Top Quark Mass Measurement

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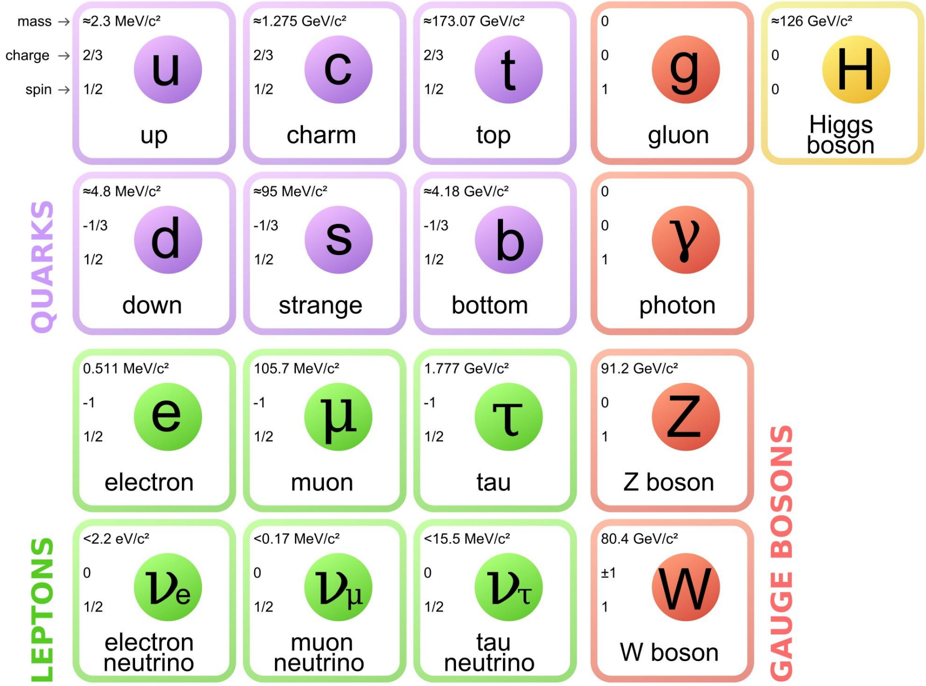
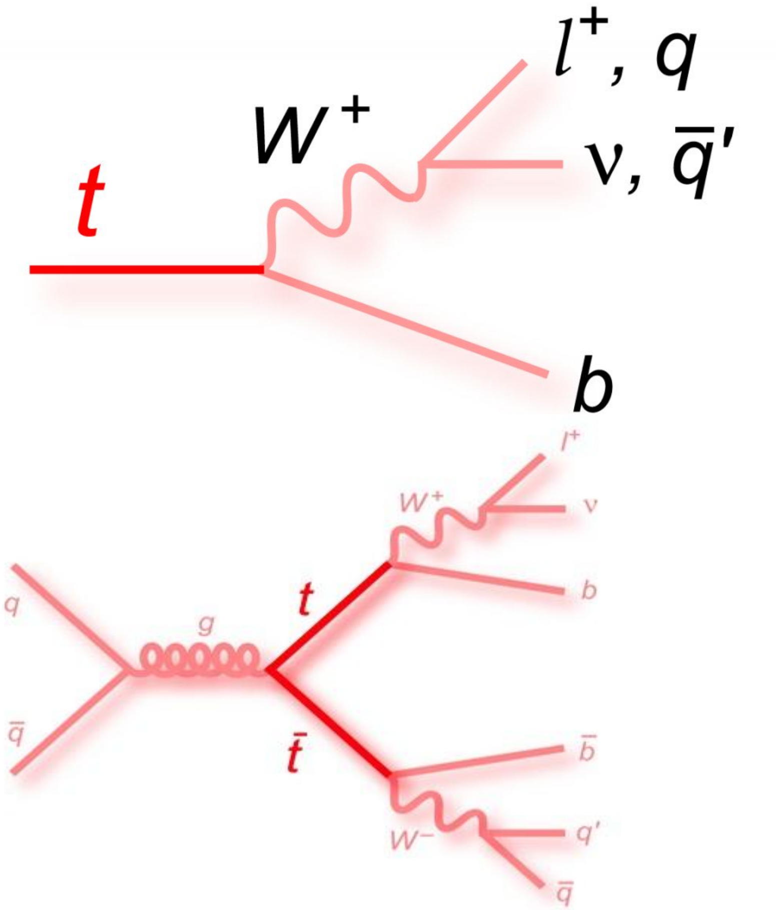
Motivation



mass →
charge →
spin →
≈2.3 MeV/c²
2/3
1/2
u
up
≈1.275 GeV/c²
2/3
1/2
c
charm
≈173.07 GeV/c²
2/3
1/2
t
top
0
0
1
g
gluon
≈126 GeV/c²
0
0
H
Higgs boson
≈4.8 MeV/c²
-1/3
1/2
d
down
≈95 MeV/c²
-1/3
1/2
s
strange
≈4.18 GeV/c²
-1/3
1/2
b
bottom
0
0
1
γ
photon
QUARKS
0.511 MeV/c²
-1
1/2
e
electron
105.7 MeV/c²
-1
1/2
μ
muon
1.777 GeV/c²
-1
1/2
τ
tau
91.2 GeV/c²
0
1
Z
Z boson
<2.2 eV/c²
0
1/2
νe
electron neutrino
<0.17 MeV/c²
0
1/2
νμ
muon neutrino
<15.5 MeV/c²
0
1/2
ντ
tau neutrino
80.4 GeV/c²
±1
1
W
W boson
LEPTONS
GAUGE BOSONS

Top Quark

- $\tau \cong 10^{-24}$ s
- *Decays before hadronization*



Samples

Process	Dataset(s)	Cross-section
TTJets	/TT_TuneCUETP8M2T4_13TeV-powheg-pythia8/RunIISummer16MiniAODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6-v1/MINIAODSIM	831.76
WW	/WWTo2L2Nu_13TeV-powheg/RunIISummer16MiniAODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6-v1/MINIAODSIM	12.178
WJets	/WJetsToLNu_TuneCUETP8M1_13TeV-madgraphMLM-pythia8/RunIISummer16MiniAODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6-v1/MINIAODSIM	61526.7
atW	/ST_tW_antitop_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M2T4/RunIISummer16MiniAODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6-v1/MINIAODSIM	35.85
tW	/ST_tW_top_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M2T4/RunIISummer16MiniAODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6-v1/MINIAODSIM	35.85
DY	/DYJetsToLL_M-50_TuneCUETP8M1_13TeV-madgraphMLM-pythia8/RunIISummer16MiniAODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext1-v2/MINIAODSIM	5765.4

Samples

Data
/MuonEG/Run2016B-23Sep2016_v3/MINIAOD, /MuonEG/Run2016C-23Sep2016-v1/MINIAOD, /MuonEG/Run2016D-23Sep2016-v1/MINIAOD, /MuonEG/Run2016E-23Sep2016-v1/MINIAOD, /MuonEG/Run2016F-23Sep2016-v1/MINIAOD, /MuonEG/Run2016G-23Sep2016-v1/MINIAOD, /MuonEG/Run2016H-PromptReco-v2/MINIAOD, /MuonEG/Run2016H-PromptReco_v3/MINIAOD

Event Selection

- Dilepton channel
- Leptons
  - $|\eta| \leq 2.4$
  - pT > 20 GeV
  - Opposite charges (μ-, e+ or μ+ , e-)
  - Dilepton invariant mass > 12 GeV
- Jets
  - 2 jets or more with pT > 30 GeV
  - $|\eta| \leq 2.5$
  - 1 or 2 b-tagged jets

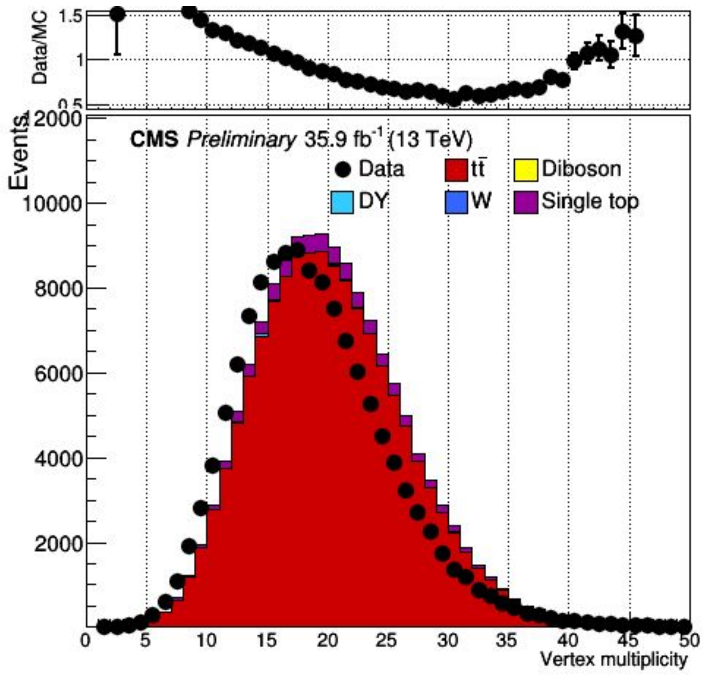
Process	Number of events
Single top	6438 ± 92
W	0.0 ± 0.0
Diboson	182 ± 8
$t\bar{t}$	138101 ± 238
DY	339 ± 76
Total from simulations	145061 ± 76
Data	131120

Corrections

PU reweighting

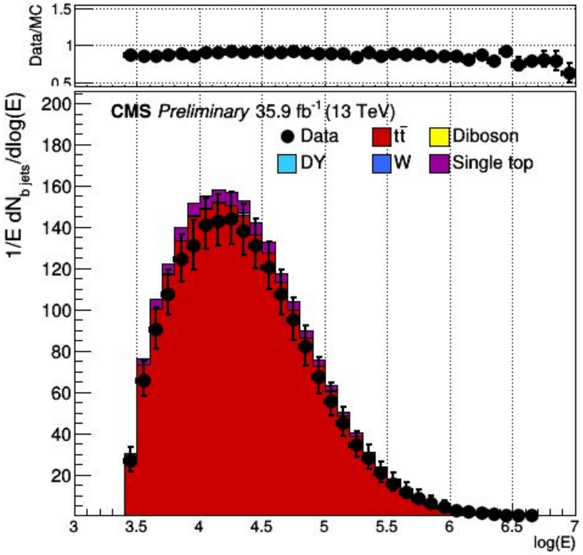
Lepton Scale Factors

Jet Energy Corrections: JES, JER

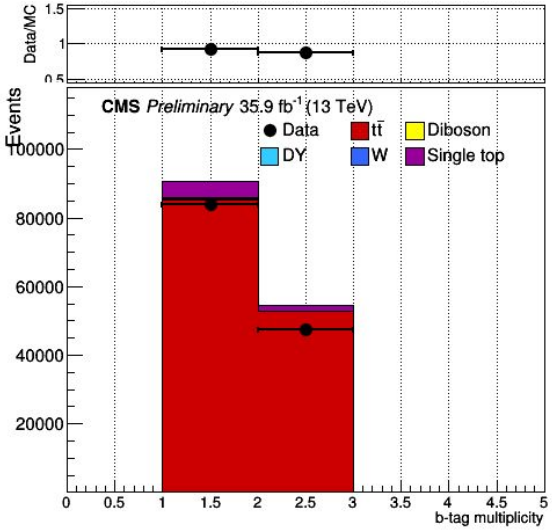


Number of PV (before pileup reweighting)

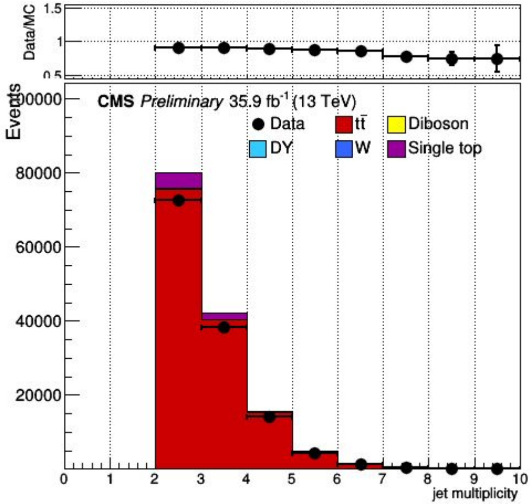
Control Plots



Bjet energy normalized



Number of b-tagged jets



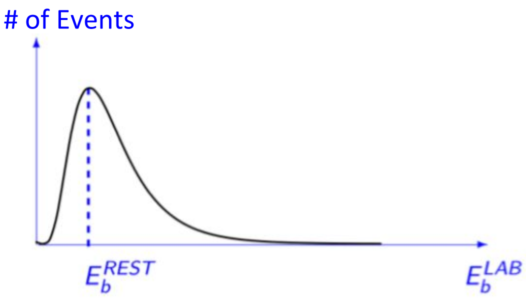
Number of Jets

Analysis Method

2-body decay kinematic in reference to top-quark

$$m_t = E_{b,peak} + \sqrt{m_W^2 - m_b^2 + E_{b,peak}^2}$$

The top mass can be inferred from the energy peak position of the spectrum



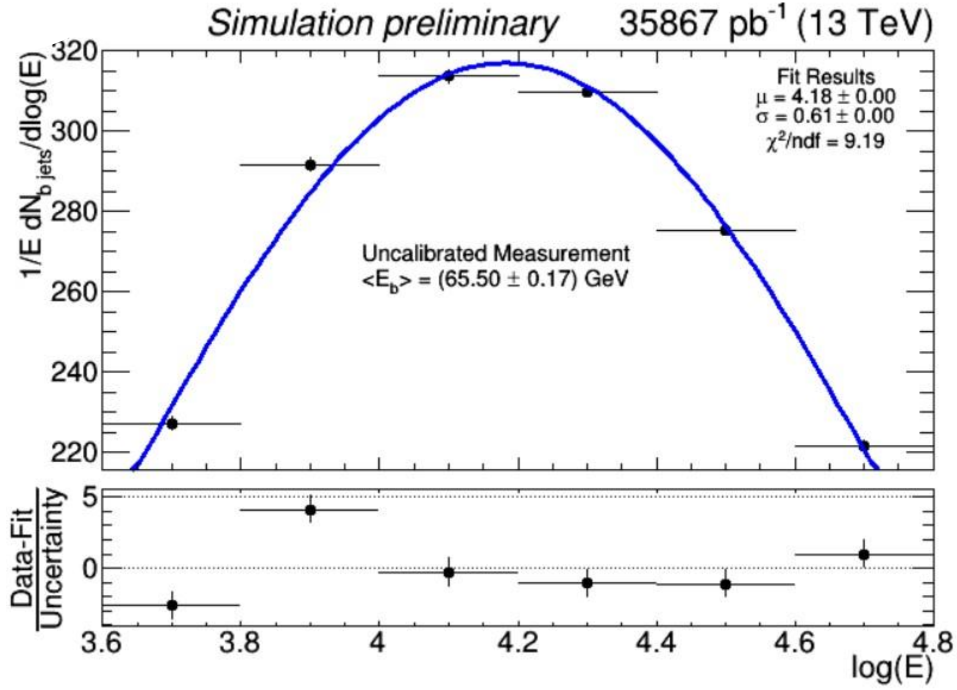
Calibration

We can fit a gaussian to our simulated data and get the b-jet energy peak

However

Bias will push the position of the energy peak away from the what we would expect from theory:

$$m_t = E_{b,peak} + \sqrt{m_W^2 - m_b^2 + E_{b,peak}^2}$$



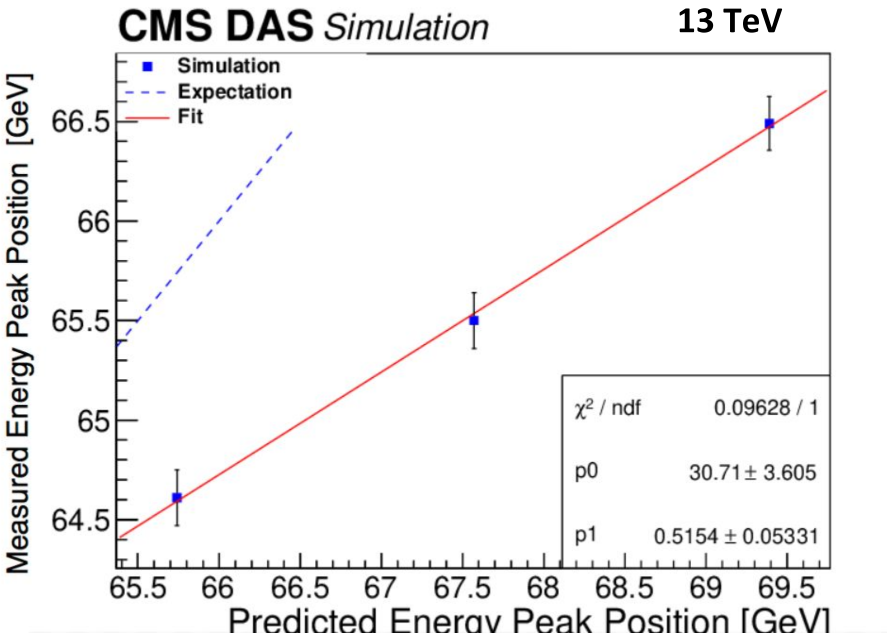
Calibration

We calibrate by

Generating pseudo-experiments with Poissonian fluctuations and fit as before

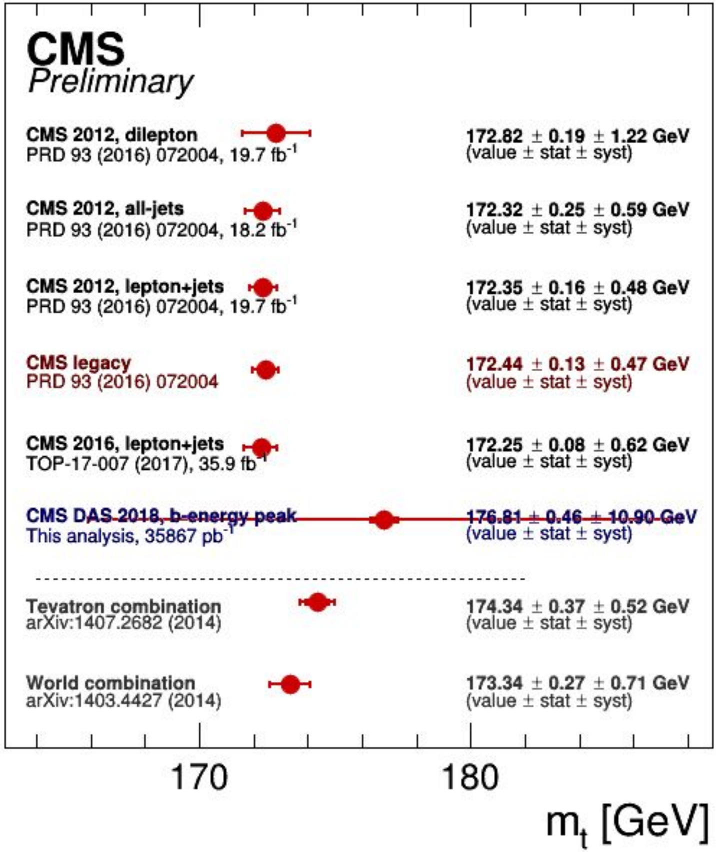
Giving us a distribution of peak positions

Take the mean of all the peak positions to complete the calibration curve



Results

M_t = 176.81 ± 0.46 ± 10.90 GeV

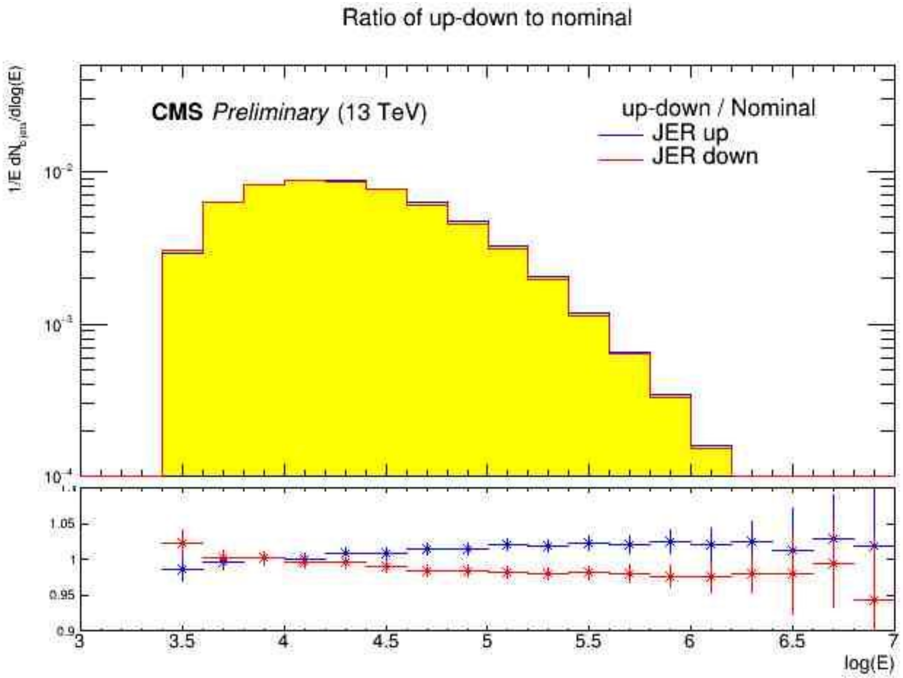


Systematics

- Add/subtract systematic error sources to E_b to get up/down samples.
- Fill histograms with the corrected jet energy.
- Fit the up/down histograms. Obtain upper/lower bounds for E_b peak.
- Propagate the b-jet peak uncertainties to the top mass uncertainties.
- Taking the difference of the upper and lower bound of the top mass and dividing it by 2, will give an estimate on the top mass uncertainty.
- Systematics are uncorrelated, they can be added in quadrature to get total systematic uncertainty.

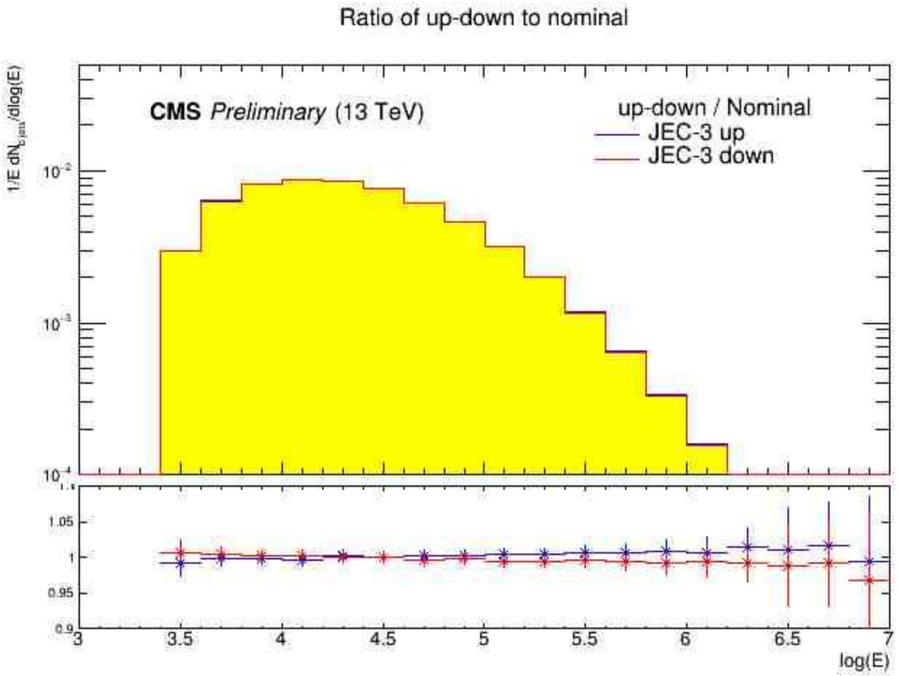
Systematics

Jet Energy Resolution Correction



Systematics

Jet Energy Correction - 3 (MPF- Bias)



Systematics (Experimental & Theoretical)

Source	Eb_Unc	Mt_Unc
fsr	0.96966121	1.59389210
isr	0.06059295	0.09960038
scale	0.15380771	0.25282324
PileUp	0.00800787	0.01316304
topPt	0.64277315	1.05656599
LeptonSF	0.00010492	0.00017247
JER	4.64521108	7.63562074
JEC	0.13846414	0.22760206
Total	**6.61862303**	**10.87944002**

- It has been observed in several analyses at 8 and 13 TeV that the **top-quark pT** is not perfectly reproduced in simulations.
- So, simulations are not corrected for **top-quark measurements** but they need to be reweighed so that the top-quark pT distribution matches the one observed in data in order to consider this mis-modeling as a source of systematic uncertainty.
- On the left side, we calculated the error propagation of b-peak energy for each uncertainty types. As can be seen, the JER is the dominant uncertainty and the Pile-Up and Lepton is the less dominant uncertainty.

Conclusion

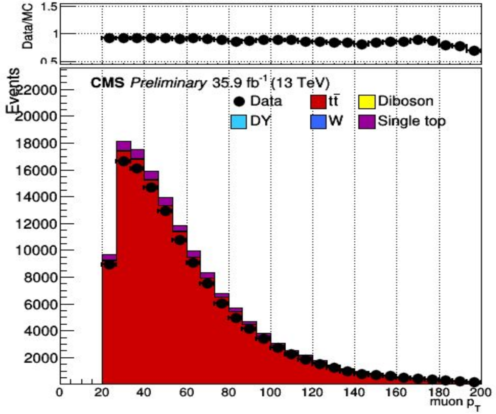
The top mass can be measured using the peak energy from b-jets which come from top decays.

The measured value is 176.8±10.9 GeV, which is compatible with all other precision measurements.

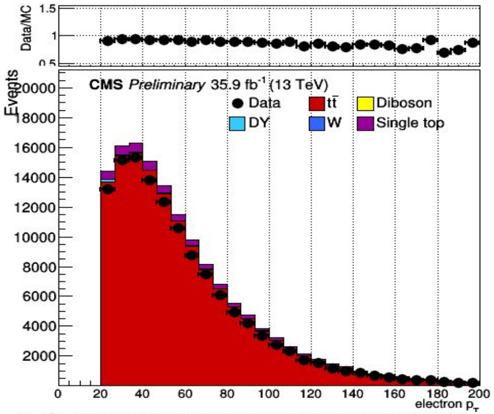
The dominant systematic uncertainty is the jet energy resolution.

Additional Material

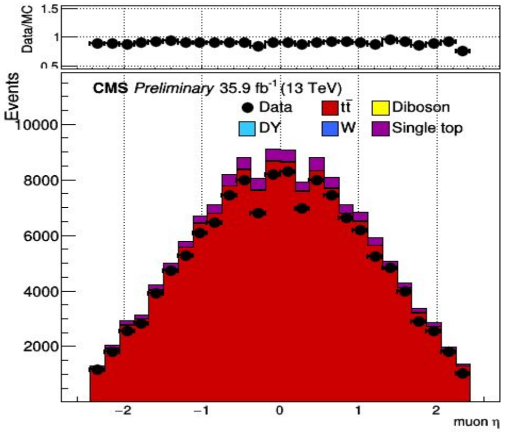
Control Plots Continued



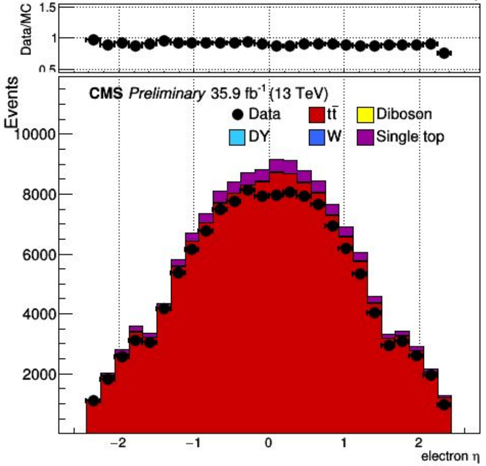
Muon pt



Electron pt



Muon eta



Eletron eta