Measurement of the tt¯ production cross section in pp collisions at s√=8 TeV in dilepton final states containing one lepton

Khachatryan, V ; Sirunyan, A M ; Tumasyan, A ; Canelli, F ; Amsler, C ; Chiochia, V ; De Cosa, A ; Hinzmann, A ; Hreus, T ; Kilminster, B ; Lange, C ; Millan Mejias, B ; Ngadiuba, J ; Robmann, P ; Ronga, F J ; Taroni, S ; Verzetti, M ; Yang, Y

Abstract: The top-quark pair production cross section is measured in final states with one electron or muon and one hadronically decaying lepton from the process tt¯→( )( )bb¯ , where =e, . The data sample corresponds to an integrated luminosity of 19.6 fb −1 collected with the CMS detector in proton–proton collisions at s=8 TeV . The measured cross section tt¯=257±3 (stat)±24 (syst)±7 (lumi) pb , assuming a top-quark mass of 172.5 GeV, is consistent with the standard model prediction.

DOI: https://doi.org/10.1016/j.physletb.2014.10.032

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-PH-EP/2013-037
2014/10/29

CMS-TOP-12-026

Measurement of the $\mathrm{t\bar{t}}$ production cross section in pp collisions at $\sqrt{s} = 8\,\mathrm{TeV}$ in dilepton final states containing one τ lepton

The CMS Collaboration*

Abstract

The top-quark pair production cross section is measured in final states with one electron or muon and one hadronically decaying τ lepton from the process $\mathrm{t\bar{t}} \rightarrow (\ell\nu_\ell)(\tau\nu_\tau)\mathrm{b\bar{b}}$, where $\ell = \mathrm{e}, \mu$. The data sample corresponds to an integrated luminosity of $19.6\,\mathrm{fb}^{-1}$ collected with the CMS detector in proton-proton collisions at $\sqrt{s} = 8\,\mathrm{TeV}$. The measured cross section $\sigma_{\mathrm{t\bar{t}}} = 257 \pm 3\,(\mathrm{stat}) \pm 24\,(\mathrm{syst}) \pm 7\,(\mathrm{lumi})\,\mathrm{pb}$, assuming a top-quark mass of $172.5\,\mathrm{GeV}$, is consistent with the standard model prediction.

Published in Physics Letters B as doi:10.1016/j.physletb.2014.10.032.

*See Appendix A for the list of collaboration members

1 Introduction

Top quarks at the CERN LHC are mostly produced in pairs with the subsequent decays $t\bar{t} \rightarrow W^{+}bW^{-}\bar{b}$. The decay modes of the two W bosons determine the event signature. The dilepton decay channel corresponds to the case in which both W bosons decay into leptons, where the term lepton usually refers to electrons or muons, as studied in Refs. [1, 2]. In this letter we measure the production cross section of top-quark pairs by considering dilepton decays where one W boson promptly decays into $\ell\nu_{\ell}$, with $\ell = e$ or μ, and the other decays into $\tau\nu_{\tau}$, $t\bar{t} \rightarrow (\ell\nu_{\ell})(\tau\nu_{\tau})b\bar{b}$. The expected fraction of these events is 4/81 of all $t\bar{t}$ decays. The τ lepton is identified by means of its hadronic decay products, with a branching fraction $\mathcal{B}(\tau \rightarrow \text{hadrons} + \nu_{\tau}) \simeq 65\%$, to produce a narrow jet with a small number of charged hadrons, denoted as τ_{h}. The cross section is measured by counting the number of $\ell\tau_{h} + X$ events consistent with originating from $t\bar{t}$ production, after subtracting the contributions from other processes, and correcting for the efficiency of the event selection. A similar method was used in pp collisions at a centre-of-mass energy of $\sqrt{s} = 7\,\text{TeV}$ [3]. This "τ dilepton" channel is of particular interest because it is a natural background process to the search for a charged Higgs boson [4, 5] with a mass smaller than that of the top quark. In this case, the production chain $t\bar{t} \rightarrow H^{+}bW^{-}\bar{b}$, with $H^{+} \rightarrow \tau^{+}\nu_{\tau}$ (or the corresponding charge-conjugate particles) could give rise to differences with respect to the standard model (SM) prediction of the number of $t\bar{t}$ events with a τ lepton [6]. The present measurement is based on data collected by the CMS experiment in pp collisions at $\sqrt{s} = 8\,\text{TeV}$ corresponding to an integrated luminosity of $19.6\,\text{fb}^{-1}$. The relative accuracy of this measurement improves over previous results [7–11], thanks to the inclusion of additional data and improved analysis techniques.

The CMS detector is briefly introduced in Section 2, followed by details of the simulated samples in Section 3, and a brief description of the event reconstruction and event selection in Section 4. The descriptions of the background determination and the systematic uncertainties are given in Sections 5 and 6, respectively. The measurement of the cross section is discussed in Section 7, and the results are summarised in Section 8.

2 The CMS detector

The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter and 13 m in length, providing a magnetic field of 3.8 T. Within the superconducting solenoid volume are a silicon pixel and strip tracker, a lead tungstate crystal electromagnetic calorimeter, and a brass/scintillator hadron calorimeter, each composed of a barrel and two endcap sections. The calorimetry provides high-resolution energy and direction measurements of electrons and hadronic jets. Muons are identified using gas-ionization detectors embedded in the steel flux-return yoke outside the solenoid. Extensive forward calorimetry complements the coverage provided by the barrel and endcap detectors. The CMS experiment uses a right-handed coordinate system, with the origin at the nominal interaction point, the x axis pointing to the centre of the LHC ring, the y axis pointing up (perpendicular to the LHC plane), and the z axis along the anticlockwise-beam direction. The polar angle θ is measured from the positive z axis and the azimuthal angle φ is measured in the x-y plane. Charged particle trajectories are measured covering $0 < \varphi \leq 2\pi$ in azimuth and $|\eta| < 2.5$, where the pseudorapidity η is defined as $\eta = -\ln[\tan(\theta/2)]$. The detector is nearly hermetic, allowing for energy balance measurements in the plane transverse to the beam directions. A two-level trigger system selects the most interesting proton-proton collision events for use in physics analyses. A more detailed description of the CMS detector can be found elsewhere [12].

3 Data and simulation samples

Events are selected online by a trigger requiring a single isolated electron (muon) with transverse momentum $p_{\mathrm{T}} > 27\,(24)\,\mathrm{GeV}$ and $|\eta| < 2.5\,(2.1)$.

This measurement makes use of simulated samples of $\mathrm{t\bar{t}}$ events as well as other processes that mimic the $\ell\tau_{\mathrm{h}}$ decay signature. These samples are used to optimise the event selection, to calculate the acceptance for $\mathrm{t\bar{t}}$ events, and to estimate some of the backgrounds in the analysis.

The signal acceptance and $\mathrm{t\bar{t}}$ dilepton background are evaluated using a version of MADGRAPH which includes the effects of spin correlations [13, 14]. The number of expected $\mathrm{t\bar{t}}$ events is estimated with the next-to-next-to-leading-order (NNLO) SM cross section of $251.7^{+6.3}_{-8.6}\,(\mathrm{scale}) \pm 6.5\,(\mathrm{PDF})\,\mathrm{pb}$ [15–19] for a top-quark mass of 172.5 GeV, where the first uncertainty is due to renormalisation and factorisation scales, and the second is due to the choice of parton distribution functions (PDFs). The generated events are subsequently processed with PYTHIA 6.426 [20] which performs the hadronisation of partons. Soft radiation is matched to the contributions from direct emissions accounted for in the matrix-element calculations using the k_{T}-MLM approach [21]. The τ lepton decays are simulated using TAUOLA 27.121.5 [22], which accounts for the τ-lepton polarization.

The samples containing W+jet and Z+jet events are simulated using the MADGRAPH 5.1.3.30 event generator [23]. The electroweak production of single top quarks is considered as a background process and is simulated with POWHEG 1.0, r1380 [24–28]. The diboson production processes WW, WZ, and ZZ are generated with PYTHIA 6.424. In each case, the PYTHIA parameters for the underlying event are set according to the Z2* tune [29], which uses the CTEQ6L PDFs [30].

Simulated events are processed using the full CMS detector simulation based on GEANT4 [31, 32], followed by a detailed trigger emulation and event reconstruction. For both signal and background events, additional pp interactions (pileup) in the same or nearby bunch crossings are simulated with PYTHIA and superimposed on the hard collision, using a pileup multiplicity distribution that reflects the luminosity profile of the analysed data.

4 Event selection

Events are reconstructed with the particle-flow (PF) algorithm [33, 34], which combines information from all sub-detectors to identify and reconstruct individual electrons, muons, photons, charged and neutral hadrons. The primary collision vertex is chosen as the reconstructed vertex with the largest $\sum p_{\mathrm{T}}^2$ of the associated tracks. Electrons are identified with a multivariate discriminant combining several quantities describing the track quality, the shape of the energy deposits in the electromagnetic calorimeter, and the compatibility of the measurements from the tracker and the electromagnetic calorimeter [35], and are reconstructed with an average efficiency of approximately 95%. Muons are identified with additional requirements on the quality of the track reconstruction and on the number of measurements in the tracker and the muon systems [36], and are reconstructed with an average efficiency of approximately 96%. Charged and neutral particles provide the input to the anti-k_{T} jet clustering algorithm with a distance parameter of 0.5 [37]. The jet momentum is determined from the vector sum of particle momenta in the jet. After jet energies are corrected for additional pileup contributions and for detector effects, they are found in simulations to be within 5–10% of the actual jet momentum [38]. The missing transverse energy $E_{\mathrm{T}}^{\mathrm{miss}}$ is calculated as the magnitude of the vector sum of momenta from all reconstructed particles in the plane transverse to the beam.

In addition, higher-level observables such as b-tagging discriminators and lepton isolation variables are used. The lepton relative isolation is defined as the transverse energy contributions deposited by charged hadrons ($E_{\mathrm{T,\,ch}}$), neutral hadrons ($E_{\mathrm{T,\,nh}}$), and photons ($E_{\mathrm{T,\,ph}}$) in a cone of radius $R = \sqrt{(\Delta\varphi)^2 + (\Delta\eta)^2} = 0.4$ centered on the lepton candidate track, relative to the lepton's transverse momentum (p_{T}), $I_{\mathrm{rel}} = (E_{\mathrm{T,\,ch}} + E_{\mathrm{T,\,nh}} + E_{\mathrm{T,\,ph}})/p_{\mathrm{T}}$. An electron (muon) candidate is considered to be non-isolated and is rejected if $I_{\mathrm{rel}} > 0.1$ ($>$0.12).

The hadronic products of the τ-lepton decay are reconstructed using a jet as the initial seed, and are then classified as having one or three charged hadrons with the "hadron-plus-strips" algorithm [39, 40]. In the "hadron-plus-strips" algorithm, calorimeter energy deposits clustered along strips in the φ direction are used for neutral pion identification. Then, the decay modes, four-momenta, and isolation quantities of the τ_{h} are determined, and the following categories are considered: single hadron, hadron plus a strip, hadron plus two strips, and three hadrons. These categories together encompass approximately 95% of hadronic τ-lepton decays. The sum of the charged hadron charges provides the τ_{h} charge. The τ_{h}-jet momentum is required to match the direction of the original jet within a maximum distance $R = 0.1$. Isolation criteria require that there be no additional charged hadrons with $p_{\mathrm{T}} > 1.0\,\mathrm{GeV}$ or photons with transverse energy $E_{\mathrm{T}} > 1.5\,\mathrm{GeV}$ within a cone of size $R = 0.5$ around the direction of the τ_{h} jet. Electrons and muons misidentified as τ_{h} are suppressed using algorithms that combine information from the tracker, calorimeters, and muon detectors [12]. The τ_{h} identification efficiency is defined as the ratio of the number of selected τ_{h} candidates divided by the number of hadronic τ-lepton decays in $\mathrm{t\bar{t}}$ events; the ratio depends on p_{T} and η of the τ_{h}, and is on average 50% for $p_{\mathrm{T}}^{\tau_{\mathrm{h}}} > 20\,\mathrm{GeV}$, with a probability of approximately 1% for generic jets to be misidentified as a τ_{h} jet.

The combined secondary vertex (CSV) algorithm [41] is used to identify jets originating from the hadronisation of b quarks. The algorithm combines the information about track impact parameters and secondary vertices within jets into a likelihood discriminant to provide separation between b jets and jets originating from light quarks, gluons, or charm quarks. The output of this CSV discriminant has values between zero and one; a jet with a CSV value above a certain threshold is referred to as being "b tagged". We choose a working point where the b-tagging efficiency is approximately 60%, as measured in a data sample of events enriched with jets from semileptonic b-hadron decays. The misidentification rate of light-flavour jets is estimated from inclusive jet studies and is measured to be about 0.1% for jets with $p_{\mathrm{T}} > 30\,\mathrm{GeV}$.

Events are preselected by requiring exactly one isolated electron (muon) with transverse momentum $p_{\mathrm{T}} > 35\,(30)\,\mathrm{GeV}$ and $|\eta| < 2.5\,(2.1)$, at least two jets with $p_{\mathrm{T}} > 30\,\mathrm{GeV}$, and one additional jet with $p_{\mathrm{T}} > 20\,\mathrm{GeV}$. The selected jets must be within $|\eta| < 2.4$. The electron or muon is required to be separated from any jet in the (η, φ) plane by a distance $R > 0.4$. Events with any additional loosely isolated, $I_{\mathrm{rel}} < 0.2$, electron (muon) of $p_{\mathrm{T}} > 15\,(10)\,\mathrm{GeV}$ are rejected. Further event selection requirements include $E_{\mathrm{T}}^{\mathrm{miss}} > 40\,\mathrm{GeV}$ and only one τ_{h} with $p_{\mathrm{T}} > 20\,\mathrm{GeV}$ and $|\eta| < 2.4$. The τ_{h} and the lepton are required to have electric charges of opposite sign (OS). At least one of the jets is required to be identified as originating from b-quark hadronisation (b-tagged).

Figure 1 shows, for the sum of the $\mathrm{e}\tau_{\mathrm{h}}$ and $\mu\tau_{\mathrm{h}}$ final states, a comparison between data and simulation of the number of b-tagged jets in each event $N_{\text{b-tag}}$ after all the selection criteria have been applied. The distributions of the τ_{h} p_{T} and $E_{\mathrm{T}}^{\mathrm{miss}}$ after the final event selection are shown in the left and right panels of Fig. 2, respectively. The distributions show agreement between the observed numbers of events and the expected numbers of signal and background events obtained from the simulated distributions normalised to the integrated luminosity of

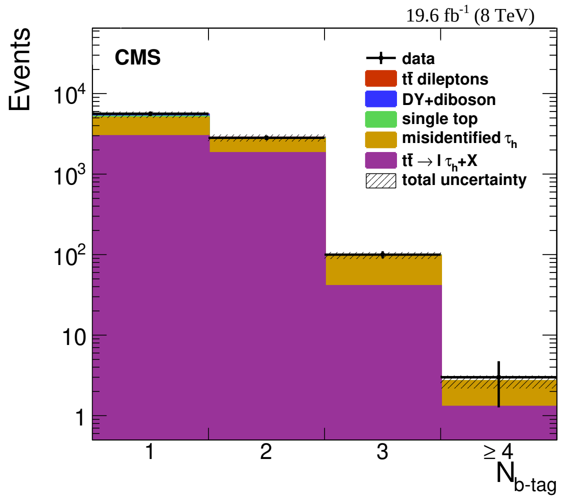

Figure 1: The b-tagged jet multiplicity after the full event selection. The simulated contributions are normalised to the SM predicted values. The hatched area shows the total uncertainty.

the selected data sample.

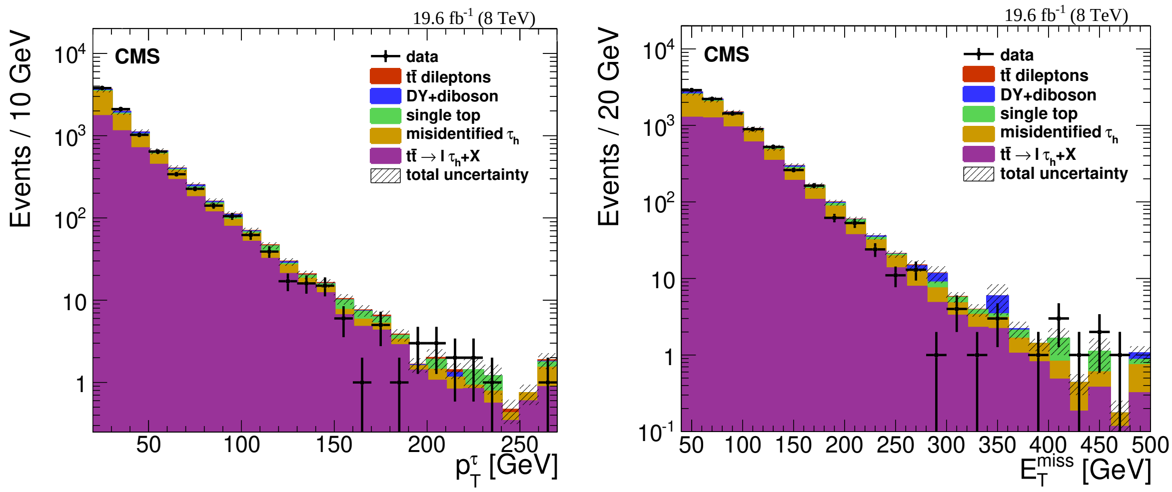

Figure 2: Distribution of the τ_h p_T (left) and E_T^{miss} (right) after the full event selection, for the eτ_h and $\mu\tau_h$ channels combined. The simulated contributions are normalised to the SM predicted values. The hatched area shows the total uncertainty. The last bins include the overflow events.

Following the final selection, additional kinematic features of the $t\bar{t}$ events are studied to evaluate the agreement between the observed data and the predicted sum of signal and background. For each event, two invariant mass combinations are reconstructed by pairing the τ_h with the two candidate b-jets: (1) in events with two or more b-tagged jets, the two combinations are based on the two b-tagged jets with the highest value of the discriminator; (2) in events with one b-tagged jet, this is used for the first combination, while the non-b-tagged jet with the highest p_T is used to form the second combination. For the two combinations, the invariant mass with the lowest value is shown in Fig. 3 (left), for the eτ_h and $\mu\tau_h$ channels combined.

For each event, the top-quark mass m_{top} is reconstructed using the KINb algorithm [42, 43]. Due to the multiple neutrinos in the event, the reconstruction of m_{top} leads to an underconstrained system. The KINb algorithm applies constraints on the W boson mass, the mass difference between the top and anti-top quark, and the longitudinal momentum of the $t\bar{t}$ system. For each event, solutions to the kinematic equations are evaluated, varying the jet momenta and the direction of $E_{\mathrm{T}}^{\mathrm{miss}}$ within their resolutions. For each set of variations and each lepton-jet combination, the kinematic equations allow up to four solutions; the one with the lowest $\mathrm{t\bar{t}}$ invariant mass is accepted if the mass difference between the two top quarks is less than 3 GeV. For each event, the accepted solutions corresponding to the two possible lepton-jet combinations are counted and the combination with the largest number of solutions is chosen and m_{top} is obtained by fitting the peak of this distribution. The events in which solutions are found are shown in Fig. 3 (right). Data are in agreement with the expected sum of signal and background events.

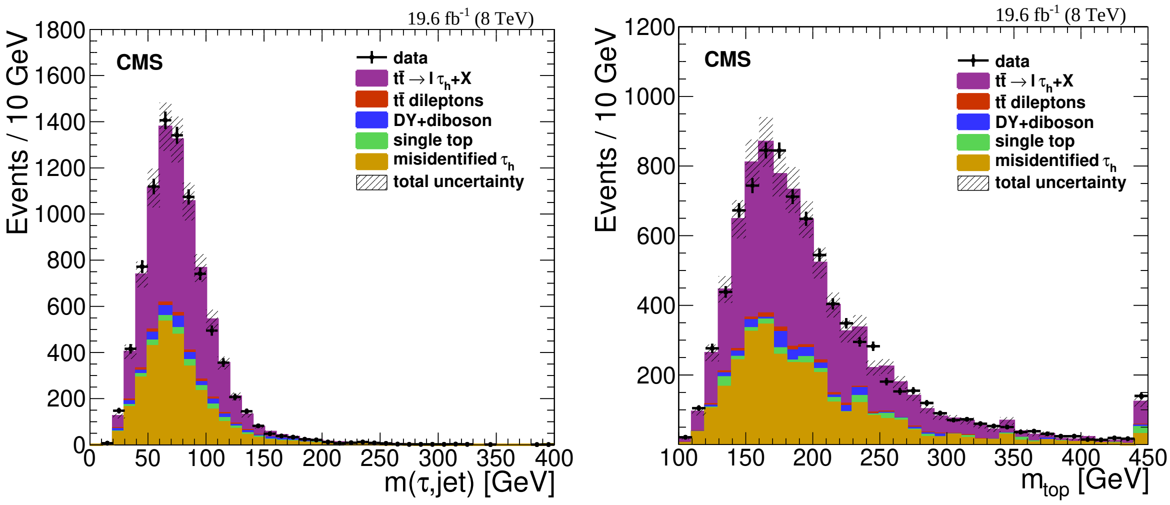

Figure 3: (left) Minimum invariant mass reconstructed by pairing the τ_{h} with either a b-tagged jet or with the highest p_{T} non b-tagged jet, as described in the text. (right) Distribution of the reconstructed top-quark mass m_{top} for the $\ell\tau_{\mathrm{h}}$ candidate events after the full event selection. Data (points) are compared with the sum of signal and background yields, for the $\mathrm{e}\tau_{\mathrm{h}}$ and $\mu\tau_{\mathrm{h}}$ channels combined. The simulated contributions are normalised to the SM predicted values. The hatched area shows the total uncertainty. The last bins include the overflow events.

5 Background estimate

The main background (misidentified τ_{h}) comes from events with one lepton (electron or muon), significant $E_{\mathrm{T}}^{\mathrm{miss}}$, and three or more jets, where one jet is misidentified as a τ_{h} jet [6]. The dominant source is $\mathrm{t\bar{t}}$ lepton+jet events. The misidentified τ_{h} background accounts also for events with W bosons produced in association with jets, either genuine W+jet or single-top-quark production, and for QCD multijet events. In order to estimate this background from data, the misidentification probability $w(\mathrm{jet} \to \tau_{\mathrm{h}})$ is parameterised as a function of the jet p_{T}, η, and width (R_{jet}). The quantity R_{jet} is defined as $\sqrt{\sigma_\eta^2 + \sigma_\varphi^2}$, where σ_η (σ_φ) expresses the extent in η (φ) of the jet cluster [38].

The probability $w(\mathrm{jet} \to \tau_{\mathrm{h}})$ is evaluated from two control samples:

- $w_{W+\mathrm{jets}}$: from a W+jet event sample, selected by requiring one isolated muon with $p_{\mathrm{T}} > 20\,\mathrm{GeV}$ and $|\eta| < 2.1$, and at least one jet with $p_{\mathrm{T}} > 20\,\mathrm{GeV}$ and $|\eta| < 2.4$;
- w_{QCD}: from a QCD multijet sample, triggered by one jet with $p_{\mathrm{T}} > 40\,\mathrm{GeV}$, selected by requiring events to have at least two jets with $p_{\mathrm{T}} > 20\,\mathrm{GeV}$ and $|\eta| < 2.4$, where the triggering jet is removed from the misidentification rate calculation to avoid a trigger bias.

Both probabilities are evaluated in simulated events as well as in data, with good agreement found between the results from simulation and data [39].

The number of events containing misidentified τ_h candidates is then determined as

$$N^{\text{misid}} = \sum_{i}^{M} \sum_{j}^{m} w_i^j(\text{jet} \to \tau) - N^{\text{other}}, \tag{1}$$

where j is the jet index of event i, and m is the number of jets in each event and M is the total number of events. The quantity N^{other} is the expected $\simeq$20% contamination from signal and other processes to the misidentified background as estimated from simulated samples. The value of N^{other} is evaluated by applying the procedure described above to simulated events of $Z/\gamma^* \to \tau\tau$, single-top-quark production, diboson production, and the $t\bar{t}$ processes included in the misidentified τ_h background estimation.

Jets in QCD multijet events originate mainly from gluons, while in W+jet events they are predominantly from quarks. The quark and gluon composition in the misidentified τ_h events lies between these two control samples. As $w_{\text{QCD}} < w_{\text{W+jets}}$, the actual N^{misid} value is under- (over-) estimated by applying the w_{QCD} ($w_{\text{W+jets}}$) probability. We determine from data the rate for the misidentification of a jet to be identified as a τ_h, and from simulation the quark/gluon composition in the W+jet and multijet samples. From these quantities we derive the following combination:

$$\langle N^{\text{misid}} \rangle = SF_{\text{W+jet}} \times N^{\text{misid}}_{\text{W+jet}} + SF_{\text{QCD}} \times N^{\text{misid}}_{\text{QCD}}, \tag{2}$$

where the misidentification rates, extracted from the data control samples discussed above, are combined with the scale factors SFs determined from the set of equations describing the quark/gluon composition of the samples: $SF_{\text{QCD}} = 0.83$ and $SF_{\text{W+jet}} = 0.17$. The corresponding systematic uncertainty is obtained from Eq. (2) by weighting the relative deviations of $N^{\text{misid}}_{\text{W+jet}}$ and $N^{\text{misid}}_{\text{QCD}}$ from $\langle N^{\text{misid}} \rangle$ with the related scale factors. This results in an uncertainty of 7% for both $e\tau_h$ and $\mu\tau_h$ channels.

The efficiency of the OS requirement ε_{OS} is determined from simulated lepton+jet $t\bar{t}$ events and is applied in order to obtain the misidentified τ_h background after the final event selection $N^{\text{misid}}_{\text{OS}}$, where $N^{\text{misid}}_{\text{OS}} = \varepsilon_{\text{OS}} \cdot N^{\text{misid}}$. We find values of $\varepsilon_{\text{OS}} = 0.729 \pm 0.002\,(\text{stat}) \pm 0.004\,(\text{syst})$ for the $e\tau_h$ selection and $\varepsilon_{\text{OS}} = 0.731 \pm 0.002\,(\text{stat}) \pm 0.003\,(\text{syst})$ for the $\mu\tau_h$ selection, where all sources of systematic uncertainty are accounted for in the modelling of the simulated $t\bar{t}$ lepton+jet events.

6 Systematic uncertainties

Several sources of systematic uncertainty are considered and listed in Table 1. They are related both to the signal reconstruction efficiency, background determination, and luminosity measurement (Experimental uncertainties) and to the theoretical assumptions on the $t\bar{t}$ production (Theoretical uncertainties). In Table 1 and in what follows, relative values refer to the cross section uncertainty unless explicitly stated otherwise.

Table 1: List of systematic uncertainties in the cross section measurement, and their combination. Lepton reconstruction uncertainties are uncorrelated, while all other uncertainties are assumed 100% correlated.

Source	Uncertainty [%]		
	$e\tau_h$	$\mu\tau_h$	Combined
Experimental uncertainties:			
τ_h jet identification	6.0	6.0	6.0
τ_h misidentification background	4.3	4.3	4.3
τ_h energy scale	2.4	2.5	2.5
b-jet tagging, jet misidentification	1.6	1.6	1.6
jet energy scale, jet energy resolution, E_T^{miss}	1.9	1.9	1.9
lepton reconstruction	0.8	0.6	0.5
other backgrounds	0.6	0.7	0.7
luminosity	2.6	2.6	2.6
Theoretical uncertainties:			
matrix element-parton shower matching	1.7	1.3	1.5
factorisation/renormalisation scale	2.9	2.9	2.9
generator	1.5	1.5	1.5
hadronisation	1.7	1.7	1.7
top-quark p_T modelling	0.7	0.5	0.6
parton distribution functions	0.8	0.7	0.7
total systematic uncertainty	9.6	9.5	9.5

Experimental uncertainties

Regarding the τ_h reconstruction, the uncertainty associated to the identification efficiency amounts to 6%, while the contribution relative to the τ_h jet energy scale is 2.4% (2.5%) for the $e\tau_h$ ($\mu\tau_h$) channel, as estimated by varying the p_T of the τ_h jet by 3% [39, 40]. The uncertainty in the τ_h identification efficiency includes the uncertainty in charge determination which is estimated to be smaller than 1%. The uncertainty related to the misidentified τ_h background process, discussed in Section 5, is obtained by propagating the 7% uncertainty on $\langle N^{misid} \rangle$ to the cross section determination and results in 4.3% for both channels. It also includes the uncertainty in the OS efficiency determination.

The reconstruction of a light flavour jet as a b quark is defined as mistagging. The uncertainty due to b (mis)tagging is estimated to reflect the data-to-simulation scale factors and corresponding uncertainties for b-tagging and mistagging efficiencies [41]. When propagated to the cross section measurement, they amount to 1.6% for both $e\tau_h$ and $\mu\tau_h$ channels.

The jet energy scale (JES) uncertainty is estimated [38] by varying the jet energy within the p_T- and η-dependent JES uncertainties per jet, and taking into account the uncertainty due to pileup and parton flavour. The jet energy resolution (JER) is estimated by smearing the jet energy in simulation within the η-dependent JER uncertainties per jet. The JES and JER uncertainties are propagated in order to estimate the uncertainty of the E_T^{miss} scale. In addition, modelling of the E_T^{miss} component, which is not clustered in jets, is also considered. The resulting uncertainty from propagating these effects to the cross section measurement is 1.9% for both the $e\tau_h$ and $\mu\tau_h$ channels.

Uncertainties due to trigger, lepton identification, isolation, and lepton energy scale are calculated from independent samples with a “tag-and-probe” method [35, 36], and yield 0.8% (0.6%)

for the $e\tau_h$ ($\mu\tau_h$) channel.

An overall 0.6% (0.7%) uncertainty for the $e\tau_h$ ($\mu\tau_h$) channel is due to other minor backgrounds, accounting for the uncertainties related to the theoretical cross sections, JES, and b-tagging in these simulated samples, and the $\ell \to \tau_h$ ($\ell = e, \mu$) misidentification in the $Z/\gamma^* \to \ell^+\ell^-$ and $t\bar{t}$ dilepton processes.

Finally, the integrated luminosity is known with 2.6% accuracy [44].

Theoretical uncertainties

The theoretical uncertainty due to the matrix element (ME) and parton shower (PS) matching is estimated by varying up and down by a factor of two the threshold between jet production at the ME level and via PS, and it results in 1.7% (1.3%) for the $e\tau_h$ ($\mu\tau_h$) channel.

The modelling uncertainty in the signal acceptance due to the factorisation and renormalisation scale choices is estimated by varying them simultaneously up and down by a factor of two from the nominal value equal to the Q^2 in the event, with an uncertainty of 2.9% found for both channels.

The uncertainty due to the choice of the generator is estimated as the relative difference between the acceptances evaluated with MADGRAPH and POWHEG [24–26, 45] after the full event selection and results in 1.5%. In a similar way, the uncertainty in the hadronisation scheme is evaluated from the relative differences between the acceptances from POWHEG+PYTHIA and POWHEG+HERWIG samples, estimated prior to the b-tagging or τ_h jet requirement, resulting in a 1.7% uncertainty.

We consider the uncertainty related to the top-quark p_T scale modelling by varying the top-quark p_T spectrum and evaluating the change in the signal acceptance, resulting in 0.6%, and the uncertainty related to the PDF variations following the PDF4LHC prescriptions [17], resulting in 0.7%.

7 Cross section measurement

The number of expected signal and background events as well as the number of observed events after all selections are summarised in Table 2. The statistical and systematic uncertainties are also shown. The $t\bar{t}$ production cross section measured from τ dilepton events is $\sigma_{t\bar{t}} = (N - B)/(L \cdot A_{\text{tot}})$, where N is the number of observed candidate events, B is the estimate of the background and L is the integrated luminosity. The total acceptance A_{tot} is the product of the branching fractions, geometrical and kinematic acceptance, trigger, lepton identification, and the overall reconstruction efficiency. It is evaluated with respect to the inclusive $t\bar{t}$ sample. After the OS requirement and assuming a top-quark mass $m_{\text{top}} = 172.5\,\text{GeV}$, we obtain:

$$A_{\text{tot}}(e\tau_h) = 0.04333 \pm 0.00017\,(\text{stat}) \pm 0.00300\,(\text{syst})\,\%;$$
$$A_{\text{tot}}(\mu\tau_h) = 0.05370 \pm 0.00021\,(\text{stat}) \pm 0.00376\,(\text{syst})\,\%.$$

The statistical uncertainties are due to the limited number of simulated events and the systematic uncertainties are estimated by accounting for all sources listed in Table 1. The statistical and systematic uncertainties listed in Table 2 are propagated to the final cross section measurements:

$$\sigma_{t\bar{t}}(e\tau_h) = 255 \pm 4\,(\text{stat}) \pm 24\,(\text{syst}) \pm 7\,(\text{lumi})\,\text{pb};$$
$$\sigma_{t\bar{t}}(\mu\tau_h) = 258 \pm 4\,(\text{stat}) \pm 24\,(\text{syst}) \pm 7\,(\text{lumi})\,\text{pb}.$$

Table 2: Number of expected events for signal (assuming $m_{\mathrm{top}} = 172.5\,\mathrm{GeV}$) and backgrounds. The background from misidentified τ_{h} is estimated from data, while the other backgrounds are estimated from simulation. Statistical and systematic uncertainties are shown.

Source	$\mathrm{e}\tau_{\mathrm{h}}$	$\mu\tau_{\mathrm{h}}$
misidentified τ_{h}	$1341 \pm 3 \pm 94$	$1653 \pm 3 \pm 116$
$\mathrm{t\bar{t}} \to (\ell\nu_\ell)(\ell\nu_\ell)\mathrm{b\bar{b}}$	$55 \pm 1 \pm 3$	$68 \pm 2 \pm 4$
$\mathrm{Z}/\gamma^* \to \mathrm{ee}, \mu\mu$	$11 \pm 5 \pm 5$	$12 \pm 5 \pm 5$
$\mathrm{Z}/\gamma^* \to \tau\tau$	$85 \pm 14 \pm 8$	$166 \pm 20 \pm 18$
single top quark	$104 \pm 7 \pm 9$	$133 \pm 8 \pm 10$
dibosons	$15 \pm 1 \pm 1$	$19 \pm 1 \pm 1$
total expected background	$1611 \pm 17 \pm 95$	$2051 \pm 22 \pm 118$
expected signal yield	$2134 \pm 9 \pm 170$	$2632 \pm 11 \pm 212$
data	3779	4767

The BLUE method [46] is used to combine the cross section measurements in the $\mathrm{e}\tau_{\mathrm{h}}$ and $\mu\tau_{\mathrm{h}}$ channels, yielding weights of 0.47 and 0.53, respectively. Lepton reconstruction uncertainties are uncorrelated, while all other uncertainties are assumed 100% correlated. With this method we obtain a combined result of $\sigma_{\mathrm{t\bar{t}}} = 257 \pm 3\,(\mathrm{stat}) \pm 24\,(\mathrm{syst}) \pm 7\,(\mathrm{lumi})\,\mathrm{pb}$, in agreement with the NNLO expectation of $251.7\,^{+6.3}_{-8.6}\,(\mathrm{scales}) \pm 6.5\,(\mathrm{PDF})\,\mathrm{pb}$. Following the most recent conventions for the treatment of PDF and scale uncertainties the same calculation yields $252.9\,^{+6.4}_{-8.6}\,(\mathrm{scale}) \pm 11.7\,(\mathrm{PDF} + \alpha_{\mathrm{S}})\,\mathrm{pb}$ [15–19]. The dependence on the top-quark mass has been studied for the range 160–185 GeV and is well described by a linear variation. If we adjust our result to the current world average value of 173.3 GeV [47], we obtain a cross section that is lower by 3.1 pb.

8 Summary

A measurement of the $\mathrm{t\bar{t}}$ production cross section in the channel $\mathrm{t\bar{t}} \to (\ell\nu_\ell)(\tau\nu_\tau)\mathrm{b\bar{b}}$ is presented, where ℓ is an electron or a muon, and the τ lepton is reconstructed through its hadronic decays. The data sample corresponds to an integrated luminosity of $19.6\,\mathrm{fb}^{-1}$ collected in proton-proton collisions at $\sqrt{s} = 8\,\mathrm{TeV}$. Events are selected by requiring the presence of one isolated electron or muon, two or more jets (at least one of which is b-tagged), significant missing transverse energy, and one τ. The largest background contribution is estimated from data and consists of $\mathrm{t\bar{t}}$ events with one W boson decaying into jets, where one jet is misidentified as a τ. The measured cross section is $\sigma_{\mathrm{t\bar{t}}} = 257 \pm 3\,(\mathrm{stat}) \pm 24\,(\mathrm{syst}) \pm 7\,(\mathrm{lumi})\,\mathrm{pb}$ for a top-quark mass of 172.5 GeV. This measurement improves over previous results in this decay channel, and it is in good agreement with the standard model expectation and other measurements of the $\mathrm{t\bar{t}}$ cross section at same centre-of-mass energy.

Acknowledgements

We congratulate our colleagues in the CERN accelerator departments for the excellent performance of the LHC and thank the technical and administrative staffs at CERN and at other CMS institutes for their contributions to the success of the CMS effort. In addition, we gratefully acknowledge the computing centres and personnel of the Worldwide LHC Computing Grid for delivering so effectively the computing infrastructure essential to our analyses. Finally, we acknowledge the enduring support for the construction and operation of the LHC and the CMS detector provided by the following funding agencies: BMWFW and FWF (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MES (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIENCIAS (Colombia); MSES and CSF (Croatia); RPF (Cyprus); MoER, ERC IUT and ERDF (Estonia); Academy of Finland, MEC, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NIH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); NRF and WCU (Republic of Korea); LAS (Lithuania); MOE and UM (Malaysia); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); MBIE (New Zealand); PAEC (Pakistan); MSHE and NSC (Poland); FCT (Portugal); JINR (Dubna); MON, RosAtom, RAS and RFBR (Russia); MESTD (Serbia); SEIDI and CPAN (Spain); Swiss Funding Agencies (Switzerland); MST (Taipei); ThEPCenter, IPST, STAR and NSTDA (Thailand); TUBITAK and TAEK (Turkey); NASU and SFFR (Ukraine); STFC (United Kingdom); DOE and NSF (USA).

Individuals have received support from the Marie-Curie programme and the European Research Council and EPLANET (European Union); the Leventis Foundation; the A. P. Sloan Foundation; the Alexander von Humboldt Foundation; the Belgian Federal Science Policy Office; the Fonds pour la Formation à la Recherche dans l'Industrie et dans l'Agriculture (FRIA-Belgium); the Agentschap voor Innovatie door Wetenschap en Technologie (IWT-Belgium); the Ministry of Education, Youth and Sports (MEYS) of the Czech Republic; the Council of Science and Industrial Research, India; the HOMING PLUS programme of Foundation for Polish Science, cofinanced from European Union, Regional Development Fund; the Compagnia di San Paolo (Torino); the Consorzio per la Fisica (Trieste); MIUR project 20108T4XTM (Italy); the Thalis and Aristeia programmes cofinanced by EU-ESF and the Greek NSRF; and the National Priorities Research Program by Qatar National Research Fund.

References

[1] ATLAS Collaboration, "Measurement of the $t\bar{t}$ production cross-section using $e\mu$ events with b-tagged jets in pp collisions at $\sqrt{s} = 7$ and 8 TeV with the ATLAS detector", (2014). arXiv:1406.5375.

[2] CMS Collaboration, "Measurement of the $\mathrm{t\bar{t}}$ production cross section in the dilepton channel in pp collisions at $\sqrt{s} = 8\,\mathrm{TeV}$", *JHEP* **02** (2014) 024, doi:10.1007/JHEP02(2014)024, arXiv:1312.7582.

[3] CMS Collaboration, "Measurement of the top quark pair production cross section in pp collisions at $\sqrt{s} = 7$ TeV in dilepton final states containing a τ", *Phys. Rev. D* **85** (2012) 112007, doi:10.1103/PhysRevD.85.112007, arXiv:1203.6810.

[4] J. F. Gunion, H. E. Haber, G. L. Kane, and S. Dawson, "The Higgs Hunter's Guide". Frontiers in Physics. Addison-Wesley, 1990.

[5] A. Djouadi, "The anatomy of electro-weak symmetry breaking Tome II: The Higgs bosons in the minimal supersymmetric model", *Phys. Rept.* **459** (2008) 1, doi:10.1016/j.physrep.2007.10.005, arXiv:hep-ph/0503173.

[6] CMS Collaboration, "Search for a light charged Higgs boson in top quark decays in pp collisions at $\sqrt{s} = 7$ TeV", *JHEP* **07** (2012) 143, doi:10.1007/JHEP07(2012)143, arXiv:1205.5736.

[7] CDF Collaboration, "The $\mu\tau$ and $e\tau$ decays of top quark pairs produced in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV", *Phys. Rev. Lett.* **79** (1997) 3585, doi:10.1103/PhysRevLett.79.3585, arXiv:hep-ex/9704007.

[8] CDF Collaboration, "A search for $t \to \tau\nu q$ in $t\bar{t}$ production", *Phys. Lett. B* **639** (2006) 172, doi:10.1016/j.physletb.2006.06.030, arXiv:hep-ex/0510063.

[9] D0 Collaboration, "Measurement of the $t\bar{t}$ production cross section and top quark mass extraction using dilepton events in $p\bar{p}$ collisions", *Phys. Lett. B* **679** (2009) 177, doi:10.1016/j.physletb.2009.07.032, arXiv:0901.2137.

[10] CDF Collaboration, "Study of top quark production and decays involving a tau lepton at CDF and limits on a charged Higgs boson contribution", *Phys. Rev. D* **89** (2014) 091101, doi:10.1103/PhysRevD.89.091101, arXiv:1402.6728.

[11] ATLAS Collaboration, "Measurement of the top quark pair cross section with ATLAS in pp collisions at $\sqrt{s} = 7$ TeV using final states with an electron or a muon and a hadronically decaying τ lepton", *Phys. Lett. B* **717** (2012) 89, doi:10.1016/j.physletb.2012.09.032, arXiv:1205.2067.

[12] CMS Collaboration, "The CMS experiment at the CERN LHC", *JINST* **3** (2008) S08004, doi:10.1088/1748-0221/3/08/S08004.

[13] J. Alwall et al., "MadGraph 5: going beyond", *JHEP* **06** (2011) 128, doi:10.1007/JHEP06(2011)128, arXiv:1106.0522.

[14] J. Alwall et al., "The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations", *JHEP* **07** (2014) 079, doi:10.1007/JHEP07(2014)079, arXiv:1405.0301.

[15] M. Czakon, P. Fiedler, and A. Mitov, "The total top quark pair production cross section at hadron colliders through $O(\alpha_S^4)$", *Phys. Rev. Lett.* **110** (2013) 252004, doi:10.1103/PhysRevLett.110.252004, arXiv:1303.6254.

[16] M. Czakon and A. Mitov, "Top++: A program for the calculation of the top pair cross-section at hadron colliders", *Comput. Phys. Commun.* **185** (2014) 2930, doi:10.1016/j.cpc.2014.06.021, arXiv:1112.5675.

[17] M. Botje et al., "The PDF4LHC Working Group Interim Recommendations", (2011). arXiv:1101.0538.

[18] J. Gao et al., "CT10 next-to-next-to-leading order global analysis of QCD", *Phys. Rev. D* **89** (2014) 033009, doi:10.1103/PhysRevD.89.033009, arXiv:1302.6246.

[19] NNPDF Collaboration, "Parton distributions with LHC data", *Nucl. Phys. B* **867** (2013) 244, doi:10.1016/j.nuclphysb.2012.10.003, arXiv:1207.1303.

[20] T. Sjöstrand, S. Mrenna, and P. Z. Skands, "PYTHIA 6.4 physics and manual", *JHEP* **05** (2006) 026, doi:10.1088/1126-6708/2006/05/026, arXiv:hep-ph/0603175.

[21] J. Alwall et al., "Comparative study of various algorithms for the merging of parton showers and matrix elements in hadronic collisions", *Eur. Phys. J. C* **53** (2008) 473, doi:10.1140/epjc/s10052-007-0490-5, arXiv:0706.2569.

[22] P. Golonka et al., “The tauola-photos-F environment for the TAUOLA and PHOTOS packages, release II”, *Comput. Phys. Commun.* **174** (2006) 818, doi:10.1016/j.cpc.2005.12.018, arXiv:hep-ph/0312240.

[23] P. Artoisenet, R. Frederix, O. Mattelaer, and R. Rietkerk, “Automatic spin-entangled decays of heavy resonances in Monte Carlo simulations”, *JHEP* **03** (2013) 015, doi:10.1007/JHEP03(2013)015, arXiv:1212.3460.

[24] P. Nason, “A New method for combining NLO QCD with shower Monte Carlo algorithms”, *JHEP* **11** (2004) 040, doi:10.1088/1126-6708/2004/11/040, arXiv:hep-ph/0409146.

[25] S. Frixione, P. Nason, and C. Oleari, “Matching NLO QCD computations with parton shower simulations: the POWHEG method”, *JHEP* **11** (2007) 070, doi:10.1088/1126-6708/2007/11/070, arXiv:0709.2092.

[26] S. Alioli, P. Nason, C. Oleari, and E. Re, “A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX”, *JHEP* **06** (2010) 043, doi:10.1007/JHEP06(2010)043, arXiv:1002.2581.

[27] S. Alioli, P. Nason, C. Oleari, and E. Re, “NLO single-top production matched with shower in POWHEG: s- and t-channel contributions”, *JHEP* **09** (2009) 111, doi:10.1088/1126-6708/2009/09/111, arXiv:0907.4076. [Erratum: doi:10.1007/JHEP02(2010)011].

[28] E. Re, “Single-top Wt-channel production matched with parton showers using the POWHEG method”, *Eur. Phys. J. C* **71** (2011) 1547, doi:10.1140/epjc/s10052-011-1547-z, arXiv:1009.2450.

[29] CMS Collaboration, “Measurement of the underlying event activity at the LHC with $\sqrt{s} = 7$ TeV and comparison with $\sqrt{s} = 0.9$ TeV”, *JHEP* **11** (2011) 109, doi:10.1007/JHEP09(2011)109, arXiv:1107.0330.

[30] P. M. Nadolsky et al., “Implications of CTEQ global analysis for collider observables”, *Phys. Rev. D* **78** (2008) 013004, doi:10.1103/PhysRevD.78.013004, arXiv:0802.0007.

[31] GEANT4 Collaboration, “GEANT4—a simulation toolkit”, *Nucl. Instrum. Meth. A* **506** (2003) 250, doi:10.1016/S0168-9002(03)01368-8.

[32] J. Allison et al., “GEANT4 developments and applications”, *IEEE Trans. Nucl. Sci.* **53** (2006) 270, doi:10.1109/TNS.2006.869826.

[33] CMS Collaboration, “Particle flow event reconstruction in CMS and performance for jets, taus, and $E_{\mathrm{T}}^{\mathrm{miss}}$”, CMS Physics Analysis Summary CMS-PAS-PFT-09-001, 2009.

[34] CMS Collaboration, “Commissioning of the particle flow event reconstruction with the first LHC collisions recorded in the CMS detector”, CMS Physics Analysis Summary CMS-PAS-PFT-10-001, 2010.

[35] CMS Collaboration, “Electron reconstruction and Identification at $\sqrt{s} = 7$ TeV”, CMS Physics Analysis Summary CMS-PAS-EGM-10-004, 2010.

[36] CMS Collaboration, “Performance of CMS muon reconstruction in pp collision events at $\sqrt{s} = 7$ TeV”, *JINST* **7** (2012) P10002, doi:10.1088/1748-0221/7/10/P10002, arXiv:1206.4071.

[37] M. Cacciari, G. P. Salam, and G. Soyez, “The anti-k_t jet clustering algorithm”, *JHEP* **04** (2008) 063, doi:10.1088/1126-6708/2008/04/063, arXiv:0802.1189.

[38] CMS Collaboration, “Determination of jet energy calibration and transverse momentum resolution in CMS”, *JINST* **6** (2011) P11002, doi:10.1088/1748-0221/6/11/P11002, arXiv:1107.4277.

[39] CMS Collaboration, “Performance of tau lepton reconstruction and identification in CMS”, *JINST* **7** (2012) P01001, doi:10.1088/1748-0221/7/01/P01001, arXiv:1109.6034.

[40] CMS Collaboration, “Evidence for the 125 GeV Higgs boson decaying to a pair of τ leptons”, *JHEP* **05** (2014) 104, doi:10.1007/JHEP05(2014)104, arXiv:1401.5041.

[41] CMS Collaboration, “Identification of b-quark jets with the CMS experiment”, *JINST* **8** (2013) P04013, doi:10.1088/1748-0221/8/04/P04013, arXiv:1211.4462.

[42] CMS Collaboration, “Measurement of the top-quark mass in $\mathrm{t\bar{t}}$ events with dilepton final states in pp collisions at $\sqrt{s} = 7$ TeV”, *Eur. Phys. J. C* **72** (2012) 2202, doi:10.1140/epjc/s10052-012-2202-z, arXiv:1209.2393.

[43] CMS Collaboration, “Measurement of the $\mathrm{t\bar{t}}$ production cross section and the top quark mass in the dilepton channel in pp collisions at $\sqrt{s} = 7$ TeV”, *JHEP* **07** (2011) 049, doi:10.1007/JHEP07(2011)049, arXiv:1105.5661.

[44] CMS Collaboration, “CMS luminosity based on pixel cluster counting - Summer 2013 Update”, CMS Physics Analysis Summary CMS-PAS-LUM-13-001, 2013.

[45] S. Alioli, S.-O. Moch, and P. Uwer, “Hadronic top-quark pair-production with one jet and parton showering”, *JHEP* **01** (2012) 137, doi:10.1007/JHEP01(2012)137, arXiv:1110.5251.

[46] L. Lyons, D. Gibaut, and P. Clifford, “How to combine correlated estimates of a single physical quantity”, *Nucl. Instrum. Meth. A* **270** (1988) 110, doi:10.1016/0168-9002(88)90018-6.

[47] ATLAS, CDF, CMS, and D0 collaborations, “First combination of Tevatron and LHC measurements of the top quark mass”, (2014). arXiv:1403.4427.

A The CMS Collaboration

Yerevan Physics Institute, Yerevan, Armenia
V. Khachatryan, A.M. Sirunyan, A. Tumasyan

Institut für Hochenergiephysik der OeAW, Wien, Austria
W. Adam, T. Bergauer, M. Dragicevic, J. Erö, C. Fabjan[1], M. Friedl, R. Frühwirth[1], V.M. Ghete, C. Hartl, N. Hörmann, J. Hrubec, M. Jeitler[1], W. Kiesenhofer, V. Knünz, M. Krammer[1], I. Krätschmer, D. Liko, I. Mikulec, D. Rabady[2], B. Rahbaran, H. Rohringer, R. Schöfbeck, J. Strauss, A. Taurok, W. Treberer-Treberspurg, W. Waltenberger, C.-E. Wulz[1]

National Centre for Particle and High Energy Physics, Minsk, Belarus
V. Mossolov, N. Shumeiko, J. Suarez Gonzalez

Universiteit Antwerpen, Antwerpen, Belgium
S. Alderweireldt, M. Bansal, S. Bansal, T. Cornelis, E.A. De Wolf, X. Janssen, A. Knutsson, S. Luyckx, S. Ochesanu, B. Roland, R. Rougny, M. Van De Klundert, H. Van Haevermaet, P. Van Mechelen, N. Van Remortel, A. Van Spilbeeck

Vrije Universiteit Brussel, Brussel, Belgium
F. Blekman, S. Blyweert, J. D'Hondt, N. Daci, N. Heracleous, J. Keaveney, S. Lowette, M. Maes, A. Olbrechts, Q. Python, D. Strom, S. Tavernier, W. Van Doninck, P. Van Mulders, G.P. Van Onsem, I. Villella

Université Libre de Bruxelles, Bruxelles, Belgium
C. Caillol, B. Clerbaux, G. De Lentdecker, D. Dobur, L. Favart, A.P.R. Gay, A. Grebenyuk, A. Léonard, A. Mohammadi, L. Perniè[2], T. Reis, T. Seva, L. Thomas, C. Vander Velde, P. Vanlaer, J. Wang

Ghent University, Ghent, Belgium
V. Adler, K. Beernaert, L. Benucci, A. Cimmino, S. Costantini, S. Crucy, S. Dildick, A. Fagot, G. Garcia, J. Mccartin, A.A. Ocampo Rios, D. Ryckbosch, S. Salva Diblen, M. Sigamani, N. Strobbe, F. Thyssen, M. Tytgat, E. Yazgan, N. Zaganidis

Université Catholique de Louvain, Louvain-la-Neuve, Belgium
S. Basegmez, C. Beluffi[3], G. Bruno, R. Castello, A. Caudron, L. Ceard, G.G. Da Silveira, C. Delaere, T. du Pree, D. Favart, L. Forthomme, A. Giammanco[4], J. Hollar, P. Jez, M. Komm, V. Lemaitre, C. Nuttens, D. Pagano, L. Perrini, A. Pin, K. Piotrzkowski, A. Popov[5], L. Quertenmont, M. Selvaggi, M. Vidal Marono, J.M. Vizan Garcia

Université de Mons, Mons, Belgium
N. Beliy, T. Caebergs, E. Daubie, G.H. Hammad

Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil
W.L. Aldá Júnior, G.A. Alves, L. Brito, M. Correa Martins Junior, T. Dos Reis Martins, C. Mora Herrera, M.E. Pol

Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil
W. Carvalho, J. Chinellato[6], A. Custódio, E.M. Da Costa, D. De Jesus Damiao, C. De Oliveira Martins, S. Fonseca De Souza, H. Malbouisson, D. Matos Figueiredo, L. Mundim, H. Nogima, W.L. Prado Da Silva, J. Santaolalla, A. Santoro, A. Sznajder, E.J. Tonelli Manganote[6], A. Vilela Pereira

Universidade Estadual Paulista [a], Universidade Federal do ABC [b], São Paulo, Brazil
C.A. Bernardes[b], S. Dogra[a], T.R. Fernandez Perez Tomei[a], E.M. Gregores[b], P.G. Mercadante[b], S.F. Novaes[a], Sandra S. Padula[a]

Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria
A. Aleksandrov, V. Genchev[2], P. Iaydjiev, A. Marinov, S. Piperov, M. Rodozov, S. Stoykova, G. Sultanov, V. Tcholakov, M. Vutova

University of Sofia, Sofia, Bulgaria
A. Dimitrov, I. Glushkov, R. Hadjiiska, V. Kozhuharov, L. Litov, B. Pavlov, P. Petkov

Institute of High Energy Physics, Beijing, China
J.G. Bian, G.M. Chen, H.S. Chen, M. Chen, R. Du, C.H. Jiang, S. Liang, R. Plestina[7], J. Tao, X. Wang, Z. Wang

State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing, China
C. Asawatangtrakuldee, Y. Ban, Y. Guo, Q. Li, W. Li, S. Liu, Y. Mao, S.J. Qian, D. Wang, L. Zhang, W. Zou

Universidad de Los Andes, Bogota, Colombia
C. Avila, L.F. Chaparro Sierra, C. Florez, J.P. Gomez, B. Gomez Moreno, J.C. Sanabria

University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia
N. Godinovic, D. Lelas, D. Polic, I. Puljak

University of Split, Faculty of Science, Split, Croatia
Z. Antunovic, M. Kovac

Institute Rudjer Boskovic, Zagreb, Croatia
V. Brigljevic, K. Kadija, J. Luetic, D. Mekterovic, L. Sudic

University of Cyprus, Nicosia, Cyprus
A. Attikis, G. Mavromanolakis, J. Mousa, C. Nicolaou, F. Ptochos, P.A. Razis

Charles University, Prague, Czech Republic
M. Bodlak, M. Finger, M. Finger Jr.[8]

Academy of Scientific Research and Technology of the Arab Republic of Egypt, Egyptian Network of High Energy Physics, Cairo, Egypt
Y. Assran[9], A. Ellithi Kamel[10], M.A. Mahmoud[11], A. Radi[12,13]

National Institute of Chemical Physics and Biophysics, Tallinn, Estonia
M. Kadastik, M. Murumaa, M. Raidal, A. Tiko

Department of Physics, University of Helsinki, Helsinki, Finland
P. Eerola, G. Fedi, M. Voutilainen

Helsinki Institute of Physics, Helsinki, Finland
J. Härkönen, V. Karimäki, R. Kinnunen, M.J. Kortelainen, T. Lampén, K. Lassila-Perini, S. Lehti, T. Lindén, P. Luukka, T. Mäenpää, T. Peltola, E. Tuominen, J. Tuominiemi, E. Tuovinen, L. Wendland

Lappeenranta University of Technology, Lappeenranta, Finland
T. Tuuva

DSM/IRFU, CEA/Saclay, Gif-sur-Yvette, France
M. Besancon, F. Couderc, M. Dejardin, D. Denegri, B. Fabbro, J.L. Faure, C. Favaro, F. Ferri, S. Ganjour, A. Givernaud, P. Gras, G. Hamel de Monchenault, P. Jarry, E. Locci, J. Malcles, J. Rander, A. Rosowsky, M. Titov

Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France
S. Baffioni, F. Beaudette, P. Busson, C. Charlot, T. Dahms, M. Dalchenko, L. Dobrzynski, N. Filipovic, A. Florent, R. Granier de Cassagnac, L. Mastrolorenzo, P. Miné, C. Mironov, I.N. Naranjo, M. Nguyen, C. Ochando, P. Paganini, S. Regnard, R. Salerno, J.B. Sauvan, Y. Sirois, C. Veelken, Y. Yilmaz, A. Zabi

Institut Pluridisciplinaire Hubert Curien, Université de Strasbourg, Université de Haute Alsace Mulhouse, CNRS/IN2P3, Strasbourg, France
J.-L. Agram[14], J. Andrea, A. Aubin, D. Bloch, J.-M. Brom, E.C. Chabert, C. Collard, E. Conte[14], J.-C. Fontaine[14], D. Gelé, U. Goerlach, C. Goetzmann, A.-C. Le Bihan, P. Van Hove

Centre de Calcul de l'Institut National de Physique Nucleaire et de Physique des Particules, CNRS/IN2P3, Villeurbanne, France
S. Gadrat

Université de Lyon, Université Claude Bernard Lyon 1, CNRS-IN2P3, Institut de Physique Nucléaire de Lyon, Villeurbanne, France
S. Beauceron, N. Beaupere, G. Boudoul[2], E. Bouvier, S. Brochet, C.A. Carrillo Montoya, J. Chasserat, R. Chierici, D. Contardo[2], P. Depasse, H. El Mamouni, J. Fan, J. Fay, S. Gascon, M. Gouzevitch, B. Ille, T. Kurca, M. Lethuillier, L. Mirabito, S. Perries, J.D. Ruiz Alvarez, D. Sabes, L. Sgandurra, V. Sordini, M. Vander Donckt, P. Verdier, S. Viret, H. Xiao

Institute of High Energy Physics and Informatization, Tbilisi State University, Tbilisi, Georgia
Z. Tsamalaidze[8]

RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany
C. Autermann, S. Beranek, M. Bontenackels, M. Edelhoff, L. Feld, O. Hindrichs, K. Klein, A. Ostapchuk, A. Perieanu, F. Raupach, J. Sammet, S. Schael, H. Weber, B. Wittmer, V. Zhukov[5]

RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany
M. Ata, E. Dietz-Laursonn, D. Duchardt, M. Erdmann, R. Fischer, A. Güth, T. Hebbeker, C. Heidemann, K. Hoepfner, D. Klingebiel, S. Knutzen, P. Kreuzer, M. Merschmeyer, A. Meyer, P. Millet, M. Olschewski, K. Padeken, P. Papacz, H. Reithler, S.A. Schmitz, L. Sonnenschein, D. Teyssier, S. Thüer, M. Weber

RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany
V. Cherepanov, Y. Erdogan, G. Flügge, H. Geenen, M. Geisler, W. Haj Ahmad, A. Heister, F. Hoehle, B. Kargoll, T. Kress, Y. Kuessel, J. Lingemann[2], A. Nowack, I.M. Nugent, L. Perchalla, O. Pooth, A. Stahl

Deutsches Elektronen-Synchrotron, Hamburg, Germany
I. Asin, N. Bartosik, J. Behr, W. Behrenhoff, U. Behrens, A.J. Bell, M. Bergholz[15], A. Bethani, K. Borras, A. Burgmeier, A. Cakir, L. Calligaris, A. Campbell, S. Choudhury, F. Costanza, C. Diez Pardos, S. Dooling, T. Dorland, G. Eckerlin, D. Eckstein, T. Eichhorn, G. Flucke, J. Garay Garcia, A. Geiser, P. Gunnellini, J. Hauk, G. Hellwig, M. Hempel, D. Horton, H. Jung, A. Kalogeropoulos, M. Kasemann, P. Katsas, J. Kieseler, C. Kleinwort, D. Krücker, W. Lange, J. Leonard, K. Lipka, A. Lobanov, W. Lohmann[15], B. Lutz, R. Mankel, I. Marfin, I.-A. Melzer-Pellmann, A.B. Meyer, J. Mnich, A. Mussgiller, S. Naumann-Emme, A. Nayak,

O. Novgorodova, F. Nowak, E. Ntomari, H. Perrey, D. Pitzl, R. Placakyte, A. Raspereza, P.M. Ribeiro Cipriano, E. Ron, M.Ö. Sahin, J. Salfeld-Nebgen, P. Saxena, R. Schmidt[15], T. Schoerner-Sadenius, M. Schröder, C. Seitz, S. Spannagel, A.D.R. Vargas Trevino, R. Walsh, C. Wissing

University of Hamburg, Hamburg, Germany
M. Aldaya Martin, V. Blobel, M. Centis Vignali, A.r. Draeger, J. Erfle, E. Garutti, K. Goebel, M. Görner, J. Haller, M. Hoffmann, R.S. Höing, H. Kirschenmann, R. Klanner, R. Kogler, J. Lange, T. Lapsien, T. Lenz, I. Marchesini, J. Ott, T. Peiffer, N. Pietsch, J. Poehlsen, T. Poehlsen, D. Rathjens, C. Sander, H. Schettler, P. Schleper, E. Schlieckau, A. Schmidt, M. Seidel, V. Sola, H. Stadie, G. Steinbrück, D. Troendle, E. Usai, L. Vanelderen

Institut für Experimentelle Kernphysik, Karlsruhe, Germany
C. Barth, C. Baus, J. Berger, C. Böser, E. Butz, T. Chwalek, W. De Boer, A. Descroix, A. Dierlamm, M. Feindt, F. Frensch, M. Giffels, F. Hartmann[2], T. Hauth[2], U. Husemann, I. Katkov[5], A. Kornmayer[2], E. Kuznetsova, P. Lobelle Pardo, M.U. Mozer, Th. Müller, A. Nürnberg, G. Quast, K. Rabbertz, F. Ratnikov, S. Röcker, H.J. Simonis, F.M. Stober, R. Ulrich, J. Wagner-Kuhr, S. Wayand, T. Weiler, R. Wolf

Institute of Nuclear and Particle Physics (INPP), NCSR Demokritos, Aghia Paraskevi, Greece
G. Anagnostou, G. Daskalakis, T. Geralis, V.A. Giakoumopoulou, A. Kyriakis, D. Loukas, A. Markou, C. Markou, A. Psallidas, I. Topsis-Giotis

University of Athens, Athens, Greece
A. Panagiotou, N. Saoulidou, E. Stiliaris

University of Ioánnina, Ioánnina, Greece
X. Aslanoglou, I. Evangelou, G. Flouris, C. Foudas, P. Kokkas, N. Manthos, I. Papadopoulos, E. Paradas

Wigner Research Centre for Physics, Budapest, Hungary
G. Bencze, C. Hajdu, P. Hidas, D. Horvath[16], F. Sikler, V. Veszpremi, G. Vesztergombi[17], A.J. Zsigmond

Institute of Nuclear Research ATOMKI, Debrecen, Hungary
N. Beni, S. Czellar, J. Karancsi[18], J. Molnar, J. Palinkas, Z. Szillasi

University of Debrecen, Debrecen, Hungary
P. Raics, Z.L. Trocsanyi, B. Ujvari

National Institute of Science Education and Research, Bhubaneswar, India
S.K. Swain

Panjab University, Chandigarh, India
S.B. Beri, V. Bhatnagar, N. Dhingra, R. Gupta, U.Bhawandeep, A.K. Kalsi, M. Kaur, M. Mittal, N. Nishu, J.B. Singh

University of Delhi, Delhi, India
Ashok Kumar, Arun Kumar, S. Ahuja, A. Bhardwaj, B.C. Choudhary, A. Kumar, S. Malhotra, M. Naimuddin, K. Ranjan, V. Sharma

Saha Institute of Nuclear Physics, Kolkata, India
S. Banerjee, S. Bhattacharya, K. Chatterjee, S. Dutta, B. Gomber, Sa. Jain, Sh. Jain, R. Khurana, A. Modak, S. Mukherjee, D. Roy, S. Sarkar, M. Sharan

Bhabha Atomic Research Centre, Mumbai, India
A. Abdulsalam, D. Dutta, S. Kailas, V. Kumar, A.K. Mohanty[2], L.M. Pant, P. Shukla, A. Topkar

Tata Institute of Fundamental Research, Mumbai, India
T. Aziz, S. Banerjee, S. Bhowmik[19], R.M. Chatterjee, R.K. Dewanjee, S. Dugad, S. Ganguly, S. Ghosh, M. Guchait, A. Gurtu[20], G. Kole, S. Kumar, M. Maity[19], G. Majumder, K. Mazumdar, G.B. Mohanty, B. Parida, K. Sudhakar, N. Wickramage[21]

Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
H. Bakhshiansohi, H. Behnamian, S.M. Etesami[22], A. Fahim[23], R. Goldouzian, A. Jafari, M. Khakzad, M. Mohammadi Najafabadi, M. Naseri, S. Paktinat Mehdiabadi, B. Safarzadeh[24], M. Zeinali

University College Dublin, Dublin, Ireland
M. Felcini, M. Grunewald

INFN Sezione di Bari [a], Università di Bari [b], Politecnico di Bari [c], Bari, Italy
M. Abbrescia[a,b], L. Barbone[a,b], C. Calabria[a,b], S.S. Chhibra[a,b], A. Colaleo[a], D. Creanza[a,c], N. De Filippis[a,c], M. De Palma[a,b], L. Fiore[a], G. Iaselli[a,c], G. Maggi[a,c], M. Maggi[a], S. My[a,c], S. Nuzzo[a,b], A. Pompili[a,b], G. Pugliese[a,c], R. Radogna[a,b,2], G. Selvaggi[a,b], L. Silvestris[a,2], G. Singh[a,b], R. Venditti[a,b], P. Verwilligen[a], G. Zito[a]

INFN Sezione di Bologna [a], Università di Bologna [b], Bologna, Italy
G. Abbiendi[a], A.C. Benvenuti[a], D. Bonacorsi[a,b], S. Braibant-Giacomelli[a,b], L. Brigliadori[a,b], R. Campanini[a,b], P. Capiluppi[a,b], A. Castro[a,b], F.R. Cavallo[a], G. Codispoti[a,b], M. Cuffiani[a,b], G.M. Dallavalle[a], F. Fabbri[a], A. Fanfani[a,b], D. Fasanella[a,b], P. Giacomelli[a], C. Grandi[a], L. Guiducci[a,b], S. Marcellini[a], G. Masetti[a,2], A. Montanari[a], F.L. Navarria[a,b], A. Perrotta[a], F. Primavera[a,b], A.M. Rossi[a,b], T. Rovelli[a,b], G.P. Siroli[a,b], N. Tosi[a,b], R. Travaglini[a,b]

INFN Sezione di Catania [a], Università di Catania [b], CSFNSM [c], Catania, Italy
S. Albergo[a,b], G. Cappello[a], M. Chiorboli[a,b], S. Costa[a,b], F. Giordano[a,2], R. Potenza[a,b], A. Tricomi[a,b], C. Tuve[a,b]

INFN Sezione di Firenze [a], Università di Firenze [b], Firenze, Italy
G. Barbagli[a], V. Ciulli[a,b], C. Civinini[a], R. D'Alessandro[a,b], E. Focardi[a,b], E. Gallo[a], S. Gonzi[a,b], V. Gori[a,b,2], P. Lenzi[a,b], M. Meschini[a], S. Paoletti[a], G. Sguazzoni[a], A. Tropiano[a,b]

INFN Laboratori Nazionali di Frascati, Frascati, Italy
L. Benussi, S. Bianco, F. Fabbri, D. Piccolo

INFN Sezione di Genova [a], Università di Genova [b], Genova, Italy
F. Ferro[a], M. Lo Vetere[a,b], E. Robutti[a], S. Tosi[a,b]

INFN Sezione di Milano-Bicocca [a], Università di Milano-Bicocca [b], Milano, Italy
M.E. Dinardo[a,b], P. Dini[a], S. Fiorendi[a,b,2], S. Gennai[a,2], R. Gerosa[2], A. Ghezzi[a,b], P. Govoni[a,b], M.T. Lucchini[a,b,2], S. Malvezzi[a], R.A. Manzoni[a,b], A. Martelli[a,b], B. Marzocchi, D. Menasce[a], L. Moroni[a], M. Paganoni[a,b], S. Ragazzi[a,b], N. Redaelli[a], T. Tabarelli de Fatis[a,b]

INFN Sezione di Napoli [a], Università di Napoli 'Federico II' [b], Università della Basilicata (Potenza) [c], Università G. Marconi (Roma) [d], Napoli, Italy
S. Buontempo[a], N. Cavallo[a,c], S. Di Guida[a,d,2], F. Fabozzi[a,c], A.O.M. Iorio[a,b], L. Lista[a], S. Meola[a,d,2], M. Merola[a], P. Paolucci[a,2]

INFN Sezione di Padova [a], Università di Padova [b], Università di Trento (Trento) [c], Padova, Italy
P. Azzi[a], N. Bacchetta[a], D. Bisello[a,b], A. Branca[a,b], R. Carlin[a,b], P. Checchia[a], M. Dall'Osso[a,b], T. Dorigo[a], M. Galanti[a,b], F. Gasparini[a,b], U. Gasparini[a,b], P. Giubilato[a,b], A. Gozzelino[a], K. Kanishchev[a,c], S. Lacaprara[a], M. Margoni[a,b], A.T. Meneguzzo[a,b], M. Passaseo[a], J. Pazzini[a,b], N. Pozzobon[a,b], P. Ronchese[a,b], F. Simonetto[a,b], E. Torassa[a], M. Tosi[a,b], P. Zotto[a,b], A. Zucchetta[a,b], G. Zumerle[a,b]

INFN Sezione di Pavia [a], Università di Pavia [b], Pavia, Italy
M. Gabusi[a,b], S.P. Ratti[a,b], C. Riccardi[a,b], P. Salvini[a], P. Vitulo[a,b]

INFN Sezione di Perugia [a], Università di Perugia [b], Perugia, Italy
M. Biasini[a,b], G.M. Bilei[a], D. Ciangottini[a,b], L. Fanò[a,b], P. Lariccia[a,b], G. Mantovani[a,b], M. Menichelli[a], F. Romeo[a,b], A. Saha[a], A. Santocchia[a,b], A. Spiezia[a,b,2]

INFN Sezione di Pisa [a], Università di Pisa [b], Scuola Normale Superiore di Pisa [c], Pisa, Italy
K. Androsov[a,25], P. Azzurri[a], G. Bagliesi[a], J. Bernardini[a], T. Boccali[a], G. Broccolo[a,c], R. Castaldi[a], M.A. Ciocci[a,25], R. Dell'Orso[a], S. Donato[a,c], F. Fiori[a,c], L. Foà[a,c], A. Giassi[a], M.T. Grippo[a,25], F. Ligabue[a,c], T. Lomtadze[a], L. Martini[a,b], A. Messineo[a,b], C.S. Moon[a,26], F. Palla[a,2], A. Rizzi[a,b], A. Savoy-Navarro[a,27], A.T. Serban[a], P. Spagnolo[a], P. Squillacioti[a,25], R. Tenchini[a], G. Tonelli[a,b], A. Venturi[a], P.G. Verdini[a], C. Vernieri[a,c,2]

INFN Sezione di Roma [a], Università di Roma [b], Roma, Italy
L. Barone[a,b], F. Cavallari[a], G. D'imperio[a,b], D. Del Re[a,b], M. Diemoz[a], M. Grassi[a,b], C. Jorda[a], E. Longo[a,b], F. Margaroli[a,b], P. Meridiani[a], F. Micheli[a,b,2], S. Nourbakhsh[a,b], G. Organtini[a,b], R. Paramatti[a], S. Rahatlou[a,b], C. Rovelli[a], F. Santanastasio[a,b], L. Soffi[a,b,2], P. Traczyk[a,b]

INFN Sezione di Torino [a], Università di Torino [b], Università del Piemonte Orientale (Novara) [c], Torino, Italy
N. Amapane[a,b], R. Arcidiacono[a,c], S. Argiro[a,b,2], M. Arneodo[a,c], R. Bellan[a,b], C. Biino[a], N. Cartiglia[a], S. Casasso[a,b,2], M. Costa[a,b], A. Degano[a,b], N. Demaria[a], L. Finco[a,b], C. Mariotti[a], S. Maselli[a], E. Migliore[a,b], V. Monaco[a,b], M. Musich[a], M.M. Obertino[a,c,2], G. Ortona[a,b], L. Pacher[a,b], N. Pastrone[a], M. Pelliccioni[a], G.L. Pinna Angioni[a,b], A. Potenza[a,b], A. Romero[a,b], M. Ruspa[a,c], R. Sacchi[a,b], A. Solano[a,b], A. Staiano[a], U. Tamponi[a]

INFN Sezione di Trieste [a], Università di Trieste [b], Trieste, Italy
S. Belforte[a], V. Candelise[a,b], M. Casarsa[a], F. Cossutti[a], G. Della Ricca[a,b], B. Gobbo[a], C. La Licata[a,b], M. Marone[a,b], D. Montanino[a,b], A. Schizzi[a,b,2], T. Umer[a,b], A. Zanetti[a]

Chonbuk National University, Chonju, Korea
T.J. Kim

Kangwon National University, Chunchon, Korea
S. Chang, A. Kropivnitskaya, S.K. Nam

Kyungpook National University, Daegu, Korea
D.H. Kim, G.N. Kim, M.S. Kim, D.J. Kong, S. Lee, Y.D. Oh, H. Park, A. Sakharov, D.C. Son

Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea
J.Y. Kim, S. Song

Korea University, Seoul, Korea
S. Choi, D. Gyun, B. Hong, M. Jo, H. Kim, Y. Kim, B. Lee, K.S. Lee, S.K. Park, Y. Roh

University of Seoul, Seoul, Korea
M. Choi, J.H. Kim, I.C. Park, S. Park, G. Ryu, M.S. Ryu

Sungkyunkwan University, Suwon, Korea
Y. Choi, Y.K. Choi, J. Goh, D. Kim, E. Kwon, J. Lee, H. Seo, I. Yu

Vilnius University, Vilnius, Lithuania
A. Juodagalvis

National Centre for Particle Physics, Universiti Malaya, Kuala Lumpur, Malaysia
J.R. Komaragiri, M.A.B. Md Ali

Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico
H. Castilla-Valdez, E. De La Cruz-Burelo, I. Heredia-de La Cruz[28], R. Lopez-Fernandez, A. Sanchez-Hernandez

Universidad Iberoamericana, Mexico City, Mexico
S. Carrillo Moreno, F. Vazquez Valencia

Benemerita Universidad Autonoma de Puebla, Puebla, Mexico
I. Pedraza, H.A. Salazar Ibarguen

Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico
E. Casimiro Linares, A. Morelos Pineda

University of Auckland, Auckland, New Zealand
D. Krofcheck

University of Canterbury, Christchurch, New Zealand
P.H. Butler, S. Reucroft

National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan
A. Ahmad, M. Ahmad, Q. Hassan, H.R. Hoorani, S. Khalid, W.A. Khan, T. Khurshid, M.A. Shah, M. Shoaib

National Centre for Nuclear Research, Swierk, Poland
H. Bialkowska, M. Bluj, B. Boimska, T. Frueboes, M. Górski, M. Kazana, K. Nawrocki, K. Romanowska-Rybinska, M. Szleper, P. Zalewski

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
G. Brona, K. Bunkowski, M. Cwiok, W. Dominik, K. Doroba, A. Kalinowski, M. Konecki, J. Krolikowski, M. Misiura, M. Olszewski, W. Wolszczak

Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal
P. Bargassa, C. Beirão Da Cruz E Silva, P. Faccioli, P.G. Ferreira Parracho, M. Gallinaro, F. Nguyen, J. Rodrigues Antunes, J. Seixas, J. Varela, P. Vischia

Joint Institute for Nuclear Research, Dubna, Russia
I. Golutvin, V. Karjavin, V. Konoplyanikov, V. Korenkov, G. Kozlov, A. Lanev, A. Malakhov, V. Matveev[29], V.V. Mitsyn, P. Moisenz, V. Palichik, V. Perelygin, S. Shmatov, S. Shulha, N. Skatchkov, V. Smirnov, E. Tikhonenko, A. Zarubin

Petersburg Nuclear Physics Institute, Gatchina (St. Petersburg), Russia
V. Golovtsov, Y. Ivanov, V. Kim[30], P. Levchenko, V. Murzin, V. Oreshkin, I. Smirnov, V. Sulimov, L. Uvarov, S. Vavilov, A. Vorobyev, An. Vorobyev

Institute for Nuclear Research, Moscow, Russia
Yu. Andreev, A. Dermenev, S. Gninenko, N. Golubev, M. Kirsanov, N. Krasnikov, A. Pashenkov, D. Tlisov, A. Toropin

Institute for Theoretical and Experimental Physics, Moscow, Russia
V. Epshteyn, V. Gavrilov, N. Lychkovskaya, V. Popov, G. Safronov, S. Semenov, A. Spiridonov, V. Stolin, E. Vlasov, A. Zhokin

P.N. Lebedev Physical Institute, Moscow, Russia
V. Andreev, M. Azarkin, I. Dremin, M. Kirakosyan, A. Leonidov, G. Mesyats, S.V. Rusakov, A. Vinogradov

Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
A. Belyaev, E. Boos, M. Dubinin[31], L. Dudko, A. Ershov, A. Gribushin, V. Klyukhin, O. Kodolova, I. Lokhtin, S. Obraztsov, M. Perfilov, S. Petrushanko, V. Savrin

State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia
I. Azhgirey, I. Bayshev, S. Bitioukov, V. Kachanov, A. Kalinin, D. Konstantinov, V. Krychkine, V. Petrov, R. Ryutin, A. Sobol, L. Tourtchanovitch, S. Troshin, N. Tyurin, A. Uzunian, A. Volkov

University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
P. Adzic[32], M. Ekmedzic, J. Milosevic, V. Rekovic

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
J. Alcaraz Maestre, C. Battilana, E. Calvo, M. Cerrada, M. Chamizo Llatas, N. Colino, B. De La Cruz, A. Delgado Peris, D. Domínguez Vázquez, A. Escalante Del Valle, C. Fernandez Bedoya, J.P. Fernández Ramos, J. Flix, M.C. Fouz, P. Garcia-Abia, O. Gonzalez Lopez, S. Goy Lopez, J.M. Hernandez, M.I. Josa, G. Merino, E. Navarro De Martino, A. Pérez-Calero Yzquierdo, J. Puerta Pelayo, A. Quintario Olmeda, I. Redondo, L. Romero, M.S. Soares

Universidad Autónoma de Madrid, Madrid, Spain
C. Albajar, J.F. de Trocóniz, M. Missiroli, D. Moran

Universidad de Oviedo, Oviedo, Spain
H. Brun, J. Cuevas, J. Fernandez Menendez, S. Folgueras, I. Gonzalez Caballero, L. Lloret Iglesias

Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain
J.A. Brochero Cifuentes, I.J. Cabrillo, A. Calderon, J. Duarte Campderros, M. Fernandez, G. Gomez, A. Graziano, A. Lopez Virto, J. Marco, R. Marco, C. Martinez Rivero, F. Matorras, F.J. Munoz Sanchez, J. Piedra Gomez, T. Rodrigo, A.Y. Rodríguez-Marrero, A. Ruiz-Jimeno, L. Scodellaro, I. Vila, R. Vilar Cortabitarte

CERN, European Organization for Nuclear Research, Geneva, Switzerland
D. Abbaneo, E. Auffray, G. Auzinger, M. Bachtis, P. Baillon, A.H. Ball, D. Barney, A. Benaglia, J. Bendavid, L. Benhabib, J.F. Benitez, C. Bernet[7], G. Bianchi, P. Bloch, A. Bocci, A. Bonato, O. Bondu, C. Botta, H. Breuker, T. Camporesi, G. Cerminara, S. Colafranceschi[33], M. D'Alfonso, D. d'Enterria, A. Dabrowski, A. David, F. De Guio, A. De Roeck, S. De Visscher, M. Dobson, M. Dordevic, N. Dupont-Sagorin, A. Elliott-Peisert, J. Eugster, G. Franzoni, W. Funk, D. Gigi, K. Gill, D. Giordano, M. Girone, F. Glege, R. Guida, S. Gundacker, M. Guthoff, J. Hammer,

M. Hansen, P. Harris, J. Hegeman, V. Innocente, P. Janot, K. Kousouris, K. Krajczar, P. Lecoq, C. Lourenço, N. Magini, L. Malgeri, M. Mannelli, J. Marrouche, L. Masetti, F. Meijers, S. Mersi, E. Meschi, F. Moortgat, S. Morovic, M. Mulders, P. Musella, L. Orsini, L. Pape, E. Perez, L. Perrozzi, A. Petrilli, G. Petrucciani, A. Pfeiffer, M. Pierini, M. Pimiä, D. Piparo, M. Plagge, A. Racz, G. Rolandi[34], M. Rovere, H. Sakulin, C. Schäfer, C. Schwick, A. Sharma, P. Siegrist, P. Silva, M. Simon, P. Sphicas[35], D. Spiga, J. Steggemann, B. Stieger, M. Stoye, D. Treille, A. Tsirou, G.I. Veres[17], J.R. Vlimant, N. Wardle, H.K. Wöhri, H. Wollny, W.D. Zeuner

Paul Scherrer Institut, Villigen, Switzerland
W. Bertl, K. Deiters, W. Erdmann, R. Horisberger, Q. Ingram, H.C. Kaestli, D. Kotlinski, U. Langenegger, D. Renker, T. Rohe

Institute for Particle Physics, ETH Zurich, Zurich, Switzerland
F. Bachmair, L. Bäni, L. Bianchini, P. Bortignon, M.A. Buchmann, B. Casal, N. Chanon, A. Deisher, G. Dissertori, M. Dittmar, M. Donegà, M. Dünser, P. Eller, C. Grab, D. Hits, W. Lustermann, B. Mangano, A.C. Marini, P. Martinez Ruiz del Arbol, D. Meister, N. Mohr, C. Nägeli[36], F. Nessi-Tedaldi, F. Pandolfi, F. Pauss, M. Peruzzi, M. Quittnat, L. Rebane, M. Rossini, A. Starodumov[37], M. Takahashi, K. Theofilatos, R. Wallny, H.A. Weber

Universität Zürich, Zurich, Switzerland
C. Amsler[38], M.F. Canelli, V. Chiochia, A. De Cosa, A. Hinzmann, T. Hreus, B. Kilminster, C. Lange, B. Millan Mejias, J. Ngadiuba, P. Robmann, F.J. Ronga, S. Taroni, M. Verzetti, Y. Yang

National Central University, Chung-Li, Taiwan
M. Cardaci, K.H. Chen, C. Ferro, C.M. Kuo, W. Lin, Y.J. Lu, R. Volpe, S.S. Yu

National Taiwan University (NTU), Taipei, Taiwan
P. Chang, Y.H. Chang, Y.W. Chang, Y. Chao, K.F. Chen, P.H. Chen, C. Dietz, U. Grundler, W.-S. Hou, K.Y. Kao, Y.J. Lei, Y.F. Liu, R.-S. Lu, D. Majumder, E. Petrakou, Y.M. Tzeng, R. Wilken

Chulalongkorn University, Faculty of Science, Department of Physics, Bangkok, Thailand
B. Asavapibhop, N. Srimanobhas, N. Suwonjandee

Cukurova University, Adana, Turkey
A. Adiguzel, M.N. Bakirci[39], S. Cerci[40], C. Dozen, I. Dumanoglu, E. Eskut, S. Girgis, G. Gokbulut, E. Gurpinar, I. Hos, E.E. Kangal, A. Kayis Topaksu, G. Onengut[41], K. Ozdemir, S. Ozturk[39], A. Polatoz, K. Sogut[42], D. Sunar Cerci[40], B. Tali[40], H. Topakli[39], M. Vergili

Middle East Technical University, Physics Department, Ankara, Turkey
I.V. Akin, B. Bilin, S. Bilmis, H. Gamsizkan, G. Karapinar[43], K. Ocalan, S. Sekmen, U.E. Surat, M. Yalvac, M. Zeyrek

Bogazici University, Istanbul, Turkey
E. Gülmez, B. Isildak[44], M. Kaya[45], O. Kaya[46]

Istanbul Technical University, Istanbul, Turkey
H. Bahtiyar[47], E. Barlas, K. Cankocak, F.I. Vardarlı, M. Yücel

National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine
L. Levchuk, P. Sorokin

University of Bristol, Bristol, United Kingdom
J.J. Brooke, E. Clement, D. Cussans, H. Flacher, R. Frazier, J. Goldstein, M. Grimes, G.P. Heath, H.F. Heath, J. Jacob, L. Kreczko, C. Lucas, Z. Meng, D.M. Newbold[48], S. Paramesvaran, A. Poll, S. Senkin, V.J. Smith, T. Williams

Rutherford Appleton Laboratory, Didcot, United Kingdom
K.W. Bell, A. Belyaev[49], C. Brew, R.M. Brown, D.J.A. Cockerill, J.A. Coughlan, K. Harder, S. Harper, E. Olaiya, D. Petyt, C.H. Shepherd-Themistocleous, A. Thea, I.R. Tomalin, W.J. Womersley, S.D. Worm

Imperial College, London, United Kingdom
M. Baber, R. Bainbridge, O. Buchmuller, D. Burton, D. Colling, N. Cripps, M. Cutajar, P. Dauncey, G. Davies, M. Della Negra, P. Dunne, W. Ferguson, J. Fulcher, D. Futyan, A. Gilbert, G. Hall, G. Iles, M. Jarvis, G. Karapostoli, M. Kenzie, R. Lane, R. Lucas[48], L. Lyons, A.-M. Magnan, S. Malik, B. Mathias, J. Nash, A. Nikitenko[37], J. Pela, M. Pesaresi, K. Petridis, D.M. Raymond, S. Rogerson, A. Rose, C. Seez, P. Sharp[†], A. Tapper, M. Vazquez Acosta, T. Virdee

Brunel University, Uxbridge, United Kingdom
J.E. Cole, P.R. Hobson, A. Khan, P. Kyberd, D. Leggat, D. Leslie, W. Martin, I.D. Reid, P. Symonds, L. Teodorescu, M. Turner

Baylor University, Waco, USA
J. Dittmann, K. Hatakeyama, A. Kasmi, H. Liu, T. Scarborough

The University of Alabama, Tuscaloosa, USA
O. Charaf, S.I. Cooper, C. Henderson, P. Rumerio

Boston University, Boston, USA
A. Avetisyan, T. Bose, C. Fantasia, P. Lawson, C. Richardson, J. Rohlf, D. Sperka, J. St. John, L. Sulak

Brown University, Providence, USA
J. Alimena, E. Berry, S. Bhattacharya, G. Christopher, D. Cutts, Z. Demiragli, A. Ferapontov, A. Garabedian, U. Heintz, G. Kukartsev, E. Laird, G. Landsberg, M. Luk, M. Narain, M. Segala, T. Sinthuprasith, T. Speer, J. Swanson

University of California, Davis, Davis, USA
R. Breedon, G. Breto, M. Calderon De La Barca Sanchez, S. Chauhan, M. Chertok, J. Conway, R. Conway, P.T. Cox, R. Erbacher, M. Gardner, W. Ko, R. Lander, T. Miceli, M. Mulhearn, D. Pellett, J. Pilot, F. Ricci-Tam, M. Searle, S. Shalhout, J. Smith, M. Squires, D. Stolp, M. Tripathi, S. Wilbur, R. Yohay

University of California, Los Angeles, USA
R. Cousins, P. Everaerts, C. Farrell, J. Hauser, M. Ignatenko, G. Rakness, E. Takasugi, V. Valuev, M. Weber

University of California, Riverside, Riverside, USA
J. Babb, K. Burt, R. Clare, J. Ellison, J.W. Gary, G. Hanson, J. Heilman, M. Ivova Rikova, P. Jandir, E. Kennedy, F. Lacroix, H. Liu, O.R. Long, A. Luthra, M. Malberti, H. Nguyen, M. Olmedo Negrete, A. Shrinivas, S. Sumowidagdo, S. Wimpenny

University of California, San Diego, La Jolla, USA
W. Andrews, J.G. Branson, G.B. Cerati, S. Cittolin, R.T. D'Agnolo, D. Evans, A. Holzner, R. Kelley, D. Klein, M. Lebourgeois, J. Letts, I. Macneill, D. Olivito, S. Padhi, C. Palmer, M. Pieri, M. Sani, V. Sharma, S. Simon, E. Sudano, M. Tadel, Y. Tu, A. Vartak, C. Welke, F. Würthwein, A. Yagil, J. Yoo

University of California, Santa Barbara, Santa Barbara, USA
D. Barge, J. Bradmiller-Feld, C. Campagnari, T. Danielson, A. Dishaw, K. Flowers, M. Franco

Sevilla, P. Geffert, C. George, F. Golf, L. Gouskos, J. Incandela, C. Justus, N. Mccoll, J. Richman, D. Stuart, W. To, C. West

California Institute of Technology, Pasadena, USA
A. Apresyan, A. Bornheim, J. Bunn, Y. Chen, E. Di Marco, J. Duarte, A. Mott, H.B. Newman, C. Pena, C. Rogan, M. Spiropulu, V. Timciuc, R. Wilkinson, S. Xie, R.Y. Zhu

Carnegie Mellon University, Pittsburgh, USA
V. Azzolini, A. Calamba, B. Carlson, T. Ferguson, Y. Iiyama, M. Paulini, J. Russ, H. Vogel, I. Vorobiev

University of Colorado at Boulder, Boulder, USA
J.P. Cumalat, W.T. Ford, A. Gaz, E. Luiggi Lopez, U. Nauenberg, J.G. Smith, K. Stenson, K.A. Ulmer, S.R. Wagner

Cornell University, Ithaca, USA
J. Alexander, A. Chatterjee, J. Chu, S. Dittmer, N. Eggert, N. Mirman, G. Nicolas Kaufman, J.R. Patterson, A. Ryd, E. Salvati, L. Skinnari, W. Sun, W.D. Teo, J. Thom, J. Thompson, J. Tucker, Y. Weng, L. Winstrom, P. Wittich

Fairfield University, Fairfield, USA
D. Winn

Fermi National Accelerator Laboratory, Batavia, USA
S. Abdullin, M. Albrow, J. Anderson, G. Apollinari, L.A.T. Bauerdick, A. Beretvas, J. Berryhill, P.C. Bhat, K. Burkett, J.N. Butler, H.W.K. Cheung, F. Chlebana, S. Cihangir, V.D. Elvira, I. Fisk, J. Freeman, Y. Gao, E. Gottschalk, L. Gray, D. Green, S. Grünendahl, O. Gutsche, J. Hanlon, D. Hare, R.M. Harris, J. Hirschauer, B. Hooberman, S. Jindariani, M. Johnson, U. Joshi, K. Kaadze, B. Klima, B. Kreis, S. Kwan, J. Linacre, D. Lincoln, R. Lipton, T. Liu, J. Lykken, K. Maeshima, J.M. Marraffino, V.I. Martinez Outschoorn, S. Maruyama, D. Mason, P. McBride, K. Mishra, S. Mrenna, Y. Musienko[29], S. Nahn, C. Newman-Holmes, V. O'Dell, O. Prokofyev, E. Sexton-Kennedy, S. Sharma, A. Soha, W.J. Spalding, L. Spiegel, L. Taylor, S. Tkaczyk, N.V. Tran, L. Uplegger, E.W. Vaandering, R. Vidal, A. Whitbeck, J. Whitmore, F. Yang

University of Florida, Gainesville, USA
D. Acosta, P. Avery, D. Bourilkov, M. Carver, T. Cheng, D. Curry, S. Das, M. De Gruttola, G.P. Di Giovanni, R.D. Field, M. Fisher, I.K. Furic, J. Hugon, J. Konigsberg, A. Korytov, T. Kypreos, J.F. Low, K. Matchev, P. Milenovic[50], G. Mitselmakher, L. Muniz, A. Rinkevicius, L. Shchutska, M. Snowball, J. Yelton, M. Zakaria

Florida International University, Miami, USA
S. Hewamanage, S. Linn, P. Markowitz, G. Martinez, J.L. Rodriguez

Florida State University, Tallahassee, USA
T. Adams, A. Askew, J. Bochenek, B. Diamond, J. Haas, S. Hagopian, V. Hagopian, K.F. Johnson, H. Prosper, V. Veeraraghavan, M. Weinberg

Florida Institute of Technology, Melbourne, USA
M.M. Baarmand, M. Hohlmann, H. Kalakhety, F. Yumiceva

University of Illinois at Chicago (UIC), Chicago, USA
M.R. Adams, L. Apanasevich, V.E. Bazterra, D. Berry, R.R. Betts, I. Bucinskaite, R. Cavanaugh, O. Evdokimov, L. Gauthier, C.E. Gerber, D.J. Hofman, S. Khalatyan, P. Kurt, D.H. Moon, C. O'Brien, C. Silkworth, P. Turner, N. Varelas

The University of Iowa, Iowa City, USA
E.A. Albayrak[47], B. Bilki[51], W. Clarida, K. Dilsiz, F. Duru, M. Haytmyradov, J.-P. Merlo, H. Mermerkaya[52], A. Mestvirishvili, A. Moeller, J. Nachtman, H. Ogul, Y. Onel, F. Ozok[47], A. Penzo, R. Rahmat, S. Sen, P. Tan, E. Tiras, J. Wetzel, T. Yetkin[53], K. Yi

Johns Hopkins University, Baltimore, USA
B.A. Barnett, B. Blumenfeld, S. Bolognesi, D. Fehling, A.V. Gritsan, P. Maksimovic, C. Martin, M. Swartz

The University of Kansas, Lawrence, USA
P. Baringer, A. Bean, G. Benelli, C. Bruner, J. Gray, R.P. Kenny III, M. Malek, M. Murray, D. Noonan, S. Sanders, J. Sekaric, R. Stringer, Q. Wang, J.S. Wood

Kansas State University, Manhattan, USA
A.F. Barfuss, I. Chakaberia, A. Ivanov, S. Khalil, M. Makouski, Y. Maravin, L.K. Saini, S. Shrestha, N. Skhirtladze, I. Svintradze

Lawrence Livermore National Laboratory, Livermore, USA
J. Gronberg, D. Lange, F. Rebassoo, D. Wright

University of Maryland, College Park, USA
A. Baden, A. Belloni, B. Calvert, S.C. Eno, J.A. Gomez, N.J. Hadley, R.G. Kellogg, T. Kolberg, Y. Lu, M. Marionneau, A.C. Mignerey, K. Pedro, A. Skuja, M.B. Tonjes, S.C. Tonwar

Massachusetts Institute of Technology, Cambridge, USA
A. Apyan, R. Barbieri, G. Bauer, W. Busza, I.A. Cali, M. Chan, L. Di Matteo, V. Dutta, G. Gomez Ceballos, M. Goncharov, D. Gulhan, M. Klute, Y.S. Lai, Y.-J. Lee, A. Levin, P.D. Luckey, T. Ma, C. Paus, D. Ralph, C. Roland, G. Roland, G.S.F. Stephans, F. Stöckli, K. Sumorok, D. Velicanu, J. Veverka, B. Wyslouch, M. Yang, M. Zanetti, V. Zhukova

University of Minnesota, Minneapolis, USA
B. Dahmes, A. Gude, S.C. Kao, K. Klapoetke, Y. Kubota, J. Mans, N. Pastika, R. Rusack, A. Singovsky, N. Tambe, J. Turkewitz

University of Mississippi, Oxford, USA
J.G. Acosta, S. Oliveros

University of Nebraska-Lincoln, Lincoln, USA
E. Avdeeva, K. Bloom, S. Bose, D.R. Claes, A. Dominguez, R. Gonzalez Suarez, J. Keller, D. Knowlton, I. Kravchenko, J. Lazo-Flores, S. Malik, F. Meier, G.R. Snow

State University of New York at Buffalo, Buffalo, USA
J. Dolen, A. Godshalk, I. Iashvili, A. Kharchilava, A. Kumar, S. Rappoccio

Northeastern University, Boston, USA
G. Alverson, E. Barberis, D. Baumgartel, M. Chasco, J. Haley, A. Massironi, D.M. Morse, D. Nash, T. Orimoto, D. Trocino, R.J. Wang, D. Wood, J. Zhang

Northwestern University, Evanston, USA
K.A. Hahn, A. Kubik, N. Mucia, N. Odell, B. Pollack, A. Pozdnyakov, M. Schmitt, S. Stoynev, K. Sung, M. Velasco, S. Won

University of Notre Dame, Notre Dame, USA
A. Brinkerhoff, K.M. Chan, A. Drozdetskiy, M. Hildreth, C. Jessop, D.J. Karmgard, N. Kellams, K. Lannon, W. Luo, S. Lynch, N. Marinelli, T. Pearson, M. Planer, R. Ruchti, N. Valls, M. Wayne, M. Wolf, A. Woodard

The Ohio State University, Columbus, USA
L. Antonelli, J. Brinson, B. Bylsma, L.S. Durkin, S. Flowers, C. Hill, R. Hughes, K. Kotov, T.Y. Ling, D. Puigh, M. Rodenburg, G. Smith, B.L. Winer, H. Wolfe, H.W. Wulsin

Princeton University, Princeton, USA
O. Driga, P. Elmer, P. Hebda, A. Hunt, S.A. Koay, P. Lujan, D. Marlow, T. Medvedeva, M. Mooney, J. Olsen, P. Piroué, X. Quan, H. Saka, D. Stickland[2], C. Tully, J.S. Werner, S.C. Zenz, A. Zuranski

University of Puerto Rico, Mayaguez, USA
E. Brownson, H. Mendez, J.E. Ramirez Vargas

Purdue University, West Lafayette, USA
E. Alagoz, V.E. Barnes, D. Benedetti, G. Bolla, D. Bortoletto, M. De Mattia, Z. Hu, M.K. Jha, M. Jones, K. Jung, M. Kress, N. Leonardo, D. Lopes Pegna, V. Maroussov, P. Merkel, D.H. Miller, N. Neumeister, B.C. Radburn-Smith, X. Shi, I. Shipsey, D. Silvers, A. Svyatkovskiy, F. Wang, W. Xie, L. Xu, H.D. Yoo, J. Zablocki, Y. Zheng

Purdue University Calumet, Hammond, USA
N. Parashar, J. Stupak

Rice University, Houston, USA
A. Adair, B. Akgun, K.M. Ecklund, F.J.M. Geurts, W. Li, B. Michlin, B.P. Padley, R. Redjimi, J. Roberts, J. Zabel

University of Rochester, Rochester, USA
B. Betchart, A. Bodek, R. Covarelli, P. de Barbaro, R. Demina, Y. Eshaq, T. Ferbel, A. Garcia-Bellido, P. Goldenzweig, J. Han, A. Harel, A. Khukhunaishvili, G. Petrillo, D. Vishnevskiy

The Rockefeller University, New York, USA
R. Ciesielski, L. Demortier, K. Goulianos, G. Lungu, C. Mesropian

Rutgers, The State University of New Jersey, Piscataway, USA
S. Arora, A. Barker, J.P. Chou, C. Contreras-Campana, E. Contreras-Campana, D. Duggan, D. Ferencek, Y. Gershtein, R. Gray, E. Halkiadakis, D. Hidas, A. Lath, S. Panwalkar, M. Park, R. Patel, S. Salur, S. Schnetzer, S. Somalwar, R. Stone, S. Thomas, P. Thomassen, M. Walker

University of Tennessee, Knoxville, USA
K. Rose, S. Spanier, A. York

Texas A&M University, College Station, USA
O. Bouhali[54], A. Castaneda Hernandez, R. Eusebi, W. Flanagan, J. Gilmore, T. Kamon[55], V. Khotilovich, V. Krutelyov, R. Montalvo, I. Osipenkov, Y. Pakhotin, A. Perloff, J. Roe, A. Rose, A. Safonov, T. Sakuma, I. Suarez, A. Tatarinov

Texas Tech University, Lubbock, USA
N. Akchurin, C. Cowden, J. Damgov, C. Dragoiu, P.R. Dudero, J. Faulkner, K. Kovitanggoon, S. Kunori, S.W. Lee, T. Libeiro, I. Volobouev

Vanderbilt University, Nashville, USA
E. Appelt, A.G. Delannoy, S. Greene, A. Gurrola, W. Johns, C. Maguire, Y. Mao, A. Melo, M. Sharma, P. Sheldon, B. Snook, S. Tuo, J. Velkovska

University of Virginia, Charlottesville, USA
M.W. Arenton, S. Boutle, B. Cox, B. Francis, J. Goodell, R. Hirosky, A. Ledovskoy, H. Li, C. Lin, C. Neu, J. Wood

Wayne State University, Detroit, USA
C. Clarke, R. Harr, P.E. Karchin, C. Kottachchi Kankanamge Don, P. Lamichhane, J. Sturdy

University of Wisconsin, Madison, USA
D.A. Belknap, D. Carlsmith, M. Cepeda, S. Dasu, L. Dodd, S. Duric, E. Friis, R. Hall-Wilton, M. Herndon, A. Hervé, P. Klabbers, A. Lanaro, C. Lazaridis, A. Levine, R. Loveless, A. Mohapatra, I. Ojalvo, T. Perry, G.A. Pierro, G. Polese, I. Ross, T. Sarangi, A. Savin, W.H. Smith, C. Vuosalo, N. Woods

†: Deceased
1: Also at Vienna University of Technology, Vienna, Austria
2: Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland
3: Also at Institut Pluridisciplinaire Hubert Curien, Université de Strasbourg, Université de Haute Alsace Mulhouse, CNRS/IN2P3, Strasbourg, France
4: Also at National Institute of Chemical Physics and Biophysics, Tallinn, Estonia
5: Also at Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
6: Also at Universidade Estadual de Campinas, Campinas, Brazil
7: Also at Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France
8: Also at Joint Institute for Nuclear Research, Dubna, Russia
9: Also at Suez University, Suez, Egypt
10: Also at Cairo University, Cairo, Egypt
11: Also at Fayoum University, El-Fayoum, Egypt
12: Also at British University in Egypt, Cairo, Egypt
13: Now at Ain Shams University, Cairo, Egypt
14: Also at Université de Haute Alsace, Mulhouse, France
15: Also at Brandenburg University of Technology, Cottbus, Germany
16: Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary
17: Also at Eötvös Loránd University, Budapest, Hungary
18: Also at University of Debrecen, Debrecen, Hungary
19: Also at University of Visva-Bharati, Santiniketan, India
20: Now at King Abdulaziz University, Jeddah, Saudi Arabia
21: Also at University of Ruhuna, Matara, Sri Lanka
22: Also at Isfahan University of Technology, Isfahan, Iran
23: Also at Sharif University of Technology, Tehran, Iran
24: Also at Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Tehran, Iran
25: Also at Università degli Studi di Siena, Siena, Italy
26: Also at Centre National de la Recherche Scientifique (CNRS) - IN2P3, Paris, France
27: Also at Purdue University, West Lafayette, USA
28: Also at Universidad Michoacana de San Nicolas de Hidalgo, Morelia, Mexico
29: Also at Institute for Nuclear Research, Moscow, Russia
30: Also at St. Petersburg State Polytechnical University, St. Petersburg, Russia
31: Also at California Institute of Technology, Pasadena, USA
32: Also at Faculty of Physics, University of Belgrade, Belgrade, Serbia
33: Also at Facoltà Ingegneria, Università di Roma, Roma, Italy
34: Also at Scuola Normale e Sezione dell'INFN, Pisa, Italy
35: Also at University of Athens, Athens, Greece
36: Also at Paul Scherrer Institut, Villigen, Switzerland
37: Also at Institute for Theoretical and Experimental Physics, Moscow, Russia

38: Also at Albert Einstein Center for Fundamental Physics, Bern, Switzerland
39: Also at Gaziosmanpasa University, Tokat, Turkey
40: Also at Adiyaman University, Adiyaman, Turkey
41: Also at Cag University, Mersin, Turkey
42: Also at Mersin University, Mersin, Turkey
43: Also at Izmir Institute of Technology, Izmir, Turkey
44: Also at Ozyegin University, Istanbul, Turkey
45: Also at Marmara University, Istanbul, Turkey
46: Also at Kafkas University, Kars, Turkey
47: Also at Mimar Sinan University, Istanbul, Istanbul, Turkey
48: Also at Rutherford Appleton Laboratory, Didcot, United Kingdom
49: Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom
50: Also at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
51: Also at Argonne National Laboratory, Argonne, USA
52: Also at Erzincan University, Erzincan, Turkey
53: Also at Yildiz Technical University, Istanbul, Turkey
54: Also at Texas A&M University at Qatar, Doha, Qatar
55: Also at Kyungpook National University, Daegu, Korea