LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

$B \to D^{**}\ell\nu$ Analysis at Belle II

Prospects for Measuring the q^2 Spectrum and Branching Franctions

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Belle II

Bundesministerium
für Bildung
und Forschung

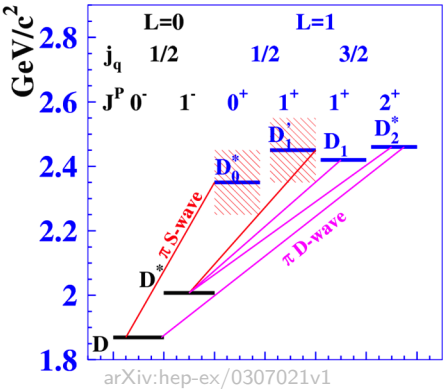
Introduction

The D^{**}s

- The modelling of mesons with one light and one heavy quark (e.g. B,D) is simplified by taking the heavy quark limit ($m_Q \to \infty$).
- Then the D^{**}s are the P-wave ($L = 1$) excitations of the D meson.
- They form two doublets under the angular momentum of the lighter quark ($j_q = L + s_q$):

$$j_q = 3/2 : \{D_1(2420),\ D_2^*(2460)\} : \Gamma = \mathcal{O}(10)\ \text{MeV}$$

$$j_q = 1/2 : \{D_1'(2430),\ D_0^*(2300)\} : \Gamma = \mathcal{O}(100)\ \text{MeV}$$



arXiv:hep-ex/0307021v1

Motivation

	$\mathcal{B}(B^- \to D^{**}\,\ell\,\overline{\nu}) \times \mathcal{B}(D^{**} \to D^{(*)}\pi)$ (%)	
	BaBar (2009)[1]	Belle (2008)[2]
D_1	$0.29 \pm 0.03 \pm 0.03$	$0.42 \pm 0.07 \pm 0.07$
$D_2^{'}$	$0.15 \pm 0.02 \pm 0.01$	$0.18 \pm 0.06 \pm 0.03$
D_1	$0.27 \pm 0.04 \pm 0.05$	< 0.07 @90% C.L.
D_0^*	$0.26 \pm 0.05 \pm 0.04$	$0.24 \pm 0.04 \pm 0.06$

[1] arXiv:0808.0333v2 [2] arXiv:0711.3252v2

- Discrepancy between two previous measurements.

- The decay into the narrow modes are predicted to dominate, this has been contradicted by measurements to date: "The $1/2 - 3/2$ puzzle".

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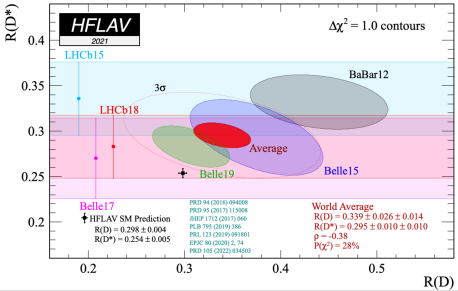

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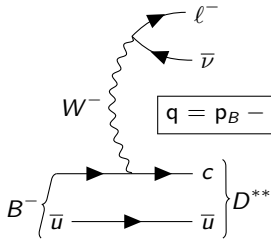

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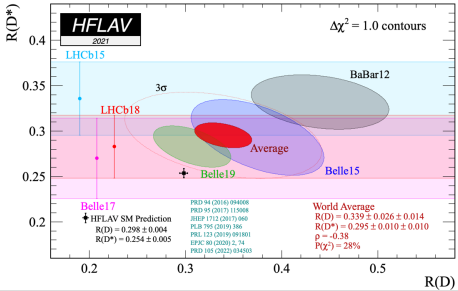
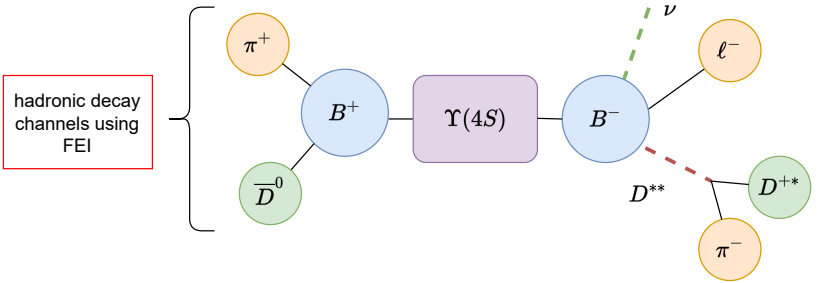


Reconstruction Strategy

in CM Frame

$$E_\nu = E_{Tag} - (E_\ell + E_{D^*} + E_\pi)$$
$$\vec{p}_\nu = -\vec{p}_{Tag} - (\vec{p}_\ell + \vec{p}_{D^*} + \vec{p}_\pi)$$



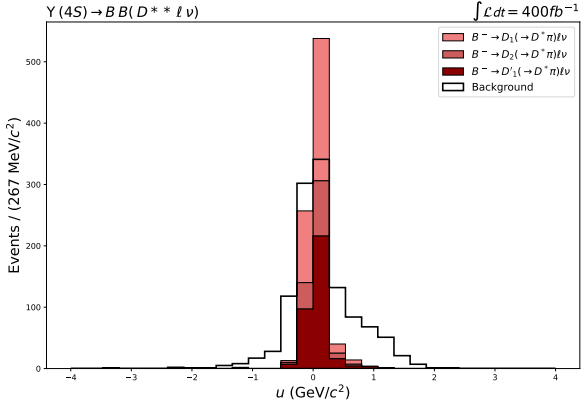
One of the B mesons was reconstructed in various hadronic decay channels.

Only the D_1, D_1', and D_2 modes which decay into the reconstructed signal channel are included in the analysis.

Selection

u variable

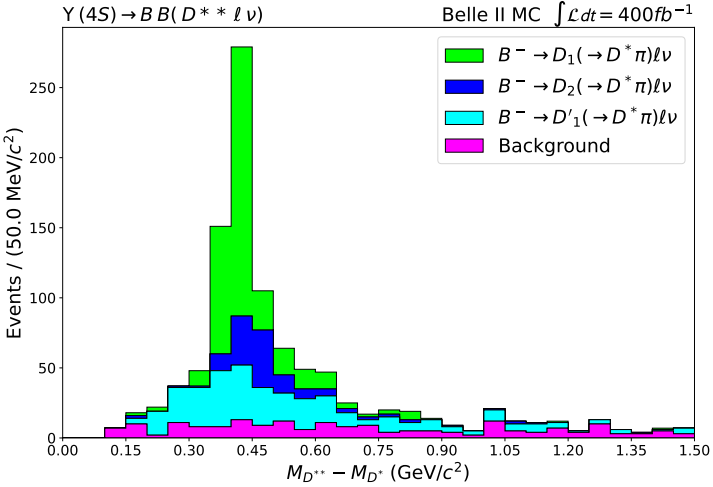
- Since there is one ν in the events with a signal decay, a cut on $u = (E_{miss} - p_{miss}c)/c^2$ is applied.



Cuts applied

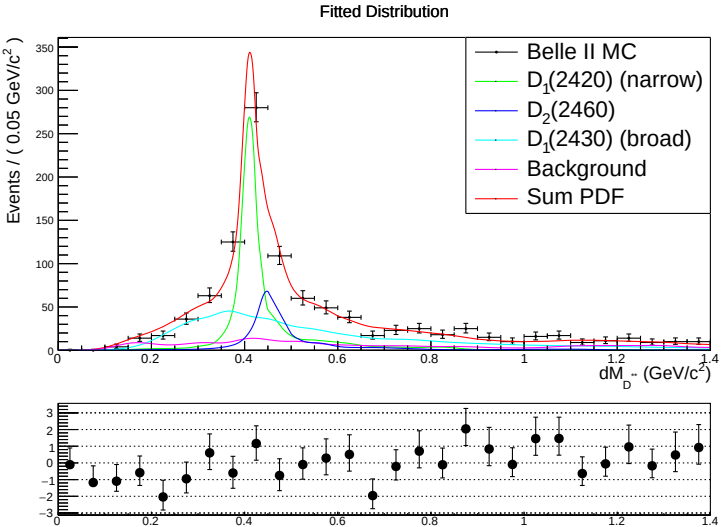
- $-0.12\,\mathrm{GeV/c^2} < u < 0.24\,\mathrm{GeV/c^2}$
- $p_{miss} > 0.05\,\mathrm{GeV/c}$

Fit Variable



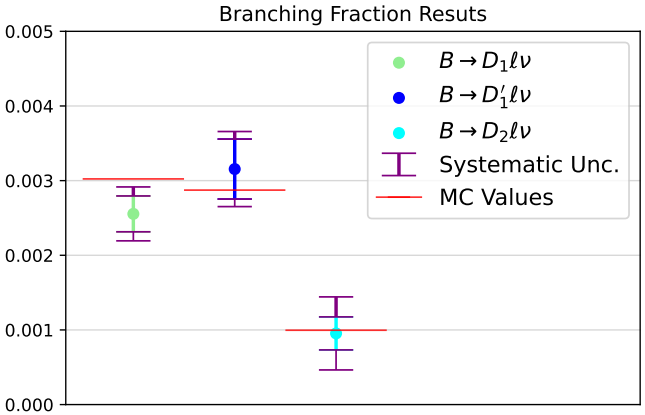
- The D^{**} $\Delta M = (M_{D^{**}} - M_{D^*})$ was used as the fitting variable to extract signal yields.
- ΔM is determined with better resolution than the mass of D^{**}
- The PDFs for each category were created by **Kernel Density Estimation** using $2.4\,\text{ab}^{-1}$ signal and $600\,\text{fb}^{-1}$ background MC.

Fitting



- The PDFs were fitted to the $400\,\mathrm{fb}^{-1}$ MC sample using an **unbinned extended maximum likelihood (ML) fit**.

Branching Fractions



Comparison of statistical uncertainties to previous results

Babar measurement was made on $417\,\text{fb}^{-1}$ of data

- D_1 : 9.2% $<$ 10.34%
- D_1' : 12.5% $<$ 14.89%
- D_2 : 15.32% $>$ 13.33%

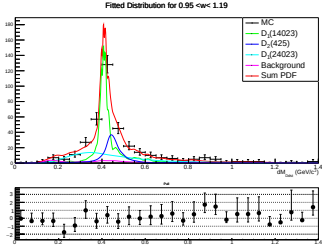
Belle measurement was made on $657 \times 10^6 B\overline{B}$ events.

- D_1 : 5.4% $<$ 16.67%
- D_2 : 13.30% $<$ 33.33%

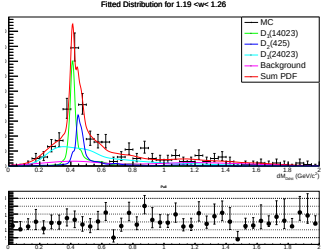
q^2 Study

$$w = \frac{m_B^2 + {m_{D^{**}}}^2 - q^2}{2 m_B m_{D^{**}}} \quad \text{and} \quad q^2 = (p_B - p_{D^{**}})^2$$

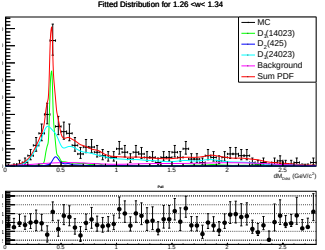
- The ML fit to the ΔM distribution was repeated in three bins of w to obtain the w shape.



$0.95 < w < 1.19$
$[3.30 < q^2 < 9.44]$

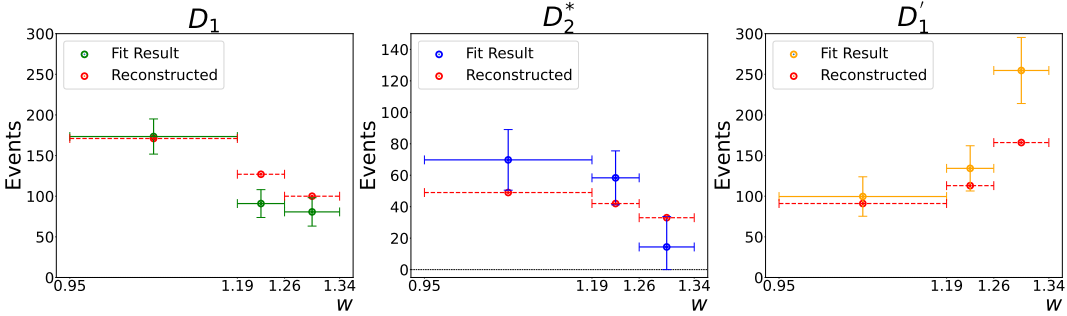


$1.19 < w < 1.26$
$[1.51 < q^2 < 3.30]$

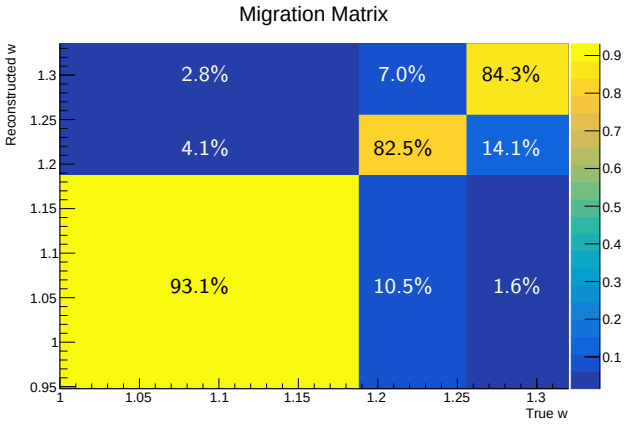


$1.26 < w < 1.34$
$[-0.53 < q^2 < 1.51]$

Fit Results


D_1
Fit Result
Reconstructed
Events
w
0.95
1.19
1.26
1.34
D_2^*
Fit Result
Reconstructed
Events
w
$D_1^{'}$
Fit Result
Reconstructed
Events
w

Unfolding



- There was non-negligible amount of bin migrations in the reconstructed w distribution due to finite detector resolution.

$$M_{ij} = \frac{N_{rec}^{(ij)}}{N_{gen}^{j}}$$

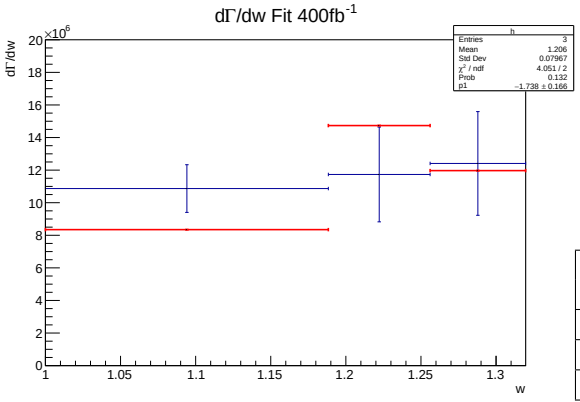
- The distribution is corrected for this effect by unfolding:

$$N_{rec}^{i} = \sum_{j=1}^{N_{bins}} M_{ij} N_{gen}^{j}$$

$$\iff \vec{v}_{rec} = M\vec{v}_{gen}$$

$$\iff \vec{v}_{gen} = M^{-1}\vec{v}_{rec}$$

$d\Gamma/dw$ Fit and Systematics



- The Bernlochner,Ligeti and Robinson(BLR)(2018) differential decay amplitude ($d\Gamma/dw$) was fitted (χ^2-fit) to obtain τ', with other parameters fixed.
- Fit result $\tau' = -1.738 \pm 0.166$ (9.6%)
- MC value: $\tau' = -1.6$
- $\left[\text{Belle result } \tau' = -1.8 \pm 0.3(16.67\%)\right]$

Systematic Uncertainty on τ'

	Absolute	Relative (%)
PDF Creation	0.0280	1.611
LeptonID Efficiency	0.0020	0.108
Slow π Efficiency	0.0004	0.026
$\Delta M_{D^{**}}$ Fit Bias	0.0121	0.696
Total	0.0306	1.759

Summary and Outlook

Summary

- I have studied the semileptonic B meson decays into the $D^{**}s$ which are orbital excitations of the D meson.
- The measurements on their branching fractions to this date show large uncertainties and some unresolved questions, hence I worked towards obtaining a measurement of these at Belle II.
- I have attempted fitting a form factor variable to the w distribution of the $B \to D^{**}\ell\nu$ decay.

Outlook

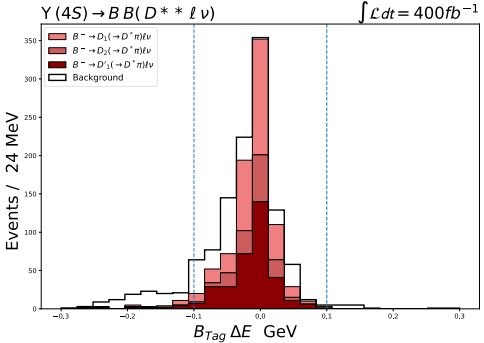
- Eventually performing the measurement on data.

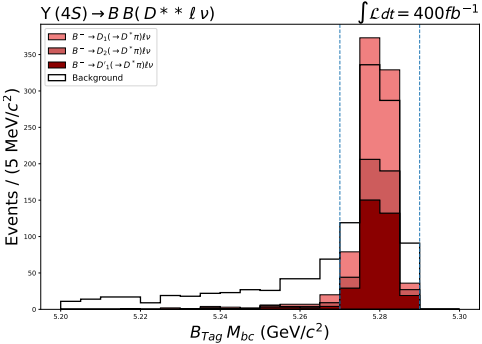
Thank you for your attention

Some Selection Variables

Tag Side

- $-0.1\,\mathrm{GeV} < \Delta E = E_B - \frac{1}{2}E_{CMS} < 0.1\,\mathrm{GeV}$
- $5.27\,\mathrm{GeV}^2 < M_{bc} = \sqrt{\frac{1}{4}E_{CMS}^2 - |p_B|^2} < 5.29\,\mathrm{GeV/c}^2$





Branching Fractions

- The branching fractions were calculated using:

$$\mathcal{B}(B^- \to D^{**}\ell^-\nu) \times \mathcal{B}(D^{**} \to D^{*+}\pi^-) = \frac{N_{D^{**}}}{N_{B^-B^+} \times \epsilon_{rec} \times \mathcal{B}(D^{*+} \to D^0\pi^+) \times \sum \mathcal{B}(D^0 decays)}$$

	$\mathcal{B}(B^- \to D^{**}\ell^-\nu) \times \mathcal{B}(D^{**} \to D^{*+}\pi^-)$	
D^{**}	MC (%)	Fit (%)
D_1	0.3023	$0.2555 \pm 0.0240(9.40\%)$
D_2^*	0.0996	$0.0953 \pm 0.0221(23.20\%)$
$D_1\prime$	0.2873	$0.3155 \pm 0.0402(12.73\%)$