Search for the Standard Model Higgs boson in ttH production

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On behalf of the LIP ttH Team

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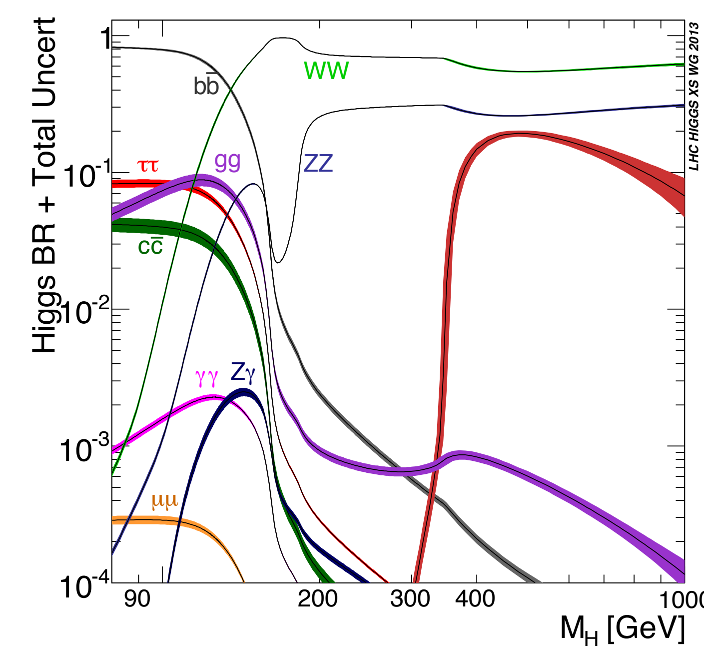
Introduction

Higgs Boson-like particle discovered
at the LHC by both ATLAS and CMS in July 2012!

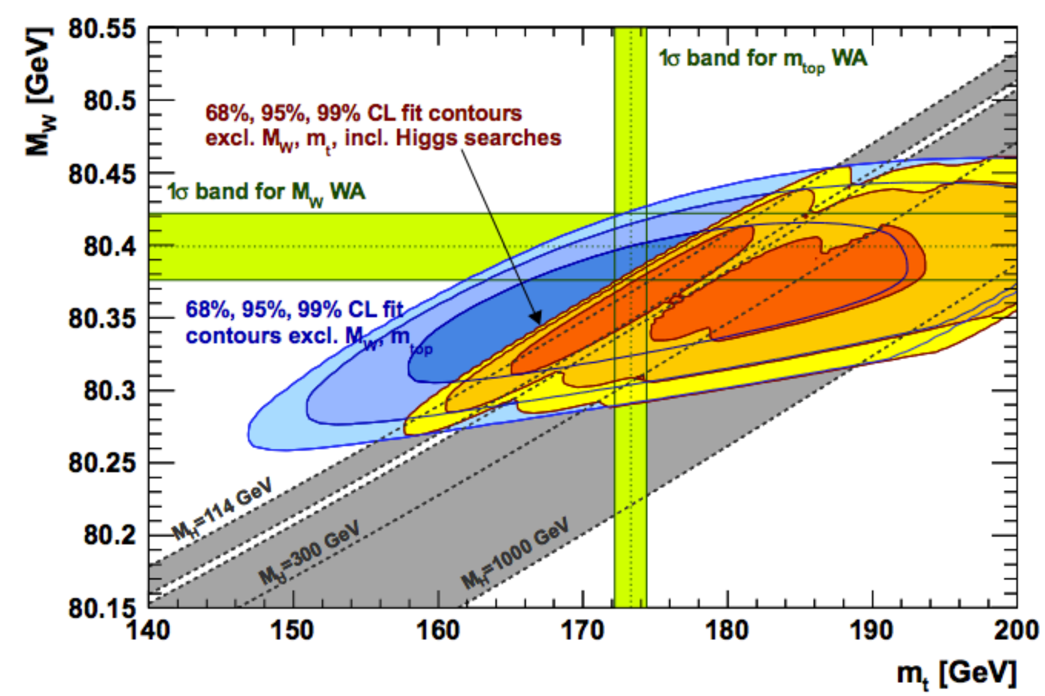
What do we know so far?

- Higgs mass = 125.5±0.6 GeV
- ggH production and H → γγ decays yield indirect evidence of ttH coupling;
- Evidence for fermionic decay modes:
  - ATLAS: H→ττ(4.1 σ)
  - CMS: combination of H → ττ and H → bb (4.0 σ)



Why ttH?

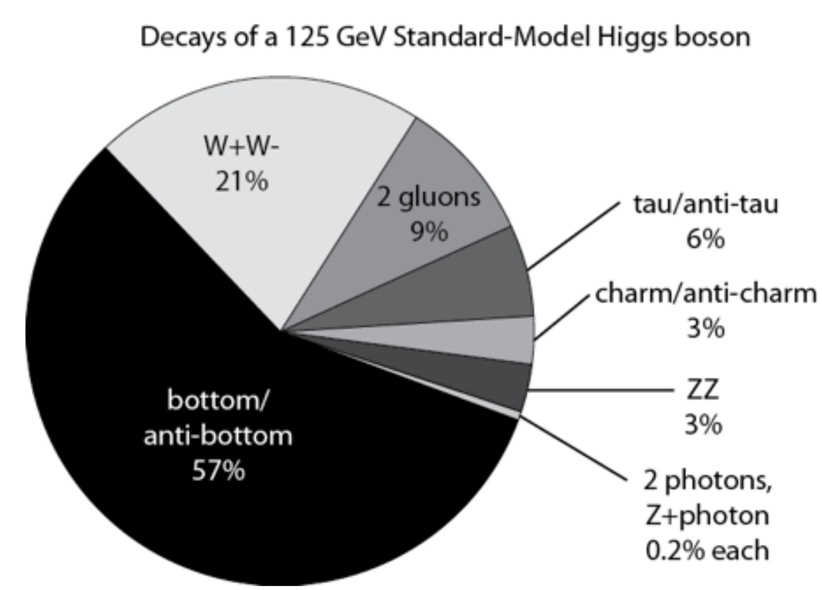
- Top Yukawa coupling to Higgs predicted ~1
- Role evident from M_W-M_t constraints on M_H
- ttH => only production mode directly sensitive to top-Higgs Yukawa coupling: $\sigma_{t\bar{t}H} \propto g^2_{t\bar{t}H}$
- Sensitive to New Physics (via higher-dim. operators)
- Allow to probe New Physics in loop-induced couplings (ggH, Hγγ, HZγ)



ttH Topology & Event Selection

For low M_H, $H \rightarrow bb$ is the dominant decay

Consider Top and W decays:

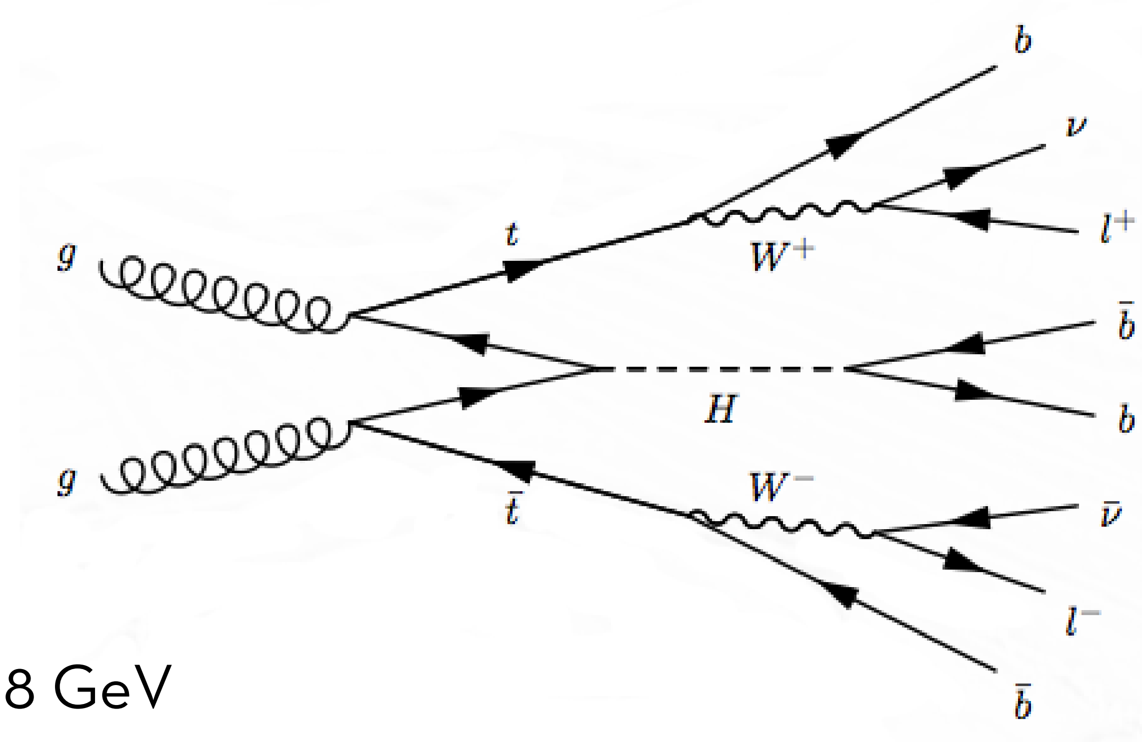


l+jets

- Exactly 1 lepton with $p_T > 25$ GeV & $|\eta| < 2.5$;
- At least 4 jets $p_T > 25$GeV & $|\eta| < 2.5$, with at least 2 b-tagged ones;
- Veto of dilepton events;

Dilepton

- Exactly 2 leptons of opposite charge:
  - leading $e^\pm$: $p_T > 25$GeV & $|\eta| < 2.5$
  - subleading $e^\pm$: $p_T > 15$GeV
  - $\mu^\pm$: $p_T > 25$GeV & $|\eta| < 2.5$
- At least 2 jets, with at least 2 b-tagged ones;
- For $e\mu$: $H_T > 130$ GeV
- For ee & $\mu\mu$: $M_{ll} > 15$ GeV & $|M_{ll} - 91\text{ GeV}| \leq 8$ GeV



B-tagged Jets with 70% efficiency 1% of light-jets mistag rate

Data at $\sqrt{s}$=8TeV recorded in 2012: $\mathcal{L}_{int}$ = 20.3 fb^{-1}

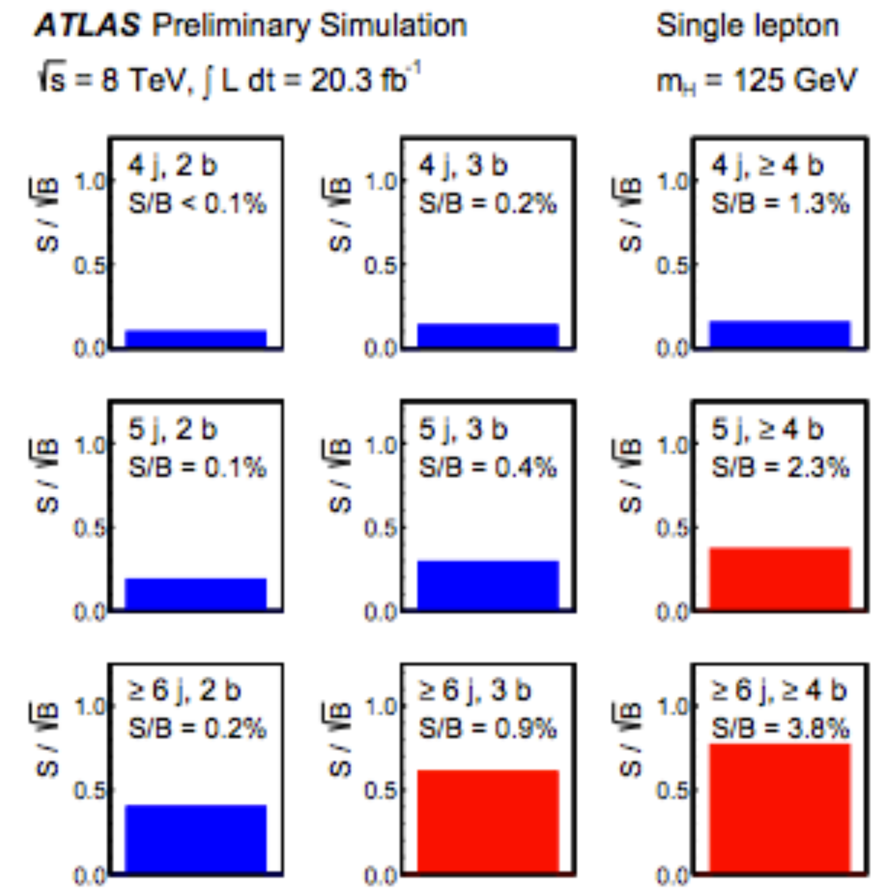
Analysis Strategy

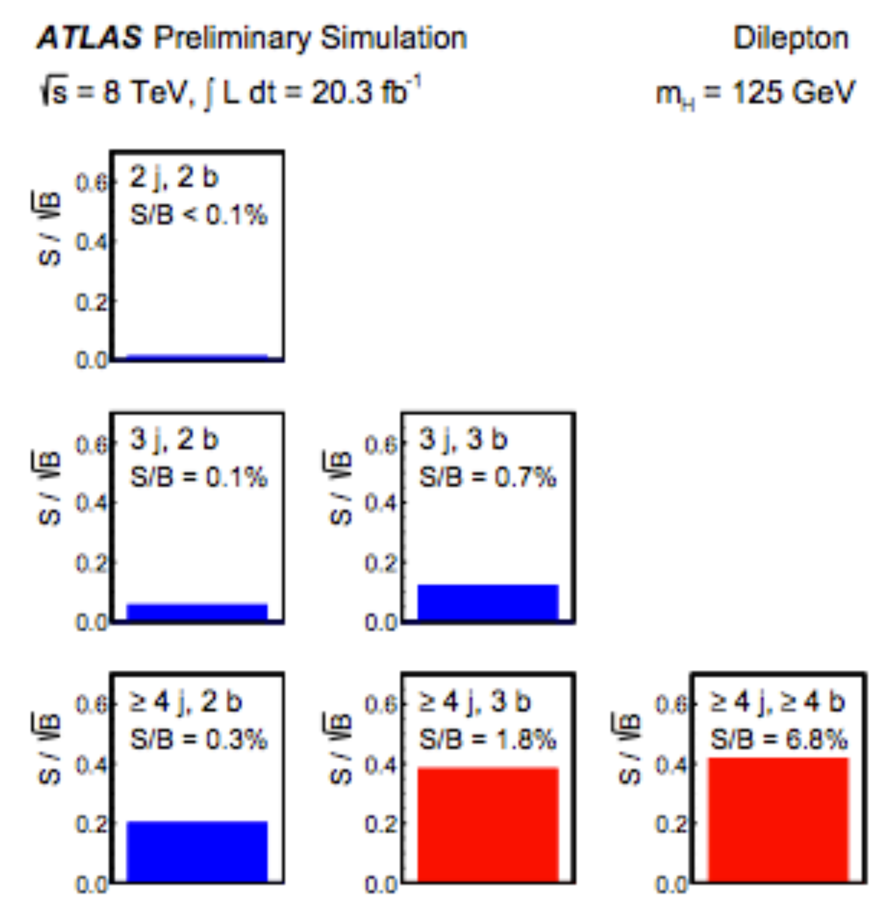
Divide the events according to jet and b-tag multiplicity:

- Improve sensitivity by keeping separate regions with different $S/\sqrt{B}$
- Maximising statistical power
- Signal depleted regions used to control backgrounds normalisation
- Different topologies to control/reduce systematic uncertainties

Choose suitable discriminant variable in each channel

Perform hypothesis testing including in-situ constraining of systematic uncertainties



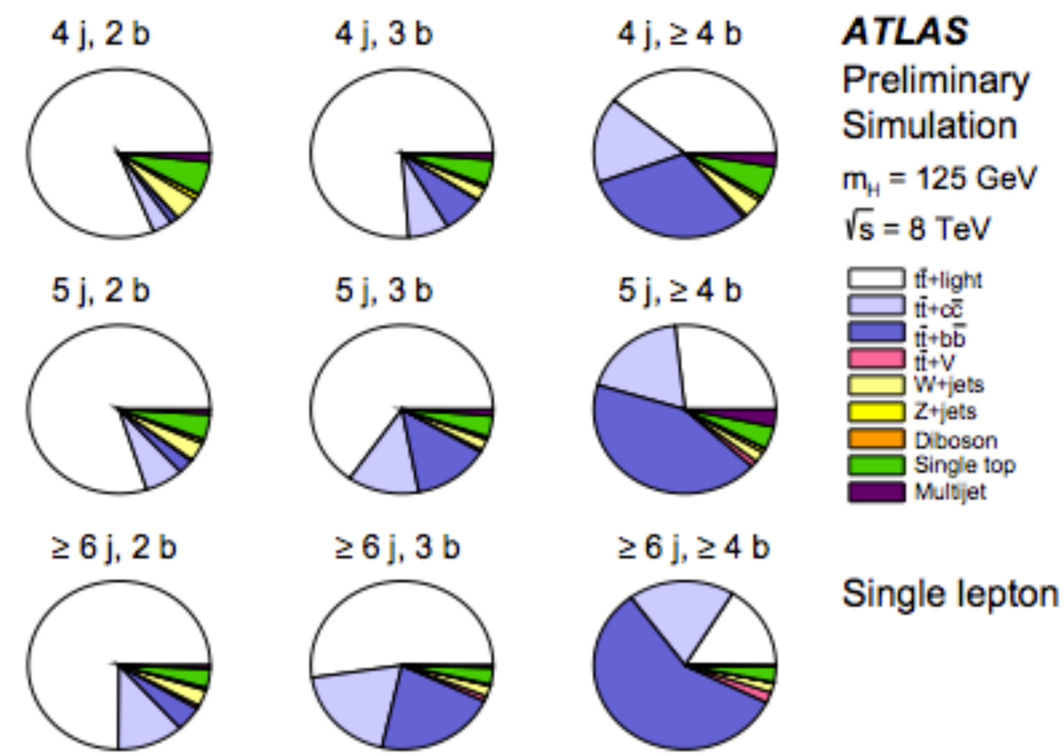


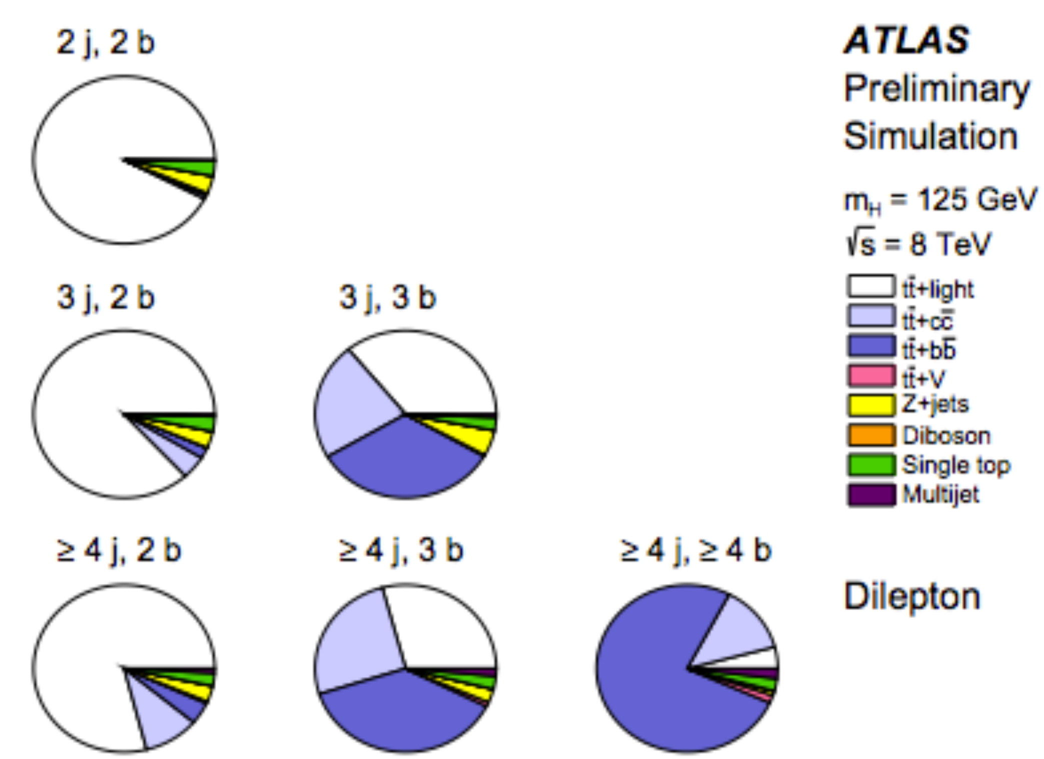
Background Processes

Similar final state topologies that can mimic ttH signal:

- tt+jets: Powheg+Pythia
  =>including tt+HF (same signature as ttH)
- ttZ, ttW: Madgraph+Pythia
- W+jets: Alpgen+Pythia
- Z+jets: Alpgen+Herwig
- Dibosons: Alpgen+Herwig
- Single top: Powheg/AcerMC + Pythia
- Multijet: data driven

Extensive and detailed background studies for better separation of the ttH signal





Analysis Method

Divide the events according to nJets/nTag simultaneous template fit to multiple regions:

l+jets	2 b-tags	3 b-tags	>= 4 b-tags
4 jets	H_T^{had}	H_T^{had}	H_T^{had}
5 jets	H_T^{had}	NN	NN
>=6 jets	H_T^{had}	NN	NN

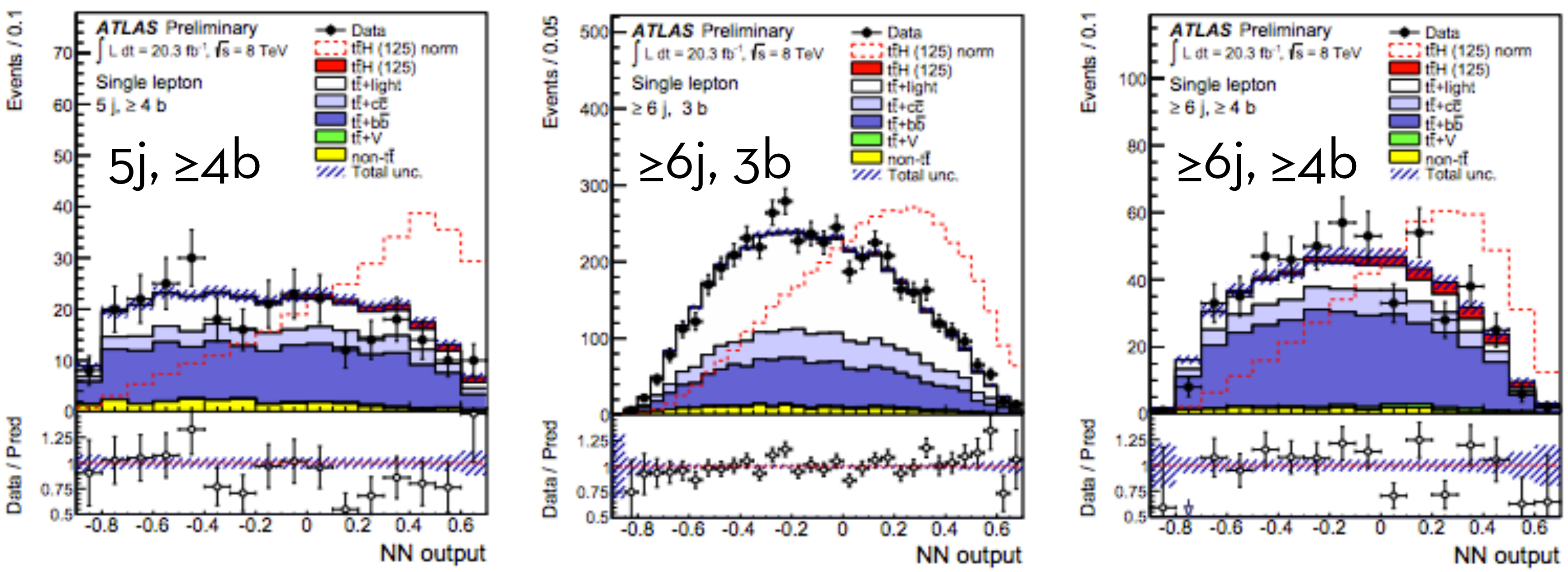
dilepton	2 b-tags	3 b-tags	>= 4 b-tags
2 jets	H_T		
3 jets	H_T	NN	
>=4 jets	H_T	NN	NN

Different discriminants used in various regions:

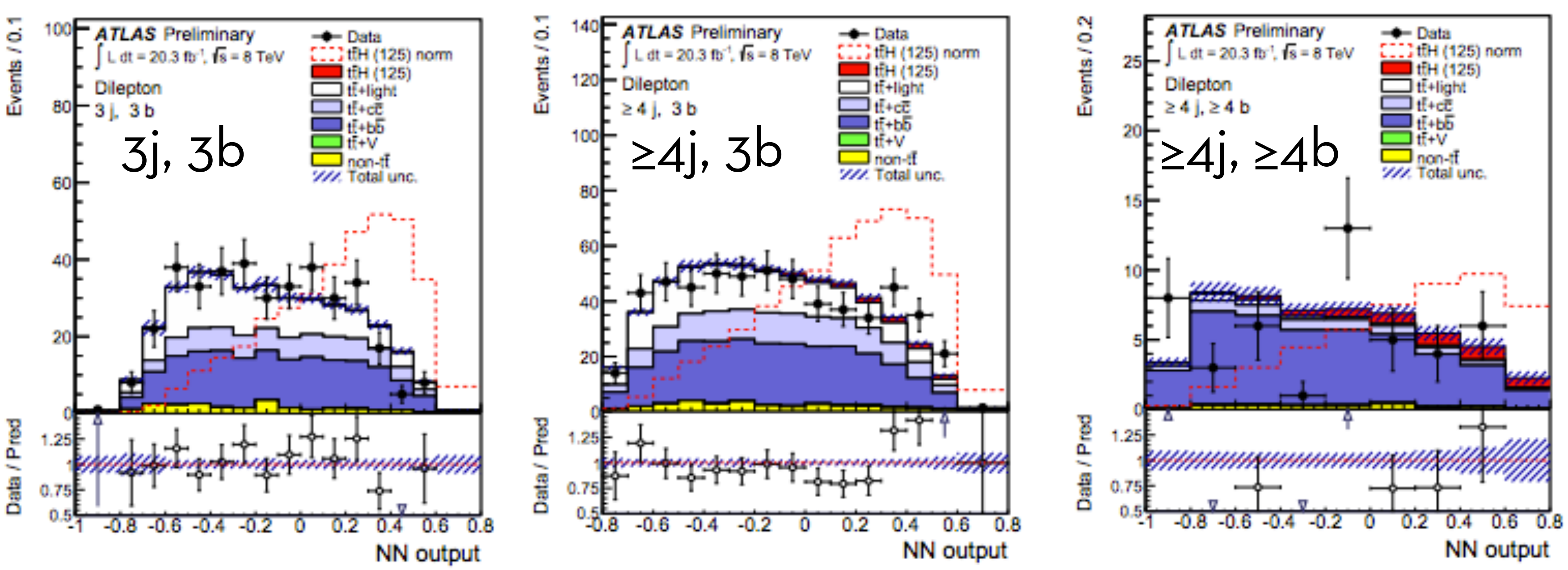
- Background regions - using as unique analysis variable:
  H_T^{had} = scalar sum of jets P_T (l+jets)
  H_T = scalar sum of jets and leptons P_T (dilepton)
- l+jets, 5 jets, 3 b-tags region - train a NN tt+bb & tt+cc versus tt+light jets and use its output as discriminant variable
- Signal regions - using multivariate discriminants for signal extraction: train a NN ttH versus ttbar in each of the regions and use its output as discriminant variable

NN Outputs in Signal Regions

l+jets



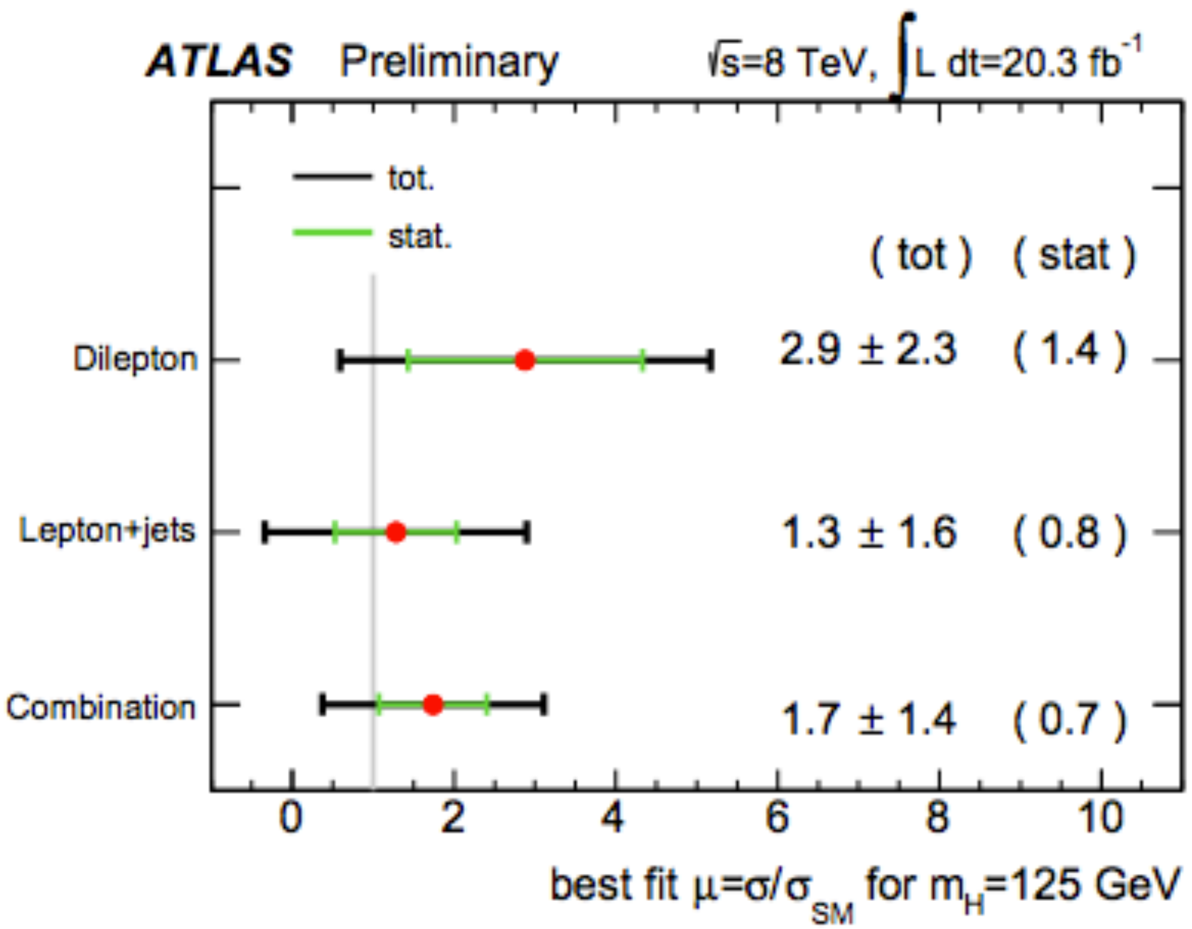
dilepton

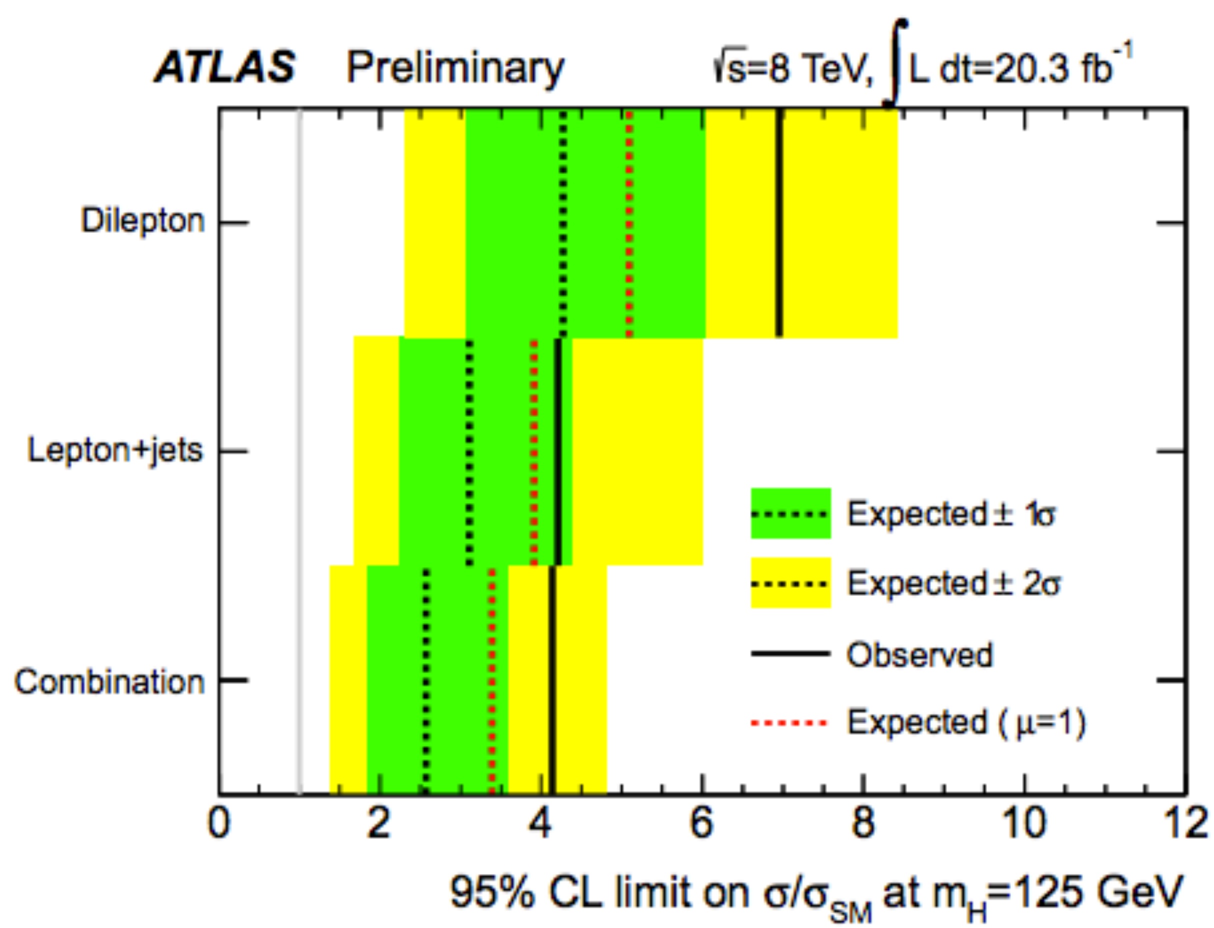


- l+jets and dilepton fits consistent with each other
- Fit reduces background uncertainty by a factor ~5-6 in most sensitive channels
- Results here coming from combined S+B fit

Results

95% CL upper limit on σ/σ_{SM}	observed	-2 σ	-1 σ	median	+1 σ	+2 σ	median ($\mu = 1$)
Single Lepton	4.2	1.7	2.2	3.1	4.4	6.0	3.9
Dilepton	7.0	2.3	3.1	4.3	6.1	8.4	5.1
Combination	4.1	1.4	1.9	2.6	3.6	5.0	3.4





talk at moriond yesterday

Conclusions

- A search was performed for Higgs boson produced is association with a top quark pair

- Most sensitive ttH, H→bb result at the LHC:

  Observed limit: 4.1 x SM
  Expected limit: 2.6 x SM

  Best fit μ =1.7±1.4

CMS @ 8 TeV combination of l+jets, dilepton and τ channels:
obs (exp) = 5.2 (4.1) @ mH=125GeV CMS-PAS-HIG-13-019

- Most sensitive ttH search in ATLAS for the moment:

  ttH, H→γγ: obs(exp)=4.7(5.4) @mH=126.8GeV ATLAS-CONF-2013-080

- Further improvements expected as the analysis moves to publication in the near future

ttH Work & Plans at LIP

- One year to prepare run-II analyses
- FCT-funded exploratory project to develop ttH studies:
  - Building up the team – hiring 1 new postdoc + 1 master student
  - International team involving theorists and ATLAS experimentalists
  - Local team involves LIP-Lisbon + Coimbra + Minho
  - In sync with local expertise in Higgs, top and jets
- Project aims:
  - Search for novel variables to discriminate background
  - Explore reconstruction methods – reduce combinatorial background
  - Exploit ttH potential for measuring Higgs properties and bring new knowledge on the Higgs sector:
    e.g. CP sensitivity complementary to H->ZZ
- Ongoing work:
  - Focusing on dilepton ttH, H->bb
  - Data-driven studies of Z+jets background for ttH analysis
  - Improving analysis software
  - Studies of jet reconstruction
- Building up know-how in local team - aiming for run II analysis

Thanks!

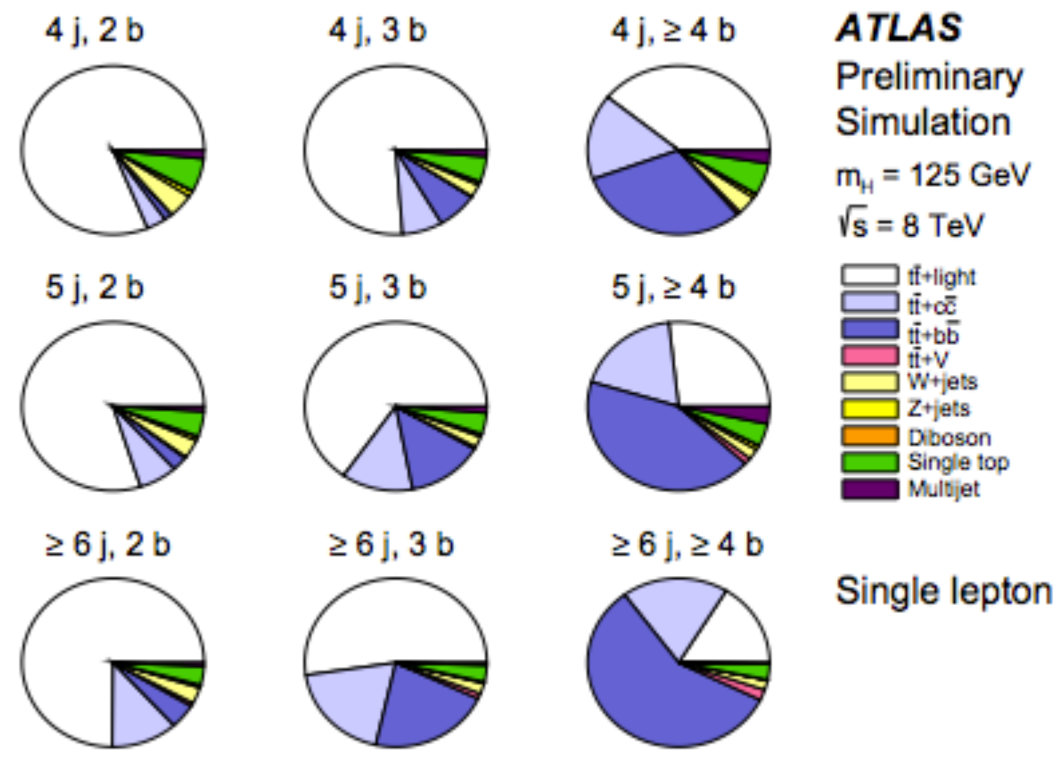
Backup Slides

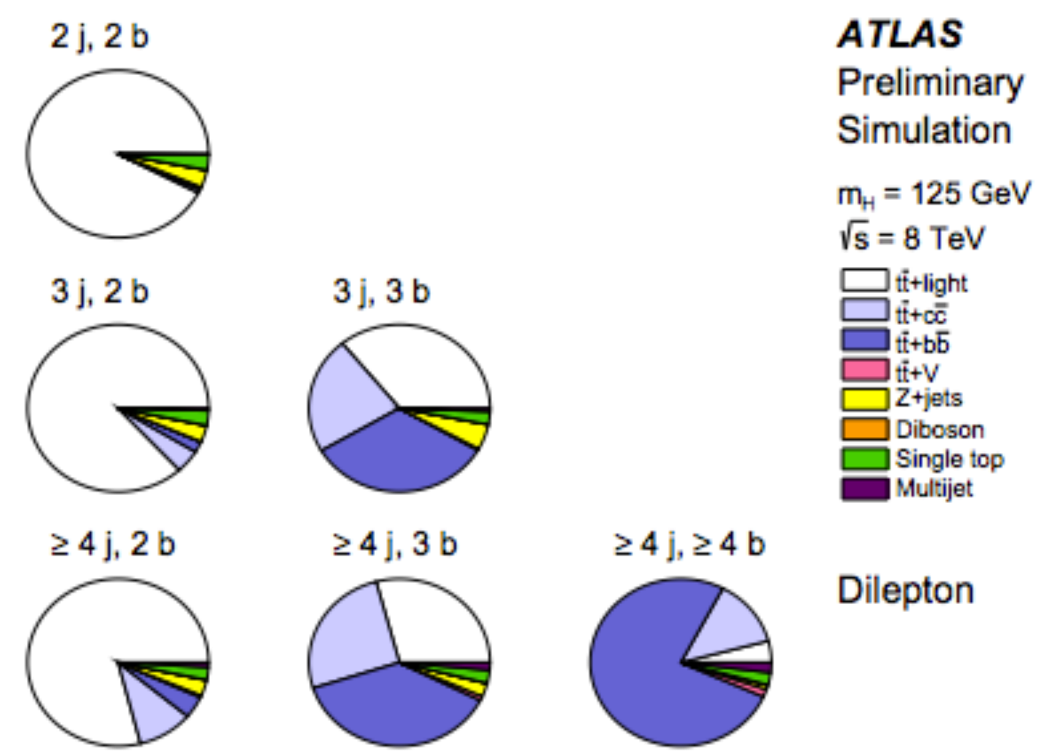
Background Processes

Extensive and detailed background studies for better separation of the ttH signal:

- Main Background tt+jets:
  - top pT and tt pair pT improved by correcting MC to match dedicated measurement @ √s=7TeV (ATLAS-CONF-2013-099)
  - Modelling of tt+HF jets (normalisation & kinematics), comparable to dedicated ME-PS MCs such as Madgraph.
  - Rate of tt+bb and tt+cc calibrated to data using background-enriched bins in signal regions.

- Z+jets data driven: ZpT spectrum & HF component





Multivariate Discriminants: NN

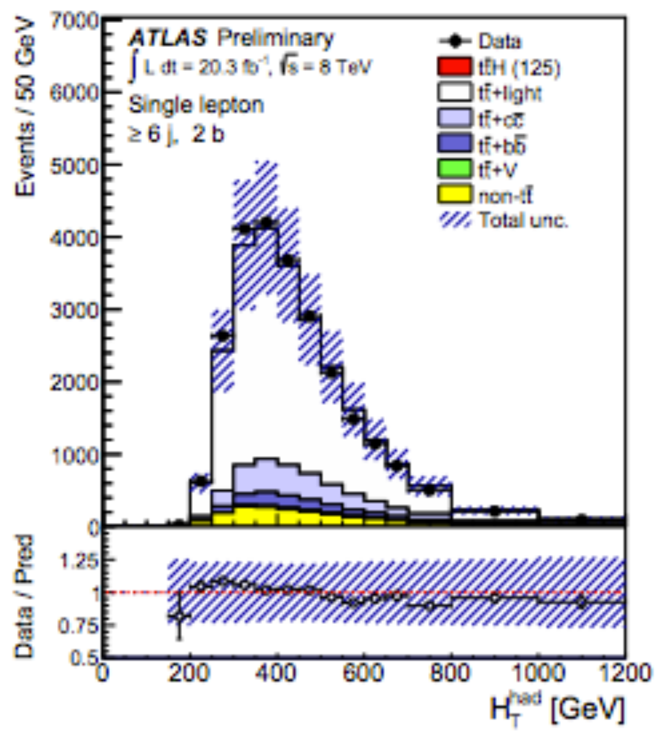
NN is used to discriminate signal from the background in the topologies with significant expected ttH signal contribution

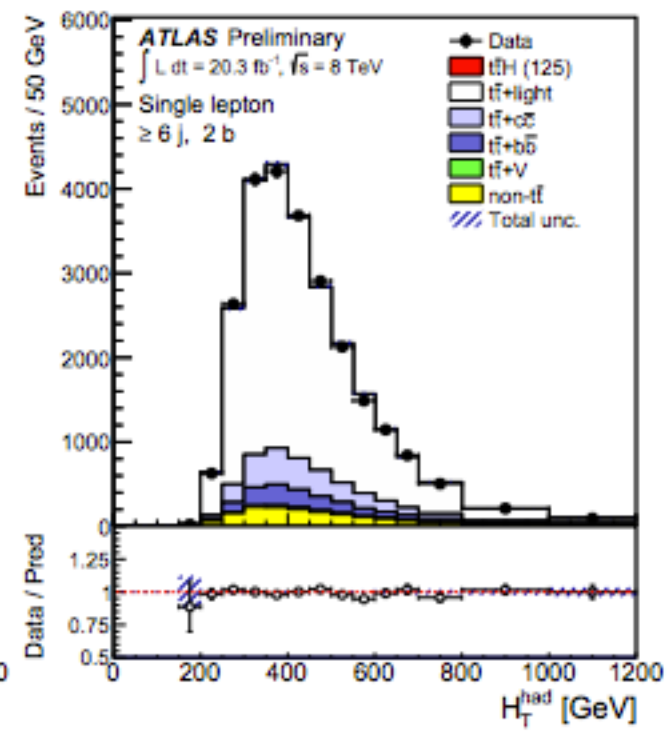
Variables considered:

- object kinematics: pT and η of the lepton and each jet
- global event variables: H_T^{had}, M_{eff}, $N^{jets}_{pT>40GeV}$, E_T^{miss}
- event shape variables: the centrality and the Fox-Wolfram moments
- object pair properties: pT^{bb}, $M_{bb}^{min\Delta R}$, ΔR_{bb}^{avg} of the jet pair with the largest vectorial sum pT, the largest invariant mass or the smallest ΔR

H_T Pre- and Post-fit Distributions

l+jets





dilepton