Summary of the CMS ridge publication

A. Knutsson (DESY),

Ridge Discussion Meeting, DESY, November 1st

"Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC"
JHEP 1009:091,2010, arXiv:1009.4122 [hep-ex]

Outline

- **Introduction**
- **Correlation function definition**
- **Correlation function anatomy**
- **Results**

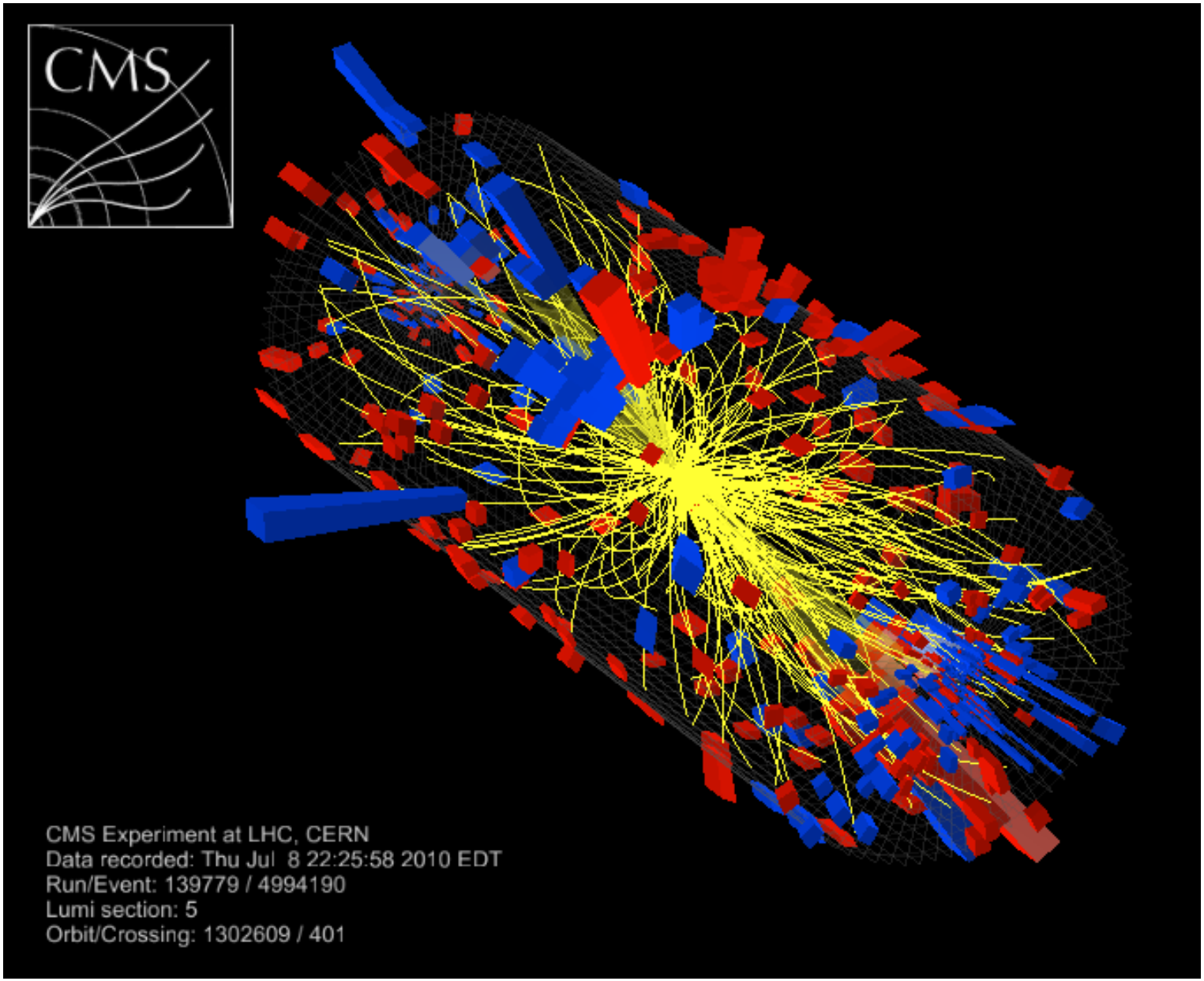
Acknowledgement:
Major parts of the talk are cut and paste from talk by *Gábor I. Veres (CERN)* given at QCD at LHC, Trento, Sept 28, 2010

Introduction

- The 2 particle correlations in Δφ and Δη were measured for charged particles by CMS at 0.9, 2.36 and **7 TeV**
    - In minimum bias events.
    - In high multiplicity events (7 TeV):
      Selected with the CMS high multiplicity track trigger
      Multiplicity for charged particles with pt>0.4 in |eta|<2.4.
      This multiplicity also classify the events (independent of pt-bin).

- The measurements were performed integrated in, as well as in bins of, the charged particle transverse momenta, and for events with different charge particle multiplicities.

High multiplicity event

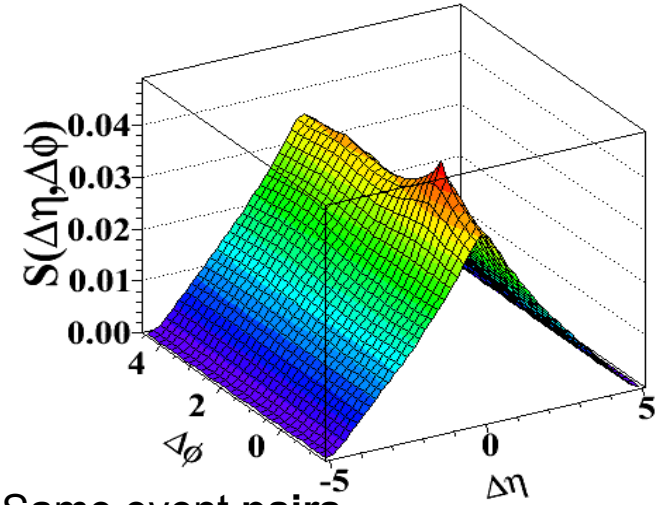


268 reconstructed particles in the tracker in a single pp collision:
the highest multiplicity event in ~70 billion inelastic events sampled (1/pb)

Correlation Function Definition

Signal distribution:

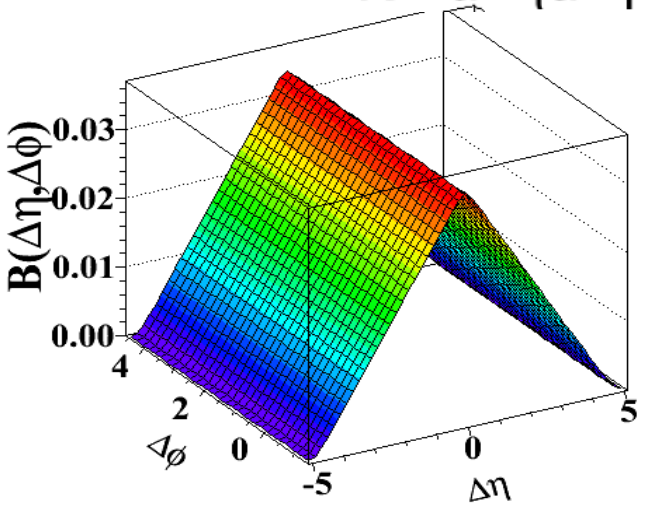
$$S_N(\Delta\eta,\Delta\varphi) = \frac{1}{N(N-1)}\frac{d^2N^{signal}}{d\Delta\eta d\Delta\varphi}$$



Same event **pairs**

Background distribution:

$$B_N(\Delta\eta,\Delta\varphi) = \frac{1}{N^2}\frac{d^2N^{bkg}}{d\Delta\eta d\Delta\varphi}$$

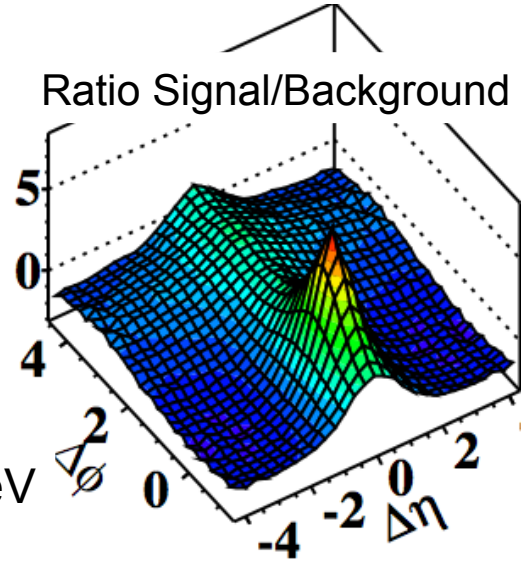


Mixed event **pairs**

$$\Delta\eta = \eta_1 - \eta_2$$

$$\Delta\varphi = \varphi_1 - \varphi_2$$

Ratio Signal/Background

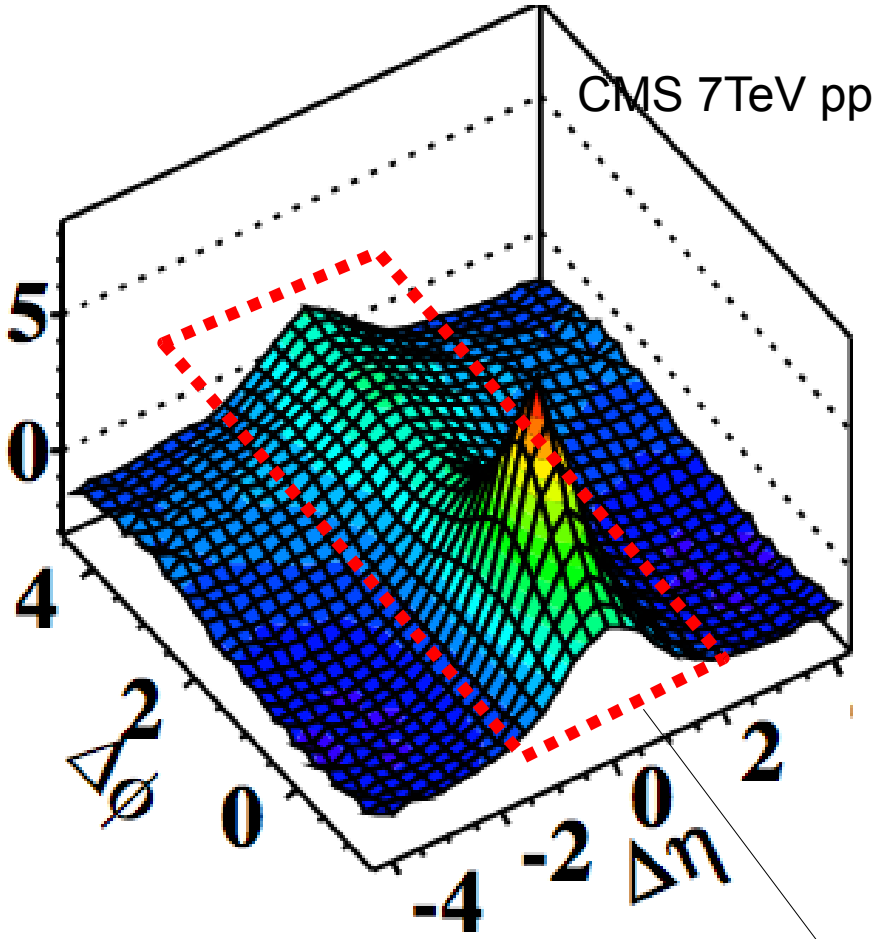


CMS pp 7TeV

$$R(\Delta\eta,\Delta\varphi) = \left\langle (N-1)\left(\frac{S_N(\Delta\eta,\Delta\varphi)}{B_N(\Delta\eta,\Delta\varphi)} - 1\right)\right\rangle_N$$

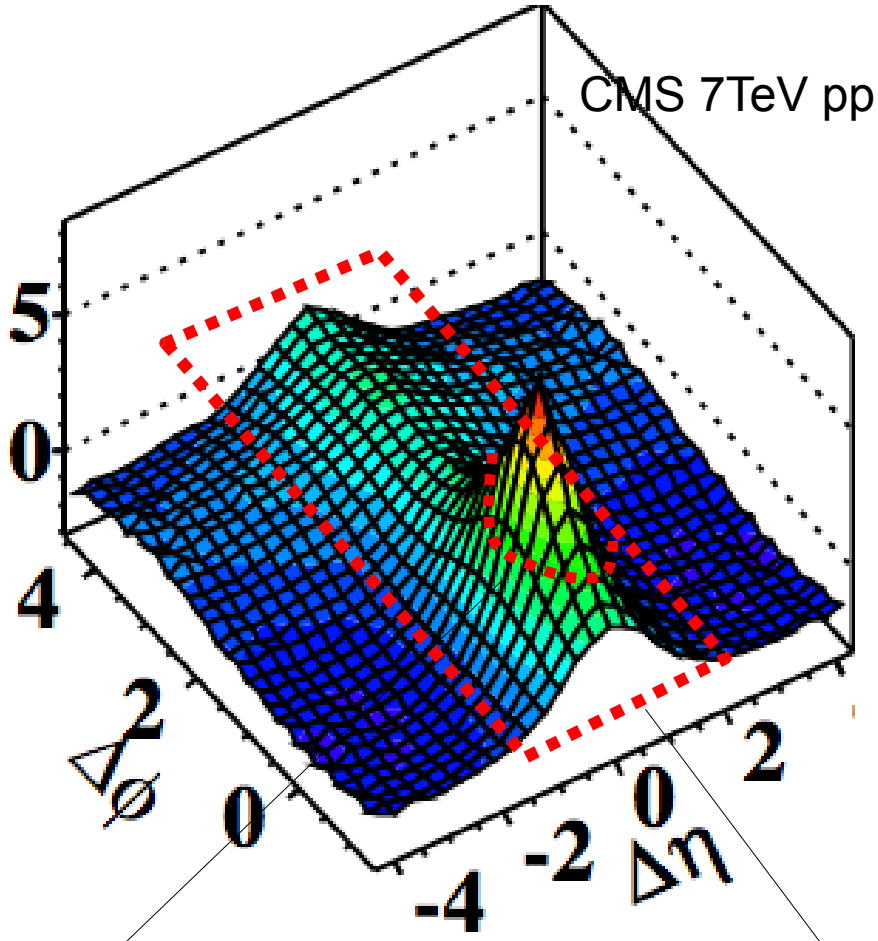
p_T-inclusive two-particle angular correlations in minimum bias collisions

Ridge Atonomy



Short-range correlations (|Δη| < 2):
String fragmentation, resonances, ...

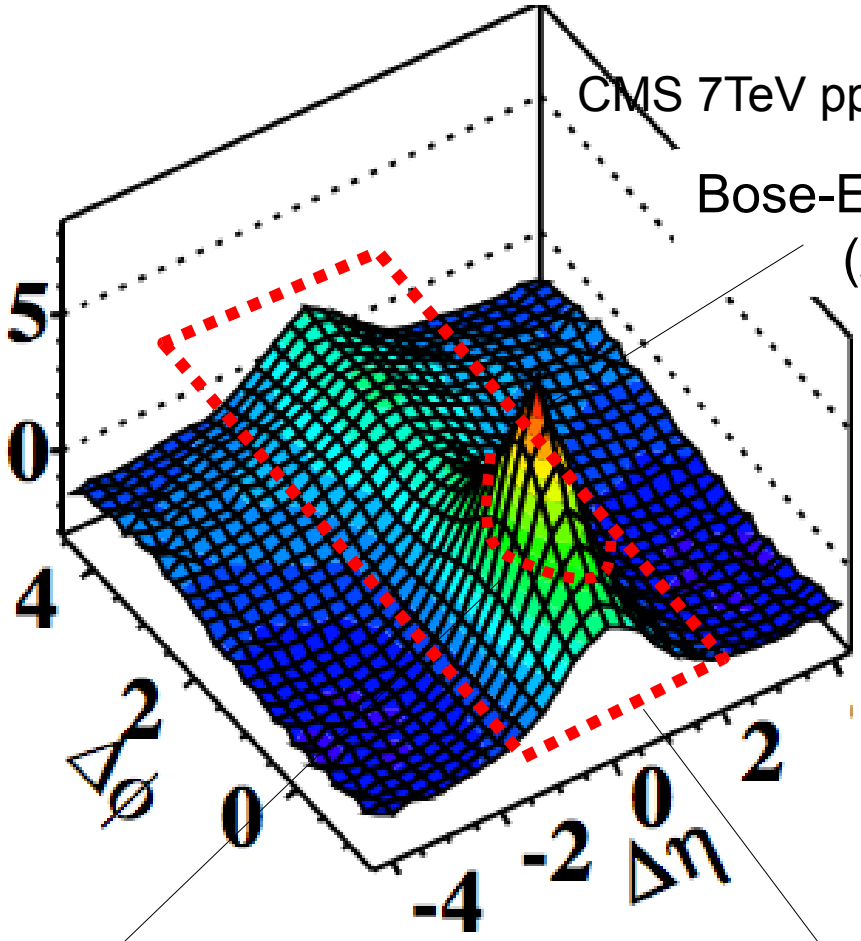
Ridge Atonomy



"Near-side" , Δφ~ 0 jet peak:
Correlation of particles
within a single jet

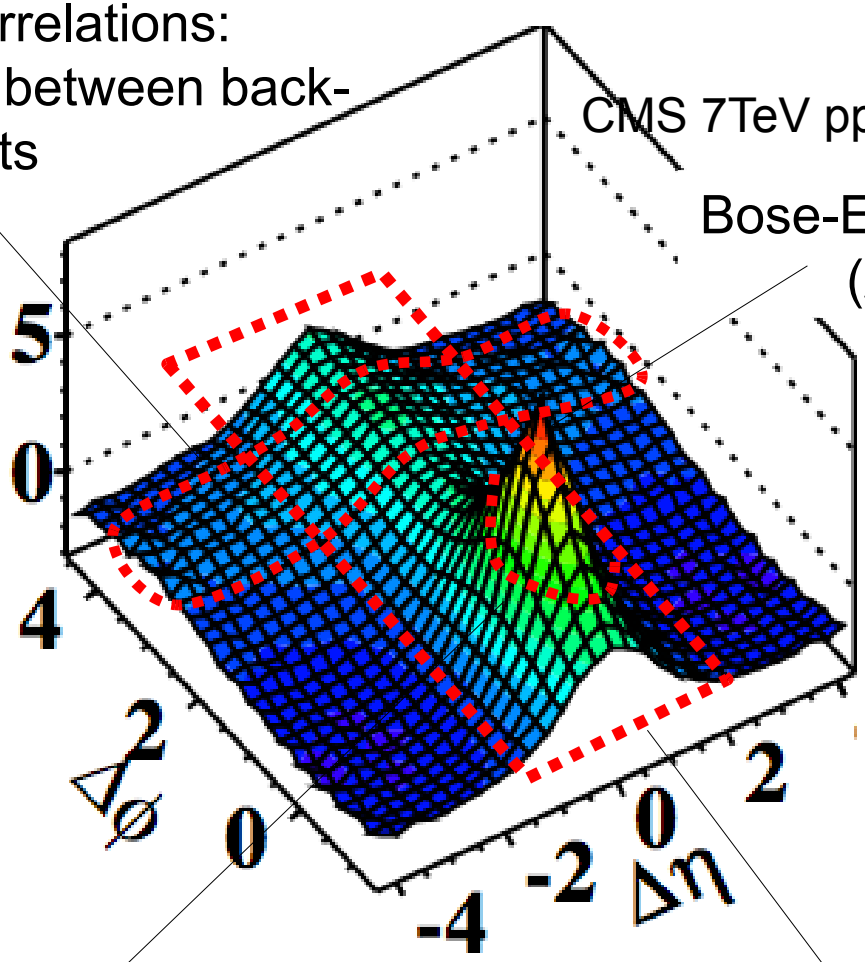
Short-range correlations (|Δη| < 2):
String fragmentation, resonances, ...

Ridge Atonomy



Ridge Atonomy

"Away-side" jet correlations:
Correlation of particles between back-to-back jets



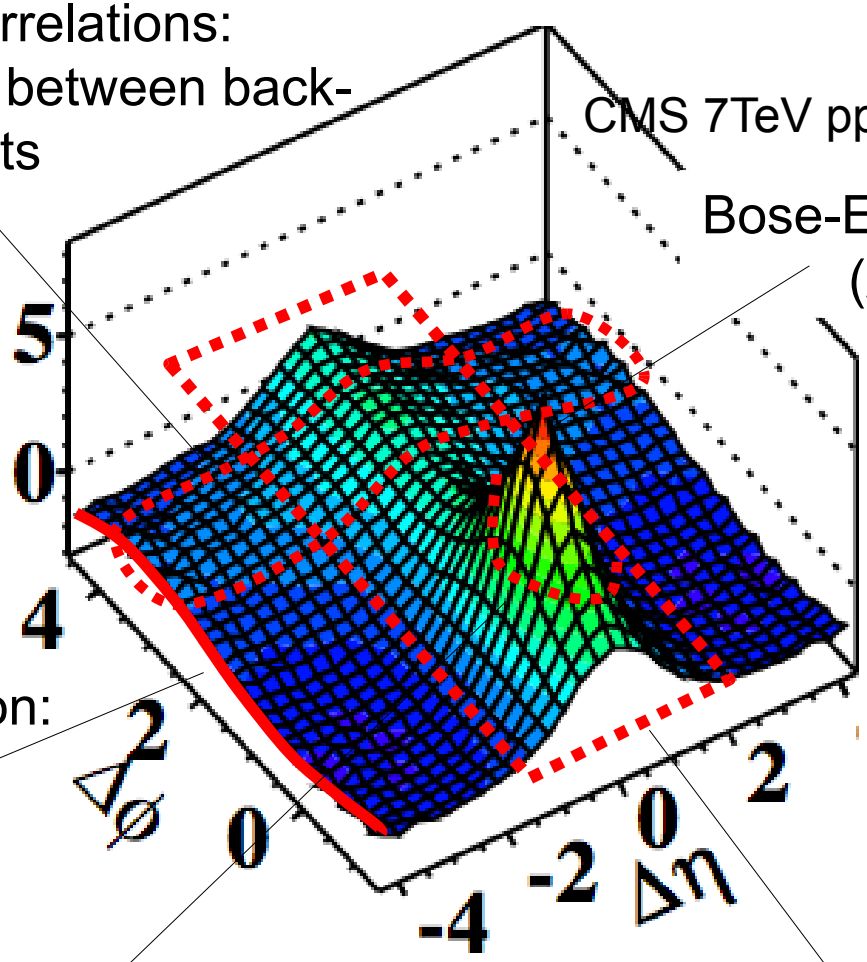
Bose-Einstein correlations:
$(\Delta\varphi,\Delta\eta) \sim (0,0)$

"Near-side" , $\Delta\varphi \sim 0$ jet peak:
Correlation of particles within a single jet

Short-range correlations ($|\Delta\eta| < 2$):
Resonances, string fragmentation, "clusters"

Ridge Atonomy

"Away-side" jet correlations:
Correlation of particles between back-to-back jets



Bose-Einstein correlations:
$(\Delta\varphi,\Delta\eta) \sim (0,0)$

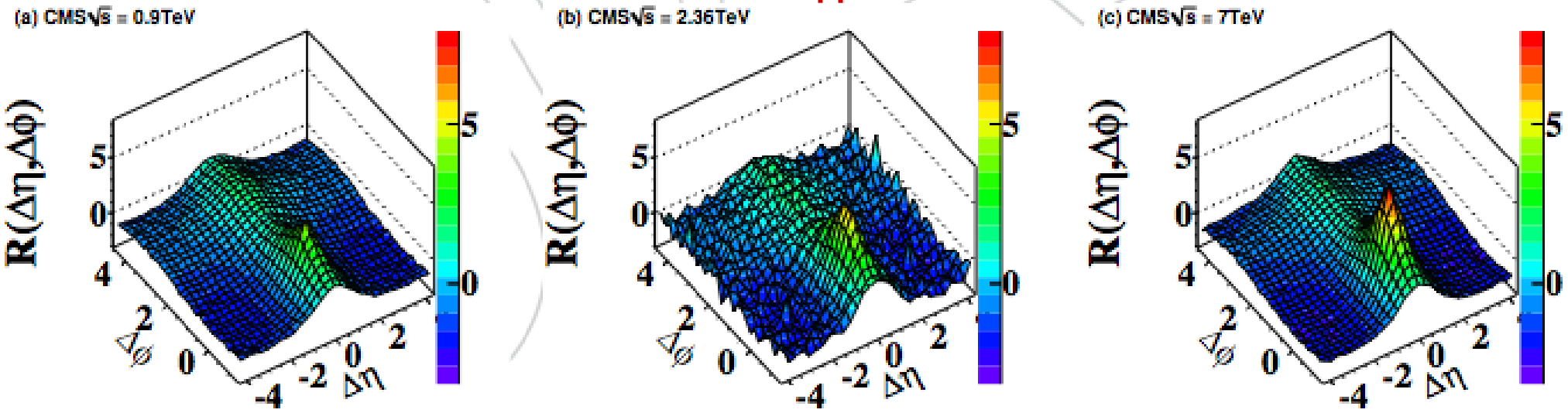
Momentum conservation:
$\sim -\cos(\Delta\varphi)$

"Near-side" , $\Delta\varphi \sim 0$ jet peak:
Correlation of particles within a single jet

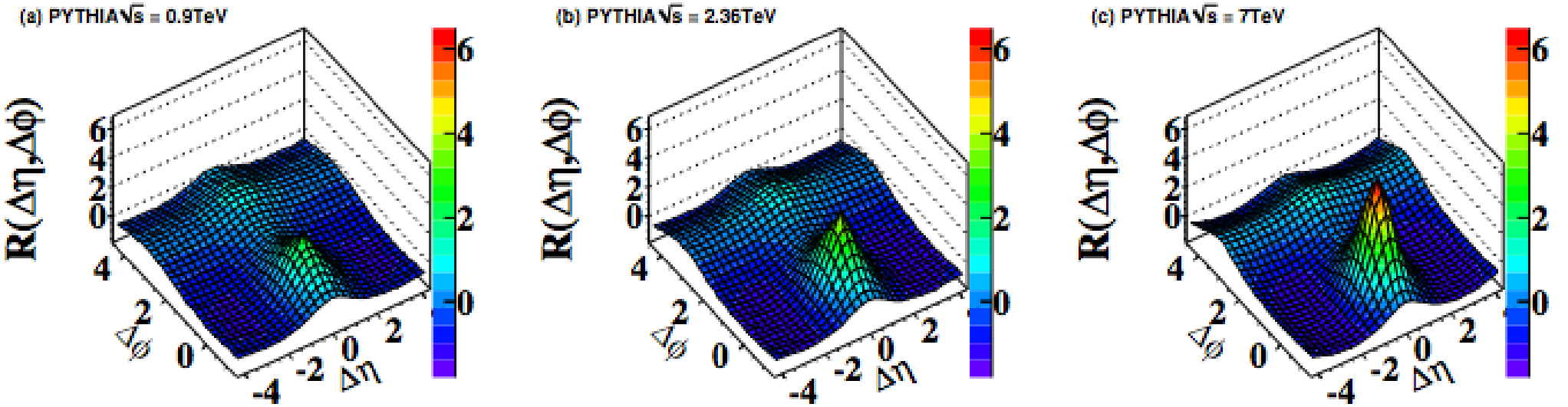
Short-range correlations ($|\Delta\eta| < 2$):
Resonances, string fragmentation, "clusters"

Results - MB

CMS pp Data



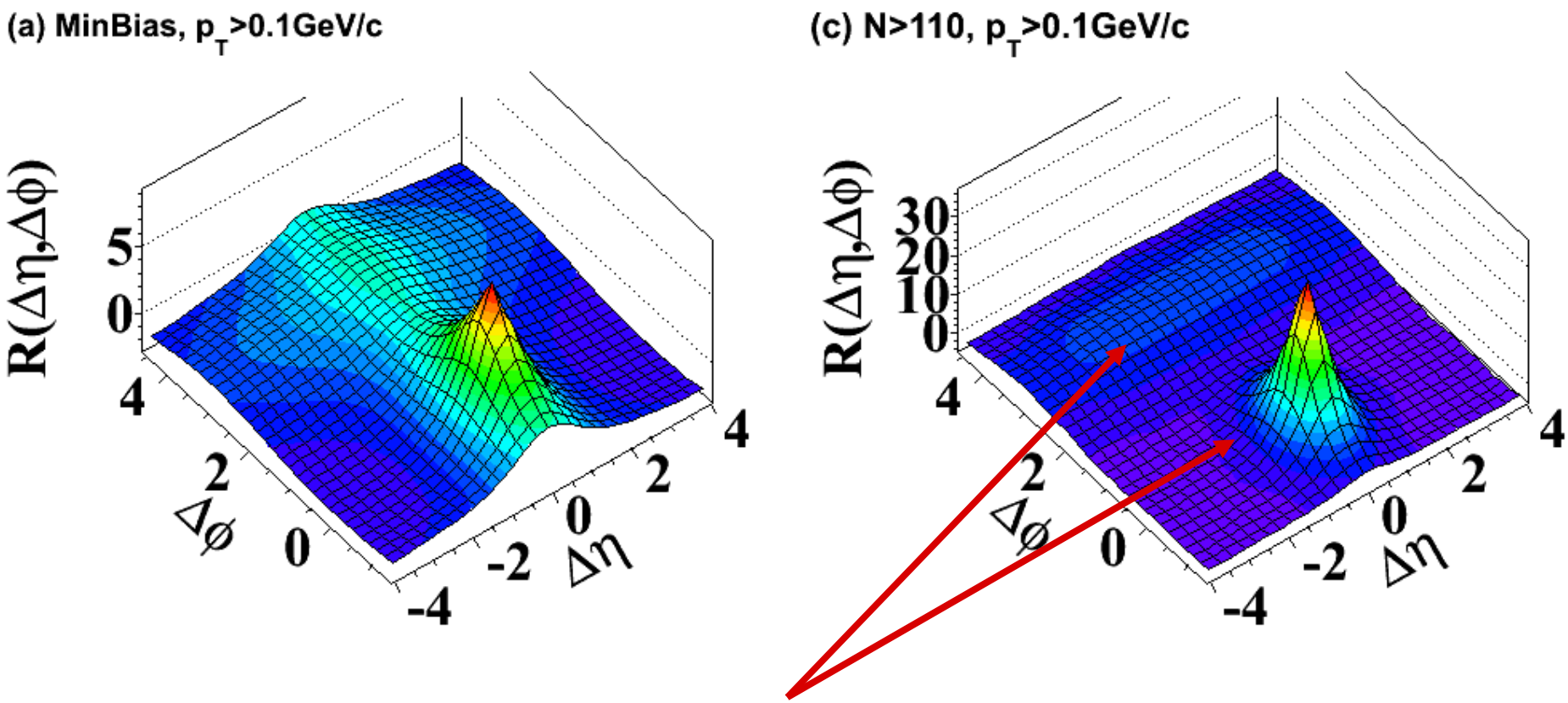
Pythia D6T



Results – N > 110

MinBias

high multiplicity (N>110)



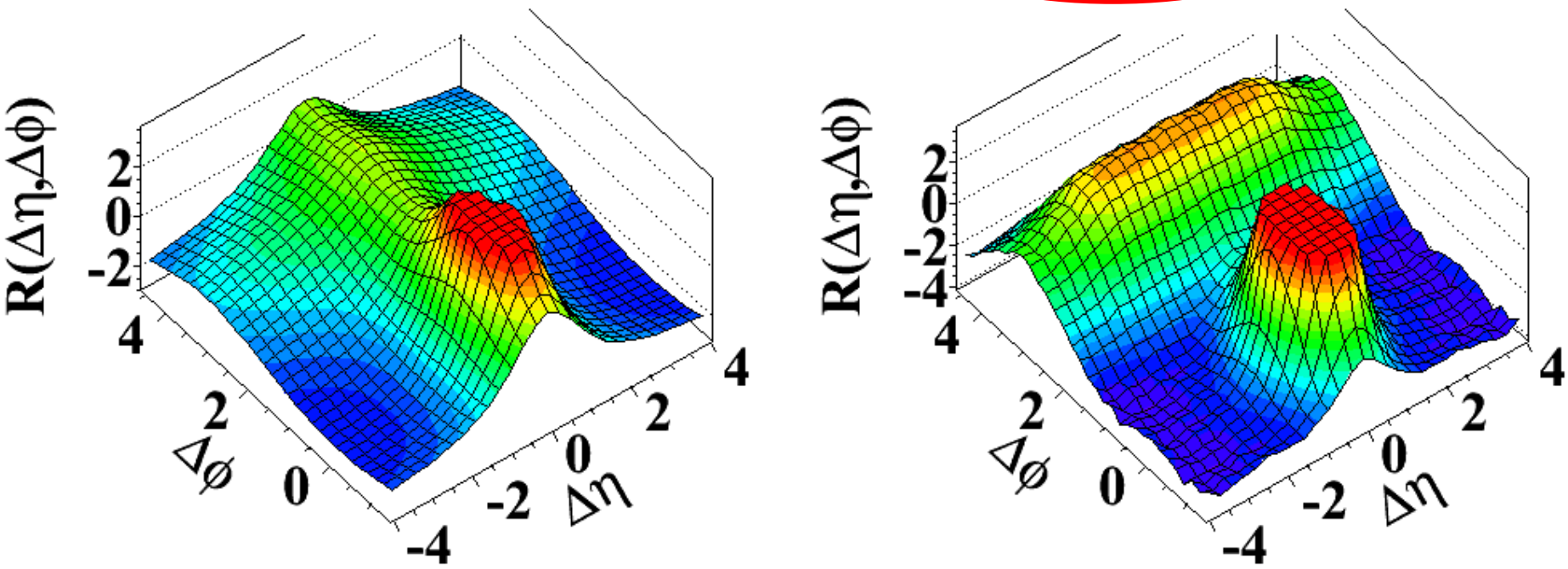
Jet peak/away-side correlations enhanced in high multiplicity events.
Abundant jet production in high multiplicity sample.

Results – N > 110

MinBias

high multiplicity (N>110)

pt-integrated



After cuting off the jet peak at (0,0) we can observe:

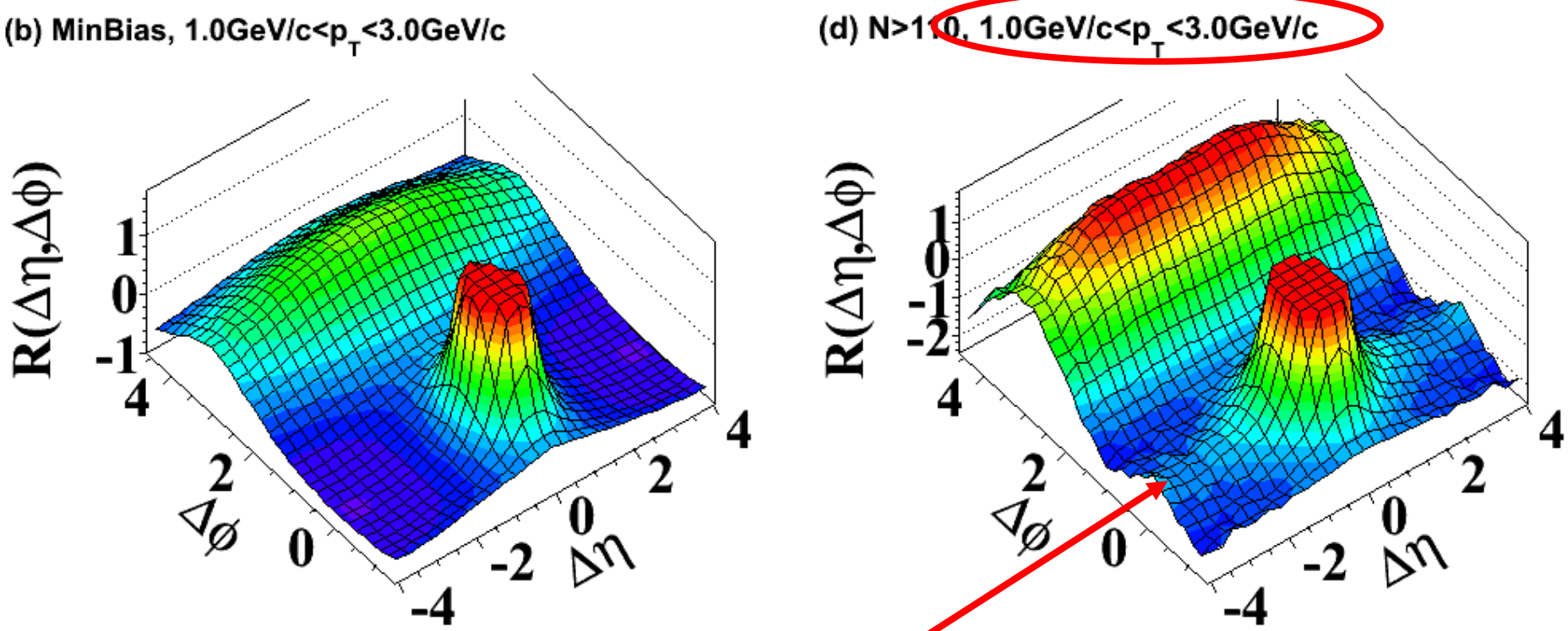
Structure of away-side ridge (back-to-back jets).

Possibly small effect at large |Δη| around Δφ ~ 0

Results – N > 110

MinBias

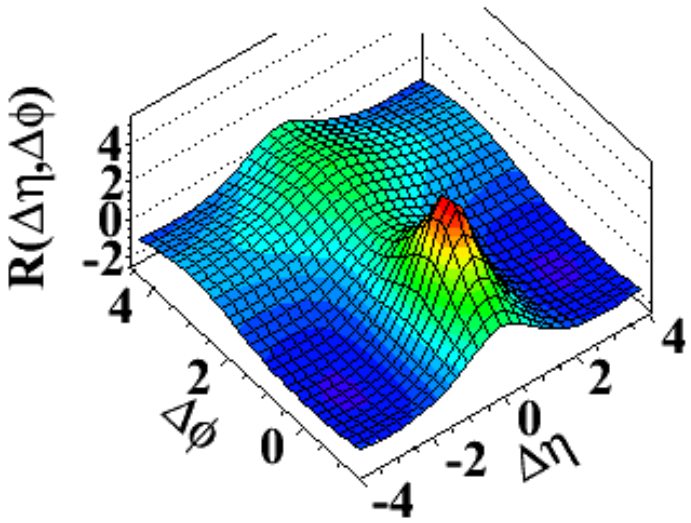
high multiplicity (N>110)



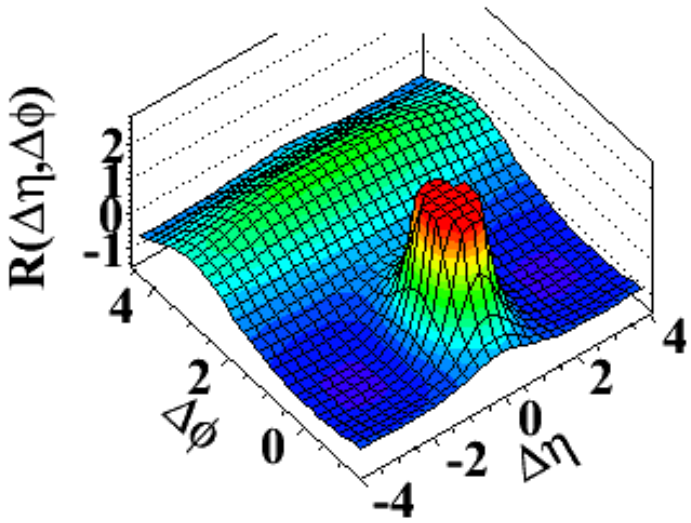
Pronounced new structure at large |Δη| around Δφ ~ 0 !

Pythia 8

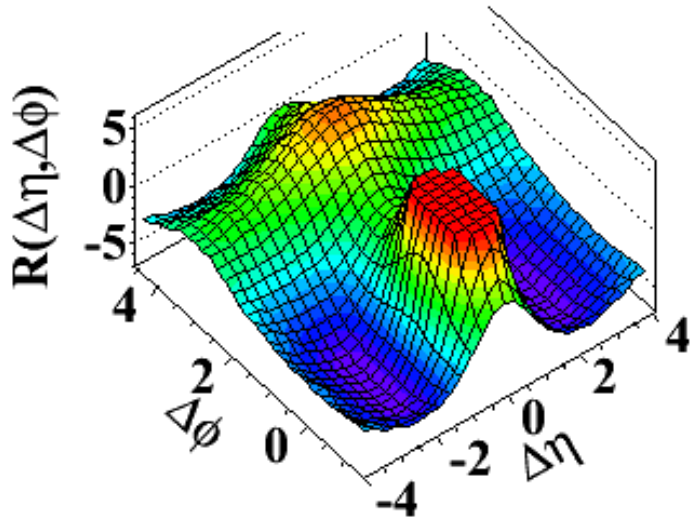
(a) MinBias, p_T>0.1GeV/c



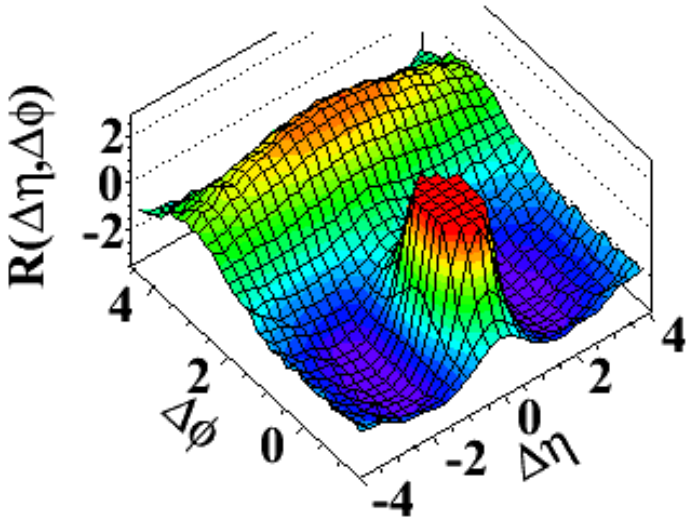
(b) MinBias, 1.0GeV/c<p_T<3.0GeV/c



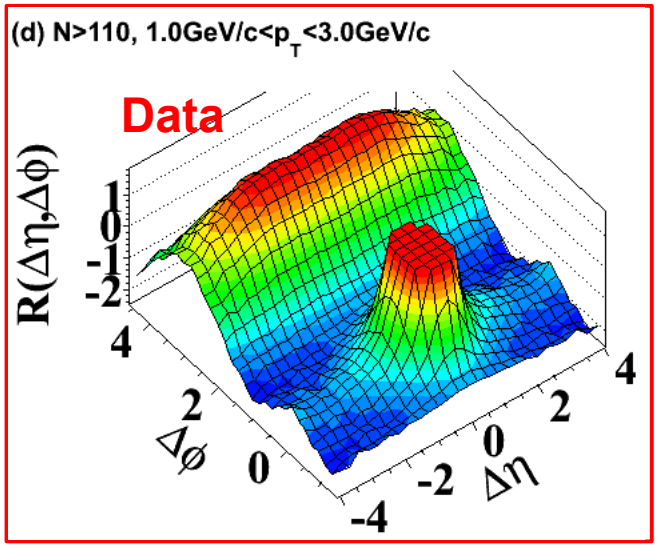
(c) N>110, p_T>0.1GeV/c



(d) N>110, 1.0GeV/c<p_T<3.0GeV/c



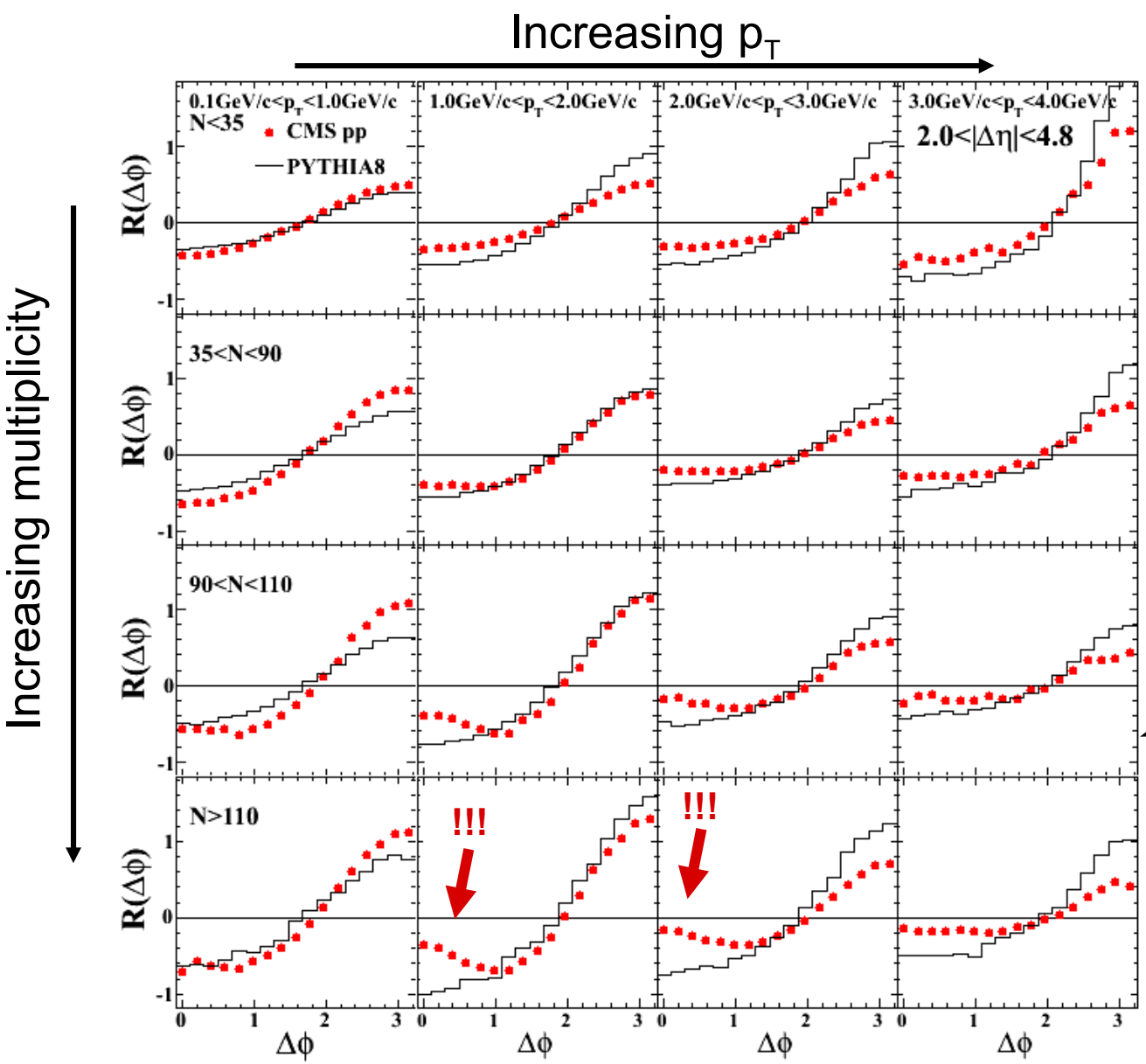
(d) N>110, 1.0GeV/c<p_T<3.0GeV/c



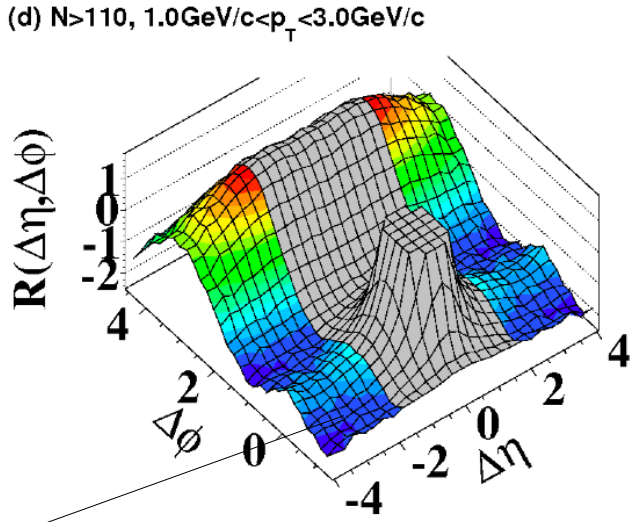
No ridge seen in Pythia 8

Same for Herwig++, madgraph, PYTHIA6

Results



Project |Δη| > 2 onto Δφ



(Fully corrected 7 TeV data.)

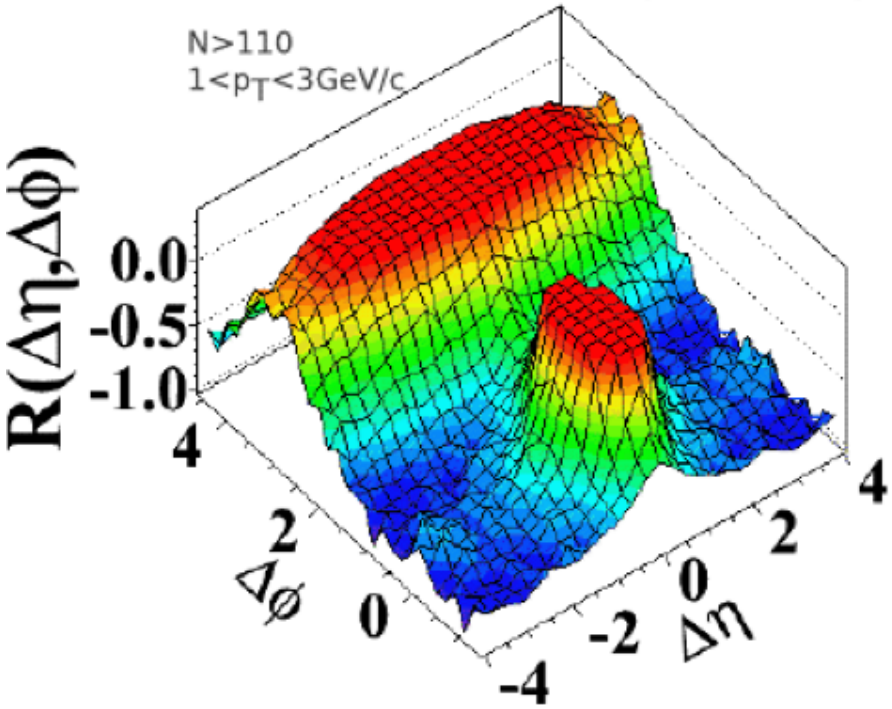
"Ridge" maximal for highest multiplicity and 1 < p_T < 3 GeV/c

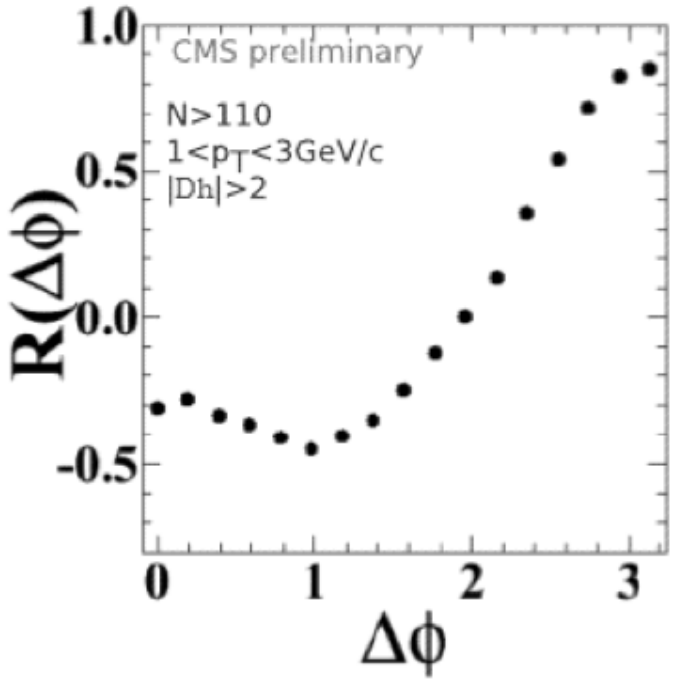
Cross-checks

Photon-Photon Correlations

Many cross-checks were done...
Here is one example.

Use ECAL "photon" signal
Mostly single photons from p^0's
No efficiency, and p_T, f smearing corrections





Qualitative confirmation
Independent detector, independent reconstruction

Gábor Veres ECT* Trento – QCD at the LHC, September 28, 2010

Summary

- **The results of the CMS measurement**

  "Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC"
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  were summarized.

- **An unexpected correlation effect has been observed at large $|\Delta\eta|$ around $\Delta\varphi \sim 0$. - "The Ridge":**

  - **Most pronounced at high multiplicities (N > 110)**
  - **Most pronounced at 1 < pt < 3 GeV**
  - **Not observed at low multiplicity events**
  - **Not observed in Monte Carlo generators**