

Underlying Event Measurements using CMS Detector at LHC

December 13, 2018

Manisha Lohan

(On behalf of CMS Collaboration)

Panjab University, Chandigarh (India)

DAE-BRNS HEP Symposium 2018

IITM, Chennai (India)

December 10 – 14, 2018

Underlying Event

Underlying Event (UE): Anything that does not originate from hard scatter outgoing partons.

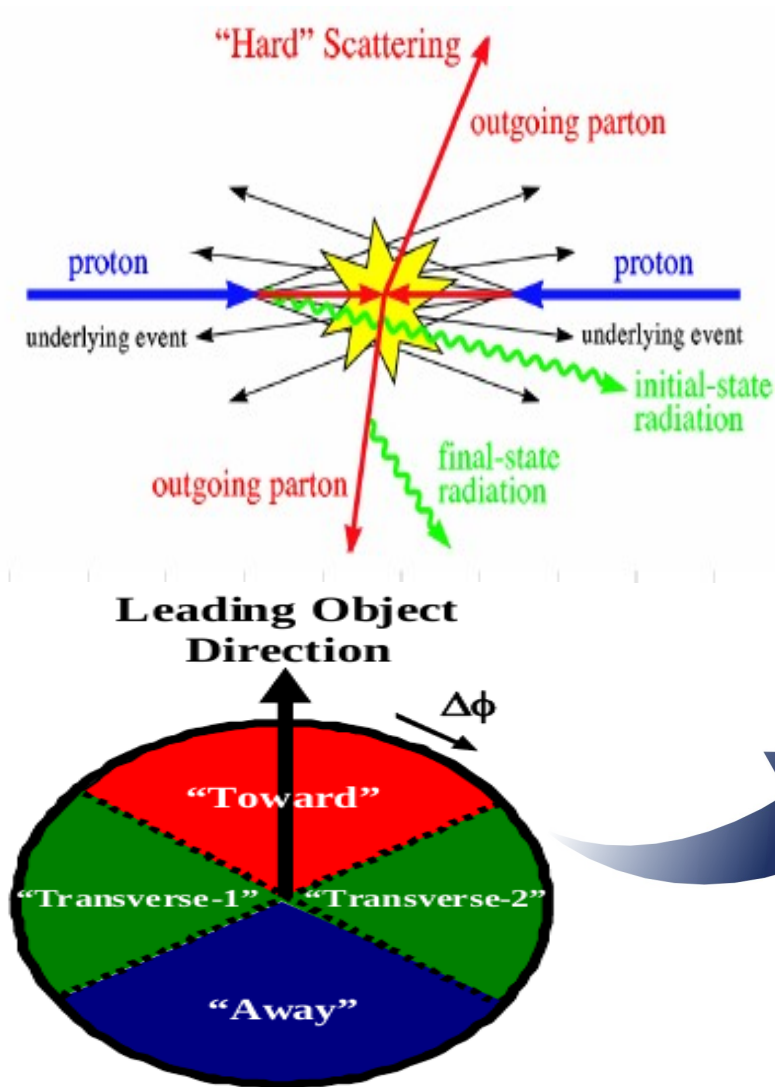
Components of UE

- ✓ Initial State Radiation (ISR).
- ✓ Final State Radiation (FSR).
- ✓ Multiple Parton Interactions (MPI).
- ✓ Beam Beam Remnants (BBR).

Regions of Measurements

- ✓ Towards Region: $|\Delta\Phi| < 60^\circ$
 $\Delta\Phi$ - (the leading object, charged particle)
- ✓ Away Region: $|\Delta\Phi| > 120^\circ$
- ✓ Transverse Region: $60^\circ < |\Delta\Phi| < 120^\circ$

- ✓ TransMax: Maximum value of UE observable.
- ✓ TransMin: Minimum value of UE observable.



History of UE Measurements

- ✓ **Leading Charged Particles and Jets @ 13 TeV – CMS-PAS-FSQ-15-007.**
- ✓ **Drell-Yan Events @ 13 TeV – JHEP 07 (2018) 032**
- ✓ **ttbar Events @ 13 TeV – submitted to EPJC, arXiv: 1807:02810**
- ✓ **ttbar Events @ 13 TeV (μ + jets channel) – CMS PAS TOP-15-017**



Presented today!!

Motivation

- ✓ At LHC, every kind of physics begins with a QCD process. Also total cross-section at LHC has maximum contributions from the inelastic interactions which are dominated by low p_T (soft) processes.
 - Low p_T processes are an important background for precision measurements and particle identification.
 - ◆ Study of low p_T processes via Underlying Event measurements is presented.

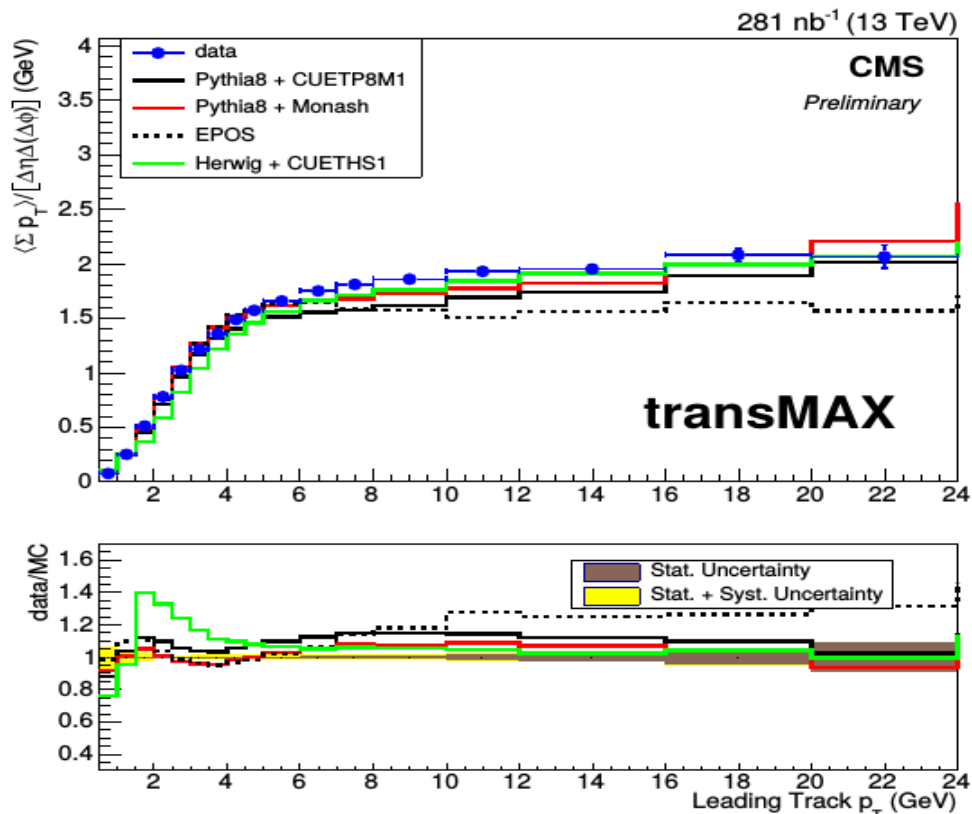
Importance of UE

- Better modeling of MC simulation.
- To probe hadron production.

UE Measurements → Leading Charged Particles & Jets

(CMS-PAS-FSQ-15-007)

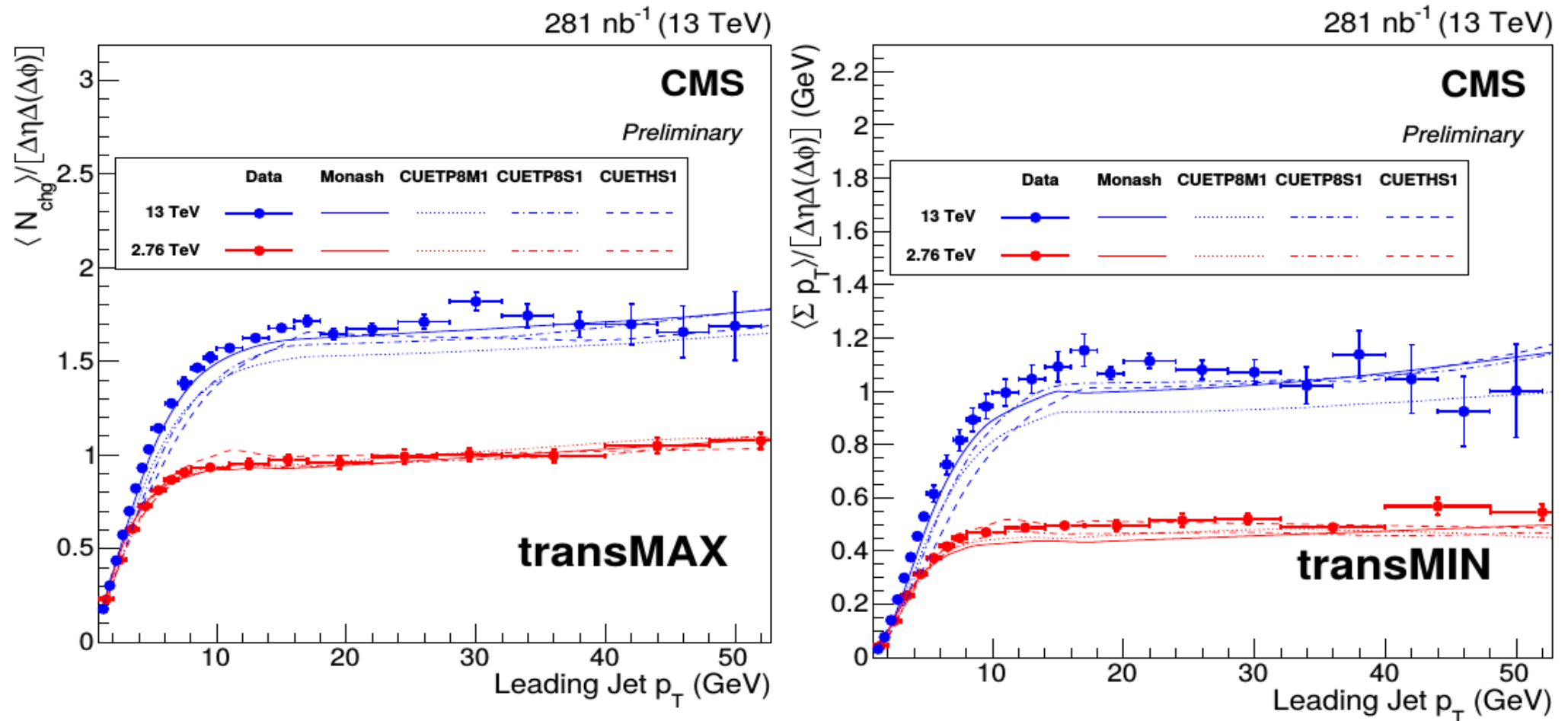
- ✓ Proton-proton (p-p) collisions data collected @ 13 TeV has been used, corresponding to an integrated luminosity of 281 nb^{-1} .
- ✓ Leading charged particles having $p_T > 0.5 \text{ GeV}$ and $|\eta| < 2$, jets having $p_T > 1 \text{ GeV}$ and $|\eta| < 2$ are used for analysis.



- ✓ Unfolded distribution of energy density as a function of leading track p_T is compared with MCs predictions. Monash tune of PYTHIA8 provides the best description of data.

UE Measurements → Leading Charged Particles & Jets

(CMS-PAS-FSQ-15-007)

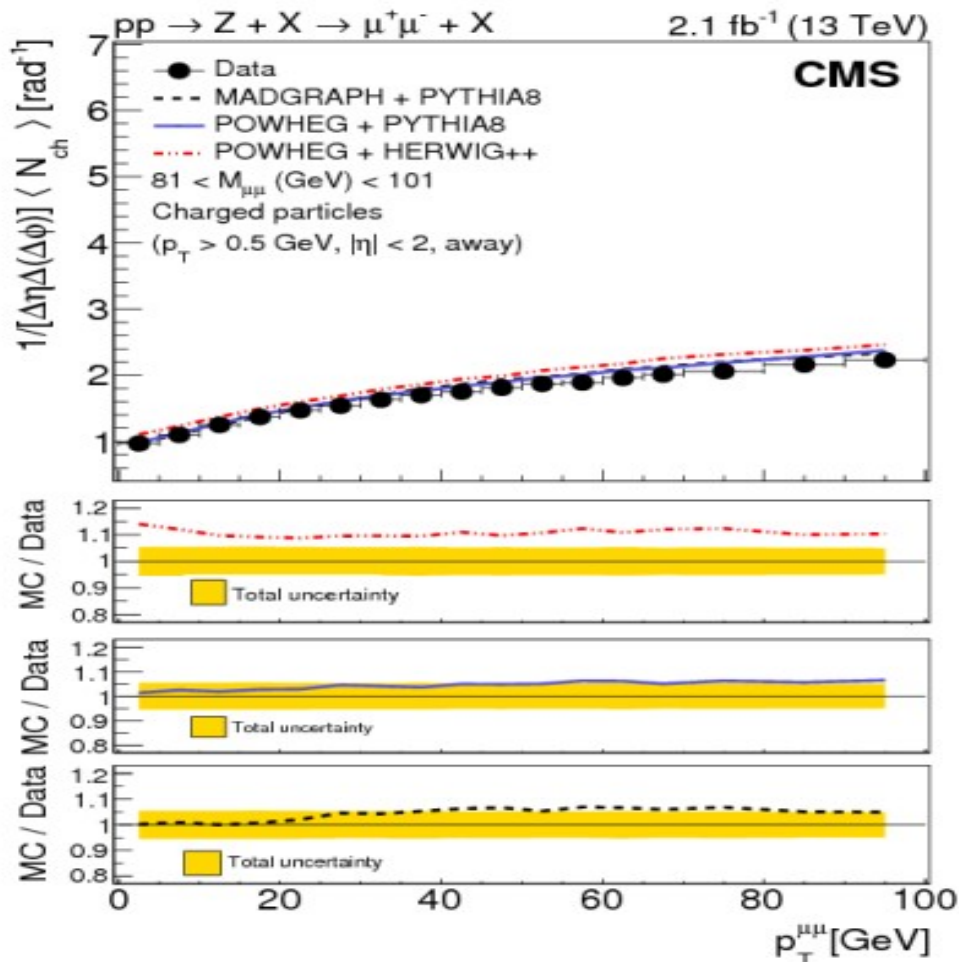


- ✓ UE densities at 2.76 TeV are compared with the same at 13 TeV for both, data & PYTHIA8 as well as Herwig++ MCs. UE activity grows strongly (60-70%) with increase in centre-of-mass energy.

UE Measurements → Drell-Yan Events

JHEP 07 (2018) 032

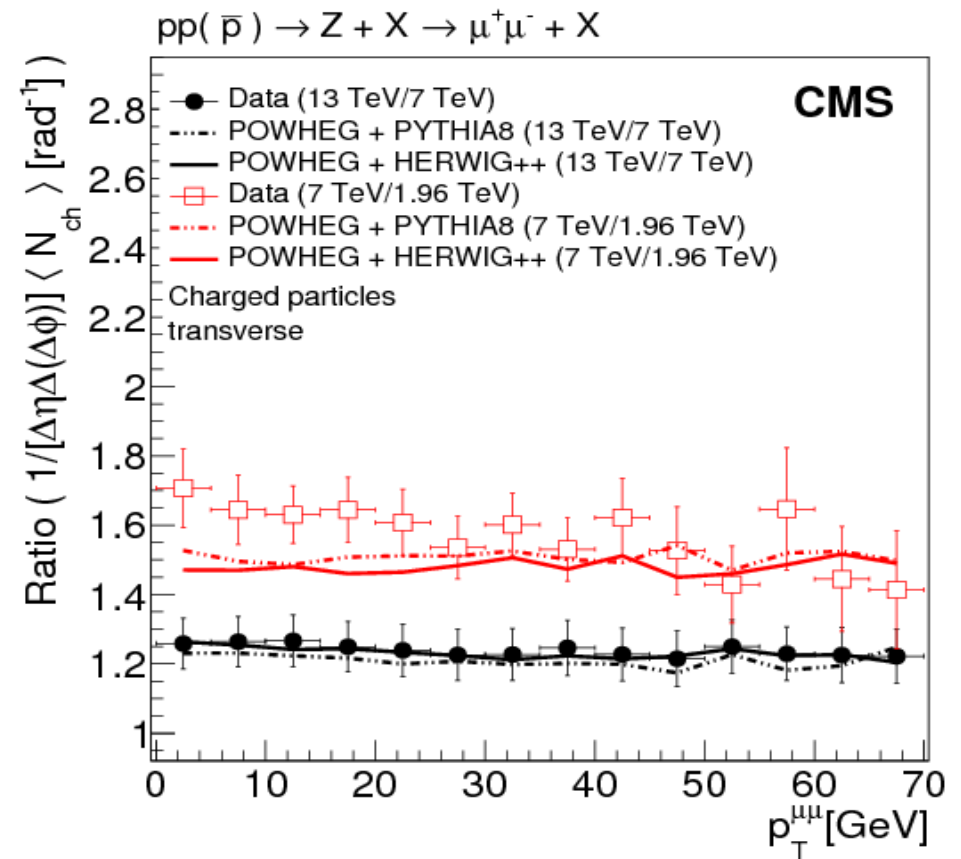
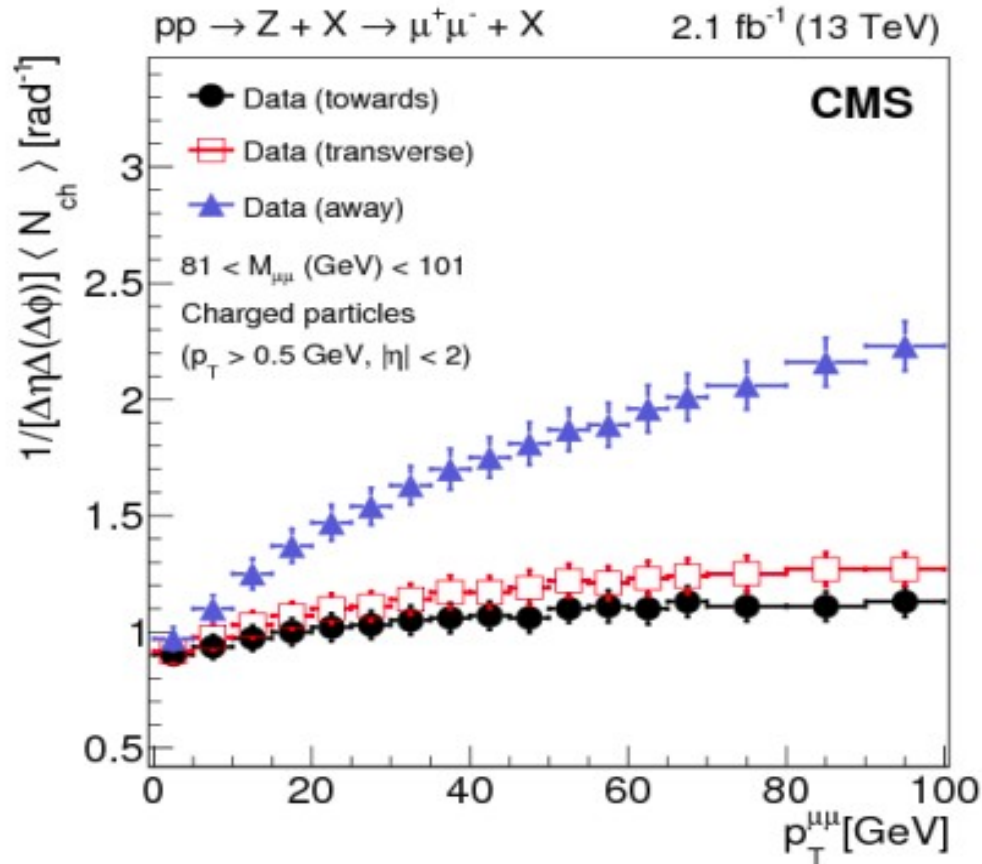
- ✓ p-p collisions data collected @ 13 TeV has been used, corresponding to an integrated luminosity of 2.1 fb^{-1} .
- ✓ Inclusive Z boson events are used for analysis ($Z \rightarrow \mu^+\mu^-$).



- ✓ Unfolded distributions of particle density in the away region as a function of $p_T^{\mu\mu}$ is compared with MC predictions. POWHEG and MADGRAPH in combination with PYTHIA8 gives the best description of data (within 5%).

UE Measurements → Drell-Yan Events

JHEP 07 (2018) 032



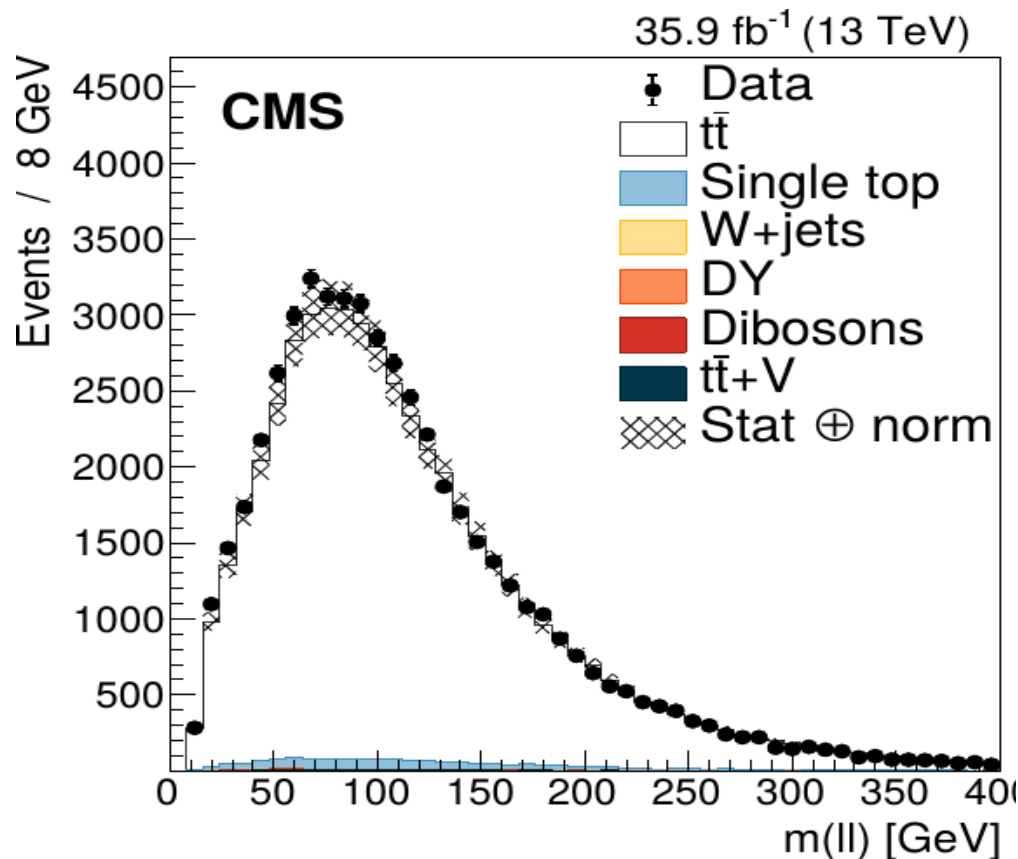
- ✓ **Away Region - Fast rise in UE activity due to recoiling hadronic activity.**
- ✓ **Towards and Transverse Region - Slow growth due to large spatial separation.**

- ✓ **UE activity shows 25-30% rise on moving from 7 to 13 TeV.**
- ✓ **UE activity shows 60-80% rise on moving 1.96 TeV to 7 TeV.**

UE Measurements → ttbar Events

- ✓ p-p collisions data @ 13 TeV, corresponding to an integrated luminosity of 35.9 fb^{-1} .
- ✓ Events having one electron, one muon and two jets (originated from fragmentation and hadronization of b quark) are used for the analysis.

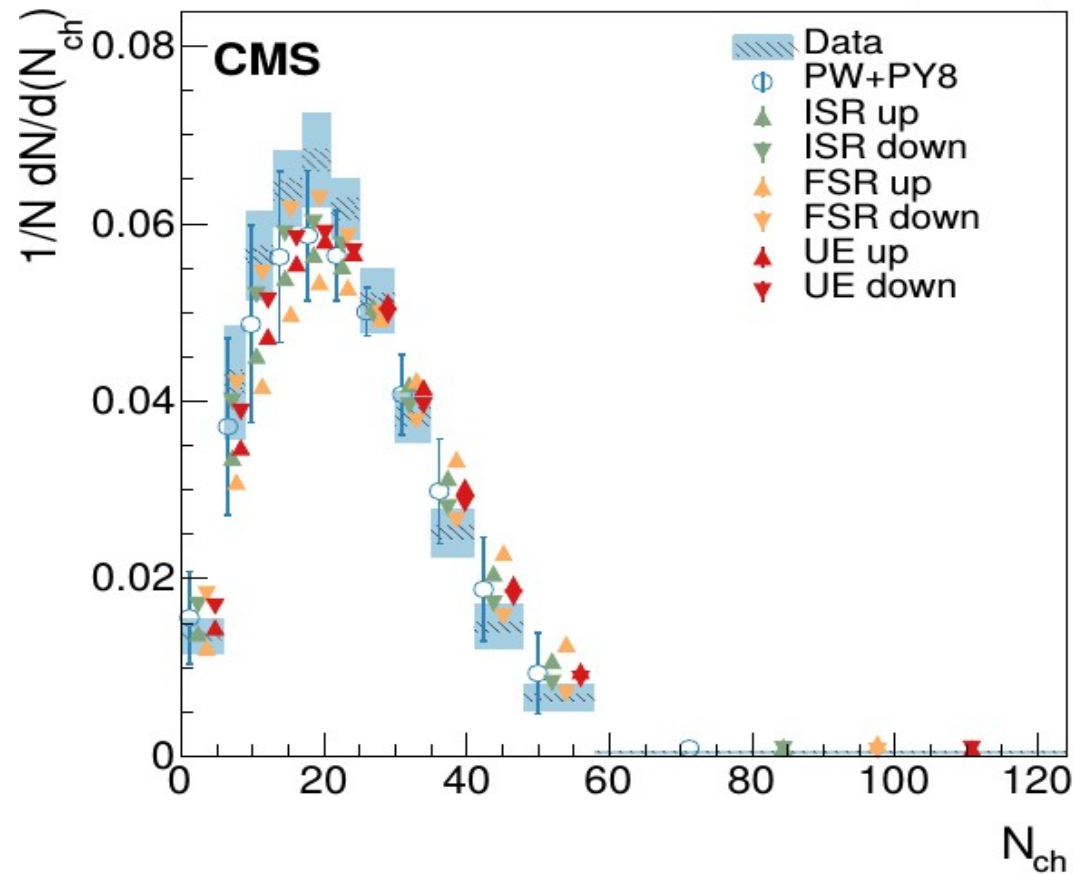
[arXiv: 1807.02810](https://arxiv.org/abs/1807.02810)



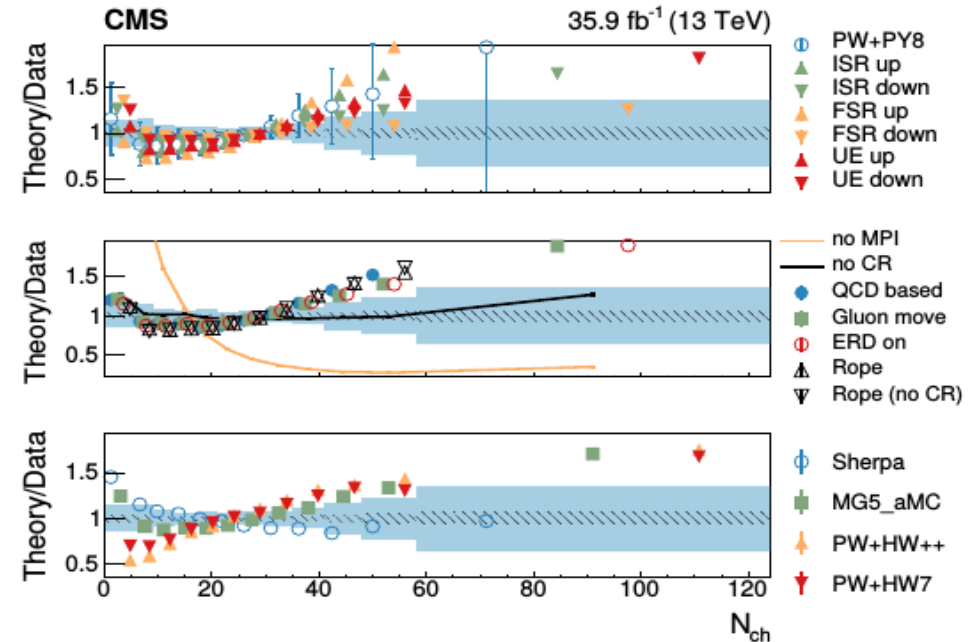
- ✓ **Dilepton mass, $m(\text{ll})$ variable distribution is compared to the sum of expectations of signal and backgrounds. Shaded region represents the total uncertainty. The $m(\text{ll})$ variable is estimated with a resolution $>2\%$.**

UE Measurements → ttbar Events

35.9 fb⁻¹ (13 TeV)



[arXiv: 1807.02810](https://arxiv.org/abs/1807.02810)



- ✓ The differential cross-section as a function of N_{ch} corrected data is compared to POWHEG+PYTHIA8 predictions as well as to different setups (obtained by varying the parameters of CUETP8M2T4 tune) – Left. Data is compared to different models – Right. Shaded region represents the total uncertainty. POWHEG+PYTHIA8 setup shows overall nice agreement with the data.

Summary

- ✓ UE activity shows strong growth with increase in centre-of-mass energy.
- ✓ Comparison of UE activity has been done in different regions, shows fast rise in away region as compared to towards and transverse regions.
- ✓ UE measurements in top quark pair production show no deviation from universality hypothesis even at higher energies.
- ✓ Results are valuable feedback to further constrain phenomenological models, useful for the understanding of particle production at low p_T .

