ATLAS MC tuning strategy

Andy Buckley
University of Edinburgh

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Introduction

ATLAS published new MC tunings for PYTHIA and HERWIG+JIMMY last year, in conjunction with the release of detector-corrected MB and UE data at 900 GeV and 7 TeV: the so-called AMBT1 and AUET1 tunings.

Extra observables, e.g. use of a track p_T threshold reduced to 100 MeV, and higher statistics at 7 TeV (particularly important for UE profiles) give a more complete dataset for MC tuning, and these generator tunes are being revisited for ATLAS' MC11 production.

In this talk, I'll summarise what is going into these tunes, as a springboard for discussion. Apologies that I can't show any new preliminary results, as these would require full ATLAS approval.

Past / present

HERWIG+JIMMY AUET1

JIMMY model is only valid for secondary scattering in the presence of a hard interaction: "AUET1" uses ATLAS and CDF UE data, but no min bias. Tuning weights emphasise ATLAS 7 TeV, exclude soft region. Also, $p_\perp^{\mathrm{sum}} > N_{\mathrm{ch}}$ observable: no colour reconnection model.

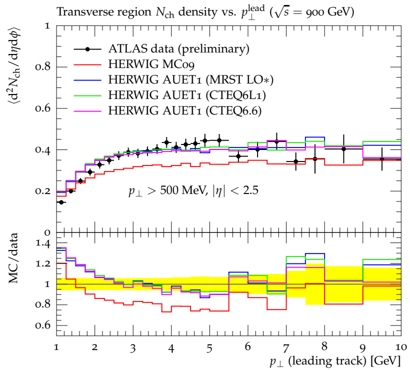
PTRMS (primordial $k_\perp$) no-width default fixed: Z p_T spectrum low-p_T region analysis systematics improved by using MC10 rather than MC09 MC@NLO.

Manual $\sqrt{s}$ evolution ansatz used, same as that in PYTHIA. Model has fewer tuning params than PYTHIA (both good and bad!): just a 3 param tune. But note that shower and hadronisation not really tuned! Tunes for 3 PDFs: LO$*$, CTEQ6L & CTEQ66.

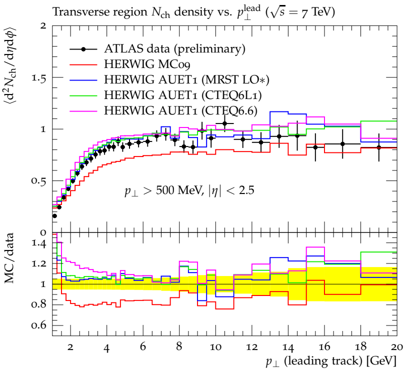
Mostly stable hadronic radius and energy evolution. $\hat{p}_\perp^0$ seen to be ordered by magnitude of gluon PDF at low-x: nice physics sanity check.

AUET1 vs. ATLAS underlying event data

900 GeV

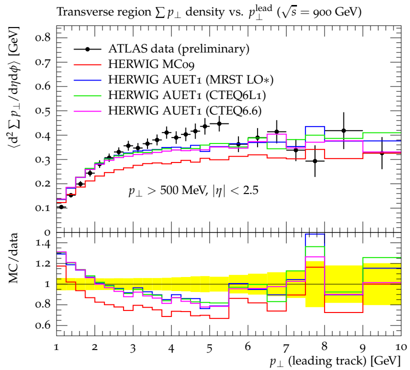


7 TeV



AUET1 vs. ATLAS underlying event data

900 GeV



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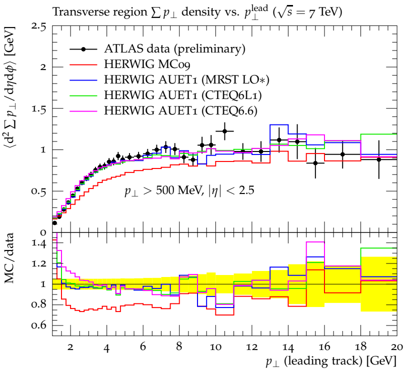

AUET1 vs. ATLAS underlying event data

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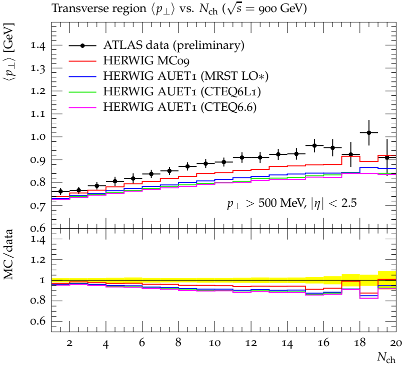

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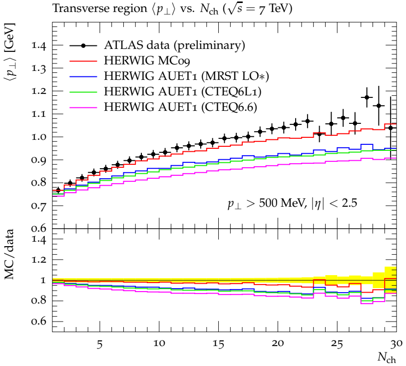
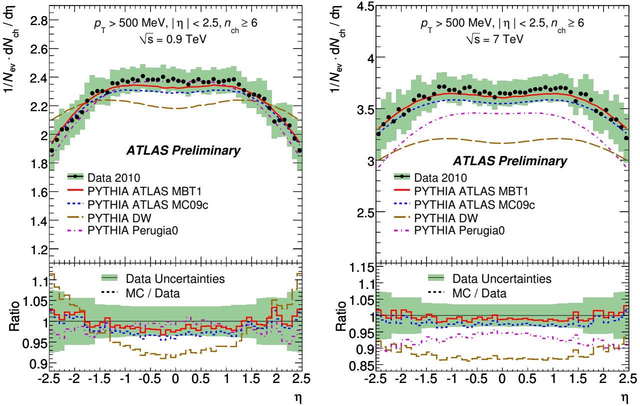


PYTHIA AMBT1

First LHC-data tune of PYTHIA was from ATLAS: AMBT1 (ATLAS Minimum Bias Tune #1). 8 parameter tune, done in two stages (rough/fine). Tune weights emphasise ATLAS 7 TeV data description.



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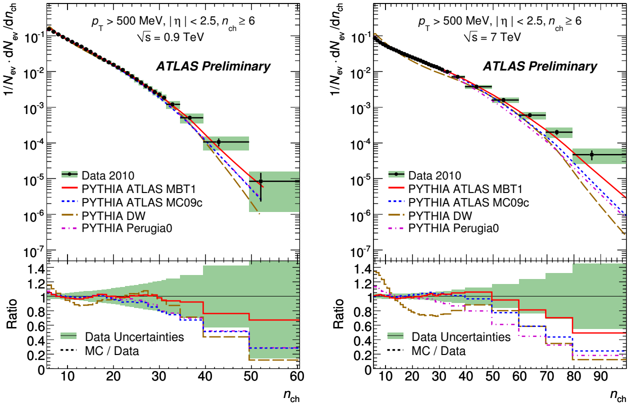

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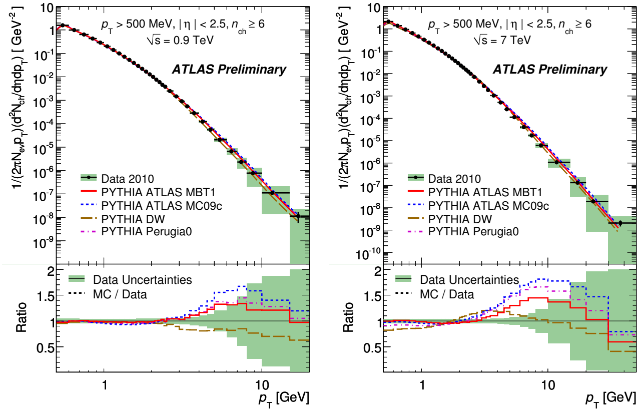

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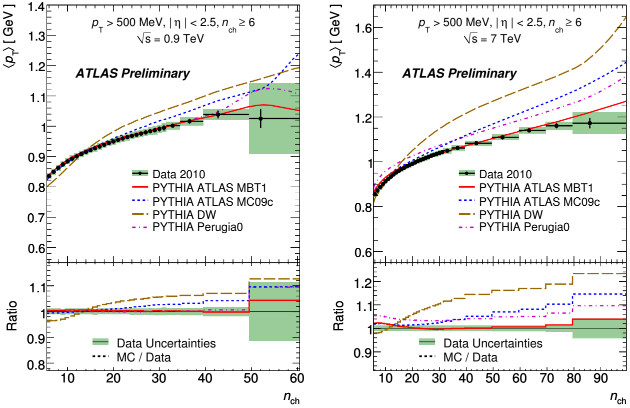

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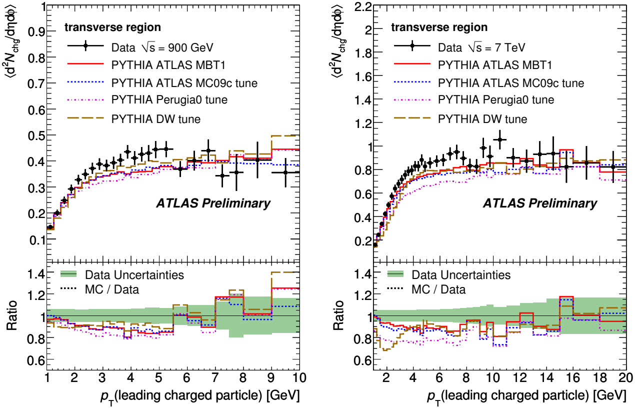

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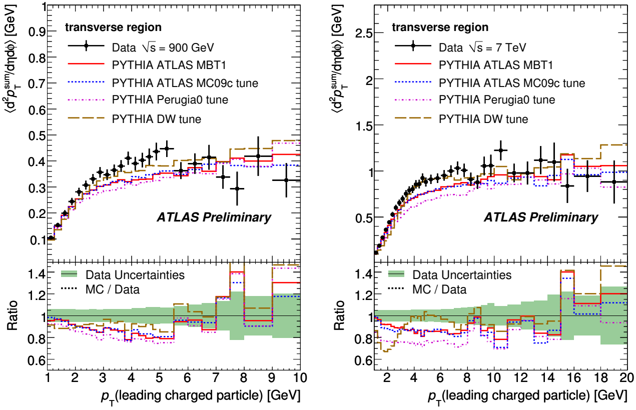
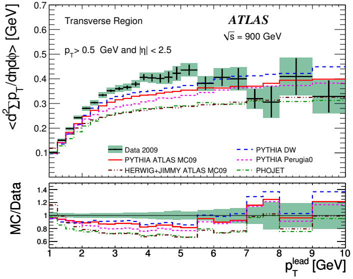
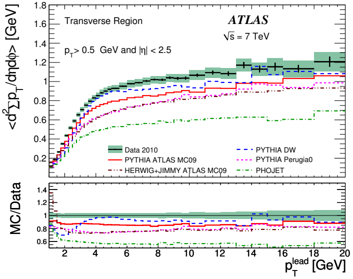


ATLAS UE measurements: results

$\sum p_T$, transverse region, 900 GeV and 7 TeV

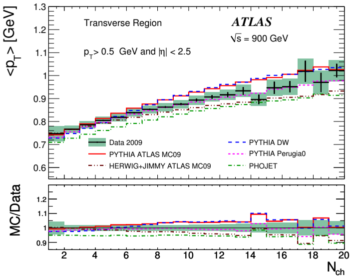


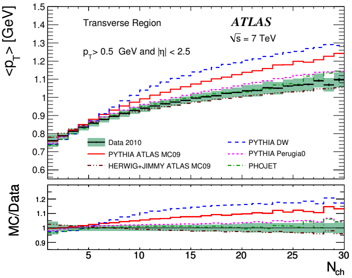


Variety of different MC predictions! PHOJET totally uncompetitive for UE (and not a general-purpose MC, anyway). Note low stats and no AMBT1/AUET1 in plots.

ATLAS UE measurements: results

$\langle p_T \rangle$ vs. n_{ch}, transverse region, 7 TeV, 500 MeV track p_T cut

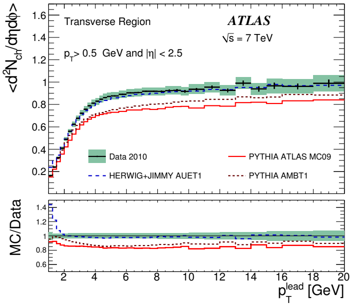


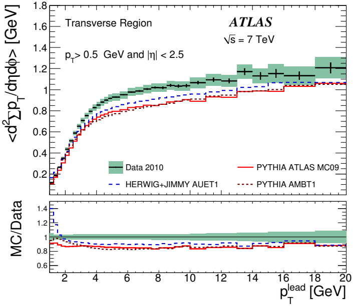


Strongly influenced by tuning of colour reconnection models: variety of MC model predictions. JIMMY surprisingly good!

ATLAS UE measurements: results

N_{ch} & $\sum p_T$, transverse region, 7 TeV – 500 MeV cut

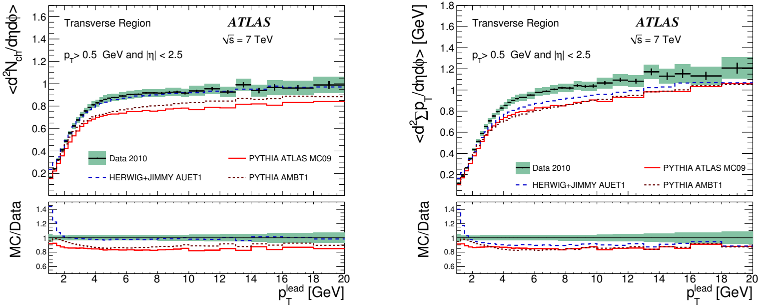




AUET1 looking good on N_{ch}, not so hot on $\sum p_T$.
AMBT1 undershooting both.

ATLAS UE measurements: results

N_{ch} & $\sum p_T$, transverse region, 7 TeV – 100 MeV cut



AUET1 now looking good for $\sum p_T$: confusion!
AMBT1 consistently undershooting again.

Present / future

Next round of ATLAS MC tuning: H+J AUET2

AMBT1 and AUET1 are nice tunes, but suffer from lack of 7 TeV UE statistics at the time of construction. Slightly more UE activity is wanted in both. We move from LO$*$ to LO$**$ as the main ATLAS production PDF.

For HERWIG+JIMMY, we use the same mock-up of the PYTHIA MPI evolution ansatz as for AUET1: a three-parameter tune with MB-like regions excluded. Done for 9 PDFs so far $\Rightarrow$ generally good agreement but we suspect the model is at the limit of its capabilities. Dbn shapes are $\sim$not modifiable.

However, these three parameters can absorb nearly all PDF effects on UE observables. Interesting parameter distributions…but sorry, I can't show them in public!

Separate HERWIG shower tuning for AlpGen will likely be based on CTEQ6L1 variant of this tune.

Next round of ATLAS MC tuning: PYTHIA

For PYTHIA it is not entirely clear if the model will optimally describe min bias and UE at the same time: an excellent fit to MB slightly undershoots UE…but there are a lot of parameters and surprising things can be done with colour reconnection. Pragmatically, good parameterisations of pile-up and UE are valuable things in their own right for physics studies.

We also take this opportunity to sort out some issues with the PYTHIA shower and hadronisation tuning. Divide tune into 4 block-param tuning stages: flavour, FS fragmentation, ISR, MPI.

Again, we hope to make a separate PYTHIA shower tuning for AlpGen, based on the CTEQ6L1 variant of this tune.

PYTHIA p_T-ordered FSR and hadronisation

PYTHIA p_T-ordered shower was never really tuned in ATLAS – MC09 tuning was intended to be merged with existing MC08 samples, hence no variation of light fragmentation parameters. AMBT1 was concentrated purely on updating MPI parameters for first soft QCD observables.

Most recent tune of PYTHIA FSR and hadronisation was the Professor tune set from 2008, which uses LEP and JADE experiment and PDG-collated data to constrain the models. With more experience of how to get good automated tuning results, we can now do much better.

Tune uses the same observables as the Professor tune: event shapes, charged multiplicities, p_T-spectra w.r.t. thrust axes, etc., plus identified particle rates and spectra, and differential jet rates. Include the b-fragmentation params in the tune: excellent agreement is possible. Flavour params get exact same values as in original Prof 2008 tune.

See also work by Šárka Todorova on *even* better descriptions possible using a helix-string based hadronisation model with PYTHIA: arXiv:1012.5778

PYTHIA p_T-ordered initial state shower

PYTHIA AMBT1 (using the p_T-ordered shower) produces too-narrow transverse jet shapes. Spotted by Peter Skands in CDF jet shapes, resulting in PYTHIA Perugia 2010 tune. In this, Λ_{QCD} for "IFSR" emissions uses the value for FSR (tuned in FSR stage) rather than that for ISR (taken from PDF).

We follow a similar tuning ansatz to improve the jet shape predictions of the ATLAS tune but with PARP(72) as a tune parameter. This partially motivated the shift of PDF to LO$**$, because Λ_{QCD} is *higher* in the LO$*$ PDF than in FSR, i.e. a direct setting to the FSR value would probably *worsen* the agreement!

Theory validity of these multiple α_s scales? What modelling deficiencies are being masked by requiring quite different scales for the same physical param in different parts of the model?

PYTHIA p_T-ordered initial state shower (2)

Observables in tune:

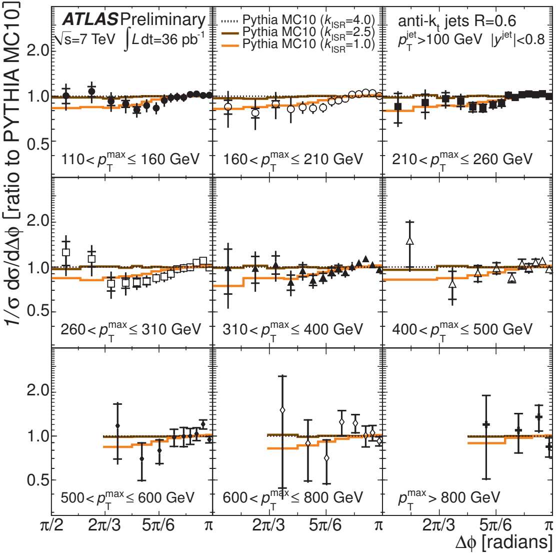
- CDF 2005 jet shapes (of course)
- DØ dijet azimuthal decorrelation
- ATLAS track jet longitudinal fragmentation functions
- ATLAS dijet decorrelation
- ATLAS jet shapes
- ATLAS W+1 jet p_T spectra (electron and muon channels)
- *Low end* of CDF Z p_T spectrum to constrain intrinsic $k_\perp$.

ATLAS data gets highest weight, with balance between $||$ and $\perp$ jet shapes required. *Parameterised* description looks excellent. We have taken care to avoid using PYTHIA to fit inclusive p_T spectra or regions where multijet modeling would be required.

Other debate over factors like PARP(67), which boosts or suppresses the ISR starting scale – big influence on e.g. $t\bar{t}$ observables but no data available with a lot of sensitivity: how best to treat this?

A handle on PARP(67)?

- Study effect of k_{ISR} = PARP(67) on ATLAS dijet data: favours low value
- CMS sees the opposite effect – but for a different (Q^2 PS/MI model)
- Maybe we should stop fudging stuff that is not really PYTHIA's forté?!



PYTHIA MPI

We mostly know what to do here! Most tuning familiarity is with these parameters and observables.

Leaving this part to the end means that the least-constrained model is given as little room to play in as possible: the good description of perturbative modelling aspects should help.

Two open questions:

- Can we really use the 100 MeV track p_T cut data? Not possible for JIMMY AUET2.
- Can a single tune describe both MB and UE, or do we need separate AMBT2 and AUET2 tunes for different purposes?

Only one way to find out! Any suggestions for useful things to do at this stage?

Also tuning to CTEQ6L1 (LO) and CTEQ66 (NLO) – the former particularly important for AlpGen tuning.

Time to move on…

Growing consensus that this should be the last ATLAS tuning round where all the emphasis is placed on the Fortran generators. JIMMY in particular is looking very stretched.

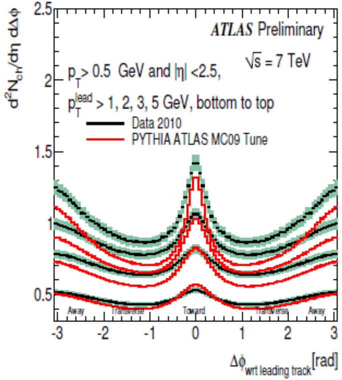
Herwig++ and Pythia 8 have more developed soft QCD models than JIMMY and PYTHIA: we are at the stage where we can describe all this data with tuning, so the distinguishing MC features in future should be the more advanced perturbative treatments like merging, matching, etc. …and coming up with MPI observables that these models can't describe well (or reducing the number of model parameters!)

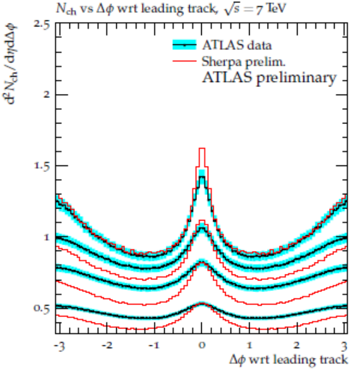
H++ has shower issues as seen in LEP data: it's important that this is fixed for detailed physics studies. Sherpa has a lot of interesting high-p_T physics in it – I'm sure lots of others are also eagerly awaiting the KMR soft-QCD model.

MPI can't do *everything* in UE!

UE at LHC 7000 GeV – included in tuning

ATLAS-CONF-2010-081 – left plot taken from ATLAS note





(from Hendrik Hoeth, MPI@LHC)

Summary

- AMBT2/AUET2 tunes underway for PYTHIA and HERWIG/JIMMY, for use in MC11: ATLAS dijets, jet shapes, MB, and UE. PYTHIA in particular is a very comprehensive tune. Many PDFs for JIMMY, 3 PDFs for PYTHIA.
- Using Rivet and Professor for all our tuning: not mentioned, but there is also likely to be use of Professor eigentunes for systematics of selected tune stages, as requested by physics groups.
- We won't be tuning PYTHIA to the LHC flavour observables in this round: that requires a good description of more general initial-state effects as a base for tuning (cf. strangeness obsvs – put them in Rivet, please!). Perhaps this will happen within ATLAS…but I'd also encourage LHCb and ALICE to take a look at our tunes when released and put some flavour/excited states polish on this part of the model!
- New MC MPI models: new releases of H++ (soon) and Sherpa (long-term) in particular. Attention will be shifting to these over the next year, starting with Pythia 8.