



# SEARCH FOR MANIFESTATIONS OF NEW PHYSICS AT **LHC**

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NEW TRENDS IN HIGH ENERGY PHYSICS, BUDVA, MONTENEGRO 29 SEPTEMBER 2018





## THE STANDARD MODEL (SM)

- Great! But still many unknowns:
  - SM particles  $\rightarrow$  only~5% of universe
  - Baryon asymmetry
  - Neutrino issues O
  - **CP** Violation
  - Hierarchy problem

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## THE STANDARD MODEL (SM)

- Great! But still many unknowns:
- SM particles → only~5% of usikov
  Baryon asymmetry by Dimitry Kazakov
  Menice talk given by Dimitry Kazakov
  See the nice 1 issues

CP Violation

### Hierarchy problem

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## BEYOND THE STANDARD MODEL (BSM)

- We need new physics to understand
  - SM particles → only~5% of universe
  - Baryon asymmetry
  - Neutrino issues
  - CP Violation
  - Hierarchy problem

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### WHERE IS NEW PHYSICS?



... ARE WE LOOKING EVERYWHERE?

## ROADMAP / WHERE TO GO?

- Indirect Searches: Test / validate SM
  - Precision measurements
  - Rare processes
- Direct searches for BSM
  - Search for new physics models
  - Signature driven searches

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### ROADMAP / WHERE TO GO?

- Indirect Searches: Test / validate SM
- cision measurements Direct searches for BSM

  - Signature driven searches

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### THE ROAD SO FAR: TESTING THE SM



### RARE DECAYS



## LEPTON FLAVOR UNIVERSALITY(LFU)

- SM predicts the same electroweak couplings to all three lepton flavours (LFU)
- Measuring the ratio of the production rates of different flavours
  - If there is an anomaly  $\Rightarrow$  Sign for new physics!

First measurement of R(D\*-) with 3 prong  $\tau$  decay  $\mathcal{R}(D^{*-}) \equiv \mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)/\mathcal{B}(B^0 \to D^{*-}\mu^+\nu_\mu)$ LHCB, PRL 120 (2018) 171802

Inclusion of this result to the world average:

### ~4 $\sigma$ LFU VIOLATION

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See P.Krokovny's talk to find out more about anomalies: e.g.Angular distribution anomaly 3.4 $\sigma$ 







## TEST OF LEPTON UNIVERSALITY MOST PRECISE MEASUREMENT OF $R_{K^{*0}}$ AT LHCB





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$$R_{K} = \frac{BR(B^{+} \rightarrow K^{+}\mu^{+}\mu)}{BR(B^{+} \rightarrow K^{+}e^{+}e^{-})}$$

### UP TO 2.6σ STANDARD DEVIATION









### THE ROAD SO FAR: SEARCHES FOR BSM



NEWEST RESULTS FROM ATLAS AND CMS EXPLORED ALMOST 80 FB<sup>-1</sup> DATA ≈8000 TRILLION P-P COLLISIONS

### STATUS OF THE BSM SEARCHES

- Exploring the TeV Mass Scales thanks to LHC, hundreds of papers published so far.
- Impossible to cover all these searches, in this talk only highlights and latest results with the largest datasets ~80fb<sup>-1</sup>!



Simplified models, summaries, scans, combinations...

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### **ATLAS Exotics Searches\* - 95% CL Upper Exclusion Limits**

Status: July 2018

	Model	$\ell,\gamma$	Jets†	$\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$	∫£ dt[fb	<sup>-1</sup> ] Limit	·		Reference
Extra dimensions	ADD $G_{KK} + g/q$ ADD non-resonant $\gamma\gamma$ ADD QBH ADD BH high $\sum p_T$ ADD BH multijet RS1 $G_{KK} \rightarrow \gamma\gamma$ Bulk RS $G_{KK} \rightarrow WW/ZZ$ Bulk RS $g_{KK} \rightarrow tt$ 2UED / RPP	$\begin{array}{c} 0 \ e, \mu \\ 2 \ \gamma \\ - \\ \geq 1 \ e, \mu \\ - \\ 2 \ \gamma \\ multi-channe \\ 1 \ e, \mu \\ 1 \ e, \mu \end{array}$	1 - 4 j - 2 j $\ge 2 j$ $\ge 3 j$ - el $\ge 1 b, \ge 1 J/2$ $\ge 2 b, \ge 3 j$	Yes    2j Yes Yes	36.1 36.7 37.0 3.2 3.6 36.7 36.1 36.1 36.1	MD           Ms           Mth           Mth           GKK mass           GKK mass           SKK mass           KK mass	7.7 TeV 8.6 TeV 8.9 TeV 8.2 TeV 9.55 TeV 4.1 TeV 2.3 TeV 3.8 TeV 1.8 TeV	n = 2 n = 3  HLZ NLO n = 6 $n = 6, M_D = 3 \text{ TeV, rot BH}$ $n = 6, M_D = 3 \text{ TeV, rot BH}$ $k/\overline{M}_{Pl} = 0.1$ $k/\overline{M}_{Pl} = 1.0$ $\Gamma/m = 15\%$ Tier (1,1), $\mathcal{B}(A^{(1,1)} \rightarrow tt) = 1$	1711.03301 1707.04147 1703.09127 1606.02265 1512.02586 1707.04147 CERN-EP-2018-179 1804.10823 1803.09678
Gauge bosons	$\begin{array}{c} \mathrm{SSM}\ Z' \to \ell\ell\\ \mathrm{SSM}\ Z' \to \tau\tau\\ \mathrm{Leptophobic}\ Z' \to bb\\ \mathrm{Leptophobic}\ Z' \to tt\\ \mathrm{SSM}\ W' \to \ell\nu\\ \mathrm{SSM}\ W' \to \tau\nu\\ \mathrm{HVT}\ V' \to WV \to qqqq \ \mathrm{model}\\ \mathrm{HVT}\ V' \to WH/ZH \ \mathrm{model}\ \mathrm{B}\\ \mathrm{LRSM}\ W'_R \to tb \end{array}$	2 e, μ 2 τ - 1 e, μ 1 e, μ 1 τ I B 0 e, μ multi-channe	_ 2 b ≥ 1 b, ≥ 1J/2 _ _ 2 J el	_ _ Yes Yes _	36.1 36.1 36.1 79.8 36.1 79.8 36.1 36.1	Z' mass Z' mass Z' mass Z' mass W' mass W' mass V mass V' mass V' mass	4.5 TeV 2.42 TeV 2.1 TeV 3.0 TeV 5.6 TeV 3.7 TeV 4.15 TeV 2.93 TeV 3.25 TeV	$\Gamma/m = 1\%$ $g_V = 3$ $g_V = 3$	1707.02424 1709.07242 1805.09299 1804.10823 ATLAS-CONF-2018-017 1801.06992 ATLAS-CONF-2018-016 1712.06518 CERN-EP-2018-142

 $\int \mathcal{L} dt = (3.2 - 79.8) \text{ fb}^{-1}$ 

### **ATLAS** Preliminary $\sqrt{s} = 8, 13 \text{ TeV}$

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HEAVY NEUTRINOS VECTOR LIKE QUARKS SUPERSYMMETRY AXIGLUONS UNCONVENTIONAL LONG LIVED PARTICLES TECHNICOLORS DISAPPERAING TRACKS COMPOSITENESS DARK QCD GRAVITONS DISPLACED VERTICES NEW GAUGE BOSONS LEPTOQUARKS COLORONS DARK PHOTONS LIGHT Z' BOSON CONTACT INTERACTIONS

DARK MATTER





VECTOR LIKE QUARKS SUPERSYMMETRY AXIGLUONS UNCONVENTIONAL LONG LIVED PARTICLES TECHNICOLORS DISAPPERAING TRACKS COMPOSITENESS DARK QCD GRAVITONS DISPLACED VERTICES NEW GAUGE BOSONS LEPTOQUARKS COLORONS DARK PHOTONS LIGHT Z' BOSON CONTACT INTERACTIONS

DARK MATTER

### HEAVY NEUTRINOS









### LEPTOQUARKS



### LEPTOOUARKS(LQ)

- What?
  - Hypothetical color-triplet bosons
  - Both lepton and baryon number with fractional electric charge, decay to a lepton and jet
- Why?
  - Grand Unification Theories, SUSY, technicolor, composite models,  $E_{6,...}$
  - Provides explanations to **LFUV** and anomalous magnetic moment of the muon

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## EXCITING





## LO-SINGLE PRODUCTION

- More sensitive than pair production in higher masses
  - $\lambda$  (Yukawa coupling) plays important role
- Final state:  $\tau \tau$ b depending on the subsequent decays of  $\tau$ :
  - Hadronic final state:  $\tau_{had} \tau_{had} b$
  - Leptonic final state:  $\ell_{had} \tau_{had} b$





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### <u>CMS-EXO-17-029</u>





## LO-PAIR PRODUCTION

- Search for both Dark Matter and LQ using a new approach: (M.Baker et al, JHEP12(2015)120)
  - DM particle is either annihilated or produced in conjunction with a partner X.
- Searching for a peak in the LQ candidate mass spectrum  $\bullet$



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### USING 77.4 FB<sup>-1</sup> DATA

### <u>CMS-EXO-17-015</u>



AND UP TO 1000GEV FOR M<sub>DM</sub>≈425GEV









### DARK MATTER



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...but if DM candidate recoil against other particles...











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YOU HAVE NOTHING TO SEE ...but if DM candidate recoil against other particles...





### MONO-X SEARCHES







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YOU HAVE NOTHING TO SEE ...but if DM candidate recoil against other particles...





### MONO-X SEARCHES



### MONO-V SEARCHES

- Hadronic decays of W(qq) and Z(qq)
- High  $p_T \Rightarrow$  collimated decay products  $\Rightarrow$  larger radius jet cone
- Boson tagging using boosted topologies and jet substructure techniques



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### SUBMITTED TO JHEP: <u>ARXIV1807.11471</u>

# W w













## MONO-H SEARCHES

- DM production in association with a Higgs boson
- H(bb): High branching fraction to bb pair
- New jet reconstruction method depending on the p<sub>T</sub> of the small jets



 $\bar{q}$ 

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### ATLAS-CONF-2018-039





- DM production in association with a Higgs boson
  - invariant mass reconstruction than H(bb)



ZY

FIRST SEARCH IN ASSOCIATION WITH H FIRST COMBINATION OF THE YY AND THE

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...but when DM mediator couples to SM particles...











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YOU HAVE NOTHING TO SEE ...but when DM mediator couples to SM particles...







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Leptophobic axial-vector Z' model

### **W**HIGH MASS DIJET SEARCHES



### DIJET RESONANCE SEARCHES 0.4 δ Bin 10<sup>8</sup> 0.3 Events this is what we 10<sup>7</sup> 0.25 F record 0.2 10<sup>6</sup> 0.15 10<sup>°</sup> 0.1 $10^{4}$ 0.05 $10^{3}$ 100 300

3000

4000

m<sub>ii</sub> [GeV]

IN HIGH MASS DIJET SEARCHES LOWER BOUND: LIMITED WITH

2000

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1000

600

Leptophobic axial-vector Z' model



### THE HIGH LEVEL TRIGGER THRESHOLDS



## DIJET RESONANCE SEARCHES



IGH MASS DIJET SEARCHES LOWER BOUND: IMITED WITH THE HIGH LEVEL TRIGGER THRESHOLDS
TRIGGER LEVEL ANALYSIS(TLA) LOWER BOUND: LIMITED WITH LEVEL 1 THRESHOLDS

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## DIJET RESONANCE SEARCHES



IGH MASS DIJET SEARCHES LOWER BOUND:LIMITED WITH THE HIGH LEVEL TRIGGER THRESHOLDS TRIGGER LEVEL ANALYSIS LOWER BOUND:LIMITED WITH LEVEL 1 THRESHOLDS DIJET+ISR ANALYSIS LOWER BOUND: LIMITED WITH THE SEPERATION OF DI-JETS

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# DIJET RESONANCE SEARCHES



HIGH LEVEL TRIGGER THRESHOLDS INTED IN THE REARCHES LOWER BOUND: WI THE ΤН TRIGGER LEVEL ANALYSIS(TLA) LOWER BOUND:LIMITED WITH LEVEL 1 THRESHOLDS POIJET + ISR ANALYSIS LOWER BOUND: LIMITED WITH THE SEPERATION OF DI-JETS BOOSTED DIJET+ISR ANALYSIS

![](_page_36_Picture_4.jpeg)

# DIJET RESONANCE SEARCHES

b

h

![](_page_37_Figure_1.jpeg)

## NOT ONLY SEARCHING FOR THE HIGH MASS REGIONS, BUT ALSO EXPLORING THE LOW MASS **REGIONS!**

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LATEST RESULTS

AND 8 TEV RESULTS

X

 $\wedge \wedge \wedge$ 

![](_page_37_Picture_4.jpeg)

![](_page_37_Picture_5.jpeg)

# DIJET RESONANCE SEARCHES

![](_page_38_Figure_1.jpeg)

## LHC PROVIDING THE STRONGEST LIMITS, BUT THERE IS STILL ROOM FOR NEW PHYSICS! AIM IS TO REACH THE LOWER COUPLING VALUES

![](_page_38_Picture_4.jpeg)

![](_page_38_Picture_5.jpeg)

![](_page_38_Picture_6.jpeg)

# DARK MATTER SUMMARY

## COMBINING THE RESULTS FROM MONO-X AND DIJET SEARCHES

![](_page_39_Figure_2.jpeg)

![](_page_39_Picture_6.jpeg)

## SUPERSYMMETRY

# SUPERSYMMETRY

- New boson/fermion supersymmetric partner to each boson/fermion in the SM
- Motivations for SUSY
  - Hierarchy problem, unification of forces
  - Candidate for the observed Dark Matter...
- Very rich variety of of signatures

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ATLAS SUSY Searches* - 95% CL Lower Limits July 2018 ATL									<b>ATLAS</b> Preliminary $\sqrt{s} = 7, 8, 13$ TeV		
	Model	$e, \mu, \tau, \gamma$	Jets	$E_{ m T}^{ m miss}$	∫ <i>L dt</i> [fb	- <sup>-1</sup> ] Ma	ss limit		$\sqrt{s} = 7, 8$	<b>TeV</b> $\sqrt{s} = 13$ TeV	Reference
Ñ	$\tilde{q}\tilde{q},\tilde{q}{\rightarrow}q\tilde{\chi}^0_1$	0 mono-jet	2-6 jets 1-3 jets	Yes Yes	36.1 36.1	$ ilde{q}$ [2x, 8x Degen.] $ ilde{q}$ [1x, 8x Degen.]	0.43	0.9 0.71	1.55	$m( ilde{\mathcal{X}}_1^0){<}100GeV$ $m( ilde{q}){-}m( ilde{\mathcal{X}}_1^0){=}5GeV$	1712.02332 1711.03301
Irche	$\tilde{g}\tilde{g},  \tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	ĩg ĩg		Forbidden	2.0 0.95-1.6	$m(\tilde{\chi}_{1}^{0}) < 200  \text{GeV}$ $m(\tilde{\chi}_{1}^{0}) = 900  \text{GeV}$	1712.02332 1712.02332
/e Sea	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}(\ell\ell)\tilde{\chi}_1^0$	3 e,μ ee,μμ	4 jets 2 jets	- Yes	36.1 36.1	ĩg ĩg ĩg			1.85 1.2	$m(\tilde{\chi}^0_1)$ <800 GeV $m(\tilde{g})$ =50 GeV	1706.03731 1805.11381
clusiv	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qqWZ\tilde{\chi}_1^0$	0 3 <i>e</i> , µ	7-11 jets 4 jets	Yes	36.1 36.1	r B B B		0.98	1.8	$m( ilde{\chi}_1^0)$ <400 GeV $m( ilde{g})$ - $m( ilde{\chi}_1^0)$ =200 GeV	1708.02794 1706.03731
Ч	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$	0-1 <i>e</i> ,μ 3 <i>e</i> ,μ	3 <i>b</i> 4 jets	Yes -	36.1 36.1	ğ ğ β			2.0 1.25	$m( ilde{\mathcal{X}}_1^0){<}200\mathrm{GeV}$ $m( ilde{g}){-}m( ilde{\mathcal{X}}_1^0){=}300\mathrm{GeV}$	1711.01901 1706.03731
	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_1^0 / t \tilde{\chi}_1^{\pm}$		Multiple Multiple Multiple		36.1 36.1 36.1	$egin{array}{ccc}  ilde{b}_1 & Forbidden \  ilde{b}_1 & eta_1 & eba_1 & eba_1 & eba_1 &$	Forbidden Forbidden	0.9 0.58-0.82 0.7	$m( ilde{\mathcal{K}}_1^0)$	$\begin{array}{l} m(\tilde{\chi}_{1}^{0}){=}300 \ \mathrm{GeV}, \ BR(b\tilde{\chi}_{1}^{0}){=}1\\ m(\tilde{\chi}_{1}^{0}){=}300 \ \mathrm{GeV}, \ BR(b\tilde{\chi}_{1}^{0}){=}BR(t\tilde{\chi}_{1}^{\pm}){=}0.5\\ {=}200 \ \mathrm{GeV}, \ m(\tilde{\chi}_{1}^{\pm}){=}300 \ \mathrm{GeV}, \ BR(t\tilde{\chi}_{1}^{\pm}){=}1 \end{array}$	1708.09266, 1711.03301 1708.09266 1706.03731
arks tion	$\tilde{b}_1 \tilde{b}_1, \tilde{t}_1 \tilde{t}_1, M_2 = 2 \times M_1$	Multiple Multiple			36.1 36.1	$\tilde{t}_1$ $\tilde{t}_1$ Forbidden		0.7 0.9		$m( ilde{\mathcal{X}}_1^0)$ =60 GeV $m( ilde{\mathcal{X}}_1^0)$ =200 GeV	1709.04183, 1711.11520, 1708.03247 1709.04183, 1711.11520, 1708.03247
len. squa	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow Wb \tilde{\chi}_1^0 \text{ or } t \tilde{\chi}_1^0$ $\tilde{t}_1 \tilde{t}_1, \tilde{H} \text{ LSP}$	0-2 $e, \mu$ (	0-2 jets/1-2 Multiple Multiple	b Yes	36.1 36.1 36.1	$egin{array}{ccc} ella _1 & & & & & & & & & & & & & & & & & & $		1.0 0.4-0.9 0.6-0.8	$m( ilde{\mathcal{X}}_1^0)$ $m( ilde{\mathcal{X}}_1^0)$	$ m(\tilde{\chi}_{1}^{0})=1 \text{ GeV} $ $ m(\tilde{\chi}_{1}^{\pm})=m(\tilde{\chi}_{1}^{0})=5 \text{ GeV}, \tilde{t}_{1} \approx \tilde{t}_{L} $ $ m(\tilde{\chi}_{1}^{\pm})=m(\tilde{\chi}_{1}^{0})=5 \text{ GeV}, \tilde{t}_{1} \approx \tilde{t}_{L} $	1506.08616, 1709.04183, 1711.11520 1709.04183, 1711.11520 1709.04183, 1711.11520
3 <sup>rd</sup> g direc	$\tilde{t}_1 \tilde{t}_1$ , Well-Tempered LSP	0	Multiple	Voc	36.1	$\tilde{t}_1$		0.48-0.84	$m( ilde{\mathcal{X}}_1^0)$	$= 150 \text{ GeV}, \text{ m}(\tilde{\chi}_1^{\pm}) \cdot \text{m}(\tilde{\chi}_1^0) = 5 \text{ GeV}, \tilde{t}_1 \approx \tilde{t}_L$	1709.04183, 1711.11520
	$I_1I_1, I_1 \rightarrow CX_1 / CC, C \rightarrow CX_1$	0	mono-jet	Yes	36.1	$\tilde{t}_1$ $\tilde{t}_1$ $\tilde{t}_1$	0.46 0.43	0.85		$ \begin{array}{l} m(\tilde{t}_1) = 0 \text{ GeV} \\ m(\tilde{t}_1, \tilde{c}) - m(\tilde{\chi}_1^0) = 50 \text{ GeV} \\ m(\tilde{t}_1, \tilde{c}) - m(\tilde{\chi}_1^0) = 5 \text{ GeV} \end{array} $	1805.01649 1711.03301
	$\tilde{t}_2\tilde{t}_2,  \tilde{t}_2 \rightarrow \tilde{t}_1 + h$	1-2 <i>e</i> , <i>µ</i>	4 <i>b</i>	Yes	36.1	ĩ <sub>2</sub>		0.32-0.88		$m( ilde{\chi}_1^0)$ =0 GeV, $m( ilde{t}_1)$ - $m( ilde{\chi}_1^0)$ = 180 GeV	1706.03986
	$ ilde{\chi}_1^{\pm}  ilde{\chi}_2^0$ via $WZ$	<b>2-3</b> e, μ ee, μμ	<u>-</u> ≥ 1	Yes Yes	36.1 36.1			0.6		$m( ilde{\chi}_1^0){=}0\ m( ilde{\chi}_1^\pm){-}m( ilde{\chi}_1^0){=}10\ GeV$	1403.5294, 1806.02293 1712.08119
W ect	$ \begin{split} &\tilde{\chi}_{1}^{\pm} \tilde{\chi}_{2}^{0} \text{ via } Wh \\ &\tilde{\chi}_{1}^{\pm} \tilde{\chi}_{1}^{\mp} / \tilde{\chi}_{2}^{0}, \tilde{\chi}_{1}^{+} \rightarrow \tilde{\tau} \nu(\tau \tilde{\nu}), \tilde{\chi}_{2}^{0} \rightarrow \tilde{\tau} \tau(\nu \tilde{\nu}) \end{split} $	<i>ℓℓ/ℓγγ/ℓbb</i> 2 τ	-	Yes Yes	20.3 36.1	$ \begin{array}{c} \tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0} & 0.26 \\ \tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0} & \\ \tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0} & 0.22 \end{array} $		0.76	$m( ilde{\mathcal{X}}_1^\pm) ext{-}m( ilde{\mathcal{X}}$	$m(\tilde{\chi}_{1}^{0})=0$ $m(\tilde{\chi}_{1}^{0})=0, m(\tilde{\tau}, \tilde{\nu})=0.5(m(\tilde{\chi}_{1}^{\pm})+m(\tilde{\chi}_{1}^{0}))$ $m(\tilde{\chi}_{1}^{0})=100 \text{ GeV}, m(\tilde{\tau}, \tilde{\nu})=0.5(m(\tilde{\chi}_{1}^{\pm})+m(\tilde{\chi}_{1}^{0}))$	1501.07110 1708.07875 1708.07875
di m	$\tilde{\ell}_{\mathrm{L,R}}\tilde{\ell}_{\mathrm{L,R}},  \tilde{\ell} {\rightarrow} \ell \tilde{\chi}_{1}^{0}$	2 e, µ 2 e, µ	0 ≥ 1	Yes Yes	36.1 36.1	<i>ι̃</i> <i>č</i> 0.18	0.5			$m( ilde{\mathcal{X}}_1^0){=}0 \ m( ilde{\mathcal{X}}_1^0){=}5\ GeV$	1803.02762 1712.08119
	$\tilde{H}\tilde{H},\tilde{H}{ ightarrow}h\tilde{G}/Z\tilde{G}$	0 4 <i>e</i> , <i>µ</i>	$\geq 3b$	Yes Yes	36.1 36.1	<i>H</i> 0.13-0.23 <i>H</i> 0.3		0.29-0.88		$ \begin{array}{l} BR(\tilde{\chi}^0_1 \to h\tilde{G}) = 1 \\ BR(\tilde{\chi}^0_1 \to Z\tilde{G}) = 1 \end{array} $	1806.04030 1804.03602
pe	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	36.1	$egin{array}{ccc}  ilde{\chi}_1^{\pm} & \  ilde{\chi}_1^{\pm} & 0.15 \end{array} \end{array}$	0.46			Pure Wino Pure Higgsino	1712.02118 ATL-PHYS-PUB-2017-019
Long-live particle	Stable $\tilde{g}$ R-hadron Metastable $\tilde{g}$ R-hadron, $\tilde{g} \rightarrow qq \tilde{\chi}_1^0$ GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$ , long-lived $\tilde{\chi}_1^0$ $\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow eev/e\mu v/\mu\mu v$	SMP 2 $\gamma$ displ. $ee/e\mu/\mu$	- Multiple - -	- Yes -	3.2 32.8 20.3 20.3	$\tilde{g}$ $\tilde{g}  [\tau(\tilde{g}) = 100 \text{ ns}, 0.2 \text{ ns}]$ $\tilde{\chi}_{1}^{0}$ $\tilde{g}$	0.44		1.6 1.6 1.3	<b>2.4</b> $m(\tilde{\chi}_1^0)=100 \text{ GeV}$ $1 < \tau(\tilde{\chi}_1^0) < 3 \text{ ns, SPS8 model}$ $6 < c\tau(\tilde{\chi}_1^0) < 1000 \text{ mm, } m(\tilde{\chi}_1^0)=1 \text{ TeV}$	1606.05129 1710.04901, 1604.04520 1409.5542 1504.05162
٧٢	$ \begin{array}{l} LFV \ pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e\mu/e\tau/\mu\tau \\ \tilde{\chi}_{1}^{\pm}\tilde{\chi}_{1}^{\mp}/\tilde{\chi}_{2}^{0} \rightarrow WW/Z\ell\ell\ell\ell\nu\nu \\ \tilde{g}\tilde{g}, \ \tilde{g} \rightarrow qq\tilde{\chi}_{1}^{0}, \ \tilde{\chi}_{1}^{0} \rightarrow qqq \end{array} $	eμ,eτ,μτ 4 e,μ 0 4	- 0 -5 large- <i>R</i> j∉ Multiple	- Yes ets -	3.2 36.1 36.1 36.1	$ \begin{split} \tilde{v}_{\tau} \\ \tilde{\chi}_{1}^{\pm} / \tilde{\chi}_{2}^{0} & [\lambda_{i33} \neq 0, \lambda_{12k} \neq 0] \\ \tilde{g} & [m(\tilde{\chi}_{1}^{0}) = 200 \text{ GeV}, 1100 \text{ GeV}] \\ \tilde{g} & [\lambda_{112}'' = 2e{-}4, 2e{-}5] \end{split} $		0.82	1.9 1.33 1.3 1.9 5 2.0	$\lambda'_{311}$ =0.11, $\lambda_{132/133/233}$ =0.07 m $(\tilde{\chi}^0_1)$ =100 GeV Large $\lambda''_{112}$ m $(\tilde{\chi}^0_1)$ =200 GeV, bino-like	1607.08079 1804.03602 1804.03568 ATLAS-CONF-2018-003
RF	$\tilde{g}\tilde{g}, \tilde{g} \to tbs / \tilde{g} \to tt\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to tbs$ $\tilde{t}\tilde{t}, \tilde{t} \to t\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to tbs$ $\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \to bs$ $\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \to b\ell$	0 2 e. u	Multiple Multiple 2 jets + 2 <i>b</i>	, - -	36.1 36.1 36.7 36 1	$ \tilde{g}  [\lambda''_{323} = 1, 1e-2] \\ \tilde{g}  [\lambda''_{323} = 2e-4, 1e-2] \\ \tilde{\ell}_1  [qq, bs] \\ \tilde{\ell}_1 $	0.5 0.42	5 1.05 0.61	1.8 2.1 0.4-1.45	m $(\tilde{\chi}_1^0)$ =200 GeV, bino-like m $(\tilde{\chi}_1^0)$ =200 GeV, bino-like BR $(\tilde{t}_1 \rightarrow he/hu)$ >20%	ATLAS-CONF-2018-003 ATLAS-CONF-2018-003 1710.07171 1710.05544
	-1/1) • 1 - 100					·					

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

 $10^{-1}$ 

Mass scale [TeV]

ΤZ

# SUPERSYMMETRY

## Simplified signatures excluded up to **TeV Scale**

**ATLAS SUSY Searcl** July 2018 Model  $\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$  $\tilde{g}\tilde{g}, \, \tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$  $\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}(\ell\ell)\tilde{\chi}_1^0$  $\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq$ Still ple ĝĝ, ĝ→ti  $ilde{b}_1 ilde{b}_1, ilde{b}_1$ unexpl  $\tilde{b}_1 \tilde{b}_1, \tilde{t}_1 \tilde{t}_1, M_2 = 2 \times M_1$  $\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0 \text{ or } t\tilde{\chi}_1^0$  $\tilde{t}_1 \tilde{t}_1, \tilde{H} LSP$  $\tilde{t}_1 \tilde{t}_1$ , Well-Tempered LSP  $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow c \tilde{\chi}_1^0 / \tilde{c} \tilde{c}, \tilde{c} \rightarrow c \tilde{\chi}_1^0$  $\tilde{t}_2 \tilde{t}_2, \, \tilde{t}_2 \rightarrow \tilde{t}_1 + h$  $ilde{\chi}_1^{\pm} ilde{\chi}_2^0$  via WZEW direct Electrov pro Direct  $\tilde{\chi}_1^+ \tilde{\chi}_1^-$  prod., long-lived  $\tilde{\chi}_1^\pm$ Stable  $\tilde{g}$  R-hadron Metastable  $\tilde{g}$  R-hadron,  $\tilde{g} \rightarrow qq \tilde{\chi}_1^0$ GMSB,  $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$ , long-lived  $\tilde{\chi}_1^0$  $\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow eev/e\mu v/\mu\mu v$ LFV  $pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e\mu/e\tau/\mu\tau$  $\begin{aligned} \tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\pm} / \tilde{\chi}_2^0 &\to WW/Z\ell\ell\ell\ell\nu\nu \\ \tilde{g}\tilde{g}, \, \tilde{g} \to qq\tilde{\chi}_1^0, \, \tilde{\chi}_1^0 \to qqq \end{aligned}$  $\tilde{g}\tilde{g}, \tilde{g} \to tbs \ / \ \tilde{g} \to t\bar{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to tbs$  $\tilde{t}\tilde{t}, \tilde{t} \rightarrow t\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow tbs$  $\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow bs$  $\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\ell$ 

Inclusive Searches

arks

3<sup>rd</sup> gen. squarh direct productio

Long-lived particles

RPV

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only a selection of the available mass limits on new state henomena is shown. Many of the limits are based on

10

<b>nes* - 95% CL Lower Limits</b> $\sqrt{s} = 7.8.13 \text{ Te}$										
$\mu,  au, \gamma$	Jets	$E_{ m T}^{ m miss}$	$\int \mathcal{L} dt [fb$	<sup>-1</sup> ] Mas	s limit		$\sqrt{s}=7,$	, 8 TeV	$\sqrt{s} = 13 \text{ TeV}$	Reference
0 nono-jet	2-6 jets 1-3 jets	Yes Yes	36.1 36.1	$ ilde{q}$ [2×, 8× Degen.] $ ilde{q}$ [1×, 8× Degen.]	0.43	0.71	1.55		$m( ilde{\chi}_1^0){<}100\mathrm{GeV}\ m( ilde{q}){=}5\mathrm{GeV}$	1712.02332 1711.03301
0	2-6 jets	Yes	36.1	251 <u>25</u> 1		Forbidden	2.0 0.95-1.6	0	$m( ilde{\chi}^0_1){<}200\mathrm{GeV}\ m( ilde{\chi}^0_1){=}900\mathrm{GeV}$	1712.02332 1712.02332
3 е,µ ее,µµ	4 jets 2 jets	- Yes	36.1 36.1	755 F2			1.85 1.2		$m({ ilde{\mathcal{X}}}_1^0){<}800{ m GeV}$ $m({ ilde{g}}){=}50{ m GeV}$	1706.03731 1805.11381
nt		f Ι		mass		0.98	1.8		$m( ilde{\chi}_1^0)$ <400 GeV $m( ilde{g})$ - $m( ilde{\chi}_1^0)$ =200 GeV	1708.02794 1706.03731
	y U	YCS:		/ 111/035			2.0 1.25	0	${\sf m}( ilde{\chi}_1^0){<}200{ m GeV}\ {\sf m}( ilde{g}){ m -}{\sf m}( ilde{\chi}_1^0){ m =}300{ m GeV}$	1711.01901 1706.03731
ore	ed	m	od	el space	en en	0.9 0.58-0.82 0.7	m(	$m( ilde{\mathcal{X}}_1^0)=30$ $( ilde{\mathcal{X}}_1^0)=200GeV$	$m(\tilde{\chi}_{1}^{0})=300 \text{ GeV}, BR(b\tilde{\chi}_{1}^{0})=1$ 0 GeV, BR $(b\tilde{\chi}_{1}^{0})=BR(t\tilde{\chi}_{1}^{\pm})=0.5$ /, $m(\tilde{\chi}_{1}^{\pm})=300 \text{ GeV}, BR(t\tilde{\chi}_{1}^{\pm})=1$	1708.09266, 1711.03301 1708.09266 1706.03731
	Multiple Multiple		36.1 36.1	t <sub>1</sub> <i>t</i> <sub>1</sub> Forbidden		0.7			${f m}( ilde{\chi}_1^0)$ =60 GeV ${f m}( ilde{\chi}_1^0)$ =200 GeV	1709.04183, 1711.11520, 1708.03247 1709.04183, 1711.11520, 1708.03247
0-2 <i>e</i> , µ	0-2 jets/1-2 Multiple Multiple	b Yes	36.1 36.1 36.1	$egin{array}{ccc}  ilde{t}_1 & & & & & \\  ilde{t}_1 & & & Forbidden & & & \end{array}$		1.0 0.4-0.9 0.6-0.8	m( m(	$h( ilde{\chi}^0_1) = 150  \mathrm{GeV}$ $h( ilde{\chi}^0_1) = 300  \mathrm{GeV}$	$\begin{split} m(\tilde{\chi}_1^0) &= 1 \text{ GeV} \\ \textit{\textit{I}}, m(\tilde{\chi}_1^{\pm}) \cdot m(\tilde{\chi}_1^0) &= 5 \text{ GeV}, \tilde{\tau}_1 \approx \tilde{\tau}_L \\ \textit{\textit{I}}, m(\tilde{\chi}_1^{\pm}) \cdot m(\tilde{\chi}_1^0) &= 5 \text{ GeV}, \tilde{\tau}_1 \approx \tilde{\tau}_L \end{split}$	1506.08616, 1709.04183, 1711.11520 1709.04183, 1711.11520 1709.04183, 1711.11520
0	Multiple 2c	Yes	36.1 36.1	$ ilde{t}_1$ $ ilde{t}_1$		0.48-0.84 0.85	m(	$\mathfrak{t}(\tilde{\chi}_1^0)$ =150 GeV	$V, m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0) = 5 \text{ GeV}, \tilde{t}_1 \approx \tilde{t}_L$ $m(\tilde{\chi}_1^0) = 0 \text{ GeV}$	1709.04183, 1711.11520 1805.01649
0	mono-jet	Yes	36.1	$\tilde{t}_1$ $\tilde{t}_1$	0.46 0.43				$ \begin{array}{c} m(\tilde{t}_1,\tilde{c}) - m(\tilde{\chi}_1^0) = 50 \text{ GeV} \\ m(\tilde{t}_1,\tilde{c}) - m(\tilde{\chi}_1^0) = 5 \text{ GeV} \end{array} $	1805.01649 1711.03301
1-2 <i>e</i> ,μ	4 <i>b</i>	Yes	36.1	ĩ <sub>2</sub>		0.32-0.88		$m(\tilde{\chi}_1^0) = 0$	0 GeV, m $( ilde{t}_1)$ -m $( ilde{\chi}_1^0)$ = 180 GeV	1706.03986
2-3 е, µ ее. ии	- > 1	Yes Ves	36.1 36.1		0.	.6			$m( ilde{\chi}_1^{\pm}){=}0$ $m( ilde{\chi}_1^{\pm}){=}10~GeV$	1403.5294, 1806.02293 1712.08119
vea	ak p	orc	odu	action inc	reasi	ngly	$m( ilde{m{arkappa}}_1^\pm)$ -r	$m( ilde{\chi}_1^0)$ =100 G	$\begin{split} & m(\tilde{\chi}_1^0) {=} 0 \\ {=} 0, \ m(\tilde{\tau}, \tilde{\nu}) {=} 0.5 (m(\tilde{\chi}_1^{\pm}) {+} m(\tilde{\chi}_1^0)) \\ eV, \ m(\tilde{\tau}, \tilde{\nu}) {=} 0.5 (m(\tilde{\chi}_1^{\pm}) {+} m(\tilde{\chi}_1^0)) \end{split}$	1501.07110 1708.07875 1708.07875
2 e,μ 2 e,μ		Yes Yes	36.1 36.1						$m( ilde{\mathcal{X}}_1^0){=}0\ m( ilde{\mathcal{X}}_1^0){=}5\ GeV$	1803.02762 1712.08119
<b>) [ ] ]</b> 4 e,μ	ISII	19			J21				$ BR(\tilde{\chi}^0_1 \to h\tilde{G}) = 1 \\ BR(\tilde{\chi}^0_1 \to Z\tilde{G}) = 1 $	1806.04030 1804.03602
sapp. trk	1 jet	Yes	36.1	$egin{array}{c}  ilde{\chi}_1^\pm \  ilde{\chi}_1^\pm & \textbf{0.15} \end{array}$	0.46				Pure Wino Pure Higgsino	1712.02118 ATL-PHYS-PUB-2017-019
SMP	- Multiple	-	3.2 32.8	$\tilde{g}$ $\tilde{g} = [\tau(\tilde{g}) = 100 \text{ ns} 0.2 \text{ ns}]$			1.6	24	$m/\tilde{k}^0$ )-100 GeV	1606.05129 1710.04901.1604.04520
2 γ I. ee/eµ/µ	- μ -	Yes -	20.3 20.3	$\tilde{\chi}_1^0$ $\tilde{g}$	0.44		1.3	6 < <i>c</i> τ	$1 < \tau(\tilde{\chi}_1^0) < 3$ ns, SPS8 model $(\tilde{\chi}_1^0) < 1000$ mm, m $(\tilde{\chi}_1^0) = 1$ TeV	1409.5542 1504.05162
εμ,ετ,μτ	-	-	3.2	$\tilde{v}_{\tau}$		0.92	1.9		$\lambda'_{311}=0.11, \lambda_{132/133/233}=0.07$	1607.08079
0 4	-5 large- <i>R</i> je Multiple	ets -	36.1 36.1	$\tilde{g}  [m(\tilde{\chi}_1^0) = 200 \text{ GeV}, 1100 \text{ GeV}] \\ \tilde{g}  [\lambda_{112}^0 = 2e-4, 2e-5]$		1.05	1.3 1.9 5 2.0	0	$m(\tilde{\chi}_1) = 100 \text{ GeV}$ Large $\lambda''_{112}$ $m(\tilde{\chi}_1^0) = 200 \text{ GeV}$ , bino-like	1804.03568 ATLAS-CONF-2018-003
	Multiple		36.1	$\tilde{g}$ [ $\lambda''_{323}$ =1, 1e-2] $\tilde{g}$ [ $\lambda''_{}$ =2e-4, 1e-2]	0.55	1.01	1.8 2.	2.1	$m(\tilde{\chi}_1^0)$ =200 GeV, bino-like	ATLAS-CONF-2018-003
0	2 jets + 2 $l$	, -	36.7	$\tilde{t}_1  [qq, bs]$	0.42 0.6	61	0.4.1.45		$\frac{1}{R} \frac{1}{2} \frac{1}$	1710.07171
2 θ,μ	2.6		30.1				0.4-1.40		$\Box H(l_1 \rightarrow be/b\mu) > 20\%$	1710.05544

Mass scale [TeV]

43

# SUSY: EWK PRODUCTION

- Search for pair-produced electroweakinos
- Different signal regions: Mass differences in the range of 100-600 GeV

![](_page_43_Figure_3.jpeg)

## SUBMITTED TO PRD, ARXIV.1806.02293

![](_page_43_Figure_5.jpeg)

![](_page_43_Figure_6.jpeg)

HIGH/INTERMEDIATE-MASS SPLITTING: EXCLUSION UP TO 600 GEV

![](_page_43_Picture_10.jpeg)

![](_page_43_Picture_11.jpeg)

![](_page_43_Picture_12.jpeg)

44

NEW GAUGE BOSONS

# NEW BOSONS: WITH DIBOSONS

- Benchmarks: Spin-1 Heavy Vector Triplet Model (HVT) and spin-2 graviton  $G_{KK}$ ightarrow
- Hadronic decay channel of WW,WZ,ZZ
- New jet reconstruction methods using tracker (<u>ATL-PHYS-PUB-2017-015</u>)

![](_page_45_Figure_4.jpeg)

## <u>ATLAS-CONF-2018-016</u>

![](_page_45_Picture_7.jpeg)

![](_page_45_Figure_9.jpeg)

![](_page_45_Picture_10.jpeg)

![](_page_45_Figure_11.jpeg)

![](_page_45_Picture_12.jpeg)

![](_page_45_Picture_13.jpeg)

# NEW BOSONS: WITH LEPTONS

- Benchmarks: Superstring-inspired model ( $\Psi$ ), Sequential Standard Model(SSM)
  - $Z'_{SSM/\Psi}$  (CMS) & W'\_{SSM} (ATLAS)

![](_page_46_Figure_4.jpeg)

# COMBINATIONS

- Diboson+II+Iv combination:
  - qqqq, vvqq, lvqq, llqq, lvv, lvv, lvll, llll, qqbb, vvbb, lvbb, and llbb final states = Combined **Bosonic**
  - |v + || final states = Combined Leptonic
  - Combination of **Bosonic+Leptonic**

![](_page_47_Figure_5.jpeg)

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## SUBMITTED TO PRL, ARXIV.1808.02380

![](_page_47_Figure_8.jpeg)

## BENCHMARKS

Model $\setminus$ Decay mode	WW	WZ	ZZ	WH	ZH	$\ell \nu$
HVT	Z'	W'		W'	Z'	W'
Bulk RS	$G_{\rm KK}$		$G_{\rm KK}$			
Scalar	$\operatorname{Scalar}$		$\operatorname{Scalar}$			

![](_page_47_Picture_12.jpeg)

![](_page_47_Picture_13.jpeg)

![](_page_47_Picture_14.jpeg)

![](_page_48_Picture_0.jpeg)

VECTOR LIKE QUARKS

# VECTOR LIKE QUARKS

- What?
  - Spin 1/2, ferminoic top/bottom quarks
  - Singlet, doublet or triplet
  - Produced via FCNC or SM-like processes
  - Preferentially decay to 3rd generation
  - Left and right handed components transform identically under SU(2) x U(1) gauge transformations
- Why?
  - Solves hierarchy problem, baryon asymmetry
  - GUTs, little Higgs, composite Higgs...

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	Charge	Decay Mode					
T singlet	+2/3	$T \rightarrow W^+b, Zt, Ht$					
B singlet	-1/3	$B  ightarrow W^-$	t, Zb, Hb				
(T,B) doublet	(+2/3,-1/3)	$T \rightarrow W^+b, Zt, Ht$	$B \rightarrow W^{-}t, Zb, Hb$				
(X,T) doublet	(+5/3,+2/3)	$X \rightarrow W^+ t$	$T \rightarrow Zt, Ht$				
(B,Y) doublet	(-1/3,-4/3)	$B \rightarrow Zb, Hb$	$Y \rightarrow W^- b$				

![](_page_49_Figure_12.jpeg)

![](_page_49_Figure_13.jpeg)

## SINGLE PRODUCTION

## PAIR PRODUCED

![](_page_49_Picture_16.jpeg)

![](_page_49_Picture_17.jpeg)

![](_page_49_Picture_18.jpeg)

# VLQ-PAIR PRODUCTION

- Up to 1 TeV of VLQ mass, dominant production mechanism is pair production
  - Rich final states / Many different searches for VLQ T and B
    - Lepton+jets, dilepton+jets (same/opposite sign), 3lepton+jets
- General strategy: Scan different branching fractions to W, Z and H

![](_page_50_Figure_5.jpeg)

![](_page_50_Figure_7.jpeg)

## SUBMITTED PRL, <u>ARXIV.1808.02343</u> ΤO

![](_page_50_Figure_9.jpeg)

# VLQ-COMBINATIONS

- Each analysis excludes the the different regions in the branching ratio triangles
- Combination of different analysis are giving the best sensitivity

![](_page_51_Figure_3.jpeg)

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## SUBMITTED TO PRL arxiv.1808.02343

![](_page_51_Figure_8.jpeg)

STRONG SENSITIVITY WITH COMBINATIONS FROM ATLAS AND CMS SINGLET T(B) UP TO 1.31(1.24)TEV

![](_page_51_Picture_10.jpeg)

![](_page_51_Picture_11.jpeg)

# WE ARE LOOKING FOR NEW PHYSICS IN MANY WAYS...

## PRECISION

## RARE DECAYS

DARK MATTER

# LEPTOQUARKS NEW GAUGE BOSONS VECTOR LIKE QUARKS

SUSY

# ... AND THERE ARE MUCH MORE SEARCHES THAT I COULD NOT MENTION...

![](_page_53_Picture_1.jpeg)

# SUMMARY

- Searches for new physics in a vast variety of channels
- Many new methods and performance studies to improve searches
- the significant portion of phase space and chasing for new physics everywhere!

## STAY TUNED FOR THE NEW RESULTS AND HOPEFULLY FOR NEW PHYSICS!

LHC performing extremely well! Lots of data to analyse and much more data will be there

No significant excess found yet, but we are narrowing down the possibilities, excluding

![](_page_54_Picture_8.jpeg)

# BACK UP

![](_page_55_Picture_1.jpeg)

# LARGE HADRON COLLIDER

![](_page_56_Picture_1.jpeg)

![](_page_56_Picture_2.jpeg)

![](_page_56_Picture_4.jpeg)

![](_page_56_Picture_5.jpeg)

![](_page_56_Picture_6.jpeg)

![](_page_56_Picture_7.jpeg)

# LHC DATA/PERFORMANCE

- Excellent performance from LHC!
  - Doubled the design luminosity
  - Challenging conditions, large pile up

![](_page_57_Figure_4.jpeg)

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![](_page_57_Figure_6.jpeg)

## AT THE END OF RUN2:

150 FB<sup>-1</sup> DATA TO ATLAS AND CMS 5 FB<sup>-1</sup> DATA TO LHCB

Plenty of data to analyse!

![](_page_57_Picture_10.jpeg)

![](_page_57_Picture_11.jpeg)

![](_page_57_Picture_12.jpeg)

## Exciting days ahead, more data will come!

## HIGH LUMINOSITY LHC: 3000FB-1

## LHC

		LS	51	13-14 Te	YETS			LS2		
7 TeV	8 TeV	splice consolidation button collimators R2E project				SPS CC			injector up cryogenics i dispersi suppress collimati	
2011	2012	2013	2014	2015	2016		2017	20	18	20
	75% nominal luminosity	experiment	beam pipes	nominal lu	minosity				experir p	nent u hrase
	30 fb <sup>-1</sup>						150	fb⁻¹		

RUN3:300 FB-1

HL\_LHC

![](_page_58_Figure_7.jpeg)

![](_page_58_Picture_8.jpeg)

3000 fb<sup>-1</sup>

![](_page_58_Picture_10.jpeg)

# PRECISION

![](_page_59_Figure_1.jpeg)

![](_page_59_Picture_3.jpeg)

# PRECISION

![](_page_60_Figure_1.jpeg)

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![](_page_60_Picture_3.jpeg)

# ANOMALIES IN ANGULAR DISTRIBUTIONS

![](_page_61_Figure_1.jpeg)

## 

![](_page_61_Figure_5.jpeg)

![](_page_61_Picture_9.jpeg)

# MODEL INDEPENDENT LIMITS

![](_page_62_Figure_1.jpeg)

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## SEE THE TALK FROM L.HENKELMANN

![](_page_62_Picture_5.jpeg)

![](_page_62_Picture_6.jpeg)

full reco-level sensitivity

![](_page_62_Picture_8.jpeg)

![](_page_62_Picture_9.jpeg)

![](_page_62_Picture_10.jpeg)

# MONO-JET SEARCHES

- Initial state radiation jet recoils against missing transverse energy (E<sub>T</sub><sup>miss</sup>)
  - Not only DM, weakly interacting new particles: SUSY, extra dimensions
- Search for an excess in the E<sub>T</sub><sup>miss</sup> spectrum
- Dominant background : Z(vv)+jets
- Ongoing work to reduce the systematics!

![](_page_63_Figure_6.jpeg)

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## <u>JHEP 01 (2018) 126</u>

![](_page_63_Figure_11.jpeg)

ONE SIGNATURE MANY INTERPRETATION

![](_page_63_Picture_13.jpeg)

![](_page_63_Picture_16.jpeg)

# MONO-TOP SEARCHES

## <u>CMS, ARXIV: 1807.06522</u>

![](_page_64_Figure_2.jpeg)

![](_page_64_Figure_3.jpeg)

- DM association with tops
  - Strong limits!

![](_page_64_Figure_7.jpeg)

- DM association with tops
  - Hadronic decay channel with top tagging methods
    - Assuming FCNC

![](_page_64_Picture_11.jpeg)

![](_page_64_Picture_12.jpeg)

# A TYPICAL DIJET RESONANCE SEARCH

![](_page_65_Figure_1.jpeg)

◎ OVERWHELMING LARGE DIJET BACKGROUND
◎ UPPER BOUND ON THE RESONANCE MASS LIMITED BY THE COLLISION ENERGY
◎ GOING TO LOWER MASS POINTS CHALLENGING DUE TO THE LARGE BACKGROUND
◎ NEW APPROACHES NEEDED TO EXPLORE LOWER MASS VALUES ✓

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![](_page_65_Figure_4.jpeg)

![](_page_65_Picture_5.jpeg)

66

# DARK MATTER SUMMARY Combining the results from mono-X and dijet searches

![](_page_66_Figure_1.jpeg)

![](_page_66_Picture_4.jpeg)

# DARK MATTER SUMMARY

![](_page_67_Figure_1.jpeg)

## ATLAS LEPTHOPHILIC

Merve Sahinsoy/New Trends in High Energy Physics 2018

## CMS LEPTHOPHILIC

![](_page_67_Picture_6.jpeg)

# SUSY: SIMPLIFIED MODELS

![](_page_68_Figure_4.jpeg)

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## Chargino and stop pair production 2 opposite charged leptons, large E<sub>T</sub><sup>miss</sup>

![](_page_68_Picture_9.jpeg)

![](_page_68_Picture_10.jpeg)

# SUSY SUMMARY

![](_page_69_Figure_1.jpeg)

![](_page_69_Figure_2.jpeg)

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## ELECTROWEAK CHARGINO-NEUTRALINO **PRODUCTION SUMMARY**

![](_page_69_Picture_7.jpeg)

# VH SEARCH

- One signature, many interpretations
  - 2HDM, HVT, W', Z', DM etc...
- Different analysis regions, different backgrounds
  - $H_{\rightarrow}$  bb, 1b or 2b tag
  - V  $\rightarrow$  0,1,2 leptons: Z  $\rightarrow$  II, W  $\rightarrow$  Iv & Z  $\rightarrow$  vv

![](_page_70_Figure_6.jpeg)

![](_page_70_Figure_9.jpeg)

# DIBOSON LIMIT SUMMARY

- Many final states exists in VV/VH channels
- Each individual analysis aiming for different final states, complementary searches using all the objects
  - Comparison for the sensitivities of different channels for HVT model for Z' and W'

![](_page_71_Figure_4.jpeg)

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![](_page_71_Picture_9.jpeg)

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## NEW BOSONS:Z'

- Dilepton final state:
  - Combined limits for electron and muon channels
- Benchmarks: Z' Sequential Standard Model(SSM) and Z' superstring-inspired model  $\bullet$



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### <u>CMS, JHEP06(2018)120</u>

### ATLAS, JHEP10(2017)182







- through its fully hadronic decay channel
- different limits



# LONG LIVED AND UNCONVENTIONAL





### DARK PHOTON







## REFERENCES

- https://twiki.cern.ch/twiki/bin/view/AtlasPublic
- http://cms-results.web.cern.ch/cms-results/public-results/publications/
- M.Baker et al, JHEP12(2015)120
- ATLAS Collaboration, Improving jet substructure performance in ATLAS using Track-CaloClusters, ATL-PHYS-PUB-2017-015, 2017, <u>https://cds.cern.ch/record/2275636</u>

