Soft QCD Measurements in ATLAS

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on behalf of the ATLAS Collaboration

UNIVERSITY OF LIVERPOOL

Workshop on Discovery Physics at LHC
Protea Hotel, Kruger Gate, South Africa, 5-10 December 2010

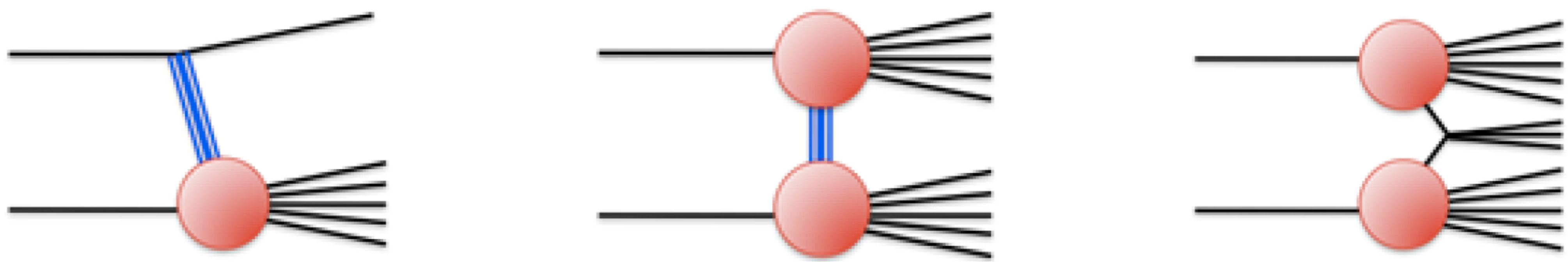
Overview

- A brief introduction to soft QCD physics at the LHC
- Minimum bias measurements
    - Phase space with restricted and enhanced diffractive content
    - Underlying Event measurements
    - Pythia MC tunes to the data
- The latest high precision measurements

The proton-proton cross section

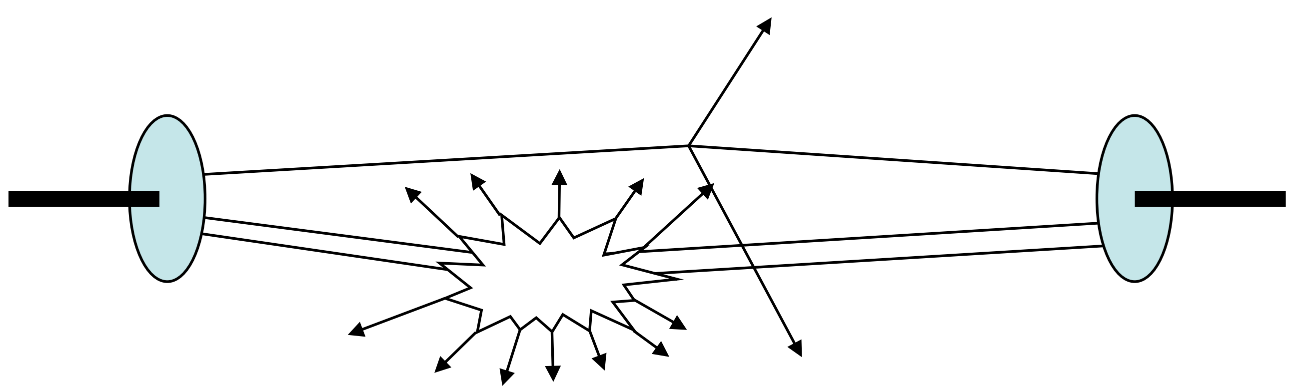
$\sigma_{total} = \sigma_{elastic} + \sigma_{inelastic}$

$\sigma_{inelastic} = \sigma_{single\text{-}diffractive} + \sigma_{double\text{-}diffractive} + \sigma_{non\text{-}diffractive}$



Generator	σ_{DD} (mb)	σ_{SD} (mb)	σ_{ND} (mb)	σ_{inel} (mb)	$(\sigma_{SD} + \sigma_{DD})/\sigma_{inel}$
Pythia	9.3	13.7	48.5	71.5	32.2%
Phojet	3.9	10.7	61.6	76.2	19.2%

The Underlying Event



The underlying background of soft partonic interactions, on which the hard interaction is overlaid. There are also related effects such as initial and final state radiation, etc....

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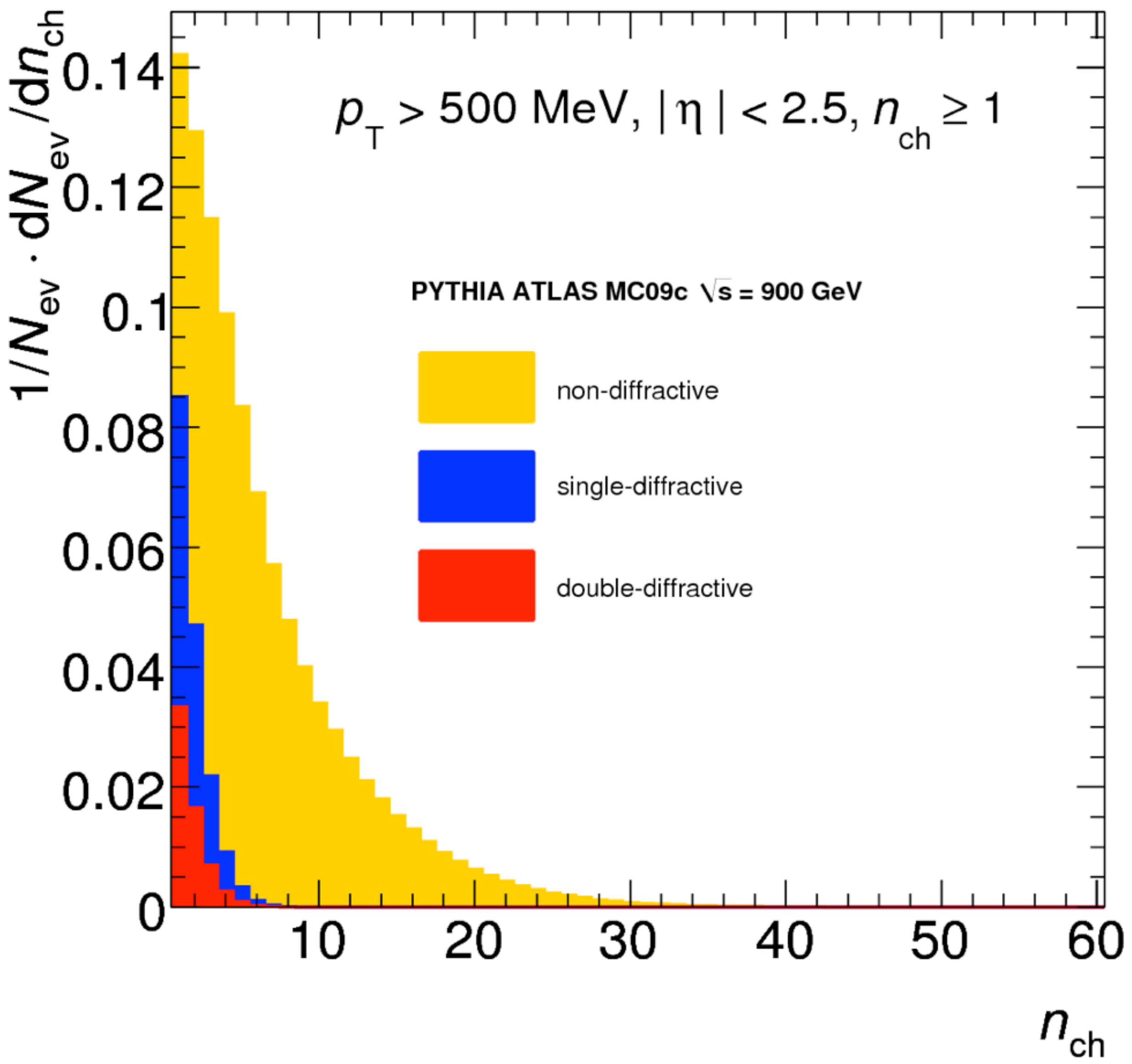
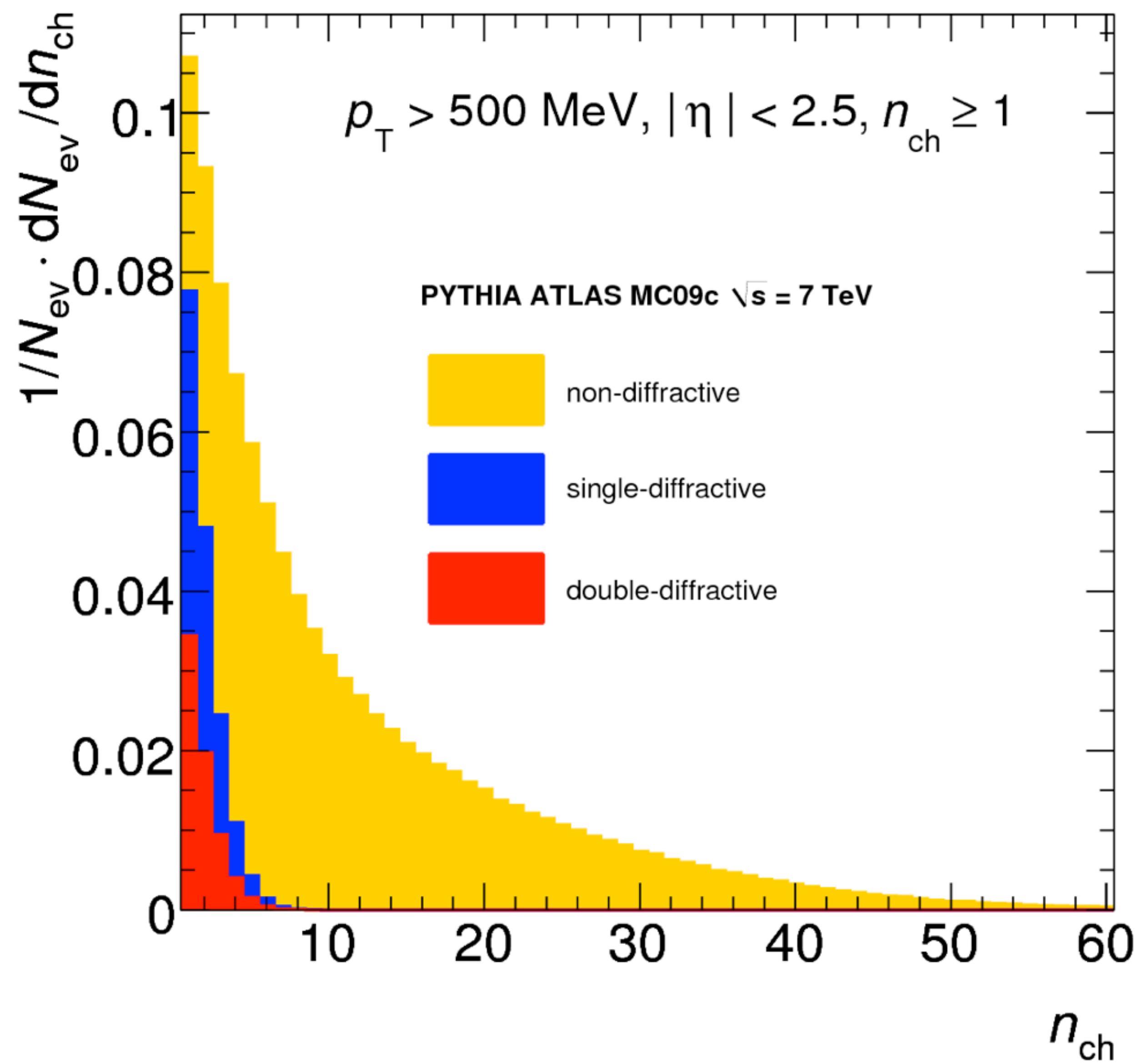
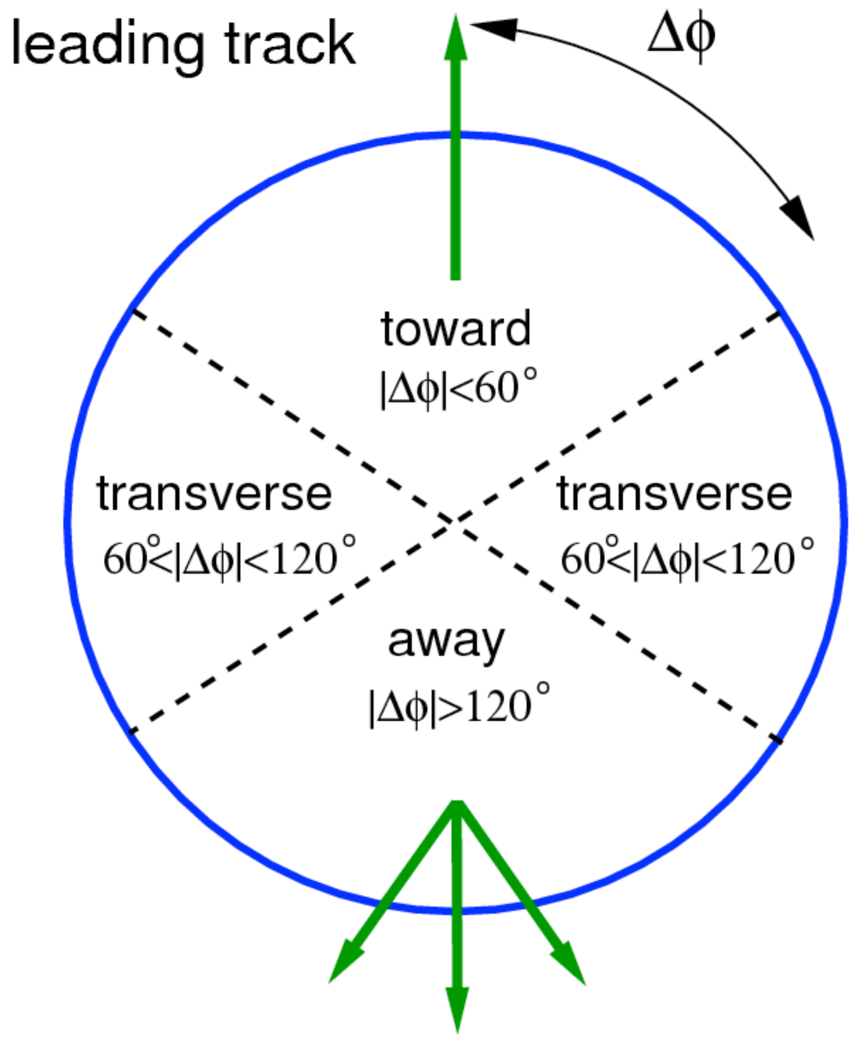
The inelastic cross section

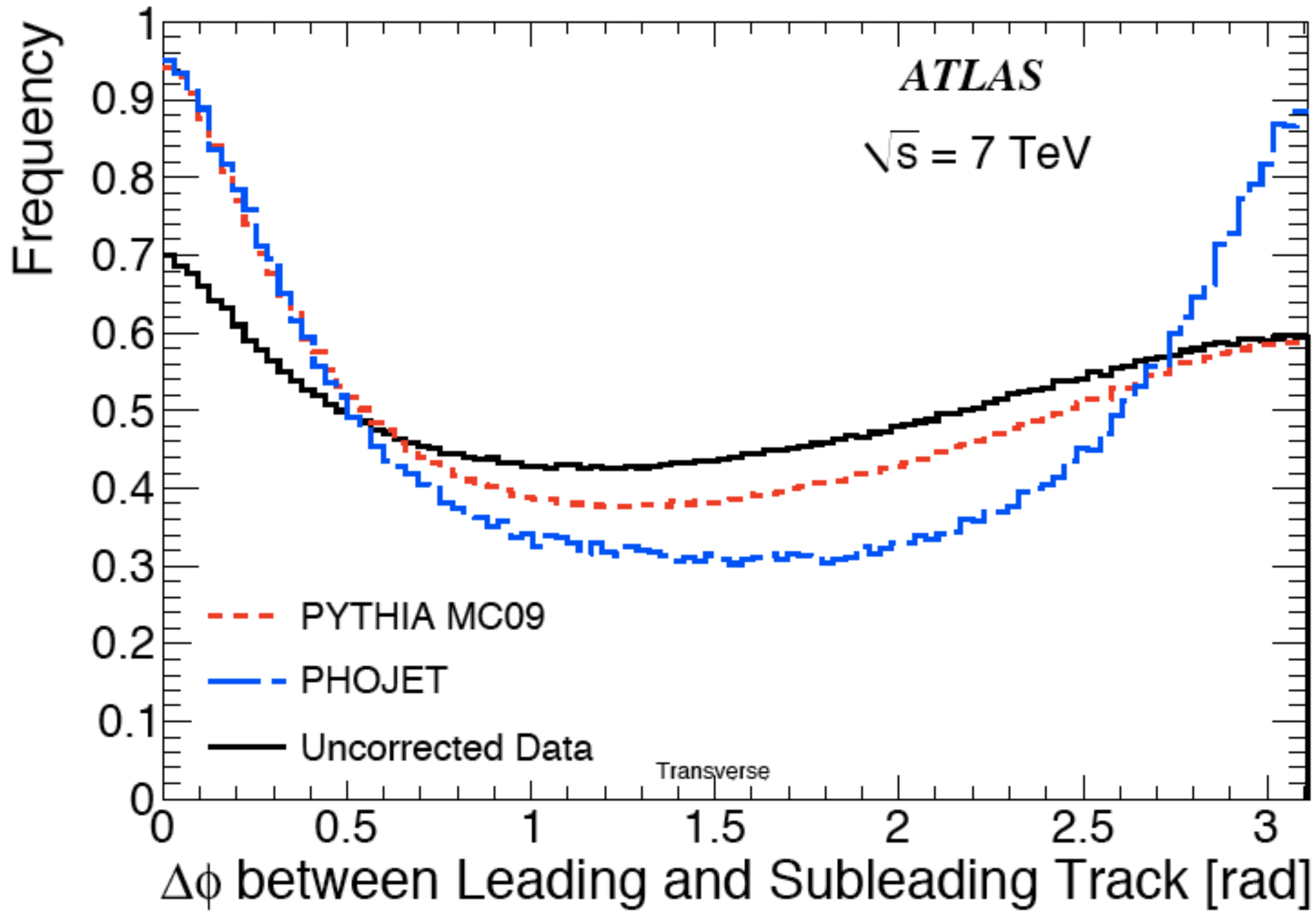




- The combined diffractive contribution dominates at the very lowest particle multiplicities - but how accurate is the model?
- Use a minimum number of tracks to reduce the diffractive component and tune the non-diffractive Pythia model

Underlying Event studies





- Use the leading track to define a preferential azimuthal direction on an event by event basis
- Look at the charged particle activity with respect to this preferential direction
- In particular, the transverse region gives information on the underlying event
- Provide more constraints on MC models

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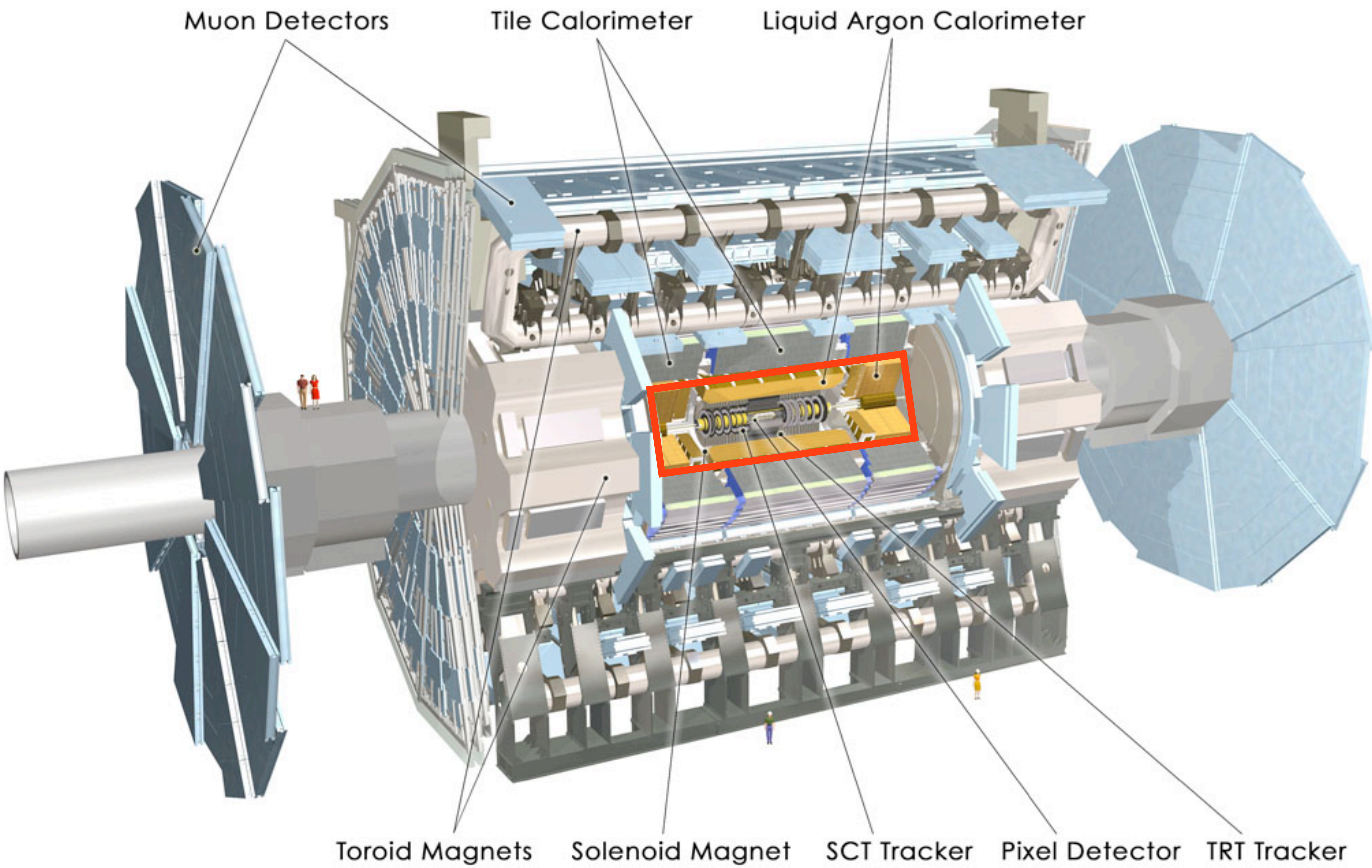
The ATLAS detector



The principle component of the ATLAS detector used here is the Inner Tracker (highlighted), which must have good data quality for all data considered in the analysis

Events are triggered using scintillators at z ± 3.56m and $2.09 < |\eta| < 3.84$

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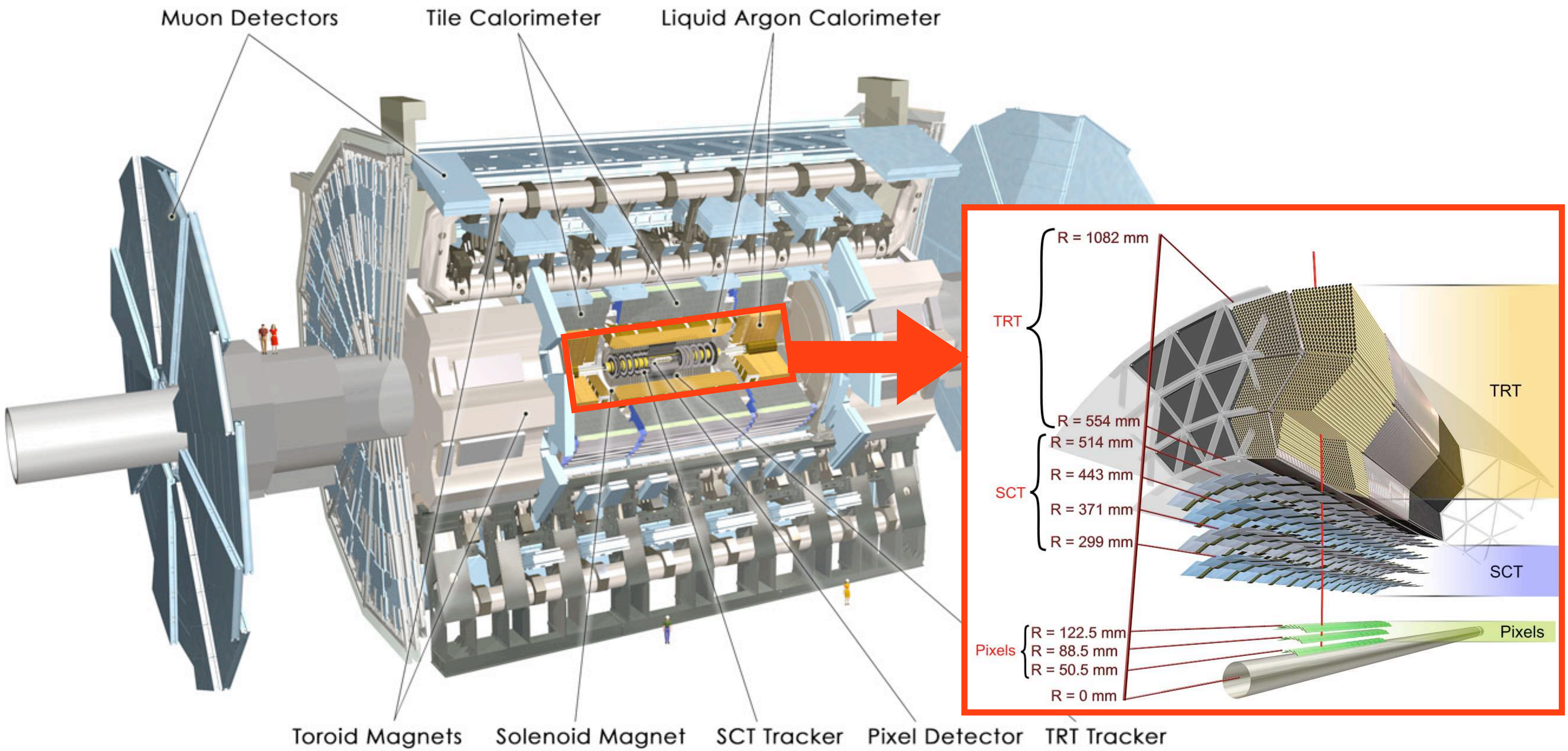
The ATLAS detector



- The Inner Tracker reconstructs charged particles for |η|< 2.5 with 1.5-2.0% p_T precision
- In the barrel region, tracks typically have 11 Pixel+SCT hits and 30 TRT hits
- Excellent vertex reconstruction efficiency also provides effective pileup rejection

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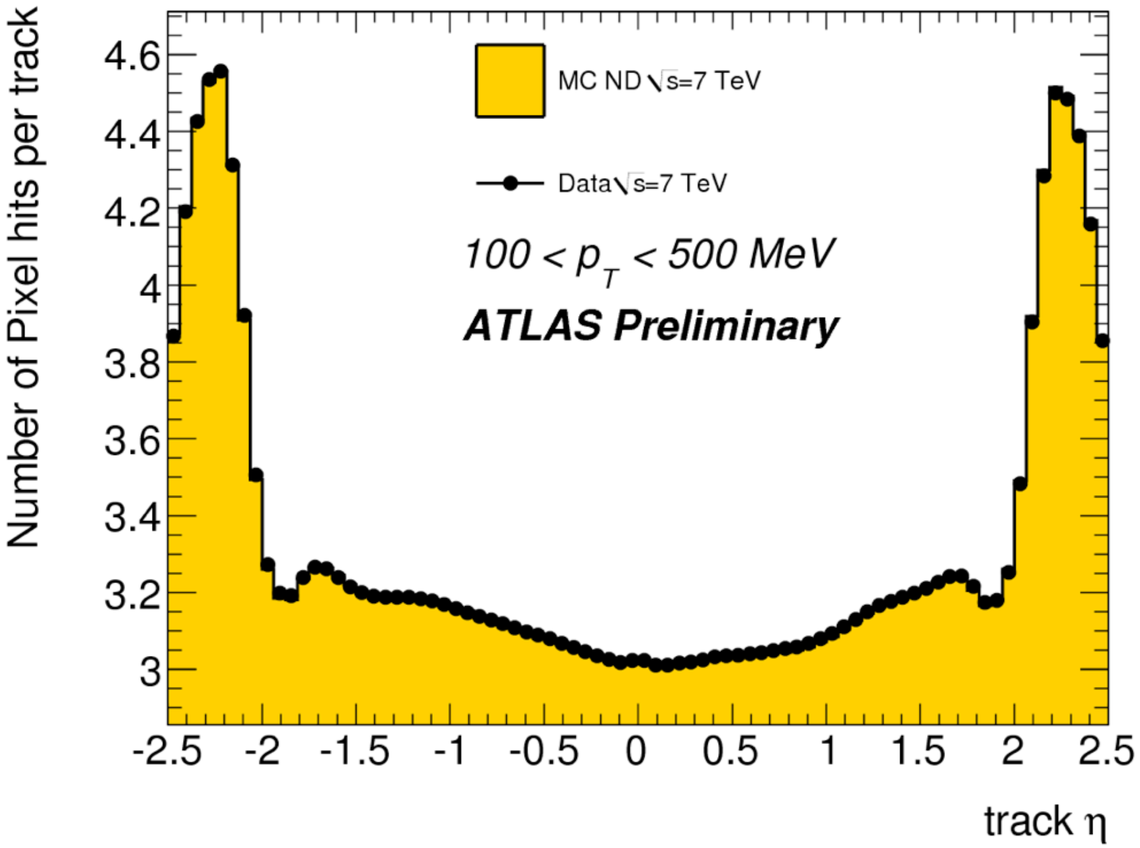
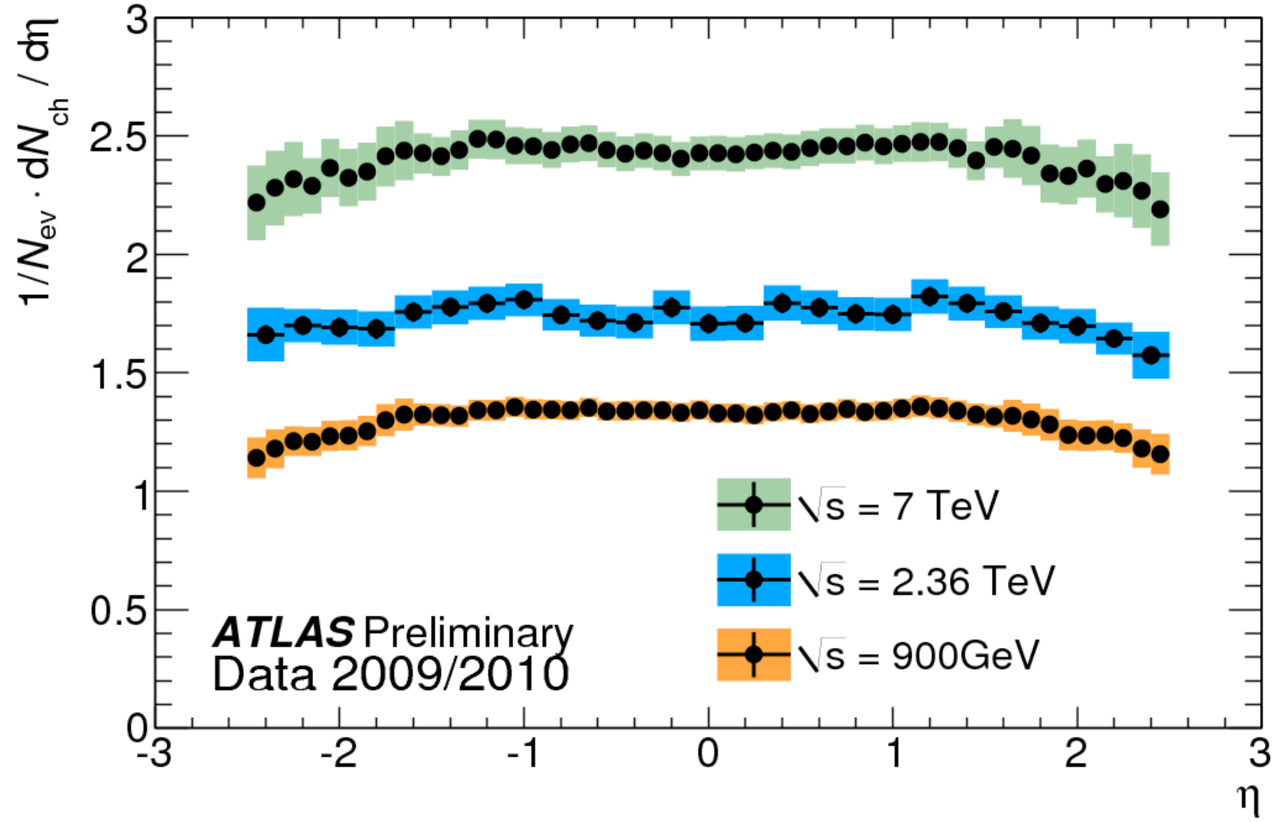
The datasets





- Several datasets analysed using a well-understood tracking detector in all cases:
  - Data at $\sqrt{s}$=0.9, 2.36 and 7 TeV (concentrate on larger 0.9 and 7 TeV datasets)
  - Minimum track p_T of 500 MeV (first measurements) and 100 MeV
  - Data unfolded back to the inelastic pp cross section (not corrected for diffraction)
- See talk by Salvador Martí i García for more on the Inner Tracker performance

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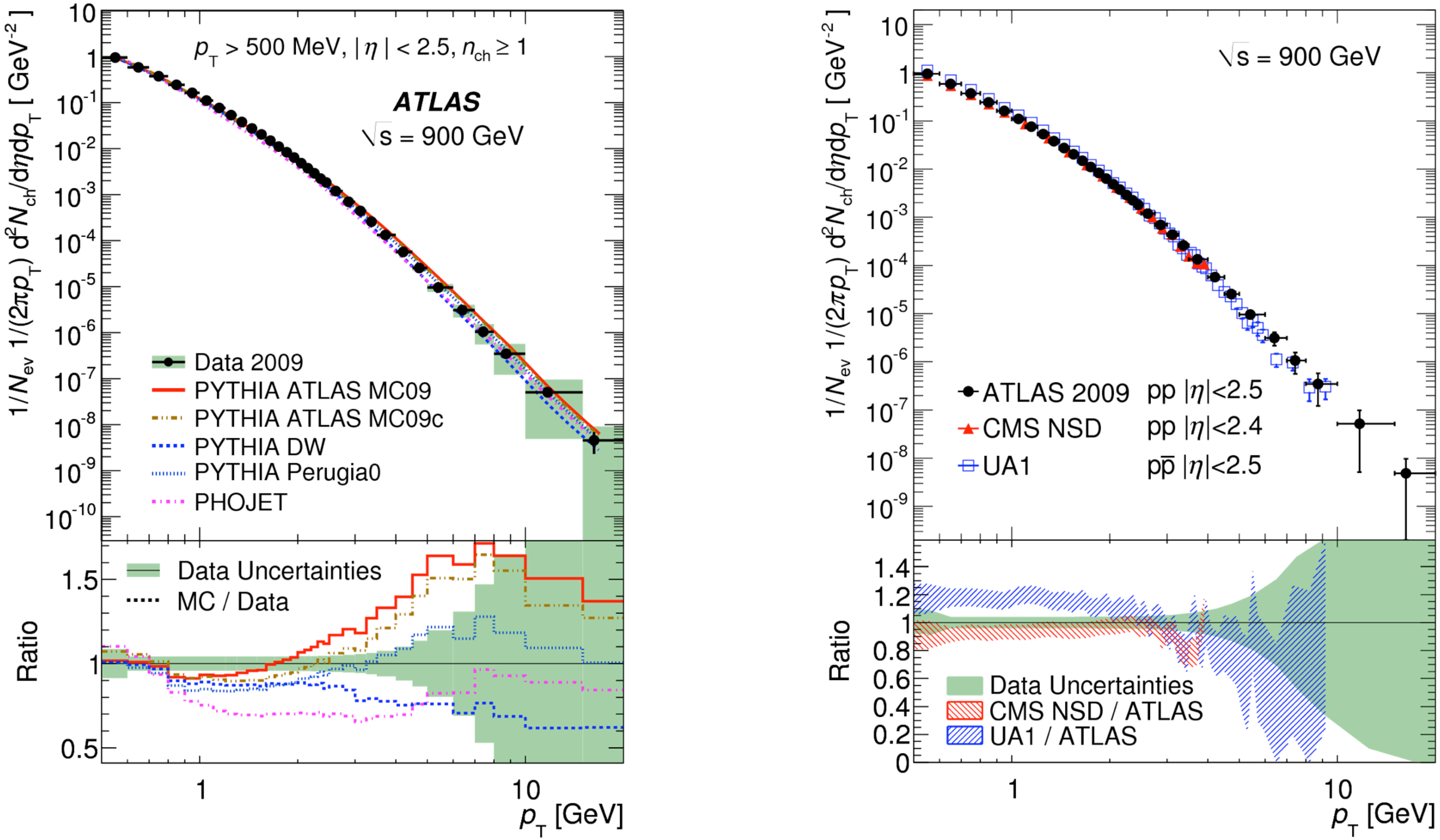
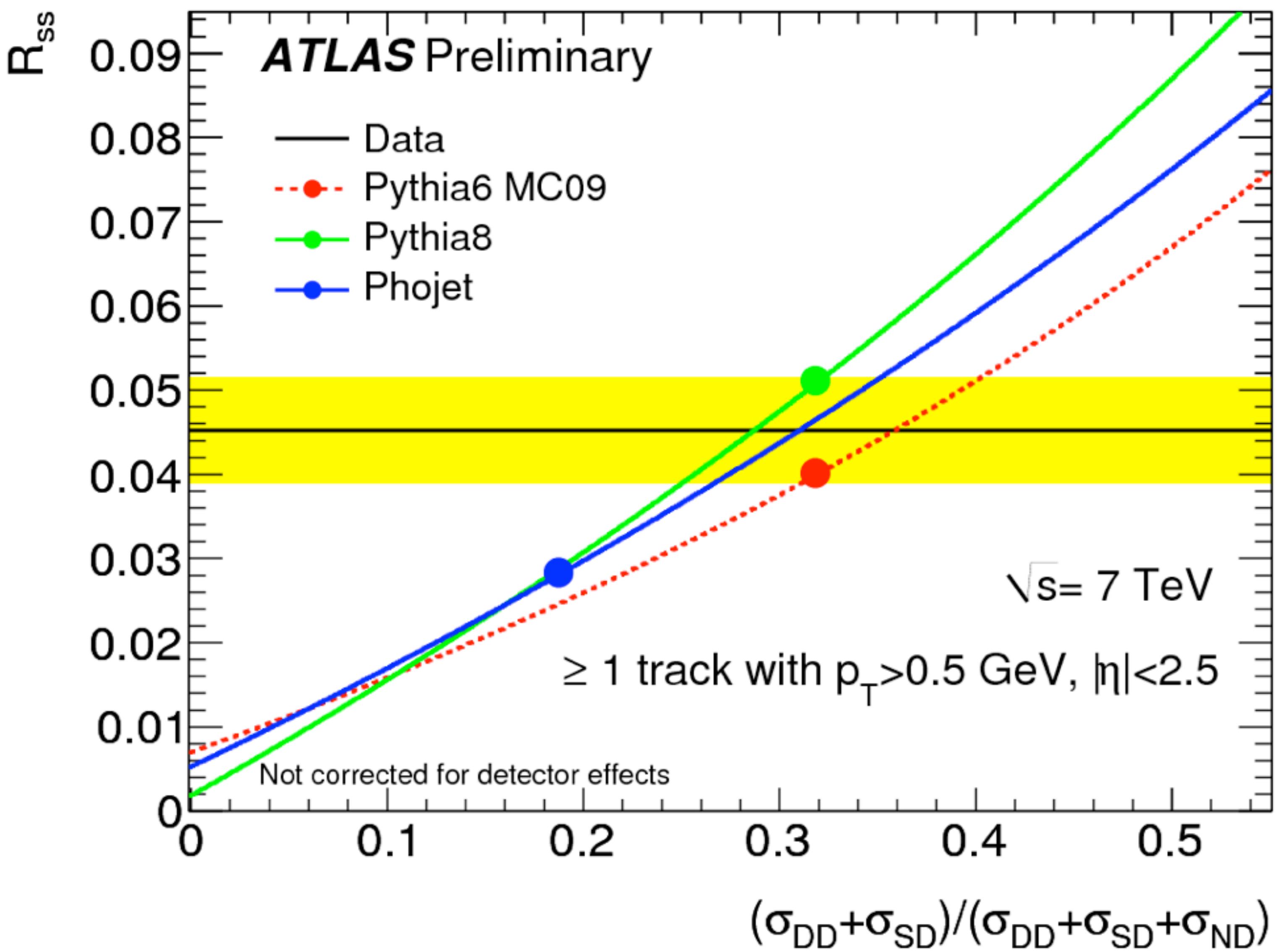
Comparison to Models and Other Data



- Models in evident need of tuning to describe the physics
- CMS data “missing” Single Diffractive component, suggests only a rate difference

A closer look at Diffraction



Measure events where activity is only seen on a single side (SS) of the detector - diffraction enhanced

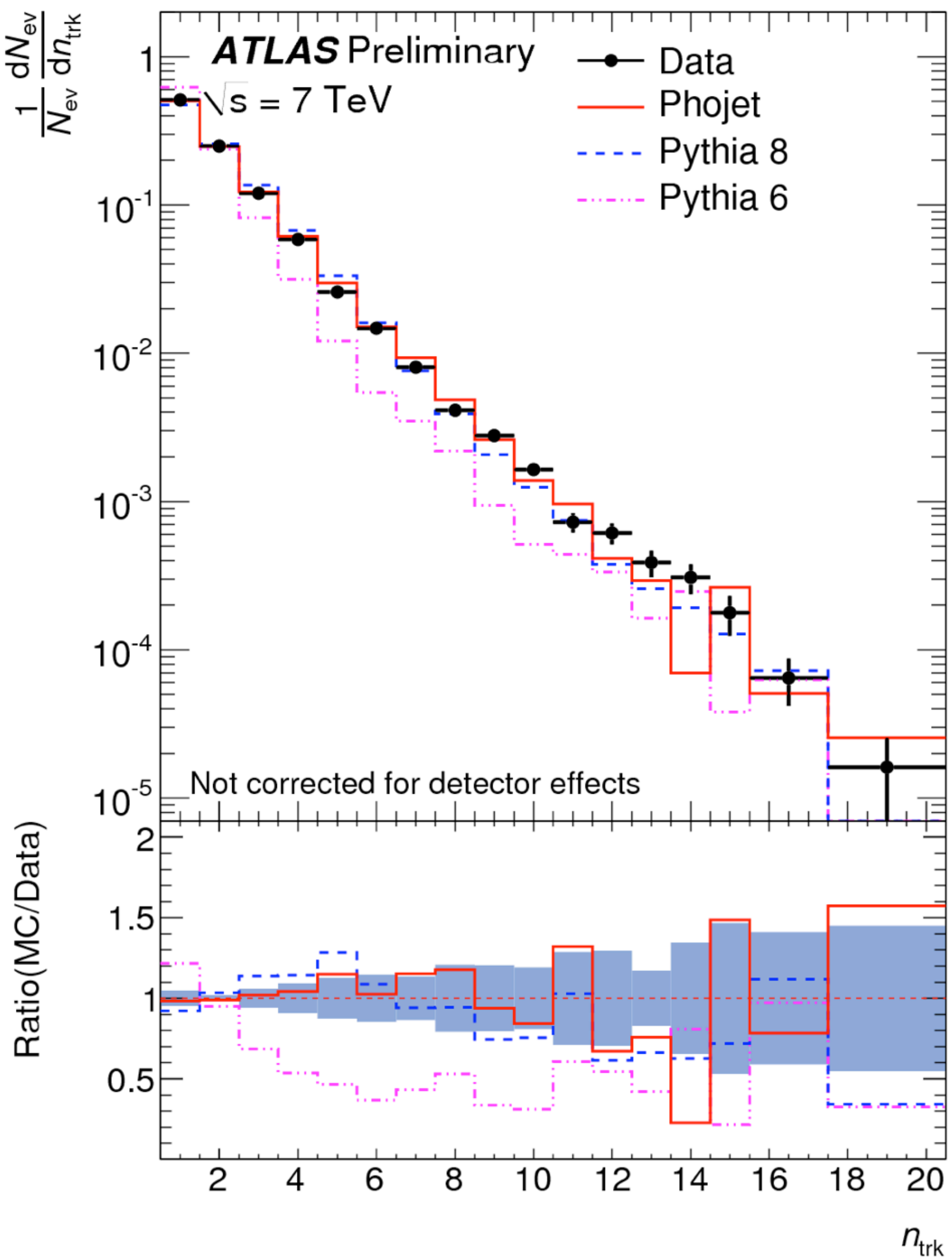
Rate of these events, R_{SS}, is sensitive to the fraction of single and double diffractive cross sections

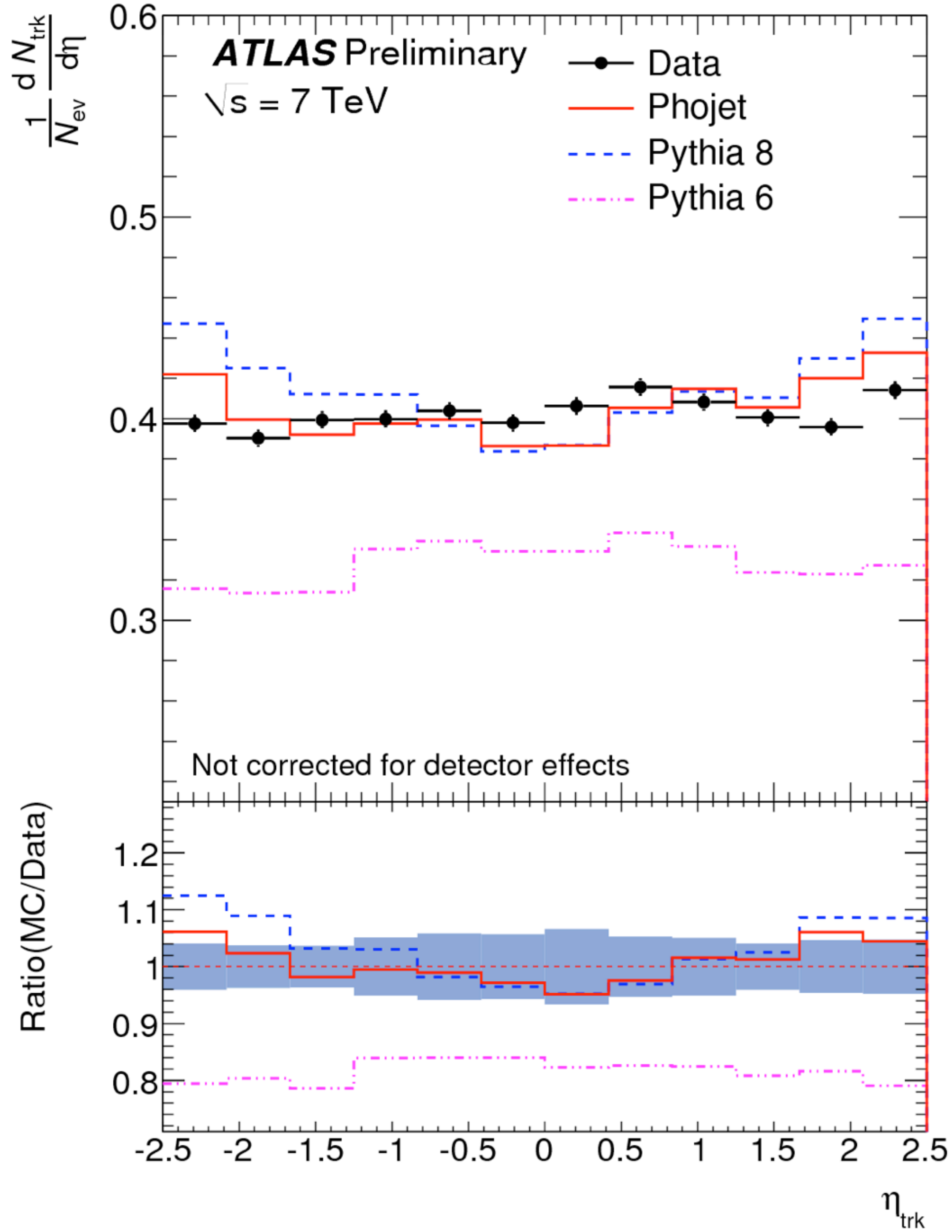
Compare to various models:

- Pythia6 is missing hard diffraction
- Pythia8 and Phojet both attempt to model hard diffraction

- Rate of diffractive events in good agreement with Pythia
- Phojet rate prediction is not consistent with the data
- All models require a combined diffractive component of ~30%

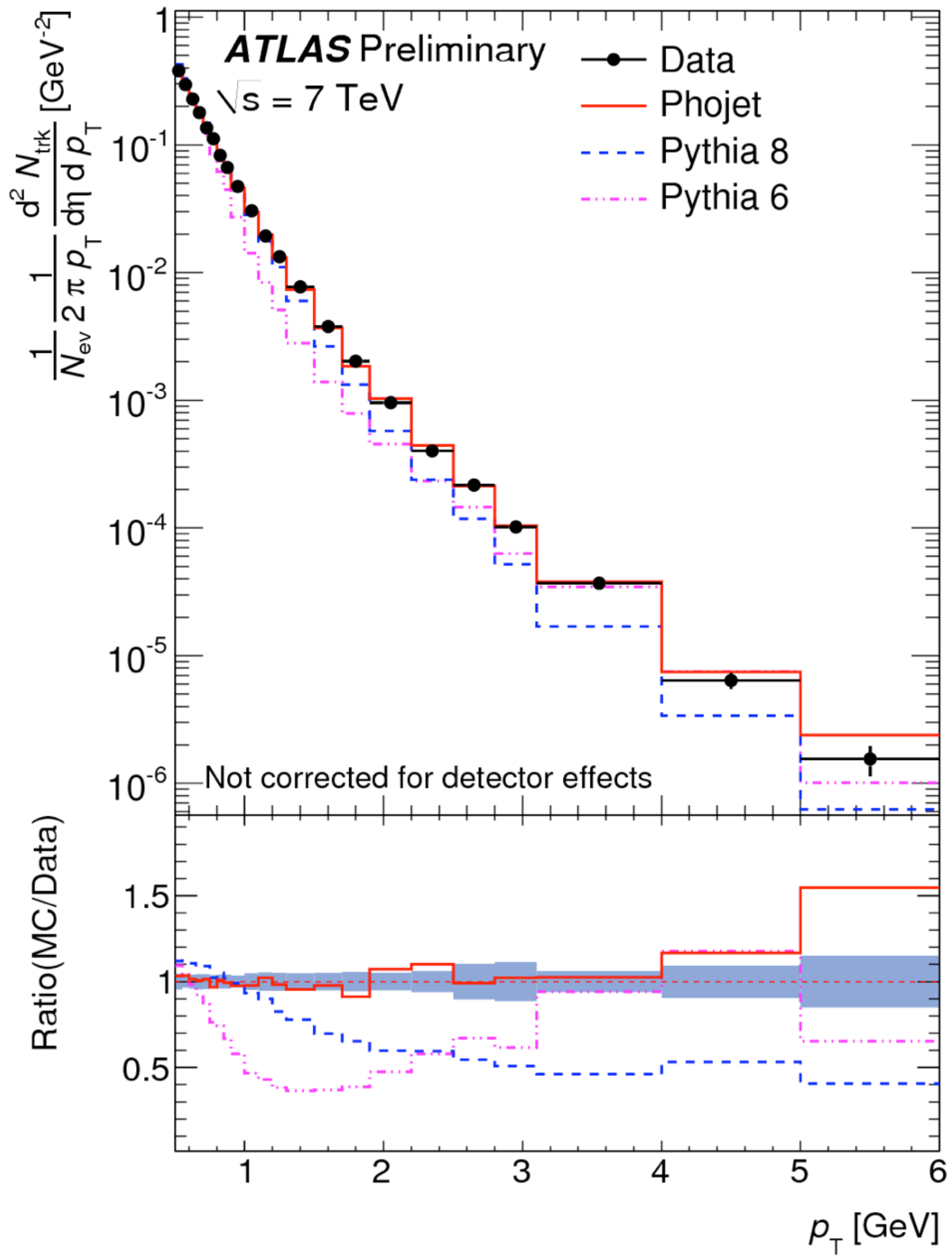
Diffractive Physics Model

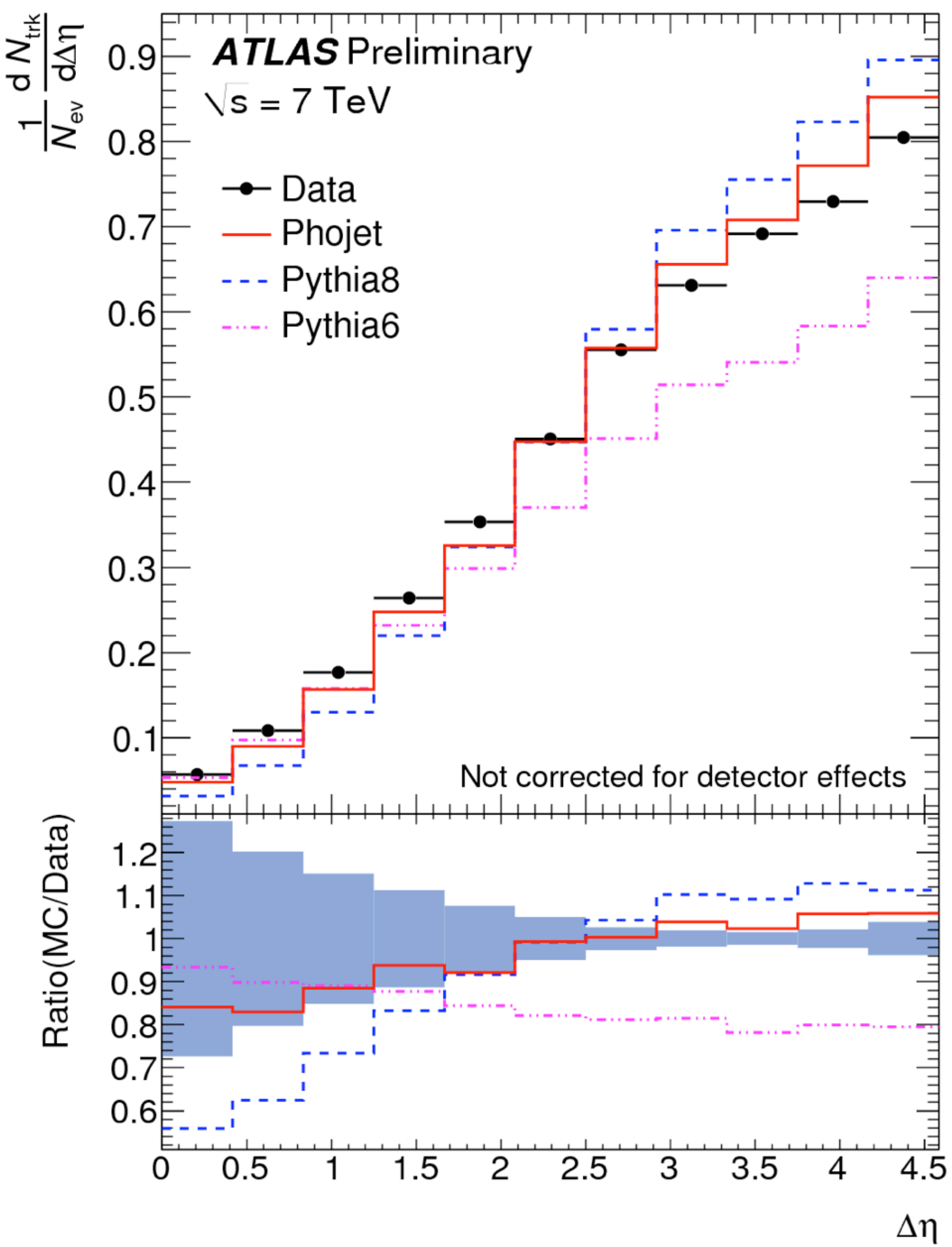




Phojet describes the charged particle multiplicity of the diffractive enhanced sample very well, as does Pythia8 (which includes hard diffraction) - Pythia6 fails

Diffractive Physics Model

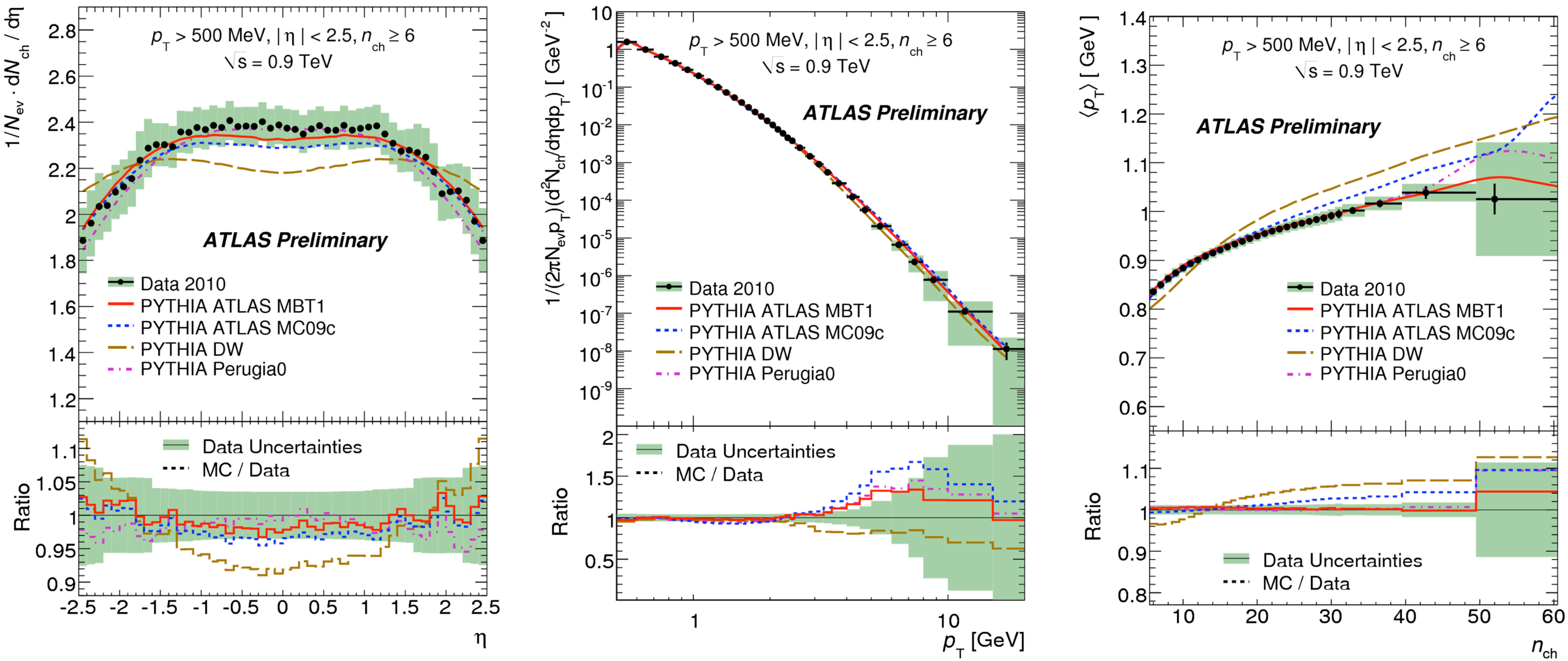




Phojet describes the p_T dependence of the diffractive enhanced sample very well except at the largest p_T, while the Pythia models are much softer than the data

Phojet also provides the best overall description of the rapidity gap in the event

Non-diffractive enhanced sample √s = 0.9 TeV



- Reduce the diffractive components in the sample by demanding 6 or more tracks
- Tune Pythia to describe this sample, Pythia ATLAS MBT1
- The tune also includes measurements at √s = 7 TeV...

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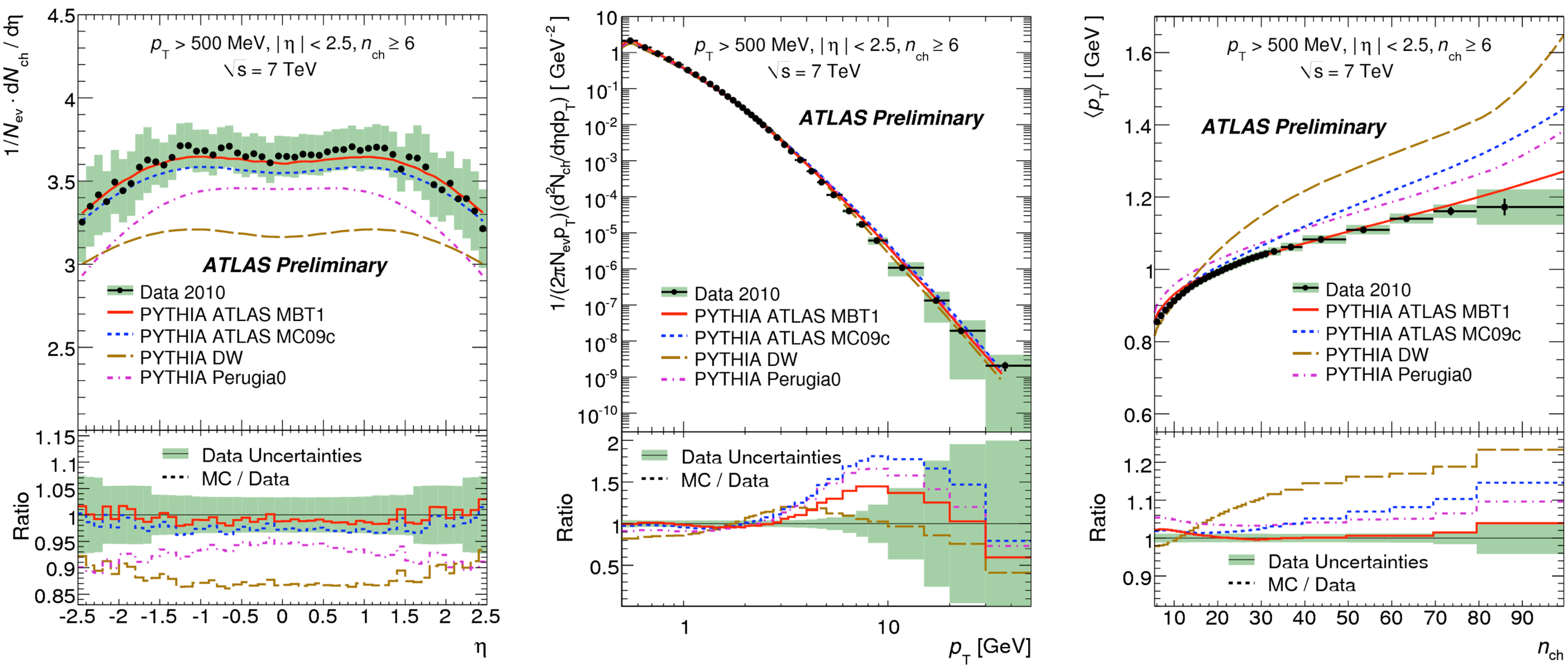
Non-diffractive enhanced sample $\sqrt{s}$ = 7 TeV



- Reduce the diffractive components in the sample by demanding 6 or more tracks
- Tune Pythia to describe this sample, Pythia ATLAS MBT1
- The tune also includes measurements sensitive to the Underlying Event...

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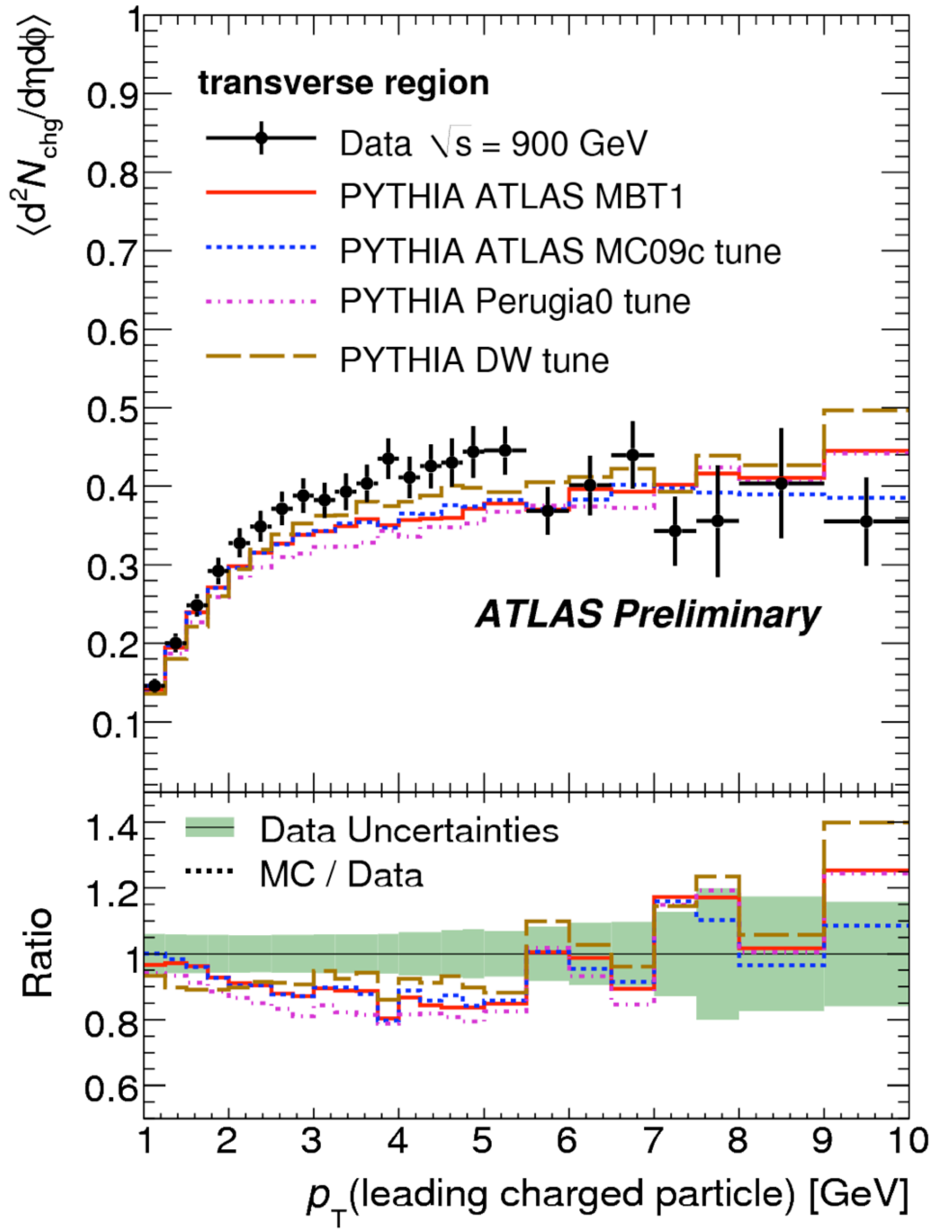
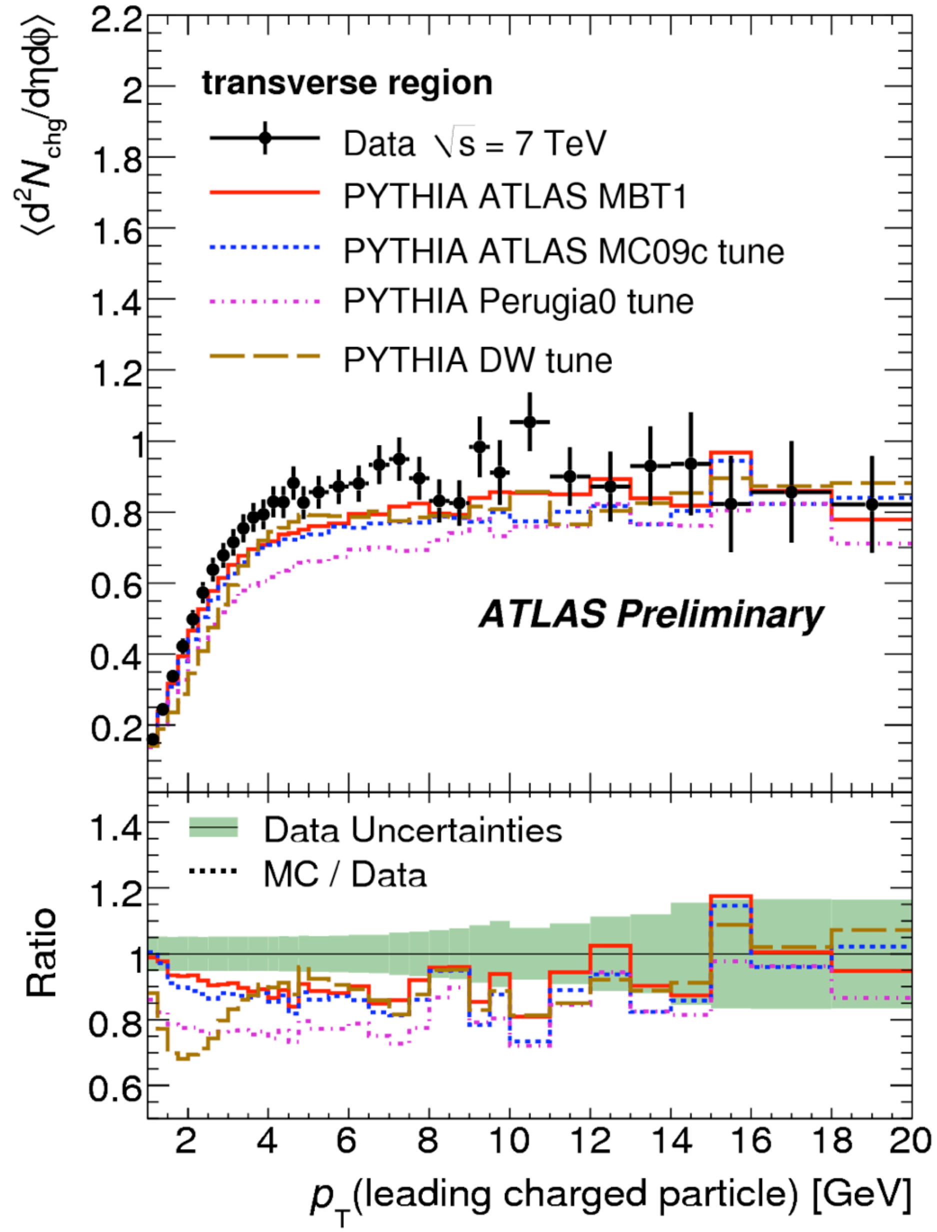
Underlying Event data used in Pythia tune





- Underlying Event physics measurements also provide constraints on the MC models
- Look at the activity (charged particle density) in the transverse region

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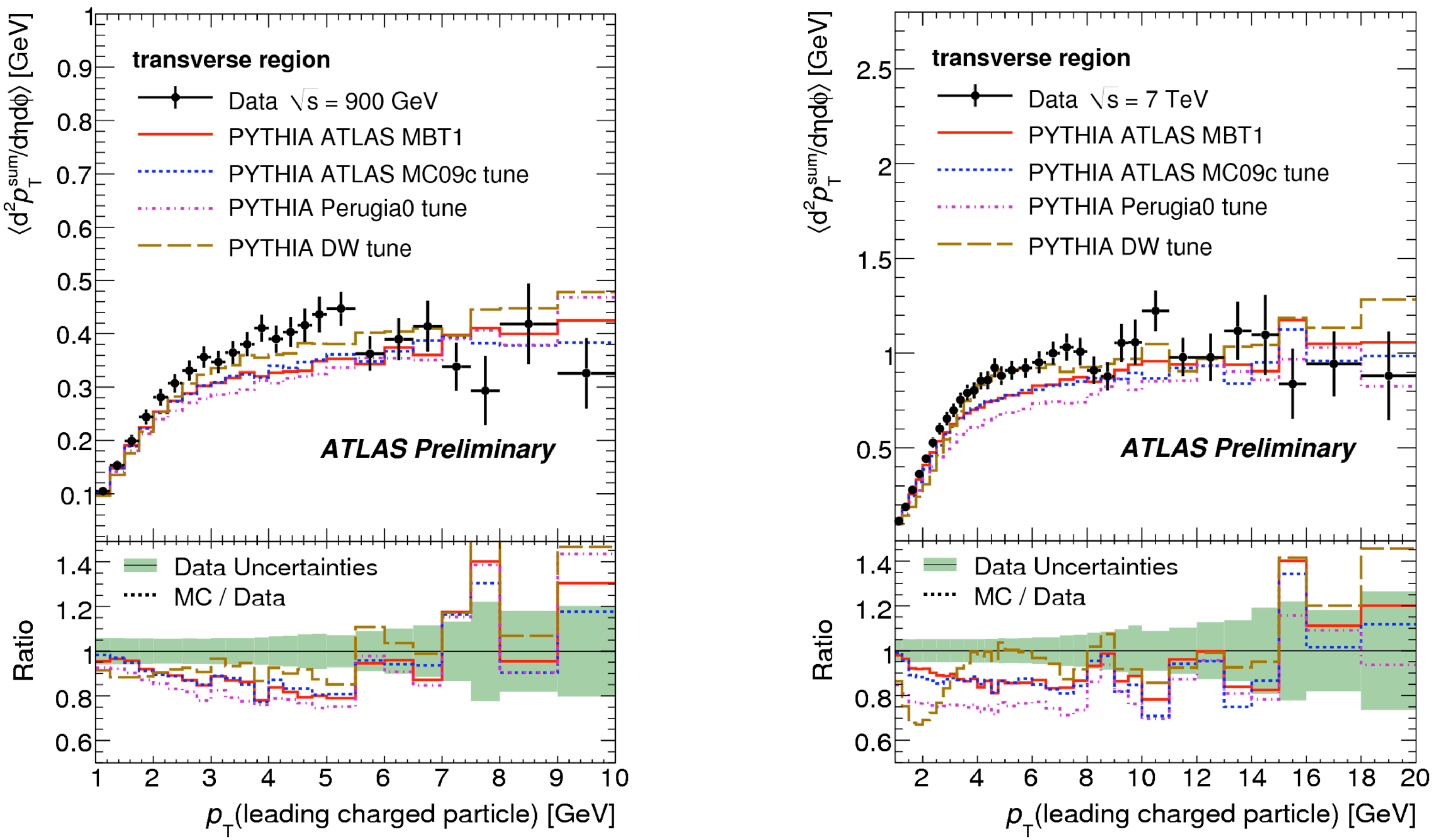
Underlying Event data used in Pythia tune



- Underlying Event physics measurements also provide constraints on the MC models
- Look at the charged particle p_T sum in the transverse region
- Indications are that more data are needed

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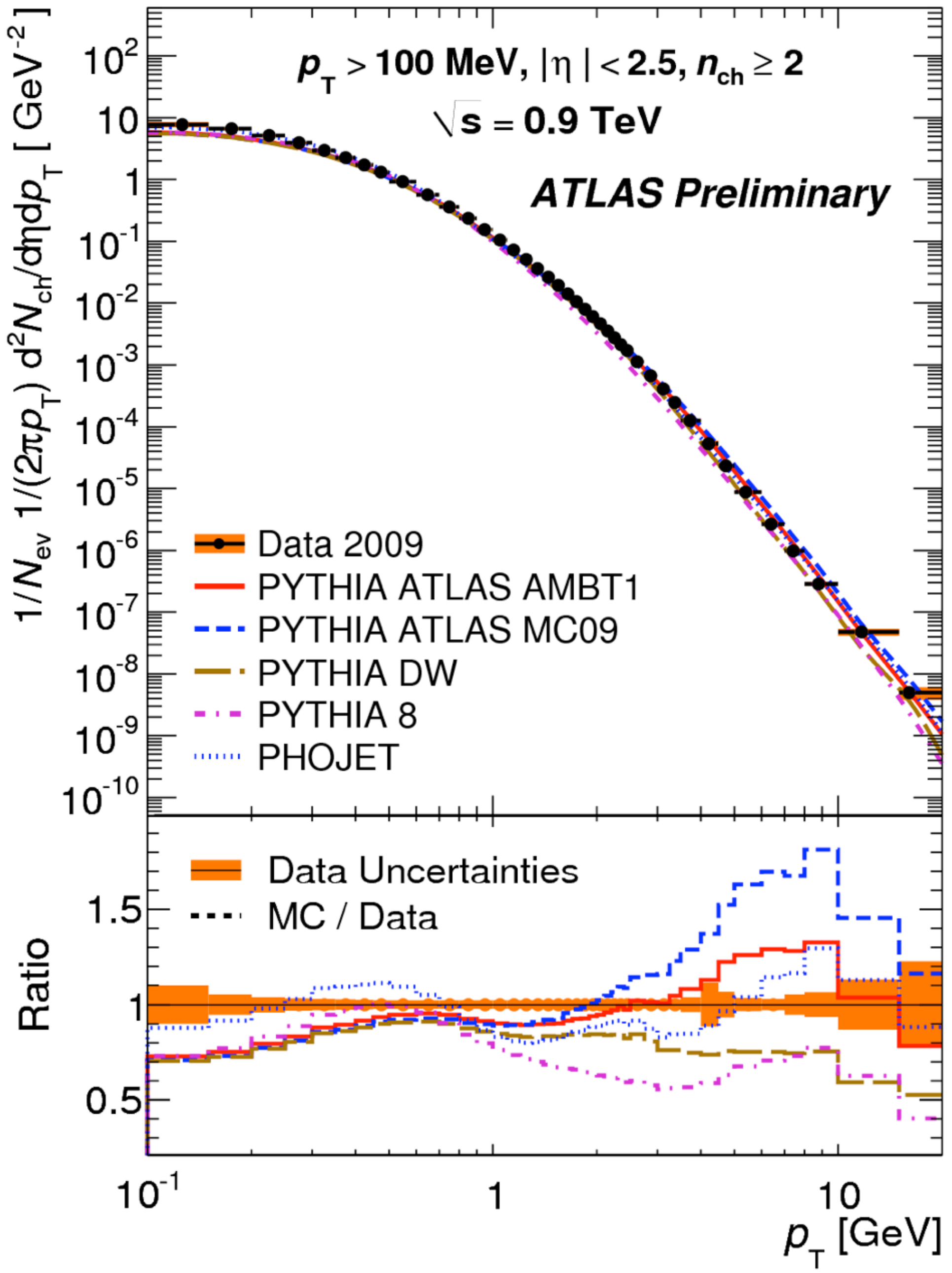
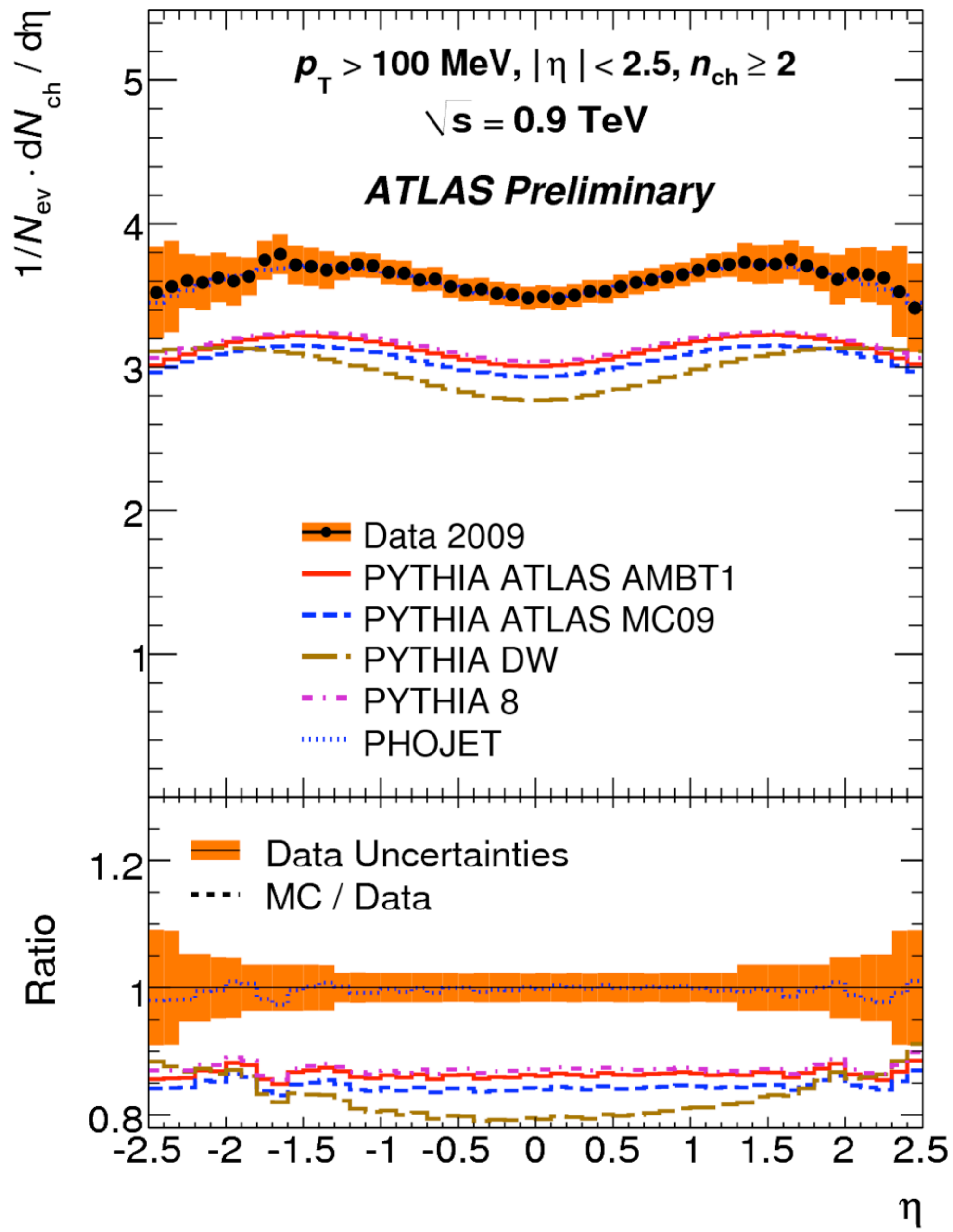
New Minimum Bias data at lower p_T - $\sqrt{s}$ = 0.9 TeV





- Rate and p_T dependence of the data at lower p_T poorly described by Pythia, even using the AMBT1 tune to the same data at higher p_T (> 500 MeV)

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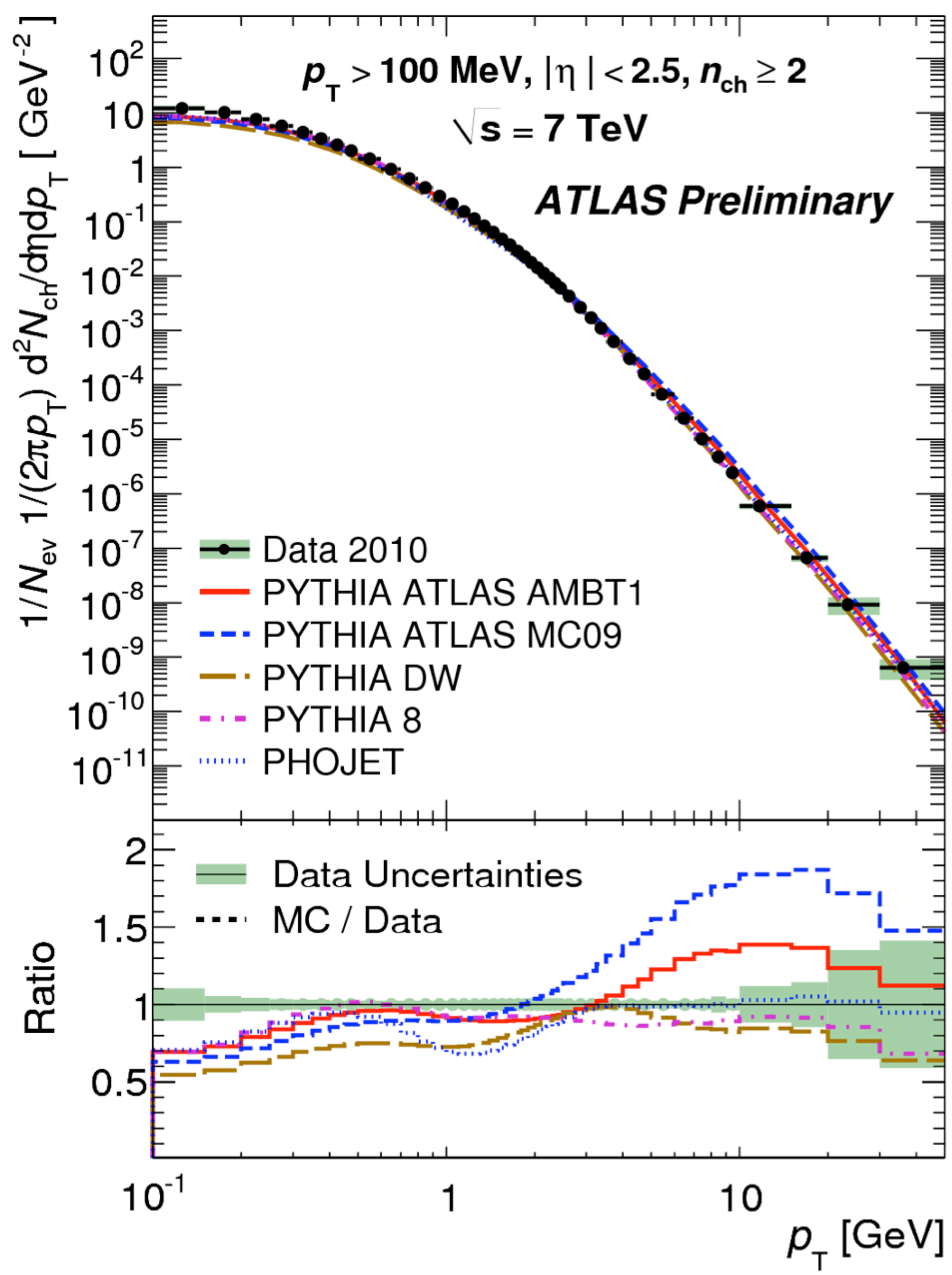
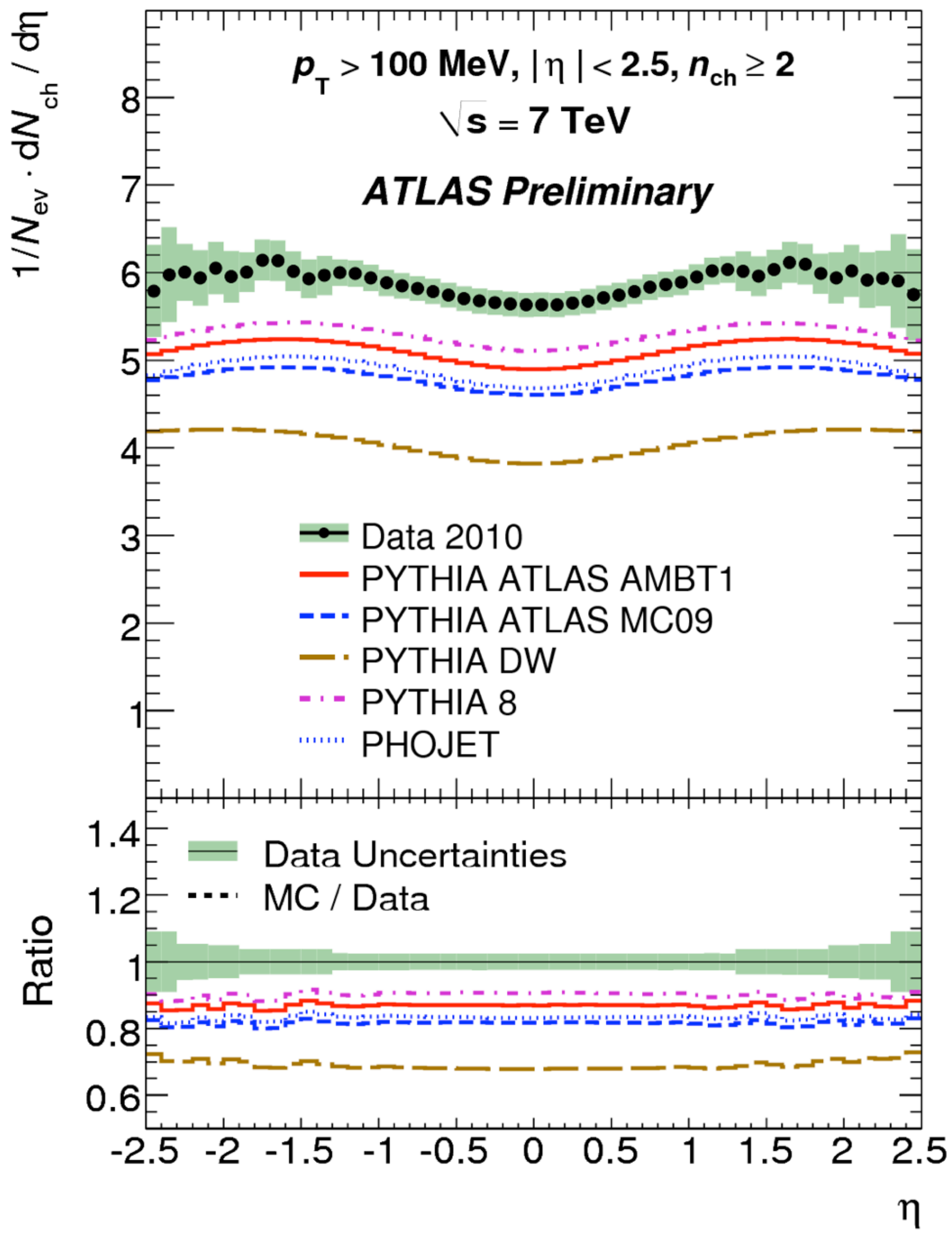
New Minimum Bias data at lower p_T - $\sqrt{s}$ = 7 TeV





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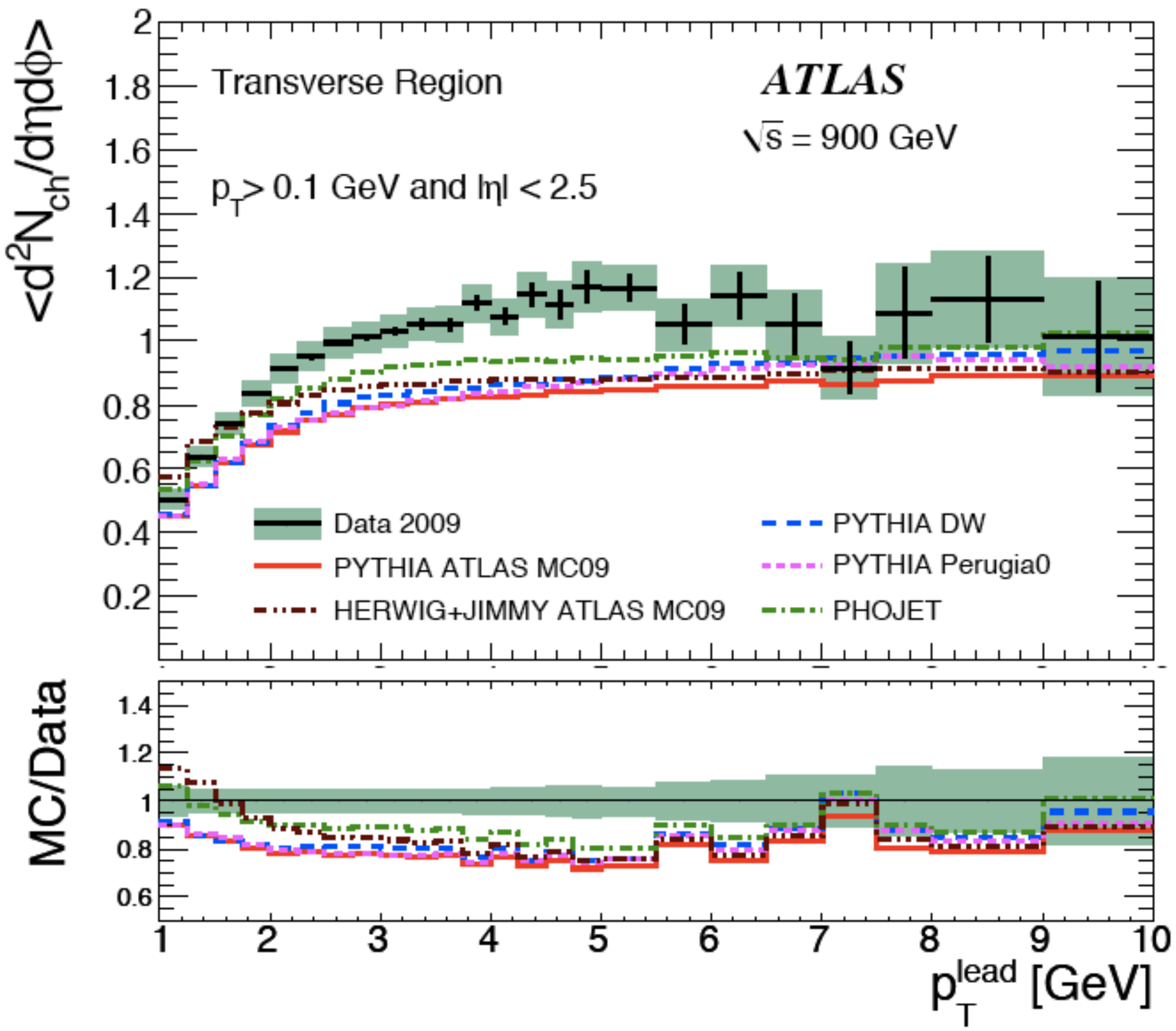
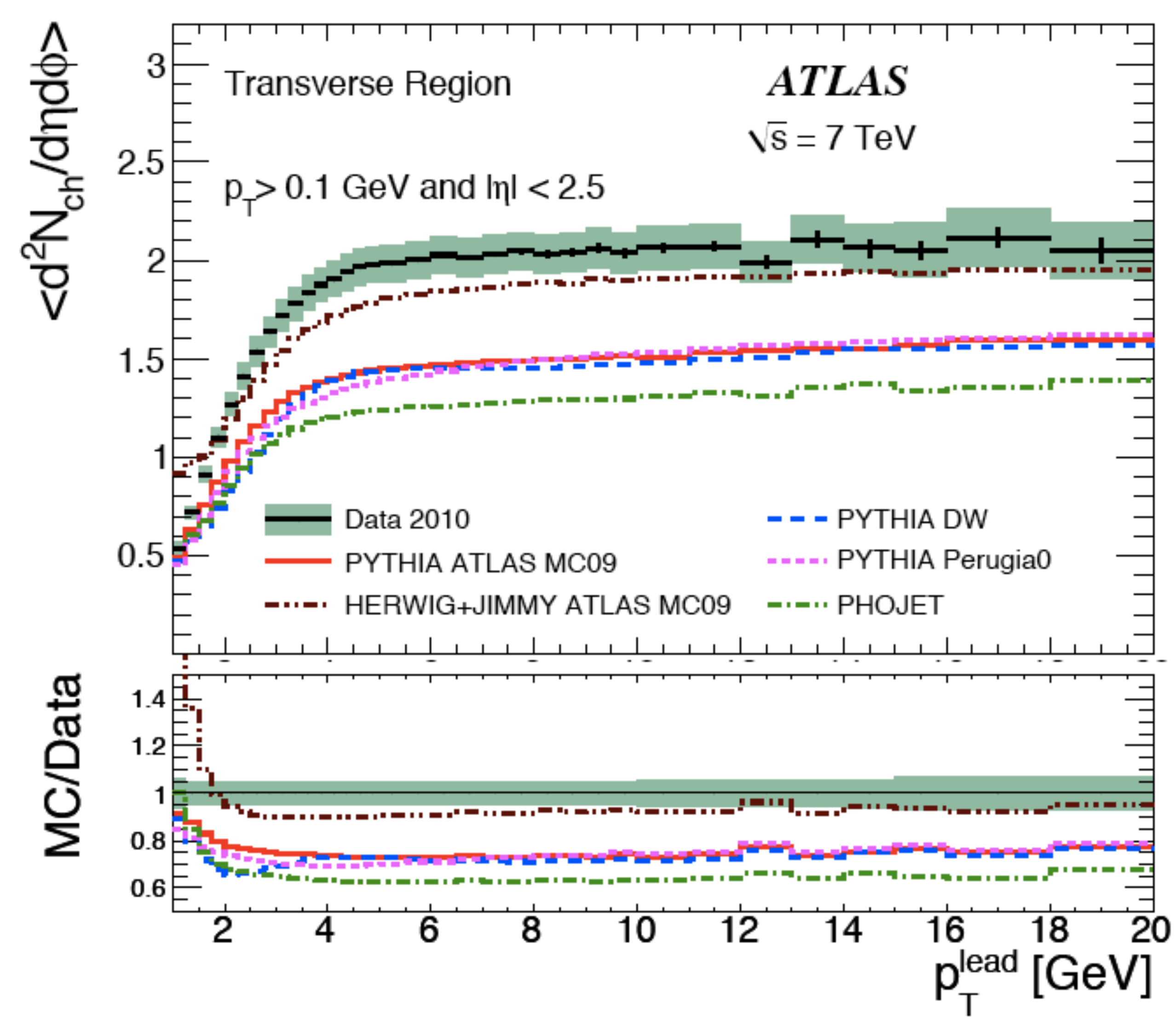
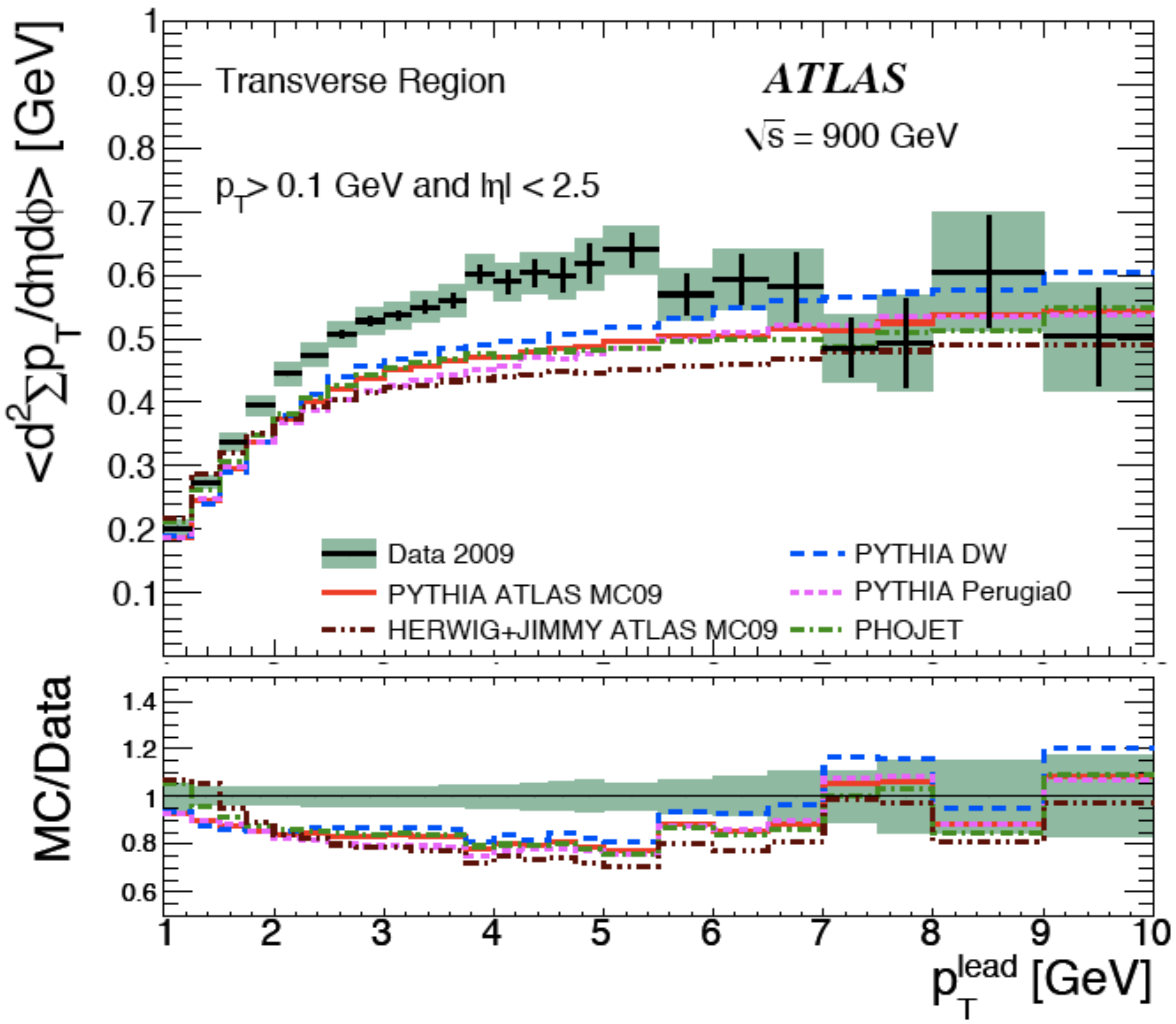
New Underlying Event data

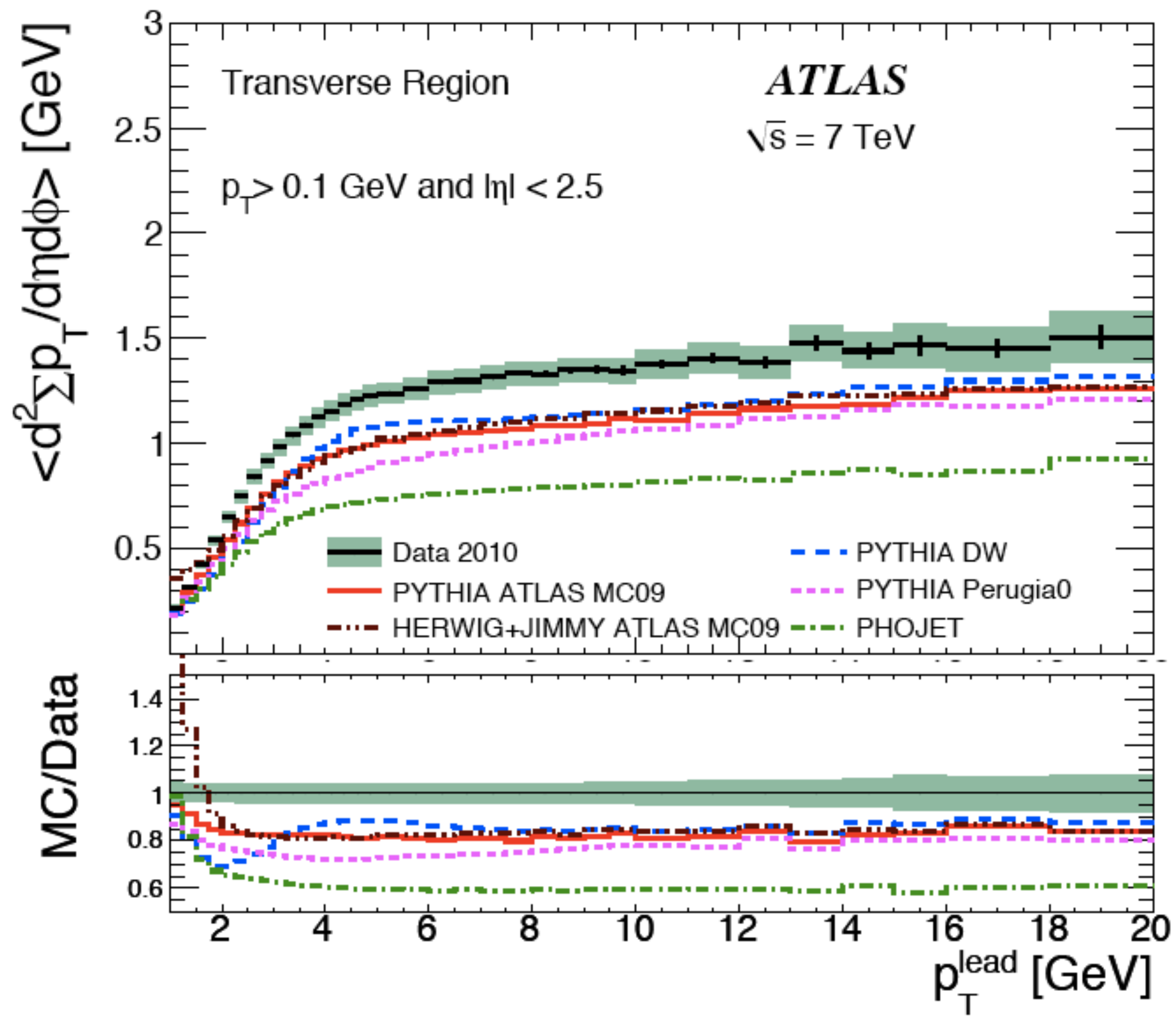




- Measurements sensitive to the Underlying Event show clear differences to the models
- Undershoot of MC predictions in the transverse region even more pronounced at lower p_T

New Underlying event data





- Measurements sensitive to the Underlying Event show clear differences to the models
- These more precise Underlying Event data will be used to constrain future tunes

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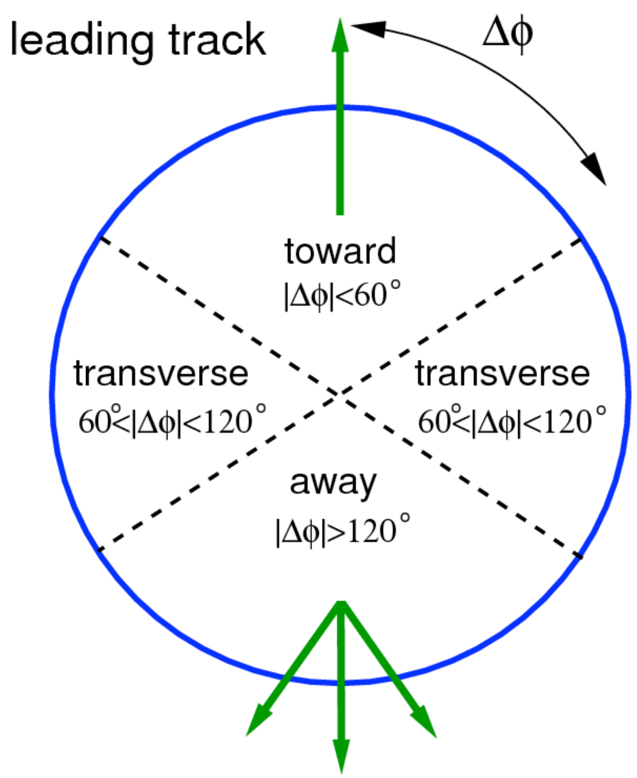
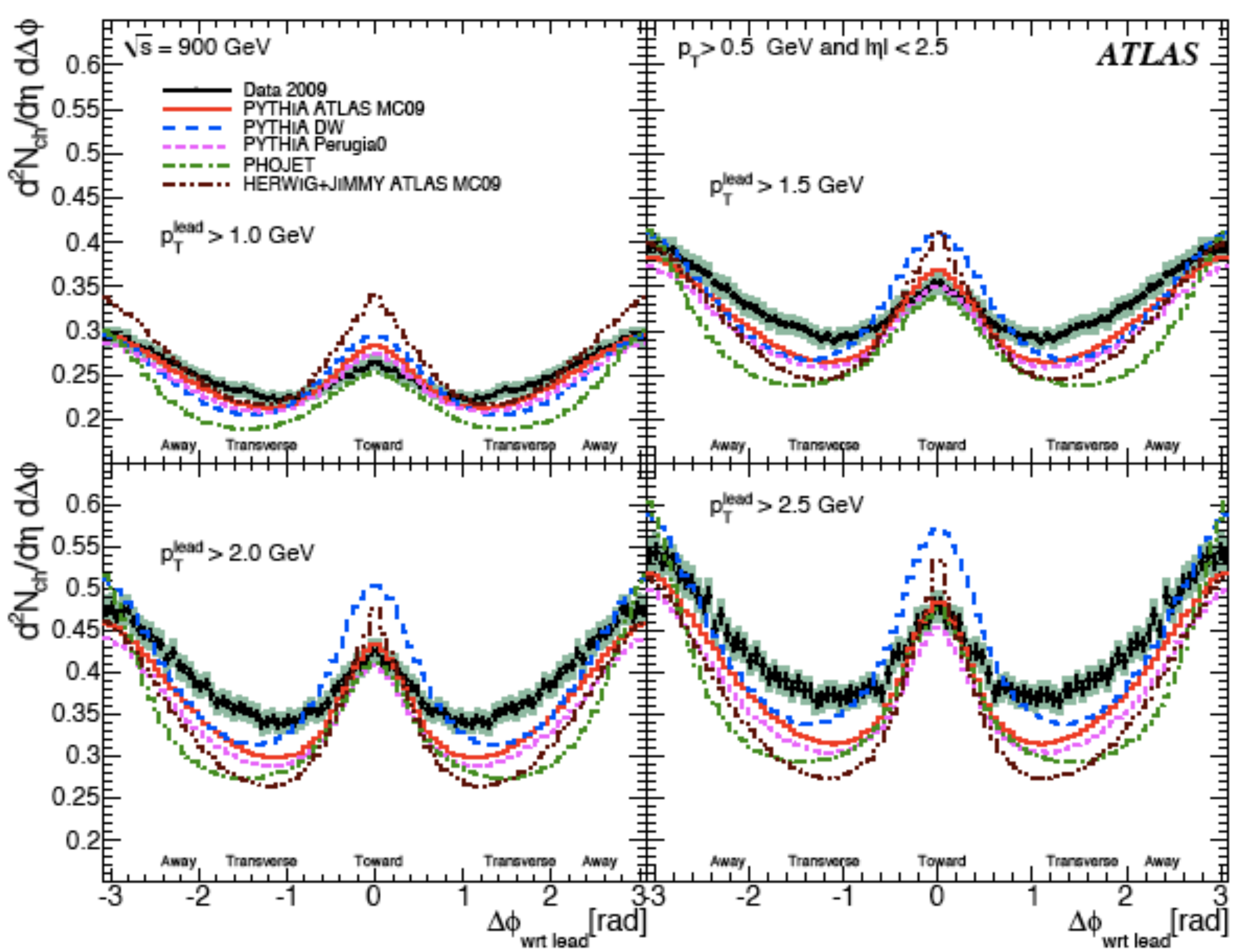
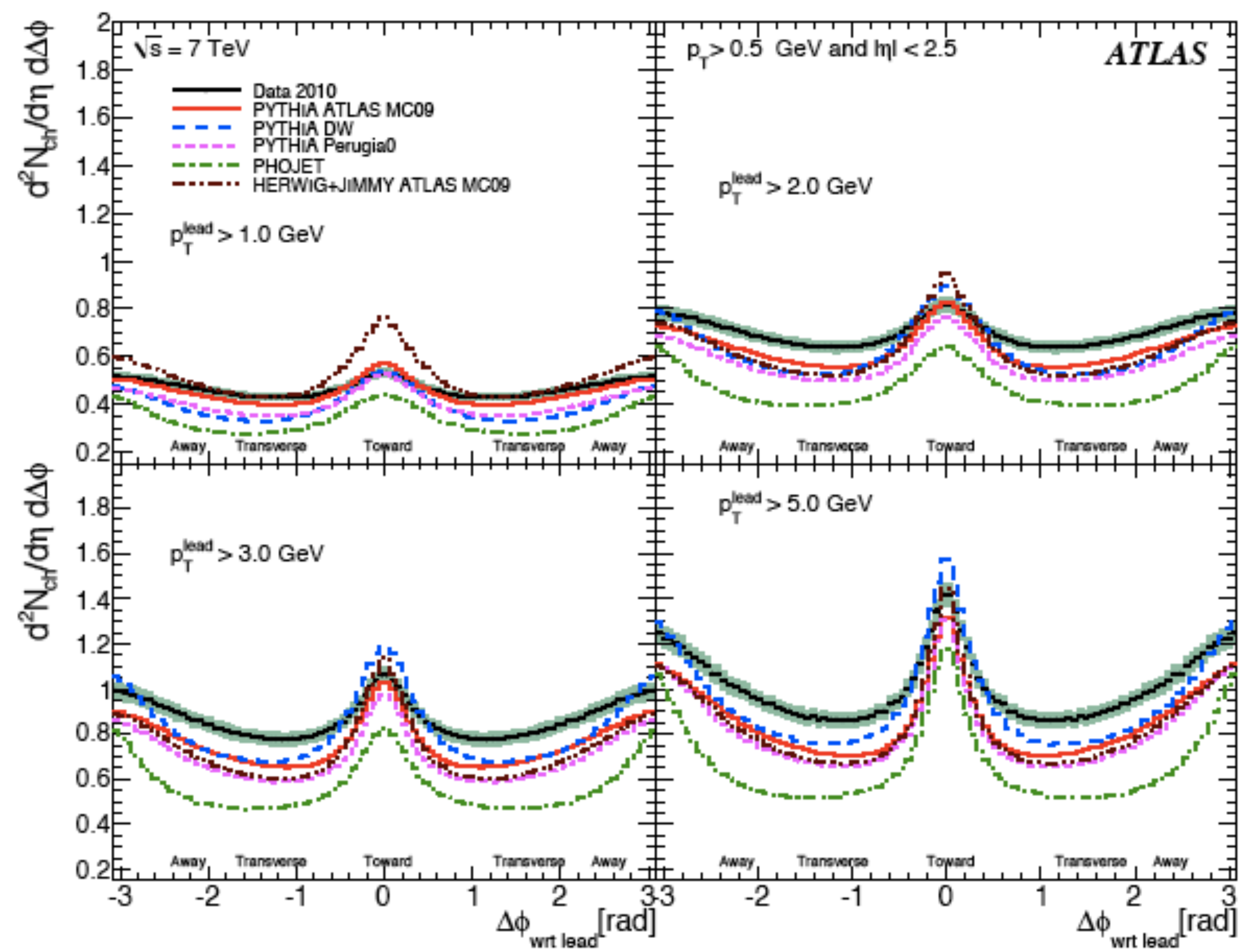
New Underlying Event data

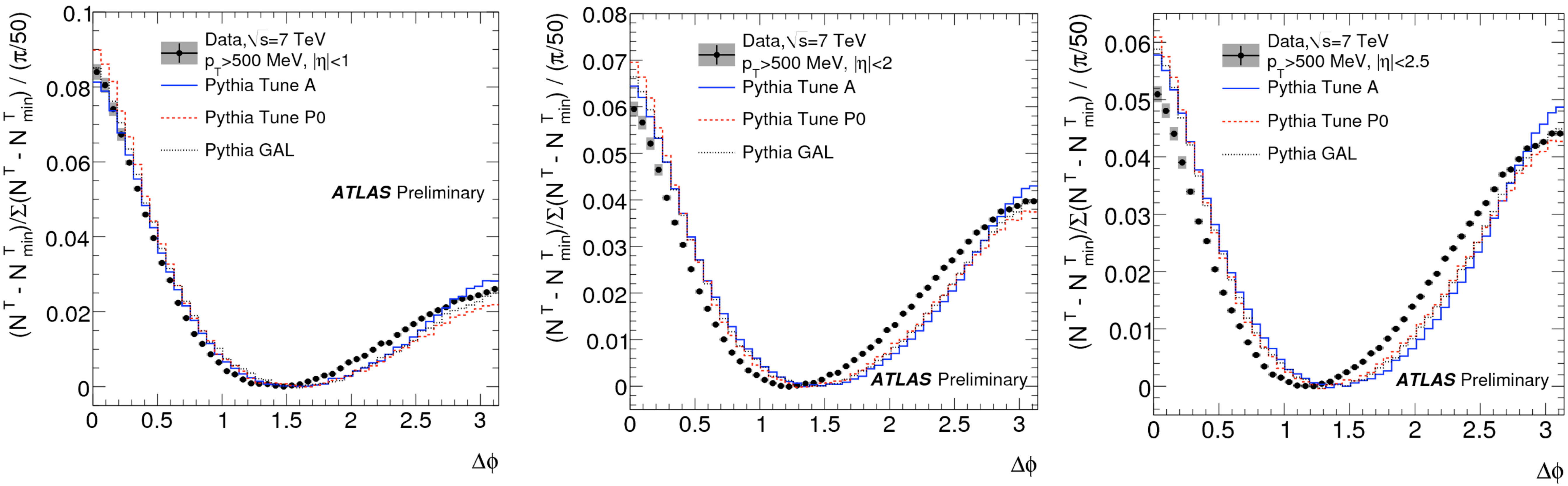


Looking at the whole Δϕ distribution, it's clear that the models do not reproduce the particle correlations, especially at low p_T where the shape is also not described





Angular correlations



- Subtract the average activity and look for correlations in $\Delta\phi$ in different η regions in particle production above this background of activity
- Expected toward and away structure clearly observed
- At central rapidities, the models describe the data reasonably well
- At larger rapidities the models fail to describe the data

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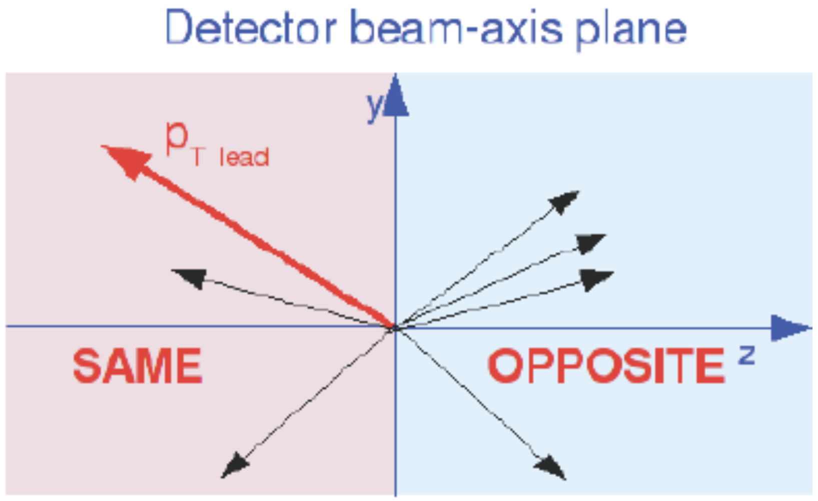
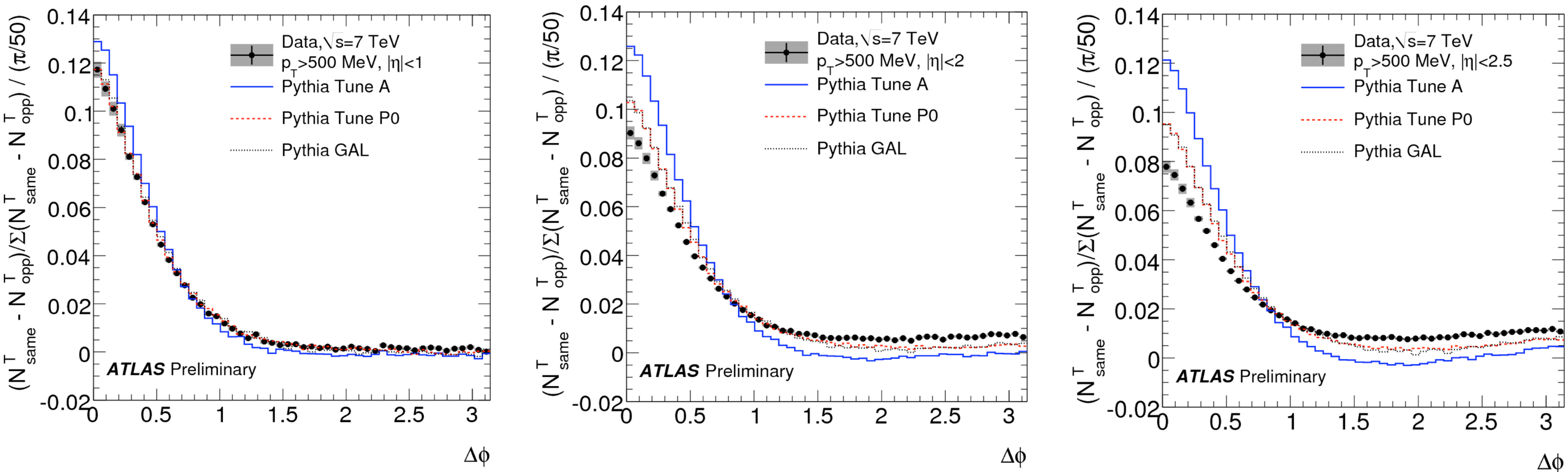
Angular correlations



Now subtract opposite hemispheres in $\pm z$

Look at correlations in $\Delta\phi$ in different η regions



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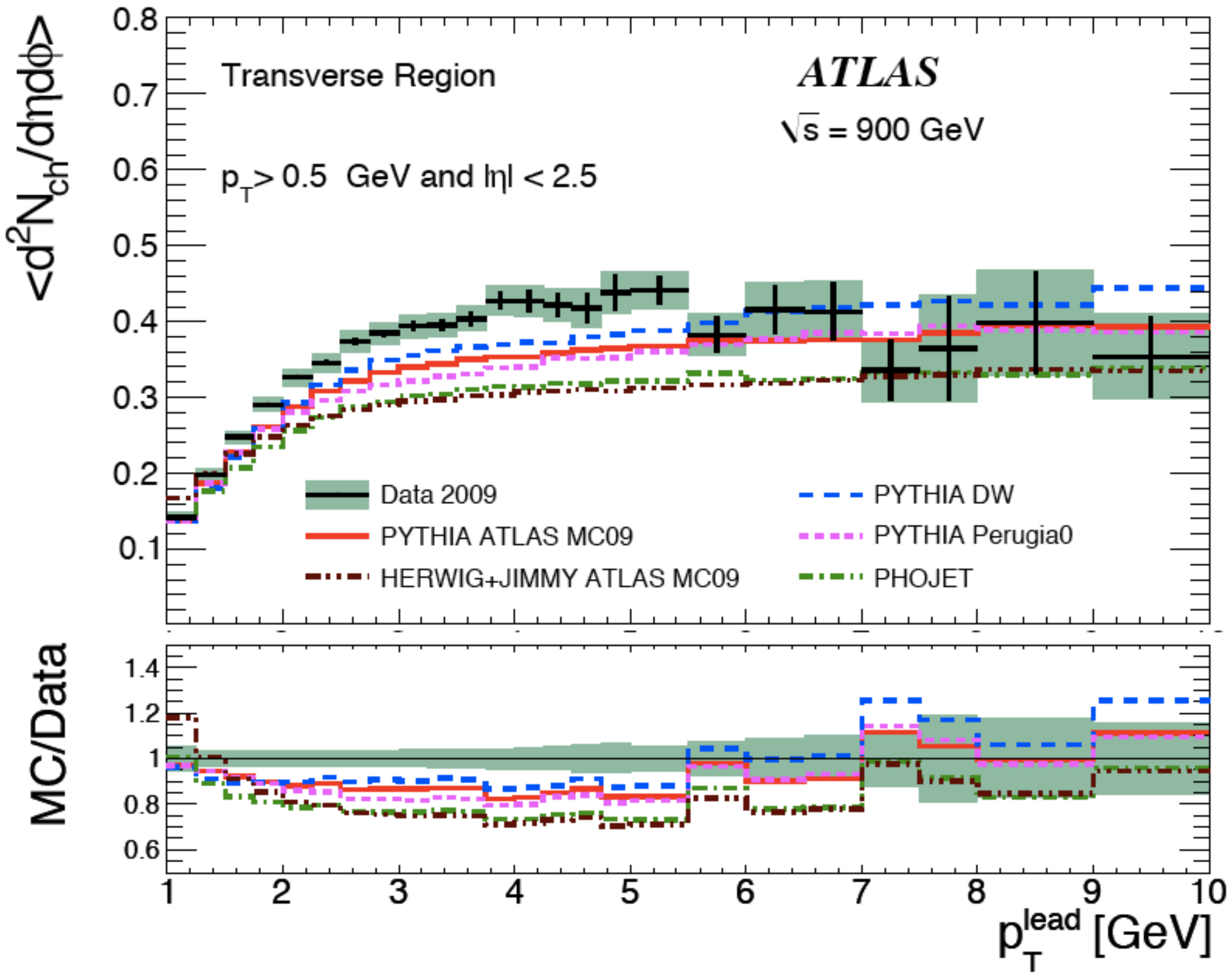
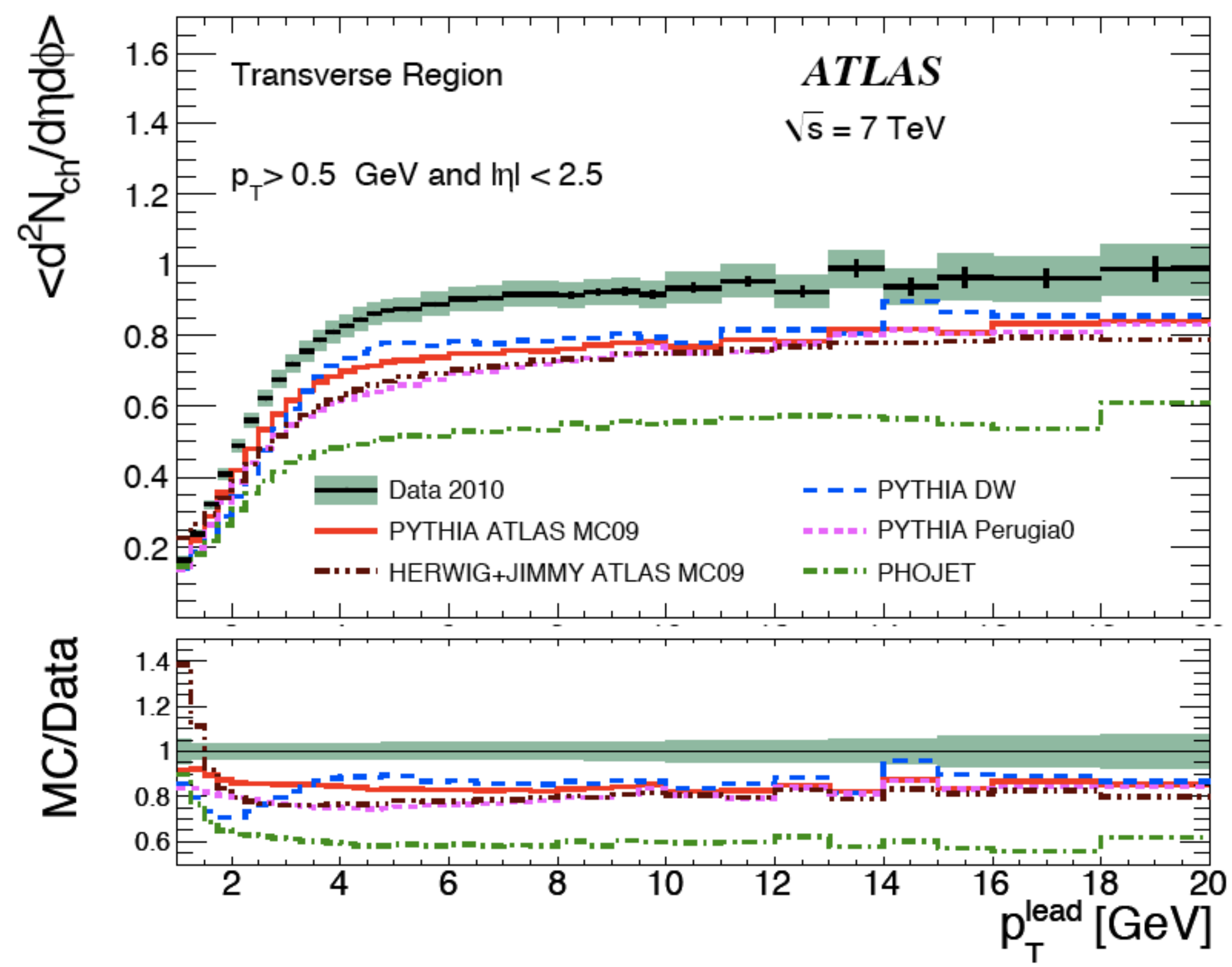
Summary

- Minimum bias proton-proton collision data taken by the ATLAS detector at three centre of mass energies, $\sqrt{s}$=0.9, 2.36 and 7 TeV have been analysed
- Measurements sensitive to the effects of soft QCD and the Underlying Event have been compared to the various models, in diffraction restricted and enhanced phase space
- Diffraction:
    - Pythia describes the rate, Phojet describes the physics
- Non-diffractive and Underlying Event measurements:
    - The data have been used to tune the MC models, providing Pythia tune AMBT1
- Overall, the AMBT1 tune describes the ATLAS higher p_T (> 500 MeV) data well
- When compared to lower p_T (> 100 MeV) data, the tune fails
- Higher precision data covering a larger phase space have now been analysed
- Stay tuned for further developments!

Backup slides

New Underlying event data with p_T>500 MeV





- Measurements sensitive to the Underlying Event show clear differences to the models
- These more precise Underlying event data will be used to constrain future tunes