PRL **106,** 082001 (2011) PHYSICAL REVIEW LETTERS week ending
25 FEBRUARY 2011

Measurement of the Isolated Prompt Photon Production Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV

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(Received 3 December 2010; revised manuscript received 15 January 2011; published 23 February 2011)

The differential cross section for the inclusive production of isolated prompt photons has been measured as a function of the photon transverse energy E_T^γ in pp collisions at $\sqrt{s} = 7$ TeV using data recorded by the CMS detector at the LHC. The data sample corresponds to an integrated luminosity of 2.9 pb^{-1}. Photons are required to have a pseudorapidity $|\eta^\gamma| < 1.45$ and $E_T^\gamma > 21$ GeV, covering the kinematic region $0.006 < x_T < 0.086$. The measured cross section is found to be in agreement with next-to-leading-order perturbative QCD calculations.

DOI: 10.1103/PhysRevLett.106.082001 PACS numbers: 13.85.Qk, 12.38.Bx

The measurement of isolated prompt photon production in proton-proton (pp) collisions provides a test of perturbative quantum chromodynamics (pQCD) and the possibility to constrain the parton distribution functions (PDF) of the proton. Such a measurement complements deep-inelastic scattering, Drell-Yan pair production, and jet production measurements [1–3]. At the Large Hadron Collider (LHC) [4], a significant increase of center-of-mass energy with respect to previous collider experiments [5–9] allows the exploration of new kinematic regions in the hard-interaction processes in hadron-hadron collisions [10]. Isolated prompt photon production also represents a background to searches for new phenomena involving photons in the final state.

In high-energy pp collisions, single prompt photons are produced directly in qg Compton scattering and $q\bar{q}$ annihilation, and in the fragmentation of partons with large transverse momentum. Photons are also produced in the decay of hadrons, which can mimic prompt production. This background, mostly from the decays of energetic π^0 and η mesons, can be reduced by imposing isolation criteria on the photon candidates.

This Letter presents a measurement of the differential production cross section of isolated prompt photons as a function of the photon transverse energy E_T^γ in pp collisions at $\sqrt{s} = 7$ TeV. The analyzed data sample corresponds to $2.9 \pm 0.3\ \text{pb}^{-1}$ of integrated luminosity, as recorded by the CMS detector at the LHC [11]. Isolated prompt photons with a pseudorapidity $|\eta^\gamma| < 1.45$ and $E_T^\gamma > 21$ GeV are studied. Here, $\eta^\gamma = -\ln[\tan(\theta/2)]$ and $E_T^\gamma = E^\gamma \sin(\theta)$, where E^γ is the photon energy and θ is the polar angle of the photon momentum measured with respect to the counterclockwise beam direction. This measurement exploits the difference between the electromagnetic shower profiles of prompt photons and of photon pairs from neutral-meson decays.

Photons are detected in the lead tungstate ($PbWO_4$) crystal electromagnetic calorimeter (ECAL), covering $|\eta| < 3.0$, comprising barrel and end cap sections. The analysis presented in this Letter is restricted to the barrel section, which covers $|\eta| < 1.479$. Light produced in the crystals is read out by avalanche photodiodes (APD) in the ECAL barrel. The ECAL barrel granularity is $\Delta\eta \times \Delta\phi = 0.0174 \times 0.0174$, where ϕ is the azimuthal angle measured with respect to the beam direction. The ECAL has an ultimate energy resolution better than 0.5% for unconverted photons with transverse energies above 100 GeV [12]. In 2010 collision data, for $E_T > 20$ GeV, this resolution is already better than 1% in the barrel [13]. Surrounding the ECAL there is a brass and scintillator sampling hadron calorimeter (HCAL), covering $|\eta| < 3.0$. For $|\eta| < 1.479$, the calorimeter modules are arranged in projective towers with a segmentation of $\Delta\eta \times \Delta\phi = 0.0870 \times 0.0870$. The ECAL and HCAL surround a tracking system with multiple silicon pixel and microstrip layers, covering $|\eta| < 2.5$. Both the tracker and the calorimeters are immersed in a 3.8 T axial magnetic field. A detailed description of the CMS detector can be found in Ref. [14].

Photons are reconstructed from clusters of energy deposited in the ECAL, using the same algorithm and granularity at the trigger level and in the offline analysis. Energy deposits within $|\Delta\phi| < 0.304$ and $|\Delta\eta| < 0.044$ are grouped into clusters [15]. The clustering algorithm efficiently reconstructs the energy of photons that convert in the material in front of the ECAL. The clustered energy is corrected taking into account interactions in the material in front of the ECAL and electromagnetic shower containment [16]; the correction is parametrized as a function of cluster size, η, E_T, and is on average 1%. The triggers used to collect the analyzed data sample require the presence of

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at least one reconstructed electromagnetic cluster with a minimum transverse energy of 20 or 25 GeV. The trigger is fully efficient for $E_T^\gamma > 21$ GeV and $|\eta^\gamma| < 1.45$, defining the phase space of the measurement. Depending on the LHC instantaneous luminosity, rate-reduction factors were applied to the triggers at 20 GeV. Consequently, photons with $E_T^\gamma < 26$ GeV are taken from a restricted data set having an integrated luminosity of $2.1 \pm 0.2\ \mathrm{pb}^{-1}$. No photon isolation criteria are applied at the trigger level.

The event selection requires at least one reconstructed primary interaction vertex consistent with a pp collision [17]. The time of the ECAL signals is required to be compatible with that of collision products [18]. Topological selection criteria are used to suppress direct interactions in the ECAL APDs [19]. The residual contamination has an effect smaller than 0.2% on the measured cross section over the entire E_T^γ range considered. Contamination from noncollision backgrounds is estimated to be negligible [16].

Photon candidates are built from ECAL energy clusters fully contained in the barrel section. The photon candidate pseudorapidity is corrected for the position of the primary interaction vertex. The absolute photon energy scale is determined with electrons from reconstructed Z-boson decays with an uncertainty estimated to be less than 1%. Consistent results are obtained with low-energy photons from π^0 decays. The linearity of the response of detector and electronics has been measured with laser light and test beams, to a precision better than 1% in the energy range probed in this Letter [13]. Showers initiated by charged hadrons are rejected by requiring $E^{\mathrm{HCAL}}/E^\gamma < 0.05$, where E^{HCAL} is the sum of energy in the HCAL towers within $R < 0.15$, with $R^2 = (\eta - \eta^\gamma)^2 + (\phi - \phi^\gamma)^2$. Electrons are rejected by requiring the absence of hits in the first two layers of the pixel detector that would be consistent with an electron track matching the observed location and energy of the photon candidate (pixel veto requirement).

The photon candidates must satisfy three isolation requirements that reject photons produced in hadron decays: (1) $\mathrm{Iso}_{\mathrm{TRK}} < 2\ \mathrm{GeV}/c$, where $\mathrm{Iso}_{\mathrm{TRK}}$ is the sum of the p_T of tracks compatible with the primary event vertex in an annulus $0.04 < R < 0.40$, excluding a rectangular strip of $\Delta\eta \times \Delta\phi = 0.015 \times 0.400$ to remove the photon's own energy if it converts into an e^+e^- pair; (2) $\mathrm{Iso}_{\mathrm{ECAL}} < 4.2$ GeV, where $\mathrm{Iso}_{\mathrm{ECAL}}$ is the transverse energy deposited in the ECAL in an annulus $0.06 < R < 0.40$, excluding a rectangular strip of $\Delta\eta \times \Delta\phi = 0.04 \times 0.40$; and (3) $\mathrm{Iso}_{\mathrm{HCAL}} < 2.2$ GeV, where $\mathrm{Iso}_{\mathrm{HCAL}}$ is the transverse energy deposited in the HCAL in an annulus $0.15 < R < 0.40$. The requirements were designed with two other objectives in mind. First, the use of relatively loose photon identification and isolation selection criteria reduces the dependence of the results on the details of the simulation of the detector noise, the underlying event, and event pile-up. Second, the shape of the isolation regions is designed to allow the use of electrons to determine the efficiency of the isolation requirements in data. The isolation requirements also reduce the uncertainty on the signal due to the knowledge of the photon fragmentation functions. In total, 4×10^5 photon candidates fulfill the selection criteria.

While the isolation requirements remove the bulk of the neutral-meson background, a substantial contribution remains, mainly caused by fluctuations in the fragmentation of partons, where neutral mesons carry most of the energy and are isolated. A modified second moment of the electromagnetic energy cluster about its mean η position, $\sigma_{\eta\eta}$, is used to measure the isolated prompt photon yield. It is calculated as

$$\sigma_{\eta\eta}^2 = \sum_{i=1}^{25} w_i(\eta_i - \bar{\eta})^2 \Big/ \sum_{i=1}^{25} w_i,$$

where $w_i = \max(0, 4.7 + \ln(E_i/E))$, E_i is the energy of the ith crystal in a group of 5×5 centered on the one with the highest energy, and $\eta_i = \hat{\eta}_i \times \delta\eta$, where $\hat{\eta}_i$ is the η index of the ith crystal and $\delta\eta = 0.0174$; E is the total energy of the group and $\bar{\eta}$ the average η weighted by w_i in the same group [20]. Since $\sigma_{\eta\eta}$ expresses the extent in η of the cluster, it discriminates between clusters belonging to isolated prompt photons, for which the $\sigma_{\eta\eta}$ distribution is very narrow and symmetric, and photons produced in hadron decays, for which the distribution is dominated by a long tail towards higher values. Given the axial configuration of the CMS magnetic field, interactions with the material in front of the ECAL have a small influence on the shower profile along the η direction, such that $\sigma_{\eta\eta}$ is not affected by uncertainties on the modeling of such effects. The mean of the $\sigma_{\eta\eta}$ distributions is found to be independent of the number of reconstructed interaction vertices, and therefore it does not show sensitivity to pileup interactions.

The isolated prompt photon yield is estimated with a binned extended maximum likelihood fit to the $\sigma_{\eta\eta}$ distribution with the expected signal and background components. This is performed in each E_T^γ bin using MINUIT [21]. The signal component shape is obtained from photon events generated with PYTHIA 6.420 [22] and the D6T parameter set [23], and simulated with GEANT 4 [24]. The $\sigma_{\eta\eta}$ distribution of electrons from Z-boson decays is observed to be shifted when comparing data and simulated events. The shift is $+(8 \pm 3) \times 10^{-5}$ and corresponds to 0.9% of the average of the simulated photon $\sigma_{\eta\eta}$ values, which are corrected for the observed shift. The background component shape is extracted from data by taking the $\sigma_{\eta\eta}$ distribution of events in a background-enriched isolation sideband defined by requiring $2 < \mathrm{Iso}_{\mathrm{TRK}} < 5\ \mathrm{GeV}/c$, while keeping all other selection criteria unchanged. This choice provides a sufficient number of events while minimizing the bias to the $\sigma_{\eta\eta}$ distribution due to the positive

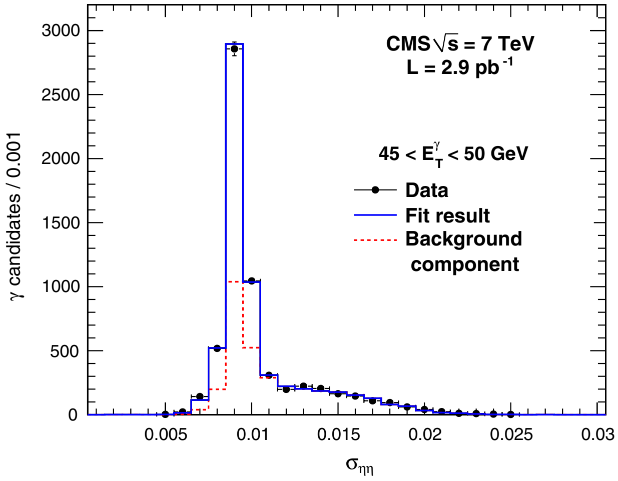

FIG. 1 (color online). Measured $\sigma_{\eta\eta}$ distribution for photons with $45 < E_T^\gamma < 50$ GeV. The fit result (solid) and the background component (dashed) are also shown.

correlation between $\sigma_{\eta\eta}$ and $\mathrm{Iso}_{\mathrm{TRK}}$. Both signal and background shapes are obtained separately for each E_T^γ bin. Figure 1 illustrates the result of the two-component fit for the $45 < E_T^\gamma < 50$ GeV bin, which is representative of the fits in all E_T^γ bins. The isolated prompt photon signal yield, N^γ, is extracted with this fitting procedure. For $\sigma_{\eta\eta} < 0.01$, the fraction of isolated prompt photons in data after full selection increases from 38% at $E_T^\gamma =$ 25 GeV to 80% at $E_T^\gamma = 100$ GeV.

The differential cross section as a function of E_T^γ is defined as

$$d^2\sigma/dE_T^\gamma d\eta^\gamma = N^\gamma/(L\ \mathcal{U}\ \epsilon\ \Delta E_T^\gamma\ \Delta\eta^\gamma),$$

where ΔE_T^γ is the size of the E_T^γ bin, $\Delta\eta^\gamma = 2.9$, L is the integrated luminosity, and $\mathcal{U}$ denotes bin-by-bin corrections that account for E_T^γ reconstruction effects and finite detector resolution in η^γ and isolation quantities. The overall efficiency ϵ is the product of the photon trigger, reconstruction, and selection efficiencies. The trigger is fully efficient for $E_T^\gamma > 21$ GeV and $|\eta^\gamma| < 1.45$, as previously mentioned. The efficiency of the isolation criteria is measured in data using an electron sample from Z-boson decays and is found to be higher than in simulation by $\rho_\epsilon = 1.035 \pm 0.017(\mathrm{stat} + \mathrm{syst})$. The photon reconstruction and selection efficiencies are determined from PYTHIA events with prompt photons and are scaled by ρ_ϵ. The estimated efficiency is $\epsilon = 0.916 \pm 0.034(\mathrm{stat} + \mathrm{syst})$ and does not change appreciably with E_T^γ or η^γ. Using events generated with PYTHIA, the values of $\mathcal{U}$ are calculated as a function of E_T^γ for prompt photons with $|\eta^\gamma| < 1.45$ and particle-level isolation less than 5 GeV. The latter is defined as the sum of the p_T of simulated particles within $R < 0.4$. The resulting values of $\mathcal{U}$ decrease from 1.01 to 0.97 as E_T^γ increases and are listed in Table I.

The total systematic uncertainty on the measured cross section includes contributions from the uncertainties in the shapes of the $\sigma_{\eta\eta}$ distributions of signal and background, the efficiency, the photon energy scale, the binning of the $\sigma_{\eta\eta}$ distributions, and the $\mathcal{U}$ corrections. The largest contribution is due to the limited knowledge of the background component shape, which affects the measurement for two reasons. First, photon candidates selected from the isolation sideband have more associated activity in the isolation region than the true background. This effect is investigated by comparing the sideband and true $\sigma_{\eta\eta}$ distributions in simulated dijet events. Events from the sideband emphasize the tail of the background $\sigma_{\eta\eta}$ distribution, such that the cross section values extracted using the true background $\sigma_{\eta\eta}$ distribution are systematically lower by 15% for $E_T^\gamma < 85$ GeV and 7% otherwise. Second, the sideband

TABLE I. Isolated prompt photon cross section for $|\eta^\gamma| < 1.45$ and in bins of E_T^γ. Uncertainties in the cross sections are statistical. An additional 11% luminosity uncertainty is not included in the systematic uncertainty (third column). The last column reports the corrections for finite detector resolution. A correction to account for extra activity ($C = 0.97 \pm 0.02$) is applied to the theoretical predictions, as explained in the text.

E_T^γ (GeV)	$d^2\sigma/dE_T^\gamma d\eta^\gamma$ (nb/GeV)	Systematic uncertainty (%)	$\mathcal{U}$
21–23	2.17 ± 0.03	$+13, -16$	1.01
23–26	1.39 ± 0.02	$+13, -16$	1.01
26–30	0.774 ± 0.010	$+13, -16$	1.01
30–35	0.402 ± 0.006	$+13, -16$	1.00
35–40	0.209 ± 0.004	$+13, -16$	1.00
40–45	$(124.4 \pm 2.8) \times 10^{-3}$	$+13, -16$	1.00
45–50	$(74.0 \pm 2.1) \times 10^{-3}$	$+13, -16$	1.00
50–60	$(40.3 \pm 1.0) \times 10^{-3}$	$+13, -16$	1.00
60–85	$(12.36 \pm 0.35) \times 10^{-3}$	$+14, -16$	0.99
85–120	$(2.43 \pm 0.12) \times 10^{-3}$	$+14, -9$	0.98
120–300	$(0.188 \pm 0.013) \times 10^{-3}$	$+13, -9$	0.97

requirements also select some prompt photons. This effect is investigated by comparing the isolation sideband $\sigma_{\eta\eta}$ distributions of simulated samples with and without prompt photons. Samples with prompt photons enhance the peaking part of the background distribution, such that the cross section values extracted using the samples without prompt photons are systematically higher by 12%. These two effects are checked with data by changing the isolation sideband limits so as to accentuate each of them. The observed variations in the extracted cross section agree with the estimated systematic uncertainties given above. The systematic uncertainty on the cross section due to the efficiencies is $\pm 3.8\%$, independent of E_T^γ and is dominated by the uncertainty in the efficiency of the pixel veto requirement. The full inefficiency of the pixel veto requirement, estimated with simulated events, is assigned to the systematic uncertainty and is mostly due to the rejection of prompt photons that convert in, or before, the first layer of the pixel detector. The use of simulation to estimate this inefficiency is supported by the 10% accuracy with which the material distribution is known [25]. All the other sources of uncertainty have an effect on the measured cross section smaller than $\pm 3\%$.

The measured isolated prompt photon cross section as a function of E_T^γ, including both statistical and total systematic uncertainties, is reported in Table I. The 11% overall uncertainty on the integrated luminosity is considered separately. The data are shown in Fig. 2, together with next-to-leading order (NLO) pQCD predictions from JETPHOX 1.1 [26] using the CT10 PDFs [1] and the BFG set II of fragmentation functions (FF) [27]. The renormalization, factorization, and fragmentation scales (μ_R, μ_F, and μ_f) are all set to E_T^γ. The hadronic energy surrounding the photon is required to be at most 5 GeV within $R < 0.4$ at the parton level. To estimate the effect of the choice of theory scales in the predictions, the three scales are varied independently and simultaneously between $E_T^\gamma/2$ and $2E_T^\gamma$. Retaining the largest variations the predictions change by $(+30, -22)\%$ to $(+12, -6)\%$ with increasing E_T^γ. The uncertainty on the predictions due to the PDFs is estimated from the envelope of predictions obtained using three global-fit parametrizations, CT10, MSTW2008 [3], and NNPDF2.0 [2], as recommended by the PDF4LHC Working Group [28]. This uncertainty is about $\pm 6\%$ over the considered E_T^γ range. Predictions obtained using the CTEQ6.1M PDFs [29], extensively used in previous comparisons with data, are consistent with those obtained with CT10 to within 3%. Finally, using the BFG set I of FFs instead of the BFG set II yields negligible differences in the predictions. The theoretical predictions include an additional correction factor $C(E_T^\gamma)$ to account for the presence of contributions from the underlying event and parton-to-hadron fragmentation, which tend to increase the energy in the isolation cone. Using simulated PYTHIA events, C is determined as the ratio between the isolated fraction of the

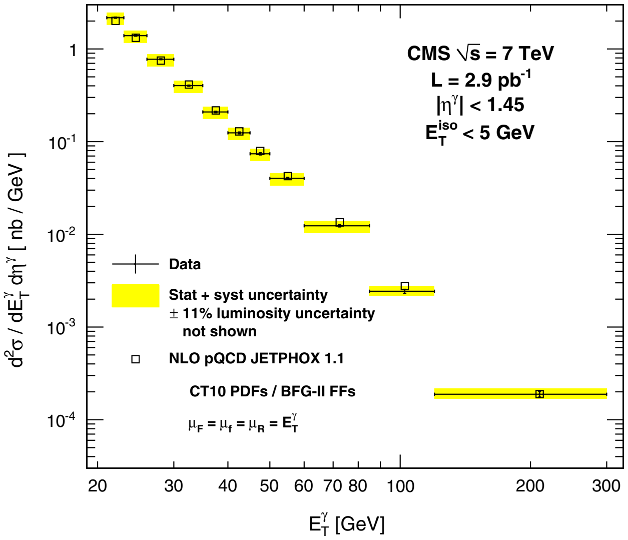

FIG. 2 (color online). Measured isolated prompt photon differential cross section and NLO pQCD predictions, as a function of E_T^γ. The vertical error bars show the statistical uncertainties, while the shaded areas show the statistical and systematic uncertainties added in quadrature. A correction to account for extra activity ($C = 0.97 \pm 0.02$) is applied to the theoretical predictions, as explained in the text. The 11% luminosity uncertainty on the data is not included.

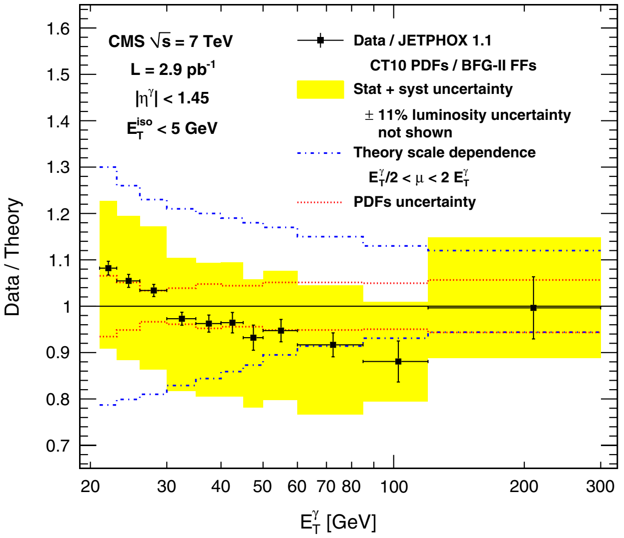

FIG. 3 (color online). Ratio of the measured isolated prompt photon differential cross section to the NLO pQCD predictions. The vertical error bars show the statistical uncertainties, while the shaded areas show the statistical and systematic uncertainties added in quadrature. The 11% luminosity uncertainty on the data is not included. The two sets of curves show the uncertainties on the theoretical predictions due to their dependency on the renormalization, factorization, and fragmentation scales, and on the PDFs. A correction to account for extra activity ($C = 0.97 \pm 0.02$) is applied to the theoretical predictions, as explained in the text.

total prompt photon cross section at the hadron level and the same fraction obtained after turning off both multiple-parton interactions and hadronization. Four different sets of PYTHIA parameters (Z2 [30], D6T, DWT, and Perugia-0 [31]) are considered. The value $C = 0.97 \pm 0.02$ is taken as the correction, its uncertainty covering the results obtained with the different PYTHIA parameter sets. As expected, the correction reduces the predicted cross section, since the presence of extra activity results in some photons failing the isolation requirements.

Predictions from NLO pQCD are found to be in good agreement with the measured cross sections, as shown in Figs. 2 and 3. The measured pattern is better described by the theoretical predictions than in previous measurements at lower $\sqrt{s}$ and higher $x_T = 2E_T/\sqrt{s}$ [8,9,32–37].

In conclusion, a measurement of the differential cross section for the production of isolated prompt photons with $21 < E_T^\gamma < 300$ GeV and $|\eta^\gamma| < 1.45$ in pp collisions at $\sqrt{s} = 7$ TeV has been presented. This measurement is performed in the kinematic regime $0.006 < x_T < 0.086$, probing a previously unexplored region at low x_T, and agrees with NLO pQCD predictions in the whole x_T range. This measurement establishes a benchmark for photon identification and background estimation, and constrains the rate of one of the background processes affecting searches for new physics involving photons.

We wish to congratulate our colleagues in the CERN accelerator departments for the excellent performance of the LHC machine. We thank the technical and administrative staff at CERN and other CMS institutes, and acknowledge support from the following: FMSR (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MES (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIENCIAS (Colombia); MSES (Croatia); RPF (Cyprus); Academy of Sciences and NICPB (Estonia); Academy of Finland, ME, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NKTH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); NRF and WCU (Korea); LAS (Lithuania); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); PAEC (Pakistan); SCSR (Poland); FCT (Portugal); JINR (Armenia, Belarus, Georgia, Ukraine, Uzbekistan); MST and MAE (Russia); MSTD (Serbia); MICINN and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); TUBITAK and TAEK (Turkey); STFC (U.K.); DOE and NSF (U.S.).

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[1] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P.M. Nadolsky, J. Pumplin, and C.-P. Yuan, Phys. Rev. D **82**, 074024 (2010).

[2] R.D. Ball, L.D. Debbio, S. Forte, A. Guffanti, J.I. Latorre, J. Rojo, and M. Ubiali (NNPDF Collaboration), Nucl. Phys. **B838**, 136 (2010); arXiv:1002.4407.

[3] A.D. Martin, W.J. Stirling, R.S. Thorne, and G. Watt, Eur. Phys. J. C **63**, 189 (2009).

[4] L. Evans and P. Bryant, JINST **3**, S08001 (2008).

[5] M. Diakonou *et al.*, Phys. Lett. B **87**, 292 (1979).

[6] T. Ferbel and W.R. Molzon, Rev. Mod. Phys. **56**, 181 (1984).

[7] J.A. Appel *et al.* (UA2 Collaboration), Phys. Lett. B **176**, 239 (1986).

[8] V.M. Abazov *et al.* (D0 Collaboration), Phys. Lett. B **639**, 151 (2006); **658**, 285(E) (2008).

[9] T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. D **80**, 111106 (2009).

[10] R. Ichou and D. d'Enterria, Phys. Rev. D **82**, 014015 (2010).

[11] CMS Collaboration, Report No. CMS-PAS-EWK-10-004, 2010.

[12] P. Adzic *et al.*, JINST **2**, P04004 (2007).

[13] CMS Collaboration, Report No. CMS-PAS-EGM-10-003, 2010.

[14] R. Adolphi *et al.* (CMS Collaboration), JINST **3**, S08004 (2008).

[15] CMS Collaboration, Report No. CMS-TDR-008-1, 2006.

[16] CMS Collaboration, Report No. CMS-PAS-EGM-10-005, 2010.

[17] V. Khachatryan *et al.* (CMS Collaboration), Eur. Phys. J. C **70**, 1165 (2010).

[18] S. Chatrchyan *et al.* (CMS Collaboration), JINST **5**, T03011 (2010).

[19] CMS Collaboration, Report No. CMS-NOTE- 2010-012, 2010.

[20] T.C. Awes *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **311**, 130 (1992).

[21] F. James and M. Roos, Comput. Phys. Commun. **10**, 343 (1975).

[22] T. Sjöstrand, S. Mrenna, and P.Z. Skands, J. High Energy Phys. 05 (2006) 026.

[23] M.G. Albrow *et al.* (TeV4LHC QCD Working Group), arXiv:hep-ph/0610012.

[24] S. Agostinelli *et al.* (GEANT 4 Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).

[25] CMS Collaboration, Report No. CMS-PAS-TRK-10-003, 2010.

[26] S. Catani, M. Fontannaz, J.P. Guillet, and E. Pilon, J. High Energy Phys. 05 (2002) 028.

[27] L. Bourhis, M. Fontannaz, and J.P. Guillet, Eur. Phys. J. C **2**, 529 (1998).

[28] M. Botje *et al.* (PDF4LHC Working Group), arXiv:1101.0538.

[29] J. Pumplin, D.R. Stump, J. Huston, H.-L. Lai, P. Nadolsky, and W.-K. Tung, J. High Energy Phys. 07 (2002) 012.

[30] R. Field, arXiv:1010.3558.

[31] P.Z. Skands, arXiv:1003.4220v1, p. 284.

[32] F. Abe *et al.* (CDF Collaboration), Phys. Rev. Lett. **68**, 2734 (1992).

[33] F. Abe *et al.* (CDF Collaboration), Phys. Rev. D **48**, 2998 (1993).

[34] F. Abe *et al.* (CDF Collaboration), Phys. Rev. Lett. **73**, 2662 (1994).

[35] S. Abachi *et al.* (D0 Collaboration), Phys. Rev. Lett. **77**, 5011 (1996).

[36] B. Abbott *et al.* (D0 Collaboration), Phys. Rev. Lett. **84**, 2786 (2000).

[37] D. E. Acosta *et al.* (CDF Collaboration), Phys. Rev. D **70**, 074008 (2004).

V. Khachatryan,[1] A. M. Sirunyan,[1] A. Tumasyan,[1] W. Adam,[2] T. Bergauer,[2] M. Dragicevic,[2] J. Erö,[2] C. Fabjan,[2] M. Friedl,[2] R. Frühwirth,[2] V. M. Ghete,[2] J. Hammer,[2,b] S. Hänsel,[2] C. Hartl,[2] M. Hoch,[2] N. Hörmann,[2] J. Hrubec,[2] M. Jeitler,[2] G. Kasieczka,[2] W. Kiesenhofer,[2] M. Krammer,[2] D. Liko,[2] I. Mikulec,[2] M. Pernicka,[2] H. Rohringer,[2] R. Schöfbeck,[2] J. Strauss,[2] A. Taurok,[2] F. Teischinger,[2] W. Waltenberger,[2] G. Walzel,[2] E. Widl,[2] C.-E. Wulz,[2] V. Mossolov,[3] N. Shumeiko,[3] J. Suarez Gonzalez,[3] L. Benucci,[4] L. Ceard,[4] K. Cerny,[4] E. A. De Wolf,[4] X. Janssen,[4] T. Maes,[4] L. Mucibello,[4] S. Ochesanu,[4] B. Roland,[4] R. Rougny,[4] M. Selvaggi,[4] H. Van Haevermaet,[4] P. Van Mechelen,[4] N. Van Remortel,[4] V. Adler,[5] S. Beauceron,[5] F. Blekman,[5] S. Blyweert,[5] J. D'Hondt,[5] O. Devroede,[5] R. Gonzalez Suarez,[5] A. Kalogeropoulos,[5] J. Maes,[5] M. Maes,[5] S. Tavernier,[5] W. Van Doninck,[5] P. 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