CMS Monte Carlo plans for Run2

Efe Yazgan
for the CMS Top PAG

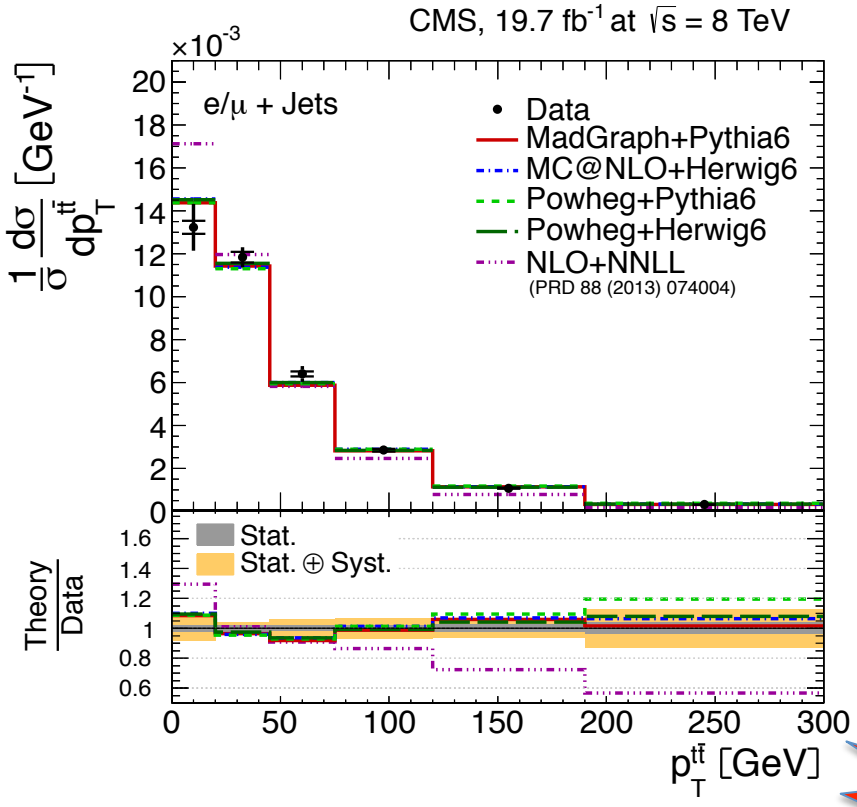
TOPLHCWG Open Meeting
20-21 May 2015

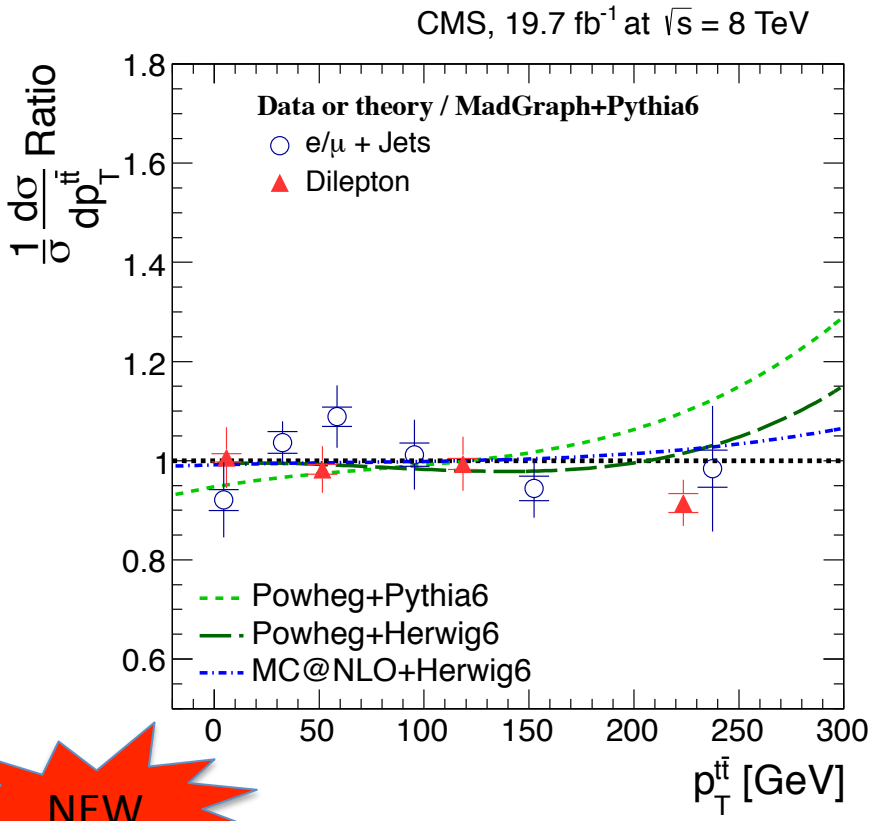
Outline

- Run I Monte Carlo
- Monte Carlo plans for Run II
  - Signal Generation
  - Systematics
- Future plans for tuning
  - Underlying event studies

Run I MC

- **MadGraph (w/ 3 additional partons)+Pythia6** describes most of the differential distributions from data reasonably well except top p_T.





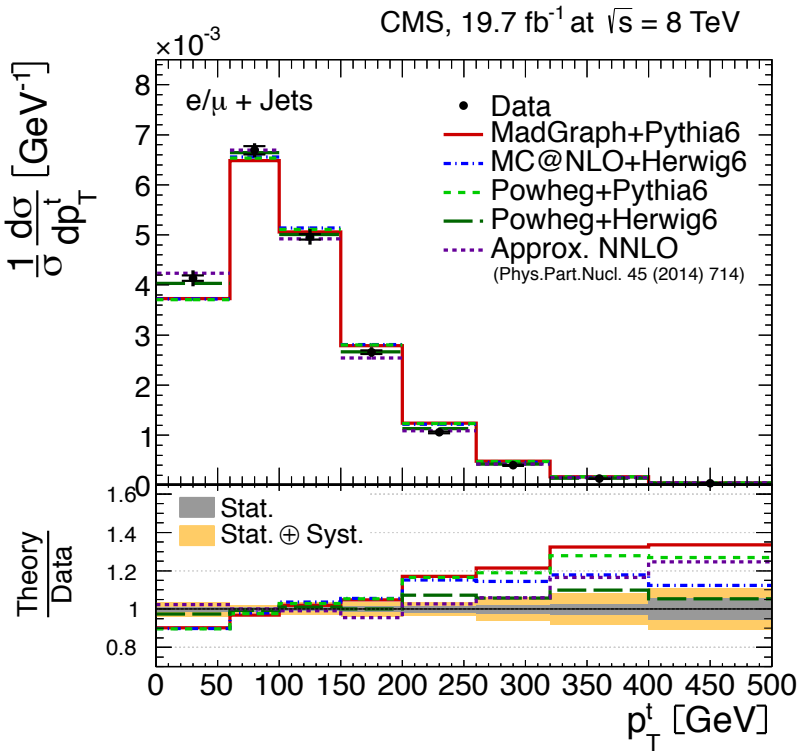
NEW

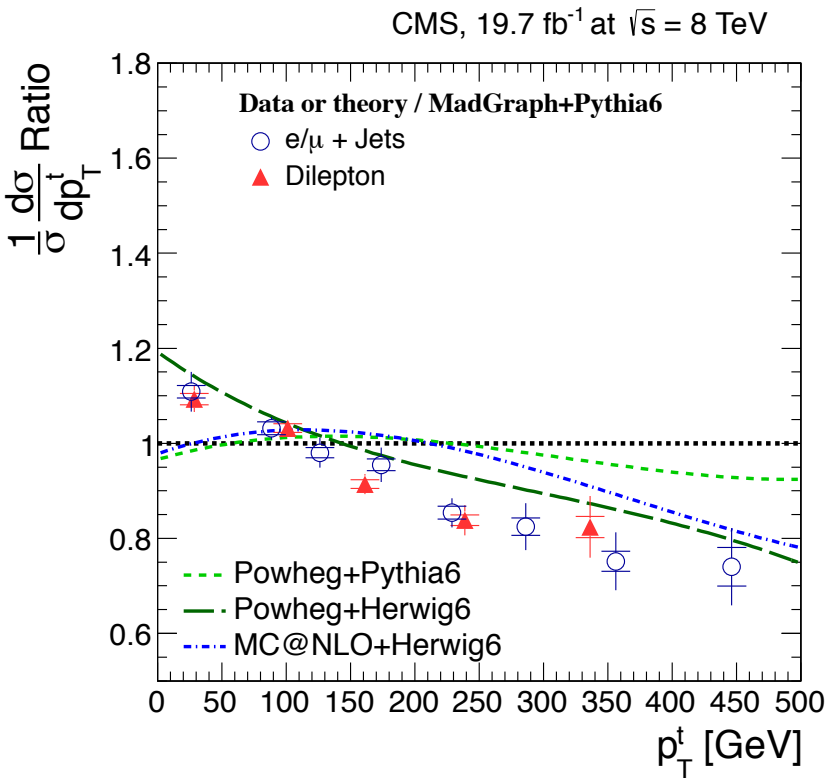
Data corrected to parton level (before decay after radiation)

CMS-TOP-12-028, arXiv:1505.04480

Run I MC

- **Powheg+Herwig** and **approx. NNLO calculation** provide the best description of the data.





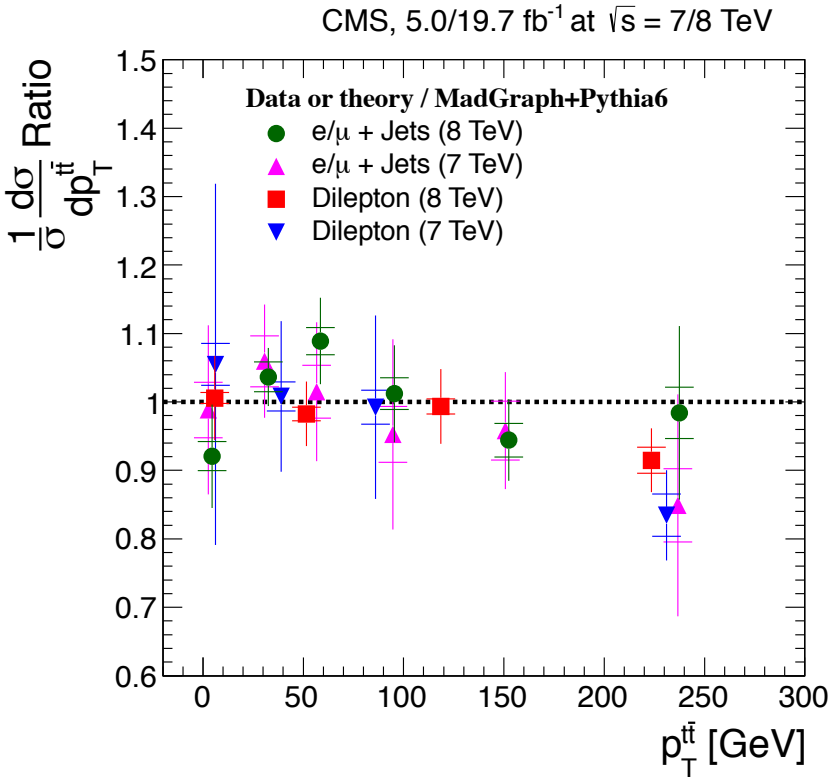
NEW

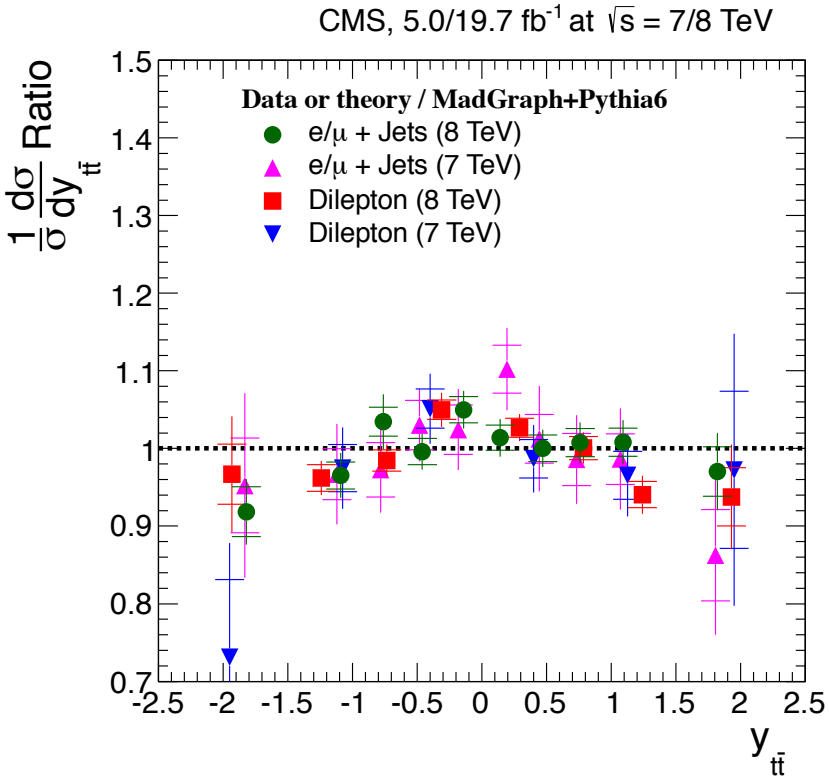
CMS-TOP-12-028, arXiv:1505.04480

Run I MC

- For all distributions the trend is the same for 7 and 8 TeV and in lepton+jets and dilepton measurements.

NEW

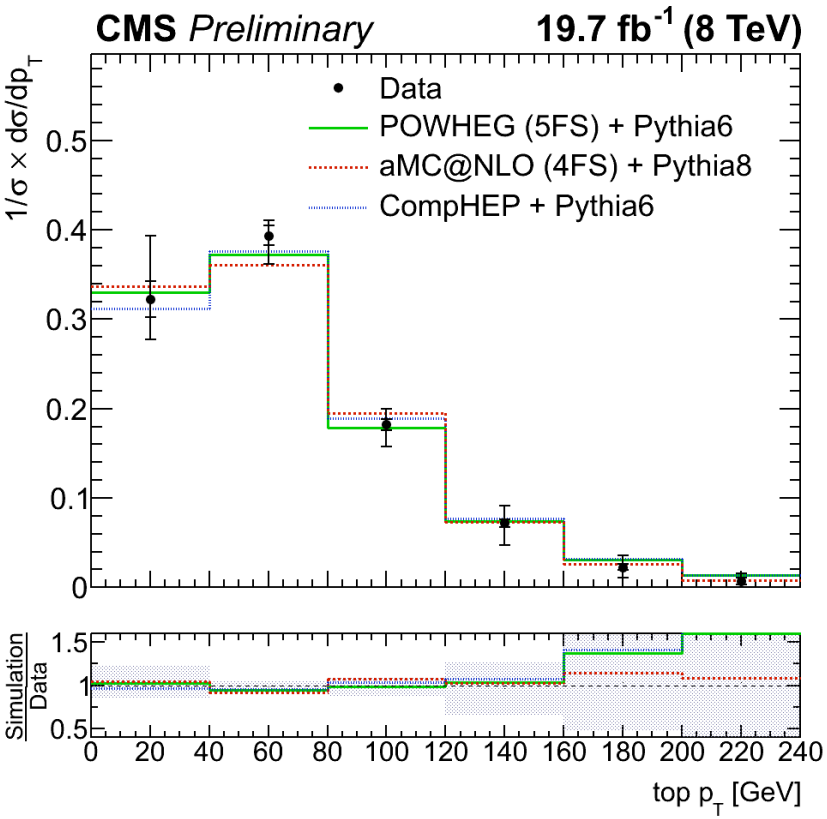


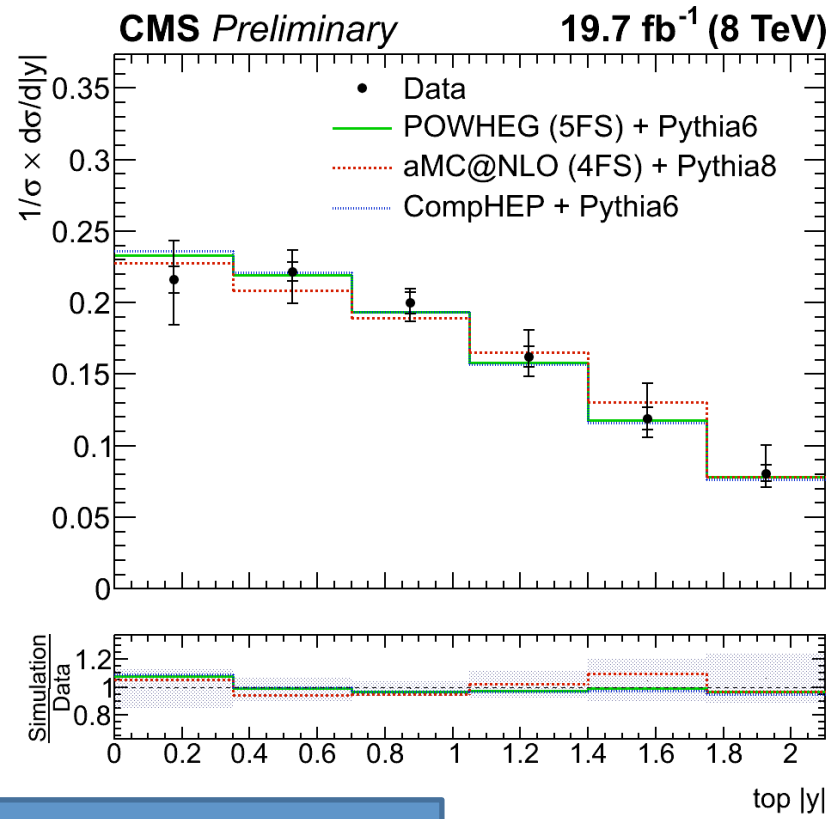


CMS-TOP-12-028, arXiv:1505.04480

Differential Measurements in the single top t-channel

- Different implementations for b-quark modeling in the initial state for NLO generators.
- CompHep: combination of 2→2 and 2→3 processes based on the p_T spectrum of the second b quark (as an NLO approximation).
- Data distributions (corrected to parton level) are described well by both NLO and LO MCs + Pythia6.





CMS-PAS-TOP-14-004

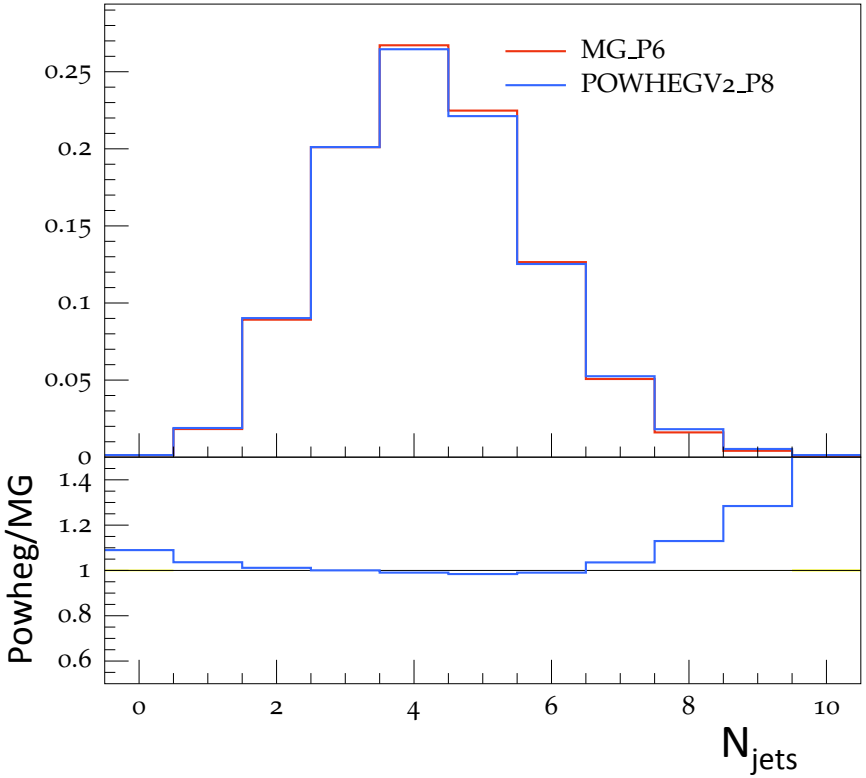
Signal Samples for Run II

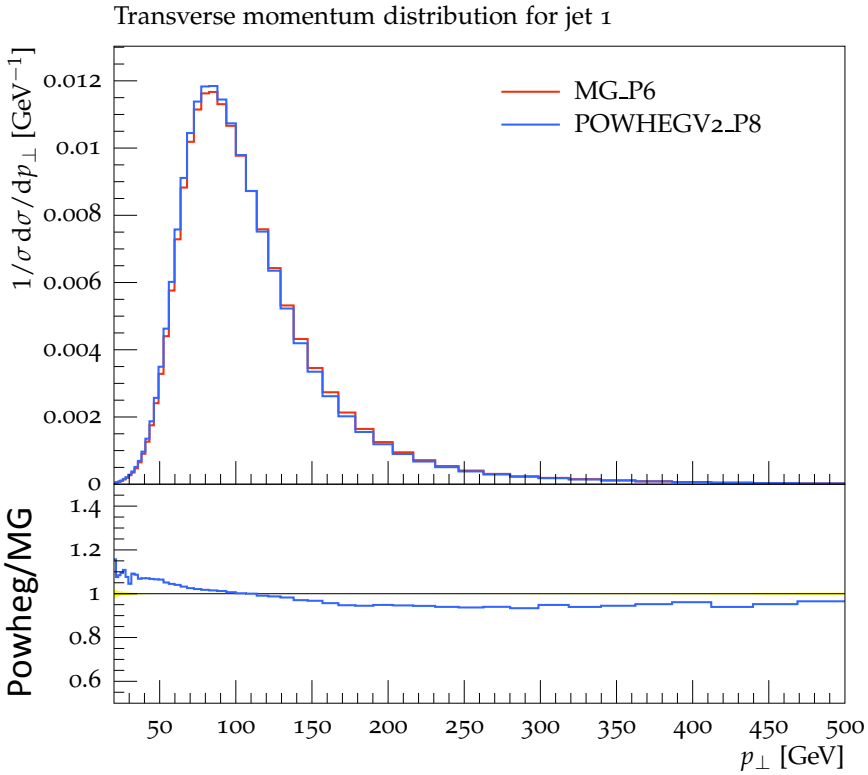
- Run II measurements at ultimate precision require dedicated effort in top quark event modeling.
- CMS Run II measurements being exercised using new generation of NLO+PS MCs (in parallel, validation ongoing using Run I data)
  - Expect to provide better understanding of signal and backgrounds.
  - Reduce (dominant) systematic uncertainties from theory w.r.t. Run I.
    - Smaller scale uncertainties.
    - Smaller k-factors
    - Smaller/negligible matching uncertainties.
  - Matrix element Q^2 scale and PDF variations through weights.
  - New parton showers: Herwig++ and P8, improved B-decay tables
  - *ttbar samples sensitive to issues in jet matching.*

Signal Samples for Run II

- Main signal samples at 13 TeV
  - Powheg_v2 + Pythia 6/8
  - MG5_aMC@NLO + Pythia8 [LO]: $t\bar{t}$+0,1,2,3 jets: MLM
  - MG5_aMC@NLO + Pythia8 [NLO]: $t\bar{t}$+0,1,2 jets: FxFx merging
  - Single top: 4 flavor-scheme → for event generation in general for any b-initiated process at the LHC - see e.g. Maltoni et al. JHEP 04 (2013) 095.
  - PDFs: NNPDF2.3 (LO), NNPDF3.0 (NLO) with LHAPDF6.
  - New tunes: CUETP8, 4C

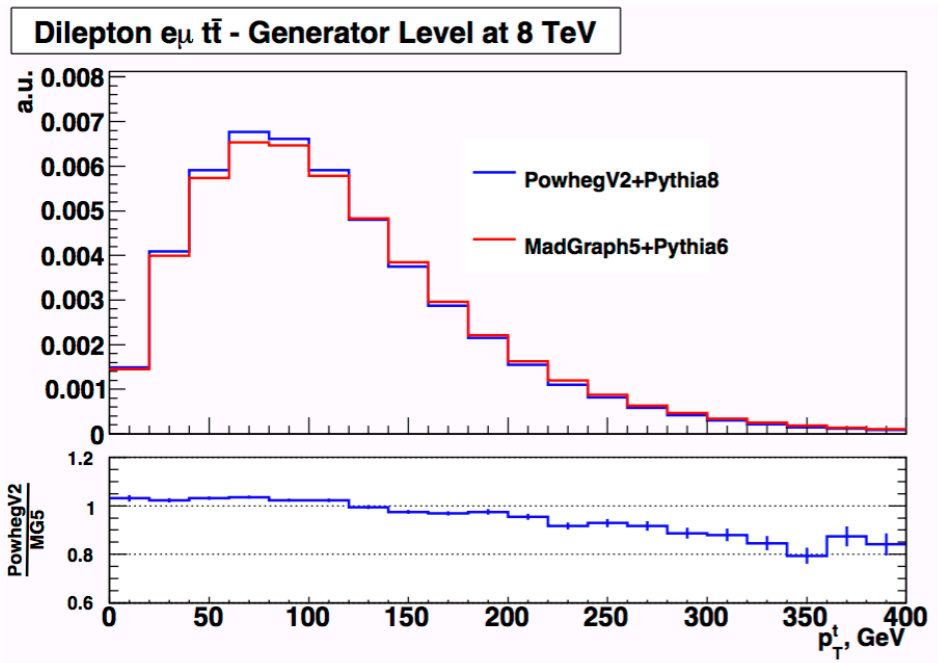
Preliminary Validation of New MCs at 8 TeV

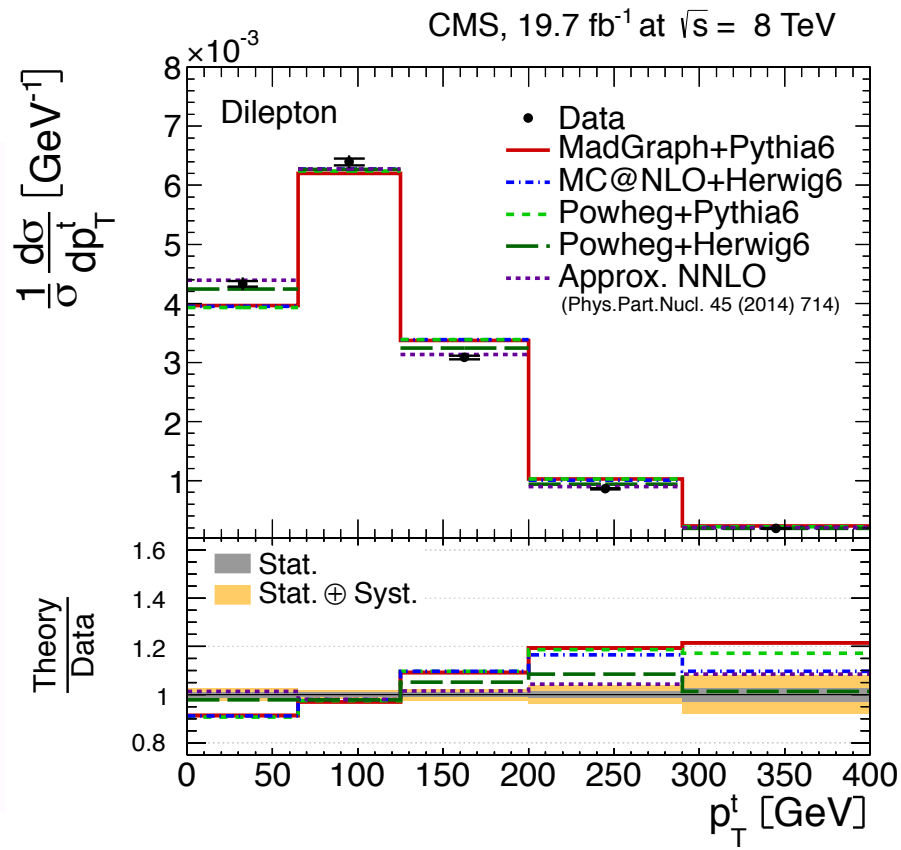




- Inclusive ttbar sample.
- p_T(jet) > 30 GeV.

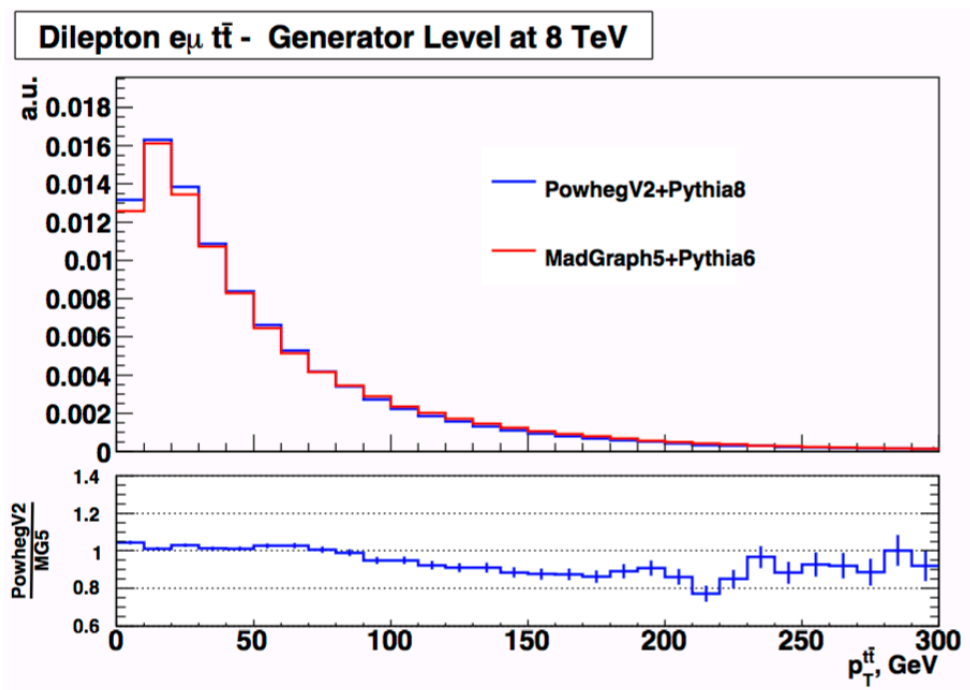
Preliminary Validation of New MCs at 8 TeV

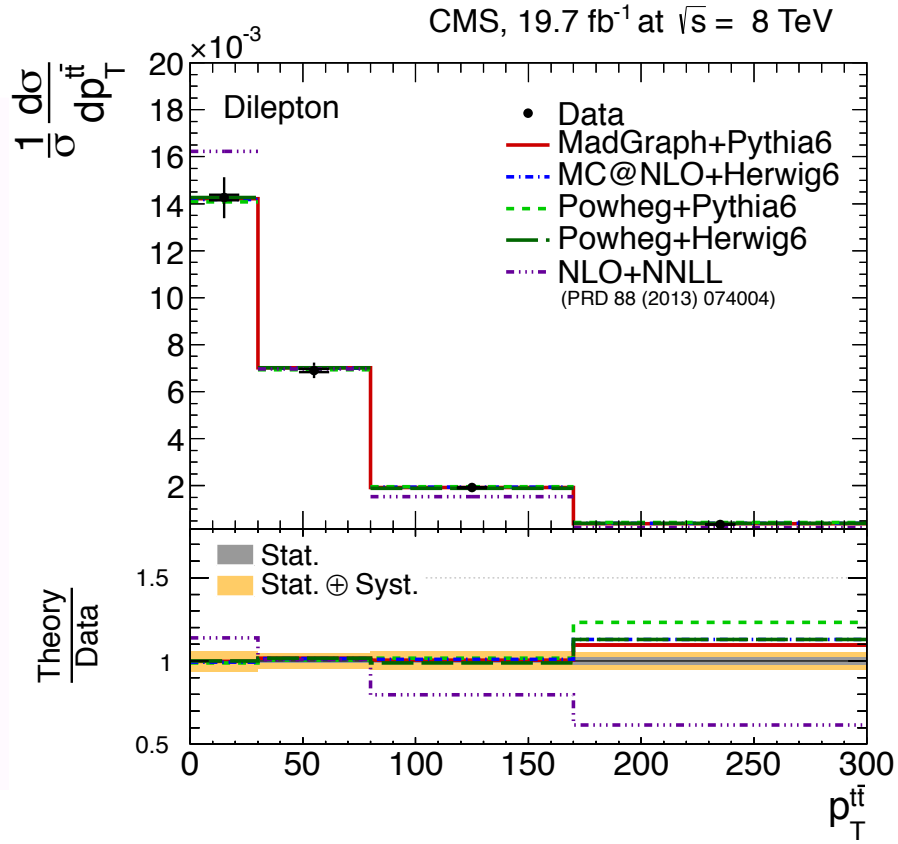




- PowhegV2+Pythia8 (hdamp=m_t) with CT10 PDF.
- MadGraph5+Pythia6 with CTEQ6L1.
- "Parton level top quarks" before decay after radiation.
- Preliminary conclusion: Powhegv2/Data ~ 1 w/o a slope.

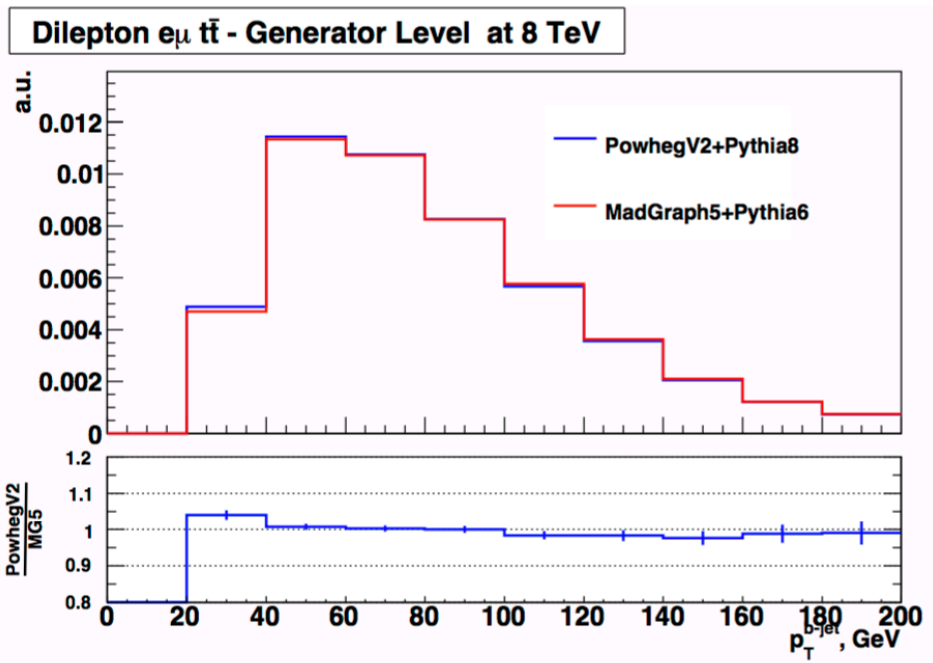
Preliminary Validation of New MCs at 8 TeV

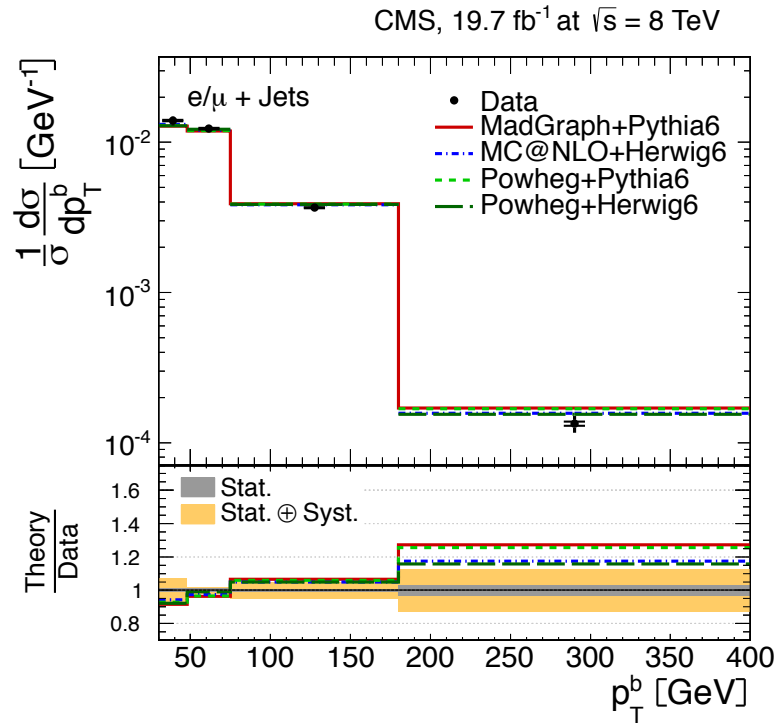




- "Parton level top quarks" before decay after radiation.
- Preliminary conclusion: PowHegv2/Data OK.

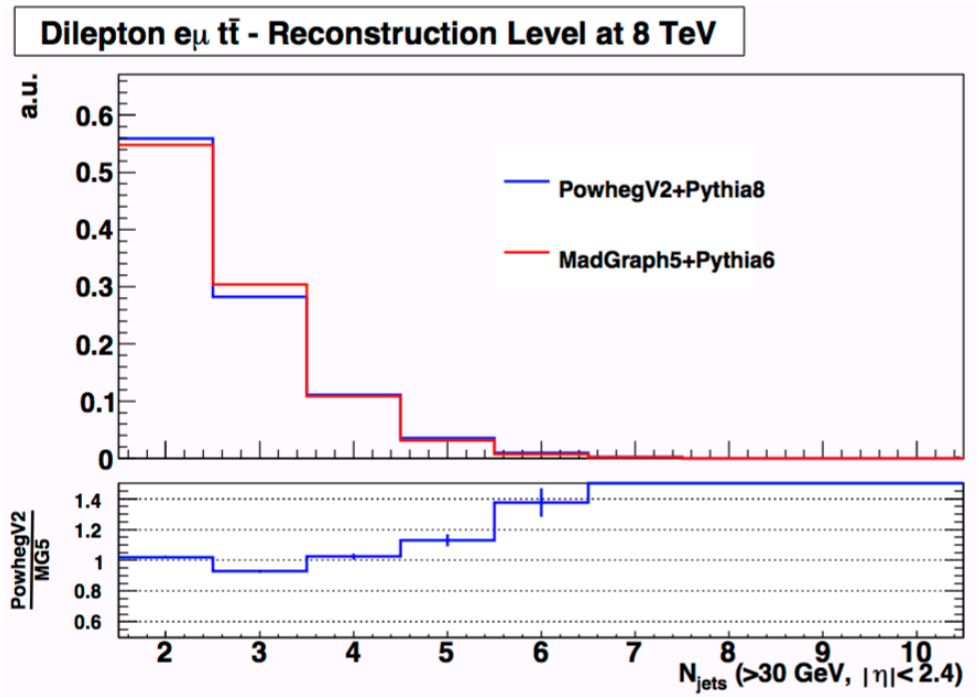
Preliminary Validation of New MCs at 8 TeV

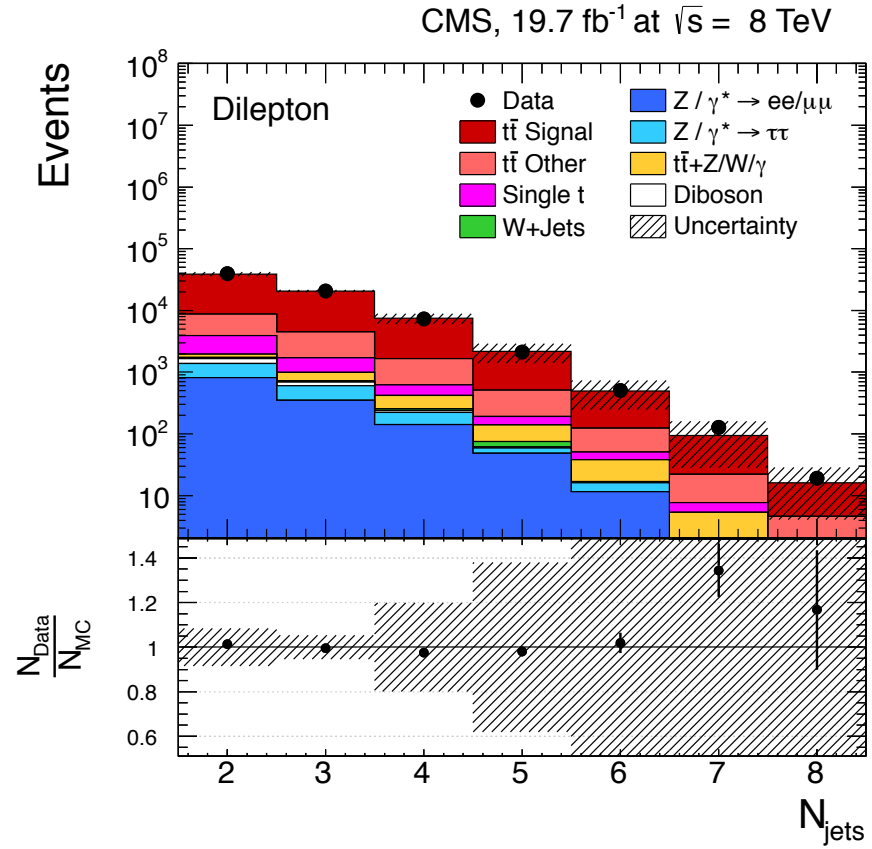




- b-jet defined in fiducial volume: two b-jets, matched to B-hadrons (matched to its mother top quark) with pT > 30 GeV within |η|<2.4.
- Preliminary conclusion: PowHegv2/Data ~OK.
  - Possible discrepancy at high p_T to be investigated.

Preliminary Validation of New MCs at 8 TeV





- Reco-level comparison.

ME and PS Scales and Variations

Scale definitions:

$$Q = \sqrt{\frac{p_{T,t}^2 + p_{T,\bar{t}}^2}{2} + m_t^2}\,(MG5\_aMC@NLO),$$

$$Q = \sqrt{m_t^2 + p_{T,t}^2}\,(Powhegv2),$$

$$Q = \sqrt{m_t^2 + \sum p_T^2(j)}\,(MadGraph)$$

- Matrix element Q^2 scale variations through weights in MG5_aMC@NLO and in Powhegv2.
  - In Powheg not to underestimate scale variations hdamp = finite.
    - hdamp separates the singular (R_s) and finite (R_f) fractions of the real matrix element by setting

$$R_f \rightarrow \frac{p_T^2}{hdamp + p_T^2}$$

(see ATL-PHYS-PUB-2014-005)

Powhegv2 ME Q^2 Scale Variations

```
//<weightgroup name='hdamp_variation' combine='envelope'>
…
//<weight id='3010'> muR=1 muF=1 hdamp=86.25 </weight>
//<weight id='3011'> muR=1 muF=2 hdamp=86.25 </weight>
//<weight id='3012'> muR=1 muF=0.5 hdamp=86.25 </weight>
//<weight id='3013'> muR=2 muF=1 hdamp=86.25 </weight>
//<weight id='3014'> muR=2 muF=2 hdamp=86.25 </weight>
//<weight id='3015'> muR=2 muF=0.5 hdamp=86.25 </weight>
//<weight id='3016'> muR=0.5 muF=1 hdamp=86.25 </weight>
//<weight id='3017'> muR=0.5 muF=2 hdamp=86.25 </weight>
//<weight id='3018'> muR=0.5 muF=0.5 hdamp=86.25 </weight>
…
```

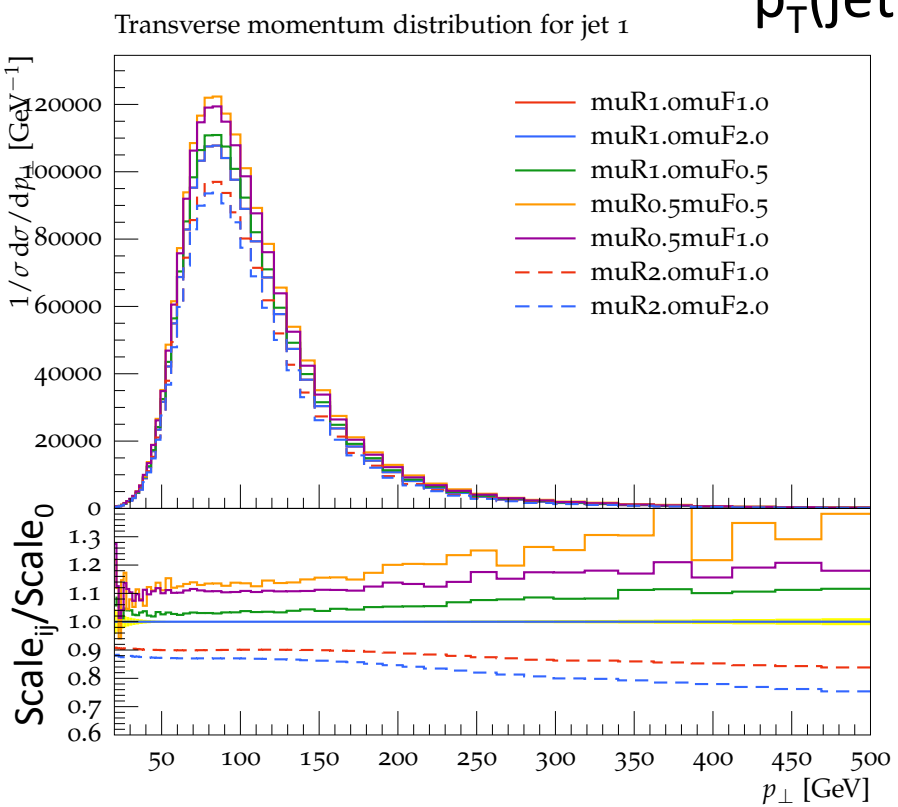
→8 (+1 default) variations for each hdamp choice (0, $m_t/2$, m_t, $2m_t$).

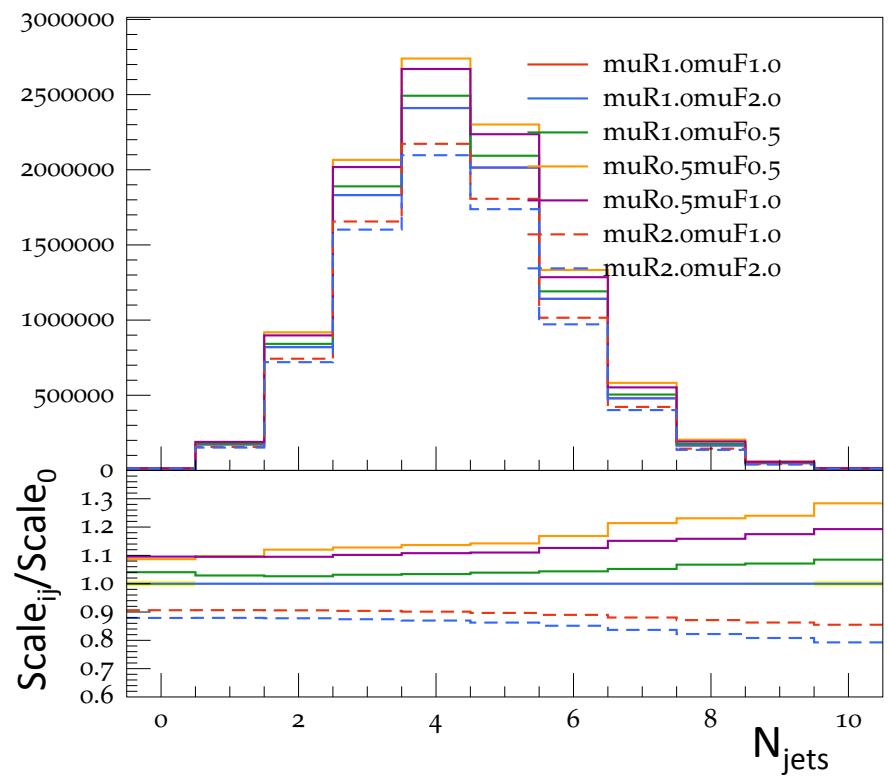
- Plan to use the envelope of μ_R and μ_f variations (marked blue), i.e. all except the anti-diagonal extremes.

Preliminary ME Q^2 Scale Variations

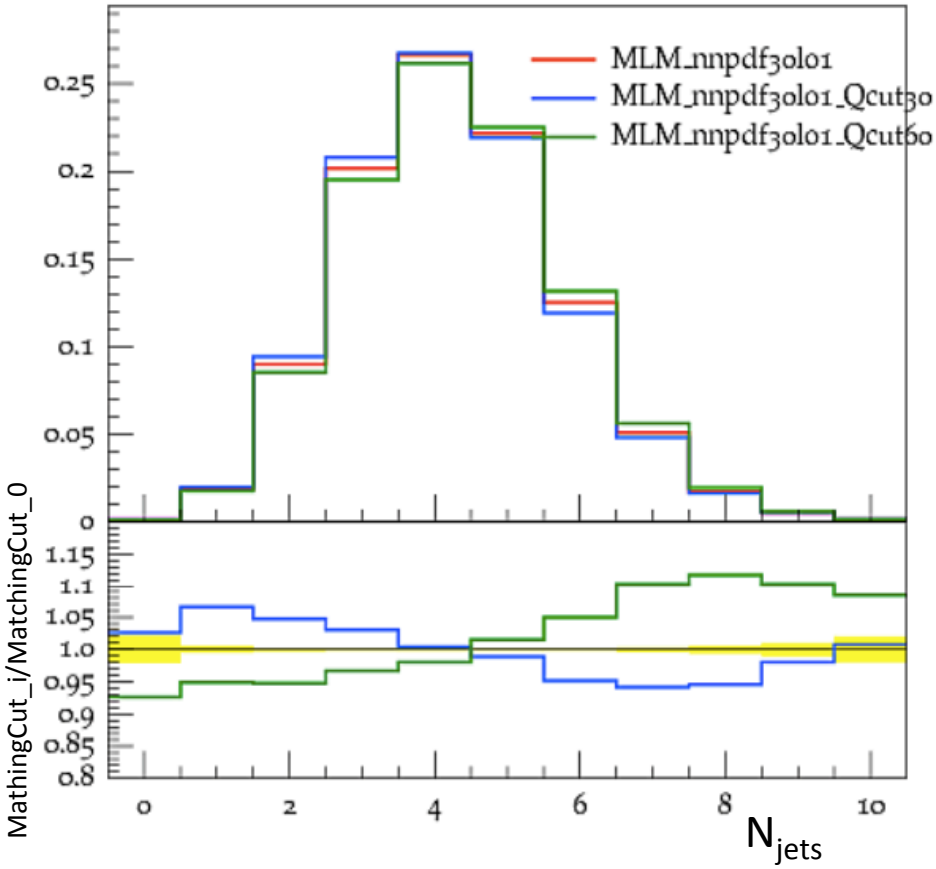
- ME scale variations in Powhegv2+Pythia8 (@8 TeV)
- hdamp = m_t

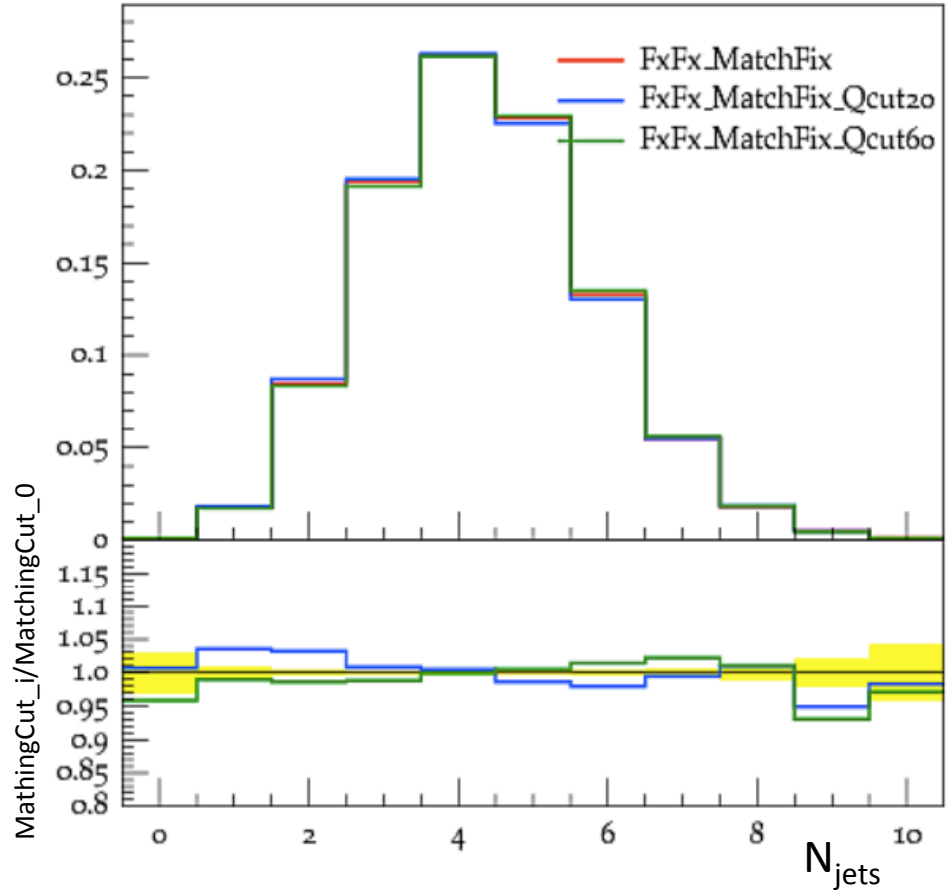
p_T(jet)>30 GeV





Matching Systematics





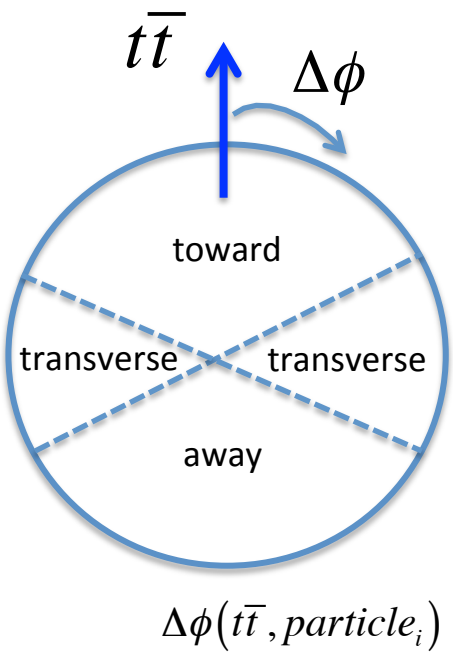
- p_T(jet)>30 GeV
- Expected behavior at LO and NLO.
- Ignore matching scale uncertainties at NLO?

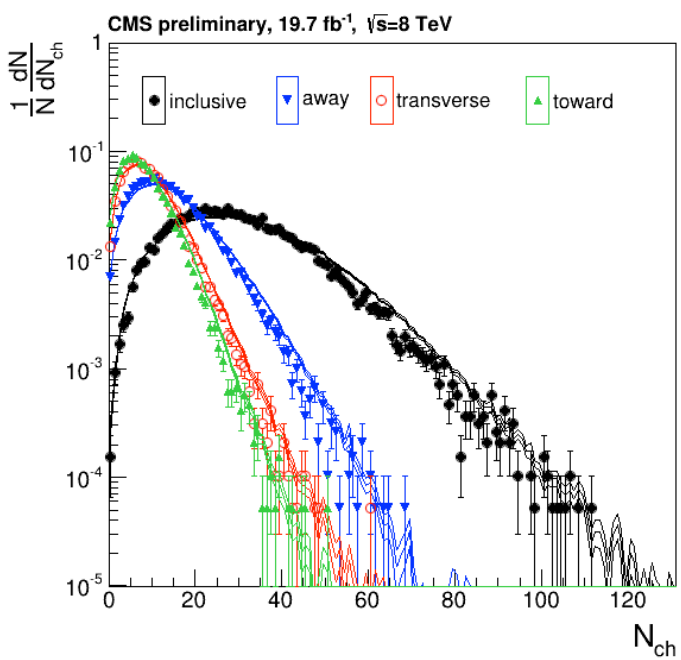
Plans for Tuning

- Underlying event and charmed meson properties studies for improved description of ttbar events → more precise top mass determination with better understood systematics.
- Dilepton channel with 2 b-tags → 96% purity
- Hard-process and pile-up subtracted.
  - All particle-flow candidates that is used in the reconstruction of b-tagged jets and leptons are removed.
- Recoil effects factorized event-by-event

$$\vec{p}_T(t\bar{t}) \approx \vec{p}_T(b_1) + \vec{p}_T(b_2) + \vec{p}_T(\ell) + \vec{p}_T(\ell') + \vec{p}_T^{miss}$$

CMS-TOP-13-007



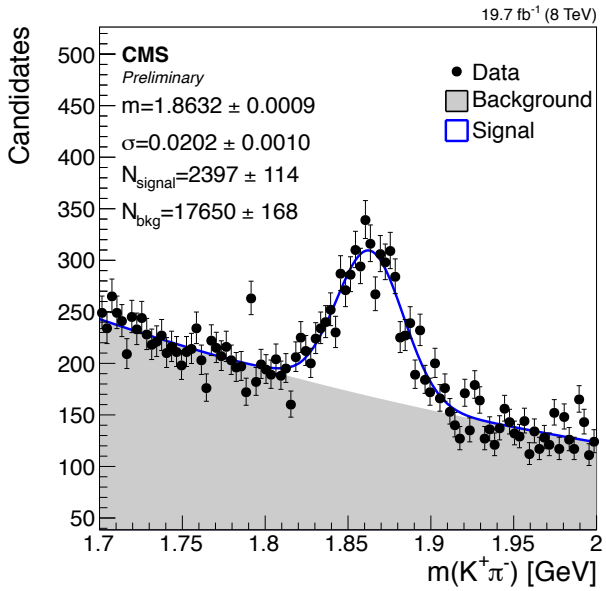


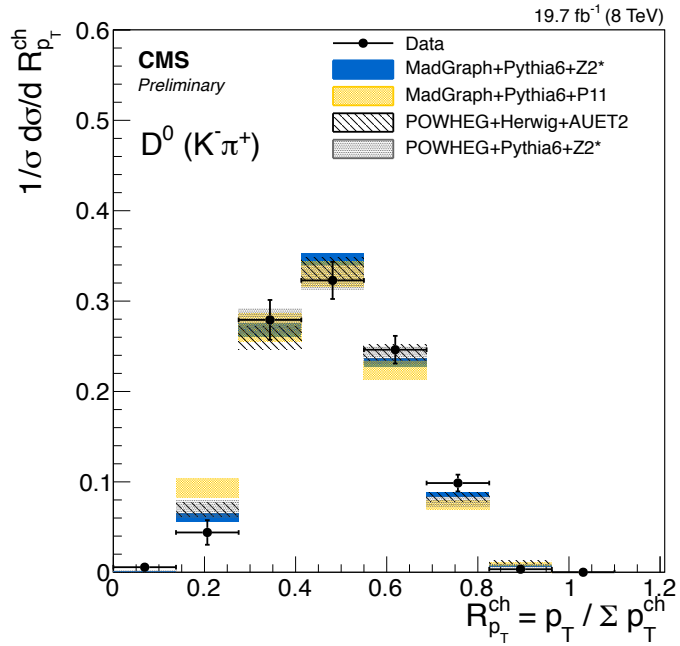
- Fair agreement between MG +P6 tune Z2* predictions and data in the variables to characterize the soft charged activity.
- Higher multiplicity predicted in the away region.
  - Correlated with the presence of an additional jet in the event.

Plans for Tuning

CMS-TOP-13-007

- Charmed mesons (D^0, $D^{+/-}$, J/ψ) reconstructed in b-jets from ttbar events → sensitive to uncertainties in the description of b-fragmentation and tunes.





All opposite-charged pairs among the 3 leading-p_T charged hadrons.
Identify D^0 flavour → require an additional soft lepton in the same jet, as originating from semi-leptonic decays of $B^{\pm}$ and B^0.

$\sigma(D^0)$ vs $p_T(D^0)/(\Sigma p_T$ of the charged particles clustered in the jet).

- Good agreement
  - with MG+P6 w/ Z2* and P11 tunes.
  - with Powheg+Herwig w/ AUET2 tune and +Pythia6+Z2* tune.
- With more statistics and precision at Run II, we might have significant constraints on tunes using ttbar events.

Summary and Conclusions

- New generation of NLO+PS MCs.
  - Default generators Powhegv2+Pythia8 and/or MG5_aMC@NLO [NLO] + Pythia 8.
  - ME scale and PDF variations through weights in the samples.
  - Minimal matching uncertainty in NLO samples.
  - + Herwig++ and other generators being commissioned.
- Tuning: use 13 TeV data with the methods developed at 8 TeV in CMS.