ROE consists of a wrong/too large combination of charged tracks/photons, while for the signal some objects can be missing.
Features of $B^+ \rightarrow K^+ \nu \bar{\nu}$
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Signal identification exploiting topological features of $B^+ \rightarrow K^+\nu\bar{\nu}$
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- For example the event shape:

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\begin{align*}
B\bar{B} & \quad B(\rightarrow K\nu\bar{\nu})\bar{B} & \quad q\bar{q}
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- For example the event shape:
  
  $B\bar{B} \quad B(\rightarrow K\nu\bar{\nu})\bar{B} \quad q\bar{q}$

- But also:
  - other variables related to the event features;
  - variables related to the kinematics of the signal $K$ candidate;
  - variables related to the ROE;
  - variables related to the $D^0/D^+$ suppression.
Features of $B^+ \rightarrow K^+ \nu \bar{\nu}$
Features of $B^+ \rightarrow K^+ \nu \overline{\nu}$

- Variables related to the event topology.
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- Variables related to the event topology.

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Multivariate classification
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- train BDT\textsubscript{1} on 1.6M signal events and
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• train BDT$_2$ - same features - on the events with BDT$_1 > 0.9$ among 100 fb$^{-1}$ events of generic background and 1.6M events of signal:
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  (+10%, up to ~50%)
  IN THE HIGH PURITY REGION
  (+35% purity at 4% signal eff.)
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Filippo Dattola | $b \rightarrow s \nu \bar{\nu}$ at Belle II
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Validation using \( B^+ \to K^+ J/\psi \to \mu^+ \mu^- \)

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Excellent Data-MC agreement for the BDT’s.
Validation using off-resonance data
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Investigation of the Data-MC agreement between simulated continuum and off-resonance data in CR2-CR3.
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Investigation of the Data-MC agreement between simulated continuum and off-resonance data in CR2-CR3.

1D projection of 2D CR2-CR3

Regions = \{SR, CR1, CR2, CR3\}

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Validation using off-resonance data


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Fit procedure
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Extended Maximum Likelihood Binned Fit:
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\[\begin{array}{c|c|c|c}
   & 10 & 11 & 12 \\
\hline
0.99 & 7 & 8 & 9 \\
\hline
0.97 & 4 & 5 & 6 \\
\hline
0.95 & 1 & 2 & 3 \\
\hline
0.93 & & & \\
\end{array}\]
Fit procedure

Extended Maximum Likelihood Binned Fit:

\[ f(n, a | \eta, \chi) = \]

\( \eta = \) parameter of interest
\( \chi = \) nuisance parameters

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Extended Maximum Likelihood Binned Fit:

\[ f(n, a \mid \eta, \chi) = \prod_{r \in \text{regions}} \prod_{b \in \text{bins}} \text{Pois}(n_{rb} \mid \nu_{rb}(\eta, \chi)) \]

Simultaneous measurements of multiple regions

\( \eta \) = parameter of interest
\( \chi \) = nuisance parameters

Regions = \{SR, CR1, CR2, CR3\}

\[
\begin{array}{ccc}
10 & 11 & 12 \\
7 & 8 & 9 \\
4 & 5 & 6 \\
1 & 2 & 3 \\
\end{array}
\]
Fit procedure

Extended Maximum Likelihood Binned Fit:

$$f(n, a | \eta, \chi) = \prod_{r \in \text{regions}} \prod_{b \in \text{bins}} \text{Pois}(n_{rb} | \nu_{rb}(\eta, \chi)) \prod_{\chi} c_{\chi}(a_{\chi} | \chi)$$

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\]

Simultaneous measurements of multiple regions

\[\eta = \text{parameter of interest}\]
\[\chi = \text{nuisance parameters}\]

- Templates for bkg’s and signal yields from simulation.

- **Systematic uncertainties** (normalisations of bkg’s yields, BR of the leading B-decays, PID correction, ...) as (175) nuisance parameters: event count modifiers.

- 1 parameter of interest: signal strength \(\mu\): multiplicative factor with respect to the SM expectation.

---

**Regions** = \{SR, CR1, CR2, CR3\}

<table>
<thead>
<tr>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

\[p_T(K^+) [\text{GeV/c}]\]

\[\mu = 1 \rightarrow \text{SM BF} = 4.6 \times 10^{-6}\]
Fit to the Data
Fit to the Data

- Measured signal strength $\mu$
Fit to the Data

- Measured signal strength $\mu$

\[
\mu = 4.2^{+2.9}_{-2.8} \text{ (stat)}^{+1.8}_{-1.6} \text{ (syst)} = 4.2^{+3.4}_{-3.2}
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\[
\text{BR}(B^+ \to K^+ \nu \bar{\nu}) = 1.9^{+1.3}_{-1.3} \text{ (stat)}^{+0.8}_{-0.7} \text{ (syst)} \times 10^{-5} = 1.9^{+1.6}_{-1.5} \times 10^{-5}
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- Consistent with the SM expectation ($\mu = 1$) at $\text{CL} = 1\sigma$. 

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Fit to the Data

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- Consistent with the bkg-only hypothesis ($\mu = 0$) at CL = $1.3\sigma$. 
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![CLs upper limit scan graph](image-url)
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- **Data vs post-fit predictions in CR1 + SR**
Fit to the Data

- Measured signal strength $\mu$

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- Signal efficiency (in the signal region SR)

Integrated efficiency in the SM $q^2$ spectrum = 4.3%
Measurement summary...
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- This measurement represents the **first search for** $B^+ \rightarrow K^+ \nu \bar{\nu}$ **performed with an inclusive tagging** and the **first measurement using Belle II in its nominal configuration.**
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<table>
<thead>
<tr>
<th>Experiment</th>
<th>Year</th>
<th>Observed limit on $\text{BR}(B^+ \rightarrow K^+ \nu \bar{\nu})$</th>
<th>Approach</th>
<th>Data [fb$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BABAR</td>
<td>2013</td>
<td>&lt; $1.6 \times 10^{-5}$ \cite{PhysRevD87,112005}</td>
<td>SL + Had tagging</td>
<td>429</td>
</tr>
<tr>
<td>Belle</td>
<td>2013</td>
<td>&lt; $5.5 \times 10^{-5}$ \cite{PhysRevD87,111103(R)}</td>
<td>Had tagging</td>
<td>711</td>
</tr>
<tr>
<td>Belle</td>
<td>2017</td>
<td>&lt; $1.9 \times 10^{-5}$ \cite{PhysRevD96,091101(R)}</td>
<td>SL tagging</td>
<td>711</td>
</tr>
<tr>
<td>Belle II</td>
<td>2021</td>
<td>&lt; $4.1 \times 10^{-5}$</td>
<td>Inclusive tagging</td>
<td>63</td>
</tr>
</tbody>
</table>
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- When converted to the same luminosity, the Belle II inclusive tagging performs 10–20% better than the semileptonic tagging and a factor 3.5 better than the hadronic tagging.
...and future perspectives
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- More data: $3 \times$ larger sample ready to be analysed.
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$10^5 \times \sigma_{BR}$ uncertainty for next analyses, assuming 25% improvement + 40% $K^0_S$

<table>
<thead>
<tr>
<th></th>
<th>63 fb$^{-1}$</th>
<th>197 fb$^{-1}$</th>
<th>450 fb$^{-1}$</th>
<th>(450 + 700) fb$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(arXiv:2104.12624)</td>
<td>(Summer 2021 – current lumi)</td>
<td>(Summer 2022 – expected)</td>
<td>(+ Belle I sample)</td>
</tr>
<tr>
<td>$\sigma_{BR}(K^+)$</td>
<td>1.55</td>
<td>0.78</td>
<td>0.52</td>
<td>0.32</td>
</tr>
<tr>
<td>$\sigma_{BR}(K^+ + K^0_S)$</td>
<td>–</td>
<td>0.68</td>
<td>0.45</td>
<td>0.28</td>
</tr>
</tbody>
</table>

*Preliminary*
Supplemental material
The $B^+ \rightarrow K^+ \nu \bar{\nu}$ decay

Scenarios beyond the SM $\rightarrow$ possible contribution of right-handed operators $Q_R^l$

$$\mathcal{H}_{\text{eff.}} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_l (C_L^l Q_L^l + C_R^l Q_R^l)$$

where

$$Q_{L(R)}^l = \left( \bar{s}_{L(R)} \gamma^\mu b_{L(R)} \right) \left( \bar{\nu}_{L(R)} \gamma^\mu \nu_{L(R)} \right) \quad l = e, \mu, \tau$$

2 combinations of 6 Wilson Coefficients:

$$\text{Br}(B \rightarrow K \nu \bar{\nu}) = \frac{1}{3} \sum \epsilon^2 l \left( 1 - 2 \eta^2 \right),$$

$$\text{Br}(B \rightarrow K^* \nu \bar{\nu}) = \frac{1}{3} \sum \epsilon^2 l \left( 1 + \kappa \eta \right),$$

$$\epsilon = \sqrt{|C_L^l|^2 + |C_R^l|^2},$$

$$\eta = -\text{Re} \left( C_L^l C_R^{l*} \right) / |C_L^l|^2 + |C_R^l|^2.$$

Constraint on new-physics contributions: Wilson coefficients $C_L^{\text{NP}}$ and $C_R$ normalised to the SM value of $C_L$ (Belle II from expected 50 ab$^{-1}$).

Significant increase in the $B \rightarrow K^{(*)}\nu \bar{\nu}$ decay BR can be accommodated in models describing CC and NC anomalies with leptoquarks. [arXiv:2107.01080v2]
SuperKEKB

- Asymmetric-energy $e^+e^-$ collider operating at $\sqrt{s} = 10.58$ GeV $\rightarrow \Upsilon(4S)$ resonance.

- Second generation B factory based on the **nanobeam scheme**: major upgrade of its predecessor KEKB.

- **World highest instantaneous luminosity**: $3.12 \times 10^{34}$ cm$^{-2}$ s$^{-1}$.

- **Peak luminosity projections:**

- **Nano-beam scheme:**

Filippo Dattola | $b \rightarrow s \nu \bar{\nu}$ at Belle II
The Belle II detector

New detector with respect to the predecessor Belle.

- Electromagnetic Calorimeter ECL (CsI(Tl) crystals)
- KL and muon detector (resistive plates and scintillators)
- 1.5T Magnet
- (7 GeV) electrons $e^-$
- (4 GeV) positrons $e^+$
- Vertex Detector (pixels detector PXD and silicon strips detector)
- Central Drift Chamber (cylindrical wire chamber with 14336 sense wires)
- Particle ID: Time-of-Propagation counter (barrel) Aerogel RICH (fwd)
Features of $B^+ \rightarrow K^+ \nu \bar{\nu}$

- Number of reconstructed tracks in the event.
More on multivariate classification

- No overfitting observed neither for BDT1 nor for BDT2.

- Signal sensitivity of BDT1:
Reweighting of continuum MC

Discrepancies between simulated continuum and off-resonance data.

Data-driven correction by means of an additional fastBDT: BDT$_c$.

- Select simulated continuum (100 fb$^{-1}$) with BDT$_1 > 0.9$;
- Select off-resonance data (9 fb$^{-1}$) with BDT$_1 > 0.9$;
- Train BDT$_c$ with the set of 51 variables using data as signal and simulation as bkg;
- Being $p$ the BDT$_c$ score, apply the event weight $p/(1-p) = P(\text{Data - like})/P(\text{MC - like})$ to correct the simulated continuum.

Before reweighting: no perfect overlap at 0.5 $\rightarrow$ mismodelling.

Protection against large weights: clipping at $w = 10$

Continuum MC yields scaled up to Data of normalisation ratio 1.22

Filippo Dattola | $b \rightarrow s\nu\bar{\nu}$ at Belle II
Definition of the fit region

Optimised bin boundaries set up in the $p_T(K^+) \times \text{BDT}_2$ space:

Bins 4,5,6,7,8,9,10,11,12:
- **Signal Region (SR)**: fit of data at the $\Upsilon(4S)$ resonance;
- **Control Region 2 (CR2)**: fit of off-resonance data.

Bins 1,2,3:
- **Control Region 1 (CR1)**: fit of data at the $\Upsilon(4S)$ resonance;
- **Control Region 3 (CR3)**: fit of off-resonance data.

Control Region 1-2-3 to constrain bkg’s yields.
The fit region

- 1 signal region + 3 control regions.

**Bin boundaries in the SR** specifically optimised by minimisation of the expected upper limit on the BR($B^+ \rightarrow K^+ \nu \bar{\nu}$).

<table>
<thead>
<tr>
<th>Region</th>
<th>2D Bin Boundary Definition</th>
<th>Physics Processes</th>
<th>√$s$</th>
</tr>
</thead>
</table>
| Signal Region (SR)| $p_T(K^+)$ ∈ [0.5, 2.0, 2.4, 3.5] GeV/c  
BDT$_2$ ∈ [0.95, 0.97, 0.99, 1.0] | signal + all backgrounds | $\Upsilon(4S)$ |
| Control Region 1 (CR1) | $p_T(K^+)$ ∈ [0.5, 2.0, 2.4, 3.5] GeV/c  
BDT$_2$ ∈ [0.93, 0.95] | signal + all backgrounds | $\Upsilon(4S)$ |
| Control Region 2 (CR2) | $p_T(K^+)$ ∈ [0.5, 2.0, 2.4, 3.5] GeV/c  
BDT$_2$ ∈ [0.95, 0.97, 0.99, 1.0] | continuum backgrounds | off-resonance ($-60$ MeV/c$^2$) |
| Control Region 3 (CR3) | $p_T(K^+)$ ∈ [0.5, 2.0, 2.4, 3.5] GeV/c  
BDT$_2$ ∈ [0.93, 0.95] | continuum backgrounds | off-resonance ($-60$ MeV/c$^2$) |

**CR 1-2-3** to constrain bkg yields.

Filippo Dattola | $b \rightarrow s \nu \bar{\nu}$ at Belle II
Identification of $B^+ \rightarrow K^+ J/\psi \rightarrow \mu^+ \mu^-$ events

1720 data events from 63 fb$^{-1}$ + bkg suppressed to percent level.

Filippo Dattola | $b \rightarrow s\nu \bar{\nu}$ at Belle II
Results of the validation on $B^+ \rightarrow K^+ J/\psi \rightarrow \mu^+ \mu^-$
Background composition in the fit region

- $B^0\bar{B}^0$ signal side:

- $B^0\bar{B}^0$ tag side:

- $B^+B^-$ signal side:

- $B^+\bar{B}^-$ tag side:
Validation in the BDT sideband

- Agreement between $Y(4S)$ on-resonance data and simulation in the sideband $0.9 < BDT_1 < 0.99$ and $BDT_2 < 0.7$:

- Only if the continuum background is scaled by a factor of 1.22 as obtained from the comparison with off-resonance data, the data/MC ratio is then 1.00 in the moderate BDT sideband.
SM form factor vs $q^2$

- $q^2$ spectrum from PHSP simulation compared to the SM form factor from [J. High Energ. Phys. 2015, 184 (2015)] as a function of $q^2$. 
**Fit procedure**

- **pyhf modifiers and constraints:**

$$
V_{cb}(\phi) = \sum_{s \in \text{samples}} V_{scb}(\eta, \chi) = \sum_{s \in \text{samples}} \left( \prod_{\kappa \in \kappa} \kappa_{scb}(\eta, \chi) \right) \left( V_{scb}^0(\eta, \chi) + \sum_{\Delta \in \Delta} \Delta_{scb}(\eta, \chi) \right).
$$

<table>
<thead>
<tr>
<th>Description</th>
<th>Modification</th>
<th>Constraint Term $c_{\chi}$</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncorrelated Shape</td>
<td>$\kappa_{scb}(\gamma_b) = \gamma_b$</td>
<td>$\prod_b \text{Pois}(r_b = \sigma_b^{-2}</td>
<td>\rho_b = \sigma_b^{-2} \gamma_b)$</td>
</tr>
<tr>
<td>Correlated Shape</td>
<td>$\Delta_{scb}(\alpha) = f_p(a</td>
<td>\Delta_{scb,a=-1}, \Delta_{scb,a=1})$</td>
<td>$\text{Gaus}(a = 0</td>
</tr>
<tr>
<td>Normalisation Unc.</td>
<td>$\kappa_{scb}(\alpha) = g_p(\alpha</td>
<td>\kappa_{scb,a=-1}, \kappa_{scb,a=1})$</td>
<td>$\text{Gaus}(a = 0</td>
</tr>
<tr>
<td>MC Stat. Uncertainty</td>
<td>$\kappa_{scb}(\gamma_b) = \gamma_b$</td>
<td>$\prod_b \text{Gaus}(\delta_{\gamma_b} = 1</td>
<td>\gamma_b, \delta_b)$</td>
</tr>
<tr>
<td>Luminosity</td>
<td>$\kappa_{scb}(\lambda) = \lambda$</td>
<td>$\text{Gaus}(\delta = \lambda_0</td>
<td>\lambda, \sigma_\lambda)$</td>
</tr>
<tr>
<td>Normalisation</td>
<td>$\kappa_{scb}(\mu_0) = \mu_0$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data-driven Shape</td>
<td>$\kappa_{scb}(\tau_b) = \tau_b$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fit validation

- **Test with injected signal:**
  
  Check the pulls \( \frac{\mu_{\text{fit}} - \mu_{\text{inj.}}}{\sigma_\mu} \)

- **Test the fit quality:**
  
  Check the p-value of the fit on observations

---

**No biases observed ✔**

**High p-value ✔**

**Good agreement with \( \chi^2 \) ✔**

Filippo Dattola | \( b \rightarrow s \nu \bar{\nu} \) at Belle II
Cross validation of PyHf with a simplified Gaussian model
Fit to the Data

- Profile likelihood scan for the signal strength $\mu$:

Asymmetric uncertainty on $\mu$ estimated by fitting the scanned points with an asymmetric parabola $f(x) = (x/\sigma^-)^2$ for $x < 0$ and $f(x) = (x/\sigma^+)^2$ for $x > 0$. 

Filippo Dattola | $b \rightarrow s\nu\bar{\nu}$ at Belle II
Fit to the Data

• Post-fit shifts of the bkg’s normalisations.

• 50% pre-fit uncertainty attached to each of the bkg’s normalisations.

• No post-fit shift wrt to expectations for $B^+B^-$ and $B^0\bar{B}^0$ that are the larger bkg’s.

• Post-fit shift of $\sim 1\sigma$ wrt to the expectations for some continuum sources ($c\bar{c}, s\bar{s}$) consistent with the observed Data-MC normalisation discrepancy.
Fit to the Data

• Post-fit predictions for continuum vs off-resonance data.
Fit to the Data

- Correlation of post-fit shifts of the bkg’s normalisations.

\[
\mathcal{L} \, dt = (63 + 9) \text{ fb}^{-1}
\]
Limit vs uncertainties

Belle II simulation

Normal 90% CL $\times 10^{-5}$

- all
- stat+norm+mcStat
- stat+norm
- stat+mcStat
- stat

Filippo Dattola | $b \rightarrow s\nu\bar{\nu}$ at Belle II