Long-Range, Near-Side Angular Correlations in Proton-Proton Interactions in CMS

Guido Tonelli
CERN, INFN&University of Pisa

Gunther Roland
Massachusetts Institute of Technology (MIT)

On behalf of the CMS Collaboration

Today we have submitted the paper

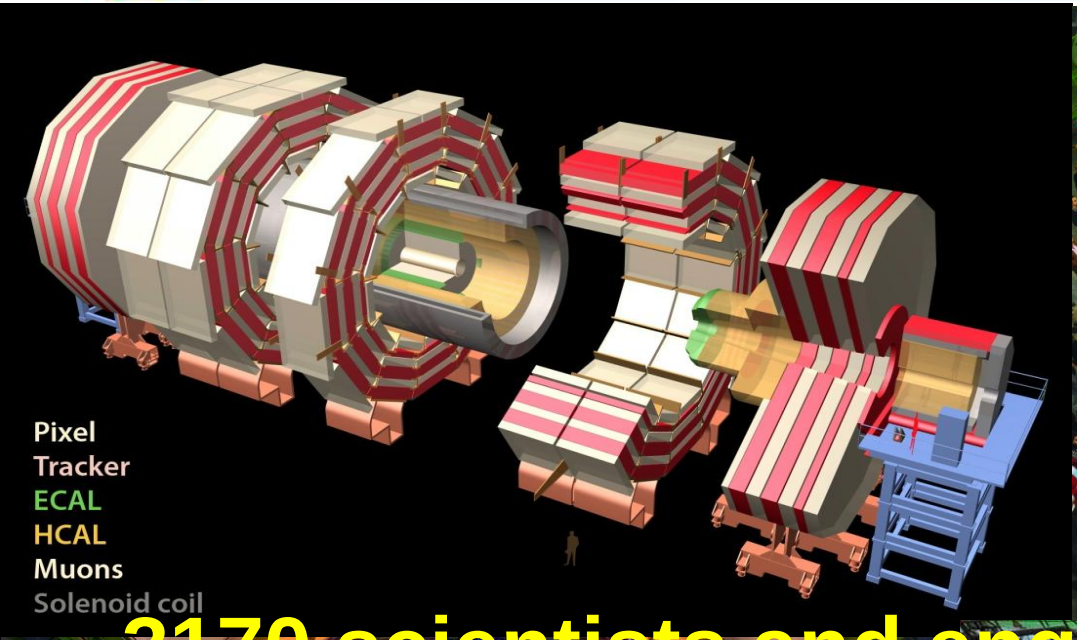
Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC

Abstract

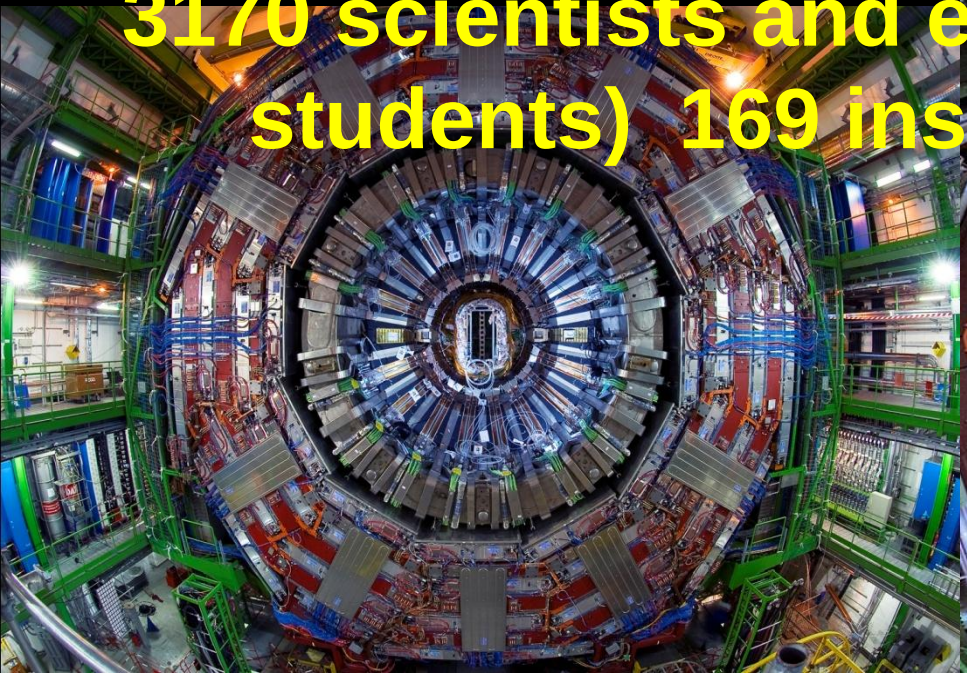
Results on two-particle angular correlations for charged particles emitted in proton-proton collisions at center-of-mass energies of 0.9, 2.36, and 7 TeV are presented, using data collected with the CMS detector over a broad range of pseudorapidity (η) and azimuthal angle (ϕ). Short-range correlations in $\Delta\eta$, which are studied in minimum bias events, are characterized using a simple "independent cluster" parametrization in order to quantify their strength (cluster size) and their extent in η (cluster decay width). Long-range azimuthal correlations are studied differentially as a function of charged particle multiplicity and particle transverse momentum using a 980 nb^{-1} data set at 7 TeV. In high multiplicity events, a pronounced structure emerges in the two-dimensional correlation function for particle pairs with intermediate p_T of 1–3 GeV/c, $2.0 < |\Delta\eta| < 4.8$ and $\Delta\phi \approx 0$. This is the first observation of such a long-range, near-side feature in two-particle correlation functions in pp or $p\bar{p}$ collisions.

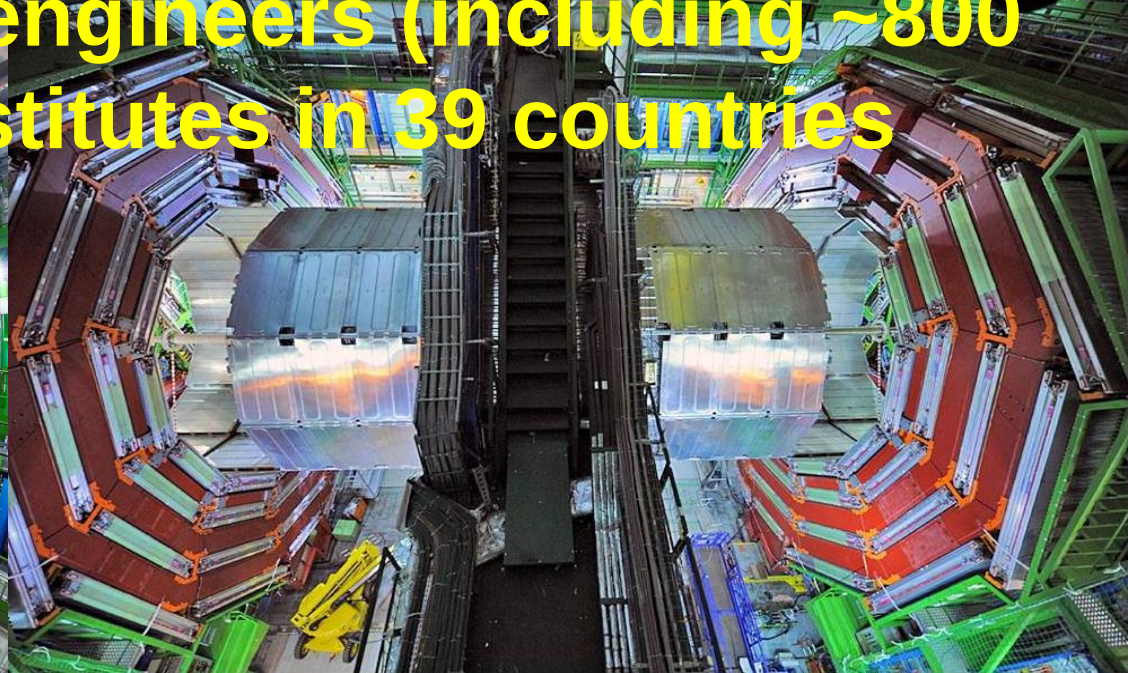
CERN-PH-EP-2010-031 Submitted to arXiv and JHEP

The CMS Collaboration

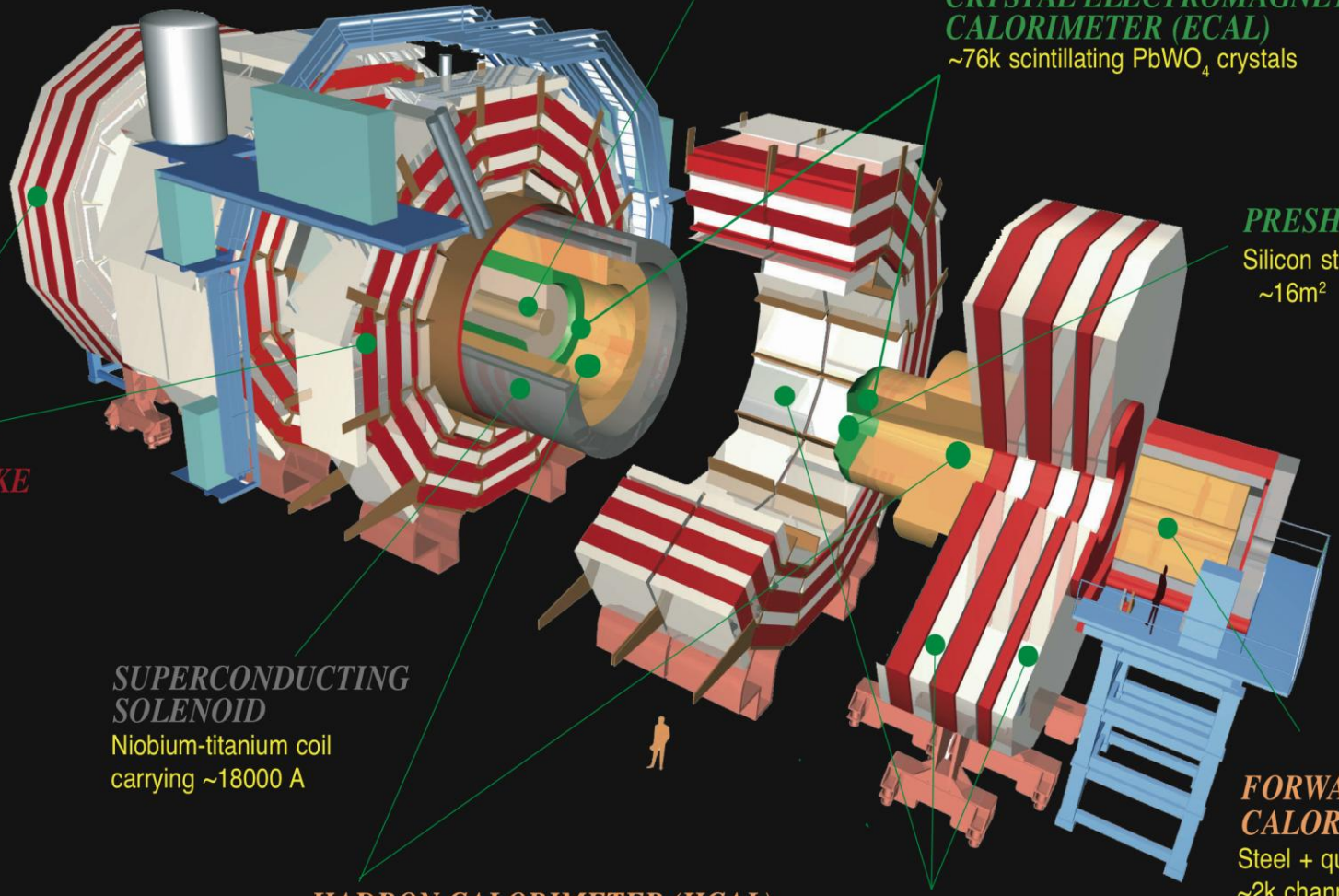


3170 scientists and engineers (including ~800 students) 169 institutes in 39 countries





CMS Detector



SILICON TRACKER
Pixels (100 x 150 μm²)
~1m² ~66M channels
Microstrips (80-180μm)
~200m² ~9.6M channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76k scintillating $PbWO_4$ crystals

PRESHOWER
Silicon strips
~16m² ~137k channels

STEEL RETURN YOKE
~13000 tonnes

SUPERCONDUCTING SOLENOID
Niobium-titanium coil
carrying ~18000 A

FORWARD CALORIMETER
Steel + quartz fibres
~2k channels

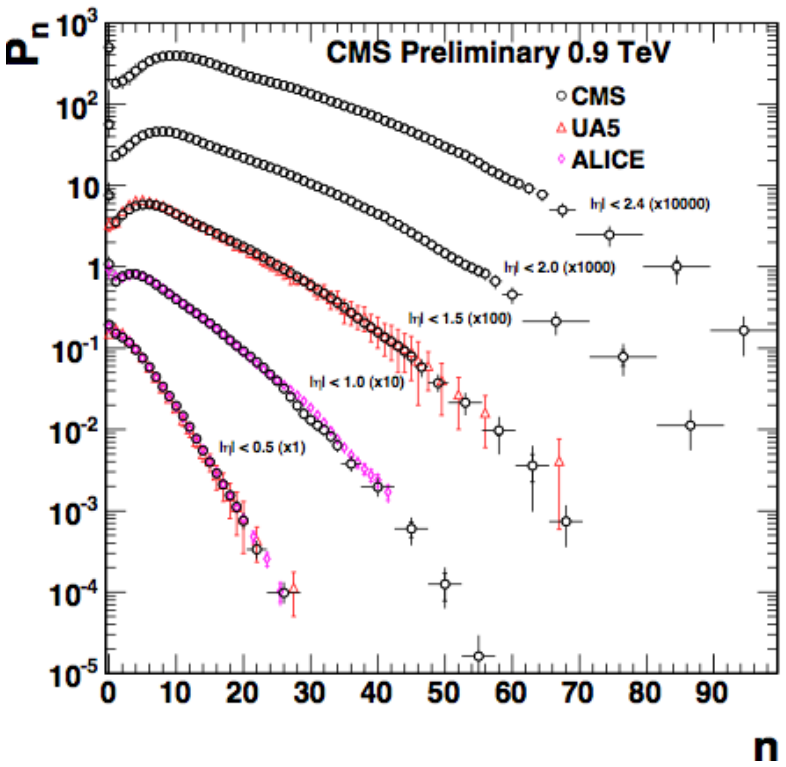
HADRON CALORIMETER (HCAL)
Brass + plastic scintillator
~7k channels

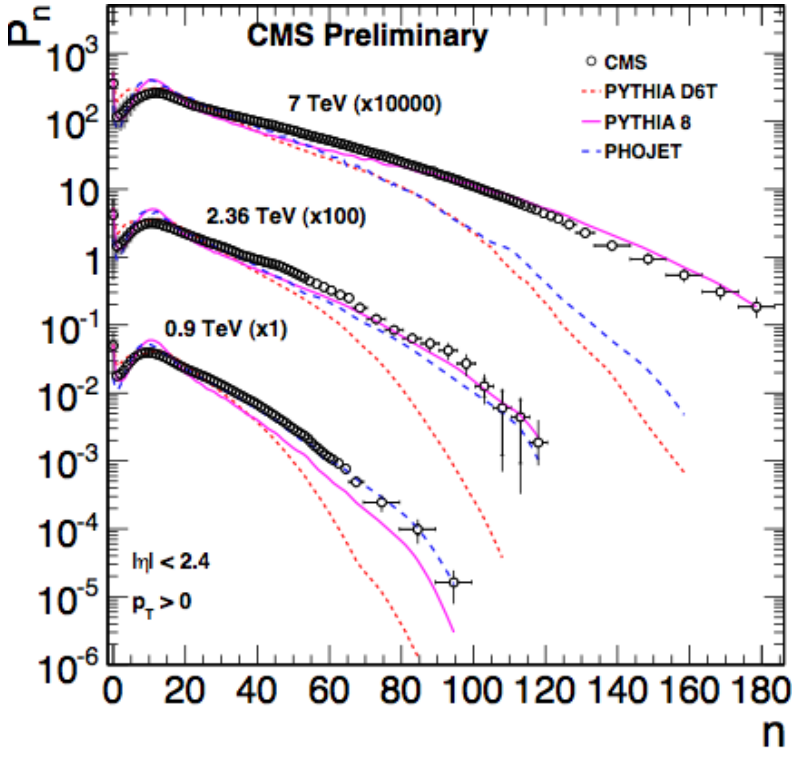
MUON CHAMBERS
Barrel: 250 Drift Tube & 480 Resistive Plate Chambers
Endcaps: 473 Cathode Strip & 432 Resistive Plate Chambers

Total weight	**: 14000 tonnes**
Overall diameter	**: 15.0 m**
Overall length	**: 28.7 m**
Magnetic field	**: 3.8 T**

High multiplicity studies in Minimum Bias events

Since March 30 we are exploring inch-by-inch the new territory made accessible by the LHC, starting from Minimum Bias collisions.

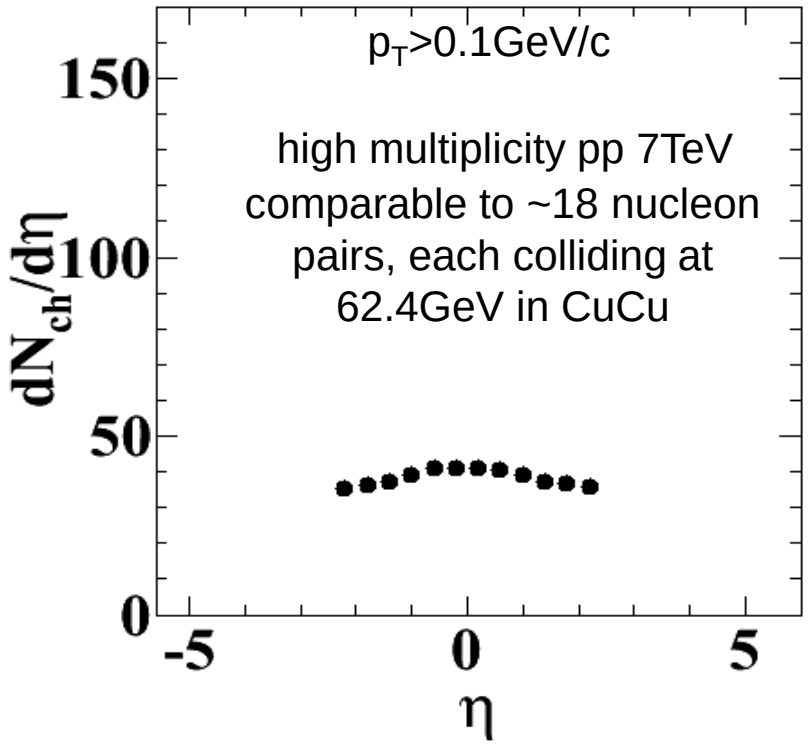




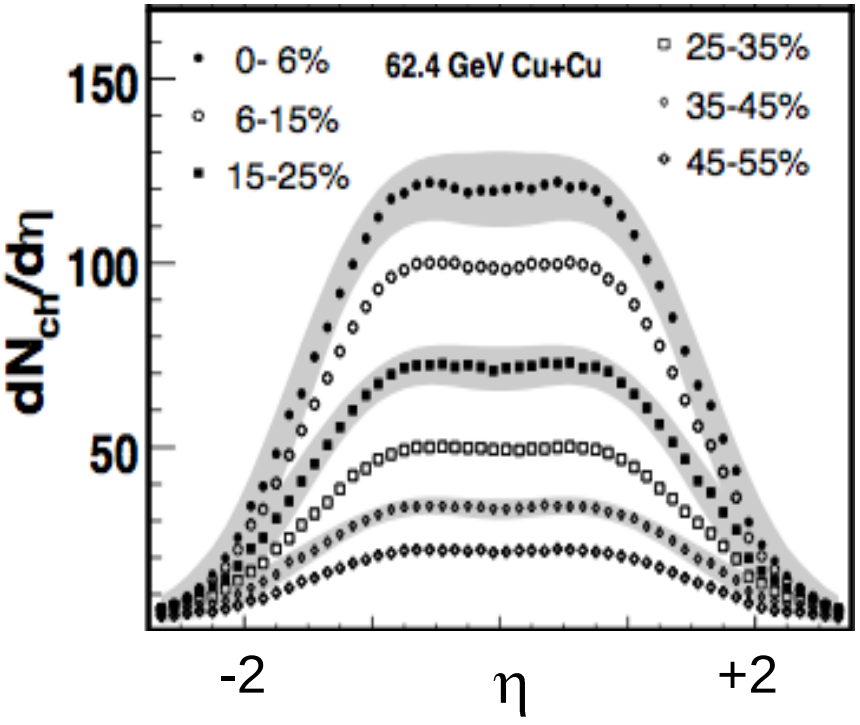
In this effort we try to make the best possible use of the large eta coverage of our detector, the redundancy of the apparatus and the flexibility of our trigger system. Given the preliminary results of studies of properties of minimum bias events, it was also natural to start collecting a large statistics sample of high multiplicity events.

Additional motivation for high multiplicity studies

CMS



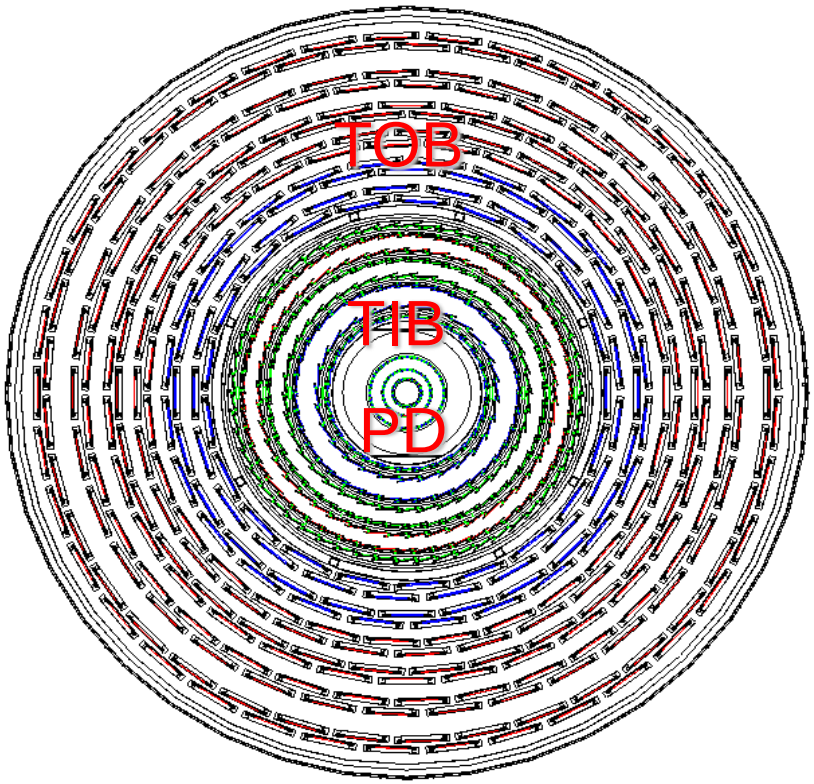
PHOBOS

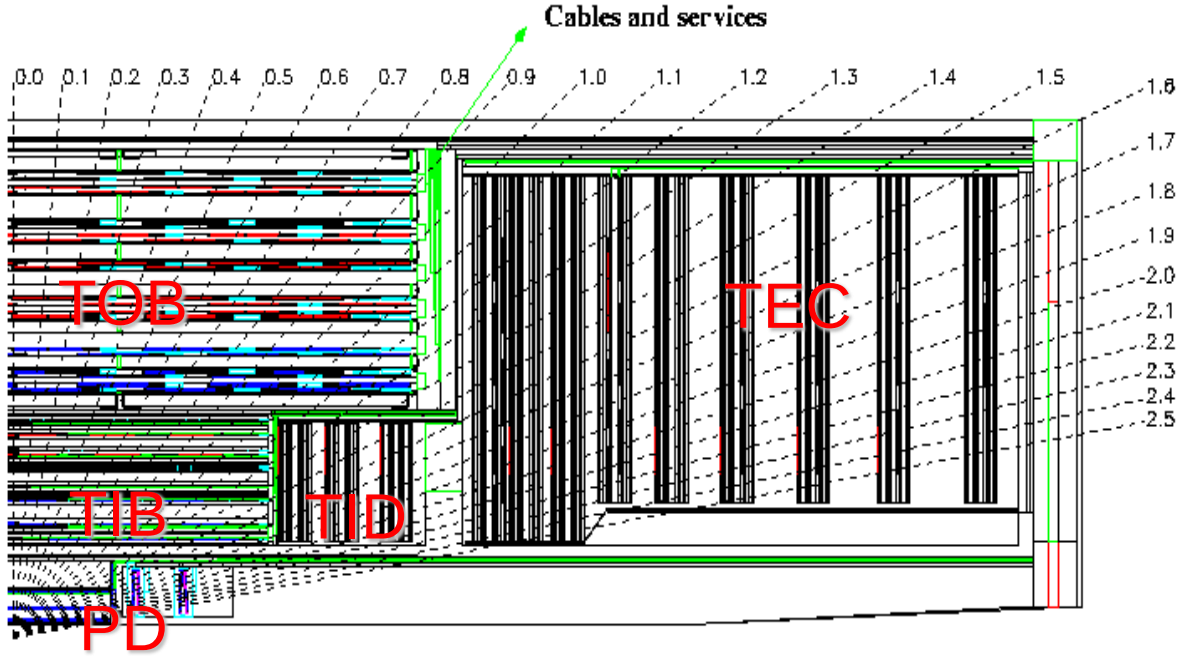


The particle densities in the high multiplicity events of proton-proton collisions at 7TeV begin to approach those in high-energy collisions of nuclei such as Copper.

It was considered natural to study the two particle angular correlations in LHC and compare the results with the ones obtained in relativistic heavy ion colliders like RHIC.

The CMS All Silicon Tracker

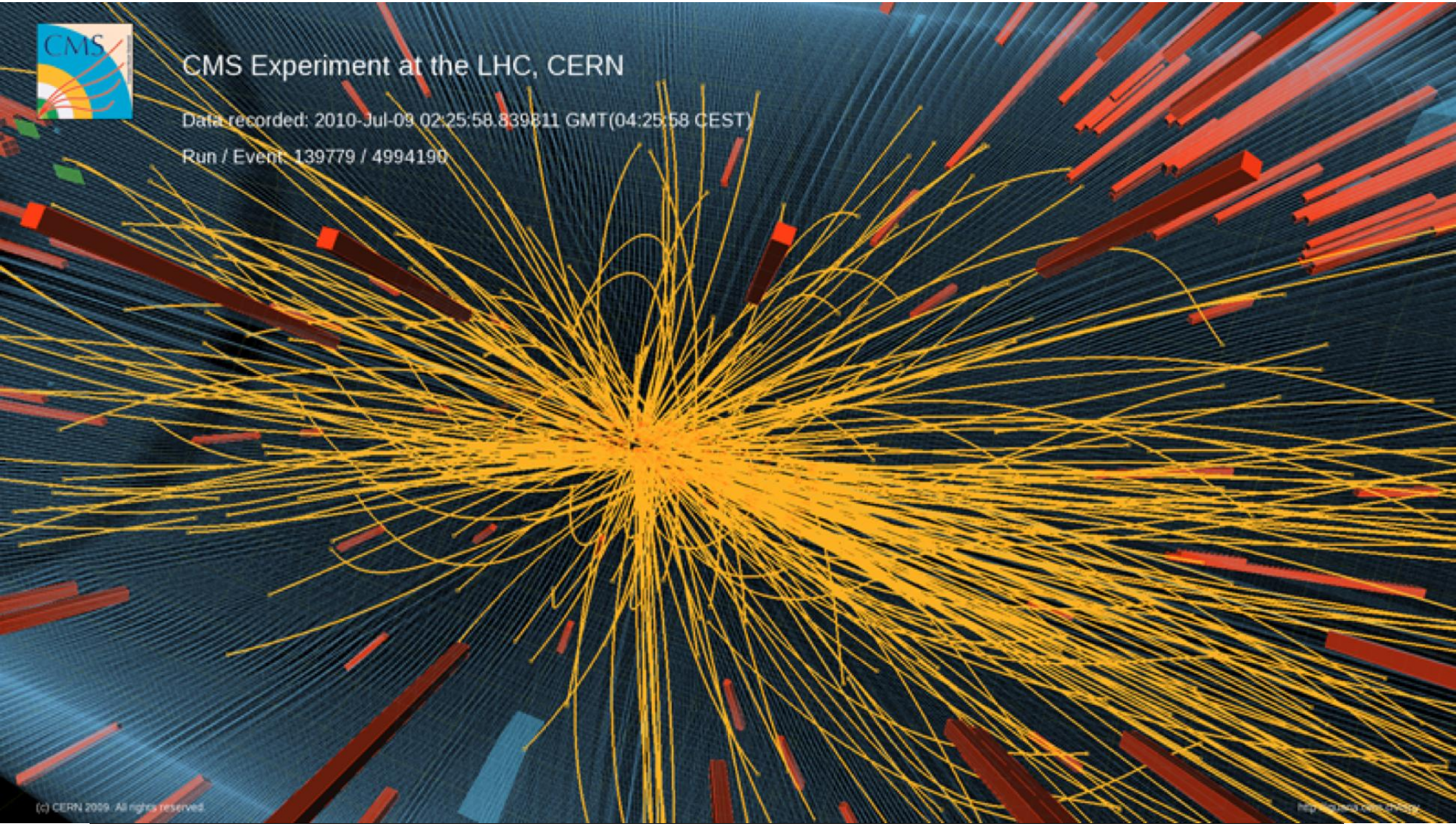




- Coverage up to **|η|<2.5**; extremely high granularity, due to the small cell size and high longitudinal segmentation, to keep low occupancy (~ a few%) also at LHC nominal luminosity.

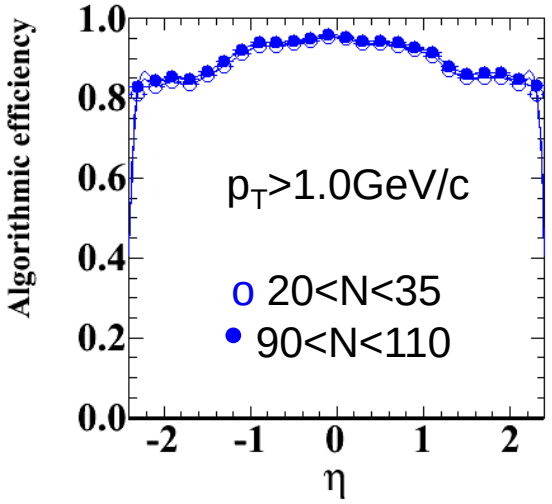
- It is the largest Silicon Tracker ever built: Strips: 9.3M channels; Pixels: 66M channels. **Operational fractions: strips 98.1%; pixel 98.3%**

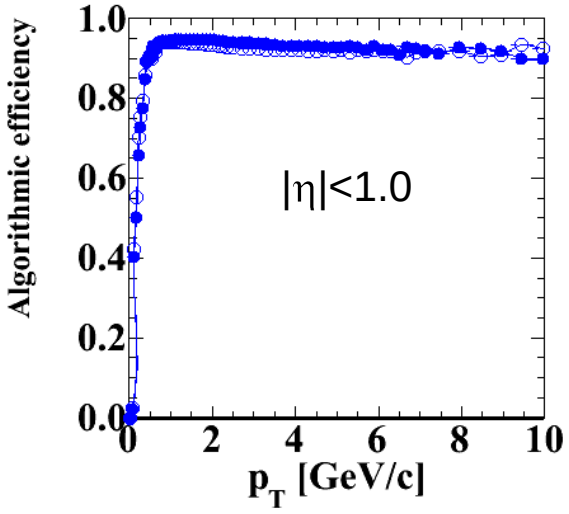
High multiplicity events at 7 TeV



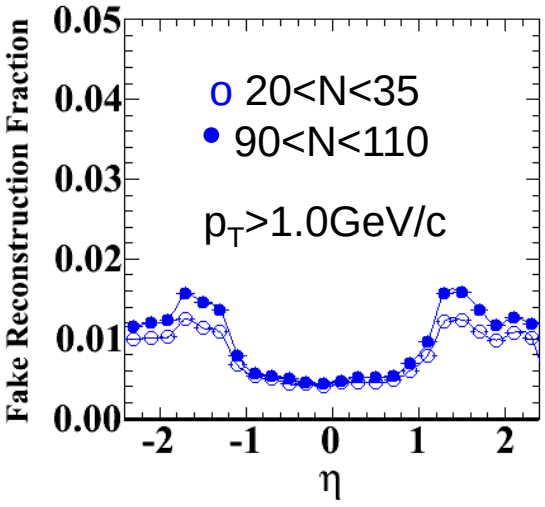
Tracking Performance in high multiplicity events

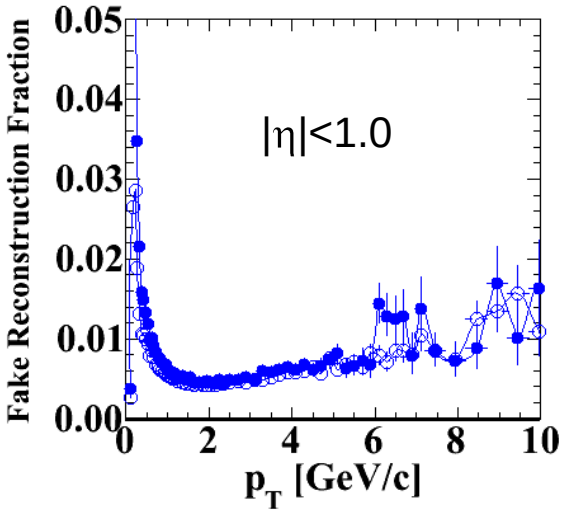
Tracking Algorithmic Efficiency:





Fake rate:





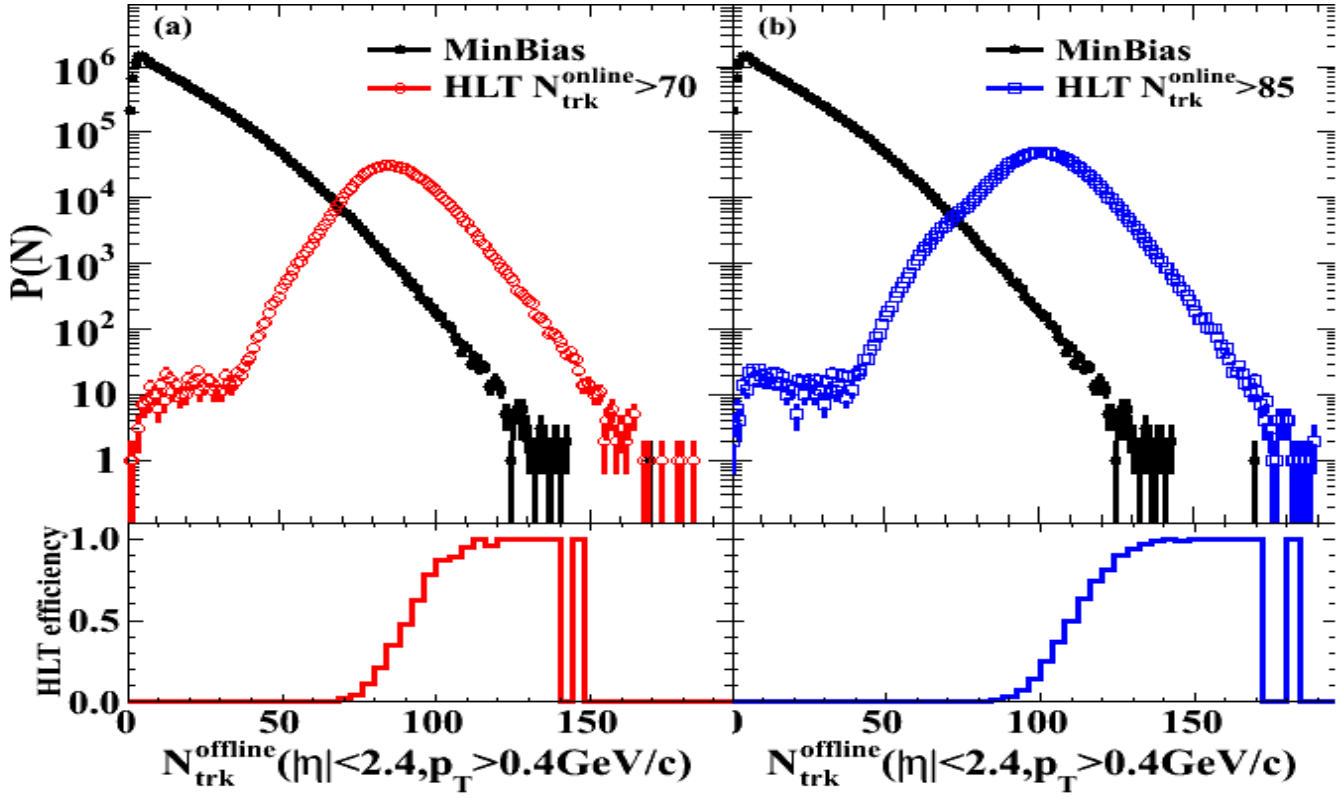
The highest particle density in high multiplicity events today is ~1 order of magnitude lower wrt to the typical particle density of LHC collisions at $L = 10^{34} cm^{-2} s^{-1}$.

The CMS Tracker has been designed to tackle thousands of tracks per event as will be the case with LHC running in pp at nominal luminosity.

It is foreseen to provide good tracking performance also for the imminent Heavy Ion running of LHC where we expect to have order of 10^4 tracks per event.

Triggering on high multiplicity

A **dedicated high multiplicity trigger** was implemented in the two levels of the CMS trigger system. Level 1 (L1): Sum of the total E_T (ECAL, HCAL, and HF) > 60 GeV.
High-level trigger (HLT): Number of online tracks built from 3 pixel detector layers > 70 and 85.



Statistics for high multiplicity events enhanced by O(10^3).
Total datasets corresponding to 980nb^{-1}

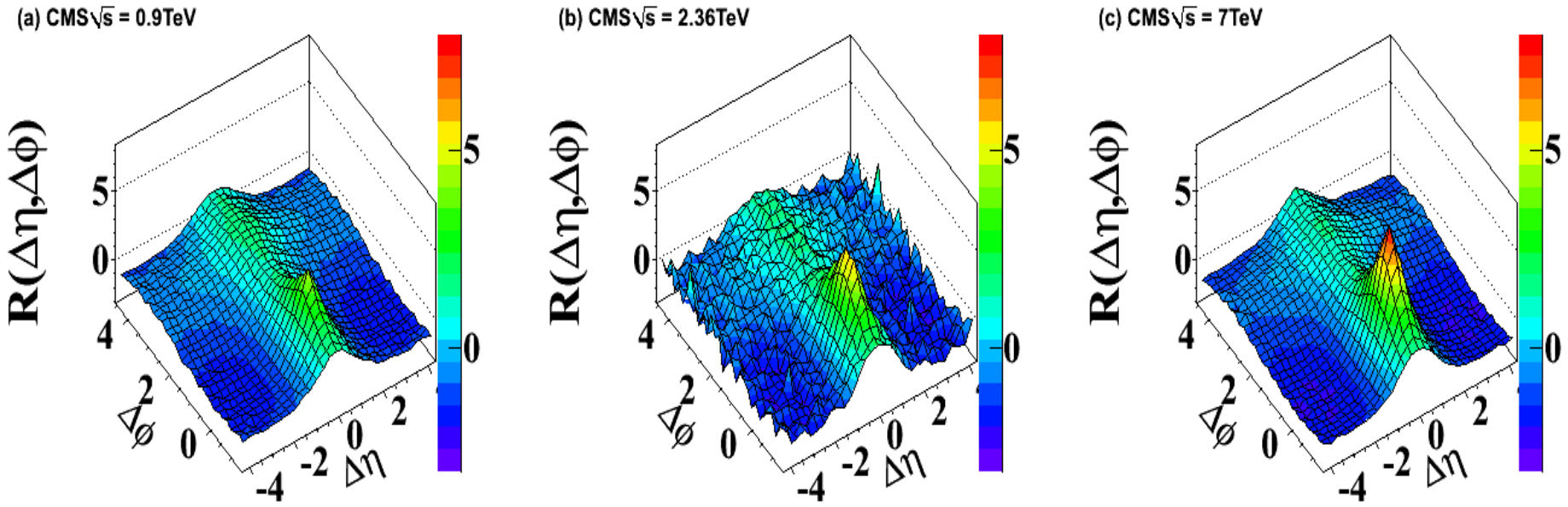
Two-particle angular correlations

We started studying the correlation function
For minimum bias events at different energies
in p_T inclusive distributions

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

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

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



p_T-inclusive two-particle angular correlations in Minimum Bias collisions

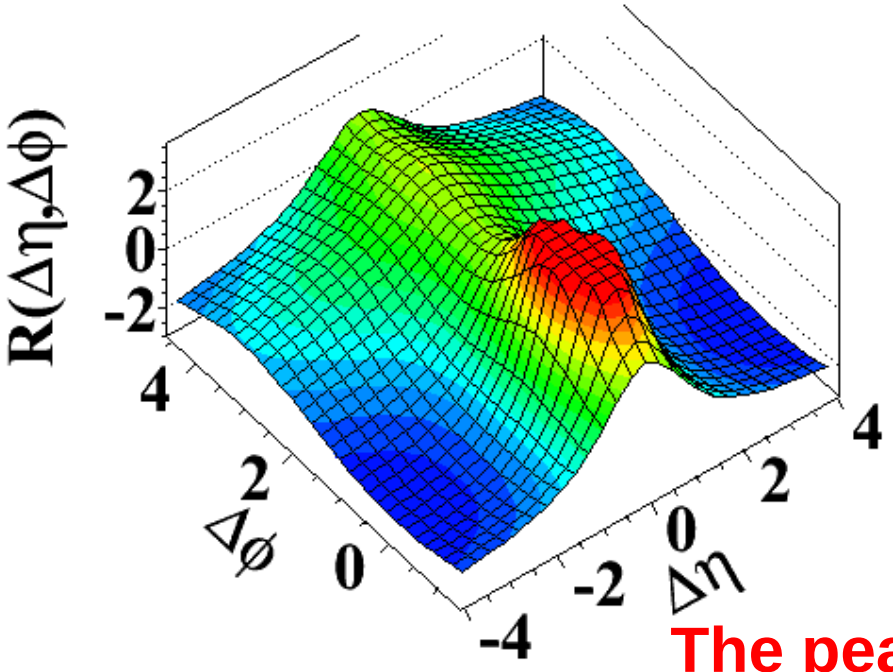
Then we used the high statistics data sets to study **the high multiplicity sample in different p_T bins.**

Results for inclusive p_T

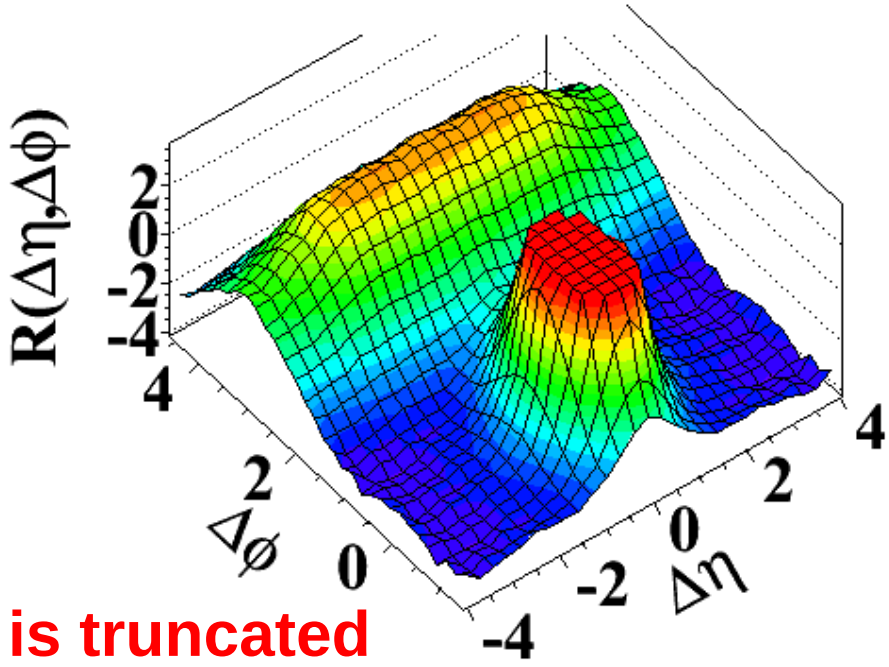
Minimum Bias
no cut on multiplicity

High multiplicity data set
and N > 110

(a) MinBias, p_T>0.1GeV/c



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



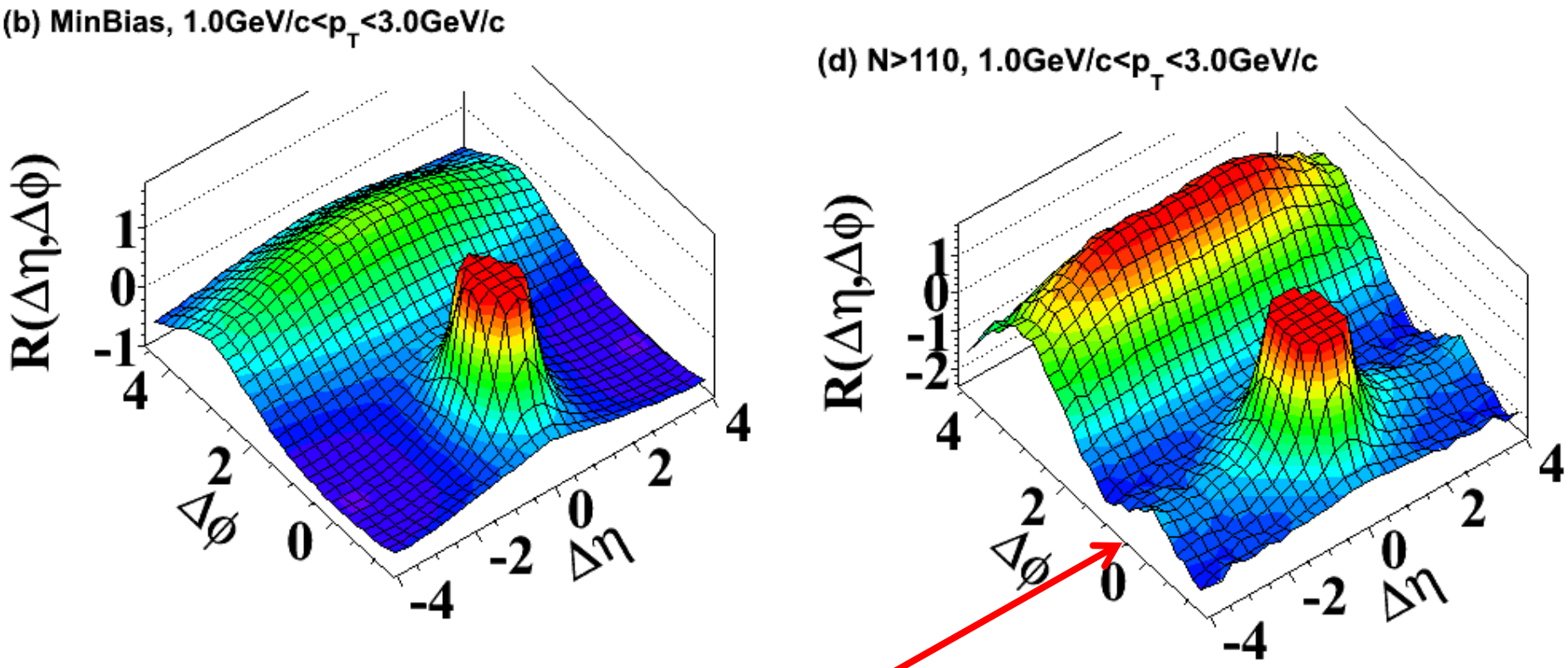
The peak is truncated in both distributions

Back-to-back jet correlations enhanced in high multiplicity sample.

Results for intermediate p_T:1-3GeV/c

Minimum Bias
no cut on multiplicity

High multiplicity data set
and N>110



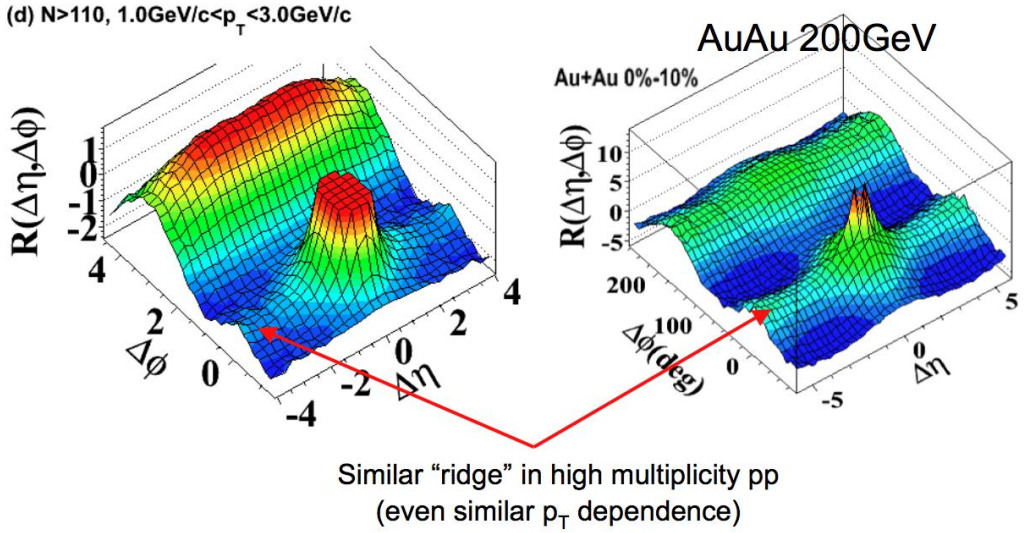
New "ridge-like" structure extending to large $\Delta\eta$ at $\Delta\phi \sim 0$

First observation of a ridge-like structure in pp collisions

The new feature is clearly seen for large rapidity differences $2 < |\Delta\eta| < 4.8$ in events with N ~ 90 or higher. The enhancement is most evident in the intermediate p_T range $1 < p_T < 3$ GeV/c.

This is the first observation of such a long-range, near-side feature in two-particle correlation functions in pp or p-pbar collisions.

It is a small effect, however, very interesting. Although there are also differences, it resembles a similar feature observed at RHIC that was interpreted as being due to the hot and dense matter formed in relativistic heavy ion collisions.



First conclusion.

The new feature has appeared in our analysis around middle of July in the hottest days of the preparation for ICHEP. We have immediately set-up an independent analysis (control group) and organized a full set of tests and cross-checks to kill the effect. **Gunther will report on the analysis and further cross-checks in full detail.**

If we are here today it is because we didn't succeed to kill it.

We have therefore submitted the paper to expose our findings to the scrutiny of the scientific community at large.

Since there are a number of potential explanations, today's presentation is focussed on the experimental evidence in the interest of fostering a broader discussion on the subject.

We are planning many additional studies aimed at producing a better understanding of the dynamics of the effect. The incoming Heavy Ion run will be an additional important test bench.