Run2 MC data comparisons

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for the CMS TOP PAG

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Outline

- Overview of ttbar NLO MC setups in CMS for Run2:
  - **Madgraph5 + Pythia 8 with MLM merging** (tt+0,1,2,3j)
  - **Madgraph5_aMC@NLO + Pythia 8 with FxFx merging** (tt+0,1,2j)
  - **Madgraph5_aMC@NLO + Pythia 8 / Herwig++**
  - **POWHEG + Pythia 8 (default setup for Run 2)**
  - **POWHEG + Herwig++/Herwig7**

- Run2 Event Tuning: CMS-TOP-16-021
  - α_s(ISR)+hdamp Tuning with POWHEG + PYTHIA 8
  - Based on Monash tune + MPI/CR parameters

- **UE in ttbar events** measured from 2015 data
  - CMS-TOP-15-017

CMS Pythia Tunes for Run2

- **CUETP8M1**: pre-13 TeV CMS Pythia8 tune for 13 TeV based on Monash
  - α_s^{ISR}= 0.1365 (Pythia8 default)

- **CUETP8M2T4** : event tune with α_s(ISR)=0.1108 and MPI/color reconnection parameters (NNPDF3.0)
  - **Default tune for 2016 ttbar production**:

- **New tune** : currently working on the update with NNPDF3.1(PDF induces MPI/CR variations)
  - **Default tune for 2017 ttbar production**

Jet Multiplicity at √s=13TeV and Shower α_s +h_{damp} Tuning

CMS-TOP-16-011

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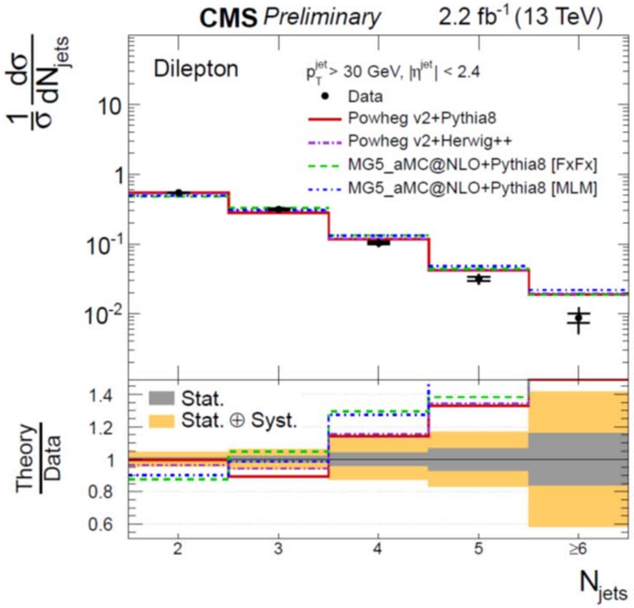
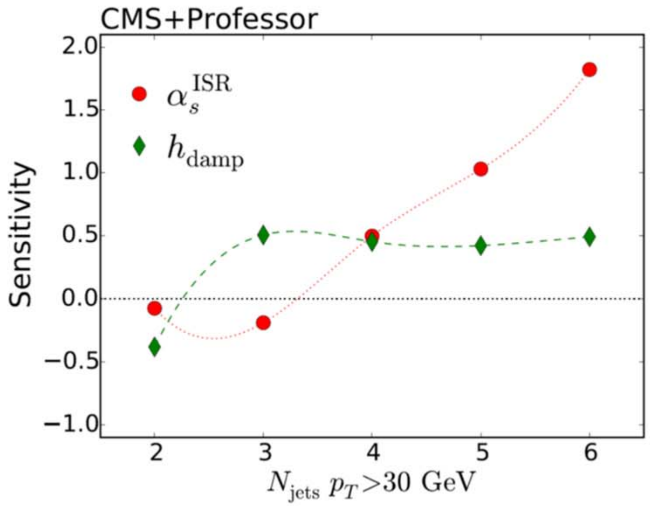


- Predictions overshooted the data for large jet multiplicities when out of the box parameters are used in Monash-based tunes

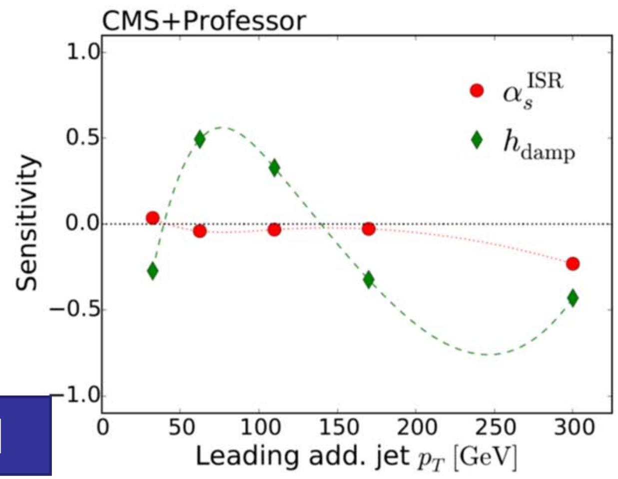
Monash Tune: Skands, Carrazza, Rojo. EPJ C74(2014)1

- POWHEG: hdamp (h_{damp}) is the model parameter that controls ME/PS matching and effectively regulates the high-p_T radiation by damping real emissions generated by POWHEG with a factor of $h^2_{\mathrm{damp}}/\left(p_T^2 + h^2_{\mathrm{damp}}\right)$. The default value is equal to the top-quark mass $m_t = 172.5\,\mathrm{GeV}$ used in simulation.
- PYTHIA 8: SpaceShower:alphaSvalue (α_s^{ISR}) is the value of the strong coupling at m_Z used for the initial-state shower. LEP event shapes [25] yielded $\alpha_s^{\mathrm{FSR}} = 0.1365$ for the final state shower. The default for both α_s^{FSR} and α_s^{ISR} are taken to be this value.



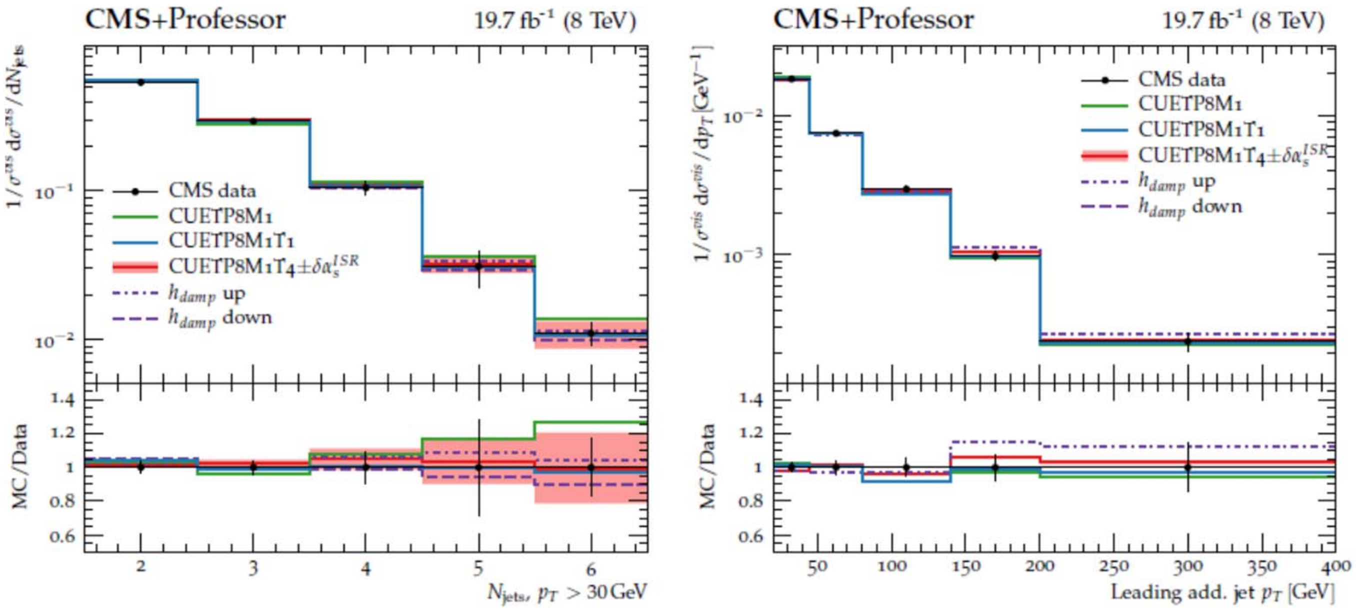
Effect on:

- **2/3-jet**
- **Lead. Add. Jet pT**
- **Njets > 3**



CMS-TOP-16-021

CMS Shower α_s +h_{damp} +UE Tuning



CMS-PAS-TOP-16-021

$$\alpha_s^{ISR} = 0.1108^{+0.0145}_{-0.0142}$$

$$h_{damp} = 1.581^{+0.658}_{-0.585} \times m_t$$

(pThard = 0, pTdef = 1)

- Fixing α_s to 0.1108, a new UE tune is derived optimizing MPI and color reconnection.

Tuned with 8TeV data

- Fit to UE observables at 13 TeV:
  - Charged-particle multiplicity vs leading track p_T and η.
  - Σp_T (in MIN & MAX regions) vs leading track p_T.
- Predictions with the new tune compared to independent measurements
- *New tune is used in Run 2 (2016) ttbar samples.*

ATLAS (h_{damp}=1.5m_{top}, α_S^{ISR}=0.127) and CMS h_{damp} values compatible.

ATL-PHYS-PUB-2016-020

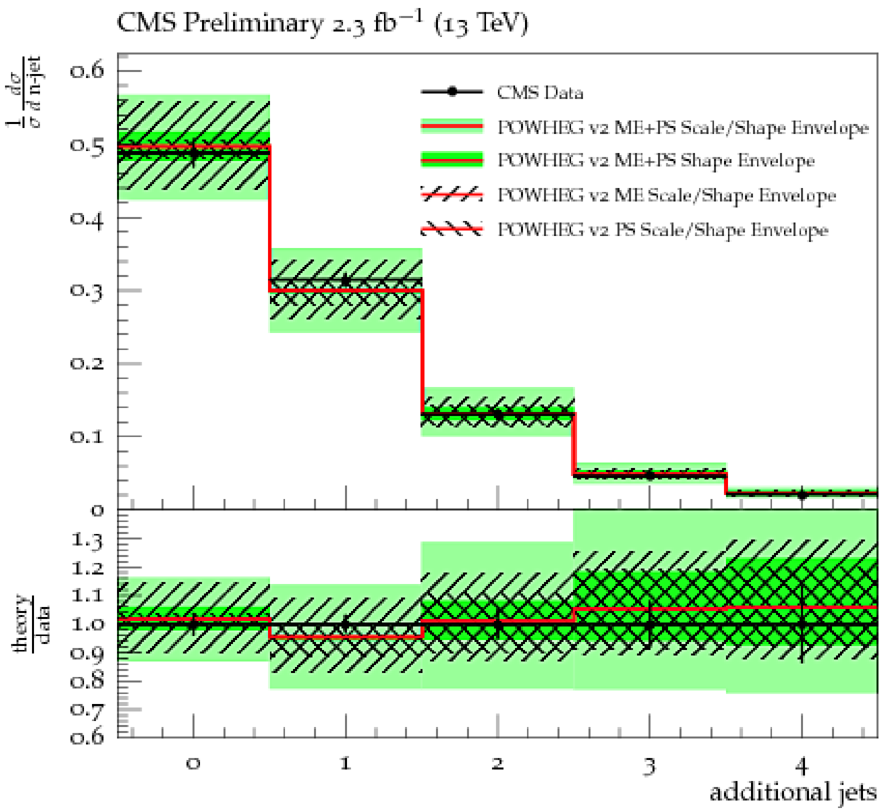
Parameters of the current tune in use

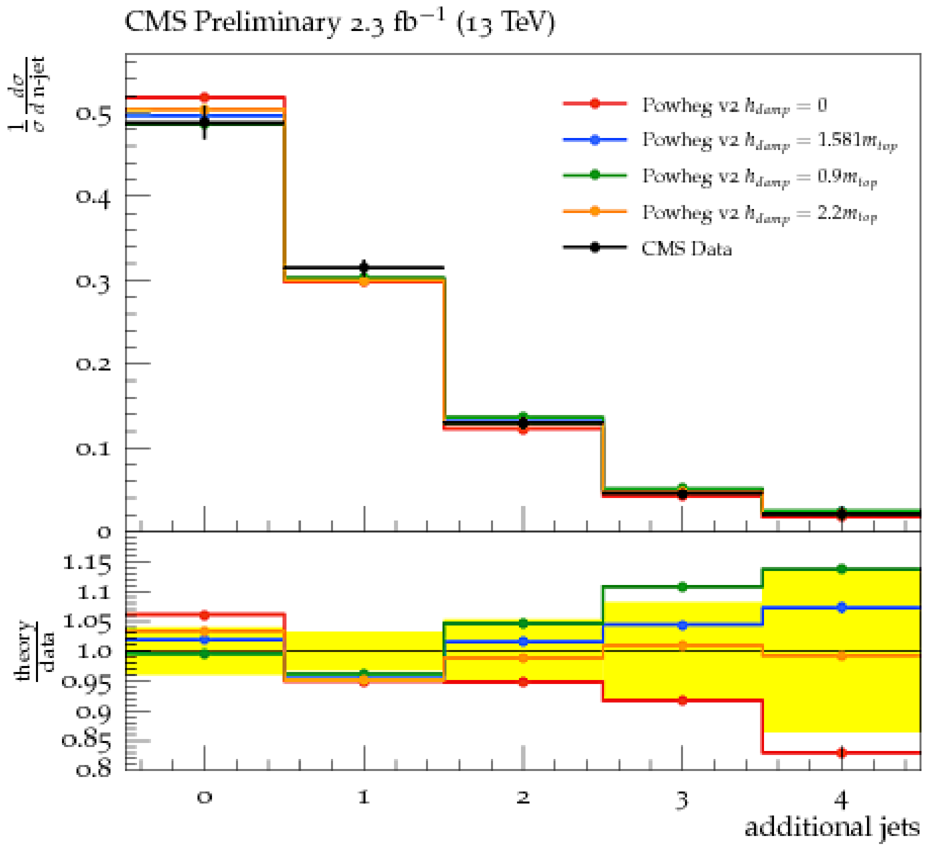
- **CUETP8M2T4**
- The UE parameters are determined by fitting UE observables measured at 13 TeV:
  - Forward energy flow as a function of pseudorapidity, $dE/d\eta$;
  - Central charged-particle multiplicity as a function of η, $dN/d\eta$;
  - UE observables, i.e. charged-particle multiplicity and ΣpT, in MIN and MAX regions, as a function of the leading jet pT
- New tune checked with Z+jets as well

	CUETP8M1	CUETP8M2T4
Tune	pp 14	pp 14
Tune	ee 7	ee 7
MultipartonInteractions ecmPow	0.2521	0.2521
SpaceShower:alphaSvalue	0.1365	0.1108
PDF pSet LHAPDF6	NNPDF23_lo_qed_as_0130	NNPDF30_lo_as_0130
MultipartonInteractions:pT0Ref	2.40	2.20
MultipartonInteractions:expPow	1.6	1.6
ColourReconnection:range	1.8	6.6

RIVET GEN studies in TOP-16-021

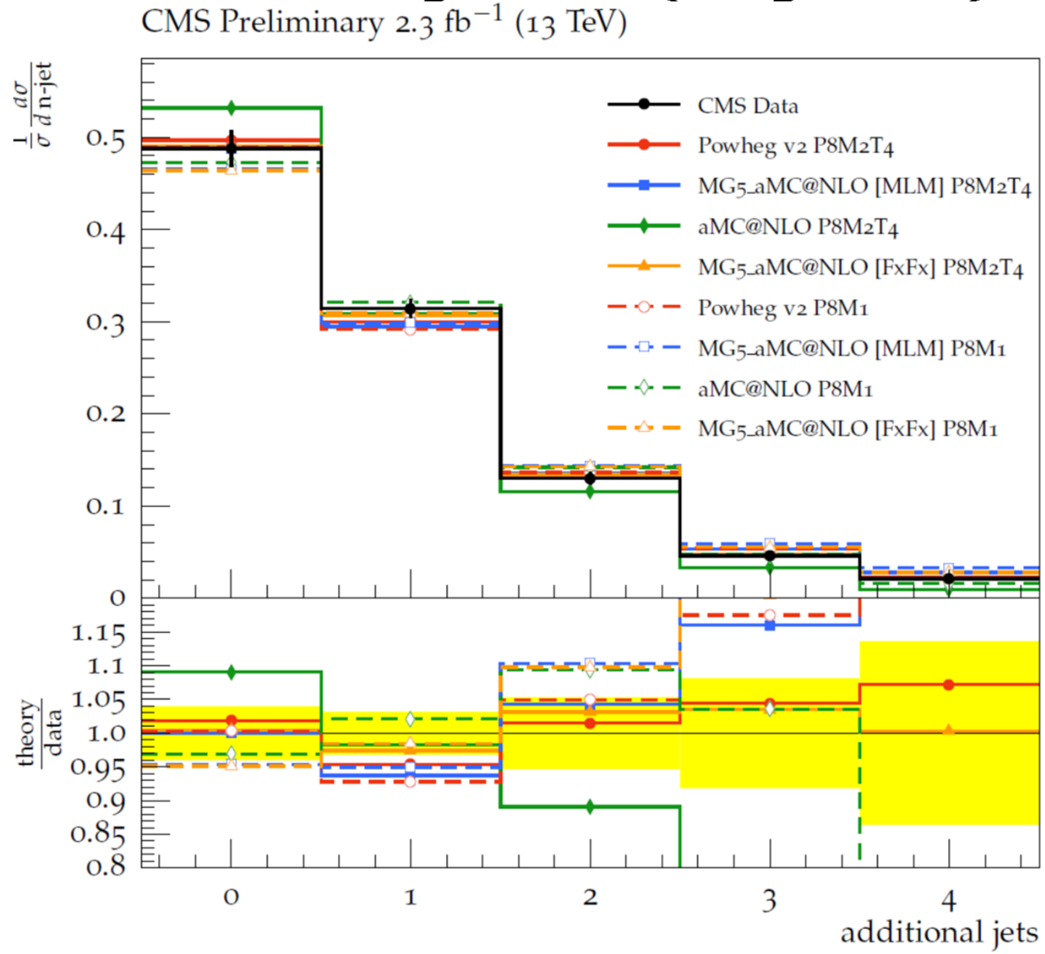
Check of TuneCUETP8M2T4 with **13TeV data**





- Good agreement of the Tune within uncertainties with data (**2015 l+jet 13TeV**)

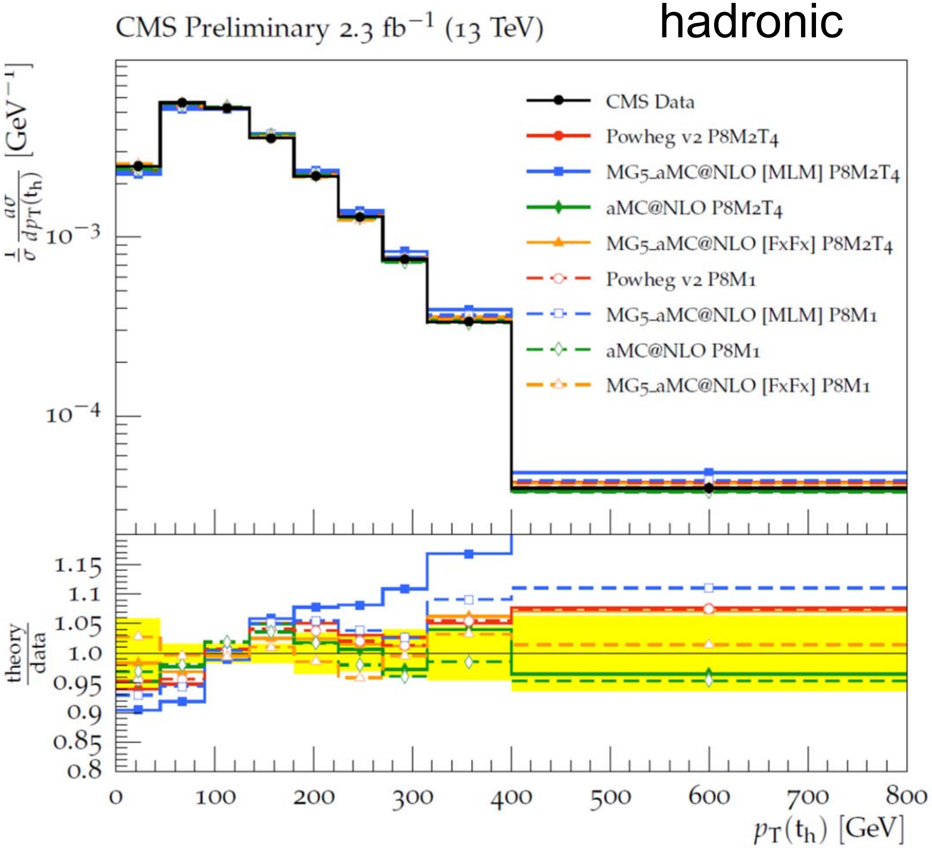
Additional jets (l+jets)

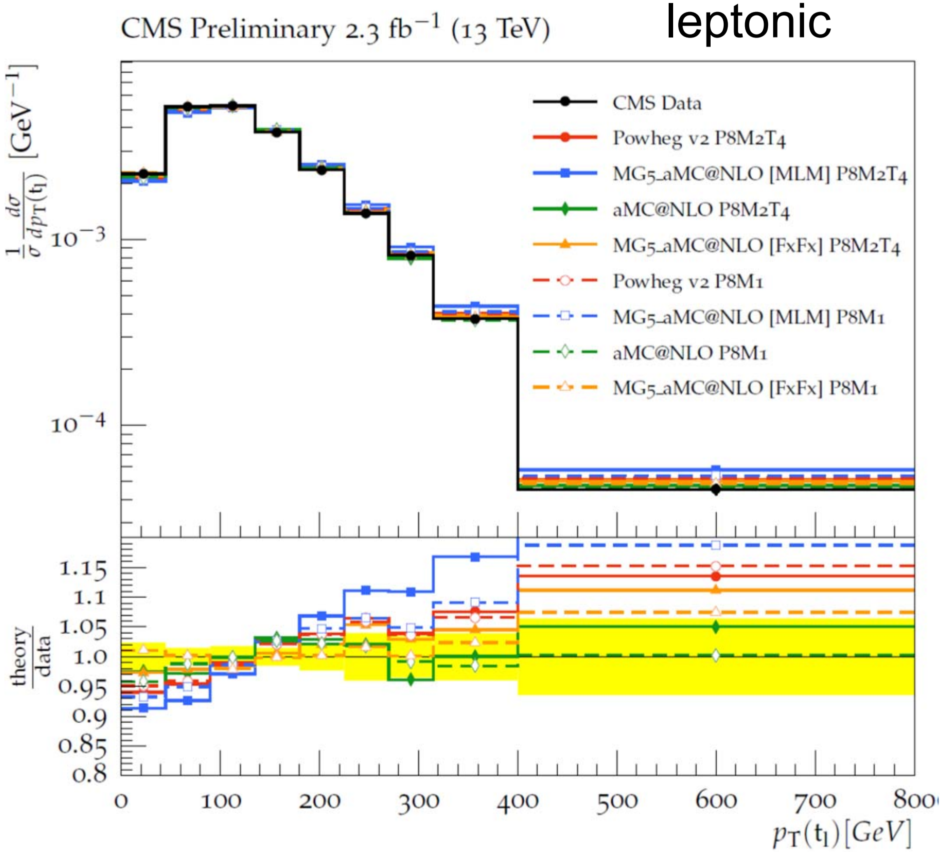


Check of TuneCUETP8M2T4 with **13TeV data** and other MC generators

- **MG5_aMC@NLO [FxFx]+Pythia8**: Almost as good as Powheg
  - Dedicated studies needed to tune MG5_aMC@NLO considering matching options.
- **MG5_aMC@NLO [MLM]** and **aMC@NLO + Pythia8** with the new CMS tune not good

The Top Quark pT

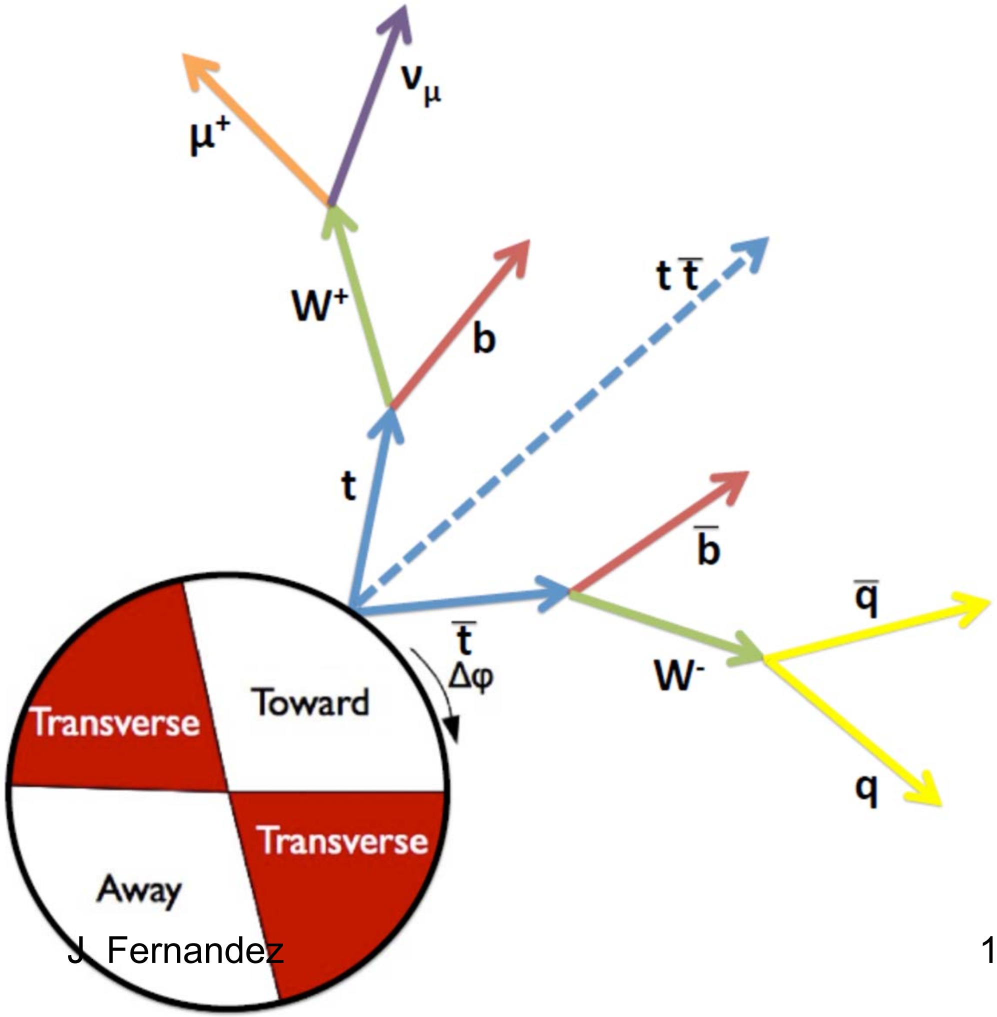




- aMC@NLO shows best agreement with data.
- Powheg compatible within uncertainties

Effect of the tune on top quark pT

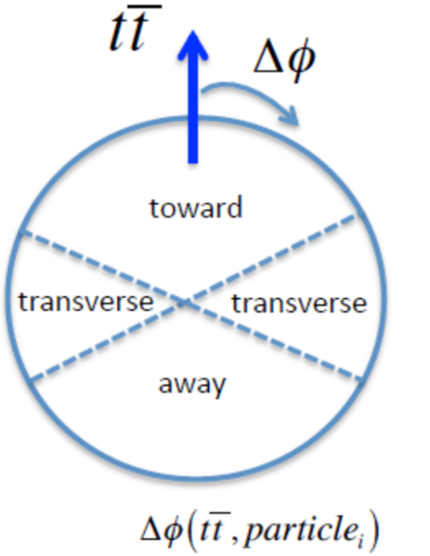
UE measurement with $t\bar{t}$



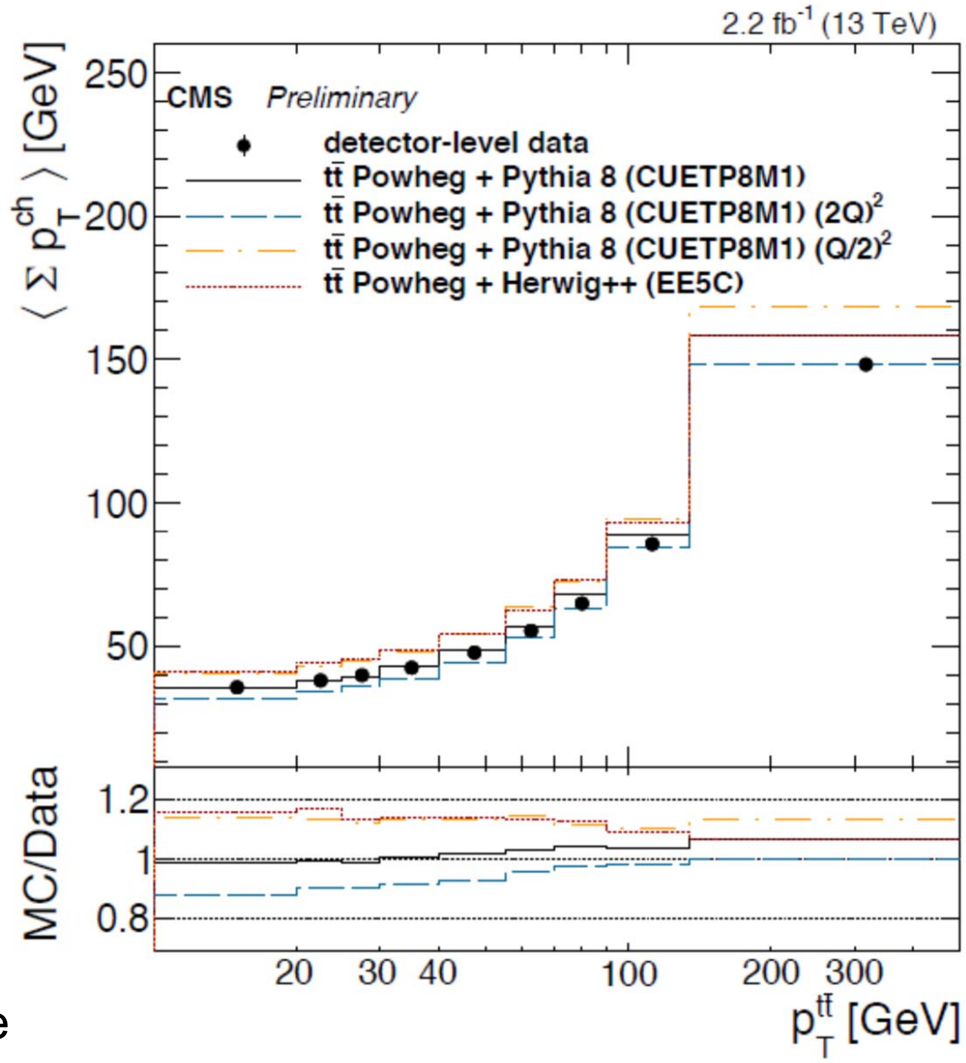
CMS-TOP-15-017

Using Monash tune
CUETP8M1
α_S(ISR)=0.1365

UE measurement in ttbar (I)



pT(ch)>0.5 GeV, |η| < 2.1



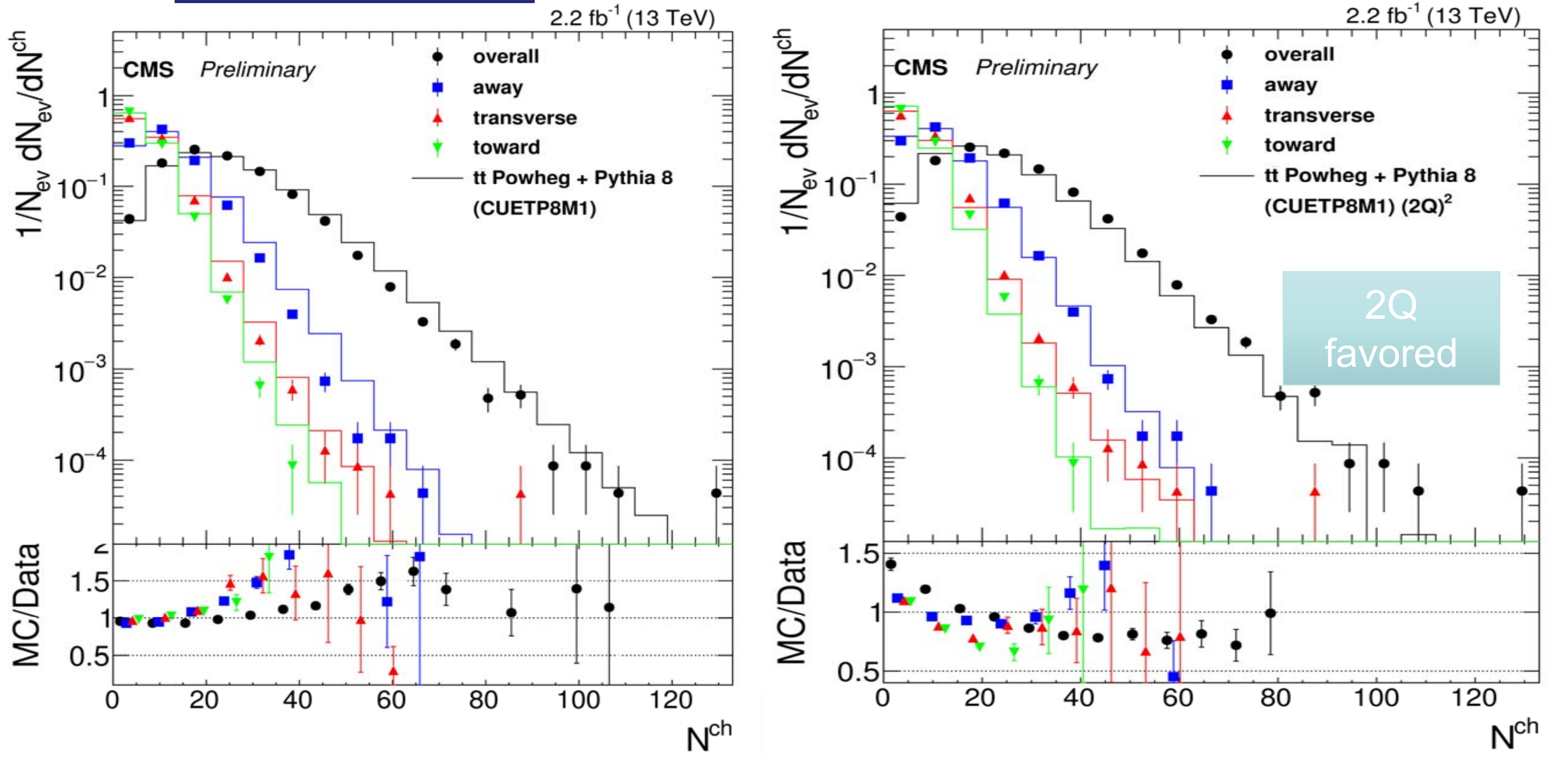
CMS-TOP-15-017

- Fair agreement between Powheg + Pythia8 CUETP8M1 tune predictions
- UE is sensitive to QCD scales / ISR
- A complete measurement of UE in ttbar events may lead to more precise top mass with better understood systematics.

UE measurement in ttbar (II)

CMS-TOP-15-017

μ+jets



- Measurement of charged particle multiplicity and mean/summed pT
- Sensitive to UE, ISR, PS cutoffs

UE measurement in ttbar (III)

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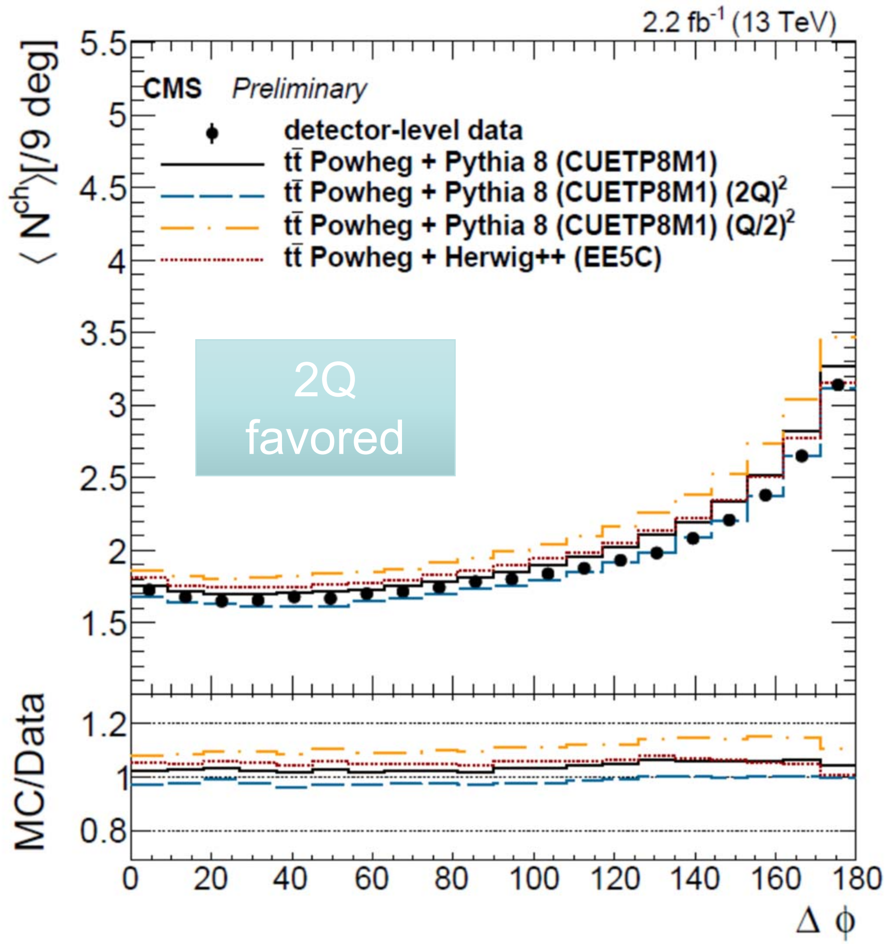
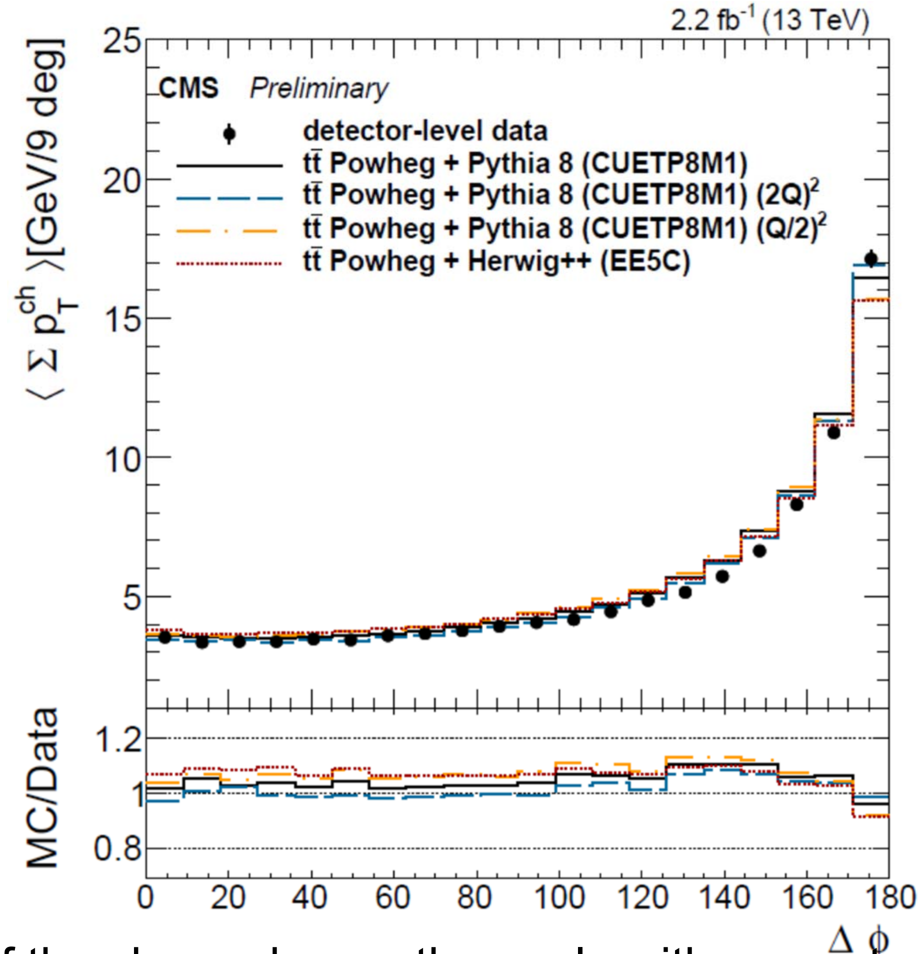
μ+jets





- The number of charged particles/Sum of the charged p_T vs the angle with respect to the event-by-event axis defined using p_T(tt)

Summary and conclusions

- Extensive suite of generator setups tried and more in the pipeline for 2017:
  - POWHEG+ PYTHIA 8 as default for Run2
  - Moving from Herwig++ to Herwig7 ASAP and trying Sherpa
- Preliminary tuning of α_S(ISR) value to match 8TeV data at high jet multiplicities
  - makes the agreement at 13TeV for POWHEG+Pythia8 as good as 8TeV data with MG+Pythia6
  - to be updated with NNPDF3.1
- UE measurement with $t\bar{t}$ favoring PS scale up

EXTRA/BACKUP

Work in progress

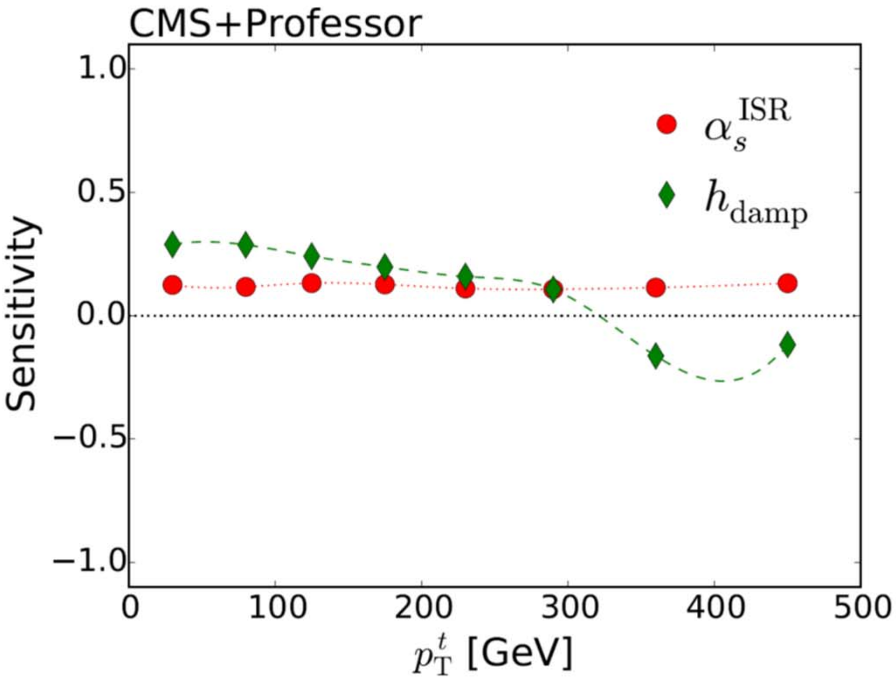
- Sherpa and **Herwig 7** in development
  - Interface to CMSSW being created, testing first samples

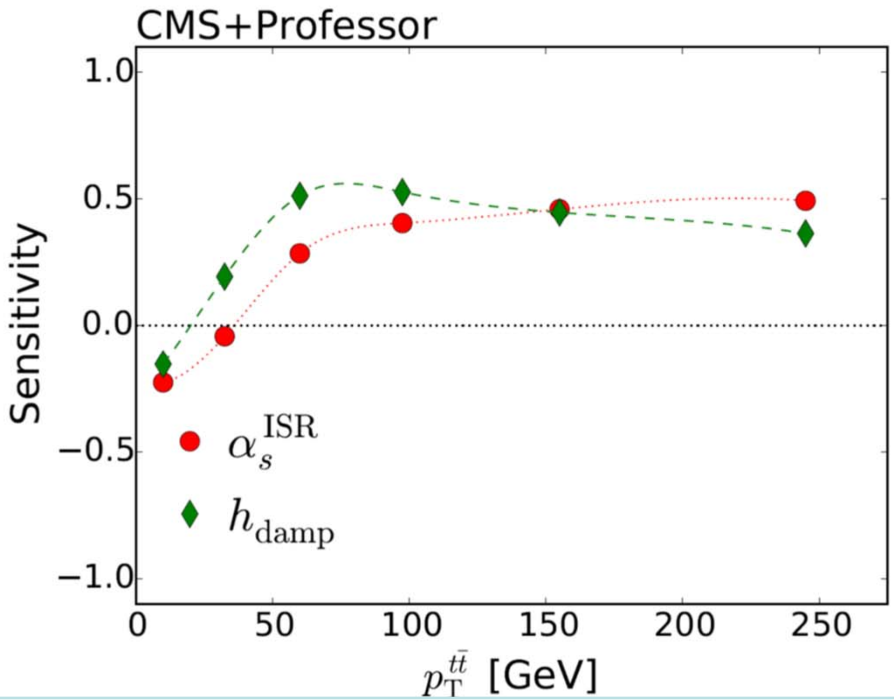
- Trying EvtGen in **POWHEG** + **Pythia 8**
  - Using latest DECAY_NOLONGLIFE.DEC with long-lived states removed, to properly inject GEANT

- Testing improved handling of resonances (with radiation in decay corrected at NLO) in **POWHEG** (ttb_NLO_dec), as well as Spin Correlations disabled .

- Testing of NLO+PS generator for t tbar and Wt production and decay including non-resonant and interference effect: b_bbar_4l process in **POWHEG**

Other sensitivity plots





There is good sensitivity for both alpha_s and hdamp however pt(ttbar) is strongly correlated to Njets which we already use. We could have used pt(ttbar) instead of Njets, however, we don't have the size and bin-to-bin correlation of all systematic uncertainties for pt(ttbar)

Plots not in PAS.
Only in the twiki