Measurements of the total transverse energy in pseudorapidity bins in proton-proton collisions at $\sqrt{s}$=7 TeV with ATLAS

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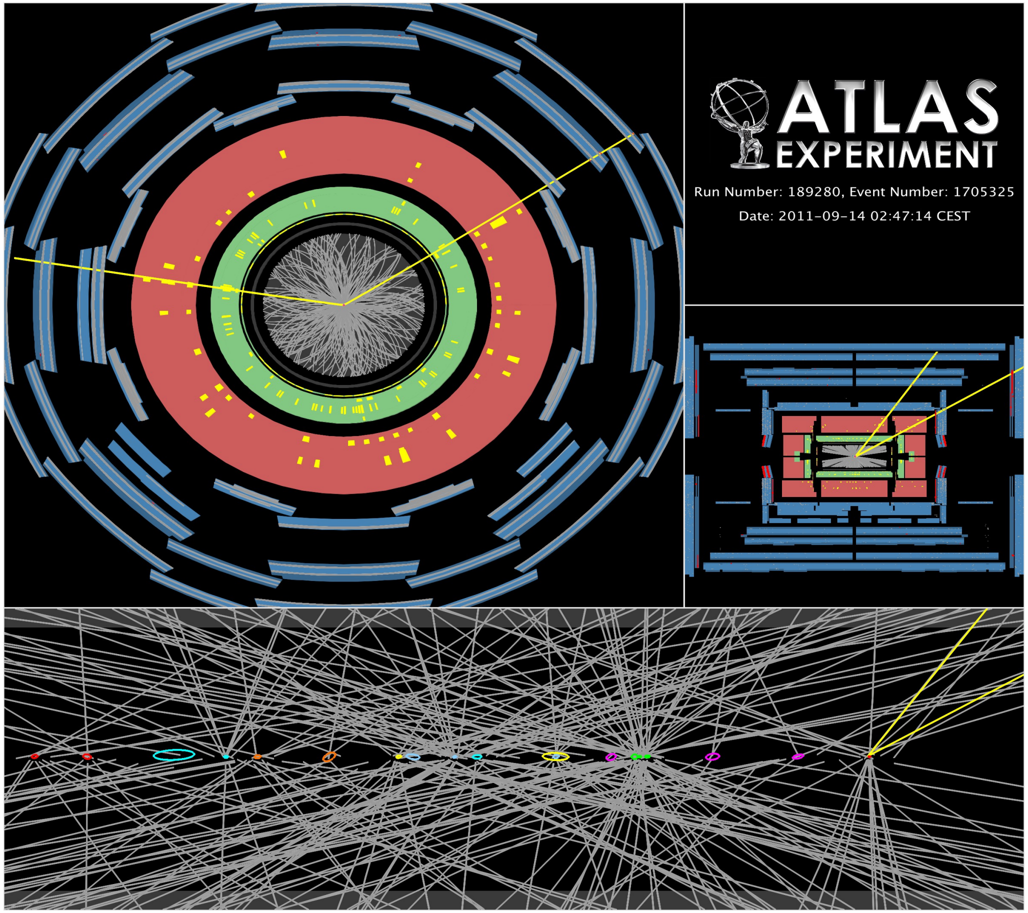
IOP parallel session

Introduction and motivation

Dominant process at the LHC is gluon-gluon interaction.

- At almost every event triggered in ATLAS, there will be low p_T (or soft) QCD processes underlying the hard physics



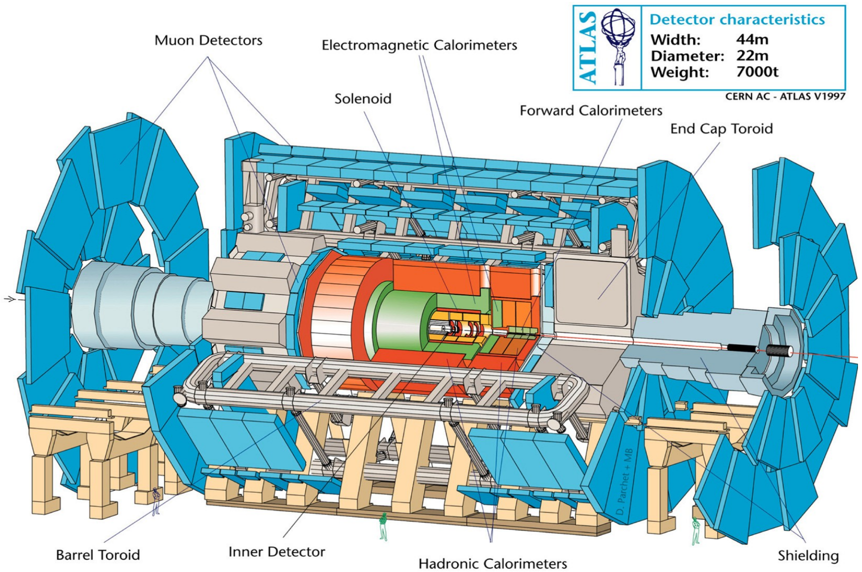
- Soft QCD is non-perturbative – can not derive from 1st principles

Motivates 'tuning' of Monte Carlo (MC) models to experimental data.

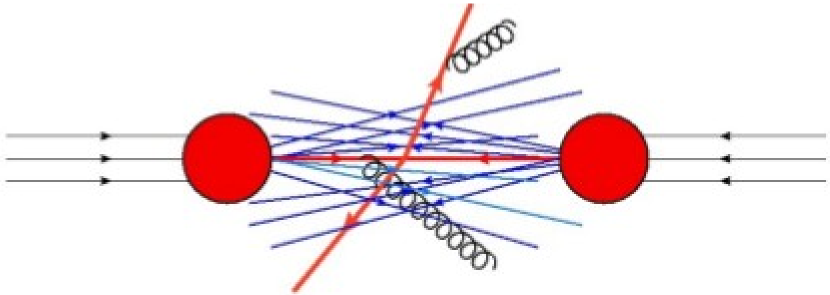
Analysis aims

To best simulate these soft processes, need as much information as possible.

- Utilise full coverage of ATLAS detector (|η| < 4.9)
  - Tricky, since for |η| > 2.5 we have no tracking information



- Use event topologies that are ideal for probing soft activity
  - Minimum bias: select as much physics as possible – allows us to understand the huge level of 'pile-up' at the LHC
  - Di-jets: select events with a hard process, then measure the soft activity



(a) an interesting event in ATLAS - the underlying event as blue lines; hard scatter as red lines

Variables

Here we use 2 variables to measure soft activity:

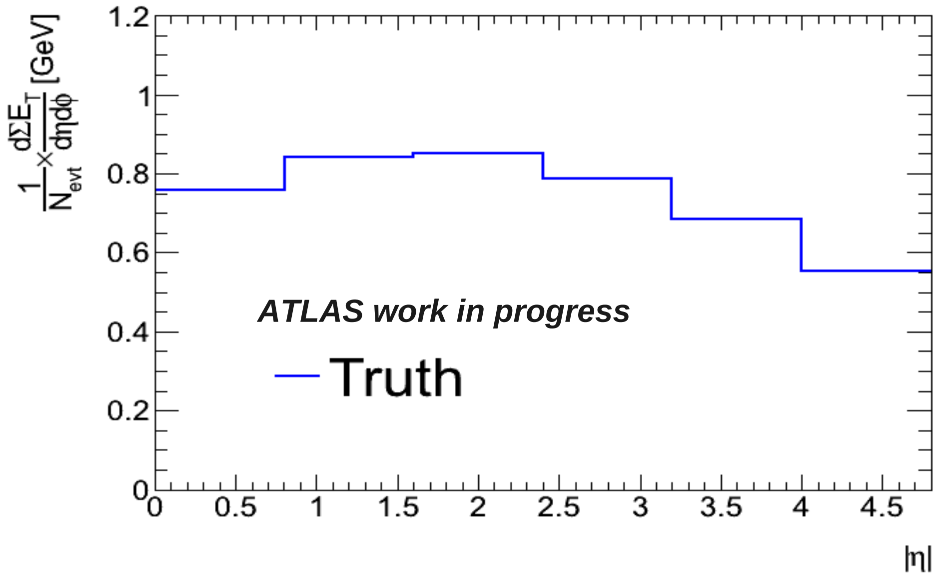
1. The mean ΣE_T per unit η-Φ as a function of |η|

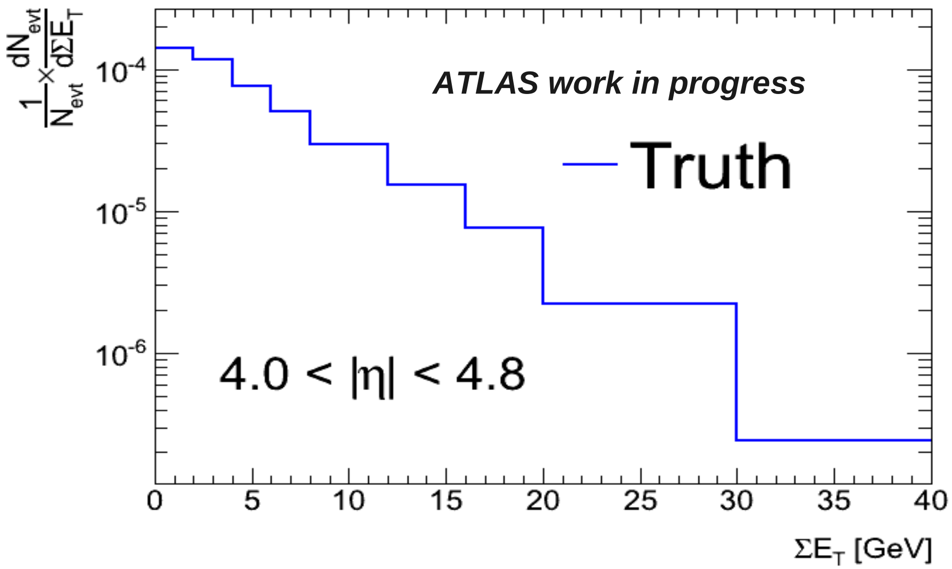
$$\frac{1}{N_{\mathrm{evt}}}\frac{d\Sigma E_{\mathrm{T}}}{d\eta d\phi}$$

This is also called the 'E_T density'.

2. The ΣE_T distribution in each bin of |η|

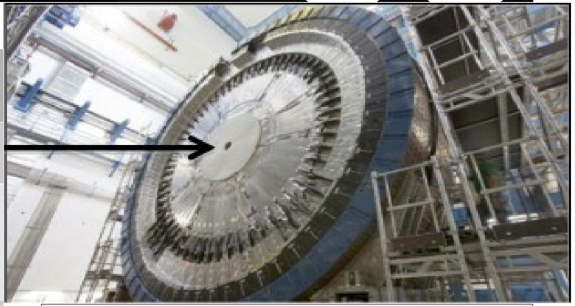
$$\frac{1}{N_{\mathrm{evt}}}\frac{dN_{\mathrm{evt}}}{d\Sigma E_{\mathrm{T}}}$$





Minimum bias: selection criteria

	Truth	Reconstructed
Event	2 central ($\|\eta\| < 2.5$) charged particles with pT > 250 MeV	Single arm trigger
		Single primary vertex with two p_T > 150 MeV tracks
		No pile-up vertices with > 5 associated tracks
Particle	Stable, lifetime > 10ps, where $\|p_{charged}\|$ > 500 MeV and $\|p_{neutral}\|$ > 200 MeV	All EM-scale topological clusters with $\|\eta\| < 4.8$



Minimum bias trigger scintillators on Liquid Argon cryostat

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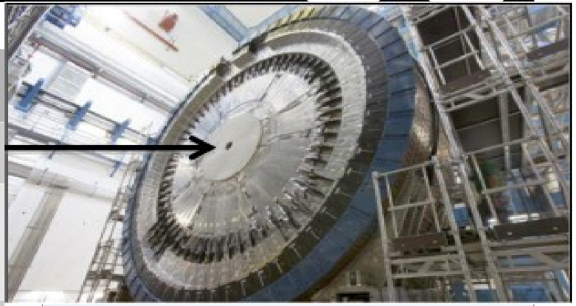

Minimum bias trigger scintillators on Liquid Argon cryostat

Summary:

- ensure a collision has occurred
- veto pile-up
- select all calorimeter clusters
- compare to truth particles that make it to the detector

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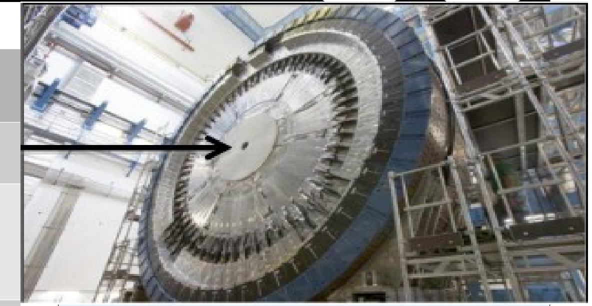

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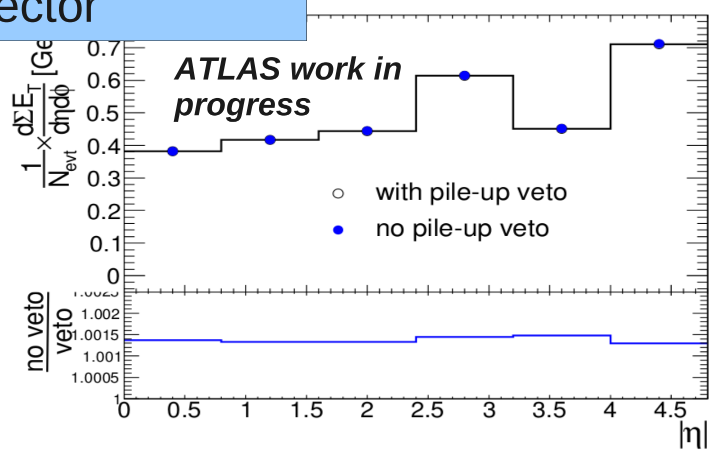
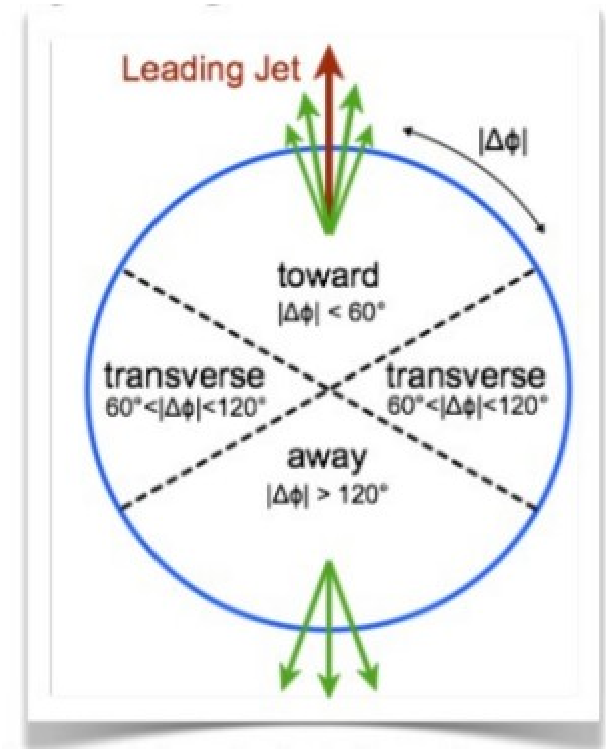
NB. pile-up

- For our MB results, peak <μ> = 0.007
- Compare pile-up veto versus no veto
  - Difference ~0.1%
- Residual pile-up ~0.005%



Di-jets: selection criteria

- Same as minimum bias, but ensure we have 2 balanced, back-to-back jets in the event



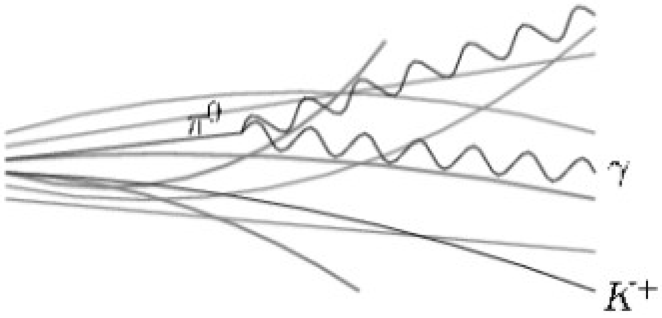
- This selection gives us a central di-jet topology
- To best analyse the effects of the underlying event (UE) in such a hard-scatter system, use Rick Field's phase space approach
  - Transverse region ($60^{o} < |\Delta\Phi| < 120^{o}$) most sensitive to the UE

Some studies

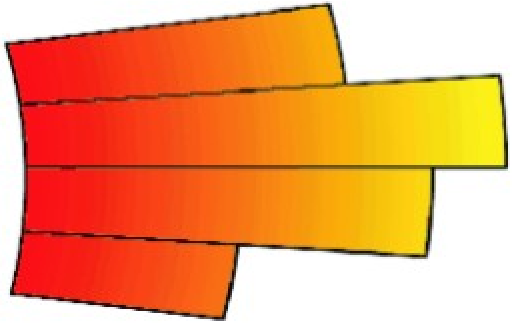
In order to analyse data that best reflects the physics we are sensitive to, numerous support studies were conducted:

- Include all clusters – convenient cancellation when summing positive and negative energy noise clusters
- Truth particle selection – by mapping truth particles onto their reconstructed counterparts, we determined what particles we are sensitive to at the detector level

With this knowledge, a Bayesian iterative unfolding of the data was performed to correct the clusters back to the particle level



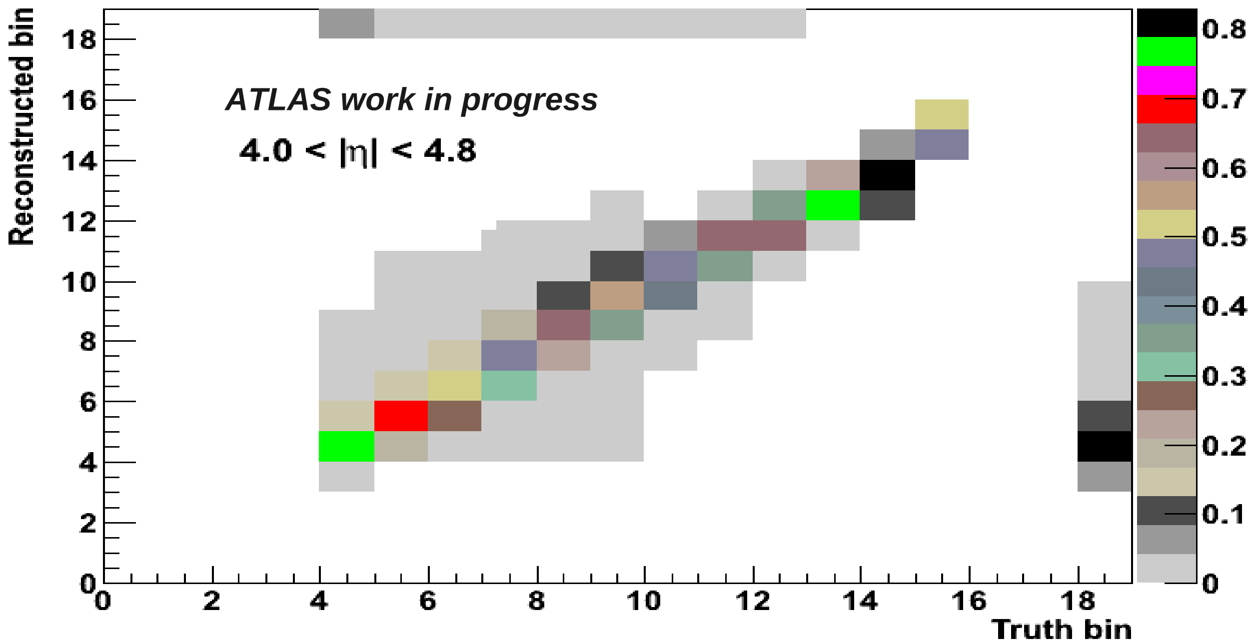
particle level



detector level

Using the Imagiro software package, an iterative Bayesian unfolding was performed on the ΣE_T distribution in each |η| bin

- Before unfolding the MC was re-weighted to the data, as it describes it very poorly in the forward region
- An example Pythia6 AMBT1 transfer matrix, for the highest (|η| > 4.0) bin in minimum bias, is shown below
  - Note the significant bin migrations



Taking the mean of the unfolded distribution and dividing by the |η| bin width returns the E_T density

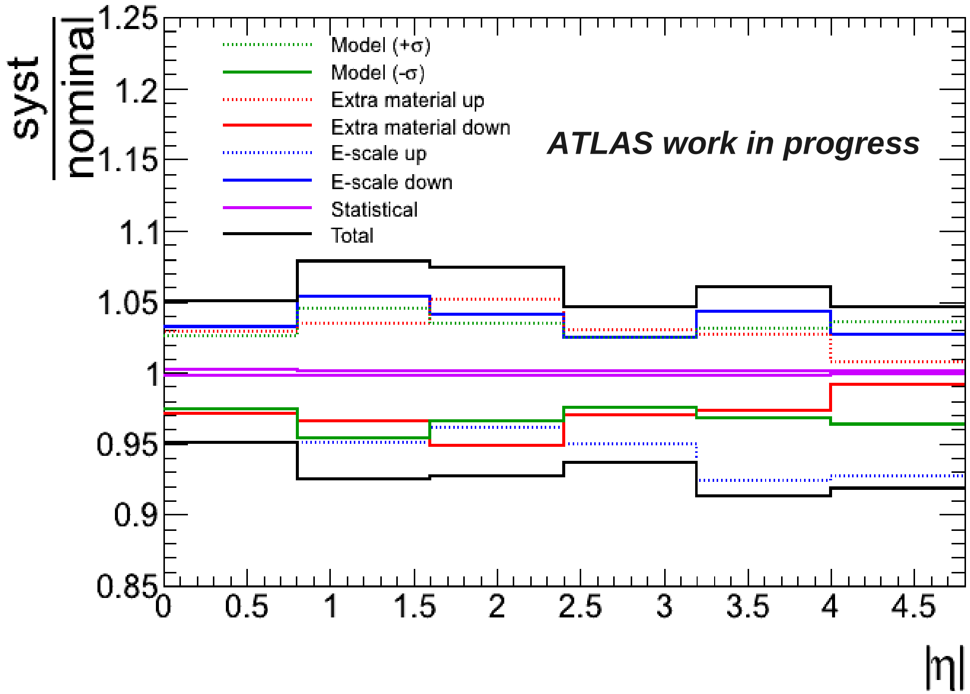
Systematic uncertainties

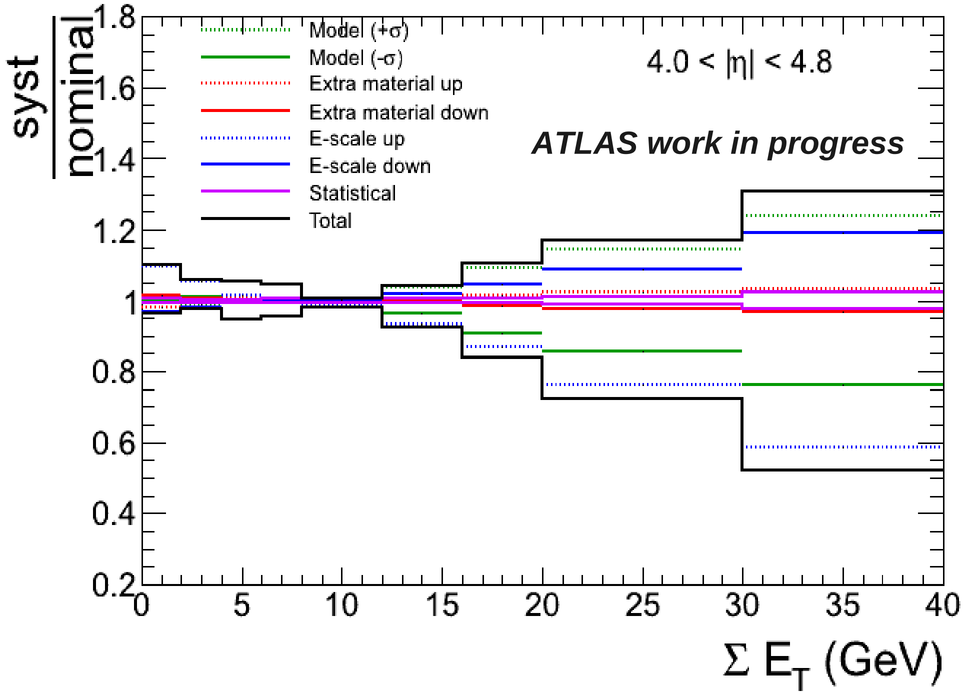
The 3 primary systematic effects in both analyses are:

- Difference between MC and data energy response
  - Probe using $\pi^0 \rightarrow \gamma\gamma$ candidates for the EM particles; E/p and test-beam results for the hadronic scale
- Model dependence when unfolding
  - Compare data unfolded using various MC models and tunes
- Effects of an incorrect detector material simulation
  - Compare reconstructed MC between standard and extra-material ATLAS geometries

The di-jet analysis also counts the jet energy scale as an additional systematic error.

Systematic uncertainties: minimum bias





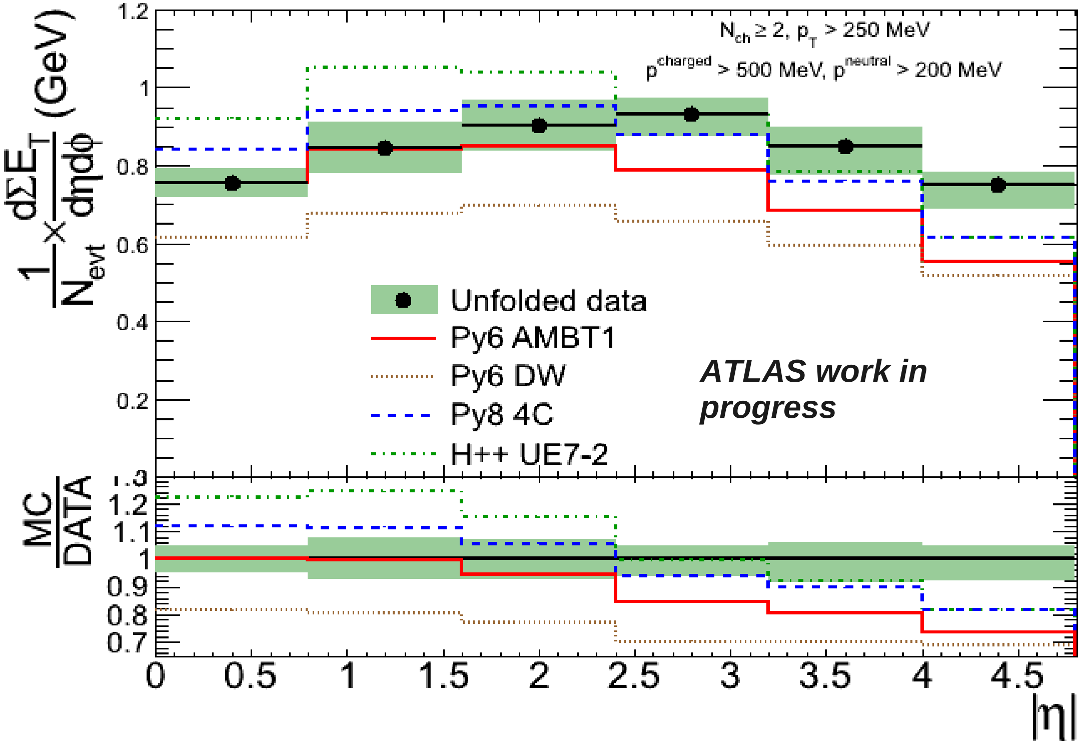
Summary of systematic uncertainties in the minimum bias analysis:

Left: E_T density

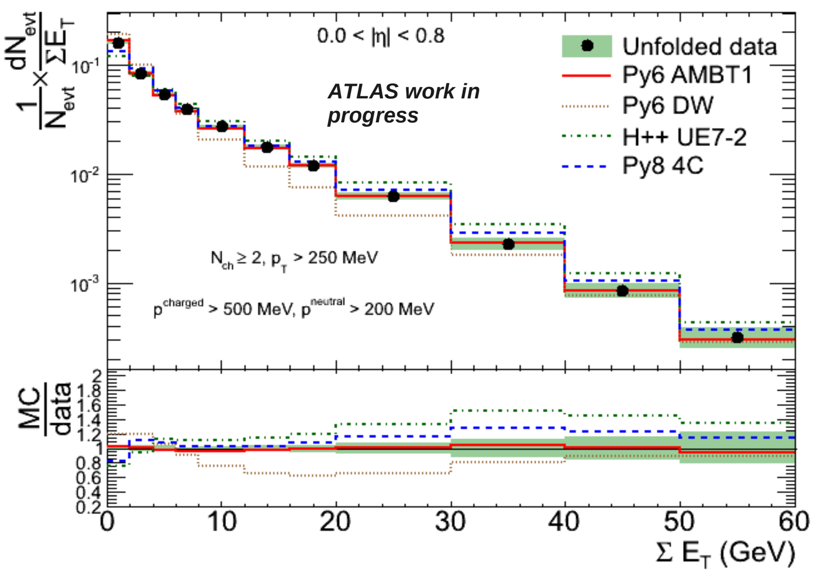
Right: ΣE_T distribution in highest bin in |η|

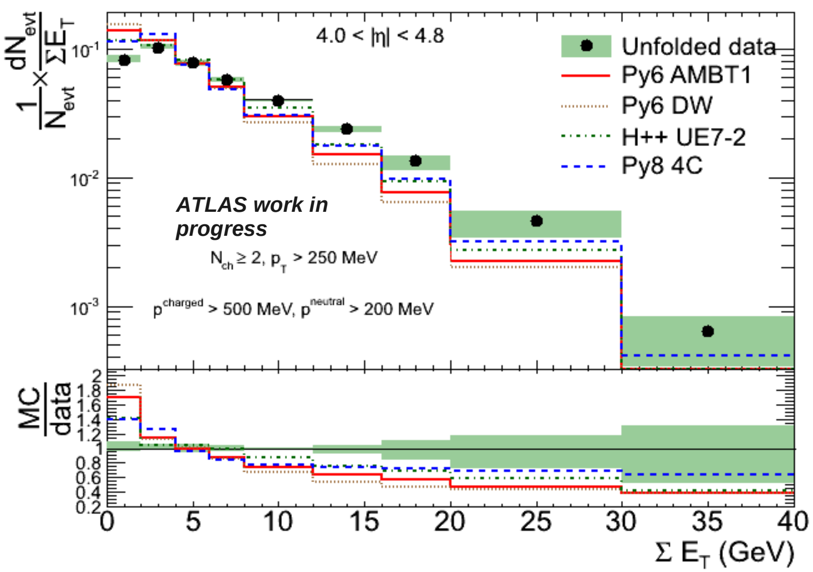
All ΣE_T distributions and di-jet equivalents in backup.

Results: minimum bias

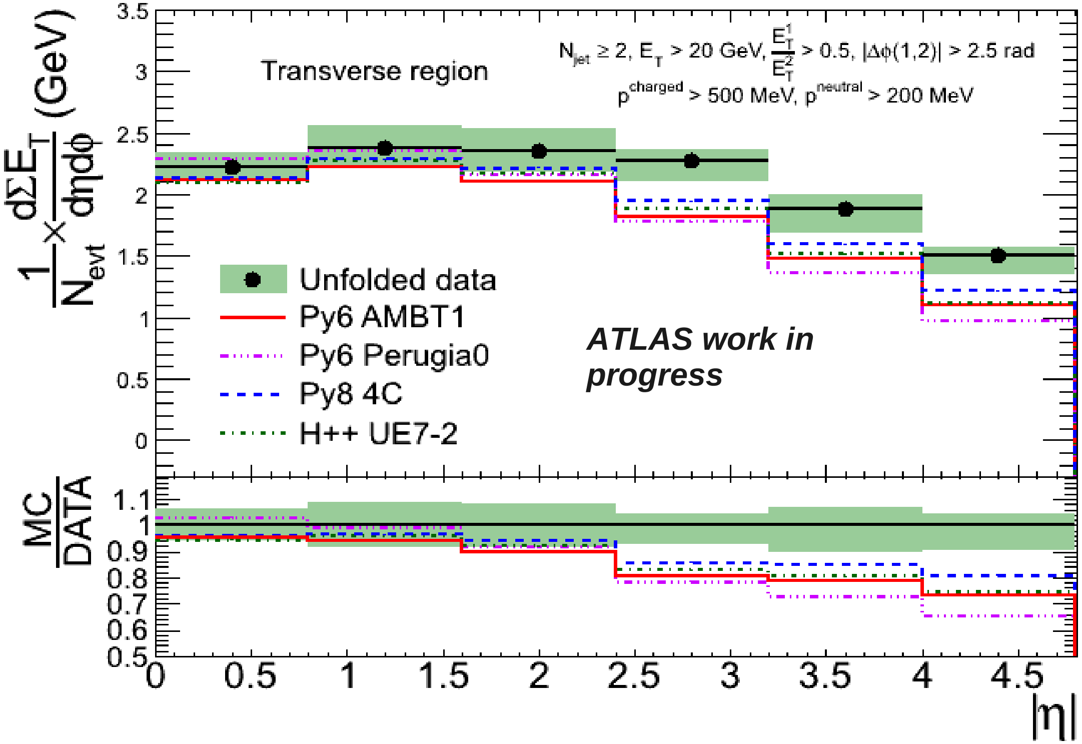


- Pythia6 AMBT1 does best in the central region
- All MCs under-predict the degree of activity in the forward region, with H++ 2.5.1 UE7-2 and Py8 4C performing best here
- Pythia6 DW gets the shape (η-dependence) best, but generally under-predicts in all bins

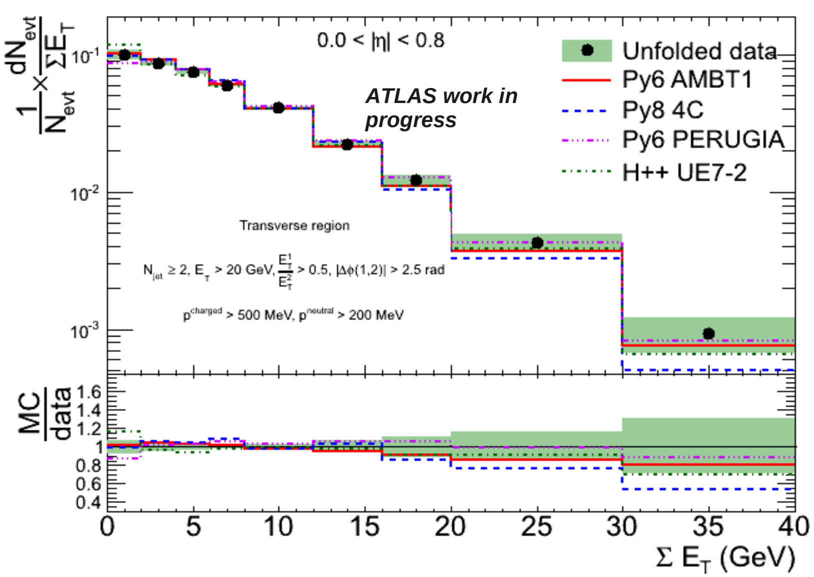


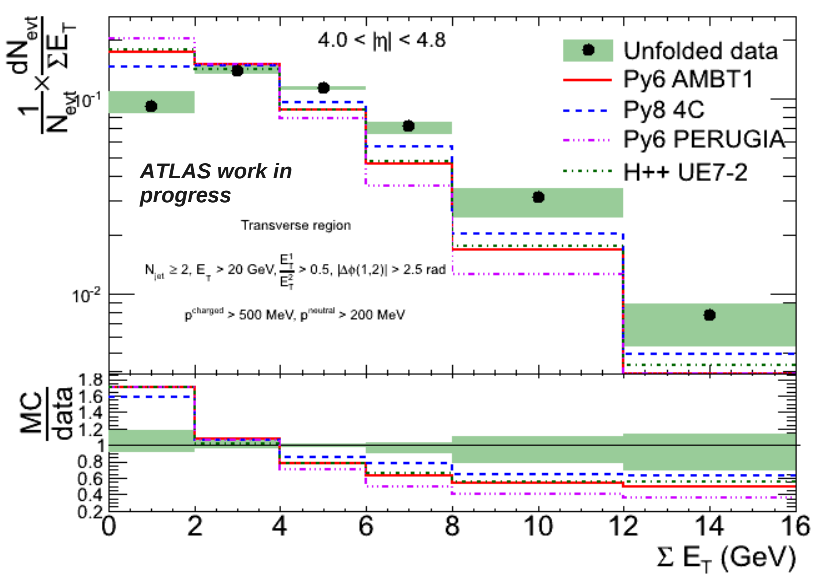


Results: central di-jets, transverse region



- Transverse region shows approximately 3 times more energy than the minimum bias
  - Expected, since hard scatter biases to head-on collisions – more parton-parton interactions
- Similar relation between data and MC
  - All models and tunes tend to under-predict the activity





Conclusions

The ΣE_T distributions in different $|\eta|$ bins as well as the E_T density, up to $|\eta| < 4.8$, has been measured in minimum bias and dijet events.

- Data used has been corrected for detector effects, back to the level of stable truth particles
- In general, all MC predictions underestimate the amount of activity in the forward region $|\eta| > 2.4$, for both minimum bias and di-jet
- We have also investigated the effect of PDF choice, which changes the relative forward to central energy
  - These results will be in the published note

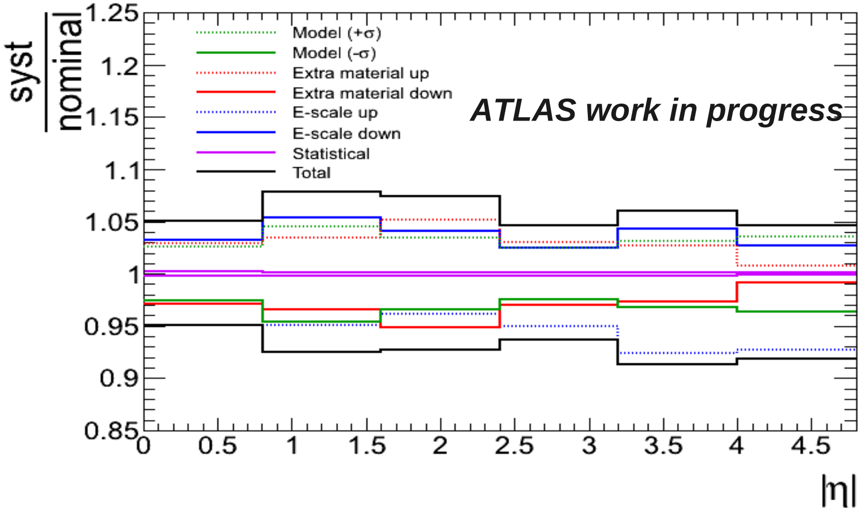
This information is being used to tune the next batch of ATLAS MC.

- Both analyses also offer complete correlation tables, allowing tuners to use them concurrently
- We are on the way to a better understanding of forward physics at hadron colliders

Thanks for listening!

Backup

Systematic uncertainties: minimum bias



Summary of systematic uncertainties in the minimum bias analysis:

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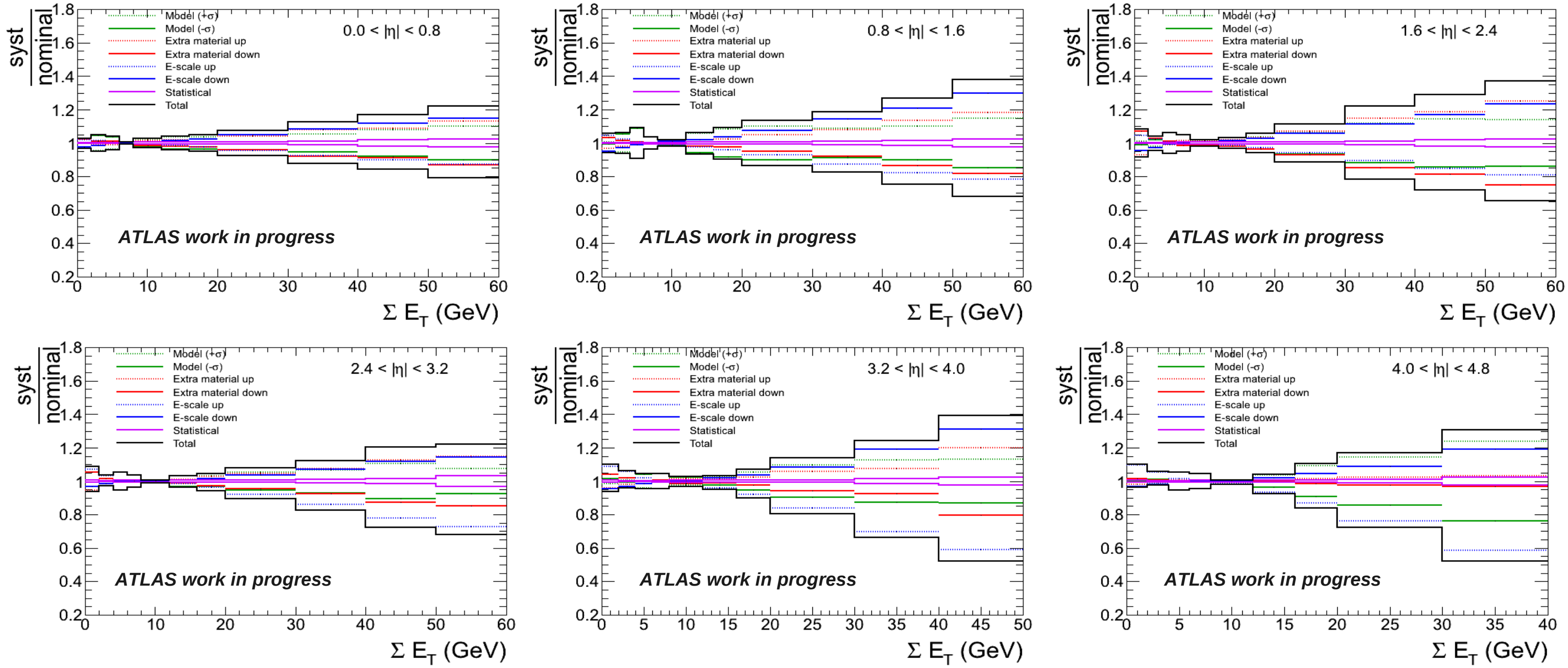
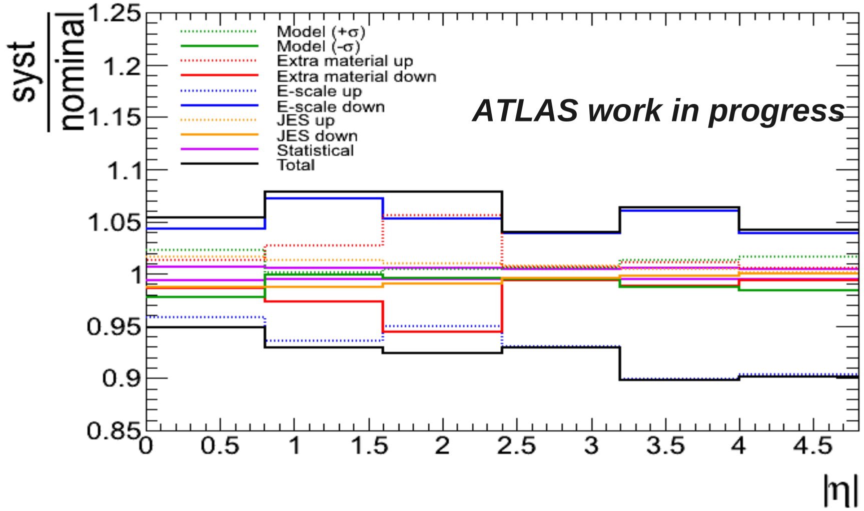
Below: ΣE_T



Systematic uncertainties: di-jets



Summary of systematic uncertainties in the di-jet analysis:

Left: E_T density

Below: ΣE_T