Optimization Procedure in the Search for Spin-0 Supersymmetric Partner of Top Quark Using 150 fb^{-1} of $\sqrt{s}$ = 13 TeV *pp* Collisions using the ATLAS Detector

Stefio Yosse Andrean
PhD thesis supervisor: Christophe Clement

Partikeldagarna 2018, Lund

Introduction

What is supersymmetry?

$$Q|Fermion> = |Boson>$$

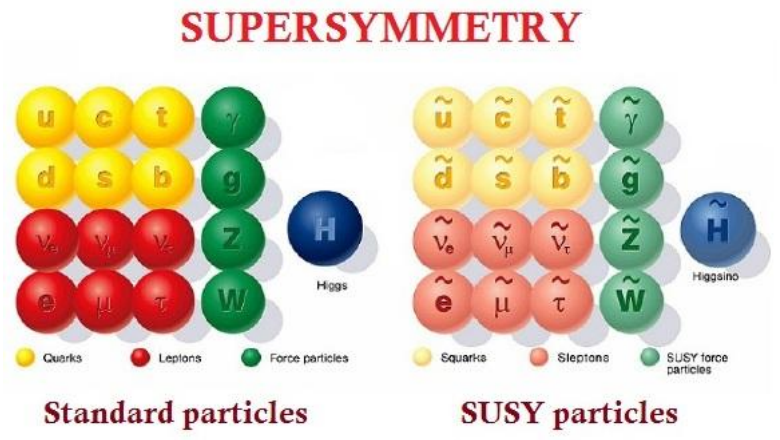


image : https://ep-news.web.cern.ch

What's so great about SUSY?

- Supersymmetric particles cancel SM particles on Higgs-boson mass contribution = **solves hierarchy problem**
- On some models, lightest supersymmetric particle is electrically neutral and interact weakly = **dark matter candidate**

Mass-dependent signature

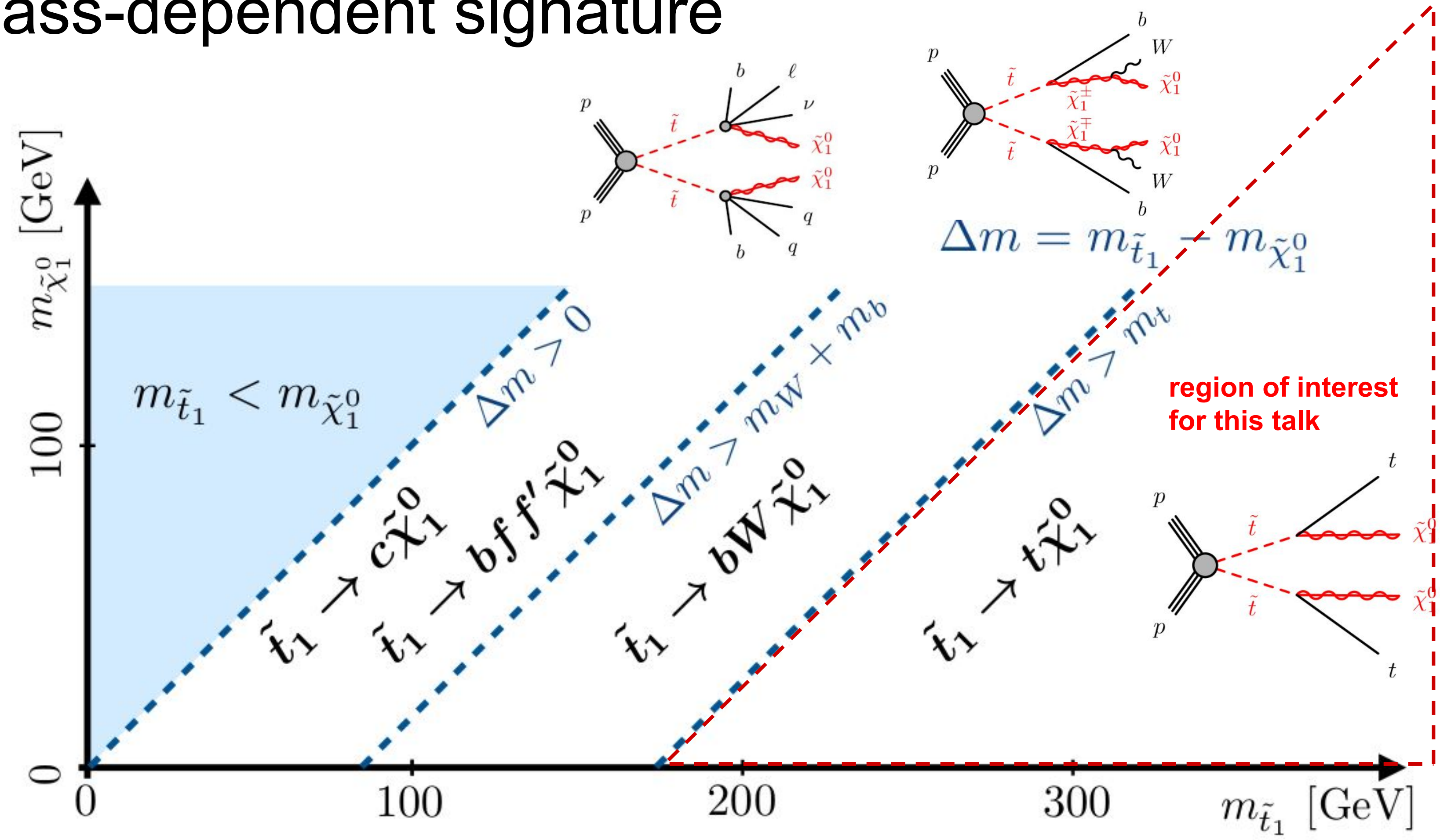


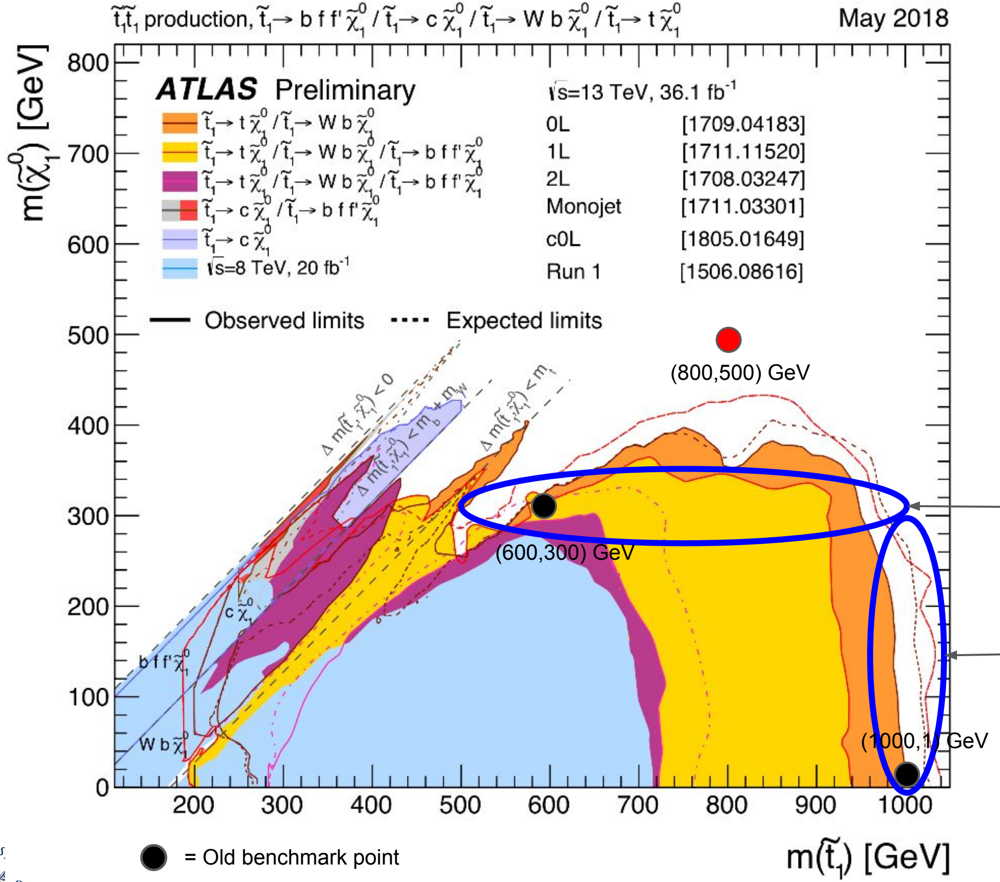
figure: arXiv:1711.11520

Last result

Our region of interest is divided into two signal regions (SR): tN_medium, and tN_high

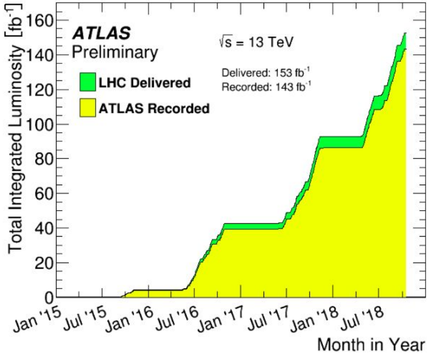
Optimization was done on ● **benchmark points**: (600,300) GeV and (1000,1) GeV; respectively

figure: arXiv:1711.11520



● = Old benchmark point

● = New benchmark point



Lumi plot: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2

With the new data volume, we need to re-optimize these with ● **new benchmark points**!

Signal Characteristics

Preselection

Variables	Preselection
Trigger	$E_{\mathrm{T}}^{\mathrm{miss}}$ trigger
Data quality	jet cleaning, primary vertex
Second lepton veto	no additional baseline lepton
Number of lepton, tightness	= 1 'loose' lepton
Lepton p_T [GeV]	> 25
$N_{\mathrm{jet}}, N_{\mathrm{b\text{-}jet}}$	$(\geq 4, \geq 0)$
Jet p_T [GeV]	> (25, 25, 25, 25)
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 230
m_{T} [GeV]	> 30
m_{T2}^{τ} based τ-veto [GeV]	> 80
$\Delta\phi(j_{1,2}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})$	> (0.4, 0.4)

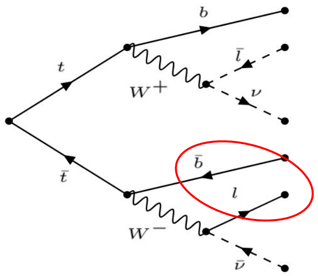
Variables to optimize:

1. N_{jet}
2. $N_{\mathrm{b\text{-}jet}}$
3. Leading jet p_T
4. $E_{\mathrm{T}}^{\mathrm{miss}}$
5. $E_{\mathrm{T},\perp}^{\mathrm{miss}}$
6. $H_{\mathrm{T,sig}}^{\mathrm{miss}}$
7. m_{T}
8. am_{T2}
9. $m_{\mathrm{top}}^{\mathrm{reclustered}}$
10. $\Delta R(b, l)$

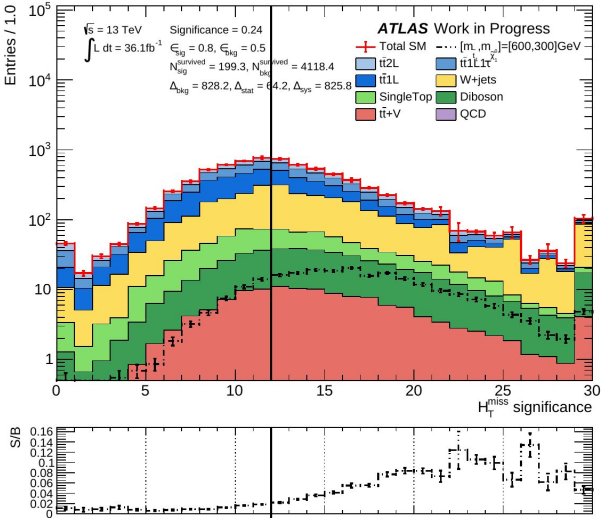
$$H_{\mathrm{T,sig}}^{\mathrm{miss}} = \frac{|\vec{H}_{\mathrm{T}}^{\mathrm{miss}}| - M}{\sigma_{|\vec{H}_{\mathrm{T}}^{\mathrm{miss}}|}}$$

H_T is the negative vectorial sum of the signal jet and signal lepton momenta.
$\sigma_{|\vec{H}_{\mathrm{T}}^{\mathrm{miss}}|}$ is calculated from jet energy uncertainties.
Targets events with no invisible particles

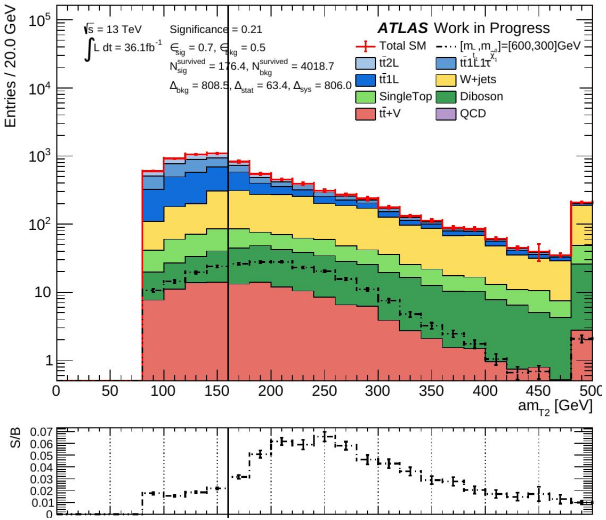
am_{T2} targets dileptonic ttbar events where one of the lepton is not reconstructed.



H_T^{miss} significance scan - Iteration 1



am_{T2} scan - Iteration 1



The Optimization Algorithm

Declare variables to be evaluated as cuts for the signal region
- Lower / upper cut
- Interval range / binning

↓

Loop through the cross section and luminosity normalized samples, apply preselection

↓

For each variable distribution:
- Do significance scan to determine where best to put the cut
- Apply damping to prevent too many events being cut away at early iterations
- Save the best cut with best significance

↓

Pick the best variable that gives the best significance

↓

Apply the chosen variable as cut for the next iteration (→ loops back to "For each variable distribution")

↓ If $\Delta\text{significance} < \text{threshold}$

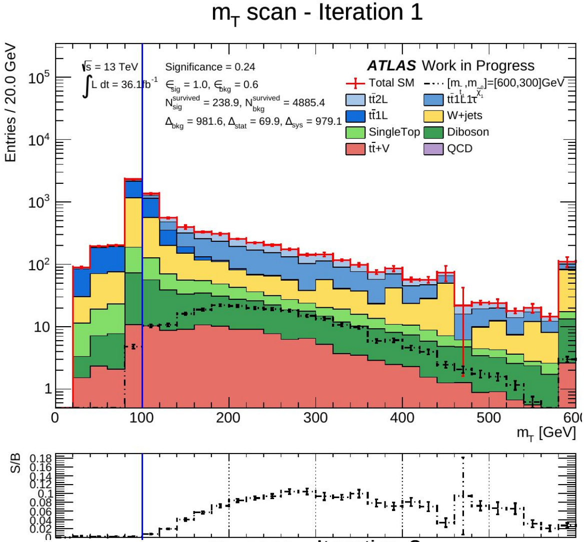
Break

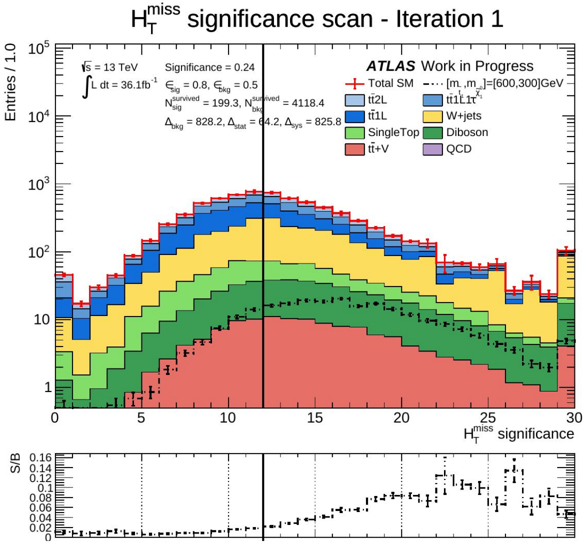
Damping: $\epsilon_{bkg} > \frac{0.5}{2^{n-1}}$

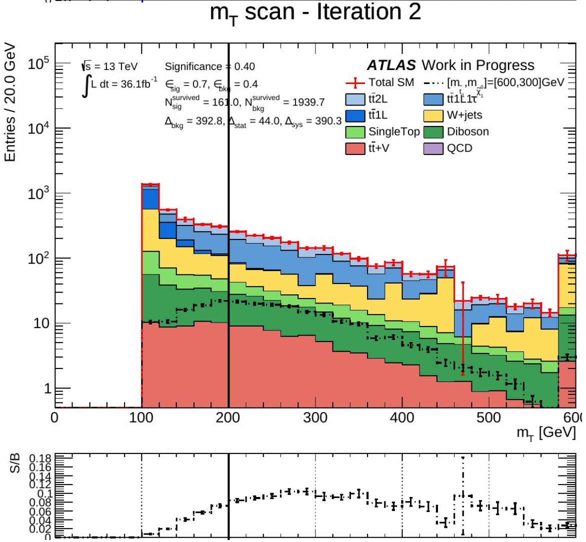
$$\Delta_{bkg} = \sqrt{\Delta_{stat}^2 + \Delta_{sys}^2}$$
$$\Delta_{sys} = \sqrt{(0.2B)^2 + (\Delta_{MC})^2}$$

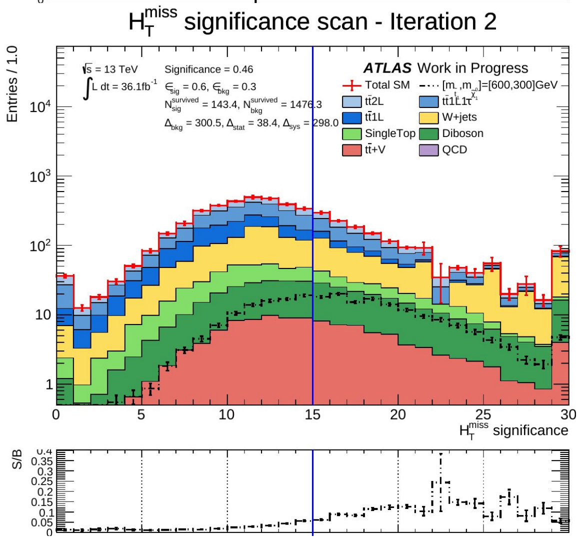
Significance calculation according to https://www.pp.rhul.ac.uk/~cowan/stat/notes/SigCalcNote.pdf

A look at the output

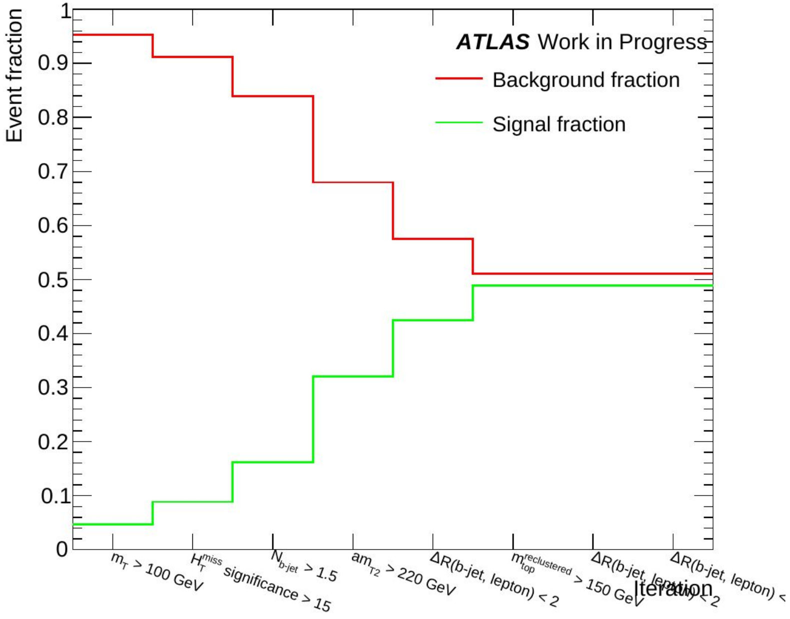




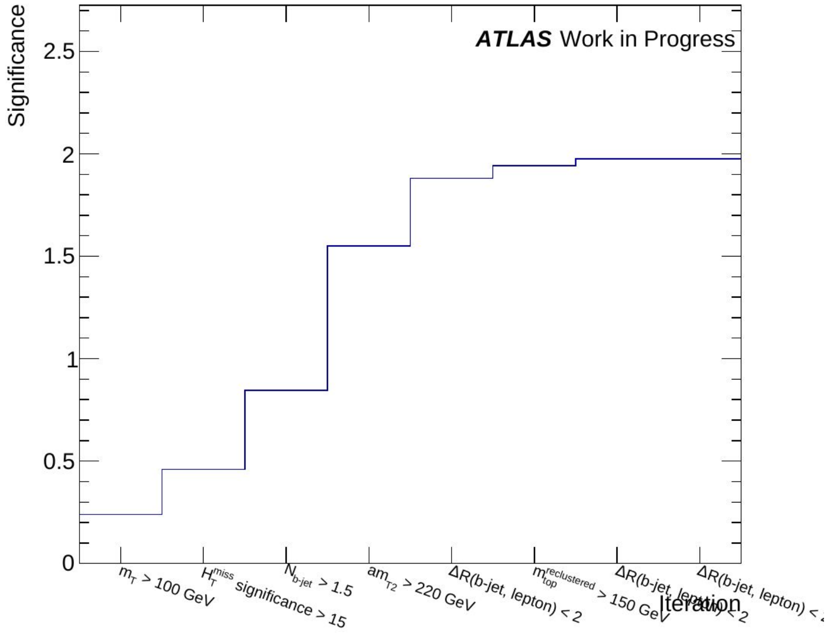




Output

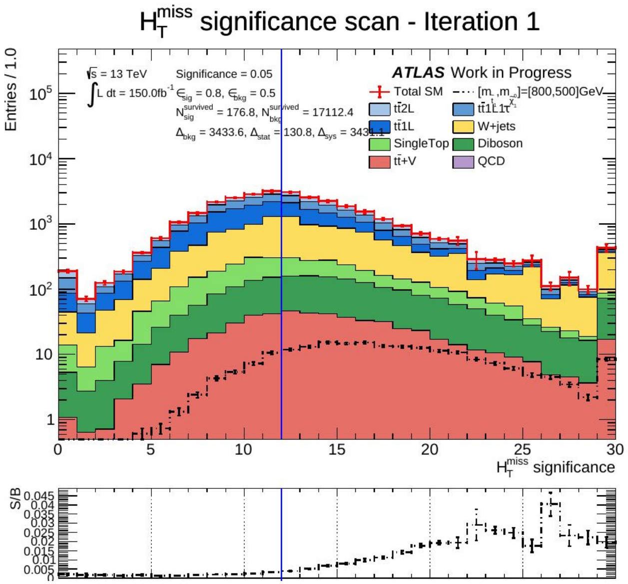


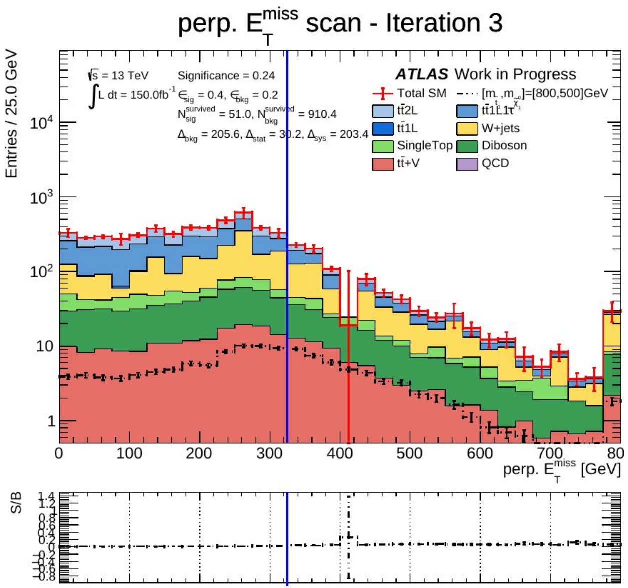
At each iteration, the signal fraction increases, which translates to improvement in significance

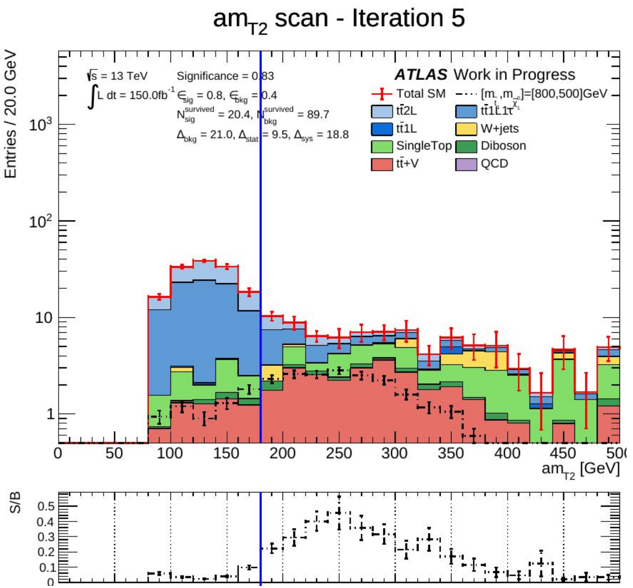


Then, the cuts are collected to define the signal region

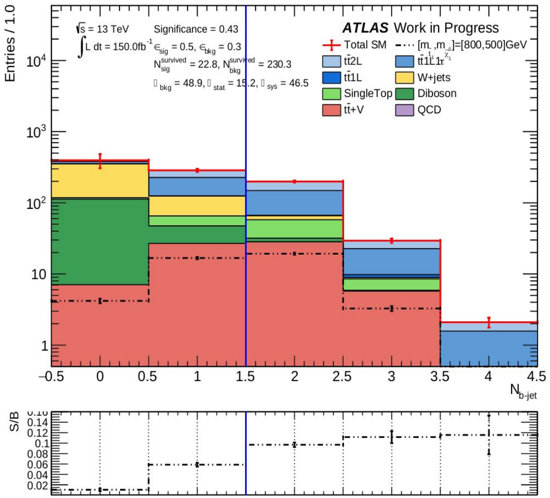
Run on 150 fb^{-1} simulated data, using new benchmark point: $(m_{\tilde{t}}, m_{\tilde{\chi}}) = (800, 500)\text{GeV}$



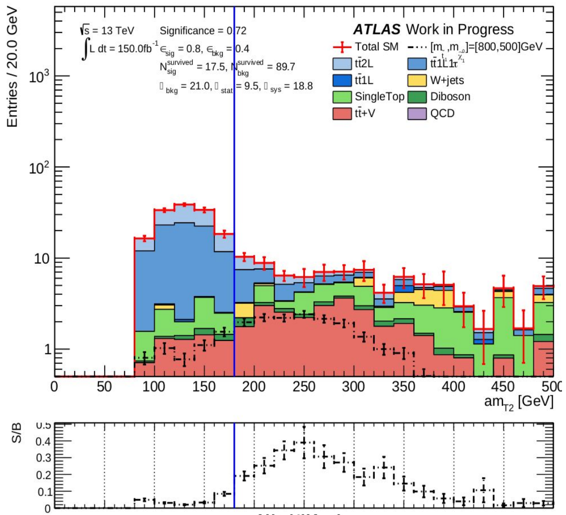




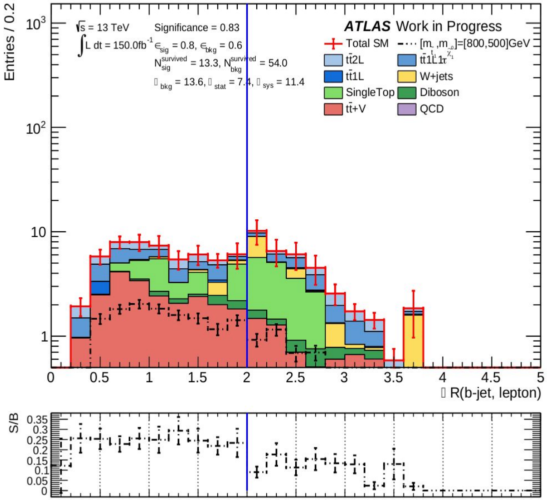
n_bjet_4

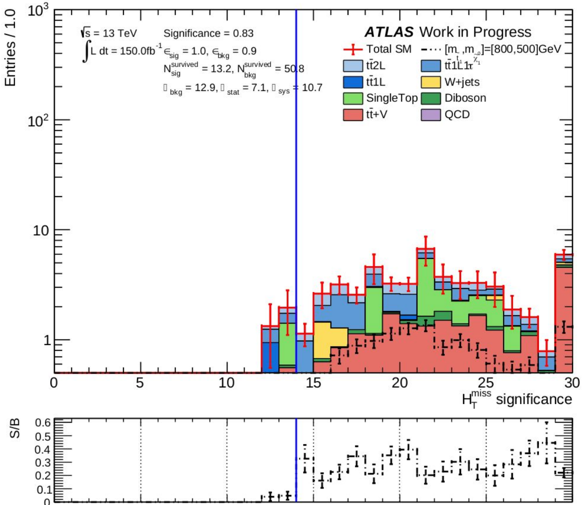


amt2_5



dr_bjet_lep_6





Output Summary

Cuts	$m(\tilde{t}, \tilde{\chi}_1^0) = (600, 300)$ GeV, 36.1 fb^{-1}	$m(\tilde{t}, \tilde{\chi}_1^0) = (800, 500)$ GeV, 150 fb^{-1}
$N_{\text{jet}}, N_{\text{b-jet}}$	$(\geq 4^*, \geq 2)$	$(\geq 4^*, \geq 2)$
Jet p_T [GeV]	$> (25, 25, 25, 25)^*$	$> (25, 25, 25, 25)^*$
$E_{\text{T}}^{\text{miss}}$ [GeV]	$> 230^*$	$> 230^*$
$E_{\text{T},\perp}^{\text{miss}}$ [GeV]	-	> 325
$H_{\text{T,sig}}^{\text{miss}}$	> 15	> 14
m_{T} [GeV]	> 100	> 200
am_{T2} [GeV]	> 220	> 180
$m_{\text{top}}^{\text{reclustered}}$ [GeV]	> 150	-
$\Delta R(b, l)$	< 2.0	< 2.0

* = applied by preselection

So now we have we working algorithm that can choose optimum cuts.
But these are not the final cuts yet...

Sensitivity Improvement by E_T^{miss} slicing

We optimize at a specified point , but we don't know how much of an area will that cover.

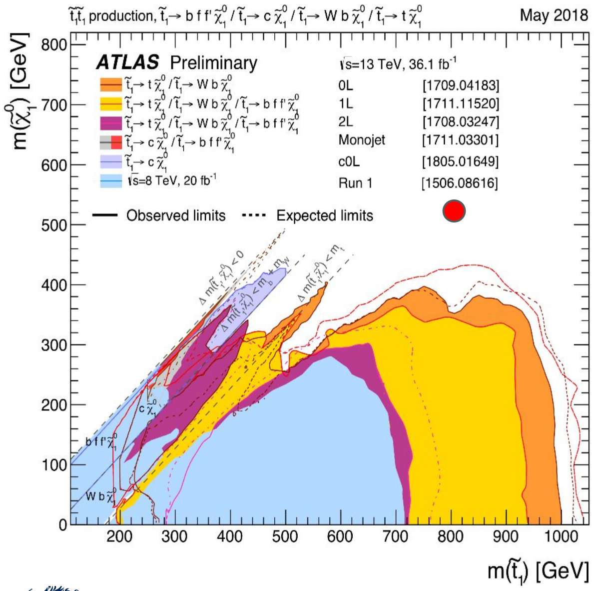
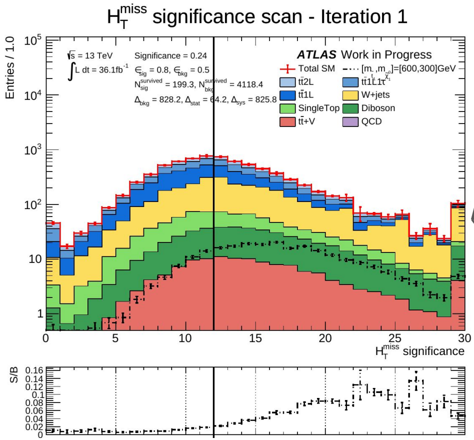
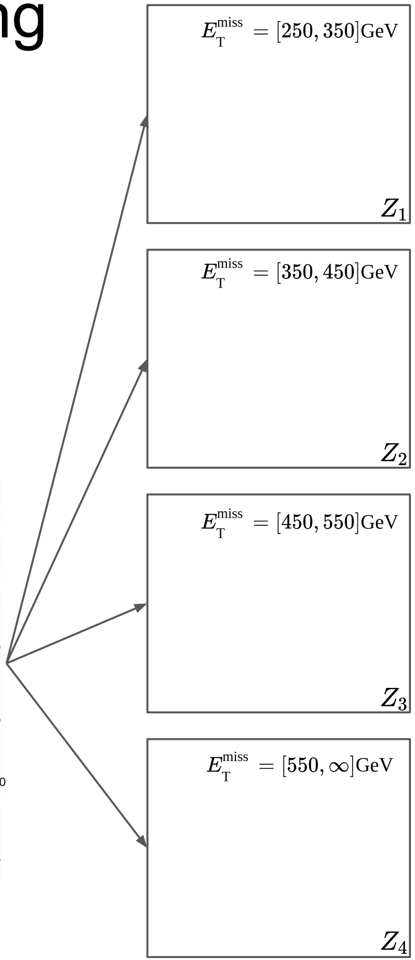


figure: arXiv:1711.11520

<u>To maximize the sensitivity area</u>: Split the variable distribution into different E_T^{miss} slices.





Do the significance (Z_i) scan on these slices.

Combine Z_i's into Z_{comb}

Maximize Z_{comb}

This will protect us from E_T^{miss} dependency of the signal point

Work in progress...

Conclusion

- Re-optimization is necessary to benefit from this increase in data
  - New variables and technique, eg. boosted top tagging
- Framework for re-optimization is demonstrated

Next steps:

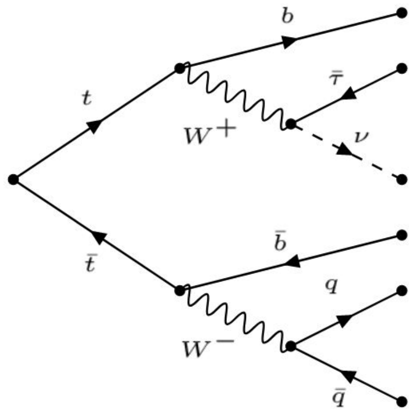
- Investigate slicing in $E_{\mathrm{T}}^{\mathrm{miss}}$ to further improve the significance
- Study how the new Signal Region(s) impact the Control Regions

The very significant increase in data set size (36 fb^{-1}) to now 150 fb-^{1} will allow us to probe a significantly larger part of the parameter space, stay tuned!

BACKUP

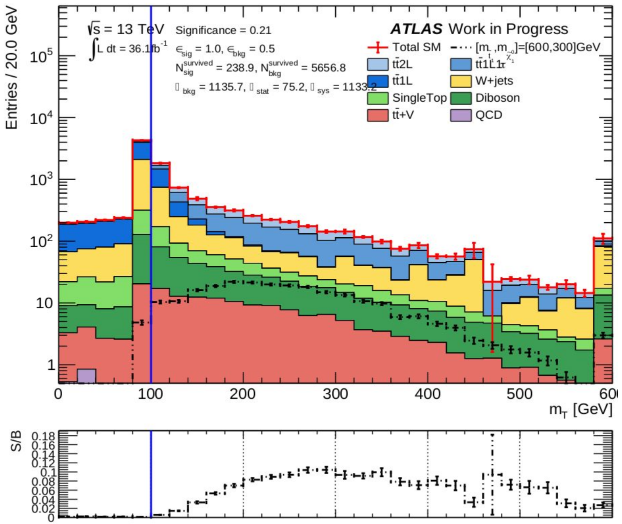
Additional Variables Info

m_{T2}^{tau} targets ttbar events where one of the W bosons decays via hadronic tau.

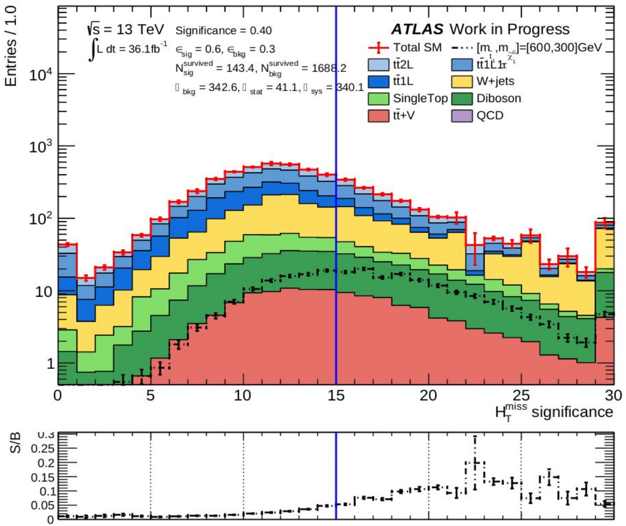


Cut at every iteration, run 36 fb^{-1}

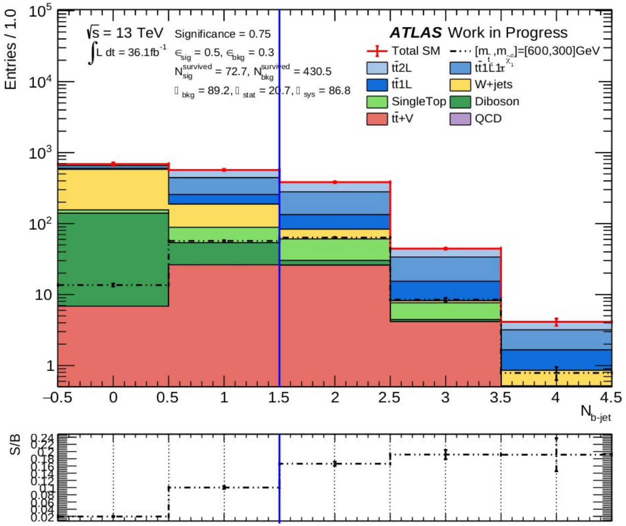
mt_1



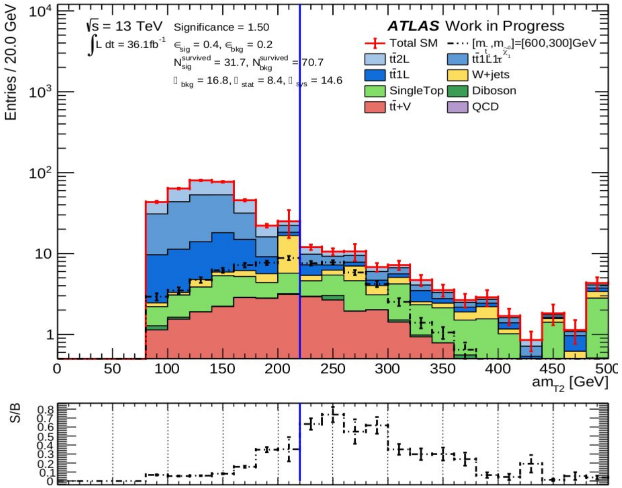
ht_sig_2



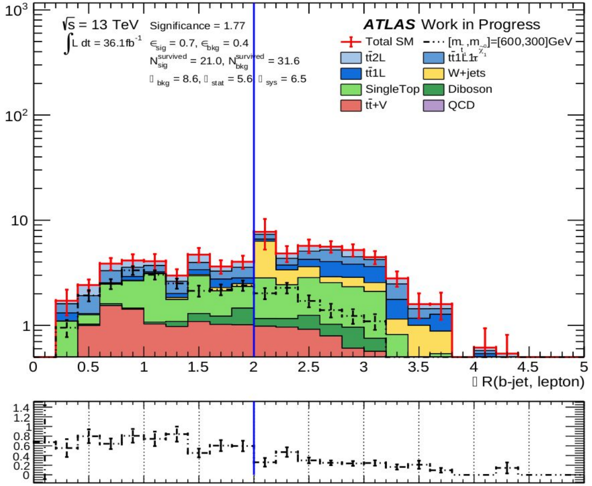
n_bjet_3



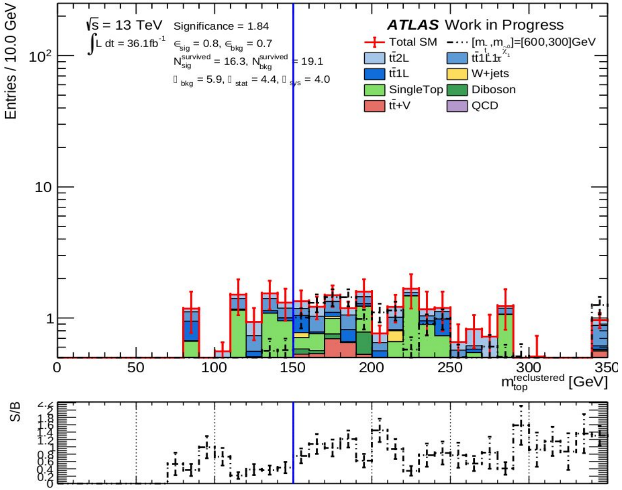
amt2_4



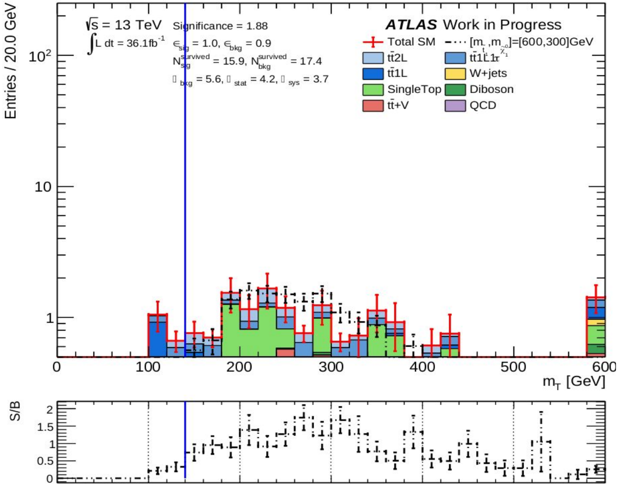
dr_bjet_lep_5



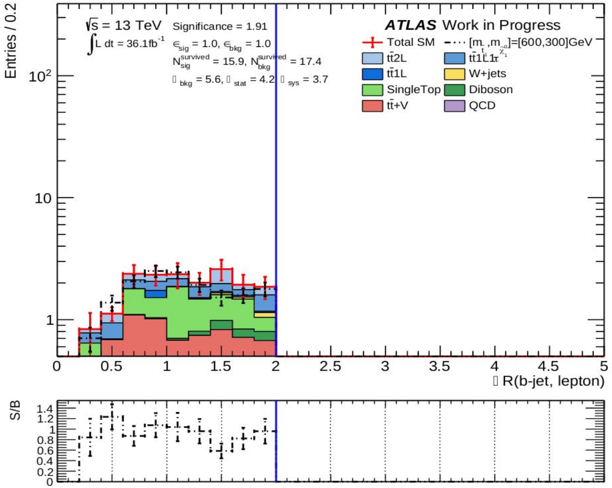
hadtop_cand_m[0]_6



mt_7



dr_bjet_lep_8



dr_bjet_lep_9