Leptonic scale factors in the 4tops analysis

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Electron definition

- **Multivariate ele ID** developed inside the SUSY group
  - Cuts on MVA discriminant based on electron η, p_{T}
  - Tight WP
- **MultiIso with LepAware JEC**
  - Cuts on MiniIsolation, lepton-jet p_{T} ratio and $p_{\mathrm{T}}^{\mathrm{rel}}$
  - Tight WP
- **2D isolation**
  - Tight WP
- **3D isolation**
  - Tight WP

Electron scale factors

Electrons (Data/FullSim MC) SFs

Preliminary SFs for electrons using legacy 2016 data are available in ROOT file with stat+syst uncertainties. Please use these SFs on top of reco SFs provided by EGM POG here. Cut based IDs (no iso) are derived using Fall17V2 ID cuts without any cuts on reIIso. For MVA ID working points please refer to these slides. Working points for LeptonMVA and MultiIso are same as Moriond17.

Data: Run2016*-17Jul2018*v1

MC: RunIISummer16MiniAODv3

GTs used to derive SFs (relevant for LeptonMVA and MultiIso which use JECs): 94X_dataRun2_v10, 94X_mcRun2_asymptotic_v3

- This https://twiki.cern.ch/twiki/bin/viewauth/CMS/SUSLeptonSF has links to ROOT files containing SFs
- η, p_{T} dependent scale factors
- **Remark**: TWiki says to apply these SFs on top of EGM POG SFs

Electron scale factors

- `2016LegacyReReco_ElectronTight_Fall17V2.root`
  - Contains **EGM POG scale factors**
- `ElectronScaleFactors_Run2016.root`
  - Contains many different TH2Fs
  - Use `Run2016_MVATightTightIP2D3D`, description: Run2016 (Legacy) e **SF for MVA Tight ID + TightIP2D + TightIP3D, wrt Reco electrons**
  - Use `Run2016_MultiIsoT`, description: Run2016 (Legacy) e **SF for MultiIsoTight, wrt MVA Tight ID + ID Emu + TightIP2D + TightIP3D**
- Those histograms seems to be what we need
- But what's ID Emu? We are not using it AFAIK
- No other SFs are available though...

Muon definition

- **Muon ID** developed **by MUO POG**: https://twiki.cern.ch/twiki/bin/view/CMS/SWGuideMuonIdRun2
  - Medium WP
- **MultiIso with LepAware JEC**
  - Cuts on MiniIsolation, lepton-jet p_T ratio and p_T^{rel}
  - Medium WP
- **2D isolation**
  - Tight WP
- **3D isolation**
  - Tight WP

Muon scale factors

Muons

Data - leading order FullSim MC comparison

The results use the full rereco 2016 dataset. Uncertainties on the SFs in the provided root files are only statistical and can be neglected. Systematics of the method come from the variations of the mass window, tag definitions (allowing more or less bkg), fitting functions, number of mass bins in the fit, and from residual pile-up dependency. We suggest a 3% uncertainty per muon leg (ID+IP+ISO) that was used for ICHEP (also related to some residual dependency of the SF vs the hadronic activity). Tracking SF are not recommended anymore.

Unfortunately, the person who produced these SFs has left CERN, and the links below are broken. Plots with SFs can be found here. Some of the root files have been uploaded by analyzers who had saved them locally, but others are missing: if you have a root file which you used for a Moriond17 analysis, please upload it to the twiki and add a link in the table below.

- This https://twiki.cern.ch/twiki/bin/viewauth/CMS/SUSLeptonSF has links to ROOT files containing SFs
- η, p_{T} dependent scale factors

Muon scale factors

- `TnP_NUM_MediumID_DENOM_generalTracks_VAR_map_pt_eta.root`
  - Contains **SF for MediumID**
  - Taken from SUSLeptonSF Twiki
  - **Different from SF from MUO POG page, why?!?**
- `TnP_NUM_MultiIsoMedium_DENOM_MediumID_VAR_map_pt_eta.root`
  - Contains **SF for the MultiIso medium WP**. Denominator is MediumID muons
- `TnP_NUM_TightIP2D_DENOM_MediumID_VAR_map_pt_eta.root`
  - Contains **SF for the tight 2-dim IP WP**. Denominator is MediumID muons
- `TnP_NUM_TightIP3D_DENOM_MediumID_VAR_map_pt_eta.root`
  - Contains **SF for the tight 3-dim IP WP**. Denominator is MediumID muons

Tau scale factors

MC Matching

Most corrections depend on the origin of the reconstructed object, e.g. whether it is a true hadronic tau decay, a muon, an electron, or a jet that gives rise to a reconstructed tau. Therefore, we should agree on MC matching recipes early on and make sure this matching information is available for all samples and objects so that the corrections can be applied later on.

The origin of the reconstructed object is taken as the type of gen particle that matches the object most closely in dR. If there is no match within dR<0.2 with any of the first 5 types in the table below, the object is classed as jet/pu fake. The values correspond to those given in the corresponding sync ntuple branches. See these slides for more information.

Value	Type	Gen level object properties
1	Prompt electron	(pdgId=11 or pdgId=-11), pT>8 GeV, status flag IsPrompt
2	Prompt muon	(pdgId=13 or pdgId=-13), pT>8 GeV, status flag IsPrompt
3	$\tau \to e$	(pdgId=11 or pdgId=-11), pT>8 GeV, status flag IsDirectPromptTauDecayProduct
4	$\tau \to \mu$	(pdgId=13 or pdgId=-13), pT>8 GeV, status flag IsDirectPromptTauDecayProduct
5	$\tau \to \tau_h$	Gen-tau jet, rebuilt by summing 4-momenta of visible gen tau decay products, excluding electrons and muons. The pT of the gen tau jet should be >15 GeV. Only consider the decay products of those gen taus that fulfill status flag IsPrompt.
6	jet/pu fake	Anything that doesn't fall in any of the above categories

- **Bad news from the DeepTau SF side**
- For the VSjet discriminator SF we need matching with truth
- **Not enough information** to create "gen hadronic tau" objects (point 5)
- Info about daughters of gen particles is stored in miniAOD only
- **Need to implement this in BSM framework**

Scale factors usage

```
float myEleSF = 1.0;
for (int i = 0; i < myelesMVAT->size(); i++) {

    myEleSF *= EGammaSF->GetBinContent(EGammaSF->FindBin(myelesMVAT->at(i).Eta(),myelesMVAT->at(i).Pt()));
    myEleSF *= SUSYEleIDplusIPSF->GetBinContent(SUSYEleIDplusIPSF->FindBin(myelesMVAT->at(i).Eta(),myelesMVAT->at(i).Pt()));
    myEleSF *= SUSYEleISOSF->GetBinContent(SUSYEleISOSF->FindBin(myelesMVAT->at(i).Eta(),myelesMVAT->at(i).Pt()));
}
if (myEleSF == 0) myEleSF = 1.0;
float myMuSF = 1.0;
for (int i = 0; i < mymuonsT->size(); i++) {

    myMuSF *= MuonIDSF->GetBinContent(MuonIDSF->FindBin(mymuonsT->at(i).Pt(), fabs(mymuonsT->at(i).Eta())));
    myMuSF *= MuonISOSF->GetBinContent(MuonISOSF->FindBin(mymuonsT->at(i).Pt(), fabs(mymuonsT->at(i).Eta())));
    myMuSF *= MuonIP2DSF->GetBinContent(MuonIP2DSF->FindBin(mymuonsT->at(i).Pt(), fabs(mymuonsT->at(i).Eta())));
    myMuSF *= MuonIP3DSF->GetBinContent(MuonIP3DSF->FindBin(mymuonsT->at(i).Pt(), fabs(mymuonsT->at(i).Eta())));

}
if (myMuSF == 0) myMuSF = 1.0;
```

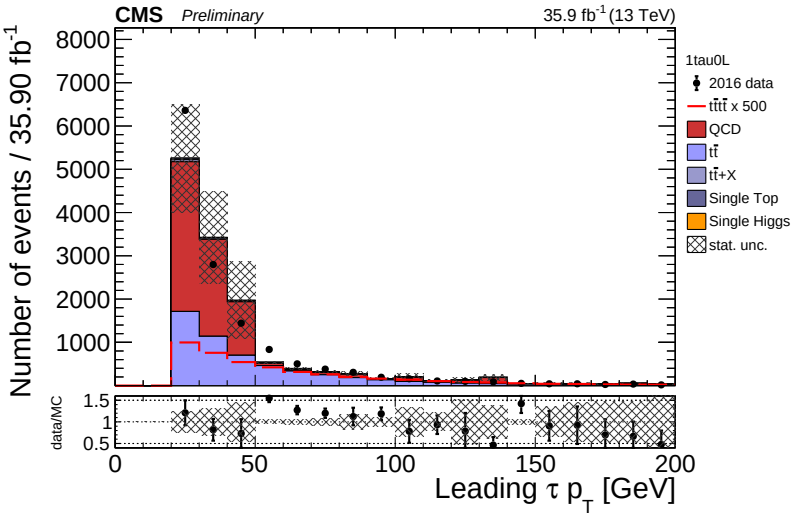
- Usage is actually very simple
- Have to check what to do when p_T or η out of range

Data/MC agreement plots

1tau0L

Data events: 13693
signal events: 8.78554
ttbar events: 5389.6
QCD events: 7679
tt+X events: 171.034
single top events: 111.117
single Higgs events: -0.292551
total MC events: 13350.5
data/MC agreement: 2.56573%

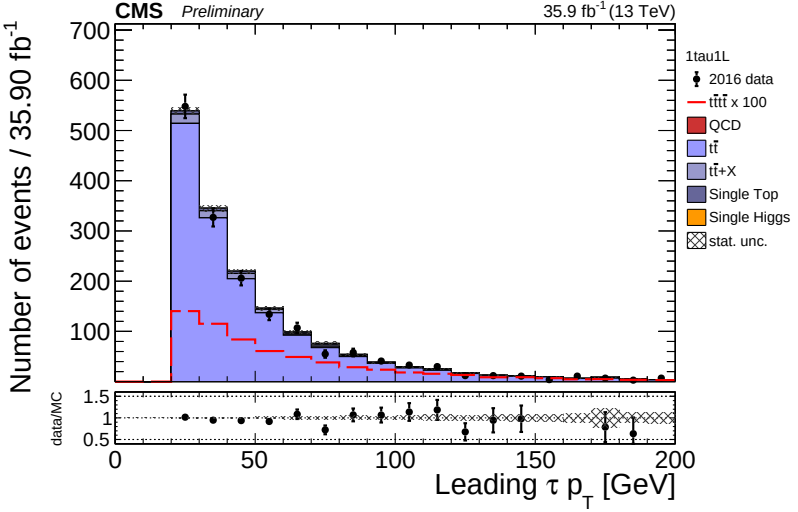
Data/MC agreement



1tau1L

Data events: 1633
signal events: 6.46899
ttbar events: 1570.35
QCD events: 2.20767
tt+X events: 73.3412
single top events: 31.7227
single Higgs events: 0.029302
total MC events: 1677.65
data/MC agreement: -2.66172% (previously: -6.0947%)

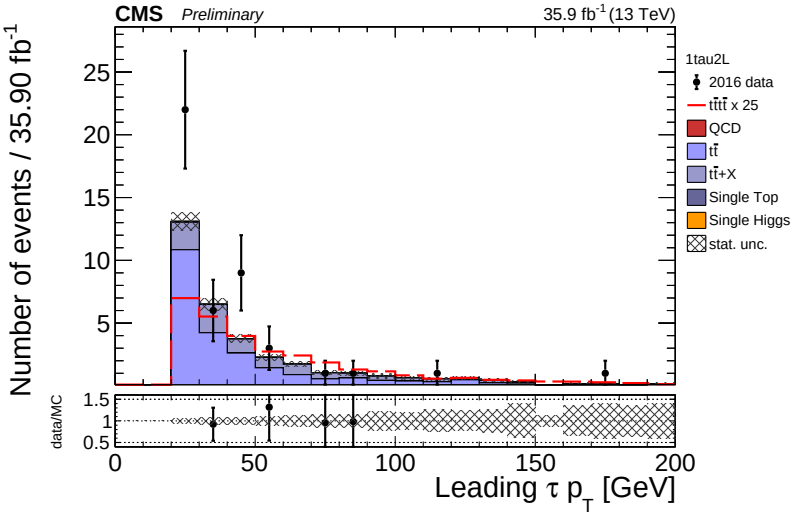
Data/MC agreement



1tau2L

Data events: 44
signal events: 1.24755
ttbar events: 24.4849
QCD events: 0
tt+X events: 9.98816
single top events: 0.216959
single Higgs events: 0.00010434
total MC events: 34.6901
data/MC agreement: 26.8374% (previously: 18.4015%)

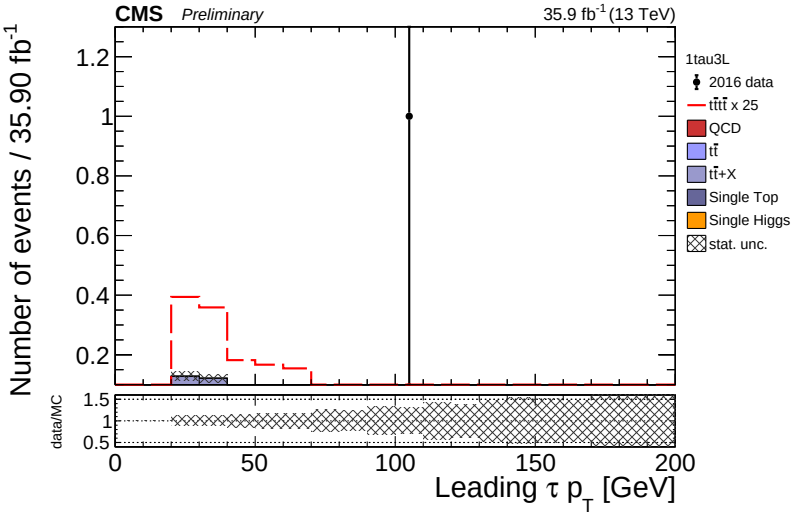
Data/MC agreement



1tau3L

Data events: 1
signal events: 0.0711158
ttbar events: 0
QCD events: 0
tt+X events: 0.56731
single top events: 0.00224964
single Higgs events: 0
total MC events: 0.56956
data/MC agreement: 75.5741%

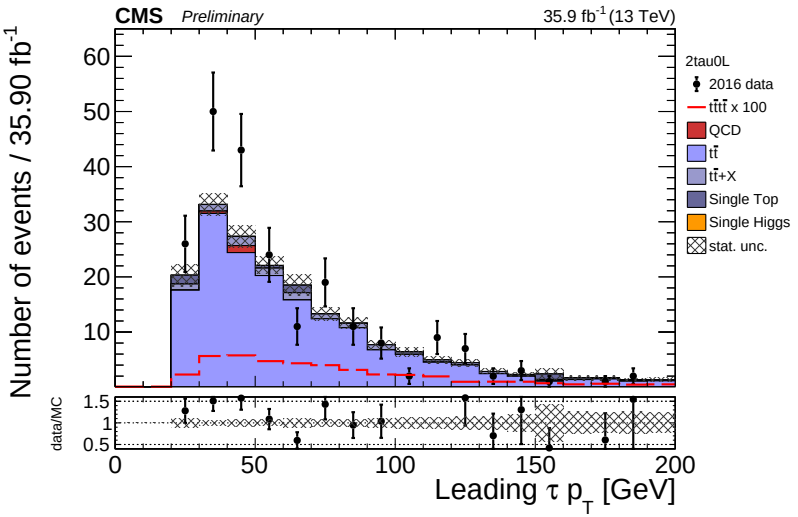
Data/MC agreement



2tau0L

Data events: 225
signal events: 0.441411
ttbar events: 168.271
QCD events: 1.70299
tt+X events: 13.0018
single top events: 6.33067
single Higgs events: 0.0157843
total MC events: 189.323
data/MC agreement: 18.8447%

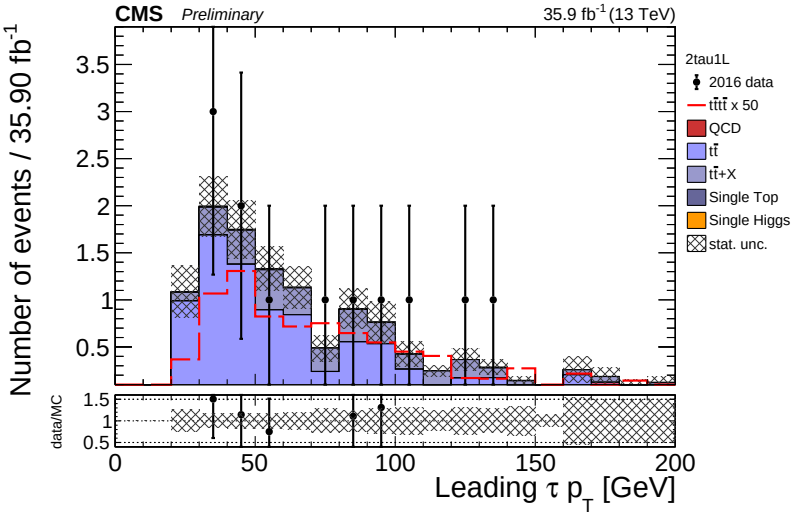
Data/MC agreement



2tau1L

Data events: 13
signal events: 0.174785
ttbar events: 8.63095
QCD events: 0
tt+X events: 3.65918
single top events: 0.0758465
single Higgs events: 0
total MC events: 12.366
data/MC agreement: 5.12715%

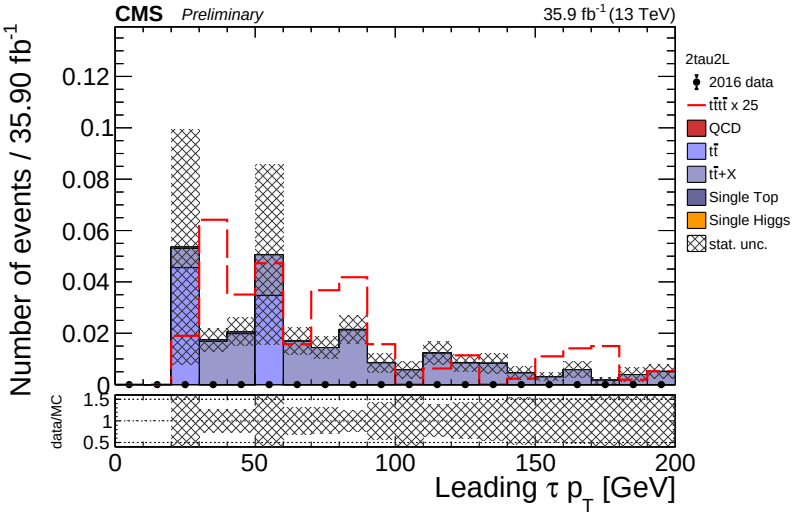
Data/MC agreement



2tau2L

Data events: 0
signal events: 0.0147807
ttbar events: 0.0802532
QCD events: 0
tt+X events: 0.196236
single top events: 0.00222102
single Higgs events: 0
total MC events: 0.27871
data/MC agreement: -100%

Data/MC agreement

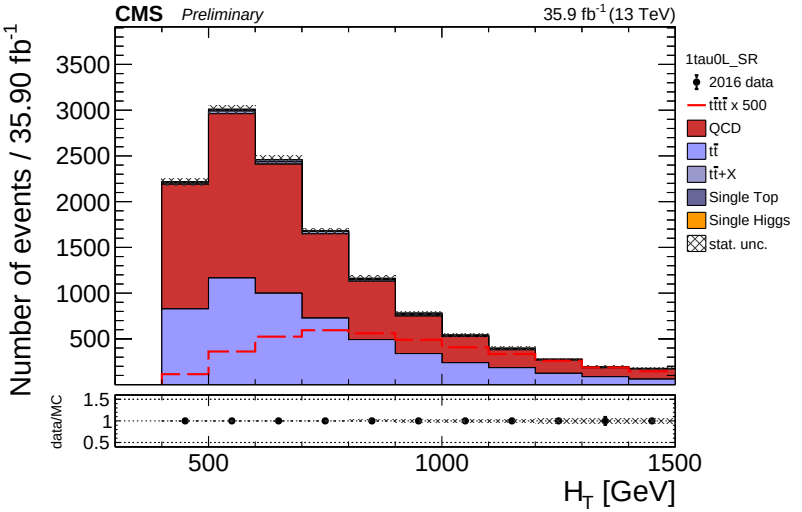


H_T distributions

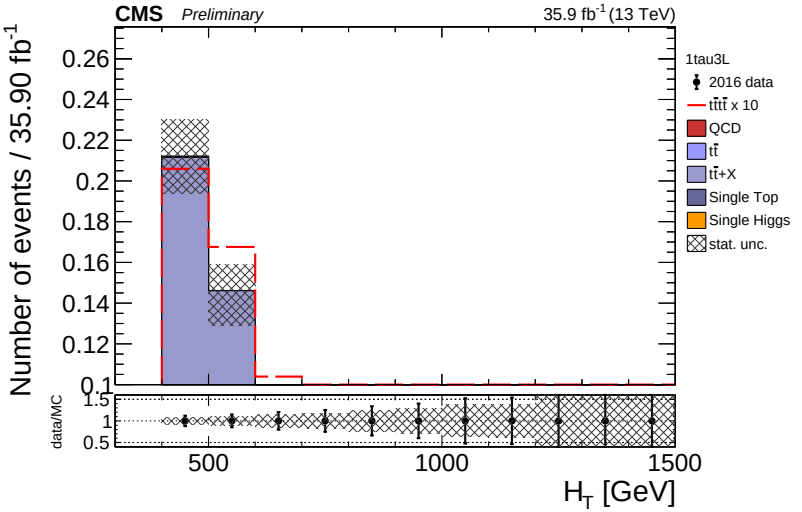
H_T distributions

- For categories in which we don't have a BDT, check H_T distributions
- **Do they discriminate between signal and background?**

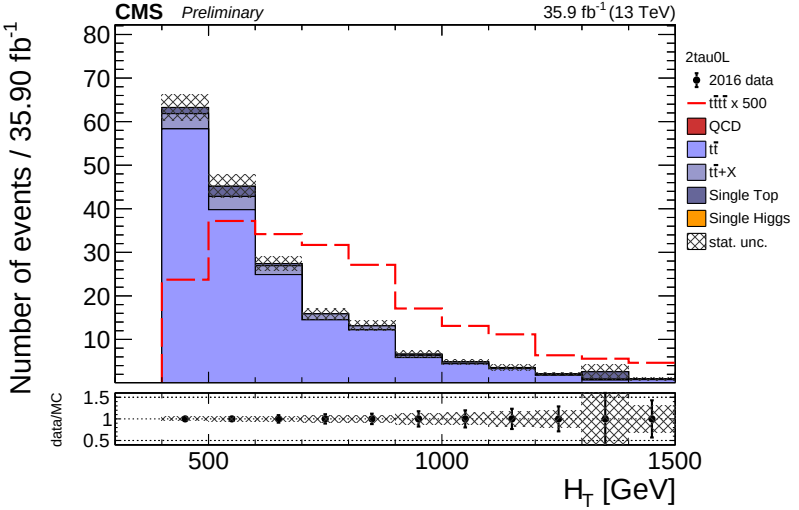
H_T distributions



H_T distributions



H_T distributions



H_T distributions