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

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

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

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

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

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

Svende Braun, Alex Fernez, Manuel Franco Sevilla, Phoebe Hamilton, Yipeng Sun

University of Maryland

16th May 2021

Introduction

			Run 1: Nsim = 924M / Ndisk = 65M					
Run 1 $\mathscr{R}\left(D^{0,*}\right)$ request								
#	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**		2.9
2	D0/D*+	B0 → D*+ μ ν	11574020	5.9%	88.6	**6.2**	45.6%	1.4
3	D0	B- → D*0 μ ν	12573031	6.0%	222.9	**15.6**		2.2
4	D0	B- → D0 τ ν	12573000	5.4%	7.3	**0.5**		2.9
5	D0/D*+	B0 → D*+ τ ν	11574010	5.0%	19.6	**1.4**	4.8%	1.4
6	D0	B- → D*0 τ ν	12573021	5.0%	17.0	**1.2**		2.2
7	D0/D*+	B0 → D**+ μ ν	11873010	5.0%	126.7	**8.9**		4.0
8	D0/D*+	B0 → D**+ τ ν	11873030	4.9%	1.1	**0.1**	25.2%	2.0
9	D0/D*+	B- → D**0 μ ν	12873010	5.7%	103.1	**7.2**		4.0
10	D0/D*+	B- → D**0 τ ν	12873030	4.9%	1.7	**0.1**		2.0
11	D0	B- → D**(→D0ππ) μ ν	12675010	5.5%	15.5	**1.1**		2.7
12	D0	B0 → D**(→D0ππ) μ ν	11674400	5.0%	15.6	**1.1**		2.7
13	D0/D*+	B- → D**(→D*+ππ) μ ν	12675400	5.4%	11.0	**0.8**	7.7%	4.0
14	D0/D*+	B0 → D**(→D*+ππ) μ ν	11676010	5.0%	10.5	**0.7**		4.0
15	D0	B- → D**(→D*0ππ) μ ν	12675430	5.4%	18.5	**1.3**		4.0
16	D0	Bs → Ds**(→D0K) μ ν	13873000	5.5%	1.3	**0.1**	0.6%	0.9
17	D*+	Bs → D**+μ ν	13874000	5.4%	4.7	**0.3**		1.6
18	D0	B0 → D0(Xc → μ νX')X	11873000	4.6%	37.8	**2.6**		1.8
19	D0	B0 → D0(Ds → τν)X	11873020	5.4%	2.4	**0.2**	9.7%	4.0
20	D0	B+ → D0(Xc → μ νX')X	12873000	5.0%	40.9	**2.9**		1.8
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**		3.6
23	D*+	B0 → D*+(Ds → τ ν) X	11874070	5.6%	3.9	**0.3**	6.5%	4.0
24	D*+	B+ → D*+ (Xc → μ ν X')X	12874010	4.6%	12.0	**0.8**		3.6
25	D*+	B+ → D*+(Ds → τ ν) X	12874030	5.0%	2.3	**0.2**		4.0

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

#	Sample	Name	MC ID	ε_gen	Nsim [M]	Ndisk [M]	% total request	MC/ data fit
			Run 1: Nsim = 924M / Ndisk = 65M					
1	D0	B- → D0 μ ν	12573010	7.0%	110.0	7.7	45.6%	2.9
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		2.2
4	D0	B- → D0 τ ν	12573000	5.4%	7.3	0.5	4.8%	2.9
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		2.2
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		2.0
9	D0/D*+	B- → D**0 μ ν	12873010	5.7%	103.1	7.2		4.0
10	D0/D*+	B- → D**0 τ ν	12873030	4.9%	1.7	0.1		2.0
11	D0	B- → D**(→D0ππ) μ ν	12675010	5.5%	15.5	1.1	7.7%	2.7
12	D0	B0 → D**(→D0ππ) μ ν	11674400	5.0%	15.6	1.1		2.7
13	D0/D*+	B- → D**(→D*+ππ) μ ν	12675400	5.4%	11.0	0.8		4.0
14	D0/D*+	B0 → D**(→D*+ππ) μ ν	11676010	5.0%	10.5	0.7		4.0
15	D0	B- → D**(→D*0ππ) μ ν	12675430	5.4%	18.5	1.3		4.0
16	D0	Bs → Ds**(→D0K) μ ν	13873000	5.5%	1.3	0.1	0.6%	0.9
17	D*+	Bs → D**+μ ν	13874000	5.4%	4.7	0.3		1.6
18	D0	B0 → D0(Xc → μ νX')X	11873000	4.6%	37.8	2.6	9.7%	1.8
19	D0	B0 → D0(Ds → τν)X	11873020	5.4%	2.4	0.2		4.0
20	D0	B+ → D0(Xc → μ νX')X	12873000	5.0%	40.9	2.9		1.8
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%	3.6
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		3.6
25	D*+	B+ → D*+(Ds → τ ν) X	12874030	5.0%	2.3	0.2		4.0

MCMC fit in Run 1 muonic $\mathscr{R}\left(D^{0,*}\right)$ ANA note

$D_1^+\mu\nu$ IsoDst yield	1.12e4 ±3.35e3
$D_1^0\mu\nu$ IsoDst yield	0 ±5.59e4
$D_{1'}^+\mu\nu$ IsoDst yield	1.36e4 ±4.28e3
$D_{1'}^0\mu\nu$ 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
$D_{s1'}^+\mu\nu$ 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

- 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

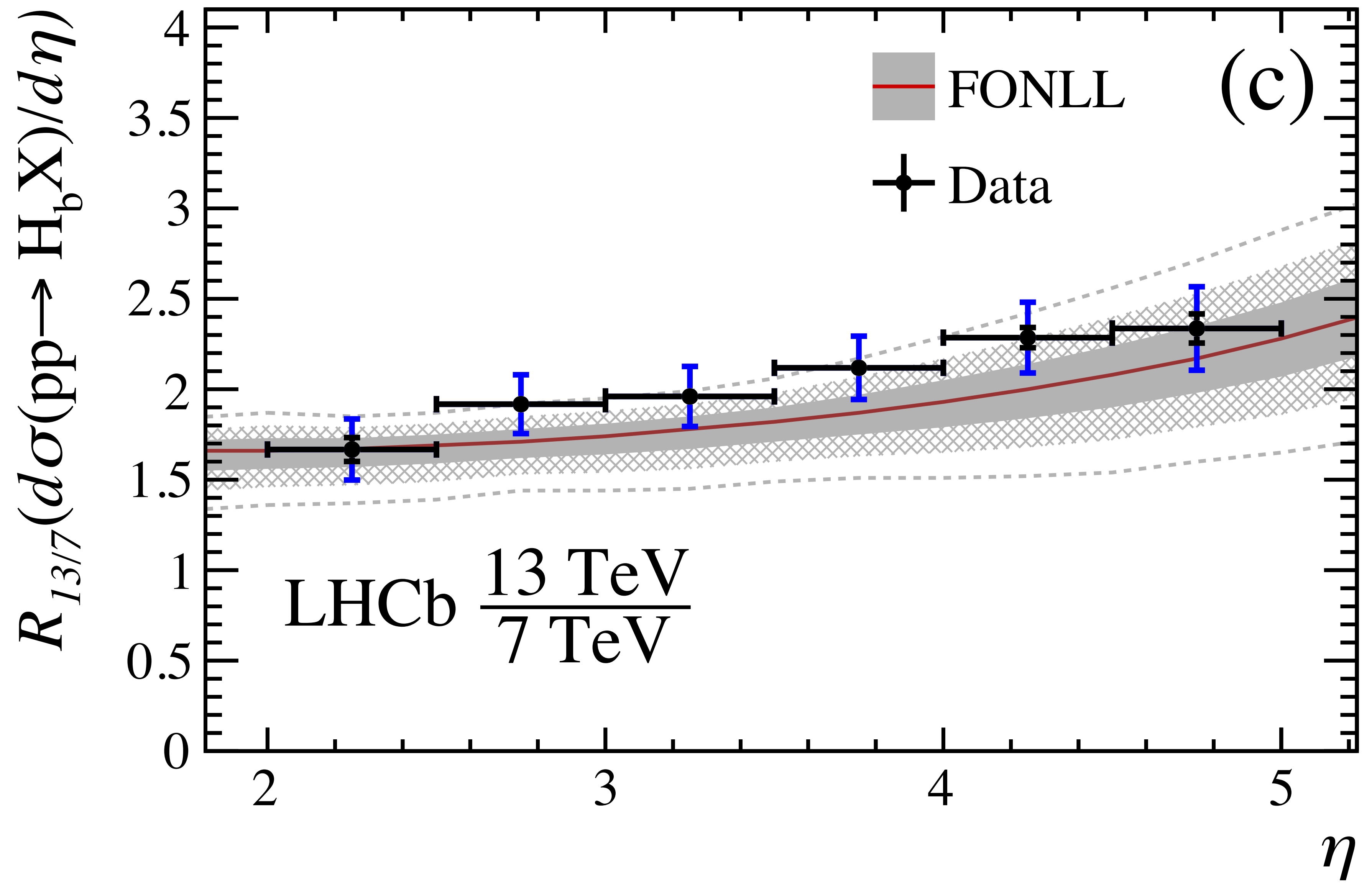
Cross section and luminosity increase

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

Ratio increases with η



Actual ratio around 1.8

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

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)

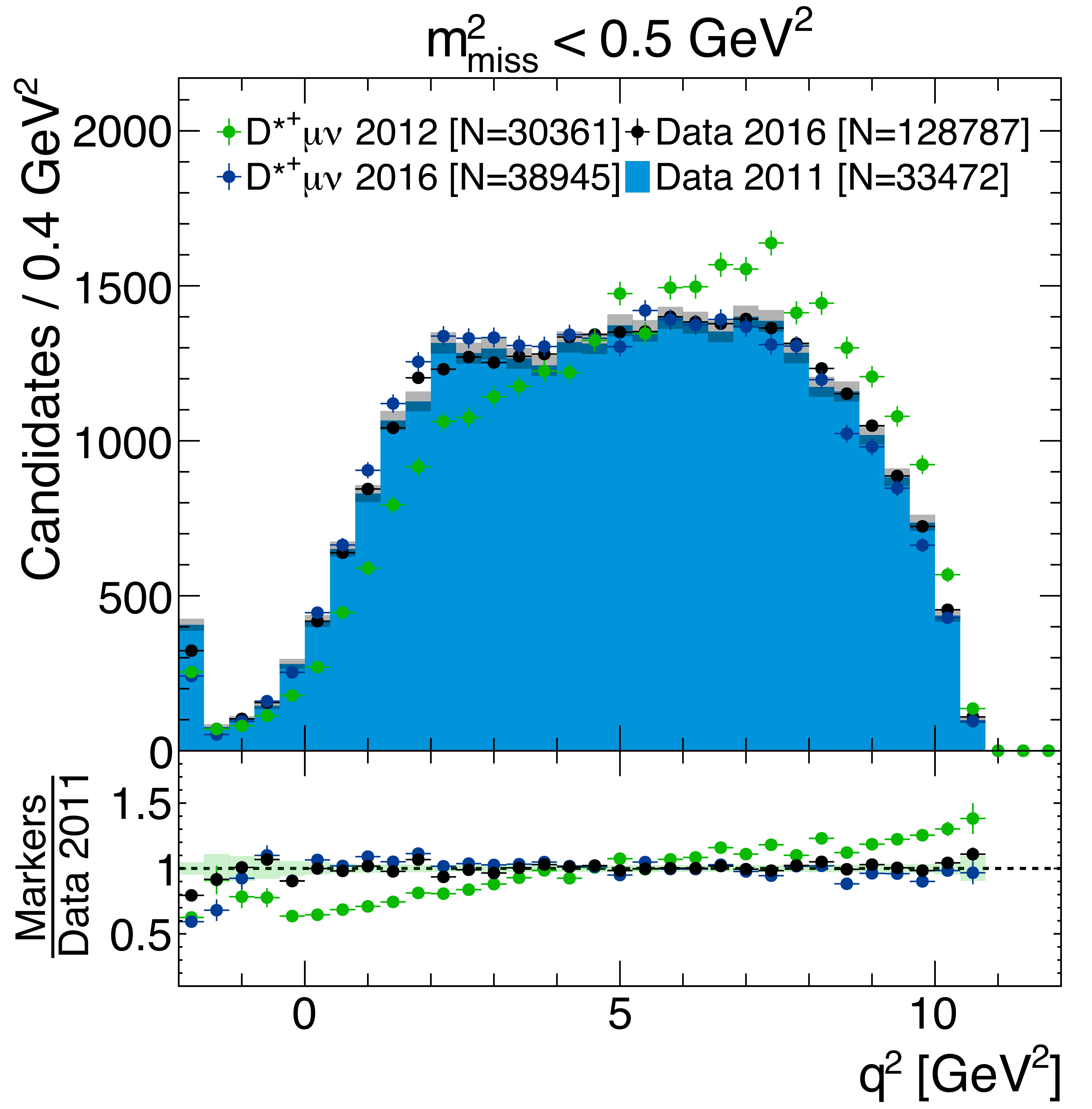
$\epsilon_{\rm gen}$ in table from official MC production

$\epsilon_{\rm filter}$ 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						Run 2: Nsim = 7,057M / Ndisk = 1,623M				
#	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	45.6%	2.9	12573012	9.0%	676.4	155.6	53.1%
2	D0/D*+	B0 → D*+ μ ν	11574020	5.9%	88.6	6.2		1.4	11574021	8.0%	1195.0	274.9	
3	D0	B- → D*0 μ ν	12573031	6.0%	222.9	15.6		2.2	12773410	8.1%	1877.5	431.8	
4	D0	B- → D0 τ ν	12573000	5.4%	7.3	0.5	4.8%	2.9	12573001	7.3%	46.5	10.7	6.5%
5	D0/D*+	B0 → D*+ τ ν	11574010	5.0%	19.6	1.4		1.4	11574011	6.8%	263.6	60.6	
6	D0	B- → D*0 τ ν	12573021	5.0%	17.0	1.2		2.2	12773400	6.8%	145.5	33.5	
7	D0/D*+	B0 → D**+ μ ν	11873010	5.0%	126.7	8.9	25.2%	4.0	11874430	7.7%	671.1	154.4	16.7%
8	D0/D*+	B0 → D**+ τ ν	11873030	4.9%	1.1	0.1		2.0	11874440	6.6%	10.5	2.4	
9	D0/D*+	B- → D**0 μ ν	12873010	5.7%	103.1	7.2		4.0	12873450	7.7%	482.3	110.9	
10	D0/D*+	B- → D**0 τ ν	12873030	4.9%	1.7	0.1		2.0	12873460	6.6%	15.7	3.6	
11	D0	B- → D**(→D0ππ) μ ν	12675010	5.5%	15.5	1.1	7.7%	2.7	12675011	7.4%	107.3	24.7	5.9%
12	D0	B0 → D**(→D0ππ) μ ν	11674400	5.0%	15.6	1.1		2.7	11674401	7.4%	118.6	27.3	
13	D0/D*+	B- → D**(→D*+ππ) μ ν	12675400	5.4%	11.0	0.8		4.0	12675402	7.3%	51.8	11.9	
14	D0/D*+	B0 → D**(→D*+ππ) μ ν	11676010	5.0%	10.5	0.7		4.0	11676012	7.3%	52.9	12.2	
15	D0	B- → D**(→D*0ππ) μ ν	12675430	5.4%	18.5	1.3		4.0	12875440	7.3%	86.8	20.0	
16	D0	Bs → Ds**(→D0K) μ ν	13873000	5.5%	1.3	0.1	0.6%	0.9	13874020	7.5%	26.5	6.1	1.2%
17	D*+	Bs → D**+μ ν	13874000	5.4%	4.7	0.3		1.6	13674000	7.4%	54.8	12.6	
18	D0	B0 → D0(Xc → μ νX')X	11873000	4.6%	37.8	2.6	9.7%	1.8	11894600	6.3%	395.3	90.9	12.3%
19	D0	B0 → D0(Ds → τν)X	11873020	5.4%	2.4	0.2		4.0	11894200	7.3%	11.3	2.6	
20	D0	B+ → D0(Xc → μ νX')X	12873000	5.0%	40.9	2.9		1.8	12896300	6.7%	421.2	96.9	
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	6.5%	3.6	11894610	6.4%	215.5	49.6	4.4%
23	D*+	B0 → D*+(Ds → τ ν) X	11874070	5.6%	3.9	0.3		4.0	11894210	7.5%	17.9	4.1	
24	D*+	B+ → D*+ (Xc → μ ν X')X	12874010	4.6%	12.0	0.8		3.6	12895400	6.4%	63.2	14.5	
25	D*+	B+ → D*+(Ds → τ ν) X	12874030	5.0%	2.3	0.2		4.0	12895000	6.8%	11.1	2.6	



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	$\chi^2_{\text{track}}/\text{ndf}$	< 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
	$\chi^2_{\text{vertex}}/\text{ndf}$	< 10	< 10
	FDχ^2	> 40	> 25
	Sum track p_{T}	–	> 2500 MeV
	Child pair DOCA	–	< 0.1 mm
μ	IPχ^2	–	> 16
$D^0\mu$	$\chi^2_{\text{vertex}}/\text{ndf}$	–	> 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
	$\chi^2_{\text{fit}}/\text{DOF}$	< 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
	$\chi^2_{\text{fit}}/\text{DOF}$	< 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

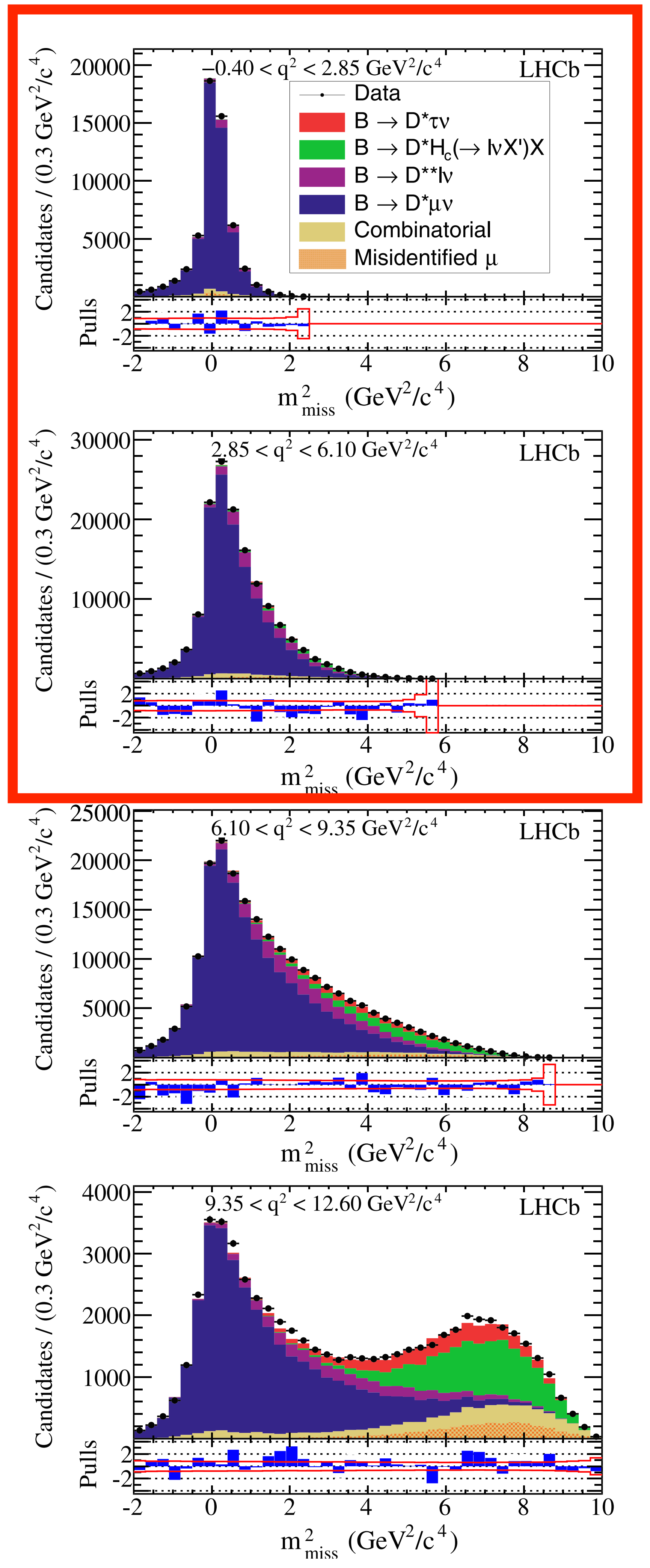
ε increases ~40% with Run 1 cuts

Cut	Data 2011	Data 2016	Ratio $\times$ 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	$\boxed{1.37}$
$q^2 > 6$ GeV^2	42,474	163,669	1.37
Cut	Data 2011	Data 2016	Ratio $\times$ 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

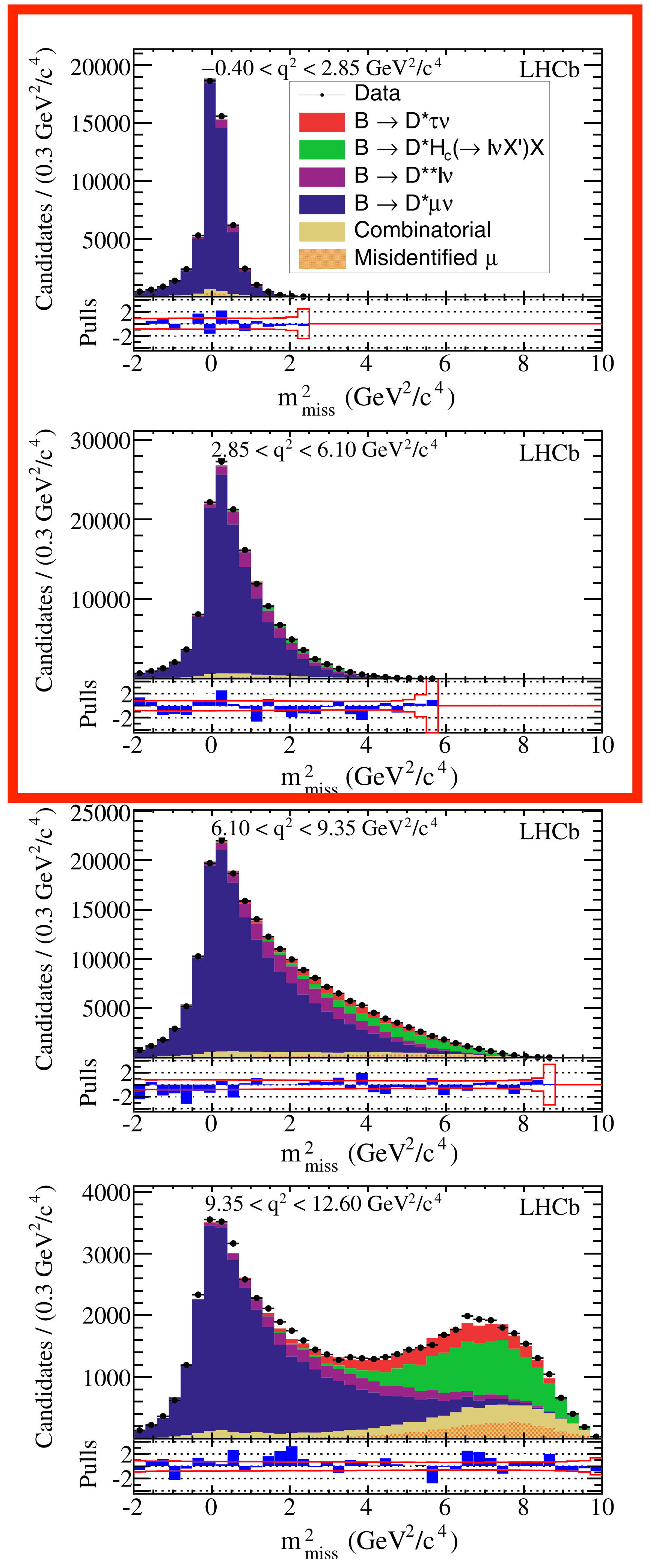
ε increases ~40% with Run 1 cuts

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	$\boxed{1.37}$
$q^2 > 6$ 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	$\boxed{2.73}$
$q^2 > 6$ 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]

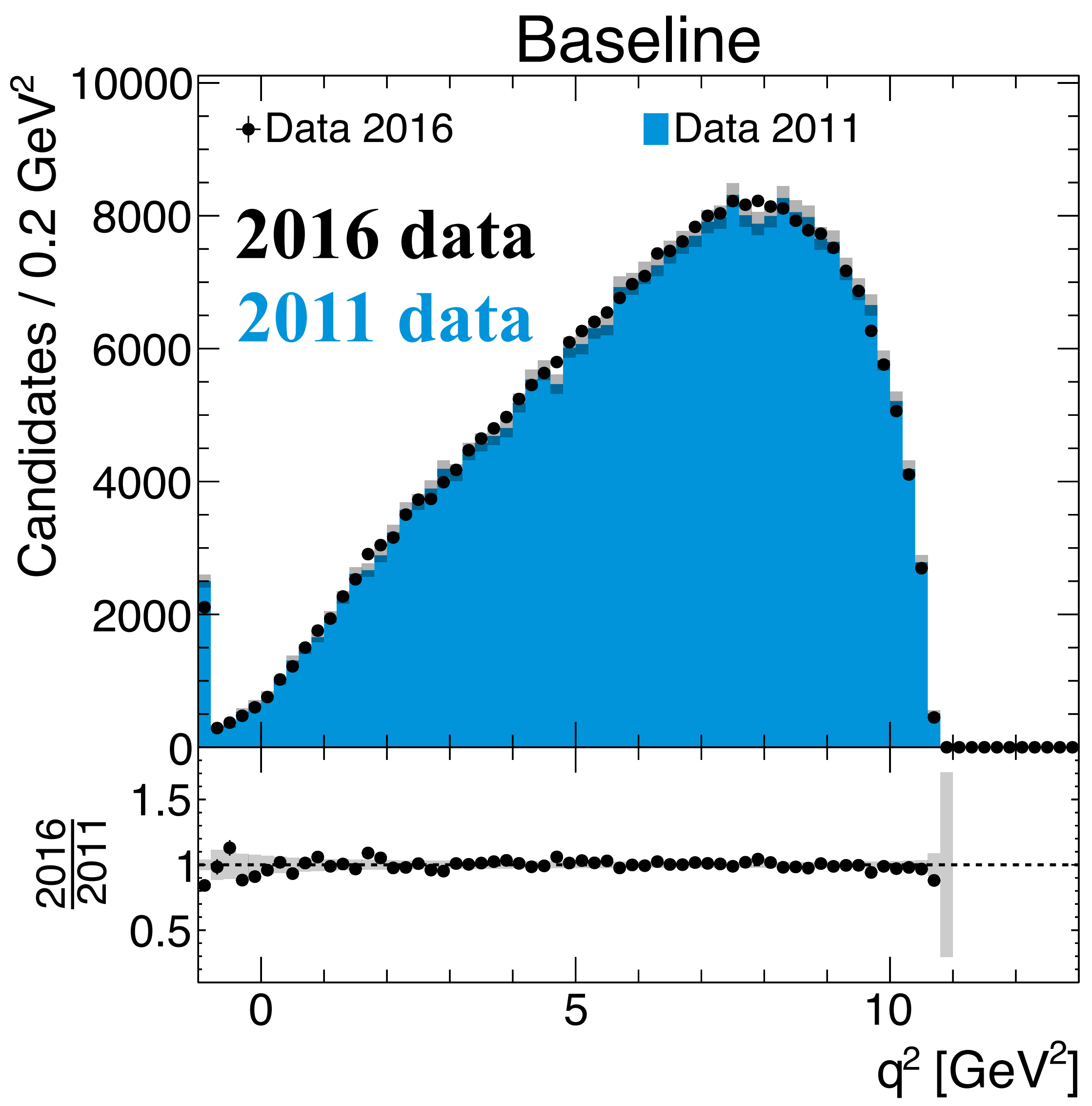
Cut	$D^{*+}\tau\nu$ 2011	$D^{*+}\tau\nu$ 2016	Ratio × 1.00
L0	3,403	3,796	1.12
+ HLT1	1,234	2,040	1.65
+ HLT2	498	1,113	2.23
+ Full strip.	53	152	2.87
+ Kaon	53	138	2.60
+ Pion	53	128	2.42
+ $D^0 \to K\pi$	44	110	2.50
+ μ	43	97	2.26
+ $D^{*+} \to D^0\pi$	41	86	2.10
+ $B^0 \to D^{*+}\mu$	29	79	2.72
+ 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

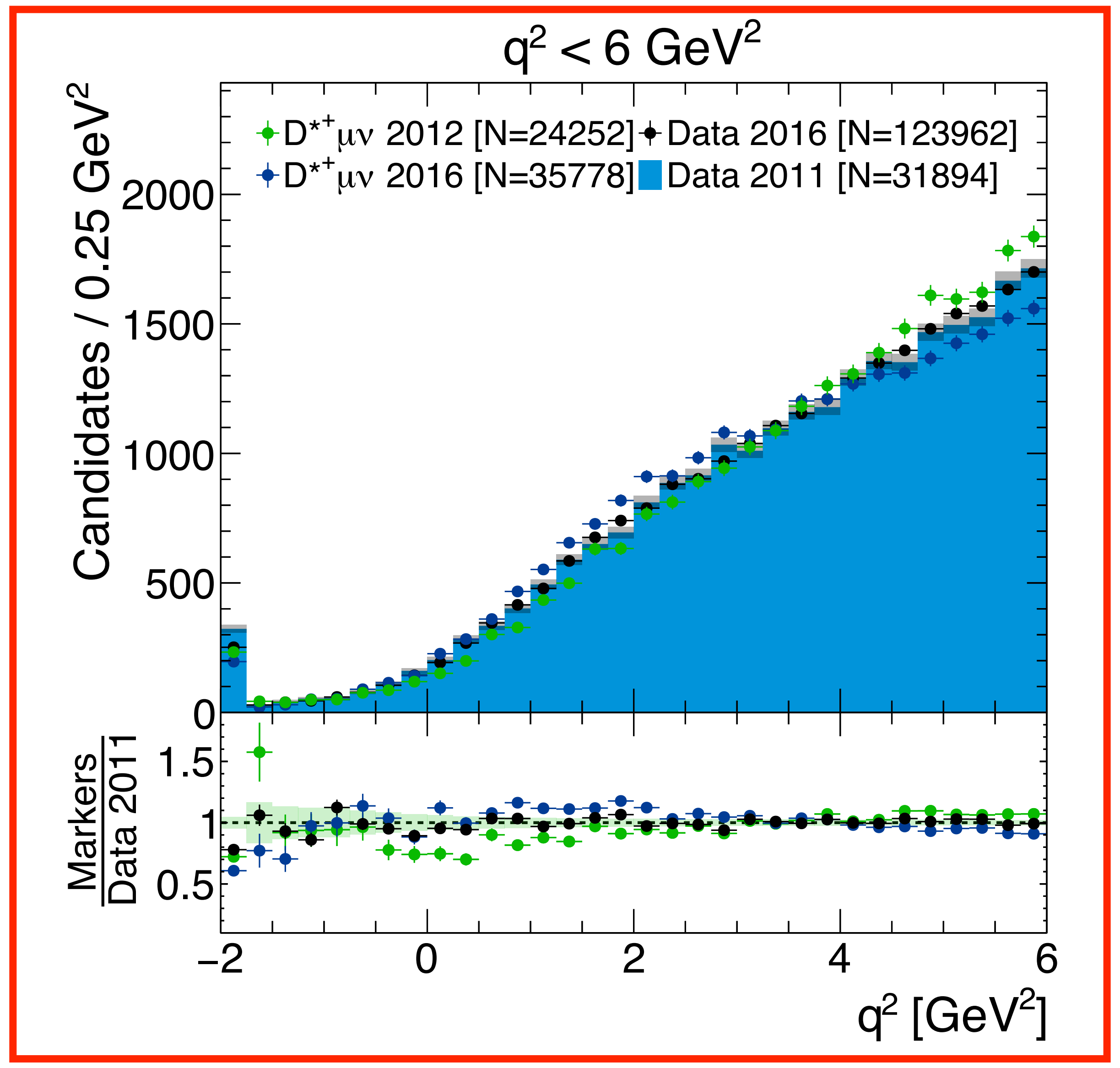
Cut	$D^{**}\mu\nu$ 2011	$D^{**}\mu\nu$ 2016	Ratio × 1.00
L0	32,364	36,978	1.14
+ HLT1	13,606	21,264	1.56
+ HLT2	5,533	12,177	2.20
+ Full strip.	206	723	3.51
+ Kaon	206	630	3.06
+ Pion	206	574	2.79
+ $D^0 \to K\pi$	185	516	2.79
+ μ	179	453	2.53
+ $D^{*+} \to D^0\pi$	150	366	2.44
+ $B^0 \to D^{*+}\mu$	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

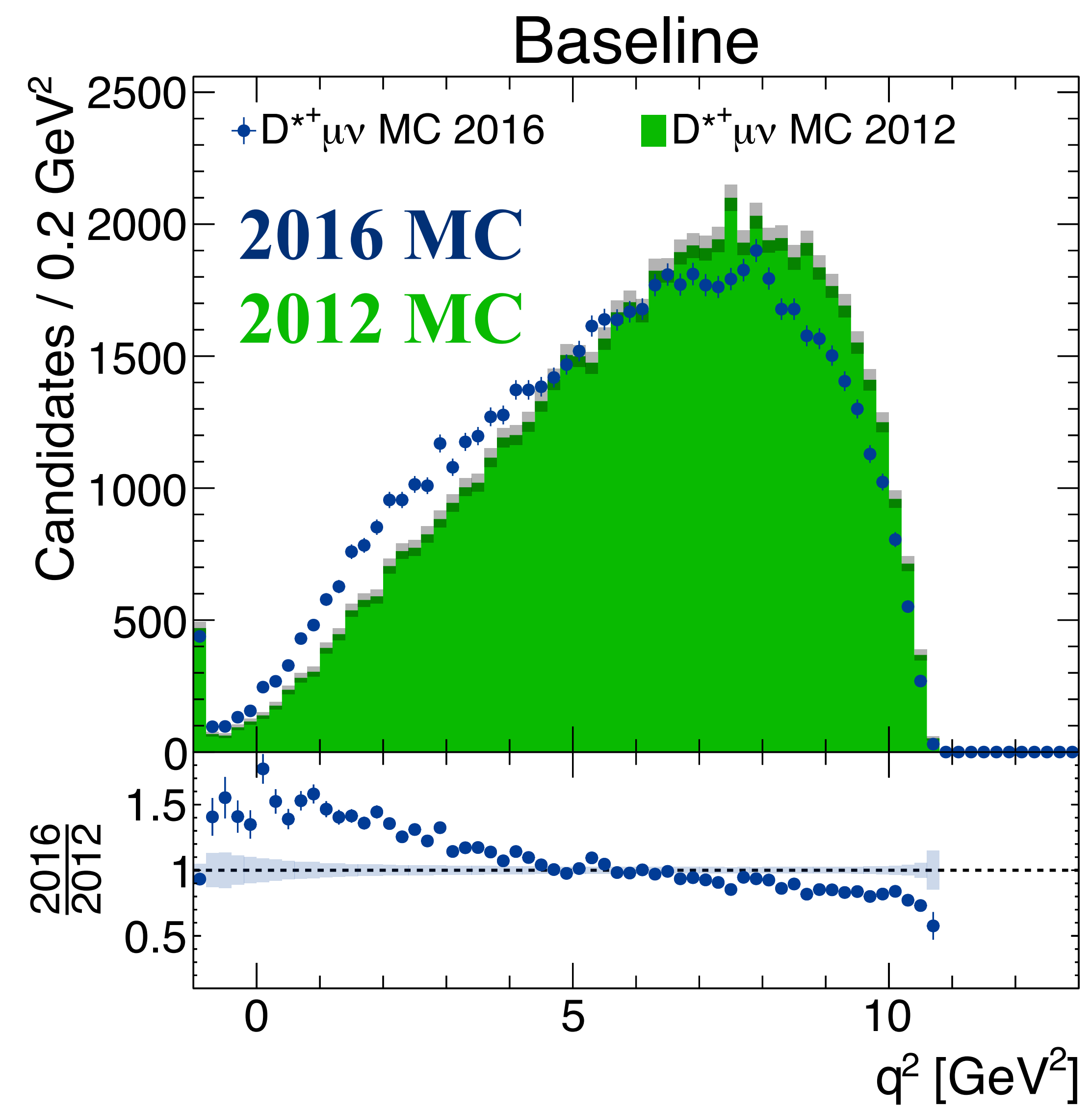
Cut	$D^{**}\mu\nu$ 2011	$D^{**}\mu\nu$ 2016	Ratio × 1.00
L0	32,364	36,978	1.14
+ HLT1	13,606	21,264	1.56
+ HLT2	5,533	12,177	2.20
+ Full strip.	206	723	3.51
+ Kaon	206	591	2.87
+ Pion	206	486	2.36
+ $D^0 \to K\pi$	185	326	1.76
+ μ	179	289	1.61
+ $D^{*+} \to D^0\pi$	150	235	1.57
+ $B^0 \to D^{*+}\mu$	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

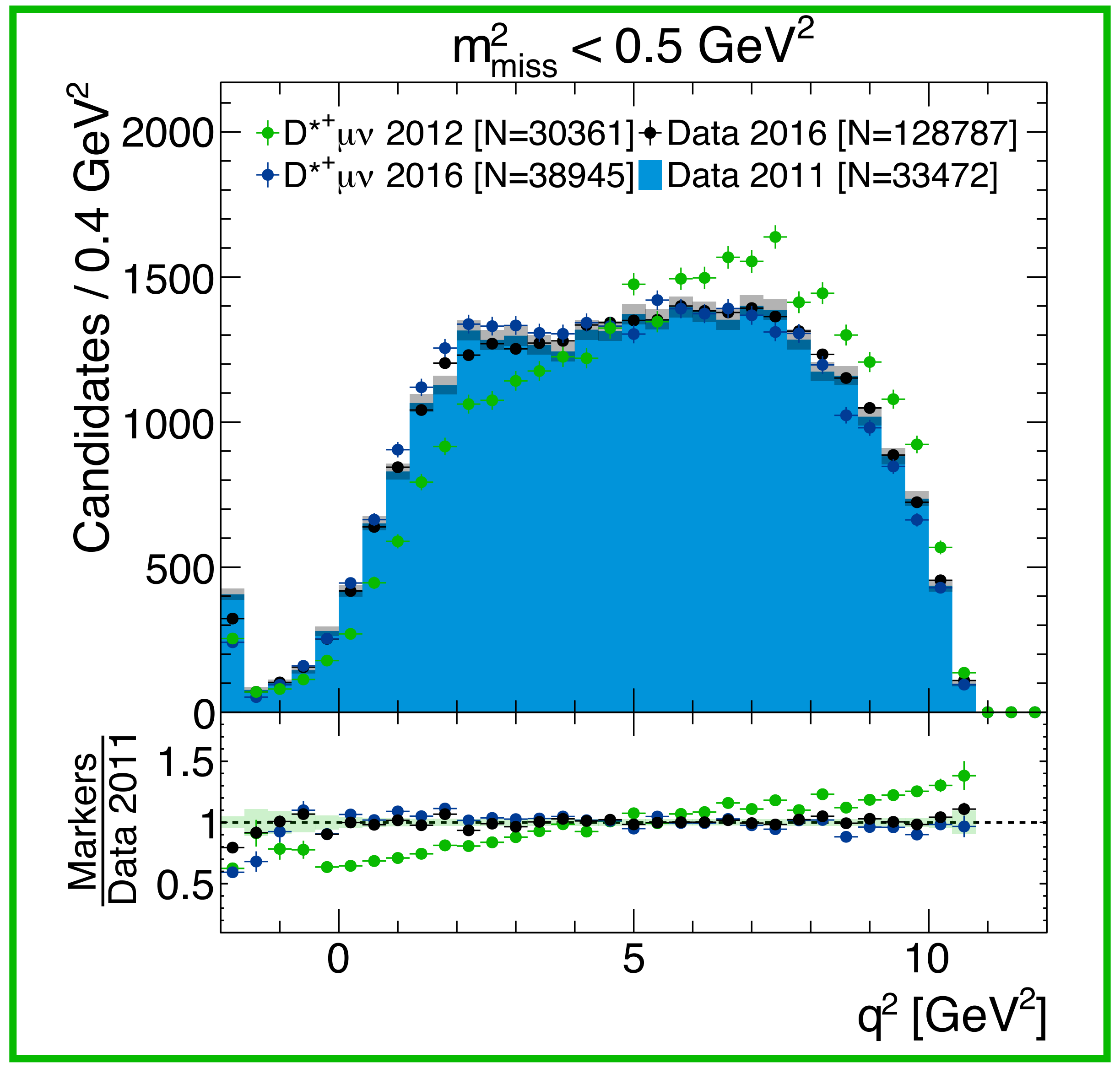
ε can increase ~110% with looser cuts (needs optimization)

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

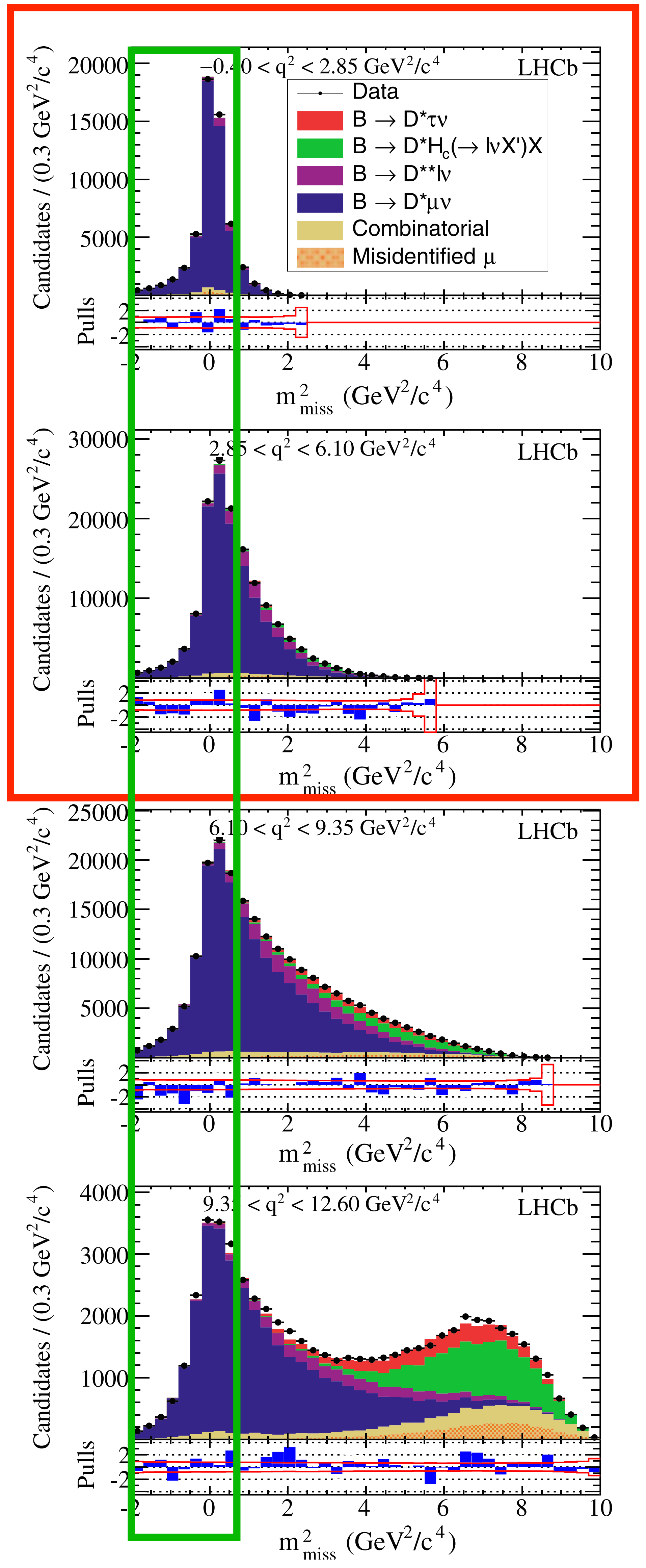




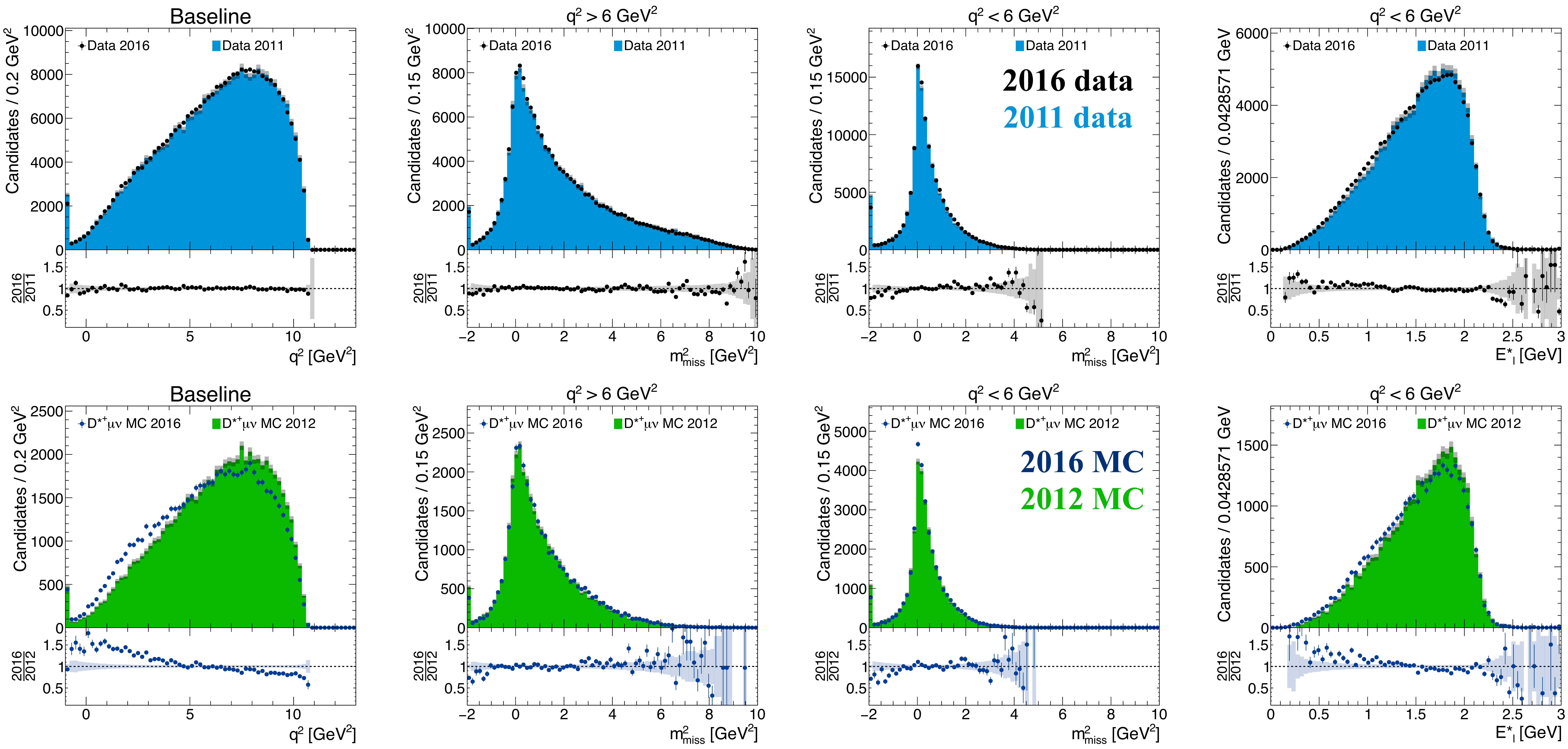




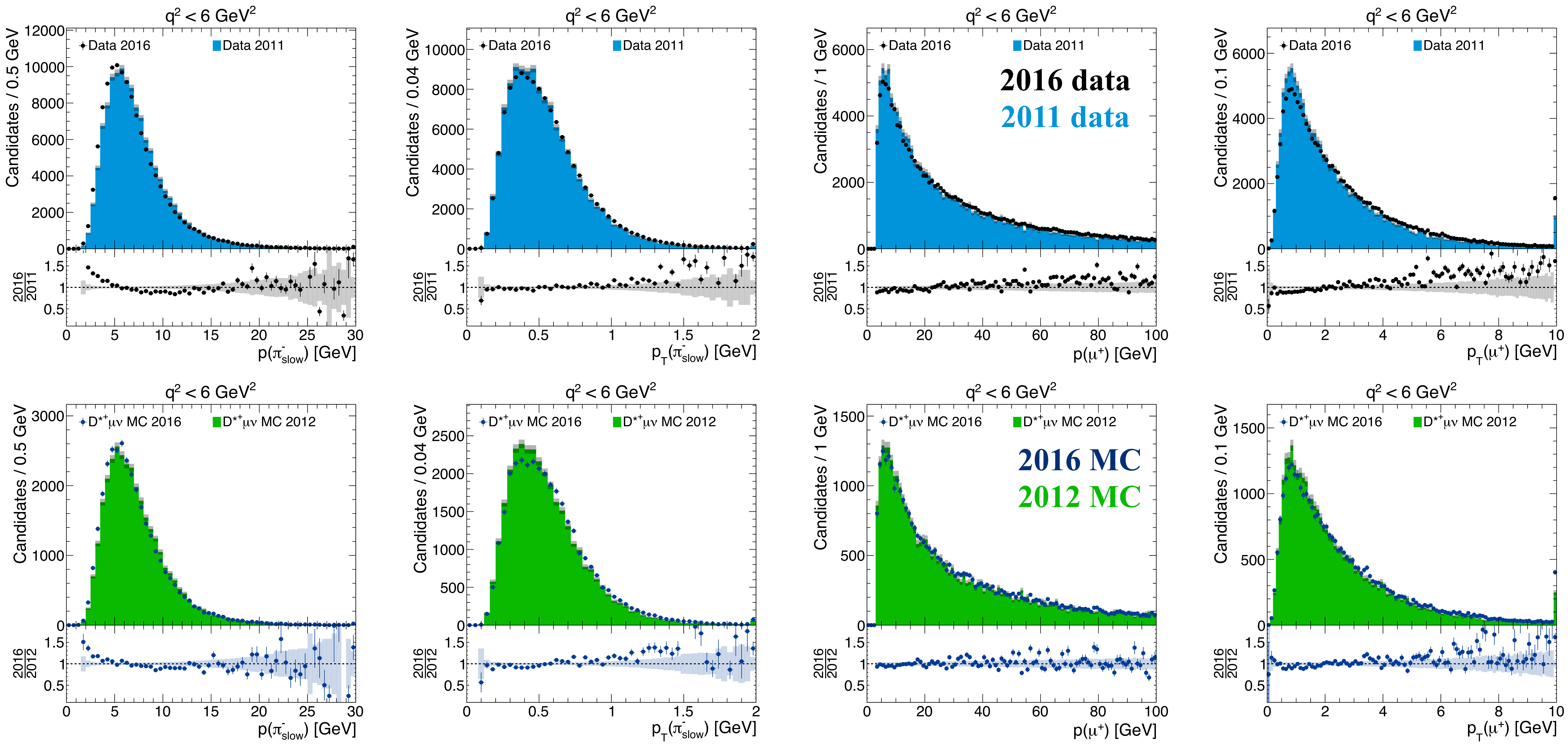
- Use **low q^2** and **low m_{miss}** regions to look at data
  - Pretty pure in $D^{*+}l\nu$
- Compare with FS MC
  - Run 1 $D^{*+}l\nu$ (11574020)
  - Run 2 $D^{*+}l\nu$ (11574021)
- Updated FFs for $D^0 l\nu$, $D^* l\nu$, $D^{*+}l\nu$
  - Bug in Run 1 $D^{*+}l\nu$ FFs, so larger improvement there



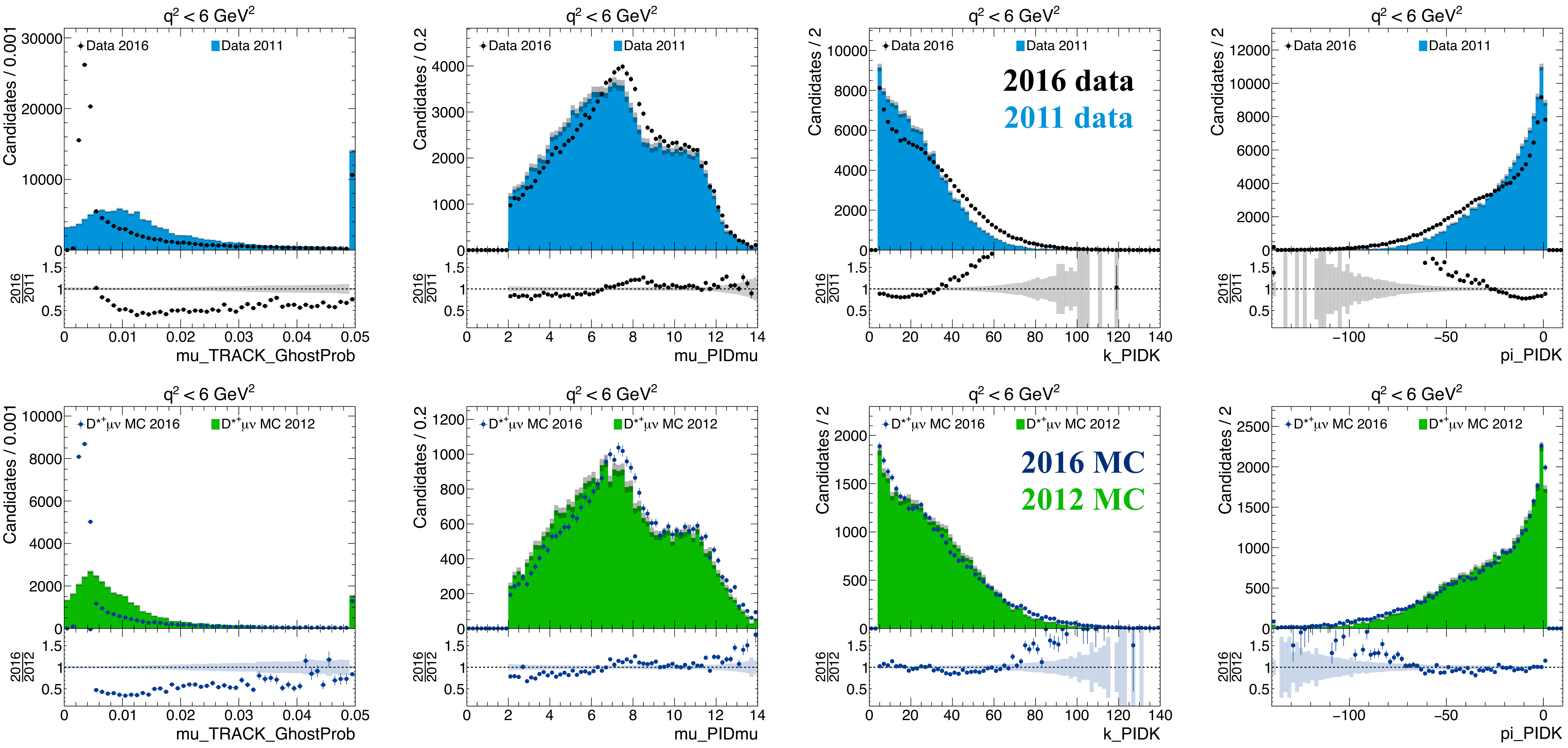
$D^{*+}\mu\nu$ Run 1-2: fit variables stable



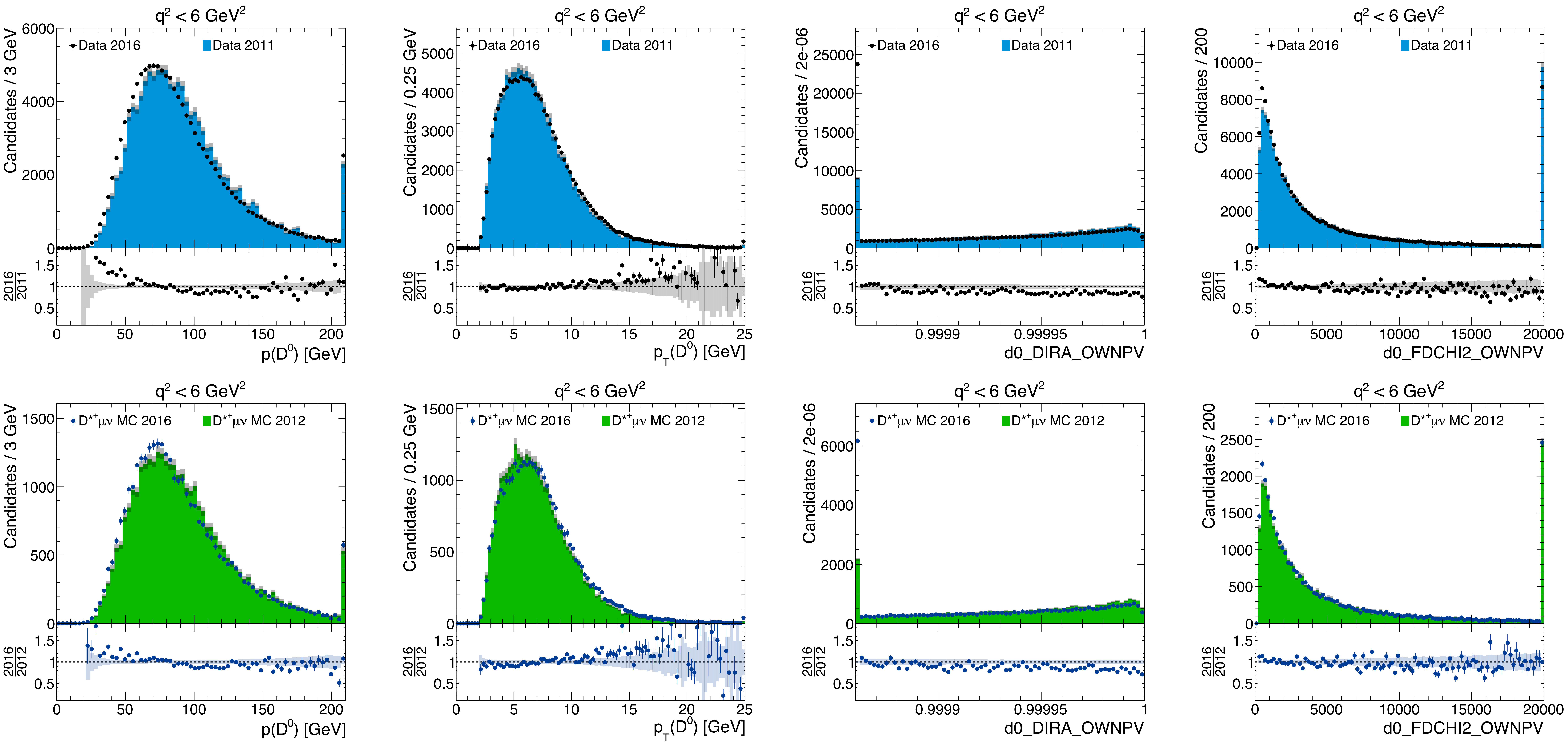
Run 1 vs Run 2: slight shift to higher p(μ)



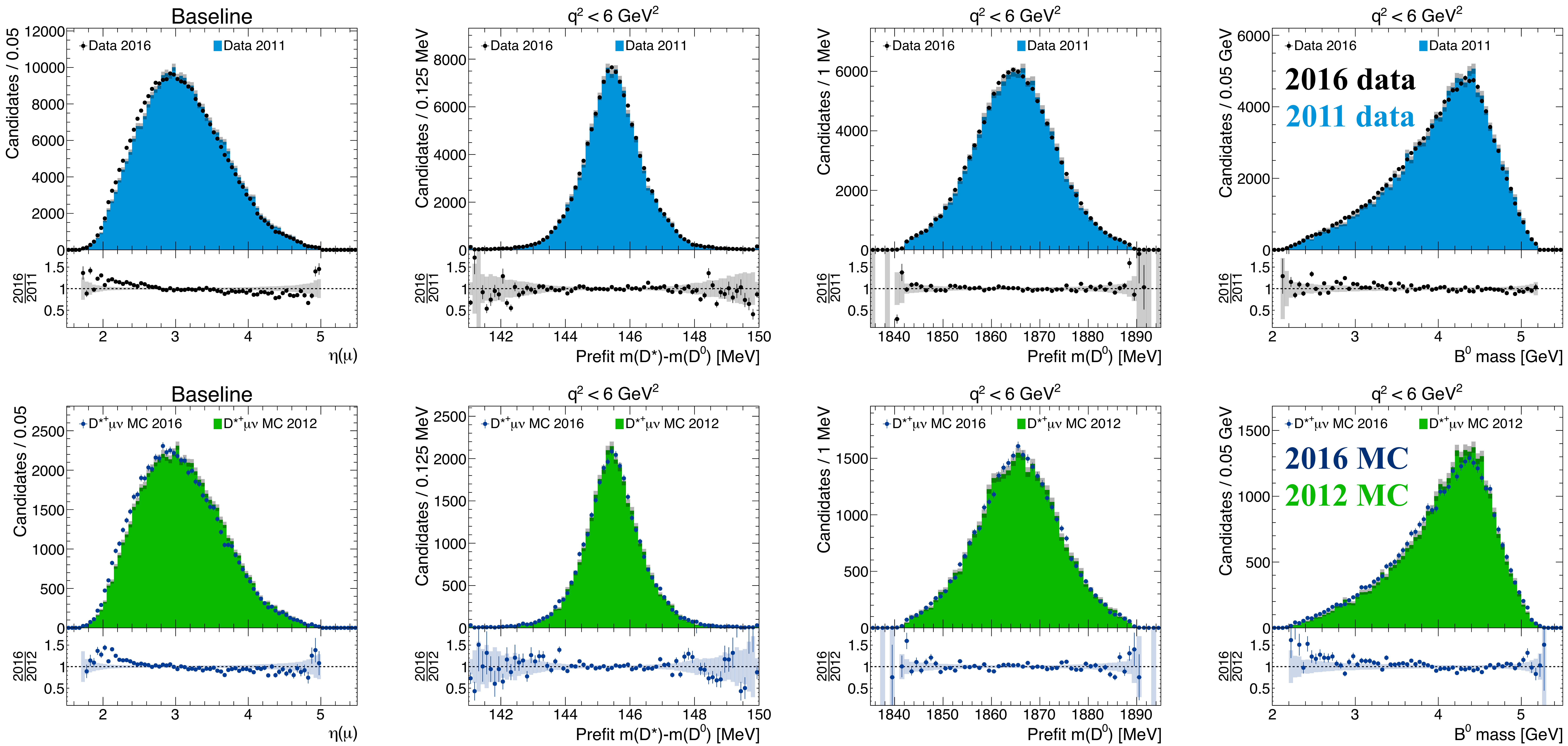
Run 1 vs Run 2: GhostProb, PID new algorithms



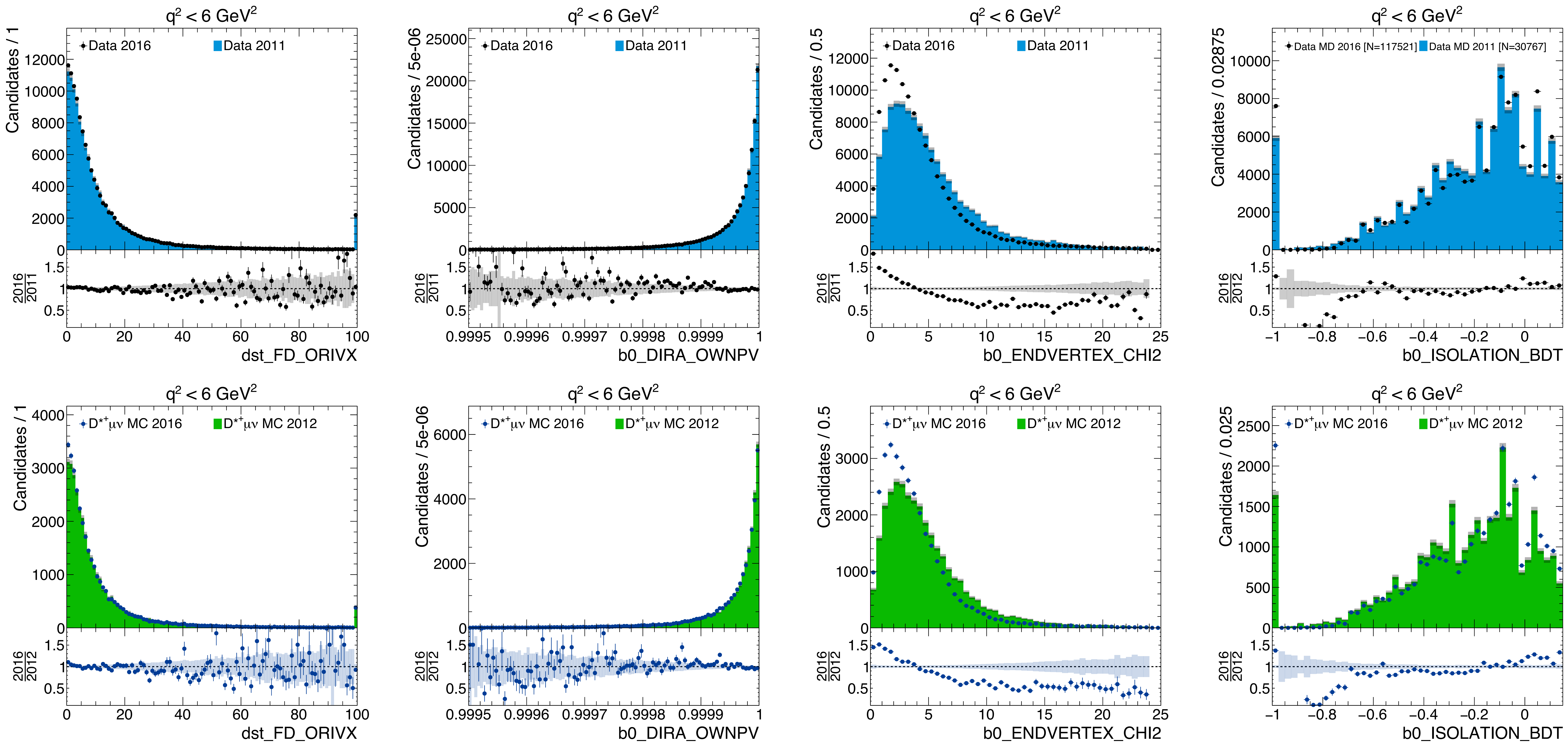
Run 1 vs Run 2: D^0



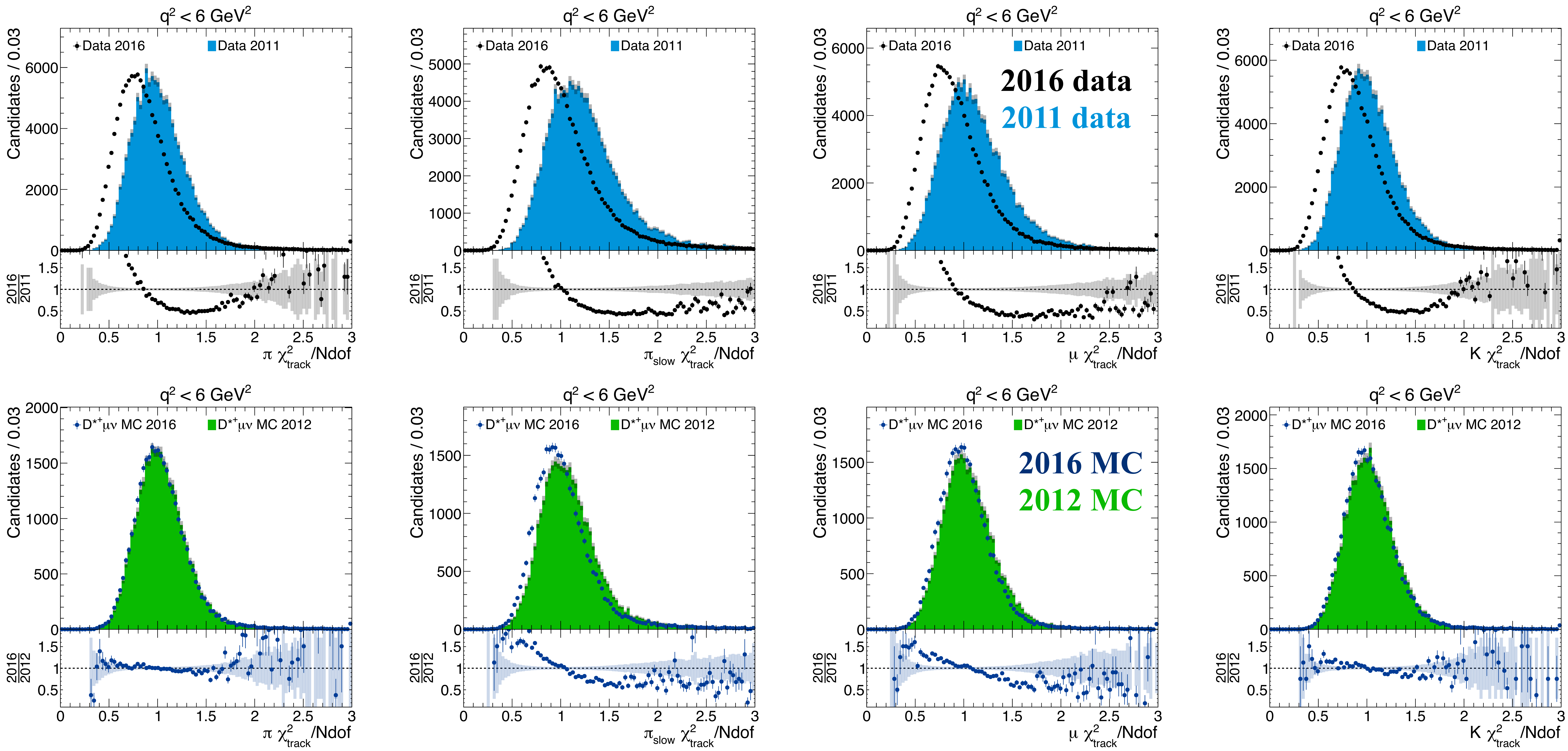
Run 1 vs Run 2: masses stable



Run 1 vs Run 2: D*+, B0



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 ± 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 ± 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	$9.98e3 \pm 1.97e3$

h_sigmuALT:	447,759 /	824,550 =	54.3%	MC/data = 1.4	(data = 331,000)
h_D1_ALT:	49,702 /	116,926 =	42.5%	MC/data = 4.4	(data = 11,200)
h_D1p_ALT:	56,162 /	123,432 =	45.5%	MC/data = 4.1	(data = 13,600)
h_D2_ALT:	14,593 /	37,366 =	39.1%	MC/data = 4.5	(data = 3,220)
h_D1tau_ALT:	7,934 /	23,146 =	34.3%	MC/data = 17.3	(data = 459)
h_D1ptau_ALT:	9,243 /	24,411 =	37.9%	MC/data = 20.1	(data = 459)
h_D2tau_ALT:	2,494 /	12,493 =	20.0%	MC/data = 5.4	(data = 459)
h_uDDmu:	12,232 /	31,231 =	39.2%	MC/data = 0.5	(data = 24,300)
h_dDDmu:	76,181 /	158,290 =	48.1%	MC/data = 3.1	(data = 24,300)
h_dDDtau:	12,522 /	35,914 =	34.9%	MC/data = 11.6	(data = 1,080)
h_uDDtau:	3,756 /	14,724 =	25.5%	MC/data = 3.5	(data = 1,080)

In several cases, same yield distributed among several templates

Also, no direct correspondence with MC samples (eg, all 3 D states go into same MC sample)**

Stats in D^0 templates

MCMC fit in ANA note

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

h_Dmu_ALT:	1,046,699 / 1,756,634 =	59.6%	MC/data = 2.9	(data = 366,000)
h_uDstmuALT:	2,016,223 / 3,007,737 =	67.0%	MC/data = 2.2	(data = 917,000)
h_dDstmuALT:	130,725 / 220,313 =	59.3%	MC/data = 1.9	(data = 69,500)
h_dD0muALT:	69,506 / 116,990 =	59.4%	MC/data = 7.3	(data = 9,560)
h_uD0muALT:	166,622 / 273,263 =	61.0%	MC/data = 8.2	(data = 20,200)
h_dD1muALT:	46,733 / 90,997 =	51.4%	MC/data = 12.8	(data = 3,660)
h_uD1muALT:	71,112 / 135,724 =	52.4%	MC/data = 1.5	(data = 48,000)
h_dD1pmuALT:	69,767 / 119,139 =	58.6%	MC/data = 8.6	(data = 8,150)
h_uD1pmuALT:	84,198 / 142,911 =	58.9%	MC/data = 11.4	(data = 7,380)
h_dD2muALT:	24,724 / 48,576 =	50.9%	MC/data = 4.8	(data = 5,200)
h_uD2muALT:	53,974 / 99,014 =	54.5%	MC/data = 33.1	(data = 1,630)
h_dD0tauALT:	759 / 10,704 =	7.1%	MC/data = 0.4	(data = 1,740)
h_uD0tauALT:	2,449 / 13,351 =	18.3%	MC/data = 1.4	(data = 1,740)
h_dD1tauALT:	557 / 10,411 =	5.3%	MC/data = 0.3	(data = 1,740)
h_uD1tauALT:	1,182 / 11,391 =	10.4%	MC/data = 0.7	(data = 1,740)
h_dD1ptauALT:	719 / 10,702 =	6.7%	MC/data = 0.4	(data = 1,740)
h_uD1ptauALT:	1,295 / 11,479 =	11.3%	MC/data = 0.7	(data = 1,740)
h_dD2tauALT:	272 / 9,994 =	2.7%	MC/data = 0.2	(data = 1,740)
h_uD2tauALT:	769 / 10,764 =	7.1%	MC/data = 0.4	(data = 1,740)
h_Dpipimu:	104,002 / 163,837 =	63.5%	MC/data = 2.7	(data = 38,200)
h_Dstzpipimu:	76,026 / 122,350 =	62.1%	MC/data = 6.1	(data = 12,400)
h_Dstppipimu:	16,824 / 36,598 =	46.0%	MC/data = 4.7	(data = 3,590)
h_sDs1pmuALT:	5,986 / 19,009 =	31.5%	MC/data = 0.9	(data = 7,030)
h_sDs2muALT:	6,767 / 19,805 =	34.2%	MC/data = 1.6	(data = 4,200)
h_uDDmu:	99,209 / 187,273 =	53.0%	MC/data = 1.3	(data = 74,900)
h_dDDmu:	36,395 / 77,123 =	47.2%	MC/data = 0.5	(data = 74,900)
h_uDDtau:	44,154 / 77,180 =	57.2%	MC/data = 9.7	(data = 4,550)
h_dDDtau:	4,613 / 16,677 =	27.7%	MC/data = 1.0	(data = 4,550)