Measurement of jet activity in top-quark pair events at 13 TeV

Helmholtz Alliance Meeting

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DESY
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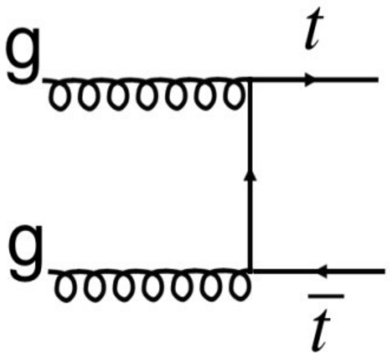
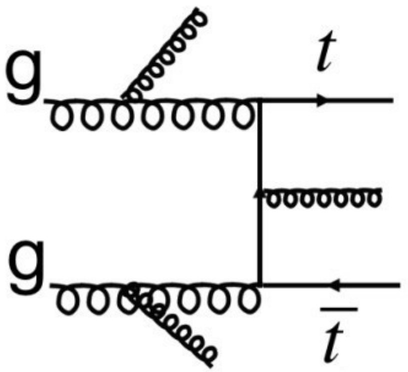
Motivation

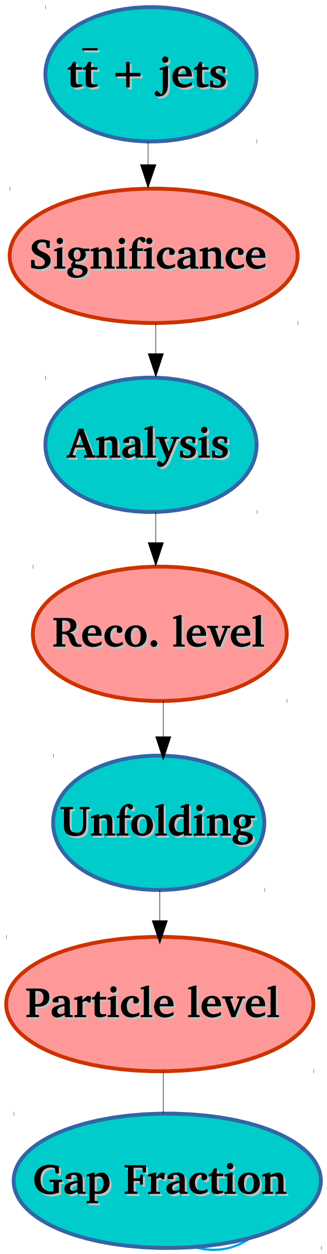
- Additional jets from QCD radiations can arise with $t\bar{t}$ production.
  - **Additional jets** : are jets originated from QCD processes other than $t\bar{t}$ production



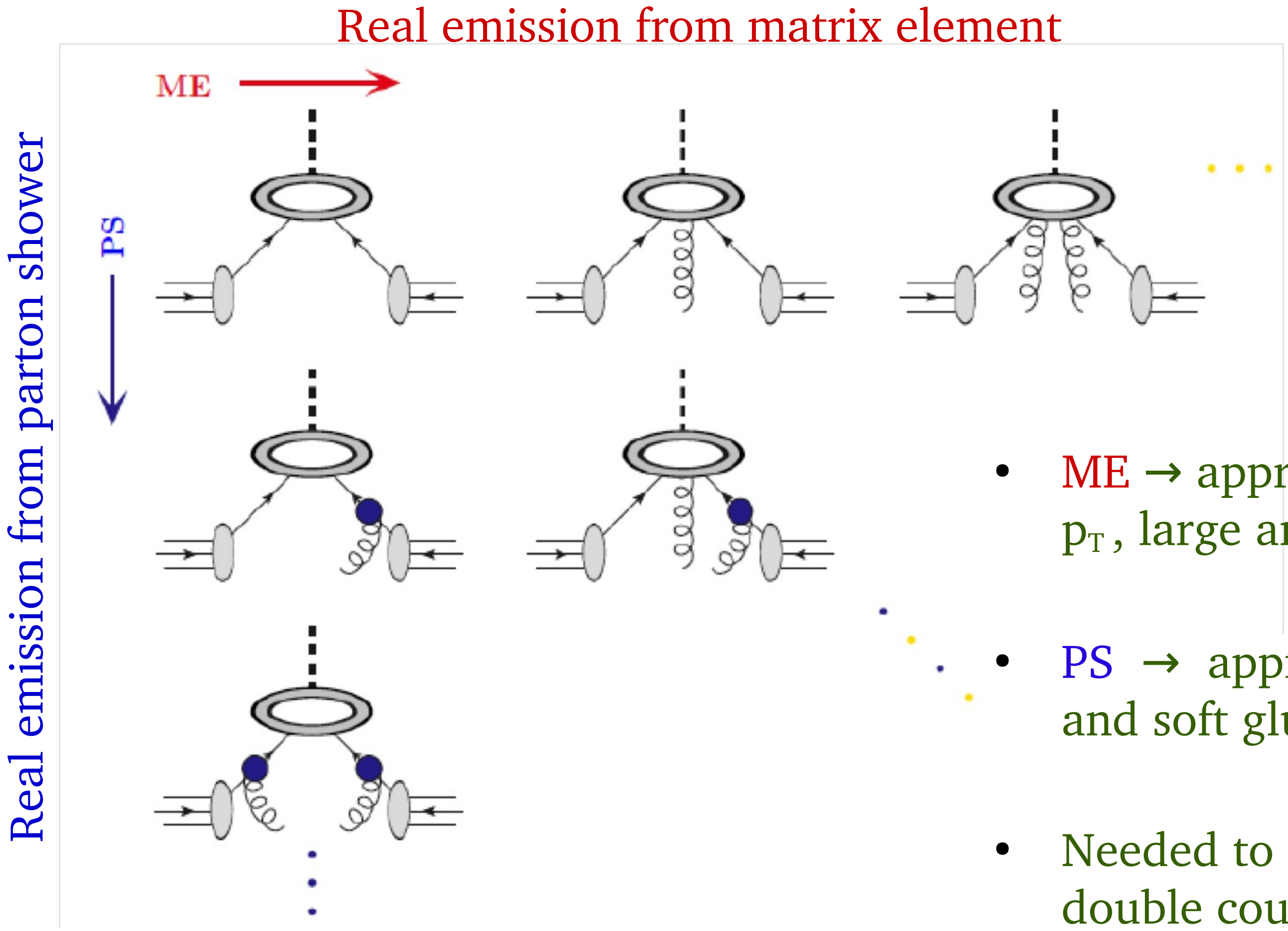


- Measurement of additional jets is important to test QCD model predictions to higher orders

- $t\bar{t}$+jets is background to many New Physics searches

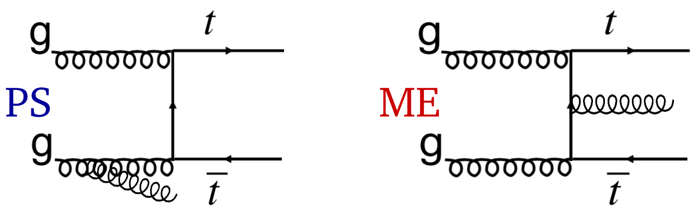


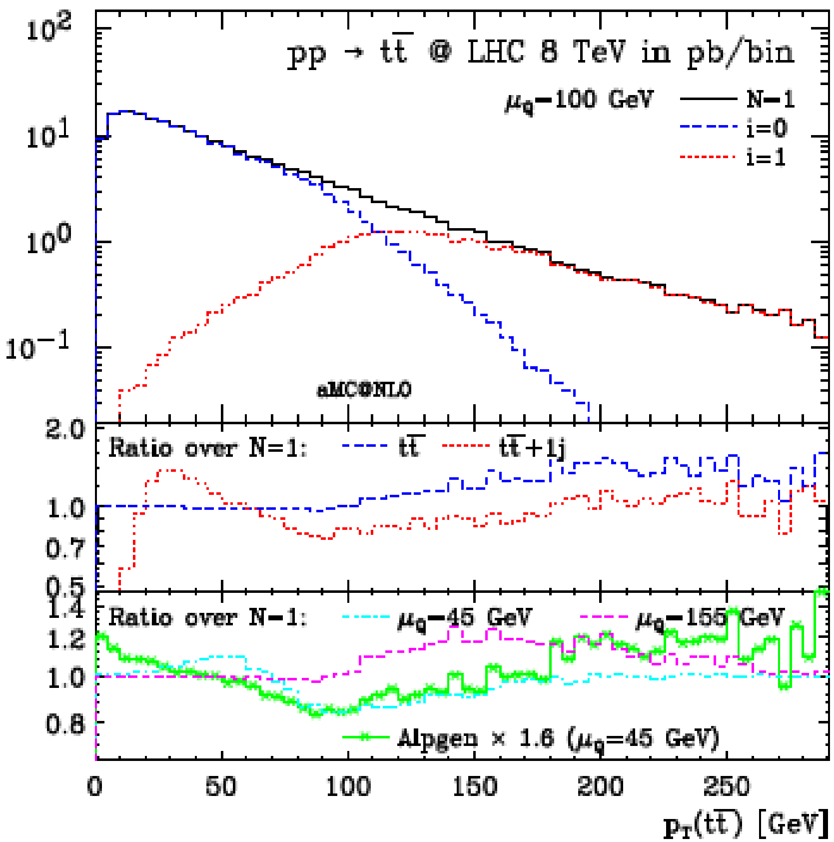
Additional jet emission



- ME → appropriate to model higher p_T, large angle gluon emissions
- PS → appropriate for the collinear and soft gluon emissions
- Needed to add up all graphs without double counting → matching and merging

ME and PS Generators





arXiv:1209.6215

- NLO ME generators
  Powheg, Madgraph5_aMC@NLO, MEPS@NLO Sherpa
- Parton shower generators
  Pythia6/8, Herwig++/7, MEPS@NLO matching with Sherpa PS

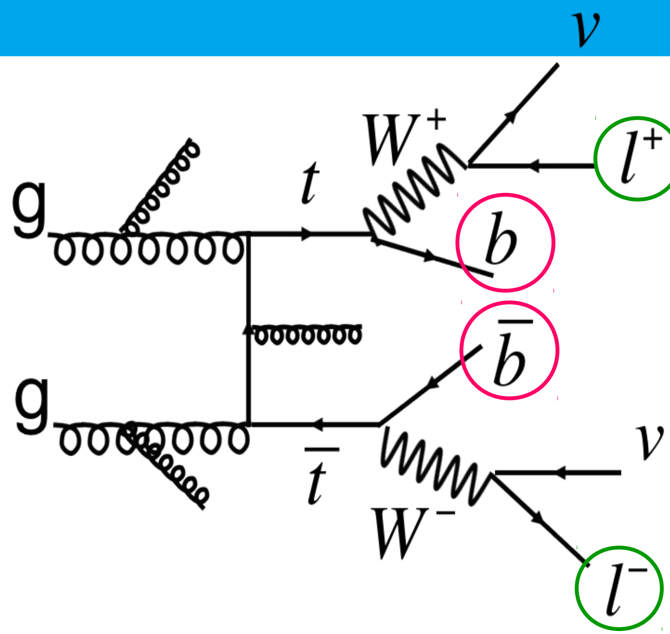
low p_T: PS parameter tuning

intermediate p_T: tuning of matching and merging procedures

high p_T: tests of higher order ME

Analysis strategy

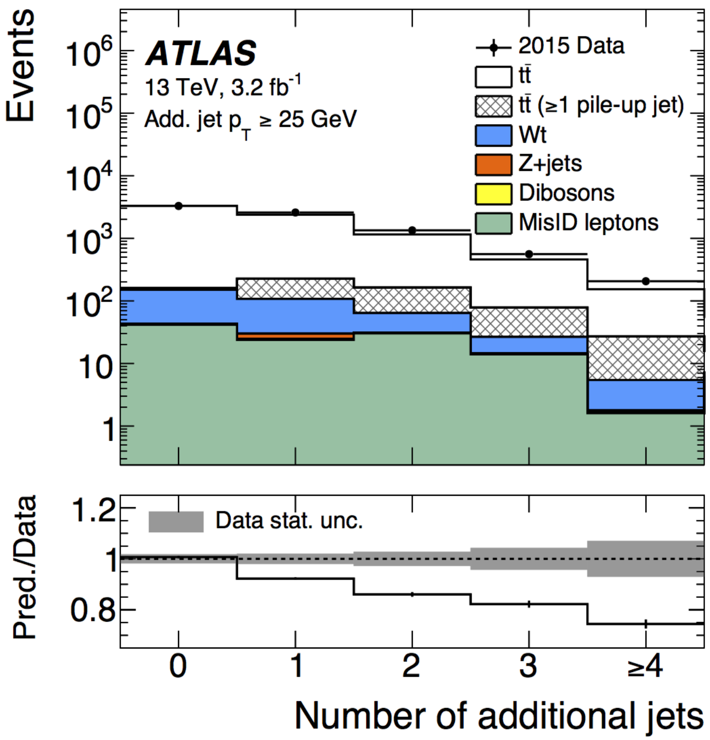
- Analysis in $e\mu$ channel using 3.2 fb^{-1} of *pp* collision data at $\sqrt{s}$ = 13 TeV (2015 data)
  - very small background, smaller systematics uncertainties
  - clean $t\bar{t}$ final state: 2 OS $e\mu$ plus 2 bjets
  - all other jets are considered as **additional jets**



Observables

- Additional jets multiplicity with different p_T thresholds (25, 40, 60 and 80 GeV)
  - sensitive to matching of the ME with PS
  - modeling of QCD radiation
- p_T spectra of two b-jets in $t\bar{t}$ event
  - modeling of top quark p_T
- p_T spectrum of leading additional jet in $t\bar{t}$ event
  - modeling of QCD radiation and $t\bar{t}$ system p_T

Detector level distributions in data & MC



Object selection :

- Opposite sign $e\mu$ pair
- e : ($p_T > 25$GeV, |η| < 2.47, not in (1.37 ≤ |η| ≤ 1.52))
- μ : ($p_T > 25$ GeV, |η| < 2.5)
- ≥ 2 b-tagged jets

Backgrounds:

single top ~ 3%
misidentified leptons ~ 1.5%
Z/γ* + jets ~ 0.1%
diboson < 0.1%

Basline MC : Powheg+Pythia6 (FullSim)
NLO matrix element: Powheg with CT10 PDFs
PS+hadronisation+UE: Pythia6 + Perugia 2012 tune
ME/PS matching parameter: $h_{damp} = m_{top} = 172.5$ GeV

Background MC:
Wt : Powheg+Pythia6
Z/γ*+jets: Sherpa
Dibosons: Sherpa

Unfolding from detector level to particle level

$$N^{i}_{\mathrm{unfold}} = \frac{1}{f^{i}_{\mathrm{eff}}} \cdot \sum_{j} (M^{-1})^{\mathrm{part},i}_{\mathrm{reco},j} \cdot f^{j}_{\mathrm{accept}} (N^{j}_{\mathrm{data}} - N^{j}_{\mathrm{bg}})$$

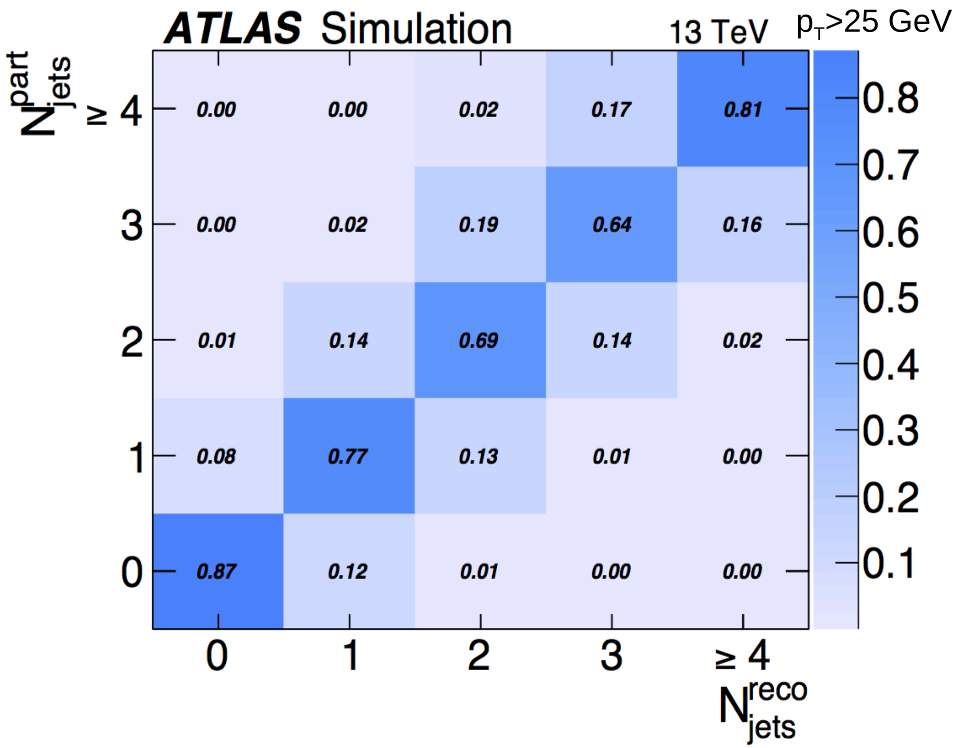
Efficiency correction bin-by-bin

$$f^{i}_{\mathrm{eff}} = \frac{N^{i}_{\mathrm{reco}\wedge\mathrm{part}}}{N^{i}_{\mathrm{part}}}$$

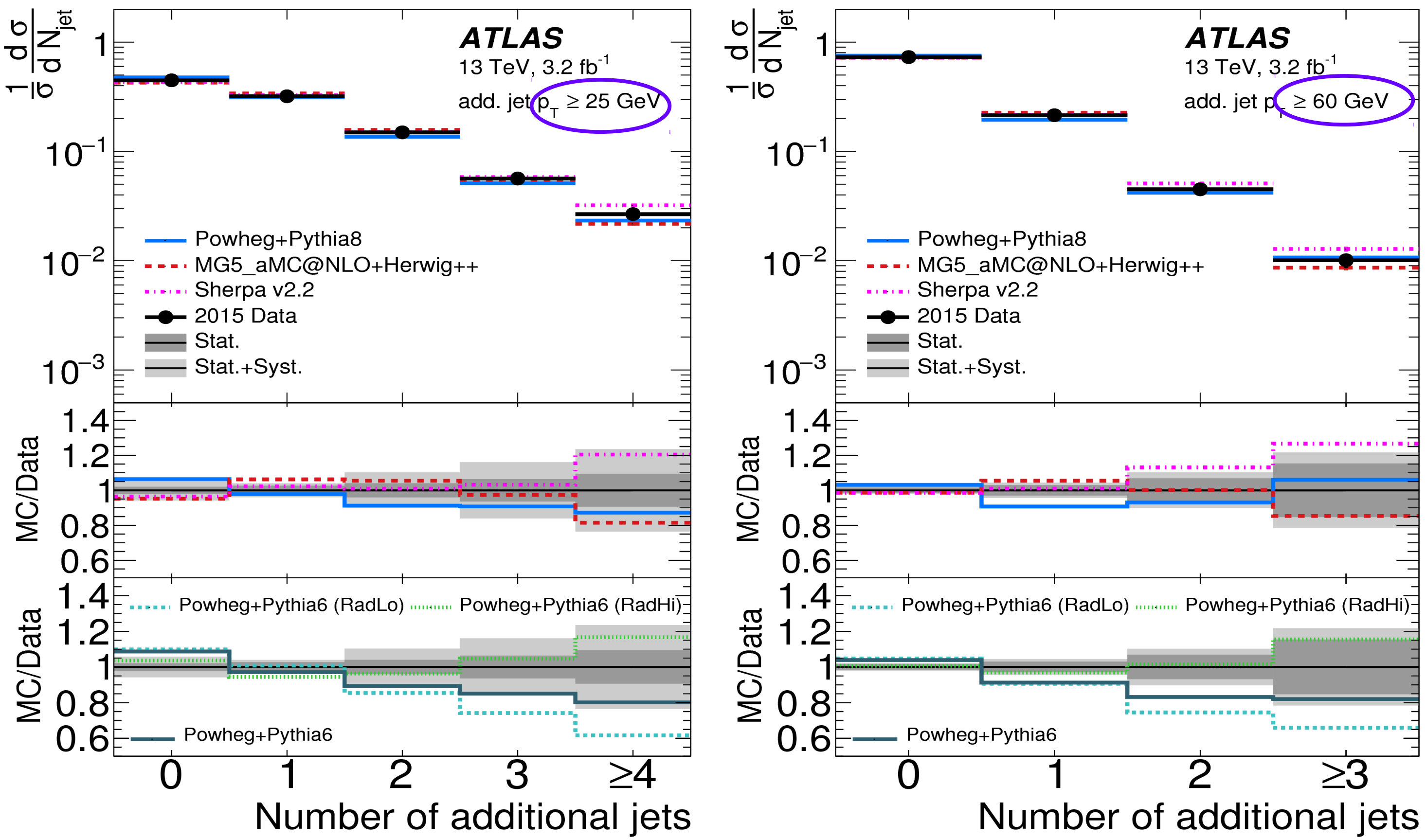
Migration matrix correction via iterative Bayesian unfolding

Acceptance correction bin-by-bin

$$f^{j}_{\mathrm{accept}} = \frac{N^{j}_{\mathrm{reco}\wedge\mathrm{part}}}{N^{j}_{\mathrm{reco}}}$$



Unfolded additional jets multiplicity



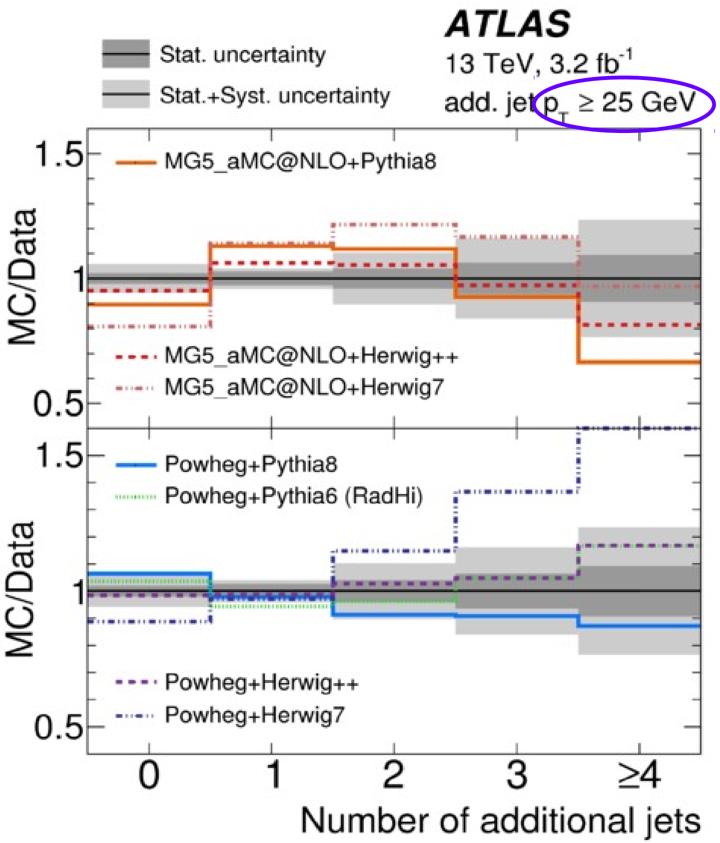
Powheg+Pythia6 with different level of radiations

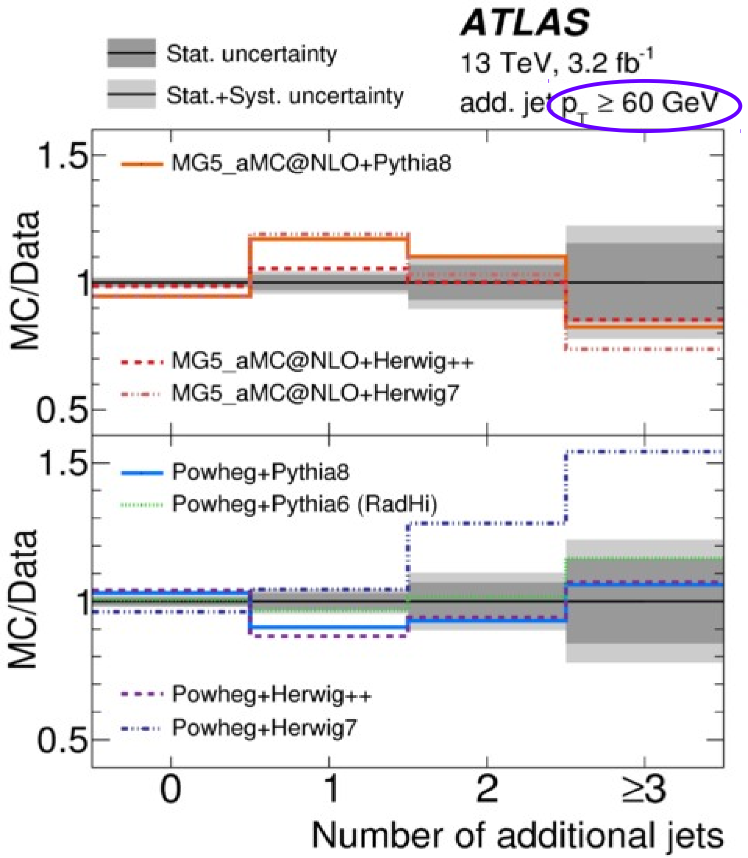
Data agree best with 'radHi' prediction.

Central prediction tends to predict lower jet multiplicity.

- Data is compared with predictions : different PS generators as well as different ME generator
  - Most predictions are within uncertainties

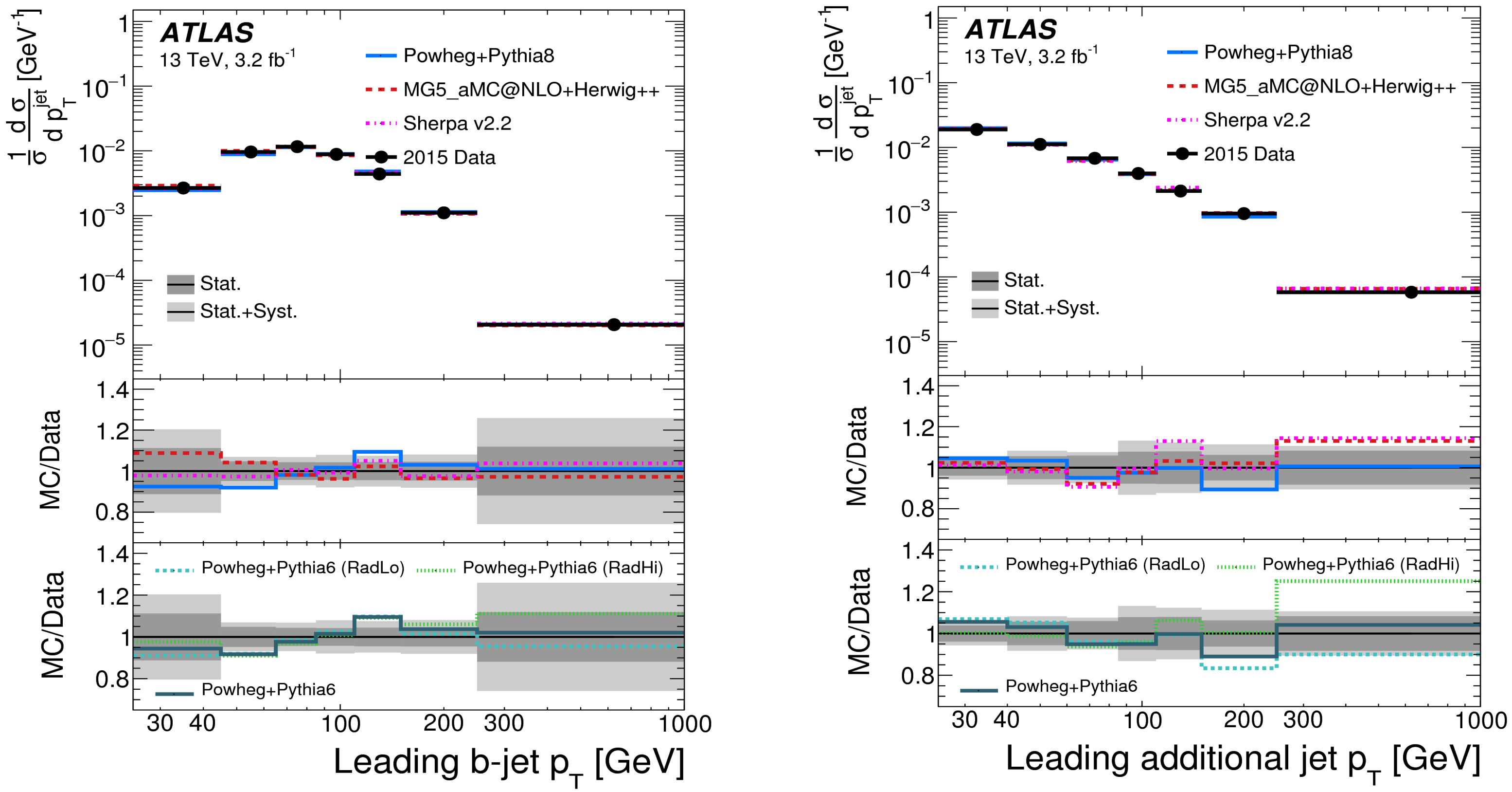
Unfolded additional jets multiplicity





- MG5_aMC@NLO Predictions agree within 5-10% regardless of which PS used (except Herwig7), and Powheg predictions vary slightly more.
- The variations are larger when using different ME but same PS.

Unfolded jet p_T distribution



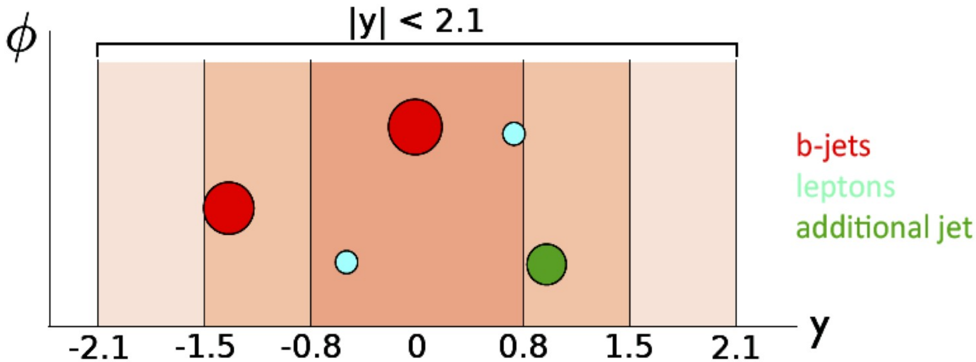
- Predictions from Powheg+Pythia8, MG5_aMC@NLO+Herwig++ and Sherpa vary mostly within 5-11%
  - give reasonable description of data within total uncertainties

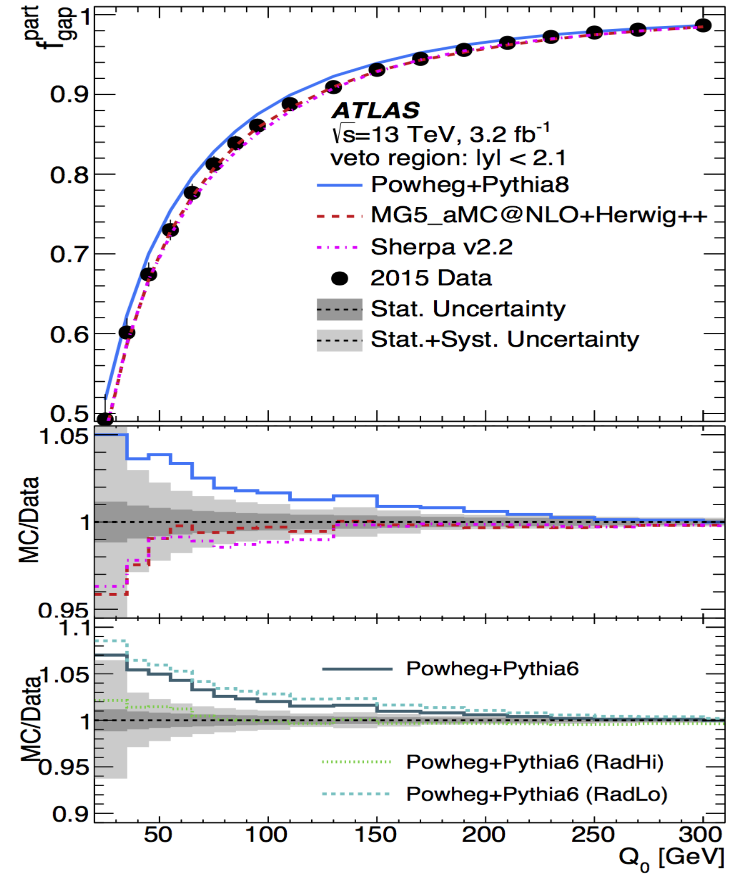
Gap fraction measurements for additional jets

$$f_{gap}(Q_0) = \frac{n(Q_0)}{N_{t\bar{t}}}$$

gap: range in rapidity with no additional jets

Fraction of events with no additional jet activity above a certain p_T threshold (Q_0) in various rapidity regions





- Sherpa and MG5_aMC@NLO+Herwig++ agree well within uncertainties
  - Powheg+Pythia8 has slightly higher gap fraction ⇒ predicts too little radiation
- Powheg+Pythia6(RadHi) agrees well with data

Summary

- Differential cross section measurements for various physics quantities derived from $t\bar{t}$+jets final state
  - important for tests of higher order QCD and SM predictions

- Different measurements are compared to various Monte Carlo predictions and give consistent results within uncertainties.
  - Except a few where the deviation is significant

- Powheg+Pythia6 (RadHi), MG_aMC@NLO+Herwig++ described the data best for all observables.
  - Comparison with matched/merged generator Sherpa looks promising

- Looking forward …
  - 2016 data: More statistics, improved sensitivity, more observables.

Thank you for your attention!!