New Tunes of PYTHIA6 to Minimum Bias and Underlying Event Data

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WHAT

WHY

HOW

RESULTS

Introduction

LHC experiments at CERN: new energy regime

Understanding of Proton – Proton Collisions

- $\sigma_{tot} = \sigma_{elastic} + \sigma_{inelastic}$

  @ 7 TeV: ~100mb ~25mb ~70mb

- Inelastic proton – proton collisions are a mixture of hard and soft processes, and are difficult to simulate.
- The general-purpose Monte Carlo generators attempt to describe them

Current QCD models

Perturbative approach	Phenomenological approach
High Pt scattering (pQCD)	Low Pt scattering (non pQCD)
One Free parameter	Many Free parameters
$\alpha_s (Q^2)$	e.g. P_{T0} , P_{CR} …
Well known	Parameters need to be tuned to describe the data

Tuning

"The process of finding the optimal parameter set of the model for which the MC agree with the data best"

Contemporary Research

- Testing QCD models and tuning their free parameters has started in early 1980's using $e^+e^- \rightarrow$ hadrons
- In 2002 by R.Field , Underlying Event data using ppbar interaction at Tevatron (simple manual parameters adjustment)
- In 2008, pre LHC tunings to UE and Min Bias
- Increased activity , LHC data available since 2010
- ATLAS Tuning Task Force
- Tuning procedure turned out to be more complex than originally thought

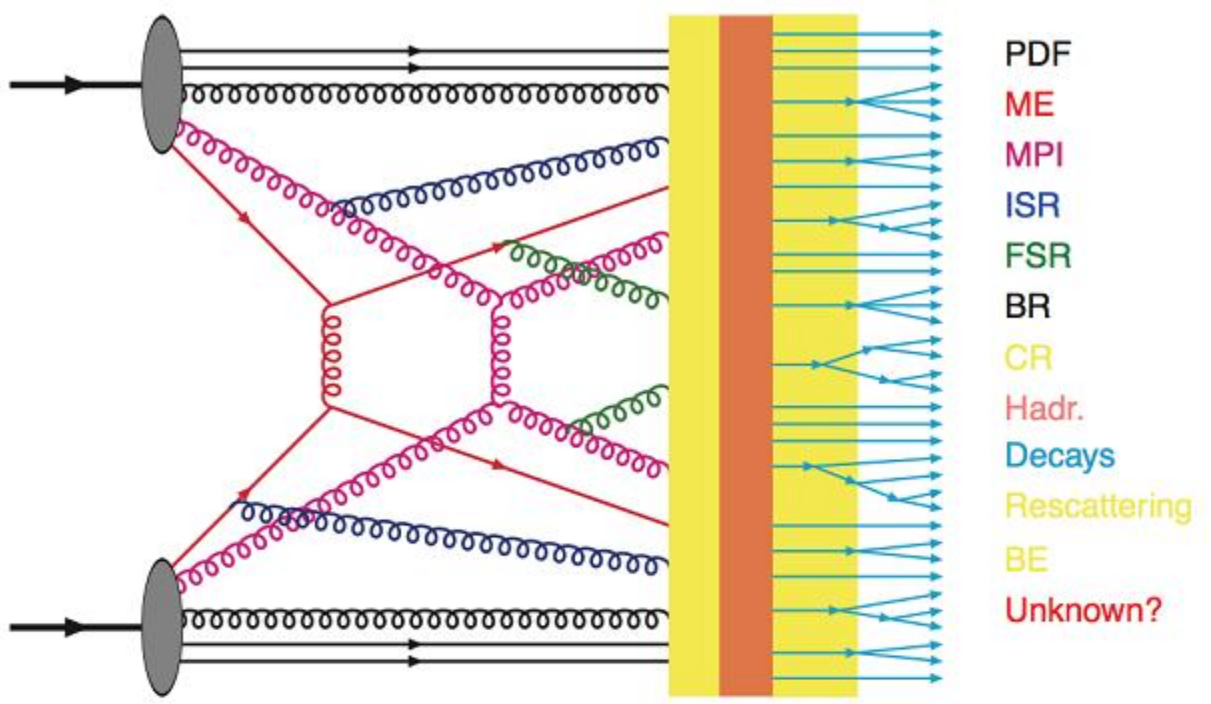
Tuning Method

- **Linear parameterization of Observables**
  - Most efficient with the possibility of iteration
  - Allows variation of many parameters
- **Monte Carlo generation**
  - Selection of central values for the parameters
  - each parameter varies in 4 steps
- **Fit (this) Prediction to data**
  - minimized $\chi2$ (data-MC), using statistical + systematical errors

Hadronisation Model

- **Transition of colored objects into colorless hadrons**
- String model: Many free parameters (long list !)
- Tuned to e^+e^- data, (ALEPH)
- Done by Prof. Gerald Rudolph

Main Physics Components (PYTHIA 6)



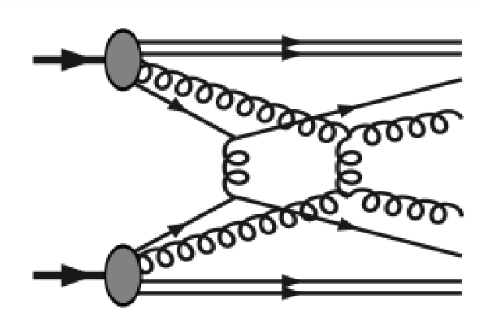
pp Interaction Model

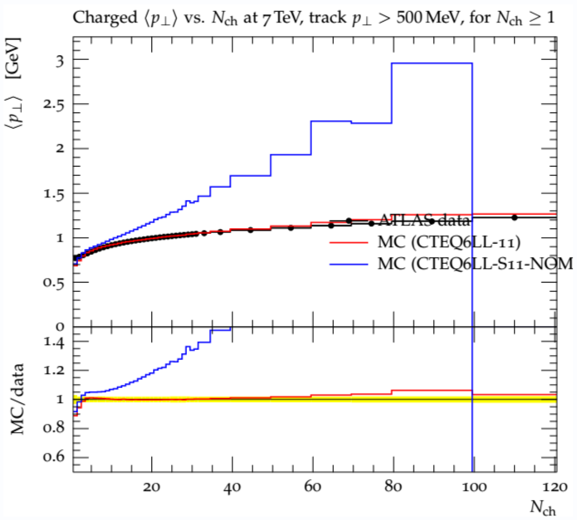
Switches and Parameters

Switches/Parameters	Value	Description
MSTP(52)	2	PDF taken from LHAPDF
MSTP(81)	21	MPI Model: New scenario
PARP(82)	variable	Cut off Pt0
PARP(90)	variable	Energy evolution of Pt0
PARP(89)	7000 GeV	Reference energy scale
MSTP(3)	1	Different Λ_{QCD}
PARP(1)	variable	Λ (ME)
PARP(61)	0.19 GeV	Λ (ISR)
PARP(72)	variable	Λ (FSR)
MSTP(82)	5	Matter Distribution
PARP(83)	variable	Matter overlap shape parameter
MSTP(95)	6	CR Model: Color annealing
PARP(78)	variable	Probability for color reconnection
PARP(77)	variable	Suppression parameter

MPI

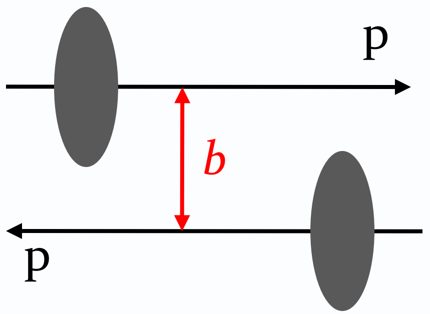
- Many parton parton interactions per pp event, most have small Pt
- Not visible as separate jets, but contribute to event activity
- Solid evidence that MPI play central role for event
- LO Cross section for 2→2 interaction diverges at Pt → 0
- Requires an empirical dampening at small Pt
- Pt0 adjustable parameter





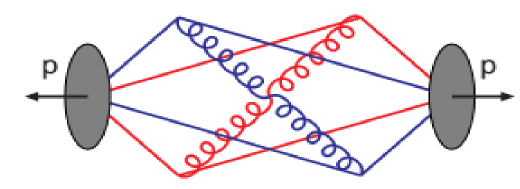
Matter Distribution

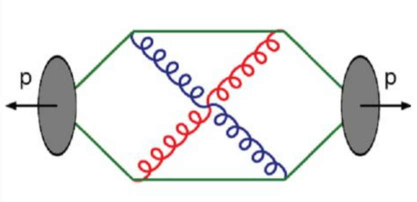
- Events are distributed in impact parameter b (varying impact parameter)
  - Central collisions are more active
  - Overlap of hadrons during collision
  - Hadronic matter overlap $\mathcal{O}$ (b) $\propto$ exp(-b^d)
  - d= PARP(83)
  - Matter distribution shape parameter
  - Interpolate between Gaussian and Exponential distribution



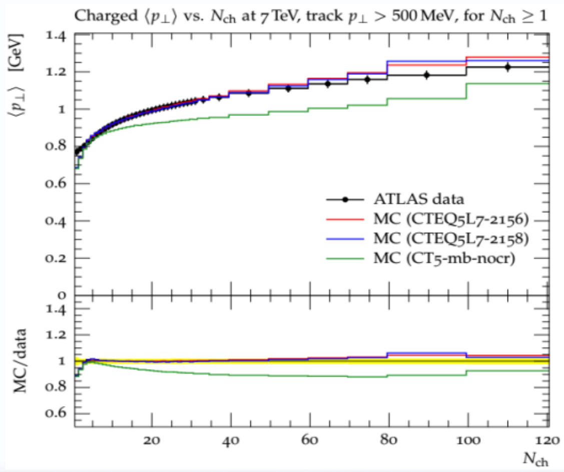
Color Reconnections

- Out going partons are color connected with the beam remnant
- Rearrangement of final state color connection such that overall string length becomes as small as possible





- PARP(78) sets overall color reconnection strength
- PARP(77) supress reconnection among high Pt string pieces
- Large amount of reconnection needed to match data



Data used for tuning

Observable, ATLAS Minimum Bias Data	ECM
Nch, Track Pt>500MeV, Nch≥1	7TeV
Pt, Track Pt>500 MeV, Nch≥1	7TeV
Eta, Track Pt> 500MeV, Nch≥1	7TeV
<Pt>vs Nch, Track Pt>500MeV, Nch≥1	7TeV
Nch, Track Pt>500MeV, Nch≥6 *(Diffraction Suppressed)*	7TeV
Pt, Track Pt>500 MeV, Nch≥6 *(Diffraction Suppressed)*	7TeV
Eta, Track Pt> 500MeV, Nch≥6 *(Diffraction Suppressed)*	7TeV
Nch, Track Pt>500MeV, Nch≥1	0.9TeV
Pt, Track Pt>500 MeV, Nch≥1	0.9TeV
Eta, Track Pt> 500MeV, Nch≥1	0.9TeV
<Pt>vs Nch, Track Pt>500MeV, Nch≥1	0.9TeV
Nch, Track Pt>500MeV, Nch≥6 *(Diffraction Suppressed)*	0.9TeV
Pt, Track Pt>500 MeV, Nch≥6 *(Diffraction Suppressed)*	0.9TeV
Eta, Track Pt> 500MeV, Nch≥6 *(Diffraction Suppressed)*	0.9TeV

Data used for tuning

Observable, ATLAS Underlying Event data	ECM
Transverse region Nch density vs pT (leading track)	7TeV
Toward region Nch density vs pT (leading track)	7TeV
Away region Nch density vs pT (leading track)	7TeV
Transverse region ∑pT density vs pT (leading track)	7TeV
Toward region ∑pT density vs pT (leading track)	7TeV
Away region ∑pT density vs pT (leading track)	7TeV
Transverse region <pT> density vs pT (leading track)	7TeV
Toward region <pT> density vs pT (leading track)	7TeV
Away region <pT> density vs pT (leading track)	7TeV
Transverse region <pT> density vs Nch	7TeV
Toward region <pT> density vs Nch	7TeV
Away region <pT> density vs Nch	7TeV

Data used for tuning

Observable, ATLAS Underlying Event data	ECM
Transverse region Nch density vs pT (leading track)	0.9TeV
Toward region Nch density vs pT (leading track)	0.9TeV
Away region Nch density vs pT (leading track)	0.9TeV
Transverse region ∑pT density vs pT (leading track)	0.9TeV
Toward region ∑pT density vs pT (leading track)	0.9TeV
Away region ∑pT density vs pT (leading track)	0.9TeV
Transverse region <pT> density vs pT (leading track)	0.9TeV
Toward region <pT> density vs pT (leading track)	0.9TeV
Away region <pT> density vs pT (leading track)	0.9TeV
Transverse region <pT> density vs Nch	0.9TeV
Toward region <pT> density vs Nch	0.9TeV
Away region <pT> density vs Nch	0.9TeV

Data used for tuning

Observable, Cluster Based ATLAS UE	ECM
Transverse region Nch density vs pT (leading cluster)	7TeV
Transverse region ∑pT density vs pT (leading cluster)	7TeV
Transverse region Nch density vs pT (leading cluster)	0.9TeV
Transverse region ∑pT density vs pT (leading cluster)	0.9TeV

CDF II MB Data	ECM
<pT>vs Nch	1.96 TeV

PDF Sets Used

PDF Type	PDF Sets	LHAPDF Code
Leading Order	CTEQ5L	19070
	CTEQ6LL	10042
	MSTW2008	21000
Modified Leading Order	MRSTMCAL(LO**)	20651
	MRST2007(LO*)	20650
	CT09MC2	100772
Next-to-Leading Order	CTEQ66	10550
	CT10	10800
	MSTW2008	21100

List of Tuned Parameters

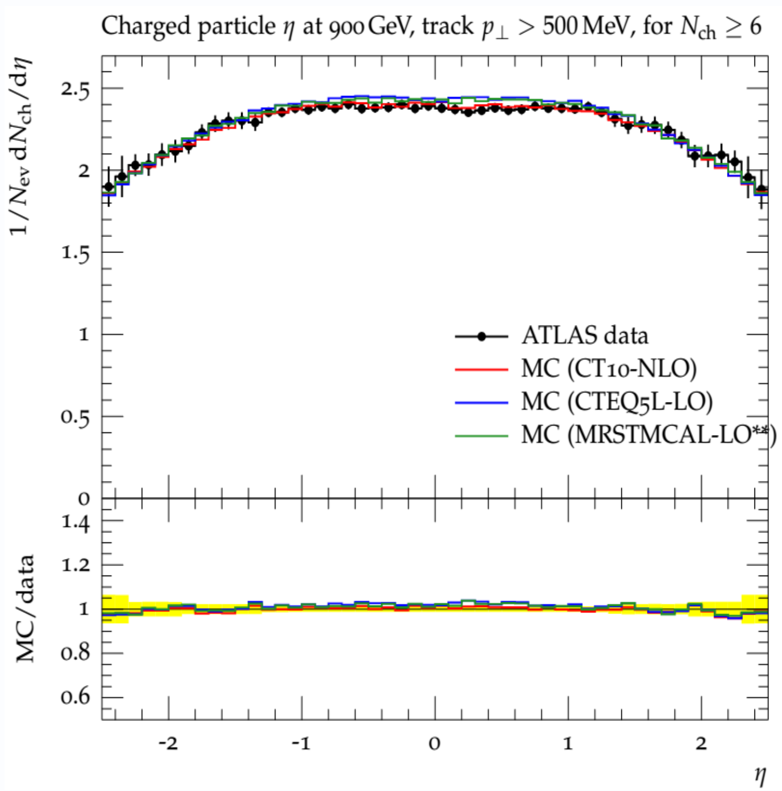
(for three different PDFs)

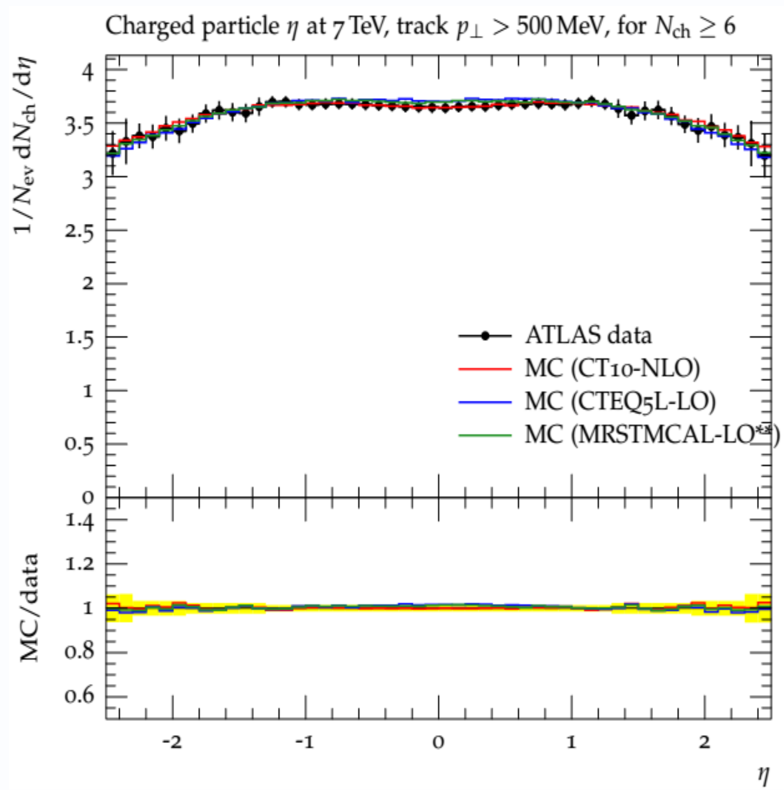
Parameter	CTEQ5L LO	MRST LO**	CT10 nLO	Symbol
PARP(82)	2.91	2.74	2.11	$P_{\perp 0}$ (GeV)
PARP(90)	0.24	0.22	0.17	ECM dep.
PARP(83)	1.80	1.81	1.95	d_{MO}
PARP(78)	0.43	0.43	0.51	P_{CR}
PARP(77)	0.90	0.90	0.90	CR suppr.
PARP(1)	0.16	0.07	0.18	Λ_{ME} (GeV)
PARP(72)	0.52	0.58	0.46	Λ_{FSR} (GeV)

Chi^2/Ndof	1.17	1.10	1.17

Pseudo-rapidity, η

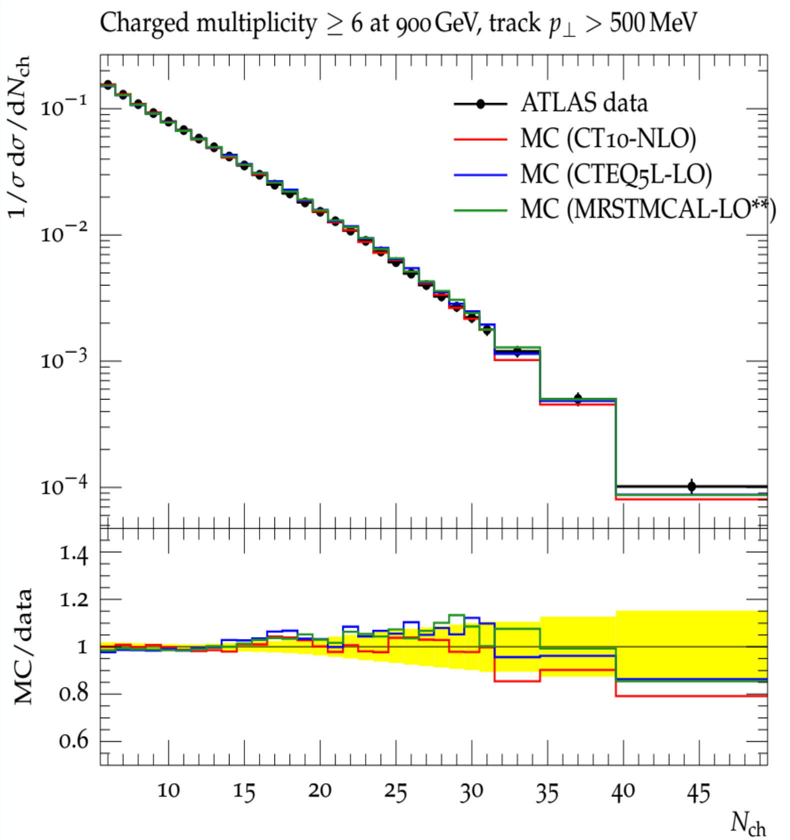
Sensitive to PARP(82)

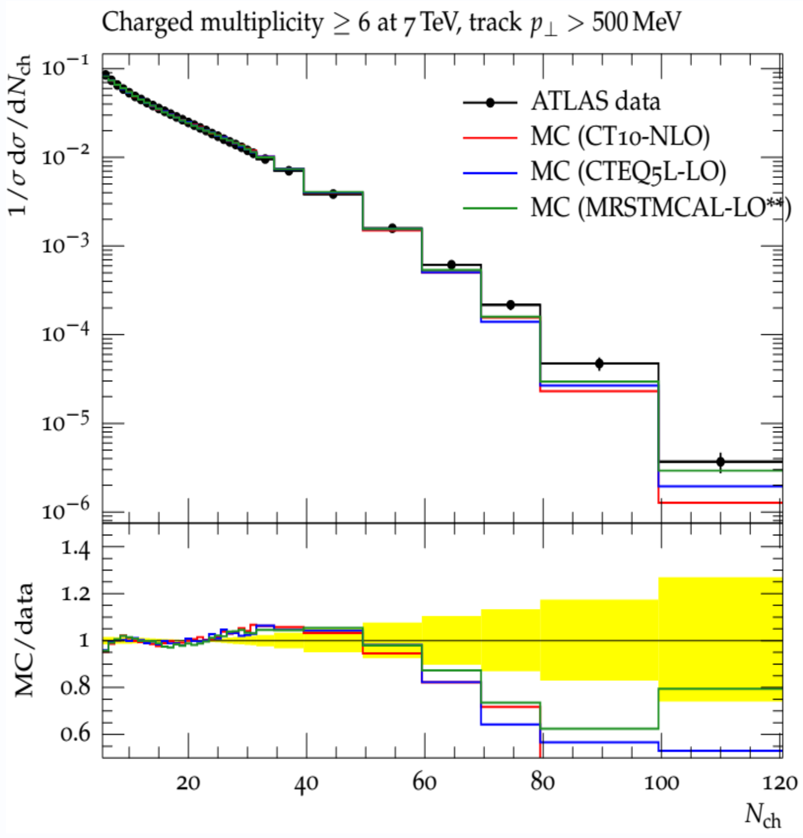




Charged Particle multiplicity

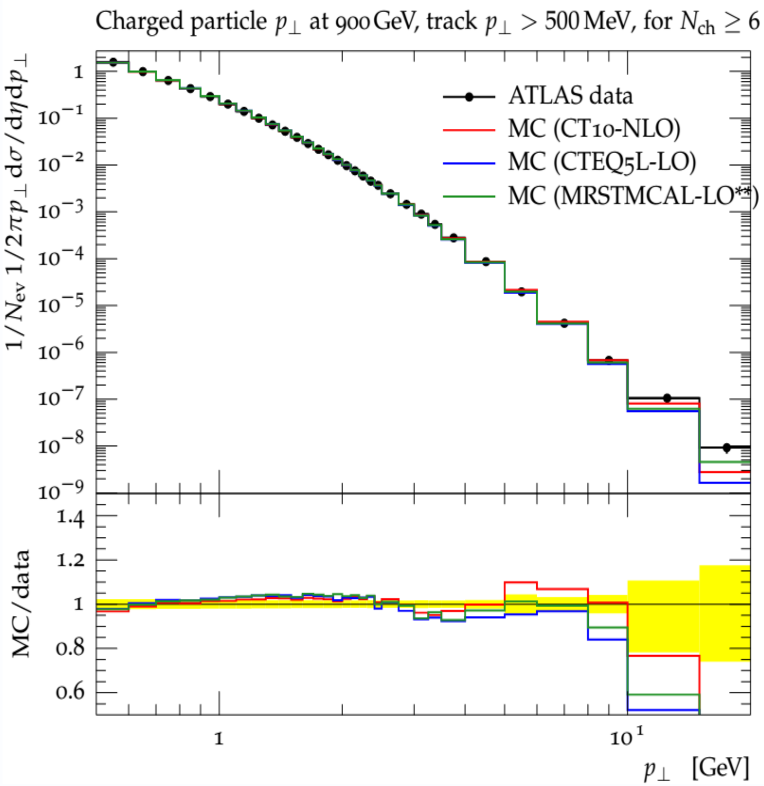
Shape influenced by PARP(83)

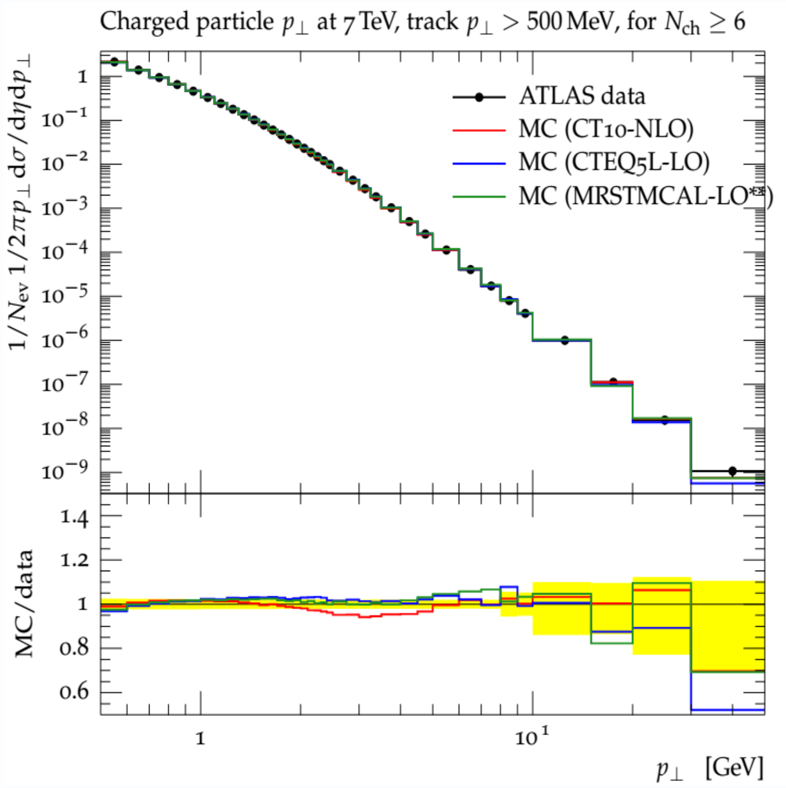




Transverse Momentum

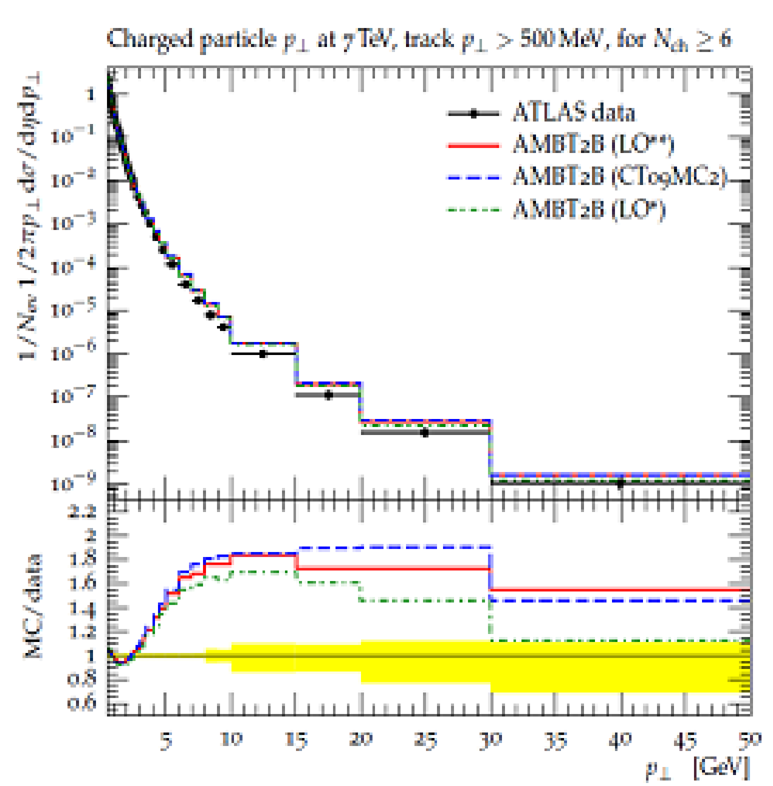
Sensitive to PARP(78) and PARP (72)

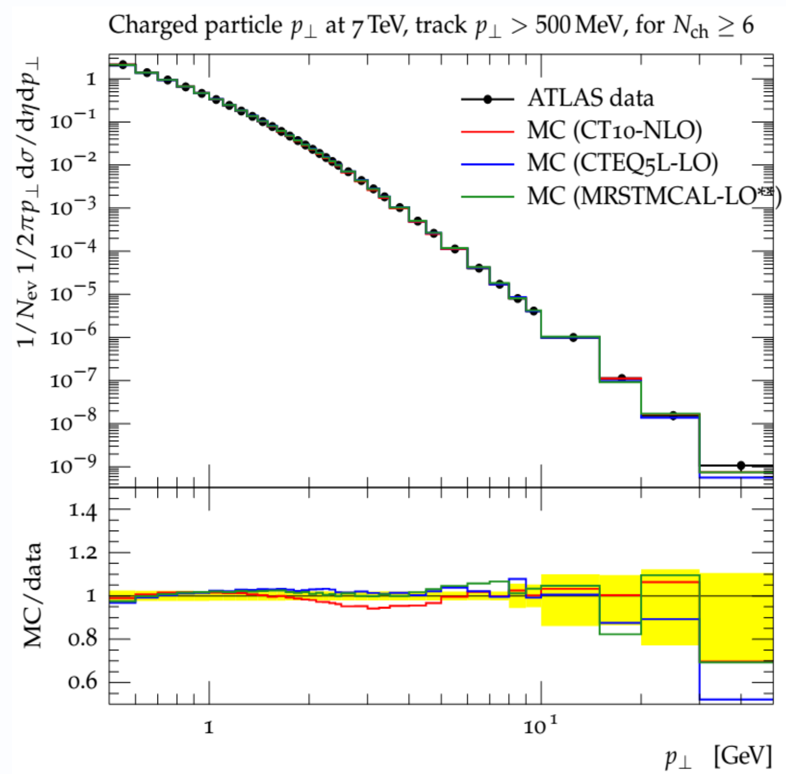




Transverse Momentum

Sensitive to PARP(78) and PARP (72)





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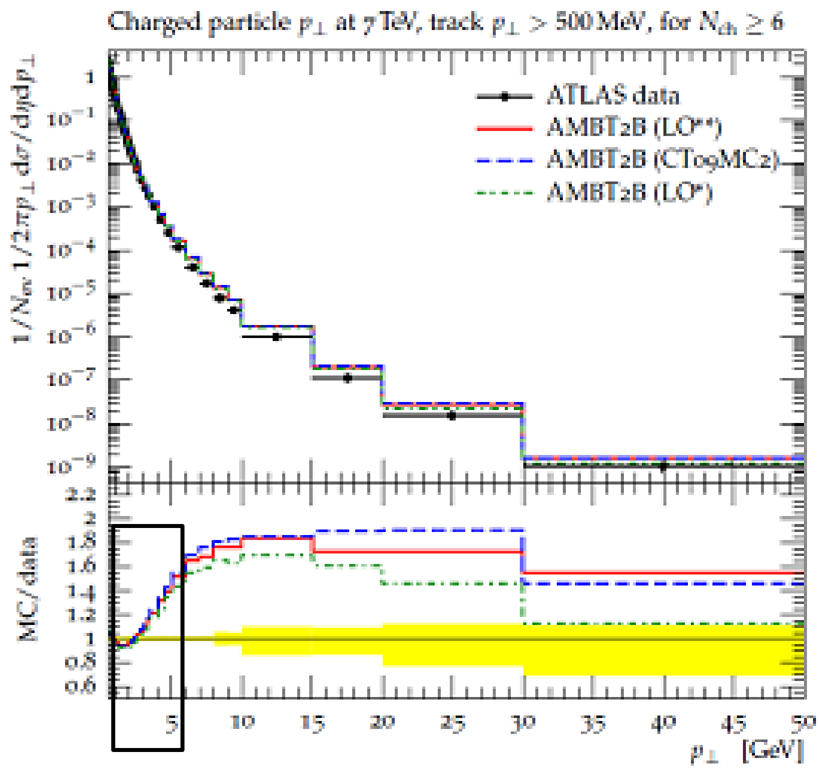
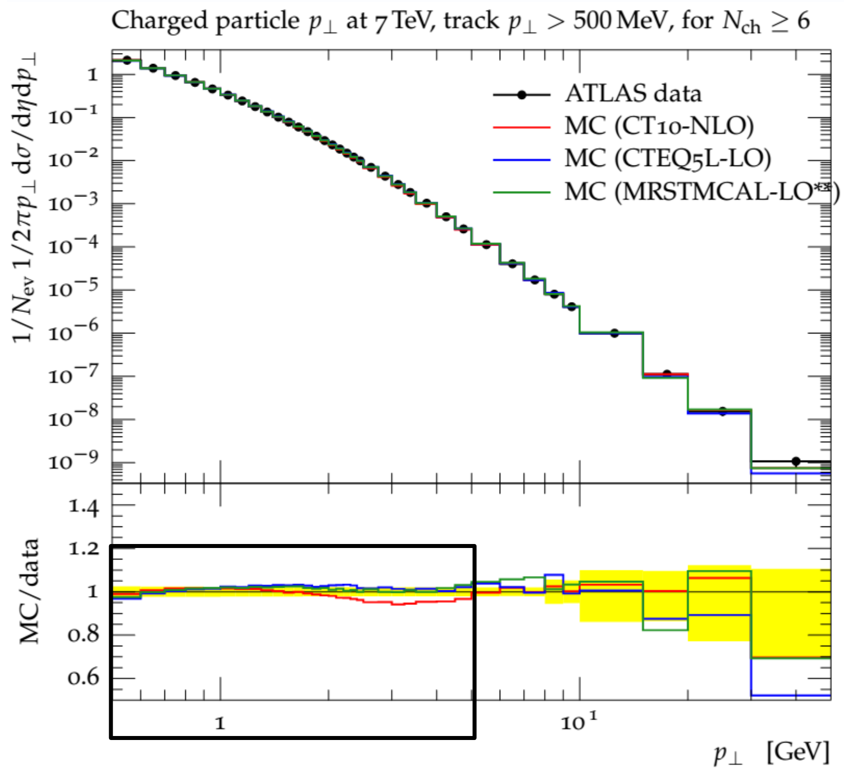
Transverse Momentum

Sensitive to PARP(78) and PARP (72)





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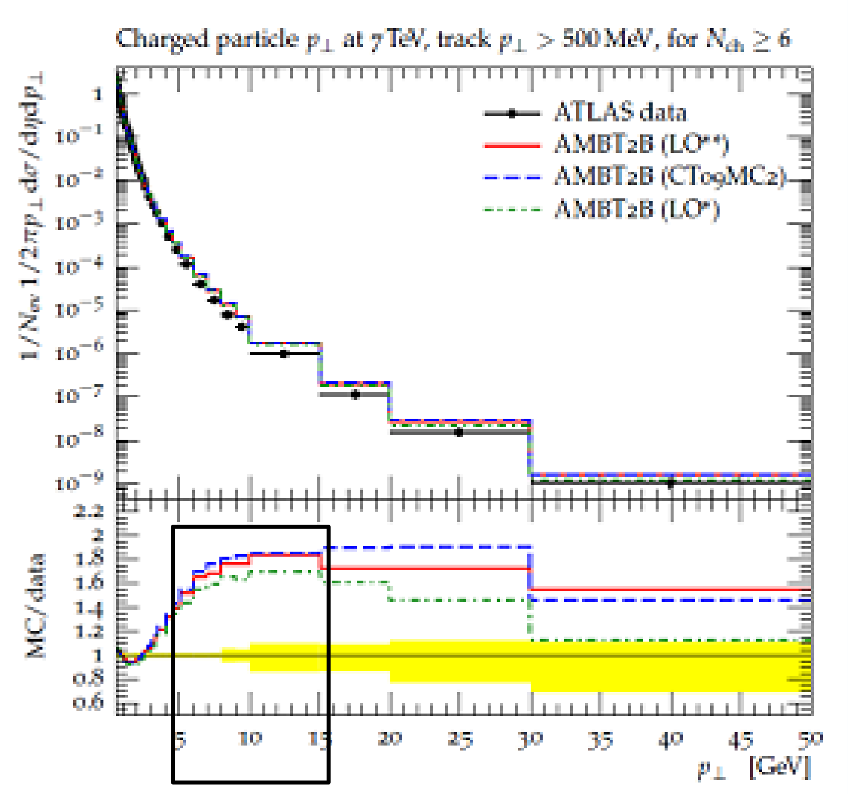
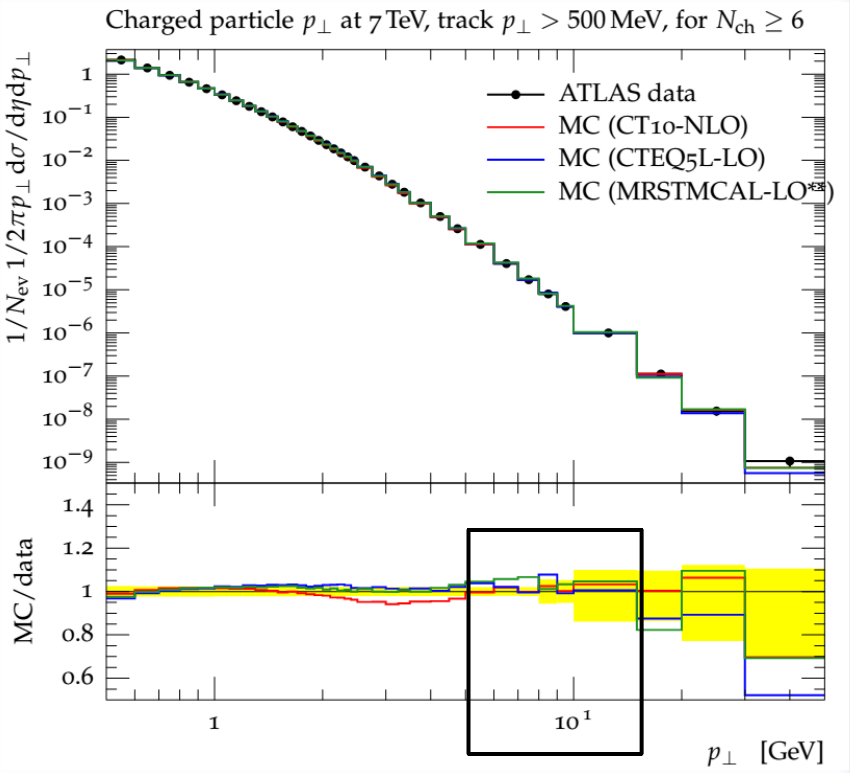
Transverse Momentum

Sensitive to PARP(78) and PARP (72)





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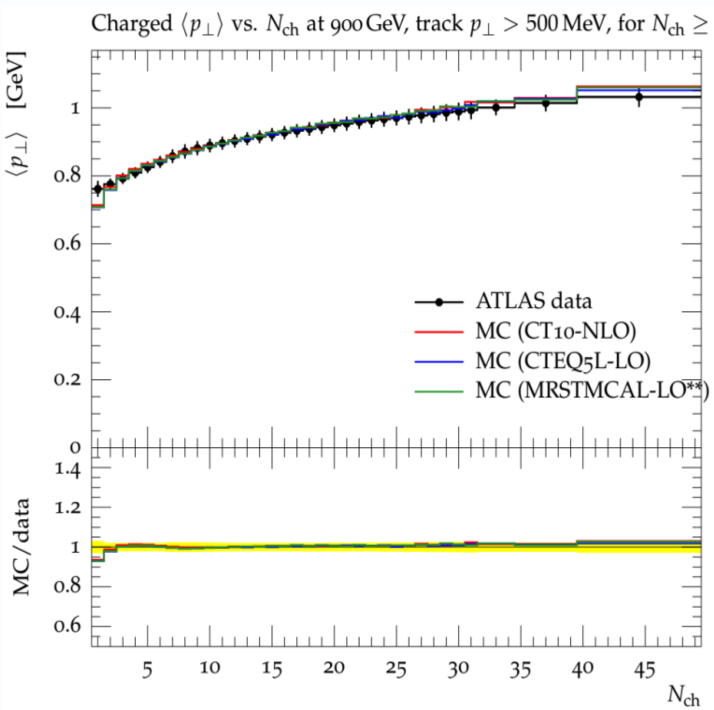
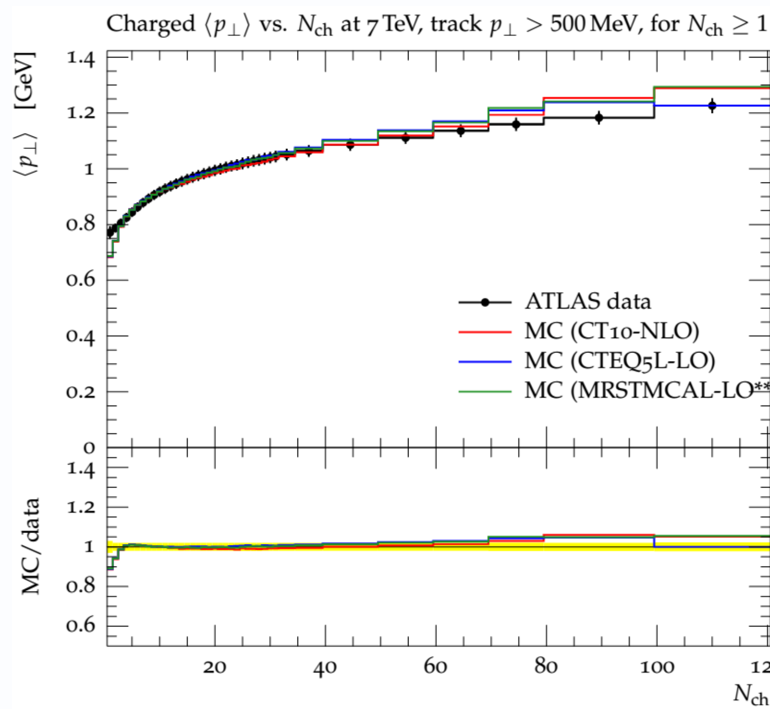
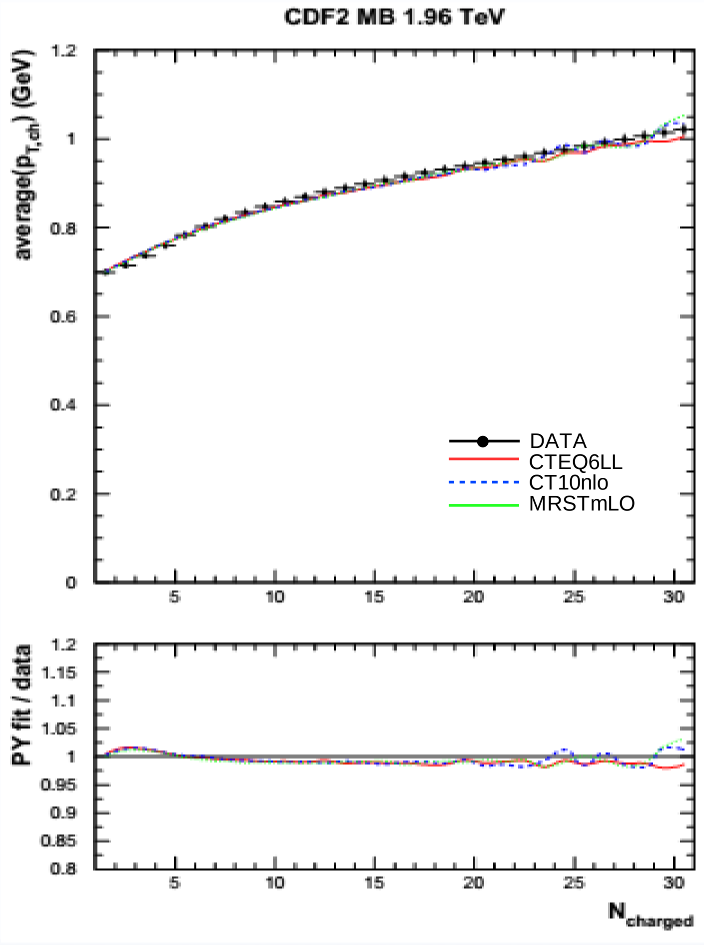
Average P_t vs. N_{CH}

Sensitive to PARP(78)

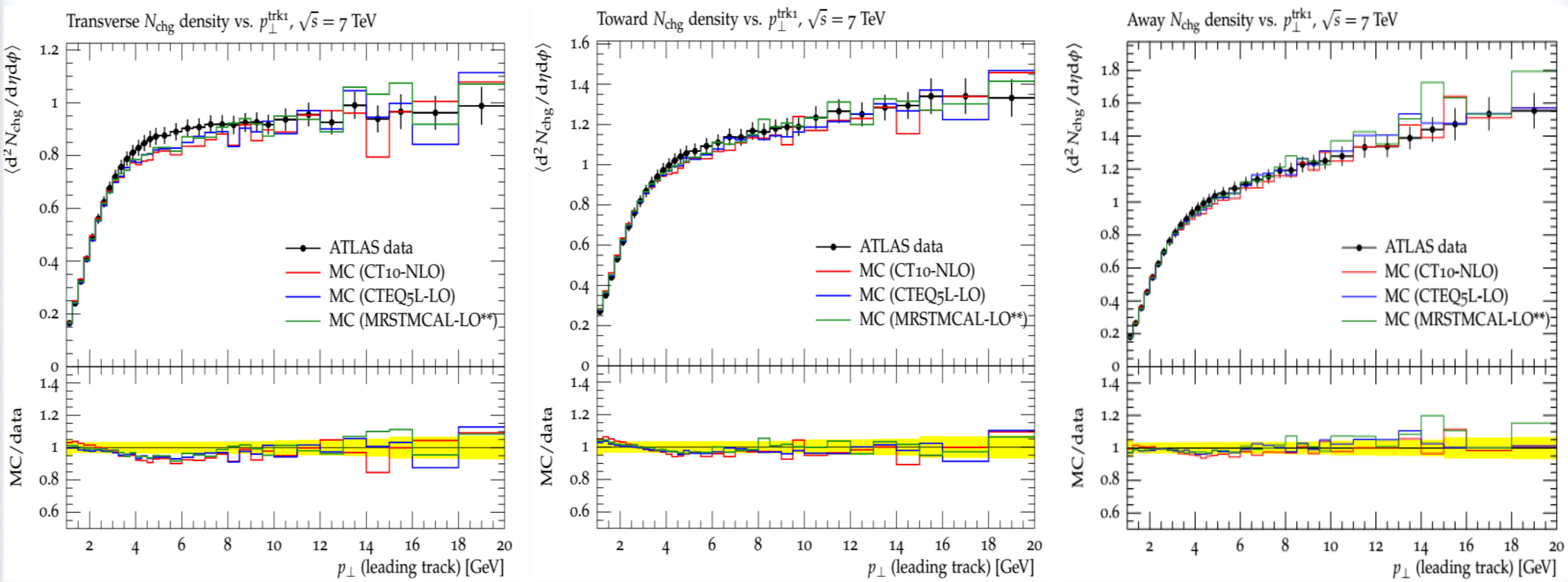




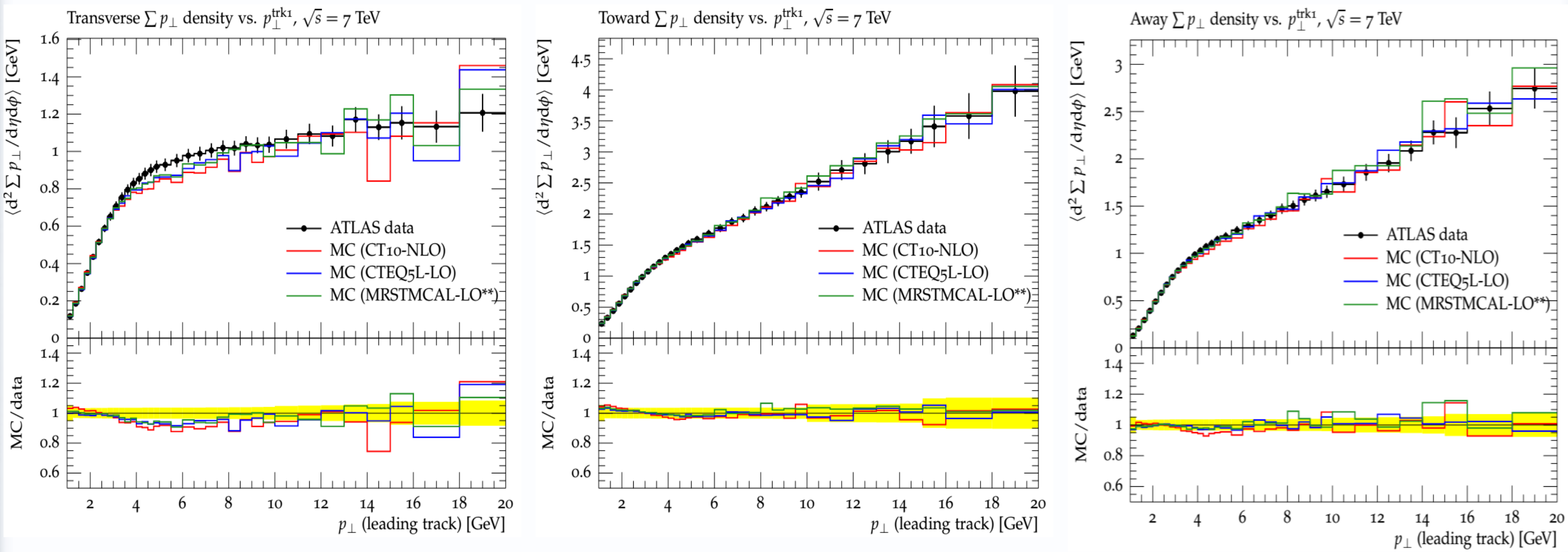
Average P_t vs. N_{CH}



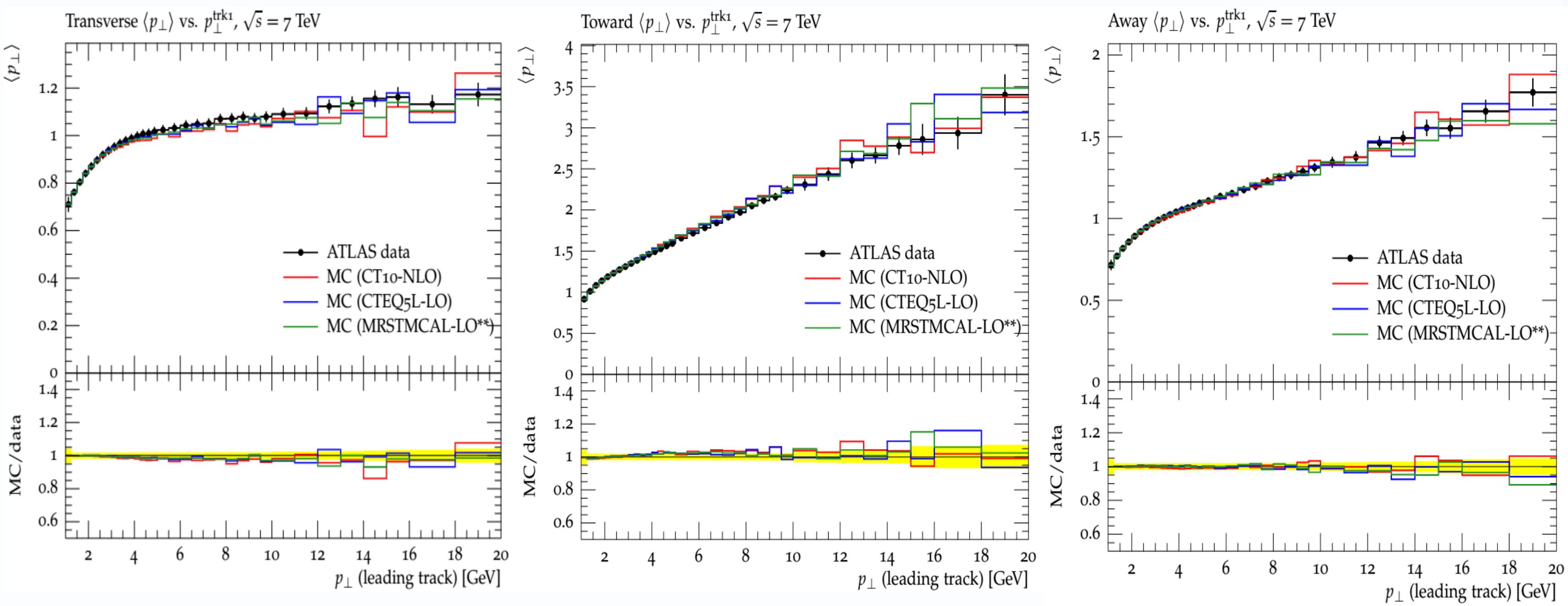
Nch density vs pT (leading track)



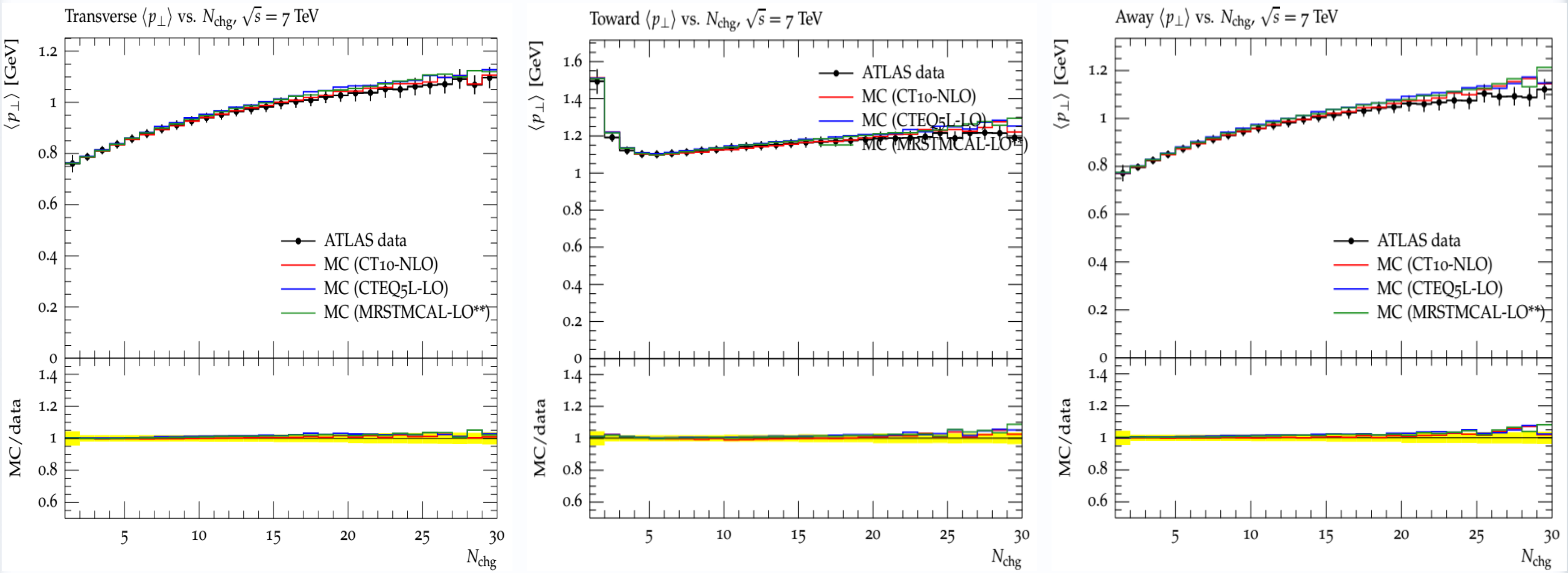
Sum Pt density vs pT (leading track)



<Pt>vs pT (leading track)



<Pt> vs Nch



Transverse ⟨p⊥⟩ vs. Nchg, √s = 7 TeV
Toward ⟨p⊥⟩ vs. Nchg, √s = 7 TeV
Away ⟨p⊥⟩ vs. Nchg, √s = 7 TeV
⟨p⊥⟩ [GeV]
MC/data
Nchg
ATLAS data
MC (CT10-NLO)
MC (CTEQ5L-LO)
MC (MRSTMCAL-LO**)

Summary

- First combined tunes of PYTHIA6 to the Minimum Bias and Underlying event data are presented at three center of mass energies 0.9, 1.9 and 7TeV using three different types of PDFs.

  (Not possible in latest ATLAS tunes!)*

- Equally good descriptions of ATLAS Min Bias and UE data are obtained for all three types of PDFs.

  (Not possible in latest ATLAS tunes!)*

- The Pt spectrum for pt>3 GeV is now well described also in case of mLO PDFs ⇒ small Lambda_ME values ≈75MeV.

  (Not possible in latest ATLAS tunes!).*

- For a better data description, it is important to consider all PDF dependent parameters for tuning.

- Lambda_ME is very sensitive to the selected data and PDF type, so should be treated accordingly.

* ATL-PHYS-PUB-2011-008, ATL-PHYS-PUB-2011-009

Thank you

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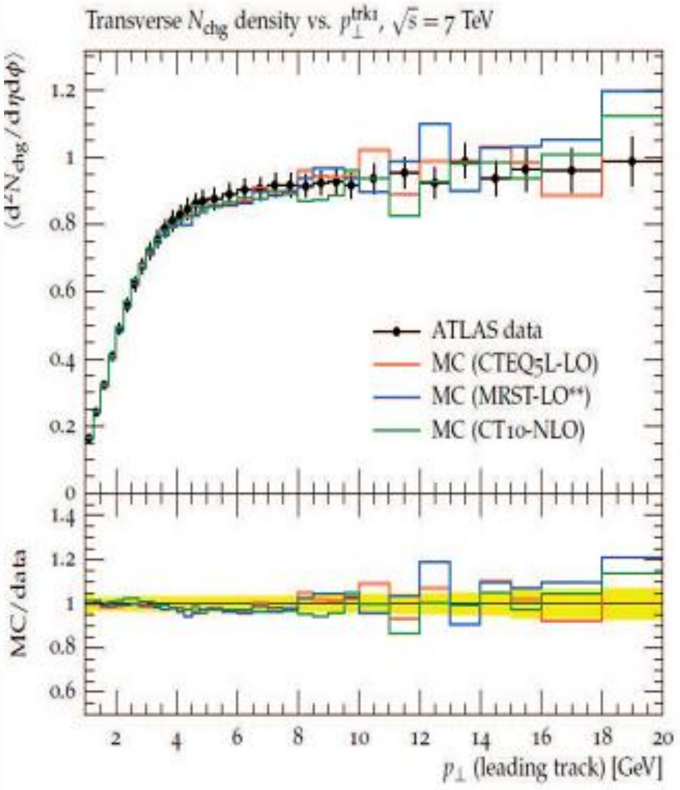

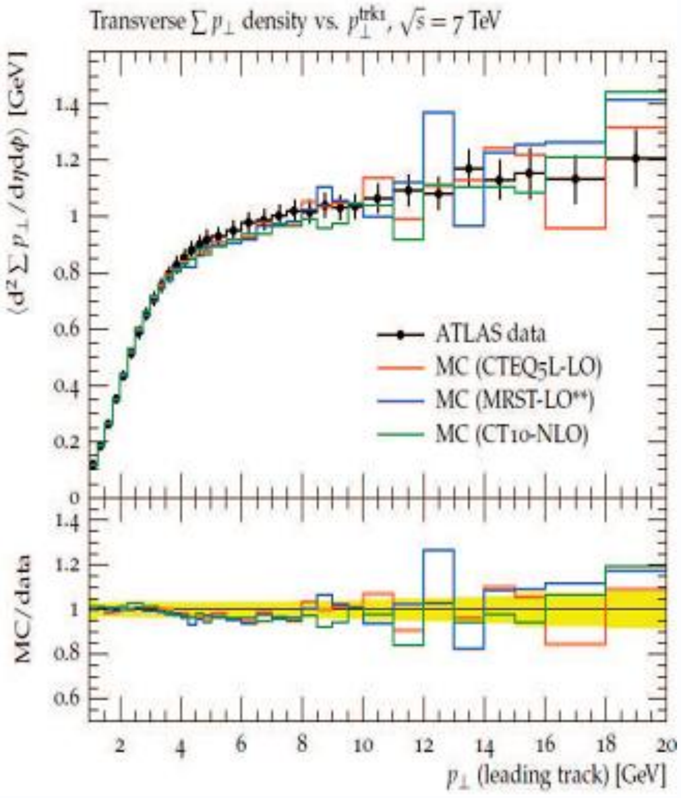

UE tunes

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"Since it has already been seen that tuning to LHC and Tevatron data with three different centre-of-mass energies is impossible with the current models for energy extrapolation"

ATL-PHYS-PUB-2012-003

"...as it was found to be impossible to simultaneously describe all the desired observables. In particular, including both ATLAS minimum bias and underlying even observables..."

ATL-PHYS-PUB-2011-008

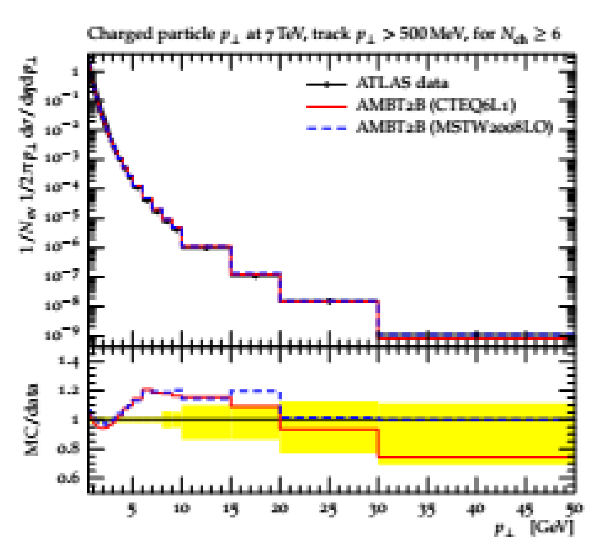
"...as it was found that NLO PDF led to sufficiently different results in MPI model tuning that the fit results were not reliable."

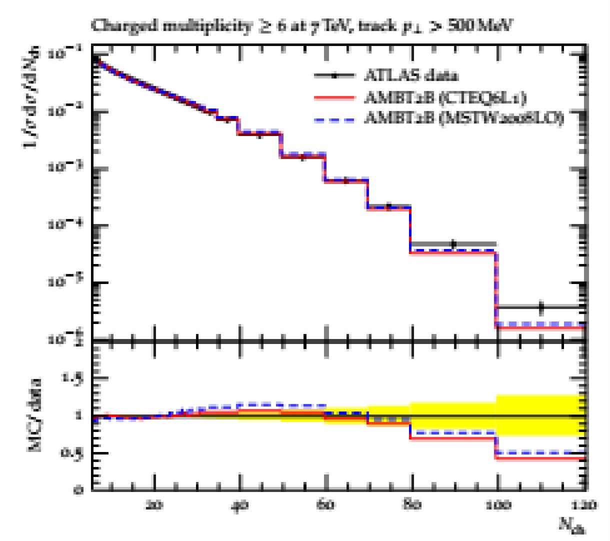
ATL-PHYS-PUB-2011-014

"A more surprising observation is that mLO PDFs,....,lead to several anomalous features in MPI dominated distributions. The most obvious of these is seen in the minimum bias charged particle pt spectrum."

ATL-PHYS-PUB-2011-009

BACKUP SLIDE





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