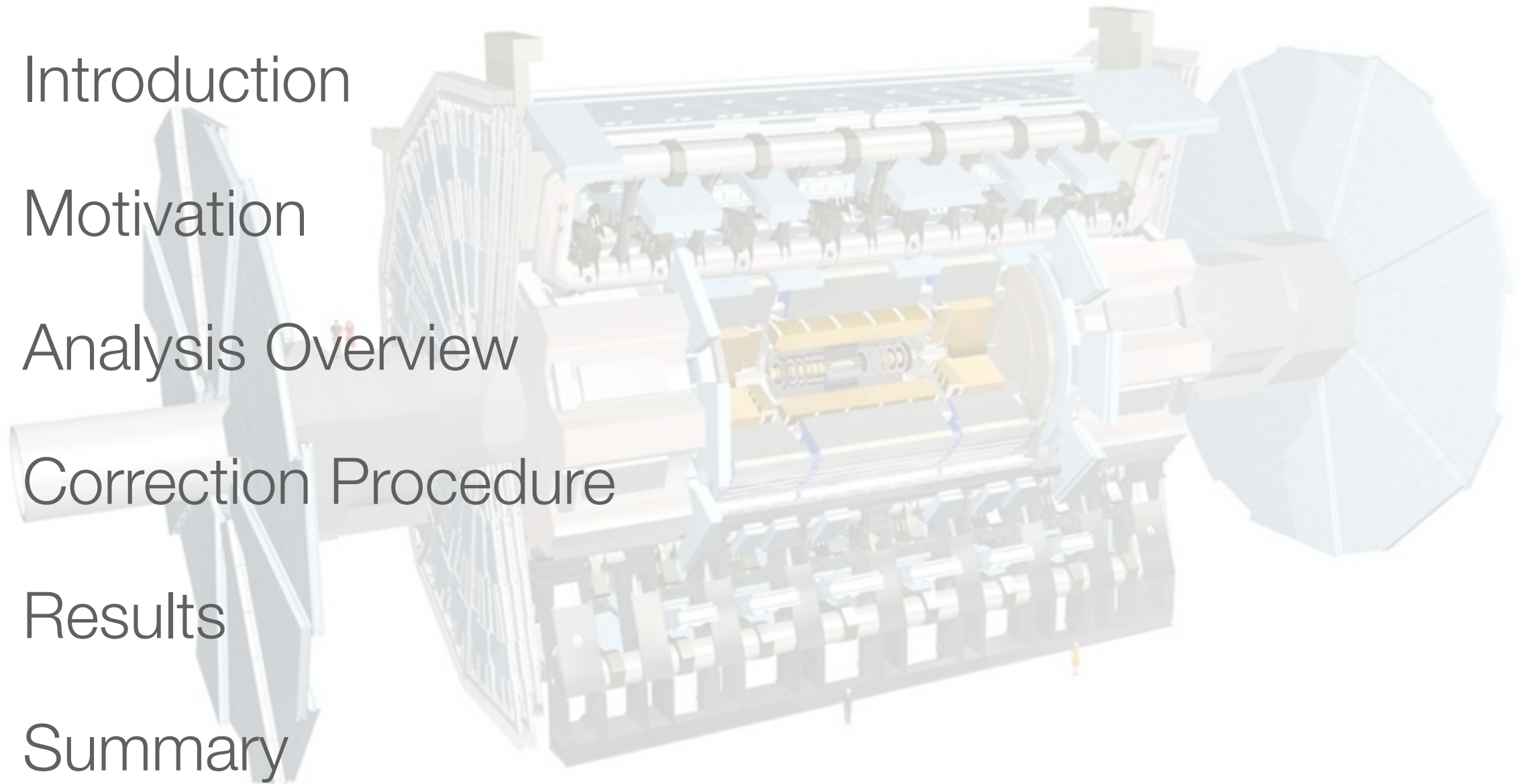# Measurement of Inclusive Two-Particle Angular Correlations in ATLAS

Cristina Oropeza Barrera
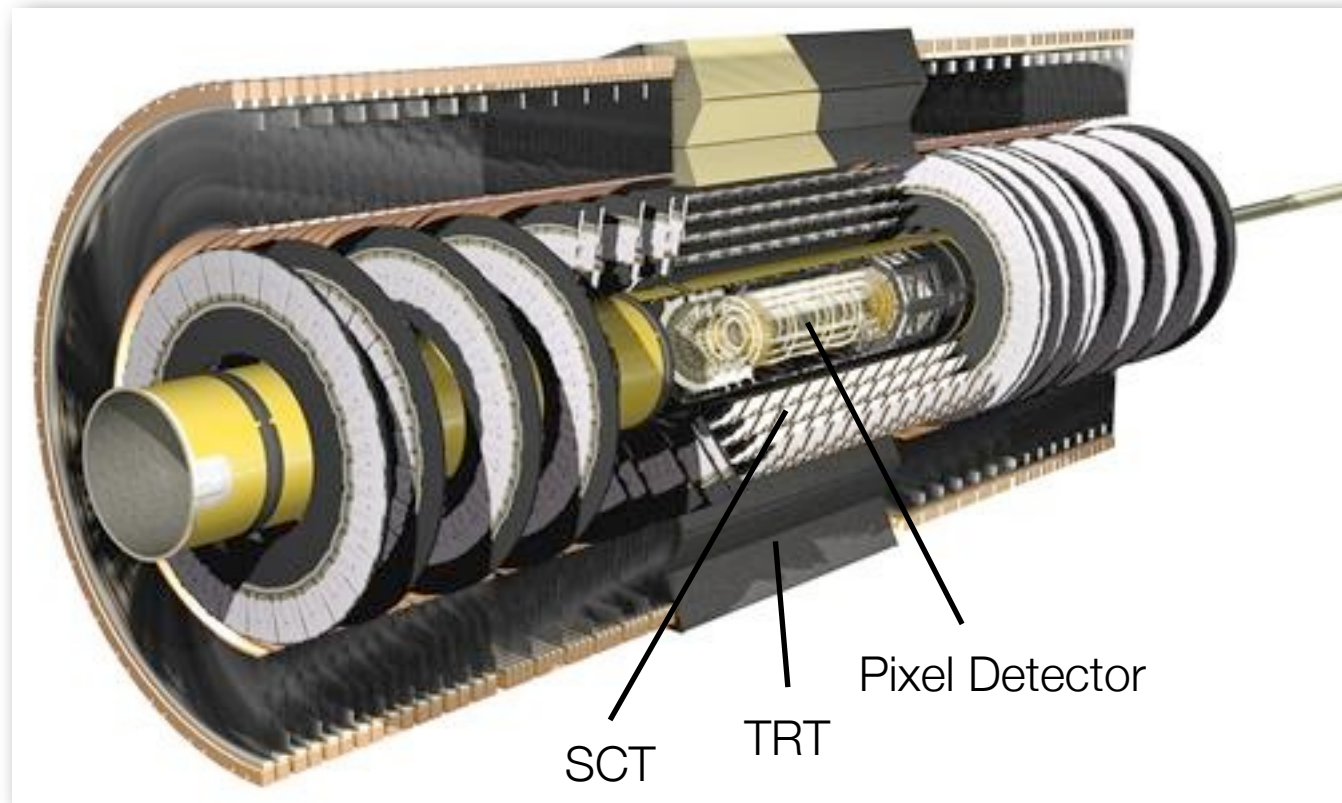
Experimental Particle Physics, School of Physics & Astronomy
University of Glasgow

Outline

- Introduction

- Motivation

- Analysis Overview

- Correction Procedure

- Results

- Summary

Introduction

SCT TRT Pixel Detector

Inner Detector - $|\eta| < 2.5$

Sub-systems:
Silicon Pixel Detector, SemiConductor Tracker (SCT) and Transition Radiation Tracker (TRT).

Purpose: primary and secondary vertex identification, accurate measurement of the momentum of particles and robust pattern recognition.

Minimum Bias Trigger Scintillator (MBTS) - $2.1 < |\eta| < 3.8$

Plastic scintillators inside the calorimeter end-caps, 3.6 m from the interaction point on each side of the detector. This is the only trigger requirement in these measurements.

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).
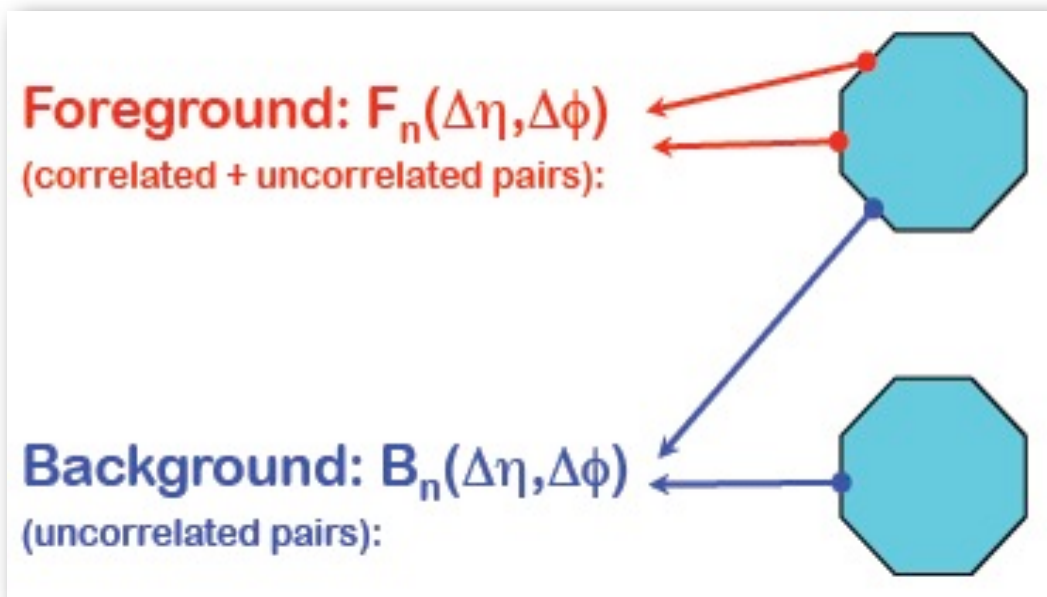

final-state particles

?

incoming partons
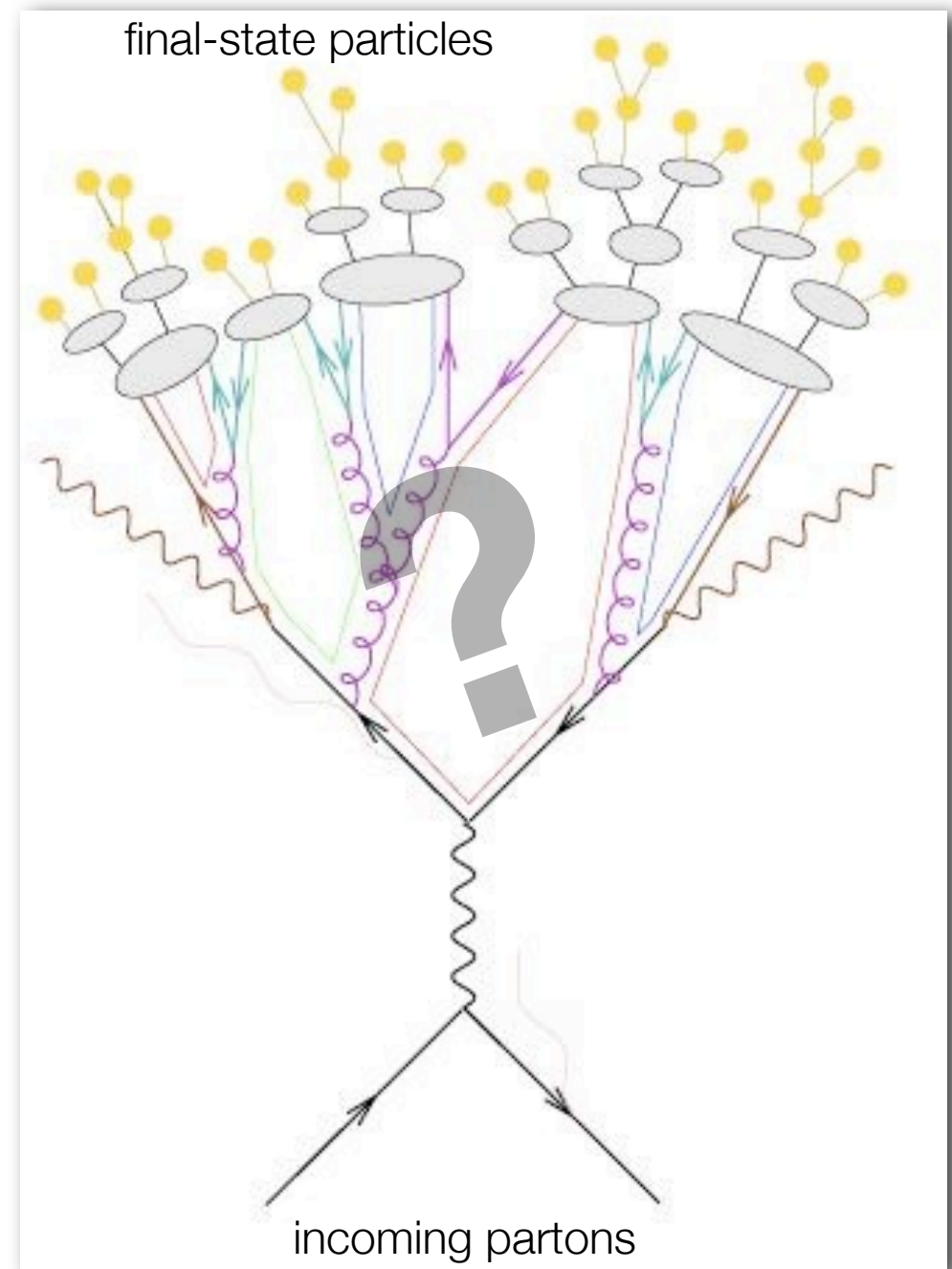
Analysis Overview

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

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

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

Foreground: $F_n(\Delta\eta,\Delta\phi)$
(correlated + uncorrelated pairs):

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

Background: $B_n(\Delta\eta,\Delta\phi)$
(uncorrelated pairs):

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

N_{ch} is the average track multiplicity.

Analysis Overview

To explore in more detail the structure of the correlation function, we will also look at its projections in both Δη and Δφ.

These projections are obtained by first integrating the foreground and the background two-dimensional distributions separately and then taking the ratio of the two and normalising by the average track multiplicity:

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

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

Data Samples and Event Selection

Events where the ID was fully operational, and the solenoid magnetic field was on, were required:

- to have been triggered by the single-arm, level 1 Minimum Bias Trigger Scintillators,
- to contain at least one primary vertex,
- to not have a second vertex associated to more than four tracks (to remove events with more than one interaction per bunch crossing),
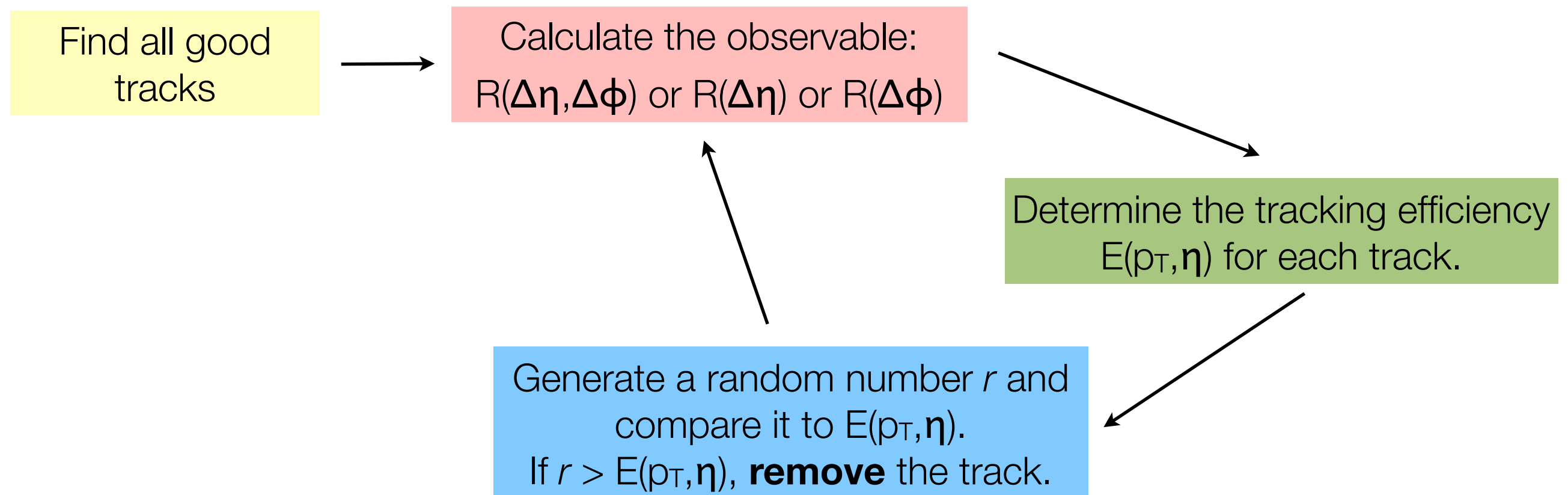- to contain at least two tracks in the phase-space:
  - $p_T > 100$ MeV
  - $|\eta| < 2.5$

$\sqrt{s}$	Events	Tracks
900 GeV	357,523	4,532,663
7 TeV	10,066,072	209,809,430

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

Determine the tracking efficiency E(p_T,η) for each track.

Generate a random number r and compare it to E(p_T,η).
If $r >$ E(p_T,η), **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.

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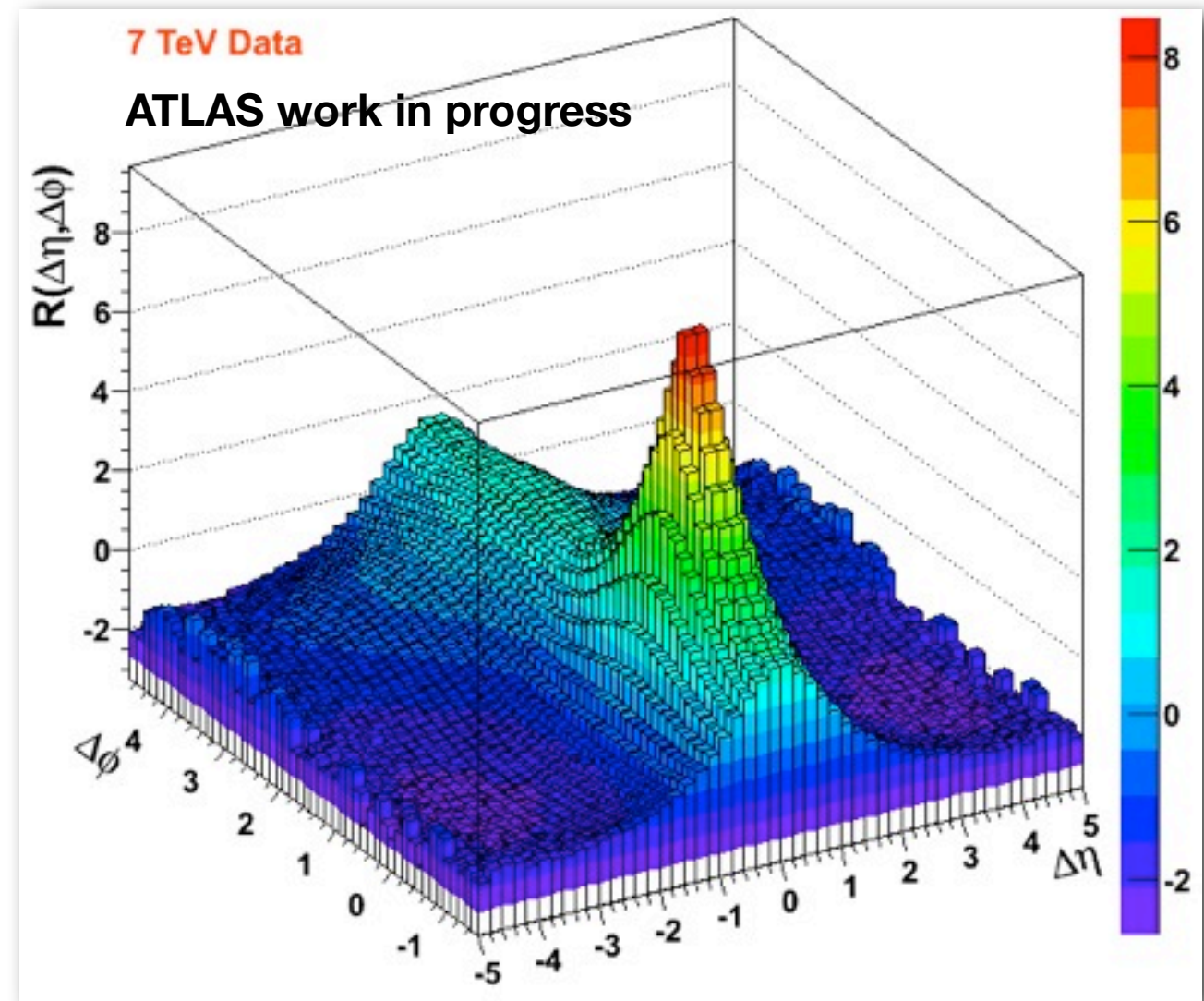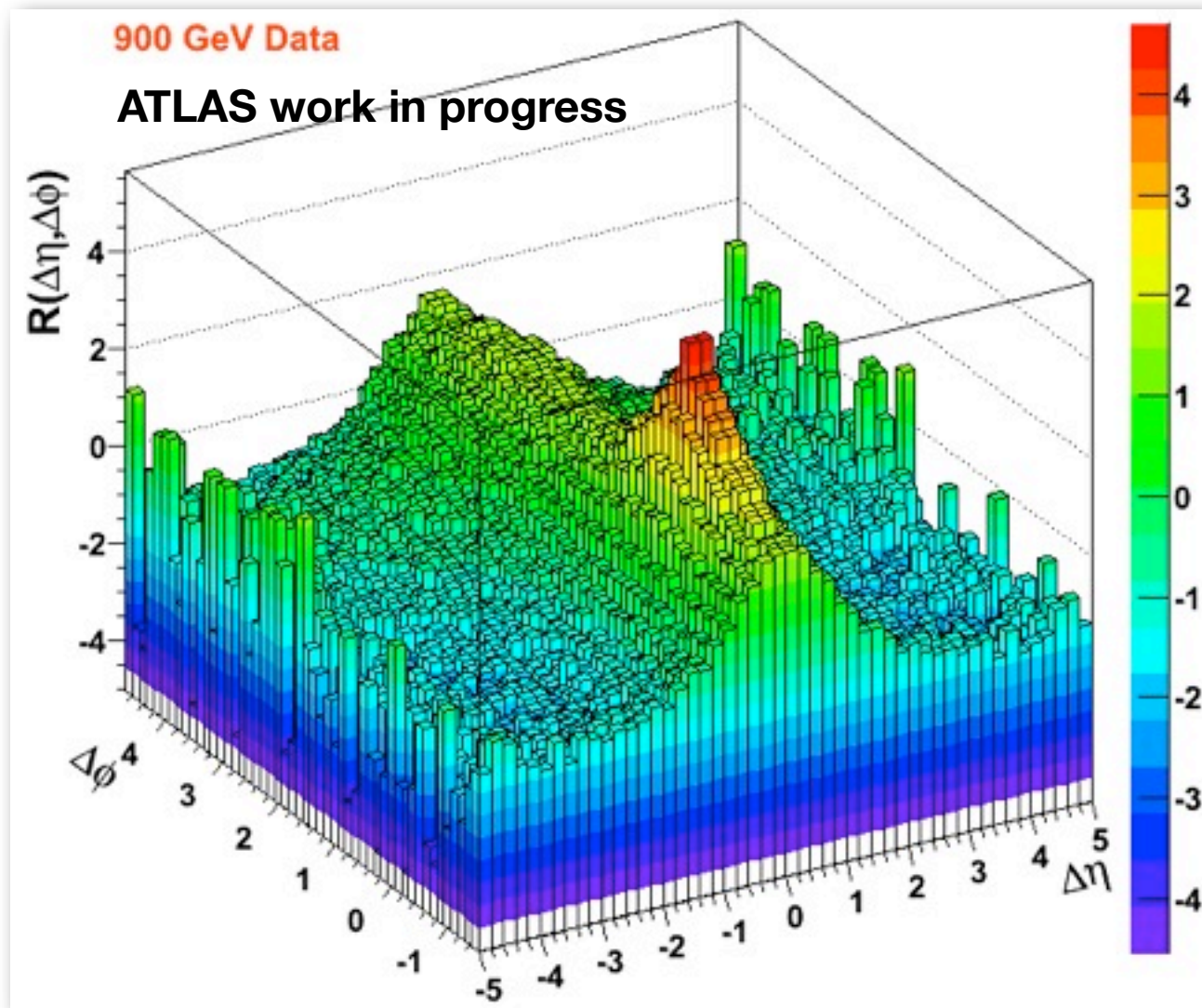By extrapolating this fit to -1, an estimate of the true value can be made.

Testing the method in R($\Delta\eta$) in MC
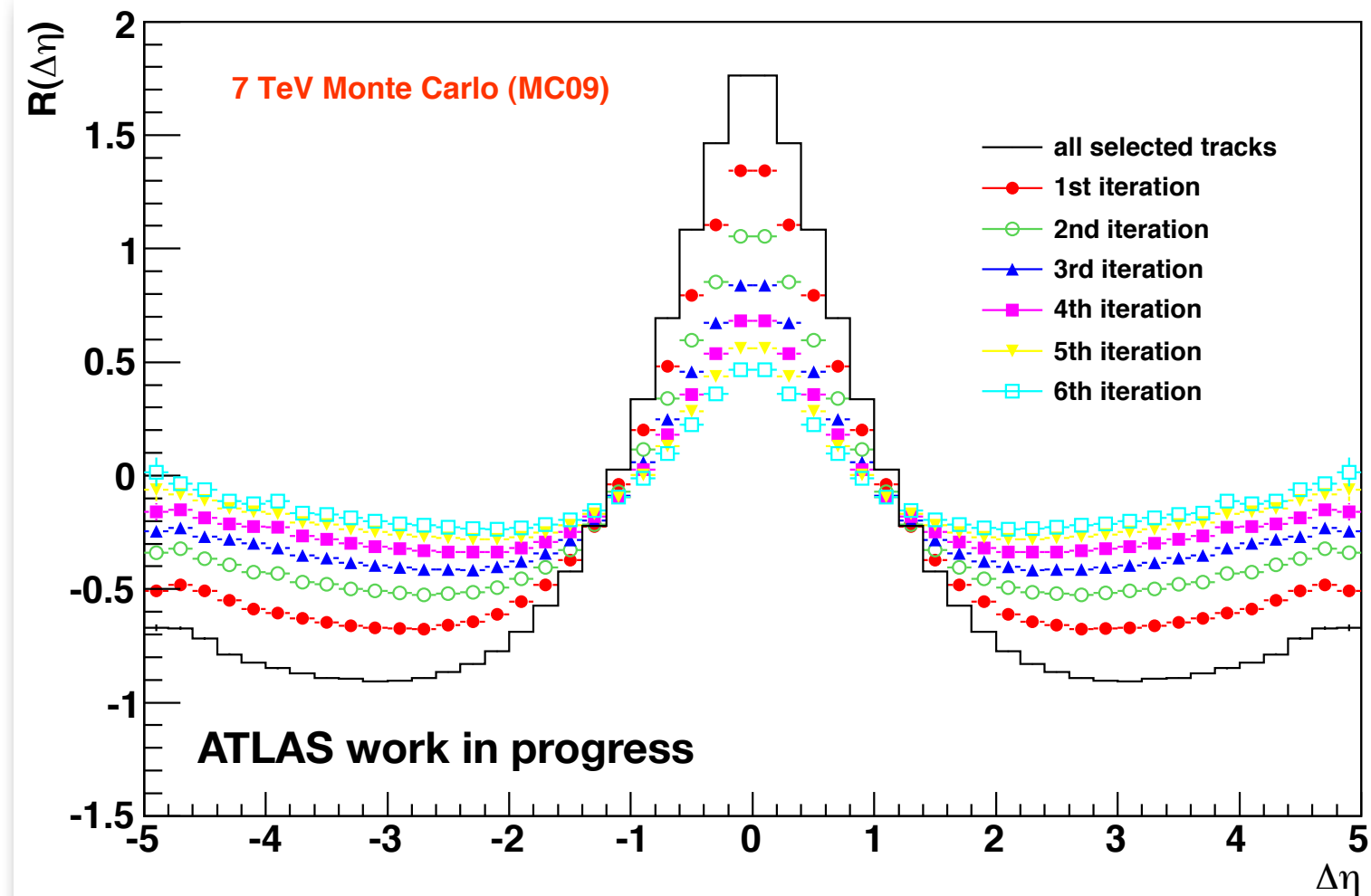
Correction Procedure

Testing the method in R(Δη) in MC
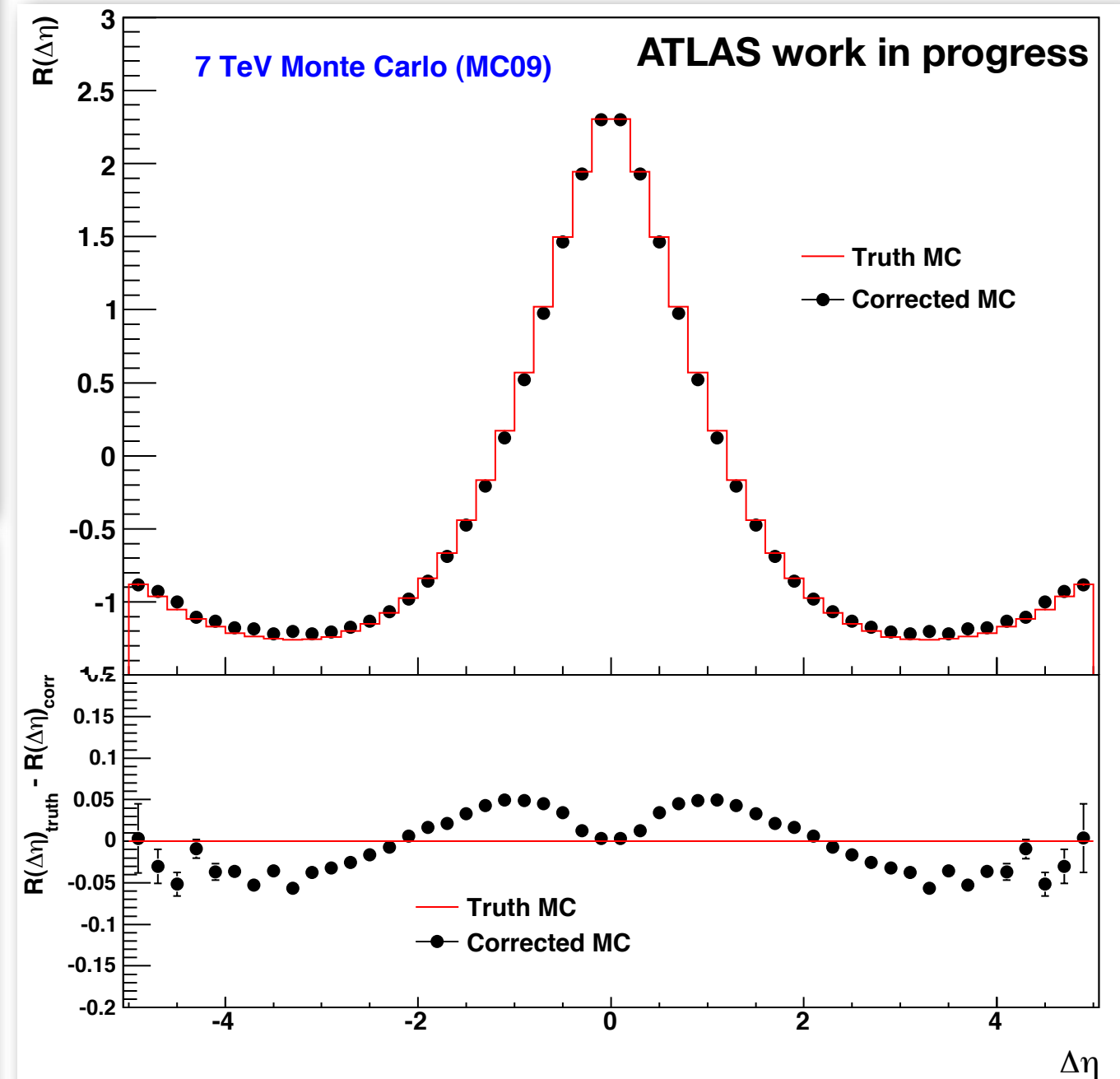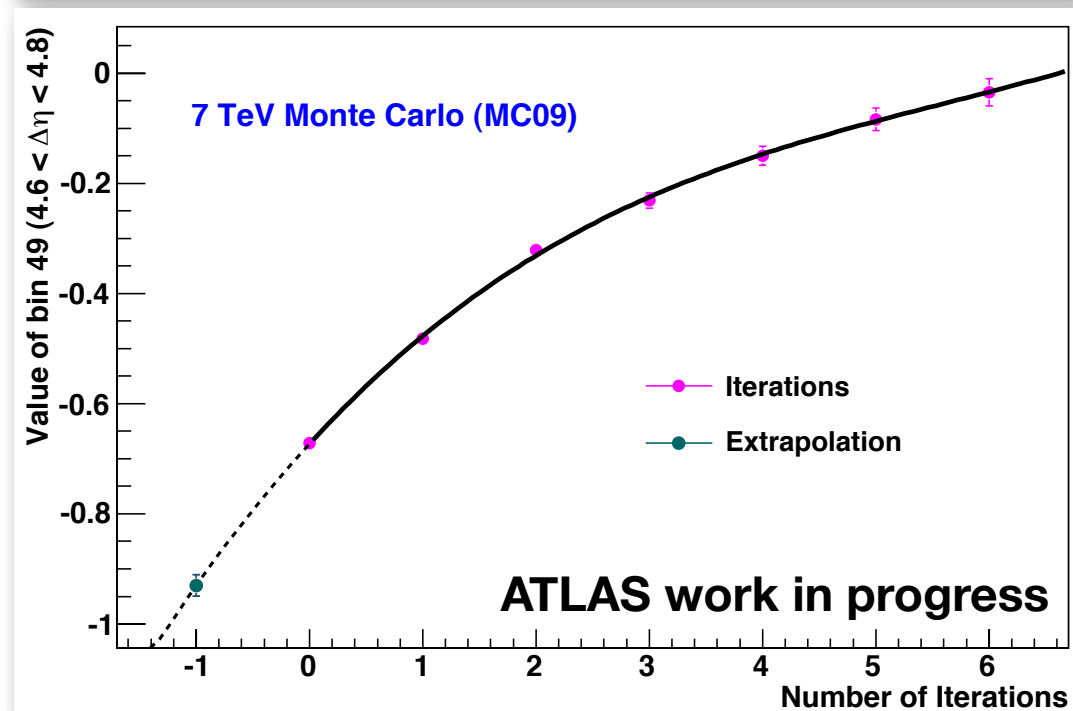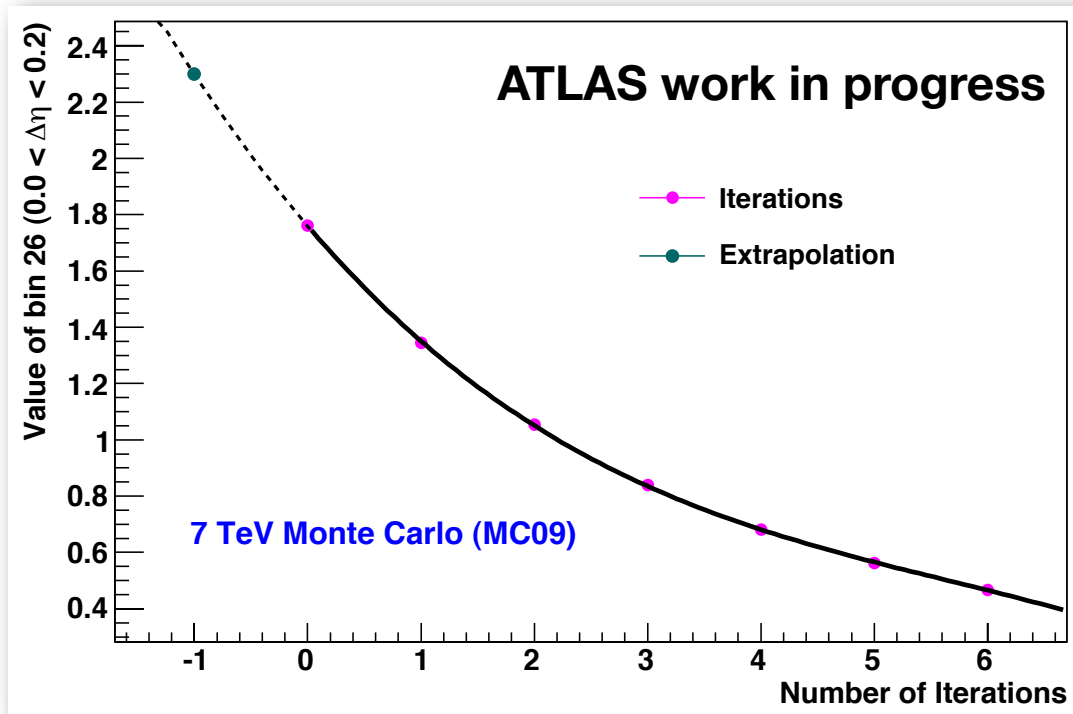
Results

Corrected inclusive two-particle correlation functions in Δη and Δφ.

Results - Δη projections (7 TeV)

0 < Δφ < π/2 (near-side)

π/2 < Δφ < π (away-side)
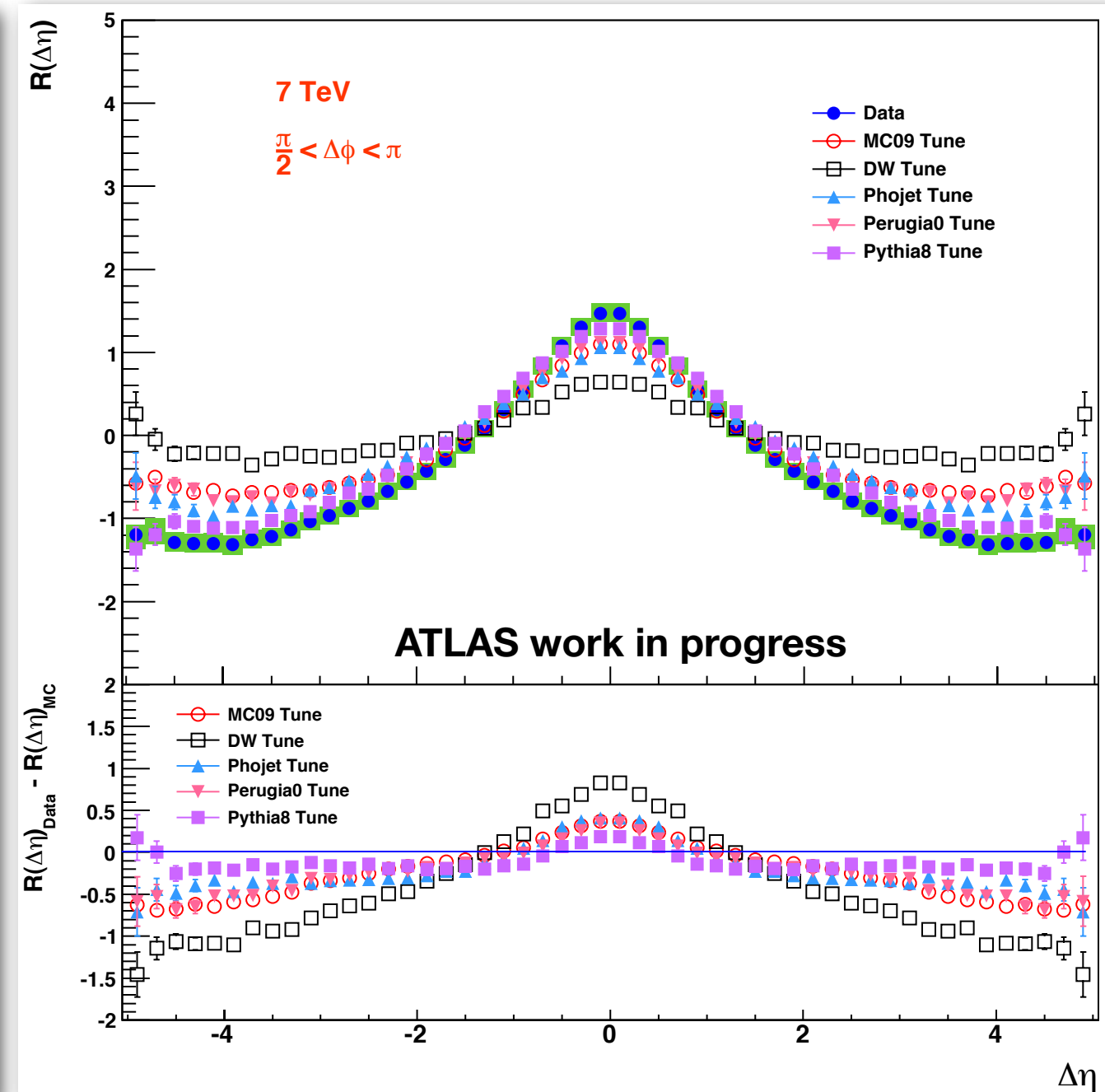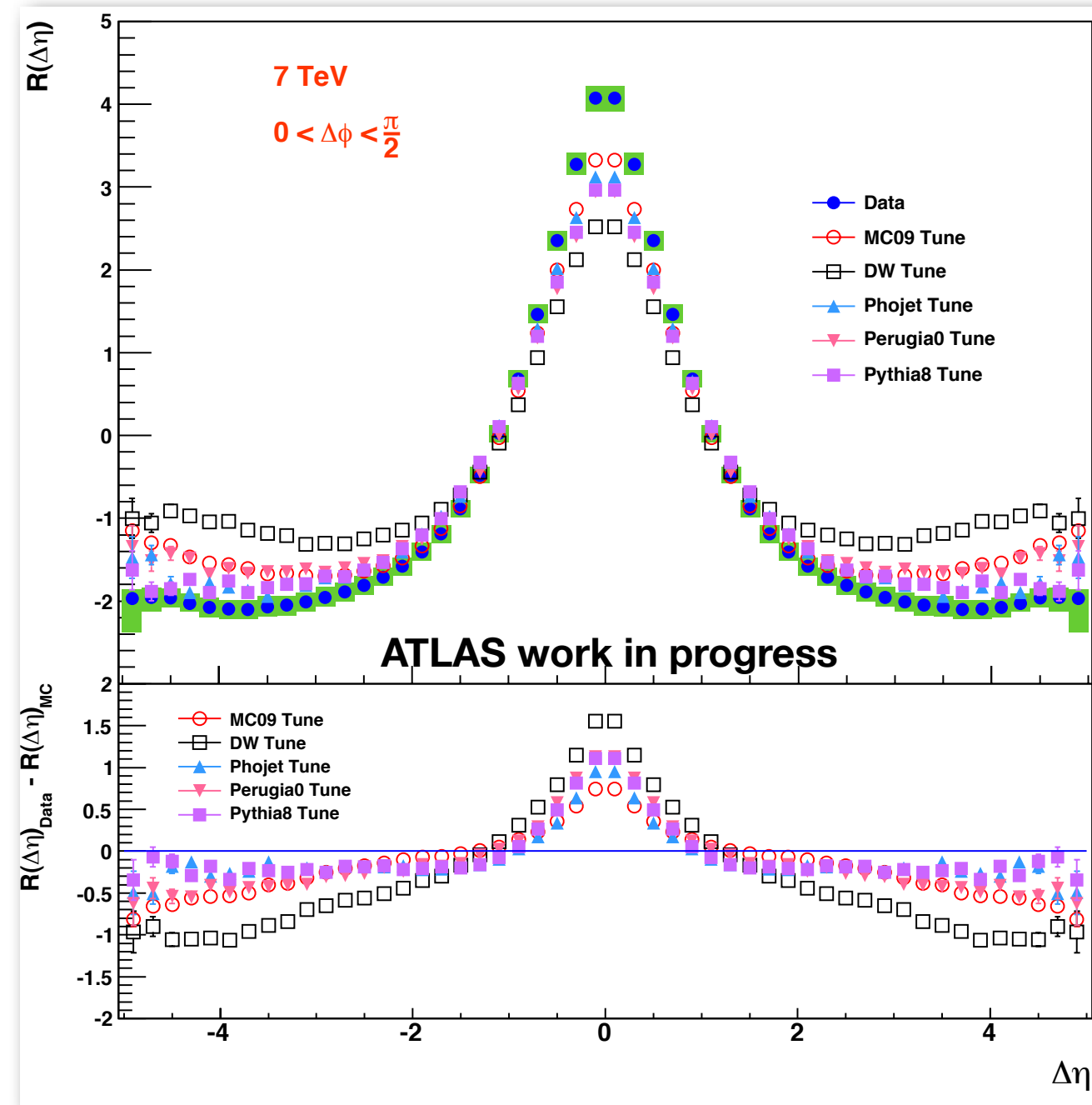
Results - Δφ projections (7 TeV)

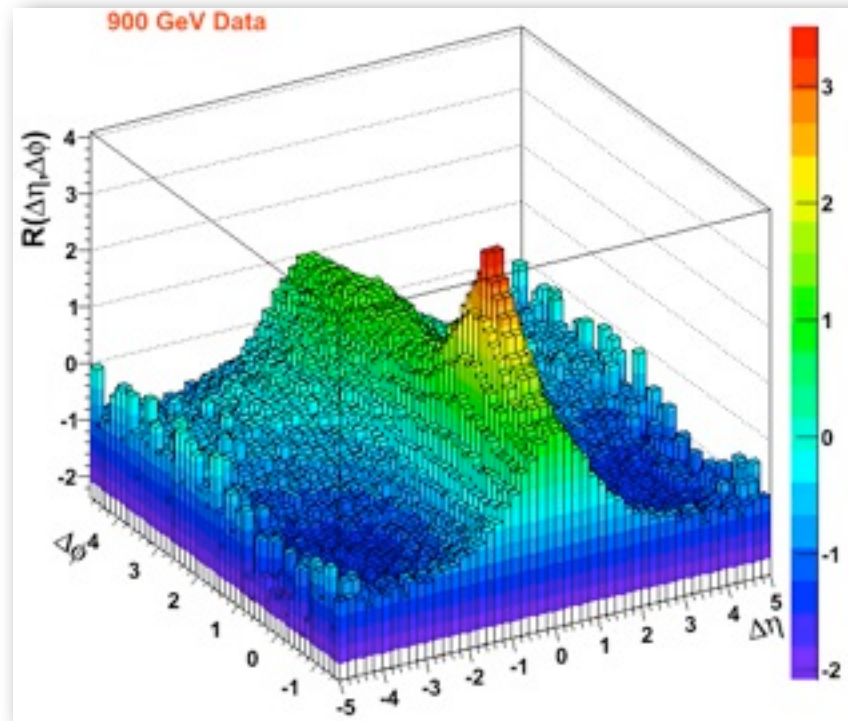$0 < Δη < 2$ (short-range)
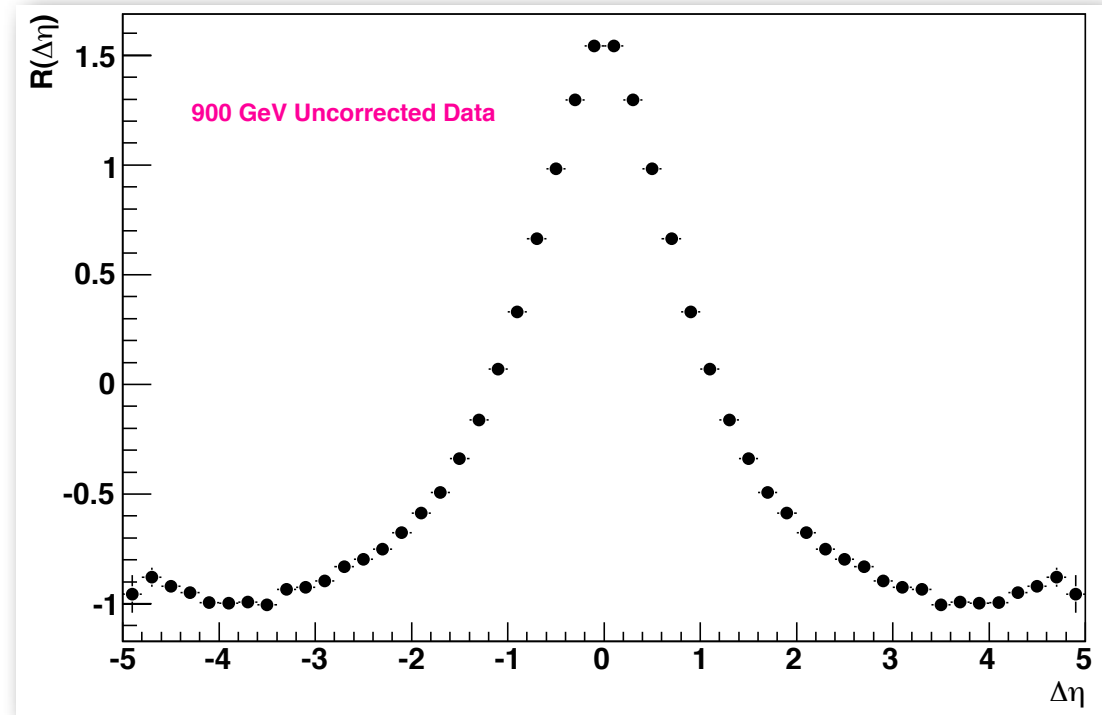
$2 < Δη < 5$ (long-range)
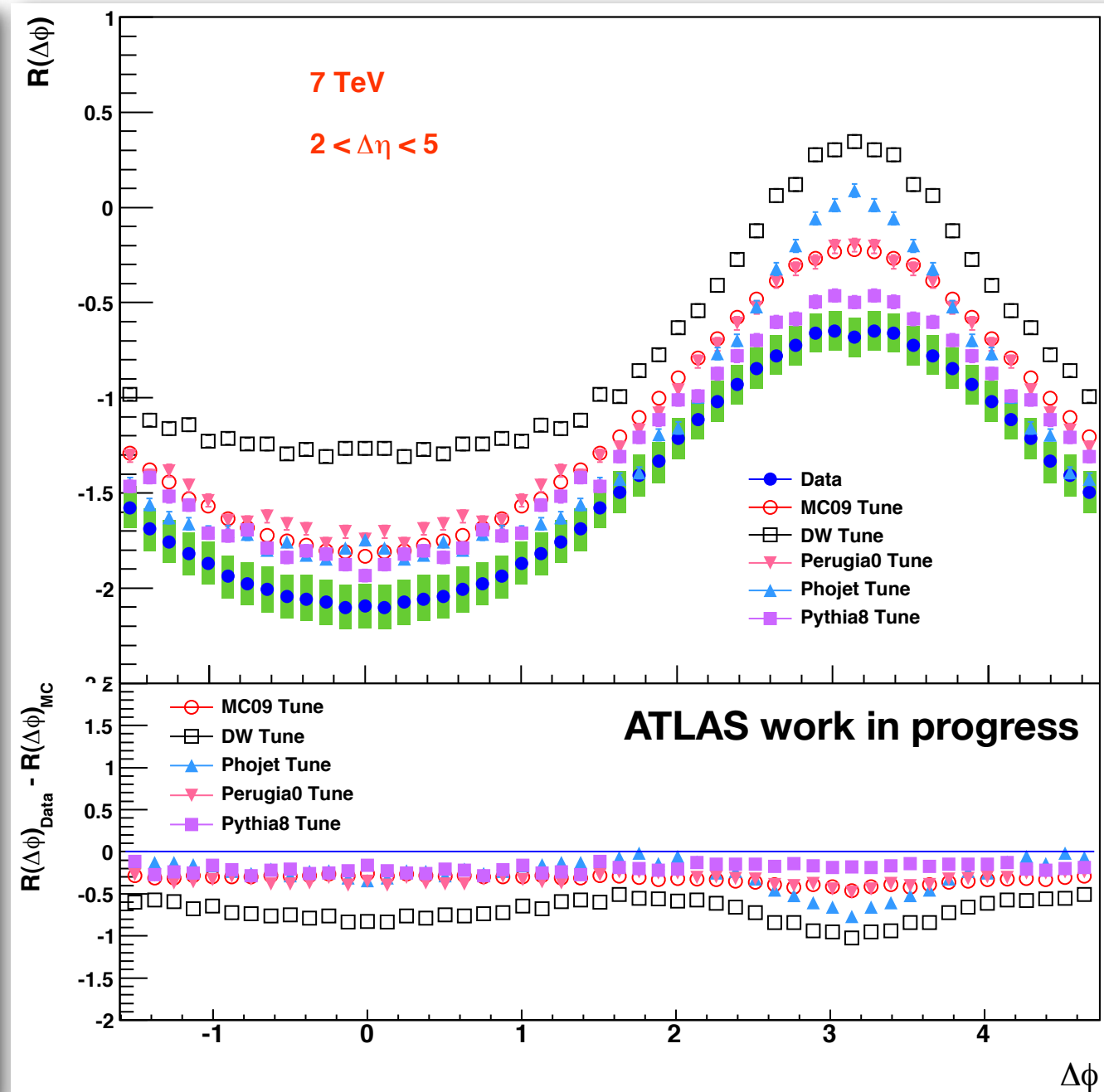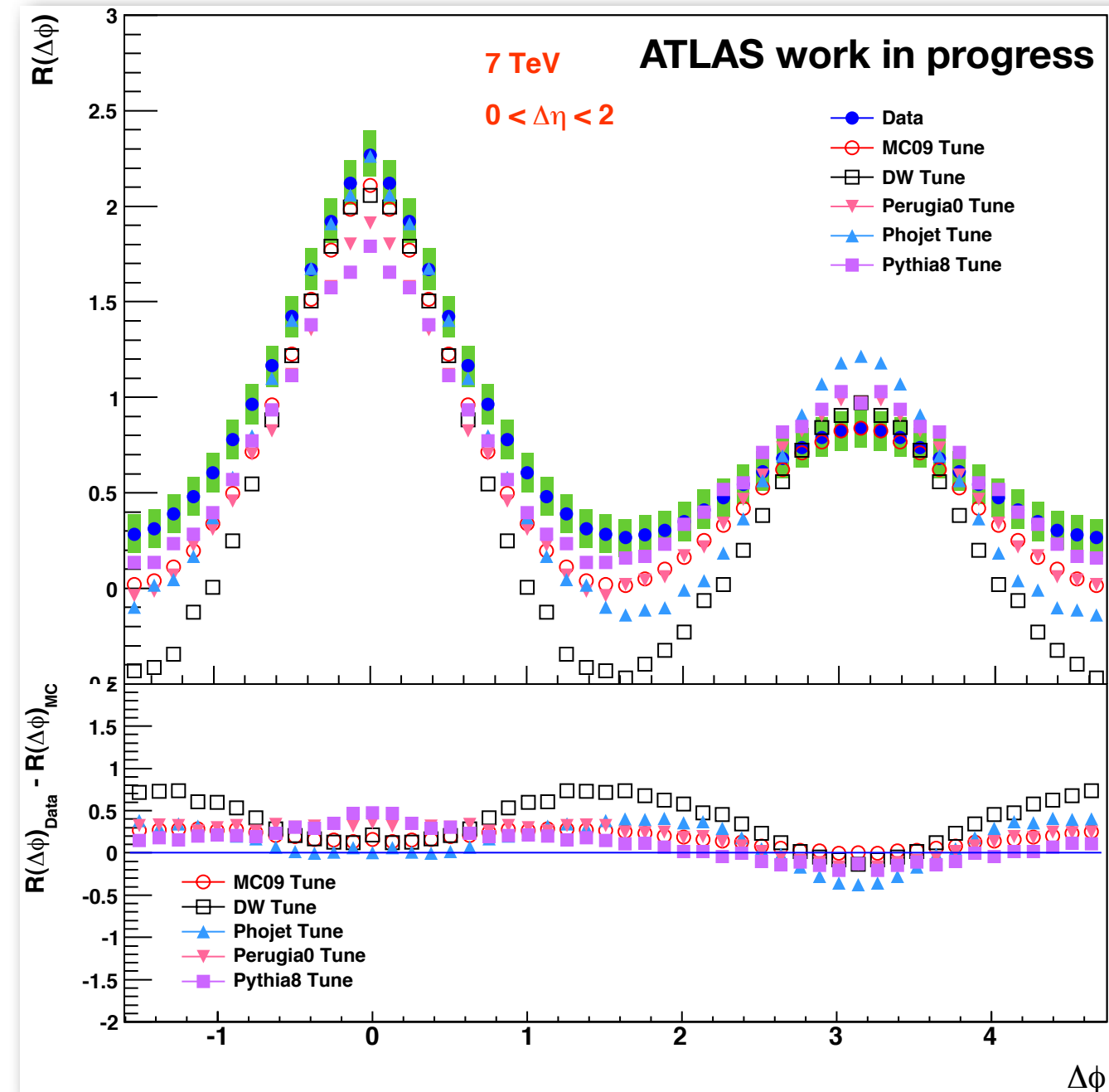
Summary

- 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). For 900 GeV, only the MC09 tune was available for analysis (see 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.
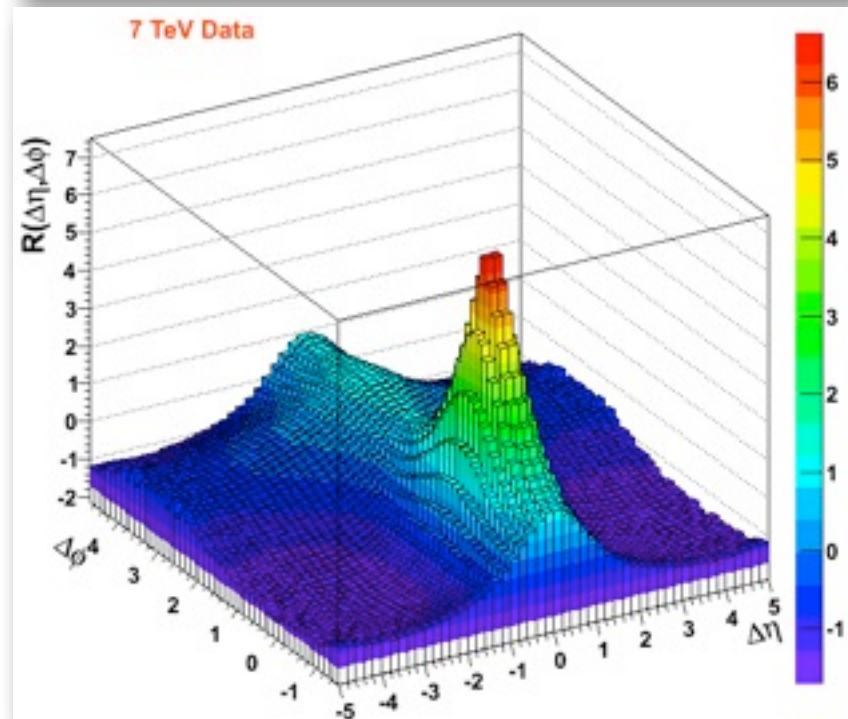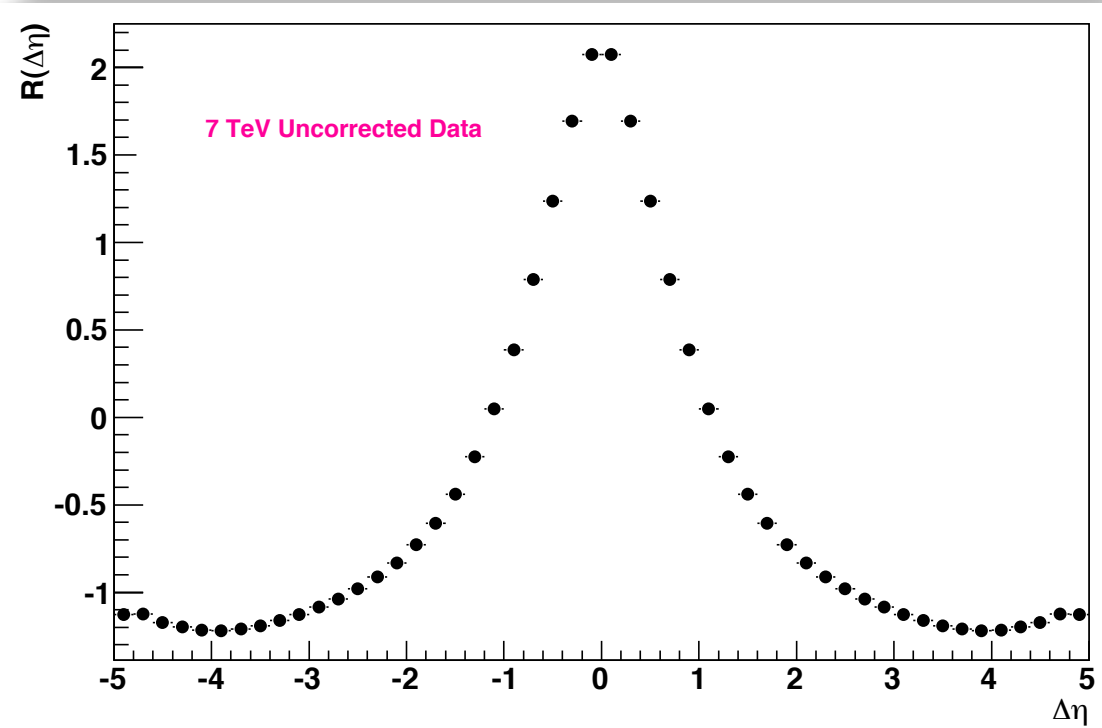
Extra Slides

Uncorrected distributions

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.

Statistical and Systematic Uncertainties

I. Uncertainties on the Efficiencies

- Tracking: material description in MC (p_T and η dependent - from 2% to 15% in the lowest p_T bin), track selection (1% to all bins), turn-on of p_T curve (5% in the first bin), badly measured high-pT tracks (above 10 GeV).
- Vertex and Trigger: approximately 1% in the first multiplicity bin, decreasing rapidly.

II. 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.
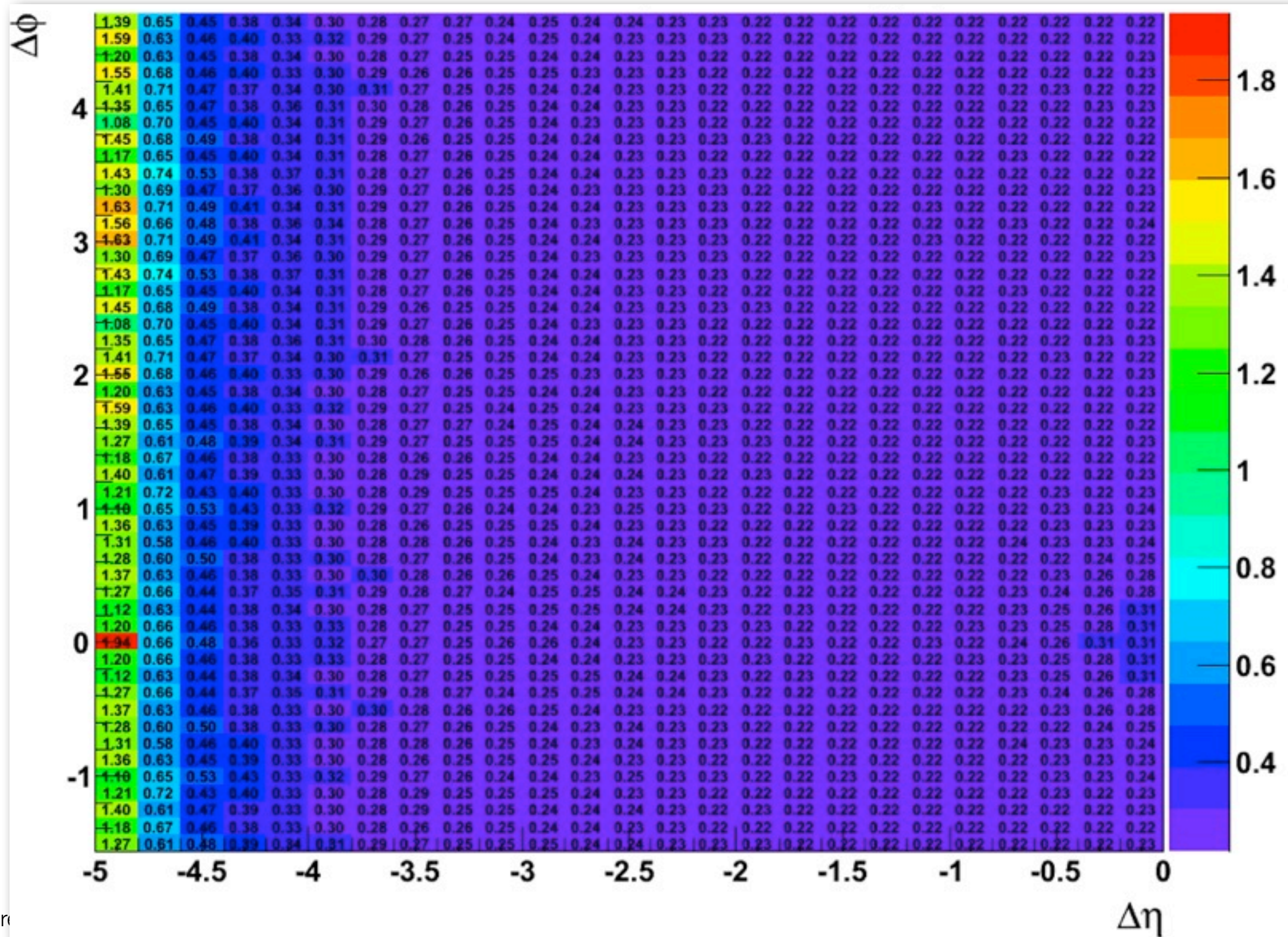
III. Non-closure in Monte Carlo

Absolute difference between truth and corrected MC as a function of R_{corr}.

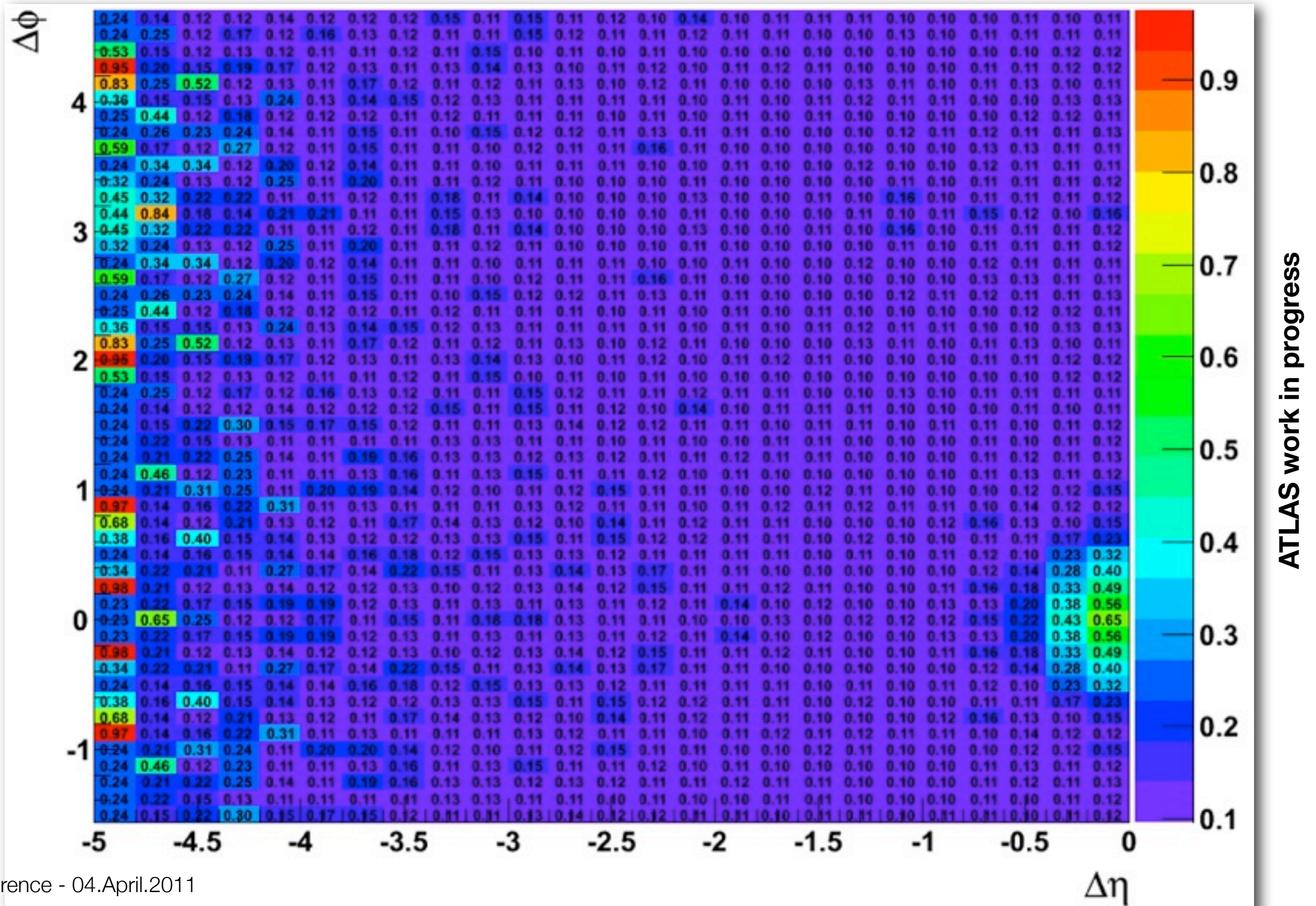An absolute uncertainty of 0.05 is assigned to all bins of R in data.
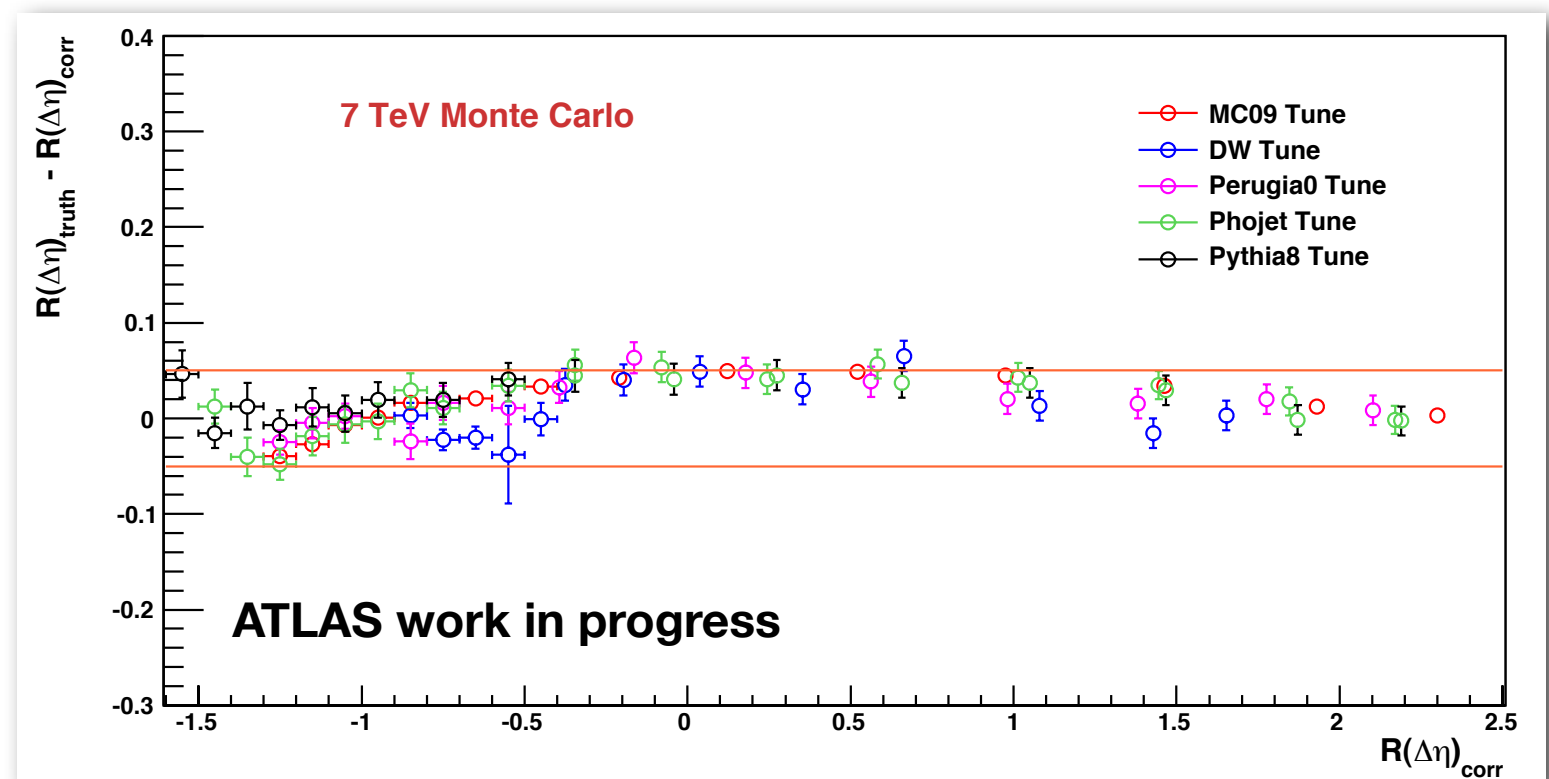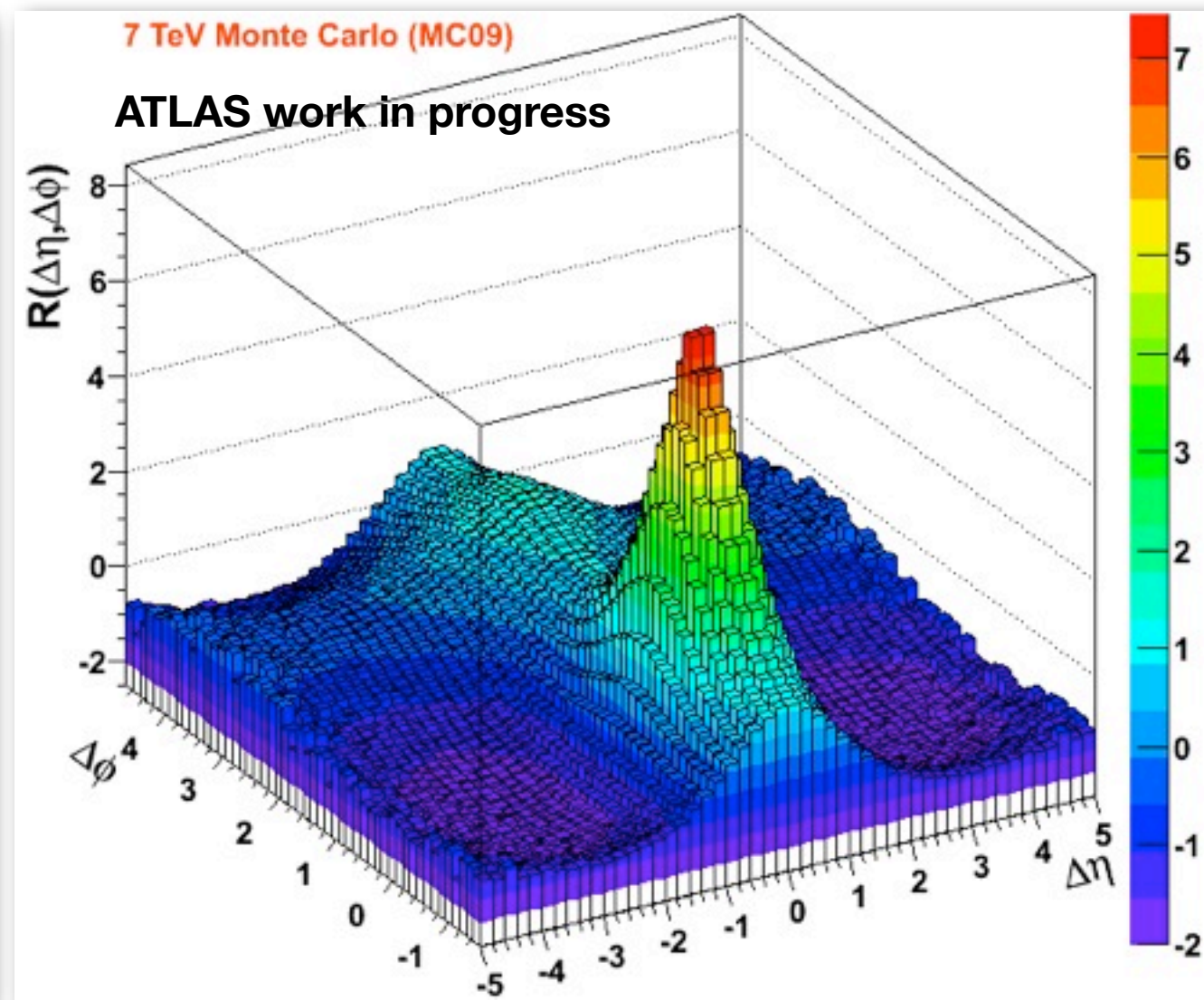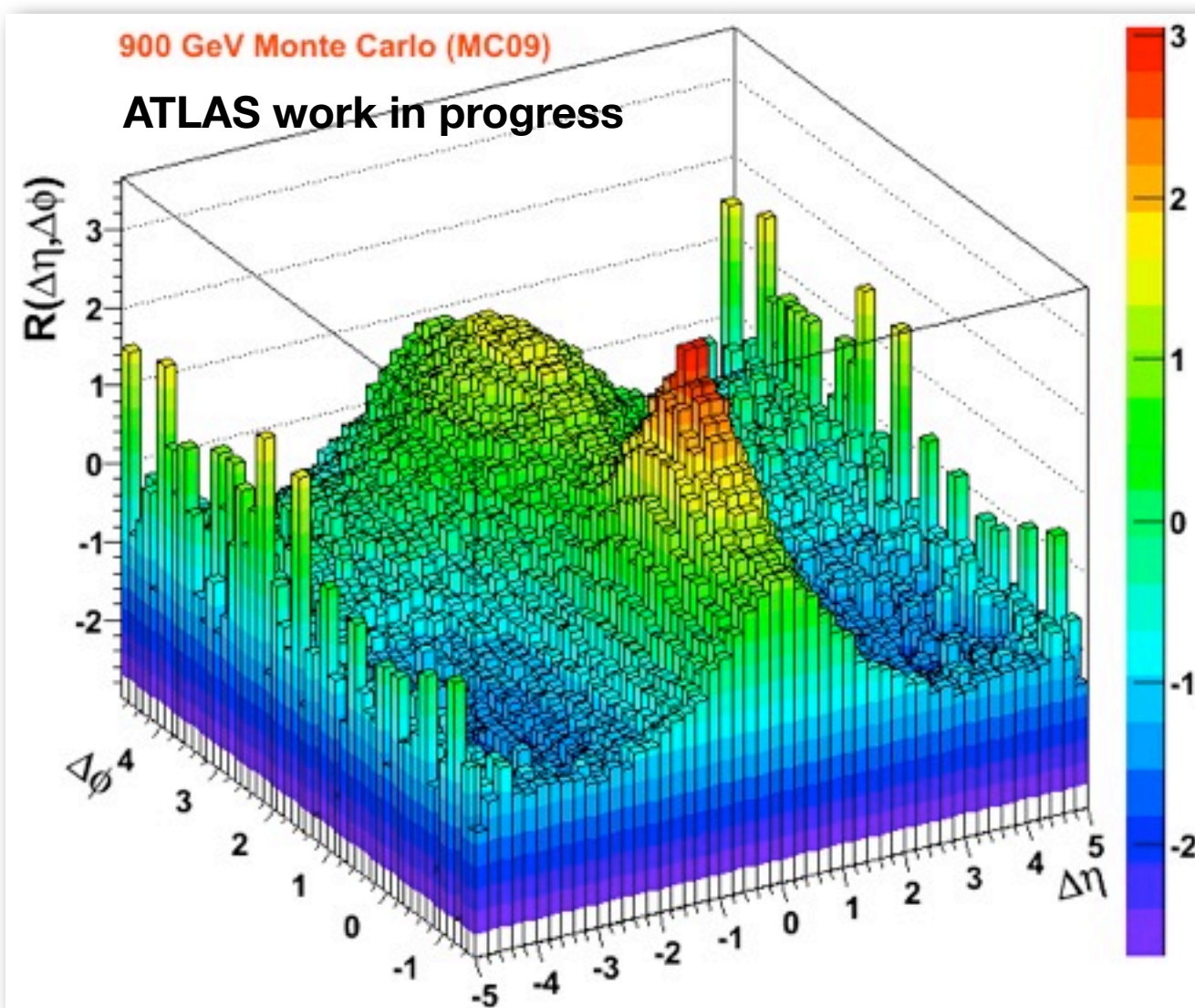
Total Uncertainties for 2D Distributions

Total Uncertainties for 2D Distributions
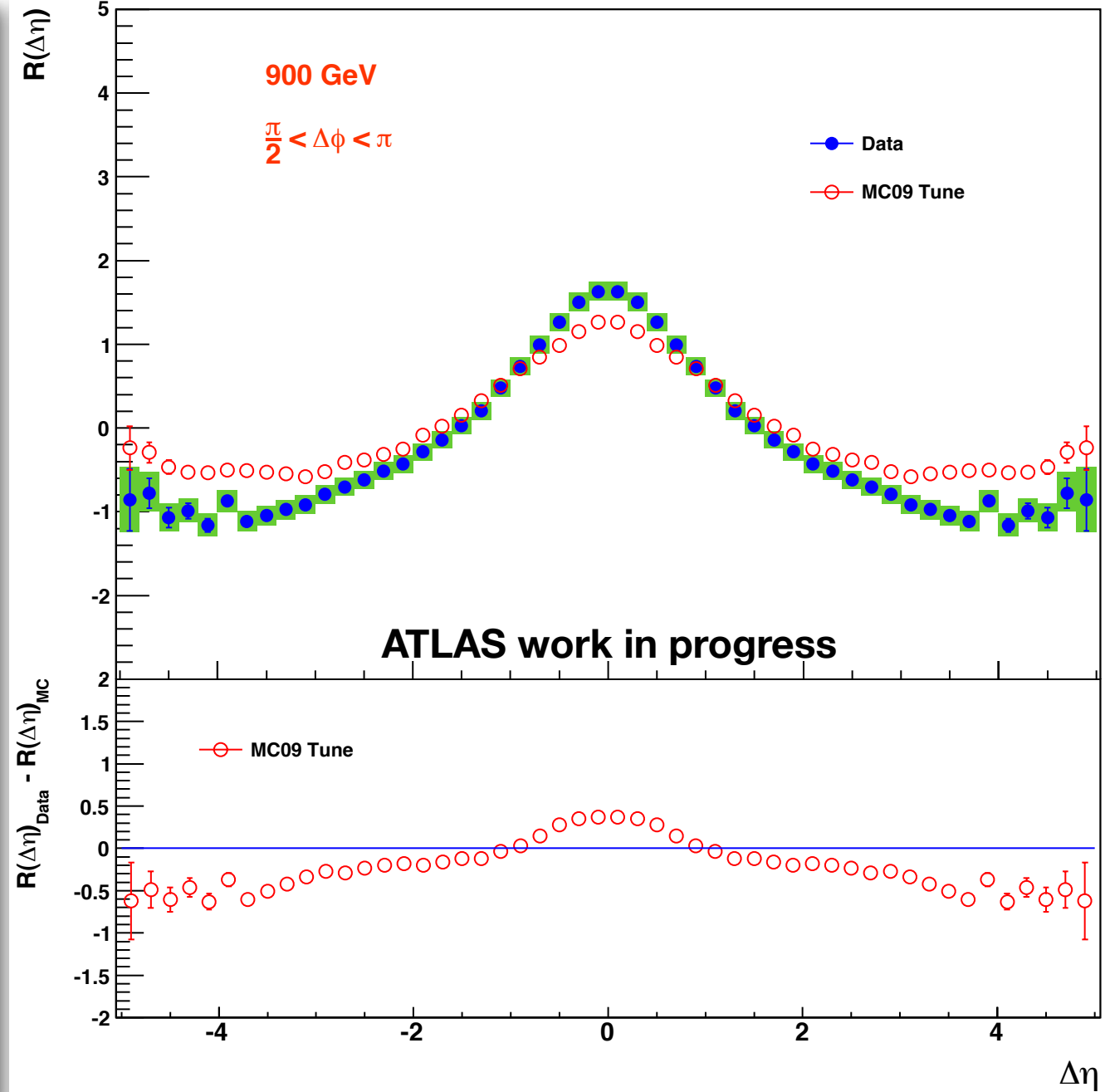
Results - 2D distributions Monte Carlo MC09
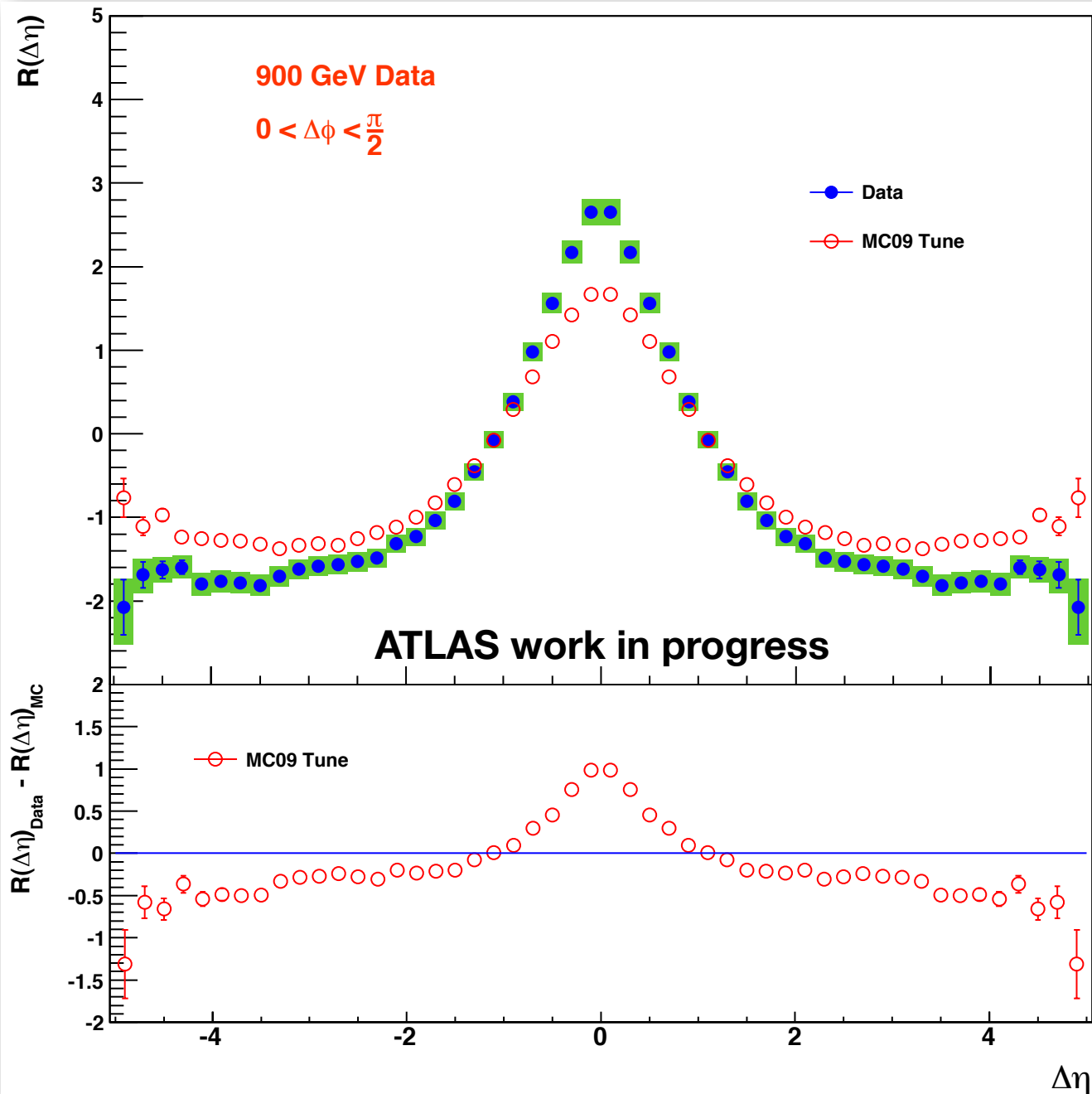
Same complex structure is seen in Monte Carlo, MC09 Tune, however the strength of the correlation seen in data is not reproduced.

Results - Δη projections (900 GeV)

0 < Δφ < π/2 (near-side)   π/2 < Δφ < π (away-side)

Results - Δφ projections (900 GeV)

0 < Δη < 2 (short-range)

2 < Δη < 5 (long-range)