Highlights of non-SUSY searches for physics beyond the SM from the CMS Detector at the LHC

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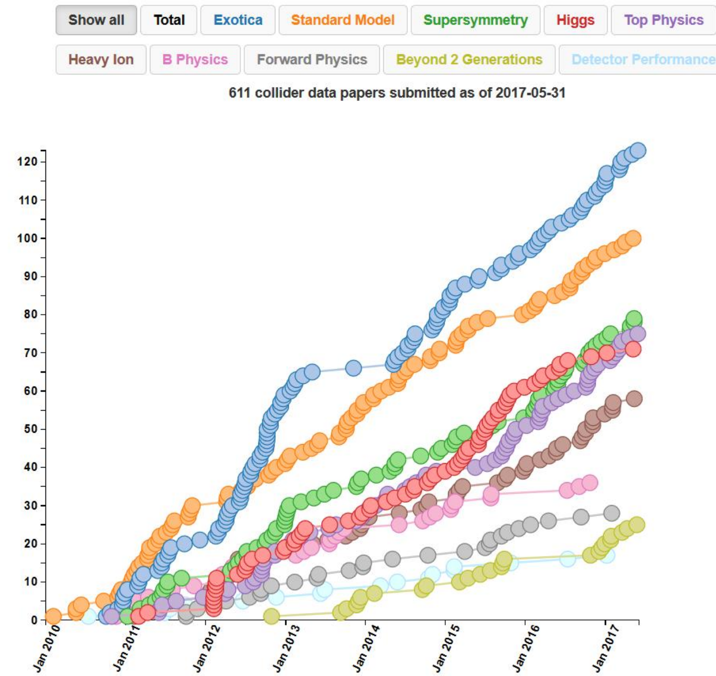
Outline: Non-SUSY Physics BSM (Exotica)

- ❑ Higgs beyond SM (extra Higgs, non-standard decays)
- ❑ Extended gauge models
- ❑ Extra dimensions (incl. microscopic black holes)
- ❑ Dark Matter (WIMPs)
- ❑ Leptoquarks
- ❑ Beyond 3rd Generation
- ❑ Compositeness, GUT-inspired scenario etc



CMS Higgs Public Physics Results

http://cms-results.web.cern.ch/cms-results/public-results/publications/HIG/

CMS Exotica Public Physics Results

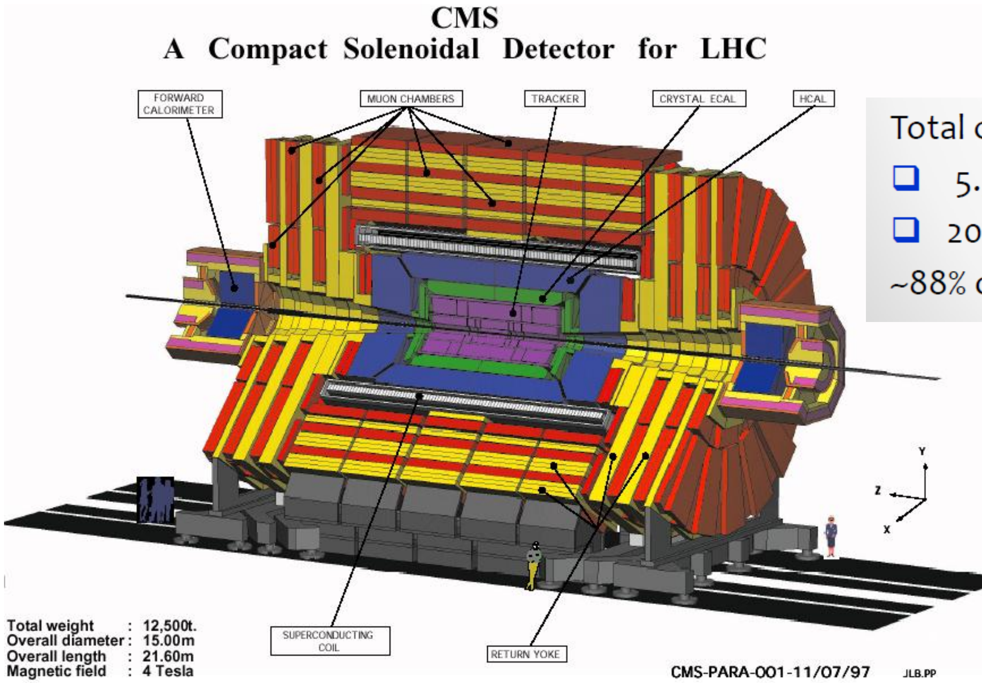
http://cms-results.web.cern.ch/cms-results/public-results/publications/EXO/

CMS Beyond-two-generations (B2G) Public Physics Results

http://cms-results.web.cern.ch/cms-results/public-results/publications/B2G/

CMS Performance and Data

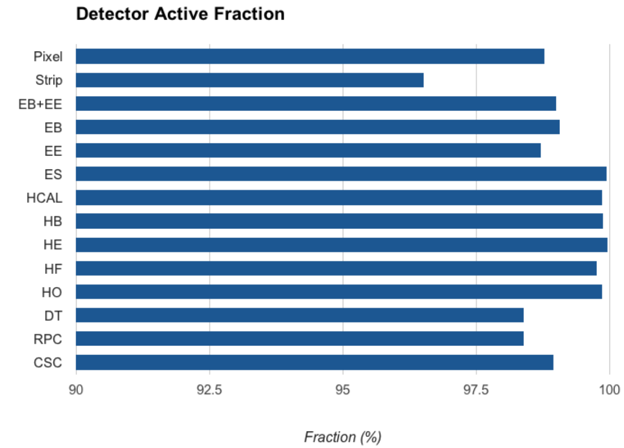
Large general-purpose particle physics detector



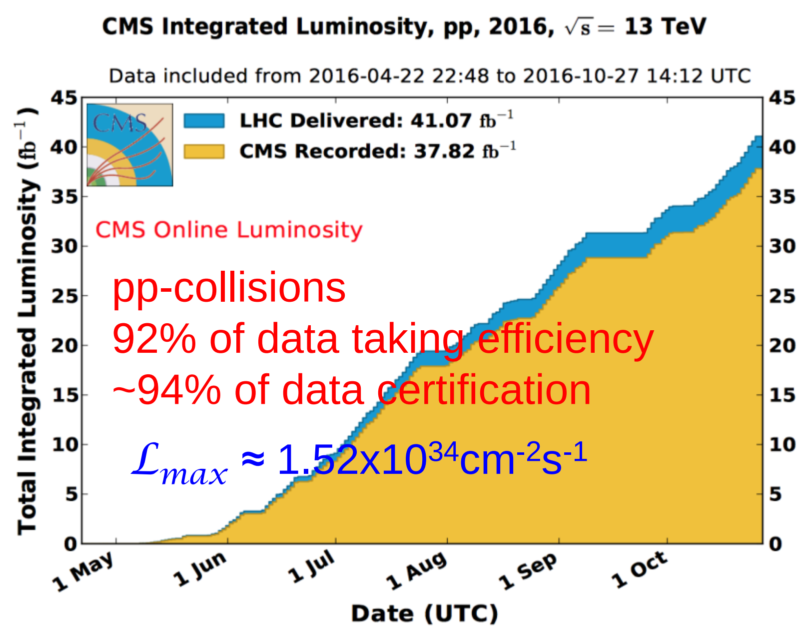
Total certified good data

- 5.32 fb-1 @ 7 TeV
- 20.65fb-1 @ 8 TeV

~88% of delivered lumi



Total weight	*12 500 t*
Overall diameter	*15.00 m*
Overall length	*21.6 m*
Magnetic field	*3.8 Tesla*



pp-collisions

92% of data taking efficiency

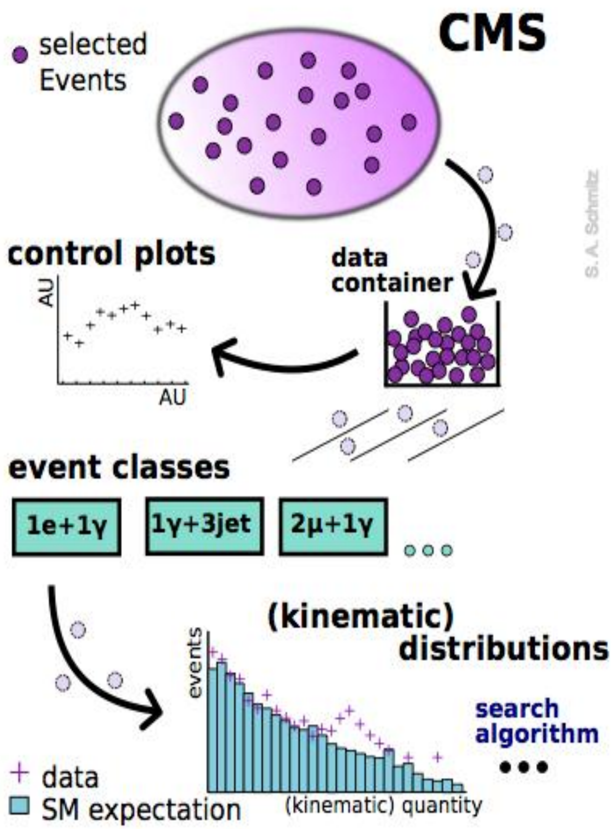
~94% of data certification

$\mathcal{L}_{max} \approx 1.52\text{x}10^{34}\text{cm}^{-2}\text{s}^{-1}$

Detector subsystems are designed to measure: the energy and momentum of photons, electrons, muons, jets, missing E_T up to a few TeV

A General Search View!

CMS-EXO-10-021

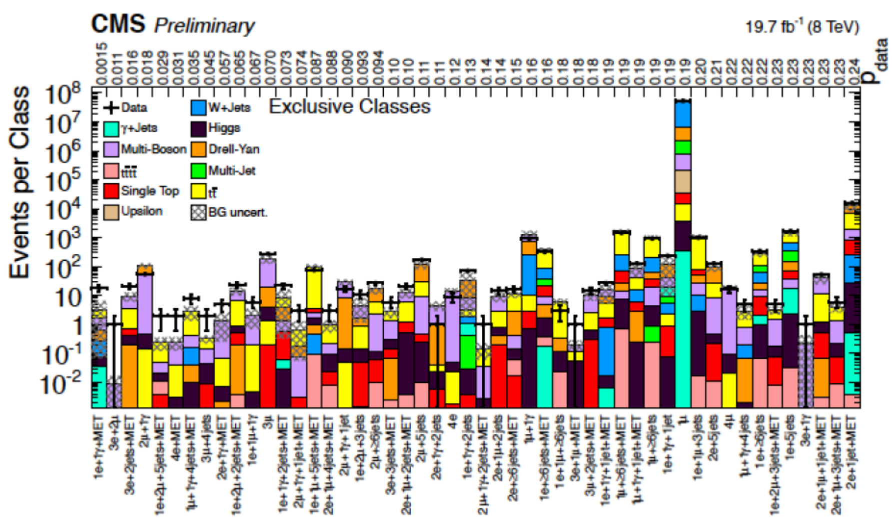


Model independent search

- Divide events into exclusive classes
- Study deviations from SM predictions in a statistical way

Distributions in each class

- $\sum p_T$ - Most general
- $M_{inv}^{(T)}$ - Good for resonances
- MET - Escaping particles

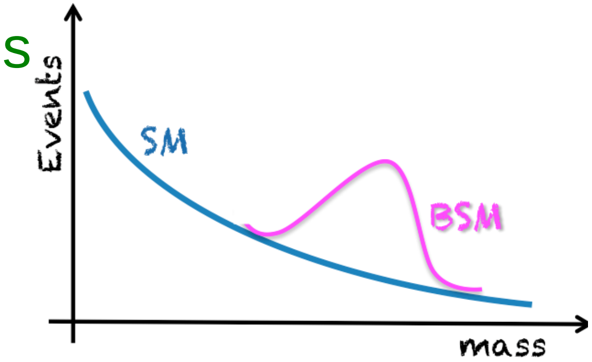


Rates (exclusive classes) as expected for 19.7 fb^{-1} for CMS
→muons, electrons, photons, MET

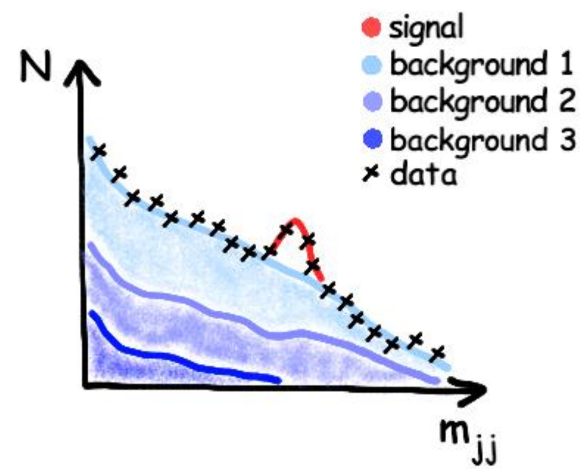
Analysis ongoing for 13 TeV

Landscape of Signals

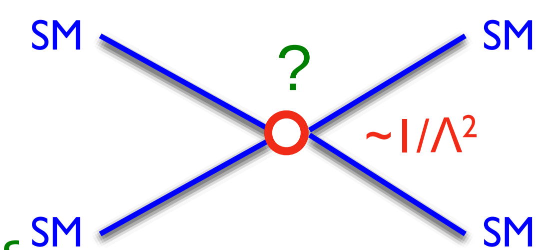
- Heavy Resonances and Non-Resonant Signals (extended gauge models, extra dimensions, technicolor)
  $\Rightarrow$ dileptons, dijets, diphotons, ttbar, VV, HH



- Non-Resonant Signals (extra dimensions, compositeness)
  $\Rightarrow$ dileptons, dijets, diphotons

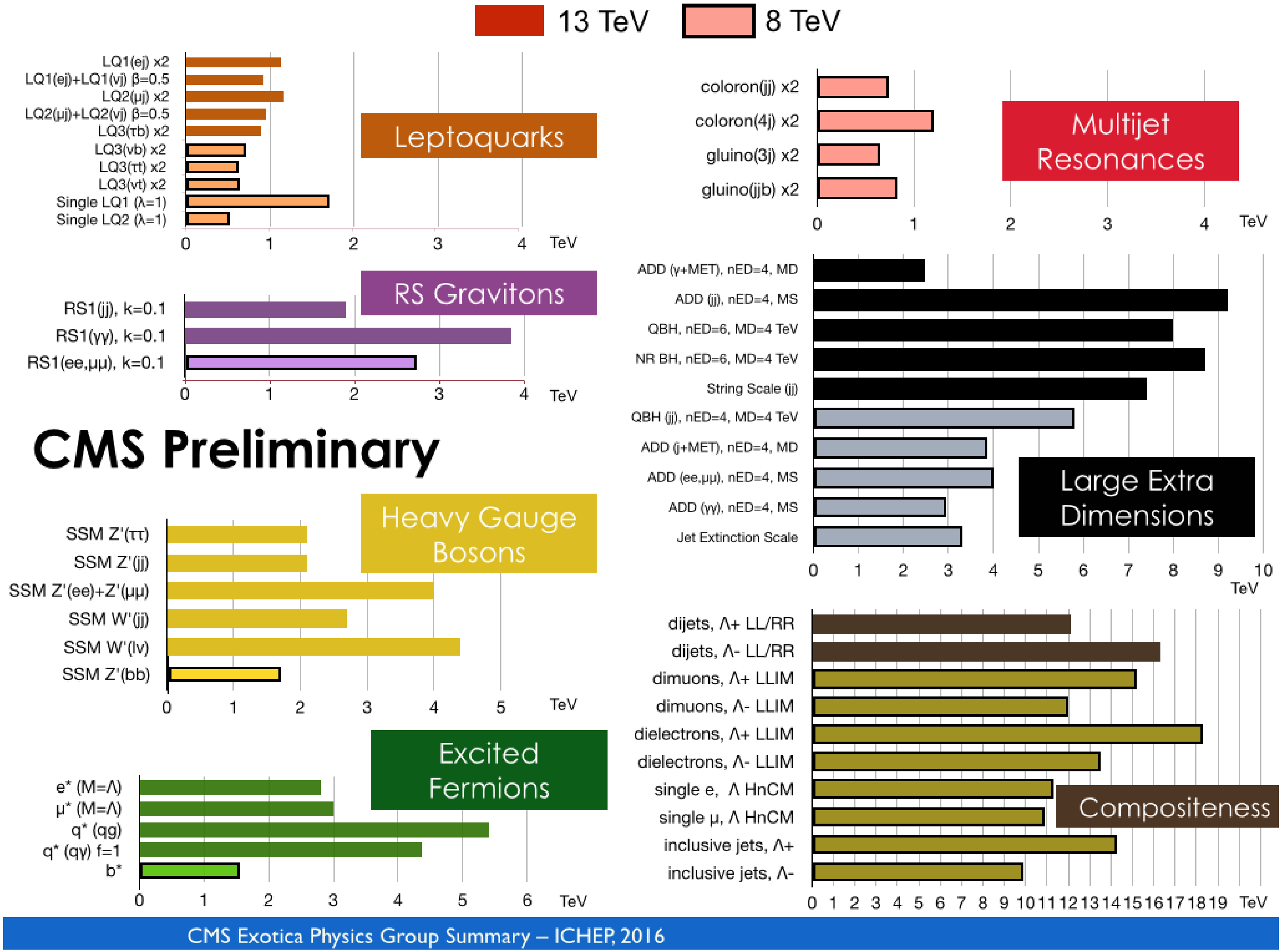


- Mono-particle + Missing ET (extended gauge models, extra dimensions, technicolor) $\Rightarrow$ mono-jet + MET, mono-photon + MET, mono-lepton + MET



- High-multiplicity events (microscopic black holes, leptoquarks, 4th Generation) $\Rightarrow$ all particles, leptons + jet(s)

ICHEP 2016 Exotica Summary (95% C.L.)

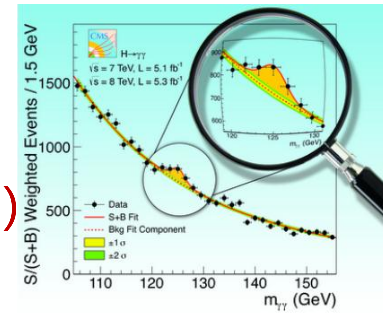


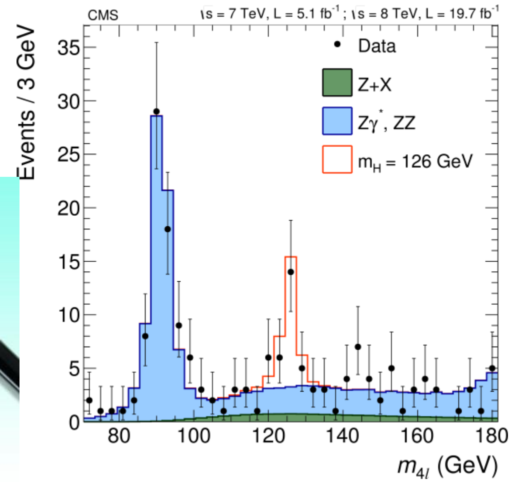
Properties of Higgs Boson: Legacy of Run1

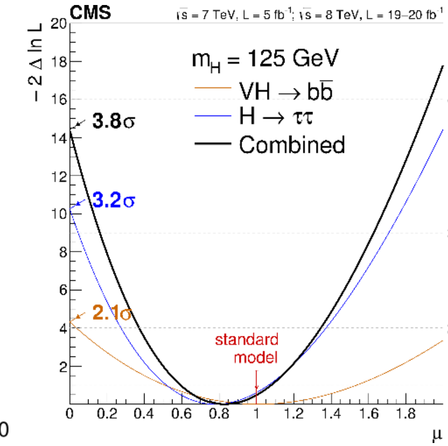
Higgs boson was observed in decays
- ✓ bosons: $\gamma\gamma$ (5.7σ), ZZ (6.8σ), WW (4.3σ)
- ✓ fermions: bb (2.6σ) and $\tau\tau$ (3.2σ)

Higgs is 0^+ state (J^P)

Higgs width: < 22 MeV
(4.15 MeV in SM)

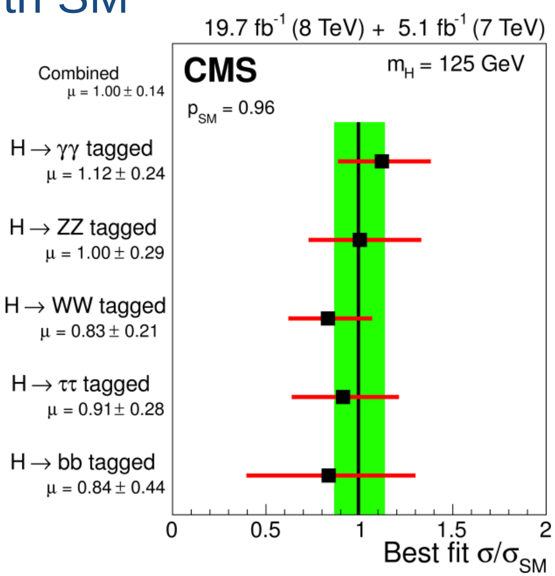


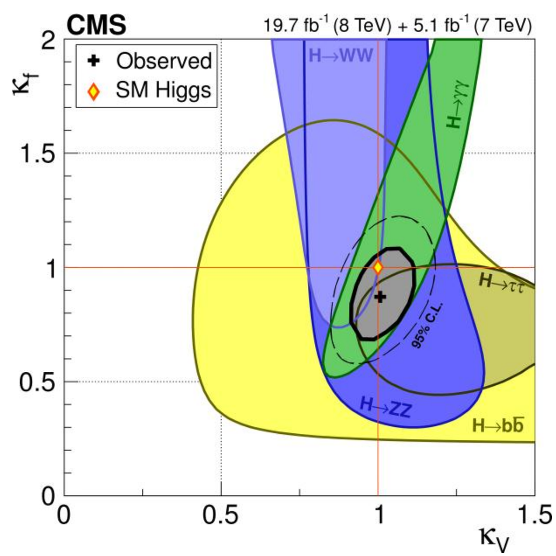


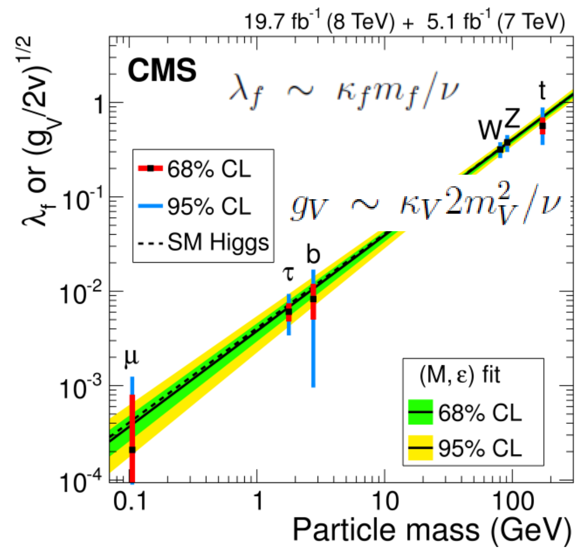


Signal strength is fully compatible with SM

Couplings fits SM predictions





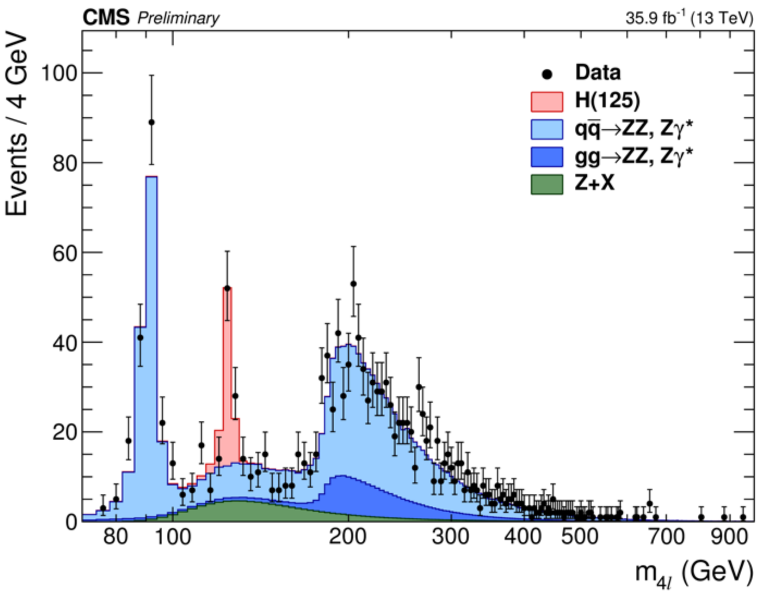


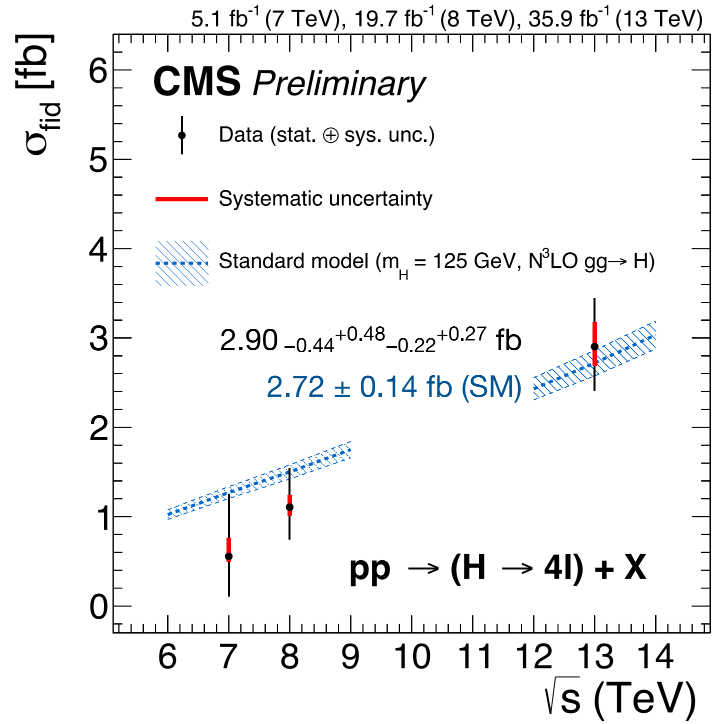
No significant signal non-SM Higgs: any additional Higgs will indicate new physics

Higgs Boson: The first look vs Run2 Data

$m_H = 125.26 \pm 0.20(stat.) \pm 0.08(sys.)$ GeV

CMS-HIG-16-041





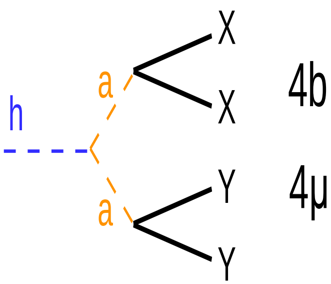
$$\mu = \frac{\sigma}{\sigma_{SM}} =$$

$$1.05^{+0.15}_{-0.14}(stat)^{+0.11}_{-0.09(sys)}$$

- $\Gamma_H = 0.00^{+0.41}_{-0.00}$ GeV with only on-shell
  - Tighter limit than Run 1
- $\Gamma_H = 10^{+14}_{-10}$ MeV with both on-shell and off-shell
  - With strong theory assumptions
  - With only 12.9 fb^{-1}

Non-Standard Higgs Decays

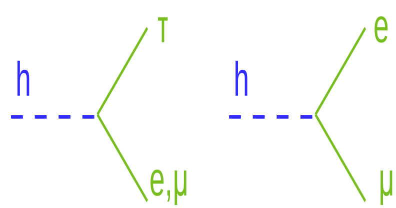
Higgs Decays to new particles



X and Y are SM particles

Flavor violating couplings

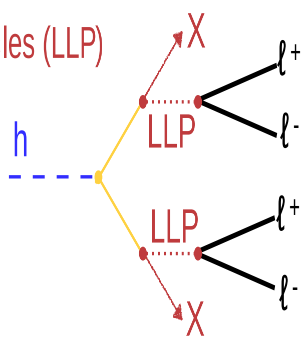
lepton decays



FV in quark sector also considered

Long lived particles (LLP)

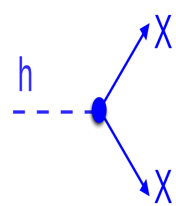
Many possible signatures that are sensitive to a broad range of lifetimes



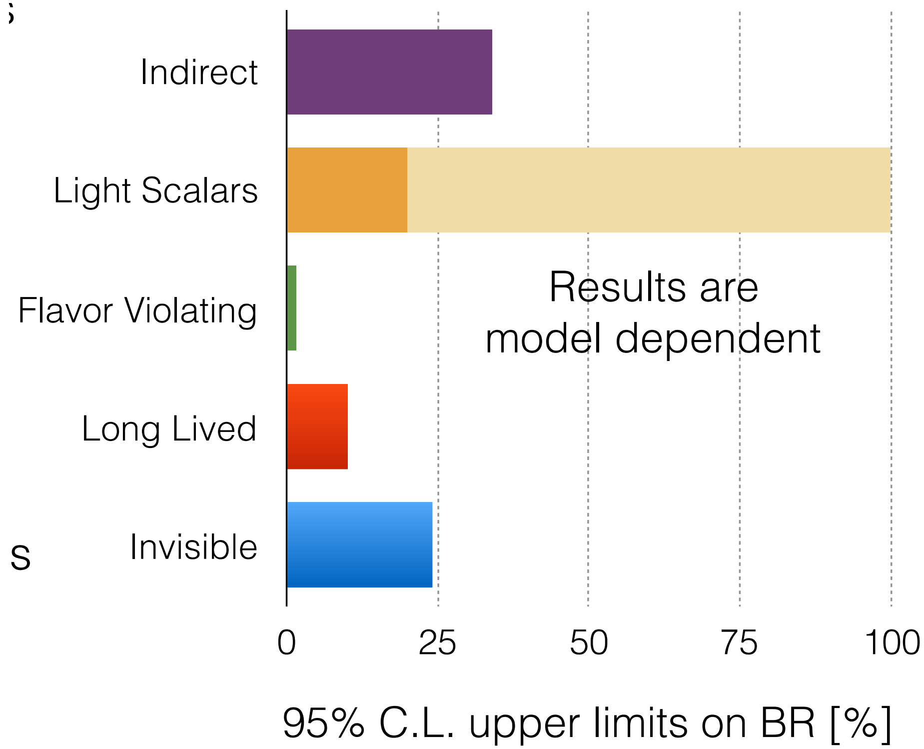
2x2ℓ lepton jets

Nx2ℓ (4x2ℓ...) also possible

Invisible Decays

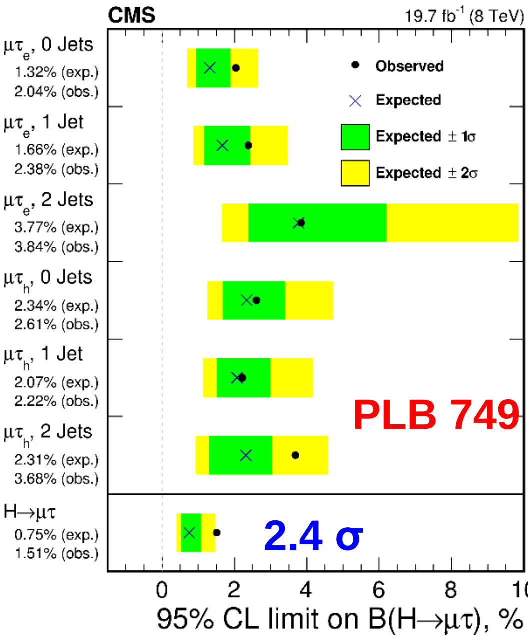


X gives E_T^{miss} signature



More results expected soon with full 13 TeV dataset

LFV Decays: H →μτ, eτ



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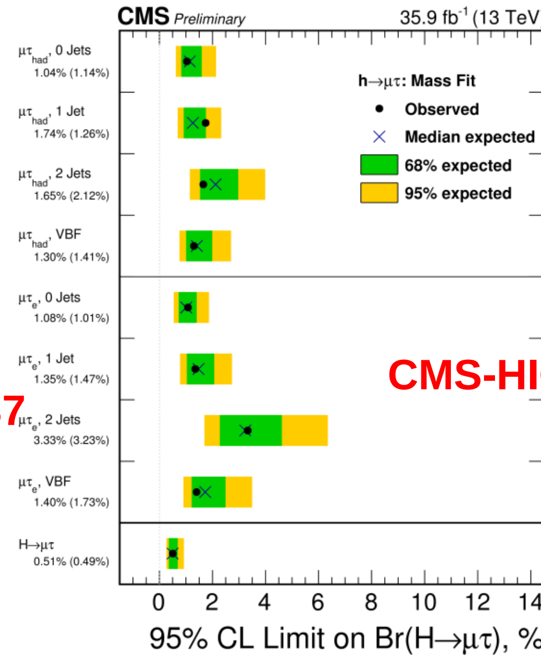
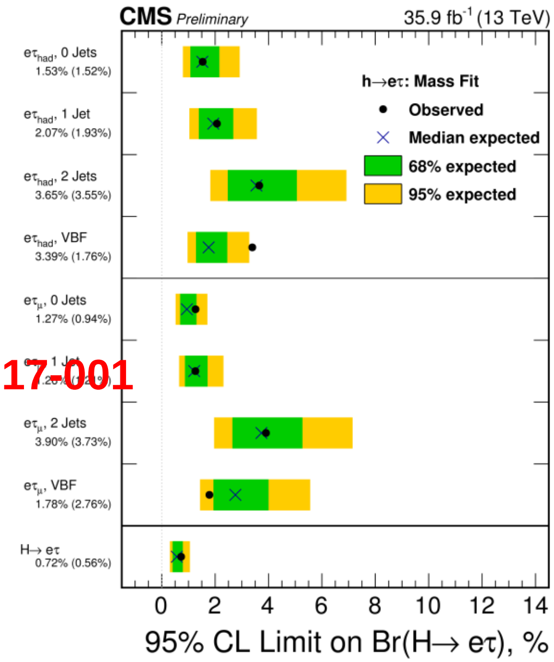


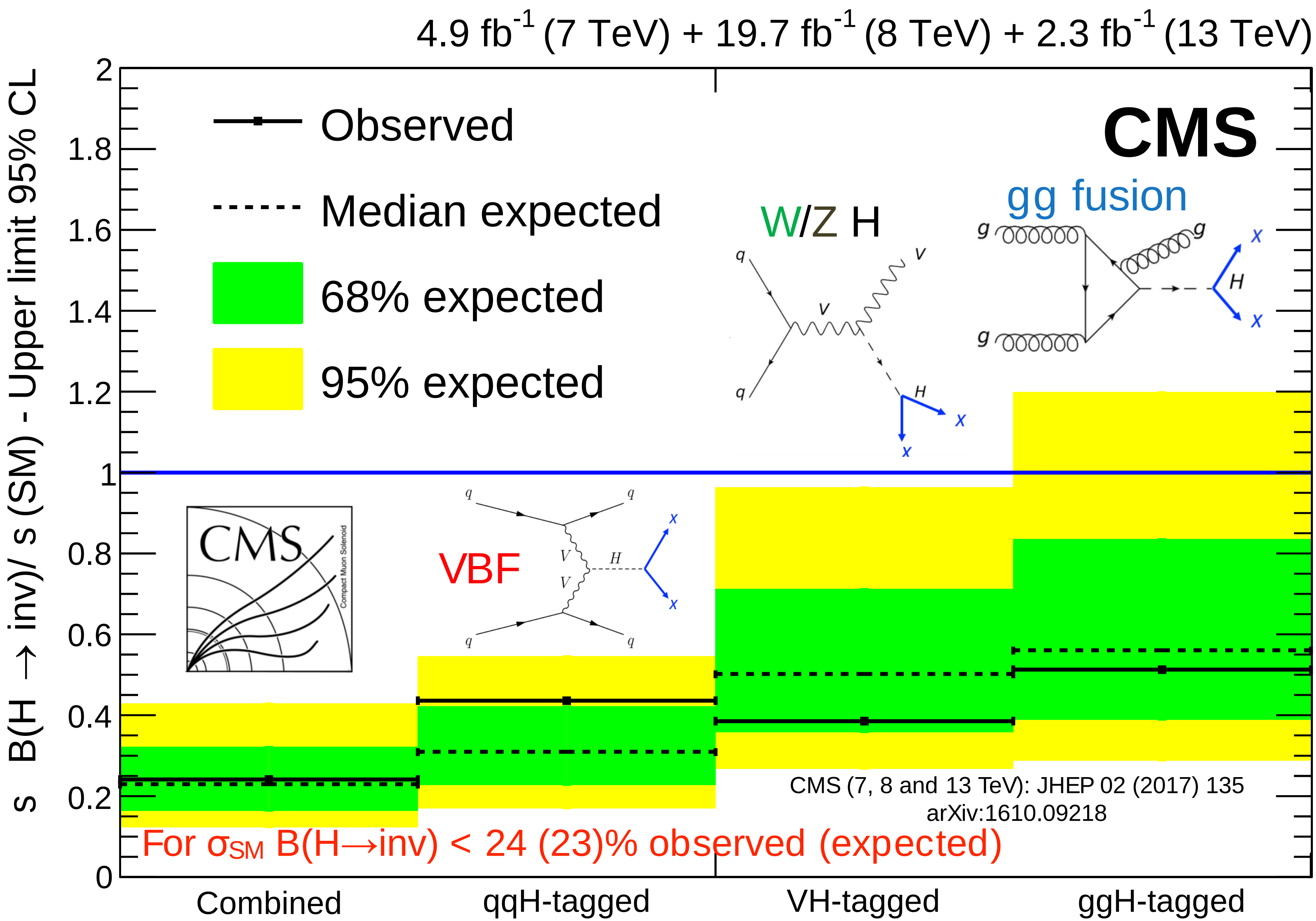
CMS-HIG-17-001



	Observed(Expected) limits (%)		Best fit branching fraction (%)	
	M_{col}-fit	BDT-fit	M_{col}-fit	BDT-fit
$H \to \mu\tau$	<0.51 (0.49) %	<0.25 (0.25)%	0.02 ± 0.20%	0.00 ± 0.12 %
$H \to e\tau$	<0.72 (0.56) %	<0.61 (0.37) %	0.23 ± 0.24 %	0.30 ± 0.18 %

The 2016 data does NOT show an excess!

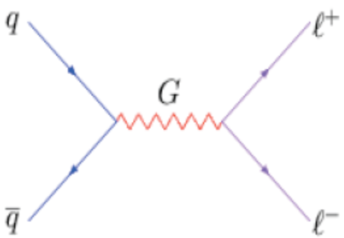
Higgs Invisible Decays



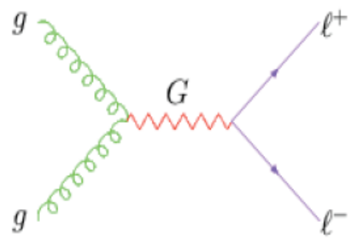
Heavy Resonances

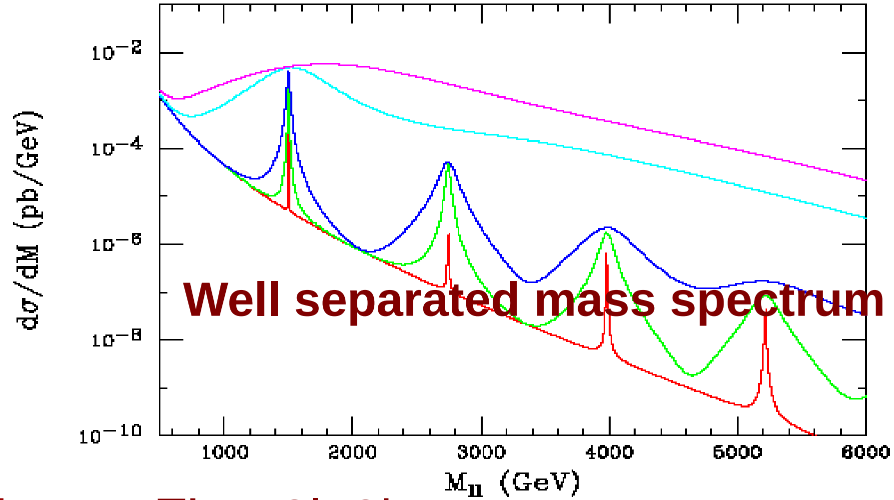
New Physics ($Z'/Z_{KK}/G_{KK}$) contributions to SM processes:

$q\bar{q} \rightarrow l^+l^-$



$gg \rightarrow l^+l^-$





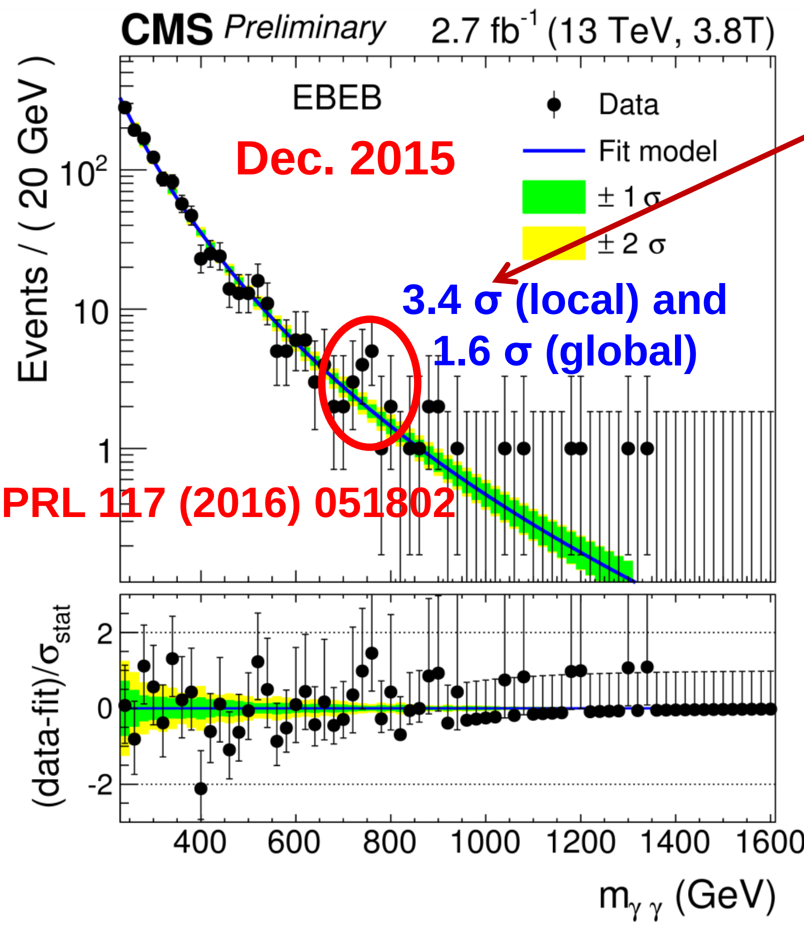
- ❑ Extended gauge models (LRMs and GUT-inspired models): extra gauge boson Z' → 2l, 2jets
- ❑ TeV^{-1} model of flat EDs: KK excit. of SM gauge bosons Z_{KK} → 2l, 2jets
- ❑ Randall-Sundrum model of AdS_5 EDs: Kaluza-Klein graviton excitations
- ❑ Technicolor: ρT → WZ

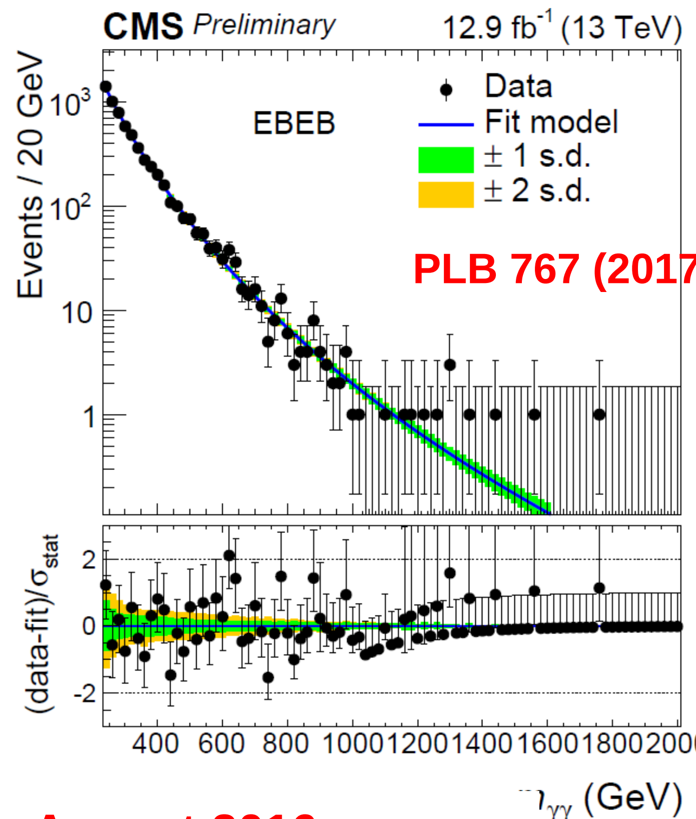
Signals: di-leptons/di-jets/di-photons resonance states in high (~TeV) invariant mass range ⇒ new particles would be observed as a bump, excess in the mass spectrum

Excellent momentum and energy resolutions are required !!

750 GeV Excess in Diphotons?

The promising 750GeV diphoton resonance was background oscillation.





The lower mass limits for Randall-Sundrum gravitons range from 1.95 to 4.45 TeV for coupling parameters between 0.01 and 0.2.

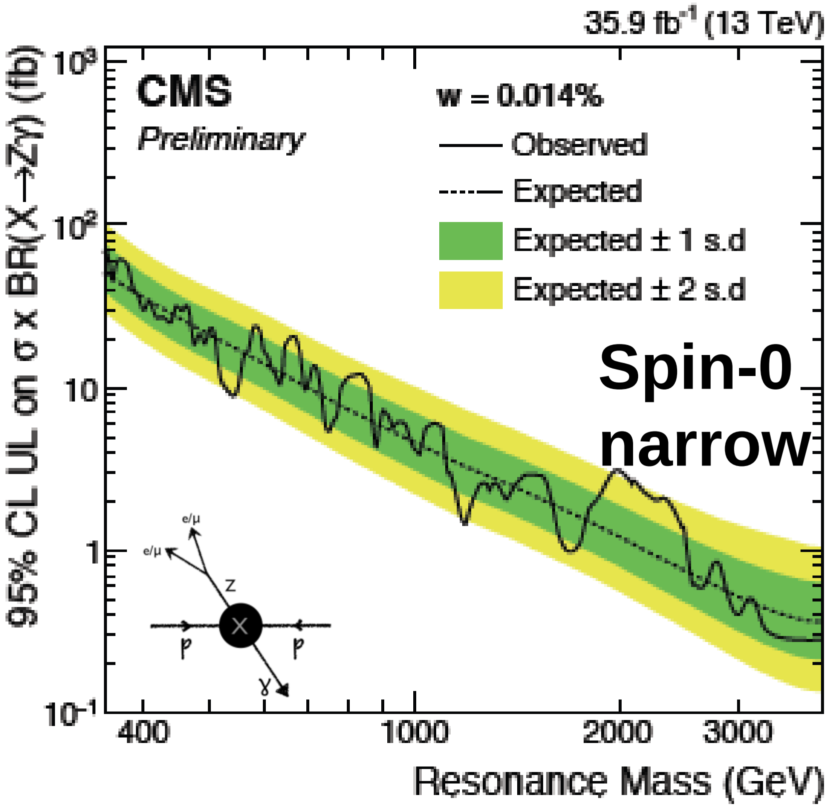
August 2016:
The excess is NOT seen in the new data from 2016!

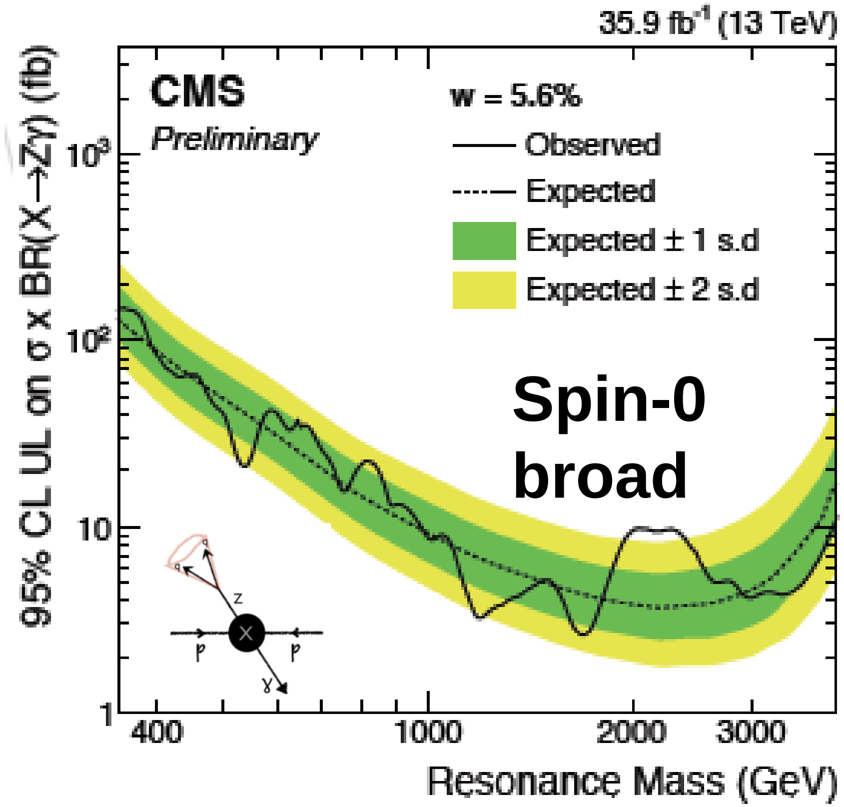
Search for high mass Zγ Resonances

EXO-17-005

In the wake of the (mild) 750 GeV diphoton excess in 2015…
-> A search in the Zγ channel

Combining leptonics and hadronic Z decay channels



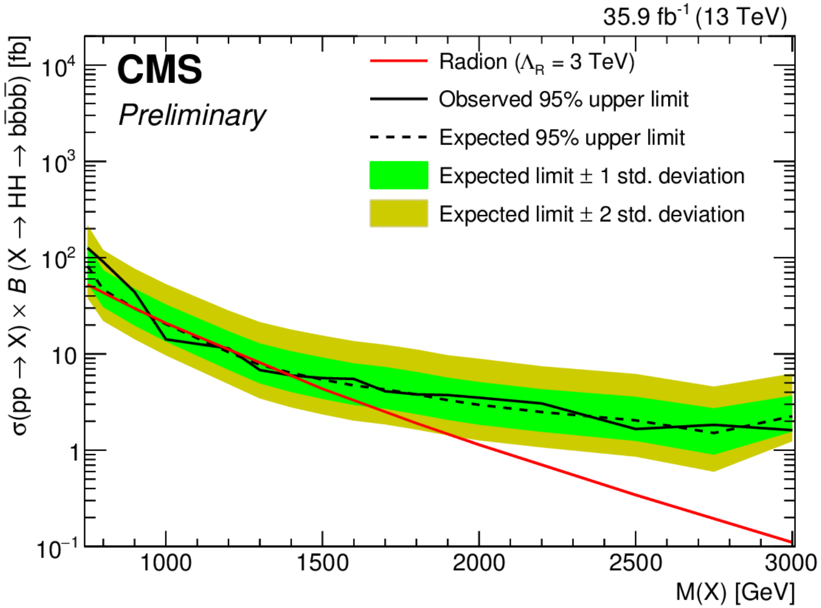


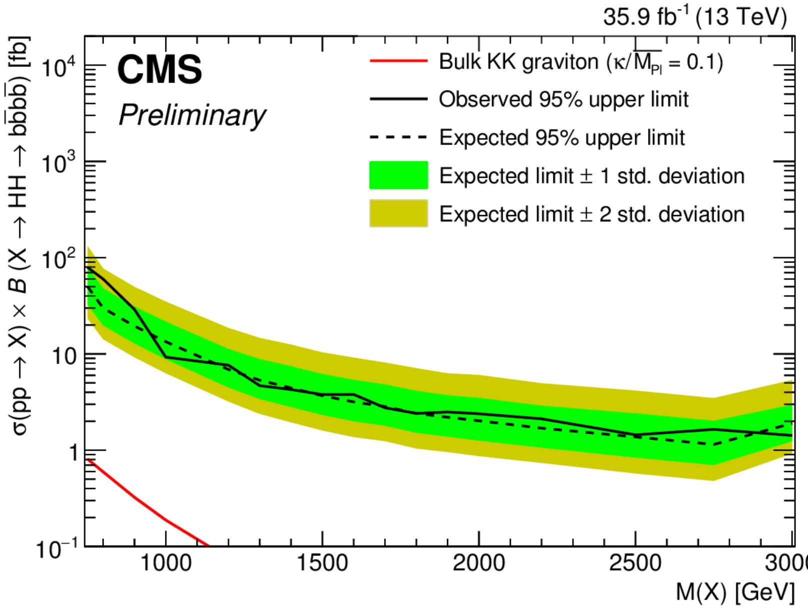
No sign of a new resonance – especially not at 750 GeV ☺

X->HH -> 2b2bbar

B2G-16-026

Higgs bosons are highly boosted and is reconstructed as one hadronic jet





Limits on bulk gravitons and radions (RS model)

For a mass scale Λ_R of 3 TeV, exclude radions 970-1450 at 95% CL

Resonance Mass (GeV)	Radion		Bulk graviton	
	Expected (fb)	Observed (fb)	Expected (fb)	Observed (fb)
750	81.6	125.9	50.2	79.4
800	46.4	90.4	29.9	59.9
900	29.8	44.0	19.5	29.0
1000	20.4	14.2	13.4	9.3
1200	10.4	11.4	6.9	7.6
1400	6.3	6.0	4.4	4.3
1600	4.7	5.5	3.2	3.8
1800	3.8	3.8	2.4	2.4
2000	3.0	3.5	2.0	2.4
2500	2.0	1.7	1.4	1.4
3000	2.3	1.6	1.9	1.4

Dileptons: Z' and RS1 Limits

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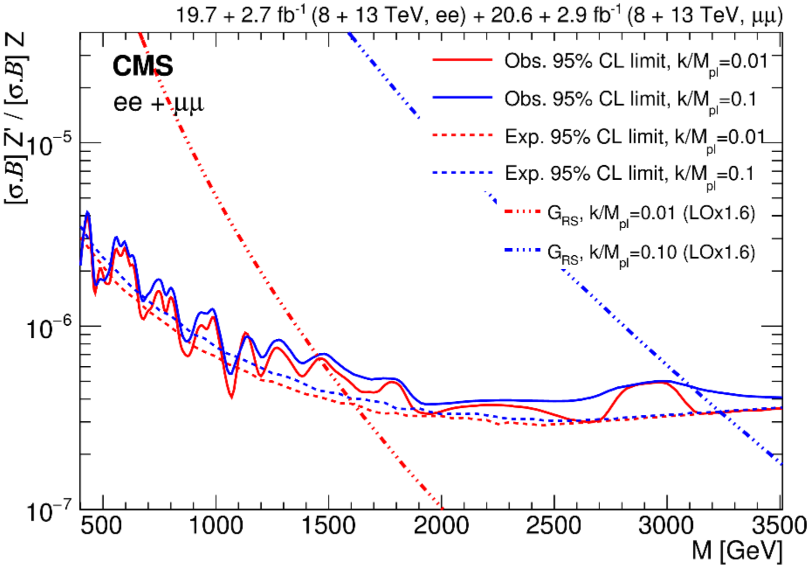
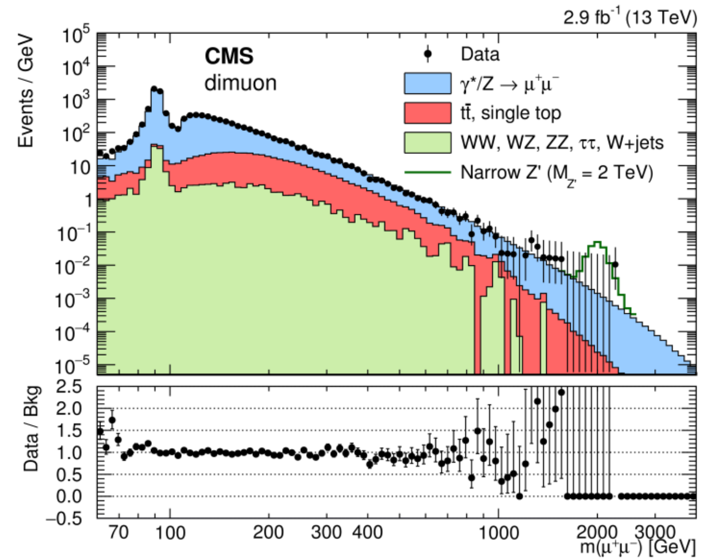
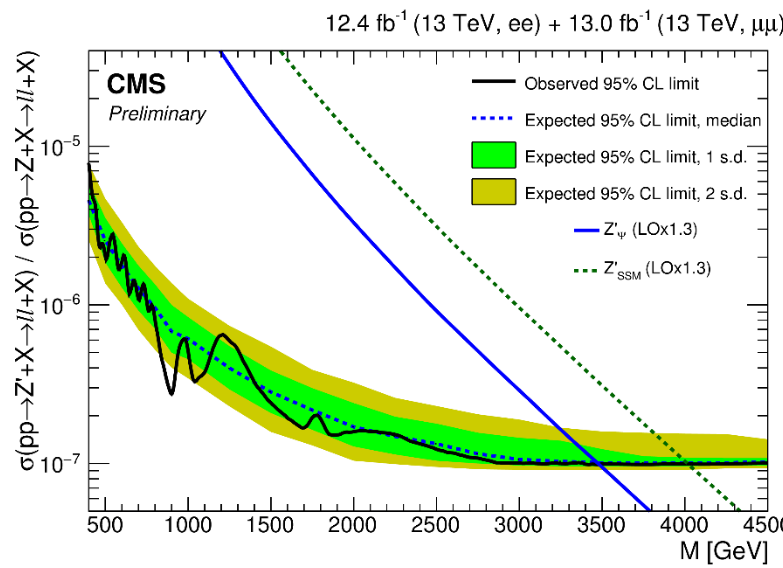




Channel	G_{KK} $(k/\overline{M}_{Pl} = 0.01)$		G_{KK} $(k/\overline{M}_{Pl} = 0.10)$	
	Obs. (TeV)	Exp. (TeV)	Obs. (TeV)	Exp. (TeV)
ee	1.46	1.48	2.78	2.93
$\mu^+\mu^-$	1.26	1.41	3.03	3.03
ee + $\mu^+\mu^-$	1.46	1.61	3.11	3.23
ee + $\mu^+\mu^-$ 13 TeV only	1.38	1.45	2.98	3.15

CMS-PAS-EXO-16-031

Channel	Z'_{SSM}		Z'_{ψ}	
	Obs. (TeV)	Exp. (TeV)	Obs. (TeV)	Exp. (TeV)
ee	3.65	3.65	3.10	3.10
$\mu^+\mu^-$	3.75	3.75	3.20	3.20
ee + $\mu^+\mu^-$	4.0	4.0	3.50	3.50

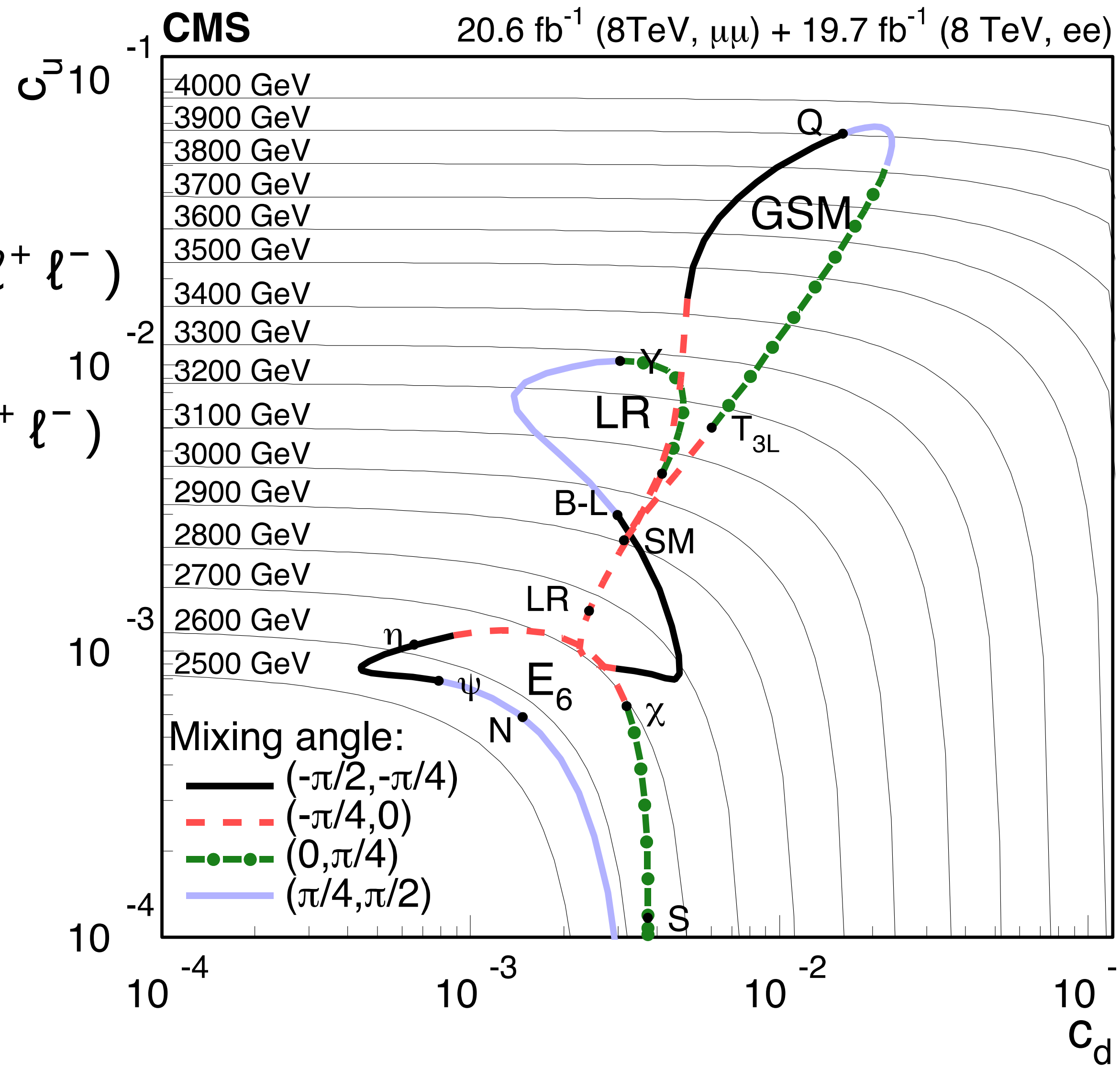


Dileptons: Extra Gauge Bosons

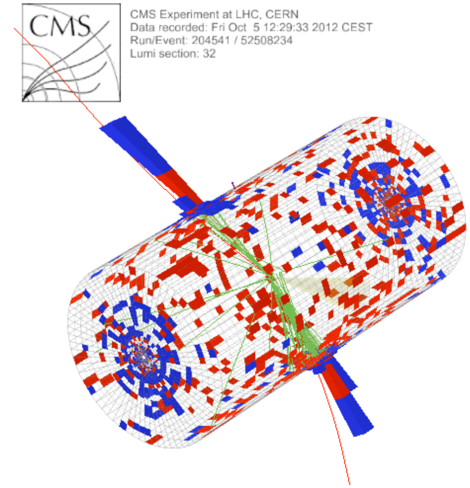
JHEP 04 (2015) 025

$$c_u = \frac{g'^2}{2}(g_V^{u\,2} + g_A^{u\,2})Br(\ell^+\ell^-)$$

$$c_d = \frac{g'^2}{2}(g_V^{d\,2} + g_A^{d\,2})Br(\ell^+\ell^-)$$

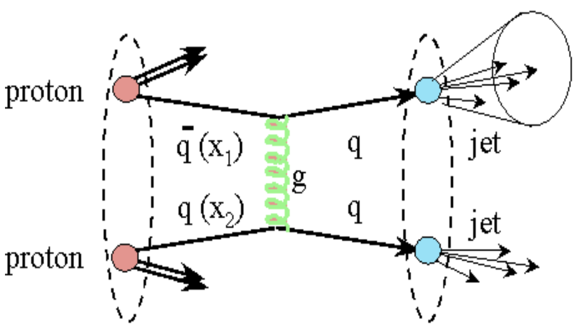


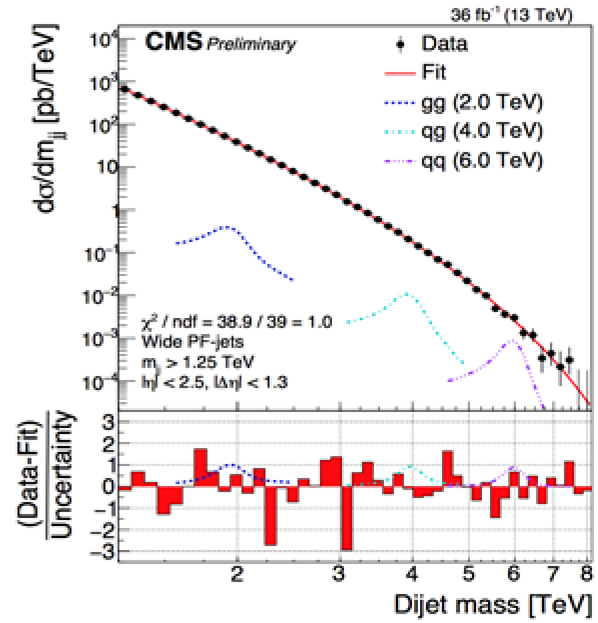
Dijets

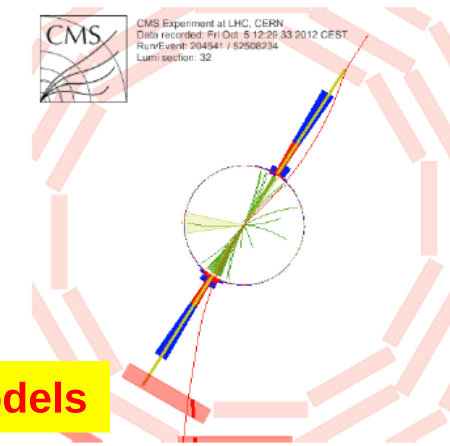


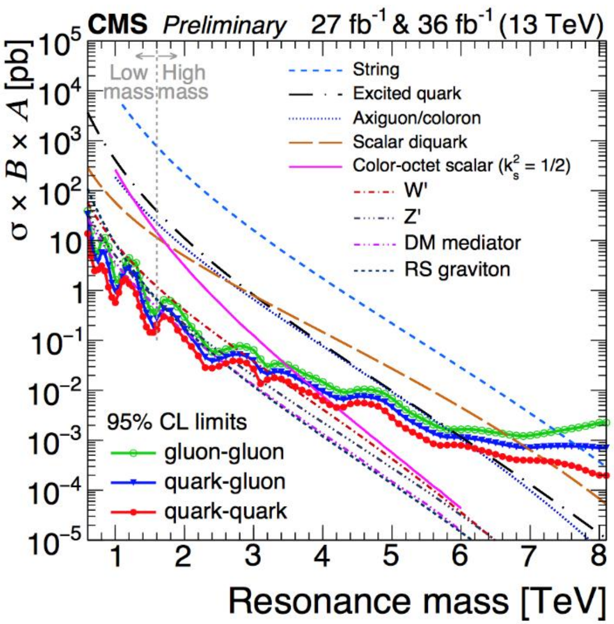
CMS-PAS-EXO-16-056

Select events with dijets with mass > 1.25 TeV or with mass > 500 GeV







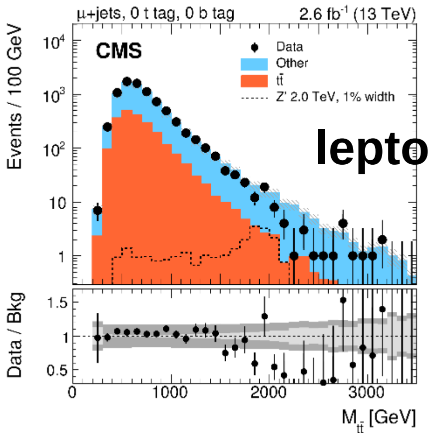


No signal observed/Testing many models

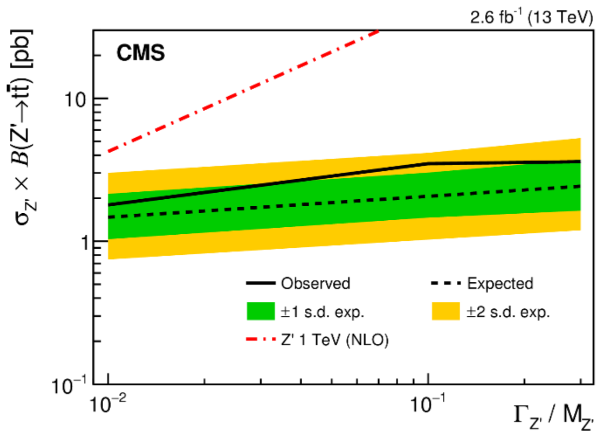
Model	Final State	Observed (expected) mass limit [TeV] 36 fb^{-1} 13 TeV	12.9 fb^{-1} 13 TeV	2.4 fb^{-1} 13 TeV	20 fb^{-1} 8 TeV
String	qg	7.7 (7.7)	7.4 (7.4)	7.0 (6.9)	5.0 (4.9)
Scalar diquark	qq	7.2 (7.4)	6.9 (6.8)	6.0 (6.1)	4.7 (4.4)
Axigluon/coloron	$q\bar{q}$	6.1 (6.0)	5.5 (5.6)	5.1 (5.1)	3.7 (3.9)
Excited quark	qg	6.0 (5.8)	5.4 (5.4)	5.0 (4.8)	3.5 (3.7)
Color-octet scalar ($k_s^2 = 1/2$)	gg	3.4 (3.6)	3.0 (3.3)	—	—
W′	$q\bar{q}$	3.3 (3.6)	2.7 (3.1)	2.6 (2.3)	2.2 (2.2)
Z′	$q\bar{q}$	2.7 (2.9)	2.1 (2.3)	—	1.7 (1.8)
RS Graviton ($k/M_{PL} = 0.1$)	$q\bar{q}$, gg	1.7 (2.1)	1.9 (1.8)	—	1.6 (1.3)
DM Mediator ($m_{DM} = 1$ GeV)	$q\bar{q}$	2.6 (2.5)	2.0 (2.0)	—	—

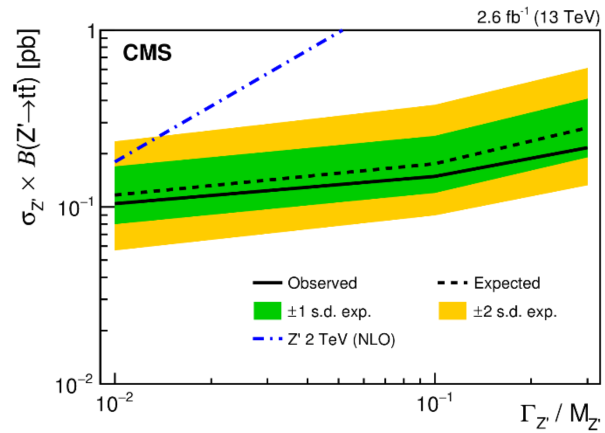
ttbar resonances

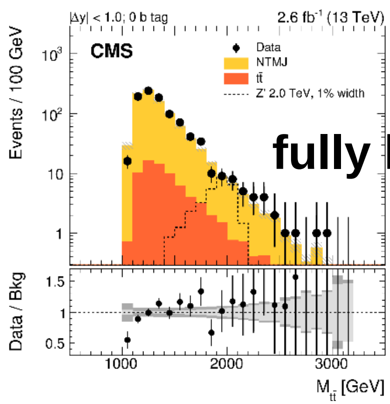
arXiv:1704.03366



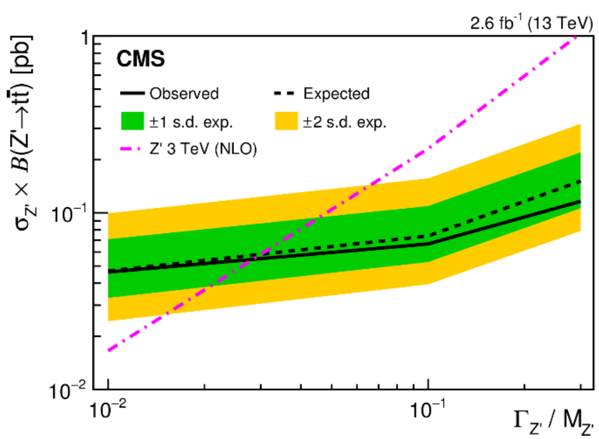
lepton+jets

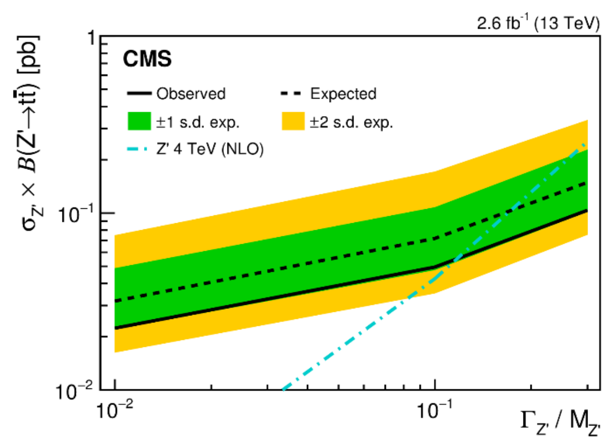






fully hadronic





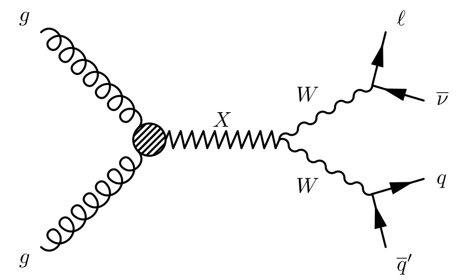
Excluded mass ranges [TeV]

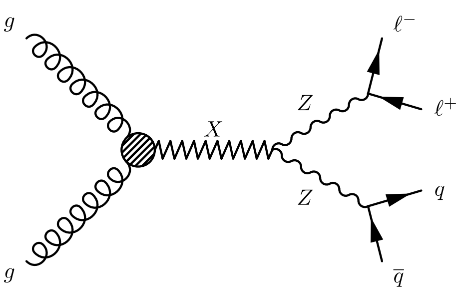
	Z' ($\Gamma/M = 1\%$)		Z' ($\Gamma/M = 10\%$)		Z' ($\Gamma/M = 30\%$)		RS KK Gluon	
Result	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.
Lepton+jets	0.6 – 2.1	0.6 – 2.3	0.5 – 3.5	0.5 – 3.4	0.5 – 4.0	0.5 – 4.0	0.5 – 2.9	0.5 – 2.9
Fully hadronic	1.2 – 1.8	1.4 – 1.8	1.0 – 3.2	1.0 – 3.5	1.0 – 3.7	1.0 – 4.0	1.0 – 2.6	1.0 – 2.4
Combined	0.6 – 2.4	0.6 – 2.5	0.5 – 3.7	0.5 – 3.9	0.5 – 4.0	0.5 – 4.0	0.5 – 3.1	0.5 – 3.3

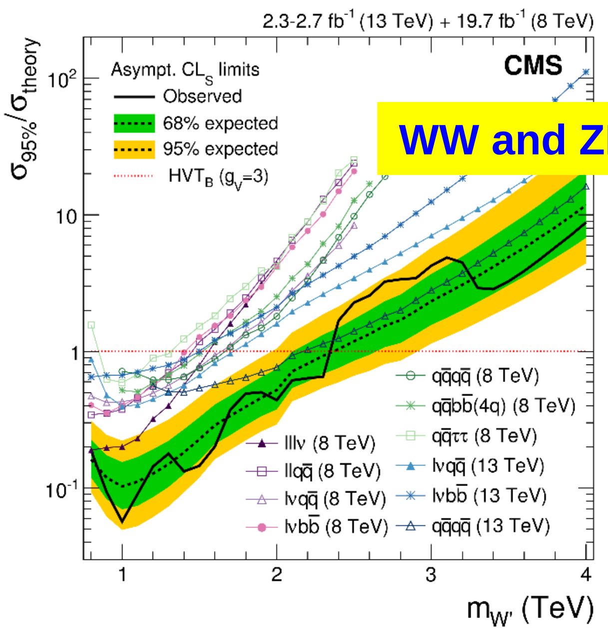
Dibosons: WW, WZ, ZZ, WH, and ZH

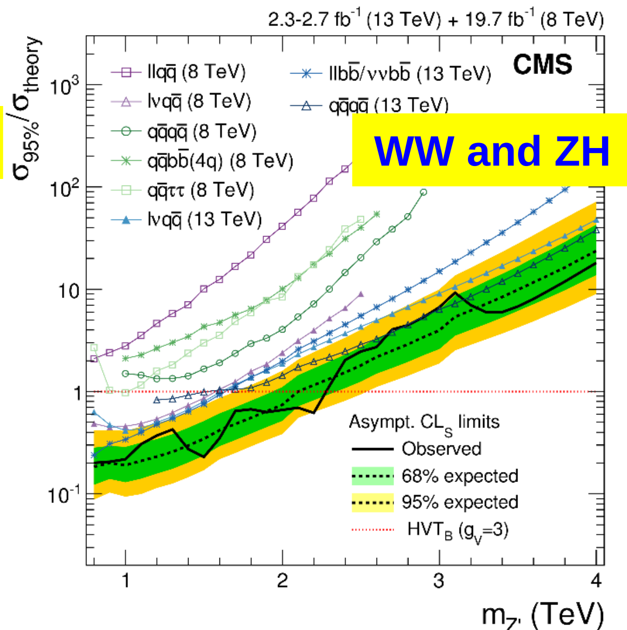
The benchmark models considered are a heavy vector triplet (HVT) model and the Gbulk graviton in the Randall–Sundrum (RS) WED model: HV and Gbulk decaying into pairs of boosted bosons

arXiv:1705.09171









The limits on the X-sections

95% confidence level lower limits in the HVT on the masses of W' and Z' singlets at 2.3 TeV, and on a heavy vector triplet at 2.4 TeV

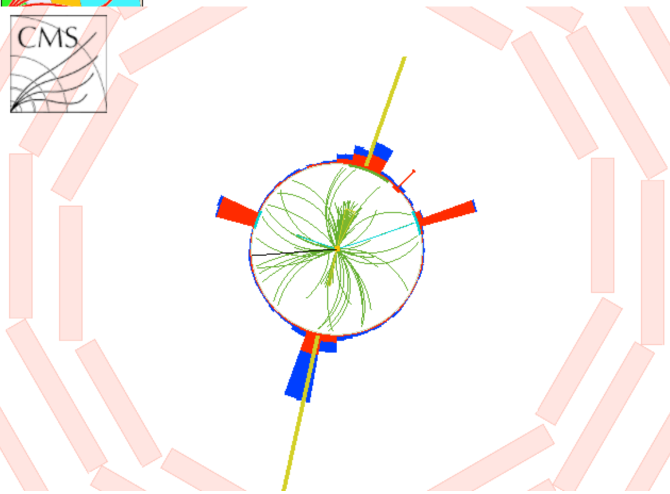
Cross section at 13 TeV [fb]

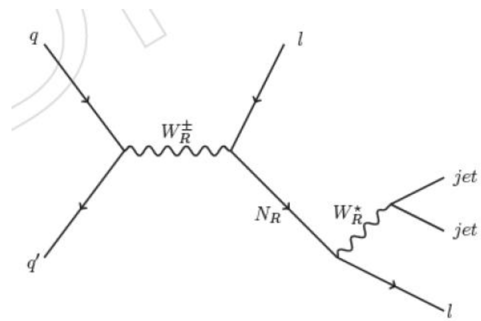
Mass	HVT A/B				RS bulk	
	W′		Z′		G_{bulk}	
[TeV]	WZ	WH	WW	ZH	WW	ZZ
0.6	4170/—	3215/—	2097/—	1789/—	406.8	203.4
0.8	1258/680	1074/878	635/354	576/485	76.1	38.0
1.0	492/464	443/501	247/229	231/264	20.5	10.2
1.5	81.7/105	77.8/108	39.8/51.1	38.6/53.6	1.80	0.901
2.0	19.8/27.9	19.2/28.3	9.32/13.1	9.16/13.5	0.240	0.120
2.5	5.70/8.37	5.60/8.44	2.61/3.84	2.58/3.90	0.0449	0.0224
3.0	1.79/2.68	1.77/2.70	0.808/1.21	0.801/1.23	0.00982	0.00491
3.5	0.584/0.888	0.579/0.891	0.264/0.402	0.262/0.405	0.00420	0.00210
4.0	0.192/0.296	0.191/0.296	0.0887/0.136	0.0883/0.137	0.00244	0.00122

(Lepton-Lepton) + (Jet-Jet) Resonance

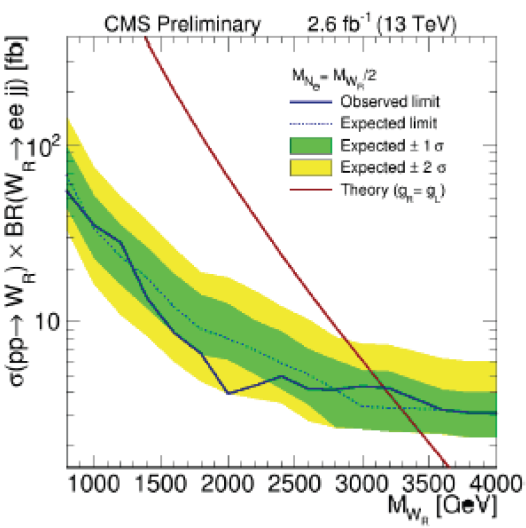
EXO-16-045

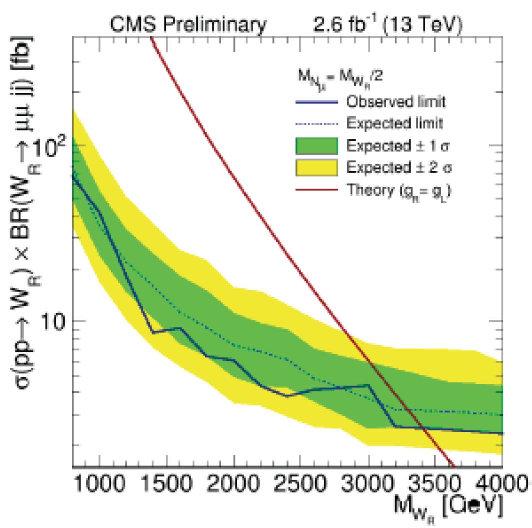
W_R and heavy neutrino from LR models

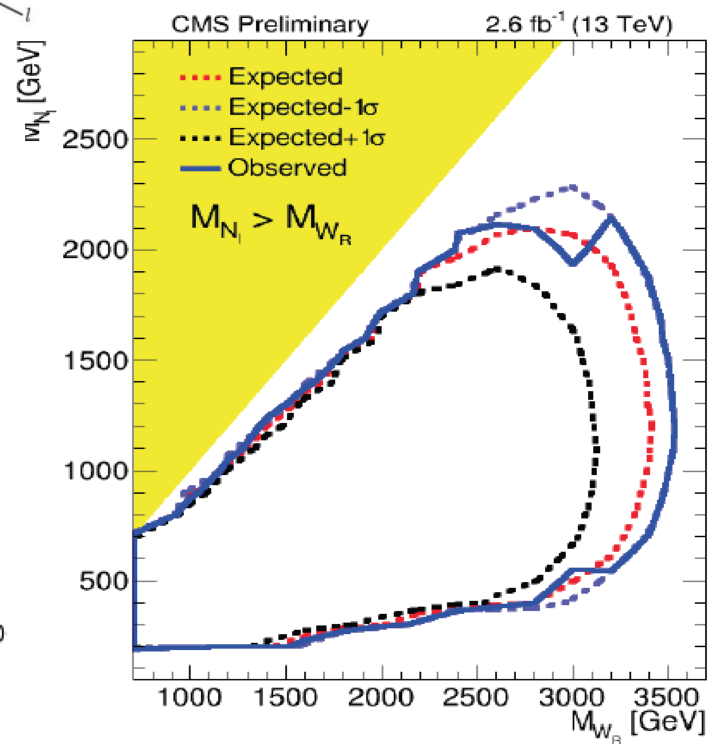




Search in 2 jets and 2 lepton final states



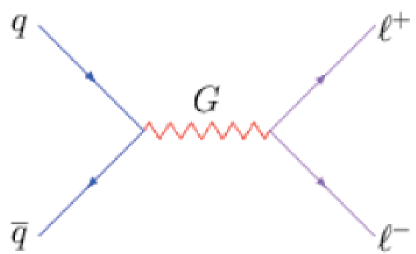


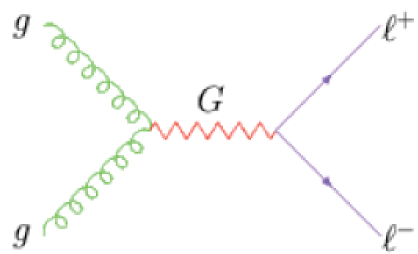


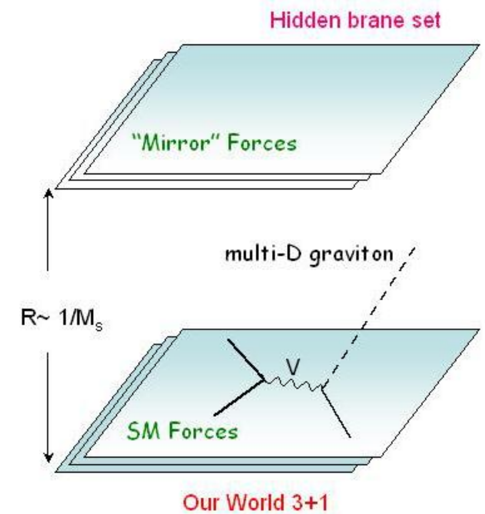
Non-Resonant Signals

- ADD-graviton contribution in the SM processes (Drell-Yan, diphotons productions)

$q\bar{q} \to l^+l^-$ $\qquad$ $gg \to l^+l^-$



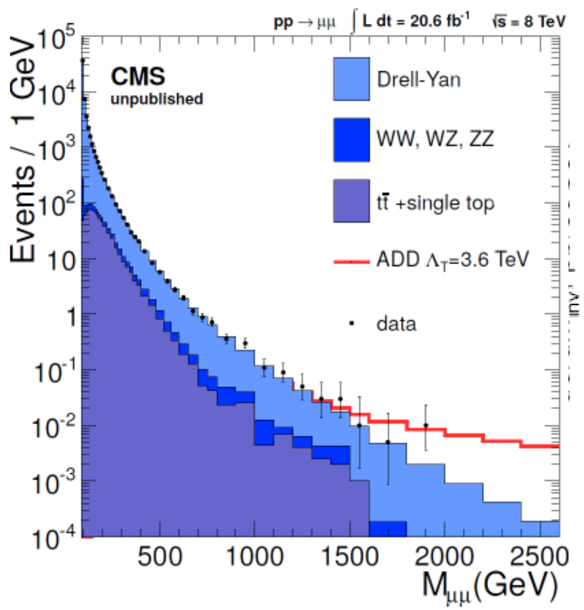


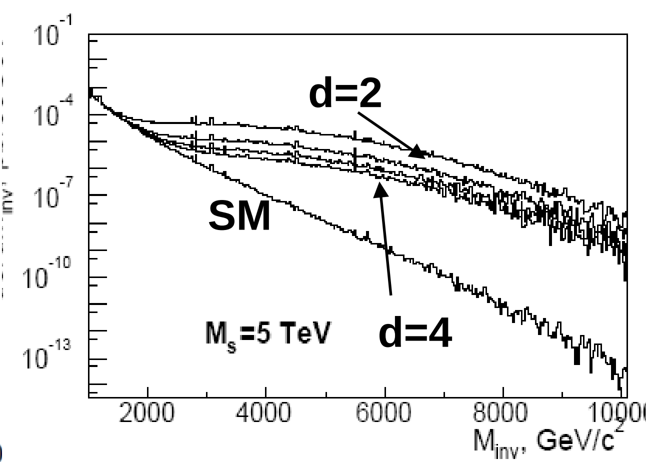


- Compositeness

<u>Signals:</u>

excess in di-particle spectrum

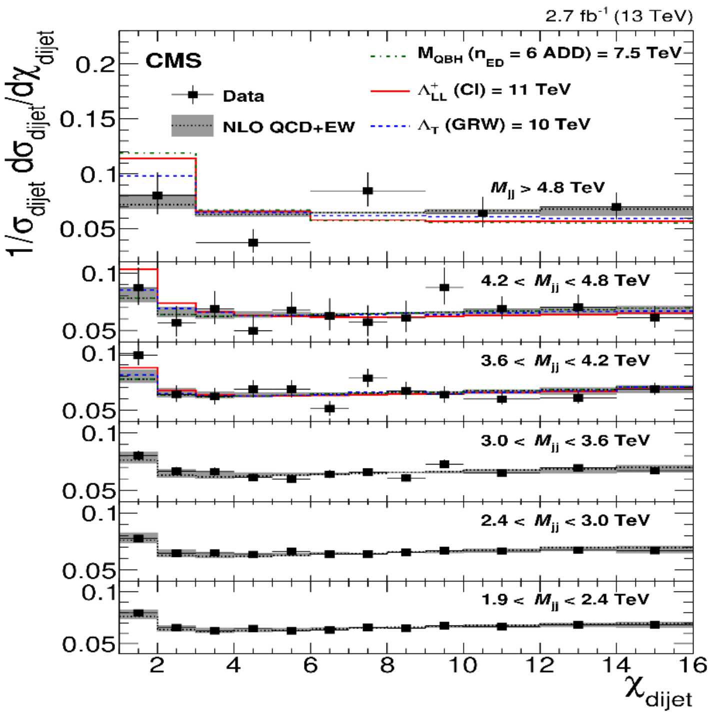




Nonresonant Dijets: CI and ED

arXiv:1703.09986

$$\chi_{\text{dijet}} = (1 + |\cos\theta^*|)/(1 - |\cos\theta^*|)$$



Model	Observed lower limit (TeV)	Expected lower limit (TeV)
$\Lambda^{+}_{LL/RR}$ (NLO)	11.5	12.1±1.2
$\Lambda^{-}_{LL/RR}$ (NLO)	14.7	17.3±3.4
Λ^{+}_{VV} (NLO)	13.3	13.9±1.2
Λ^{-}_{VV} (NLO)	18.6	22.2±5.4
Λ^{+}_{AA} (NLO)	13.3	13.9±1.2
Λ^{-}_{AA} (NLO)	18.6	22.1±5.1
$\Lambda^{+}_{(V-A)}$ (NLO)	8.4	9.5±1.6
$\Lambda^{-}_{(V-A)}$ (NLO)	8.4	9.5±1.7
ADD Λ_T (GRW)	9.4	9.8±1.2
ADD M_S (HLZ) $n_{ED} = 2$	10.1	10.6±1.3
ADD M_S (HLZ) $n_{ED} = 3$	11.2	11.7±1.4
ADD M_S (HLZ) $n_{ED} = 4$	9.4	9.8±1.2
ADD M_S (HLZ) $n_{ED} = 5$	8.5	8.9±1.1
ADD M_S (HLZ) $n_{ED} = 6$	7.9	8.2±1.0
$n_{ED} = 6$ ADD QBH M_{QBH}	7.8	7.7±0.3
$n_{ED} = 1$ RS QBH M_{QBH}	5.3	5.3±0.4

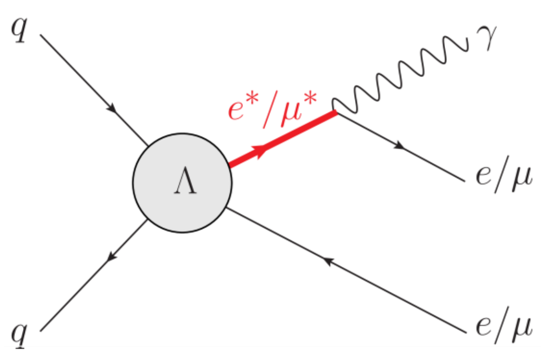
The 95% confidence level lower limits for the contact interaction scale Λ are in the range 8.4-18.6 TeV.

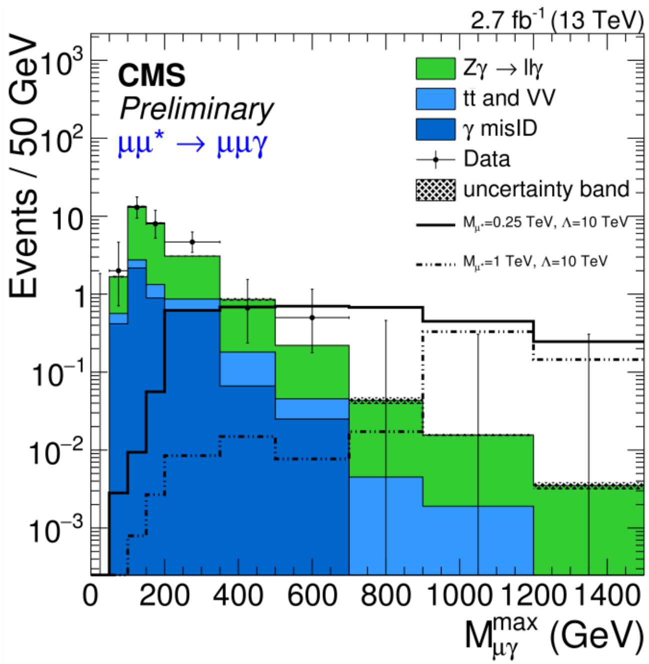
Excluded are quantum black holes with masses up to 7.8 TeV in the ADD model for *n* = 6, and up to 5.3 TeV in the Randall-Sundrum model for *n* = 1.

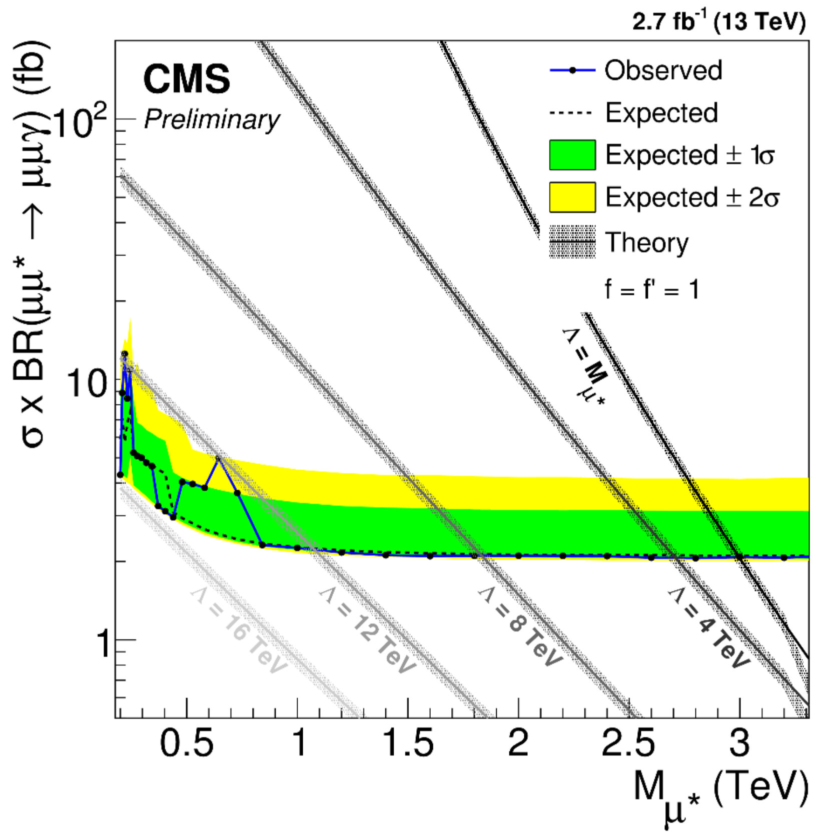
The lower limits for the scales of ADD models, ΛT (GRW) and *MS* (HLZ), are in the range 7.9-11.2 TeV, and are the most stringent set of limits available.

Compositeness: excited leptons

CMS-PAS-EXO-16-009







Search channel	$M_\ell^* = \Lambda$[TeV] observed (expected)	Best limit on Λ
$ee\gamma$	2.8 (2.9)	14(13) TeV
$\mu\mu\gamma$	3.0 (3.0)	15(15) TeV

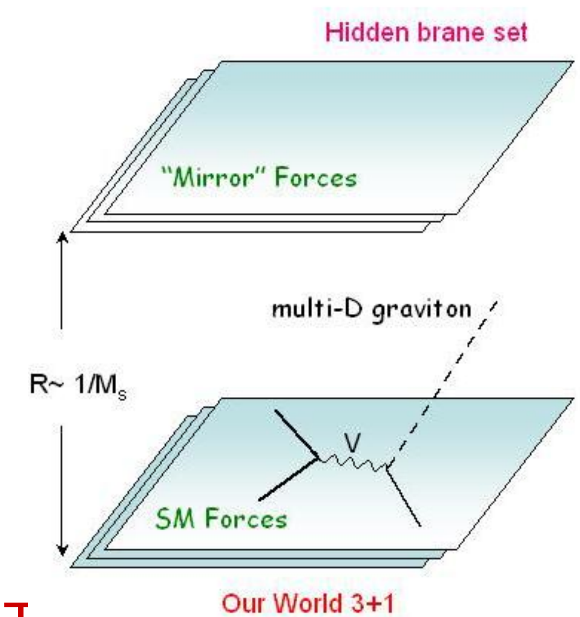
Mono-Particle + MET

- Extra gauge bosons (W′) predicted by extended gauge models (left-right symmetric models and GUT-inspired models)

- Kaluza-Klein graviton emission in large flat extra-dimensions (ADD model)

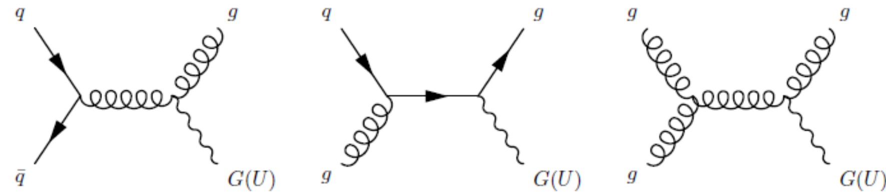
- Dark Matter

- Technicolor



Signals: lepton + MET, photon +MET, jet +MET

Jet/photon + MET: ADD

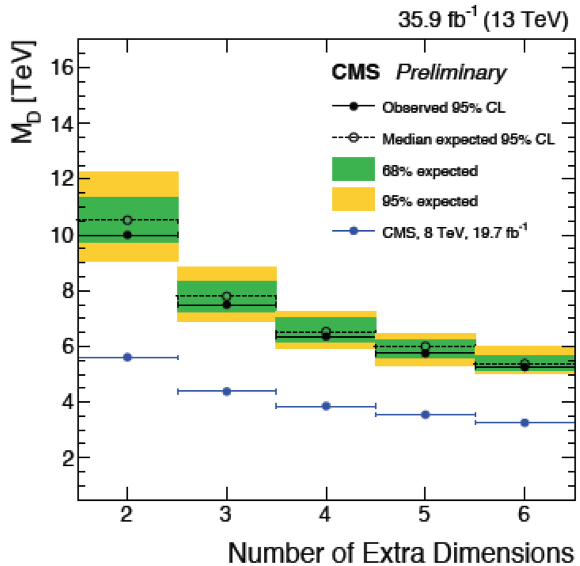


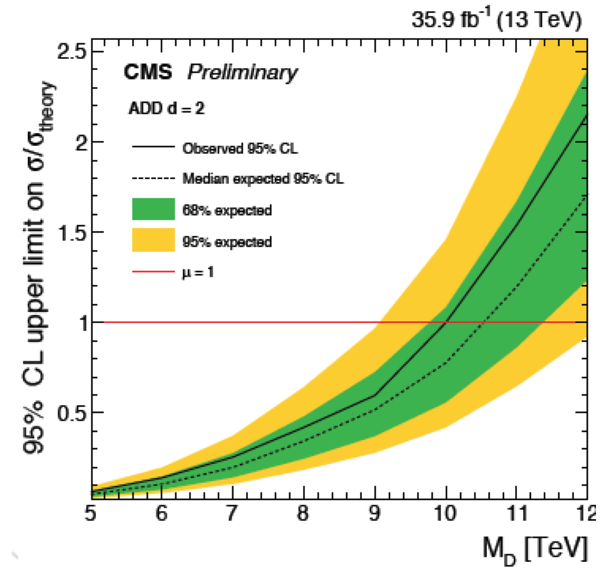
Jet + MET CMS-EXO-16-048

p_T jet > 100/250 GeV
MET > 250 GeV

Monojets searches are typically the among the most sensitive ones

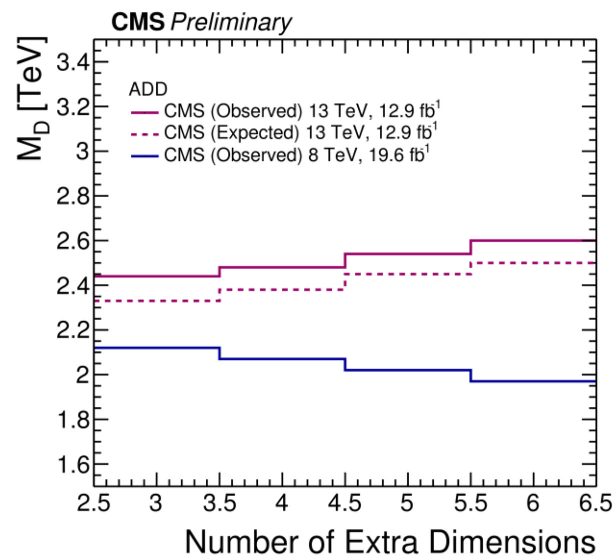
Limits on M_D between 6 and 10 TeV



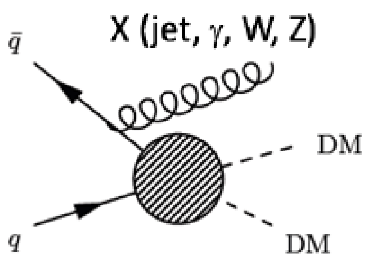


photon + MET CMS-PAS-EXO-16-039

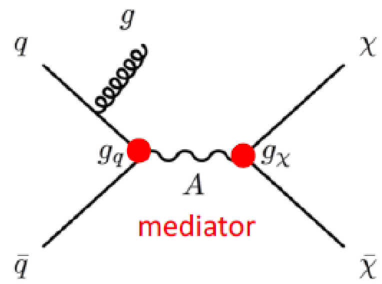
n	Obs. limit (TeV)	Exp. limit (TeV)
3	2.44	2.33
4	2.48	2.38
5	2.54	2.45
6	2.60	2.50



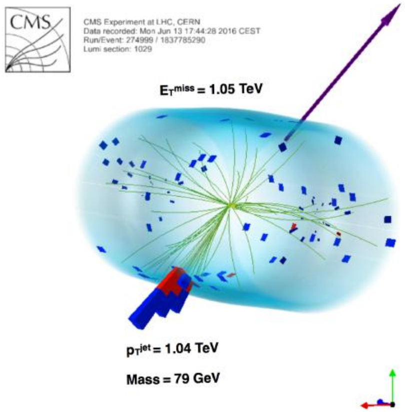
DM Production at LHC



EFT model (Run 1)

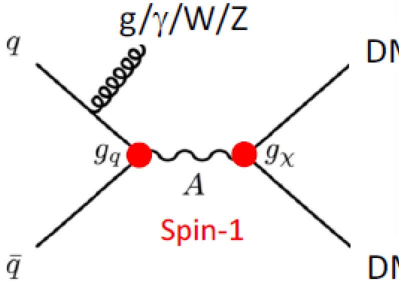


Simplified model (Run 2)



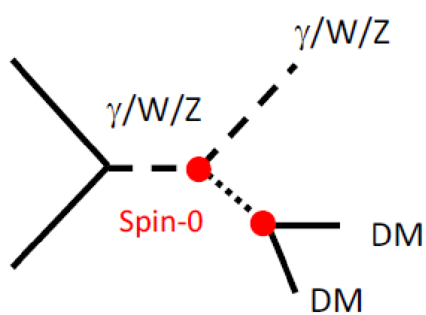
with light quarks

Mono-jet
Mono-photon
Mono-W/Z



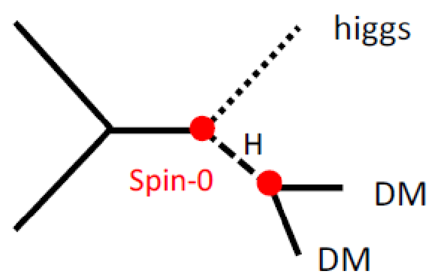
with γ/W/Z

Mono-Photon
Mono-W/Z



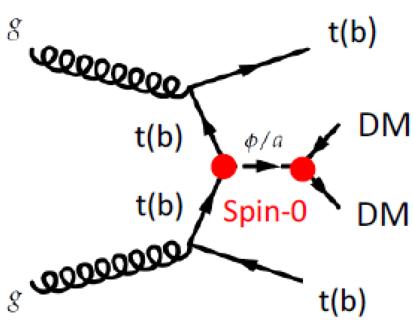
associate with higgs

Mono-H



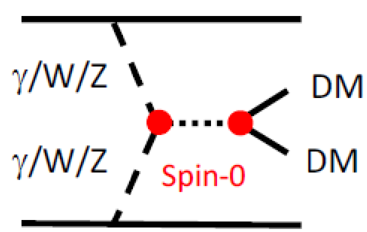
with heavy quarks

TT(BB) pair



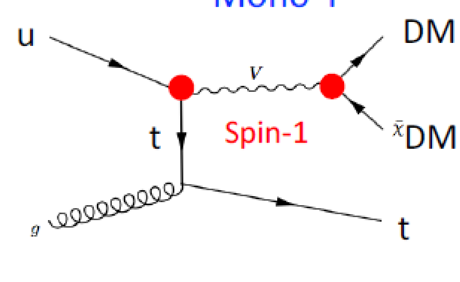
VBF

VBF-invisible

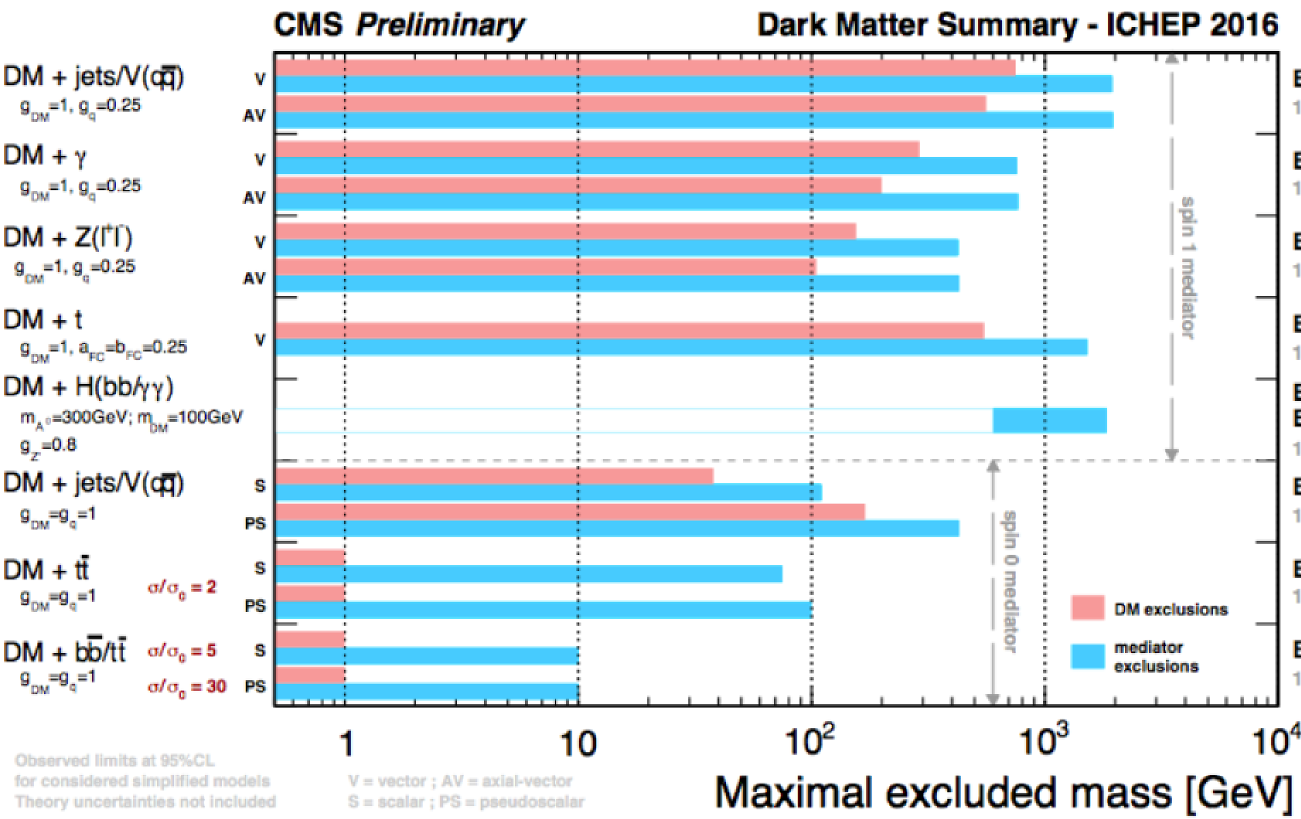


FCN

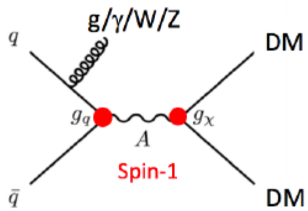
Mono-T

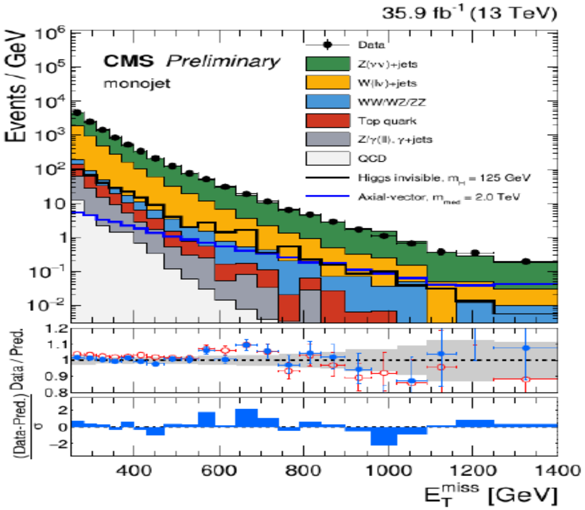


Dark Matter: Summary of ICHEP2016

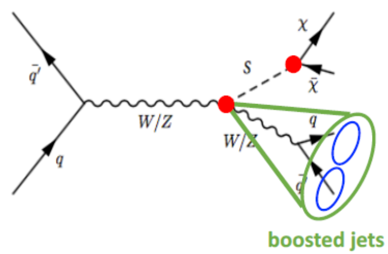


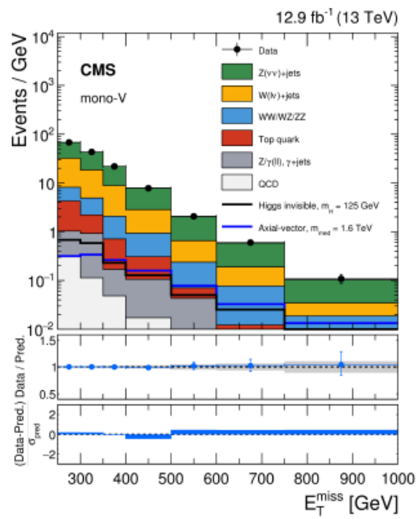
DM: Exclusion Limits on Mediators

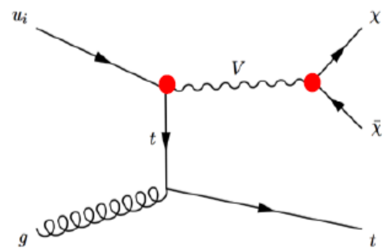


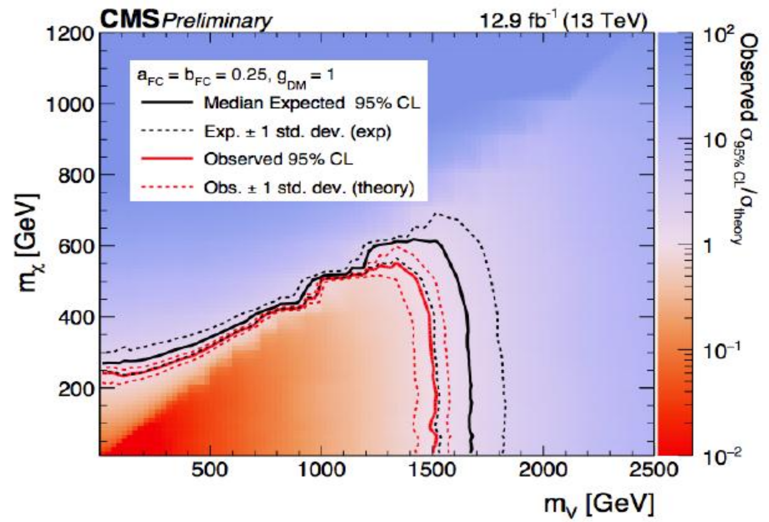


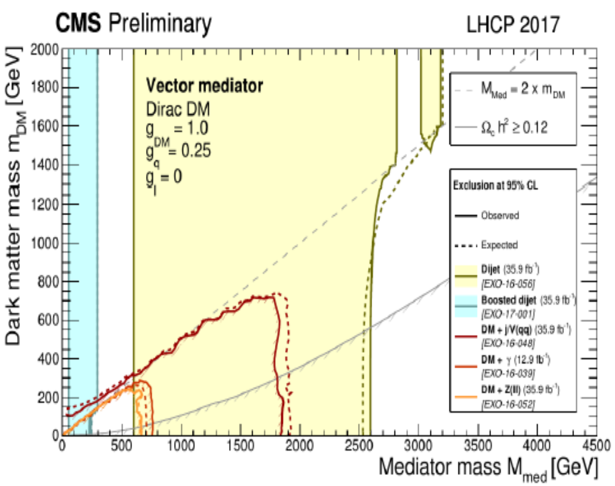
Mono-V(hadronic)



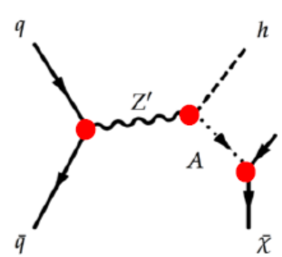




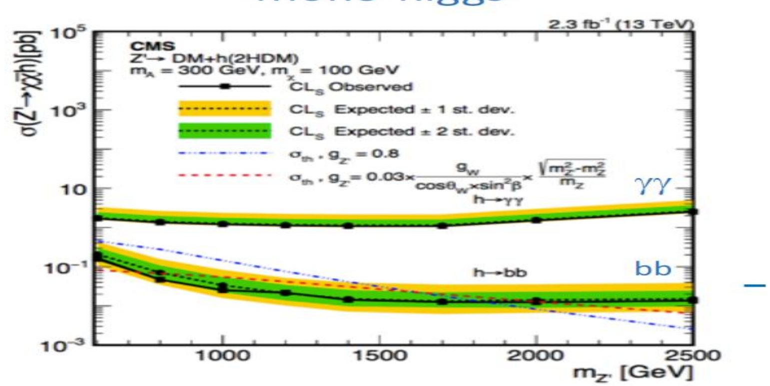




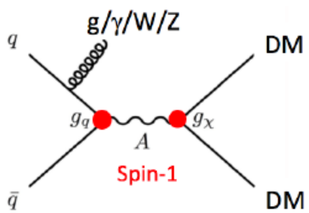
Mono-higgs

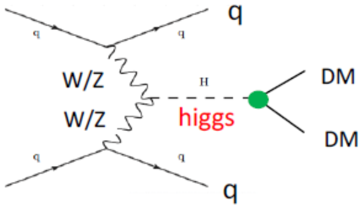


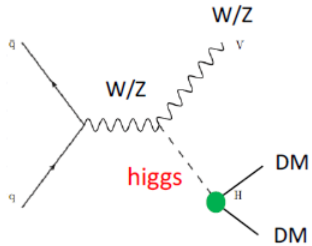
Mono-higgs

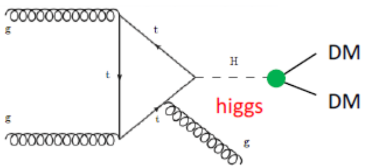


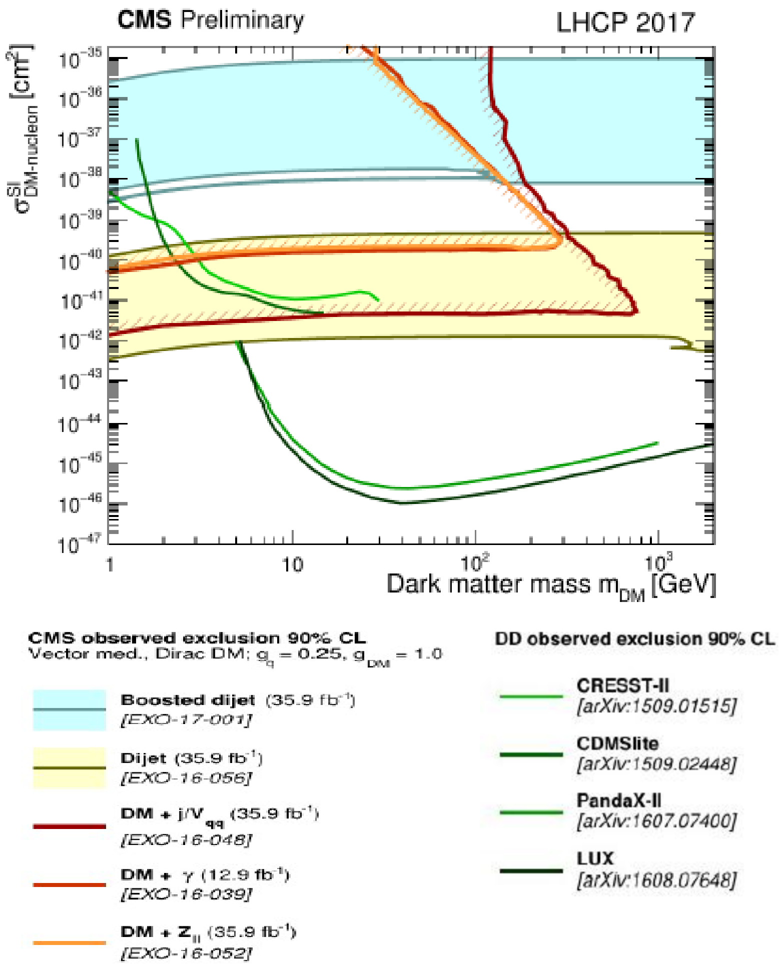
DM: Exclusion Limits on DM-N scattering











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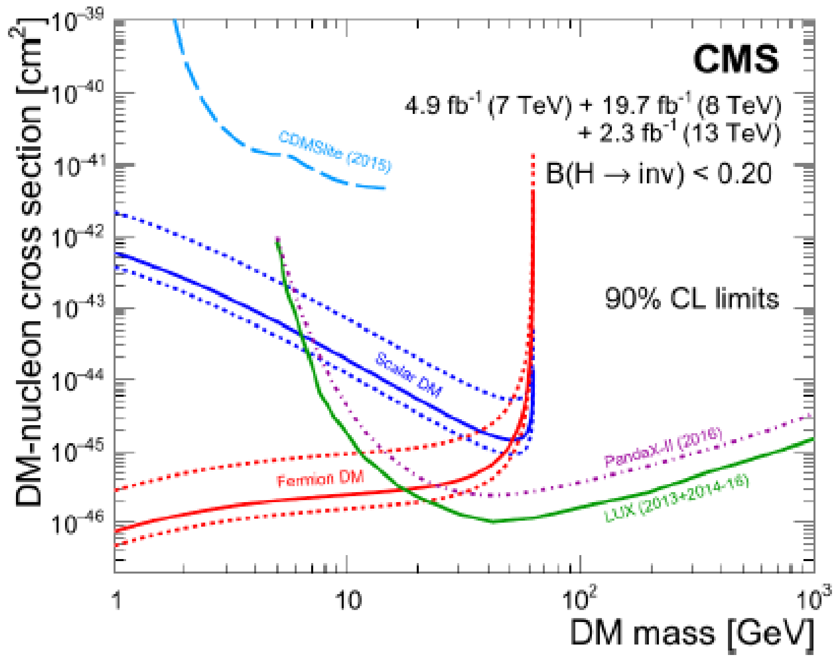
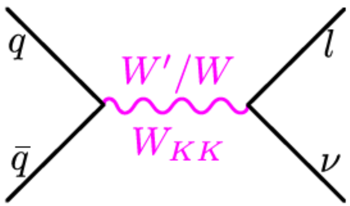
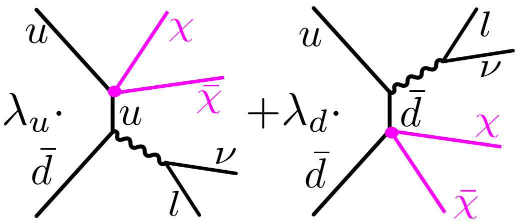
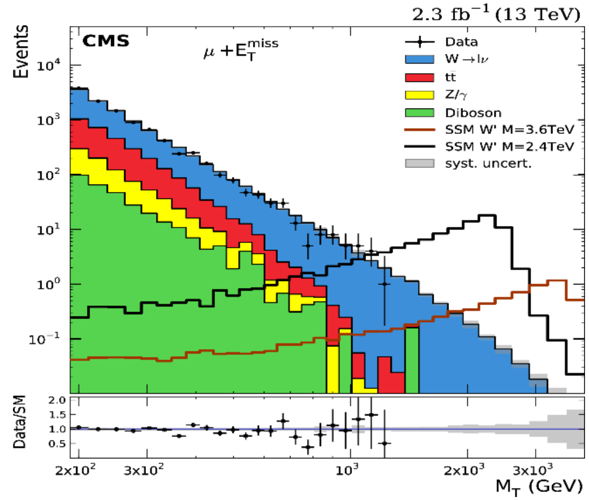


Leptons + MET: W'/TeV-1/DM/Split-UED

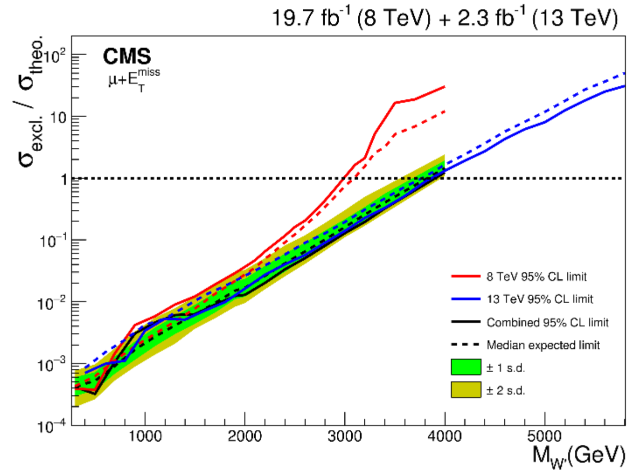
arXiv:1612.09274





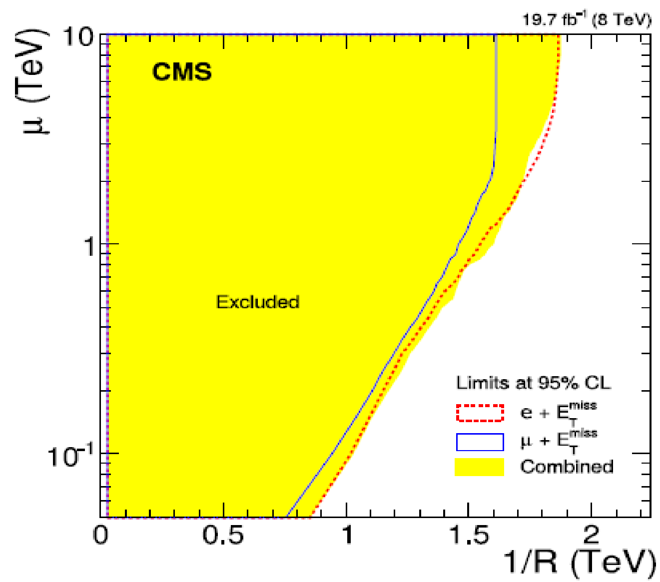


$$M_T = \sqrt{2 p_T^\ell E_T^{miss} \left(1 - \cos[\Delta\phi(\ell, \vec{p}_T^{\,miss})]\right)}.$$

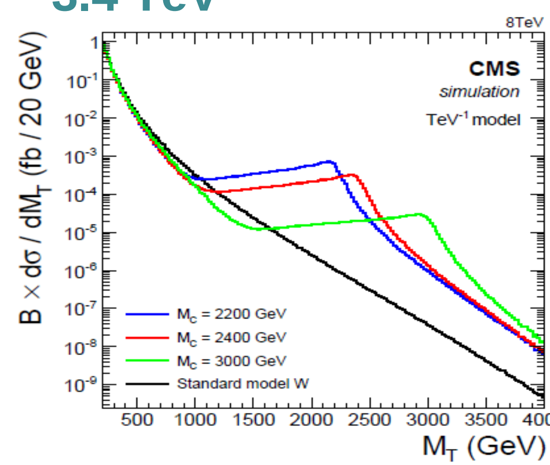


The lower bound on compactification scale Mc of TeV^{-1} is 3.4 TeV

PRD 91 (2015) 092005



The lower mass limit in sUED:
1.74 TeV for μ = 0.05 TeV
3.71 TeV for μ = 10 TeV
μ is bulk mass parameter of sUED
R is radius of ED

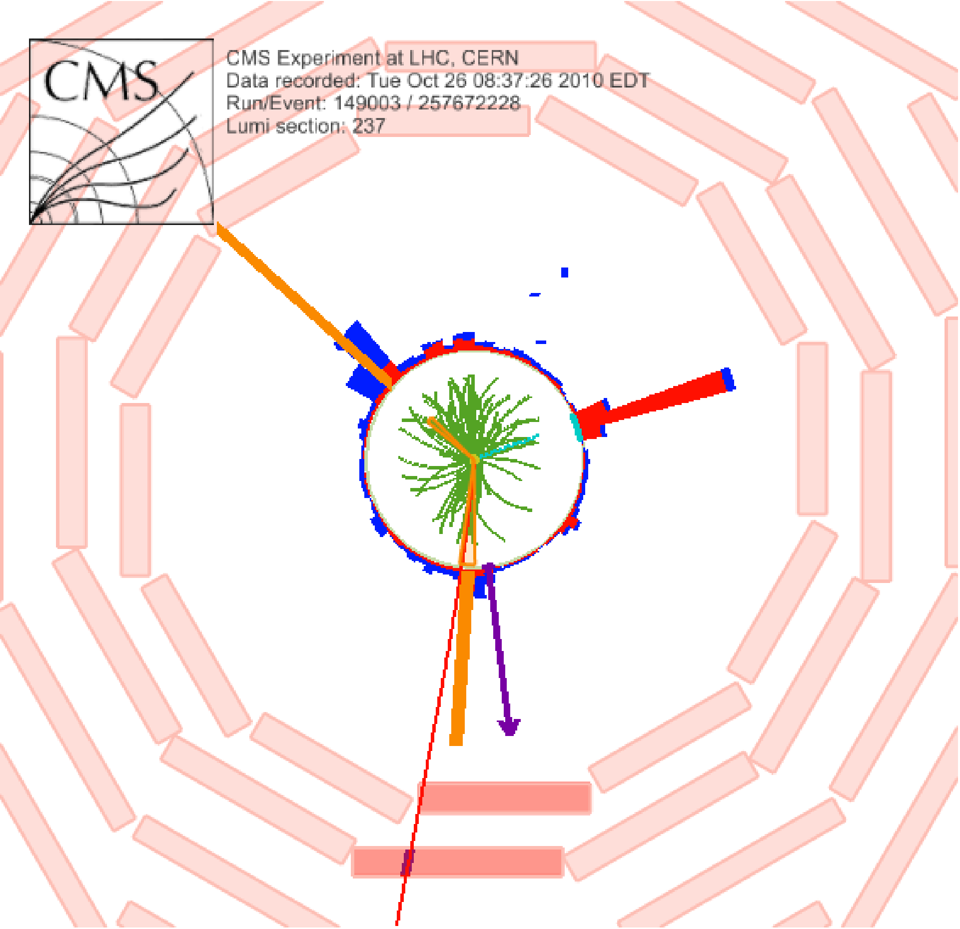


Multiparticle Events

- Black Holes
- Leptoquarks
- etc

<u>Signals:</u> jets + leptons + photons + MET

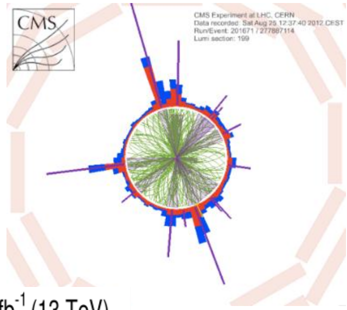
$$\boxed{S_T \equiv \sum E_T}$$

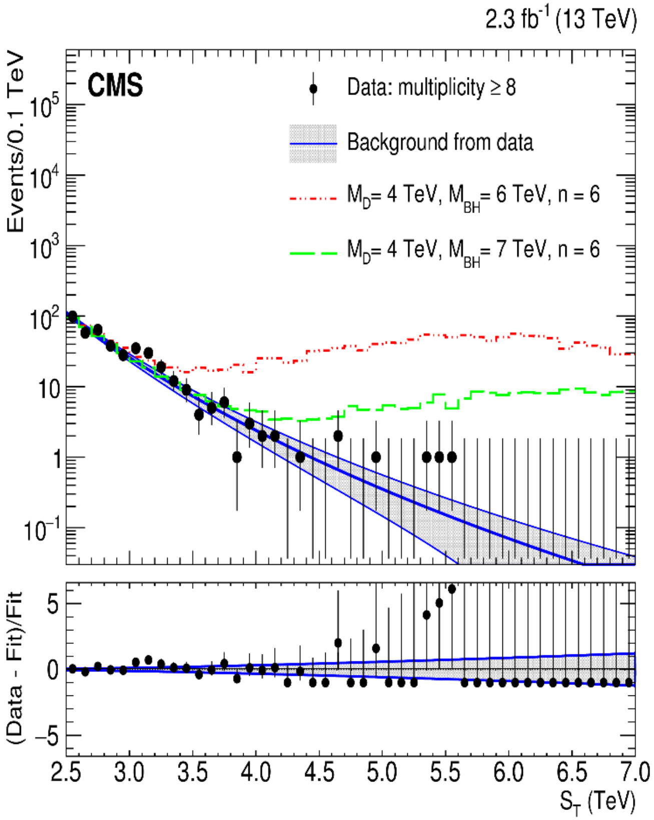


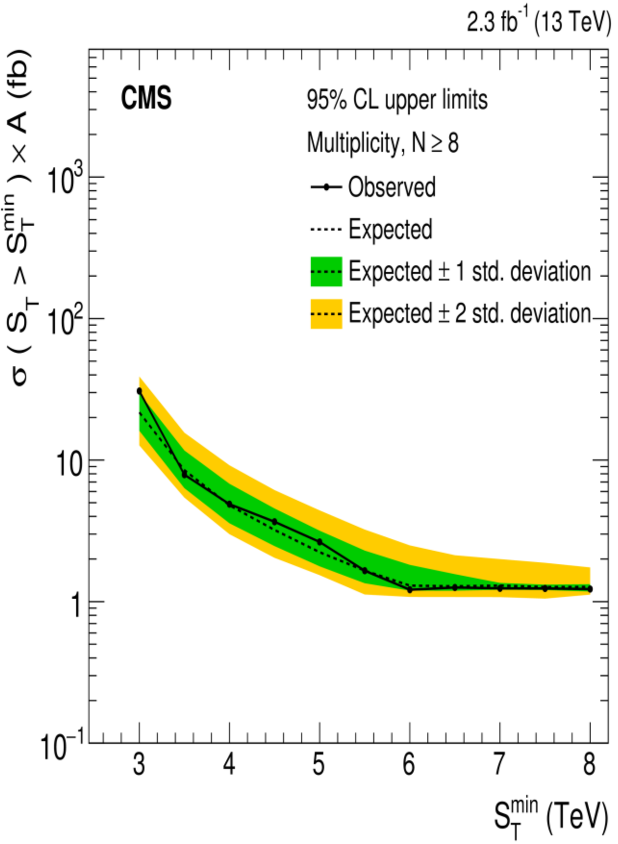
Microscopic Black Holes

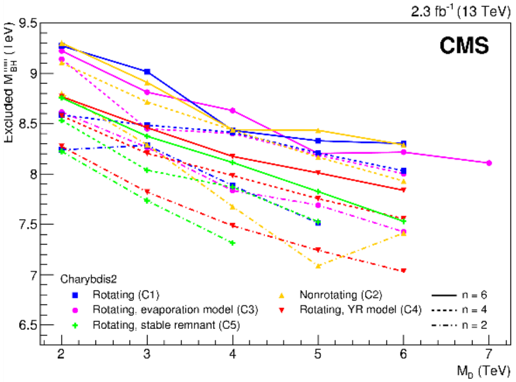
arXiv:1705.01403

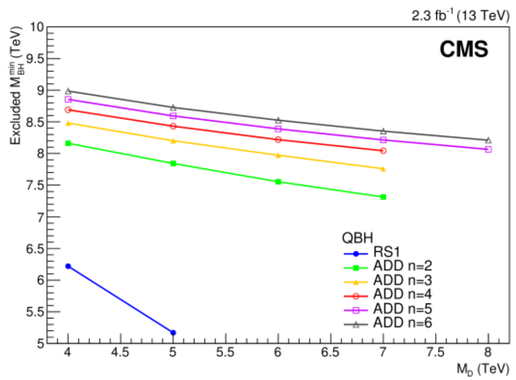
$$S_T = \sum E_T$$





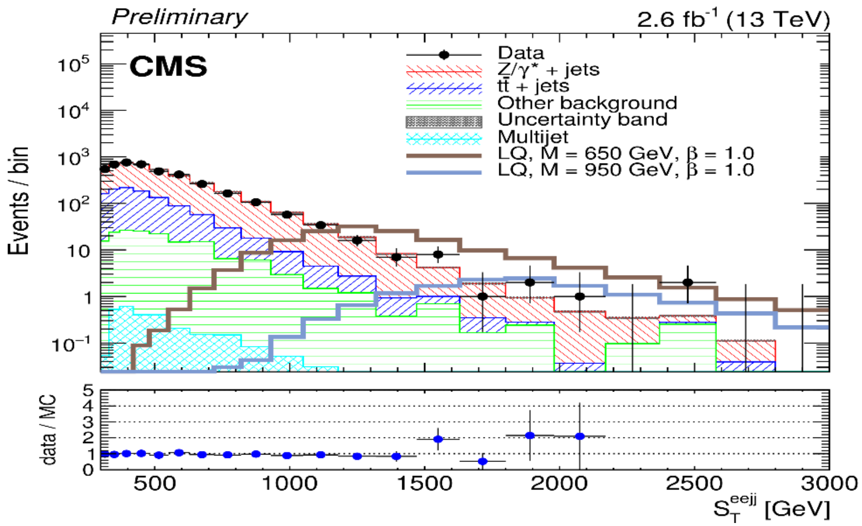




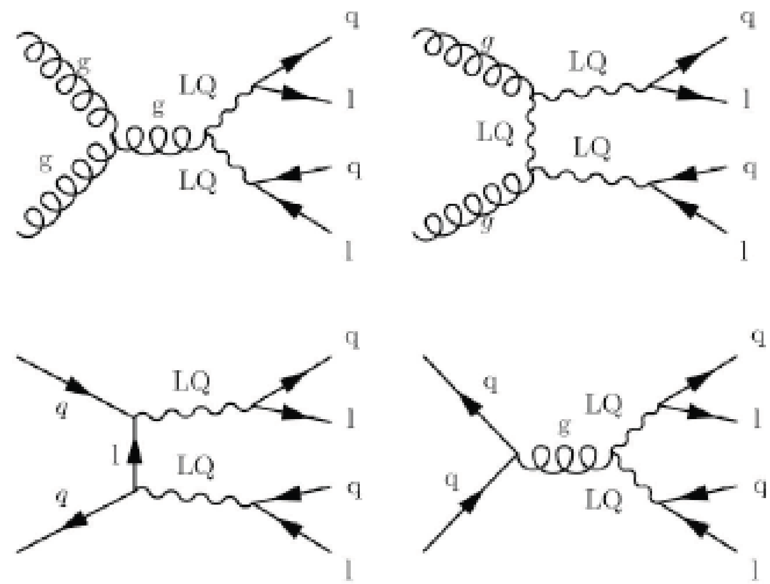


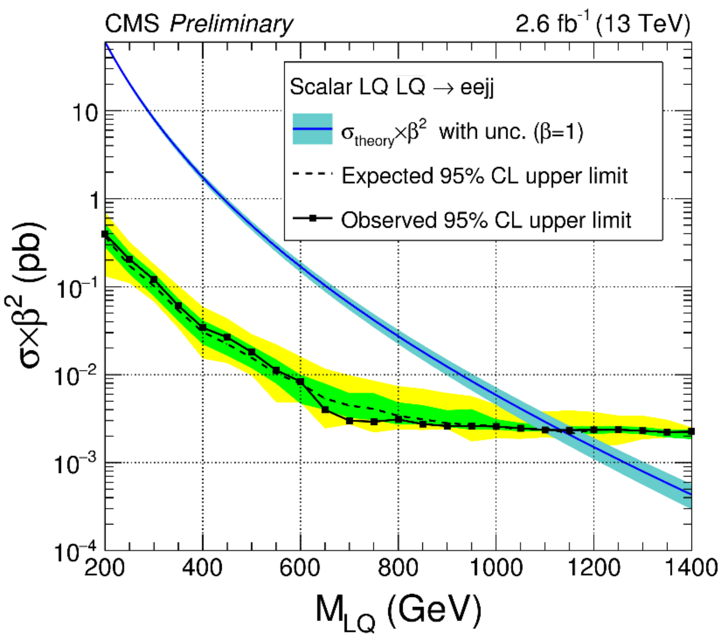
Semiclassical black holes and string balls with masses as high as 9.5 TeV, and quantum black holes with masses as high as 9.0 TeV are excluded, thus significantly extending limits set at a center-of-mass energy of 8 TeV with the LHC Run 1 data.

Leptoquarks



CMS-PAS-EXO-16-043





S_T is the sum of the magnitudes of the p_T of the two leading electrons and two leading jets.

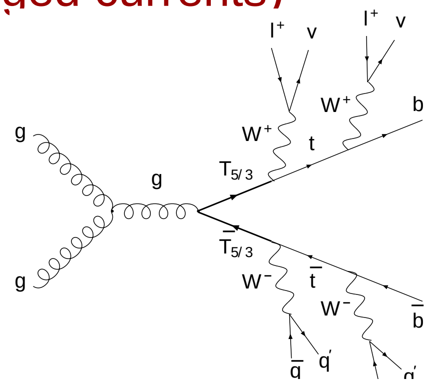
A 95% C.L. lower limit is set on the mass of a second-generation scalar leptoquark at 1130 (920) GeV for β = 1 (0.5)

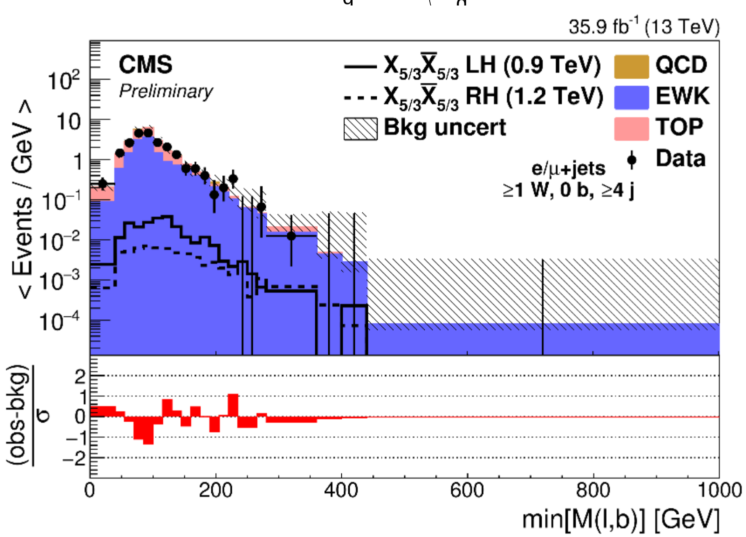
Beyond 3rd Generation: Vector-like Quarks

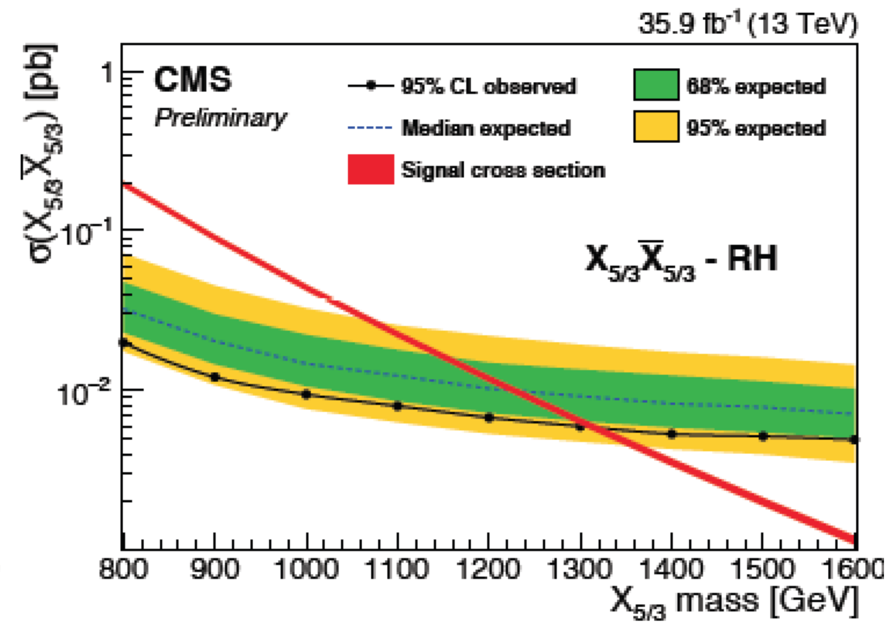
B2G-17-008

Extra generation of fermions

- SM group extension (+2/3, -1/3) is strongly limited by EW tests and Higgs itself
- vector-like fermions (+2/3, -1/3, +5/3, -4/3): $SU(2)_L x SU(2)_R$ symmetry (V-structure of charged currents)

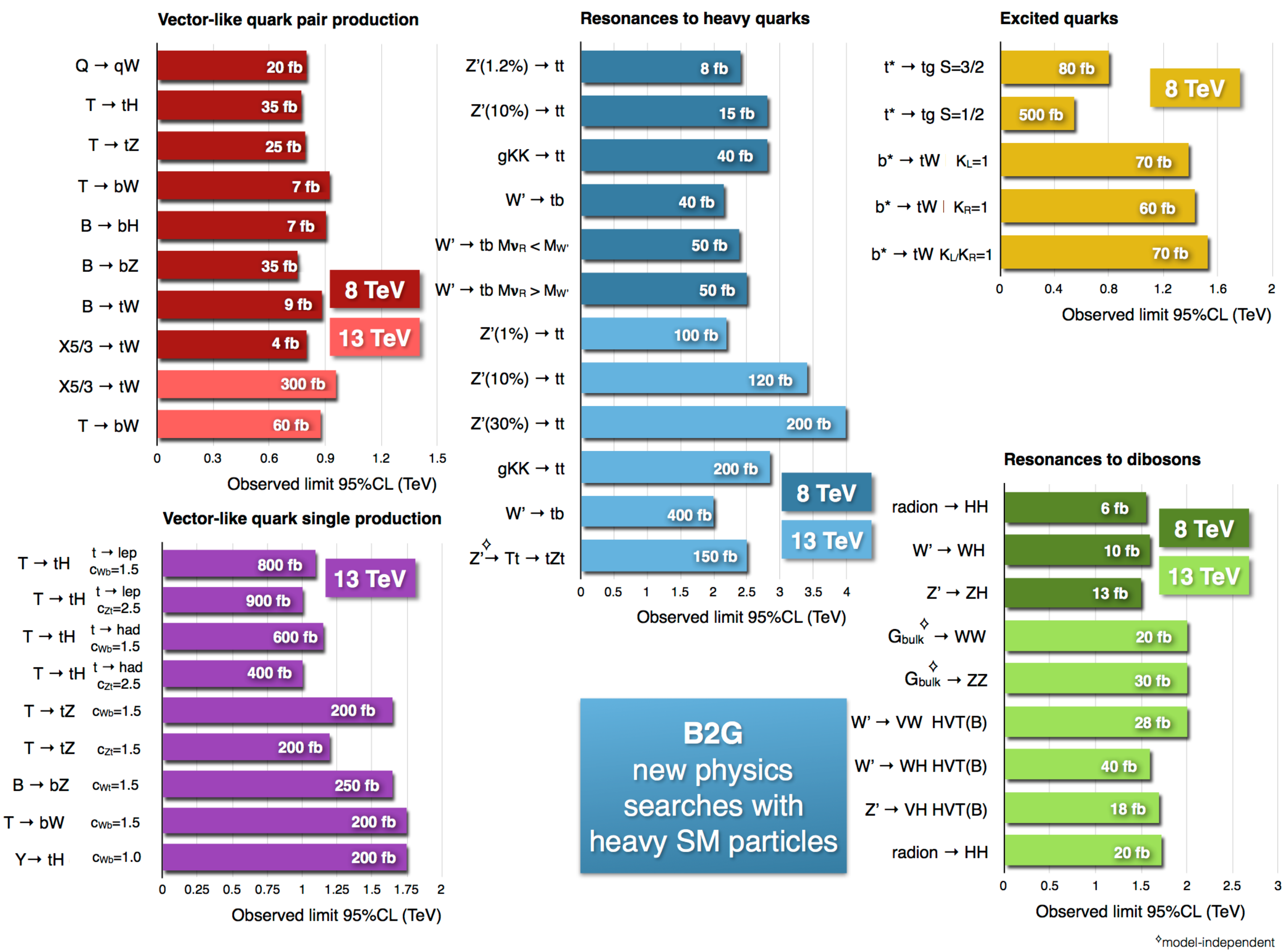






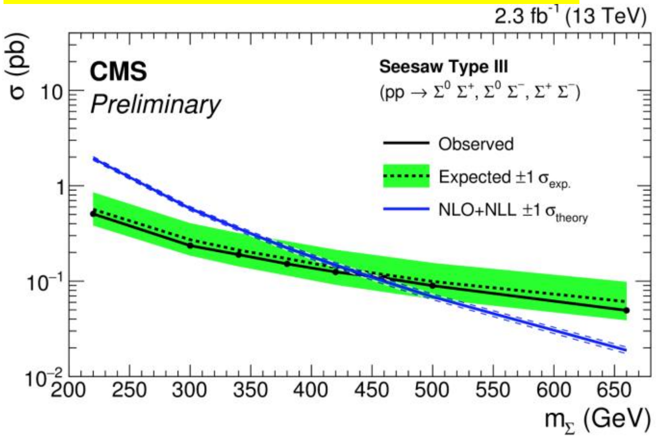
Mass Limits of 1.30 (1.32) TeV excluded at 95% for left (right)-handed couplings

CMS B2G Summary (95% C.L.)

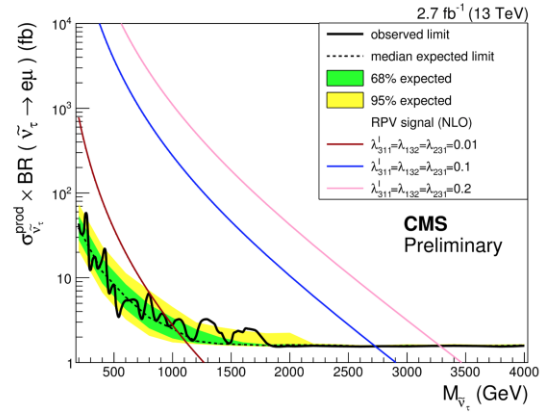


Many More Searches…

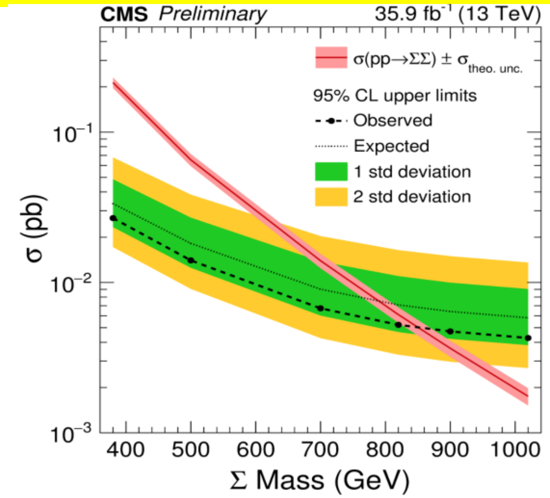
Heavy fermions EXO-16-001



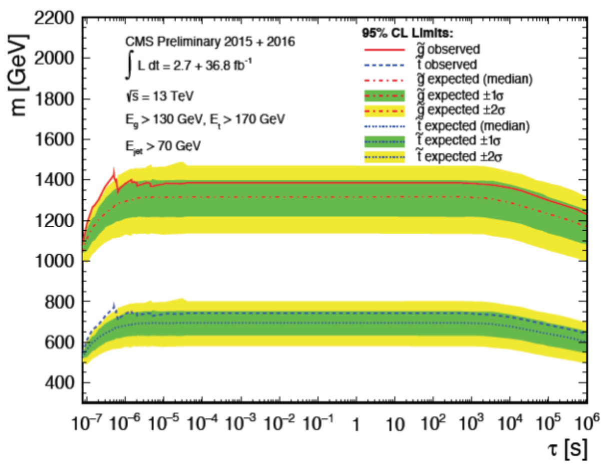
LFV Resonances HIG-16-001



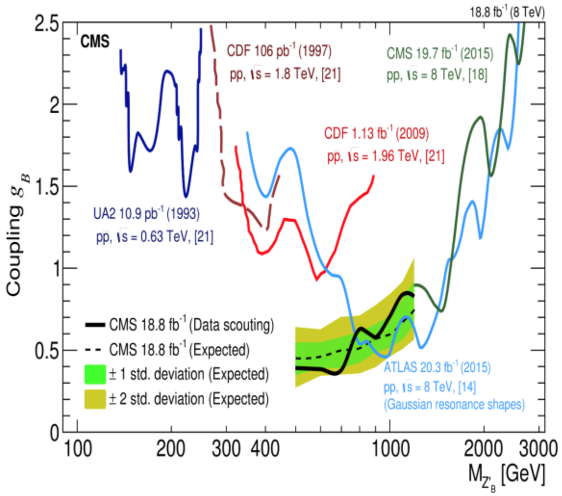
Seesaw type III EXO-17-006



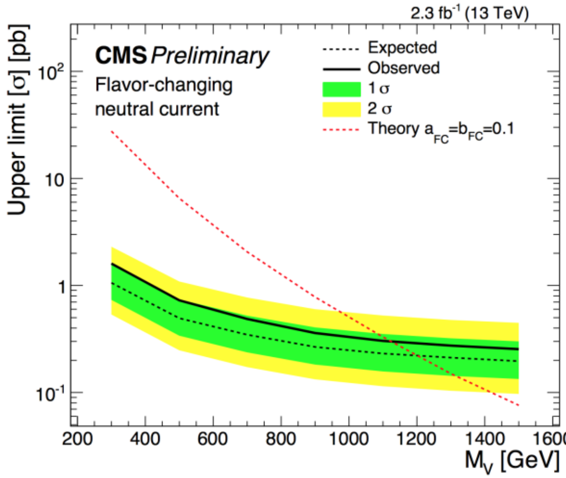
Stopped Long Lived Particles: EXO-16-004



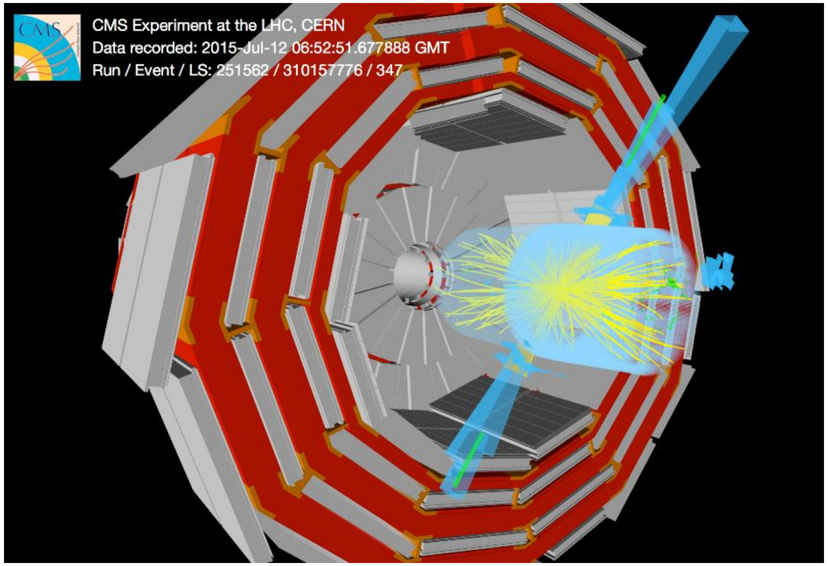
Di-jets / data scouting EXO-14-005

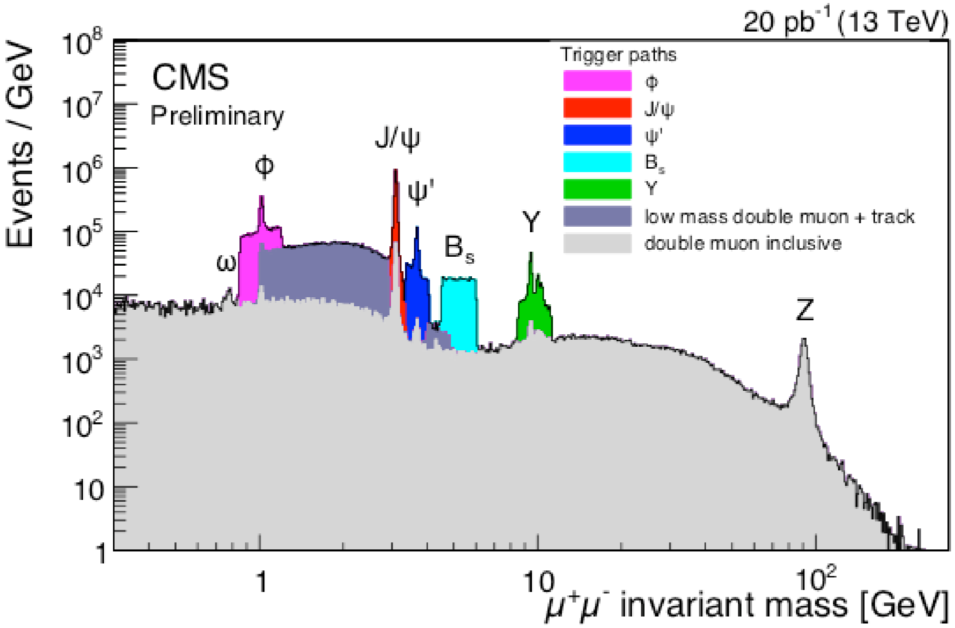


Mono-top EXO-16-017



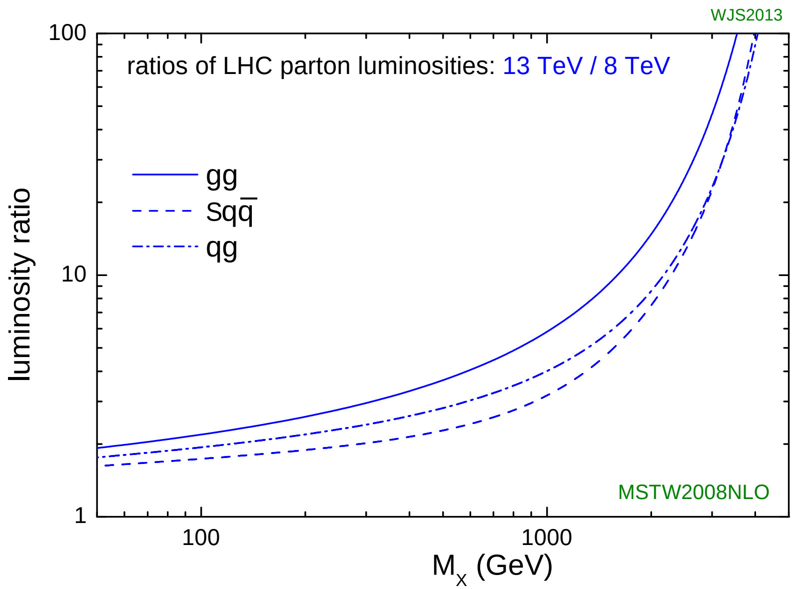
Attobarn BSM Physics



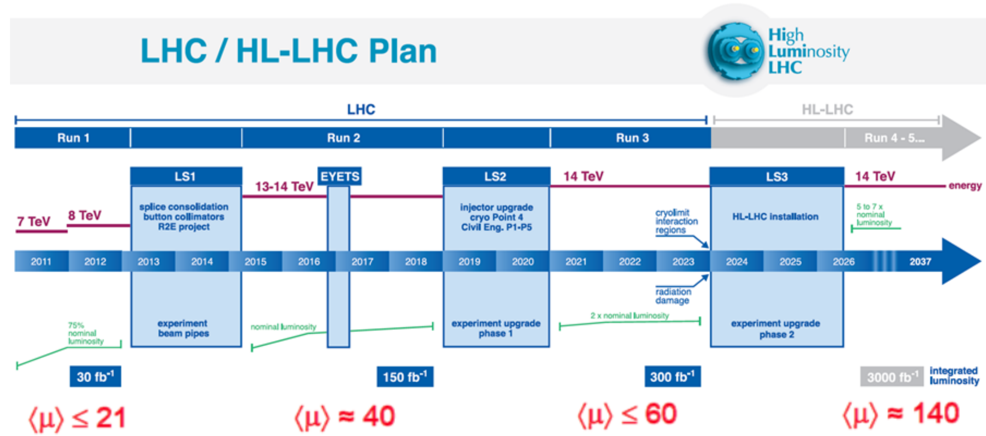


LHC is the machine for discoveries

Energy



Luminosity



dijet resonances → x100 (M= 4-5 TeV)

we will be in an unexplored region on day 1 !

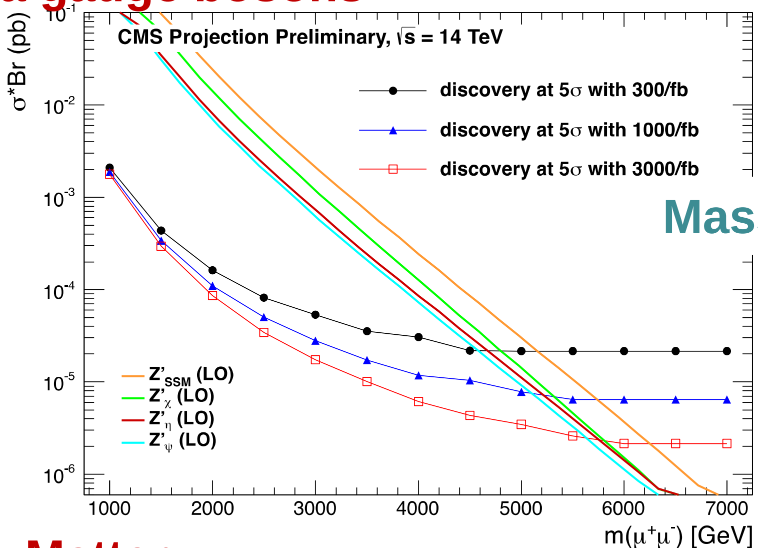
Z’→ x13 (M= 3 TeV)

we will be in an unexplored region with 1-2 fb^{-1} !

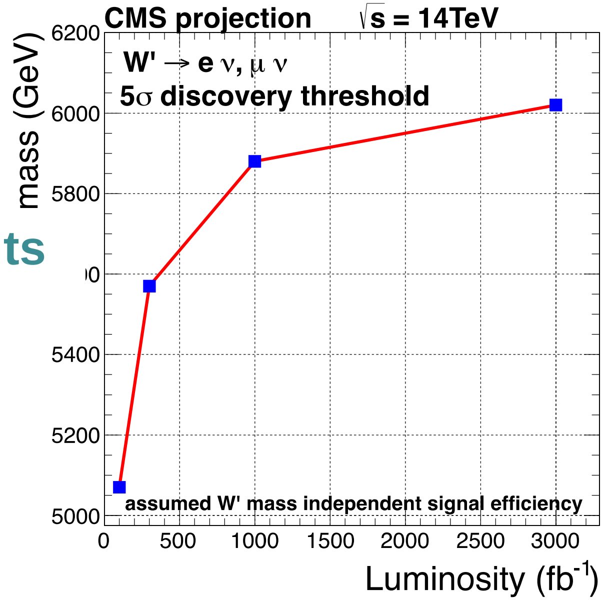
… some expectations

arXiv:1307.7135

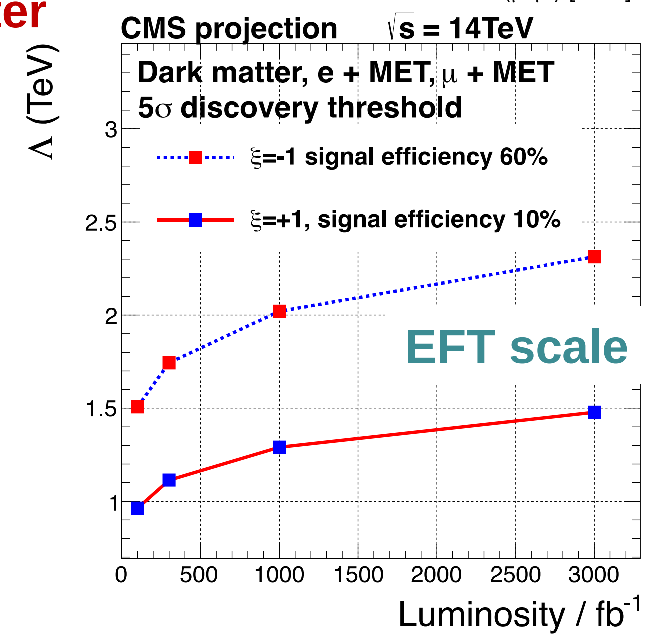
Extra gauge bosons



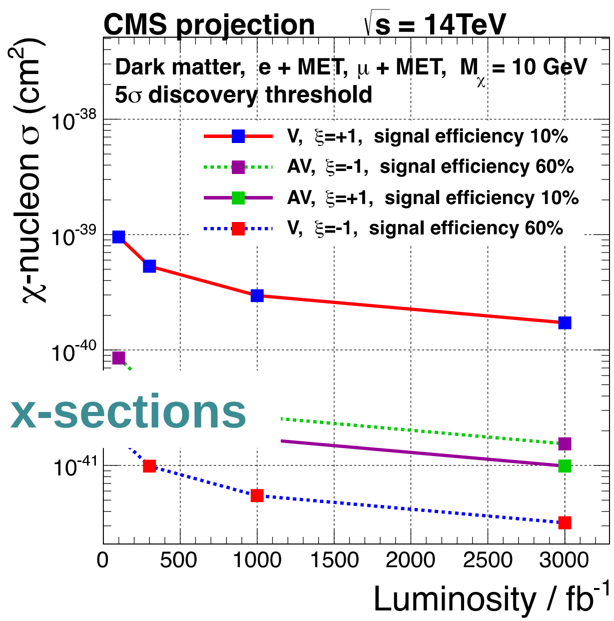
Mass limits



Dark Matter



EFT scale

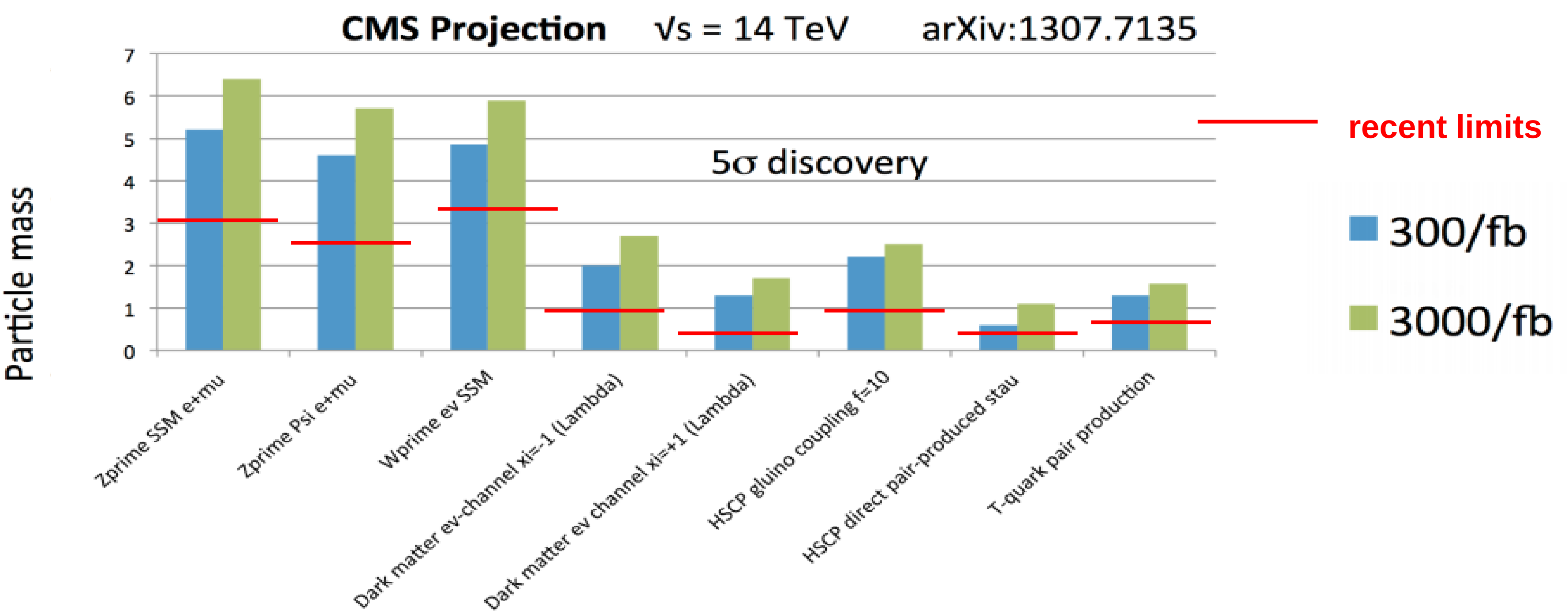


DM x-sections

… some expectations

Projected performance of selected BSM searches with an upgraded CMS detector at the LHC and HL-LHC:

- expected limits for masses of new particle will be increased up to 2-3 times



- High Luminosity allows to separate spin hypothesis of new states if it will be discovered: spin-1 Z' and spin-2 graviton separation significances reach 5σ for 3000 fb^{-1} only

Conclusions

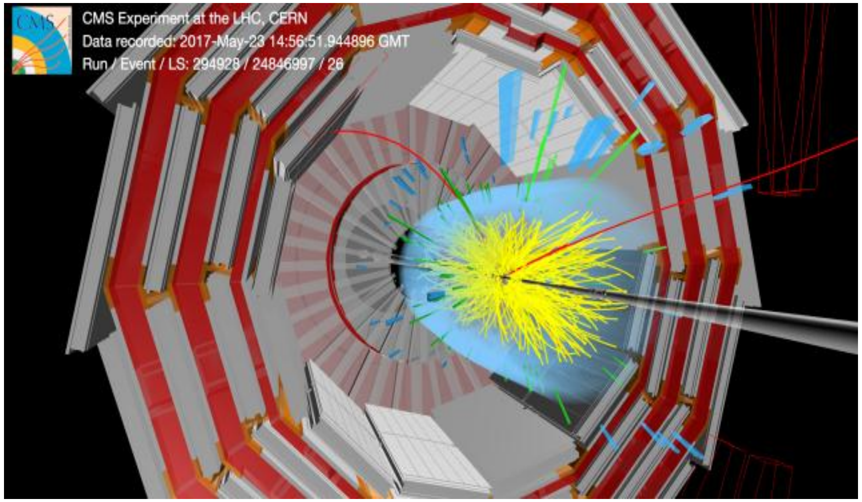
- CMS performed a wide program for search of particles and phenomena

- Run1 data (2010-2012) demonstrate triumph of Standard Model

  (many Exotica and SUSY Model were tested and new limits are derived)

- Run2 at 13 TeV was started in 3rd June 2015
  - ✓ no significant signal of new physics was found so far
  - ✓ previous excesses have not been confirmed

- Now LHC re-started
- ✓ expected ~ 90 fb-1 in 2017-2018
- ✓ in total around 130 fb-1 in Run2
- ✓ Run1 searches is being fully repeated
- ✓ new final states and new analysis techniques

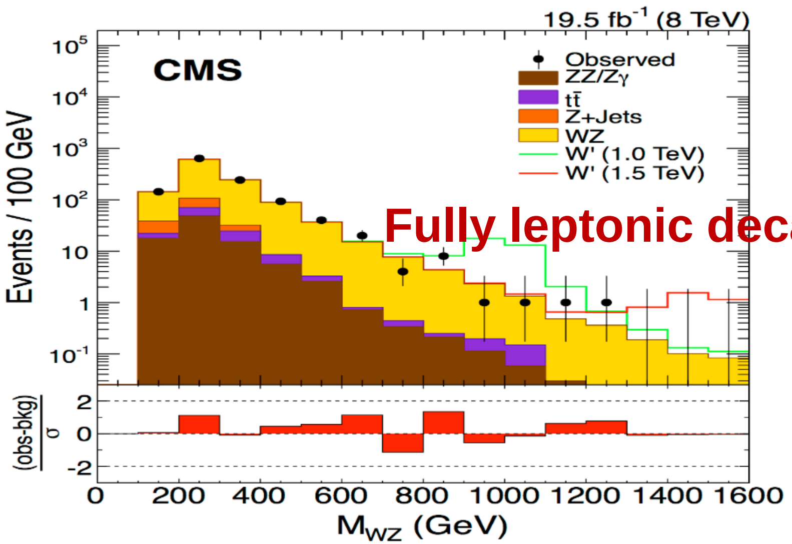


Collisions recorded by the CMS detector on 23 May 2017 at the start of the year's physics run

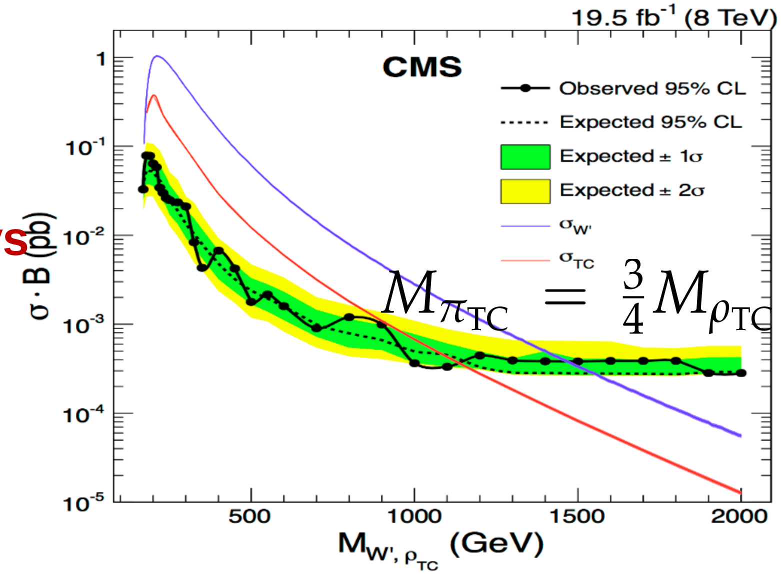
Thank you for your attention

Dibosons: EGM/Technicolor

PLB 740 (2015) 83

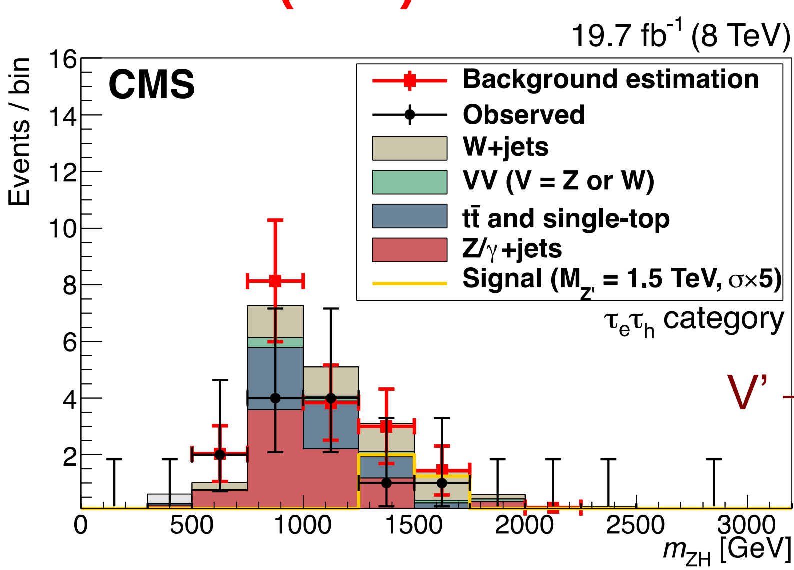


Fully leptonic decays



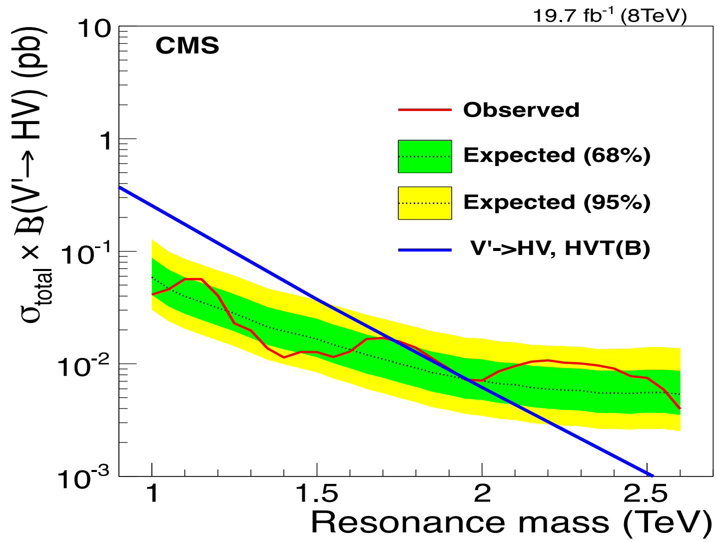
$$M_{\pi_{TC}} = \frac{3}{4} M_{\rho_{TC}} - 25\,\mathrm{GeV}$$

PLB 748 (2015) 255

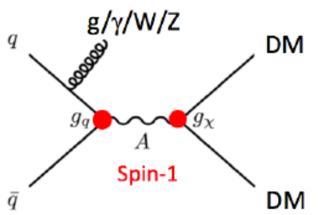


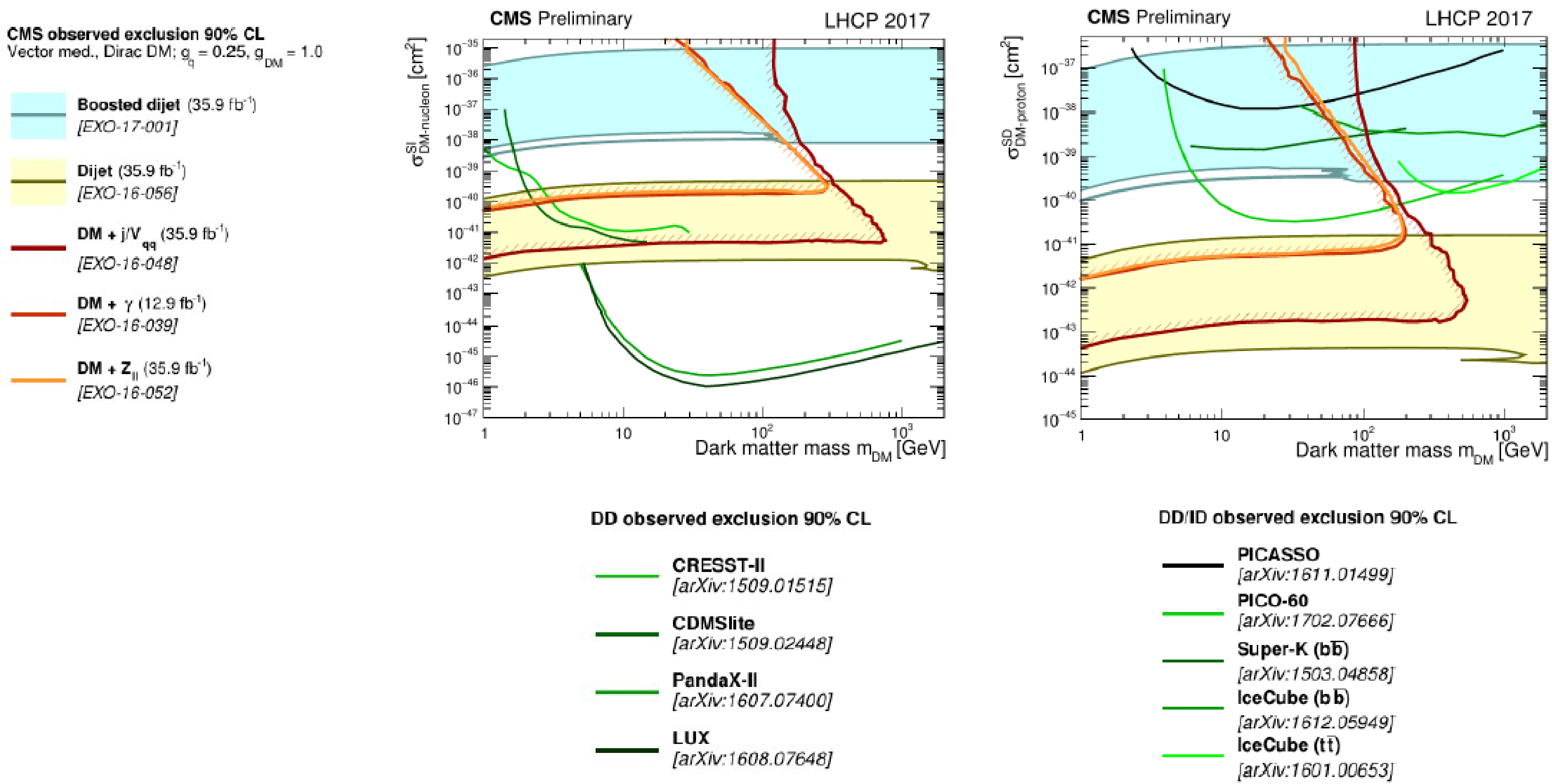
V' → HV

arXiv:1506.01443



DM: Exclusion Limits on spin-1 med.

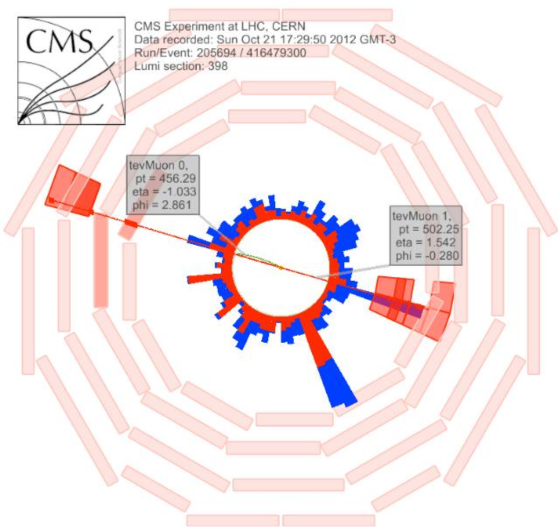


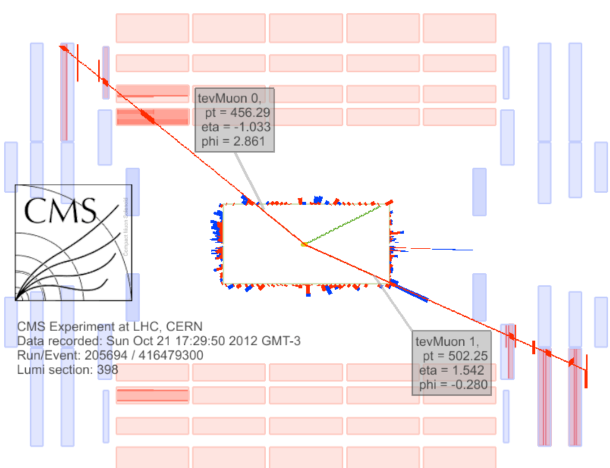


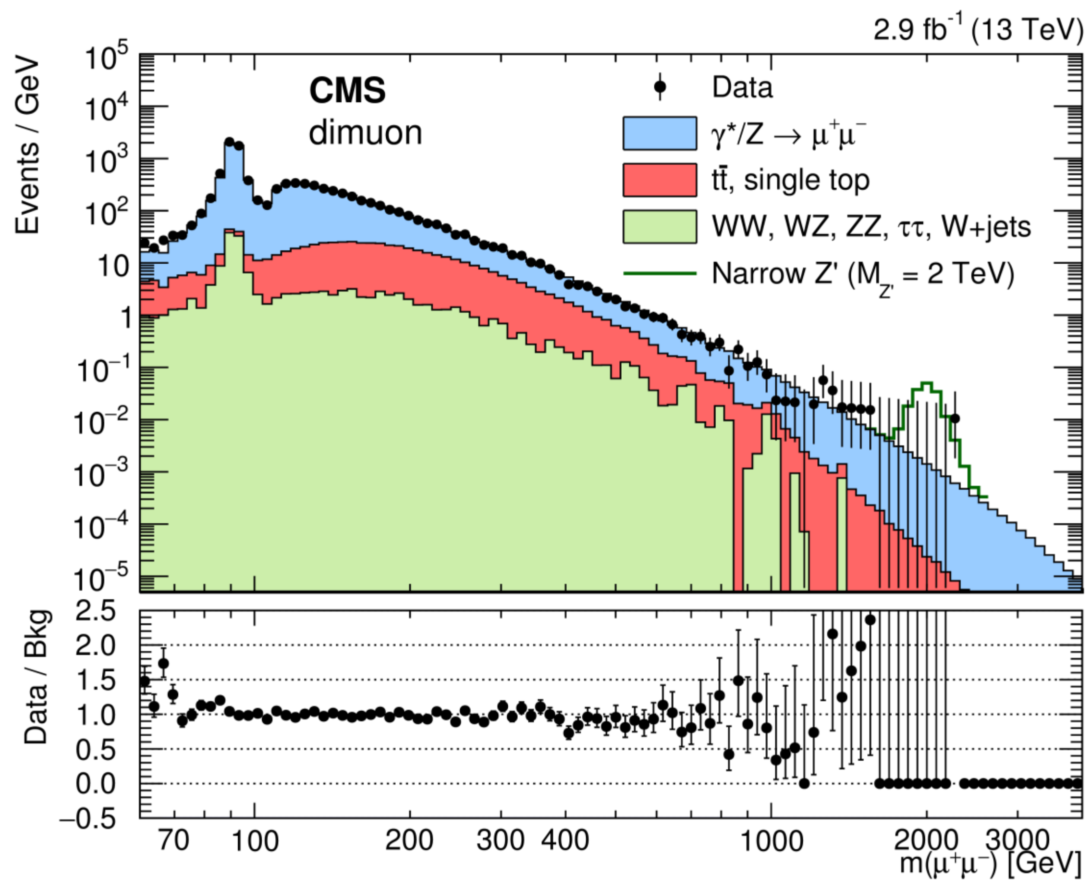
Dileptons: Mass Spectrum

M(μ+μ-) = 1871 GeV and Track pT > 3 GeV

PLB 768 (2017) 57

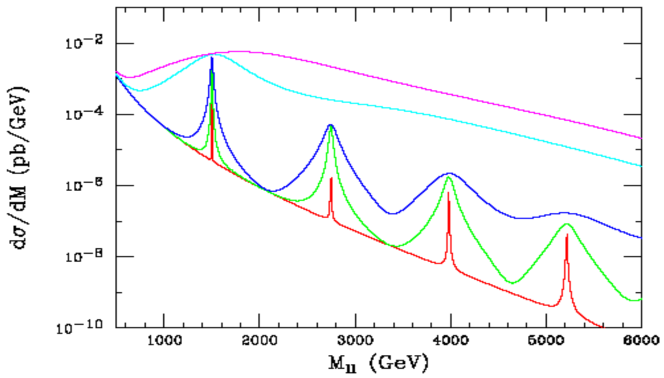






Heavy Resonances

- Extra gauge bosons predicted by extended gauge models (left-right symmetric models and GUT-inspired models)
- Kaluza-Klein graviton excitations arising in extra dimensions models with curved bulk space (Randall-Sundrum model)
  - Small extra spatial dimensions, Curved bulk space (AdS_5 - slice)
  - Well separated graviton mass spectrum



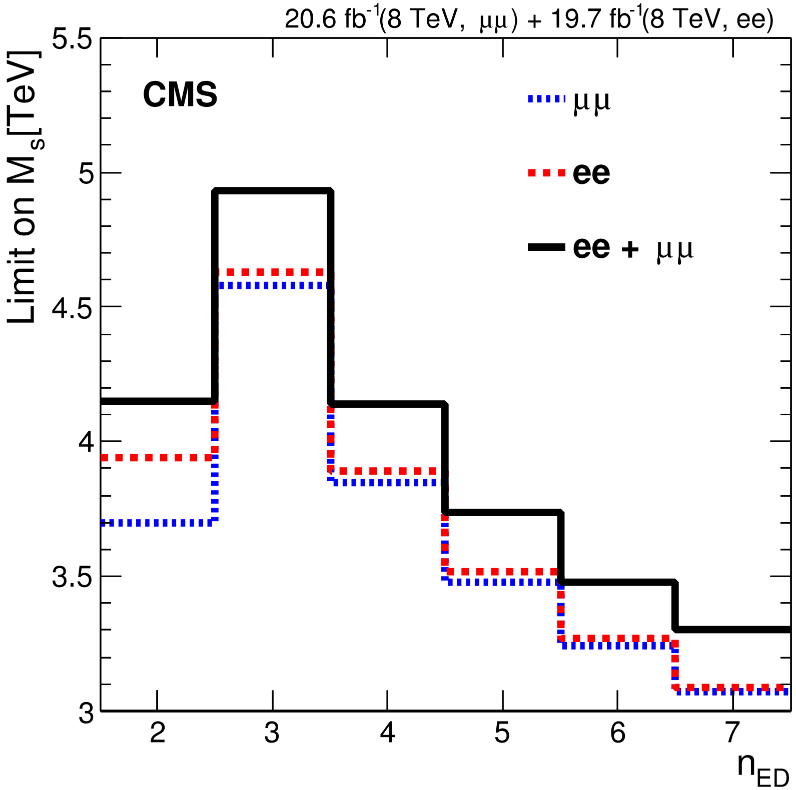
- Kaluza-Klein excitations of SM gauge bosons in large flat extra-dimensions (TeV-1 Models)
  - Bosons could also propagate in the bulk
  - Fermions are localized at the same (opposite) orbifold point: destructive (constructive) interference between SM gauge bosons and KK excitations
- Technicolor

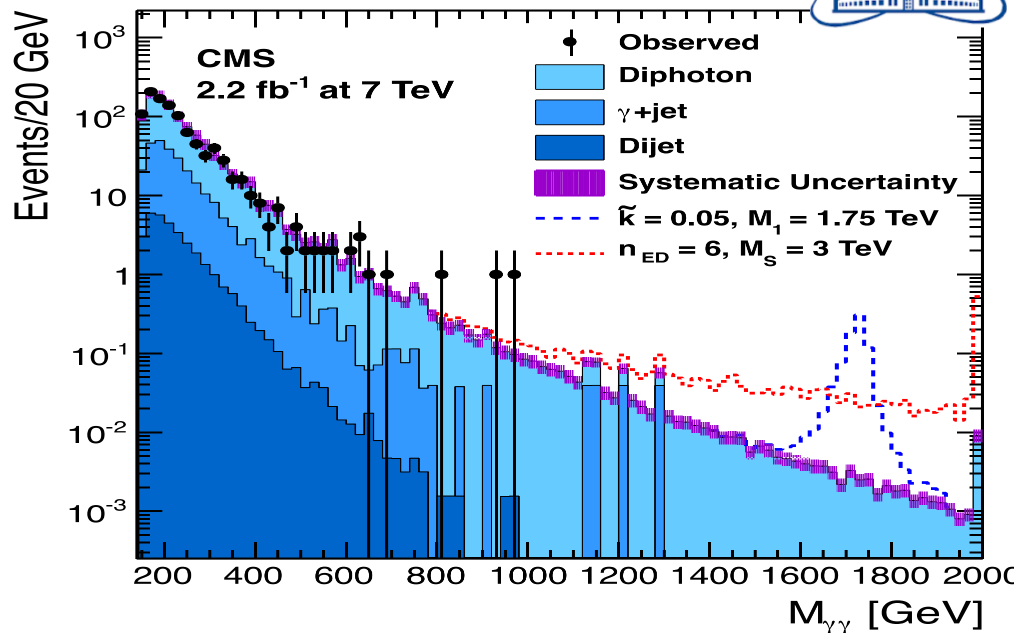
Signals: di-leptons/di-jets/di-photons resonance states in high (~TeV) invariant mass range ⇒ new particles would be observed as a bump, excess in the mass spectrum

Excellent momentum and energy resolutions are required !!

ADD Limits **PRL 108 (2012) 111801**

JHEP 04 (2015) 025





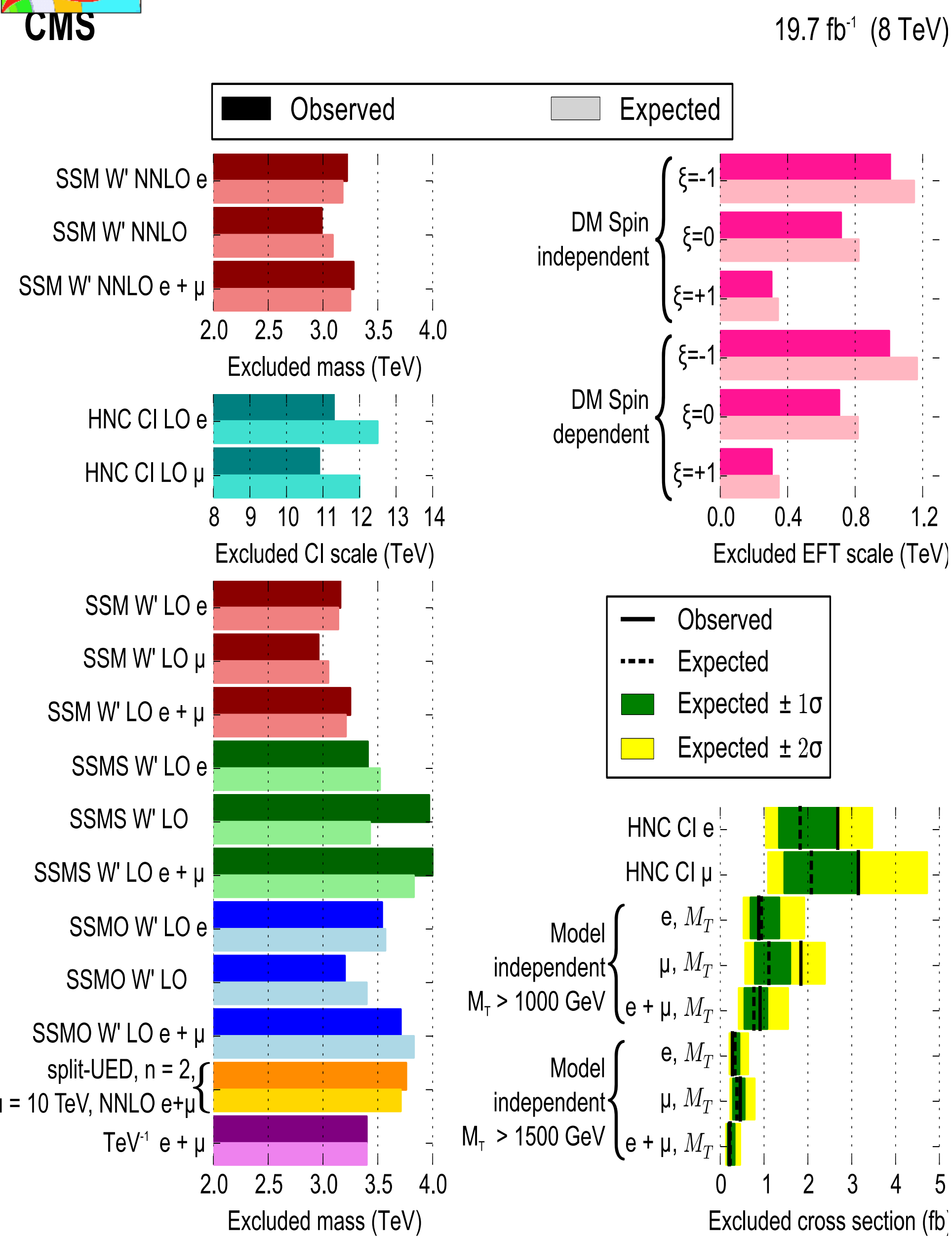
The effective Planck scale less than 2.3-2.8 TeV is excluded

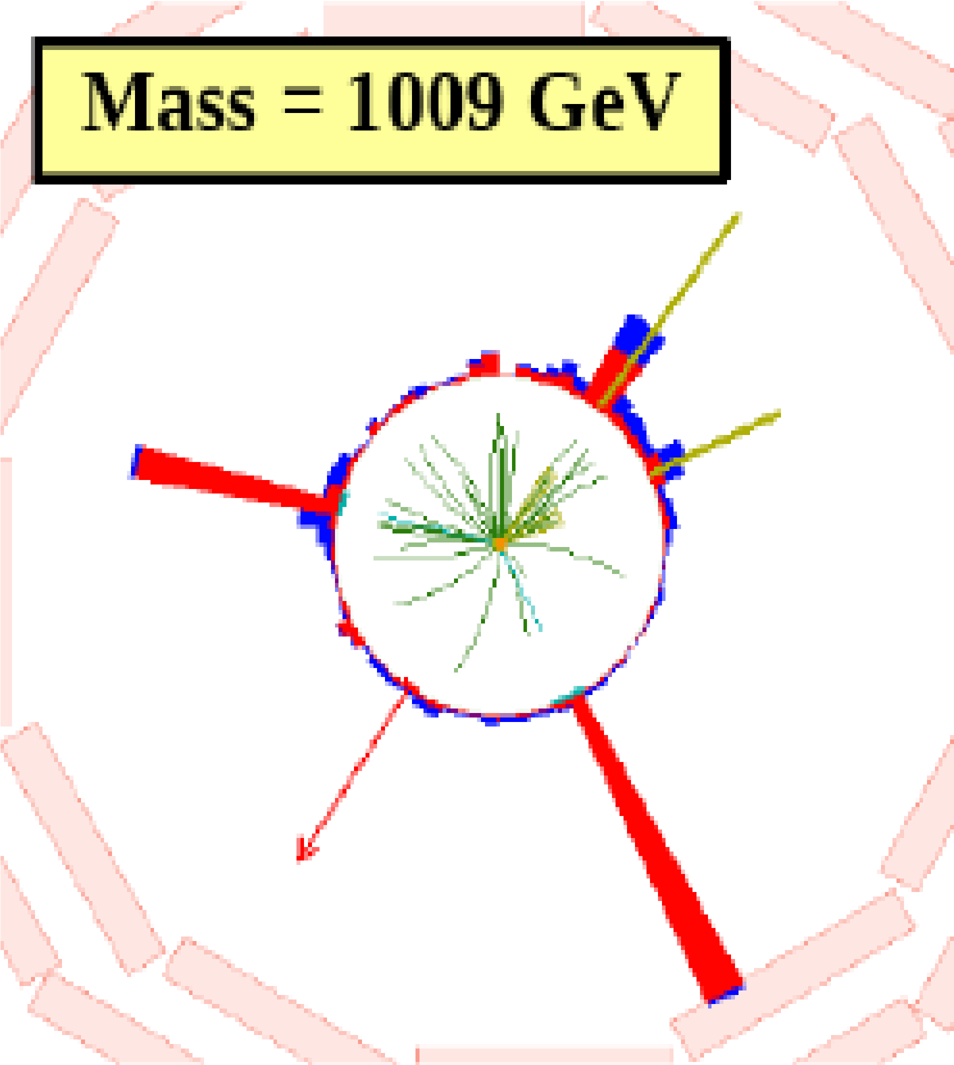
Two conventions for the ultraviolet cutoff scale of the divergent sum of the KK graviton excitations

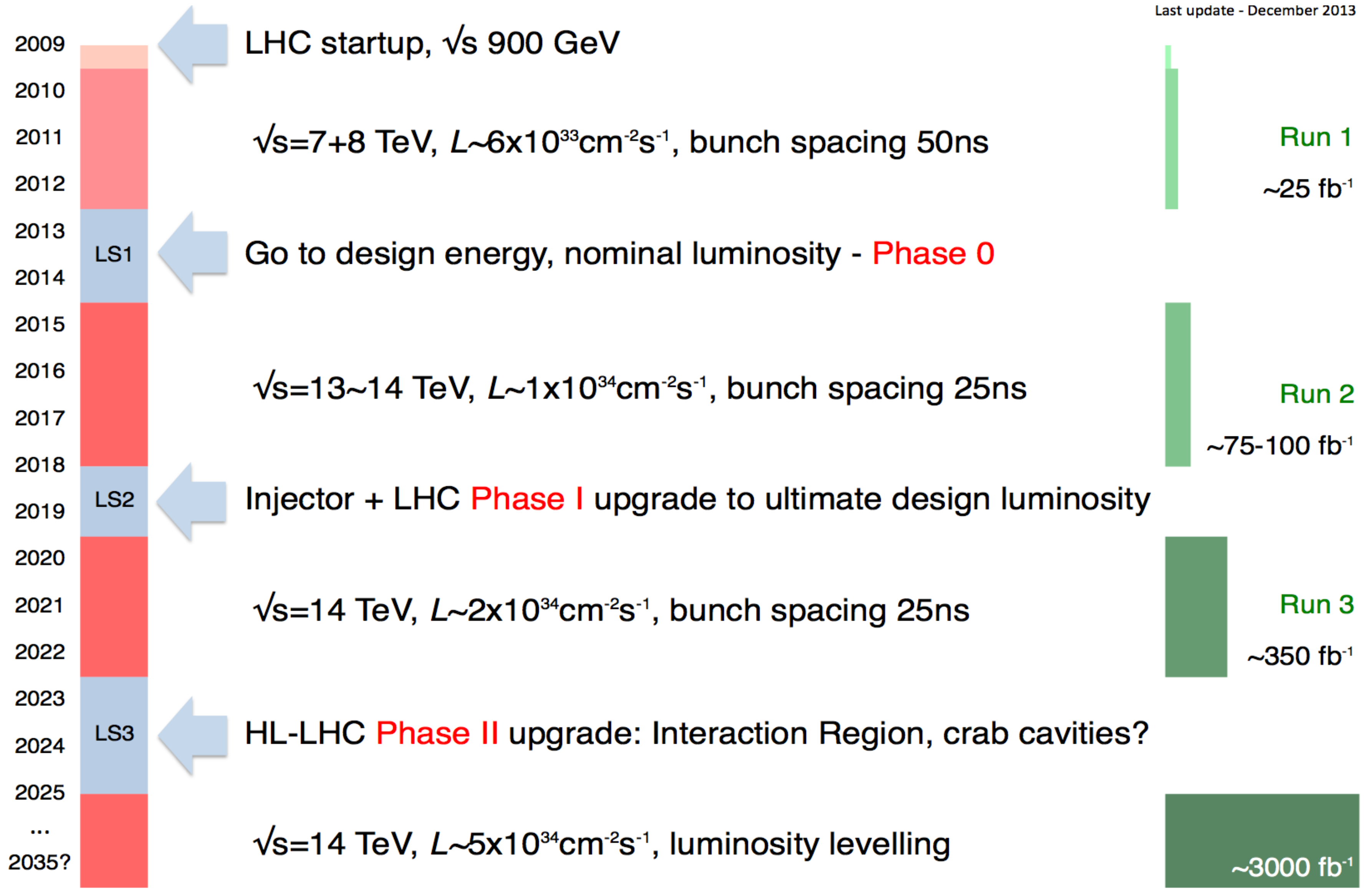
ADD K-factor	Limit	Λ_T (TeV) [GRW]	M_S (TeV) [HLZ] $n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$
$\mu\mu$ and ee, $m_{\ell\ell} > 2.0$ TeV, $\sigma_s < 0.09$ fb (0.10 fb expected) at 95% CL								
1.0	expected	3.99	3.88	4.74	3.99	3.60	3.35	3.17
1.3	expected	4.13	4.13	4.91	4.13	3.73	3.47	3.28
1.0	observed	4.00	3.90	4.75	4.00	3.61	3.36	3.18
1.3	observed	4.14	4.15	4.93	4.14	3.74	3.48	3.30

$$\Lambda_T^{-4} = \begin{cases} M_S^{-4} \log\left(\frac{M_S^2}{M_{\ell\ell}^2}\right), & n_{ED} = 2; \\ \frac{2}{n_{ED}-2} M_S^{-4}, & n_{ED} > 2, \end{cases}$$

Summary of Leptons + MET







Last update - December 2013
2009
2010
2011
2012
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2014
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2020
2021
2022
2023
2024
2025
...
2035?
LS1
LS2
LS3
LHC startup, √s 900 GeV
√s=7+8 TeV, L~6x10³³cm⁻²s⁻¹, bunch spacing 50ns
Go to design energy, nominal luminosity - Phase 0
√s=13~14 TeV, L~1x10³⁴cm⁻²s⁻¹, bunch spacing 25ns
Injector + LHC Phase I upgrade to ultimate design luminosity
√s=14 TeV, L~2x10³⁴cm⁻²s⁻¹, bunch spacing 25ns
HL-LHC Phase II upgrade: Interaction Region, crab cavities?
√s=14 TeV, L~5x10³⁴cm⁻²s⁻¹, luminosity levelling
Run 1
~25 fb⁻¹
Run 2
~75-100 fb⁻¹
Run 3
~350 fb⁻¹
~3000 fb⁻¹