

Semileptonic B decay branching fraction

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- update of semileptonic branching fractions
- summary

D_1 decays

- BF of D^{**} will have an impact on the semileptonic measurements as mostly only the modes with charged pions are measured
- recently LHCb measured the $D_1 \rightarrow D\pi^+\pi^-$ decay (PHYSICAL REVIEW D 84, 092001 (2011)) which is not included in the MC
- modified the DECAY_BELLE2.DEC accordingly:
 - using double BF ratio
$$BF(B \rightarrow D_1\pi^+) \times BF(D_1^0 \rightarrow D^0\pi^+\pi^-)_{nonD^*} / BF(B \rightarrow D_1\pi^+) \times BF(D_1^0 \rightarrow D^{*0}\pi^+) = 0.430108$$
from LHCb measurement (assumed ratio is the same for D_1^0 and D_1^+)
 - modes with π^0 are inferred assuming isospin symmetry

channel	BF
$BF(D_1 \rightarrow D^*\pi^+)$	0.399427
$BF(D_1 \rightarrow D^*\pi^0)$	0.199714
$BF(D_1 \rightarrow D\pi^+\pi^-)$	0.171797
$BF(D_1 \rightarrow D\pi^0\pi^-)$	0.114531
$BF(D_1 \rightarrow D\pi^0\pi^0)$	0.114531

- updated the ratio of
 $BF(D_2 \rightarrow D\pi^+)/BF(D_2 \rightarrow D^*\pi^+) = 1.498 \pm 0.140$ (was around 2 in MC)
- weighted average of D_2^0 and D_2^+ from PDG 2017
- unmeasured modes with π^0 are inferred from isospin symmetry

channel	BF
$BF(D_2 \rightarrow D\pi^+)$	0.399795
$BF(D_2 \rightarrow D\pi^0)$	0.199898
$BF(D_2 \rightarrow D^*\pi^+)$	0.266871
$BF(D_2 \rightarrow D^*\pi^0)$	0.133436

Semileptonic branching fractions

- use PDG 2017 as input
- ignored semi-inclusive $B \rightarrow D^{(*)}\pi^+ l\nu$ as already covered by $B \rightarrow D^{**}l\nu$ with $D^{**} \rightarrow D^{(*)}\pi^+$
- PDG ignores Belle measurement for D_1' (only upper limit), bit biased to Babar measurement
- for D_2 only use measurement for $B \rightarrow D_2 l\nu$ with $D_2 \rightarrow D\pi^+$ (more precise than $D_2 \rightarrow D^*\pi^+$)
- assume isospin symmetry: $BF(B^+) = \tau_{+0} BF(B^0)$ to perform averages ($\tau_{+0} = 1.076 \pm 0.004$ HFLAV 2016)

channel	B^+ PDG 2017	B^0 PDG 2017	isospin avg for B^+
$(B \rightarrow D\pi^+\pi^-\nu)_{nonD^*}$	0.0016 ± 0.0004	0.0013 ± 0.0005	0.0015 ± 0.0003
$B \rightarrow D^*\pi^+\pi^-\nu$	0.0008 ± 0.0005	0.0014 ± 0.0005	0.0011 ± 0.0004
$B \rightarrow D_0(D\pi^+)\nu$	0.0025 ± 0.0005	0.0030 ± 0.0012	0.0026 ± 0.0005
$B \rightarrow D_1(D^*\pi^+)\nu$	0.0030 ± 0.0002	0.0028 ± 0.0003	0.0030 ± 0.0002
$B \rightarrow D_1'(D^*\pi^+)\nu$	0.0027 ± 0.0006	0.0031 ± 0.0009	0.0029 ± 0.0005
$B \rightarrow D_2(D\pi^+)\nu$	0.0015 ± 0.0002	0.0012 ± 0.0003	0.0015 ± 0.0001
$B \rightarrow Dl\nu$	0.0227 ± 0.0011	0.0219 ± 0.0012	0.0231 ± 0.0008
$B \rightarrow D^*l\nu$	0.0569 ± 0.0012	0.0493 ± 0.0011	0.0549 ± 0.0008
Total Sum:	0.0918 ± 0.0019	0.0840 ± 0.0024	0.0907 ± 0.0015

Possible contributions from non-resonant $B \rightarrow D^{(*)}\pi l\nu$

- existing measurements for $(B \rightarrow D^{(*)}\pi^\pm l\nu)_{inclusive}$ and for exclusive $B \rightarrow D^{**}l\nu$ with $D^{**} \rightarrow D^{(*)}\pi^\pm$
- same final state \Rightarrow exclusive and possible non-resonant contribution included in inclusive measurement
- current status of the measurements PDG 2017:

channel	$BF(B^+) [\%]$	$BF(B^0) [\%]$	isospin avg
$\sum D^{**}(D^*\pi^\pm)l\nu$	0.674 ± 0.068	0.658 ± 0.095	0.684 ± 0.057
$(D^*\pi^\pm l\nu)_{incl}$	0.610 ± 0.060	0.490 ± 0.080	0.583 ± 0.049
$\Delta = incl - excl$	-0.064 ± 0.091	-0.168 ± 0.124	-0.101 ± 0.075
Δ_{max}	$+0.064$	$+0.007$	0.005
$\sum D^{**}(D\pi^\pm)l\nu$	0.403 ± 0.052	0.421 ± 0.124	0.410 ± 0.048
$(D\pi^\pm l\nu)_{incl}$	0.420 ± 0.050	0.430 ± 0.060	0.436 ± 0.040
$\Delta = incl - excl$	$+0.017 \pm 0.072$	$+0.009 \pm 0.138$	0.026 ± 0.063
Δ_{max}	$+0.119$	$+0.193$	0.114

$$\Delta_{max} = incl + \sigma_{incl} - (excl - \sigma_{excl})$$

Summary PDG 2017 values

- $BF(D\pi^\pm l\nu)_{incl} - \sum BF(D^{**}(D\pi^\pm)l\nu)$ consistent with zero but due to large uncertainties some space for non-resonant $D\pi^\pm l\nu$
- $BF(D^*\pi^\pm l\nu)_{incl} - \sum BF(D^{**}(D^*\pi^\pm)l\nu)$ doesn't support a non-resonant contribution

BUT

- HFLAV includes upper limit in averages (PDG does not)
- for $B \rightarrow D\pi l\nu$ consistent with PDG
- isospin averaged HFLAV values for $D^*\pi^\pm l\nu$:
 - $BF(B^+ \rightarrow D^*\pi^\pm l\nu)_{incl} = (0.569 \pm 0.049)\%$
 - $\sum BF(B^+ D^{**}(D^*\pi^\pm)l\nu) = (0.488 \pm 0.041)\%$
- so HFLAV values would allow non-resonant $D^*\pi^\pm l\nu$ of order of 0.1%

Proposal to fill the gap

- PDG 2017: $BF(B^- \rightarrow X_c l \nu)_{incl} - \sum BF(B^- \rightarrow X_c l \nu)_{excl} \approx 0.7\%$
- my proposal to fill the gap (discussion very welcome)
 - put as much non-resonant $B \rightarrow D^{(*)} \pi l \nu$ as uncertainties allow
 - fill the rest with $B \rightarrow D^{(*)} \eta l \nu$ (never measured!)
 - final states of η will not interfere with measured contributions
($BF(\eta \rightarrow \gamma\gamma) = 39\%$; $BF(\eta \rightarrow 3\pi^0) = 33\%$;
 $BF(\eta \rightarrow \pi^+\pi^-\pi^0) = 23\%$; $BF(\eta \rightarrow \pi^+\pi^-\gamma) = 4\%$)

resulting BF

channel	BF [%]	model
$D^* \pi^+ l \nu$	0.10	GOITY_ROBERTS
$D^* \pi^0 l \nu$	0.05	GOITY_ROBERTS
$D \pi^+ l \nu$	0.10	GOITY_ROBERTS
$D \pi^0 l \nu$	0.05	GOITY_ROBERTS
$D^* \eta l \nu$	0.20	PHSP
$D \eta l \nu$	0.20	PHSP
sum	0.70	

final branching fractions

- correct for the unmeasured $D^{**} \rightarrow D^{(*)}\pi^0$ modes, and $D_1 \rightarrow D\pi\pi$
- reduced the $B \rightarrow D\pi\pi l\nu$ by the rate already covered by $B \rightarrow D_1 l\nu$ with $D_1 \rightarrow D\pi\pi$
- for B^+ only added measured $B \rightarrow D_s K^+ l\nu$ decays (PDG 2017)
- B^0 BF from the isospin averaged B^+ BF: $BF(B^0) = BF(B^+)/\tau_{+0}$
- still missing $\approx 0.9\%$ BF between inclusive $B \rightarrow X_c l\nu$ measurement and sum of exclusive measurements
- added hypothetical $B \rightarrow D^{(*)}\eta l\nu$ decays (unmeasured)
- if decay model unknown use PHSP

final branching fractions

WARNING: NOT updated yet!! (will updated as soon as new gap model is implemented in the DECAY_BELLE2.DEC)

channel	BF Bp	BF B0	decay model
$D^* l \nu$	0.0549	0.0511	HQET3
$D l \nu$	0.0231	0.0214	HQET3
$D_1 l \nu$	0.00757	0.00704	LLSW
$D_0 l \nu$	0.00389	0.00362	LLSW
$D_1' l \nu$	0.00431	0.00401	LLSW
$D_2 l \nu$	0.00373	0.00347	LLSW
$D^* \pi l \nu$	0.0000	0.0000	
$D \pi l \nu$	0.0000	0.0000	
$D \pi^+ \pi^- l \nu$	0.00023	0.00021	PHSP
$D \pi^+ \pi^0 l \nu$	0.00015	0.00014	PHSP
$D \pi^0 \pi^0 l \nu$	0.00015	0.00014	PHSP
$D^* \pi^+ \pi^- l \nu$	0.00113	0.00105	PHSP
$D^* \pi^+ \pi^0 l \nu$	0.00075	0.00070	PHSP
$D^* \pi^0 \pi^0 l \nu$	0.00075	0.00070	PHSP
$D_s^* K^+ l \nu$	0.0003		PHSP
$D_s K^+ l \nu$	0.0003		PHSP
$D \eta l \nu$	0.00460	0.00455	PHSP
$D^* \eta l \nu$	0.00460	0.00455	PHSP
sum	0.11048	0.10268	

- presented model for semileptonic BF
- several assumptions used
- pull request started:
<https://stash.desy.de/projects/B2/repos/software/pull-requests/1739/overview>

BACKUP