Searching for dark matter in dilepton production processes at the LHC

The Nuclear Physics Section of the Department of Physical Sciences of the Russian Academy of Sciences

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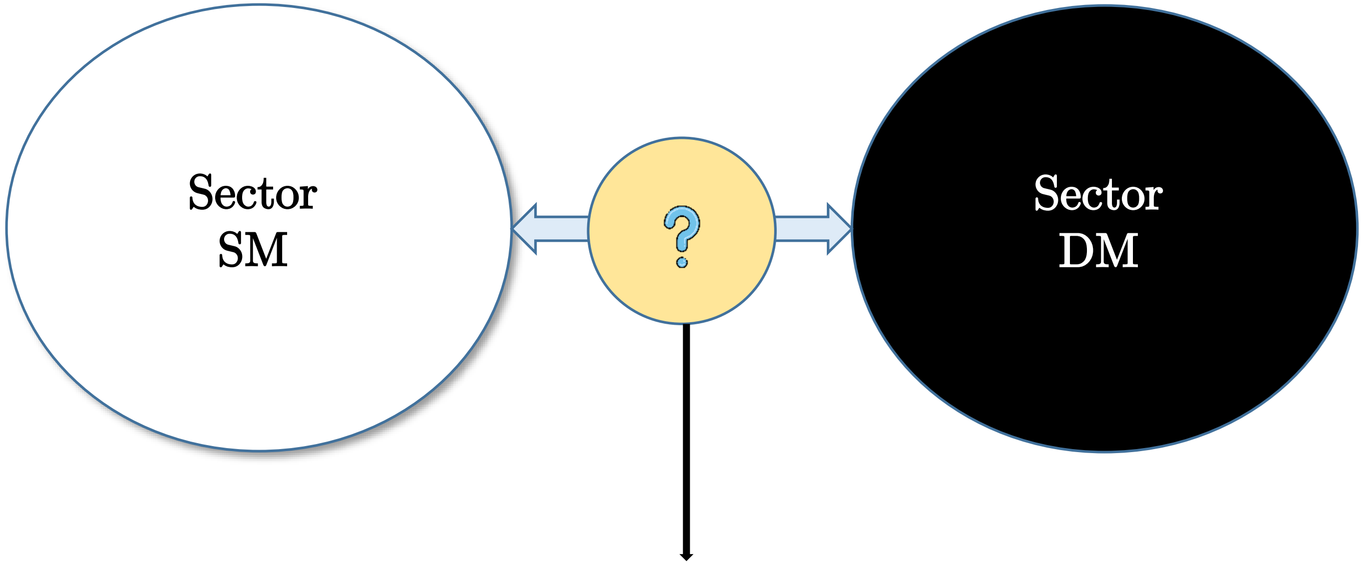
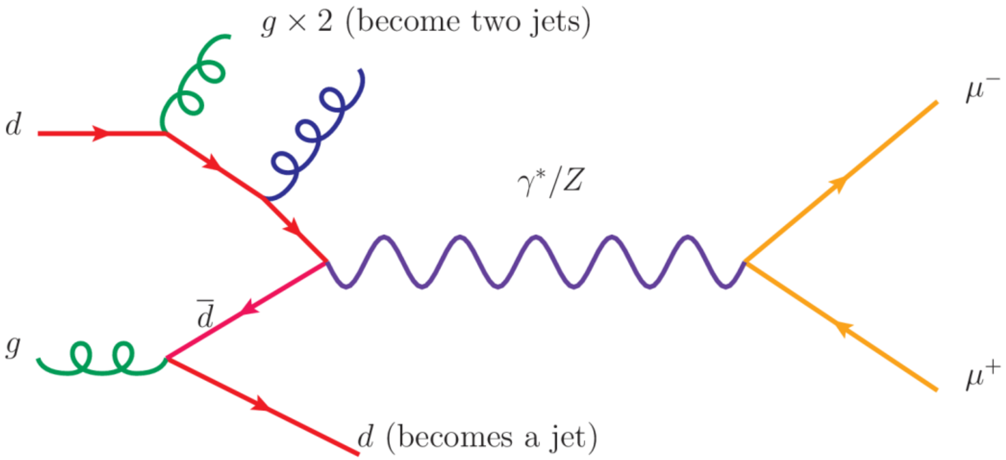
Simplified dark matter scenarios



Axial-vector	Vector
$g_q = 0.1,$	$g_q = 0.01,$
$g_l = 0.01.$	$g_l = 0.01.$
$g_{DM} = 1.0$	$g_{DM} = 1.0$

The Drell-Yan process is the main background in the search for signals of new physics beyond the Standard Model (SM), particularly in the search for candidate particles for the role of the Dark Matter



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Generated event samples and leptons selections

The signal is modeled with the convolution of a Breit–Wigner function to model the intrinsic decay width of the resonance

Z'$_{SSM}$ and Z'$_{\psi}$
- PYTHIA 8

Drell-Yan
- POWHEG v2
- FEWZ 3.1.b2

ttbar, tW, tbarW
- POWHEG v2
- PYTHIA 8
- TOP++ NNLO

WW, ZZ, WZ
- POWHEG v2
- PYTHIA 8
- MADGRAPH5 aMC@NLO version 2.2.2

tautaubar
- POWHEG v2

W+jets
- MADGRAPH5 aMC@NLO version 2.2.2
- MCFM 6.6

Muon selections

- high accuracy of the p_T calculation: $\delta p_T/p_T < 0.3$
- Isolation: (IsoPt < 0.1)
- Identification: "Global" and "Traker" muons, Tracker layers>6, PixelHits>1, MuonHits>1
- Kinematic cuts: -2.4 $< |\eta| <$ 2.4, $p_T >$ 53 GeV
- HLT trigger: HLT Mu50, HLT OldMu100, HLT TkMu100

Electron selections

- Isolation: IsoPt $<$ 5 GeV
- Identification: $|d_{xy}|<0.02$
- Kinematic cuts: $E_T >$ 35 GeV, $|\eta_{Barrel}|) < 1.4442$ and $1.566<|\eta_{Endcap}| < 2.5$
- HLT trigger: HLT_DoubleEle33_CaloIdL_MW, HLT_DoubleEle33_CaloIdL_GsfTrkIdVL

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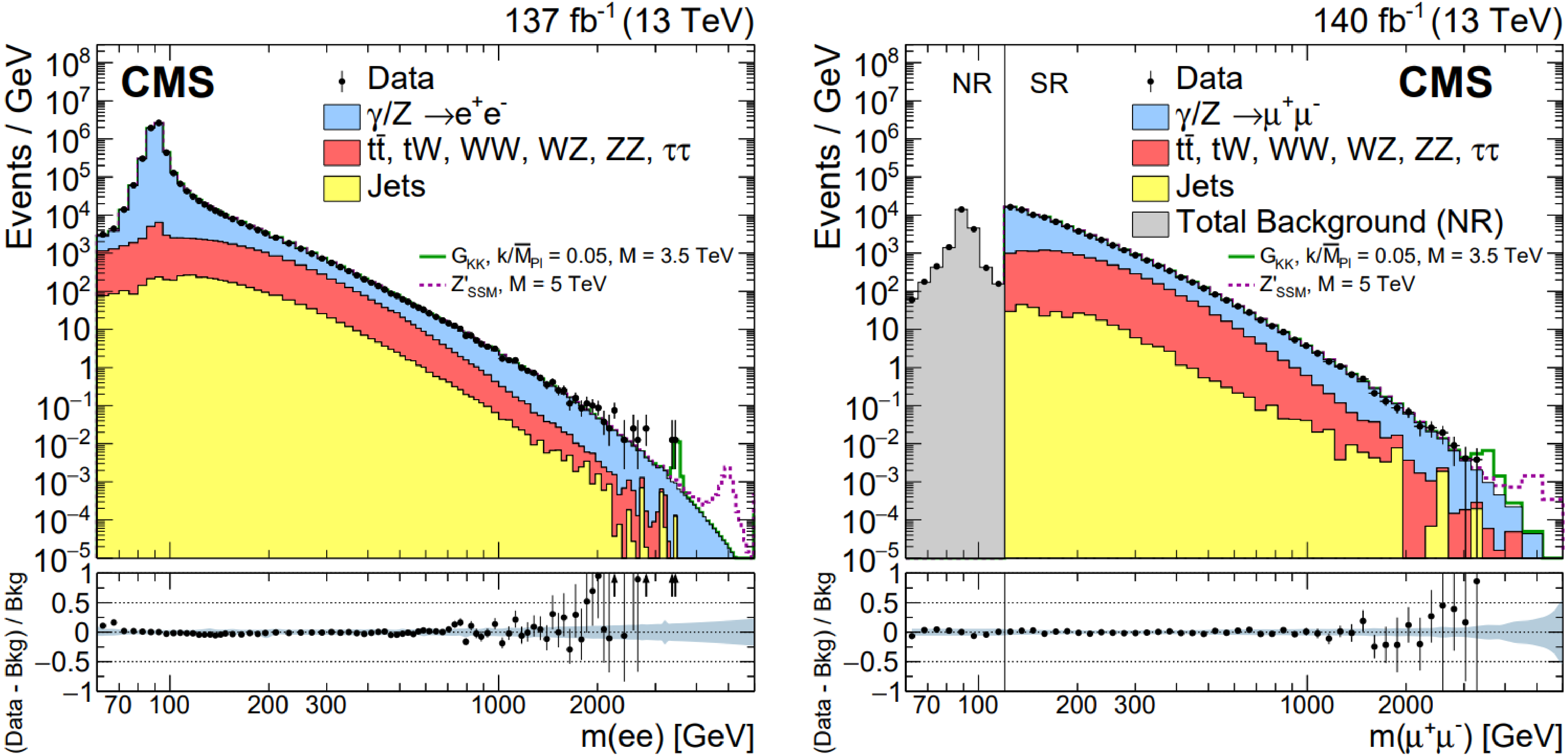
Distribution by invariant mass



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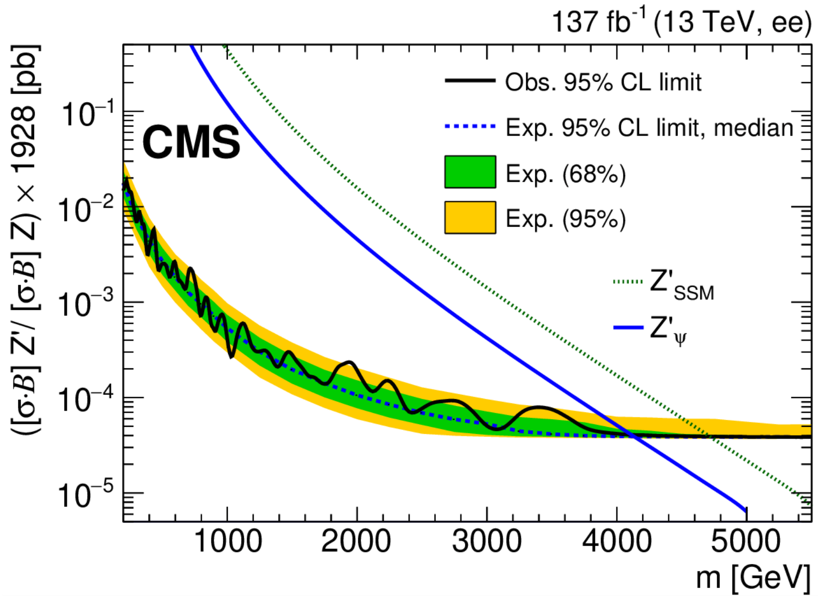
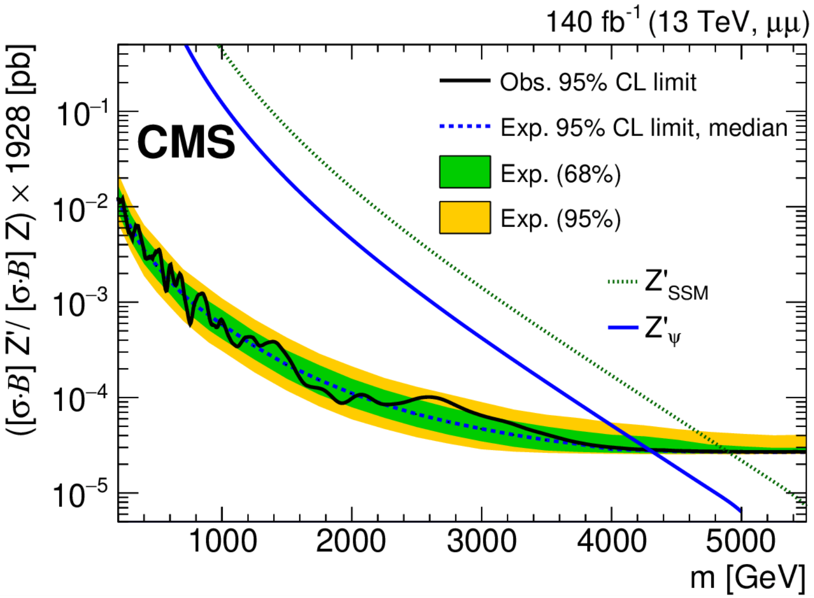
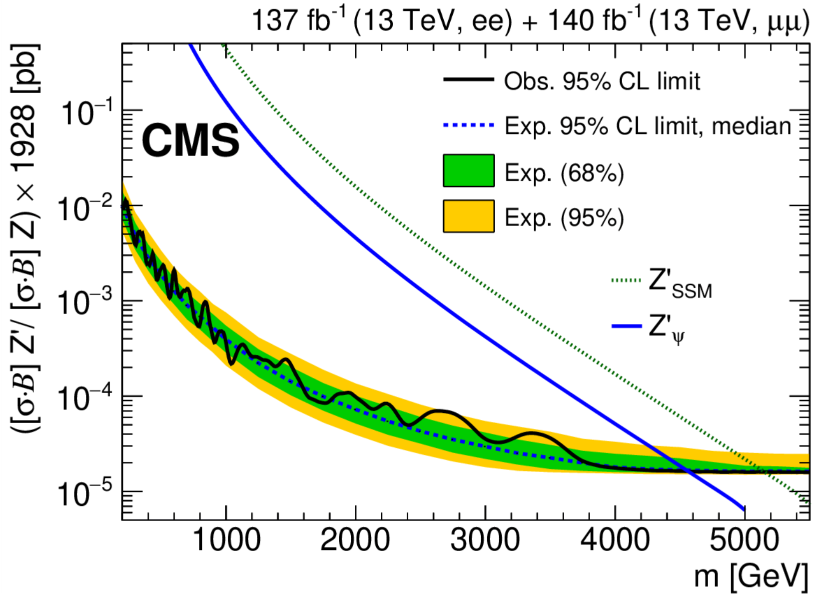
Upper limits on the ratio $\sigma_{Z'}/\sigma_{Z0}$





	Z'_{SSM} [TeV]		Z'_{ψ} [TeV]	
Channel	Obs	Exp	Obs.	Exp
ee	4.72	4.72	4.11	4.13
μμ	4.89	4.9	4.29	4.3
ee + μμ	5.15	5.14	4.56	4.55



$$R_\sigma = \frac{\sigma(pp \to Z'+X \to ll + X)}{\sigma(pp \to Z + X \to ll + X)}$$

This method allows to study the limits for any theoretical scenarios predicting a new mediators with spin 1

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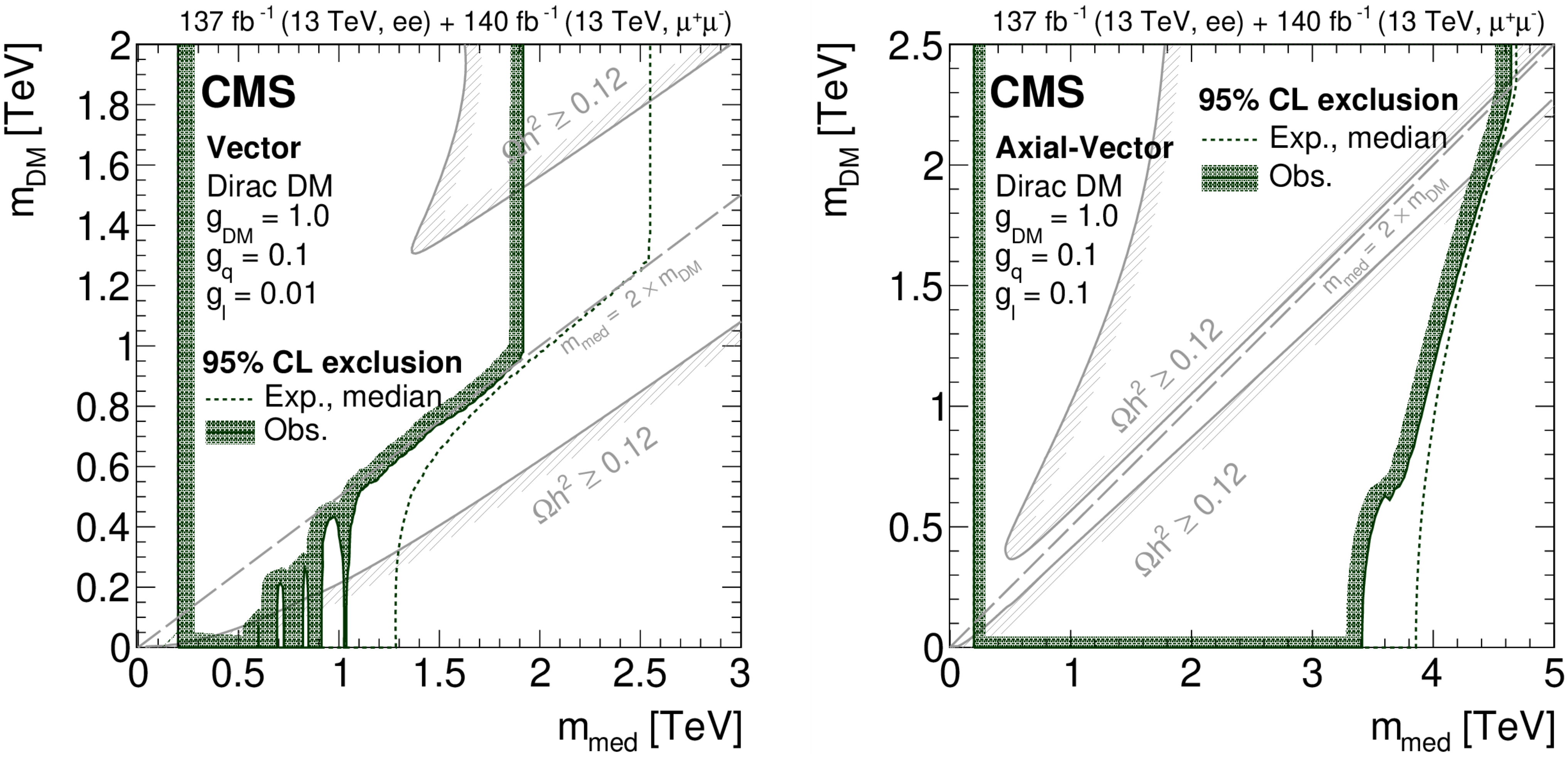
Upper limits on the masses of the DM particle



For spin-1 resonances that act as a mediator between SM particles and dark matter (DM), exclusion limits are set in the mass plane of the mediator and DM particles. For large values of m_{DM}, mediator masses below 1.92 (4.64) TeV are excluded in a model where the mediator is a vector (axial vector) with small (large) coupling to leptons. For $m_{DM} = 0$, these limits are reduced to 1.04 and 3.41 TeV, respectively

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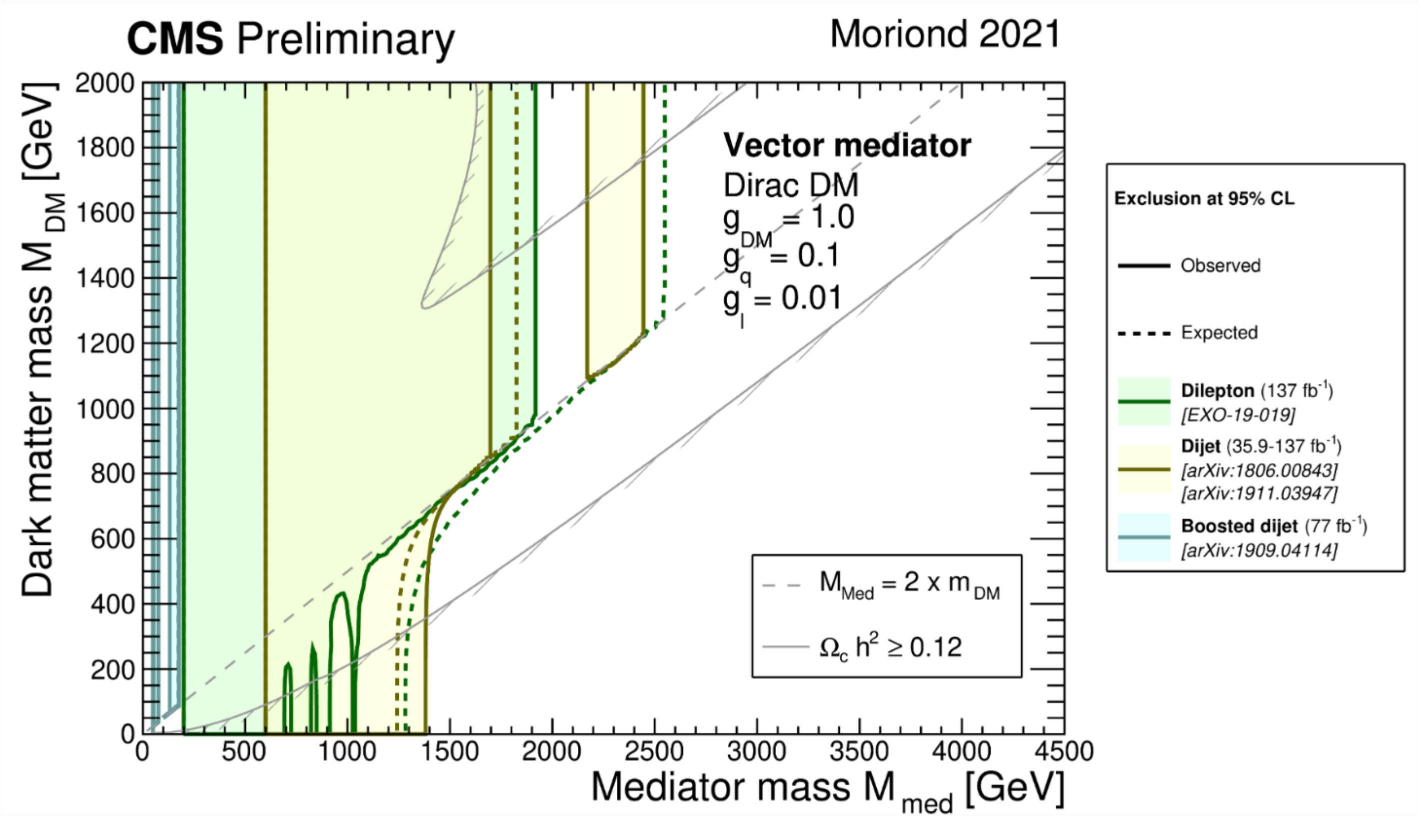
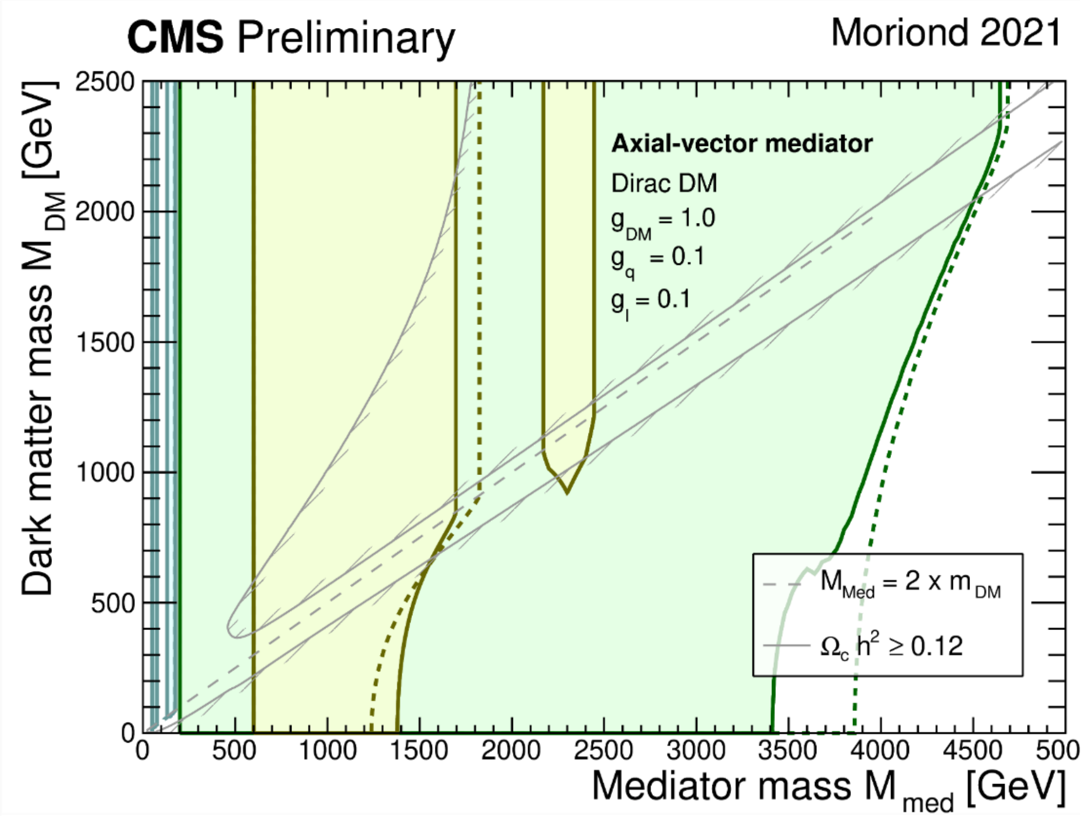
Upper limits on the masses of the DM particle





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Conclusions

- A search for resonant new phenomena in the dilepton invariant mass spectrum in proton-proton collisions at $\sqrt{s} = 13$ TeV corresponding to an integrated luminosity of up to 140 fb^{-1} has been presented

- Upper limits on the mass of a dark matter particle have been obtained

- For spin-1 resonances that act as a mediator between SM particles and dark matter (DM), exclusion limits are set in the mass plane of the mediator and DM particles. For large values of m_{DM}, mediator masses below 1.92 (4.64) TeV are excluded in a model where the mediator is a vector (axial vector) with small (large) coupling to leptons. For $m_{DM} = 0$, these limits are reduced to 1.04 and 3.41 TeV, respectively

- No significant deviation from SM expectation is observed

- Currently, research is being conducted within this scenario with dark matter based on open CMS data.

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Thanks for your attention!

Back up, electron analysis

Table 1: Data sets, as well as corresponding run-ranges, luminosities, and Json files in 2016, 2017, and 2018.

Dataset Name	Run Range	L (fb^{-1})
X = DoubleEG, SingleElectron, SinglePhoton, and SingleMuon.		
/X/Run2016B-17Jul2018_ver2-v1/MINIAOD	272007-275376	5.75
/X/Run2016C-17Jul2018-v1/MINIAOD	275657-276283	2.57
/X/Run2016D-17Jul2018-v1/MINIAOD	276315-276811	4.24
/X/Run2016E-17Jul2018-v2/MINIAOD	276831-277420	4.03
/X/Run2016F-17Jul2018-v1/MINIAOD	277772-278808	3.11
/X/Run2016G-17Jul2018-v1/MINIAOD	278820-280385	7.58
/X/Run2016H-17Jul2018-v1/MINIAOD	280919-284044	8.65
Run 2016	275657-284044	35.92
JSON: Cert_271036-284044_13TeV_23Sep2016ReReco_Collisions16_JSON.txt		
X = DoubleEG, SingleElectron, SinglePhoton, and SingleMuon.		
/X/Run2017B-31Mar2018-v1/MINIAOD	297046-299329	4.79
/X/Run2017C-31Mar2018-v1/MINIAOD	299368-302029	9.63
/X/Run2017D-31Mar2018-v1/MINIAOD	302030-303434	4.25
/X/Run2017E-31Mar2018-v1/MINIAOD	303824-304797	9.32
/X/Run2017F-31Mar2018-v1/MINIAOD	305040-306462	13.54
Run 2017	297046-306462	41.53
JSON: Cert_294927-306462_13TeV_EOY2017ReReco_Collisions17_JSON.txt		
X = EGamma and SingleMuon.		
/X/Run2018A-17Sep2018-v2/MINIAOD	315252-316995	13.70
/X/Run2018B-17Sep2018-v1/MINIAOD	317080-319310	7.06
/X/Run2018C-17Sep2018-v1/MINIAOD	319337-320065	6.89
/X/Run2018D-22Jan2019-v2/MINIAOD	320673-325175	31.74
Run 2018	315252-325175	59.40
JSON: Cert_314472-325175_13TeV_17SeptEarlyReReco2018ABC_PromptEraD_Collisions18_JSON.txt		
Full run2	275657-325175	136.85

sample	xsection(pb)	xs precision
ZToEE_NNPDF30_13TeV-powheg_M_50_120	1975	NLO
ZToEE_NNPDF30_13TeV-powheg_M_120_200	19.32	NLO
ZToEE_NNPDF30_13TeV-powheg_M_200_400	2.73	NLO
ZToEE_NNPDF30_13TeV-powheg_M_400_800	0.241	NLO
ZToEE_NNPDF30_13TeV-powheg_M_800_1400	1.68E-2	NLO
ZToEE_NNPDF30_13TeV-powheg_M_14000_2300	1.39E-3	NLO
ZToEE_NNPDF30_13TeV-powheg_M_2300_3500	8.948E-5	NLO
ZToEE_NNPDF30_13TeV-powheg_M_3500_4500	4.135E-6	NLO
ZToEE_NNPDF30_13TeV-powheg_M_4500_6000	4.56E-7	NLO
ZToEE_NNPDF30_13TeV-powheg_M_6000_Inf	2.06E-8	NLO
DYJetsToLL_M-50_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8 (for $Z \to \tau\tau$)	5765.4	NNLO
ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/	19.47	app.NNLO
ST_tW_antitop_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/	19.47	app.NNLO
TTTo2L2Nu_TuneCUETP8M2_ttHtranche3_13TeV-powheg	87.31	NNLO
TTToLL_MLL_500To800_TuneCUETP8M1_13TeV-powheg-pythia8	0.326	NNLO
TTToLL_MLL_800To1200_TuneCUETP8M1_13TeV-powheg-pythia8	3.26E-2	NNLO
TTToLL_MLL_1200To1800_TuneCUETP8M1_13TeV-powheg-pythia8	3.05E-3	NNLO
TTToLL_MLL_1800ToInf_TuneCUETP8M1_13TeV-powheg-pythia8	1.74E-4	NNLO
WWTo2L2Nu_13TeV-powheg	12.178	NNLO
WWTo2L2Nu_Mll_200To600_13TeV-powheg	1.39	NNLO
WWTo2L2Nu_Mll_600To1200_13TeV-powheg	5.7E-2	NNLO
WWTo2L2Nu_Mll_1200To2500_13TeV-powheg	3.6E-3	NNLO
WWTo2L2Nu_Mll_2500ToInf_13TeV-powheg	5.4E-5	NNLO
WZTo3LNu_TuneCUETP8M1_13TeV-powheg-pythia8	4.42965	NLO
WZTo2L2Q_13TeV_amcatnloFXFX_madspin_pythia8	6.331	NLO
ZZTo2L2Nu_13TeV_powheg_pythia8	0.564	NLO
ZZTo4L_13TeV_powheg_pythia8	1.212	NLO
ZZTo2L2Q_13TeV_powheg_pythia8	1.999	NLO

Table 2: 2016 MC samples (dataset=/*/RunIISummer16MiniAODv3-PUMoriond17_94X_mcRun2_asymptotic_v3*/MINIAODSIM)

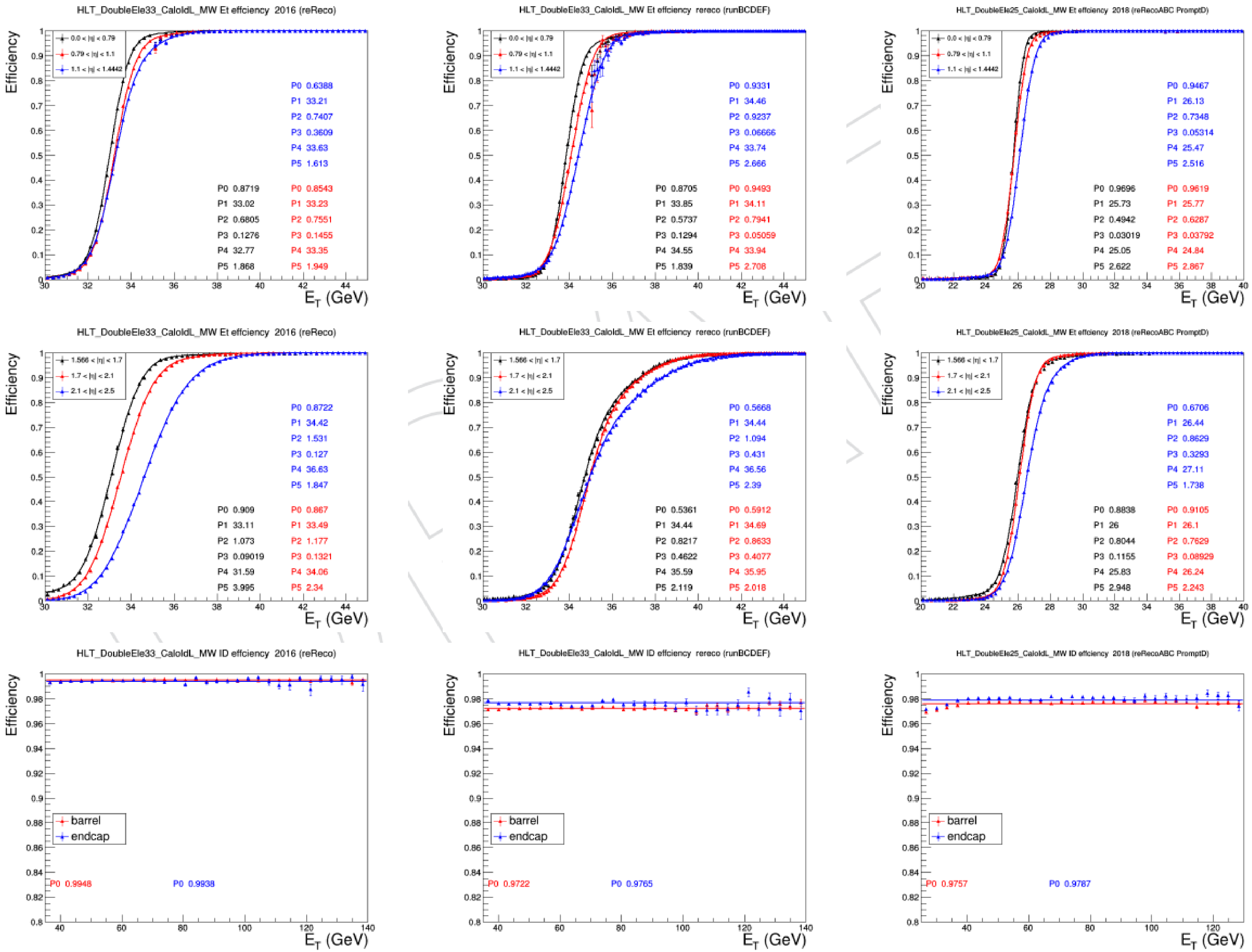
sample	xsection(pb)	xs precision	year
ZToEE_NNPDF31_13TeV-powheg_M_50_120	2112.90	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_120_200	20.56	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_200_400	2.89	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_400_800	0.252	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_800_1400	1.71E-2	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_14000_2300	1.37E-3	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_2300_3500	8.178E-5	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_3500_4500	3.191E-6	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_4500_6000	2.787E-7	NLO	
ZToEE_NNPDF31_13TeV-powheg_M_6000_Inf	9.56E-9	NLO	
DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8 (for $Z \to \tau\tau$)	5765.4	NNLO	
ST_tW_top_5f_NoFullyHadronicDecays_TuneCP5_13TeV-powheg-pythia8	19.47	app.NNLO	2017 and 2018
ST_tW_antitop_5f_NoFullyHadronicDecays_TuneCP5_13TeV-powheg-pythia8	19.47	app.NNLO	2017 and 2018
TTTo2L2Nu_TuneCP5_13TeV-powheg-pythia8	87.31	NNLO	2017 and 2018
TTToLL_MLL_500To800_*to*_NNPDF31_13TeV-powheg	0.326	NNLO	2017
TTToLL_MLL_800To1200_*to*_NNPDF31_13TeV-powheg	3.26E-2	NNLO	2017
TTToLL_MLL_1200To1800_*to*_NNPDF31_13TeV-powheg	3.05E-3	NNLO	2017
TTToLL_MLL_1800ToInf_*to*_NNPDF31_13TeV-powheg	1.74E-4	NNLO	2017
WWTo2L2Nu_NNPDF31_TuneCP5_13TeV-powheg-pythia8	12.178	NNLO	2017 and 2018
WWTo2L2Nu_MLL_200To600_NNPDF31_13TeV-powheg	1.39	NNLO	2017
WWTo2L2Nu_MLL_600To1200_v1_NNPDF31_13TeV-powheg	5.7E-2	NNLO	2017
WWTo2L2Nu_MLL_1200To2500_NNPDF31_13TeV-powheg	3.6E-3	NNLO	2017
WWTo2L2Nu_MLL_2500ToInf_NNPDF31_13TeV-powheg	5.4E-5	NNLO	2017
WZTo3LNu_13TeV-powheg-pythia8	4.42965	NLO	2017
WZTo3LNu_TuneCP5_13TeV-powheg-pythia8	4.42965	NLO	2018
WZTo2L2Q_13TeV_amcatnloFXFX_madspin_pythia8	6.331	NLO	2017 and 2018
ZZTo2L2Nu_13TeV_powheg_pythia8	0.564	NLO	2017
ZZTo2L2Nu_TuneCP5_13TeV_powheg_pythia8	0.564	NLO	2018
ZZTo4L_TuneCP5_13TeV_powheg_pythia8	1.212	NLO	2017
ZZTo4L_TuneCP5_13TeV_powheg_pythia8	1.212	NLO	2018
ZZTo2L2Q_13TeV_amcatnloFXFX_madspin_pythia8	1.999	NLO	2017 and 2018

Table 3: 2017 MC samples (dataset=/*/RunIIFall17MiniAODv2-PU2017_12Apr2018_94X_mc2017_realistic_v14/MINIAODSIM) and 2018 MC samples (dataset=/*/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15/MINIAODSIM).

Year	path	Runs
2016	HLT_DoubleEle33_CaloIdL_MW	All except runs 276453 to 278822
	HLT_DoubleEle33_CaloIdL_GsfTrkIdVL	runs 276453 to 278822
2017	HLT_DoubleEle33_CaloIdL_MW	All
2018	HLT_DoubleEle25_CaloIdL_MW	All

Table 5: Summary of the signal triggers

DRAFT

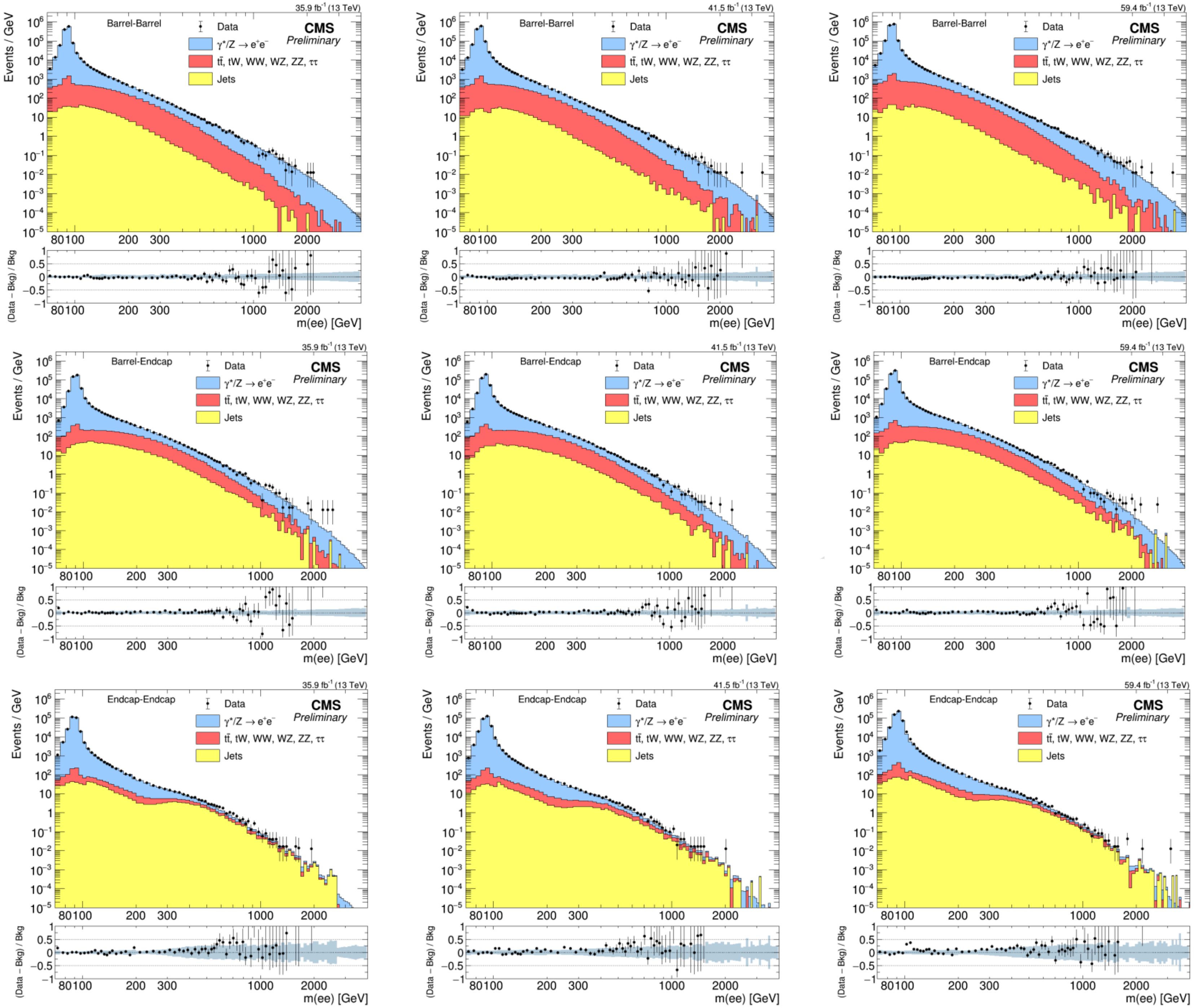

HLT_DoubleEle33_CaloIdL_MW Et effciency 2016 (reReco)
Efficiency
0.0 < |η| < 0.79
0.79 < |η| < 1.1
1.1 < |η| < 1.4442
P0 0.6388
P1 33.21
P2 0.7407
P3 0.3609
P4 33.63
P5 1.613
P0 0.8719
P1 33.02
P2 0.6805
P3 0.1276
P4 32.77
P5 1.868
P0 0.8543
P1 33.23
P2 0.7551
P3 0.1455
P4 33.35
P5 1.949
E_T (GeV)
HLT_DoubleEle33_CaloIdL_MW Et effciency rereco (runBCDEF)
P0 0.9331
P1 34.46
P2 0.9237
P3 0.06666
P4 33.74
P5 2.666
P0 0.8705
P1 33.85
P2 0.5737
P3 0.1294
P4 34.55
P5 1.839
P0 0.9493
P1 34.11
P2 0.7941
P3 0.05059
P4 33.94
P5 2.708
HLT_DoubleEle25_CaloIdL_MW Et effciency 2018 (reRecoABC PromptD)
P0 0.9467
P1 26.13
P2 0.7348
P3 0.05314
P4 25.47
P5 2.516
P0 0.9696
P1 25.73
P2 0.4942
P3 0.03019
P4 25.05
P5 2.622
P0 0.9619
P1 25.77
P2 0.6287
P3 0.03792
P4 24.84
P5 2.867
HLT_DoubleEle33_CaloIdL_MW Et effciency 2016 (reReco)
1.566 < |η| < 1.7
1.7 < |η| < 2.1
2.1 < |η| < 2.5
P0 0.8722
P1 34.42
P2 1.531
P3 0.127
P4 36.63
P5 1.847
P0 0.909
P1 33.11
P2 1.073
P3 0.09019
P4 31.59
P5 3.995
P0 0.867
P1 33.49
P2 1.177
P3 0.1321
P4 34.06
P5 2.34
HLT_DoubleEle33_CaloIdL_MW Et effciency rereco (runBCDEF)
P0 0.5668
P1 34.44
P2 1.094
P3 0.431
P4 36.56
P5 2.39
P0 0.5361
P1 34.44
P2 0.8217
P3 0.4622
P4 35.59
P5 2.119
P0 0.5912
P1 34.69
P2 0.8633
P3 0.4077
P4 35.95
P5 2.018
HLT_DoubleEle25_CaloIdL_MW Et effciency 2018 (reRecoABC PromptD)
P0 0.6706
P1 26.44
P2 0.8629
P3 0.3293
P4 27.11
P5 1.738
P0 0.8838
P1 26
P2 0.8044
P3 0.1155
P4 25.83
P5 2.948
P0 0.9105
P1 26.1
P2 0.7629
P3 0.08929
P4 26.24
P5 2.243
HLT_DoubleEle33_CaloIdL_MW ID effciency 2016 (reReco)
barrel
endcap
P0 0.9948
P0 0.9938
HLT_DoubleEle33_CaloIdL_MW ID effciency rereco (runBCDEF)
P0 0.9722
P0 0.9765
HLT_DoubleEle25_CaloIdL_MW ID effciency 2018 (reRecoABC PromptD)
P0 0.9757
P0 0.9787

Variable	Barrel	Endcap
	Acceptance selections	
E_T	$E_T > 35\,\text{GeV}$	$E_T > 35\,\text{GeV}$
η	$\lvert\eta_{SC}\rvert < 1.4442$	$1.566 < \lvert\eta_{SC}\rvert < 2.5$
	Identification selections	
`isEcalDriven`	true	true
$\Delta\eta_{in}^{seed}$	$\lvert\Delta\eta_{in}^{seed}\rvert < 0.004$	$\lvert\Delta\eta_{in}^{seed}\rvert < 0.006$
$\Delta\phi_{in}$	$\lvert\Delta\phi_{in}\rvert < 0.06$	$\lvert\Delta\phi_{in}\rvert < 0.06$
H/E	$H/E < 1/E + 0.05$	$H/E < 5/E + 0.05$
$\sigma_{i\eta i\eta}$	-	$\sigma_{i\eta i\eta} < 0.03$
$\frac{E_{1\times5}}{E_{5\times5}}, \frac{E_{2\times5}}{E_{5\times5}}$	$\frac{E_{1\times5}}{E_{5\times5}} > 0.83$ or $\frac{E_{2\times5}}{E_{5\times5}} > 0.94$	-
Inner lost layer hits	lost hits ≤ 1	lost hits ≤ 1
Impact parameter, d_{xy}	$\lvert d_{xy}\rvert < 0.02$	$\lvert d_{xy}\rvert < 0.05$
	Isolation selections	
EM + had depth 1 isolation, *iso*	$iso < 2 + 0.03E_T + 0.28\rho$	$iso < 2.5 + 0.28\rho$ ($E_T < 50\,\text{GeV}$) else $iso < 2.5 + 0.03(E_T - 50\,\text{GeV}) + 0.28\rho$
p_T isolation (V7), *isopt*	$isopt < 5\,\text{GeV}$	$isopt < 5\,\text{GeV}$

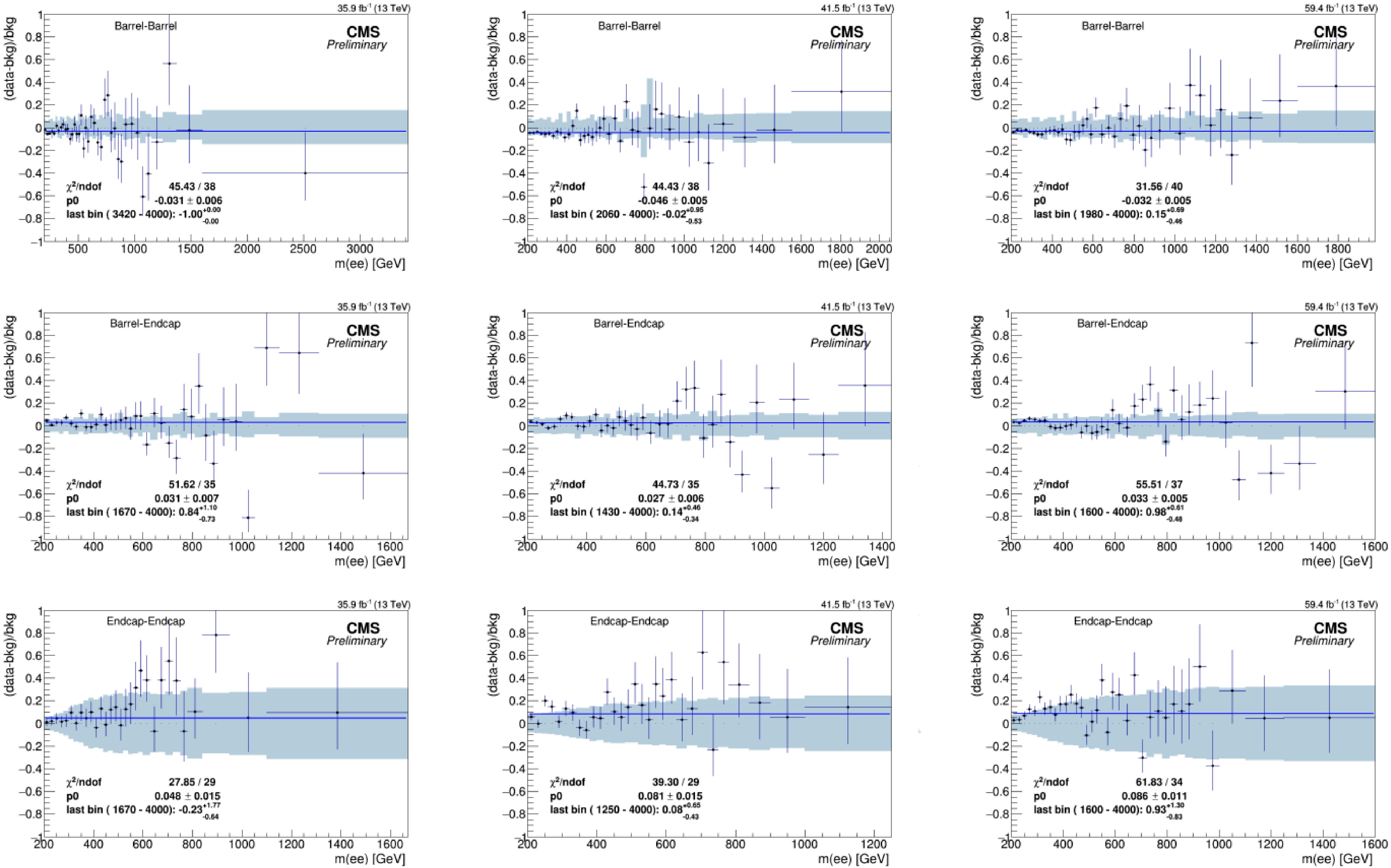
Table 6: Definitions of HEEP ID V7.0 selections.

Variable	Barrel	Endcap
	Acceptance selections	
E_T	$E_T > 35\,\text{GeV}$	$E_T > 35\,\text{GeV}$
η	$\lvert\eta_{SC}\rvert < 1.4442$	$1.566 < \lvert\eta_{SC}\rvert < 2.5$
	Identification selections	
`isEcalDriven`	true	true
$\Delta\eta_{in}^{seed}$	$\lvert\Delta\eta_{in}^{seed}\rvert < 0.004$	$\lvert\Delta\eta_{in}^{seed}\rvert < 0.006$
$\Delta\phi_{in}$	$\lvert\Delta\phi_{in}\rvert < 0.06$	$\lvert\Delta\phi_{in}\rvert < 0.06$
H/E	$H/E < 1/E + 0.05$	$H/E < (-0.4 + 0.4\lvert\eta\rvert)\rho/E + 0.05$
$\sigma_{i\eta i\eta}$	-	$\sigma_{i\eta i\eta} < 0.03$
$\frac{E_{1\times5}}{E_{5\times5}}, \frac{E_{2\times5}}{E_{5\times5}}$	$\frac{E_{1\times5}}{E_{5\times5}} > 0.83$ or $\frac{E_{2\times5}}{E_{5\times5}} > 0.94$	-
Inner lost layer hits	lost hits ≤ 1	lost hits ≤ 1
Impact parameter, d_{xy}	$\lvert d_{xy}\rvert < 0.02$	$\lvert d_{xy}\rvert < 0.05$
	Isolation selections	
EM + had depth 1 isolation, *iso*	$iso < 2 + 0.03E_T + 0.28\rho$	$iso < 2.5 + (0.15 + 0.07\lvert\eta\rvert)\rho$, ($E_T < 50\,\text{GeV}$) $iso < 2.5 + 0.03(E_T - 50\,\text{GeV}) + (0.15 + 0.07\lvert\eta\rvert)\rho$, ($E_T > 50\,\text{GeV}$)
p_T isolation (V7), *isopt*	$isopt < 5\,\text{GeV}$	$isopt < 5\,\text{GeV}$

Table 7: Definitions of HEEP ID V7.0-2018Prompt selections.



35.9 fb^{-1} (13 TeV)
41.5 fb^{-1} (13 TeV)
59.4 fb^{-1} (13 TeV)
Barrel-Barrel
Barrel-Endcap
Endcap-Endcap
CMS
Preliminary
Data
$\gamma^*/Z \rightarrow e^+e^-$
$t\bar{t}$, tW, WW, WZ, ZZ, $\tau\tau$
Jets
Events / GeV
(Data − Bkg) / Bkg
m(ee) [GeV]


35.9 fb^{-1} (13 TeV)
Barrel-Barrel
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 45.43 / 38
p0 -0.031 ± 0.006
last bin (3420 - 4000): $-1.00^{+0.00}_{-0.00}$
41.5 fb^{-1} (13 TeV)
Barrel-Barrel
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 44.43 / 38
p0 -0.046 ± 0.005
last bin (2060 - 4000): $-0.02^{+0.95}_{-0.53}$
59.4 fb^{-1} (13 TeV)
Barrel-Barrel
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 31.56 / 40
p0 -0.032 ± 0.005
last bin (1980 - 4000): $0.15^{+0.69}_{-0.46}$
35.9 fb^{-1} (13 TeV)
Barrel-Endcap
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 51.62 / 35
p0 0.031 ± 0.007
last bin (1670 - 4000): $0.84^{+1.10}_{-0.73}$
41.5 fb^{-1} (13 TeV)
Barrel-Endcap
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 44.73 / 35
p0 0.027 ± 0.006
last bin (1430 - 4000): $0.14^{+0.46}_{-0.34}$
59.4 fb^{-1} (13 TeV)
Barrel-Endcap
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 55.51 / 37
p0 0.033 ± 0.005
last bin (1600 - 4000): $0.98^{+0.61}_{-0.48}$
35.9 fb^{-1} (13 TeV)
Endcap-Endcap
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 27.85 / 29
p0 0.048 ± 0.015
last bin (1670 - 4000): $-0.23^{+1.77}_{-0.64}$
41.5 fb^{-1} (13 TeV)
Endcap-Endcap
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 39.30 / 29
p0 0.081 ± 0.015
last bin (1250 - 4000): $0.08^{+0.65}_{-0.43}$
59.4 fb^{-1} (13 TeV)
Endcap-Endcap
CMS
Preliminary
(data-bkg)/bkg
m(ee) [GeV]
χ^2/ndof 61.83 / 34
p0 0.086 ± 0.011
last bin (1600 - 4000): $0.93^{+1.30}_{-0.83}$

Back up, muon analysis

Data set	Run range
/SingleMuon/Run2017B-31Mar2018-v1	297050 – 299329
/SingleMuon/Run2017C-31Mar2018-v1	299368 – 302029
/SingleMuon/Run2017D-31Mar2018-v1	302031 – 302663
/SingleMuon/Run2017E-31Mar2018-v1	303824 – 304797
/SingleMuon/Run2017F-31Mar2018-v1	305045 – 306460
/SingleMuon/Run2018A-17Sep2018-v2	315257 – 316995
/SingleMuon/Run2018B-17Sep2018-v1	317080 – 319077
/SingleMuon/Run2018C-17Sep2018-v1	319337 – 320065
/SingleMuon/Run2018D-22Jan2019-v2	320673 – 325172

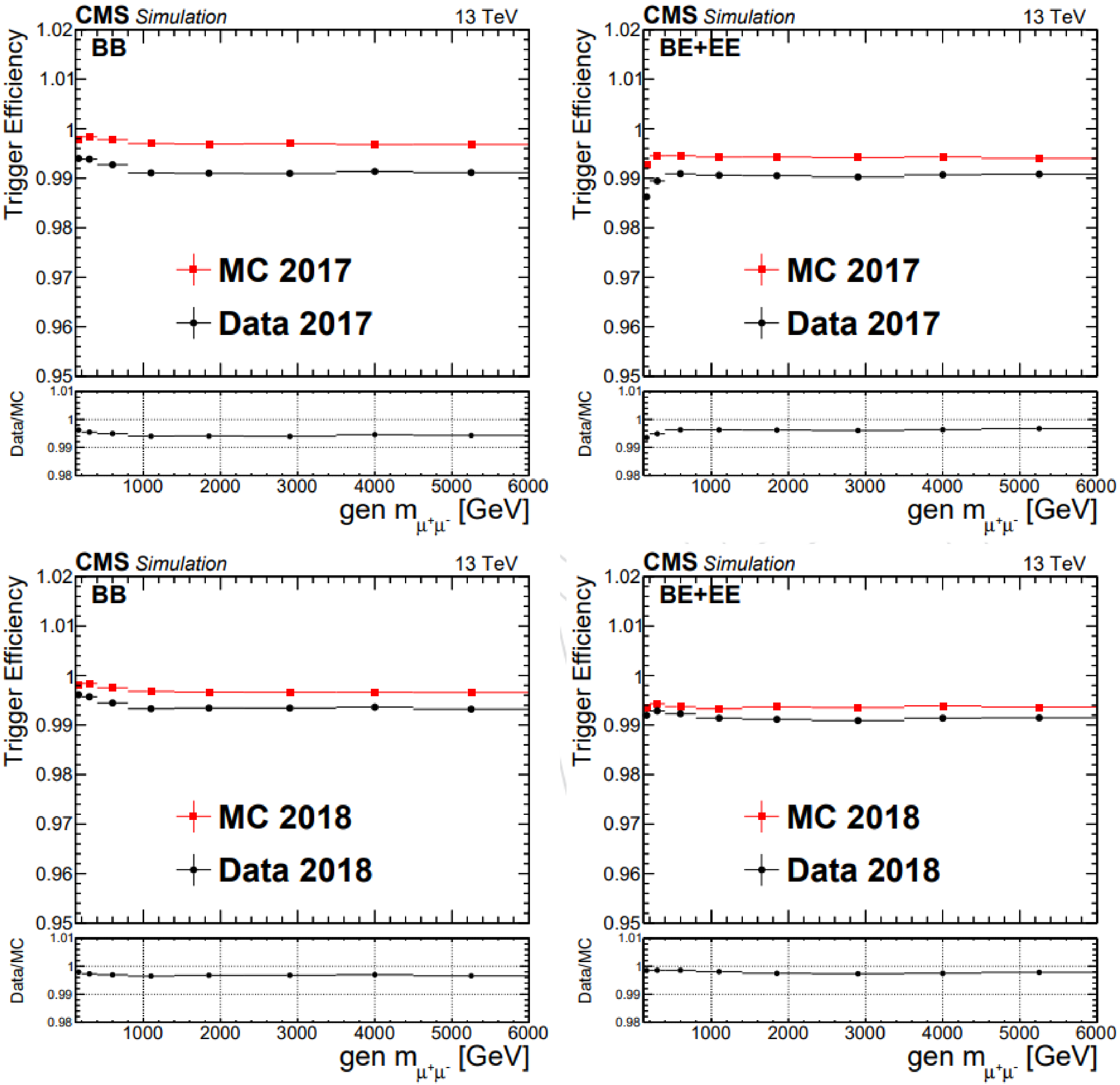
Table 1: Data sets used in this analysis for 2017 and 2018.

Process	σ (pb)	Order	Events
ZToMuMu_NNPDF31_13TeV-powheg_M_50_120	2112.904	NLO	2863000
ZToMuMu_NNPDF31_13TeV-powheg_M_120_200	20.553	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_200_400	2.886	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_400_800	0.2517	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_800_1400	0.01707	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_1400_2300	0.001366	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_2300_3500	0.00008178	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_3500_4500	0.000003191	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_4500_6500	0.0000002787	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_6000_Inf	0.000000009569	NLO	100000
DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8	5765.4	NNLO	29082237
DYJetsToLL_M-50_TuneCP5_13TeV-madgraphMLM-pythia8	5765.4	NNLO	49748967
TTTo2L2Nu_TuneCP5_13TeV-powheg-pythia8	87.31	NNLO	79140880
TTToLL_MLL_500To800_NNPDF31_13TeV-powheg-pythia8 (to be done)	0.326	NLO	200000
TTToLL_MLL_800To1200_NNPDF31_13TeV-powheg-pythia8 (to be done)	3.26E-2	NLO	199800
TTToLL_MLL_1200To1800_NNPDF31_13TeV-powheg-pythia8	3.05E-3	NLO	20617
TTToLL_MLL_1800ToInf_NNPDF31_13TeV-powheg-pythia8	1.74E-4	NLO	1157
ST_tW_top_5f_inclusiveDecays_TuneCP5_13TeV-powheg-pythia8	35.6	NNLO	6952830
ST_tW_antitop_5f_inclusiveDecays_TuneCP5_13TeV-powheg-pythia8	35.6	NNLO	6933094
WW_TuneCP5_13TeV-pythia8	12.178	NNLO	1999000
WWTo2L2Nu_Mll_200To600_13TeV-powheg (to be done)	1.386	NNLO	200000
WWTo2L2Nu_Mll_600To1200_13TeV-powheg (to be done)	5.6665E-2	NNLO	200000
WWTo2L2Nu_Mll_1200To2500_13TeV-powheg (to be done)	3.557E-3	NNLO	200000
WWTo2L2Nu_Mll_2500ToInf_13TeV-powheg (to be done)	5.395E-5	NNLO	38969
WZ_TuneCP5_13TeV-pythia8	47.13	NLO	1000000
ZZ_TuneCP5_13TeV-pythia8	16.523	NLO	990064
ZprimeToMuMu_M-5000_TuneCP5_13TeV-madgraphMLM-pythia8	6.76E-5	NLO	100000
RSGravToEEMuMu_kMpl-001_M-250_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-750_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-1000_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-1500_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-2000_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-2500_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-3000_TuneCP5_13TeV-pythia8 (to be done)			49657
RSGravToEEMuMu_kMpl-001_M-3500_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-4000_TuneCP5_13TeV-pythia8 (to be done)			50000

Table 2: Summary of simulated background process samples for 2017 samples.

Process	σ (pb)	Order	Events
ZToMuMu_NNPDF31_13TeV-powheg_M_50_120	2112.904	NLO	2982000
ZToMuMu_NNPDF31_13TeV-powheg_M_120_200	20.553	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_200_400	2.886	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_400_800	0.2517	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_800_1400	0.01707	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_1400_2300	0.001366	NLO	104000
ZToMuMu_NNPDF31_13TeV-powheg_M_2300_3500	0.00008178	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_3500_4500	0.000003191	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_4500_6500	0.0000002787	NLO	100000
ZToMuMu_NNPDF31_13TeV-powheg_M_6000_Inf	0.000000009569	NLO	100000
DYJetsToLL_M-50_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8	5765.4	NNLO	997561
DYJetsToLL_M-50_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	5765.4	NNLO	100194597
TTTo2L2Nu_TuneCP5_13TeV-powheg-pythia8	87.31	NNLO	64330000
TTToLL_MLL_500To800_TuneCUETP8M1_13TeV-powheg-pythia8 (to be done)	0.326	NLO	200000
TTToLL_MLL_800To1200_TuneCUETP8M1_13TeV-powheg-pythia8 (to be done)	3.26E-2	NLO	199800
TTToLL_MLL_1200To1800_TuneCUETP8M1_13TeV-powheg-pythia8 (to be done)	3.05E-3	NLO	200000
TTToLL_MLL_1800ToInf_TuneCUETP8M1_13TeV-powheg-pythia8 (to be done)	1.74E-4	NLO	40829
ST_tW_top_5f_inclusiveDecays_TuneCP5_13TeV-powheg-pythia8	35.6	NNLO	9640000
ST_tW_antitop_5f_inclusiveDecays_TuneCP5_13TeV-powheg-pythia8	35.6	NNLO	7695000
WW_TuneCP5_13TeV-pythia8	118.7	NNLO	7920000
WWTo2L2Nu_Mll_200To600_13TeV-powheg (to be done)	1.386	NNLO	200000
WWTo2L2Nu_Mll_600To1200_13TeV-powheg (to be done)	5.6665E-2	NNLO	200000
WWTo2L2Nu_Mll_1200To2500_13TeV-powheg (to be done)	3.557E-3	NNLO	200000
WWTo2L2Nu_Mll_2500ToInf_13TeV-powheg (to be done)	5.395E-5	NNLO	38969
WZ_TuneCP5_13TeV-pythia8	47.13	NLO	1979000
ZZ_TuneCUETP8M1_13TeV-pythia8	16.523	NLO	990064
ZprimeToMuMu_M-5000_TuneCP5_13TeV-pythia8	6.76E-5	NLO	100000
RSGravToEEMuMu_kMpl-001_M-250_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-750_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-1000_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-1500_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-2000_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-2500_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-3000_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-3500_TuneCP5_13TeV-pythia8 (to be done)			50000
RSGravToEEMuMu_kMpl-001_M-4000_TuneCP5_13TeV-pythia8 (to be done)			50000

Table 3: Summary of simulated background process samples for 2018 samples.


CMS Simulation
13 TeV
BB
BE+EE
Trigger Efficiency
Data/MC
MC 2017
Data 2017
MC 2018
Data 2018
gen $m_{\mu^+\mu^-}$ [GeV]

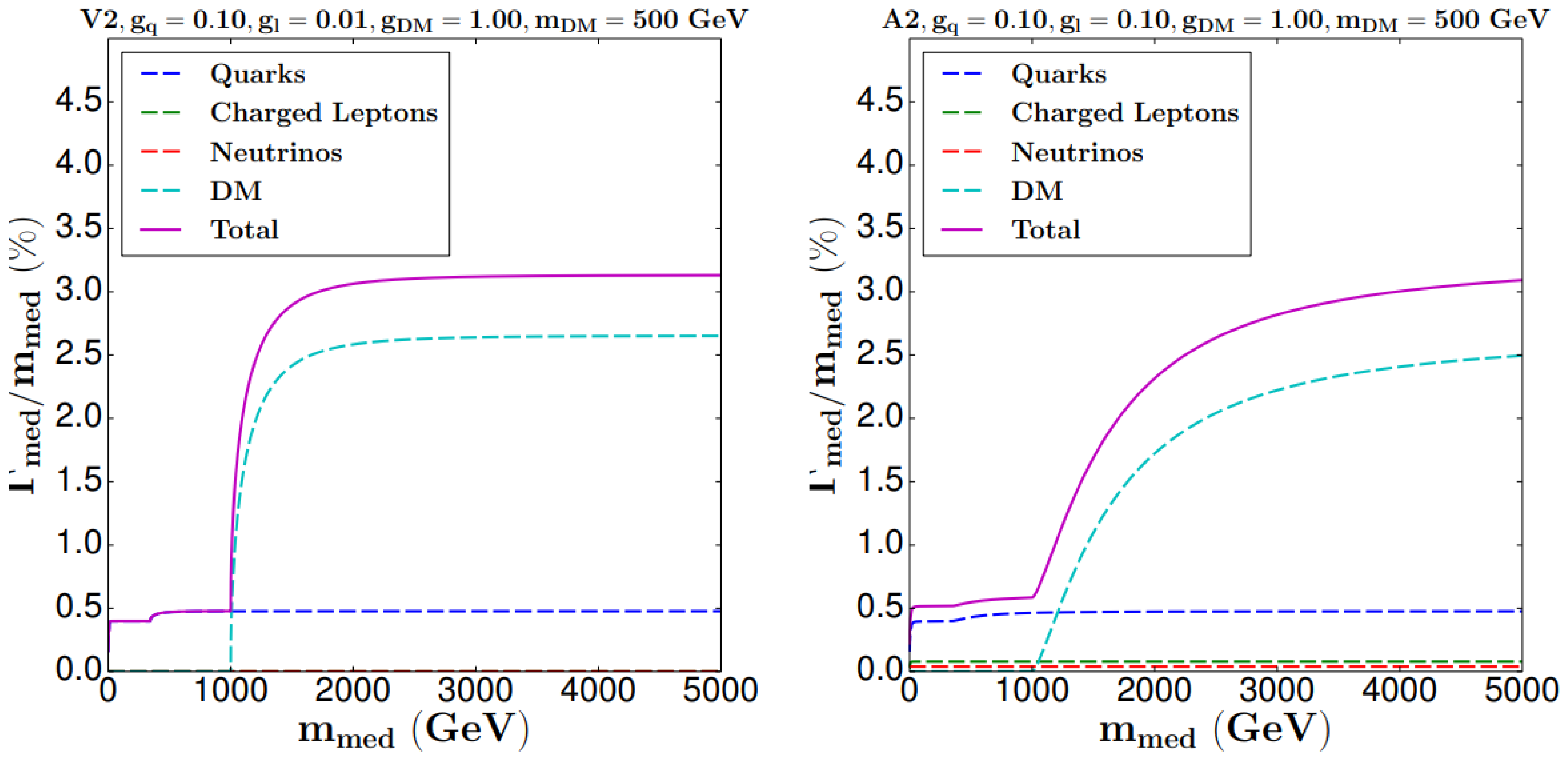


Figure 66: Total decay widths, as well as decay widths into the different final states, for the V2 and A2 Dark Matter models as a function of the mediator mass for a DM mass of 500 GeV.