ATLAS Tunes for MPI

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Introduction

Introduction

- Bulk of QCD interactions occur at low energy scale
- Measurements cannot be described completely via perturbative QCD methods

$\Rightarrow$ Introduction of phenomenological models

  - Proton from factor
  - IR cutoff parameter for perturbative scatters
  - Interaction between MPI and hadronisation

$\Rightarrow$ Implemented in different Monte Carlo (MC) generators

- Introduction of *a priori* unknown parameters $\rightarrow$ tuned to data
- Today: Present the latest ATLAS Pythia8 MPI tunes for different PDF sets

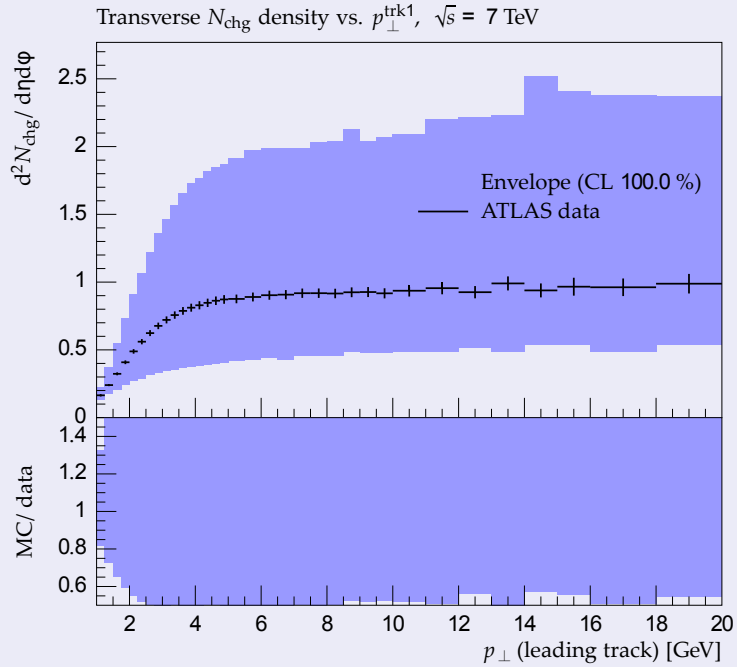
General Tuning Idea

General

- Model dependent parameters need to be tuned with data
- Use observables which are sensitive to parameter variations and are corrected to particle level

$\Rightarrow$ Find the set of parameters (tune) with the best description compared to data

Envelope



Tuning Framework in ATLAS

Tuning Workflow

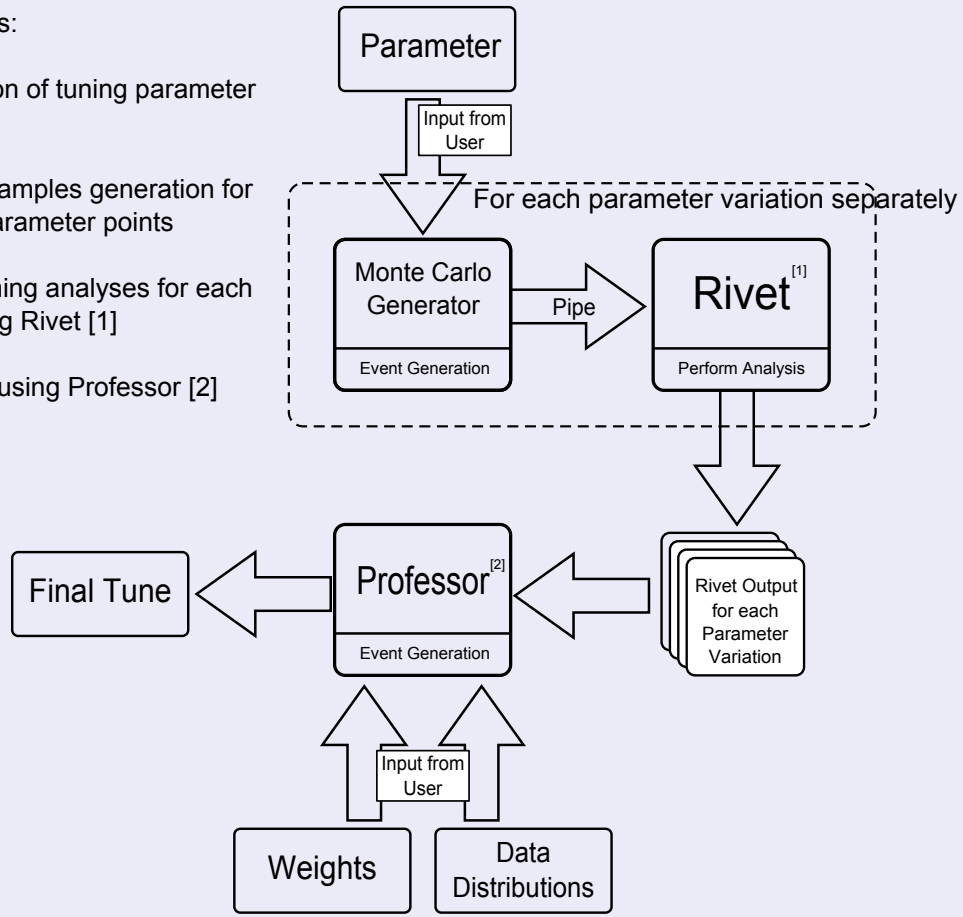
Main Steps:

1) Definition of tuning parameter space

2) Event samples generation for random parameter points

3) Performing analyses for each event using Rivet [1]

4) Tuning using Professor [2]



[1] A. Buckley, J. Butterworth, L. Lonnblad, H. Hoeth, J. Monk, et al., Rivet user manual, arXiv:1003.0694 [hep-ph]
[2] A. Buckley, H. Hoeth, H. Lacker, H. Schulz, and J. E. von Seggern, Systematic event generator tuning for the LHC, arXiv:0907.2973 [hep-ph]

ATLAS Pythia 8 tune parameter 1/2

Pythia 8 in ATLAS soft QCD physics

- Long term replacement in ATLAS for PYTHIA6
- Used for different soft QCD simulations, e.g. MPI samples, pileup simulation, hybrid combination of other MC generators, ...

Tuning Parameters for MPI tune

- **MultipleInteractions:pT0Ref**: Cutoff parameter for MPI, equates to PARP(82) in PYTHIA 6
- **MultipleInteractions:ecmPow**: Power of the energy-rescaling for the $pT0$ cutoff, equates to PARP(90) in PYTHIA 6
- **BeamRemnants:reconnectRange**: Effects the probability for color reconnection, equates to PARP(77), PARP(78) in PYTHIA 6
- **MultipleInteractions:a1**: Constant term for the width of the Gaussian matter function

ATLAS Pythia 8 tune parameter 2/2

Some More Details...

- Using the *pT0Ref* and *emcPow* parameter, the actual $pT0$ is defined as:

$$pT0(\sqrt{s}) = pT0Ref \times \left(\frac{\sqrt{s}}{1800}\right)^{emcPow}$$

- x-dependent hadronic matter distribution (**MultipleInteractions:bProfile** = 4)

$$\rho(r,x) \propto \frac{1}{a^3(x)}\exp(-\frac{r^2}{a^2(x)}) \ , \ a(x) = a_0(1 + a_1 ln(1/x))$$

- Turn off **SpaceShower:rapidityOrder**
- Include single and double diffraction
- Particles are defined as stable if $c\tau > 10$ mm

Parton Density Functions

PDF Sets

- the tune was performed for a various number of different PDFs
- **Leading Order PDFs:**
  - CTEQ6L1
  - MSTW08LO
  - NNPDF21 LO
- **Modified Leading Order PDFs:**
  - MRST2007 (LO*)
  - MRSTMCal (LO**)
- **Next-to Leading Order PDFs:**
  - CTEQ6.6
  - CT10
  - NNPDF21 NLO
  - MSTW2008NLO

Measurements

Input Measurements for the tune

- Soft QCD measurements at $\sqrt{s} = 900$ GeV and 7 TeV at ATLAS were used for the tuning
- Mixed combination of LHC and Tevatron was not used $\rightarrow$ not possible to find a common tune for three CM energies with the current energy extrapolation model
- ATLAS minimum bias data for different requirements on p_T and N_{ch}
- ATLAS underlying event data using a leading track and cluster
- Distributions at $\sqrt{s} = 7$ TeV and $p_T > 500$ MeV got higher weight in the tuning process
- Weights were not changed between the PDFs
- The starting point was the 4C-like parameter configuration
  - Discrete MPI model is more like 4Cx, due to x-dependent hadronic matter distribution

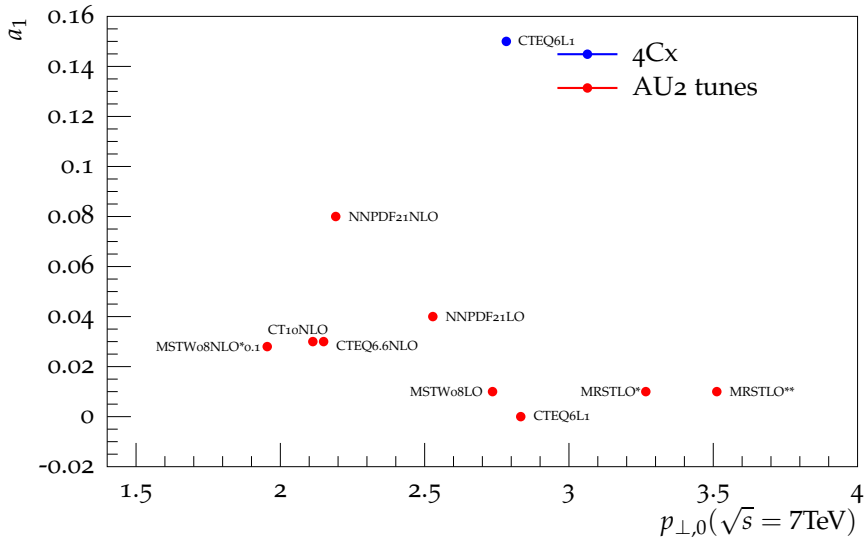
Tuning Results

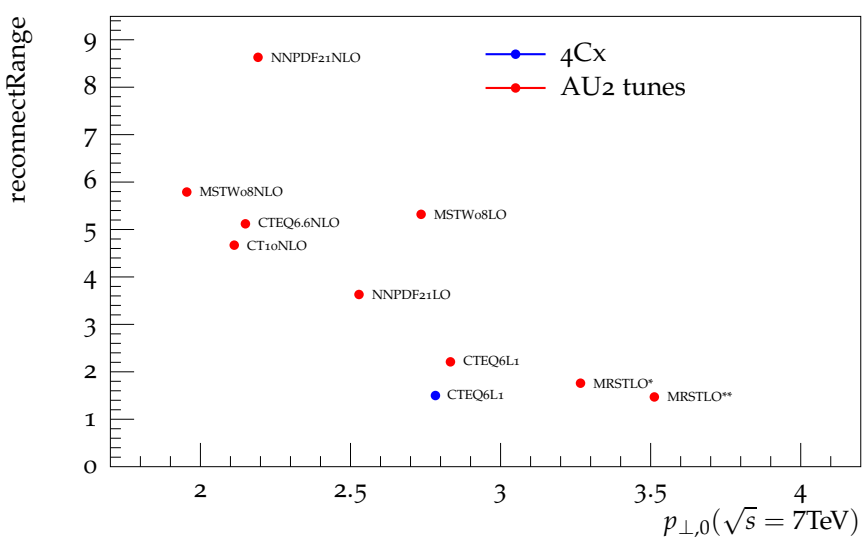
Results

- A minimum bias tune (A2) was performed for LO PDFs and a underlying event tune for all PDFs
- The results can be found in following table:

PDF	pT0Ref	ecomPow	a1	reconnectRange	Tune:pp
Minimum-bias tunes: A2					
CTEQ 6L1	2.18	0.22	0.06	1.55	7
MSTW2008 LO	1.90	0.30	0.03	2.28	8
Underlying event tunes: AU2					
CTEQ 6L1	2.13	0.21	0.00	2.21	9
NNPDF 2.1 LO	1.98	0.18	0.04	3.63	–
MSTW2008 LO	1.87	0.28	0.01	5.32	10
NNPDF 2.1 NLO	1.74	0.17	0.08	8.63	–
CTEQ 6.6	1.73	0.16	0.03	5.12	–
CT10	1.70	0.16	0.10	4.67	11
MSTW2008 NLO	1.51	0.19	0.28	5.79	–
MRST2007 LO*	2.39	0.24	0.01	1.76	–
MRST2007 LO**	2.57	0.23	0.01	1.47	–

Correlation of Tuning Parameter





- A clustering behavior of the parameters for the different PDF types can be observed
- Anti-correlation between the between the parameter for color reconnection at the cutoff $pT0$

Parton Flux

Parton Flux Correlation

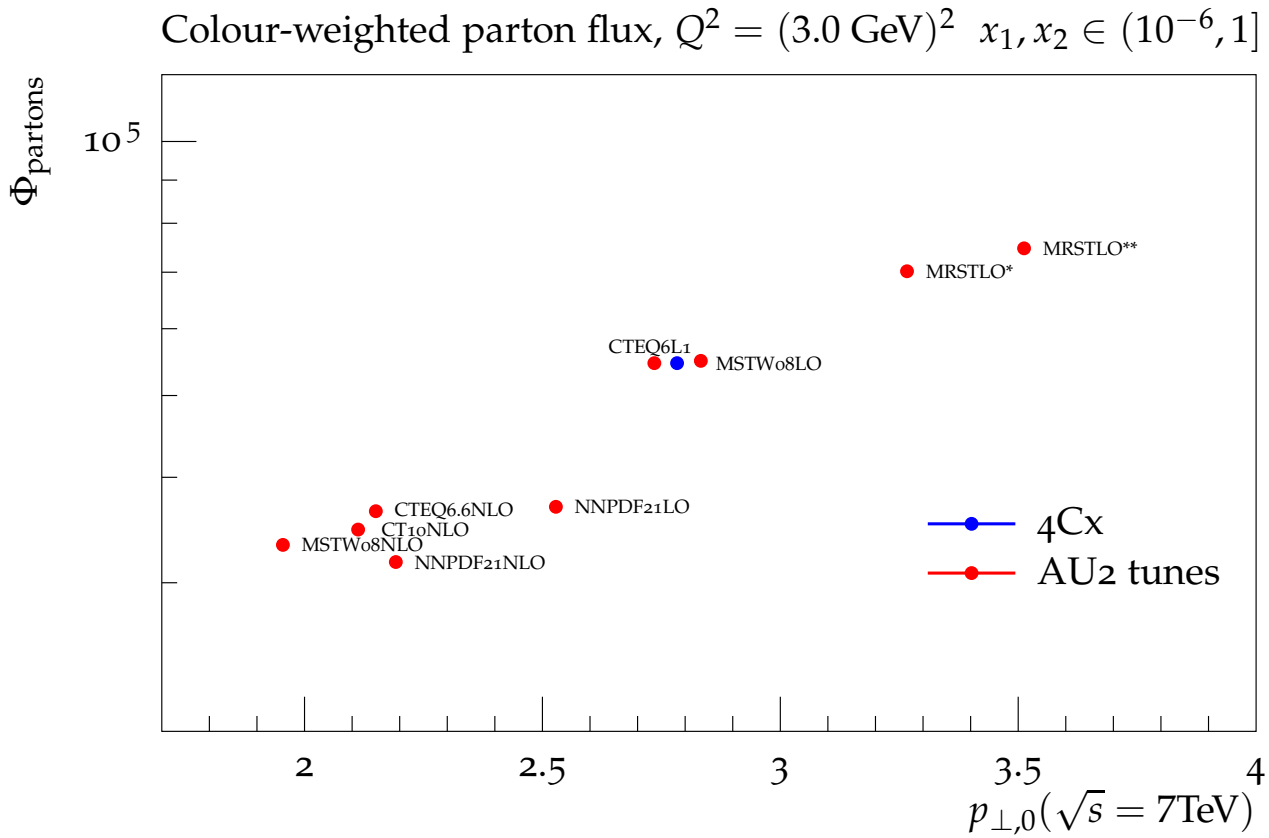
- To investigate the effects, the correlation between a color weighted parton flux Φ_{partons} and $pT0$ was calculated

$$\Phi_{\text{partons}} = \iint\limits_{x_1 x_2 > \tau_{\text{min}}} \mathrm{d}x_1 \mathrm{d}x_2 N(x_1, Q^2) \cdot N(x_2, Q^2)$$

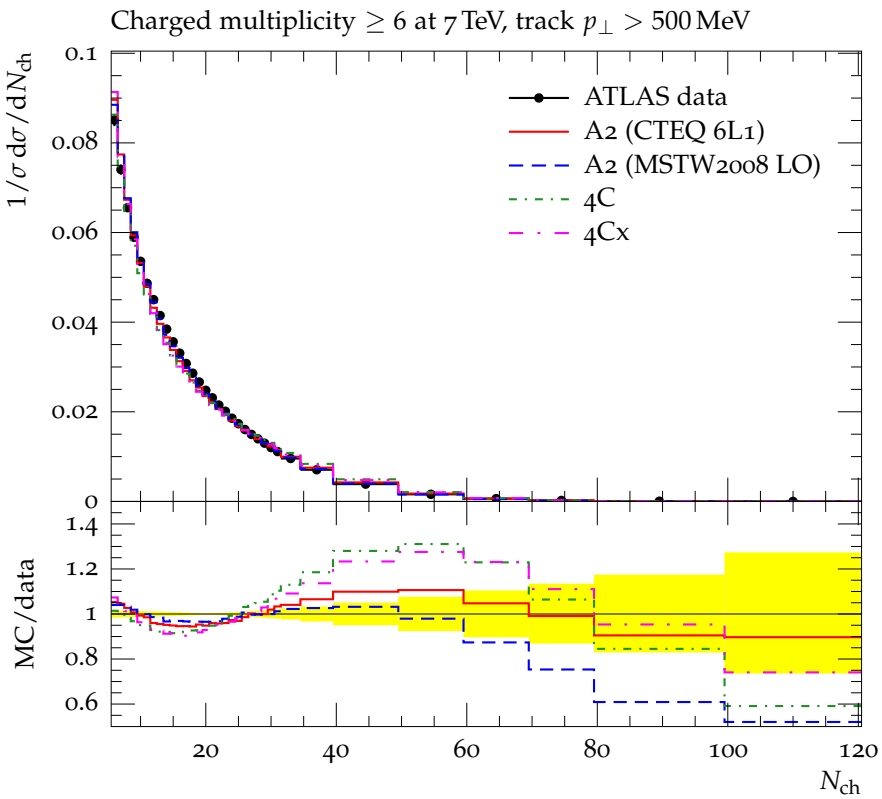
$$N(x, Q^2) = \sum_{\text{quarks}} (q(x, Q^2) + \bar{q}(x, Q^2)) + \frac{9}{4} g(x, Q^2)$$

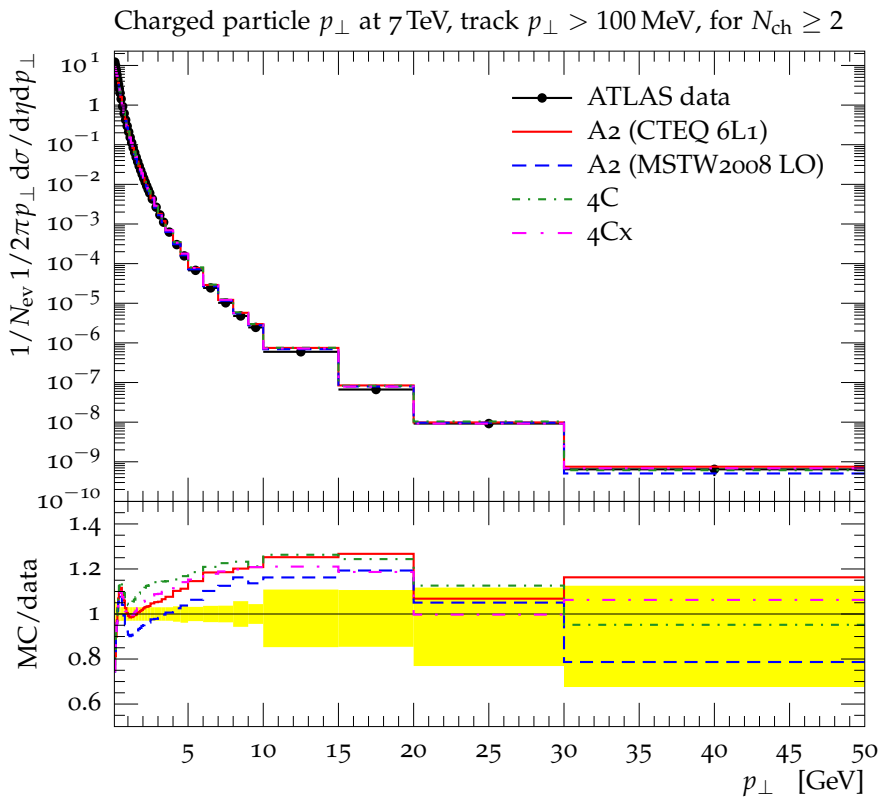
- Scale $Q^2 = (3.0)^2 \text{GeV}^2$ and lower cutoff for momentum fractions $\tau_{\text{min}} = 4.0 * Q^2 / E_{cm}$
- A clear correlation between the parton flux and the cutoff parameter could be observed

Parton Flux

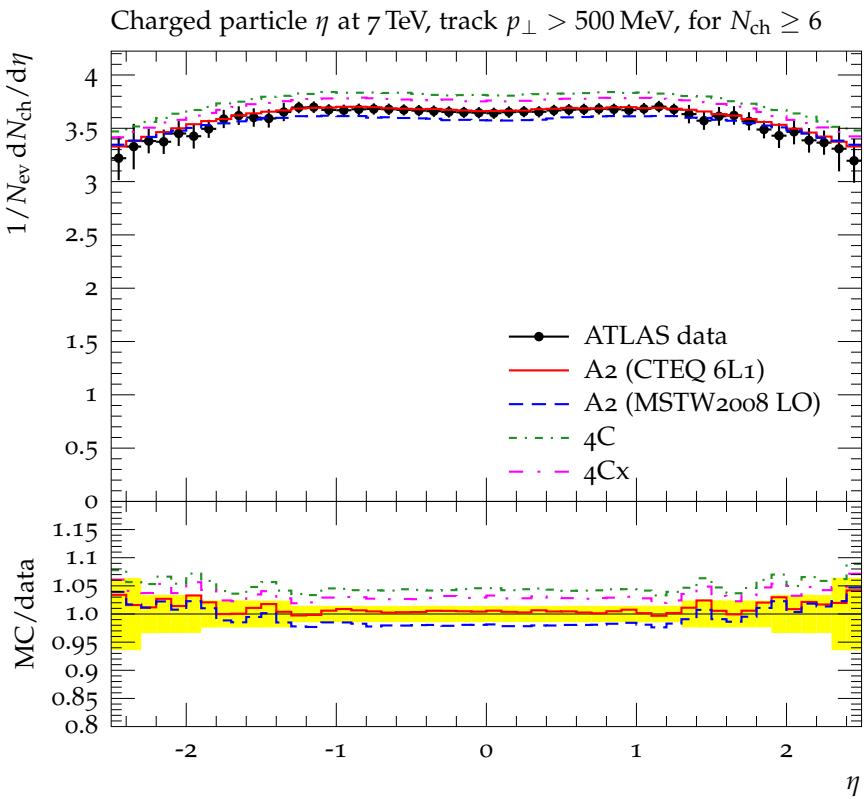

Colour-weighted parton flux, $Q^2 = (3.0\,\text{GeV})^2$ $x_1, x_2 \in (10^{-6}, 1]$
Φ_{partons}
10^5
MRSTLO**
MRSTLO*
CTEQ6L1
MSTW08LO
CTEQ6.6NLO
CT10NLO
MSTW08NLO
NNPDF21NLO
NNPDF21LO
4Cx
AU2 tunes
2
2.5
3
3.5
4
$p_{\perp,0}(\sqrt{s} = 7\text{TeV})$

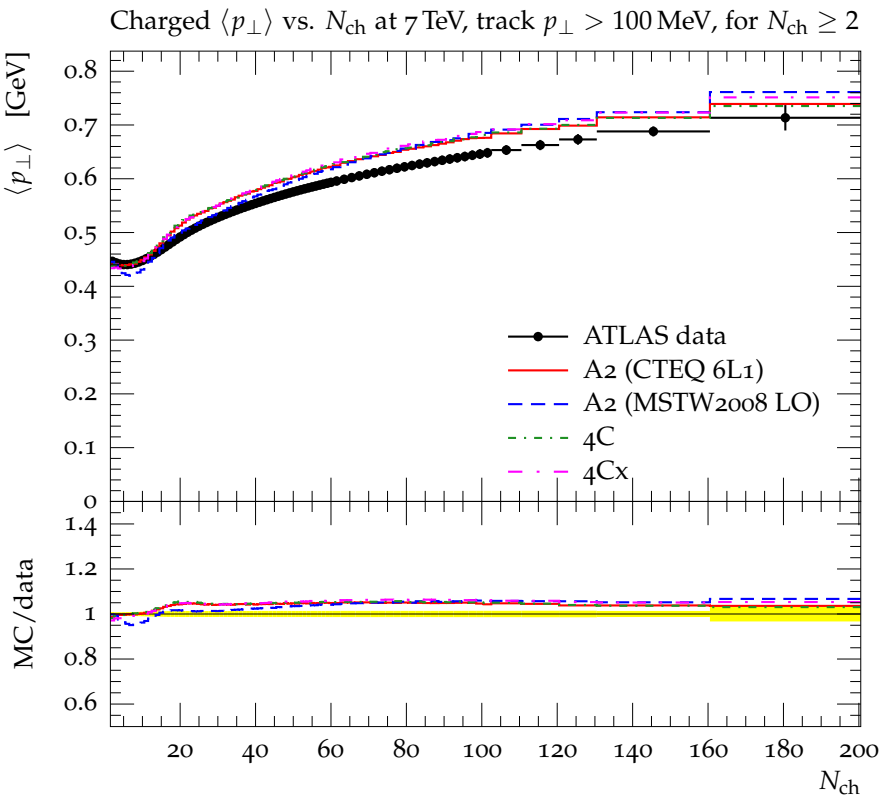
Tuning Results for Minimum Bias Measurements 1/2



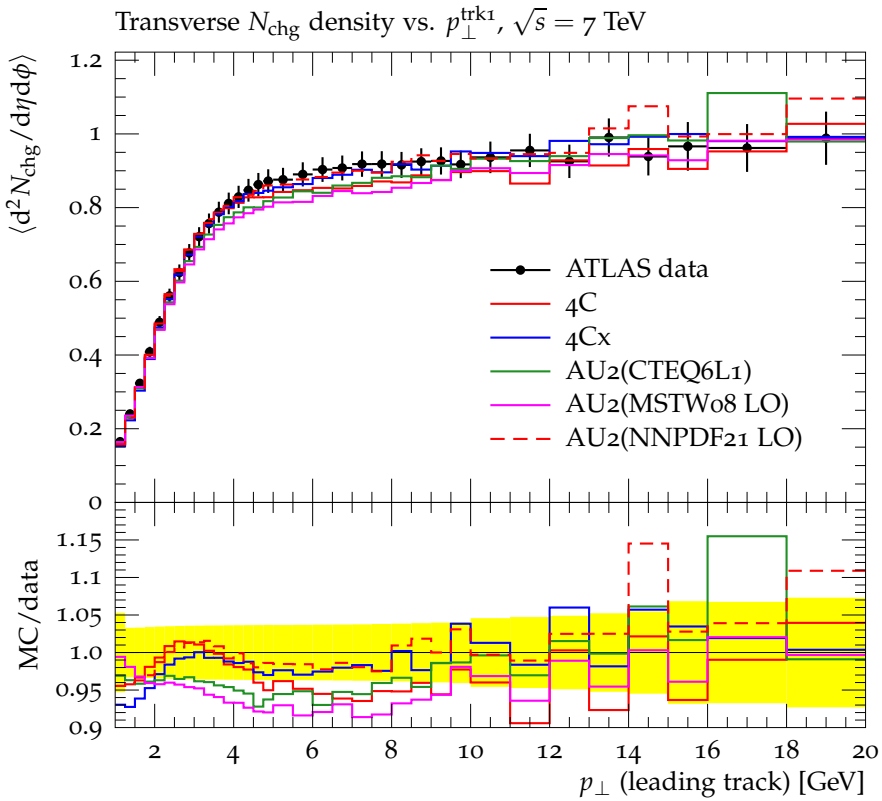


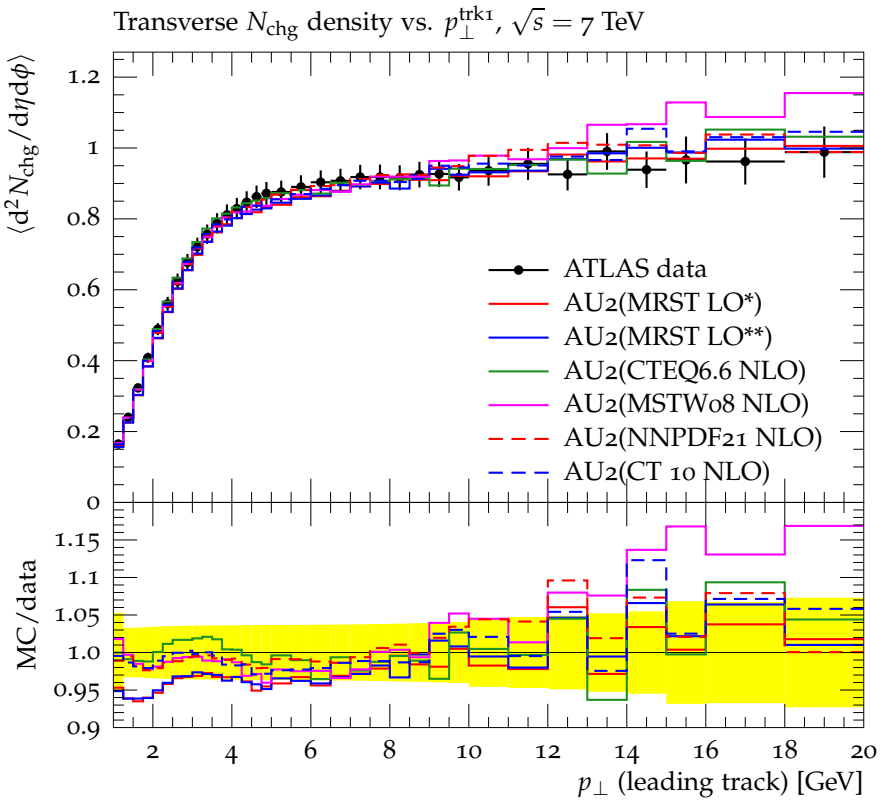
Tuning Results for Minimum Bias Measurements 2/2



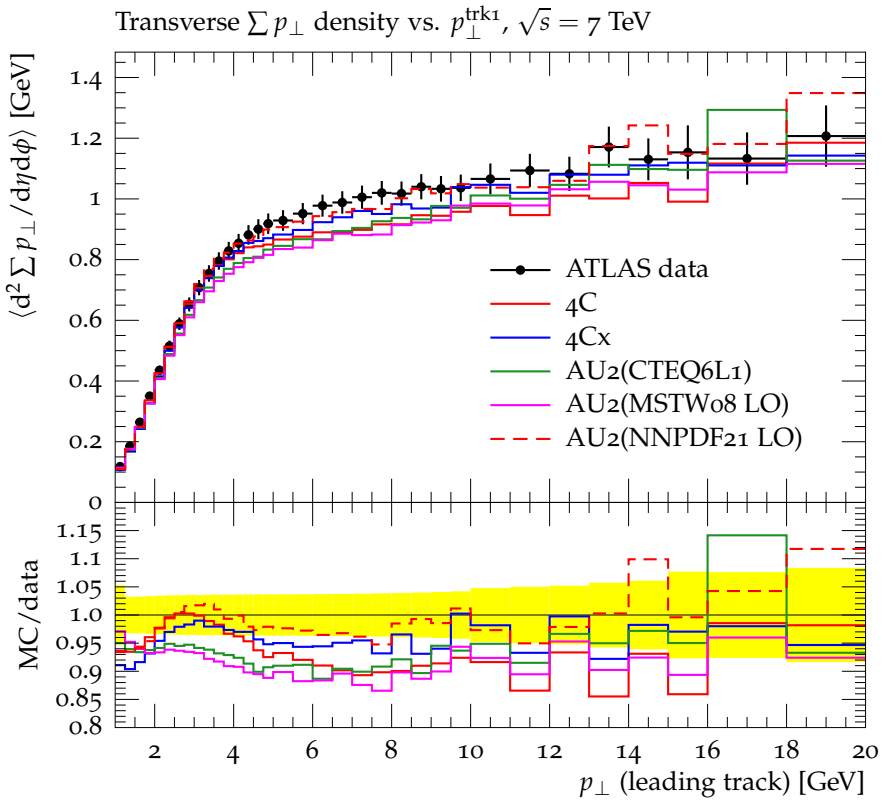


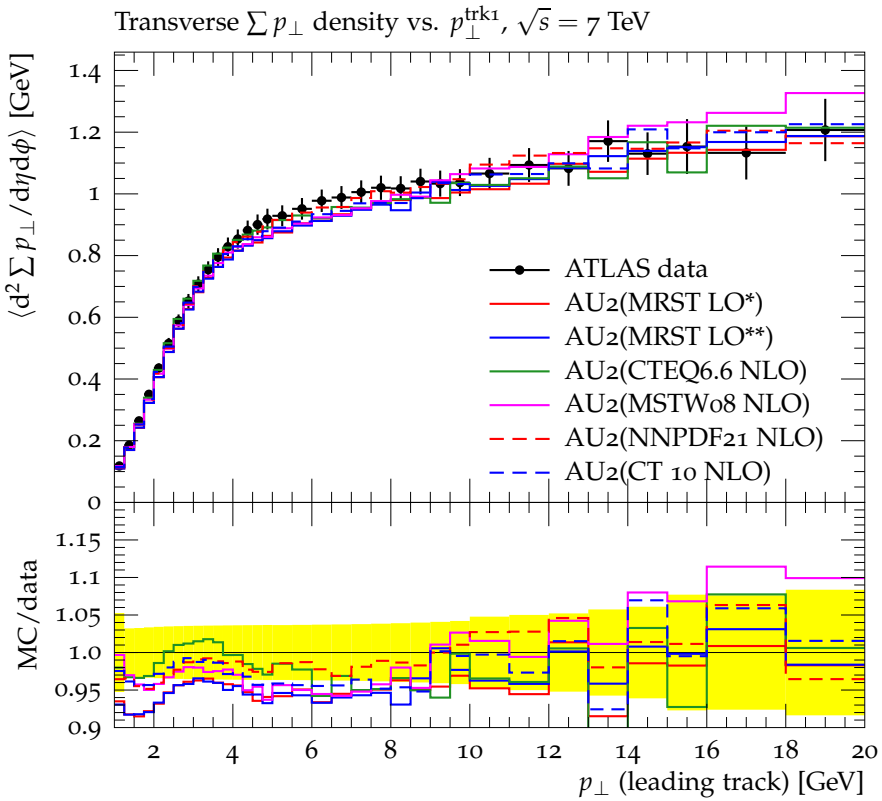
Tuning Results for Underlying Event Measurements 1/3



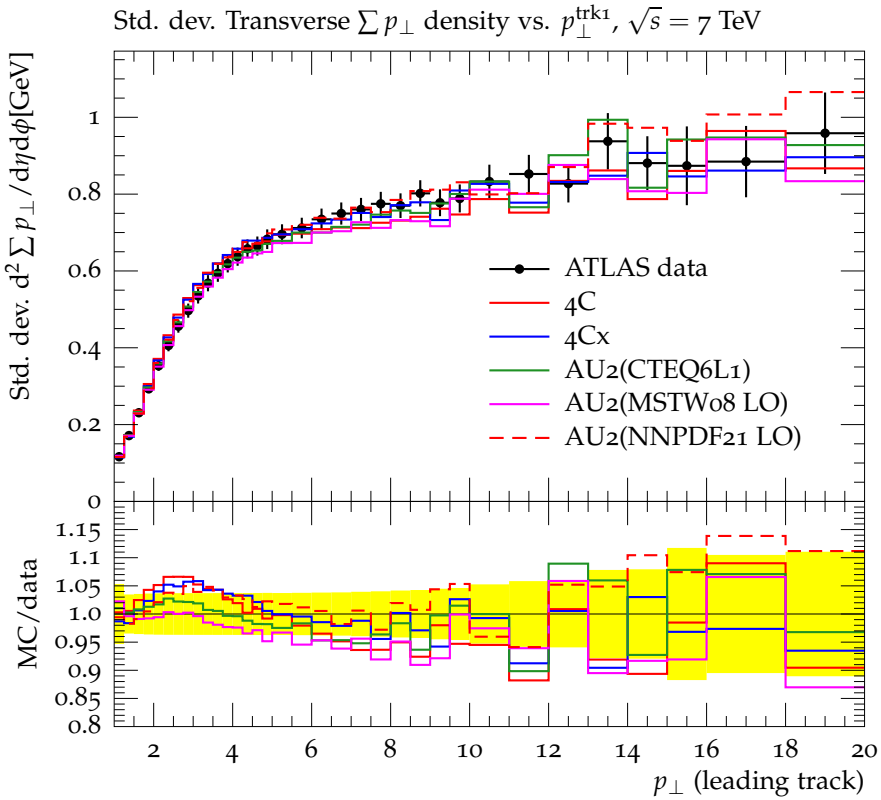


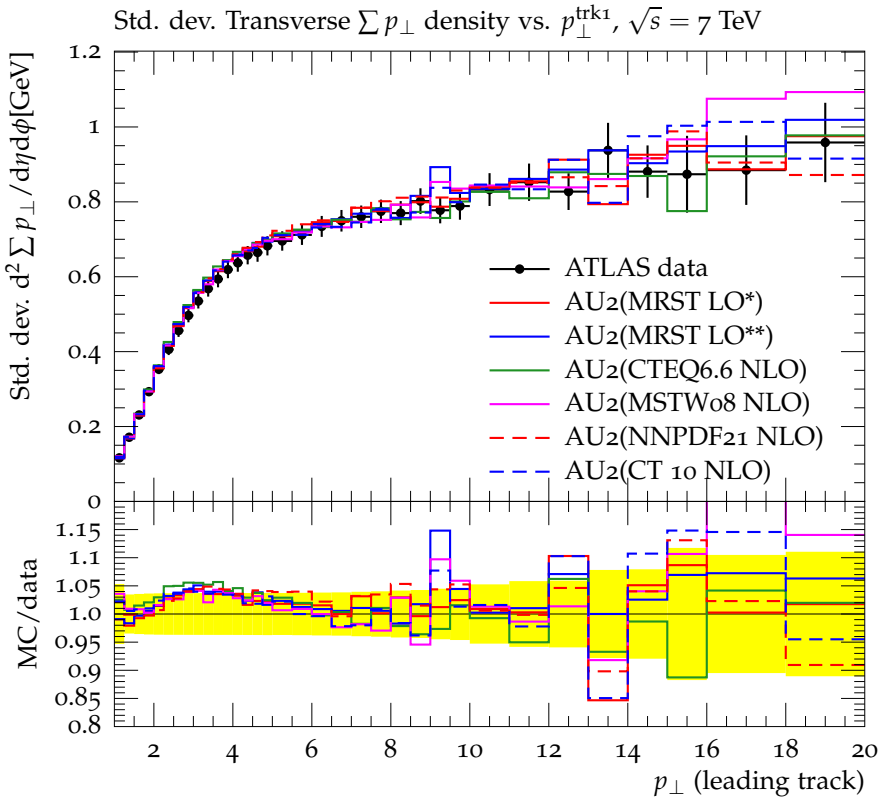
Tuning Results for Underlying Event Measurements 2/3





Tuning Results for Underlying Event Measurements 3/3





Summary &Outlook

Summary

- ATLAS tunes for Pythia8 using a x-dependent matter distribution were presented for various number of PDFs
- Good references are the AMBT2B CTEQ6L1 and AUET2B LO**, which provides a similar level of performance as of PYTHIA 6 for MC11 with different PDFs
- Use NLO PDFs for UE tunes, but LO PDFs for MB tunes (MB tunes with NLO PDFs gives bad results)

References

- The ATLAS Collaboration, *Summary of ATLAS Pythia 8 tunes* https://cdsweb.cern.ch/record/1474107. ATL-PHYS-PUB-2012-003
- T. Sjostrand, S.Mrenna, and P. Skands, *A brief introduction to Pythia 8.1*, Comput. Phys. Commun. 178 (2008) 852-867, arXiv:0710.3820 [hep-ph]

Summary &Outlook

Outlook

- New soft QCD analyses are being released(see ATLAS UE talk) and will be included in future tunes
- New tunes with different diffraction models are being investigated:
  - Bruni and Ingelman
  - Donnachie and Landshoff
  - Berger et al. and Streng
  - MBR (Minimum Bias Rockefeller)

→ Try to get a combined tune for minimum bias and underlying events

- Tuning of the Pythia 8 shower setup using jet shapes and jet gaps analysis
- Tuning of matched MC setups , e.g.: Powheg + Pythia 8
- Common tune for all energies available (Tevatron+LHC) and combined MB/UE tune

Thanks for your attention!
Stay tuned!