PDFs in MC and MC tuning

Judith Katzy (DESY)
On behalf of ATLAS MC group

outline

- Study: pdf effects in pythia's soft QCD models
- Use case: MC generators and pdfs used in ATLAS
- Discussion: open issues related to pdfs in MCs

New ATLAS tunes of Pythia6 and Pythia8 to different pdfs

- Pythia6: 2-stage tune of parton shower, multi-parton-interaction model (MPI) and color reconnection (CR) tunes done with 5 different pdfs:
  - LO*, LO**, CT09MC2, CTEQ6L1, MSTW2008LO
- Pythia8: MPI and CR tunes with 2 different pdfs:
  - LO**, CTEQ6L1

Study pdf effects in Pythia's soft QCD models

New ATLAS pythia6 tune

- 2-stage tune:
  1. Shower
  2. Multi-parton-interaction model (MPI) and color reconnection (CR)
- Tunes done for 5 pdfs: LO*, LO**, CT09MC2 , CTEQ6L1, MSTW2008LO

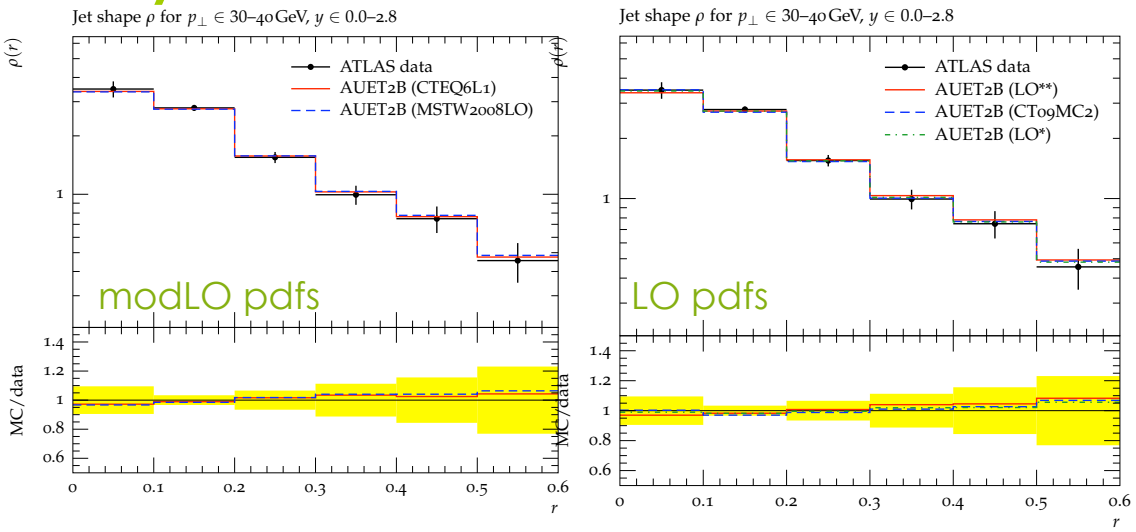
- Tunes are performed as χ^2 minimisation between data and an interpolated MC response function using the Rivet and Professor tools

- Distribution of statistical weight of the various observables during parameter optimisation identical for all pdfs

Pythia6 - shower tune

- Tune shower parameters:
  - Initial State Radiation kt cut-off PARP(62)
  - ISR scale factor on as evaluation scale PARP(64)
  - Λ_{QCD} for FSR off ISR partons PARP(72)
- Observables:
  - ATLAS and CDF Jet shapes
  - ATLAS trackjet fragmentation
  - ATLAS and D0 dijet decorrelations

Pythia6 – shower results



Good description of all observables reached after tuning

Description	Parameter	LO**	LO*	CT09MC2	MSTW2008LO	CTEQ6L1
ISR cut-off	PARP(62)	2.17	2.29	2.20	1.26	1.13
ISR scale factor on α_S eval. scale	PARP(64)	0.60	0.57	0.73	1.11	0.68
Λ_{QCD} for FSR off ISR	PARP(72)	0.43	0.42	0.36	0.49	0.53

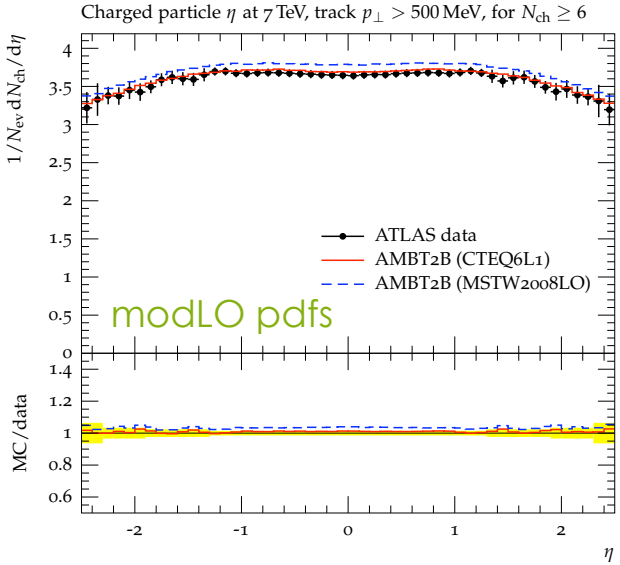
Optimised ISR cut-off parameters similar for LO pdfs and mLO pdfs
LO pdfs have highest values for Λ_{QCD} of FSR off ISR

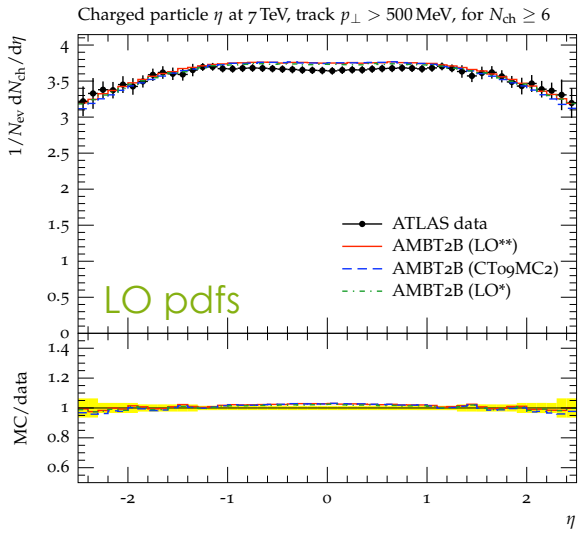
Pythia6 and Pythia8 – MPI tunes

- Tune parameters:
  - MPI: Pt0 cut-off of MPI model and its evolution with cms energy, matter distribution
  - CR: its strength and suppression of fast moving strings
- Main observables:
  - Min.bias: ATLAS minimum bias charged particle production data at 900GeV and 7 TeV: $dn_{ch}/deta$, dn_{ch}/dp_t, $\langle p_t \rangle$ vs N_{ch}, N_{ch} with different data samples varying in N_{ch} and p_{tmi}
  - Underlying event: ATLAS charged particle production in transverse region at 900 GeV and 7 TeV: N_{ch} vs p_t, Σ pt vs pt

    For pythia6 in addition CDF underlying event data
- Tunes:
  - Only to min.bias observables: AMBT2B (Pythia6) AM1(Pythia8)
  - Only to underlying event observables: AUET2B(Pythia6), AU1(Pythia8)
  - To all observables: A1(Pythia8)

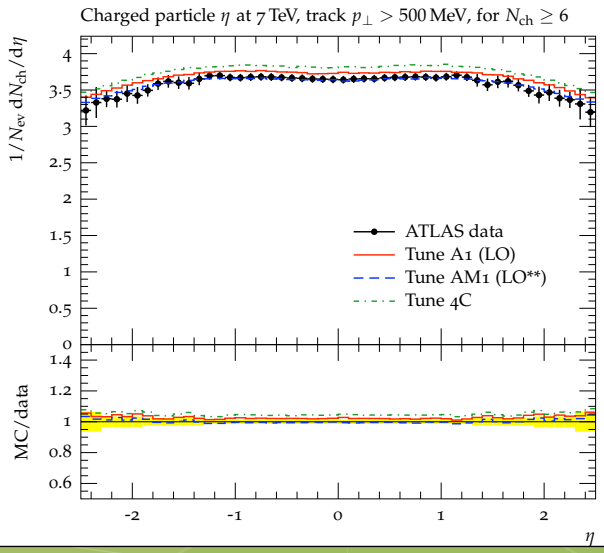
MB: Charged particle production





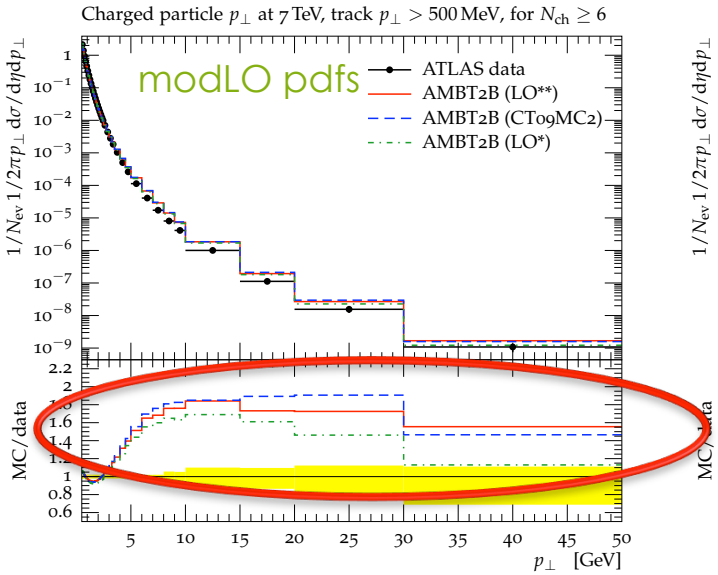
Pythia6

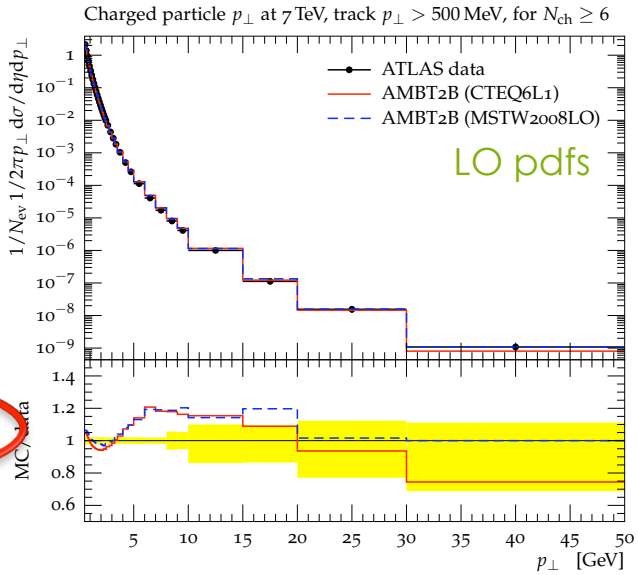
Good description of charged particle production in min.bias events



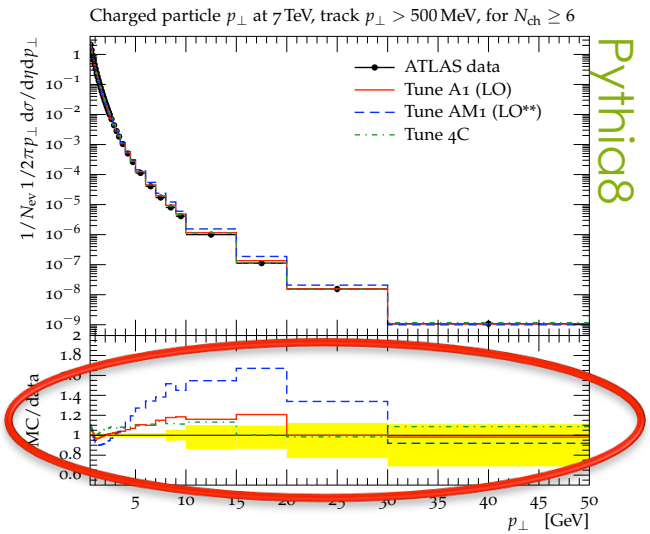
Pythia8

MB: charged particle p_t

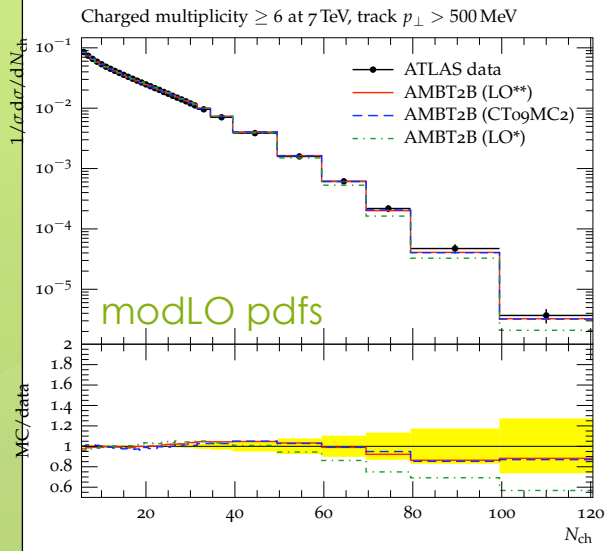


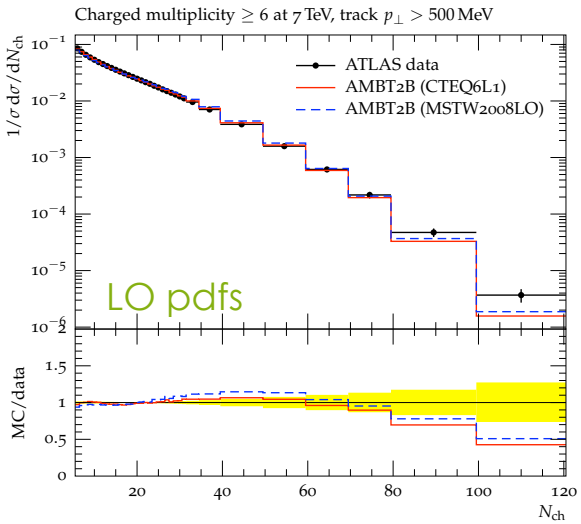


All MC adapted pdfs have problems to describe charged particle p_t while LO pdfs can describe it



MB: charged particle multiplicity

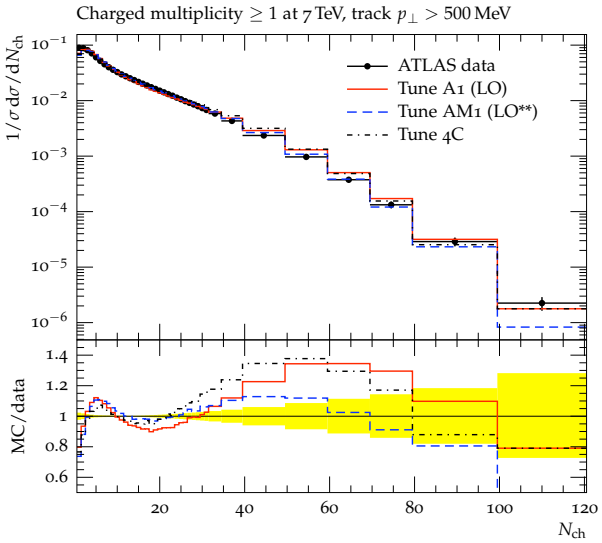




Pythia6

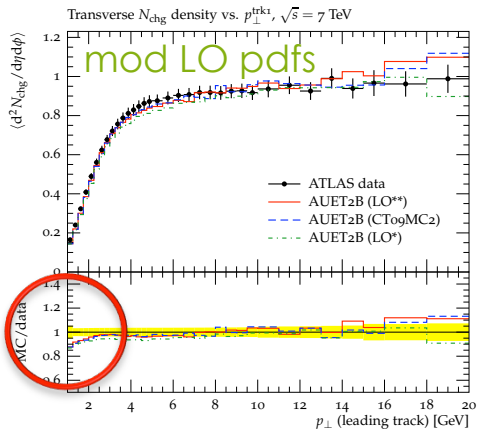
Pdfs that fail in pt spectrum are the ones describing the high Nch tail

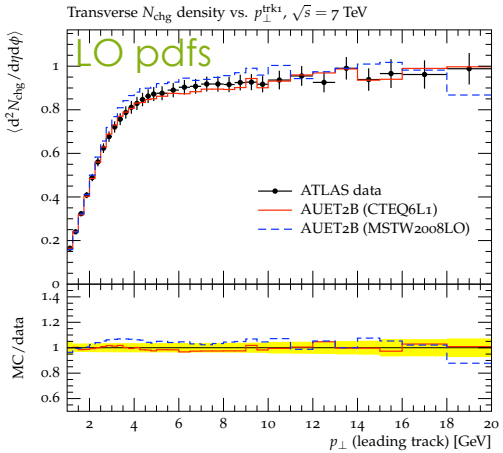
Effect even more pronounced for events with Nch >20 and charged particles with pt>100 MeV



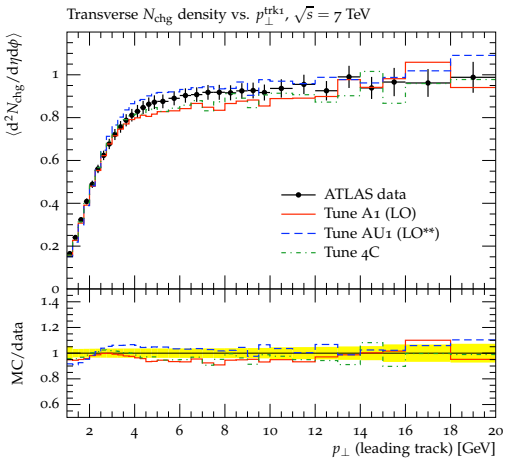
Pythia8

Charged particle density in underlying event





Pythia6

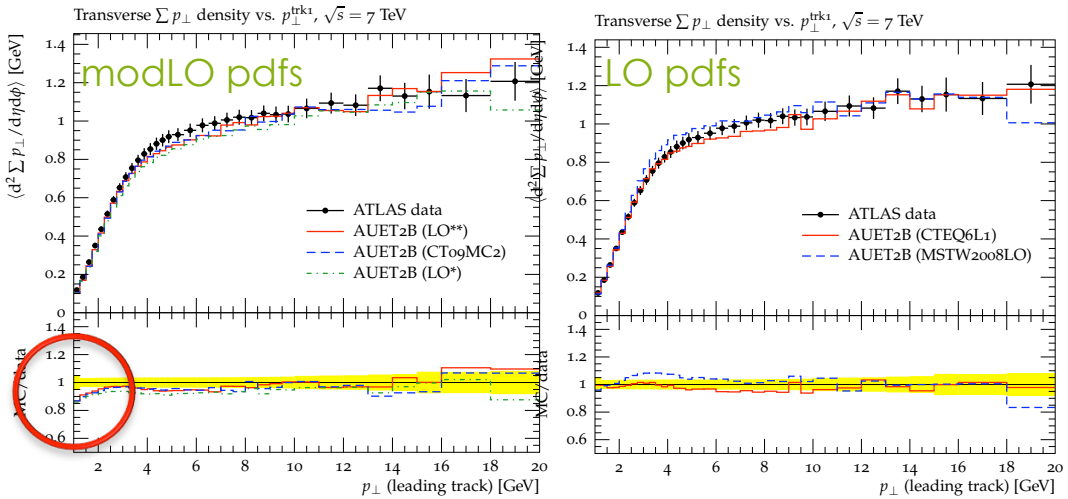


Pythia8

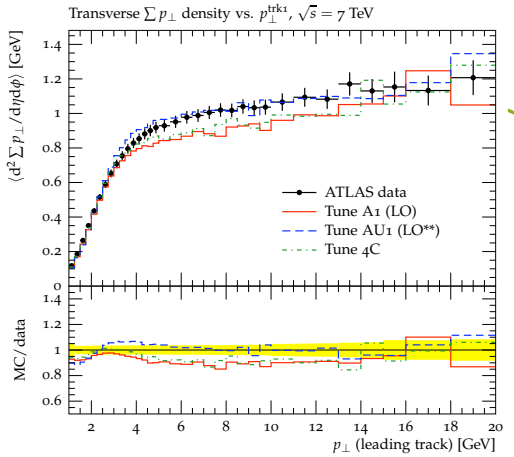
Slight deviation of mod LO pdfs in "minimum bias" region due to incompatibility of slopes in UE ramp and plateau

LO pdfs very good description – CTEQ6L1 best

Σp_t density in underlying event



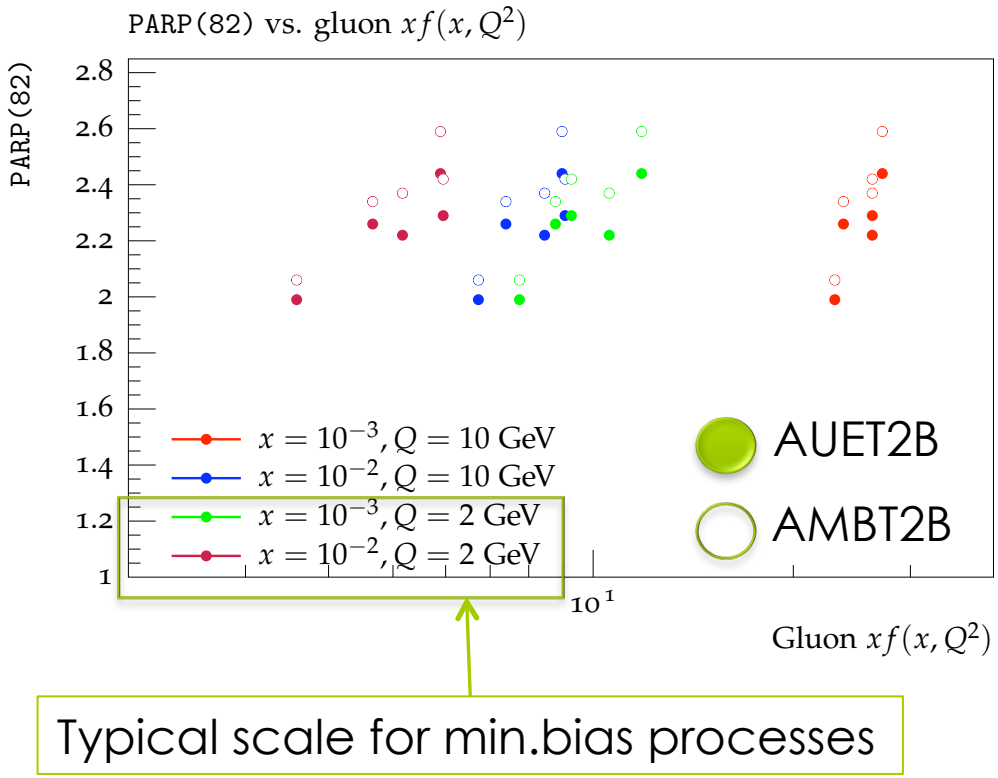
Pythia6



Pythia8

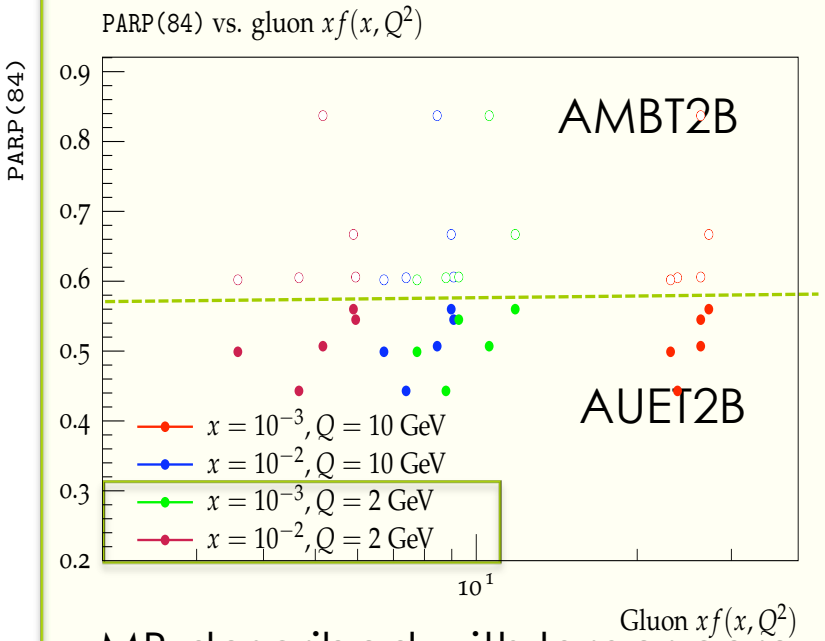
Same behaviour as N_{ch} density:
Min.bias region problematic for mod LO pdfs in Pythia6

Influence of gluon density on ptmin cut-off



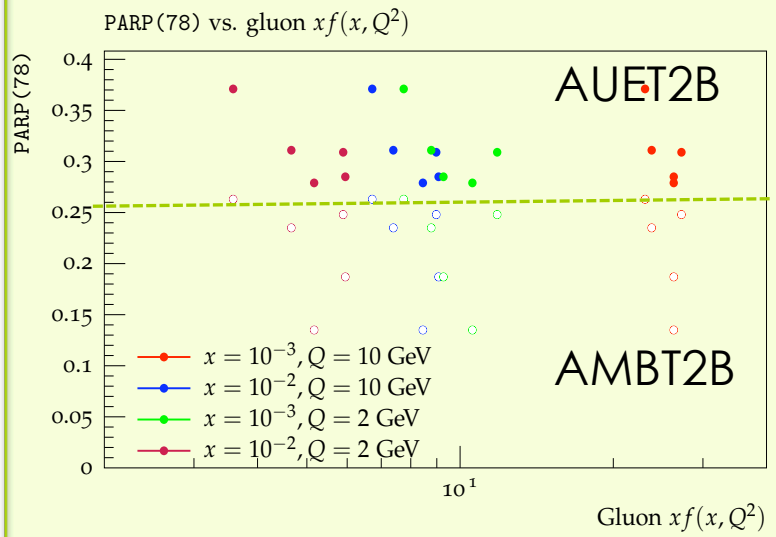
At low scales p_{tmin} cut-off correlated with gluon density (as expected from the model)

Influence of gluon density on model parameters



MB described with larger core of double Gaussian than UE

MB described with less color reconnection than UE data



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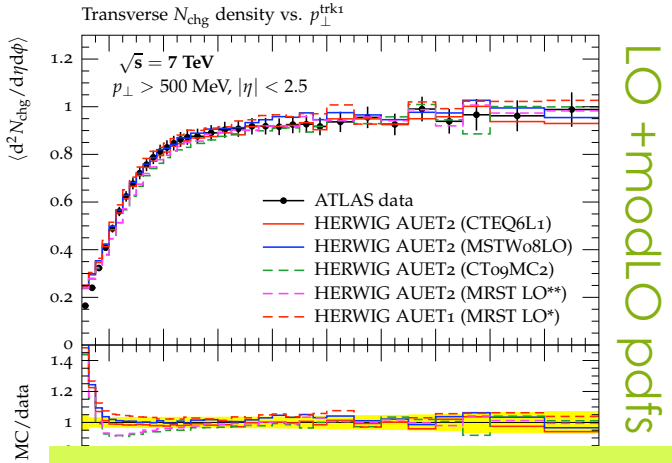
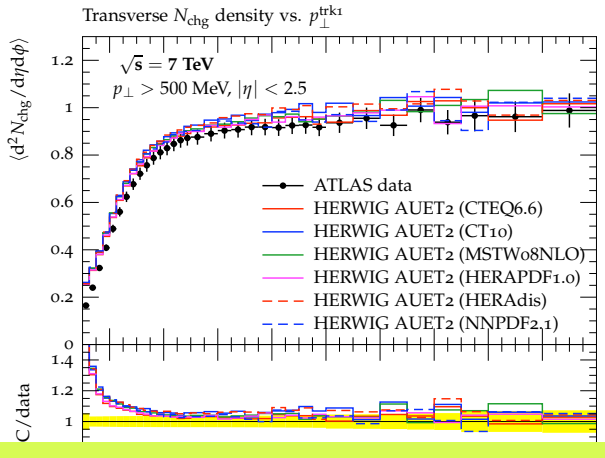
Herwig tunes with multi-pdfs

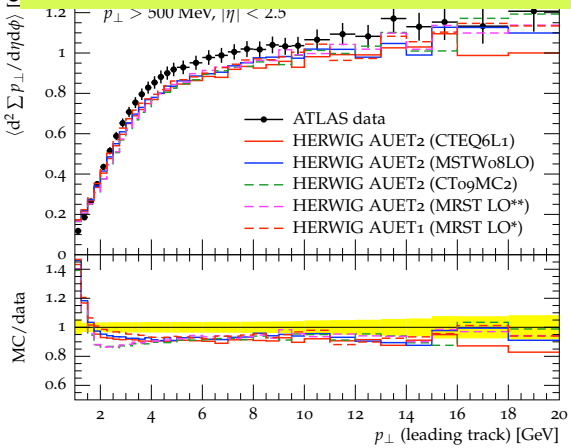


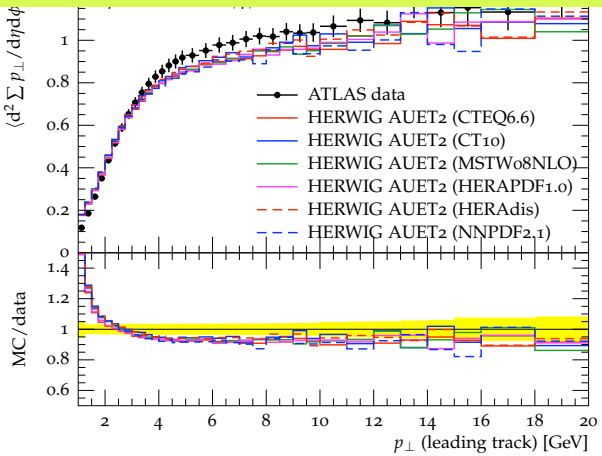
LO +modLO pdfs



NLO pdfs

Model doesn't aim to describe min.bias
Model fails to describe Nch and Σpt with one parameter set
Similar quality of data desciption for all pdfs





Conclusions from pythia tunes with different pdfs

- MC adapted pdfs fail to describe pt spectrum of min.bias data
- Tension in underlying event distributions between low p_{tlead} rise and high p_{tlead} plateau with MC adapted pdfs
- LO pdfs – in particular CTEQ6L1 – give best describe of data
- Tunes to NLO pdfs are under study

LO vs MC adapted pdfs

- LO pdfs best in describing min.bias distributions
- MC adapted pdfs okay for underlying event and their use is justified through the behaviour at the hard ME

MC generators & their pdfs in ATLAS

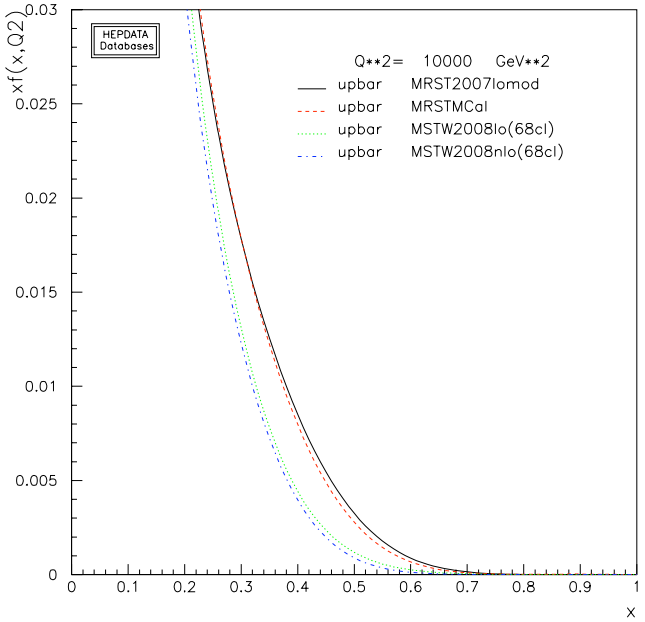
- NLO generators (POWHEG,MC@NLO) with NLO pdfs used where available – mostly SM with low parton multiplicity final state
- POWHEG allows to use different pdfs for ME and shower part, i.e. NLO in ME, LO for pythia/herwig shower
- LO generators still needed for multi-leg final states, soft QCD (pile-up!), SUSY and other BSM models
- Still need for appropriate pdfs describing LO models – currently LO pdfs seem to do this best
- Updated LO pdfs from the pdf fitters welcomed…

Questions and discussion points

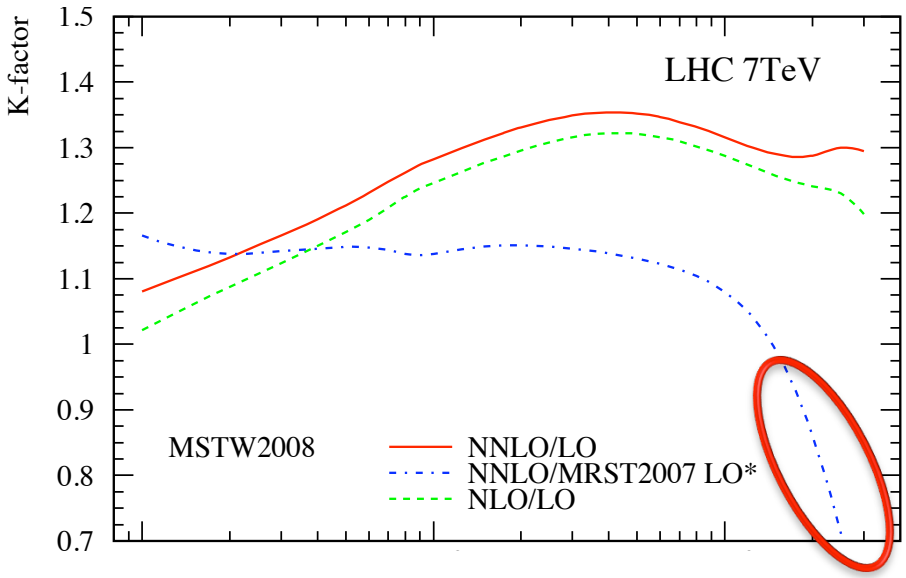
Guidelines on uncertainties due to LO pdfs?

- Option 1:
  - Check whether results depend significantly on pdf
  - quote pdf used for the calculation/results
  - Derive results with at least 2 different pdfs to show that pdf dependence exist
- Option 2:
  - Derive results with different LO pdfs and take variations as systematic uncertainty
- Deprecated treatment:
  - Take error from NLO pdfs (where they exist) and vary around central value of LO pdf
- Option 3:PDF fitters to provide error sets for LO pdfs as e.g. MSTW2008LO and experimentalist use these
- More options…?
- How to relate with other systematic uncertainties like scale variations, model uncertainties…?

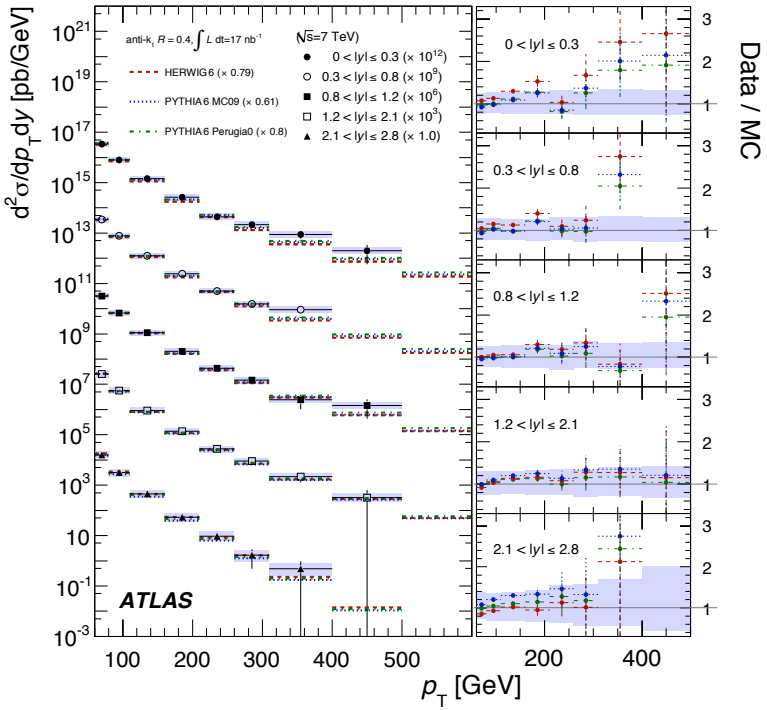
Problem with LO* pdf for high mass final states



NC DY cross section



QCD dijet pt spectrum



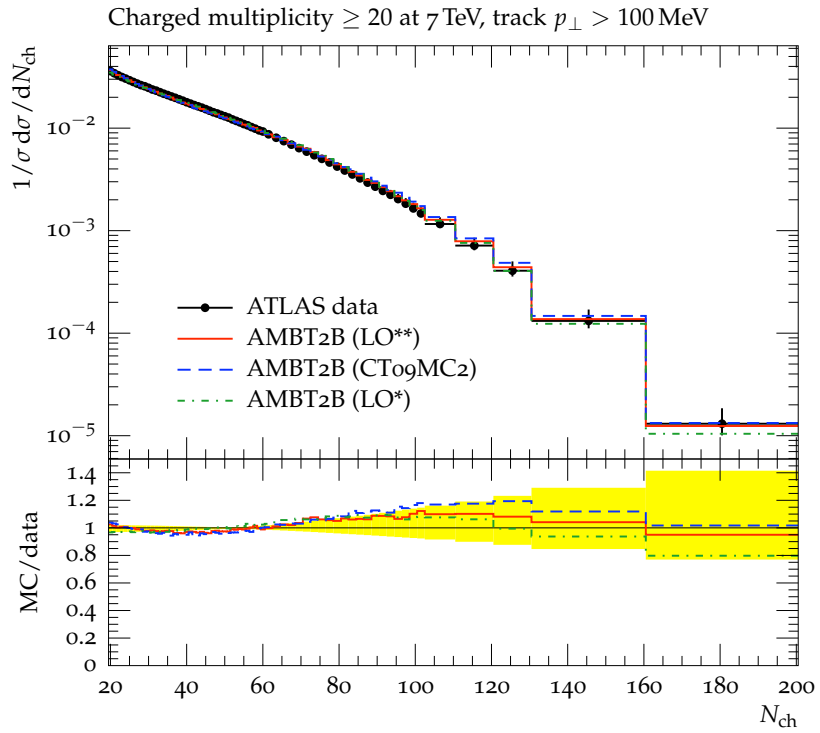
Note: only one NLO MC generator for this process yet (POWHEG)

Analysis also use NLOJet++ with Correction factors for hadronisation Derived from Pythia and Herwig

Flat k-factors for modLO pdfs possible?

Back-up slides

Backup – Nch with pt>100MeV



- MC@NLO+herwig, same pdf
- POWHEG+pythia/herwig with different pdfs possible
- Alpgen LO pdf
- Pythia, Herwig and other LO generators for SUSY, exotic models and soft QCD

Optimised Pythia6 parameters

Tune type	PDF	PARP(77)	PARP(78)	PARP(82)	PARP(84)	PARP(90)
AMBT2B	CTEQ6L1	0.357	0.235	2.34	0.605	0.246
	MSTW2008LO	0.533	0.263	2.06	0.602	0.284
	MRST LO*	0.659	0.135	2.37	0.837	0.265
	MRST LO**	1.101	0.248	2.59	0.667	0.255
	CT09MC2	0.900	0.187	2.42	0.606	0.244
AUET2B	CTEQ6L1	0.491	0.311	2.26	0.443	0.249
	MSTW2008LO	0.597	0.371	1.99	0.499	0.266
	MRST LO*	0.845	0.279	2.22	0.507	0.267
	MRST LO**	0.901	0.309	2.44	0.560	0.241
	CT09MC2	0.869	0.285	2.29	0.545	0.212

Xg(x)