Top quark mass measurement from b-jet energy spectrum at 13 TeV

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Motivation

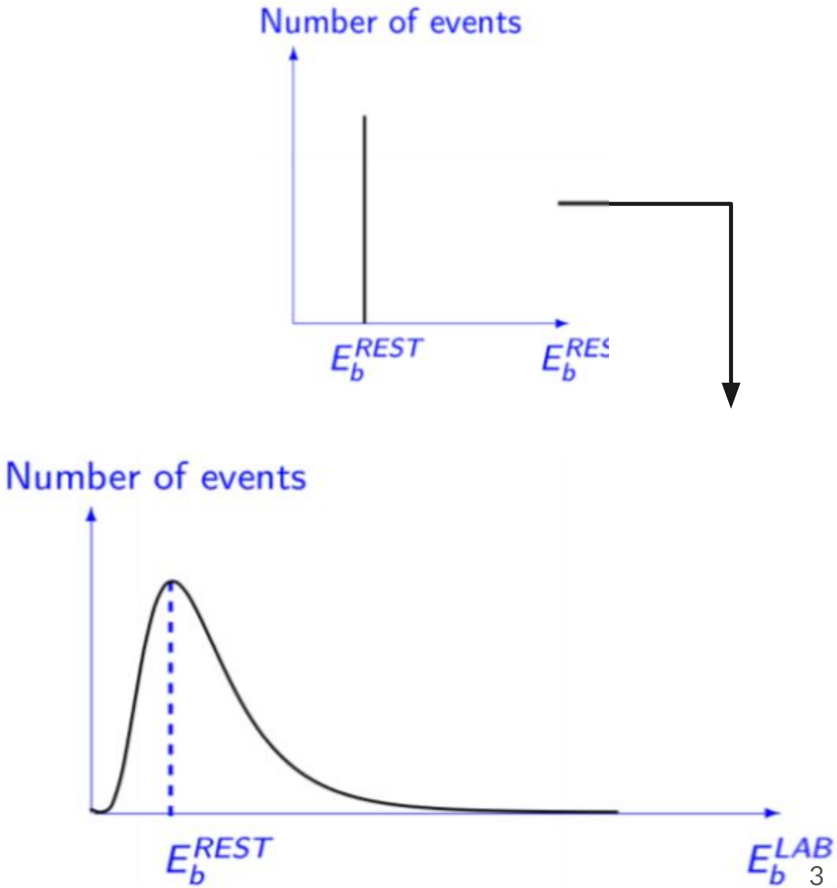
- Free parameter needed to be measured within the standard model
    - Top production in 2016 (σttbar = 832 pb)
- Strongest coupling to the Higgs mechanism
    - Provides a key variable to subsequent measurements
- Concise measurement provides a place to search for rare decay modes
    - B_s -> $\mu^+\mu^-$

Extracting Top Mass

- Considering two body decay from the top quark in the rest frame

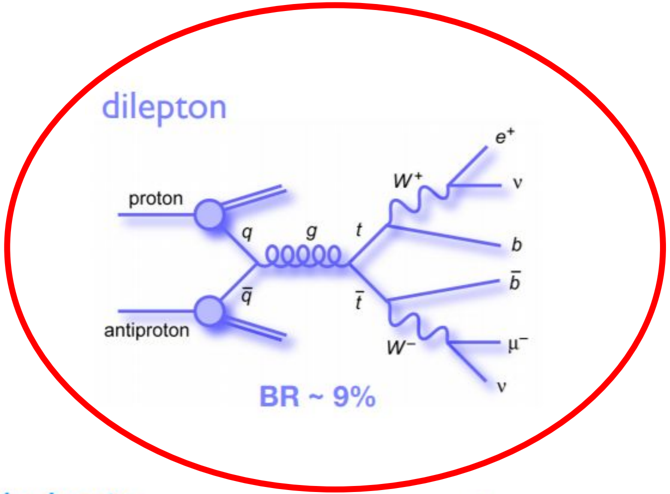
$$M_t = E_b^{rest} + \sqrt{M_W^2 - M_b^2 + (E_b^{rest})^2}$$

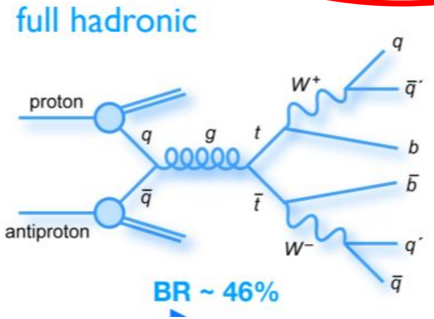
- Knowing the energy of the BJet provides us all we need to get the top mass

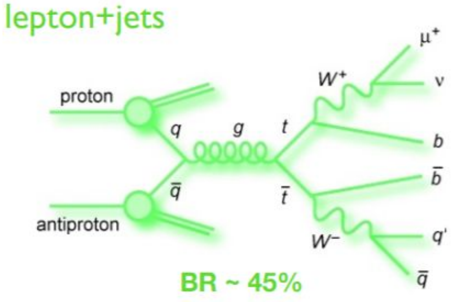


Search Method

- Single top production rare compared to TTbar, reconstruction contains unknowns
- TTbar final states includes dilepton, lepton+jet, and fully hadronic .
- Dilepton channel provides clear signature, provide clean and easy cuts to make for event selection
- **Thus, TTbar -> 2l + 2b is our search signal**







Selection of the EMu Events

Triggers:

- Mu8_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL
- Mu17_Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL

Leptons:

- Events have exactly one electron and one muon
- $p_T > 20$ GeV and |η| ≤ 2.4
- IIsolationI < 0.15(0.12) in a cone of radius 0.3(0.4)

Jets

- ≥2 jets with $p_T > 30$ GeV and |η| ≤ 2.5
- 1 or 2 b-tagged jets (CSV > 0.405)

Event Yields

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

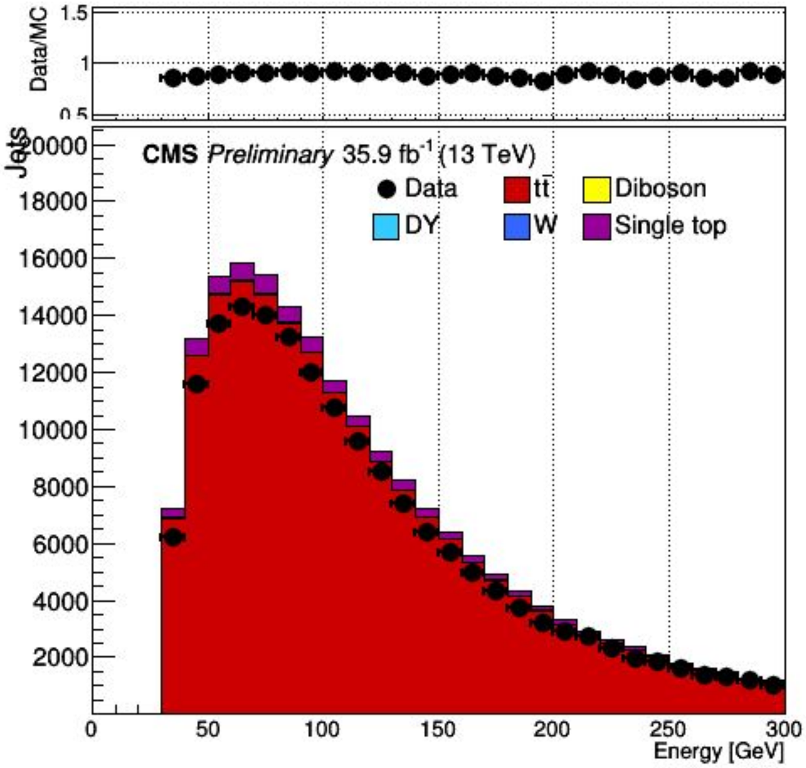
- Signal:
    - ttbar
- Background:
    - W+jets
    - Diboson
    - Single-top
    - Drell-Yan

Energy Spectrum:

- Energy peak has a correlation of the top mass

- Asymmetrical, hard to fit

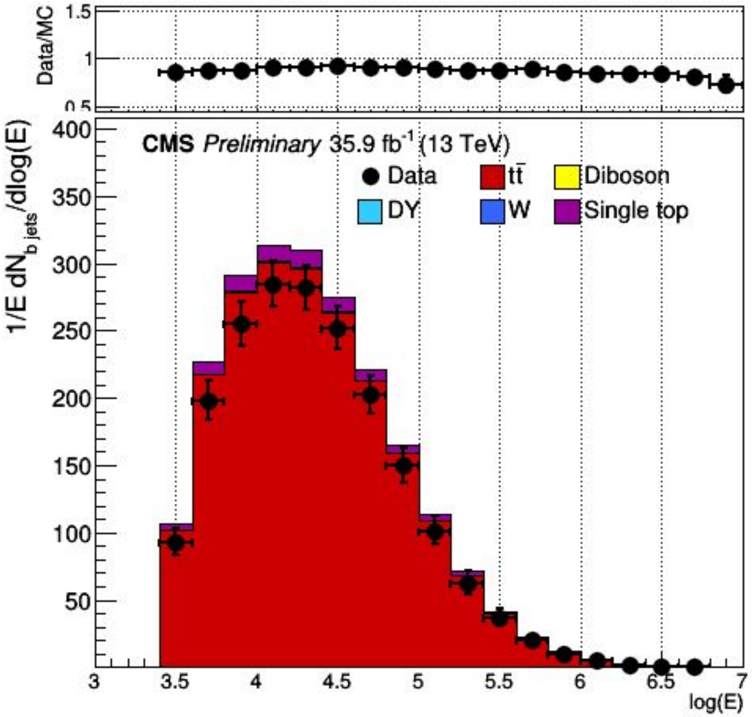
Pt/



B-jet Energy

Log Energy Spectrum

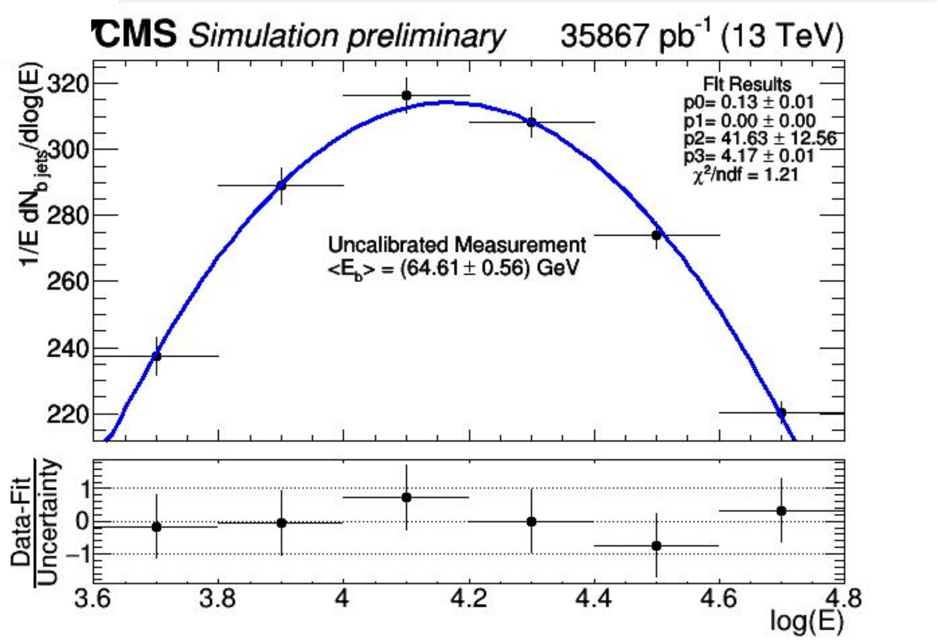
- To find information from the data we first convert the energy into a reweighed log plot of the b-jet energy
- This makes the data symmetric about its peak and much easier to fit



Log of b-jet energy

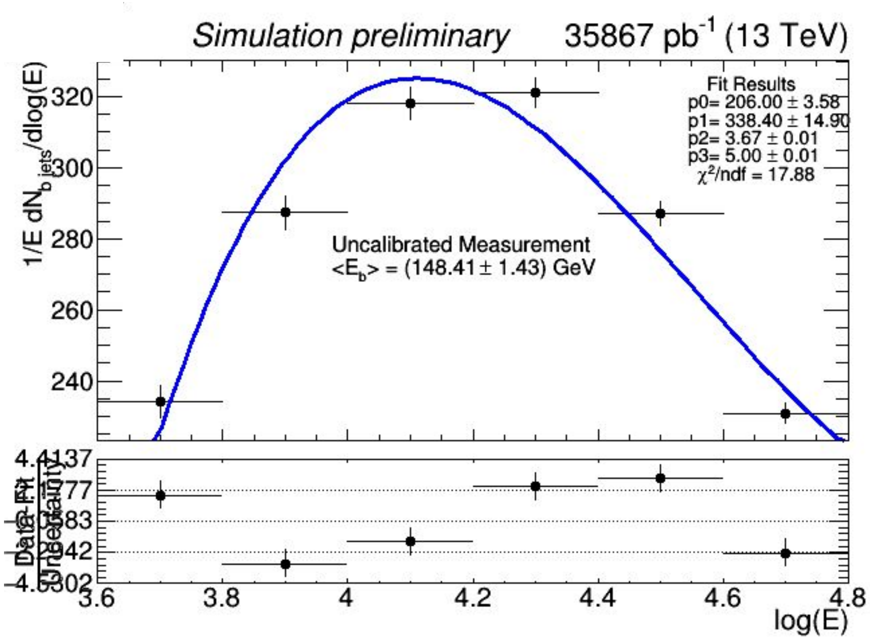
Fit Function

- After event selection is finished we are ready to extract information from the data
- First we must do a fit to the b-jet energy spectrum
- We considered using a polynomial fit and a Gaussian fit



Gaussian or Polynomial

- The polynomial fit function showed potential because it had lower Chi^2 values and uncertainties on the peaks
- However for certain data it would not produce a proper fit or the uncertainty on the peak
- In the end we decided to use the Gaussian fit function to analyze the data



Why calibration is necessary?

Without calibration our values for the mean b-jet peak would be lower and result in lower values of top mass.

We correct the measurement from several sources of bias, such as:

- **Reconstruction**: unmeasured energy
- **Event Selection**: jet pT, b-tag, etc.
- **Purity**: Misidentified b-jets, background events

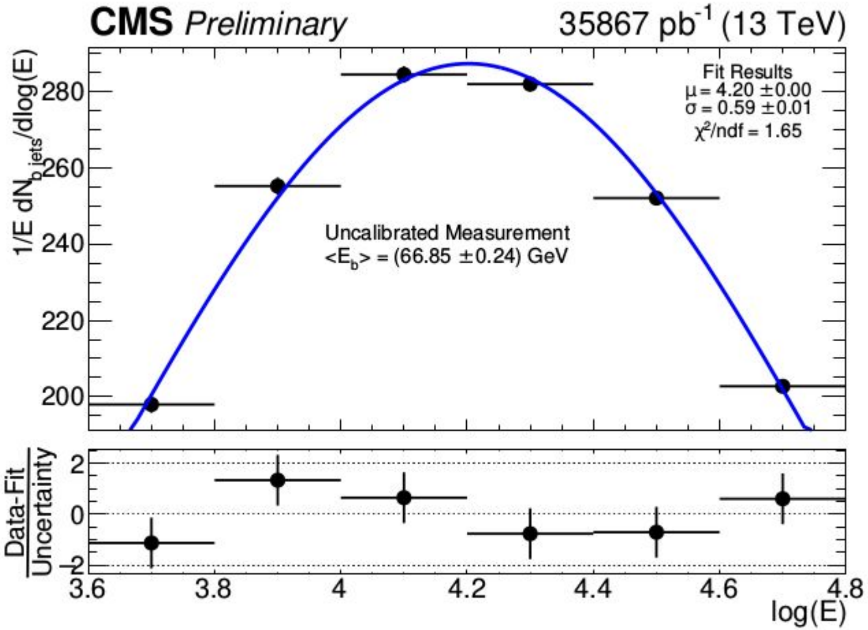
Calibration Procedure

From MC simulation of different top masses, we compute the energy peak of the b-jets and fit with a Gaussian

- M_t = 169.5 GeV
- M_t = 172.5 GeV
- M_t = 175.5 GeV

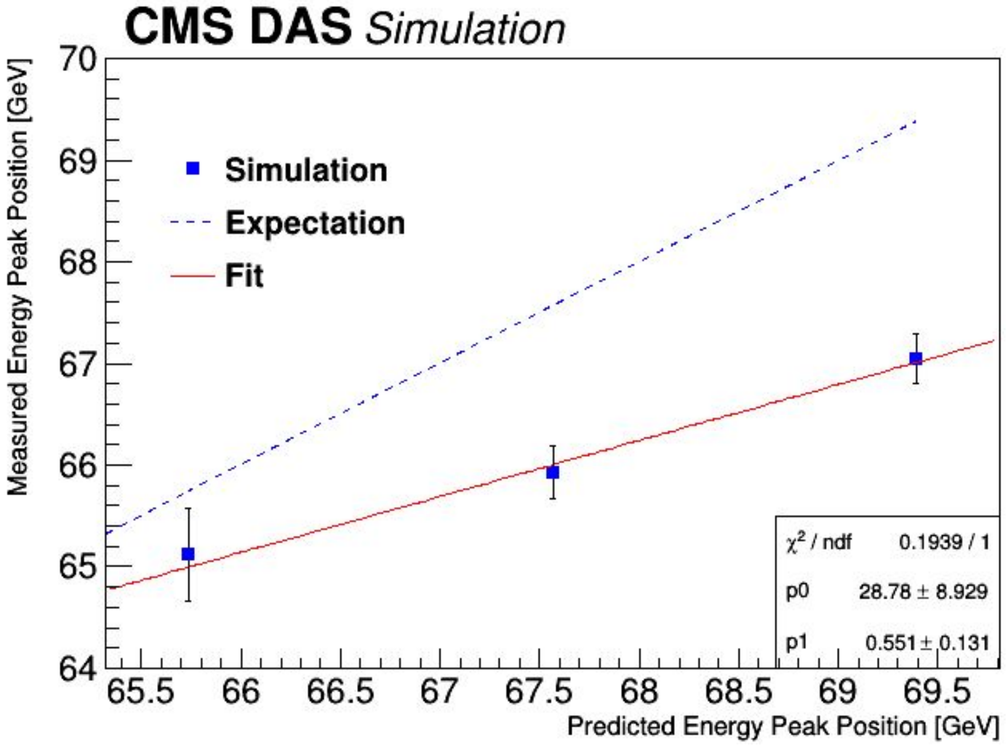
2000 pseudo-experiments were created from the expected b-jet energy spectrum in log scale for the top mass values.

We use a Poisson distribution on number of events in each bin. Finally, for each mass, we plot the peak distributions.



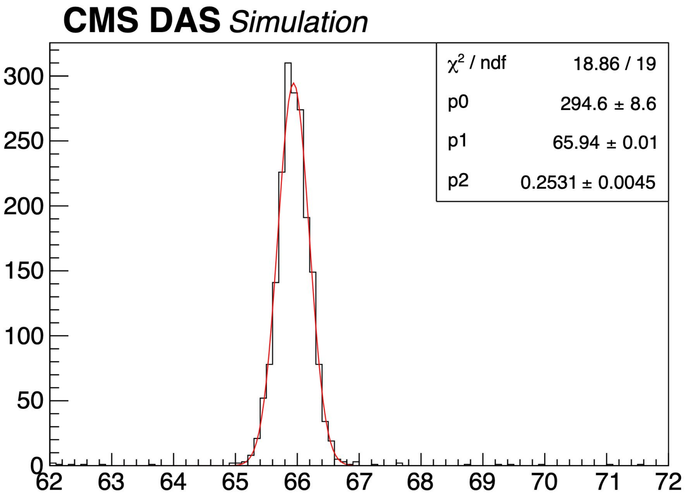
Calibration Plot

- For the three top masses, a fit is done between the expected and measured b energy peak.
- Extract the fit parameters and apply to get calibrated b-peak energy.
- Uncertainties associated are propagated applying the covariance matrix.

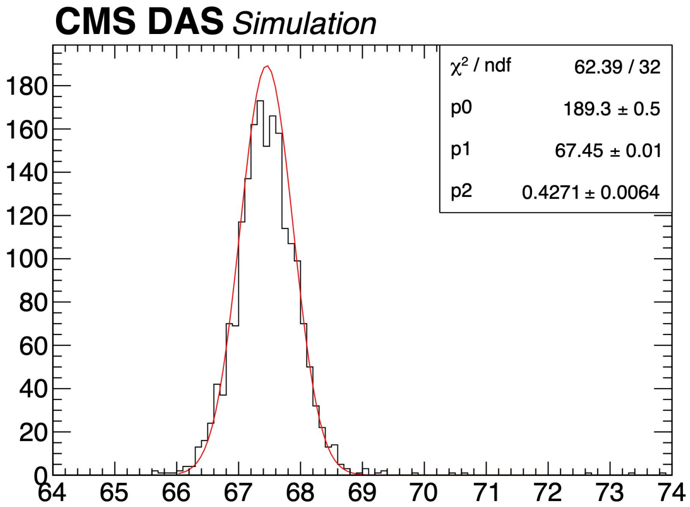


Calibration Performance

From the Eb distribution for Mt= 172.5 GeV



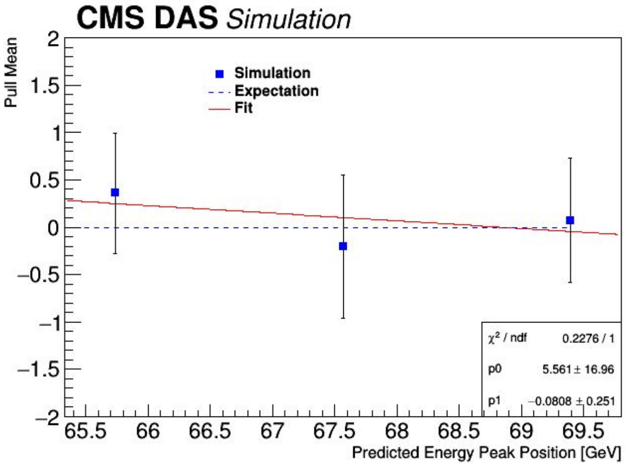
Before calibration
Mt= 169.82 GeV

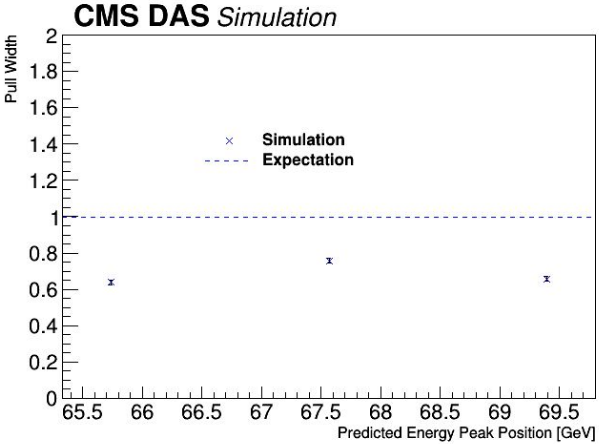


After calibration
Mt= 172.3 GeV

Calibration Performance

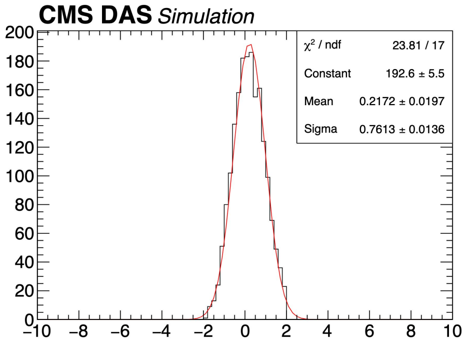
- Create the Pull distribution for each value of predicted top mass.
- Pull = $(E^{Peak}_{calibrated} - E^{Peak}_{predicted})/\Delta E^{Peak}_{calibrated}$
- Zero mean points towards no bias --->Results agree with the theoretical prediction.
- Width distribution is theoretically 1.
- Our width values range from 0.69 to 0.81 -->Lower values indicate overestimation of statistical uncertainty.



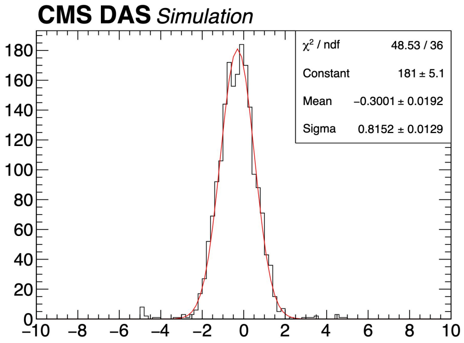


Calibration Performance

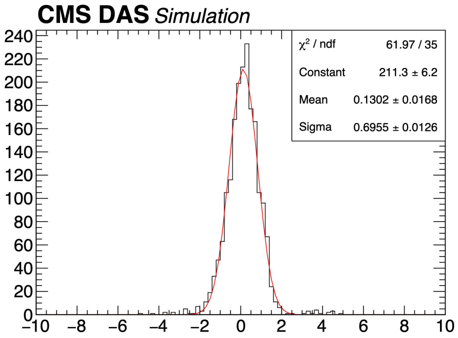
- Pull distributions for three different cases show calibration gives mean of the pull distributions close to zero.



Top mass = 169.5 GeV



Top mass = 172.5 GeV



Top mass = 175.5 GeV

Systematic Uncertainties

Even with infinite statistics, the error on a result will never be zero!

Such errors are called "**systematic uncertainties**", and typical origins are:

- ➢ **Imperfect modeling/simulation**
- ➢ **Lacking understanding of experiment**
- ➢ **Uncertainty in parameters involved**
- ➢ **Uncertainty associated with corrections**
- ➢ **Theoretical uncertainties/limitations**

While the statistical uncertainty is Gaussian and scales like , the systematic uncertainties do not necessarily follow this rule…

When **statistical** uncertainty is largest, more data will improve precision.
When **systematic** uncertainty is largest, more understanding will improve precision.

Theoretical Systematic Uncertainties

	δE_{peak} [GeV]	δm_t [GeV]
Final State Radiation	0,87	1,43
Initial State Radiation	0,099	0,16
Q^2 scale [Parton Shower]	0,009	0,018
Top P_t reweighting	1,63	2,67

- ➢ It has been observed in several analyses at 8 and 13 TeV that the **top-quark pT** is not perfectly reproduced in simulations.
- ➢ 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.

Experimental Systematic Uncertainties

- Jet energy resolution (JER)
- Jet energy scale (JES)
  - uncorrelated group
  - In-situ correlation group
  - Flavor
- Pileup
- b-tagging, trigger and lepton selection efficiencies
- Background normalization

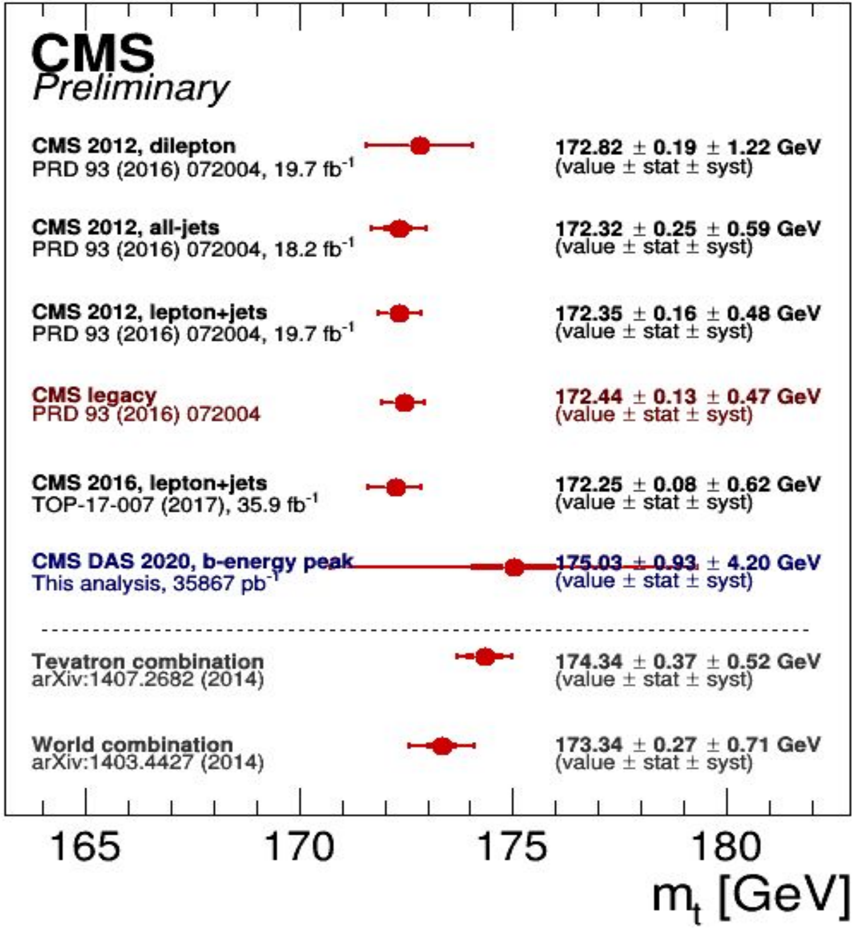
Experimental Systematic Uncertainties

	δE_{peak} [GeV]	δm_t [GeV]
Jet Energy Resolution	1.72	1.928
Pileup	0.0115	0.02286
Lepton Scale Factor	0.003	0.01257
Jet Energy Scale	1.3123	2.1572
Total (Theory + Exp)	**2.8472**	**4.197**

Results

Final results for the top mass:

$M_t = 175.03 \pm 0.93 \pm 4.20$ GeV
(value ± stat ± syst)



Summary

- Precise measurements of top mass is required for the radiative correction for W, Z and Higgs mass.
- Extracted top mass from b-jet energy spectrum in dilepton events.
- Our measurement yields the top mass value to be 175.03 ± 0.93 ± 4.20 GeV .
- Good result for such a small time window. ;)