Recent Minimum Bias Results from ATLAS

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Introduction

Minimum bias results at 900 GeV published march 2010 in Phys Lett B 688, Issue 1, 21-42

Results presented by W. Bell in last workshop

This talk focuses on ATLAS minimum bias measurements at √s=7 TeV

(documented in ATLAS-CONF-2010-024, 21 April 2010)

Results based on the first ~6.8 μb^{-1} of 7TeV data recorded by the ATLAS experiment on 30th March 2010 using a single-arm minimum-bias trigger (369673 events)

Charged particle multiplicity studied in events with at least one primary charged particle (N_{ch}>=1) produced within the kinematic range |η|< 2.5 and p_T > 500 MeV

Aim is to have a model independent measurement of charged particle multiplicity for specific phasespace, no removal of single diffractive component

Corrected distributions obtained using:

- ✓Trigger and vertex efficiency from data
- ✓Track reconstruction efficiency from simulation
- ✓systematic uncertainty of tracking efficiency based on data/simulation comparison

Event and track selection

Event level requirements:

- Level 1 MBTS single-arm trigger,
- primary vertex in event
- pile-up veto: reject events with a second primary vertex with 4 or more tracks
- >=1 “primary track” in event

“Primary track” selection:

- track p_T > 500 MeV,
- a minimum of one Pixel and six* SCT (Semiconductor Tracker) hits on the track
- $|d0_{PV}| < 1.5$ mm and $|z0_{PV}|\sin\theta < 1.5$ mm, impact parameters with respect to primary vertex

* requiring six SCT hits was found to be crucial to remove fake high p_T tracks

Trigger efficiency

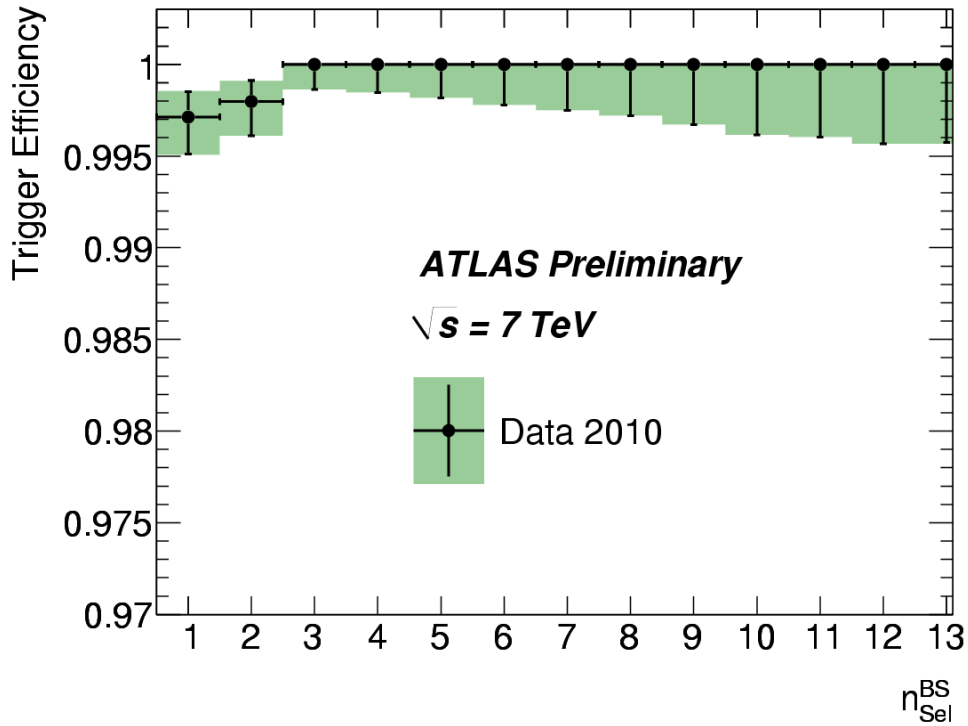
Analysis trigger: L1 MBTS single-arm minimum-bias trigger

High voltage and threshold settings improved with respect to 900 GeV analysis so that a single MIP trigger signal is accepted with higher efficiency

Measure trigger efficiency of L1 MBTS with respect to control trigger

Control trigger: random trigger coincident with colliding bunches with at least 4 pixel clusters and at least 4 SCT space points at L2

The single-arm trigger was measured to be almost fully efficient for chosen phasespace except for slightly lower efficiency in low multiplicity events



Minimum Bias Trigger Scintillators (MBTS)

2 units in η (2.09 < η < 2.82, 2.82< η < 3.84)

z = —3560 mm, 8 units in φ

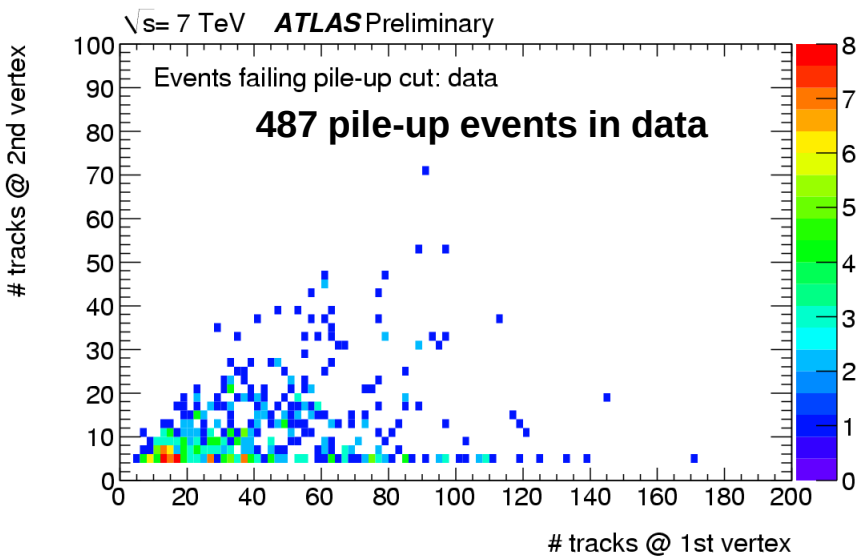
n^{BS}_{Sel}=number of tracks passing "good track" criteria but using $|d0_{BS}|$ < 4mm instead of $d0_{PV}/z0_{PV}$ cuts

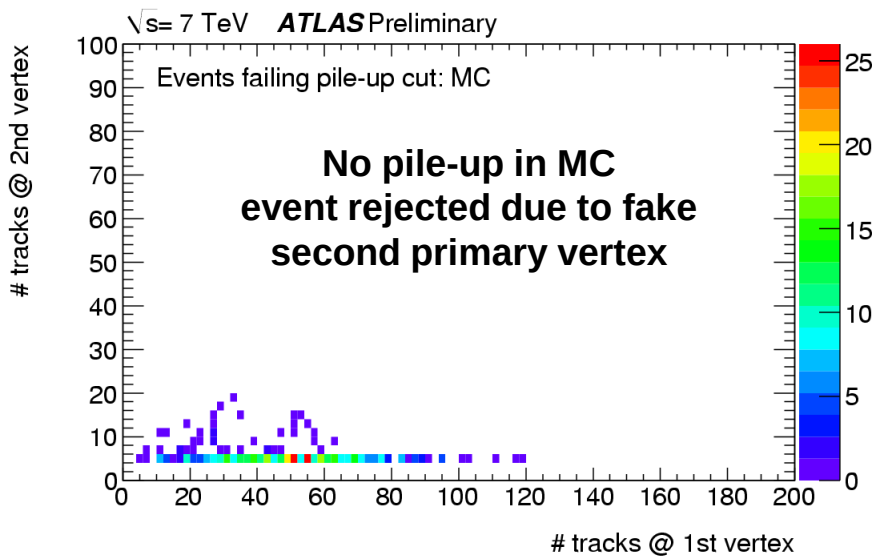
Pile-up veto

Original 900 GeV analysis allowed only a single primary vertex reconstructed per event

Recent analysis takes into account possibility of multiple proton-proton interactions inside same bunch crossing by allowing reconstruction of multiple primary vertices

pile-up veto: reject events with a second primary vertex with 4 or more tracks





Expected fraction of pile-up events is 10^{-3} at LHC conditions for this data

487 events were removed by pile-up veto, corresponding to 0.1% of our data

Fraction of removed events that are not true pile-up is estimated to be 0.03%.

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Vertex reconstruction efficiency

Primary vertex is constrained to beamspot position and requires at least two tracks with:

track p_T > 100 MeV

$|d0_{BS}|$< 4 mm

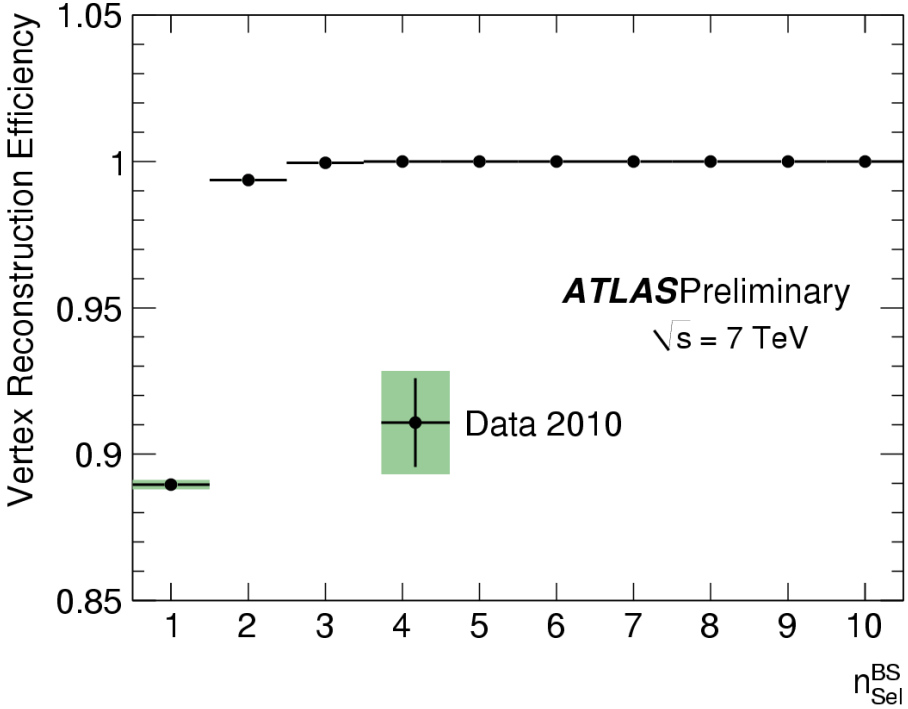
>=1 pixel hit

>=4 SCT hit

>=6 SCT+Pixel hits

Vertex reconstruction efficiency is measured in data using all MBTS1 events

For n^{BS}_{Sel}<3, vertex reconstruction efficiency is corrected in bins of η



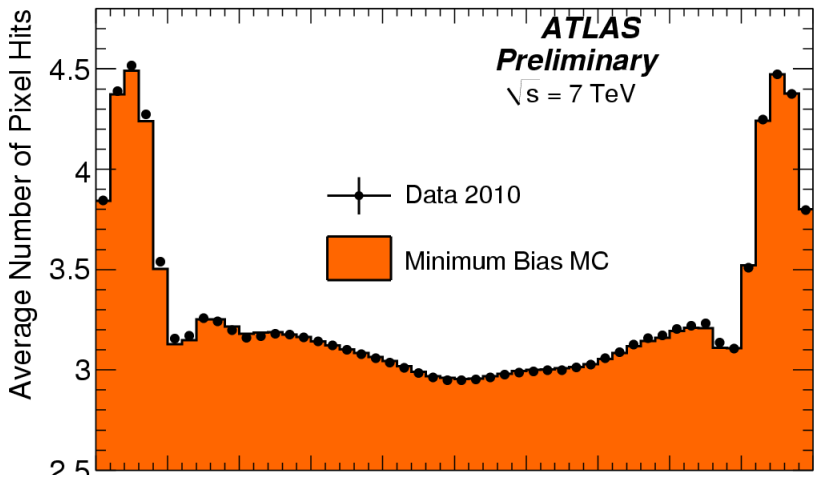
n^{BS}_{Sel}=number of tracks passing "good track" criteria but using $|d0_{BS}|$ < 4mm instead of $d0_{PV}/z0_{PV}$ cuts

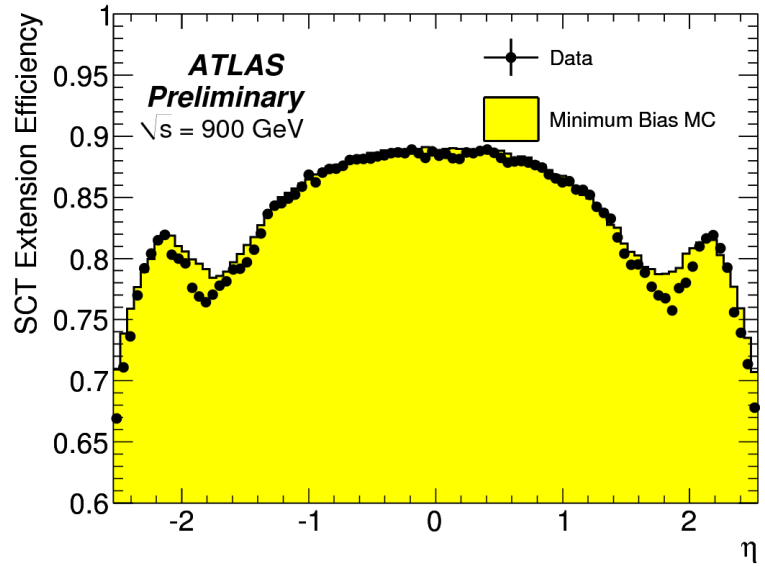
Data/simulation comparison

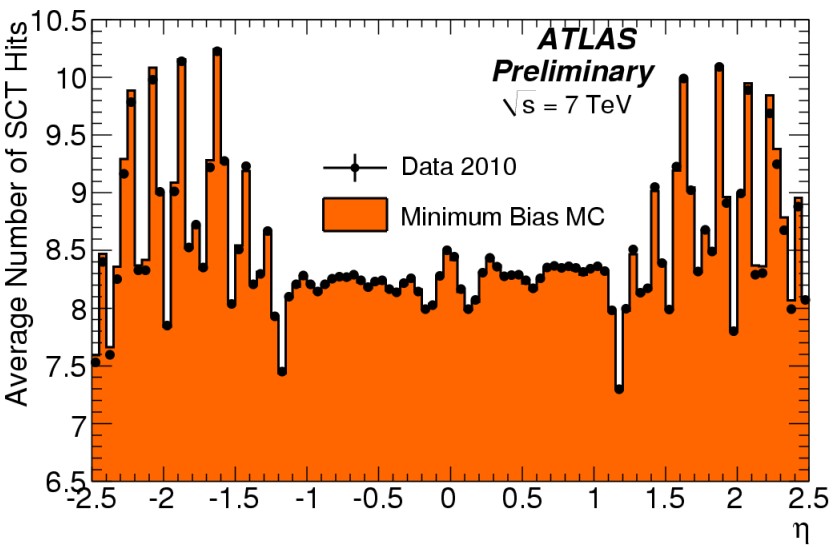
Track reconstruction efficiency is determined from simulation

Simulation of the silicon detectors describes the data to high accuracy

Differences in simulation/data are expressed as systematic uncertainty on the tracking efficiency







Largest systematic uncertainty comes from material description in simulation

upper limit of 10% uncertainty on material gives 3% uncertainty on track reconstruction efficiency

Disagreement between data/simulation for the SCT extension efficiency adds an increased uncertainty in specific eta regions

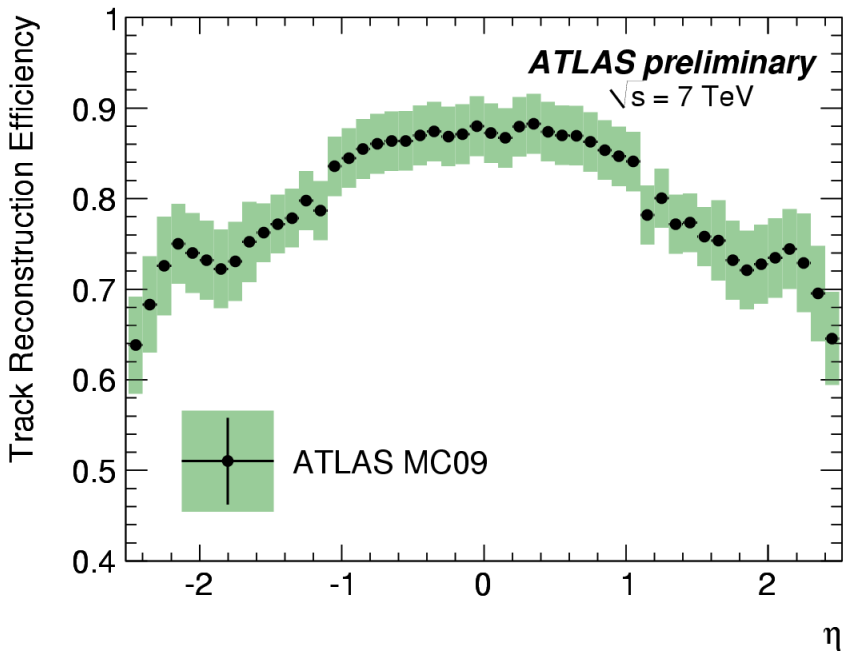
Track reconstruction efficiency

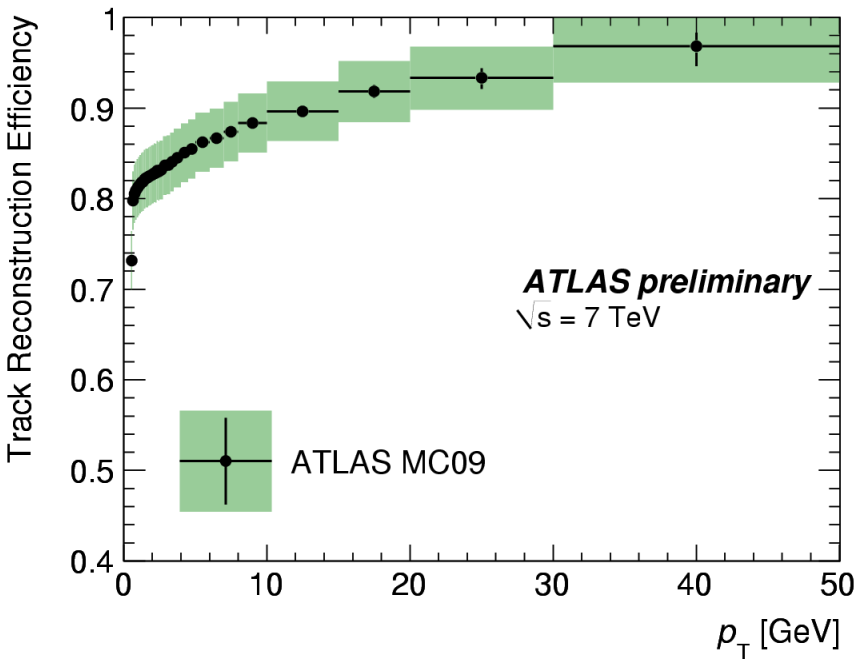
Track reconstruction efficiency is determined from MC sample using 10 million non-diffractive events at 7 TeV collissions from ATLAS MC09 tune

Efficiency based on track-truth matching between track and MC particle within a ΔR cone of 0.05

$$\epsilon_{\mathrm{bin}}(p_{\mathrm{T}},\eta) = \frac{N_{\mathrm{rec}}^{\mathrm{matched}}(p_{\mathrm{T}},\eta)}{N_{\mathrm{gen}}(p_{\mathrm{T}},\eta)}$$

The bin size varies with p_T and was determined by the statistics available in the simulation sample





Correction for track reconstruction efficiency is made using 2D efficiency vs p_T and eta to remove model dependence from p_T and eta distributions

Systematic uncertainty tracking efficiency

ATLAS preliminary

Systematic Uncertainty	Systematic
Truth Primary Definition	$\pm 0.4\%$
Track Selection	$\pm 1\%$
Material	$\pm 3\%$
Alignment	$\pm 1\%$
SCT Extension	$\pm 6\%$ $(2.2 < \lvert\eta\rvert < 2.5)$ $\pm 4\%$ $(1.6 < \lvert\eta\rvert < 2.2)$
Particle Composition	$\pm 0.2\%$
Resolution	$\pm 1\%$ $(0.5 < p_{\mathrm{T}} < 0.6$ GeV$)$
Total	3.8 % $(p_{\mathrm{T}} > 0.6$ GeV, $\eta = 0)$ 3.9 % $(0.5 < p_{\mathrm{T}} < 0.6$ MeV, $\eta = 0)$ 7.1 % $(p_{\mathrm{T}} > 0.6$ MeV, $2.4 < \eta < 2.5)$

All uncertainties are quoted relative to the track reconstruction efficiency except for the uncertainty due to the material which is absolute

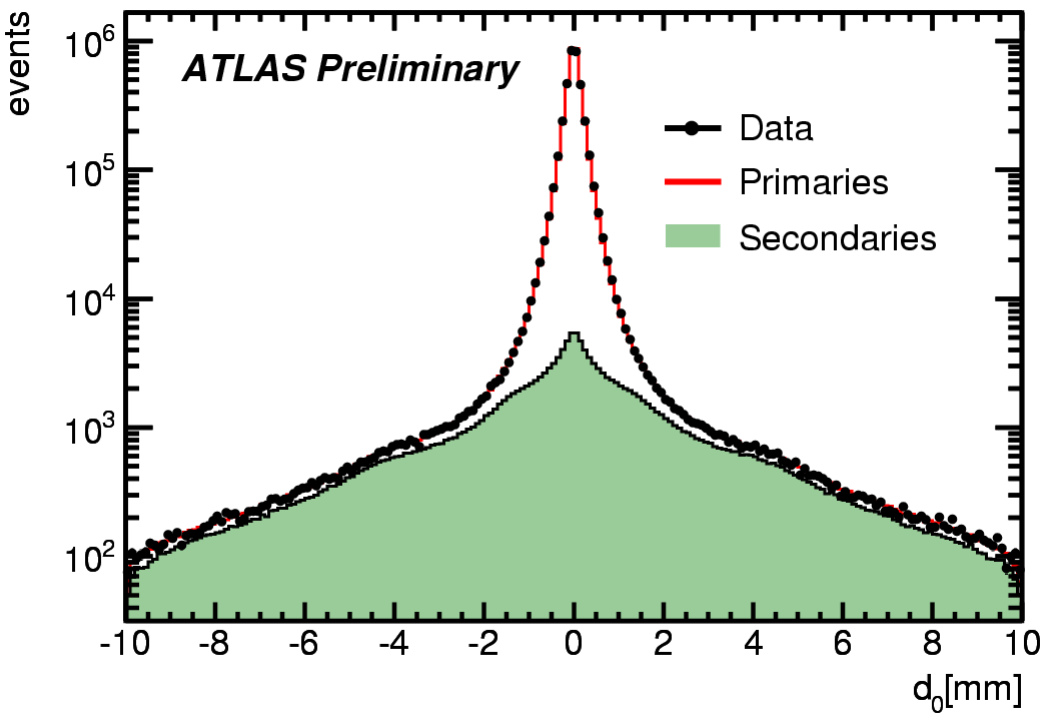
Fraction of secondaries

A correction has to be made for the fraction of tracks from secondary particles that passed our primary track selection cuts

The number of secondary particles is estimated from data by fitting the tails of the impact parameter distribution with templates describing the distribution from primaries and secondaries

The fraction of secondaries within |d0|<1.5 mm was found to be be 2.25±0.02(stat)±0.11(syst)%

Fraction of fake tracks was found to be neglible



Correction procedure

Events lost due to trigger and vertex requirements are corrected using a weight per event:

$$w_{\mathrm{ev}}(n_{\mathrm{Sel}}^{\mathrm{BS}}) = \frac{1}{\varepsilon_{\mathrm{trig}}(n_{\mathrm{Sel}}^{\mathrm{BS}})} \cdot \frac{1}{\varepsilon_{\mathrm{vtx}}(n_{\mathrm{Sel}}^{\mathrm{BS}})}$$

where $\varepsilon_{\mathrm{trig}}(n_{\mathrm{Sel}}^{\mathrm{BS}})$ and $\varepsilon_{\mathrm{vtx}}(n_{\mathrm{Sel}}^{\mathrm{BS}})$ are the trigger and vertex reconstruction efficiencies.

The p_T and η distributions of selected tracks are corrected by using a weight for each track:

$$w_{\mathrm{trk}}(p_{\mathrm{T}}, \eta) = \frac{1}{\varepsilon_{\mathrm{bin}}(p_{\mathrm{T}}, \eta)} \cdot (1 - f_{\mathrm{sec}}(p_{\mathrm{T}})) \cdot (1 - f_{\mathrm{okr}}(p_{\mathrm{T}}, \eta))$$

where ε_{bin} is the track reconstruction efficiency, $f_{\mathrm{sec}}(p_{\mathrm{T}})$ is the fraction of secondaries and $f_{\mathrm{okr}}(p_{\mathrm{T}}, \eta)$ is the fraction of the selected tracks produced by particles outside the kinematic range

The N_{ch} distribution from the data is obtained by using a matrix $M_{Nch,Nsel}$, that relates the number of selected tracks N_{sel} to the number of charged particles N_{ch}

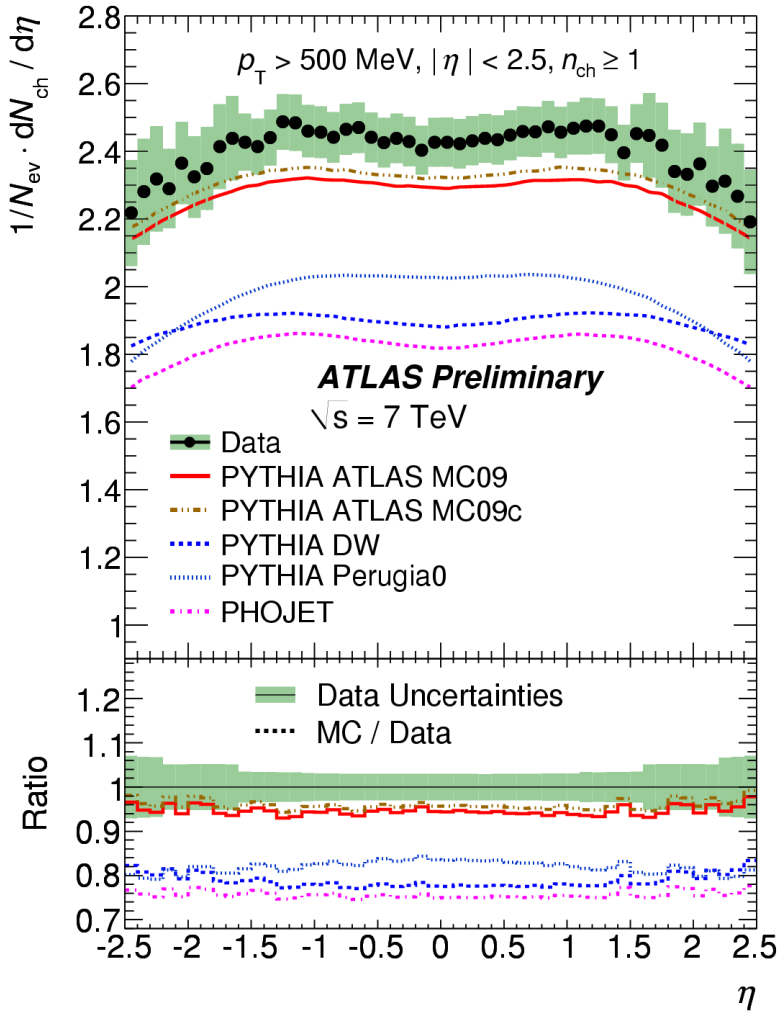
$M_{Nch,Nsel}$ is populated from MC but the resulting distribution is N_{ch} used to re-populate the matrix and the correction is re-applied to remove model dependence. This procedure is repeated till it converges after four iterations

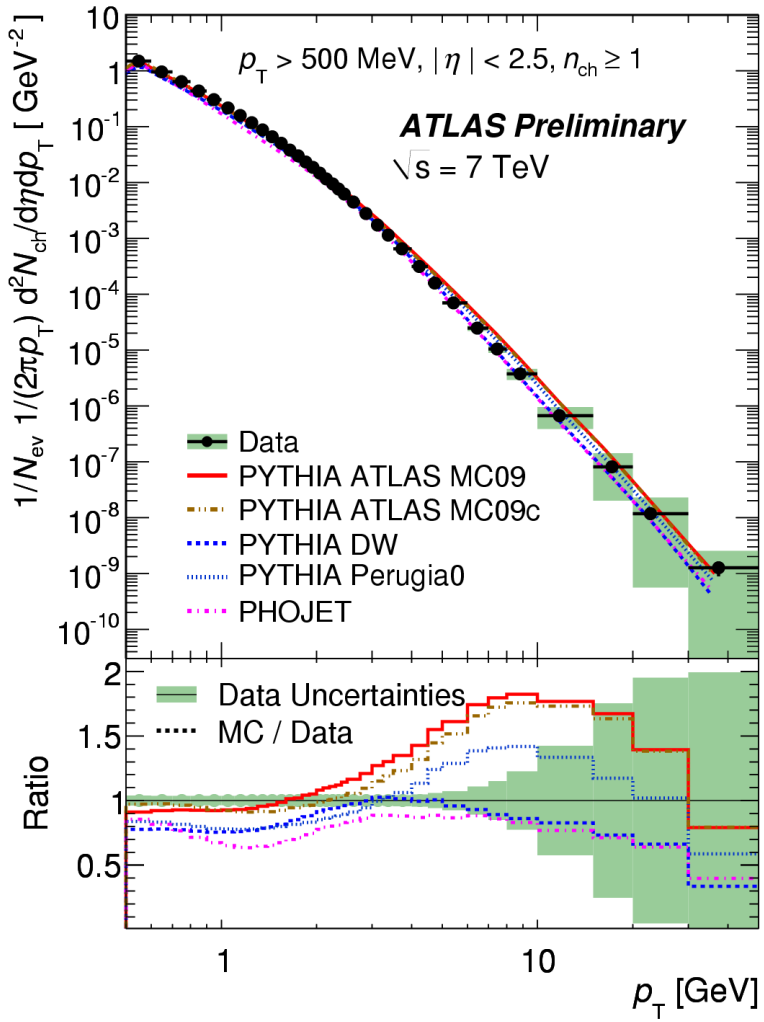
Charged particle multiplicity vs η and p_T

Measured distribution best described by the ATLAS MC09c tune

- predicts same shape for η distribution but is about 5% lower
- predicts a significantly harder spectrum at p_T>4 GeV

Measured charged particle multiplicity $1/N_{ev} \cdot dN_{ch}/d\eta$ at η=0 is 2.418±0.004(stat)±0.076(syst)

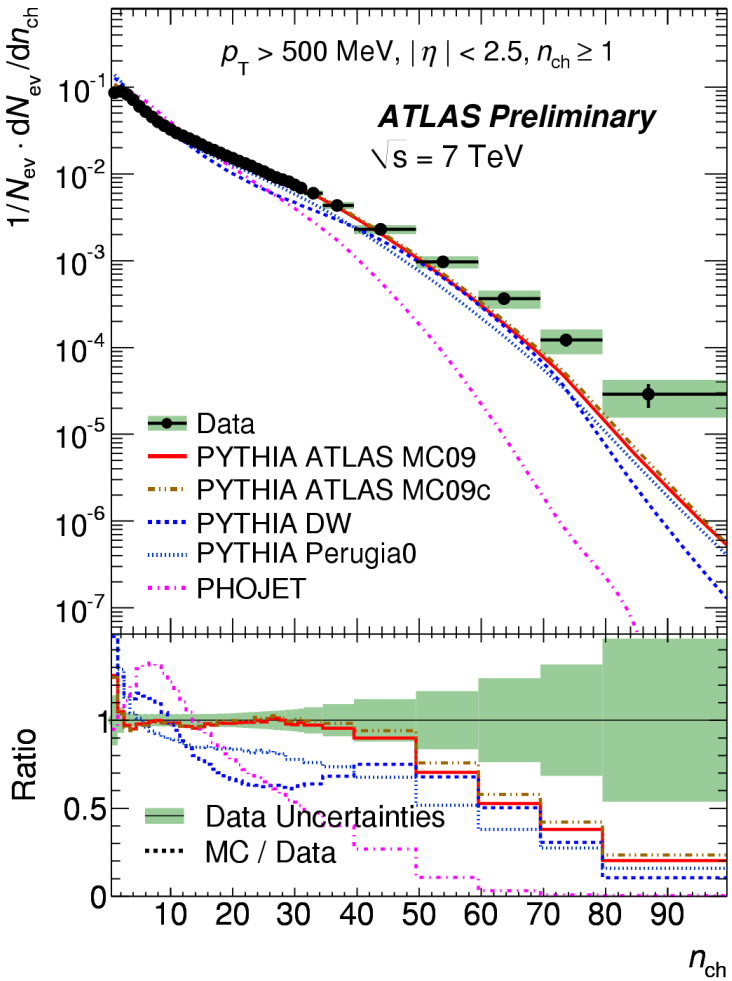




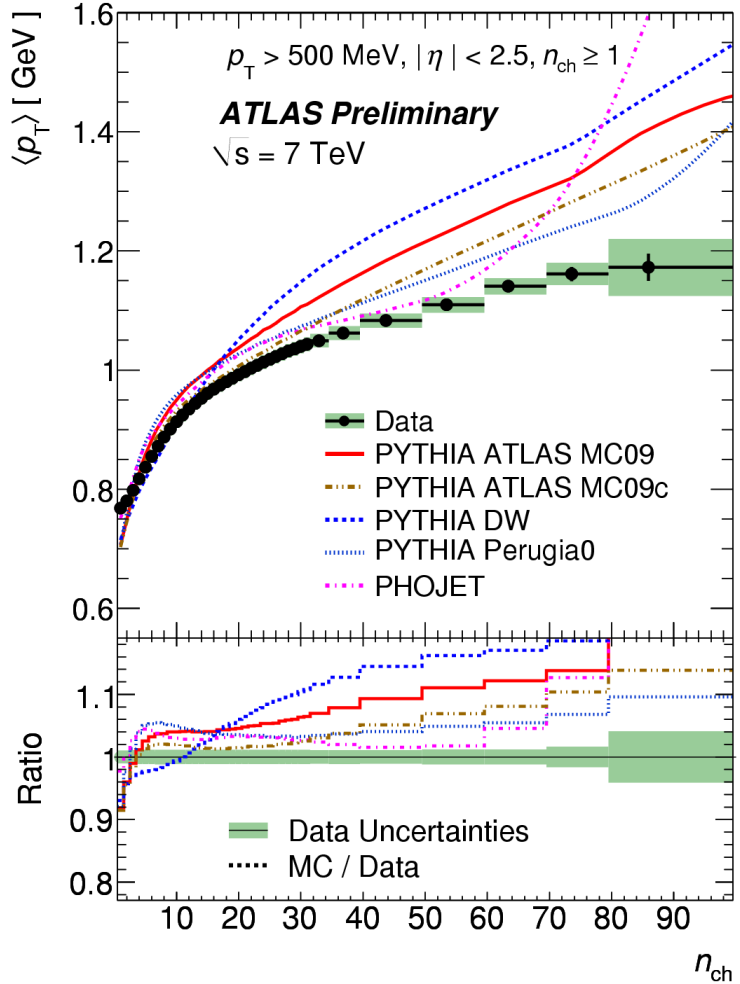
1/Nev ·$dN_{ch}/d\eta$ vs N_{Nch} and $<p_T>$

Charged particle multiplicity versus

number of charged particles N_{ch}



average transverse momentum $<p_T>$



Excess of model over data at lower N_{ch} highly influenced by the modelling of diffractive events

At N_{ch} > 50 data exceeds PYTHIA tunes by ~70%.

At N_{ch}>60 model shows a rise not seen in the data

Table of systematic uncertainties

ATLAS preliminary

Systematic uncertainty on the number of events, N_{ev}	
Trigger efficiency	0.2%
Vertex-reconstruction efficiency	$< 0.1\%$
Track-reconstruction efficiency	0.8%
Different Monte Carlo tunes	0.4%
Total uncertainty on N_{ev}	1.2%

Systematic uncertainty on $(1/N_{ev})\cdot(dN_{ch}/d\eta)$ at $\eta = 0$	
Track-reconstruction efficiency	3.8%
Trigger and vertex efficiency	$< 0.1\%$
Secondary fraction	0.1%
Total uncertainty on N_{ev}	-0.9%
Total uncertainty on $(1/N_{ev})\cdot(dN_{ch}/d\eta)$ at $\eta = 0$	2.9%

ATLAS minimum bias results

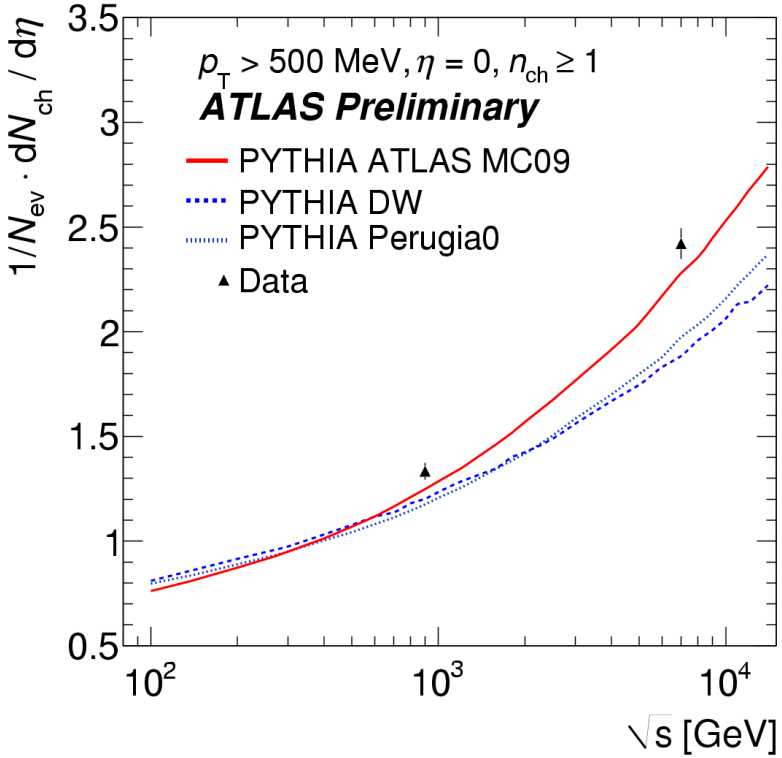
Charged particle multiplicity studied in events with at least one primary charged particle (N_{ch}>=1) produced within the kinematic range |η|< 2.5 and p_T > 500 MeV

Measurement results for $1/N_{ev} \cdot dN_{ch}/d\eta$ at η=0

√s=900 GeV: 1.333±0.003(stat)±0.040(syst)

√s=7 TeV: 2.418±0.004(stat)±0.076(syst)

Energy dependence of the multiplicity is described within 5% by ATLAS MC09 tune of PYTHIA



Additional ATLAS results available for alternative phasespace: N_{ch}>=6

- Removes a large fraction of the diffractive component in order to assist tuning of models on ATLAS data

ATLAS Tuning results presented by Judith Katzy later this afternoon

Up-coming ATLAS minimum bias results

An update of the charged particle multiplicy measurement at 900 GeV and 7 TeV that includes tracks with p_T<500 MeV to be finalized for ICHEP:

- low-pt means larger fraction of tracks from diffractive events to study diffractive processes
- requires detailed study of systematics for low-pt tracks that do not pass through the full ATLAS inner detector and require different track selection criteria
- more runs included than 7 TeV data presented today (~10 million events) which allows to extend the range of N_{ch} of p_T studied
- the new analysis includes track p_T up to 100 GeV, which requires more detailed study of fake high p_T tracks

Analysis results for p-p collisions at √s 2.36 TeV close to being finalized:

- data taken at 2.36 TeV had ATLAS SCT detector in "standby" (silicon biased with 20 Volt instead of 150 Volt) as a result efficiency not well described by simulation
- tracking efficiency studied from data using pixel-only tracks