Jet Substructure Measurements in Top Quark Production in CMS

Torben Dreyer for the CMS collaboration

LHC Days 2018

Split, Croatia

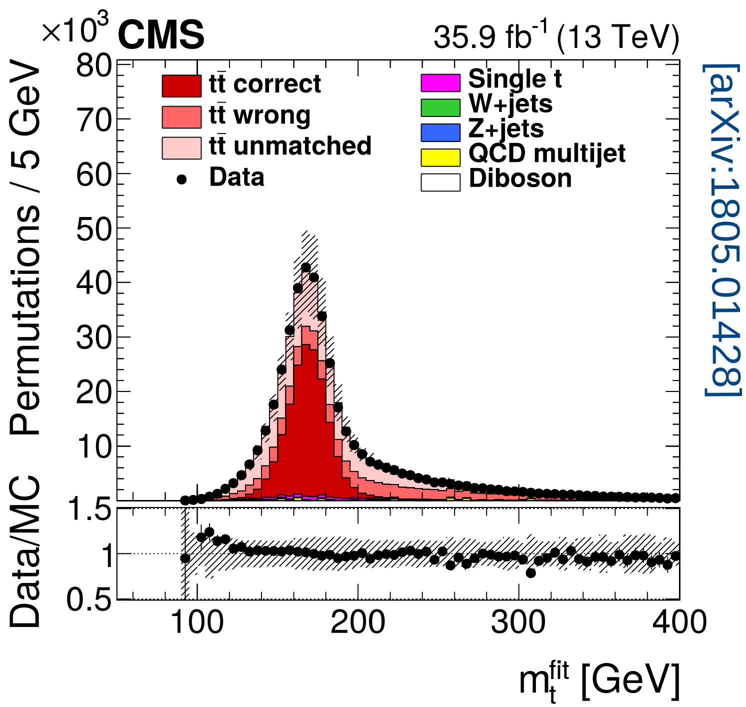
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Top mass

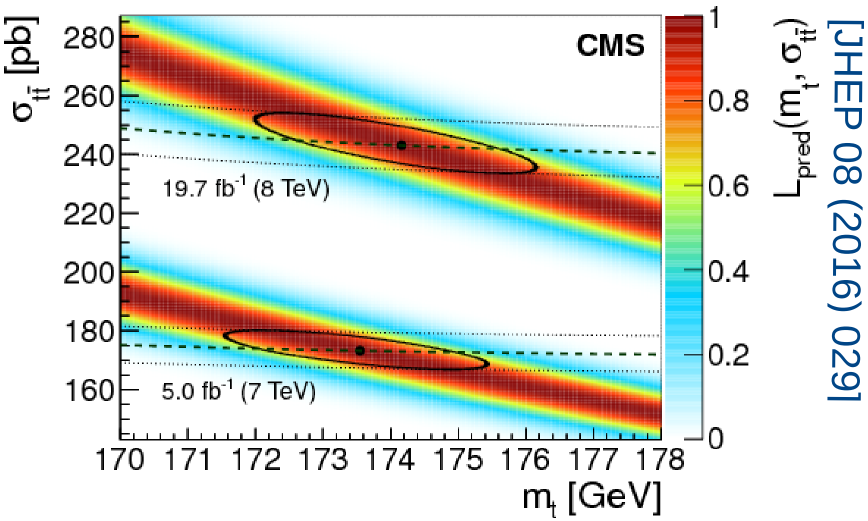
- Recent top mass measurements:
  - $m_t = 172.25 \pm 0.08$ (stat+JSF) ± 0.62 (syst) GeV
  - Very precise!

  → Measurement using event generators

  → Connection to well defined mass not precisely known



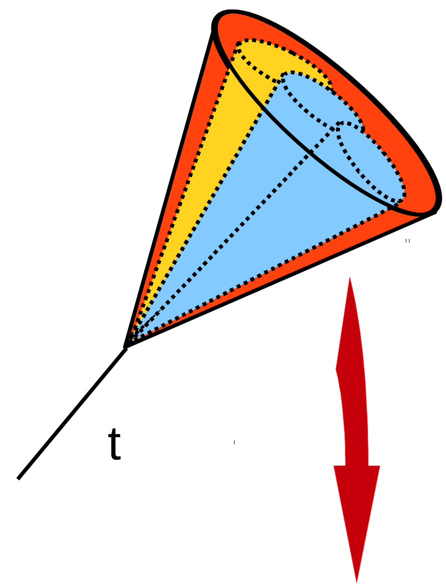
- pole mass from inclusive cross section
  - Measurement of $\sigma_{t\bar{t}} \rightarrow m_t$
  - $m_t = 173.8\ ^{+1.7}_{-1.8}$ GeV
  - Larger uncertainties



- Better understanding of m_t crucial

Boosted top analytic calculations

- Calculation of jet substructure in boosted top at particle level
- Fully merged top jets
- Consistent treatment of color and hadronization effects



- **Comparison to MC**

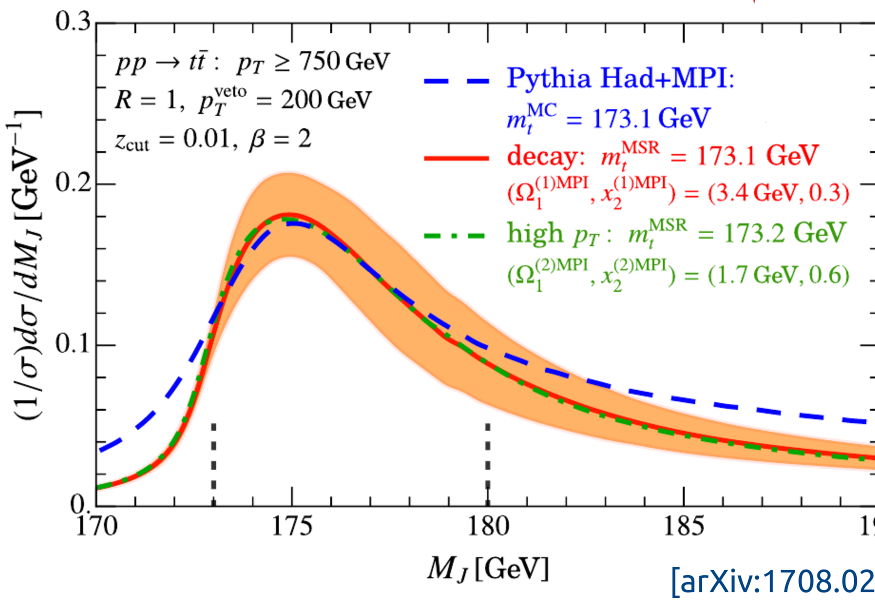
  → calibration of the top mass in MC

  e^+e^- collisions: [Phys.Rev.Lett. 117 (2016)]

- **Comparison to data**

  → well defined top mass

  pp collisions: [A. H. Hoang, S. Mantry, A. Pathak et.al, arXiv:1708.02586]



[arXiv:1708.02586]

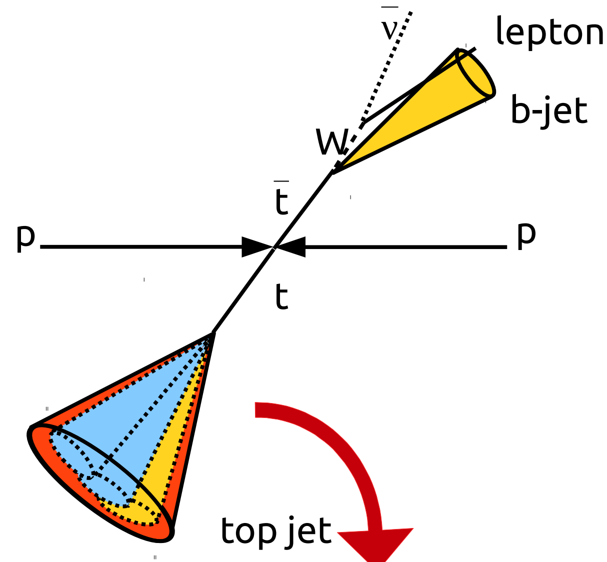
→ **our goal:** measurement in data

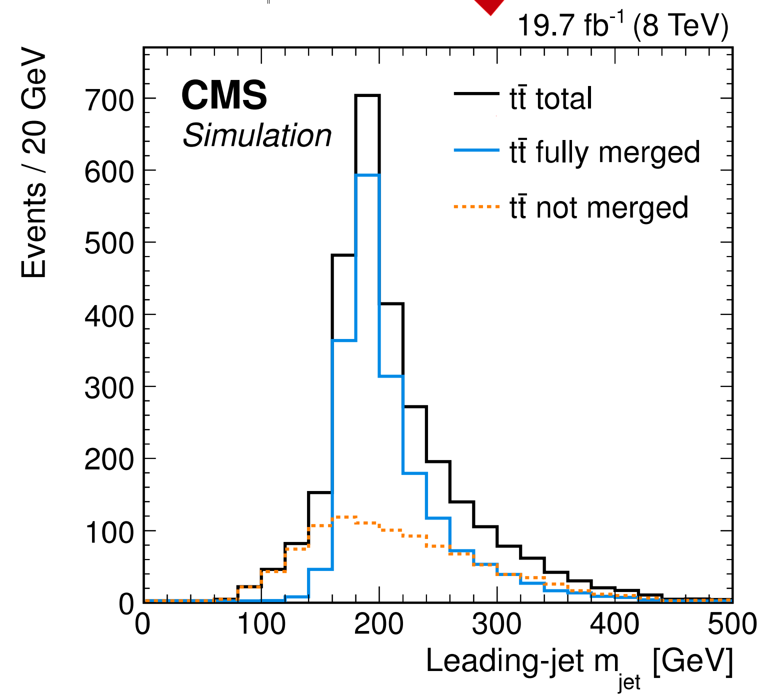
Measurement of top jet mass

[Eur.Phys.J.C77 (2017) no.7, 467]

- First measurement of the jet mass distribution
- Unfolded to particle level
- 8 TeV data
- Lepton+jets $t\bar{t}$ decays

- Top quarks reconstructed with
  - Cambridge/Aachen jets R=1.2
  - p_T > 400 GeV

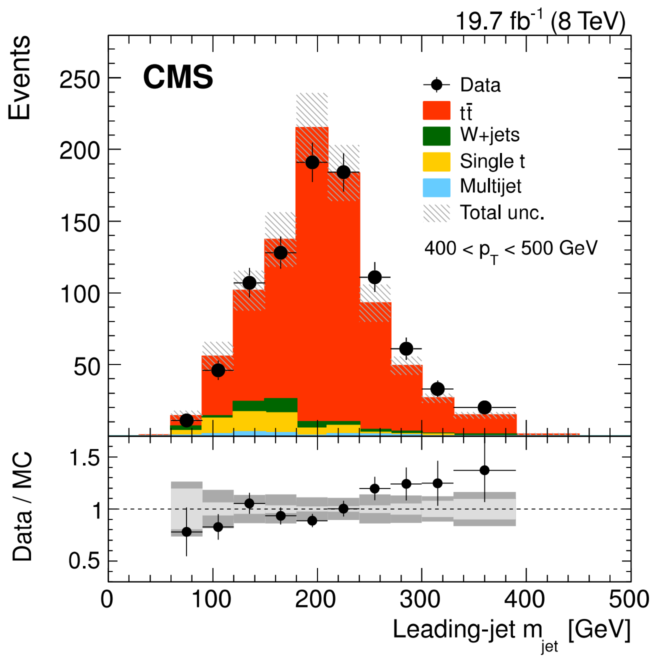


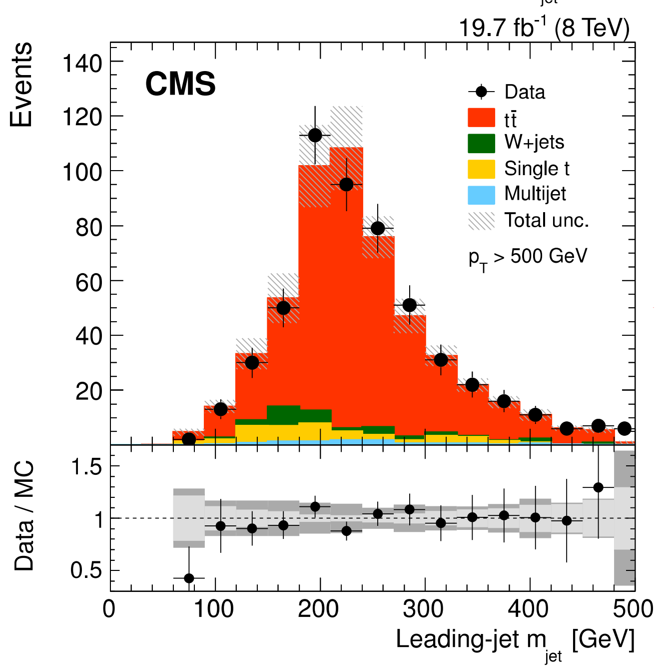


[Eur.Phys.J.C77 (2017) no.7, 467]

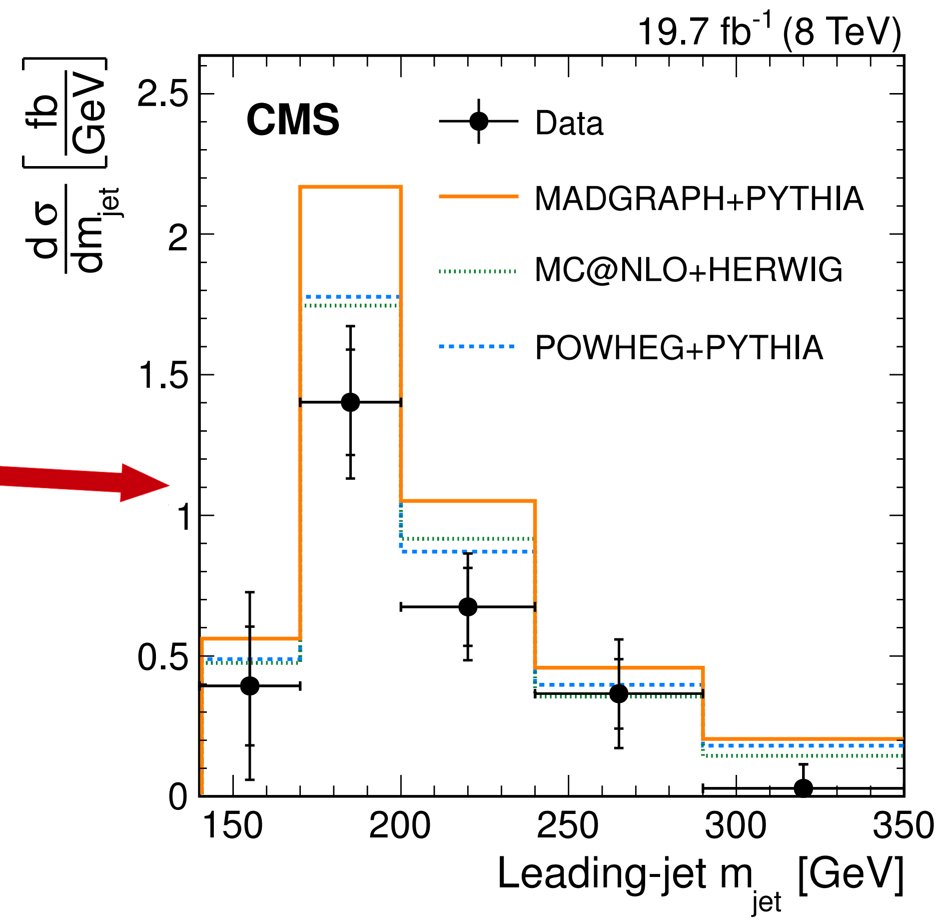
Differential cross section

[Eur.Phys.J.C77 (2017) no.7, 467]





Unfolding to particle level

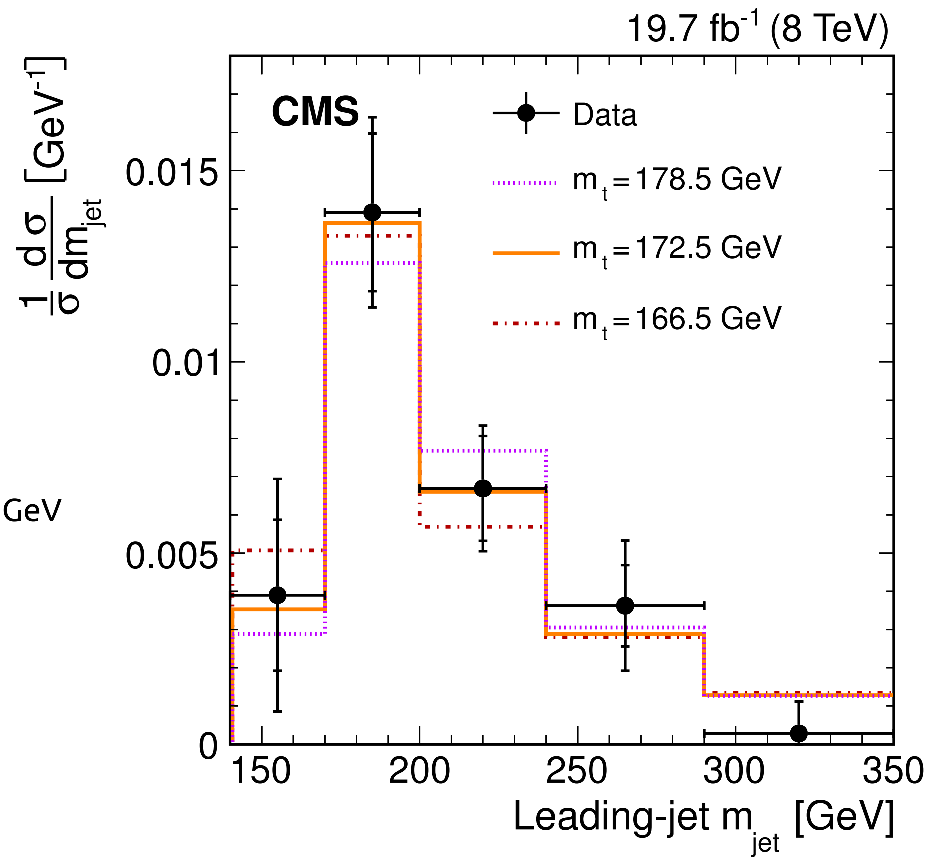


Top mass extraction [Eur.Phys.J.C77 (2017) no.7, 467]

- Extract m_t from normalized cross section
  - no analytic calculations available
- Extraction of MC top mass (sensitivity test!)
  - Result:

    m_t = 170.8 ± 9.0 GeV

    = 170.8 ± 6.0 (stat.) ± 2.8 (syst) ± 4.6 (model) ± 4.0 (theo) GeV
  - Stat. Uncertainties dominant



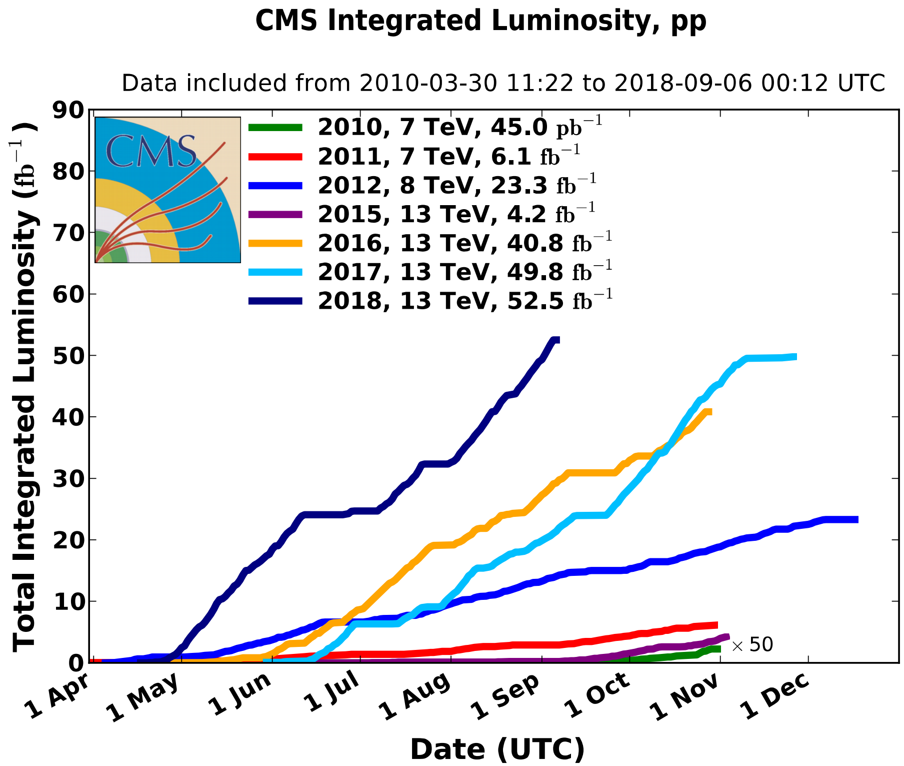
- Long time goal
  - well defined mass from comparison to calculations!

13 TeV prospects

- Higher statistics on 13 TeV
  - Smaller jets
  - More p_T bins and sideband regions
- Grooming
  - Better mass/reconstruction resolution

    → finer binning

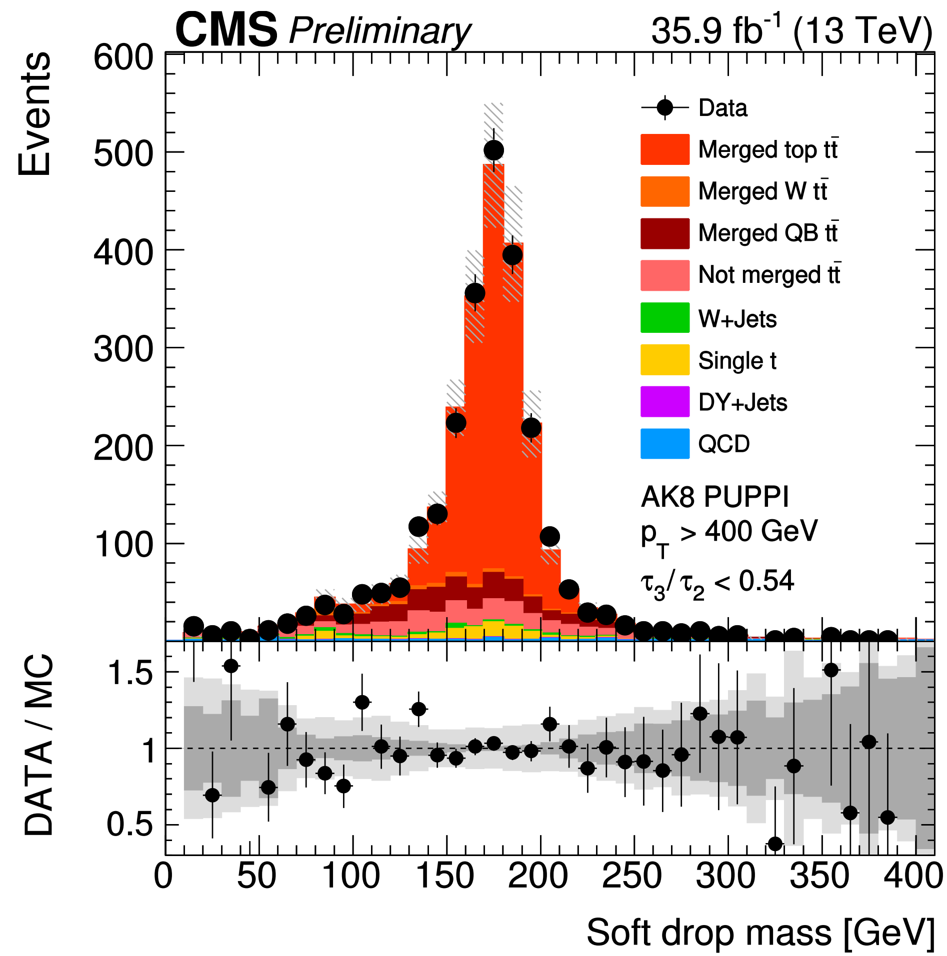
    → higher sensitivity on m_t
- Study new jet algorithms (e.g. XCone)
- Large improvements expected on both stat. and syst. uncertainties



Jet mass at 13 TeV

- Jet mass from top tagging studies
  - Anti-k_T jets R = 0.8
  - PUPPI pileup subtraction
  - Soft drop groomed
  - μ + jets channel

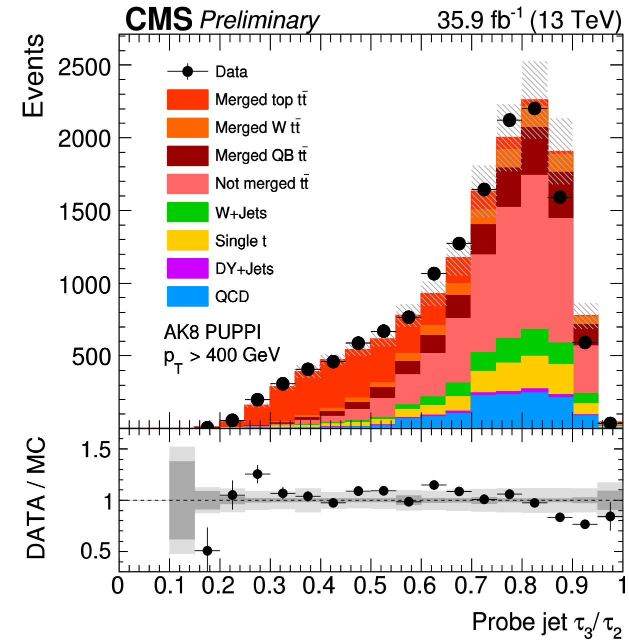
- High statistics
- Narrow mass peak



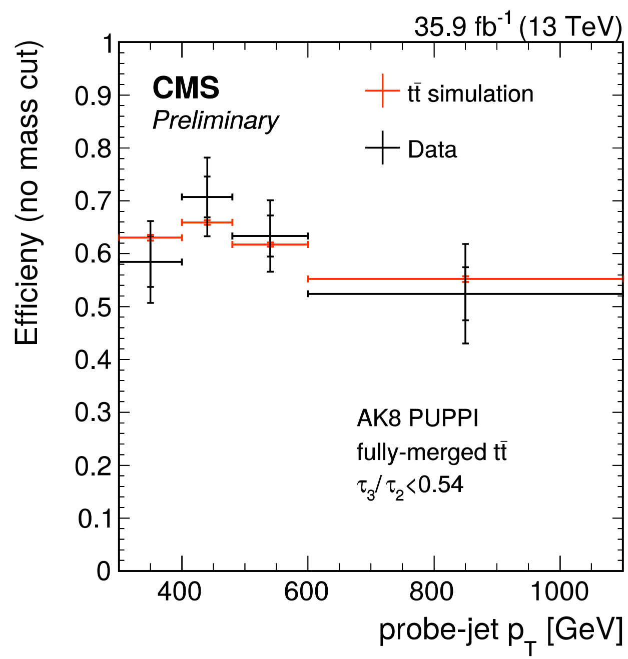
[CMS-DP-2017-026]

Jet substructure at 13 TeV

- Many boosted tops at 13 TeV
- Jet substructure important for top tagging
- Example: N-subjettiness τ_N [JHEP 1103 (2011) 015]
  - Estimator for a N-subjets hypothesis
  - Slight disagreement for high values of τ_3/τ_2
  - Tagging efficiency described by MC
- Jet substructure further important for
  - b tagging, quark-gluon discrimination, ...



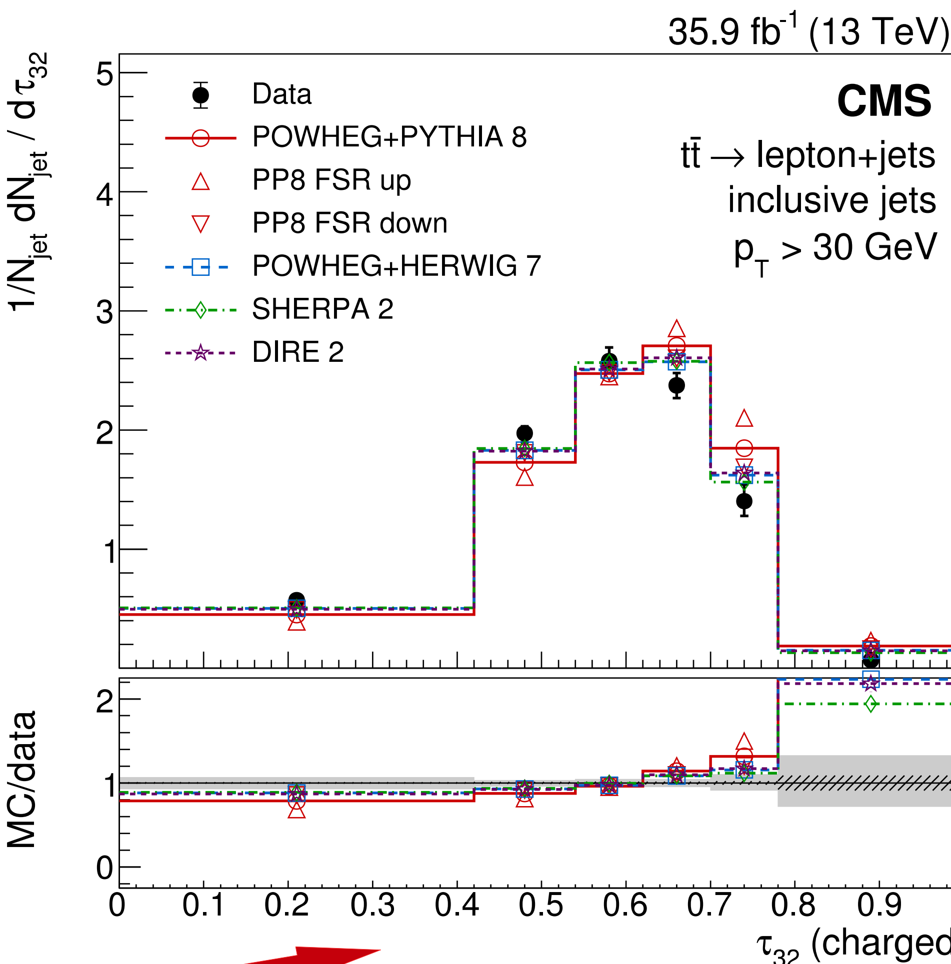
[CMS-DP-2017-026]



[CMS-DP-2017-026]

Jet substructure at 13 TeV

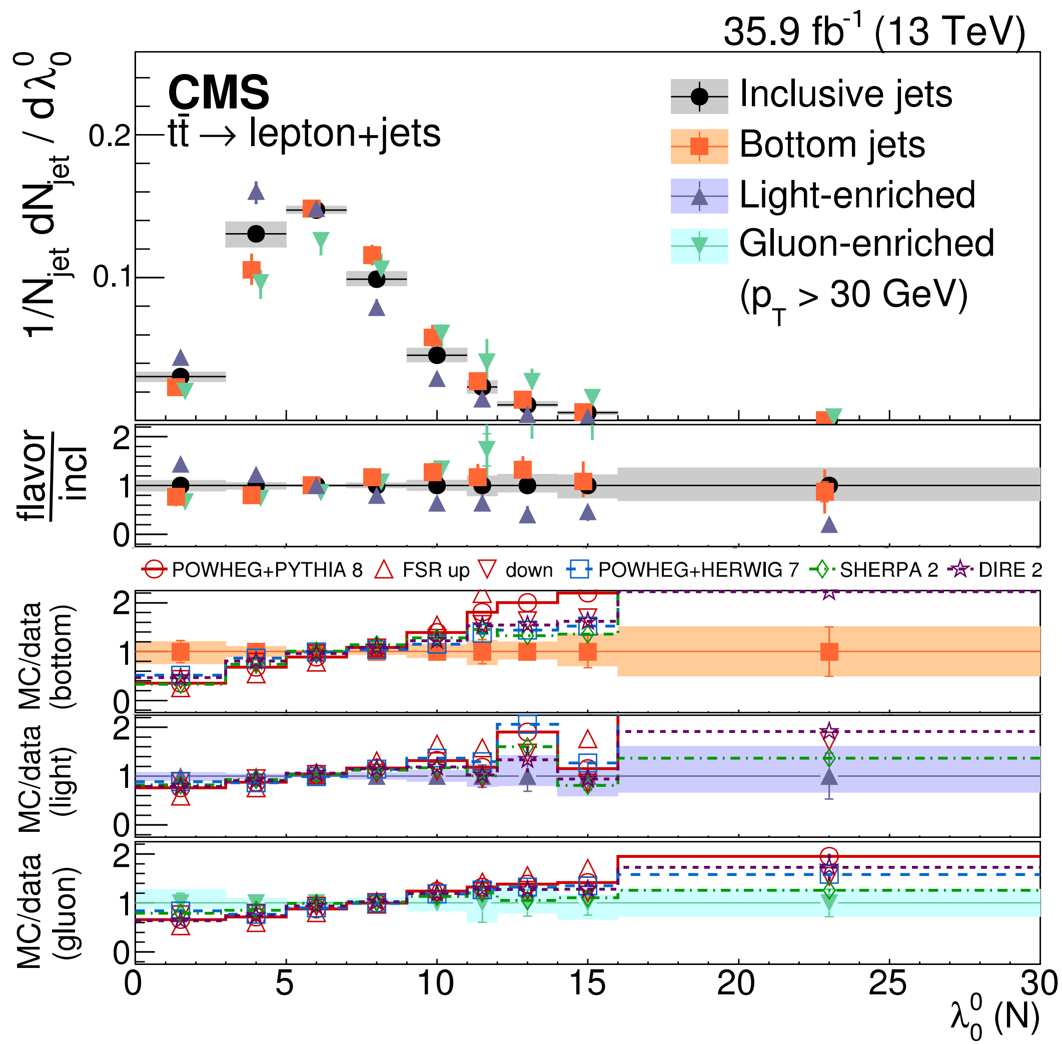
- First measurement of several substructure variables $t\bar{t}$ production in CMS
- Resolved $t\bar{t}$ decays – lepton+jets channel
- Important input for
  - MC simulation tuning
  - Calculations of substructure
- Improve understanding of substructure
- Slight disagreement for high values of τ_3/τ_2



[arXiv:1808.07340]

Jet substructure at 13 TeV

- Measured for different jet flavor
- In samples enriched with
  - b jets
  - Light quark jets
  - Gluon jets
- Here:
  - charged particle multiplicity
  - Important for quark-gluon discrimination
- Slightly worse description for b jets

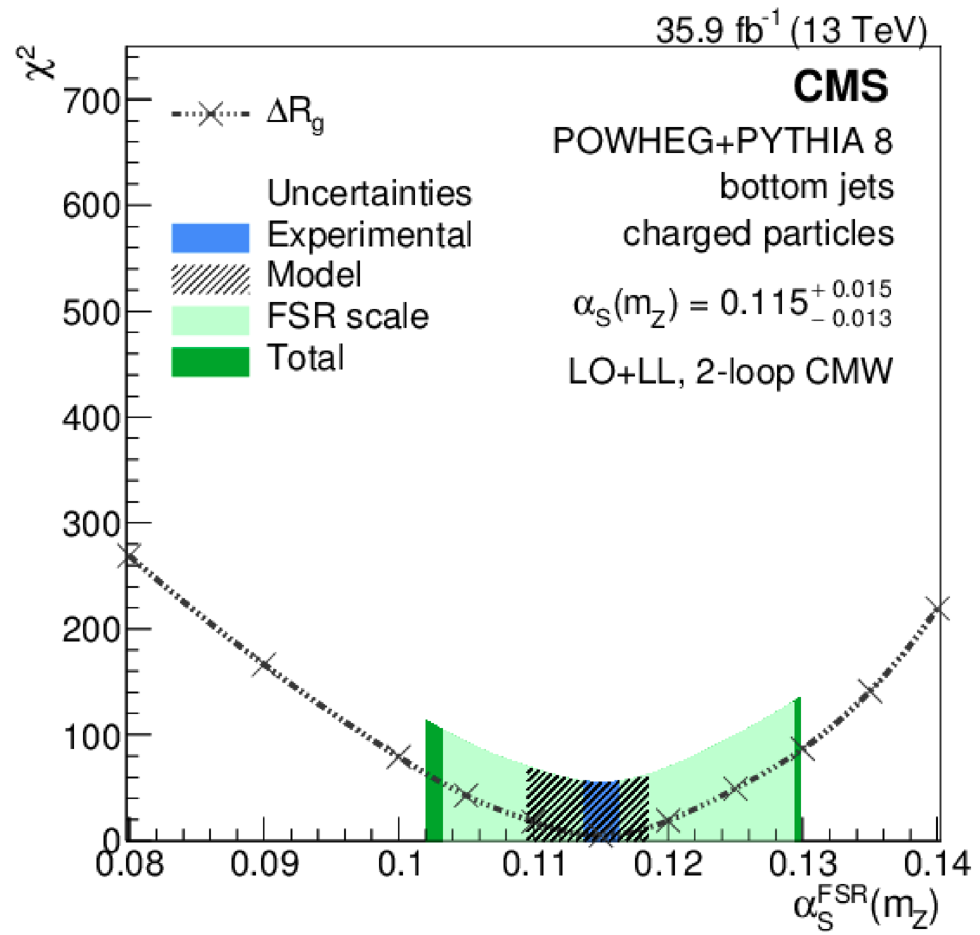


[arXiv:1808.07340]

Extraction of α_s from Jet Substructure

- Value of $\alpha_s(m_Z)$ extracted
  - From ΔR_g : angle between groomed subjets (Soft-drop)
  - b-jet sample
  - Charged particles

$\alpha_s(m_Z) = 0.115^{+0.015}_{-0.013}$

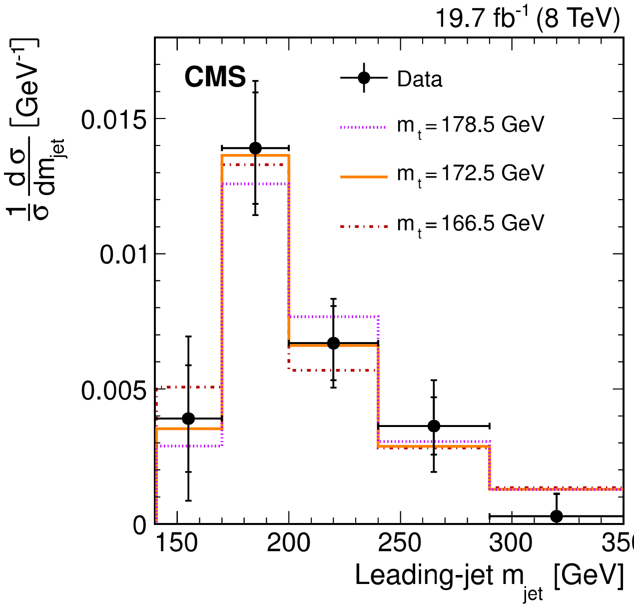


- Leading order plus leading log accuracy
- Limited by FSR scale variations

[arXiv:1808.07340]

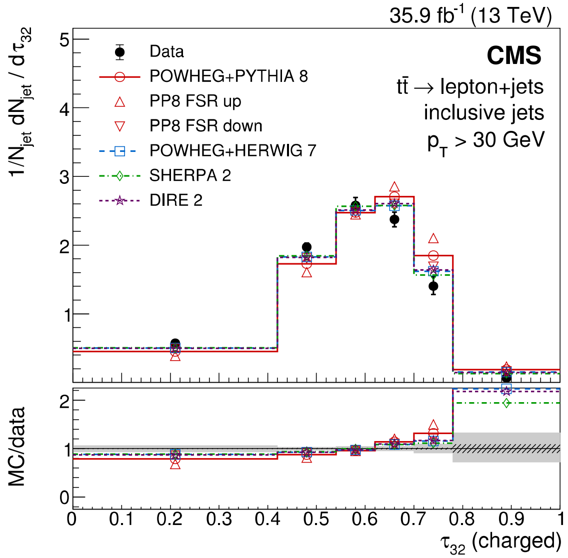
Summary

- **Boosted top jet mass**
  - First measurement at 8 TeV
  - 13 TeV measurement in progress
  - Goals: → comparison to theory calculations
    → extraction of well defined top mass



[Eur.Phys.J.C77 (2017) no.7, 467]

- **Jet substructure at 13 TeV**
  - Measured in resolved $t\bar{t}$
  - Important input for simulation and calculations
  - Extraction of α_s from jet substructure



[arXiv:1808.07340]

→ better understanding of MC and fundamental physics of jet substructure