Inclusive Two-Particle Angular Correlations in ATLAS

Cristina Oropeza Barrera, University of Glasgow
On behalf of the ATLAS Collaboration

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- Description of the analysis:
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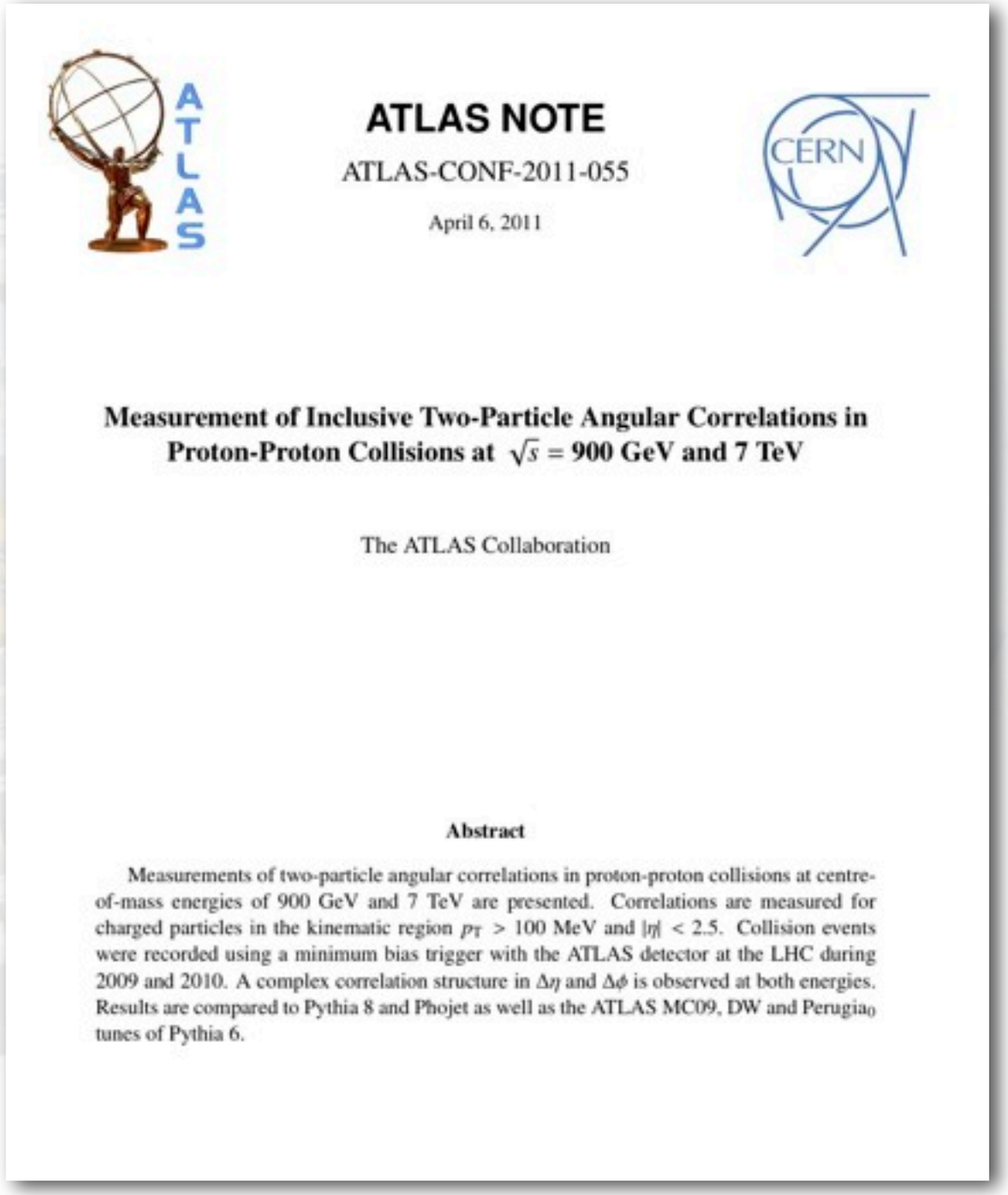


ATLAS NOTE

ATLAS-CONF-2011-055

April 6, 2011

Measurement of Inclusive Two-Particle Angular Correlations in Proton-Proton Collisions at $\sqrt{s}$ = 900 GeV and 7 TeV

The ATLAS Collaboration

Abstract

Measurements of two-particle angular correlations in proton-proton collisions at centre-of-mass energies of 900 GeV and 7 TeV are presented. Correlations are measured for charged particles in the kinematic region $p_T > 100$ MeV and $|\eta| < 2.5$. Collision events were recorded using a minimum bias trigger with the ATLAS detector at the LHC during 2009 and 2010. A complex correlation structure in $\Delta\eta$ and $\Delta\phi$ is observed at both energies. Results are compared to Pythia 8 and Phojet as well as the ATLAS MC09, DW and Perugia$_0$ tunes of Pythia 6.

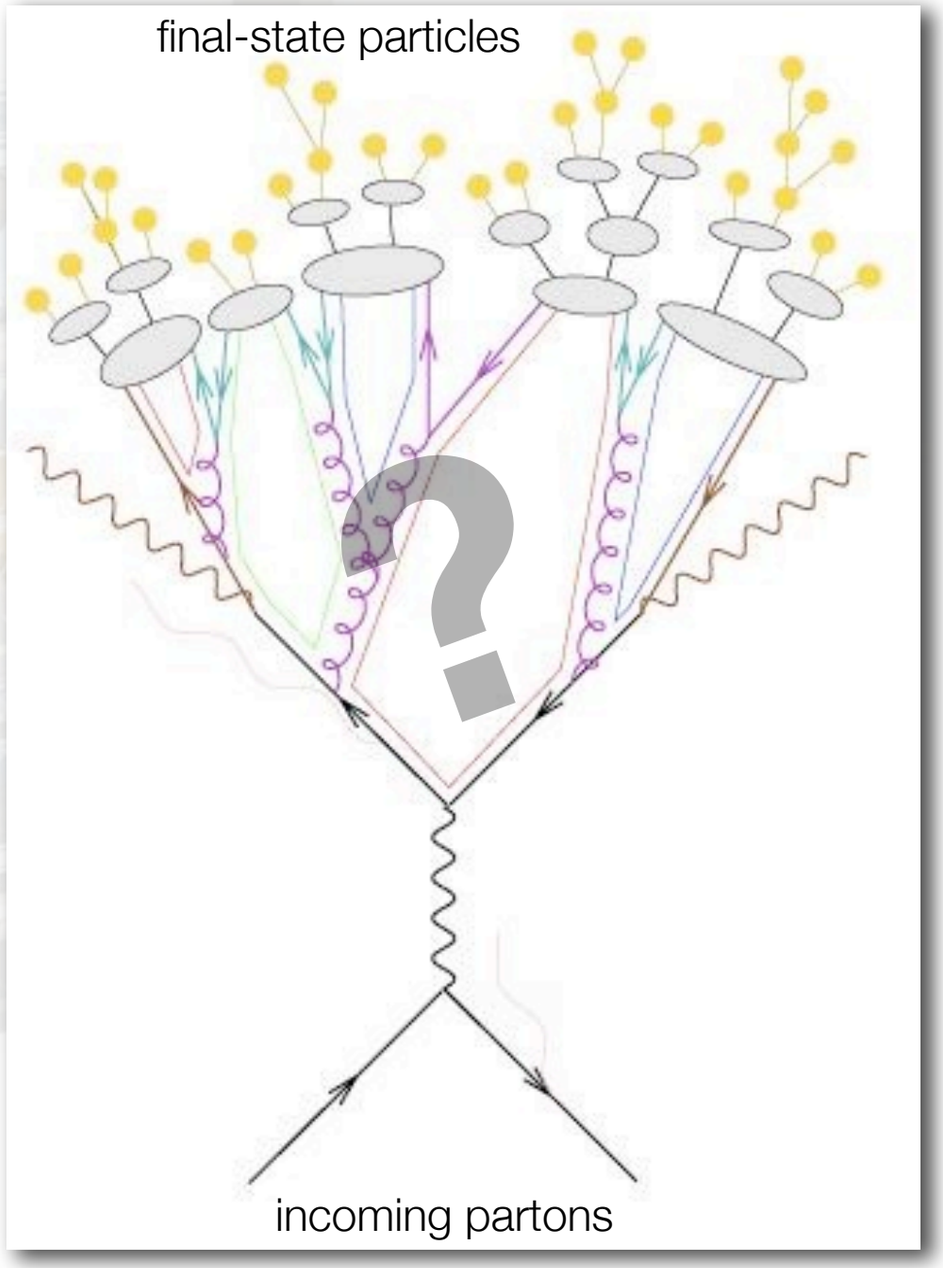
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-055/

Motivation

- Models to describe dynamics of multi-particle production are incomplete: limited explanation of emission of soft radiation.

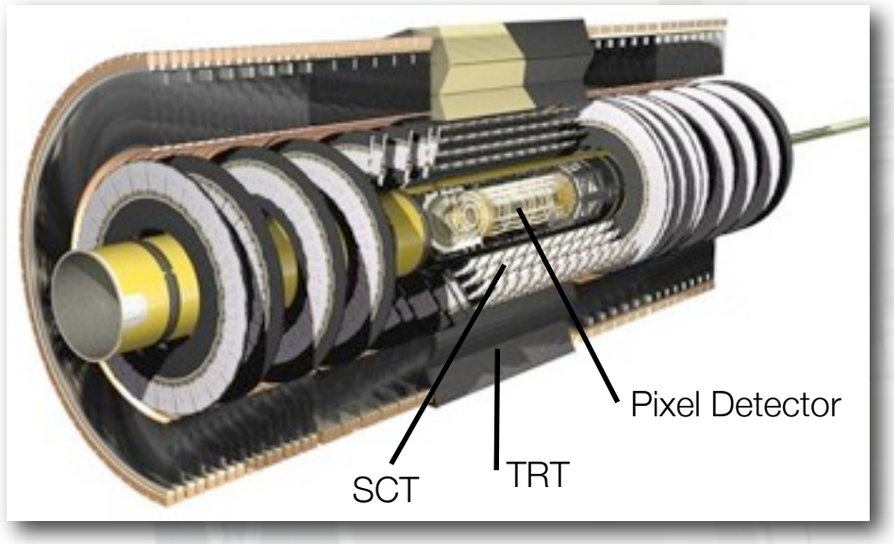
- Study of correlations between final state particles allows us to investigate the underlying mechanisms of particle production at LHC energies.

- Identify important dynamical information that can be incorporated in models to gain a better and more global picture (tuning).



Data Samples and Event Selection

The data samples used in this analysis:



Energy	Integrated Luminosity
900 GeV	7 μb^{-1}
7 TeV	190 μb^{-1}

Limited dataset, low luminosity, low pile-up

Event Requirements

- ATLAS Inner Detector fully operational and solenoid at 2T,
- triggered by a single-arm, level 1 Minimum Bias Trigger Scintillator,
- at least one primary vertex,
- if there is a second vertex it should not be associated to more than four tracks (to remove events with more than one interaction per bunch crossing),
- to contain at least two tracks in the phase-space:
  - $p_T > 100$ MeV
  - $|\eta| < 2.5$

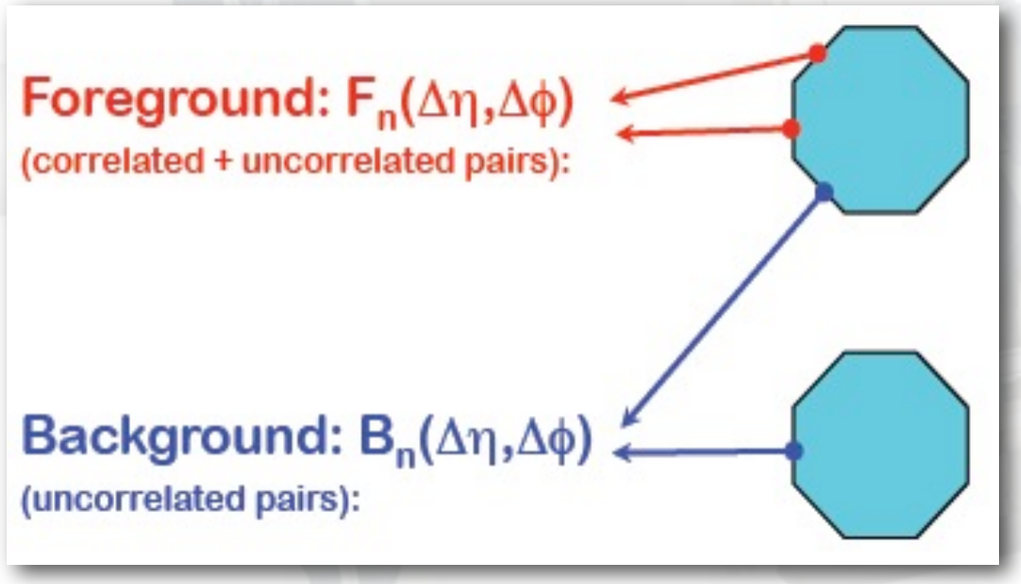
Same as minimum bias analysis

Analysis Overview

The inclusive two-particle angular correlation function is given by:

$$R(\Delta\eta, \Delta\phi) = \frac{\langle (N_{ch} - 1)\, F(N_{ch}, \Delta\eta, \Delta\phi) \rangle_{ch}}{B(\Delta\eta, \Delta\phi)} - \langle N_{ch} - 1 \rangle_{ch}$$

where $\langle ... \rangle_{ch}$ indicates an average over contributions from all particle multiplicities.



Correlations between emissions in a single event. Normalised by the total number of events.

Distribution of uncorrelated pairs. Particles pairs made from independent events. Normalised by its integral.

N_{ch} is the average particle multiplicity.

Correction Procedure

To account for inefficiencies in the vertex and trigger selection, the foreground and multiplicity distributions were weighted event-by-event with:

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

The effect of tracking inefficiencies is corrected for using a data-driven method.

Find all good tracks

→

Calculate the observable:
R(**Δη**,**Δϕ**) or R(**Δη**) or R(**Δϕ**)

→

Determine the tracking efficiency $E(p_T,\eta)$ for each track.

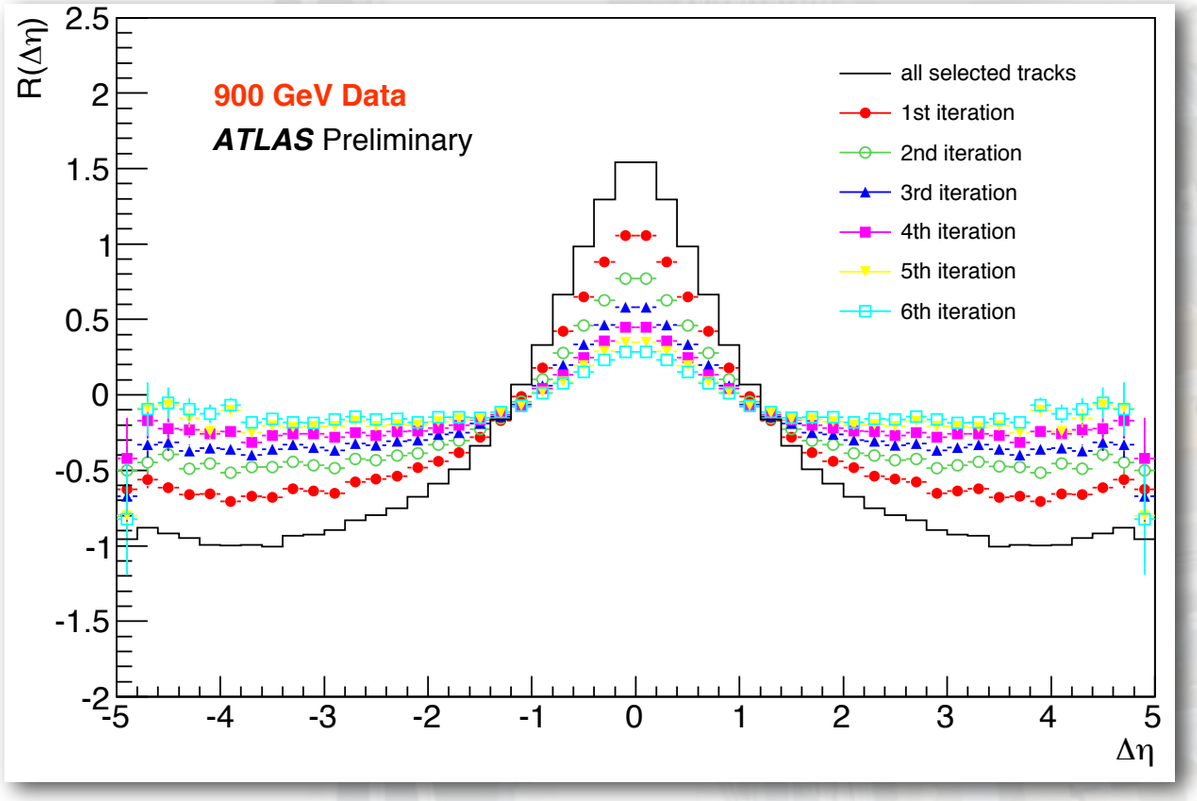
→

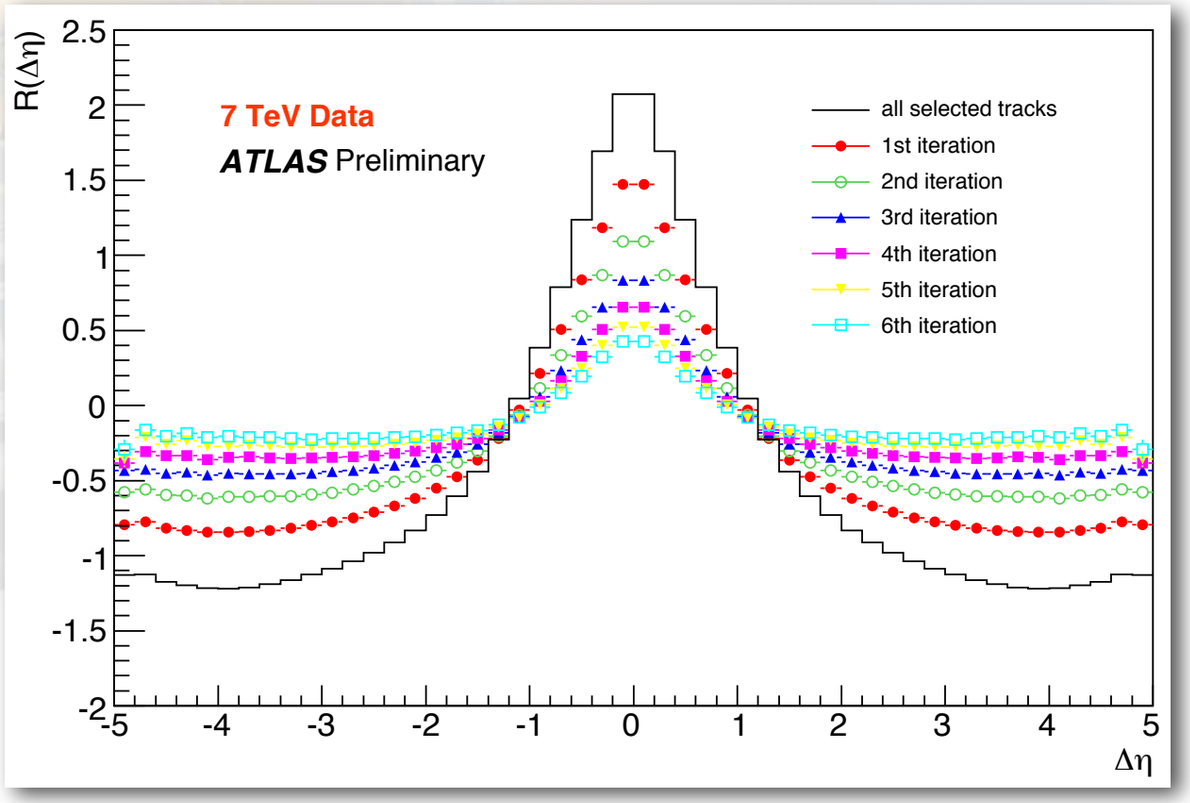
Generate a random number *r* and compare it to $E(p_T,\eta)$.
If $r > E(p_T,\eta)$, **remove** the track.

→

Correction Procedure

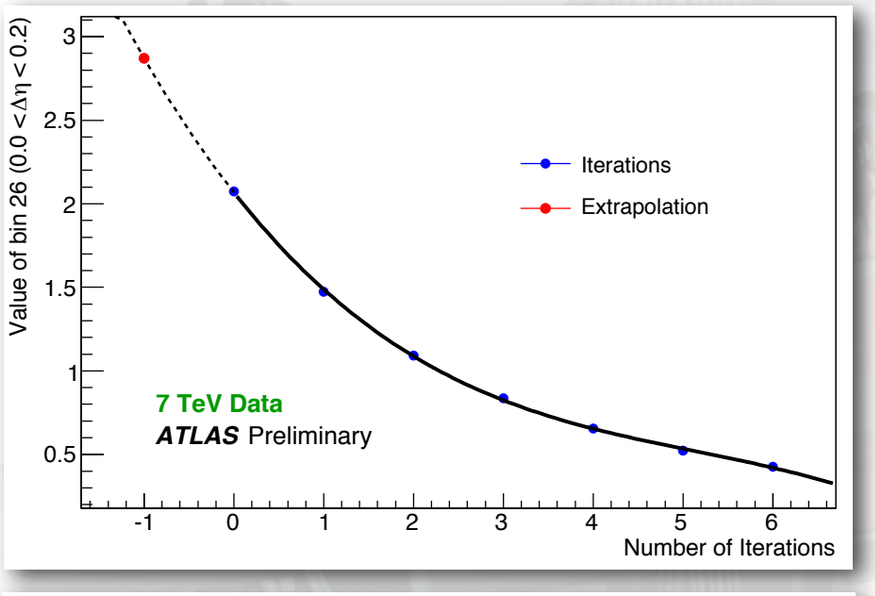
Each iteration corresponds to an additional application of the detector effect on the data.
The -1 iteration corresponds to the observable when no detector effects are present.

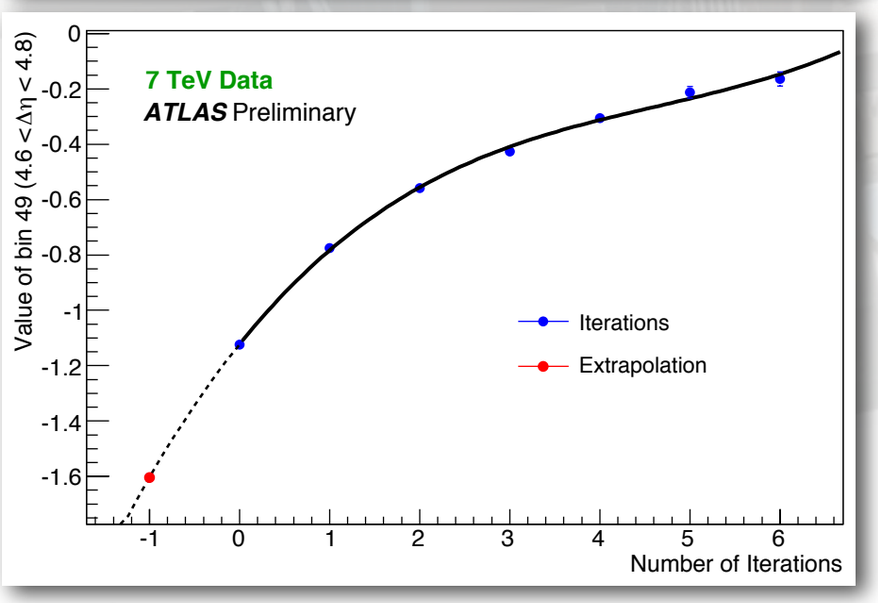




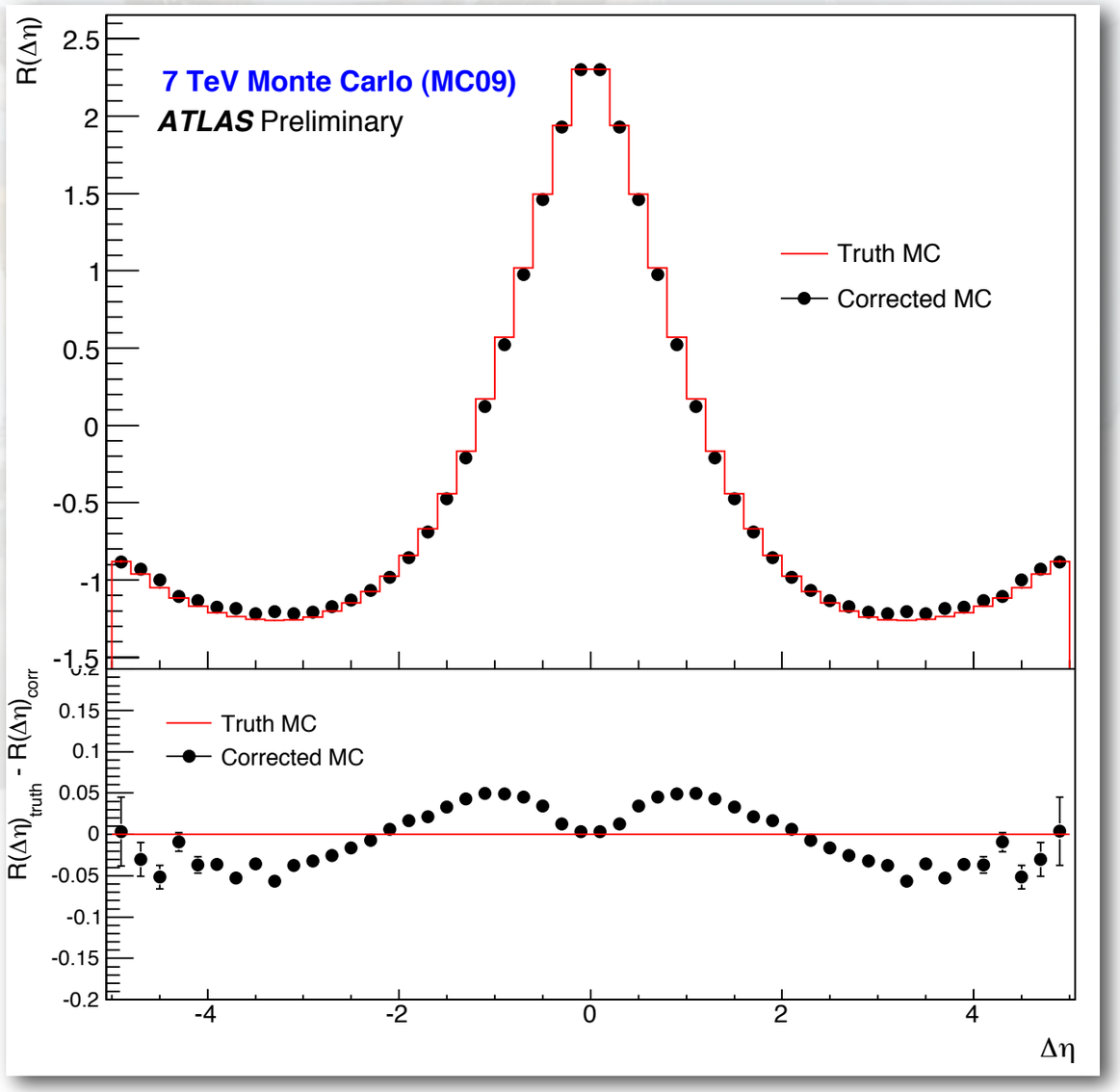
Correction Procedure

The value of (each bin of) the observable is plotted as a function of the iteration number (0, 1, ..., N) and fitted using a third-degree polynomial. By extrapolating this fit to -1, an estimate of the true value can be made.





Testing method in Monte Carlo:



Statistical and Systematic Uncertainties

I. Extrapolation to N=-1

The statistical error in the corrected value will be the result of propagating the statistical uncertainties in the parameters of the fit.

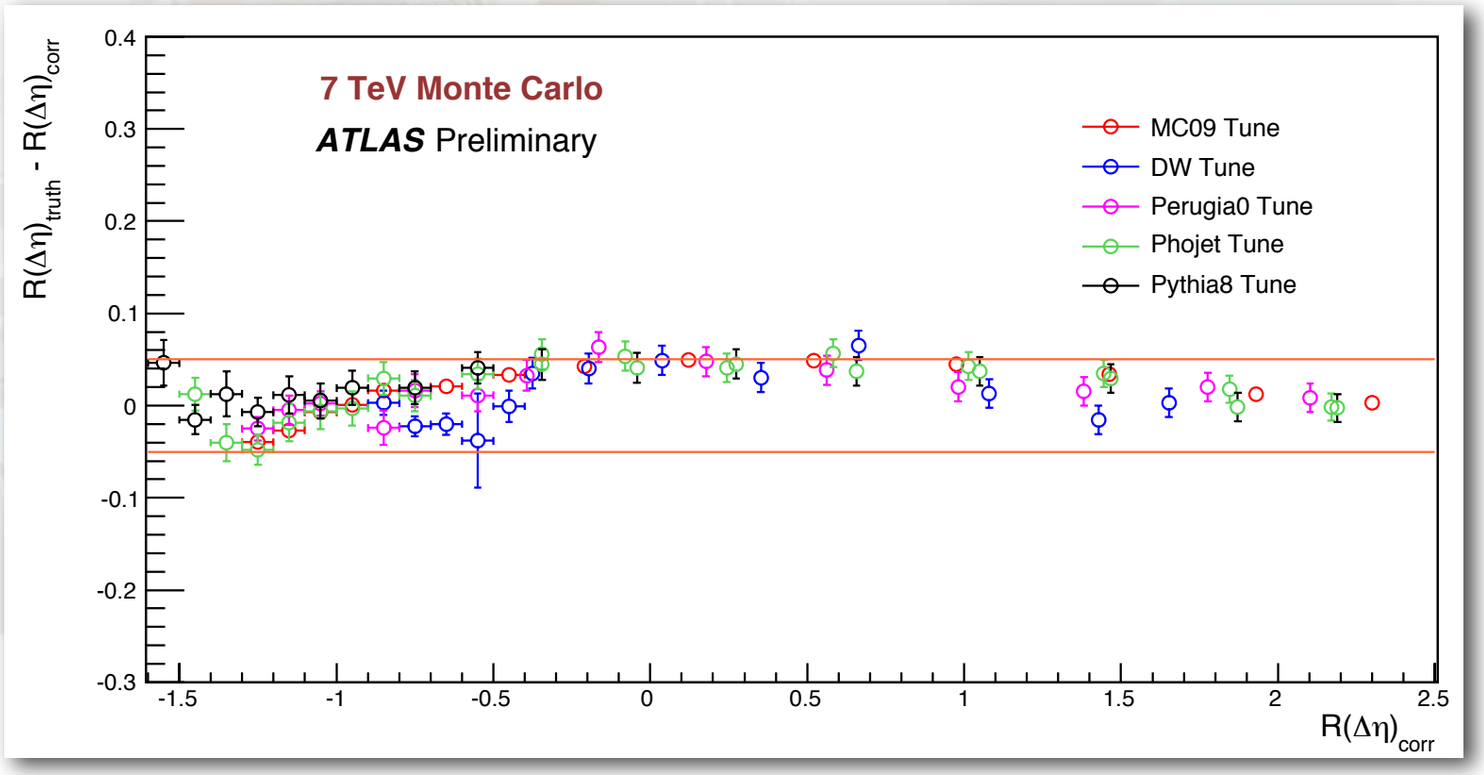
II. Uncertainties on the Efficiencies

Determined by varying the efficiencies up or down and propagating through the analysis.

III. Non-closure in Monte Carlo

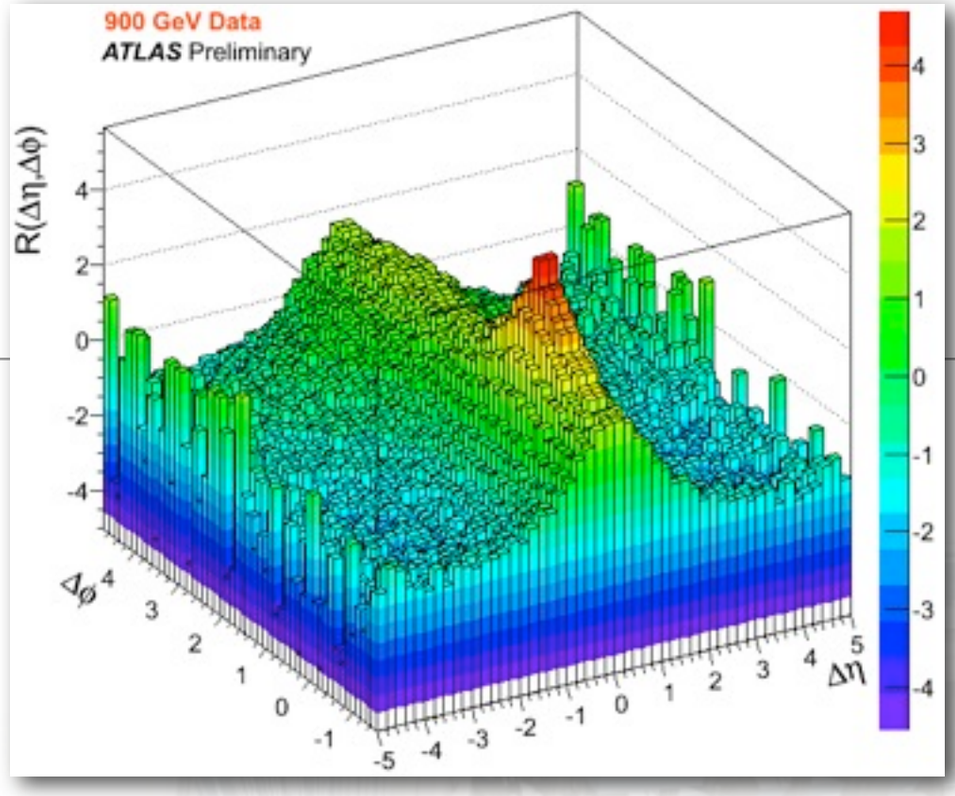
MC studies on the absolute difference between truth and corrected MC as a function of R_{corr} in different models.

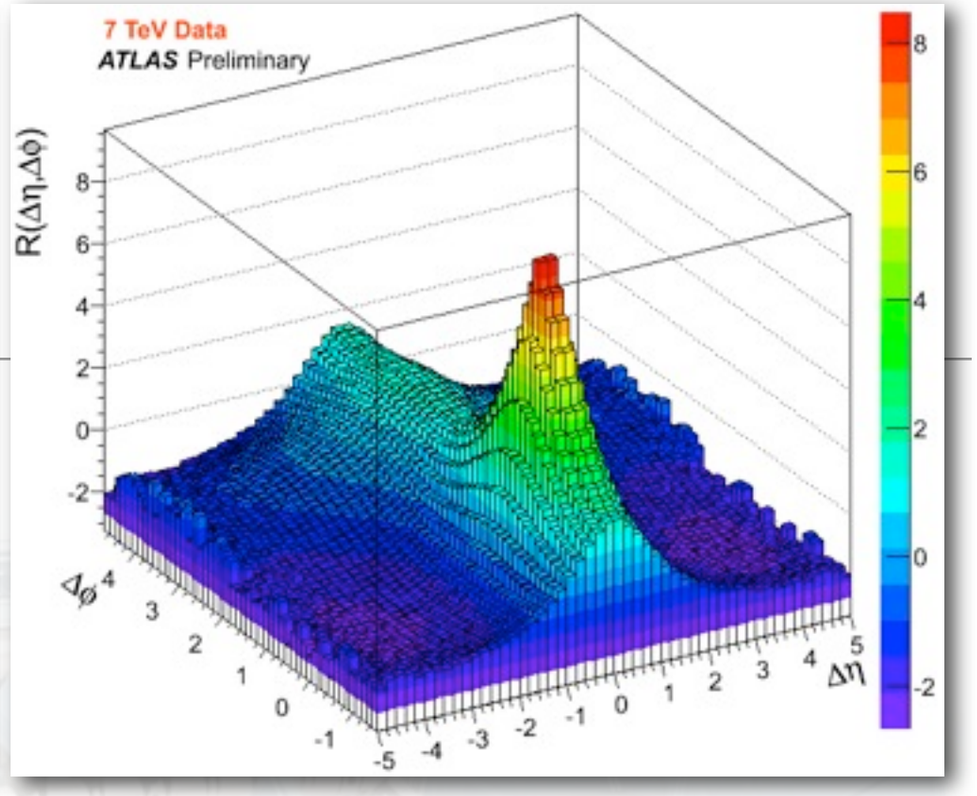
An absolute uncertainty of 0.05 is assigned to all bins of R in data.

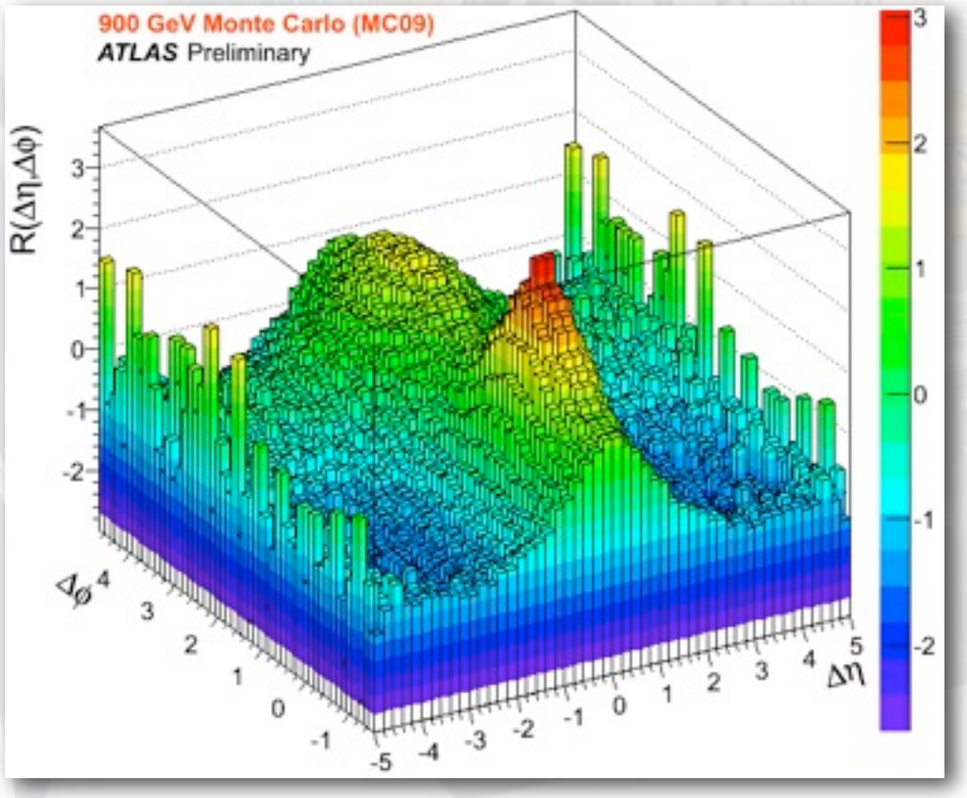


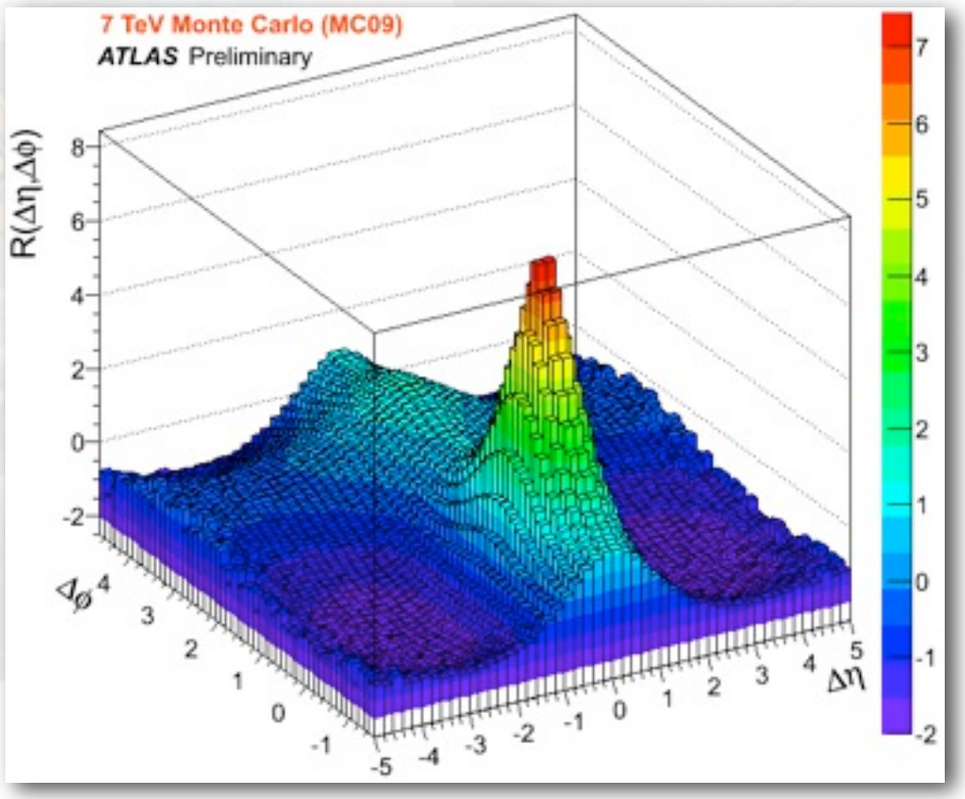
Results

$R(\Delta\eta,\Delta\phi)$









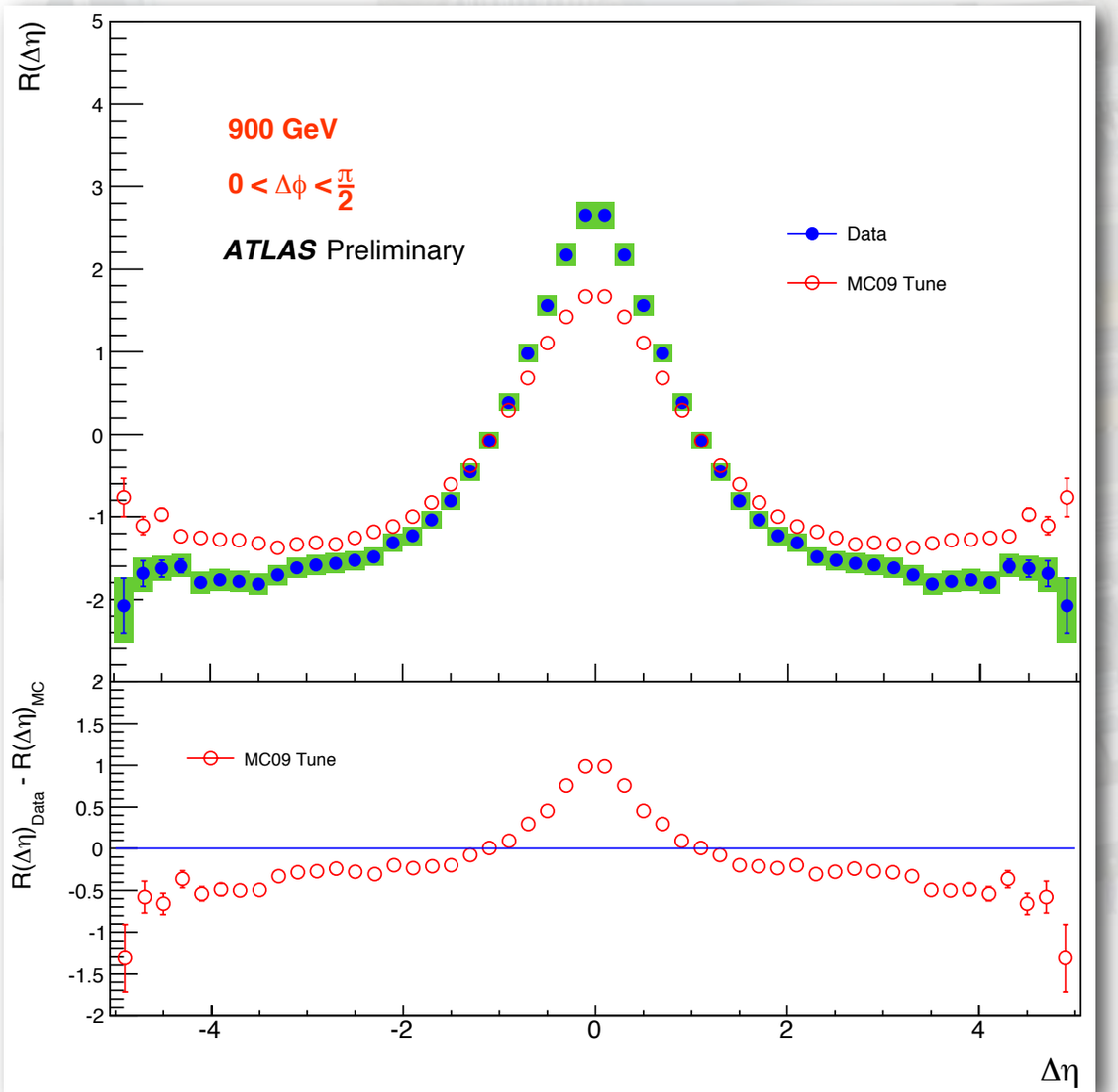
Corrected inclusive two-particle correlation functions in $\Delta\eta$ and $\Delta\phi$. Same complex structure is seen in Monte Carlo, MC09 Tune, however the strength of the correlation seen in data is not reproduced.

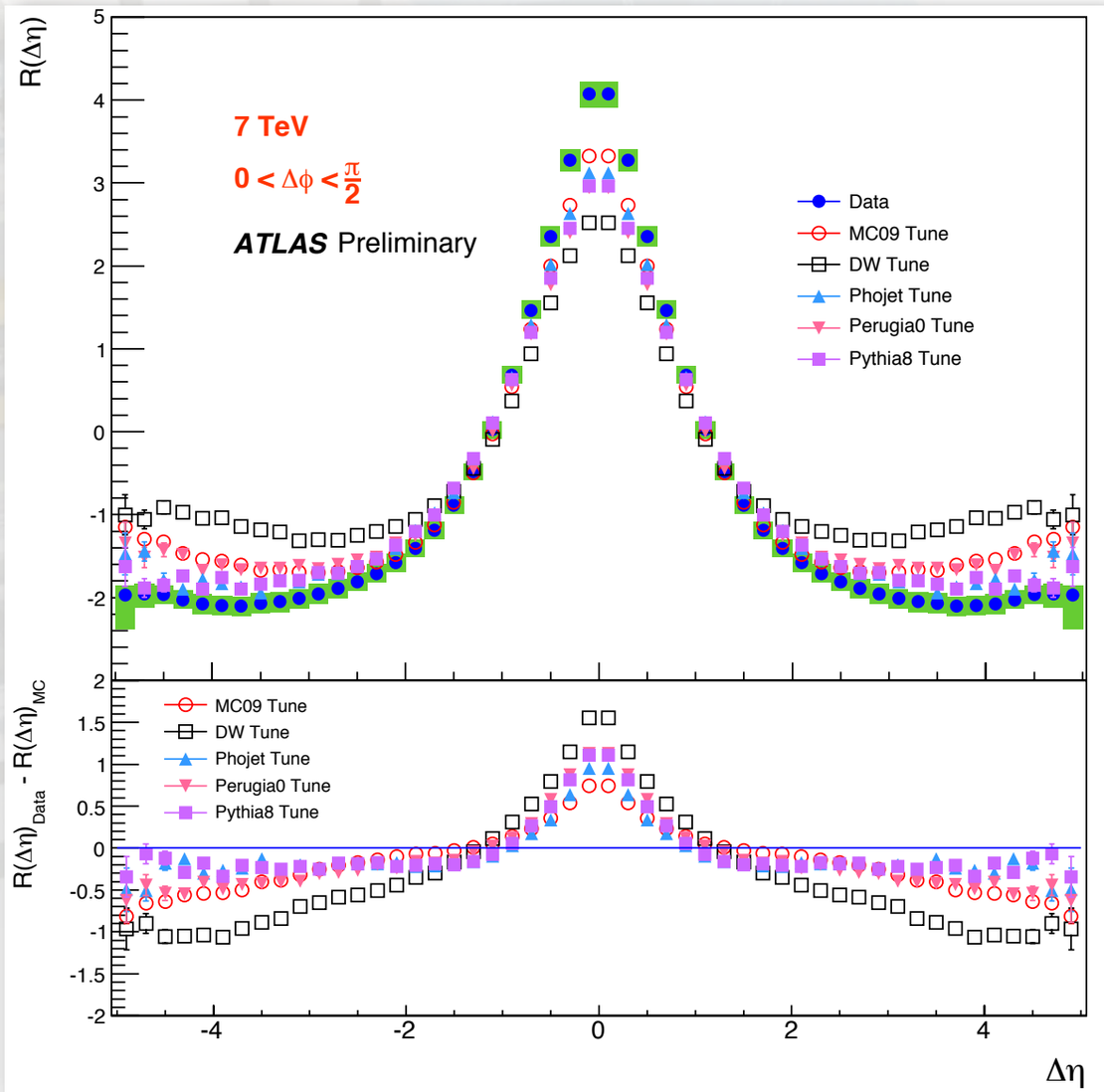
Results

Near-side correlations: integrating $0 < \Delta\phi < \pi/2$.

Dominated by the peak at (0,0). At 7 TeV, Pythia 8 and Phojet have better agreement in the tails of the distribution while MC09 is closer in the peak.

R(Δη)



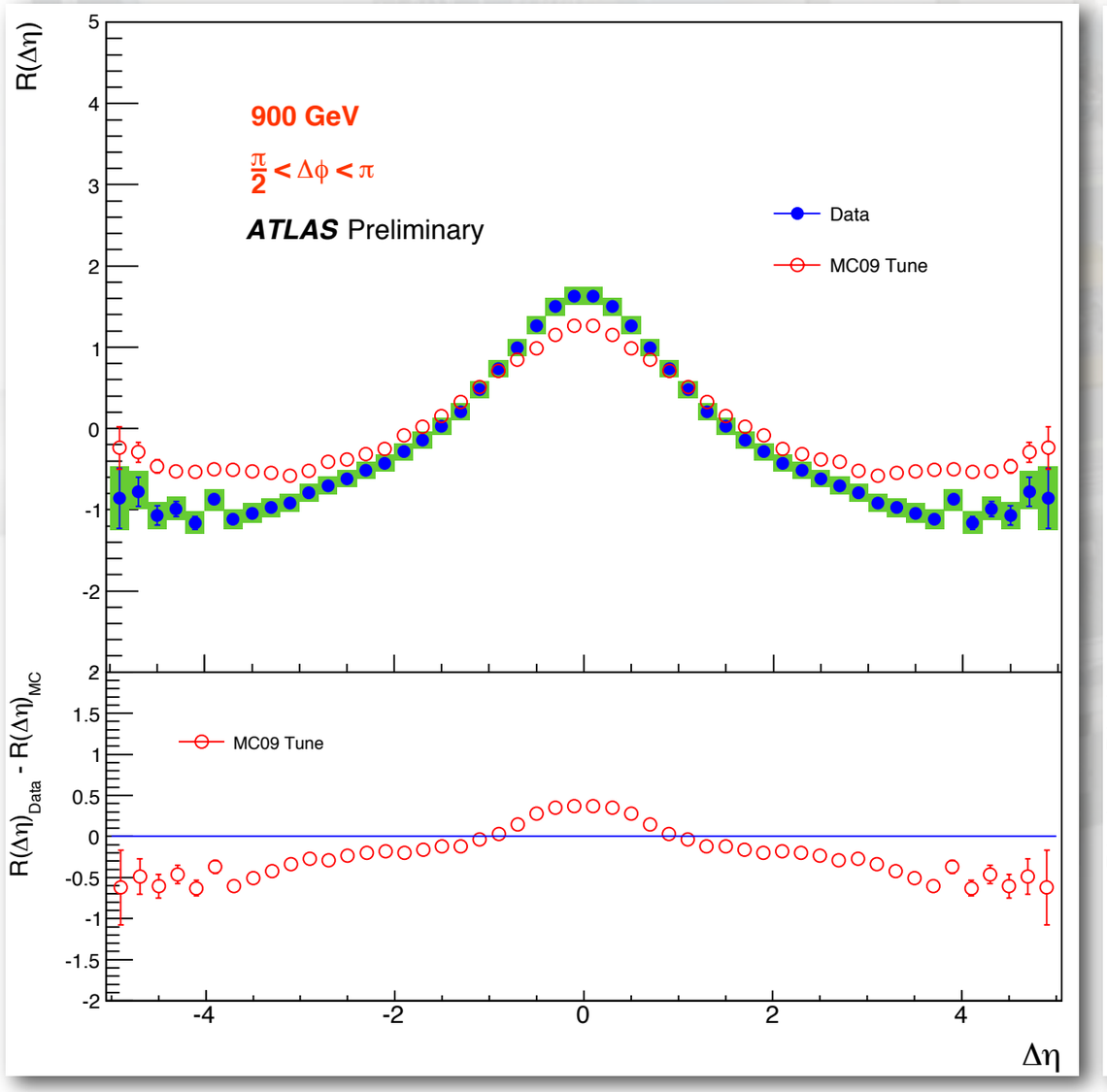


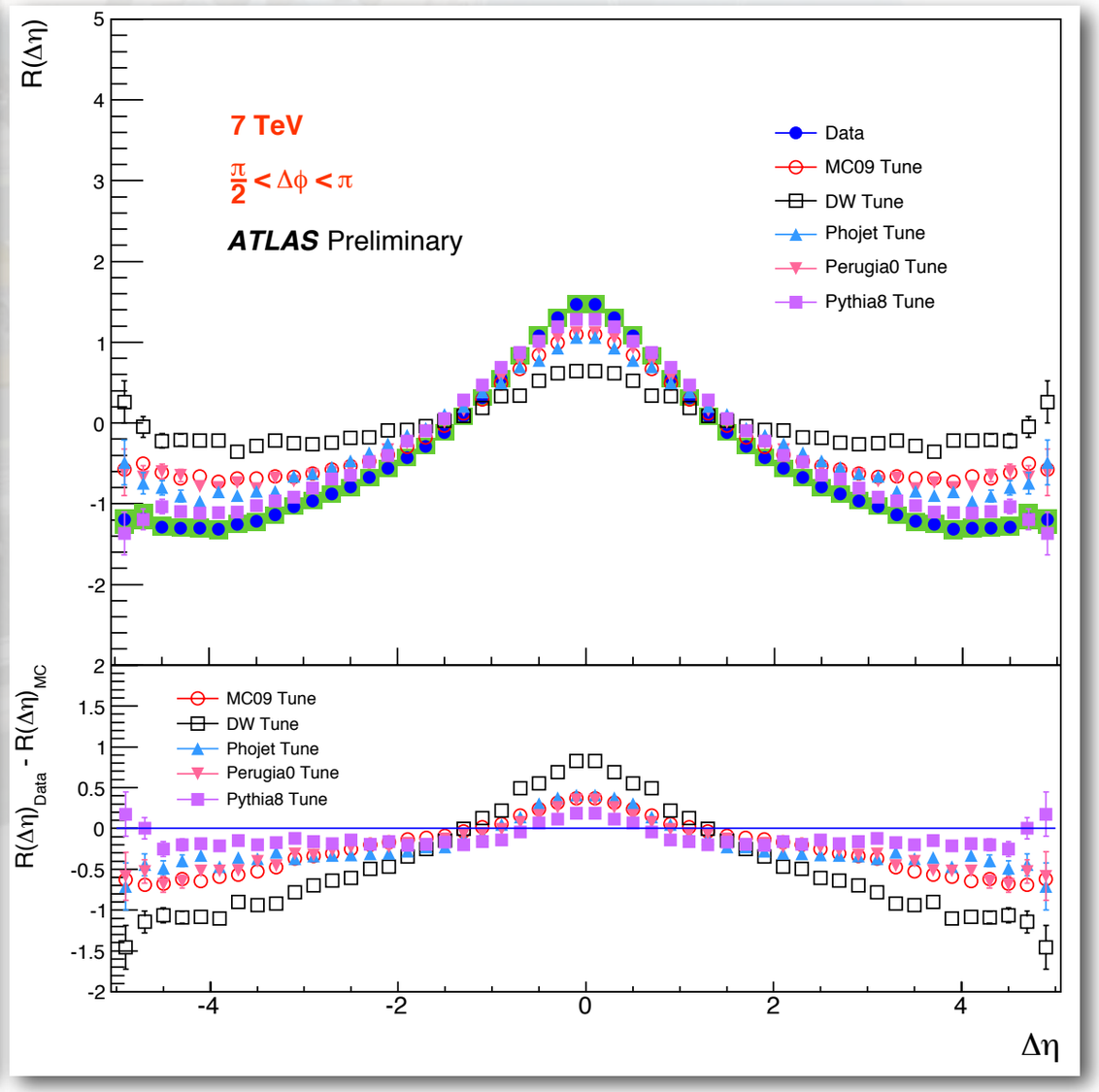
Results

Away-side correlations: integrating $\pi/2 < \Delta\phi < \pi$.

Dominated by the ridge structure around $\Delta\phi=\pi$. With the exception of DW, the tunes seem to perform better in these distributions.

R(Δη)



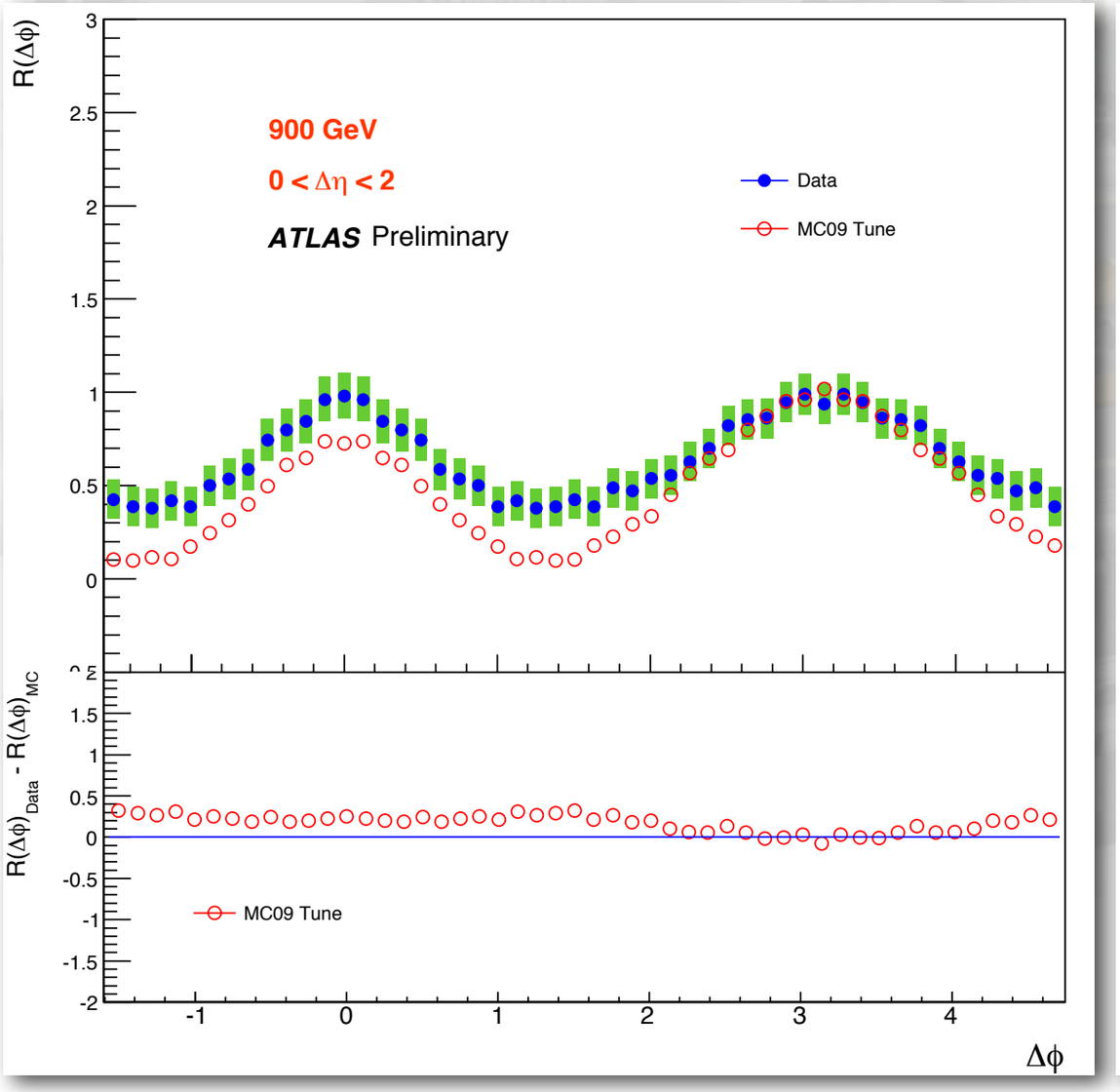


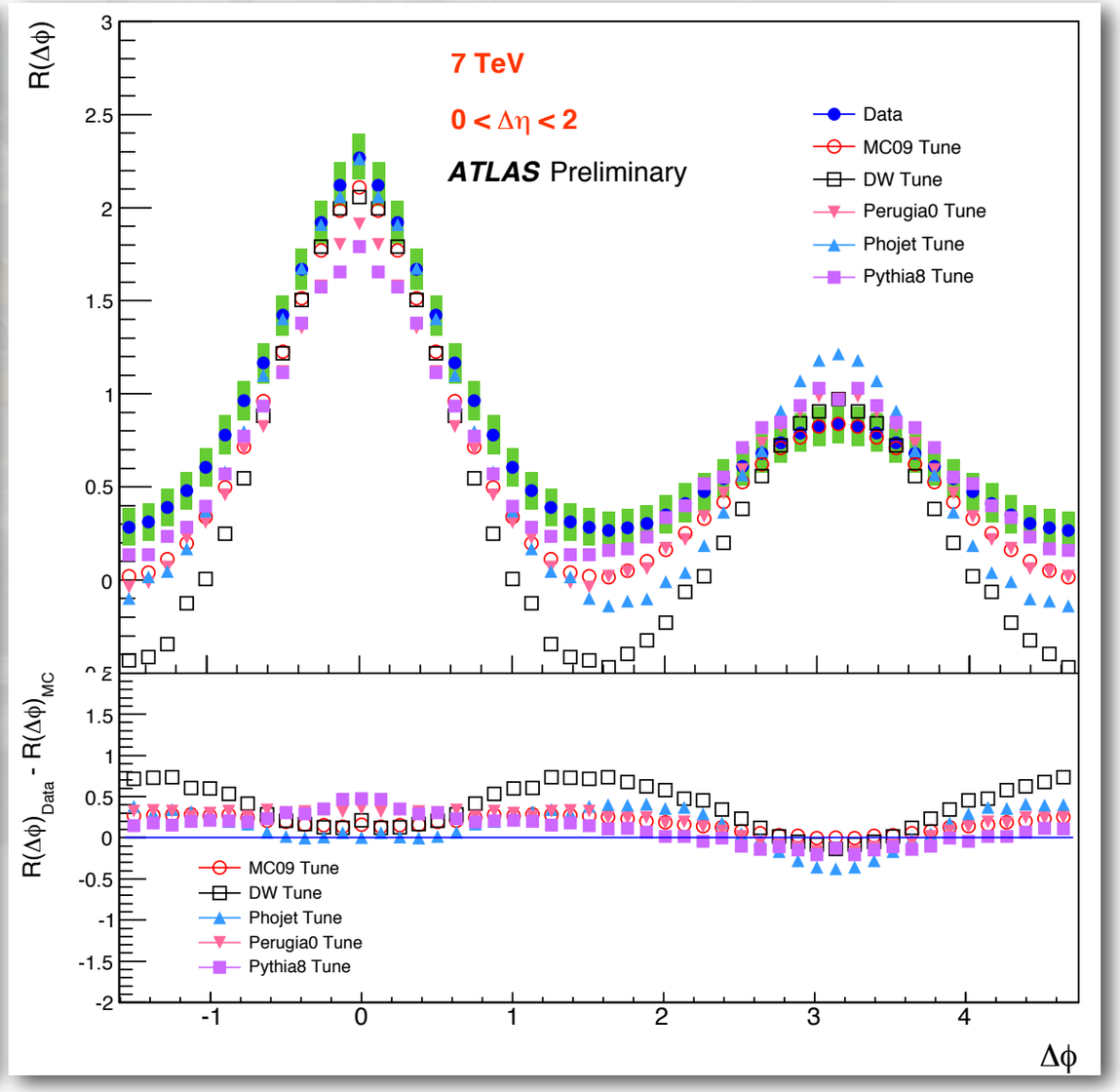
Results

Short-range correlations: integrating $0 < \Delta\eta < 2$.

Two-peak structure. Similar to underlying event distributions. Back-to-back recoil. Most of the tunes agree well with data in a small region around $\Delta\phi=\pi$.

$R(\Delta\phi)$



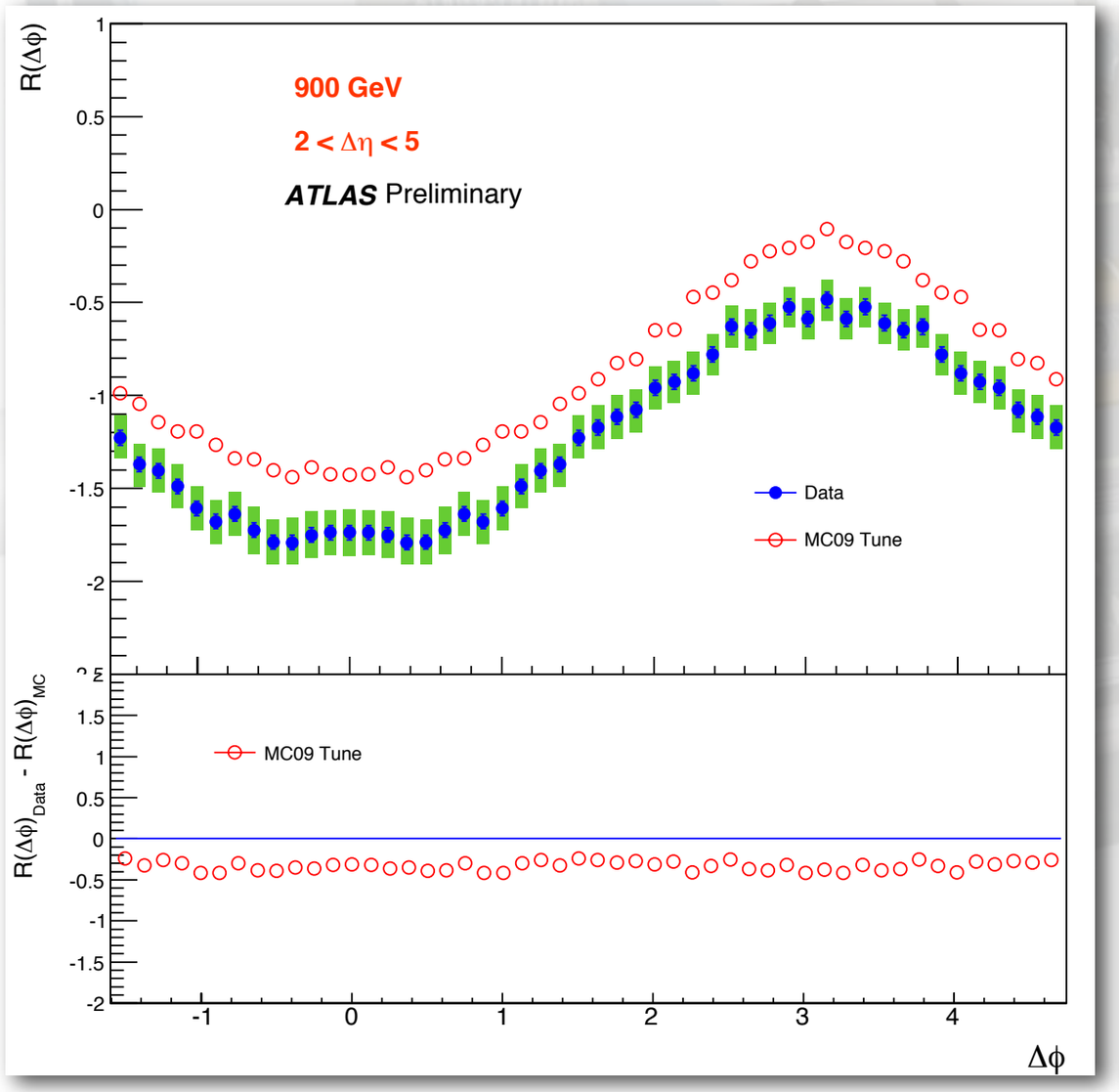


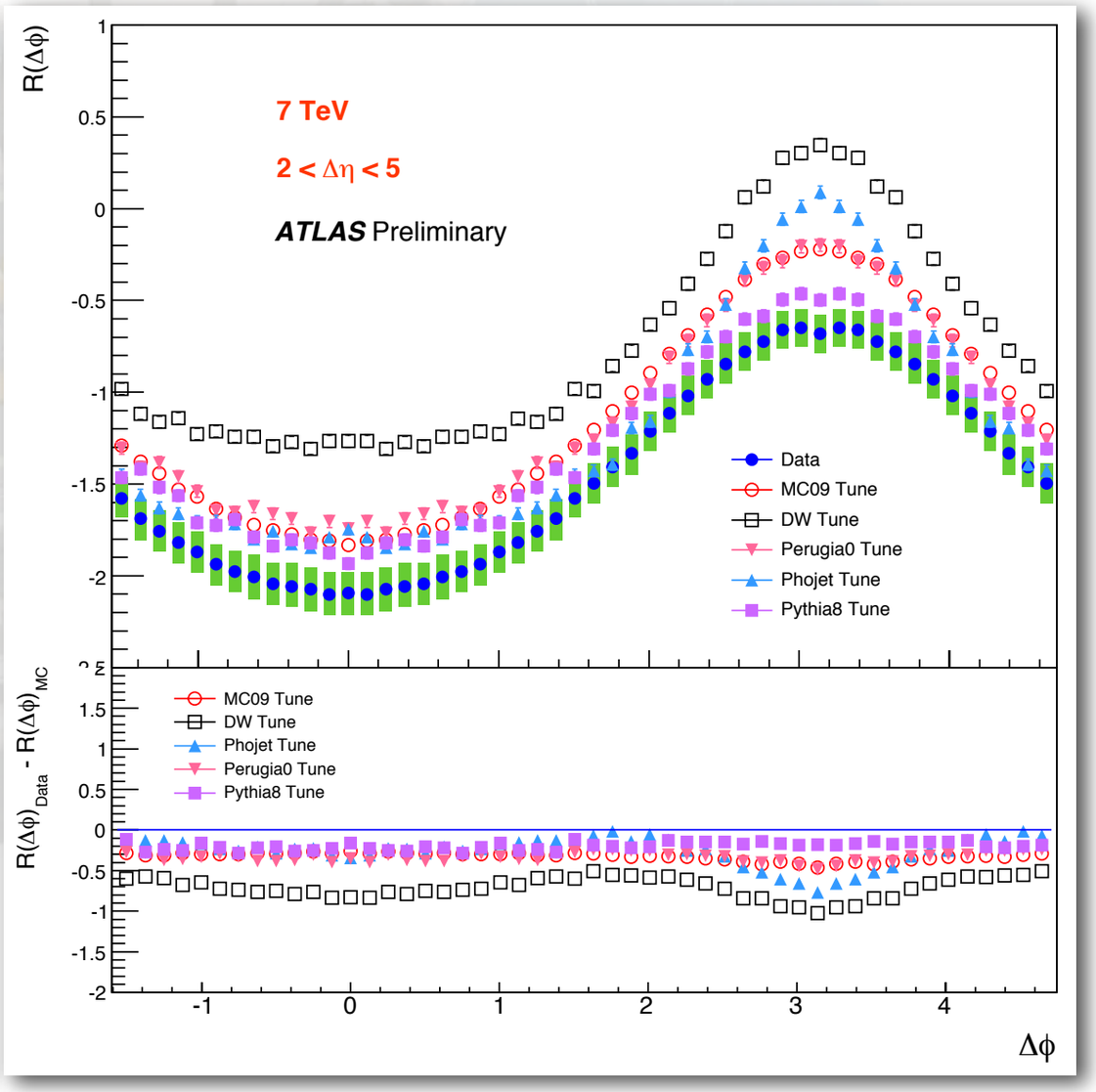
Results

Long-range correlations: integrating $2 < \Delta\eta < 5$.

Underlying structure away from the peak at (0,0). The absolute difference between data and the different models is flat across $\Delta\phi$. Pythia 8 is closest and DW (old tune) is worst.

$R(\Delta\phi)$





Summary

- The two-particle angular correlation function in $\Delta\eta$ and $\Delta\phi$ has been measured for p_T inclusive minimum bias events in pp collisions at 900 GeV and 7 TeV.

- A complex structure was observed at both energies. It was explored in more detail by projecting the two-dimensional distribution into both $\Delta\eta$ and $\Delta\phi$.

- The results have been compared to different Monte Carlo tunes: MC09, Phojet, DW, Perugia$_0$ and Pythia 8 (further information on these tunes in Extra Slides).

- None of the models reproduce the strength of the correlations seen in data. The Pythia 8 tune at 7 TeV is the closest in all distributions.

Thanks!

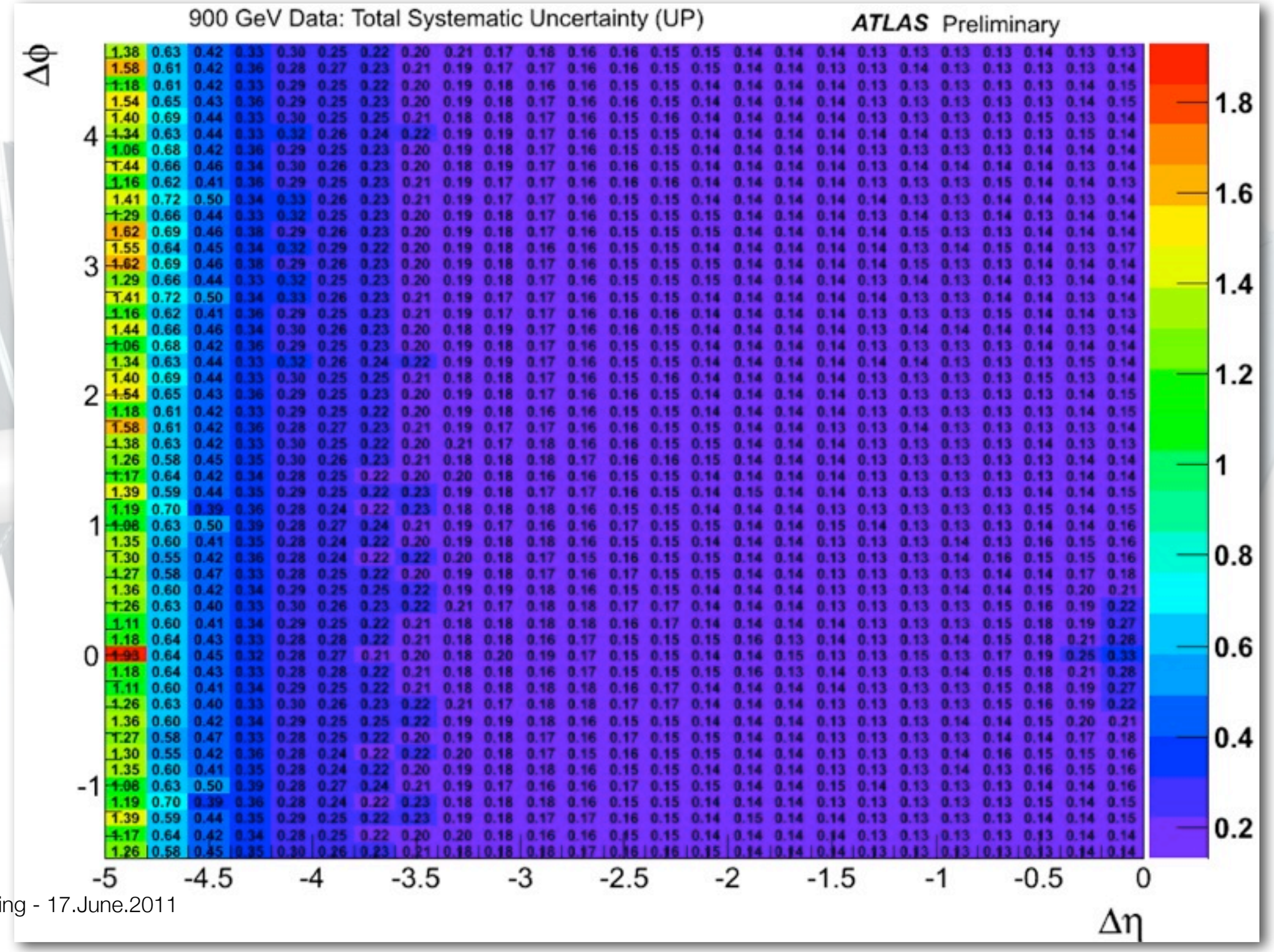
Extra Slides

Monte Carlo Models

- Pythia 6.4.21 tunes:
  - MC09: produced by the ATLAS Collaboration to describe a range of minimum bias and underlying event data from the Tevatron; uses MRST LO* PDF.
  - DW: older tune to CDF underlying event and Drell-Yan data; uses the older virtuality-ordered shower and non-interleaved MPI model.
  - Perugia$_0$: tuned to Tevatron; uses CTEQ 5L PDF and the new p_T ordered shower and the MPI is interleaved with the initial state radiation.
- Phojet 1.12.1.35: separate hard and soft diffractive contributions; not yet tuned to recent experimental data.
- Pythia 8.130: adds to the MPI model of Pythia 6 by also interleaving the final state radiation; includes an updated model for diffraction that allows harder colour singlet exchange; uses CTEQ 5L PDF.

Total Uncertainties for 2D distributions

900 GeV



Total Uncertainties for 2D distributions

7 TeV