

Determination of the Top-Quark Mass from the m_{1b} Distribution

in Dileptonic Top-Pair Events at $\sqrt{s} = 8 \text{ TeV}$

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02.12.2014

- Motivation -

- Event Selection & m_{1b} Definition -

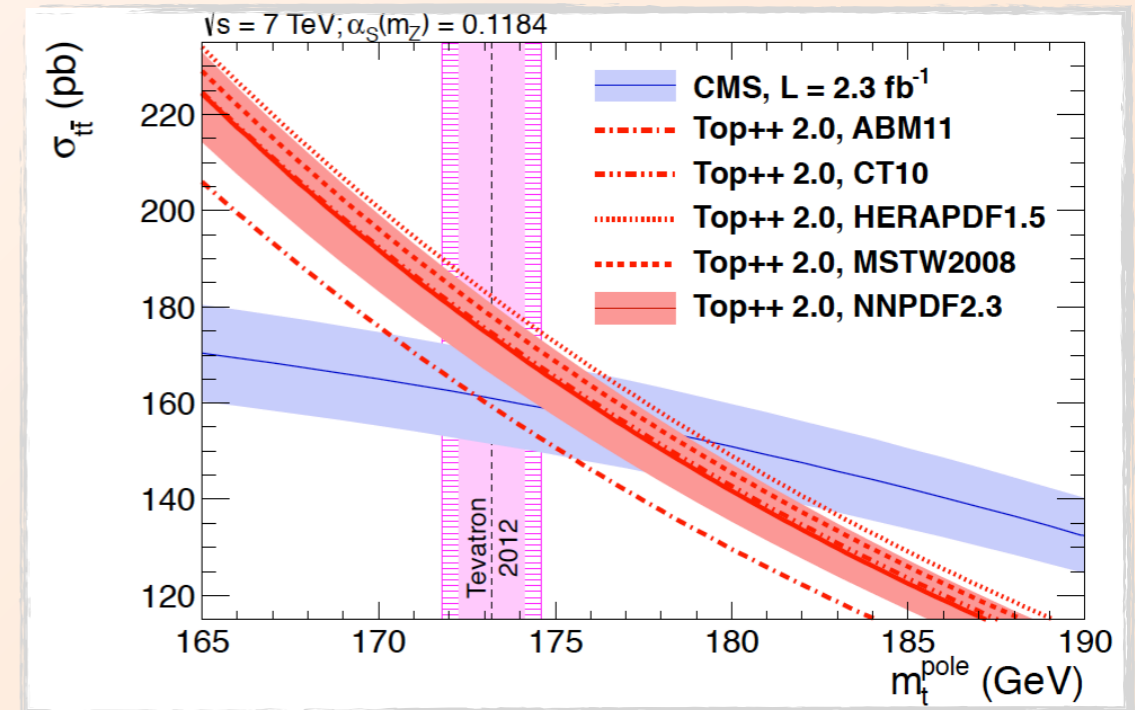
- Extraction: Method -

- Results -

- Summary -



- Inclusive $t\bar{t}$ cross sections used to extract $m_{t,\text{pole}}$ at NNLO
- Taking advantage of different slope of $\sigma_{\text{pred}}(m_t)$ and $\sigma_{\text{meas}}(m_t)$



(PLB 728 (2014) 496)

Next step:

- Extract m_t from differential cross sections
- Possibly more sensitive to m_t , more clear theoretical interpretation
- Step to simultaneous m_t , pdf, α_s extraction

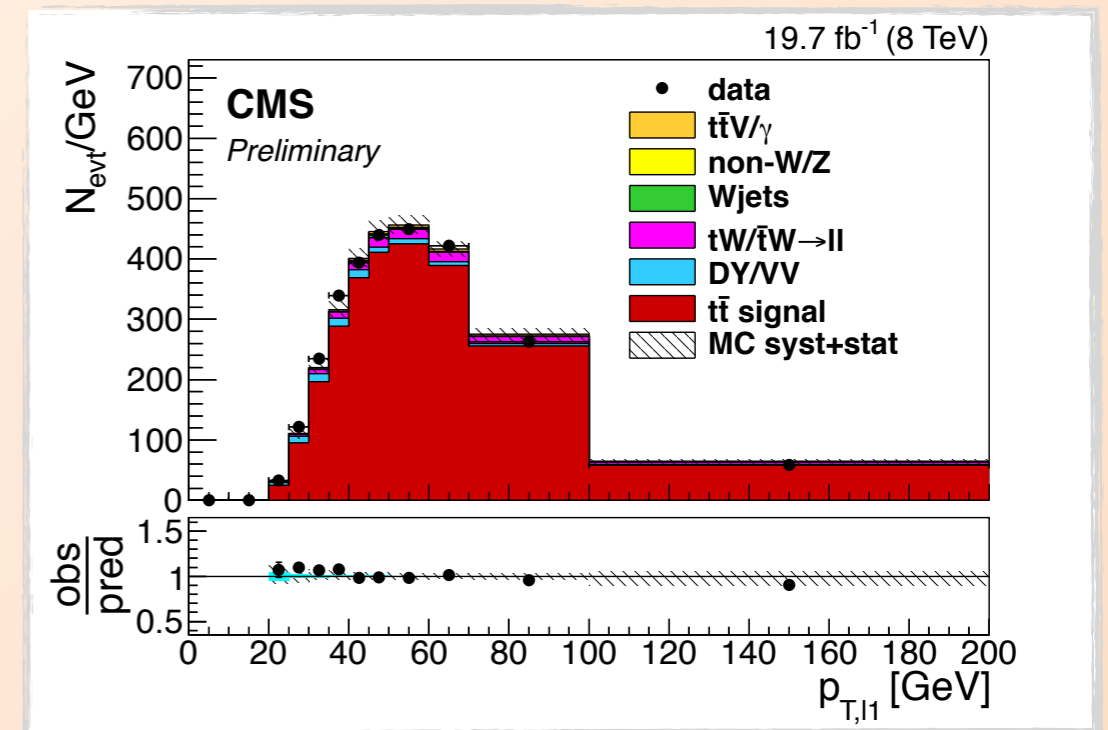
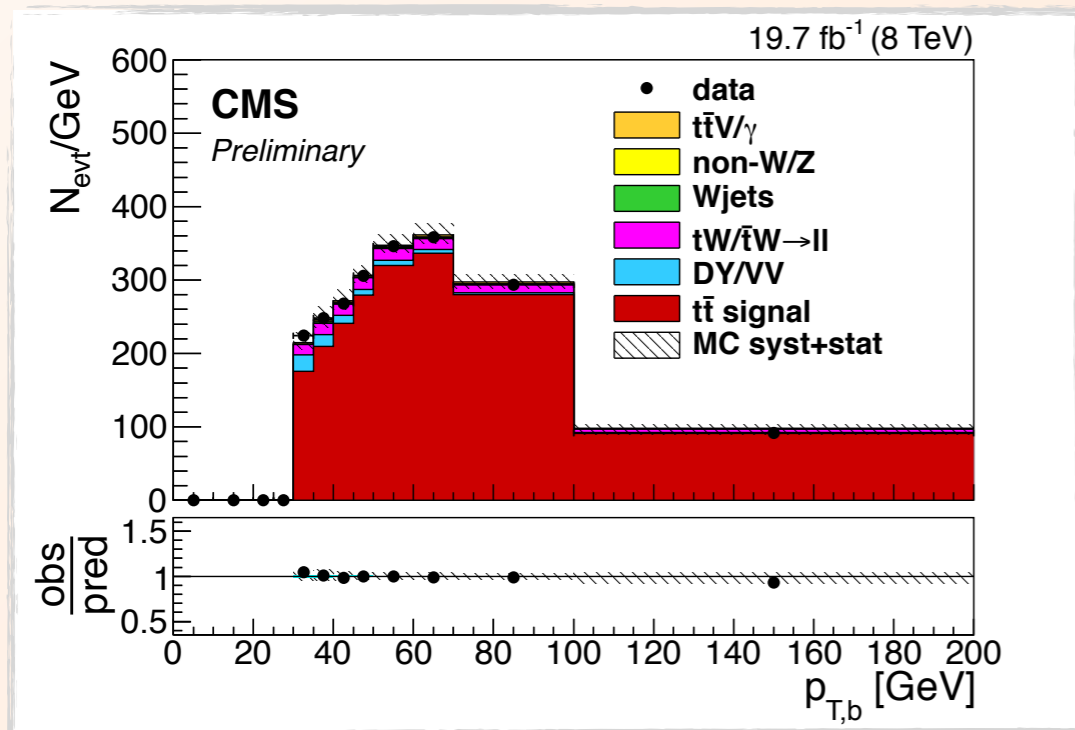
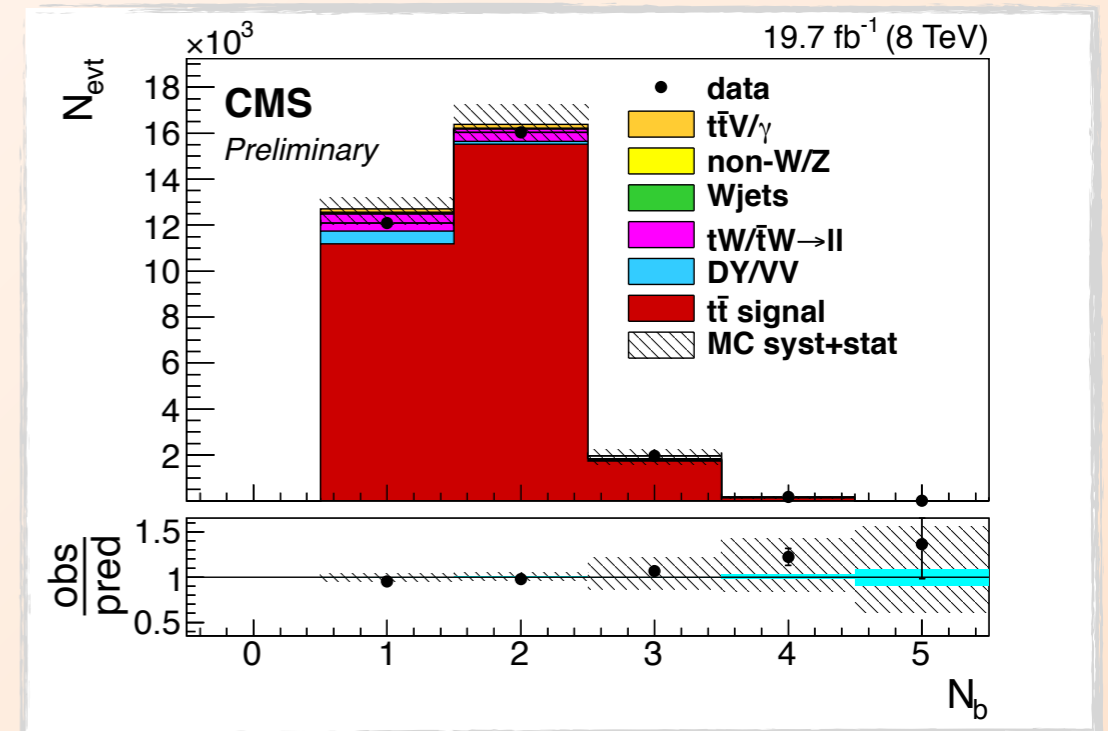
➔ Observable sensitive to m_t , measurement + prediction

Reference: CMS PAS-TOP-14-014



Event Selection and m_{1b} Definition

- Full 2012, 8 TeV dataset (19.7 fb^{-1})
- Signal: MadGraph+Pythia (7 mass-points)
- Selection
 - ▶ ≥ 2 opposite charged isolated leptons $e\mu$
 - ▶ Remove low $m_{ll} < 20 \text{ GeV}$
 - ▶ ≥ 2 high p_T jets
 - ▶ ≥ 1 b-tagged jet



- Definition on **generator** and **reconstruction** level

leading b:

- ▶ b-quark from top / b-jet
- ▶ $|\eta| < 2.4, p_T > 30 \text{ GeV}$

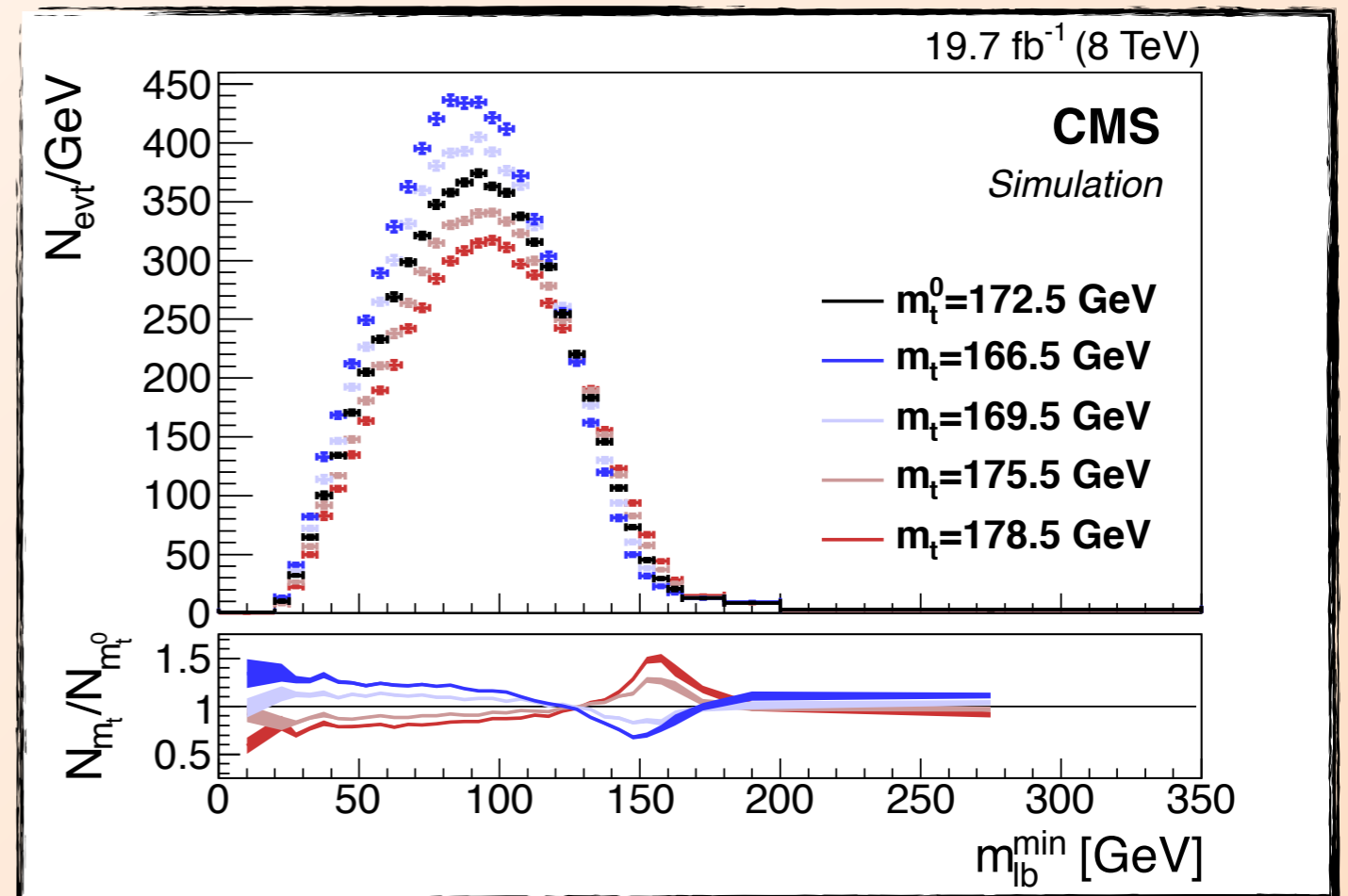
2 x l:

- ▶ Status 3 ME leptons from top (e/ μ /tau(\rightarrow e, μ)) / selected oppositely charged lepton pair
- ▶ $|\eta| < 2.4, p_T > 20 \text{ GeV}$

$m_{lb,min}$:

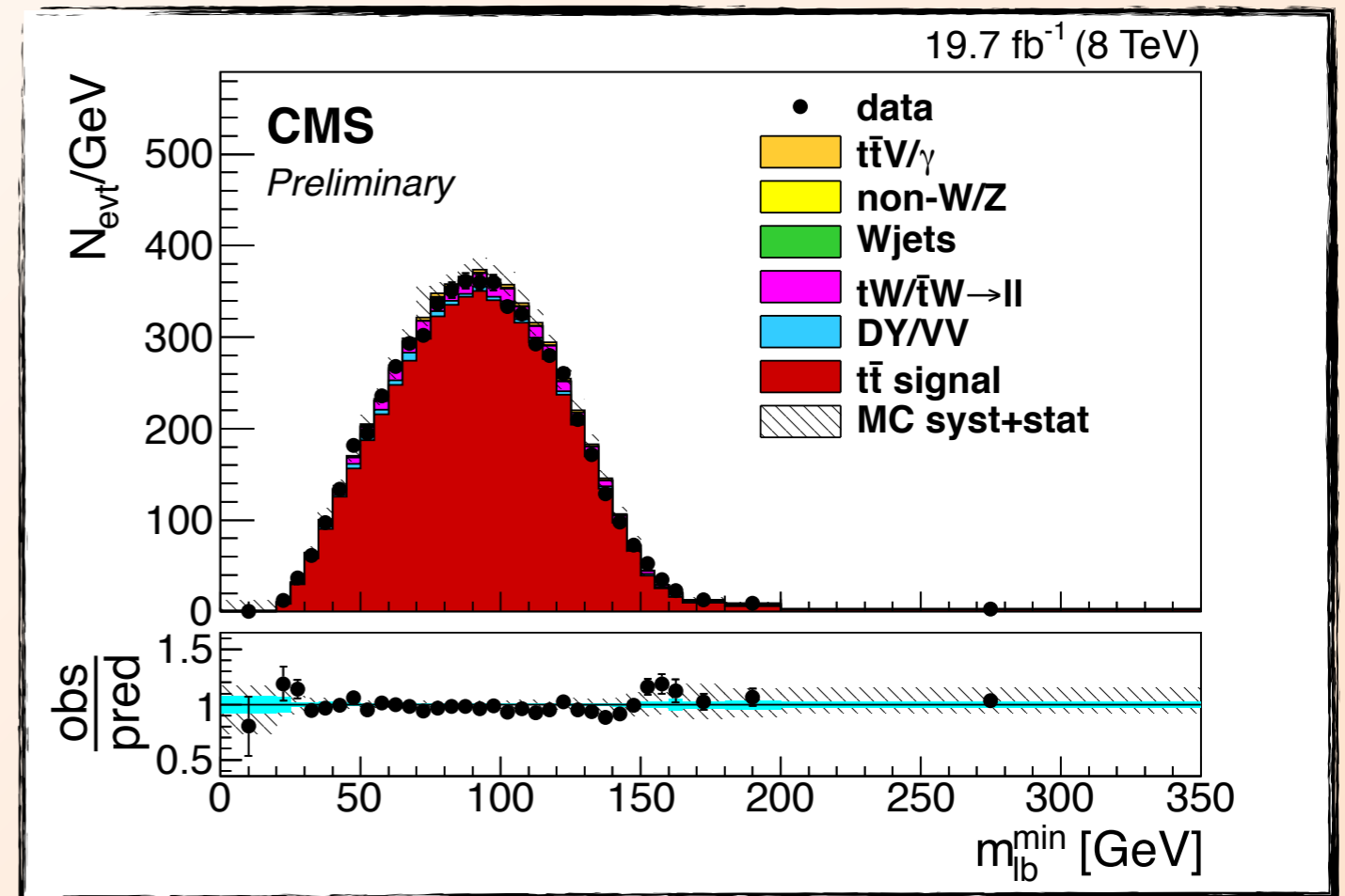
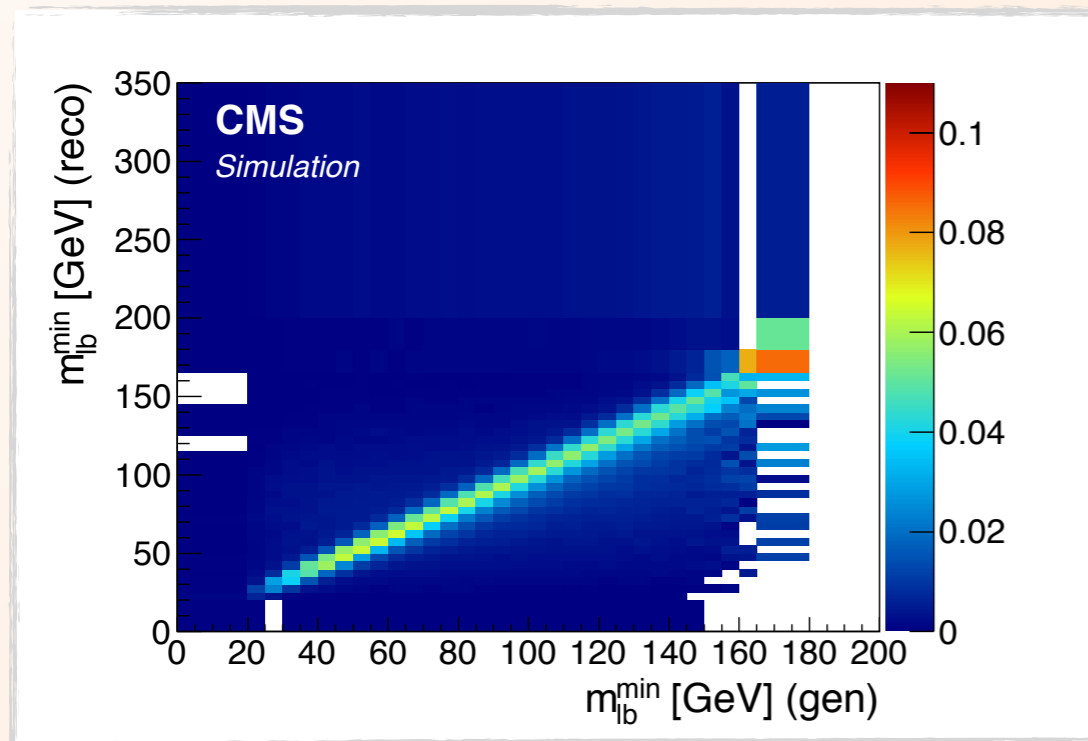
- ▶ use smaller m_{lb} of 2 combinations

- ➔ Combines production rate and decay shape
- ➔ Leading b-jet: smaller JES uncertainties
- ➔ Lepton kinematics known to high precision
- ➔ Visible phase space (vis. PS)



MadGraph+Pythia normalized to NNLO+NNLL

- Good data/MC agreement
- Low background
- Only small contribution of migrations from outside visible PS



- τ decays, efficiencies included in response matrix

$$\vec{x}_{reco} = \mathcal{L} \cdot M^{resp} \vec{x}_{pred}$$

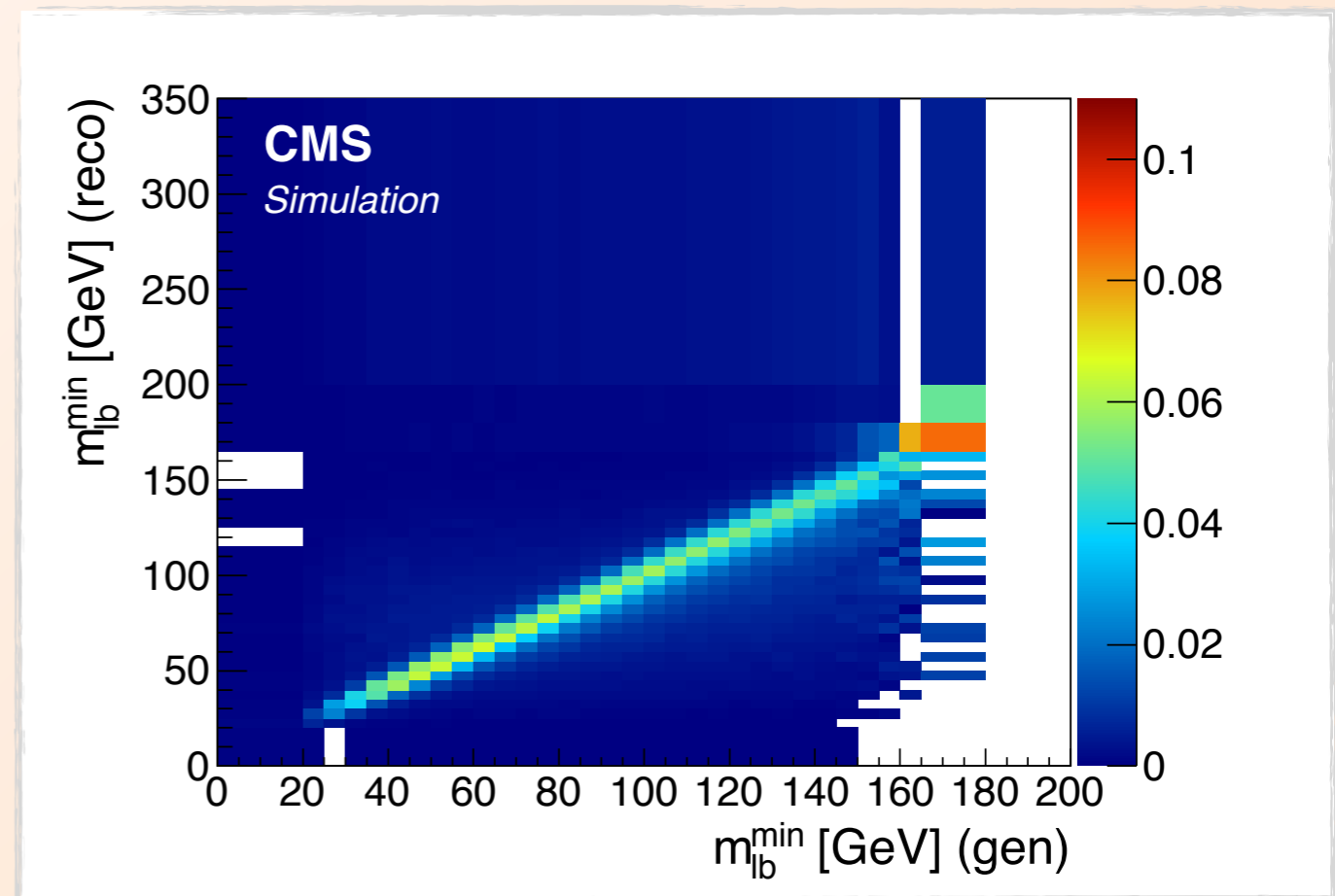
- Strong correlation between reconstructed and generated $m_{lb,min}$

- Use reconstruction level distributions
- Compare to MadGraph on reconstruction level
- Fold theory:

$$M_{ij}^{resp} = N_{ij} / \sum_{j=0}^n N_{ij}$$

$$\vec{x}_{reco} = \mathcal{L} \cdot M^{resp} \vec{x}_{pred}$$

- Separate matrix for each systematic variation / m_t
- Reflects:
 - ▶ Detector modeling uncertainties
 - ▶ Signal modeling uncertainties (reconstruction efficiencies)

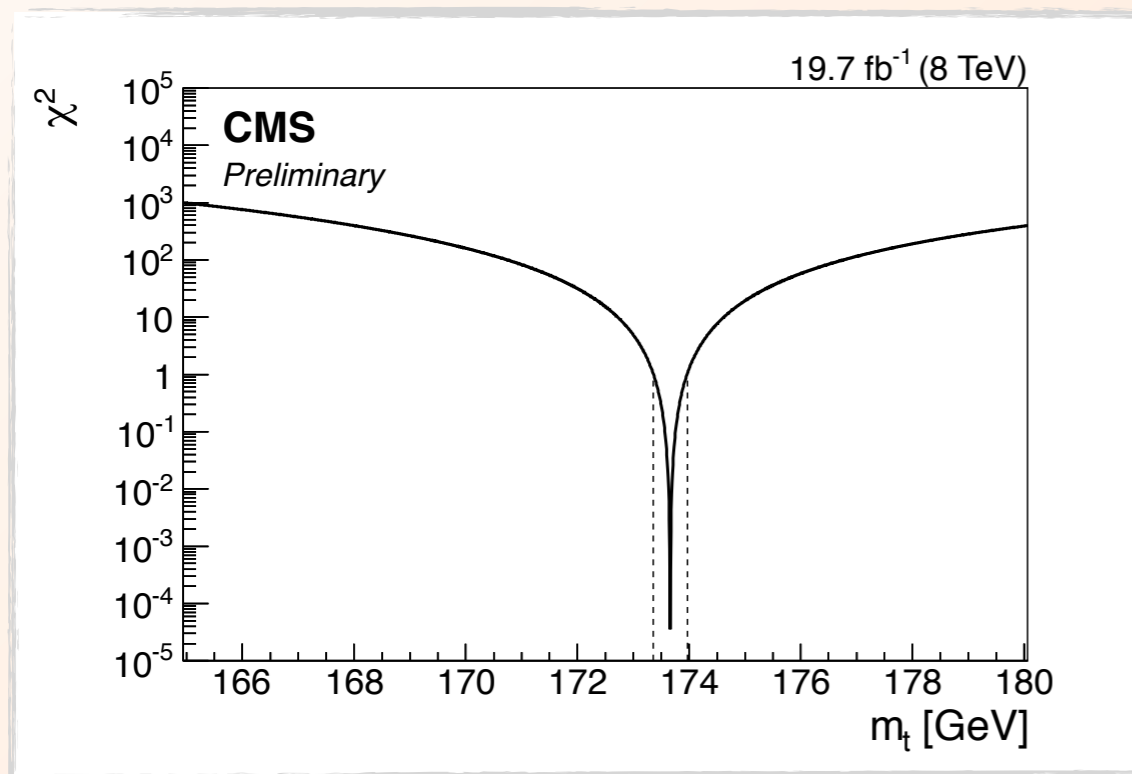
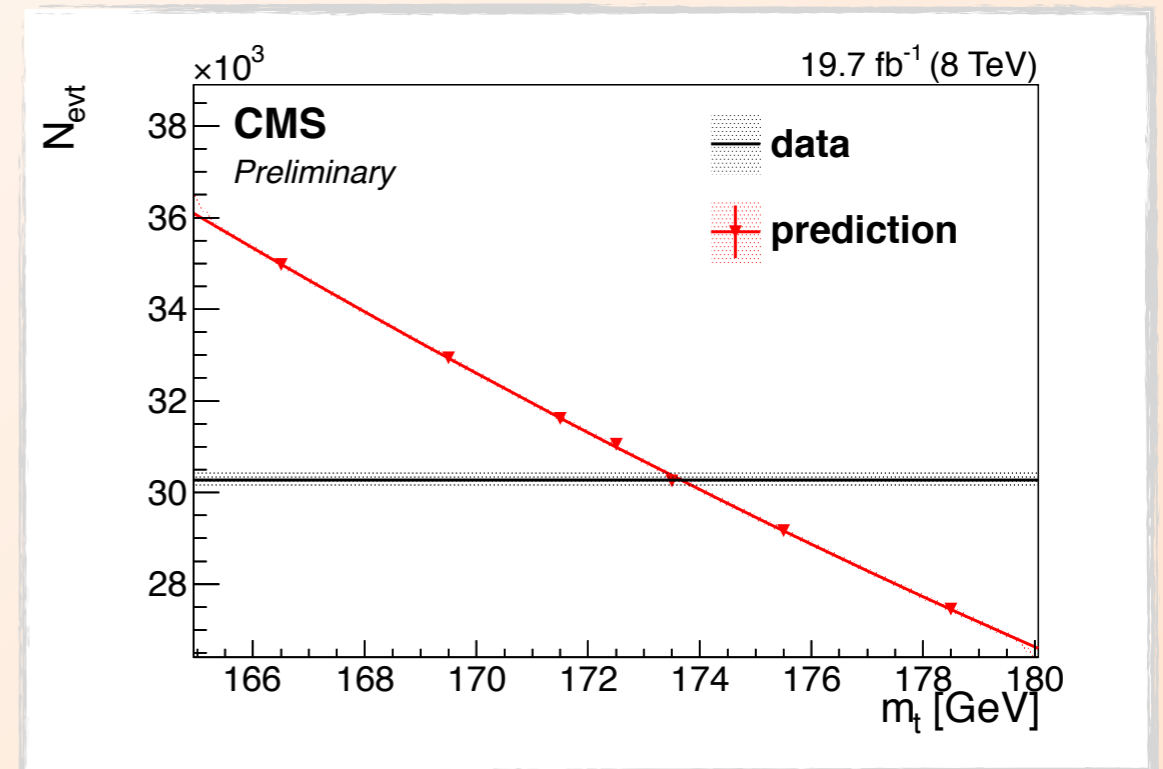


- No additional unfolding/regularization uncertainties
- No stat. correlations between bins of reconstructed distribution
- Here: Fold theory within visible phase space



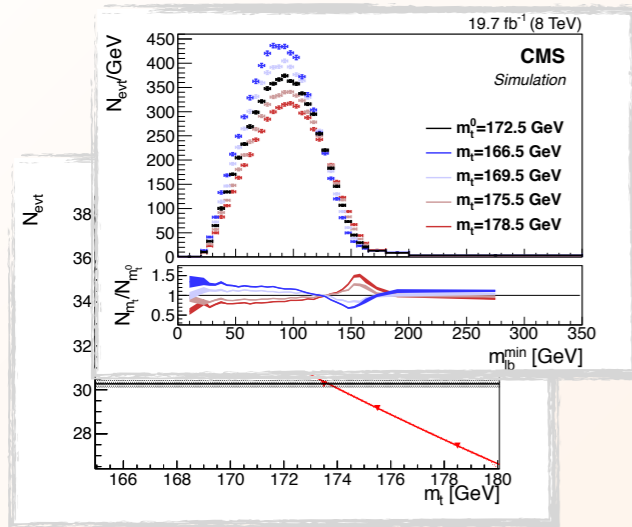
Top-Mass Extraction: Method

- Fit m_t -dependence of prediction, N_{pred} , with 2nd order polynomial
 - ▶ Includes backgrounds
 - ▶ Use statistical uncertainty (mostly background) from central point $\rightarrow \sigma_{\text{pred}}$
 - ▶ Parametrization uncertainties not included here (\rightarrow see systematics)
- Data yield N_{data} : constant with σ_{data}



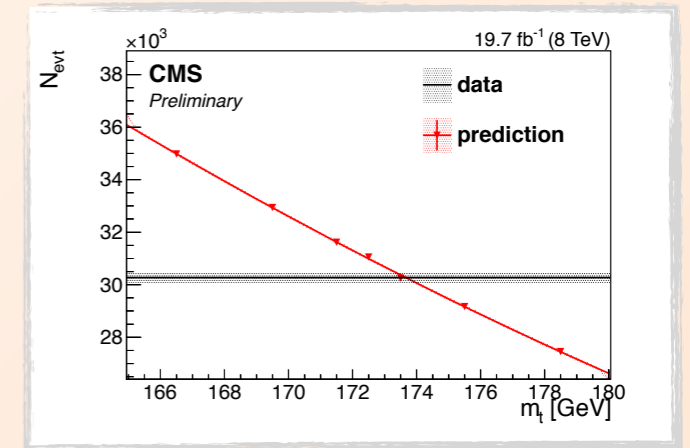
- Define estimator
$$\chi^2 = \frac{(N_{\text{pred}} - N_{\text{data}})^2}{\sigma_{\text{pred}}^2 + \sigma_{\text{data}}^2}$$
- Extract top mass from minimum of $\chi^2(m_t)$
- For total rate or in bins of any distribution (m_{lb})

Method Overview



prediction:
either
or + data

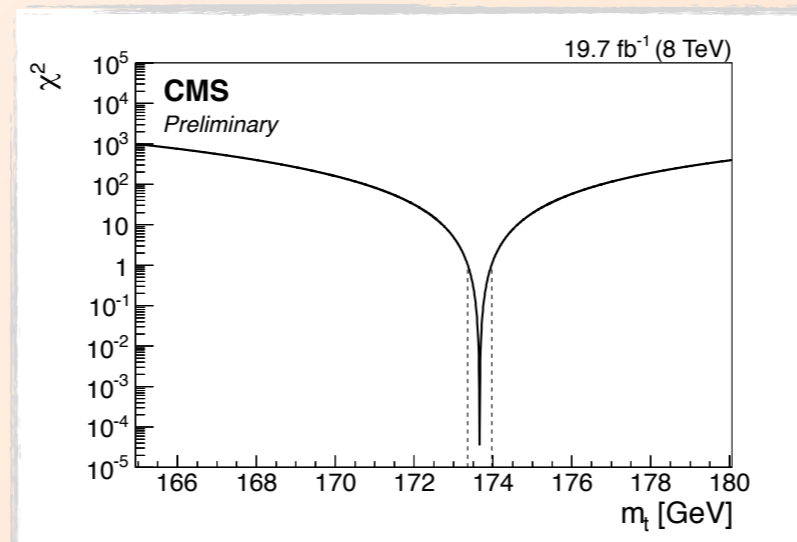
$$N_{\text{pred},i}(m_t)$$



- For each m_{lb} bin:
 - Derive m_t dependence of pred (fit)
 - Construct $\chi^2(m_t)$
- Combine bins
 - No stat correlations \rightarrow sum χ^2 over bins
- Determine m_t
 - Repeat for each syst. variation

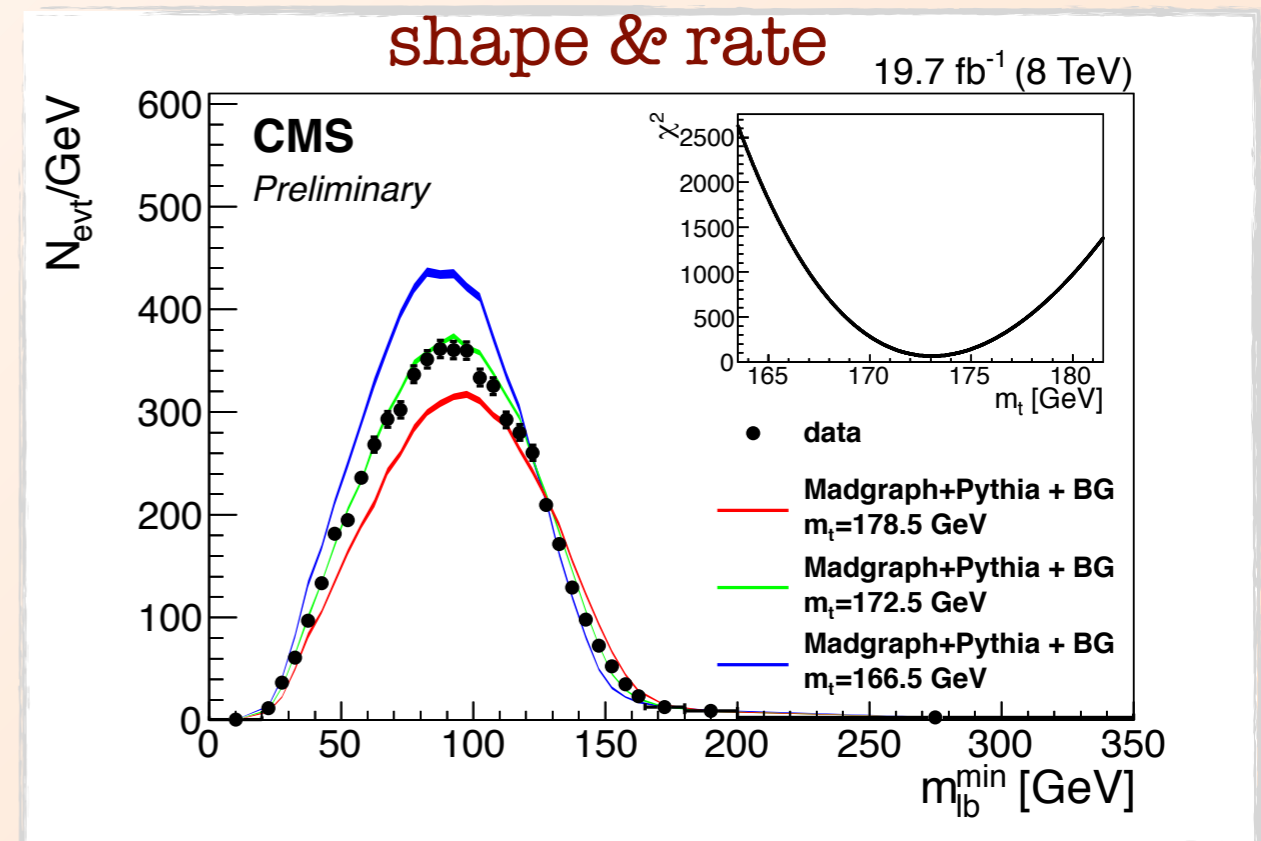
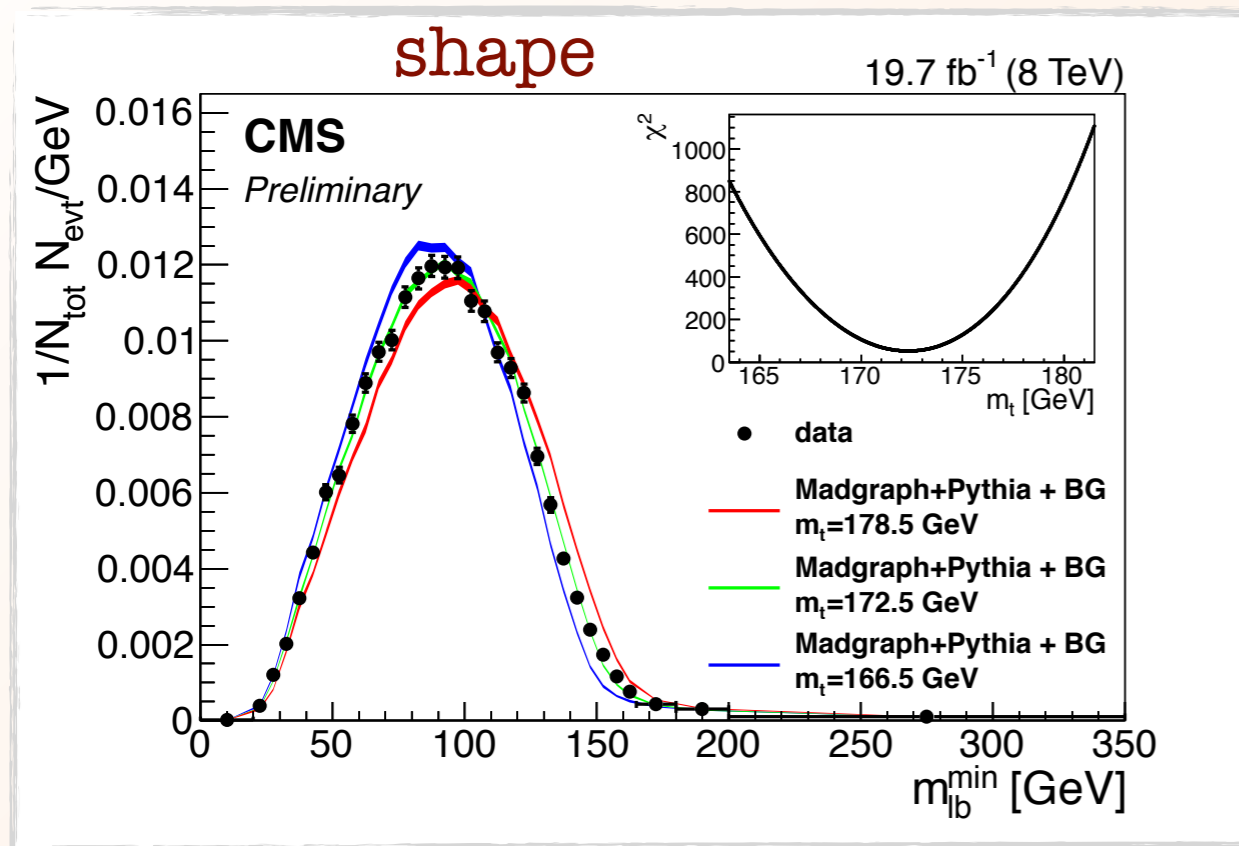
$$\chi^2 = \frac{(N_{\text{pred}} - N_{\text{data}})^2}{\sigma_{\text{MC}}^2 + \sigma_{\text{data}}^2}$$

m_t
rate
shape & rate
shape





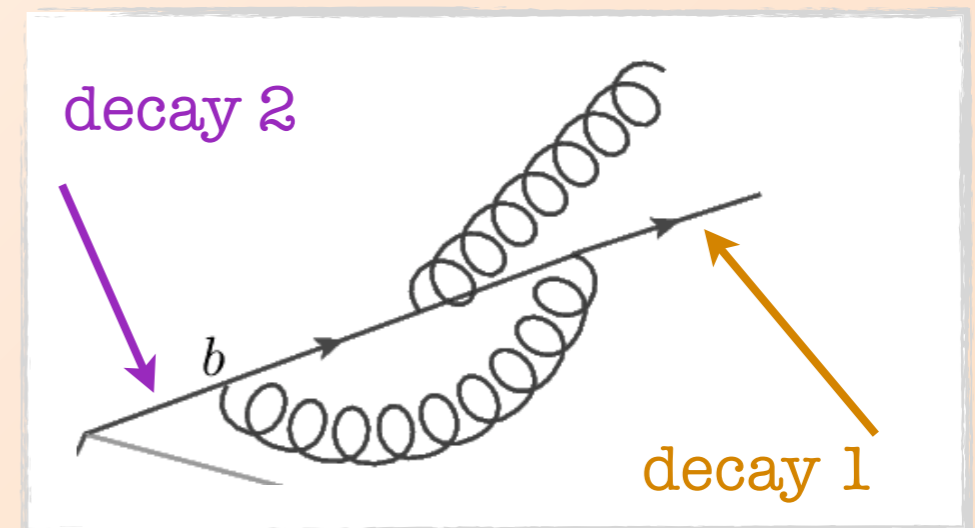
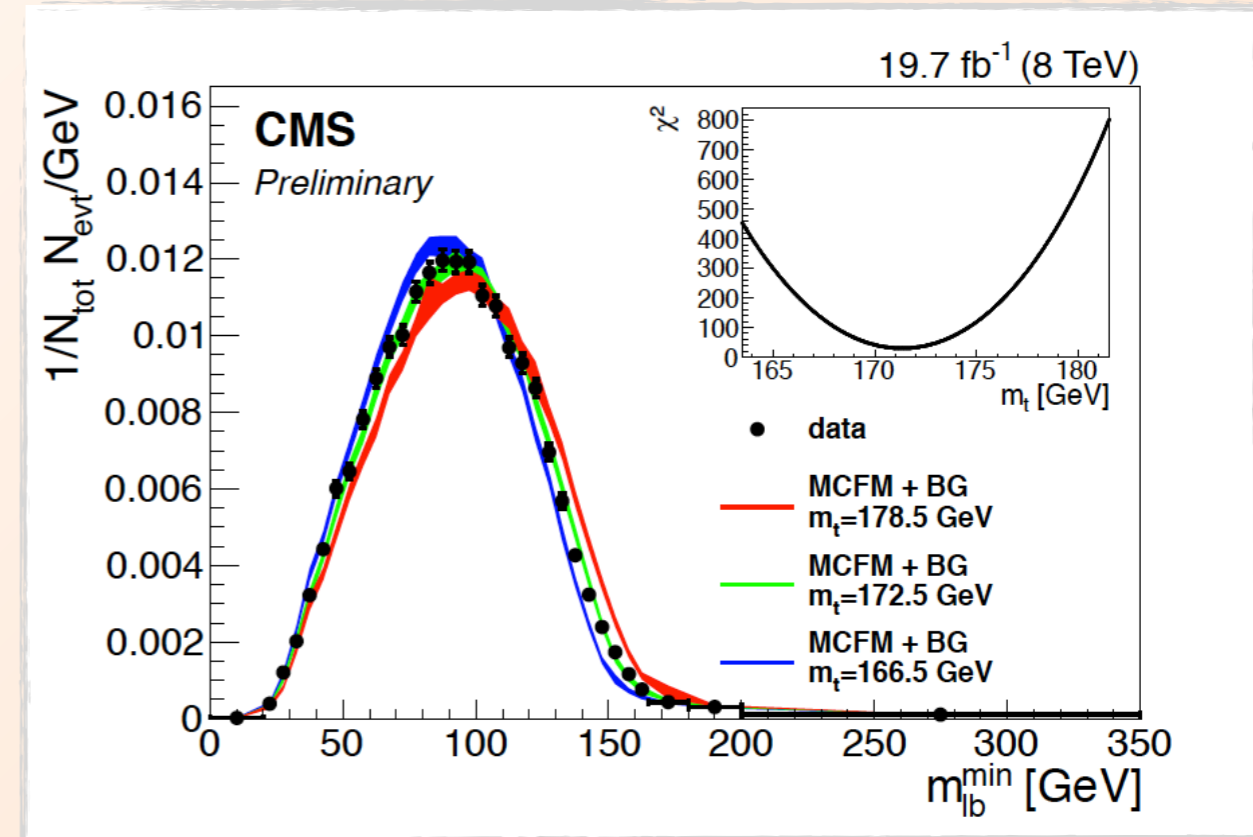
Top-Mass Extraction: Results



only stat uncertainties

- MadGraph+Pythia + background processes
- Extraction performed for shape only, shape & rate and rate-only
- Repeated for each systematic uncertainty

- Use MCFM to simulate $m_{lb,min}$ distribution in. vis PS
- Fold to detector level and extract top mass
 - ▶ normalized (rate underestimated)
- Pure MCFM NLO / LO
- NLO production + decay 1
 - ▶ Real and virt. corrections in decay & production
- **NLO production + decay 2**
 - ▶ Real and virt. corrections in production only
(Closest to MadGraph ME level)
- Plain LO (no FSR)
- Uncertainties similar to MadGraph+Pythia

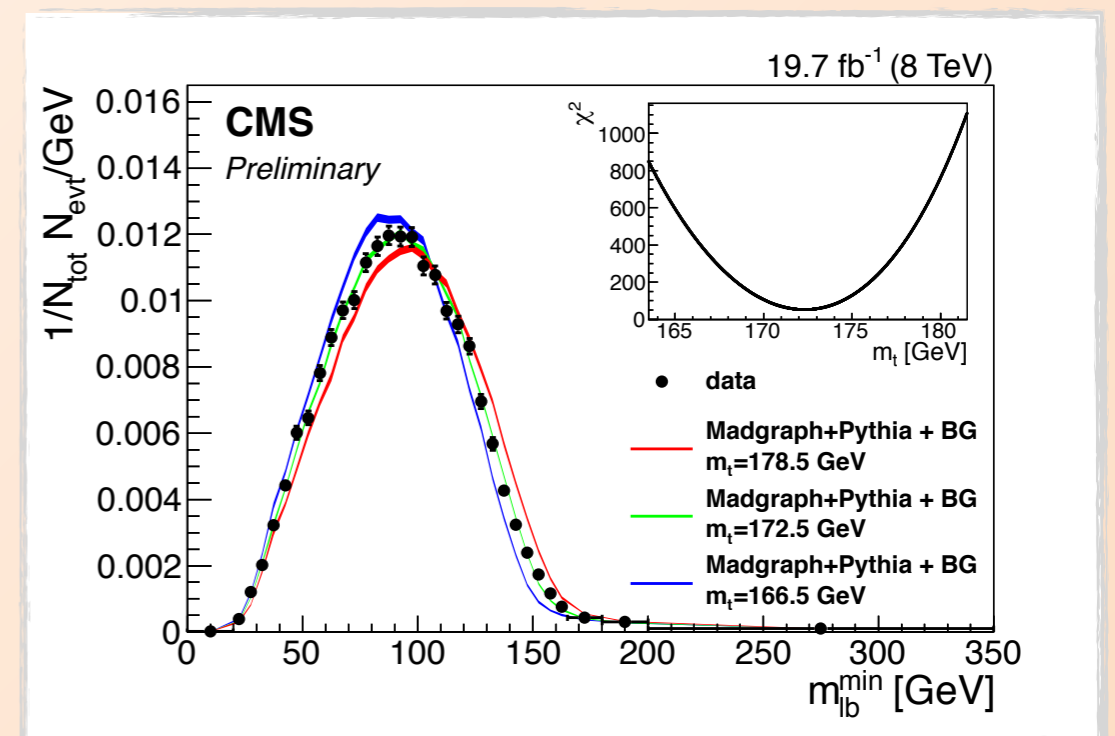


- M_{lb} shows low m_t -sensitivity wrt. higher orders in production
- Overall consistent results from “shape”, “shape & rate” and “rate” based extraction

Dominant uncertainties (experimental/theory):

- Rate:
 - ▶ normalization uncertainties, JES
 - ▶ signal normalization
- Shape & rate:
 - ▶ partial cancellation of JES uncertainties
 - ▶ signal normalization
- Shape → smallest total uncertainty
 - ▶ JES
 - ▶ Q^2 scale

Prediction	Fit method	Fitted m_t [GeV] from m_{lb}^{\min}
MADGRAPH+PYTHIA	shape+rate	173.1 $^{+1.9}_{-1.8}$
MADGRAPH+PYTHIA	rate	173.7 $^{+3.5}_{-3.4}$
MADGRAPH+PYTHIA	shape	172.3 $^{+1.3}_{-1.3}$
MCFM (LO)	shape	171.5 $^{+1.1}_{-1.1}$
MCFM (NLO)	shape	171.4 $^{+1.0}_{-1.1}$





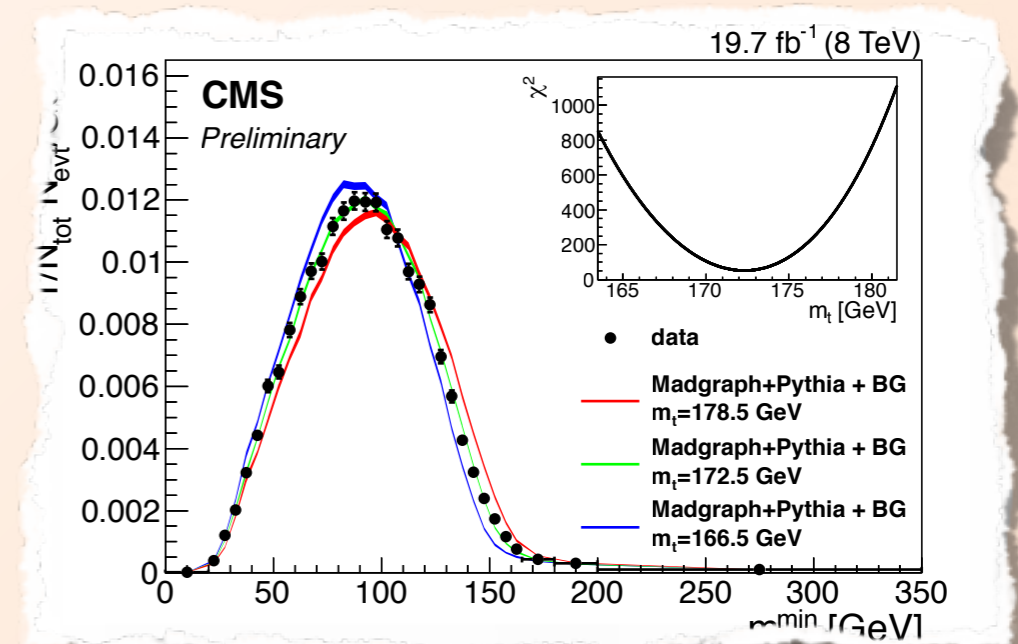
Summary

- Extracted top mass from reco-level m_{lb} distributions & total rate with MadGraph+Pythia

- ▶ From shape: $m_t = 172.3 \pm 1.3$ GeV
- ▶ All “MadGraph+Pythia mass”-values consistent
- ▶ Partial cancellation of uncertainties in shape+rate extraction

- Extracted using folded MCFM LO/NLO

- ▶ No unfolding/regularization effects
- ▶ Low sensitivity of m_{lb} to production mechanism



Available on the CERN CDS information server

CMS PAS TOP-14-014

CMS Physics Analysis Summary

Contact: cms-pag-conveners-top@cern.ch

2014/11/02

Determination of the top-quark mass from the lepton-b-jet invariant mass distribution in dileptonic $t\bar{t}$ events using proton-proton collision data at $\sqrt{s} = 8$ TeV

The CMS Collaboration



BACKUP

- Based on fitted $N_{\text{pred}}(m_t)$ (per bin)
- Data toys:
 - ▶ Random yield (Poisson) around N_{pred}
 - ▶ Same statistics as data
- Prediction toys:
 - ▶ Signal
 - Random yield (Poisson) with tt MC statistics
 - Uncorrelated for each mass point
 - ▶ Background
 - Random yield (Poisson) with background MC statistics
 - Correlated for each mass point
 - ▶ Scaled back to luminosity and added
- Extract m_t and evaluate $m_{t,\text{in}}$ vs. $m_{t,\text{out}}$ ($\times 10^5$)
- ➔ No bias
- ➔ Stat uncertainties estimated correctly

private work

