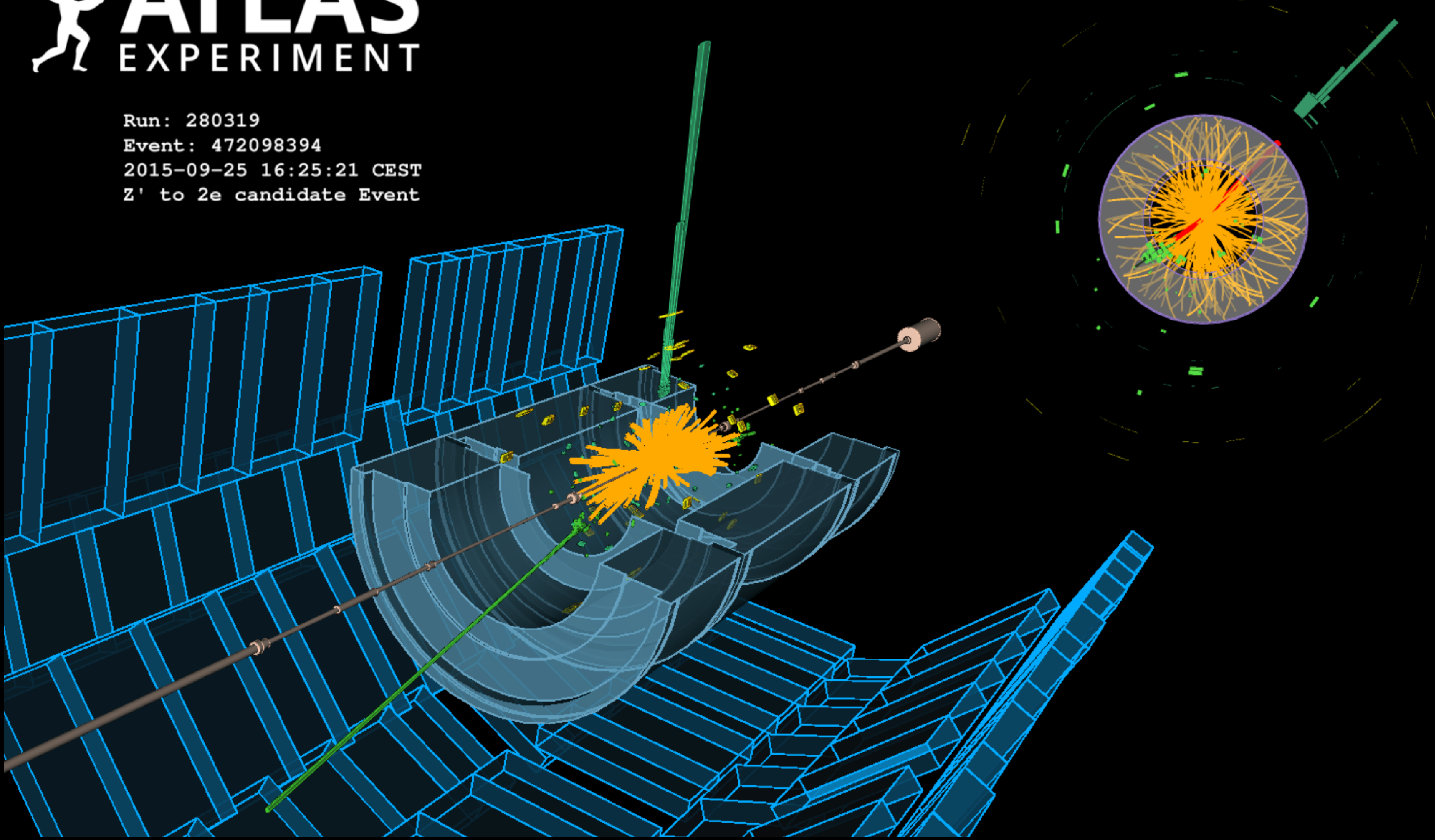
Di-Electron Event

High Mass Dielectron

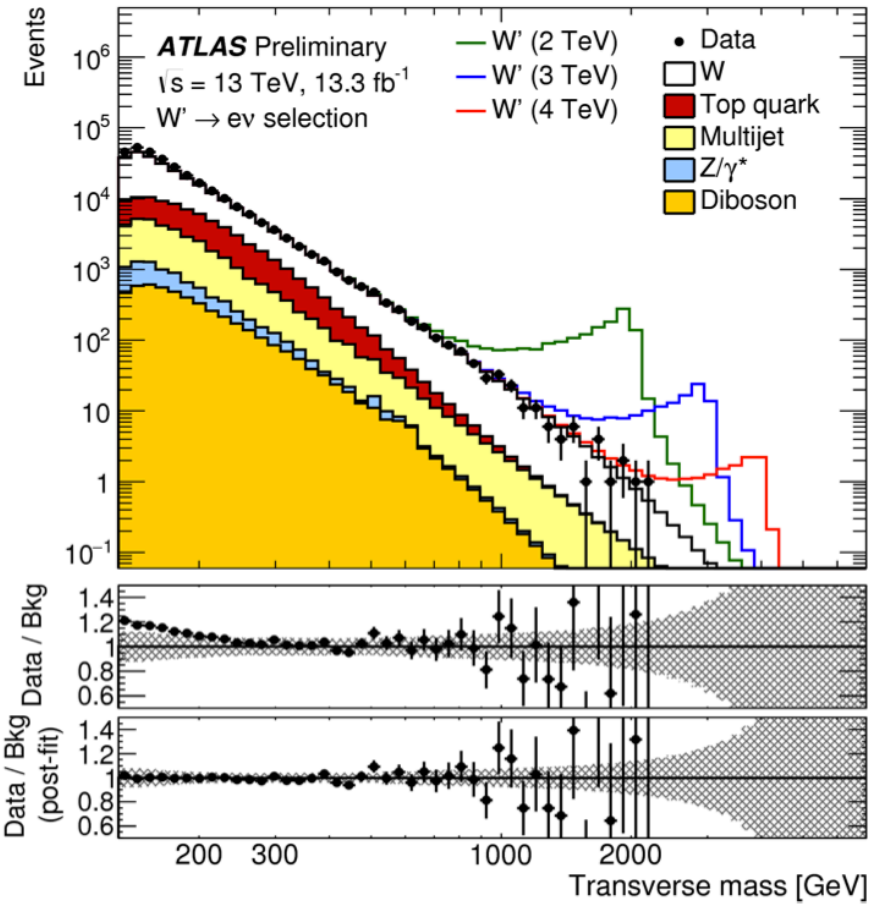
ET_1 = 370 GeV ET_2 = 246 GeV

m_{ee} = 1.8 TeV

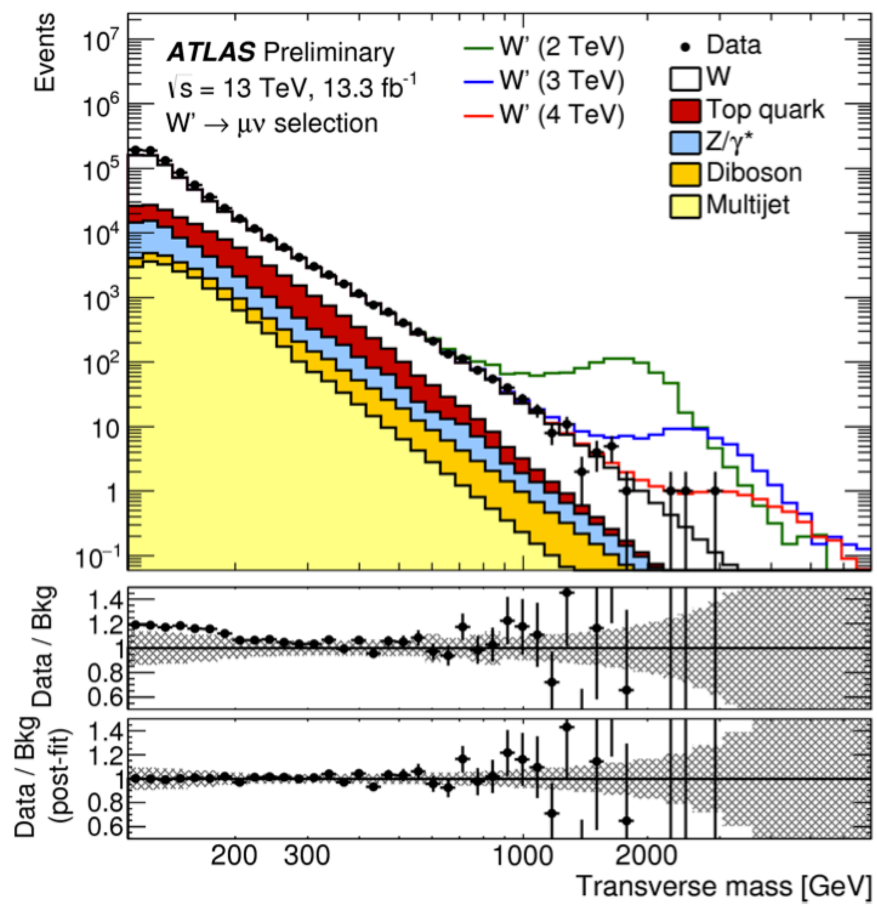


Search for High Mass W'

ATLAS-CONF-2016-061



Electron channel



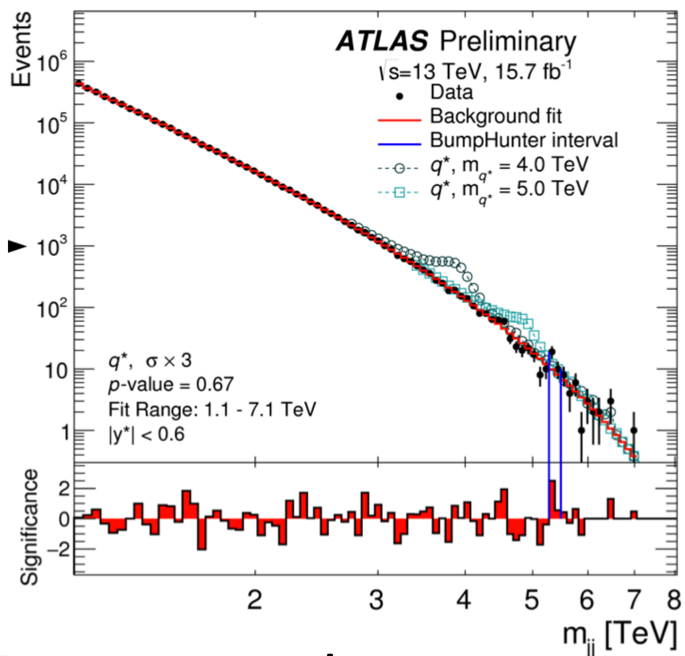
Muon channel

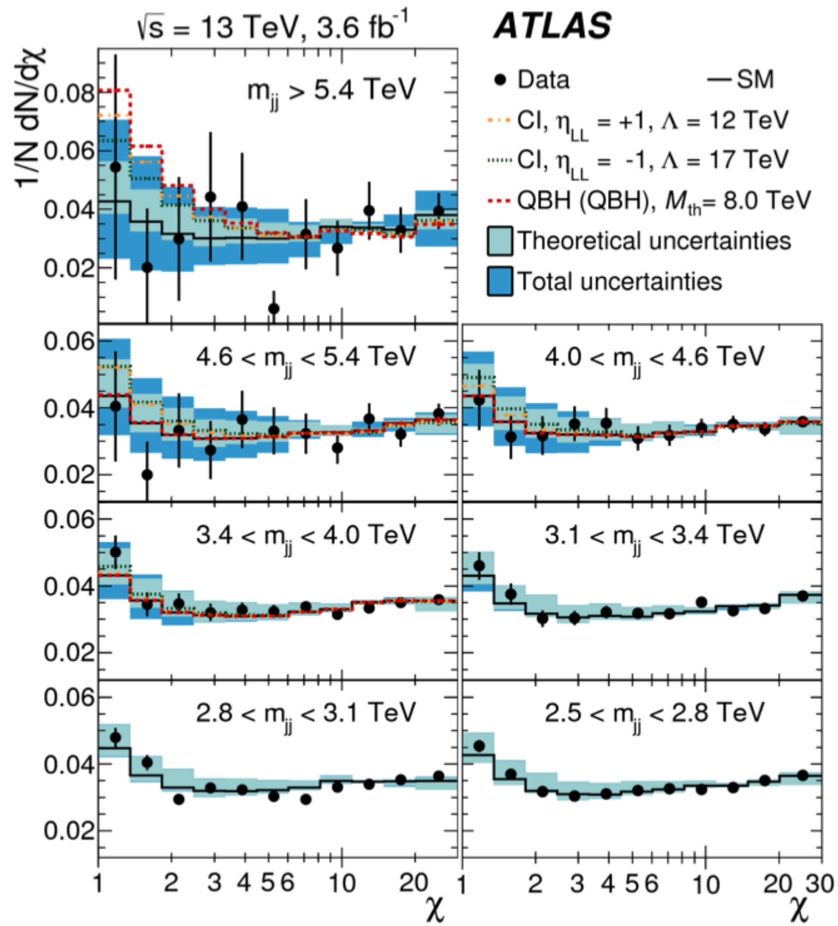
- Importance of systematic uncertainty related to MET in the low mass
- Similarly the extrapolation of the efficiencies and the calibration at very high pT is very important: not a low hanging fruit!

Di-jet Searches

Resonant and non resonant search

ATLAS-CONF-2016-069





Resonant search

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

Non-resonant search

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

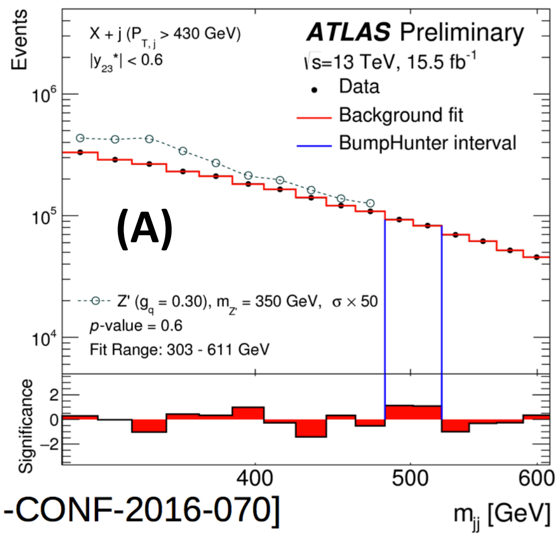
$$\chi = e^{2|y^*|} \sim \frac{1 + \cos\theta^*}{1 - \cos\theta^*}$$

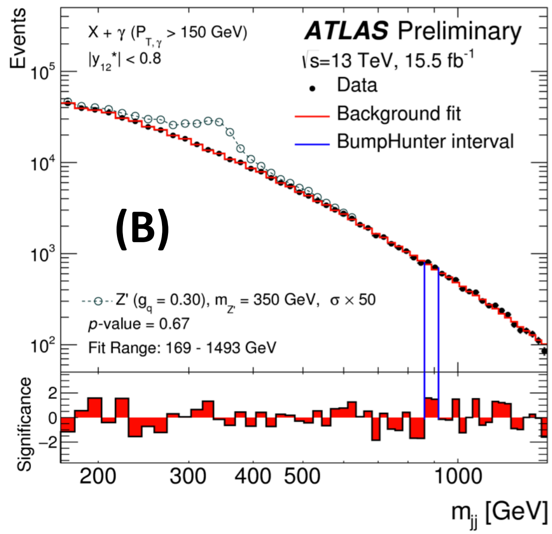
Interpret in terms of limits on Contact interaction.

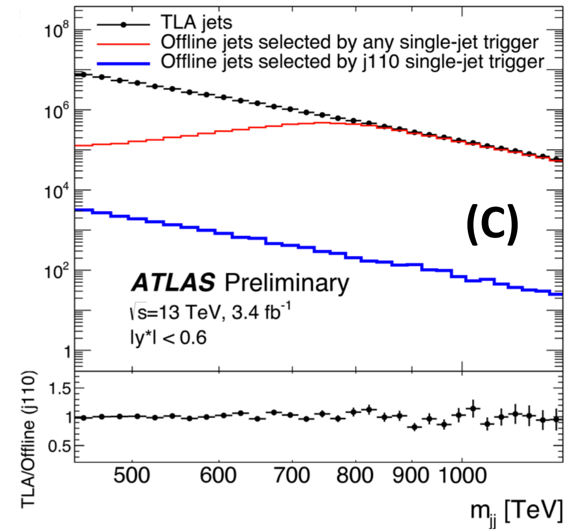
Limits on CI mass scale of up to 20 TeV

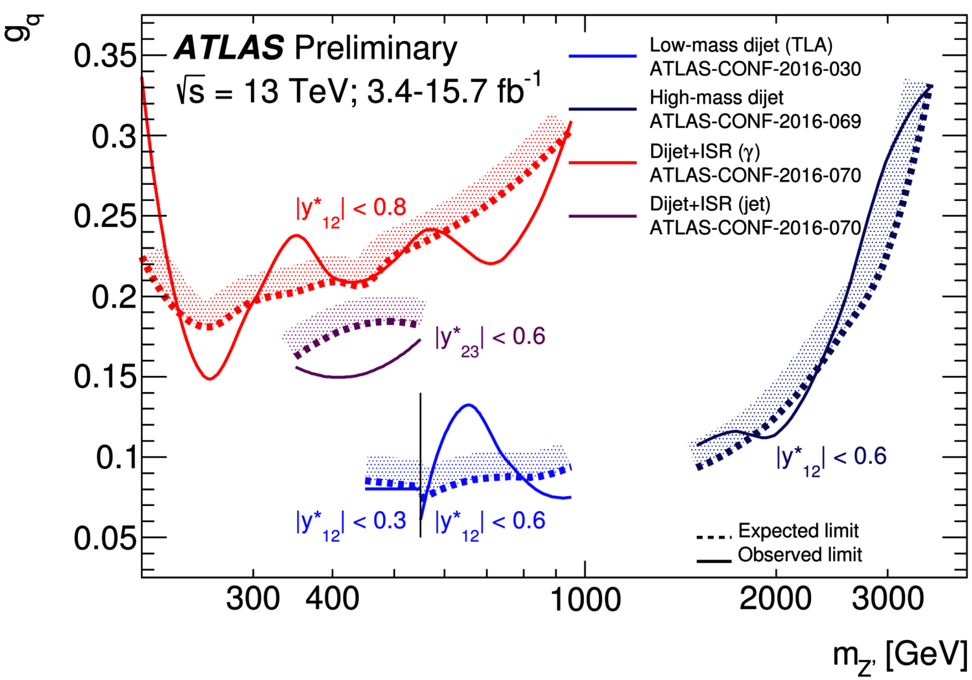
Di-jet Searches

Investigating the intermediate mass range









(A) Trigger Level Analysis

Only small necessary information is stored and the analysis is done at trigger level, calibration is particularly non trivial in this case.

ATLAS-CONF-2016-030

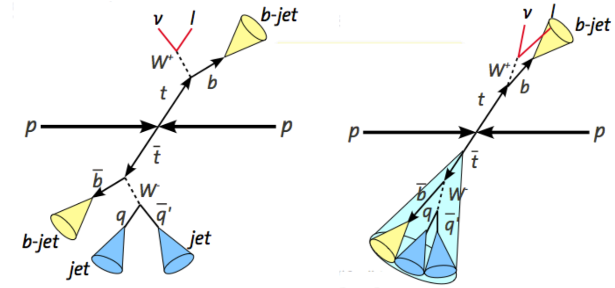
(B) ISR with photon ATLAS-CONF-2016-070

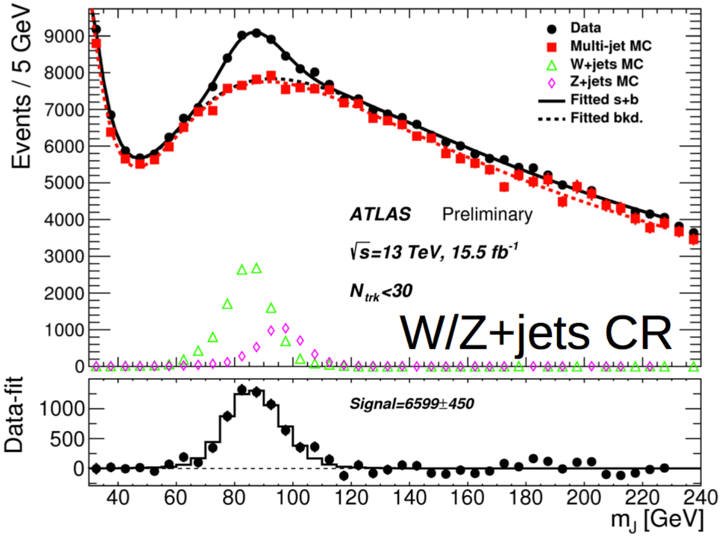
Use ISR photon for triggering and look at recoiling jet pairs

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

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

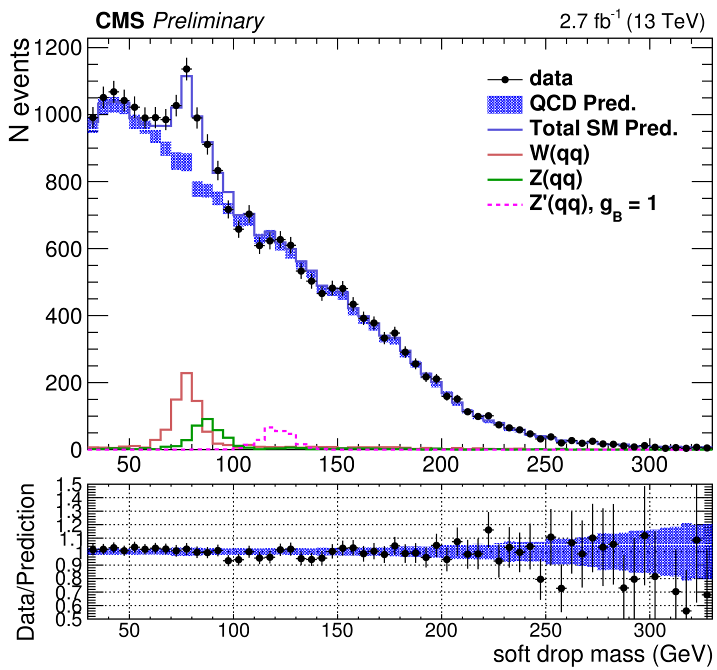
Jet Substructure

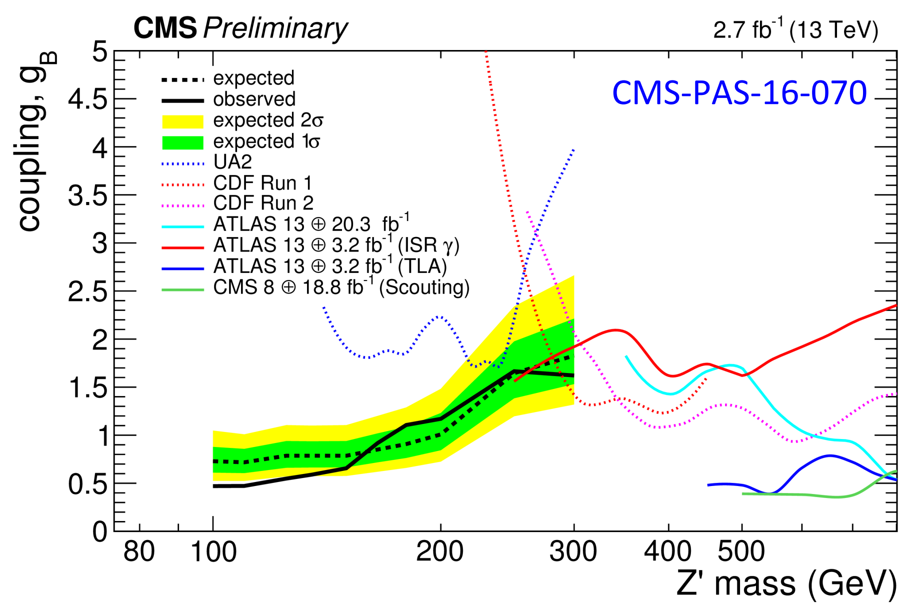




Nominal boson tagging algorithm

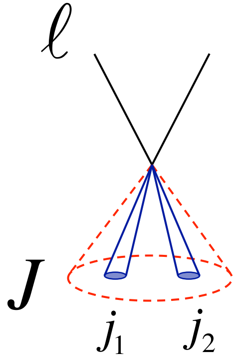
- Large R-jet algorithms used to tag hadronic decays of particles such as W, Z, Higgs and the top.
- Algorithms use substructure of jets.
- Pileup subtraction is very important, and a large number algorithms have been developed.
- Overall performance is very impressive!



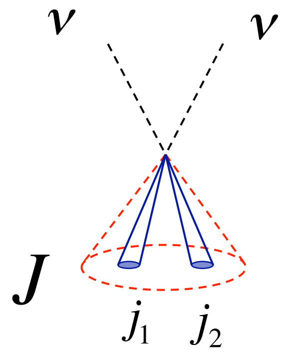


Searches for a Resonance in Diboson VV Final States

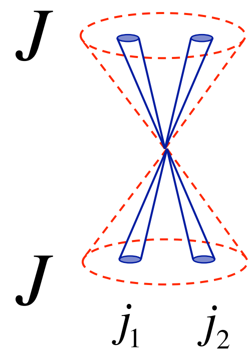
ZV (with Z to **dilepton**)



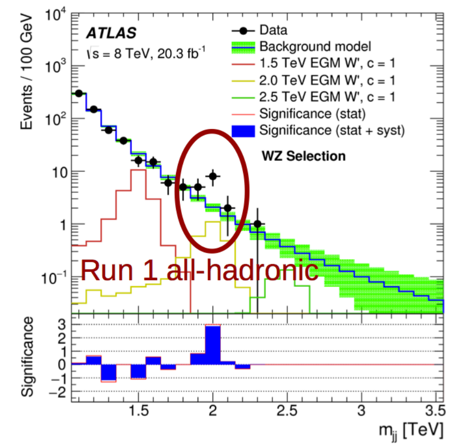
ZV (with Z to **νν**)



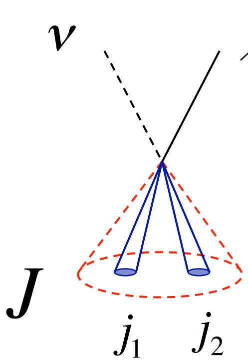
VV to **JJ**



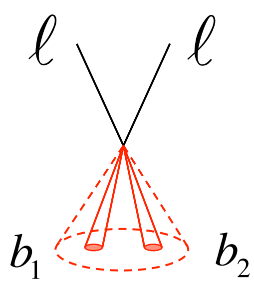
Modest excess Run-1
observed at Run 1 to be checked



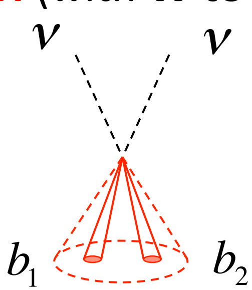
WV (with W to **lν**)



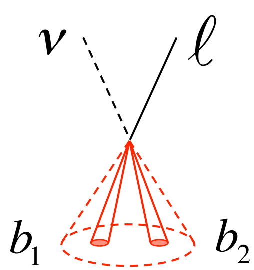
Z**H** (with **Z to dilepton**)

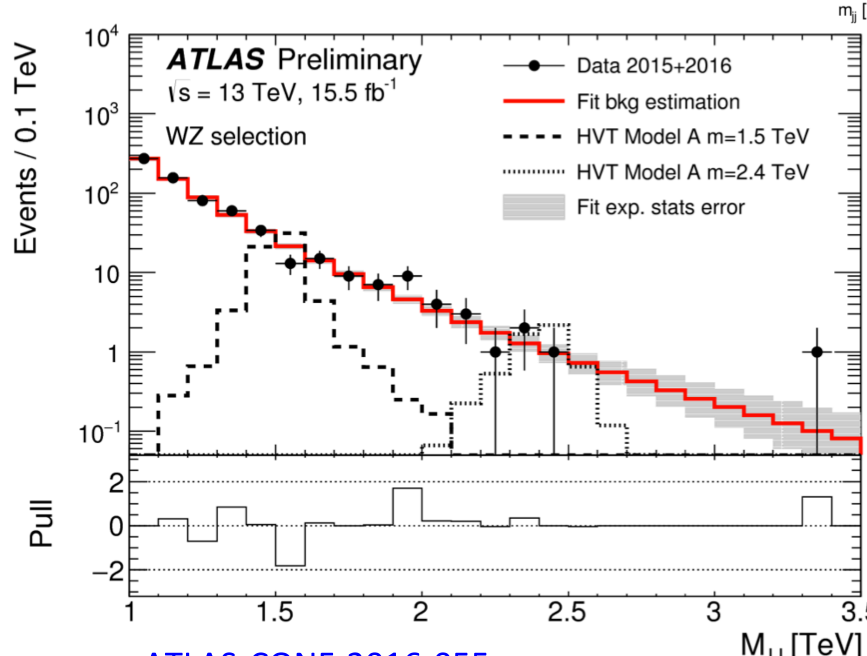


W**H** (with **W to lν**)



Z**H** (with **Z to νν**)

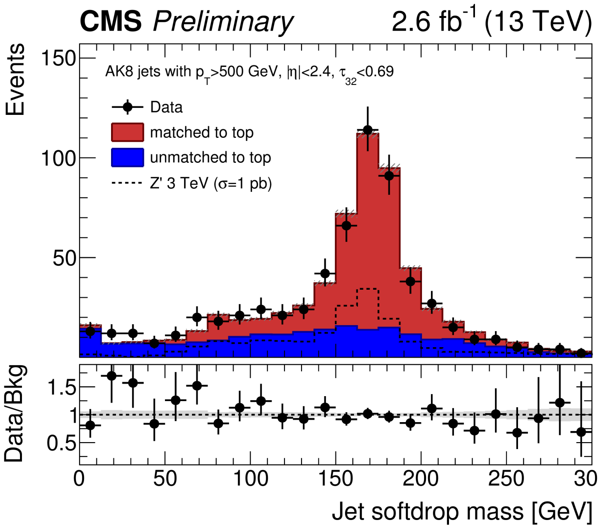


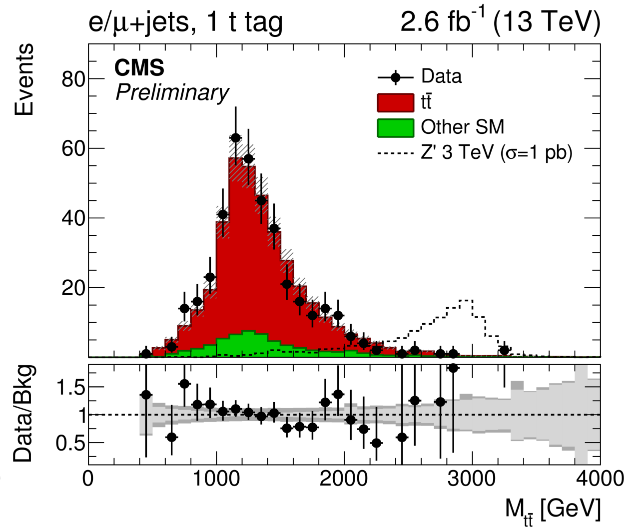


ATLAS-CONF-2016-055

Top Pair Resonance Searches

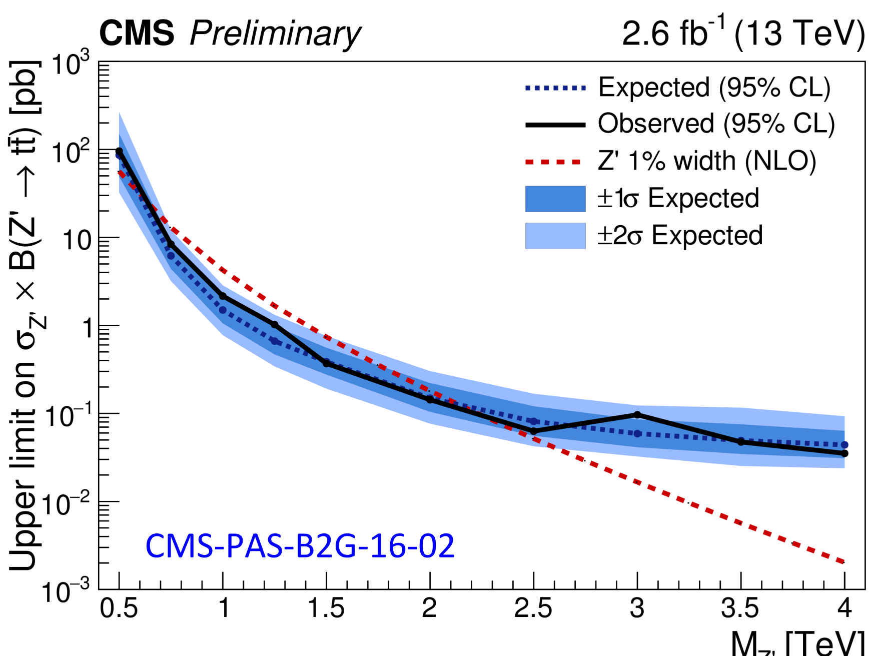
Using boosted jets substructure techniques





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

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



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

Possible non-negligible interference signal and background neglected.

Searches for Vector Like Quarks

- Additional (sequential) 4th generation is ruled out by the Higgs couplings.
  Would be significantly changed in case of a 4th generation.

- Mass terms for fermions strongly interacting, i.e. Quarks which transform as $SU(2)_L$ are gauge invariant and therefore do not need to couple to the Higgs.

- Found in many models: Composite Higgs, extra dimensions, little Higgs.

- Complex channels looking for T(2/3), B(1/3): Ht+X, Wt+X, Wb+X, Zb+X, Zt+X (Performed at Run 2) so far and T(5/3) 4tops final state.

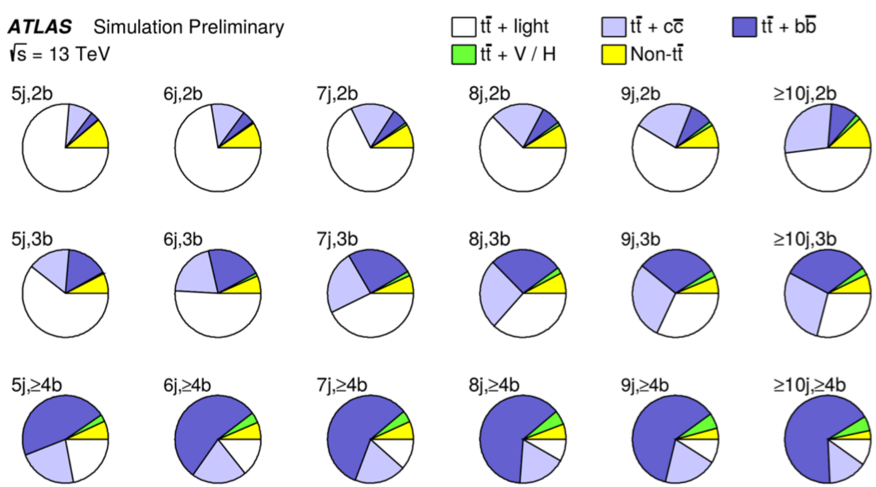
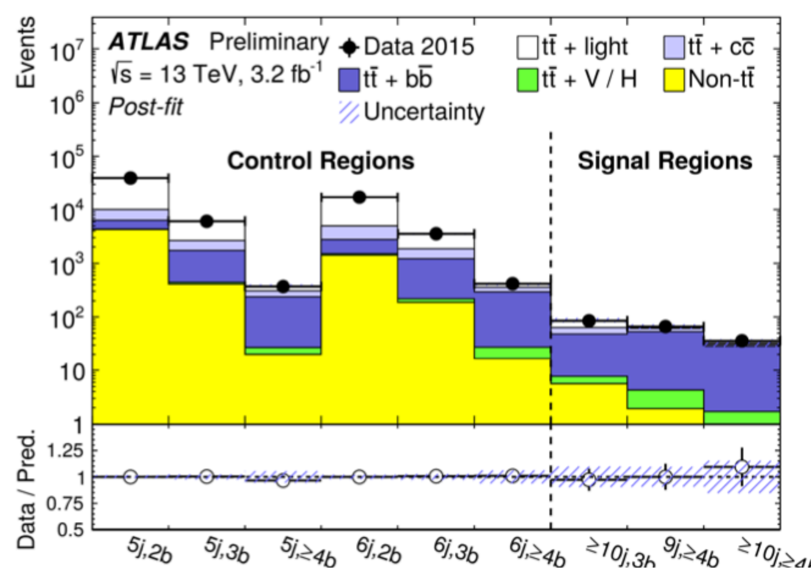


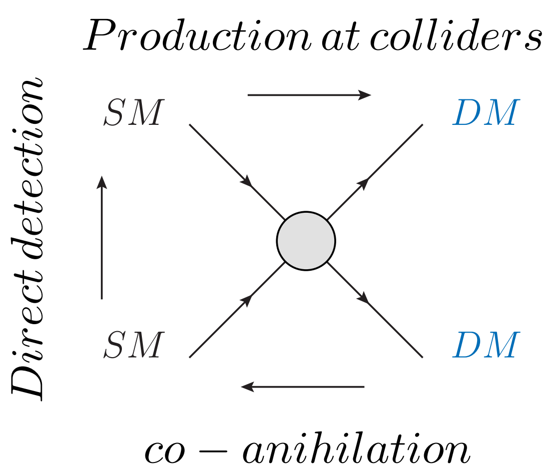
Illustration of the reach in complexity of signature with up to 10 jets with 4 b-tags.

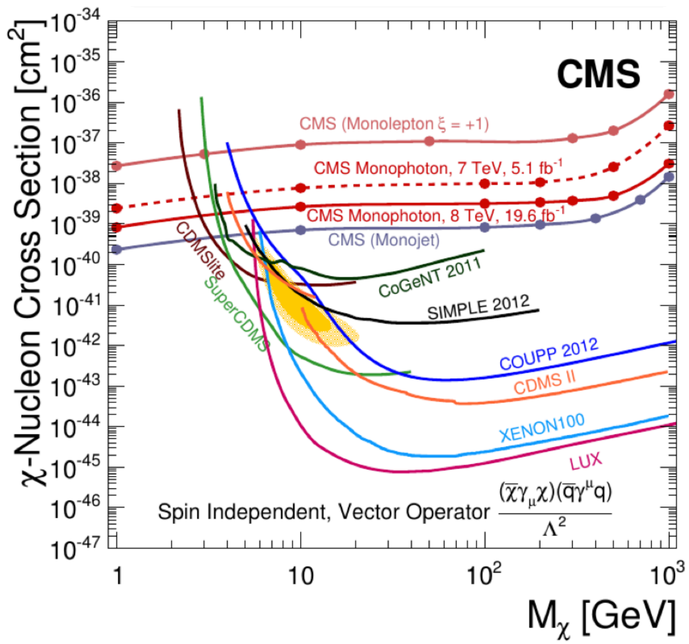


ATLAS-CONF-2016-020

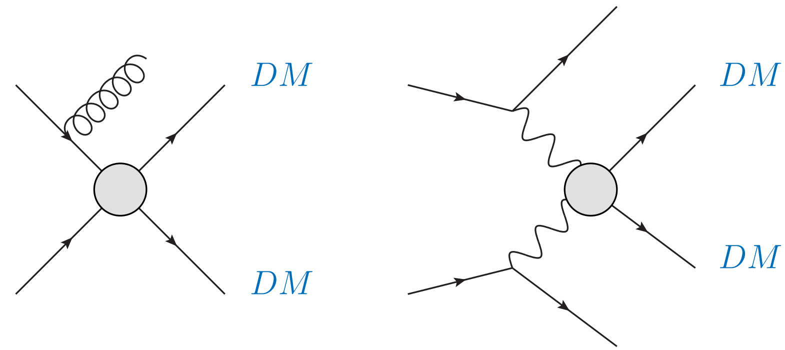
Dark Matter Searches

Complementarity
Of course ourstanding if seen in a lab!





LHC more typical scenarios
The gluon below can be replaced by a photon, vector boson, Higgs boson, etc…



A wealth searches for DM at the LHC:

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

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

The Mono-Jet Search

Phs. Rev. D94 032005

Selection requirements

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

Backgrounds

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

Signal region

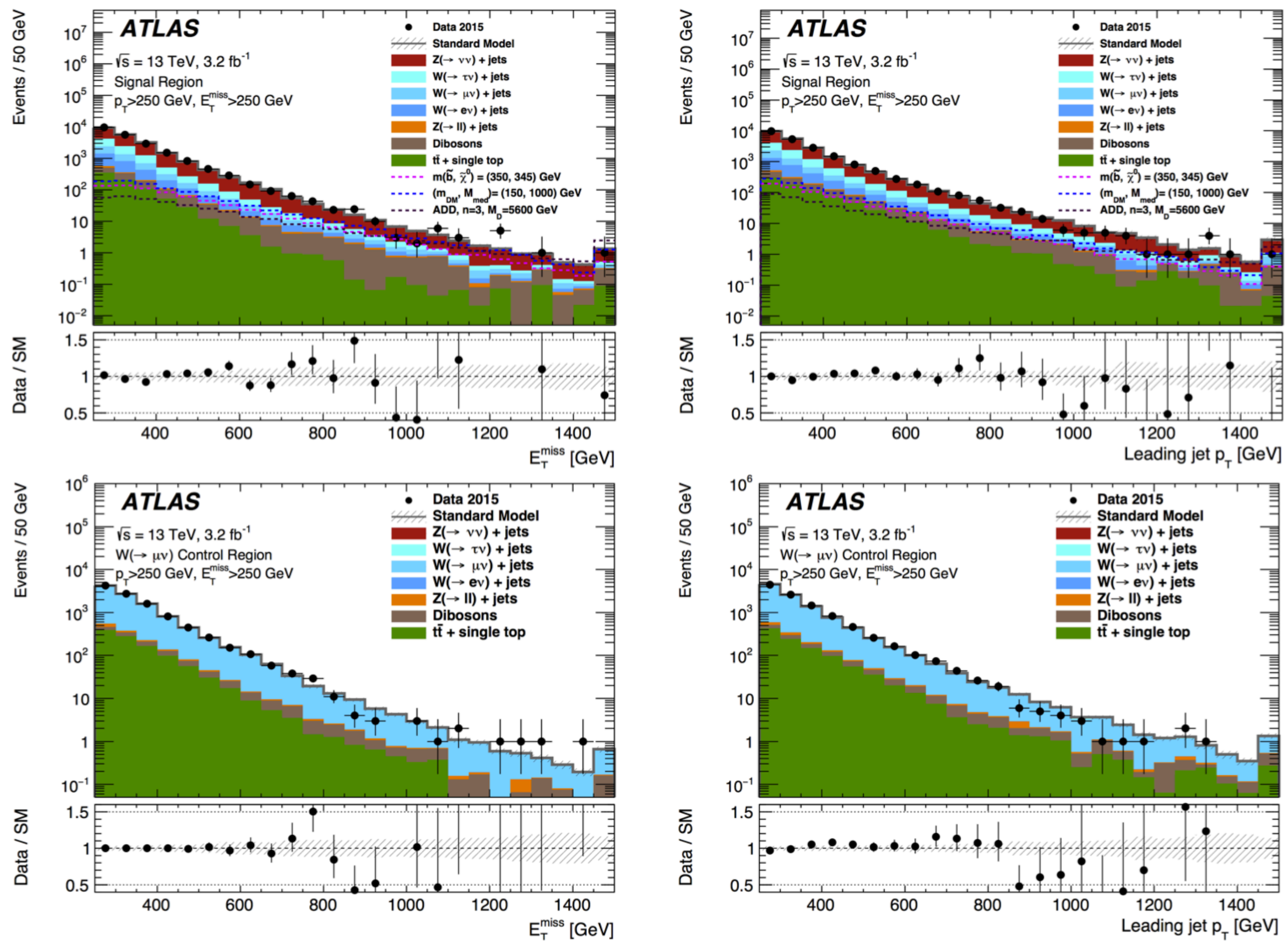
Excellent data-prediction agreement

Main background Z(vv)+jets and W(lv) +jets

Control region

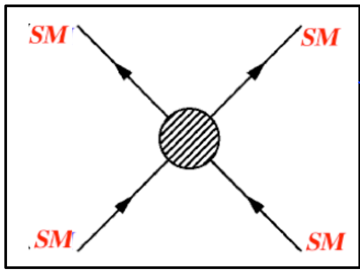
W+jets control region complements a lower statistics Z(ll) control region

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

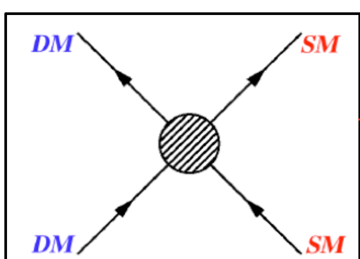


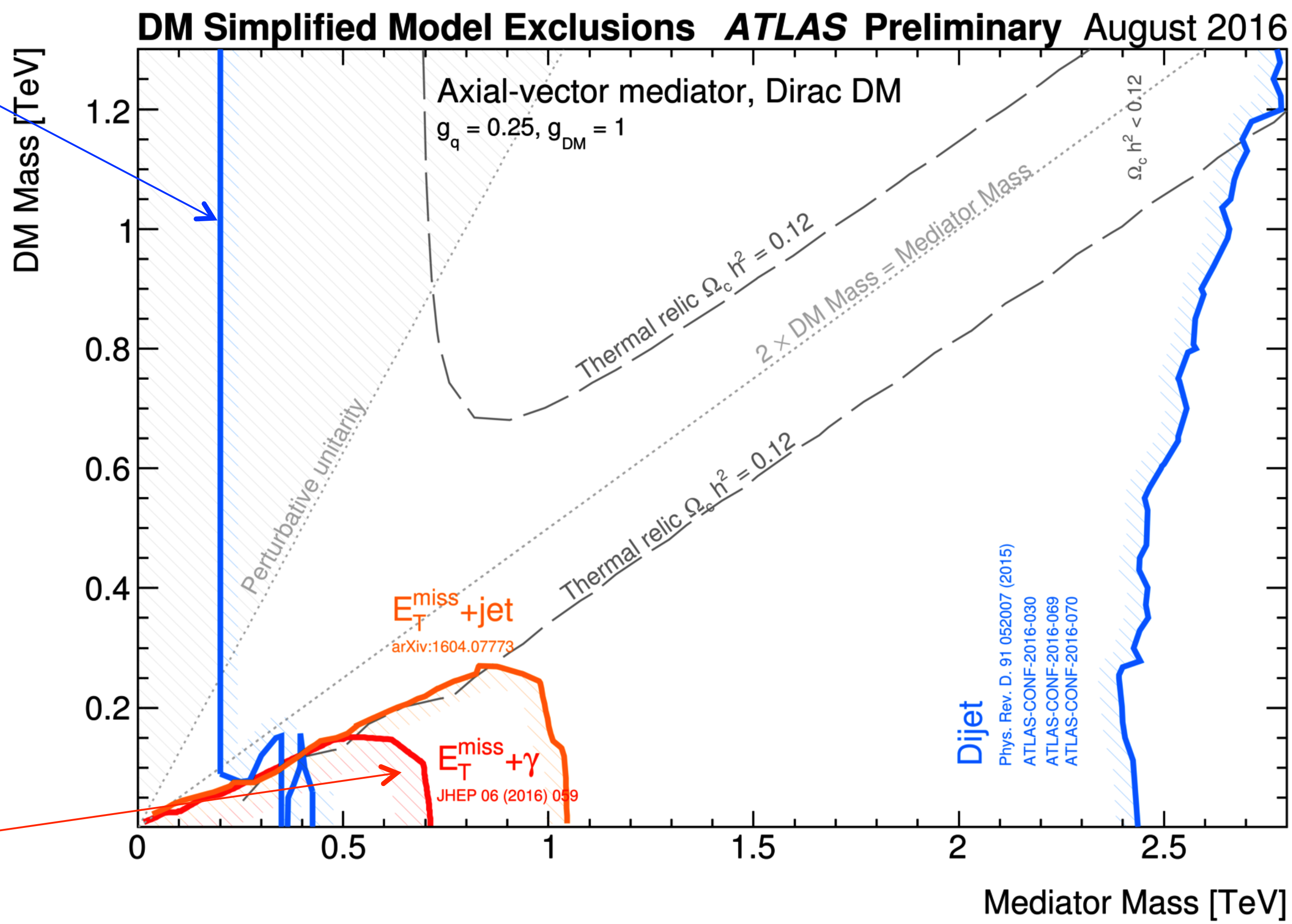
Interplay DM and Mediator Searches

Using the di-jet search down to the low mass range



Limits from direct searches of the mediator are mostly independent of the DM mass





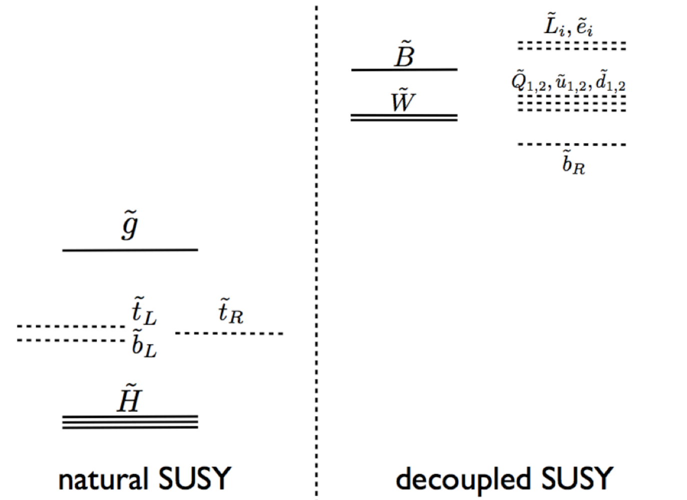
Searches for (RPC) Supersymmetry

… and Additional Higgs bosons

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

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

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



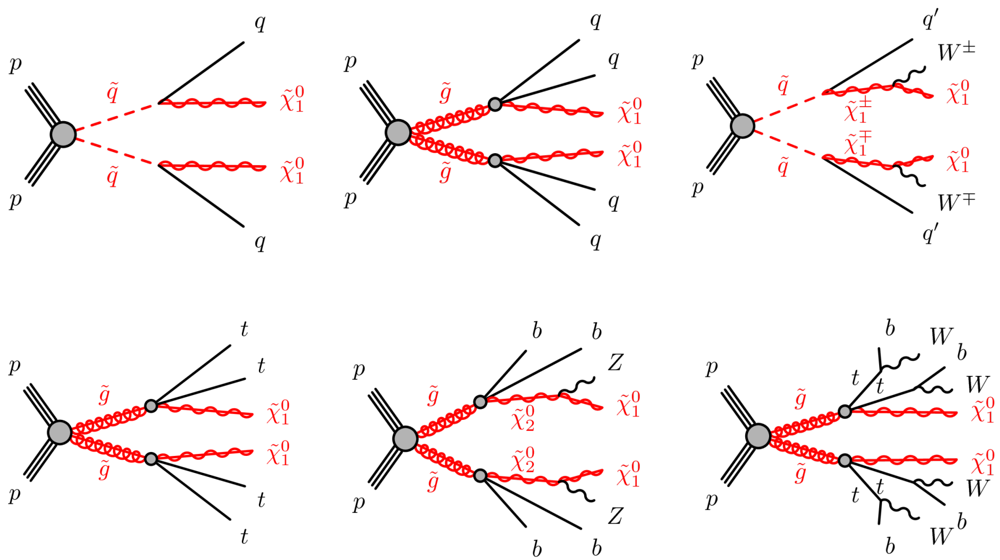
The paradigm scenario (still fully open at the LHC) of O(natural) SUSY

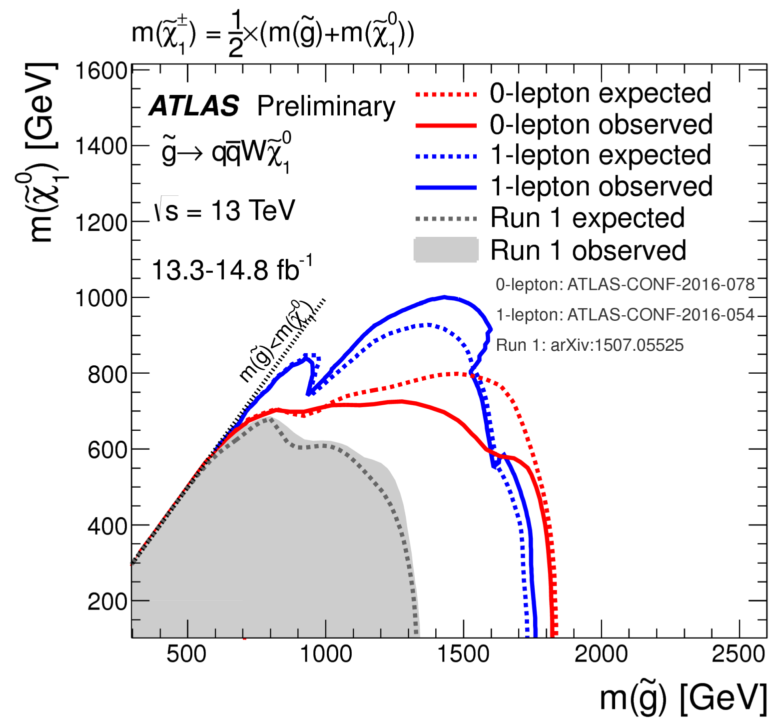
Main searches:

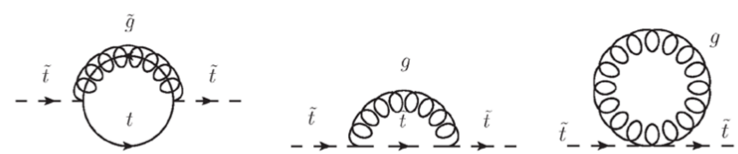
- Gluino and squarks searches in (0L, 1L, 2L, 3L, b-jets, top, etc…)
- 3d generation searches in many channels for stop and sbottom (0L, 1L, 2L, taus, etc…)
- Searches for charginos and neutralinos "EW SUSY searches", in (2L, 3L, 2taus, WZ, WH, etc…)
- Compressed scenarios: search for low pT stuff (soft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

Strong SUSY Searches (Squarks and gluinos)

Very large number of possible topologies in the gluino (or squark) production:







Main channels covering all possibilities:

- 0L with N-jets (from 2 up to 10)
- 1L with N-jets (from 2 to 6)
- 2L, 3L and 4L with jets
- Multiple b-jets or top

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

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

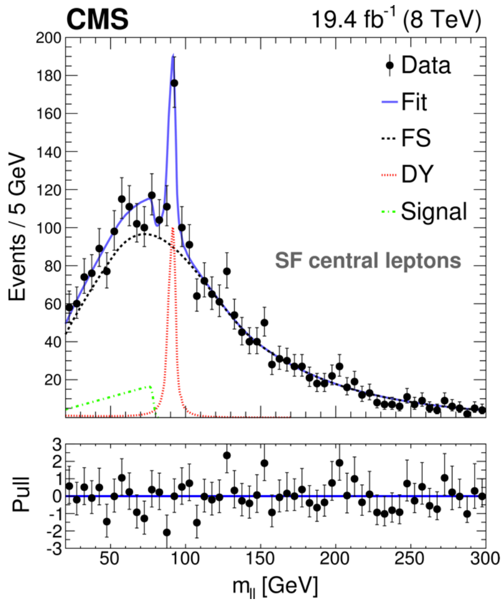
The 2L (OS-SF) strong production saga

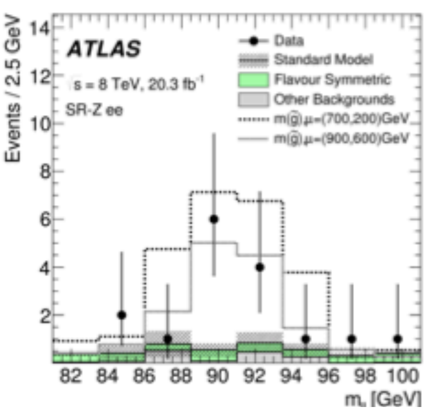
Run 1

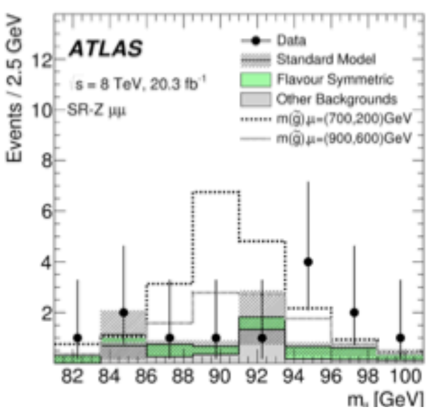
Run 2

CMS Edge analysis

Below Z mass 2.2σ excess

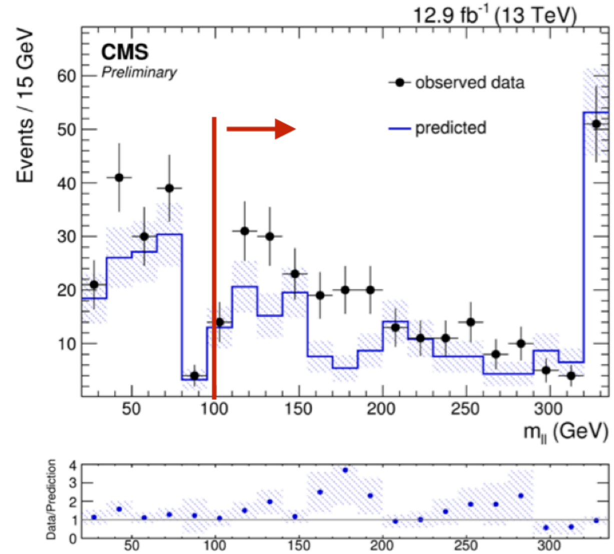


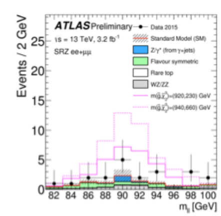




ATLAS On-Z Analysis 3.3σ excess

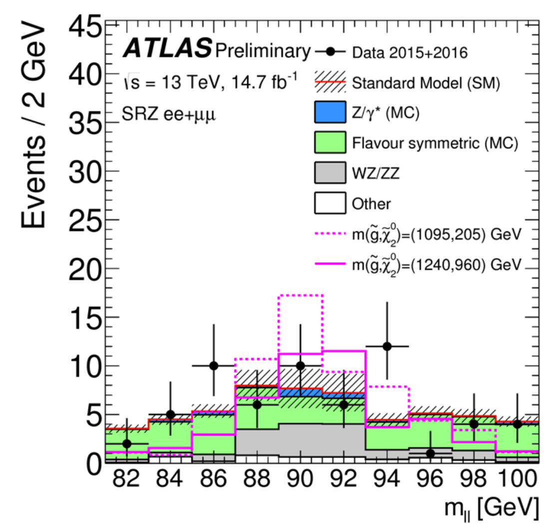
~3σ excess in the high mass





10 Events expected
20 observed 2.2σ

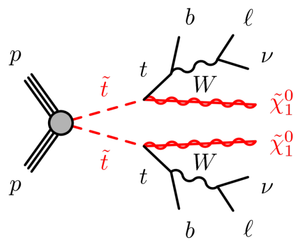
No excess



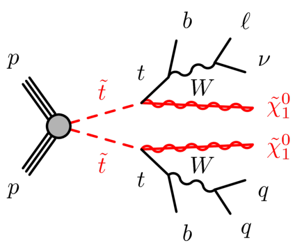
Stop Searches

$\tilde{t} \to t\chi$

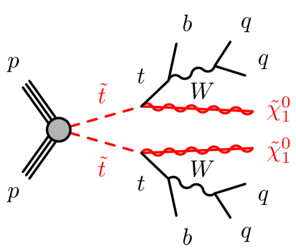
Stop 2-Leptons



Stop 1-Lepton

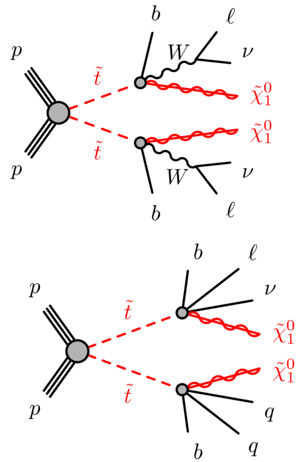


Stop 0-Lepton



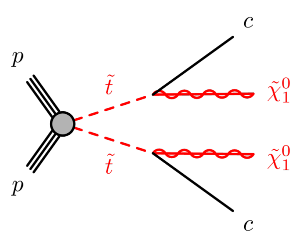
$\tilde{t} \to bW\chi$

Stop 1,2-Leptons

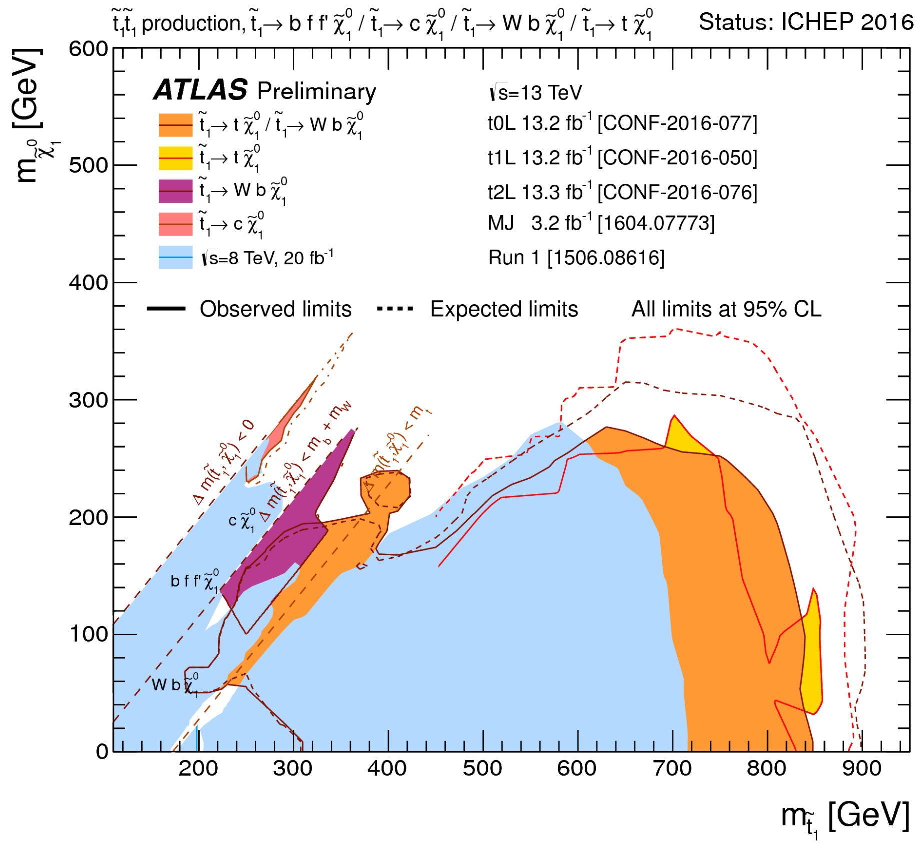


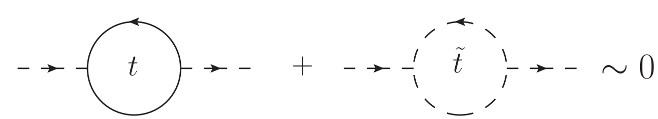
$\tilde{t} \to c\chi$

Mono-jet search



Large number of categories searched





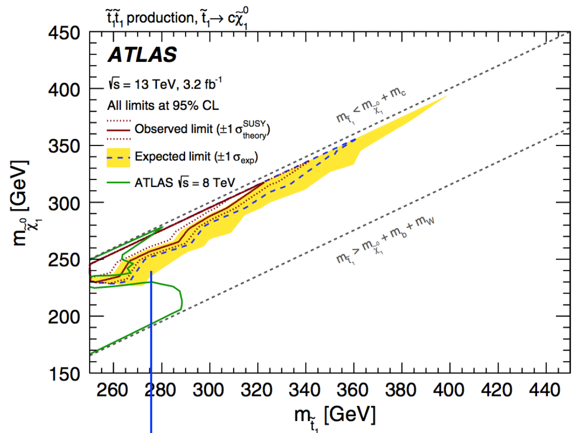
Not so natural SUSY: Stops > 800 GeV

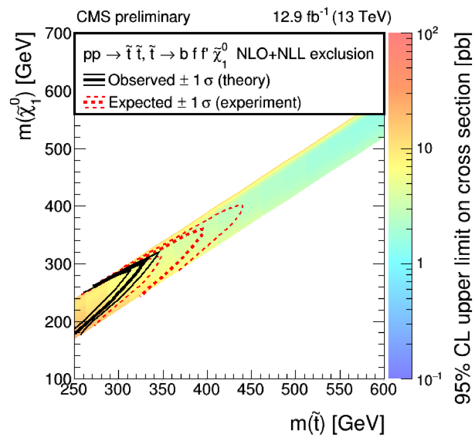
~Tuning of factor 20

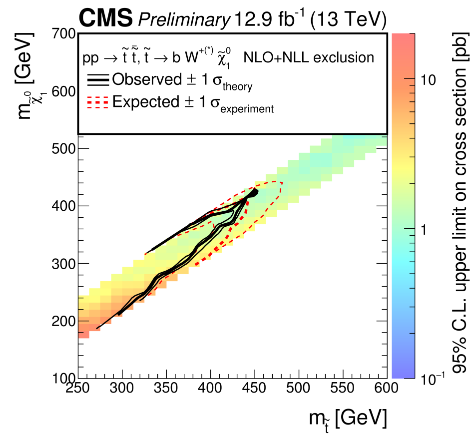
Stop Searches

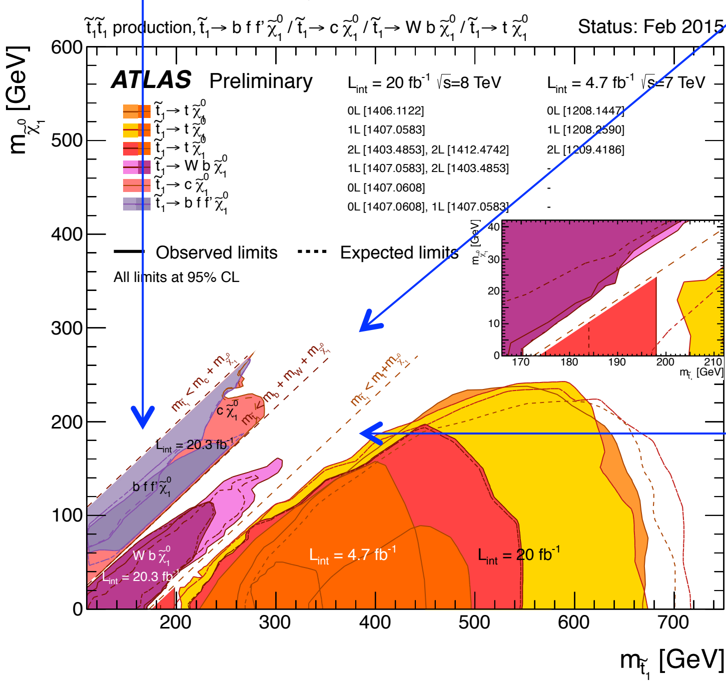
Completing the Picture in Compressed Scenarios

$$m_{\tilde{t}} \rightarrow m_c + m_\chi$$



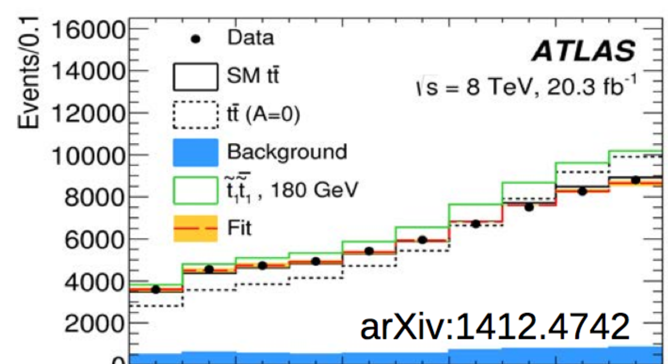






$$m_{\tilde{t}} \rightarrow m_W + m_b + m_\chi$$

$$m_{\tilde{t}} \rightarrow m_t + m_\chi$$



Spin correlations in tt production

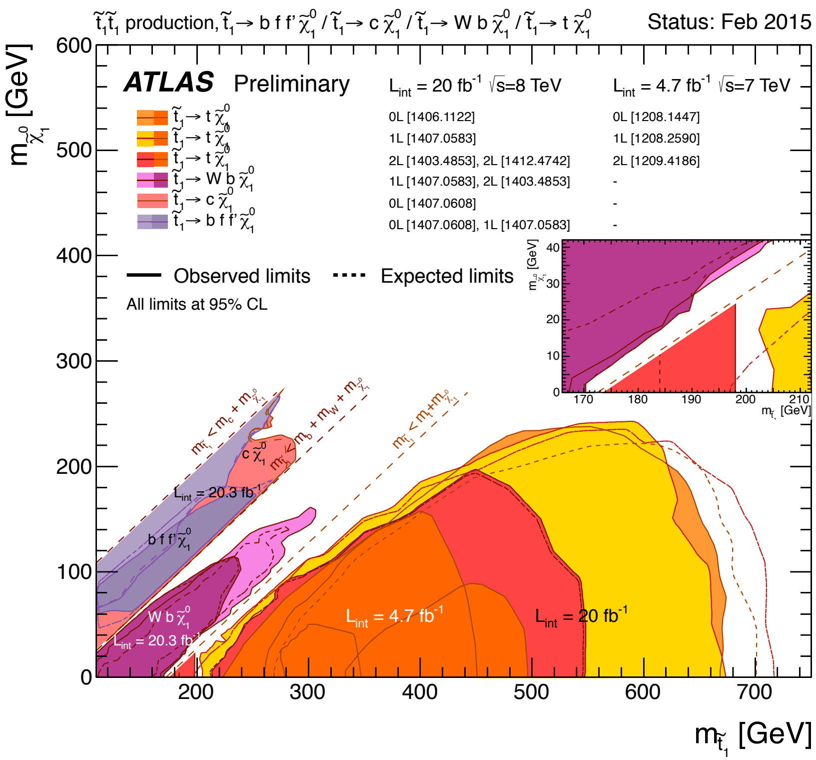
Stop Searches

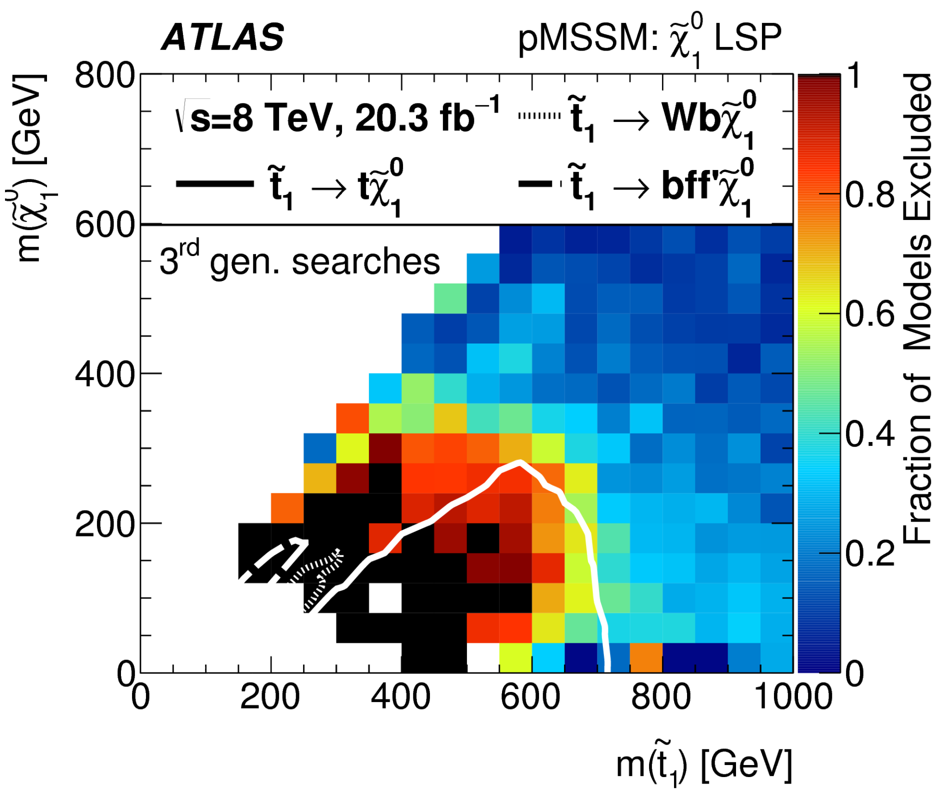
Completing the Picture in the pMSSM

pMSSM Survey

Survey of the 19 MSSM parameters using existing constraints

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





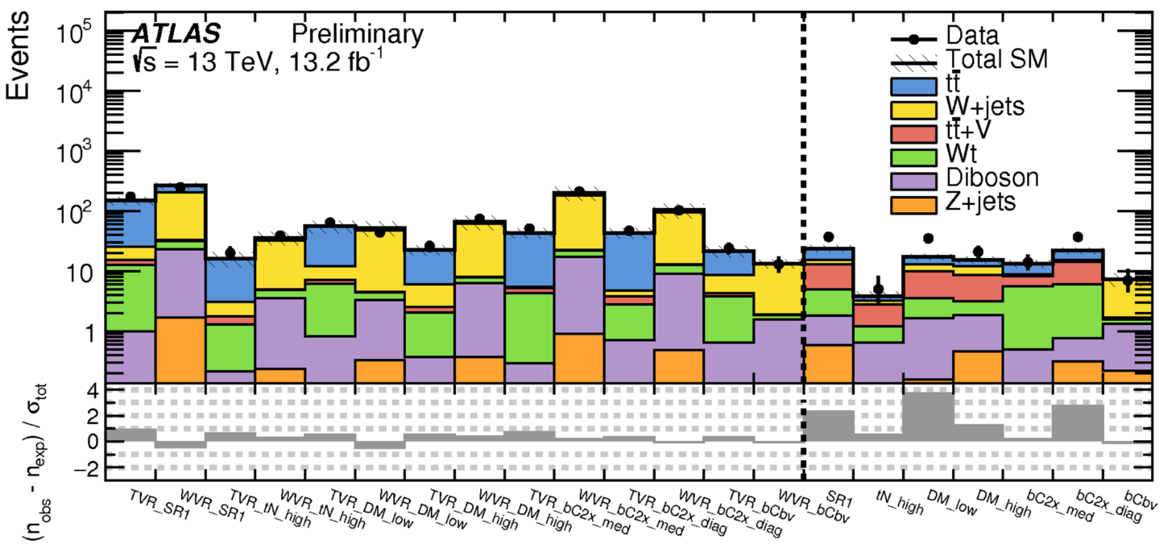
Experimental constraints effectively cover the excluded region well in the pMSSM

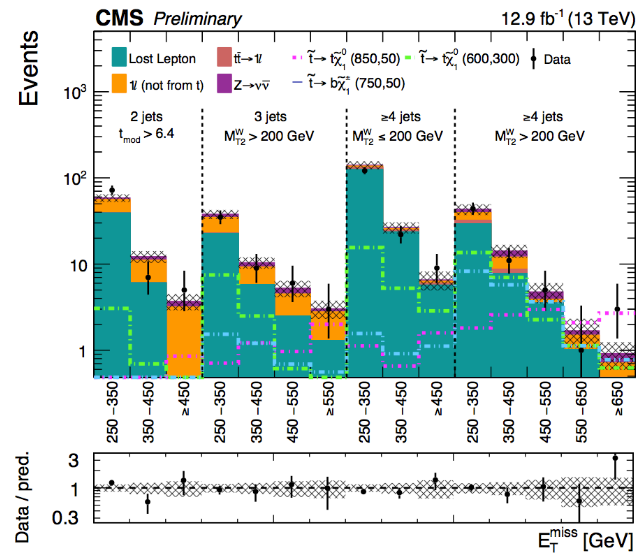
Example SUSY 1L Stop Searches

Search done in many categories with different kinematic requirements:

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

Categories are correlated!





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

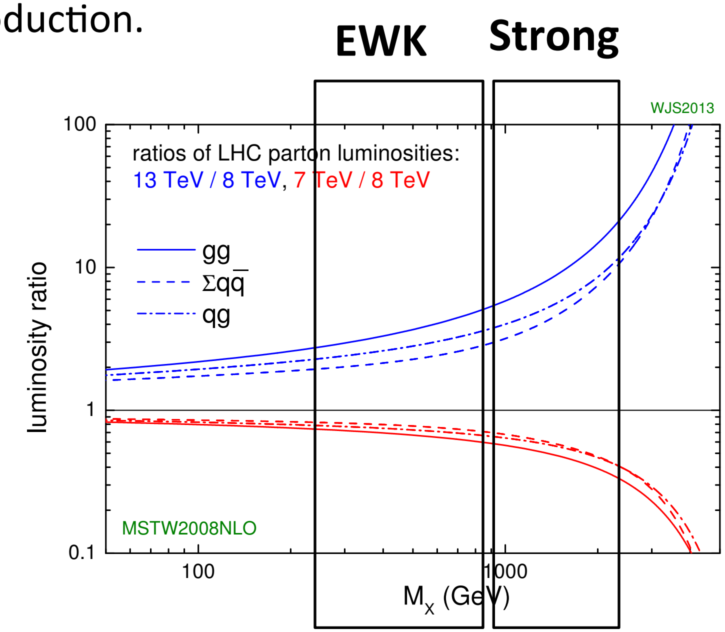
No excess seen in CMS for similar topology

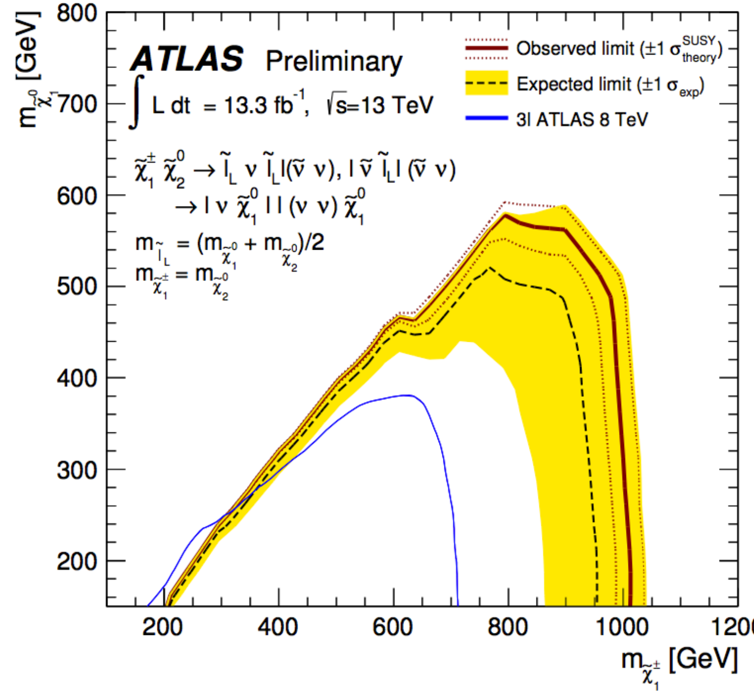
Electroweak Production

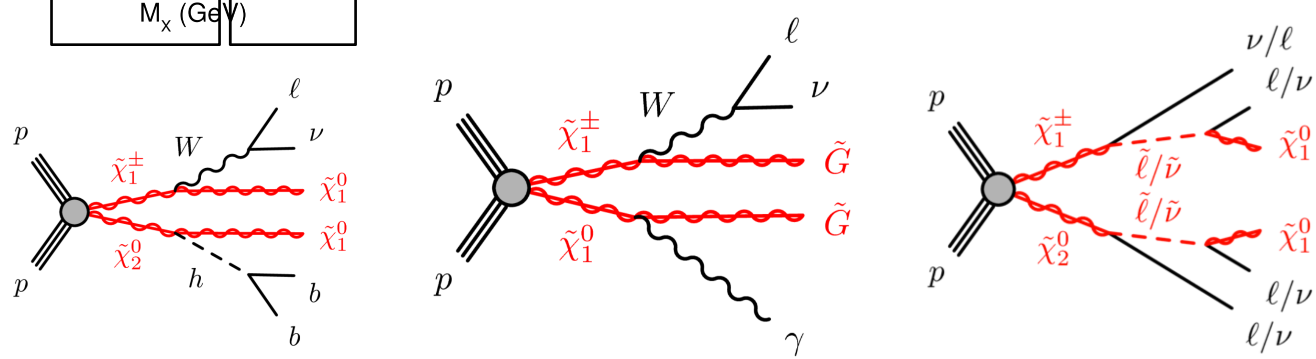
Search for Neutralinos, Charginos and sleptons:

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

Topologies with 1 or 4 leptons (including taus) in the final state and final states with photons And typically less jet activity than the strong production.

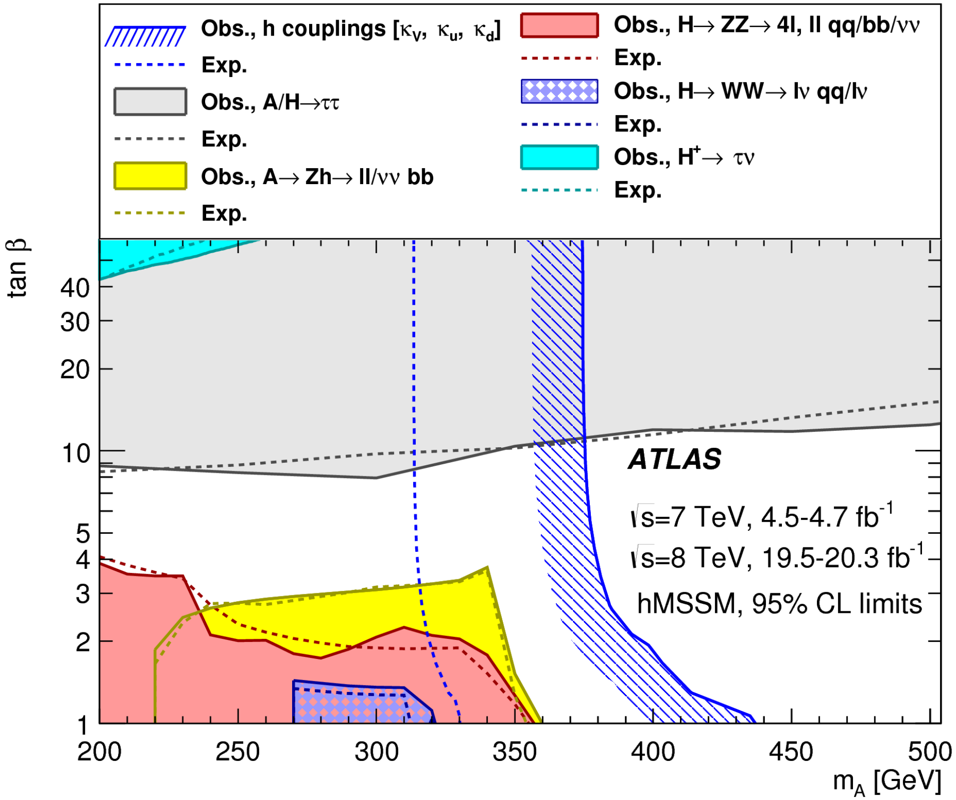


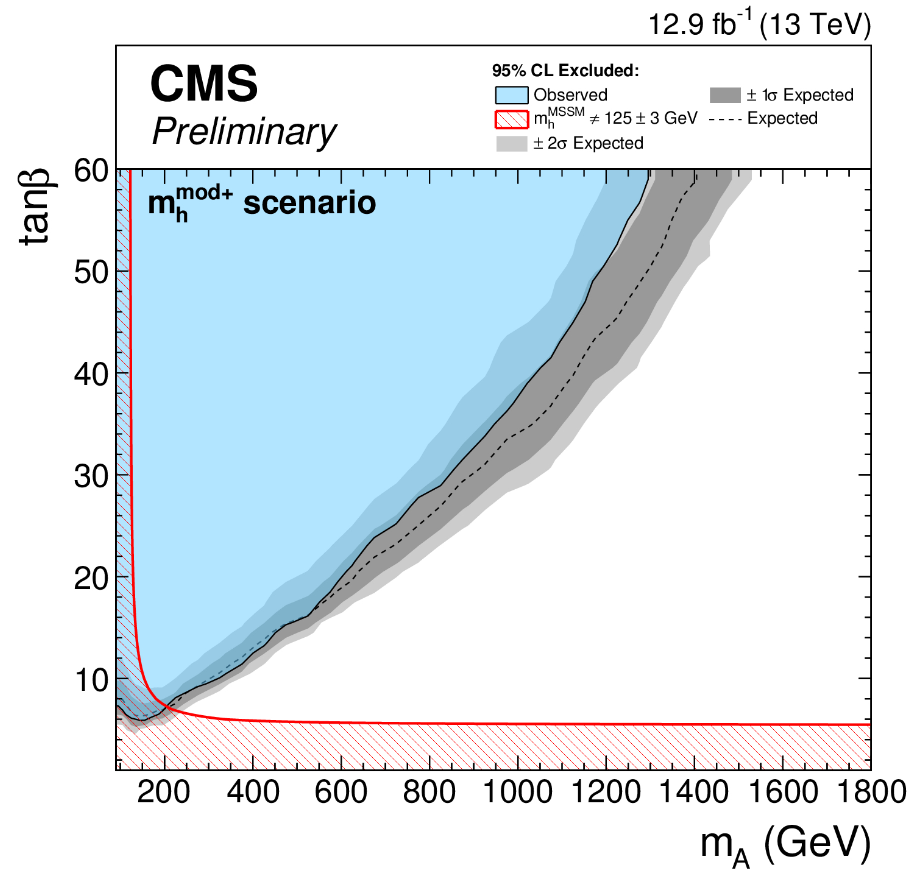


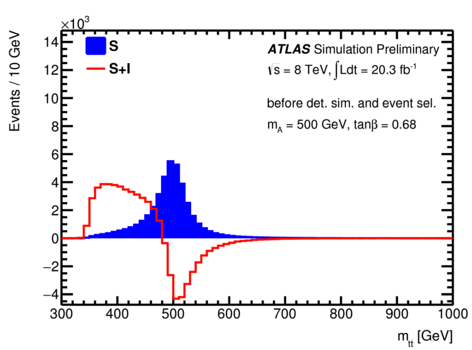


Searches for Additional Higgs bosons

MSSM needs fine tuning in order to accommodate the Higgs mass







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

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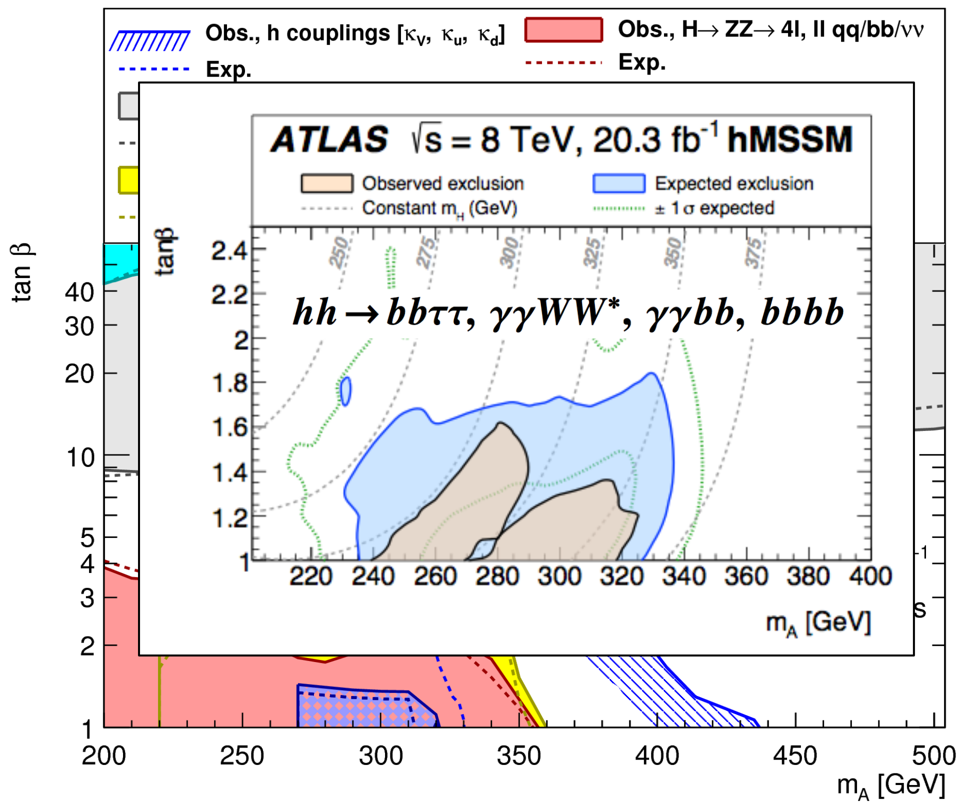

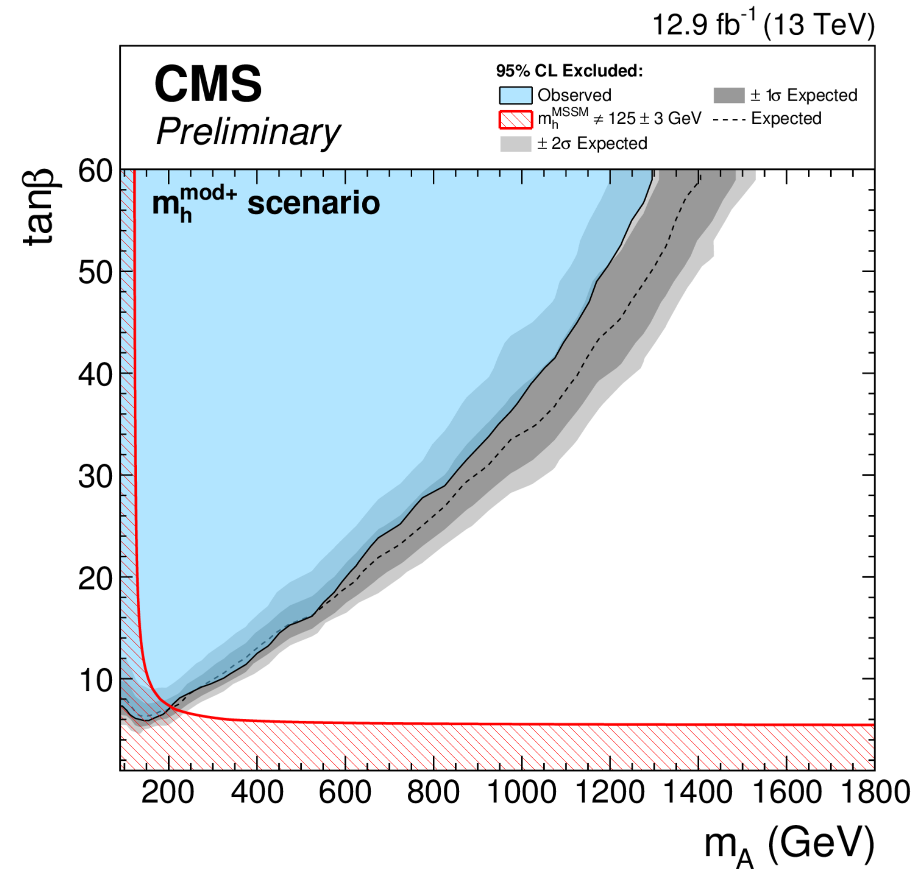

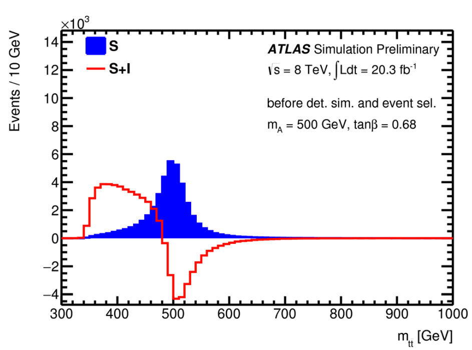

- Complementarity between Higgs couplings and direct searches
- Complete the low tan beta region important
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Unconventional Signatures

Typical scenarios

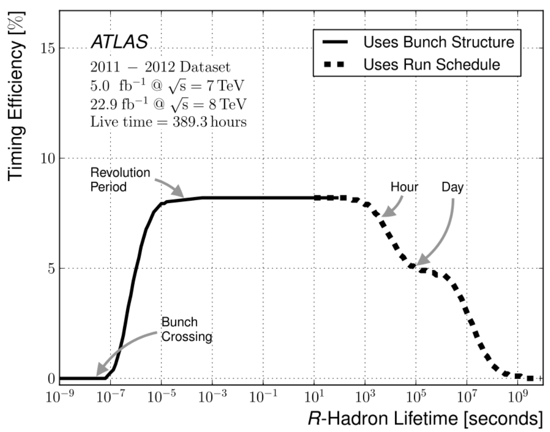
- Specific SUSY models
- Hidden valley models

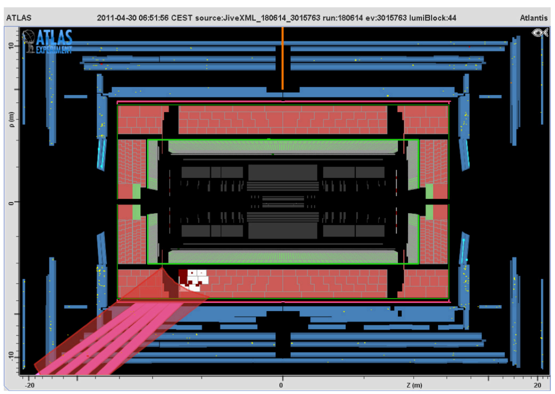
Topologies

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

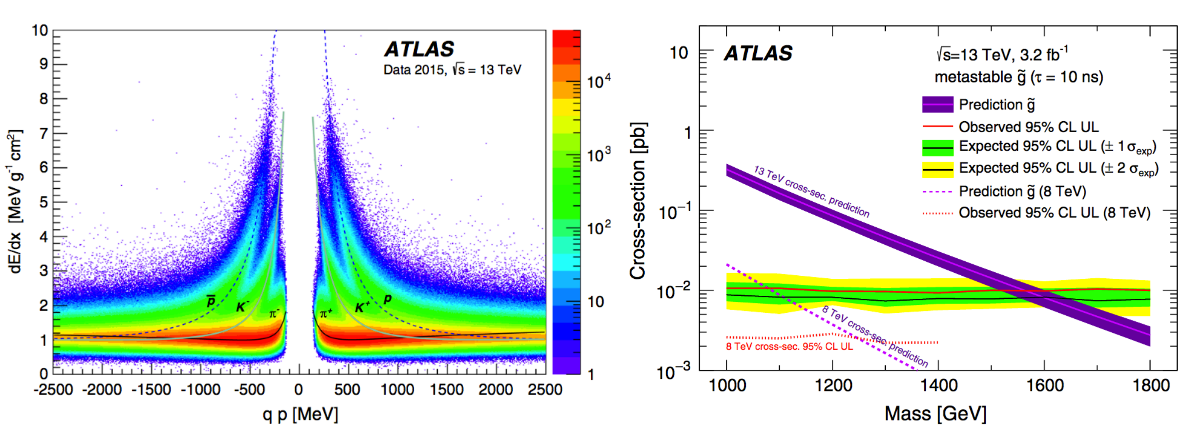
These are very difficult analyses requiring specific non standard reconstruction algorithms.

Stopped Gluino Search



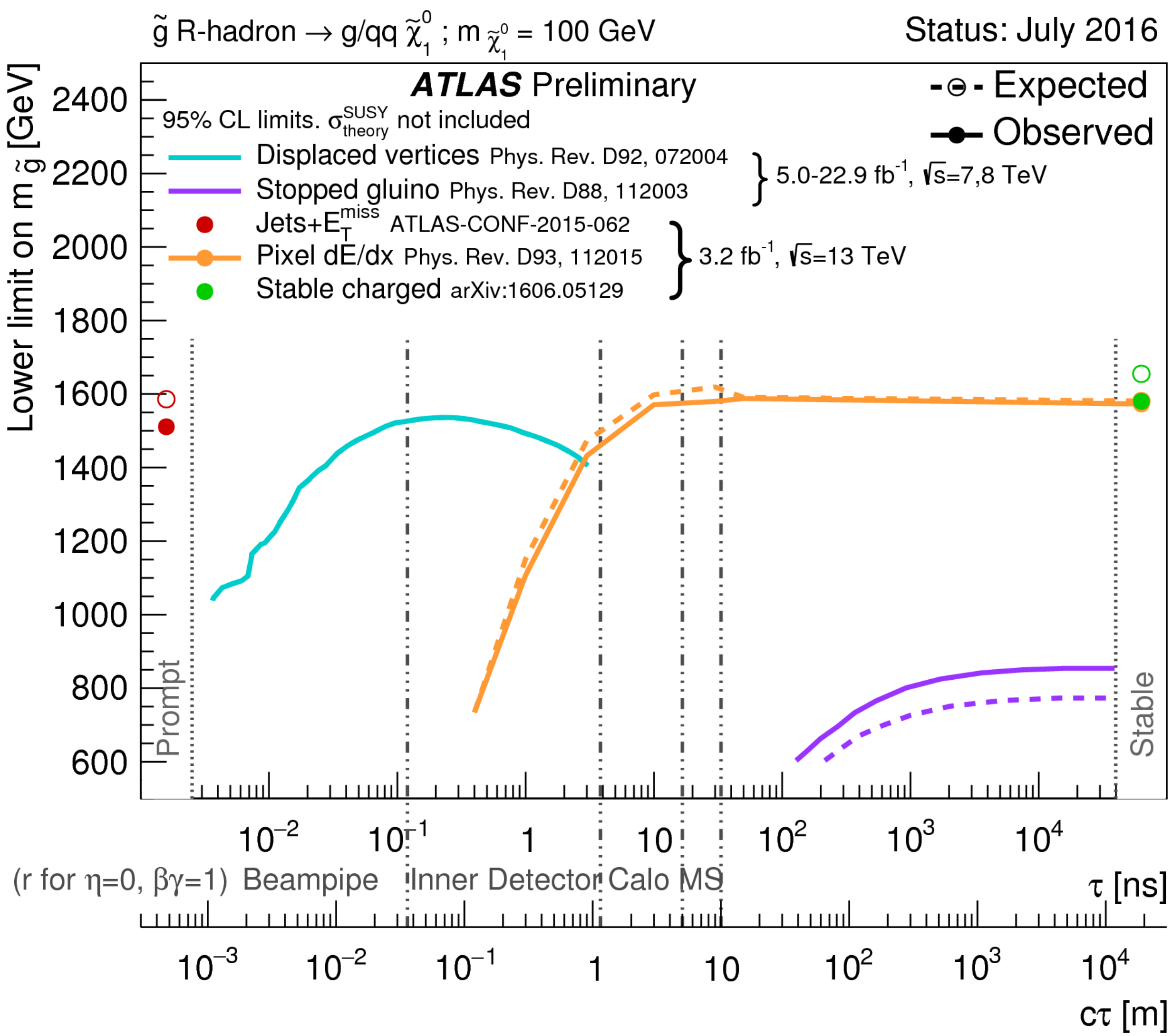


Pixel dE/dx search



Unconventional Signatures

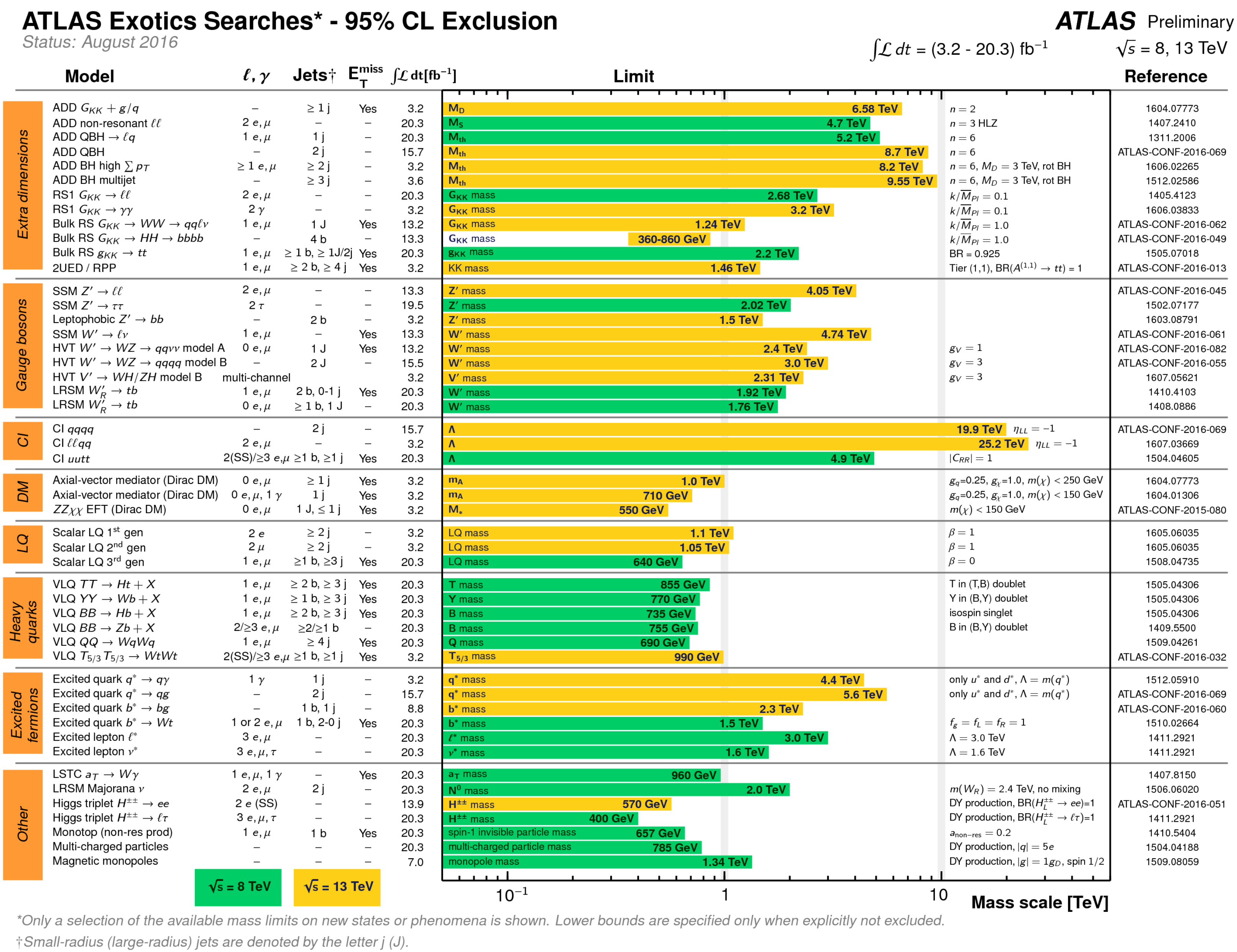
Overview of searches Run 2 in perspective: starting to cover ground for searches for LLP



Exotics Overview

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

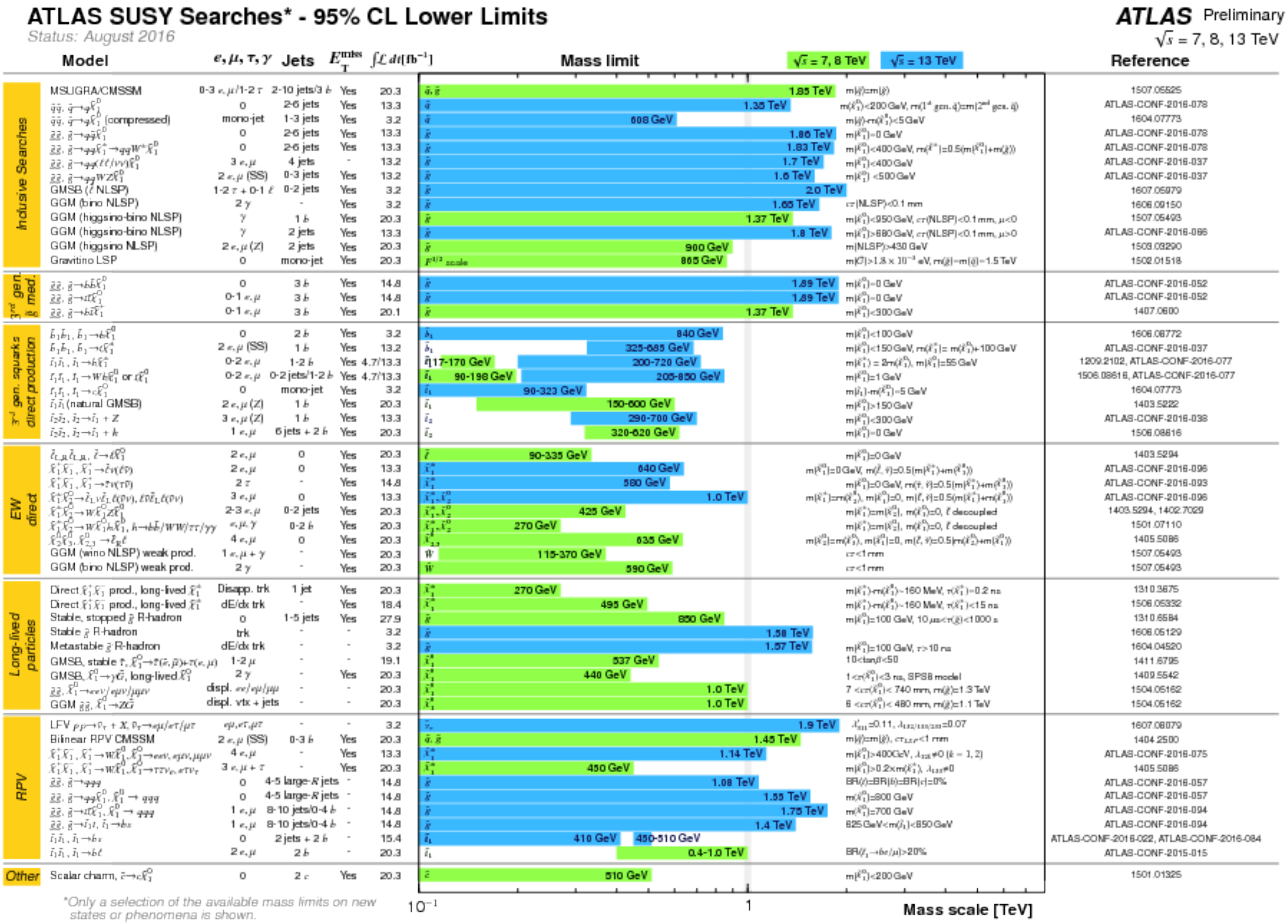
Also illustrates the large number of searches not covered in this talk



SUSY Overview

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

Also illustrates the large number of searches not covered in this talk



Mini Searches Summary

No significant excess has been observed so far

Non significant excesses to keep an eye on:

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

Summary and Conclusions (I)

- The LHC has been extremely successful at Run 1 (both in machine performance and in results of fundamental importance).

- Measurements performed so far are in agreement with the SM and therefore do not yield indications for new physics beyond the SM.

- With the higher centre-of-mass energy, the outstanding results expected from the Run 2 are the direct searches for new physics. The strategy is to look exhaustively at all possible scenarios and topologies.

- The LHC is now half way through the Run-2, with approximately 1/4 of the data expected for the entire Run 2 (reappraised goal of 150 fb^{-1}).

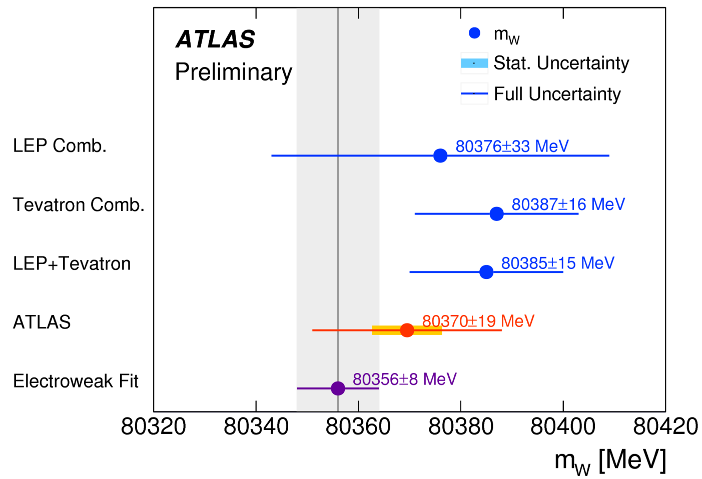
- Approximately 1/3 of the available luminosity at high energy, has been analyzed so far. A good fraction but by far not all searches foreseen have already been performed. No significant sign of new physics was found.

- This dataset is just a small fraction of the Run 2 dataset (~10%) and very small fraction of the total HL-LHC dataset (~1%). This is just the beginning and there are any more exciting challenges ahead!

Summary and Conclusions (II)

- Meanwhile and in preparation for the more difficult search cases, important SM, Higgs, and top measurements are being prepared at Run 2.

- Milestone measurements with the 7 TeV Run 1 data taken in 2011 are just being presented



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

Thank you!