Results from Searches for Exotic Phenomena

W', Z', extra dimensions, excited quarks, new resonances...

Alex Martyniuk, UCL
On behalf of the ATLAS and CMS collaborations

PIC-2017
Sept. 6, 2017

Rough Outline

1. Intro: Exotics @ LHC
2. Tools of the trade
   - The LHC, ATLAS, & CMS
3. Searches
   - Resonant
   - Non-resonant
   - Plain WHAT?! signals
4. Summary

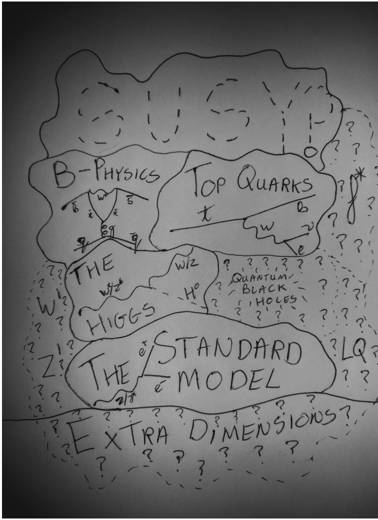
As you can imagine I can only cover a small subset of the area!

What ‘counts’ as exotic phenomena?

- This question is **largely answered** by the internal physics group **structures** of ATLAS and CMS
- Exotic phenomena are **not**:
  - SM Processes (obviously)
  - B-physics (obviously separate from the SM)
  - Top-quark measurements (also separate)
  - Higgs-boson measurements (also, also separate)
  - SUSY (just a copy of the SM)
- This leaves us with **everything** that falls through the **cracks** between the above groups
- So, basically **anything** left that could make a **physicist** go:

“Huh... That looks weird...”

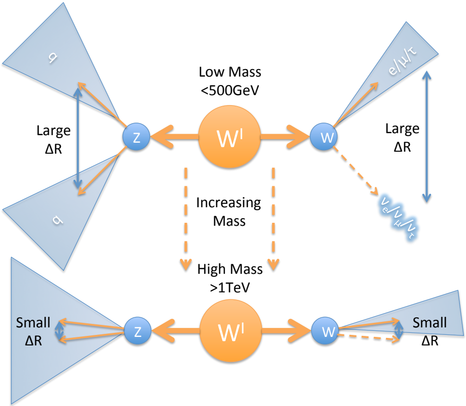
- That is a lot of **weird** to cover in one talk...
  - Heavy gauge bosons, W' & Z'
  - Leptoquarks
  - Excited fermions
  - Extra-dimension models with *KK* resonances
  - Black holes (quantum or otherwise)
- I won’t **succeed**... Or even **try**....



ATLAS Exotics Results [1]
CMS Exotica Results [2]

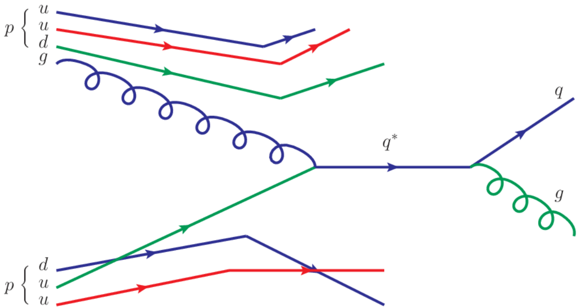
Models – Additional Bosons

- Many BSM models Contain **additional bosons**
  - **Heavy vector triplet** (HVT): Additional W', Z' particles at high mass
  - **Left-Right symmetry** models: $W_R^{\pm}$ partner for the $W_L^{\pm}$
  - **Extended Higgs** sectors: New partners to the Higgs
  - **Scalar leptoquarks**: Bosons that couple to quark/lepton pairs



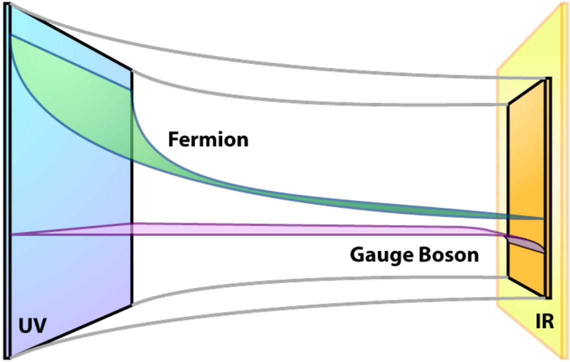
- Aiming to answer a **wide variety** of questions
  - Light neutrino masses (LRSM)
  - Nature of EW-symmetry breaking (Extended Higgs)
  - Flavour-sector anomalies (Leptoquarks)
  - Phenomenological bridge between theory/experiment (HVT)

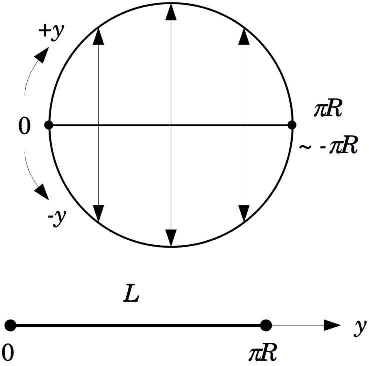
- Some models seek to **extend** the fermionic sectors with additional **particle Content**
- Ask the questions:
  - Are quarks and leptons **fundamental**?
  - Are there only **three** generations?
  - Or, **why** are there three generations?



- Models include:
  - **Compositeness** models: $E < \Lambda$ Contact interactions, $E > \Lambda$ expect new particles and interactions
  - **Vector-like quarks** (VLQ): New top partners that do not couple to the Higgs

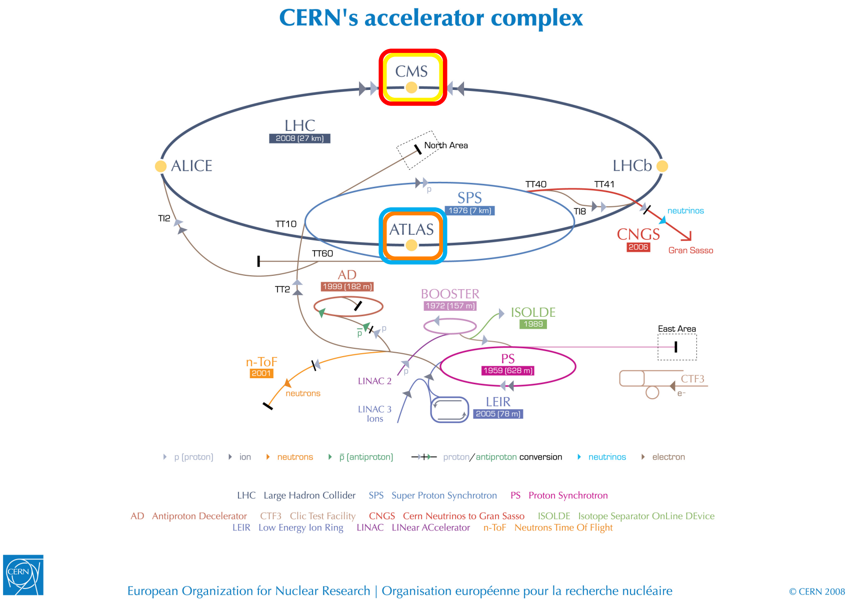
- Models with **extra dimensions** (ED) offer solutions to the **hierarchy** Problem
- These models (ADD, RS1, RS-Bulk) involve **curved**, sometimes **warped**, ED



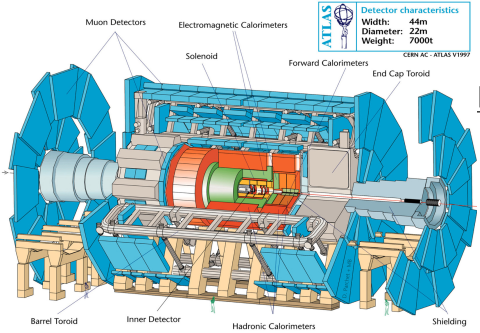


- The **momentum** of SM particles Propagating in the ED, **appears** to an observer living in 3D as additional **rest mass**
  - Gain multiple Kaluza-Klein modes for each particle
  - Spacing dependant upon the shape/size of the ED
- Observe G^{*}_{KK}, Kaluza-Klein modes of the **graviton**

The tools – LHC

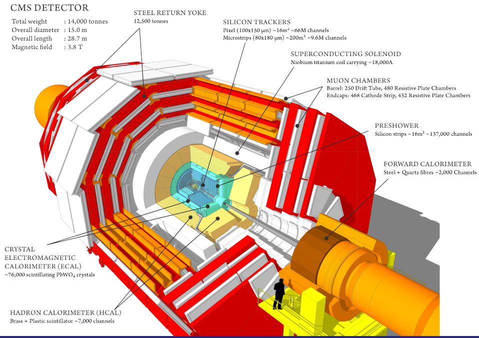


The General Purpose Detectors



Differences

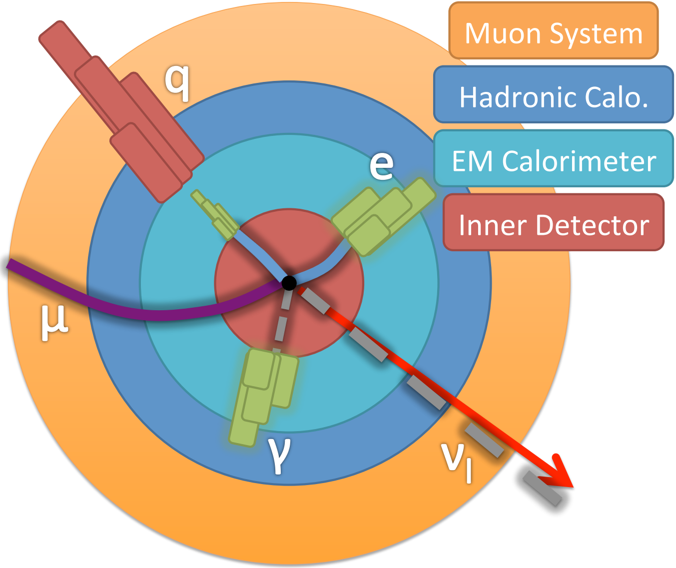
- **Detector-technology** choices
- *B*-field **CONFiguration**: Solenoid vs Solenoid+Toroid
- **Size/weight** (though both are colossal!)



Similarities

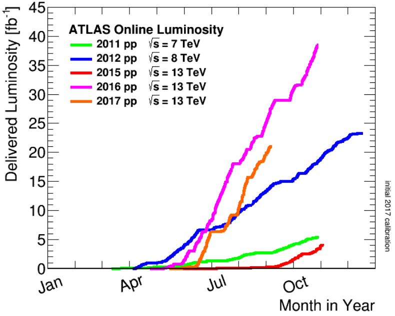
- **Cylindrical** detectors: barrel & end-caps
- **Concentric** detectors: Tracking, EM$\rightarrow$had-calorimetry, muon chambers
- Close to 4π solid-angle coverage
- Hardware/software **combined** trigger systems

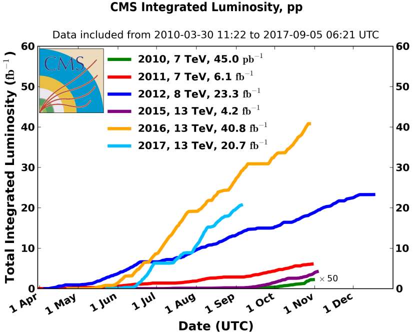
The General Purpose Diagram



Data recorded

- The LHC has the **pedal to the metal**
- Collisions now **flooding** into the detectors, at record breaking instantaneous luminosities and pile-up
- Some Problems are **nice** to have... (for a while...)

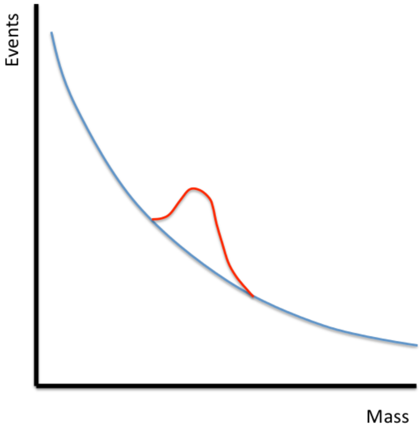




Resonances – $X \rightarrow YY$: Bump!

- Resonance searches are the **classic collider methodology** in searches for **new particles** and their excitations
- The **majority** of exotics searches follow this methodology
- Try to **infer** the presence of a **new particle** by combining its decay Products
  - Reconstruct 4-vectors of decay Products
  - Combine and plot the invariant mass
- In **essence** they boil down to,

  "Look for an unexpected peak on a smooth background"
- Often **one decay** channel can be used to search for a **wide range** of models

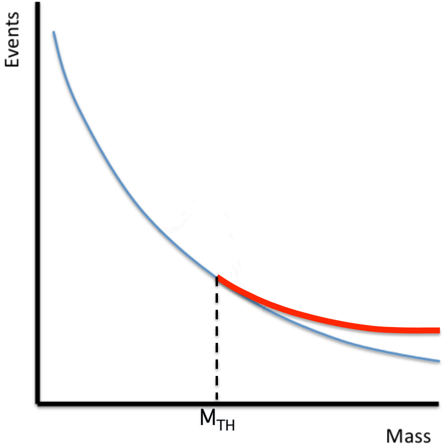


Non-resonant – $X \to YY$: Deviation!

- In some models, the **BSM signal** appears as a **non-resonant** deviation from the background:
  - **Contact interactions** occurring below the Λ at which new physics appears
  - In the **large extra-dimension** ADD model the KK–modes are **so close** together that they become **unresolvable**
- In **essence** they boil down to,

  "Look for a deviation to the expected slope of the SM background Process"

- Much more **subtle** than a bump!
- Deviation would begin at a **threshold mass**, M_{TH}, e.g. at the mass of the **first** KK–mode



The workhorse searches: *qq* & *ll*

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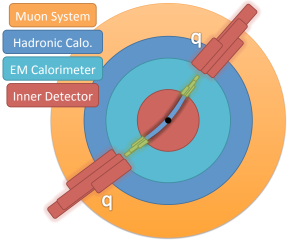
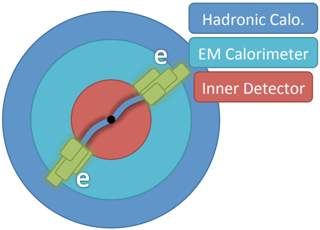
- The **dijet** and **dileptonic** searches form the **backbone** of the exotica(s) Programs
  - Sensitive to a **wide** range of models
  - Relatively '**simple**' analyses, select objects, combine, model backgrounds
  - Push searches to the **highest** invariant mass ranges possible ($m_{jj} = \mathcal{O}(8\ \mathrm{TeV})$)
  - Very **sensitive** in early data, gains reduce with increasing data

Dijet:



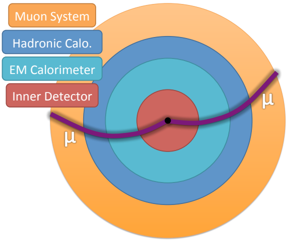
- Two, back to back high-p_{T} jets
- Large QCD initiated multijet backgrounds

Dielectron:



- Two, back-to-back isolated high-p_{T} electrons
- Large Drell-Yan backgrounds

Dimuon:



- Two, back to back isolated high-p_{T} muons
- Large Drell-Yan backgrounds

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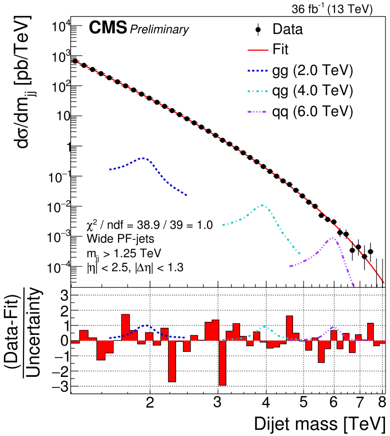
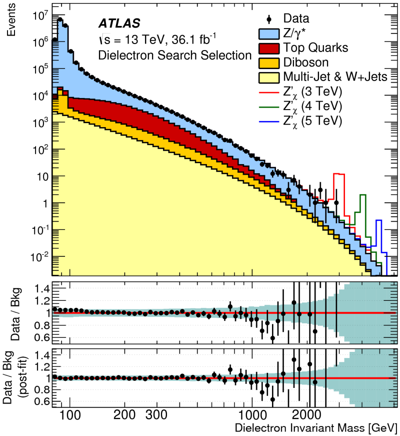
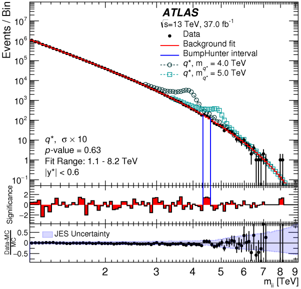
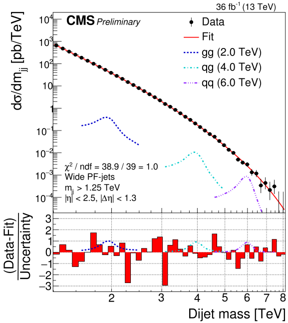
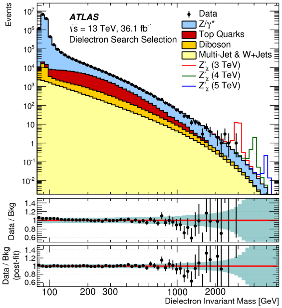


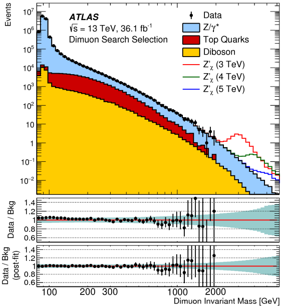


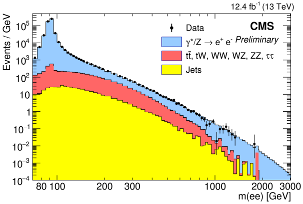
Nothing seen, in any...



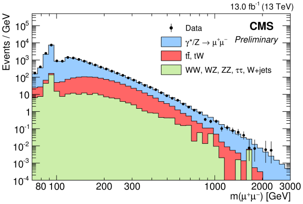






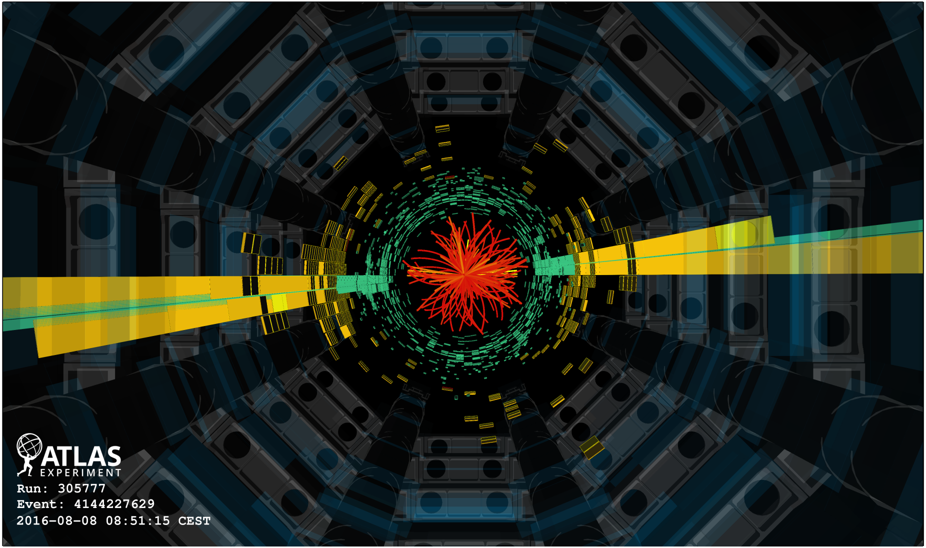


[3, 4]



[5, 6]

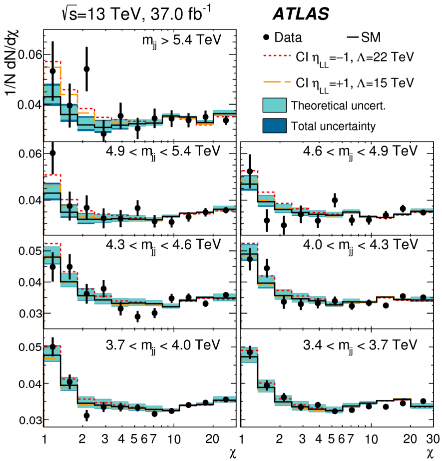
Nothing is pretty spectacular

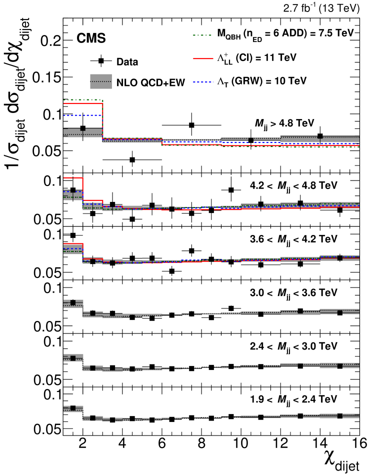


Angular analysis – Digging deeper

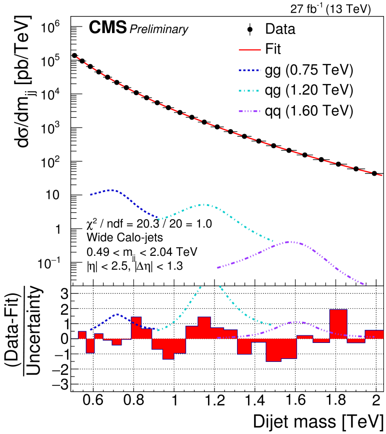
- Can look into the **angular distributions** of the dijet system, a different **handle** on the system [7, 4]
  - **Sensitive** to Contact interactions, extra-dimensions...
  - Would all alter the **angular** distributions Produced

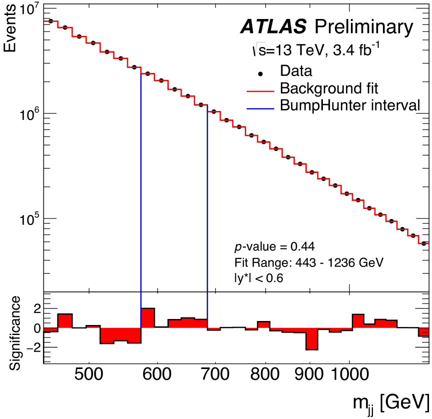
$$\chi = e^{|y_1 - y_2|}$$



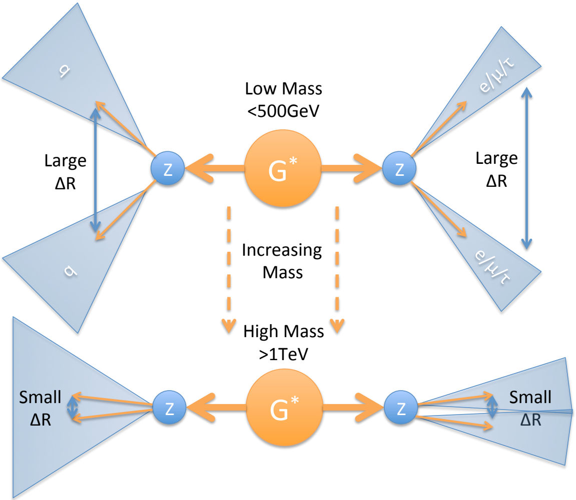


- **Limited** at lower dijet masses by the **thresholds** run in hadronic jet triggers
- **Reduce** the size of event saved, therefore can save **more events** in same bandwidth
  - Only save **minimal** trigger jet information in the event, run the analysis on **trigger-level jets!**
  - Can therefore push trigger thresholds down to **lower energies** [8, 9]





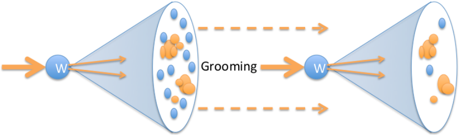
Aside: Boosting objects – Collimation



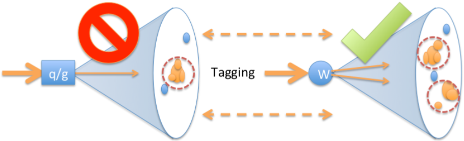
- For example: vector bosons have mass $\mathcal{O}$**(0.1 TeV)**
- If we are interested in particles of mass $\geq \mathcal{O}$**(1 TeV)**
- Therefore the decays of the form, $X \rightarrow VV$ with **large** m_X, lead to vector bosons with **very high** p_{T}
- Boosted decay Products become more **collimated**
- Have **sufficient granularity** to resolve most leptonic decays
- subjets begin to **merge** in hadronic decays at high m_X
- **Rule of thumb** for angular separation of decay Products: $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2} \approx \frac{2m}{p_{\mathrm{T}}}$

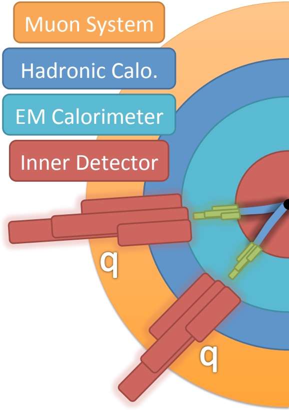
Event Selection – $X \rightarrow qq$

1. **Reconstruct** events with **high**-p_T jets
   - Use **large-enough-R** parameter jet to collect **'all' radiation** from the original X decay
2. **Groom** the jets
   - Signal: Remove **unwanted** jet Constituents not from the signal, e.g. **pile-up**
   - Background: **Preserve** the background characteristics



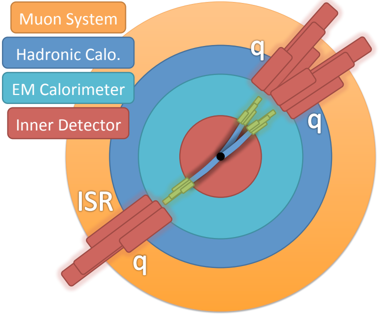
3. **Tag** as bosonic jet (or indeed a Higgs or top jet)
   - Use **differences** between signal and background jet characteristics to **reject** background jets

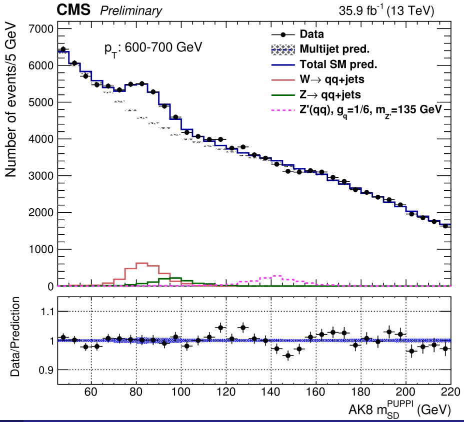




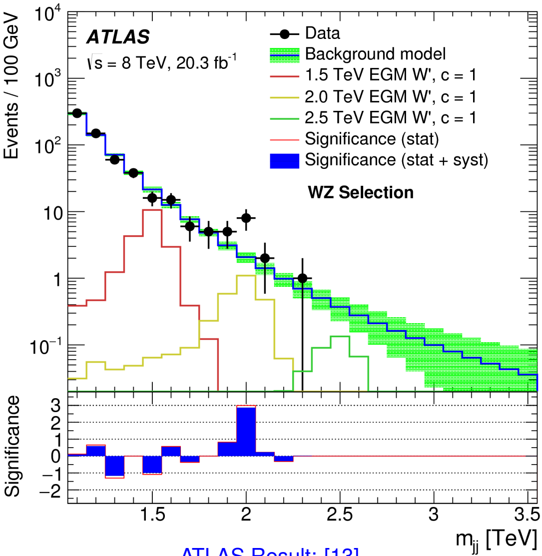
ISR analysis – Digging deeper

- Going to **lower** dijet masses is **difficult** at hadron colliders
  - **Large** jet trigger thresholds
  - **Huge** multi-jet backgrounds at low p_T
- Trigger on an ISR jet, **balancing** the dijet system from the signal
- Use jet **substructure** techniques to pull the **two-Pronged** signal out from the **single-Pronged** background jets





- **Powerful** analysis, able to search for **fully hadronic** final states below $m_{jj} < 140$ GeV! [10, 11, 12]

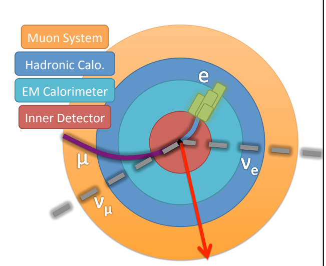


ATLAS Result: [13]

Diboson searches

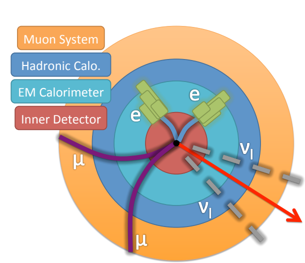
- Many particles in BSM models couple **strongly** to the electroweak sector, ∴ decays to $W/Z/H$ are **enhanced** (HVT, extended Higgs sectors, RS-Bulk...)
- Many **distinctive signature** combinations to search for:
  - $W \to l\nu$, $W \to qq$
  - $Z \to ll$, $Z \to \nu\nu$, $Z \to qq$
  - $H \to bb$
- Plethora of search channels can be made from combinations of these decays

W: leptonic decays:



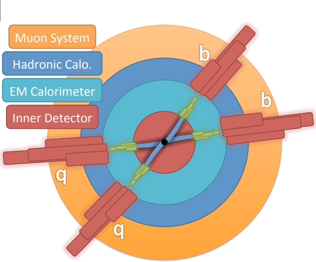
- Pro: Clean lepton trigger
- Con: E_T^{miss}, smaller BR

Z: leptonic decays:



- Pro: Clean lepton trigger
- Con: Smallest BR

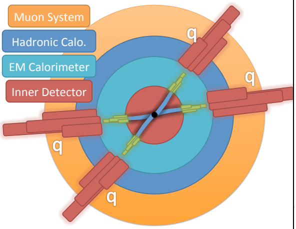
W/*Z*/*H*: hadronic decays:

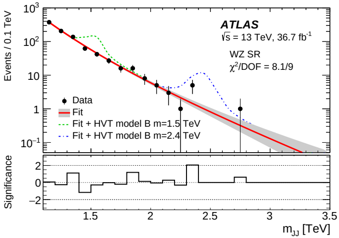


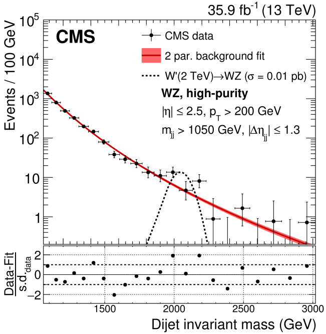
- Pro: Large BR
- Con: Huge backgrounds!

VV searches – Hadronic hiccups gone

- Large **branching fraction** in this channel
- Also a **huge** multi-jet background
- Use jet **substructure** to pick out **two-Pronged** signal from **one-Pronged** background



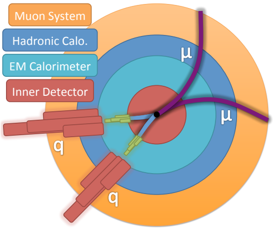


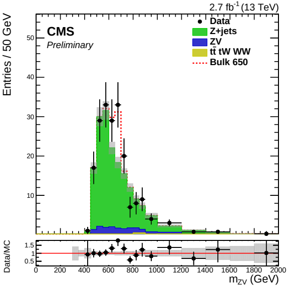


- Grooming@ATLAS: **Trimmed** jets, remove subjets with p_{T} share below threshold [14]
- Grooming@CMS: **Soft-drop**, removes wide-angle soft Constituents [15]
- Tagging@ATLAS: $D_2^{\beta=1}$+jet mass and n_{trk} [16]
- Tagging@CMS: n-subjettiness+jet mass [17]
- **No excess seen** anymore @2 TeV, was **not borne** out by more data [18, 19]

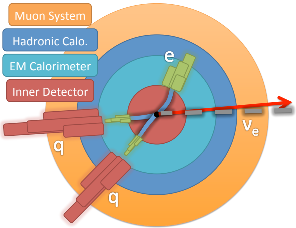
VV searches – Leptonic channels

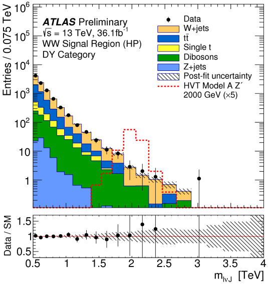
$VZ \to llqq$: [20, 21]



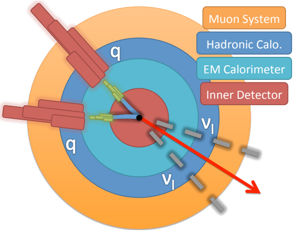


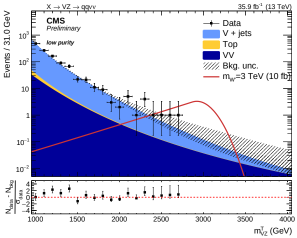
$VW \to l\nu qq$: [22, 19]





$VZ \to \nu\nu qq$: [23, 24]





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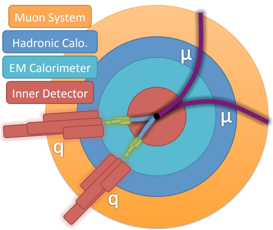
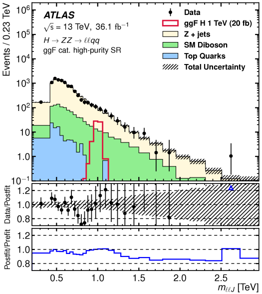
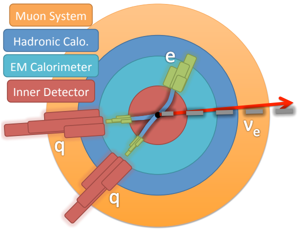
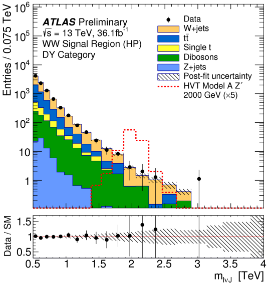


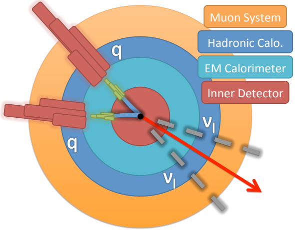


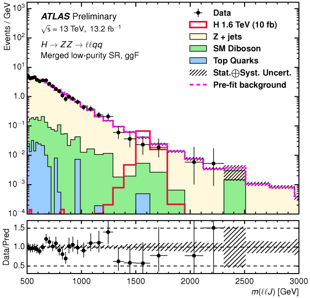
$VW \to l\nu qq$: [22, 19]



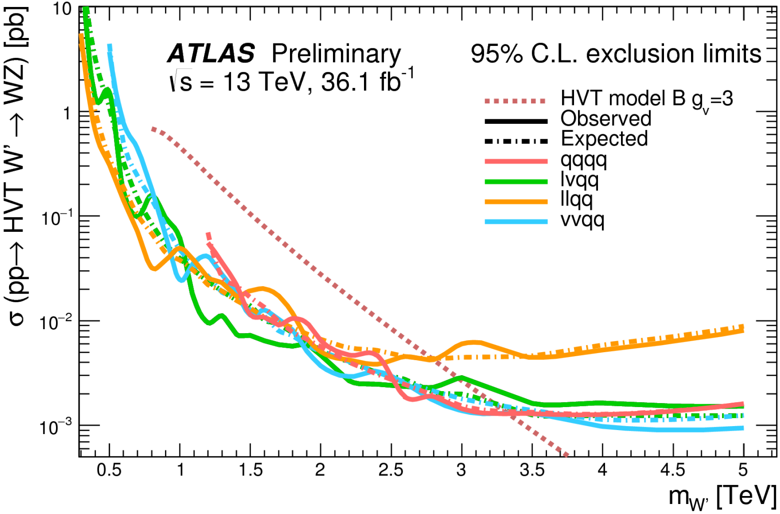


$VZ \to \nu\nu qq$: [23, 24]





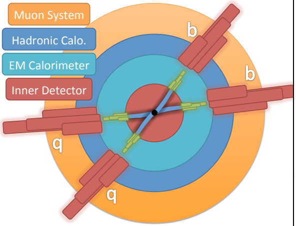
VV searches – Summary

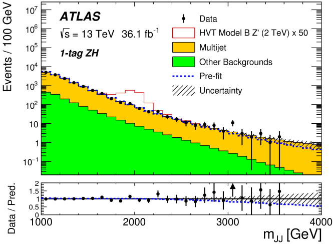


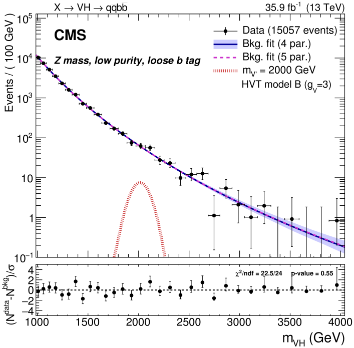
ATLAS Exotics Results [1], CMS B2G Summary

VH searches – Hadronic

- Searches are already **using** $H \to bb$!
  - We only just have $\geq 3\sigma$ evidence from VH
- Similar Pro/Cons to the $VVJJ$ channel
  - Large branching fraction in this channel
  - Also a huge multi-jet background



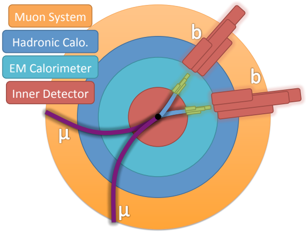


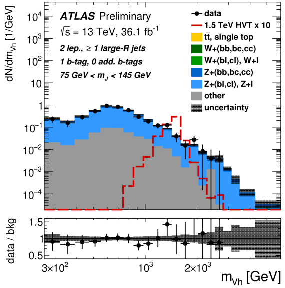


- Use the same **tagging** techniques to tag the V side
- **Tag** the H decay with 1/2 || loose/tight b-tags
- **No excess** seen by CMS, **slight excess** seen at 3 TeV by ATLAS [25, 26]
- Local (global) significance of 3.3σ (2.1σ)
- Been here before, let **more data** show us the **way forwards**

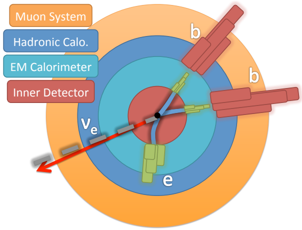
VH searches – Semi-Leptonic

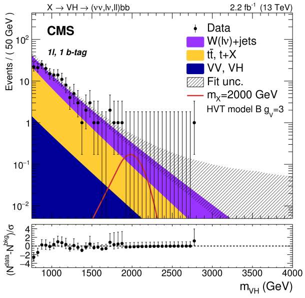
$VH \to llqq$: [27, 28]



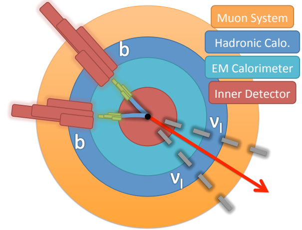


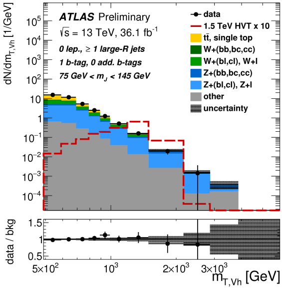
$VH \to l\nu qq$: [27, 28]

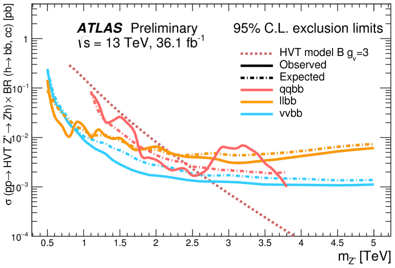


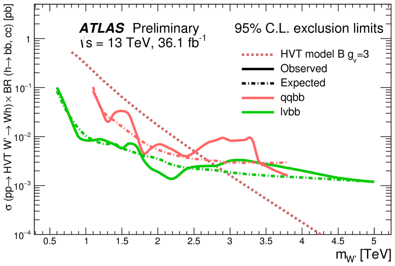


$VH \to \nu\nu qq$: [27, 28]





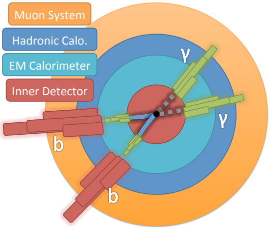




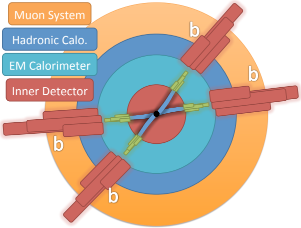
ATLAS Exotics Results [1], CMS B2G Summary

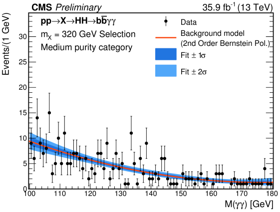
- Also searching for **di-Higgs** production
  - Measuring λ_{HHH} is a **long-term goal** of the LHC to define the **Higgs potential**
  - **Observation** now of *HH* production would be **evidence** for new physics

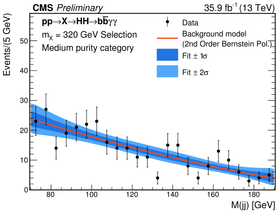
$HH \to bb\gamma\gamma$: [29, 30]

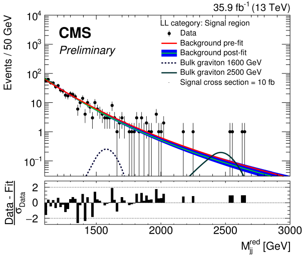


$HH \to bbbb$: [31, 32]



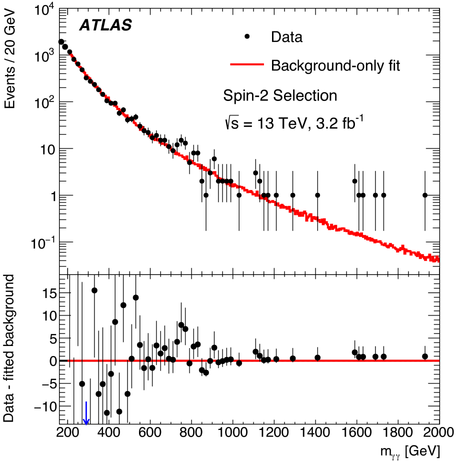


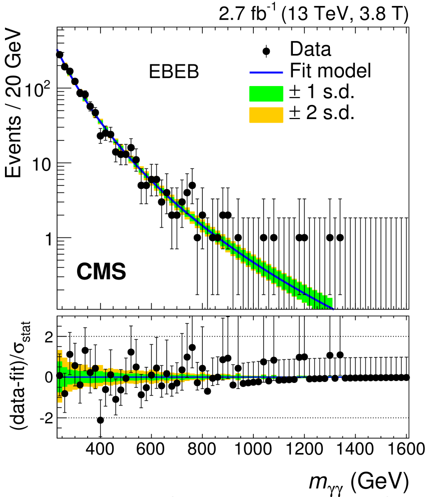




$\gamma\gamma$ searches: Some excitement!

- Some **excitement** in this channel in the early Run-2 data, local (global) $\approx 3.5\sigma$ (1.7σ)
- **'Bump'** seen by **both** ATLAS and CMS at 750 GeV [33, 34]

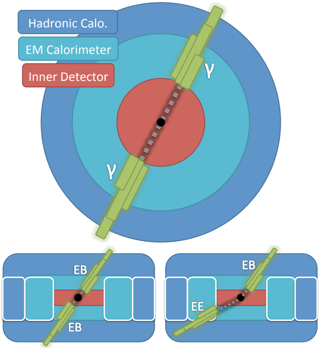




- Absolute **deluge** of theory papers, even papers modelling the flood [35] and awards for papers/citations in theory blogs, Resonaances

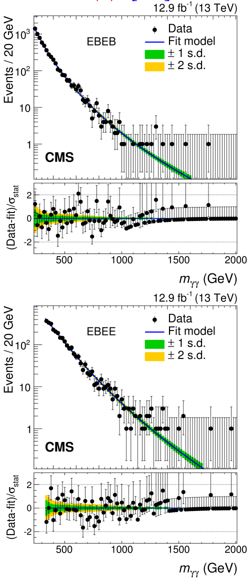
$\gamma\gamma$ searches: Excitement faded

- Deceptively simple analysis, back-to-back high-p_T photon pairs
  - Devil as always in the details

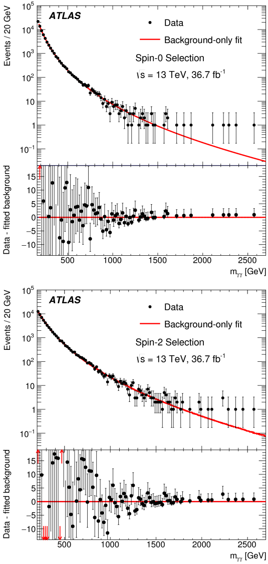


- CMS splits into barrel/endcap selections
- ATLAS splits into spin-0/2 targeted selections

CMS: $X \to \gamma\gamma$: [36]



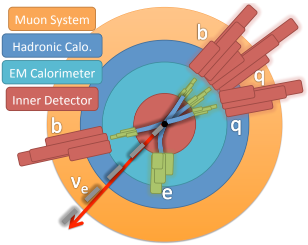
ATLAS: $X \to \gamma\gamma$: [37]



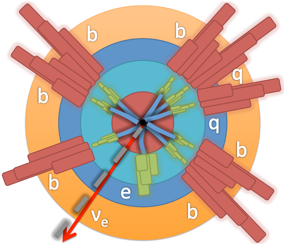
3rd-Gen Searches

- The **mass hierarchy** in the fermion sector is an **unanswered** question
- **Reasonable** to expect couplings of new physics to the **third generation** fermions
- **Many, many** models such predict enhanced production, and therefore **many** searches are made. Too many to cover here!
- Many of these signals fall into the:
  “If you miss this, what exactly were you looking for?”
  category
- Otherwise known as:
  “My whole detector is lit up like a Christmas tree!”

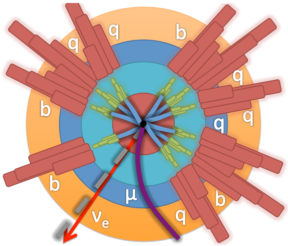
$t\bar{t}$ resonances:



$TT \to tHtH$:

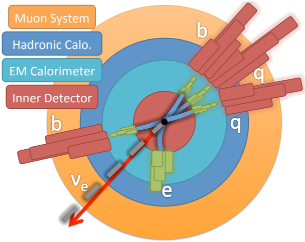


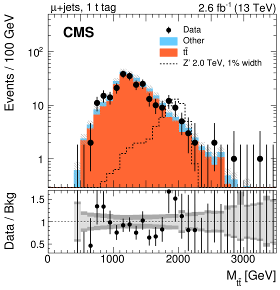
$X \to tttt$:



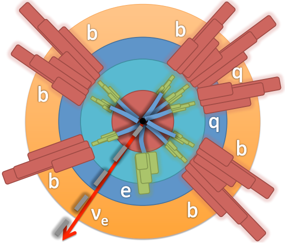
3rd-Gen Searches

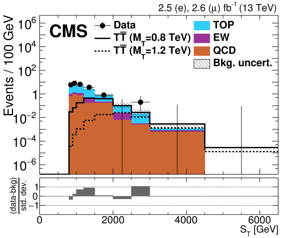
$t\bar{t}$ resonances: [38, 39]



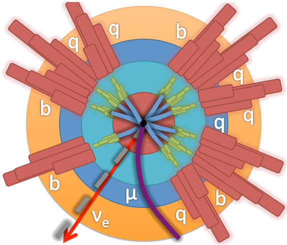


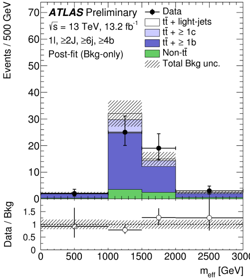
$TT \to tHtH$: [40, 41]

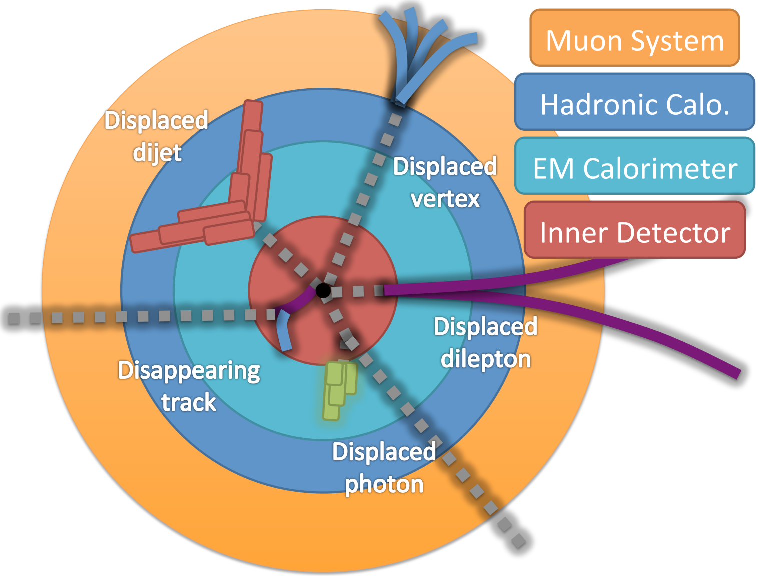




$X \to tttt$: [41, 42]

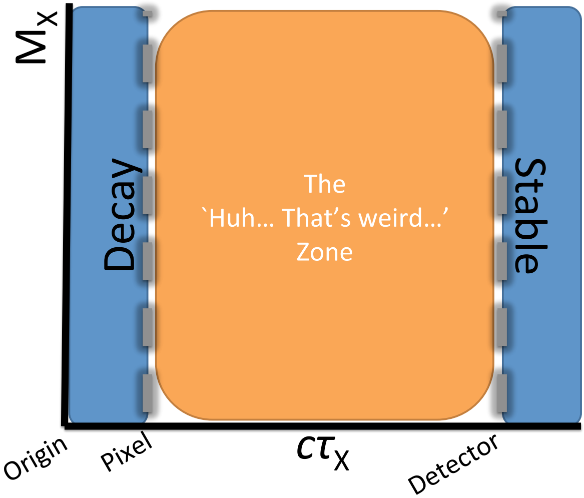






Muon System
Hadronic Calo.
EM Calorimeter
Inner Detector
Displaced dijet
Displaced vertex
Displaced dilepton
Disappearing track
Displaced photon

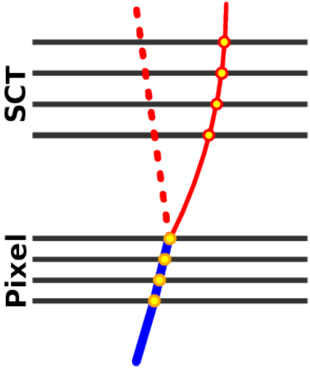
Hey! You're using the detector wrong!!!

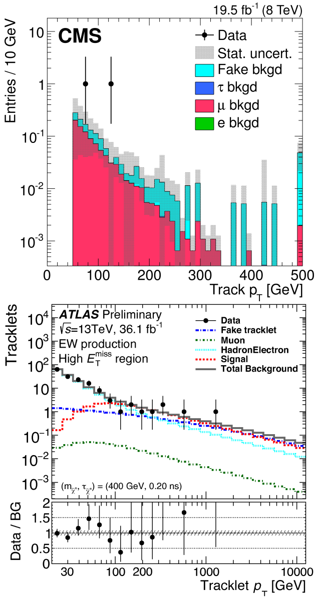


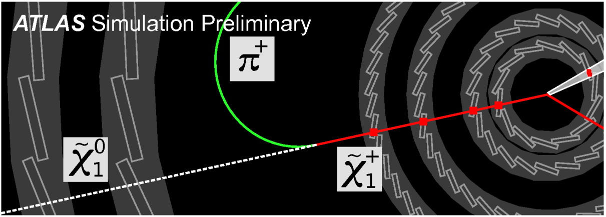
- Particles have '**long**' lifetimes, but **decay within** the detector volume are **not** usually covered by standard analyses
- Standard reconstruction techniques **do not work**
  - Vertexing assumptions: **Wrong**
  - Jet reconstruction: **Wrong**
  - Track reconstruction: **Wrong**
  - .....
- This area (as with all exotics) is a **lecture series** on its own
- I won't do it **justice**, at all

Disappearing tracks

- Looking for particles (e.g. charginos) with **meta-stable** lifetimes
- **Decay** in inner detector to SM+LSP
- Look for **tracklets**, i.e. short tracks not picked up by standard tracking [43, 44]

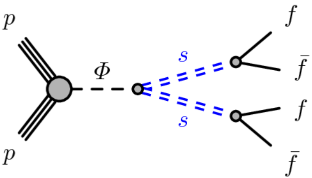


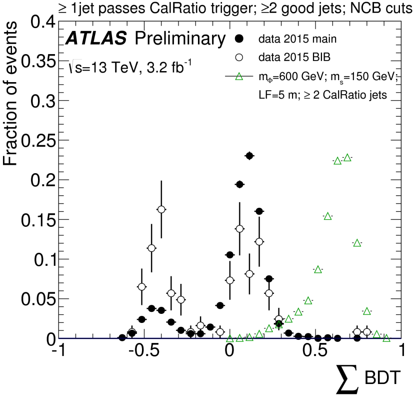




Displaced dijets

- Looking for particles that decay **within** the calorimeters
- **No** inner detector tracks, **just** a pair of jets in the calorimeter
- Picked out by a **BDT** based on jet Properties [45]
- **Nothing seen** by this analysis or any of the 'unusual' analyses
- We should **keep doing them**, we only get **one LHC** and we should **squeeze** it till the pips come out!
- Use the detectors in **weird, wonderful ways** that they were never intended for!



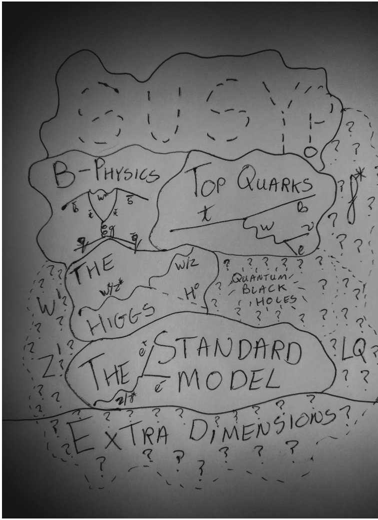


Summary

- As I said at the **beginning**, I had no chance of **covering** everything...
  - Please feel free to peruse the back catalog of hits from the experiments
- We have the **Higgs**, but **nothing else** new...
  - We have even started using the Higgs in searches
- We are using our detectors in ways they were **not designed** to be used, and with methods that **did not exist** when we started
- The LHC is **only** $\mathcal{O}(1\%)$ into its **final dataset**
- We have a lot of rocks to **look under** and corners to **shine light into**
- **Hopefully** at some point soon a **physicist** will go:

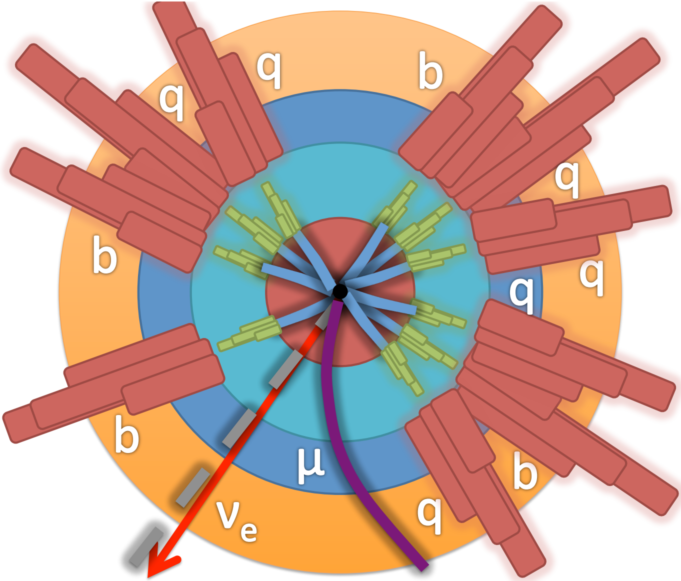
"Huh... That looks weird..."

- That could be the **start** of a **wild theory** becoming **standard physics**...
- Until that day we will **keep looking!**



ATLAS Exotics Results [1]
CMS Exotica Results [2]

Backup



ATLAS Exotics Summary – [1]

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: July 2017

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 37.0)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 8, 13$ TeV

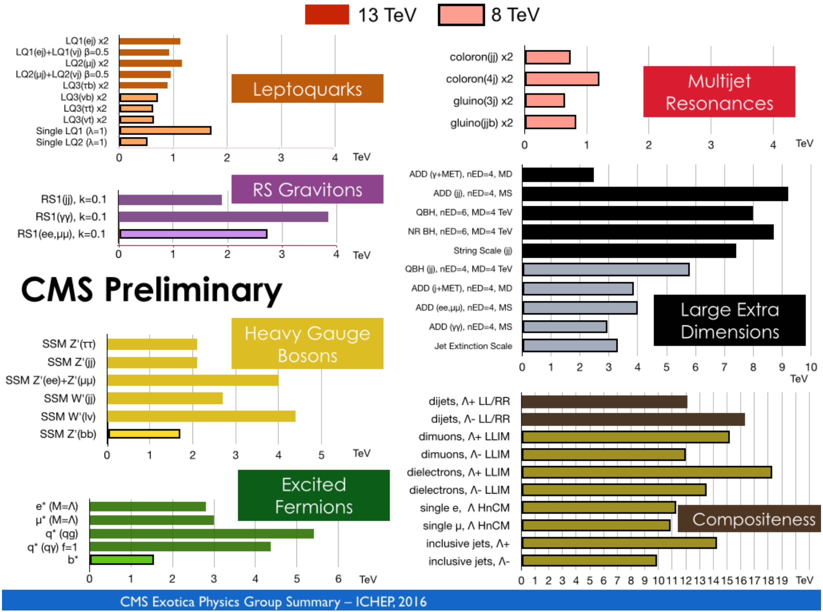
	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt [\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	0 e, μ	1 – 4 j	Yes	36.1	M_D 7.75 TeV	$n = 2$	ATLAS-CONF-2017-060
	ADD non-resonant $\gamma\gamma$	2 γ	–	–	36.7	M_S 8.6 TeV	$n = 3$ HLZ NLO	CERN-EP-2017-132
	ADD QBH	–	2 j	–	37.0	M_{th} 8.9 TeV	$n = 6$	1703.09217
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \gamma\gamma$	2 γ	–	–	36.7	G_{KK} mass 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$	CERN-EP-2017-132
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	1 e, μ	1 J	Yes	36.1	G_{KK} mass 1.75 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2017-051
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 3 j	Yes	13.2	KK mass 1.6 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \to tt) = 1$	ATLAS-CONF-2016-104
Gauge bosons	SSM $Z' \to \ell\ell$	2 e, μ	–	–	36.1	Z' mass 4.5 TeV		ATLAS-CONF-2017-027
	SSM $Z' \to \tau\tau$	2 τ	–	–	36.1	Z' mass 2.4 TeV		ATLAS-CONF-2017-050
	Leptophobic $Z' \to bb$	–	2 b	–	3.2	Z' mass 1.5 TeV		1603.08791
	Leptophobic $Z' \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	3.2	Z' mass 2.0 TeV	$\Gamma/m = 3\%$	ATLAS-CONF-2016-014
	SSM $W' \to \ell\nu$	1 e, μ	–	Yes	36.1	W' mass 5.1 TeV		1706.04786
	HVT $V' \to WV \to qqqq$ model B	0 e, μ	2 J	–	36.7	V' mass 3.5 TeV	$g_V = 3$	CERN-EP-2017-147
	HVT $V' \to WH/ZH$ model B	multi-channel			36.1	V' mass 2.93 TeV	$g_V = 3$	ATLAS-CONF-2017-055
	LRSM $W'_R \to tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	37.0	Λ 21.8 TeV η_{LL}^-		1703.09217
	CI $\ell\ell qq$	2 e, μ	–	–	36.1	Λ 40.1 TeV η_{LL}^-		ATLAS-CONF-2017-027
	CI $uutt$	2(SS)/$\geq$3 e,μ	$\geq$1 b, $\geq$1 j	Yes	20.3	Λ 4.9 TeV	$\lvert C_{RR} \rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	1 – 4 j	Yes	36.1	m_{med} 1.5 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 400$ GeV	ATLAS-CONF-2017-060
	Vector mediator (Dirac DM)	0 e, μ, 1 γ	≤ 1 j	Yes	36.1	m_{med} 1.2 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 480$ GeV	1704.03848
	$VV\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	M_* 700 GeV	$m(\chi) < 150$ GeV	1608.02372
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	$\geq$1 b, $\geq$3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht + X$	0 or 1 e, μ	≥ 2 b, ≥ 3 j	Yes	13.2	T mass 1.2 TeV	$\mathcal{B}(T \to Ht) = 1$	ATLAS-CONF-2016-104
	VLQ $TT \to Zt + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	36.1	T mass 1.16 TeV	$\mathcal{B}(T \to Zt) = 1$	1705.10751
	VLQ $TT \to Wb + X$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	T mass 1.35 TeV	$\mathcal{B}(T \to Wb) = 1$	CERN-EP-2017-094
	VLQ $BB \to Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	B mass 700 GeV	$\mathcal{B}(B \to Hb) = 1$	1505.04306
	VLQ $BB \to Zb + X$	2/$\geq$3 e, μ	$\geq$2/$\geq$1 b	–	20.3	B mass 790 GeV	$\mathcal{B}(B \to Zb) = 1$	1409.5500
	VLQ $BB \to Wt + X$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	B mass 1.25 TeV	$\mathcal{B}(B \to Wt) = 1$	CERN-EP-2017-094
	VLQ $QQ \to WqWq$	1 e, μ	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
Excited fermions	Excited quark $q^* \to qg$	–	2 j	–	37.0	q^* mass 6.0 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1703.09127
	Excited quark $q^* \to q\gamma$	1 γ	1 j	–	36.7	q^* mass 5.3 TeV	only u^* and d^*, $\Lambda = m(q^*)$	CERN-EP-2017-148
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	13.3	b^* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LRSM Majorana ν	2 e, μ	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	2,3,4 e, μ (SS)	–	–	36.1	$H^{\pm\pm}$ mass 870 GeV	DY production	ATLAS-CONF-2017-053
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H_L^{\pm\pm} \to \ell\tau) = 1$	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{non-res} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g \rvert = 1 g_D$, spin 1/2	1509.08059

$\sqrt{s} = 8$ TeV $\sqrt{s} = 13$ TeV

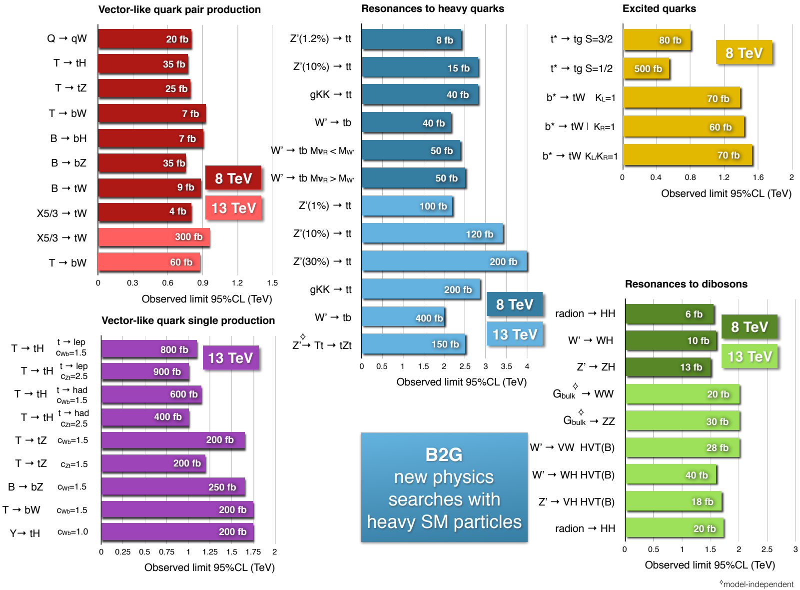
10^{-1} 1 10 **Mass scale [TeV]**

*Only a selection of the available mass limits on new states or phenomena is shown.

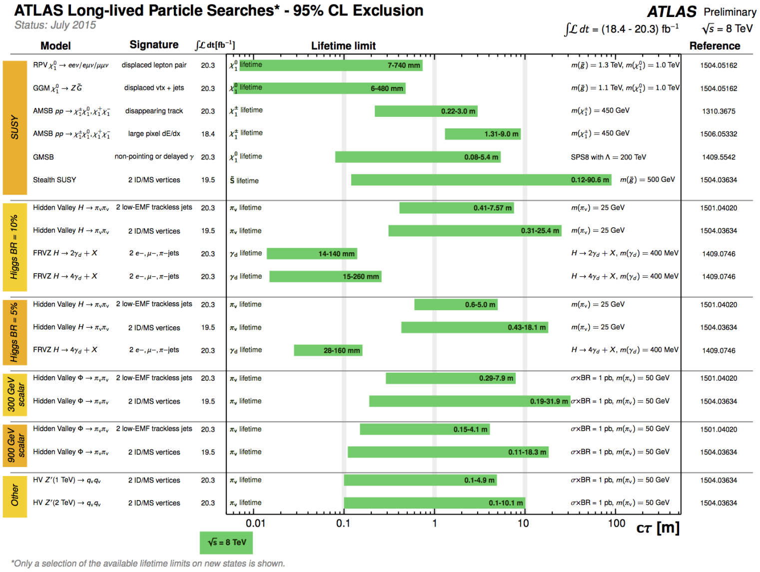
†Small-radius (large-radius) jets are denoted by the letter j (J).

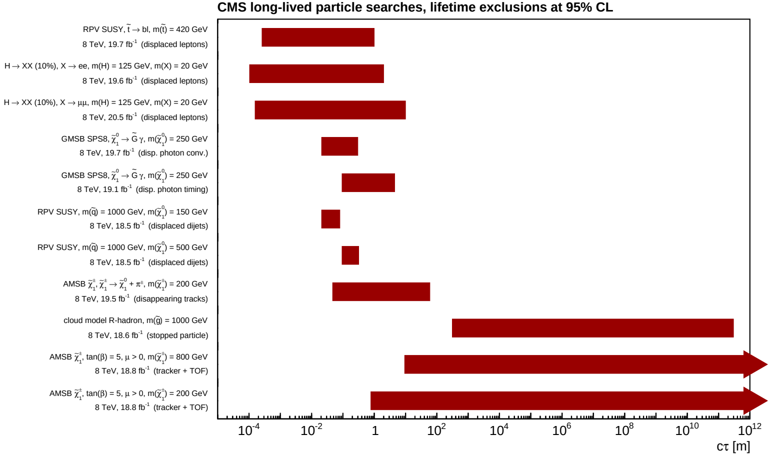

13 TeV
8 TeV
LQ1(ej) x2
LQ1(ej)+LQ1(νj) β=0.5
LQ2(μj) x2
LQ2(μj)+LQ2(νj) β=0.5
LQ3(τb) x2
LQ3(νb) x2
LQ3(ττ) x2
LQ3(νt) x2
Single LQ1 (λ=1)
Single LQ2 (λ=1)
Leptoquarks
0 1 2 3 4 TeV
RS Gravitons
RS1(jj), k=0.1
RS1(γγ), k=0.1
RS1(ee,μμ), k=0.1
0 1 2 3 4 TeV
CMS Preliminary
Heavy Gauge Bosons
SSM Z'(ττ)
SSM Z'(jj)
SSM Z'(ee)+Z'(μμ)
SSM W'(jj)
SSM W'(lν)
SSM Z'(bb)
0 1 2 3 4 5 TeV
Excited Fermions
e* (M=Λ)
μ* (M=Λ)
q* (qg)
q* (qγ) f=1
b*
0 1 2 3 4 5 6 TeV
coloron(jj) x2
coloron(4j) x2
gluino(3j) x2
gluino(jjb) x2
Multijet Resonances
0 1 2 3 4 TeV
ADD (γ+MET), nED=4, MD
ADD (jj), nED=4, MS
QBH, nED=6, MD=4 TeV
NR BH, nED=6, MD=4 TeV
String Scale (jj)
QBH (jj), nED=4, MD=4 TeV
ADD (j+MET), nED=4, MD
ADD (ee,μμ), nED=4, MS
ADD (γγ), nED=4, MS
Jet Extinction Scale
Large Extra Dimensions
0 1 2 3 4 5 6 7 8 9 10 TeV
dijets, Λ+ LL/RR
dijets, Λ- LL/RR
dimuons, Λ+ LLIM
dimuons, Λ- LLIM
dielectrons, Λ+ LLIM
dielectrons, Λ- LLIM
single e, Λ HnCM
single μ, Λ HnCM
inclusive jets, Λ+
inclusive jets, Λ-
Compositeness
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 TeV
CMS Exotica Physics Group Summary – ICHEP, 2016

CMS B2G Summary – [2]

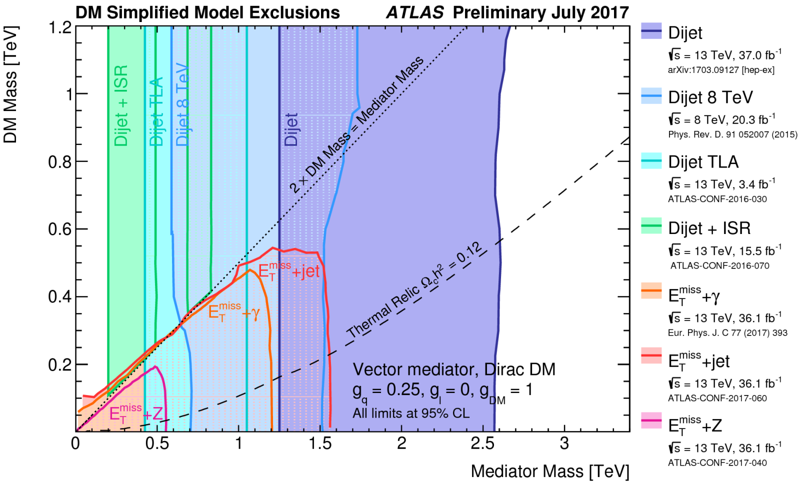


ATLAS LLP Summary – [1]

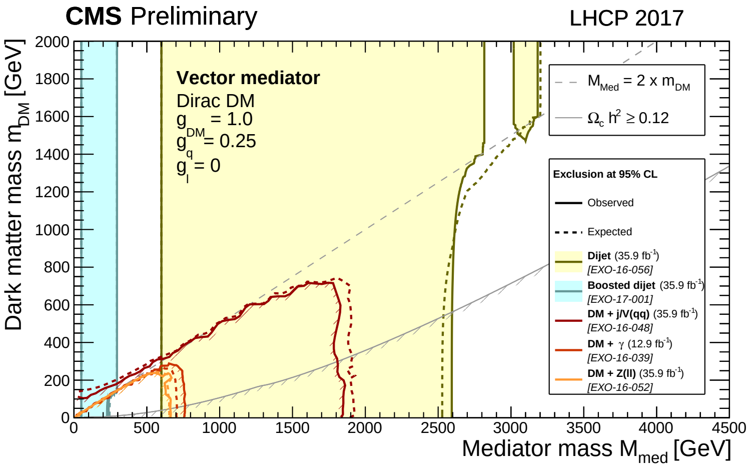



CMS long-lived particle searches, lifetime exclusions at 95% CL
RPV SUSY, $\tilde{t} \to bl$, $m(\tilde{t})$ = 420 GeV
8 TeV, 19.7 fb^{-1} (displaced leptons)
$H \to XX$ (10%), $X \to ee$, m(H) = 125 GeV, m(X) = 20 GeV
8 TeV, 19.6 fb^{-1} (displaced leptons)
$H \to XX$ (10%), $X \to \mu\mu$, m(H) = 125 GeV, m(X) = 20 GeV
8 TeV, 20.5 fb^{-1} (displaced leptons)
GMSB SPS8, $\tilde{\chi}^0_1 \to \tilde{G}\gamma$, $m(\tilde{\chi}^0_1)$ = 250 GeV
8 TeV, 19.7 fb^{-1} (disp. photon conv.)
GMSB SPS8, $\tilde{\chi}^0_1 \to \tilde{G}\gamma$, $m(\tilde{\chi}^0_1)$ = 250 GeV
8 TeV, 19.1 fb^{-1} (disp. photon timing)
RPV SUSY, $m(\tilde{q})$ = 1000 GeV, $m(\tilde{\chi}^0_1)$ = 150 GeV
8 TeV, 18.5 fb^{-1} (displaced dijets)
RPV SUSY, $m(\tilde{q})$ = 1000 GeV, $m(\tilde{\chi}^0_1)$ = 500 GeV
8 TeV, 18.5 fb^{-1} (displaced dijets)
AMSB $\tilde{\chi}^\pm_1$, $\tilde{\chi}^\pm_1 \to \tilde{\chi}^0_1 + \pi^\pm$, $m(\tilde{\chi}^\pm_1)$ = 200 GeV
8 TeV, 19.5 fb^{-1} (disappearing tracks)
cloud model R-hadron, $m(\tilde{g})$ = 1000 GeV
8 TeV, 18.6 fb^{-1} (stopped particle)
AMSB $\tilde{\chi}^\pm_1$, tan(β) = 5, μ > 0, $m(\tilde{\chi}^\pm_1)$ = 800 GeV
8 TeV, 18.8 fb^{-1} (tracker + TOF)
AMSB $\tilde{\chi}^\pm_1$, tan(β) = 5, μ > 0, $m(\tilde{\chi}^\pm_1)$ = 200 GeV
8 TeV, 18.8 fb^{-1} (tracker + TOF)
10^{-4}
10^{-2}
1
10^{2}
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}
cτ [m]

ATLAS DM Summary – [1]



- A lot of these searches can be **reinterpreted** as DM signals, see Koji's talk **next**!



- A lot of these searches can be **reinterpreted** as DM signals, see Koji's talk **next**!

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