

Multijet cross sections and ratios in pp collisions at $\sqrt{s}=13$ TeV with CMS

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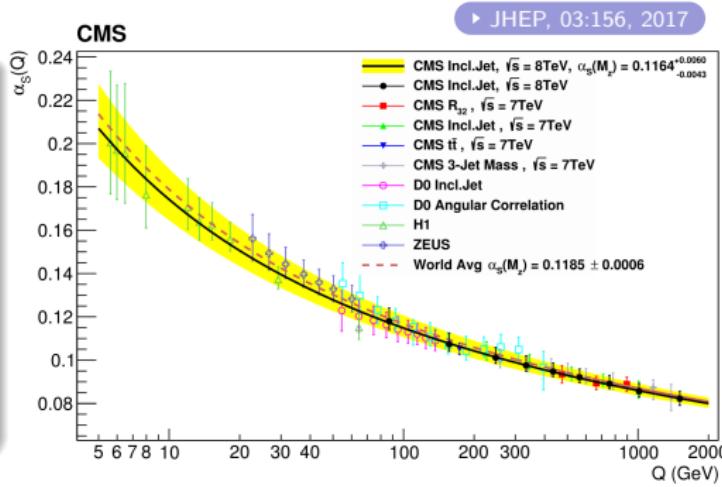
Introduction – Motivation

- Measurement of inclusive differential 2-,3-,4-,5-jet event cross sections $\frac{d\sigma}{dH_{T,2}/2}$ and ratios:

$$R_{mn} = \frac{\left[\frac{d\sigma}{d(H_{T,2}/2)} \right]_{(m\text{-jet})}}{\left[\frac{d\sigma}{d(H_{T,2}/2)} \right]_{(n\text{-jet})}}, \quad m > n$$

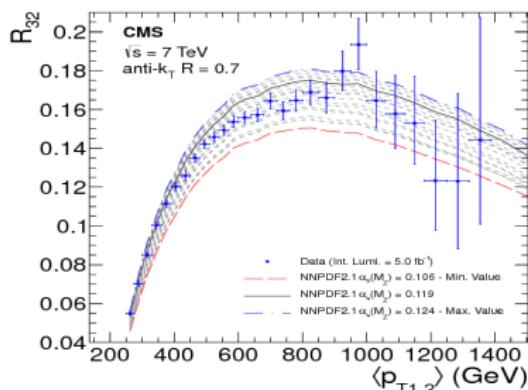
Cross section ratios

- $R_{mn} = \frac{\sigma_{m\text{-jet}}}{\sigma_{n\text{-jet}}} \sim \alpha_s^{m-n} \rightarrow R_{32}, R_{43} \sim \alpha_s$ and $R_{42} \sim \alpha_s^2$.
- Determination of $\alpha_s(M_Z)$ using higher order ratios.
- Investigation of α_s running at TeV scale.

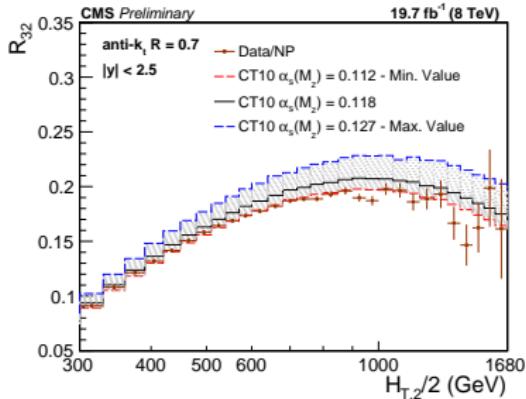


Introduction – Observables and analysis strategy

Previous R_{32} measurements



► Eur.Phys.J.C 73 (2013)10, 2604



► SMP-16-008

- Measurement of the inclusive differential jet event cross sections:

$$\frac{d\sigma}{dH_{T,2}/2} = \frac{1}{\mathcal{L}} \frac{N_e}{\Delta(H_{T,2}/2)}$$

as a function of:

$$H_{T,2}/2 = \frac{p_{T,1} + p_{T,2}}{2}$$

Introduction – Observables and analysis strategy

- **Data Samples:** 2018 Data → $\mathcal{L}_{int} = 59.82 \text{ fb}^{-1}$.
- **MC Samples:** Official CMS Monte Carlo Samples and RIVET toolkit.
- **Corrections:** Standard recommendations on Data and MC.

Event Selection

- Require leading and sub-leading jets:
 - $p_T > 150 \text{ GeV}$
 - $|y| < 2.5$
- Require the rest of the jets:
 - $p_T > 150 \text{ GeV}$
 - $|y| < 2.5$
- Deduce multiplicity from remaining list of jets in the event.

Jet parameters

- **Jet type:** PFchs jets
- **Jet algorithm:** anti- k_T
- **Jet size:** $R=0.8$

Unfolding

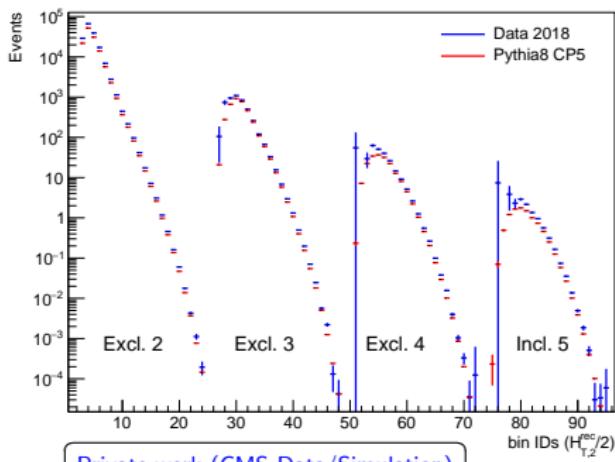
Data Unfolding

- Unsmearing of the detector effects.
- Detector level → Particle level spectrum

Least square minimisation

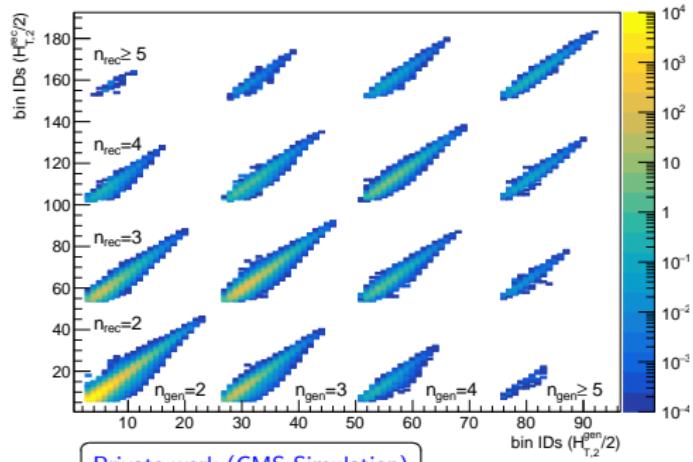
TUnfold package: $\chi^2 = (Ax + b - y)^T V^{-1} (Ax + b - y)$

Distributions at Particle/Generator Level



Private work (CMS Data/Simulation)

Response matrix 4×4

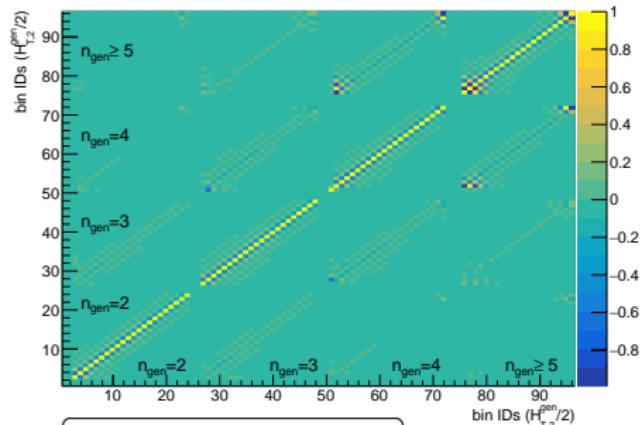


Private work (CMS Simulation)

Unfolding

Cross sections

Correlation matrix 4×4

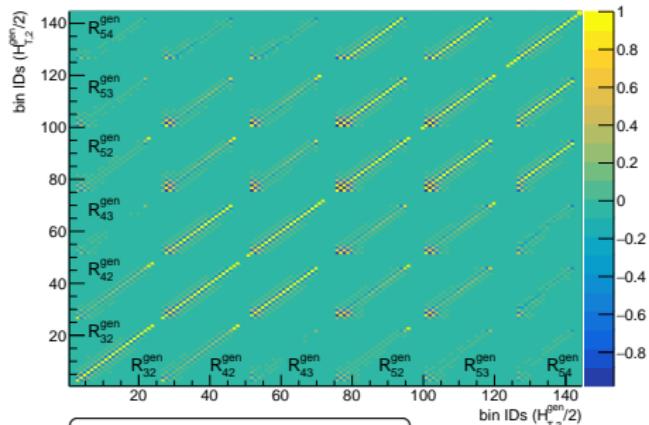


Private work (CMS Simulation)

- 4×4 correlation matrix.
- Non-negligible correlations and anti-correlations among $H_{T,2}/2$ bins and also among distributions with different multiplicity.

Ratios

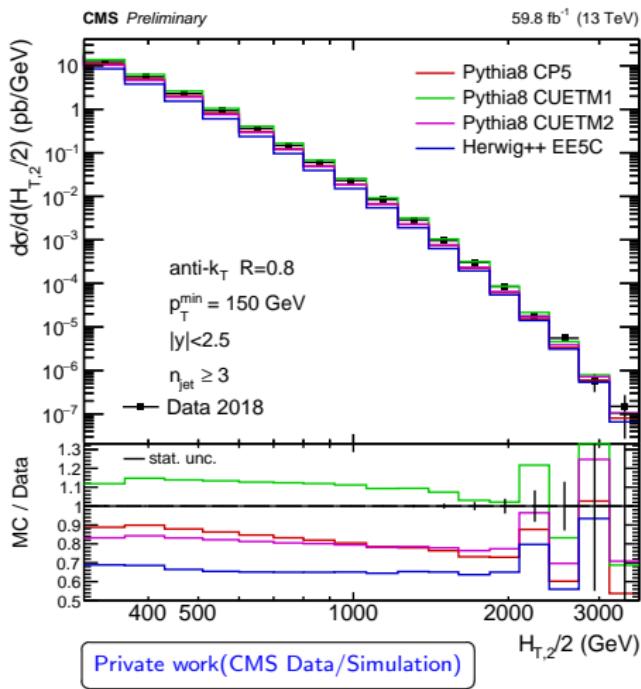
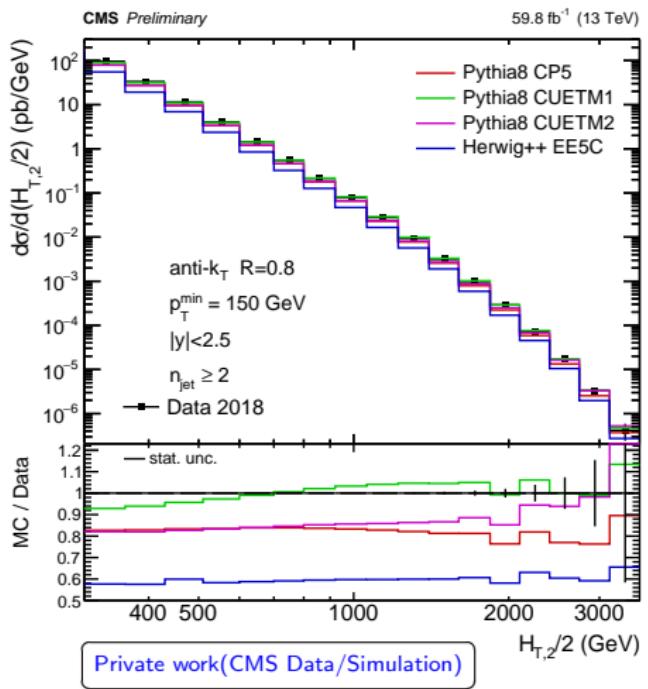
Correlation matrix 6×6



Private work (CMS Simulation)

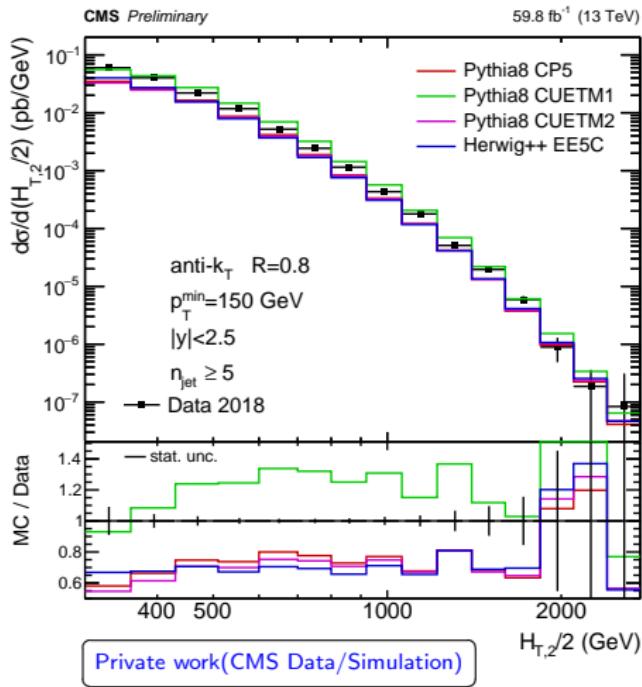
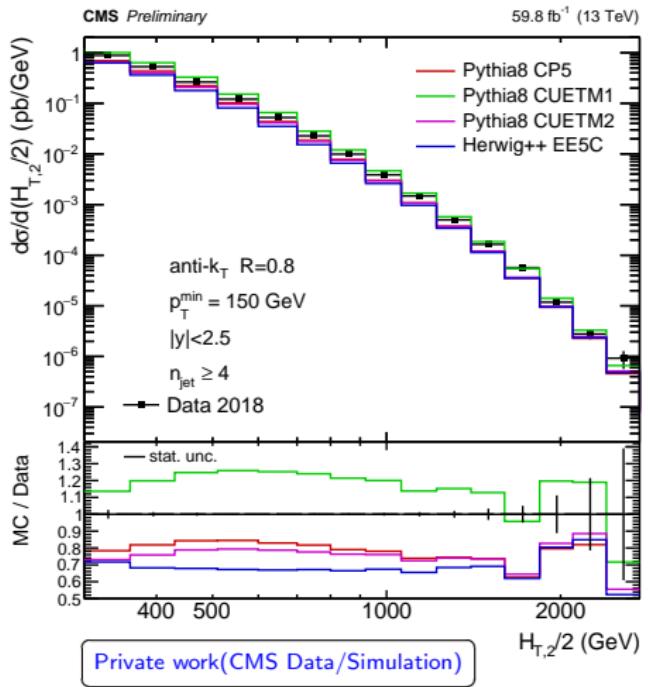
- 6×6 correlation matrix.
- Strong correlations and anti-correlations among $H_{T,2}/2$ bins and among R_{mn} ratios.

Particle level – Cross section distributions



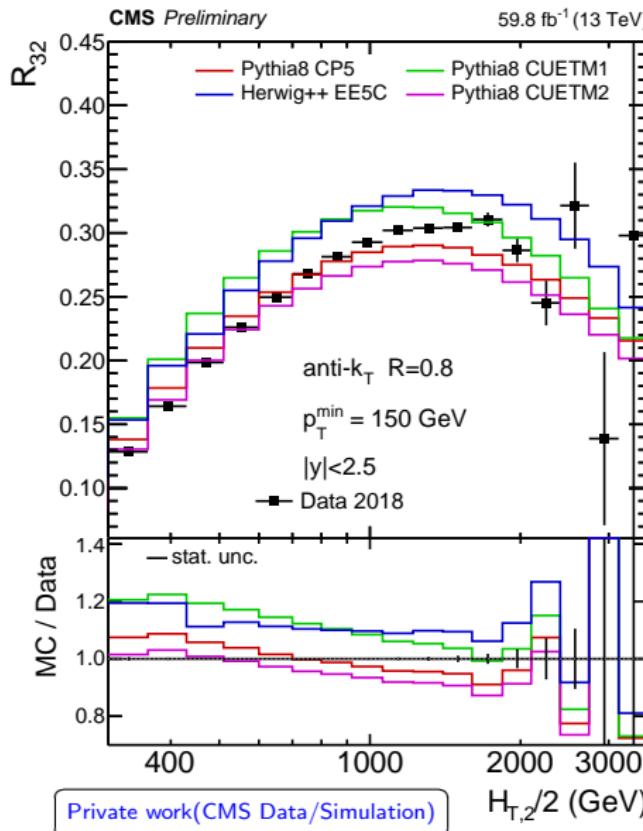
- **P8 CP5:** 2jet(3jet) $\sim 10 - 18\%$ (10 - 25%).
- **P8 CUETM1:** 2jet(3jet) $\sim 5 - 7\%$ (5 - 15%).
- **P8 CUETM2:** 2jet(3jet) $\sim 5 - 17\%$ (15 - 20%).
- **Herwig++:** 2jet(3jet) $\sim 36 - 40\%$ (30 - 35%).

Particle level – Cross section distributions



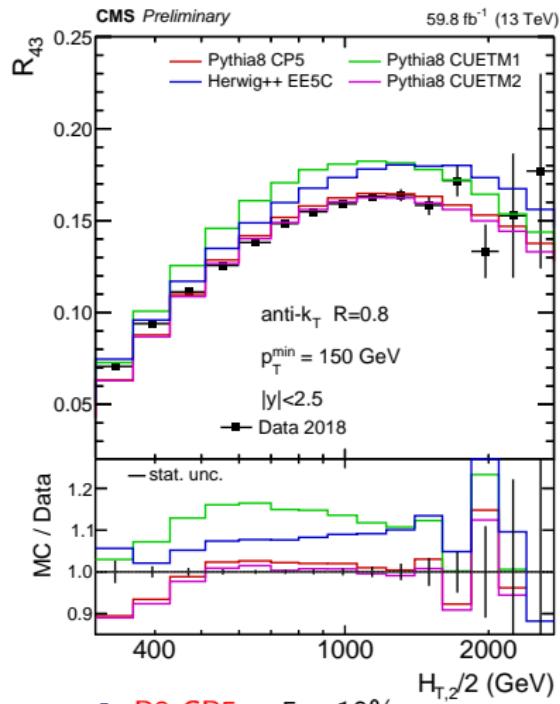
- P8 CP5: 4jet(5jet)~15 – 25%(20 – 40%).
- P8 CUETM2: 4jet(5jet)~20 – 30%(30 – 35%).
- P8 CUETM1: 4jet(5jet)~10 – 20%(5 – 20%).
- Herwig++: 4jet(5jet)~30%(30 – 35%).

Particle level – R_{32}



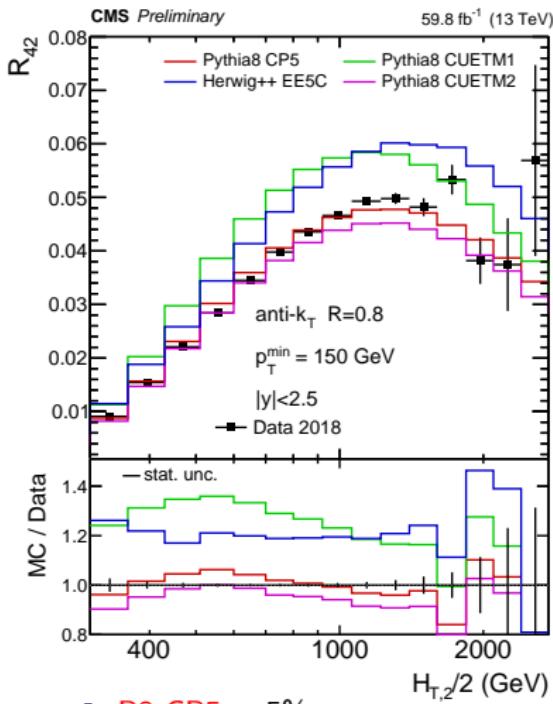
- P8 CP5 $\sim 5 - 10\%$.
- P8 CUETM1 $\sim 5 - 20\%$.
- P8 CUETM2 $\sim 5\%$.
- Herwig++ $\sim 10 - 20\%$.

Particle level – R_{43}, R_{42}



- P8 CP5 $\sim 5 - 10\%$.
- P8 CUETM1 $\sim 5 - 15\%$.
- P8 CUETM2 $\sim 5 - 10\%$.
- Herwig++ $\sim 5 - 10\%$.

Private work (CMS Data/Simulation)



- P8 CP5 $\sim 5\%$.
- P8 CUETM1 $\sim 20 - 30\%$.
- P8 CUETM2 $\sim 5 - 10\%$.
- Herwig++ $\sim 20 - 25\%$.

Summary and plans

Summary

- ① Use of 2018 Data and Monte Carlo event generators.
- ② Measurement of R_{mn} observables using similar strategy to $R_{\Delta\phi}$ analysis.

Future plans

- Data analysis
 - ① Extract systematic uncertainties.
 - ② Extend to full Run 2 and/or Run 3.
- Theory
 - ① Fixed-order predictions @NLO for inclusive 2- and 3-jet cross sections and R_{32} observable.
 - ② Predictions for inclusive 4-, 5-jet cross sections: Sherpa+NJET up to 5 jets @NLO.
 - ③ Investigate other PDF sets (ABMP16, CT18, MSHT20).
 - ④ Predictions @NNLO.

THANK YOU!