Highlights of the latest ATLAS results

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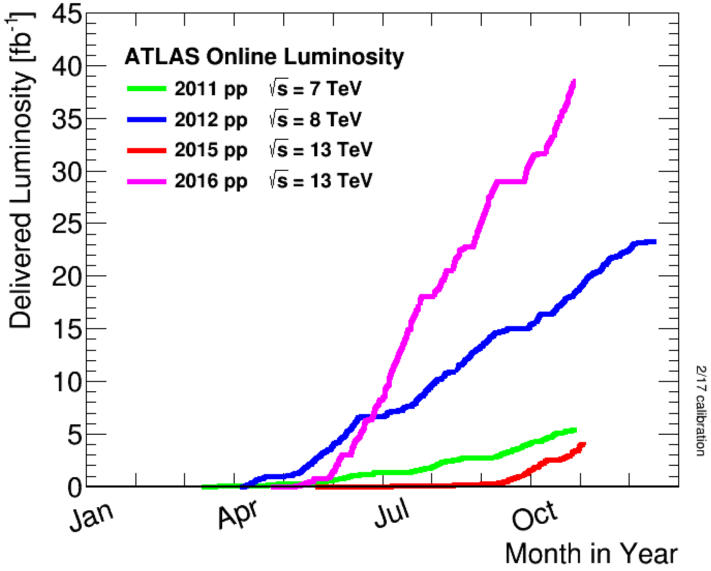
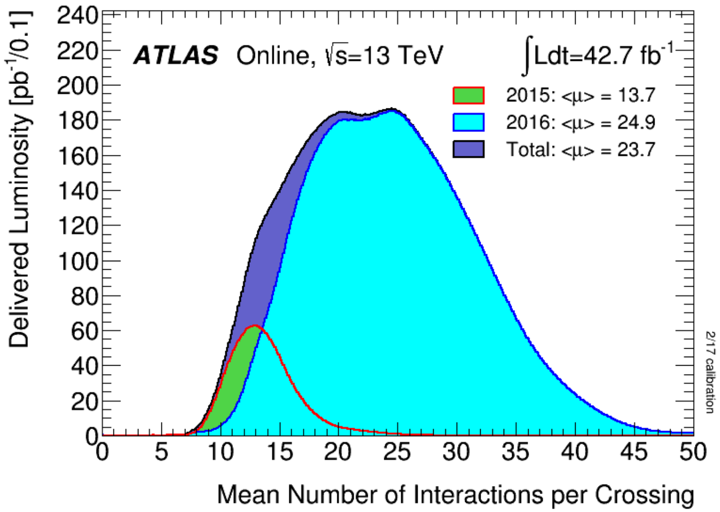
Outline

The results and status of ATLAS are given in the following aspects:

- Higgs (SM/BSM)
- SUSY
- Exotics
- Upgrades

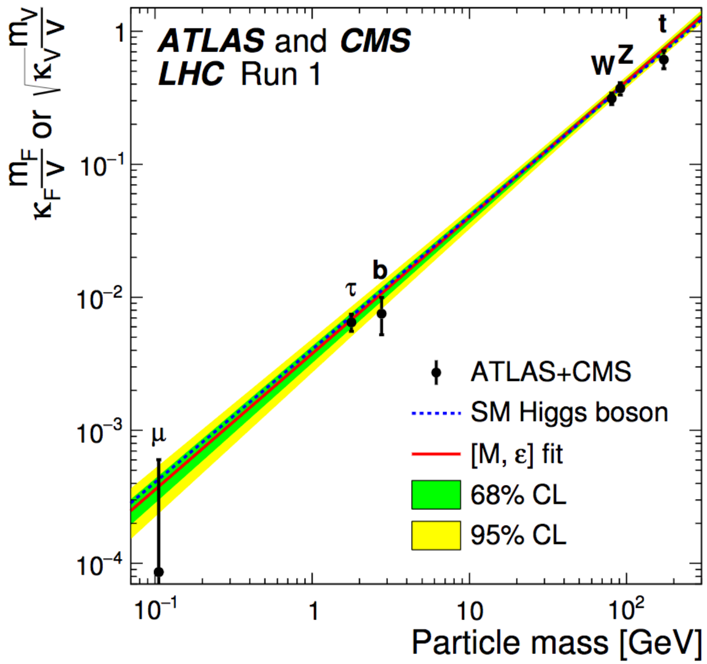




Higgs results

Legacy from Run-1

[JHEP 08 (2016) 045]
[PRL 114 191803]



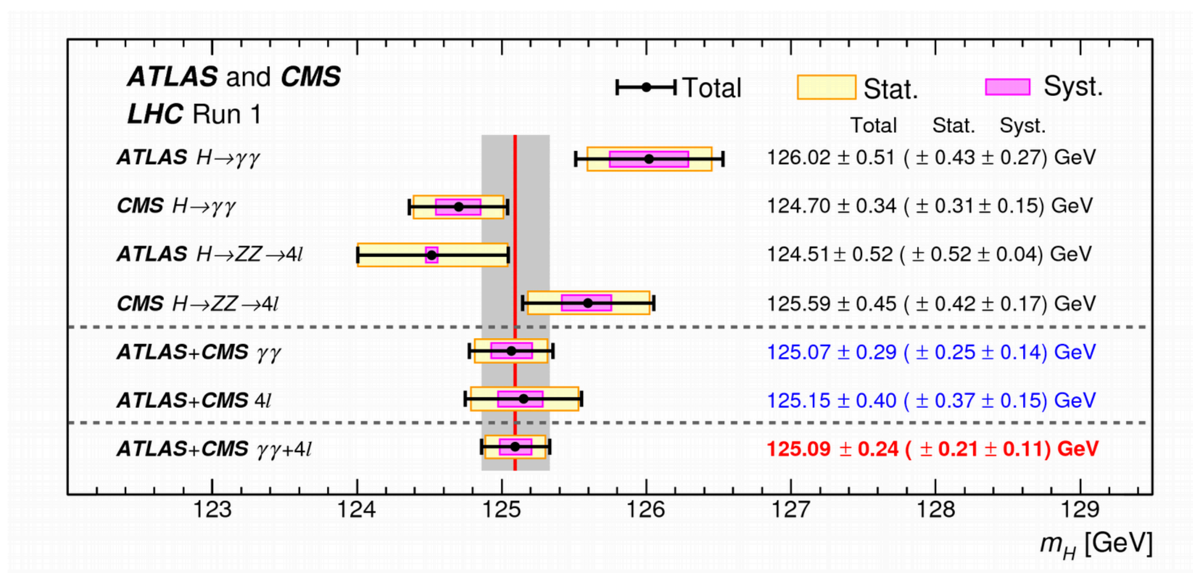
Production process	Measured significance (σ)	Expected significance (σ)
VBF	5.4	4.6
WH	2.4	2.7
ZH	2.3	2.9
VH	3.5	4.2
ttH	4.4	2.0
Decay channel		
$H \to \tau\tau$	5.5	5.0
$H \to bb$	2.6	3.7

Discovery of VBF Higgs and H→tautau decay

Higgs mass is measured to

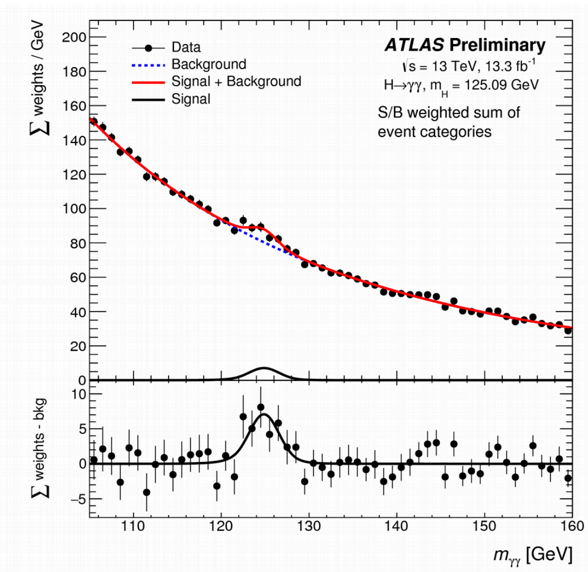
125.09 ± 0.24 GeV

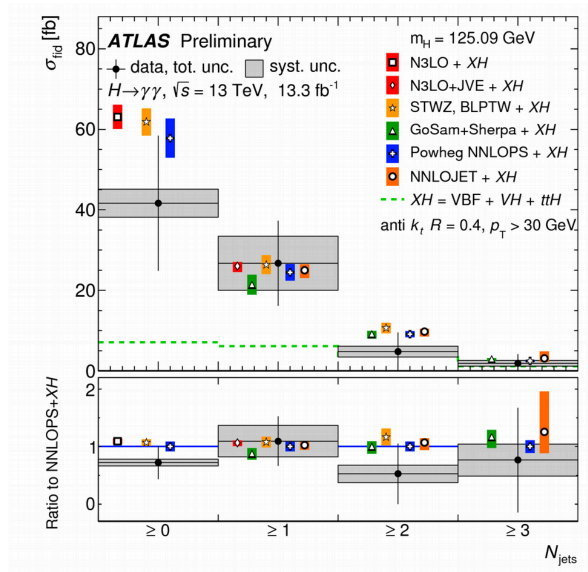
Based on ZZ and γγ,
ATLAS and CMS combined

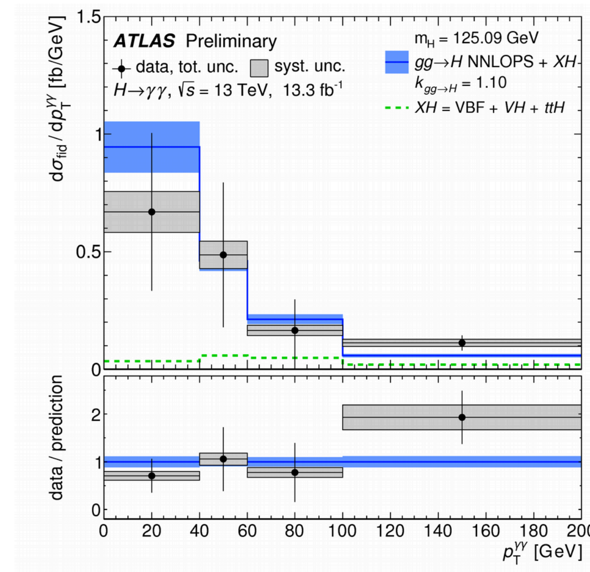


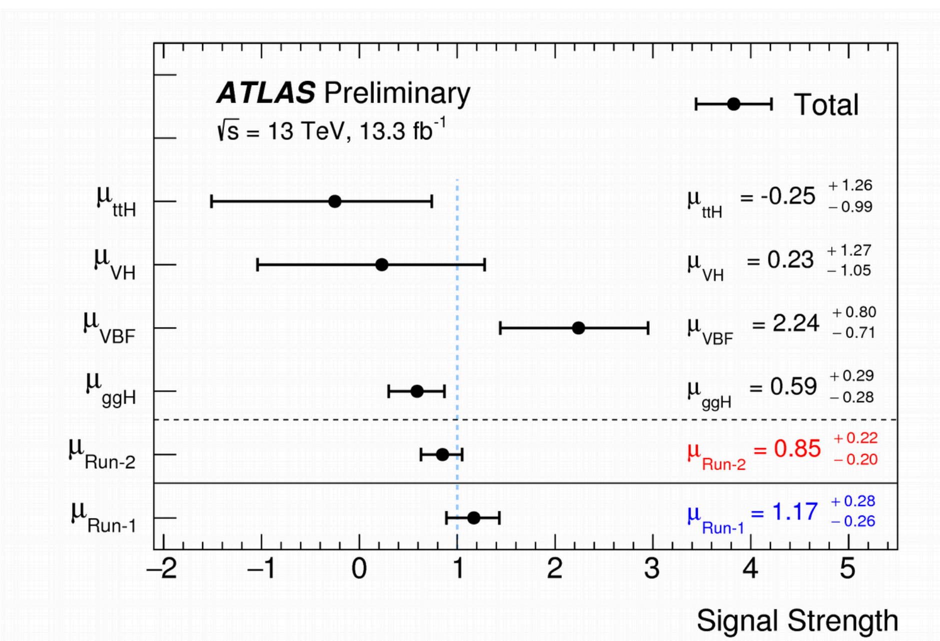
H→γγ

[ATL-CONF-2016-067]







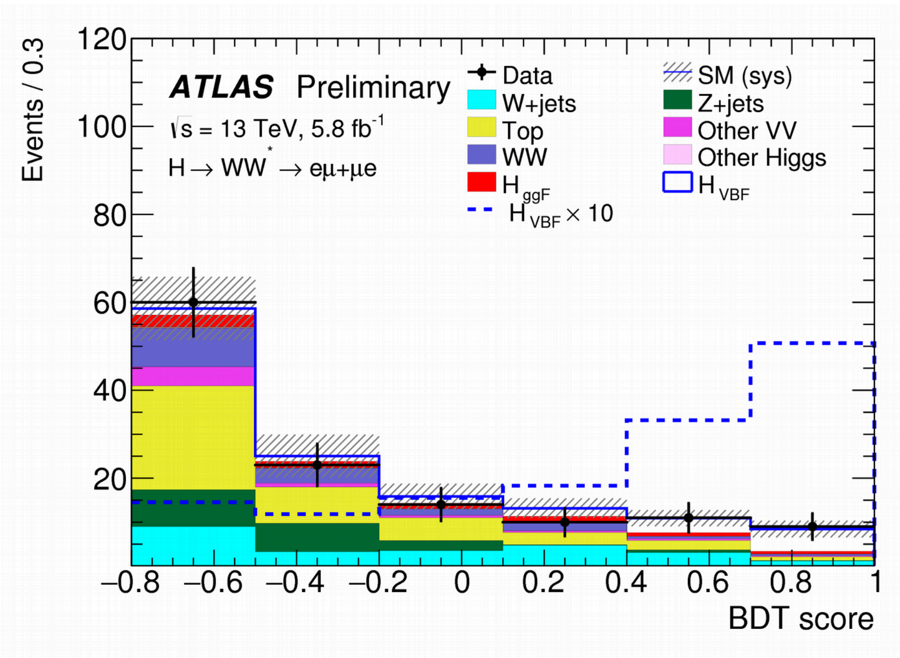


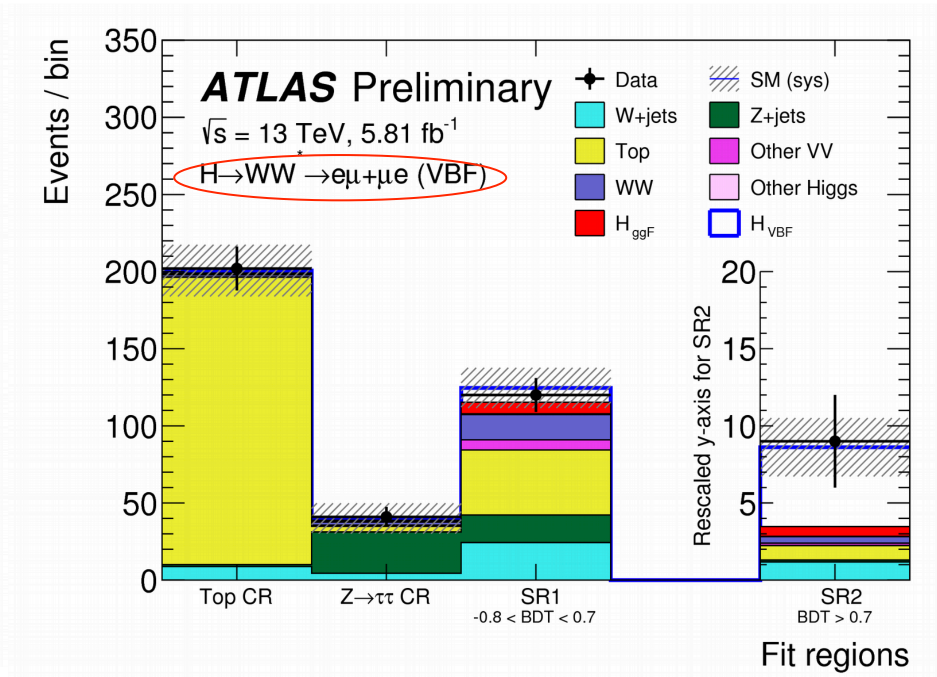
With more data collected at Run-2, we can

1) separate the signal region into ggH, VBF, VH and ttH categories
2) make differencial distributions, e.g., N_{jet} and $p_{T,H}$
3) compare fiducial cross sections in different regions (baseline, VBF, single lepton)

H→WW

[ATL-CONF-2016-112]



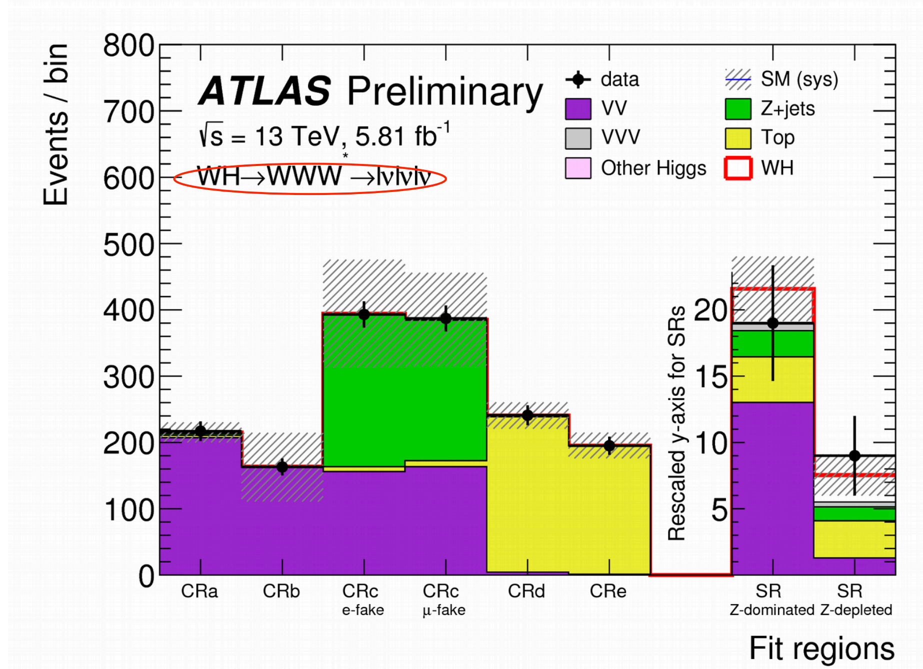


The analysis can separate into VBF and WH trilepton categories

VBF: BDT based on jets and leptons
WH: large MET, ≤1 jet

$$\mu_{\text{VBF}} = 1.7^{+1.0}_{-0.8}(\text{stat})^{+0.6}_{-0.4}(\text{sys})$$ 1.9σ (1.2σ exp)

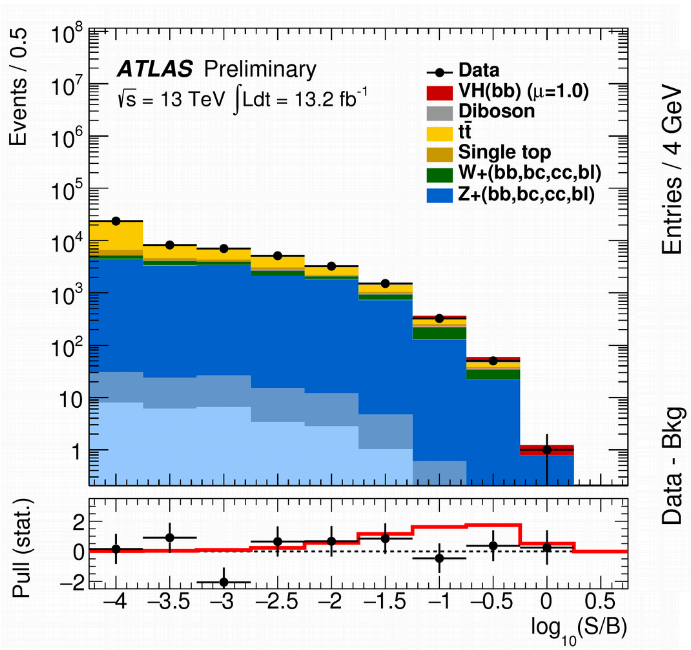
$$\mu_{WH} = 3.2^{+3.7}_{-3.2}(\text{stat})^{+2.3}_{-2.7}(\text{sys})$$ 0.77σ (0.24σ exp)

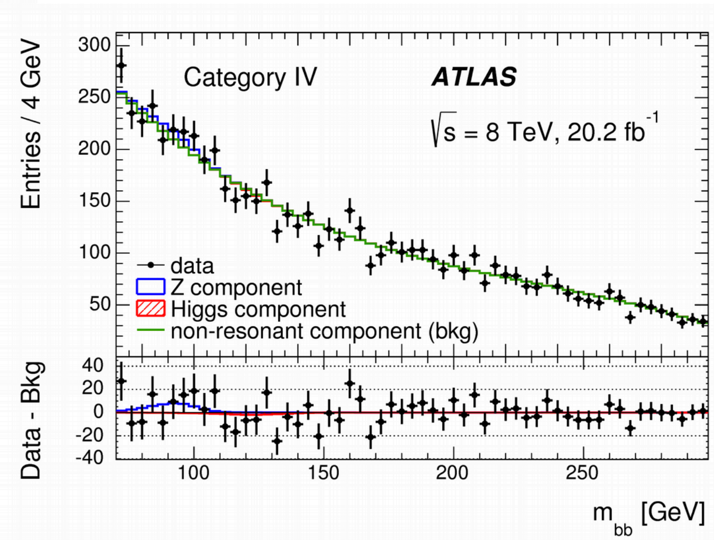


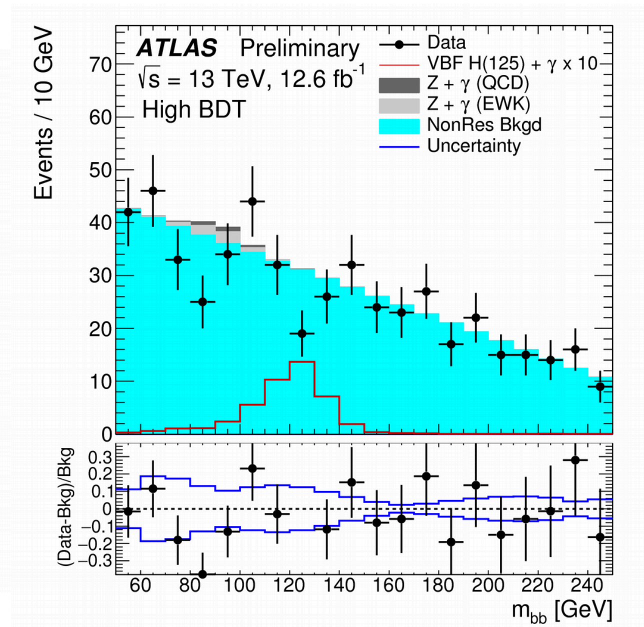
H→bb

[ATL-CONF-2016]
[JHEP 11 (2016) 112]
[ATL-CONF-2016-063]

The search is made in the VH, VBF and VBF+γ channels:







VBF

VH

VBF+γ

Search is further divided into 0/1/2 leptons

Background is high, and signal sensitivity is low

0.42σ (1.94σ exp)

Trigger: 2j+2b, or b-jet + forward jets

Use BDT to reduce background, then fit m(bb) spectrum

μ=-0.8 ± 2.3
<4.4 (5.4 exp)

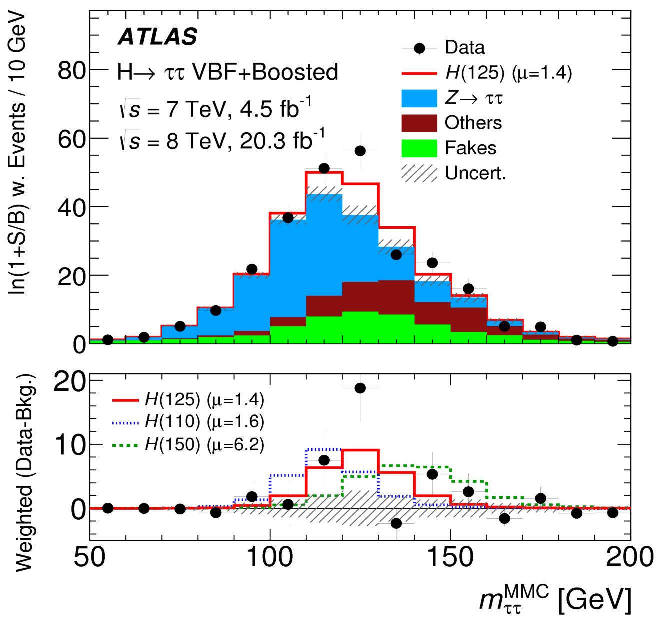
Use extra radiated photon to trigger

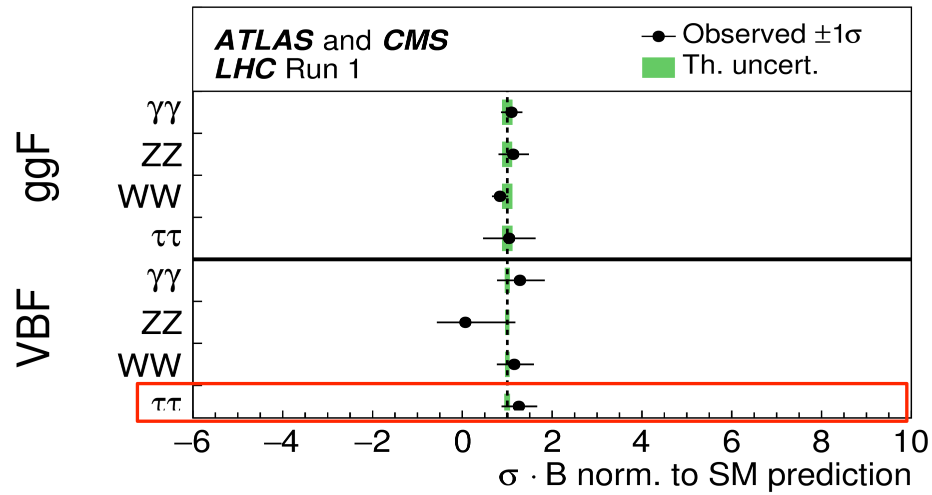
Lower background, sensitivity similar to VBF

$\mu = -3.9^{+2.8}_{-2.7}$
<4.0 (6.0 exp)

H→ττ

[JHEP 04 (2015) 117]
[JHEP 08 (2016) 045]





❖ Combined run-1 sensitivity of ATLAS/CMS already exceeds 5σ:

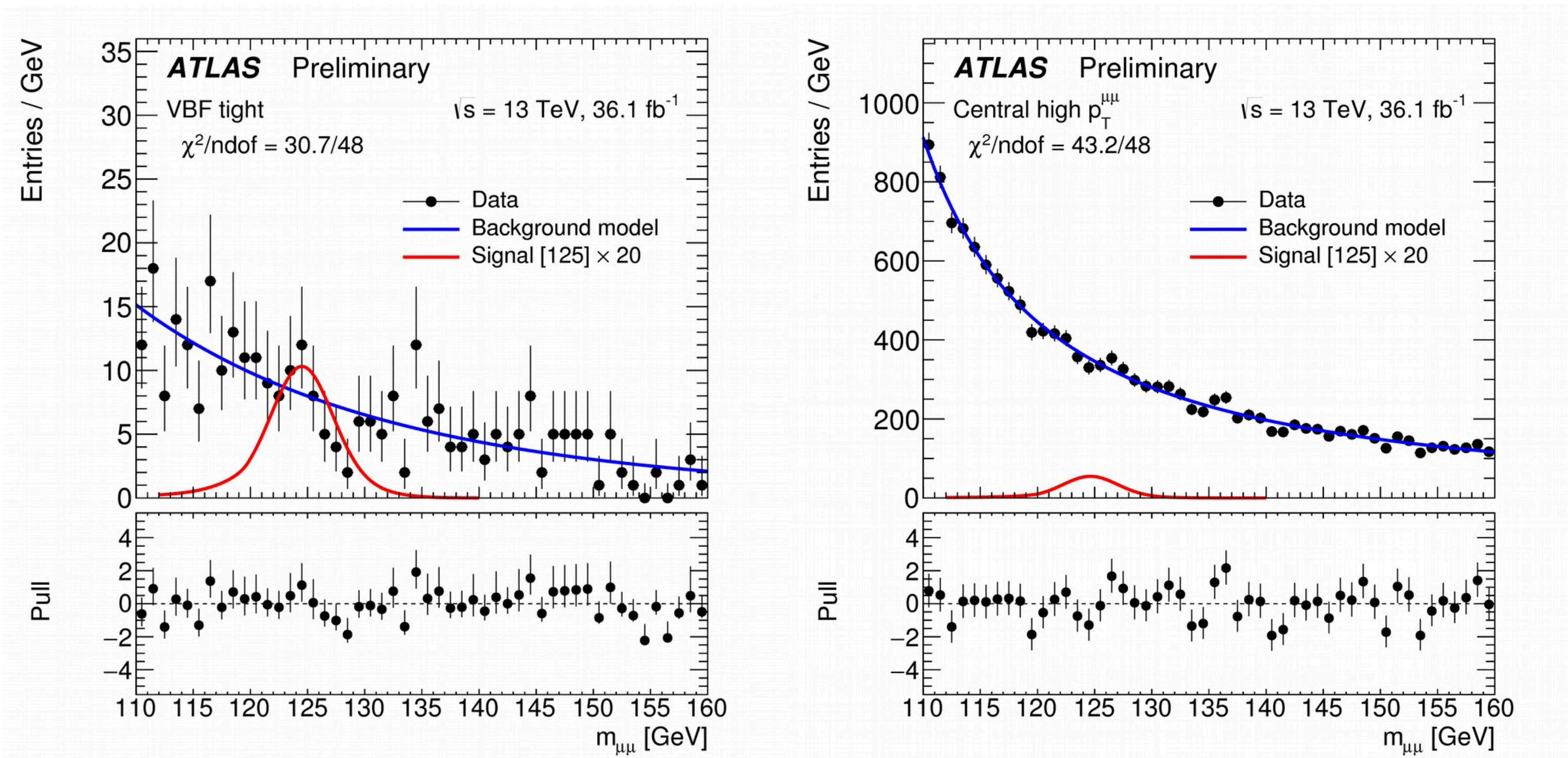
	ATLAS	CMS	ATLAS+CMS
$\mu^{\tau\tau}$	$1.41^{+0.40}_{-0.36}$	$0.88^{+0.30}_{-0.28}$	$1.11^{+0.24}_{-0.22}$
Obs. (Exp.) p0	4.4(3.3)	3.4(3.7)	5.5(5.0)

❖ H→ττ is one of the best channels to search for VBF production. It is a very sensitive channel for CP in both HVV and Hff couplings

❖ In the 2HDM model, the H→ττ rate is often enhanced, and Higgs can also have mixed CP. This makes the H→ττ channel very special

$H \rightarrow \mu\mu$

[ATL-CONF-2017-014]



Separate into VBF and ggH categories

The ggH region is further separated into different dimuon p_T and muon η regions

Full 2016 Run-2 data is used

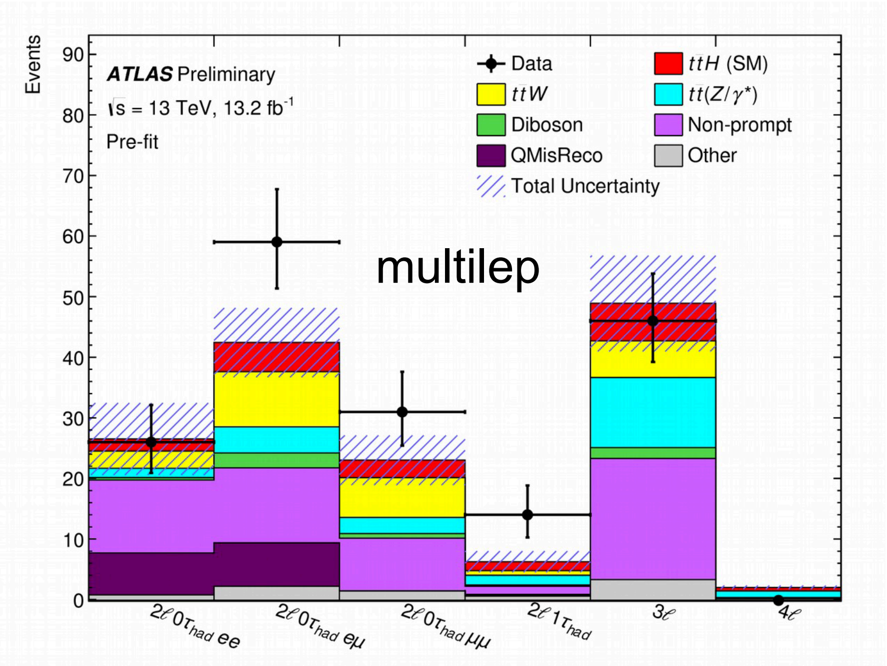
$\mu = -0.11^{+1.49}_{-1.51}$ Run-2

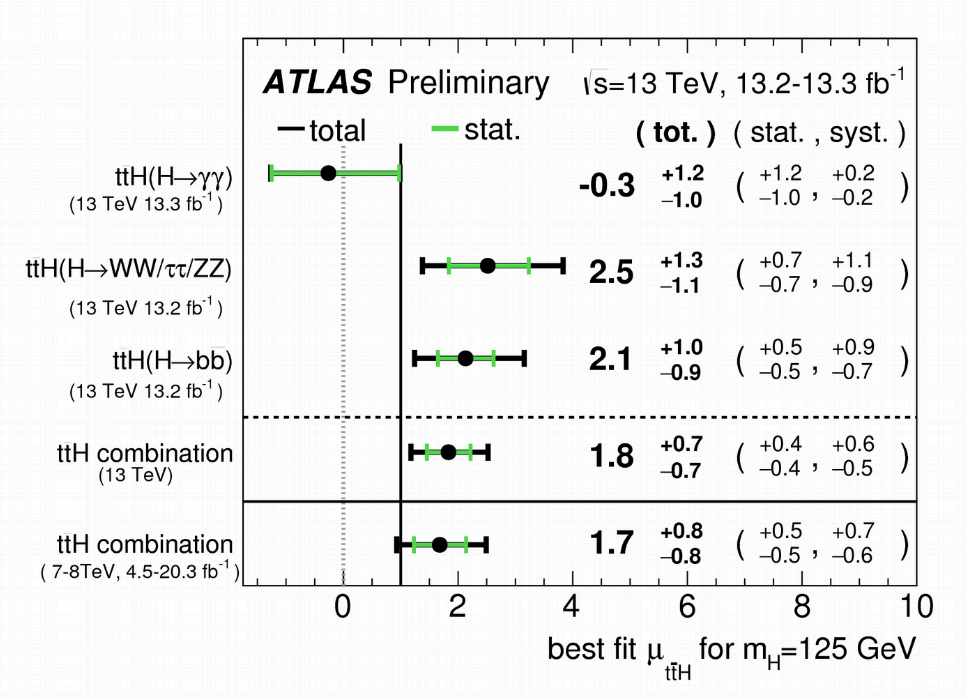
<3.0 (3.1 exp) Run-2

<2.7 (2.8 exp) Run-1+2

ttH

bb: [ATL-CONF-2016-080]
multilep: [ATL-CONF-2016-058]
γγ: [ATL-CONF-2016-067]
combined: [ATL-CONF-2016-068]





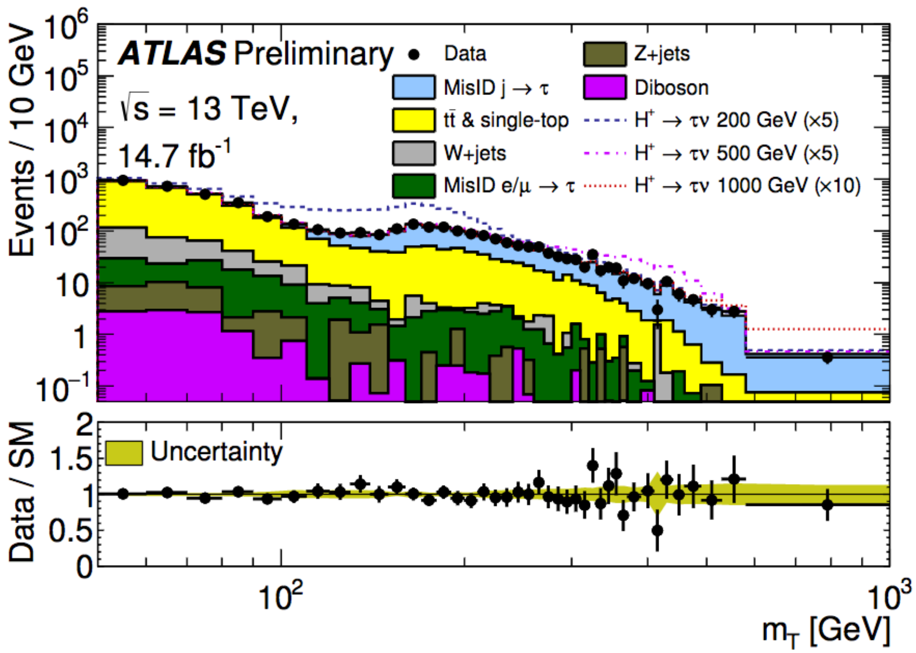
Channel	Significance	
	Observed [σ]	Expected [σ]
$t\bar{t}H,\ H\to\gamma\gamma$	-0.2	0.9
$t\bar{t}H,\ H\to(WW,\tau\tau,ZZ)$	2.2	1.0
$t\bar{t}H,\ H\to b\bar{b}$	2.4	1.2
$t\bar{t}H$ combination	2.8	1.8

The search is separated into γγ, bb and multilepton (WW,ZZ,ττ) channels

Sensitivity exceeds Run-1

$H^{\pm} \rightarrow \tau\nu$

[ATL-CONF-2016-088]

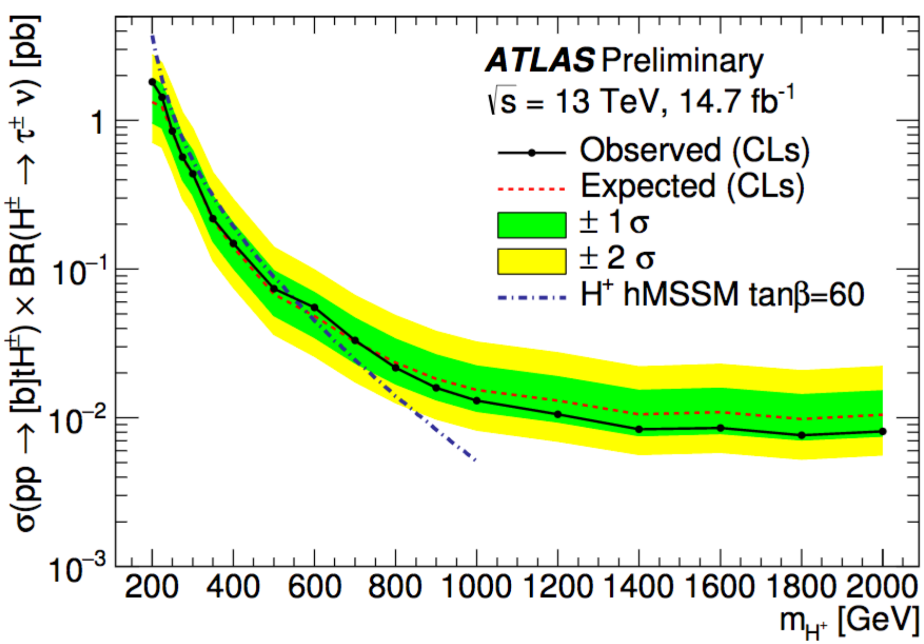


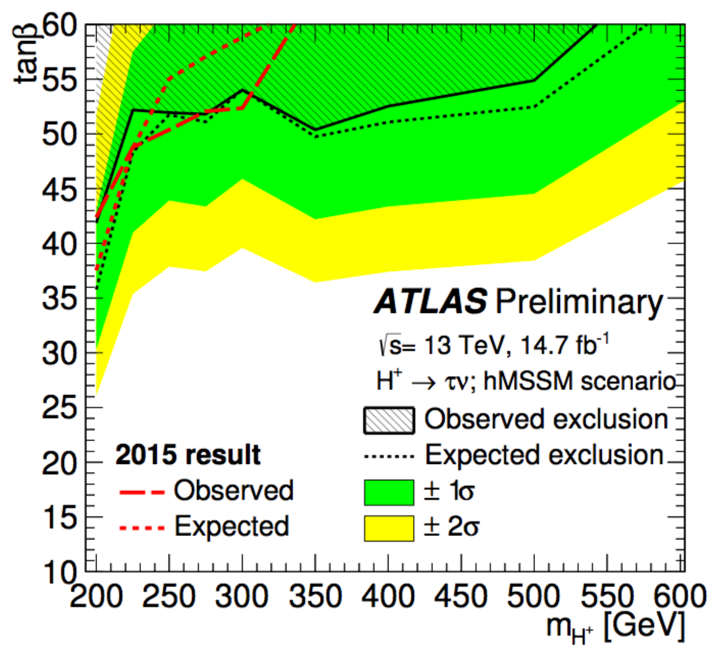
Require a high p_T hadronic tau, at least 3 jets out of which ≥1 b-jet, and large MET

Use transverse mass as the discriminant

$$m_T = \sqrt{2 p_T^{\tau} E_T^{miss} (1 - \cos \Delta\phi_{\tau, E_T^{miss}})}$$

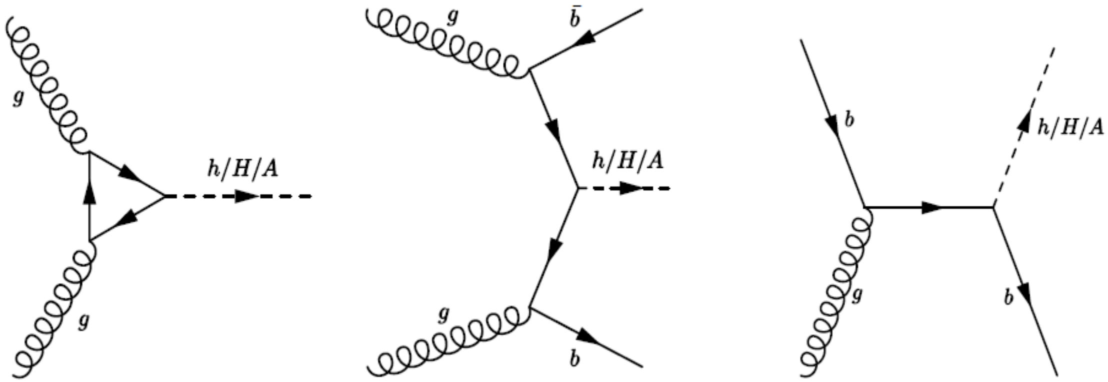
hMSSM : use measured h mass of 125 GeV to predict other Higgs' decays and masses





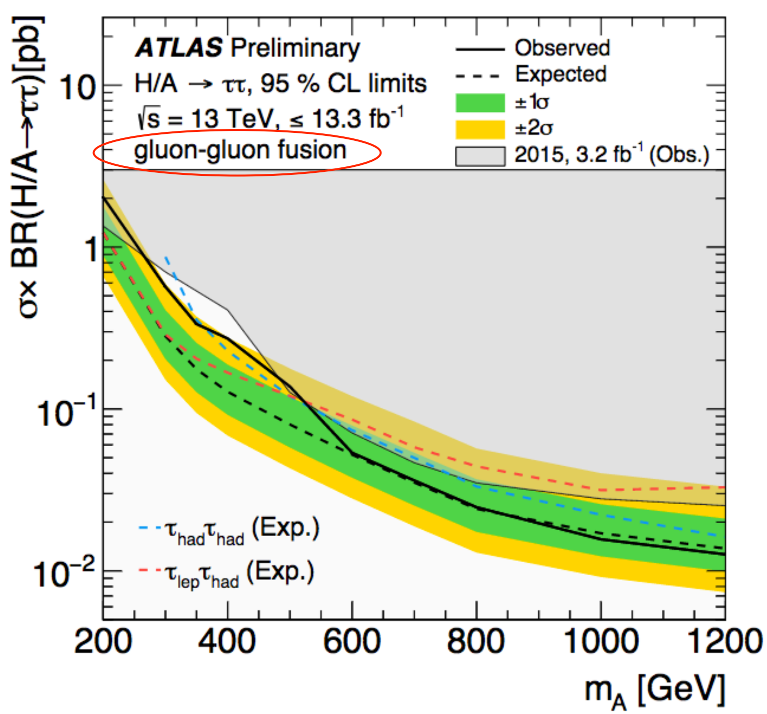
A/H→ττ

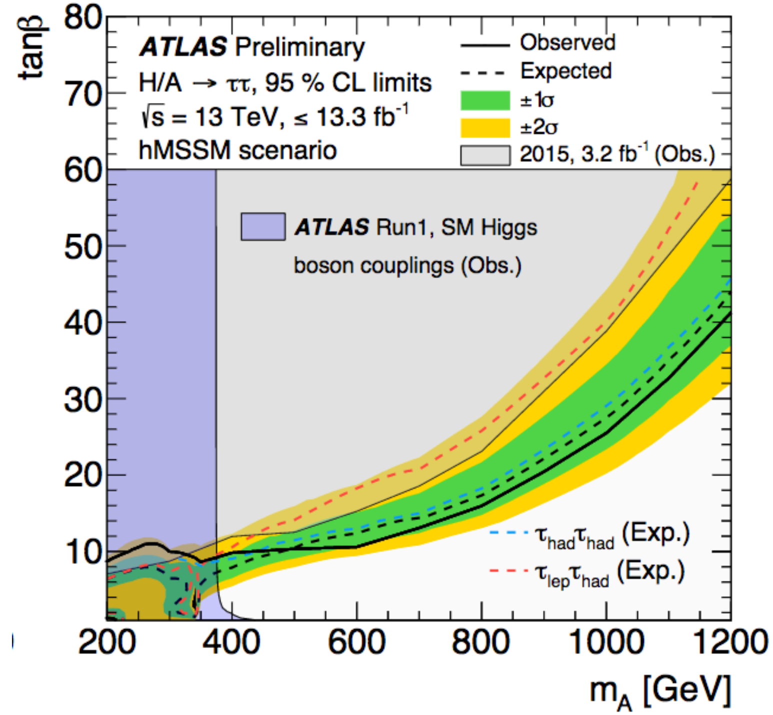
[ATL-CONF-2016-085]



Sensitive to A→ττ especially at high tanβ

Use $\tau_l\tau_h$ and $\tau_h\tau_h$ channels and separate into b-veto (ggF) and b-tagged (b-jet associated) regions





SUSY results

0-lepton

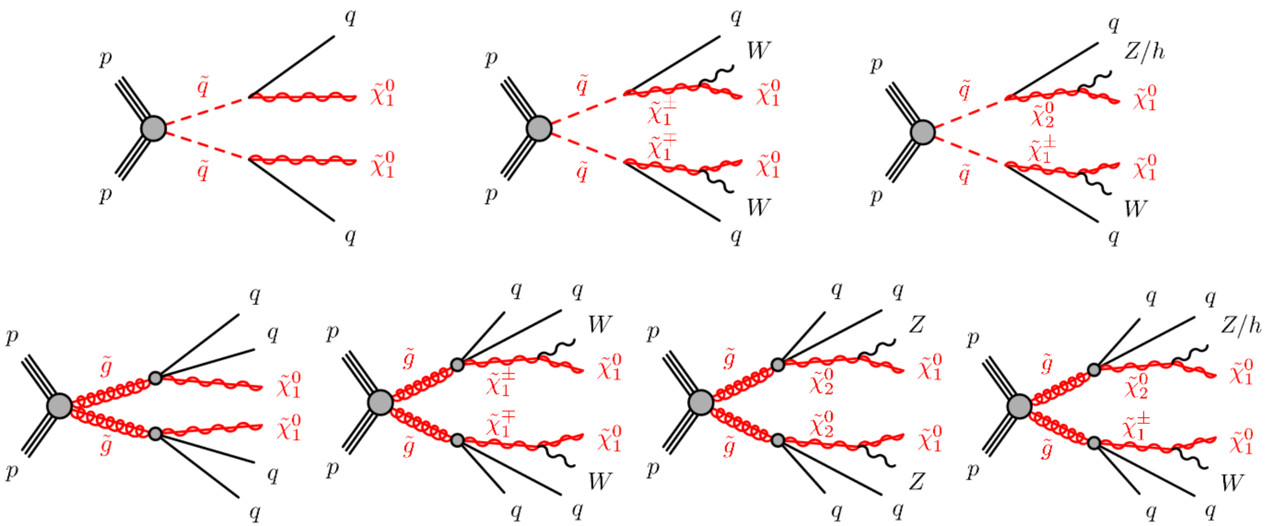
[ATL-CONF-2017-022]

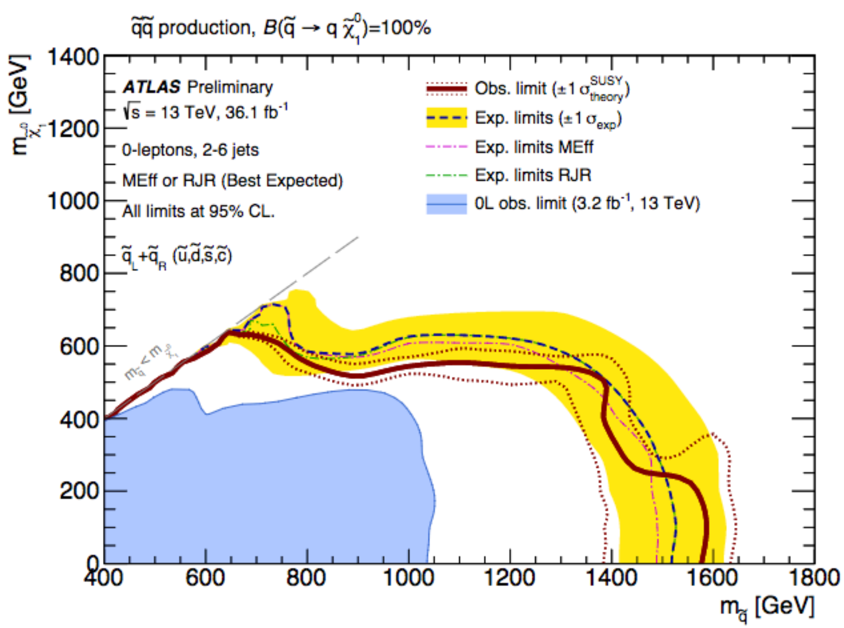
Traditional 0-lep channel looking for squark and gluino productions

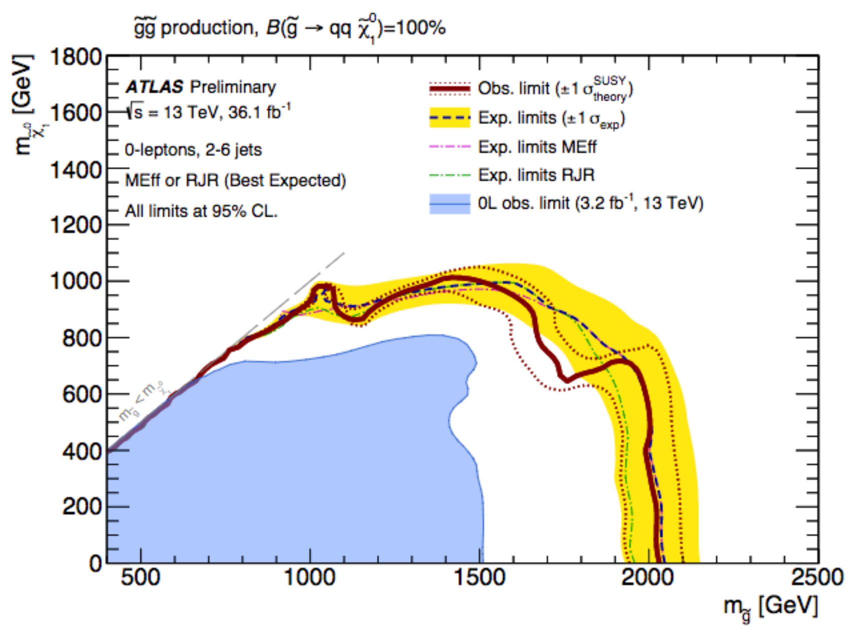
Large m_{eff} as discriminant

Direct decay: 2-5 jets

With W/Z: 5-6 jets







Exclude ~1.5 TeV squarks and ~2 TeV gluinos

0/1-lepton+b-jets

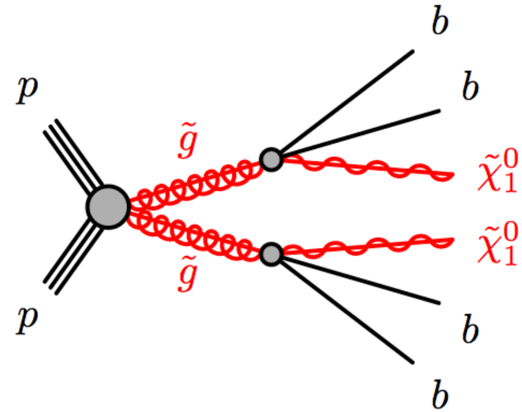
[ATL-CONF-2017-021]

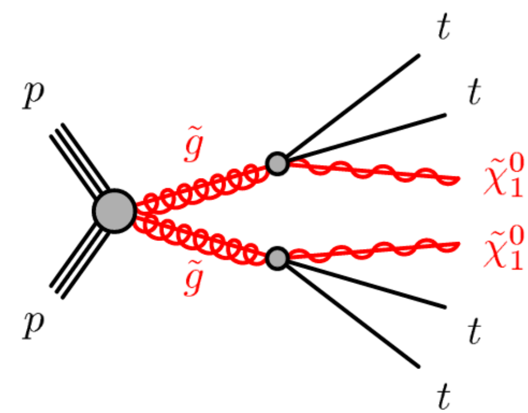
Assume squark is much heavier than gluino. Use b-jets and lepton to suppress QCD:

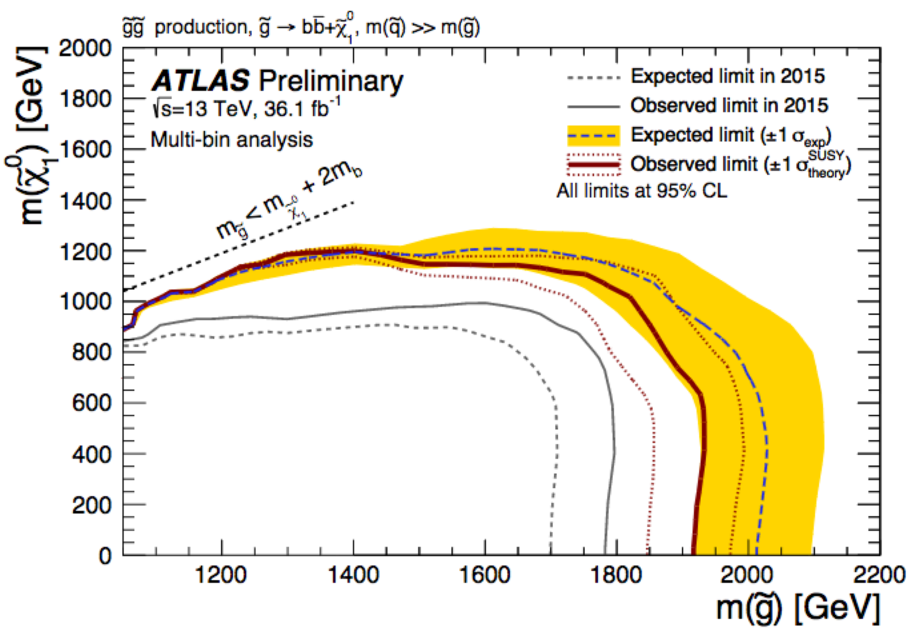
At least 3 b-jets

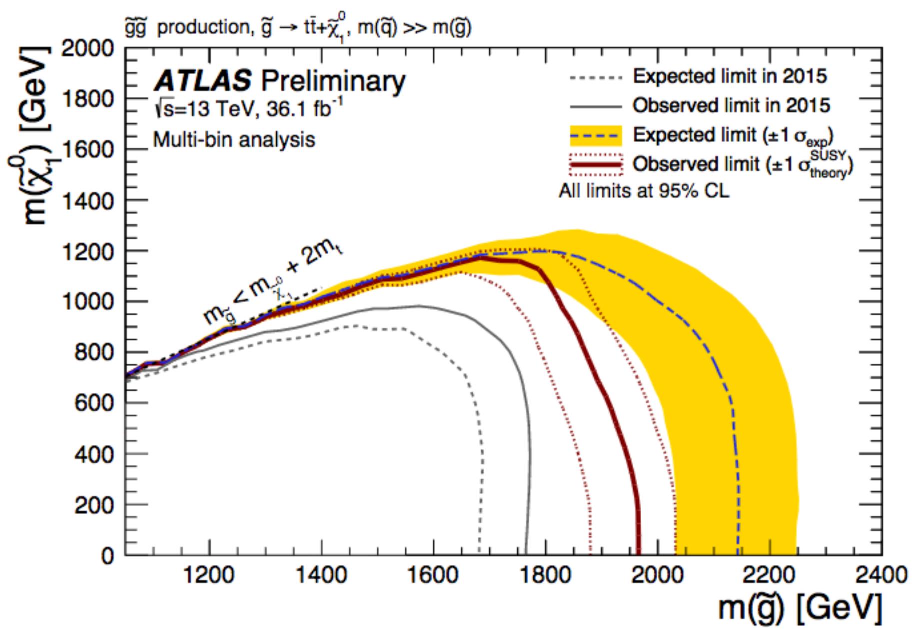
Large m_{eff} and MET

Decay to b's: 5-7 jets
Decay to tops: 7-8 jets



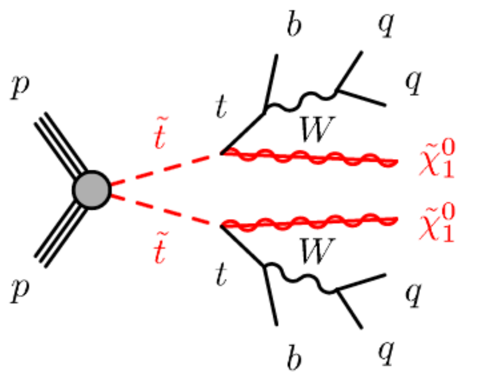


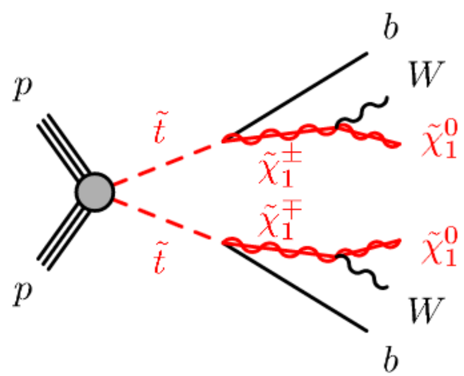


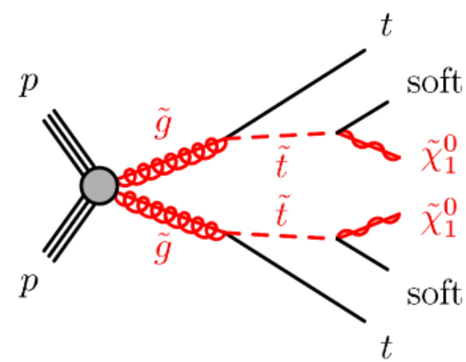


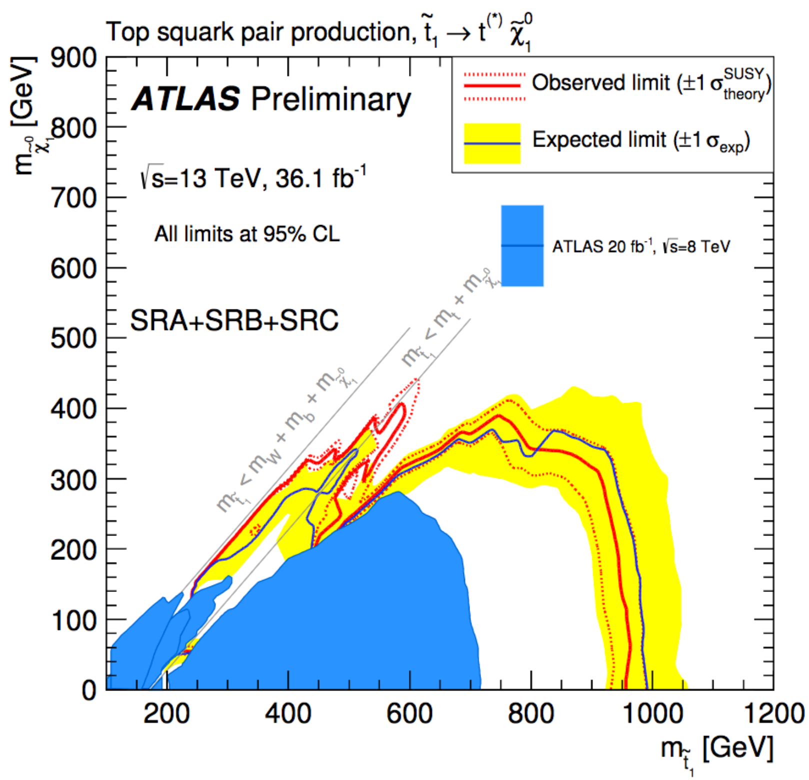
Stop pair with 0-lepton

[ATL-CONF-2017-020]









Stop search is important for Higgs mass stablization

At least 4 jets, large MET

SRA/SRB: $\Delta m(\tilde{t}, \tilde{\chi}_1^0) > m_t$

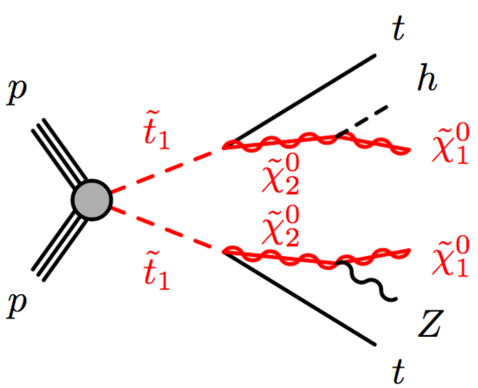
SRC: $\Delta m(\tilde{t}, \tilde{\chi}_1^0) \approx m_t$, use ISR jets

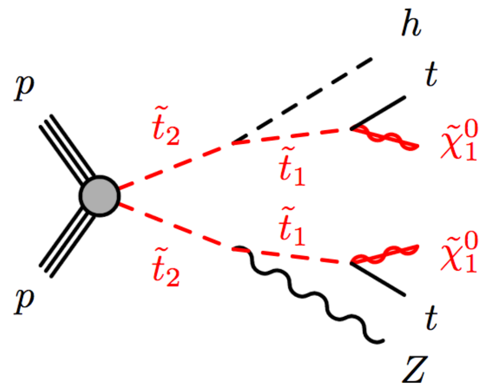
Use $m_{T,b}$ to suppress ttbar, and recluster R=0.4 antiKt jets with R=1.2 for close top daughters

Much improved limits w.r.t. Run-1

Stop pair with H/Z

[ATL-CONF-2017-019]

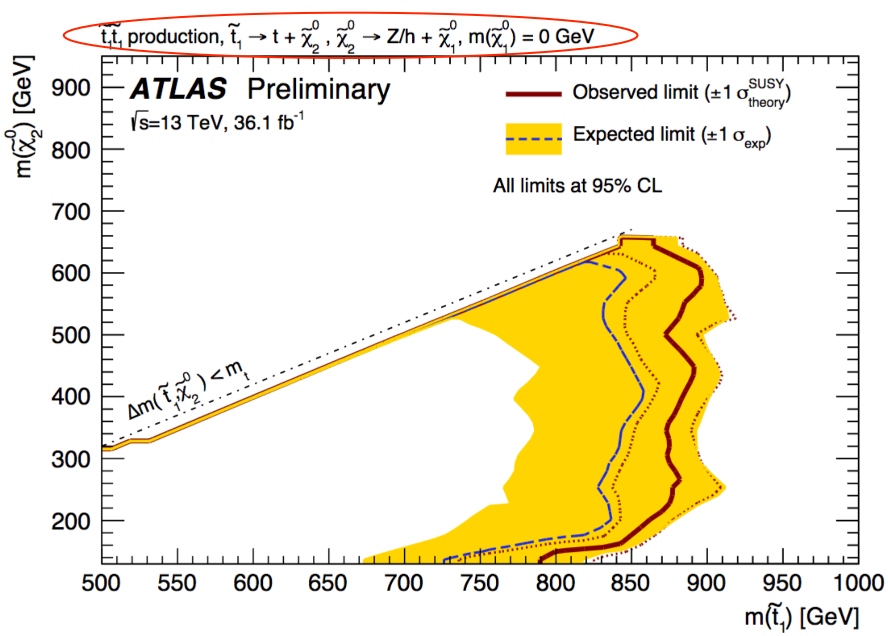


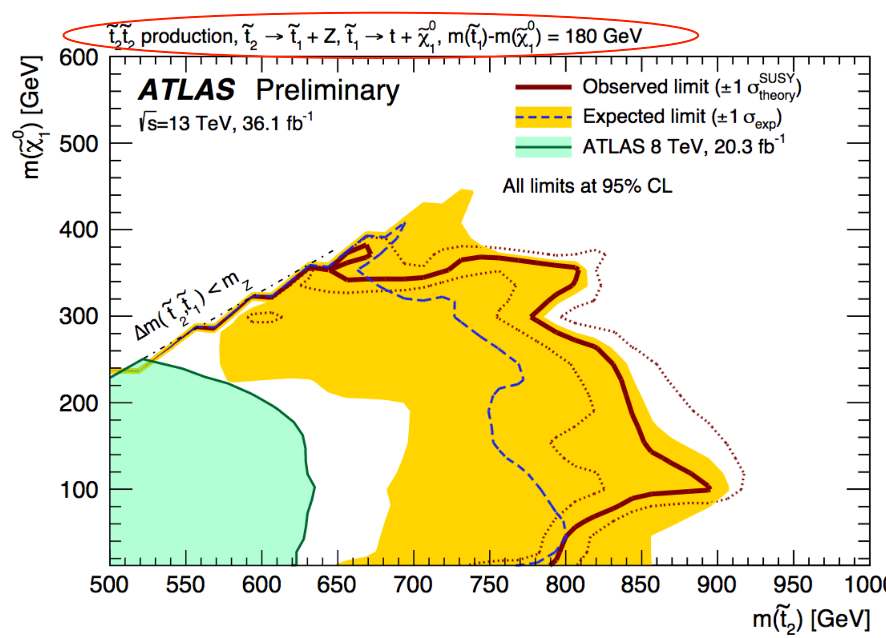


Split the SR into H(bb) and Z(ll) enhanced regions

1 lepotn + 4 b-jets

3 leptons + 1 b-jet

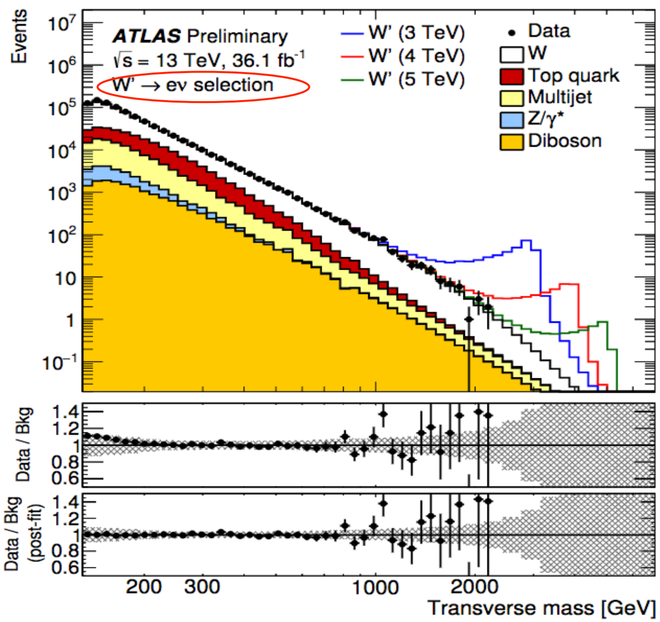


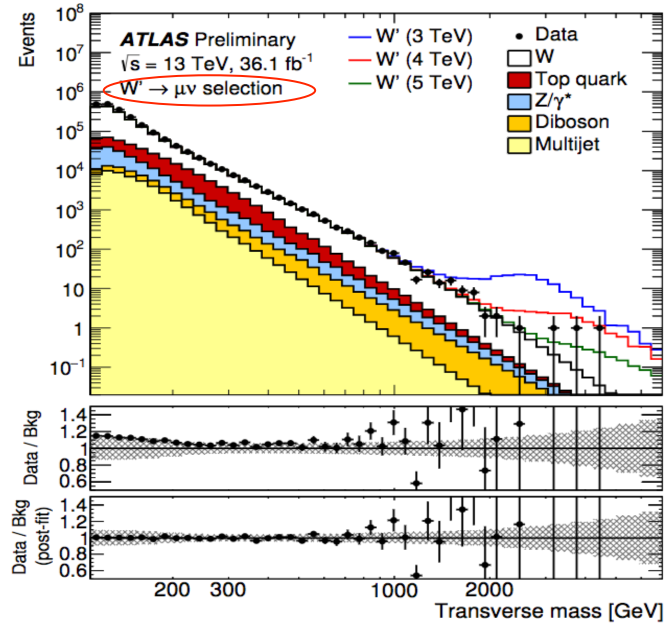


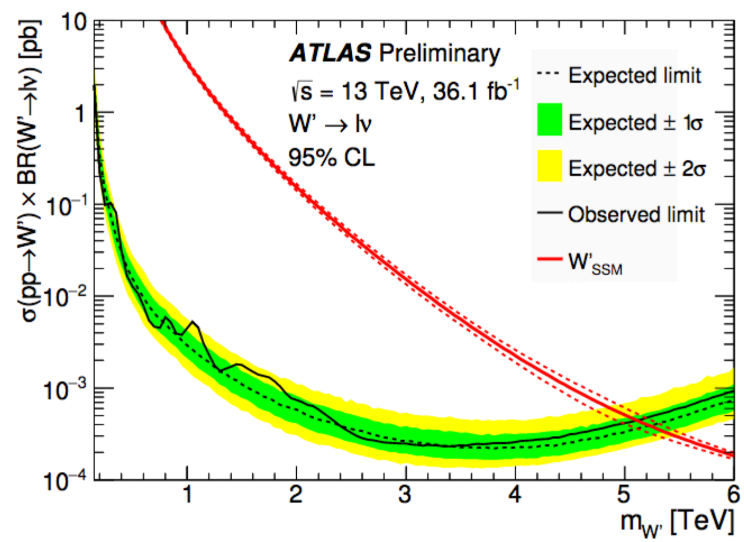
Exotics results

W'→lν

[ATL-CONF-2017-016]



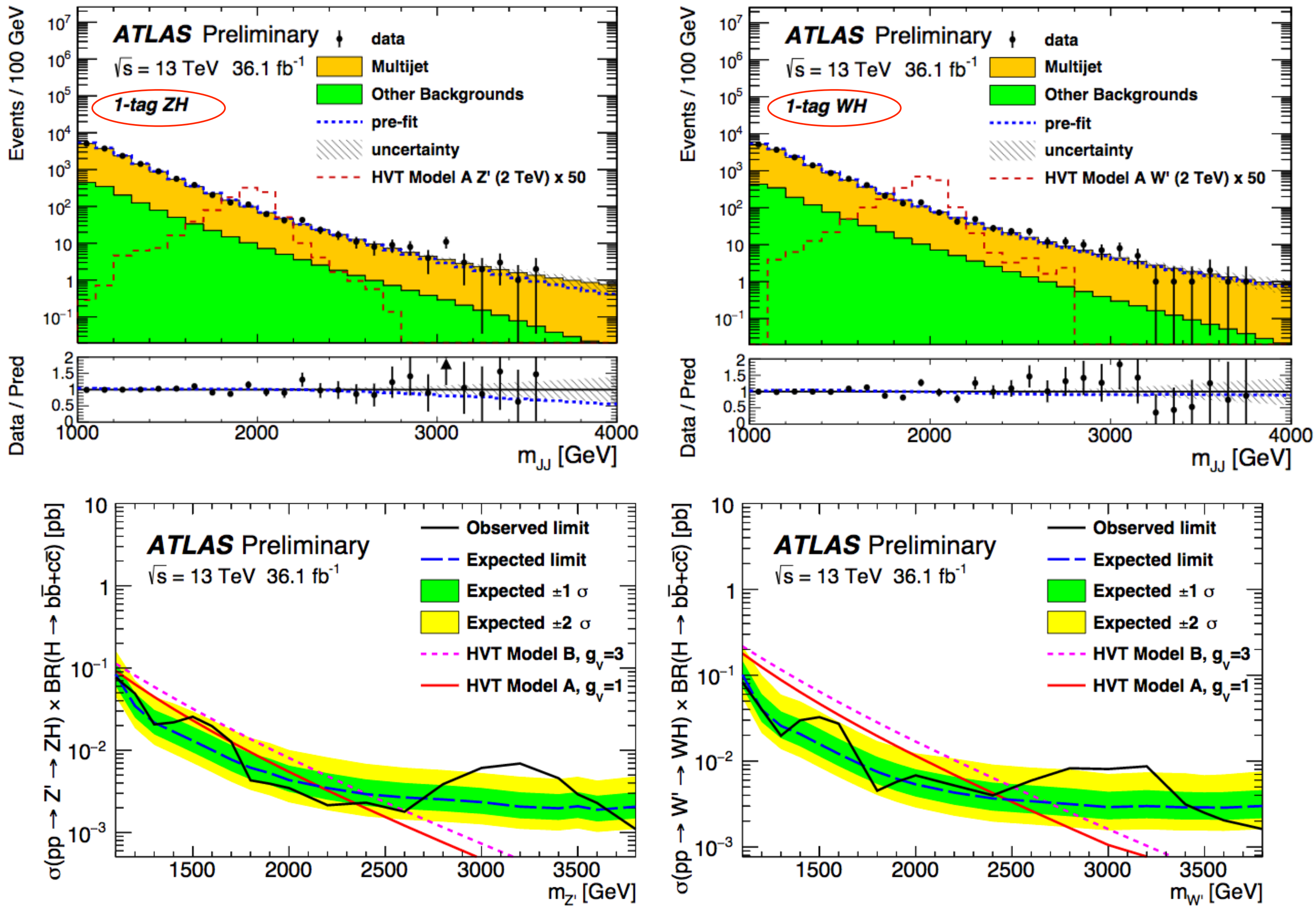




Decay	$m_{W'}$ lower limit [TeV] Expected	Observed
$W' \to e\nu$	5.09	5.22
$W' \to \mu\nu$	4.70	4.45
$W' \to \ell\nu$	5.22	5.11

VH→qqbb

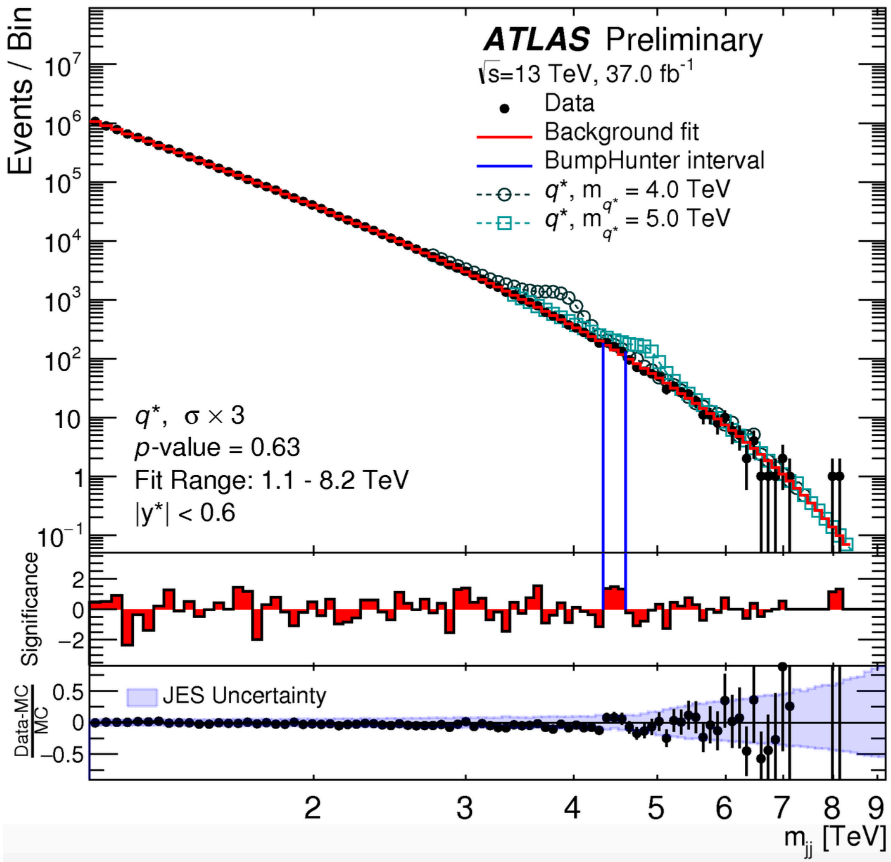
[ATL-CONF-2017-018]

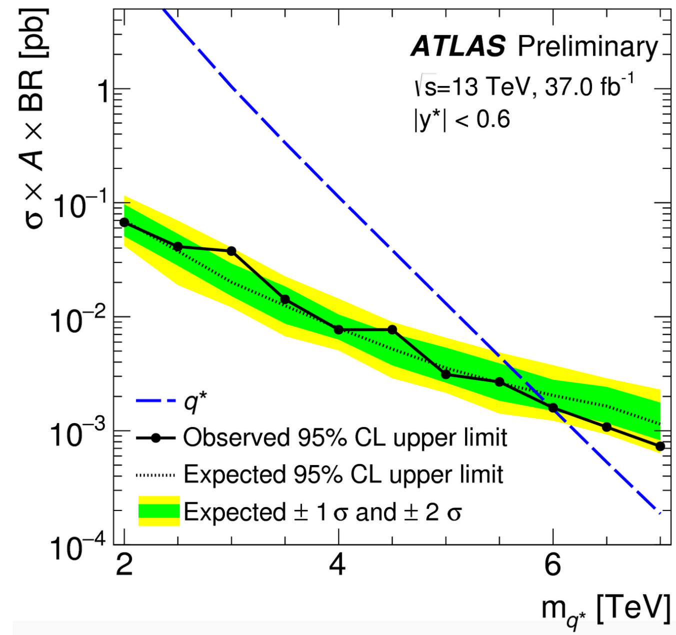


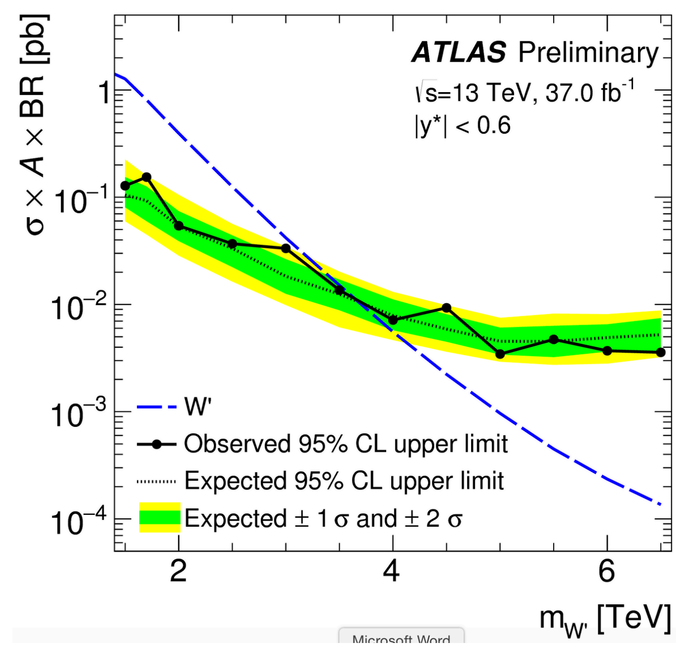
3.2σ local (2.2σ global) is observed at ~ 3 TeV

Dijet resonance

[ATLAS-EXOT-2016-021]







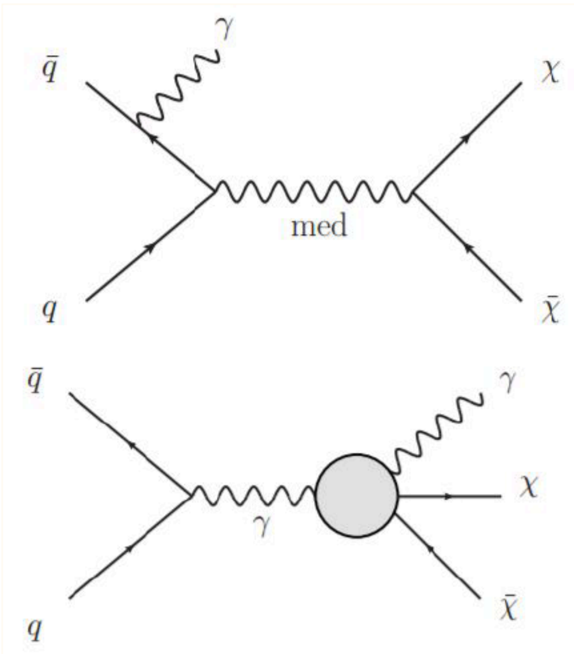
Definition of y*: $e^{2|y^*|} \sim \dfrac{1+\cos\theta^*}{1-\cos\theta^*}$

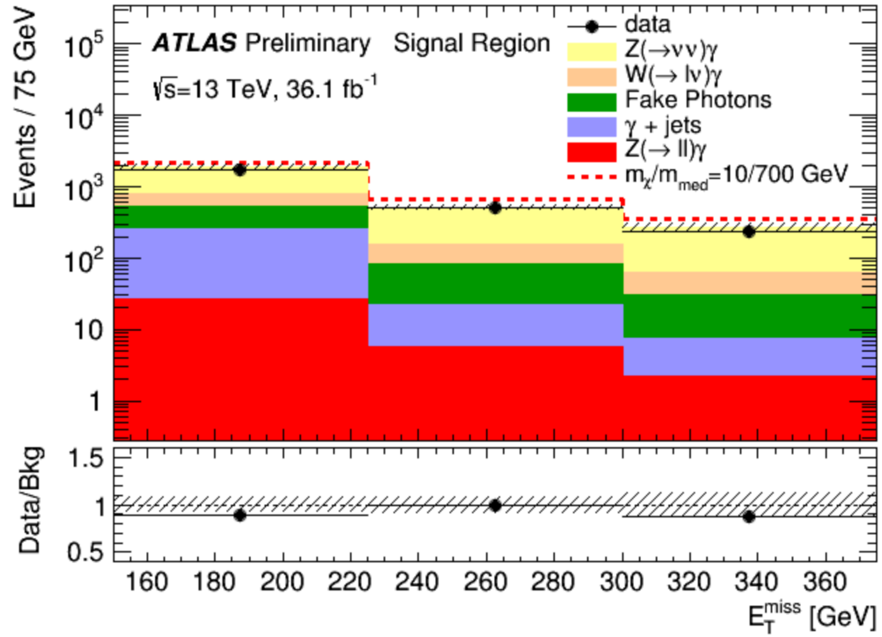
Dijet resonance: q*, W', Z', Quantum Black Hole…

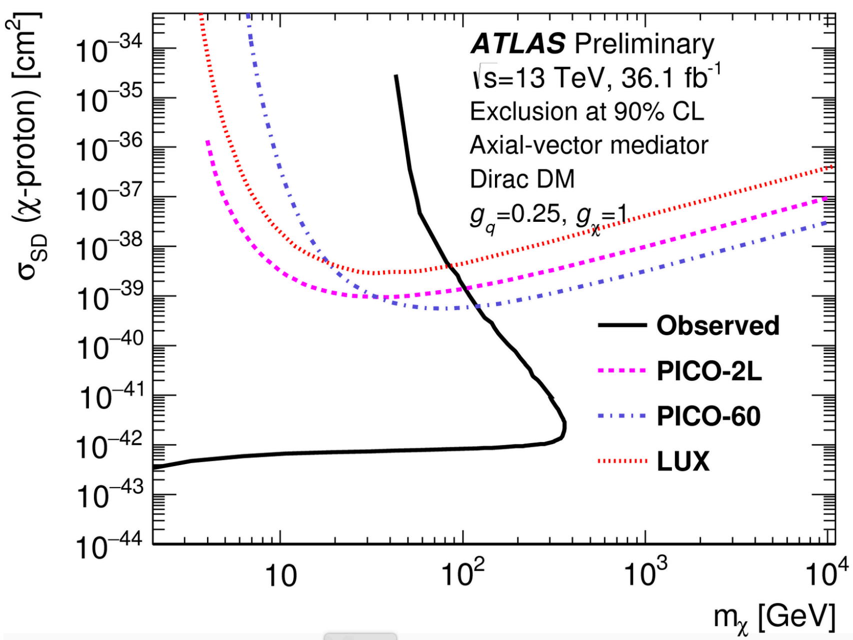
Sliding window fit. No significant excess

Dark Matter : γ+MET

[ATLAS-EXOT-2016-032]







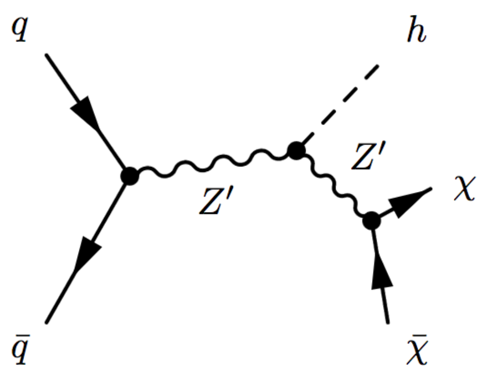
At colliders, X+MET is important for low mass DM, in particular for spin-dependent interactions

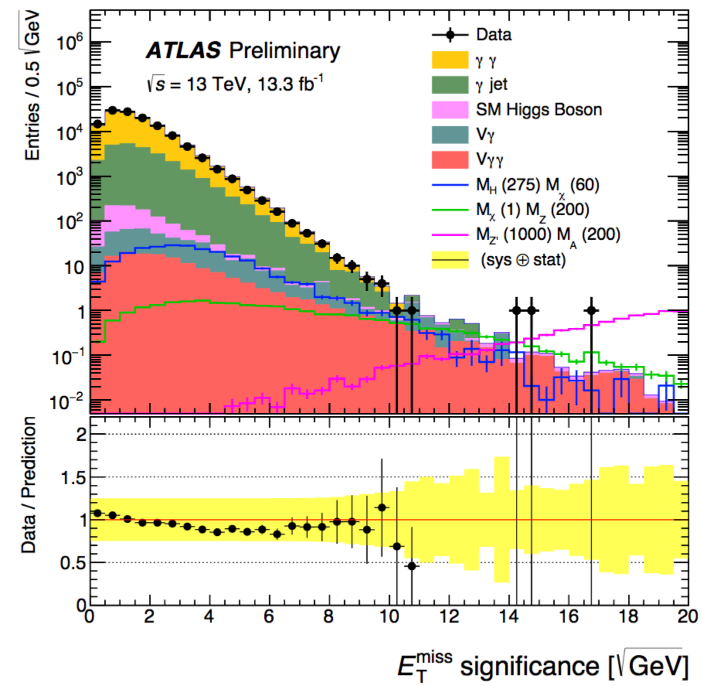
Limits on DM production can be set on vector or axial-vector type of mediators

γ+MET: require at least one photon with large MET

Dark Matter : H→γγ+MET

[ATLAS-EXOT-2016-087]

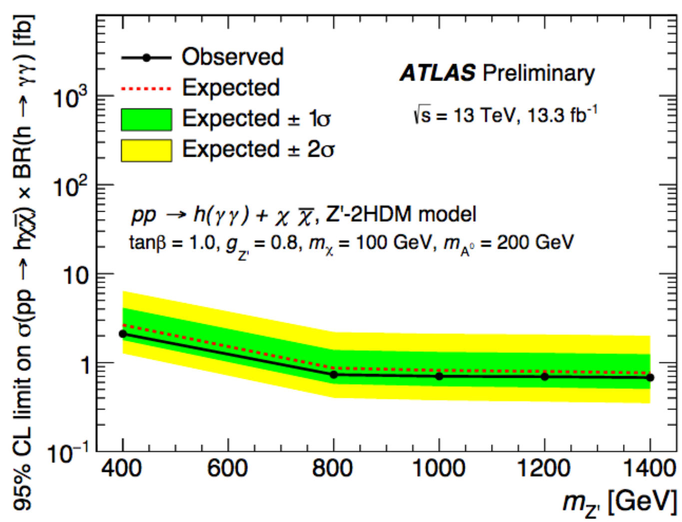


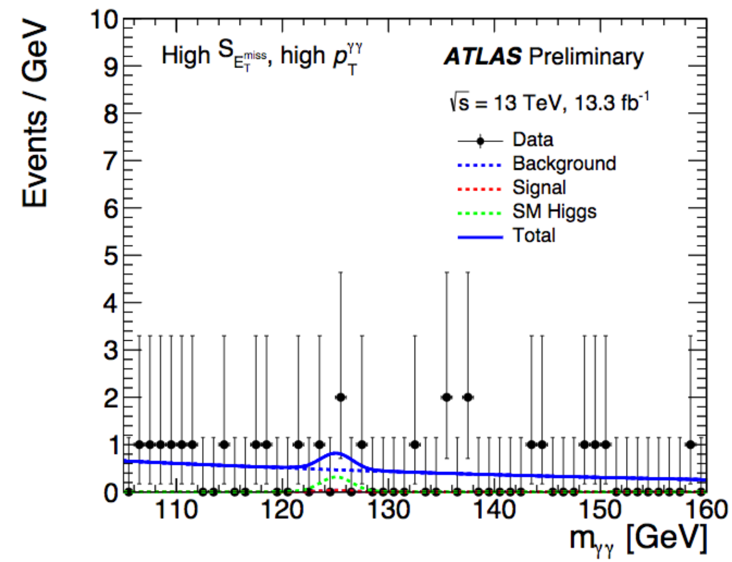


Based on the MET significance and $p_T(\gamma\gamma)$:

$$S_{E_T^{miss}} = E_T^{miss} / \sqrt{\sum E_T}$$

Fit to the $m(\gamma\gamma)$ spectrum

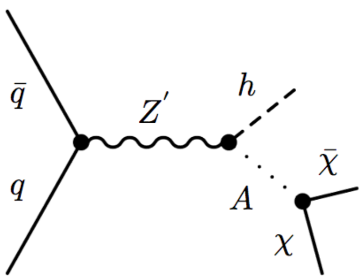


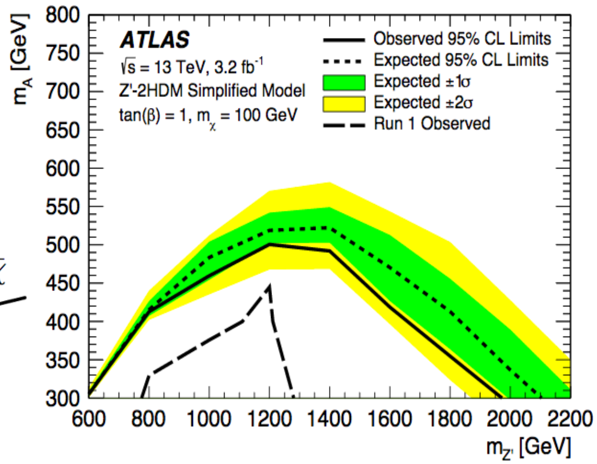


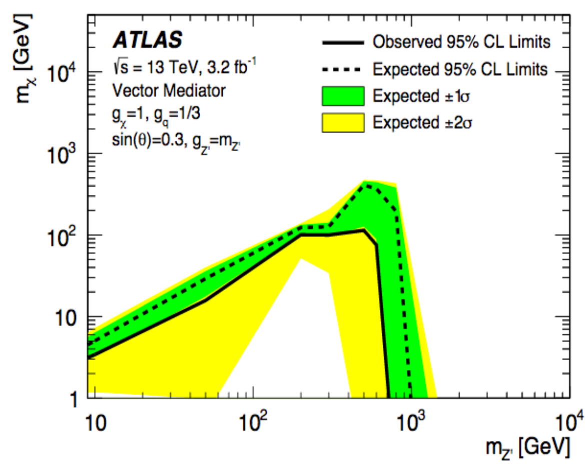
Dark Matter : bb+MET

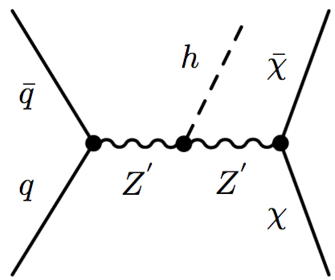
[PLB 765 (2016) 11]
[ATL-CONF-2016-086]

Search for DM via H→bb+MET:

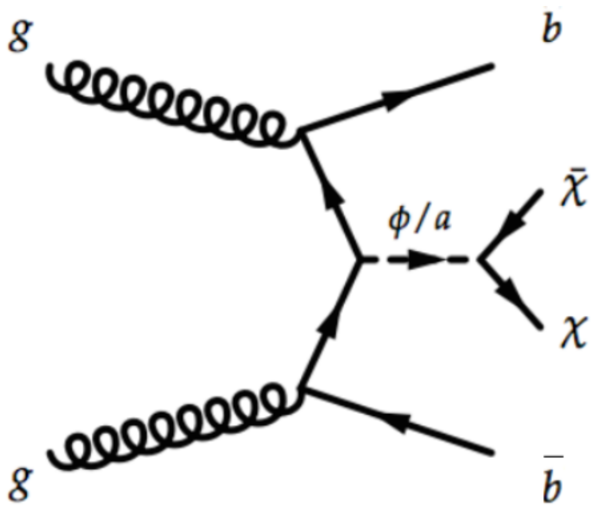


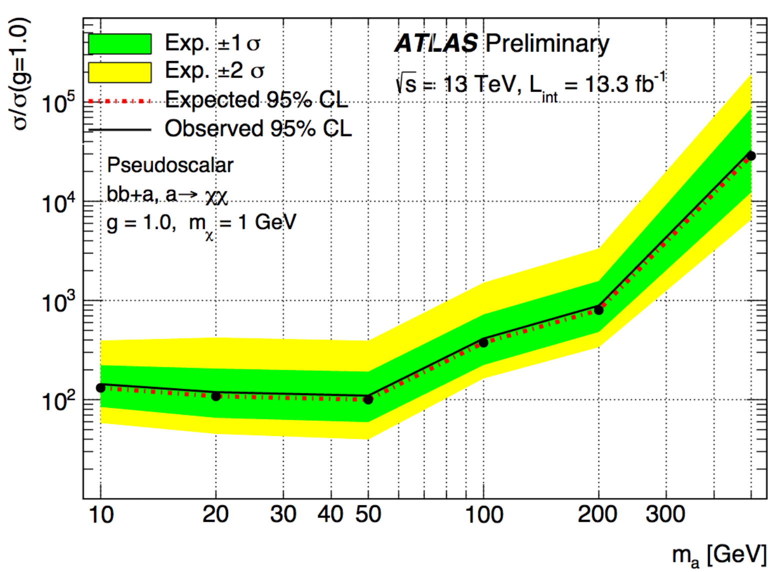






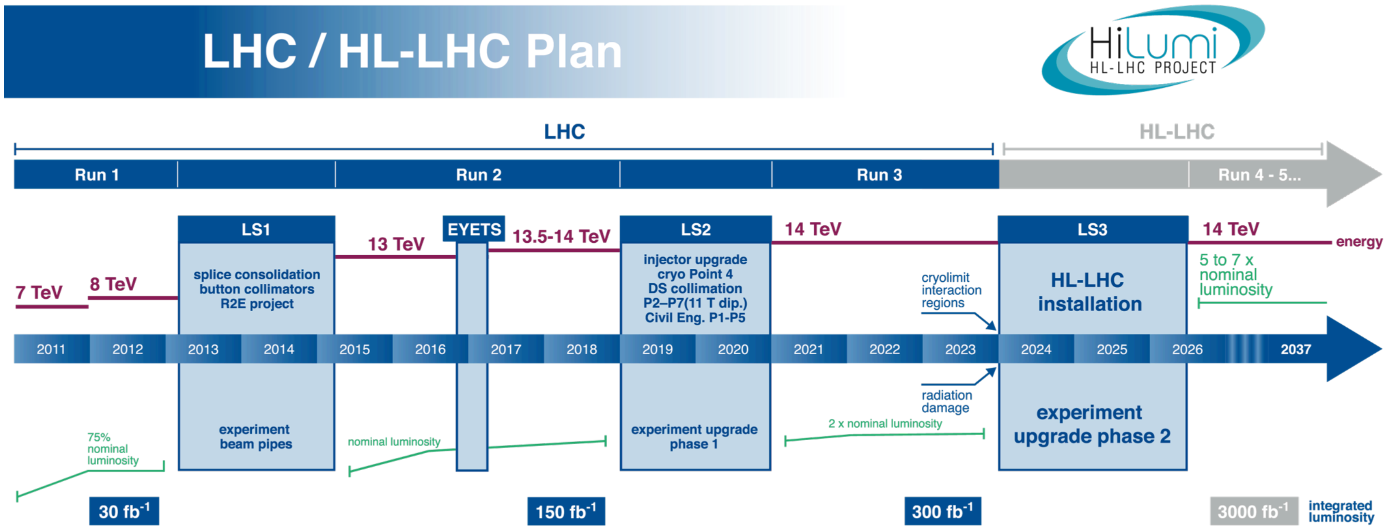
Search for DM via scalar/pseudoscalar mediator with bb+MET:





ATLAS upgrade

LHC plan the ATLAS upgrades



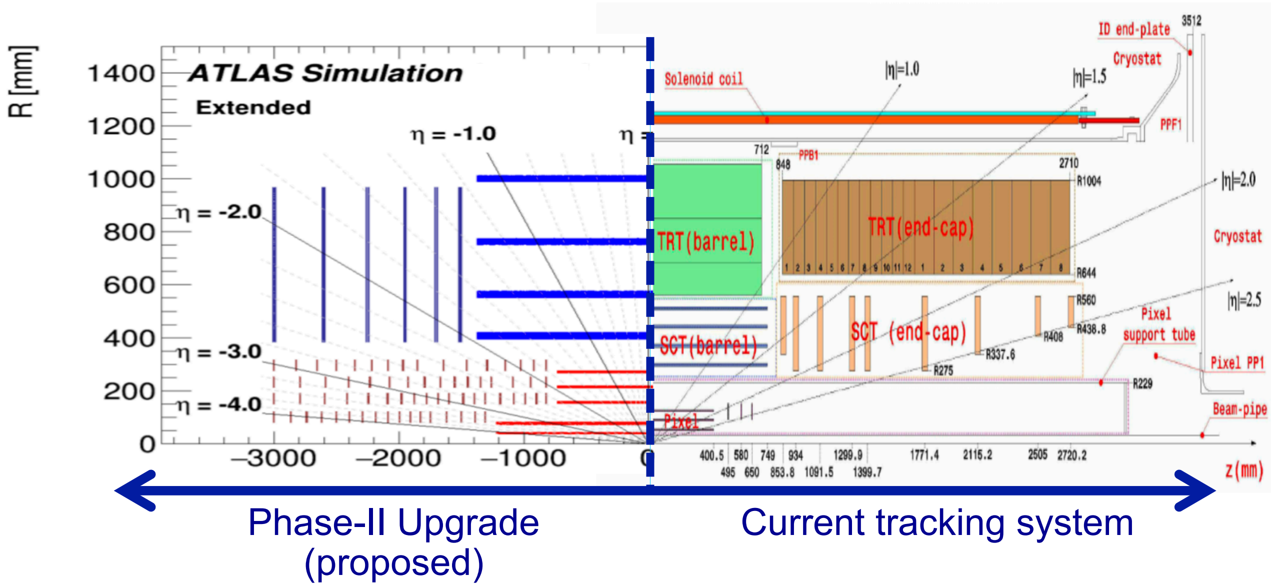
- Phase-I Upgrade for L=2-3×10^{34} cm^{-2}s^{-1}. In the advanced stages – production started
- Phase-II Upgrade for L=5-7.5×10^{34} cm^{-2}s^{-1}. Have to cope with the high pileup rate of $<\mu_{PU}>$= 140-200. In the design and prototyping stage

Major upgrades to ATLAS:

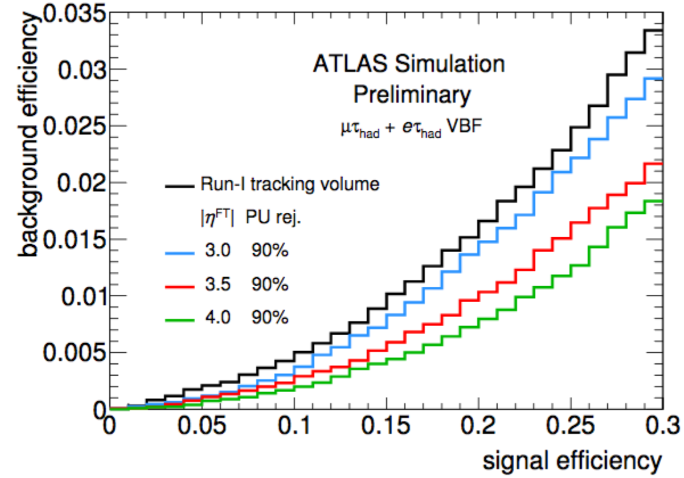
Tracking	Extend to $|\eta|<4.0$. All silicon
Calorimeter	Update all readout electronics. Timing in EM endcap (to reject pileup)
Trigger	Tracking added at L1, larger bandwith, finer granularity
Muon	New endcap wheel to reject fake L1 muons (Phase-I)

New Inner Tracker - ITk

[ATL-COM-UPGRADE-2017-006]
[ATL-PHYS-PUB-2014-018]



H→ττ projection:



Inner detector completely replaced with all-silicon tracker

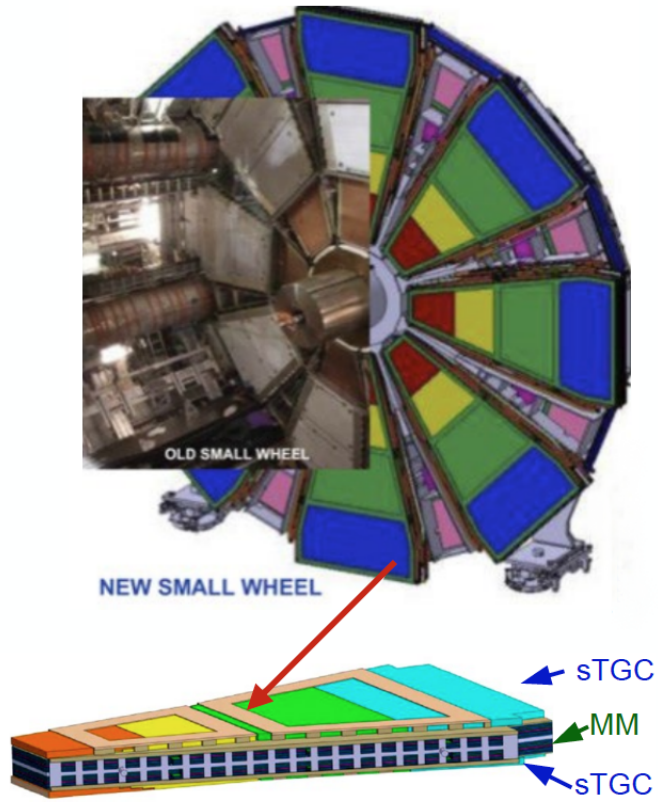
Extended coverage up to |η|<4.0

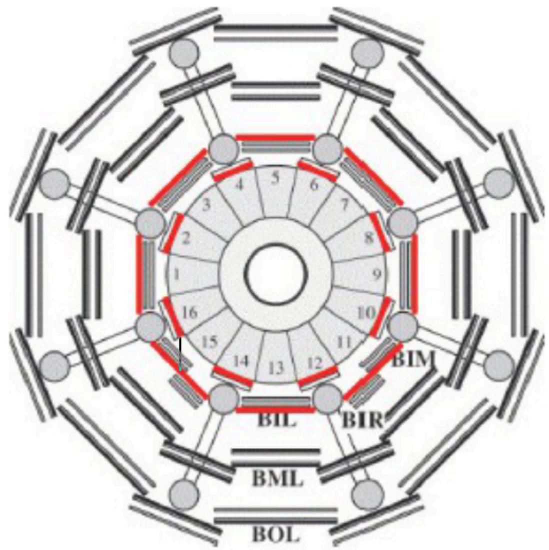
Reduced material in front of calorimeters. Low occupancy in pixel and strip layers

Pixels : 5 inner layers + forward: design study underway to decide on extended or inclined layout (the barrel)

Strips : 4 long barrels + 6 endcap disks

Muon and Timing detector





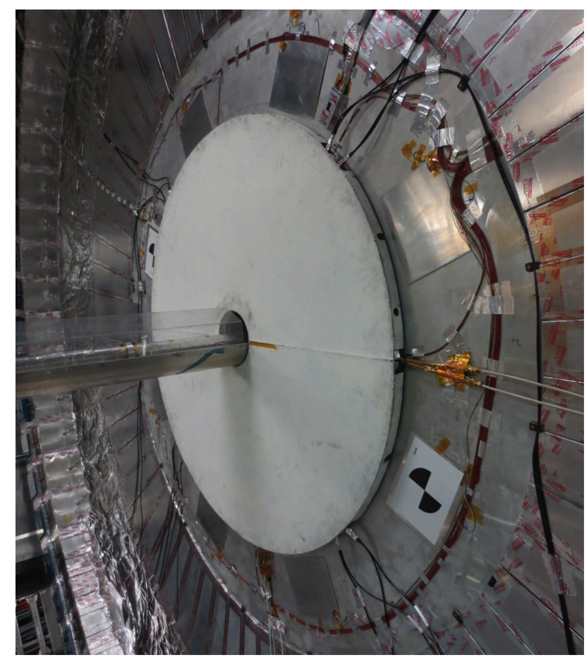
Phase-II Muon upgrade:

New Inner RPC layers in the barrel

Phase-I : replace inner wheel of muon endcap with New Small Wheel – microMegas (MM) and small strip thin-gap chambers (sTGC)

A timing detector :

Thin, high-granularity timing detector in the front of the endcap calorimeter (2.5< $|\eta|$<4.2)



ATLAS Scoping layouts

[CERN-LHCC-2015-020]

Detector System	Scoping Scenarios Reference (275 MCHF)	Middle (235 MCHF)	Low (200 MCHF)
Inner Tracker			
Pixel Detector	$\|\eta\| \leq 4.0$	$\|\eta\| \leq 3.2$	$\|\eta\| \leq 2.7$
Barrel Strip Detector	✓	✓ [No stub layer]	✓ [No stereo in layers #2,#4] [Remove layer #3] [No stub layer]
Endcap Strip Detector	✓	✓ [Remove 1 disk/side]	✓ [Remove 1 disk/side]
Calorimeters			
LAr Calorimeter Electronics	✓	✓	✓
Tile Calorimeter Electronics	✓	✓	✓
Forward Calorimeter	✓	✗	✗
High Granularity Precision Timing Detector	✓	✗	✗

Summary

With about 36 fb^{-1} of Run-2 data collected, many new physics are available and outperforms Run-1

Precision and differencial measurements in the bosonic Higgs decays are possible. $H\rightarrow\tau\tau$ is discovered (Run-1), but $H\rightarrow bb$ still needs time

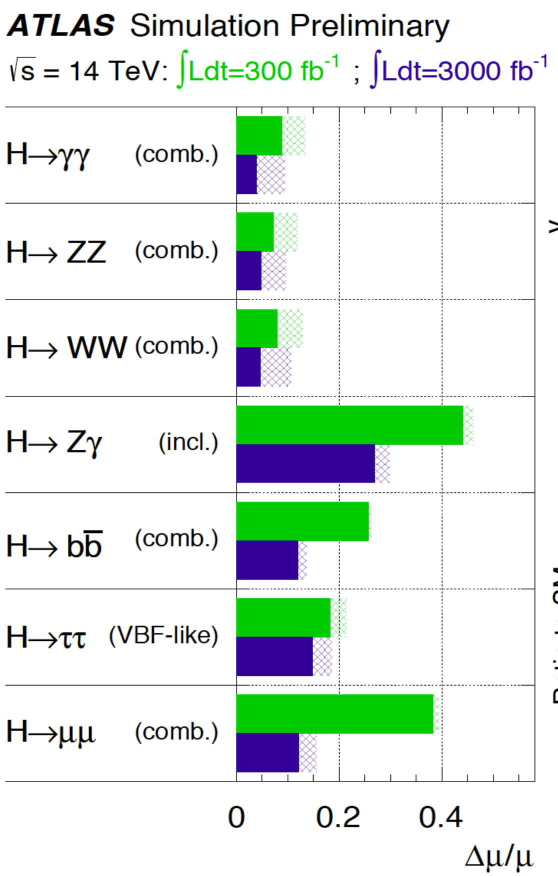
No significant excesses are observed in BSM Higgs, SUSY, and Exotics searches so far, and limits are getting tighter with more data

The upgrade programs will prepare ATLAS for high-luminosity LHC runs. A number of key improvement will be made to cope high pileups and detector degradations

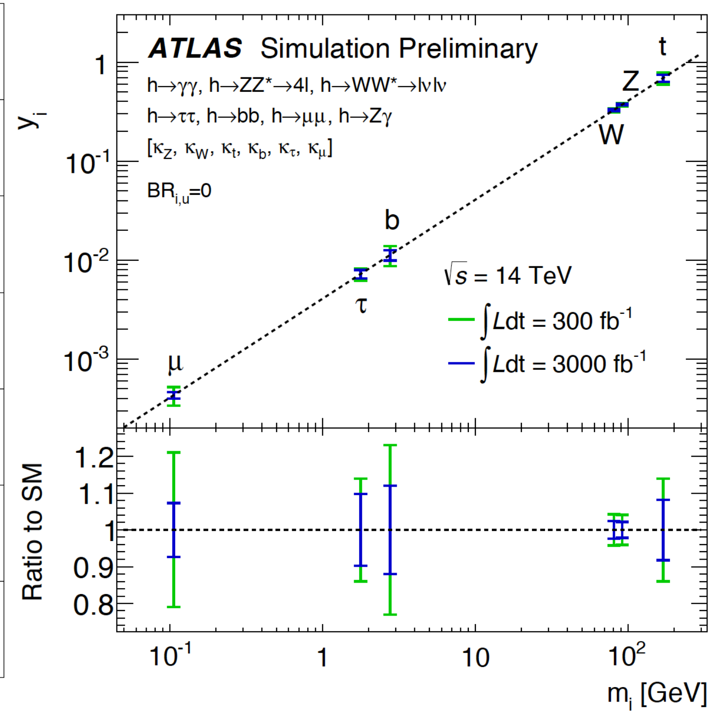
Not all latest results are included. Many are still going on. Stay tuned!

Extra Slides

Higgs prospects for HL-LHC [ATL-PHYS-PUB-2014-016/017]



Coupling versus mass:

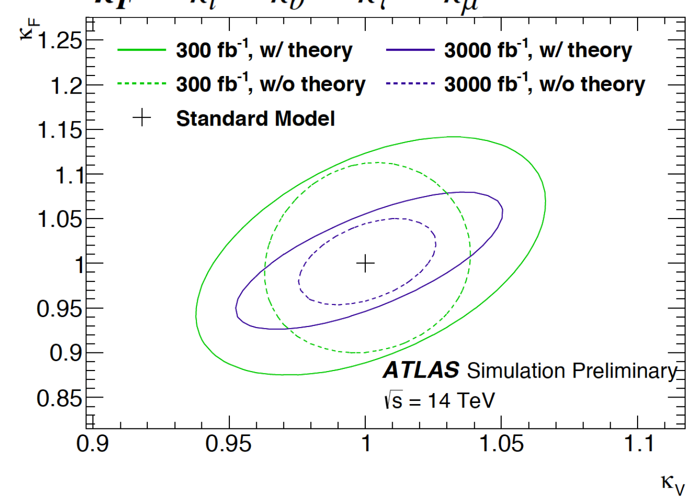


Errors on individual factors:

Nr.	Coupling	300 fb^{-1} Theory unc.: All	Half	None
8	κ_Z	8.1%	7.9%	7.9%
	κ_W	9.0%	8.7%	8.6%
	κ_t	22%	21%	20%
	κ_b	23%	22%	22%
	κ_τ	14%	14%	13%
	κ_μ	21%	21%	21%
	κ_g	14%	12%	11%
	κ_γ	9.3%	9.0%	8.9%
	$\kappa_{Z\gamma}$	24%	24%	24%

$\kappa_V = \kappa_Z = \kappa_W$

$\kappa_F = \kappa_t = \kappa_b = \kappa_\tau = \kappa_\mu$



More precise measurements of Higgs production and decay rates: ~10% (~20%) for the boson (fermion) decay

More precise determination of the Higgs mass and width

Test of the SM in the Higgs sector and probe for new physics such as MSSM, rare/new/invisible Higgs decay

Use EFT and differential variables for advanced Higgs property tests