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Measurement of the differential dijet production cross section in proton–proton collisions at $\sqrt{s} = 7$ TeV ☆

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ABSTRACT

A measurement of the double-differential inclusive dijet production cross section in proton–proton collisions at $\sqrt{s} = 7$ TeV is presented as a function of the dijet invariant mass and jet rapidity. The data correspond to an integrated luminosity of 36 pb^{-1}, recorded with the CMS detector at the LHC. The measurement covers the dijet mass range 0.2 TeV to 3.5 TeV and jet rapidities up to $|y| = 2.5$. It is found to be in good agreement with next-to-leading-order QCD predictions.

In Quantum Chromodynamics (QCD), events with two high transverse momentum jets (dijets) arise in proton–proton collisions from parton–parton scattering, where the outgoing scattered partons manifest themselves as hadronic jets. The invariant mass M_{JJ} of the two jets is related to the proton momentum fractions $x_{1,2}$ carried by the scattering partons: $M_{\text{JJ}}^2 = x_1 \cdot x_2 \cdot s$, where $\sqrt{s}$ is the centre-of-mass energy of the colliding protons. The dijet cross section as a function of M_{JJ} can be precisely calculated in perturbative QCD and allows also a sensitive search for physics beyond the Standard Model, such as dijet resonances or contact interactions. In this Letter, the measurement of the double-differential inclusive dijet production cross section ($\text{p} + \text{p} \to \text{jet} + \text{jet} + \text{X}$) is reported as a function of the dijet invariant mass and jet rapidity at $\sqrt{s} = 7$ TeV. The data were collected with the Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) during the 2010 run and correspond to an integrated luminosity of 36 pb^{-1}. The measured cross section is compared to the QCD predictions in an unexplored kinematic region, beyond the reach of previous measurements [1–3]. The parton momentum fractions probed in this measurement correspond to $8 \cdot 10^{-4} \leqslant x_1 \cdot x_2 \leqslant 0.25$. Dedicated searches for dijet resonances and contact interactions with the CMS detector have been reported elsewhere [4–6].

The CMS coordinate system has its origin at the centre of the detector, with the z-axis pointing along the direction of the counterclockwise beam. The azimuthal angle is denoted as ϕ, the polar angle as θ, and the pseudorapidity is defined as $\eta = -\ln[\tan(\theta/2)]$. The central feature of the CMS detector is a superconducting solenoid, of 6 m internal diameter, that produces an axial magnetic field of 3.8 T. Within the field volume are the silicon pixel and strip tracker, a lead-tungstate crystal electromagnetic calorimeter (ECAL) and a brass/scintillator hadronic calorimeter. Outside the field volume, in the forward region ($3 < |\eta| < 5$), is an iron/quartz-fiber hadronic calorimeter. Muons are measured in gas detectors embedded in the steel return yoke outside the solenoid, in the pseudorapidity range $|\eta| < 2.4$. A detailed description of the CMS experiment can be found in Ref. [7].

Jets are reconstructed using the anti-k_{T} clustering algorithm [8] with size parameter $R = 0.7$. The clustering is performed using four-momentum summation, where the chosen size parameter allows for the capture of most of the parton shower and improves the dijet mass resolution with respect to smaller sizes. The rapidity y and the transverse momentum p_{T} of a jet with energy E and momentum $\vec{p} = (p_x, p_y, p_z)$ are defined as $y = \frac{1}{2}\ln(\frac{E+p_z}{E-p_z})$ and $p_{\text{T}} = \sqrt{p_x^2 + p_y^2}$, respectively. The inputs to the jet clustering algorithm are the four-momentum vectors of the reconstructed particles. Each such particle is reconstructed with the particle-flow technique [9] which combines the information from several subdetectors. The resulting jets require an additional energy correction

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Table 1
The integrated luminosity for each of the data samples.

Min. jet p_T (GeV)	30	50	70	100	140
$\mathcal{L}_{\mathrm{eff}}$ (pb^{-1})	0.32	3.2	8.6	19	36

to take into account the non-linear and non-uniform response of the CMS calorimetric system to the neutral-hadron component of the jet (the momentum of charged hadrons and photons is measured accurately by the tracker and the ECAL, respectively). The jet-energy corrections are derived using simulated events, generated by PYTHIA6.4.22 (PYTHIA6) [10] and processed through the CMS detector simulation based on GEANT4 [11], and *in situ* measurements with dijet and photon + jet events [12]. An offset correction is also applied to take into account the extra energy clustered in jets due to additional proton–proton interactions within the same bunch crossing (pile-up). The jet-energy correction depends on the η and p_T of the jet, and is applied as a multiplicative factor to the jet four-momentum vector. The multiplicative factor is in general smaller than 1.2, and approximately uniform in η. For a jet $p_T = 100$ GeV the typical factor is 1.1, decreasing towards 1.0 with increasing p_T. The dijet mass is calculated from the corrected four-momentum vectors of the two jets with the highest p_T (leading jets): $M_{\mathrm{JJ}} = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2}$. The relative dijet-mass resolution, estimated from the simulation, ranges from 7% at $M_{\mathrm{JJ}} = 0.2$ TeV to 3% at $M_{\mathrm{JJ}} = 3$ TeV.

The data samples used for this measurement were collected with single-jet high level triggers (HLT) [13] which required at least one jet in the event to satisfy the condition $p_T > 30$, 50, 70, 100 and 140 GeV, respectively, in uncorrected jet transverse momentum. The online jet reconstruction used only calorimetric information and the resulting HLT jets had typically much lower energy response than the offline particle-flow jets. The lower-p_T triggers were prescaled and the corresponding integrated luminosity of each trigger sample, $\mathcal{L}_{\mathrm{eff}}$, is listed in Table 1. In the offline analysis, events are further required to have at least one well reconstructed proton–proton interaction vertex [14] and at least two reconstructed particle-flow jets with $p_{T1} > 60$ GeV and $p_{T2} > 30$ GeV (corrected). In order to suppress non-physical events, the two leading jets must satisfy loose identification criteria: each jet should contain at least two particles, one of which is a charged hadron. Furthermore, the jet energy fraction carried by neutral hadrons and photons should be less than 99%. If either of the leading jets fails the identification criteria, the event is discarded. The measurement is performed in five rapidity regions, defined by the maximum absolute rapidity $|y|_{\max} = \max(|y_1|, |y_2|)$ of the two leading jets in the event. The use of the variable $|y|_{\max}$ divides the phase space of the dijet system into exclusive rapidity bins, which correspond to different scattering angles at the centre-of-mass frame. Low values of $|y|_{\max}$ probe the large-angle scattering (*s channel*), while large values of $|y|_{\max}$ probe the small-angle scattering (*t channel*). For the construction of the invariant mass spectrum, each dijet-mass bin is populated by events collected only with the fully efficient trigger with the highest threshold. The efficiency of each trigger path, as a function of M_{JJ}, was measured using events collected with a lower threshold single-jet trigger and cross-checked with events collected with single-muon triggers.

The double-differential cross section is defined as

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}M_{\mathrm{JJ}}\,\mathrm{d}|y|_{\max}} = \frac{\mathcal{C}}{\epsilon\mathcal{L}_{\mathrm{eff}}}\frac{N}{\Delta M_{\mathrm{JJ}}\Delta|y|_{\max}}, \tag{1}$$

where N is the number of events in the bin, $\mathcal{L}_{\mathrm{eff}}$ is the integrated luminosity of the data sample from which the events are taken,

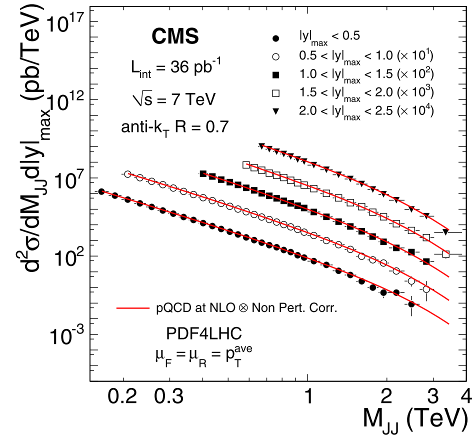

Fig. 1. Measured double-differential dijet production cross sections (points), scaled by the factors shown in the figure, as a function of the dijet invariant mass, in bins of the variable $|y|_{\max}$, compared to the theoretical predictions (curves). The horizontal error bars represent the bin widths, while the vertical error bars represent the statistical uncertainties of the data.

$\mathcal{C}$ is a correction factor for bin-to-bin migration, ϵ is the product of the trigger and event selection efficiencies (greater than 99%), and ΔM_{JJ} and $\Delta|y|_{\max}$ are the invariant mass and rapidity bin widths, respectively. The width of the mass bins is progressively increased, proportional to the mass resolution. The correction factor $\mathcal{C}$ is taken from the simulation, as follows. Jets reconstructed with the same clustering algorithm from generated particles are smeared according to the simulated energy resolution and the correction factor $\mathcal{C}$ is defined as the ratio of the generated over the smeared numbers of events in a given dijet-mass bin. It ranges between 0.95 and 0.98, depending on the dijet mass and the rapidity region. Fig. 1 shows the double-differential cross section as a function of the dijet mass in different bins of $|y|_{\max}$. The exact mass ranges and the cross-section values are reported in Tables 2–6. The quoted reference mass for each bin is the mass value m_0 that satisfies the equation $f(m_0)(m_2 - m_1) = \int_{m_1}^{m_2} f(m)\,\mathrm{d}m$, where m_1, m_2 are the bin boundaries and $f(m) = A \cdot (m/\sqrt{s})^{-a} \cdot (1 - m/\sqrt{s})^b$, with parameters obtained from a fit to the mass spectrum. The definition of the reference mass follows the approach described in [15].

The systematic uncertainty on the measured cross section is asymmetric and dominated by the uncertainty on the jet-energy scale. The latter varies between 3% and 5% [12] and is approximately uniform in η, introducing a 15% (60%) uncertainty on the cross section at $M_{\mathrm{JJ}} = 0.2$ TeV (3 TeV). The uncertainty on the integrated luminosity is estimated to be 4% [16] and propagates directly to the cross section. The jet-energy resolution uncertainty of 10% [17] propagates to the dijet mass resolution, which affects the unsmearing correction, introducing a 1% uncertainty on the cross section. Other sources of experimental uncertainty, such as the jet angular resolution and the Monte Carlo p_T spectrum used to calculate the smearing effect, introduce negligible uncertainties on the cross section. The quoted experimental systematic uncertainties of the individual dijet-mass bins are almost 100% correlated.

The theoretical prediction for the double-differential cross sections consists of a next-to-leading-order QCD calculation and a non-perturbative correction to account for the multiparton interactions (MPI) and hadronisation effects. The NLO calculations are done using the NLOJet++ program (v2.0.1) [18] within the framework of the fastNLO package (v1.4) [19] at renormalization and factorization scales (μ_R and μ_F) equal to the average transverse momentum p_T^{ave} of the two jets. The NLO calculation is performed

Table 2
Double-differential dijet mass cross section in the rapidity range $|y|_{max} < 0.5$. The reference mass is the point at which the cross section is drawn in Figs. 1 and 2 and is calculated as described in the text. The experimental systematic uncertainties of the individual dijet-mass bins are almost 100% correlated.

Mass range (TeV)	Reference mass (TeV)	Measured cross section (pb/TeV)	Statistical uncertainty %	Systematic uncertainty %
[0.156, 0.176]	0.165	1.32×10^6	−1.1, +1.1	−10, +11
[0.176, 0.197]	0.186	7.26×10^5	−1.4, +1.4	−10, +12
[0.197, 0.220]	0.208	4.12×10^5	−1.8, +1.8	−11, +12
[0.220, 0.244]	0.231	2.35×10^5	−0.7, +0.7	−11, +12
[0.244, 0.270]	0.256	1.39×10^5	−0.9, +0.9	−11, +12
[0.270, 0.296]	0.282	8.18×10^4	−0.7, +0.7	−11, +13
[0.296, 0.325]	0.310	5.08×10^4	−0.9, +0.9	−11, +13
[0.325, 0.354]	0.339	3.18×10^4	−1.1, +1.1	−11, +13
[0.354, 0.386]	0.369	2.04×10^4	−1.3, +1.3	−12, +13
[0.386, 0.419]	0.402	1.28×10^4	−1.1, +1.1	−12, +14
[0.419, 0.453]	0.435	8.22×10^3	−1.4, +1.4	−12, +14
[0.453, 0.489]	0.470	5.42×10^3	−1.6, +1.6	−12, +14
[0.489, 0.526]	0.507	3.65×10^3	−1.4, +1.5	−13, +14
[0.526, 0.565]	0.545	2.44×10^3	−1.7, +1.7	−13, +15
[0.565, 0.606]	0.585	1.58×10^3	−2.1, +2.1	−13, +15
[0.606, 0.649]	0.627	1.05×10^3	−2.5, +2.5	−13, +16
[0.649, 0.693]	0.670	7.35×10^2	−2.9, +3.0	−14, +16
[0.693, 0.740]	0.716	5.05×10^2	−3.4, +3.5	−14, +16
[0.740, 0.788]	0.763	3.62×10^2	−4.0, +4.2	−14, +17
[0.788, 0.838]	0.812	2.45×10^2	−4.8, +5.0	−15, +17
[0.838, 0.890]	0.863	1.77×10^2	−5.5, +5.8	−15, +18
[0.890, 0.944]	0.916	1.13×10^2	−6.8, +7.2	−15, +18
[0.944, 1.000]	0.971	7.94×10^1	−7.9, +8.5	−16, +19
[1.000, 1.118]	1.055	4.76×10^1	−7.0, +7.5	−16, +20
[1.118, 1.246]	1.178	2.72×10^1	−8.9, +9.8	−17, +21
[1.246, 1.383]	1.310	1.14×10^1	−13, +15	−18, +22
[1.383, 1.530]	1.452	6.24	−17, +21	−19, +24
[1.530, 1.687]	1.604	2.48	−26, +35	−20, +26
[1.687, 1.856]	1.766	9.85×10^{-1}	−40, +60	−22, +28
[1.856, 2.037]	1.941	4.59×10^{-1}	−54, +97	−23, +31
[2.037, 2.332]	2.170	4.69×10^{-1}	−43, +68	−25, +34
[2.332, 2.659]	2.479	8.45×10^{-2}	−83, +230	−29, +40

Table 3
Double-differential dijet mass cross section in the rapidity range $0.5 < |y|_{max} < 1.0$. The reference mass is the point at which the cross section is drawn in Figs. 1 and 2 and is calculated as described in the text. The experimental systematic uncertainties of the individual dijet-mass bins are almost 100% correlated.

Mass range (TeV)	Reference mass (TeV)	Measured cross section (pb/TeV)	Statistical uncertainty %	Systematic uncertainty %
[0.197, 0.220]	0.208	1.74×10^6	−0.8, +0.9	−11, +12
[0.220, 0.244]	0.231	1.02×10^6	−1.1, +1.1	−11, +12
[0.244, 0.270]	0.256	6.00×10^5	−1.4, +1.4	−11, +12
[0.270, 0.296]	0.282	3.64×10^5	−1.7, +1.8	−11, +12
[0.296, 0.325]	0.310	2.22×10^5	−0.7, +0.7	−11, +13
[0.325, 0.354]	0.339	1.38×10^5	−0.8, +0.9	−11, +13
[0.354, 0.386]	0.369	8.64×10^4	−1.0, +1.0	−12, +13
[0.386, 0.419]	0.402	5.42×10^4	−0.8, +0.8	−12, +13
[0.419, 0.453]	0.435	3.55×10^4	−1.0, +1.0	−12, +14
[0.453, 0.489]	0.470	2.34×10^4	−1.1, +1.2	−12, +14
[0.489, 0.526]	0.507	1.53×10^4	−0.9, +0.9	−12, +14
[0.526, 0.565]	0.545	1.01×10^4	−1.1, +1.1	−13, +15
[0.565, 0.606]	0.585	6.90×10^3	−1.3, +1.3	−13, +15
[0.606, 0.649]	0.627	4.60×10^3	−1.6, +1.6	−13, +15
[0.649, 0.693]	0.670	3.15×10^3	−1.4, +1.4	−13, +16
[0.693, 0.740]	0.716	2.14×10^3	−1.7, +1.7	−14, +16
[0.740, 0.788]	0.763	1.48×10^3	−2.0, +2.0	−14, +16
[0.788, 0.838]	0.812	1.04×10^3	−2.3, +2.4	−14, +17
[0.838, 0.890]	0.863	7.42×10^2	−2.7, +2.8	−15, +17
[0.890, 0.944]	0.916	5.01×10^2	−3.2, +3.3	−15, +18
[0.944, 1.000]	0.971	3.37×10^2	−3.8, +4.0	−15, +18
[1.000, 1.118]	1.055	2.08×10^2	−3.4, +3.5	−16, +19
[1.118, 1.246]	1.178	9.94×10^1	−4.7, +4.9	−17, +20
[1.246, 1.383]	1.310	5.38×10^1	−6.1, +6.5	−18, +22
[1.383, 1.530]	1.452	2.73×10^1	−8.3, +9.0	−19, +23
[1.530, 1.687]	1.604	9.70	−13, +15	−20, +25
[1.687, 1.856]	1.766	5.73	−17, +20	−21, +27
[1.856, 2.037]	1.941	3.66	−20, +25	−23, +30
[2.037, 2.332]	2.170	1.12	−28, +38	−25, +33
[2.332, 2.659]	2.479	2.52×10^{-1}	−54, +97	−28, +39
[2.659, 3.019]	2.819	7.62×10^{-2}	−83, +230	−32, +47

Table 4
Double-differential dijet mass cross section in the rapidity range $1.0 < |y|_{max} < 1.5$. The reference mass is the point at which the cross section is drawn in Figs. 1 and 2 and is calculated as described in the text. The experimental systematic uncertainties of the individual dijet-mass bins are almost 100% correlated.

Mass range (TeV)	Reference mass (TeV)	Measured cross section (pb/TeV)	Statistical uncertainty %	Systematic uncertainty %
[0.386, 0.419]	0.402	1.84×10^5	−2.2, +2.3	−12, +13
[0.419, 0.453]	0.435	1.21×10^5	−2.7, +2.8	−12, +13
[0.453, 0.489]	0.470	7.77×10^4	−3.3, +3.4	−12, +14
[0.489, 0.526]	0.507	5.26×10^4	−1.2, +1.2	−12, +14
[0.526, 0.565]	0.545	3.56×10^4	−1.5, +1.5	−12, +14
[0.565, 0.606]	0.585	2.31×10^4	−1.8, +1.8	−13, +15
[0.606, 0.649]	0.627	1.60×10^4	−2.1, +2.1	−13, +15
[0.649, 0.693]	0.670	1.04×10^4	−1.6, +1.6	−13, +15
[0.693, 0.740]	0.716	7.20×10^3	−1.8, +1.9	−13, +16
[0.740, 0.788]	0.763	4.98×10^3	−2.2, +2.2	−14, +16
[0.788, 0.838]	0.812	3.35×10^3	−2.6, +2.7	−14, +16
[0.838, 0.890]	0.863	2.34×10^3	−2.0, +2.1	−14, +17
[0.890, 0.944]	0.916	1.65×10^3	−2.4, +2.5	−15, +17
[0.944, 1.000]	0.971	1.18×10^3	−2.8, +2.9	−15, +18
[1.000, 1.118]	1.055	6.61×10^2	−2.6, +2.6	−16, +19
[1.118, 1.246]	1.178	3.22×10^2	−2.6, +2.7	−16, +20
[1.246, 1.383]	1.310	1.57×10^2	−3.6, +3.7	−17, +21
[1.383, 1.530]	1.452	7.86×10^1	−4.9, +5.1	−18, +22
[1.530, 1.687]	1.603	3.80×10^1	−6.8, +7.3	−19, +24
[1.687, 1.856]	1.766	1.75×10^1	−9.6, +11	−20, +26
[1.856, 2.037]	1.941	8.32	−13, +15	−22, +28
[2.037, 2.332]	2.170	3.33	−17, +20	−23, +31
[2.332, 2.659]	2.478	1.83	−21, +26	−26, +35
[2.659, 3.019]	2.819	4.51×10^{-1}	−40, +60	−29, +41

Table 5
Double-differential dijet mass cross section in the rapidity range $1.5 < |y|_{max} < 2.0$. The reference mass is the point at which the cross section is drawn in Figs. 1 and 2 and is calculated as described in the text. The experimental systematic uncertainties of the individual dijet-mass bins are almost 100% correlated.

Mass range (TeV)	Reference mass (TeV)	Measured cross section (pb/TeV)	Statistical uncertainty %	Systematic uncertainty %
[0.565, 0.606]	0.585	6.68×10^4	−3.1, +3.2	−12, +14
[0.606, 0.649]	0.627	4.52×10^4	−3.7, +3.9	−12, +14
[0.649, 0.693]	0.670	3.05×10^4	−4.5, +4.7	−12, +14
[0.693, 0.740]	0.716	2.02×10^4	−1.7, +1.7	−13, +15
[0.740, 0.788]	0.763	1.47×10^4	−2.0, +2.0	−13, +15
[0.788, 0.838]	0.812	1.04×10^4	−2.3, +2.4	−13, +15
[0.838, 0.890]	0.863	6.92×10^3	−2.8, +2.8	−13, +16
[0.890, 0.944]	0.916	4.77×10^3	−2.1, +2.1	−14, +16
[0.944, 1.000]	0.971	3.41×10^3	−2.4, +2.4	−14, +16
[1.000, 1.118]	1.055	2.04×10^3	−2.1, +2.2	−14, +17
[1.118, 1.246]	1.178	1.04×10^3	−2.0, +2.0	−15, +18
[1.246, 1.383]	1.310	5.20×10^2	−2.7, +2.7	−16, +19
[1.383, 1.530]	1.452	2.60×10^2	−3.6, +3.8	−17, +21
[1.530, 1.687]	1.604	1.45×10^2	−4.7, +5.0	−18, +22
[1.687, 1.856]	1.766	6.31×10^1	−5.1, +5.3	−19, +24
[1.856, 2.037]	1.941	3.24×10^1	−6.8, +7.3	−21, +26
[2.037, 2.332]	2.170	1.18×10^1	−8.9, +9.7	−23, +29
[2.332, 2.659]	2.479	4.37	−14, +16	−26, +34
[2.659, 3.019]	2.820	1.52	−22, +28	−29, +41
[3.019, 3.854]	3.344	1.31×10^{-1}	−48, +79	−35, +54

Table 6
Double-differential dijet mass cross section in the rapidity range $2.0 < |y|_{max} < 2.5$. The reference mass is the point at which the cross section is drawn in Figs. 1 and 2 and is calculated as described in the text. The experimental systematic uncertainties of the individual dijet-mass bins are almost 100% correlated.

Mass range (TeV)	Reference mass (TeV)	Measured cross section (pb/TeV)	Statistical uncertainty %	Systematic uncertainty %
[0.649, 0.693]	0.670	1.00×10^5	−2.5, +2.5	−13, +15
[0.693, 0.740]	0.716	6.70×10^4	−2.9, +3.0	−13, +15
[0.740, 0.788]	0.763	4.63×10^4	−3.5, +3.6	−13, +15
[0.788, 0.838]	0.812	3.29×10^4	−4.1, +4.2	−13, +15
[0.838, 0.890]	0.863	2.31×10^4	−4.8, +5.0	−13, +16
[0.890, 0.944]	0.916	1.52×10^4	−1.8, +1.9	−14, +16
[0.944, 1.000]	0.971	1.11×10^4	−2.1, +2.2	−14, +16

Table 6 (*Continued*)

Mass range (TeV)	Reference mass (TeV)	Measured cross section (pb/TeV)	Statistical uncertainty %	Systematic uncertainty %
[1.000, 1.118]	1.055	6.41×10^3	−1.9, +1.9	−14, +16
[1.118, 1.246]	1.178	3.26×10^3	−2.6, +2.6	−14, +17
[1.246, 1.383]	1.310	1.59×10^3	−2.2, +2.3	−15, +18
[1.383, 1.530]	1.452	8.39×10^2	−3.0, +3.1	−16, +18
[1.530, 1.687]	1.604	4.01×10^2	−4.2, +4.4	−16, +19
[1.687, 1.856]	1.766	1.80×10^2	−4.1, +4.2	−17, +21
[1.856, 2.037]	1.941	8.96×10^1	−5.6, +5.9	−18, +22
[2.037, 2.332]	2.170	3.75×10^1	−6.8, +7.2	−19, +24
[2.332, 2.659]	2.479	9.44	−9.4, +10	−22, +27
[2.659, 3.019]	2.819	3.52	−15, +17	−25, +32
[3.019, 3.854]	3.338	3.29×10^{-1}	−31, +43	−30, +41

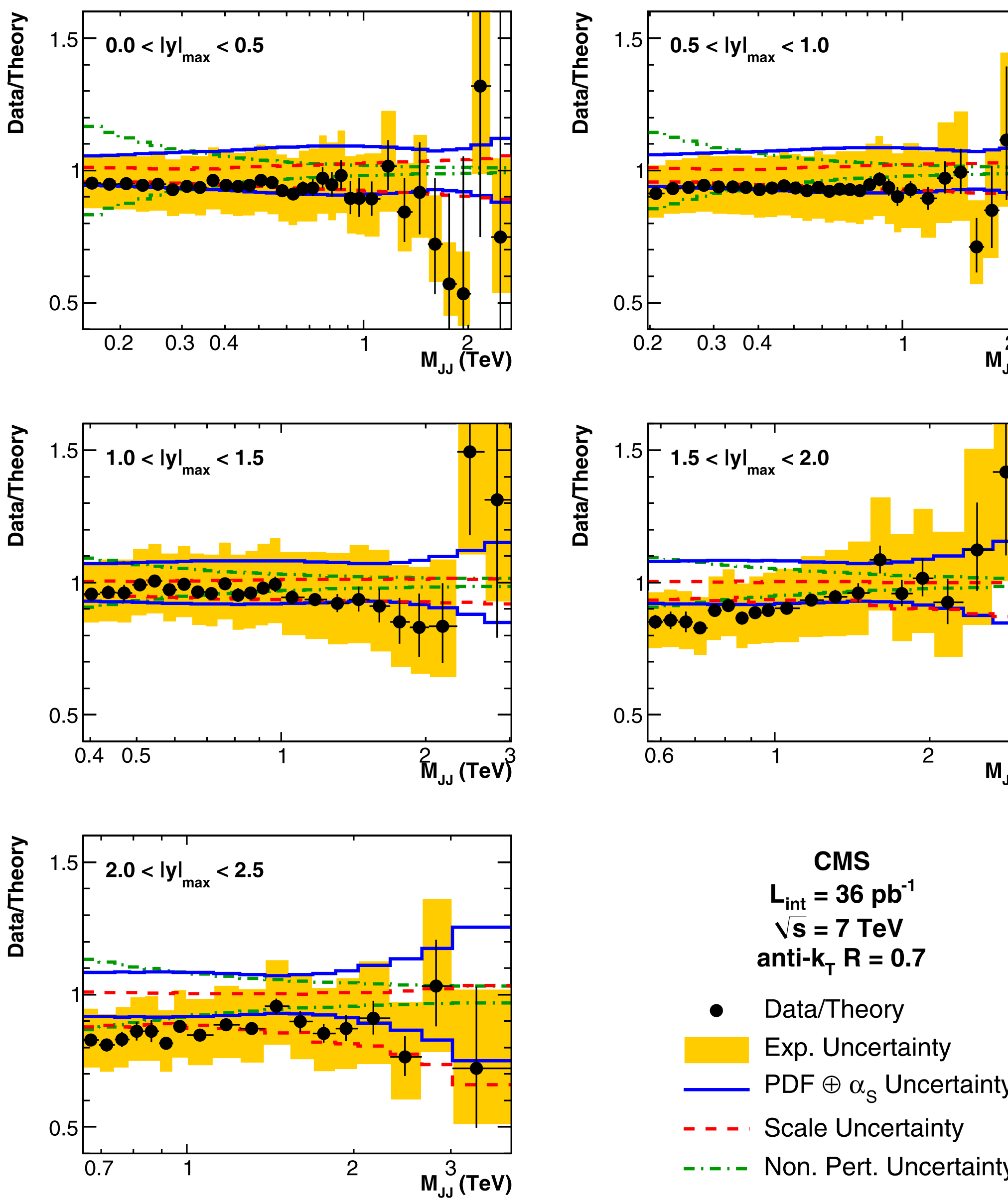

Fig. 2. Ratio of the measured double-differential dijet production cross section over the theoretical prediction in different rapidity bins. The solid band represents the total experimental systematic uncertainty due to the jet-energy scale, the integrated luminosity and the dijet-mass resolution, and is shown relative to the points. The vertical error bars on the points represent the statistical uncertainties and the horizontal ones indicate the bin width. The theoretical uncertainties due to PDF and the strong coupling constant $\alpha_S(M_Z)$ (solid blue), renormalization and factorization scales (dashed red), and non-perturbative effects (dashed-dotted green) are shown as curves around unity. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this Letter.)

using the CT10 [20], MSTW2008NLO [21] and NNPDF2.0 [22] parton distribution functions (PDF) at the corresponding three default values of the strong coupling constant $\alpha_S(M_Z) = 0.1180$, 0.1202 and 0.1190, respectively, recommended by the PDF4LHC working group [23]. The central value of the NLO calculation is taken as the average of the minimum and the maximum values predicted by the envelope of the 68% confidence level uncertainty of the three PDF. The non-perturbative effects are estimated from the simulation, using the event generators PYTHIA6 (tunes D6T [24] and Z2 [25]) and HERWIG++ 2.4.2 [26]. The chosen Monte Carlo models are representative of the possible values of the non-perturbative corrections, both due to their different physics description (PYTHIA6 vs. HERWIG++) and due to the different settings within a given model (PYTHIA6 tune D6T vs. tune Z2). The non-perturbative correction is defined as the ratio of the cross section predicted with the nominal generator settings divided by the cross section predicted with the MPI and hadronisation switched off. The central value of the non-perturbative correction is calculated from the average of the three models considered, and ranges from 30% at the lowest dijet mass value in each rapidity region, to 5% at $M_{\mathrm{JJ}} = 3$ TeV. The PDF variation introduces a 5% (30%) uncertainty on the theoretical prediction at a dijet mass of 0.2 TeV (3 TeV), while the variation of $\alpha_S(M_Z)$ by 0.002 introduces an additional 2–4% uncertainty. The renormalization and factorization scale uncertainty is estimated as the maximum deviation at the six points $(\mu_F/p_{\mathrm{T}}^{\mathrm{ave}}, \mu_R/p_{\mathrm{T}}^{\mathrm{ave}}) = (0.5, 0.5)$, $(2, 2)$, $(1, 0.5)$, $(1, 2)$, $(0.5, 1)$, $(2, 1)$, introducing a $+2\%$ ($+8\%$), -5% (-13%) uncertainty at $M_{\mathrm{JJ}} = 0.2$ TeV (3 TeV) in the central rapidity bin ($|y|_{\max} < 0.5$), and $+2\%$ ($+5\%$), -10% (-32%) uncertainty at $M_{\mathrm{JJ}} = 0.7$ TeV (3 TeV) in the outermost rapidity bin ($2.0 < |y|_{\max} < 2.5$). An additional uncertainty of 15% (2%) at $M_{\mathrm{JJ}} = 0.2$ TeV (3 TeV) is caused by the non-perturbative correction. Overall, the PDF uncertainty dominates at high masses, while the non-perturbative correction uncertainty is dominant at low masses.

Fig. 2 shows the comparison between the data and the theoretical prediction in the various bins of $|y|_{\max}$. It also shows the components of the theoretical uncertainty. The agreement observed for the entire mass range and in all rapidity bins is good. The experimental uncertainty is comparable to the theoretical uncertainty and the data can be used to constrain the ingredients of the QCD calculations.

In summary, a measurement of the double-differential dijet cross section as a function of the dijet mass and $|y|_{\max}$ has been presented. Using 36 pb^{-1} of data from proton–proton collisions at $\sqrt{s} = 7$ TeV collected with the CMS detector, the measurement covers the dijet-mass range from 0.2 TeV to 3.5 TeV in five rapidity bins, up to $|y|_{\max} = 2.5$. The data are in good agreement with the theoretical prediction, showing that QCD accurately describes the parton–parton scattering in this kinematic region.

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