Search for charged Higgs bosons in $H^+ \to Wh$ decays with the ATLAS detector

Simon Grewe

86. DPG-Frühjahrstagung Dresden

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grewe@mpp.mpg.de

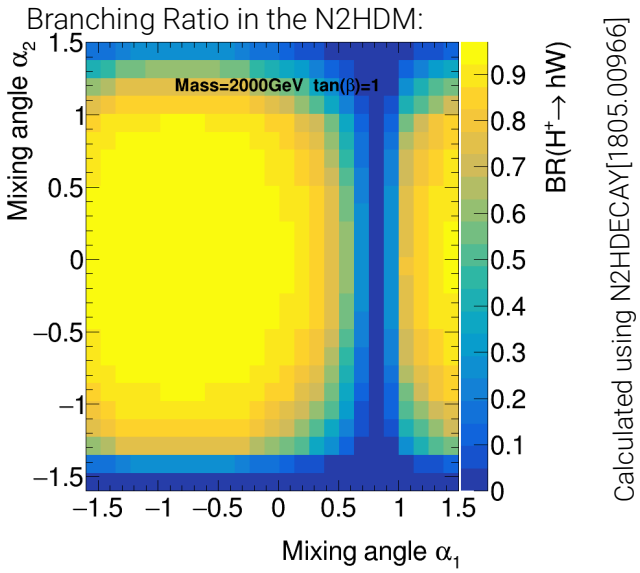
ATLAS EXPERIMENT

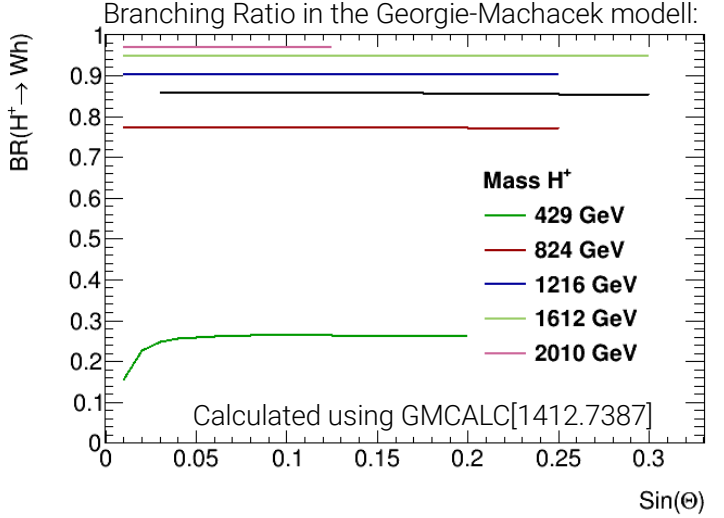
FSP ATLAS
Erforschung von Universum und Materie

MAX-PLANCK-INSTITUT FÜR PHYSIK

Motivation

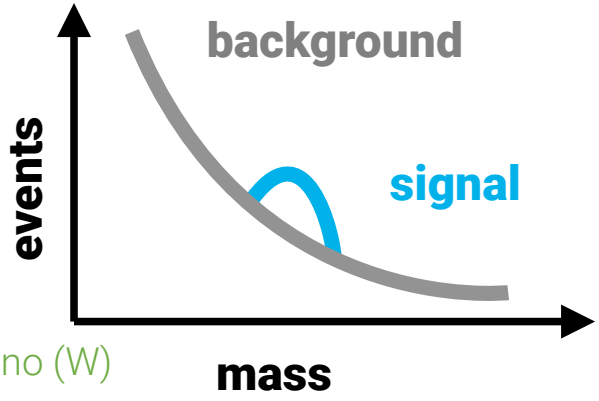
- Many extensions of the SM extend the Higgs sector and predict charged scalars H^+
- The decay $H^+ \rightarrow Wh$ (h is the 125 GeV Higgs boson) is so far not covered at the LHC
  - Previous searches focused on $H^+ \rightarrow tb$ and $H^+ \rightarrow \tau\nu$
- $H^+ \rightarrow Wh$ is the dominant decay in certain models:
  - 2-Higgs-Doublet-Model
  - Next-to-2Higgs-Doublet Model
  - Georgi-Machacek Model
  - 3HDM

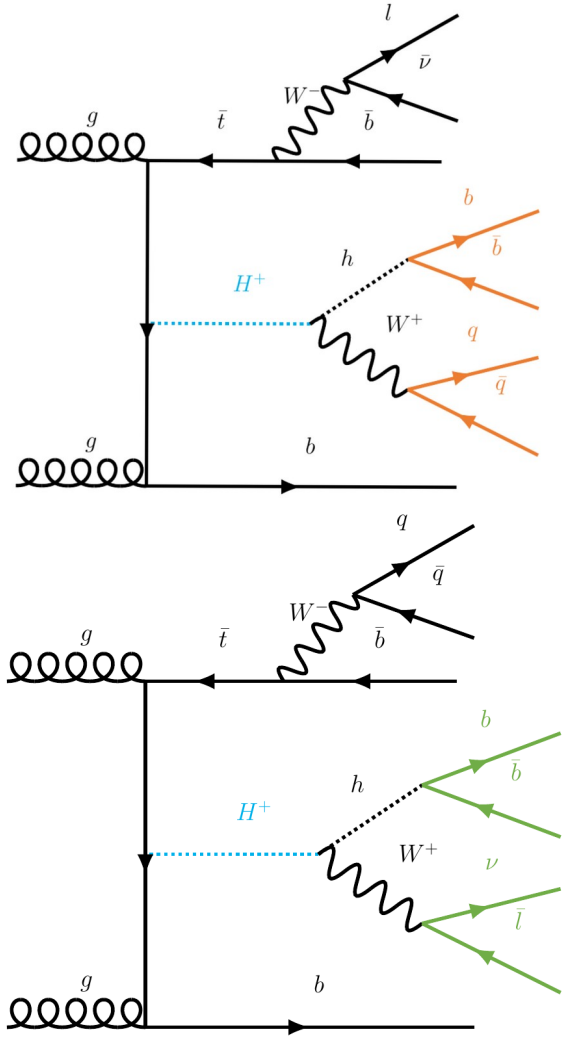




Analysis strategy

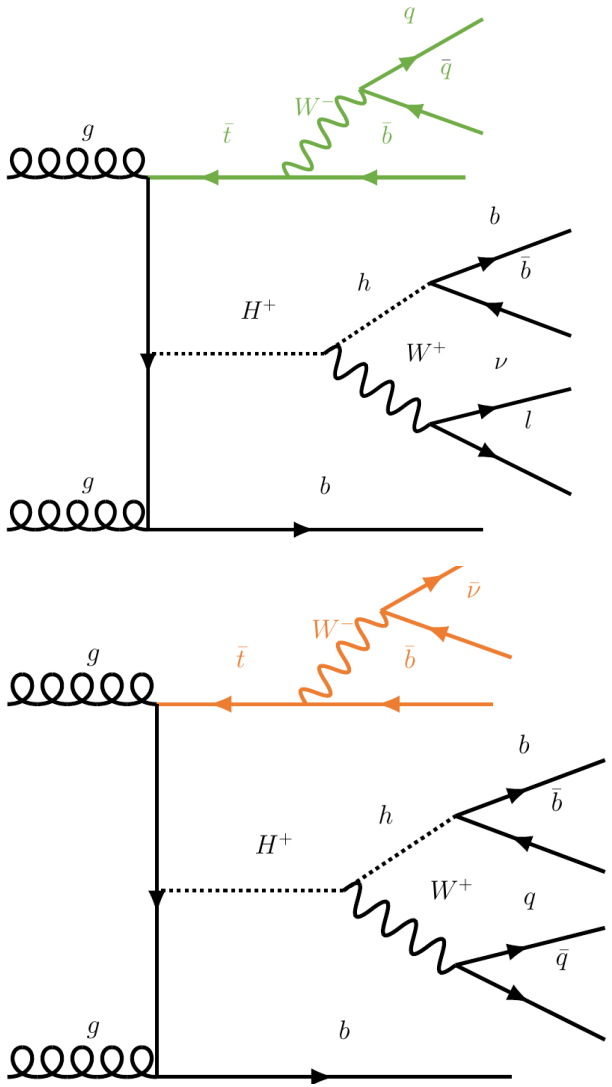
- Reconstruct H^+ out of the final state
  - Search for an excess of events in inv. mass spectrum („Bump-Hunt“)
- H^+ is produced in association with a top and bottom quark
- Final state with:
  - 1 charged lepton
  - 6 or more jets
  - 4 b-tagged jets
  - Missing transverse momentum
- Reconstruct H^+ out of:
  - $H^+ \rightarrow$ lvbb: 2 jets (Higgs)+ lepton and neutrino (W)
  - $H^+ \rightarrow$ qqbb: 2 jets (Higgs)+ 2 Jets (W)
- Challenges:
  - Distinguish the 2 decay modes (identical final state)
  - reconstruct H^+ from this complicated final state





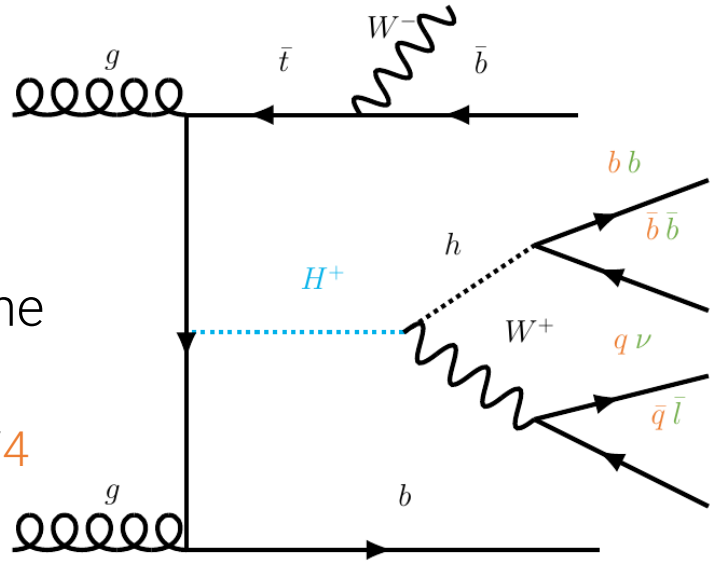
Signal classification

- A method to distinguish the $H^+ \rightarrow qqbb$ & $H^+ \rightarrow lvbb$ decays is needed
- Reconstruct a leptonically decaying top-quark ($t \rightarrow lvb$)
  - Reconstruct from lepton + neutrino +b-jet
- If a leptonically decaying top-quark can be reconstructed successfully classify event as: $H^+ \rightarrow qqbb$
  - Else classify as event as $H^+ \rightarrow lvbb$

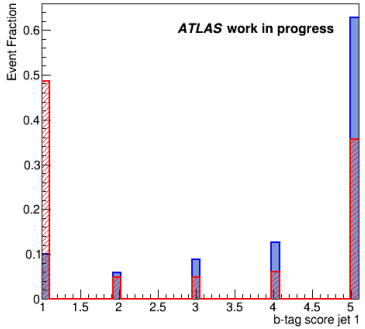


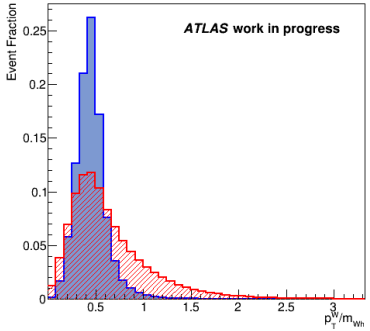
Signal reconstruction

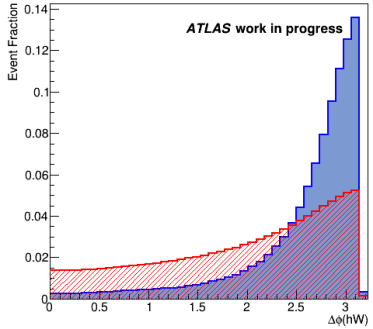
- Reconstruct H^+ out of the final state
  - reconstruct W^+ out of a Lepton & E_T^{miss}/ 2 Jets
  - reconstruct h out of 2 Jets
- Train a BDT for each decay channel to reconstruct the H^+
  - Signal: correct combination 2 Jets+ Lepton & E_T^{miss} /4 Jets stemming from H^+ decay
  - Combinatorial background: all other combination

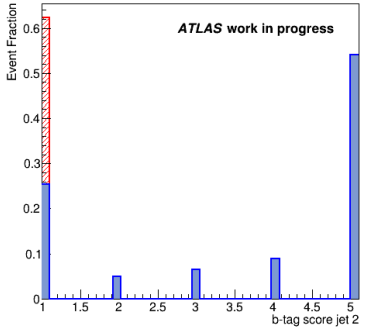


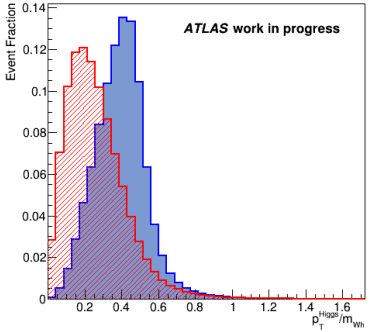
Input variable used in the training of the lvbb BDT

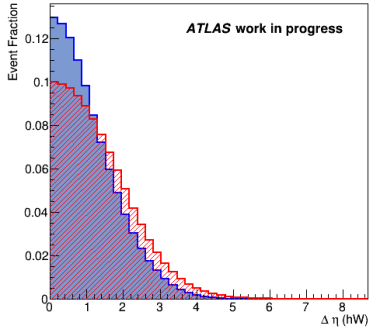


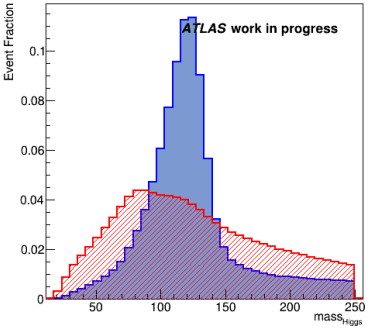


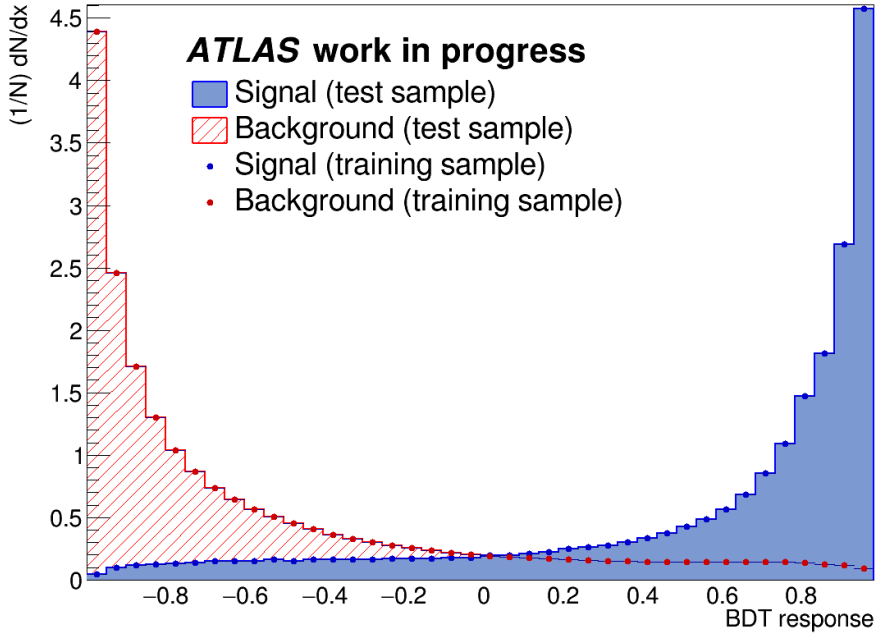








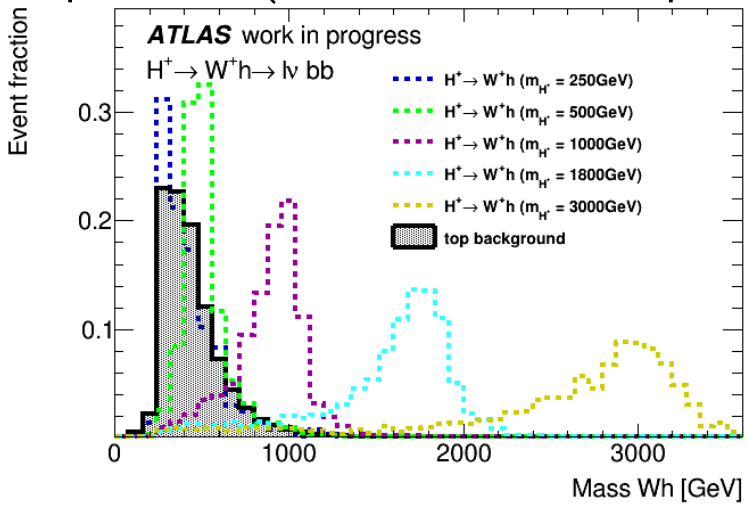


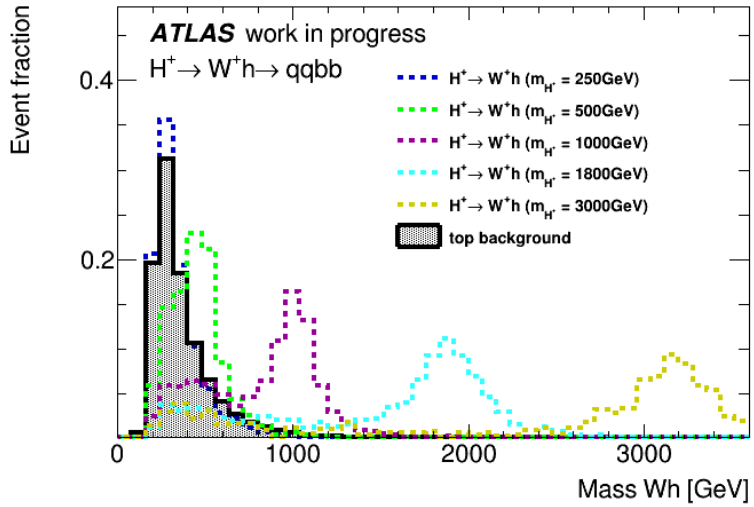


The response of the trained BDT to signal and combinatorial background (on the example of the lvbb BDT)

BDT application

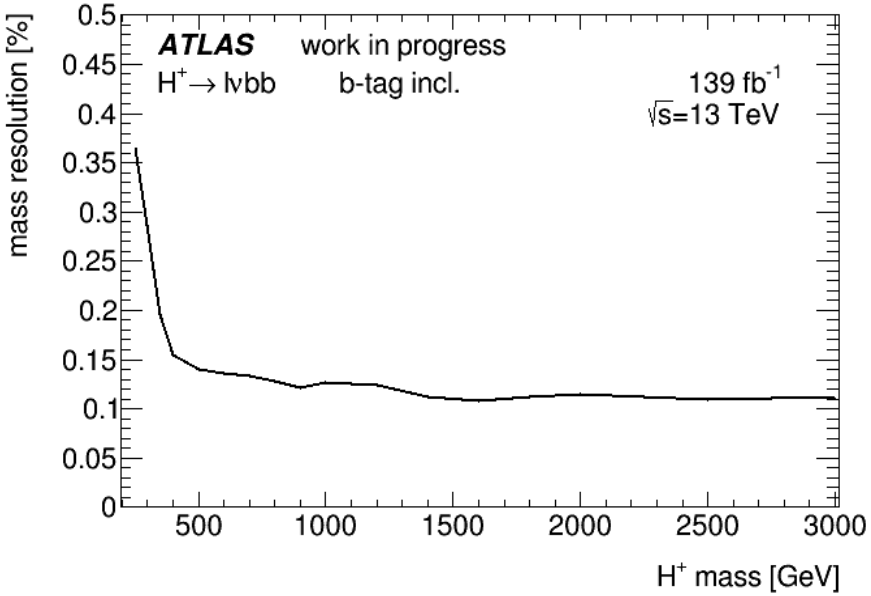
- Evaluate the BDT for all possible lvjj/jjjj combinations in the event
- Choose the $H^+ \rightarrow$ lvbb/qqbb candidate with the highest BDT response (max BDT Response) as H^+

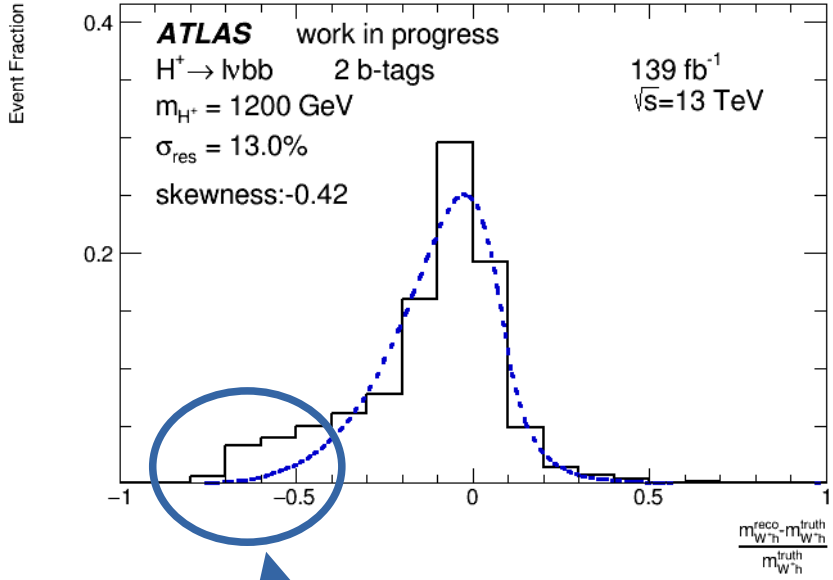




H^+ mass resolution

- Calculate: $\frac{m^{reco}_{W^+h} - m^{truth}_{W^+h}}{m^{truth}_{W^+h}}$
- Fit an asymetric *Bukin*-funktion to the distributions
- Take the variance as the mass-resolution
- Large tails stem from wrongly classified events

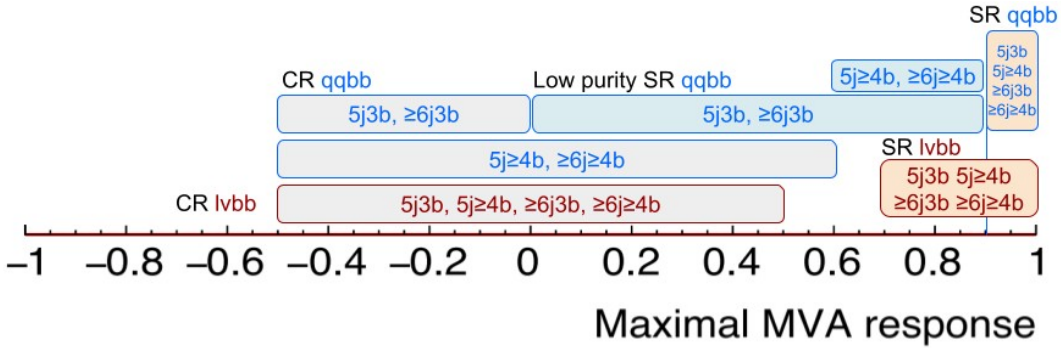


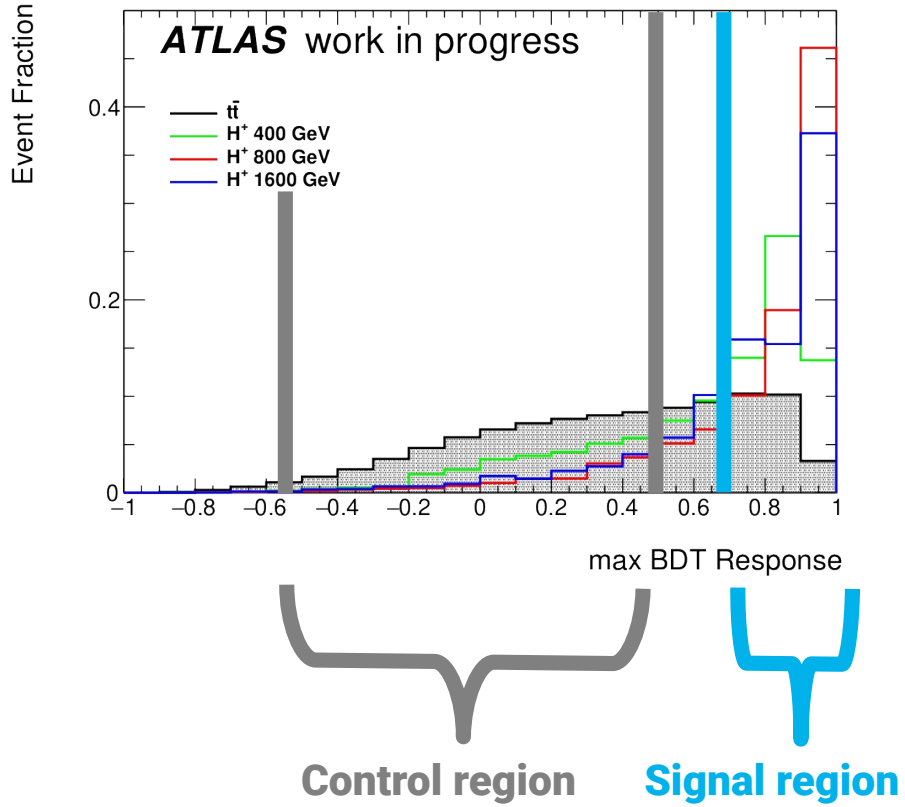


missclassified qqbb events

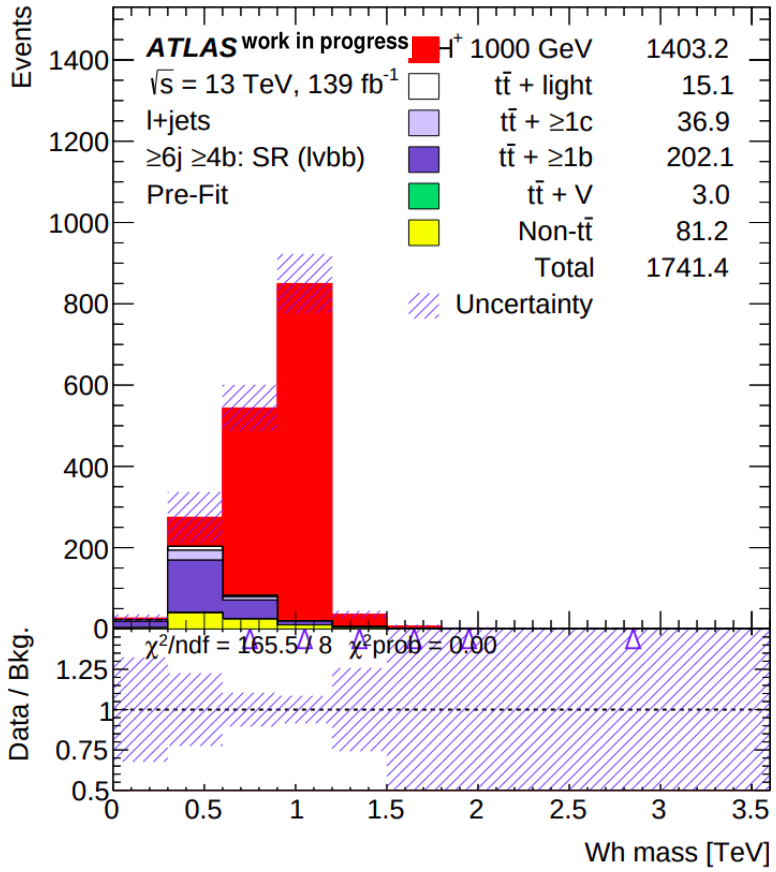
Signal and control regions

- Split the regions by the jet and b-jet multiplicities
- The *max BDT Response* distribution is distinct between signal and background
  - Top quark pairs are the dominant background process
- Define signal and control regions by cuts on the *max BDT Response variable*
  - maximise/minimize $s/\sqrt{b}$



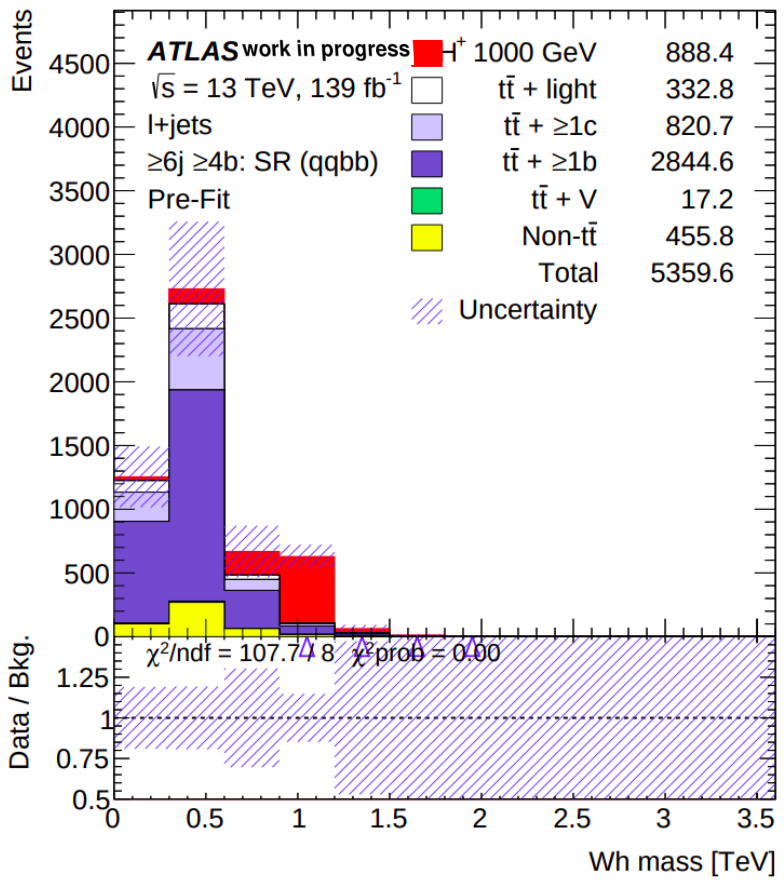


Signal region m_{wh} distributions

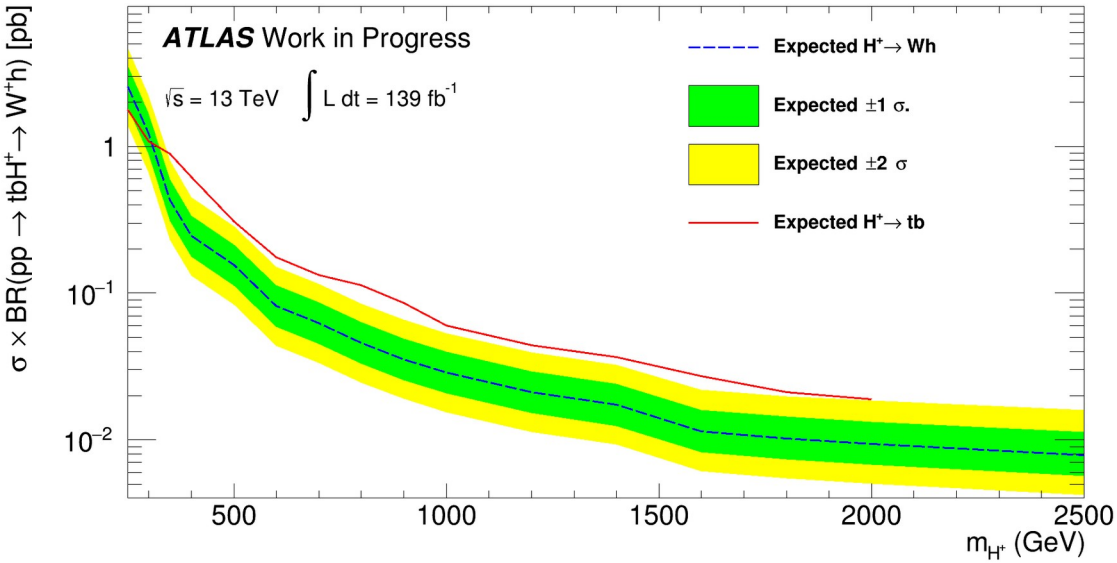


tt is the dominant background

lvbb channel has higher sensitivity (larger s/b)



Limits on σ(pp→ tbH⁺)x BR(H⁺→ Wh)



- Signal regions are still b*linded*
- *Maximum Likelihood Fit* on the reconstructed H⁺ mass spectrum
- Fit the signal strength μ and the tt normalisation factor
  - Fit all regions simultaneously
  - All systematic and statistical uncertainties are taken into account
- Expected limits are stronger compared to ATLAS H⁺ → tb search [2102.10076]
  - Same final state is analyzed
  - Similar background contributions

Conclusion

- $H^+ \rightarrow Wh$ is studied for the first time at the LHC
  - H^+ is produced in association with a top- and bottom-quark
- A complete analysis strategy for the $H^+ \rightarrow Wh$ search was developed
  - The mass of a reconstructed top quark is used to distinguish the $H^+ \rightarrow l\nu bb$ and $H^+ \rightarrow qqbb$ decay channels
  - Boosted Decision Trees are used to reconstruct the $H^+ \rightarrow Wh$ decay out of a complicated final state
  - The preliminary expected limits are comparable with existing H^+ searches