Minimum bias measurements at ATLAS

Alex Kastanas
On behalf of the ATLAS collaboration

Motivation

- The study presented looks at inelastic interactions at the LHC.
- The minimum bias spectrum at 900 GeV, 2.36 TeV and 7 TeV, the current operating beam energy of LHC.
- These energies not measured before and no data available to tune Monte Carlo.
- The determination of the minimum bias spectrum is important not only in itself but also in modeling the additional effects this has in MC simulations.
- As luminosities increase this will be necessary for pileup studies.
- MC parameters tuned to this energy to improve MC used for physics analysis in ATLAS.

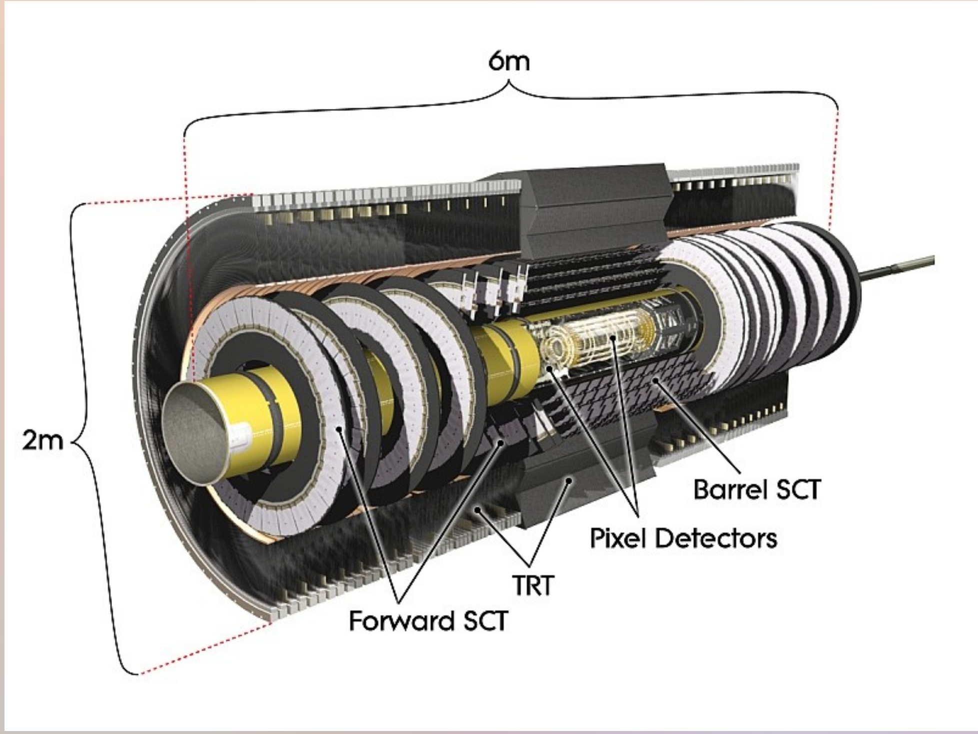
Overview

- Results included in the paper cover the energies that the LHC produced 900 GeV, 2.36 TeV and 7 TeV.
- The primary and most inclusive phase space of the analysis is 100 MeV and $n_{ch} > 1$.

Energy	Int. Luminosity	# of tracks
900 Gev	~ 7 μb^{-1}	~ 4.5 million
2.36 TeV	~ 6k events	~ 40 thousands
7 TeV	190 μb^{-1}	~ 210 million

ATLAS Inner Detector

- **Pixel:** Three layers and three disks in the end caps. It is the innermost detector providing excellent vertexing and tracking capabilities.
- **SCT:** Four additional double layers and nine disks of silicon micro strips
- **TRT:** Straw tube detector providing ~30 additional measurements and improved p_T resolution.



Coverage: | η | < 2.5

Tracking

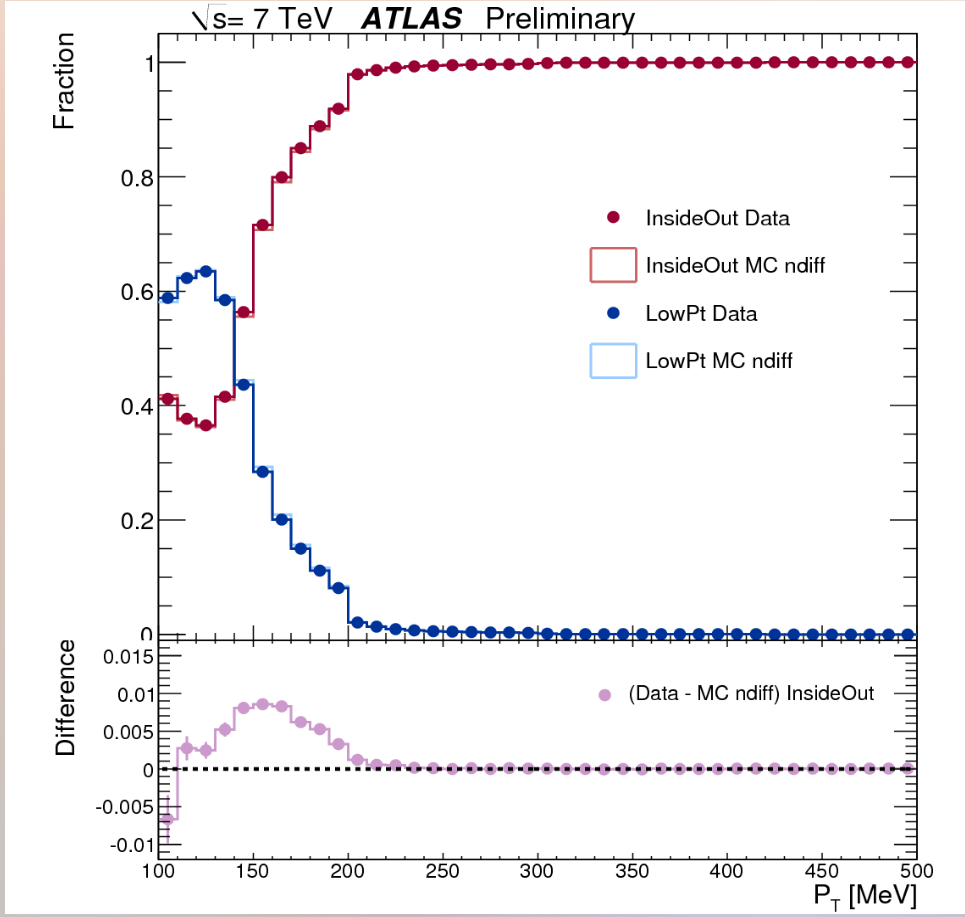
ATLAS Inner Detector combined tracks were used for the analysis:

- NewT, 500 MeV and above
- LowPt, 100 – 500 MeV

Both tracking algorithms have an overlap in their Pt region, to ensure continuity.

In the case of the 2.36 TeV data, the SCT detector was in standby mode.

- This requires additional corrections.



Trigger

- The trigger used for the Minimum Bias is the Minimum Bias Trigger Scintillator (MBTS).
- These are plastic scintillators.
- Set inside the calorimeter end-caps.
- 3.6 m from the interaction point on each side.
- **Coverage: $2.1 < |\eta| < 3.8$**
- This is the only trigger requirement for these measurements.

Event Selection

Select events with at least:

- A single arm MBTS trigger fired, for least trigger bias.
- A primary vertex reconstructed:
  - At least two tracks with $P_T > 100$ MeV
  - $|d_0| < 4$ mm w.r.t. beamspot
- No secondary vertex with more than four tracks.
- Other parameters are phase space dependent.

Phase Spaces

Primary phase space:

- $p_T > 100$ MeV $|\eta| < 2.5$ $n_{ch} \geq 2$

Other phase spaces as above but:

- $p_T > 500/2500$ MeV , $n_{ch} \geq 1$
  - 500 MeV checked for all CoM energies.
- $p_T > 500/1000$ MeV , $n_{ch} \geq 1$, $|\eta| < 0.8$
  - Common for all LHC experiments.
- $p_T > 500$ MeV , $n_{ch} \geq 6$ and $n_{ch} \geq 20$

p_T	n_{ch}	η
100 MeV	2	2.5
500 MeV	1	2.5
2500 MeV	1	2.5
500 MeV	1	0.8
1000 MeV	1	0.8
500 MeV	6	2.5

Distributions produced

The distributions produced are the following:

- $1/N_{ev}\, dN_{ev}/dn_{ch}$
- $1/N_{ev}\, dN_{ev}/d\eta$
- $1/2\pi p_T\, 1/N_{ev}\, d^2 n_{ch}/d\eta dp_T$
- $\langle p_T \rangle$ vs n_{ch}

These are shown for two phase spaces

- $p_T > 100$ MeV / $n_{ch} \geq 2$ / $|\eta| < 2.5$ **900 MeV and 7 TeV**
- $p_T > 500$ MeV / $n_{ch} \geq 1$ / $|\eta| < 2.5$ **2.36 TeV**

Corrections

- Event-wise corrections are applied for trigger and vertexing:

$$w_{ev}(n_{sel}^{BS}) = \frac{1}{w_{trig}(n_{sel}^{BS})} \cdot \frac{1}{w_{trig}(n_{sel}^{BS})}$$

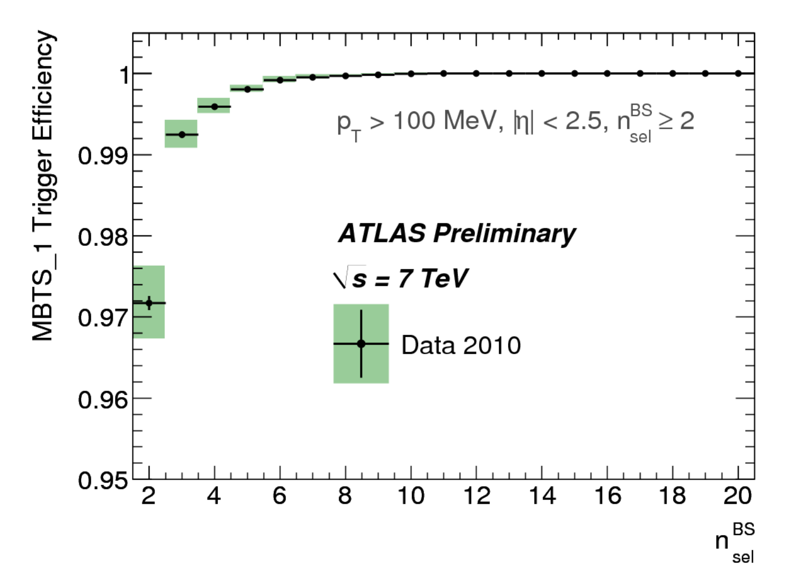
- Track-wise corrections are applied to correct for tracking efficiency, tracks outside of kinematic range and secondaries. These are applied as a function of track p_T and η:

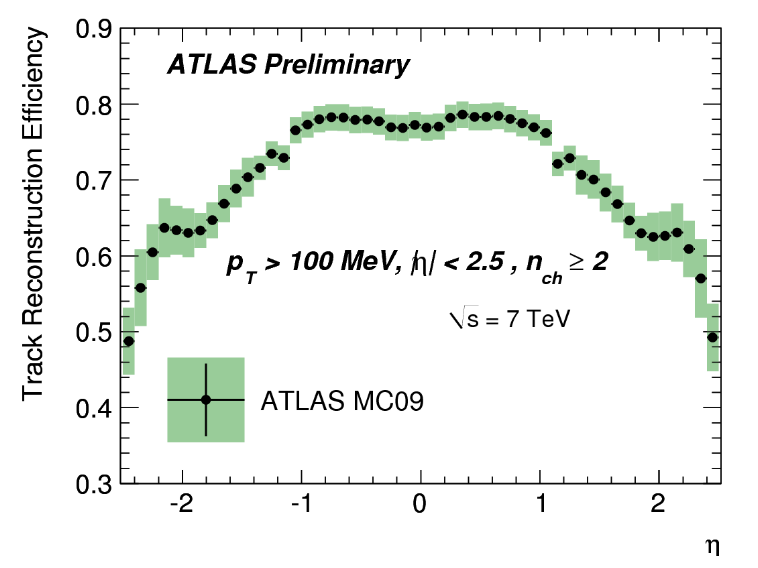
$$w_{trk}(p_T, \eta) = \frac{1}{\epsilon_{trk}(p_T, \eta)} \cdot (1 - f_{OKR}(p_T, \eta)) \cdot (1 - f_{sec}(p_T, \eta))$$

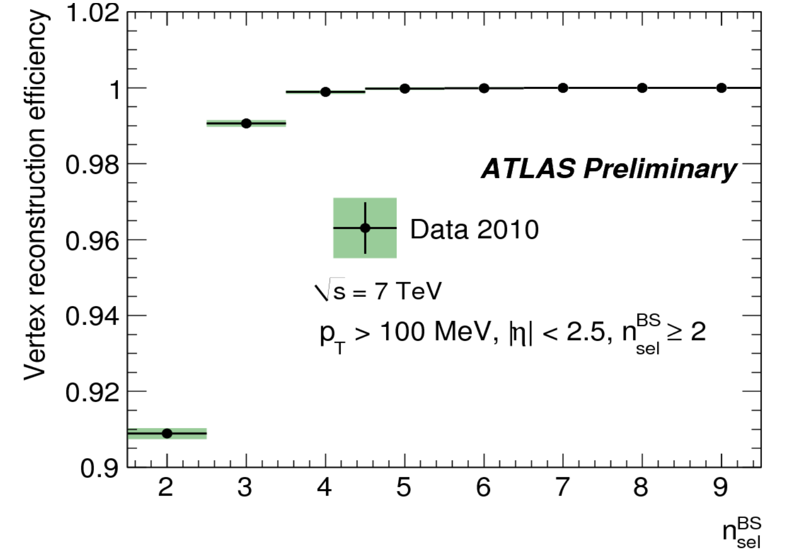
Correction for events with $n_{ch} \geq 2$ but $n_{sel} < 2$:

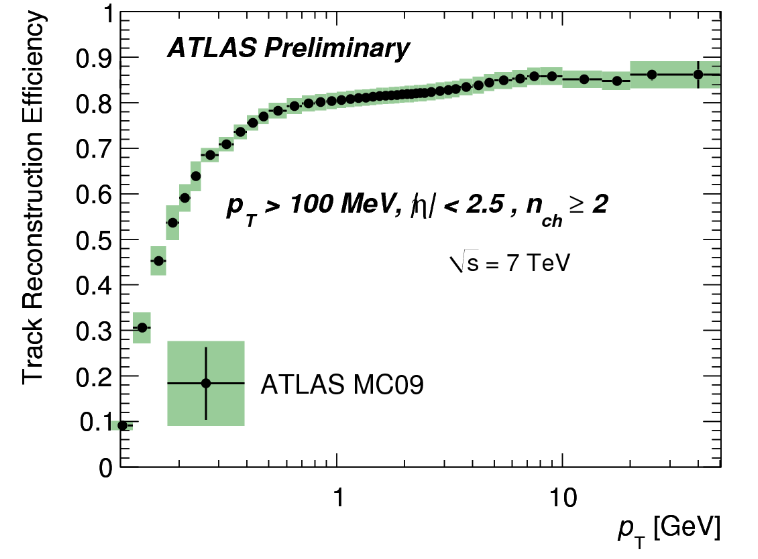
$$w_{mig}(n_{ch}) = \frac{1}{1 - (1 - \epsilon_{trk})^{n_{ch}} - n_{ch} \cdot (1 - \epsilon_{trk})^{n_{ch} - 1}}$$

Efficiencies



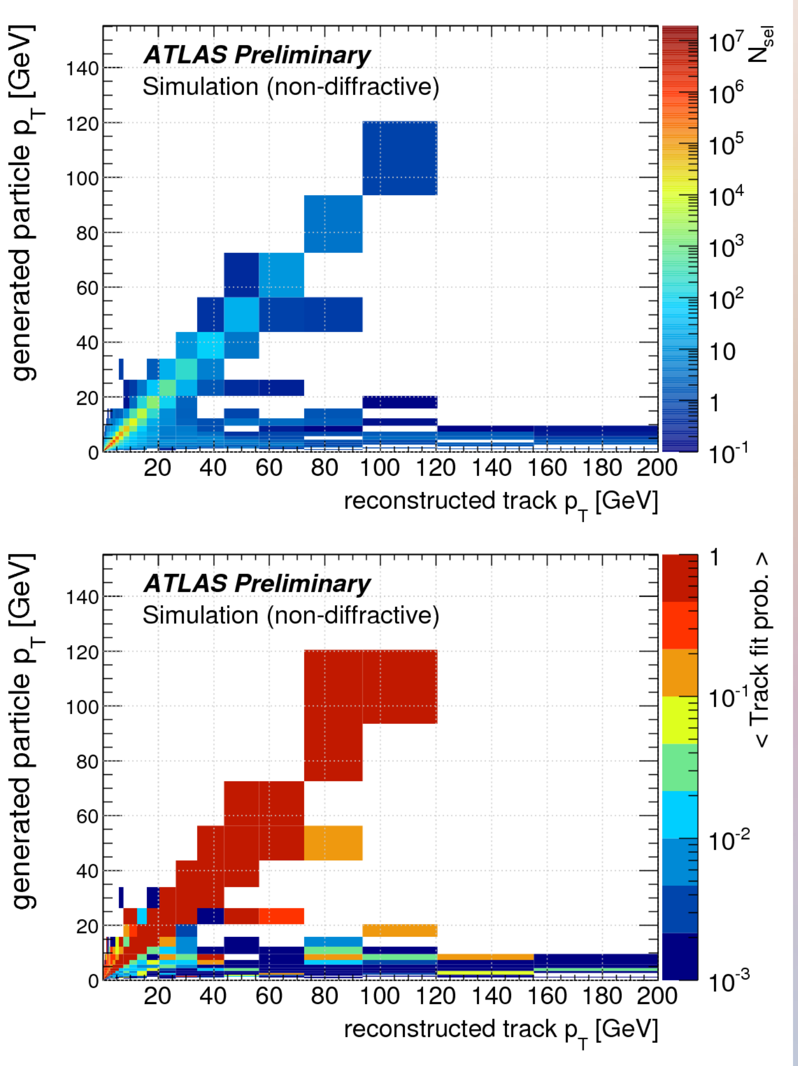






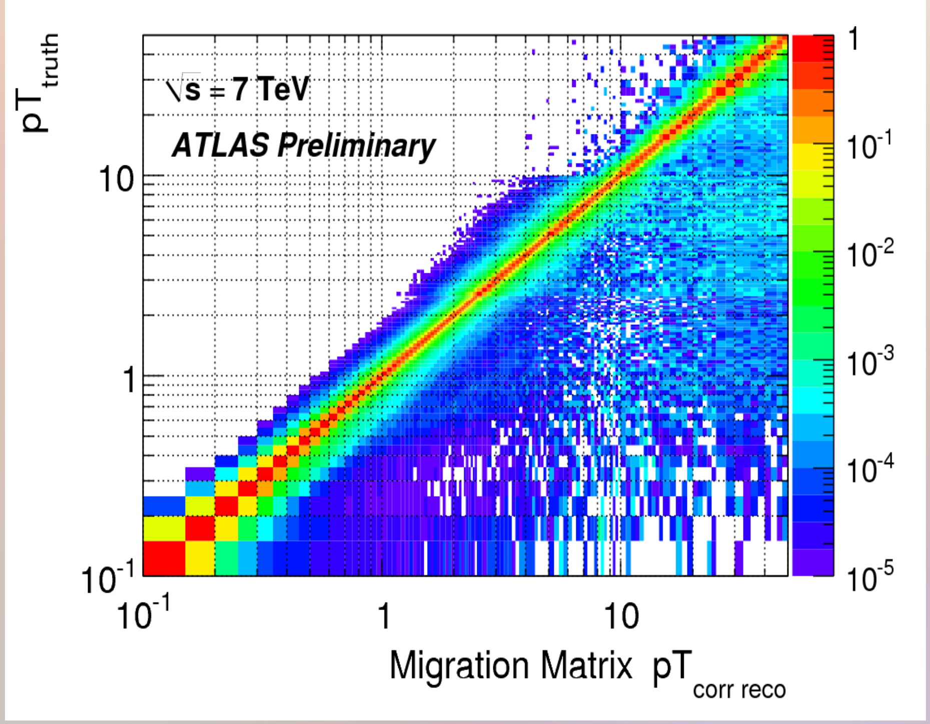
High p_T Tracks

- For high p_T tracks additional corrections are needed.
- This is due to the large extrapolation distance for tracks between Pixel and SCT end cap disks (~1 m).
- This is applied in the form of a cut on the χ^2 track fit probability if p_T> 10 GeV.

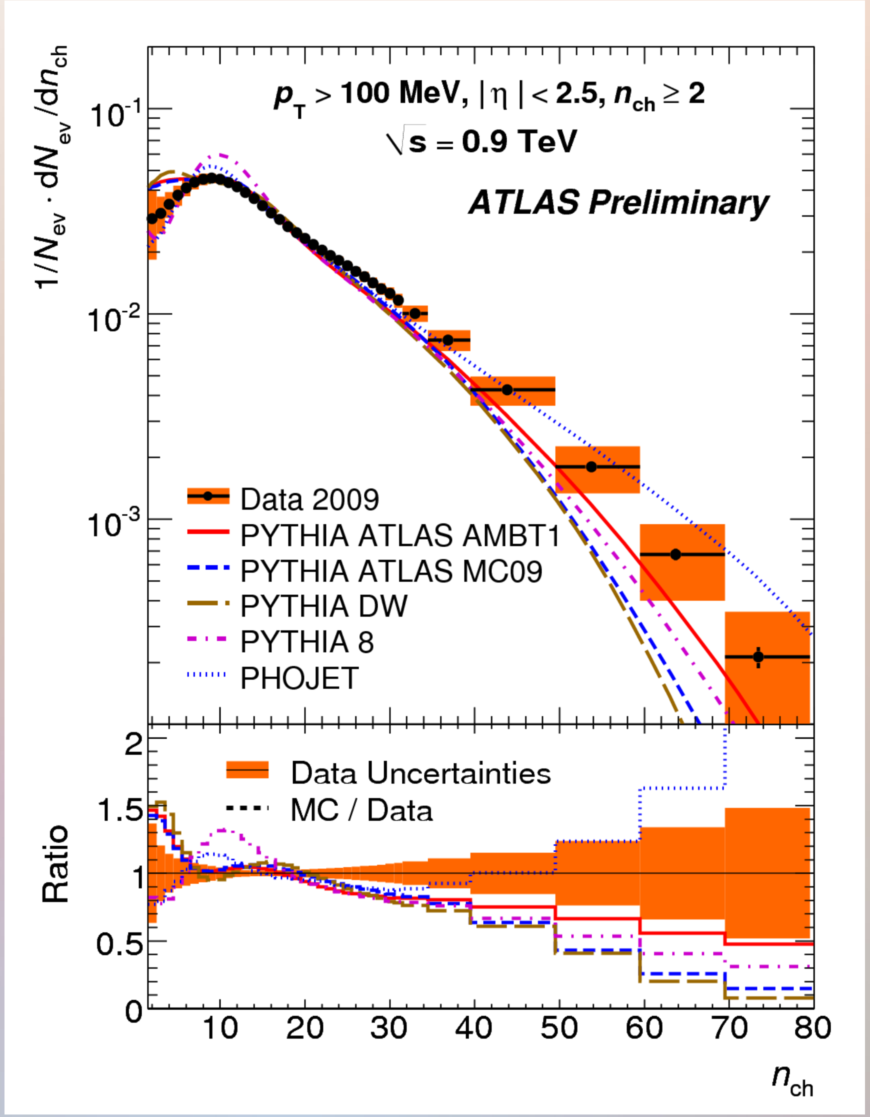


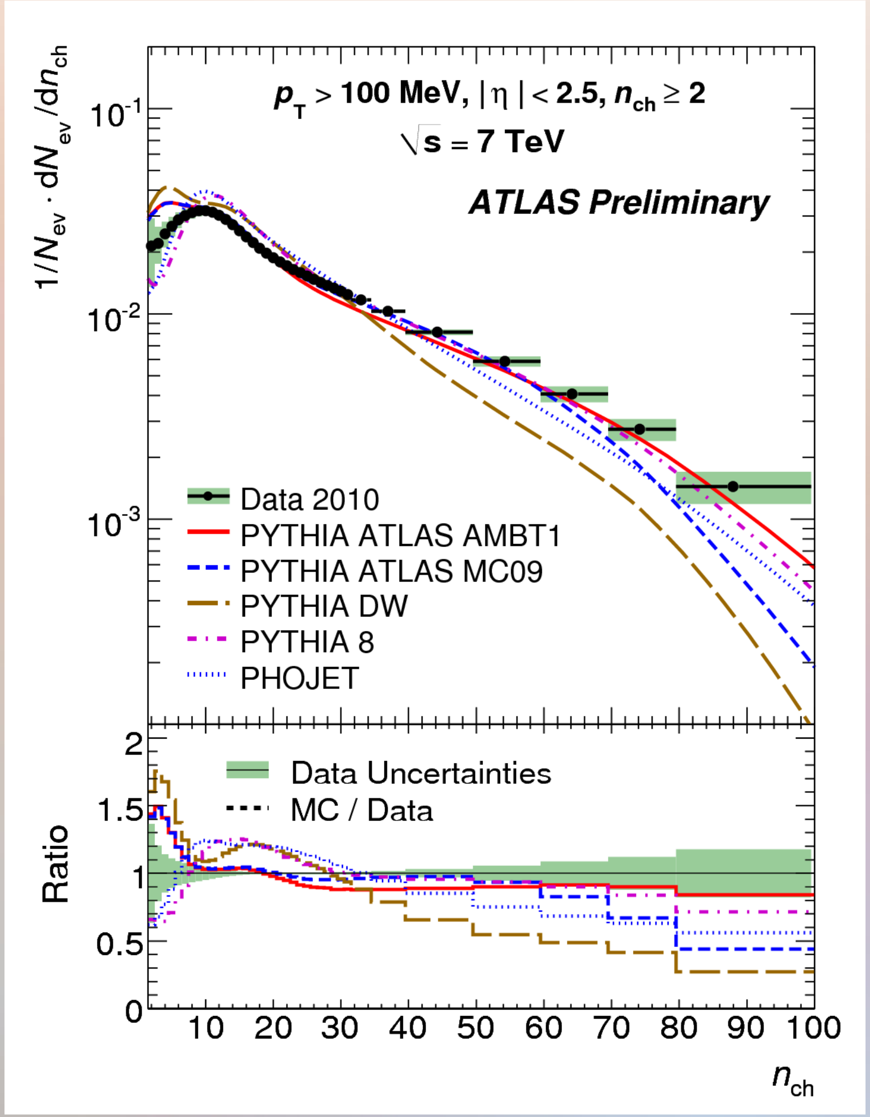
Bayesian Unfolding

- Iterative Bayesian unfolding is used for the n_{sel} and p_T distributions.
- Migrates from selected tracks to particle level distribution.
- For the p_T distribution it accounts for detector effects on the p_T distribution.
- For the $<p_T>$ vs n_{ch} plots the migration is only done for n_{sel} .

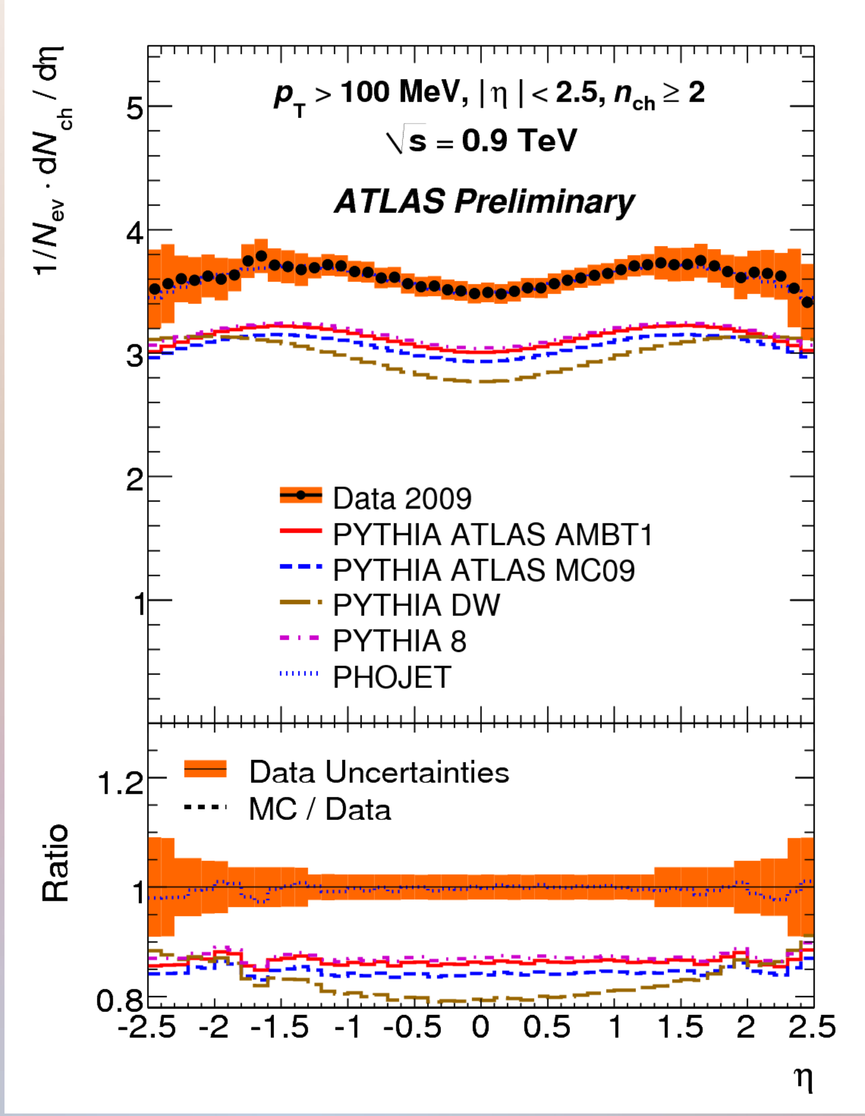


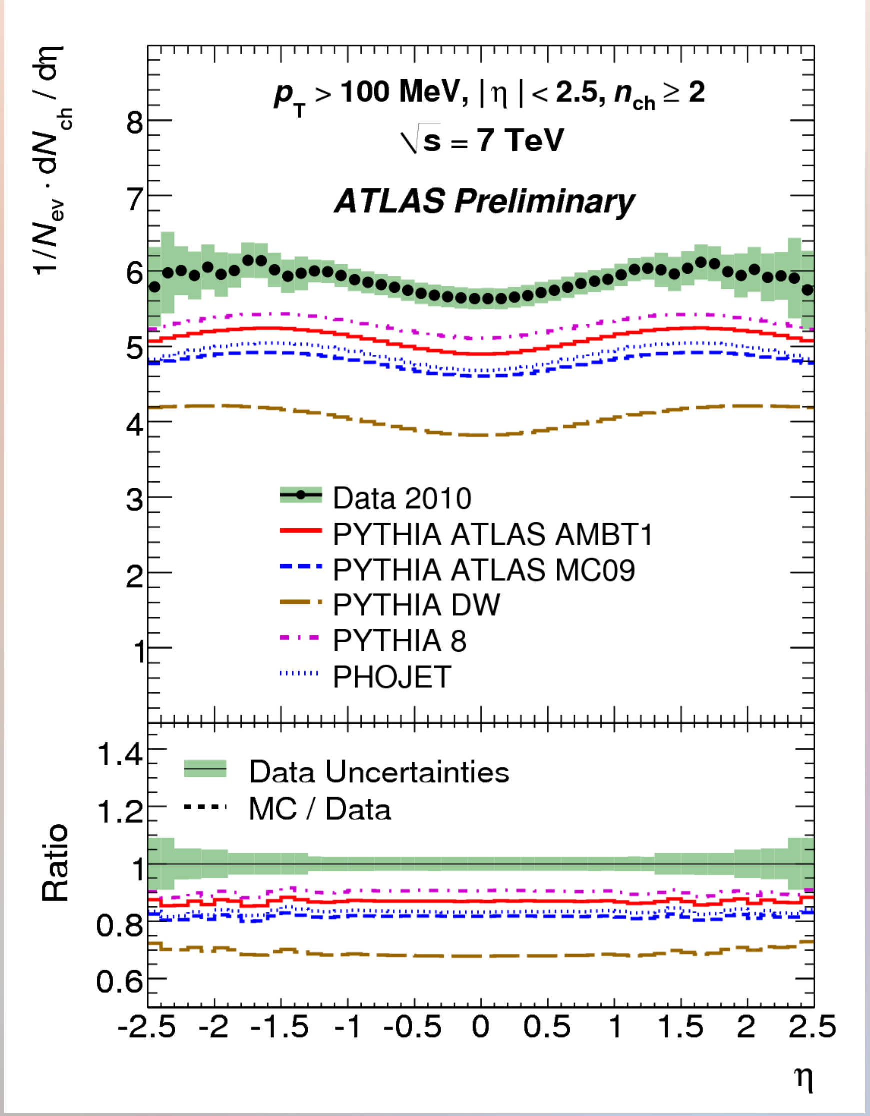
$1/N_{ev}\ dN_{ev}/dn_{ch}$



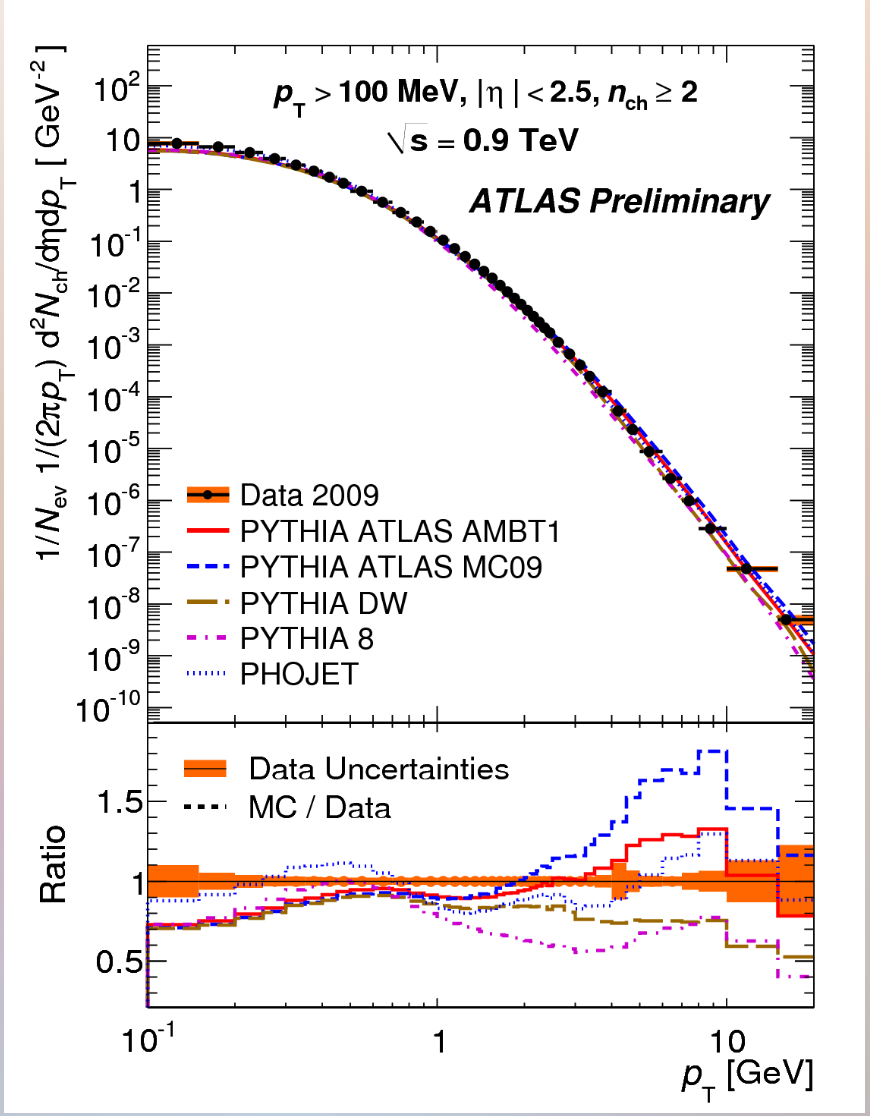


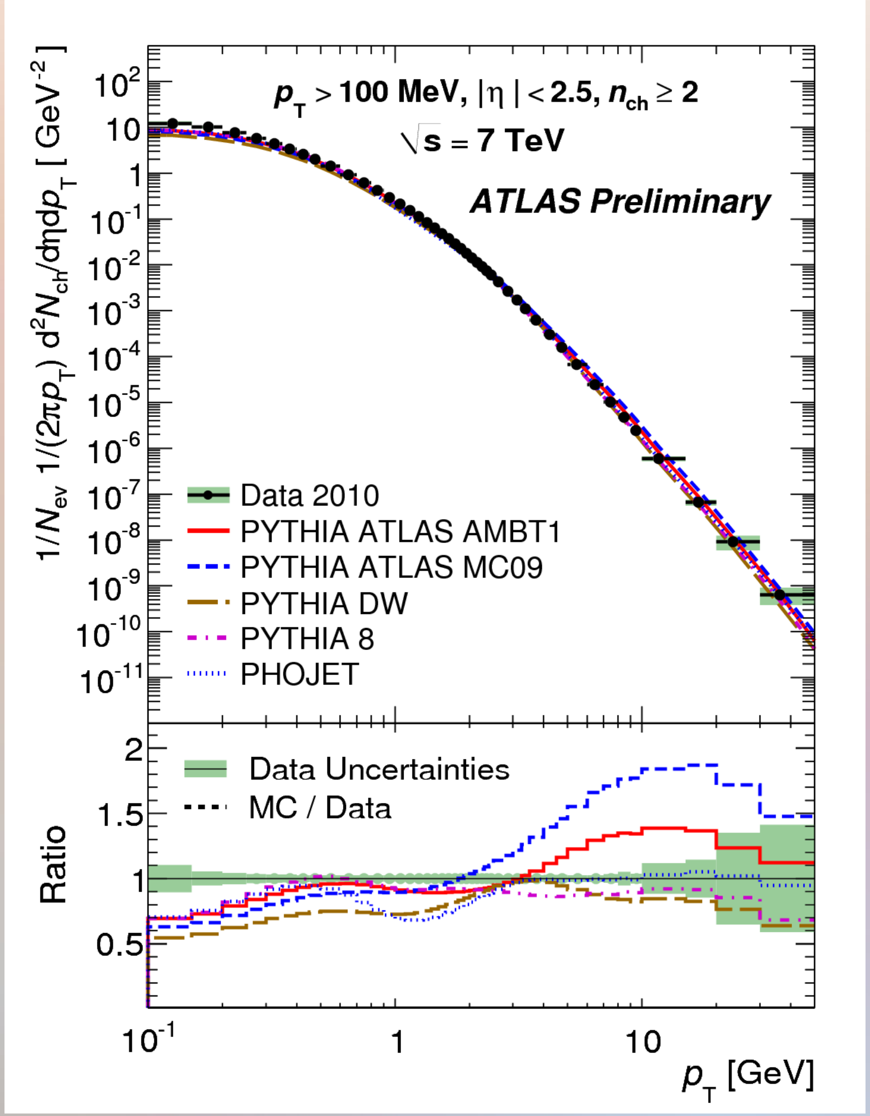
$1/N_{ev}\ dN_{ch}/d\eta$



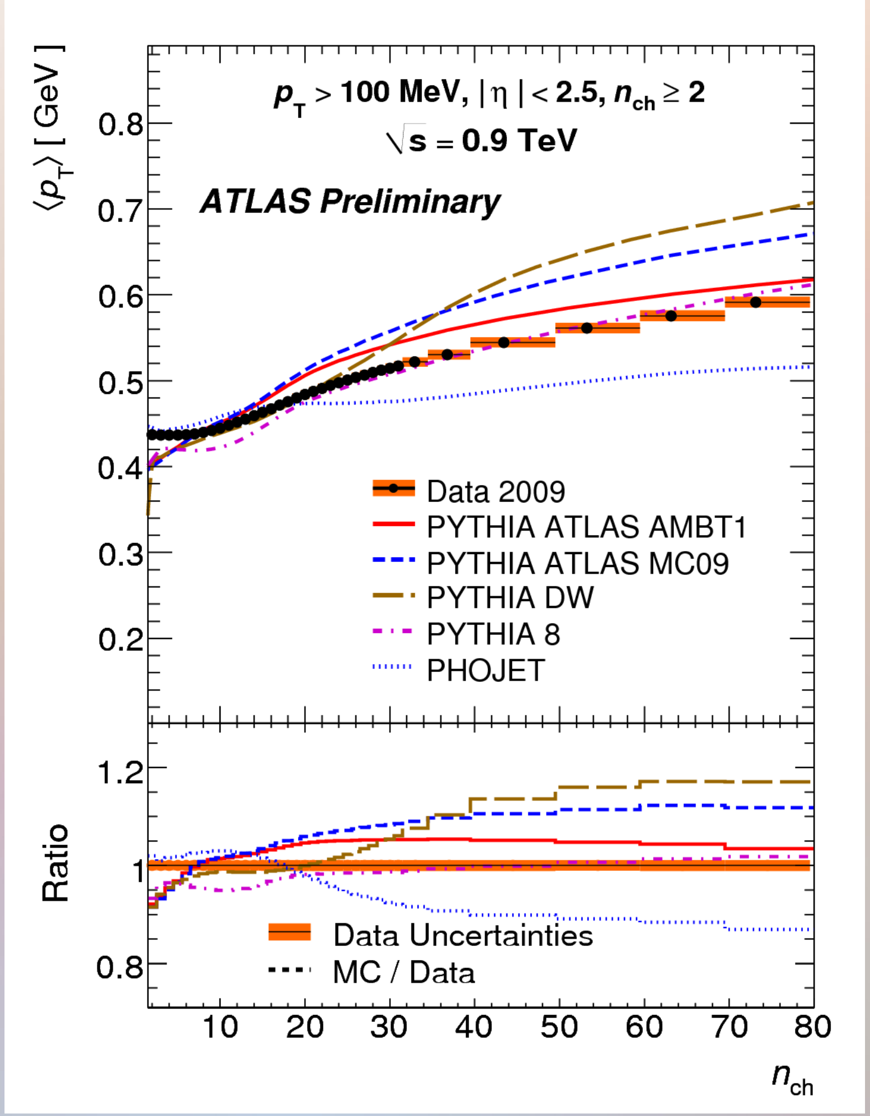


$1/N_{ev}\ 1/2\pi p_T\ dn_{ch}/d\eta dp_T$

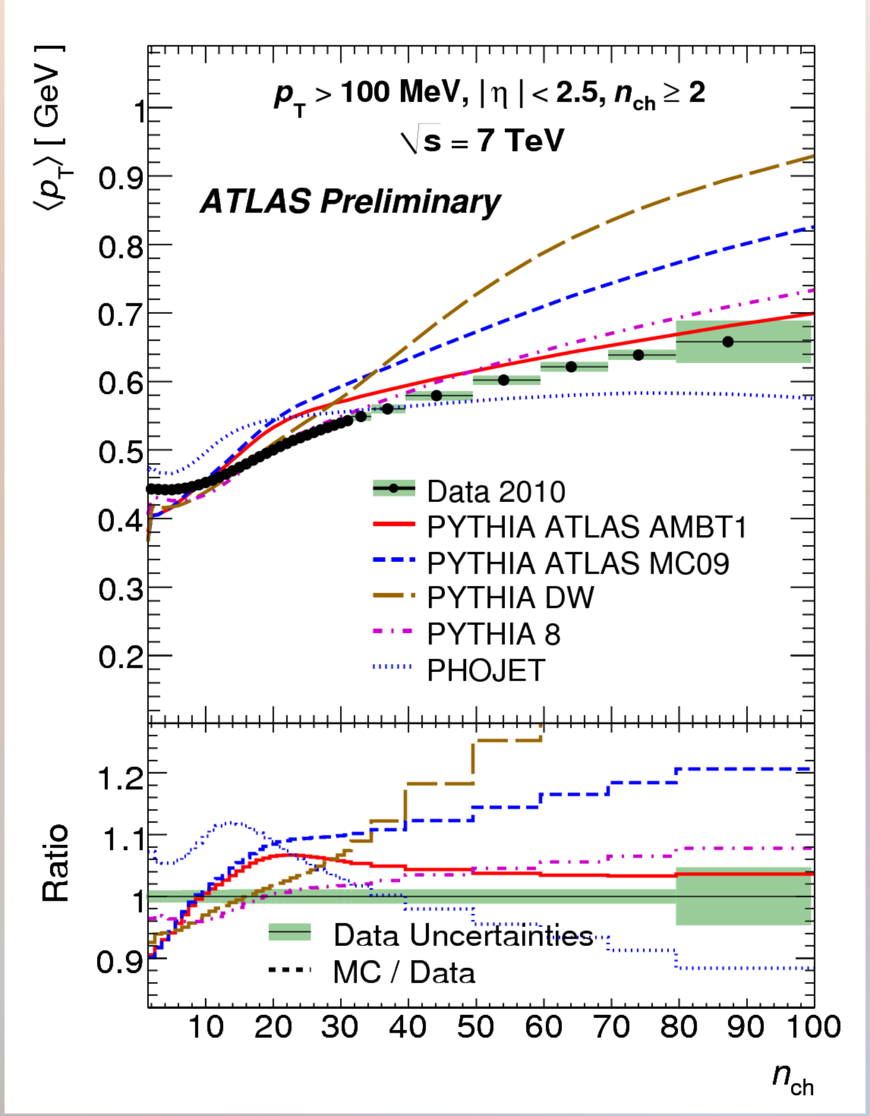




$<p_T>$ vs n_{ch}

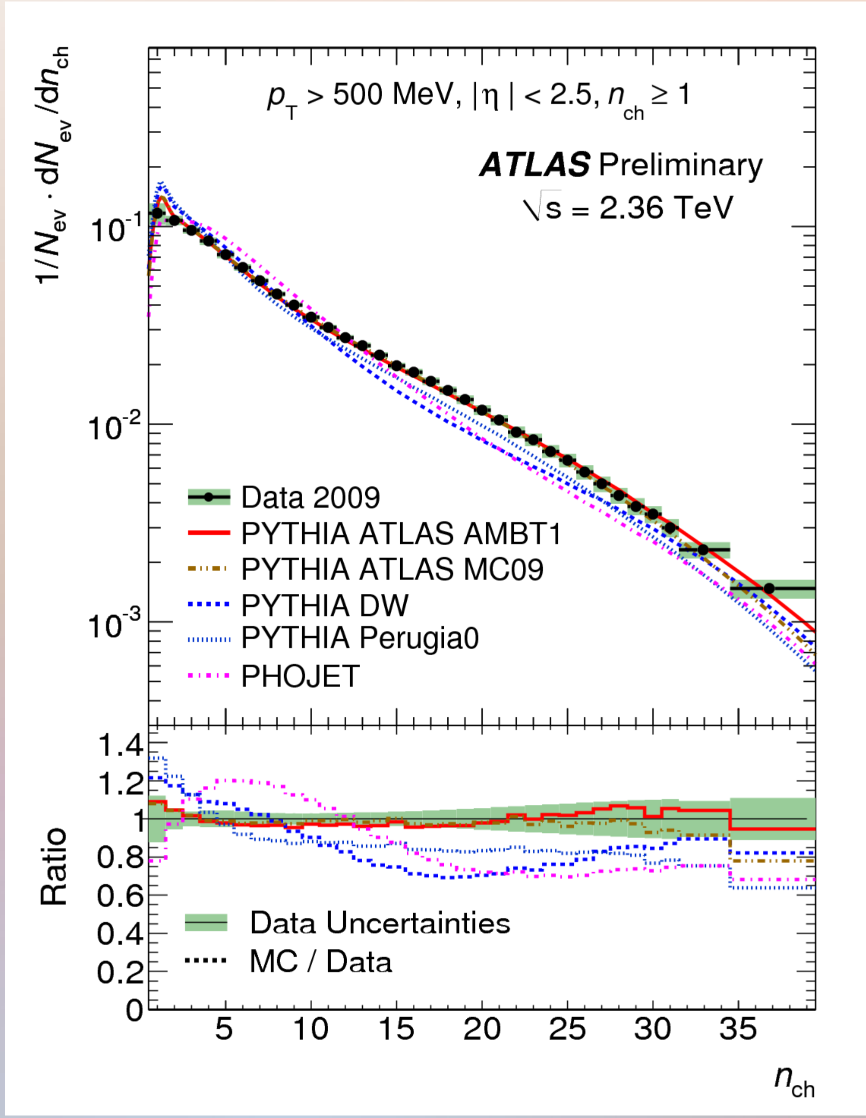


⟨p_T⟩ [GeV]
p_T > 100 MeV, |η| < 2.5, n_ch ≥ 2
√s = 0.9 TeV
ATLAS Preliminary
Data 2009
PYTHIA ATLAS AMBT1
PYTHIA ATLAS MC09
PYTHIA DW
PYTHIA 8
PHOJET
Ratio
Data Uncertainties
MC / Data
n_ch



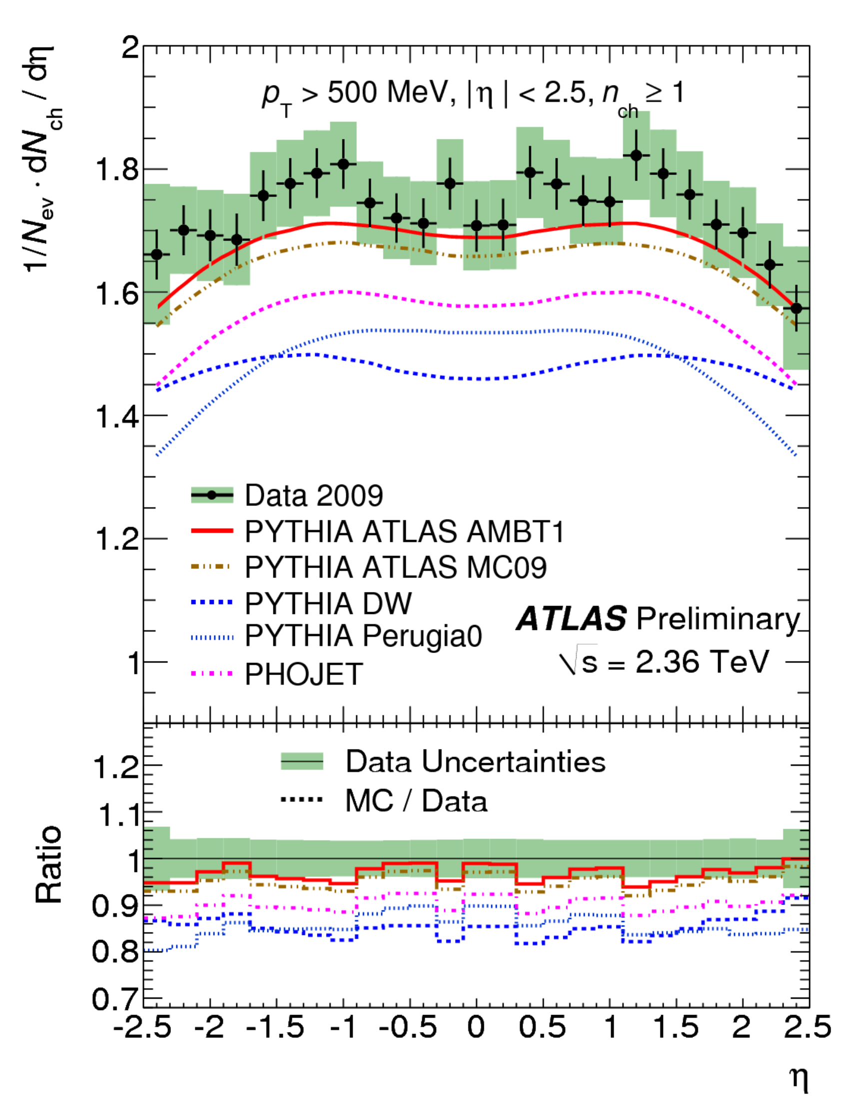
⟨p_T⟩ [GeV]
p_T > 100 MeV, |η| < 2.5, n_ch ≥ 2
√s = 7 TeV
ATLAS Preliminary
Data 2010
PYTHIA ATLAS AMBT1
PYTHIA ATLAS MC09
PYTHIA DW
PYTHIA 8
PHOJET
Ratio
Data Uncertainties
MC / Data
n_ch

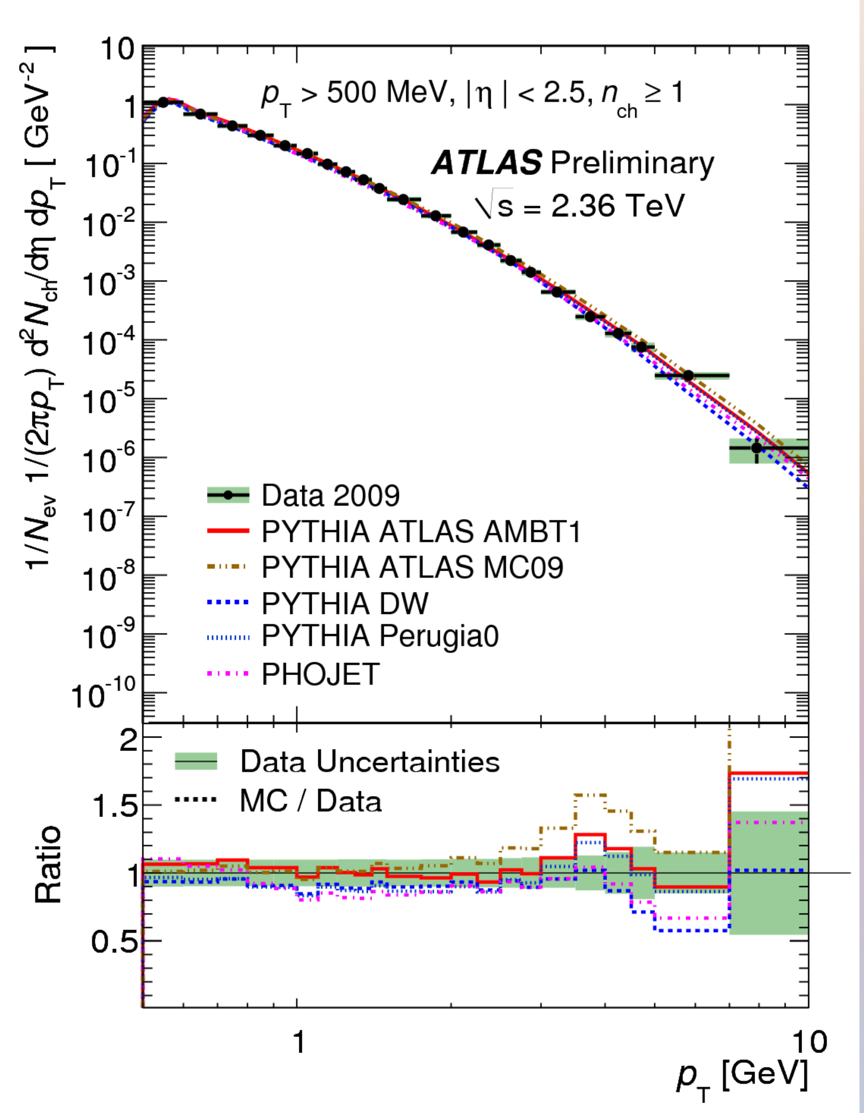
2.36 TeV data



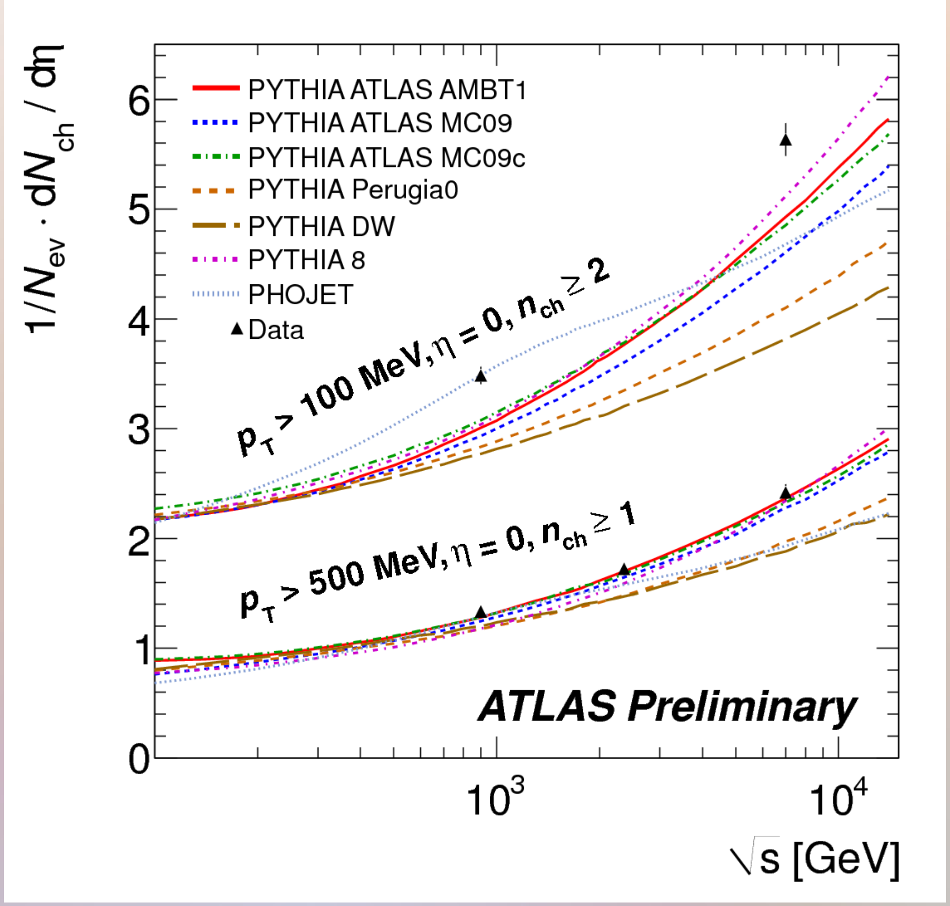
- These plots also done for the 2.36 TeV.
- Main change is that the SCT was in standby mode.
- Both combined and Pixel only tracks were used to compensate for this.
- **Pixel only:** Used for the n_{ch} and η plots.
- **Combined:** Used for the p_T plots as the resolution is comparable to full ID on.

2.36 TeV plots





Overview



Three measurements done for minimum bias.

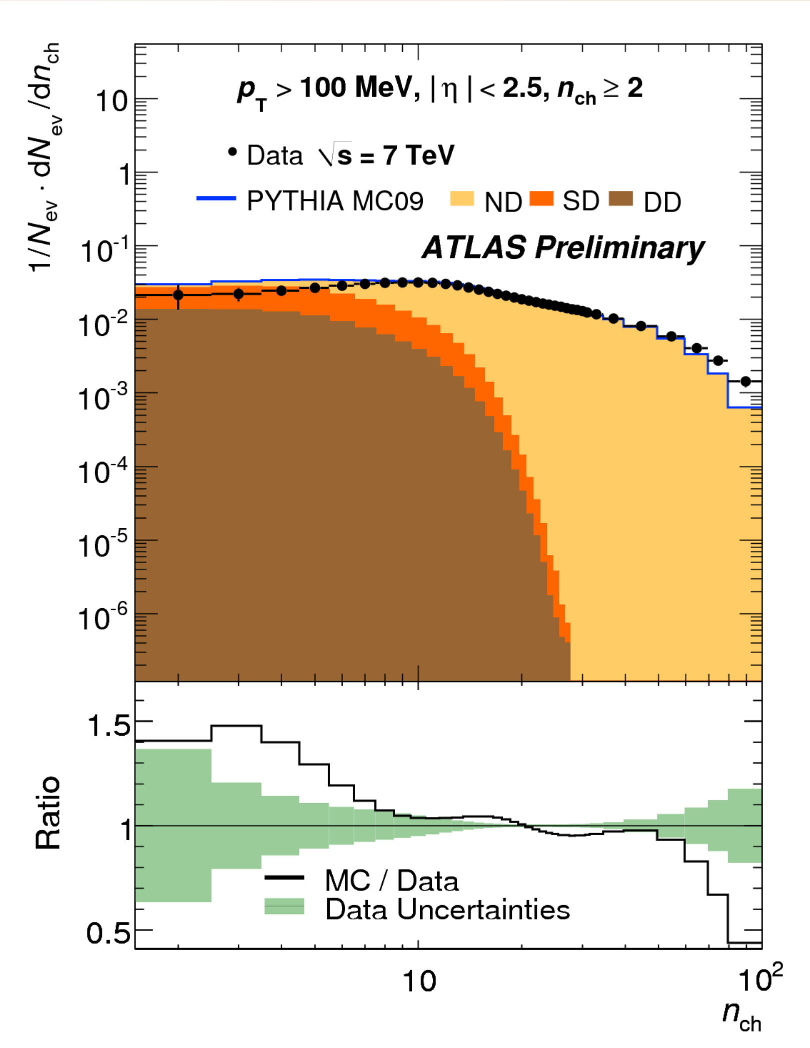
Three different energies.

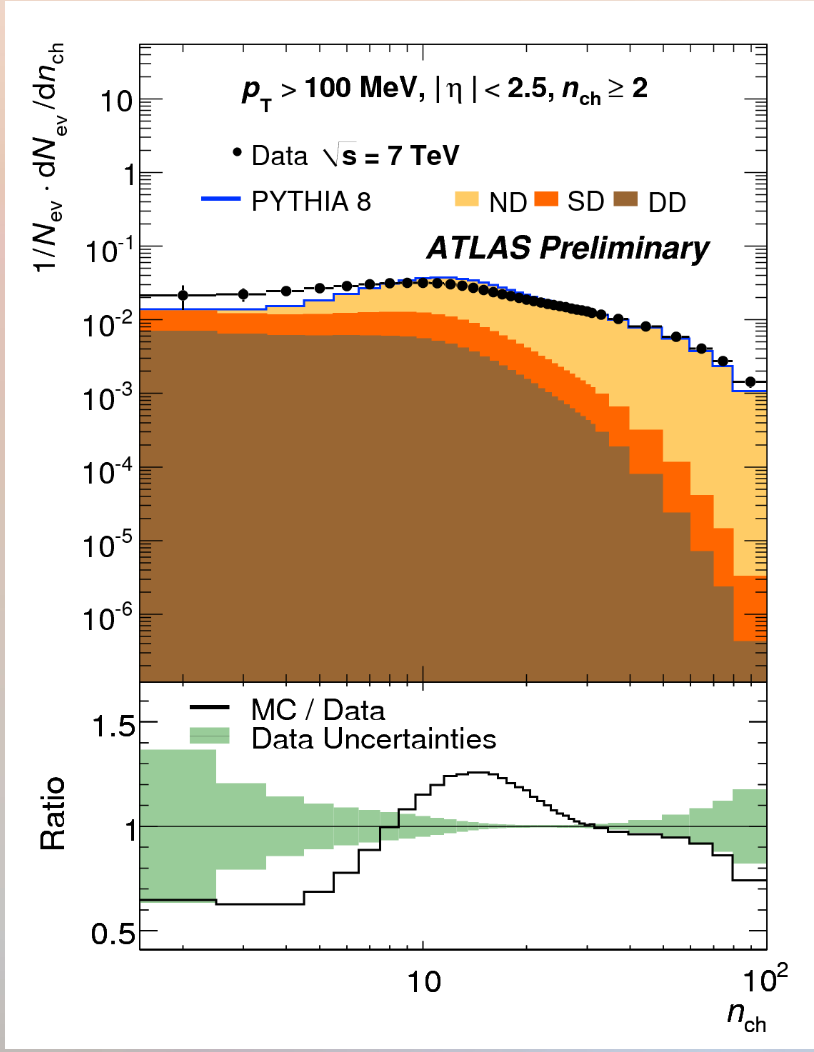
Different phase spaces checked.

- For comparisons with results of other experiments or isolating different components.

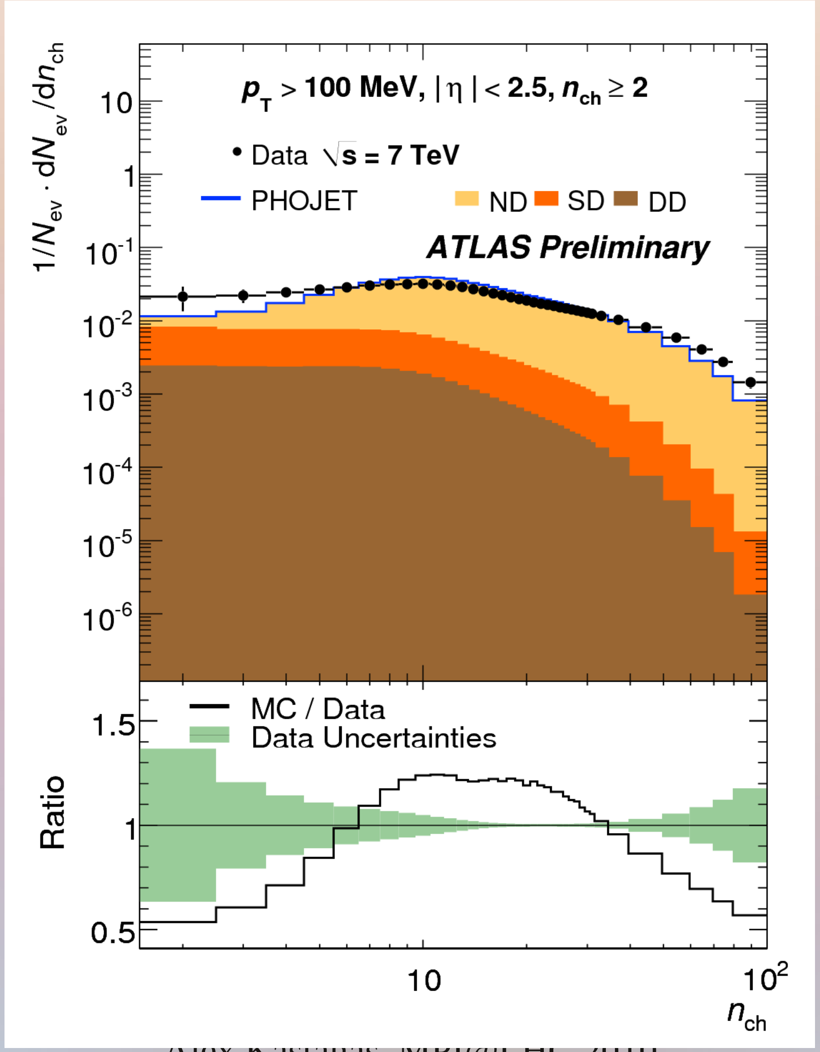
Backup Slides

Diffractive contributions



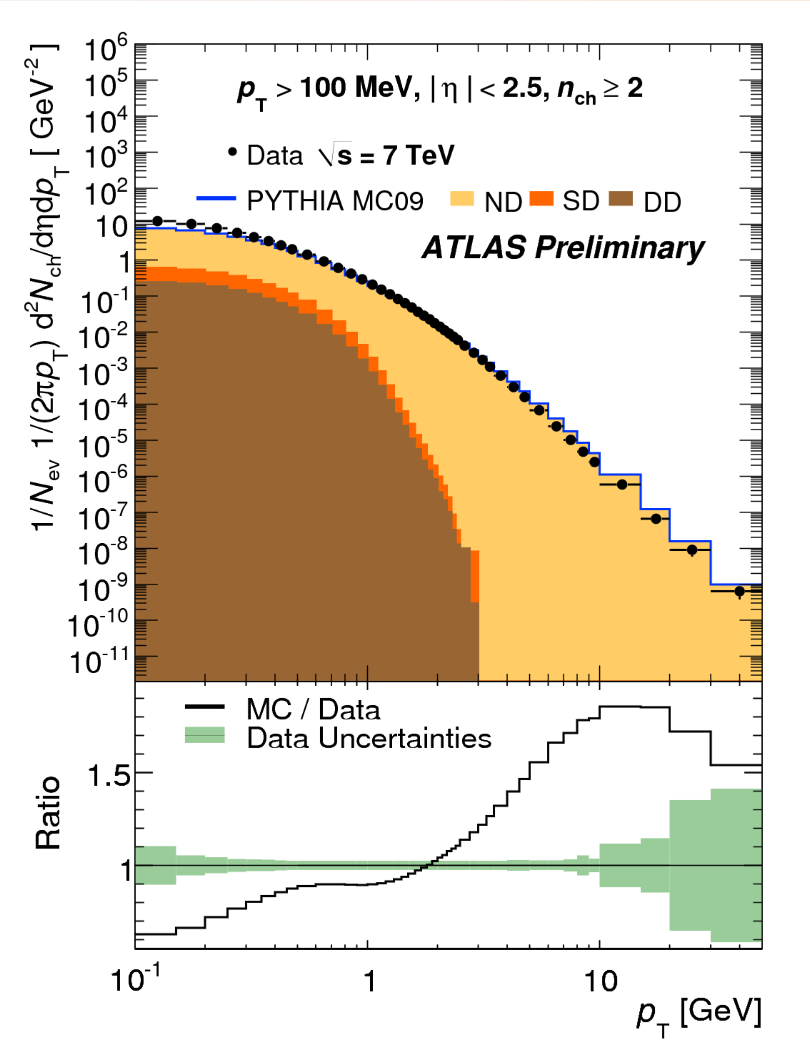


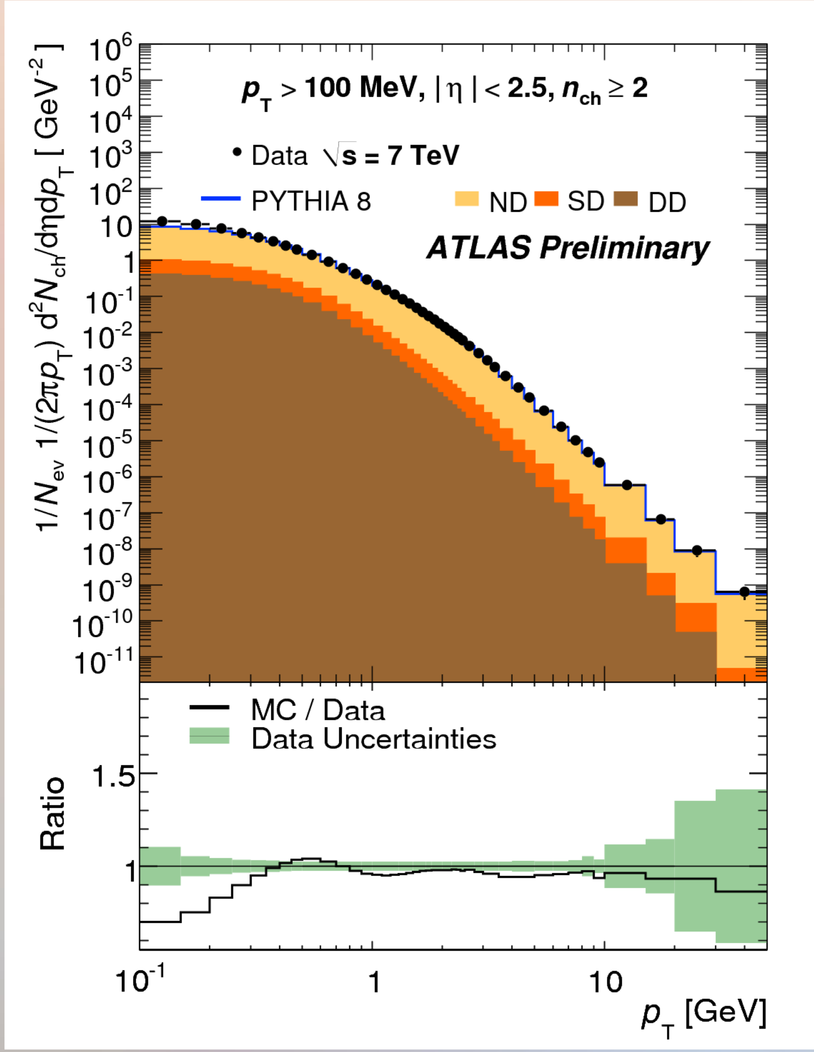
Diffractive contributions



Diffractive contributions

p_T





Diffractive contributions
p_T