Transverse Energy Flow and Charged Particle Event Shapes with ATLAS

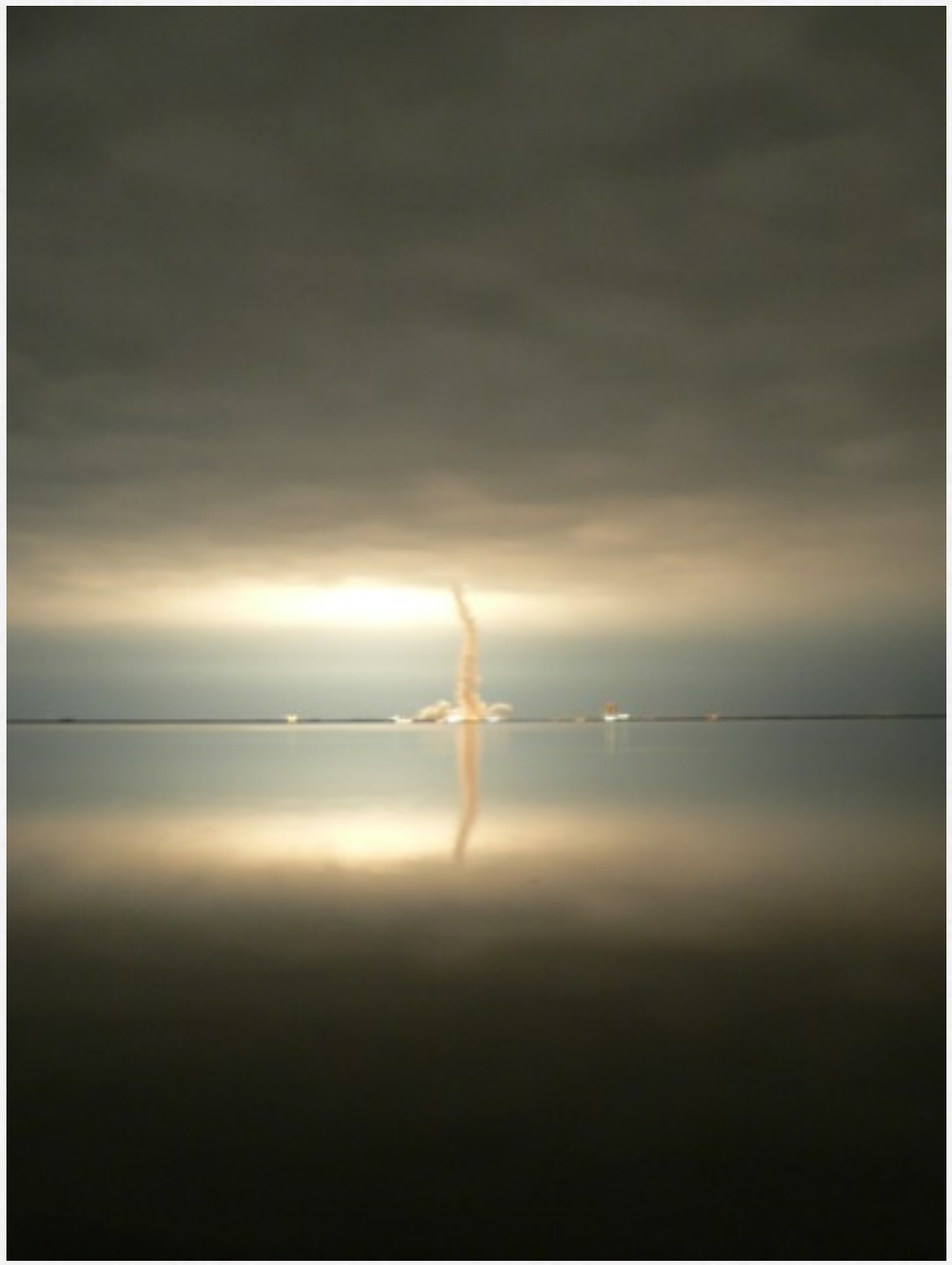
Deepak Kar
University of Glasgow
On behalf of the ATLAS Collaboration

DIS, Marseille, April 2013

Overview

- Event shape observables: continuous measure of geometric properties of energy flow, sensitive to transition between non-perturbative to perturbative regime. arXiv:1207.6915
- Transverse energy flow: uses the full acceptance of the calorimeter, extra handle on soft particle production. JHEP11 (2012) 033

Event Shape Observables



Event Shape Observables

Transverse thrust $\tau_\perp$

$$\tau_\perp = \tau_T = 1 - \max_{\hat{n}_T} \frac{\sum_i |\mathbf{p}_{T,i} \cdot \hat{n}_T|}{\sum_i |\mathbf{p}_{T,i}|} \qquad |\hat{n}_T| = 1$$

Transverse momentum flow along the thrust axis
$0 \leq \tau_\perp \leq 1 - \frac{2}{\pi} \approx 0.36$

Thrust Minor T_M

$$T_M = \frac{\sum_i |\mathbf{p}_{T,i} \times \hat{n}_M|}{\sum_i |\mathbf{p}_{T,i}|} \qquad \hat{n}_M = \hat{n}_T \times \hat{z}$$

Out-of-eventplane transverse momentum flow
$0 \leq T_M \leq 1$

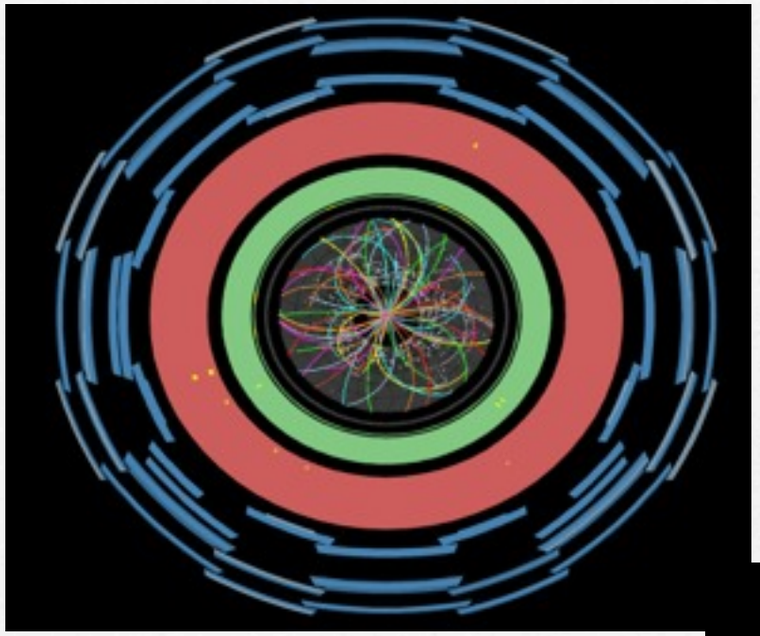
Transverse sphericity $S_\perp$

$$S_{xy} = \sum_i \begin{bmatrix} p_{x,i}^2 & p_{x,i}p_{y,i} \\ p_{x,i}p_{y,i} & p_{y,i}^2 \end{bmatrix} \qquad \lambda_2^{xy} > \lambda_1^{xy} = \text{Eigenvalues of } S_{xy}$$

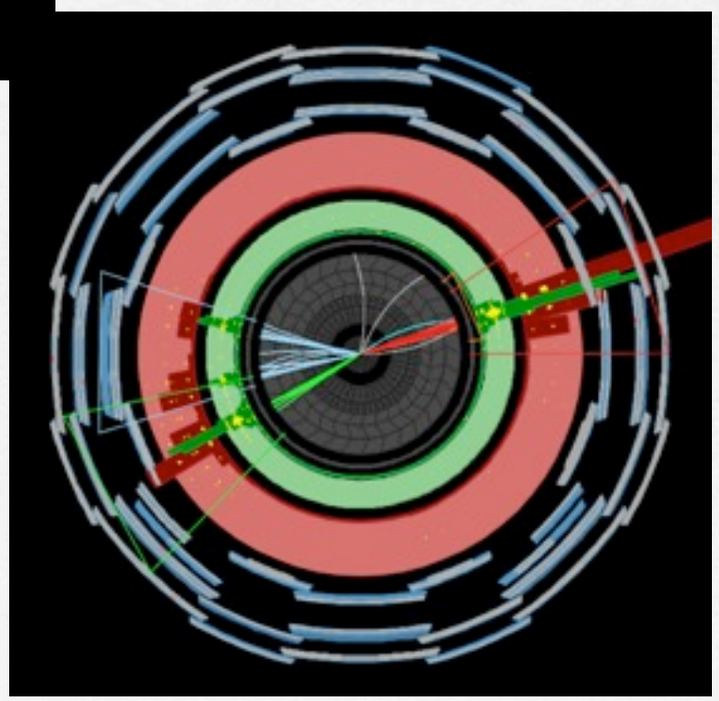
and

$$S_\perp = \frac{2\lambda_2^{xy}}{\lambda_1^{xy} + \lambda_2^{xy}}$$

Isotropy of transverse momentum flow
$0 < S_\perp \leq 1$



Spherical Event



Pencil-like Event

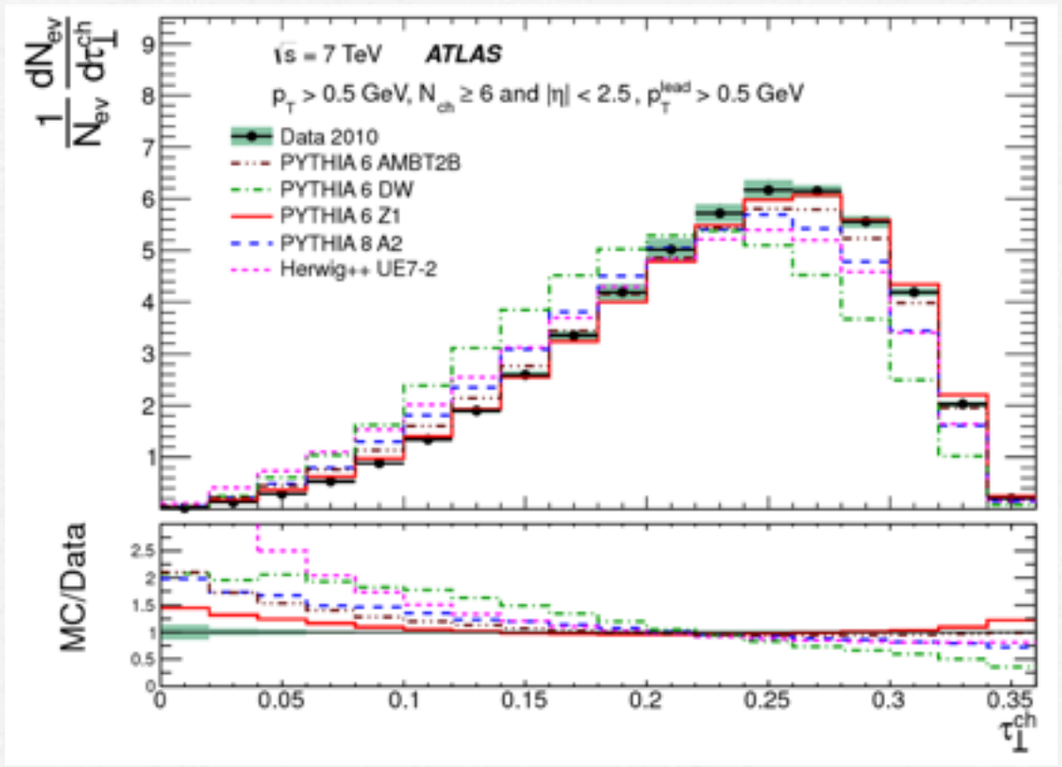
MC Models/Tunes

- Pythia 6 DW: Tevatron-era tune with virtuality ordered shower.
- Pythia 6 AMBT1: First ATLAS MB tune with (early) LHC data, pT ordered shower.
- Pythia 6 AMBT2B/AUET2B: Improved (ISR description) ATLAS tunes for MB/UE.
- Pythia 6 Z1: CMS tune, focussed on UE.
- Pythia 8 4C: Author tune, for both MB and UE.
- Pythia 8 A2: ATLAS tune, for MB.
- Herwig++ UE7-2: Dedicated UE tune at 7 TeV.
- Epos LHC: Air shower MC, LHC 7 TeV (MB) specific "tune".

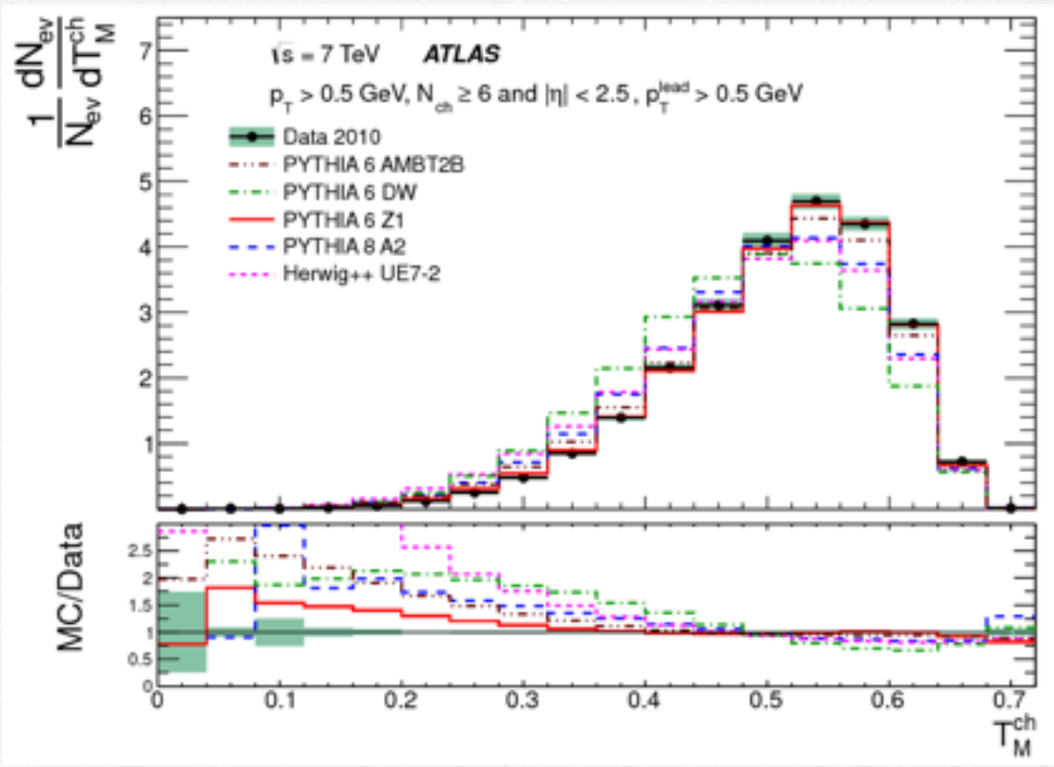
arXiv:1207.6915

Inclusive Differential Distributions

Transverse Thrust



Transverse Thrust Minor

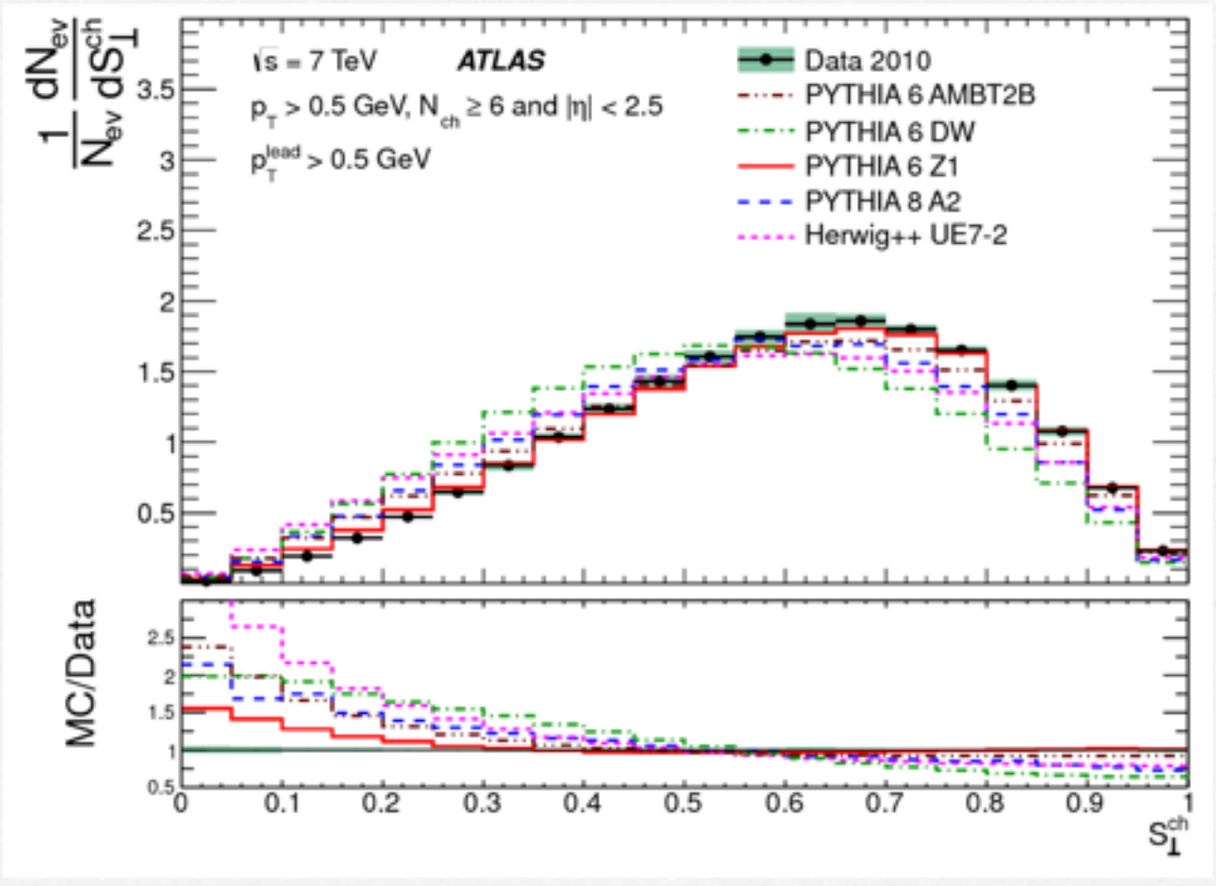


Prevalence of spherical events; Pythia6 Z1 tune describes the data the best.

arXiv:1207.6915

Inclusive Differential Distributions

Transverse Spehericity

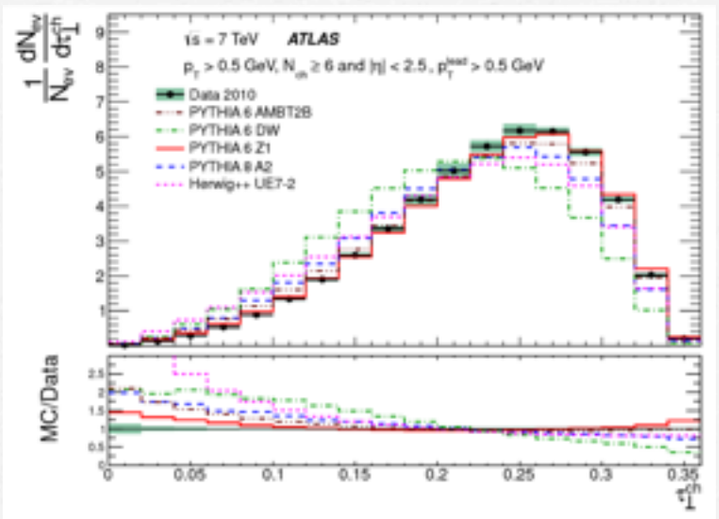


Again more spherical events; Pythia6 Z1 tune describes the data the best, DW and Herwig++ the worst.

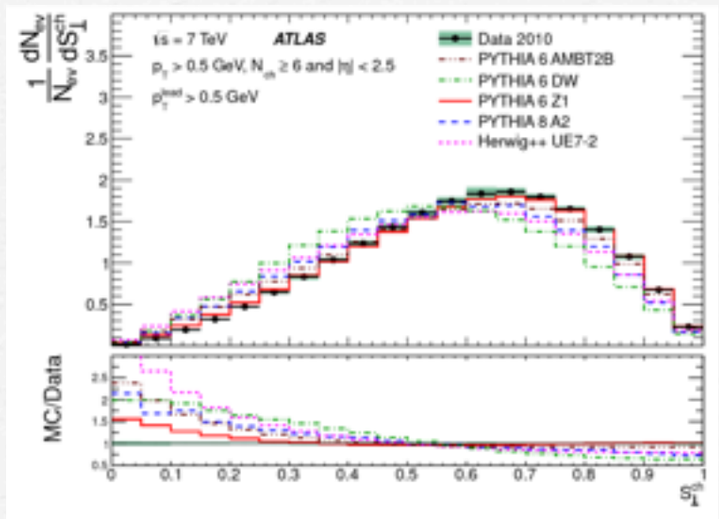
arXiv:1207.6915

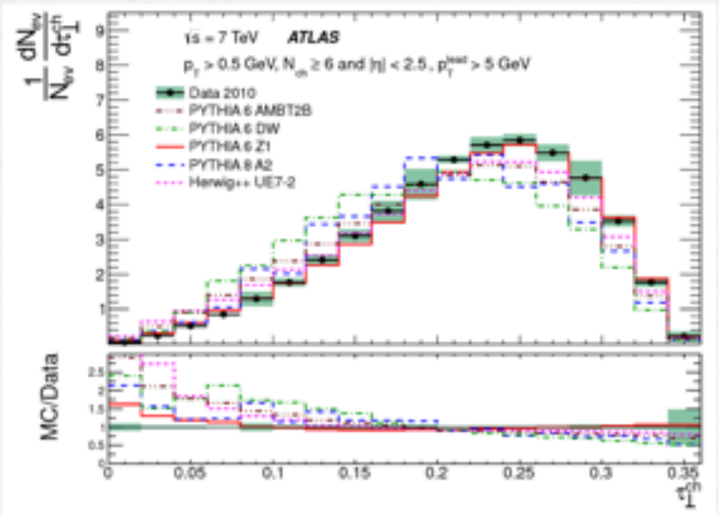
Moving to Higher Lead p_T

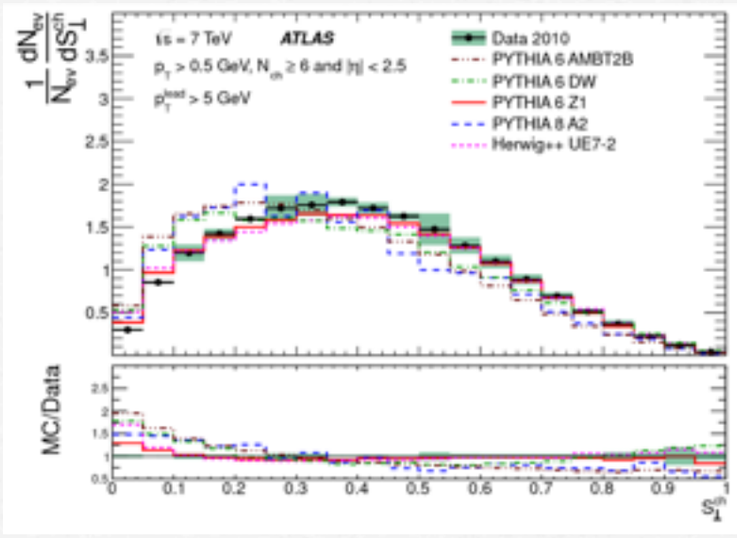
Transverse Thrust



Transverse Spehericity







low lead p_T

high lead p_T

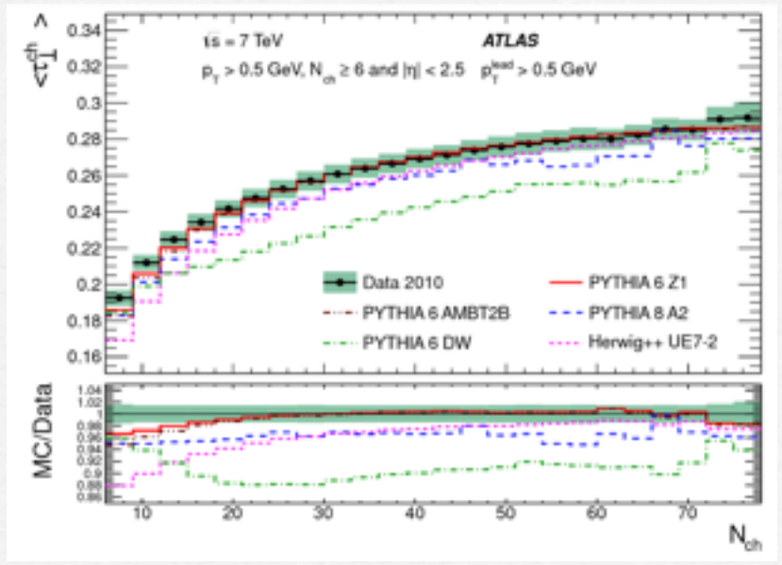
Sphericity moves to more "jet-like" events, but not thrust.

UE-tunes describe the data better!

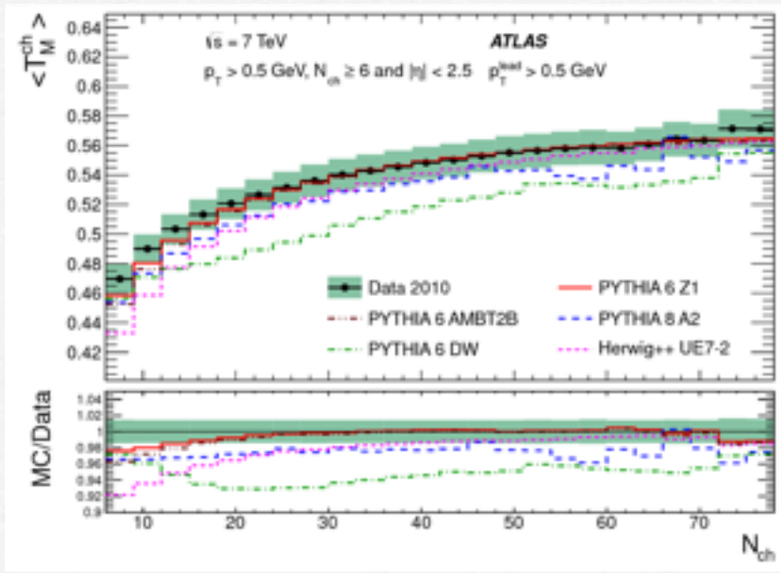
arXiv:1207.6915

Against Multiplicity

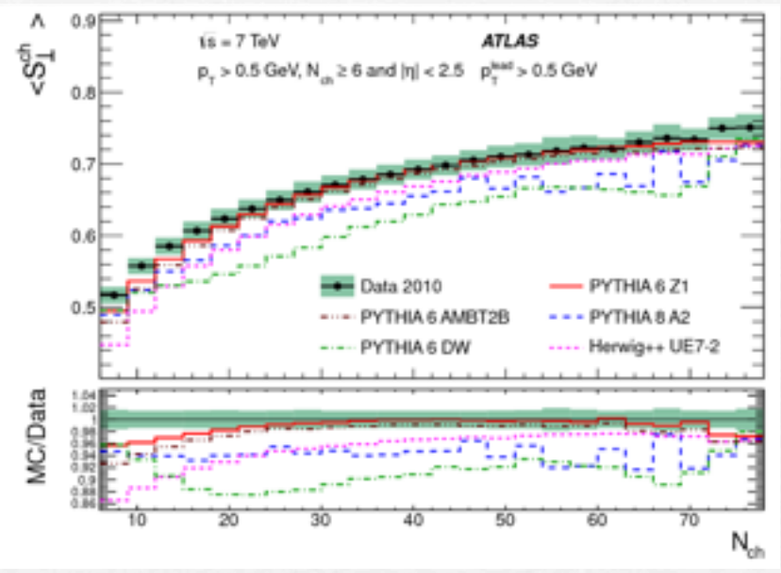
Transverse Thrust



Transverse Thrust Minor



Transverse Spehericity

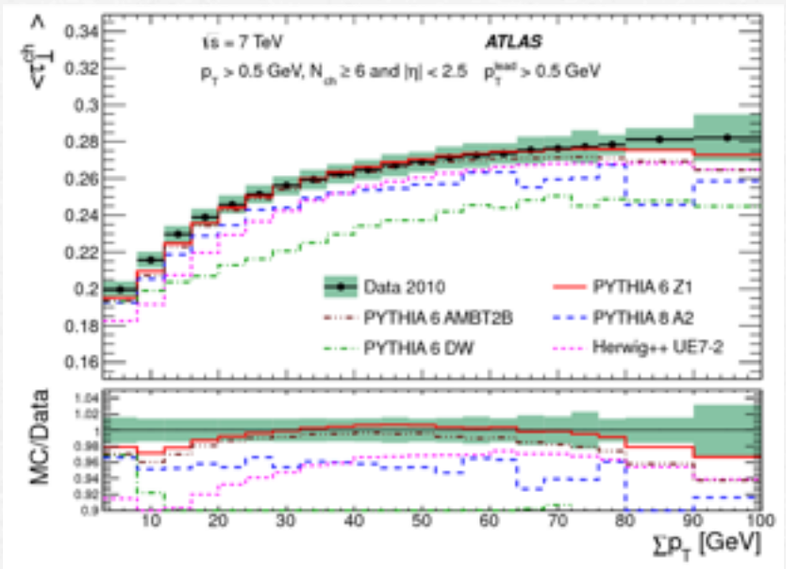


Mean values increase to values consistent with peak positions.

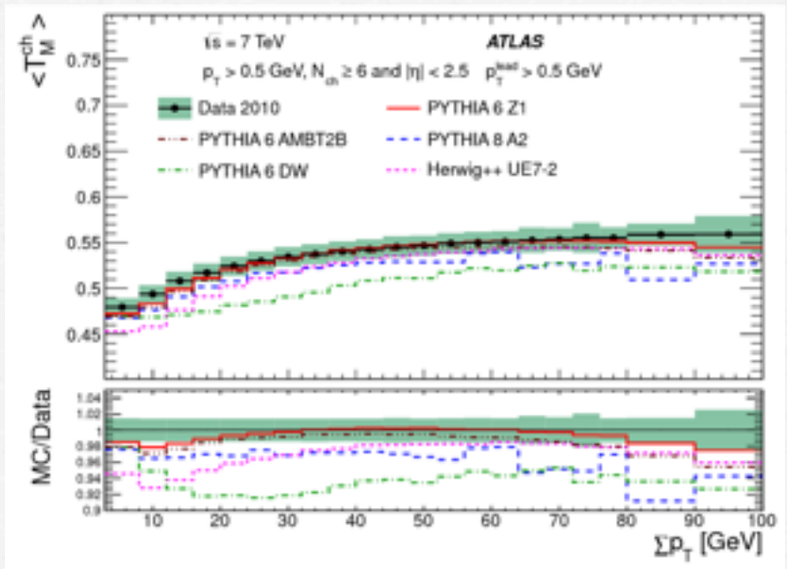
arXiv:1207.6915

Against Summed p_T

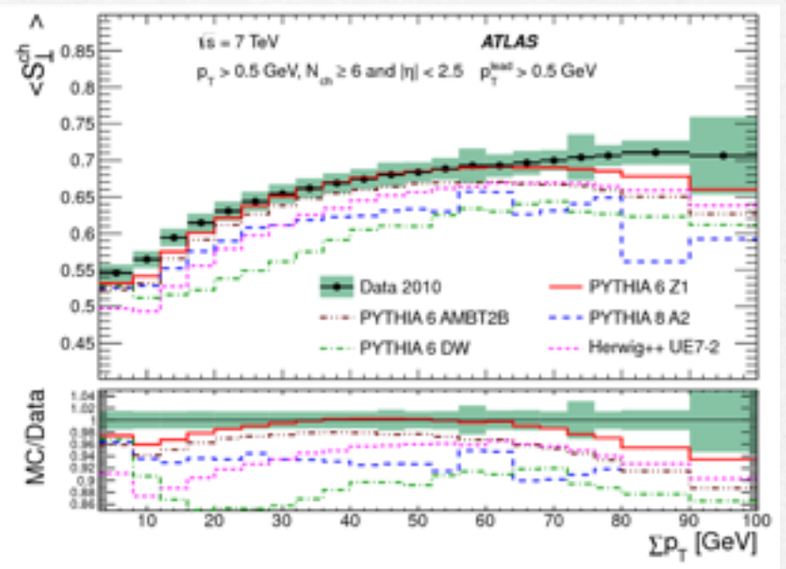
Transverse Thrust



Transverse Thrust Minor



Transverse Spehericity



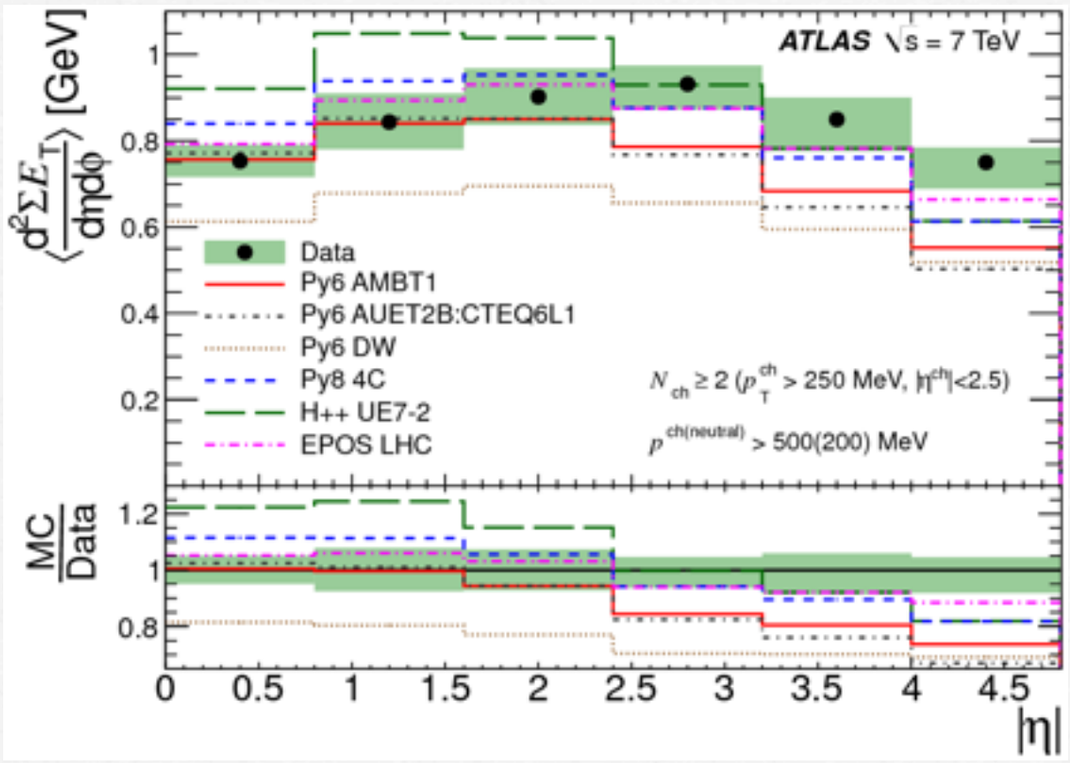
Less spherical events before the plateau; except Pythia6 DW, most MC models/tunes describe the data better than differential distributions.

Transverse Energy Flow

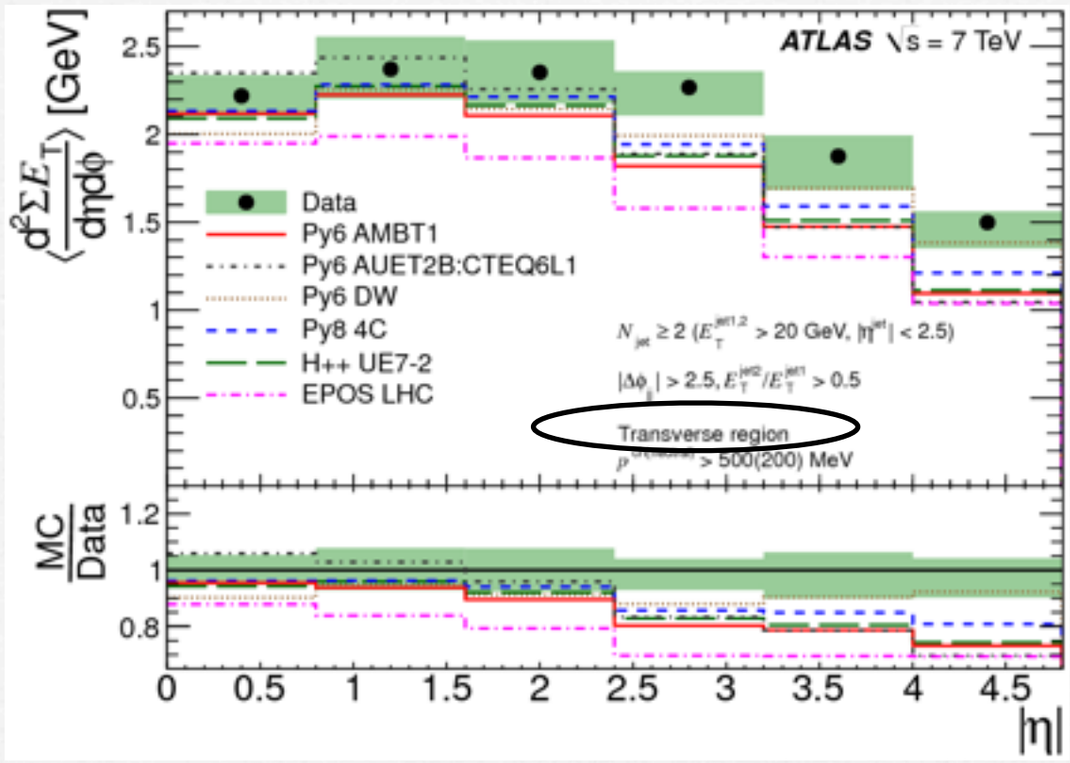
JHEP11 (2012) 033

Transverse Energy Flow

Inclusive topology



Dijet topology

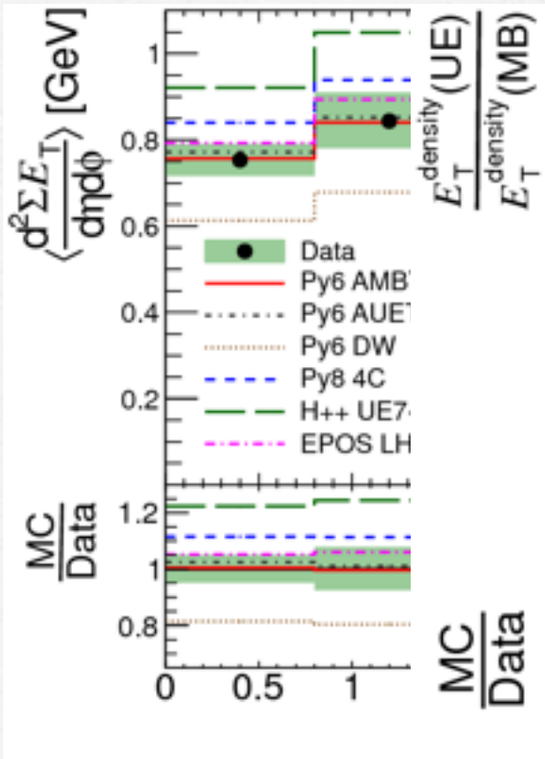


More low momentum particles in central region;
EPOS and Pythia6 AMBT1 are the best overall.

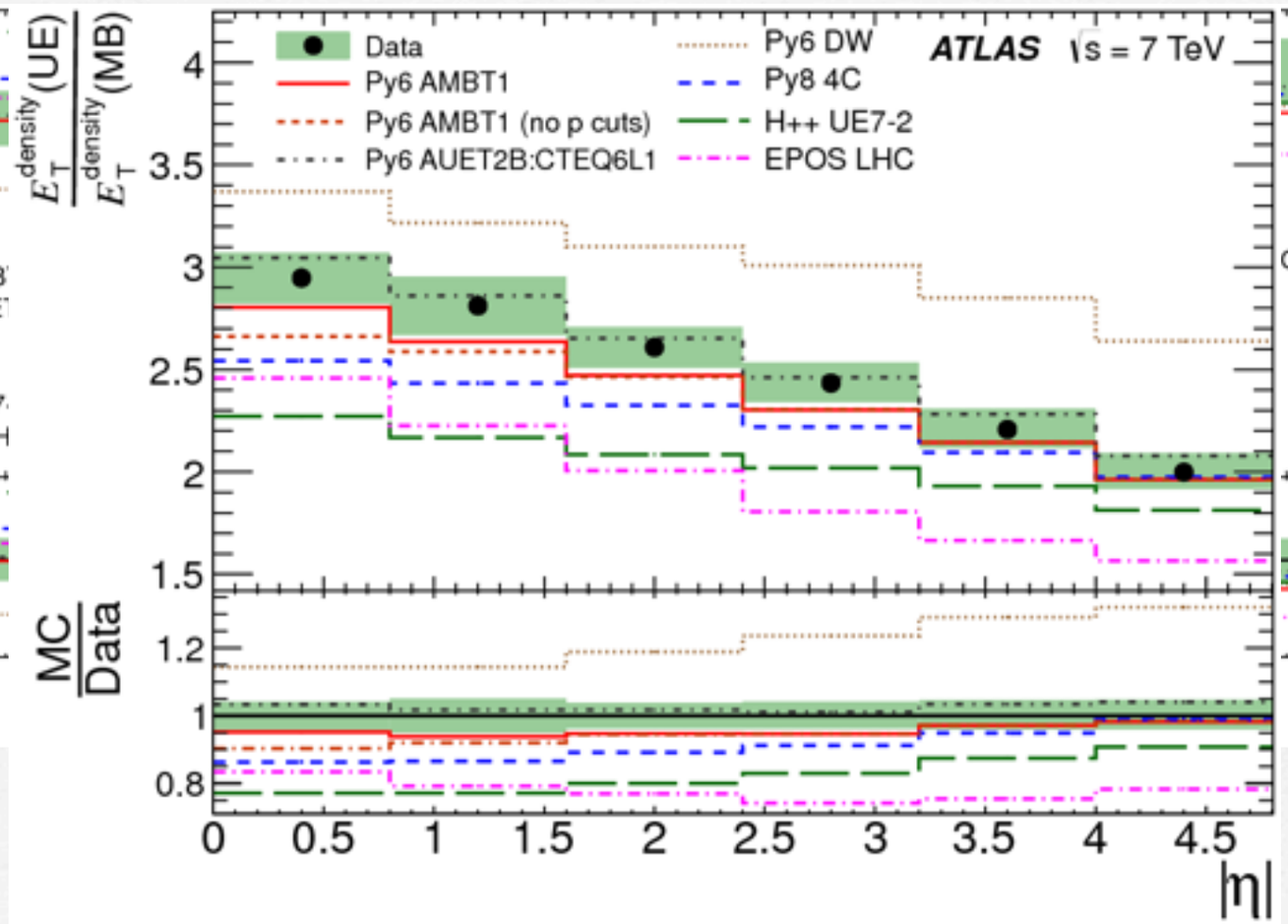
JHEP11 (2012) 033

Transverse Energy Flow

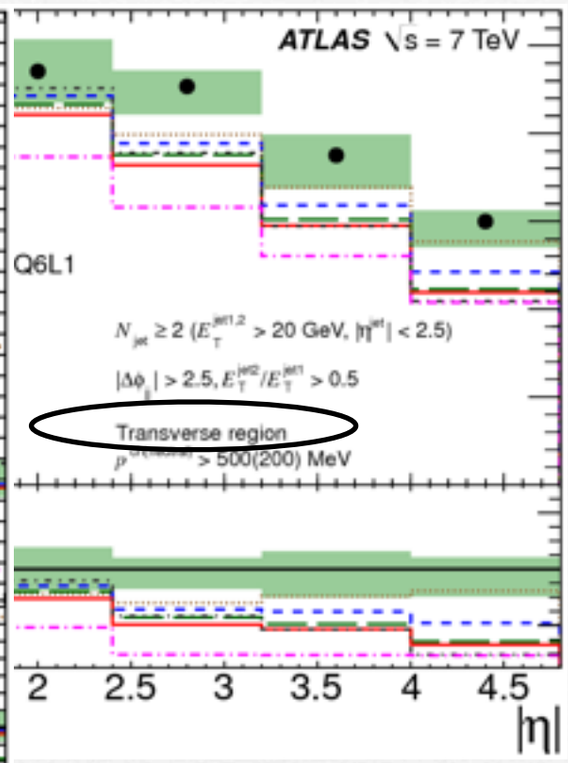
Inclusive topology



Ratio



Dijet topology



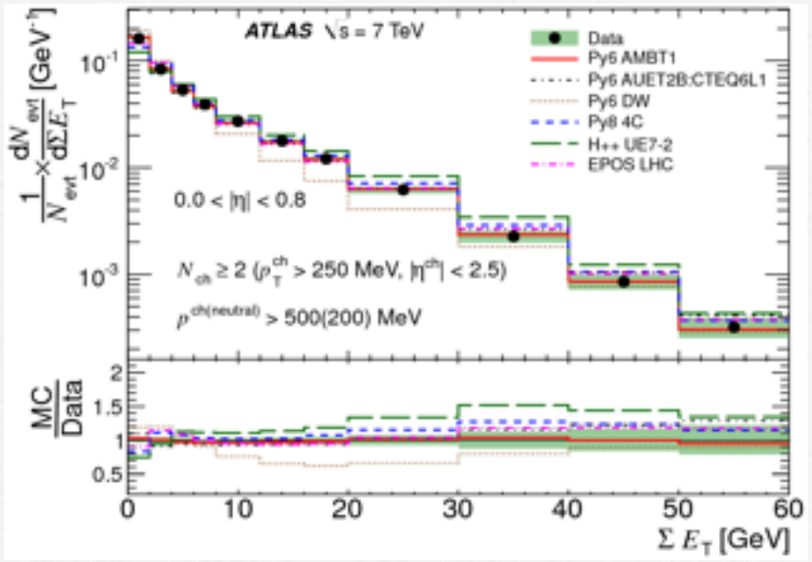
More energy in dijet events

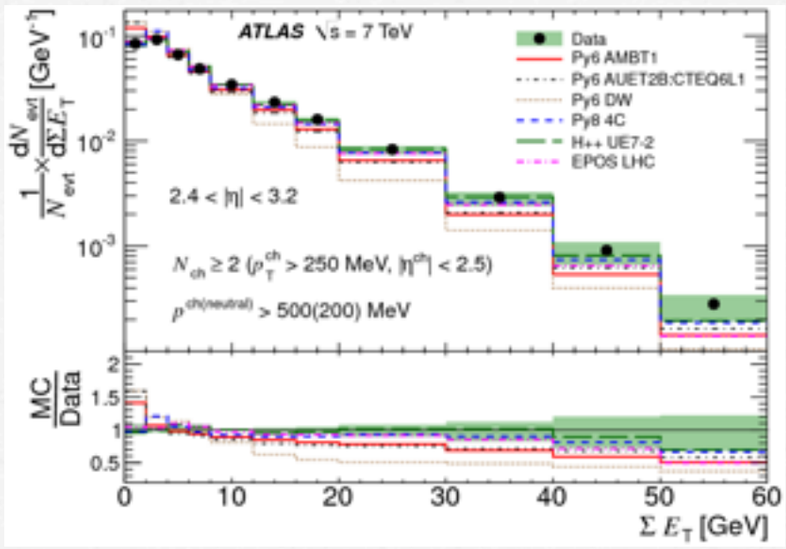
JHEP11 (2012) 033

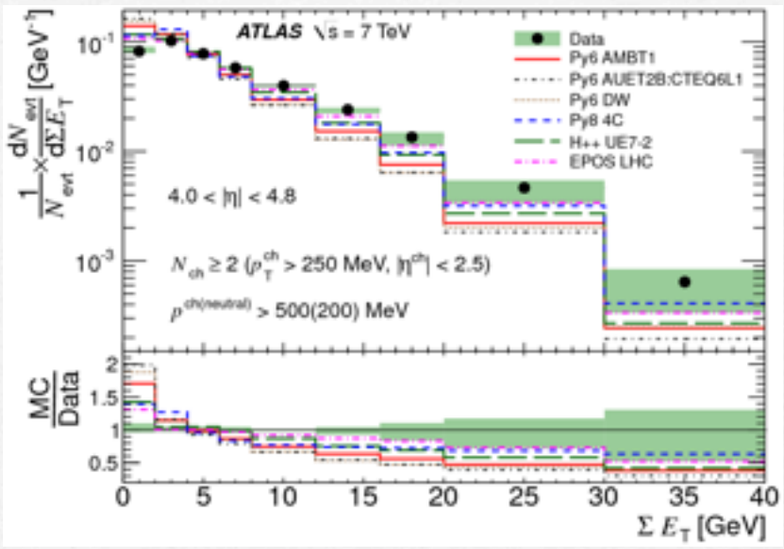
From Central to Forward

Inclusive topology

low η → high η







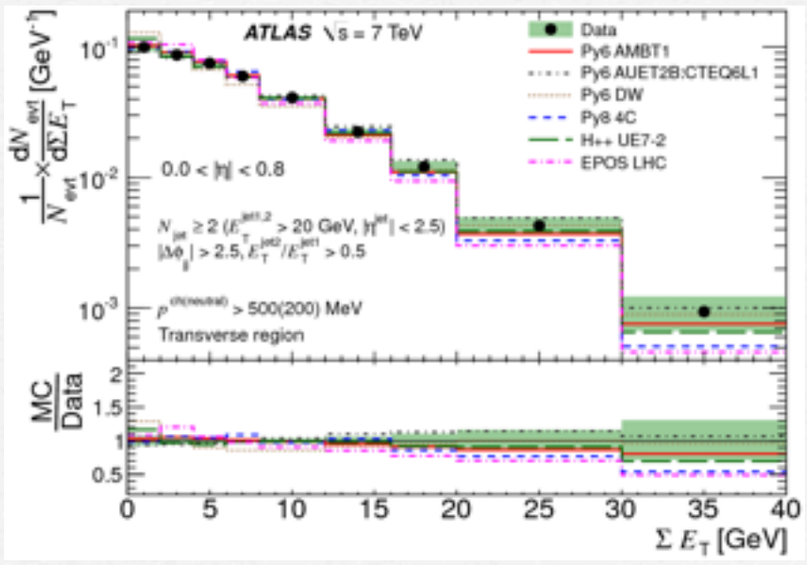
All MC's do better in central region but underestimate the data at high pseudorapidity.

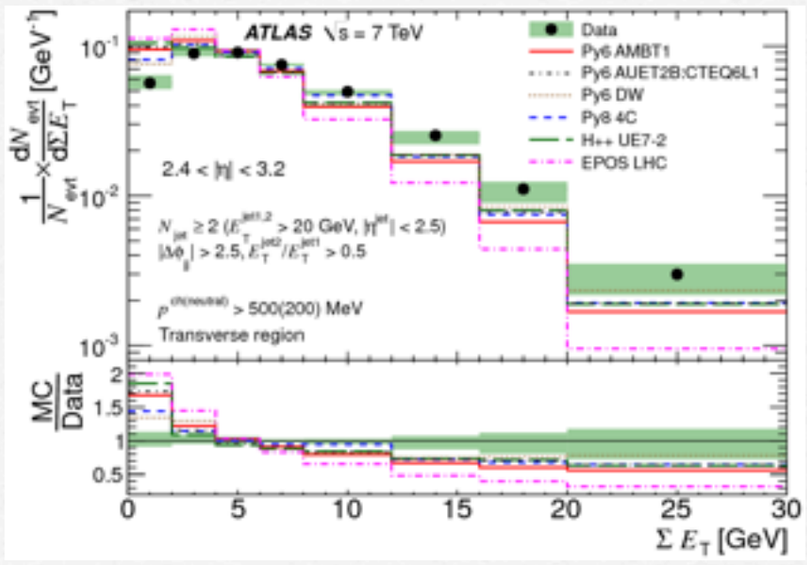
JHEP11 (2012) 033

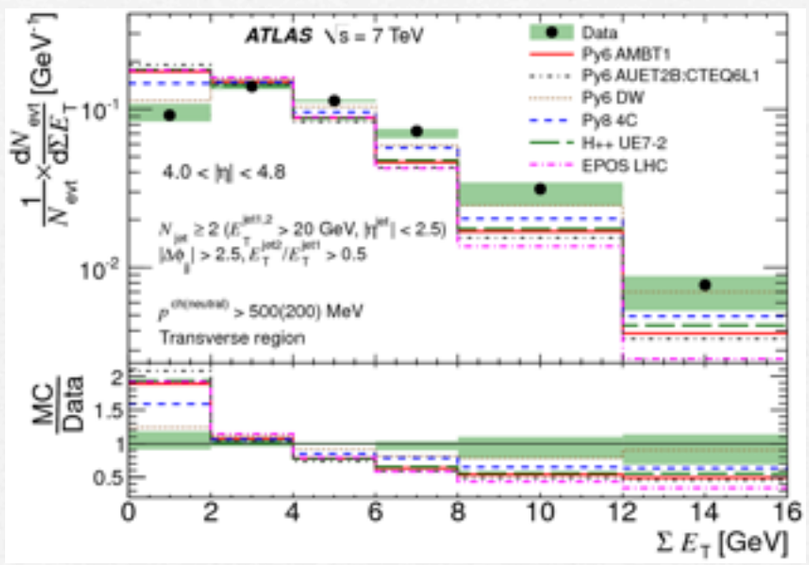
From Central to Forward

Dijet topology

low η → high η





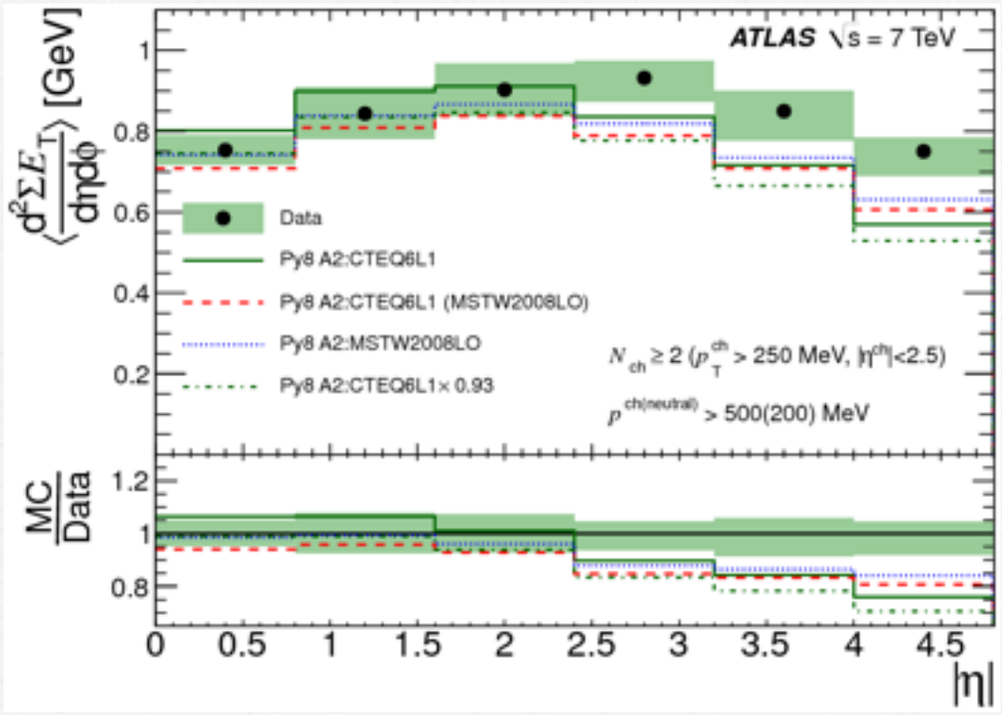


Similar story, but EPOS worse for central region too, UE tunes do better.

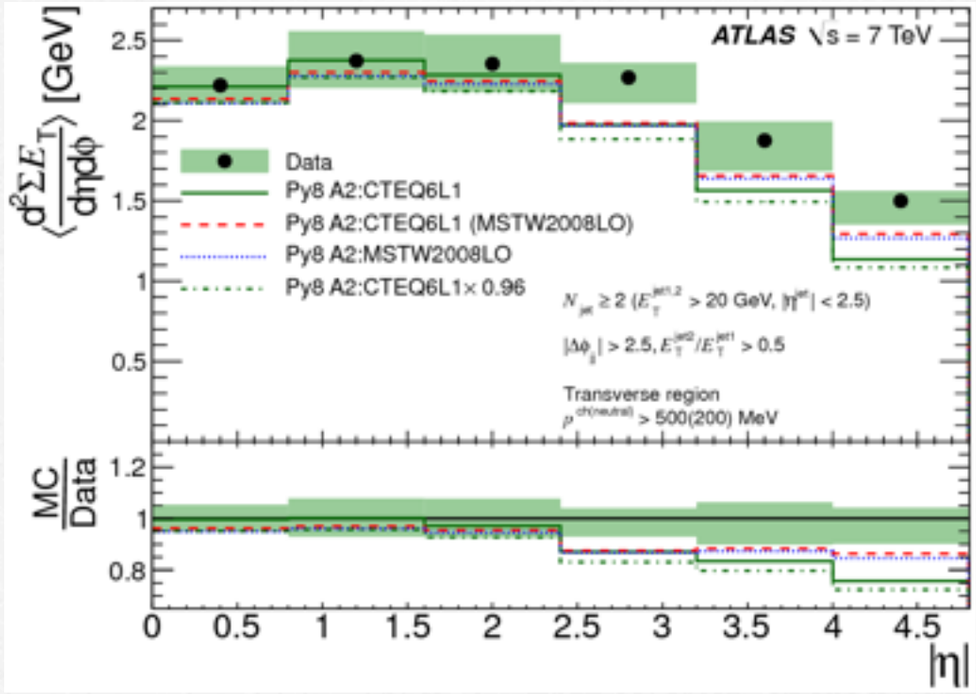
JHEP11 (2012) 033

PDF Dependence

Inclusive topology



Dijet topology



Pythia 8 tune A2 with different PDF are tried; more high and low-x gluons in MSTW.

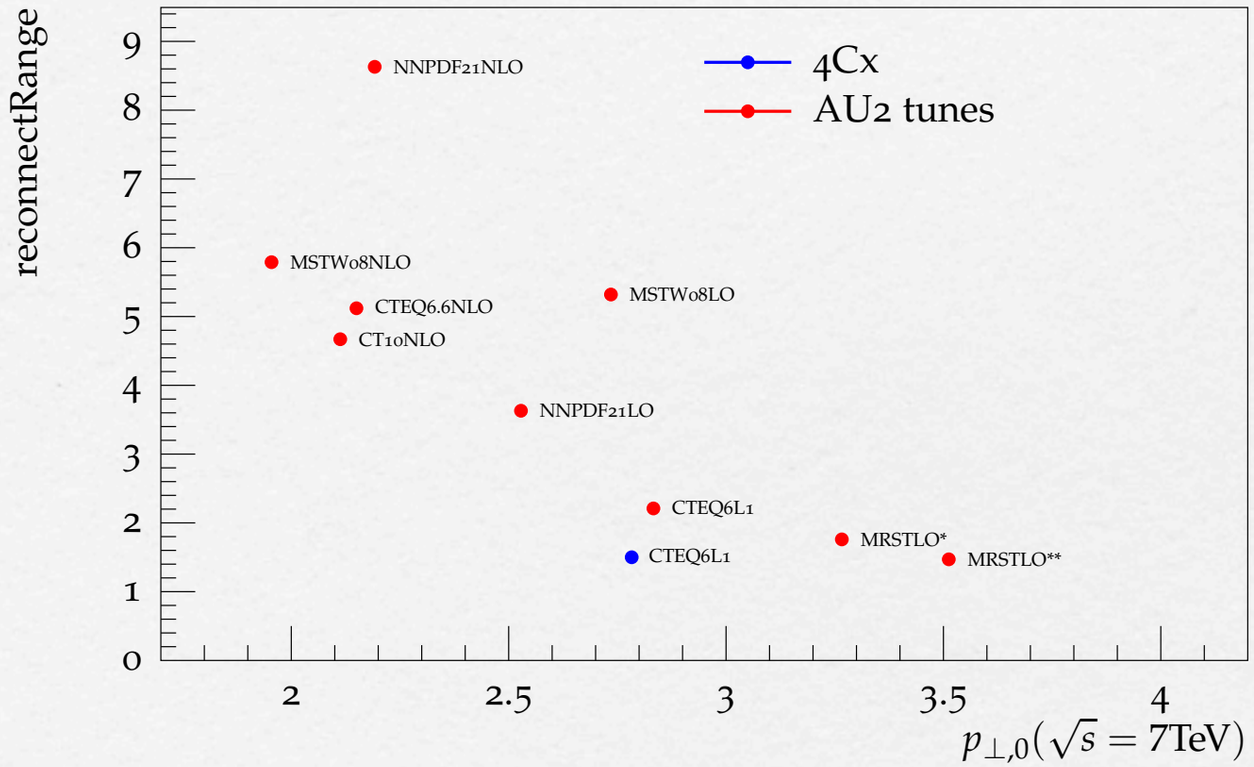
PDF Dependence of Tunes

BONUS

- MB tunes prefer slightly higher values of MPI p_T cutoff (and hence less MPI activity) than in the corresponding UE tunes, but this effect is small compared to that due to the variation between PDFs.

- NLO PDF tunes seem to demand a stronger color reconnection strength but somewhat lower MPI p_T cutoff and energy exponent than LO/mLO PDFs.

ATL-PHYS-PUB-2012-003



Similar behaviour also seen during earlier Herwig+Jimmy tuning

Summary

- Complimentary measurements to traditional minimum-bias and underlying event results (See Oldrich Kepka's talk on Thursday) in understanding soft-QCD at the LHC energy regime.
- Modelling the energy flow in forward region is critical for different measurements and searches.
- Crucial input to MC tuning as we move to higher LHC centre-of-mass energies.

NEW PREDICTIONS (10 years)

1. QCD tests & applications will greatly improve, incorporating NLO, NNLO,...and a theory of fragmentation and hadronization.
2. Atlas and CMS will discover a candidate Higgs particle.
3. There will be convincing evidence for Susy particles.
4. Plans will be underway to build a LC (at Cern) to explore the superworld and the US will join CERN.
5. There will be direct detection of the Dark Matter wind.
6. Alice will see a crossover to the perturbative quark-gluon plasma.
7. Some new Z mesons will be discovered.
8. Gravitational waves and B modes will be observed.
9. String theory will start to be a **theory** with predictions.
10. We will have a plausible explanation of why Λ is so small.

David Gross: EPS 2011