

NEW QCD RESULTS FROM CMS

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OUTLINE

CMS detector overview (very fast!)

Bulk properties

- Transverse momentum and pseudo-rapidity
- Charged particle multiplicities
- Two-particle correlations
- Underlying event measurement
- Inclusive jet studies
 - Measurement of the Inclusive Jet Cross
 - Hadronic Event Shapes
 - Jet Transverse Structure
 - Measurement of the 3-jet to 2-jet Cross Section Ratio
- Conclusions



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CMS DETECTOR OVERVIEW





CHARGED PARTICLE PSEUDO-RAPIDITY DISTRIBUTIONS

Phys. Rev. Lett. : 105 (2010) , pp. 022002



- Events reconstructed using the silicon pixel and strip tracker
- inelastic non-single-diffractive (NDS) interactions event selected
- The charged particle multiplicity (dN_{ch}/dη) distribution was calculated as the weighted average of the following three different reconstruction methods
 - Pixel hits, Pixel hit pairs, Reconstructed tracks
- The measurement at $\sqrt{s} = 0.9$ TeV is in agreement with the previous measurements.

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CHARGED HADRON PT SPECTRA



PAS :QCD-10-06

Events reconstructed using the silicon pixel and strip tracker in range $|\eta|$ < 2.4

- Charged-hadron yield (NSD) vs P_{T} data have systematics errors smaller that symbols!
- The average transverse momentum of charged hadrons was obtained from the fits of the transverse-momentum spectrum
- CMS data follow, with previous experiment data, a quadratic function of ln(s) [Nucl. Phys. B335]

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- Multiplicity (n) is measured by counting the number of tracks associated with primary vertex
- results shown needing to improve (tuning of) models
- so far no model is able to describe simultaneously multiplicity and p_T distributions over whole range and at different \sqrt{s}



Wednesday, December 1, 2010

PAS :QCD-10-04



TWO-PARTICLE CORRELATIONS



- Two particle angular correlation (R_N) is obtained using the charged tracks with p_T > 0.5 GeV/c
- Signal distribution (S_N) is obtained from the tracks with in the same event
- Background distribution (B_N) is obtained using the tracks from different events (mixing).



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

$$B_N(\Delta\eta,\Delta\phi) = \frac{1}{N^2} \frac{d^2 N^{\text{mixed}}}{d\Delta\eta d\Delta\phi}$$



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TWO-PARTICLE CORRELATIONS





PYTHIA describes the correlation data poorly both K_{eff} and decay width δ

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10⁴

PYTHIA p+p, default

10²

PAS: QCD-10-02

 10^{3}

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√s (GeV)

PYTHIA p+p, D6T

TWO-PARTICLE CORRELATIONS

2-D two-particle correlation functions for 7 TeV pp minimum bias events (a and b) and for high multiplicity track events (N>110) (c and d). The sharp near-side peak from jet correlations is cut off in order to better illustrate the structure outside that

region. Pronounced structure at large $\delta\eta$ around $\delta\phi$ ~0



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UNDERLYING EVENT (UE) STUDIES



- Clusters of tracks, "track jet", with the largest p_T are called the leading object. These are expected to reflect the direction of the parton in the hard scattering.
- Three topological directions defined are
 - Towards , Away, Transverse
- Transverse region is expected to be sensitive to underlying event
- Main observables: charged multiplicity density (dN_{ch}/d η d ϕ) and energy density Σ p_T/d η d ϕ
- A good description of UE properties is crucial fro precision measurements of SM processes and the search of new physics at LHC
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UE: DENSITIES IN TRANSVERSE REGIONS



Fast rise for $p_T < 8$ GeV/c (4 GeV/c), attributed mainly to the increase of MPI activity, followed by a Plateau-like region with \approx constant average number of selected particles and a slow increase of $\sum p_T$, in a saturation regime.

Increase of the activity with \sqrt{s} also corroborates MPIs (growth with PDFs).

• Poor description of the rise. P0 has the worst shape. CW underestimates the plateau regions. D6T, with slower energy dependency of the p_T cut-off, overestimates the plateau regions.

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UE: PARTICLE DENSITIES IN TRANSVERSE REGION



- Normalized distributions for multiplicity, Σp_T and p_T are presented for leading track jet of $p_T > 3 \& 20 \text{ GeV/c}$
- The distributions get harder upon on the selection of harder scale indicating the increase in the UE as the hard scale increases
- The observation of 10 GeV/c in p_T indicates the presence of hard component in the transverse region
 PAS QCD-10-001

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INCLUSIVE JET CROSS-SECTION

- Events are collected from a combination of Minimum Bias and jet triggers.

- Inclusive jet cross section uses ansatz unfolding to get to the particle level

- Main systematics for inclusive jet cross section, as for most other jet analyses: jet energy scale (5%), jet resolutions (10%) and luminosity (11%)

Inclusive jet p_T spectra are in good agreement with NLO theory



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HADRONIC EVENT SHAPES



• Event shapes provide geometric information about energy flow in hadronic events

- Essential for tuning parton shower and non-perturbative components of Monte Carlo event generators
- Event shapes are less sensitive to jet reconstruction and jet energy scale and experimental resolution
- The event shape distributions from PYTHIA 6 and HERWIG++ show satisfactory agreement with the data, while discrepancies are found between the data and predictions from ALPGEN, MadGraph and PYTHIA 8.

PAS QCD-10-013

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JETTRANSVERSE SHAPE



- Jet transverse shapes probe transition between hard pQCD and soft gluon radiation
- Good agreement between the data and theoretical models is observed
 - At low jet transverse momentum (20< p_T<30 GeV) the predicted transverse jet shape as measured from charged particles differs slightly from the measured data, with Pythia tune D6T predicting too narrow and Herwig predicting too broad jets.





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DI-JET MASS DISTRIBUTION



• Search for narrow resonances in di-jet final states. Sensitive to coupling of any new massive object to quarks and gluons.

 95% CL mass limits String resonances >2.1TeV, Excited quarks >1.14TeV Axigluons/Colorons >1.06TeV, E6 Diquarks>0.58TeV. e

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• Systematic due to jet energy correction and luminosity is minimal in the ratios

- The overall multiplicative correction factor to the data is within $\pm 5\%$ of unity
- The ratio plateaus at value of about 0.8 in agreement with predictions of PYTHIA and MadGraph MC calculations





CONCLUSIONS

- The CMS experiment at the LHC performs extremely well: has recorded ≈50 pb⁻¹ (pp) of data and will continue recording more data next year.
- Less than 6 months after start-up at 7 TeV, with 3 pb⁻¹ in hand there is already an amazing plethora of results
- QCD studies progressing well on all fronts (high and low-pt)
- Starting to make comparisons with theoretical predictions
- Stay tuned for more updates and new results....

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References: Gateway to collection of all CMS Results: <u>https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults</u>

- PAS QCD-09-10 : "Transverse momentum and pseudo-rapidity distributions of charged hadrons in proton-proton collisions at SQRT(s)=0.9 and 2.36 TeV"
- PAS QCD-10-06 : "Transverse-momentum and pseudo-rapidity distributions of charged hadrons in pp collisions at sqrt(s) = TeV"
- PAS QCD-10-04 : "Charged particle multiplicities at sqrt(s)=0.9, 2.36 and 7 TeV"
- PAS QCD-10-02 : "Two-particle correlations and cluster properties from two-particle angular correlations in p+p collisions at sqrt(s) = 0.9, 2.36TeV and 7 TeV"
- PAS QCD-10-011 : "Measurement of the Inclusive Jet Cross Section in pp Collisions at 7 TeV"
- PAS QCD-10-013 : "Hadronic Event Shapes in pp Collisions at 7 TeV"
- PAS QCD-10-014 : "Jet Transverse Structure and Momentum Distribution in pp Collisions at 7 TeV"
- PAS QCD-10-012 : "Measurement of the 3-jet to 2-jet Cross Section Ratio in pp Collisions at sqrt(s) = 7 TeV"
- PAS QCD-10-001 & CERN-PH-EP/2010-014, submitted to EPJC: "First Measurement of the Underlying Event Activity at the LHC with $\sqrt{s} = 0.9 \text{ TeV}$ ".
- PAS QCD-10-010: "Measurement of the Underlying Event Activity at the LHC with $\sqrt{s} = 7$ TeV and Comparison with $\sqrt{s} = 0.9$ TeV".
- PAS QCD-10-005: "Measurement of the Underlying Event Activity with the Jet Area/Median Approach at 0.9 TeV".

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