ATLAS results on new physics searches

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ATLAS EXPERIMENT

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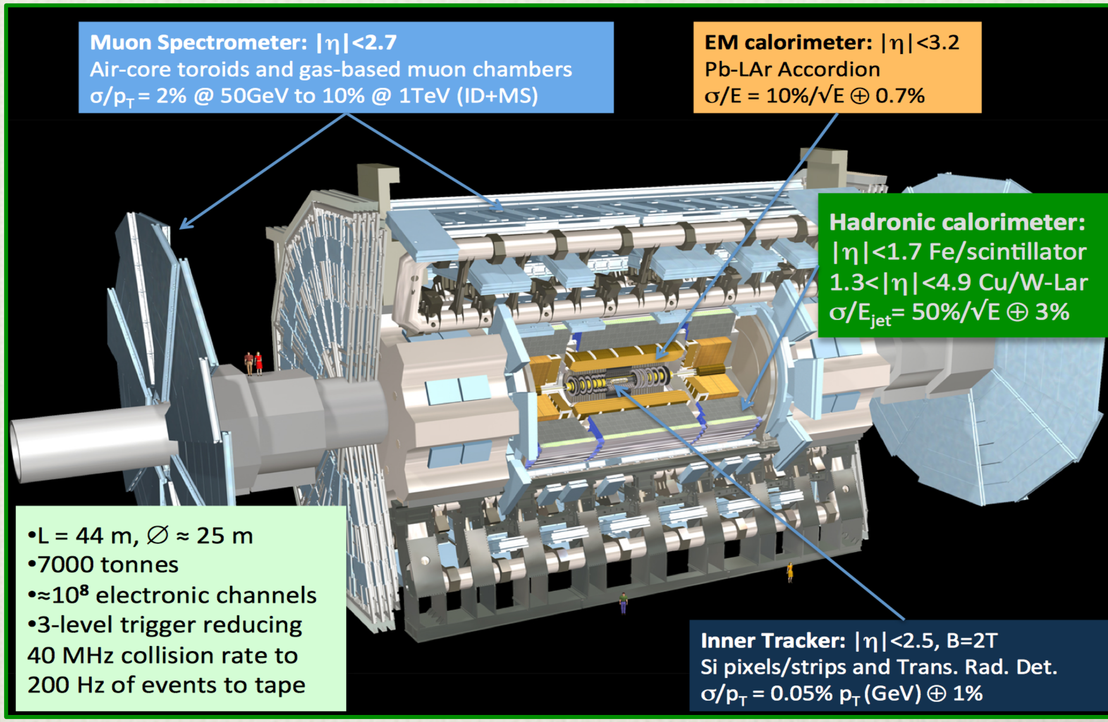
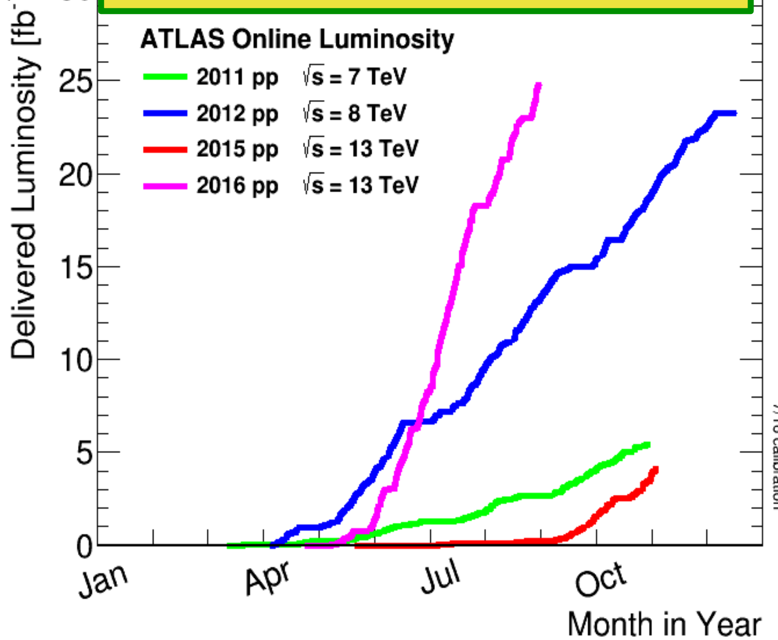
LHC and ATLAS

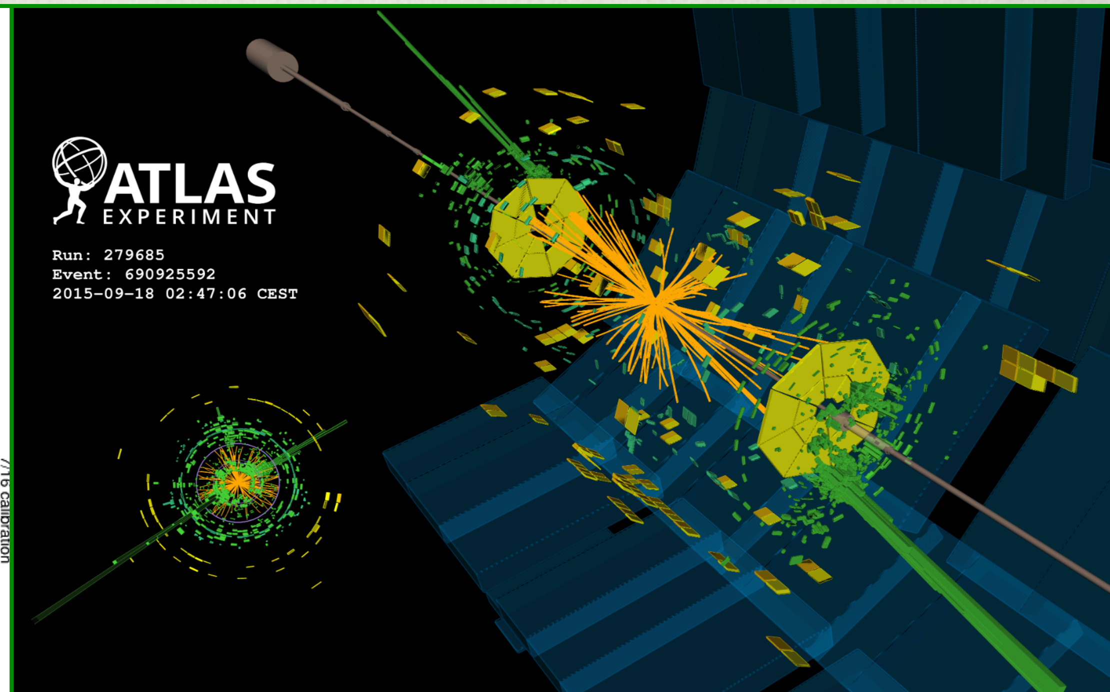
Excellent performance of LHC and ATLAS in Run2:

- 13 TeV c.m. energy, ~1.1×10^{34} $cm^{-2}s^{-1}$ peak luminosity, 25 ns bunch spacing
- ~3.2 fb^{-1} integrated luminosity in 2015
- >25 fb^{-1} so far in 2016, ~100 fb^{-1} by the end of Run2



Results reported so far in 2016 with 3-15 fb^{-1}

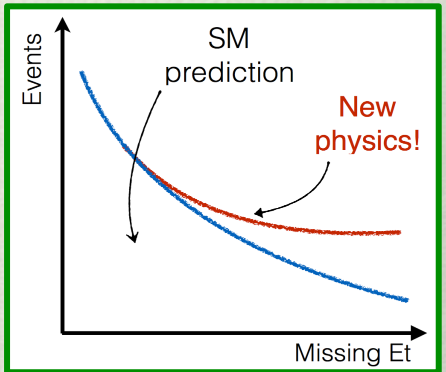




General strategy for new physics searches

- Event selection performed through sensitive observables (e.g. missing transverse energy, invariant mass, etc.) to maximize signal from background discrimination ➔ "Signal Regions" (SRs)
- Compare data to background ➔ data driven estimates or by MC, normalized through fit to dedicated "Control Regions" (CRs):
  - ✓ New physics would produce deviations from background predictions
  - ✓ If no deviation ➔ set limits on new physics cross sections x BR
- Results interpreted in specific signal models

Searches rely on accurate modeling of the Standard Model backgrounds



***Large number of new physics analyses*, only *few selected new results from ATLAS* shown here, e.g. they don't include:**

- ***Long Lived Particles, Mediator through dijets (see R. Rosten's talk at TeVPA2016)***
- ***EW SUSY production, SUSY R-Parity Violation, Multi-Charged Particles, Magnetic Monopoles,…***

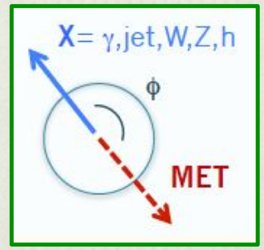
Whole list of analyses (SUSY, Exotics, Higgs) in

- *https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults*
- *https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults*
- *https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults*

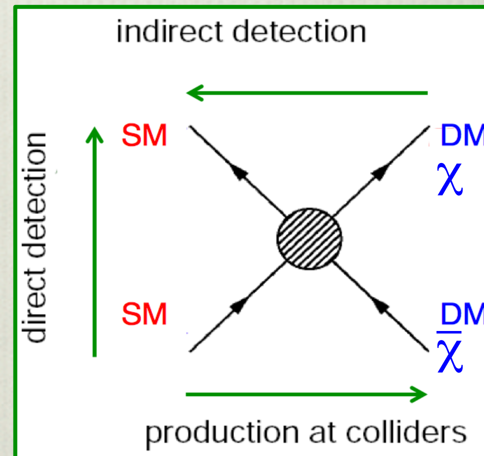
Dark Matter (DM) searches at LHC

- If DM couples to Standard Model (SM) particles very weakly (WIMPs), it may be observed as directly pair-produced at a collider ➔Signature at LHC: **triggerable object X** (γ, jet,W,Z,H,etc.) recoiling against **invisible DM** $\chi\chi$ resulting in missing transverse energy E_T^{Miss} (energy imbalance in detector)

"Mono-X searches"
(see also C.S.Moon's talk, non Mono-X DM searches in R.Rosten's talk)



- Collider searches are complementary to direct (WIMP-nucleon scattering) and indirect (WIMP annihilation) detection



Search	Data	Reference paper
E_T^{miss}+jet	2015	Paper: EXOT-2015-03
$E_T^{miss}+\gamma$	2015	Paper: EXOT-2015-05
E_T^{miss}+Z($\rightarrow \ell\ell$)	2015+2016	Note: ATLAS-CONF-2016-056
E_T^{miss}+W/Z($\rightarrow qq$)	2015	Paper: EXOT-2015-08
E_T^{miss}+H($\rightarrow bb$)	2015	Note: ATLAS-CONF-2016-019
E_T^{miss}+H($\rightarrow \gamma\gamma$)	2015+2016	Note: ATLAS-CONF-2016-087
E_T^{miss}+H($\rightarrow \ell\ell\ell\ell$)	2015	Note: ATLAS-CONF-2015-059
E_T^{miss}+b-jets	2015+2016	Note: ATLAS-CONF-2016-086
$E_T^{miss}+t\bar{t}$ (0ℓ)	2015+2016	Note: ATLAS-CONF-2016-077
$E_T^{miss}+t\bar{t}$ (1ℓ)	2015+2016	Note: ATLAS-CONF-2016-050
$E_T^{miss}+t\bar{t}$ (2ℓ)	2015+2016	Note: ATLAS-CONF-2016-076

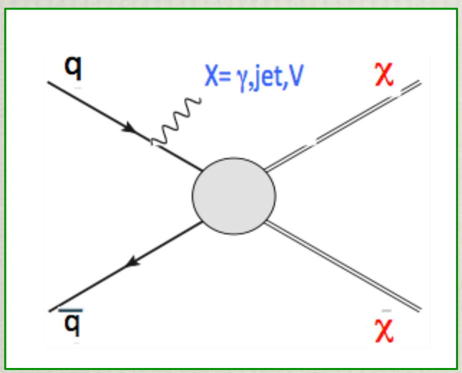
- *13 TeV Results in this talk:*

✓ *Mono-photon*
✓ *Mono-jet*
✓ *Mono W/Z*
✓ *Mono H (-> γγ,bb)*

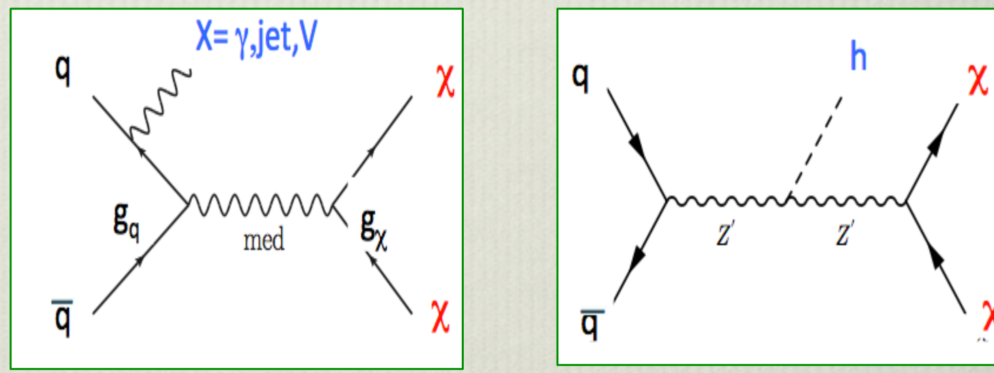
Dark Matter through Mono-X

Mono-X searches in ATLAS: models

- $\chi\chi$ interpretation inside:
  - ✓ More complete models (e.g. SUSY R-parity conserving, WIMPS as SUSY Lightest particles)
  - ✓ "Simplified" models ➔ mediator (med) exchanged in s-channel, DM particle is a stable Dirac fermion χ, 5 parameters: M_{med},Γ_{med},m_χ,g_q,g_χ
  - ✓ Effective Field Theory (EFT) ➔ **(Run1 approach)** 2 parameters, m_χ and mass of the very heavy mediator M_*, valid only when M_* is much larger than the energy of the interaction (not always true at LHC)



EFT

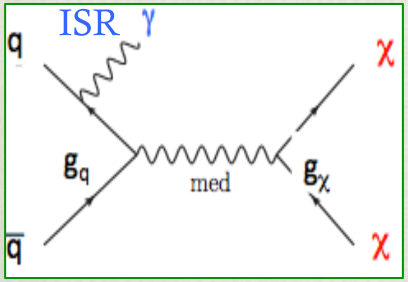


Simplified Models

Common effort between the ATLAS and CMS Collaborations and the theory community (DM Forum) to direct the DM searches in Run2 to benchmark simplified models, improved analysis techniques, common rules to present results *(arXiv:1507.00966, arXiv: 1506.03116v3)*

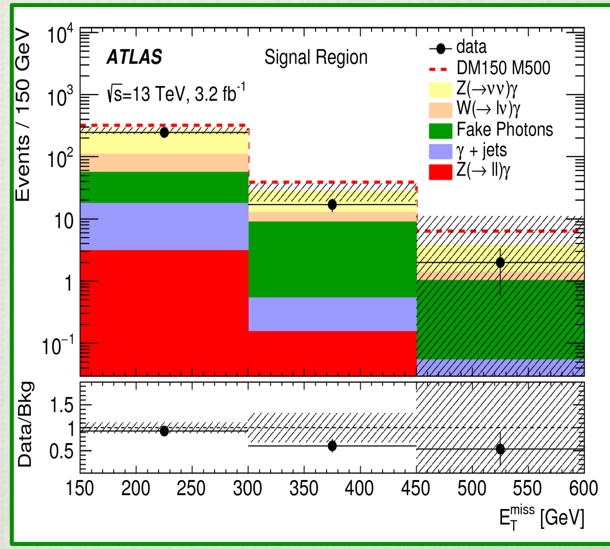
Mono-photon search (JHEP06 (2016) 059)

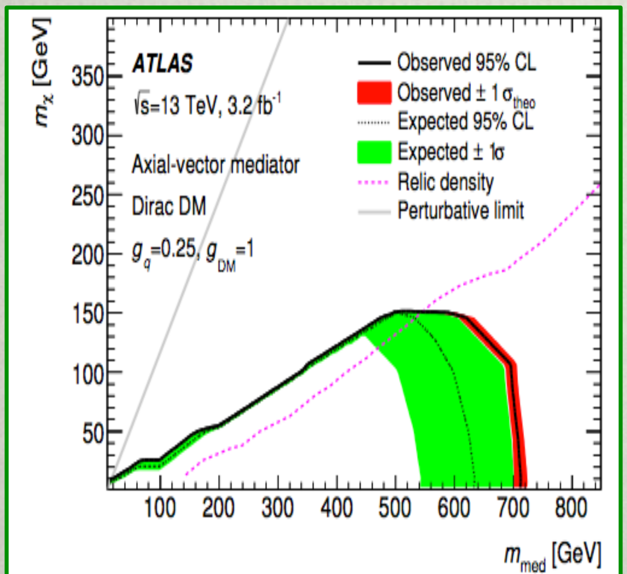
- **Clean signature**: High p_T photon (>150 GeV)+E_T^{Miss} (>150 GeV)+$\Delta\phi(\gamma - E_T^{Miss})$>0.4+veto on l and jets
- **Main backgrounds**: $Z \rightarrow \nu\nu+\gamma$ (irreducible), $W \rightarrow l\nu+\gamma$, γ+jets, fake photons (electrons, jets)



Simplified Models (Dirac DM, axial-vector mediator couplings g_q=0.25 and g_χ=1): 95% CL excluded m_χ < 150 GeV for m_{med} ~ 700 GeV

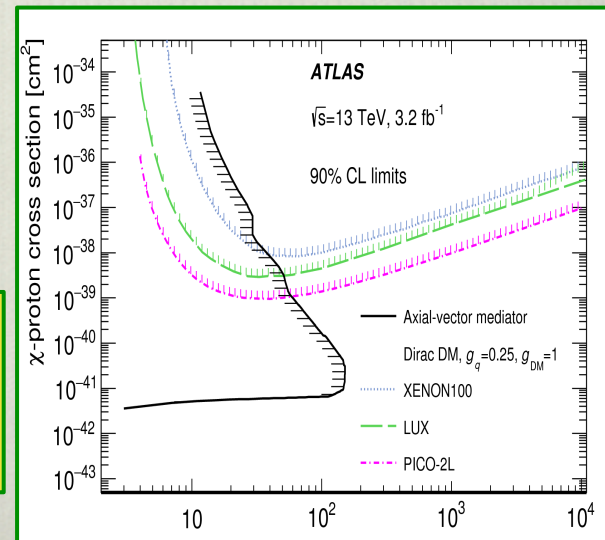
	SR
Observed events	264
Fitted Background	295±34
$Z(\to \nu\nu)\gamma$	171±29
$W(\to \ell\nu)\gamma$	58±9
$Z(\to \ell\ell)\gamma$	3.3±0.6
γ + jets	15±4
Fake photons from electrons	22±18
Fake photons from jets	26±12
Pre-fit background	249±29





Comparison with Direct Detection: 90% CL limits on spin-dependent WIMP-proton cross section $\sigma_{SD}(\chi$-p): $\sigma_{SD}(\chi$-p) < 10^{-41} cm^2 for m_χ < ~150 GeV

Direct Production complement Direct Detection (through DM-nucleon scattering in deep underground detectors) below 10 GeV



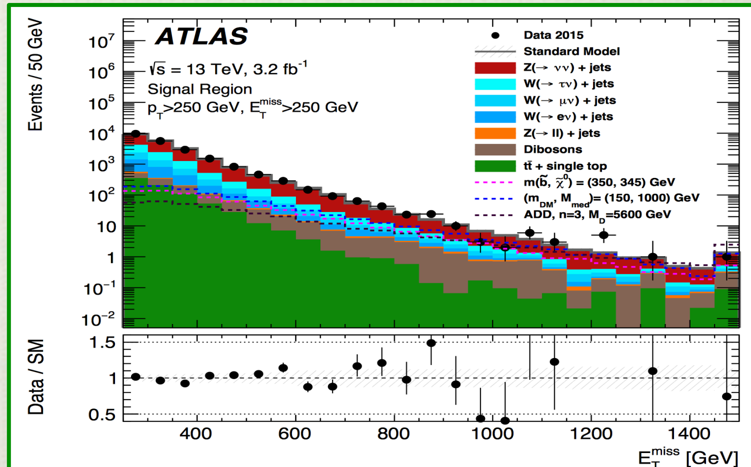
Prescription in arXiv:1603.04156

Mono-jet search (arXiv.1604.07773v1)

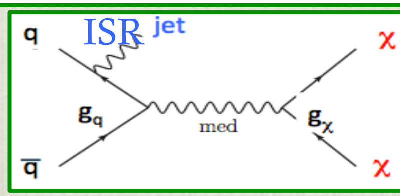
- **More complex signature but larger x-section (compared to Mono-photon)**: High p_T jet (>250 GeV)+E_T^{Miss} (>250 GeV)+max 4 Jets with p_T > 30 GeV+$\Delta\phi(p_T \text{ jet} - E_T^{Miss})$>0.4+lepton veto
- **Main backgrounds**: $Z \rightarrow \nu\nu(\tau\tau)$+jets (irreducible), $W \rightarrow l\nu$+jets
- **Multiple SRs:**

Inclusive signal region	IM1	IM2	IM3	IM4	IM5	IM6	IM7
E_T^{miss} (GeV)	> 250	> 300	> 350	> 400	> 500	> 600	> 700
Exclusive signal region	EM1	EM2	EM3	EM4	EM5	EM6	
E_T^{miss} (GeV)	[250–300]	[300–350]	[350–400]	[400–500]	[500–600]	[600–700]	

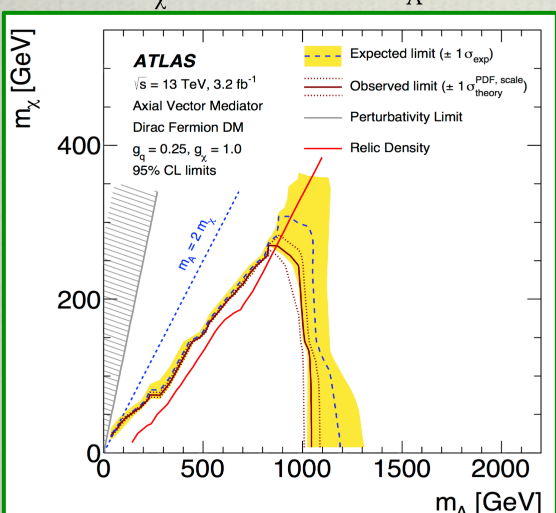
Signal Region	IM1	IM2	IM3	IM4	IM5	IM6	IM7
Observed events (3.2 fb^{-1})	21447	11975	6433	3494	1170	423	185
SM prediction	21730 ± 940	12340 ± 570	6570 ± 340	3390 ± 200	1125 ± 77	441 ± 39	167 ± 20
Signal Region	EM1	EM2	EM3	EM4	EM5	EM6	
Observed events (3.2 fb^{-1})	9472	5542	2939	2324	747	238	
SM prediction	9400 ± 410	5770 ± 260	3210 ± 170	2260 ± 140	686 ± 50	271 ± 28	



95% CL Exclusion limits in simplified Models: Dirac DM, axial-vector mediator, couplings g_q=0.25 and g_χ=1: exclude m_χ < 250 GeV for m_A ~ 1 TeV



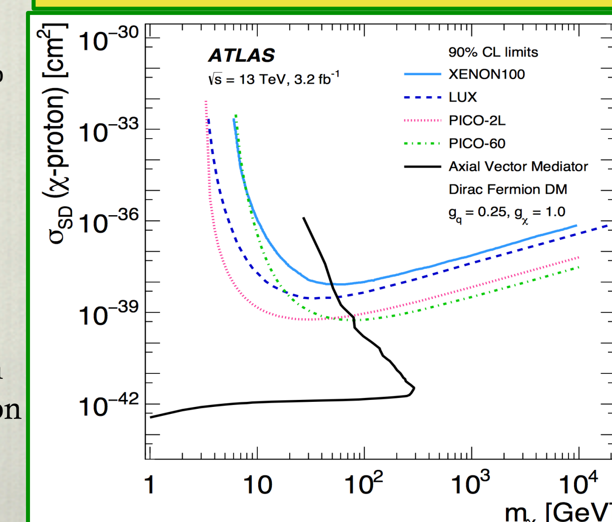
Direct Production complement Direct Detection below 10 GeV: better limit than Mono-photon



Comparison with direct detection: 90% CL limits on spin-dependent WIMP-proton cross section $\sigma_{SD}(\chi\text{-}p)$: $\sigma_{SD}(\chi\text{-}p)$ < 10^{-42} cm^2 for m_χ < 300 GeV

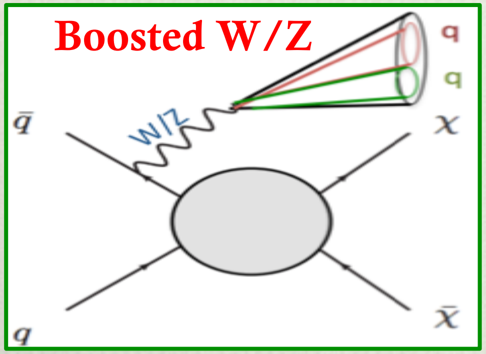
DM relic density (Planck, Wmap) line crosses the excluded region

- below relic abundance curve: DM over production
- above relic abundance curve: DM under production

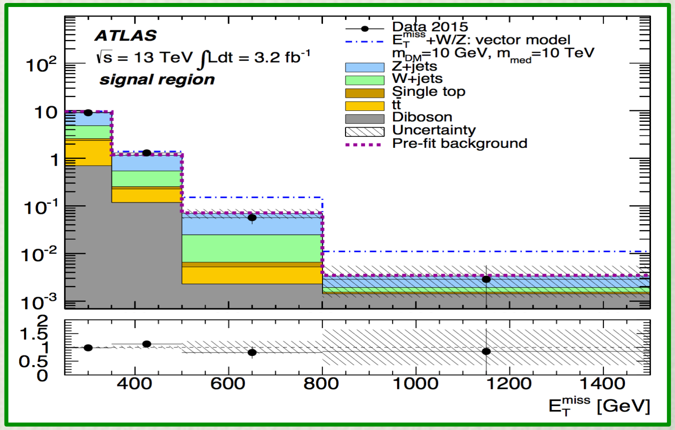


Mono-W/Z search (arXiv:1608.02372, ATLAS-CONF-2016-056)

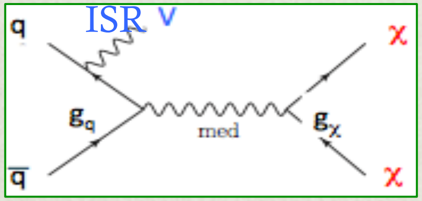
- **Signature**: Large R jet (R=1) with 2 substructures for boson tagging and p_T > 200 GeV+ E_T^{Miss} (>200 GeV)
- **Main backgrounds**: Z+jets, W+jets, ttbar
- **Complements** mono-jet search with different production modes. Hadronic channel has strong sensitivity.



Process	Events
Z+jets	544 ± 33
W+jets	275 ± 24
$t\bar{t}$ and single-top	211 ± 19
Diboson	89 ± 12
Total Background	1120 ± 47
Data	1121

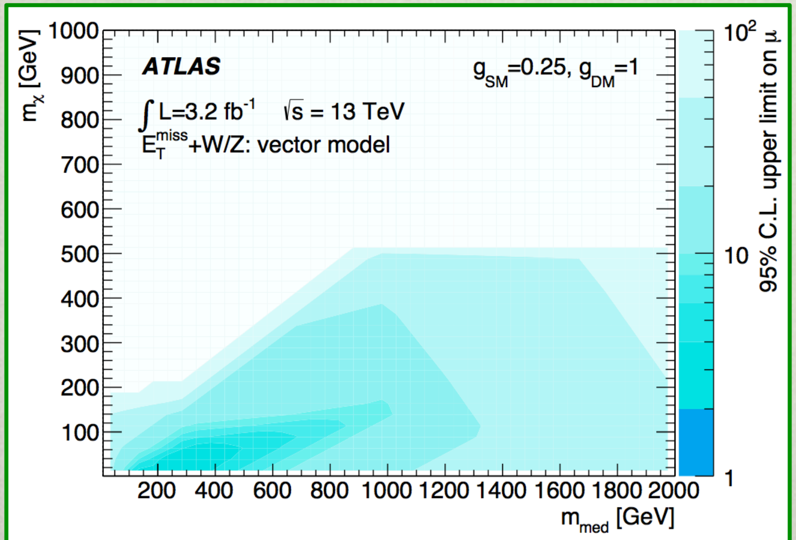


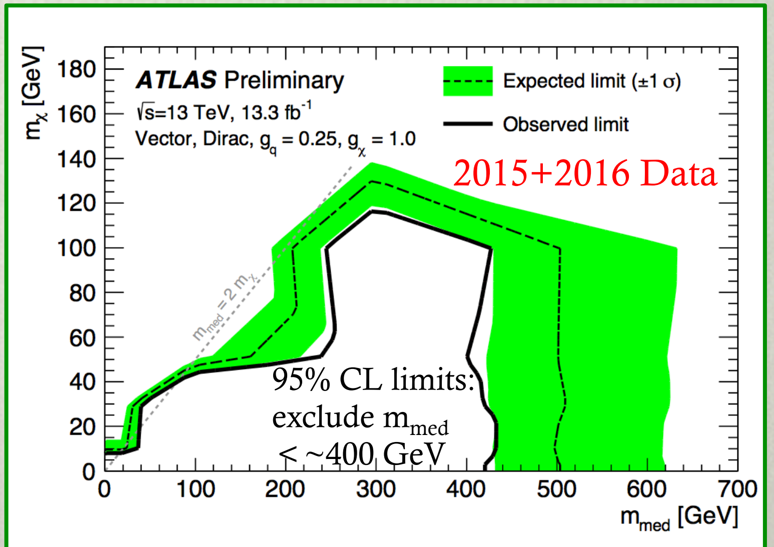
Exclusion limits in simplified Models: vector mediator, couplings g_q=0.25 and g_χ=1, 95% CL limits on signal strenght μ in (m_{med},m_χ) plane



Mono-Z (Z → ll)

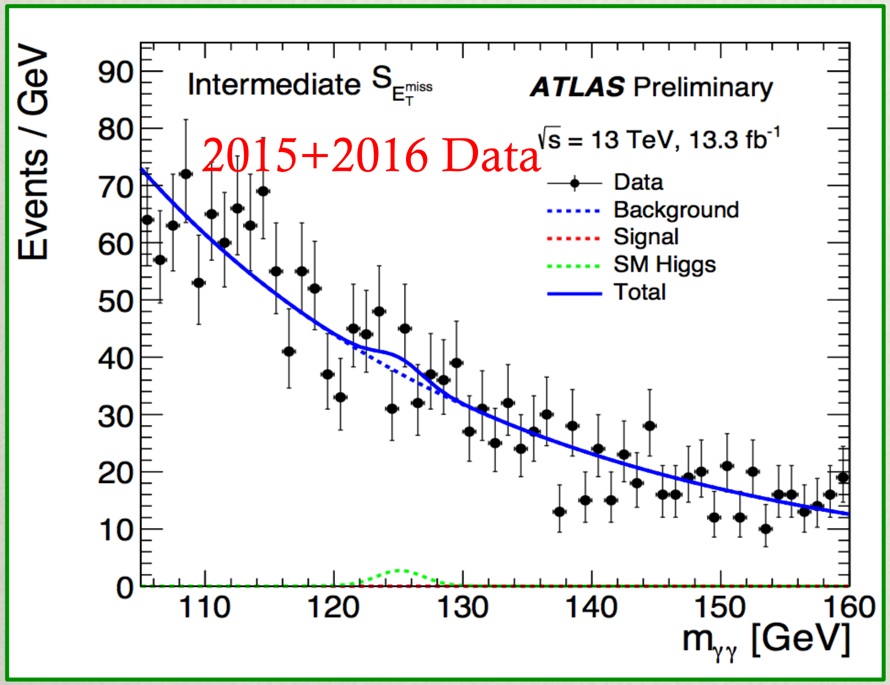
- **Signature:** very clean, but low statistics
- **Main Background**: ZZ → νν+ll (irreducible)

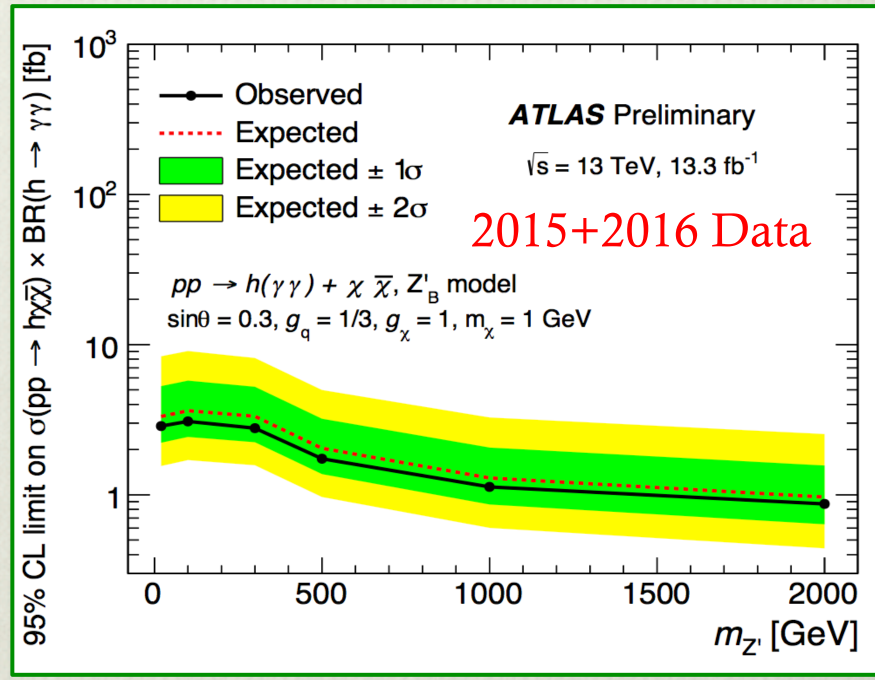




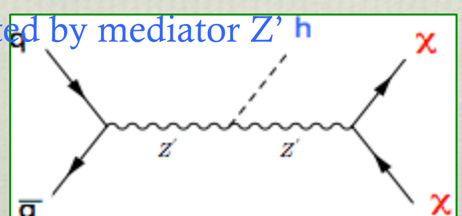
Mono-H(H→γγ) search (ATLAS-CONF-2016-087)

- **Low BR, but clean signature**: at least 2 photons ($105 < m_{\gamma\gamma} < 160$ GeV) + E_T^{Miss} (>100 GeV)
- **Backgrounds**: γγ,γ+jet, evaluated directly from data-driven fit
- **No excess** found in data





Radiated by mediator Z'



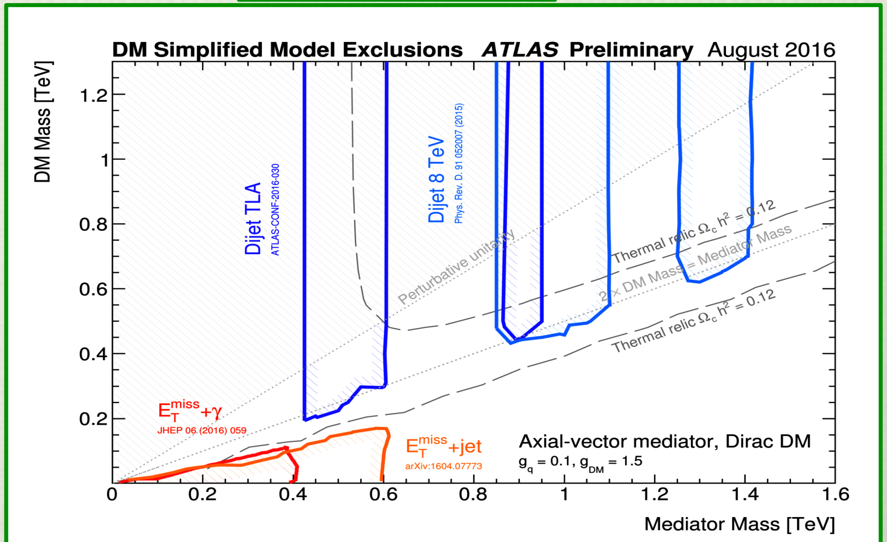
Mono-H(H→bb) in backup slides

Limits in simplified Models: Dirac DM, vector mediator couplings g_q=1/3 and g_χ=1: 95%CL exclusion limit on $\sigma(pp \rightarrow H\chi\chi) \times BR(H \rightarrow \gamma\gamma)$ vs m_{med} (3fb@50 GeV)

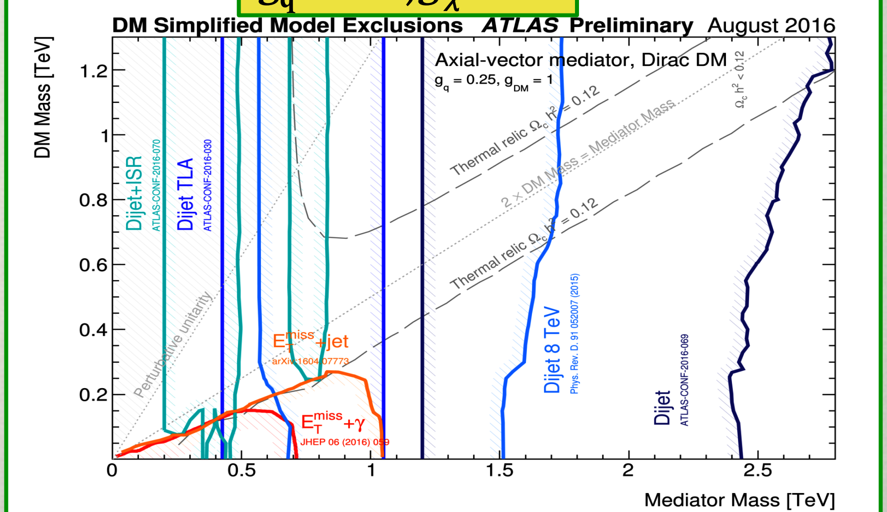
DM (Mono-X+Di-jets) ATLAS Summary

- **95%CL exclusion** in (m_χ,m_{med}) plane by Mono-Photon, Mono-Jet and Di-jet DM searches
- **Dirac DM, axial-vector mediator**
- Di-jet searches (see R. Rosten's talk) in the context of DM: DM mediator also give rise to di-jet events. Results highly depend on choice of coupling parameters
- **Complementarity** between di-jet and Mono-X searches

g_q=0.1,g_χ=1.5



g_q=0.25,g_χ=1.0

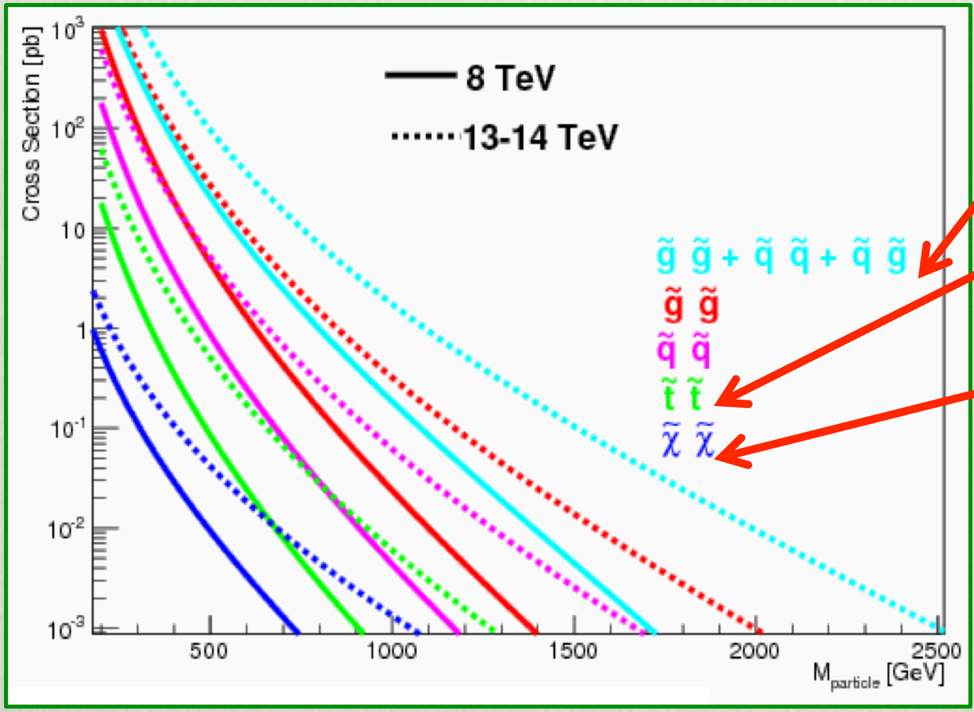


Mono-photon and Mono-jet interpretation in other New Physics scenarios in backup slides

Supersymmetry

SUSY searches in ATLAS

- **Supersymmetry** is a favoured, non-exotic, SM extension.
- Introduces a superpartner for each SM particle, with spin altered by ½ and 5 Higgs bosons
- Provides a possible DM candidate (Lightest SUSY particle, LSP) assuming R-parity conservation
  ➔Large E_T^{Miss} $R = (-1)^{3(B-L)+2S}$ R=+1 (SM) R=-1 (SUSY)
- **Models:** Minimal SUSY Standard Model (MSSM) has more than 100 parameters ➔ a huge phase space to look into, with many possible signatures



Strong production:
- ✓ *targeting gluinos and 1st and 2nd generation squarks, largest cross-sections*

3rd generation:
- ✓ *targeting stop and sbottoms, the lowest mass squarks*

Electroweak production:
- ✓ *targeting Electroweakinos, Sleptons*

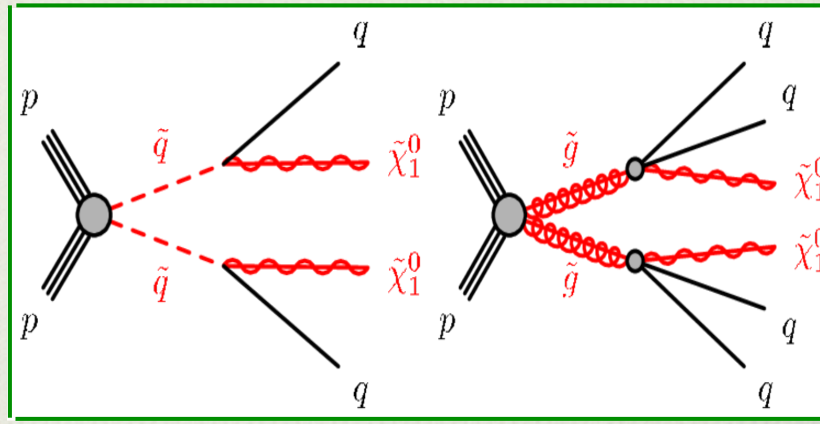
RPV/LL:
- ✓ *targeting R-parity violating models and long lived sparticles*
- ✓ *More exotic model*

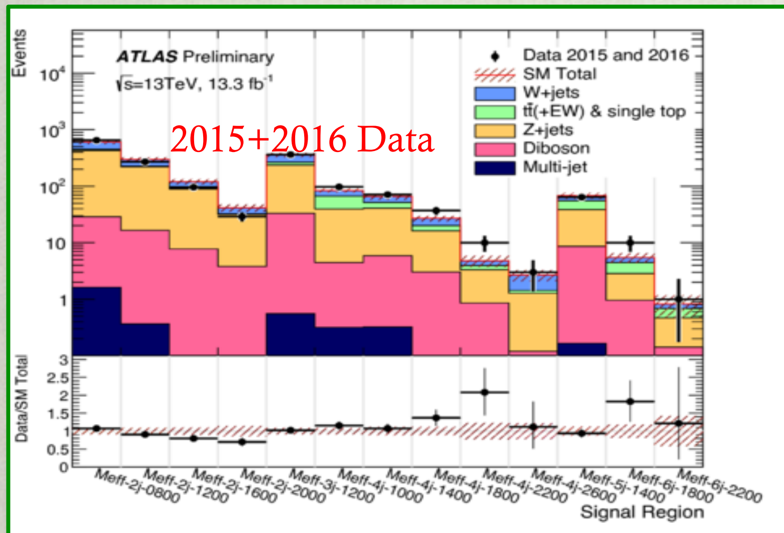
Only focus on few searches in this talk

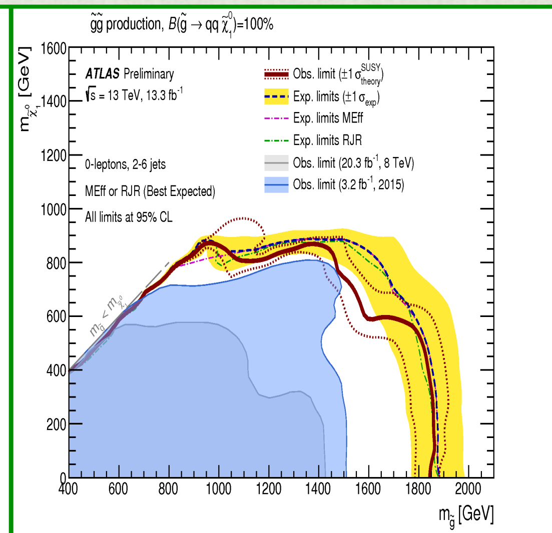
Strong production: Gluino and squarks, 0-leptons+jets+E_T^{Miss}

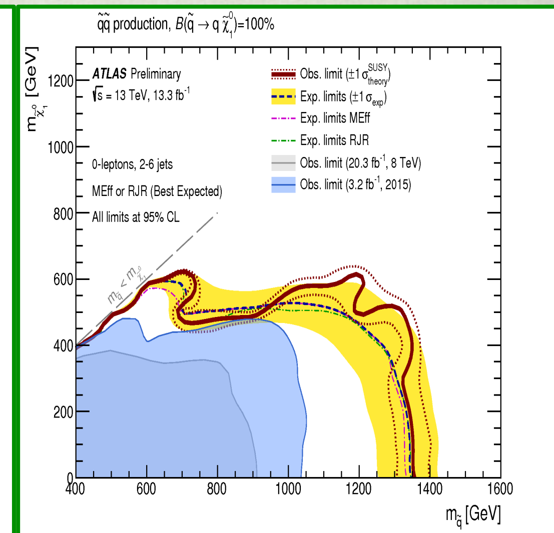
(ATLAS-CONF-2016-078)

- **Model:** inclusive final state, only gluinos (or 1st and 2nd generation squarks) and LSP ($\tilde{\chi}_1^0$) in the model
- **Selection:** based on cuts on E_T^{Miss} and $m_{eff} = E_T^{Miss} + \Sigma_{jet} p_T$ (large activity expected in the event), and on Recursive Jigsaw Reconstruction (RJR) techniques
- **Signal Regions:** 30 SRs in total









95% CL Exclusion limits in simplified Models: exclude $m_{\tilde{g}} < 1.86$ TeV and $m_{\tilde{q}} < 1.35$ TeV for $m_{LSP} = 0$ GeV.

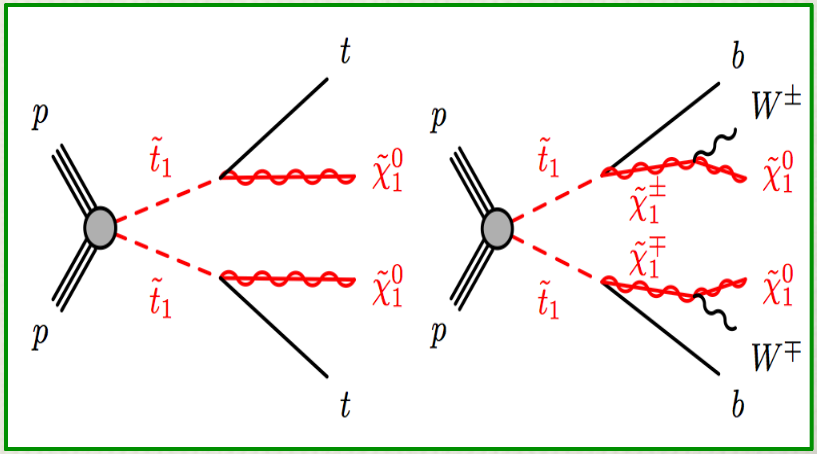
3^{rd} Generation: Stop decays – 1 lepton (e,μ) (ATLAS-CONF-2016-050)

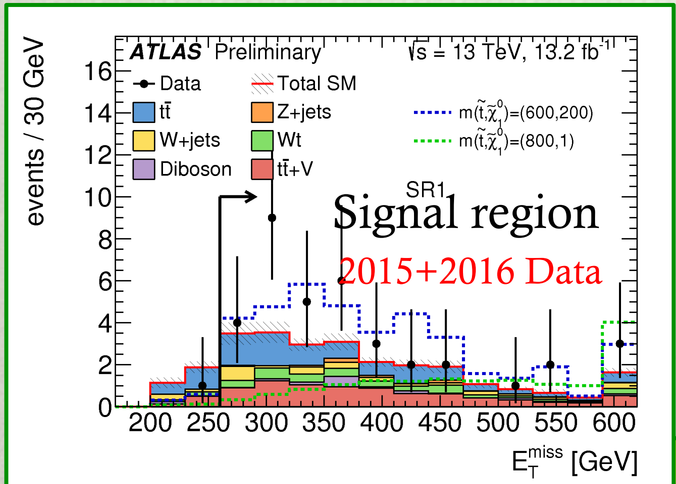
- **Decays:** stop decays in $t\tilde{\chi}_1^0$ and $b\tilde{\chi}_1^\pm$,

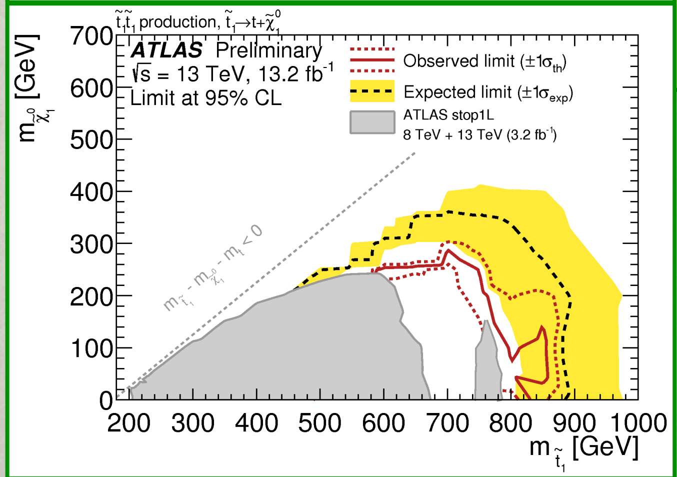
DM scenario with a spin-0 med. (scalar or pseudo-scalar)

- **Main Background**: ttbar, Wt, W+jets, ttbar+Z($\rightarrow\nu\nu$)
- **Multiple SRs:** >=1 b-jet and based on cuts on E_T^{Miss},

m_T (l-E_T^{Miss}), m_{T2}

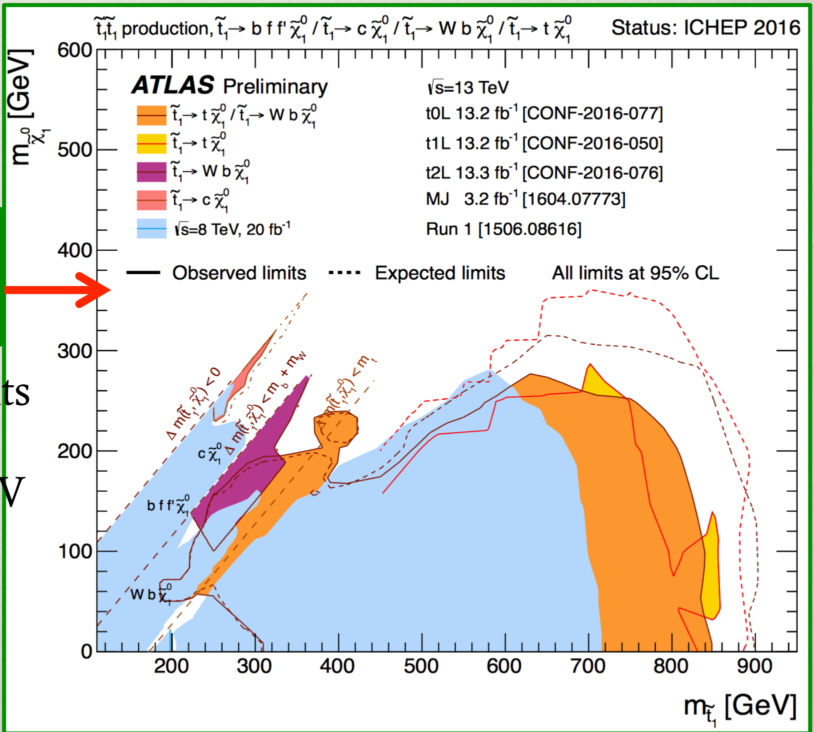






Summary for stop decays in neutralino

95% CL Exclusion limits in simplified Models: exclude m_{stop} < 830 GeV for m_{LSP} = 0 GeV and BRs = 100%



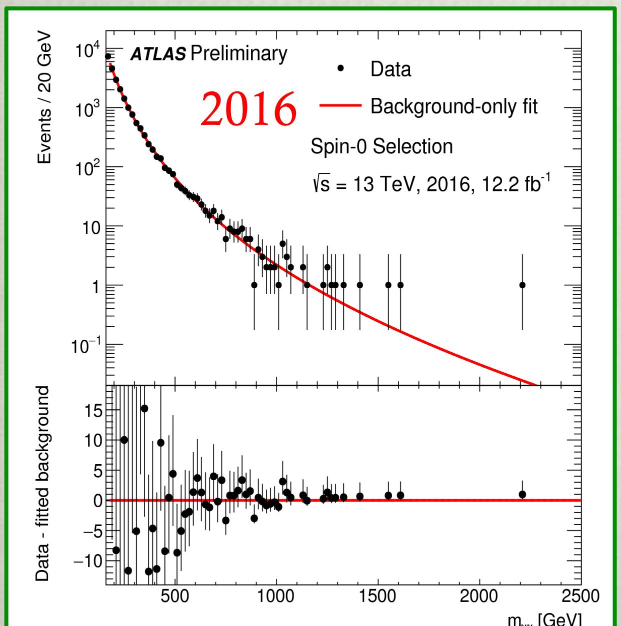
New resonances

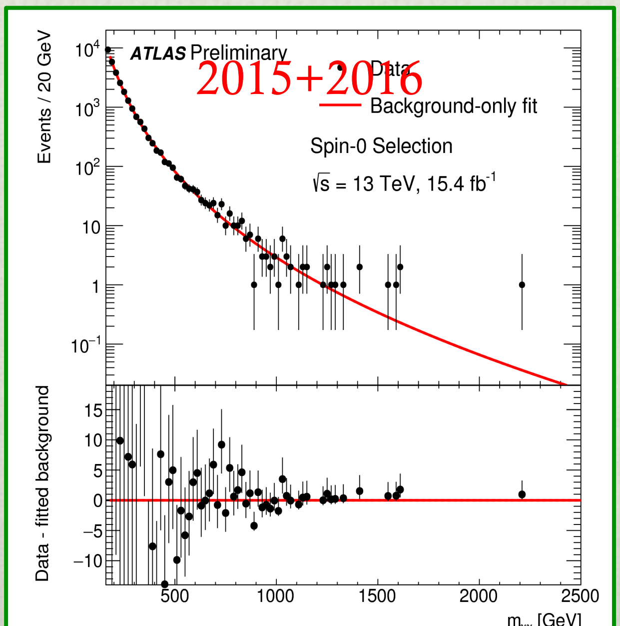
More on New Resonances, TeV-scale gravity and Quantum Black Holes, GUT, Beyond SM Higgs… in backup slides

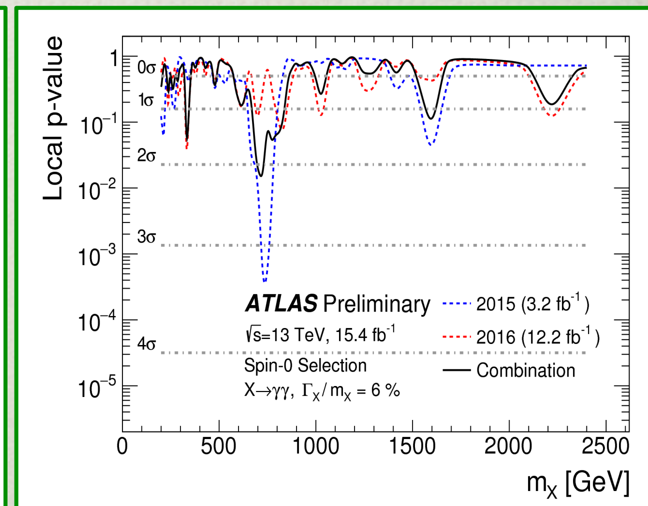
Di-photon search (ATLAS-CONF-2016-059)

- Many theories beyond the SM predict narrow **resonances** or broad non- resonant deviations from the SM ➔ excess in sensitive observables (invariant mass, …)
- **Models** for di-γ final states ➔ Spin-0 (e.g. predicted in models with Extended Higgs Sector) and Spin-2 (Randall-Sundrum graviton, RSG)
- **Signature:** 2 isolated γ
- **Main Background:** γγ, γ+jet,jet+jet, modelled with a fit to data for Spin-0 and a shape prediction (NLO) for Spin-2
- **Results from 2015 Data:** Broad excesses around $m_{\gamma\gamma}$ = 750 GeV in both analyses (width ~45 GeV), 3.8-3.9σ local significances, 2.1σ global significance

No significant excess in 2016 data Spin-0 analysis



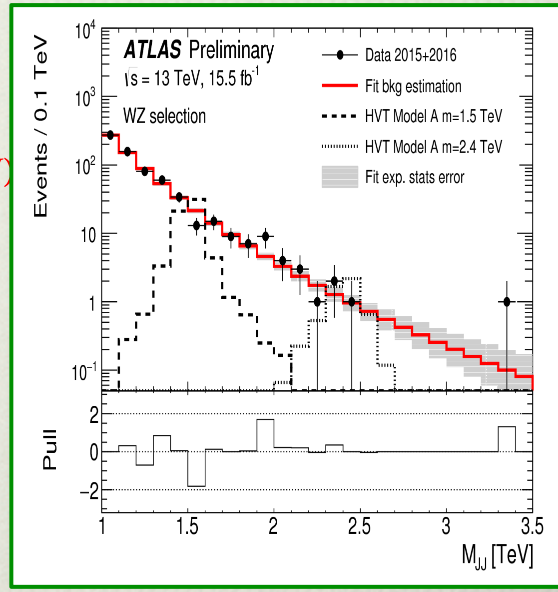




2.3 σ local significance @ 710 GeV for combined dataset (Γ_x/m_x=6%)

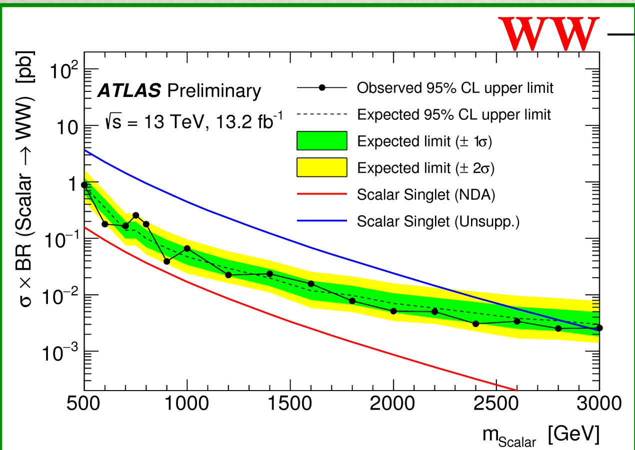
Search for heavy di-boson resonances (ATLAS-CONF-2016-055,062,082,083)

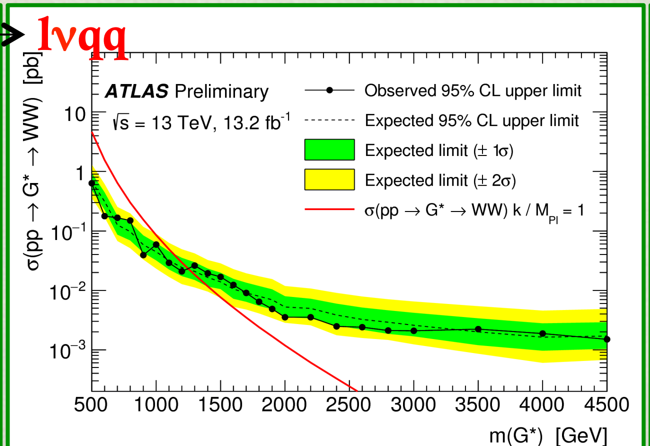
- ➢ Narrow charged or neutral **resonances** (500-3000 GeV) decaying to WW/WZ/ZZ/WH/ZH
- ➢ **Signatures:** ννqq, lνqq, llqq, qqqq,qq$b\bar{b}$ in final states, W/Z ⟶ qq identified through Large R jet
- ➢ **Models:**
- ✓ model with a new heavy **scalar** in the extended Higgs sector
- ✓ simplified model with a **spin-1** heavy vector-boson triplet (HVT) W'(Z')→WZ (WW)
- ✓ bulk Randall-Sundrum model with heavy **spin-2** graviton (RSG), G_* → WW,ZZ
- ➢ **Results from Run1 Data:** Broad excesses around m_{jj} = 2 TeV in full hadronic channel, local significances of 2.6-3.4σ, global significance of 2.5σ, not confirmed in Run 2 (2015 + 2016 13 TeV data)

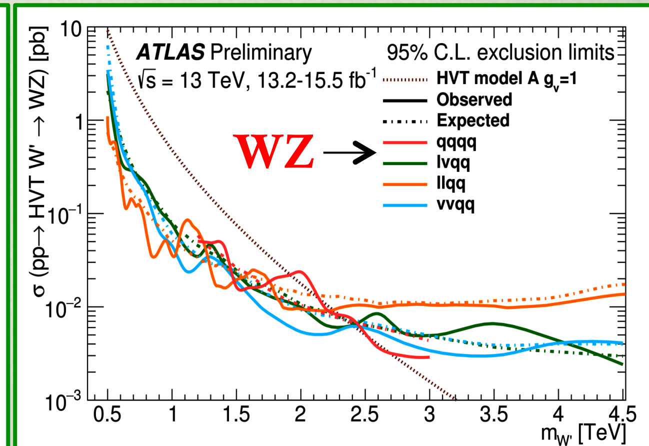


Run2 Data

WW ⟶ lνqq



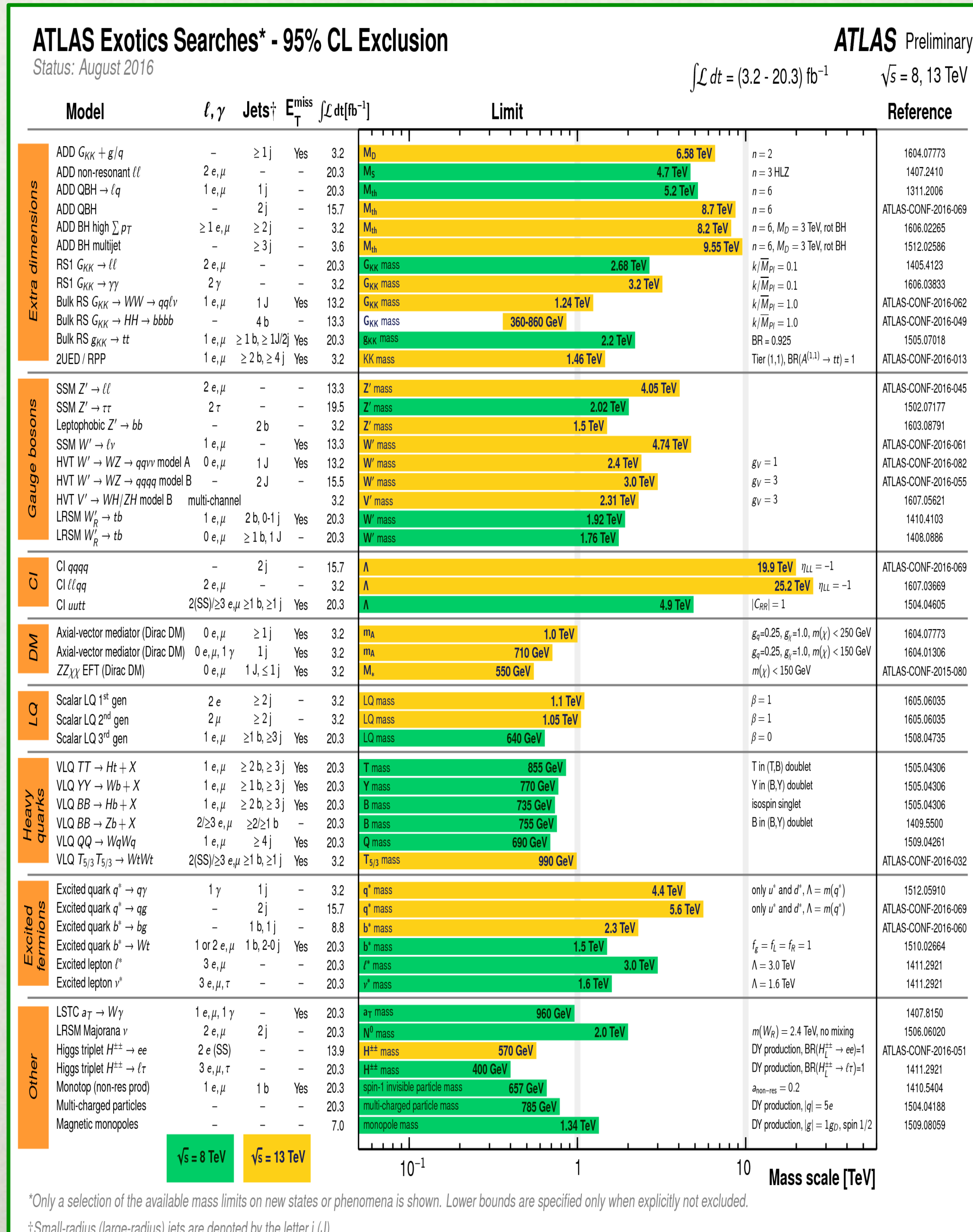




95% CL exclude scalar singlet with m<3 TeV in Unsupp. scenario, G_* with m<~1.2 TeV, HVT W' with m < ~2.5 TeV

Conclusions and outlook

- Intensive searches for **Dark Matter and new physics** at LHC Run2
- **No evidences** were found (…but it could be around the corner!)
- Several **limits improved** with 2015 and 2016 data, but a larger statistics is expected before the end of the year (**>30 fb^{-1}**)
- The high energy regime and amount of data promise good sensitivity to large scale physics and the opportunity to learn more about our universe



Thank you for your attention

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: August 2016

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}	$\int \mathcal{L}\, dt [fb^{-1}]$	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
	$\tilde q\tilde q$, $\tilde q \to q\tilde\chi^0_1$	0	2-6 jets	Yes	13.3	$\tilde q$ 1.35 TeV	$m(\tilde\chi^0_1)$<200 GeV, $m(1^{st}$ gen. $\tilde q)$=$m(2^{nd}$ gen. $\tilde q)$	ATLAS-CONF-2016-078
	$\tilde q\tilde q$, $\tilde q \to q\tilde\chi^0_1$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde q$ 608 GeV	$m(\tilde q)$-$m(\tilde\chi^0_1)$<5 GeV	1604.07773
	$\tilde g\tilde g$, $\tilde g \to q\bar q\tilde\chi^0_1$	0	2-6 jets	Yes	13.3	$\tilde g$ 1.86 TeV	$m(\tilde\chi^0_1)$=0 GeV	ATLAS-CONF-2016-078
	$\tilde g\tilde g$, $\tilde g \to qq\tilde\chi^{\pm}_1 \to qqW^{\pm}\tilde\chi^0_1$	0	2-6 jets	Yes	13.3	$\tilde g$ 1.83 TeV	$m(\tilde\chi^0_1)$<400 GeV, $m(\tilde\chi^{\pm})$=0.5($m(\tilde\chi^0_1)$+$m(\tilde g)$)	ATLAS-CONF-2016-078
	$\tilde g\tilde g$, $\tilde g \to qq(\ell\ell/\nu\nu)\tilde\chi^0_1$	3 e,μ	4 jets	-	13.2	$\tilde g$ 1.7 TeV	$m(\tilde\chi^0_1)$<400 GeV	ATLAS-CONF-2016-037
	$\tilde g\tilde g$, $\tilde g \to qqWZ\tilde\chi^0_1$	2 e,μ (SS)	0-3 jets	Yes	13.2	$\tilde g$ 1.6 TeV	$m(\tilde\chi^0_1)$ <500 GeV	ATLAS-CONF-2016-037
	GMSB ($\tilde\ell$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	$\tilde g$ 2.0 TeV		1607.05979
	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	$m(\tilde\chi^0_1)$<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	13.3	$\tilde g$ 1.8 TeV	$m(\tilde\chi^0_1)$>680 GeV, $c\tau$(NLSP)<0.1 mm, μ>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 × 10^{-4} eV, $m(\tilde g)$=$m(\tilde q)$=1.5 TeV	1502.01518
3rd gen. $\tilde g$ med.	$\tilde g\tilde g$, $\tilde g \to b\bar b\tilde\chi^0_1$	0	3 b	Yes	14.8	$\tilde g$ 1.89 TeV	$m(\tilde\chi^0_1)$=0 GeV	ATLAS-CONF-2016-052
	$\tilde g\tilde g$, $\tilde g \to t\bar t\tilde\chi^0_1$	0-1 e,μ	3 b	Yes	14.8	$\tilde g$ 1.89 TeV	$m(\tilde\chi^0_1)$=0 GeV	ATLAS-CONF-2016-052
	$\tilde g\tilde g$, $\tilde g \to b\bar t\tilde\chi^+_1$	0-1 e,μ	3 b	Yes	20.1	$\tilde g$ 1.37 TeV	$m(\tilde\chi^0_1)$<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde b_1\tilde b_1$, $\tilde b_1 \to b\tilde\chi^0_1$	0	2 b	Yes	3.2	$\tilde b_1$ 840 GeV	$m(\tilde\chi^0_1)$<100 GeV	1606.08772
	$\tilde b_1\tilde b_1$, $\tilde b_1 \to t\tilde\chi^{\pm}_1$	2 e,μ (SS)	1 b	Yes	13.2	$\tilde b_1$ 325-685 GeV	$m(\tilde\chi^0_1)$<150 GeV, $m(\tilde\chi^{\pm}_1)$= $m(\tilde\chi^0_1)$+100 GeV	ATLAS-CONF-2016-037
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to b\tilde\chi^{\pm}_1$	0-2 e,μ	1-2 b	Yes	4.7/13.3	$\tilde t_1$ 117-170 GeV; 200-720 GeV	$m(\tilde\chi^{\pm}_1)$ = 2$m(\tilde\chi^0_1)$, $m(\tilde\chi^0_1)$=55 GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to Wb\tilde\chi^0_1$ or $t\tilde\chi^0_1$	0-2 e,μ	0-2 jets/1-2 b	Yes	4.7/13.3	$\tilde t_1$ 90-198 GeV; 205-850 GeV	$m(\tilde\chi^0_1)$=1 GeV	1506.08616, ATLAS-CONF-2016-077
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to c\tilde\chi^0_1$	0	mono-jet	Yes	3.2	$\tilde t_1$ 90-323 GeV	$m(\tilde t_1)$-$m(\tilde\chi^0_1)$=5 GeV	1604.07773
	$\tilde t_1\tilde t_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde t_1$ 150-600 GeV	$m(\tilde\chi^0_1)$>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	13.3	$\tilde t_2$ 290-700 GeV	$m(\tilde\chi^0_1)$<300 GeV	ATLAS-CONF-2016-038
	$\tilde t_2\tilde t_2$, $\tilde t_2 \to \tilde t_1 + h$	1 e,μ	6 jets + 2 b	Yes	20.3	$\tilde t_2$ 320-620 GeV	$m(\tilde\chi^0_1)$=0 GeV	1506.08616
EW direct	$\tilde\ell_{L,R}\tilde\ell_{L,R}$, $\tilde\ell \to \ell\tilde\chi^0_1$	2 e,μ	0	Yes	20.3	$\tilde\ell$ 90-335 GeV	$m(\tilde\chi^0_1)$=0 GeV	1403.5294
	$\tilde\chi^+_1\tilde\chi^-_1$, $\tilde\chi^+_1 \to \tilde\ell\nu(\ell\tilde\nu)$	2 e,μ	0	Yes	20.3	$\tilde\chi^{\pm}_1$ 140-475 GeV	$m(\tilde\chi^0_1)$=0 GeV, $m(\tilde\ell,\tilde\nu)$=0.5($m(\tilde\chi^{\pm}_1)$+$m(\tilde\chi^0_1)$)	1403.5294
	$\tilde\chi^+_1\tilde\chi^-_1$, $\tilde\chi^+_1 \to \tilde\tau\nu(\tau\tilde\nu)$	2 τ	-	Yes	20.3	$\tilde\chi^{\pm}_1$ 355 GeV	$m(\tilde\chi^0_1)$=0 GeV, $m(\tilde\tau,\tilde\nu)$=0.5($m(\tilde\chi^{\pm}_1)$+$m(\tilde\chi^0_1)$)	1407.0350
	$\tilde\chi^{\pm}_1\tilde\chi^0_2 \to \tilde\ell_L\nu\tilde\ell_L\ell(\tilde\nu\nu)$, $\ell\tilde\nu\tilde\ell_L\ell(\tilde\nu\nu)$	3 e,μ	0	Yes	20.3	$\tilde\chi^{\pm}_1,\tilde\chi^0_2$ 715 GeV	$m(\tilde\chi^{\pm}_1)$=$m(\tilde\chi^0_2)$, $m(\tilde\chi^0_1)$=0, $m(\tilde\ell,\tilde\nu)$=0.5($m(\tilde\chi^{\pm}_1)$+$m(\tilde\chi^0_1)$)	1402.7029
	$\tilde\chi^{\pm}_1\tilde\chi^0_2 \to W\tilde\chi^0_1 Z\tilde\chi^0_1$	2-3 e,μ	0-2 jets	Yes	20.3	$\tilde\chi^{\pm}_1,\tilde\chi^0_2$ 425 GeV	$m(\tilde\chi^{\pm}_1)$=$m(\tilde\chi^0_2)$, $m(\tilde\chi^0_1)$=0, $\tilde\ell$ decoupled	1403.5294, 1402.7029
	$\tilde\chi^{\pm}_1\tilde\chi^0_2 \to W\tilde\chi^0_1 h\tilde\chi^0_1$, $h \to b\bar b/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde\chi^{\pm}_1,\tilde\chi^0_2$ 270 GeV	$m(\tilde\chi^{\pm}_1)$=$m(\tilde\chi^0_2)$, $m(\tilde\chi^0_1)$=0, $\tilde\ell$ decoupled	1501.07110
	$\tilde\chi^0_2\tilde\chi^0_3$, $\tilde\chi^0_{2,3} \to \tilde\ell_R\ell$	4 e,μ	0	Yes	20.3	$\tilde\chi^0_{2,3}$ 635 GeV	$m(\tilde\chi^0_2)$=$m(\tilde\chi^0_3)$, $m(\tilde\chi^0_1)$=0, $m(\tilde\ell,\tilde\nu)$=0.5($m(\tilde\chi^0_2)$+$m(\tilde\chi^0_1)$)	1405.5086
	GGM (wino NLSP) weak prod.	1 e,μ + γ	-	Yes	20.3	$\tilde W$ 115-370 GeV	$c\tau$<1 mm	1507.05493
	GGM (bino NLSP) weak prod.	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 $\tilde\chi^{\pm}_1$	Disapp. trk	1 jet	Yes	20.3	$\tilde\chi^{\pm}_1$ 270 GeV	$m(\tilde\chi^{\pm}_1)$-$m(\tilde\chi^0_1)$~160 MeV, $\tau(\tilde\chi^{\pm}_1)$=0.2 ns	1310.3675
	Direct $\tilde\chi^+_1\tilde\chi^-_1$ prod., long-lived $\tilde\chi^{\pm}_1$	dE/dx trk	-	Yes	18.4	$\tilde\chi^{\pm}_1$ 495 GeV	$m(\tilde\chi^{\pm}_1)$-$m(\tilde\chi^0_1)$~160 MeV, $\tau(\tilde\chi^{\pm}_1)$<15 ns	1506.05332
	Stable, stopped $\tilde g$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde g$ 850 GeV	$m(\tilde\chi^0_1)$=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	$m(\tilde\chi^0_1)$=100 GeV, τ>10 ns	1604.04520
	GMSB, stable $\tilde\tau$, $\tilde\chi^0_1 \to \tilde\tau(\tilde e,\tilde\mu)$+$\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde\chi^0_1$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde\chi^0_1 \to \gamma\tilde G$, long-lived $\tilde\chi^0_1$	2 γ	-	Yes	20.3	$\tilde\chi^0_1$ 440 GeV	1<$\tau(\tilde\chi^0_1)$<3 ns, SPS8 model	1409.5542
	$\tilde g\tilde g$, $\tilde\chi^0_1 \to eev/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde\chi^0_1$ 1.0 TeV	7 <$c\tau(\tilde\chi^0_1)$< 740 mm, $m(\tilde g)$=1.3 TeV	1504.05162
	GGM $\tilde g\tilde g$, $\tilde\chi^0_1 \to Z\tilde G$	displ. vtx + jets	-	-	20.3	$\tilde\chi^0_1$ 1.0 TeV	6 <$c\tau(\tilde\chi^0_1)$< 480 mm, $m(\tilde g)$=1.1 TeV	1504.05162
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	λ'_{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
	$\tilde\chi^+_1\tilde\chi^-_1$, $\tilde\chi^+_1 \to W\tilde\chi^0_1$, $\tilde\chi^0_1 \to ee\nu, e\mu\nu, \mu\mu\nu$	4 e,μ	-	Yes	13.3	$\tilde\chi^{\pm}_1$ 1.14 TeV	$m(\tilde\chi^0_1)$>400GeV, $\lambda_{12k}\neq0$ (k = 1, 2)	ATLAS-CONF-2016-075
	$\tilde\chi^+_1\tilde\chi^-_1$, $\tilde\chi^+_1 \to W\tilde\chi^0_1$, $\tilde\chi^0_1 \to \tau\tau\nu_e, e\tau\nu_\tau$	3 e,μ + τ	-	Yes	20.3	$\tilde\chi^{\pm}_1$ 450 GeV	$m(\tilde\chi^0_1)$>0.2×$m(\tilde\chi^{\pm}_1)$, $\lambda_{133}\neq0$	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
	$\tilde g\tilde g$, $\tilde g \to qq\tilde\chi^0_1$, $\tilde\chi^0_1 \to qqq$	0	4-5 large-R jets	-	14.8	$\tilde g$ 1.55 TeV	$m(\tilde\chi^0_1)$=800 GeV	ATLAS-CONF-2016-057
	$\tilde g\tilde g$, $\tilde g \to \tilde t_1 t$, $\tilde t_1 \to bs$	2 e,μ (SS)	0-3 b	Yes	13.2	$\tilde g$ 1.3 TeV	$m(\tilde t_1)$<750 GeV	ATLAS-CONF-2016-037
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to bs$	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	-	20.3	$\tilde t_1$ 0.4-1.0 TeV	BR($\tilde t_1 \to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde c \to c\tilde\chi^0_1$	0	2 c	Yes	20.3	$\tilde c$ 510 GeV	$m(\tilde\chi^0_1)$<200 GeV	1501.01325

10^{-1} — 1 — Mass scale [TeV]

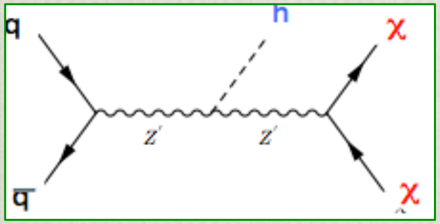
*Only a selection of the available mass limits on new states or phenomena is shown.

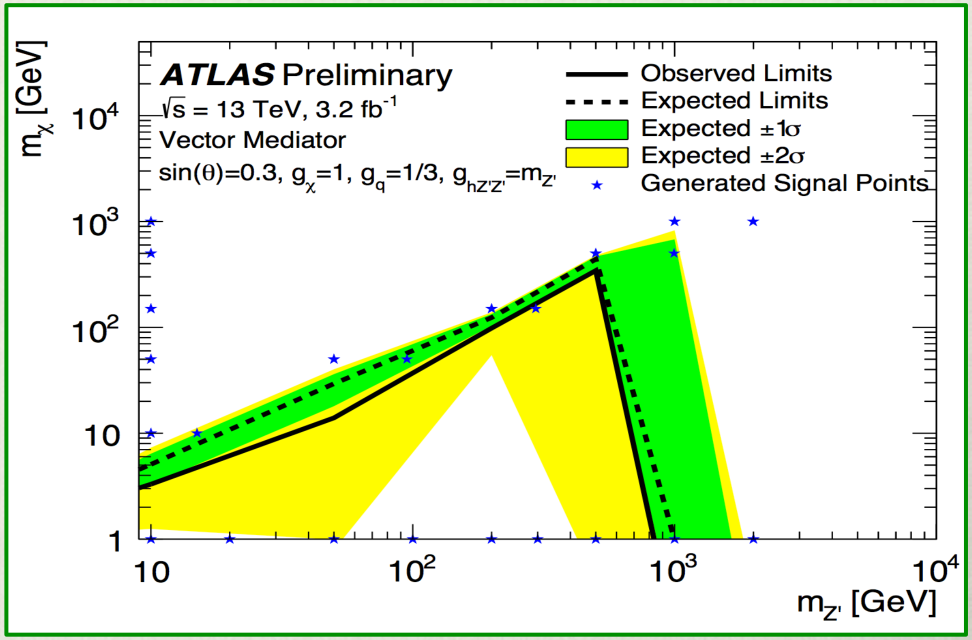
Backup slides

Mono-H($H \rightarrow bb$) search (ATLAS-CONF-2016-019)

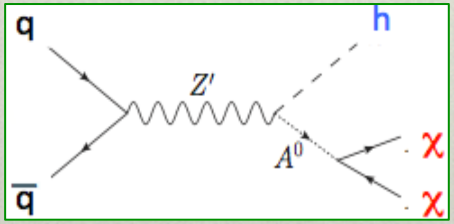
- **More complex signature but more statistics than $H \rightarrow \gamma\gamma$)**: high p_T bbbar (resolved or merged in a large R jet) + E_T^{Miss} + p_T^{Miss} +lepton veto
- **Backgrounds**: Z+jets, W+jets, ttbar

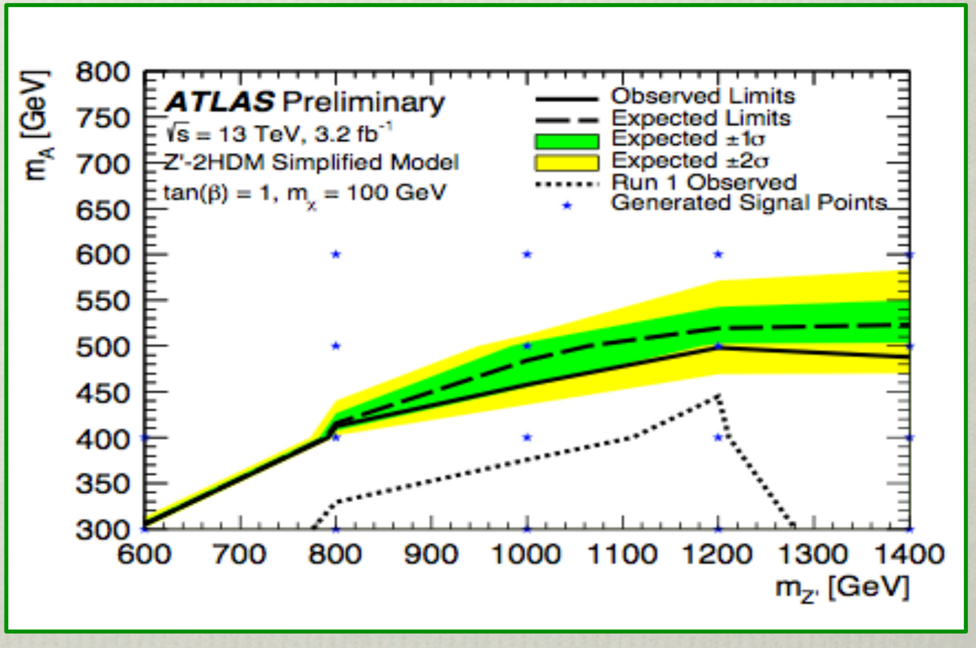
95%CL Exclusion limits in simplified Models: lepto-phobic Z' vector mediator $(U1)_B$, couplings $g_q=1/3$ and $g_\chi=1$, $\sin\theta = 0.3$, exclude $m_{Z'} < 900$ GeV in $(m_{Z'},m_\chi)$ plane





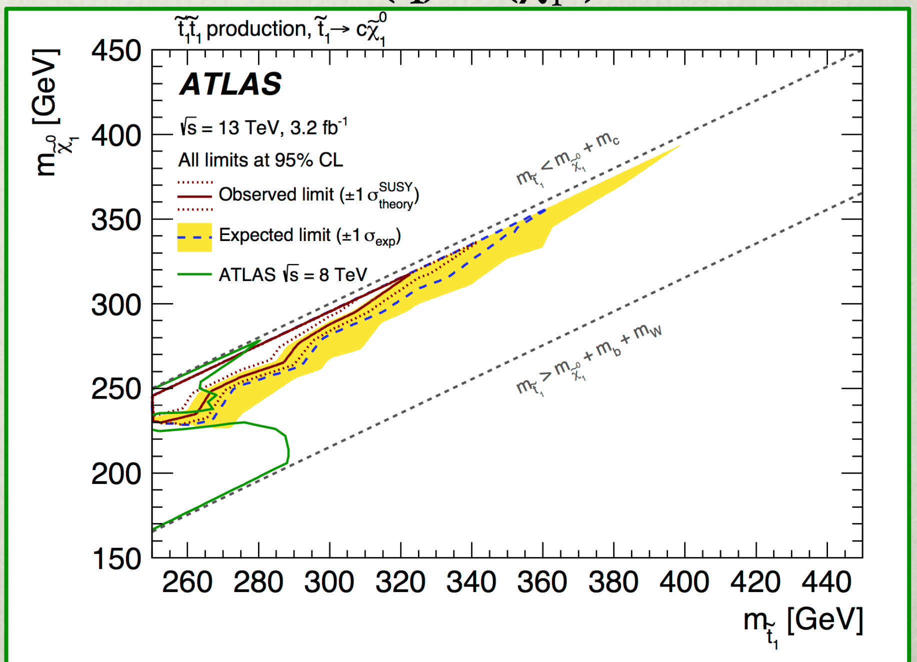
95%CL Exclusion limits in simplified Models: Z' – 2HDM with 2 Higgs doublets, $\tan\beta=1$, $Z' \rightarrow hA$, psudoscalar $A \rightarrow \chi\chi$, exclude $m_A <$ 500 GeV in $(m_{Z'},m_A)$ plane for a wide interval of $m_{Z'}$





Interpretation of Mono-X searches in other New Physics scenarios (arxiv.1604.01306v1,arxiv.1604.07773v1)

- Mono-(Photon,Jet) interpretation within ADD (Arkani-Hamed, Dimopoulos, Dvali) Large Extra Space Dimensions → 95% CL lower limits on M_D, fundamental Planck scale in 4+n dimensions:
  - ✓ M_D > 6.58 TeV for n=2; M_D > 4.31 TeV for n=6 (Mono-Jet)
  - ✓ M_D > 2.3 TeV for n=2; M_D > 2.8 TeV for n=6 (Mono-Photon)
- Mono-Jet interpretation within squark production model in SUSY compressed scenarios → squark pair production with $\Delta m = m(\tilde{q})-m(\tilde{\chi}_1^0)$ small:
  - ✓ Stop $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$
  - ✓ Sbottom $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$
  - ✓ Squark $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ (q=u,d,s,c)



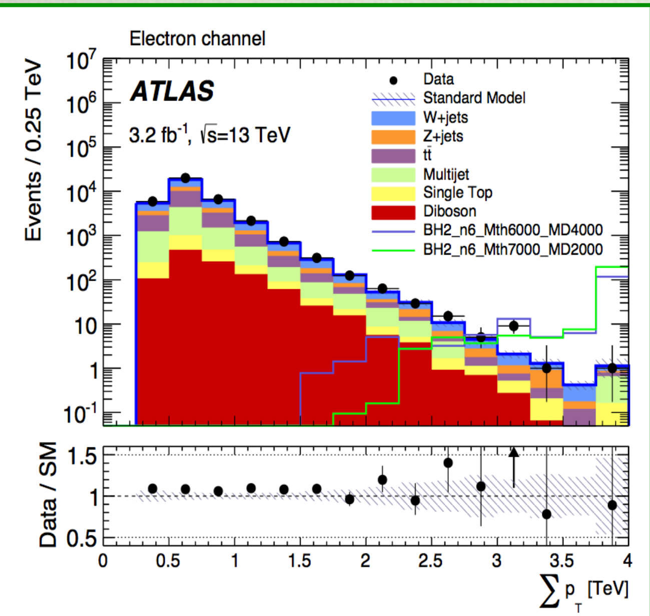
TeV-scale gravity and QBH

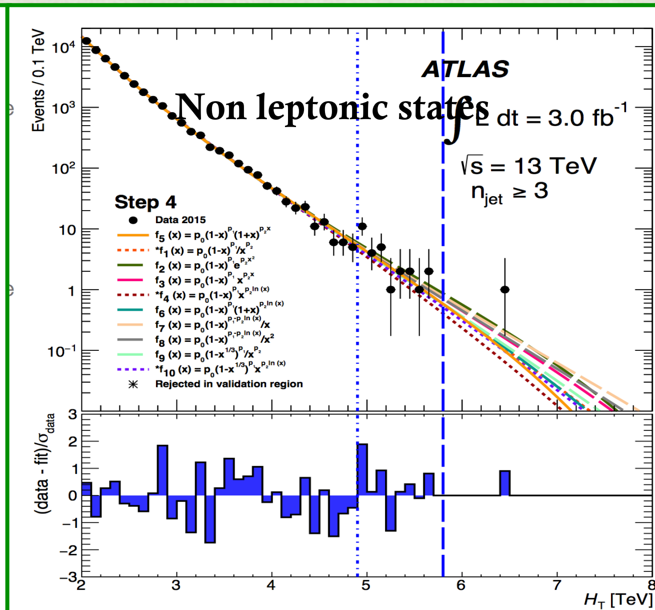
(JHEP03 (2016) 026,ATLAS-CONF-2016-006,ATLAS-CONF-2016-069, arXiv:1607.08079,JHEP06(2016)041)

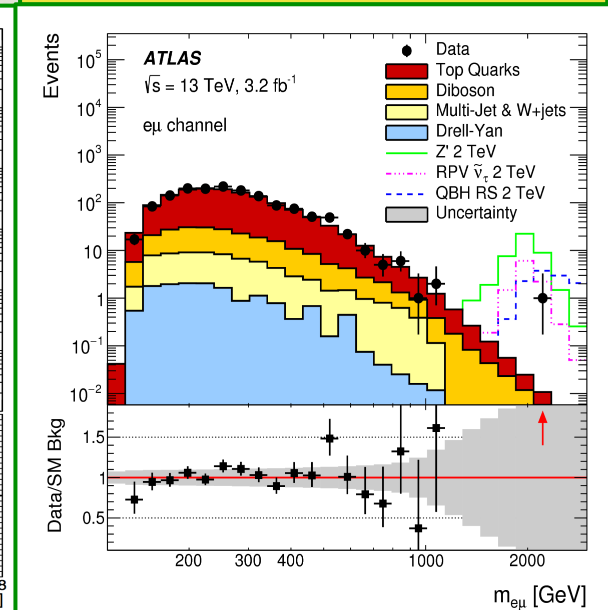
- **Models in 4+n dimensions:** allow strong gravity at a fundamental gravitational scale M_D ~ EW scale
  ➔ production of microscopic black holes above fundamental gravity scale M_D
- **Signature:** semi-classical microscopic BH equally produce any particle ➔high multiplicity final states,
  QBH (scale ~ M_D @TeV) are instead dominated by 2-bodies final states at the LHC
- **Main Background:** W/Z+jets, QCD multi-jets, ttbar (depending on the final state)

Multi-particle final state: l+jets or multi-jets

2-body final state with different flavour leptons





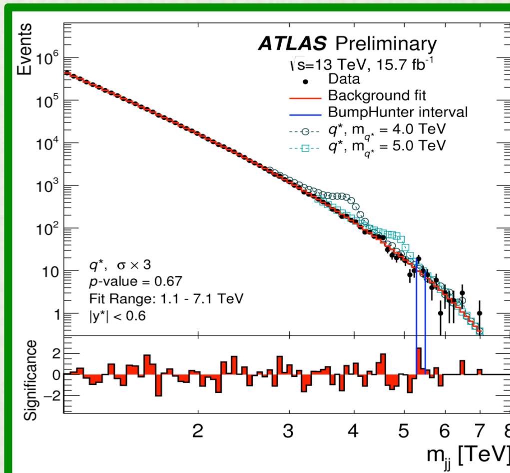


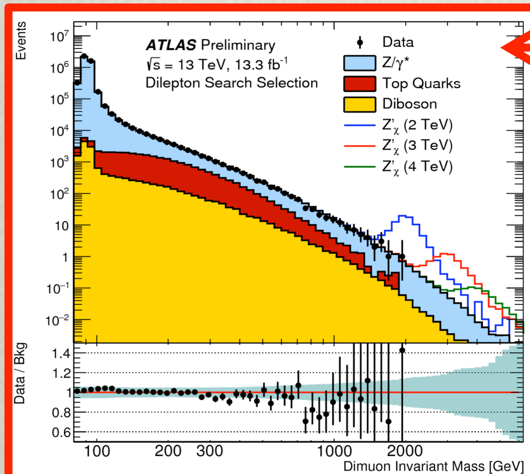
95% CL Exclusion limits on semi-classical BH with n=6 @M_D=5 TeV: exclude M < 7.4 TeV (l+jets) and M < 9 TeV (multi-jets)

95% CL Exclusion limits on QBH with n=6 ADD: m_{QBH} > 4.5 TeV (> 8.7 for dijet analysis, > 6.2 for γ-jet analysis)

Limits on new physics from high mass di-jet and angular distribution (ATLAS-CONF-2016-069)

Model	95% CL Exclusion limit Observed 13 TeV	Expected 13 TeV
Quantum black holes, ADD (BlackMax generator)	8.7 TeV	8.7 TeV
Excited quark	5.6 TeV	5.5 TeV
W'	2.9 TeV	3.3 TeV
W^*	3.3 TeV	3.3 TeV
Contact interactions (η_{LL} =+1)	12.6 TeV	13.7 TeV
Contact interactions (η_{LL} =-1)	19.9 TeV	23.7 TeV

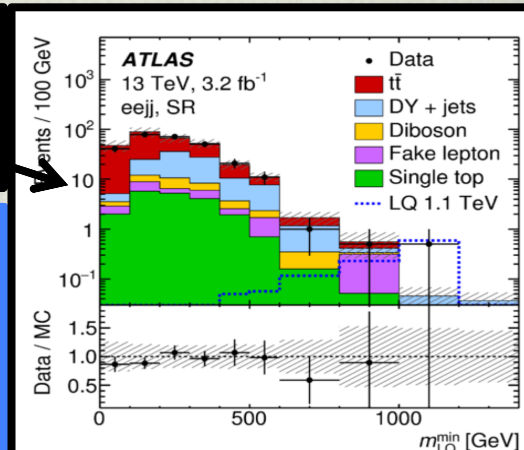




Limits on new physics from di-lepton (ATLAS-CONF-2016-045)

- ✓ Benchmark Sequential Standard Model: Z'_{SSM} M>4.05 TeV
- ✓ Grand Unified E6 - motivated models: Z'_{E6} M>3.36-3.66 TeV

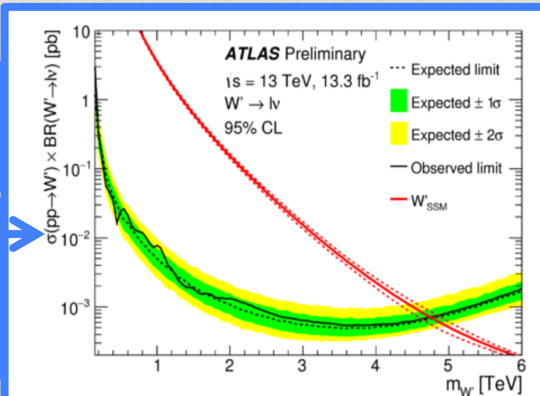
Limits on scalar Leptoquarks (LQ): GUTs & models with substructure (arXiv:1605.06035)



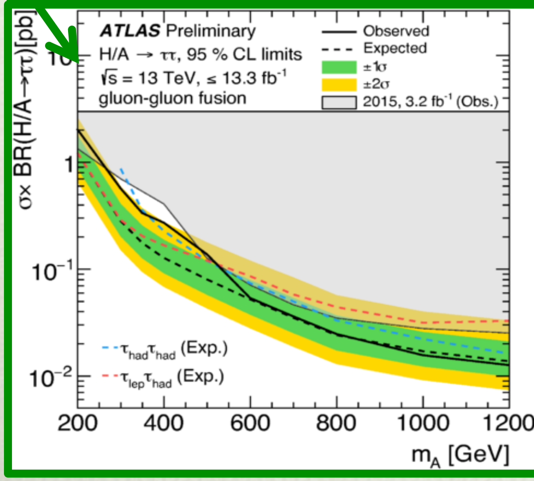
- ✓ m_{LQ1}>1.10 TeV ; m_{LQ2}>1.05 TeV

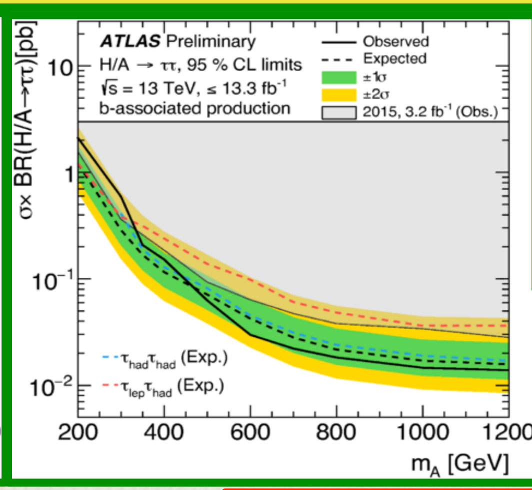
Limits on new physics from 1 lepton+E_T^{Miss} (ATLAS-CONF-2016-061)

- ✓ Benchmark Sequential Standard Model: W'_{SSM}: M>4.74 TeV



Beyond Standard Model Higgs: MSSM H/A → ττ (ATLAS-CONF-2016-085)



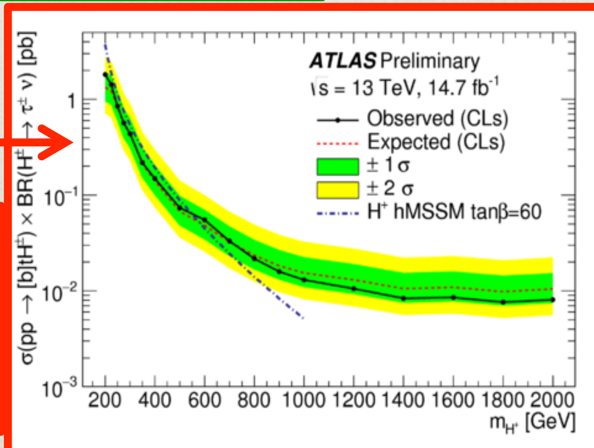


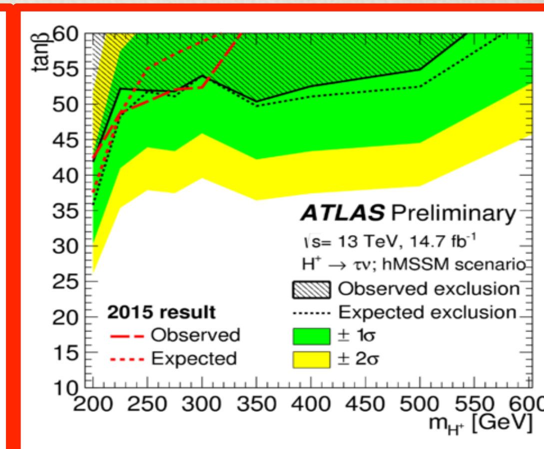
Model independent upper limits on σxBR:

- ✓ ggH limits: 2.0-0.013 pb for m_A=200-1200 GeV
- ✓ bbH limits: 2.1-0.014 pb for m_A=200-1200 GeV

Beyond Standard Model Higgs: $H^\pm \rightarrow \tau\nu$ (ATLAS-CONF-2016-088)

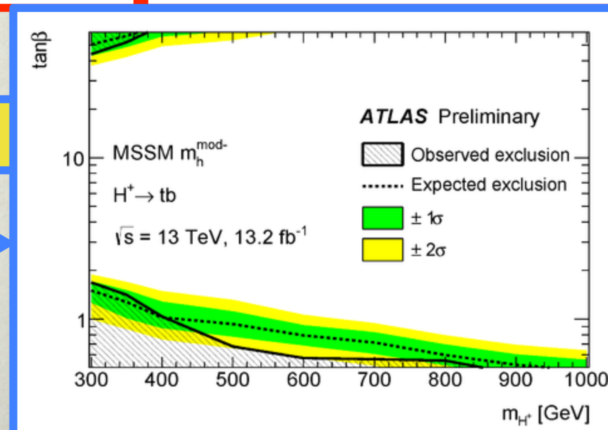
- ✓ Limits on σxBR : 2.0-0.008 pb for $m_{H\pm}$ 200-2000 GeV
- ✓ 95%CL exclusion in hMSSM: $\tan\beta$ >42-60 for $m_{H\pm}$ 200-540 GeV





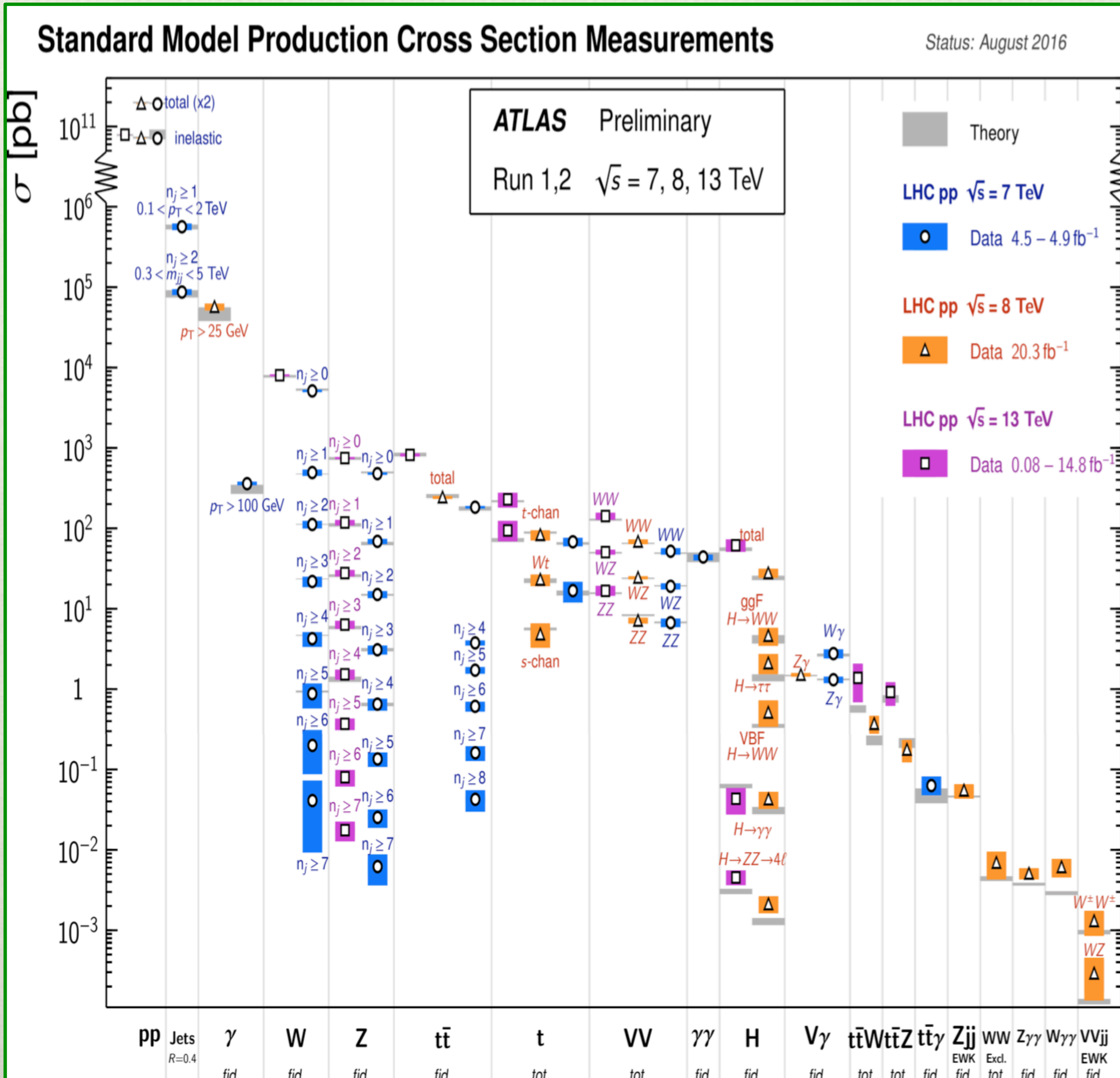
Beyond Standard Model Higgs: $H^\pm \rightarrow tb$ (ATLAS-CONF-2016-089)

95%CL exclusion in MSSM m_h^{mod-}:
$\tan\beta$ <1.7-0.5 @ $m_{H\pm}$ = 300-855 GeV

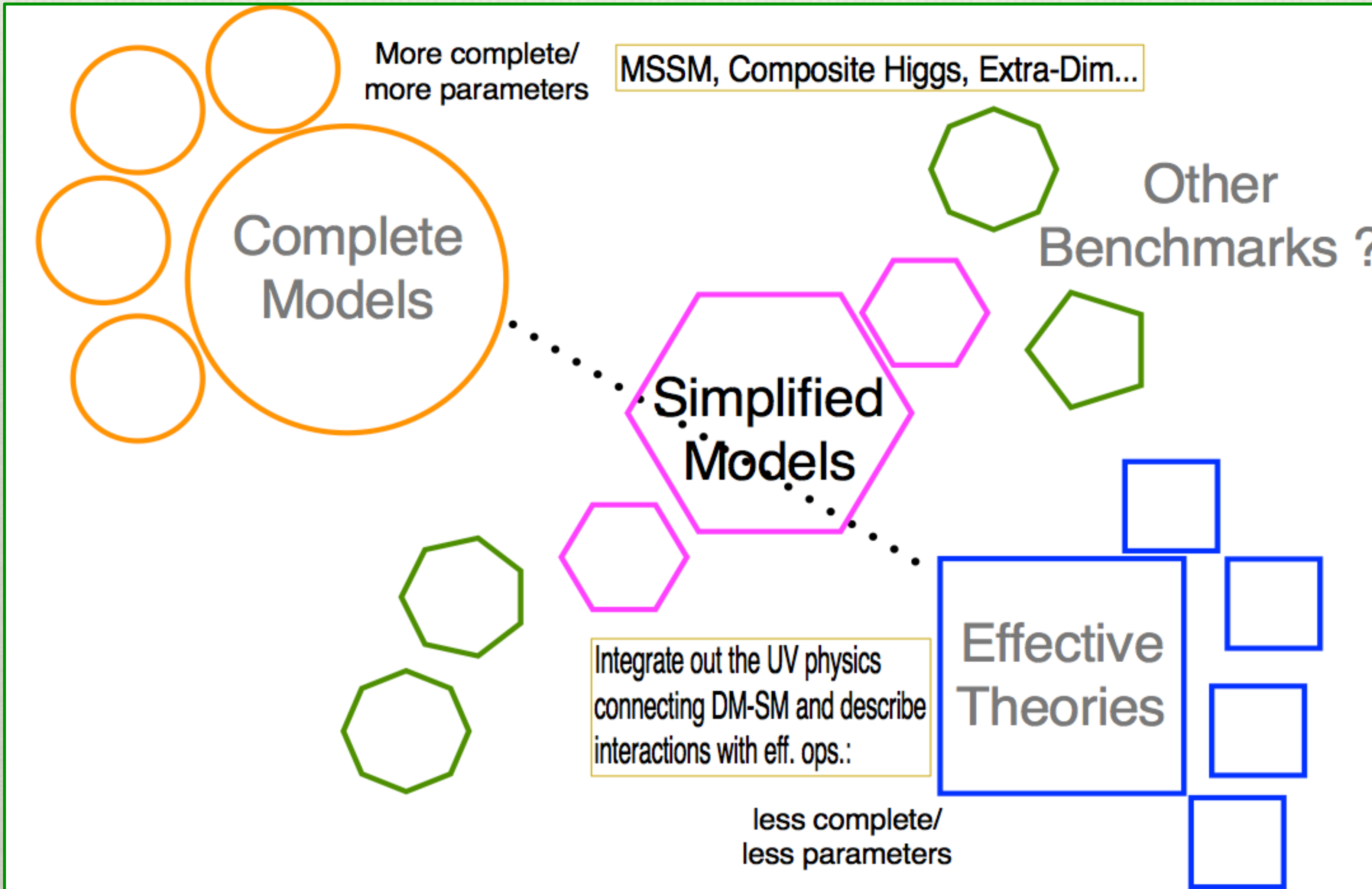


SM Measurements

- Impressive agreement between data and theory up to NNLO + NNLL
- SM cross section measurements: 7, 8, 13 TeV
- Inclusive Jet cross sections shows that QCD works well and fits data over 10 order of magnitude



DM Models



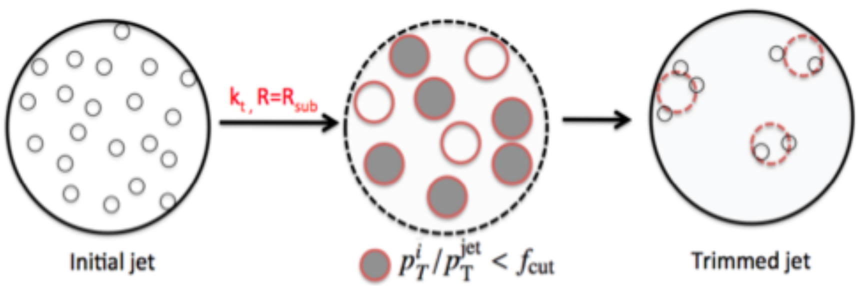
More complete/
more parameters
MSSM, Composite Higgs, Extra-Dim...
Complete
Models
Other
Benchmarks ?
Simplified
Models
Effective
Theories
Integrate out the UV physics
connecting DM-SM and describe
interactions with eff. ops.:
less complete/
less parameters

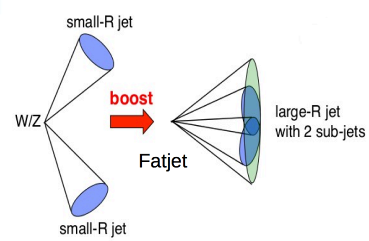
Large R jets and W/Z (had) tagging

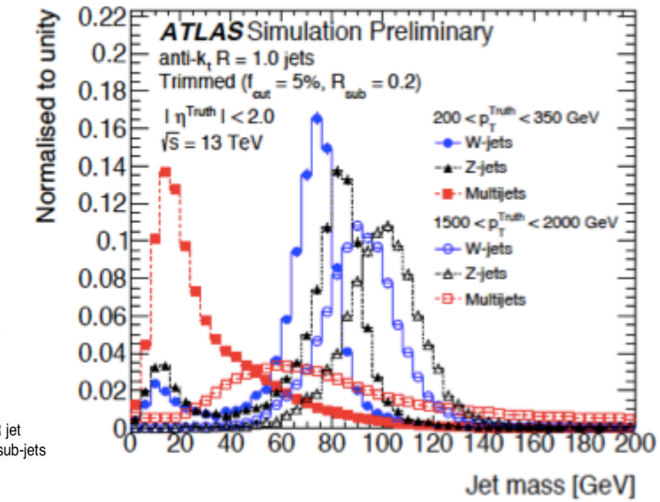
Large R jets provide efficient reconstruction of massive boosted objects whose decay products are sufficiently collimated

Trimming: recluster kt subjects, remove those with pTi/pTjet<f_{cut}

- ✧ Improve resolution of jet mass of W/Z vs multijets
- ✧ No dependence of jet mass vs Npv after trimming

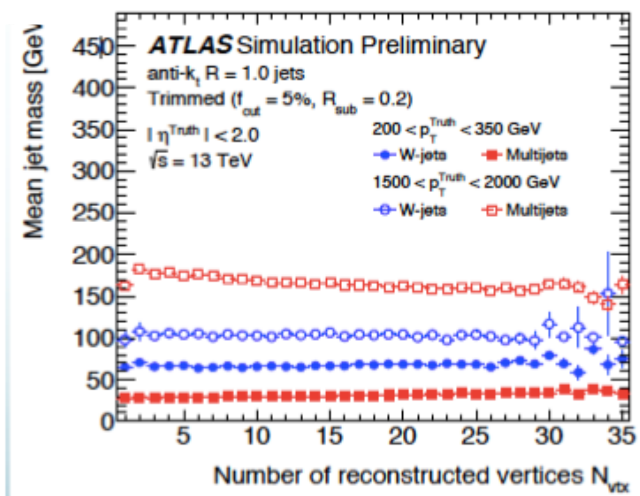




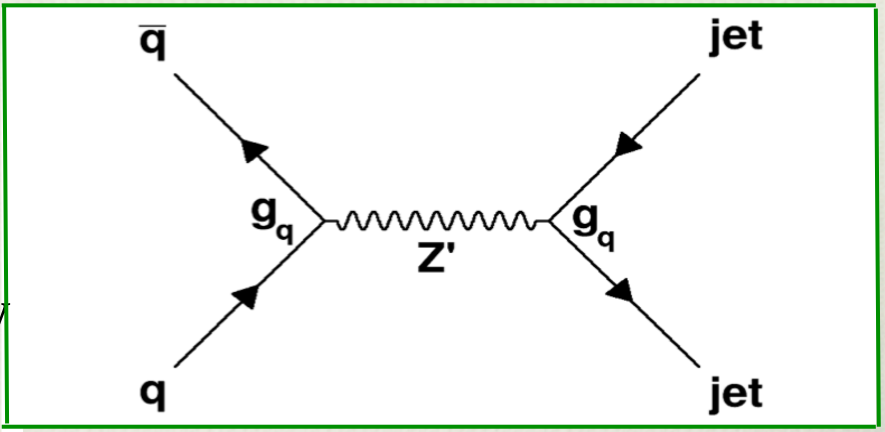


Criteria adopted in mono-W/Z (had):

- ✧ Large R-jets: Antikt with R=1
- ✧ Trimmed with R_{sub}=0,2, f_{cut}=0.05
- ✧ Using pT dependent selection on jet mass and jet substructure variable D2 that selects jets with 2 concentrations of energy
- ✧ D2 selection provides constant efficiency of 50% for W/Z



Di-jet resonances searches



Look for resonance in dijet spectrum

- ➢ More sensitive than mono-X searches over wider range of mediator masses.
- ➢ But an observed excess not necessarily related to DM (Excited quarks,new heavy gauge bosons,quantum black holes and contact interaction can be probed)

Three search strategies

1) High mass dijet search

- ✓ High rate -> high threshold required
- ✓ Probe mediator mass > 1.5 TeV

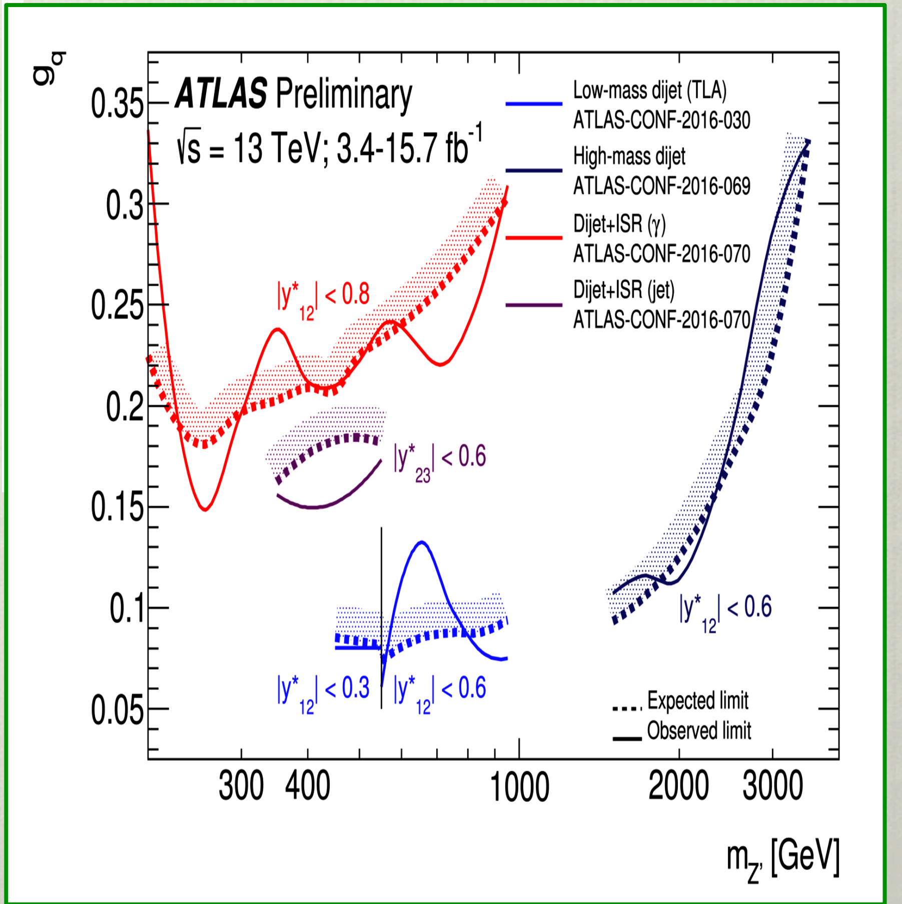
(ATLAS-CONF 2016-069)

2) Low mass dijet search performed with trigger objects

(ATLAS-CONF 2016-030)

3) Select ISR photon or jet to probe lower Masses avoiding high jet trigger thresholds

(ATLAS-CONF 2016-070)



SUSY models

SUSY breaking
Gravity, Gauge, Anomaly,
Dilaton/Moduli, Mirage, Gaugino,
D-term, Z-prime, …

R-Parity conservation

SUSY models possibly with
extra matter/gauge bosons

NMSSM, USSM,
μνSSM, E6SSM,
PQNMSSM,…

Various forms of
SUSY spectra

MSSM, mSUGRA,
NUHM, Natural, Split,
Compressed, Stealth, …

LSP?

Neutralino, SM,
Gravitino, Axino, …

Transverse mass definition

Transverse mass m_T

$$m_T^2(\mathbf{p}_T^1, \mathbf{p}_T^2) = [E_T^1 + E_T^2]^2 - [\mathbf{p}_T^1 + \mathbf{p}_T^2]^2$$

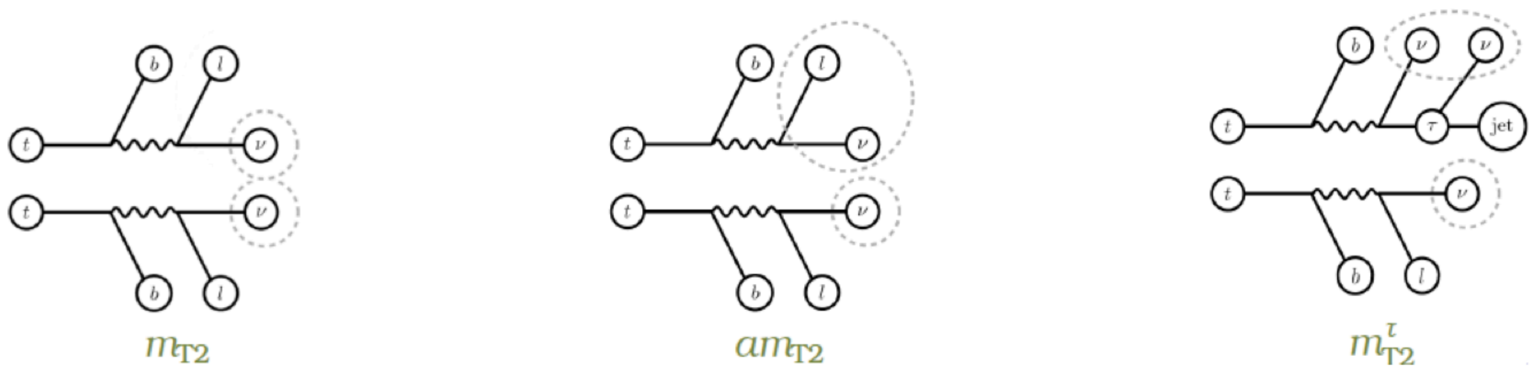
- $m_T \equiv m_T(\ell, E_T^{miss}) = \sqrt{2 p_T^\ell E_T^{miss}[1 - \cos\Delta\phi(\mathbf{p}_T^\ell, \mathbf{p}_T^{miss})]}$ bounded by m_W: reduce $WW, Wt, t\bar{t}$

Stransverse mass m_{T2}

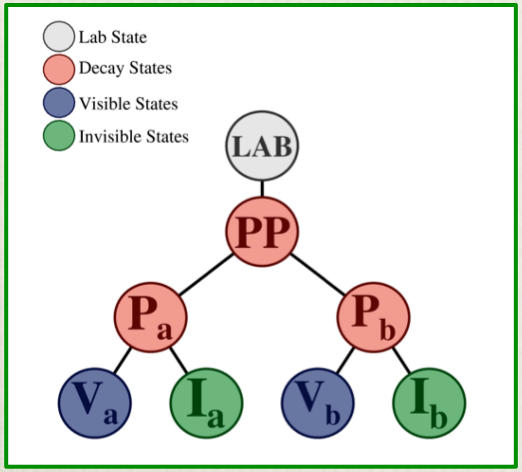
- generalization of m_T to pair decay with final state consisting of 2 visible objects and E_T^{miss}

$$m_{T2}(\mathbf{p}_T^1, \mathbf{p}_T^2, \mathbf{q}_T) = \min_{\mathbf{q}_T^1 + \mathbf{q}_T^2 = \mathbf{q}_T} \left\{ \max[m_T(\mathbf{p}_T^1, \mathbf{q}_T^1), m_T(\mathbf{p}_T^2, \mathbf{q}_T^2)] \right\}$$

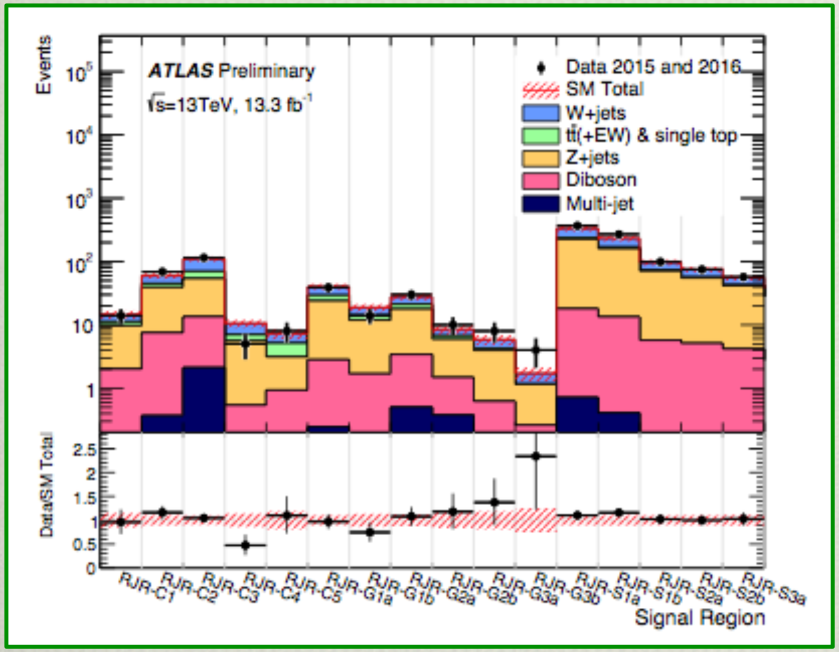
- $m_{T2} \equiv m_{T2}(\mathbf{p}_T^{l_1}, \mathbf{p}_T^{l_2}, \mathbf{p}_T^{miss})$ bounded by m_W: reduce $WW, Wt, t\bar{t} \to 2\ell$
- am_{T2} bounded by m_t: reduce $t\bar{t} \to 2\ell$ with a lost lepton
- m_{T2}^τ bounded by m_W: reduce $t\bar{t} \to \ell\tau^{had}$



RJigsaw



- **Recusive Jigsaw Reconstruction (RJR) technique**: method used as a basis to define the kinematic variables on an event-by-event basis -> given external constraints on the invisible system, exploits minimizations of the masses of intermediate particle states with respect to unknown quantities.



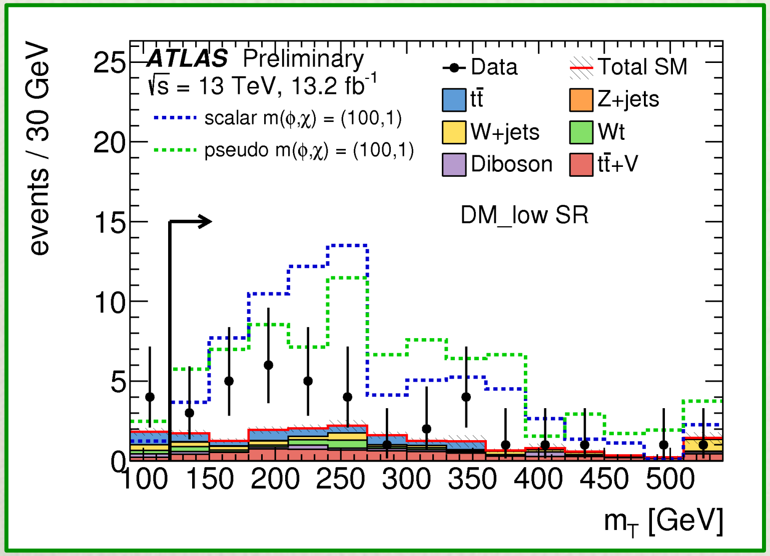
- The RJR algorithm fix rules for **resolving combinatorics**

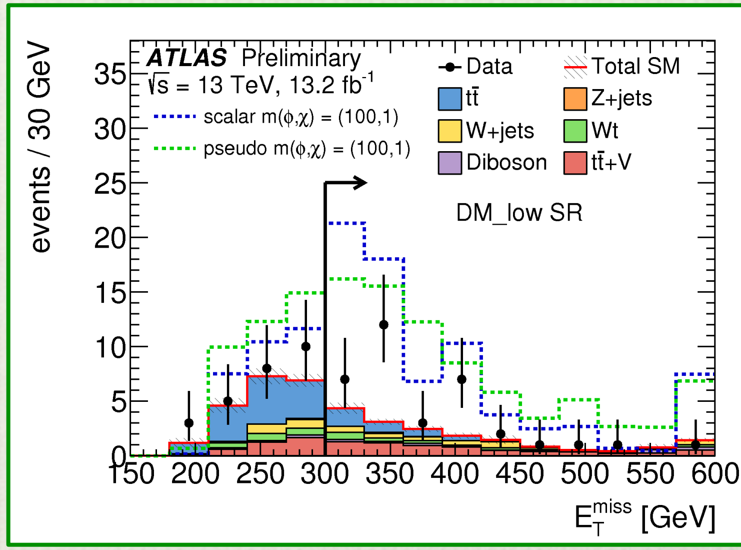
- A four-momentum hypothesis is assigned to each invisible state. The **RJR variable** construction involves, for each level in the decay tree, kinematic variables in the rest frame

- For the correct decay tree topology, variables from different rest frames should encode different information

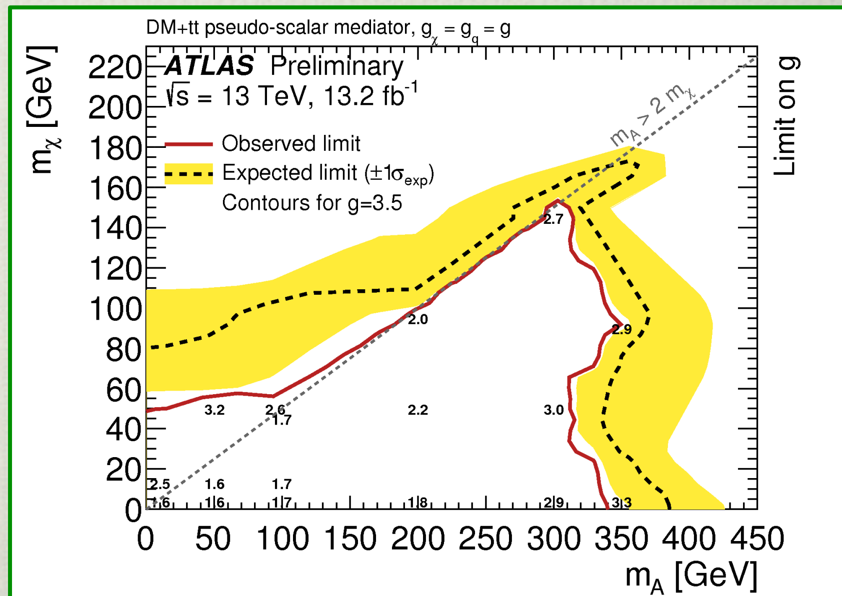
(ATLAS-CONF-2016-078)

3rd Generation: Stop decays – excess in 1 lepton channel (ATLAS-CONF-2016-050)



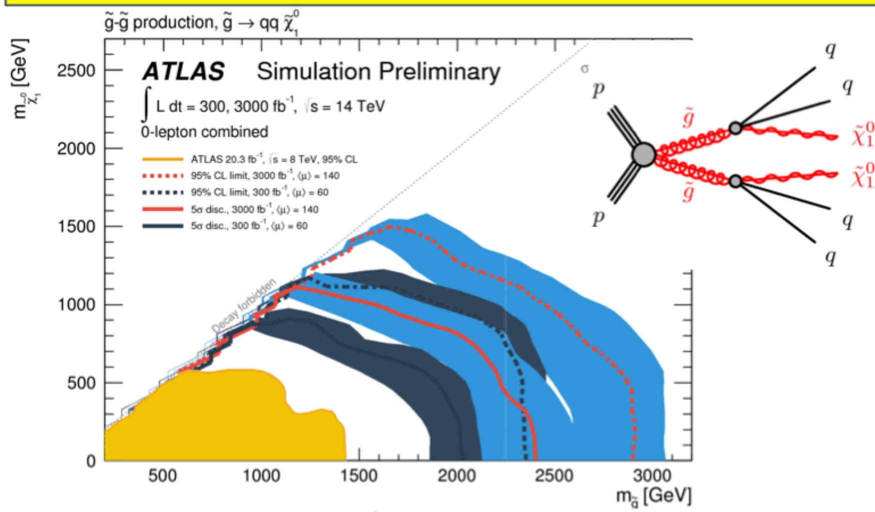


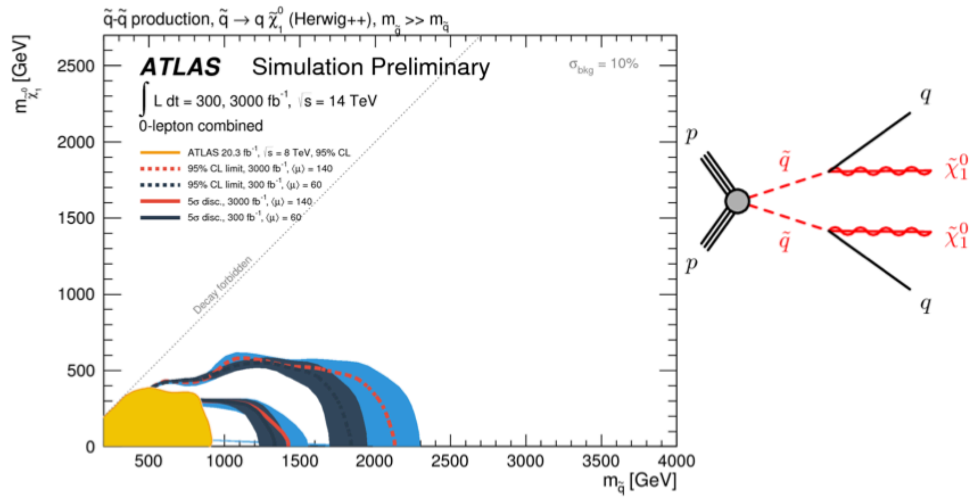
Signal region	SR1	tN_high	bC2x_diag	bC2x_med	bCbv	DM_low	DM_high
Observed	37	5	37	14	7	35	21
Total background	24 ± 3	3.8 ± 0.8	22 ± 3	13 ± 2	7.4 ± 1.8	17 ± 2	15 ± 2
$t\bar{t}$	8.4 ± 1.9	0.60 ± 0.27	6.5 ± 1.5	4.3 ± 1.0	0.26 ± 0.18	4.2 ± 1.3	3.3 ± 0.8
W+jets	2.5 ± 1.1	0.15 ± 0.38	1.2 ± 0.5	0.63 ± 0.29	5.4 ± 1.8	3.1 ± 1.5	3.4 ± 1.4
Single top	3.1 ± 1.5	0.57 ± 0.44	5.3 ± 1.8	5.1 ± 1.6	0.24 ± 0.23	1.9 ± 0.9	1.3 ± 0.8
$t\bar{t}+V$	7.9 ± 1.6	1.6 ± 0.4	8.3 ± 1.7	2.7 ± 0.7	0.12 ± 0.03	6.4 ± 1.4	5.5 ± 1.1
Diboson	1.2 ± 0.4	0.61 ± 0.26	0.45 ± 0.17	0.42 ± 0.20	1.1 ± 0.4	1.5 ± 0.6	1.4 ± 0.5
Z+jets	0.59 ± 0.54	0.03 ± 0.03	0.32 ± 0.29	0.08 ± 0.08	0.22 ± 0.20	0.16 ± 0.14	0.47 ± 0.44
$t\bar{t}$ NF	1.03 ± 0.07	1.06 ± 0.15	0.89 ± 0.10	0.95 ± 0.12	0.73 ± 0.22	0.90 ± 0.17	1.01 ± 0.13
W+jets NF	0.76 ± 0.08	0.78 ± 0.08	0.87 ± 0.07	0.85 ± 0.06	0.97 ± 0.12	0.94 ± 0.13	0.91 ± 0.07
Single top NF	1.07 ± 0.30	1.30 ± 0.45	1.26 ± 0.31	0.97 ± 0.28	–	1.36 ± 0.36	1.02 ± 0.32
$t\bar{t}+W/Z$ NF	1.43 ± 0.21	1.39 ± 0.22	1.40 ± 0.21	1.30 ± 0.23	–	1.47 ± 0.22	1.42 ± 0.21
p_0 (σ)	0.012 (2.2)	0.26 (0.6)	0.004 (2.6)	0.40 (0.3)	0.50 (0)	0.0004 (3.3)	0.09 (1.3)
$N^{\rm limit}_{\rm non-SM}$ exp. (95% CL)	$12.9^{+5.5}_{-3.8}$	$5.5^{+2.8}_{-1.1}$	$12.4^{+5.4}_{-3.7}$	$9.0^{+4.2}_{-2.7}$	$7.3^{+3.5}_{-2.2}$	$11.5^{+5.0}_{-3.4}$	$9.9^{+4.6}_{-2.9}$
$N^{\rm limit}_{\rm non-SM}$ obs. (95% CL)	26.0	7.2	27.5	9.9	7.2	28.3	15.6

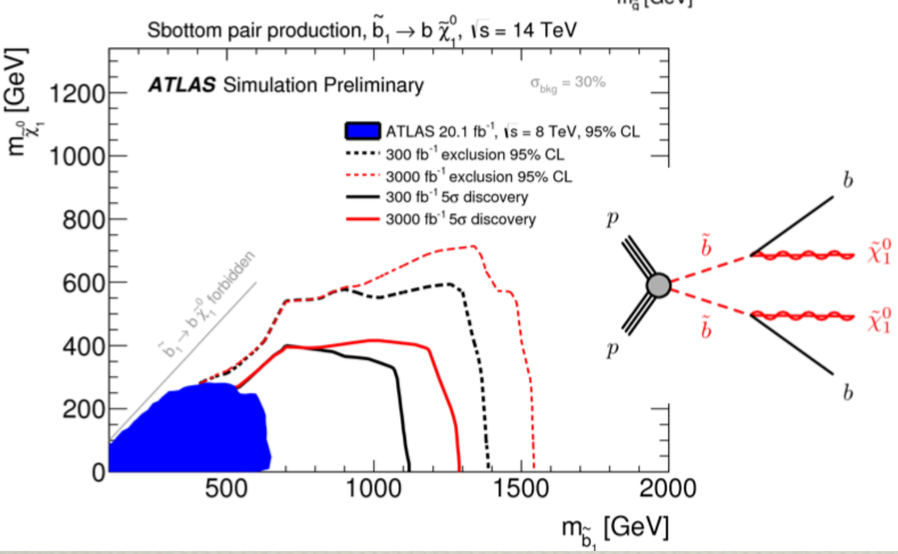


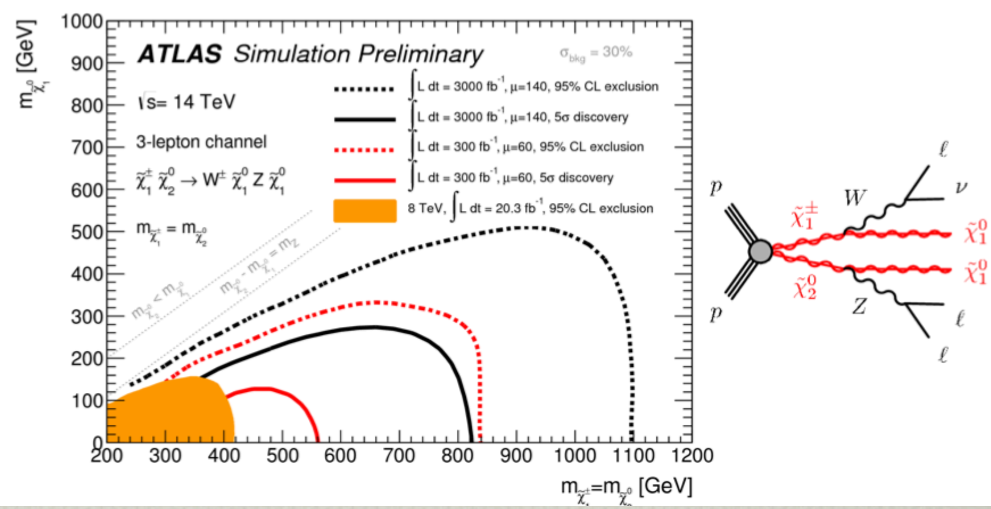
SUSY prospects (ATLAS-PHYS-PUB-2014-010)

- ATLAS studied long term prospects for the (HL-)LHC with 300, 3000 fb^{-1}@14 TeV
- Discovery potential up **to 2.5 TeV gluinos, 1.3 TeV squarks/sbottom and 800 GeV Electroweakinos**



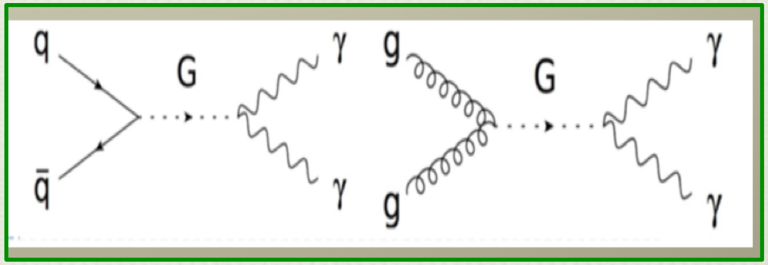






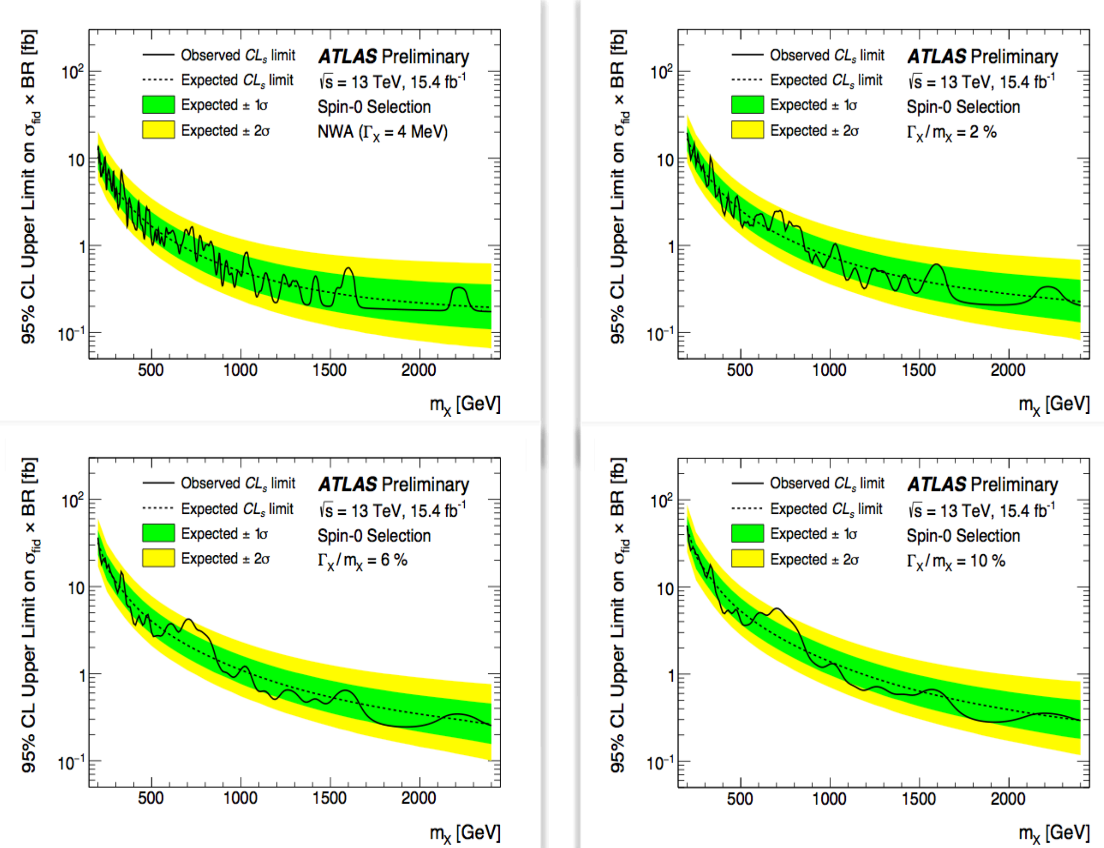
Di-photon models

- Spin 0 - Extended Higgs sector?
  - Example: 2HDM
  - 5 physical states: h^0, H^0, A^0, $H^\pm$
    - scalars and/or pseudo-scalars can have sizable BR to di-photons
- Spin 2: Randall-Sundrum graviton?
  - predicts tower of Kaluza-Klein (KK) graviton excitations with first states at TeV mass scale
  - Phenomenology
    - m_{G*}: mass of lightest KK excitation
    - κ/M_{pl}: dimensionless coupling to SM fields
      - κ: curvature scale of extra dimension
      - M_{pl}: reduced Planck scale



- *Hundred's of theory papers*
  - *cascading heavy quarks, new gauge bosons Z'+X, quirks, hidden valleys? ...*
- *Mostly about a new heavy resonance:*
  - *Dark matter mediators, technipions, Goldstones, Axions, Radions/dilatons, gravitons/any spin 2, Higgs bosons, ...*
- *Some SUSY possibilities*
  - *enhanced MSSM, sneutrino in RPV, sgoldstinos and other SUSY, ...*

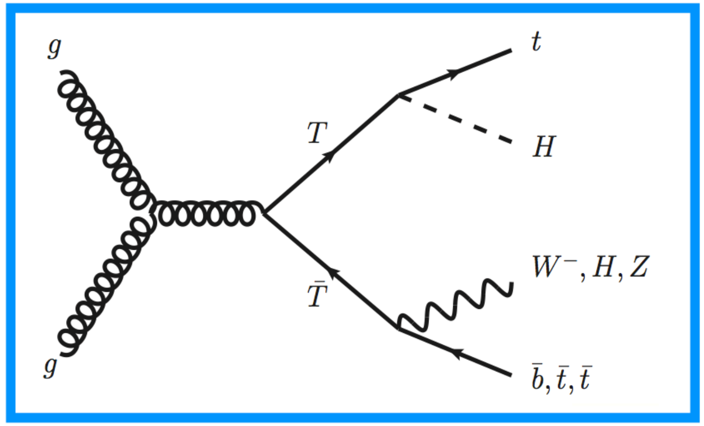
Di-photon new limits



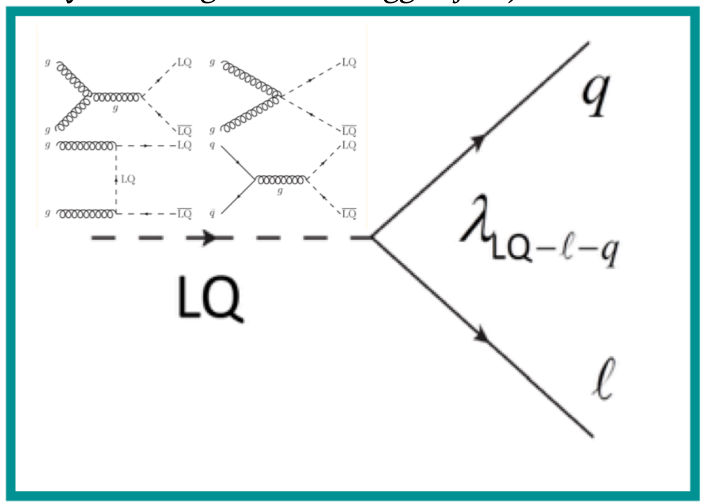
Upper limits on σxBR in 2 photons of a spin-0 particle as a function of its mass, for different values of the width

Vector-like quarks, Leptoquarks, simple SM extension models

- Compositeness models remain among the few naturally motivated models not yet excluded. One prediction is **vector-like quarks**
  - Couple to 3rd generation quarks
  - Permit flavour-changing neutral current decays
- Second potential consequence (also consequence of GUTs) is **leptoquarks**
  - Essentially fill in the holes of the SU(5) matrix. Mediate interactions between leptons & quarks of same generation.
  - Pair-produced at LHC; decay gives lq
- Another GUT consequence is additional standard-model like **heavy vector bosons**, W' and Z'
  - Simplest are "sequential standard model" SSM: same couplings as SM W and Z with larger masses



(pair production of up-type vector quarks T to Wb, Zt, and Ht ->**One lepton**, high MET, and **plenty of jet activity** including several b- tagged jets)



LQ **pair production**: 2 leptons (ATLAS: exactly 2 e or μ) and $\geq$ 2 jets . Discriminating variable: **minimum m_{LQ}**, lepton-jet pairs chosen for smallest mass difference