# Unfolding distributions of semileptonic decays

## Implications of LHCb measurements and prospects

Marta Calvi, Mark Smith

20 October 2022

Universita & INFN, Milano-Bicocca
Imperial College, London

# The issue

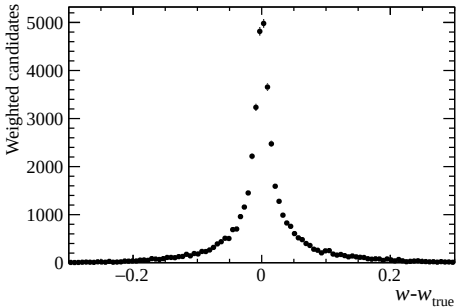
A question of how we present our data

- Experiment could fit everything ourselves directly (FFs, WCs)
  - No need to unfold or efficiency correct
  - Difficult to combine separate measurements
  - Difficult to re-interpret with new theory advances
  - Results dependent on choices of analyst
- We can provide the data publicly
  - Efficiency corrected, unfolded distributions
  - Re-interpretable and combinable

Really this is a bigger conversation than just unfolding - it is what we provide publicly from our data.

- Always a missing neutrino $\rightarrow$ limited $q^2$/ angular resolution.
  - There are tricks we can play to help eg. [Ciezarek, Lupato, Rotondo, Vesterinen]

$B_s^0 \rightarrow D_s^{*+}\mu\nu$: [JHEP 12, 144 (2020)]



# Examples

Some examples from LHCb:

- $\Lambda_b \to \Lambda_c^- \mu^+ \nu_\mu$
- $B_s^0 \to D_s^{*-} \mu^+ \nu_\mu$
- $B_s^0 \to K^- \mu^+ \nu_\mu$
- $B_s^0 \to D_s^- \mu^+ \nu_\mu$

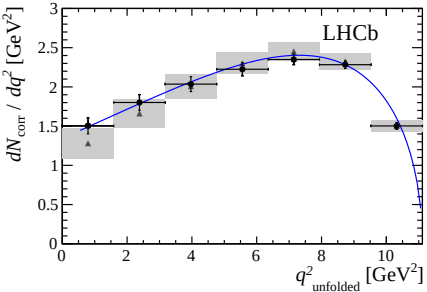
[PRD 96,112005 (2017)]
[JHEP 12,144 (2020)]

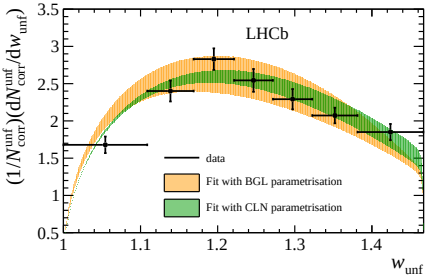
## $\Lambda_b \to \Lambda_c^- \mu^+ \nu_\mu$

- 3fb$^{-1}$: Provide unfolded spectrum $\frac{d\Gamma}{dq^2}$ and correlation matrix. Can be compared with theory predictions (two in the plot). Fit to measure the slope of the Isgur-Wise Function.

## $B_s^0 \to D_s^{*-} \mu^+ \nu_\mu$

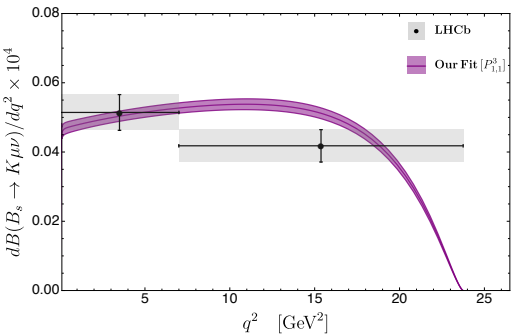
- 1.7fb$^{-1}$: Provide unfolded spectrum $\frac{d\Gamma}{dq^2}$ and correlation matrix. Fit with CLN and BGL parametrization.



## $B_s^0 \to K^- \mu^+ \nu_\mu$

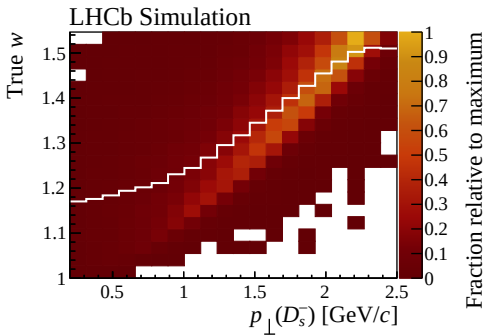
- BF in two bins of $q^2$
  - Includes effect of migration between bins
- $|V_{ub}|/|V_{cb}|$ extracted separately for each bin
  $\to$ discrepancy
  - Ascribed to the FF calculations in each bin
- Ideally fit the differential shape to extract $|V_{ub}|$ [PRD 104, 114041 (2021)]

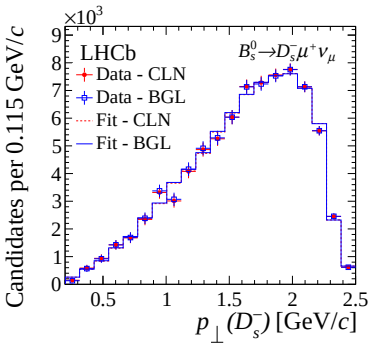


[PRD 101, 072004 (2020)]

## $B_s^0 \to D_s^- \mu^+ \nu_\mu$

- Measurement of $|V_{cb}|$ with $B_s^0$ decays
- Fit the FF parameters as well using a 'proxy' variable: $p_\perp(D_s^-)$
- $p_\perp(D_s^-)$ is highly correlated with $q^2$



# Options

- Experimental fit
  - We fit the data and provide parameters and uncertainties
- Do not unfold
  - Provide bkg subtracted differential distributions in reconstructed variables
  - Provide covariance and response matrices with measured yields, theorists fit
- Unfold
  - Provide differential distributions in true variables
  - Some systematic uncertainty from unfolding method
- Distributions of proxy variables
  - Provide bkg subtracted differential distribution in eg. $p_\perp$
  - Good experimental resolution - theorists can calculate and fit

Future measurement possibilities (no timescales)

- angular analysis of $B^0 \to D^{(*)-}\mu^+\nu_\mu$, $B^0 \to D^{(*)-}\tau^+\nu_\tau$
- $V_{cb}$ and differential distributions of $B \to D^{(*)}\mu\nu$
- $V_{ub}$ and shape of $B_s^0 \to K^-\mu^+\nu_\mu$

# Practicalities

Where does this information go?

- CDS, HEPData

What is feasible experimentally?

- More data implies more dimensions (implies more simulation)
- Can we reliably provide unfolded distributions in 3/4 dimensions?
- How many bins can we provide?