# Measurement of Normalized Differential Cross Section for the ttbar Production in the Dilepton Channel in pp Collisions at a center-of-mass energy of 13 TeV

Dajeong Jeon (University of Seoul)
on behalf of CMS Collaboration

# Introduction

Normalized differential cross sections for top quark pair production are measured in the dilepton (electron or muon) decay channel in proton-proton collisions at a center-of-mass energy of 13 TeV. The measurement is performed at particle level.

▪ Analysis Goal
*Measure TTbar cross section as a function of kinematic properties of leptons, bjets and top quarks in particle level.*

# Analysis Channel

- ▪ What does Particle level mean?
  pseudo top is reconstructed
  using best combination of particle
  level objects.
  defined signal at the generator
  level using pseudo top objects.



Parton level   π, K, ...

q, g

p

Particle Jet   Energy depositions
in calorimeters

p



**TTbar**
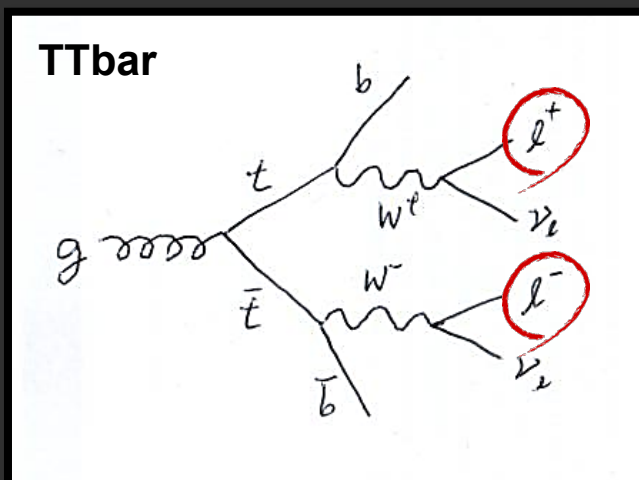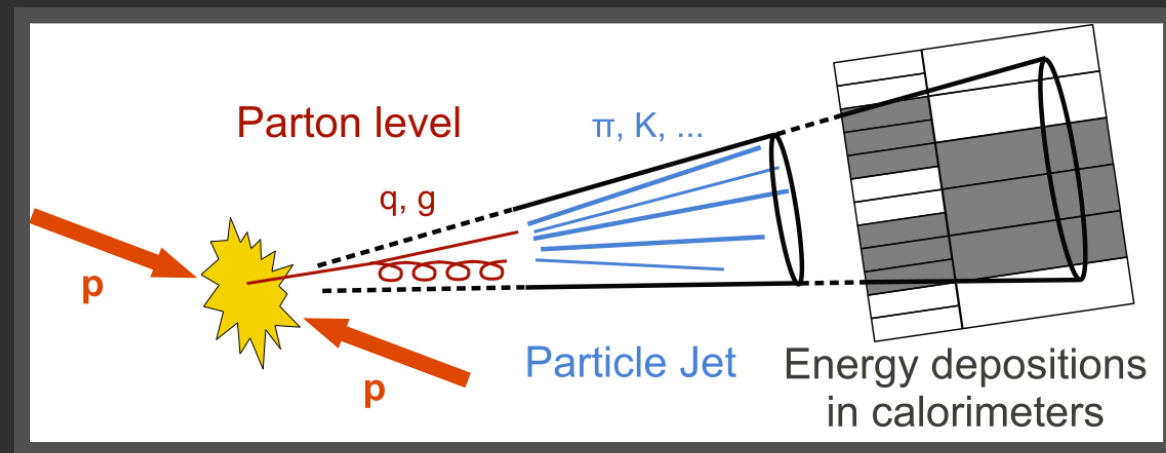
Representative Feynman-diagram o
f Signal

- ▪ How to get Top?
  We can only obtain final state objects (lepton
  s, jets and MET).
  We can reconstruct Top quark with that.

# Analysis overview

- Event selection

- Background estimation

- Top quark reconstruct

- Unfolding (correct for detector effects to particle level)

- Get normalized <u>differential cross section</u> distribution

The definition of the normalized differential cross section is

$$\frac{1}{\sigma}\frac{d\sigma}{dX}$$

where X is $p_T^l$, $p_T^j$, $p_T^t$, $y^t$, $p_T^{t\bar{t}}$, $y^{t\bar{t}}$, $M^{t\bar{t}}$, and $\Delta\phi^{t\bar{t}}$.

# Samples

- Real data
Run2015, integrated luminosity $2.2 fb^{-1}$
Triggered by

> Double electron trigger: electron > 17 & electron >12 GeV
> Double muon trigger: muon > 17 & muon > 8 GeV
> Muon-electron trigger: muon > 17 & electron > 12 GeV or
> muon > 8 & electron > 17 GeV

- Monte-Carlo Simulation
- Signal: ttbar (generated with powheg)
- Background: *ttothers, Drell-Yan, WJets,
Single top, Diboson (WW, WZ, ZZ)

*ttothers: Events from ttbar sample that does not contain pseudo-top pair are considered as ttothers even though they could contain two leptons in the final state.



**Drell-Yan**
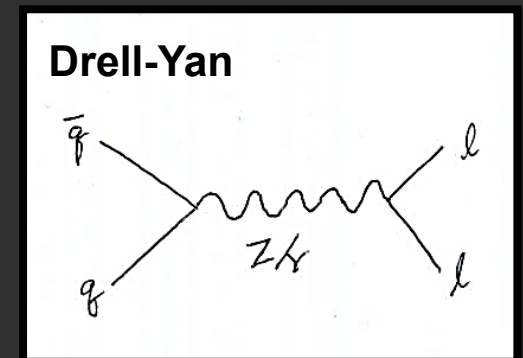
**Representative Feynman-dia gram of Background**

# Event Selection

- Dilepton cut
  At least two opposite signed leptons events, Invariant mass of leptons > 20 GeV

- Z boson veto cut
  The Invariant mass vetoed near Z boson mass (91±15 GeV) events for ee, mumu channels

- Jet multiplicity cut
  At least two jets events

- Missing transverse momentum (MET) cut
  MET > 40 GeV events for ee, mumu channels
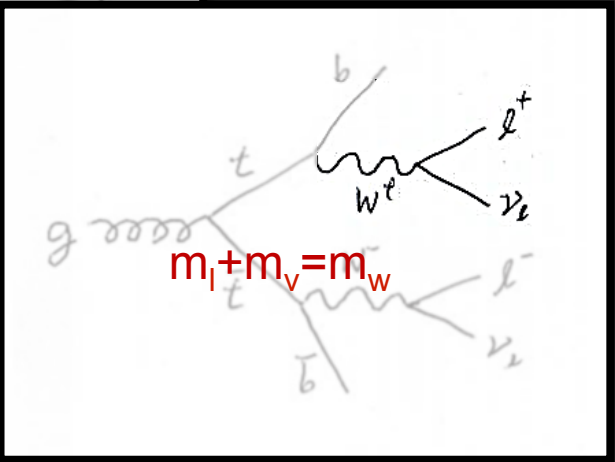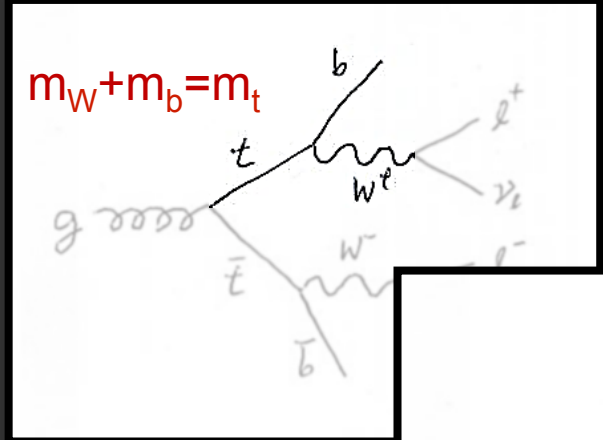
- b-jet cut
  At least one b-jet

# Event Selection
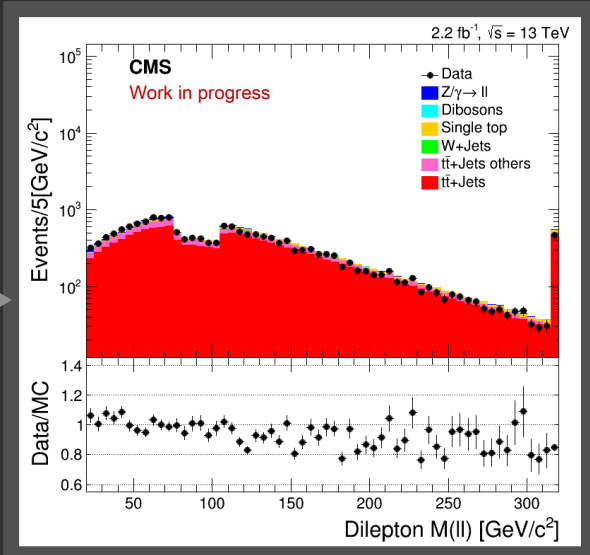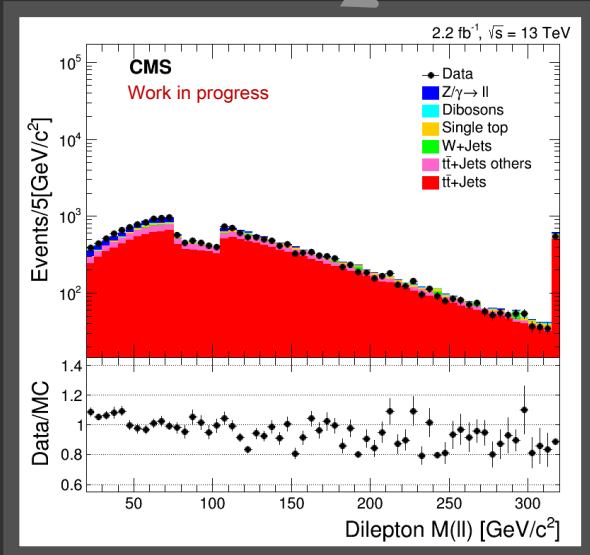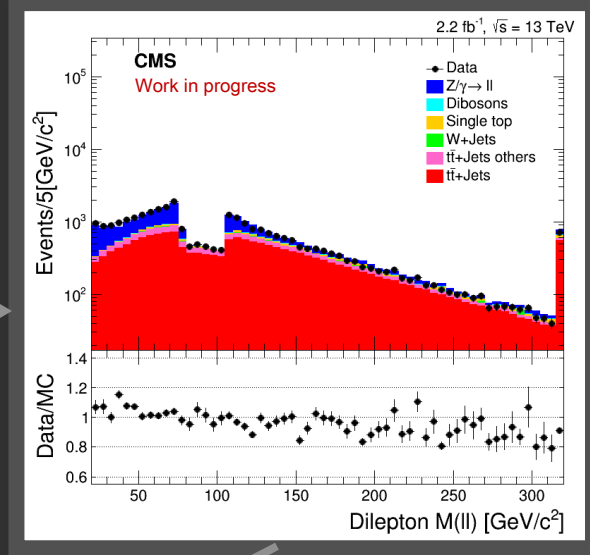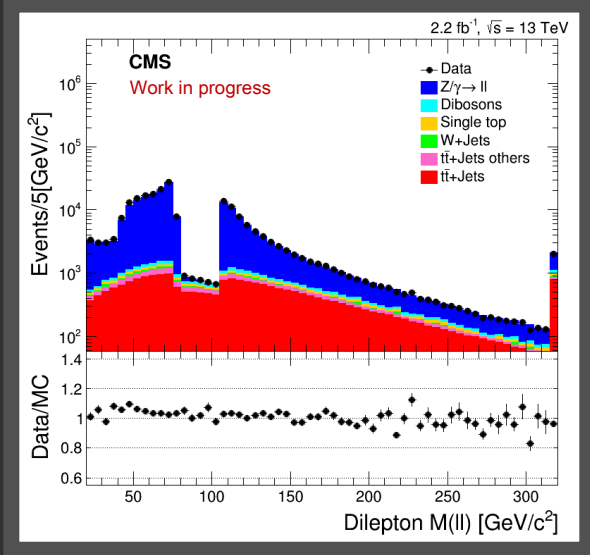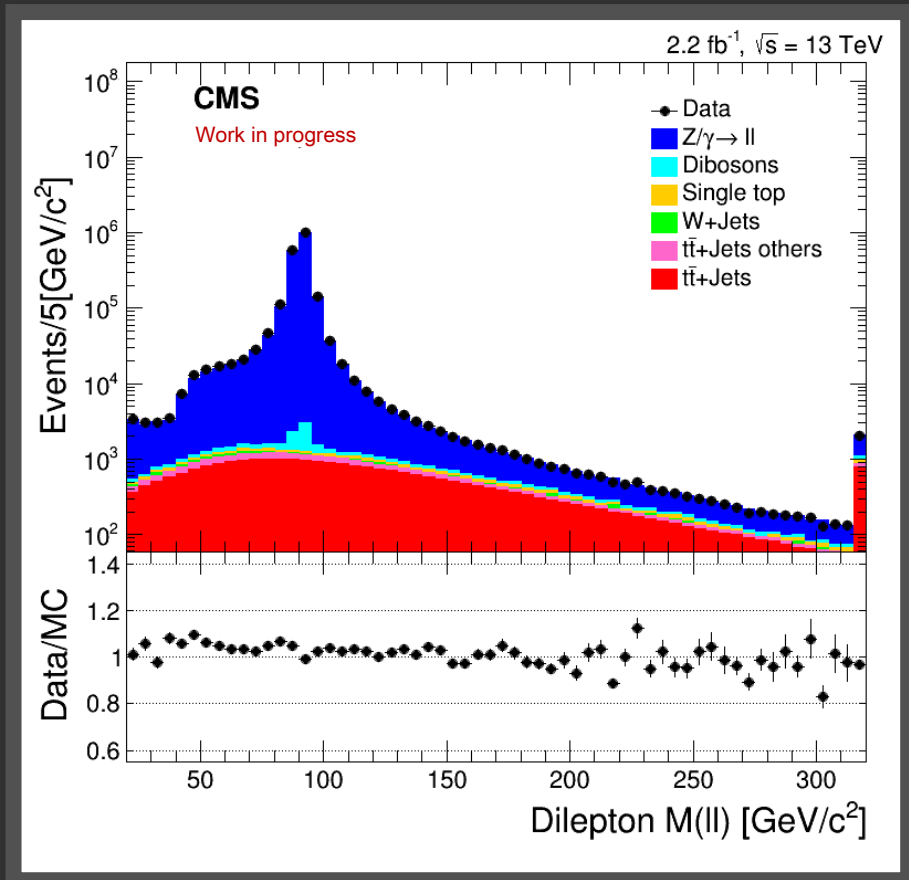
# Top reconstruction

- Constraints

  2 eque$tion\ from\ m{\downarrow}t\ ,m{\downarrow}t$

  2 $equetion\ from\ m{\downarrow}W{\uparrow}+\ \ ,\ m{\downarrow}W{\uparrow}-$

  2 $equetion\ from\ (p{\downarrow}v+p{\downarrow}v\ ){\downarrow}T=MET$



$m_W+m_b=m_t$

$m_l+m_v=m_w$

- Measured input

  2 jets, 2 leptons, MET

- Reconstructing each event <u>100 times</u> and smearing inputs
  - top mass fixed to 172.5 GeV
  - W mass at reconstruction level
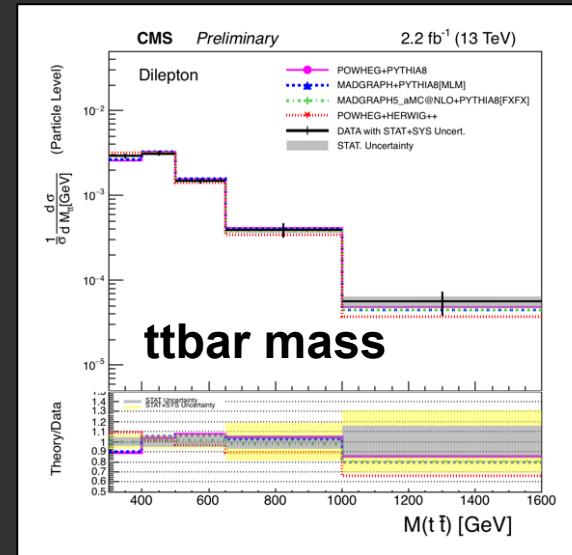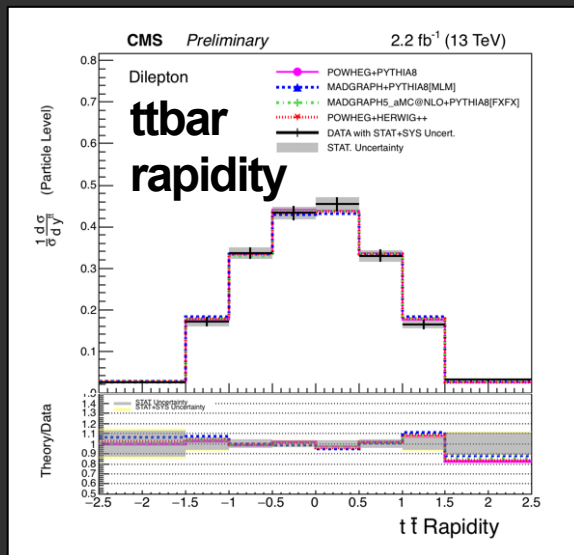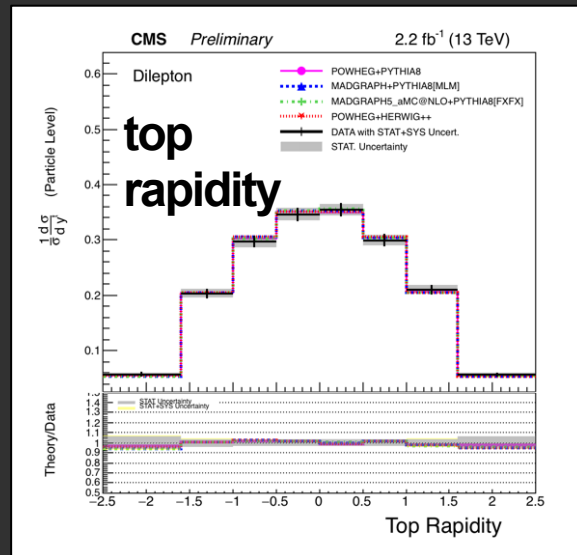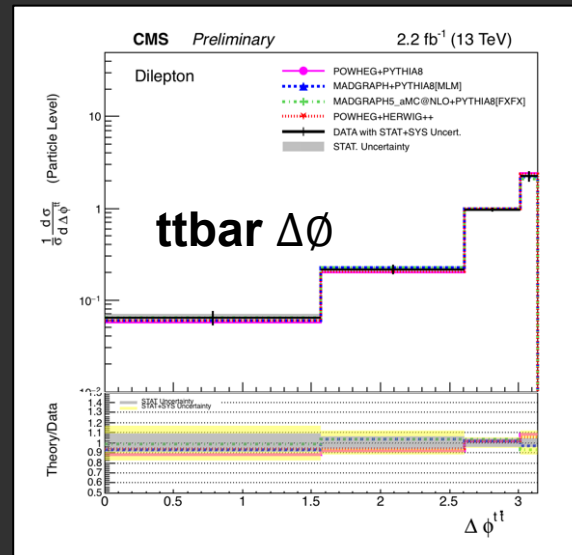    smeared accordingly to W mass distribution

$$p^{top}_{x,y,z}=\frac{1}{w}\sum_{i=0}^{100} w_i\cdot\left(p^{top}_{x,y,z}\right)_i$$

# Top reconstruction



lepton pT

Jet pT
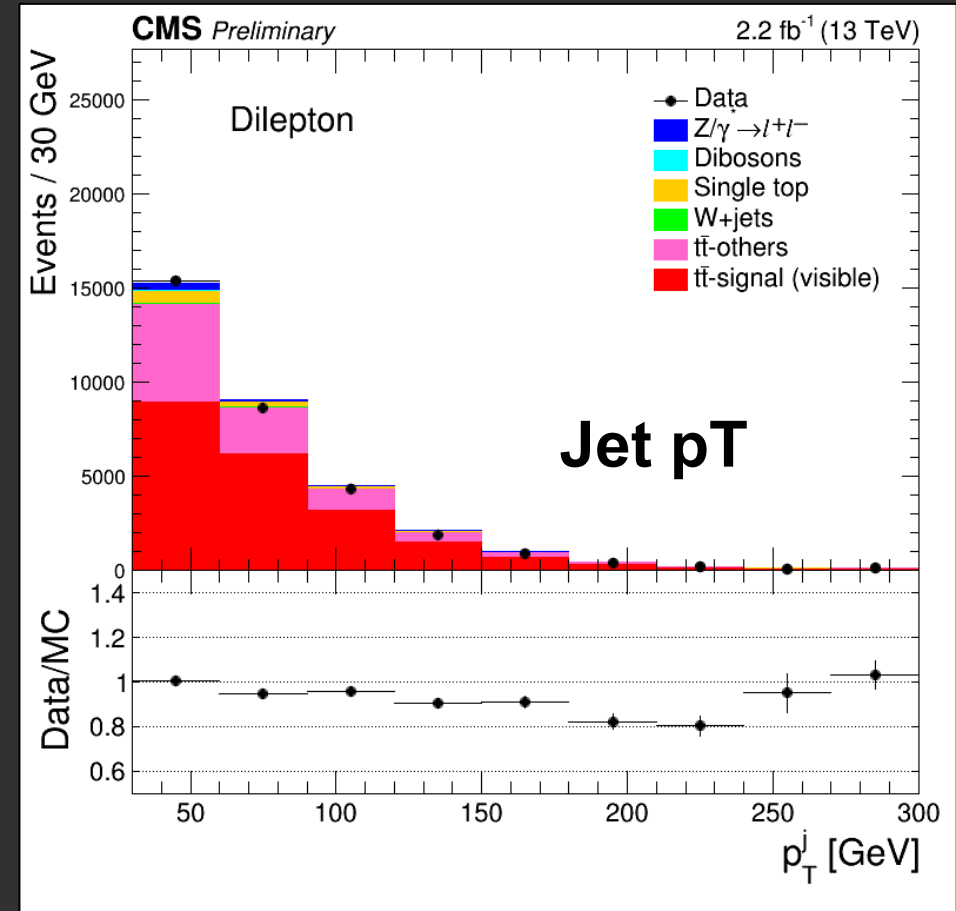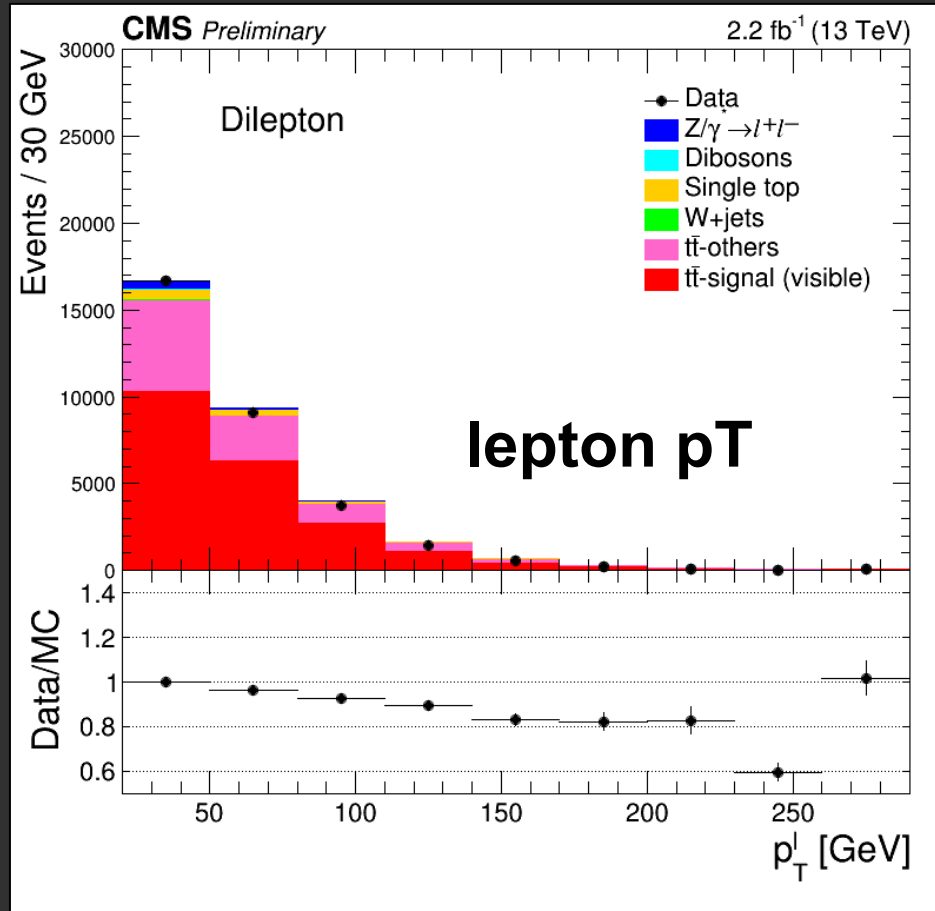
# Differential cross section
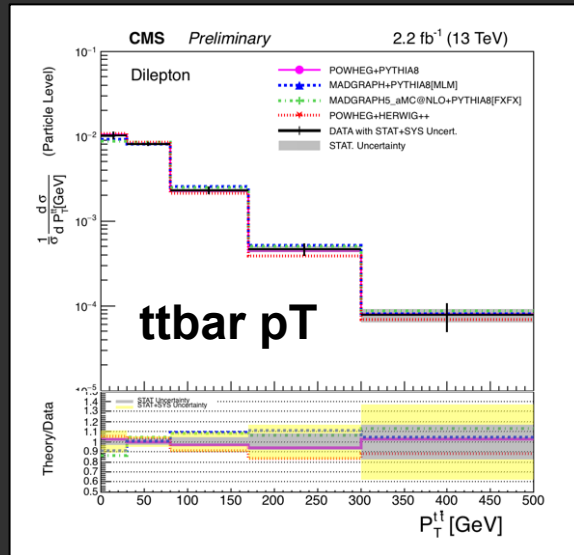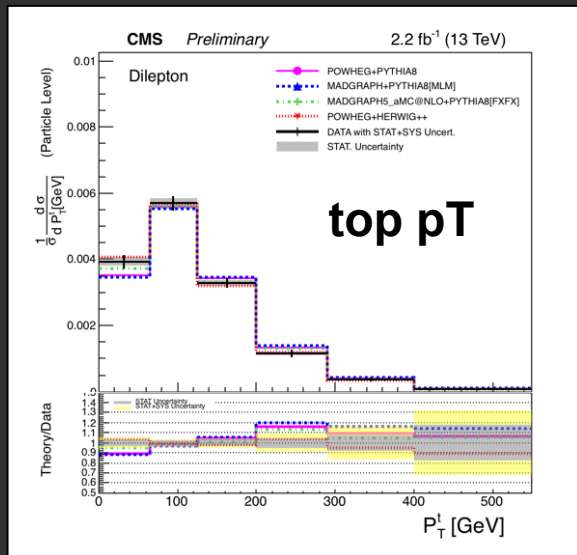
# Summary

- Normalized differential cross sections of top quark pair production in the dilepton decay channel are measured at particle level in visible phase space with respect to top pT ,top y, ttbar pT, ttbar y, ttbar M and ttbar Δφ . The measured differential cross sections are found to be in agreement with the standard model prediction.

# Back up

# Event Selection
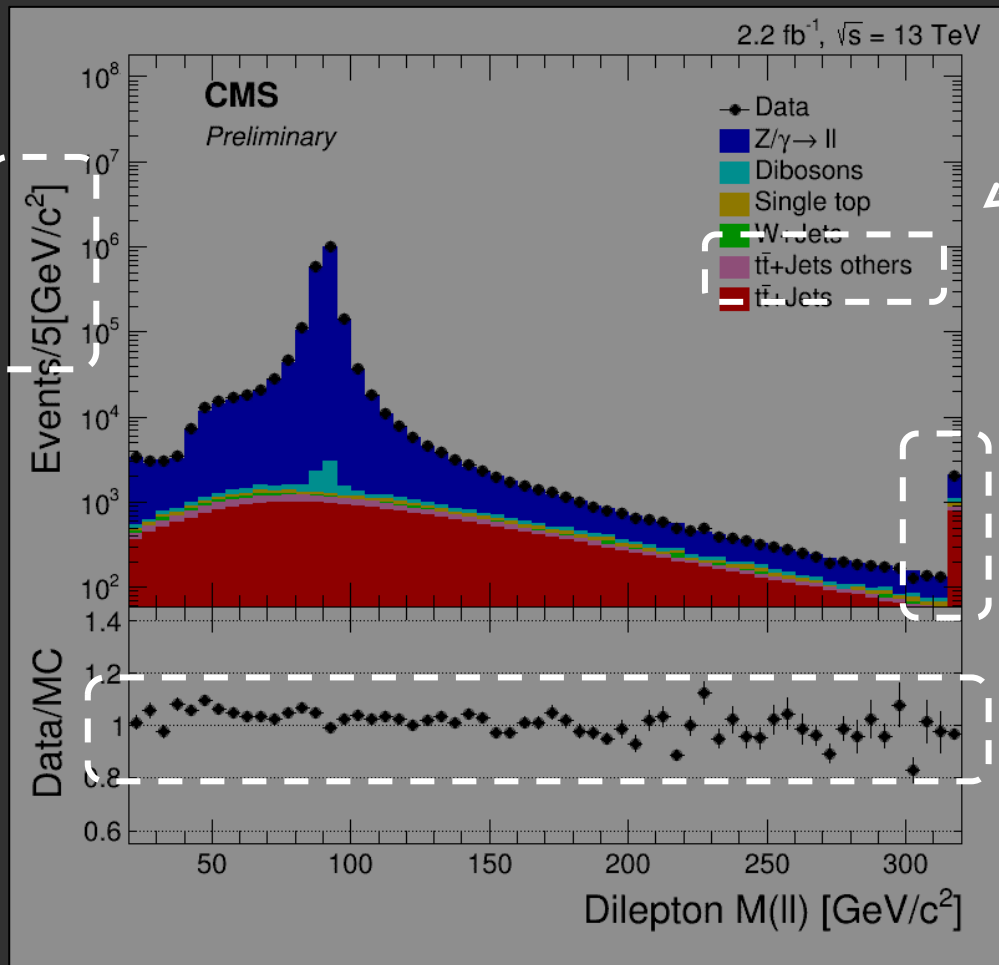


Size of each bins.

Fake events in TTbar sample

Added overflow to Last bin.

Data and MC show Well agreement.

- At least two opposite signed leptons
- Invariant mass of leptons >20 GeV

# Samples

| Channel | Data Sample | Run range |
|---------|-------------|-----------|
| Double Muon | Run2015C_25ns-16Dec2015-v1 | 254227 - 256464 |
| | Run2015D-16Dec2015-v1 | 256630 - 260627 |
| Double EG | Run2015C_25ns-16Dec2015-v1 | 254227 - 256464 |
| | Run2015D-16Dec2015-v1 | 256630 - 260627 |
| MuonEG | Run2015C_25ns-16Dec2015-v1 | 254227 - 256464 |
| | Run2015D-16Dec2015-v2 | 256630 - 260627 |

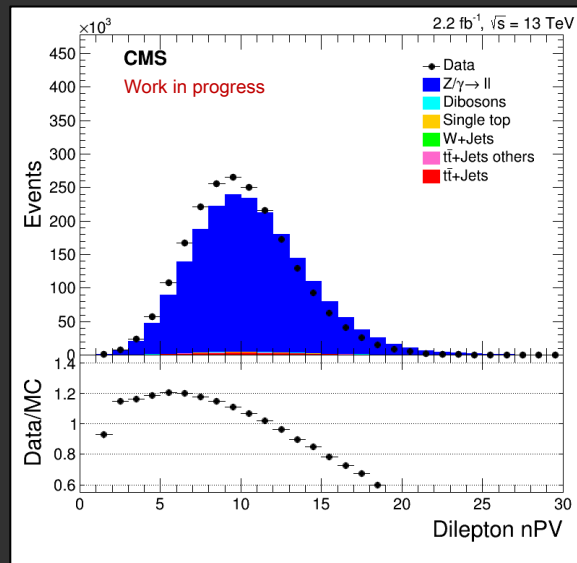| Channel | Trigger |
|---------|---------|
| Double Muon | HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL_DZ |
| | HLT_Mu17_TrkIsoVVL_TkMu8_TrkIsoVVL_DZ |
| Double EG | HLT_Ele17_Ele12_CaloIdL_TrackIdL_IsoVL_DZ |
| MuonEG | HLT_Mu17_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL |
| | HLT_Mu8_TrkIsoVVL_Ele17_CaloIdL_TrackIdL_IsoVL |

| MC Sample | Cross-section [$pb$] |
|-----------|----------------------|
| TT_TuneCUETP8M1_13TeV-powheg-pythia8 | 831.8 |
| TTJets_TuneCUETP8M1_13TeV-madgraphMLM-pythia8 | 831.8 |
| TTJets_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8 | 831.8 |
| DYJetsToLL_M-50_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8 | 6025.2 |
| DYJetsToLL_M-10to50_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8 | 18610 |
| ST_tW_top_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M1 | 35.6 |
| ST_tW_antitop_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M1 | 35.6 |
| WJetsToLNu_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8 | 61526.7 |
| WW_TuneCUETP8M1_13TeV-pythia8 | 118.7 |
| WZ_TuneCUETP8M1_13TeV-pythia8 | 47.1 |
| ZZ_TuneCUETP8M1_13TeV-pythia8 | 16.5 |

# Event yield table

| Selection Dilepton | Di-lepton S1 | Z Mass veto S2 | Two jets S3 | MET S4 | b-tagging S5 | kin.fit S6 |
|---|---|---|---|---|---|---|
| $t\bar{t}$ + *Jets*:powheg | 27572 ± 22.53 | 24705 ± 21.33 | 17845 ± 18.13 | 16155 ± 17.25 | 15096 ± 16.67 | 12833 ± 15.37 |
| $t\bar{t}$ others:powheg | 4447 ± 9.05 | 3917 ± 8.49 | 2823 ± 7.21 | 2582 ± 6.90 | 2387 ± 6.63 | 2198 ± 6.36 |
| Single top-t$W$ | 3111 ± 15.50 | 2798 ± 14.71 | 1065 ± 9.07 | 961 ± 8.62 | 840 ± 8.06 | 580 ± 6.70 |
| VV | 6945 ± 34.28 | 3542 ± 29.08 | 322 ± 7.86 | 227 ± 7.18 | 70 ± 3.99 | 45 ± 3.18 |
| $W$ + *jets* | 976 ± 88.84 | 918 ± 86.15 | 66 ± 23.22 | 71 ± 24.06 | 15 ± 11.10 | 2 ± 4.03 |
| $Z/\gamma* \to ll$ | 2050082 ± 588.96 | 177627 ± 250.30 | 8526 ± 63.48 | 1381 ± 21.26 | 399 ± 10.58 | 299 ± 9.52 |
| Bkg. total | 2065563 ± 596.88 | 188804 ± 266.84 | 12804 ± 69.03 | 5224 ± 34.70 | 3714 ± 18.97 | 3125 ± 14.23 |
| MC total | 2093136 ± 597.31 | 213509 ± 267.69 | 30650 ± 71.37 | 21379 ± 38.75 | 18811 ± 25.26 | 15959 ± 20.95 |
| Data | 2134232 | 220526 | 30413 | 20795 | 17975 | 15110 |

# Correction

- Pileup reweight
Pileup events (additional collisi
on events) distribution is assum
ed during the MC production
and reweighted to match the
pileup effect observed in the r
eal data.



**Before weighting**

**After weighting**

- Drell-Yan estimation
Drell-Yan simulation sample is made using a data-driven me
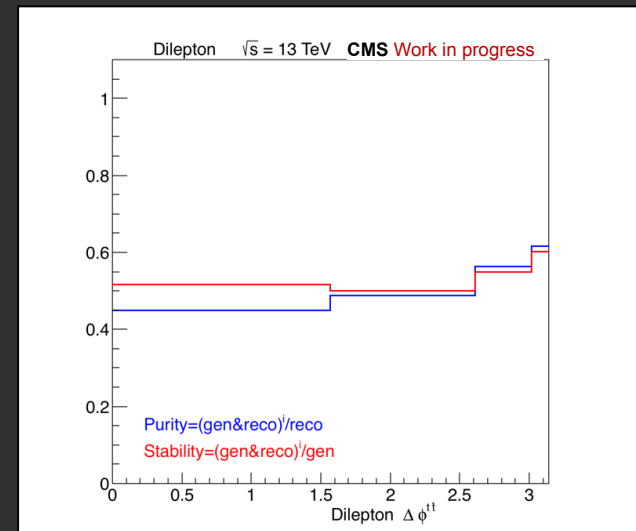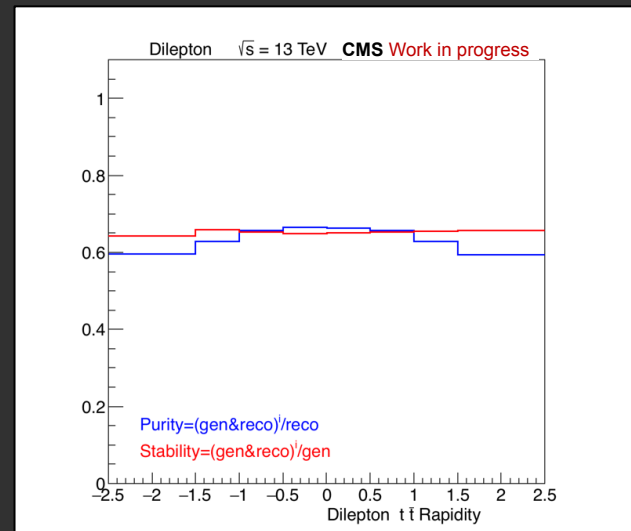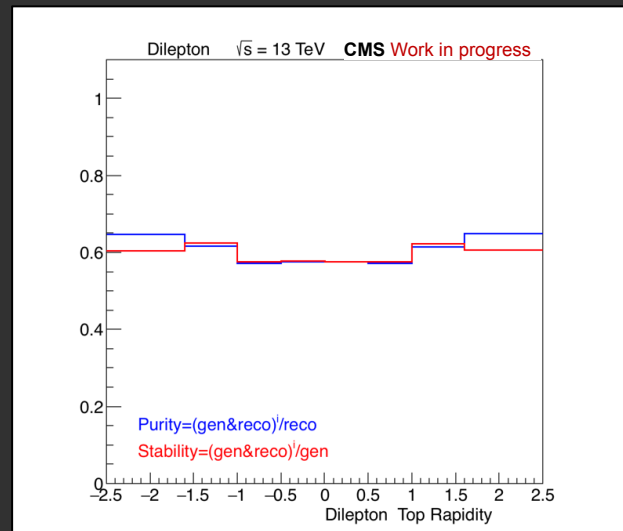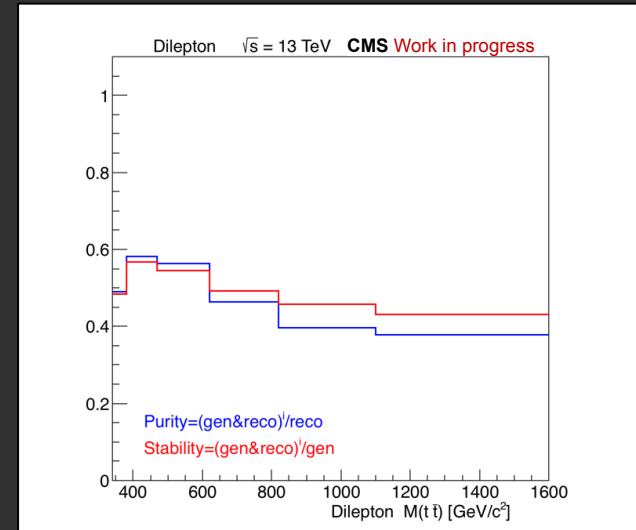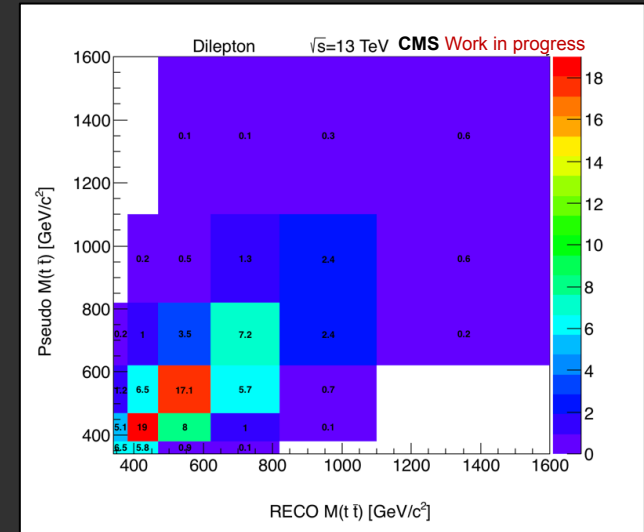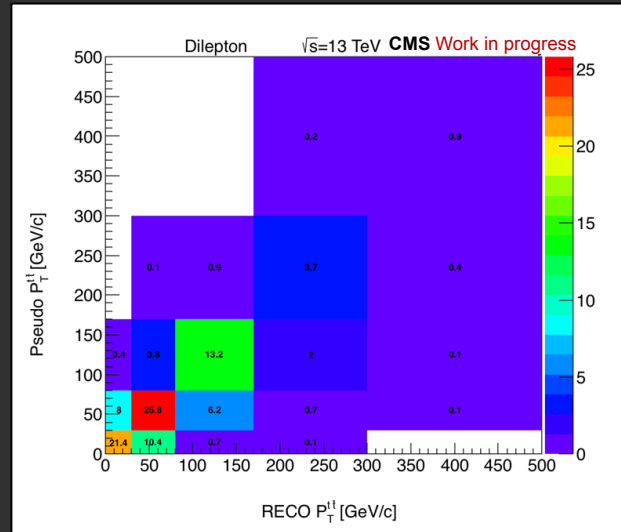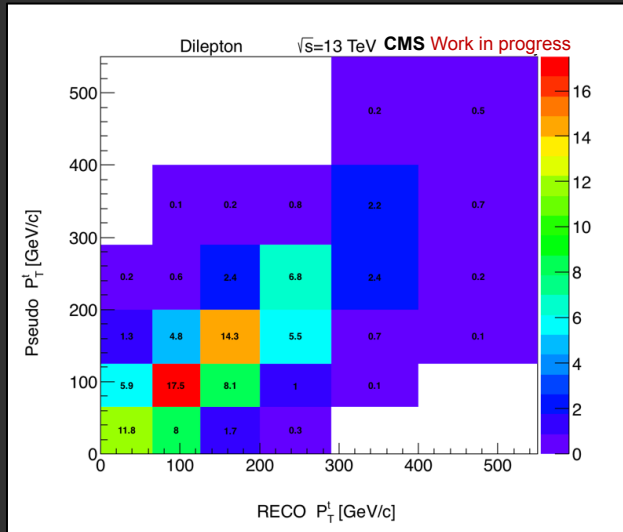thod. So, it need to be estimated respect to real data.
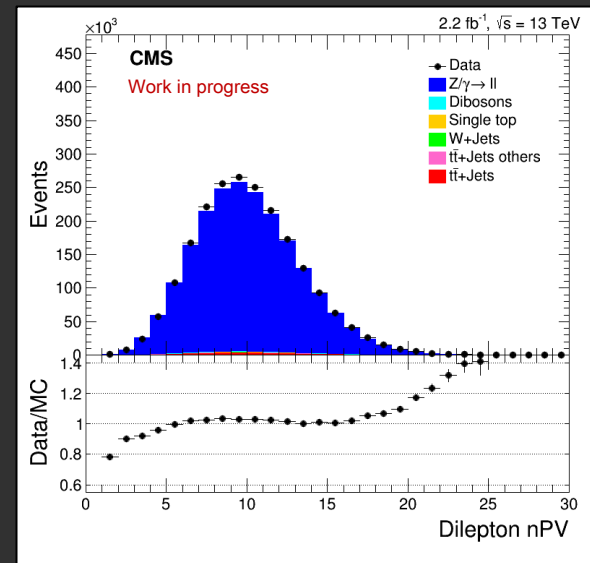
# Purity & stability
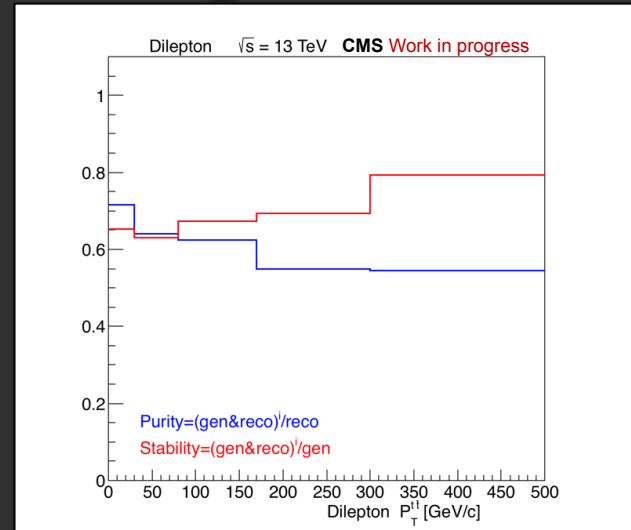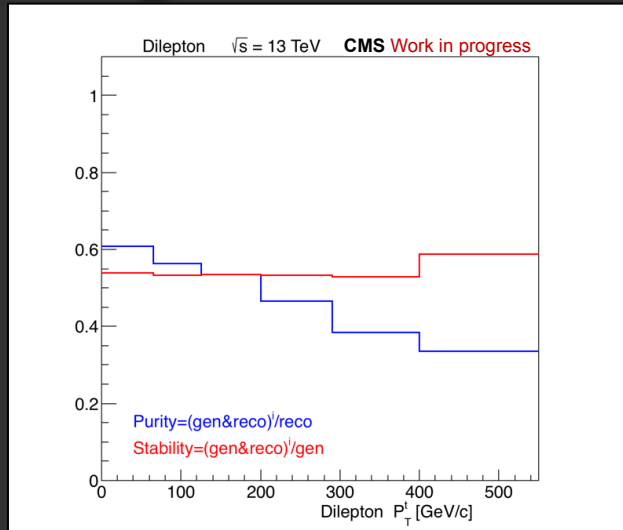
# Response matrix
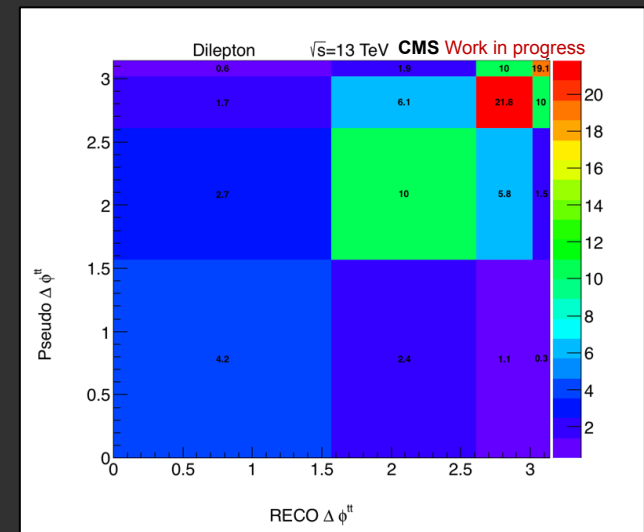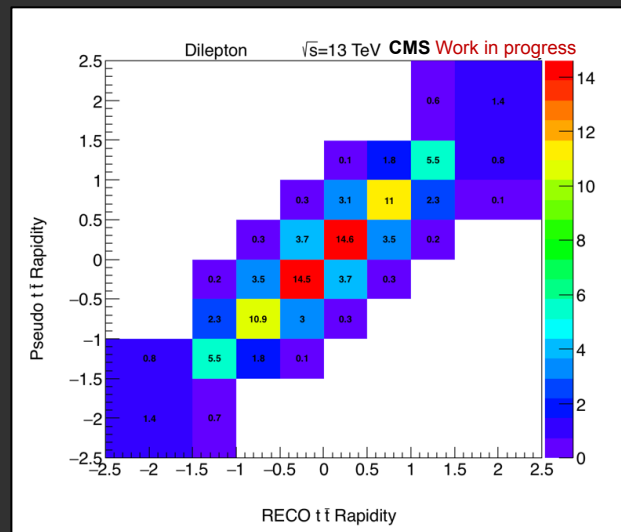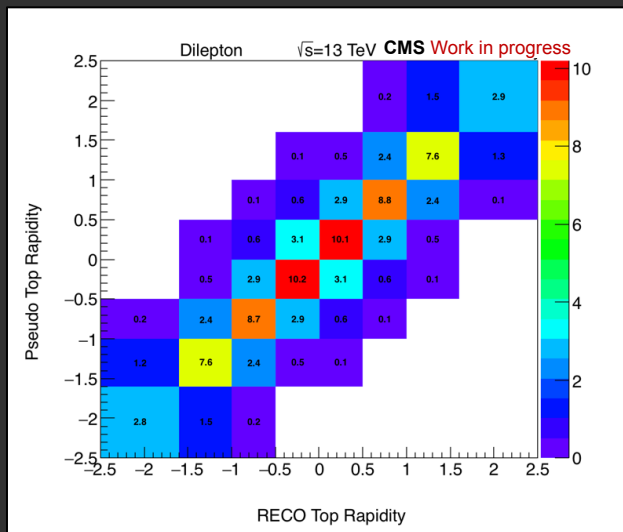
# Systematic uncertainties