Professor tunes of Pythia 6 to LO & mLO PDFs

Andy Buckley
IPPP, Durham University & UCL

PDF4LHC meeting, 2009-05-28

Modified LO PDFs

Traditional PDFs are in principle unique, process independent (by factorisation) physical quantities. In practice, dependence on the fixed-order ME used to unfold them from data.

MC generators are not physical truth — they are models with approximations. Matching a LO ME to an LO PDF may not give the best possible results. But using NLO PDFs with LO ME gens isn't always a good idea either.

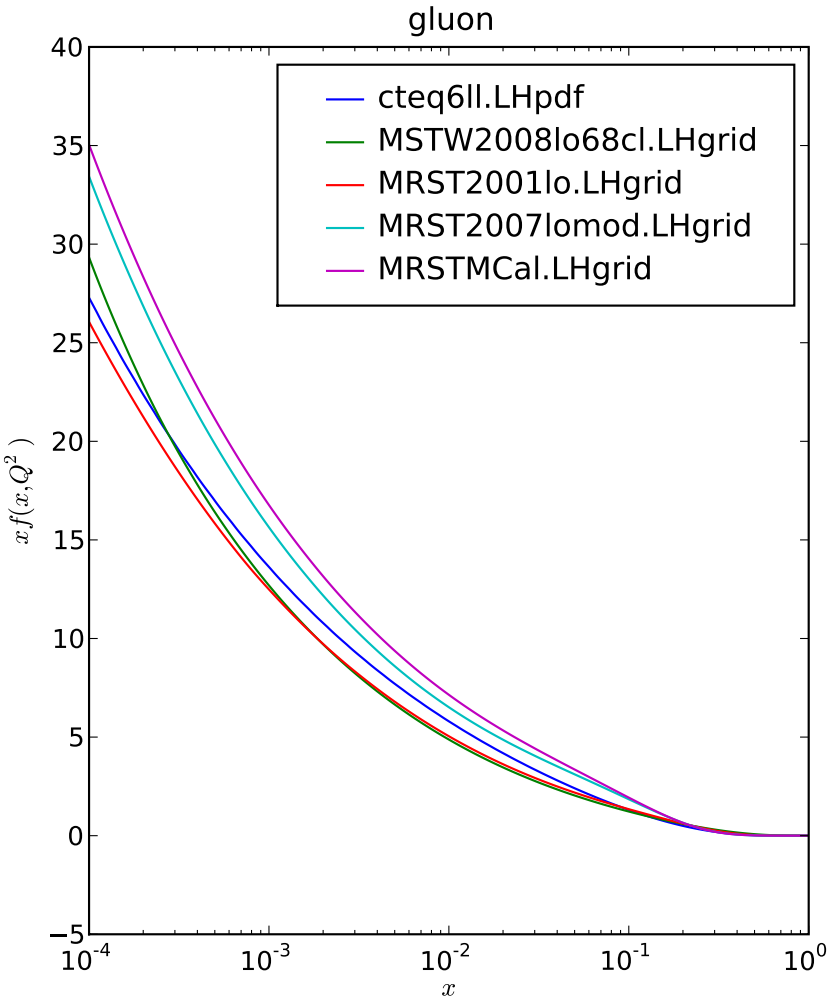
mLO PDFs developed for MRST sets by Thorne & Sherstnev:

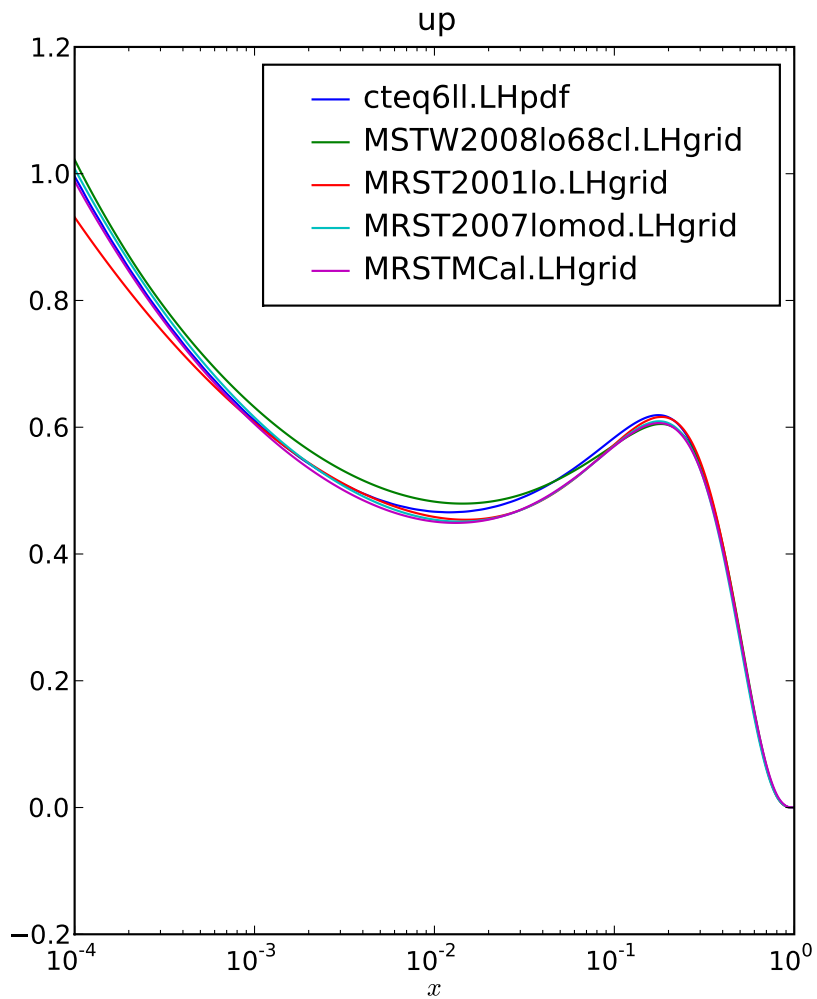
- LO* — relax momentum sum rule, NLO α_s running
- LO** — using $p_\perp^2$ rather than Q^2 as scale in α_s evol, like MC

Should be able to give better results with LO MC, but also affect initial state params. Can't draw any global conclusions unless we have comparable tunes of gens to several different PDF paradigms.

mLO vs. LO $f(x, Q^2)_i$

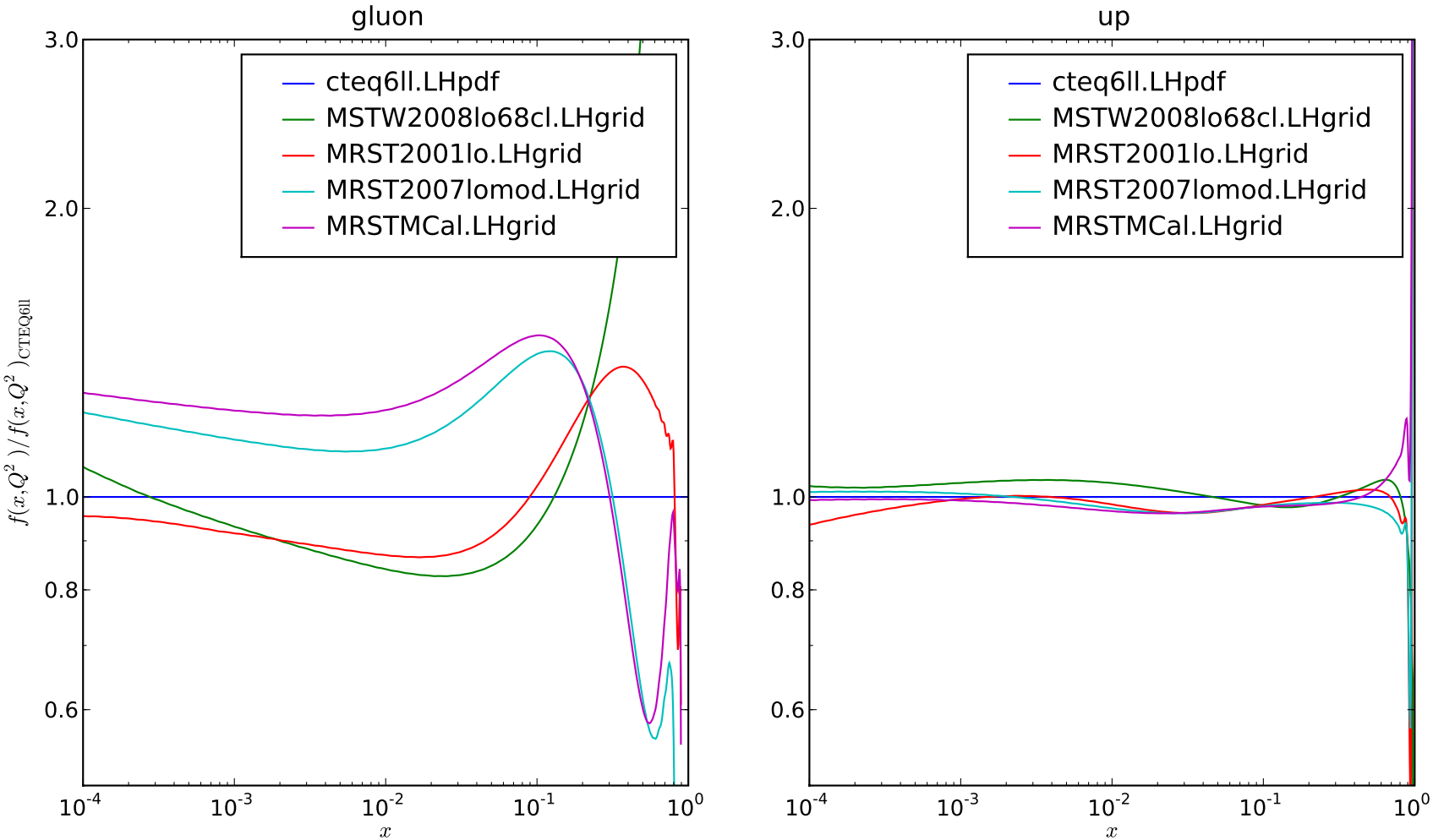
From LHAPDF 5.7.0, $Q^2 = 10\ \mathrm{GeV}^2$:





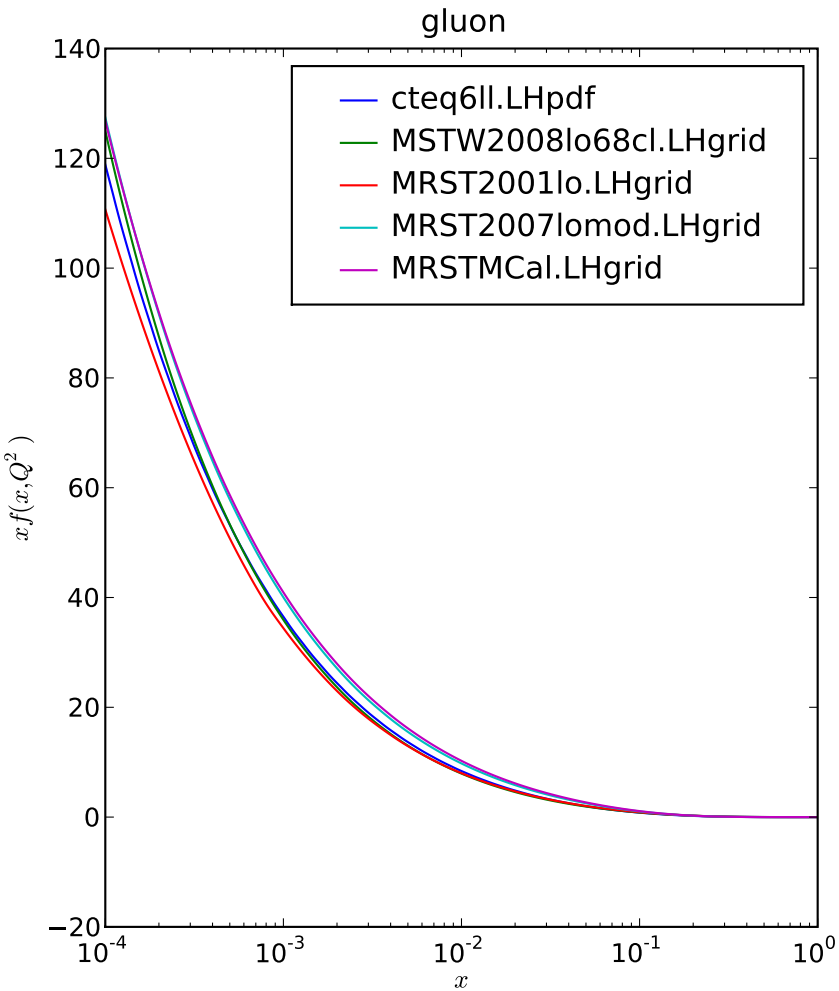
mLO vs. LO ratios $f(x,Q^2)_i \,/\, f(x,Q^2)_{\text{CTEQ6ll}}$

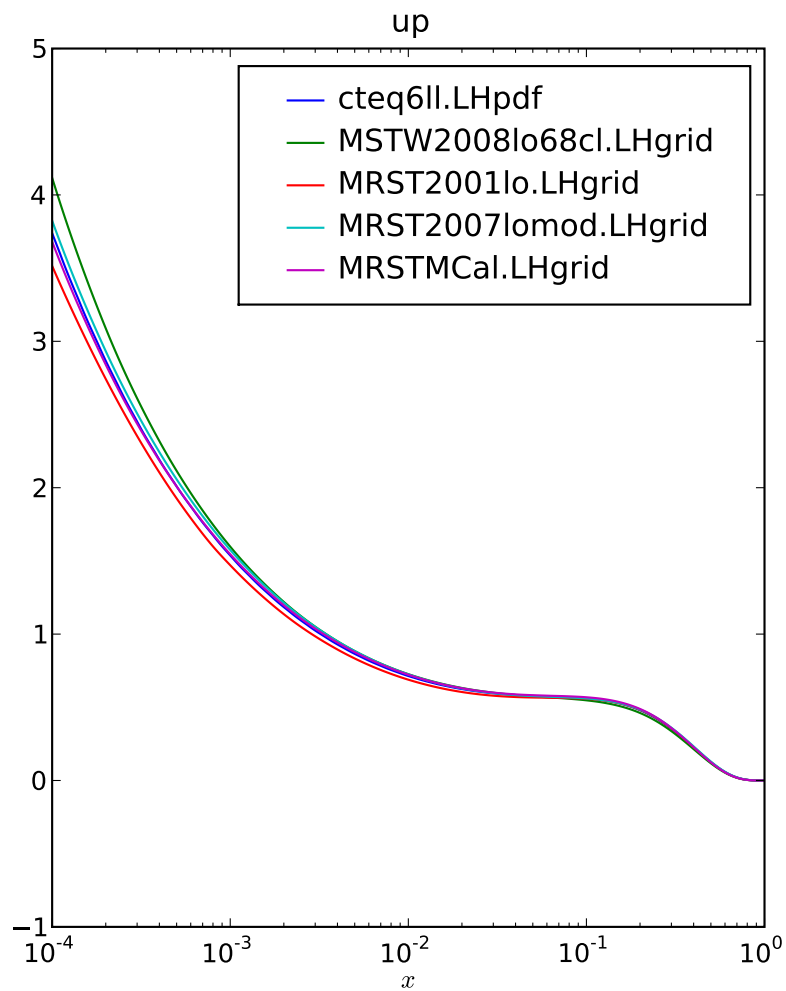
From LHAPDF 5.7.0, $Q^2 = 10\ \text{GeV}^2$:



mLO vs. LO $f(x, Q^2)_i$

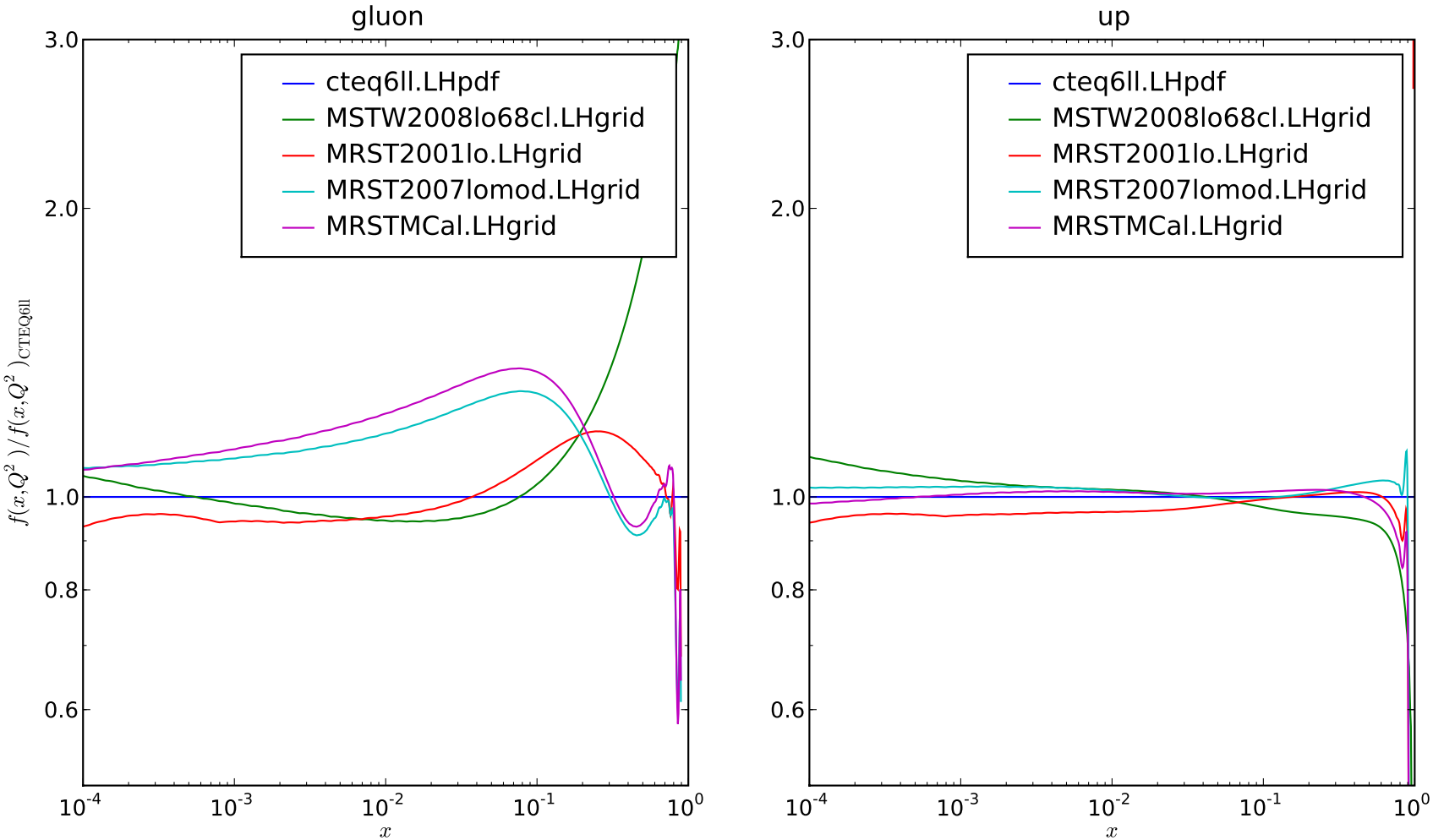
From LHAPDF 5.7.0, $Q^2 = 6400$ GeV^2:





mLO vs. LO ratios $f(x,Q^2)_i \,/\, f(x,Q^2)_{\text{CTEQ6ll}}$

From LHAPDF 5.7.0, $Q^2 = 6400\ \text{GeV}^2$:



Tunings

We have run Rivet/Professor tunes of Pythia 6.4.19* with input data using LO CTEQ6ll (current Atlas standard PDF) and the LO*(*) mLO PDFs. Roughly equivalent to Professor tune of Py6 with default PDF.

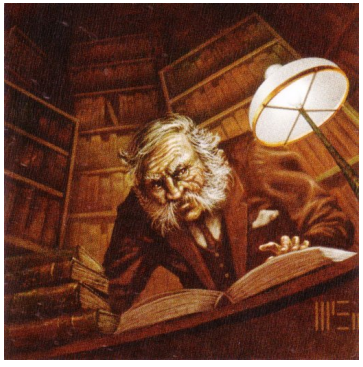
Comparing also to Atlas MC08 tuning by Arthur Moraes. Lots of known deficiencies! There are now many globally better tunes on the market.

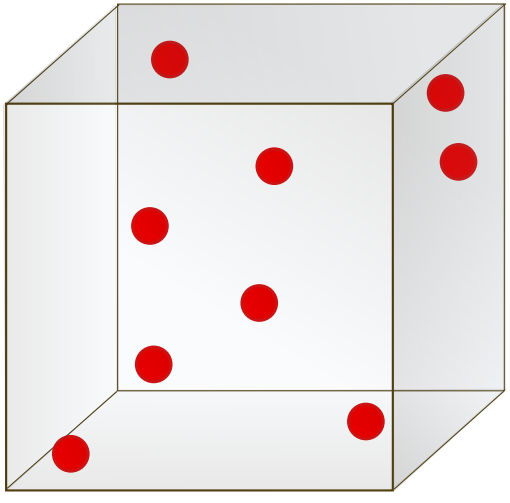
Professor tunes are based on a previous Professor tuning of Pythia 6 flavour and fragmentation parameters to LEP event shape and identified particle multiplicity / momentum spectrum data. MPI mode switches set in the "SØ" configuration.

Data used: **CDF 2001, CDF 2000 Z pT, DØ 2004, CDF 2002, CDF 2008 leading jet, MB & Drell-Yan.** Want more at smaller $\sqrt{s}$.

Professor

Professor tuning system (AB, Lund, Dresden/Berlin) extends DELPHI approach: polynomial binwise parameterisation with SVD. Implemented in Python with SciPy & PyMinuit.



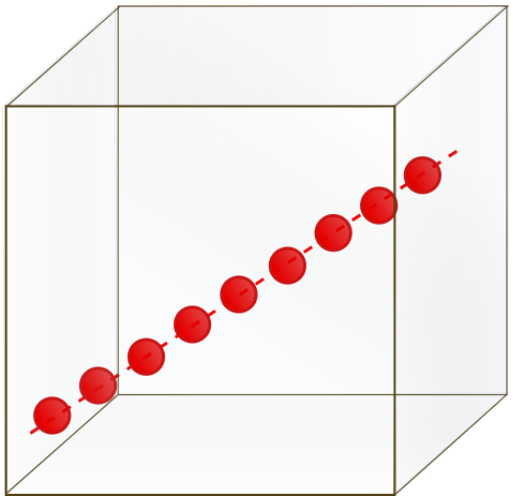


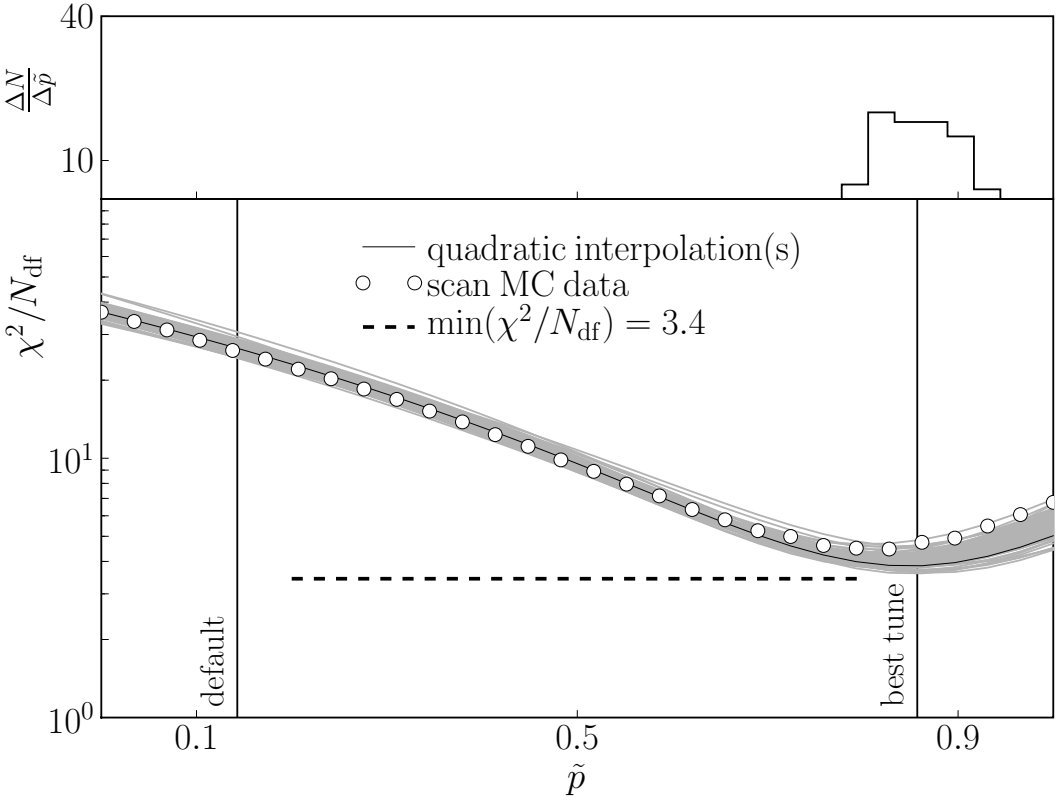
1. Sample N random MC runs from n-param hypercube using Rivet
2. For each bin b in each Rivet distribution, use the N points to fit an interpolation function using a singular value decomposition.
3. Construct overall χ^2 function and (numerically) minimise
4. Test optimised point by scanning around it in param and lin comb directions

Ask me for details...

Verifying the interpolation

A line scan of χ^2/N_{DoF} for Pythia 6 vs DELPHI event shapes through 3D param space (σ_{string}, Λ_{QCD}, Lund a) around a Professor-predicted minimum:





Similar behaviour up to 10D for UE: big improvements over existing tunes, new PDF tunes (e.g. hybrid LO*(*)) semi-trivial. Tunes & system to be used by Atlas and CMS this year.

Tune switches compared

ATLAS tune is essentially the default with new MPI model. Prof tunes based around Skands' SØ tune setup, since it gives good description of UE.

Switch		ATLAS tune	Professor tunes
MSTP(70)	ISR cutoff scheme	0	2
MSTP(72)	ISR–FSR max scale	1	0
MSTP(81)	MPI model	21	21
MSTP(82)	MPI overlap fn.	4	5
MSTP(88)	Remnant jn. collapse	1	0
MSTP(90)	Prim. $k_\perp$ compensation.	1*	0
MSTP(95)	Colour reconnections	1*	6
MSTJ(11)	Frag function	3	5

Not sure why ATLAS uses Peterson frag fn. — Prof Bowler tune to LEP data is much better for B hadronisation.

Tune parameters compared

Absolute values

Param		Atlas tune	Professor tunes CTEQLL	LO*	LO**
PARP(64)	ISR α_s scale	1.0	0.89	0.92	0.97
PARP(71)	FSR max virt.	4.0	1.72	1.29	1.20*
PARP(78)	FS colour reconn.	0.3	0.17	0.14	0.13
PARP(79)	Remnant x enh.	2.0	1.10	1.11	3.69
PARP(80)	Remnant cnctn.	0.1	———	0.01	———
PARP(82)	MPI $p_{\perp 0}$	2.1	1.83	2.10	2.28
PARP(83)	Matter overlap 1	0.8	1.72	1.68	1.67
PARP(84)	Matter overlap 2	0.7	———	N/A	———
PARP(89)	MPI reg ref scale	1800	———	1800	———
PARP(90)	MPI reg power	0.16	0.20	0.20	0.21
PARP(91)	$k_\perp$ width	2.0	1.85	2.15	2.11
PARP(93)	$k_\perp$ cutoff	5.0	6.86	6.79	5.08

Tune parameters compared

Ratios p/p_{default}

Param		Atlas tune	Professor tunes CTEQLL	LO*	LO**
PARP(64)	ISR α_s scale	1	0.89	0.92	0.97
PARP(71)	FSR max virt.	1	0.43	0.32	0.30*
PARP(78)	FS colour reconn.	1	0.57	0.47	0.47
PARP(79)	Remnant x enh.	1	0.55	0.55	1.85
PARP(80)	Remnant cnctn.	1	———	0.10	———
PARP(82)	MPI $p_{\perp 0}$	1.05	0.91	1.05	1.14
PARP(83)	Matter overlap 1	1.60	3.44	3.36	3.34
PARP(84)	Matter overlap 2	1.75	———	N/A	———
PARP(89)	MPI reg ref scale	1	———	1	———
PARP(90)	MPI reg power	1	1.25	1.25	1.31
PARP(91)	$k_\perp$ width	1	0.92	1.08	1.06
PARP(93)	$k_\perp$ cutoff	1	1.37	1.36	1.02

Comments on params

First, note that the UE/ISR mode switches are very different between Prof and Atlas: they are really different models. Esp. matter overlaps very different, but param meaning is totally different...

Strong trend between the 3 Prof tunes is the rise in $p_{\perp 0}$ to counter the increasing low-x gluon. This was independently tested in a manual tuning by Markus Warsinsky.

Prof wants (consistently) more MPI screening at LHC energies than default: backs up observations by Rick Field & Peter Skands. But intention is not to predict LHC UE characteristics — that really requires LHC data.

Caveats: most norms missing, and would like reference MB/UE data from lower energies than Tevatron in fit.

Tune quality

CTEQ6ll gives a *slightly* better fit than either mLO PDF against this UE data. But there's hardly anything in it.

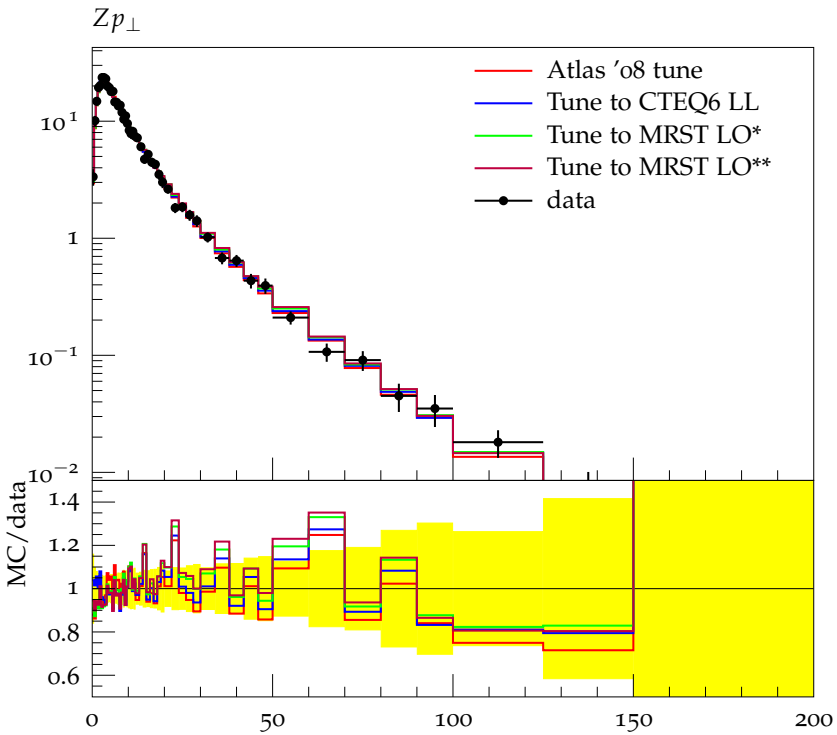
Normalisations to cross-sections largely missing, until this info stored in HepMC (from 2.5.0). Important!

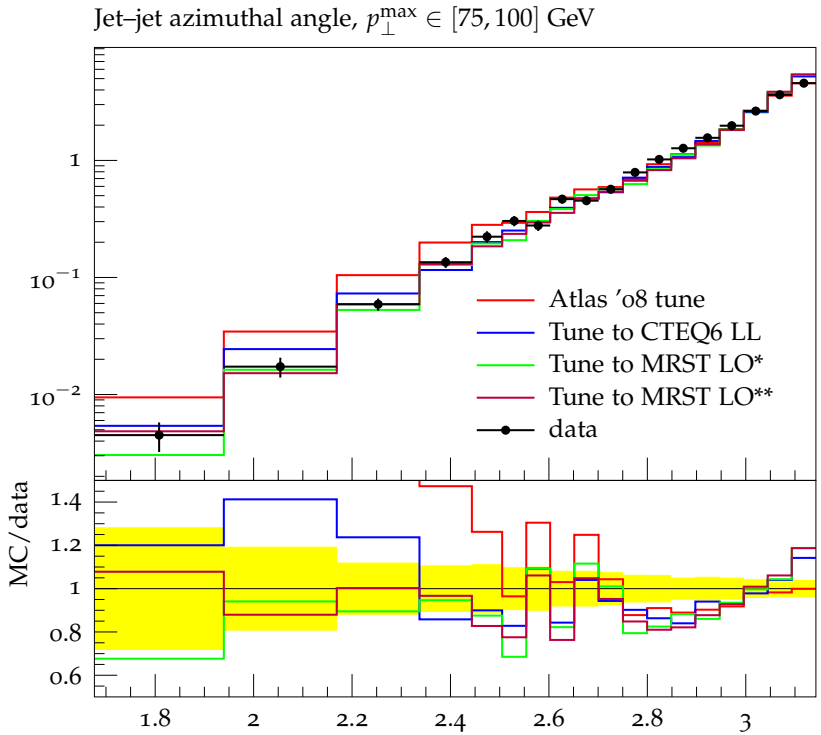
Problem with Z $p_\perp$ analysis — photon clustering has been added to development version of Rivet but missing here: could affect primordal $k_\perp$. Aside: publish DY dilepton-cone $p_\perp$!

Problems with CDF 2004 MAX/MIN cones (not used here). Hard to tell if problem is in implementation or paper. . . after much debugging we're stuck.

Selected distributions

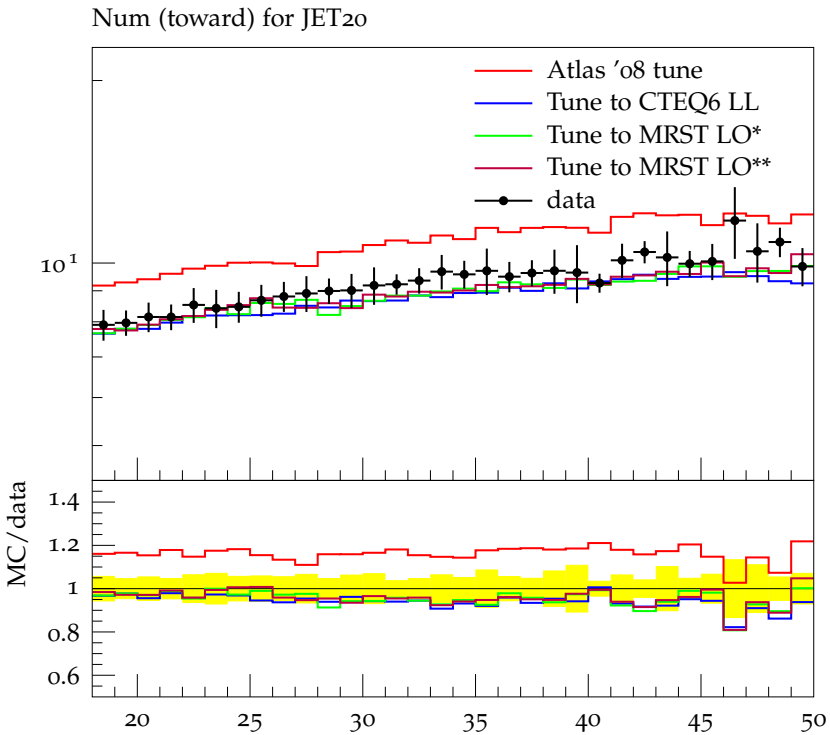
Constraints from CDF 2000 & DØ 2004

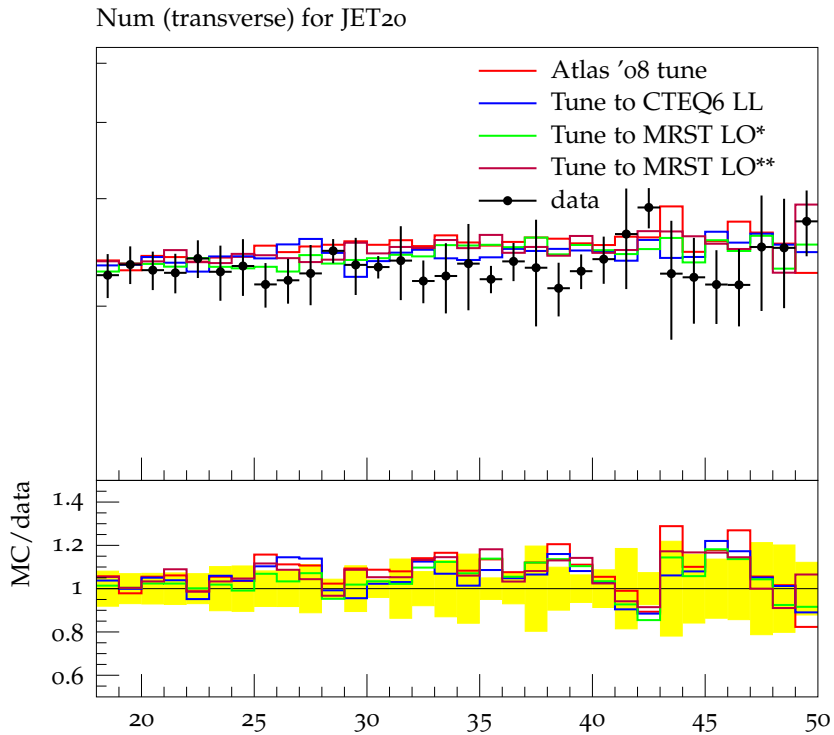




Selected distributions

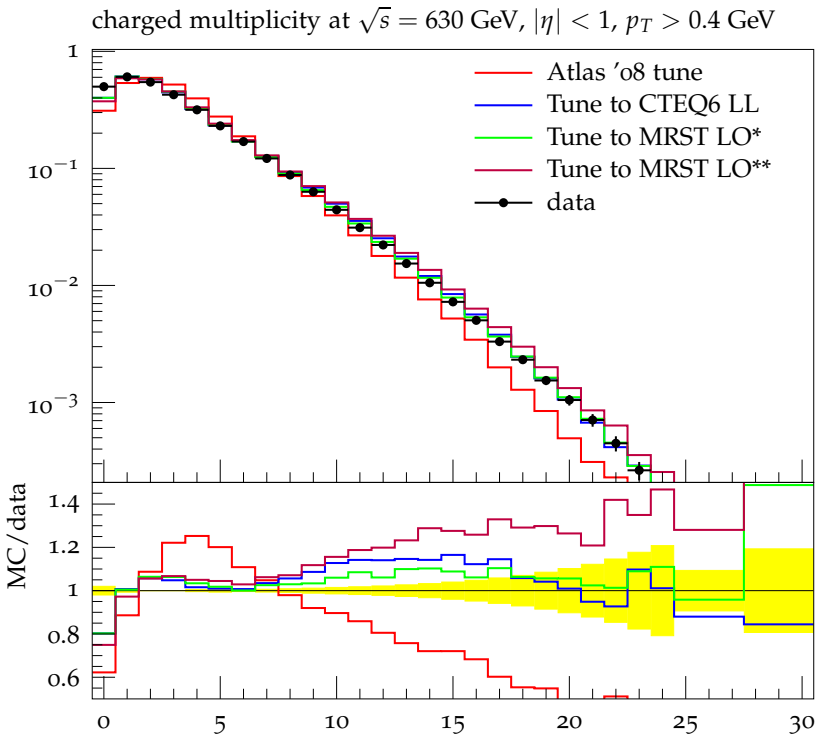
CDF 2001 Field–Stuart UE analysis ($\sqrt{s} = 1800$ GeV)

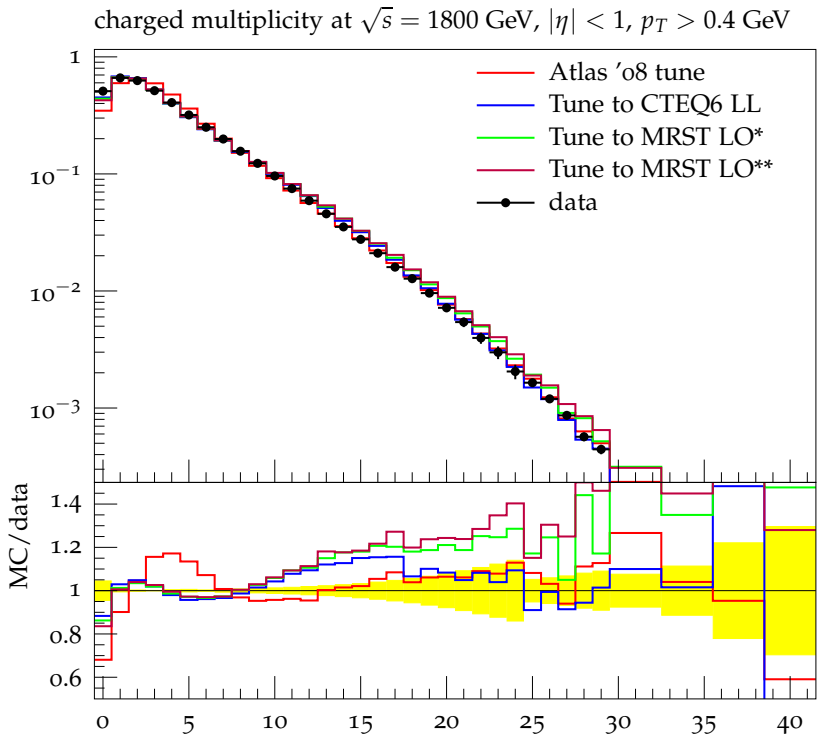




Selected distributions

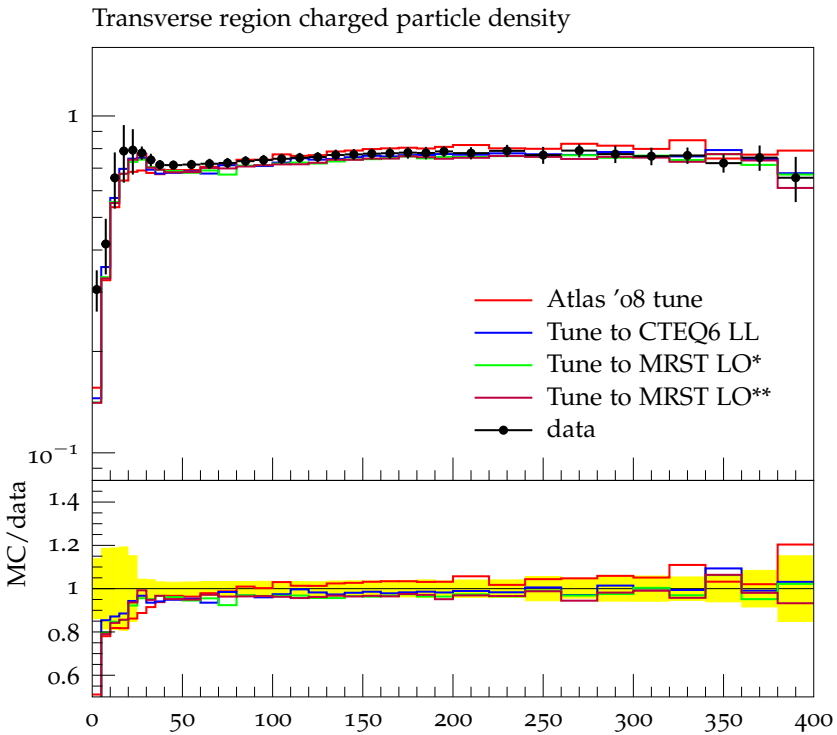
CDF 2002 min bias analysis ($\sqrt{s} = 630$ & 1800 GeV)

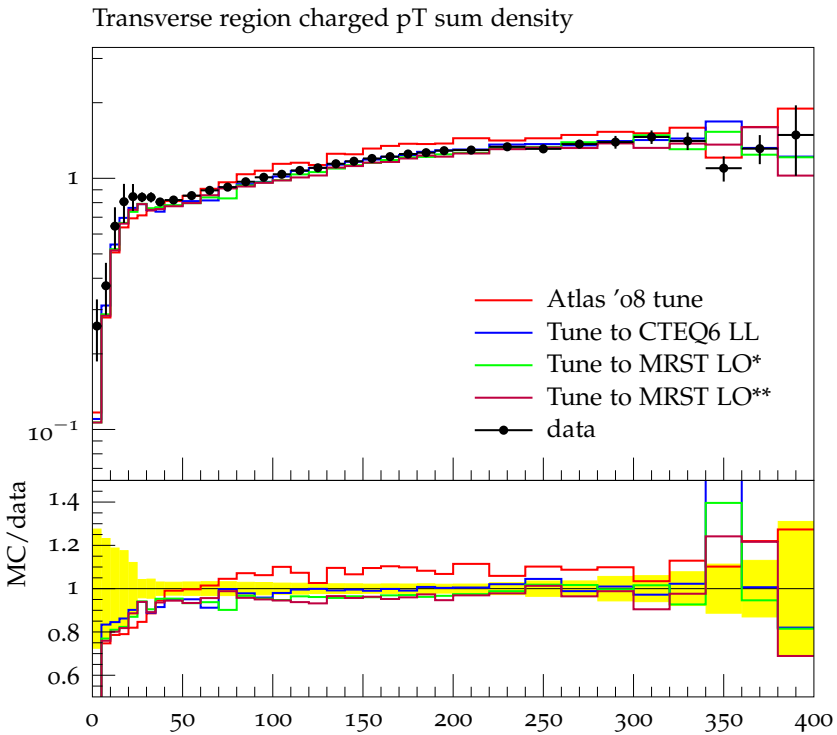




Selected distributions

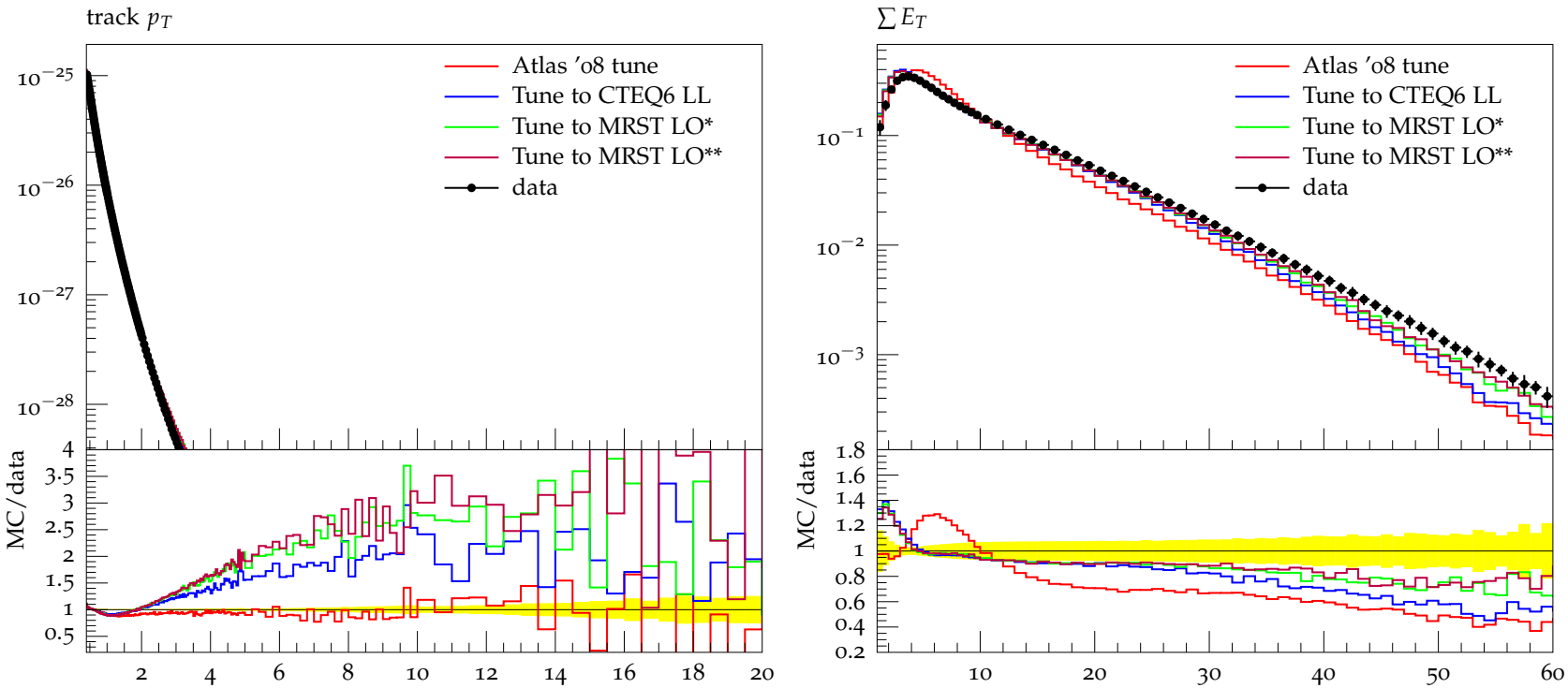
CDF 2008 leading jets UE analysis ($\sqrt{s} = 1960$ GeV)





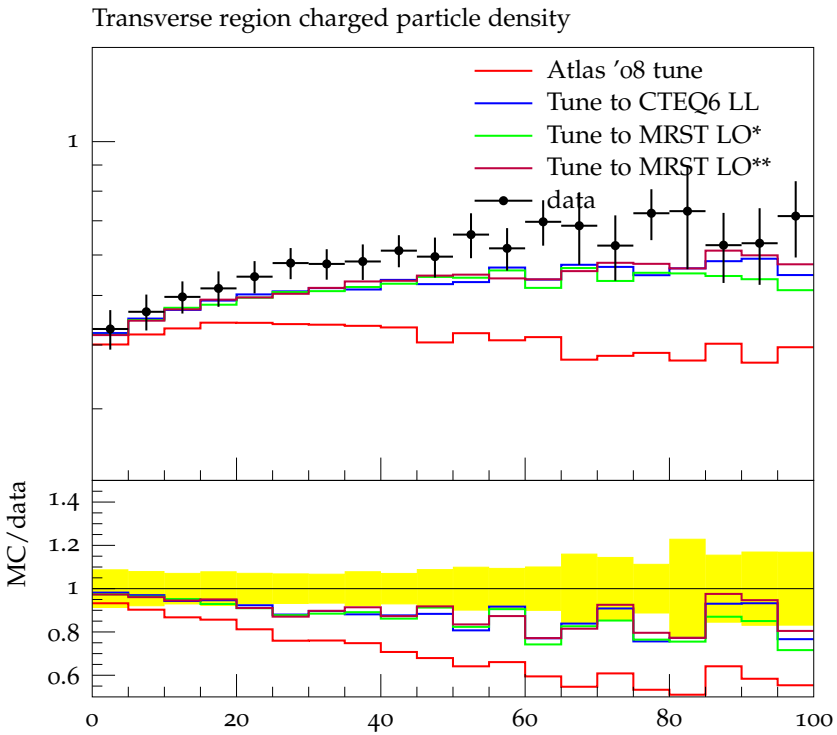
Selected distributions

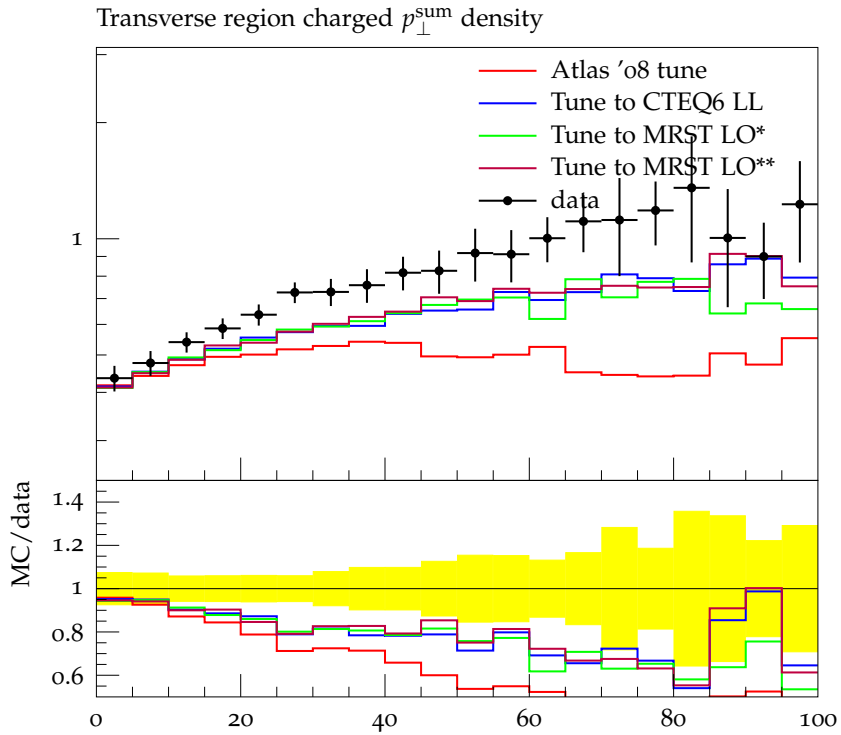
CDF 2008 min bias analysis ($\sqrt{s} = 1960$ GeV)



Selected distributions

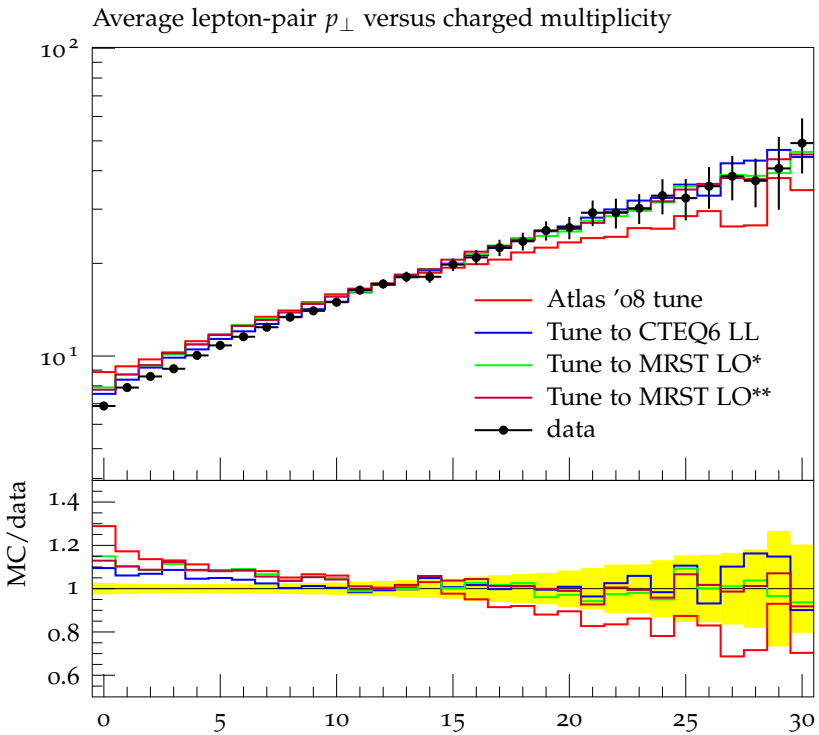
CDF 2008 Drell-Yan UE analysis ($\sqrt{s} = 1960$ GeV)

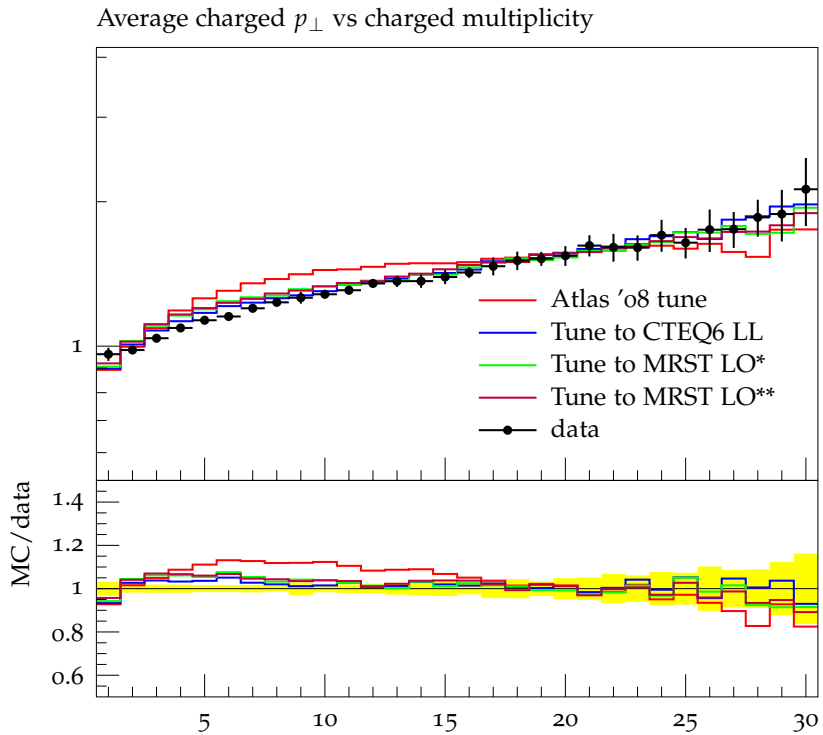




Selected distributions

CDF 2008 Drell-Yan UE analysis ($\sqrt{s} = 1960$ GeV)





Summary

It is possible to achieve good tunes with all 3 PDFs. All Prof tunes are better than the existing Atlas tune (FSR untuned $\Rightarrow$ DY UE problem?). All plots online at
http://www.ippp.dur.ac.uk/~buckley/py6-mlo/

mLO no better on UE obs, but then UE isn't meant to be the strength of mLO PDFs... And remember the (temporary) lack of normalisations.

mLO PDFs have been shown to give better-than-LO results in the signal sample test cases, and there is no opposition to their use from UE/MB data fits.

Main thing is to make a decision and then measure reality!