Search for neutral MSSM Higgs bosons in the decay mode $H/h/A \to \tau^+\tau^- \to \mu + e + 4\nu$ with the ATLAS detector

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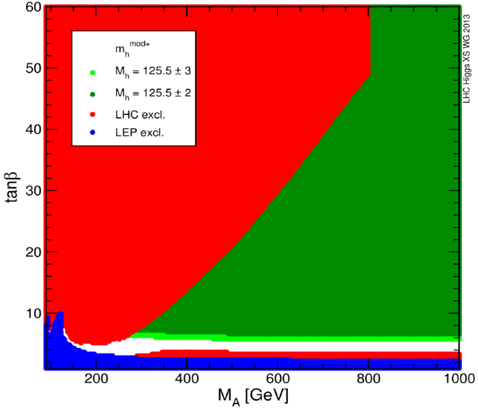
Overview

- Motivation and MSSM Higgs phenomenology.
- Analysis strategy for $H/h/A \to \tau^+\tau^- \to \mu + e + 4\nu$ search

Why Search for BSM Higgses?

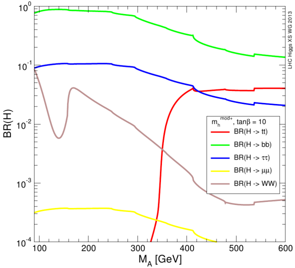
- MSSM Higgs sector is composed by five Higgs bosons: $h^0, H^0, A^0, H^{\pm}$
- The 125 GeV SM-like Higgs can be easily accommodated within the MSSM
- Still plenty of room for Beyond Standard Model Higgses

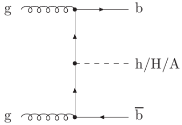


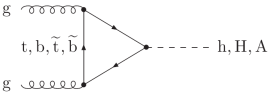
Neutral MSSM Higgs Phenomenology

For Large regions of parameter space $(tan\beta, mA)$:

- One of the Higgs bosons (usually h) has SM-like couplings
- The others (H,A) decouple from gauge bosons and has enhanced couplings to down-type fermions for large tanβ
- Decay into tau pairs is the second most dominant
- Higgs production: gluon fusion and b-associated





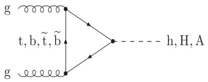


Analysis Strategy

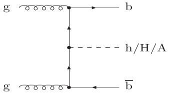
Search for:
$h^0/H^0/A^0 \rightarrow \tau^+ \tau^-$

Final state: $\tau^+ \tau^- \rightarrow \mu\ e + 4\nu$

gluon fusion:



b-associated:



Event Category

B-Jet Veto

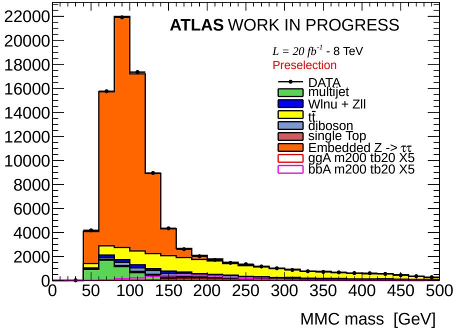
B-Jet Tag

Signature:

one electron + one muon + missing transverse energy

Main backgrounds:
$Z \rightarrow \tau\tau$; top quarks ; QCD multi-jet

Event Selections



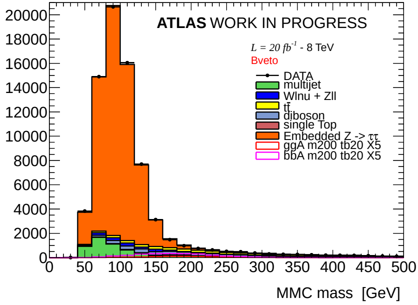
Preselections:

- Trigger
- Exactly 1 muon (P_T> 10 GeV) ; Exactly 1 electron (P_T> 15 GeV)
- Leptons with opposite charge
- Leptons should be isolated

MMC: Missing Mass Calculator, invariant mass considering neutrinos.

Further Selections

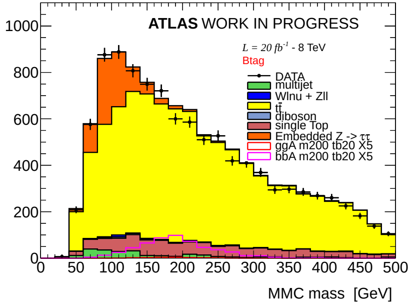
B-Veto



Preselections

b-jet = 0

B-Tag

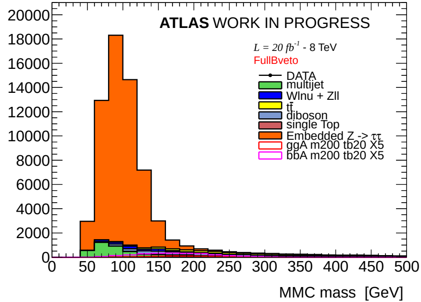


Preselections

b-jet = 1

Further Selections

B-Veto

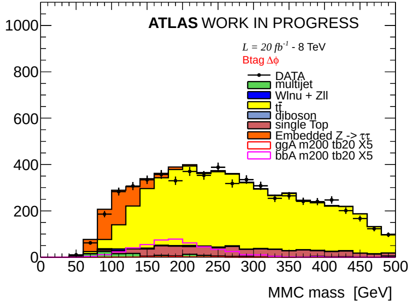


Preselections

\# b-jet = 0

Lepton back-to-back and collinear with neutrinos

B-Tag



Preselections

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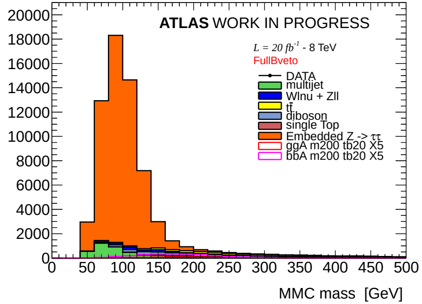
Lepton back-to-back and collinear with neutrinos

Further Selections

B-Veto

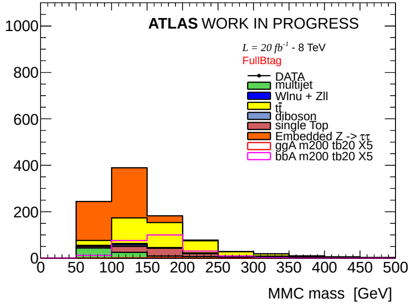


Preselections

\# b-jet = 0

Lepton back-to-back and collinear with neutrinos

B-Tag



Preselections

\# b-jet = 1

Lepton back-to-back and collinear with neutrinos

$\Sigma Jet_{P_T} < 100\text{GeV}$ &

$E_T^{miss} + Lepton_{P_T} < 125\text{GeV}$

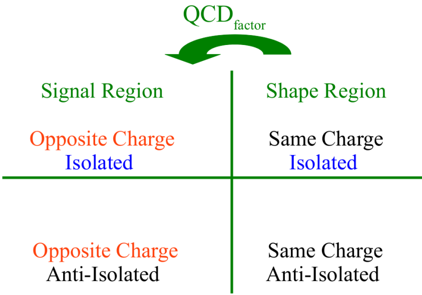
Data-Driven Background Estimation: QCD

- Lepton isolation and charge correlation are used for defining 3 additional control regions

- Assumptions:
  - Control regions are signal free
  - Isolation and charge properties are uncorrelated

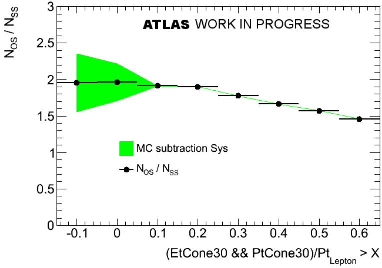
- $N_{QCD}^{SR} = N_{iso}^{same-charge} \times QCD_{factor}$

- $QCD_{factor} = N_{anti-iso}^{opp.charge} / N_{anti-iso}^{same-charge}$



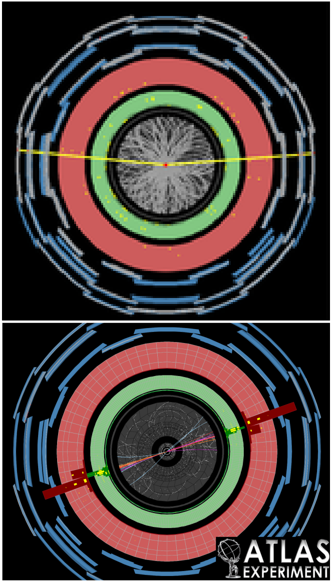
Uncertainty on QCD Estimation

- To some extend leptons charge and isolation are correlated
- Uncertainty estimation: determine the impact of a variation of isolation selection on QCD_{factor}
- Systematics uncertainty of 15% due to correlation between lepton charge and isolation

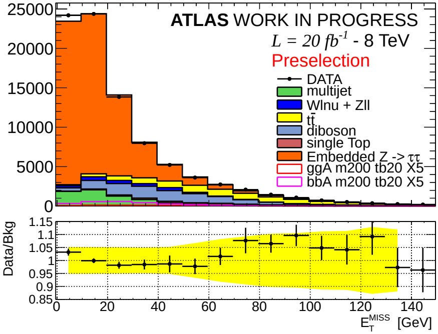


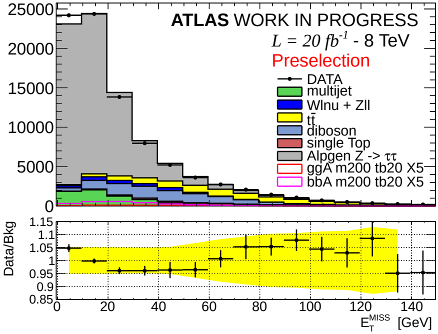
Data-Driven Background Estimation: $Z \rightarrow \tau\tau$

- "Embedded" $Z \rightarrow \tau\tau$ events:
- $Z \rightarrow \mu\mu$ events are selected from data
- Muons are substituted with simulated τ leptons
- All the kinematic properties are perfectly modelled (except τ), they come from data!
- Drawbacks: recovering trigger and lepton reconstruction efficiency is difficult



Embedding vs Simulation

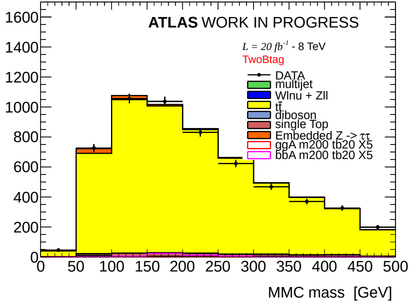




Embedding presents improvements in some kinematic variables like missing transverse energy.

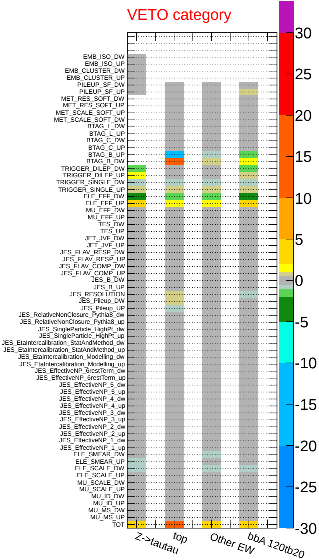
Data-Driven Background Estimation: top Quark

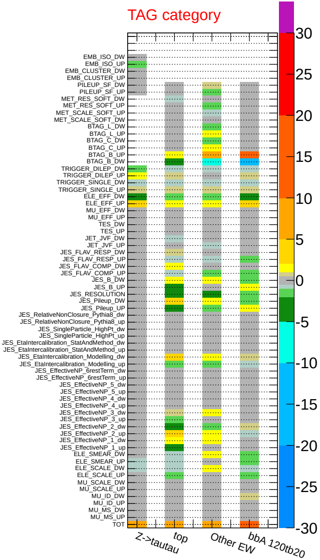
- Control region defined by requesting 2 b-tagged jets
- Extrapolation of top quark to the signal region based on simulation relative efficiencies
- Avoid uncertainties due to cross-section calculation and luminosity measurement
- Drawbacks: additional systematic uncertainty on the estimated efficiencies



Summary of Experimental Uncertainties

ATLAS WORK IN PROGRESS





Summary of Main Systematics

ATLAS WORK IN PROGRESS

Source	Uncertainties on the event yield (%)							
	bbA $m_A = 120$		Emb. $Z \to \tau\tau$		Top		Other	
b-tag	2	11.	–	–	12	2.5	1	5
cross section	20		5		–		7	
Jet E. Scale	-	2	-	-	-	5	-	4
Luminosity	3.6		3.6		–		3.6	
Electron Identification	2	2	3	3	1.5	2	2	1.5
Trigger	1.2	1	1.5	1.2	1.	1	1	1

Table: Uncertainties for B-Veto and B-Tag event category respectively.

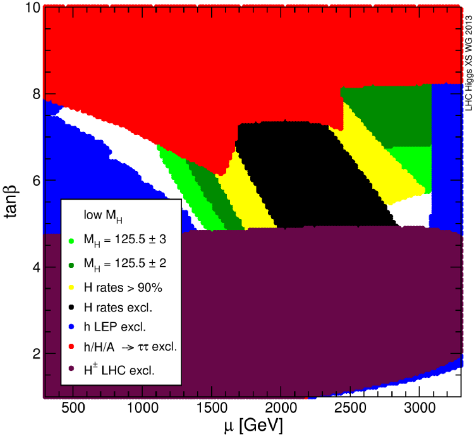
Summary

- Cut based analysis for the search for MSSM $h/H/A \rightarrow \tau_l\tau_l$ in the fully leptonic final state, optimised for exclusion limits with 20 fb^{-1} of 8 TeV data.
- Data-driven background estimation for main background processes
- Dominant systematics uncertainties from b-tagging and cross section calculations
- The analysis is currently under ATLAS approval

Thanks!

Backup Slides

Alternative scenario



- Article by Drees:
- 96 GeV < mA < 152 GeV .
- $5.5 < \tan\beta < 12.5$
- 95 GeV < mh < 101
- 123 < mH < 128 (the SM-like Higgs)

Embedding $Z \to \tau\tau$ Trigger problem