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Measurement of $H \rightarrow \tau\tau$ in the $\tau_{lep} + \tau_{had}$ final state using the ATLAS detector

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on the behalf of the ATLAS collaboration

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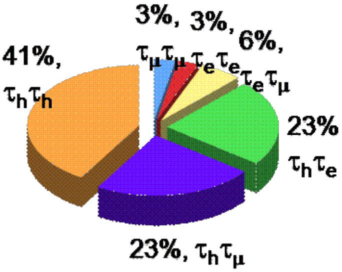
Bundesministerium
für Bildung
und Forschung

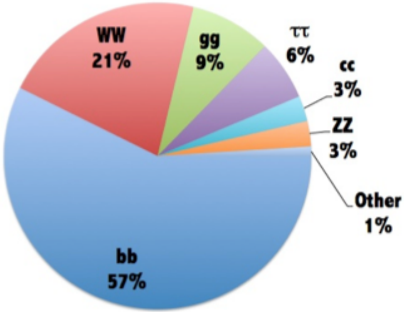
BMBF-Forschungsschwerpunkt
ATLAS-EXPERIMENT
Physik bei höchsten Energien mit dem ATLAS-Experiment am LHC
FSP 103
ATLAS

$H \to \tau\tau$ search motivation

- In the SM, $H \to \tau\tau$ is currently the only accessible decay at LHC to establish Higgs-Yukawa coupling to leptons



$H \to \tau\tau$ decay modes



Higgs decay modes

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG

Run 2 coupling measurement

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- Cut-based analysis using 2015+2016 datasets collected at $\sqrt{s}$= 13 TeV
  - Multivariate analysis ongoing in parallel to increase final sensitivity

- Harmonisation across different channels to use similar signal regions and similar object definitions

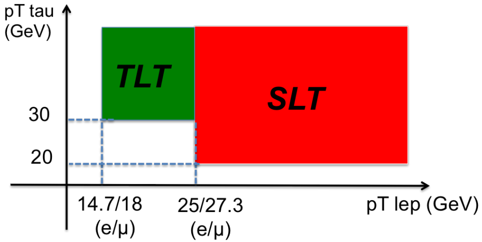
	lep-lep lep-had had-had
VBF region	$p_T^{lead.jet} > 40$ GeV (70 GeV for had-had), $p_T^{sublead.jet} > 30$ GeV
	$\Delta\eta$ (jets) > 3 in opp. hemisphere, M (jets) > 400 GeV
Boosted region	Fail VBF region, $p_T^H > 100$ GeV

- Combined fit on the di-tau mass (*MMC*) based on Maximum Likelihood Estimation (*MLE*) to determine the signal strength

$$\mu = \frac{\sigma \times BR}{(\sigma \times BR)_{SM}}$$

Event selection for the $\tau_{lep} + \tau_{had}$ final state

- Preselection cuts:
  - Trigger: Single Lepton Trigger (SLT) + Tau Lepton Trigger (TLT) combination
  - Lepton features:
    - Isolation requirement
    - Good reconstruction quality (medium ID)
    - $p_T > 14.7$ GeV (muon), 18 GeV (electron)
  - Hadronic tau features:
    - Good reconstruction quality (medium ID)
    - $|\eta| < 2.4$, $|q| = 1$, $p_T > 20$ GeV
  - Opposite sign between lepton and hadronic tau
  - No b-jets
  - $M_T(lep, MET) < 70$ GeV



- Control region (CR) definitions:
  - QCD CR: invert cut on lep. isolation
  - W CR: invert cut on $M_T(lep, MET)$
  - Top CR: invert cut on b-jets and $M_T(lep, MET) > 40$ GeV

Fake estimation

- Possible sources of fakes for mis-reconstructed electrons or muons (leptonic side):
    - no data driven strategy at the moment to estimate this low contribution

- Possible sources of fakes for mis-reconstructed hadronic taus (hadronic side)
    - Contribution from electrons strongly reduced using:
        - Geometrical overlap removal (ORL)
        - Electron Likelihood rejection (LLH)
        - Electron BDT rejection

    - Contribution from jets estimated using two techniques:
        - OS-SS method (backup)
        - Fake Factor method (default)

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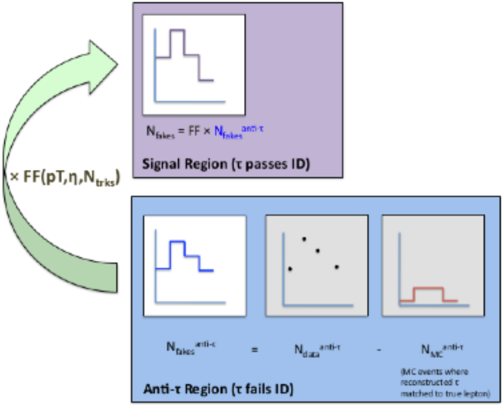
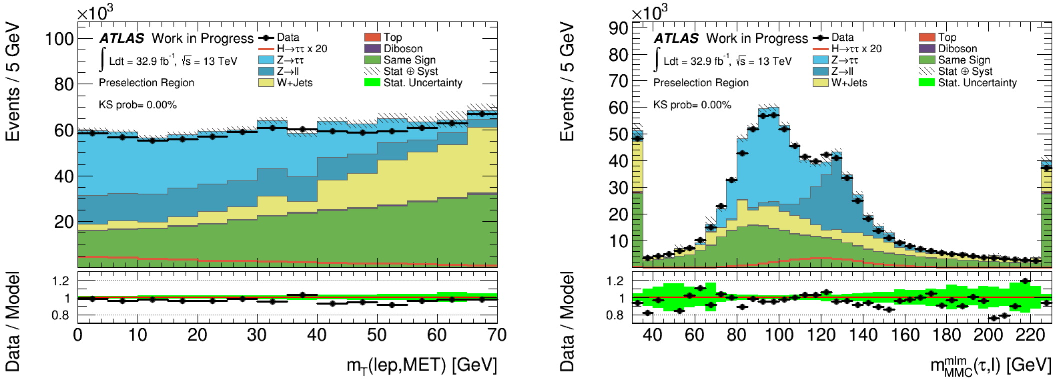
- Data driven technique
- Consider events where a tau is faked by a jet; invert tau ID (anti-tau)
- $N_{jet\to\tau} = (N^{fail,SR}_{Data} - N^{fail,SR}_{MC,nojet\to\tau}) * FF_{SR}$
- *Fakes* normalisation is obtained from the transfer factor (FF_{SR}) from anti-tau region to signal region
- Shape of *Fakes* are taken from anti-tau region in Data



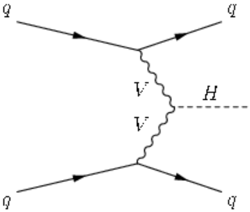
Detector level plots at pre-selection



- Overall, good Data/MC modelling for key-variables in the analysis

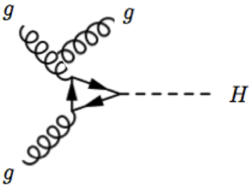
Signal regions for cut-based analysis

- VBF region
  - $p_T^{lead.jet} > 40$ GeV
  - $p_T^{sublead.jet} > 30$ GeV
  - $\Delta\eta$ (jets) > 3, opposite hemisphere
  - Jets visible mass $(M_{jj}) > 400$ GeV
  - $min(\eta^{jet}) < \eta^{lep/tau}$ and $max(\eta^{jet}) > \eta^{lep/tau}$
  - $MET > 20$ GeV
  - $\Delta R(l, \tau) < 3$ and $\Delta\eta(l, \tau) < 1.5$
- Split in *Loose* and *Tight* regions based on M_{jj}



VBF Higgs production

- Boosted region:
  - Fail VBF region requirements
  - $p_T^H > 100$ GeV
  - $MET > 20$ GeV
  - tau $p_T > 30$ GeV
  - $\Delta R(l, \tau) < 2.5$ and $\Delta\eta(l, \tau) < 1.5$
- Split in *High* and *Low* regions based on p_T^H



ggF (+ 1 jet) Higgs production

Detector level plots in signal regions

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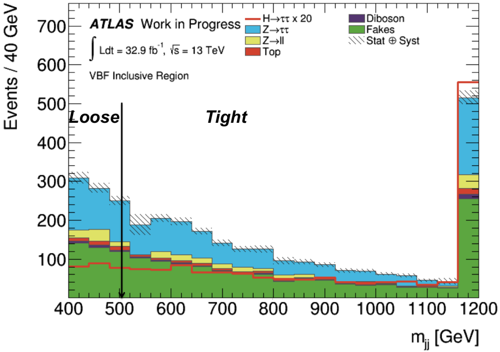
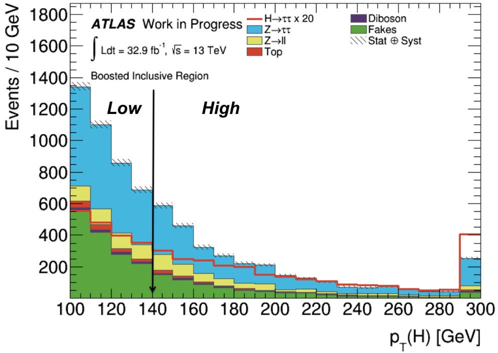
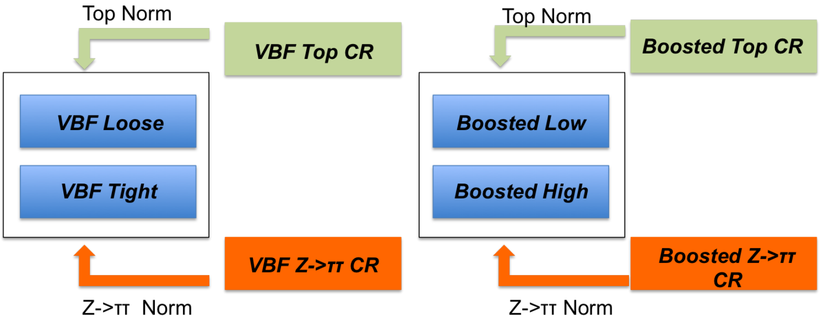




- Splitting in sub-regions will increase significance in the fit

Fit model for the $\tau_{lep} + \tau_{had}$ final state



- Boosted (VBF) Top CR : region defined using Boost (VBF) selection and inverting cut on b-jets and $M_T(lep, MET) > 40$ GeV
- Boosted (VBF) Z CR: region defined using $Z \to ll$ + low MET events and Boost (VBF) selection
- Used to get normalisation in signal regions

Summary and outlook

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- Analysis in ongoing to perform cross-section measurement for $H \rightarrow \tau\tau$ in Run 2 using 2015+2016 dataset

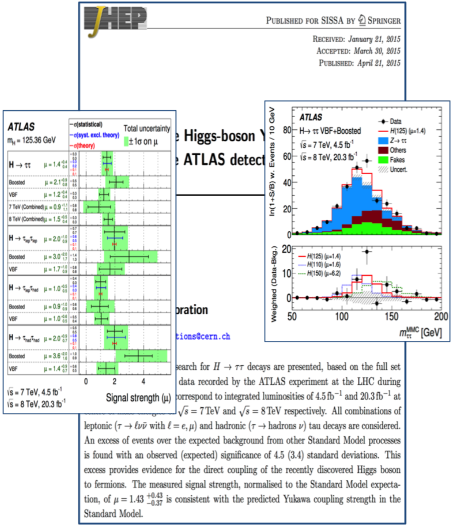
- Precision measurements like Higgs differential cross-section and Higgs decay properties will follow after having established the cross section measurement

Thanks For Your Attention

Backup

Run 1 coupling measurement results

- Run1 paper: JHEP04(2015)117
- Split in VBF and Boosted categories to enrich VBF and ggH topologies, respectively
- Analysis used both BDT and cut-based (CB) approach
- Focus on BDT result due to better performance
  - Observed (Expected) significance: 4.5 (3.4) σ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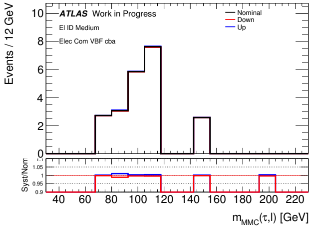
…earch for $H \to \tau\tau$ decays are presented, based on the full set … data recorded by the ATLAS experiment at the LHC during … correspond to integrated luminosities of 4.5 fb^{-1} and 20.3 fb^{-1} at … $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 8 TeV respectively. All combinations of leptonic ($\tau \to \ell\nu\bar{\nu}$ with $\ell = e, \mu$) and hadronic ($\tau \to$ hadrons ν) tau decays are considered. An excess of events over the expected background from other Standard Model processes is found with an observed (expected) significance of 4.5 (3.4) standard deviations. This excess provides evidence for the direct coupling of the recently discovered Higgs boson to fermions. The measured signal strength, normalised to the Standard Model expectation, of $\mu = 1.43\ ^{+0.43}_{-0.37}$ is consistent with the predicted Yukawa coupling strength in the Standard Model.

Systematic errors

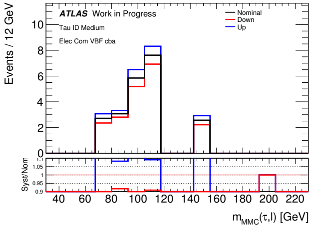
- Systematics are coming from different used object:
  - muons: identification, reconstruction, tracks association
  - electrons: identification, detector effects (temperature, etc.)
  - taus: energy scale, identification
  - jets: energy scale, b-tagging, resolution
  - MET: resolution, energy scale

- Both kinematic and weight systematics are taken into account for the final fit

- In total more than 150 systematic variation



Elec Eff. ID syst. for $Z \to \tau\tau$ process



Tau Eff. ID syst. for $Z \to \tau\tau$ process