A simultaneous analysis of $B \to D\ell\nu$ and $B \to D^*\ell\nu$ decays

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Gap modes

Gap modes

- In our MC, the gap channels $D^{(*)}\pi\pi\ell\nu$ and $D^{(*)}\eta\ell\nu$ have been generated with phase-space leading to a very soft lepton momentum.
- It seems physically less plausibile than a decay kinematic in which the hadronic particles are more correlated to each other.
- **Idea**: remove these gap modes in our MC sample and replaced them by

$$B \to [D^{**} \to D^{(*)}\pi\pi]\ell\nu \qquad B \to [D^{**} \to D^{(*)}\eta]\ell\nu$$

Process	Sim.events	Lumi (ab-1)	D** FF model
$B \to [D_1^{'} \to D\pi\pi]\ell\nu$	$8 \cdot 10^6$	B0: 16, B+: 14	BLR
$B \to [D_0^{*} \to D\pi\pi]\ell\nu$	$8 \cdot 10^6$	B0: 16, B+: 14	BLR
$B \to [D_1^{'} \to D^{*}\pi\pi]\ell\nu$	$8 \cdot 10^6$	B0: 3.2, B+: 2.8	BLR
$B \to [D_0^{*} \to D^{*}\pi\pi]\ell\nu$	$8 \cdot 10^6$	B0: 3.2, B+: 2.8	BLR
$B \to [D_0^{*} \to D\eta]\ell\nu$	$8 \cdot 10^6$	B0: 1.8, B+: 1.8	BLR
$B \to [D_1^{'} \to D^{*}\eta]\ell\nu$	$8 \cdot 10^6$	B0: 1.8, B+: 1.8	BLR

Skims completed on grid, reconstruction completed.

Gap modes

- Same approach for the semitauonic gap modes.

Process	Sim.events	Lumi (ab-1)	D** FF model
$B \to [D_1^{'} \to D\pi\pi]\tau\nu$	$3 \cdot 10^6$	B0: 44.2, B+: 40.8	BLR
$B \to [D_0^{*} \to D^{*}\pi\pi]\tau\nu$	$3 \cdot 10^6$	B0: 12.8, B+: 11.1	BLR
$B \to [D_0^{*} \to D\eta]\tau\nu$	$3 \cdot 10^6$	B0: 6.3, B+: 6.5	BLR
$B \to [D_1^{'} \to D^{*}\eta]\tau\nu$	$3 \cdot 10^6$	B0: 6.3, B+: 6.5	BLR

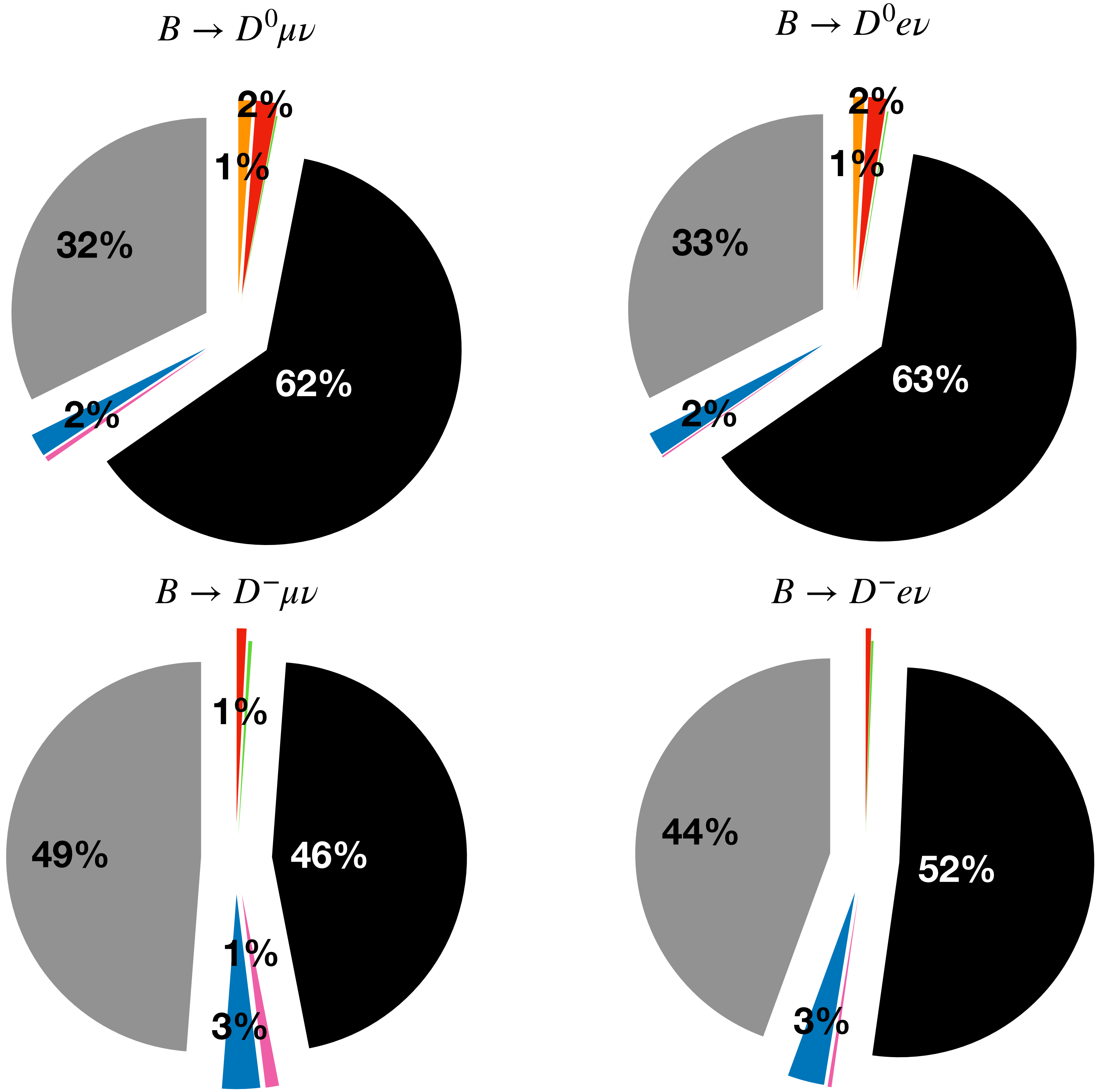
Skims completed on grid, reconstruction completed.

NB: Only MC15ri samples are available.

$X\ell\nu$ composition

- Studied the $X\ell\nu$ component after all the corrections (BR and gap modes):

1. $D\tau\nu$;
2. $D^*\tau\nu$;
3. $D^{**}\tau\nu$;
4. Gap (τ)
5. Gap (ℓ)
7. $D^{(*)}\ell\nu$
8. $D^{**}\ell\nu$



$X\ell\nu$ composition

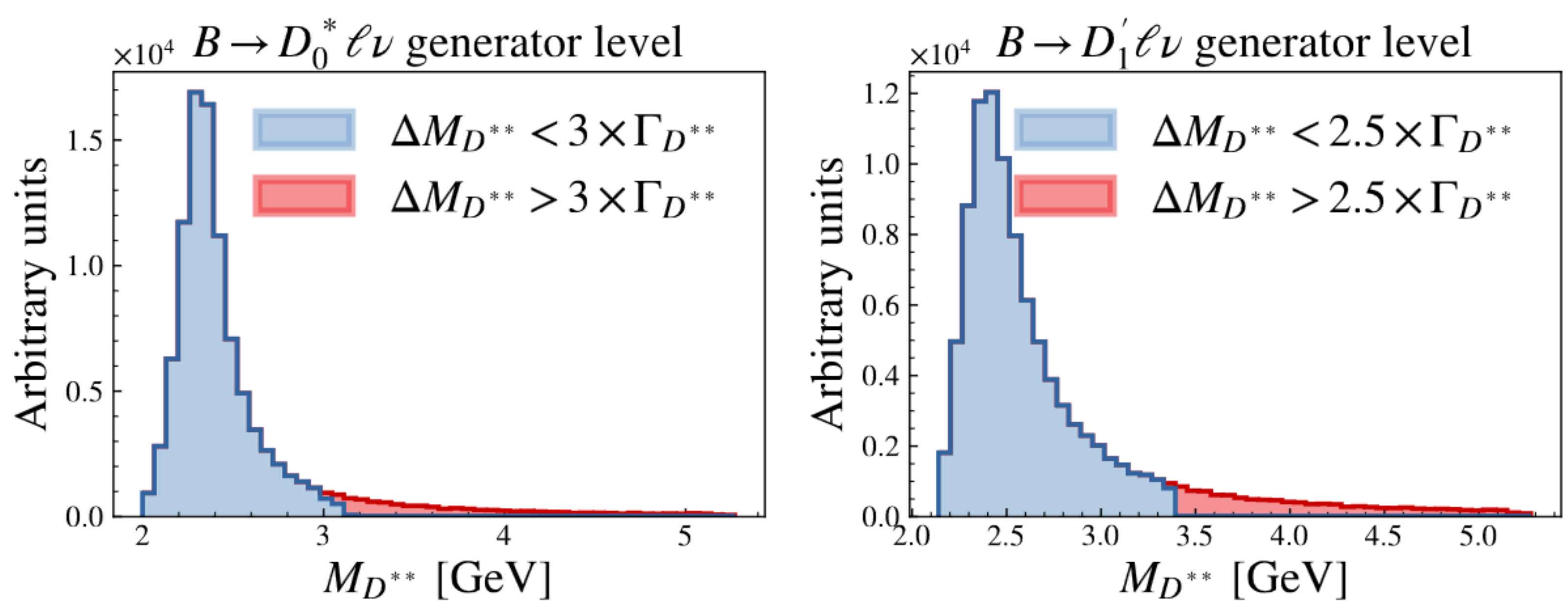
- $X\ell\nu$ component dominated by gap modes and $D^{**}\ell\nu$ decays:

1. $D^{*}\ell\nu$ decays: no need a FF reweight, less than 1% of the total $X\ell\nu$ (~ 6/7%);

2. $D\tau\nu$, $D^{*}\tau\nu$ and $D^{**}\tau\nu$: same as 1.

3. Gap modes and $D^{**}\ell\nu$ decays: already simulated with the correct FF model (BLR).

- Issue is spotted with the modelling D_0^* and $D_1^{'}$.
- Due to their large width, some events are generated with D^{**} mass larger than the nominal one —> unphysical enhancement in the $w \sim 1$ region.



Events that exceed 3 times the width of D_0^* and 2.5 times of $D_1^{'}$ are rejected.

Efficiency

Efficiency

Evaluate the # of events produced:

$N_{prod}^{D^0\ell\nu} = \sigma_{Y(4(S))} \cdot f_{+-} \cdot \mathscr{L} \cdot \mathscr{B}(B^+ \to D^0\ell\nu) \cdot \mathscr{B}(D^0 \to K\pi)$ = 746 408

$N_{prod}^{D^-\ell\nu} = \sigma_{Y(4(S))} \cdot f_{00} \cdot \mathscr{L} \cdot \mathscr{B}(B^0 \to D^-\ell\nu) \cdot \mathscr{B}(D^- \to K\pi\pi)$ = 1 540 010

$N_{prod}^{D^{*0}\ell\nu} = \sigma_{Y(4(S))} \cdot \mathscr{L} \cdot \mathscr{B}(B^+ \to D^{*0}\ell\nu) \cdot (f_{+-} + f_{00} \cdot \frac{\tau_{B^0}}{\tau_{B^+}} \cdot \mathscr{B}(D^{*-} \to D^0X)) \cdot \mathscr{B}(D^0 \to K\pi)$ = 2 803 003

$N_{prod}^{D^{*-}\ell\nu} = \sigma_{Y(4(S))} \cdot f_{00} \cdot \mathscr{L} \cdot \mathscr{B}(B^0 \to D^{*-}\ell\nu) \cdot \mathscr{B}(D^{*-} \to D^-X) \cdot \mathscr{B}(D^- \to K\pi\pi)$ = 1 224 546

Where $\sigma_{Y(4(4S))} = 1.1nb$, $\mathscr{L} = 1444/fb$, $f_{+-} = 0.515$, $f_{00} = 0.483$, $\mathscr{B}(B^+ \to D^0\ell\nu) = 2.31\,\%$, $\mathscr{B}(B^0 \to D^-\ell\nu) = 2.14\,\%$, $\mathscr{B}(B^+ \to D^{*0}\ell\nu) = 5.49\,\%$, $\mathscr{B}(B^0 \to D^{*-}\ell\nu) = 5.11\,\%$, $\mathscr{B}(D^0 \to K\pi) = 3.95\,\%$, $\mathscr{B}(D^- \to K\pi\pi) = 9.38\,\%$, $\mathscr{B}(D^{*-} \to D^-X) = 33.3\,\%$ and $\mathscr{B}(D^{*-} \to D^0X) = 66.7\,\%$.
BR are taken from dec files.

Given the N_{prod}, we can evaluate the efficiency:

$$\epsilon = \frac{N_{reco}}{N_{prod}}$$

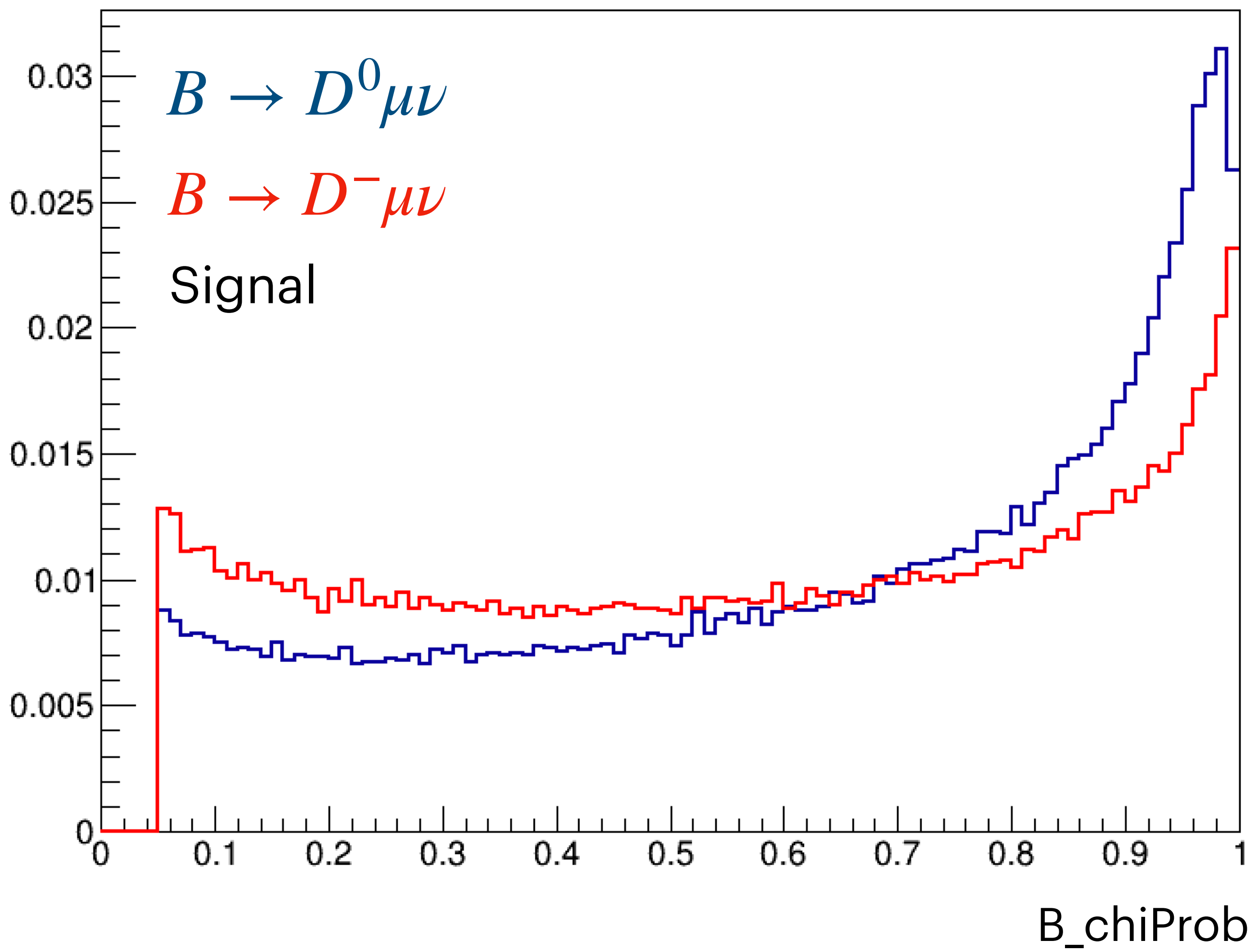
Efficiency: muon sample

	Nprod	Nreco	Our efficiency	Efficiency (Philipp)
$D^0\mu\nu$	746 408	156 809	(21.00 +- 0.03)%	20%
$D^{*0}\mu\nu$	2 818 431	515 671	(18.30 +- 0.01)%	—
$D^-\mu\nu$	1 540 010	138 679	(9.00 +- 0.02)%	6%
$D^{*-}\mu\nu$	1 187 773	76 424	(6.43 +- 0.02)%	—

Why the $D^-\ell\nu$ efficiency is ~2.5 times lower than $D^0\ell\nu$?

TreeFitter probability

- Could the treeFitter probability cut be the cause of the drop in the efficiency for the $D^{-}\ell\nu$ channel?



- Reprocess a small bucket (26) w/o the treeFitter probability cut.

TreeFitter probability

- Reprocess a small bucket (26) w/o the treeFitter probability cut.

$D^{-}\mu\nu$	Nreco	Efficiency
PID cuts + InvM cut + chiProb>0	6910	43.31%
PID cuts + InvM cut + chiProb>0.05	5742	35.99%

$D^{0}\mu\nu$	Nreco	Efficiency
PID cuts + InvM cut + chiProb>0	4970	64.27%
PID cuts + InvM cut + chiProb>0.05	4540	58.71%

The TreeFitter probability cut doesn't explain the drop in the efficiency observed for the $D^{-}\ell\nu$.
Other possibility: geometric acceptance?

Backup

BR reweight: muon and electron sample

Update branching fractions

Decay	$\mathcal{B}(B^+)$	$\mathcal{B}(B^0)$
$B \to D\ell^+\nu_\ell$	$(2.4098 \pm 0.0709) \cdot 10^{-2}$	$(2.2396 \pm 0.0664) \cdot 10^{-2}$
$B \to D^*\ell^+\nu_\ell$	$(5.5023 \pm 0.1146) \cdot 10^{-2}$	$(5.1137 \pm 0.1082) \cdot 10^{-2}$
$B \to D_1\ell^+\nu_\ell$	$(6.6322 \pm 1.0894) \cdot 10^{-3}$	$(6.1638 \pm 1.0127) \cdot 10^{-3}$
$B \to D_0^*\ell^+\nu_\ell$	$(4.2000 \pm 0.7500) \cdot 10^{-3}$	$(3.9033 \pm 0.6972) \cdot 10^{-3}$
$B \to D_1'\ell^+\nu_\ell$	$(4.2000 \pm 0.9000) \cdot 10^{-3}$	$(3.9033 \pm 0.8366) \cdot 10^{-3}$
$B \to D_2^*\ell^+\nu_\ell$	$(2.9337 \pm 0.3248) \cdot 10^{-3}$	$(2.7265 \pm 0.3020) \cdot 10^{-3}$
$B \to D\pi\pi\ell^+\nu_\ell$	$(0.6228 \pm 0.8857) \cdot 10^{-3}$	$(0.5788 \pm 0.8232) \cdot 10^{-3}$
$B \to D^*\pi\pi\ell^+\nu_\ell$	$(2.1600 \pm 1.0247) \cdot 10^{-3}$	$(2.0074 \pm 0.9523) \cdot 10^{-3}$
$B \to D_sK\ell^+\nu_\ell$	$(0.3000 \pm 0.1421) \cdot 10^{-3}$	-
$B \to D_s^*K\ell^+\nu_\ell$	$(0.2900 \pm 0.1942) \cdot 10^{-3}$	-
$B \to D\eta\ell^+\nu_\ell$	$(3.7700 \pm 3.7700) \cdot 10^{-3}$	$(4.0920 \pm 4.0920) \cdot 10^{-3}$
$B \to D^*\eta\ell^+\nu_\ell$	$(3.7700 \pm 3.7700) \cdot 10^{-3}$	$(4.0920 \pm 4.0920) \cdot 10^{-3}$
$B \to X_c\ell^+\nu_\ell$	$(10.8 \pm 0.4) \cdot 10^{-2}$	$(10.1 \pm 0.4) \cdot 10^{-2}$

MC (dec file)

$\mathscr{B}(B^+)(MC)$	$\mathscr{B}(B^0)(MC)$
$2.31 \cdot 10^{-2}$	$2.14 \cdot 10^{-2}$
$5.49 \cdot 10^{-2}$	$5.11 \cdot 10^{-2}$
$7.57 \cdot 10^{-3}$	$7.04 \cdot 10^{-3}$
$3.89 \cdot 10^{-3}$	$3.62 \cdot 10^{-3}$
$4.31 \cdot 10^{-3}$	$4.01 \cdot 10^{-3}$
$3.73 \cdot 10^{-3}$	$3.47 \cdot 10^{-3}$
$0.23 \cdot 10^{-3}$	$0.21 \cdot 10^{-3}$
$1.13 \cdot 10^{-3}$	$1.05 \cdot 10^{-3}$
$0.30 \cdot 10^{-3}$	-
$0.30 \cdot 10^{-3}$	-
$2.01 \cdot 10^{-3}$	$2.17 \cdot 10^{-3}$
$2.01 \cdot 10^{-3}$	$2.17 \cdot 10^{-3}$
-	-

The correction of the branching fractions leads to a modification of the form:

$$N_j^{new} = N_j^{MC} \frac{\mathscr{B}_j^{new}}{\mathscr{B}_j^{MC}}$$

where N_j^{MC} is the # of events in MC for the j-component, $\mathscr{B}_j^{new}$ is the update branching fraction and $\mathscr{B}_j^{MC}$ is the branching fraction in MC.

BR reweight: semitauonic decays

	B+ dec file	B+ Update BR	B0 dec file	B0 Update BR
$B \to D\tau\nu$	0.69%	(0.72 +- 0.02)%	0.64%	(0.67 +- 0.02)%
$B \to D*\tau\nu$	1.42%	(1.41 +- 0.03)%	1.32%	(1.31 +- 0.03)%
$B \to D_0^*\tau\nu$	0.13%	(0.034 +- 0.014)%	0.13%	(0.031 +- 0.01)%
$B \to D_1'\tau\nu$	0.20%	(0.025 +- 0.01)%	0.20%	(0.023 +- 0.009)%
$B \to D_1\tau\nu$	0.13%	(0.066 +- 0.013)%	0.13%	(0.062 +- 0.012)%
$B \to D_2^*\tau\nu$	0.20%	(0.021 +- 0.004)%	0.20%	(0.019 +- 0.003)%
$B \to D\pi\pi\tau\nu$	—	(0.007 +- 0.010)%	—	(0.0066 +- 0.094)%
$B \to D^*\pi\pi\tau\nu$	—	(0.025 +- 0.011)%	—	(0.023 +- 0.011)%
$B \to D\eta\tau\nu$	—	(0.043 +- 0.043)%	—	(0.047 +- 0.047)%
$B \to D^*\eta\tau\nu$	—	(0.043 +- 0.043)%	—	(0.047+- 0.047)%

The correction of the branching fractions leads to a modification of the form:

$$N_j^{new} = N_j^{MC} \frac{\mathscr{B}_j^{new}}{\mathscr{B}_j^{MC}}$$

Efficiency: electron sample

	Nprod	Nreco	Our efficiency	Efficiency (Philipp)
$D^0 e\nu$	746 408	141 926	(19.01 +- 0.03)%	19%
$D^{*0} e\nu$	2 818 431	439 280	(15.59 +- 0.01)%	—
$D^- e\nu$	1 540 010	124 445	(8.08 +- 0.02)%	6%
$D^{*-} e\nu$	1 187 773	65 720	(5.53 +- 0.02)%	—

Why the $D^-\ell\nu$ efficiency is ~2.5 times lower than $D^0\ell\nu$?