Developments in (ATLAS) MC generator tuning

Andy Buckley
University of Edinburgh

QCD@LHC, 2011-08-22

MC tuning in a nutshell

- MC tuning is a necessary evil. It's effectively the *absence* of physics, so we like to avoid it when possible.

MC tuning in a nutshell

- MC tuning is a necessary evil. It's effectively the *absence* of physics, so we like to avoid it when possible.
- But it's not always possible!
- Non-perturbative, or non-factorisable models like hadronisation and MPI require ansatz treatments and will for the forseeable future require fitting to data.

MC tuning in a nutshell

- MC tuning is a necessary evil. It's effectively the *absence* of physics, so we like to avoid it when possible.
- But it's not always possible!
- Non-perturbative, or non-factorisable models like hadronisation and MPI require ansatz treatments and will for the forseeable future require fitting to data.
- Tuning was historically done manually and very ad hoc. Improvement with the original DELPHI PROFESSOR system – reanimated as the Python-based Professor system.
- Briefly, Professor is an interpolation/parameterising system for general expensive functions. Some numerical trickery to make it work, some neat systematics ideas, handy UIs for generally digging into tune details.

MC tuning in a nutshell

- MC tuning is a necessary evil. It's effectively the *absence* of physics, so we like to avoid it when possible.
- But it's not always possible!
- Non-perturbative, or non-factorisable models like hadronisation and MPI require ansatz treatments and will for the forseeable future require fitting to data.
- Tuning was historically done manually and very ad hoc. Improvement with the original DELPHI PROFESSOR system – reanimated as the Python-based Professor system.
- Briefly, Professor is an interpolation/parameterising system for general expensive functions. Some numerical trickery to make it work, some neat systematics ideas, handy UIs for generally digging into tune details.

In an ideal world we wouldn't need to do any of this!

Toolkit updates

Ok, ok, one more slide on the tools of the trade…

- New versions of AGILe (1.3.0), Rivet (1.6.0), and Professor (1.3.0) released recently.
- Significant improvements:
  - Rivet: bug fixes in W/Z finder projections, first contributed CMS analyses, script improvements. Histo upgrade with implicit use of weight vectors on the way.
  - Professor: some significant changes, e.g. generalised polynominal interpolators, ability to specify extra systematic errors in χ^2 calculation, experimental support for handling correlated errors, constrained eigentunes, improved sampling range checking, plus general tweaks and bug fixes.
  - AGILe: it shouldn't really matter, since we should be ditching the Fortran generators, but AGILe now supports user-supplied meta-parameter functions, can read in MadGraph/POWHEG/etc. LHEF files in PYTHIA and HERWIG, and includes a two-level `--filter` option which can improve I/O performance by a factor of 4.

Recent MC tuning activity

- MC tuning in recent years has been mainly done by ATLAS (incl. Rivet/Professor authors), by CMS (Rick Field *et al*), and by generator authors (PYTHIA6 by Peter Skands, Pythia8 by Richard Corke, Herwig++ by Andrzej Siodmok, Sherpa by Hendrik Hoeth and others)
- This talk will mainly focus on ATLAS results and some personal follow-ups on these, but first a mention of a couple of other activities of interest:
  - Consistent shower α_s treatments in PY6: Sherpa have been saying this for years! Important for AlpGen, perhaps for POWHEG (e.g. Λ_{CMW} in ISR). *Avoid* tuning when we can!
  - There are far too many tunes: especially for PYTHIA6. Reduce redundancy: how many UE systematics do you really need?! "Tune killing" Les Houches project: see next slide.

Tune killing

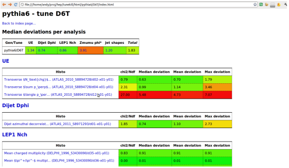
- Les Houches project: quantitatively compare tunes and generators on a set of agreed data.
- Direct comparison on a wide range of physics is itself very useful.
- Info on underperforming tunes can be used to either advocate discarding them or starting work on a replacement.
- It's just a way of gathering relevant information to guide decision making on which tunes to use. No-one has to follow the recommendations, although if you insist on keeping an evidently broken tune, people may laugh at you.


file:///home/andy/proj/hep/tunekill/html/index.html

Tune comparisons

Median deviations per gen/tune and analysis:

Gen	Tune	UE	Dijet Dphi	LEP1 Nch	Zmumu phi*	Jet shapes	*Total*
herwig	2.5.0	0.96	1.12	1.13	1.80	0.64	1.13
pythia6	AMBT1	0.52	0.36	2.97	0.79	0.54	0.56
	AMBT2	0.80	1.24	0.57	2.87	0.49	0.99
	AUET2	0.47	0.89	0.57	3.10	0.25	0.65
	D6T	1.34	0.74	0.86	3.91	1.20	1.83
	DW	2.60	1.10	0.85	3.89	0.71	2.74
	P2010	0.76	1.36	1.81	1.04	0.62	0.89
	P2011	0.41	1.30	0.57	1.75	0.30	0.57
	Z2	0.44	0.84	2.74	1.03	0.41	0.59
	profQ2	1.69	0.91	0.32	2.17	0.30	1.63
pythia8	4C	0.87	1.08	0.82	3.41	0.06	1.11
sherpa	1.3.0	2.19	0.88	1.23	1.35	0.86	1.36


file:///home/andy/proj/hep/tunekill/html/pythia6/D6T/index.html

pythia6 - tune D6T

Back to index page...

Median deviations per analysis

Gen/Tune	UE	Dijet Dphi	LEP1 Nch	Zmumu phi*	Jet shapes	*Total*
pythia6/D6T	1.34	0.74	0.86	3.91	1.20	1.83

UE

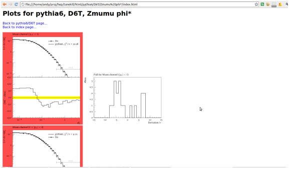
Histo	chi2/Ndf	Median deviation	Mean deviation	Max deviation
Transverse N_chg... (ATLAS_2010_S8894728/d02-x01-y01)	0.79	0.63	0.70	1.79
Transverse $\sum p_\perp$... (ATLAS_2010_S8894728/d04-x01-y01)	2.31	0.99	1.14	3.46
Transverse $\langle p_\per... (ATLAS_2010_S8894728/d12-x01-y01)	27.00	5.48	4.73	7.07

Dijet Dphi

Histo	chi2/Ndf	Median deviation	Mean deviation	Max deviation
Dijet azimuthal decorrelat... (ATLAS_2011_S8971293/d01-x01-y01)	1.85	0.74	1.10	2.73

LEP1 Nch

Histo	chi2/Ndf	Median deviation	Mean deviation	Max deviation
Mean charged multiplicity (DELPHI_1996_S3430090/d35-x01-y01)	0.83	0.91	0.91	0.91
Mean π^+/π^- multipl... (DELPHI_1996_S3430090/d36-x01-y01)	0.00	0.01	0.01	0.01

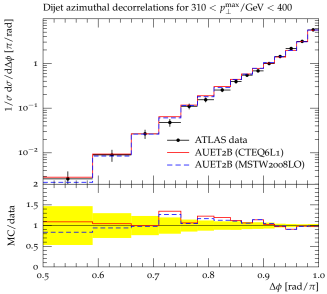


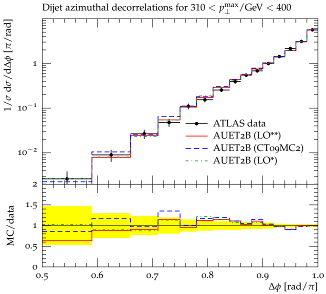
MC tuning results from ATLAS

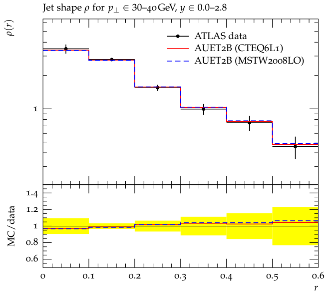
- Significant tuning effort in ATLAS – still rather focused on the "old" Fortran generators. Actually lots of overlap with Peter Skands' tuning work for PYTHIA, but increasing Pythia 8 effort.
- Results are MC tunes like PYTHIA and HERWIG MC09, AMBT1…
- …and now the whole families of JIMMY AUET2, and PYTHIA AUET2B/AMBT2B tunes. Tuning for many PDFs and with systematic soft QCD variations, using ATLAS data. Described in the following slides.
- Latest PYTHIA tunes are full-chain tunes including LEP data for hadronisation and FSR, and ATLAS and Tevatron data for the parton shower and MPI stages. Excellent description of e^+e^- data – but not shown here!
- JIMMY tunes are simpler – three-parameter MPI tunes using the PYTHIA MPI energy evolution ansatz.

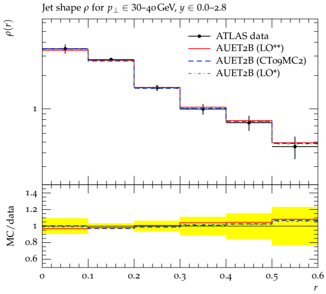
PYTHIA A∗T2B shower tunes

Also PYTHIA A∗T2 tunes, with a very different shower.



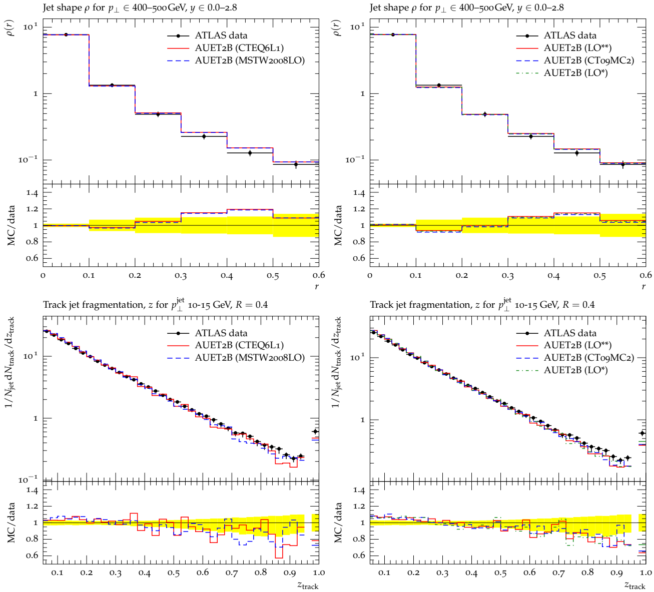






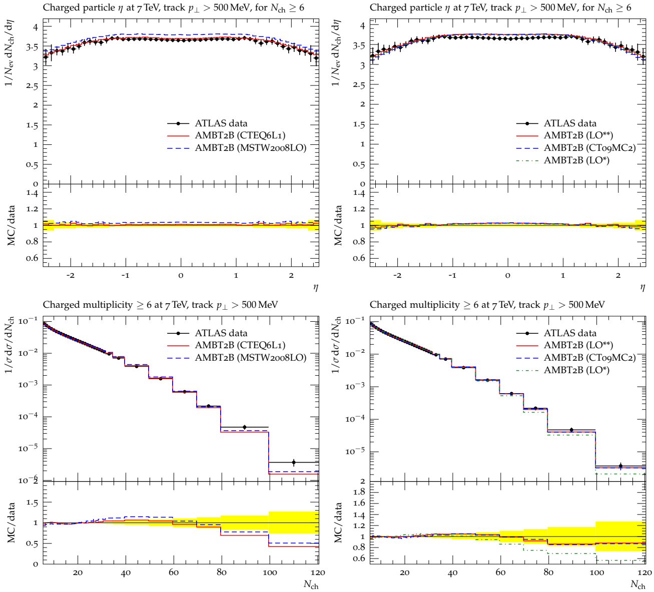
PYTHIA A∗T2B shower tunes

Also PYTHIA A∗T2 tunes, with a very different shower.



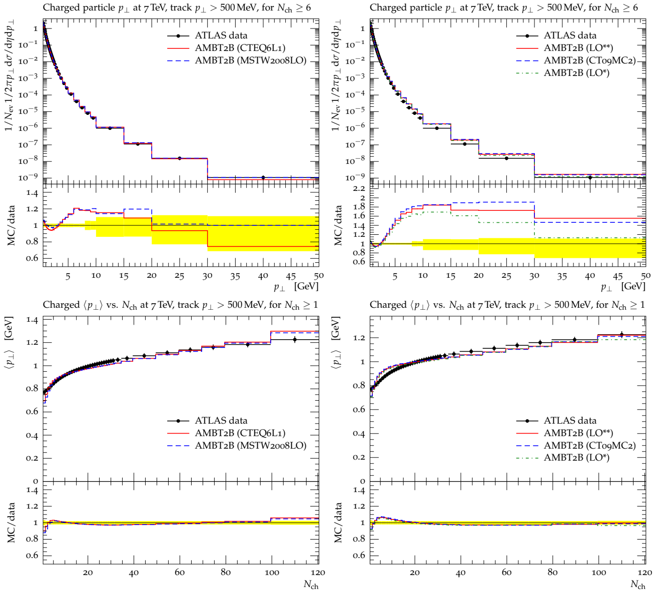
PYTHIA AMBT2B

MPI tunes to min bias data, using the previously shown shower setup



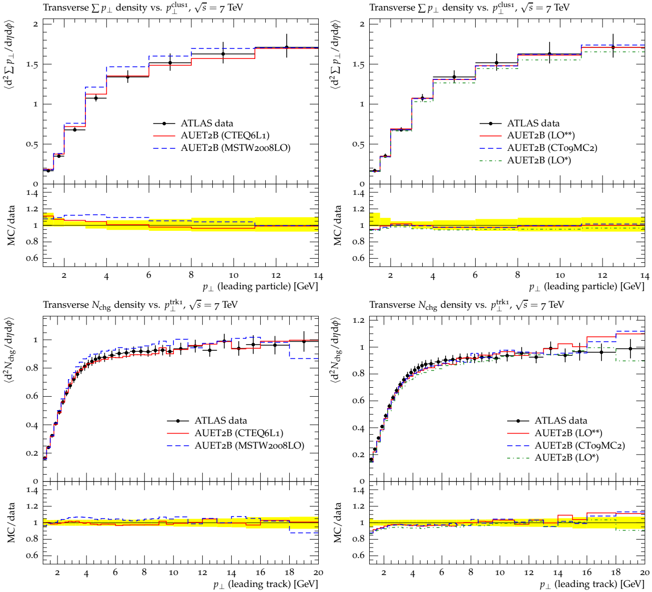
PYTHIA AMBT2B

MPI tunes to min bias data, using the previously shown shower setup



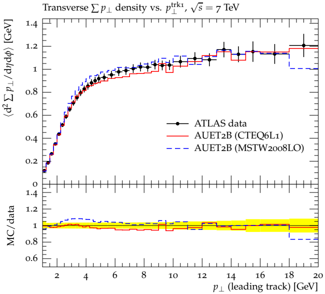
AUET2B

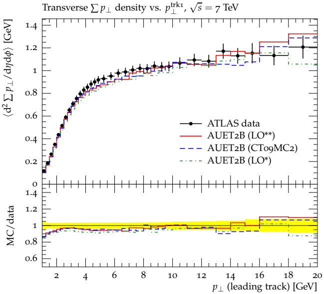
MPI tunes to underlying event data, using the previously shown shower setup

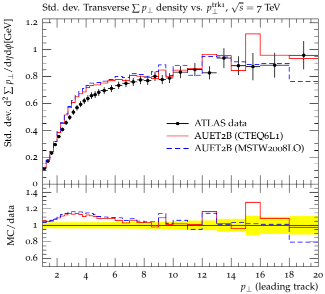


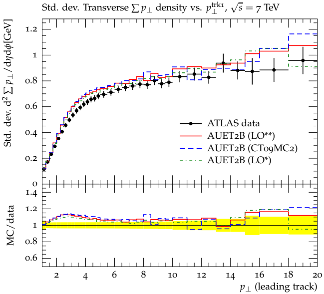
AUET2B

MPI tunes to underlying event data, using the previously shown shower setup



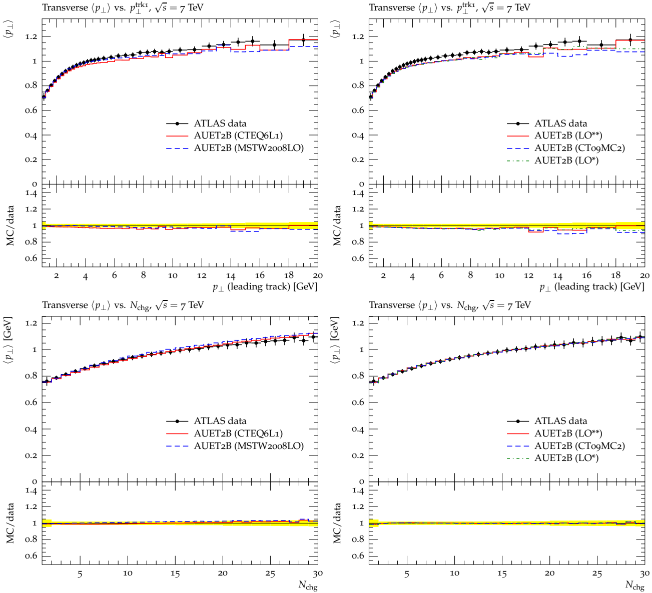






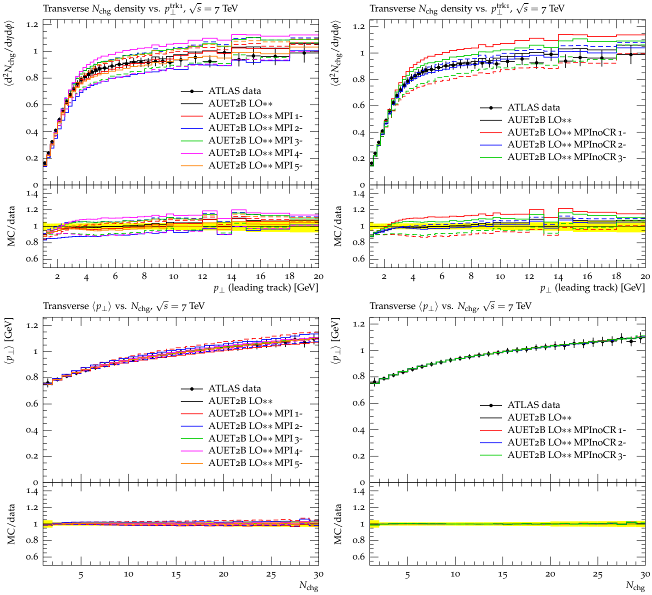
AUET2B

MPI tunes to underlying event data, using the previously shown shower setup

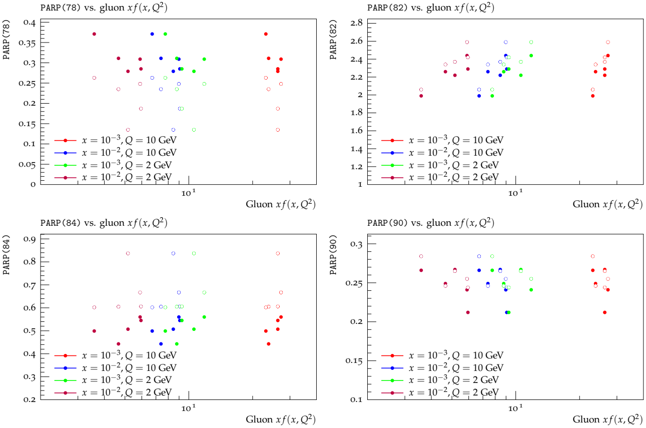


Eigentunes

Correlated $\Delta\chi^2 = 1$ parameter variations, with and without CR

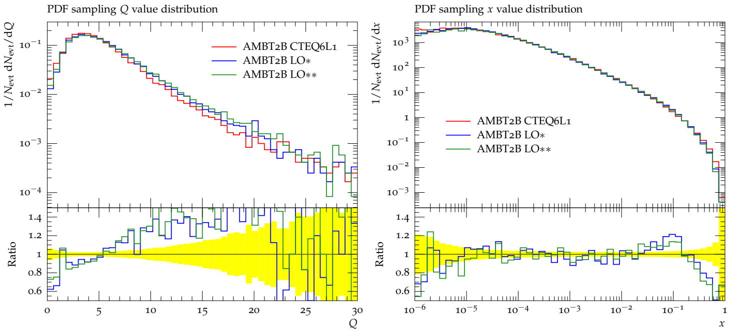


Understanding the mLO PDF effects on MPI



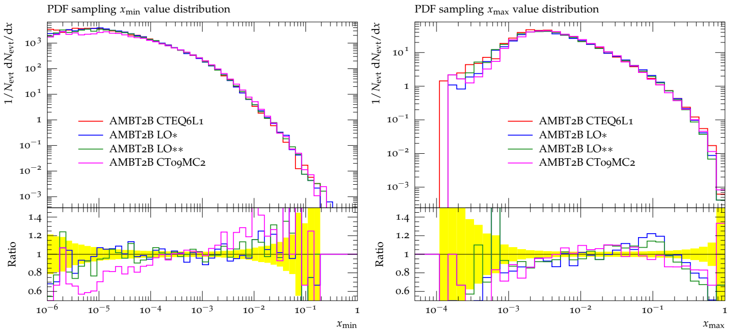
Correlations of parameter values with PDF $xf(x)$ values.

Understanding the mLO PDF effects on MPI



Differences in Q and x PDF sampling for different tunes.

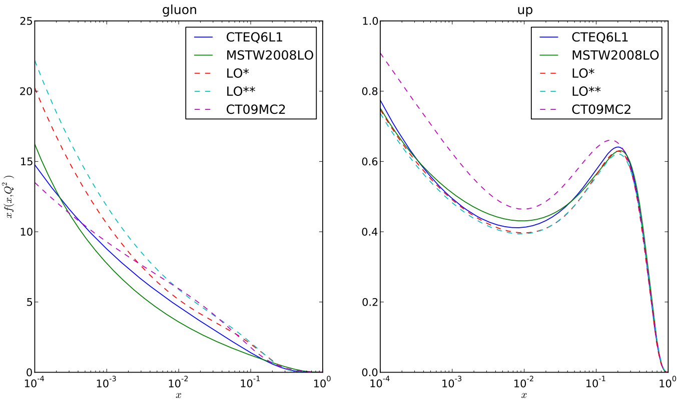
Understanding the mLO PDF effects on MPI



Differences in Q and x PDF sampling for different tunes.

Understanding the mLO PDF effects on MPI

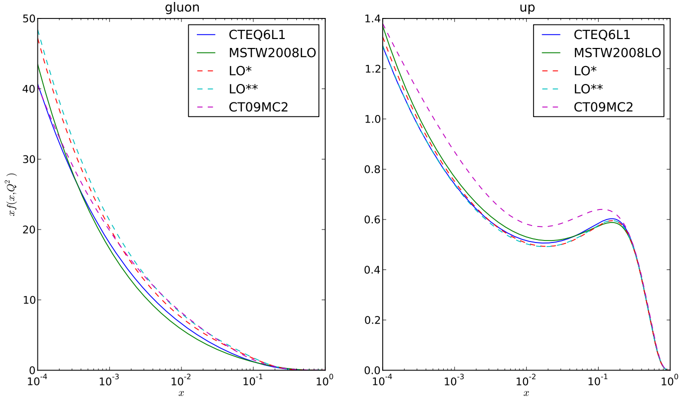
$Q = 2\,\text{GeV}$



Any obvious mLO vs. LO groupings in the PDFs themselves?

Understanding the mLO PDF effects on MPI

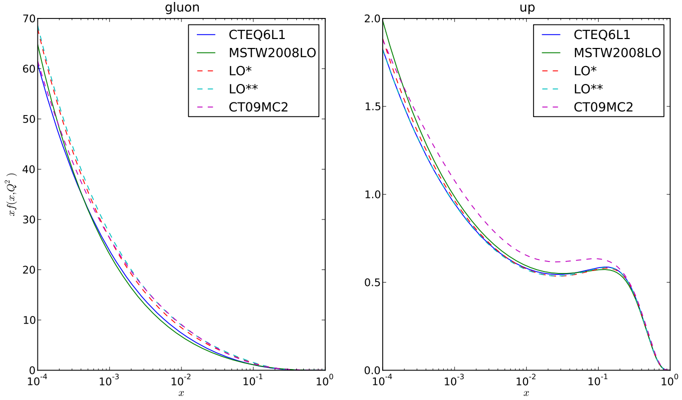
$Q = 5\,\text{GeV}$



Any obvious mLO vs. LO groupings in the PDFs themselves?

Understanding the mLO PDF effects on MPI

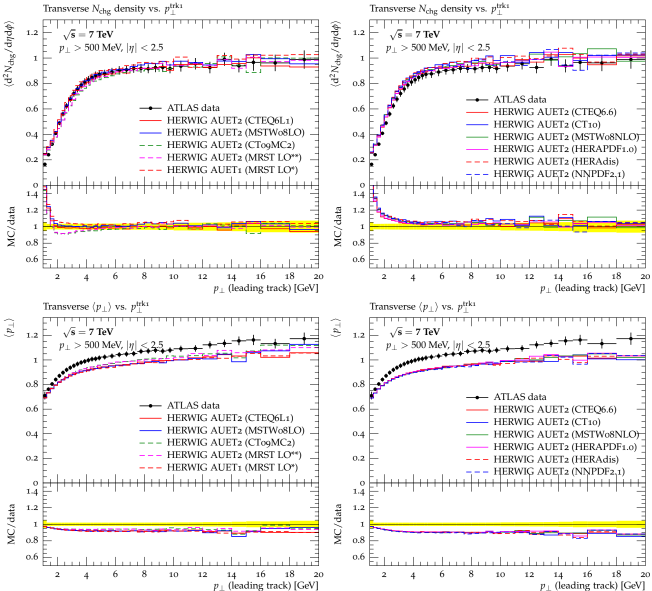
$Q = 10\,\text{GeV}$



Any obvious mLO vs. LO groupings in the PDFs themselves?

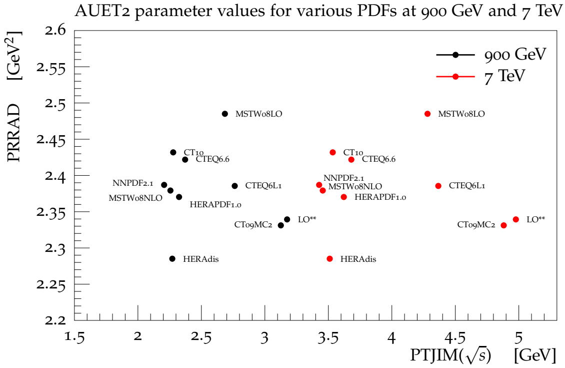
HERWIG+JIMMY AUET2

Last ATLAS tunes of JIMMY – good description of UE level, but MPI model is too restricted for more.



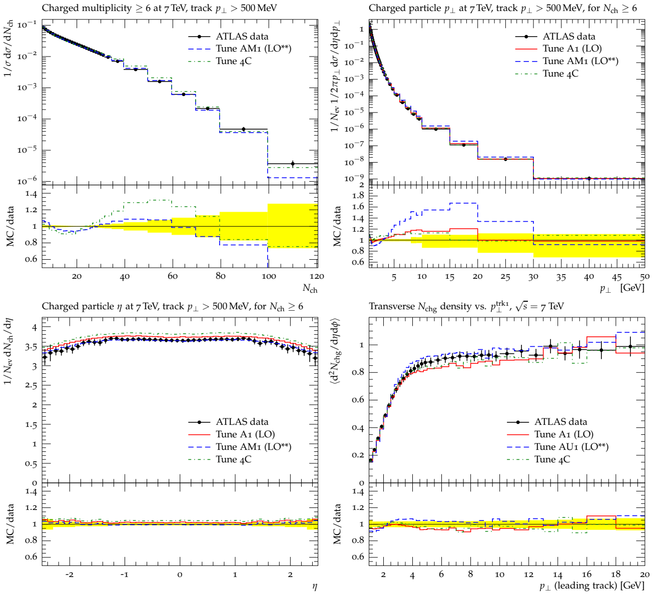
HERWIG+JIMMY AUET2

Last ATLAS tunes of JIMMY – good description of UE level, but MPI model is too restricted for more.

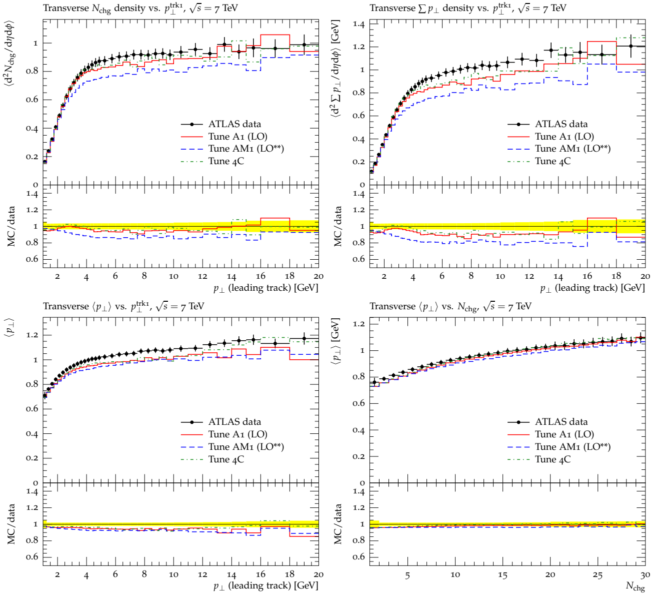


Scatter of MPI $p_\perp$ cutoff highlights groupings by PDF type.

Pythia 8 tunes



Pythia 8 tunes



Summary

- New sets of PYTHIA6 ATLAS tunes produced for MC11 simulation: AMB/UET2 and AMB/UET2B. Main features are shower tuning to QCD jet structure and use of many PDFs. PDF grouping features studied. MPI essentially described, if not fully understood, at 7 TeV.
- Interesting feature observed re. features in MPI-dominated plots when modified LO PDFs are used. Similar untuneable features seen for LO$*$, LO$**$, and CT09MC2. The latter is interesting because in many ways it is a much more distinct PDF from LO$*(*)$ than even the LO PDFs. Some ideas on how to identify the cause of these features. Also related to NP correction anomalies?
- Pythia 8 tunes also produced: reasonable description of data, but no very significant improvement over the existing 4C tune.
- Continuation studies for NLO PDFs and investigating the effect of an x-dependent proton size in Pythia 8. Future plans to test/tune hadronisation flavour content to LHC data, and to attempt fully consistent ME/shower setups.
- Have we shot ourselves in the foot? Tuning tool development has not encouraged e.g. POWHEG authors to understand tune/merging issues. Let's tune less, and get picky about what we allow ourselves to tune. **Models should be allowed to fail. . .**