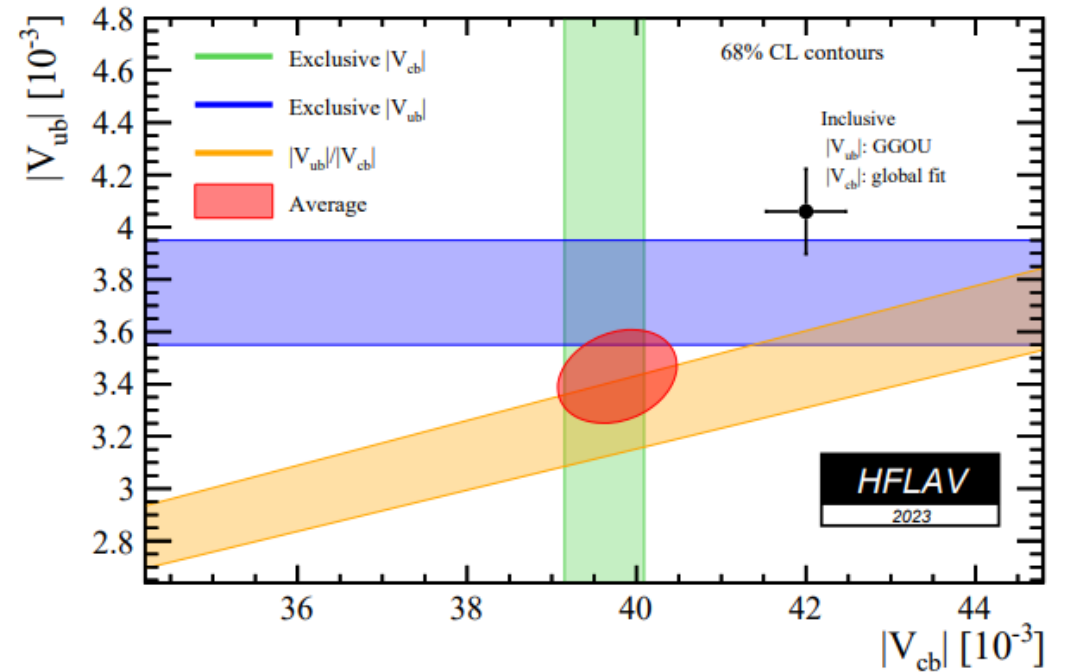
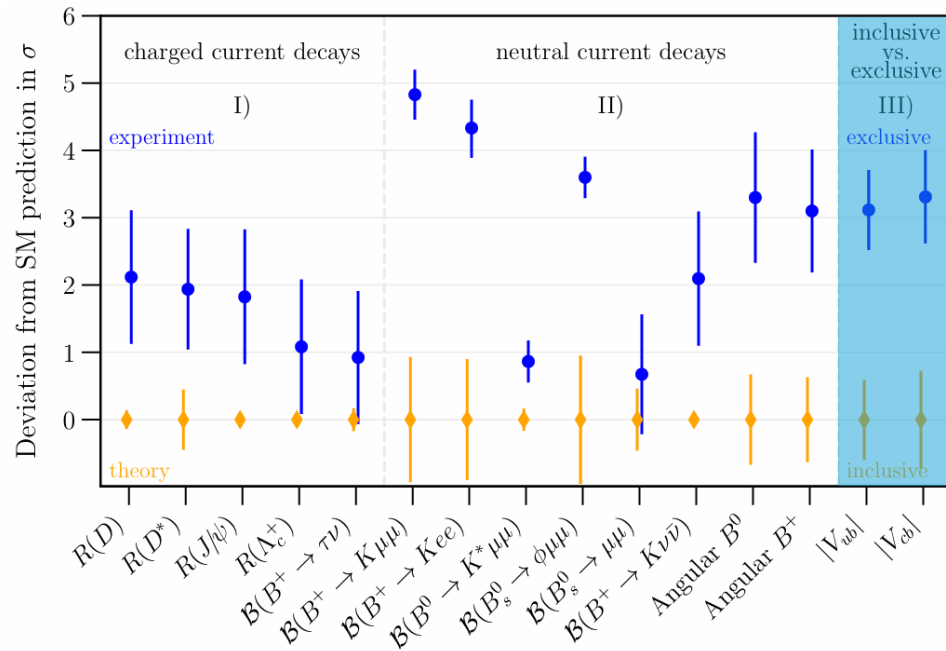


Semi-leptonic decays with multi-hadron final states

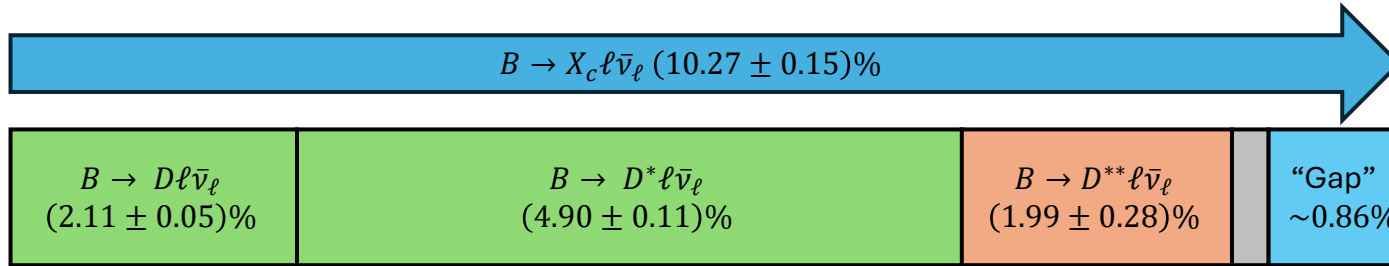
Markus Prim - CmF RA2 Kick-Off
markus.prim@uni-bonn.de

Status quo

- Precision on $|V_{xb}|$ is not limited by the individual measurements but on the different results from inclusive and exclusive determinations



$\bar{B} \rightarrow X_c \ell \bar{\nu}_\ell$ Decays



Problems with $B \rightarrow D^{**} \ell \bar{\nu}_\ell$

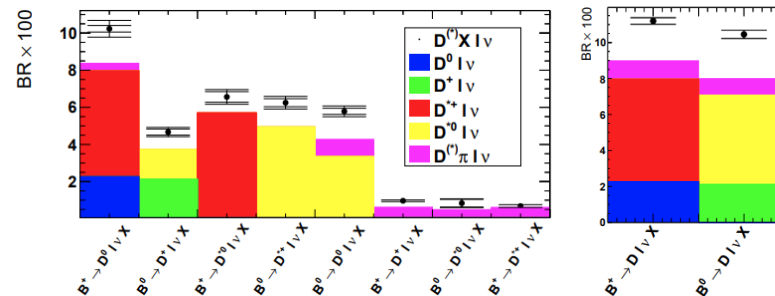
Exclusive $B \rightarrow D^{(*)} \pi \ell \bar{\nu}_\ell$ are being tackled already, from both experiment (work in progress) and theory: **Phys. Rev. D 110 (2024) 9, L091502** and **2509.12133**

Charm normalization wrong?

Is it possible to design a $D \rightarrow K\pi$ measurement with sufficient precision at Belle II?

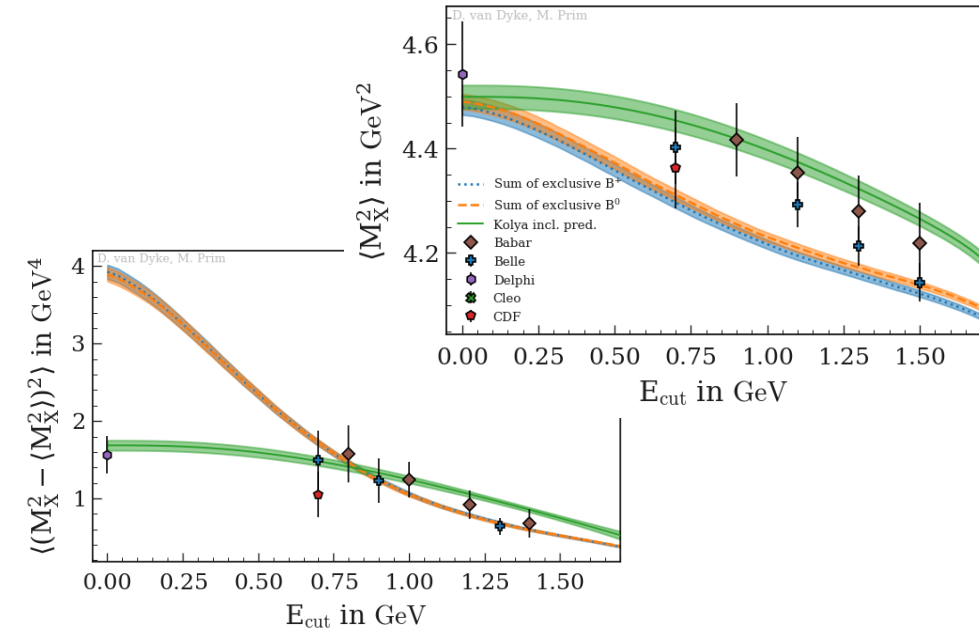
Inclusive \neq Sum of exclusive
Unknown decay modes?

We have some information on what might be in there



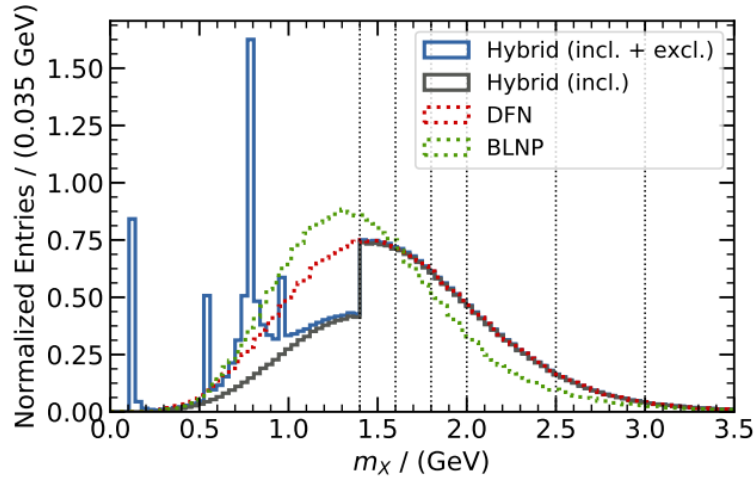
Markus Prim

Not only branching ratios do not match, but also moments of the spectra! (Although a lot assumptions go into the SEM-cocktail)



Proposed measurement: $B \rightarrow D^{(*)} X \ell \bar{\nu}_\ell$
to bridge between exclusive and inclusive measurements, and to tune the $B \rightarrow X_c \ell \bar{\nu}_\ell$ modelling in terms of multiplicities.
Related theory \rightarrow See Thomas' part

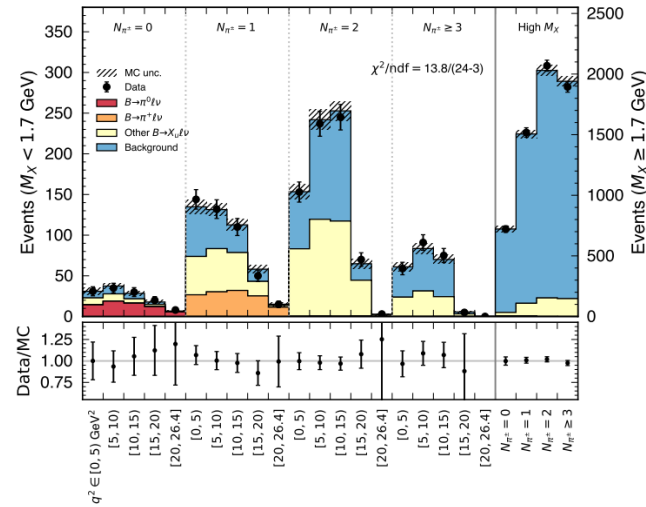
$\bar{B} \rightarrow X_u \ell \bar{\nu}_\ell$ Decays



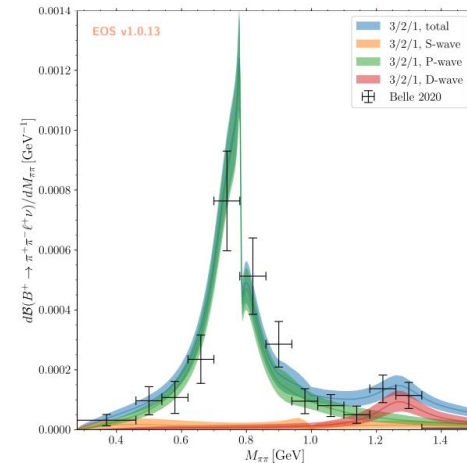
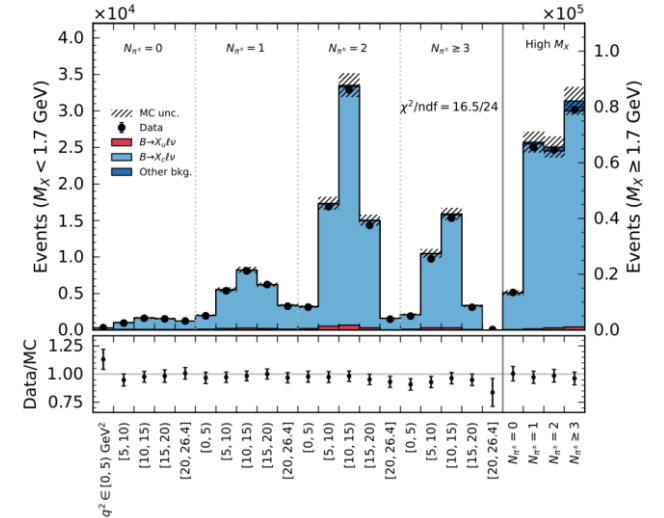
Modelling of multi-pion final states poorly understood, we rely on the so-called **hybrid model**.

Proposed measurement: $B \rightarrow \pi X \ell \bar{\nu}_\ell + \text{others}$

E.g., directly test the novel model-independent parameterizations described in Phys. Rev. D 112 (2025) 1, 1, by measuring the contribution from different partial waves in a model-independent way



π -multiplicities have been studied in inclusive measurements in Phys. Rev. Lett. 131 (2023) 21, 211801



Modelling is Limiting

- Both the gap in $\bar{B} \rightarrow X_c \ell \bar{\nu}_\ell$ and the hybrid in $\bar{B} \rightarrow X_u \ell \bar{\nu}_\ell$ are limiting assumption in the systematics budget of our precision measurements of $|V_{xb}|$ and $R(D^{(*)})$
- Semi-inclusive decays
 - allow us to bridge between exclusive and inclusive measurements
 - are relatively unexplored from both theory and experiment
 - allow us to test quark-hadron duality