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Very Forward Jets as A Probe for Low-x Parton Evolution

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JETS in high energy hadron-hadron collisions emerge from the interaction of partons at high transverse momenta . The dynamic of hadron jets in proton-proton collisions provides essential information about Parton scattering. The studying of very forward dijet events is very important to enhance the sensitivity to very small-x Parton dynamics. Azimuthal angle decorrelation is a sensitive probe for details of QCD radiation in hard parton scattering. A study of azimuthal angle decorrelations of Mueller-Navelet and inclusive dijet cross-section in proton-proton collisions were performed for jets with pT>5 GeV and different values of pseudorapidity $\Delta\eta$ using different Monte Carlo generators samples at = 13 TeV. This work using various Monte-Carlo generators to make comparison that allows distinguishing among various Monte-Carlo generators and their tunes. Monte Carlo generator samples used are Pythia8 CUETP8M1, Pythia8 MBR and EPOS-LHC. For each value of pseudorapidity $\Delta\eta$, the dijet cross-section and $\Delta\varphi$ distributions for MN dijets are measured.

Keywords : Forward dijet event, Azimuthal angle decorrelation, Mueller-Navelet, MN dijets

Introduction

Jets in high energy hadron-hadron collisions emerge from the interaction of partons at high transverse momenta . The cross-section of jet production can be described as a series in perturbative quantum chromodynamics. Inclusive jet production measured over a wide range in transverse momenta and as a function of rapidity, y is well described by predictions from pQCD and used to constrain the Parton densities [1,2]. The production of dijets has also been measured at highest energies, and a good description by theory has been obtained [3, 4].

QCD is well tested in hard processes, and the data are successfully described by perturbative QCD calculations within the framework of collinear factorization and Dokshitzer- Gribov-Lipatov-Altarelli-Parisi (DGLAP) evolution equations [5–6]. The dynamic of hadron jets in proton-proton collisions provides essential information about Parton scattering. Perturbative QCD at the leading order (LO) predicts the production of a back-to-back in azimuthal angle ϕ jets in hard parton scattering. Azimuthal angles decorrelations of jets are due to higher-order effects described by the parton showering in the initial and final states of the scattering process.

When the separation in pseudorapidity ($\Delta\eta$) between the jets is very small or, particular vast regions of phase space are probed. At small pseudorapidity separation between jets, both jets move in a similar direction with a small invariant dijet mass. The dijet system has to be balanced by one or more additional jets. A different scenario is obtained at large $\Delta\eta$, when the jets are opposite in η, and a large dijet invariant mass is obtained. In this region, additional soft partons can be emitted between the jets (BFKL [7–9] predicts an increase of radiation for increasing $\Delta\eta$). Previous measurements of dijet production at large rapidity separation [10,11] are reasonably well described by Monte Carlo event simulation or calculations at next to leading order in pQCD, and no significant sign for BFKL effects is observed.

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The presented measurements have initially been motived by a search for BFKL effects (Mueller-Navelet jets [12]). Still, they are also interested in a more general sense of how well the differential cross-section for high transverse momentum jets is described with the different theoretical approaches. Is there a region where the available calculations fail to describe the measurement. The region of large Δη is of importance since it constitutes a non-reducible background for vector-boson-fusion measurements. The region of small Δη is of relevance because of its non-reducible background to heavy boosted objects.

In this work several observables connected to azimuthal angle decorrelation anddijet cross section of Mueller-Navelet jetsarestudied. The most straight for wardobservableis the distribution of azimuthalangled difference, Δ,between Mueller-Naveletjets. A study of a zimuthal angle decorrelations of Mueller-Navelet and inclusive dijet cross section in proton-proton collisions was performed for jets with >5 GeV and different values of pseudorapidity □□ using data collected with the CMS detector at the LHC in 2015 at = 13 TeV.

Monte Carlo (MC) Samples

Table 1 contains some mote Carlo (MC) samples used for this work. The PYTHIA Monte Carlo generator [13, 14] uses the Donnachie-Landshoff parameterization [15] for the total hadronic cross-section. Various models may be used for the elastic and diffractive cross-section (unless stated differently, the default Schuler-Sjo strand model [16, 17] is used). In contrast, the remainder of the total cross-section is used to normalize the nondiffractive part, which is generated through low- "minimum-bias" processes. Event samples are generated with different diffractive and underlying event tunes: the Z2* [18] tune is used for the PYTHIA6 (version 6.426) sample, while PYTHIA8 (version 8.205) samples are generated with the Monash [19], CUETM1[20], Donnachie-Landshoff (DL) [21], and Minimum-Bias-Rockefeller (MBR) [22] tunes. These tunes differ in their parameters used to describe initial and final

TABLE 1. Summary of Monte Carlo samples with some of the main parameters.

MC generator	Number 0f Events
Pythia8 Tune MBR	4862000
Pythia8 Tune CUETP8M1	4917500
EPOS-LHC	4978400

state Parton showers, multi-party interactions, and hadronization. The DL and MBR tunes also use an alternative diffraction model, with the MBR model based on a phenomenological renormalized-Regge-theory model [22, 23].

The EPOS-LHC and event generator are partially designed to "bridge the gap" between collider and cosmic-ray physics by simultaneously providing descriptions for both event classes. EPOS-LHC is based on RGT (Regge-Gribov theory)

Event Selection

This analysis is based on ppcollisionMC generator models at 13 TeV. The transverse jet momenta that all jets must have > 5 GeV, but for pseudorapidity, the are three states:

1. $\eta_1 > 0$ for the first jet, and< 0 for the second jet where $\Delta\eta = |\eta_1 - \eta_2|$.
2. $\eta_1 > 0$, and another jet in the CASTOR detector area.
3. $\eta_1 > 3$, where it is in HF range, the second jet has $\eta_2 < -4.25$.

For each value for pseudorapidity, there is one plot describing the cross-section and azimuthal decorrelations of dijet.

Jet Selection

In order to obtain Mueller-Navelet type jets, the following criteria are applied.Jets were reconstructed using anti-k_t algorithm[25] with cone radius of R = 0.4.

- The events have been selected which have jets with pT> 5 GeV.
- Selecttwojetsforeacheventwiththelargestrapidity separation andtagthemmostforward and most backward jets.

Δ ϕ Distribution

The azimuthal angle differences Δϕ and dijet cross-section Δη are plotted in Fig. 1 and Fig. 2 for the first state (section 2), Fig. 3 and Fig. 4 for the second state and Fig. 5 and Fig. 6 for the third. For each value η there is two plots for the cross-section and azimuthal decorrelations of dijet. As shown in Fig. 1, it describes the dijet cross-section in which the two jets have>5 GeV, and η_1>0 for the first jet, and η_2<0 for the second jet where $\Delta\eta = |\eta_1 - \eta_2|$. The peak delta-eta is around 1 for these jets. The dijet azimuthal decorrelations is shown in Fig. 2. This was the first state of measuring the dijet cross-section.

The second state describes the correlation between one jet having η_1>0 and another in the CASTOR detector. The peak delta-eta is around 5.5 for these jets, as shown in Fig. 3, which shows

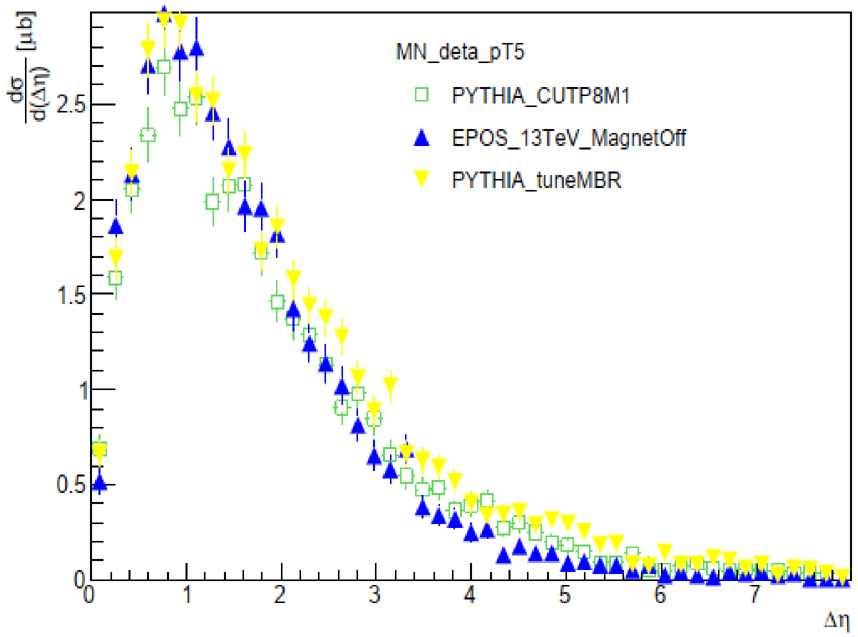

Fig. 1. Inclusive dijet cross section as a function of Δη with both jets with P_T > 5 GeV and Δη > 0. It shows comparison for the three MC models Pythia8 TuneCUETP8M1, Pythia8 TuneMBR and Epos LHC.

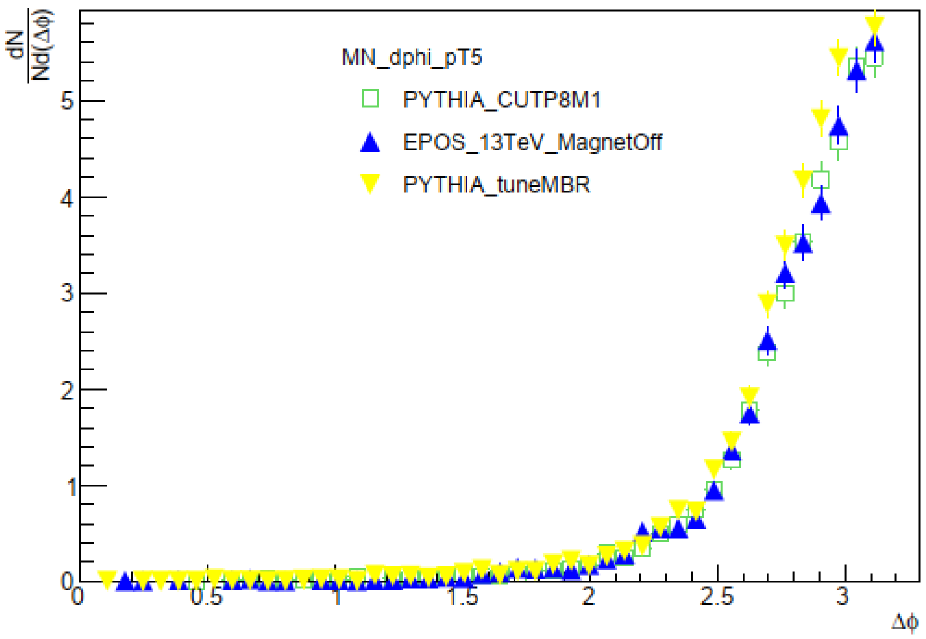

Fig. 2. Comparison of shape of Δ distributions for dijets for Pythia8 TuneCUETP8M1, Pythia8 TuneMBR and Epos LHC. With GeV and Δη> 0.

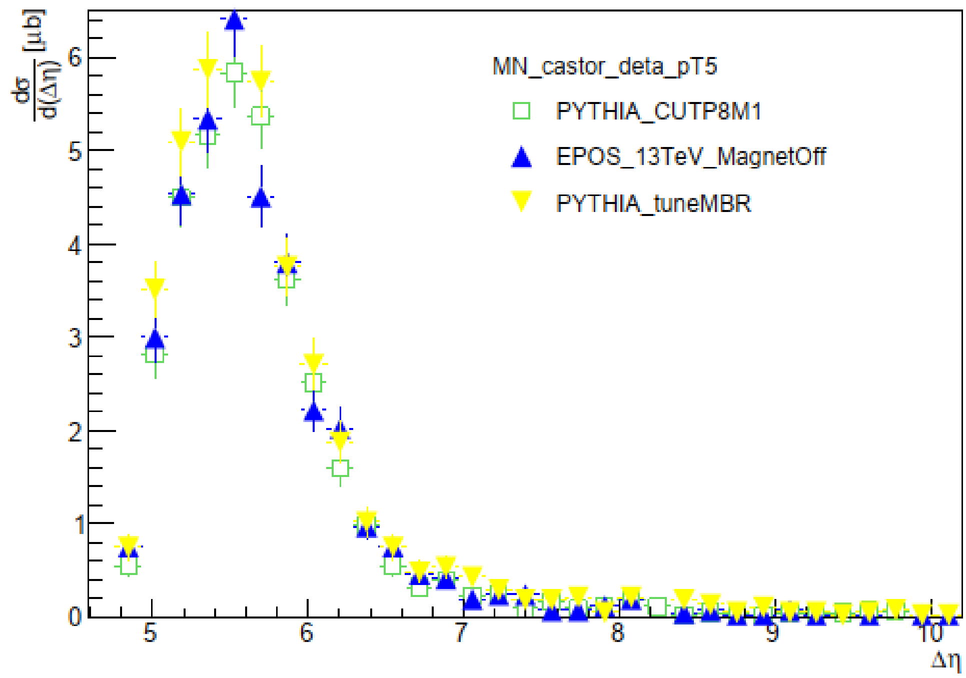

Fig. 3. Dijet cross section as a function of Δ with both jets with > 5 GeV and $\Delta\eta$> 4.5, that one jet in the positive side, and the second one in CASTOR area.It shows comparison for the three MC models Pythia8 TuneCUETP8M1, Pythia8 TuneMBR and Epos LHC

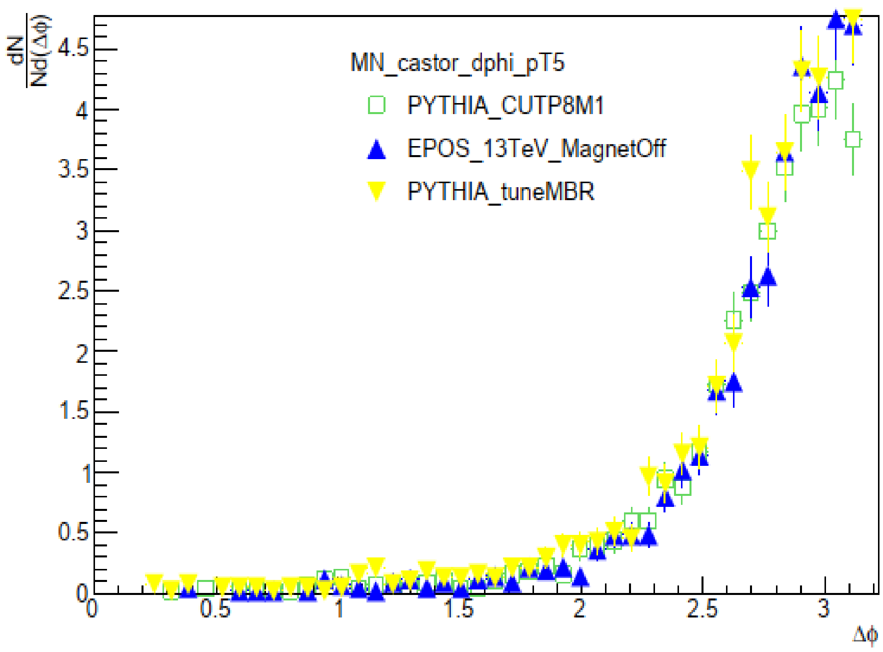

Fig. 4. Comparison of shape of Δ distributions for dijets that one jet in the positive side, and the second one in CASTOR area. for Pythia8 TuneCUETP8M1, Pythia8 TuneMBR and Epos LHC. With GeV and $\Delta\eta$> 4.5.

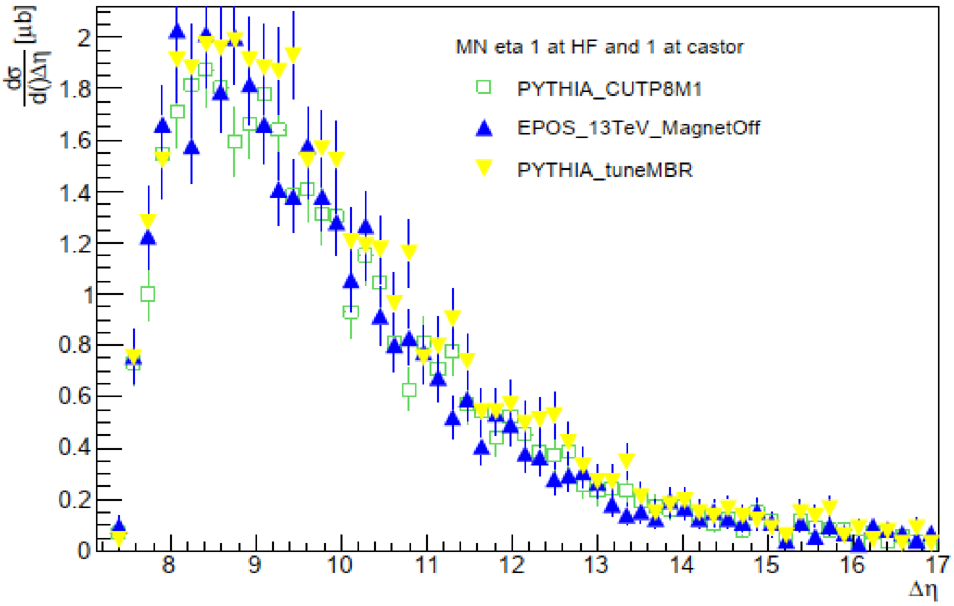

Fig. 5. MNdijet cross section as a function of Δ with both jets with > 5 GeV and Δη> 7.25. It is back-to-back dijet cross section, for Pythia8 TuneCUETP8M1, Pythia8 TuneMBR and Epos LHC.

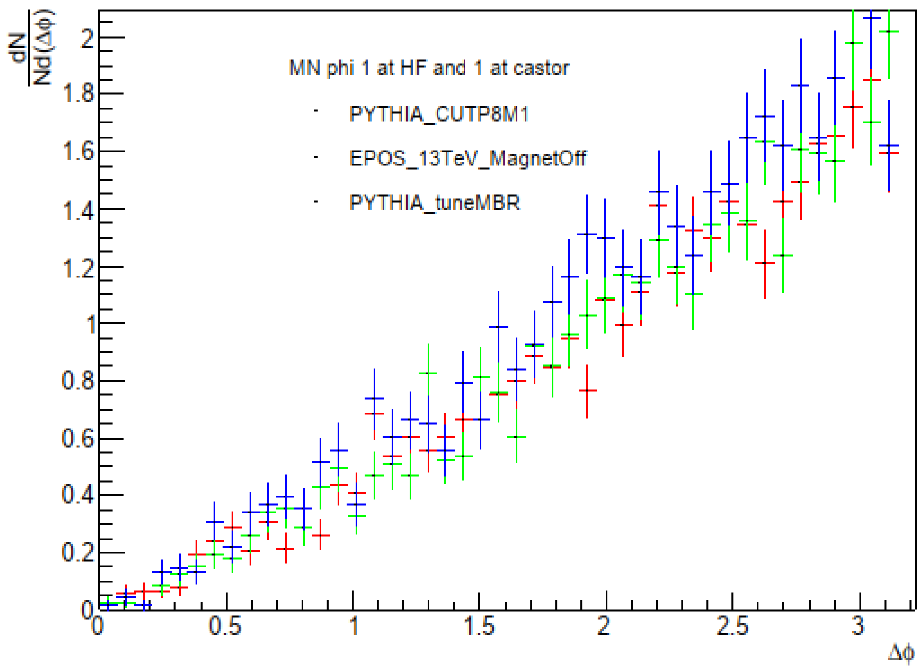

Fig. 6. Comparison of shape of Δ distributions for MNdijets for Pythia8 TuneCUETP8M1, Pythia8 TuneMBR and Epos LHC, with > 5 GeV and Δη> 7.25. It is Back-to-back dijet azimuthal decorrelations.

the dijet cross-section, and figure(4)shows dijet azimuthal decorrelations. The delta-phi remains almost unaffected.

The third state describes the correlation between one jet has η_1>3, where it is in HF range, the second jet has η_2<-4.25, the last range it combines HF to CASTOR detector in the negative side, this is shown in Fig. 5 and Fig. 6. For this configuration, the peak delta-eta is almost 9. There is significant azimuthal decorrelation observed here.

Discussion

As shown from the above figures, several observables are connected to azimuthal angle decorrelation Δϕ and dijet cross-section Δη of Mueller-Navelet jets. A study of azimuthal angle decorrelations of Mueller-Navelet and inclusive dijet cross section in proton-proton collisions was performed for jets (see sections 3 and 4) with p_(T)>5 GeV and different values of pseudorapidity Δη using data collected with the CMS detector at the LHC in 2015 at √s = 13 TeV. The azimuthal correlation Δϕ and dijet cross-section Δη of Mueller-Navelet jets are measured in three states:

1. The first jet has η< 0, and the other has $\eta 2$ > 0.
2. The first jet has η> 0, and the other has a CASTOR detector.
3. The first jet at HF (+ev direction), and the other at CASTOR detector.

The azimuthal angle differences Δϕ and dijet cross-section Δη are plotted in Fig. 1 and Fig. 2 for the first state, the peak delta-eta is around 1 for these jets. Figure 3 and Fig. 4 for the second state, where the peak delta-eta is around 5.5 for these jets, and the delta-phi remains almost unaffected. Figure 5 and Fig. 6 for the third state, the peak delta-eta is almost 9. There is significant azimuthal decorrelation observed here.

Summary

For the measurement of dijet production as a function of the separation in pseudorapidity at = √s =13 TeV was done, and dijet azimuthal decorrelations are also done. When the separation in pseudorapidity (Δη) between the jets is very small or very large special regions of phase space are probed. At small pseudorapidity separation between jets, both jets move in a similar direction with a small invariant dijet mass. The dijet system has to be balanced by one or more additional jets. A different scenario is obtained at large Δη when the jets are opposite in η, and a large dijet invariant mass is obtained. In this region, additional soft partons can be emitted between the jets (BFKL predicts an increase of radiation for increasing Δη). The presented measurements were originally motived by searching for BFKL effects (Mueller-Navelet jets).

The azimuthal correlation between central and forward jets has been measured in proton-proton collisions at the LHC recorded with the CMS detector at a centre-of-mass energy of 13 TeV is done in three states as follow:
1. The first jet has < 0, and the other has > 0.
2. The first jet has η> 0, and the other has a CASTOR detector.
3. The first jet at HF (+ev direction), and the other at CASTOR detector.

All of these studies were done with $p_T > 5\ GeV$.

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