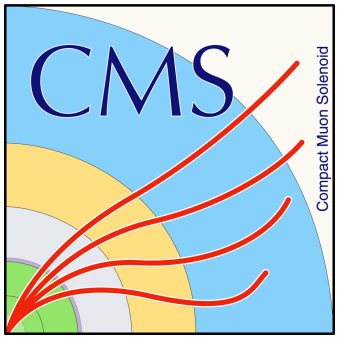
Measurement of the jet mass distribution in boosted $t\bar{t}$ production at $\sqrt{s} = 8$ TeV

CMS-PAS-TOP-15-015

Torben Dreyer, Johannes Haller, Roman Kogler



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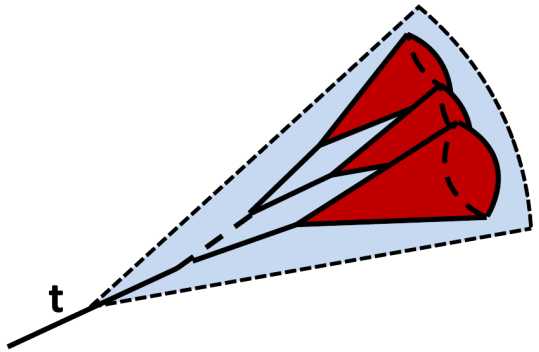
introduction

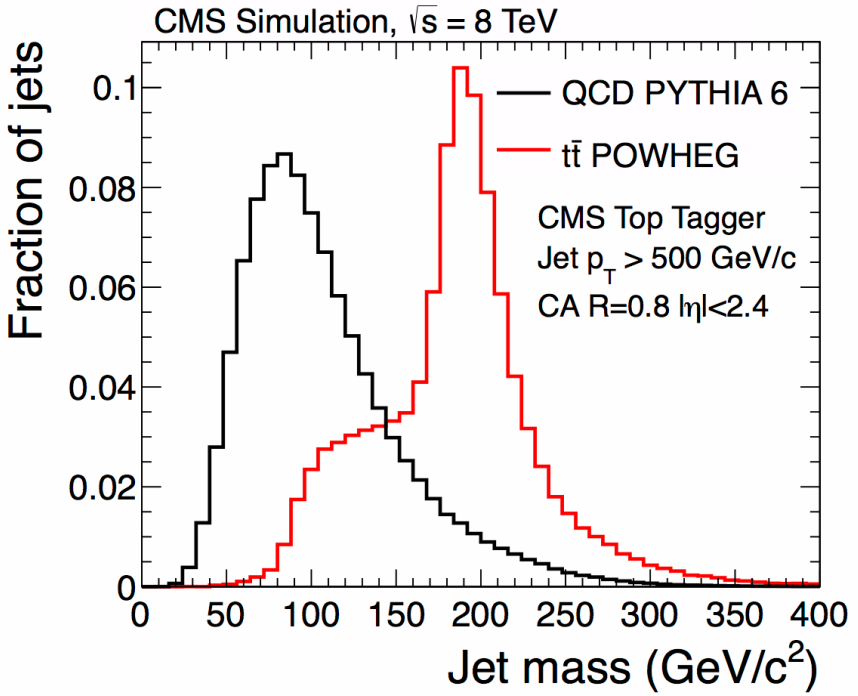
Jet Mass: invariant mass of all stable particles in a jet



boosted top quarks:

- decay products merge
- reconstruction of a full top quark decay in one large jet

→ Jet Mass ~ m_t



[CMS-PAS-JME-13-007]

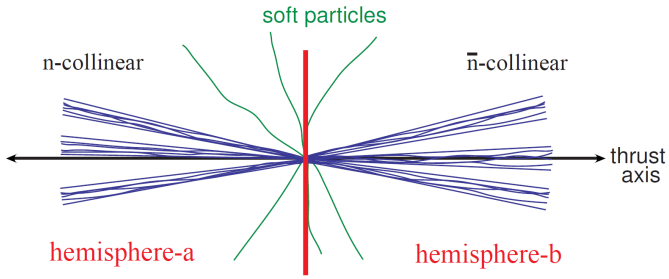
motivation:

- Jet Mass used to identify boosted top quarks (used by all top-tagging algorithms)
- test simulation of top jets (radiation, UE, ...)
- peak position sensitive to m_t

introduction

calculations of the Jet Mass from first principles possible in EFT

- calculation on particle level
- fragmentation included via soft functions



[S. Fleming, A. H. Hoang et al.]

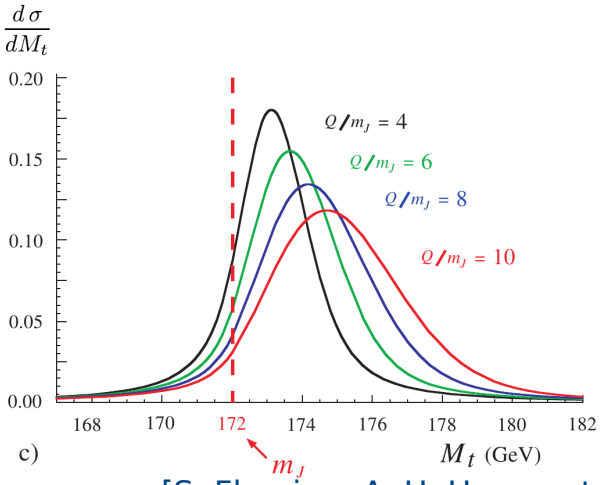
calculations for Top Quarks:

[S. Fleming, A. H. Hoang et al., Phys. Rev. D77 (2008) 074010, …, JHEP 12 (2015) 059]

- boosted top quarks in lepton-lepton collisions
- all decay products in one hemisphere ("jet")

  → extraction of m_t in well defined mass scheme possible

- LHC calculations on the way



[S. Fleming, A. H. Hoang et al.]

analysis aim:

differential and normalized differential $t\bar{t}$ cross section measurement

as a function of the leading jet mass on particle level

→ provide data for comparison to EFT calculations

→ extraction of m_t from simulation templates to estimate the sensitivity

phase space definition

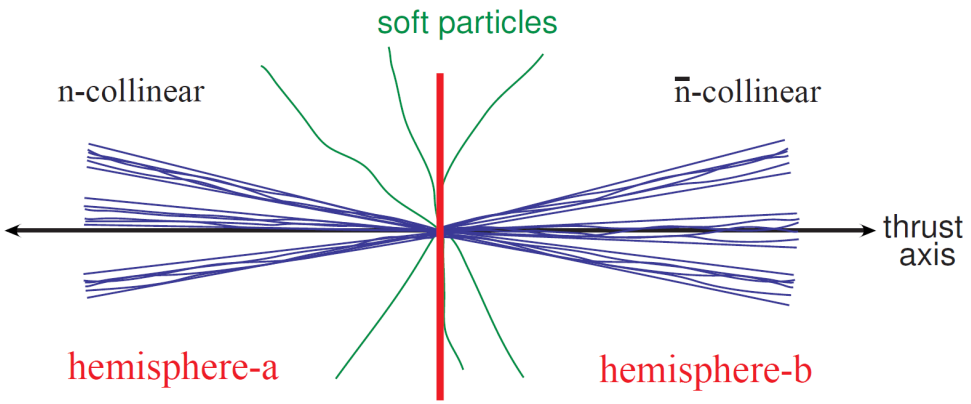
goal: phase space calculable theoretically and measurable experimentally

theory constraints:

all decay products in the jet

→ large p_T

→ veto on additional jets



[S. Fleming, A. H. Hoang et al., Phys. Rev. D77 (2008) 074010]

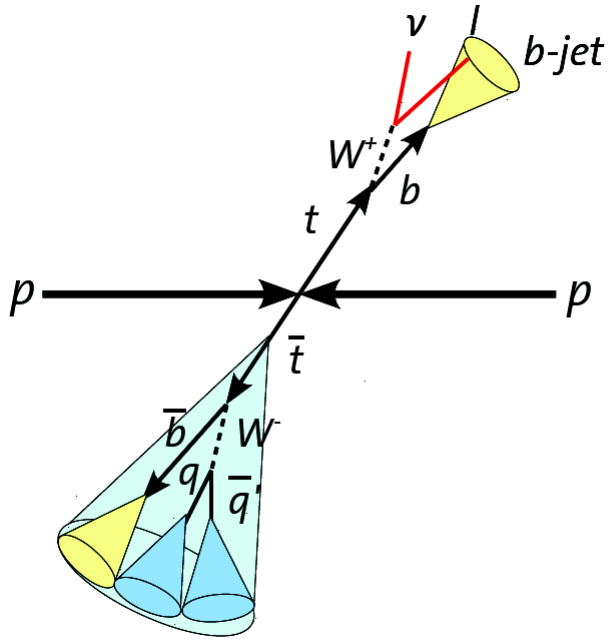
experimental constraints:

enough statistics

→ p_T not too large

→ large jets

small background



=> measurement in **lepton + jets** channel

Cambridge/Aachen (CA) jets with **R = 1.2** and **p_T > 400 GeV**

selection on particle level

measurement of the jet mass of the leading jet in $t\bar{t}$-decays

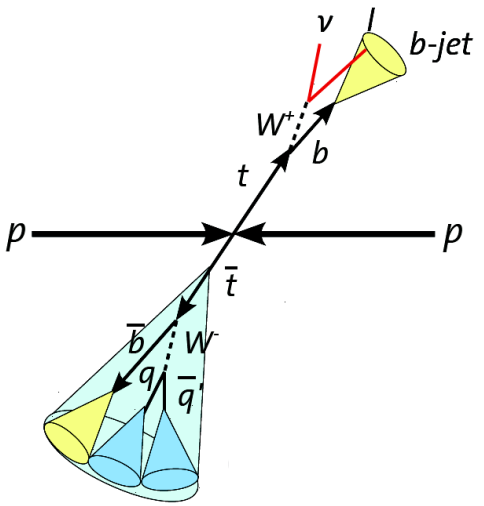
electron/muon+jets channel

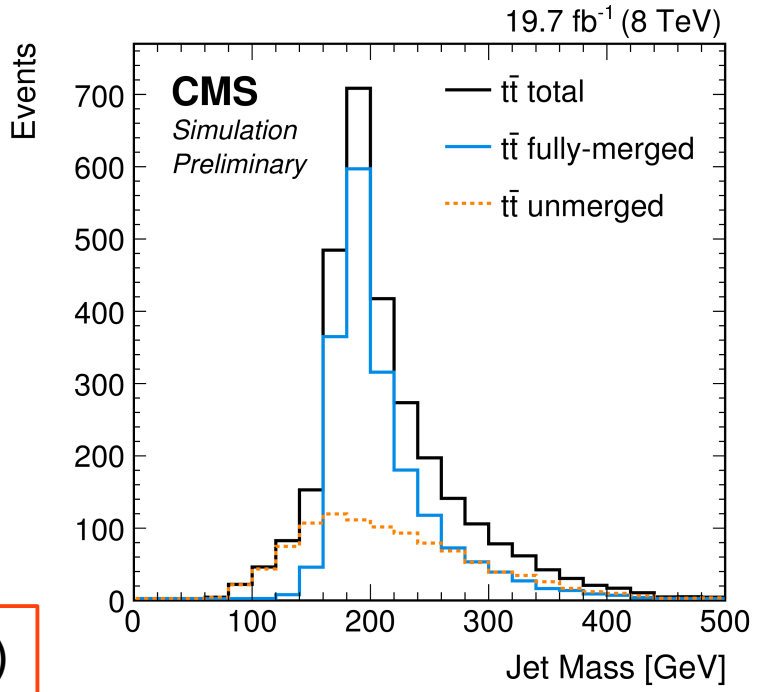
selection on particle level

- >= 1 jet with p_T > 400 GeV , $|\eta|$ < 2.5
- >= 2 jets with p_T > 150 GeV, $|\eta|$ < 2.5
- veto on additional jets with p_T > 150 GeV, $|\eta|$ < 2.5
- 1 electron/muon p_T > 45 GeV, $|\eta|$ < 2.5
- ΔR(second jet, lepton) < 1.2
- $m_{\text{leading jet}} > m_{\text{2nd jet+lepton}}$

selection agreed with theorists (A. Hoang and I. Stewart)

particle level!



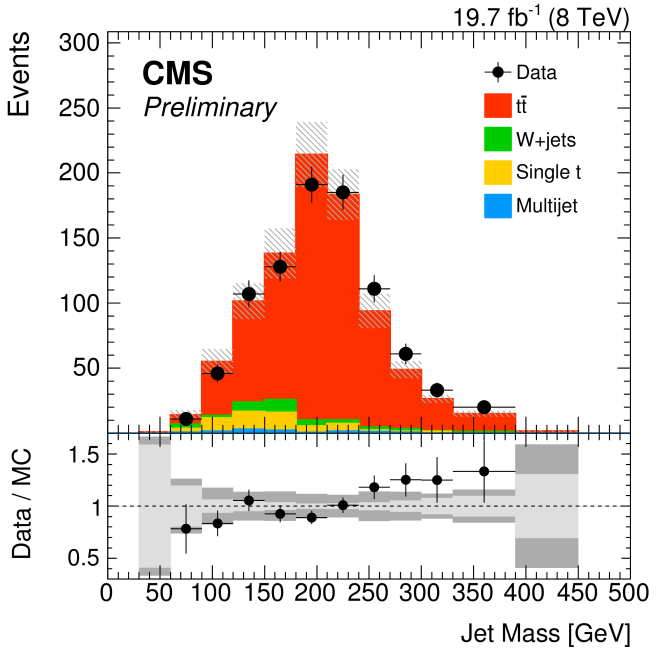


event selection

$t\bar{t}$ selection

- used to suppress backgrounds
- similar to B2G-13-008 (“Search for resonant $t\bar{t}$ production in proton-proton collisions at $\sqrt{s}$ = 8 TeV”)
- use of non-isolated leptons
- b-tagging

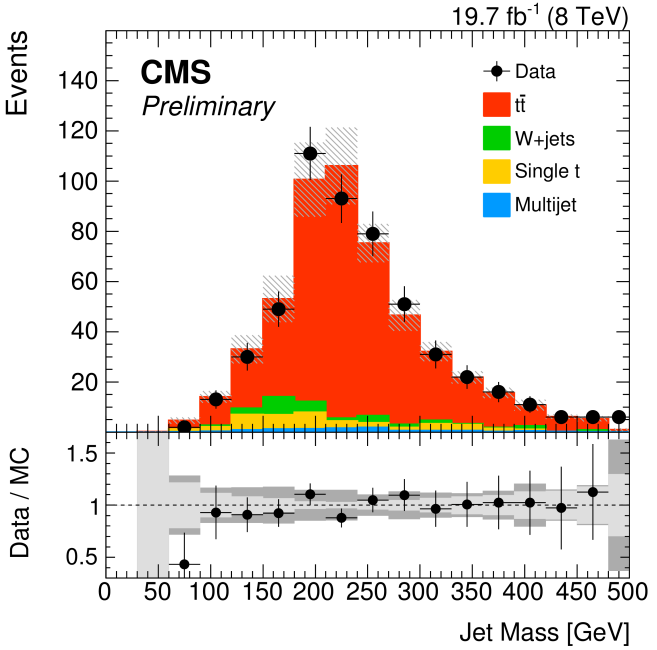
p_T > 400 GeV
p_T < 500 GeV



phase space selection

- similar selection as on particle level

p_T > 500 GeV



p_T bins

- shape of the mass distribution depends on p_T
- divide the phase space in two p_T bins
- less model dependence in the unfolding

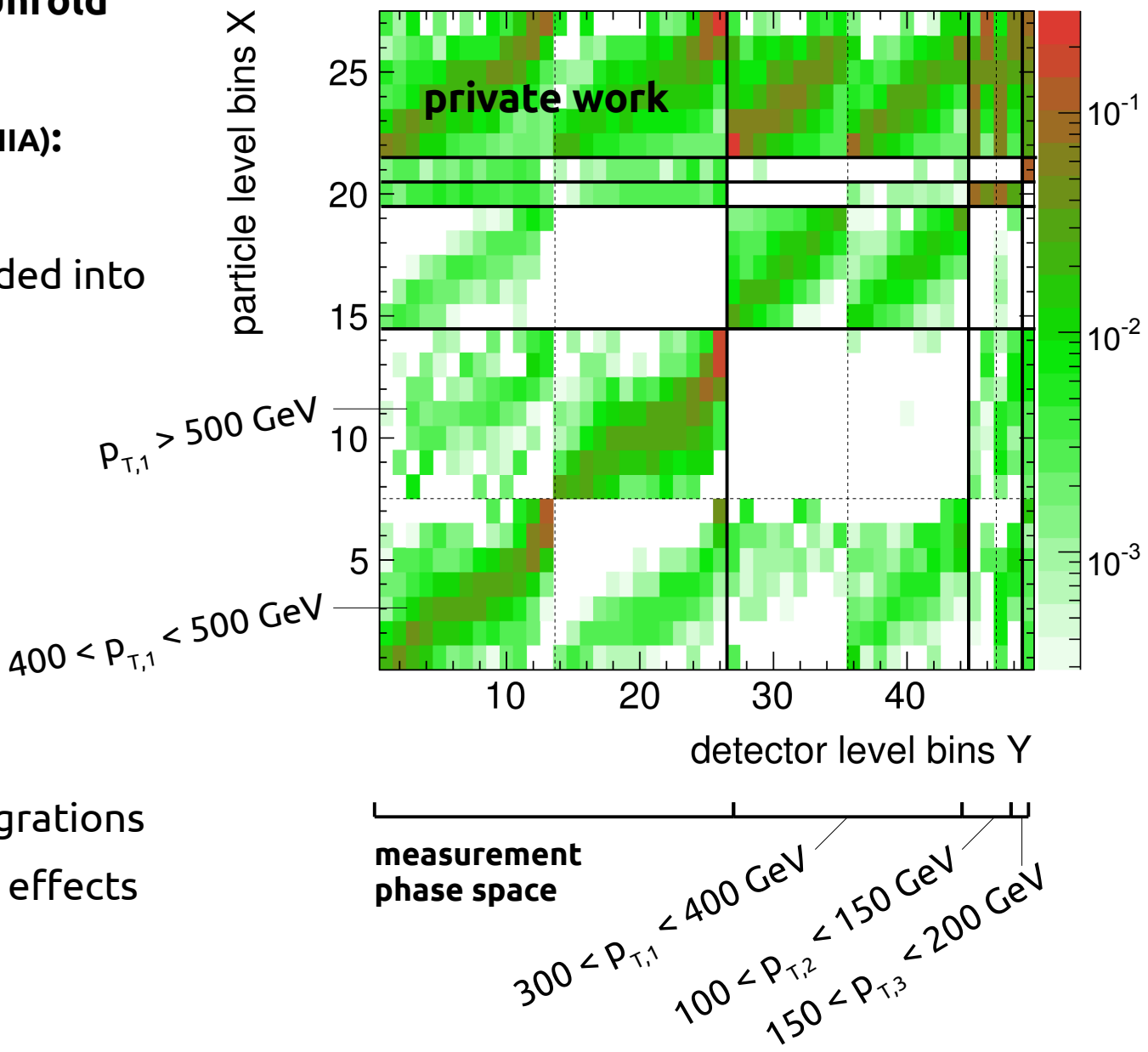
unfolding

regularized unfolding with TUnfold

response matrix (POWHEG+PYTHIA):

measurement phase space divided into two p_T bins

- 400 GeV < p_T < 500 GeV
- p_T > 500 GeV

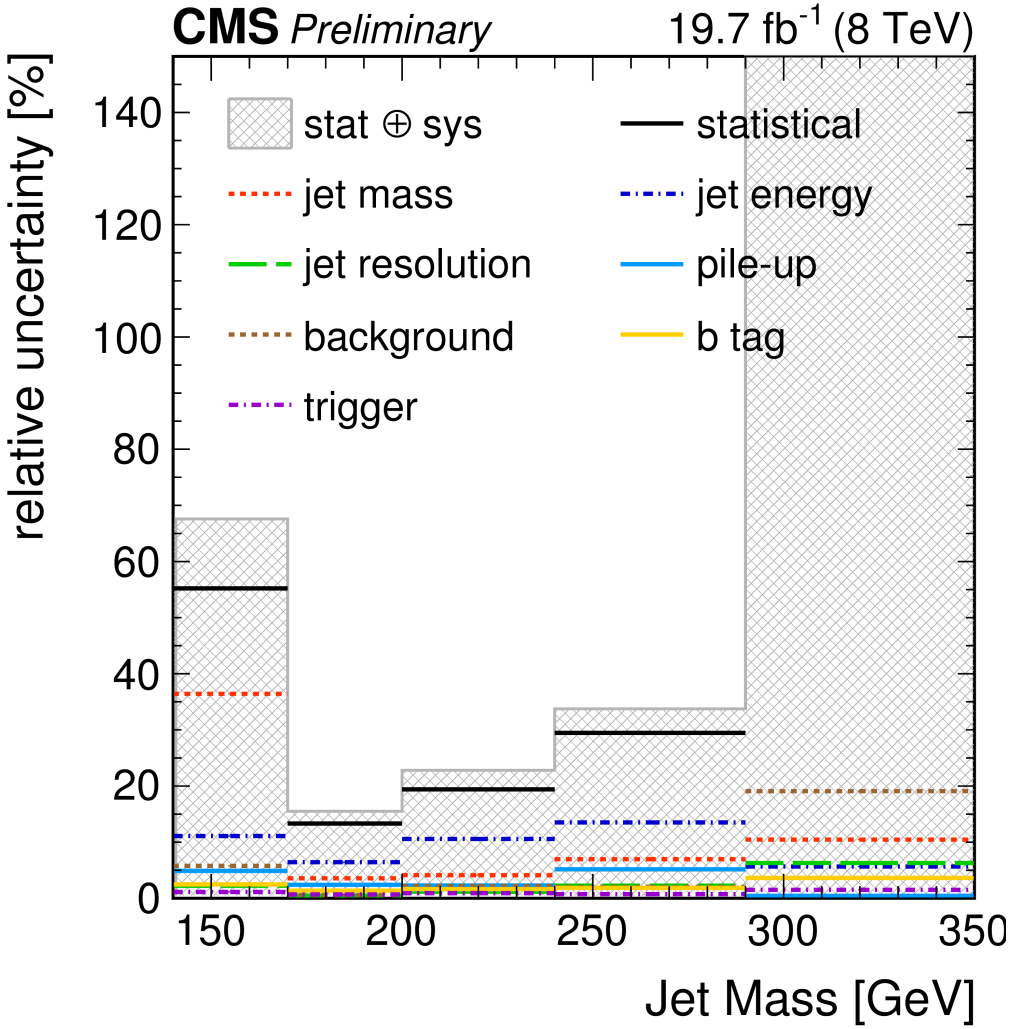


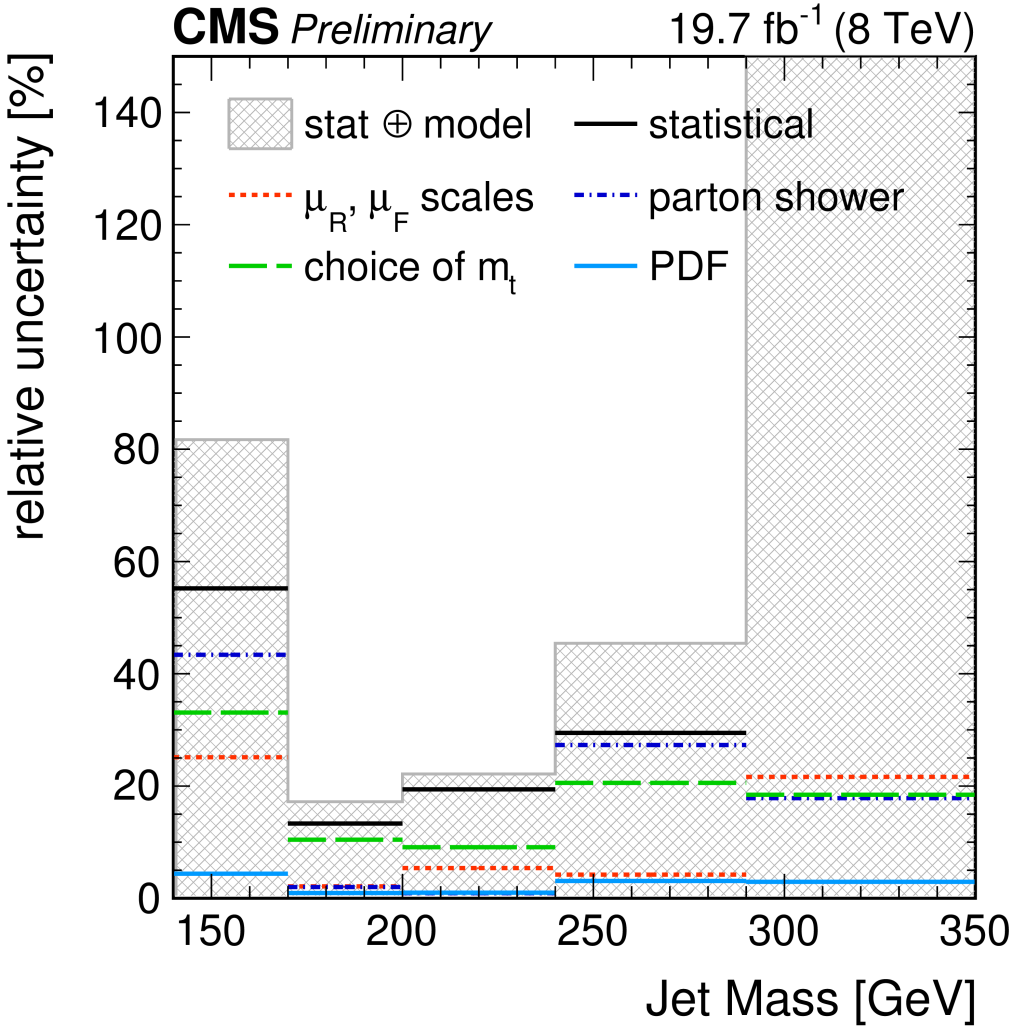
additional sideband regions:

→ more information on migrations

→ reduction of model dep. effects

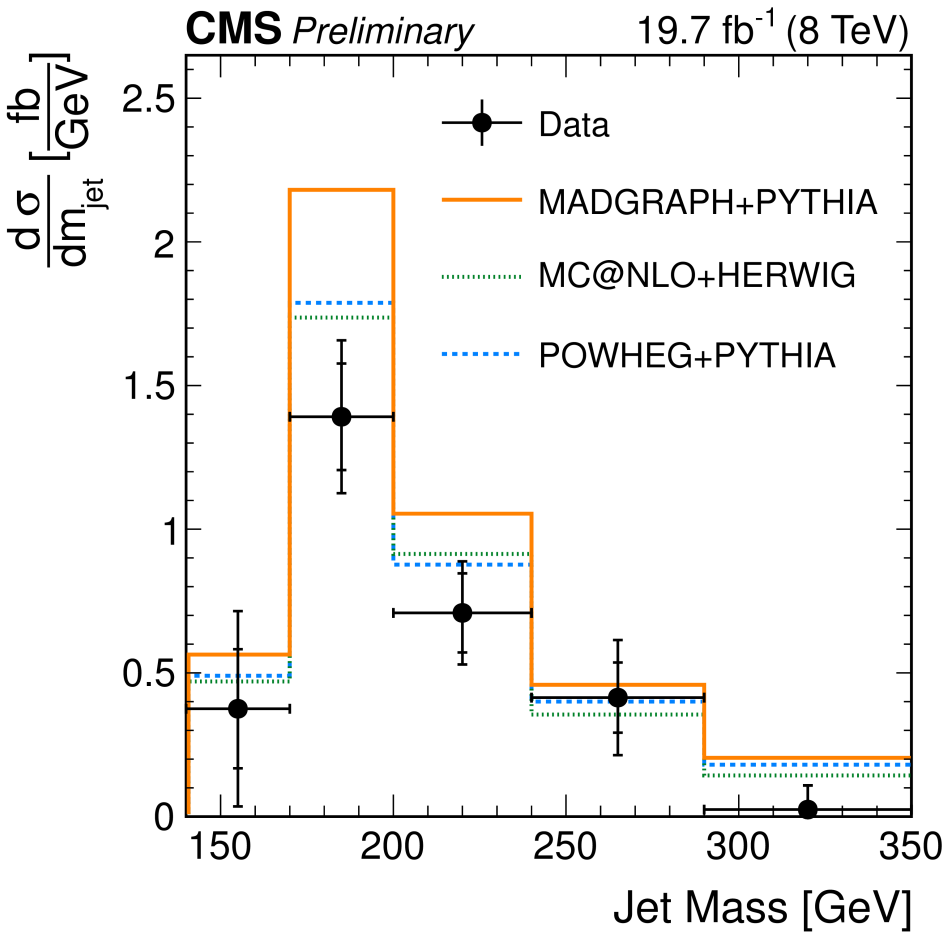
uncertainties

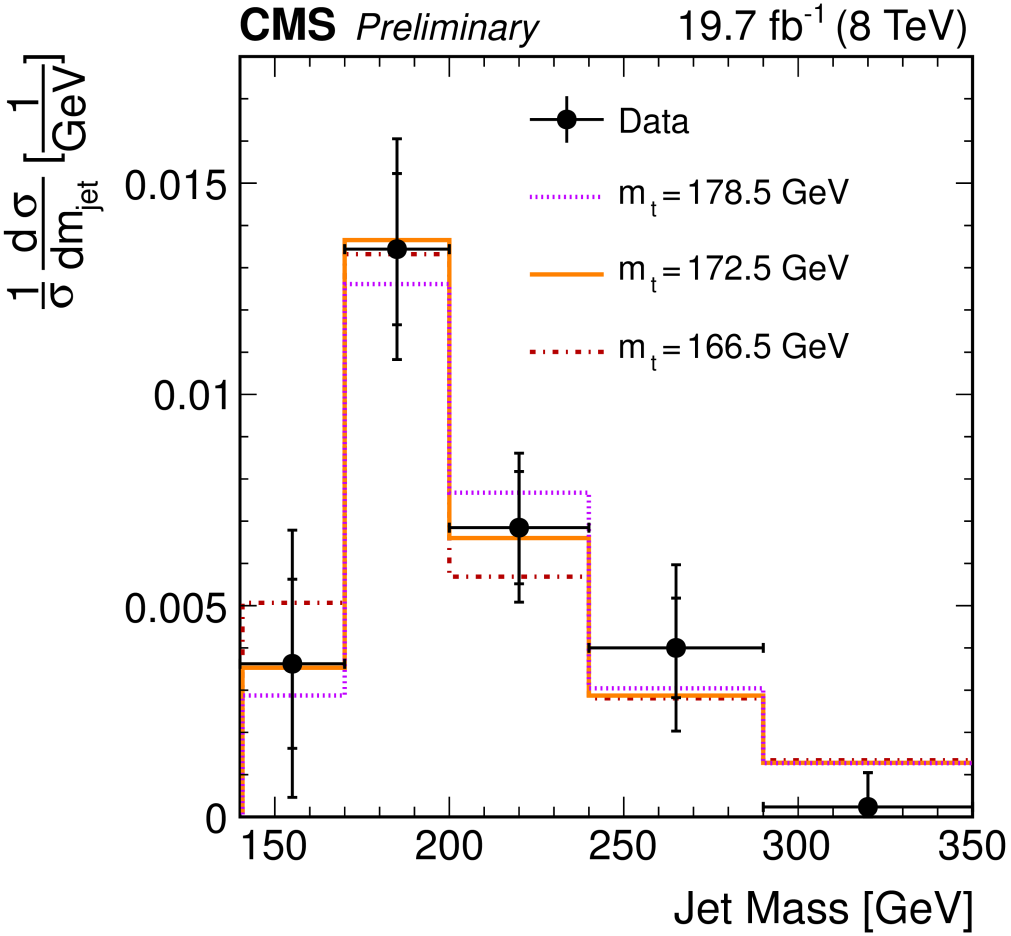




=> statistical uncertainties dominant

differential cross section





- slight overestimation of cross section in simulation
- consistent with other cross section measurements in boosted events

  [Phys. Rev. D93 (2016) 032009 (ATLAS), arXiv:1605.00116 (CMS)]
- clear sensitivity to the top mass

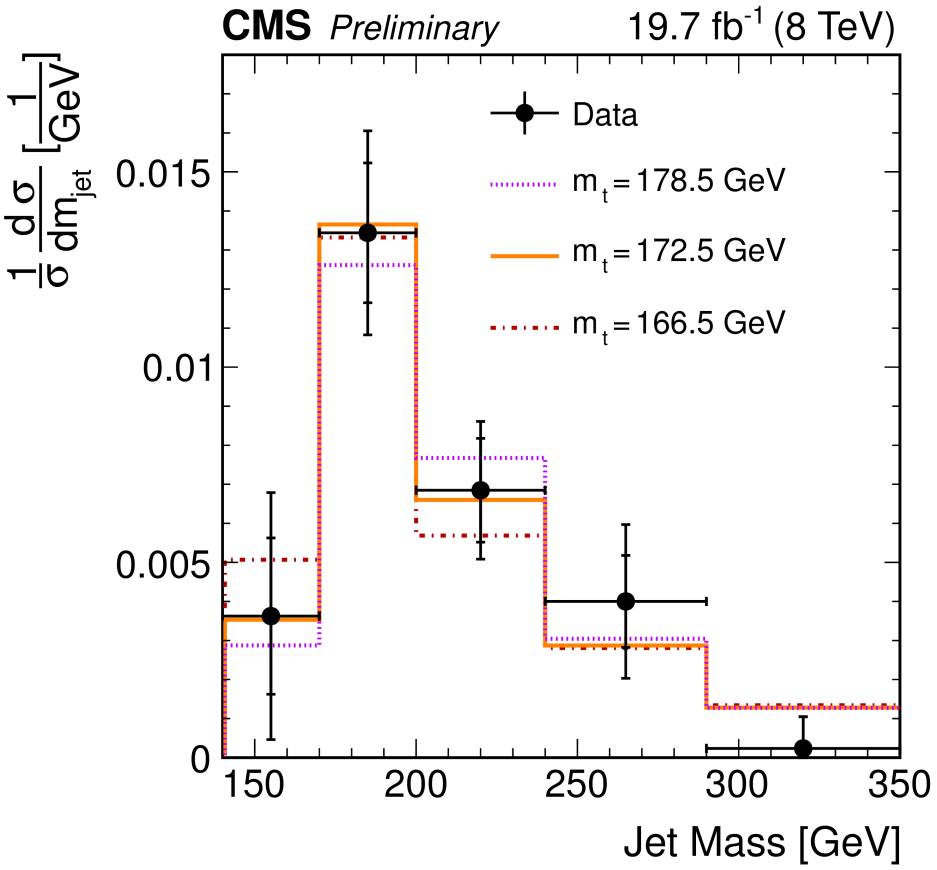
top quark mass extraction

- extract m_t from simulated templates
- use normalized cross section
- calculate χ^2 for every template:

$$\chi^2 = (\vec{m}_{\text{data}} - \vec{m}_{\text{MC}})^{\text{T}} \mathbf{C}^{-1} (\vec{m}_{\text{data}} - \vec{m}_{\text{MC}})$$

data bins — simulation bins — covariance matrix

- perform a fit to the χ^2 distribution



result:

m_t = 171.8 ± 9.5 GeV

= 171.8 ± 5.4 (stat) ± 3.0 (syst) ± 5.5 (model) ± 4.6 (theory) GeV

- just a sensitivity test!
- goal is an extraction from EFT calculations (not available for LHC yet)

summary

main result: first measurement of the differential and normalized differential $t\bar{t}$ cross section as a function of the jet mass in boosted top decays on particle level (8 TeV)

- peak position sensitive to m_t
- calculable on particle level in EFT
  - → provide data for comparison to EFT calculations
  - → new method to measure m_t without ambiguities from relation to the MC top mass
- statistical uncertainty dominant with 8 TeV data
- expect improvement with more data on 13 TeV