Systematic Uncertainty Study Part2(2017)

Four top

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Outline

Section 1

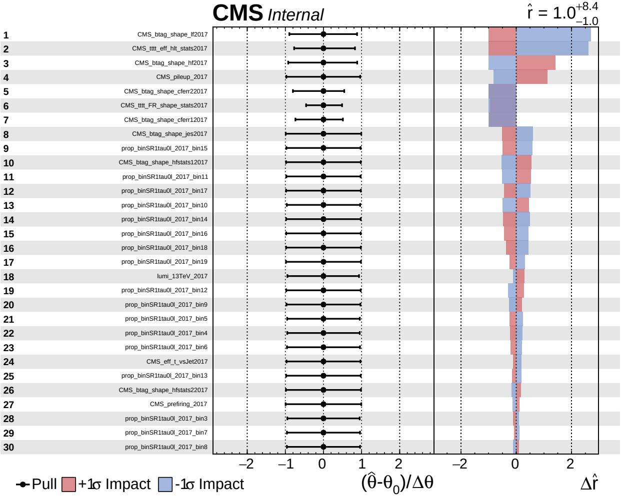
1tau0l

Fake rate uncertainty(1tau0l)

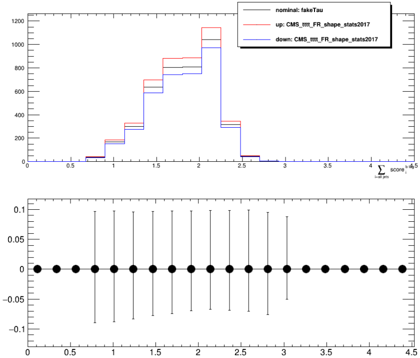
- Should we implement FR uncertainty as shape of lnN?
- FR uncertainties
  - Statistical
  - Systematic: 10% on FR
- FR uncertainty calculation
  - fake rate weight for data: $W_{FR} = \frac{FR}{1-FR}$
  - $\sigma^2(W_{FR}) = (\frac{dW}{dFR})^2 \times \sigma^2(FR) = \frac{1}{(1-FR)^4} \times \sigma^2(FR)$
  - $W \pm \sigma(W) = \frac{FR}{1-FR} \pm \frac{\sigma(FR)}{(1-FR)^2}$
  - Vary the fake rate event weight in the above way to get the up and down shape of fake tau caused by FR measurement

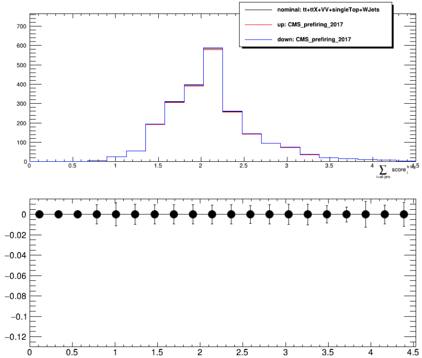
Results and impacts for 1tau0l

- Expected significance: 0.13
- Expected limit: 18.13

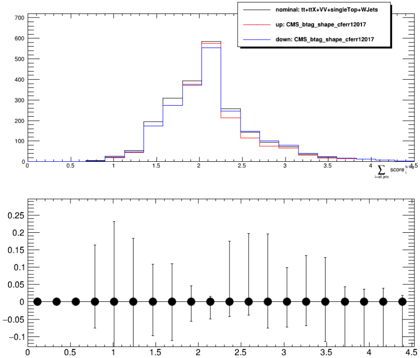


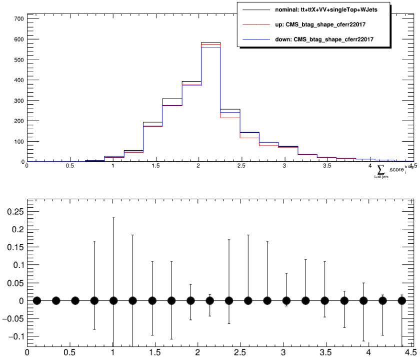
Uncertainty in event yield



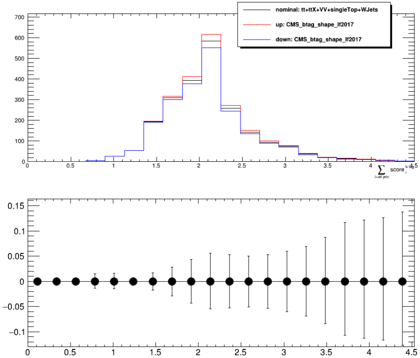


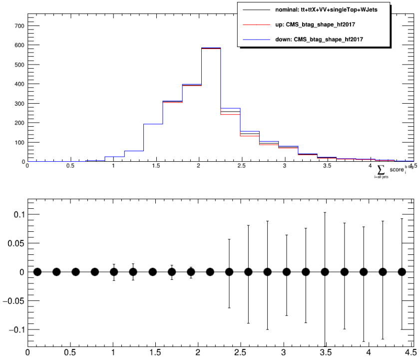
Uncertainty in event yield



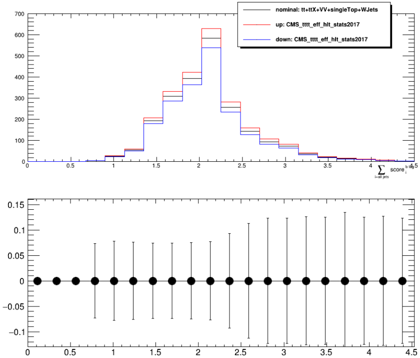


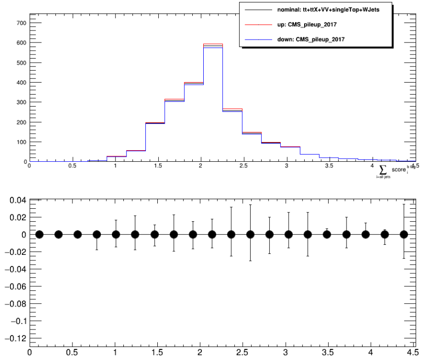
Uncertainty in event yield



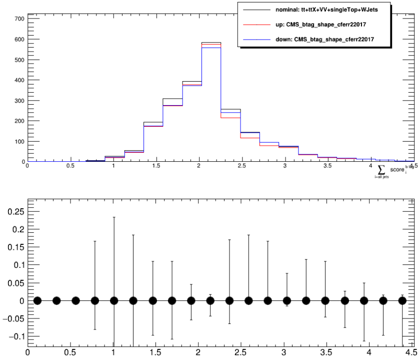


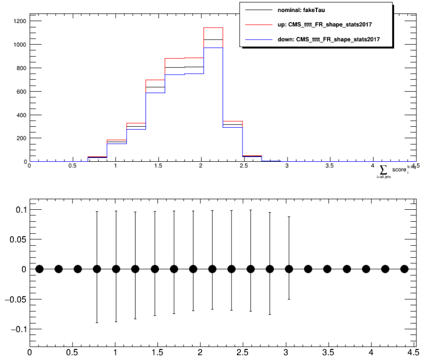
Uncertainty in event yield





Uncertainty in event yield





Datacard

```
imax * number of bins
jmax * number of processes minus 1
kmax * number of nuisance parameters
------------------------------------------------------------------------------------------------------------------------
shapes *   SR1tau0l_2017  /publicfs/cms/user/huahuil/tauOfTTTT_NanoAOD/forMVA/2017/v0baselineAddMoreSys_v58addGenBranches/mc/variableHists_v41tau0lGenTauSys/comb
------------------------------------------------------------------------------------------------------------------------
bin          SR1tau0l_2017
observation  -1
------------------------------------------------------------------------------------------------------------------------
bin         SR1tau0l_2017  SR1tau0l_2017  SR1tau0l_2017  SR1tau0l_2017      SR1tau0l_2017 SR1tau0l_2017 SR1tau0l_2017
process      tttt           singleTop      tt             ttX                VV            WJets         fakeTau
process      0              1              2              3                  4             5              6
rate         -1             -1             -1             -1                 -1     -1     -1
------------------------------------------------------------------------------------------------------------------------
lumi_13TeV_2017 lnN        1.023      1.023        1.023         1.023      1.023  1.023    1.023
CMS_pileup_2017 shape      1          1            1             1          1       1        -
CMS_prefiring_2017 shape   1          1            1             1          1       1        -
CMS_eff_t_vsJet2017 shape  1          1            1             1          1       1        -
CMS_eff_t_vsMu2017 shape  1          1            1             1          1       1        -
CMS_eff_t_vsEle2017 shape  1          1            1             1          1       1        -
CMS_tttt_eff_e_2017 shape  1          1            1             1          1       1        -
CMS_tttt_eff_m_2017 shape  1          1            1             1          1       1        -
CMS_btag_shape_jes2017 shape  1          1            1             1       1       1        -
CMS_btag_shape_hf2017 shape  1          1            1             1        1       1        -
CMS_btag_shape_lf2017 shape  1          1            1             1        1       1        -
CMS_btag_shape_hfstats12017 shape  1          1            1             1 1       1        -
CMS_btag_shape_hfstats22017 shape  1          1            1             1 1       1        -
CMS_btag_shape_lfstats12017 shape  1          1            1             1 1       1       -
CMS_btag_shape_lfstats22017 shape  1          1            1             1 1       1       -
CMS_btag_shape_cferr12017 shape  1          1            1             1   1       1       -
CMS_btag_shape_cferr22017 shape  1          1            1             1   1       1       -
CMS_tttt_eff_hlt_stats2017 shape  1          1            1             1  1       1       -
CMS_tttt_FR_shape_stats2017 shape    -          -            -             -  -       -       1
------------------------------------------------------------------------------------------------------------------------
SR1tau0l_2017 autoMCStats 10 0 1
```

Section 2

1tau1l

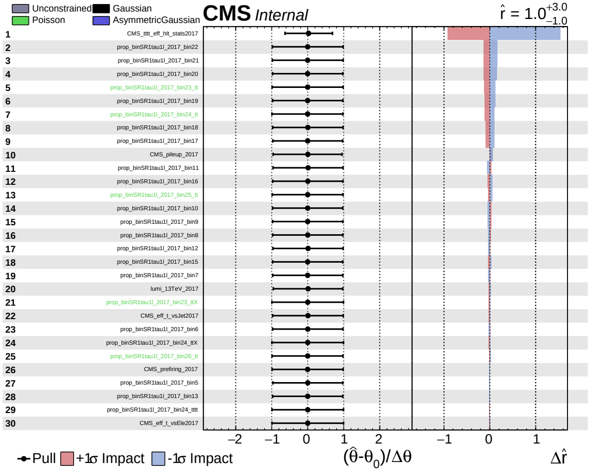
Update

- Drop b tag shape in BDT input list
- Add btag working point variables: bjetsT_HT, bjetsT_num, bjetM_num
- can we remove bjetsT variables?
- Have to measure b tag efficiency ourselves if use WP
  https://twiki.cern.ch/twiki/bin/viewauth/CMS/BTagSFMethods

Rank	Variable	Variable Importance
1	bjetsM_minDeltaR	7.904e-02
2	jets_average_deltaR	7.201e-02
3	tausT_leptonsT_invariantMass	6.922e-02
4	jets_rationHT_4toRest	6.724e-02
5	bjetsM_invariantMass	6.277e-02
6	jets_transMass	6.130e-02
7	jets_7pt	5.859e-02
8	jets_5pt	5.726e-02
9	bjetsT_HT	5.726e-02
10	bjetsM_num	5.725e-02
11	tausT_1pt	5.501e-02
12	bjetsT_num	5.498e-02
13	jets_6pt	5.489e-02
14	jets_number	5.436e-02
15	bjetsM_2pt	5.355e-02
16	bjetsM_HT	5.074e-02
17	tausT_leptonsTopMVA_chargeMulti	3.452e-02

Results and impacts for 1tau1l

- Without b tag WP uncertainty
- Expected significance: 0.48
- Expected limit: 6.28



Section 3

Systematic uncertainties

Systematic uncertainties

- Theoretical uncertainties
  - QCD scale variations and PDF
  - ISR, FSR
  - how to get them???
- Experimental uncertainties
  - Luminosity(✓)
  - Pileup reweighting(✓)
  - Trigger efficiency(✓)
  - Lepton reconstruction & identification(✓); lepton energy scale
  - Hardronic tau identification (✓); tau energy scale
  - B-tag shape correction(✓)
  - JES and JER
  - Fake rate uncertainty(only 1tau0l) (✓)
- https://twiki.cern.ch/twiki/bin/view/CMS/TopSystematics

Intergrated luminosity(log uncertainty)

- 1.2%(36.31), 2.3%(41.48), 2.5% (59.83)
- Correlation?
- https://twiki.cern.ch/twiki/bin/view/CMS/LumiRecommendationsRun2

Pileup reweighting(shape)

- Centrally provided weight files both for the nominal weights of the simulated samples, as well as to generate the varied distributions according to the cross section uncertainty(4.5% on 69.2 mb)

Prefiring(shape)

- Implementation
- Available in NanoAOD

HLT uncertainty

- SF measured ourselves
- Statistical uncertainty:
  - uncertainty calculated by root, may be undercoverage for low statistic bins
- Systematic uncertainty: not considered yet

Leptons: Efficiency of lepton, energe scale(shape)

- Efficiency SF and systematic variation provided by TOP MVA
- Energy scale

B tag shape uncertainties(shape)

- B tag weight = btag_shapeWeight* R
- btag_shape weight: provided by BTV group
  - JES
  - Purity: Vary the contamination from udsg+c (b+c) jets in heavy (light) flavor regions by $\pm 20\%$
  - Statistical:
  - Charm Jets
- R: measured ourselves
- Should we add add the uncertainty of R or not? and why?
- First attempt: only add btag_shape weight uncertainty
- Correlation across years:
- https://twiki.cern.ch/twiki/bin/view/CMS/BTagShapeCalibration

Jet: JES and JER

- JES: SF already applied in NanoAOD v9, systematic SF fetching ourselves
- JER: implemented ourselves

Section 4

Back up

Uncertainties in combine

- Log normal uncertainties
- Shape uncertainties
  - shapes will be interpolated with a 6th order polynomial for shifts below 1 σ and linearly beyond
  - normalizations are interpolated linearly in log scale just like we do for log-normal uncertainties

Datacard

- Following convention: https://twiki.cern.ch/twiki/bin/viewauth/CMS/HiggsWG/HiggsCombinationConventions

```
imax * number of bins
jmax * number of processes minus 1
kmax 6 number of nuisance parameters
------------------------------------------------------------------------------------------------------------------------------------
shapes *   SR1tau1l_2017  /publicfs/cms/user/huahuil/tauOfTTTT_NanoAOD/forMVA/2017/v4baselineBtagRUpdated_v57ovelapWithTausF/mc/variableHists_v1sysVariation1tau1l/combine/templatesForCombine1tau1l.root $PROCESS_SR_BDT $PROCESS_$SYSTEMATIC_BDT
------------------------------------------------------------------------------------------------------------------------------------
bin          SR1tau1l_2017
observation  -1
------------------------------------------------------------------------------------------------------------------------------------
bin          SR1tau1l_2017  SR1tau1l_2017  SR1tau1l_2017  SR1tau1l_2017
process       tttt           singleTop      tt             ttX
process       0              1              2              3
rate          -1             -1             -1             -1
------------------------------------------------------------------------------------------------------------------------------------
lumi_13TeV_2017 lnN        1.023      1.023        1.023         1.023
CMS_pileup_2017 shape      1          1            1             1
CMS_prefiring_2017 shape   1          1            1             1
CMS_eff_t_vsJet2017 shape  1          1            1             1
CMS_tttt_eff_e_2017 shape  1          1            1             1
CMS_tttt_eff_m_2017 shape  1          1            1             1
------------------------------------------------------------------------------------------------------------------------------------
SR1tau1l_2017 autoMCStats 10 0 1
```

Section 5

Impact

Impact plot

- "impact" of each uncertainty
  - $\Delta\mu$: $\theta_i^{postfit} \pm 1\sigma$, other θ the default pre fit value
  - the shift in the signal strength, with respect to the best-fit, that is induced if a given nuisance parameter is shifted by its ±1σ post-fit uncertainty values. with all other parameters profiled as normal
  - Effectively a measure of the correlation between the NP and the POI, useful for determining which NPs have the largest effect on the POI uncertainty
- $(\widehat{\theta} - \theta_I)/\sigma_I(thepull)$
  - there are other ways to define the pulls
  - where θ and θ_0 are the post and pre-fit values of the nuisance parameter and $\delta\theta$is the pre-fit uncertainty
  - $(\widehat{\theta} - \theta_I)/\sigma_I$ is the error bar, $\widehat{\theta} - \theta_I$ is the central value I think
  - symmetric error bars show the post-fit uncertainty divided by the pre-fit uncertainty meaning that parameters with error bars smaller than $\pm1\sigma$re constrained in the fit.

Understand impacts and pulls

- How to interpretate the pull?
- How to connect the impact to the uncertainty of significance?

calculate impact with combine

- combineTool.py -M Impacts -d workspace_part3.root -m 200 –rMin -1 –rMax 2 –robustFit 1 –doInitialFit
  - perform an initial fit for the signal strength and its uncertainty
  - I guess for fit for μ here, NP is kept as normal, no fit to NP here
- combineTool.py -M Impacts -d workspace_part3.root -m 200 –rMin -1 –rMax 2 –robustFit 1 –doFits
  - run the impacts for all the nuisance parameters
  - Fit for each NP, vary and then fit for μ
  - When fit for each NP, is other NP and μ profiled as normal? I guess yes
- combineTool.py -M Impacts -d workspace_part3.root -m 200 –rMin -1 –rMax 2 –robustFit 1 –output impacts.json
  - collect all the output and convert it to a json file
- plotImpacts.py -i impacts.json -o impacts
- How to be blind? the data_obs is actually MC(s+b)
- http://cms-analysis.github.io/HiggsAnalysis-CombinedLimit/part3/nonstandard/#nuisance-parameter-impacts

Questions

- What should be our binning strategy and why?
  - Maybe group low statistic bins together because the best result is a tradeoff between statistic uncertainty and systematic uncertainties
- Should we group the subprocesses together or not?
  - When add subprocesses, the uncertainty is recalculated for each bin using error propagation formula, this could be problematic
- How to treat correlated and uncorrelated uncertainties?
- Correlation of impacts and significance
  - The high correlation of impacts doesn’t neccesarily mean the it will impact significance
- Why no uncertainty of significance

Questions

- How the b tag shape SF and systematic uncertainty is measured

How to do systematic study?

- Expected significance and limit after considering systematic uncertainties
  - How does them change and why?
- Impact plot
- https://twiki.cern.ch/twiki/bin/view/CMS/TopSystematics

Look elsewhere effect