MUELLER–NAVELET JETS AT THE CMS*

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In this paper, a brief description of a measurement of Mueller–Navelet dijet angular decorrelations is presented. The measurement is sensitive to effects of BFKL evolution. The experimental results are presented as function of the rapidity separation y between jets, and compared to the predictions of various Monte Carlo models and NLL BFKL calculations.

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1. Introduction

Due to large calorimetric coverage, data collected by the Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) provides a valuable testing ground for the QCD in the low-x region. The variable x denotes the fraction of the proton longitudinal momentum carried by an interacting parton. In this paper, a measurement of angular decorrelation of jets widely separated in the rapidity is described [1]. Angular decorrelation is a measure of $\Delta\phi$, where $\Delta\phi = \phi_1 - \phi_2$ is the difference between the azimuthal angles ϕ_1 and ϕ_2 of the jets most forward and backward in rapidity. The measurement is sensitive to low-x effects, such as BFKL evolution. In the low-x region, the standard approach to QCD perturbative calculations, where powers of $\log(Q^2)$ are summed, (DGLAP — Dokshitzer–Gribov–Lipatov–Altarelli–Parisi [2–6]) may be not sufficient. The alternative approach is the BFKL (Balitsky–Fadin–Kuraev–Lipatov [7–9]) equation, where powers of $\log(1/x)$ are summed. The aim of the measurement is to observe, for the first time, BFKL effects in the experimental data. The results are compared to both DGLAP- and BFKL-based MC generators, and to NLL BFKL calculations.

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2. Experimental setup

A complete description of the CMS detector can be found in [10]. In this section, a brief description of selected detector subsystems especially important for the presented analyses is given.

To measure momenta of charged particles, the CMS uses a superconducting solenoid that provides 3.8 T magnetic field parallel to the beam axis. Tracks of charged particles are measured by silicon pixel detectors and strip trackers for rapidity $|y| < 2.5$. Electromagnetic calorimeter (ECAL) and hadronic calorimeter (HCAL) extend to $|y| < 3$. ECAL is a lead tungstate crystal calorimeter with cells grouped in towers of size $\Delta y \times \Delta\phi = 0.0174 \times 0.0174$ in the central part of the detector ($|y| < 1.5$) and 0.05×0.05 in $1.5 < |y| < 3.0$ region. The HCAL is a sampling calorimeter made of alternating layers of the absorber and the scintillator. The segmentation in the central part of HCAL is 0.087×0.087 and 0.17×0.17 in $1.6 < |\eta| < 3$. The Hadronic Forward (HF) calorimeter is the calorimeter covering the most forward pseudorapidity region from $|y| = 3$ to $|y| = 5.2$. The HF detector is located 11.2 m from the nominal interaction point and consists of steel absorbers containing embedded quartz fibres. The granularity of HF is 0.175×0.175 up to $|y| < 4.7$ and 0.175×0.35 at larger pseudorapidities. The calorimetric coverage of the CMS detector extends to rapidities $y = 5.2$. For jets with transverse momenta $p_{\mathrm{T}} = 35$ GeV such rapidity range corresponds to exchanged objects x of the order of 10^{-4}.

3. Events selection and data analysis

Mueller–Navelet (MN) [11] dijets are defined as the pair of jets with the largest separation in rapidity Δy from all pairs of jets in the event. Only jets with $p_{\mathrm{T}} > 35$ GeV are considered. For each MN pair, the angular distance is calculated: $\Delta\phi = \phi_1 - \phi_2$. Not only $\Delta\phi$ distributions are studied, but also the average cosines: $C_n = \langle \cos(n(\Delta\phi - \pi)) \rangle$ for $n \in \{1, 2, 3\}$, corresponding to the coefficients of a Fourier series in $\Delta\phi$, and their ratios. Ratios of correlation factors are predicted to be more sensitive to BFKL evolution than $\Delta\phi$ distributions. The measurement is done as a function of Δy, where effects of BFKL should be more pronounced for large rapidity separation.

The analysis is based on 2010 data collected at 7 TeV. Jets are defined using the anti-k_{t} [12] algorithm with cone radius $R = 0.5$. In addition to a standard single-jet trigger, a dedicated forward–backward trigger is used. It selects events with jets with uncorrected transverse momenta over 15 GeV and separation by at least 6.0 units of rapidity. This trigger provides a larger sample of rare events with large Δy. Two samples are merged with an algorithm described in [1]. The efficiency of the triggers for the jet sample considered is estimated to be 100%.

All results are corrected for experimental effects, such as finite jet p_{T} resolution, to the stable particle level. Corrections are evaluated using Pythia 6 [13] and Herwig++ [14] predictions passed through full detector simulation. The correction factors for each observable were calculated using Monte Carlo, from the ratio of the bin contents before and after detector simulation. Differences of correction factor between Pythia 6 and Herwig++ are taken as an input to systematic uncertainty. Correction factors for presented analysis are from 0 to 40%. Implementing correction to the stable particle level allows a direct comparison of experimental data to theoretical predictions corrected for non-perturbative effects.

The largest contribution to the systematic uncertainty of the measurement comes from the Jet Energy Scale. Smaller contributions to the systematic uncertainty comes from correction factors accounting for the finite resolution of the detector, and pile-up.

4. Results

In Fig. 1, $\Delta\phi$ distributions for the bin with the smallest Δy $(0<\Delta y<3.0)$ and the largest Δy $(6.0 < \Delta y < 9.4)$ are presented. The systematic uncertainties are shown as a grey band. Results are compared to different Monte Carlo predictions. For the most central rapidity bin $(0 < \Delta y < 3.0)$, the DGLAP-based Monte Carlo generators Pythia 6 and Herwig++ provide a good description of the data. For large y separation, DGLAP-based generators show deviation outside experimental uncertainty for small $\Delta\phi$. The BFKL based generator Cascade [15] shows too large decorrelation compared to the data. The best description is provided by Herwig++.

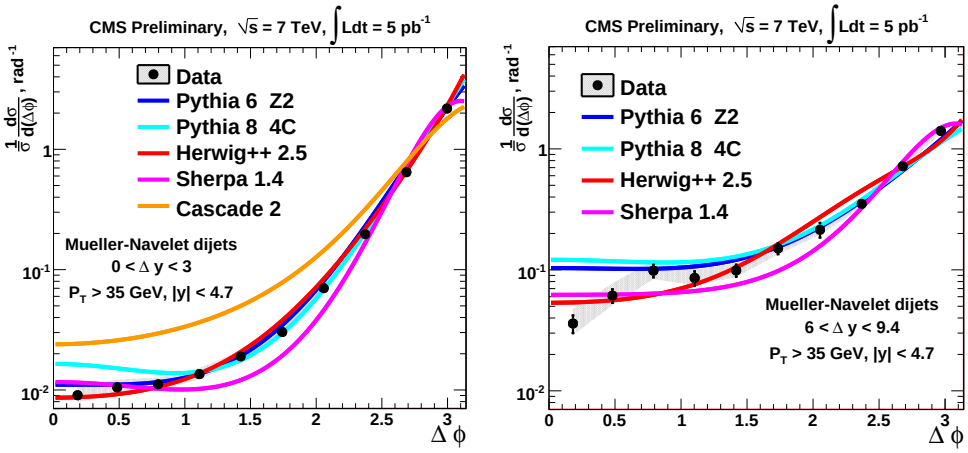


Fig. 1. Results for measurements of $\Delta\phi$ for two bins of Δy, compared to different Monte Carlo predictions.

In Fig. 2 results of C_1 measurement are presented. Average cosines decrease with increasing Δy. Pythia 6 and Pythia 8 [16], Herwig++ provide good description of experimental data. Nevertheless, DGLAP-based generators show slightly stronger decorrelation than observed. Cascade, incorporating BFKL elements, strongly overestimates decorrelation.

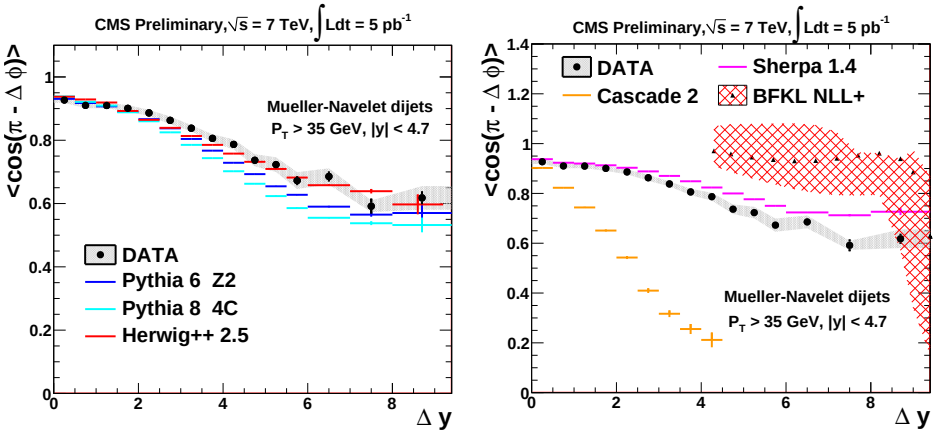


Fig. 2. Results for measurements of $C_1 = \langle \cos(\Delta\phi - \pi) \rangle$ for different Δy, compared to Monte Carlo predictions.

Other observables that are predicted to suppress DGLAP contribution are ratios of correlation factors. The measured C_2/C_1 ratios are presented in Fig. 3. DGLAP-based Monte Carlos provide good description of the

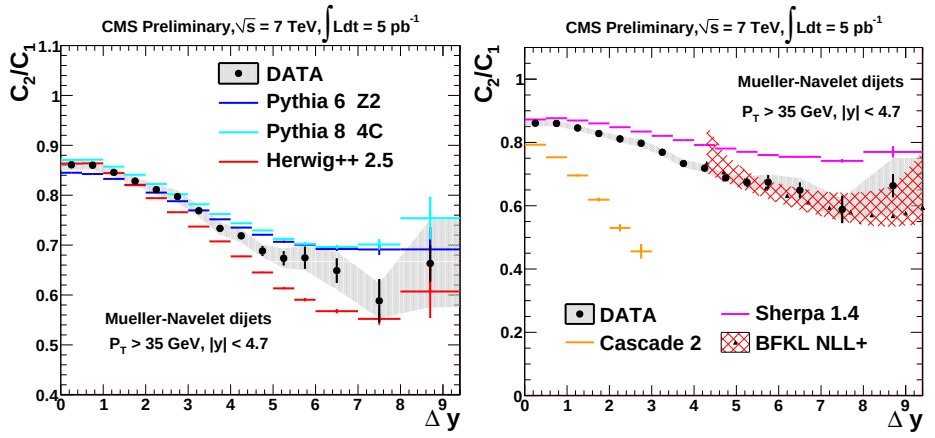


Fig. 3. Results for measurements of $C_2/C_1 = \langle \cos 2(\Delta\phi - \pi) \rangle \,/\, \langle \cos(\Delta\phi - \pi) \rangle$ for different Δy, compared to Monte Carlo predictions.

data, within experimental uncertainties. There is a difference between Pythia generators and Herwig++. Cascade underestimates and Sherpa [17] overestimates C_2/C_1 values. The NLL BFKL calculations [18] provide a good description of ratios, nevertheless they are predicted with large theoretical uncertainties.

5. Summary

A measurement of the angular correlations between Mueller–Navelet dijets, expected to be sensitive to BFKL evolution effects, has been performed as a function of separation in rapidity between the jets. While no clear indication of BFKL effects was observed in the data, discrepancies between various theoretical predictions and the data require further studies.

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