Jet Substructure Measurements in Top Quark Production in CMS

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Top mass

- Recent top mass measurements:
  - $m_t = 172.25 \pm 0.08$ (stat+JSF) $\pm 0.62$ (syst) GeV
  - Very precise!
  - Measurement using event generators
  - Connection to well defined mass not precisely known

- Pole mass from inclusive cross section
  - Measurement of $\sigma_{tt} \rightarrow m_t$
  - $m_t = 173.8^{+1.7}_{-1.8}$ 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


→ **our goal**: measurement in data
Measurement of top jet mass

- 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

Unfolding to particle level
Top mass extraction

- Extract $m_t$ from normalized cross section
  - no analytic calculations available

- Extraction of MC top mass (sensitivity test!)
  - Result:
    - $m_t = 170.8 \pm 9.0 \text{ GeV}$
    - $= 170.8 \pm 6.0 \text{ (stat.)} \pm 2.8 \text{ (syst)} \pm 4.6 \text{ (model)} \pm 4.0 \text{ (theo)} \text{ GeV}$
  - 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. XCones)
- 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
  - $\mu +$ 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 $\tau_N$ [JHEP 1103 (2011) 015]
    - Estimator for a N-subjets hypothesis
    - Slight disagreement for high values of $\tau_3/\tau_2$
    - Tagging efficiency described by MC
- Jet substructure further important for
  - $b$ tagging, quark-gluon discrimination, ...
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 $\tau_3/\tau_2$

[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 $\alpha_s$ from Jet Substructure

- Value of $\alpha_s(m_Z)$ extracted
  - From $\Delta R_g$ : 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: \( \rightarrow \) comparison to theory calculations
    \( \rightarrow \) extraction of well defined top mass

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

\( \rightarrow \) better understanding of MC and fundamental physics of jet substructure