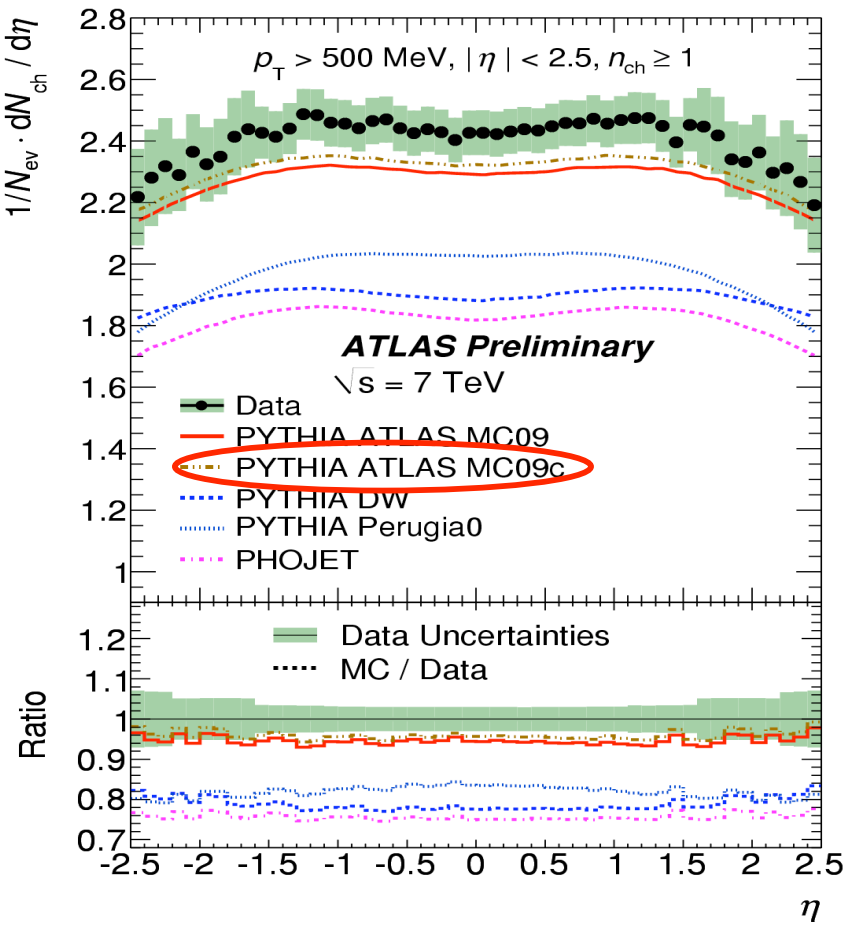
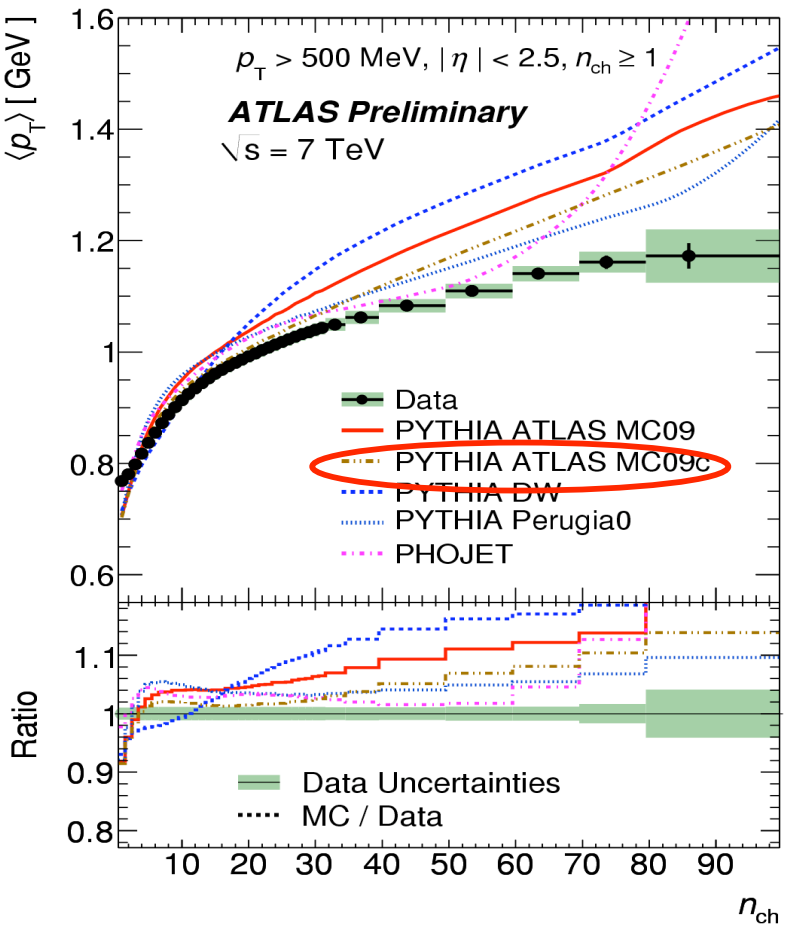
Charged particle multiplicities in p p interactions at $\sqrt{s}$ = 0.9 and 7 TeV in a diffractive limited phase-space and a new Pythia tune.

Judith Katzy (DESY)
On behalf of the ATLAS Collaboration

Min. Bias 1.5 results

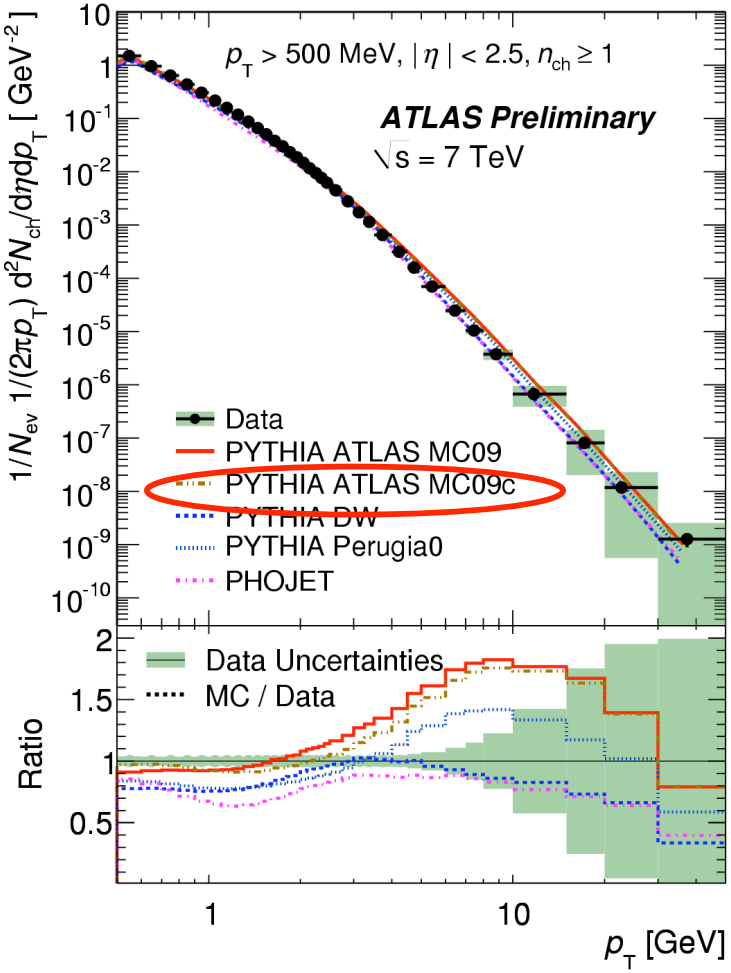


5% difference

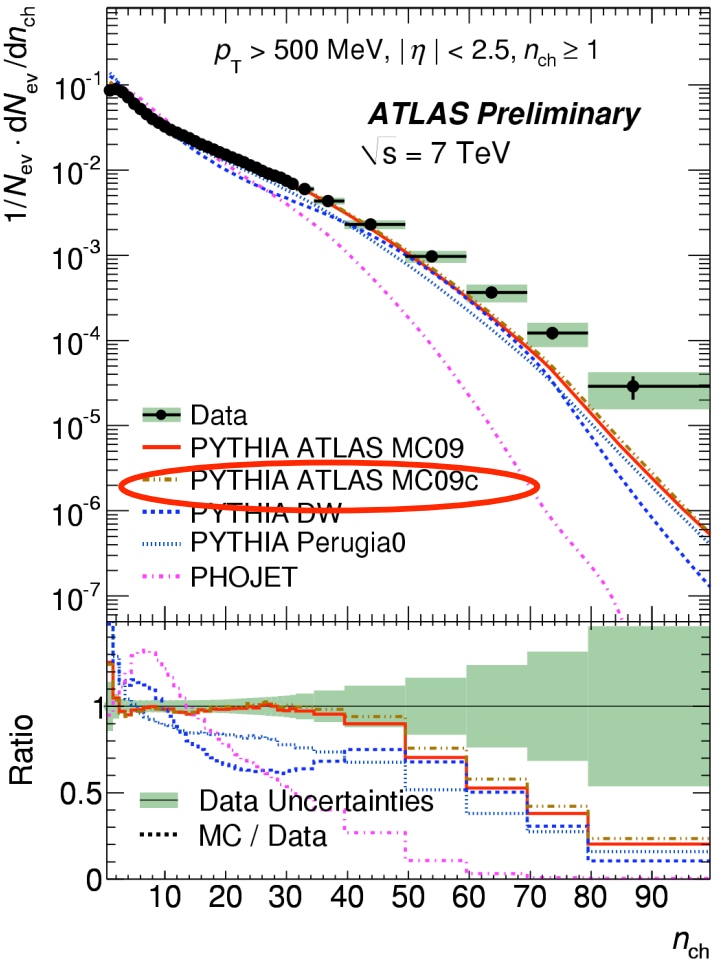


Shape difference at high n_{ch}

Min. Bias 1.5 results



Up to 200% overshoot at pt>5



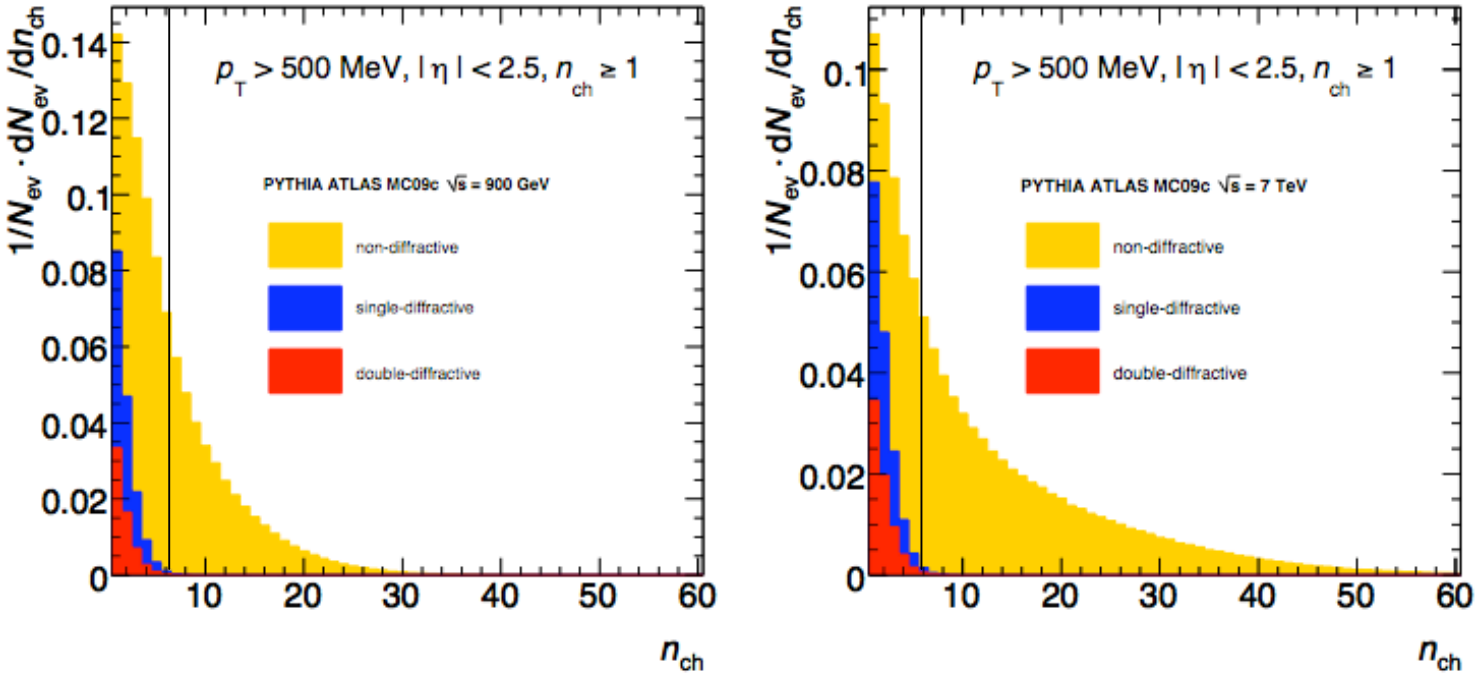
up to 90% undershoot at nch > 50

Diffraction

Due to our un-biased event selection the data sample contains 16% diffractive events at 900 GeV according to pythia6 - other experiments use two-arm triggers which suppress single diffractive events

Diffractive cross sections and differential distributions only very roughly known for LHC
However, all models predict Diffractive events mostly at low n_{ch}

Example: pythia6 predictions



Build diffractive suppressed sample with $n_{ch} \geq 6$

The data

Min.Bias 1.5 data sample and analysis as presented in

- ATLAS first paper for 900 GeV
- ATLAS-CONF-2010-024 for 7 TeV

In addition: cut on number of charged particles: $n_{ch} \geq 6$

Resulting number of events:

	$n_{ch} \geq 1$	$n_{ch} \geq 6$
7TeV:	369673	231665
900 GeV:	326201	157896

Result

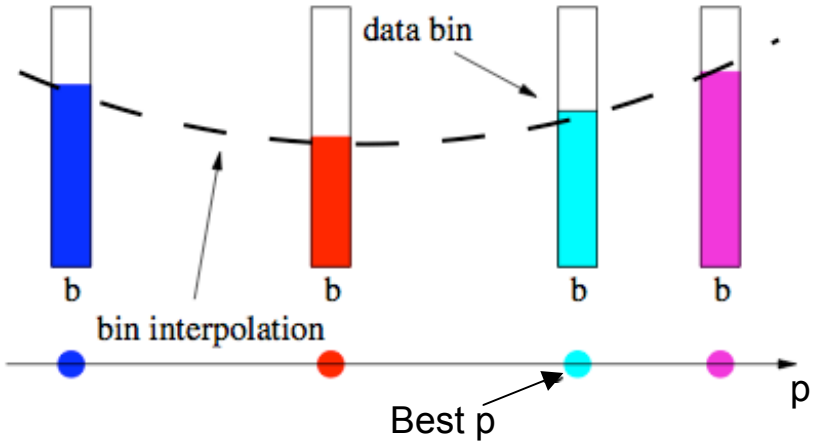
- Data samples with n_{ch} >=4,6,8
  - for tuning $n_{ch} \geq 6$ is used
  - other data sets are used for comparison with tuning results
- No differences are found in data-mc comparisons between the various data-sets
  - no diffractive contributions are left that could influence the tune

The Atlas Minium Bias Tune 1

- Adaption of the already good MC09c tune to the new LHC data
- Tune of the underlying event and color reconnection parameters
- Inclusion of new parameter (parp77) for suppression of color reconnection in fast moving strings to describe <pt> vs n_{ch}
- Tune performed as 5 (7) parameter tune with the Professor Tuning Tool

Tuning with Professor Tool - method

1. Build fast analytic model of the generator:
   - Random sampling: N parameter points in n-dimensional space
   - Run generator and fill histograms (Rivet)
   - For (each) bin: use $\tilde{N}$ points to fit interpolation (2^{nd} or 3^{rd} order polynomial)
2. Construct overall (now trivial) $\chi^2 = \sum_{bins} \frac{(interpolation - data)^2}{error^2}$
3. Numerically minimize using `pyMinuit, SciPy`



Tuning with Professor Tool - execution

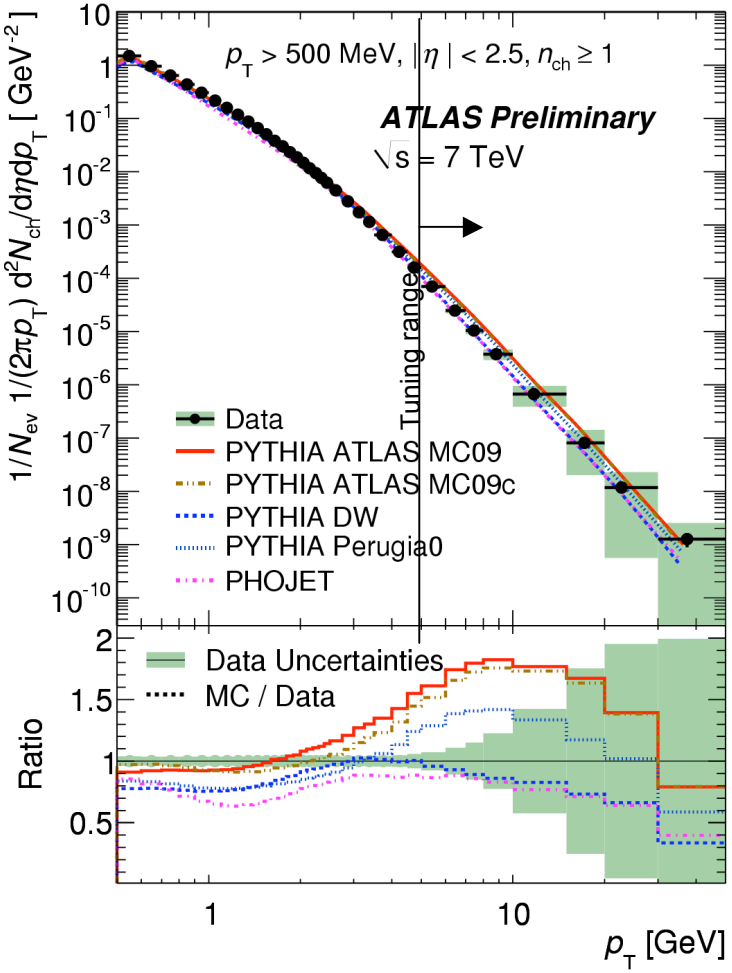
- Generate at 152 random points for 5 parameter scan to oversample
- Use oversampling to check stability and sensitivity of paramters

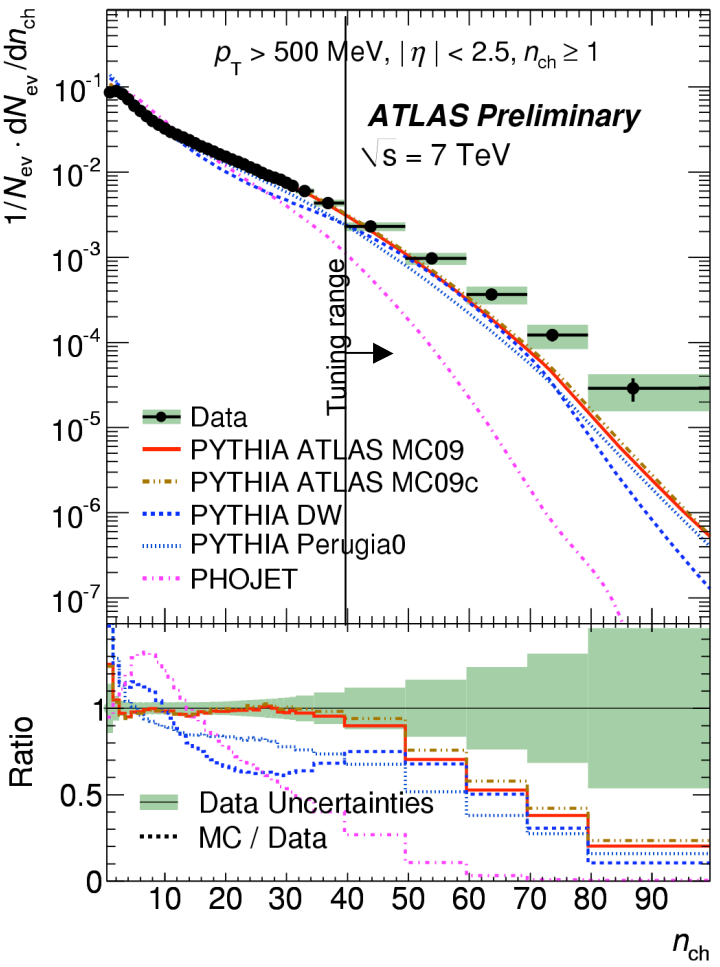
Remember:

$$\chi^2 = \sum_{bins} \frac{(interpolation - data)^2}{error^2}$$

The details

Use weights and regions of the data distributions to force the tuning of the interesting regions





Minimum bias observables for tuning

Analysis	Observable	Tuning range
ATLAS 0.9 TeV, minimum bias, $N_{ch} \geq 6$	$\frac{1}{N_{evt}} \frac{dN_{ch}}{d\eta}$	-2.5 – 2.5
ATLAS 0.9 TeV, minimum bias, $N_{ch} \geq 6$	$\frac{1}{2\pi\Delta\eta p_T} \frac{1}{N_{evt}} \frac{dN_{ch}}{dp_T}$	≥ 5.0
ATLAS 0.9 TeV, minimum bias, $N_{ch} \geq 6$	$\frac{1}{N_{evt}} \frac{dN_{ev}}{dN_{ch}}$	≥ 20
ATLAS 0.9 TeV, minimum bias, $N_{ch} \geq 6$	$\langle p_T \rangle$ vs. N_{ch}	≥ 10
ATLAS 7 TeV, minimum bias, $N_{ch} \geq 6$	$\frac{1}{N_{evt}} \frac{dN_{ch}}{d\eta}$	-2.5 – 2.5
ATLAS 7 TeV, minimum bias, $N_{ch} \geq 6$	$\frac{1}{2\pi\Delta\eta p_T} \frac{1}{N_{evt}} \frac{dN_{ch}}{dp_T}$	≥ 5.0
ATLAS 7 TeV, minimum bias, $N_{ch} \geq 6$	$\frac{1}{N_{evt}} \frac{dN_{ev}}{dN_{ch}}$	≥ 40
ATLAS 7 TeV, minimum bias, $N_{ch} \geq 6$	$\langle p_T \rangle$ vs. N_{ch}	≥ 10

Tune dominated by trying to fit
the high n_{ch} and high pt tails of the minimum bias data

Other ATLAS data sets

ATLAS 0.9 TeV, UE	$\langle \frac{d^2 N_{chg}}{d\eta d\phi} \rangle$ (towards)	≥ 5.5 GeV
ATLAS 0.9 TeV, UE	$\langle \frac{d^2 N_{chg}}{d\eta d\phi} \rangle$ (transverse)	≥ 5.5 GeV
ATLAS 0.9 TeV, UE	$\langle \frac{d^2 N_{chg}}{d\eta d\phi} \rangle$ (away)	≥ 5.5 GeV
ATLAS 0.9 TeV, UE	$\langle \frac{d^2 \sum p_T}{d\eta d\phi} \rangle$ (towards)	≥ 5.5 GeV
ATLAS 0.9 TeV, UE	$\langle \frac{d^2 \sum p_T}{d\eta d\phi} \rangle$ (transverse)	≥ 5.5 GeV
ATLAS 0.9 TeV, UE	$\langle \frac{d^2 \sum p_T}{d\eta d\phi} \rangle$ (away)	≥ 5.5 GeV
ATLAS 7 TeV, UE	$\langle \frac{d^2 N_{chg}}{d\eta d\phi} \rangle$ (towards)	≥ 10 GeV
ATLAS 7 TeV, UE	$\langle \frac{d^2 N_{chg}}{d\eta d\phi} \rangle$ (transverse)	≥ 10 GeV
ATLAS 7 TeV, UE	$\langle \frac{d^2 N_{chg}}{d\eta d\phi} \rangle$ (away)	≥ 10 GeV
ATLAS 7 TeV, UE	$\langle \frac{d^2 \sum p_T}{d\eta d\phi} \rangle$ (towards)	≥ 10 GeV
ATLAS 7 TeV, UE	$\langle \frac{d^2 \sum p_T}{d\eta d\phi} \rangle$ (transverse)	≥ 10 GeV
ATLAS 7 TeV, UE	$\langle \frac{d^2 \sum p_T}{d\eta d\phi} \rangle$ (away)	≥ 10 GeV

"plateau" region of underlying event in minimum bias analysis
Included; very small influence on tune due to large uncertainties in data

Tevatron data

- CDF run I underlying event in dijet events
- CDF run I underlying event in min/max cones
- D0 run II dijet angular correlation (phi distributions)
- CDF run II min.bias (<pt> vs n_{ch})
- CDF run I Zpt

Guarantee consistency with Tevatron data

Excluded: CDF 2002 min.bias as conflicts between this and ATLAS data sets are found and couldn't be resolved

Parameters used for tuning

Parameter	related model	MC09c value	scanning range	AMBT1 value
PARP(62)	ISR cut-off	1.0	fixed	1.025
PARP(93)	primordial kt	5.0	fixed	10.0
PARP(77)	CR suppression	0.0	0.25 – – – 1.15	1.016
PARP(78)	CR strength	0.224	0.2 – – – 0.6	0.538
PARP(83)	MPI (matter fraction in core)	0.8	fixed	0.356
PARP(84)	MPI (core of matter overlap)	0.7	0.0 – – – 1.0	0.651
PARP(82)	MPI (p_T^{min})	2.31	2.1 – – – 2.5	2.292
PARP(90)	MPI (energy extrapolation)	0.2487	0.18 – – – 0.28	0.250

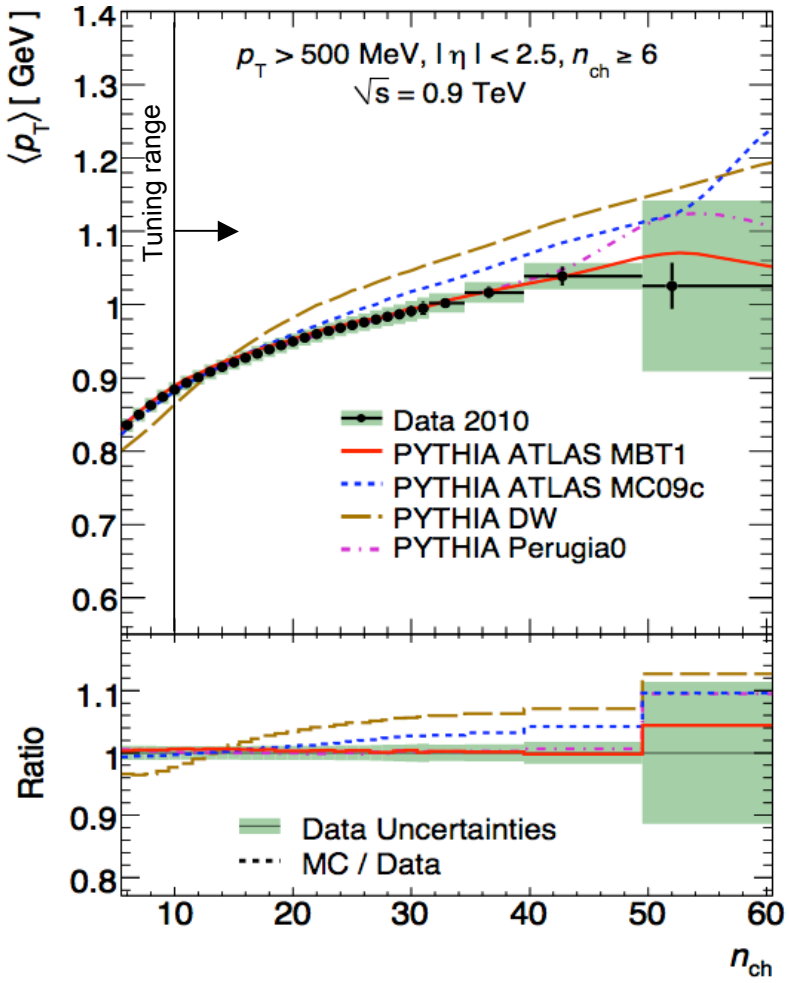
Table 4: Comparison of MC09c and resulting optimised parameters (AMBT1). The range for parameter variations in AMBT1 are also given.

Tune parameters related to MPI and color reconnection!

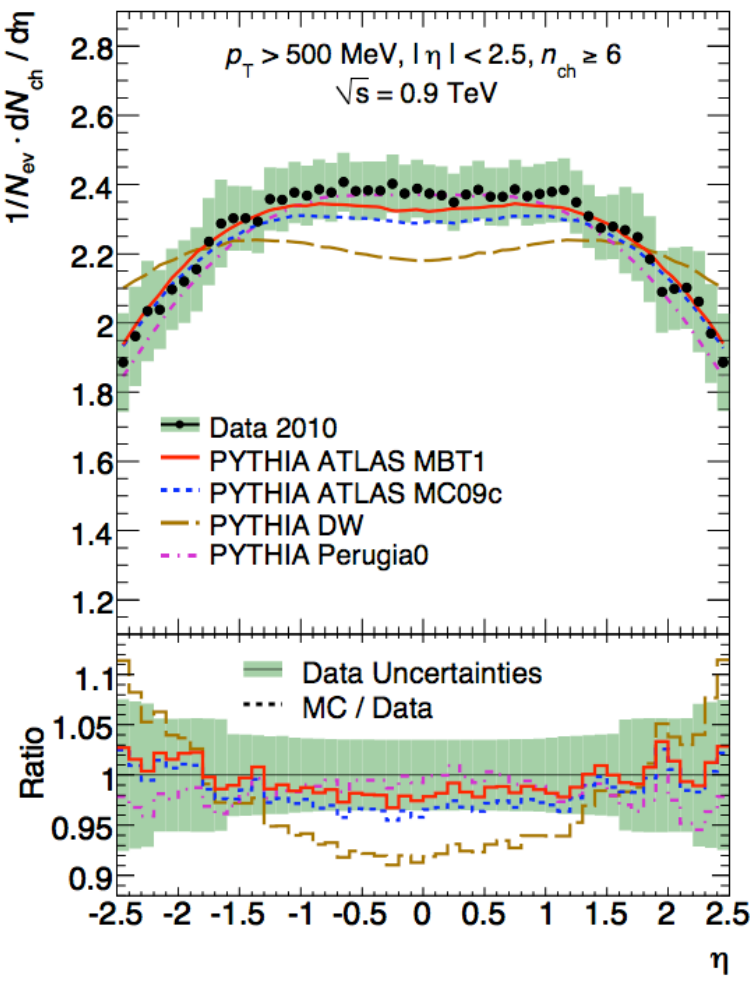
Note that
- PARP(78) and PARP(77) are strongly correlated
- PARP(82) and PARP(84) are strongly anti-correlated

Comparisons with data

min.bias1.5T at 900 GeV



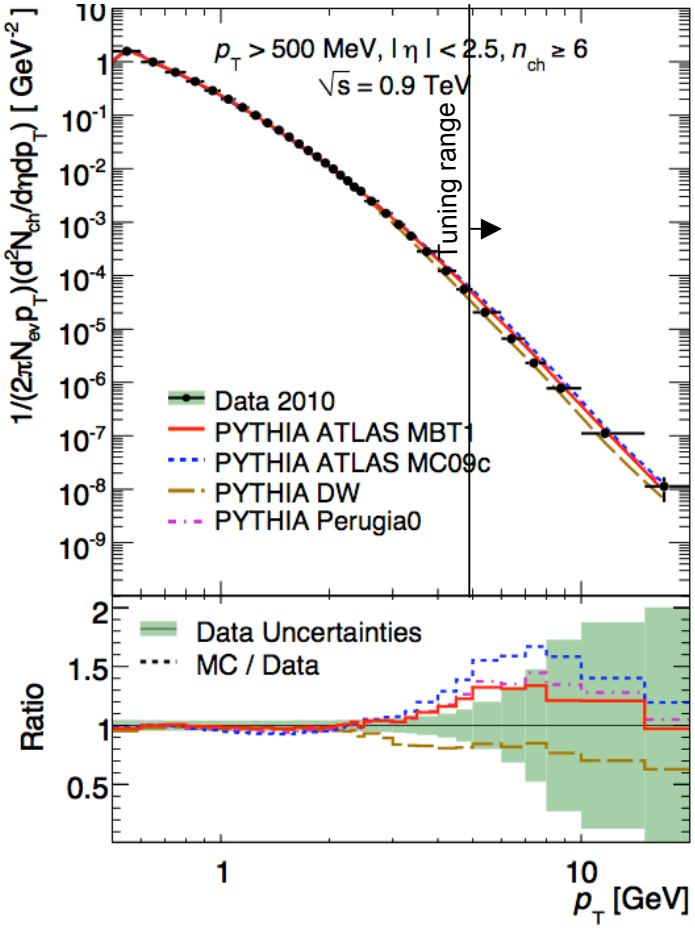
Perfect description



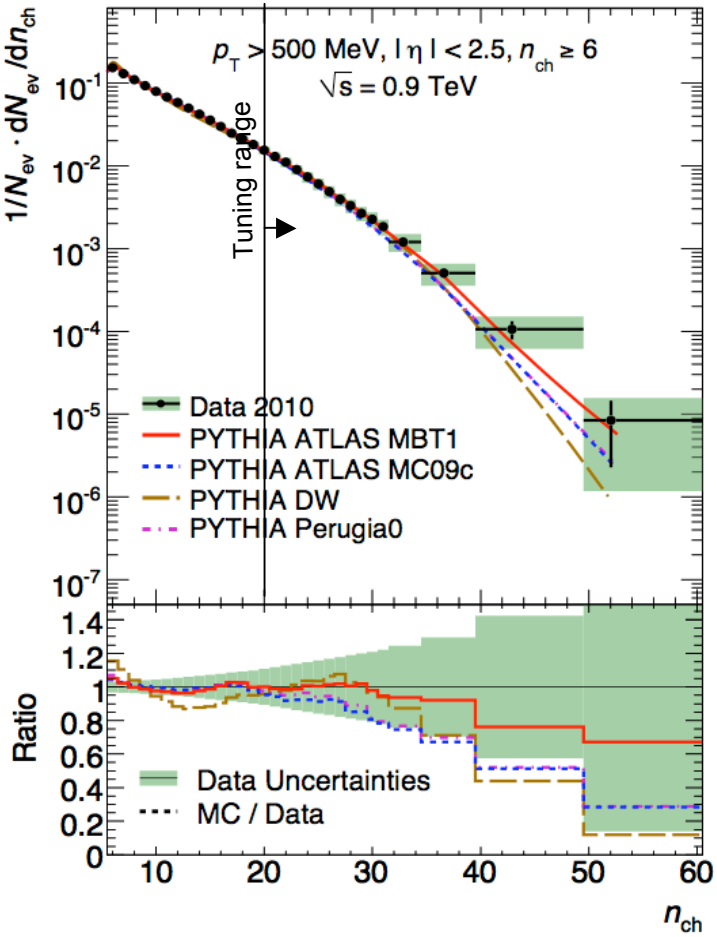
Description within 3%

Comparisons with data

min.bias1.5T at 900 GeV



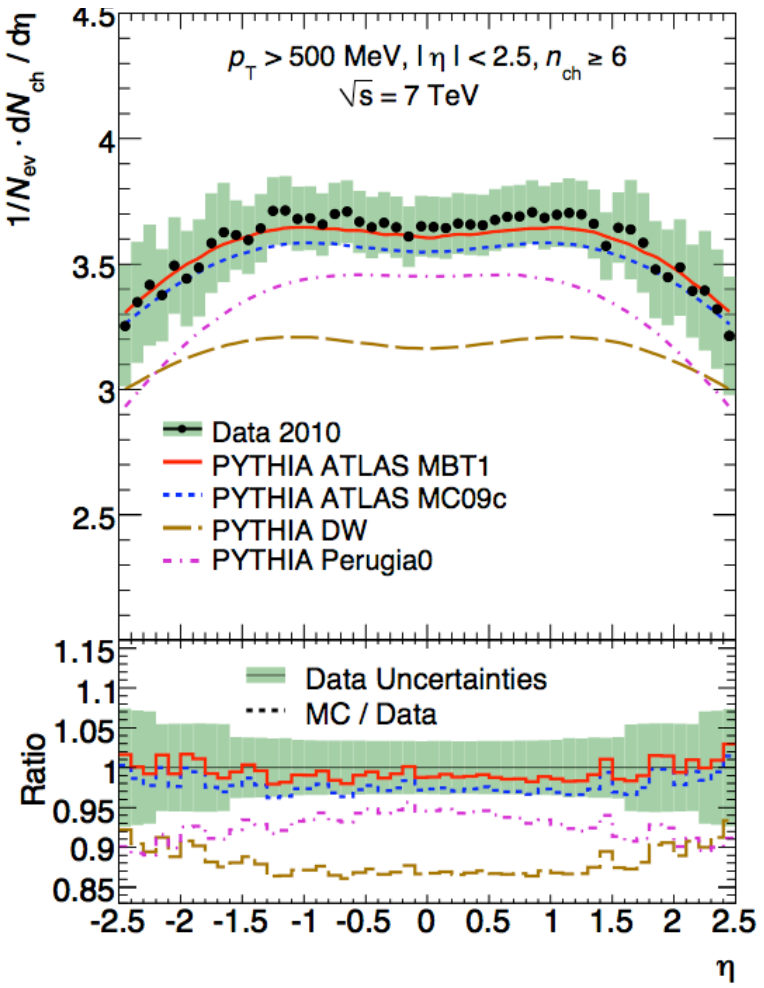
Good description up to ~4GeV
Slightly harder than systematic errors at at>4GeV

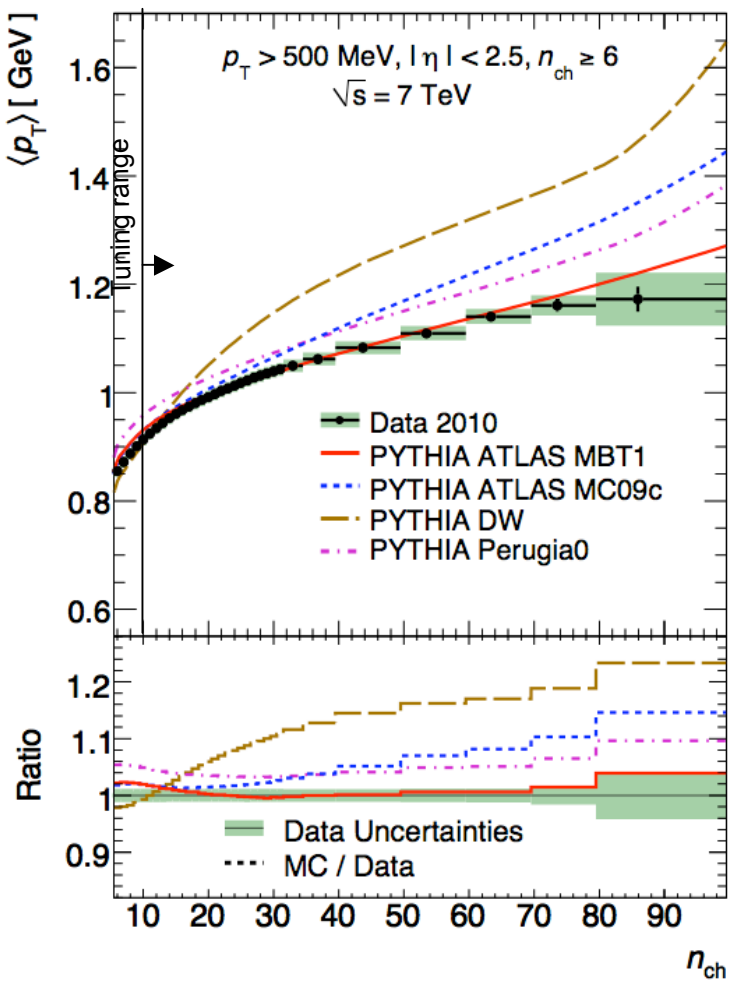


Good description within errors

Comparisons with data

min.bias1.5T at 7 TeV

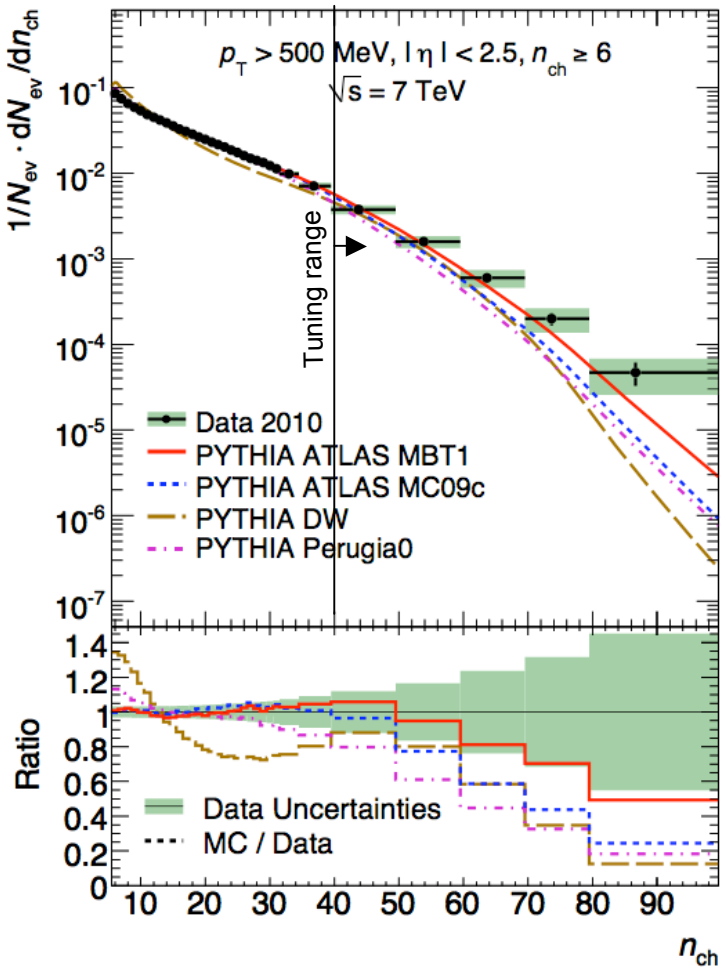




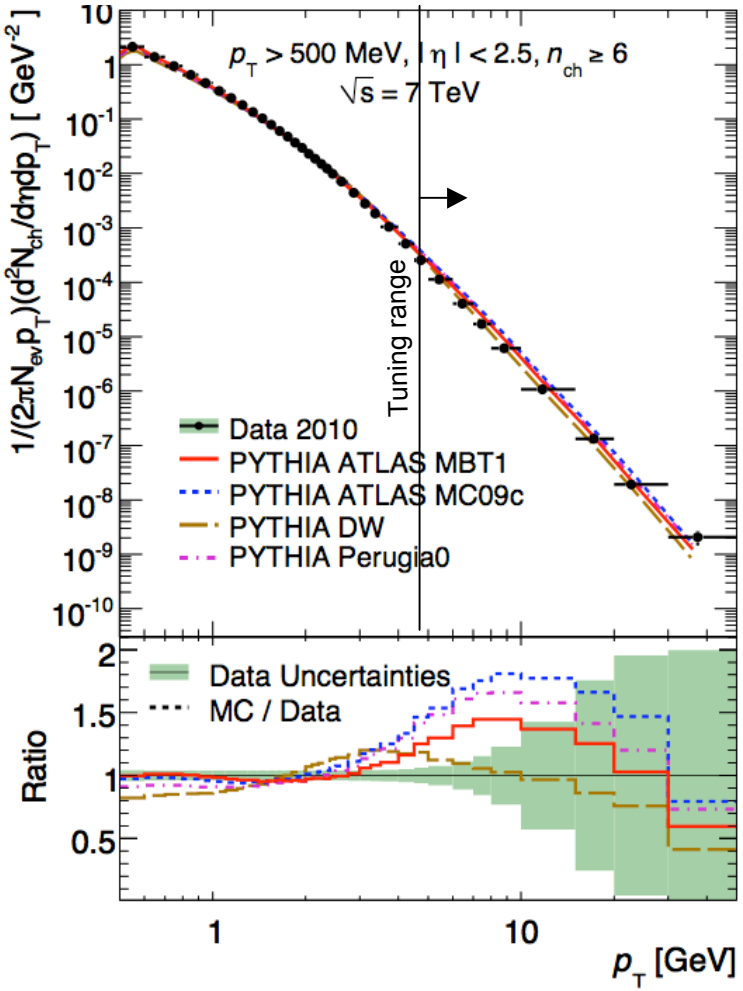
Description within 2%!

Comparisons with data

min.bias1.5T at 7 TeV

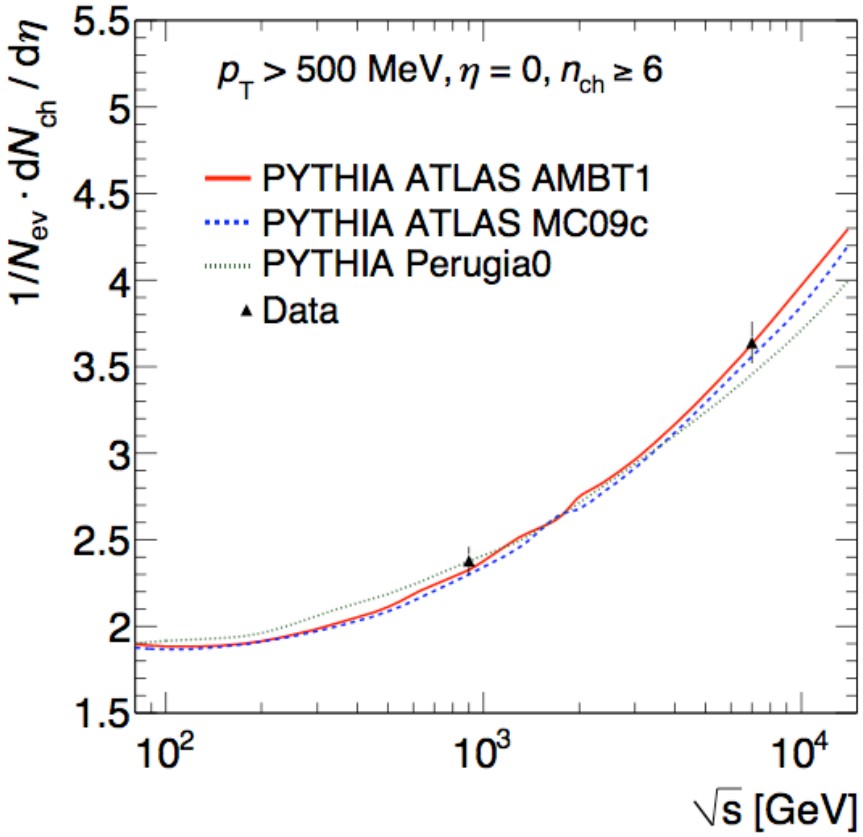


Description within errors



Very good description up to ~4GeV
Deviations at high pt reduced to 50%

Energy dependence of $<N_{ch}>$ at $\eta=0$



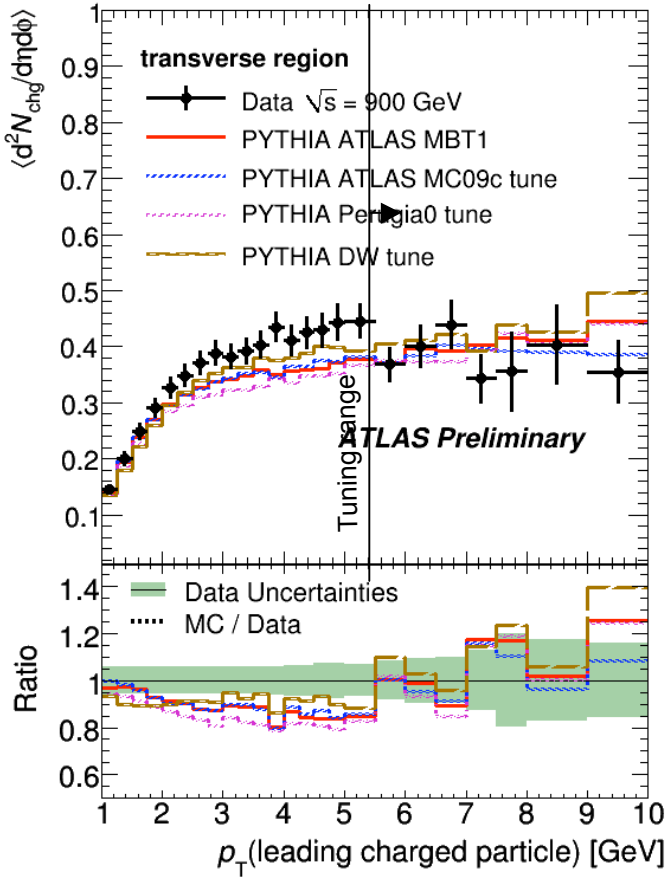
Both ATLAS tunes agree with data
AMBT1 predicts slightly more particles
Perugia0 10% lower than mean value
Differences of MC predictions are of similar size for 14 TeV

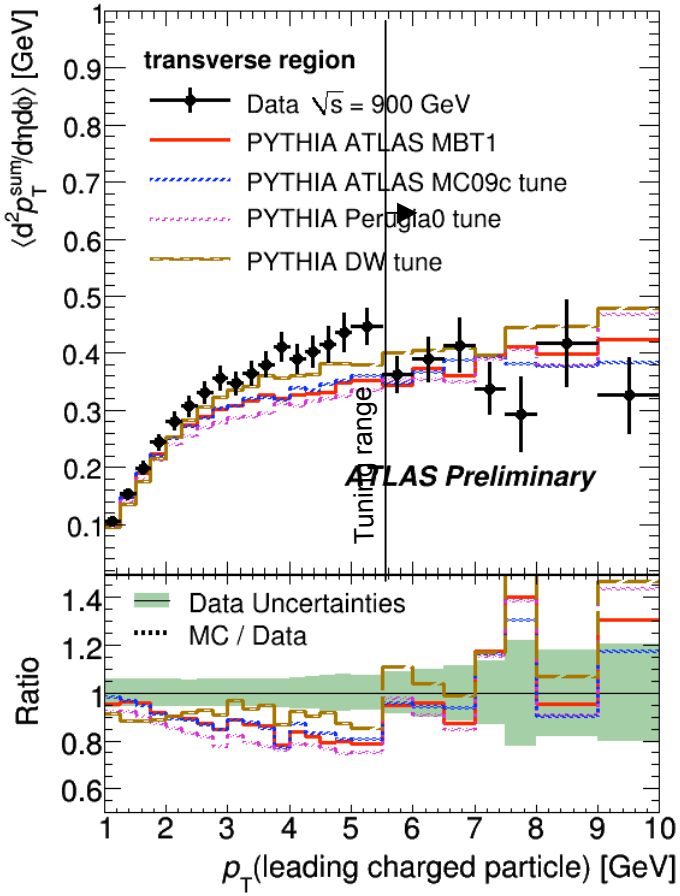
Minimum Bias summary

- Most minimum bias distributions well descripted also outside the tuning range
- Remaining differences in pt spectrum at high pt
- Physics interpretation in terms of models difficult due to high correlation of some parameters

Comparisons with data

min.bias leading track at 900 GeV

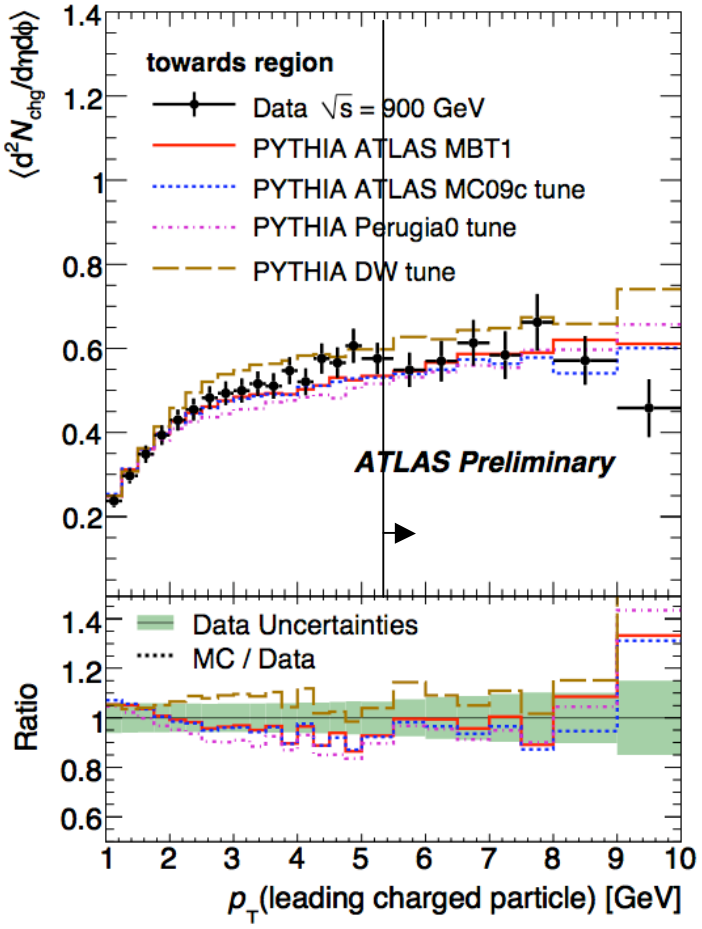


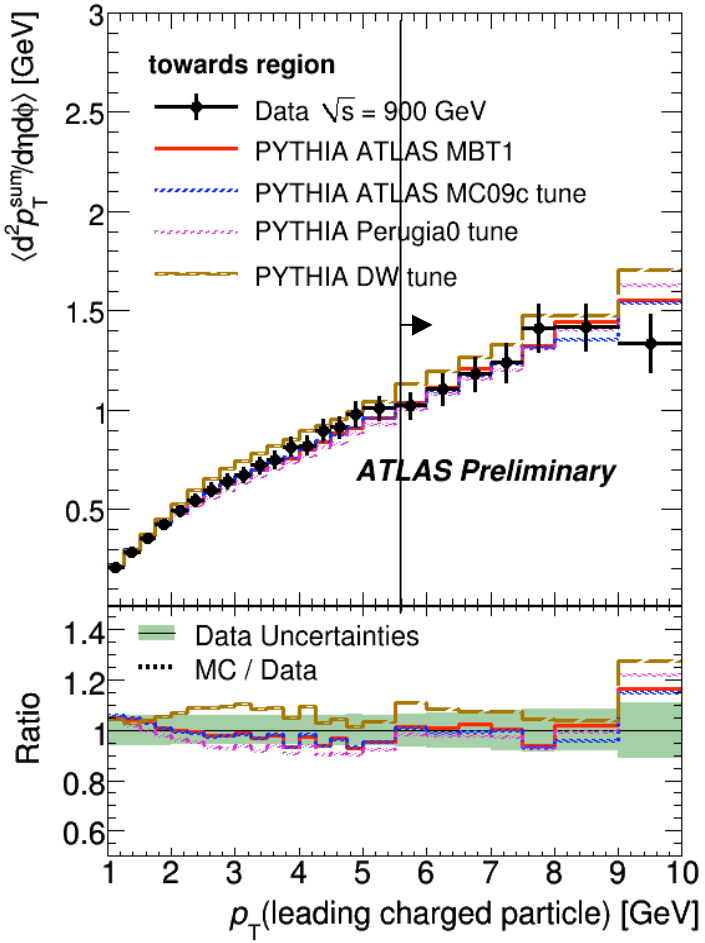


No change to MC09, agreement within uncertainties at pt>6GeV

Comparisons with data

min.bias leading track at 900 GeV

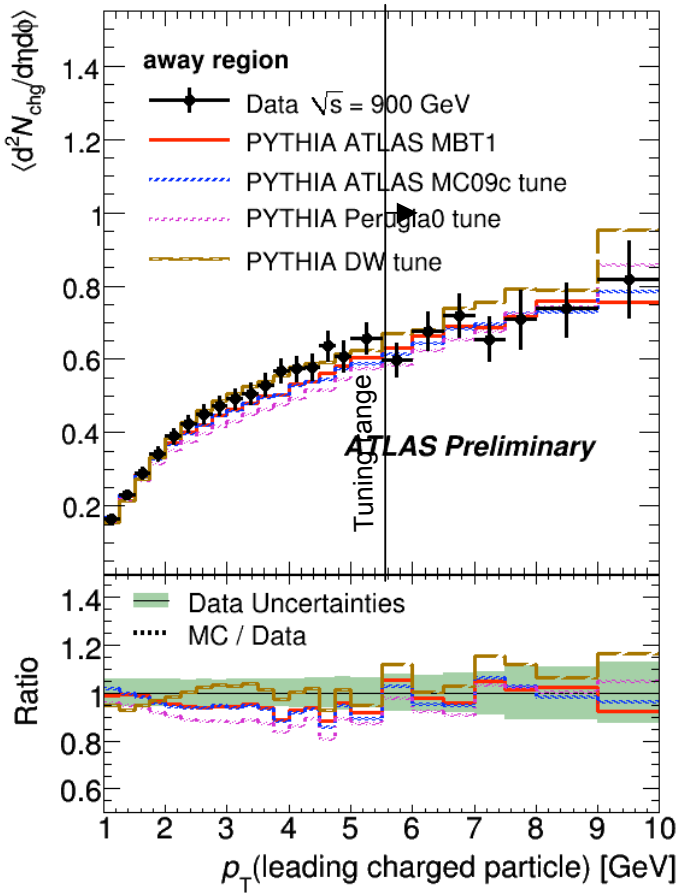


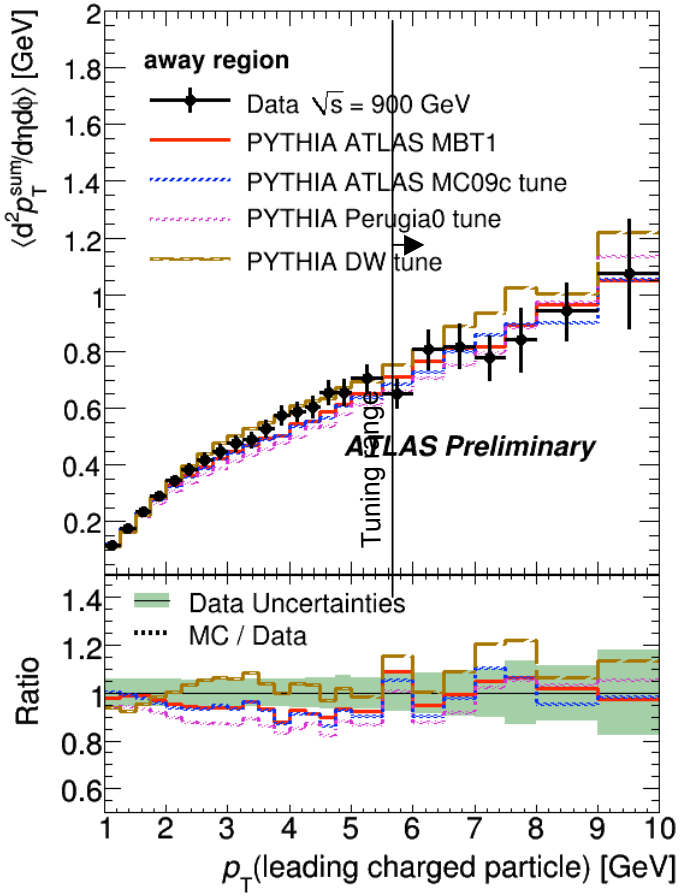


No change to MC09c, very good agreement with data

Comparisons with data

min.bias leading track at 900 GeV

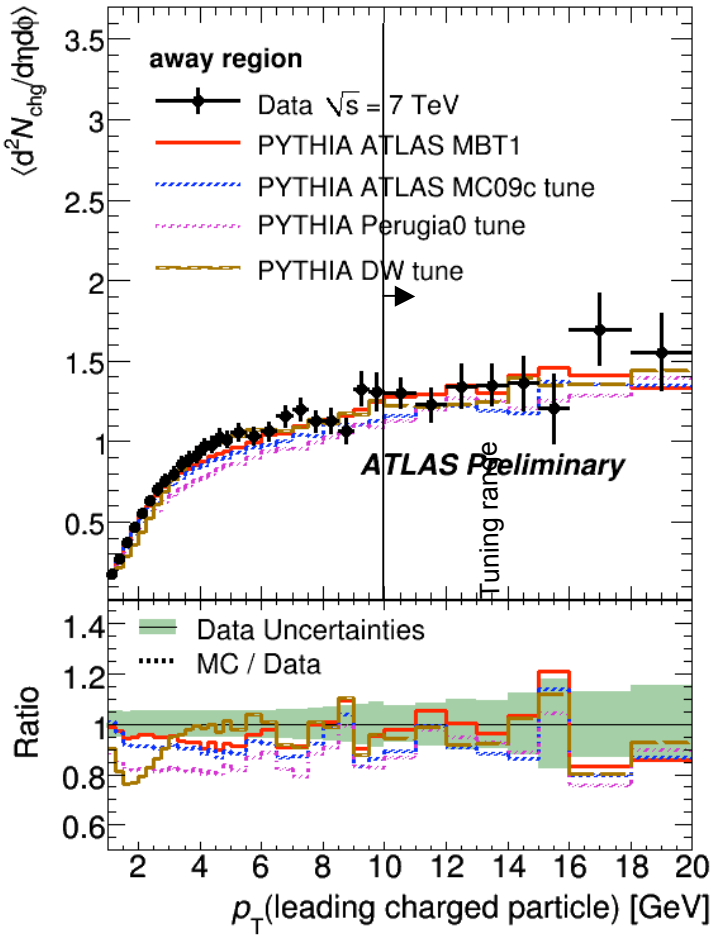


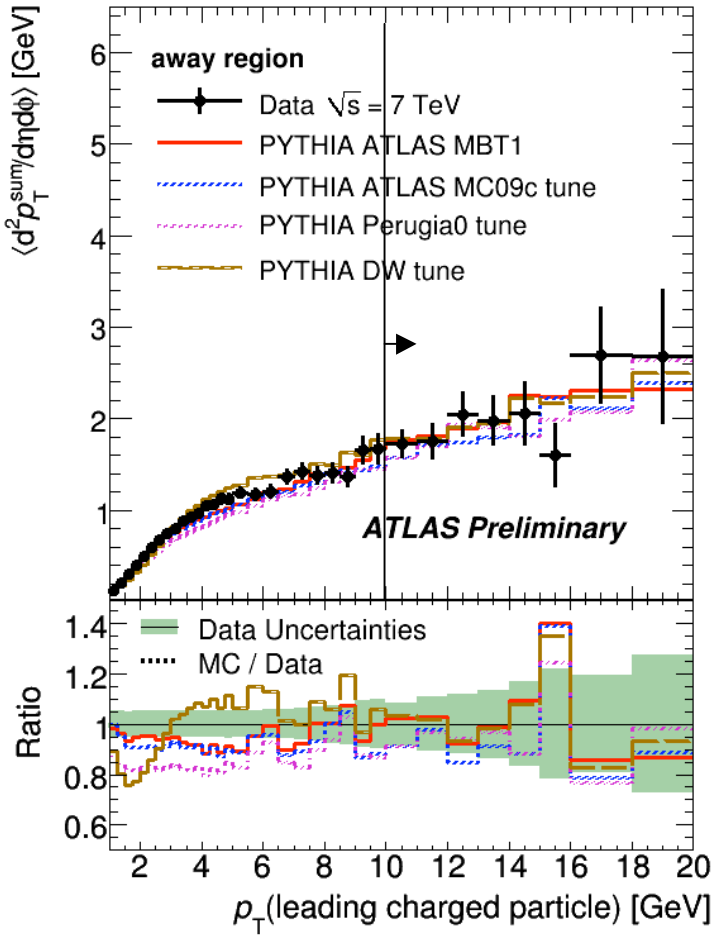


No change to MC09, agreement within 10%

Comparisons with data

min.bias leading track at 7 TeV

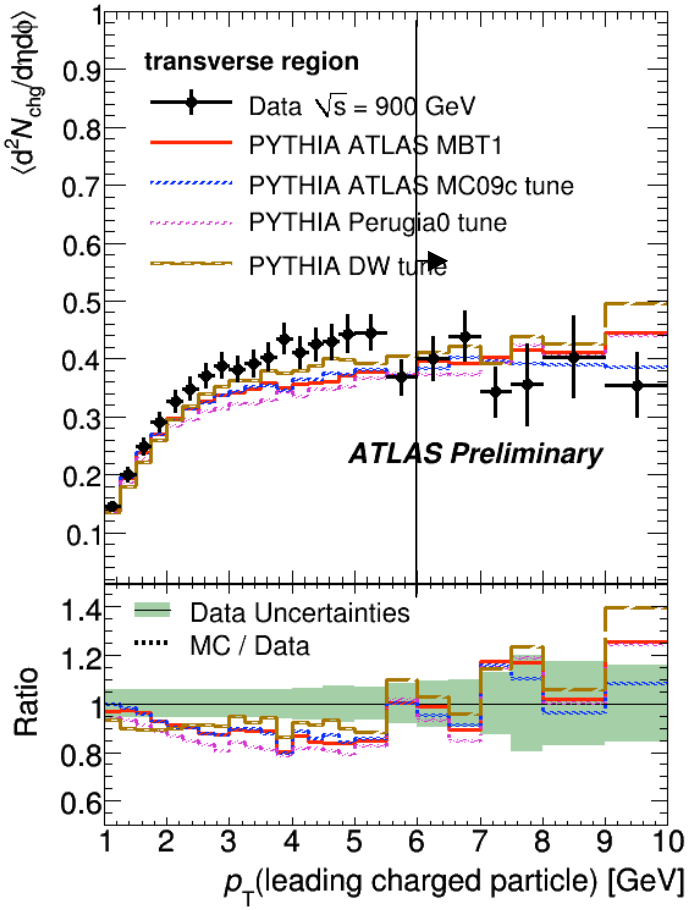


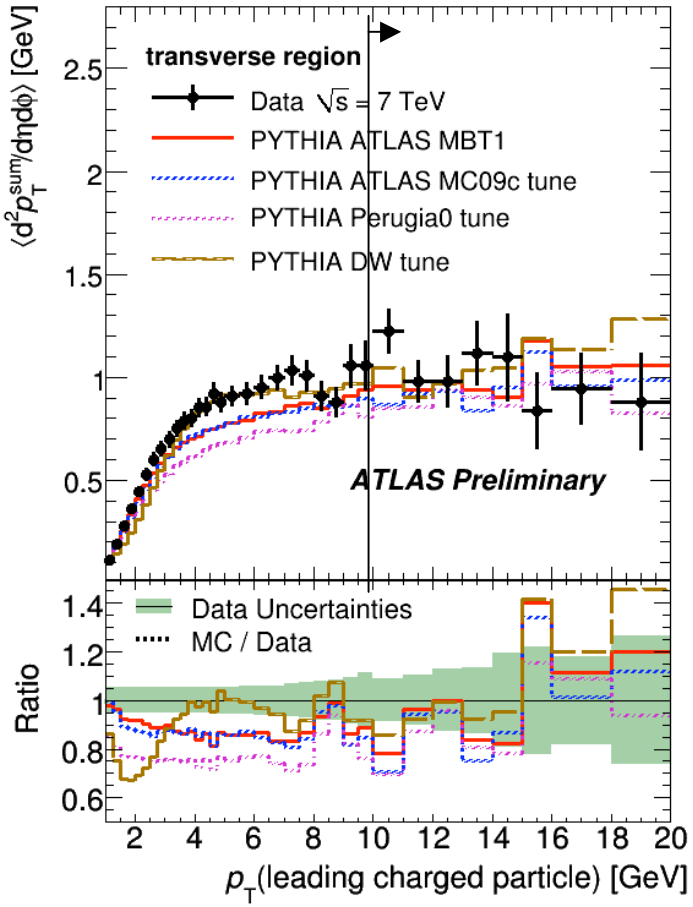


Slightly higher predictions for AMBT1, agreement with data within 10%

Comparisons with data

min.bias leading track at 7 TeV

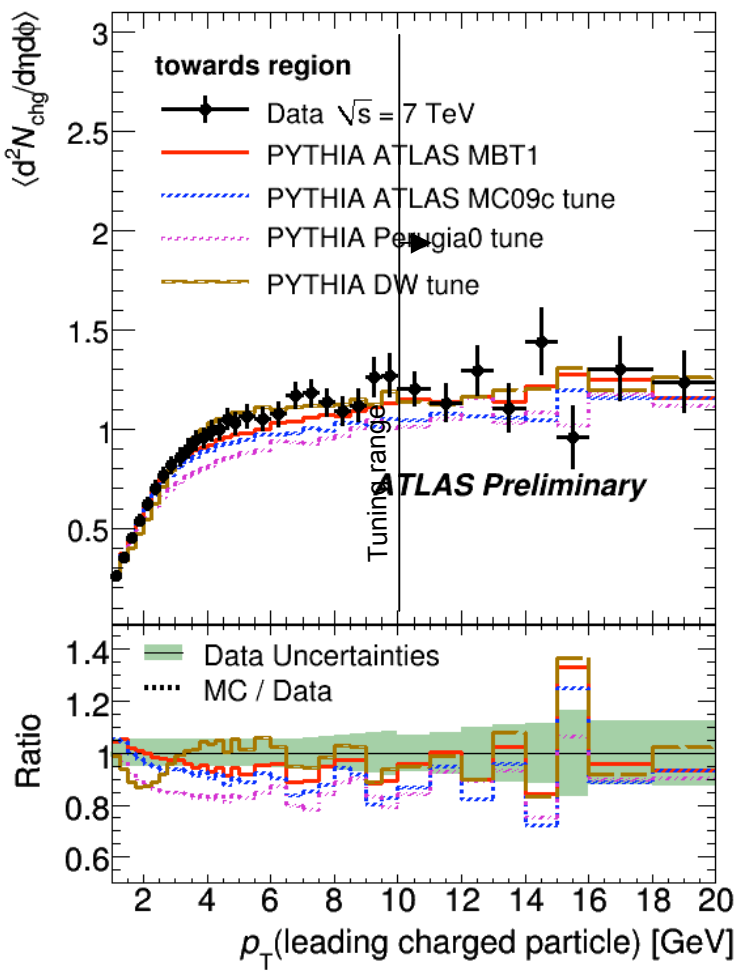


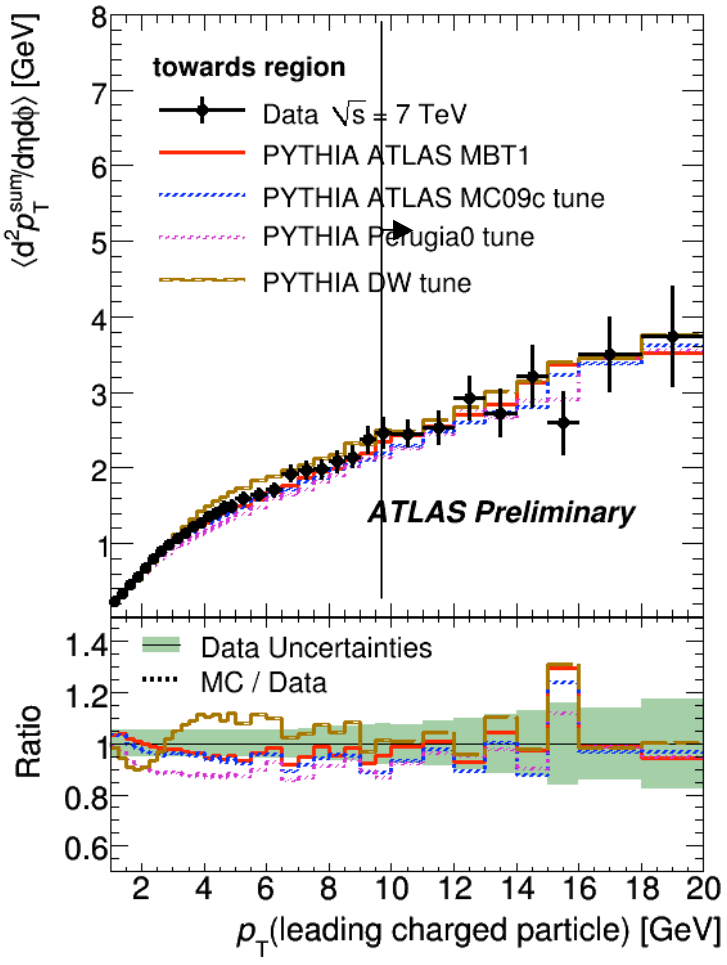


AMBT1 not significantly changed compared to MC09c
Reasonable description of distributions at $pt_{leadingtrack}$>10GeV

Comparisons with data

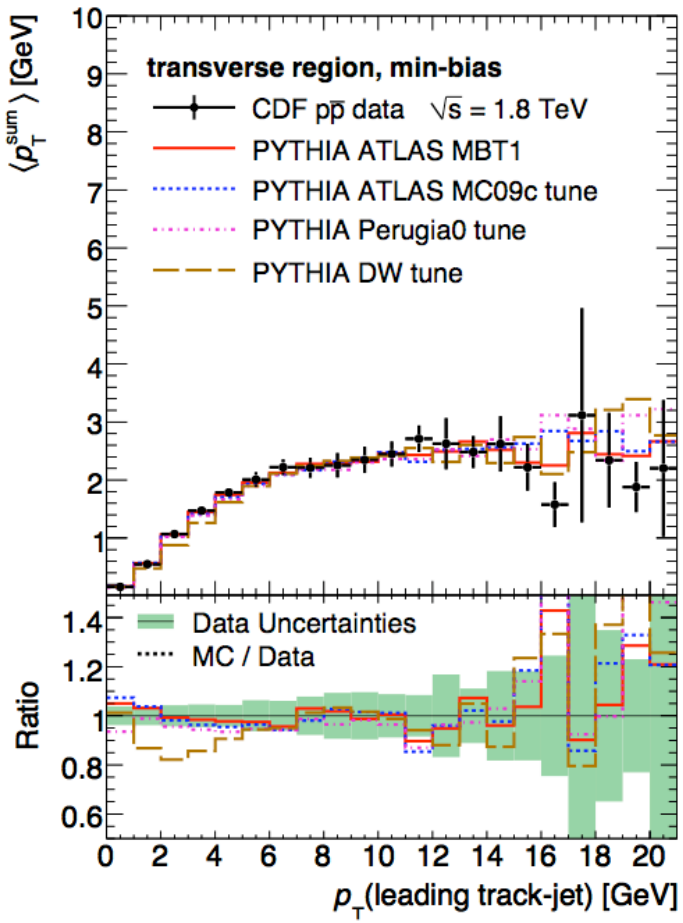
min.bias leading track at 7 TeV

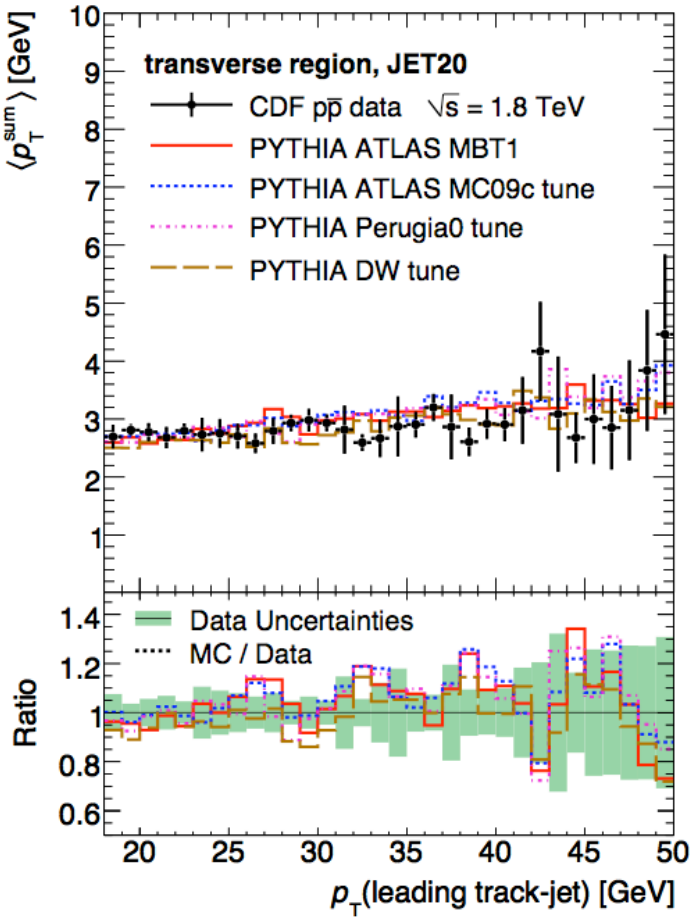




Slight improvement compared to MC09, agreement with data within 10%

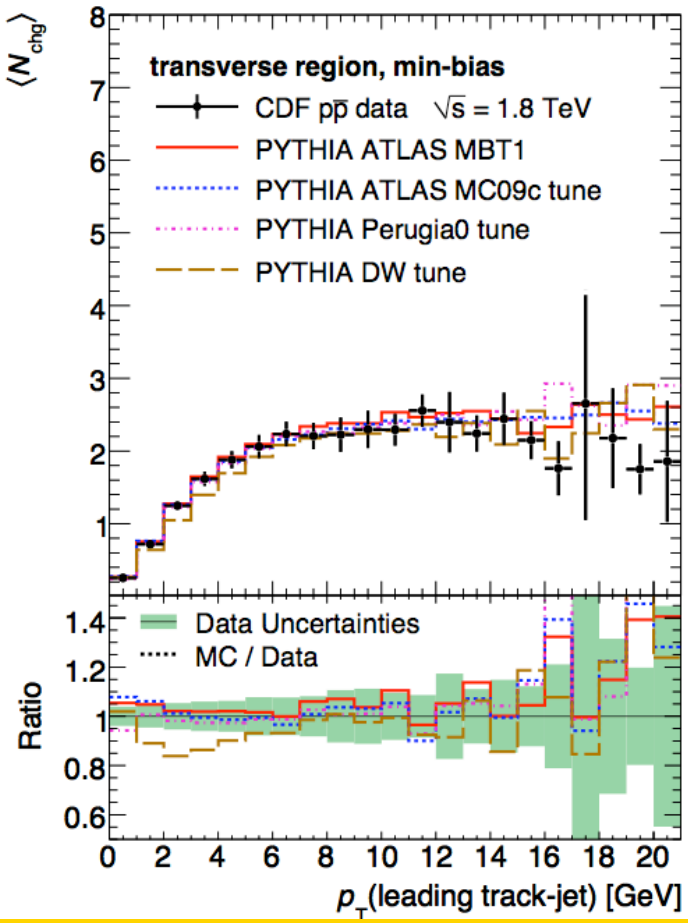
Comparison to CDF run I

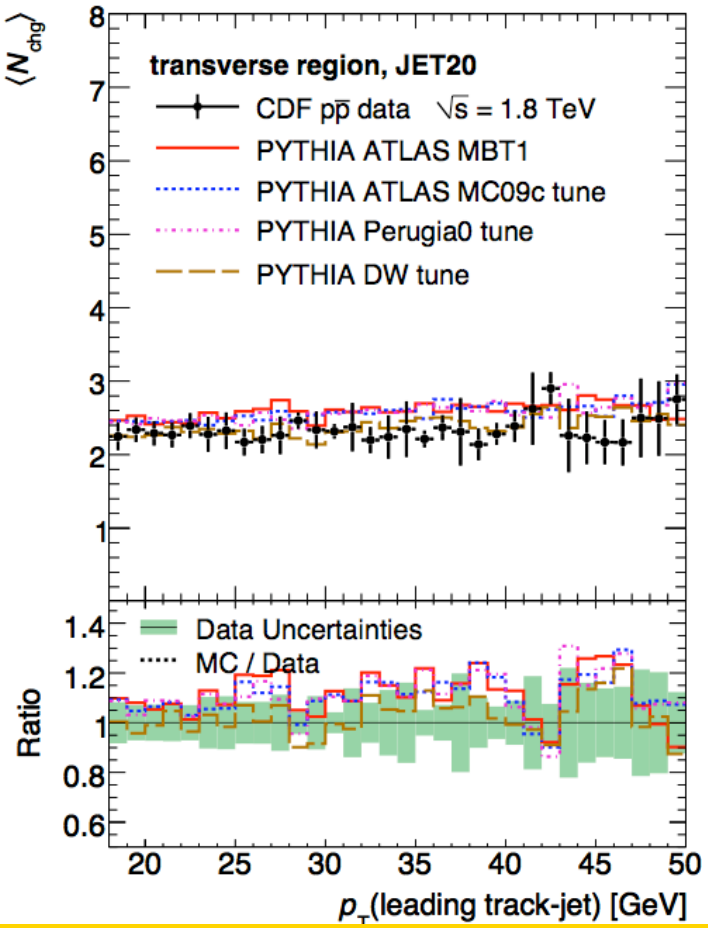




Very good agreement - no change to MC09c

Comparison with CDF run I





Very good agreement - basically no change to MC09c

Summary

- new measurement of charged particles with pt>500MeV and $|\eta|<2.5$ in diffractive suppressed phase space
- First ATLAS tune to LHC data
- Agreement within 10% or better for all ATLAS min.bias distributions except high pt region
- Remaining differences in pt spectrum of charged particles above 4 GeV
- Underlying event region in minimum bias data in high pt region described - however large statistical uncertainties of the data limit precise model comparisons