Searches for Exotic Phenomena in CMS
BSM@CMS@LHC

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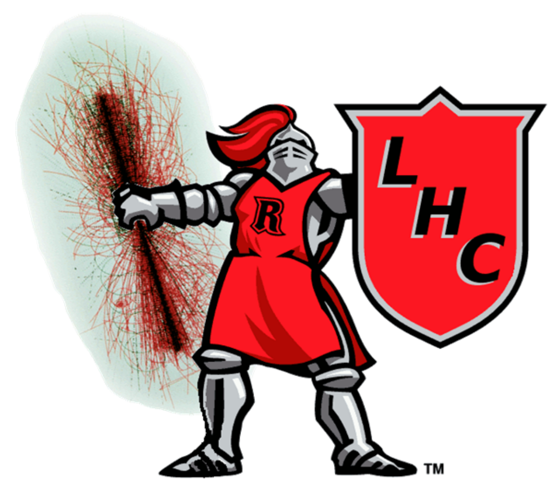
Rutgers University
On behalf of the CMS experiment

Interpreting the LHC Run 2 data and Beyond, ICTP, Trieste.
May27-31, 2019



CMS BSM in this conference

Yesterday: SM and BSM Higgs physics in CMS by Javier Cuevas Maestro

This morning: Recent results from SUSY searches in CMS by Scarlet Norberg
(Thanks for a nice detector/performance overview!)

Tomorrow: Dark Matter searches in CMS by Cedric Gerald Prieels

Also,
Thursday: Near Future Long-Lived Particle Searches at the LHC by Albert De Roeck

This talk: Results from CMS Exotica and B2G (Beyond Second Generation) groups.
(Alternate title: Fifty searches in fifty minutes)

Disclaimers and warnings:

Preference given to recent results (proportional to inverse fb of data)

CMS is responsible for the factual contents. Editorial comments, opinions, and bad jokes are mine.

All theory material is superficial. Lagrangians and $F^{\mu\nu}$s are meant to look me smart.

$L\hbar c$

- The energy frontier (>~ 5 TeV states routinely probed).
- The biggest & most powerful microscope (10^{-19} m)
- A powerful telescope and a time machine that reaches all the way back to 10-100 picoseconds post big-bang.
- Built to study SU2xU1 unification: W/Z mass makes weak interaction "weak".

At the EWSB mass scale (~100GeV), the length scale is proton/1000:

$$\hbar c = 200 MeV\, fm = (100 GeV)(2 \times 10^{-18} m)$$

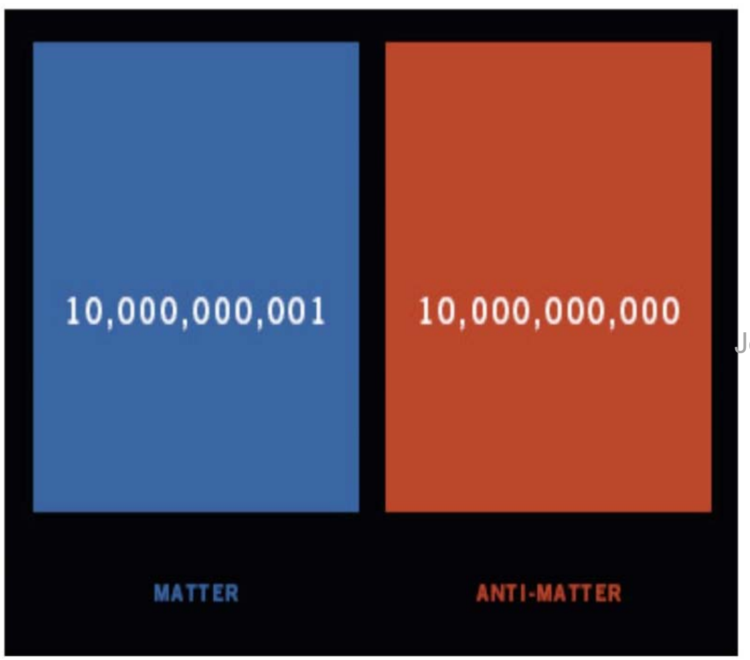
At the contact interaction scale ("are elementary particles point particles?"), the length scale is an order of magnitude finer

$$\hbar c = 200 MeV\, fm = (2 TeV)(10^{-19} m)$$

Fundamental questions for the LHC

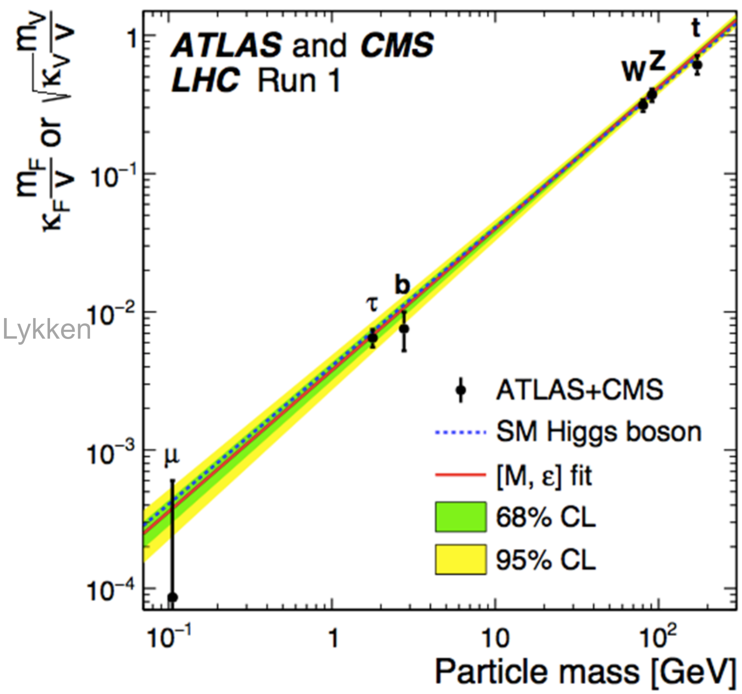
(A view from the theoretical mountain top)

- Is there a Higgs boson? (answered). Is it the Higgs boson? (quite likely, but we hope not.)
- Why is the electroweak scale (so) different from the Planck scale (and on the other side, from the β–decay scale.)
- What (new) physics ruled the day (!) 10-100psec after the big bang? How to explain the 10^{-11} baryon asymmetry?
- What is dark matter?
- Why three generations, flavor…

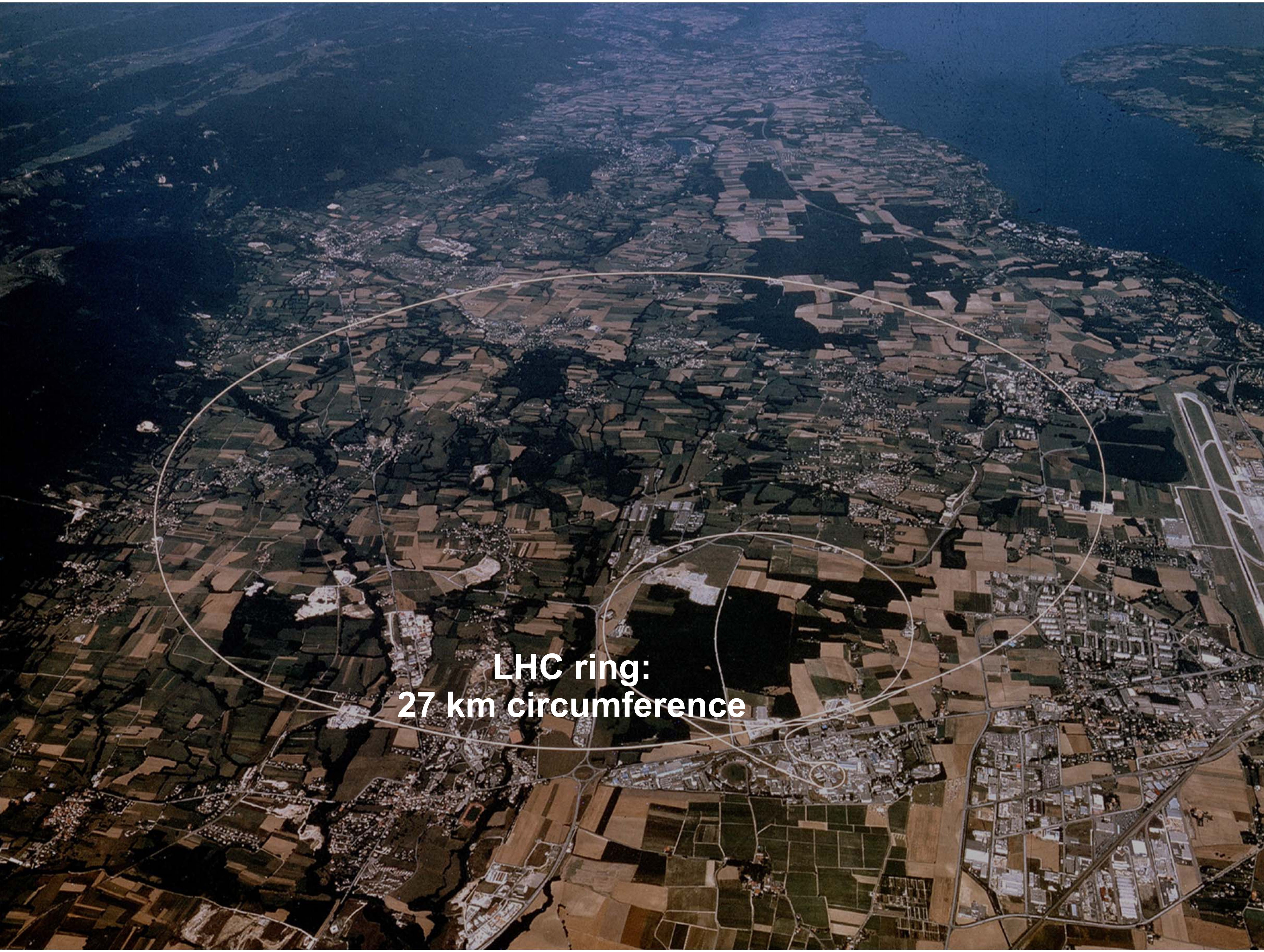


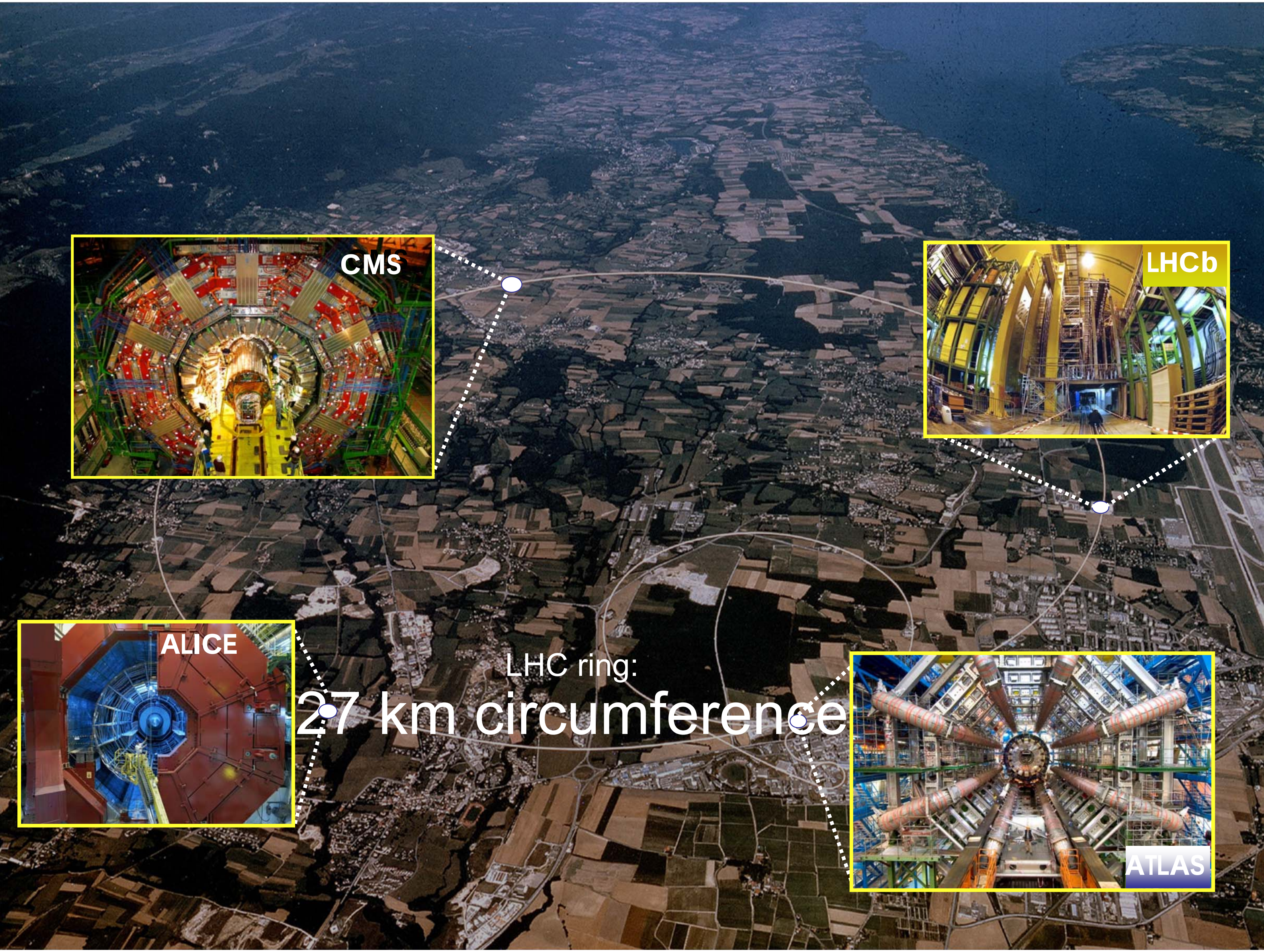
Sunil Somalwar, ICTP'19

Joe Lykken



Higgs is 0^+, and has SM couplings

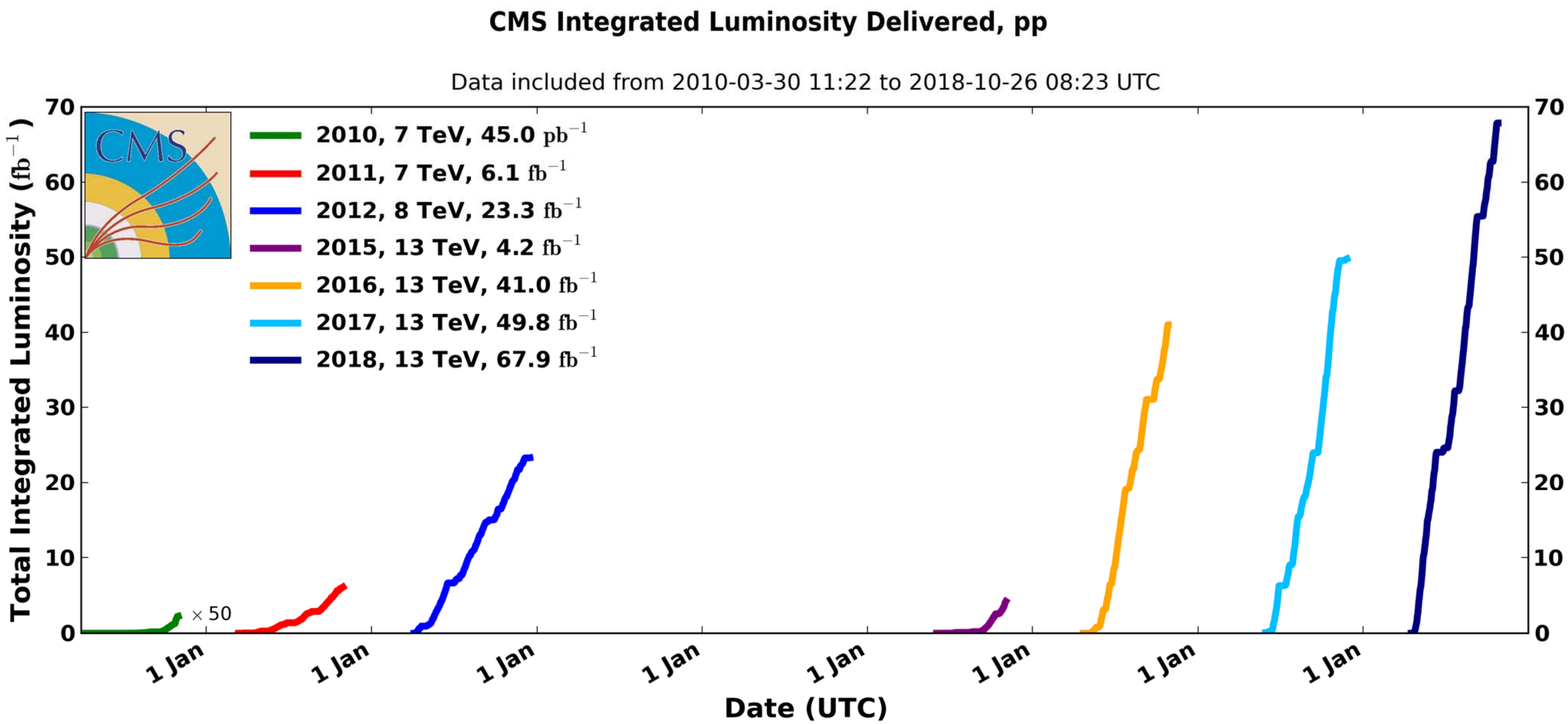

LHC ring:
27 km circumference


CMS
LHCb
ALICE
LHC ring:
27 km circumference
ATLAS

Luminosity and Cross section

- Cross section has units of area, m^2 (size of the microscopic "target" object or process)
- Small cross sections are in units of barn, e.g. picobarn = pb = 10^{-40} $m^2 = (10^{-20}$ $m)^2$
- LHC data is measured in units of *inverse* cross section, called (integrated) luminosity.
- On an average, 1 inverse pb worth of collision data contains 1 event for a process that has one pb cross section.
- [The proton size is roughly a fermi = 10^{-15}m, so it takes a lot of proton-proton collisions to pinpoint a 10^{-18}m needle in the proton haystack.]
- To maximize the rate of luminosity delivery, LHC has dense bunches of protons 25nsec (=25ft) apart from each other in counter-circulating beams. They must collide head on.

LHC Luminosity



- LHC has been running well!
- ~35/pb to ~2500x35/pb in a few years.

Particles Lingo

Tracks, photons, jets

"Leptons": electrons and muons, i.e., charged light leptons

Tau (theorist): Tau lepton, i.e., the heaviest of the charged leptons

Tau (experimentalist): Reconstructed hadronic decay of the tau lepton

Pt: Transverse momentum. Longitudinal quantities often not useful in pp collisions

Missing pt, aka ptmiss, missing ET, MET: due to neutrinos or anything not detectable.

HT/LT: scalar sums of jet or lepton pt's

ST, also effective mass: sum of HT, LT and missing pt

MT: Transverse mass (useful when there is a neutrino)

(pseudo)rapidity: relativistic version of polar angle

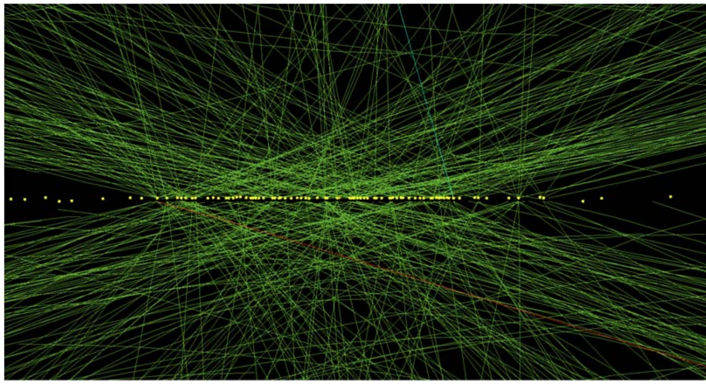
Isolated track/lepton etc: Not much else in a DR around the object

Vertex: Collision location, where most charged particles come from (78 vertices in the picture below)

Pileup: Number of vertices (due to separate pp collisions) in an event.

Prompt: From the vertex, not displaced. (b-jets are displaced)

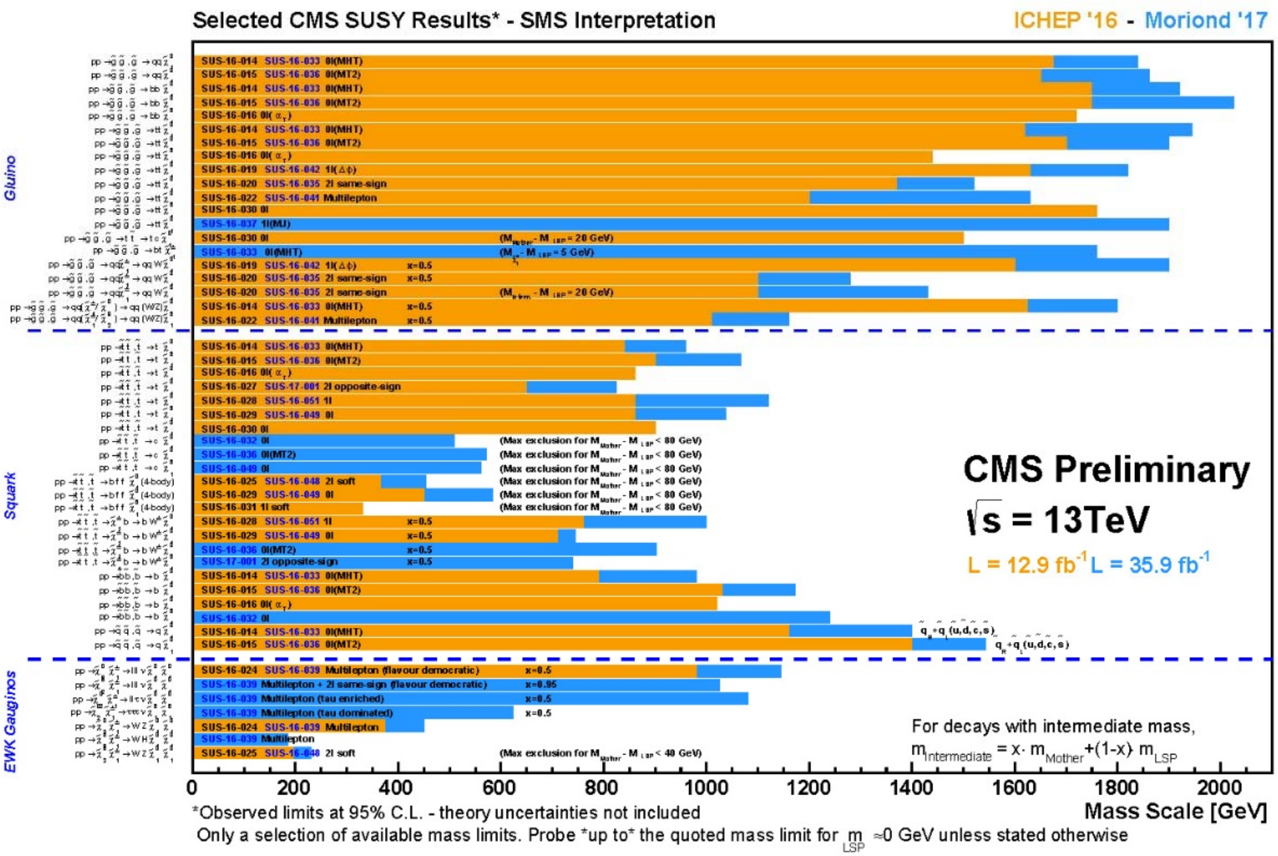
MC: Monte Carlo = simulated events



Is there a preferred way to break the SM?

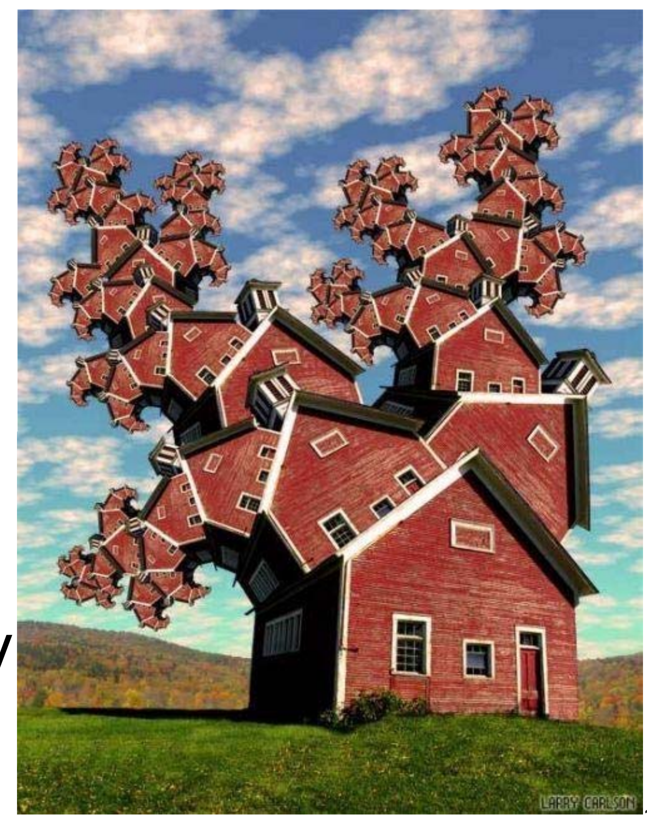
- Go for the highest possible mass reach. New particles: dijet resonance, W’, Z’, boosted….
- Programmatic, e.g., Supersymmetry. R-parity? Or ask questions.eg: Top quark is the heaviest particle we have. Does it decay unusually, e.g. top quark → charm quark + higgs? Maybe the new particles are long-lived.
- For the first time since the 1970’s, the experimentalist playground is unsupervised by theorists. (W/Z, top, higgs were anticipated.)
- Stick to the electroweak scale (100-200GeV)? Maybe there is a higgs ghost (or two). *(Would the SM higgs have been discovered by now if it(s properties) were not anticipated?)*
- Keep hammering at the Standard Model (what else is there?) to seek Beyond Standard Model physics.

BSM: supersymmetry status



- squarks/gluinos
- electroweak/electrohiggs
- 3rd generation
- RPC/RPV, long-lived
- Compressed spectra
- tau's…

$$[Q^\alpha, H] = i\overline{f_u}$$



House of susy signatures

One slide on "exotic" models

- ED, ADD: ADD model has 4+n dimensions but only gravity in Extra Dimensions. Exchanged virtual KK graviton modifies SM.

- W'/Z'/HVT: Simplified Heavy Vector Triplet model(s) for W'/Z'.
  Model A: weakly coupled vector resonances from gauge group extension.
  Model B: strong scenarios (composite Higgs models)

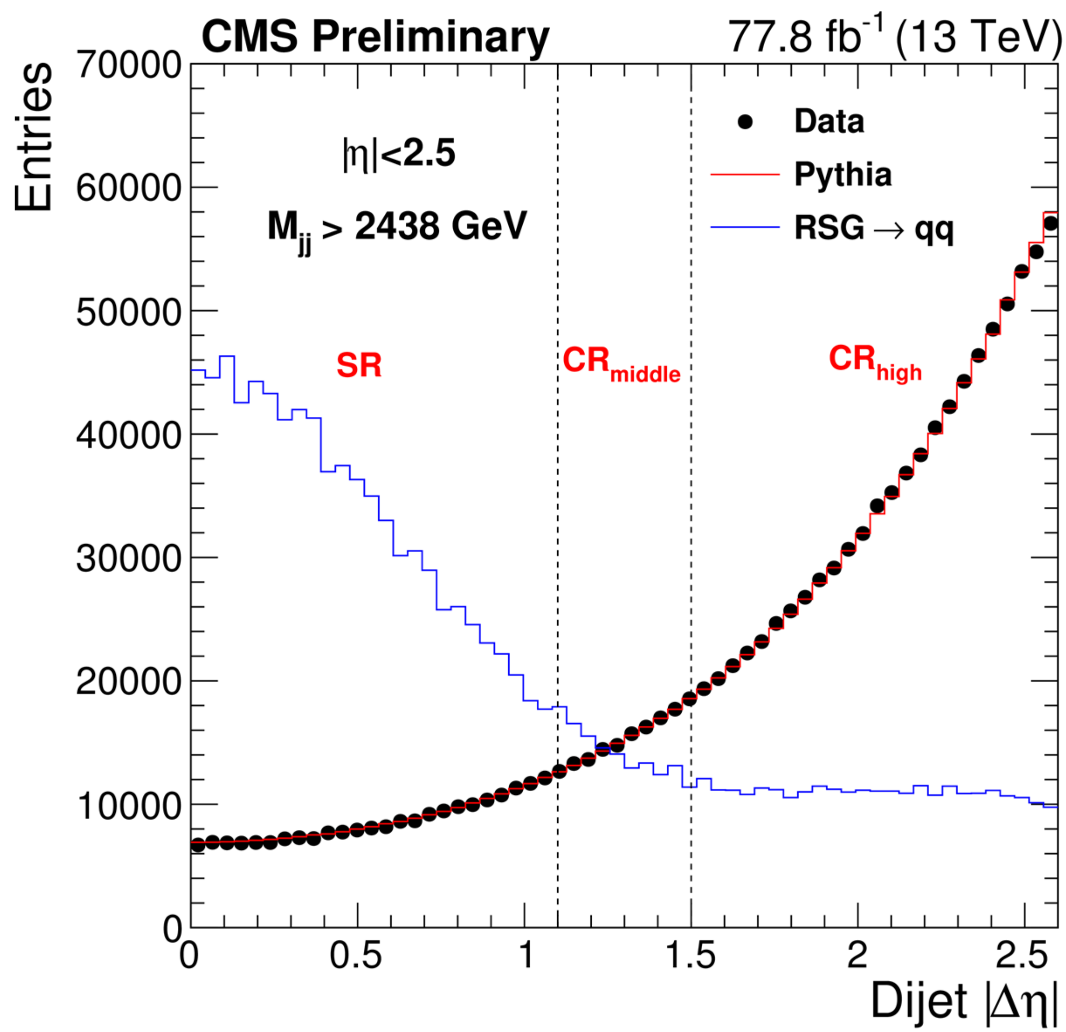
- VLQ/VLL: Vector like quarks/leptons. Workaround for particles formerly known as 4th generation. BR's are free parameters, e.g. b'$\rightarrow$tW, bZ, bH.

- Seesaw: Heavy partners who keep neutrinos light. Several models bring the mass down from Planck scale to LHC. Prolific processes which generate them in association with leptons, W/Z/H. (more later)

- Dark Matter @ collider: Brute force version of the SUSY LSP (neutralino). Produce a Z'-like mediator against a hefty recoil, decay to invisible DM pair. Also, direct production (e.g. susy neutralino), long-lived particle search.

Dijet resonance (high mass, no substructure)
(CMS EXO 17-026)

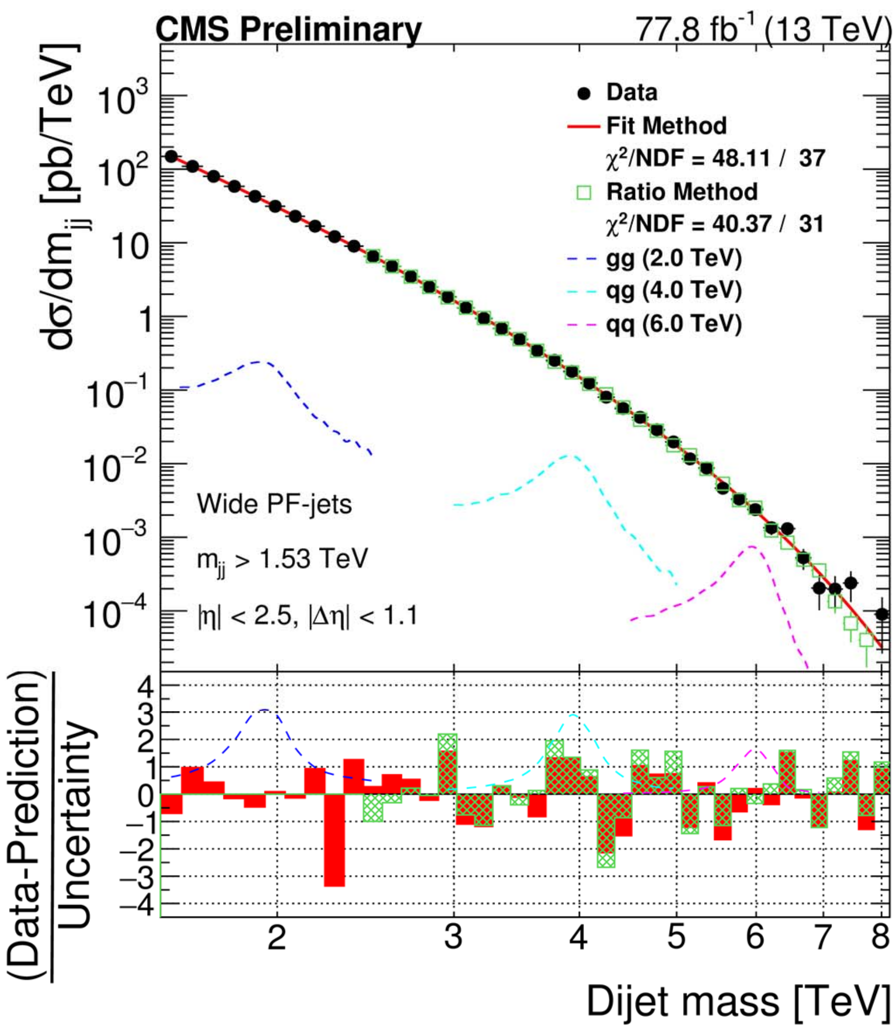
- Signature: pp → Z' (etc) → qq
- Background: QCD estimated with data-validated MC transfer function from CR-high to SR. Consistent with and better than the parametric fit. CR-middle for higher correction.
- Data: 78/fb (2016+17)

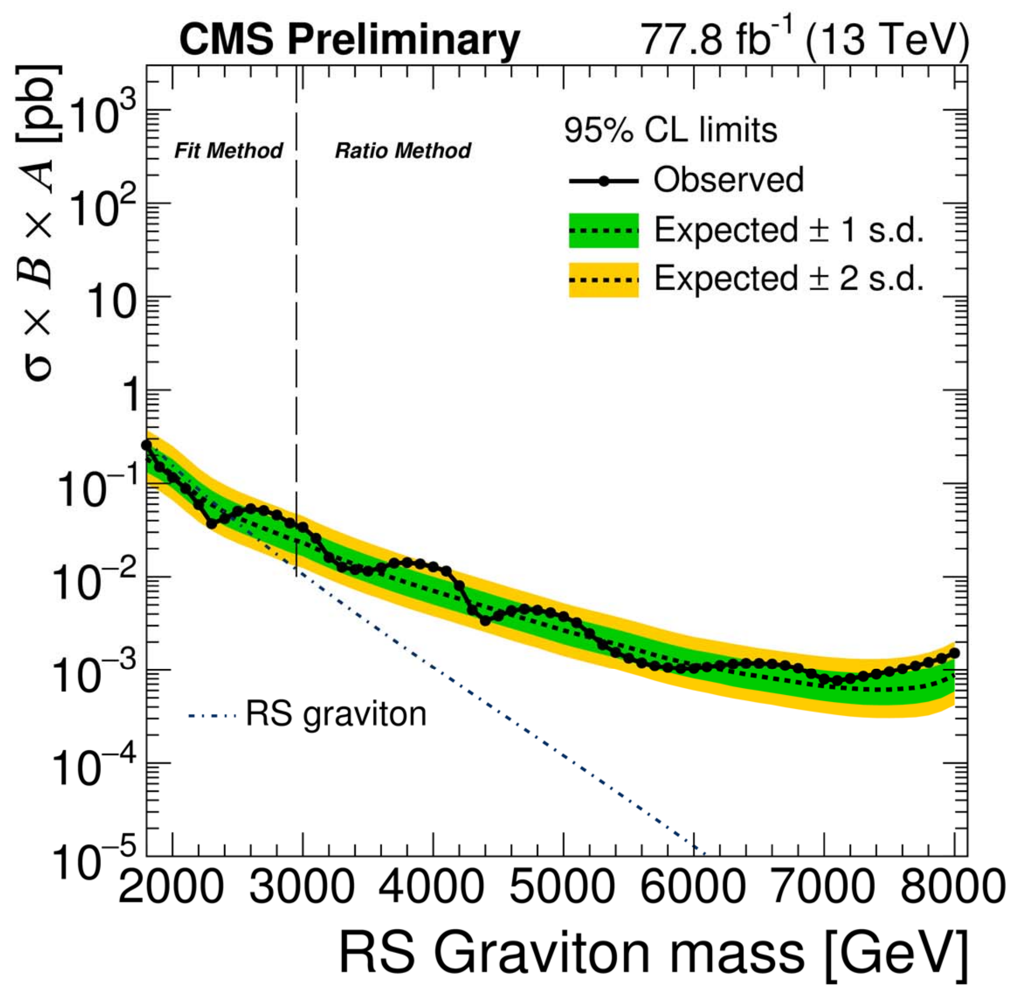


Dijet resonance (high mass, no substructure)

(CMS EXO 17-026)

This is as close to Geiger-Nuttall plot as we get in terms of orders of magnitude covered

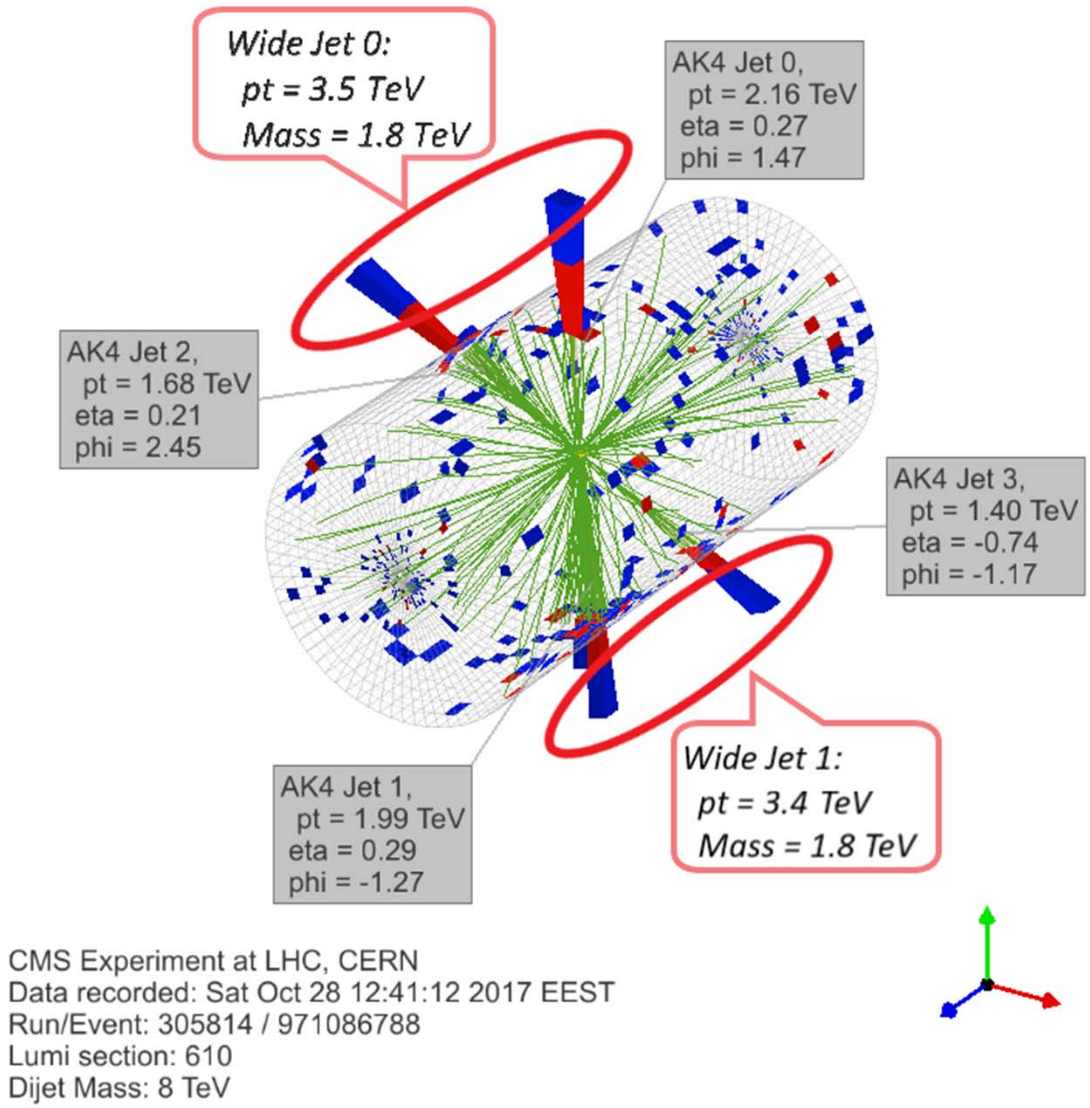


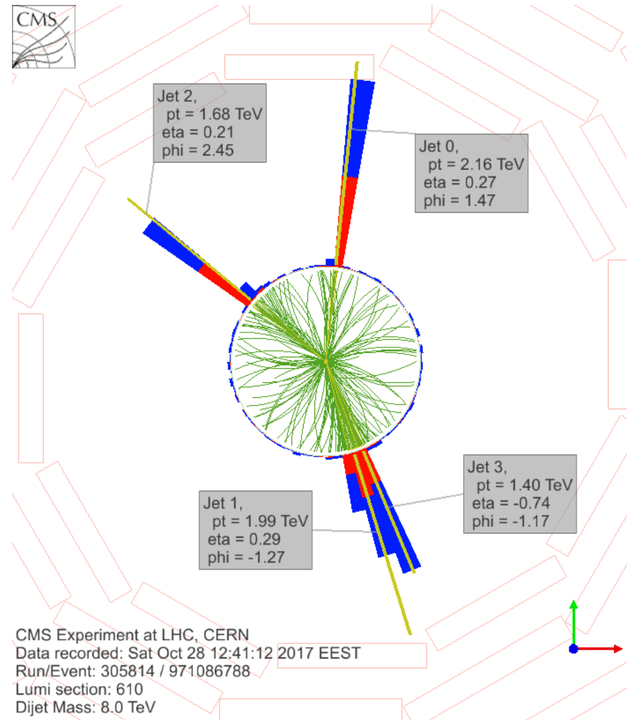


Dijet resonance (high mass, no substructure)

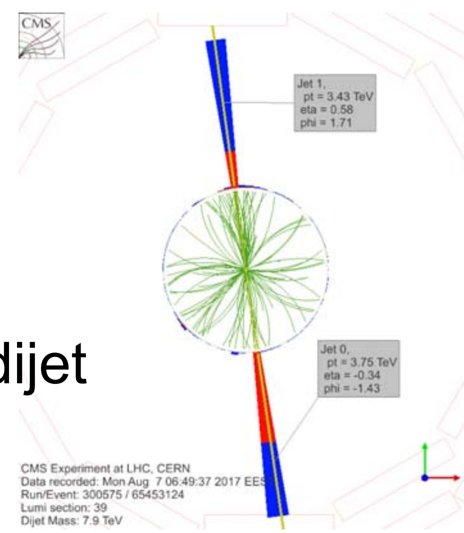
(CMS EXO 17-026)

8TeV dijet





…and a 7.9TeV dijet

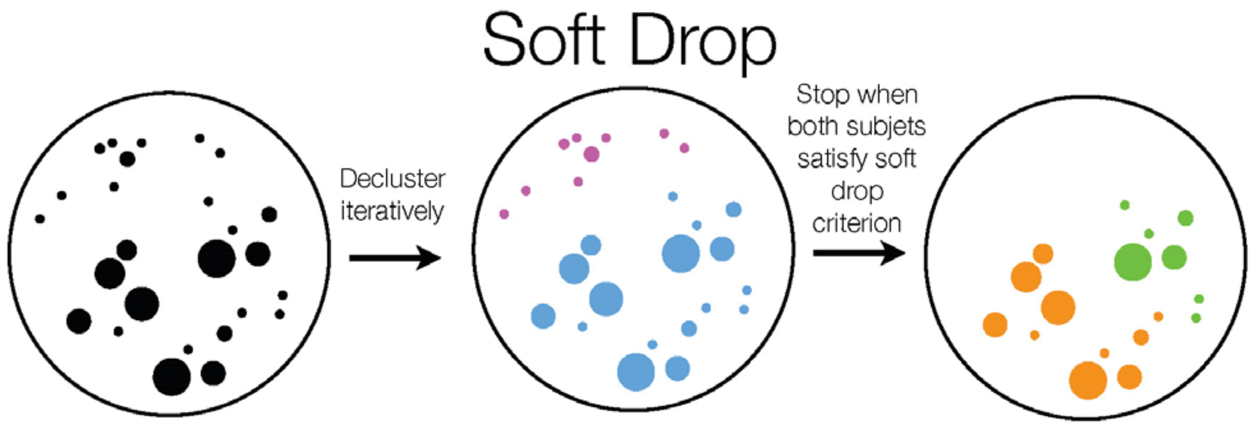


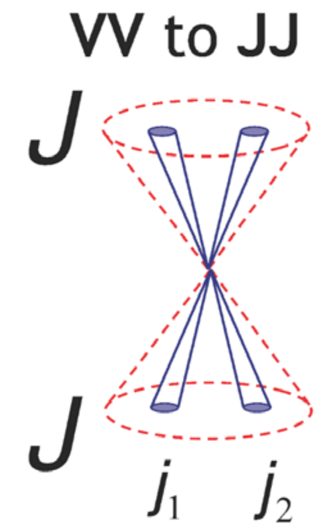
Jet substructure

Terminology: Boosted/merged fatjet/large-R, AK10 & D2. Resolved jet
→substructure. Puppi, pruning, subjettiness (=3 for top, 2 for W/Z), tau2/tau1, etc

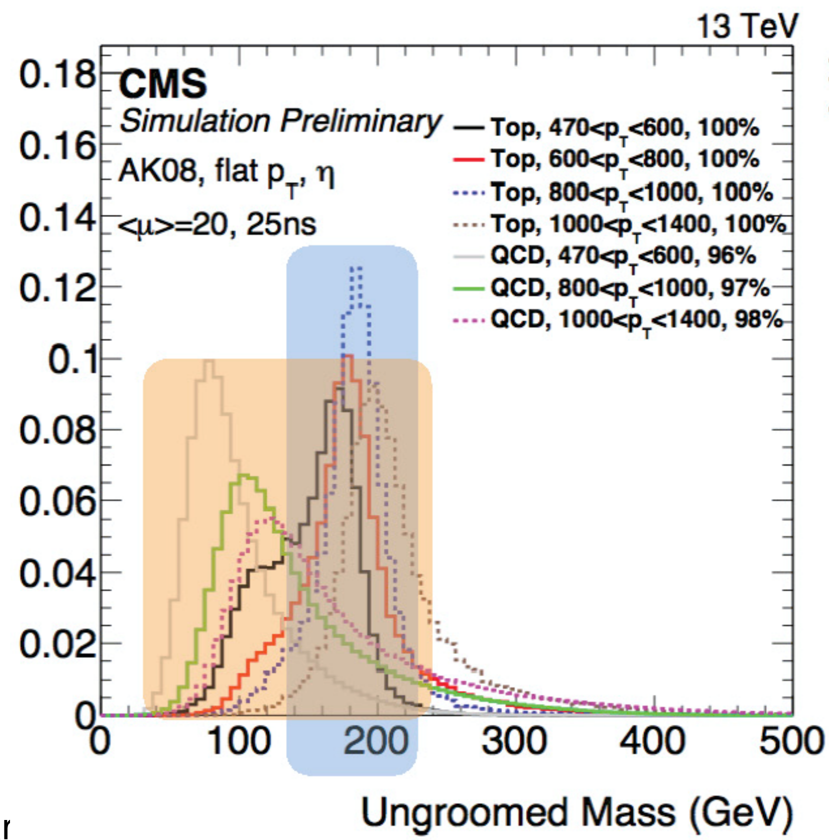
X tagger

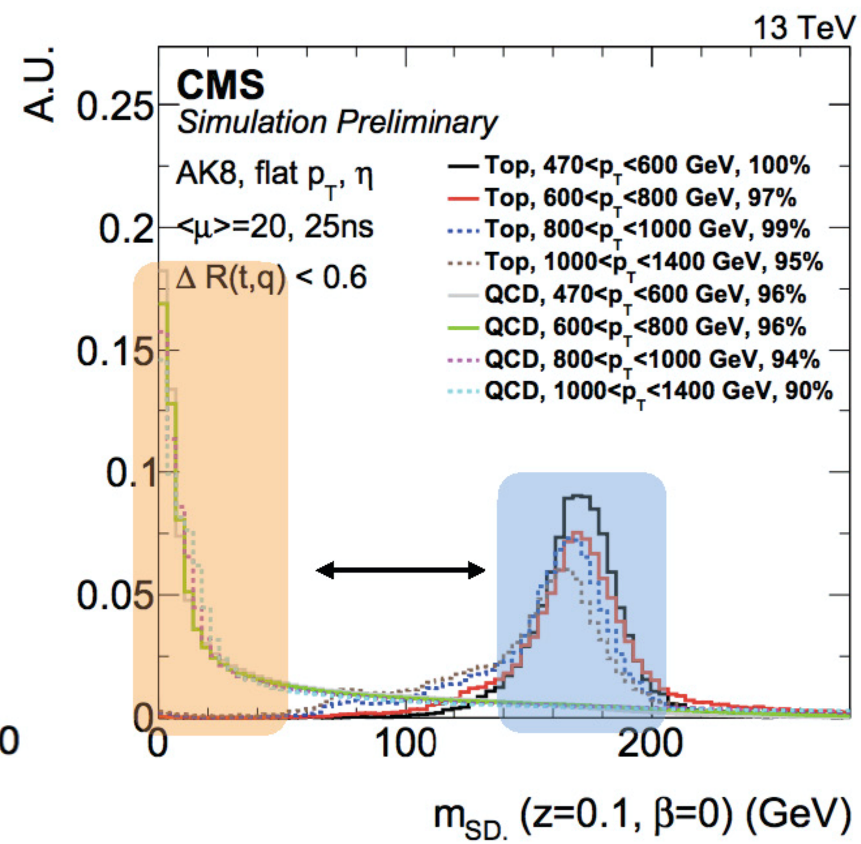
(X=W,Z,H,t)





Merged-top separation from QCD after grooming





Thx: Robin Erbacher

Editorial lament: why are substructure analyses flourishing lately?

- A statement that the hierarchy problem is getting worse
  - Using a 13000 GeV machine for a 100 GeV problem!
  - We haven't seen pp → X → V/H with MX ~< 500GeV.
  - As MX climbs to ~1-2 TeV, boosted V/H → substructure!

- Similarly: Using an ISR jet for efficiency/triggering (sacrificing cross section)

- Are we missing something below ~500GeV?

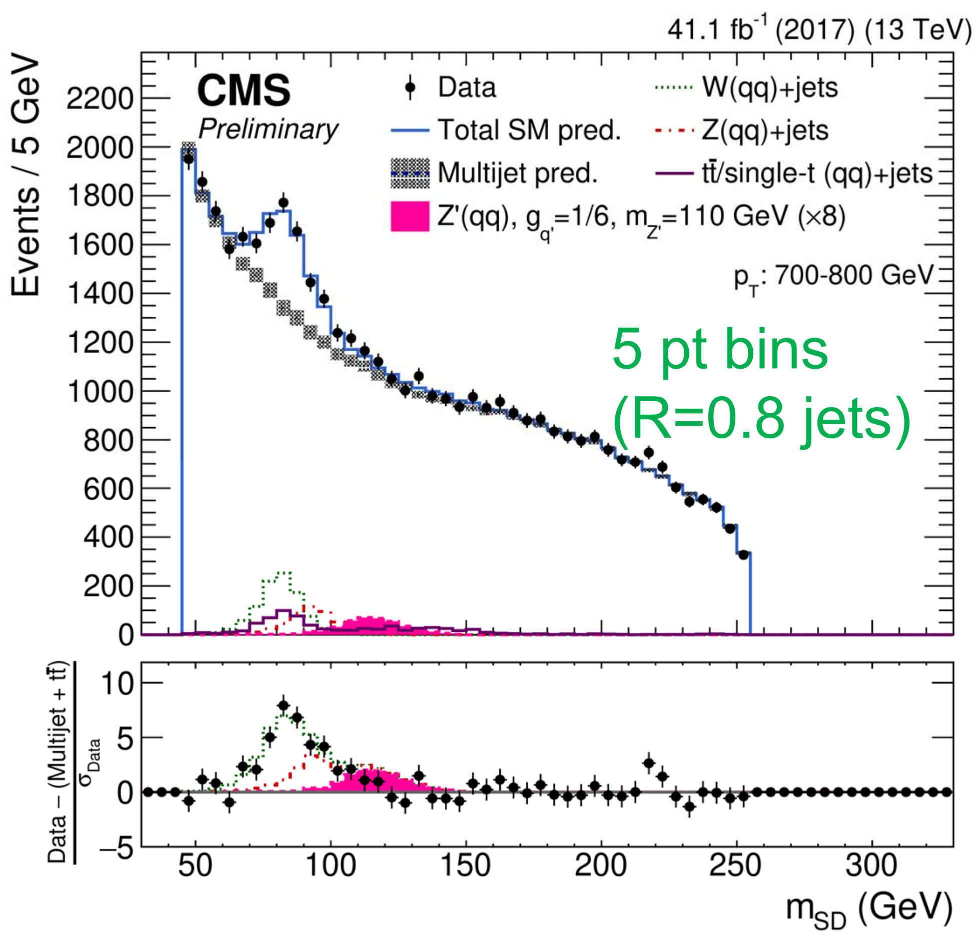
(Later: inclusive searches focusing on the EWSB mass scale)

Dijet resonance (low mass → boosted)

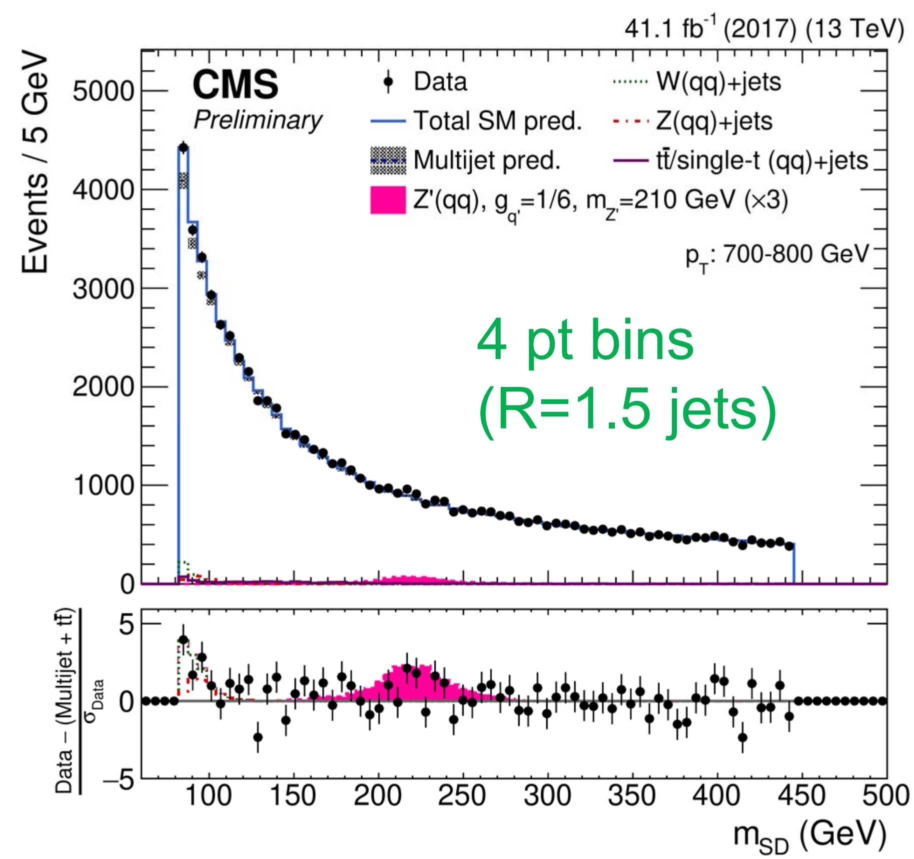
(CMS EXO 18-012)(updated/improved exo-17-001)

- Signature: pp → Z' + ISR jet → (qq) + jet. Merged dijet (from Z'). (50-450GeV mass)
- Trigger: With a hefty ISR jet
- Background: QCD
- Data: 77/fb (2016+2017)

2016: R=0.8 jets
2017: Also R=1.5 jets



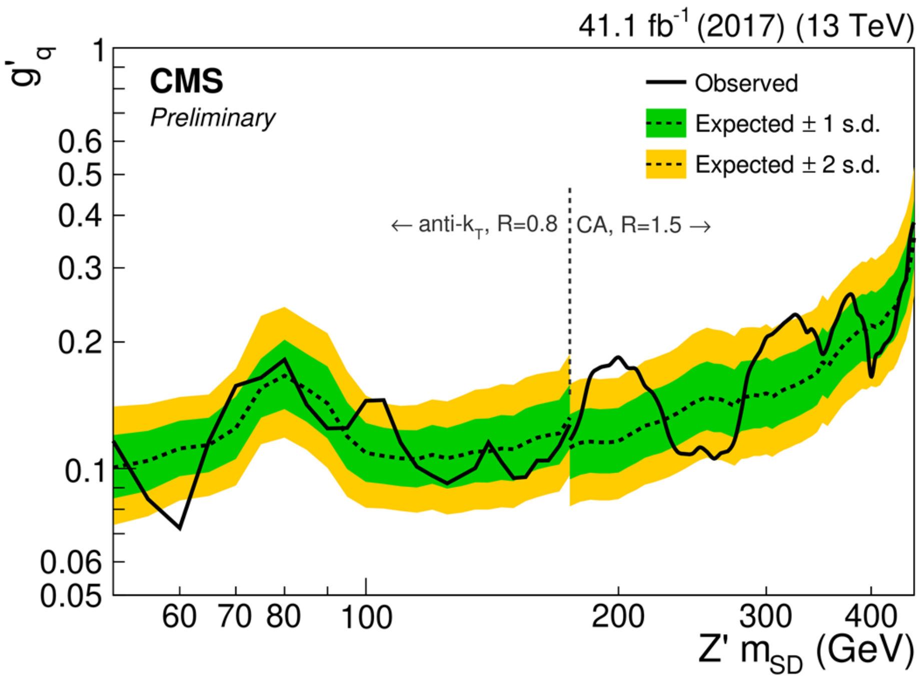
5 pt bins
(R=0.8 jets)



4 pt bins
(R=1.5 jets)

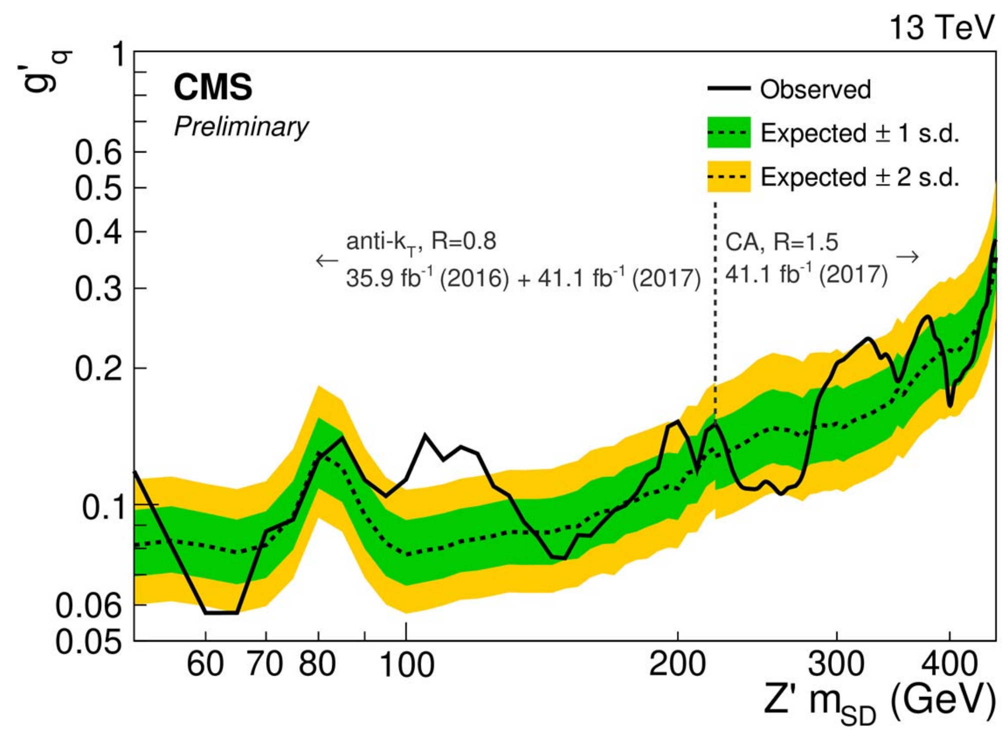
Dijet resonance (low mass → boosted)

(CMS EXO 18-012)(updated/improved exo-17-001)



←2017 only
Both 0.8 and 1.5 jets

Combined →
(transition to get best sensitivity)



When is a bump not a bump? If it moves

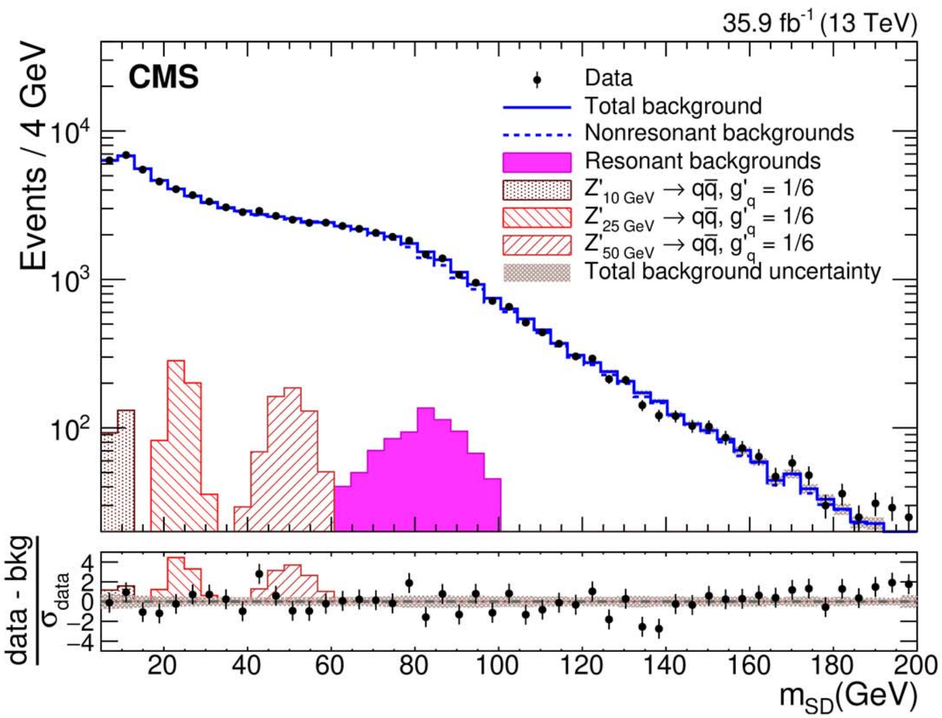
How low can you go? (in mass)

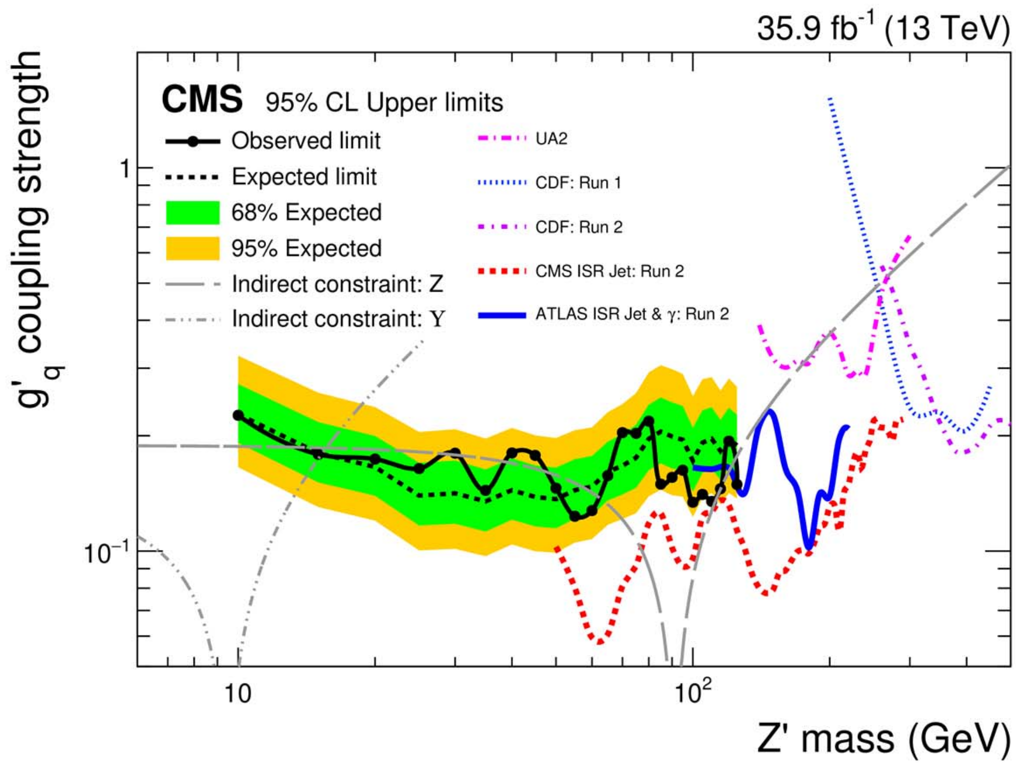
>>>> Use an ISR photon for triggering purposes

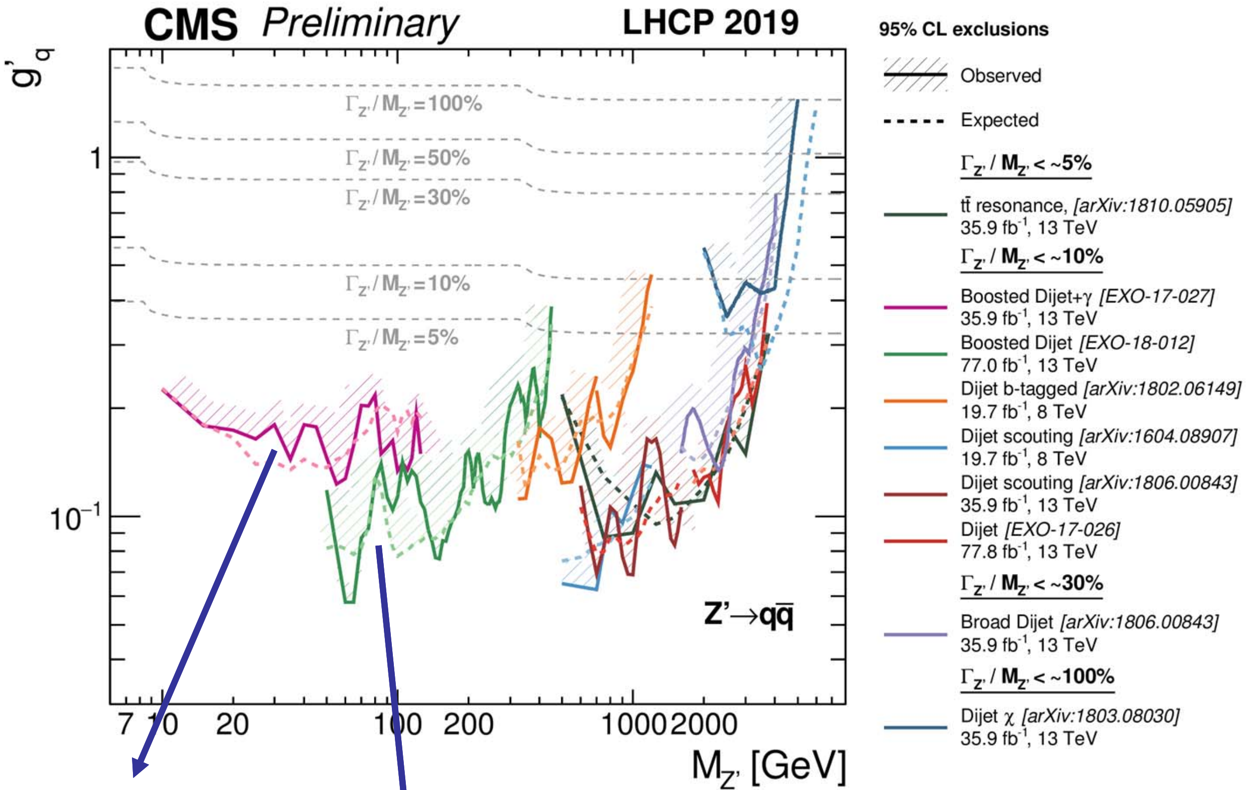
Dijet resonance (very low mas)

(CMS EXO 17-027)

- Signature: pp → Z' + ISR photon. Merged dijet (from Z') down to 10GeV mass
- Trigger: With a hefty ISR photon (pt>175GeV)(offline 200GeV)
- Background: QCD   Data: 36/fb (2016)

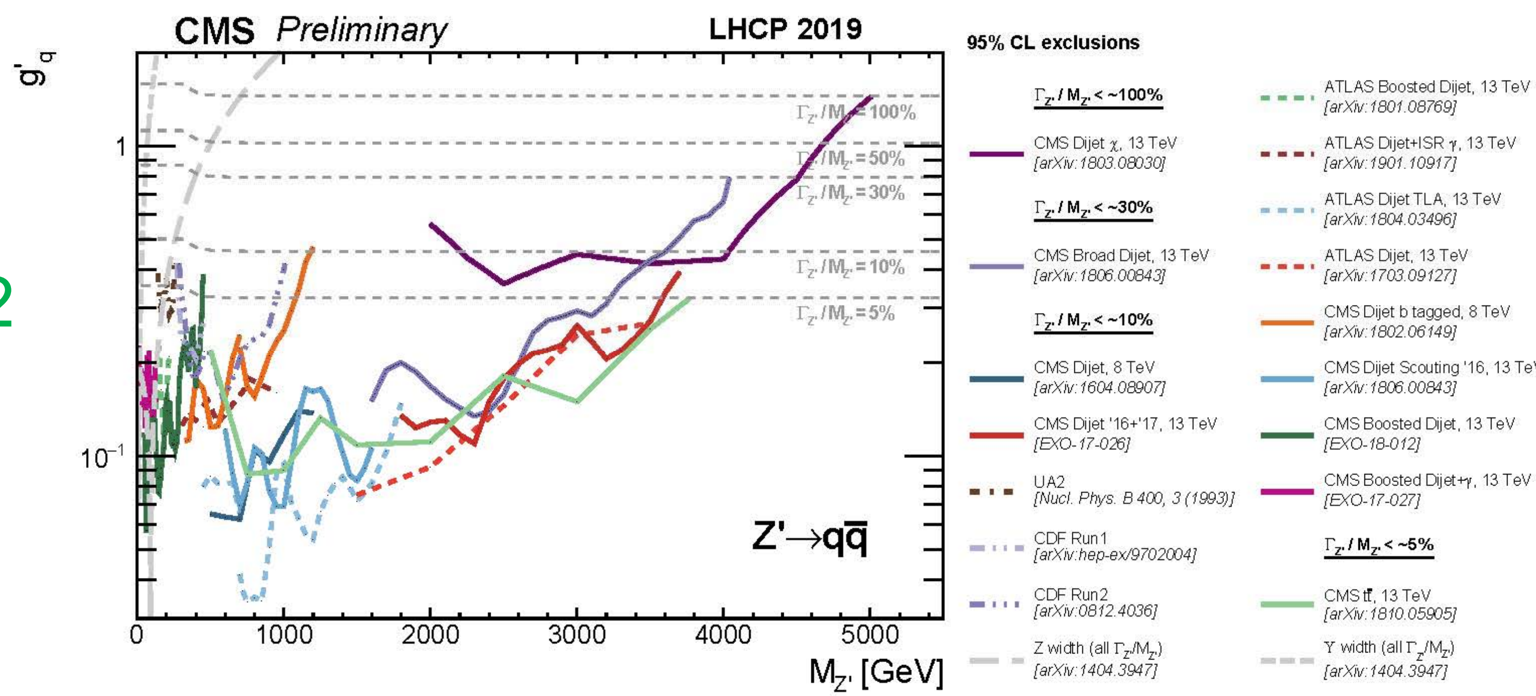






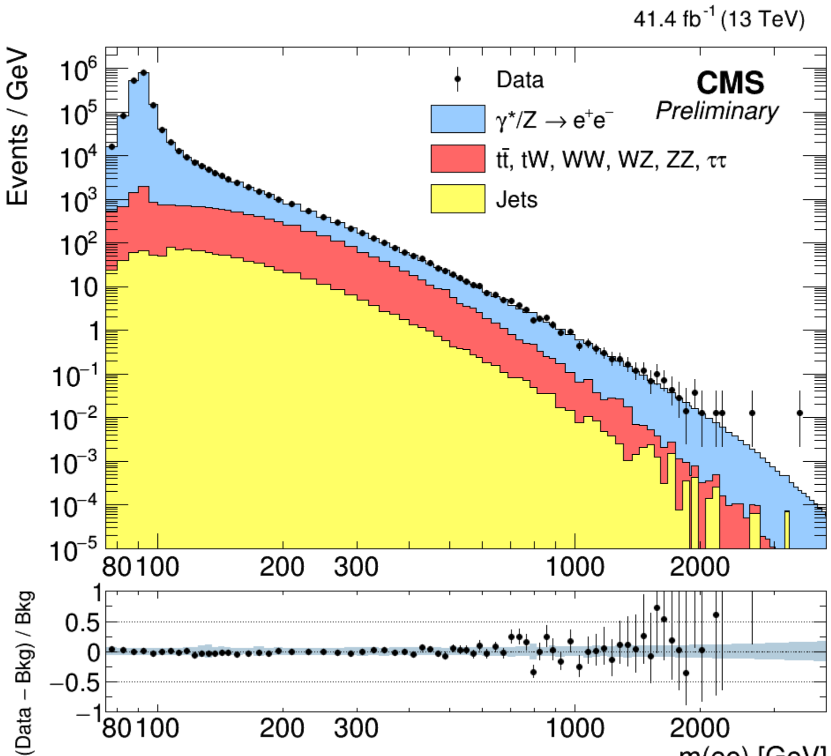
EXO-17-027

EXO-18-012

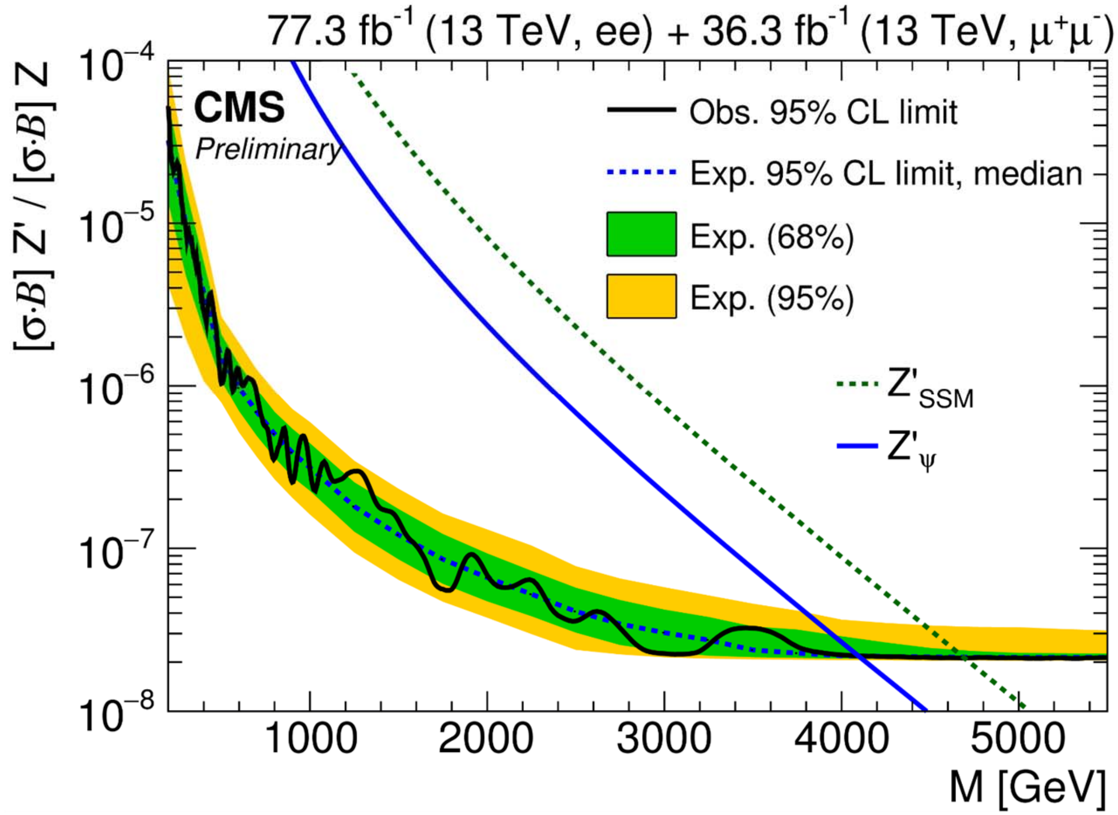


High Mass Resonant Dielectrons (36+41 fb^{-1})

(CMS EXO-18-006)



Pt>35GeV



Z'ψ – GUT E6

- Vector-Like Quarks (VLQ)
- Vector-Like Leptons (VLL)

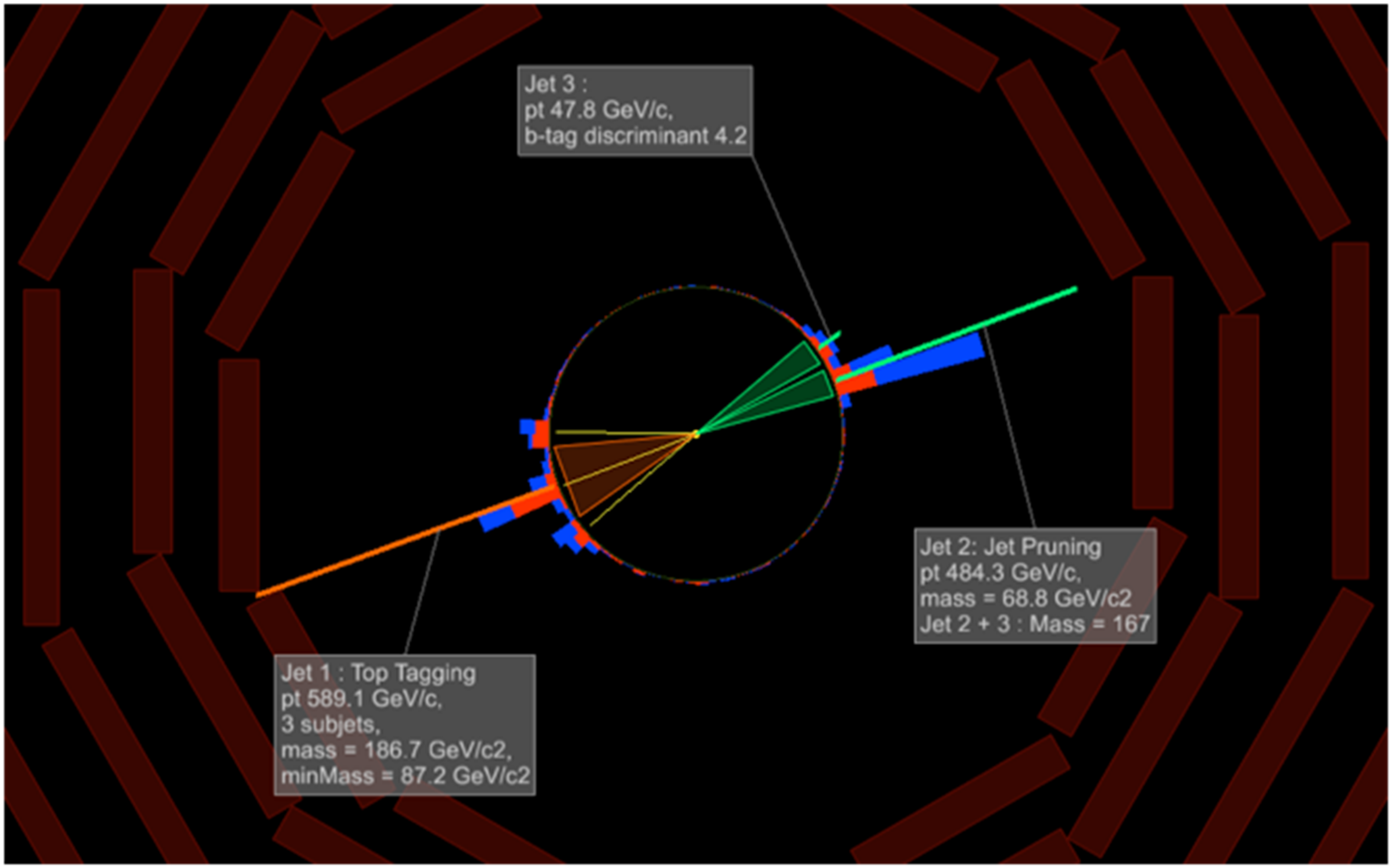
searches formerly known as the 4th generation

VLQ B→ tW,bZ/H
VLQ T→ bW, tZ/H

As VLQ mass reach keeps going up,

- Boosted W/Z, top, Higgs
- VLQ Pair-production → → Single-production
- …. And (new physics)^2

Triple tag ttbar → [t→qqq] + [(W→qq)+b]



BEST: Boosted Event Shape Tagger (fully hadronic)

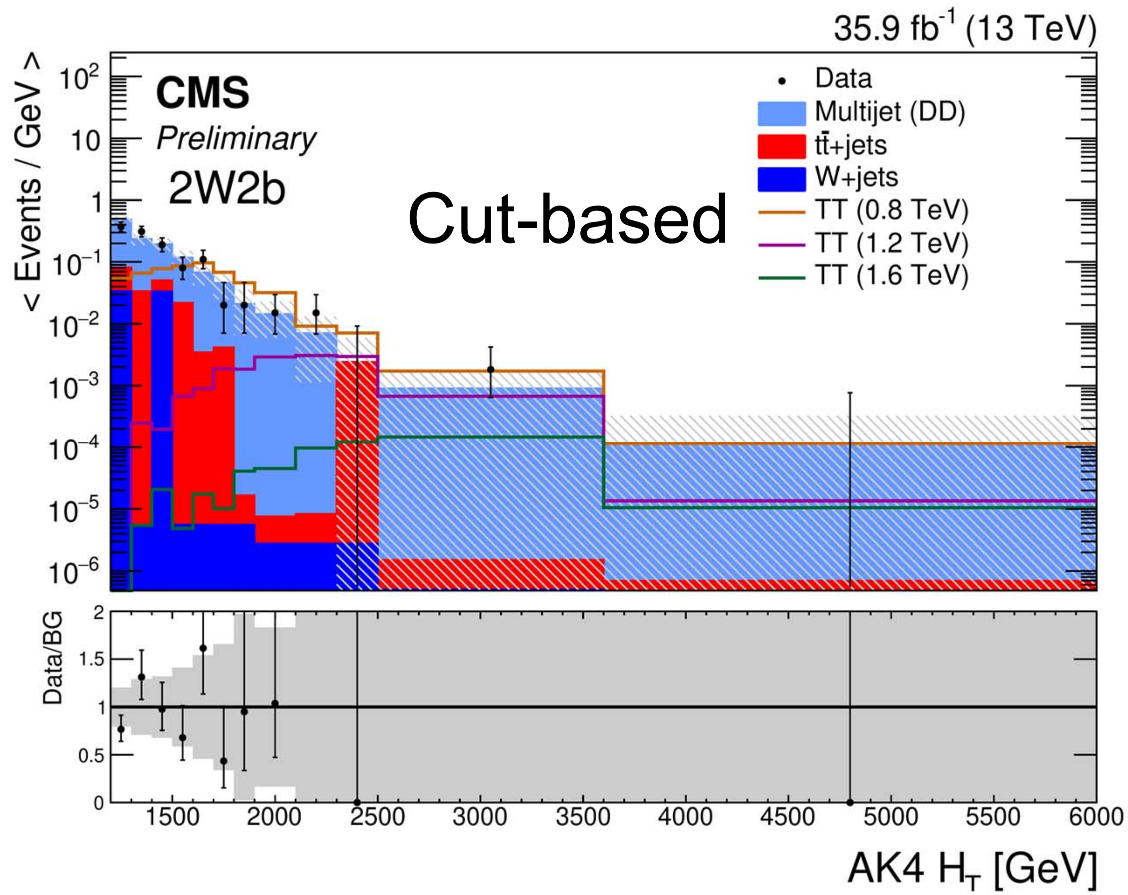
(B2G-17-005)

PAIR

- Signature: a) heavy object multiplicity + HT, b) T→bW cut-based
- Substructure: AK8 t,W/Z,H
- Backgrounds: QCD, Data-driven
- Physics/Models: B and T
- Data: 35.9/fb (2016)
- Machine Learning: Neural Nets

  (and cut-and-count as well)

  (6 jet categories t,W,Z,H,b,light) for (a)

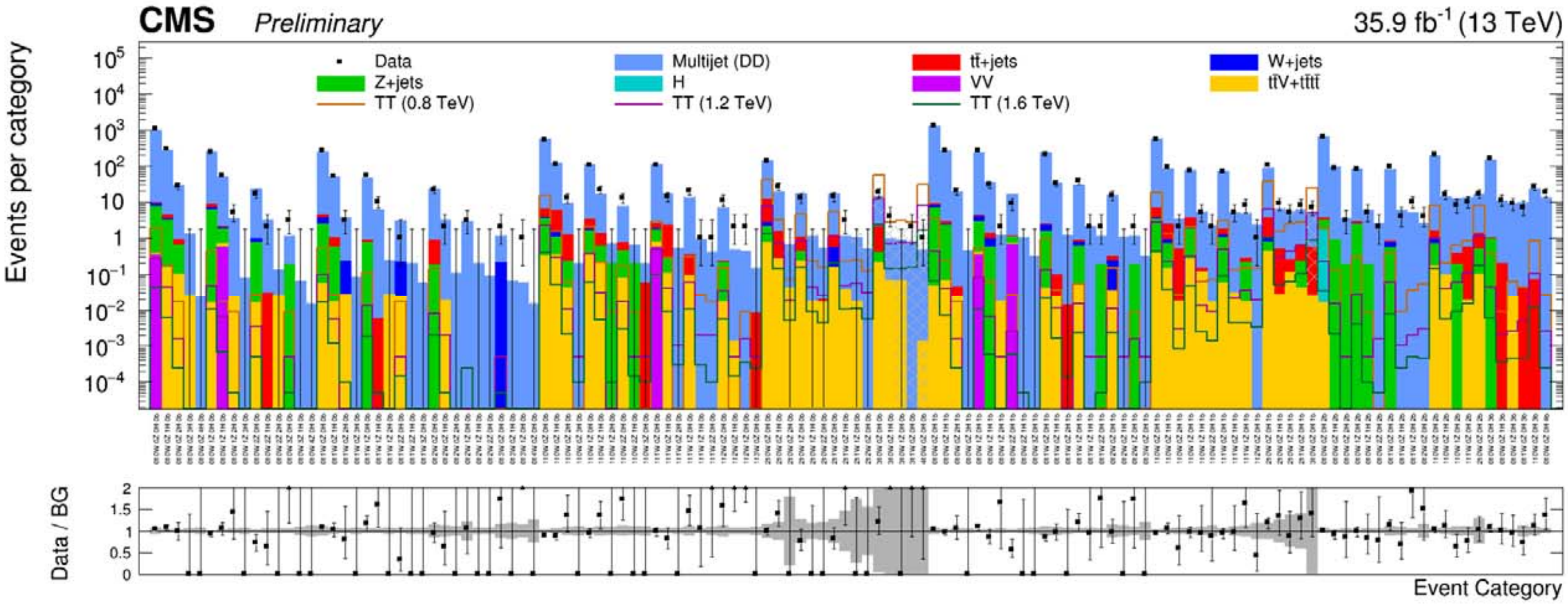


- Cut based search better for T→b+W and B→b+Z.
- NN does better with T→t+Z/H and B→tW,bH modes (i.e. with t or H in the final state)

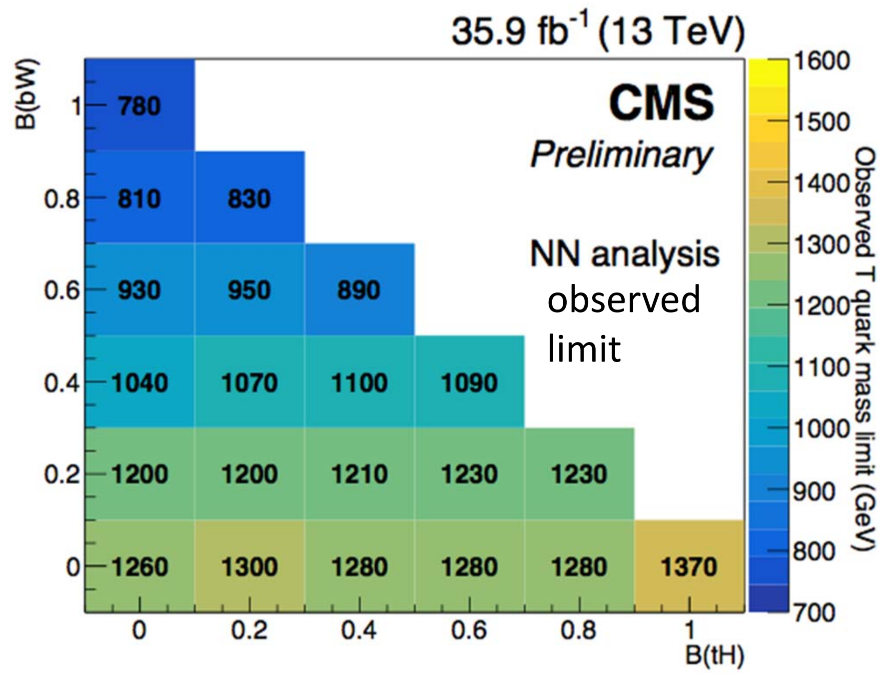
BEST: Boosted Event Shape Tagger (fully hadronic)

(B2G-17-005)

PAIR



NN-based



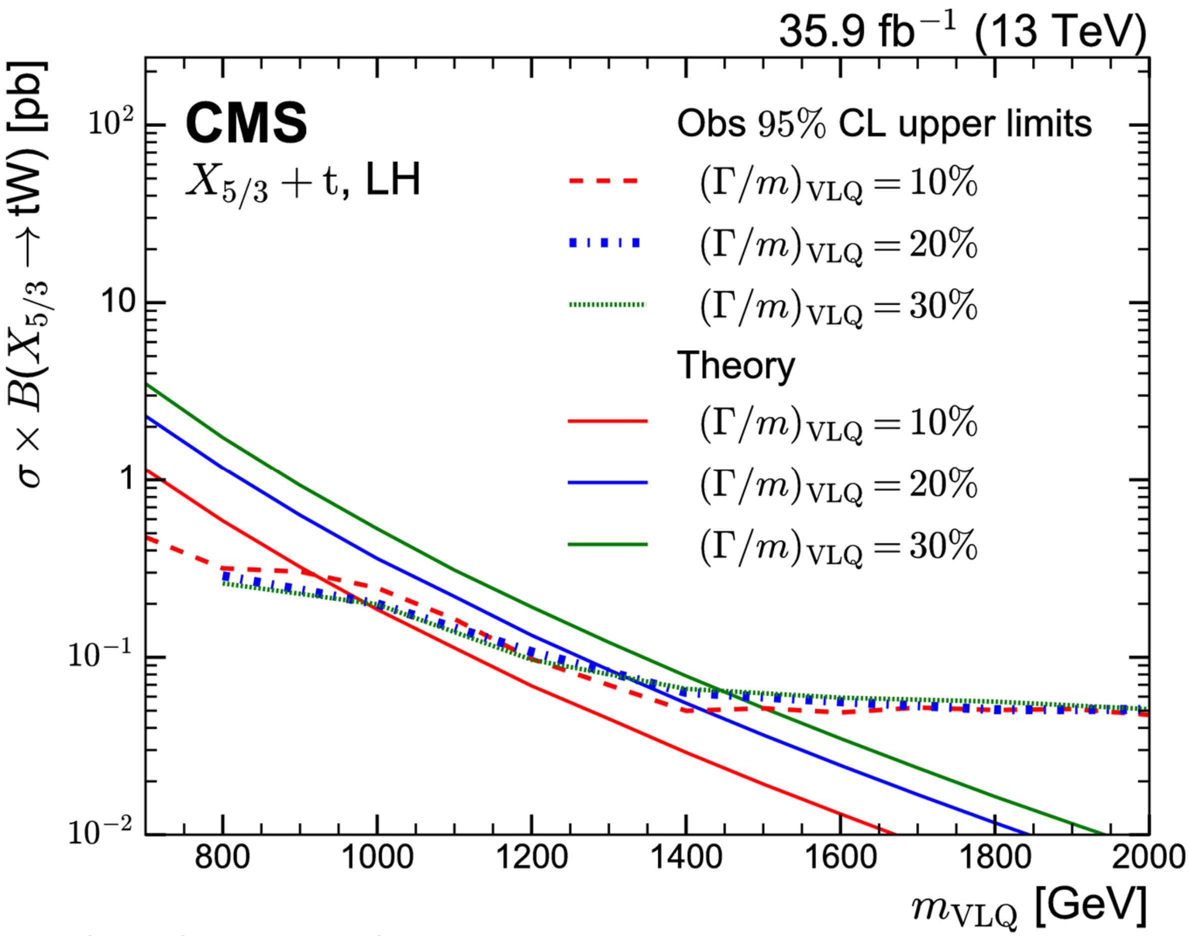
NN analysis observed limit

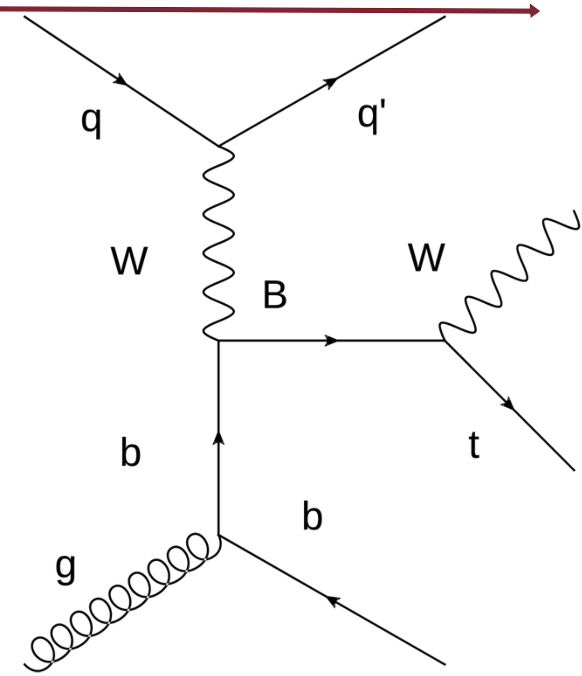
B/$X_{5/3}$ → tW lepton+jets
(B2G-17-018)

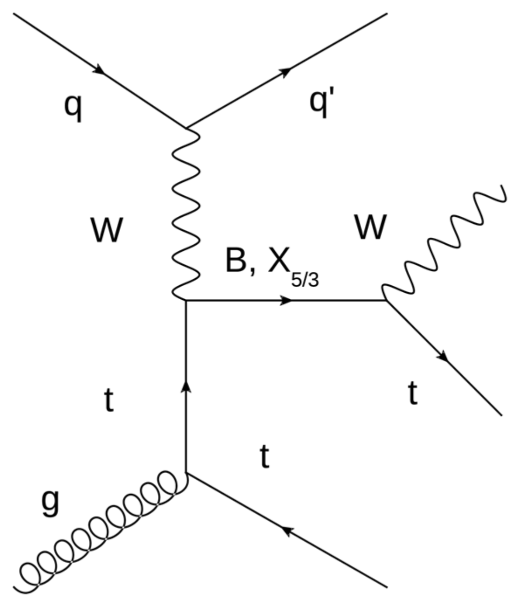
SINGLE

Boosted W or top, MET, high pt lepton (form ST) 2016

Varying widths in limit

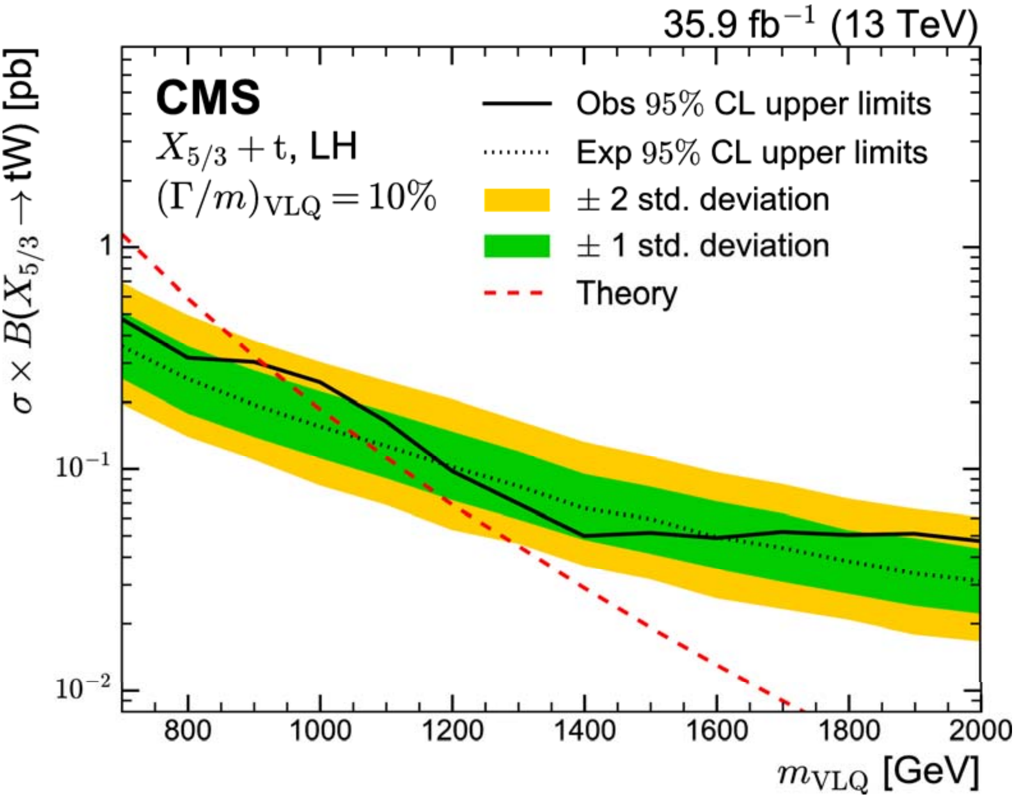


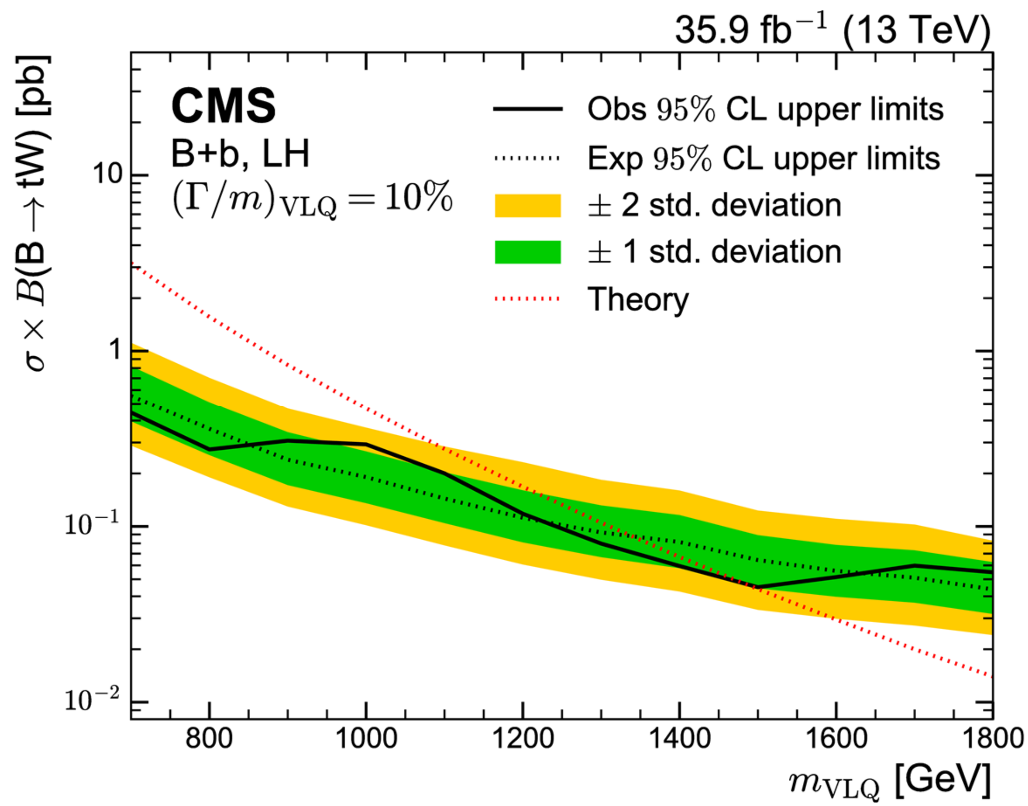




$B/X_{5/3}$ → tW lepton+jets
(B2G-17-018)

SINGLE





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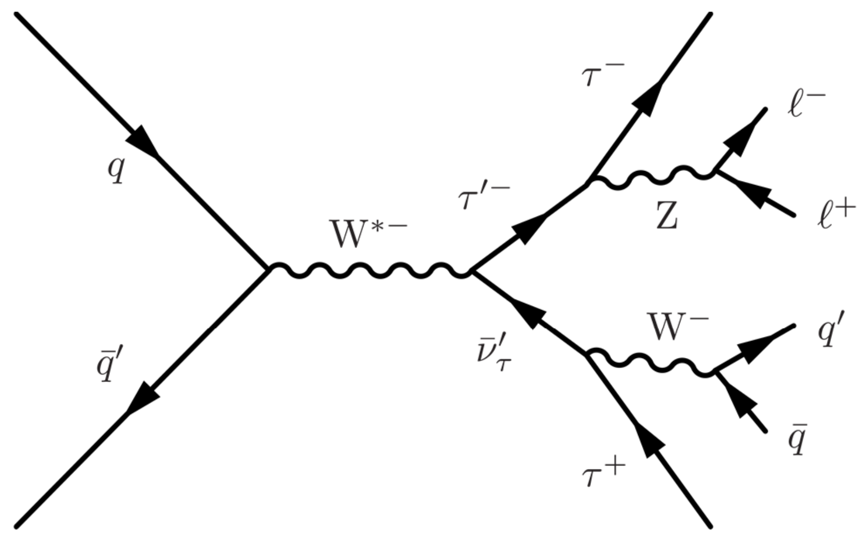
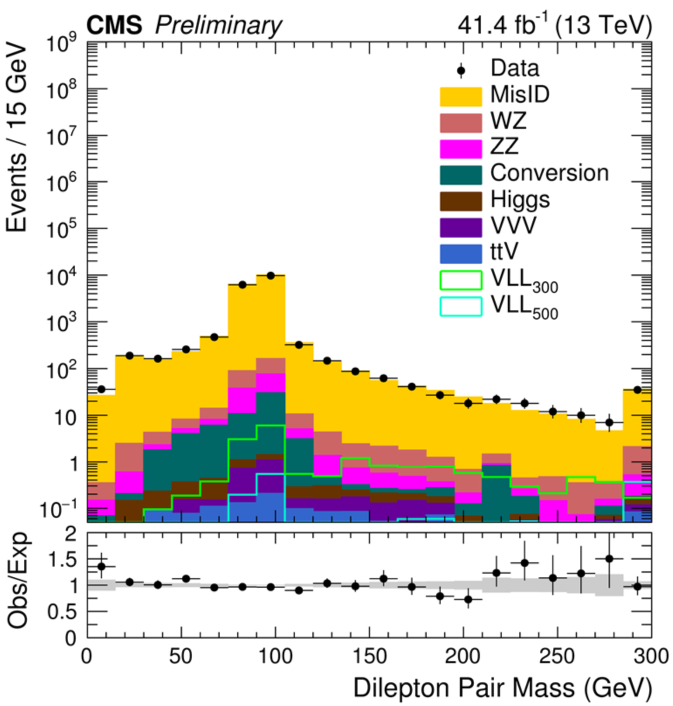
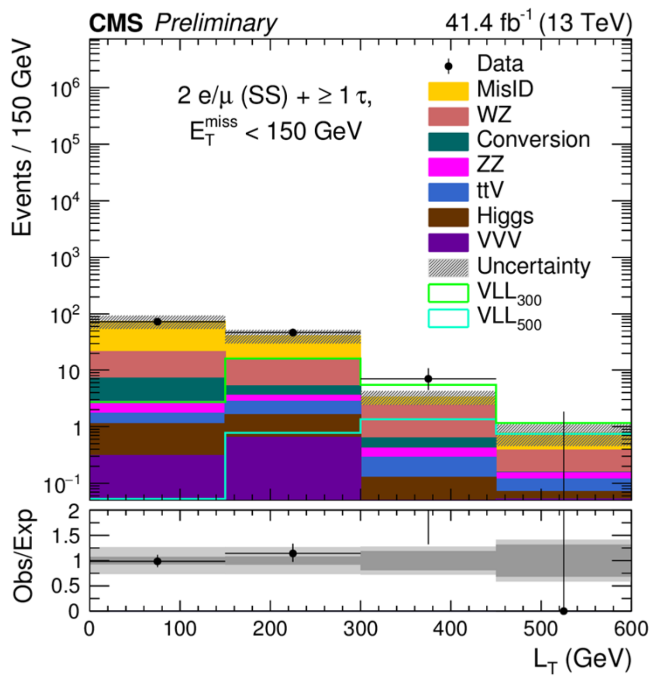
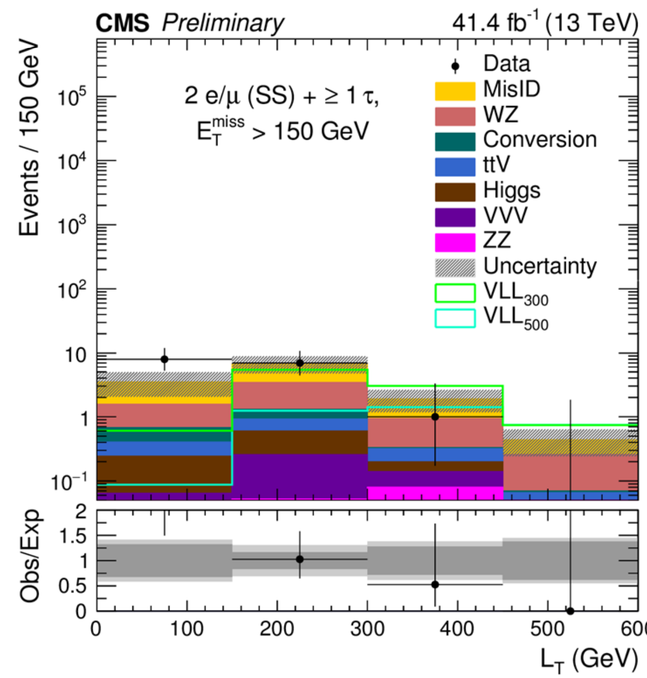
Vector-Like Leptons (VLL): Inclusive multileptons with hadronic tau's
(EXO-18-005)

- Signature: 2 or 3 light leptons and a tau (leptonic or hadronic)
- Backgrounds: WZ,ZZ,Z+fakes, ttbar+fakes
- Physics/Models: VLL
- Data: 41.4/fb (2017)

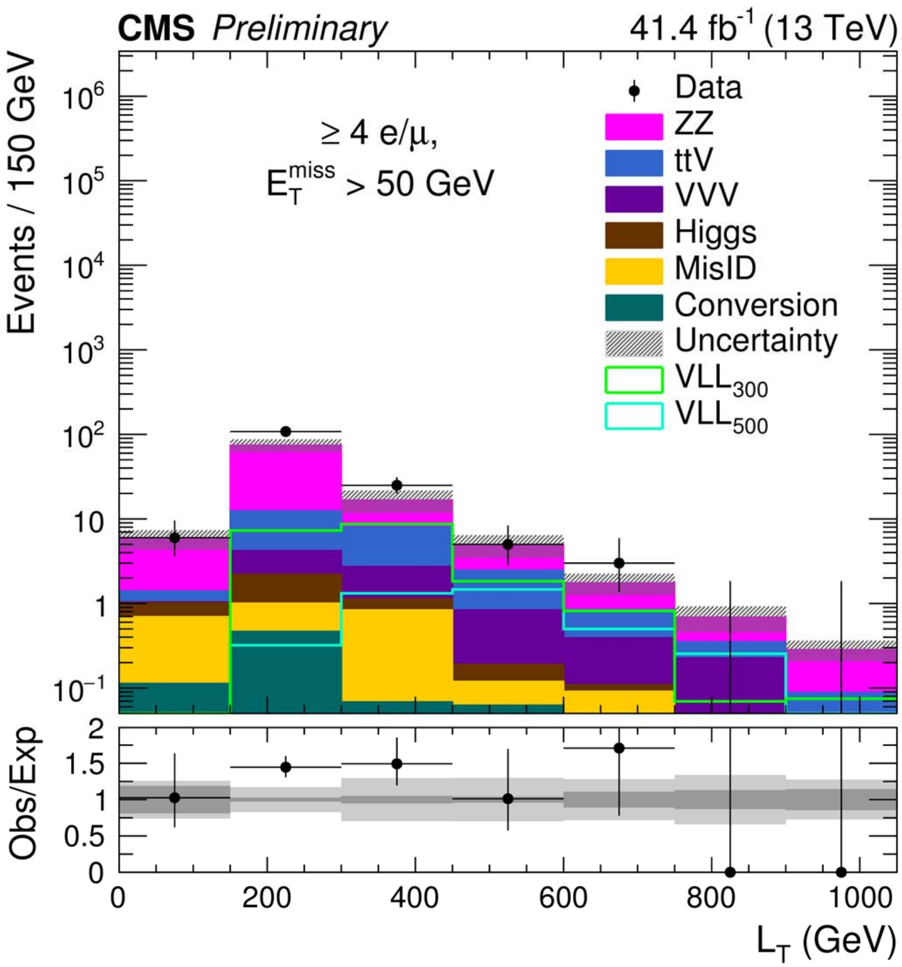


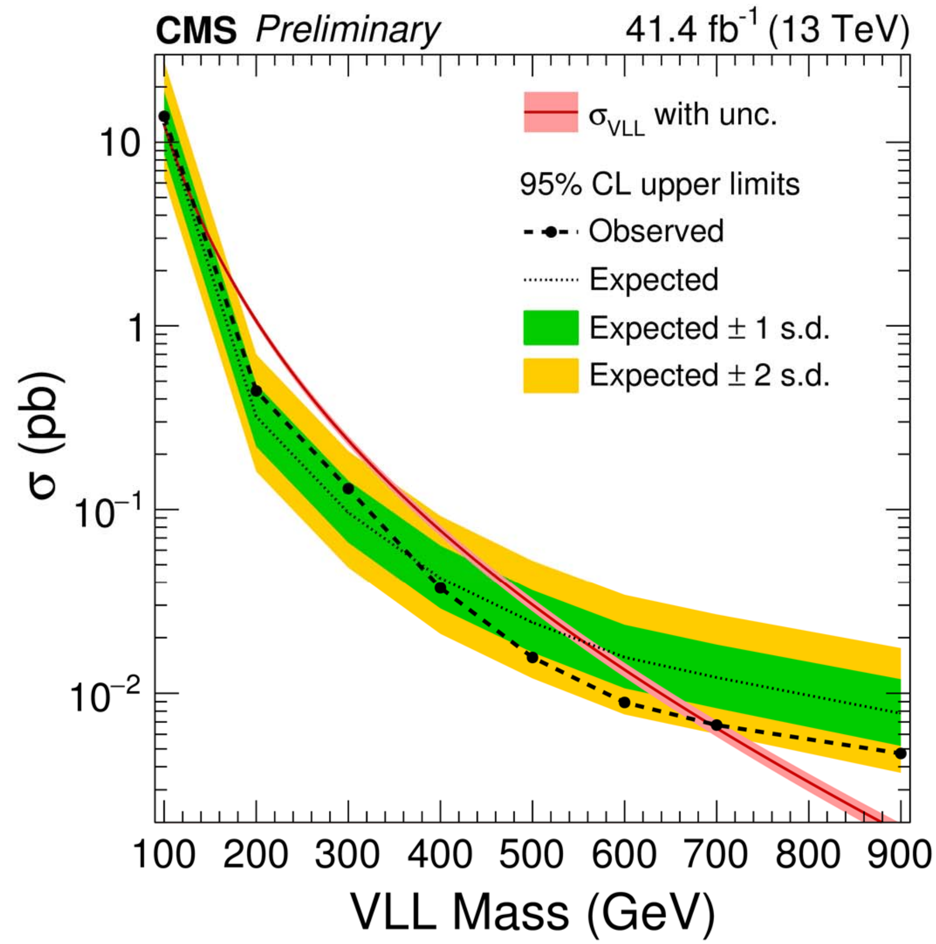




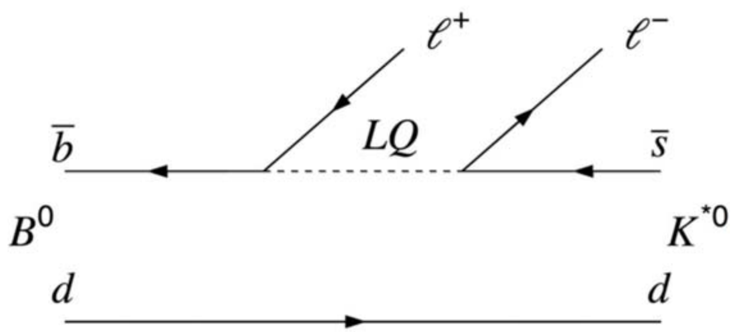


Vector-Like Leptons (VLL): Inclusive multileptons with hadronic tau's
(EXO-18-005)

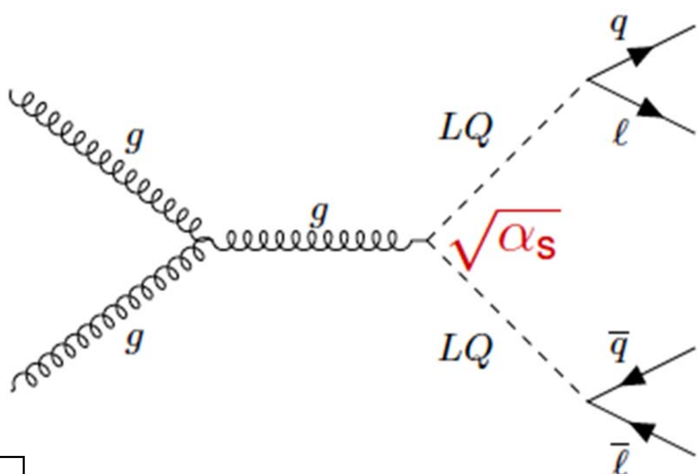




• LQ – Leptoquarks



LHCb

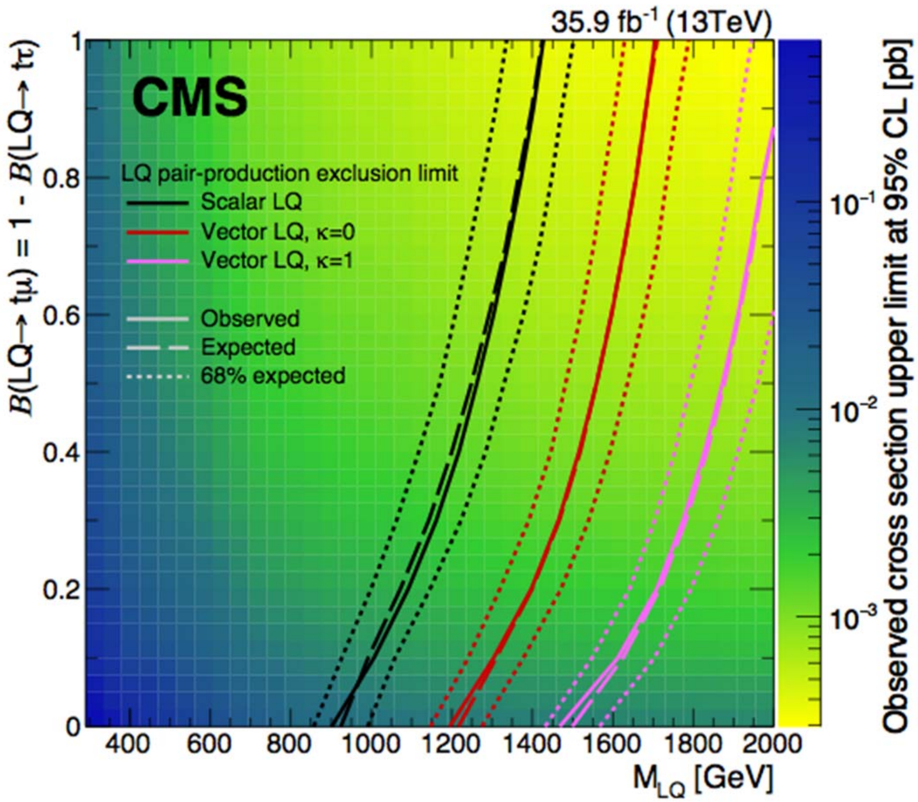


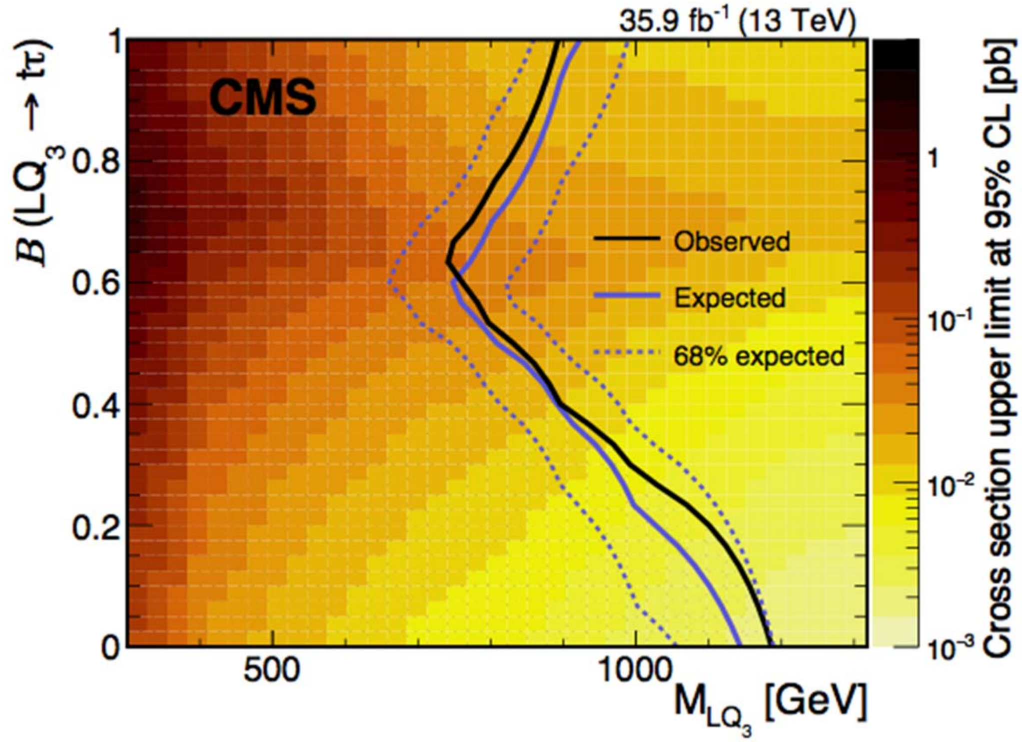
CMS

"RK – a ratio that describes how often a B+ meson decays to a charged kaon and either a μ+μ– or an e+e– pair, and therefore provides a powerful test of lepton universality. The more precise measurement, officially revealed at Rencontres de Moriond on 22 March, suggests that the intriguing current picture of flavour anomalies persists…"

Leptoquarks

Combination of LQLQ→τττt and LQLQ→tμtμ searches. Constrains cross-generational couplings (≠$\mathcal{B}$)



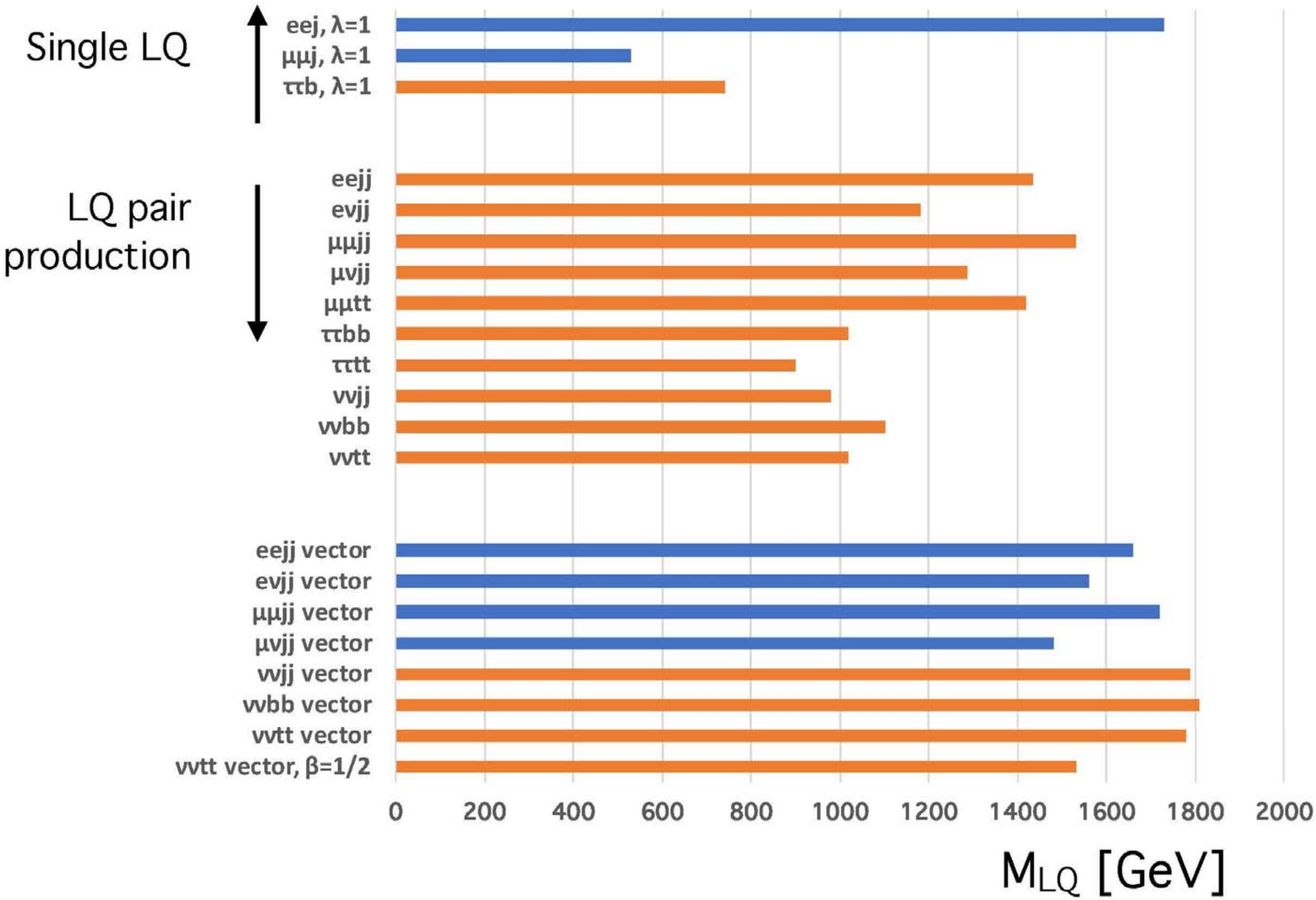


Use both LQLQ→τττt and LQLQ→bνbν results to set limits as a function of $\mathcal{B}$ for LQ3

SUO#454/#574;35#534;,
HSMF#:;#534;,#:3:

Vdgh#Fuhglw#Jrelq#Iudfkhu

Leptoquarks



Sunil Somalwar, ICTP'19

- Neutrinos at LHC

(eh?)

Seesaw (leptonic searches)

With $M_{Majorana} >> M_{Dirac}$,

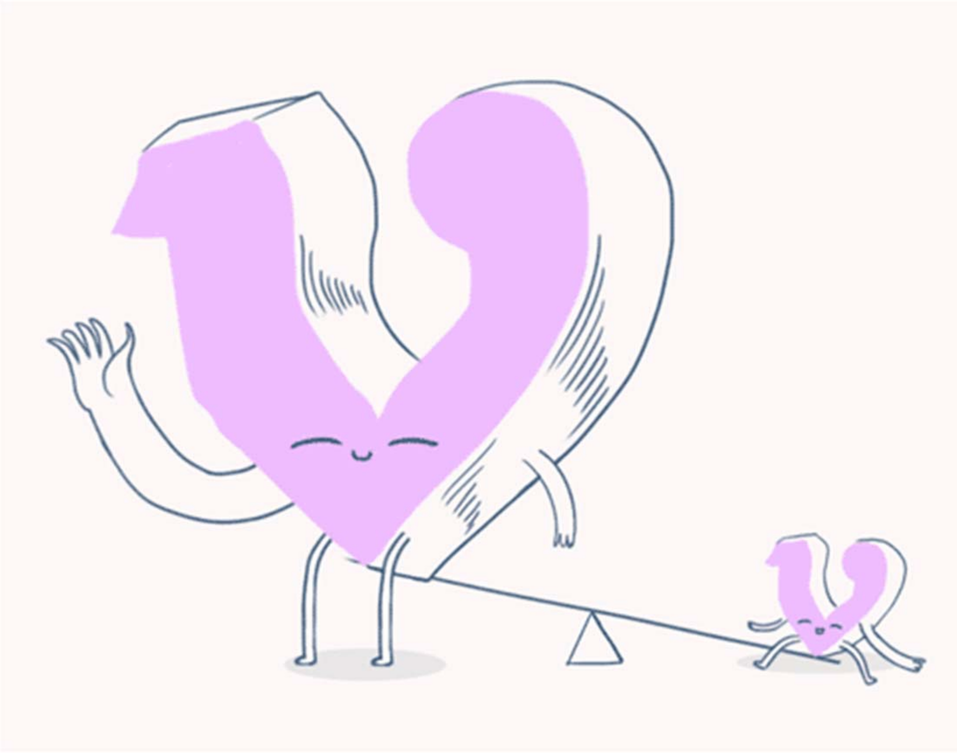
- $M_{heavy} \sim M_{Majorana}$
- $M_{light} \sim M_{Dirac} * (M_{Dirac} / M_{Majorana})$

Type-I ν_R SU(2) singlet fermion
Type-II Δ^{0+-} SU(2) triplet scalar
Type-III Σ^{0+-} SU(2) triplet fermion

Type III processes:

$\Sigma^+ \rightarrow W^+\nu$ OR Zl^+ OR Hl^+

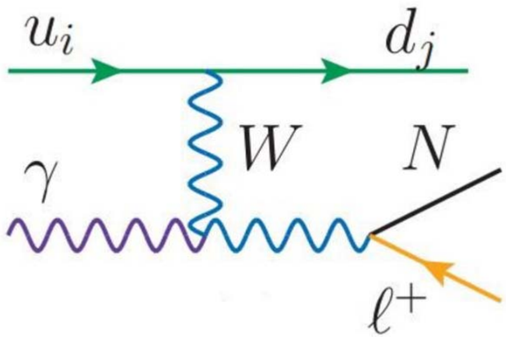
$\Sigma^0 \rightarrow Wl^+$ OR $Z\nu$ OR $H\nu$

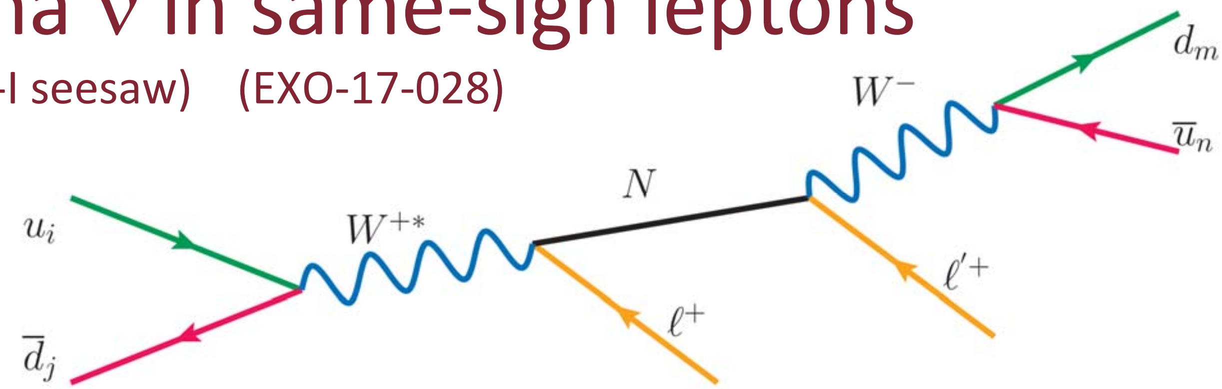


Credit: Sandbox Studio, Chicago & Ana Kova

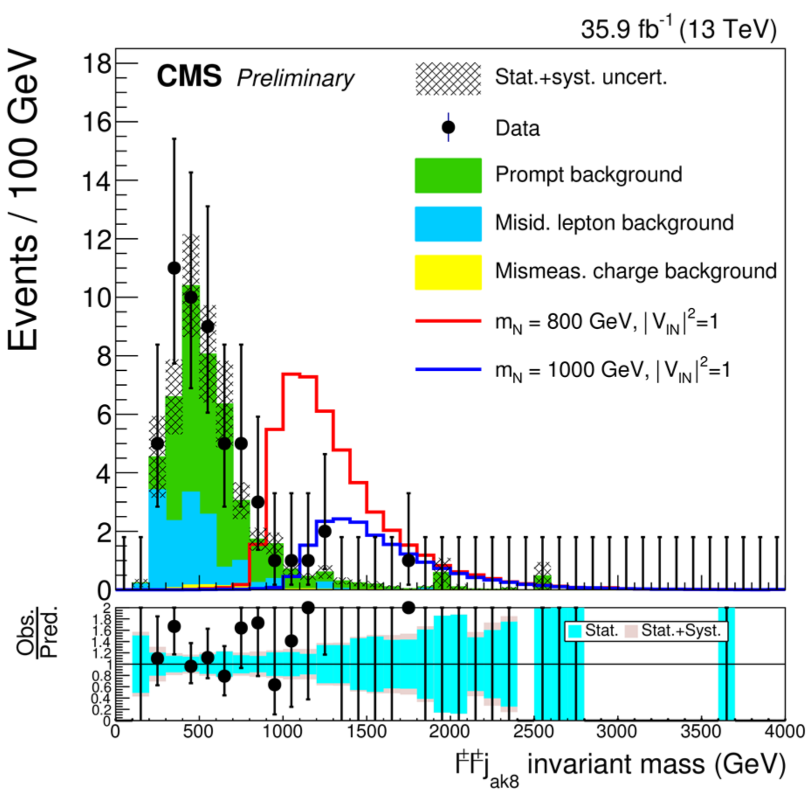
Heavy Majorana ν in same-sign leptons

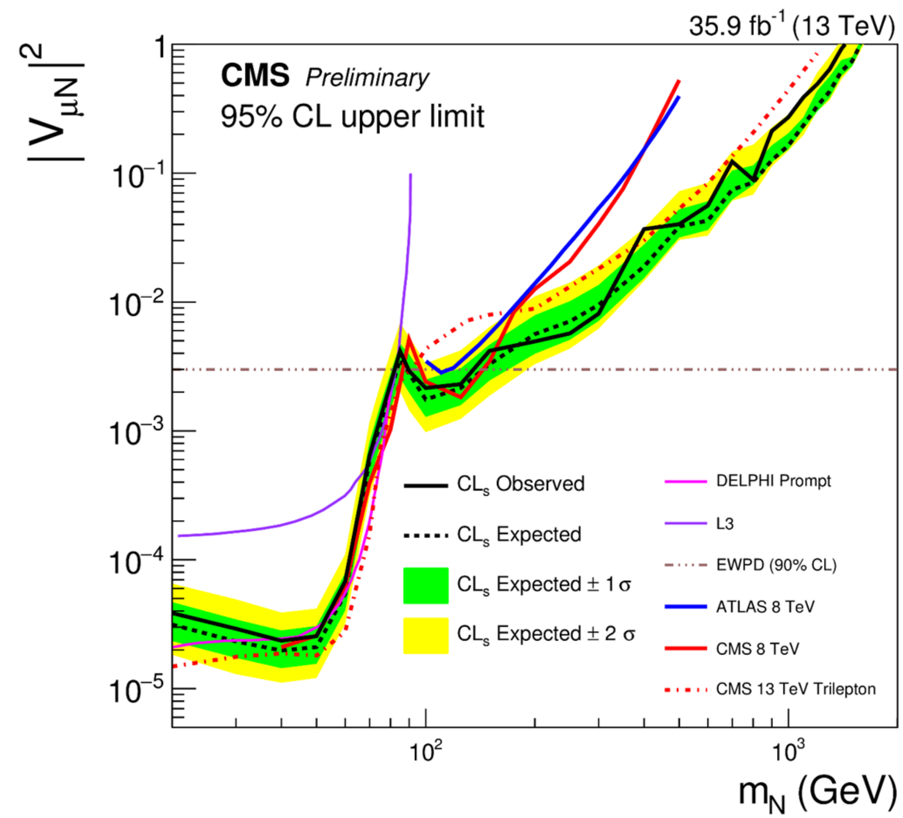
(Type-I seesaw) (EXO-17-028)





- Signature: Same-sign ee/μμ + j. (Majorana →SS=OS). ~resonant signal
  Background: prompt, mis-id including e charge flip



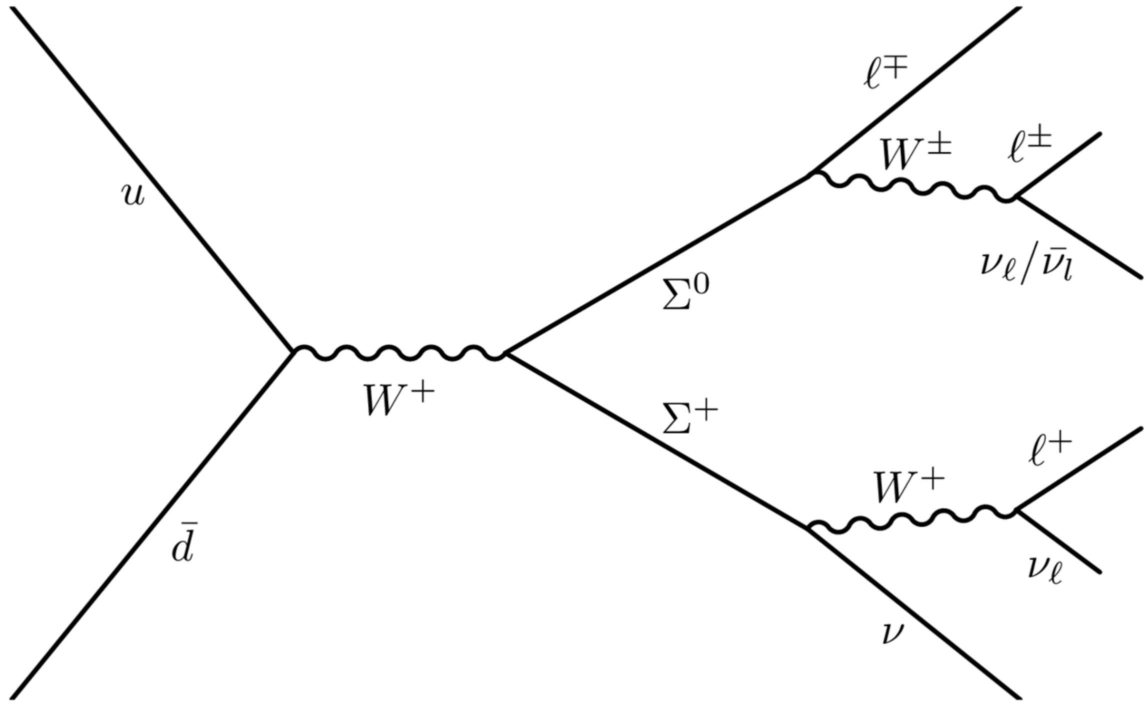


Neutrinos on a seesaw: Inclusive multileptons
(EXO-19-002)(New! Full Run2 data!!)

Type-III seesaw

Pair produced heavy Σ triplet →multileptons

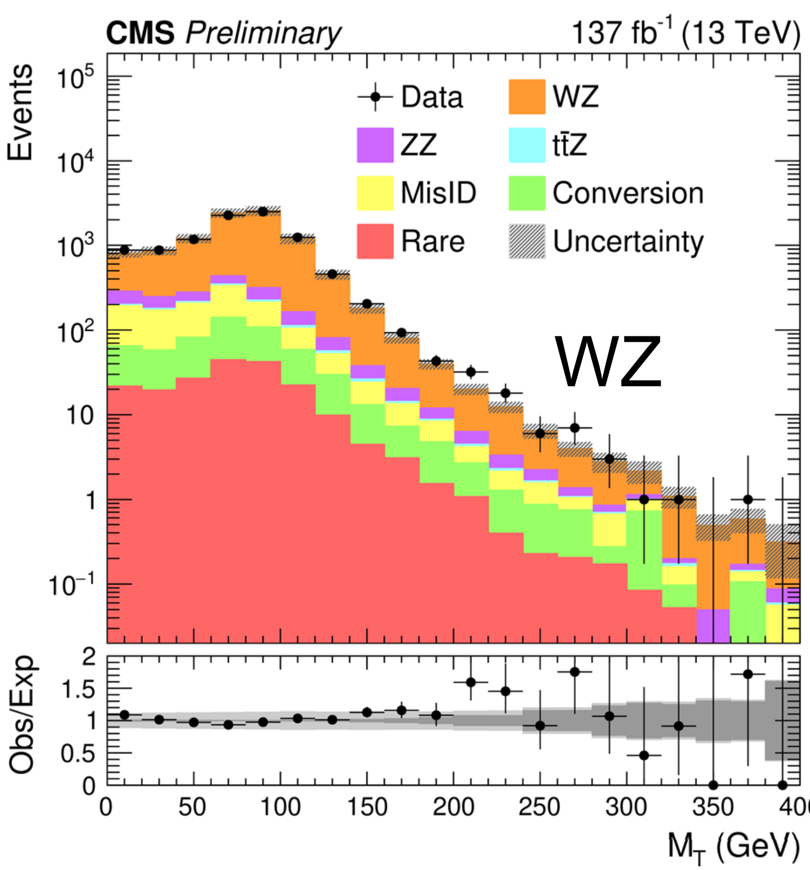
Total 27 processes including higgs in the final state

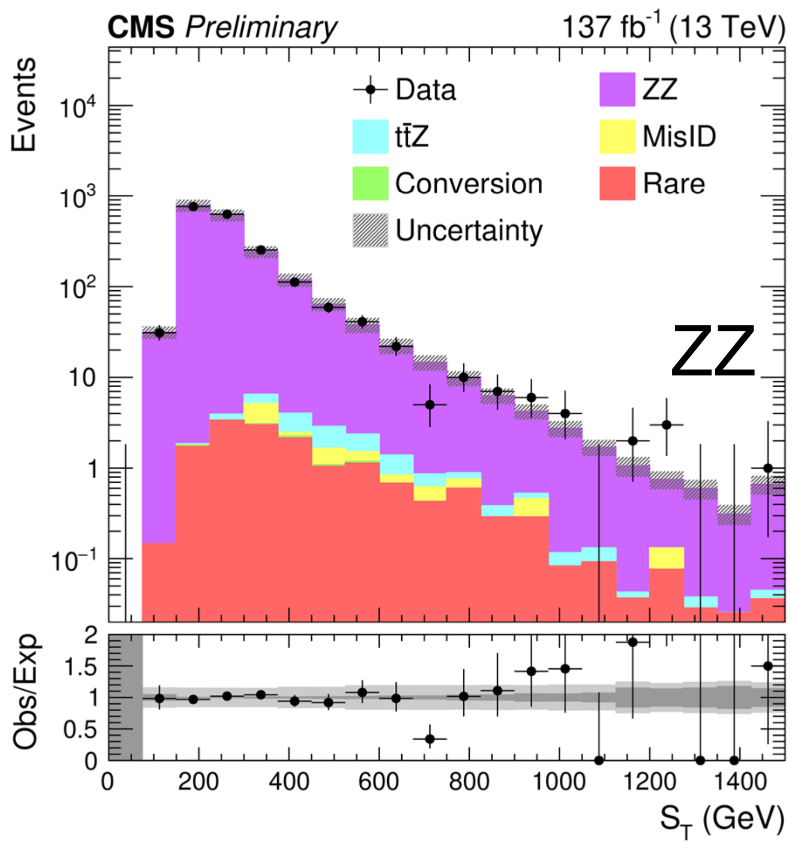


- Signature: 3 or more e's and mu's, lead pt >25GeV, bins of flavor and kinematics (on/off-Z etc). Look for excess in LT+MET bins. (LT=Lepton pt scalar sum)
- Background: Z+jets, ttbar data-driven matrix method with tight/loose rates from low-MET on-Z region. (Prompt) WZ, ZZ - normalized MC.

Seesaw with Inclusive multileptons, contd (EXO-19-002)

Label	N_ℓ	N_{OSSF}	M_{OSSF}	N_b	p_T^{miss}	Variable	Binning scheme	
Signal model: type-III seesaw								
3L below-Z	3	1	< 76 GeV	–	–	$L_T + p_T^{miss}$	$0 - 1200$ GeV	6 bins
3L on-Z	3	1	$76 - 106$ GeV	–	> 100 GeV	M_T	$0 - 700$ GeV	7 bins
3L above-Z	3	1	> 106 GeV	–	–	$L_T + p_T^{miss}$	$0 - 1600$ GeV	8 bins
3L OSSF0	3	0	–	–	–	$L_T + p_T^{miss}$	$0 - 1200$ GeV	6 bins
4L OSSF1	≥ 4	1	–	–	–	$L_T + p_T^{miss}$	$0 - 1000$ GeV	5 bins
4L OSSF2	≥ 4	2	–	–	> 100 GeV if double on-Z	$L_T + p_T^{miss}$	$0 - 1200$ GeV	6 bins



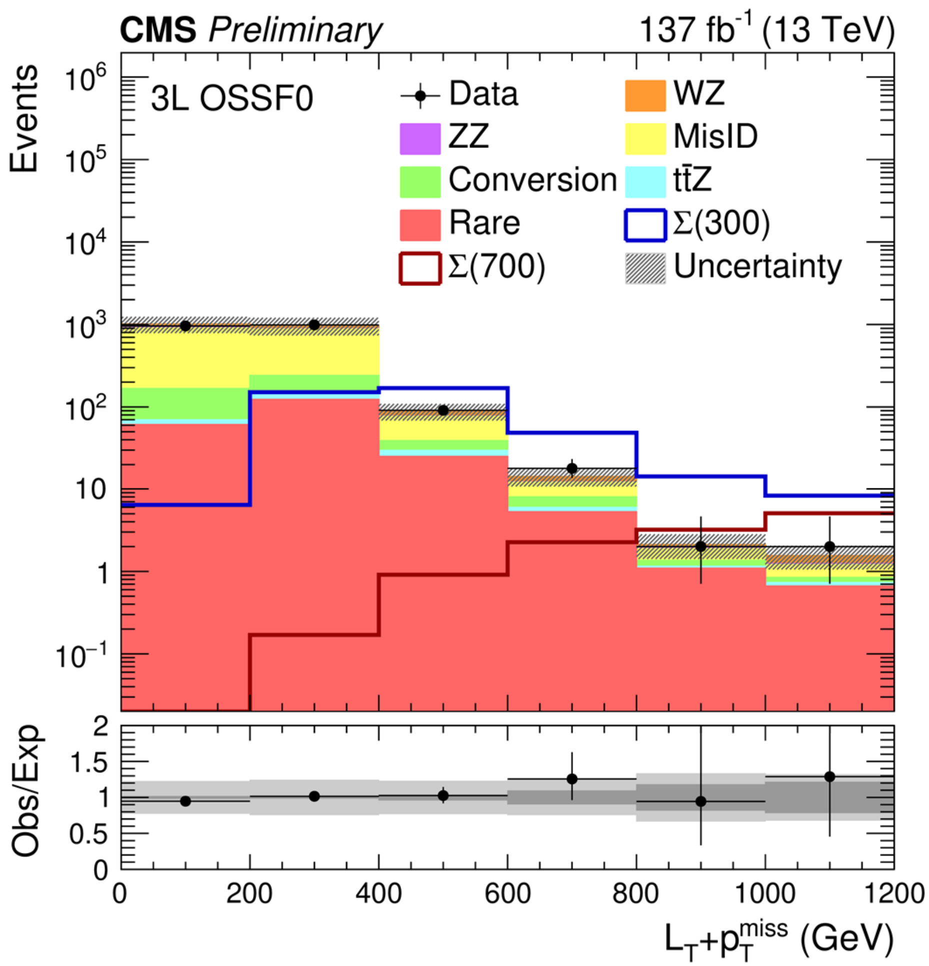


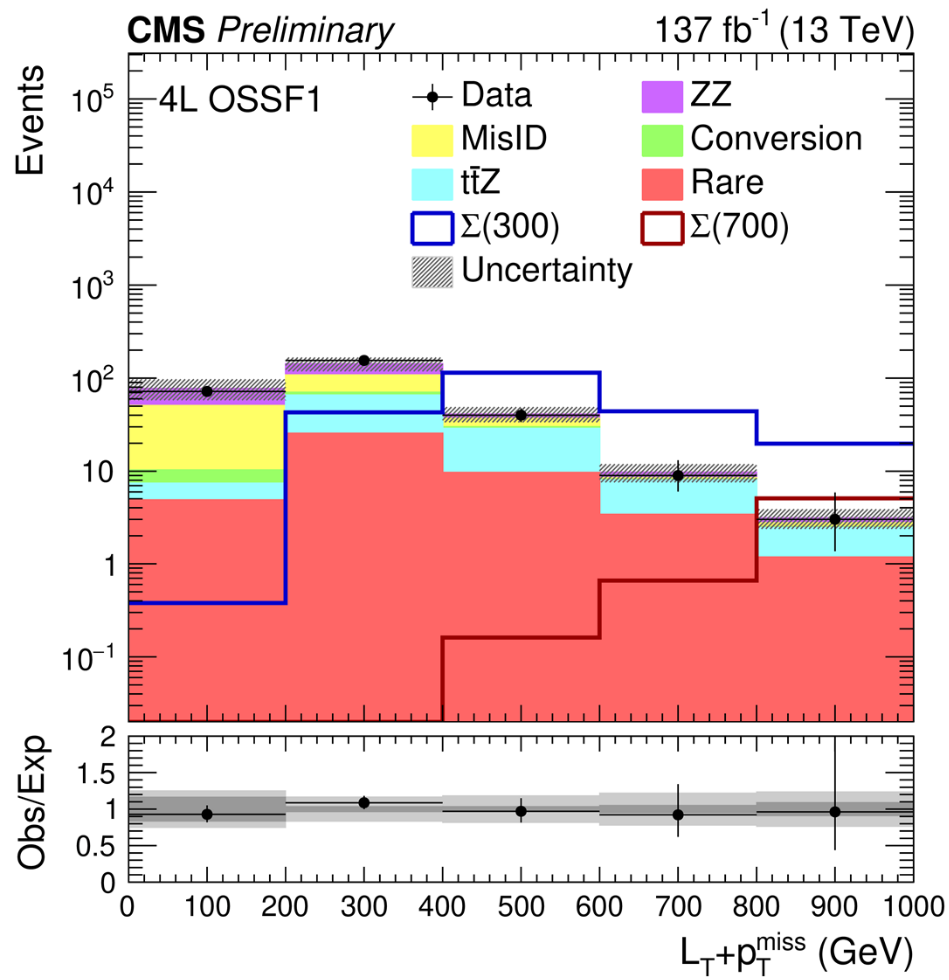
Seesaw with Inclusive multileptons, contd (EXO-19-002)

3L, OSSF0

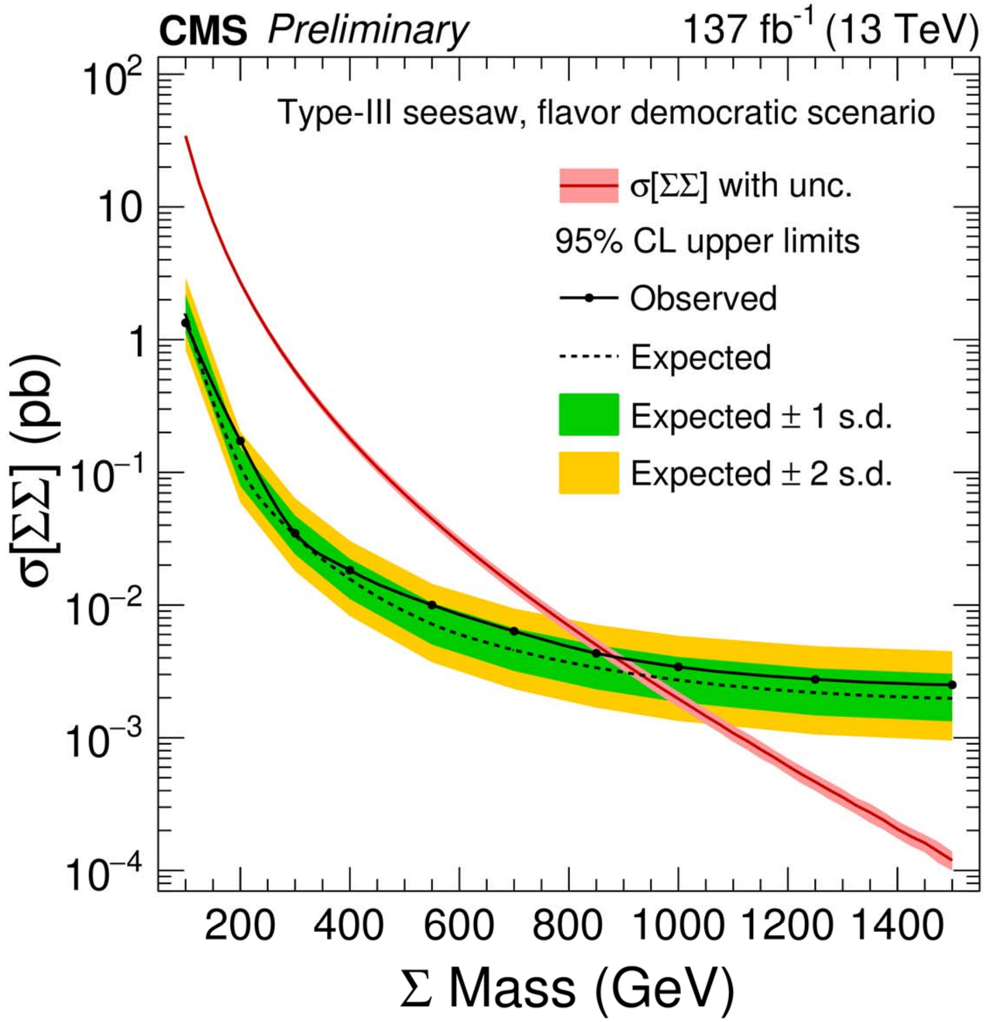
Signal regions

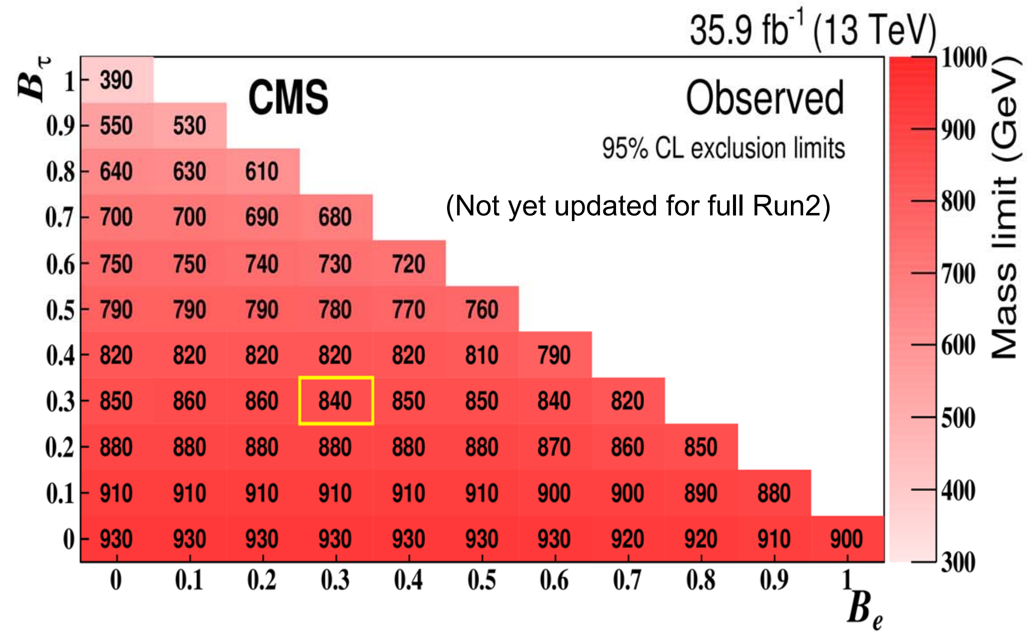
4L, OSSF1





Seesaw with inclusive multileptons, contd (EXO-19-002)



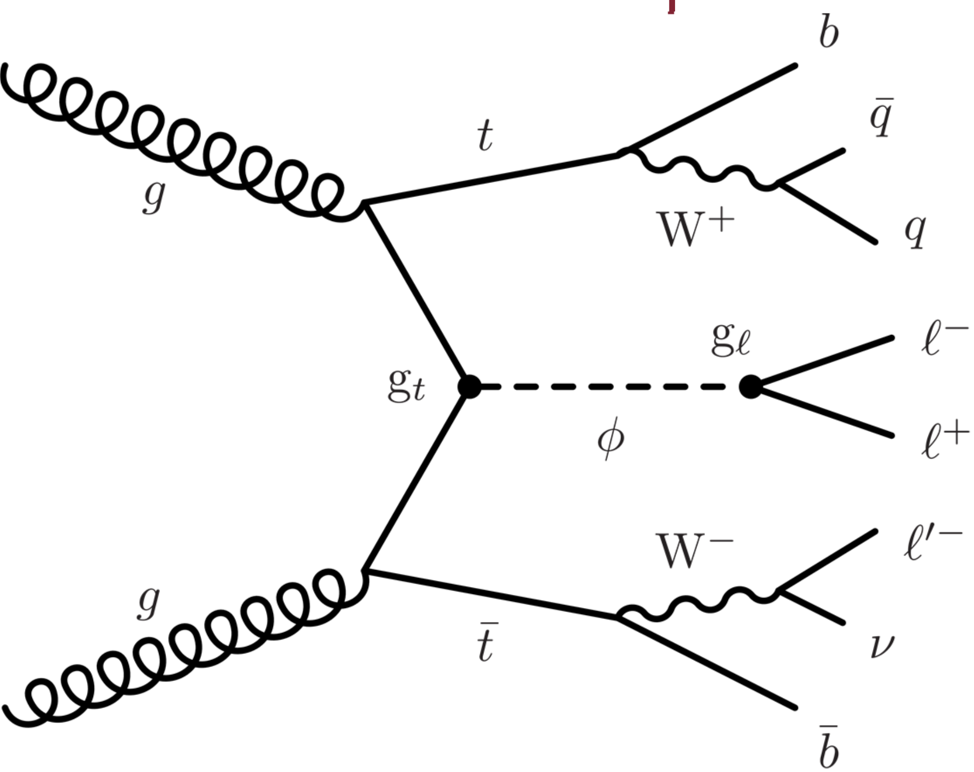


- Eye on the prize: EWSB scale
→generalized scalar searches

sure, pseudoscalars too.

…. and vector if it explains g-2 *and* LHCb flavor anomalies

$t\bar{t}\phi$ with $\phi \rightarrow \mu\mu$ or ee



ϕ can be a scalar or a pseudoscalar

Production ~ square of Yukawa to top (g_t^2)

Decay BR(f→ll) ~ (relative) square of Yukawa to lepton (g_l^2)

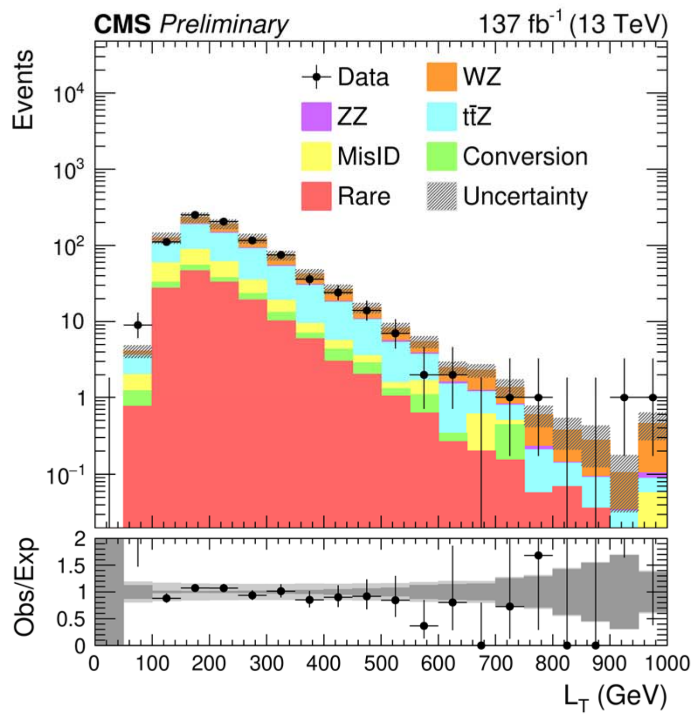
Prompt decays

- The multilepton seesaw search EXO-19-002 is an *inclusive* search: very little retooling needed to repurpose it efficiently for a different multilepton signal
- Principally, add a b-tag

Inclusive multileptons: ttϕ, ϕ →μμ/ee (EXO-19-002)

Label	N_ℓ	N_{OSSF}	M_{OSSF}	N_{b}	$p_{\mathrm{T}}^{\mathrm{miss}}$	Variable	Binning scheme			
Signal model: $t\bar{t}\phi$								S_{T} (GeV)		
								$0-400$	$400-800$	>800
$3\mathrm{L}(\ell\ell)^{\star}$ 0B	3	1	off-Z	0	–	M_{OSSF}^{20}	$12-77$ GeV	13 bins	13 bins	5 bins
						M_{OSSF}^{300}	$106-356$ GeV	10 bins	10 bins	10 bins
$3\mathrm{L}(\ell\ell)^{\star}$ 1B	3	1	off-Z	≥ 1	–	M_{OSSF}^{20}	$12-77$ GeV	13 bins	13 bins	5 bins
						M_{OSSF}^{300}	$106-356$ GeV	10 bins	10 bins	10 bins
								$0-400$	>400	
$4\mathrm{L}(\ell\ell)^{\star}$ 0B	≥ 4	≥ 1	off-Z	0	–	M_{OSSF}^{20}	$12-77$ GeV	3 bins	2 bins	
						M_{OSSF}^{300}	$106-356$ GeV	3 bins	2 bins	
								inclusive		
$4\mathrm{L}(\ell\ell)^{\star}$ 1B	≥ 4	≥ 1	off-Z	≥ 1	–	M_{OSSF}^{20}	$12-77$ GeV	3 bins		
						M_{OSSF}^{300}	$106-356$ GeV	3 bins		

* $\ell = \mathrm{e}$ or μ



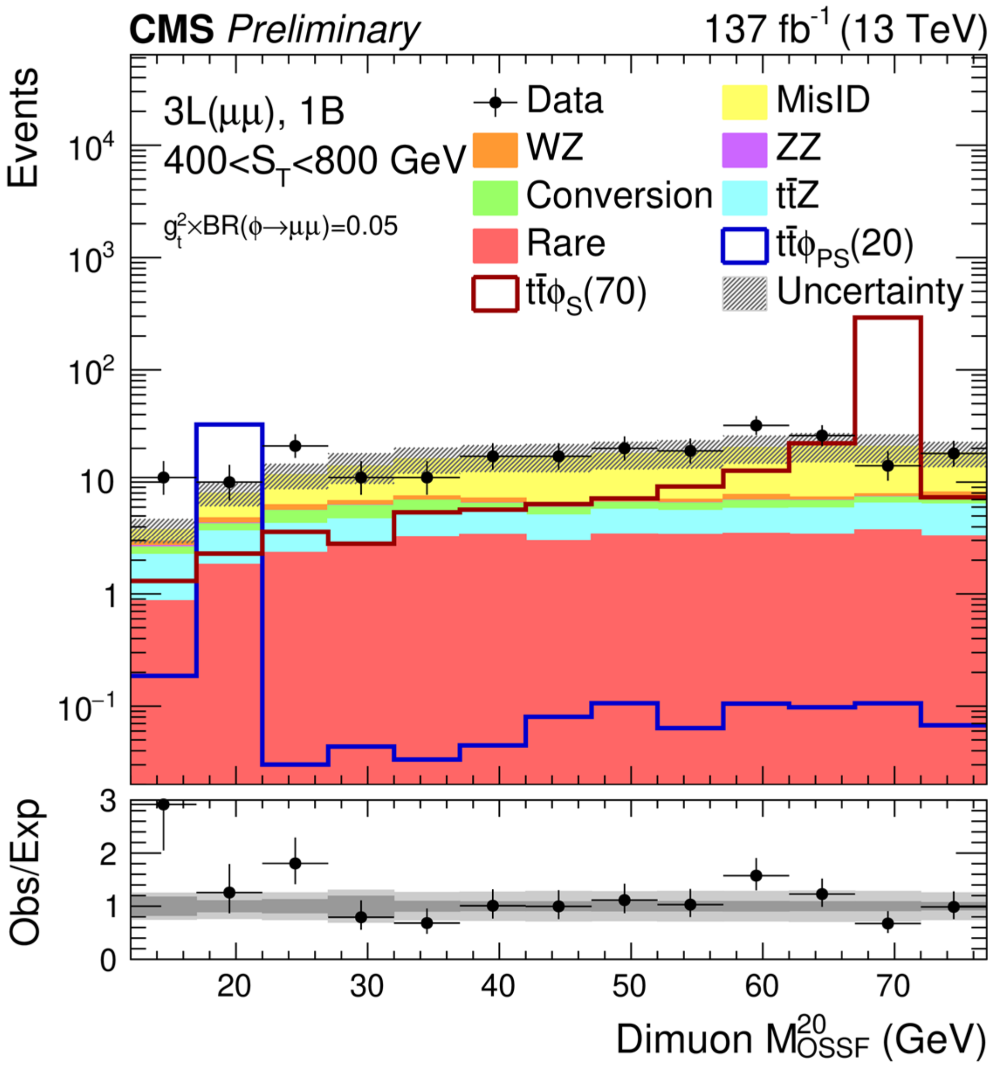
ttZ control region (on-Z with 1B)

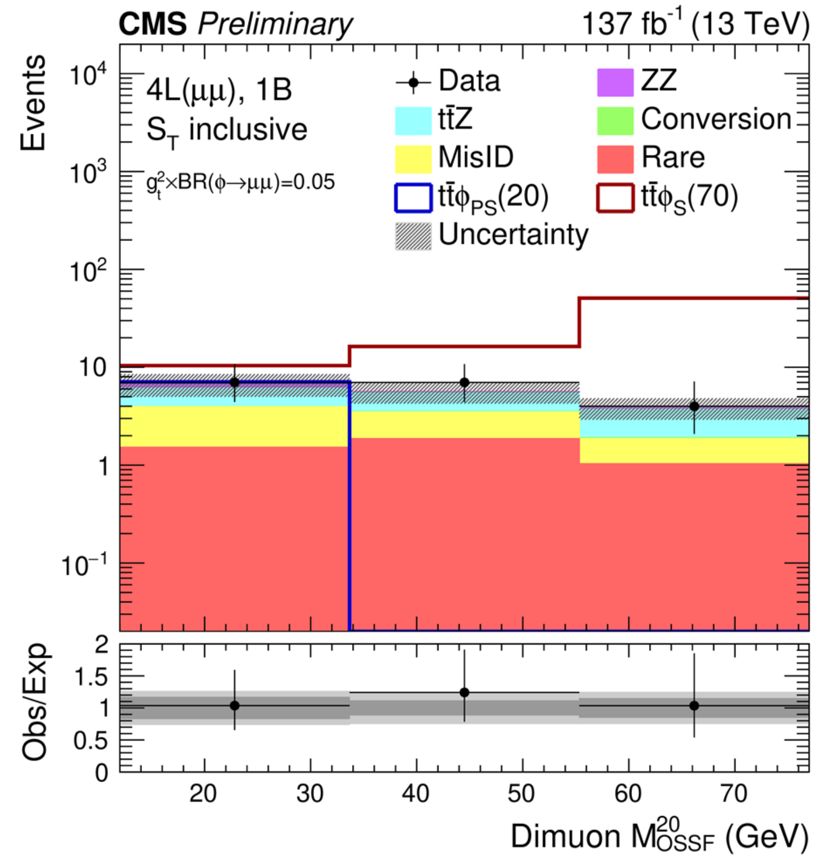
Inclusive multileptons: $t\bar{t}\phi$, $\phi \rightarrow \mu\mu/ee$ (EXO-19-002)

3L, 1B

Signal regions
(20 GeV "attractor")

4L, 1B

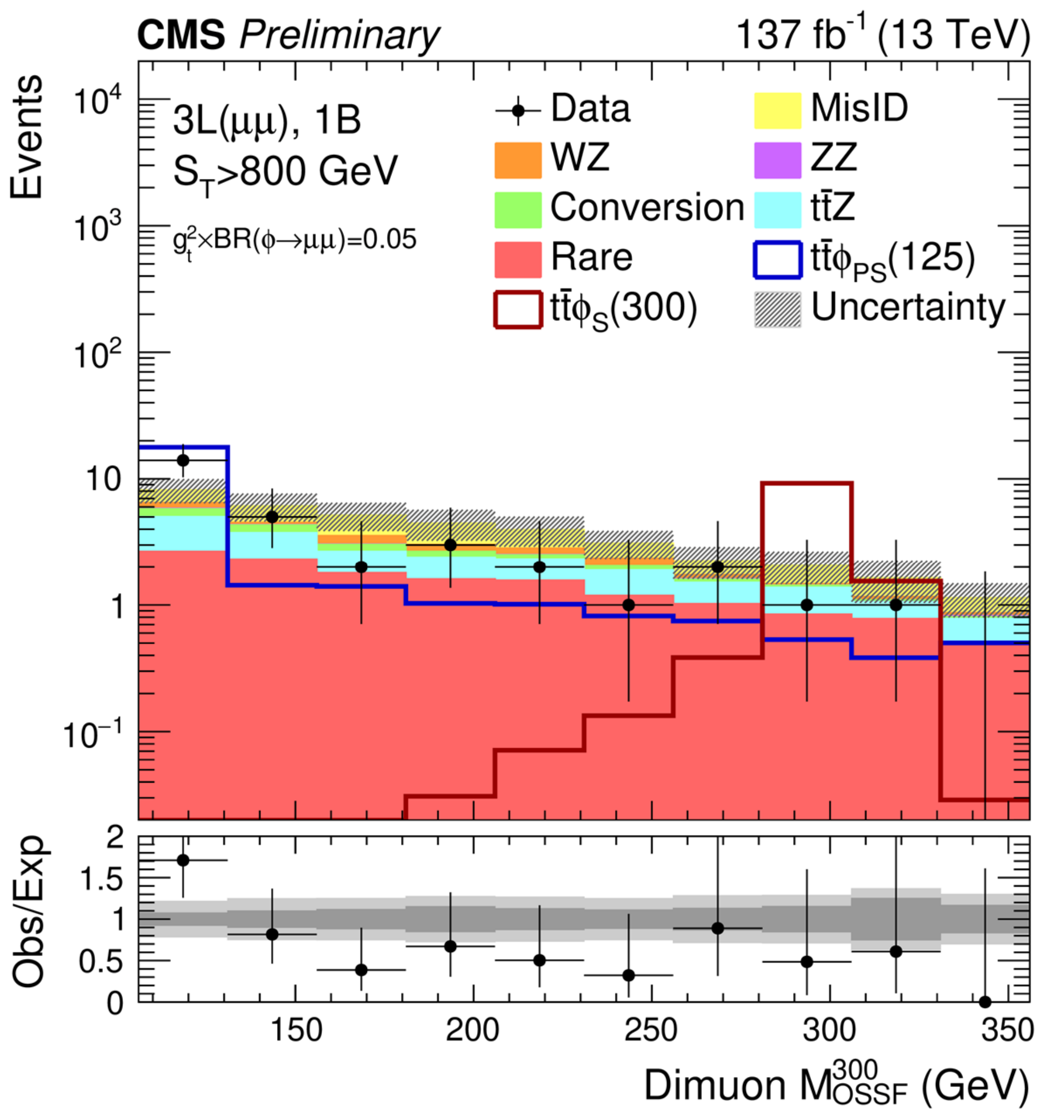




Inclusive multileptons: ttϕ, ϕ → μμ/ee (EXO-19-002)

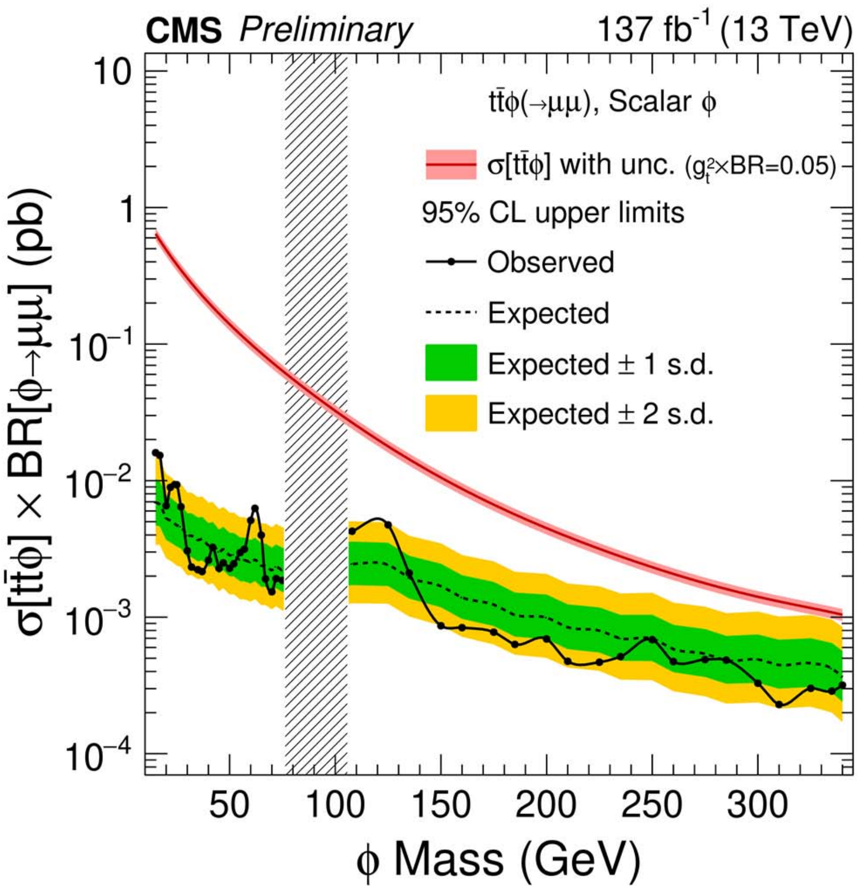
3L, 1B

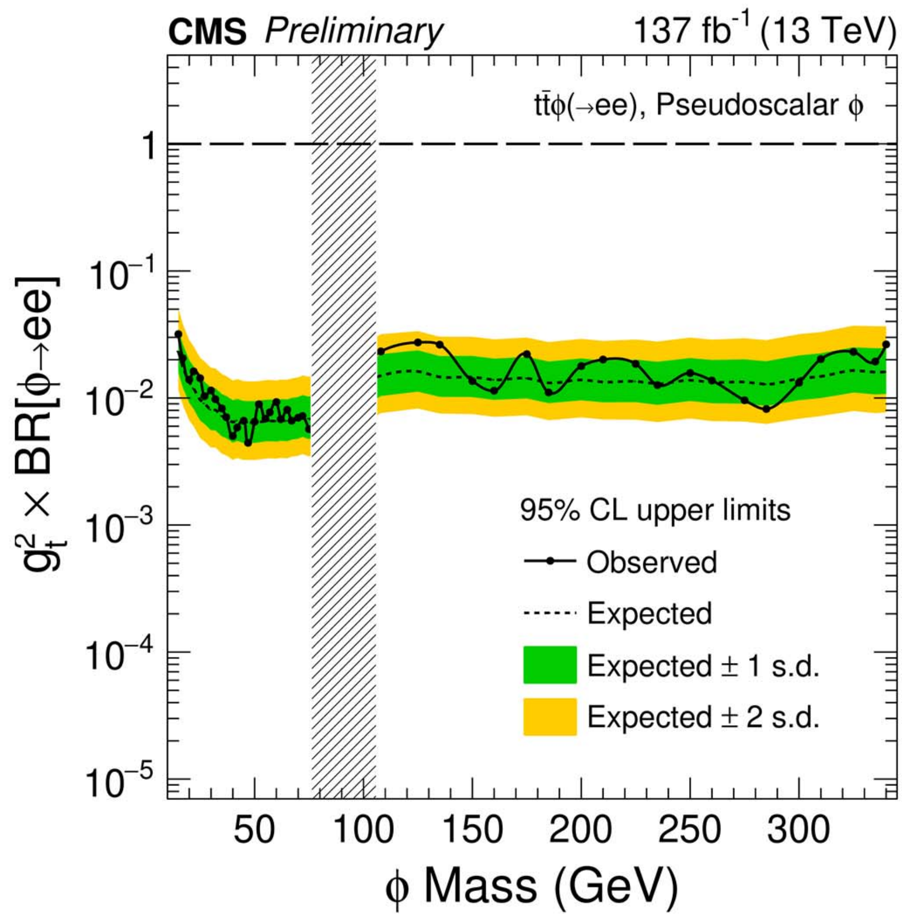
Signal regions
(300 GeV "attractor")



Sunil Somalwar, ICTP'19

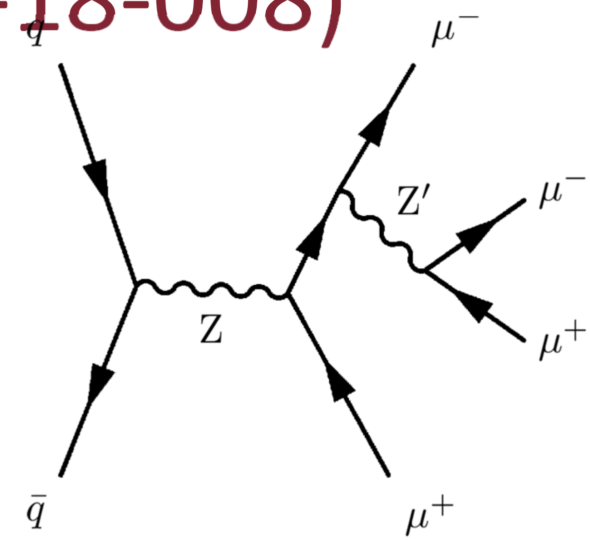
Inclusive multileptons: ttφ, φ →μμ/ee (EXO-19-002)





8 exclusions: (scalar or pseudoscalar) X (decay to ee or μμ) X (σ*BR or g_t^2*BR)

Light (10-70GeV) Z' (EXO-18-008)

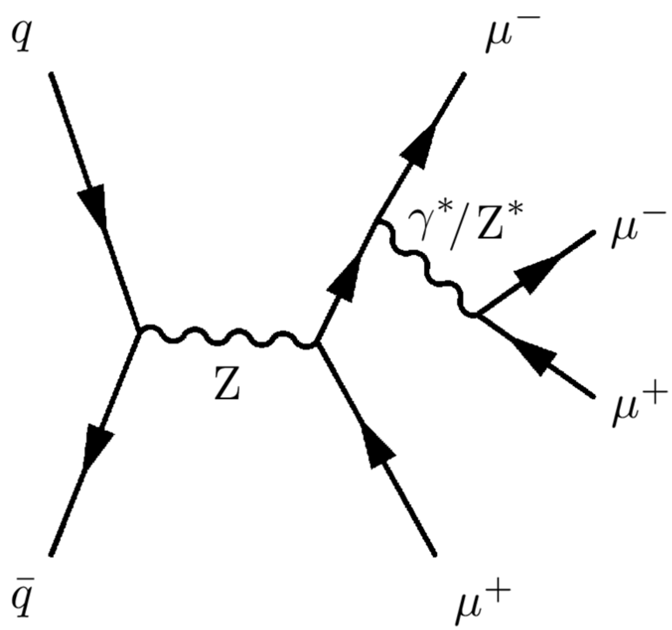


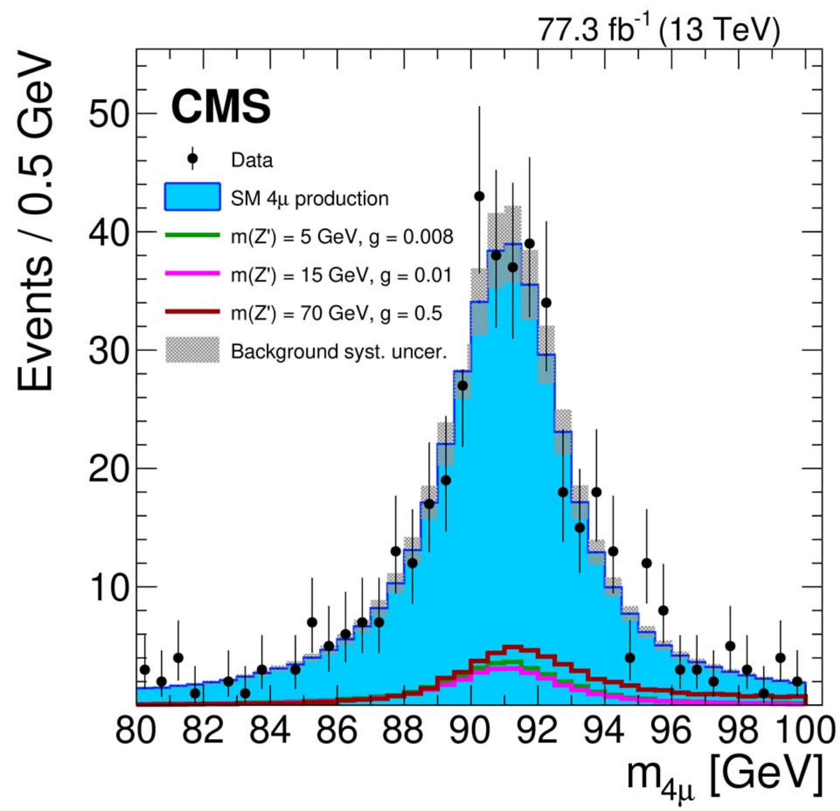
- Signature: pp → Z → μμ(Z') → μμ μμ

  [Radiative Z' in Z decay]

- Background: Z → μμ(γ) → μμ μμ
- [Radiative Dalitz in Z decay] **
- Physics/Models: $L_\mu - L_\tau$ gauge symmetry.

  (Muon g-2 & LHCb flavor anomalies)

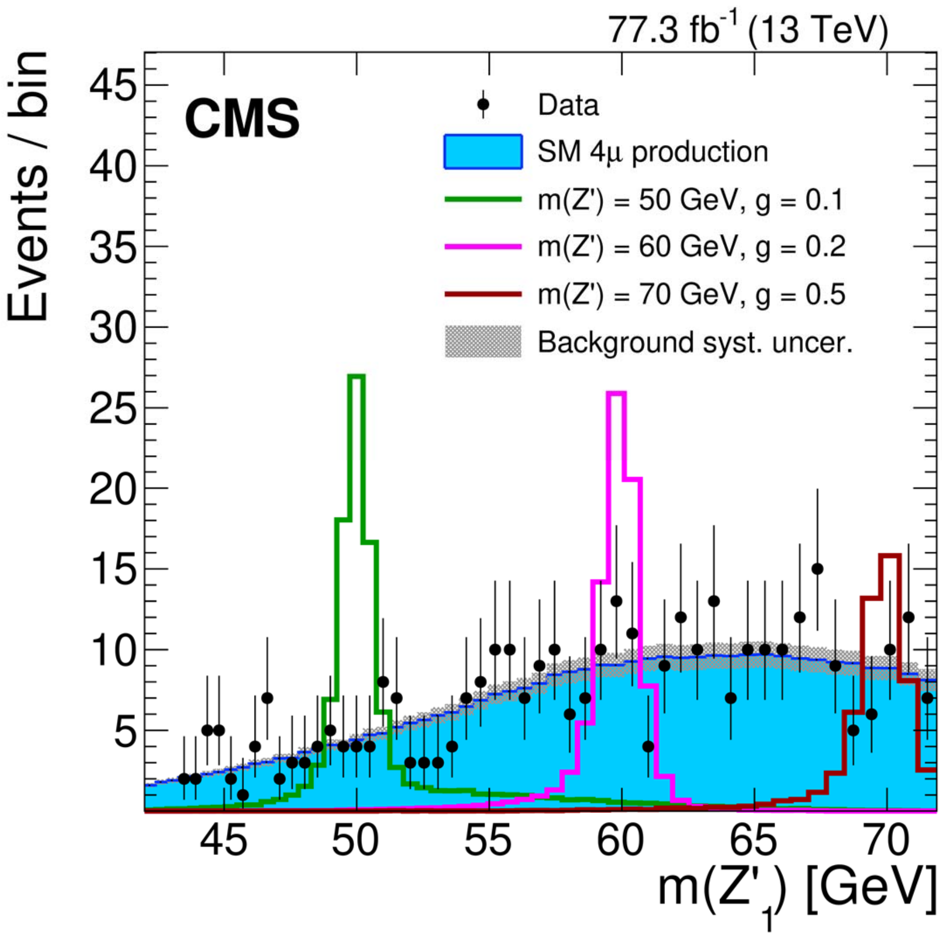




[**over coffee:radiative Dalitz backstory during the SM higgs search]

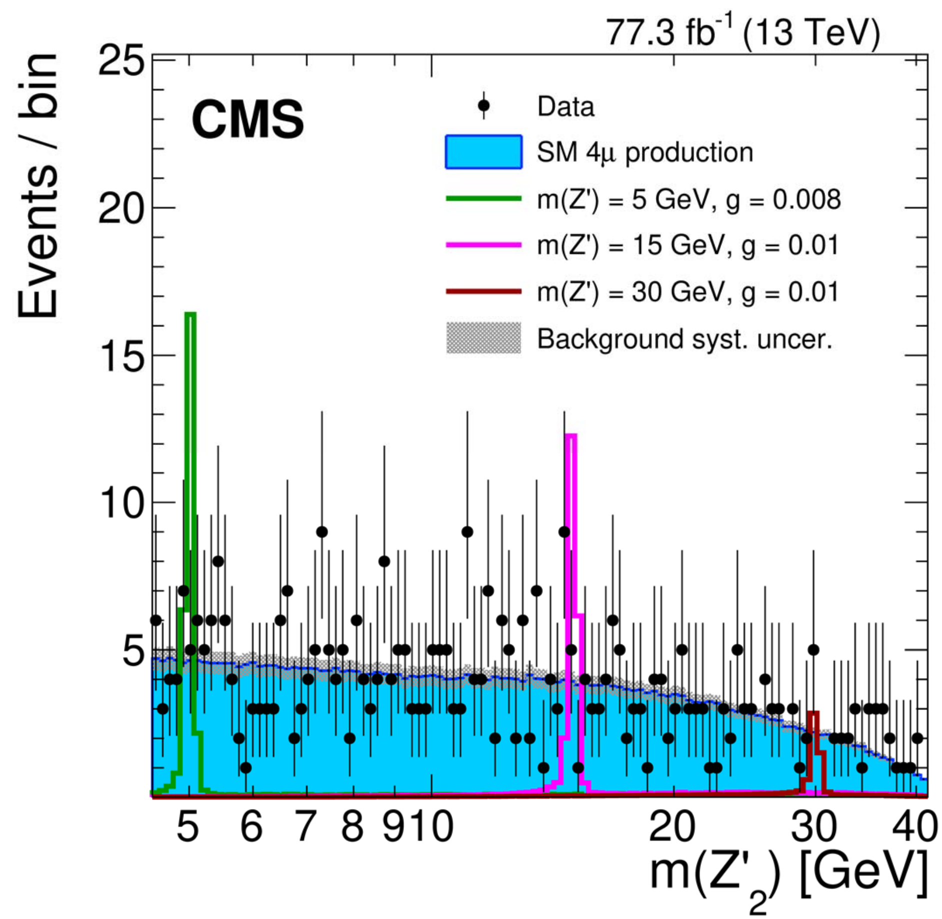
Light (10-70GeV) Z’ (EXO-18-008)

- Signature: pp → Z → μμ(Z’) → μμ μμ [Radiative Z’ in Z decay]



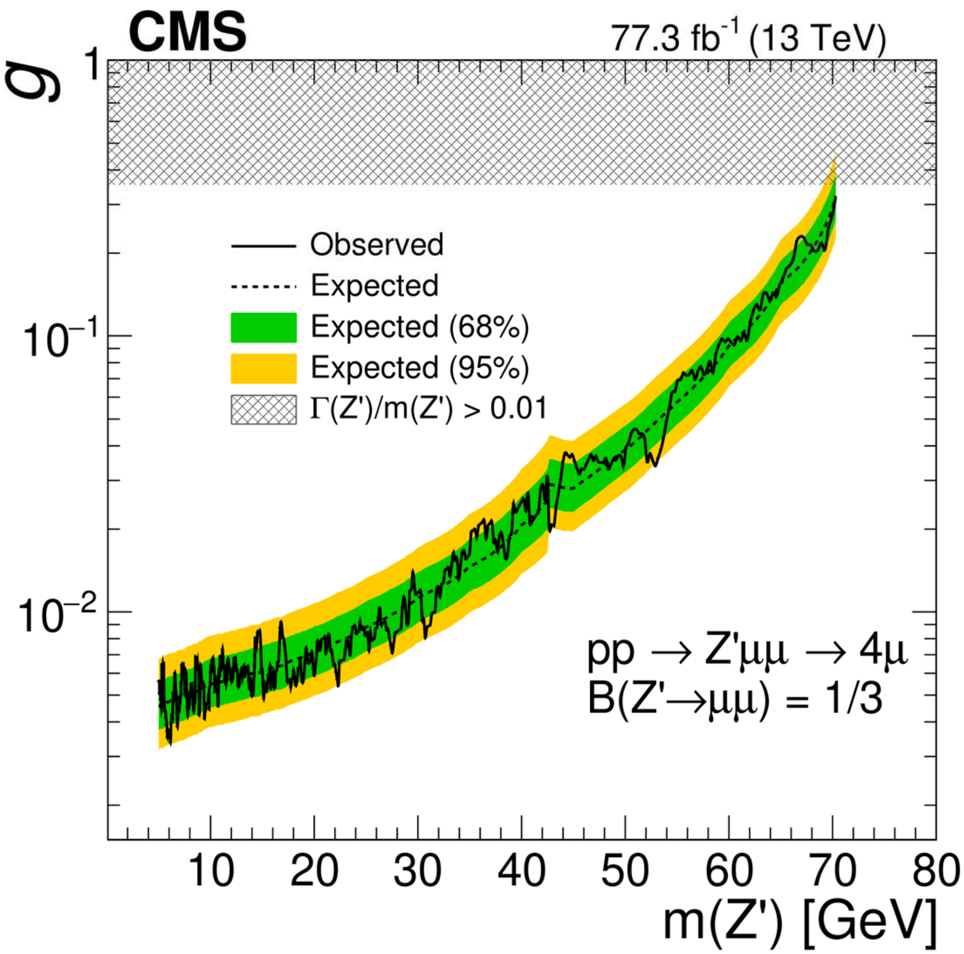
“high” mass

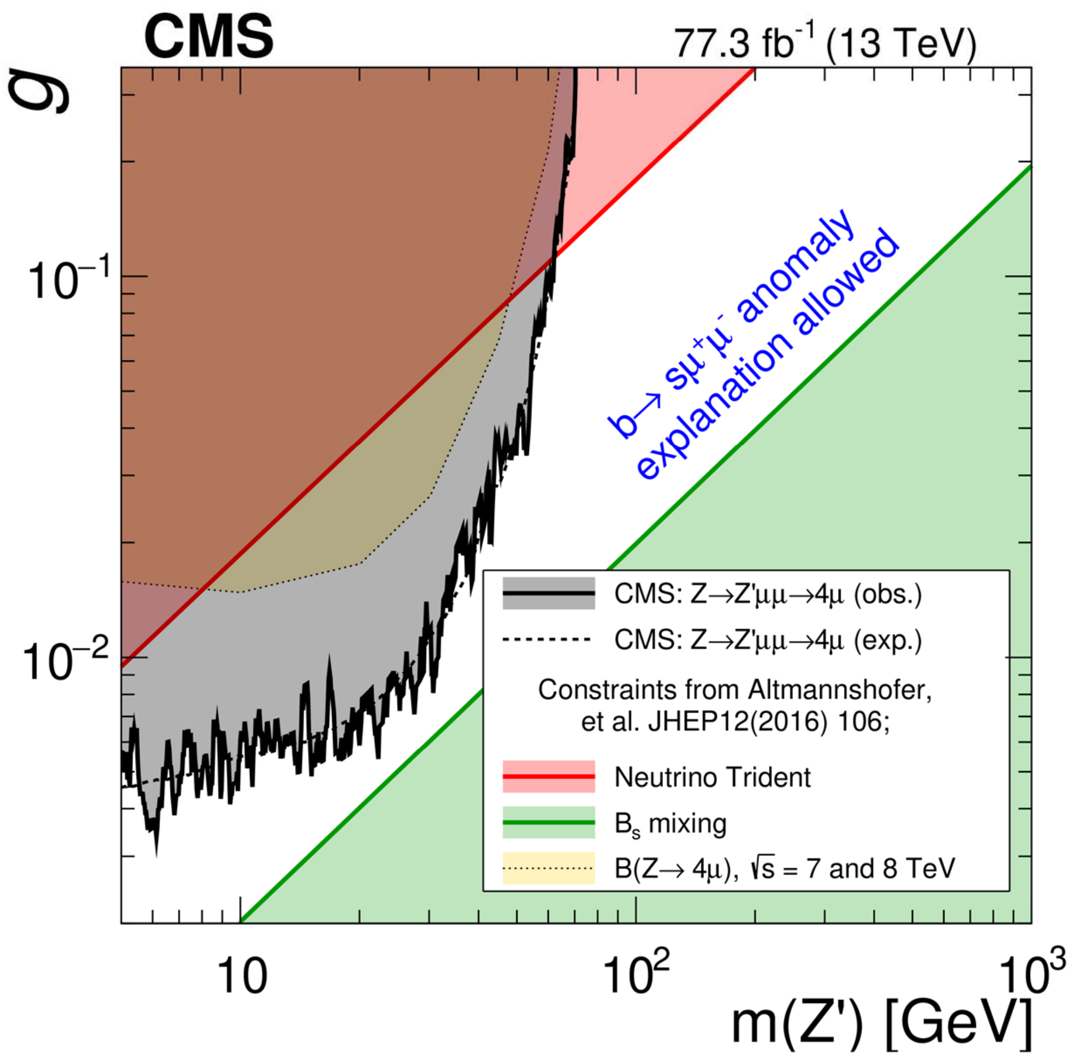
“low” mass



Light (10-70GeV) Z' (EXO-18-008)

- Signature: pp → Z → μμ(Z') → μμ μμ [Radiative Z' in Z decay]

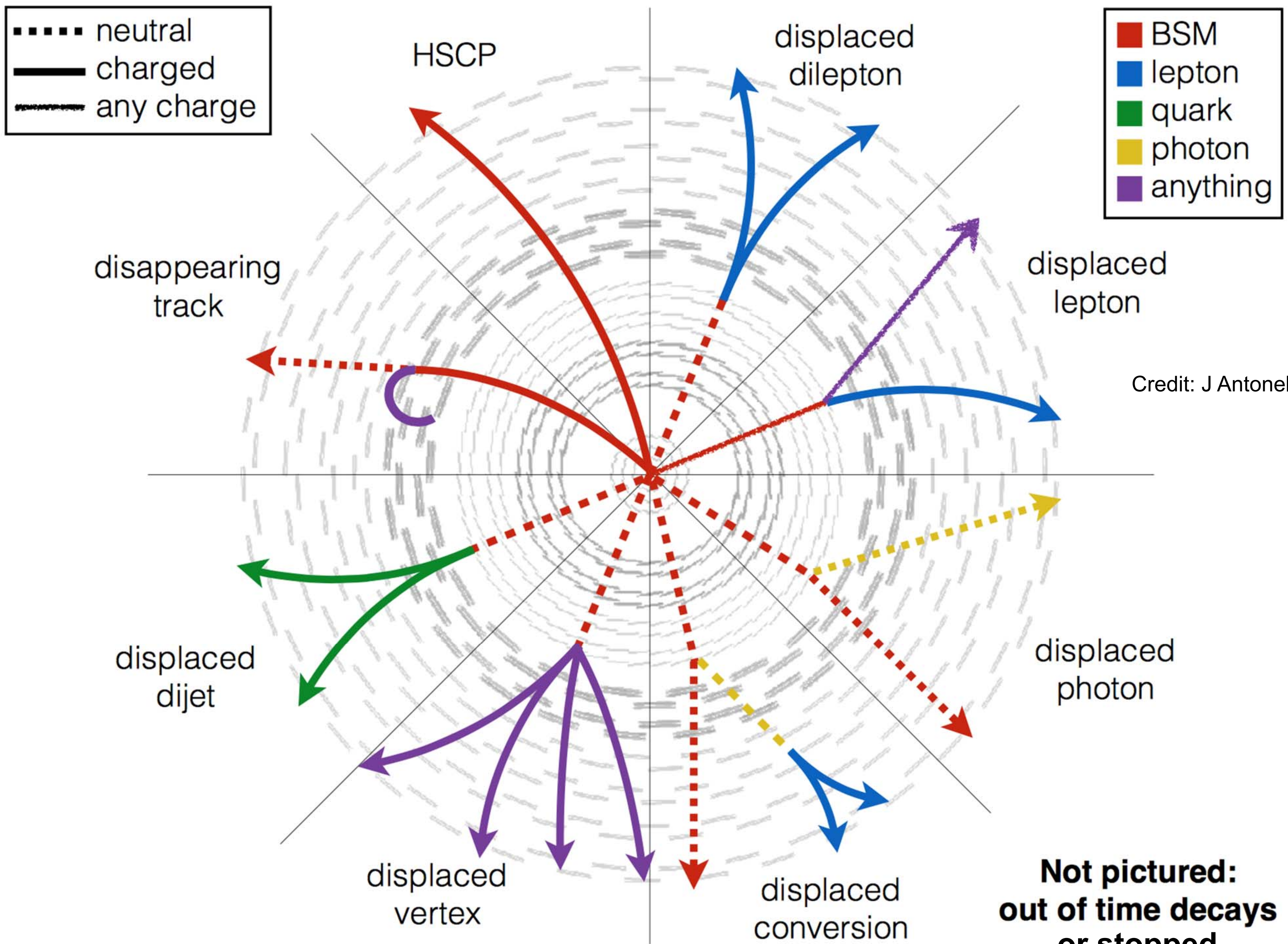




- # Long-lived

- SUSY(RPV,GM,Split),Hidden Valley, Dark xxx, Quirk, DM, Monopoles….
- Low backgrounds, but how to trigger?
- Specialized analysis

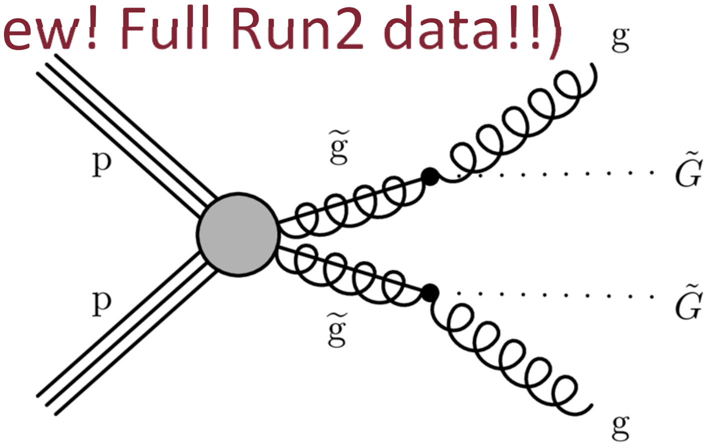
- Thursday: Near Future Long-Lived Particle Searches at the LHC by Albert De Roeck



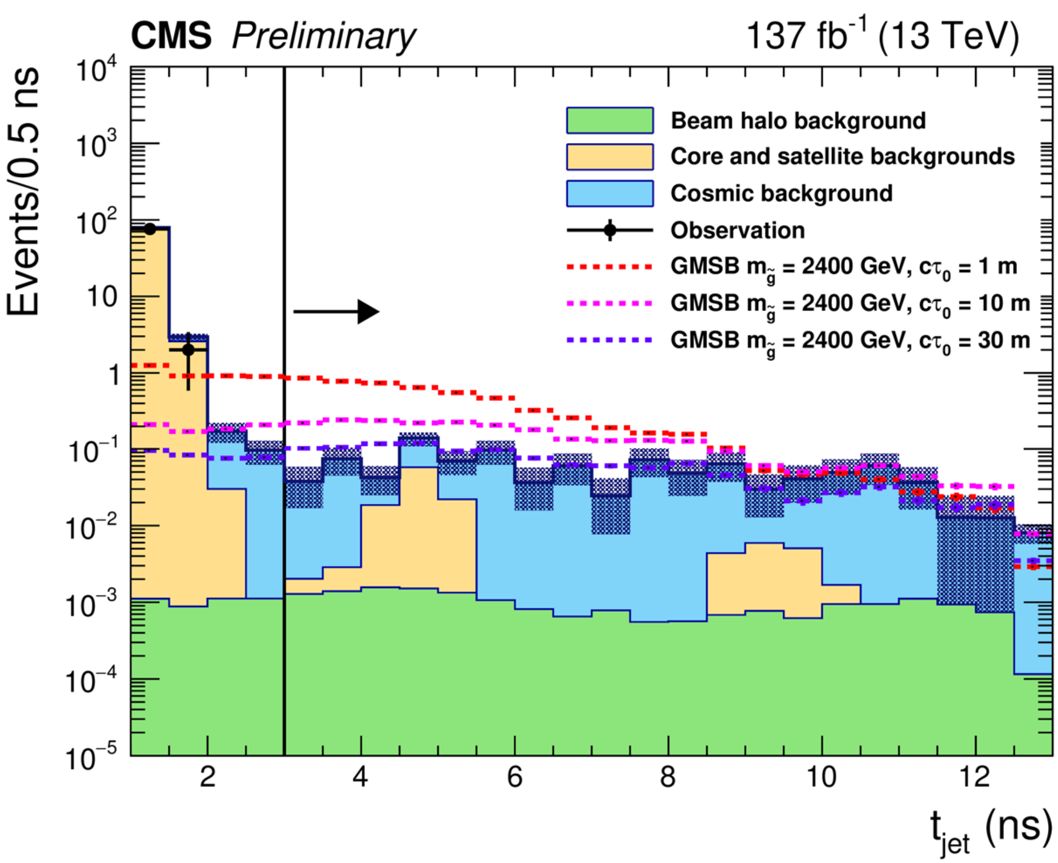
Credit: J Antonelli

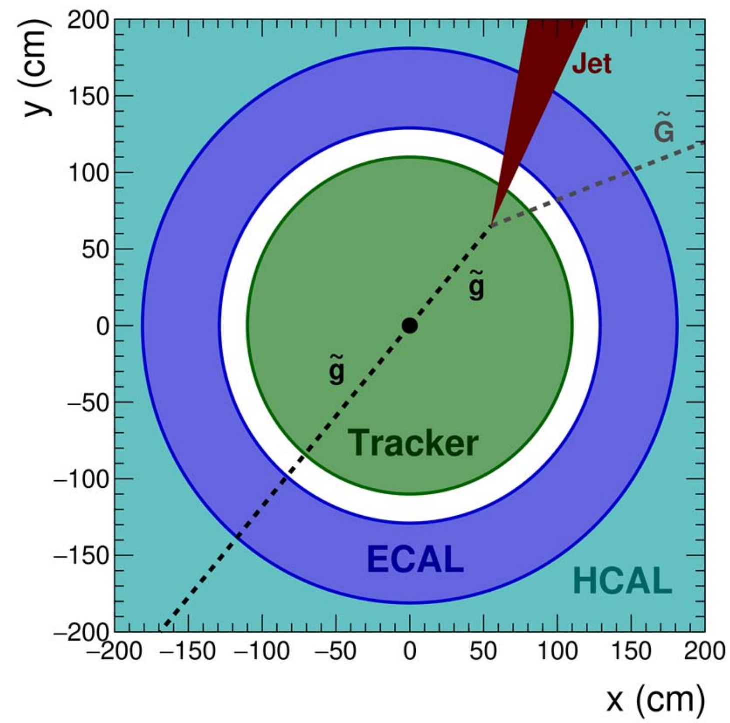
Not pictured: out of time decays or stopped

Delayed Jet+MET (EXO-19-001)(New! Full Run2 data!!)



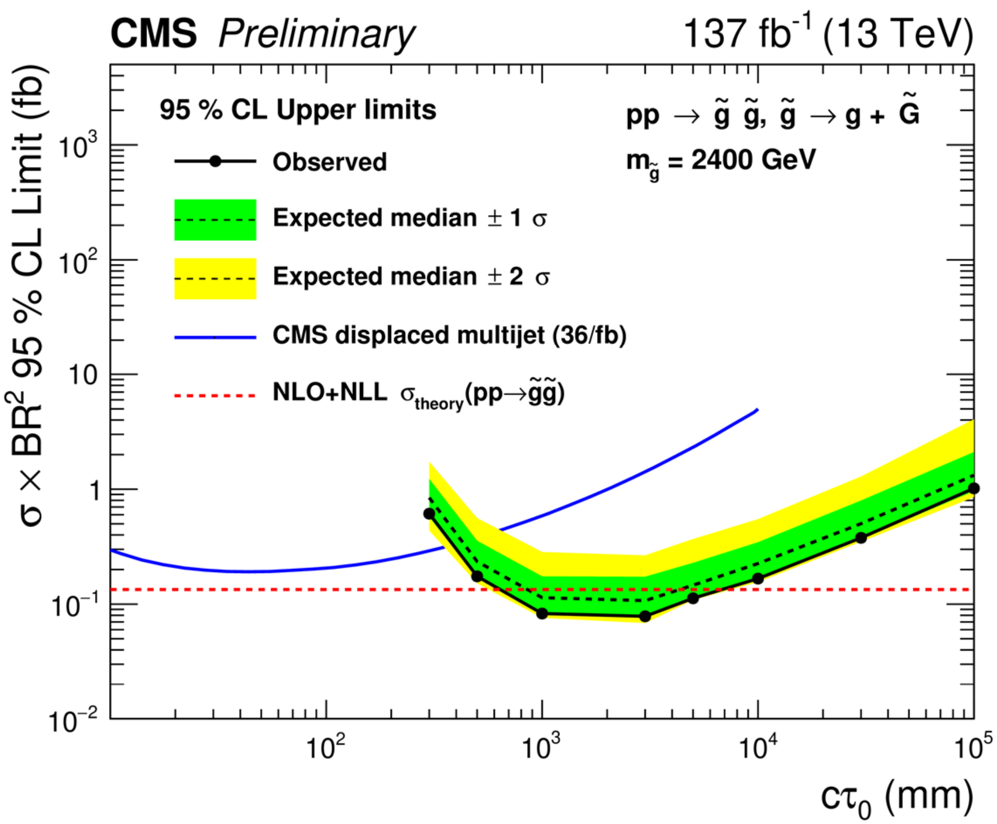
- Signature: One jet (pt>30GeV) delayed (3 to 20 ns) and MET (trigger MET>120 GeV). ECAL timing (200ps)
- Backgrounds: Cosmics, satellite bunches (data-driven)
- Physics/Models: Hidden valley, GMSB…
- Data: 137/fb (Full run 2)

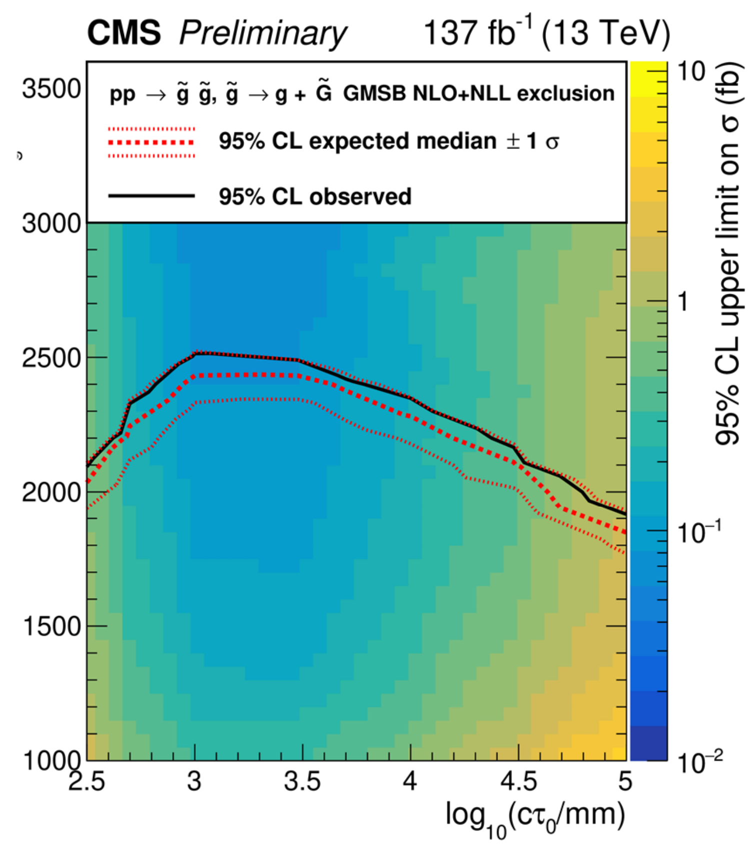




Delayed Jet+MET (EXO-19-001 contd)

Background	Prediction
Beam halo	$0.02^{+0.06}_{-0.02}$ (stat) $^{+0.05}_{-0.01}$ (syst)
Core and satellite bunches	$0.11^{+0.09}_{-0.05}$ (stat) $^{+0.02}_{-0.02}$ (syst)
Cosmics	$1.0^{+1.8}_{-1.0}$ (stat) $^{+1.8}_{-1.0}$ (syst)



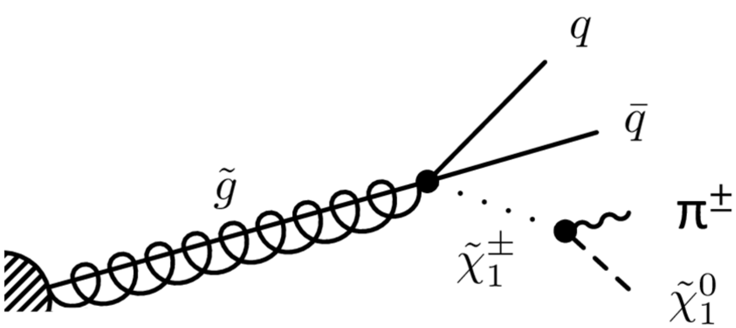


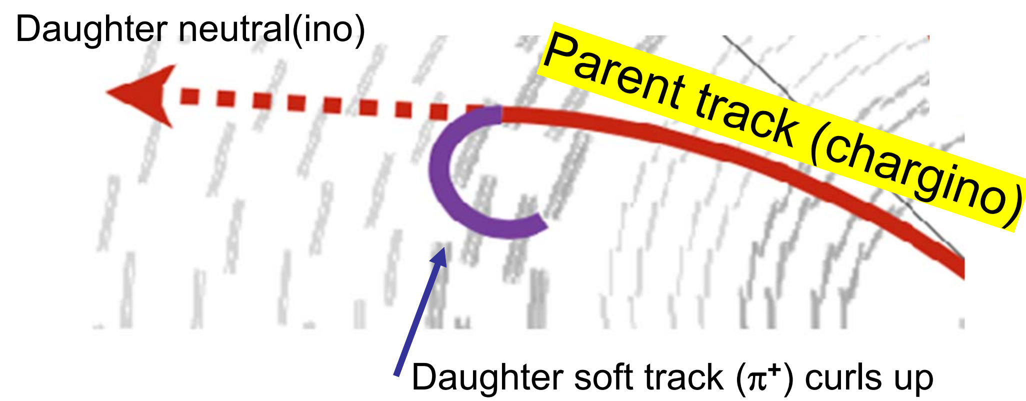
M(gluino) > 2.1TeV for 0.3<cτ<30m

Extends displaced vertex search to cτ>~1m

Disappearing (short) Tracks

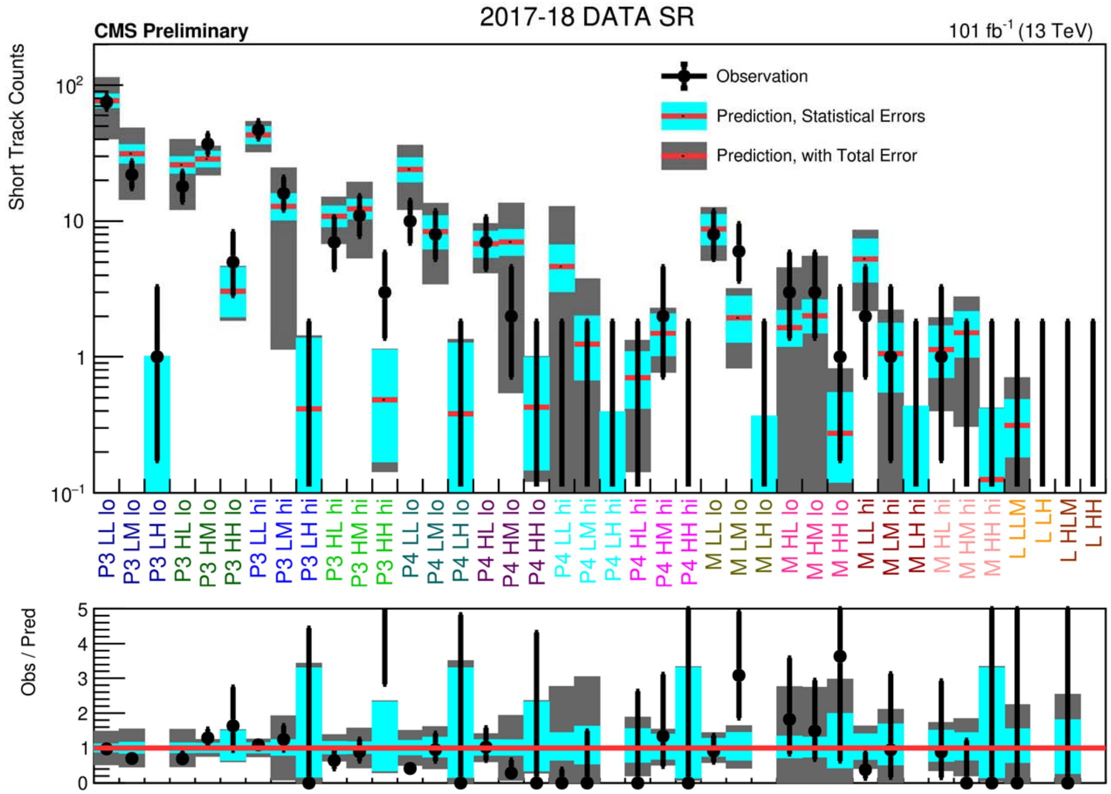
(SUS-19-005)(New! Full Run2 data!!)

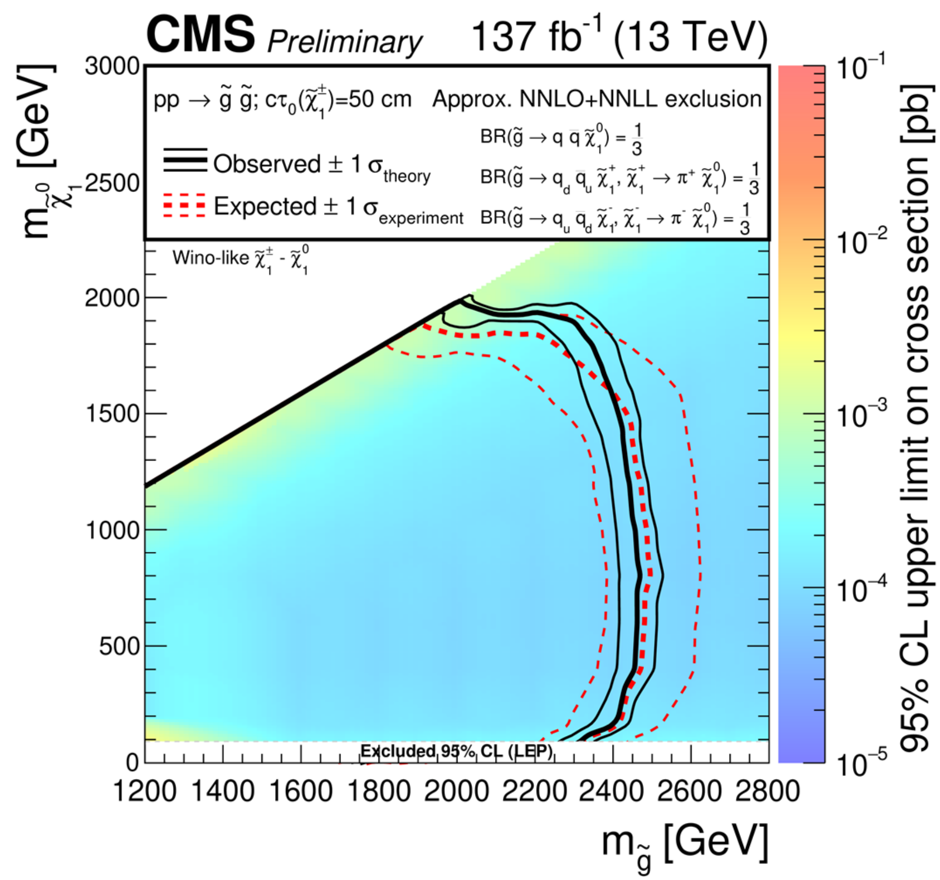




- Signature: Charged parent track disappears by decaying to neutral+soft charged
- Triggers: various pt-miss, ht-miss, HT, jet-pt combos
- Cuts: at least two jets, MT2 > 200GeV
- SR's: 68 in njet x ht x track length x track pt
- Backgrounds: fake tracks, (multiple) scatter of real tracks → poor reconstruction
- Physics/Models: compressed susy
- Data: 137/fb (Full run 2)

Disappearing (short) Tracks (contd)





Disappearing tracks extend gluino limits to 2.46TeV and neutralino to 2 TeV

• Latest and Greatest (Full Run2 Data)

Already discussed:

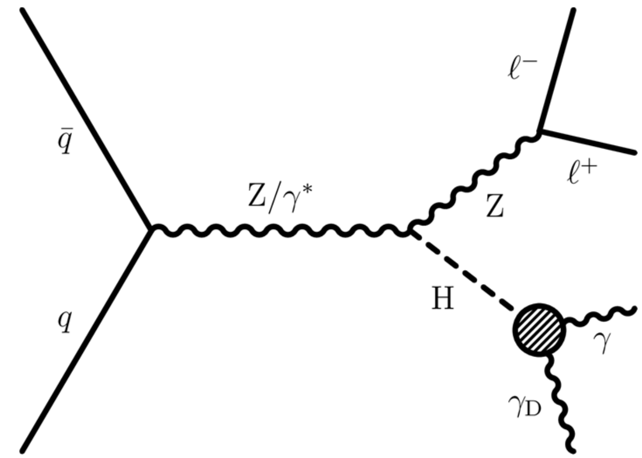
- Inclusive multileptons (seesaw and $tt\phi$)
- Delayed jets
- Disappearing tracks.

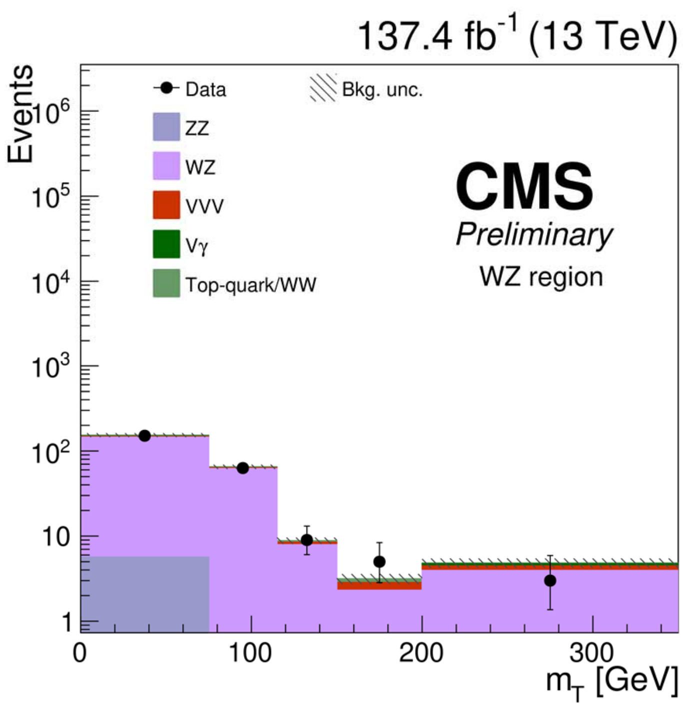
One more >>>>>>

Invisible Dark Photon Coupling to H

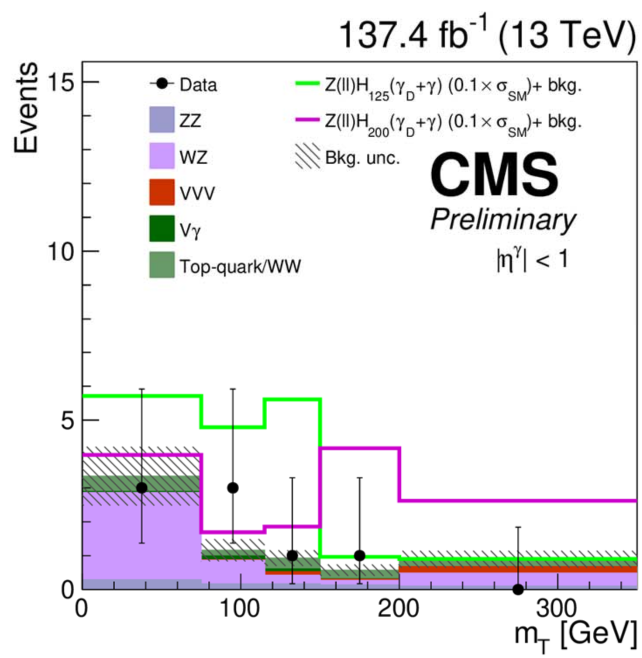
(EXO-19-007)(New! Full Run2 data!!)

- Signature: pp→ZH→(dileptons)($\gamma+\gamma_D$), Z and H back to back, reject b-tagged. Fit $m_T(\gamma + p_T^{miss})$, Z window 15Gev, m($Z\gamma > 100$GeV)
- Backgrounds: WZ, ZZ, nonresonant
- Physics/Models: higgs to invisible → susy etc
- Data: 137/fb (Full run 2)

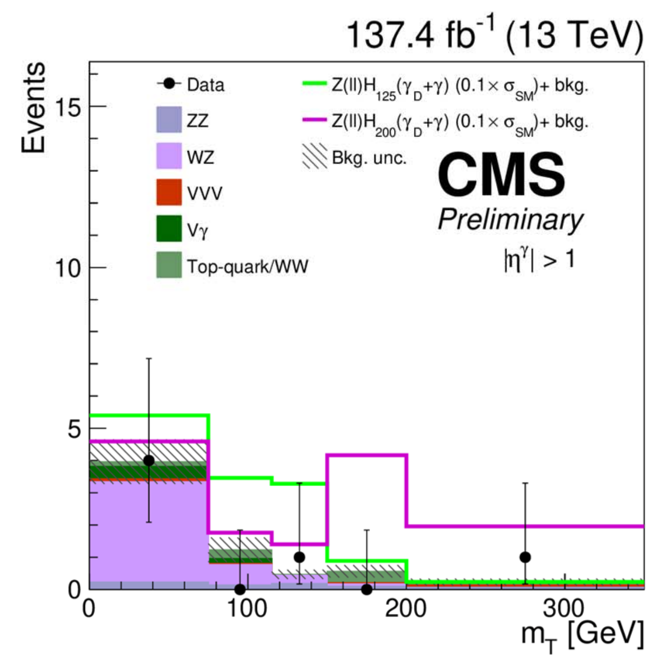




WZ control



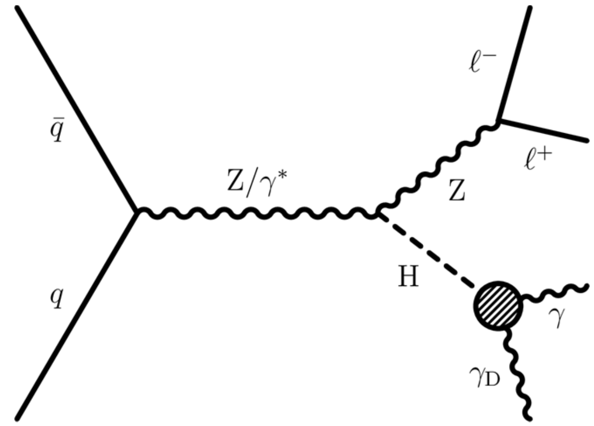
signal



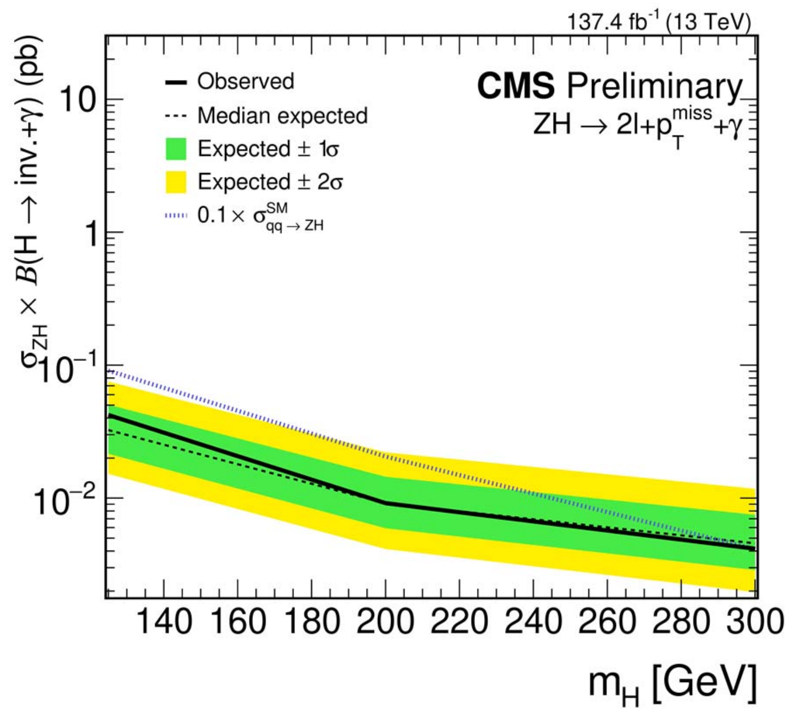
signal

Invisible Dark Photon Coupling to H (contd)

- Signature: pp→ZH→(dileptons)($\gamma+\gamma_D$)



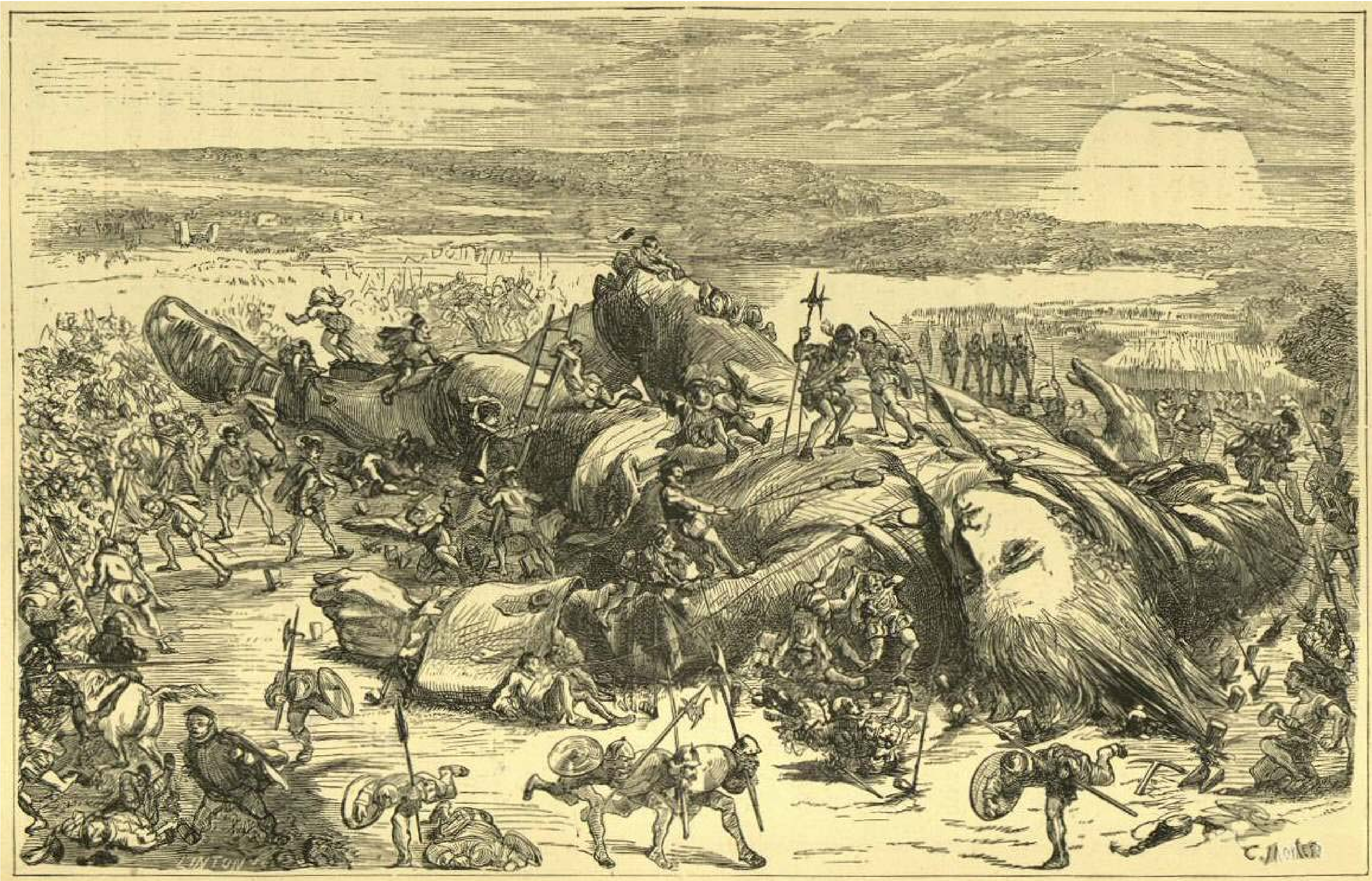
Process	Yields
Data	14
Nonresonant bkg.	2.4 ± 1.1
WZ	8.1 ± 2.0
ZZ	1.5 ± 0.3
$Z\gamma$	0.7 ± 0.7
Other bkg.	0.6 ± 0.3
Total bkg.	13.3 ± 3.8
ZH_{125} (BR=10%)	17.9 ± 1.2 (1.42 ± 0.09 %)
ZH_{200} (BR=10%)	12.3 ± 0.8 (4.32 ± 0.28 %)
ZH_{300} (BR=10%)	3.9 ± 0.2 (6.80 ± 0.34 %)



$B(H_{SM} \to \gamma + inv) < 4.6\%$ @ 95% CL

So, where do we stand?

Constraining the Standard Model



"I lay all this while, as the reader may believe, in great uneasiness."—*Page* 8.

SM Gulliver vs LHC Lilliput

LHC vs BSM Models

BSM models

LHC

Slide Credit: Stephen Martin

BSM possibilities: ways to go

New physics?

Concluding remarks

- LHC is in the midst of two data feasts. New ideas keep coming online:
  - Higgs in the final state: t', b', t→ch; electroweak Higgs, natural higgsino.
  - Generalized scalar searches for EWSB
    - Produced as daughter particles Z→Φ+x
    - Produced in association: ttΦ, VΦ
    - Decay couplings variation, e.g. bb, μμ, ττ
  - Boosted final states and substructure.
  - long live the long-lived objects.
  - generalized recoil (Dark Matter).
  - VBF..
  - Machine Learning
    - From object level to signal level (grand unification?)
    - believable or not ☺
- If Nature is kind, see you at the

  "Slepton-Photon" 202x meeting.