Missing Transverse Energy Reconstruction at the LHC : the ATLAS case

Paolo Francavilla - LPNHE Dissecting the LHC results LPNHE - Paris - 20/21 April 2017



Since we are dissecting the LHC results...

- I will try to do my part, dissecting the MET
- aka: why we did not find (yet) an astonishing excess of events when we try to unbalance them.

An event display...



An event display...



Another event display...



Another event display...



...and here the last!



...and here the last!



...and here the last!



9

49333326 Event: 2012-06-09 Date: Time: 16:08:25 CEST

on this hemisphere...

Why?

 Problem (hole) with the detector? - Several check to make sure we are not encountering problematic issues

ATLAS pp 25ns run: April-October 2016

Inner Tracker		Calorimeters		Muon Spectrometer				Magnets		Trigger	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid	L1
98.9	99.9	99.7	99.3	98.9	99.8	99.8	99.9	99.9	99.1	97.2	98.3
Good for physics: 93-95% (33.3-33.9 fb ⁻¹)											

Luminosity weighted relative detector uptime and good data quality efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at \sqrt{s} =13 TeV between April-October 2016, corresponding to an integrated luminosity of 35.9 fb⁻¹. The toroid magnet was off for some runs, leading to a loss of 0.7 fb⁻¹. Analyses that don't require the toroid magnet can use that data.

 Only events in which all the detectors had good quality of data, and not bad jets, are used in analysis



Why?

- Physics origine: neutrinos produced by SM processes:
- W(Iv) in W+jets, di-boson, multi-boson, single top, ttbar+X, H(WW), WH, etc...
 - Note that $BR(W \rightarrow Iv) \sim 32.4\%$
- Z(vv) in Z+jets, di-boson, multi-boson, H(ZZ), ZH, etc...
 - Note that $BR(Z \rightarrow vv) \sim 20\%$

Standard Model Total Production Cross Section Measurements March 2017 [L dt Reference [fb⁻¹] $\sigma = 96.07 \pm 0.18 \pm 0.91$ mb (data) PLB 761 (2016) 158 50×10⁻⁸ Δ pp COMPETE HPR1R2 (theory) σ = 95.35 ± 0.38 ± 1.3 mb (data) ٥ 8×10⁻³ Nucl. Phys. B, 486-548 (2014) COMPETE HPB : R2 (theory) σ == 190.1 ± 0.2 ± 6.4 nb (data) PLB 759 (2016) 601 0.081 w DYNNLO + CT14NNLO (theory) σ = 98.71 ± 0.028 ± 2.191 nb (data) DYNNLO + CT14NNLO (theory) ٥ 4.6 arXiv:1612.03016[hep-ex] σ = 58.43 ± 0.03 ± 1.66 nb (data) DYNNLO+CT 14 NNLC (theory) Þ JHEP (2 (2017) 117 3.2 σ = 34.24 ± 0.03 ± 0.92 nb (data) DYNNLO+CT 14 NNLC (theory) Z 20.2JHEP (2 (2017) 117 Δ σ = 29.53 ± 0.03 ± 0.77 nb (data) o 4.6 JHEP (2 (2017) 117 DYNNLO+CT14 NNLC (theory) $\sigma = 818 \pm 8 \pm 35 \, \text{pb} \, \text{(cata)}$ D 3.2 PLB 761 (2016) 136 top++ NNLO+NLL (theory) tī $\sigma = 242.9 \pm 1.7 \pm 8.6 \text{ pb} (\text{data})$ 20.2Δ EPJC 74: 3109 (2014) top++ NNLO+NNLL (theory) $\sigma = 182.9 \pm 3.1 \pm 6.4 \text{ pb} (data)$ Ó 4.6 EPJC 74: 3109 (2014) top++ NNLO+NNLL (theory $\sigma = 247 \pm 6 \pm 46 \text{ pb} \text{ (cata)}$ NLO+NLL (theory) 3.2 arXiv:1609.03920[hep-ex] t_{t-chan} $\sigma = 89.6 \pm 1.7 \pm 7.2 \pm 6.4 \text{ pb (data)}$ 20.3 arKiv:1702.02859 [hep-ex] NLO+NLL (theory) $\sigma = 68 \pm 2 \pm 8 \text{ pb} (\text{data})$ Ō PRD 90, 112006 (2014) 0 4.6 NLO+NLL (theory) $\sigma = 142 \pm 5 \pm 13 \text{ pb} \text{ (cata)}$ NNLO (theory) 3.2 arXiv: 1702.04519 [hep-ex] Theory ww PLB 763, 114 (2016) $\sigma = 68.2 \pm 1.2 \pm 4.6$ pb (data) 20.3NNLO (theory) $\sigma = 51.9 \pm 2 \pm 4.4 \text{ pb (data)}$ 0 O 4.6 PRD 87, 112001 (2013) NNLO (treary) LHC pp $\sqrt{s} = 7 \text{ TeV}$ o $\sigma = 61.5 + 10.5 - 10 + 4.3 - 3.2 \text{ pb} (data)$ 13.3ATLAS-CONF-2016-081 LHC-HXSWG YH4 (theory) Data $\sigma = 27.7 \pm 3 + 2.3 - 1.9 \, \text{pb} \, \text{(data)}$ 20.3 EPJC 76, 6 (2016) Δ Δ н LHC-HXSWG YE4 (theory) stat Þ $\sigma = 22.1 + 6.7 - 5.3 + 3.3 - 2.7 \text{ pb}$ (cata) 0 4.5 EPJC 76, 6 (2016) stat ⊕ syst LHC-HXSWG YF4 (theory) $\sigma = 94 \pm 10 + 28 - 23 \text{ pb (data)}$ NLO | NNLL (theory) 3.2 arXiv:1612.07231 [hep-ex] LHC pp $\sqrt{s} = 8$ TeV Wt $\sigma = 23 \pm 1.3 \pm 3.4 \pm 3.7 \text{ pb} (data)$ 20.3 JHEP 01, 064 (2016) NLO+NLL (theory) Data $\sigma = 16.8 \pm 2.9 \pm 3.9 \text{ pb} (\text{data})$ O 2.0 PLD 716, 142-159 (2012) Δ NLO+NL (theory) stat $\sigma = 50.6 \pm 2.6 \pm 2.5 \text{ pb} (\text{data})$ 3.2 PLB 762 (2016) 1 stat ⊕ syst MATRIX (NNLO) (theory) wz $\sigma = 24.3 \pm 0.6 \pm 0.9$ pb (data) 20.3PRD 93, 092004 (2016) MATRIX (NNLO) (theory) √s = 13 TeV LHC pp $\sigma = 19 + 1.4 - 1.3 \pm 1 \text{ pb} (\text{data})$ ٥ 4.6 EPJC 72, 2173 (2012) O MATRIX (NNLO) (theory) Data $\sigma = 16.7 + 2.2 - 2 + 1.3 - 1 \text{ pb (data)}$ 3.2 PRL 116, 101801 (2016) NNLO (theory) stat ΖZ $\sigma = 7.3 \pm 0.4 \pm 0.4 - 0.3 \text{ pb} \text{ (data)}$ 20.3 JHEP 01,099 (2017) Δ Δ NNLO (theory) $\sigma = 6.7 \pm 0.7 \pm 0.5 - 0.4 \text{ pb} \text{ (data)}$ 4.6 JHEP (3, 128 (2013) о 0 NNLO (theory) ATLAS Preliminary $\sigma = 4.8 \pm 0.8 \pm 1.6 \pm 1.3 \text{ pb} \text{ (data)}$ Δ t_{s-chan} 20.3PLB 756, 223-246 (2016) NLO+NNL (theory) $\sigma = 1.5 \pm 0.72 \pm 0.33 \text{ pb} (data)$ 3.2 EPJC 77 (2017) 40 t**īW** Madgraph5 + aMCNLO (theory) Run 1,2 $\sqrt{s} = 7, 8, 13$ TeV σ = 369 + 86 − 79 ± 44 fb (data) Δ 20.3 JHEP 11, 172 (2015) Δ. MCFM (theory) $\sigma = 0.92 \pm 0.29 \pm 0.1 \text{ pb} (data)$ 3.2 EPJC 77 (2017) 40 tīΖ Madgraph5 + aMCNLO (theory) 176 + 52 - 48 ± 24 fb (data) 20.3 JHEP 11, 172 (2015) HELAC-NLO (heory) a a cond ᅭᅭᄴ a succed 10^{11} 10^1 10^2 $10^{-5} \ 10^{-4} \ 10^{-3} \ 10^{-2} \ 10^{-1}$ 10³ 10^{6} 10^{4} 10^{5} 0.5 1 1.5 2 2.5 1 12 σ [pb] data/theory

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Why?

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- Physics origine: neutrinos produced by SM processes:
- W(Iv) in W+jets, di-boson, multi-boson, single top, ttbar+X, H(WW), WH, etc...
 - Note that $BR(W \rightarrow Iv) \sim 32.4\%$
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 - Note that $BR(Z \rightarrow vv) \sim 20\%$
 - Physics origine: New physics with weakly interacting particles
 - Dark Matter candidates
 - Lightest Supersymmetric Particles
 - etc etc...

ATLAS SUSY Searches* - 95% CL Lower Limits

St	Status: March 2017 $\sqrt{s} = 7, 8, 13 \text{ TeV}$							
	Model	e, μ, τ, γ	Jets	$E_{\mathrm{T}}^{\mathrm{miss}}$	∫£ đư[ſb	b ⁻¹] Mass limit	$\sqrt{s} = 7, 8 \text{ TeV}$ $\sqrt{s} = 13 \text{ TeV}$	Reference
Inclusive Searches	$\begin{array}{l} MSUGRA/CMSSM\\ \bar{q}\bar{q}, \bar{q} \rightarrow q\bar{x}_{1}^{\bar{q}} \\ \bar{q}\bar{q}, \bar{q} \rightarrow q\bar{x}_{1}^{\bar{q}} \\ \bar{q}\bar{q}, \bar{q} \rightarrow q\bar{x}_{1}^{\bar{q}} \\ \bar{q}\bar{q}, \bar{q} \rightarrow q\bar{q}\bar{x}_{1}^{\bar{q}} \\ \bar{g}\bar{g}, \bar{g} \rightarrow q\bar{q}\bar{x}_{1}^{\bar{q}} \rightarrow q\bar{q}W^{\pm}\bar{x}_{1}^{\bar{q}} \\ \bar{g}\bar{g}, \bar{g} \rightarrow q\bar{q}Q(\ell\ell/\nu\nu)\bar{x}_{1}^{\bar{q}} \\ \bar{g}\bar{g}, \bar{g} \rightarrow q\bar{q}W^{2}\bar{x}_{1}^{\bar{q}} \\ GMSB (\ell NLSP) \\ GGM (binoNLSP) \\ GGM (higgsino-binoNLSP) \\ GGM (higgsino-binoNLSP) \\ GGM (higgsinoNLSP) \\ GGM (higgsinoNLSP) \\ GGM (higgsinoNLSP) \\ GravitinoLSP \end{array}$	$\begin{array}{c} 0\text{-}3 \ e, \mu/1\text{-}2 \ \tau \\ 0 \\ \text{mono-jet} \\ 0 \\ 3 \ e, \mu \\ 2 \ e, \mu \ (\text{SS}) \\ 1\text{-}2 \ r + 0\text{-}1 \ e \\ 2 \ \gamma \\ \gamma \\ \gamma \\ 2 \ e, \mu \ (\text{Z}) \\ 0 \end{array}$	2-10 jeta/3 2-6 jeta 1-3 jeta 2-6 jeta 2-6 jeta 2-6 jeta 4 jeta 0-3 jeta - 1 <i>b</i> 2 jeta 2 jeta mono-jet	6 Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 36.1 36.1 13.2 13.2 3.2 20.3 13.3 20.3 20.3	ā B ā B <t< td=""><td>$\begin{array}{cccc} \mathbf{1.85 \ TeV} & \mathbf{m}(\hat{q}) - \mathbf{m}(\hat{g}) \\ \mathbf{1.57 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 200 \ \mathrm{GeV}, \ \mathbf{m}(1^d \ \mathrm{gen}, \tilde{q}) - \mathbf{m}(2^{sd} \ \mathrm{gen}, \tilde{q}) \\ & \mathbf{m}(\hat{g}) \cdot \mathbf{m}(\hat{k}_1^0) < 5 \ \mathrm{GeV} \\ \mathbf{2.02 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 200 \ \mathrm{GeV} \\ \mathbf{2.01 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 200 \ \mathrm{GeV} \\ \mathbf{2.01 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 200 \ \mathrm{GeV} \\ \mathbf{1.7 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 400 \ \mathrm{GeV} \\ \mathbf{1.6 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 500 \ \mathrm{GeV} \\ \mathbf{2.0 \ TeV} \\ \mathbf{1.85 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 500 \ \mathrm{GeV} \\ \mathbf{2.0 \ TeV} \\ \mathbf{1.85 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 500 \ \mathrm{GeV}, \ cr(\mathrm{NLSP}) < 0.1 \ \mathrm{mm}, \ \mu < 0 \\ \mathbf{m}(\hat{k}_1^0) > 500 \ \mathrm{GeV}, \ cr(\mathrm{NLSP}) < 0.1 \ \mathrm{mm}, \ \mu > 0 \\ \mathbf{m}(\hat{k}_1^0) > 680 \ \mathrm{GeV}, \ cr(\mathrm{NLSP}) < 0.1 \ \mathrm{mm}, \ \mu > 0 \\ \mathbf{m}(\hat{k}_1^0) > 1.8 \ \mathrm{TeV} & \mathbf{m}(\hat{g}) - 1.5 \ \mathrm{TeV} \\ \end{array}$</td><td>1507.05525 ATLAS-CONF-2017-022 1604.07773 ATLAS-CONF-2017-022 ATLAS-CONF-2017-022 ATLAS-CONF-2016-037 ATLAS-CONF-2016-037 1607.05978 1606.09150 1507.05493 ATLAS-CONF-2016-066 1503.03290 1502.01518</td></t<>	$\begin{array}{cccc} \mathbf{1.85 \ TeV} & \mathbf{m}(\hat{q}) - \mathbf{m}(\hat{g}) \\ \mathbf{1.57 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 200 \ \mathrm{GeV}, \ \mathbf{m}(1^d \ \mathrm{gen}, \tilde{q}) - \mathbf{m}(2^{sd} \ \mathrm{gen}, \tilde{q}) \\ & \mathbf{m}(\hat{g}) \cdot \mathbf{m}(\hat{k}_1^0) < 5 \ \mathrm{GeV} \\ \mathbf{2.02 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 200 \ \mathrm{GeV} \\ \mathbf{2.01 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 200 \ \mathrm{GeV} \\ \mathbf{2.01 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 200 \ \mathrm{GeV} \\ \mathbf{1.7 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 400 \ \mathrm{GeV} \\ \mathbf{1.6 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 500 \ \mathrm{GeV} \\ \mathbf{2.0 \ TeV} \\ \mathbf{1.85 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 500 \ \mathrm{GeV} \\ \mathbf{2.0 \ TeV} \\ \mathbf{1.85 \ TeV} & \mathbf{m}(\hat{k}_1^0) < 500 \ \mathrm{GeV}, \ cr(\mathrm{NLSP}) < 0.1 \ \mathrm{mm}, \ \mu < 0 \\ \mathbf{m}(\hat{k}_1^0) > 500 \ \mathrm{GeV}, \ cr(\mathrm{NLSP}) < 0.1 \ \mathrm{mm}, \ \mu > 0 \\ \mathbf{m}(\hat{k}_1^0) > 680 \ \mathrm{GeV}, \ cr(\mathrm{NLSP}) < 0.1 \ \mathrm{mm}, \ \mu > 0 \\ \mathbf{m}(\hat{k}_1^0) > 1.8 \ \mathrm{TeV} & \mathbf{m}(\hat{g}) - 1.5 \ \mathrm{TeV} \\ \end{array}$	1507.05525 ATLAS-CONF-2017-022 1604.07773 ATLAS-CONF-2017-022 ATLAS-CONF-2017-022 ATLAS-CONF-2016-037 ATLAS-CONF-2016-037 1607.05978 1606.09150 1507.05493 ATLAS-CONF-2016-066 1503.03290 1502.01518
3 rd gen. <u>8</u> med.	$\begin{array}{l} \widetilde{k}\widetilde{k}, \ \widetilde{k} \rightarrow bb\widetilde{k}_{1}^{0} \\ \widetilde{g}\widetilde{g}, \ \widetilde{g} \rightarrow d\widetilde{k}_{1}^{0} \\ \widetilde{g}\widetilde{g}, \ \widetilde{g} \rightarrow b\widetilde{v}\widetilde{k}_{1}^{0} \end{array}$	0 0-1 σ, μ 0-1 σ, μ	3 b 3 b 3 b	Yes Yes Yes	36.1 36.1 20.1	x x x x	1.92 TeV m(k ⁶ ₁)-s000 GeV 1.97 TeV m(k ⁶ ₁)<200 GeV	ATLAS-CONF-2017-021 ATLAS-CONF-2017-021 1407.0800
3 rd gen. squarks direct production	$ \begin{split} & \tilde{b}_{1}\tilde{b}_{1}, \tilde{b}_{1} \rightarrow b \tilde{\mathcal{R}}_{1}^{0} \\ & \tilde{b}_{1}b_{1}, \tilde{b}_{1} \rightarrow b \tilde{\mathcal{R}}_{1}^{0} \\ & \tilde{h}_{1}\tilde{h}_{1}, \tilde{h}_{1} \rightarrow b \tilde{\mathcal{R}}_{1}^{\pm} \\ & \tilde{h}_{1}\tilde{h}_{1}, \tilde{h}_{1} \rightarrow W b \tilde{\mathcal{R}}_{1}^{0} \text{ or } s \tilde{\mathcal{R}}_{1}^{0} \\ & \tilde{h}_{1}\tilde{h}_{1}, \tilde{h}_{1} \rightarrow c \tilde{\mathcal{R}}_{1}^{0} \\ & \tilde{h}_{1}\tilde{h}_{1}(\text{natural GMSB}) \\ & \tilde{h}_{2}\tilde{h}_{2}, \tilde{h}_{2} \rightarrow \tilde{h}_{1} + Z \\ & \tilde{h}_{2}\tilde{h}_{2}, \tilde{h}_{2} \rightarrow \tilde{h}_{1} + h \end{split} $	0 2 e, μ (SS) 0-2 e, μ 0 2 e, μ (Z) 3 e, μ (Z) 1-2 e, μ	2 b 1 b 1-2 b 0-2 jets/1-2 mono-jet 1 b 1 b 4 b	Yes Yes Yes Yes Yes Yes Yes Yes	3.2 13.2 0.7/13.3 20.3 3.2 20.3 36.1 36.1	δ₁ 840 GeV δ₁ 325-685 GeV l₁ 117-170 GeV 200-720 GeV l₁ 90-198 GeV 205-950 GeV l₁ 90-323 GeV 150-600 GeV l₁ 290-790 GeV 150-800 GeV l₂ 320-880 GeV 320-880 GeV	$\begin{split} & m(\tilde{\xi}_1^6){<}100GeV \\ & m(\tilde{\xi}_1^6){<}150GeV, m(\tilde{x}_1^+){=}m(\tilde{x}_1^6){+}100GeV \\ & m(\tilde{x}_1^6){=}10GeV \\ & m(\tilde{x}_1^6){=}1GeV \\ & m(\tilde{y}_1){-}m(\tilde{x}_1^6){=}5GeV \\ & m(\tilde{y}_1){-}m(\tilde{x}_1^6){=}5GeV \\ & m(\tilde{x}_1^6){=}150GeV \\ & m(\tilde{x}_1^6){=}0GeV \\ & m(\tilde{x}_1^6){=}0GeV \\ & m(\tilde{x}_1^6){=}0GeV \end{split}$	1606.08772 ATLAS-CONF-2016-037 1209.2102, ATLAS-CONF-2016-077 1506.08818, ATLAS-CONF-2017-020 1804.07773 1403.5222 ATLAS-CONF-2017-019 ATLAS-CONF-2017-019
EW direct	$ \begin{array}{l} \tilde{\ell}_{L,R}\tilde{\ell}_{1,R}, \tilde{\ell} \rightarrow \ell \tilde{x}_1^p \\ \tilde{x}_1^+ \tilde{x}_1^-, \tilde{x}_1^+ \rightarrow \tilde{\ell} \nu (\ell \tilde{\nu}) \\ \tilde{x}_1^+ \tilde{x}_1^-, \tilde{x}_1^+ \rightarrow \tilde{\tau} \nu (\tau \tilde{\nu}) \\ \tilde{x}_1^+ \tilde{x}_2^0 \rightarrow \tilde{\ell}_L \nu \tilde{\ell}_L \ell (\tilde{\nu} \nu), \ell \tilde{\tau} \tilde{\ell}_L \ell (\tilde{\nu} \nu) \\ \tilde{x}_1^+ \tilde{x}_2^0 \rightarrow W \tilde{x}_L^0 \ell \tilde{x}_L^0 \\ \tilde{x}_1^+ \tilde{x}_2^0 \rightarrow W \tilde{x}_L^0 h \tilde{x}_L^0, h \rightarrow b \tilde{b} / W W / \tau \\ \tilde{x}_2^0 \tilde{x}_3^0, \tilde{x}_{23}^0 \rightarrow \tilde{\ell}_R \ell \\ \text{GGM (wino NLSP) weak prod.} \\ \text{GGM (bino NLSP) weak prod.} \end{array} $	2 e,μ 2 e,μ 2 τ 3 e,μ 2-3 e,μ τ/γγ e,μ,γ 4 e,μ 1 e,μ + γ 2 γ	0 0 0-2 jets 0-2 <i>b</i> 0 -	Yes Yes Yes Yes Yes Yes Yes	20.3 13.3 14.8 13.3 20.3 20.3 20.3 20.3 20.3 20.3	i 90-335 GeV x̂_1^* 640 GeV x̂_1^* 580 GeV x̂_1^*, x̂_1^* 1.0 TeV x̂_1^*, x̂_1^* 425 GeV x̂_1^*, x̂_1^* 635 GeV ŷ_{2,3}^* 635 GeV ŵ 115-370 GeV ŵ 590 GeV	$\begin{split} & m(\bar{\mathcal{X}}_1^0){=}0\;GeV \\ & m(\bar{\mathcal{X}}_1^0){=}0\;GeV,\;m(\bar{\mathcal{X}},\bar{\mathcal{V}}){=}0.5(m(\bar{\mathcal{X}}_1^+){+}m(\bar{\mathcal{X}}_1^0)) \\ & m(\bar{\mathcal{X}}_1^0){=}0\;GeV,\;m(\bar{\tau},\bar{\tau}){=}0.5(m(\bar{\mathcal{X}}_1^+){+}m(\bar{\mathcal{X}}_1^0)) \\ & m(\bar{\mathcal{X}}_1^+){=}m(\bar{\mathcal{X}}_2^0),\;m(\bar{\mathcal{X}}_1^0){=}0,\;m(\bar{\mathcal{X}},\bar{\tau}){=}0.5(m(\bar{\mathcal{X}}_1^+){+}m(\bar{\mathcal{X}}_1^0)) \\ & m(\bar{\mathcal{X}}_1^+){=}m(\bar{\mathcal{X}}_2^0),\;m(\bar{\mathcal{X}}_1^0){=}0,\;\bar{\mathcal{X}}\;decoupled \\ & m(\bar{\mathcal{X}}_1^+){=}m(\bar{\mathcal{X}}_2^0),\;m(\bar{\mathcal{X}}_1^0){=}0,\;\bar{\mathcal{X}}\;decoupled \\ & m(\bar{\mathcal{X}}_2^0){=}m(\bar{\mathcal{X}}_2^0),\;m(\bar{\mathcal{X}}_1^0){=}0,\;m(\bar{\mathcal{X}}_2^0){+}m(\bar{\mathcal{X}}_1^0)) \\ & cr{<}1mm \\ & cr{<}1mm \end{split}$	1403.5294 ATLAS-CONF-2016-096 ATLAS-CONF-2016-093 ATLAS-CONF-2016-096 1403.5294, 1402.7029 1501.07110 1405.5086 1507.05493 1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^{\dagger}\tilde{\chi}_1^{-}$ prod., long-lived $\tilde{\lambda}$ Direct $\tilde{\chi}_1^{\dagger}\tilde{\chi}_1^{-}$ prod., long-lived $\tilde{\lambda}$ Stable, stopped \tilde{g} R-hadron Stable \tilde{g} R-hadron Metastable \tilde{g} R-hadron GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau$ GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$, long-lived $\tilde{\chi}_1^0$ $\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow eev/e\mu\nu/\mu\mu\nu$ GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow Z\tilde{G}$	e_1^{\pm} Disapp. trk e_1^{\pm} dE/dx trk 0 trk dE/dx trk dE/dx trk $e(e,\mu)$ 1-2 μ 2 γ displ. $ee/e\mu/\mu$ displ. vbx + je	1 jet - 1-5 jets - - - - - τ ε - - - - - - - - - - - - -	Yes Yes Yes Yes Yes	36.1 18.4 27.9 3.2 3.2 19.1 20.3 20.3 20.3	x̂1 430 GeV x̂1 495 GeV x̂ 850 GeV x̂ 850 GeV x̂ 850 GeV x̂ 10 GeV x̂1 1.0 TeV x̂1 1.0 TeV	$\begin{split} \mathbf{m}(\overline{k}_{1}^{*}) &- \mathbf{m}(\overline{k}_{1}^{*}) \sim 160 \; \text{MeV}, \; \tau(\overline{k}_{1}^{*}) = 0.2 \; \text{ns} \\ \mathbf{m}(\overline{k}_{1}^{*}) &- \mathbf{m}(\overline{k}_{1}^{*}) - 160 \; \text{MeV}, \; \tau(\overline{k}_{1}^{*}) = 15 \; \text{ns} \\ \mathbf{m}(\overline{k}_{1}^{*}) &- 100 \; \text{GeV}, \; 10 \; \mu\text{s} < \tau(\overline{k}) < 1000 \; \text{s} \\ \hline \mathbf{1.58 \; TeV} \\ \hline \mathbf{1.57 \; TeV} \\ \mathbf{m}(\overline{k}_{1}^{*}) &= 100 \; \text{GeV}, \; \tau > 10 \; \text{ns} \\ 10 < \tan\beta < 50 \\ 1 < \tau(\overline{k}_{1}^{*}) < 3 \; \text{ns}, \; \text{SPS8 model} \\ 7 < c\tau(\overline{k}_{1}^{*}) < 38 \; \text{ns}, \; \text{SPS8 model} \\ 5 < c\tau(\overline{k}_{1}^{*}) < 480 \; \text{mm}, \; \mathbf{m}(\overline{k}) = 1.3 \; \text{TeV} \\ \hline 6 < c\tau(\overline{k}_{1}^{*}) < 480 \; \text{mm}, \; \mathbf{m}(\overline{k}) = 1.1 \; \text{TeV} \end{split}$	ATLAS-CONF-2017-017 1506.05332 1310.6584 1606.05129 1804.04520 1411.6795 1409.5542 1504.05162 1504.05162
RPV	$ \begin{array}{l} LFV \ pp {\rightarrow} \hat{\mathbf{v}}_{\tau} + X, \hat{\mathbf{v}}_{\tau} {\rightarrow} e\mu/e\tau/\mu\tau \\ Bilinear \ RPV \ CMSSM \\ \tilde{x}_{1}^{+} \tilde{x}_{1}^{-}, \tilde{x}_{1}^{+} {\rightarrow} W \tilde{x}_{1}^{0}, \tilde{x}_{1}^{0} {\rightarrow} eev, e\muv_{e}, \\ \tilde{x}_{1}^{+} \tilde{x}_{1}^{-}, \tilde{x}_{1}^{+} {\rightarrow} W \tilde{x}_{1}^{0}, \tilde{x}_{1}^{0} {\rightarrow} \tau\tau v_{e}, e\tauv \\ \tilde{x}_{1}^{0}, \tilde{x}_{1}^{-} {\rightarrow} Q q q \\ \tilde{x}_{1}^{0}, \tilde{x}_{1}^{0} {\rightarrow} q q q \\ \tilde{x}_{2}^{0}, \tilde{x} {\rightarrow} q q \tilde{x}_{1}^{0}, \tilde{x}_{1}^{0} {\rightarrow} q q q \\ \tilde{x}_{2}^{0}, \tilde{x} {\rightarrow} d\tilde{x}_{1}^{0}, \tilde{x}_{1}^{0} {\rightarrow} q q q \\ \tilde{x}_{2}^{0}, \tilde{x} {\rightarrow} d\tilde{x}_{1}^{0}, \tilde{x}_{1}^{0} {\rightarrow} q q q \\ \tilde{x}_{2}^{0}, \tilde{x} {\rightarrow} d\tilde{x}_{1}^{0}, \tilde{x}_{1}^{0} {\rightarrow} dq q \\ \tilde{x}_{1}^{0}, \tilde{x}_{1} {\rightarrow} bs \\ \tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} {\rightarrow} bs \\ \tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} {\rightarrow} b\ell \end{array} $	$e\mu, e\tau, \mu\tau$ $2 e, \mu$ (SS) $\mu\mu\nu$ $4 e, \mu$ r_{τ} $3 e, \mu + \tau$ 0 4 $1 e, \mu = 8$ $1 e, \mu = 8$ 0 $2 e, \mu$	0-3 b -5 large-R ju -5 large-R ju 3-10 jets/0-4 3-10 jets/0-4 2 jets + 2 b 2 b	Yes Yes Yes sts - sts - δ - δ - δ -	3.2 20.3 13.3 20.3 14.8 14.8 36.1 36.1 15.4 20.3	P. 4. ž 4. ž 1.14 Te X [±] 450 GeV ž 1.08 TeV ž ž ž ž ž ž 1.08 TeV ž ž 1.08 TeV ž 1.08 TeV ž 1.08 TeV ž 1.08 TeV ž 0.410 GeV J1 0.4-1.0 TeV	1.9 TeV λ'_{311} =0.11, $\lambda_{132/123/231}$ =0.07 1.45 TeV $m(\bar{g})$ =m($\bar{g})$, ct_{1SF} <1 mm	1607.08079 1404.2500 ATLAS-CONF-2016-075 1405.5086 ATLAS-CONF-2016-057 ATLAS-CONF-2016-057 ATLAS-CONF-2017-013 ATLAS-CONF-2017-013 ATLAS-CONF-2016-022, ATLAS-CONF-2016-084 ATLAS-CONF-2015-015
Other	Scalar charm, $\bar{c} \rightarrow c \hat{k}_1^0$	0	20	Yes	20.3	ā 510 GeV	m(ℓ ⁰ ₁)<200 GeV	1501.01325
*Only a phén	Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on 10^{-1} 1 Mass scale [TeV] 15							

*(simplified models, c.f. refs. for the assumptions made. ATLAS Preliminary

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: March 2017

0	alus. March 2017								$\gamma s = 7, 0, 13$ lev
	Model	e, μ, τ, γ	′ Jets	$E_{\rm T}^{\rm miss}$	∫£ đư[fb	Mass limit	<i>√s</i> = 7, 8	TeV $\sqrt{s} = 13 \text{ TeV}$	Reference
Inclusive Searches	$\begin{array}{l} MSUGRA/CMSSM \\ \bar{q}\bar{q}, \bar{q} \rightarrow q\bar{\bar{\ell}}_1^0 \\ \bar{q}\bar{q}, \bar{q} \rightarrow q\bar{\bar{\ell}}_1^0 (\text{compressed}) \\ \bar{g}\bar{g}, \bar{g} \rightarrow q\bar{q}\bar{\bar{\ell}}_1^0 (\text{compressed}) \\ \bar{g}\bar{g}, \bar{g} \rightarrow q\bar{q}\bar{q}\bar{\bar{\ell}}_1^0 \\ \bar{g}\bar{g}, \bar{g} \rightarrow q\bar{q}\bar{q}\bar{\ell}_1^{d} \rightarrow q\bar{q}W^{\pm}\bar{\chi}_1^0 \\ \bar{g}\bar{g}, \bar{g} \rightarrow q\bar{q}(\ell\ell/v\gamma)\bar{\chi}_1^0 \\ \bar{g}\bar{g}, \bar{g} \rightarrow q\bar{q}W2\bar{\chi}_1^0 \\ GMSB(\ell NLSP) \\ GGM(binoNLSP) \\ GGM(higgsino-binoNLSP) \\ GGM(higgsino-binoNLSP) \\ GGM(higgsinoNLSP) \\ GGM(higgsinoNLSP) \\ GGM(higgsinoNLSP) \\ GravitinoLSP \end{array}$	$\begin{array}{c} 0\text{-}3 \ e, \mu/1\text{-}2 \ \tau \\ 0 \\ \text{mono-jet} \\ 0 \\ 3 \ e, \mu \\ 2 \ e, \mu \ (\text{SS}) \\ 1\text{-}2 \ \tau + 0\text{-}1 \ \epsilon \\ 2 \ \gamma \\ \gamma \\ \gamma \\ 2 \ e, \mu \ (Z) \\ 0 \end{array}$	2-10 jets/3 2-6 jets 1-3 jets 2-6 jets 2-6 jets 4 jets 0-3 jets 4 o-2 jets - 1 ô 2 jets 2 jets mono-jet	, Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 36.1 3.2 36.1 13.2 3.2 3.2 20.3 13.3 20.3 20.3 20.3	\$\vec{a}\$	1.85 TeV 1.57 TeV 2.02 TeV 2.01 TeV 1.7 TeV 1.6 TeV 2.0 TeV 1.85 TeV 1.85 TeV 1.85 TeV 1.87 TeV	$\begin{split} & m(\vec{q}) - m(\vec{g}) \\ & m(\vec{k}_1^0) < 200 GeV, \ m(1^d gen, \vec{q}) - m(2^{ul} gen, q) \\ & m(\vec{k}_1^0) < 200 GeV \\ & m(\vec{k}_1^0) < 200 GeV \\ & m(\vec{k}_1^0) < 200 GeV, \ m(\vec{k}^1) - 0.5 (m(\vec{k}_1^0) + m(\vec{g})) \\ & m(\vec{k}_1^0) < 200 GeV \\ & m(\vec{k}_1^0) < 400 GeV \\ & m(\vec{k}_1^0) < 500 GeV \\ & cr(NLSP) < 0.1 mm \\ & m(\vec{k}_1^0) < 950 GeV, \ cr(NLSP) < 0.1 mm, \ \mu < 0 \\ & m(\vec{k}_1^0) > 680 GeV, \ cr(NLSP) < 0.1 mm, \ \mu > 0 \\ & m(\vec{k}_1^0) > 680 GeV \\ & m(\vec{\mathcal{G}}) > 1.8 \times 10^{-4} eV, \ m(\vec{g}) - m(\vec{g}) - 1.5 TeV \end{split}$	1507.05525 ATLAS-CONF-2017-022 1604.07773 ATLAS-CONF-2017-022 ATLAS-CONF-2016-037 ATLAS-CONF-2016-037 1607.05979 1606.09150 1507.05493 ATLAS-CONF-2016-086 1508.03290 1502.01518
3 rd gen. § med.	$\begin{array}{l} \widetilde{x}\widetilde{x}, \ \widetilde{x} \rightarrow bb\widetilde{x}_{1}^{0} \\ \widetilde{x}\widetilde{y}, \ \widetilde{y} \rightarrow d\widetilde{x}_{1}^{0} \\ \widetilde{y}\widetilde{y}, \ \widetilde{y} \rightarrow b\widetilde{x}_{1}^{0} \end{array}$	Ο 0-1 e, μ 0-1 e, μ	3 b 3 b 3 b	Yes Yes Yes	36.1 36.1 20.1	й й Х	1.92 TeV 1.97 TeV 1.37 TeV	m(k ^e)-≪00 GeV m(k ^e)<200 GeV m(k ^e)<300 GeV	ATLAS-CONF-2017-021 ATLAS-CONF-2017-021 1407.0500
3 rd gen. squarks direct production	$ \begin{split} & \vec{b}_1 \vec{b}_1, \vec{b}_1 {\rightarrow} b \vec{x}_1^0 \\ & \vec{b}_1 \vec{b}_1, \vec{b}_1 {\rightarrow} t \vec{x}_1^+ \\ & \vec{t}_1 \vec{t}_1, \vec{t}_1 {\rightarrow} b \vec{x}_1^+ \\ & \vec{t}_1 \vec{t}_1, \vec{t}_1 {\rightarrow} w b \vec{x}_1^0 \text{ or } t \vec{x}_1^0 \\ & \vec{t}_1 \vec{t}_1, \vec{t}_1 {\rightarrow} w \vec{x}_1^0 \\ & \vec{t}_1 \vec{t}_1 (\text{natural GMSB}) \\ & \vec{b}_1 \vec{b}_2, \vec{t}_3 {\rightarrow} \vec{t}_1 + Z \\ & \vec{t}_2 \vec{t}_2, \vec{t}_2 {\rightarrow} \vec{t}_1 + h \end{split} $	$\begin{array}{c} 0 \\ 2 \ e, \mu \ (\text{SS}) \\ 0 \hbox{-} 2 \ e, \mu \\ 0 \hbox{-} 2 \ e, \mu \\ 0 \\ 2 \ e, \mu \ (Z) \\ 3 \ e, \mu \ (Z) \\ 1 \hbox{-} 2 \ e, \mu \end{array}$	2 b 1 b 1-2 b 0-2 jets/1-2 mono-jet 1 b 1 b 4 b	Yes Yes Yes Yes Yes Yes	3.2 13.2 .7/13.3 20.3 3.2 20.3 36.1 36.1	\$\bar{b}_1\$ 840 GeV \$\bar{b}_1\$ 325-585 GeV \$\bar{t}_1\$ 117-170 GeV 200-720 GeV \$\bar{t}_1\$ 90-198 GeV 205-950 GeV \$\bar{t}_1\$ 90-323 GeV 205-950 GeV \$\bar{t}_1\$ 90-323 GeV 150-600 GeV \$\bar{t}_2\$ 150-600 GeV \$\bar{t}_2\$ \$\bar{t}_2\$ 320-880 GeV \$\bar{t}_2\$		$\begin{split} & m(\tilde{\ell}_1^0) \! < \! 100 \mathrm{GeV} \\ & m(\tilde{\ell}_1^0) \! < \! 150 \mathrm{GeV}, \ m(\tilde{\ell}_1^0) \! = \! m(\tilde{\ell}_1^0) \! + \! 100 \mathrm{GeV} \\ & m(\tilde{\ell}_1^0) \! = \! 2m(\tilde{\ell}_1^0), \ m(\tilde{\ell}_1^0) \! = \! 55 \mathrm{GeV} \\ & m(\tilde{\ell}_1^0) \! - \! 1 \mathrm{GeV} \\ & m(\tilde{\ell}_1^0) \! - \! \mathrm{m}(\tilde{\ell}_1^0) \! = \! 5 \mathrm{GeV} \\ & m(\tilde{\ell}_1^0) \! = \! 150 \mathrm{GeV} \\ & m(\tilde{\ell}_1^0) \! = \! 0 \mathrm{GeV} \\ & m(\tilde{\ell}_1^0) \! = \! 0 \mathrm{GeV} \\ & m(\tilde{\ell}_1^0) \! = \! 0 \mathrm{GeV} \end{split}$	1606.08772 ATLAS-CONF-2016-037 1209.2102, ATLAS-CONF-2016-077 1506.08818, ATLAS-CONF-2017-020 1804.07773 1403.5222 ATLAS-CONF-2017-019 ATLAS-CONF-2017-019
EW direct	$ \begin{array}{l} \tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell \tilde{\chi}_{1}^{0} \\ \tilde{\chi}_{1}^{+} \tilde{\chi}_{1}^{-}, \tilde{\chi}_{1}^{+} \rightarrow \ell \nu (\ell \bar{\nu}) \\ \tilde{\chi}_{1}^{+} \tilde{\chi}_{1}^{-}, \tilde{\chi}_{1}^{+} \rightarrow \bar{\nu} \nu (\ell \bar{\nu}) \\ \tilde{\chi}_{1}^{+} \tilde{\chi}_{2}^{0} \rightarrow \ell \tilde{\ell}_{L} \nu \tilde{\ell}_{L} \ell (\bar{\nu} \nu), \ell \bar{\nu} \tilde{\ell}_{L} \ell (\bar{\nu} \nu) \\ \tilde{\chi}_{1}^{+} \tilde{\chi}_{2}^{0} \rightarrow W \tilde{\chi}_{1}^{0} \ell \tilde{\chi}_{1}^{0} \\ \tilde{\chi}_{1}^{+} \tilde{\chi}_{2}^{0} \rightarrow W \tilde{\chi}_{1}^{0} h \tilde{\chi}_{1}^{0}, h \rightarrow b \bar{b} / W W / \\ \tilde{\chi}_{2}^{0} \tilde{\chi}_{3}^{0}, \tilde{\chi}_{2,3}^{0} \rightarrow \tilde{\ell}_{R} \ell \\ GGM (wino NLSP) weak processing GGM (bino NLSP) weak processing for the set of the set of$	$\begin{array}{c} 2 \ e, \mu \\ 2 \ e, \mu \\ 2 \ \tau \\ 3 \ e, \mu \\ 2 \ 3 \ e, \mu \\ c \tau / \gamma \\ e, \mu, \gamma \\ 4 \ e, \mu \\ d, 1 \ e, \mu + \gamma \\ d, 2 \ \gamma \end{array}$	0 - 0-2 jets 0-2 <i>b</i> 0 -	Yes Yes Yes Yes Yes Yes Yes	20.3 13.3 14.8 13.3 20.3 20.3 20.3 20.3 20.3 20.3	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$m(\vec{x}_1^0) = 0$ $m(\vec{x}_1^0) = 0$ $m(\vec{x}_2^0) = 0$	$\begin{split} & m(\tilde{k}_{1}^{q}) \!\!=\!\! 0 \; GeV \\ & 0 \; GeV \; m(\tilde{\ell}, \tilde{r}) \!\!=\!\! 0.5 (m(\tilde{k}_{1}^{+}) \!\!+\! m(\tilde{k}_{1}^{0})) \\ & m(\tilde{\ell}_{2}^{q}) \!\!=\!\! 0 \; GeV \; m(\tilde{\tau}, \tilde{\tau}) \!\!=\!\! 0.5 (m(\tilde{k}_{1}^{+}) \!\!+\! m(\tilde{k}_{1}^{q})) \\ & m(\tilde{\ell}_{2}^{0}) \!\!=\!\! 0, \; m(\tilde{\ell}, \tilde{r}) \!\!=\!\! 0.5 (m(\tilde{k}_{1}^{+}) \!\!+\! m(\tilde{k}_{1}^{0})) \\ & m(\tilde{k}_{2}^{0}) \!\!=\!\! m(\tilde{k}_{2}^{0}) \!\!=\!\! 0, \; m(\tilde{\ell}, \tilde{r}) \!\!=\!\! 0.5 (m(\tilde{k}_{1}^{0}) \!\!+\!\!m(\tilde{k}_{1}^{0})) \\ & m(\tilde{k}_{1}^{0}) \!\!=\!\! m(\tilde{k}_{2}^{0}) \!\!=\!\! m(\tilde{k}_{2}^{0}) \!\!=\!\! 0, \; \tilde{\ell} \; decoupled \\ & m(\tilde{k}_{1}^{0}) \!\!=\!\! m(\tilde{k}_{2}^{0}) \!\!=\!\! 0, \; m(\tilde{\ell}_{2}^{0}) \!\!=\!\! 0, \; \tilde{\ell} \; decoupled \\ & m(\tilde{k}_{2}^{0}) \!\!+\!\! m(\tilde{k}_{1}^{0}) \!\!=\!\! 0, \; m(\tilde{\ell}, \tilde{v}) \!\!=\!\! 0.5 (m(\tilde{\ell}_{2}^{0}) \!\!+\!\!m(\tilde{k}_{1}^{0})) \\ & cr \!<\!\!1 \!\! nm \\ & cr \!<\!\!1 \!\! nm \end{split}$	1403.5294 ATLAS-CONF-2016-096 ATLAS-CONF-2016-093 ATLAS-CONF-2016-096 1403.5294, 1402.7029 1501.07110 1405.5086 1507.05493 1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived. Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived. Stable, stopped § R-hadron Stable § R-hadron Metastable § R-hadron GMSB, stable $t, \tilde{\chi}_1^0 \rightarrow t(\tilde{e}, \mu) +$ GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{C}$, long-lived $\tilde{\chi}_1^0$ $\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow eev/e\mu\nu/\mu\mu\nu$ GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow Z\tilde{G}$	$\hat{\chi}_1^{\pm}$ Disapp. trk $\hat{\chi}_1^{\pm}$ dE/dx trk 0 trk dE/dx trk $\tau(e,\mu)$ 1-2 μ 2 γ displ. $ee/e\mu/\mu$ displ. vtx + je	t 1 jet - 1-5 jets - - - - - - - - - - - - - - - - - - -	Yes Ves Yes Yes	36.1 18.4 27.9 3.2 3.2 19.1 20.3 20.3 20.3	x̂ [±] 430 GeV x̂ [±] 495 GeV x̂ 850 GeV x̂ 850 GeV x̂ 850 GeV x̂ 10 TeV x̂ [±] 1.0 TeV x̂ [±] 1.0 TeV	1.58 TeV 1.57 TeV	$\begin{split} & m(\tilde{\mathcal{K}}_1^*){-}m(\tilde{\mathcal{K}}_1^3){\sim}160 \; MeV, \; \tau(\tilde{\mathcal{K}}_1^*){=}0.2 \; ns \\ & m(\tilde{\mathcal{K}}_1^*){-}m(\tilde{\mathcal{K}}_1^3){\sim}160 \; MeV, \; \tau(\tilde{\mathcal{K}}_1^*){<}15 \; ns \\ & m(\tilde{\mathcal{K}}_1^0){=}100 \; GeV, \; 10 \; \mus{<}\tau(\tilde{\mathfrak{g}}){<}1000 \; s \\ & m(\tilde{\mathcal{K}}_1^0){=}100 \; GeV, \; \tau{>}10 \; ns \\ & 10{<}tar(\tilde{\mathcal{S}}_1^0){<}100 \; GeV, \; \tau{>}10 \; ns \\ & 10{<}tar(\tilde{\mathcal{K}}_1^0){<}3 \; ns, \; SPS8 \; model \\ & 7 \; {<}cr(\tilde{\mathcal{K}}_1^0){<} \; 3es \; ns, \; SPS8 \; model \\ & 6 \; {<}cr(\tilde{\mathcal{K}}_1^0){<} \; 4s0 \; nm, \; m(\tilde{\mathfrak{g}}){=}1.1 \; TeV \end{split}$	ATLAS-CONF-2017-017 1506.05332 1310.6584 1606.05129 1804.04520 1411.6795 1409.5542 1504.05162 1504.05162
RPV	$ \begin{array}{l} LFV \ pp {\rightarrow} \tilde{r}_{\tau} + X, \tilde{v}_{\tau} {\rightarrow} e\mu/e\tau/\mu \\ Bilinear \ RPV \ CMSSM \\ \tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ {\rightarrow} W \tilde{\chi}_1^0, \tilde{\chi}_1^0 {\rightarrow} eev, e\muv \\ \tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ {\rightarrow} W \tilde{\chi}_1^0, \tilde{\chi}_1^0 {\rightarrow} \tau\tau v_e, e\tau \\ \tilde{\chi}_1^0, \tilde{\chi}_1^-, \tilde{\chi}_1^+ {\rightarrow} W \tilde{\chi}_1^0, \tilde{\chi}_1^0 {\rightarrow} qqq \\ \tilde{\chi}_1^0, \tilde{\chi}_1 {\rightarrow} eqq \\ \tilde{\chi}_1^0, \tilde{\chi}_1 {\rightarrow} eqq \\ \tilde{\chi}_1^0, \tilde{\chi}_1 {\rightarrow} bs \\ \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 {\rightarrow} bs \\ \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 {\rightarrow} b\ell \end{array} $	$ex = e\mu, e\tau, \mu\tau$ $2 e, \mu (SS)$ $\gamma_{\tau} = 3 e, \mu + \tau$ $0 = 4$ $0 = 4$ $1 e, \mu = 6$ $1 e, \mu = 6$ $2 e, \mu$	0-3 b 	· Yes Yes ts · ts · δ · δ ·	3.2 20.3 13.3 20.3 14.8 14.8 36.1 36.1 15.4 20.3	\$\vec{x}\$ \$\vec{x}\$ <td< th=""><th>1.9 TeV 1.45 TeV TeV 1.55 TeV 2.1 TeV 1.65 TeV</th><th>$\begin{split} &\mathcal{X}_{311}^{c}=0.11,\mathcal{X}_{152/123/231}^{c}=0.07\\ &m(\tilde{g})=m(\tilde{g}),c\tau_{155}^{c}<1\text{ mm}\\ &m(\tilde{k}_{-}^{0})>400GeV,\mathcal{X}_{128}^{c}\neq0~(k=1,2)\\ &m(\tilde{k}_{-}^{0})>0.2\times m(\tilde{k}_{1}^{c}),\mathcal{X}_{125}^{c}\neq0\\ &BR(\ell)=BR(\ell)=BR(\ell)=0\%\\ &m(\tilde{k}_{-}^{0})=400GeV\\ &m(\tilde{k}_{-}^{0})=1\text{TeV},\mathcal{X}_{312}^{c}\neq0\\ &m(\tilde{k}_{-}^{0})=1\text{TeV},\mathcal{X}_{323}^{c}\neq0\\ &BR(\tilde{\ell}_{1}^{c}\rightarrow\delta\epsilon/\mu)>20\% \end{split}$</th><th>1607.08079 1404.2500 ATLAS-CONF-2016-075 1405.5086 ATLAS-CONF-2016-057 ATLAS-CONF-2016-057 ATLAS-CONF-2017-013 ATLAS-CONF-2017-013 ATLAS-CONF-2016-022, ATLAS-CONF-2016-004 ATLAS-CONF-2015-015</th></td<>	1.9 TeV 1.45 TeV TeV 1.55 TeV 2.1 TeV 1.65 TeV	$\begin{split} &\mathcal{X}_{311}^{c}=0.11,\mathcal{X}_{152/123/231}^{c}=0.07\\ &m(\tilde{g})=m(\tilde{g}),c\tau_{155}^{c}<1\text{ mm}\\ &m(\tilde{k}_{-}^{0})>400GeV,\mathcal{X}_{128}^{c}\neq0~(k=1,2)\\ &m(\tilde{k}_{-}^{0})>0.2\times m(\tilde{k}_{1}^{c}),\mathcal{X}_{125}^{c}\neq0\\ &BR(\ell)=BR(\ell)=BR(\ell)=0\%\\ &m(\tilde{k}_{-}^{0})=400GeV\\ &m(\tilde{k}_{-}^{0})=1\text{TeV},\mathcal{X}_{312}^{c}\neq0\\ &m(\tilde{k}_{-}^{0})=1\text{TeV},\mathcal{X}_{323}^{c}\neq0\\ &BR(\tilde{\ell}_{1}^{c}\rightarrow\delta\epsilon/\mu)>20\% \end{split}$	1607.08079 1404.2500 ATLAS-CONF-2016-075 1405.5086 ATLAS-CONF-2016-057 ATLAS-CONF-2016-057 ATLAS-CONF-2017-013 ATLAS-CONF-2017-013 ATLAS-CONF-2016-022, ATLAS-CONF-2016-004 ATLAS-CONF-2015-015
Other	Scalar charm, $\hat{c} \rightarrow c \hat{k}_1^0$	٥	20	Yes	20.3	.a 510 GeV		m(ℓ ₁ ⁶)<200 GeV	1501.01325
*Only i	Only a selection of the available mass limits on new states or 10^{-1} 1 Mass scale [TeV] 10								

*C simplified models, c.f. refs. for the assumptions made.

Mass scale [lev]

ATLAS Preliminary

 $\sqrt{r} = 7.8.13 \text{ TeV}$

ATLAS Exotics Searches* -

 ≥ 1 b, ≥ 1.4

 $\geq 2b, \geq 4$

_

 ≥ 1 j

1 j

1 **J**, ≤ 1 **j**

≥2j

≥21

≥1 b, ≥3 j

 $\geq 2b, \geq 3j$

≥2/≥1 b

≥4 j

1 j

2 j

1 b, 1 j

1 b, 2-0 j

_

2 j

-

_

1 b

√s = 13 TeV

≥1b,≥3j Yes

≥2b,≥3j Yes

Yes

Yes

Yes

Yes

Yes

Yes

Yes

Yes

_

Yes

_

_

Yes

_

-

-

Yes

_

20.3

20.3

20.3

7.0

 ℓ, γ

_

2 e. µ

1 e. µ

-

≥ 1 e, μ

_

2 e, µ

 2γ

1 e, µ

1 e.µ

1 e.u

2 c, µ

2т

_ 1 c. //

0 e,μ

1 e, µ

0 c.µ

_

 $2 e, \mu$

0 e,μ

0 e, µ

2 e

 2μ

1 e. µ

1 c, µ

1 e, µ

 $1 e, \mu$

2/≥3 e,µ

1 c, µ

1 %

_

1 or 2 e, µ

3 e, µ

3 e. µ. 7

1 e. µ. 1 γ

2 e, µ

2 e (SS)

3 e, µ, τ

1 e, µ

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

2(SS)/≥3 *e.µ* ≥1 b, ≥1 j

2(SS)/≥3 e.μ ≥1 b, ≥1 j

Status: August 2016

Model

ADD $G_{KK} + g/q$

ADD QBH $\rightarrow \ell q$

ADD BH multijet

RS1 $G_{KK} \rightarrow \ell \ell$

RS1 $G_{KK} \rightarrow \gamma \gamma$

Bulk RS $g_{RK} \rightarrow tt$

Leptophobic $Z' \rightarrow bb$

2UED / RPP

 $\operatorname{SSM} Z' \to \ell\ell$

SSM $Z' \rightarrow \tau \tau$

SSM $W' \rightarrow \ell \nu$

LRSM $W'_R \to t \dot{b}$

LRSM $W_{\rho}^{0} \rightarrow tb$

Cl qqqq

Clitigg

GL nutt

Bulk RS $G_{KK} \rightarrow WW \rightarrow gg\ell v$

Bulk RS $G_{KK} \rightarrow HH \rightarrow bbbb$

HVT $W' \rightarrow WZ \rightarrow qqnn$ model A

HVT $W' \rightarrow WZ \rightarrow aaaa \mod B$

Axial-vector mediator (Dirac DM)

ZZ_{XX} EFT (Dirac DM)

Scalar LQ 1st gen

Scalar LQ 2nd gen

Scalar LQ 3rd gen

VLQ $TT \rightarrow Ht + X$

 $VLQ YY \rightarrow Wb + X$

Magnetic monopoles

HVT $V' \rightarrow WH/ZH \mod B$ multi-channel

Axial-vector mediator (Dirac DM) = 0 $e, \mu, 1 \gamma$

ADD BH high $\sum \rho_T$

ADD QBH

Extra dimensions

Gauge bosons

5

M

g

ADD non-resonant *ll*

es* - 9	95%	6 CL	Exclusion			ATL	4S Preliminary
					$\int \mathcal{L} dt = 0$	3.2 - 20.3) fb ⁻¹	$\sqrt{s} = 8$, 13 TeV
Jets† I	E ^{miss} T	∫£ dt[fb	-1]	Limit	č.		Reference
≥ 1 j	Yes	3.2	Ma		6.58 TeV	n = 2	1604.07773
1 j 2 j	-	20.3	M _{ch} M _{ch}	5.2	TeV 8.7 TeV	n = 6 n = 6	1311.2006 ATLAS-CONE-2018-068
≥2j ≥3j	_	3.2	Mes Mes		8.2 TeV 9.55 TeV	$n = 6, M_D = 3$ TeV, rot BH $n = 6, M_D = 3$ TeV, rot BH	1606.02265 1512.02586
-	_	20.3 3.2	G _{KR} mass G _{KR} mass	2.68 TeV 3.2 TeV		$k/\overline{M}_{Pl} = 0.1$ $k/\overline{M}_{Pl} = 0.1$	1405.4123 1606.03833
1 J 4 b	Yes -	13.2 13.5	G _{KK} mass G _{KK} mass	1.24 TeV 360-860 GeV		$k/\overline{M}_{Pl} = 1.0$ $k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-062 ATLAS-CONF-2016-049
1 b, ≥ 1.0/2j ≥ 2 b, ≥ 4 j	Yes	3.2	KK mass	2.2 TeV 1.46 TeV		BR = 0.825 Tier (1,1), BR($A^{(1,1)} \rightarrow tt$) = 1	ATLAS-CONF-2016-013
_	_	13.3 19.5	Z' mass Z' mass	4.05 TeV 2.02 TeV			ATLAS-CONF-2016-045 1502.07177
26	Yes	3.2 13.3	Z' mass W' mass	1.5 TeV 4.74 T	eV		1603.08791 ATLAS-CONF-2016-061
1 J 2 J	nes —	13.2 15.5	W mass W mass	2.4 TeV 3.0 TeV 2.31 TeV		$g_V = 1$ $g_V = 3$ $g_V = 3$	ATLAS-CONF-2016-082 ATLAS-CONF-2016-055 1607.05821
2 b, 0-1 j ≥ 1 b, 1 J	Yes	20.3 20.3	W' mass W' mass	1.92 TeV 1.76 TeV		8	1410.4103
2 j	-	15.7	٨			19.9 TeV 911 1	ATLAS-CONF-2016-069

20.3	Λ	4.9 TeV	$ C_{RR} = 1$	1504.04605
3.2 3.2 3.2	ma 1.0 TeV ma 710 GeV M, 550 GeV		$\begin{array}{l} g_{\chi}{=}0.25,g_{\chi}{=}1.0,m(\chi)<250~{\rm GeV}\\ g_{\chi}{=}0.25,g_{\chi}{=}1.0,m(\chi)<150~{\rm GeV}\\ m(\chi)<150~{\rm GeV} \end{array}$	1604.07773 1604.01306 ATLAS-CONF-2015-080
3.2 3.2 20.3	LQ mass 1.1 TeV LQ mass 1.05 TeV LQ mass 540 GeV		$\beta = 1$ $\beta = 1$ $\beta = 0$	1605.06035 1605.06035 1508.04735
20.3 20.3 20.3 20.3 20.3 3.2	T mass 855 GeV Y mass 770 GeV B mass 735 GeV B mass 755 GeV Q mass 690 GeV T _{3/3} mase 990 GeV		T in (T,B) doublet Y in (B,Y) doublet isospin singlet B in (B,Y) doublet	1505.04306 1505.04306 1505.04306 1409.5500 1509.04261 ATLAS-CONF-2016-032
3.2 15.7 8.8 20.3 20.3 20.3	q" mass q" mass b" mass b" mass (" mass v" mass 1	4.4 TeV 5.6 TeV 2.3 TeV 3 TeV 3.0 TeV .6 TeV	only u^* and d^* , $\Lambda = m(q^*)$ only u^* and d^* , $\Lambda = m(q^*)$ $f_g = f_L = i_R = 1$ $\Lambda = 3.0 \text{ TeV}$ $\Lambda = 1.6 \text{ TeV}$	1512.05910 ATLAS-CONF-2016-069 ATLAS-CONF-2016-060 1510.02664 1411.2921 1411.2921
20.3 20.3 13.9	ar mass 960 GeV N ⁰ mass H ⁴⁴ mass 570 GeV	2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing DY production, BR($H_L^{\pm\pm} \rightarrow ee$)-1	1407.8150 1506.06020 ATLAS-CONF-2016-051

Heavy quarks	$\begin{array}{l} \text{VLQ } YY \rightarrow Wo + X \\ \text{VLQ } BB \rightarrow Hb + X \\ \text{VLQ } BB \rightarrow Zb + X \\ \text{VLQ } QQ \rightarrow WqWq \\ \text{VLQ } T_{5/3} T_{5/3} \rightarrow WtWt \end{array}$
Excited fermions	Excited quark $q^* \rightarrow q\gamma$ Excited quark $q^* \rightarrow qg$ Excited quark $b^* \rightarrow bg$ Excited quark $b^* \rightarrow Wt$ Excited lepton t^* Excited lepton r^*
Other	LSTC $a_T \rightarrow W_Y$ LRSM Majorana v Higgs triplet $H^{\pm\pm} \rightarrow ee$ Higgs triplet $H^{\pm\pm} \rightarrow \ell r$ Monotop (non-res prod) Multi-charged particles

*Only a selection of the available mass limits on new states or phenomena is shown. Lower bounds are specified only when explicitly not excluded.

monopole may

H^{±±} mass

spin-1 invisible particle mass

multi-charged particle mass

 10^{-1}

400 GeV

657 GeV

785 GeV

.

1.34 TeV

1

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

1411.2921

1410.5404

1504.04188

1509.08059

DY production, $BB(H_{L}^{0+} \rightarrow \ell \tau)=1$

DY production, $|g| = 1g_D$, spin 1/2.

Mass scale [TeV]

 $a_{\rm ref-res}=0.2$

10

DV production, |q| = 5e

ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

Sta	atus: August 2016			_		$\int \mathcal{L} dt = (3)$	3.2 - 20.3) fb ⁻¹	$\sqrt{s} = 8, 13 \text{ TeV}$
	Model	ί,γ	Jets†	≡miss T	∫£ dt[fb	⁻¹] Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$ ADD non-resonant $\ell\ell$ ADD QBH $\rightarrow \ell q$ ADD QBH ADD BH high $\sum p_T$ ADD BH multijet RS1 $G_{RK} \rightarrow \ell\ell$ RS1 $G_{KK} \rightarrow \gamma\gamma$ Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$ Bulk RS $G_{KK} \rightarrow tt$ 2UED / RPP	$ \begin{bmatrix} 2 & e, \mu \\ 1 & e, \mu \\ - \\ ≥ 1 & e, \mu \\ - \\ 2 & e, \mu \\ 2 & \gamma \\ 1 & e, \mu \\ - \\ 1 & e, \mu \\ - \\ 1 & e, \mu \\ 1 & e, \mu 3 $	≥ 1 j = 1 j 2 j ≥ 2 j ≥ 3 j = 1 J 4 b ≥ 1 b, ≥ 1 J/2 ≥ 2 b, ≥ 4 j	Yos 	3.2 20.3 15.7 3.2 3.6 20.3 3.2 13.2 13.2 13.5 20.3 3.2	Mo 6.58 TeV Ms 4.7 TeV Mos 5.2 TeV Mos 5.2 TeV Mos 8.7 TeV Mos 9.55 TeV GKK mass 2.68 TeV GKK mass 3.2 TeV GKK mass 3.2 TeV GKK mass 360-860 GeV BKK mass 360-860 GeV KK mass 1.46 TeV	n = 2 n = 3 HLZ n = 6 n = 6 n = 6 $n = 6, M_{D} = 3 \text{ TeV, rot BH}$ $n = 6, M_{D} = 3 \text{ TeV, rot BH}$ $k/\overline{M}_{Pl} = 0.1$ $k/\overline{M}_{Pl} = 0.1$ $k/\overline{M}_{Pl} = 1.0$ R = 0.925 Tier (1,1), $\text{ER}(A^{(1,1)} \rightarrow tt) = 1$	1604.07773 1407.2410 1311.2006 ATLAS-CONF-2016-068 1606.02295 1512.02586 1405.4123 1606.03833 ATLAS-CONF-2016-062 ATLAS-CONF-2016-049 1505.07018 ATLAS-CONF-2016-013
Gauge bosons	$\begin{array}{l} \operatorname{SSM} Z' \to \ell\ell \\ \operatorname{SSM} Z' \to rr \\ \operatorname{Leptophoble} Z' \to bb \\ \operatorname{SSM} W' \to \ell\nu \\ \operatorname{HVT} W' \to WZ \to qapp \mbox{ mode} \\ \operatorname{HVT} W' \to WZ \to qapq \mbox{ mode} \\ \operatorname{HVT} V' \to WZ \to qapq \mbox{ mode} \\ \operatorname{HVT} V' \to WH/ZH \mbox{ mode} \\ \operatorname{B} \\ \operatorname{LRSM} W'_R \to tb \\ \operatorname{LRSM} W'_R \to tb \end{array}$	2 c, μ 2 τ - 1 c, μ el A 0 e, μ el B - multi-channe 1 e, μ 0 c, μ	- 2b - 1J 2J 2b,0-1j ≥1b,1J	- Yes Yes - Yes -	13.3 19.5 3.2 13.3 13.2 15.5 3.2 20.3 20.3	Z' mass 4.05 TeV Z' mass 2.02 TeV Z' mass 1.5 TeV W' mass 4.74 TeV W' mass 2.4 TeV W' mass 3.0 TeV V' mass 2.31 TeV W' mass 1.92 TeV W' mass 1.76 TeV	$g_{V} = 1$ $g_{V} = 3$ $g_{V} = 3$	ATLAS-CONF-2016-045 1502.07177 1603.08791 ATLAS-CONF-2016-061 ATLAS-CONF-2016-082 ATLAS-CONF-2016-055 1607.05621 1410.4103 1408.0886
G	Cl qqqq Cl il qq Cl uutt	_ 2 e,μ 2(SS)/≥3 e,μ	2 j ∉≥1 b,≥1 j	- - Yes	15.7 3.2 20.3	Λ Λ Λ 4.9 TeV	$\begin{array}{c c} 19.9 \text{ TeV} & \eta_{LL} = -1 \\ \hline 25.2 \text{ TeV} & \eta_{LL} = -1 \\ C_{RR} = 1 \end{array}$	ATLAS-CONF-2016-069 1607-03669 1504.04605
МQ	Axial-vector mediator (Dirac DN Axial-vector mediator (Dirac DN $ZZ_{\chi\chi}$ EFT (Dirac DM)	M) 0e,μ M) 0e,μ.1γ 0e,μ	≥1j 1j 1J,≤1j	Yes Yes Yes	3.2 3.2 3.2	ma 1.0 TeV ma 710 GeV Ma 550 GeV	$\begin{array}{l} g_{\eta}\!=\!0.25, \ g_{\chi}\!=\!1.0, \ m(\chi) < 250 \ {\rm GeV} \\ g_{q}\!=\!0.25, \ g_{\chi}\!=\!1.0, \ m(\chi) < 150 \ {\rm GeV} \\ m(\chi) < 150 \ {\rm GeV} \end{array}$	1604.07773 1604.01306 ATLAS-CONF-2015-080
Ę	Scalar LQ 1 st gen Scalar LQ 2 nd gen Scalar LQ 3 rd gen	2 e 2 μ 1 e,μ	≥2j ≥2j ≥1 b, ≥3 j	- - Yəs	3.2 3.2 20.3	LQ mass 1.1 TeV LQ mass 1.05 TeV LQ mass 640 GeV	$\beta = 1$ $\beta = 1$ $\beta = 0$	1605.06035 1605.06035 1508.04735
Heavy quarks	$\begin{array}{l} VLQ \ TT \rightarrow Ht + X \\ VLQ \ YY \rightarrow Wb + X \\ VLQ \ BB \rightarrow Hb + X \\ VLQ \ BB \rightarrow Zb + X \\ VLQ \ BB \rightarrow Zb + X \\ VLQ \ QQ \rightarrow WqWq \\ VLQ \ T_{5/3} \ T_{5/3} \rightarrow WtWt \end{array}$	$\begin{array}{c} 1 \ e, \mu \\ 1 \ e, \mu \\ 1 \ e, \mu \\ 2 l \geq 3 \ e, \mu \\ 1 \ e, \mu \\ 2 (8 S) l \geq 3 \ e, \mu \end{array}$	$\begin{array}{l} \geq 2 \ b, \geq 3 \ j \\ \geq 1 \ b, \geq 3 \ j \\ \geq 2 \ b, \geq 3 \ j \\ \geq 2 \ b, \geq 3 \ j \\ \geq 2 \ \geq 1 \ b \\ \geq 4 \ j \\ \prime \geq 1 \ b, \geq 1 \ j \end{array}$	Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 3.2	T mass 855 GeV Y mass 770 GeV B mass 735 GeV B mass 755 GeV Q mass 690 GeV T _{3/3} mass 990 GeV	T in (T,B) doublet Y in (B,Y) doublet isospin singlet B in (B,Y) doublet	1505.04306 1505.04306 1505.04306 1409.5500 1509.04261 ATLAS-CONF-2016-032
Excited	Excited quark $q^* \rightarrow q\gamma$ Excited quark $q^* \rightarrow qg$ Excited quark $b^* \rightarrow bg$ Excited quark $b^* \rightarrow Wt$ Excited lepton l^* Excited lepton r^*	1γ 1 or 2 e, μ 3 e, μ 3 e, μ, τ	1j 2j 1b,1j 1b,2-0j - -	- - Yas - -	3.2 15.7 8.8 20.3 20.3 20.3	q' mass 4.4 TeV q' mass 5.6 TeV b' mass 2.3 TeV b' mass 1.5 TeV r' mass 3.0 TeV r' mass 1.6 TeV	only u^* and d^* , $\Lambda = m(q^*)$ only u^* and d^* , $\Lambda = m(q^*)$ $i_g = i_h = i_R = 1$ $\Lambda = 3.0 \text{ TeV}$ $\Lambda = 1.6 \text{ TeV}$	1612.05910 ATLAS-CONF-2016-069 ATLAS-CONF-2016-060 1510.02664 1411.2921 1411.2921
Other	LSTC $a_T \rightarrow W\gamma$ LRSM Majorana v Higgs triplet $H^{\pm\pm} \rightarrow ee$ Higgs triplet $H^{\pm\pm} \rightarrow c_T$ Monotop (non-res prod) Multi-charged particles Magnetic monopoles	$1 e, \mu, 1 \gamma 2 e, \mu 2 e (SS) 3 e, \mu, \tau 1 e, \mu - - - - - - - - - -$	- 2 j - 1 b - -	Yes - - Yes - -	20.3 20.3 13.9 20.3 20.3 20.3 20.3 7.0	arr mass 960 GeV N ⁰ mass 2.0 TeV H** mass 570 GeV H** mass 400 GeV sp n-1 inv sible particle mass 657 GeV multi-charged particle mass 785 GeV monopole mass 1.34 TeV	$m(W_R) = 2.4$ TeV, no mixing DY production, BR($H_L^{hh} \rightarrow ee$)-1 DY production, BR($H_L^{hh} \rightarrow \ell\tau$)=1 $\partial_{toti-res} = 0.2$ DY production, $ q = 5e$ DY production, $ g = 1g_D$, spin 1/2	1407.8150 1506.06020 ATLAS-CONF-2016-051 1411.2921 1410.5404 1504.04198 1509.08059
		√s = 8 TeV	√s = 13	TeV		10 ⁻¹ 1 10	Mass scale [TeV]	10

"Only a selection of the available mass limits on new states or phenomena is shown. Lower bounds are specified only when explicitly not excluded.

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

ATLAS Preliminary

Well established idea...

as advertised at the Metropolitan Museum @ NYC

AET参观。看多元文化。ON 發 ЕТ ОДИН МЕТ. МНОГО أكثر من عالم: UCHOS MUNDOS. ONE MET. MANY WORLDS МНОГО МИРОВ. 来МЕТ参 DOS. أكثر من عالم: DOS. أكثر من عالم: DOS.

Building the MET: Well established assumptions and measurements

- How can we measure something that is not interacting with our detector?
 - Measure all the rest, and impose the momentum conservation!
 - **0**= Σ(what we see)+Σ(what we do not see)
 (bold meaning **2D vectors** in the plane transverse to the beam axis)
 - Σ (what we do not see)= Σ (what we see) = MET

What do we see? - First qualitative try

• Charge tracks:

Momentum of the charged particles thanks to the inner tracker (e,µ,ch_had) $|\eta|$ <2.5, p_T > 500 MeV

• Energy depositions in calorimeters:

Energy deposition due to charged (e, ch_had) and neutral particles (y,neu_had) Muons deposit ~2 GeV in the calorimeter. $|\eta| < 4.9$

Muon detector:

Muon momentum can be measured thanks to the combination of the inner tracker and the muon spectrometer.

 $|\eta| < 2.7 \text{ p}_T > 7 \text{ GeV}$

First "naive" option: Use the calorimeter, and refine the measurement adding information from the muon reconstruction when there are muons.
 At the end, was not this one of the benefits in having a calorimeter up to |η|~5 ?

From the calorimeter to the objects

 We can use the calorimeter information as it is, maybe with some calibration to take into account the dead material in front of it, and the non-compensating nature of the detector,

BUT:

 if we know that there are e, γ, τ, jets in our event, maybe we can do better by using these objects, and their dedicated calibration instead of the signals from the calorimeter

→ Object based MET

additional benefit: we can inherits from each individual object its uncertainty.

This allows a consistent estimation and propagation of the errors.

- Ingredients: $E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft Term}$
- Hard pT objects
 - Electrons, $p_T > 10 \text{ GeV}$, $|\eta| < 2.47$
 - · Photons,
 - Taus
 - Jets
 - Muons
- · Rules to handle the overlap between objects
- Soft pT object
 - · They are needed to "close" the event
- · Vectorial sum on the all these on the transverse plane
 - Done!



- $\cdot \text{ Ingredients: } E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft Term} + E_{x,y}^{miss,M} + E$
- Hard pT objects
 - Electrons,
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- Hard pT objects
 - Electrons,
 - · Photons,
 - Taus p_T>10 GeV, |η|<2.5
 - Jets
 - Muons
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 - They are needed to "close" the event
- · Vectorial sum on the all these on the transverse plane
 - Done!



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- Hard pT objects
 - Electrons,
 - · Photons,
 - Taus
 - Jets p_T>7 GeV
 - Muons
- · Rules to handle the overlap between objects
- Soft pT object
 - They are needed to "close" the event
- · Vectorial sum on the all these on the transverse plane
 - Done!



- $\text{Ingredients:} \quad E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft Term} + E_{x,y}^{miss,M} + E_$
- Hard pT objects
 - · Electrons,
 - · Photons,
 - Taus
 - Jets
 - Muons $p_T > 5$ GeV, $|\eta| < 2.7$
- · Rules to handle the overlap between objects
- Soft pT object
 - · They are needed to "close" the event
- · Vectorial sum on the all these on the transverse plane
 - Done!



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- Hard pT objects
 - · Electrons,
 - · Photons,
 - Taus
 - Jets
 - Muons
- · Rules to handle the overlap between objects
- Soft pT object ???
 - They are needed to "close" the event
- · Vectorial sum on the all these on the transverse plane
- е iet no association to $e, \gamma, \mu, \tau, jets$ Soft Term₂₈

• Done!

- Ingredients: $E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft Term}$
- Hard pT objects
 - Electrons,
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 - Jets
 - Muons
- · Rules to handle the overlap between objects
- Soft pT object
 - · They are needed to "close" the event
- · Vectorial sum on the all these on the transverse plane
 - Done!

 $E_{x,y}$ Soft Term = $\Sigma p_{x,y}$ what is left out from the hard objects



SoftTerm: How to measure it?

- Which options do I have to measure the soft terms?
- Option 1: Depositions in the calorimeter
 - · + It has a good coverage in p_T and η
 - - it suffer from pile-up:
 - deterioration in resolution:

dσ^{Reso}/d(NPV)=0.5 - 1. GeV per addit. primary vertex for NPV=30: Resolution ~20-30 GeV just from pile-up effect on soft terms

SoftTerm: How to measure it?

- Which options do I have to measure the soft terms?
- Option 2: Tracking
 - + We can identify the primary vertex, and suppress any pile-up effect (but we need to identify the right primary vertex)
 - it suffer from: missing the neutrals at low p_T + forward region

- MET resolution due to Soft Terms done with tracks: 8 GeV.
- But we are slightly underestimating the Soft Term.



- Using the tracks from the primary vertex as soft terms seems to allow an improved resolution (lower MET values) in events with no real MET.
- By the end of the Run1 it become the new standard in ATLAS, and it is our default algorithm right now.
- BUT, we do not leave just of resolutions in events without EtMiss

Events with MET ~50 GeV diminished by ~ a factor 4



- Again resolution, and its dependence on pile-up and activity in the event
- ΣE_T(CST) is the scalar sum of the transverse energy, using calorimeter clusters for Soft Terms



- But for searches are are interested in tails:
- Step 0: Make sure that we do not have problematic events (detector malfunctioning)
- Step 1: reduce as much as possible the tails in SM events where do not expect real MET
- Z+jets: reduction of a factor 10⁵ for MET>120 GeV



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EtMiss Response

- In events with 0 truth MET, we expect the the MET to be average 0, irrespectively of the direction in which we project the MET.
- This is what we see in x or y directions.
- In Z+jets we have another interesting directing to test: the Z direction.
- So doing <(MET+p_T(Z)) // Z > / p_T(Z) we expect 1 for a perfect response
- MET+pT(Z) is the recoil of the Z boson





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• <(MET+p_T(Z)) // $Z > / p_T(Z)$

<MET // Z>







0











To get a feeling of the quality of the MET (and soft terms), one can project the δp_T^{soft} on the direction of the p_T^{hard} NOTE: $\delta E_T^{miss} = -\delta p_T^{soft}$

Soft Terms - Truth studies





e, μ : pT>7 GeV and $|\eta|$ <2.5 jets: anti-kt with R=0.4 with pT>20 GeV and $|\eta|$ <5 All the rest enters in the Soft Term regime.

Soft Terms - Truth studies





Not a big difference between samples.



Not a big difference between samples.

Emiss



Not a big difference between samples.

Emiss P

Soft Terms - from truth studies to measurements



Calorimeter based Soft Terms have a better closure

Systematics

Using this information to estimate the systematics



not strong dependence on sample, but some on generator-tune

Soft Terms - from truth studies to measurements



not strong dependence on sample, but some on generator-tune

Soft Terms - from truth studies to measurements



not strong dependence on sample, but some on generator-tune

- Z→µµ is particularly interesting to measure how well we "close" the MET, but no "real" MET in it.
- Checking in events with real MET:
- W+jets



 Even if we have some convolution of the resolution with the shape of the distribution of the particle level mT, we can check the linearity of our MET, and its angular resolution.





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MET or not MET

- ATLAS adopted different definitions of MET significance
- All based on the assumption that

 σ (MET) is proportional to sqrt(ΣE_T)

 Good assumption for calorimeter based MET (stochastic fluctuations)



MET or not MET

- ATLAS adopted different definitions of MET significance
- All based on the assumption that

 σ (MET) is proportional to sqrt(ΣE_T)

- Good assumption for calorimeter based MET (stochastic fluctuations)
- But $\Sigma E_T(CST)$ and $\Sigma E_T(TST)$





MET or not MET



Events / 10 GeV

10

10

10

Vs = 8 TeV, 20.3 fb⁻¹

Data 2012

Syst. Unc.

Z→µµ

tĒ

٧V



Model dependent limits

- We have seen in these days several analysis using MET to categorise events, or its shape to look for excesses.
- In most of the cases, these are interpreted in some model.
- Model dependent limits are provided, usually for "simplified" models, which can be re-interpreted in others.





ATLAS-CONF-2017-028

A bit more of information

• Attempts to provide limits which are less model dependent.

Limits in bins of MET.



For which other models is this valid?



Range in	$\sigma_{{ m vis},h+{ m DM}}^{ m obs}$	$\sigma^{\exp}_{{ m vis},h+{ m DM}}$	$\mathcal{A} imes arepsilon$
$E_{\rm T}^{\rm miss}/{ m GeV}$	[fb]	[fb]	%
[150, 200)	19.1	$18.3^{+7.2}_{-5.1}$	15
[200, 350)	13.1	$10.5^{+4.1}_{-2.9}$	35
[350, 500)	2.4	$1.7_{-0.5}^{+0.7}$	40
[500,∞)	1.7	$1.8_{-0.5}^{+0.7}$	55

Tested for a wide range of (mZ', mA)

ATLAS-CONF-2017-028

A bit more of information



 10^{2}

10°

10

13 TeV

SR : 0 lepton

b-tea

. 36.1 fb⁻

Z+jets

W+jets

SM Vh

Diboson

tt + single top

1606.05296

Unfolded measurements

- Unfolded measurements can provide very useful information on excluded phase space for searches.
- An example: 7 TeV ATLAS dijet cross section measurement, used to put limits on contact interaction.
- Another example: Butterworth et al. (1606.05296)

CONTUR Category	Rivet/ Inspire ID	Rivet description
ATLAS 7 Jets	ATLAS_2014_11325553 [28]	Measurement of the inclusive jet cross-section
	ATLAS_2014_11268975 [30]	High-mass dijet cross section
	ATLAS_2014_I1326641 [32]	3-jet cross section
	ATLAS_2014_I1307243 [31]	Measurements of jet vetoes and azimuthal decorrelations in dijet events
CMS 7 Jets	CMS_2014_I1298810 [29]	Ratios of jet pT spectra, which relate to the ratios of inclusive, differential jet cross sections
ATLAS 8 Jets	ATLAS_2015_11394679 [34]	Multijets at 8 TeV
ATLAS 7 Z Jets	ATLAS_2013_11230812 [35]	Z + jets
CMS 7 Z Jets	CMS_2015_11310737 [38]	Jet multiplicity and differential cross-sections of $Z{+}\mathrm{jets}$ events
CMS 7 W Jets	CMS_2014_I1303894 [37]	Differential cross-section of W bosons + jets
ATLAS 7 W jets	ATLAS_2014_11319490 [36]	W + jets
ATLAS 7 Photon Jet	ATLAS_2013_11263495 [42]	Inclusive isolated prompt photon analysis with 2011 LHC data
	ATLAS_2012_11093738 [44]	lsolated prompt photon $+$ jet cross-section
CMS 7 Photon Jet	CMS_2014_11266056 [45]	Photon + jets triple differential cross-section
ATLAS 7 Diphoton	ATLAS_2012_11199269 [43]	Inclusive diphoton $+X$ events
ATLAS 7 ZZ	ATLAS 2012 I1203852 [39]	Measurement of the $ZZ(*)$ production cross-section
ATLAS W/Z gamma	ATLAS_2013_11217863 [40]	W/Z gamma production

1606.05296

Unfolded measurements

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Unfolded measurements

- No unfolded measurement of MET distributions
 - Is it doable?
- MET is a complex variable, but we are getting more and more experience and understanding on it
- Is it worth doing it?
 - If yes, what can we measure? SM background with "equivalent" final state? how easy would be to use it?

Conclusions

- A lot of progresses in MET definition since the LHC first collisions
 - (and for the moment we managed to avoid big wrong tails - spoiling our searches and measurements)
- MET used in several different ways, and several different final states, from precision measurements to searches, to removal of hard to model backgrounds.

CMS

- CMS using PFlow objects to build the MET
- PU suppressed
 MET (PUPPI).







CMS

 as far as I understand, these are the resolution, after taking out the "bias"



CMS

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