Karlsruhe Institute of Technology

Belle II

$B \to V\ell\nu$ Form Factors & the Hybrid MC

Status Report

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INSTITUT FÜR EXPERIMENTELLE TEILCHENPHYSIK (ETP)

What is this about?

. . . Resonant Decays

- Different models available, commonly used are BCL, ISGW2, . . .
- Models describe the double differential decay rate $\mathrm{d}\Gamma(\mathrm{B} \to X_\mathrm{u} \ell \nu) / \mathrm{d}E_l^\mathrm{B} \mathrm{d}q^2$
- They can not produce n-π-final states

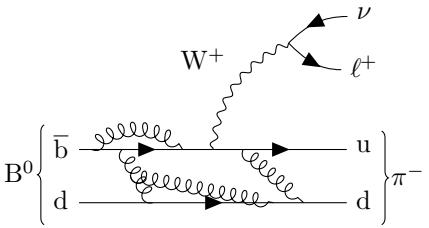
. . . Inclusive Decays

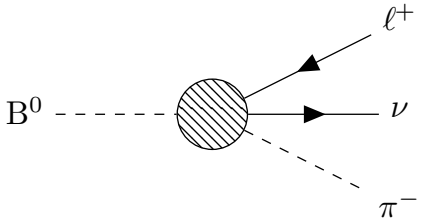
- Different models available, commonly used DFN, BLNP, . . .
- Models describe the triple differential decay rate $\mathrm{d}\Gamma(\mathrm{B} \to X_\mathrm{u} \ell \nu) / \mathrm{d}m_X \mathrm{d}E_l^\mathrm{B} \mathrm{d}q^2$
- They neither produce hadronic states with $m_X < 2m_\pi$ nor any resonant structures in the m_X spectrum

But we do not have a model which describes both at the same time!

Improvement of B $\rightarrow$ V$\ell\nu$, V = $\{\rho, \omega\}$
Predictions

- Hadronic Matrix Element can not be calculated with pertubation theory
- $\rightarrow$ described by form factors
- $\rightarrow$ form factors are parametrized by e.g. BCL expansion
- Predictions for BCL coefficients from LCSR (low q^2 region)





- Nota bene: Belle used the SLPole model, which has an implementation error and badly describes the high q^2 region if not treated with caution.

Improvement of B $\to V\ell\nu, V = \{\rho, \omega\}$ Predictions

- Assumption: BCL coefficients are the correct parametrization for the form factors.
- Up to now: Predictions rely on LCSR calculations.
- Now: Use measured differential branching fractions (Belle & BaBar) of B $\to \rho/\omega\ell\nu$ decays and fit them together with the LCSR predictions
- Input:
  - https://arxiv.org/abs/1503.05534
  - https://arxiv.org/abs/1306.2781
  - https://arxiv.org/abs/1005.3288
  - https://arxiv.org/abs/1205.6245

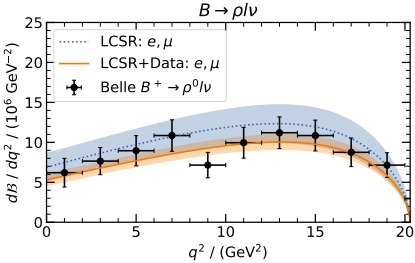
Improvement of B $\to$ V$\ell\nu$, V $= \{\rho, \omega\}$ Predictions

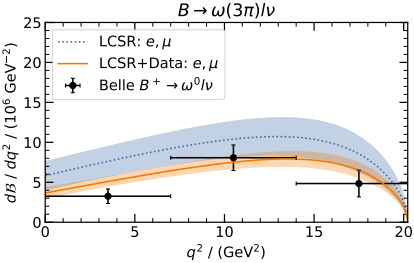
- Perform χ^2 fit:

$$\begin{aligned}
\chi^2(V_{\mathrm{ub}}, \vec{a}) &= \chi^2_{\mathrm{LCSR}}(\vec{a}) + \chi^2_{\mathrm{Data}}(V_{\mathrm{ub}}, \vec{a}), \\
\chi^2_{\mathrm{LCSR}}(\vec{a}) &= \Delta\vec{a}^T \mathbf{C}^{-1}_{\mathrm{LCSR}} \Delta\vec{a}, \\
\chi^2_{\mathrm{Data}}(V_{\mathrm{ub}}, \vec{a}) &= \sum^{\mathrm{Exp}} \Delta\vec{y}^T \mathbf{C}^{-1}_{\mathrm{meas}} \Delta\vec{y},
\end{aligned} \tag{1}$$

with $\Delta\vec{a} = (\vec{a}_{\mathrm{LCSR}} - \vec{a})$ and $\Delta\vec{y} = \left(\frac{\Delta\mathcal{B}_{\mathrm{meas}}}{\Delta q^2}\right) - \left(\frac{\Delta\mathcal{B}(V_{\mathrm{ub}}, \vec{a})}{\Delta q^2}\right)$.

Improvement of B $\to$ V$\ell\nu$, V $= \{\rho, \omega\}$
Predictions





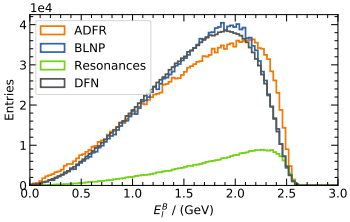
Improvement of B $\to \mathrm{V}\ell\nu$, $\mathrm{V} = \{\pi, \rho, \omega\}$ Predictions

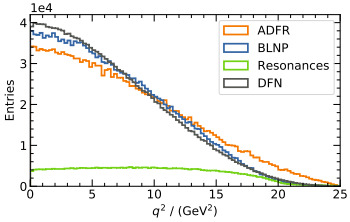
- First takeaway message:
  - Use BCL instead of SLPole model for form factors.
  - Improvement of the B $\to \mathrm{V}\ell\nu$ predictions by factor of 2
- Next step:
  - Marry inclusive and exclusive prediction
  - $\to$ Follow the Hybrid Model approach

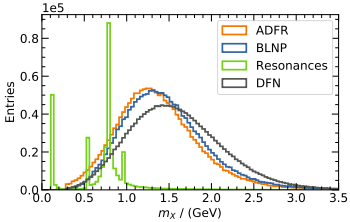
Hybrid MC: What we work with

Latest measurements and used models

B^+	$\to \pi\ell\nu$	$\to \eta\ell\nu$	$\to \eta'\ell\nu$	$\to \omega\ell\nu$	$\to \rho\ell\nu$	$\to u\ell\nu$ incl.
$\mathcal{B}$	$7.8 \cdot 10^{-5}$	$3.9 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$1.19 \cdot 10^{-4}$	$1.58 \cdot 10^{-4}$	$2.2 \cdot 10^{-3}$
Model	BCL	ISGW2	ISGW2	BCL	BCL	DFN, ADFR, BLNP







Inclusive models differ significantly!

Hybrid MC: Putting the pieces together

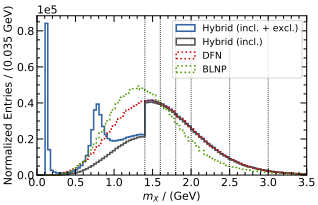
- Inclusive models predict the total inclusive rate
- $\rightarrow$ We have to subtract the resonances

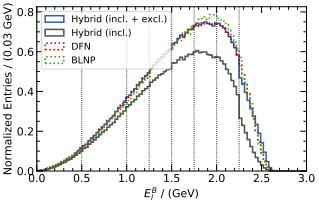
Hybrid Model

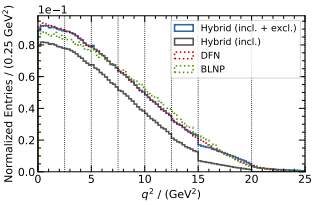
- $H_i = R_i + \omega_i N_i$, H_i: total, R_i: resonant, N_i: inclusive
- Calculate weights ω_i in the 3D phase space, so above equation holds
- Phase space bins
  - m_X = [0., 1.4, 1.6, 1.8, 2., 2.5, 3., 3.5]
  - E_l^B = [0., 0.5, 1., 1.25, 1.5, 1.75, 2., 2.25, 3.]
  - q^2 = [0., 2.5, 5., 7.5, 10., 12.5, 15., 20., 25.]

The DFN Hybrid

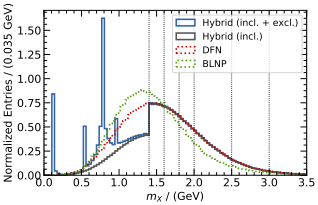
B^0

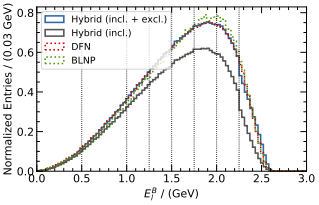


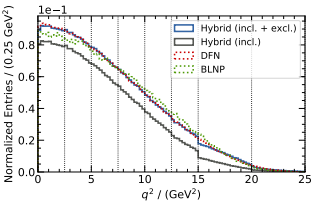




B^+







Summary

- Improvement of B $\to \mathrm{V}\ell\nu$, $\mathrm{V} = \{\pi, \rho, \omega\}$ Predictions
  - There is currently some work on the way for a new theory calculation for the LCSR predictions.
  - $\to$ form factors can be updated
  - Written reference soon available.
- Hybrid MC
  - I plan to write a confluence page which describes the procedure in detail.
- There will be software available soon to determine systematic uncertainties automatically.