SEARCH FOR PHYSICS BEYOND THE STANDARD MODEL WITH THE ATLAS DETECTOR

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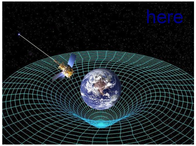
STATUS OF THE STANDARD MODEL (SM)

SM provides a mathematical description of all known particles and their interaction

- All SM cross sections of all SM heavy particles and their combination are measured
- Higgs boson discovered at the LHC in July 2012 (see Alain's talk for more details)

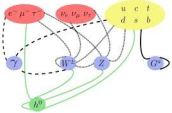
However, several experimental and theoretical problems exist with the SM:

no gravity

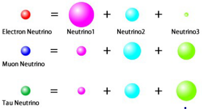


number of generations

number of bosons



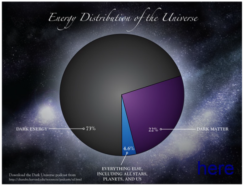
neutrinos



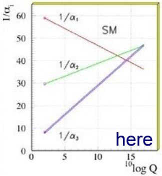
here

Matter–antimatter asymmetry

dark energy **dark matter**



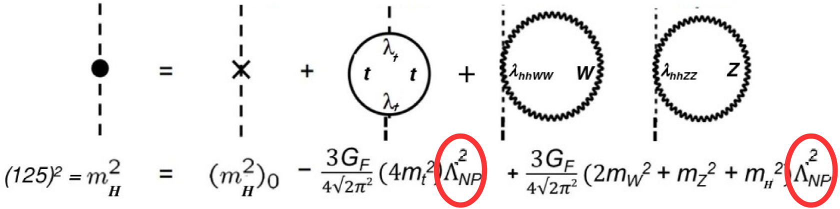
grand unification ?



THE GAUGE HIERARCHY PROBLEM

Gauge hierarchy problem in the Standard Model:

- Higgs boson couples to all massive particles → EW scale – Planck scale → large quantum correction



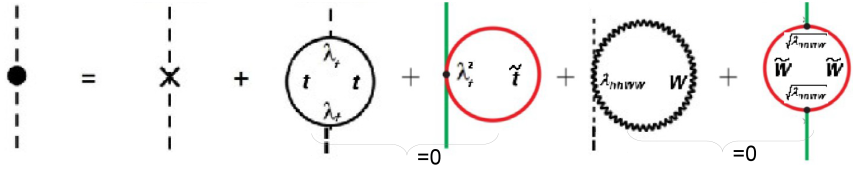
$$(125)^2 = m_H^2 = (m_H^2)_0 - \frac{3G_F}{4\sqrt{2}\pi^2}(4m_t^2)\Lambda_{NP}^2 + \frac{3G_F}{4\sqrt{2}\pi^2}(2m_W^2 + m_Z^2 + m_H^2)\Lambda_{NP}^2$$

- Large fine-tuning ($\sim 10^{17}$) required to accommodate the Higgs boson mass (125 GeV)

SUPERSYMMETRY

Supersymmetry (SUSY) can solve the gauge hierarchy problem:

- SM boson ↔ new fermion; SM fermion ↔ new scalar



$$m_h^2 = (m_h^2)_0 \underbrace{- \frac{3G_F}{4\sqrt{2}\pi^2}(4m_t^2)\Lambda_{NP}^2 + \frac{3G_F}{4\sqrt{2}\pi^2}(4m\tilde{t}^2)\Lambda_{NP}^2}_{}$$

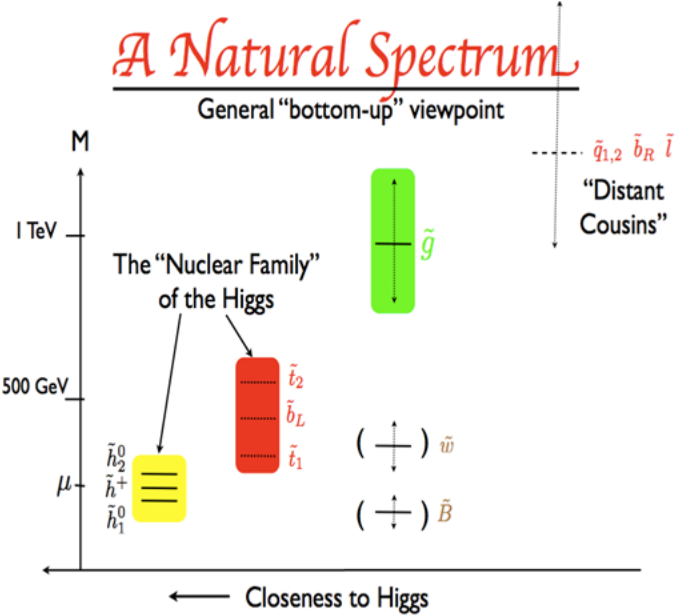
$$+ \frac{3G_F}{\sqrt{2}\pi^2}(m_t^2 - m\tilde{t}^2)\ln(\Lambda_{NP}/m_h) + \ldots.$$

$\lambda = \sqrt{2}m_t / v$

$\sqrt{2}G_F = v^2$

- The SM (positive) and SUSY (negative) corrections cancel exactly : SUSY broken!

A NATURAL SUSY SPECTRUM



OTHER BSM THEORIES

Other Beyond the Standard Model (BSM) theories:

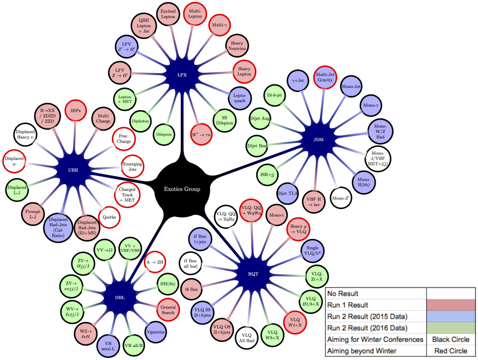
- Vector like quarks: hypothetical 1/2 spin colored particles (left- and right-handed states have the same coupling)

- Large extra dimensions: $\Lambda_{NP} \rightarrow$ scale of new space-time structure/quantum gravity
- New strong Dynamics: $\Lambda_{NP} \rightarrow$ new strong coupling scale, composite Higgs

→ Experimental signature: new particles with a mass close to Λ_{NP}

Can expect several types of final states, including or not:

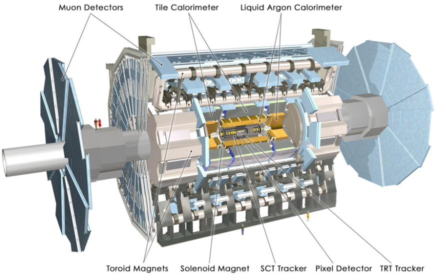
- Leptons & photons
- Hadrons (resolved or boosted)
- Di-boson resonances
- Missing transverse energy

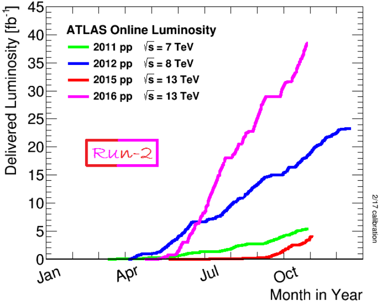


ATLAS DATA

Search for BSM physics with the ATLAS detector using Run-2 (13 TeV) data:

- Corresponding to an integrated luminosity of $\sim$36 fb^{-1}





- Results from ATLAS Supersymmetry Public Results and Exotics Public Results
- Focus on analyses obtained with full 2015 and 2016 data-sets
  (& with lot of contributions from Canadian researchers)

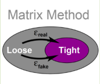
ATLAS STRATEGY TO SEARCH FOR BSM PHYSICS

SM backgrounds
tt / t, tt + Z/W,
di-bosons, V+jets, multi-jets
estimation

Main prompt SM backgrounds: semi – data driven
– using control regions (CRs) kinematically close to SRs → to min. syst. due to SR-CR extrapolation
– estimate the bkg in the signal regions (SRs) relying on MC shape using transfer factors

Minor prompt SM backgrounds: purely MC

Detector background (fakes): fully data – driven
– Using a matrix method
– Jet smearing
– Templates



Check bkg estimate in validation regions (close to SRs)

Look in signal regions → is there any excess?

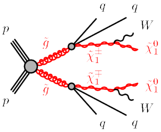
IF NOT

Set model dependent / independent exclusion limits
– cut & count
– or combined fit using CL_S formalism
(using mainly simplified BSM models)

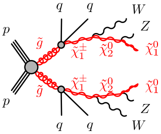
SUSY (SIMPLIFIED) MODELS

Search for SUSY with SRs optimized to maximize the sensitivity to a large # of signal models:

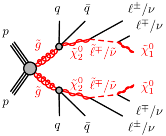
- Final states with 0→4/5 leptons, many (b-) jets, low or high E_T^{miss} (& $\tilde{\chi}_1^0$, the LSP)



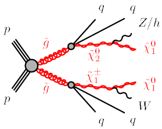
(b) 2-step



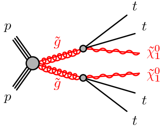
(c) 2-step



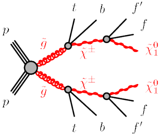
(d) sleptons



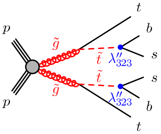
(e) 1-step



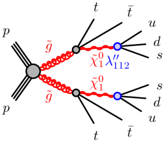
(f) gtt



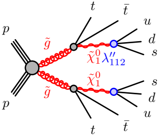
(g) gtb



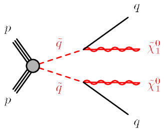
(h) Baryon-nr violating



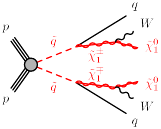
(i) Baryon-nr violating



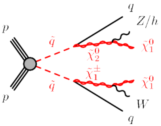
(j) Lepton-nr violating



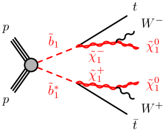
(k) sqsq



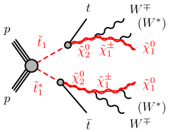
(l) sqsq



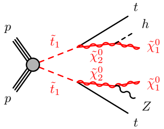
(m) sqsq



(n) sbsb



(o) stst

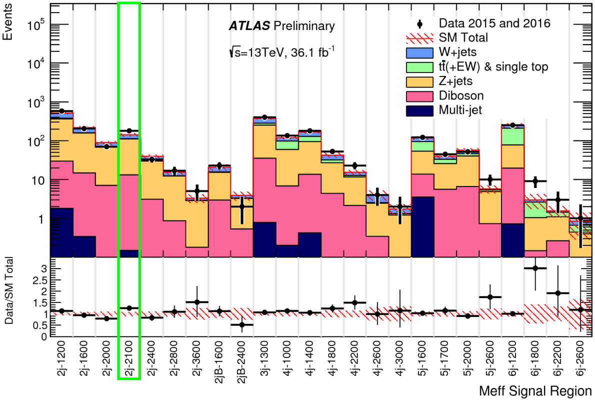


(p) stst

Search for SUSY with multi-jets final states

Final states with 0-leptons and 2→6 jets, CONF-2017-022 or 7→11 jets, CONF-2017-033

- Key variables: N_{jets}, m_{eff} or H_T, E_T^{miss}, $\Delta\Phi(\mathrm{jet}_{1,2,(3)}, E_T^{miss})_{\min} > 0.2 \rightarrow 0.8$, etc.
- Main backgrounds: W/Z+jets, $t\bar{t}$, single top, di-boson and multi-jets processes
  - Estimation using dedicated CRs, but for di-boson processes (MC simulations)

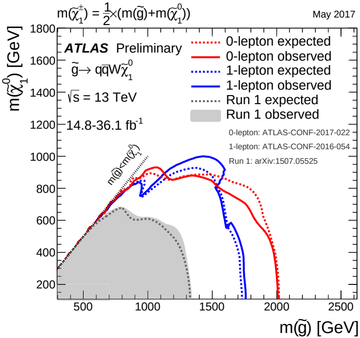


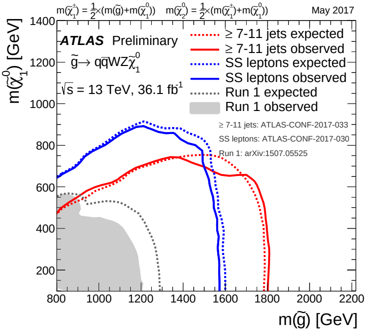
- Most significant excesses: Meff-2j-2100 (a significance of 2.14 standard deviations)

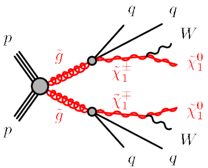
EXCLUSION LIMITS (1-STEP & 2-STEP DECAYS)

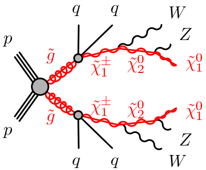
No significant excess → place limits on sparticles masses using simplified SUSY models:

- Limits obtained also with other final states (blue) → complementary of the ATLAS searches





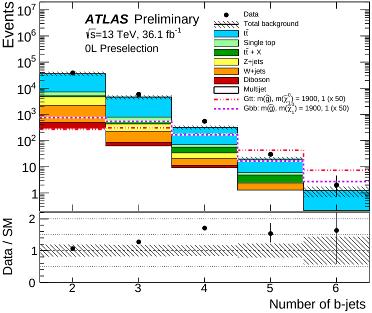


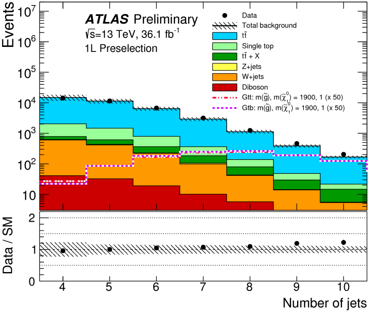


FINAL STATES WITH MULTI-b JETS

Search for SUSY with 0 or 1 lepton and ≥ 3 b-jets, ATLAS-CONF-2017-021

- Discovery strategy: cut-and-count SRs targeting compressed, intermediate and boosted reg.
- Exclusion strategy: multi-bin fit across binned orthogonal SRs in N_j and m_{eff}
- Key variables: nr. of leptons and (b-)jets, E_T^{miss}, m_{eff}, m_T, M_J^{Σ}, $\Delta\Phi(\text{jet}_{1\to 4}, E_T^{miss})_{\min}$, etc



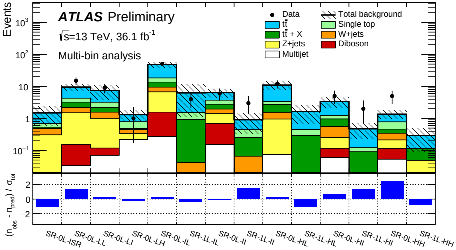


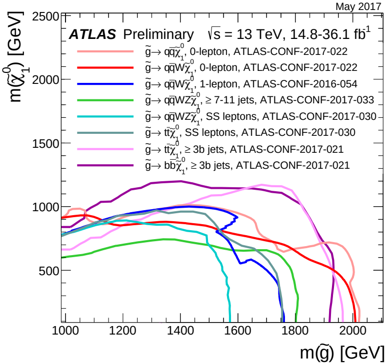
- Dominant background: $t\bar{t}$ pairs with additional high p_T jets
- $t\bar{t}$ MC simulations normalized in an 1-lepton CR and extrapolated to VRs and SRs

FINAL STATES WITH MULTI-b JETS

Results in the signal regions:

- No significant excess found above the predicted background in the SRs



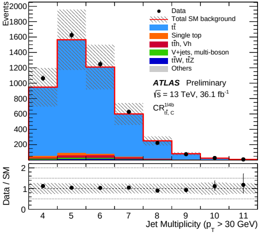


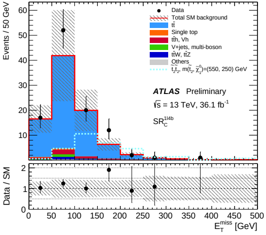
- Gluino masses excluded up to 1.9 TeV → strongest limits among all ATLAS searches

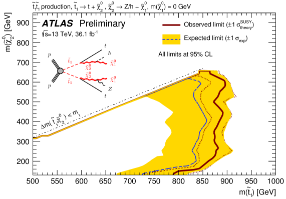
DIRECT TOP SQUARK SEARCHES

Search for direct top squarks production in events with a Z or Higgs boson, CONF-2017-019

- SRs with at least three leptons plus a b-jet (top squark decays via Z bosons)
  - Bkgs: $t\bar{t}Z$, di-boson and “fake”/non-prompt leptons
  - Dominant source of uncertainty: limited statistics
- SRs with one or two leptons and at least four b-jets (top squark decays via Higgs bosons)
  - Bkgs: $t\bar{t}$ pair production (>80%)
  - Dominant source of uncertainty: $t\bar{t}$ bkg modeling





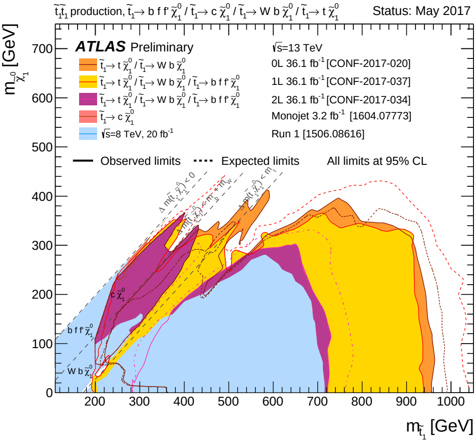


- No significant excess in any of the signal regions
- Top squarks masses excluded up to about 800 GeV

DIRECT TOP SQUARK SEARCHES

Summary of the dedicated ATLAS searches for top squark (stop) pair production

- Several top squark decay modes considered

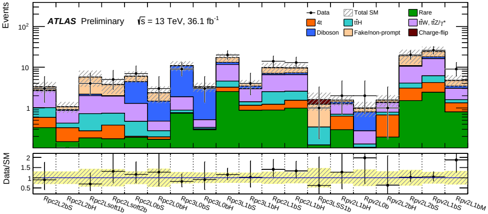


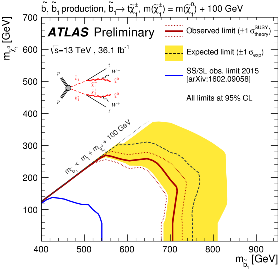
- Top squark masses excluded up to 950 GeV

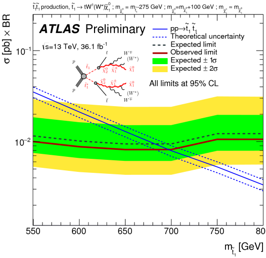
MULTI-LEPTONS SEARCHES

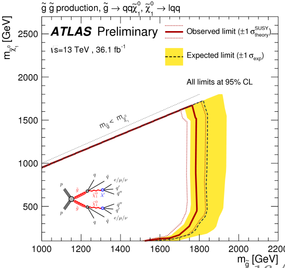
Several multi-ℓ searches available: opposite/same-charge or three leptons, CONF-2017-030

- Same-charge (SS) final states: electron charge flips and fake leptons non-negligible bkgs
- Several signal regions defined with SS or three leptons, (b-)jets, m_{eff} and E_T^{miss}
- One signal region with three leptons of same electric charge (Rpc3LSS1b)





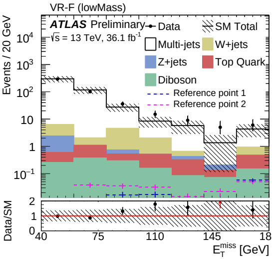


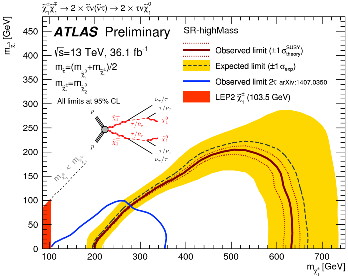


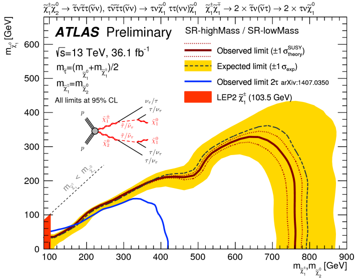
ELECTROWEAK SEARCHES

Direct searches for charginos and neutralinos in events with two or more leptons (link)

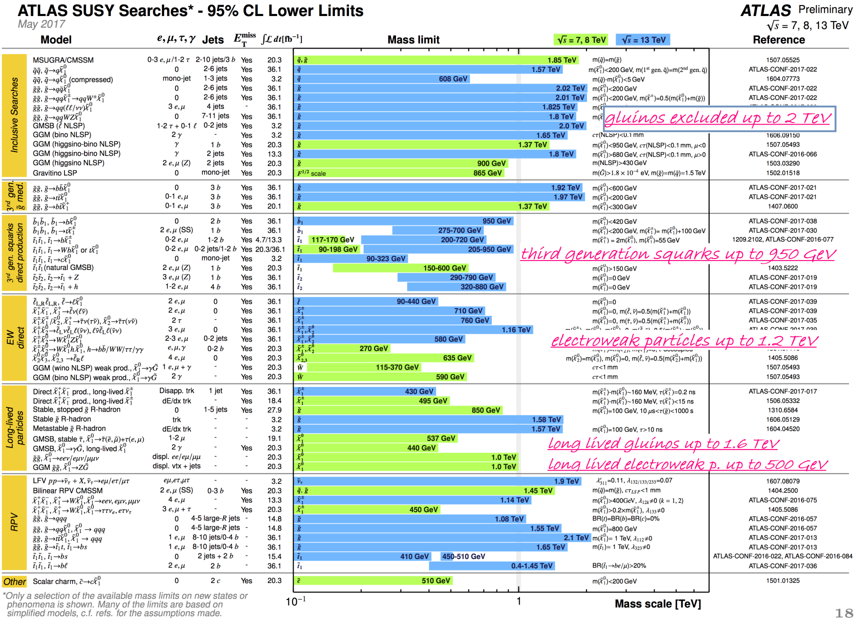
- Here focus on final states with ≥ 2 opposite-charge hadronic taus (CONF-2017-035)
- No *b*-jets or a tau lepton pair compatible with the Z boson mass
- Key variables: max transverse mass of the taus (min 70 GeV) and E_T^{miss} (min 110 GeV)
- Main bkgs: multi-jets, W+jets, di-bosons ("fake" or "real" tau candidates)







SUSY SUMMARY PLOT



ATLAS SUSY Searches* - 95% CL Lower Limits

May 2017

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

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

	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int \mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde q, \tilde g$ 1.85 TeV	$m(\tilde q)=m(\tilde g)$	1507.05525
	$\tilde q \tilde q$, $\tilde q \to q \tilde\chi_1^0$	0	2-6 jets	Yes	36.1	$\tilde q$ 1.57 TeV	$m(\tilde\chi_1^0)<200$ GeV, m(1st gen. $\tilde q$)=m(2nd gen. $\tilde q$)	ATLAS-CONF-2017-022
	$\tilde q \tilde q$, $\tilde q \to q \tilde\chi_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde q$ 608 GeV	$m(\tilde q)-m(\tilde\chi_1^0)<5$ GeV	1604.07773
	$\tilde g \tilde g$, $\tilde g \to q\bar q \tilde\chi_1^0$	0	2-6 jets	Yes	36.1	$\tilde g$ 2.02 TeV	$m(\tilde\chi_1^0)<200$ GeV	ATLAS-CONF-2017-022
	$\tilde g \tilde g$, $\tilde g \to qq\tilde\chi_1^\pm \to qqW^\pm\tilde\chi_1^0$	0	2-6 jets	Yes	36.1	$\tilde g$ 2.01 TeV	$m(\tilde\chi_1^0)<200$ GeV, $m(\tilde\chi^\pm)=0.5(m(\tilde\chi_1^0)+m(\tilde g))$	ATLAS-CONF-2017-022
	$\tilde g \tilde g$, $\tilde g \to qq(\ell\ell/\nu\nu)\tilde\chi_1^0$	3 e,μ	4 jets	-	36.1	$\tilde g$ 1.825 TeV	[illegible]	[illegible]
	$\tilde g \tilde g$, $\tilde g \to qqWZ\tilde\chi_1^0$	0	7-11 jets	Yes	36.1	$\tilde g$ 1.8 TeV	[illegible]	[illegible]
	GMSB ($\tilde\ell$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	$\tilde g$ 2.0 TeV	[illegible]	[illegible]
	GGM (bino NLSP)	2 γ	-	Yes	3.2	$\tilde g$ 1.65 TeV	$c\tau$(NLSP)<0.1 mm	1606.09150
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde g$ 1.37 TeV	$m(\tilde\chi_1^0)<950$ GeV, $c\tau$(NLSP)<0.1 mm, $\mu<0$	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	13.3	$\tilde g$ 1.8 TeV	$m(\tilde\chi_1^0)>680$ GeV, $c\tau$(NLSP)<0.1 mm, $\mu>0$	ATLAS-CONF-2016-066
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde g$ 900 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	$m(\tilde G)>1.8\times10^{-4}$ eV, $m(\tilde g)=m(\tilde q)=1.5$ TeV	1502.01518
3rd gen. $\tilde g$ med.	$\tilde g \tilde g$, $\tilde g \to b\bar b \tilde\chi_1^0$	0	3 b	Yes	36.1	$\tilde g$ 1.92 TeV	$m(\tilde\chi_1^0)<600$ GeV	ATLAS-CONF-2017-021
	$\tilde g \tilde g$, $\tilde g \to t\bar t \tilde\chi_1^0$	0-1 e,μ	3 b	Yes	36.1	$\tilde g$ 1.97 TeV	$m(\tilde\chi_1^0)<200$ GeV	ATLAS-CONF-2017-021
	$\tilde g \tilde g$, $\tilde g \to b\bar t \tilde\chi_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde g$ 1.37 TeV	$m(\tilde\chi_1^0)<300$ GeV	1407.0600
3rd gen. squarks direct production	$\tilde b_1 \tilde b_1$, $\tilde b_1 \to b\tilde\chi_1^0$	0	2 b	Yes	36.1	$\tilde b_1$ 950 GeV	$m(\tilde\chi_1^0)<420$ GeV	ATLAS-CONF-2017-038
	$\tilde b_1 \tilde b_1$, $\tilde b_1 \to t\tilde\chi_1^\pm$	2 e,μ (SS)	1 b	Yes	36.1	$\tilde b_1$ 275-700 GeV	$m(\tilde\chi_1^0)<200$ GeV, $m(\tilde\chi_1^\pm)=m(\tilde\chi_1^0)+100$ GeV	ATLAS-CONF-2017-030
	$\tilde t_1 \tilde t_1$, $\tilde t_1 \to b\tilde\chi_1^\pm$	0-2 e,μ	1-2 b	Yes	4.7/13.3	$\tilde t_1$ 117-170 GeV 200-720 GeV	$m(\tilde\chi_1^\pm)=2m(\tilde\chi_1^0)$, $m(\tilde\chi_1^0)=55$ GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde t_1 \tilde t_1$, $\tilde t_1 \to Wb\tilde\chi_1^0$ or $t\tilde\chi_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3/36.1	$\tilde t_1$ 90-198 GeV 205-950 GeV	[illegible]	[illegible]
	$\tilde t_1 \tilde t_1$, $\tilde t_1 \to c\tilde\chi_1^0$	0	mono-jet	Yes	3.2	$\tilde t_1$ 90-323 GeV	[illegible]	[illegible]
	$\tilde t_1 \tilde t_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde t_1$ 150-600 GeV	$m(\tilde\chi_1^0)>150$ GeV	1403.5222
	$\tilde t_2 \tilde t_2$, $\tilde t_2 \to \tilde t_1 + Z$	3 e,μ (Z)	1 b	Yes	36.1	$\tilde t_2$ 290-790 GeV	$m(\tilde\chi_1^0)=0$ GeV	ATLAS-CONF-2017-019
	$\tilde t_2 \tilde t_2$, $\tilde t_2 \to \tilde t_1 + h$	1-2 e,μ	4 b	Yes	36.1	$\tilde t_2$ 320-880 GeV	$m(\tilde\chi_1^0)=0$ GeV	ATLAS-CONF-2017-019
EW direct	$\tilde\ell_{L,R}\tilde\ell_{L,R}$, $\tilde\ell \to \ell\tilde\chi_1^0$	2 e,μ	0	Yes	36.1	$\tilde\ell$ 90-440 GeV	$m(\tilde\chi_1^0)=0$	ATLAS-CONF-2017-039
	$\tilde\chi_1^+\tilde\chi_1^-$, $\tilde\chi_1^+ \to \tilde\ell\nu(\ell\tilde\nu)$	2 e,μ	0	Yes	36.1	$\tilde\chi_1^\pm$ 710 GeV	$m(\tilde\chi_1^0)=0$, $m(\tilde\ell,\tilde\nu)=0.5(m(\tilde\chi_1^\pm)+m(\tilde\chi_1^0))$	ATLAS-CONF-2017-039
	$\tilde\chi_1^\pm\tilde\chi_1^\mp/\tilde\chi_2^0$, $\tilde\chi_1^+ \to \tilde\tau\nu(\tau\tilde\nu)$, $\tilde\chi_2^0 \to \tilde\tau\tau(\nu\tilde\nu)$	2 τ	-	Yes	36.1	$\tilde\chi_1^\pm$ 760 GeV	$m(\tilde\chi_1^0)=0$, $m(\tilde\tau,\tilde\nu)=0.5(m(\tilde\chi_1^\pm)+m(\tilde\chi_1^0))$	ATLAS-CONF-2017-035
	$\tilde\chi_1^\pm\tilde\chi_2^0 \to \tilde\ell_L\nu\tilde\ell_L\ell(\tilde\nu\nu)$, $\ell\tilde\nu\tilde\ell_L\ell(\tilde\nu\nu)$	3 e,μ	0	Yes	36.1	$\tilde\chi_1^\pm,\tilde\chi_2^0$ 1.16 TeV	[illegible]	[illegible]
	$\tilde\chi_1^\pm\tilde\chi_2^0 \to W\tilde\chi_1^0 Z\tilde\chi_1^0$	2-3 e,μ	0-2 jets	Yes	36.1	$\tilde\chi_1^\pm,\tilde\chi_2^0$ 580 GeV	[illegible]	[illegible]
	$\tilde\chi_1^\pm\tilde\chi_2^0 \to W\tilde\chi_1^0 h\tilde\chi_1^0$, $h \to b\bar b/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde\chi_1^\pm,\tilde\chi_2^0$ 270 GeV	[illegible]	[illegible]
	$\tilde\chi_2^0\tilde\chi_3^0$, $\tilde\chi_{2,3}^0 \to \tilde\ell_R\ell$	4 e,μ	0	Yes	20.3	$\tilde\chi_{2,3}^0$ 635 GeV	$m(\tilde\chi_2^0)=m(\tilde\chi_3^0)$, $m(\tilde\chi_1^0)=0$, $m(\tilde\ell,\tilde\nu)=0.5(m(\tilde\chi_2^0)+m(\tilde\chi_1^0))$	1405.5086
	GGM (wino NLSP) weak prod., $\tilde\chi_1^0 \to \gamma\tilde G$	1 $e,\mu + \gamma$	-	Yes	20.3	$\tilde W$ 115-370 GeV	$c\tau<1$ mm	1507.05493
	GGM (bino NLSP) weak prod., $\tilde\chi_1^0 \to \gamma\tilde G$	2 γ	-	Yes	20.3	$\tilde W$ 590 GeV	$c\tau<1$ mm	1507.05493
Long-lived particles	Direct $\tilde\chi_1^+\tilde\chi_1^-$ prod., long-lived $\tilde\chi_1^\pm$	Disapp. trk	1 jet	Yes	36.1	$\tilde\chi_1^\pm$ 430 GeV	$m(\tilde\chi_1^\pm)-m(\tilde\chi_1^0)\sim160$ MeV, $\tau(\tilde\chi_1^\pm)=0.2$ ns	ATLAS-CONF-2017-017
	Direct $\tilde\chi_1^+\tilde\chi_1^-$ prod., long-lived $\tilde\chi_1^\pm$	dE/dx trk	-	Yes	18.4	$\tilde\chi_1^\pm$ 495 GeV	$m(\tilde\chi_1^\pm)-m(\tilde\chi_1^0)\sim160$ MeV, $\tau(\tilde\chi_1^\pm)<15$ ns	1506.05332
	Stable, stopped $\tilde g$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde g$ 850 GeV	$m(\tilde\chi_1^0)=100$ GeV, 10 μs<$\tau(\tilde g)$<1000 s	1310.6584
	Stable $\tilde g$ R-hadron	trk	-	-	3.2	$\tilde g$ 1.58 TeV		1606.05129
	Metastable $\tilde g$ R-hadron	dE/dx trk	-	-	3.2	$\tilde g$ 1.57 TeV	$m(\tilde\chi_1^0)=100$ GeV, $\tau>10$ ns	1604.04520
	GMSB, stable $\tilde\tau$, $\tilde\chi_1^0 \to \tilde\tau(\tilde e,\tilde\mu)+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde\chi_1^0$ 537 GeV		
	GMSB, $\tilde\chi_1^0 \to \gamma\tilde G$, long-lived $\tilde\chi_1^0$	2 γ	-	Yes	20.3	$\tilde\chi_1^0$ 440 GeV		
	$\tilde g\tilde g$, $\tilde\chi_1^0 \to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde\chi_1^0$ 1.0 TeV		
	GGM $\tilde g\tilde g$, $\tilde\chi_1^0 \to Z\tilde G$	displ. vtx + jets	-	-	20.3	$\tilde\chi_1^0$ 1.0 TeV		
RPV	LFV $pp \to \tilde\nu_\tau + X$, $\tilde\nu_\tau \to e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	3.2	$\tilde\nu_\tau$ 1.9 TeV	$\lambda'_{311}=0.11$, $\lambda_{132/133/233}=0.07$	1607.08079
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde q, \tilde g$ 1.45 TeV	$m(\tilde q)=m(\tilde g)$, $c\tau_{LSP}<1$ mm	1404.2500
	$\tilde\chi_1^+\tilde\chi_1^-$, $\tilde\chi_1^+ \to W\tilde\chi_1^0$, $\tilde\chi_1^0 \to ee\nu, e\mu\nu, \mu\mu\nu$	4 e,μ	-	Yes	13.3	$\tilde\chi_1^\pm$ 1.14 TeV	$m(\tilde\chi_1^0)>400$GeV, $\lambda_{12k}\neq0$ ($k=1,2$)	ATLAS-CONF-2016-075
	$\tilde\chi_1^+\tilde\chi_1^-$, $\tilde\chi_1^+ \to W\tilde\chi_1^0$, $\tilde\chi_1^0 \to \tau\tau\nu_e, e\tau\nu_\tau$	3 $e,\mu + \tau$	-	Yes	20.3	$\tilde\chi_1^\pm$ 450 GeV	$m(\tilde\chi_1^0)>0.2\times m(\tilde\chi_1^\pm)$, $\lambda_{133}\neq0$	1405.5086
	$\tilde g\tilde g$, $\tilde g \to qqq$	0	4-5 large-R jets	-	14.8	$\tilde g$ 1.08 TeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2016-057
	$\tilde g\tilde g$, $\tilde g \to qq\tilde\chi_1^0$, $\tilde\chi_1^0 \to qqq$	0	4-5 large-R jets	-	14.8	$\tilde g$ 1.55 TeV	$m(\tilde\chi_1^0)=800$ GeV	ATLAS-CONF-2016-057
	$\tilde g\tilde g$, $\tilde g \to t\bar t\tilde\chi_1^0$, $\tilde\chi_1^0 \to qqq$	1 e,μ	8-10 jets/0-4 b	-	36.1	$\tilde g$ 2.1 TeV	$m(\tilde\chi_1^0)=1$ TeV, $\lambda_{112}\neq0$	ATLAS-CONF-2017-013
	$\tilde g\tilde g$, $\tilde g \to \tilde t_1 t$, $\tilde t_1 \to bs$	1 e,μ	8-10 jets/0-4 b	-	36.1	$\tilde g$ 1.65 TeV	$m(\tilde t_1)=1$ TeV, $\lambda_{323}\neq0$	ATLAS-CONF-2017-013
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to bs$	0	2 jets + 2 b	-	15.4	$\tilde t_1$ 410 GeV 450-510 GeV		ATLAS-CONF-2016-022, ATLAS-CONF-2016-084
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to b\ell$	2 e,μ	2 b	-	36.1	$\tilde t_1$ 0.4-1.45 TeV	BR($\tilde t_1 \to be/\mu$)>20%	ATLAS-CONF-2017-036
Other	Scalar charm, $\tilde c \to c\tilde\chi_1^0$	0	2 c	Yes	20.3	$\tilde c$ 510 GeV	$m(\tilde\chi_1^0)<200$ GeV	1501.01325

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

gluinos excluded up to 2 TeV

third generation squarks up to 950 GeV

electroweak particles up to 1.2 TeV

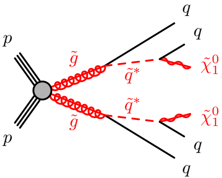
long lived gluinos up to 1.6 TeV

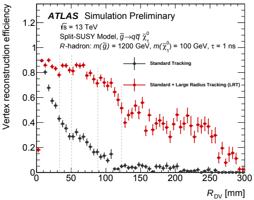
long lived electroweak p. up to 500 GeV

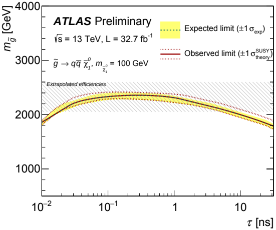
Long lived particles (LLP)

LLP final states: LLP arise from small couplings, heavy mediators, etc.

- Unique signature (lifetimes in the pico to nanoseconds range), usually negligible SM bkg
- Metastable: displaced vertices, DV O(1-10 mm) or disappearing tracks O(1-100 mm)
    - DV, CONF-2017-026: $\geq$ 1 DV with high mass and high nr. of tracks ($\geq$ 5) and E_T^{miss}
    - Bkg: hadronic interaction (material veto) and accidental crossing (dominant)





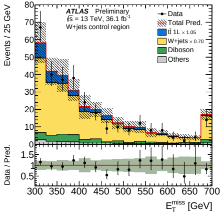


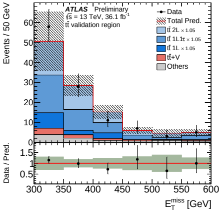
- For $\tau = 1$ ns, upper limits on the gluino mass are placed above 2.2 TeV for $\tilde{\chi}_1^0$ 100 GeV

Vector-like top quarks (T)

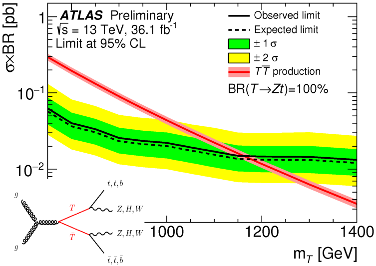
Search for vector-like top quarks ($Q=+\frac{2}{3}|e|$) with one lepton and E_T^{miss} (CONF-2017-015):

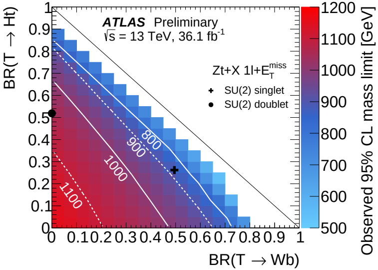
- Assuming only couplings to third gen. quarks, targeting $T\bar{T} \to Z/W/Ht + X, Z \to \nu\nu$
- Pre-selection: $\#b$-jets (≥ 1), #jets (≥ 4), E_T^{miss} (> 300 GeV), $\Delta\Phi(j_{1,2}, E_T^{miss})$ (> 4)





- Dominant bkgs: semi-leptonic $t\bar{t}$ events, single top and W+jets production
- Reduced with requirements on e.g (W) transverse mass m_T, number of boosted selected top quarks





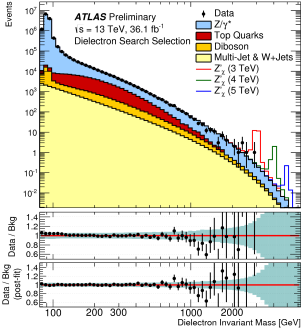
HEAVY BOSONS (Z')

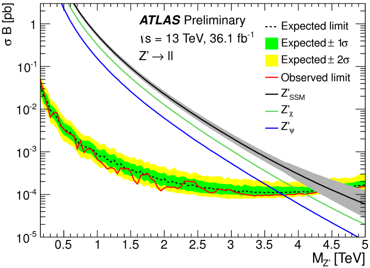
Search for Z' (spin 1) signatures with two opposite-charge lepton pairs (CONF-2017-027):

- Z': predicted by Grand Unified Theories, etc.
- In the Sequential SM (SSM), Z' has same couplings to fermions as the SM Z

If new physics, the invariant mass of the lepton pair is a great variable to look at:

- The new heavy resonance, Z', should create a bump
- Non-resonant effects should change the shape of the distribution



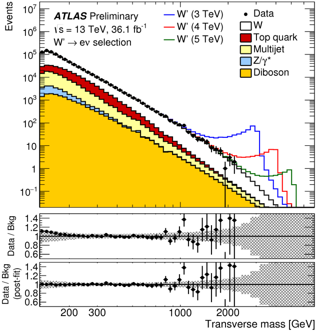


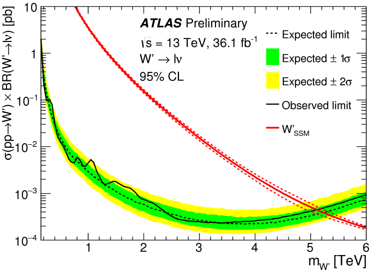
- Most significant excess at $m_{Z'} = 2.37\ \mathrm{TeV}$, in the di-electron channel (2.37σ)
- But globally much less significant, only -0.2σ

HEAVY BOSONS (W')

Search for heavy gauge boson resonance (spin 1) with one lepton and E_T^{miss} (CONF-2017-016):

- W': predicted by models with extra-dimensions, little Higgs model, etc.
- In the Sequential SM (SSM), W' has same couplings to fermions as the SM W, thus $W' \to \ell\nu$ or $W' \to qq$
- Key variables: m_T → a signal would appear as an excess at high m_T
- Main bkgs: W, $t\bar{t}$ and single top ("real", from MC) and multi-jets ("fakes", from data)





- Most significant excess is at $m_{W'} = 1.1\ \mathrm{TeV}$ in the electron channel (2.3σ)
- In the muon channel, at $m_{W'} = 5\ \mathrm{TeV}$ (1.8σ)

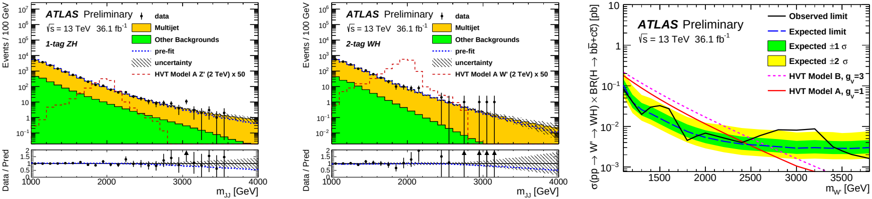
SEARCHES WITH DI-JETS EVENTS

Search for heavy resonances decaying to W or Z and a Higgs boson (VH) (CONF-2017-018)

- Only $q\bar{q}^{(')}b\bar{b}$ final states are considered
- And the high mass region ($m_{VH} > 1$ TeV) where the V and H bosons are highly boosted

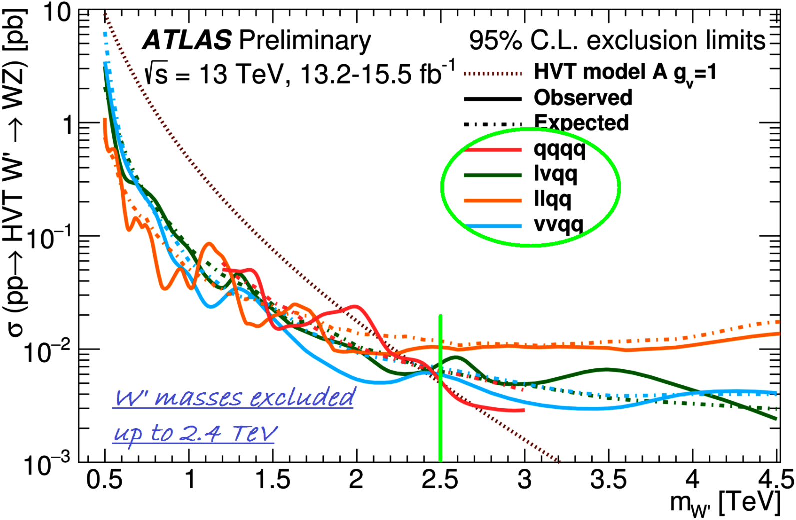
→ Final states candidates (from each boson) are reconstructed in one single jet: small bkg

- Key variable: mass of the two reconstructed (large-R) jets
- After pre-selection, main bkg (90%) from multi-jets events (taken from data)



- The largest excess observed at $m_{JJ} = 3.0$ TeV with a local significance of 3.3σ
- The global significance of this excess is 2.2σ
- Heavy resonances (Z' or W' bosons) excluded up to ∼2.5 TeV

SUMMARY OF DI-BOSON RESONANCE SEARCHES



W' masses excluded up to 2.4 TeV

*Expected and observed limits on the cross section times branching fraction to WZ for a new heavy vector boson W' at $\sqrt{s} = 13$ TeV. The different limit curves correspond to different decay modes for the W and Z bosons.

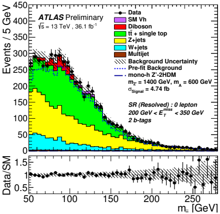
SEARCH FOR DARK MATTER (DM)

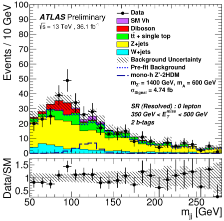
DM candidates: stable electrically-neutral particle, weakly interacting with the SM particles

- Direct detection: look directly for the mediator (di-jet resonance)
- Indirect detection: relay on signatures with high E_T^{miss} and a SM particle X (mono-X = q/g, b/t, γ, $W/Z/h$)

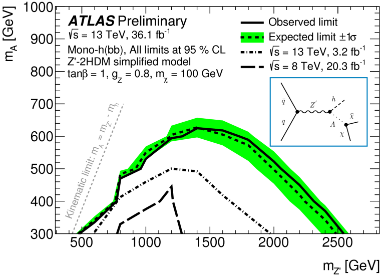
→ Today: results of the search for $pp \to Z' \to Ah \to \chi\tilde{\chi}b\bar{b}$ signals (A=pseudoscalar, CONF-2017-028)

- $E_T^{miss} > 150$ GeV, no isolated leptons and one reconstructed Higgs boson
- Dominant bkgs: $Z(\nu\nu)/W$j and $t\bar{t}$

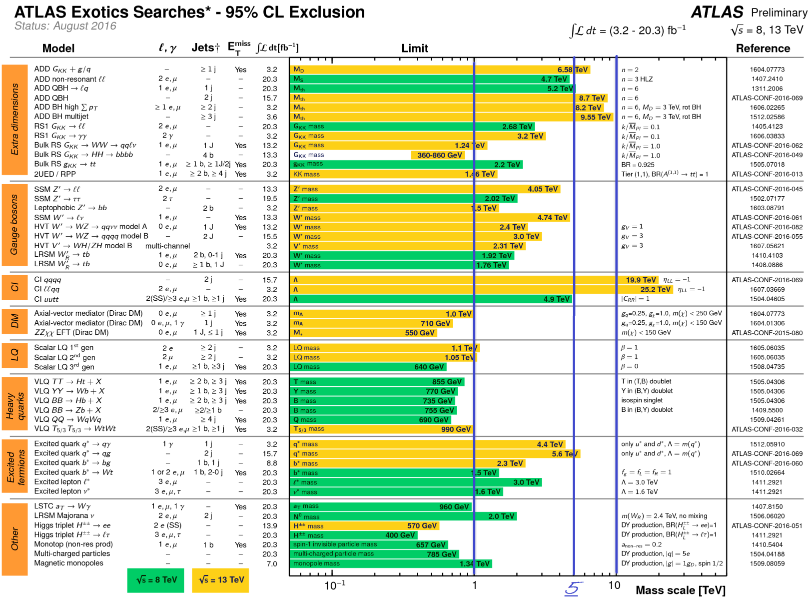




Source of uncert.	Impact [%]		
	(a)	(b)	(c)
V+jets modeling	5.0	5.7	8.2
$t\bar{t}$, single-t modeling	3.2	3.0	3.9
SM $Vh(b\bar{b})$ norm.	2.2	6.9	6.9
Signal modeling	3.9	2.9	2.1
MC statistics	4.9	11	22
Luminosity	3.2	4.5	5.4
b-tagging, track jets	1.4	11	17
b-tagging, calo jets	5.0	3.4	4.7
Jets with $R = 0.4$	1.7	3.8	2.1
Jets with $R = 1.0$	<0.1	1.2	4.7
Total systematic	10	21	36
Statistical	6	38	62
Total	12	43	71



EXOTICS SUMMARY PLOT



ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	3.2	🟨 M_D 6.58 TeV	$n = 2$	1604.07773
	ADD non-resonant $\ell\ell$	2 e, μ	–	–	20.3	🟩 M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\rightarrow \ell q$	1 e, μ	1 j	–	20.3	🟩 M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	15.7	🟨 M_{th} 8.7 TeV	$n = 6$	ATLAS-CONF-2016-069
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	🟨 M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	🟨 M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \rightarrow \ell\ell$	2 e, μ	–	–	20.3	🟩 G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \rightarrow \gamma\gamma$	2 γ	–	–	3.2	🟨 G_{KK} mass 3.2 TeV	$k/\overline{M}_{Pl} = 0.1$	1606.03833
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$	1 e, μ	1 J	Yes	13.2	🟨 G_{KK} mass 1.24 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-062
	Bulk RS $G_{KK} \rightarrow HH \rightarrow bbbb$	–	4 b	–	13.3	G_{KK} mass 🟨 360-860 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-049
	Bulk RS $g_{KK} \rightarrow tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	🟩 g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 4 j	Yes	3.2	🟨 KK mass 1.46 TeV	Tier (1,1), BR($A^{(1,1)} \rightarrow tt$) = 1	ATLAS-CONF-2016-013
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	2 e, μ	–	–	13.3	🟨 Z' mass 4.05 TeV		ATLAS-CONF-2016-045
	SSM $Z' \rightarrow \tau\tau$	2 τ	–	–	19.5	🟩 Z' mass 2.02 TeV		1502.07177
	Leptophobic $Z' \rightarrow bb$	–	2 b	–	3.2	🟨 Z' mass 1.5 TeV		1603.08791
	SSM $W' \rightarrow \ell\nu$	1 e, μ	–	Yes	13.3	🟨 W' mass 4.74 TeV		ATLAS-CONF-2016-061
	HVT $W' \rightarrow WZ \rightarrow qq\nu\nu$ model A	0 e, μ	1 J	Yes	13.2	🟨 W' mass 2.4 TeV	$g_V = 1$	ATLAS-CONF-2016-082
	HVT $W' \rightarrow WZ \rightarrow qqqq$ model B	–	2 J	–	15.5	🟨 W' mass 3.0 TeV	$g_V = 3$	ATLAS-CONF-2016-055
	HVT $V' \rightarrow WH/ZH$ model B	multi-channel			3.2	🟨 V' mass 2.31 TeV	$g_V = 3$	1607.05621
	LRSM $W'_R \rightarrow tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	🟩 W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \rightarrow tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	🟩 W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	15.7	🟨 Λ 19.9 TeV	$\eta_{LL} = -1$	ATLAS-CONF-2016-069
	CI $\ell\ell qq$	2 e, μ	–	–	3.2	🟨 Λ 25.2 TeV	$\eta_{LL} = -1$	1607.03669
	CI $uutt$	2(SS)/$\geq$3 e,μ	$\geq$1 b, $\geq$1 j	Yes	20.3	🟩 Λ 4.9 TeV	$\lvert C_{RR}\rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	≥ 1 j	Yes	3.2	🟨 m_A 1.0 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 250$ GeV	1604.07773
	Axial-vector mediator (Dirac DM)	0 e, μ, 1 γ	1 j	Yes	3.2	🟨 m_A 710 GeV	g_q=0.25, g_χ=1.0, $m(\chi) < 150$ GeV	1604.01306
	$ZZ\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	🟨 M_* 550 GeV	$m(\chi) < 150$ GeV	ATLAS-CONF-2015-080
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	🟨 LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	🟨 LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	$\geq$1 b, $\geq$3 j	Yes	20.3	🟩 LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \rightarrow Ht + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY \rightarrow Wb + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	🟩 Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB \rightarrow Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB \rightarrow Zb + X$	2/$\geq$3 e, μ	$\geq$2/$\geq$1 b	–	20.3	🟩 B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $QQ \rightarrow WqWq$	1 e, μ	≥ 4 j	Yes	20.3	🟩 Q mass 690 GeV		1509.04261
	VLQ $T_{5/3}T_{5/3} \rightarrow WtWt$	2(SS)/$\geq$3 e,μ	$\geq$1 b, $\geq$1 j	Yes	3.2	🟨 $T_{5/3}$ mass 990 GeV		ATLAS-CONF-2016-032
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	1 γ	1 j	–	3.2	🟨 q^* mass 4.4 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.05910
	Excited quark $q^* \rightarrow qg$	–	2 j	–	15.7	🟨 q^* mass 5.6 TeV	only u^* and d^*, $\Lambda = m(q^*)$	ATLAS-CONF-2016-069
	Excited quark $b^* \rightarrow bg$	–	1 b, 1 j	–	8.8	🟨 b^* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \rightarrow Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	🟩 b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	🟩 ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	🟩 ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \rightarrow W\gamma$	1 e, μ, 1 γ	–	Yes	20.3	🟩 a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e, μ	2 j	–	20.3	🟩 N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \rightarrow ee$	2 e (SS)	–	–	13.9	🟨 $H^{\pm\pm}$ mass 570 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow ee$)=1	ATLAS-CONF-2016-051
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	3 e, μ, τ	–	–	20.3	🟩 $H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	🟩 spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	🟩 multi-charged particle mass 785 GeV	DY production, $\lvert q\rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	🟩 monopole mass 1.34 TeV	DY production, $\lvert g\rvert = 1g_D$, spin 1/2	1509.08059

🟩 $\sqrt{s}$ = 8 TeV

🟨 $\sqrt{s}$ = 13 TeV

**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).

CONCLUSIONS

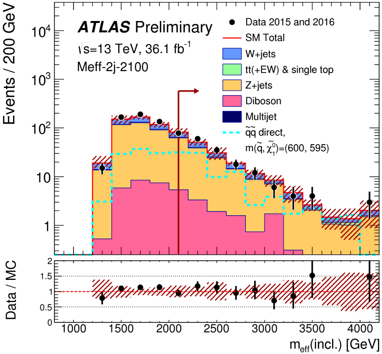
- Excellent LHC performance!
- ATLAS has a wide BSM physics program, scrutinizing each corner of the phase space
- As for today, (unfortunately) no evidence of SUSY or other BSM particles
- New limits significantly extend the Run 1 results → check out also the ATLAS public page

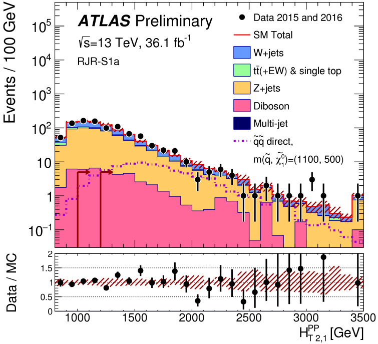
- Exciting future in front of us: at the end of the LHC Run-2 expect 120-150 fb^{-1} and by 2035 $\sim$ 3000 fb^{-1} of data!

BACKUP

Search for SUSY with multi-jets final states, 2→6 jets

- Most significant excess across m_{eff}-based SRs occurs in SR Meff-2j-2100 (LHS plot, a significance of 2.14 standard deviations)
- In RJR-based SRs, most significant excess RJR-S1a (RHS plot, 2.22σ)

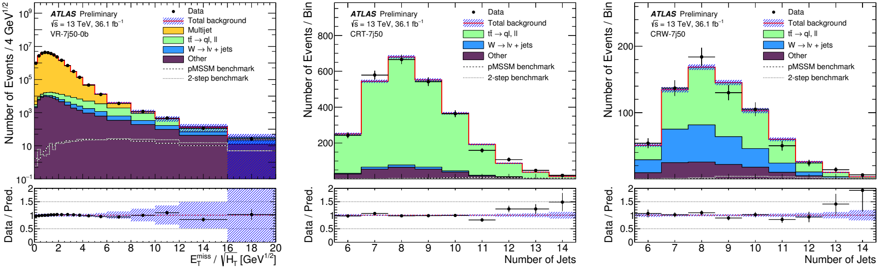




SEARCH FOR SUSY WITH MULTI-JETS FINAL STATES

Final states with 0-leptons and 7→11 jets CONF note

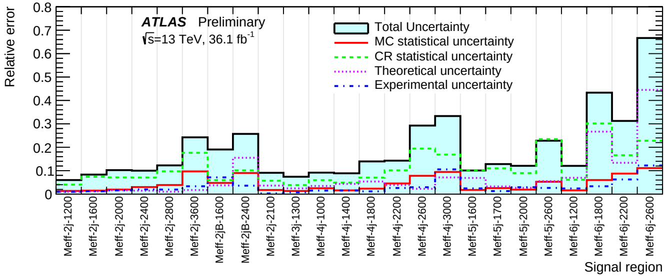
- Discriminants: E_T^{miss} over sqrt of sum of jets p_T (H_T), sum of the large-R Jets mass (M_J^{Σ})
- Main backgrounds: multi-jets, $t\bar{t}$ and W+jets processes
  - Multi-jets: using a data template fit method (LHS plot)
  - $t\bar{t}$ and W+jets: MC normalized in dedicated CRs (middle & RHS plots, after norm)



- Very good data-bkg estimation agreement in all CRs/VRs

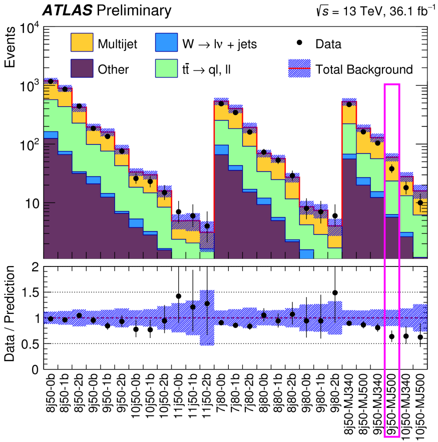
Search for SUSY with multi-jets final states

Results in the SRs: uncertainties



SEARCH FOR SUSY WITH MULTI-JETS FINAL STATES

Results in the SRs: data observation vs. background estimation



- Largest discrepancy from the SM prediction is a deficit in the 9j MJ500 SR (statistical significance around 1.8σ)
- Similar deficits are observed in other MJ SRs, but the large overlap between these SRs implies that the deficits are strongly correlated

SUSY PARTICLE

Chiral supermultiplets

Gauge sm.

	Proper states in		Spartners	Proper states in	
	interaction term	mass term		interaction term	mass term
Leptons $S = 1/2$	$\begin{pmatrix}\nu_e\\ e_L\end{pmatrix}, e_R$ $\begin{pmatrix}\nu_\mu\\ \mu_L\end{pmatrix}, \mu_R$		Sleptons $S = 0$	$\begin{pmatrix}\widetilde{\nu}_e\\ \widetilde{e}_L\end{pmatrix}, \widetilde{e}_R$ $\begin{pmatrix}\widetilde{\nu}_\mu\\ \widetilde{\mu}_L\end{pmatrix}, \widetilde{\mu}_R$	
	$\begin{pmatrix}\nu_\tau\\ \tau_L\end{pmatrix}, \tau_R$			$\begin{pmatrix}\widetilde{\nu}_\tau\\ \widetilde{\tau}_L\end{pmatrix}, \widetilde{\tau}_R$	$\widetilde{\tau}_1, \widetilde{\tau}_2, \widetilde{\nu}_\tau$
Quarks $S = 1/2$	$\begin{pmatrix}u_L\\ d_L\end{pmatrix}, u_R, d_R$ $\begin{pmatrix}c_L\\ s_L\end{pmatrix}, c_R, s_R$		Squarks $S = 0$	$\begin{pmatrix}\widetilde{u}_L\\ \widetilde{d}_L\end{pmatrix}, \widetilde{u}_R, \widetilde{d}_R$ $\begin{pmatrix}\widetilde{c}_L\\ \widetilde{s}_L\end{pmatrix}, \widetilde{c}_R, \widetilde{s}_R$	
	$\begin{pmatrix}t_L\\ b_L\end{pmatrix}, t_R, b_R$			$\begin{pmatrix}\widetilde{t}_L\\ \widetilde{b}_L\end{pmatrix}, \widetilde{t}_R, \widetilde{b}_R$	$\widetilde{t}_1, \widetilde{t}_2, \widetilde{b}_1, \widetilde{b}_2$
Gauge Bosons $S = 1$	$W^\pm, W^0, B, g$	$W^\pm, Z^0, \gamma, g$	Gauginos $S = 1/2$	$\widetilde{W}^\pm, \widetilde{W}^0, \widetilde{B}, \widetilde{g}$	Gluino $\widetilde{g}$ Neutralinos $\widetilde{\chi}^0_1, \widetilde{\chi}^0_2, \widetilde{\chi}^0_3, \widetilde{\chi}^0_4$ Charginos $\widetilde{\chi}^\pm_1, \widetilde{\chi}^\pm_2$
Higgs Boson $S = 0$	$\begin{pmatrix}H_u^+\\ H_u^0\end{pmatrix}, \begin{pmatrix}H_d^0\\ H_d^-\end{pmatrix}$	$h^0, H^0, A^0, H^\pm$	Higgsinos $S = 1/2$	$\begin{pmatrix}\widetilde{H}_u^+\\ \widetilde{H}_u^0\end{pmatrix}, \begin{pmatrix}\widetilde{H}_d^0\\ \widetilde{H}_d^-\end{pmatrix}$	
Graviton $S = 2$	G		Gravitino $S = \frac{3}{2}$	$\tilde{G}$	

Fermions and bosons in the same supermultiplet

CROSS-SECTIONS