

Overview of the Top FC Analysis

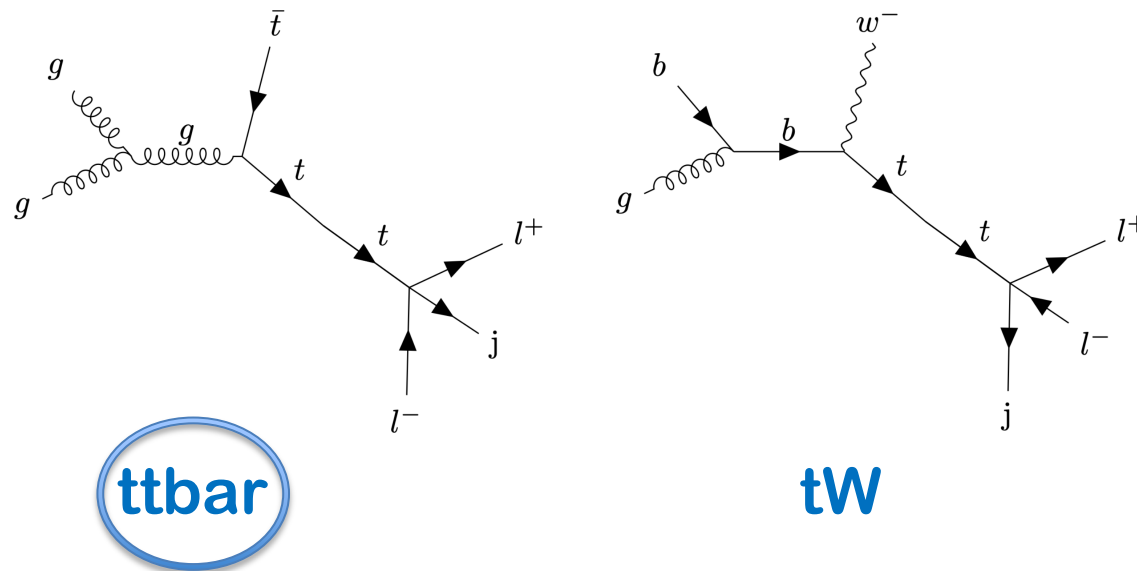
Meisam Ghasemi

Weekly meeting
2022-12-24



Flavor Changing in Top sector

In this analysis we looking for FC ($t \rightarrow u$ or $t \rightarrow c$) in top sector as the heaviest quark which may be an indicator of new flavor physics.



- Starting with **ttbar**, targeting **final states** with three leptons (a pair of OP) and a b-tagged jet (one of the tops decays leptonically via $w \rightarrow l \nu_l$)
- There are **at least** two jets – other jets might come from showering
- Presence of several charged leptons allows an efficient lepton trigger
- The leading potential backgrounds are tZ , $t\bar{t}W$, $t\bar{t}Z$, $t\bar{t}t\bar{t}$, WZ , ZZ

Analysis links

- Useful analysis links:
 - [Paper](#)
 - [Feynrules models](#): includes all the model parameters and interactions
 - [Github repo](#): includes all the analysis code from production to statistical fits

The screenshot shows a GitHub repository page for 'mgghasemi19'. The repository is titled 'Add all SM backgrounds prod' and has 17fa79a commit 2 days ago with 39 commits. The file list includes BDT_weight, FeynDiagrams, NTuple_prod, sources, util, .DS_Store, and README.md. The README is titled 'Top Flavor Changing' and describes the analysis of Flavor-Changing Neutral Currents (FCNC) of top quark. It mentions the signal of FCNC effects in the top sector and the consideration of di-lepton and tri-lepton signals. Two Feynman diagrams are shown: one for top quark production via gluon fusion and decay into a lepton pair and a jet, and another for top quark production via gluon fusion and decay into a lepton pair and a jet with a W boson. The main backgrounds in the SM are listed as single-top production in association with a gauge-boson such as Z or W boson.

Top Flavor Changing

In this analysis, we will look for Flavor-Changing Neutral Currents of top quark such as $t \rightarrow u$ or $t \rightarrow c$ which is absent at tree-level in the Standard model. The signal of FCNC effects in the top sector may be an indicator of new flavor physics beyond the Standard Model. We will consider the di-lepton and tri-lepton signals with a pair of opposite-sign same-flavor (OSSF) leptons, where a selection of a single b -tagged jet is used with the last equation and, in general $l = e, \mu$ or τ , and $l' = l$ and/or $l' \neq l$ can be considered in the tri-lepton channels.

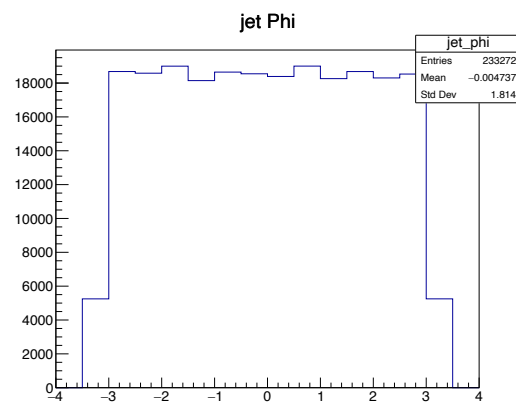
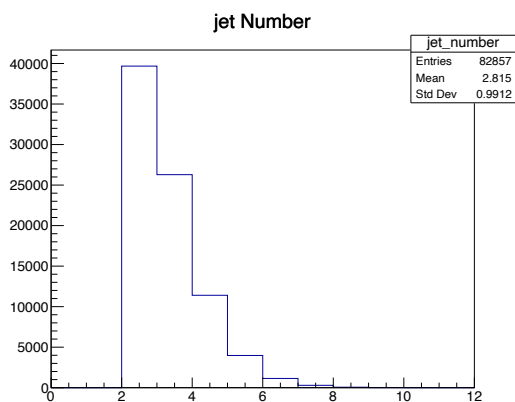
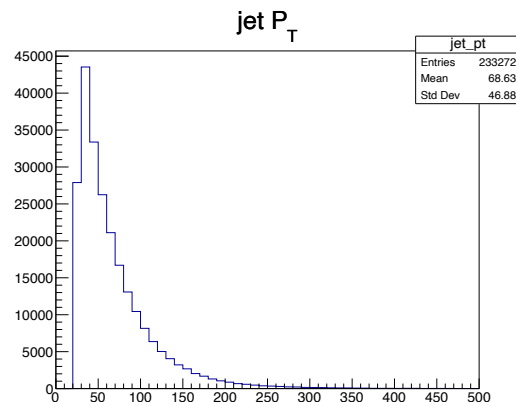
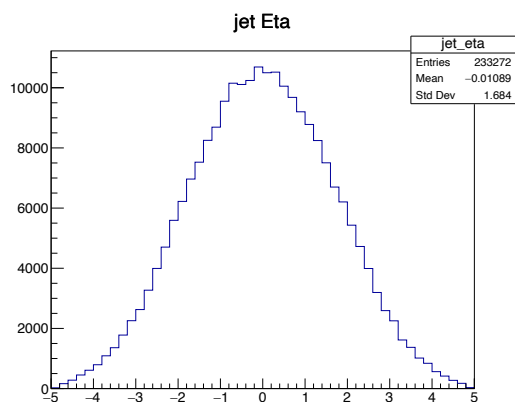
The main backgrounds in the SM for this analysis are:

- single-top production in association with a gauge-boson such as Z or W boson (in W boson case there should

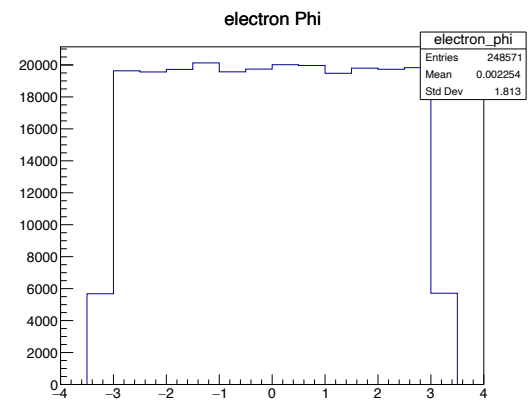
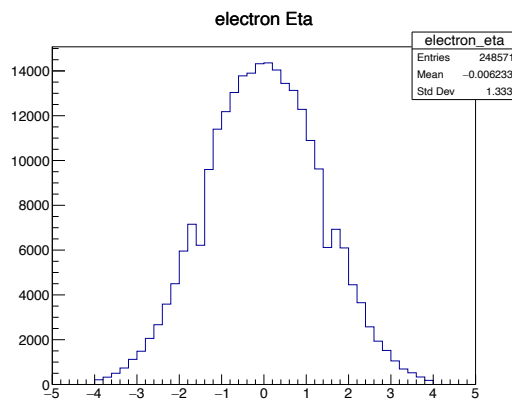
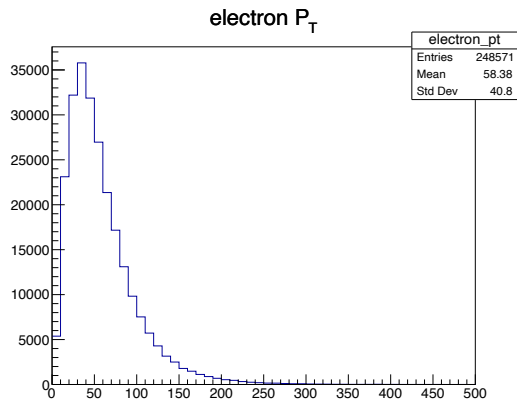
Signal generation and preselection

- Signal events are generated with MG5 (for ME) + PYTHIA (for PS and HAD) + Delphes (for HLLHC card detection). almost 3M events for both charm and up signals.
- To generate signal events, set 5 flavor scheme, all coupling to 1 (scalar-, vector-, and tensor-like), and NP scale to 1 TeV.
- The preselections applied:
 1. exactly 3 leptons (for now just electrons) with one pair of OS
 2. At least 2-jets with one b-tagged jet
 3. no minimum cuts on jet's P_T or lepton's P_T . Might be useful to have it!
 4. no lepton trigger at this level

Signal jet distributions

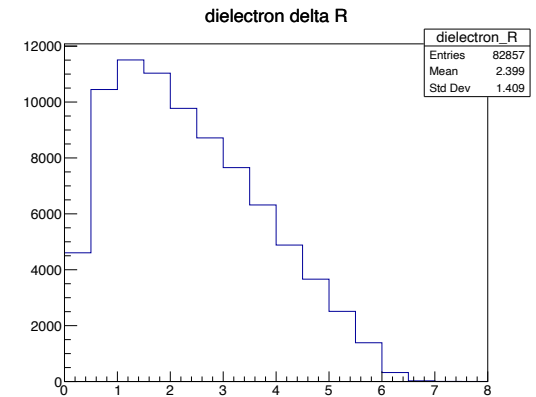
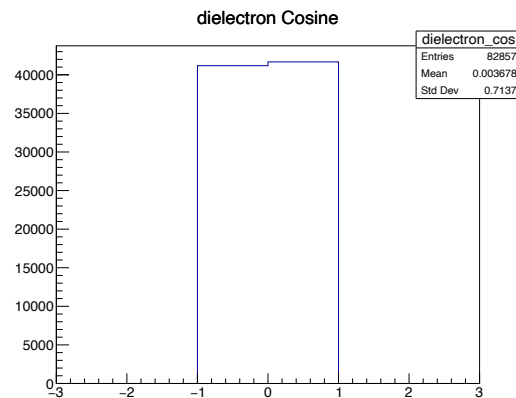
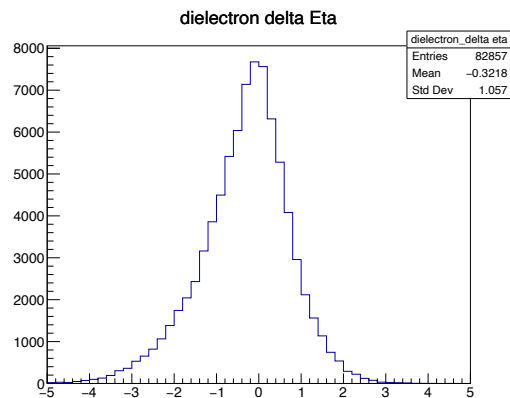


Signal lepton distributions



Signal Di-lepton distributions

- Two electrons with opposite sign and minimum $\Delta\eta$ are selected to reconstruct the FC top. The other electron and MET branch are used to reconstruct the W-boson and top mass.
- Can we change the electron selection by looking at $\Delta(M_{llq} - m_{top})$. I will consider this as an alternative.

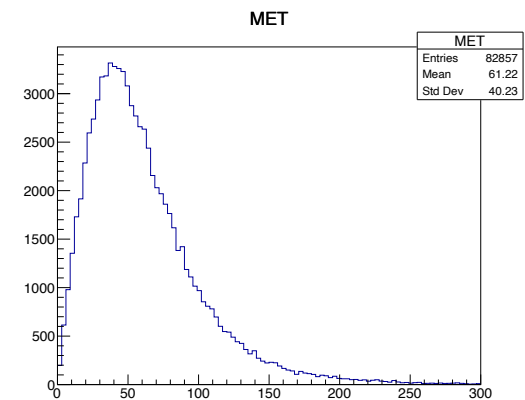
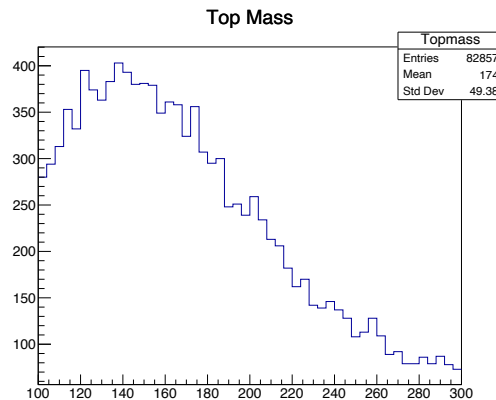
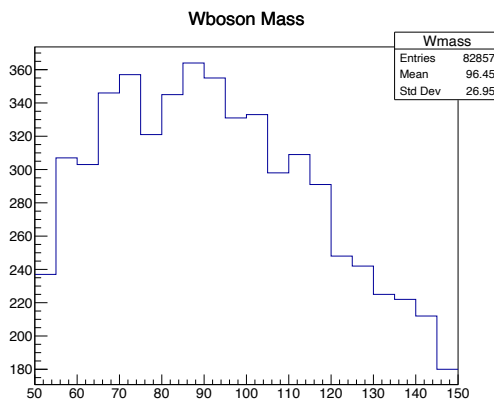


Top and W boson mass distributions

The isolated electron and MET branch are used to reconstruct the W boson. (code below)

```
met = branchMET.At(0)
histMET.Fill(met.MET)
met_vec = ROOT.TLorentzVector()
elec_vec = ROOT.TLorentzVector()
bjet_vec = ROOT.TLorentzVector()
met_vec.SetPtEtaPhiE(met.MET, met.Eta, met.Phi, met.MET)
elec_ET = ROOT.TMath.Sqrt(branchElectron.At(index[0]).PT**2 + 0.005**2)
#elec_vec.SetPtEtaPhiE(branchElectron.At(index[0]).PT, branchElectron.At(index[0]).Eta, branchElectron.At(index[0]).Phi, bra
nchElectron.At(index[0]).PT)
elec_vec.SetPtEtaPhiE(branchElectron.At(index[0]).PT, branchElectron.At(index[0]).Eta,
branchElectron.At(index[0]).Phi, elec_ET)
bjet_ET = ROOT.TMath.Sqrt(branchJet.At(bjet_index).PT**2 + 4.67**2)
bjet_vec.SetPtEtaPhiE(branchJet.At(bjet_index).PT, branchJet.At(bjet_index).Eta, branchJet.At(bjet_index).Phi, bjet_ET)
W_vec = met_vec + elec_vec
top_vec = met_vec + elec_vec + bjet_vec

mW = W_vec.Mt()
mTop = top_vec.Mt()
```

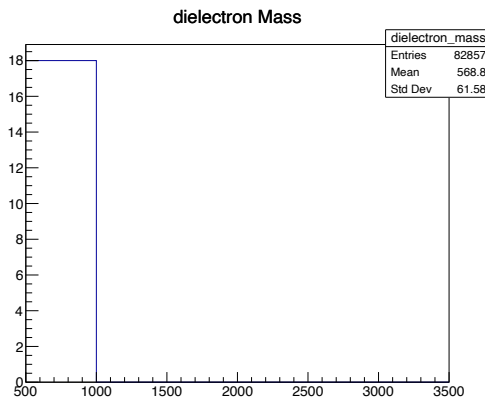


Di-lepton mass distributions

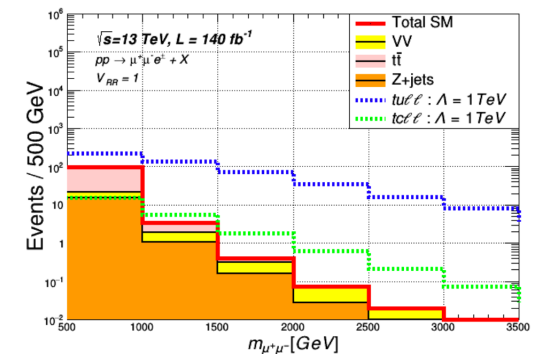
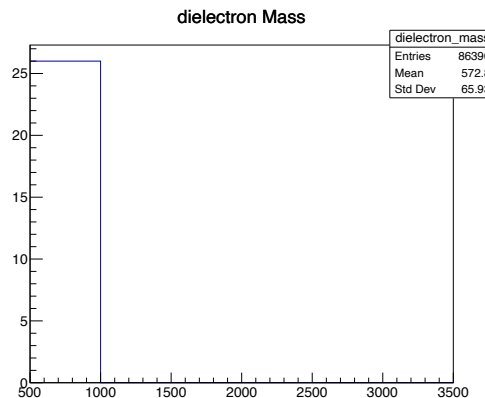
m_{ll} distribution coming from OS leptons with minimum $\Delta\eta$

```
elec_first_vec = ROOT.TLorentzVector()
elec_first_ET = ROOT.TMath.Sqrt(branchElectron.At(index[1]).PT**2 + 0.005**2)
elec_second_vec = ROOT.TLorentzVector()
elec_second_ET = ROOT.TMath.Sqrt(branchElectron.At(index[-1]).PT**2 + 0.005**2)
elec_first_vec.SetPtEtaPhiE(branchElectron.At(index[1]).PT, branchElectron.At(index[1]).Eta,
branchElectron.At(index[1]).Phi, elec_first_ET)
elec_second_vec.SetPtEtaPhiE(branchElectron.At(index[-1]).PT, branchElectron.At(index[-1]).Eta,
branchElectron.At(index[-1]).Phi, elec_second_ET)
mLL = (elec_first_vec + elec_second_vec).Mt()
histdiElectronMass.Fill(mLL)
```

Signal charm



Signal up



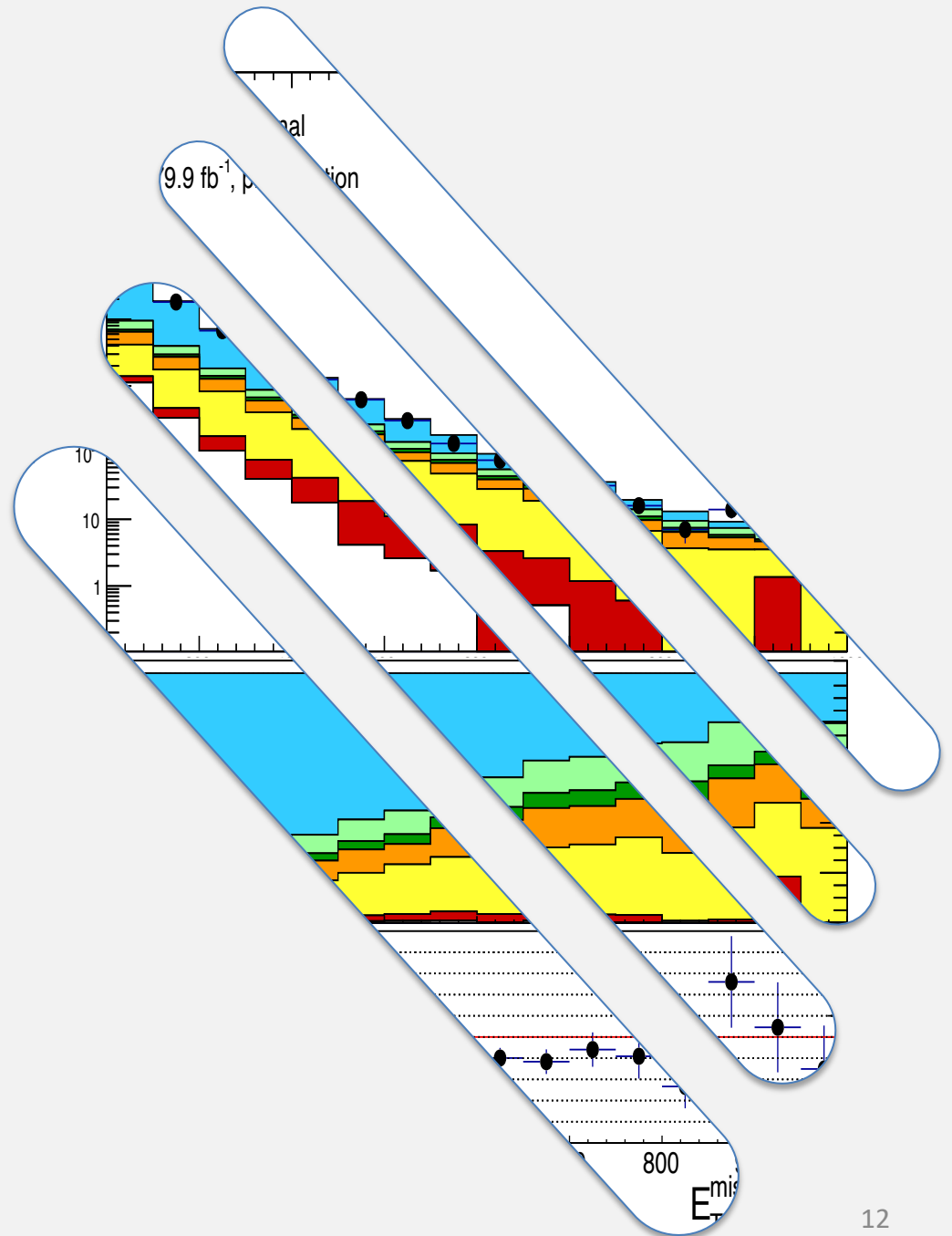
Few points to double check

- Are we happy with
 1. preselection
 - is it ok to start with just electrons and add muons later?
 - need to apply minimum P_T cut on final objects?
 - what kind of trigger need to be passed?
 2. analysis Hist production [code](#)
 - now it includes event-loop and bunch of Hist filling. At the end might be better to have final trees with object variables as branches (nearly done [code](#)).
 3. variable distributions
 - m_{top} looks fine but m_W needs more optimization. Any brilliant ideas on this ☺?
 - m_{ll} looks terrible!

Summary & ongoing

- Signal events generation is almost done. First round of analysis variables are added to the Git repo but some more optimizations are needed to get better distributions.
- Last week, starts background generation while it goes so slow cause of CPU limitation.
- Analysis tree production with important variables are nearly done [code](#). Got some issues with dynamic size array which is solved by the help from [Root forum](#) guys.
- At some point, need to discuss about the trigger to be passed on.
- Made a presentation with IPM affiliation on NLP usage in HEP ([poster](#) and [slides](#)). With NLP we can train ATLAS and CMS papers to get useful predictions on DM.
- Finished postdoc application – Just Albert, Michel Lefebvre (from UVic), and Max Swiatlowski from (CERN-triumf) sent recommendation letters.
- Your feedback is welcome and appreciated.

Backup



Definition of Key Variables

$\Delta\phi_{\min}^{4j}$ to suppress multijets in which E_T^{miss} is aligned with one jet:

$$\Delta\phi_{\min}^{4j} = \min(|\phi_1 - \phi_{E_T^{miss}}|, \dots, |\phi_4 - \phi_{E_T^{miss}}|)$$

Inclusive effective mass, to select highly energetic events:

$$m_{eff}^{incl} = \sum_{i \leq n} p_T^{ji} + \sum_{j \leq m} p_T^{lepj} + E_T^{miss}$$

m_T to remove semileptonic $t\bar{t}$ and W+jets events (region ≥ 1 lepton) :

$$m_T = \sqrt{2p_T^l E_T^{miss} (1 - \cos \Delta\phi(\vec{p}_T^{miss}, \vec{p}_T^l))}$$

$m_{T,min}^{b-jets}$ min transverse mass between E_T^{miss} and three leading b-jets:

$$m_{T,min}^{b-jets} = \min_{i \leq 3} \left(\sqrt{2p_T^{b-jeti} E_T^{miss} \left(1 - \cos \Delta\phi \left(\vec{p}_T^{miss}, \vec{p}_T^{b-jeti} \right) \right)} \right)$$

$M_J^{\Sigma,4}$ sum of the mass of re-clustered jets (higher for Gtt signal):

$$M_J^{\Sigma,4} = \sum_{i \leq 4} m_{J,i}$$

Poster

وزارت علوم، تحقیقات و فناوری
گروه کامپیوتر دانشگاه دانشگاه علم و فرهنگ به مناسبت هفته پژوهش برگزار می‌کند:

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<http://live3.usc.ac.ir/room4000>

Signal-up distributions

