



PhD Thesis – 30 Month Report

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Introduction

- Over the last year: Mostly focused on the 0L channel of the analysis

1) Introduction 2HDM + a

2) Overview over status of the analysis

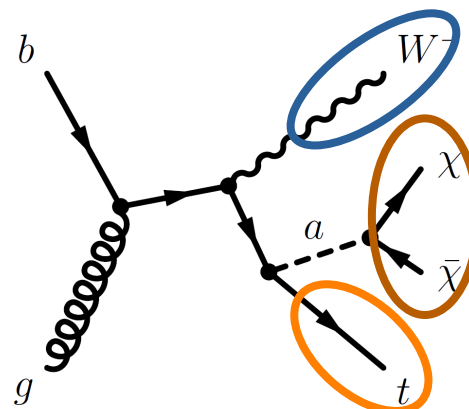
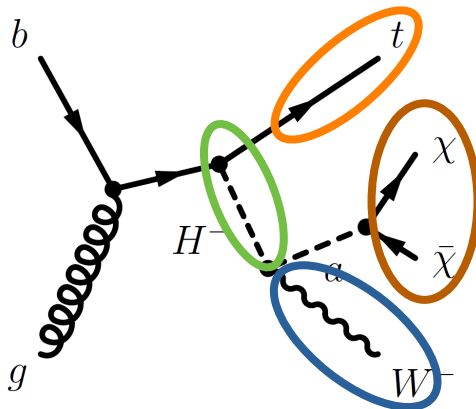
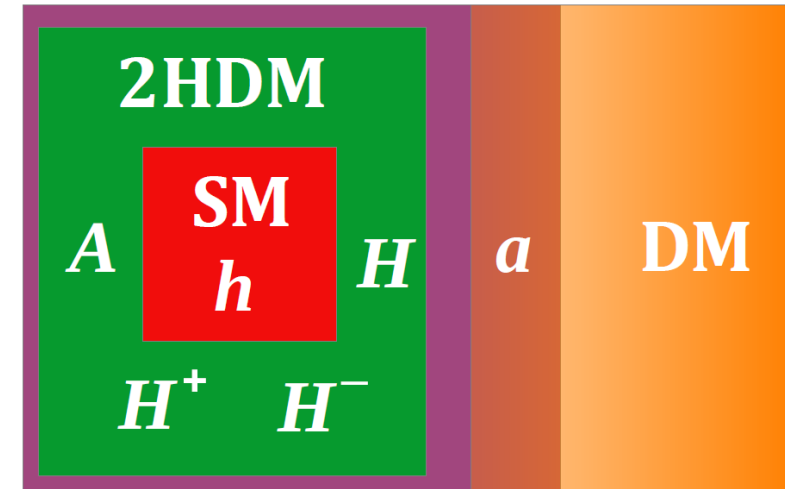
- Definition of the signal region
- Control/Validation regions
- Current status of the analysis

3) Milestones over the last year

4) Outlook

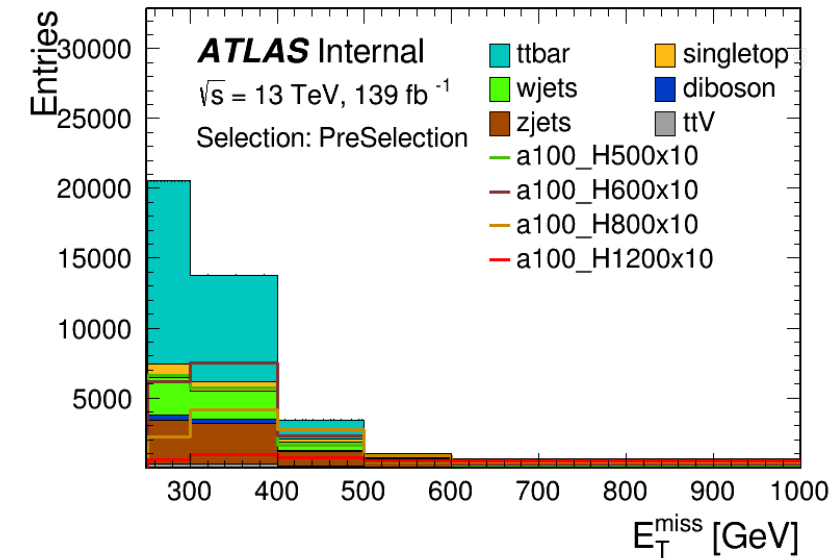
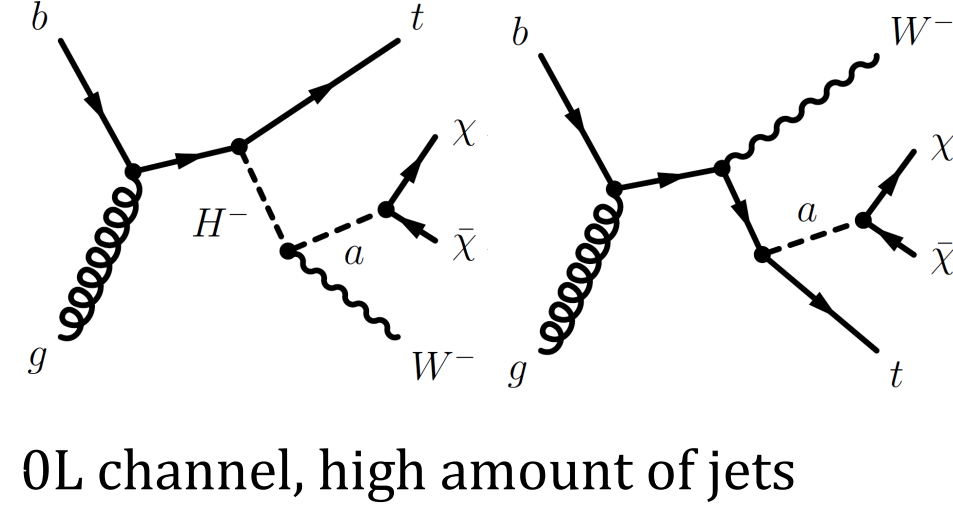
Introduction – 2HDM+a

- Basis of the analysis: 2 Higgs doublet model (2HDM)
 - Second Higgs doublet → Total of 5 Higgs bosons
- Add mediator a → Coupling to Dark Matter and 2HDM
- One new process recently explored:
(<https://arxiv.org/pdf/1712.03874.pdf>):
 - DM (MET) + top quark + W-boson
- Contribution from two main diagrams:
 - With and without charged H-boson



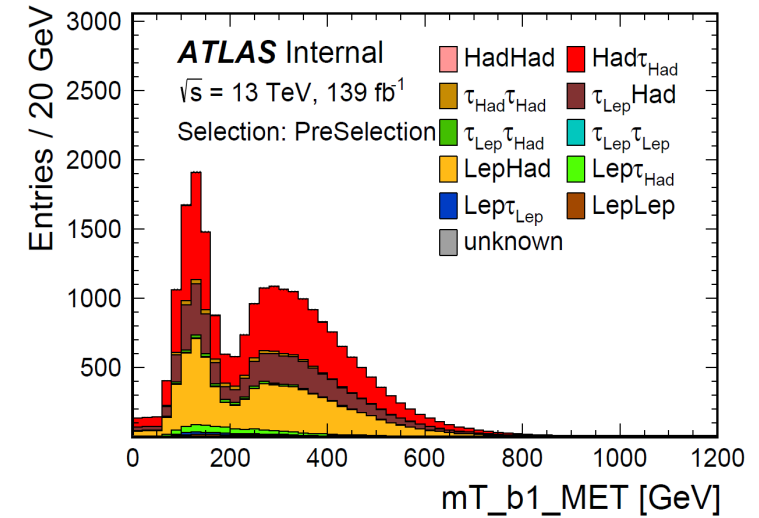
Preselection

- Most important Preselection definitions:
 - $\text{MET} > 250 \text{ GeV} \rightarrow$ High missing transverse through Dark Matter
 \rightarrow Also used to trigger events
 - $n_{\text{lep}(p_T > 4 \text{ GeV})} = 0$
 - $n_{\text{jet}(p_T > 20 \text{ GeV})} \geq 4$
 - $p_T^{\text{jet}1} \geq 100 \text{ GeV}, p_T^{\text{jet}2, \text{jet}3} \geq 60 \text{ GeV}, p_T^{\text{jet}4} \geq 40 \text{ GeV}$
 - $n_{\text{bjet}(p_T > 20 \text{ GeV})} \geq 1$
 - $p_T^{\text{bjet}1} \geq 50 \text{ GeV}, p_T^{\text{bjet}2} < 50 \text{ GeV} \rightarrow$ Reduce $t\bar{t}$ bkg
 - $\Delta\phi_{\text{jet}, \text{MET}}^{\text{min}, 4} > 0.5 \rightarrow$ Reduce QCD background
- Most dominant backgrounds:
 - $t\bar{t}$
 - z +jets
 - w +jets



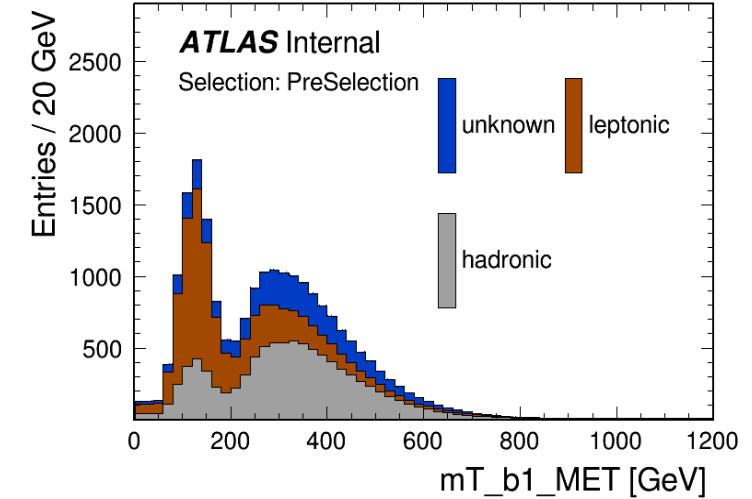
Observables in the SR – Transverse Mass

- Most dominant background: $t\bar{t}$
→ Major contribution is semi-leptonic $t\bar{t}$ with one lepton missed in the detector



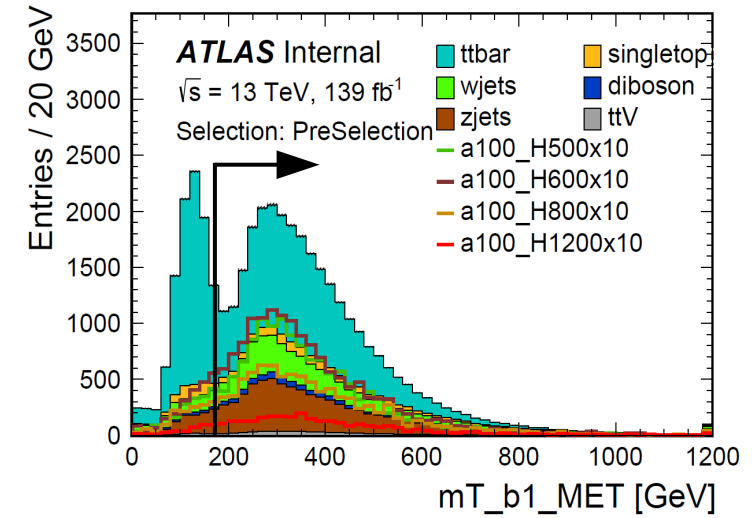
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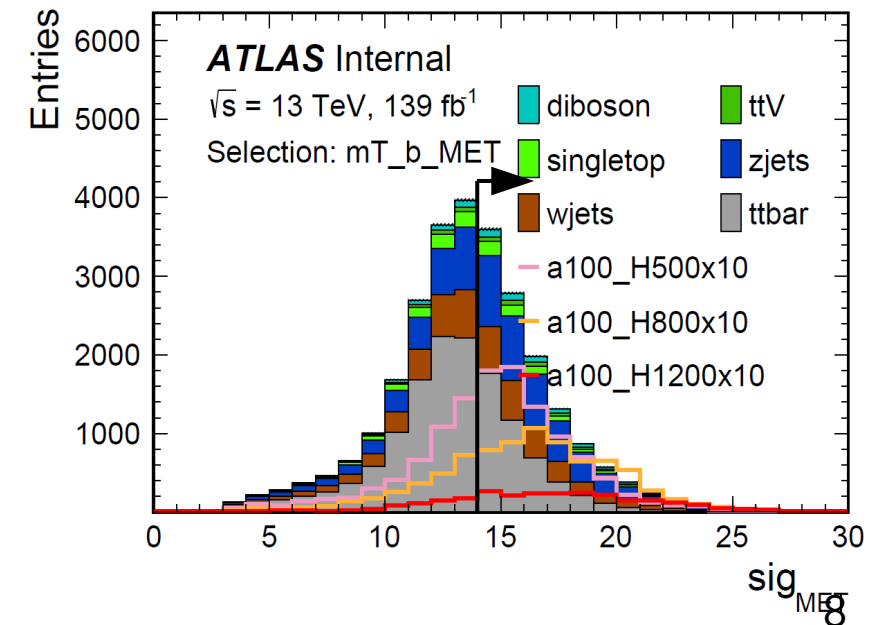
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- Transverse mass between b-jet and missing transverse momentum to reduce this part of the $t\bar{t}$ background
 - $m_T^{b1, \text{MET}} \geq 180 \text{ GeV}$



Observables in the SR – MET Significance

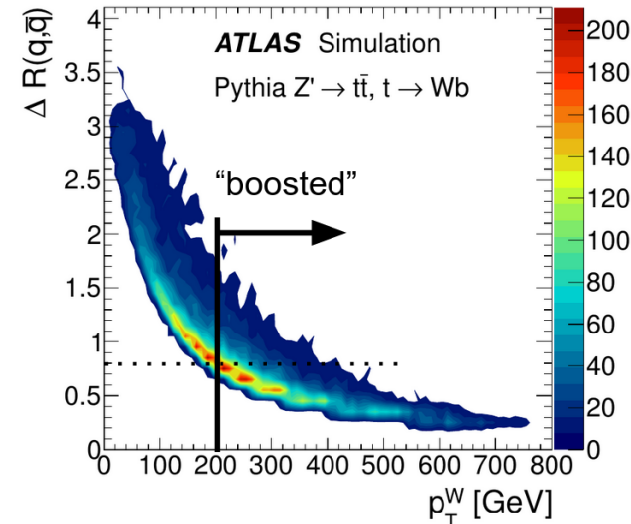
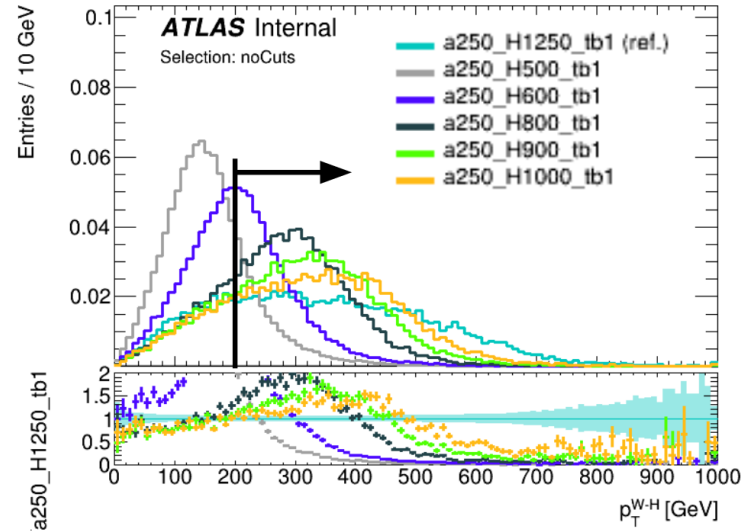
- For high MET events:
 - Higher Fake MET (MET from interacting particles) in SM background
 - Possible Sources:
 - 1) Particles outside of detector acceptance
 - 2) Inaccurately reconstructed
- Definition of MET Significance: <https://cds.cern.ch/record/2630948>
 - Using a log-likelihood ratio testing the hypothesis that there is zero real MET in the event
 - High MET Significance \leftrightarrow High chance that MET comes from invisible particles
 - $S_{\text{MET}} \geq 14$



Observables in the SR – Tagged W-bosons

- One new strategy in this analysis: Tagging W-bosons

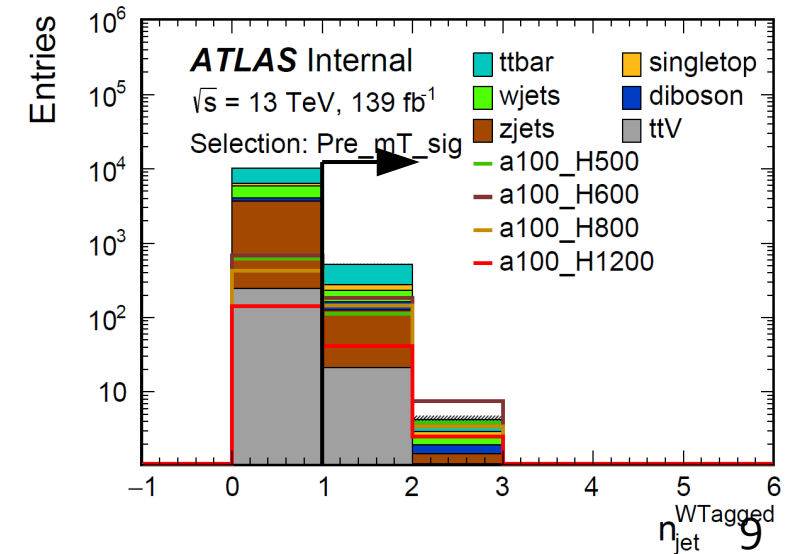
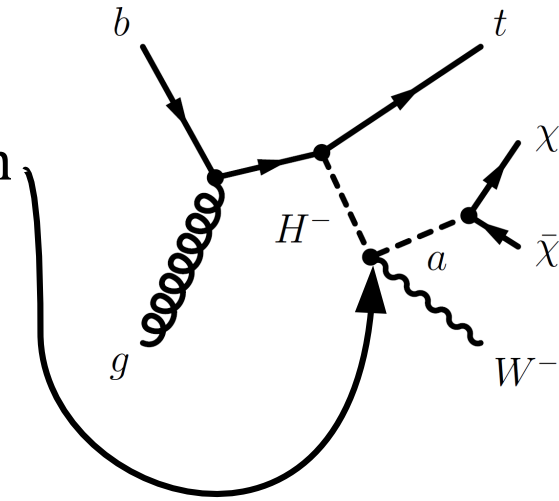
→ Expect high p_T W-bosons in the signal coming from the H-boson



<https://link.springer.com/content/pdf/10.1007>

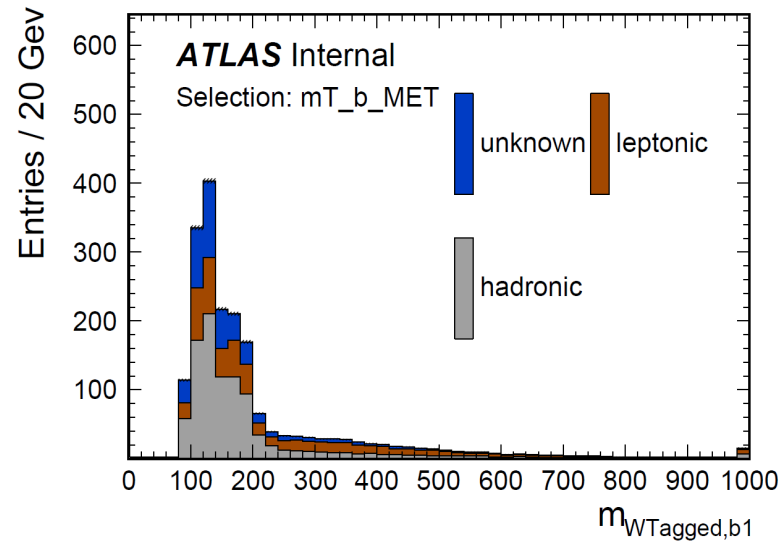
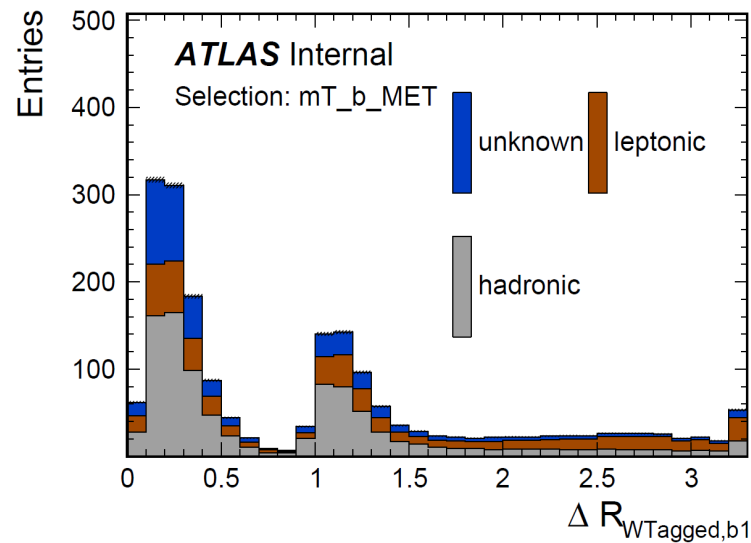
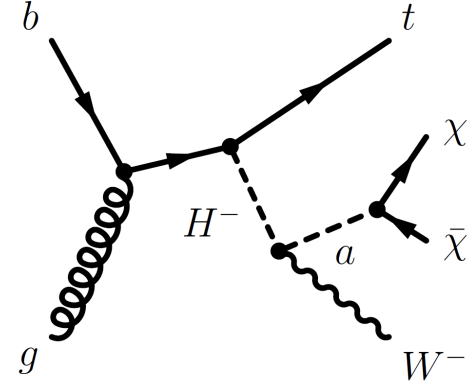
→ Not that many high p_T W-bosons in SM backgrounds

→ $n_{\text{TaggedW}} \geq 1$



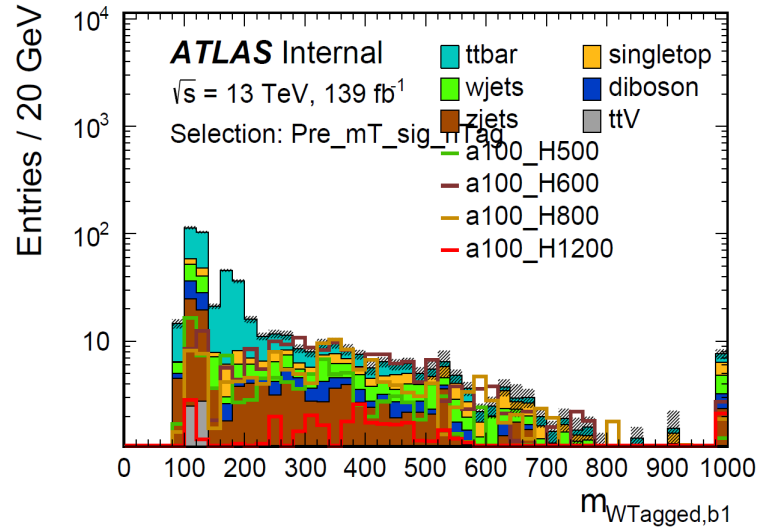
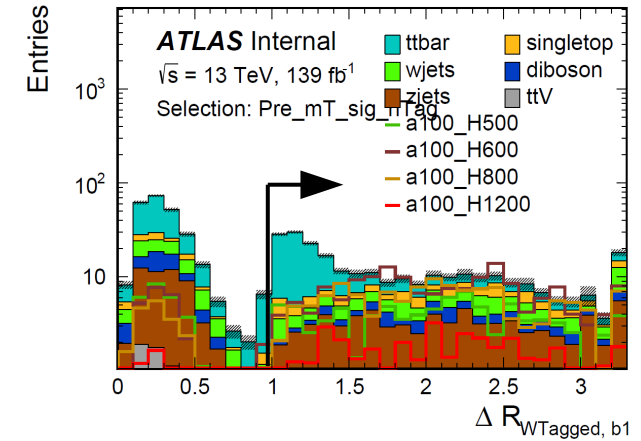
Observables in the SR – W-b-variables

- After $m_T^{b1, \text{MET}} \geq 180 \text{ GeV}$ cut: remaining $t\bar{t}$ background includes bjet coming from hadronically decaying top
 → Tagged W-boson from the same top-quark
 → Difference to signal
- Observables between tagged W-boson and b-jet to reduce $t\bar{t}$ background

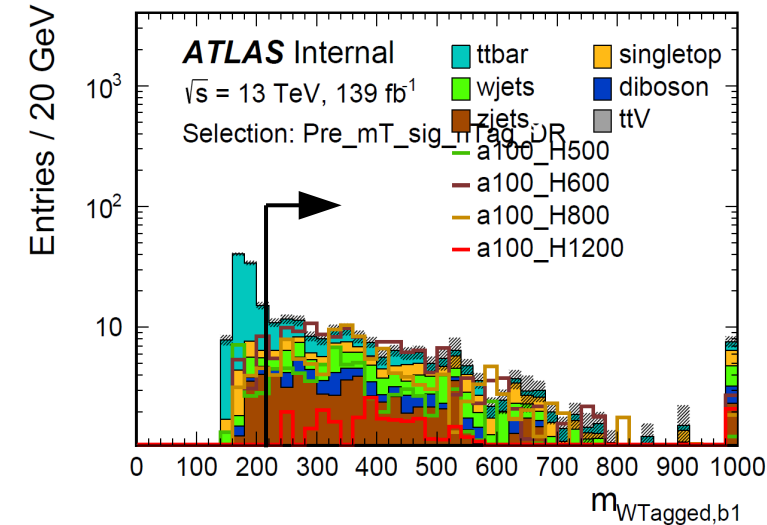


Observables in the SR – W-b-variables

- Strategy: First reduce events where the b-jet is part of the tagged W-boson
 $\rightarrow \Delta R_{W\text{Tagged}, b1} \geq 1.0$
- Remaining ttbar events peak around the top mass:



$$\Delta R_{W\text{Tagged}, b1} \geq 1.0$$



$$\rightarrow m_{W\text{Tagged}, b1} \geq 220 \text{ GeV}$$

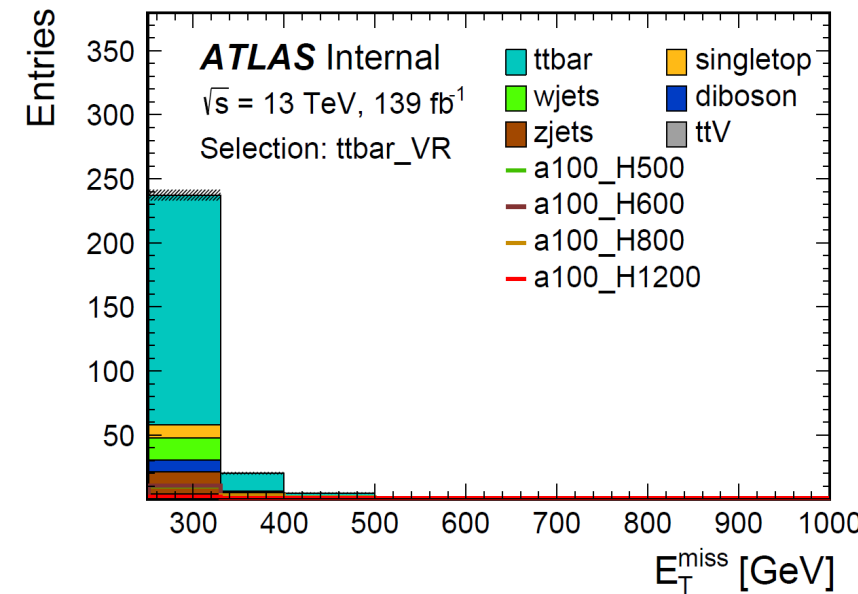
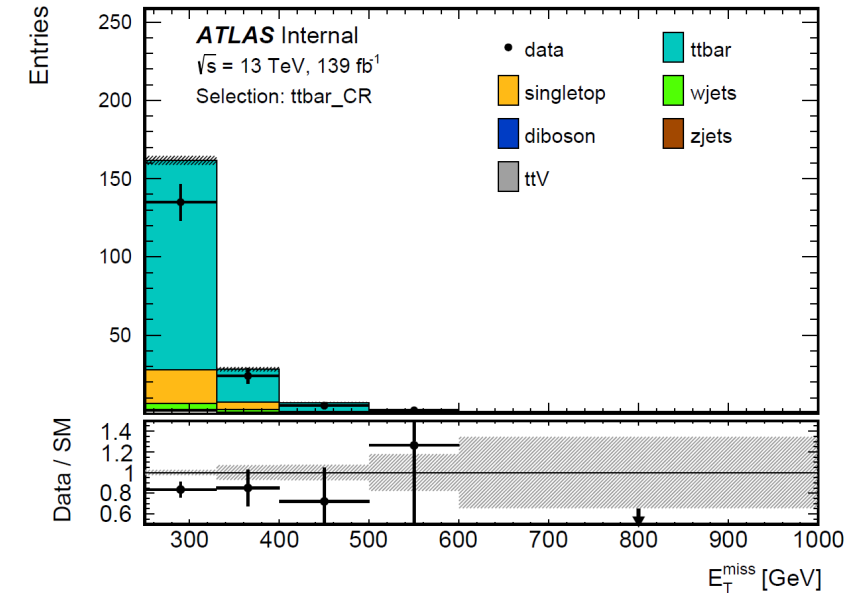
Control/Validation regions

1) ttbar CR and VR

- High semileptonic ttbar background in the SR
→ Control region semileptonic
- Staying orthogonal to 1L SR through $m_T^{\text{lep, MET}} < 130 \text{ GeV}$
→ CR unblinded
- Validation region in 0L channel
→ Invert MET significance and W-b selection cuts
- CR purity: 82%
- VR purity: 73%

2) z+jets CR in 2L channel

→ Done by Alvaro Lopez Solis



Milestones over the last year

- Previous analysis: Converting results into HEPData format
 - Efficiency and acceptance studies: <https://www.hepdata.net/record/99906>
 - Analysis made public in November 2020: <https://arxiv.org/abs/2011.09308>
- Expression of interest talk in the HQT meeting in January, 12th
 - <https://indico.cern.ch/event/984625/>
- Overview over the state of the analysis in HQT meeting in May, 18th
 - <https://indico.cern.ch/event/1027549/>

Outlook

- Finish the HistFitter setup
 - Include the Validation regions
 - Include the missing systematics
 - Get exclusion fits with combined 0L and 1L channel
 - Time frame: A few weeks
- Work on comments from the Editorial Board
- Start writing the PhD thesis in July
 - Focus on single chapters
 - Time frame: Finish at the end of the year