Run 2 $R(D^{(*)})$ Progress 8-21-20

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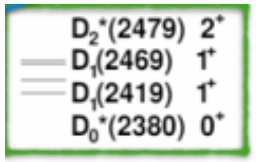
Monte Carlo Request

- A few small differences for D** run 2 dec files
  - Run 1 requested two D** samples: D^0 ($D^{**} \to D^{*+}, D^{*0}, D^0$) and D^{*+} ($D^{**} \to D^{*+}$ only) to increase D^{*+} stats
    - Run 2 will only request D^0 and ***adjust BF as needed*** for comparable D^{*+} stats for each D** (actually, just D_1, D_1', D_2^*, as $D_0^* \to D$ only)
    - Run 2 will reduce 3-body decays of D_2^* to 5%, not eliminate
    - Run 2 will change some BF ratios for D_2^*
      - $\Gamma(D^{*0}\pi)/\Gamma(D^{*+}\pi) = 2/1$ (isospin)
      - $\Gamma(D\pi)/\Gamma(D^*\pi) = 1/1$
    - Run 2 will also reduce 3-body decays of D_0^* to 5%



D^{**} (1P)

11873010 - Bd_Dststmunu-D0 (8.9M events)

$8.9 \times 0.3069 \times 0.2189 = \underline{598k}\ B^0 \to D_1'^-(\to D^{*-}\pi^0)\mu^+\nu$

$8.9 \times 0.1188 \times 0.0887 = \underline{94k}\ B^0 \to D_2^{*-}(\to D^{*-}\pi^0)\mu^+\nu$

```
Decay B0sig
  0.3069   MyD'_1-  mu+  nu_mu       PHOTOS ISGW2
  0.2970   MyD_0*-  mu+  nu_mu       PHOTOS ISGW2
  0.2772   MyD_1-   mu+  nu_mu       PHOTOS ISGW2
  0.1188   MyD_2*-  mu+  nu_mu       PHOTOS ISGW2
Decay MyD'_1+
  0.6466   MyD*0  pi+          PHOTOS VVS_PWAVE [1.0, 0.0, 0.0, 0.0, 0.0, 0.0]
  0.2189   MyD*+  pi0          PHOTOS VVS_PWAVE [1.0, 0.0, 0.0, 0.0, 0.0, 0.0]
  0.1345   MyD0   pi+  pi0     PHOTOS PHSP
Decay MyD_2*+
  0.4028   MyD0   pi+           PHOTOS TSS
  0.2613   MyD*0  pi+           PHOTOS TVS_PWAVE [0.0, 0.0, 1.0, 0.0, 0.0, 0.0]
  0.0977   MyD_0*0  pi+         PHOTOS PHSP
  0.0887   MyD*+  pi0           PHOTOS TVS_PWAVE [0.0, 0.0, 1.0, 0.0, 0.0, 0.0]
  0.0769   MyD_0*+  pi0         PHOTOS PHSP
  0.0483   MyD0   pi+  pi0      PHOTOS PHSP
  0.0121   MyD*0  pi+  pi0      PHOTOS PHSP
  0.0082   MyD*+  pi+  pi-      PHOTOS PHSP
  0.0041   MyD*+  pi0  pi0      PHOTOS PHSP
```

11874060 - Bd_Dststmunu-Dst+ (2.0M events)

$2 \times 0.4058 = \underline{812k}\ B^0 \to D_1'^-(\to D^{*-}\pi^0)\mu^+\nu$

$2 \times 0.1449 \times 0.728 = \underline{311k}\ B^0 \to D_2^{*-}(\to D^{*-}\pi^0)\mu^+\nu$

```
Decay B0sig
  0.4493   MyD_1-  mu+  nu_mu       PHOTOS ISGW2
  0.4058   MyD'_1-  mu+  nu_mu      PHOTOS ISGW2
  0.1449   MyD_2*-  mu+  nu_mu      PHOTOS ISGW2
Decay MyD'_1+
  1.0000   MyD*+  pi0      PHOTOS VVS_PWAVE [1.0, 0.0, 0.0, 0.0, 0.0, 0.0]
Decay MyD_2*+
  0.7280   MyD*+  pi0          PHOTOS TVS_PWAVE [0.0, 0.0, 1.0, 0.0, 0.0, 0.0]
  0.0979   MyD_0*0  pi+         PHOTOS PHSP
  0.0736   MyD_0*+  pi0         PHOTOS PHSP
  0.0669   MyD*+  pi+  pi-      PHOTOS PHSP
  0.0335   MyD*+  pi0  pi0      PHOTOS PHSP
```

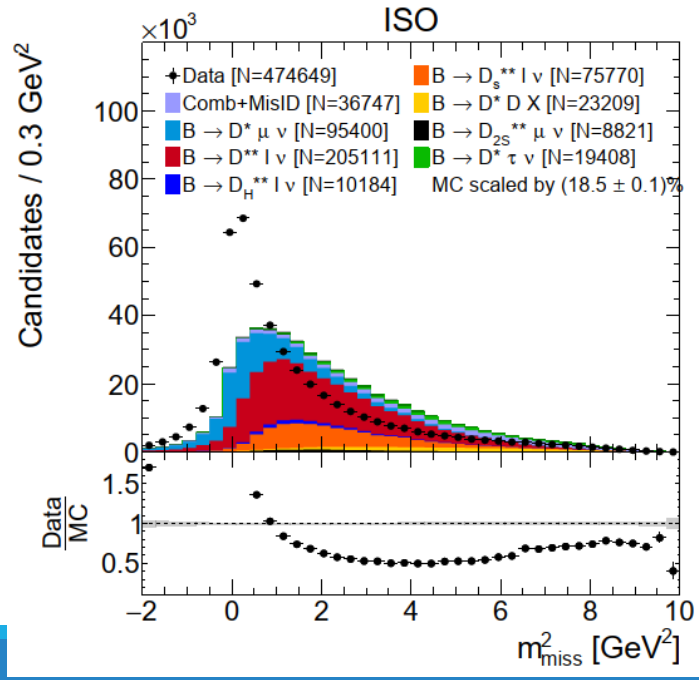
Monte Carlo Request (cont'd)

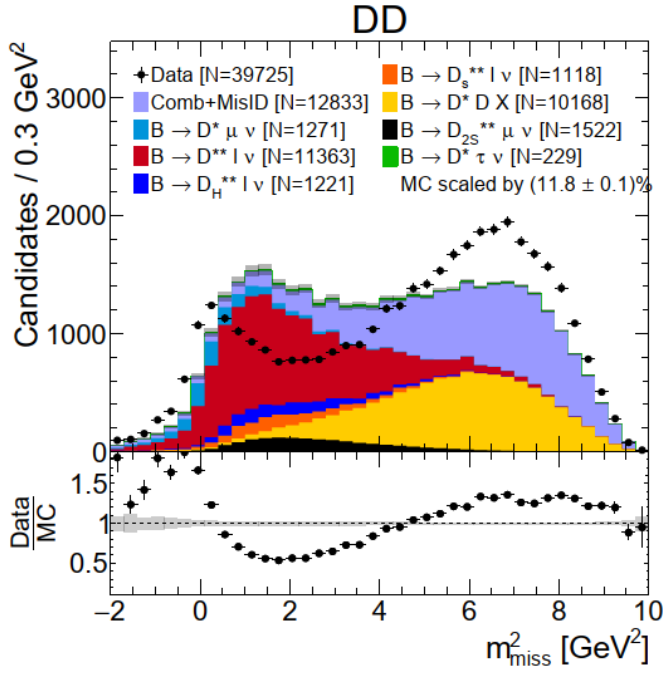
- Another small change: Increase strange D_s** stats to achieve 4x more MC than data for all channels
  - May already be fine, but just to be sure
- Checked stats for all channels against Run 1 fitted yields
- Overall, keep the same relative sample ratios as Run 1
- Svende will circulate slides (today?), we'll discuss feedback on Tuesday, and then make presentation at SL meeting Wednesday
- Request 200M FullSim and 200M tracker-only
  - May reduce to 100M if significant pushback or will take too long

				Run 1				Run 2 Tracker-only					Small FullSim	
#	Sample	MC ID	Name	NMC gen [M]	ε_gen	NMC sim [M]	NMC disk [M]	NMC gen [M]	ε_gen	NMC sim [M]	NMC disk [M]	NMC per type	NMC gen [M]	NMC disk [M]
1	D0	12573010	B- -> D0 mu nu	2114.8	5.2%	110.0	7.7	8320.4	9.3%	929.6	65.1		26.9	1.88
2	D0/D*+	11574020	B0 -> D*+mu nu	1703.3	5.2%	88.6	6.2	6701.3	8.6%	688.4	48.2		19.9	1.40
3	D0	12573031	B- -> D*0mu nu	4285.7	5.2%	222.9	15.6	16861.2	8.1%	1647.0	115.3	228.5	47.7	3.34
4	D0	12573000	B- -> D0 tau nu	140.9	5.2%	7.3	0.5	554.5	7.4%	49.3	3.5		1.4	0.10
5	D0/D*+	11574010	B0 -> D*+tau nu	376.4	5.2%	19.6	1.4	1480.8	7.5%	133.4	9.3		3.9	0.27
6	D0	12573021	B- -> D*0tau nu	327.2	5.2%	17.0	1.2	1287.3	7.1%	109.4	7.7	20.4	3.2	0.22
7	D0/D*+	11873010	B0->D^{**+}mu nu,	2569.4	4.9%	126.7	8.9	10108.7	7.0%	849.1	59.4		24.6	1.72
8	D0/D*+	11873030	B0-> D^{**+}tau nu,	22.9	4.9%	1.1	0.1	90.1	7.0%	7.6	0.5		0.2	0.02
9	D0/D*+	12873010	B--> D^{**0}mu nu,	2121.4	4.9%	103.1	7.2	8346.2	7.0%	701.1	49.1		20.3	1.42
10	D0/D*+	12873030	B--> D^{**0}tau nu,	34.4	4.9%	1.7	0.1	135.3	7.0%	11.4	0.8	109.8	0.3	0.02
11	D0	12675010	B- → D**(→D0ππ)μν	316.6	4.9%	15.5	1.1	1245.7	7.0%	104.6	7.3		3.0	0.21
12	D0	11674400	B0 → D**(→D0ππ)μν	318.7	4.9%	15.6	1.1	1253.7	7.0%	105.3	7.4		3.1	0.21
13	D0/D*+	12675400	B- → D**(→D*+ππ)μν	224.8	4.9%	11.0	0.8	884.4	7.0%	74.3	5.2		2.2	0.15
14	D0/D*+	11676010	B0 → D**(→D*+ππ)μν	214.9	4.9%	10.5	0.7	845.4	7.0%	71.0	5.0		2.1	0.14
15	D0	12675430	B- → D**(→D*0ππ)μν	378.1	4.9%	18.5	1.3	1487.7	7.0%	125.0	8.7	33.6	3.6	0.25
16	D0	13873000	Bs → Ds**(→D0K)μν	29.1	4.4%	1.3	0.1	114.5	7.0%	9.6	0.7		0.3	0.02
17	D*+	13874000	Bs -> D**+μ ν	106.6	4.4%	4.7	0.3	419.3	7.0%	35.2	2.5	3.1	1.0	0.07
18	D0	11873000	B0 → D0(Xc → μνX')X	960.7	3.9%	37.8	2.6	3779.8	7.0%	317.5	22.2		9.2	0.64
19	D0	11873020	B0 → D0(Ds → τν)X	61.4	3.9%	2.4	0.2	241.7	7.0%	20.3	1.4		0.6	0.04
20	D0	12873000	B+ → D0(Xc → μνX')X	1040.0	3.9%	40.9	2.9	4091.6	7.0%	343.7	24.1		10.0	0.70
21	D0	12873021	B+ → D0(Ds → τν)X	212.6	3.9%	8.4	0.6	836.6	7.0%	70.3	4.9	52.6	2.0	0.14
22	D*+	11874050	B0 -> D*+ (Xc -> μ ν X')X	1054.2	3.9%	41.4	2.9	4147.4	7.0%	348.4	24.4		10.1	0.71
23	D*+	11874070	B0 -> D*+(Ds -> τ ν) X	98.5	3.9%	3.9	0.3	387.6	7.0%	32.6	2.3		0.9	0.07
24	D*+	12874010	B+ -> D*+ (Xc -> μ ν X')X	305.3	3.9%	12.0	0.8	1201.3	7.0%	100.9	7.1		2.9	0.20
25	D*+	12874030	B+ -> D*+(Ds -> τ ν) X	59.6	3.9%	2.3	0.2	234.5	7.0%	19.7	1.4	35.1	0.6	0.04
						924.1	64.7			6904.5	483.3		200.0	14.0

Other things

- Yipeng and Alex working on finalizing ntuple production by carefully going through Phoebe's code for run 1
  - Yipeng looking at step 1-to-2 cuts, Alex at step 2-to-fit
  - Good agreement in plots between data/MC isn't expected for now (because there's no fit, weights aren't fully implemented from Phoebe's analysis…and for these two plots, Alex absolutely has some bugs).





Backup

Stats for D_1

11873010 - Bd_Dststmunu-D0 (8.9M events)

$8.9 \times 0.2772 \times 0.1829 =$ **451k** $B^0 \to D_1^-(\to D^{*-}\pi^0)\mu^+\nu$

```
Decay B0sig
  0.3069   MyD'_1-  mu+  nu_mu      PHOTOS ISGW2
  0.2970   MyD_0*-  mu+  nu_mu      PHOTOS ISGW2
  0.2772   MyD_1-   mu+  nu_mu      PHOTOS ISGW2
  0.1188   MyD_2*-  mu+  nu_mu      PHOTOS ISGW2
Decay MyD_0*+
  0.7677   MyD0  pi+            PHOTOS PHSP
  0.1152   MyD*0  pi+  pi0      PHOTOS PHSP
  0.0781   MyD*+  pi+  pi-      PHOTOS PHSP
  0.0390   MyD*+  pi0  pi0      PHOTOS PHSP
Decay MyD_0*0
  0.6052   MyD0  pi0            PHSP
  0.1813   MyD*0  pi+  pi-      PHOTOS PHSP
  0.1228   MyD*+  pi-  pi0      PHOTOS PHSP
  0.0907   MyD*0  pi0  pi0      PHOTOS PHSP
Decay MyD_1+
  0.5403   MyD*0  pi+        PHOTOS VVS_PWAVE [0.0, 0.0, 0.0, 0.0, 1.0, 0.0]
  0.1829   MyD*+  pi0        PHOTOS VVS_PWAVE [0.0, 0.0, 0.0, 0.0, 1.0, 0.0]
  0.1548   MyD_0*0  pi+      PHOTOS PHSP
  0.1220   MyD_0*+  pi0      PHOTOS PHSP
```

11874060 - Bd_Dststmunu-Dst+ (2.0M events)

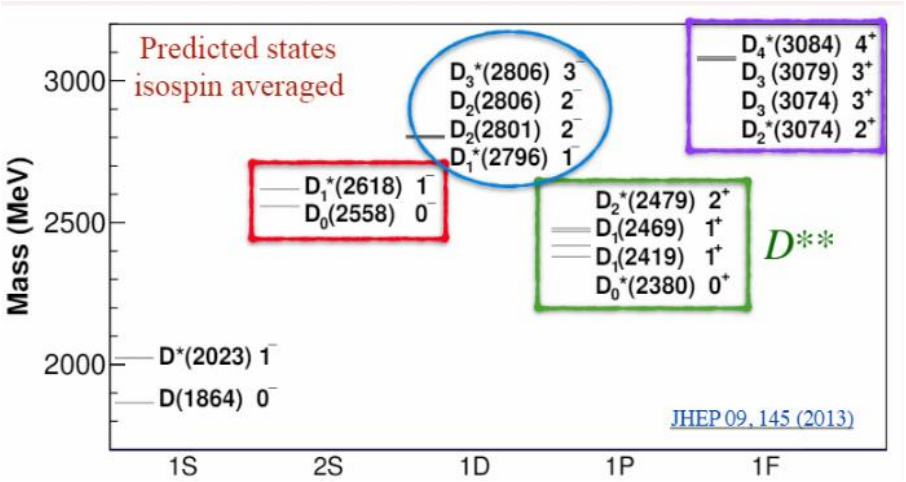
$2 \times 0.4493 \times 0.846 =$ **760k** $B^0 \to D_1^-(\to D^{*-}\pi^0)\mu^+\nu$

```
Decay B0sig
  0.4493   MyD_1-  mu+  nu_mu       PHOTOS ISGW2
  0.4058   MyD'_1-  mu+  nu_mu      PHOTOS ISGW2
  0.1449   MyD_2*-  mu+  nu_mu      PHOTOS ISGW2
Decay MyD_0*+
  0.6667   MyD*+  pi+  pi-      PHOTOS PHSP
  0.3333   MyD*+  pi0  pi0      PHOTOS PHSP
Decay MyD_0*0
  1.0000   MyD*+  pi-  pi0      PHOTOS PHSP
Decay MyD_1+
  0.8460   MyD*+  pi0        PHOTOS VVS_PWAVE [0.0, 0.0, 0.0, 0.0, 1.0, 0.0]
  0.0880   MyD_0*0  pi+      PHOTOS PHSP
  0.0660   MyD_0*+  pi0      PHOTOS PHSP
```

Keeping the same ratio as in Run 1 request, we would get 40% fewer D^{*+} events with the D^0 sample.
Could reduce $D_1^- \to D_0^*\pi$ BF, and keep the same 8.9M/2M ratio

Run 2 Monte Carlo Request (old slide)

- Overall, keep the same relative sample ratios as Run 1
- A few small differences for D**
  - Increase strange D_s** stats to achieve 4x more MC than data for all channels
    - May already be fine, but just to be sure
  - Run 1 requested two D** samples: D^0 ($D^{**}\to D^{*+},D^{*0},D^0$) and D^{*+} ($D^{**}\to D^{*+}$ only) to increase D^{*+} stats
    - Run 2 will only request D^0 and ***adjust BF as needed*** for comparable D^{*+} stats for each D** (actually, just D_1, D_1', D_2^*, as $D_0^*\to D$ only)…next slide
    - Run 2 will reduce 3-body decays of D_2^* to 5%, not eliminate
    - Run 2 will change some BF ratios for D_2^*
      - $\Gamma(D^{*0}\pi)/\Gamma(D^{*+}\pi) = 2/1$ (isospin)
      - $\Gamma(D\pi)/\Gamma(D^*\pi) = 1/1$
    - Run 2 will also reduce 3-body decays of D_0^* to 5%



Three body D** decays (from PDG & others):

$D_0^*\to D\pi\pi$	not seen	~~$D_0^*\to D^*\pi\pi$~~	
$D_1\to D\pi\pi$	seen	$D_1\to D^*\pi\pi$	not seen
$D_1'\to D\pi\pi$	not seen	$D_1'\to D^*\pi\pi$	not seen
$D_2^*\to D\pi\pi$	not seen	$D_2^*\to D^*\pi\pi$	not seen

Run 2 Monte Carlo Request (backup)

- Other differences (already discussed)
  - Generator level cuts

Old cuts →

```
tightCut.Cuts =
'[pi+]cc': "abs(GPX/GPZ) < 0.38 & abs(GPY/GPZ) < 0.28 & (GPT > 250*MeV)",
'[K-]cc':  "abs(GPX/GPZ) < 0.38 & abs(GPY/GPZ) < 0.28 & (GPT > 250*MeV)",
'[mu+]cc': "abs(GPX/GPZ) < 0.38 & abs(GPY/GPZ) < 0.28 & (GP > 2950*MeV)",
'[D0]cc':  "(piKP>15000*MeV) & (piKPT>2450*MeV)"
```

  - Stripping cuts
    - See https://github.com/umd-lhcb/lhcb-ntuples-gen/issues/22

Run 1 MC stats (backup)

For the Run 1 request, they aimed to request **4x more MC than data** using an **early estimate of the data yields** in the signal region (ISO) to **adjust the MC efficiency** of their samples, $N_{ISO}^{MC}/N_{disk}^{MC}$

$$N_{req}^{MC} = 4 \times N_{ISO}^{data} \frac{N_{disk}^{MC}}{N_{ISO}^{MC}}$$

I used the **yields from Greg's fit in ANA note** and the **efficiencies from their excel files**, to check if their MC request required updating.

In some cases (eg, DD yield) I had to distribute the yield

$D^0\mu\nu$ Iso yield	3.66e5 ±2.9e3
$D_0^{*+}\mu\nu$ Iso yield	9.56e3 ±7.77e3
$D_0^{*0}\mu\nu$ Iso yield	2.02e4 ±8.87e3
$D_1^{\prime+}\mu\nu$ Iso yield	3.66e3 ±9.85e3
$D_1^{\prime0}\mu\nu$ Iso yield	4.8e4 ±9.71e3
$D_{1\ell}^{+}\mu\nu$ Iso yield	8.15e3 ±9.84e3
$D_{1\ell}^{0}\mu\nu$ Iso yield	7.38e3 ±1.11e4
$D_2^{*+}\mu\nu$ Iso yield	5.2e3 ±5.62e3
$D_2^{*0}\mu\nu$ Iso yield	1.63e3 ±9.48e3
DD Iso yield	7.49e4 ±2.87e3
misID Iso yield	3.4e4 ±2.24e3
$D_{s1\ell}^{+}\mu\nu$ Iso yield	7.03e3 ±3.12e3
$D_{s2}^{*+}\mu\nu$ Iso yield	4.2e3 ±2.78e3
$D_s \to \tau\nu$ Iso yield	4.55e3 ±1.16e3
$(D^{**} \to D^0\pi\pi)\mu\nu$ Iso yield	3.82e4 ±1.02e4
$(D^{**} \to D^{*+}\pi\pi)\mu\nu$ Iso yield	3.59e3 ±5.2e3
$(D^{**} \to D^{*0}\pi\pi)\mu\nu$ Iso yield	1.24e4 ±5.48e3
$D^{**}\tau\nu$ Iso yield	1.74e3 ±498
Comb. Iso yield	2.37e4 ±2.73e3
$D^{*0}\mu\nu$ Iso yield	9.17e5 ±1.24e4
$D^{*+}\mu\nu$ Iso yield	6.95e4 ±1.19e4

$D^+\mu\nu$ IsoDst yield	1.12e4 ±3.35e3
$D_1^0\mu\nu$ IsoDst yield	0 ±5.59e4
$D_1^{\prime+}\mu\nu$ IsoDst yield	1.36e4 ±4.28e3
$D_1^{\prime0}\mu\nu$ IsoDst yield	561 ±3.26e3
$D_2^{*+}\mu\nu$ IsoDst yield	3.22e3 ±2.54e3
$D_2^{*0}\mu\nu$ IsoDst yield	166 ±1.9e3
DstDD IsoDst yield	2.43e4 ±1.01e3
misID IsoDst yield	4.03e3 ±652
$D_{1\ell}^{+}\mu\nu$ IsoDst yield	817 ±953
$D_{s2}^{*+}\mu\nu$ IsoDst yield	0 ±1.76e3
$D_s \to \tau\nu$ IsoDst yield	1.08e3 ±290
$D^{**}\tau\nu$ IsoDst yield	459 ±121
$D^{*+}\mu\nu$ IsoDst yield	3.31e5 ±2.07e3
Comb. IsoDst yield	1.05e3 ±451
$(D^{**} \to D^{*+}\pi\pi)\mu\nu$ IsoDst yield	1.1e4 ±2.35e3
FakeDst IsoDst yield	9.98e3 ±1.97e3

D*+ efficiencies from Dsttaunu_MC_numbers.xlsx

D0 efficiencies from D0MC Google sheet

✅ MC/data ratio generally above 4

				D0		D*+		Data/MC comparison		
#	Sample	MC ID	Description	MC ISO/disk (DOMC)	Data ISO yield (fit)	MC ISO/disk (Dsttaunu_MC)	Data ISO yield (fit)	Data "on disk" [M]	MC disk [M]	MC/data
1	D0	12573010	B- -> D0 mu nu	20.6%	366,000			1.77	7.70	4.3
2	D0/D*+	11574020	B0 -> D*+mu nu		69,500	26.6%	331,000	1.25	6.20	5.0
3	D0	12573031	B- -> D*0mu nu	25.4%	917,000			3.60	15.60	4.3
4	D0	12573000	B- -> D0 tau nu	18.5%				0.00	0.51	#DIV/0!
5	D0/D*+	11574010	B0 -> D*+tau nu			30.8%		0.00	1.37	#DIV/0!
6	D0	12573021	B- -> D*0tau nu	19.7%				0.00	1.19	#DIV/0!
7	D0/D*+	11873010	B0->D^{**+}mu nu,	2.8%	26,570	26.0%	28,020	0.94	8.87	9.4
8	D0/D*+	11873030	B0-> D^{**+}tau nu,	6.9%	607	25.6%		0.01	0.08	9.0
9	D0/D*+	12873010	B--> D^{**0}mu nu,	6.8%	77,210	7.8%	727	1.13	7.22	6.4
10	D0/D*+	12873030	B--> D^{**0}tau nu,	12.9%	1,133	9.5%		0.01	0.12	13.4
11	D0	12675010	B- → D**(→D0ππ)μν	8.0%	19,032			0.24	1.09	4.5
12	D0	11674400	B0 → D**(→D0ππ)μν	8.0%	19,168			0.24	1.09	4.6
13	D0/D*+	12675400	B- → D**(→D*+ππ)μν					#DIV/0!	0.77	#DIV/0!
14	D0/D*+	11676010	B0 → D**(→D*+ππ)μν			Ds** μ ν stats seem low, typo?		#DIV/0!	0.74	#DIV/0!
15	D0	12675430	B- → D**(→D*0ππ)μν	7.9%	12,400			0.16	1.30	8.2
16	D0	13873000	Bs → Ds**(→D0K)μν	7.5%	11,230			0.15	0.09	0.6
17	D*+	13874000	Bs -> D**+μ ν			30.4%	817	0.00	0.33	121.3
18	D0	11873000	B0 → D0(Xc → μνX')X	3.9%	29,387			0.76	2.64	3.5
19	D0	11873020	B0 → D0(Ds → τν)X	6.6%	1,269			0.02	0.17	8.8
20	D0	12873000	B+ → D0(Xc → μνX')X	6.0%	45,513			0.76	2.86	3.8
21	D0	12873021	B+ → D0(Ds → τν)X	4.6%	3,281			0.07	0.59	8.2
22	D*+	11874050	B0 -> D*+ (Xc -> μ ν X')X			15.7%	15,480	0.10	2.90	29.4
23	D*+	11874070	B0 -> D*+(Ds -> τ ν) X			29.4%	754	0.00	0.27	105.5
24	D*+	12874010	B+ -> D*+ (Xc -> μ ν X')X			8.9%	8,820	0.10	0.84	8.5
25	D*+	12874030	B+ -> D*+(Ds -> τ ν) X			12.7%	326	0.00	0.16	63.8