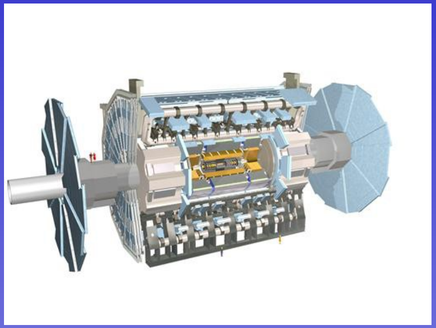


# First Atlas Results from Run II


Hernán Wahlberg

On behalf of the ATLAS Collaboration


HEP2016 - Valparaíso 6-12 January 2016

IFLP CONICET UNLP

Universidad Nacional de La Plata

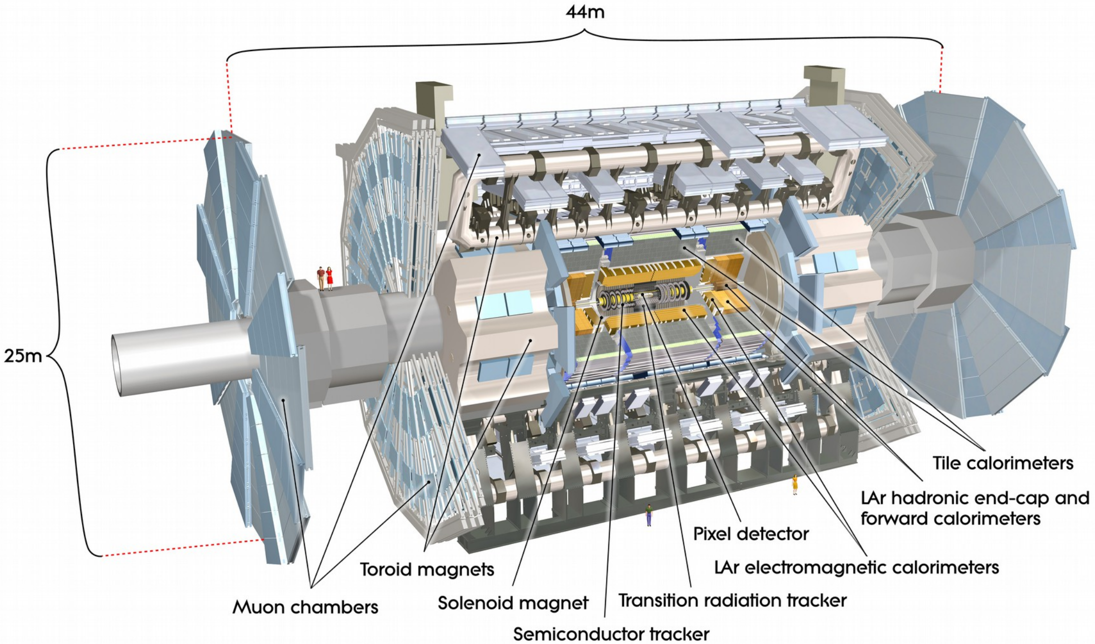
ATLAS EXPERIMENT

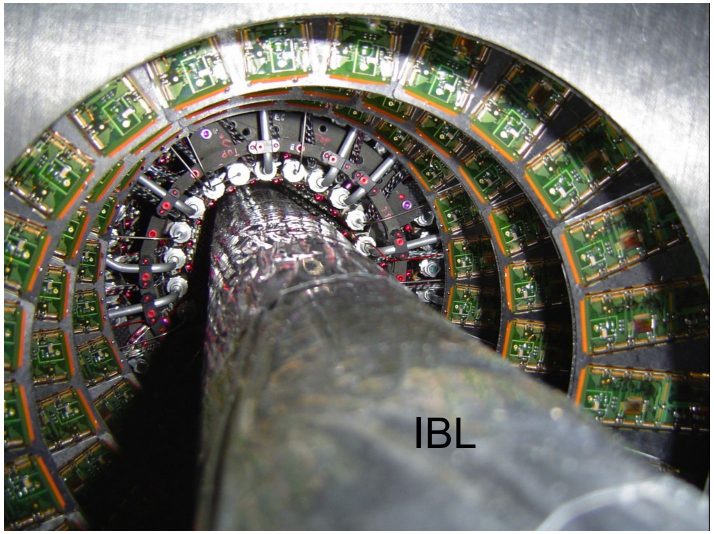
# Run II early results from 2015 13 TeV data

- Standard Model (see G. Salamanna, M. Villaplana Perez, L. Masseti this conference)
  - p-p cross section/ single top / ttbar-jets
- Higgs
  - $H \rightarrow ZZ^* \rightarrow \ell^+\ell^-\ell'^+\ell'^-$ / $H \rightarrow \gamma\gamma$ / Combined Cross Section
- Higgs / Exotic (see R. Ferrari this conference)
  - High mass: ZZ / WW / VV / VH / $\gamma\gamma$
- SUSY (see A. Soffer this conference)
  - Strong production / 0L + Jets / 1L inclusive / Z+MET / 3b / SS 3L / sbottom
- Exotics (see J. Benitez this conference)
  - Z' / W' / W Z (had) MET / LFV Z'
  - Dark Matter (see A. Nelson this conference)
- Other topics not covered in this talk:Pb + Pb Collisions (M. I. Arratia Munoz, D. V. Perepelitsa this conference) ; Future Upgrades (G. Aielli)

# ATLAS Improvements during 2013/2014 Shutdown

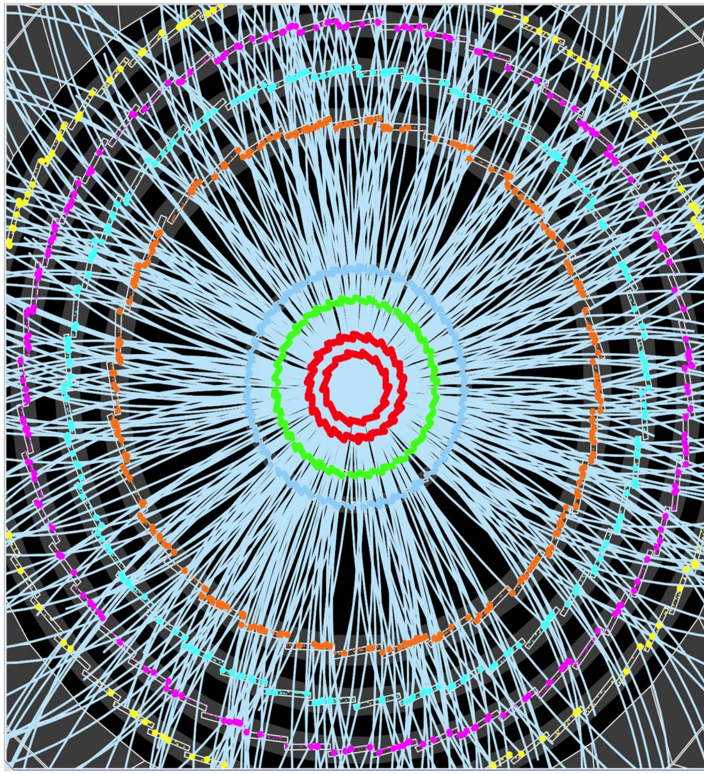
The ATLAS detector has been improved (see F. Winklmeier this conference)




- Infrastructure
  - New beam-pipe, improvements to magnet and cryogenic system
- Detector consolidation
  - Muon chambers completion and various repairs
- 4$^{th}$ silicon pixel detector layer, Insertable B-Layer (IBL)
  - Innermost Pixel detector layer at 3.3 cm from beam pipe
- Trigger/DAQ
  - Increase max L1 rate from 75kHz to 100kHz. New L1 topological trigger. New Central Trigger Processor. Merge L2 and HLT farms.

# Run II started exploring new frontiers !

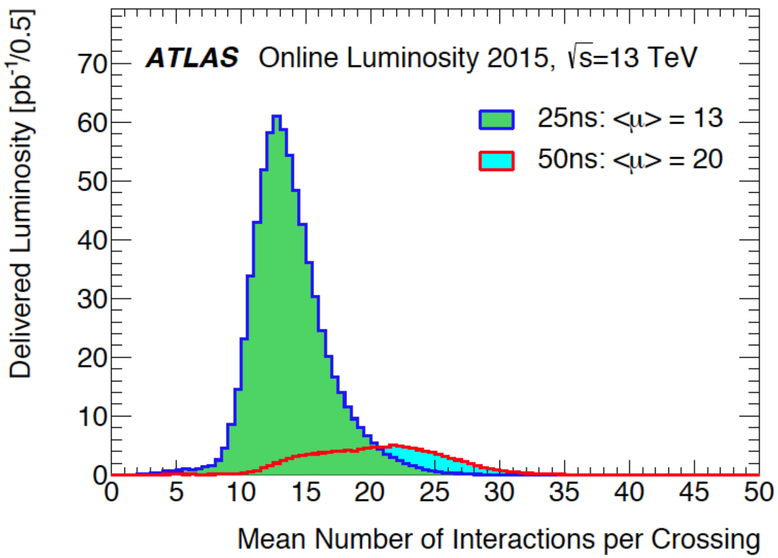


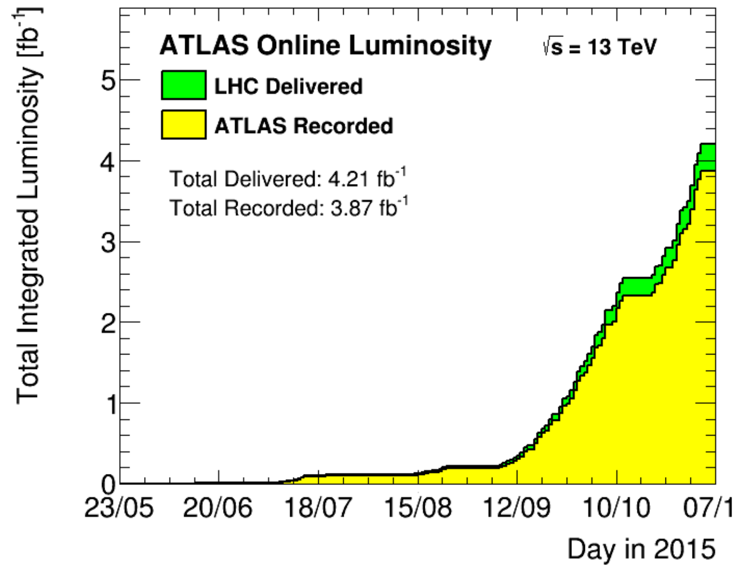

3rd of June 2015

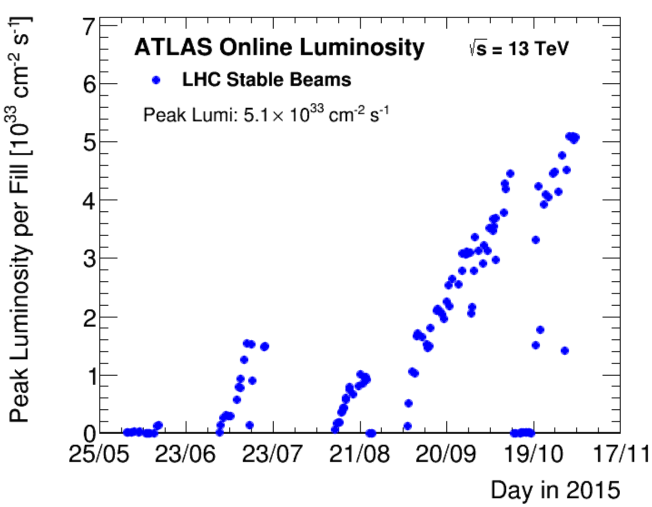
# 2015 Run II data taking

- Pileup at 2015 Run II less difficult than at Run I
  - Run I 8 TeV (mu~21) and 7 TeV (mu~9)

Data taking efficiency of 92%



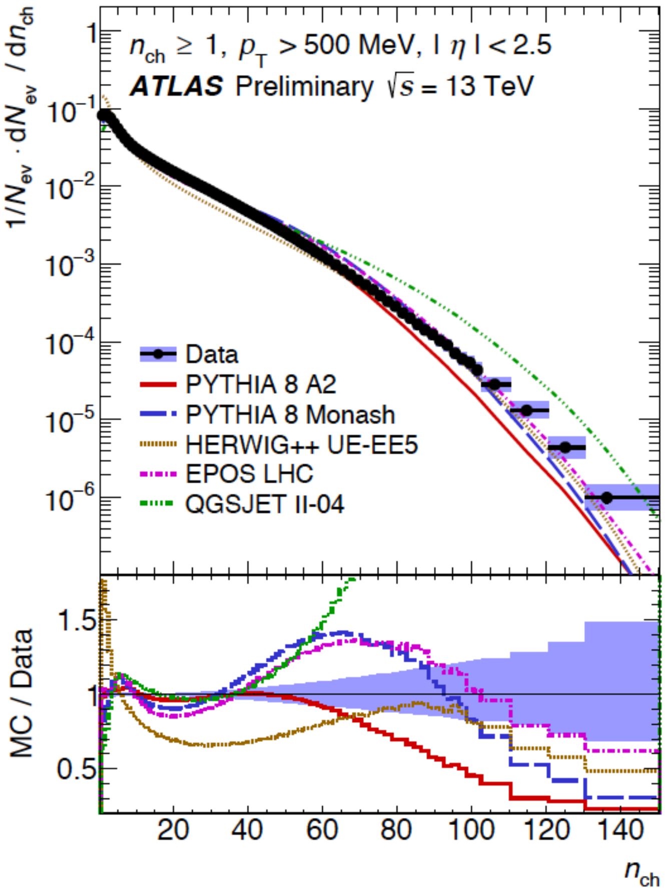

**ATLAS pp 25ns run: August-November 2015**

| Inner Tracker | | | Calorimeters | | Muon Spectrometer | | | | Magnets | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pixel | SCT | TRT | LAr | Tile | MDT | RPC | CSC | TGC | Solenoid | Toroid |
| 93.5 | 99.4 | 98.3 | 99.4 | 100 | 100 | 100 | 100 | 100 | 100 | 97.8 |
| **All Good for physics: 87.1% (3.2 $fb^{-1}$)** | | | | | | | | | | |

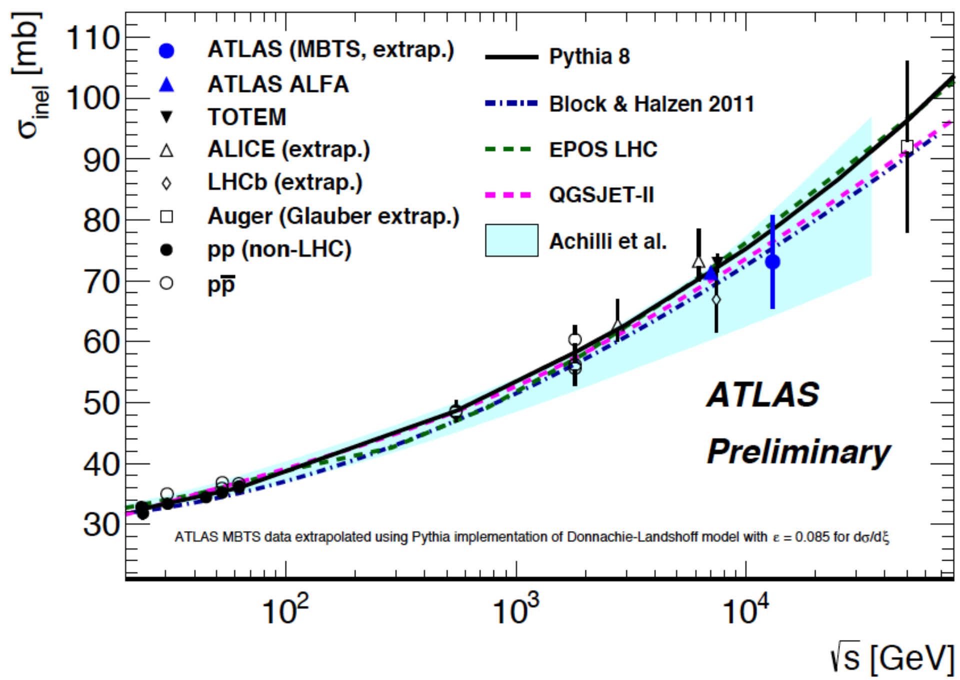
Luminosity weighted relative detector uptime and good data quality (DQ) efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at $\sqrt{s}$=13 TeV between August-November 2015, corresponding to an integrated luminosity of 3.7 $fb^{-1}$. The lower DQ efficiency in the Pixel detector is due to the IBL being turned off for two runs, corresponding to 0.2 $fb^{-1}$. Analyses that don't rely on the IBL can use those runs and thus use 3.4 $fb^{-1}$ with a corresponding DQ efficiency of 93.1%.

# SM measurements with very first Run II data (I)

Inclusive charged-particle measurements provide insight into the strong interaction in the low energy, non-perturbative QCD region




p-p inelastic cross section from Minimum Bias Trigger Scintillators (MBTS), are installed on the front faces of each end-cap calorimeter

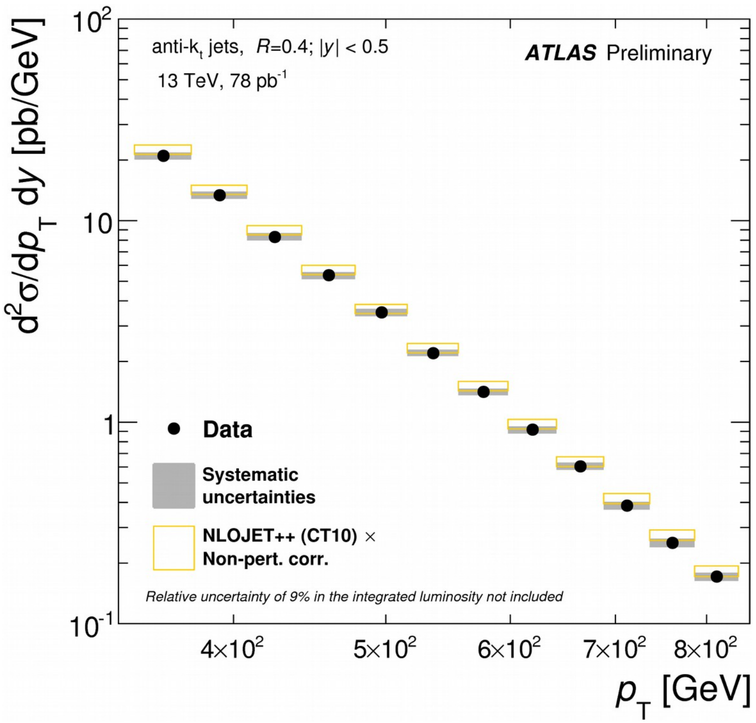



MC tunes describe the data reasonably well at this new centre-of-mass energy

ATLAS-CONF-215-028; ATLAS−CONF−2015−038

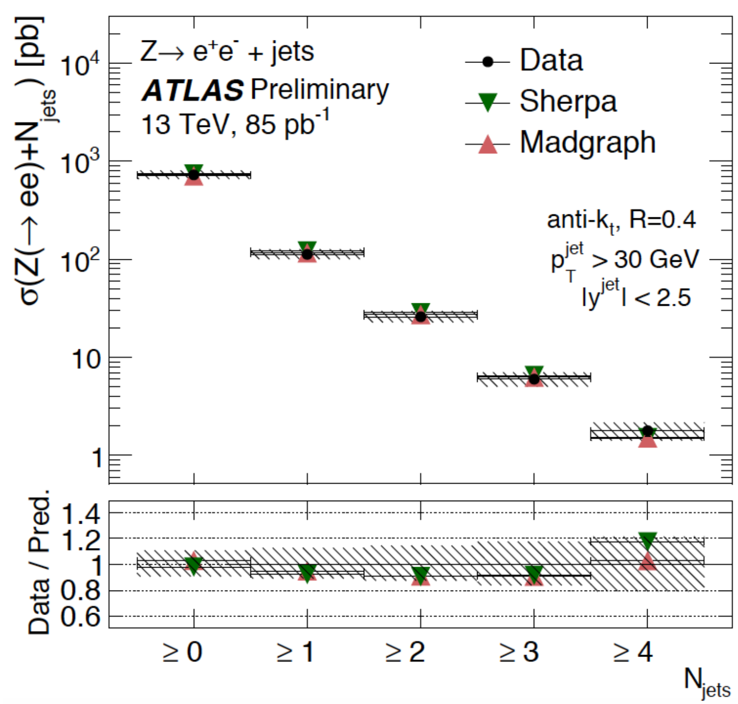
# SM measurements with very first Run II data (II)

Inclusive-jet cross section: the measurement provides a test of the validity of perturbative QCD




The predictions are consistent with the measured cross sections (jet energy scale and resolution uncertainties included)

Z+jets: represent an important test of perturbative QCD and constitute a non-negligible background for studies of the Higgs boson and searches for new phenomena

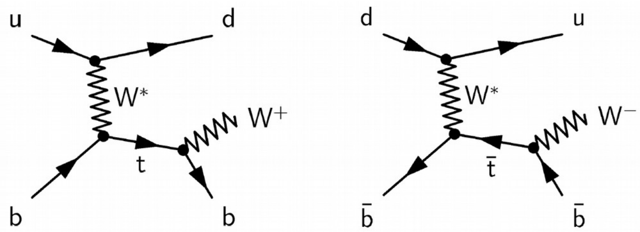



Reasonable agreement between observed cross sections and predictions from Sherpa and MadGraph

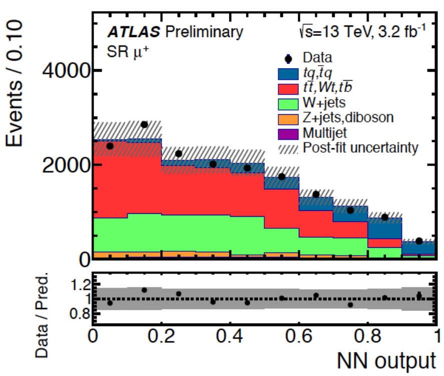
ATLAS-CONF-215-034; ATLAS−CONF−2015−041

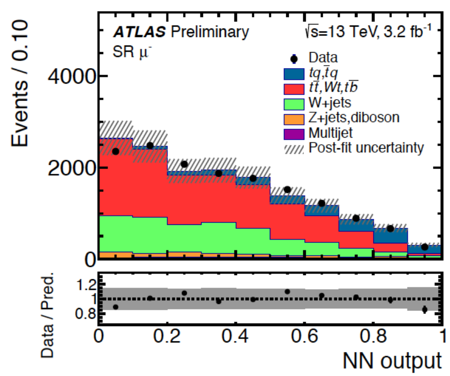
# Top quark production

## Electroweak production of single top quark




10 variables are used in the training of a Neural Network.
One output node which gives a continuous output in the interval [0; 1].

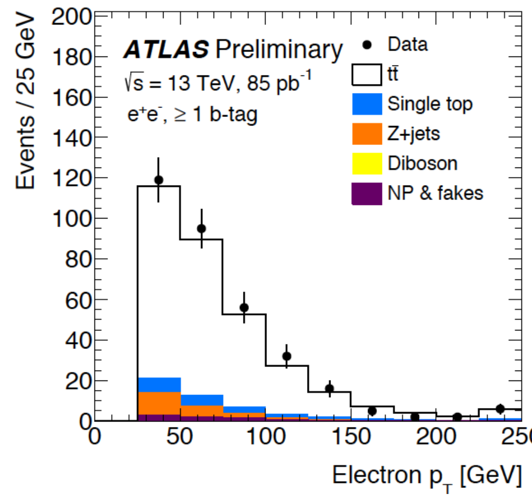


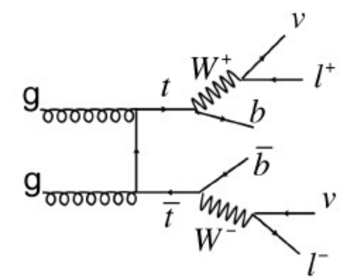



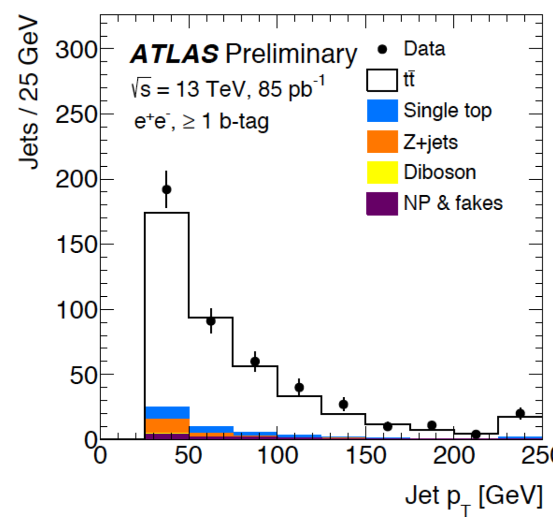

$$\sigma(tq) = 133 \pm 6\,(\text{stat.}) \pm 24\,(\text{syst.}) \pm 7\,(\text{lumi.})\ \text{pb}$$
$$= 133 \pm 25\ \text{pb},$$
$$\sigma(\bar{t}q) = 96 \pm 5\,(\text{stat.}) \pm 23\,(\text{syst.}) \pm 5\,(\text{lumi.})\ \text{pb}$$
$$= 96 \pm 24\ \text{pb},$$

(limited by systematics)

## Top pair production in lepton channels ($ee$,$\mu\mu$,$e\mu$) and b-tags jets



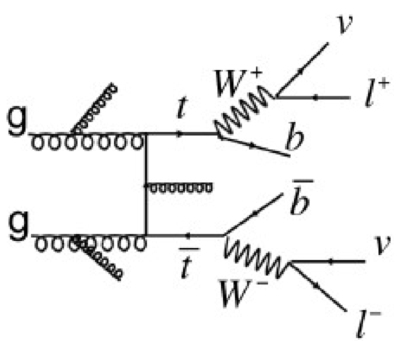

Good agreement in cross-sections and kinematics with NLO/NNLO MC predictions

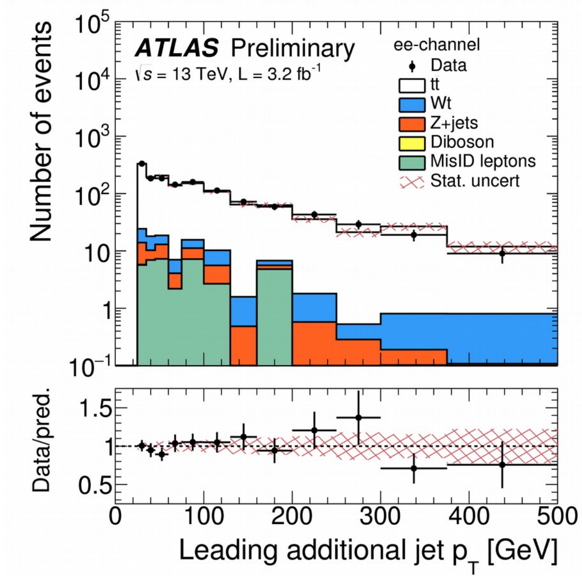
ATLAS−CONF−2015−079 ; ATLAS−CONF−2015−033 ; ATLAS−CONF−2015−049

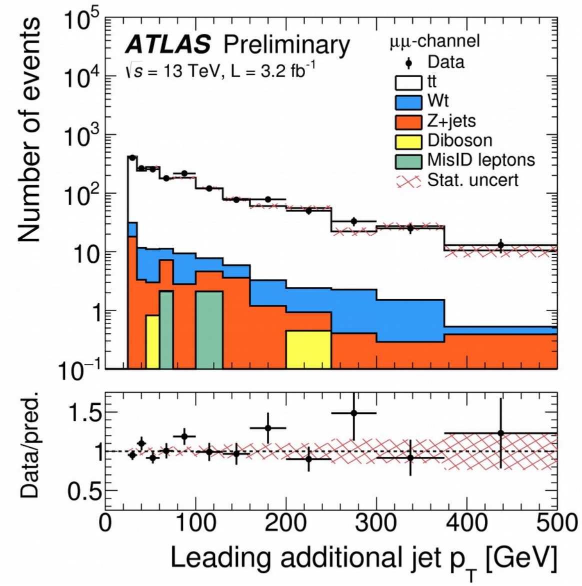
# Production of tt and jets

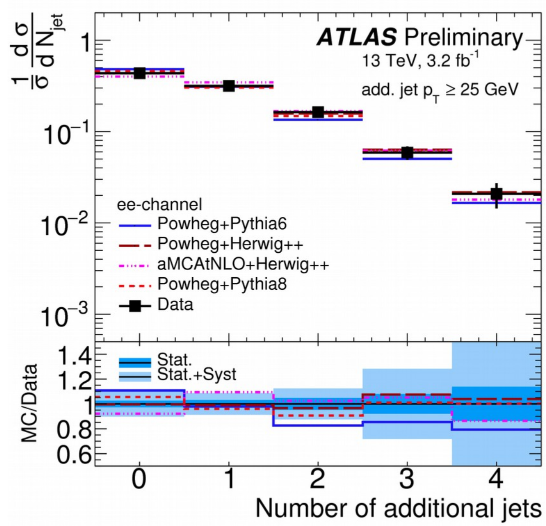
Important for ttH, MC tuning to estimate ISR/FSR uncertainties.

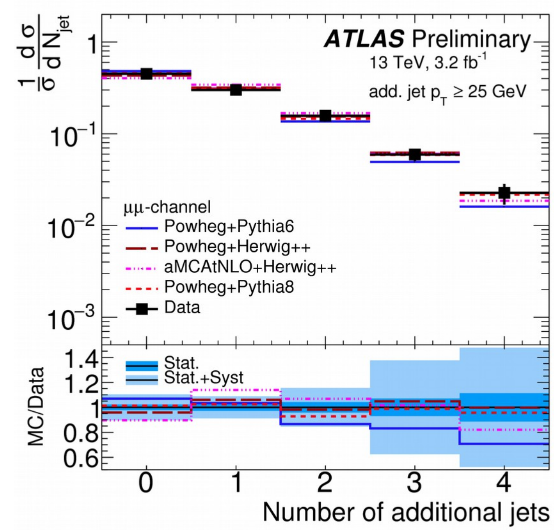
Di-lepton channels ($ee,\mu\mu,e\mu$). Good agreement of Jet kinematics



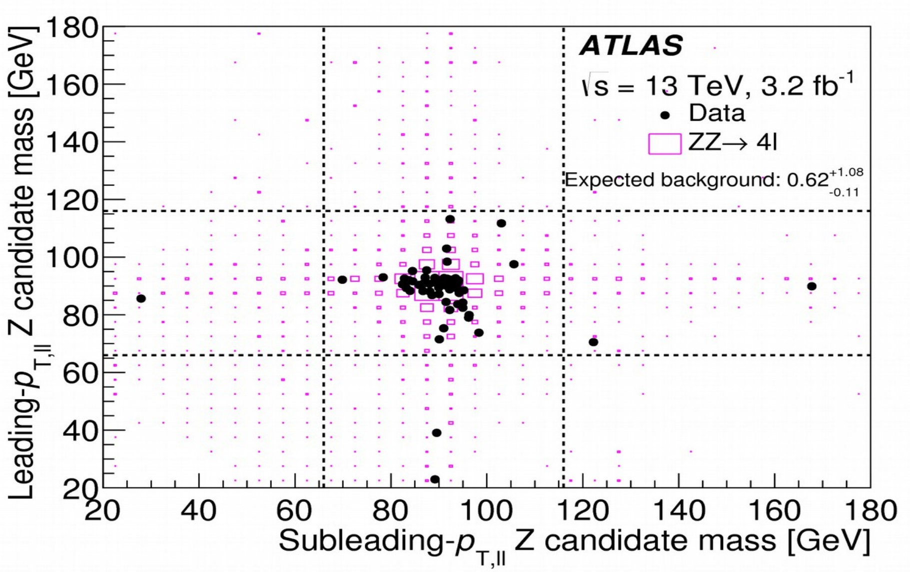



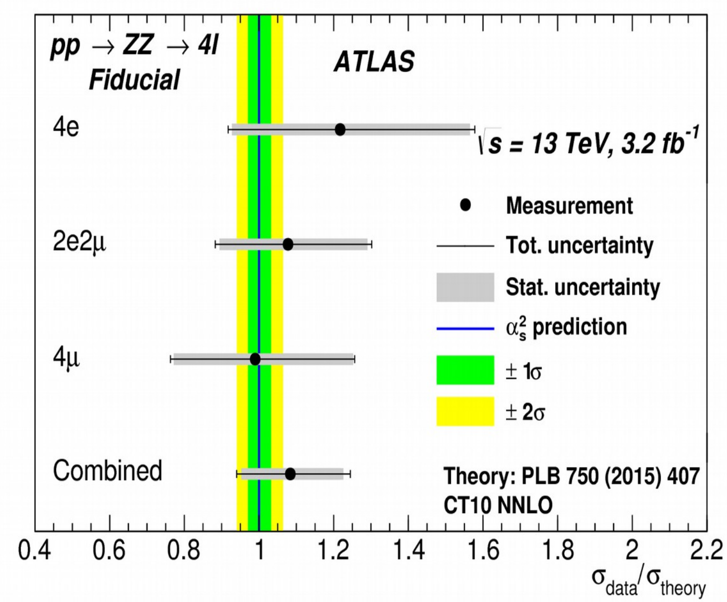

Unfolded jet multiplicity in good agreement with MC predictions

ATLAS−CONF−2015−065

# Measurement of the ZZ cross section

- Study production of pairs of Z to tests the electroweak sector of the SM
- Non-Higgs ZZ production is an important background in studies of the Higgs boson
- Background in searches for new physics producing pairs of Z bosons at high invariant mass




Measurement in the 4 lepton channel with the Z (66 < mll < 116 GeV)

| | Measurement | $O(\alpha_S^2)$ prediction |
|---|---|---|
| $\sigma^{\rm fid}_{ZZ\to e^+e^-e^+e^-}$ | $8.4\ ^{+2.4}_{-2.0}$(stat.) $^{+0.4}_{-0.2}$(syst.) $^{+0.5}_{-0.3}$(lumi.) fb | $6.9^{+0.2}_{-0.2}$ fb |
| $\sigma^{\rm fid}_{ZZ\to e^+e^-\mu^+\mu^-}$ | $14.7\ ^{+2.9}_{-2.5}$(stat.) $^{+0.6}_{-0.4}$(syst.) $^{+0.9}_{-0.6}$(lumi.) fb | $13.6^{+0.4}_{-0.4}$ fb |
| $\sigma^{\rm fid}_{ZZ\to \mu^+\mu^-\mu^+\mu^-}$ | $6.8\ ^{+1.8}_{-1.5}$(stat.) $^{+0.3}_{-0.3}$(syst.) $^{+0.4}_{-0.3}$(lumi.) fb | $6.9^{+0.2}_{-0.2}$ fb |
| $\sigma^{\rm fid}_{ZZ\to \ell^+\ell^-\ell^+\ell^-}$ | $29.7\ ^{+3.9}_{-3.6}$(stat.) $^{+1.0}_{-0.8}$(syst.) $^{+1.7}_{-1.3}$(lumi.) fb | $27.4^{+0.9}_{-0.8}$ fb |
| $\sigma^{\rm tot}_{ZZ}$ | $16.7\ ^{+2.2}_{-2.0}$(stat.) $^{+0.9}_{-0.7}$(syst.) $^{+1.0}_{-0.7}$(lumi.) pb | $15.6^{+0.4}_{-0.4}$ pb |

In agreement with NNLO prediction

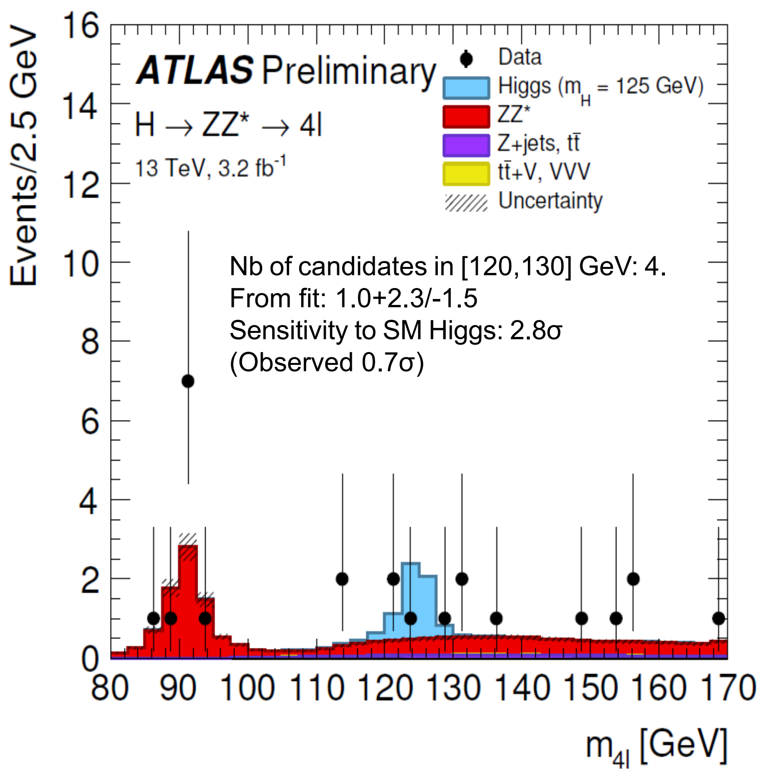
arXiv:1512.05314v1

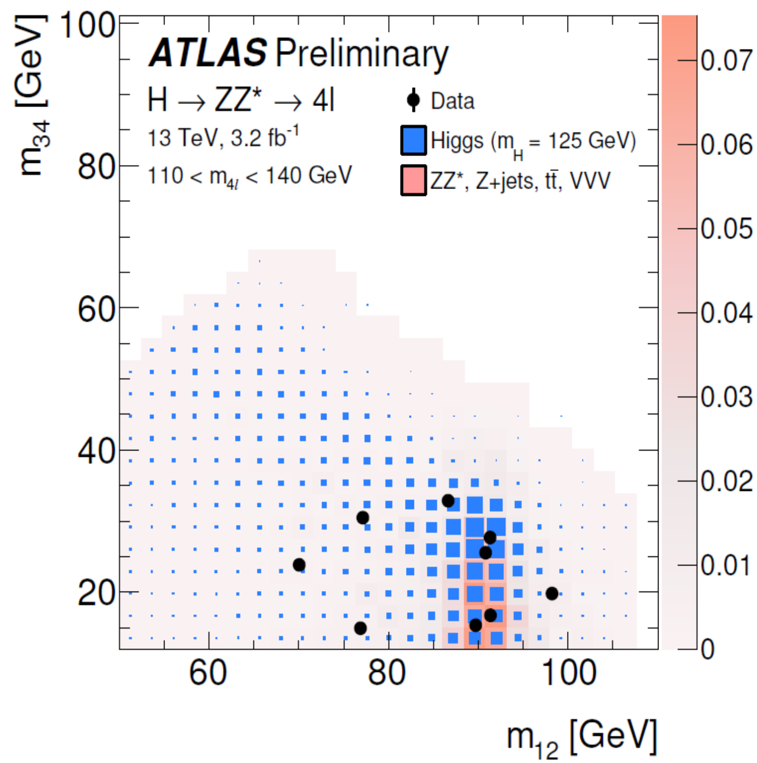
# $H \rightarrow ZZ^* \rightarrow \ell^+\ell^-\ell'^+\ell'^-$ fiducial and total cross section

One of the Higgs discovery channels, good sensitivity due to its high signal-to-background ratio, which is about 2 for each of the four final states.

The ATLAS and CMS collaborations have reported a combined measurement of the Higgs boson mass of $m_H$ = 125,09 ± 0,21(stat) ± 0,11(syst)

- Event selections are mostly the same as in Run I
- Optimized isolation and new impact parameter significance selection

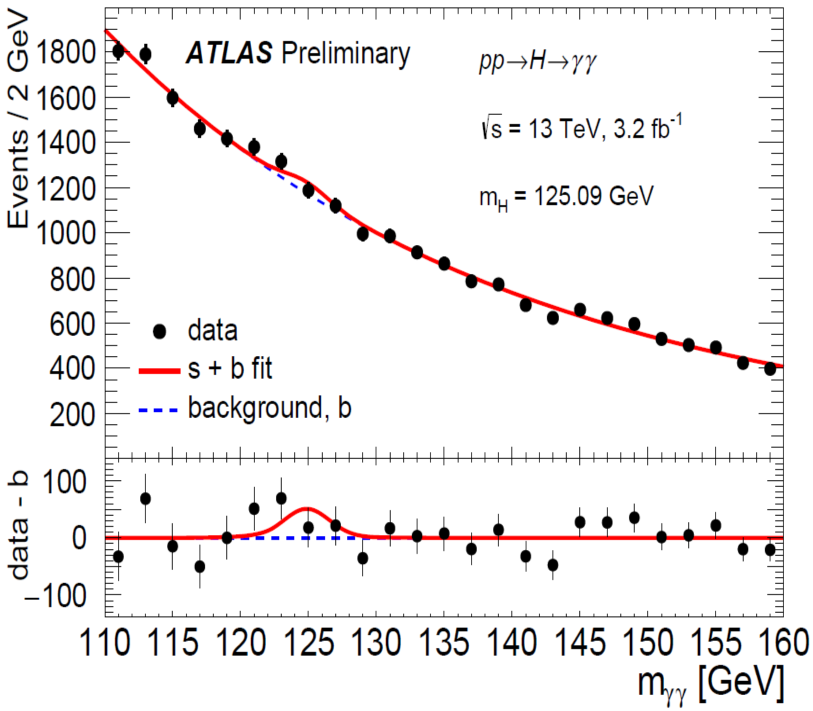


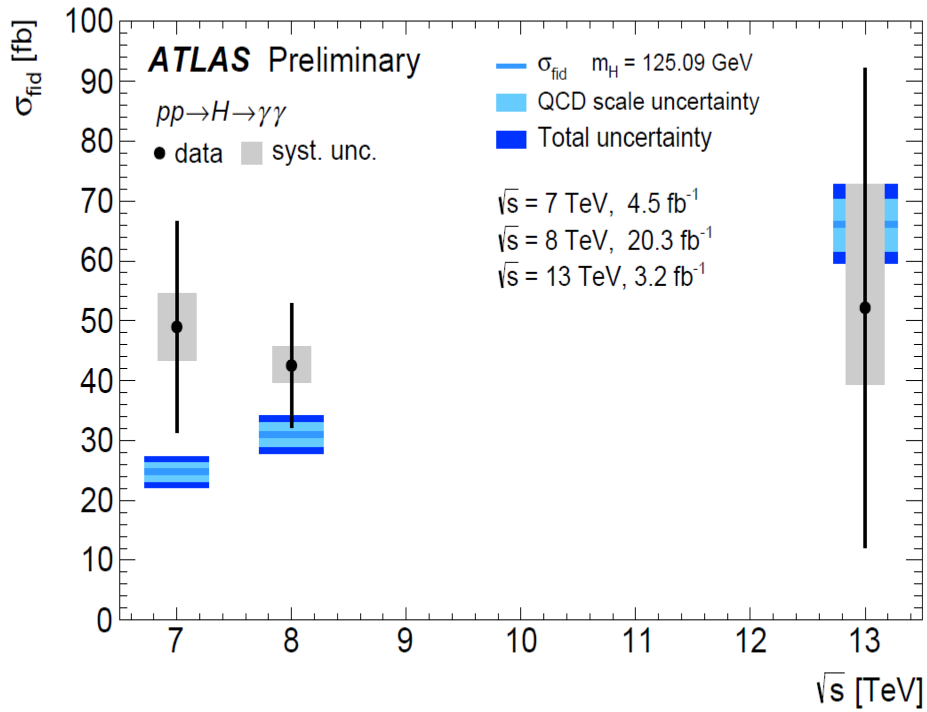




ATLAS-CONF-2015-059

# $H \rightarrow \gamma\gamma$ fiducial and total cross section

- Simple signature, the large experimental selection efficiency and the excellent invariant-mass resolution.
- The cross section at 13 TeV is measured in a fiducial region using a similar definition compared to the existing 8 TeV result (only the isolation definition is updated)

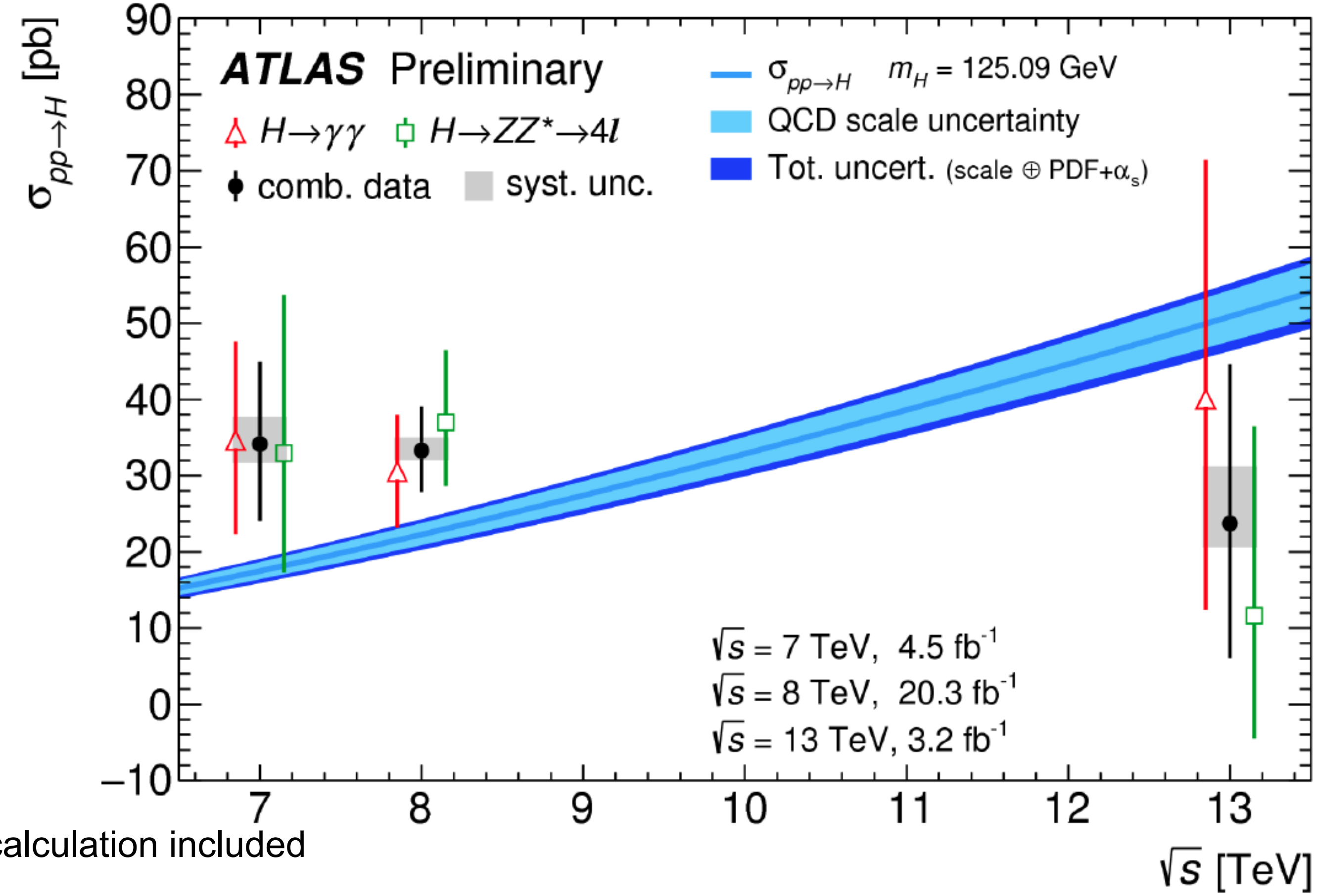



New 7 TeV calculation included

ATLAS-CONF-2015-060

# Combined cross section



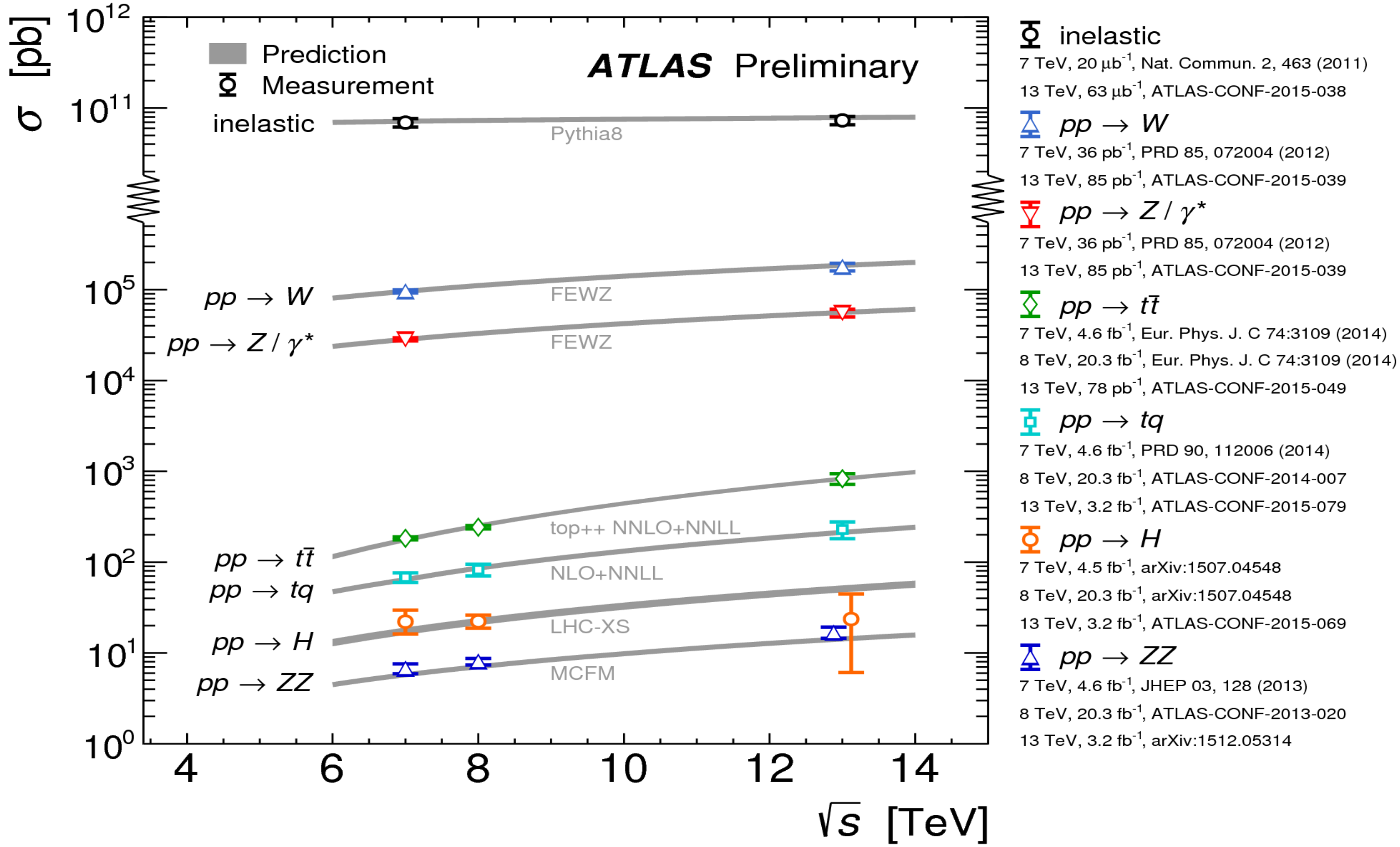

New 7 TeV calculation included

Compatibility with SM: 1.3σ

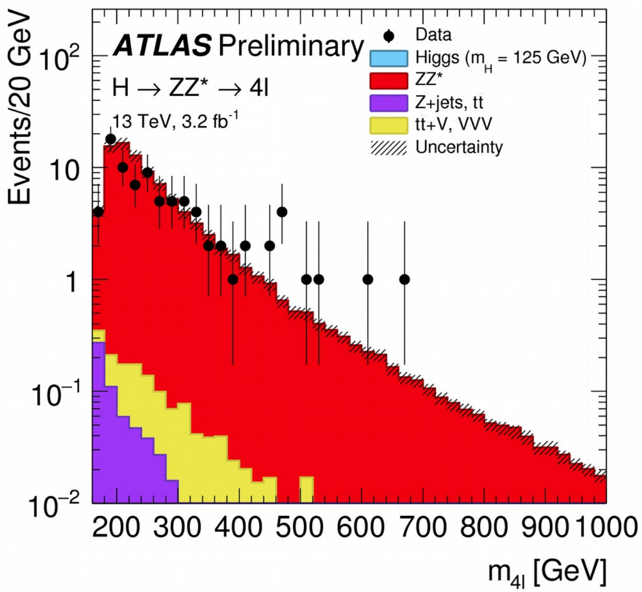
ATLAS-CONF-2015-069

# Summary of cross sections

Higgs cross section in the SM √s plot !

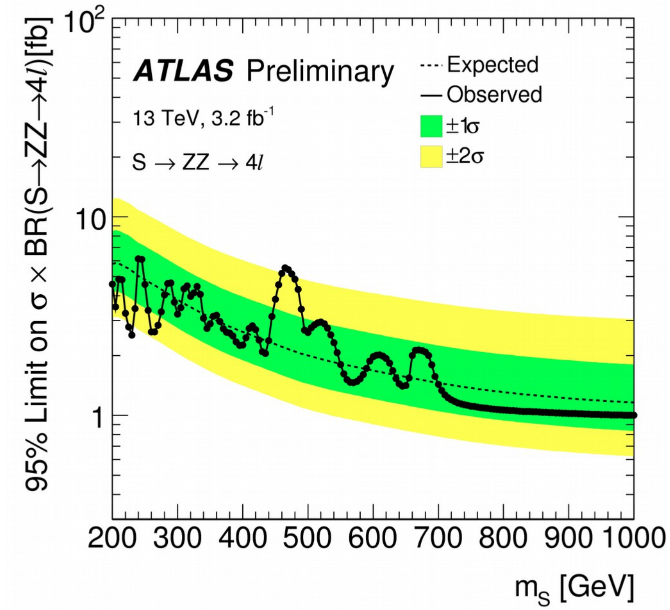


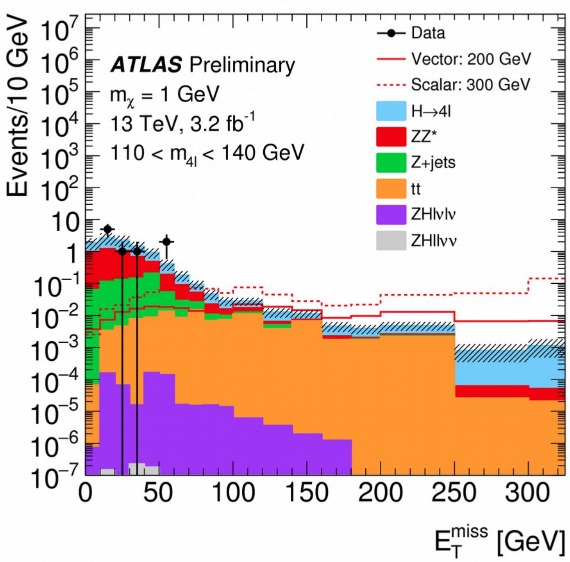
# High mass search in 4l final state and H+ MET




Search for additional heavy scalar [0.2,1] TeV $m_H$ range investigated in Narrow width approximation

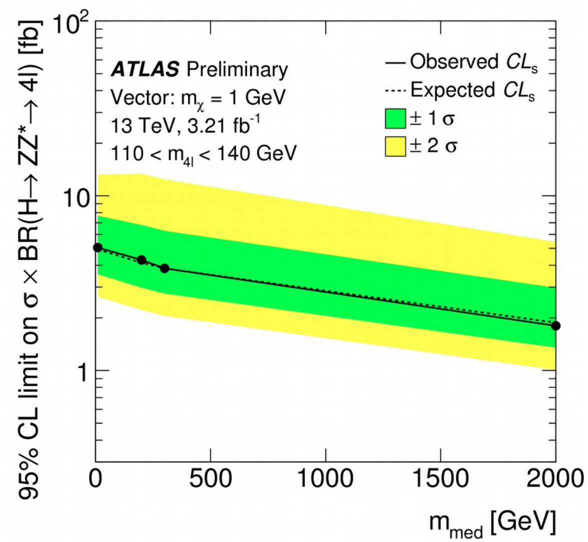
No significant excess found




Search for Dark Matter produced in association with a Higgs boson though excess at high Missing Transverse Energy (MET) in H→ZZ*→4 events

No significant excess→ limits on simplified DM models with heavy mediators

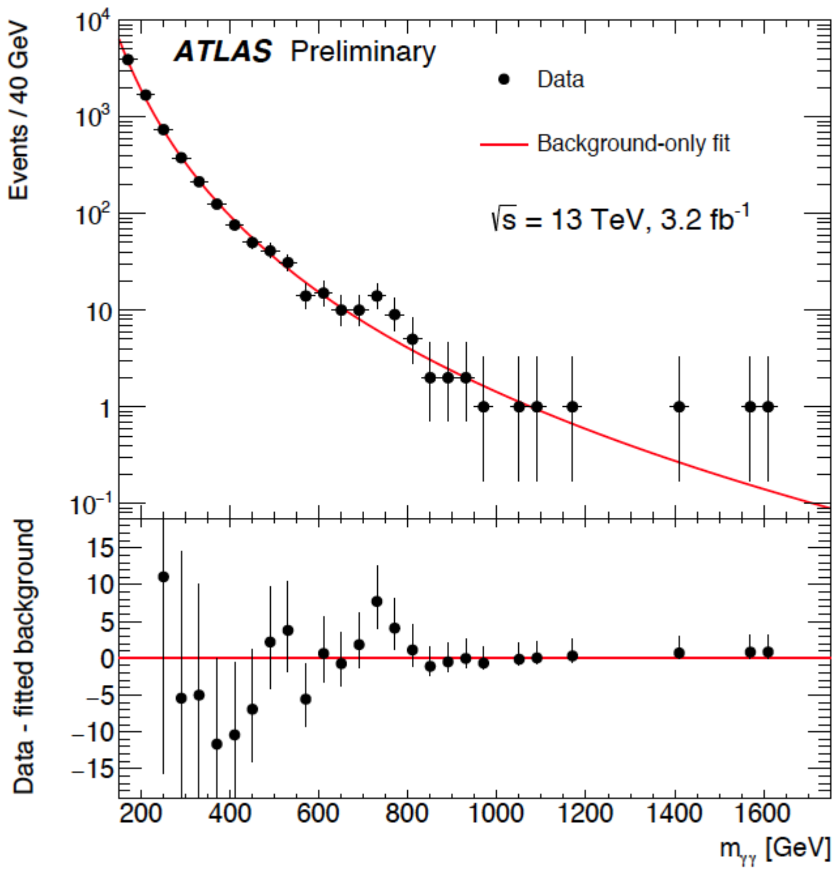


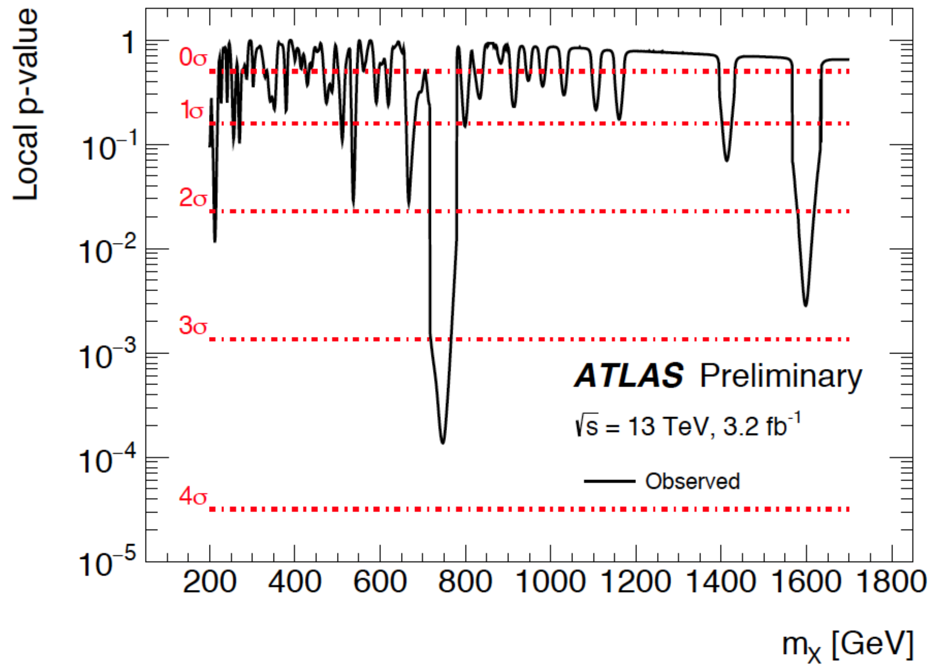

ATLAS-CONF-2015-059

# High mass search in diphoton final state

Inclusive search optimized for a scalar resonance

- Selection of two photons with $p_T/m$ thresholds of 0.3 and 0.4
- $p_T$ dependent EM and track isolation criteria




In the Narrow Width Approximation (NWA) search, an excess of 3.6σ (local) is observed at a mass hypothesis of minimal $p_0$ of 750 GeV

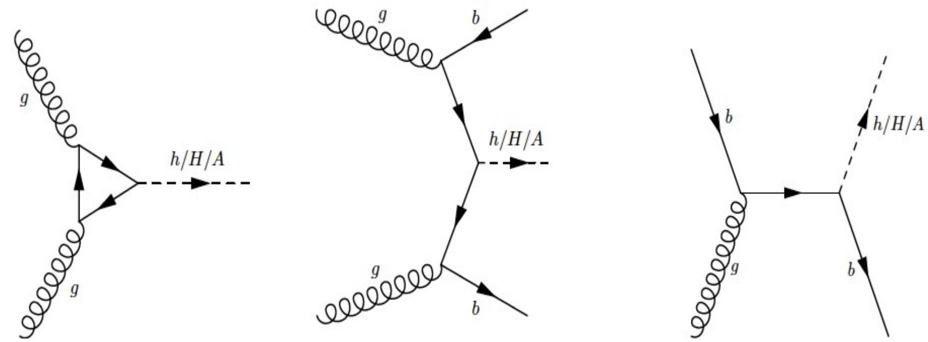
Taking into account Look Elsewhere Effect (LEE) in a mass range 0.2-2TeV a global significance of 2.0σ is found

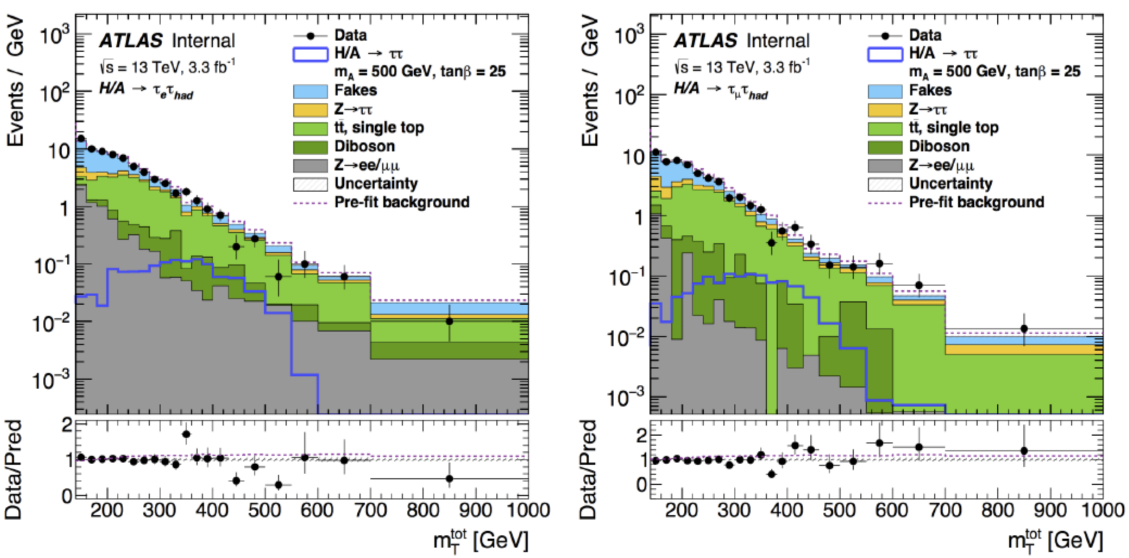
Large Width hypothesis yields 3.9σ (local) and 2.3σ (global) significance

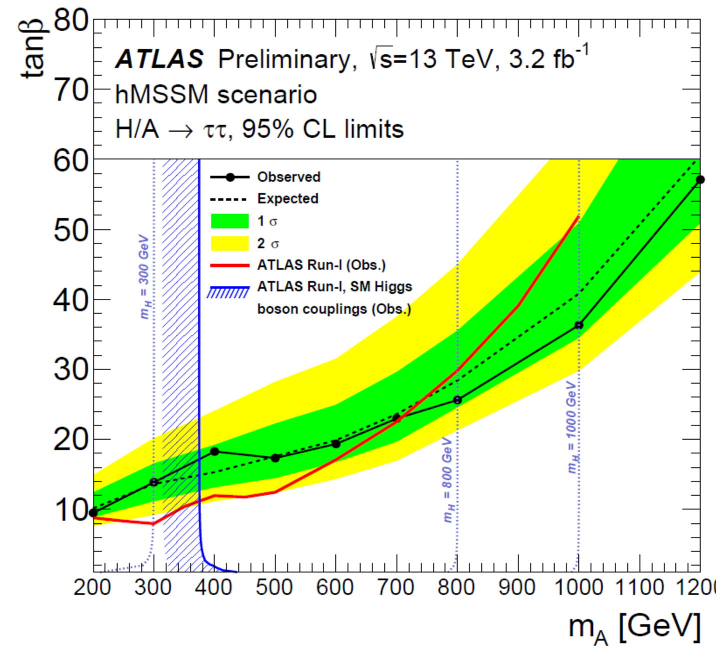
ATLAS-CONF-2015-081

# Search for supersymmetric (SUSY) Higgs H/A

$H/A \rightarrow \tau_{had}\,\tau_{had}$ / $\tau_{lep}\,\tau_{had}$ is the most important channel to probe the high $m_A$ / high tanβ parameter space of the MSSM



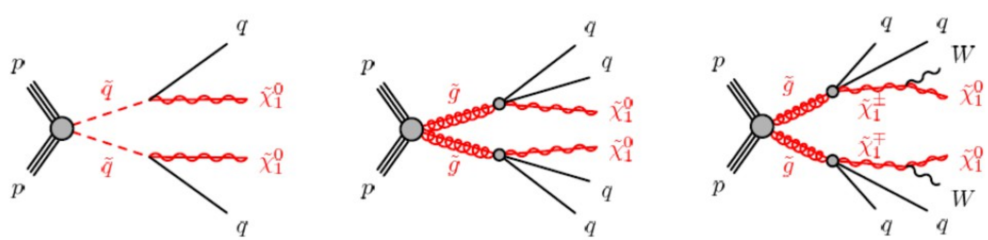

$$m_{\mathrm{T}}(a, b) = \sqrt{2p_T(a)p_T(b)(1 - \cos\Delta\phi(a, b))}$$

$$m_{\mathrm{T}}^{\mathrm{tot}} = \sqrt{m_T^2(E_{\mathrm{T}}^{\mathrm{miss}}, \tau_1) + m_{\mathrm{T}}^2(E_{\mathrm{T}}^{\mathrm{miss}}, \tau_2) + m_{\mathrm{T}}^2(\tau_1, \tau_2)}$$

Better sensitivity than Run I for high $m_A$

ATLAS-CONF-2015-061

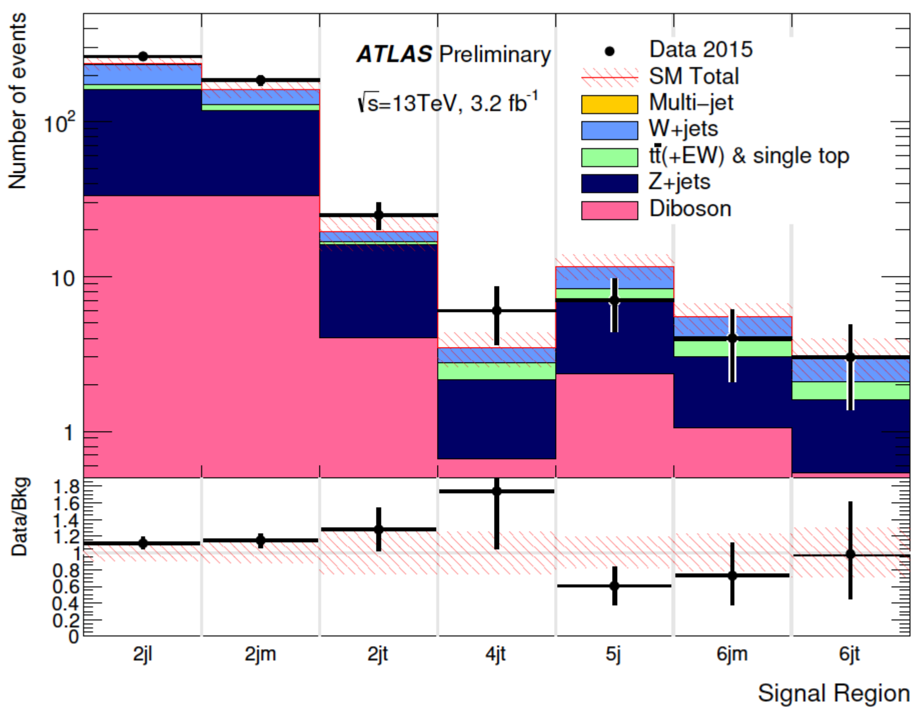
# Search SUSY in final states with jets + MET (0 lepton)

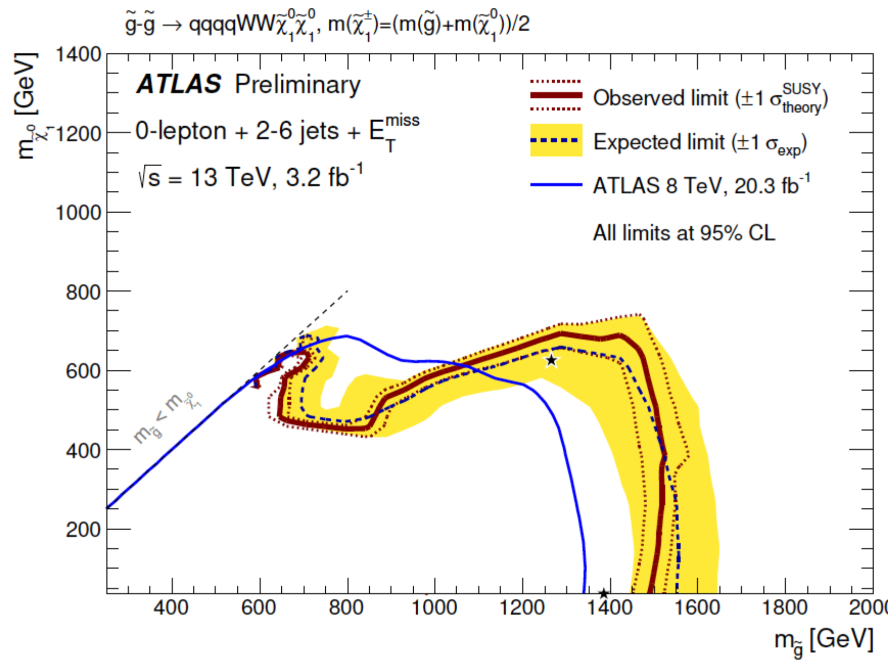


For Run II early data main focus of SUSY searches is strong production of gluinos and (to lesser extent) squarks:

Ratio of 13 TeV / 8 TeV Cross sections
Squarks and Gluinos:
1.5 TeV: 35
1 TeV : 15

Search for squarks and gluinos production in 2-4-5-6 jets different signal regions with loose, medium and tight MET selection

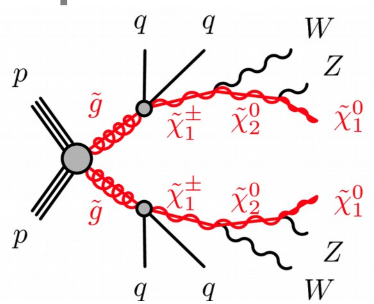



- Masses below ~1500 GeV are excluded
- Significant improvement over Run 1 limits

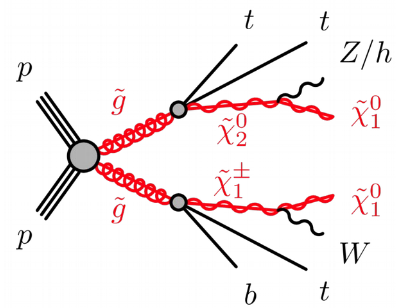
ATLAS-CONF-2015-062

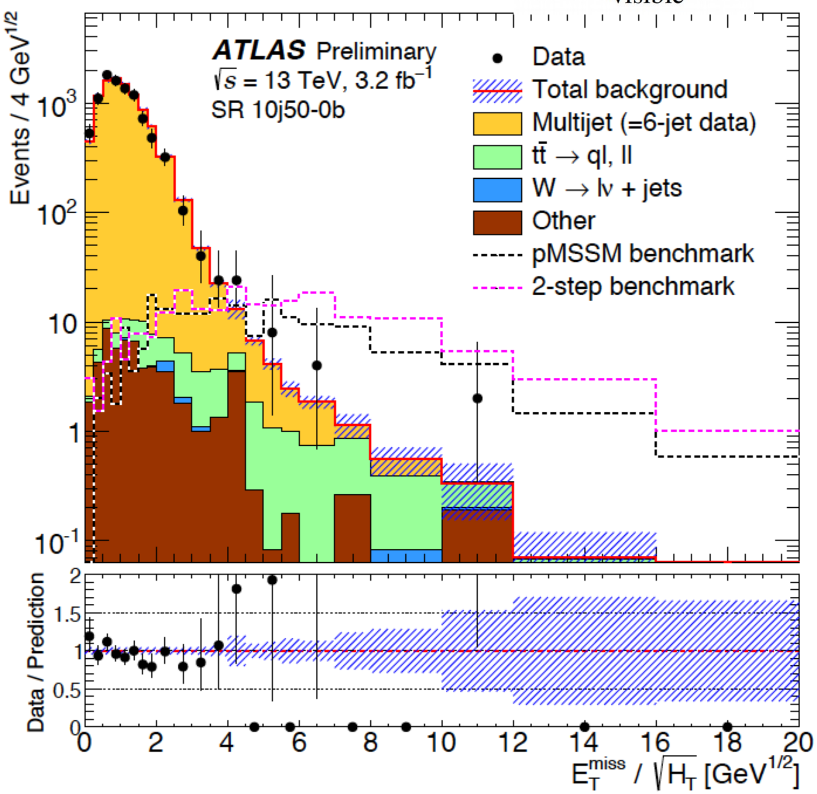
# 7-10 jets and MET (0 lepton)

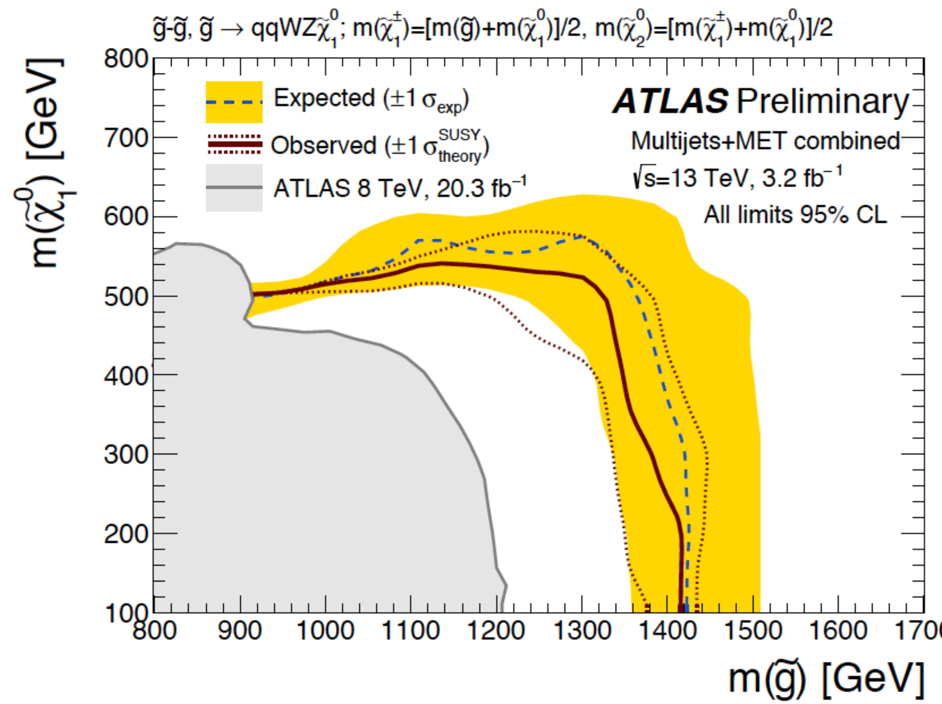


- Study two step decay chain and pMSSM inspired model
- Five SR, each also with 1 and 2 b-tags
- Use MET / $\sqrt{H_T}$ as main discriminant

$$H_T = \sum_{\text{visible}} |p_T|$$





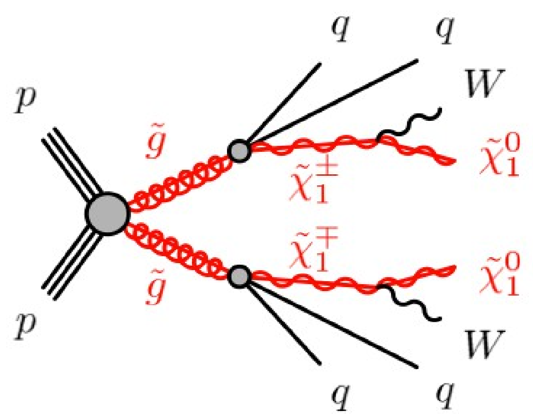



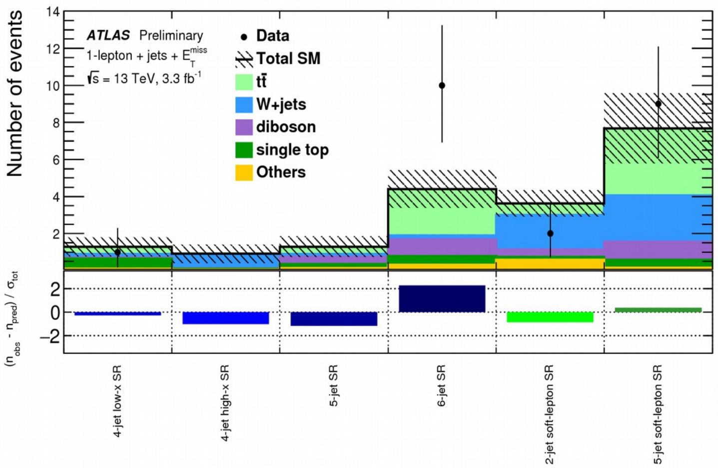

- Data agrees very well with SM prediction in all SR
- Gluino masses below ~1400 GeV are excluded at the 95% CL
- Improved limits over Run 1

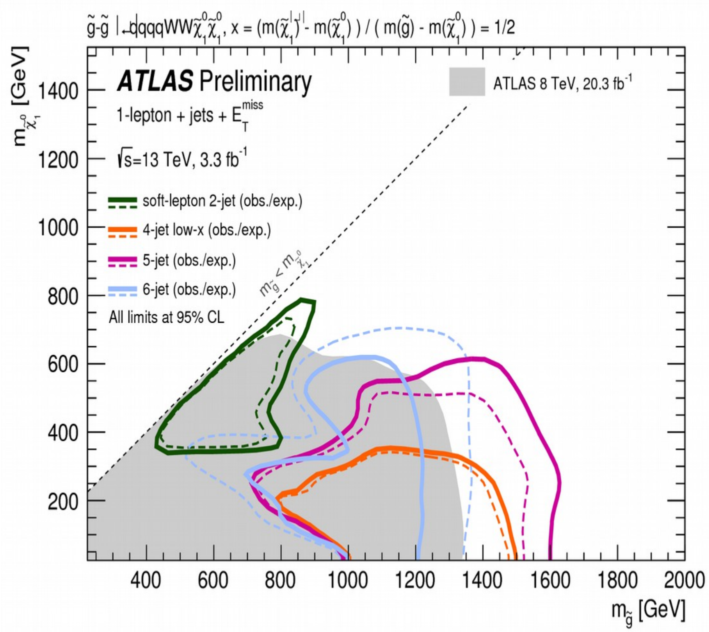
ATLAS-CONF-2015-077

# 1 lepton + jets

Signal categories in 1L and 2-4-5-6 Jets



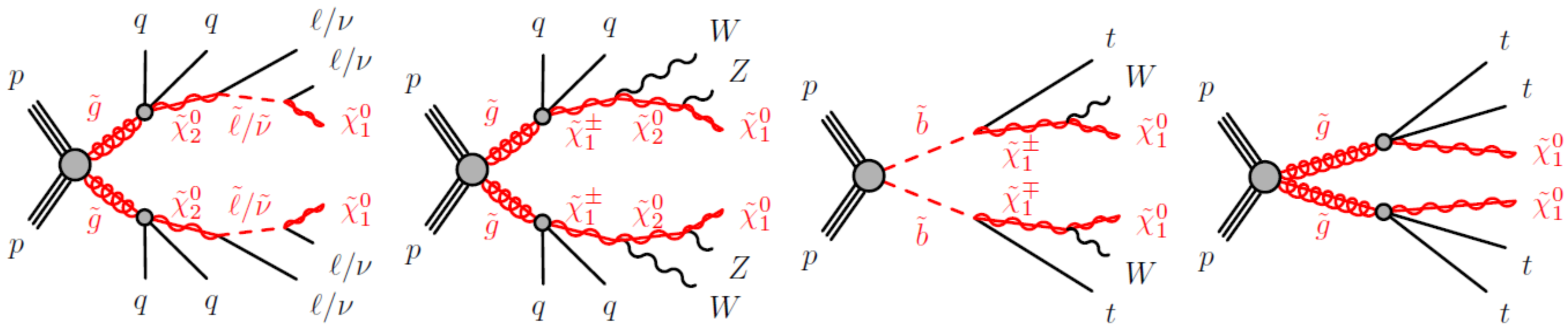



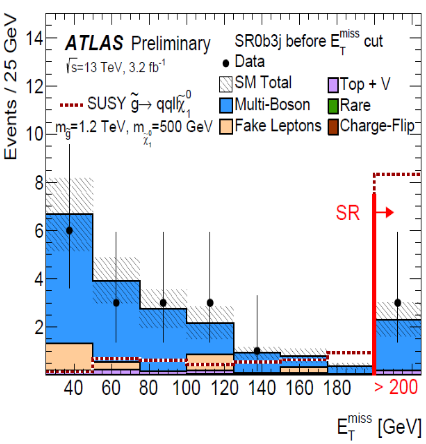

- Study two-step decay
- Data agrees with SM prediction in all SR
- Gluino masses below ~1600 GeV are excluded at the 95% CL

ATLAS-CONF-2015-076

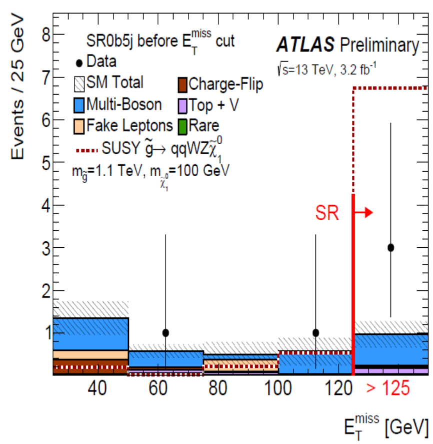
# Final states with jets & 2 same-sign leptons or 3 leptons



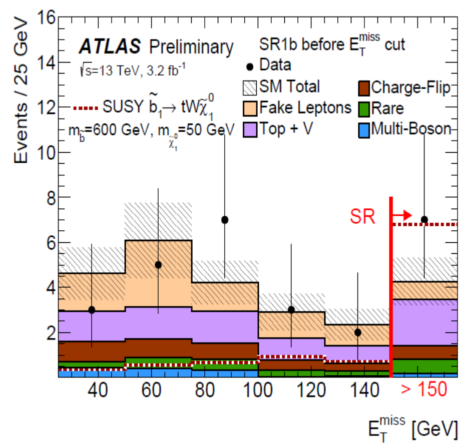
Search for strongly produced SUSY particles in SS/3L+jets events.
Low SM background from same-sign requirement



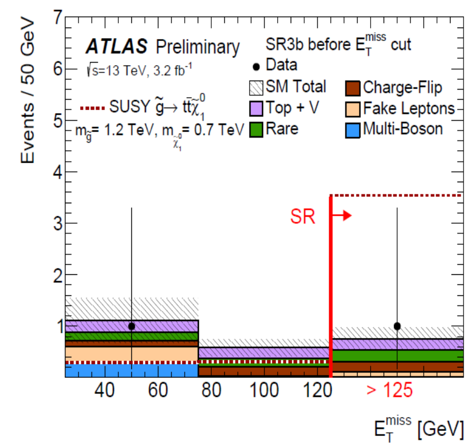

SR0b3j




SR0b5j




SR1b



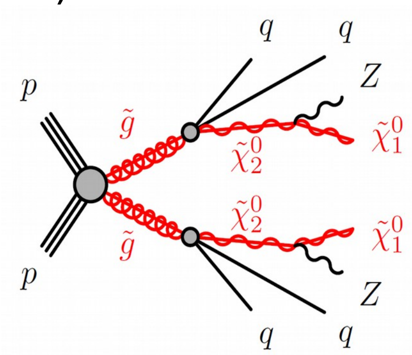

SR3b

No significant excess observed → gluino exclusion up to 1.2 TeV

ATLAS-CONF-2015-078

# Z-MET

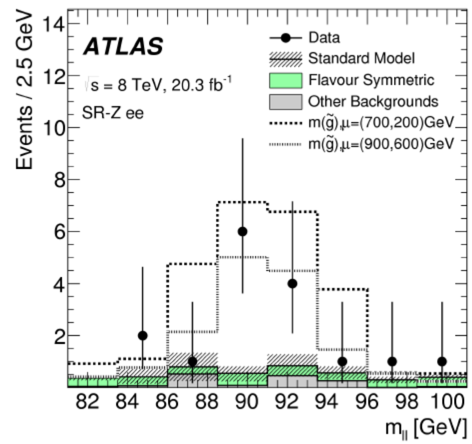
Check of an excess seen in ATLAS (not in CMS) at Run I



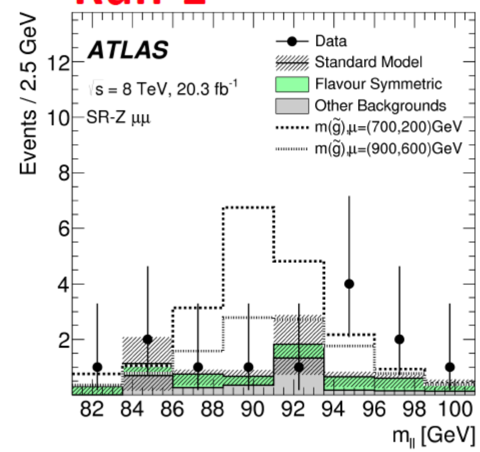

Event selection Z, 2 jets, MET>225 GeV, HT>600 GeV

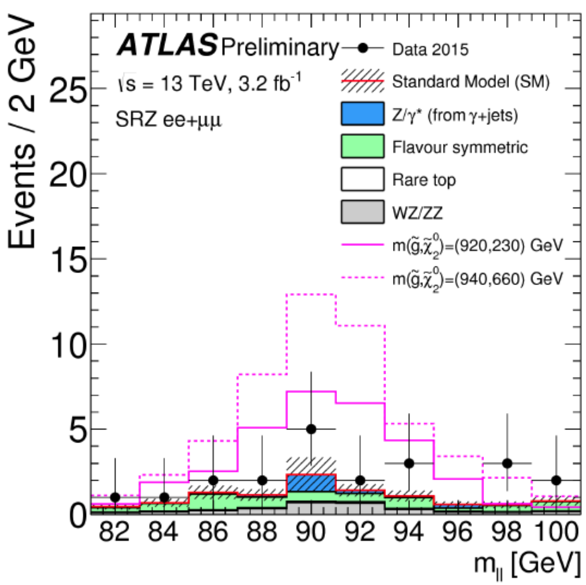
29 events obs. from 10.8 ± 2.2 exp. (3σ excess)

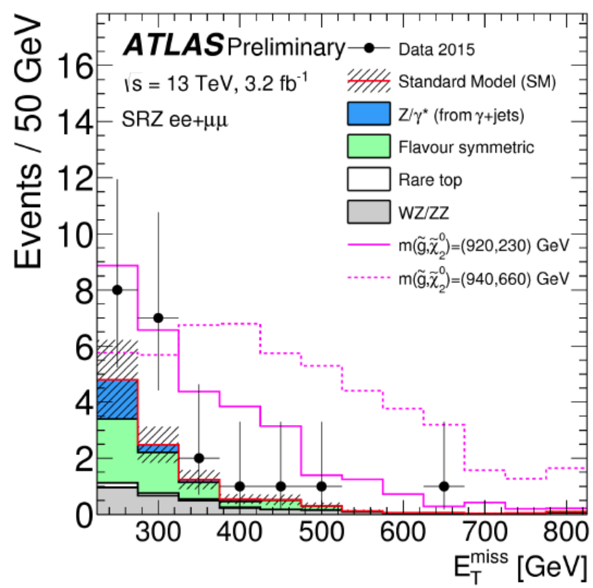
**Run-1**




**Run-1**



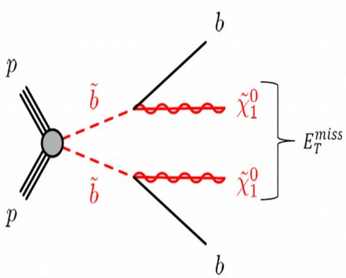

21 events obs (e/μ) and 10.4 ± 2.4 exp (2.2σ excess at intermediate MET)

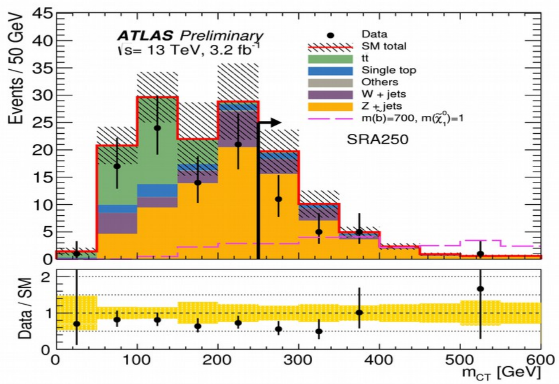
Not enough sensitivity yet to exclude the Run I excess

ATLAS-CONF-2015-082

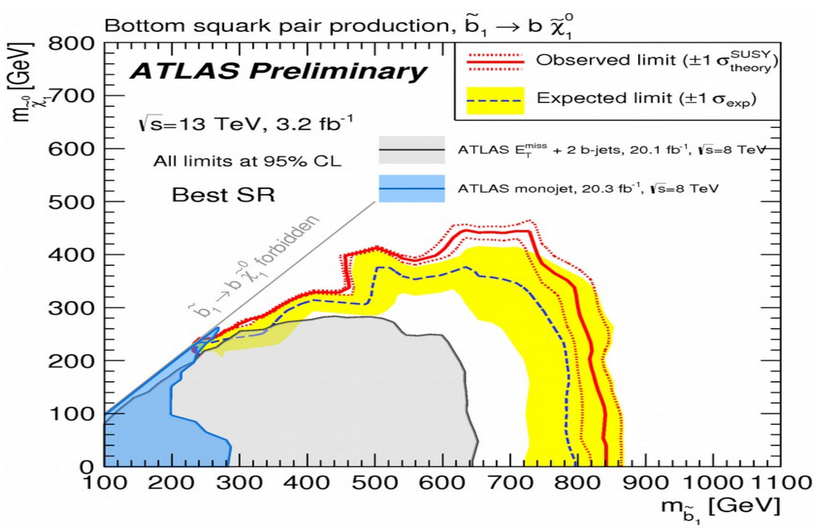
# Sbottom pair production / multi b jets

Search for direct third-generation squark pair production in final states with missing transverse momentum and two b-jets

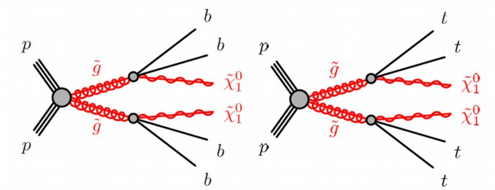


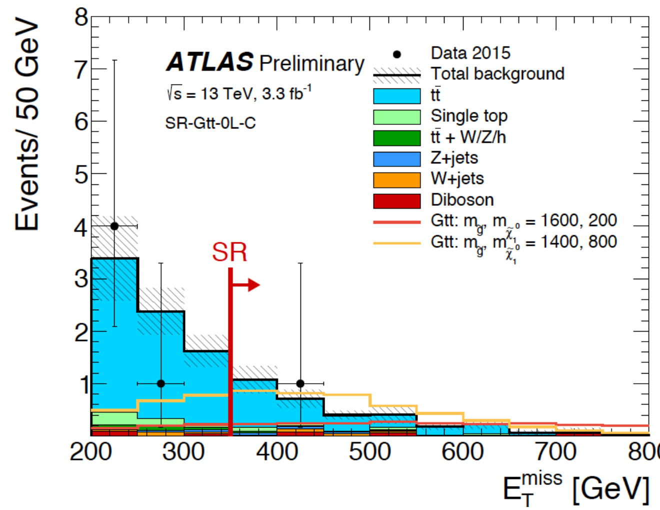



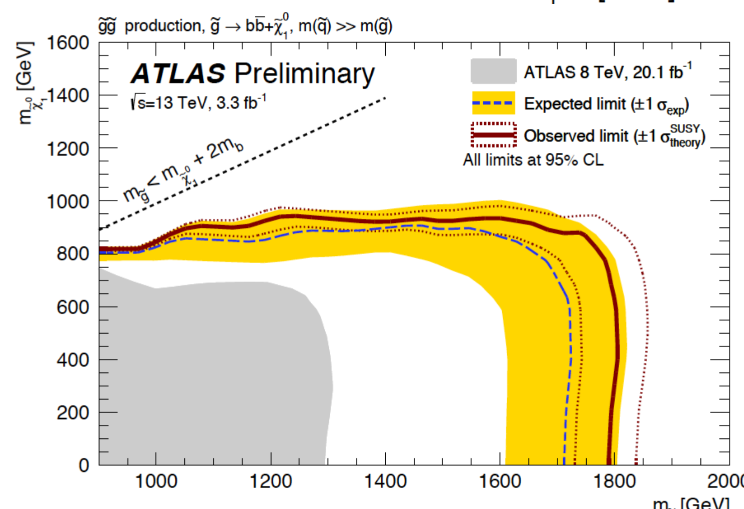

$$m_{\mathrm{CT}}^2(v_1, v_2) = [E_{\mathrm{T}}(v_1) + E_{\mathrm{T}}(v_2)]^2 - [\mathbf{p}_{\mathrm{T}}(v_1) - \mathbf{p}_{\mathrm{T}}(v_2)]^2$$




gluinos decaying via third generation squarks to the lightest neutralino



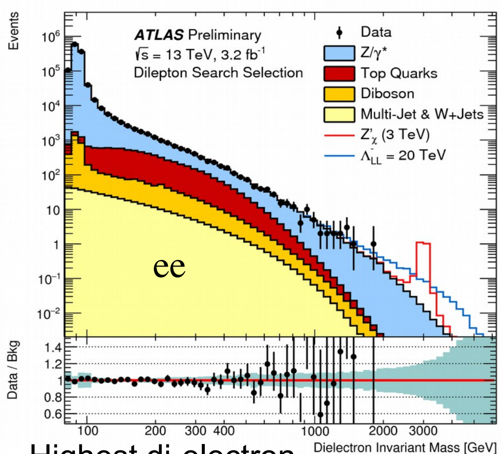




Improved limits over Run I !

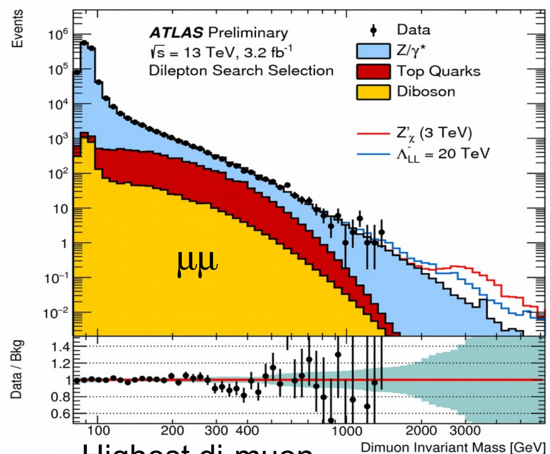
ATLAS-CONF-2015-066 ; ATLAS−CONF−2015−067

# Search Z´ / W´ in lepton decays

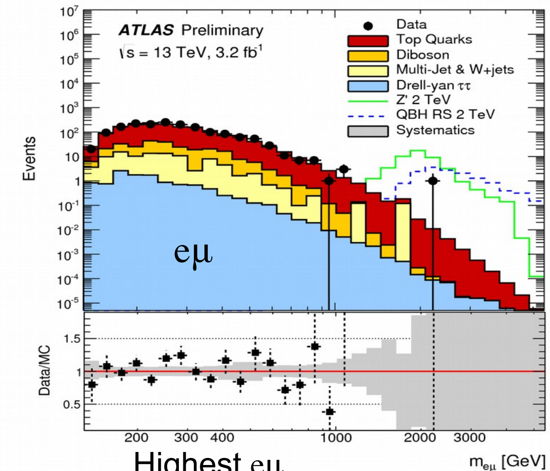
Search for resonant Z´ and non-resonant excesses in dilepton LFC and LFV (in eμ decays)
Search of resonant W´in lepton + MET



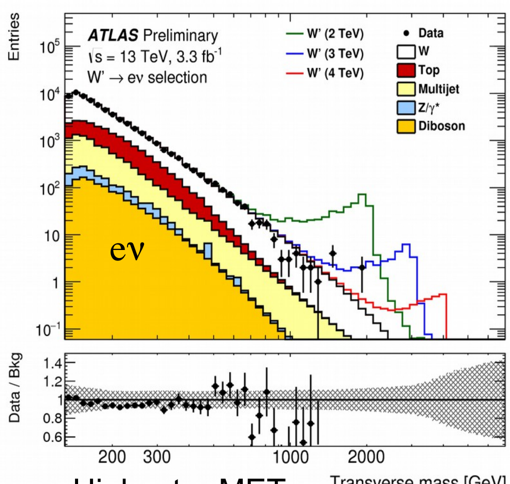

Highest di-electron
mass event at 1.8 TeV



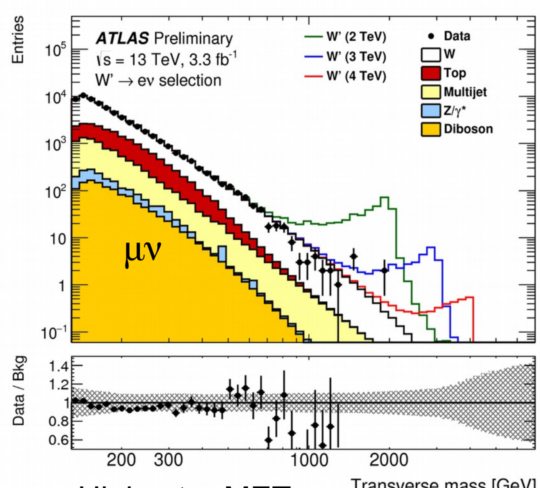

Highest di-muon
mass event at 1.4 TeV




Highest eμ
mass event at 2.1 TeV




Highest e-MET
mass event at 1.95 TeV




Highest μ-MET
mass event at 2.2 TeV

No excess found

$Z´_{SSM}$ limit at 3.4TeV for LFC (2.9 at Run I)

$Z´_{SSM}$ limit at 3.0TeV for LFV (2.5 at Run I)

$W´_{SSM}$ limit at 4.1TeV for LFV (3.2 at Run I)

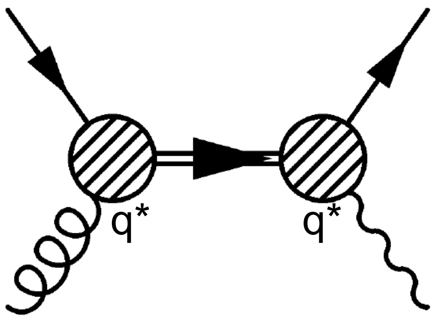
Sequential Standard Model (SSM) includes a W´an Z´ bosons with couplings to fermions identical to SM

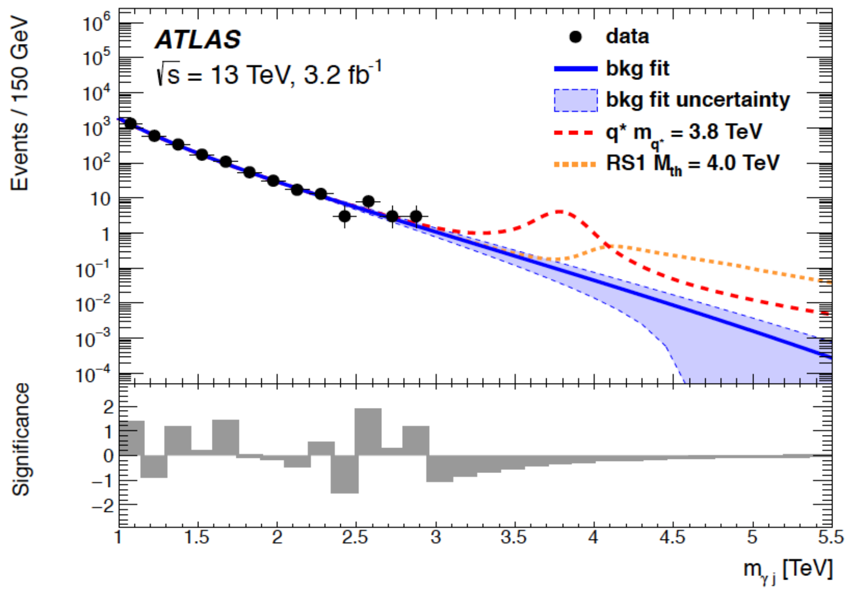
$$m_T = \sqrt{2 p_T^{\ell} E_T^{miss} \left(1 - \cos \Delta\phi_{\ell, E_T^{miss}}\right)}$$

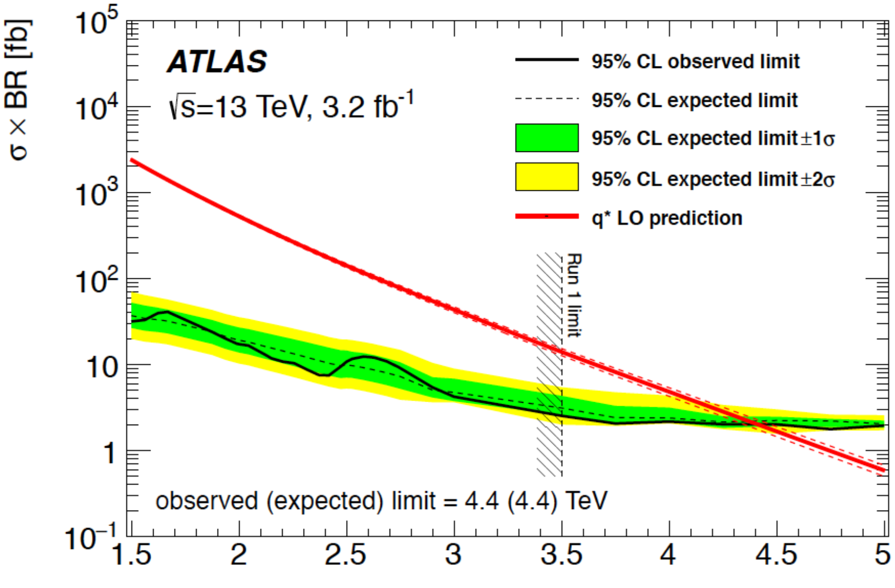
ATLAS-CONF-2015-070; ATLAS-CONF-2015-072;ATLAS-CONF-2015-063

# New phenomena in photon + jet events

Sensitive to new physics such as excited quarks and Quantum Black Holes



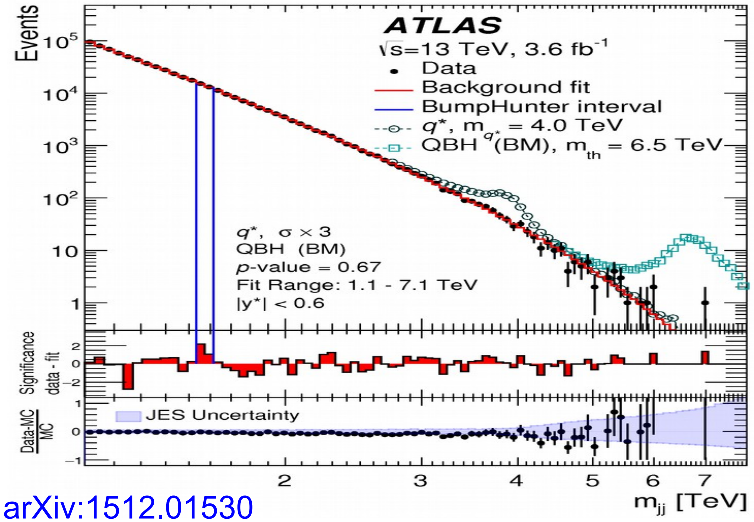




Improved limits over Run 1

No significant deviation from the background-only hypothesis is observed. Upper limits are set on the visible cross section of a generic Gaussian-shaped signal and on the production cross section times branching ratio of excited quarks and quantum black holes.

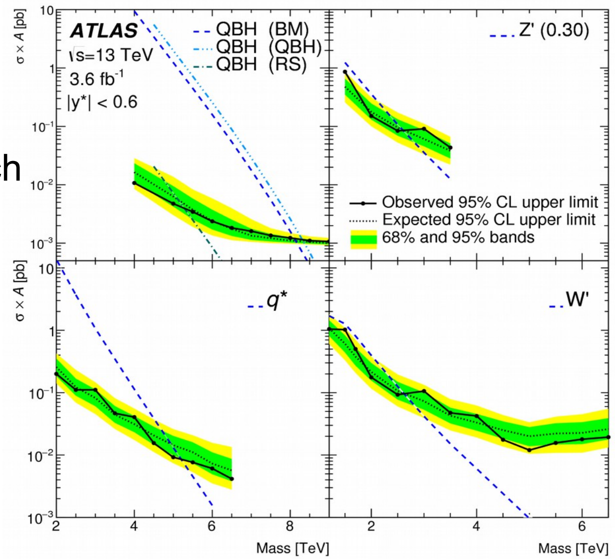
arXiv:1512.05910

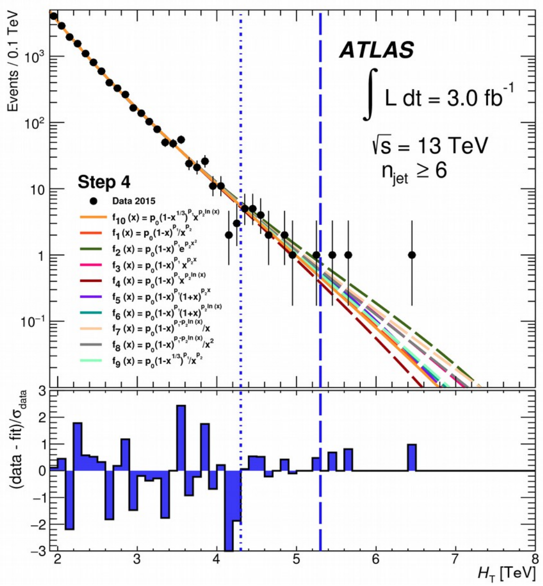
# New phenomena in dijet/multijet events



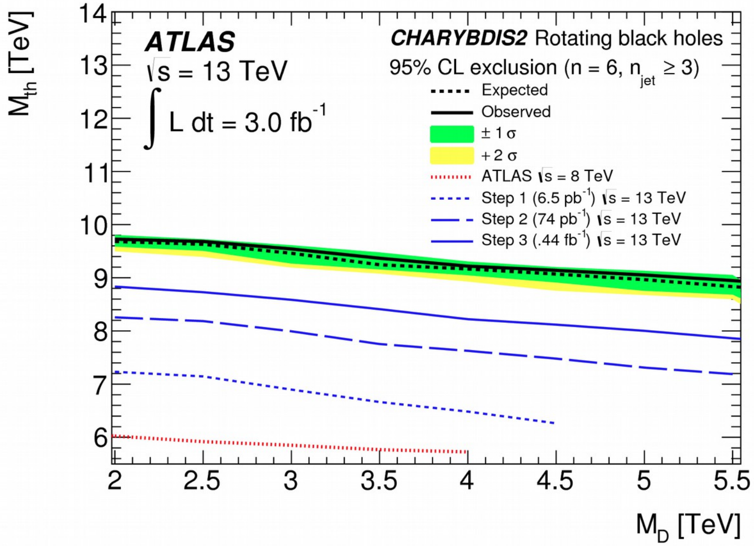

arXiv:1512.01530

dijet inv. mass search




events containing at least three jets with scalar sum of jet transverse momenta $H_T$ > 1 TeV.



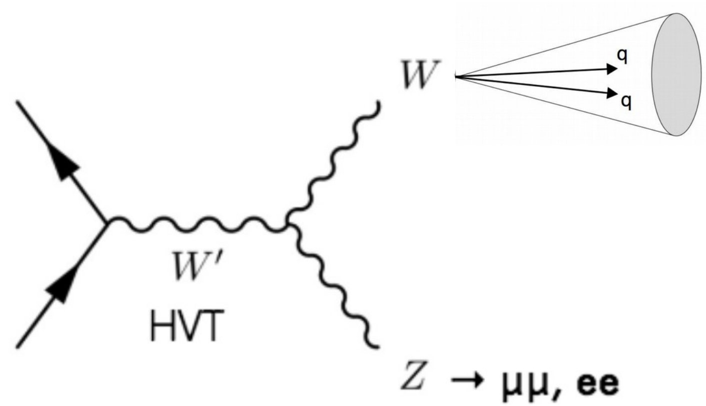

arXiv:1512.02586

# Searches in diboson final state

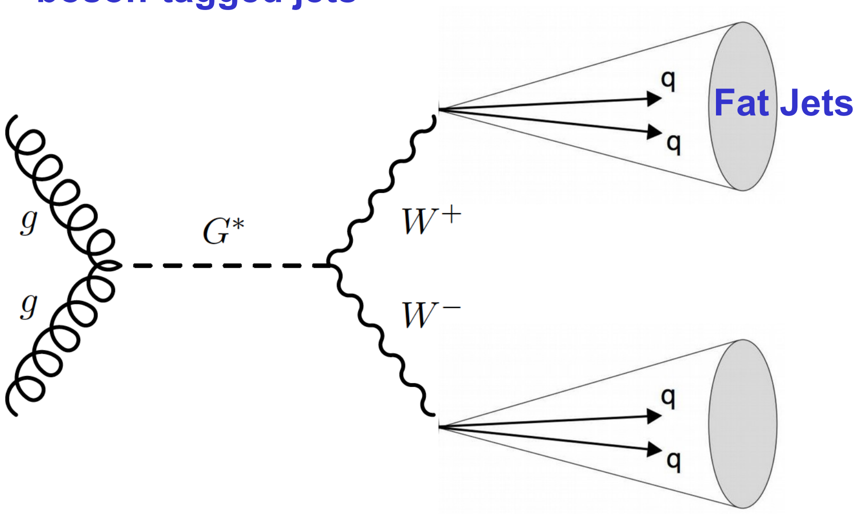
Extensions of the SM predict the existence of new particles decaying into vector-boson pairs:

- Heavy neutral Higgs H (spin-0) → ZZ
- Heavy Vector triplet (HVT) W’ (spin-1) → WZ
- Bulk Randal-Sundrum Graviton G* (spin-2) → ZZ

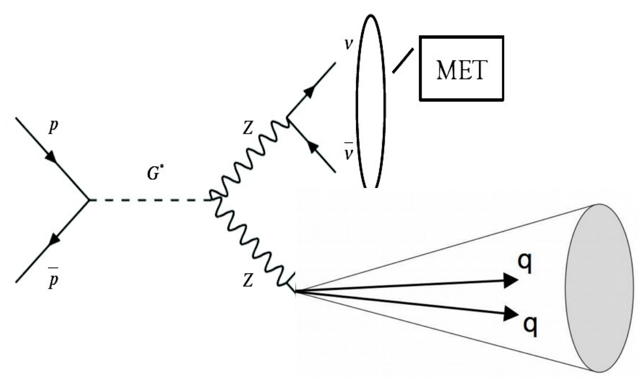
**llqq final state**




**boson-tagged jets**



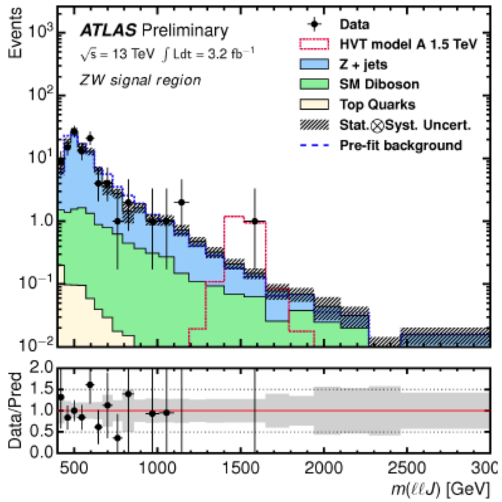

**vvqq final state**



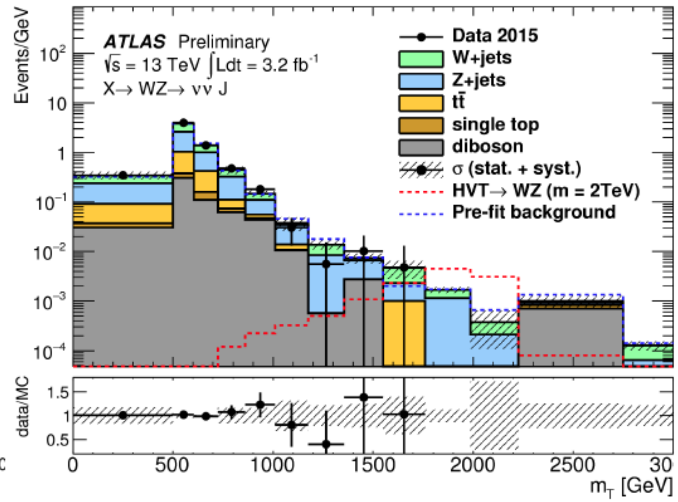

ATLAS−CONF−2015−075; ATLAS−CONF−2015−068; ATLAS−CONF−2015−071; ATLAS−CONF−2015−073

# Diboson results

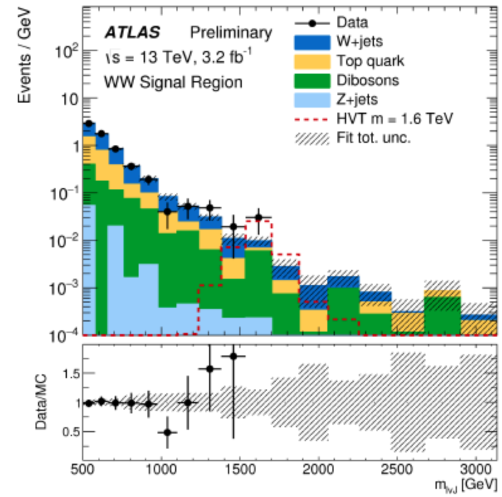
**ZV** (with Z to **dilepton**)



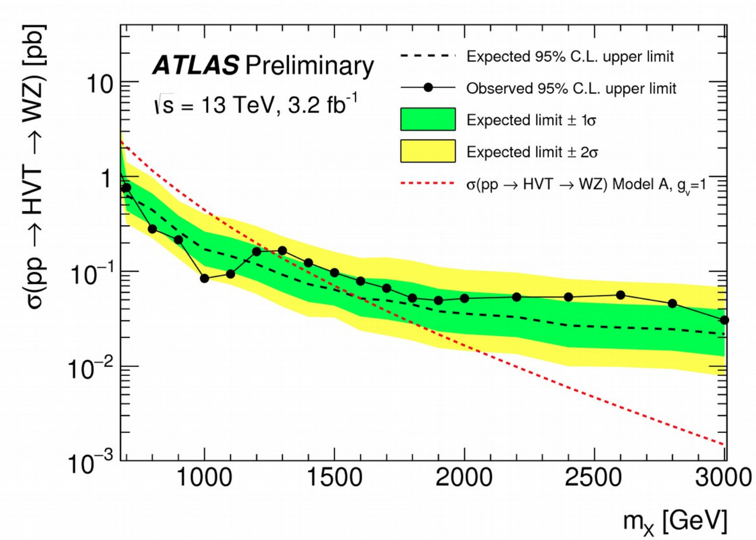

**ZV** (with Z to **νν**)




**WV** (with W to **lν**)

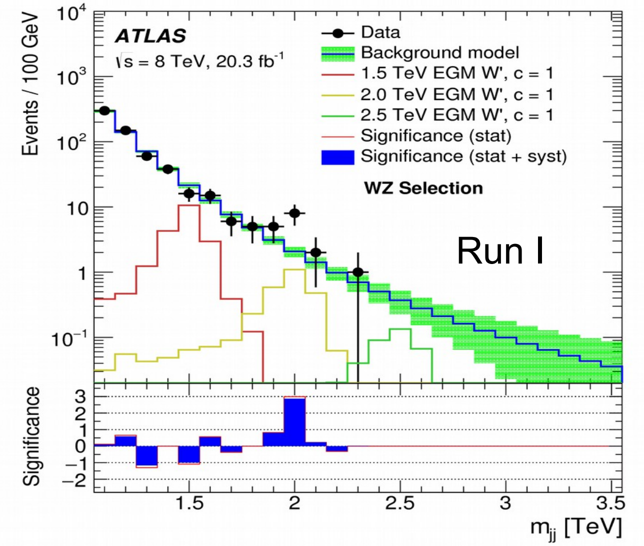



No significant excess observed. Interpretations in Heavy Vector Triplet model but also in Higgs and Graviton hypotheses

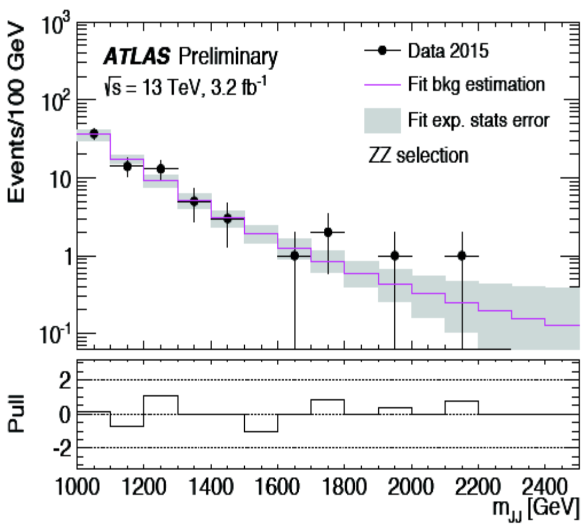


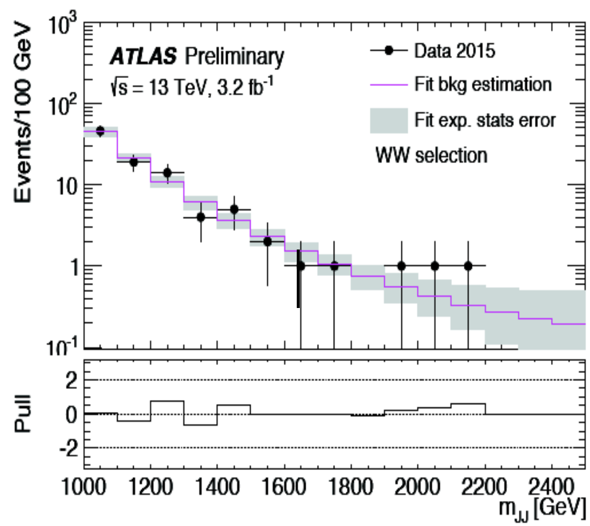
# Fully hadronic diboson decay (JJ)

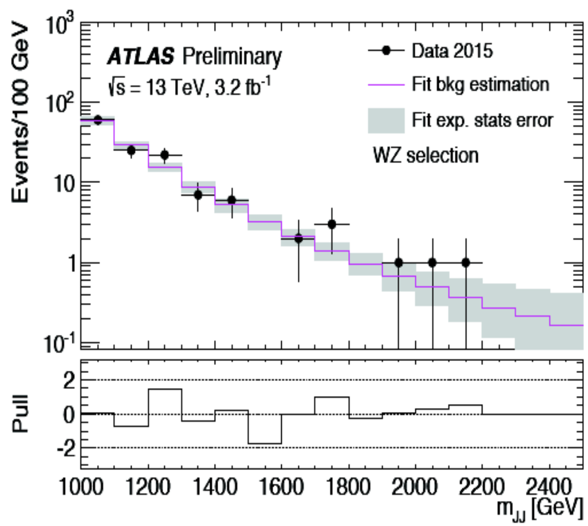
Modest excess at Run I: 3.4σ local / 2.5σ global




No significant excess observed at Run II however sensitivity still not high enough

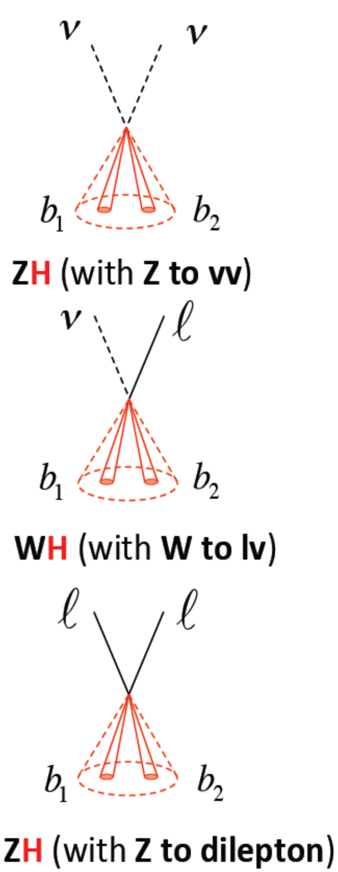


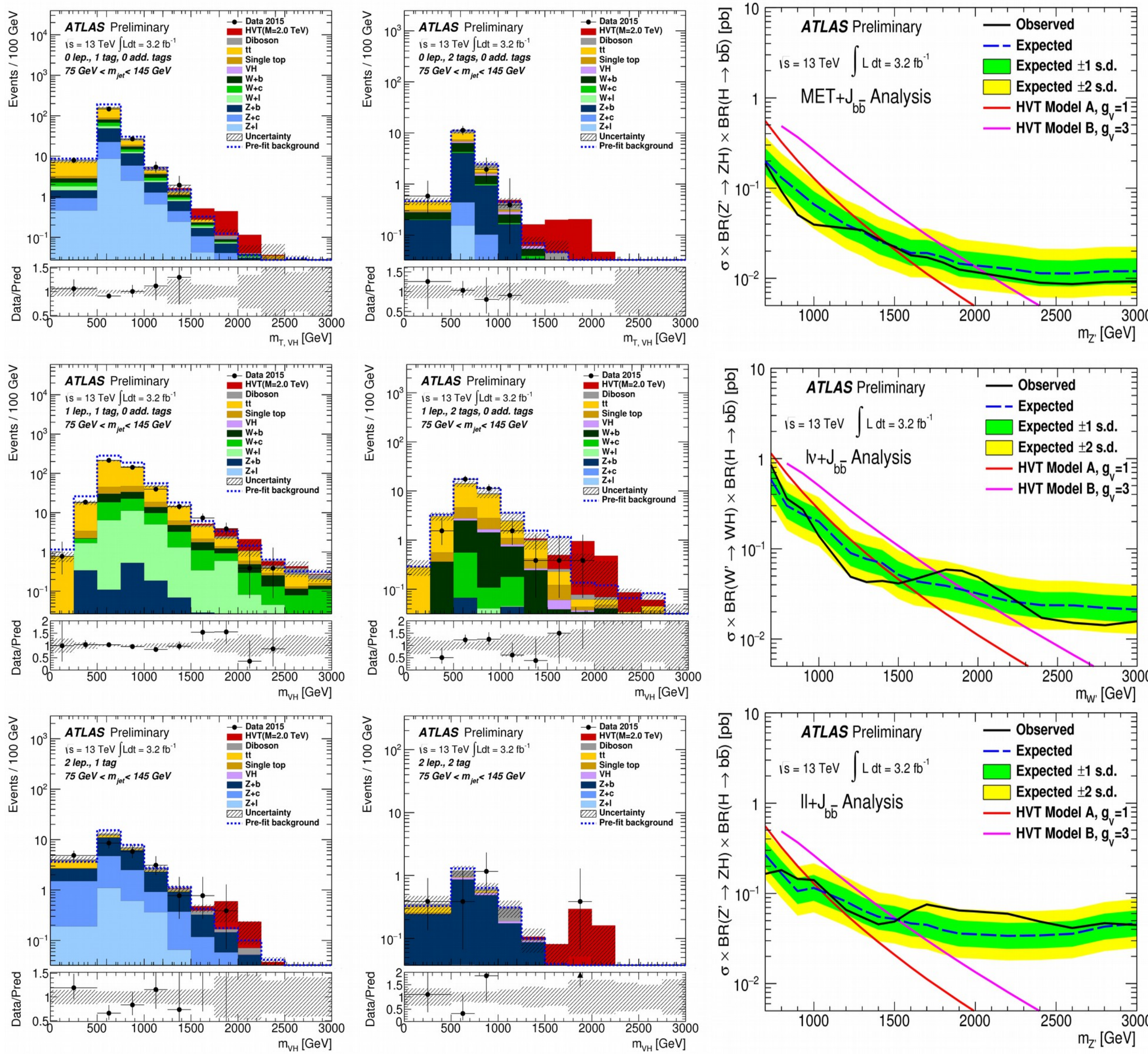



# New resonances decaying to W/Z + Higgs

Analysis Strategy: 6 regions 0L, 1L-MET and 2L-MET with at least two jets and 1 or 2 b-tags. Global fit of 6 regions simultaneously



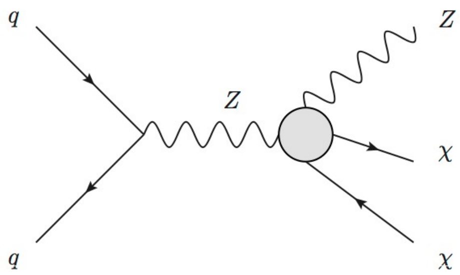

ATLAS−CONF−2015−074

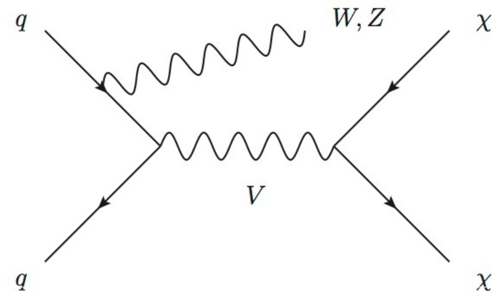
# Conclusions

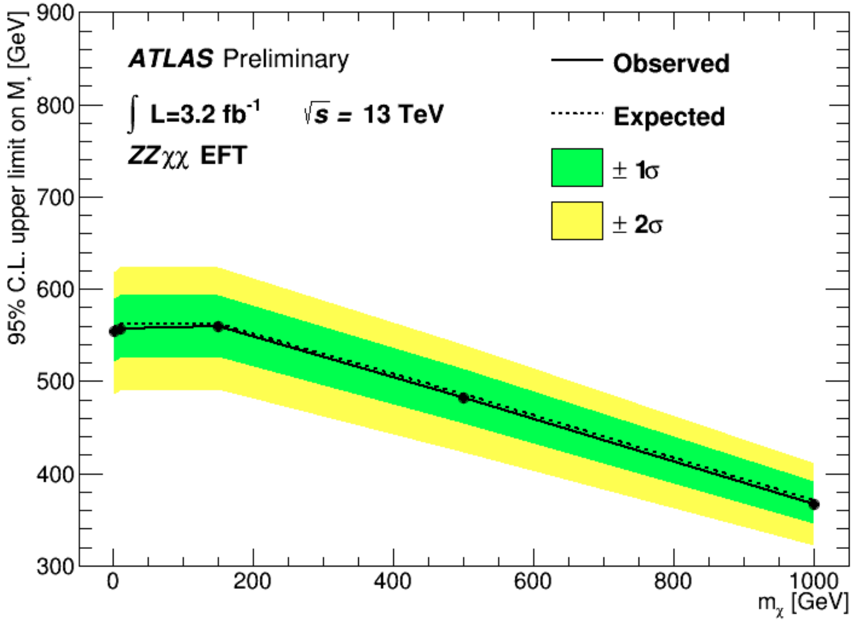
- ATLAS is performing very well at 13 TeV with 25ns collisions
- First studies for Higgs (125 GeV) production
- Many searches for new physics with sensitivity exceeding the Run I reach
- Modest deviations from the expectations of the SM were observe with a global significance of about 2 sigma (far short of that needed for a discovery):
  - Hypothetical new resonance that decays into diphoton
  - Supersymmetry searches in the channel with Z-boson and missing energy
- Strong motivation to be ready for 2016 data-taking !

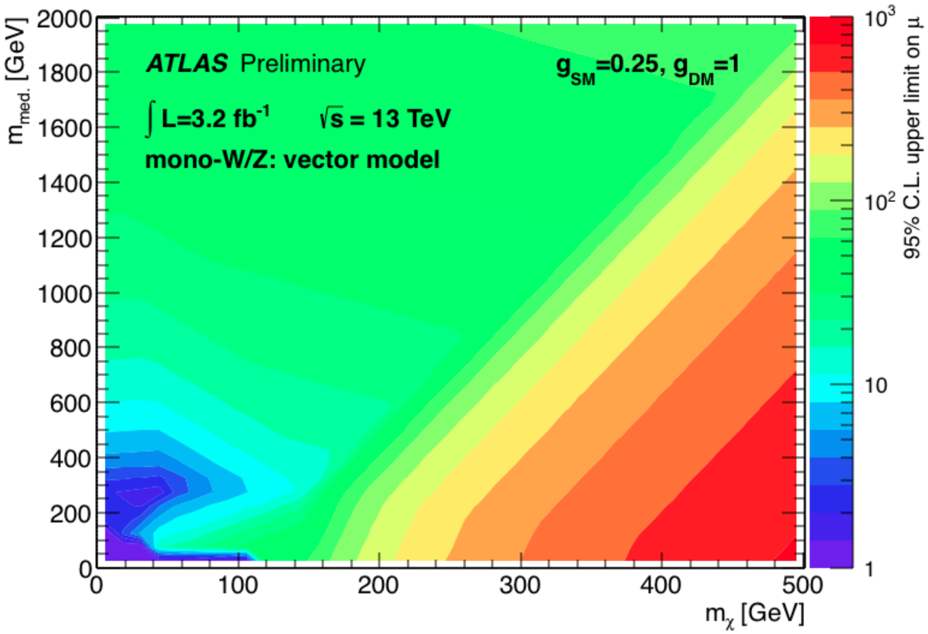
# Backup slides

# Dark matter produced in association with a hadronically decaying vector boson




ATLAS−CONF−2015−080

# Search for supersymmetric particles

For Run II early data (2015) main focus of SUSY searches is strong production of gluinos and (to lesser extent) squarks

Ratio of 13 TeV / 8 TeV Cross sections Squarks and Gluinos:

1.5 TeV: 35

1 TeV : 15