Z$\rightarrow \tau\tau$ cross−section measurement at 13TeV

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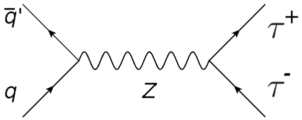
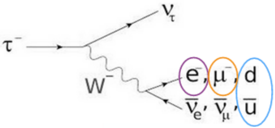
Introduction

- Goal of the analysis: Measure the Z$\rightarrow \tau\tau$ cross-section at 13 TeV (Important background for H$\rightarrow \tau\tau$ analysis)
- Signal: Drell Yan decaying into two taus, one tau decays into an electron or muon and neutrinos, the second one decays into hadrons and neutrino

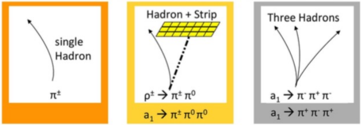




Tau Reconstruction

- HPS (Hadron+Strips Algorithm to reconstruct hadronic decay of taus)
- It is reconstructed in 3 different modes

	Decay Mode	Resonance	B[%]
leptonic decays	$\tau^- \to e^- \overline{\nu}_e \nu_\tau$		17.8
	$\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau$		17.4
1 - prong decays	$\tau^- \to \pi^- \nu_\tau$	$\pi(140)$	11.6
	$\tau^- \to \pi^- \pi^0 \nu_\tau$	$\rho(770)$	26.0
	$\tau^- \to \pi^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260)$	10.8
3 - prongs decays	$\tau^- \to \pi^- \pi^+ \pi^- \nu_\tau$	$a_1(1260)$	9.8
	$\tau^- \to \pi^- \pi^+ \pi^- \pi^0 \nu_\tau$		4.8
	Other hadronic modes		1.7
	All hadronic modes		64.8



Analysis anatomy

- Final state with muon, hadronic tau and missing transverse momentum
- The full background model consists of:
- reducible with leptons from b/c quarks and/or W decays:
    - ttbar
    - diboson production WW, WZ, ZZ (small)
    - single top tW (very small, neglected)
- reducible with fake leptons:
    - W+jets, QCD
- All backgrounds are measured in control regions where their contributions are enhanced and extrapolated using samples of same-sign (SS) and opposite-sign (OS) events from data, for which the electron or muon isolation requirement is inverted
- Veto events with more than 1 good identified and isolated muon or electron in the event
- Veto events with 2 good electrons and muons since Z$\rightarrow \mu\mu$ in particular can contaminate the signal phase space
- Require events with 0 b-tagged jets

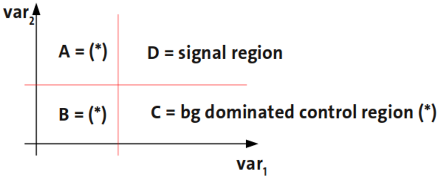
Event selection

- μ τ channel
  - Find a good muon in event (apply p_T, η, muon Identification, Muon Isolation and impact parameter cut)
  - Find a good tau in the event (apply p_T, η, decay Mode Finding, Isolation, Anti-Muon discriminator and Anti-Electron discriminator)
  - Check distance ΔR between muon and tau to greater than 0.5.
  - Make sure the Z$\rightarrow$ $\mu\mu$ process is not contaminating the mu-tau yield.

- e τ channel
  - Find a good electron in event (apply p_T, η, muon Identification, Muon Isolation and impact parameter cut)
  - Find a good tau in the event (apply p_T, η, decay Mode Finding, Isolation, Anti-Muon discriminator and Anti-Electron discriminator)
  - Check distance ΔR between electron and tau to greater than 0.5.
  - Make sure the Z$\rightarrow$ ee process is not contaminating the e-tau yield. Reject events with extra electron and jets.

QCD Background Estimation. ABCD Method

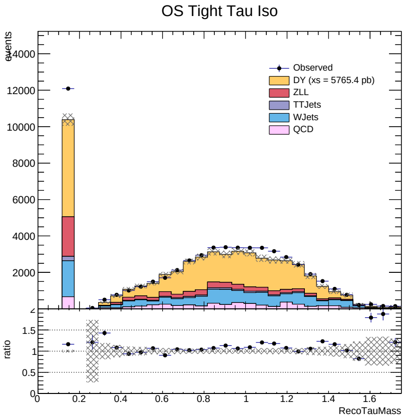
- If search region is defined by sequential cuts, e.g. on var_1 and var_2 (with discriminative power, e.g. isolation and charge)

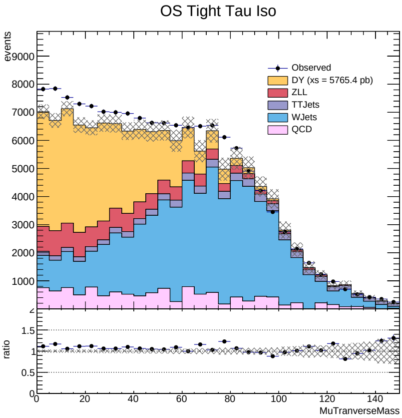


- If variables are uncorrelated (has to be verified): $N_D = \frac{N_C N_A}{N_B}$
  - shape of var_1 distribution independent of choice of var_2
  - background in signal region predicted by scaling of control sample
  - Modification for correlated variables possible, however challenging
  - For the analysis OS/SS=1.06

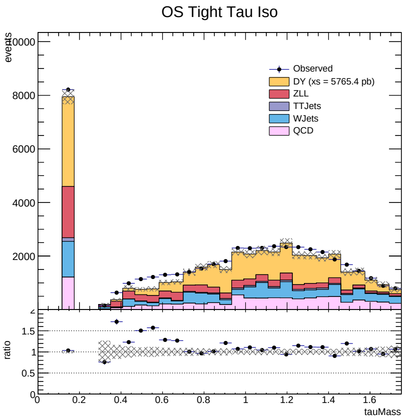
Control Plots mutau channel

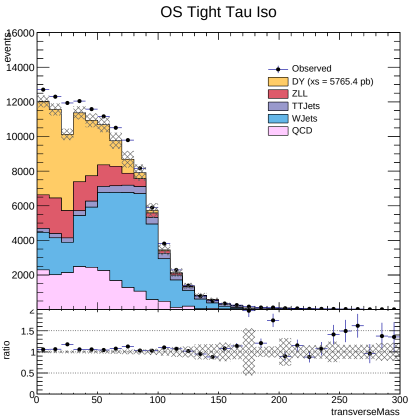
$$m_T(l, \mathrm{E}_\mathrm{T}^\mathrm{miss}) = \sqrt{(E_l + \mathrm{E}_\mathrm{T}^\mathrm{miss})^2 + (\vec{p}_l + \vec{\mathrm{E}}_\mathrm{T}^\mathrm{miss})}$$



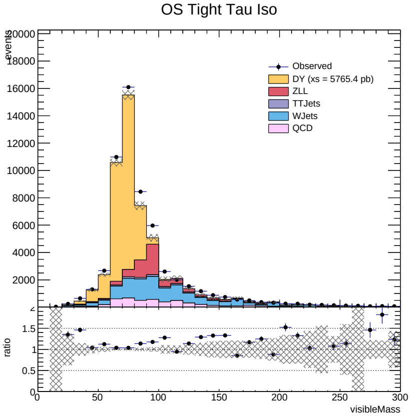


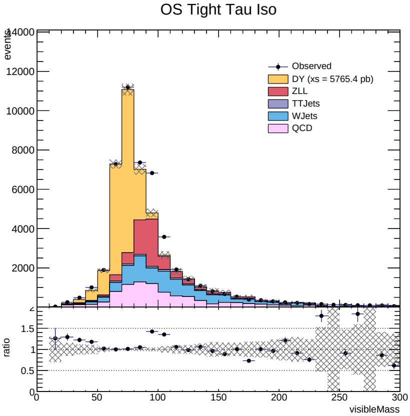
Control Plots etau channel





Final plots. Mutau channel and etau channel

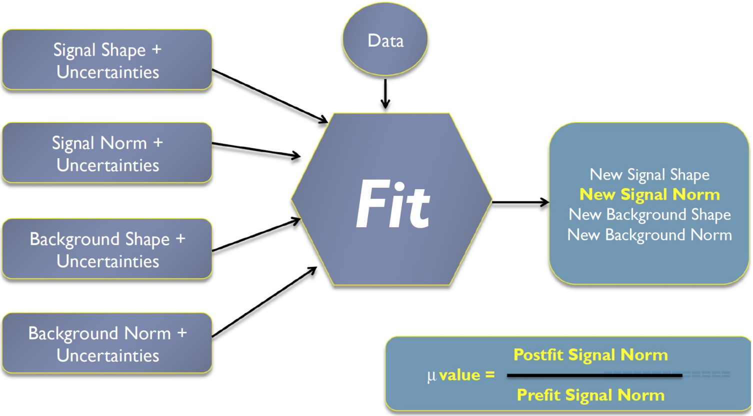




Systematic uncertainties

- Muon ID efficiency: 2%
- Muon trigger eff.: 2%
- Electron trigger eff.: 2%
- Electron ID eff.: 2%
- Tau ID eff.: 5%
- W+Jets cross-section: 10%
- Ttbar cross-section: 10%
- QCD background estimation: 30%
- Integrated luminosity: 2.5%

Fit


Signal Shape + Uncertainties
Signal Norm + Uncertainties
Background Shape + Uncertainties
Background Norm + Uncertainties
Data
Fit
New Signal Shape
New Signal Norm
New Background Shape
New Background Norm
µ value = Postfit Signal Norm / Prefit Signal Norm

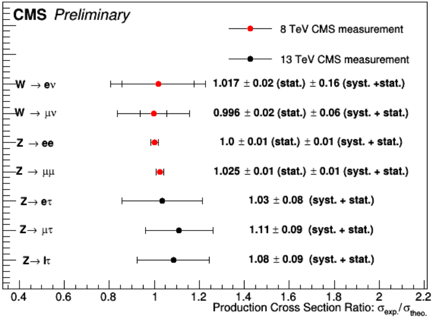
Combine tool

- Fit is performed using Higgs Combined Tool
- Combine provides a command line interface to many different statistical techniques available inside RooFit/RooStats used widely inside CMS
- The input to combine, which defines the details of the experiment, is a datacard file
- This plain ASCII file contains:
  - the number of independent sources of systematic uncertainties
  - the number of observables
  - the number of independent sources of systematic uncertainties
  - the number of events expected, for each bin and process
  - the systematic uncertainties with columns reporting the relative effect on the rate of each process in each channel

Cross Section Measurement

- Theoretical cross section is: 5765 pb
- The cross section is obtained for each final state with the following formula:
  - $\sigma(pp \to ZX) \cdot$ B $(Z \to \tau^+\tau^-) = \frac{N}{\mathcal{A}\epsilon\mathcal{B}'\mathcal{L}}$

where $\mathcal{N}$ is the number of extracted signal events, $\mathcal{A}$ is the acceptance of signal events, ϵ is the signal selection efficiency, $\mathcal{B}'$ is the branching fraction of the decay mode considered, and $\mathcal{L}$ is the integrated luminosity $(35.9 fb^{-1})$



Summary

- A measurement of the cross section for the process $pp \to ZX$ with $Z \to \tau^+\tau^-$) has been performed based on the $\tau_e\tau$ and $\tau_\mu\tau$ final state
- A clear signal is established in the visible mass distributions for both channels.
- QCD multijet process was obtained from data and the rest of the background through dedicated MC simulations.
- The cross section calculated using a maximum likelihood fit is consistent with theoretical expectations with a ratio of 1.08 ± 0.09.