A search for neutral MSSM Higgs bosons in the decay channel $\Phi \rightarrow \tau^+\tau^-$ with ATLAS

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Motivation and the MSSM Higgs Sector

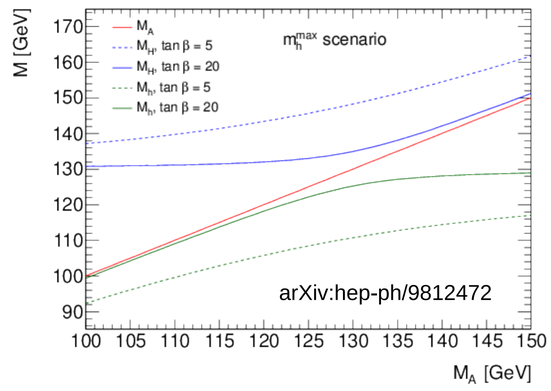
The Standard Model of Particle Physics describes all elementary particles and their interactions. It has been validated thoroughly over decades and passed all tests. However, it can not answer several questions:

- How can we explain the fine-tuning problem?
- What is dark matter?
- Is there an unification of the gauge couplings at large scales?

Supersymmetric theories can provide answers to those questions as they double the particle content. Hence, supersymmetric extensions of the Standard Model are of special interest.

Phenomenology of the Higgs sector in the Minimal Supersymmetric Standard Model (MSSM):

- two scalar doublets leading to three neutral Higgs bosons, Φ = *h/H/A*, and two charged ones, $H^{\pm}$,
- *A* is CP-odd while *h/H* are CP-even,
- two vacuum expectation values: $\tan\beta = \frac{v_d}{v_u}$
- coupling of *A* to down-type fermions is enhanced by tan β
- couplings of Φ to gauge bosons are suppressed $\rightarrow$ decays into pairs of *b* and τ become relevant
- free parameters in the m_h^{max} scenario: tan β and m_A



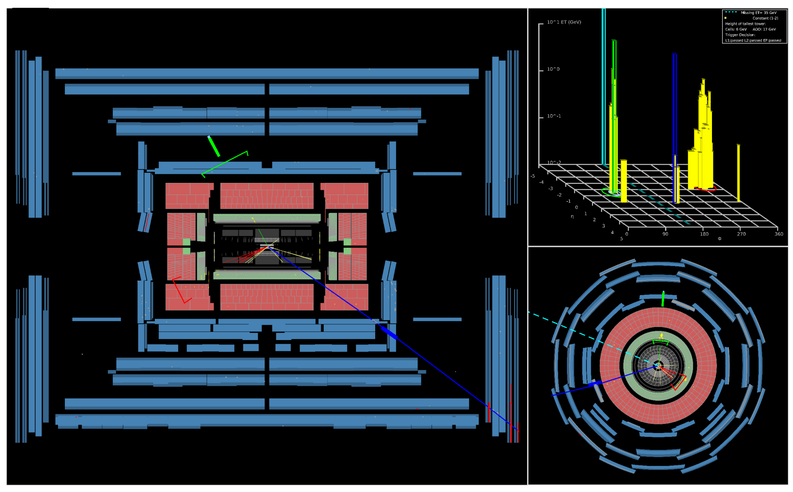
Event Selection

Signal Topology for $\Phi \rightarrow \tau^+\tau^- \rightarrow e\mu + 4\nu$

- two light leptons with opposite electric charge
- leptons are back-to-back in transverse plane
- small missing transverse energy

Event Selection

- identified electron and muon candidate with opposite electric charges
- $p_{T,e} + p_{T,\mu} + E_{T,miss} < 120$ GeV
- $\cos(\varphi_e - \varphi_{MET}) + \cos(\varphi_\mu - \varphi_{MET}) > -0.25$
- $|\varphi_e - \varphi_\mu| > 1.75$
- $30\ \text{GeV} \leq m_{e\mu} \leq 110\ \text{GeV}$



Object Definitions

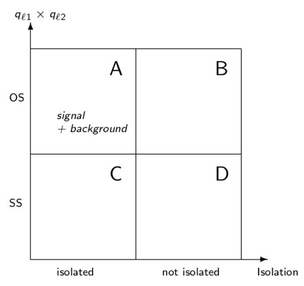
- Electrons:
  - $p_T > 15$ GeV
  - $|\eta| < 2.4$
  - well isolated, tight quality criteria
- Muons:
  - $p_T > 10$ GeV
  - $|\eta| < 2.5$
  - well isolated, tight quality criteria
- Jets:
  - $p_T > 20$ GeV
  - $|\eta| < 4.5$

Background Estimation

Background contributions

- $\gamma^*/Z \rightarrow \tau^+\tau^-$ events (estimated from simulation)
- di-boson production (normalisation from data)
- production of top – anti-top pairs (normalisation from data)
- contributions from mis-identified jets (data-driven estimate)

Data-driven fake background estimate

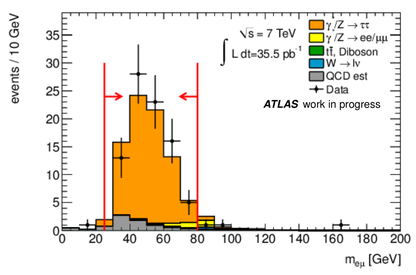


- use two uncorrelated variables:
  - lepton isolation
  - charge product of leptons
- determine event yield in background enhanced control region
- extract extrapolation factor in signal free control regions

Study of $\gamma^*/Z \rightarrow \tau^+\tau^-$ process

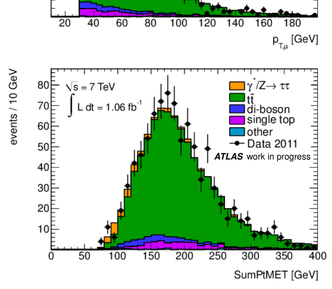
- dominant background for this analysis
- understanding tested and simulation validated on 35.5 pb^{-1} of data collected in 2010
- cross section measurement:

$$\sigma^{pp\rightarrow\gamma^*/Z}_{\text{incl}} \times \mathcal{BR}\left(\gamma^*/Z \rightarrow \tau^+\tau^-\right) = 1060 \pm 140(\text{stat.}) \pm 80(\text{syst.}) \pm 40(\text{lumi.})\ \text{pb}$$

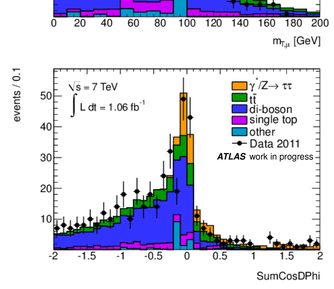


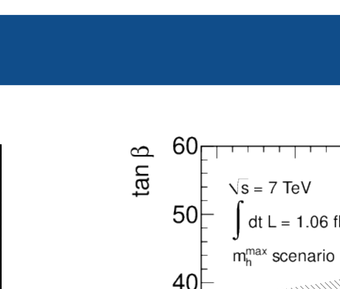
Cross checks on other background processes

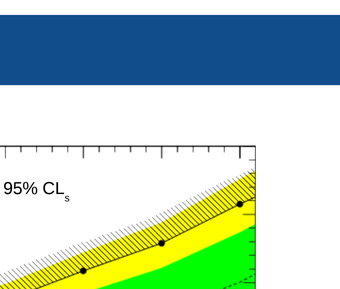
top pair events



di-boson events

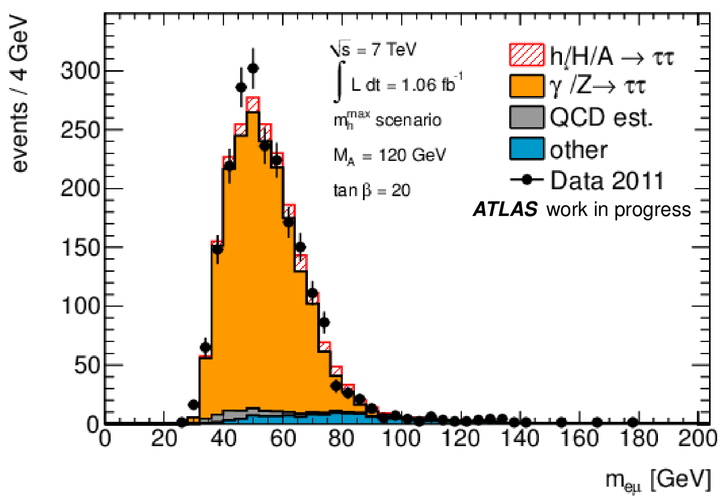


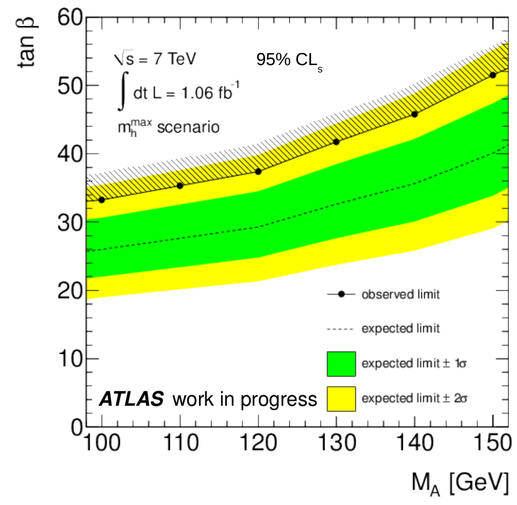




Results

- analysis is interpreted as counting experiment
- systematic uncertainties are taken into account using the profile likelihood method
- background contributions are estimated from simulation or extrapolated from sidebands
- sources of systematic uncertainties studied:
  - electron energy resolution (≈ 2.5%)
  - muon momentum resolution (≈ 1.5%)
  - jet energy scale uncertainty (≈ 5%)
  - reconstruction/identification efficiencies (≈ 4%)
  - trigger efficiencies (≈ 0.5%)
  - cross section/acceptance uncertainties (≈ 5-30%)
  - uncertainty on the luminosity measurement (≈ 3.4%)
- no significant excess of data events was observed $\rightarrow$ limits in the parameter space of the MSSM





Publications

- "*First Observation of the process $Z \rightarrow \tau\tau \rightarrow e\mu + 4\nu$ with the ATLAS Detector*", ATLAS Collaboration, ATLAS-CONF-2011-045
- "*Measurement of the $Z \rightarrow \tau\tau$ Cross Section with the ATLAS Detector*", ATLAS Collaboration, Phys.Rev.D 84 (2011) 112006, (arXiv:1108.2016)
- *"Search for neutral MSSM Higgs bosons decaying to $\tau^+\tau^-$ pairs in proton-proton collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector"*, ATLAS Collaboration, ATLAS-CONF-2011-132
- *"Search for the Standard Model Higgs boson in the $H \rightarrow \tau^+\tau^-$ decay mode with 4.7fb^{-1} of ATLAS data at 7 TeV"*, ATLAS Collaboration, ATLAS-CONF-2012-014
- *"Search for the neutral Higgs bosons of the MSSM in pp collisions at $\sqrt{s}$=7 TeV with the ATLAS detector"*, ATLAS Collaboration, CERN-PH-EP-2012-323

Talks

- "*Data-driven QCD background estimation using the ABCD – method*", 6th workshop of the $m_{\tau\tau}$ working group, Munich, March 2011
- *"Search for neutral MSSM Higgs bosons in the channel $h/H/A \rightarrow \tau^+\tau^-$ ", DPG Spring Conference, Göttingen, March 2012*

Profit from the GK

- attendance of workshops and schools (statistics, computing, analysis technique)
- research stay at CERN for 6 months
- travel money for conferences (e.g. Zurich workshop on Higgs phenomenology)

Contact Details and further Information

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DRESDEN concept

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