MC request stats proposal for muonic $D^{0,*} l\nu$ analyses

Run 2 $\mathscr{R}\left(D^{0,*}\right)$

$\mathscr{R}\left(D^{(*)}\right)_{\text{light}}$

Angular $D^{*+}\mu\nu$

CPv in $D^{*+}\mu\nu$

$D^{**0}\mu\nu$

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Tweaks on 20th May

Introduction

Run 1 $\mathscr{R}\left(D^{0,*}\right)$ request

			Run 1: Nsim = 924M / Ndisk = 65M FullSim + RICHless					
#	Sample	Name	MC ID	ε_gen	Nsim [M]	Ndisk [M]	% total request	MC/ data fit
1	D0	B- → D0 μ ν	12573010	7.0%	110.0	7.7	45.6%	2.8
2	D0/D*+	B0 → D*+ μ ν	11574020	5.9%	88.6	6.2		1.4
3	D0	B- → D*0 μ ν	12573031	6.0%	222.9	15.6		2.1
4	D0	B- → D0 τ ν	12573000	5.4%	7.3	0.5	4.8%	2.8
5	D0/D*+	B0 → D*+ τ ν	11574010	5.0%	19.6	1.4		1.4
6	D0	B- → D*0 τ ν	12573021	5.0%	17.0	1.2		2.1
7	D0/D*+	B0 → D**+ μ ν	11873010	5.0%	126.7	8.9	25.2%	4.0
8	D0/D*+	B0 → D**+ τ ν	11873030	4.9%	1.1	0.1		4.0
9	D0/D*+	B- → D**0 μ ν	12873010	5.7%	103.1	7.2		3.5
10	D0/D*+	B- → D**0 τ ν	12873030	4.9%	1.7	0.1		4.0
11	D0	B- → D**(→D0ππ) μ ν	12675010	5.5%	15.5	1.1	7.7%	3.0
12	D0	B0 → D**(→D0ππ) μ ν	11674400	5.0%	15.6	1.1		3.0
13	D0/D*+	B- → D**(→D*+ππ) μ ν	12675400	5.4%	11.0	0.8		3.0
14	D0/D*+	B0 → D**(→D*+ππ) μ ν	11676010	5.0%	10.5	0.7		3.0
15	D0	B- → D**(→D*0ππ) μ ν	12675430	5.4%	18.5	1.3		3.0
16	D0	Bs → Ds**(→D0K) μ ν	13873000	5.5%	1.3	0.1	0.6%	1.0
17	D*+	Bs → D**+μ ν	13874000	5.4%	4.7	0.3		4.0
18	D0	B0 → D0(Xc → μ νX')X	11873000	4.6%	37.8	2.6	9.7%	1.3
19	D0	B0 → D0(Ds → τν)X	11873020	5.4%	2.4	0.2		3.0
20	D0	B+ → D0(Xc → μ νX')X	12873000	5.0%	40.9	2.9		2.3
21	D0	B+ → D0(Ds → τν)X	12873021	5.6%	8.4	0.6		4.0
22	D*+	B0 → D*+ (Xc → μ ν X')X	11874050	4.8%	41.4	2.9	6.5%	4.0
23	D*+	B0 → D*+(Ds → τ ν) X	11874070	5.6%	3.9	0.3		4.0
24	D*+	B+ → D*+ (Xc → μ ν X')X	12874010	4.6%	12.0	0.8		2.9
25	D*+	B+ → D*+(Ds → τ ν) X	12874030	5.0%	2.3	0.2		3.4

- Run 1 muonic $\mathscr{R}\left(D^{0,*}\right)$ estimates **sizable impacts from MC stats** template uncertainties
  - 0.016/0.020 = 80% of statistical uncertainty for $\mathscr{R}(D^{*})$
  - 0.048/0.060 = 80% of statistical uncertainty for $\mathscr{R}\left(D^{0}\right)$
- Suffered from **25-50% reduction** in **effective MC stats** due to FF/other **reweighting**
- Our goal is to have **4 times more MC than data** to reduce impact to less than 50% of the statistical uncertainty
  - Use **tracker-only MC** and **adjust generator/filter selection** as much to trigger/stripping as possible

MC stats estimation

Run 1 $\mathcal{R}\left(D^{0,*}\right)$ request

#	Sample	Name	MC ID	ε_gen	Nsim [M]	Ndisk [M]	% total request	MC/ data fit
			Run 1: Nsim = 924M / Ndisk = 65M FullSim + RICHless					
1	D0	B- → D0 μ ν	12573010	7.0%	110.0	**7.7**	45.6%	2.8
2	D0/D*+	B0 → D*+ μ ν	11574020	5.9%	88.6	**6.2**		1.4
3	D0	B- → D*0 μ ν	12573031	6.0%	222.9	**15.6**		2.1
4	D0	B- → D0 τ ν	12573000	5.4%	7.3	**0.5**	4.8%	2.8
5	D0/D*+	B0 → D*+ τ ν	11574010	5.0%	19.6	**1.4**		1.4
6	D0	B- → D*0 τ ν	12573021	5.0%	17.0	**1.2**		2.1
7	D0/D*+	B0 → D**+ μ ν	11873010	5.0%	126.7	**8.9**	25.2%	4.0
8	D0/D*+	B0 → D**+ τ ν	11873030	4.9%	1.1	**0.1**		4.0
9	D0/D*+	B- → D**0 μ ν	12873010	5.7%	103.1	**7.2**		3.5
10	D0/D*+	B- → D**0 τ ν	12873030	4.9%	1.7	**0.1**		4.0
11	D0	B- → D**(→D0ππ) μ ν	12675010	5.5%	15.5	**1.1**	7.7%	3.0
12	D0	B0 → D**(→D0ππ) μ ν	11674400	5.0%	15.6	**1.1**		3.0
13	D0/D*+	B- → D**(→D*+ππ) μ ν	12675400	5.4%	11.0	**0.8**		3.0
14	D0/D*+	B0 → D**(→D*+ππ) μ ν	11676010	5.0%	10.5	**0.7**		3.0
15	D0	B- → D**(→D*0ππ) μ ν	12675430	5.4%	18.5	**1.3**		3.0
16	D0	Bs → Ds**(→D0K) μ ν	13873000	5.5%	1.3	**0.1**	0.6%	1.0
17	D*+	Bs → D**+μ ν	13874000	5.4%	4.7	**0.3**		4.0
18	D0	B0 → D0(Xc → μ νX')X	11873000	4.6%	37.8	**2.6**	9.7%	1.3
19	D0	B0 → D0(Ds → τν)X	11873020	5.4%	2.4	**0.2**		3.0
20	D0	B+ → D0(Xc → μ νX')X	12873000	5.0%	40.9	**2.9**		2.3
21	D0	B+ → D0(Ds → τν)X	12873021	5.6%	8.4	**0.6**		4.0
22	D*+	B0 → D*+ (Xc → μ ν X')X	11874050	4.8%	41.4	**2.9**	6.5%	4.0
23	D*+	B0 → D*+(Ds → τ ν) X	11874070	5.6%	3.9	**0.3**		4.0
24	D*+	B+ → D*+ (Xc → μ ν X')X	12874010	4.6%	12.0	**0.8**		2.9
25	D*+	B+ → D*+(Ds → τ ν) X	12874030	5.0%	2.3	**0.2**		3.4

D^{*+} HistFactory yields (D^0 in backup)

h_sigmuALT:	444,109 /	792,508 =	56.0%	MC/data = 1.4	(data = 323,024)
h_D1_ALT:	44,484 /	97,042 =	45.8%	MC/data = 5.5	(data = 8,129)
h_D1p_ALT:	52,557 /	103,069 =	51.0%	MC/data = 6.2	(data = 8,470)
h_D2_ALT:	13,255 /	25,657 =	51.7%	MC/data = 6.4	(data = 2,063)
h_D1tau_ALT:	7,681 /	13,584 =	56.5%	MC/data = 64.6	(data = 119)
h_D1ptau_ALT:	8,608 /	14,822 =	58.1%	MC/data = 69.5	(data = 124)
h_D2tau_ALT:	2,106 /	3,109 =	67.7%	MC/data = 69.8	(data = 30)
h_D2Smu:	38,530 /	71,024 =	54.2%	MC/data = 5.1	(data = 7,521)
h_uDDmu:	10,913 /	21,819 =	50.0%	MC/data = 2.9	(data = 3,806)
h_dDDmu:	68,204 /	145,507 =	46.9%	MC/data = 3.9	(data = 17,634)
h_dDDtau:	13,506 /	26,325 =	51.3%	MC/data = 130.2	(data = 104)
h_uDDtau:	3,369 /	5,371 =	62.7%	MC/data = 3.4	(data = 991)

- Scale Run 1 request by
  - **Cross section**
  - **Luminosity**
  - **MC/data** ratio **from Run 1 fit** when ratio below 4
    - Uncertainties very large and correlated (backup) → only correct cases when ratio less than 4
- Check MC efficiency roughly matches data

Cross section and luminosity increase

- "*Run 2 has 2× the cross section of Run 1*"
  - **Exactly true for 7 TeV vs 13 TeV within acceptance** 1612.05140
    - $\sigma\left(b\bar{b}\right)_{7\ \text{TeV}} = 72.0 \pm 0.3 \pm 6.8\,\mu\text{b}$ for 2 < η < 5 (295 μb total)
    - $\sigma\left(b\bar{b}\right)_{13\ \text{TeV}} = 144 \pm 1 \pm 21\,\mu\text{b}$ for 2 < η < 5 (560 μb total)
  - Use Pythia to rescale σ to 8 TeV → 83.4 μb

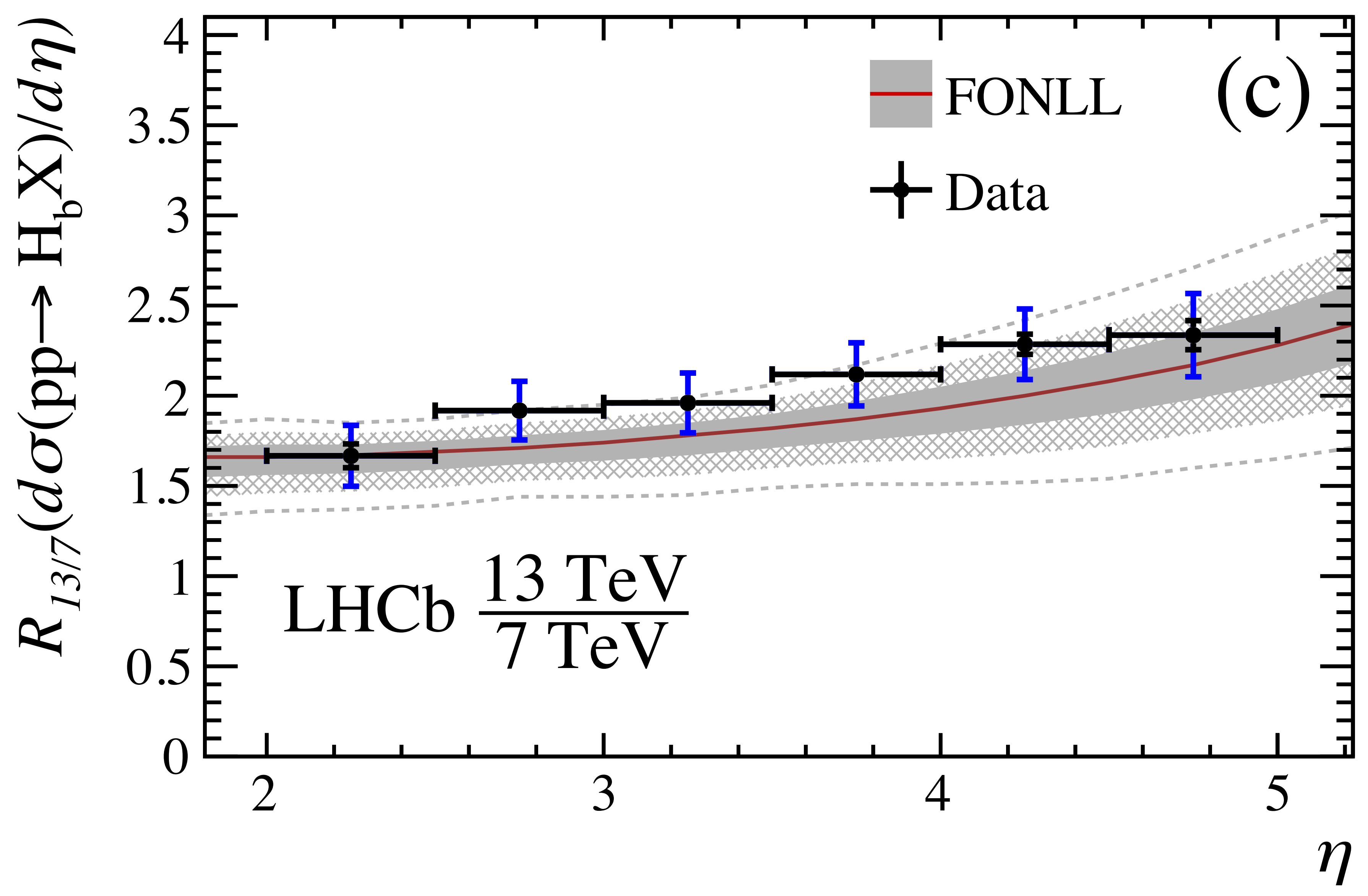
All five flavors (u,d,s,c,b) are considered in the PDFs. The total combined cross-sections given by PYTHIA are:

- 251.8 μb at 7 TeV; 291.6 μb at 8 TeV; 527.3 μb at 14 TeV.

Actual ratio around 1.8

$$\frac{\sigma\left(b\bar{b}\right)_{\text{Run 2}}}{\sigma\left(b\bar{b}\right)_{\text{Run 1}}} = \frac{144\,\mu\text{b}}{\left(72.0\,\mu\text{b}\times 1.1\ \text{fb}^{-1} + 83.4\,\mu\text{b}\times 2.0\ \text{fb}^{-1}\right)/3.1\ \text{fb}^{1}} = 1.81$$

Ratio increases with η



We expect ~1.81×5.9/3.1 = **3.44 times more B mesons** in **Run 2 than** in **Run 1**

Proposed MC stats

$$N_{\rm disk}^{\rm Run\,2} = N_{\rm disk}^{\rm Run\,1} \times \frac{\left(\boxed{\mathscr{L}\times\sigma(b\bar{b})}\times\boxed{\epsilon_{\rm gen}}\times\boxed{\epsilon_{\rm filter}}\right)^{\rm Run\,2}}{\left(\boxed{\mathscr{L}\times\sigma(b\bar{b})}\times\boxed{\epsilon_{\rm gen}}\times\boxed{\epsilon_{\rm filter}}\right)^{\rm Run\,1}} \times \frac{4}{\boxed{f_{\rm MC/data}}}$$

$\mathscr{L}\times\sigma(b\bar{b})$ ratio is 3.44 (previous slide)

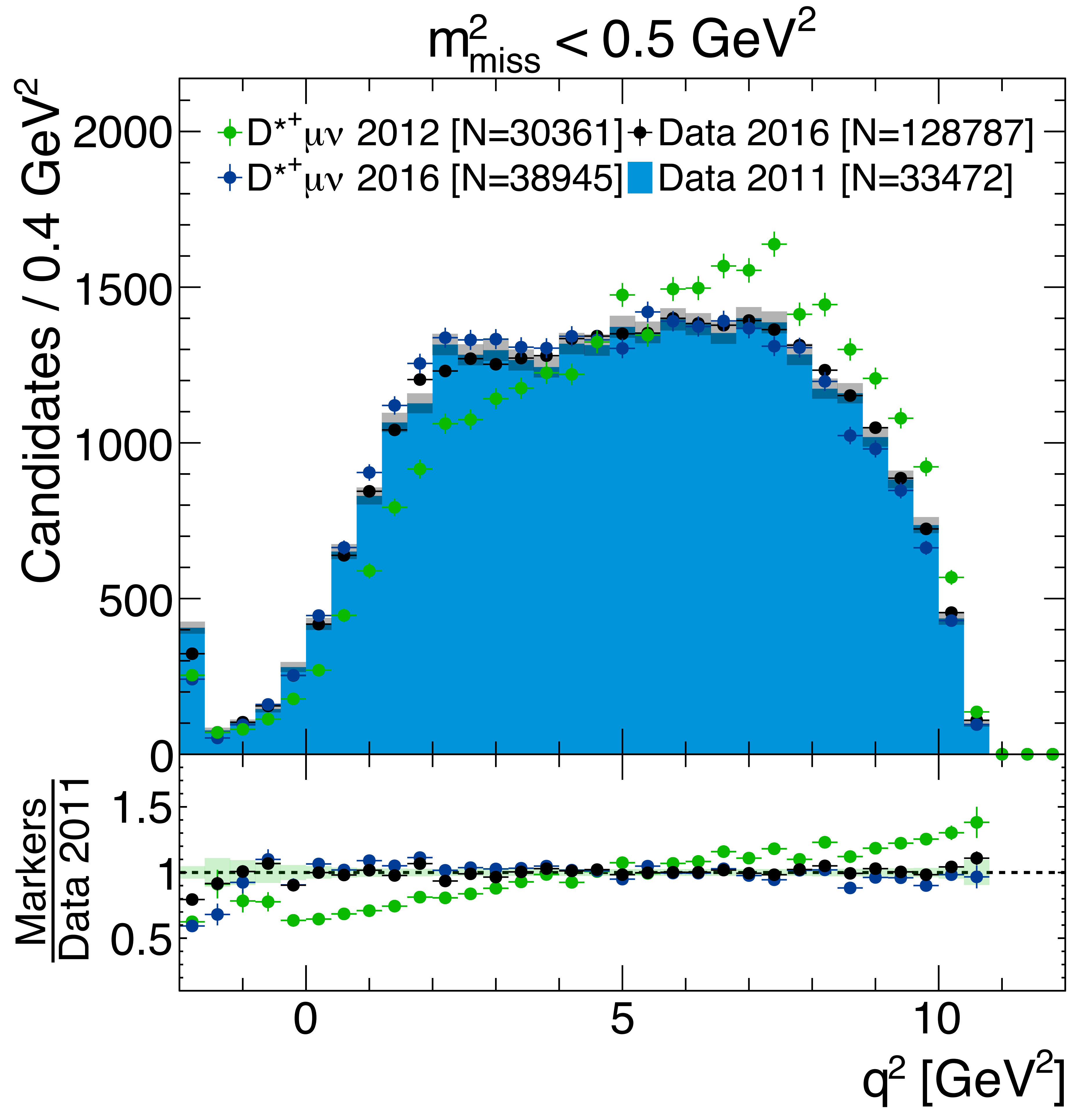
$\epsilon_{\rm gen}$ in table from official MC production

$\epsilon_{\rm filter}$ is 7% in Run 1 and 23% in Run 2 (no trigger selection)

$f_{\rm MC/data}$ from effective MC stats in templates and fitted yields in Run 1

7B events of simulated Tracker-only MC in Run 2

			Run 1: Nsim = 924M / Ndisk = 65M FullSim + RICHless						Run 2: Nsim = 7,300M / Ndisk = 1,679M Tracker-only 2015-18				
#	Sample	Name	MC ID	ε_gen	Nsim [M]	Ndisk [M]	% total request	MC/ data fit	MC ID	ε_gen	Nsim [M]	Ndisk [M]	% total request
1	D0	B- → D0 μ ν	12573010	7.0%	110.0	7.7		2.8	12573012	9.0%	700.6	161.1	
2	D0/D*+	B0 → D*+ μ ν	11574020	5.9%	88.6	6.2	45.6%	1.4	11574021	8.0%	1195.0	274.9	52.9%
3	D0	B- → D*0 μ ν	12573031	6.0%	222.9	15.6		2.1	12773410	8.1%	1966.9	452.4	
4	D0	B- → D0 τ ν	12573000	5.4%	7.3	0.5		2.8	12573001	7.3%	48.2	11.1	
5	D0/D*+	B0 → D*+ τ ν	11574010	5.0%	19.6	1.4	4.8%	1.4	11574011	6.8%	263.6	60.6	6.4%
6	D0	B- → D*0 τ ν	12573021	5.0%	17.0	1.2		2.1	12773400	6.8%	152.5	35.1	
7	D0/D*+	B0 → D**+ μ ν	11873010	5.0%	126.7	8.9		4.0	11874430	7.7%	671.1	154.4	
8	D0/D*+	B0 → D**+ τ ν	11873030	4.9%	1.1	0.1	25.2%	4.0	11874440	6.6%	5.2	1.2	16.9%
9	D0/D*+	B- → D**0 μ ν	12873010	5.7%	103.1	7.2		3.5	12873450	7.7%	551.2	126.8	
10	D0/D*+	B- → D**0 τ ν	12873030	4.9%	1.7	0.1		4.0	12873460	6.6%	7.8	1.8	
11	D0	B- → D**(→D0ππ) μ ν	12675010	5.5%	15.5	1.1		3.0	12675011	7.4%	96.6	22.2	
12	D0	B0 → D**(→D0ππ) μ ν	11674400	5.0%	15.6	1.1		3.0	11674401	7.4%	106.7	24.5	
13	D0/D*+	B- → D**(→D*+ππ) μ ν	12675400	5.4%	11.0	0.8	7.7%	3.0	12675402	7.3%	69.0	15.9	6.3%
14	D0/D*+	B0 → D**(→D*+ππ) μ ν	11676010	5.0%	10.5	0.7		3.0	11676012	7.3%	70.6	16.2	
15	D0	B- → D**(→D*0ππ) μ ν	12675430	5.4%	18.5	1.3		3.0	12875440	7.3%	115.7	26.6	
16	D0	Bs → Ds**(→D0K) μ ν	13873000	5.5%	1.3	0.1	0.6%	1.0	13874020	7.5%	23.8	5.5	0.6%
17	D*+	Bs → D**+μ ν	13874000	5.4%	4.7	0.3		4.0	13674000	7.4%	21.9	5.0	
18	D0	B0 → D0(Xc → μ νX')X	11873000	4.6%	37.8	2.6		1.3	11894600	6.3%	547.4	125.9	
19	D0	B0 → D0(Ds → τν)X	11873020	5.4%	2.4	0.2	9.7%	3.0	11894200	7.3%	15.0	3.5	12.7%
20	D0	B+ → D0(Xc → μ νX')X	12873000	5.0%	40.9	2.9		2.3	12896300	6.7%	329.6	75.8	
21	D0	B+ → D0(Ds → τν)X	12873021	5.6%	8.4	0.6		4.0	12896310	7.5%	38.6	8.9	
22	D*+	B0 → D*+ (Xc → μ ν X')X	11874050	4.8%	41.4	2.9		4.0	11894610	6.4%	194.0	44.6	
23	D*+	B0 → D*+(Ds → τ ν) X	11874070	5.6%	3.9	0.3	6.5%	4.0	11894210	7.5%	17.9	4.1	4.2%
24	D*+	B+ → D*+ (Xc → μ ν X')X	12874010	4.6%	12.0	0.8		2.9	12895400	6.4%	78.4	18.0	
25	D*+	B+ → D*+(Ds → τ ν) X	12874030	5.0%	2.3	0.2		3.4	12895000	6.8%	13.1	3.0	



MC/data in Runs 1 and 2

$\mathscr{R}\left(D^{0,*}\right)$ trigger/stripping selection

```
L0_run1 = "mu_L0Global_TIS & (b0_L0Global_TIS |
dst_L0HadronDecision_TOS)";
HLT1_run1 = "k_Hlt1TrackAllL0Decision_TOS |
pi_Hlt1TrackAllL0Decision_TOS";
HLT2_run1 = "d0_Hlt2CharmHadD02HH_D02KPiDecision_TOS";
L0_run2 = "b0_L0Global_TIS | dst_L0HadronDecision_TOS";
HLT1_run2 = "k_Hlt1TrackMVADecision_TOS |
pi_Hlt1TrackMVAeDecision_TOS  | d0_Hlt1TwoTrackMVADecision_TOS";
HLT2_run2 = "d0_Hlt2XcMuXForTauB2XcMuDecision_Dec";
```

Particle	Variable	Run 1	Run 2
K, π	χ^2_{track}/ndf	< 3	–
	p_{T}	> 800 MeV	> 200 MeV
	p	> 5000 MeV	> 5000 MeV
	Max p_{T}	> 1500 MeV	> 800 MeV
	IPχ^2	> 9	–
	DLLK	–	$> 4(K)$, $< 2(\pi)$
D^0	DIRA	> 0.99985	> 0.999
	p_{T}	> 2000 MeV	> 2000 MeV
	Mass	1815–1915 MeV	1830–1910 MeV
	χ^2_{vertex}/ndf	< 10	< 10
	FDχ^2	> 40	> 25
	Sum track p_{T}	–	> 2500 MeV
	Child pair DOCA	–	< 0.1 mm
μ	IPχ^2	–	> 16
$D^0\mu$	χ^2_{vertex}/ndf	–	> 15
	DIRA	–	> 0.999
	DOCA	–	< 0.5 mm
	FDχ^2	–	> 50

Higher efficiency in **Run 2** thanks to **new triggers** and **stripping**

Table 2: Stripping selection in Run 1 (Strippingb2D0MuXB2DMuNuForTauMuLine in S21) and Run 2 (Strippingb2D0MuXB2DMuForTauMuLine in S28r1).

Event-Level	Variable	Run 1	Run 2
GEC	nSPDhits	< 600	< 600
PV cut	nPV	≥ 1	≥ 1
Particle	**Variable**	**Selection**	
K, π	p_T	> 300 MeV	> 300 MeV
	p	> 2 GeV	> 2 GeV
	$IP\chi^2$	> 45	> 9
	`isMuon`	`False`?	`False`?
	DLLK	$> 4(K)$, $< 2(\pi)$	$> 4(K)$, $< 2(\pi)$
	GhostProb	< 0.5	< 0.5
D^0	$\lvert p_T(\pi)\rvert + \lvert p_T(K)\rvert$	> 1.4 GeV	> 2.5 GeV
	χ^2_{fit}/DOF	< 4	< 4
	DIRA	> 0.9998	> 0.999
	$FD\chi^2$	> 250	> 25
	$m - \langle m \rangle$	< 80 MeV	< 80 MeV
μ	isMuon	`True`?	`True`?
	$IP\chi^2$	> 45	> 16
	GhostProb	< 0.5	< 0.5
	PIDμ	> 2	> -200
	p	> 3 GeV	> 3 GeV
$D^0\mu$	Mass	< 10 GeV	< 10 GeV
	χ^2_{fit}/DOF	< 6	< 6
	DIRA	> 0.9995	> 0.999

ε increase in Run 2 - data

Particle	Variable	Selection
K, π	p_T	> 0.8 GeV
	p_{T} (TOS track)	> 1.7 GeV
	$IP\chi^2$	> 45
D^0	p_T	> 2 GeV
	$\ln IP$	> -3.5
	$\mathrm{IP}\chi^2$	> 9
	$DIRA$	> 0.9998
	Flight dist. χ^2 (PV)	> 250
	$m - \langle m \rangle$	< 23.4 MeV
μ	`isMuon`	true
	p	< 100 GeV
	η	$1.7 < \eta < 5$
	$DLLmu$	> 2
	$DLLe$	< 1
	BDTmu	> 0.25
	$\log_{10}(1 - \vec{p}_\mu \cdot \vec{p}_i / (\lvert p_\mu \rvert \lvert p_i \rvert))$	> -6.5
D^{*+}	$\chi^2_{\mathrm{fit}}/\mathrm{DOF}$	< 10
	$\Delta m - \langle \Delta m \rangle$	< 2 MeV
	π_sGhostProb	< 0.25
$\{D^0\mu\}$ subcomb.	$\chi^2_{\mathrm{fit}}/\mathrm{DOF}$	< 6
	$DIRA$	> 0.9995
B^0	$\chi^2_{\mathrm{fit}}/\mathrm{DOF}$	< 6
	d_{XY} (transverse FD)	< 7 mm
	$DIRA$	> 0.9995
	Mass	< 5280 MeV
	Max iso BDT in event	0.15

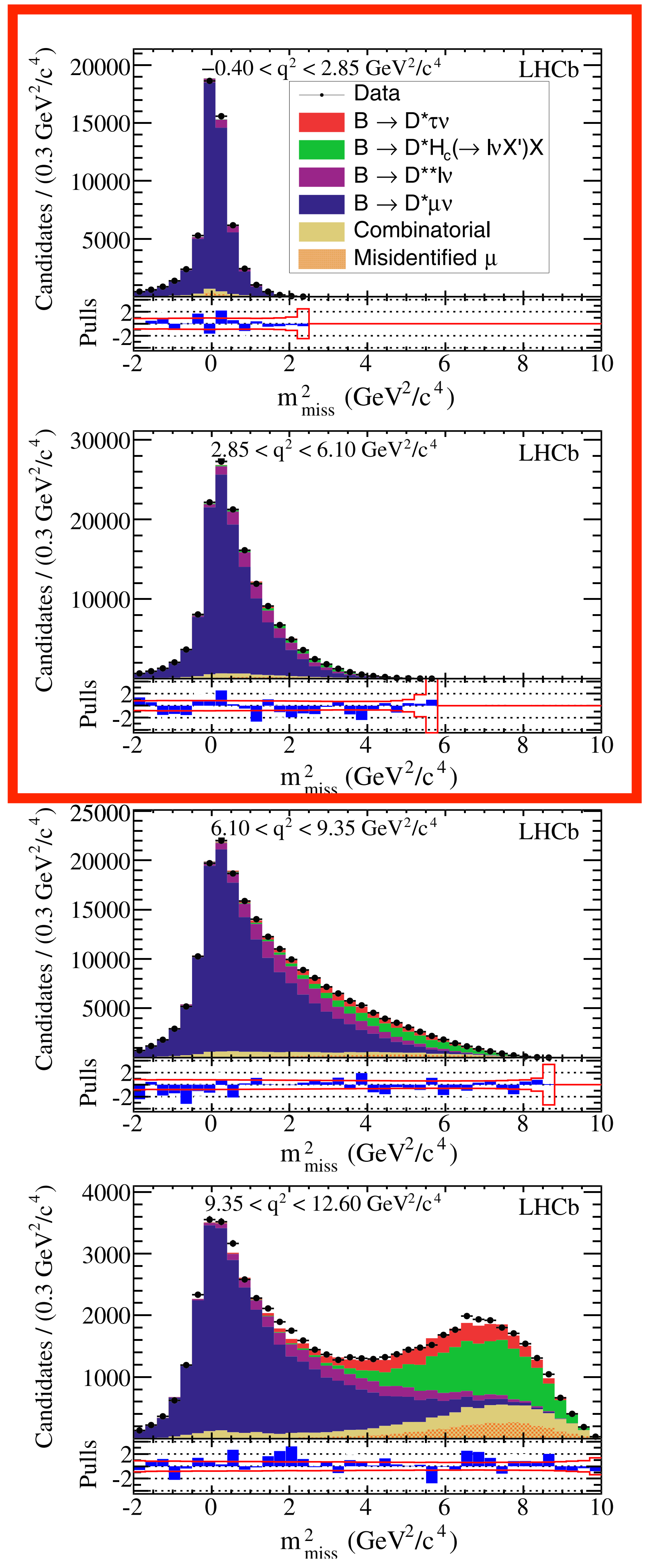
ε increases ~40% with Run 1 cuts

Cut	Data 2011	Data 2016	Ratio × 0.35
Trig. + Strip.	213,908	3,115,751	5.16
+ Kaon	213,806	2,361,759	3.91
+ Pion	213,709	1,825,670	3.03
+ $D^0 \to K\pi$	165,262	1,074,939	2.30
+ μ	155,915	888,951	2.02
+ $D^{*+} \to D^0\pi$	125,026	688,590	1.95
+ $B^0 \to D^{*+}\mu$	120,200	652,638	1.92
+ ISO	77,156	346,689	1.59
+ PID	74,754	288,795	1.37
$q^2 < 6$ GeV^2	32,280	125,126	1.37
$q^2 > 6$ GeV^2	42,474	163,669	1.37
Cut	Data 2011	Data 2016	Ratio × 0.35

Luminosity ratio of 1.41 and cross section ratio of 2

$$\frac{\epsilon^{data}_{2016}}{\epsilon^{data}_{2011}} = \frac{N^{table}_{2016}}{N^{table}_{2011}} \times \frac{\mathscr{L}_{2011}}{\mathscr{L}_{2016}} \times \frac{\sigma^{b\bar{b}}_{2011}}{\sigma^{b\bar{b}}_{2016}} = \frac{N^{table}_{2016}}{N^{table}_{2011}} \times \frac{1}{1.41 \times 2}$$

Fairly pure $D^{*+}\mu\nu$ for $q^2 < 6$ GeV^2



ε increase in Run 2 - data

Particle	Variable	Selection	Comment
K, π	p_T	> 0.8 GeV	Can be loosened to > 0.2 GeV
	p_{T} (TOS track)	> 1.7 GeV	
	$IP\chi^2$	> 45	Can be loosened to > 9
D^0	p_T	> 2 GeV	
	$\ln IP$	> -3.5	
	$\mathrm{IP}\chi^2$	> 9	
	$DIRA$	> 0.9998	Can be loosened to > 0.999
	Flight dist. χ^2 (PV)	> 250	Can be loosened to > 25
	$m - \langle m \rangle$	< 23.4 MeV	
μ	isMuon	true	
	p	< 100 GeV	
	η	$1.7 < \eta < 5$	
	$DLLmu$	> 2	
	$DLLe$	< 1	
	BDTmu	> 0.25	Not implemented yet
	$\log_{10}(1 - \vec{p}_\mu \cdot \vec{p}_i/(\lvert p_\mu\rvert \lvert p_i\rvert))$	> -6.5	$i = K, \pi, \pi_s$
D^{*+}	$\chi^2_{\mathrm{fit}}/\mathrm{DOF}$	< 10	
	$\Delta m - \langle \Delta m \rangle$	< 2 MeV	
	π_sGhostProb	< 0.25	
$\{D^0\mu\}$ subcomb.	$\chi^2_{\mathrm{fit}}/\mathrm{DOF}$	< 6	
	$DIRA$	> 0.9995	Can be loosened to > 0.999
B^0	$\chi^2_{\mathrm{fit}}/\mathrm{DOF}$	< 6	
	d_{XY} (transverse FD)	< 7 mm	
	$DIRA$	> 0.9995	Can be loosened to > 0.999
	Mass	< 5280 MeV	
	Max iso BDT in event	0.15	Needs to be optimized

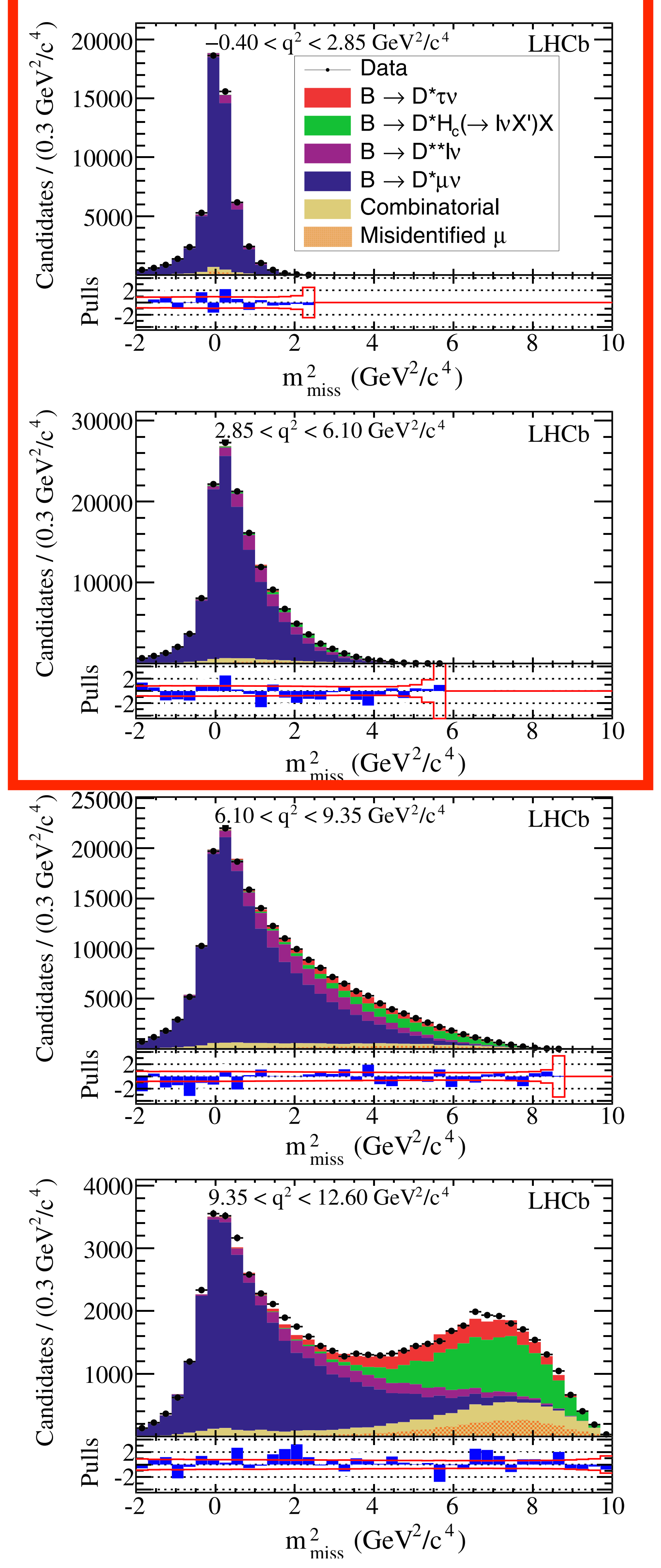
ε increases ~40% with Run 1 cuts

Cut	Data 2011	Data 2016	Ratio × 0.35
Trig. + Strip.	213,908	3,115,751	5.16
+ Kaon	213,806	2,361,759	3.91
+ Pion	213,709	1,825,670	3.03
+ $D^0 \to K\pi$	165,262	1,074,939	2.30
+ μ	155,915	888,951	2.02
+ $D^{*+} \to D^0\pi$	125,026	688,590	1.95
+ $B^0 \to D^{*+}\mu$	120,200	652,638	1.92
+ ISO	77,156	346,689	1.59
+ PID	74,754	288,795	1.37
$q^2 < 6$ GeV^2	32,280	125,126	1.37
$q^2 > 6$ GeV^2	42,474	163,669	1.37
Cut	Data 2011	Data 2016	Ratio × 0.35

ε can increase ~170% with looser cuts

Cut	Data 2011	Data 2016	Ratio × 0.35
Trig. + Strip.	213,908	3,115,751	5.16
+ Kaon	213,806	2,598,685	4.31
+ Pion	213,709	2,235,955	3.71
+ $D^0 \to K\pi$	165,262	1,767,519	3.79
+ μ	155,915	1,472,867	3.35
+ $D^{*+} \to D^0\pi$	125,026	1,104,452	3.13
+ $B^0 \to D^{*+}\mu$	120,200	1,059,868	3.12
+ ISO	77,156	581,947	2.67
+ PID	74,754	480,092	2.28
$q^2 < 6$ GeV^2	32,280	248,735	2.73
$q^2 > 6$ GeV^2	42,474	231,357	1.93
Cut	Data 2011	Data 2016	Ratio × 0.35

Fairly pure $D^{*+}\mu\nu$ for $q^2 < 6$ GeV^2



ε increase in Run 2 - MC

Cut	$D^{*+}\tau\nu$ 2011	$D^{*+}\tau\nu$ 2016	Ratio × 1.00
L0	3,403	3,796	1.12
+ HLT1	1,234	2,040	1.65
+ HLT2	498	1,113	2.23
+ Full strip.	53	152	2.87
+ Kaon	53	127	2.40
+ Pion	53	100	1.89
+ $D^0 \to K\pi$	44	76	1.73
+ μ	43	65	1.51
+ $D^{*+} \to D^0\pi$	41	57	1.39
+ $B^0 \to D^{*+}\mu$	29	52	1.79
+ ISO	27	44	1.63
+ PID	26	40	$\boxed{1.54}$
$q^2 < 6$ GeV^2	1	4	4.00
$q^2 > 6$ GeV^2	25	36	1.44
Cut	$D^{*+}\tau\nu$ 2011	$D^{*+}\tau\nu$ 2016	Ratio × 1.00

Cut	$D^{*+}\mu\nu$ 2011	$D^{*+}\mu\nu$ 2016	Ratio × 1.00
L0	62,766	71,385	1.14
+ HLT1	27,569	41,637	1.51
+ HLT2	11,669	25,804	2.21
+ Full strip.	1,086	3,119	2.87
+ Kaon	1,086	2,615	2.41
+ Pion	1,086	2,168	2.00
+ $D^0 \to K\pi$	940	1,384	1.47
+ μ	875	1,170	1.34
+ $D^{*+} \to D^0\pi$	818	1,096	1.34
+ $B^0 \to D^{*+}\mu$	785	1,041	1.33
+ ISO	649	811	1.25
+ PID	633	744	$\boxed{1.18}$
$q^2 < 6$ GeV^2	289	342	1.18
$q^2 > 6$ GeV^2	344	402	1.17
Cut	$D^{*+}\mu\nu$ 2011	$D^{*+}\mu\nu$ 2016	Ratio × 1.00

Cut	$D^{*+}\mu\nu$ 2011	$D^{*+}\mu\nu$ 2016	Ratio × 1.00
L0	62,766	71,385	1.14
+ HLT1	27,569	41,637	1.51
+ HLT2	11,669	25,804	2.21
+ Full strip.	1,086	3,119	2.87
+ Kaon	1,086	2,799	2.58
+ Pion	1,086	2,518	2.32
+ $D^0 \to K\pi$	940	2,282	2.43
+ μ	875	1,971	2.25
+ $D^{*+} \to D^0\pi$	818	1,828	2.23
+ $B^0 \to D^{*+}\mu$	785	1,773	2.26
+ ISO	649	1,389	2.14
+ PID	633	1,247	$\boxed{1.97}$
$q^2 < 6$ GeV^2	289	686	2.37
$q^2 > 6$ GeV^2	344	561	1.63
Cut	$D^{*+}\mu\nu$ 2011	$D^{*+}\mu\nu$ 2016	Ratio × 1.00

ε increases ~50% with Run 1 cuts

Signal **Normalization** **D****

Cocktail 11874091

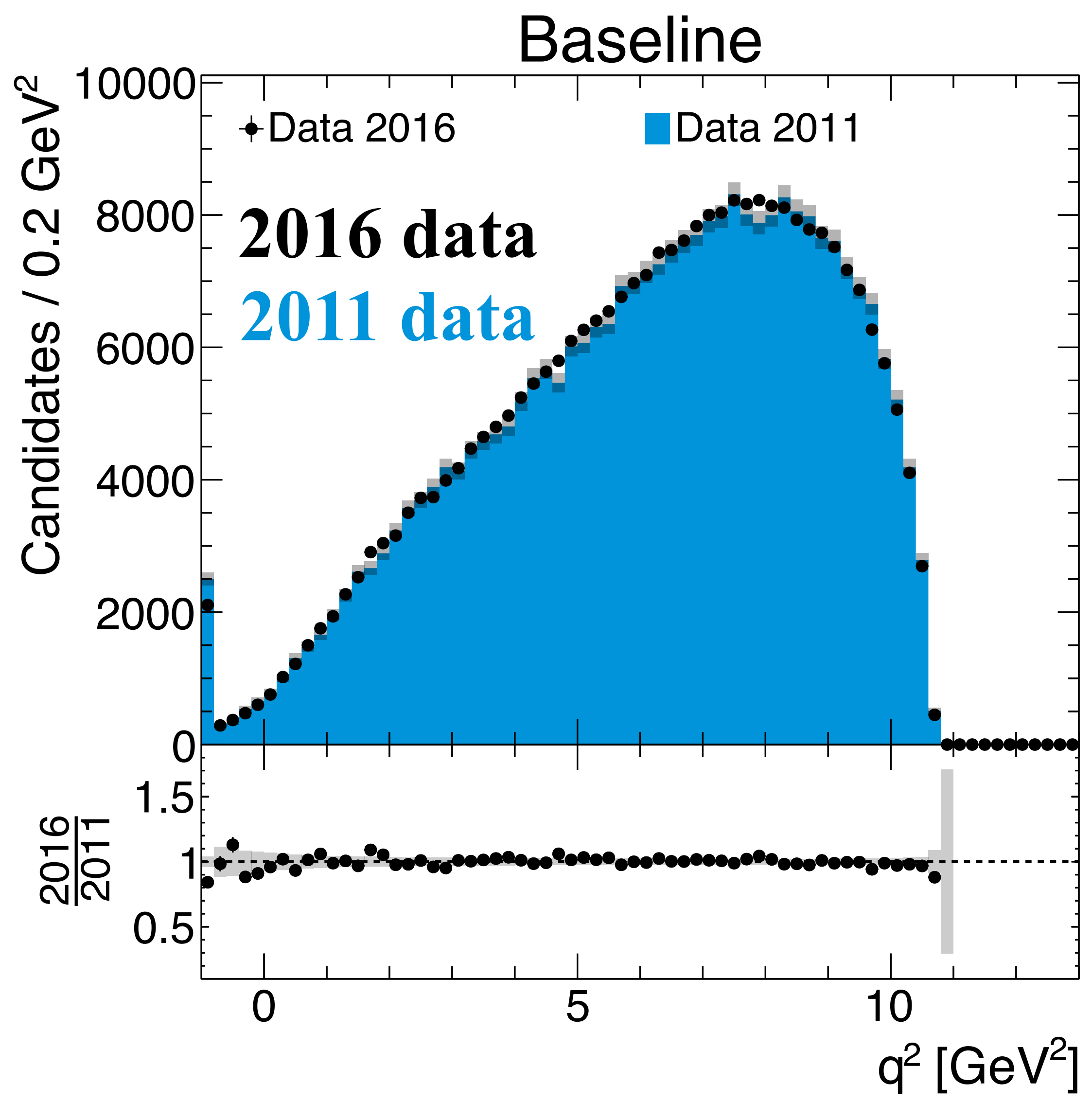
Cut	$D^{*+}\tau\nu$ 2011	$D^{*+}\tau\nu$ 2016	Ratio × 1.00
L0	3,403	3,796	1.12
+ HLT1	1,234	2,040	1.65
+ HLT2	498	1,113	2.23
+ Full strip.	53	152	2.87
+ Kaon	53	138	2.60
+ Pion	53	128	2.42
+ $D^0 \to K\pi$	44	110	2.50
+ μ	43	97	2.26
+ $D^{*+} \to D^0\pi$	41	86	2.10
+ $B^0 \to D^{*+}\mu$	29	79	2.72
+ ISO	27	64	2.37
+ PID	26	59	$\boxed{2.27}$
$q^2 < 6$ GeV^2	1	6	6.00
$q^2 > 6$ GeV^2	25	53	2.12
Cut	$D^{*+}\tau\nu$ 2011	$D^{*+}\tau\nu$ 2016	Ratio × 1.00

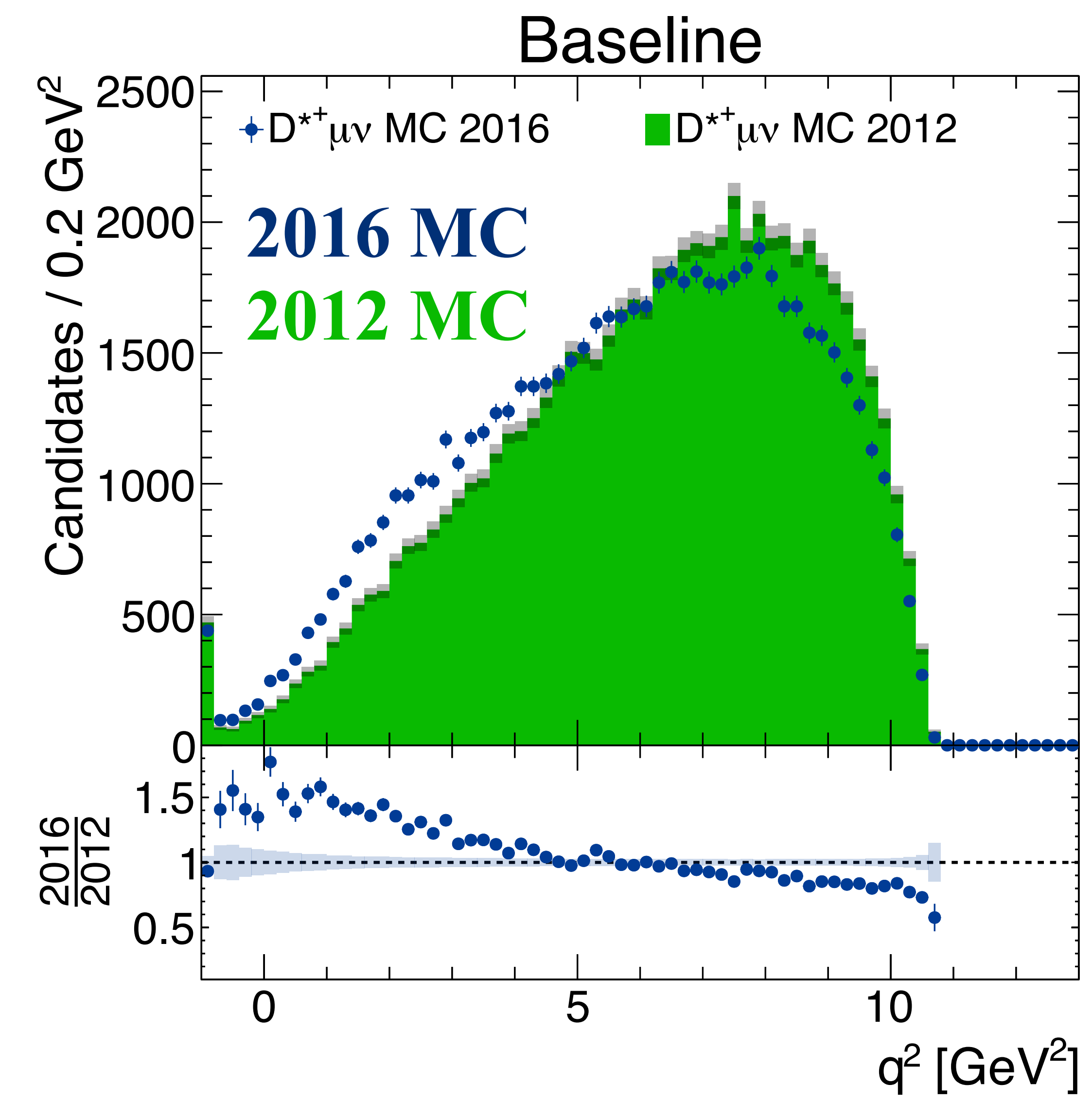
Cut	$D^{**}\mu\nu$ 2011	$D^{**}\mu\nu$ 2016	Ratio × 1.00
L0	32,364	36,978	1.14
+ HLT1	13,606	21,264	1.56
+ HLT2	5,533	12,177	2.20
+ Full strip.	206	723	3.51
+ Kaon	206	630	3.06
+ Pion	206	574	2.79
+ $D^0 \to K\pi$	185	516	2.79
+ μ	179	453	2.53
+ $D^{*+} \to D^0\pi$	150	366	2.44
+ $B^0 \to D^{*+}\mu$	140	357	2.55
+ ISO	38	124	3.26
+ PID	38	111	$\boxed{2.92}$
$q^2 < 6$ GeV^2	13	50	3.85
$q^2 > 6$ GeV^2	25	61	2.44
Cut	$D^{**}\mu\nu$ 2011	$D^{**}\mu\nu$ 2016	Ratio × 1.00

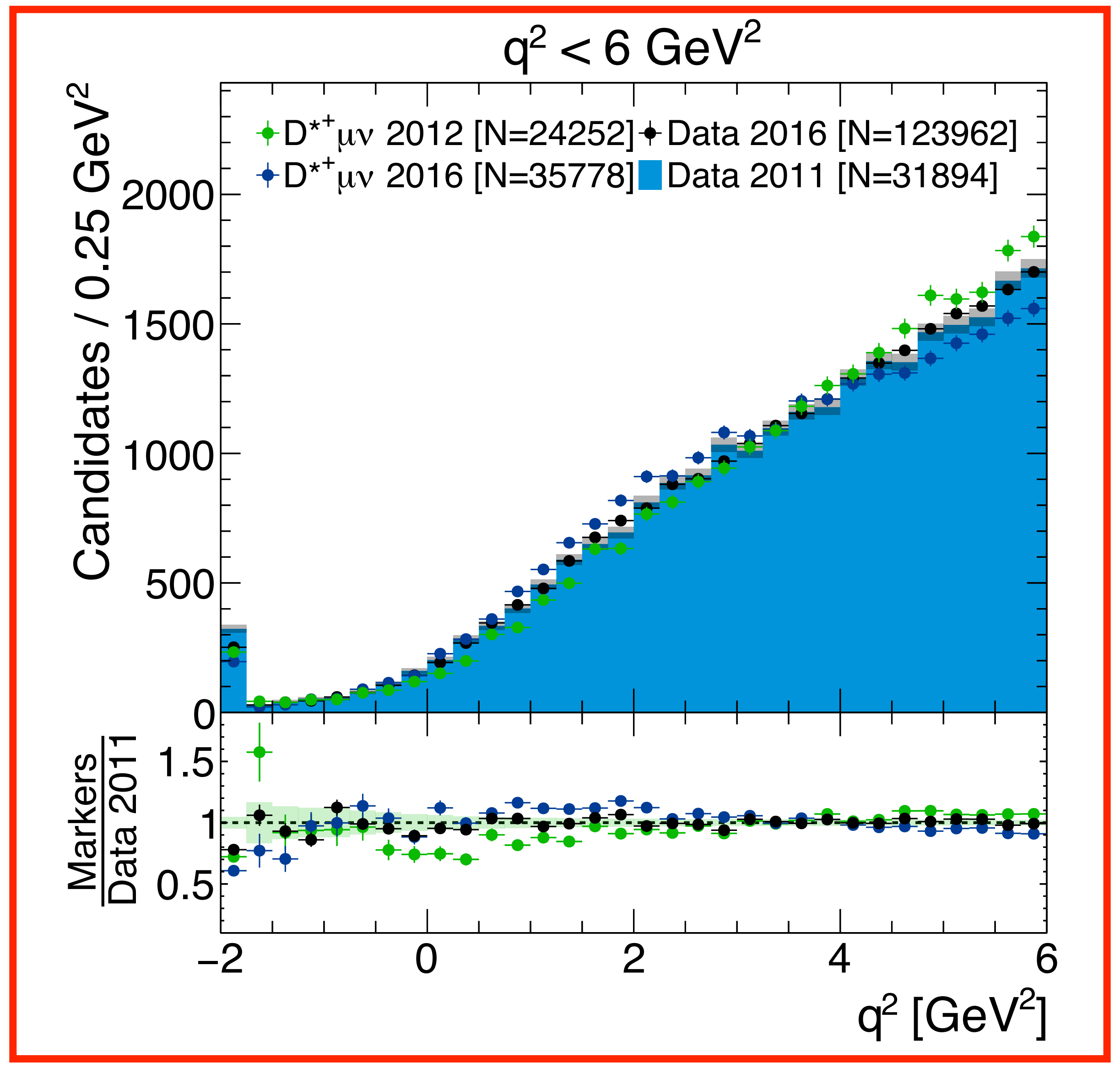
Cut	$D^{**}\mu\nu$ 2011	$D^{**}\mu\nu$ 2016	Ratio × 1.00
L0	32,364	36,978	1.14
+ HLT1	13,606	21,264	1.56
+ HLT2	5,533	12,177	2.20
+ Full strip.	206	723	3.51
+ Kaon	206	591	2.87
+ Pion	206	486	2.36
+ $D^0 \to K\pi$	185	326	1.76
+ μ	179	289	1.61
+ $D^{*+} \to D^0\pi$	150	235	1.57
+ $B^0 \to D^{*+}\mu$	140	228	1.63
+ ISO	38	74	1.95
+ PID	38	69	$\boxed{1.82}$
$q^2 < 6$ GeV^2	13	27	2.08
$q^2 > 6$ GeV^2	25	42	1.68
Cut	$D^{**}\mu\nu$ 2011	$D^{**}\mu\nu$ 2016	Ratio × 1.00

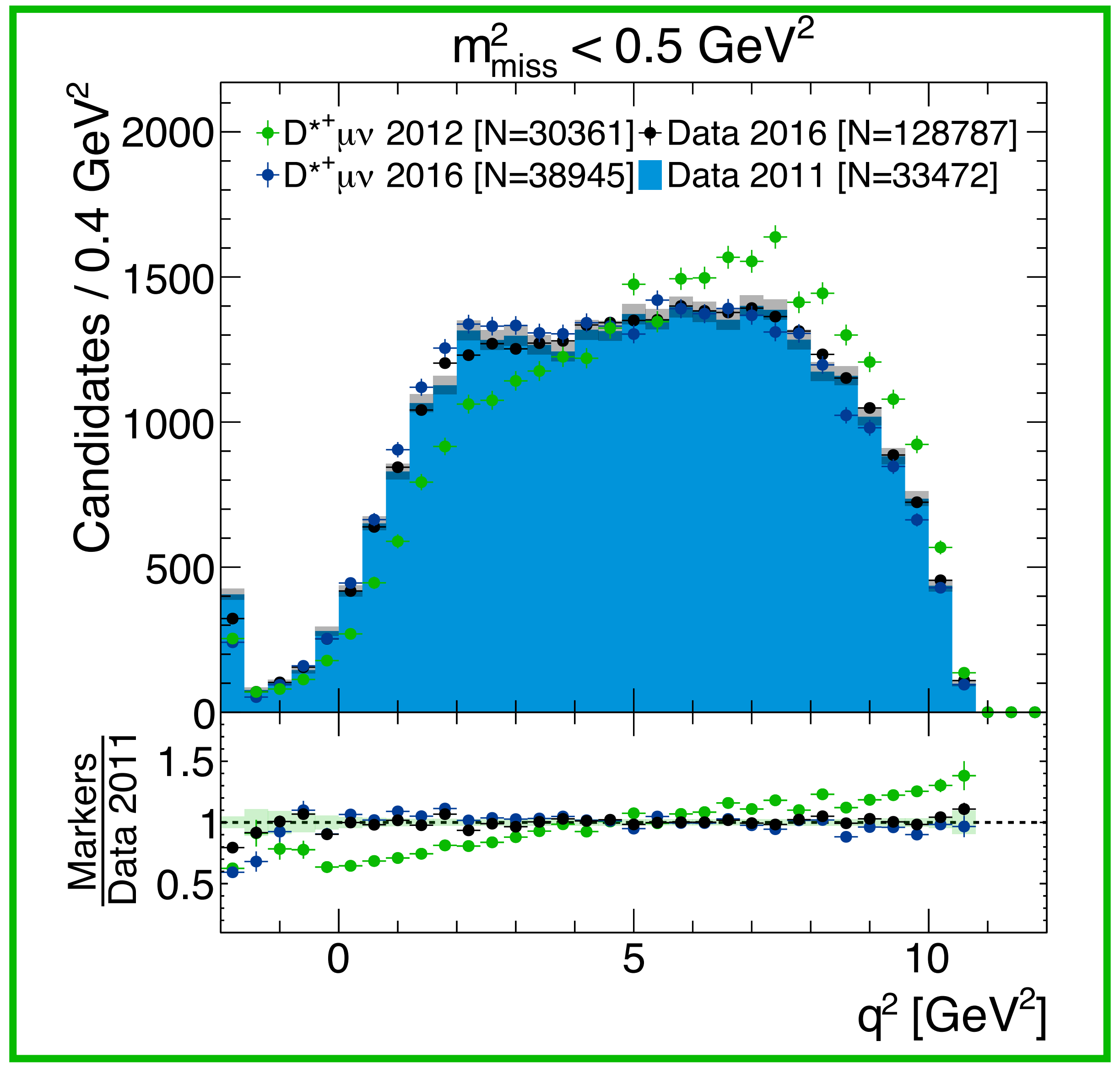
ε can increase ~110% with looser cuts (needs optimization)

New $D^{*+}\mu\nu$ FF have better agreement

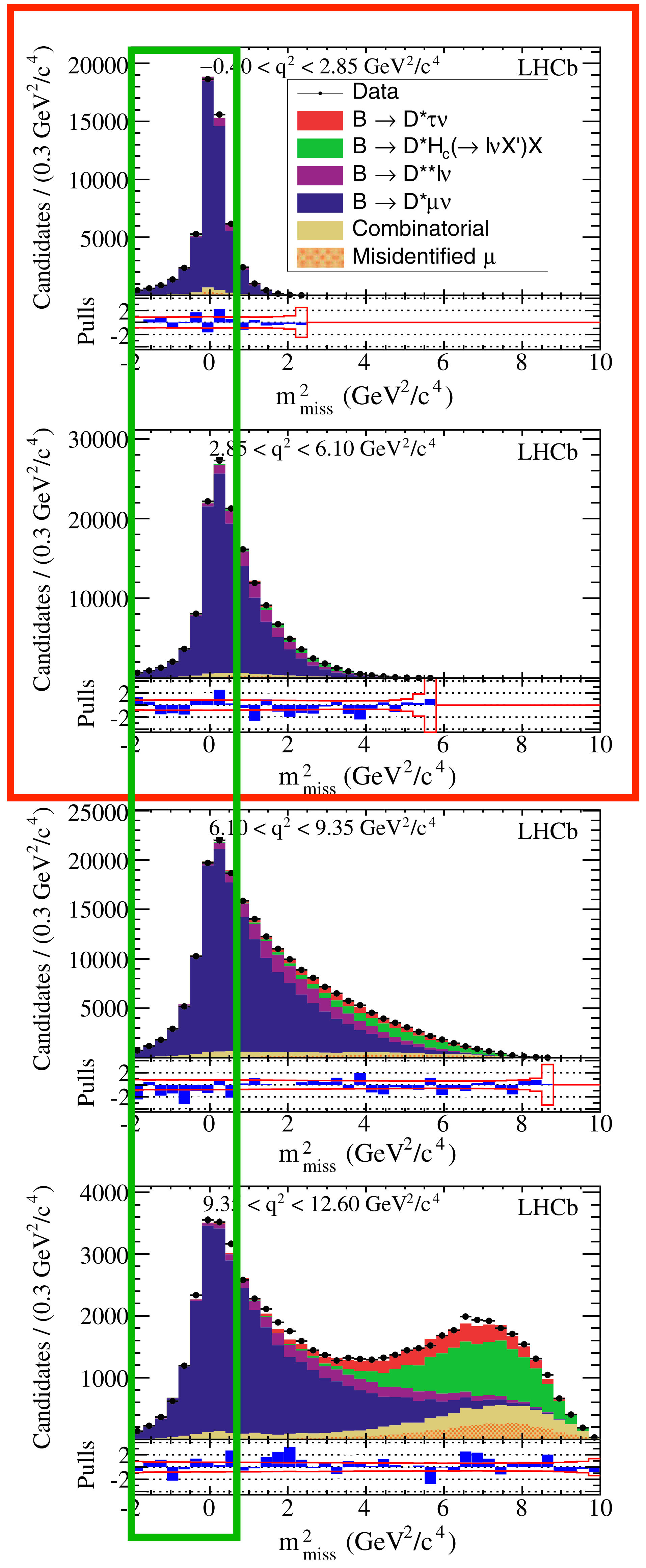




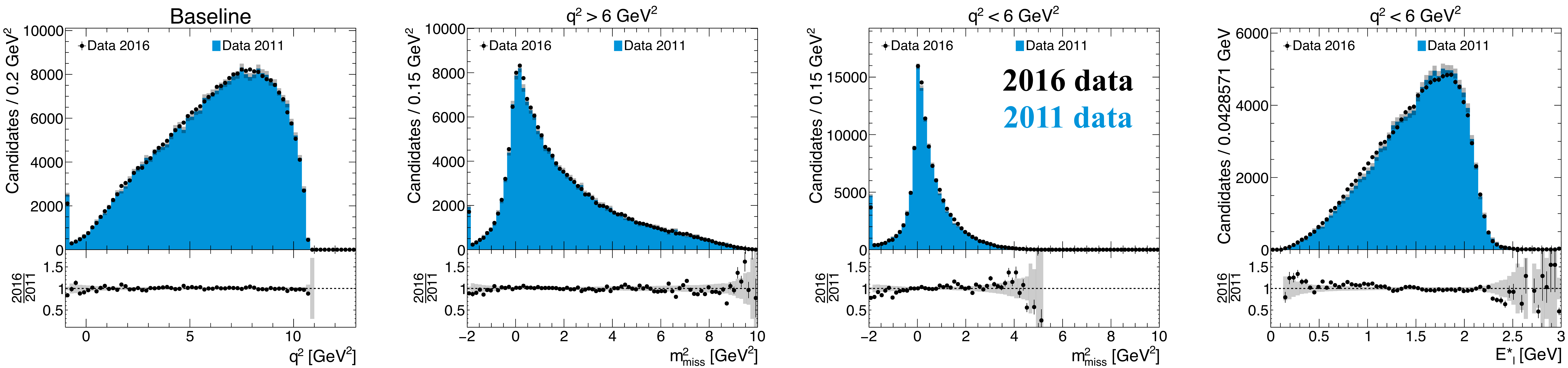


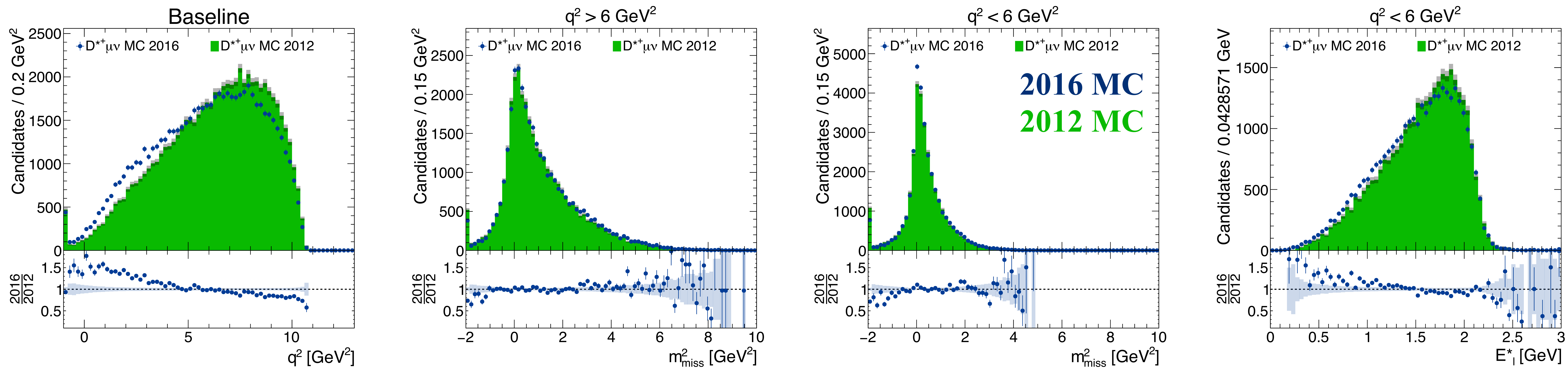


- Use **low q²** and **low m_{miss}** regions to look at data
  - Pretty pure in $D^{*+}l\nu$
- Compare with FS MC
  - Run 1 $D^{*+}l\nu$ (11574020)
  - Run 2 $D^{*+}l\nu$ (11574021)
- Updated FFs for $D^0 l\nu$, $D^* l\nu$, $D^{*+}l\nu$
  - Bug in Run 1 $D^{*+}l\nu$ FFs, so larger improvement there

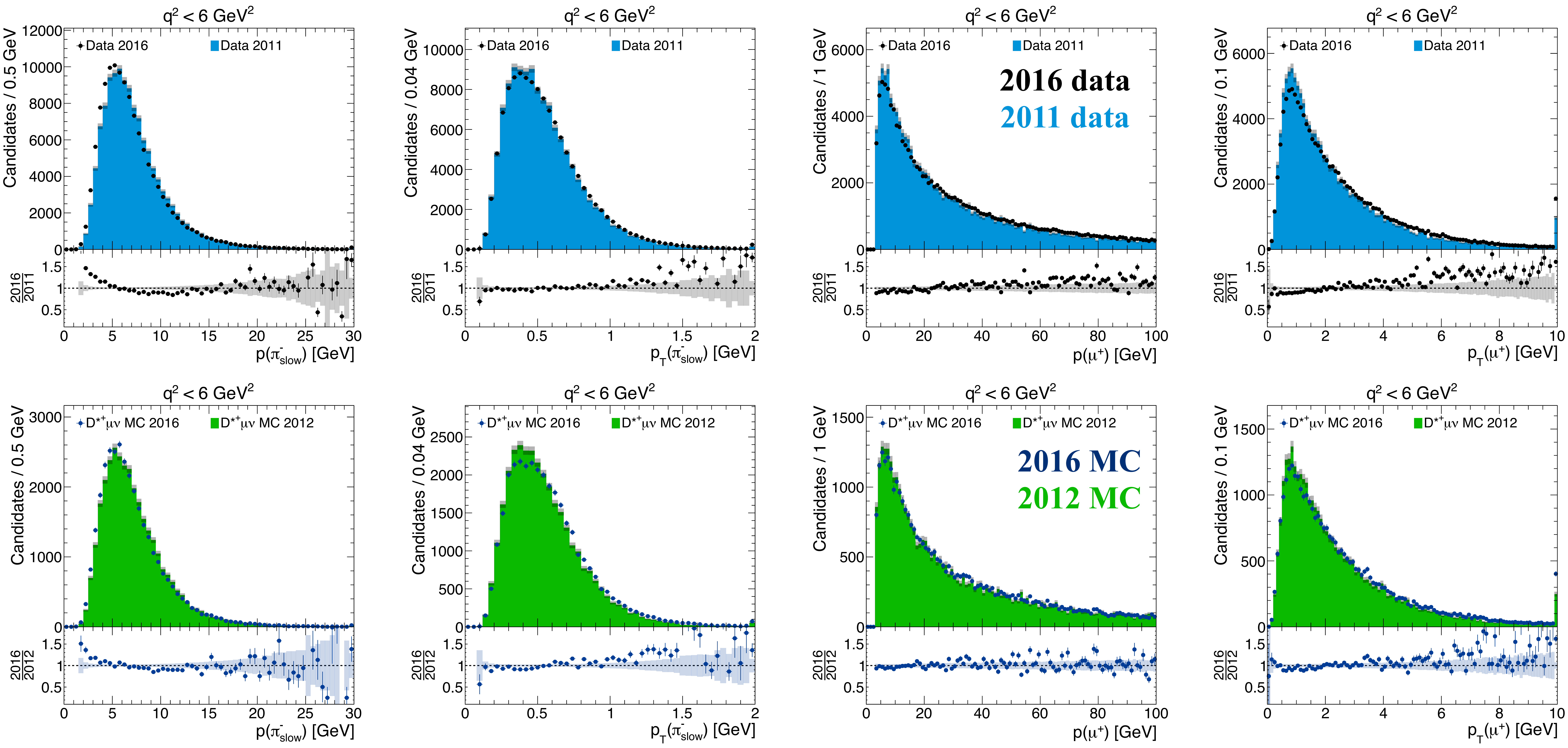


$D^{*+}\mu\nu$ Run 1-2: fit variables stable

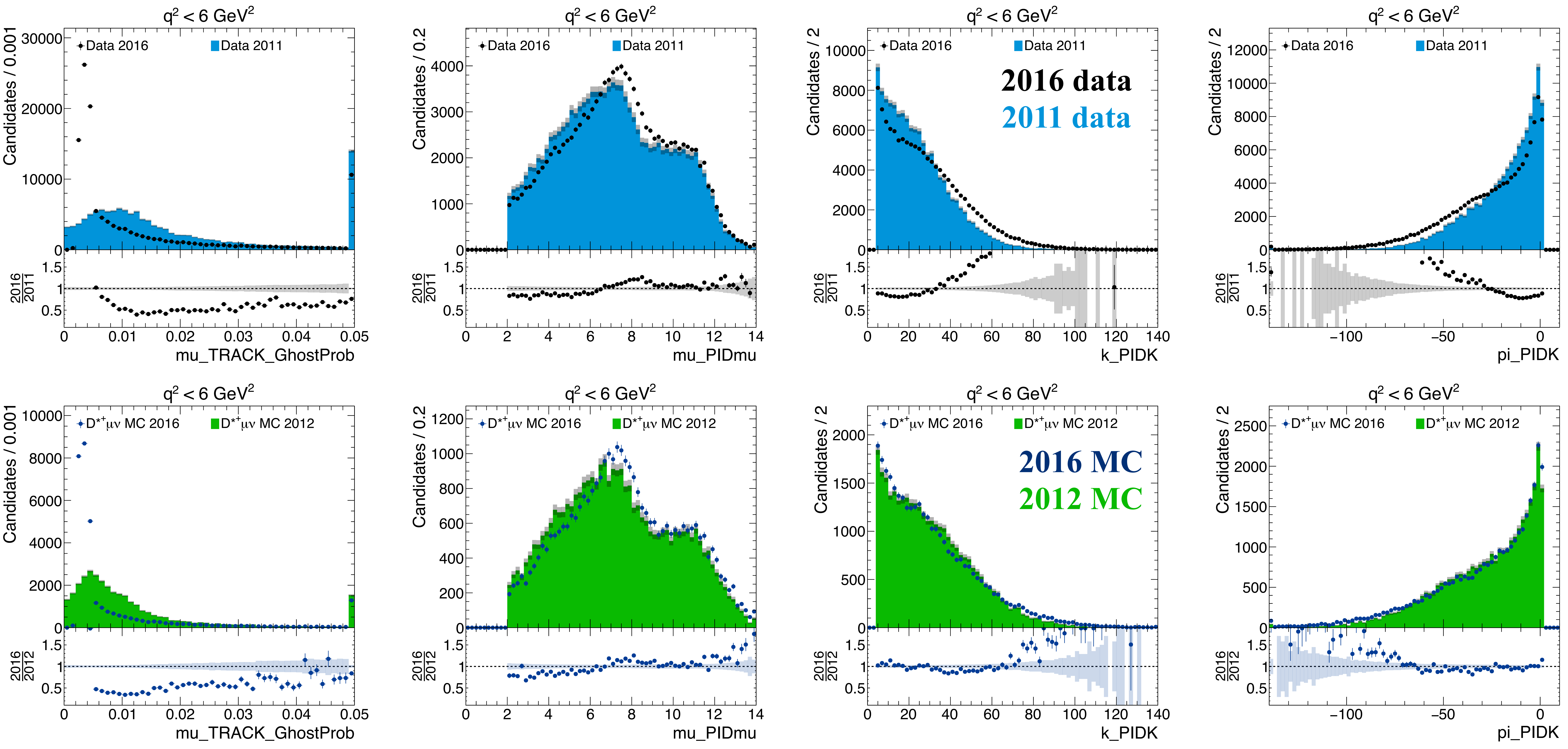




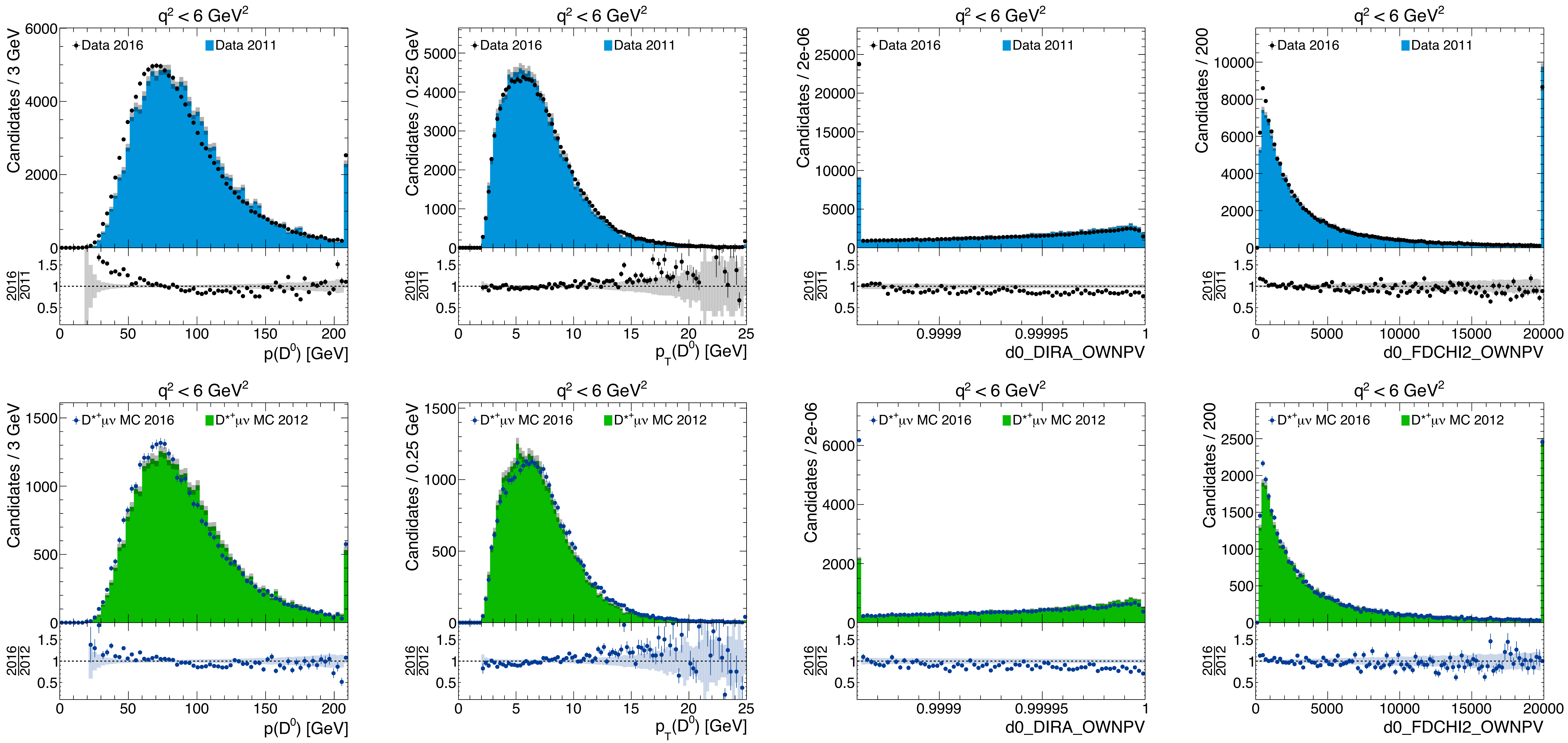
Run 1 vs Run 2: slight shift to higher p(μ)



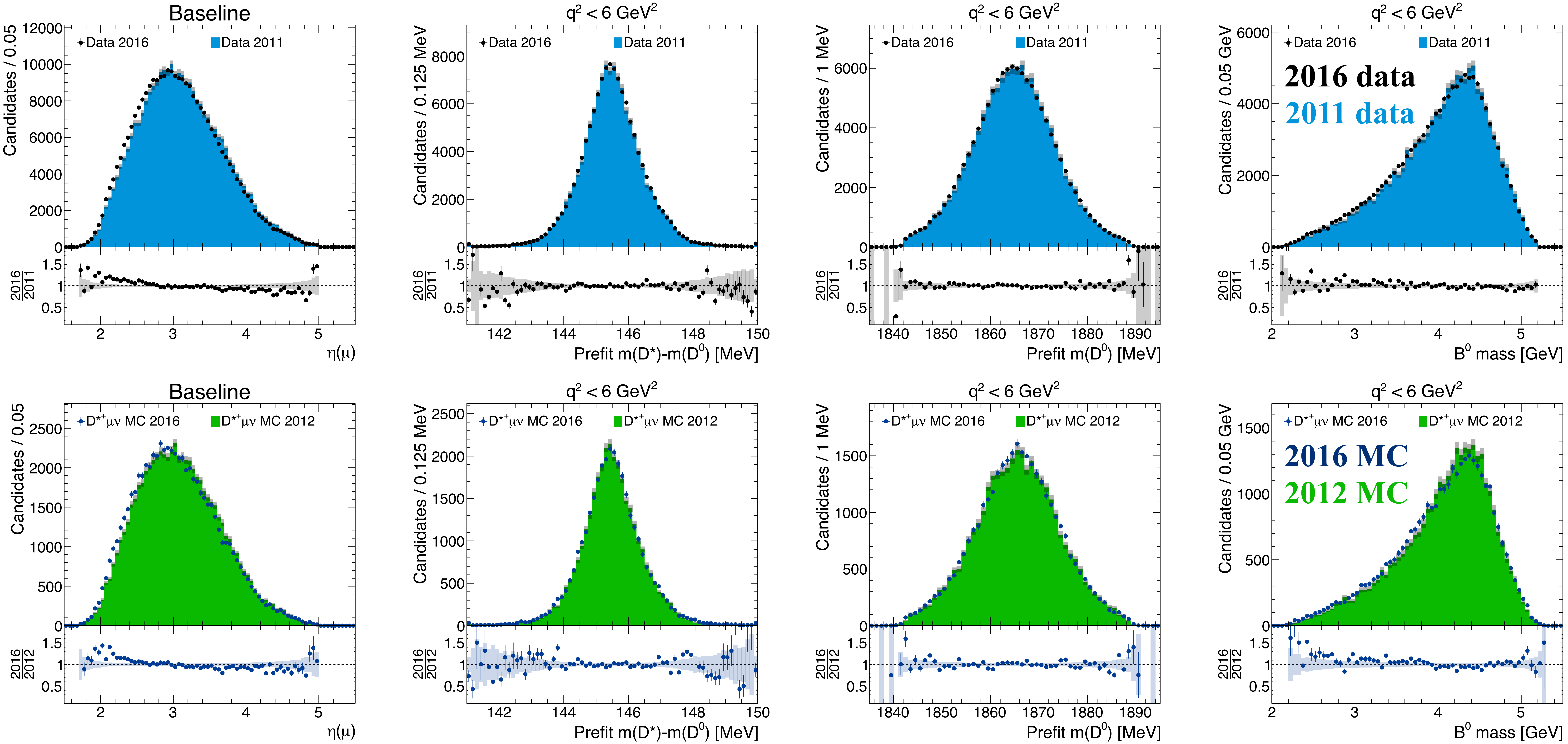
Run 1 vs Run 2: GhostProb, PID new algorithms



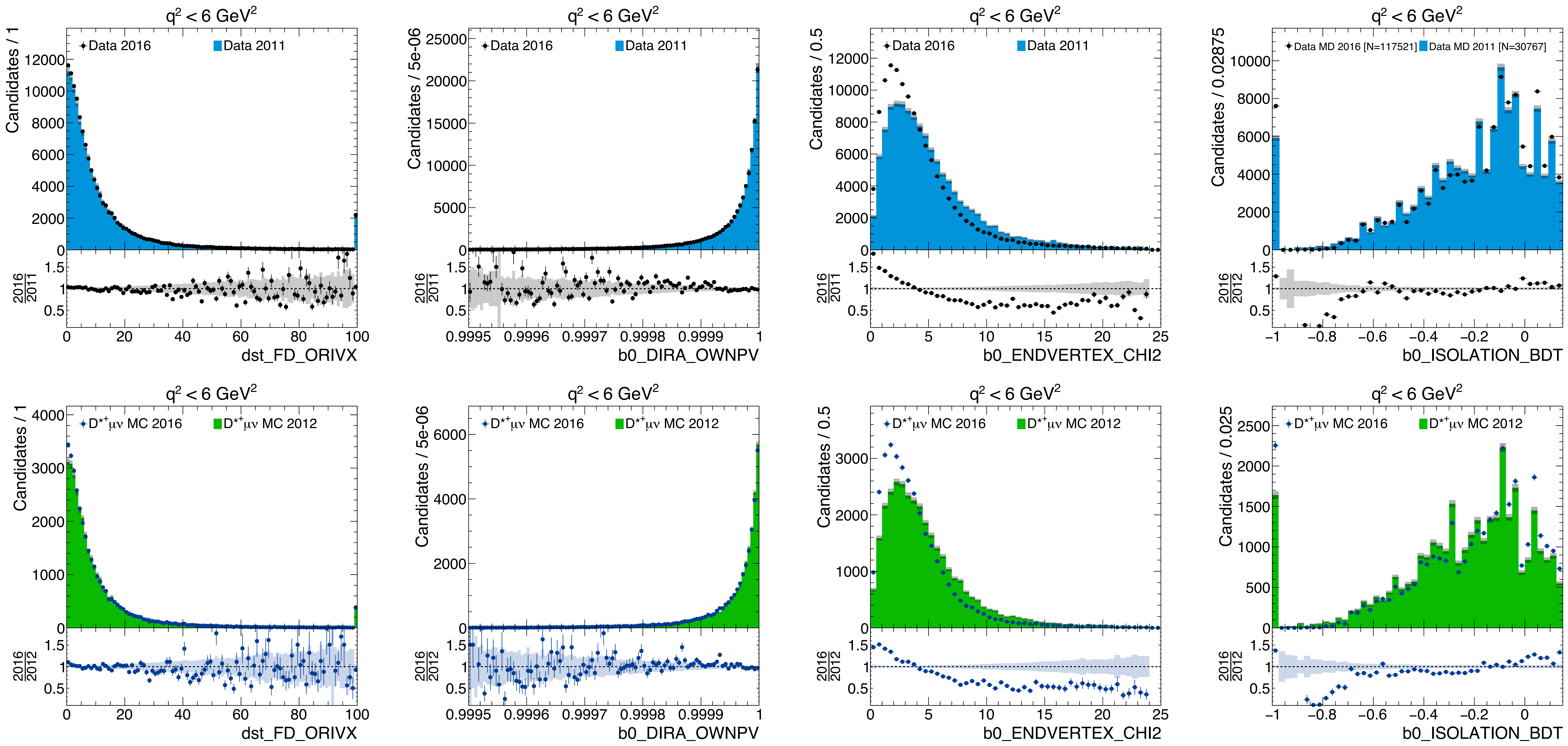
Run 1 vs Run 2: D^0



Run 1 vs Run 2: masses stable



Run 1 vs Run 2: D^{*+}, B^0



Run 1 vs Run 2: issue in 2016 track χ^2?

Backup

Run 2 MC validation

- https://github.com/umd-lhcb/group-talks-pub/blob/main/rdx/21-05-07_Yipeng_overview_MCvalidation.pdf
  - Short summary of the changes to the dec files
  - Validation of the dec files and FullSim samples
    - Estimated selection efficiencies and branching fractions
  - Tracker-only MC validation: trigger emulation and comparison of selection variables
- https://raw.githubusercontent.com/umd-lhcb/group-talks-pub/main/rdx/21-03-09_alex_run2_fullsim_validation.pdf
  - All FullSim comparison plots we have looked at
- https://raw.githubusercontent.com/umd-lhcb/group-talks-pub/main/rdx/21-04-20_alex_run2_trackeronly_validation.pdf
  - All tracker-only MC plots

Stats in D^{*+} templates

Compare effective stats in MC templates with fitted yields
Uncertainties very large and correlated → only correct cases when ratio less than 4

MCMC fit in ANA note

$D_1^+\mu\nu$ IsoDst yield	1.12e4 $\pm$3.35e3
$D_1^0\mu\nu$ IsoDst yield	0 $\pm$5.59e4
$D_{1'}^+\mu\nu$ IsoDst yield	1.36e4 $\pm$4.28e3
$D_{1'}^0\mu\nu$ IsoDst yield	561 $\pm$3.26e3
$D_2^{*+}\mu\nu$ IsoDst yield	3.22e3 $\pm$2.54e3
$D_2^{*0}\mu\nu$ IsoDst yield	166 $\pm$1.9e3
DstDD IsoDst yield	2.43e4 $\pm$1.01e3
misID IsoDst yield	4.03e3 $\pm$652
$D_{s1'}^+\mu\nu$ IsoDst yield	817 $\pm$953
$D_{s2}^{*+}\mu\nu$ IsoDst yield	0 $\pm$1.76e3
$D_s \to \tau\nu$ IsoDst yield	1.08e3 $\pm$290
$D^{**}\tau\nu$ IsoDst yield	459 $\pm$121
$D^{*+}\mu\nu$ IsoDst yield	3.31e5 $\pm$2.07e3
Comb. IsoDst yield	1.05e3 $\pm$451
$(D^{**} \to D^{*+}\pi\pi)\mu\nu$ IsoDst yield	1.1e4 $\pm$2.35e3
FakeDst IsoDst yield	9.98e3 $\pm$1.97e3

Didn't look at D**τ yields, so estimated them as D**μ×0.12×0.7×0.1741

MCMC fit in ANA note

h_sigmuALT:	444,109 /	792,508 =	56.0%	MC/data = 1.3	(data = 331,000)
h_D1_ALT:	44,484 /	97,042 =	45.8%	MC/data = 4.0	(data = 11,200)
h_D1p_ALT:	52,557 /	103,069 =	51.0%	MC/data = 3.9	(data = 13,600)
h_D2_ALT:	13,255 /	25,657 =	51.7%	MC/data = 4.1	(data = 3,220)
h_D1tau_ALT:	7,681 /	13,584 =	56.5%	MC/data = 16.7	(data = 459)
h_D1ptau_ALT:	8,608 /	14,822 =	58.1%	MC/data = 18.8	(data = 459)
h_D2tau_ALT:	2,106 /	3,109 =	67.7%	MC/data = 4.6	(data = 459)
h_uDDmu:	10,913 /	21,819 =	50.0%	MC/data = 0.4	(data = 24,300)
h_dDDmu:	68,204 /	145,507 =	46.9%	MC/data = 2.8	(data = 24,300)
h_dDDtau:	13,506 /	26,325 =	51.3%	MC/data = 12.5	(data = 1,080)
h_uDDtau:	3,369 /	5,371 =	62.7%	MC/data = 3.1	(data = 1,080)

HistFactory yields

h_sigmuALT:	444,109 /	792,508 =	56.0%	MC/data = 1.4	(data = 323,024)
h_D1_ALT:	44,484 /	97,042 =	45.8%	MC/data = 5.5	(data = 8,129)
h_D1p_ALT:	52,557 /	103,069 =	51.0%	MC/data = 6.2	(data = 8,470)
h_D2_ALT:	13,255 /	25,657 =	51.7%	MC/data = 6.4	(data = 2,063)
h_D1tau_ALT:	7,681 /	13,584 =	56.5%	MC/data = 64.6	(data = 119)
h_D1ptau_ALT:	8,608 /	14,822 =	58.1%	MC/data = 69.5	(data = 124)
h_D2tau_ALT:	2,106 /	3,109 =	67.7%	MC/data = 69.8	(data = 30)
h_D2Smu:	38,530 /	71,024 =	54.2%	MC/data = 5.1	(data = 7,521)
h_uDDmu:	10,913 /	21,819 =	50.0%	MC/data = 2.9	(data = 3,806)
h_dDDmu:	68,204 /	145,507 =	46.9%	MC/data = 3.9	(data = 17,634)
h_dDDtau:	13,506 /	26,325 =	51.3%	MC/data = 130.2	(data = 104)
h_uDDtau:	3,369 /	5,371 =	62.7%	MC/data = 3.4	(data = 991)

Stats in D^0 templates

MCMC fit in ANA note

h_Dmu_ALT:	990,974 /	1,748,625 =	56.7%	MC/data =	2.7	(data =	366,000)
h_uDstmuALT:	1,979,933 /	2,999,737 =	66.0%	MC/data =	2.2	(data =	917,000)
h_dDstmuALT:	121,138 /	212,140 =	57.1%	MC/data =	1.7	(data =	69,500)
h_dD0muALT:	66,847 /	108,792 =	61.4%	MC/data =	7.0	(data =	9,560)
h_uD0muALT:	154,502 /	265,129 =	58.3%	MC/data =	7.6	(data =	20,200)
h_dD1muALT:	45,443 /	82,670 =	55.0%	MC/data =	12.4	(data =	3,660)
h_uD1muALT:	66,653 /	127,437 =	52.3%	MC/data =	1.4	(data =	48,000)
h_dD1pmuALT:	65,941 /	110,942 =	59.4%	MC/data =	8.1	(data =	8,150)
h_uD1pmuALT:	78,430 /	134,704 =	58.2%	MC/data =	10.6	(data =	7,380)
h_dD2muALT:	24,060 /	40,204 =	59.8%	MC/data =	4.6	(data =	5,200)
h_uD2muALT:	50,256 /	90,745 =	55.4%	MC/data =	30.8	(data =	1,630)
h_dD0tauALT:	608 /	1,329 =	45.8%	MC/data =	0.3	(data =	1,740)
h_uD0tauALT:	1,789 /	4,152 =	43.1%	MC/data =	1.0	(data =	1,740)
h_dD1tauALT:	428 /	954 =	44.9%	MC/data =	0.2	(data =	1,740)
h_uD1tauALT:	1,081 /	2,014 =	53.7%	MC/data =	0.6	(data =	1,740)
h_dD1ptauALT:	519 /	1,272 =	40.8%	MC/data =	0.3	(data =	1,740)
h_uD1ptauALT:	999 /	2,103 =	47.5%	MC/data =	0.6	(data =	1,740)
h_dD2tauALT:	266 /	459 =	57.9%	MC/data =	0.2	(data =	1,740)
h_uD2tauALT:	731 /	1,369 =	53.4%	MC/data =	0.4	(data =	1,740)
h_Dpipimu:	98,306 /	155,186 =	63.3%	MC/data =	2.6	(data =	38,200)
h_Dstzpipimu:	71,983 /	113,823 =	63.2%	MC/data =	5.8	(data =	12,400)
h_Dstppipimu:	14,217 /	27,856 =	51.0%	MC/data =	4.0	(data =	3,590)
h_sDs1pmuALT:	5,613 /	10,054 =	55.8%	MC/data =	0.8	(data =	7,030)
h_sDs2muALT:	6,458 /	11,096 =	58.2%	MC/data =	1.5	(data =	4,200)
h_uDDmu:	89,930 /	181,766 =	49.5%	MC/data =	1.2	(data =	74,900)
h_dDDmu:	40,726 /	82,999 =	49.1%	MC/data =	0.5	(data =	74,900)
h_uDDtau:	41,924 /	68,678 =	61.0%	MC/data =	9.2	(data =	4,550)
h_dDDtau:	3,834 /	7,574 =	50.6%	MC/data =	0.8	(data =	4,550)

HistFactory yields

h_Dmu_ALT:	990,974 /	1,748,625 =	56.7%	MC/data =	2.8	(data =	358,214)
h_uDstmuALT:	1,979,933 /	2,999,737 =	66.0%	MC/data =	2.1	(data =	944,864)
h_dDstmuALT:	121,138 /	212,140 =	57.1%	MC/data =	1.7	(data =	71,362)
h_dD0muALT:	66,847 /	108,792 =	61.4%	MC/data =	13.9	(data =	4,802)
h_uD0muALT:	154,502 /	265,129 =	58.3%	MC/data =	23.0	(data =	6,731)
h_dD1muALT:	45,443 /	82,670 =	55.0%	MC/data =	3.3	(data =	13,901)
h_uD1muALT:	66,653 /	127,437 =	52.3%	MC/data =	2.3	(data =	29,325)
h_dD1pmuALT:	65,941 /	110,942 =	59.4%	MC/data =	10.2	(data =	6,474)
h_uD1pmuALT:	78,430 /	134,704 =	58.2%	MC/data =	9.9	(data =	7,887)
h_dD2muALT:	24,060 /	40,204 =	59.8%	MC/data =	6.2	(data =	3,901)
h_uD2muALT:	50,256 /	90,745 =	55.4%	MC/data =	10.0	(data =	5,042)
h_dD0tauALT:	608 /	1,329 =	45.8%	MC/data =	8.7	(data =	70)
h_uD0tauALT:	1,789 /	4,152 =	43.1%	MC/data =	18.2	(data =	98)
h_dD1tauALT:	428 /	954 =	44.9%	MC/data =	2.1	(data =	203)
h_uD1tauALT:	1,081 /	2,014 =	53.7%	MC/data =	2.5	(data =	429)
h_dD1ptauALT:	519 /	1,272 =	40.8%	MC/data =	5.5	(data =	95)
h_uD1ptauALT:	999 /	2,103 =	47.5%	MC/data =	8.7	(data =	115)
h_dD2tauALT:	266 /	459 =	57.9%	MC/data =	4.7	(data =	57)
h_uD2tauALT:	731 /	1,369 =	53.4%	MC/data =	9.9	(data =	74)
h_Dpipimu:	98,306 /	155,186 =	63.3%	MC/data =	65.1	(data =	1,511)
h_Dstzpipimu:	71,983 /	113,823 =	63.2%	MC/data =	1.5	(data =	49,462)
h_Dstppipimu:	14,217 /	27,856 =	51.0%	MC/data =	3.2	(data =	4,465)
h_sDs1pmuALT:	5,613 /	10,054 =	55.8%	MC/data =	1.3	(data =	4,228)
h_sDs2muALT:	6,458 /	11,096 =	58.2%	MC/data =	4.8	(data =	1,344)
h_uDDmu:	89,930 /	181,766 =	49.5%	MC/data =	2.3	(data =	38,331)
h_dDDmu:	40,726 /	82,999 =	49.1%	MC/data =	1.3	(data =	31,484)
h_uDDtau:	41,924 /	68,678 =	61.0%	MC/data =	8.7	(data =	4,845)
h_dDDtau:	3,834 /	7,574 =	50.6%	MC/data =	3.8	(data =	1,004)

Didn't look at $D^{**}\tau$ yields, so estimated them as $D^{**}\mu \times 0.12 \times 0.7 \times 0.1741$

Stats in D^0 templates

MCMC fit in ANA note

$D^0\mu\nu$ 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
$D_1^+\mu\nu$ Iso yield	3.66e3 ±9.85e3
$D_1^0\mu\nu$ Iso yield	4.8e4 ±9.71e3
$D_{1'}^+\mu\nu$ Iso yield	8.15e3 ±9.84e3
$D_{1'}^0\mu\nu$ 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
$D_{s1'}^+\mu\nu$ 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

MCMC fit in ANA note

```
      h_Dmu_ALT:   990,974 / 1,748,625 =  56.7%    MC/data =  2.7   (data = 366,000)
   h_uDstmuALT: 1,979,933 / 2,999,737 =  66.0%    MC/data =  2.2   (data = 917,000)
   h_dDstmuALT:   121,138 /   212,140 =  57.1%    MC/data =  1.7   (data =  69,500)
    h_dD0muALT:    66,847 /   108,792 =  61.4%    MC/data =  7.0   (data =   9,560)
    h_uD0muALT:   154,502 /   265,129 =  58.3%    MC/data =  7.6   (data =  20,200)
    h_dD1muALT:    45,443 /    82,670 =  55.0%    MC/data = 12.4   (data =   3,660)
    h_uD1muALT:    66,653 /   127,437 =  52.3%    MC/data =  1.4   (data =  48,000)
   h_dD1pmuALT:    65,941 /   110,942 =  59.4%    MC/data =  8.1   (data =   8,150)
   h_uD1pmuALT:    78,430 /   134,704 =  58.2%    MC/data = 10.6   (data =   7,380)
    h_dD2muALT:    24,060 /    40,204 =  59.8%    MC/data =  4.6   (data =   5,200)
    h_uD2muALT:    50,256 /    90,745 =  55.4%    MC/data = 30.8   (data =   1,630)
   h_dD0tauALT:       608 /     1,329 =  45.8%    MC/data =  0.3   (data =   1,740)
   h_uD0tauALT:     1,789 /     4,152 =  43.1%    MC/data =  1.0   (data =   1,740)
   h_dD1tauALT:       428 /       954 =  44.9%    MC/data =  0.2   (data =   1,740)
   h_uD1tauALT:     1,081 /     2,014 =  53.7%    MC/data =  0.6   (data =   1,740)
  h_dD1ptauALT:       519 /     1,272 =  40.8%    MC/data =  0.3   (data =   1,740)
  h_uD1ptauALT:       999 /     2,103 =  47.5%    MC/data =  0.6   (data =   1,740)
   h_dD2tauALT:       266 /       459 =  57.9%    MC/data =  0.2   (data =   1,740)
   h_uD2tauALT:       731 /     1,369 =  53.4%    MC/data =  0.4   (data =   1,740)
     h_Dpipimu:    98,306 /   155,186 =  63.3%    MC/data =  2.6   (data =  38,200)
  h_Dstzpipimu:    71,983 /   113,823 =  63.2%    MC/data =  5.8   (data =  12,400)
  h_Dstppipimu:    14,217 /    27,856 =  51.0%    MC/data =  4.0   (data =   3,590)
  h_sDs1pmuALT:     5,613 /    10,054 =  55.8%    MC/data =  0.8   (data =   7,030)
   h_sDs2muALT:     6,458 /    11,096 =  58.2%    MC/data =  1.5   (data =   4,200)
      h_uDDmu:     89,930 /   181,766 =  49.5%    MC/data =  1.2   (data =  74,900)
      h_dDDmu:     40,726 /    82,999 =  49.1%    MC/data =  0.5   (data =  74,900)
     h_uDDtau:     41,924 /    68,678 =  61.0%    MC/data =  9.2   (data =   4,550)
     h_dDDtau:      3,834 /     7,574 =  50.6%    MC/data =  0.8   (data =   4,550)
```