## **Di-Electron Event**

High Mass Dielectron  $ET_1 = 370 \text{ GeV } ET_2 = 246 \text{ GeV}$  $m_{ee} = 1.8 \text{ TeV}$ 



Run: 280319 Event: 472098394 2015-09-25 16:25:21 CEST Z' to 2e candidate Event

# Search for High Mass W'

ATLAS-CONF-2016-061



- Importance of systematic uncertainty related to MET in the low mass
- Similarly the extrapolation of the efficiencies and the calibration at very high pT is very important: not a low hanging fruit!

# Di-jet Searches Resonant and non resonant search

#### ATLAS-CONF-2016-069



#### **Resonnant search**

Hunt for a bump, if none interpret in terms of limits using specific signal models.

#### Non-resonnant search

Search for distortions of the fijet angular distributions in bins of di-jet mass.

Interpret in terms of limits on Contact interaction.



Limits on CI mass scale of up to 20 TeV

# **Di-jet Searches**

Investigating the intermediate mass range



. Expected limit

2000

1000

Observed limit

3000

m<sub>z</sub>, [GeV]

0.05

300

400

#### (C) ISR with jet ATLAS-CONF-2016-070

Use higher jet activity to reach lower masses using an ISR jet

## Jet Substructure





#### Nominal boson tagging algorithm

- Large R-jet algorithms used to tag hadronic decays of particles such as W, Z, Higgs and the top.
- Algorithms use substructure of jets.
- Pileup subtraction is very important, and a large number algorithms have been developed.
- Overall performance is very impressive!



### Searches for a Resonance in Diboson VV Final States



### **Top Pair Resonance Searches**

Using boosted jets substructure techniques



High mass top pairs are excellent to highlight the performance of top tagging techniues

The large number of top airs produced is very important to validate/calibrate the substructure reconstruction algorithms.

Limits ranging from 2.5 to 3.5 TeV (Depending on the assumed width of the Z')

Possible non-negligible interference signal and background neglected.

## Searches for Vector Like Quarks

- Additional (sequential) 4<sup>th</sup> generation is ruled out by the Higgs couplings.
   Would be significantly changed in case of a 4<sup>th</sup> generation.
- Mass terms for fermions strongly interacting, i.e. Quarks which transform as SU(2)<sub>L</sub> are gauge invariant and therefore do not need to couple to the Higgs.
- Found in many models: Composite Higgs, extra dimensions, little Higgs.
- Complex channels looking for T(2/3), B(1/3): Ht+X, Wt+X, Wb+X, Zb+X, Zt+X (Performed at Run 2) so far and T(5/3) 4tops final state.



Illustration of the reach in complexity of signature with up to 10 jets with 4 b-tags.



#### ATLAS-CONF-2016-020

### Dark Matter Searches

#### Complementarity

Of course ourstanding if seen in a lab!

 $Production \, at \, colliders$ 



co-anihilation



#### LHC more typical scenarios

The gluon below can be replaced by a photon, vector boson, Higgs boson, etc...



### A wealth searches for DM at the LHC:

- Mono-jet
- Mono-V (leptonic and hadronic boosted)
- Mono-Higgs
- Mono-photon
- Mono-top
- VBF invisible
- (invisible Higgs searches in general)

DM Forum benchmarks (LHC Exp. and Theory): http://arxiv.org/pdf/1507.00966.pdf

## The Mono-Jet Search

#### **Selection requirements**

- Trigger in this analysis MET>70 GeV (unprescaled)
- Reconstruction level MET above 250 GeV
- At least one jet of 250 GeV (up to four jets)
- MET should be isolated from the jets

#### Backgrounds

One of the main difficulties is the control of the Z(vv) and W(lv – where the leptons is outside the acceptance)

### Signal region

Excellent dataprediction agreement Main background Z(vv)+jets and W(lv) +jets

### **Control region**

W+jets control region complements a lower statistics Z(II) control region

Analysis will rely on the W/Z ratio at high jet mometum





# Interplay DM and Mediator Searches





## Searches for (RPC) Supersymmetry

... and Additional Higgs bosons

SUSY in a tiny nutshell: too beautiful to be wrong! Solves (almost) everything

- Naturalness
- Unification of couplings
- Dark matter candidate
- Gravity (gauging SUSY) mSUGRA

**Strategy:** Use simplified models to cover the widest possible variety of topologies. (Then more rigorously investigate the MSSM parameter space in the pMSSM, using the available searches.

#### Main searches:

- Gluino and squarks searches in (OL, 1L, 2L, 3L, b-jets, top, etc...)
- 3d generation searches in many channels for stop and sbottom (0L, 1L, 2L, taus, etc...)
- Searches for charginos and neutralinos "EW SUSY searches", in (2L, 3L, 2taus, WZ, WH, etc...)
- Compressed scenarios: search for low pT stuff (soft leptons trigger strategy is important, low pT b's, etc...)



The paradigm scenario (still fully open at the LHC) of O(natural) SUSY

## Strong SUSY Searches (Squarks and gluinos)



- OL with N-jets (from 2 up to 10)
- 1L with N-jets (from 2 to 6)
- 2L, 3L and 4L with jets
- Multiple b-jets or top

Stop also a scalar requires light gluinos to be light enough: for gluinos > 1.8 TeV ~tuning of Factor of 30

Searches focus on corridors, compressed scenarios, or very specific corners of parameter space (pMSSM)

### The 2L (OS-SF) strong production saga



Run 2

## **Stop Searches**



~Tuning of factor 20

## Stop Searches Completing the Picture in Compressed Scenarios



# Stop Searches

Completing the Picture in the pMSSM

### pMSSM Survey

Survey of the 19 MSSM parameters using existing constraints

- 300 k models investigated
- 30 G evts generated
- Signal contamination in background normalization taken into account



Experimental constraints effectively cover the excluded region well in the pMSSM

## Example SUSY 1L Stop Searches

Search done in many categories with different kinematic requirements:

- 1 electron or muon
- 4 jets or more and 1 or 2 b-tags
- Intermediate to large MET and transverse mass
- Several additional kinematic criteria



In ATLAS an excess is seen in two regions with four jets (1b) and intermediate/high MET 260-300 GeV with a p-value of  $3.3\sigma$ 

No excess seen in CMS for similar topology

12.9 fb<sup>-1</sup> (13 TeV

E<sup>miss</sup><sub>T</sub> [GeV]

≥4 iets

 $M^W > 200 \text{ GeV}$ 

T→ t<sup>2</sup> (600 300)

M<sup>W</sup> < 200 GeV

#### Categories are correlated!

# **Electroweak Production**

#### Search for Neutralinos, Charginos and sleptons:

EW production with smaller cross section required a minimum amount of luminosity.

800 <sup>800</sup> 95 و 100 ع Topologies with 1 or 4 leptons (including taus) **ATLAS** Preliminary in the final state and final states with photons Expected limit (±1  $\sigma_{exp}$ ) dt = 13.3 fb<sup>-1</sup>,  $\sqrt{s}$ =13 TeV And typically less jet activity than the strong 3I ATLAS 8 TeV 
$$\begin{split} \widetilde{\chi}_{1}^{\pm} \, \widetilde{\chi}_{2}^{0} &\to \widetilde{I}_{L} \, \nu \, \widetilde{I}_{L} | (\widetilde{\nu} \, \nu), \, | \, \widetilde{\nu} \, \widetilde{I}_{L} | \, (\widetilde{\nu} \, \nu) \\ &\to | \, \nu \, \widetilde{\chi}_{1}^{0} \, | \, | \, (\nu \, \nu) \, \widetilde{\chi}_{1}^{0} \end{split}$$
production. Strong **EWK** 600 WJS2013 100 500 ratios of LHC parton luminosities: 13 TeV / 8 TeV, 7 TeV / 8 TeV 400 gg 10 luminosity ratio Σqq 300 qg 200 400 600 800 200 1000 1200  $m_{\tilde{y}^{\pm}}$  [GeV] MSTW2008NLO 0.1 1000 100 M<sub>v</sub> (GeV)  $\nu/\ell$  $\ell/\nu$ pW  $\tilde{\chi}_1^{\pm}$  $\tilde{\chi}_1^{\pm}$ pp

# Searches for Additional Higgs bosons

MSSM needs fine tuning in order to accommodate the Higgs mass





- Complementarity between Higgs couplings and direct searches
- Complete the low tan beta region important
- Searches in tt resonances also important (Interference, not yet very sensitive)

# Searches for Additional Higgs bosons

MSSM needs fine tuning in order to accommodate the Higgs mass





- Complementarity between Higgs couplings and direct searches
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## **Unconventional Signatures**

### **Typical scenarios**

- Specific SUSY models
- Hidden valley models

### Stopped Gluino Search



### Topologies

- Highly ionizing particles (using dE/dx)
- Out-of-time jets (R-hadrons)
- Highly displaced vertices
- Kinks in tracks
- Disappearing tracks
- High lepton multiplicities

These are very difficult analyses requiring specific non standard reconstruction algorithms.

### Pixel dE/dx search



### **Unconventional Signatures**

Overview of searches Run 2 in perspective: starting to cover ground for searches for LLP



### **Exotics Overview**

**ATLAS** Preliminary

0 10 ToV

#### Summary of searches Run 2 in perspective: very large ground covered still more to come!

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

Status: August 2016

Extra dimensions

Gauge bosons

ы С

LQ DM

Heavy

Excited

Other

Model $I_{yy}$ Jets's         Emb $f_{c}$ du(n-1)         Limit         n=1         n=2         N=1	atus: August 2016							$\int \mathcal{L} dt = (3)$	3.2 - 20.3) fb <sup>-1</sup>	$\sqrt{s} = 8, 13 \text{ TeV}$
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Model	<i>ℓ</i> ,γ	Jets†	$\mathbf{E}_{T}^{miss}$	∫£ dt[fb	-1]	Limit	U U		Reference
UED $1 = \mu_{\mu}^{2} \ge 2h \ge 41$ $q = 32$ Krmss $1.46 \text{ TeV}$ The $(1.1), B(h^{(1,1)} - r_{1} = 1$ ATLAS CONFERENCE           SSM X' $\rightarrow rr$ $2 = \mu$ $-$ 15.5 $2 mas$ $2.02 \text{ TeV}$ $A = 0.5 \text{ TeV}$ $A =$	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 $G_{KK} \rightarrow \ell\ell$ RS1 $G_{KK} \rightarrow \gamma\gamma$ Bulk RS $G_{KK} \rightarrow HH \rightarrow bbbbBulk RS g_{KK} \rightarrow tt$	$ \begin{array}{c} - & 2 e, \mu \\ 1 e, \mu \\ - & - \\ 2 e, \mu \\ 2 \gamma \\ 1 e, \mu \\ - \\ 1 e, \mu \end{array} $	$\geq 1 j$ - 1 j 2 j $\geq 2 j$ $\geq 3 j$ - 1 J 4 b $\geq 1 b, \geq 1 J.$	Yes - - - - - Yes - Yes	3.2 20.3 20.3 15.7 3.2 3.6 20.3 3.2 13.2 13.3 20.3	Mp           Ms           Mth           Mth           Mth           Mth           GKK mass           GKK mass           GKK mass           GKK mass           GKK mass           GKK mass           GKK mass	2.68 Te 3.2 1.24 TeV 360-860 GeV 2.2 TeV	6.58 TeV 4.7 TeV 5.2 TeV 8.7 TeV 8.2 TeV 9.55 TeV V TeV	$\begin{array}{l} n=2 \\ n=3 \; \text{HLZ} \\ n=6 \\ n=6 \\ n=6, \; M_D=3 \; \text{TeV}, \text{ rot BH} \\ n=6, \; M_D=3 \; \text{TeV}, \text{ rot BH} \\ k/\overline{M}_{Pl}=0.1 \\ k/\overline{M}_{Pl}=0.1 \\ k/\overline{M}_{Pl}=1.0 \\ BR=0.925 \end{array}$	1604.07773 1407.2410 1311.2006 ATLAS-CONF-2016-069 1606.02255 1512.02586 1405.4123 1606.03833 ATLAS-CONF-2016-062 ATLAS-CONF-2016-069 1505.07018
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{l} \text{2UED} / \text{RPP} \\ \\ \text{SSM} \ Z' \to \ell\ell \\ \text{SSM} \ Z' \to \tau\tau \\ \text{Leptophobic} \ Z' \to bb \\ \text{SSM} \ W' \to \ell\nu \\ \text{HVT} \ W' \to WZ \to qqq\nu \text{ model} \\ \text{HVT} \ W' \to WZ \to qqqq \text{ model} \\ \text{HVT} \ W' \to WH \ ZH \text{ model} \ B \\ \text{LRSM} \ W'_R \to tb \\ \text{LRSM} \ W'_R \to tb \end{array}$	$1 e, \mu$ $2 e, \mu$ $2 \tau$ $-$ $1 e, \mu$ $A  0 e, \mu$ $B  -$ multi-channet $1 e, \mu$ $0 e, \mu$	$\geq 2 \text{ b}, \geq 4$ - - 2 \text{ b} - 2 J el 2 b, 0-1 j $\geq 1 \text{ b}, 1 \text{ J}$	j Yes – – – Yes Yes – Ves	3.2 13.3 19.5 3.2 13.3 13.2 15.5 3.2 20.3 20.3	KK mass Z' mass Z' mass W' mass W' mass V' mass V' mass W' mass W' mass W' mass	1.46 TeV 2.02 TeV 1.5 TeV 2.4 TeV 3.01 2.31 TeV 1.92 TeV 1.92 TeV	4.05 TeV 4.74 TeV feV	Tier (1,1), BR( $A^{(1,1)} \rightarrow tt$ ) = 1 $g_V = 1$ $g_V = 3$ $g_V = 3$	ATLAS-CONF-2016-013 ATLAS-CONF-2016-045 1502.07177 ATLAS-CONF-2016-061 ATLAS-CONF-2016-082 ATLAS-CONF-2016-055 1607.05621 1410.4103 1408.0886
ZZ $\chi \chi$ EFT (Dirac DM)       0 e, $\mu$ 1 J, $\leq$ Ji       Yes       3.2       M,       550 GeV $m(\chi) < 150 GeV$ ATLAS-CONF-2015-         Scalar LQ 1 <sup>di</sup> gen       2 e $\geq$ 2 j       -       3.2       LQ mass       1.1 TeV $\beta = 1$ 1605.06035         Scalar LQ 3 <sup>rdi</sup> gen       1 e, $\mu$ $\geq$ 1 b, $\geq$ 3 j       Yes       2.0 ass       640 GeV $\beta = 1$ 1605.06035         VLQ TT $\rightarrow$ Ht + X       1 e, $\mu$ $\geq$ 1 b, $\geq$ 3 j       Yes       2.0 ass       640 GeV       Yin (R) yobblet       1505.04735         VLQ TT $\rightarrow$ Ht + X       1 e, $\mu$ $\geq$ 1 b, $\geq$ 3 j       Yes       2.0 ass       Tmass       855 GeV       Yin (R) yobublet       1505.04306         VLQ BB $\rightarrow$ Hb + X       1 e, $\mu$ $\geq$ 4 b       Yes       2.0 ass       Tmass       735 GeV       Yin (R) yobublet       1505.04306       1509.04261       1509.0	Cl qqqq Cl ll qq Cl uutt Axial-vector mediator (Dirac DM) Axial-vector mediator (Dirac DM)	$\begin{array}{c} - \\ 2 \ e, \mu \\ 2(SS) \ge 3 \ e, \mu \\ 0 \ e, \mu \\ 0 \ e, \mu, 1 \ \gamma \end{array}$	$2j$ $-$ $\mu \ge 1 b, \ge 1 j$ $\ge 1 j$ $1 j$	– j Yes Yes Yes	15.7 3.2 20.3 3.2 3.2 3.2	Λ Λ Λ m <sub>A</sub> m <sub>A</sub>	1.0 TeV 710 GeV	4.9 TeV	<b>19.9 TeV</b> $\eta_{LL} = -1$ <b>25.2 TeV</b> $\eta_{LL} = -1$ $ C_{RR}  = 1$ $g_q=0.25, g_\chi=1.0, m(\chi) < 250 \text{ GeV}$ $g_q=0.25, g_\chi=1.0, m(\chi) < 150 \text{ GeV}$	ATLAS-CONF-2016-069 1607.03669 1504.04605 1604.07773 1604.01306
VLQ $TT \rightarrow Ht + X$ 1e, $\mu \geq 2$ b, $\geq 3$ jYes20.3TTTmass855 GeVTin (T,B) doublet1505.04306VLQ $YT \rightarrow Wb + X$ 1e, $\mu \geq 2$ b, $\geq 3$ jYes20.3YYmass770 GeVY'in (B,Y) doublet1505.04306VLQ $BB \rightarrow Zb + X$ 2/25 de, $\mu \geq 2/2$ 1 b-20.3BBmass755 GeVBin (B,Y) doublet1505.04306VLQ $QQ \rightarrow Wq/Wq$ 1e, $\mu \geq 2$ jb-20.3BBmass755 GeVBin (B,Y) doublet1505.04306VLQ $QQ \rightarrow Wq/Wq$ 1e, $\mu \geq 2$ ji5.3Yes20.3GGMass690 GeVH1409.5500VLQ $QQ \rightarrow Wq/Wq$ 1e, $\mu \geq 2$ ji753 mass990 GeV-0n/u and d', $\Lambda = m(q')$ 1512.05910VLQ $TS_{J3} \rightarrow WtWt2(S)/23 e, \mu \geq 1 j, i-3.2q' mass1.51500N/u and d', \Lambda = m(q')N/LAS-CONF-2016-Excited quark b^* \rightarrow dg-11-3.2q' mass1.51.51150.02664N/u and d', \Lambda = m(q')N/LAS-CONF-2016-Excited quark b^* \rightarrow bg-11-2.0b' mass1.51.61411.2211141.2221Excited quark b^* \rightarrow bg20.3A'' mass1.6TeV\Lambda = 1.61407.81501407.8150Excited quark b^* \rightarrow dg-20.3A'' mass570 GeV<$	ZZ <sub>XX</sub> EFT (Dirac DM) Scalar LQ 1 <sup>st</sup> gen Scalar LQ 2 <sup>nd</sup> gen Scalar LQ 3 <sup>rd</sup> gen	0 e, μ 2 e 2 μ 1 e, μ	$1 \text{ J, } \leq 1 \text{ j}$ $\geq 2 \text{ j}$ $\geq 2 \text{ j}$ $\geq 1 \text{ b, } \geq 3 \text{ j}$	Yes – j Yes	3.2 3.2 3.2 20.3	M. LQ mass LQ mass LQ mass	550 GeV 1.1 TeV 1.05 TeV 640 GeV		$m(\chi) < 150 \text{ GeV}$ $\beta = 1$ $\beta = 1$ $\beta = 0$	ATLAS-CONF-2015-080 1605.06035 1605.06035 1508.04735
Excited quark $q^* \rightarrow qq$ 1 $\gamma$ 1 $j$ -3.2 $q^*$ mass4.4 TeVonly $u^*$ and $d^*$ , $\Lambda = m(q^*)$ 1512.05910Excited quark $q^* \rightarrow qg$ -2 $j$ -15.7 $q^*$ mass5.6 TeVonly $u^*$ and $d^*$ , $\Lambda = m(q^*)$ ATLAS-CONF-2016-4Excited quark $b^* \rightarrow bg$ -1 $b$ , $1 j$ -8.8 $b^*$ mass2.3 TeV $f_g = f_L = f_R = 1$ ATLAS-CONF-2016-4Excited lepton $t^*$ $3 e, \mu$ 20.3 $t^*$ mass1.5 TeV $A = 3.0 \text{ TeV}$ $A = 1.6 \text{ TeV}$ ATLAS-CONF-2016-4Excited lepton $t^*$ $3 e, \mu, \tau$ 20.3 $t^*$ mass1.6 TeV $A = 1.6 \text{ TeV}$ 1411.2921LSTC $a_T \rightarrow W\gamma$ $1 e, \mu, 1\gamma$ -Yes20.3 $a_T$ mass960 GeV $M''''''''''''''''''''''''''''''''''''$	$ \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} $	1 <i>e</i> , µ 1 <i>e</i> , µ 2/≥3 <i>e</i> , µ 1 <i>e</i> , µ 2(SS)/≥3 <i>e</i> ,	$ \begin{array}{l} \geq 2  {\rm b}, \geq 3 \\ \geq 1  {\rm b}, \geq 3 \\ \geq 2  {\rm b}, \geq 3 \\ \geq 2/{\geq}1  {\rm b} \\ \geq 4  {\rm j} \\ \mu \geq 1  {\rm b}, \geq 1 \end{array} $	j Yes j Yes j Yes - Yes j Yes	20.3 20.3 20.3 20.3 20.3 3.2	T mass Y mass B mass B mass Q mass T <sub>5/3</sub> mass	855 GeV 770 GeV 735 GeV 755 GeV 690 GeV 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
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Excited quark $q^* \rightarrow q\gamma$ Excited quark $q^* \rightarrow qg$ Excited quark $b^* \rightarrow bg$ Excited quark $b^* \rightarrow Wt$ Excited lepton $\ell^*$ Excited lepton $\nu^*$	1 γ - - 1 or 2 e, μ 3 e, μ 3 e, μ, τ	1 j 2 j 1 b, 1 j 1 b, 2-0 j –	- - Yes -	3.2 15.7 8.8 20.3 20.3 20.3	q* mass       q* mass       b* mass       b* mass       ν* mass	2.3 TeV 1.5 TeV 3.0 T 1.6 TeV	4.4 TeV 5.6 TeV	only $u^*$ and $d^*$ , $\Lambda = m(q^*)$ only $u^*$ and $d^*$ , $\Lambda = m(q^*)$ $f_g = f_L = f_R = 1$ $\Lambda = 3.0$ TeV $\Lambda = 1.6$ TeV	1512.05910 ATLAS-CONF-2016-069 ATLAS-CONF-2016-060 1510.02664 1411.2921 1411.2921
$\gamma_{s} = 8 \text{ lev}$ $\gamma_{s} = 13 \text{ lev}$ $10^{-1}$ 1 10	LSTC $a_T \rightarrow W\gamma$ LRSM Majorana $\nu$ Higgs triplet $H^{\pm\pm} \rightarrow ee$ Higgs triplet $H^{\pm\pm} \rightarrow \ell \tau$ Monotop (non-res prod) Multi-charged particles Magnetic monopoles	$1 e, \mu, 1 \gamma 2 e, \mu 2 e (SS) 3 e, \mu, \tau 1 e, \mu - 5 = 8 TeV$	_ _ _ 1 b _ _ _ _ _	Yes - - Yes - 3 TeV	20.3 20.3 13.9 20.3 20.3 20.3 7.0	aT mass N <sup>6</sup> mass H <sup>±±</sup> mass H <sup>±±</sup> mass spin-1 invisible particle mass multi-charged particle mass monopole mass 	960 GeV 2.0 TeV 570 GeV 00 GeV 657 GeV 785 GeV 1.34 TeV		$m(W_R) = 2.4$ TeV, no mixing DY production, BR( $H_{\pm}^{\pm\pm} \rightarrow ee$ )=1 DY production, BR( $H_{\pm}^{\pm\pm} \rightarrow (\tau)$ =1 $g_{non-res} = 0.2$ DY production, $ g  = 5e$ DY production, $ g  = 1g_D$ , spin 1/2	1407.8150 1506.06020 ATLAS-CONF-2016-051 1411.2921 1410.5404 1504.04188 1509.08059

\*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).

### **SUSY Overview**

ATLAS Preliminary

 $\sqrt{s} = 7, 8, 13 \text{ TeV}$ 

#### Summary of SUSY Run 2 in perspective: very large ground covered still more to come! Main analyses and in compressed scenarios.

ATLAS SUSY Searches\* - 95% CL Lower Limits

Status: August 2016

	Model	$e, \mu, \tau, \gamma$	Jets	Enno	JL d1[fb	-') Mass limit	$\sqrt{s} = 7, 8$	3 TeV $\sqrt{s} = 13$ TeV	Reference
Indusive Searches	$ \begin{array}{l} MSUGRACMSSM \\ \bar{q}; \bar{q} \rightarrow q \bar{\xi}_1^D \\ \bar{q}; \bar{q} \rightarrow q \bar{\xi}_1^D ( \text{compressed} ) \\ \bar{z}; \bar{z} \rightarrow q \bar{\chi}_1^D \\ \bar{z}; \bar{z} \rightarrow q \bar{z}; \bar{z} \rightarrow q \bar{\chi}_1^D \\ \bar{z}; \bar{z} \rightarrow q \bar{z}; \bar{z} \rightarrow q \bar{\chi}_1^D \\ \bar{z}; \bar{z}; \bar{z} \rightarrow q \bar{z}; \bar{z} \rightarrow q \bar{z}; \bar{z}; \bar{z} \rightarrow q \bar{z}; \bar{z}; \bar{z}; \bar{z} \rightarrow \bar{z}; \bar{z}; \bar{z}; \bar{z}; \bar{z}; \bar{z}; \bar{z}; z$	$\begin{array}{c} 0.3 \ e, \mu/1.2 \tau \\ 0 \\ monojet \\ 0 \\ 0 \\ 3 \ e, \mu \\ 2 \ e, \mu \ (SS) \\ 1.2 \ \tau + 0.1 \ i \\ 2 \ \gamma \\ \gamma \\ 2 \ e, \mu \ (Z) \\ 0 \end{array}$	2-10 jets/3 2-6 jets 1-3 jets 2-6 jets 2-6 jets 4 jets 0-3 jets 0-2 jets - 1 b 2 jets 2 jets 2 jets mono-jet	<sup>b</sup> Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 13.3 13.3 13.3 13.2 13.2 3.2 20.3 13.3 20.3 20.3	šīš         608 GeV           šīš         608 GeV           šīš         808 GeV           šīš         8           šīš         8           šīš         8           šīš         8           šīš         8           šīš         8           šīš         900 GeV           Jīš         805 GeV	1.85 TeV .35 TeV 1.80 TeV 1.83 TeV 1.7 TeV 1.7 TeV 2.0 TeV 1.05 TeV 1.37 TeV 1.8 TeV	$\begin{split} & m[i](\mathrm{sm}[g) \\ & m[\xi]) + cp[\xi]) + cp[\mathcal{L}^{d_1}] + cp[\mathcal{L}^{d_2}] + cp[\mathcal{L}^{d_1}] + cp[\mathcal{L}^{d_1}$	1507.05525 ATLAS-CONF-2016-078 1604.07773 ATLAS-CONF-2016-078 ATLAS-CONF-2016-078 ATLAS-CONF-2016-037 ATLAS-CONF-2016-037 1607.05679 1606.00150 1507.05499 ATLAS-CONF-2016-066 1503.03290 1503.03290
3 <sup>rd</sup> gen <u>ğ</u> med.	$\underline{\mathcal{Z}}_{2}^{2}, \underline{\mathcal{Z}} \rightarrow b \overline{b} \overline{k}_{1}^{D}$ $\underline{\mathcal{Z}}_{2}^{2}, \underline{\mathcal{Z}} \rightarrow t \overline{k}_{1}^{D}$ $\underline{\mathcal{Z}}_{2}^{2}, \underline{\mathcal{Z}} \rightarrow b \overline{s} \overline{k}_{1}^{T}$	0 0-1 «.μ 0-1 «.μ	3 b 3 b 3 b	Yes Yes Yes	14.8 14.8 20.1	Ř Ř Ř	1.89 TeV 1.89 TeV 1.37 TeV	$m \tilde{k}_{1}^{0}\rangle=0$ GeV $m \tilde{k}_{1}^{0}\rangle=0$ GeV $m \tilde{k}_{1}^{0} <300$ GeV	ATLAS-CONF-2018-052 ATLAS-CONF-2018-052 1407.0600
3 <sup>rd</sup> gen, squarks direct production	$\begin{array}{l} b_1b_1, b_1 \rightarrow b \hat{k}_1^0 \\ b_1b_1, b_1 \rightarrow c \hat{k}_1^0 \\ \bar{r}_1 \bar{r}_1, \bar{r}_1 \rightarrow b \hat{k}_1^0 \\ \bar{r}_1 \bar{r}_1, \bar{r}_1 \rightarrow b \hat{k}_1^0 \\ \bar{r}_1 \bar{r}_1, \bar{r}_1 \rightarrow b \hat{k}_1^0 \\ \bar{r}_1 \bar{r}_1, \bar{r}_1 \rightarrow c \hat{k}_1^0 \\ \bar{r}_1 \bar{r}_1, \bar{r}_1 \rightarrow c \hat{k}_1^0 \\ \bar{r}_2 \bar{r}_2, \bar{r}_2 \rightarrow \bar{r}_1 + Z \\ \bar{r}_2 \bar{r}_2, \bar{r}_2 \rightarrow \bar{r}_1 + k \end{array}$	0 $2 e, \mu$ (SS) $0.2 e, \mu$ $0.2 e, \mu$ 0 $2 e, \mu(Z)$ $3 e, \mu(Z)$ $1 e, \mu$	2 b 1 b 1-2 b 0-2 jets/1-2 mono-jet 1 b 1 b 6 jets + 2 b	Yes Yes Yes Yes Yes Yes Yes	3.2 13.2 1.7/13.3 1.7/13.3 3.2 20.3 13.3 20.3	k.         940 GeV           j.         325-635 GeV           j17-170 GeV         320-720 GeV           ji         90-323 GeV           ji         320-600 GeV		$\begin{split} m \hat{k}_{1}^{0}  &< 100  \text{GeV} \\ m \hat{k}_{1}^{0}  &< 150  \text{GeV}, m(\hat{k}_{1}^{0}) = 1\pi (\hat{k}_{1}^{0}) + 100  \text{GeV} \\ m \hat{k}_{1}^{0}  &= 2\pi (\hat{k}_{1}^{0}), m \hat{k}_{1}^{0}  = 55  \text{GeV} \\ m \hat{k}_{1}^{0}  &= 16  \text{GeV} \\ m \hat{k}_{1}^{0}  &= 16  \text{GeV} \\ m \hat{k}_{1}^{0}  &= 150  \text{GeV} \\ m \hat{k}_{1}^{0}  &= 150  \text{GeV} \\ m \hat{k}_{1}^{0}  &= 16  \text{GeV} \end{split}$	1606.08772 ATLAS-CONF-2016.037 1209.2102, ATLAS-CONF-2016-077 1506.0846, ATLAS-CONF-2016-077 1604.07773 1403.5222 ATLAS-CONF-2016-038 1506.08616
EW direct	$\begin{array}{l} \tilde{\ell}_{1,\mathbf{R}}\tilde{\ell}_{1,\mathbf{R}},\tilde{\ell} \rightarrow \ell R_1^0\\ \tilde{\kappa}_1^+\tilde{\kappa}_1^-,\tilde{\kappa}_1^+\rightarrow \tilde{\ell}\nu(\ell \bar{\nu})\\ \tilde{\kappa}_1^+\tilde{\kappa}_1^-,\tilde{\kappa}_1^+\rightarrow \tilde{\nu}(\ell \bar{\nu})\\ \tilde{\kappa}_1^+\tilde{\kappa}_2^0\rightarrow \tilde{\kappa}_1^+\tilde{\kappa}_2^+\ell \tilde{\kappa}_1^0\\ \tilde{\kappa}_1^+\tilde{\kappa}_2^0\rightarrow W_1^0\tilde{\kappa}_2^+\tilde{\kappa}_1^0\\ \tilde{\kappa}_1^+\tilde{\kappa}_2^0\rightarrow W_1^0\tilde{\kappa}_1^0\\ \tilde{\kappa}_1^+\tilde{\kappa}_2^0\rightarrow W_1^0\tilde{\kappa}_1^0\\ \tilde{\kappa}_1^+\tilde{\kappa}_2^0\rightarrow \tilde{\kappa}_1^0\\ \tilde{\kappa}_1^+\tilde{\kappa}_2^0\rightarrow \tilde{\kappa}_1^0\\ \tilde{\kappa}_1^+\tilde{\kappa}_2^0\rightarrow \tilde{\kappa}_1^0\\ \tilde{\kappa}_1^+\tilde{\kappa}_1^0\end{pmatrix} \text{weak prod}\\ \text{GGM (bino NLSP) weak prod}\\ \text{GGM (bino NLSP) weak prod} \end{array}$	$2e, \mu$ $2e, \mu$ $2\tau$ $3e, \mu$ $2\cdot 3e, \mu$ $\tau/\gamma\gamma = e, \mu, \gamma$ $4e, \mu$ $1e, \mu + \gamma$ $2\gamma$	0 - 0-2 jets 0-2 k 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           \$\$i_1^*\$         640 GeV           \$\$i_1^*\$         590 GeV           \$\$i_1^*\$, \$\$i_2^*\$         1.0 TeV           \$\$i_1^*\$, \$\$i_2^*\$         425 GeV           \$\$i_1^*\$, \$\$i_2^*\$         270 GeV           \$\$i_{1,3}^*\$         035 GeV           \$\$W\$         115-370 GeV           \$\$W\$         590 GeV	$m[\tilde{x}_{1}^{(2)}]m[$	$\begin{split} & m[\tilde{e}_{1}^{2}] {=} O  GeV \\ & I  GeV,  m(\tilde{e}_{1}^{2}) {=} O  S[m[\tilde{e}_{1}^{2}) {+} m[\tilde{e}_{1}^{2}])) \\ & m[\tilde{e}_{1}^{2}] {=} O  GeV,  m(\tilde{e}_{1}^{2}) {=} S[m[\tilde{e}_{1}^{2}] {+} m[\tilde{e}_{1}^{2}])) \\ & m[\tilde{e}_{1}^{2}] {=} m[\tilde{e}_{1}^{2}] {=} D  S[m[\tilde{e}_{1}^{2}] {+} m[\tilde{e}_{1}^{2}])) \\ & m[\tilde{e}_{1}^{2}] {=} m[\tilde{e}_{1}^{2}] {=} m[\tilde{e}_{1}^{2}] {=} D  S[m[\tilde{e}_{1}^{2}] {+} m[\tilde{e}_{1}^{2}])) \\ & m[\tilde{e}_{1}^{2}] {=} m[\tilde{e}_{1}^{2}] {=} m[\tilde{e}_{1}^{2}] {=} D  S[m[\tilde{e}_{1}^{2}] {+} m[\tilde{e}_{1}^{2}])) \\ & m[\tilde{e}_{1}^{2}] {=} m[\tilde{e}_{1}^{2}] {=} m[\tilde{e}_{1}^{2}] {=} D  S[m[\tilde{e}_{1}^{2}] {+} m[\tilde{e}_{1}^{2}])) \\ & c_{2} < 1  rem \\ & c_{2} < 1  rem \end{split}$	1403 5294 ATLAS-CONF-2018-096 ATLAS-CONF-2018-093 ATLAS-CONF-2018-096 1403 5294, 1402 7029 1501.07110 1501.07110 1405.5086 1507.05493
Long-fived particles	Direct $\xi_1^* \xi_2^*$ prod., long-lived $j$ Direct $\xi_1^* \xi_2^*$ prod., long-lived $j$ Stable, stopped $j$ R-hadron Stable $j$ R-hadron Metastable $j$ R-hadron GMSB, stable $\tau$ , $\xi_1^0 \rightarrow \tau (x, p) + \tau$ GMSB, $\xi_1^0 \rightarrow \gamma \sigma$ , long-lived $\xi_2^0$ $\xi_2^*$ , $\xi_1^0 \rightarrow \nu \gamma (pp)/(pp)/$ GGM $g_2^*$ , $\xi_1^0 \rightarrow Z G$	$ \begin{array}{c} \stackrel{+}{\underset{1}{\overset{1}{\overset{1}{\overset{1}{\overset{1}{\overset{1}{\overset{1}{1$	1 jet - 1-5 jets - - - - μ - ts -	Yes Yes · · Yes ·	20.3 18.4 27.9 3.2 19.1 20.3 20.3 20.3	\$\vec{k}_1^*\$         270 GeV           \$\vec{k}_1^*\$         495 GeV           \$\vec{k}_2^*\$         850 GeV           \$\vec{k}_2^*\$         857 GeV           \$\vec{k}_1^*\$         537 GeV           \$\vec{k}_1^*\$         440 GeV           \$\vec{k}_1^*\$         1.0 TeV           \$\vec{k}_1^*\$         1.0 TeV	1.58 TeV 1.57 TeV	$\begin{split} m(\tilde{\ell}_1^*) &\leftarrow m(\tilde{\ell}_2^*) \sim 160 \; MeV, \; \tau(\tilde{\ell}_1^*) = 0.2 \; n_{\rm B} \\ m(\tilde{\ell}_1^*) &\leftarrow m(\tilde{\ell}_2^*) \sim 160 \; MeV, \; \tau(\tilde{\ell}_1^*) < 15 \; n_{\rm B} \\ m(\tilde{\ell}_2^*) &= 100 \; GeV, \; 10 \; \mu{\rm s} < \tau(\tilde{\varrho}_1^*) < 15 \; n_{\rm B} \\ m(\tilde{\ell}_2^*) &= 100 \; GeV, \; \tau > 10 \; n_{\rm B} \\ 10 \; {\rm ctan}/\tau \leq 50 \\ 1 \; < \pi(\tilde{\ell}_1^*) < < 3n_{\rm B} \; {\rm SPSB} \; {\rm model} \\ 1 \; < \pi(\tilde{\ell}_1^*) < 740 \; {\rm mrn}, \; \tau r(\tilde{\varrho}) = 1.3 \; {\rm TeV} \\ 8 \; < cr(\tilde{\ell}_1^*) < 480 \; {\rm mrn}, \; \tau r(\tilde{\varrho}) = 1.1 \; {\rm TeV} \end{split}$	1310.3675 1506.05332 1310.6584 1606.05129 1604.04520 1411.5735 1409.5542 1504.05162 1504.05162
RPV	$ \begin{array}{l} LFV pp \rightarrow \mathfrak{d}_r + X, \mathfrak{d}_r \rightarrow \mathfrak{spl}(er/p) \\ Binear \; RPV \; CMSSM \\ \mathcal{K}_1^+ \mathcal{K}_1^-, \mathcal{K}_1^+ \rightarrow \mathcal{W}_1^0, \mathcal{K}_2^0 \rightarrow \mathfrak{sev}, \mathfrak{splv}, \\ \mathcal{K}_1^+ \mathcal{K}_1^-, \mathcal{K}_1^+ \rightarrow \mathcal{W}_1^0, \mathcal{K}_1^0 \rightarrow \mathfrak{rrv}_{e,ern} \\ \mathcal{B}_2^-, \mathcal{B}^- \rightarrow \mathcal{H}_2^0, \mathcal{K}_1^0 \rightarrow \mathfrak{q} \mathfrak{q} \mathfrak{q} \\ \mathcal{B}_2^-, \mathcal{B}^- \rightarrow \mathcal{H}_2^0, \mathcal{K}_1^0 \rightarrow \mathfrak{q} \mathfrak{q} \mathfrak{q} \\ \mathcal{B}_2^-, \mathcal{B}^- \mathcal{H}_2^0, \mathcal{K}_1^0 \rightarrow \mathfrak{q} \mathfrak{q} \mathfrak{q} \\ \mathcal{B}_2^-, \mathcal{B}^- \mathcal{H}_2^0, \mathcal{H}_1^- \rightarrow \mathfrak{q} \mathfrak{q} \mathfrak{q} \\ \mathcal{B}_2^-, \mathcal{B}^- \mathcal{H}_2^0, \mathcal{H}_1^- \rightarrow \mathfrak{q} \mathfrak{q} \mathfrak{q} \\ \mathcal{B}_2^-, \mathcal{B}^- \mathcal{H}_2^0, \mathcal{H}_1^- \rightarrow \mathfrak{q} \mathfrak{q} \mathfrak{q} \\ \mathcal{B}_2^-, \mathcal{H}_2^0, \mathcal{H}_1^- \rightarrow \mathfrak{h} \mathfrak{h} \\ \mathcal{H}_2^-, \mathcal{H}_2^0, \mathcal{H}_2^- \rightarrow \mathfrak{H}_2^0 \\ \mathcal{H}_2^-, \mathcal{H}_2^0, \mathcal{H}_2^0, \mathcal{H}_2^0 \end{pmatrix}$	$r = e \mu, e \tau, \mu \tau$ $2 e, \mu$ (SS) $\mu \mu \nu = 4 e, \mu$ r = 0 = 4 0 = 4 $1 e, \mu = 8$ $1 e, \mu = 8$ 0 $2 e, \mu$	-5 large- <i>R</i> je -5 large- <i>R</i> je -10 jets/0-4 -10 jets/0-4 2 jets + 2 <i>b</i> -2 <i>b</i>	· Yes Yes ets · ets ·	3.2 20.3 13.3 20.3 14.8 14.8 14.8 14.8 15.4 20.3	\$.         \$.\$           \$.\$         \$.14 T           \$	1.9 TeV 1.45 TeV eV V 1.55 TeV 1.75 TeV 1.4 TeV	$\begin{split} \lambda_{i11}^{\prime} &= 0.11, \lambda_{i12} + u_{i12} = 0.07 \\ m[g] &= m[g], c_{12,0} < 1 \mbox{ rm} \\ m[k_1^{\prime}] > 400 \mbox{ CeV}, \lambda_{i12} \neq 0 \mbox{ (k-1)}, 2) \\ m[k_1^{\prime}] > 0.2 \times m[k_1^{\prime}], \lambda_{i12} \neq 0 \\ B(\phi) = B[(\phi) = B[(\phi) = B[(\phi) = B[(\phi) = B(\phi) = B(\phi) = B(\phi) = B(\phi) = B(\phi) \\ m[k_1^{\prime}] &= 200 \mbox{ GeV} \\ m[k_1^{\prime}] &= 200 \mbox{ GeV} \\ B25 \mbox{ GeV} < m(\beta_1) < 850 \mbox{ GeV} \\ BB((\beta_1 \to \phi/\mu) > 20\% \end{split}$	1607.08079 1404.2500 ATLAS-CONF-2018-075 1405.5086 ATLAS-CONF-2018-057 ATLAS-CONF-2018-057 ATLAS-CONF-2018-094 ATLAS-CONF-2018-094 ATLAS-CONF-2018-094 ATLAS-CONF-2018-024 ATLAS-CONF-2018-025
Other	Scalar charm, $\tilde{c} \rightarrow \tilde{\mathcal{K}}_{1}^{O}$	0	2 c	Yes	20.3	2 510 GeV		$m[\tilde{\ell}_1^0] < 200  GeV$	1501.01325
	*Only a selection of th	e available m	ass limits	s on ne	<sup>nv</sup> 1	D <sup>-1</sup>	1	Mass scale [TeV]	-

states or phenomena is shown.

# Mini Searches Summary

### No significant excess has been observed so far

### Non significant excesses to keep an eye on:

- CONF-050 Stops 1L: In (4J, 1b, high MET)  $3.3\sigma$  (No excess in CMS)
- CONF-083: V(W)H (Full hadronic boosted):  $3.5\sigma$  ( $2.5\sigma$  global) at 3 TeV
- CONF-084: Paired dijet local 2.6 $\sigma$  (2.1  $\sigma$  global) at 870 GeV
- CONF-079: Four leptons high mass 2.9 $\sigma$  (1.9  $\sigma$  global) at 705 GeV
- CONF-058: ttH ML in SS-0 $\tau$  and SS-1 $\tau$  not significant but excesses at Run-1 in ATLAS and CMS
- EXO-16-015 PAS  $\gamma$ -jet high mass 3.7 $\sigma$  (2.8  $\sigma$  global) at ~2 TeV (not seen in ATLAS with similar luminosity JHEP03 (2016) 041)
- LFV Higgs decays to  $\tau\nu$

# Summary and Conclusions (I)

- The LHC has been extremely successful at Run 1 (both in machine performance and in results of fundamental importance).
- Measurements performed so far are in agreement with the SM and therefore do not yield indications for new physics beyond the SM.
- With the higher centre-of-mass energy, the outstanding results expected from the Run 2 are the direct searches for new physics. The strategy is to look exhaustively at all possible scenarios and topologies.
- The LHC is now half way through the Run-2, with approximately 1/4 of the data expected for the entire Run 2 (reappraised goal of 150 fb<sup>-1</sup>).
- Approximately 1/3 of the available luminosity at high energy, has been analyzed so far. A good fraction but by far not all searches foreseen have already been performed. No significant sign of new physics was found.
- This dataset is just a small fraction of the Run 2 dataset (~10%) and very small fraction of the total HL-LHC dataset (~1%). This is just the beginning and there are any more exciting challenges ahead!

# Summary and Conclusions (II)

- Meanwhile and in preparation for the more difficult search cases, important SM, Higgs, and top measurements are being prepared at Run 2.
- Milestone measurements with the 7 TeV Run 1 data taken in 2011 are just being presented



- These successes are those of the entire community with the tremendous progress from the Theory. The challenges of LHC physics also rely on the entire community!

