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Evidence for the associated production of a W boson and a top quark in ATLAS at $\sqrt{s} = 7$ TeV ☆

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ABSTRACT

This Letter presents evidence for the associated production of a W boson and a top quark using 2.05 fb^{-1} of pp collision data at $\sqrt{s} = 7$ TeV accumulated with the ATLAS detector at the LHC. The analysis is based on the selection of the dileptonic final states with events featuring two isolated leptons, electron or muon, with significant transverse missing momentum and at least one jet. An approach based on boosted decision trees has been developed to improve the discrimination of single top-quark Wt events from background. A template fit to the final classifier distributions is performed to determine the cross-section. The result is incompatible with the background-only hypothesis at the 3.3σ level, the expected sensitivity assuming the Standard Model production rate being 3.4σ. The corresponding cross-section is determined and found to be $\sigma_{Wt} = 16.8 \pm 2.9$ (stat) ± 4.9 (syst) pb, in good agreement with the Standard Model expectation. From this result the CKM matrix element $|V_{tb}| = 1.03^{+0.16}_{-0.19}$ is derived assuming that the Wt production through $|V_{ts}|$ and $|V_{td}|$ is small.

1. Introduction

The observation of single top-quark production was first reported by both D0 [1] and CDF [2] experiments at the Tevatron. The observations by the two experiments are consistent with the Standard Model (SM) expectation for single top-quark production resulting from two mechanisms, the t-channel and the s-channel, measured inclusively. The third SM single top-quark production mechanism, the associated production of a top quark and a W boson, has not been observed at the Tevatron.

At the Large Hadron Collider (LHC), the electroweak production of single top-quarks represents about half of the $t\bar{t}$-pair production cross-section. First measurements of the single top-quark production [3,4] have been obtained in the t-channel at a centre-of-mass energy of 7 TeV, and show good agreement with the SM expectation. The associated production of a top quark and a W boson involves the interaction of a gluon and a b-quark emitting an on-shell W boson, as shown in the Feynman diagrams in Fig. 1. The final state thus contains two W bosons and an additional quark from the top quark decay, normally a b-quark. Next-to-leading-order Wt Feynman diagrams including a second b-quark may interfere with $t\bar{t}$-pair production. The interference should be small in the reconstructed exclusive final state with only one quark, where the largest fraction of Wt signal is expected. In this analysis, the Wt leading-order approximation is used, and the difference between leading-order and next-to-leading-order Wt calculation is considered as modelling uncertainty. Because of the massive particles in the final state, this production mechanism has an extremely low rate at the Tevatron compared to t-channel, but is expected to have a much higher cross-section at the LHC, where the available partonic energy and the gluon flux are larger. For proton–proton collisions at 7 TeV, the single top-quark Wt-channel production cross-section is estimated to be 15.7 ± 1.1 pb [5] for a top quark mass of 172.5 GeV.

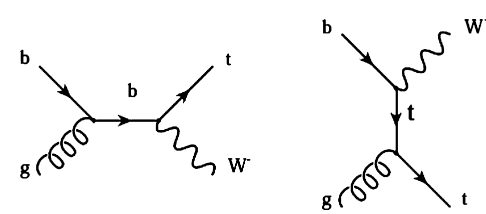

Fig. 1. Leading-order Feynman diagrams for associated production of a single top-quark and a W boson.

Since the three modes of single top-quark production are sensitive to different manifestations of physics beyond the SM, measurements of the individual cross-sections are complementary to each other and allow some sources of new phenomena to be disentangled. The production mode with both a W boson and a top quark in the final state has the special feature that both particles can be identified. Thus, the measurement of the corresponding cross-section can be sensitive to new phenomena which modify the W-t-b interaction, but insensitive to flavor-changing neutral currents (FCNCs) or new particles such as W', t' and technipions [6]. The measurement of the single top-quark Wt-channel

⋆ *E-mail address:* atlas.publications@cern.ch.

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production cross-sections therefore serves as a direct probe of the W-t-b coupling and allows the direct determination of the quark-mixing matrix element $|V_{tb}|$ [7,8]. This result can be compared to the results obtained from t- and s-channel production measurements.

In this Letter, an analysis is presented that establishes evidence for the associated production of a top quark and a W boson in the dilepton channel, with $pp \to Wt \to \ell\nu b\ell\nu$, where $\ell = e, \mu$. Events featuring two leptons and neutrinos from W boson decays and an additional jet originating from the top quark decay, are selected and analysed. The corresponding cross-section is extracted and the magnitude of the CKM matrix element $|V_{tb}|$ is derived. Comparison is made with the Tevatron average and ATLAS measurements.

2. Data and Monte Carlo simulation

The present analysis uses LHC proton–proton collision data at a centre-of-mass energy of 7 TeV collected between March and July 2011 with the ATLAS detector [9], which is composed of inner tracking detectors in a 2 tesla magnetic field surrounded by calorimeters and a muon spectrometer. The selected events were recorded based on single-electron or single-muon triggers. Detector and data-quality requirements are applied offline, resulting in a data set corresponding to an integrated luminosity of $2.05 \pm 0.08\ \text{fb}^{-1}$ [10,11].

In the following, all Monte Carlo (MC) simulations of top-quark related processes assume a top-quark mass of 172.5 GeV, and a width of 1.3 GeV, consistent with the world average value [12]. Samples of simulated events for single top-quark processes are produced with AcerMC version 3.7 [13] coupled with the MRST2007 [14] parton distribution functions (PDFs). The $t\bar{t}$-pair processes are generated using MC@NLO version 3.41 [15], interfaced with the CTEQ6.6 PDFs set [16]. All top quark samples are normalised using next-to-next-to-leading order (NNLO) cross-sections [5,17–19]. Gauge boson (W/Z) production in association with jets is simulated using the leading-order generator ALPGEN version 2.13 [20], coupled with CTEQ6L1 PDFs [21]. The diboson processes WW, WZ and ZZ are generated using ALPGEN version 2.13 with MRST2007 PDFs. In all cases, HERWIG [22] is used for the showering and is linked to the underlying event model in JIMMY version 4.31 [23]. After the event generation, all samples are passed through the full simulation of the ATLAS detector [24] based on GEANT4 [25] and are reconstructed using the same procedure as collision data. The simulation includes the effect of a variable number of proton–proton collisions per bunch crossing and is weighted to reproduce the same distribution of the number of collisions per bunch crossing as observed in data. The average number of interactions per bunch crossing is 6.2 in this data set.

3. Event reconstruction and selection

A set of general-purpose event-quality requirements [26] are applied to the data. Events are selected if they contain at least one primary vertex candidate with a minimum of five associated tracks, each reconstructed with transverse momentum (p_T) above 400 MeV. Events must not contain any jet, with p_T (calculated with the electromagnetic response for jets) greater than 20 GeV, arising from out-of-time energy depositions or from real energy depositions with a hardware or calibration problem.

Electron candidates are reconstructed using a cluster-based algorithm [27] and are required to have transverse energy $E_T > 25$ GeV and $|\eta| < 2.47$, where η denotes the pseudorapidity.[1] Events with electrons falling in the calorimeter barrel-endcap transition region, corresponding to $1.37 < |\eta| < 1.52$, are rejected. Candidates must satisfy a set of quality criteria, referred to as either "loose" or "tight" criteria [27], which for the latter, includes additional stringent requirements on the matching between the electron track candidate and the cluster. Isolation criteria require that the sum of the calorimeter transverse energy within a cone of radius $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.3$ around the electron direction (excluding the cells associated with the electron) must be less than 15% of the electron transverse energy. In addition, the sum of the p_T of all tracks within the same cone radius around the electron direction, excluding the track belonging to the electron, must be less than 10% of the electron E_T.

Muon candidates are reconstructed by combining track segments found in the inner detector and in the muon spectrometer, and are required to have $p_T > 25$ GeV and $|\eta| < 2.5$. Selected muons must additionally satisfy a series of cuts on the number of hits on the track in the various tracking sub-detectors, referred to as "tight" quality criteria [28]. The isolation requirements are the same as those for electrons. In order to reject events in which a muon emitting a hard photon is also reconstructed as an electron, events are vetoed when a selected electron–muon pair shares the same inner detector track.

Hadronic jets are reconstructed from calorimeter clusters [29] using the anti-k_t algorithm [30] with a radius parameter $R = 0.4$. To take into account the differences in calorimeter response to electrons and hadrons, a p_T- and η-dependent scale factor is applied to each jet in order to make an average energy scale correction [31]. Jets are required to have $E_T > 30$ GeV and $|\eta| < 2.5$. Jets overlapping with selected electron candidates within $\Delta R < 0.2$ are removed, keeping the electron candidate. The missing transverse momentum $\vec{E}_T^{\text{miss}}$ is calculated using the clusters identified in the calorimeter that are calibrated according to the associated reconstructed high-p_T objects. Taking also into account the energy clusters not associated to any high-p_T objects, projections of this vectorial sum in the transverse plane, correspond to the negative of the $\vec{E}_T^{\text{miss}}$ components. The missing transverse momentum is also corrected for the presence of electrons, muons, and jets [32].

A dilepton event preselection classifies the events according to exclusive ee, $e\mu$ and $\mu\mu$ categories. The following event selections are common to all three ee, $\mu\mu$ and $e\mu$ channels. Candidate events must contain two "tight" opposite-sign leptons. Events having any additional isolated leptons with p_T greater than 25 GeV are vetoed in order to ensure the orthogonality of the ee, $e\mu$ and $\mu\mu$ categories and suppress diboson backgrounds. Since the signal signature contains a single high-p_T quark from top quark decay, only events with at least one jet are selected. However, no b-tagging requirements are applied as they do not offer significant rejection over the primary background originating from $t\bar{t}$-pair events. As signal events also feature neutrinos from the leptonic decays of W bosons, the magnitude of the missing transverse momentum of the event is required to be greater than 50 GeV.

In the ee and $\mu\mu$ channels, the invariant mass of the lepton pair $m_{\ell\ell}$ is required to satisfy $m_{\ell\ell} < 81$ GeV or $m_{\ell\ell} > 101$ GeV in order to reduce the contamination from Z boson decays. In all three channels, the $Z \to \tau\tau$ background is reduced by applying a selection on the sum of the two angles in the transverse plane

[1] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z-axis along the beam pipe. The x-axis points from the IP to the centre of the LHC ring, and the y-axis points upwards. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ is the azimuthal angle around the beam pipe. The pseudorapidity η is defined in terms of the polar angle θ as $\eta = -\ln(\tan\theta/2)$.

between each lepton and the missing transverse momentum direction:

$$\Delta\phi(\ell_1, \vec{E}_{\mathrm{T}}^{\mathrm{miss}}) + \Delta\phi(\ell_2, \vec{E}_{\mathrm{T}}^{\mathrm{miss}}) > 2.5.$$

The application of this cut results in an expected rejection of 95% of $Z \to \tau\tau$ events, 30% of $Z \to ee$ and $Z \to \mu\mu$ events and 21% of $t\bar{t}$-pair events, while keeping 87% of the expected signal rate. After the selection, signal is expected mainly in events with exactly one jet. Events with at least two jets are expected to be dominated by background events and are used as control regions.

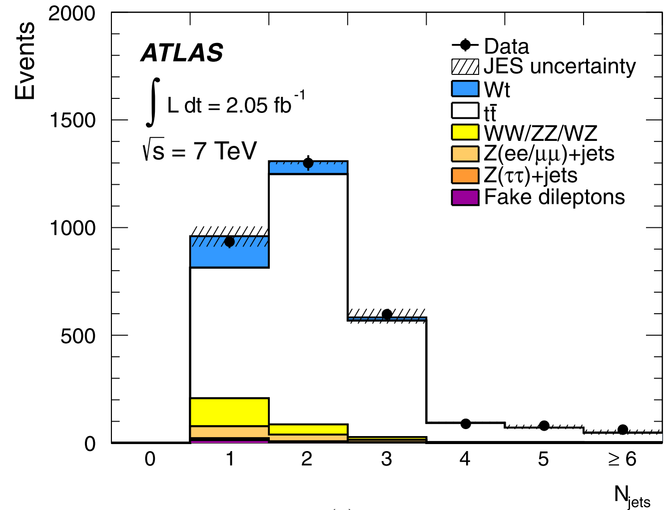
4. Background estimation

The main background originates from $t\bar{t}$-pair production in the dilepton channel $t\bar{t} \to \ell\nu b\ell\nu b$. The $t\bar{t}$-pair background is estimated using MC simulation normalised to the NNLO cross-section [17–19], and the uncertainty is further constrained by the fit of data in 2-jet and $\geqslant$3-jet bins.

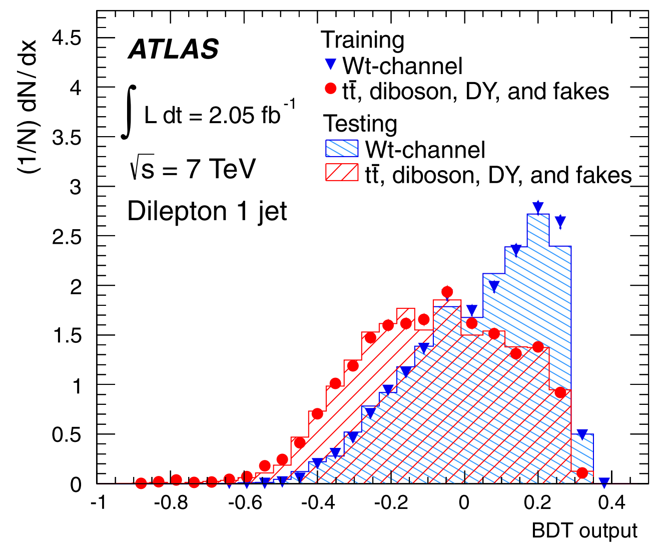
Diboson events, where initial state radiation produces a jet that passes the jet selection requirements, represent about 15% of the background in events selected with exactly one jet.

Drell–Yan including $Z^{(*)}$ events can be selected if they contain an additional jet from gluon radiation. The contribution of the Drell–Yan process to the background in the ee and $\mu\mu$ categories is determined via a data-driven procedure. In this method, orthogonal cuts on the reconstructed dilepton invariant mass $m_{\ell\ell}$ and the missing transverse momentum $E_{\mathrm{T}}^{\mathrm{miss}}$ variables are used to define a set of six regions, including two signal-enriched and four background-enriched regions for the ee final state or the $\mu\mu$ final state. The contamination of the signal regions by Drell–Yan events is estimated from data which are scaled by the measured ratio of numbers of events selected in the corresponding control regions. This scale factor is corrected for the contamination by non-Drell–Yan backgrounds (top quark production, diboson, W + jets) that are predicted by MC simulation and subtracted prior to its determination. Both the scale factor and non-Drell–Yan background-specific normalisation factors are determined using a likelihood fit of data in bins of $E_{\mathrm{T}}^{\mathrm{miss}}$. Variations by $\pm 1\sigma$ of these scale and normalisation factors are used to estimate the systematic uncertainty affecting the Drell–Yan event yield. The total uncertainty (statistical plus systematic) ranges between 10% and 35% depending upon the jet multiplicity. Drell–Yan events contribute about 5% of selected events.

Contamination of selected events by "fake dileptons" may occur if a lepton from real W/Z decay and another lepton from jet misidentification or heavy-flavour (b- and c-hadron) decays are selected, or both leptons from jet misidentification or heavy-flavour decays are selected, such as $t\bar{t}$-pair lepton + jets final state, W + jets or multijet events. These backgrounds are difficult to model accurately, so a data-driven approach based on the matrix method [33] is followed. The method builds upon the use of "tight" and "loose" lepton selection criteria mentioned in Section 3. For these backgrounds, the efficiency for a "loose" lepton to be reconstructed as a "tight" lepton is determined using a data sample enriched in multijet events, where some of the lepton quality criteria have been reversed and the isolation requirement has been removed. The "loose" to "tight" efficiency for real leptons is measured from $Z \to \ell\ell$ events using a tag-and-probe analysis technique. The composition of the selected dilepton sample is extracted by inverting a 4×4 matrix which relates the observed sample composition in terms of selected leptons of different quality to its true composition in terms of real and "fake" leptons. The background originating from these events represents less than 1% of the selected sample. The corresponding systematic uncertainty is taken conservatively at 100%.



(a)



(b)

Fig. 2. (a) Number of jets with $p_{\mathrm{T}} > 30$ GeV and $|\eta| < 2.5$ after the selection; hatched bands show the jet energy scale (JES) uncertainty. The Wt signal is normalised to the theory prediction. (b) Distribution of BDT output for the signal (Wt-channel) and background ($t\bar{t}$ diboson, Drell–Yan and fake dileptons) in signal enriched 1-jet bin. The BDT method uses 2 statistically independent sets of MC-simulated events, indicated as training and testing samples, to check both signal and background BDT output stability. The BDT weight file is derived from a training sample and applied to a testing sample.

A data-driven technique has been used to check the MC prediction of the $Z \to \tau\tau$ contamination. The selected sample is split into background- and signal-enriched regions, using the summed $\Delta\phi$ between the leptons and the $\vec{E}_{\mathrm{T}}^{\mathrm{miss}}$ direction requirement, as defined in Section 3. The $Z \to \tau\tau$ background in the signal region is extracted using the ratio of the corresponding MC estimates in both regions, scaled by the number of selected data events from which non-Drell–Yan as well as Drell–Yan ee and $\mu\mu$ backgrounds have been subtracted using MC. The difference between the purely MC-based expectations and this determination is included as a systematic error and results in an uncertainty of 60%. The $Z \to \tau\tau$ events constitute less than 1% of the selected event sample.

The jet multiplicity distribution is shown in Fig. 2(a) after the selection described in Section 3. Table 1 reports the expected signal, estimated backgrounds and total event yields in the 1-jet, 2-jet and $\geqslant$3-jet categories, with ee, $\mu\mu$ and $e\mu$ channels combined. No

Table 1
Observed and expected event yield in the selected dilepton sample in the 1-jet, 2-jet and ⩾3-jet bins for an integrated luminosity of 2.05 fb^{-1}. The Wt, $t\bar{t}$ and diboson expectations are normalised to the theory predictions. Dilepton and lepton + jets channels are included in $t\bar{t}$. Only leptonic decays of diboson events are considered. "Fake dileptons" are events with at least one fake lepton, as described in the text. Uncertainties are the sum of statistical and systematic sources added in quadrature.

	1-jet	2-jet	⩾3-jet
Wt	147 ± 13	60 ± 9	17 ± 5
$t\bar{t}$	610 ± 110	1160 ± 140	740 ± 130
Diboson	130 ± 17	47 ± 5	17 ± 4
$Z \to ee$	20 ± 2	11 ± 2	5 ± 2
$Z \to \mu\mu$	29 ± 3	28 ± 3	12 ± 3
$Z \to \tau\tau$	9 ± 6	4 ± 3	2 ± 1
Fake dileptons	11 ± 11	5 ± 5	negl.
Total bkgd.	810 ± 120	1260 ± 140	780 ± 130
Total expected	960 ± 120	1320 ± 140	790 ± 130
Data observed	934	1300	825

contamination from t-channel or s-channel single top-quark events is expected in the dilepton final state. A total of 224 signal events are expected over a background of 2840. The dominant $t\bar{t}$-pair production accounts for 75% of the background yield in 1-jet events.

5. Discriminating variables for *Wt* events

After the event selection, the signal-to-background ratio is 18% in 1-jet events, where most of the signal is expected. As no individual variable is found to carry a large discriminating power, the analysis strategy uses a multivariate approach based on the "boosted decision trees" (BDT) [34] technique in the framework of TMVA [35] to discriminate between the Wt-channel and $t\bar{t}$-pair production. The BDT method benefits from the advantage of using the correlations between variables as part of the distinguishing power. The goal is to exploit the differences between signal and background in many specific kinematic and topological distributions to form a classifier. This BDT classifier is trained using 1-jet events to maximise the expected significance without overtraining. BDT classifiers using the same input variables are also formed for 2-jet events and events with at least 3 jets: while no significant signal yield is expected in these events, the BDT output distribution serves to constrain the background normalisation.

Twenty-two variables with significant separation power are used as input to the BDT, all of which are well modelled by simulation. The two most powerful variables are $p_T^{\rm sys}$, defined as the magnitude of the vectorial sum of p_T of the leading jet, leptons and missing transverse momentum, and the ratio $p_T^{\rm sys}/\sqrt{H_T + \sum E_T}$, where H_T is the scalar sum of the two leptons and the leading jet transverse momenta, and $\sum E_T$ the scalar sum of the transverse energies of all energy deposits in the calorimeter. Other variables with lesser discriminating power are: the event centrality, the thrust and its associated pseudorapidity, the transverse momentum and pseudorapidity of the leading jet, the pseudorapidity of each lepton, the transverse momentum and pseudorapidity of the system formed by the dilepton and the leading jet, the invariant masses formed by each individual lepton with the leading jet, the missing transverse momentum, the azimuthal angle between the dilepton system and the leading jet directions, the pseudorapidity difference between the dilepton system and the leading jet, and the minimal azimuthal angle between the two leptons and the leading jet.

Fig. 2(b) displays the BDT output probability density functions for signal and background in 1-jet events. Several checks are performed to ensure that the input variables are well modelled in a

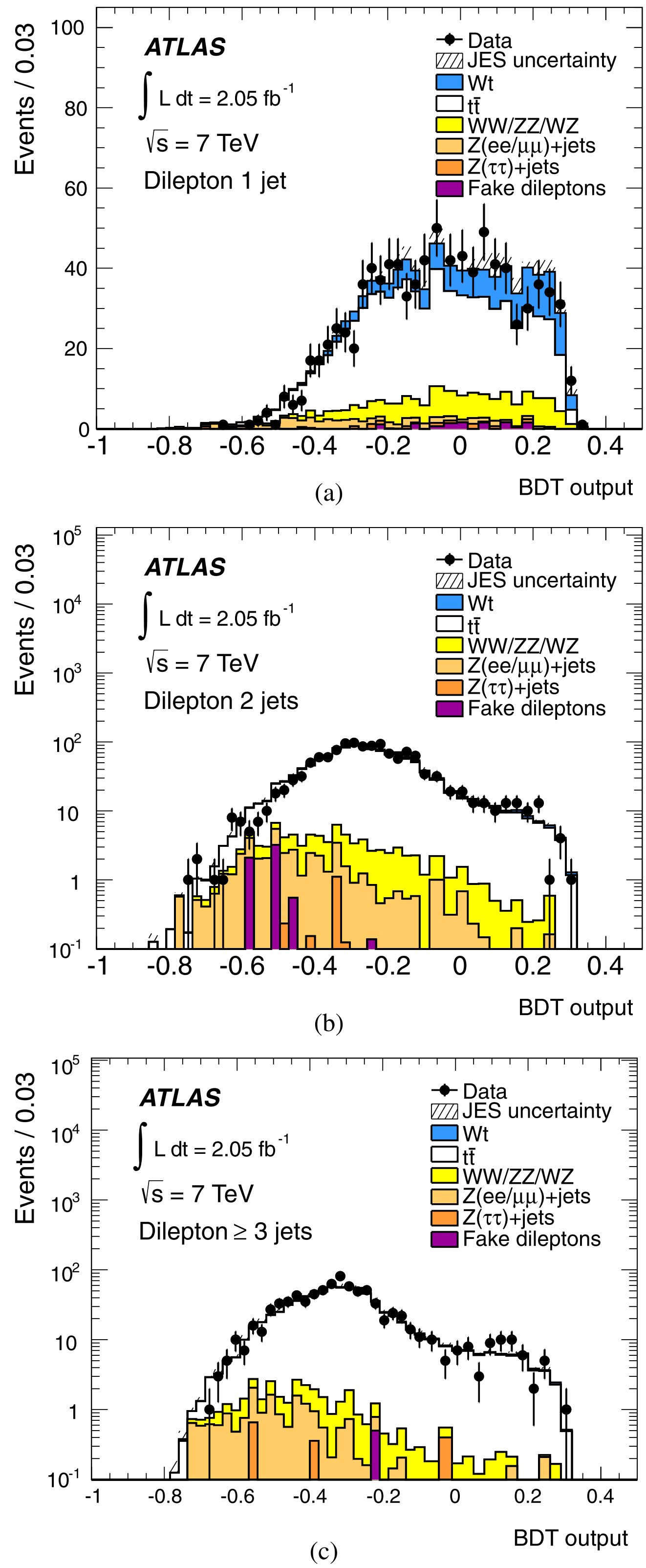


Fig. 3. BDT output for selected events in (a) 1-jet, (b) 2-jet, and (c) ⩾3-jet categories. The Wt signal is normalised to the theory prediction in all three categories.

large phase space: both background-enriched regions, defined by events with exactly two jets and with at least three jets, and regions where most of the signal events are expected. Figs. 3(a), 3(b) and 3(c) show the resulting good agreement of BDT outputs for data and MC simulation for 1-jet events, 2-jet events and events with at least 3 jets, respectively.

6. Cross-section determination

In order to determine the cross-section, a template fit is performed to the three BDT output distributions for 1-jet, 2-jet and ⩾3-jet events. The determination of the Wt-channel single top-quark production yield is treated as a counting experiment in each bin and modelled using a likelihood function in terms of Poisson and Gaussian distributions:

$$\mathcal{L}(\sigma_{Wt},\vec{\alpha}) = \prod_{i=1}^{3}\prod_{j=1}^{N_{\mathrm{bin}}}\mathcal{P}\big(N_{i,j}^{\mathrm{obs}}\big|N_{i,j}^{\mathrm{exp}}(\vec{\alpha})\big)\prod_{k=1}^{N_{\mathrm{syst}}}G(\alpha_k|0,1)$$

where the index i runs over the three jet multiplicity bins (1-jet, 2-jet and ⩾3-jet), and j runs over all bins of the corresponding BDT output distribution. The variables $N_{i,j}^{\mathrm{exp}}$ and $N_{i,j}^{\mathrm{obs}}$ are summed over the three dilepton flavour combinations. The index k runs over the list of systematic uncertainty sources, which are presented below.

The likelihood function includes a Poisson term $\mathcal{P}(N_{i,j}^{\mathrm{obs}}|N_{i,j}^{\mathrm{exp}}(\vec{\alpha}))$ in the observed number of events $N_{i,j}^{\mathrm{obs}}$ with the expectation value $N_{i,j}^{\mathrm{exp}}$ defined as the sum of the expected contributions from signal and all MC- or data-driven backgrounds in bin j for the jet multiplicity bin i. Systematic uncertainties are grouped in uncorrelated sets (k) and their effect is parameterised for each k using a nuisance parameter α_k, where $\alpha_k = 0$ maps to the nominal value and $\alpha_k = \pm 1$ map to $\pm 1\sigma$ shifts of the parameter. Piecewise-linear interpolation is used to propagate the effect of the α_k to the signal and background yields. A Gaussian shape $G(\alpha_k|0,1)$ centred at zero with unit width is used for the α_k constraint terms in the likelihood.

The contributions to the uncertainty on the fitted Wt-channel cross-section are shown in Table 2 and further described below. The main experimental source of systematic uncertainties comes from the knowledge of the jet energy scale (JES), which carries an uncertainty of 2% to 7% parameterised as a function of jet p_{T} and η [31]. The presence of a b-jet in the event is also taken into account and an extra uncertainty of 2% to 5% depending on jet p_{T} is added in quadrature to the non-b-jet uncertainty. Other experimental uncertainty sources which have been considered are the jet energy resolution, the jet reconstruction efficiency, the lepton identification efficiency, the lepton energy scale determination and resolution as well as the multiple proton–proton collision and underlying event modelling. The uncertainty in the luminosity determination is 3.7% [10,11].

Uncertainties in the simulation include the effects of the MC generator choice, the scheme used in the hadronisation and showering and models of the initial and final state radiation (ISR/FSR). Generator choice uncertainty is estimated by comparing AcerMC with MC@NLO generators for single top-quark Wt events, and comparing POWHEG with MC@NLO generators for top quark pair events. Hadronisation and showering effects are estimated using the differences seen in generated events interfaced with either PYTHIA [36] or HERWIG. Finally, ISR/FSR modelling effects are assessed on MC signal and background samples interfaced with PYTHIA. Specific tunes are used to separately vary ISR and FSR modelling via changes to $1/\Lambda_{\mathrm{QCD}}^{\mathrm{ISR}}$, the maximum parton virtuality in a space-like parton shower, the $\Lambda_{\mathrm{QCD}}^{\mathrm{FSR}}$ scale and the FSR infrared cut-off [37].

The impacts on both acceptance and kinematic distributions shapes are considered for the experimental and simulation uncertainties.

Table 2
Contributions to the uncertainty on the Wt-channel cross-section. The expected results assume the SM cross-section for the signal.

Source	$\Delta\sigma_{Wt}/\sigma_{Wt}$ [%]	
	observed	expected
Data statistics	17	17
MC statistics	< 5	< 5
Lepton energy scale/res.	< 5	< 5
Lepton efficiencies	7	6
Jet energy scale	16	14
Jet energy resolution	< 5	< 5
Jet reconstruction eff.	< 5	< 5
Generator	10	12
Parton shower	15	14
ISR/FSR	5	6
PDF	< 5	6
Pile-up	10	7
$t\bar{t}$ cross-section	6	6
Diboson cross-section	6	5
Drell–Yan estimate	< 5	< 5
Fake dileptons estimate	< 5	< 5
$Z \to \tau\tau$ estimate	< 5	< 5
Luminosity	7	7
All systematics	29	29
Total	34	33

Remaining theoretical uncertainty sources include the cross-section normalisation for the $t\bar{t}$-pair background ($^{+7\%}_{-10\%}$) [17–19] and diboson production (±5%) [33], as well as the choice of the parton distribution functions. For the latter, acceptance variations have been assessed using the CTEQ [21], MRST [38] and NNPDF [39] sets.

The cross-section is obtained by maximising the likelihood function using RooFit [40]. The total uncertainty is inferred from the shape of the profile likelihood ratio [41]:

$$-2\ln\frac{\mathcal{L}(\mathrm{data}|\sigma_{Wt},\hat{\hat{\alpha}}_{\sigma_{Wt}})}{\mathcal{L}(\mathrm{data}|\hat{\sigma}_{Wt},\hat{\vec{\alpha}})},$$

where $\hat{\vec{\alpha}}$ and $\hat{\sigma}_{Wt}$ are the parameters that maximise the likelihood with the constraint of $\hat{\sigma}_{Wt} > 0$, and $\hat{\hat{\alpha}}_{\sigma_{Wt}}$ are the nuisance parameter values that maximise the likelihood for a given σ_{Wt}. The maximisation is performed by varying all the nuisance parameters, except the systematic uncertainties due to the generator and the parton shower whose effects are estimated separately using pseudo-experiments.

The inclusion of 2-jet and ⩾3-jet events in the fit brings additional constraints on the effect of systematic uncertainties, as jet energy scale and resolution effects as well as ISR/FSR modelling directly affect the jet multiplicity distributions and the BDT outputs. These effects have been evaluated by varying the corresponding nuisance parameter central values in the fit to the data. The studies show that the fitted result for the cross-section is not biased by the models used to describe the JES and ISR/FSR uncertainties.

The fitted result for the Wt cross-section at 7 TeV is:

$$\sigma_{Wt} = 16.8 \pm 2.9\ (\mathrm{stat}) \pm 4.9\ (\mathrm{syst})\ \mathrm{pb}.$$

In order to determine the sensitivity of the analysis, an ensemble test is performed on pseudo-experiments. Systematic uncertainties are treated as nuisance parameters which are constrained using Gaussian functions. Both “background-only” and “signal + background” (where the signal rate is predicted by the

SM) hypotheses are tested via the generation of dedicated sets of pseudo-experiments. The likelihood ratio defined as

$$\mathrm{LLR} = -2\ln\frac{\mathcal{L}(\mathrm{data}|\sigma_{Wt}^{\mathrm{SM}},\ \hat{\hat{\alpha}}_{\sigma_{Wt}^{\mathrm{SM}}})}{\mathcal{L}(\mathrm{data}|0,\ \hat{\hat{\alpha}}_0)}$$

is computed for each pseudo-experiment. It is used to derive the p-value, which measures the probability for the background to fluctuate above the observed or expected number of events. This p-value is in turn interpreted in terms of significance and corresponds to a 3.3σ effect for the data. The corresponding significance for the expected value assuming the SM cross-section corresponds to a 3.4σ effect.

7. Determination of $|V_{tb}|$

A direct determination of $|V_{tb}|$ can be extracted from the cross-section, assuming that the Wt production through $|V_{ts}|$ and $|V_{td}|$ is small. The $t\bar{t}$ background, which is the only background in the analysis that involves $|V_{tb}|^2$, does not affect this determination since top quark decays to a fourth generation heavier quark is disfavoured by kinematics. The observed $|V_{tb}|^2$ is obtained by dividing the measured cross-section by the theoretical single top-quark cross-section calculated with a top quark mass of 172.5 GeV. Using $\sigma_{Wt}^{\mathrm{theory}} = 15.7(\pm 1.1) \times |V_{tb}|^2$ pb [5], the following value is obtained for $|V_{tb}|$:

$$|V_{tb}| = 1.03^{+0.16}_{-0.19},$$

where the uncertainties in the cross-section measurement and in the theoretical predictions have been added in quadrature. This result is compatible with the combination of direct measurements at the Tevatron [42]: $|V_{tb}| = 0.88^{+0.07}_{-0.07}$, and the measurement by ATLAS [3]: $|V_{tb}| = 1.13^{+0.14}_{-0.13}$.

8. Conclusion

Evidence for the production of single top-quark events in the Wt-channel is reported with 2.05 fb^{-1} of data collected at 7 TeV with ATLAS during 2011. The strategy followed consists of selecting dilepton events with at least one central jet. Drell–Yan and fake dilepton backgrounds are estimated in data, while a classifier is used to optimise the discrimination of signal and $t\bar{t}$-pair events. A fit of the classifier distributions is performed to extract the Wt-channel cross-section. The observed significance is 3.3 standard deviations for an expected sensitivity of 3.4. The corresponding fitted cross-section is $\sigma(pp \to Wt + X) = 16.8 \pm 2.9$ (stat) ± 4.9 (syst) pb. A direct determination of $|V_{tb}| = 1.03^{+0.16}_{-0.19}$ is extracted assuming that the Wt production through $|V_{ts}|$ and $|V_{td}|$ is small.

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References

[1] D0 Collaboration, V.M. Abazov, et al., Phys. Rev. Lett. 103 (2009) 092001.
[2] CDF Collaboration, T. Aaltonen, et al., Phys. Rev. Lett. 103 (2009) 092002.
[3] ATLAS Collaboration, Phys. Lett. B (2012), submitted for publication, arXiv:1205.3130 [hep-ex].
[4] CMS Collaboration, Phys. Rev. Lett. 107 (2011) 091802.
[5] N. Kidonakis, Phys. Rev. D 82 (2010) 054018.
[6] T.M.P. Tait, C.P. Yuan, Phys. Rev. D 63 (2000) 014018.
[7] N. Cabibbo, Phys. Rev. Lett. 10 (1963).
[8] M. Kobayashi, T. Maskawa, Prog. Theor. Phys. 49 (1973).
[9] ATLAS Collaboration, J. Inst. 3 (2008) S08003.
[10] ATLAS Collaboration, Eur. Phys. J. C 71 (2011) 1630.
[11] ATLAS Collaboration, Luminosity determination in pp collision at 7 TeV using the ATLAS detector at the LHC in 2011, ATLAS-CONF-2011-116 (2011), https://cdsweb.cern.ch/record/1376384.
[12] Tevatron Electroweak Working Group for CDF Collaboration and D0 Collaboration, Combination of CDF and D0 results on the mass of the top quark using up to 5.8 fb^{-1} of data, arXiv:1107.5255 [hep-ex].
[13] B.P. Kersevan, E. Richter-Was, The Monte Carlo event generator AcerMC version 2.0 with interfaces to PYTHIA 6.2 and HERWIG 6.5, hep-ph/0405247.
[14] A. Sherstnev, R. Thorne, Eur. Phys. J. C 55 (2008) 553.
[15] S. Frixione, B.R. Webber, P. Nason, MC@NLO Generator version 3.4, hep-ph/0204244, hep-ph/0305252, 2002.
[16] P.M. Nadolsky, H.-L. Lai, Q.-H. Cao, J. Huston, J. Pumplin, Phys. Rev. D 78 (2008) 013004.
[17] S. Moch, P. Uwer, Nucl. Phys. Proc. Suppl. 183 (2008) 75.
[18] U. Langenfeld, S. Moch, P. Uwer, New results for $t\bar{t}$ production at hadron colliders, arXiv:0907.2527 [hep-ph], 2009.
[19] M. Beneke, et al., Phys. Lett. B 690 (2010) 483.
Predictions in the Letter are calculated with Hathor [43] to compute approximate NNLO cross sections with $m_{\mathrm{top}} = 172.5$ GeV and CTEQ66 [44].
[20] M.L. Mangano, M. Moretti, F. Piccinini, R. Pittau, A.D. Polosa, JHEP 0307 (2003) 001.
[21] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P.M. Nadolsky, Phys. Rev. D 82 (2010) 074024.
[22] G. Corcella, et al., JHEP 0101 (2001) 010.
[23] J.M. Butterworth, J.R. Forshaw, M.H. Seymour, Z. Phys. C 72 (1996) 637.
[24] ATLAS Collaboration, Eur. Phys. J. C 70 (2010) 823.
[25] GEANT4 Collaboration, S. Agostinelli, et al., Nucl. Instrum. Methods A 506 (2003) 250.
[26] ATLAS Collaboration, Data-quality requirements and event cleaning for jets and missing transverse energy reconstruction with the ATLAS detector in proton–proton collisions at a center-of-mass energy of $\sqrt{s} = 7$ TeV, ATLAS-CONF-2010-038 (2010), https://cdsweb.cern.ch/record/1277678.
[27] ATLAS Collaboration, Eur. Phys. J. C 72 (2012) 1909.
[28] ATLAS Collaboration, JHEP 1012 (2010) 060.
[29] W. Lampl, et al., Calorimeter clustering algorithm: description and performance, ATL-LARG-PUB-2008-002 (2008), https://cdsweb.cern.ch/record/1099735.

[30] M. Cacciari, G.P. Salam, G. Soyez, JHEP 0804 (2008) 63.
[31] ATLAS Collaboration, Eur. Phys. J. C (2011), submitted for publication, arXiv:1112.6426 [hep-ex].
[32] ATLAS Collaboration, Eur. Phys. J. C 72 (2012) 1844.
[33] ATLAS Collaboration, Eur. Phys. J. C 71 (2011) 1577.
[34] L. Breiman, J. Friedman, R. Olshen, C. Stone, Classification and Regression Trees, Wadsworth Inc., 1984.
[35] A. Hoecker, et al., PoS ACAT (2007) 040, physics/0703039.
[36] T. Sjostrand, S. Mrenna, P. Skands, JHEP 0605 (2006) 026.
[37] ATLAS Collaboration, Eur. Phys. J. C 72 (2012) 2043.
[38] A. Martin, W. Stirling, R. Thorne, G. Watt, Eur. Phys. J. C 64 (2009) 653.
[39] R.D. Ball, L. Del Debbio, S. Forte, A. Guffanti, J.I. Latorre, Nucl. Phys. B 838 (2010) 136.
[40] W. Verkerke, EPJ Web of Conferences 4 (2010) 02005.
[41] G. Cowan, K. Cranmer, E. Gross, O. Vitells, Eur. Phys. J. C 71 (2011) 1554.
[42] Tevatron Electroweak Working Group for CDF Collaboration and D0 Collaboration, Combination of CDF and D0 measurements of the single top production cross section, arXiv:0908.2171 [hep-ex].
[43] M. Aliev, et al., Comput. Phys. Commun. 182 (2011) 1034.
[44] J. Pumplin, et al., JHEP 0207 (2002) 012.

ATLAS Collaboration

G. Aad [48], B. Abbott [111], J. Abdallah [11], S. Abdel Khalek [115], A.A. Abdelalim [49], O. Abdinov [10], B. Abi [112], M. Abolins [88], O.S. AbouZeid [158], H. Abramowicz [153], H. Abreu [136], E. Acerbi [89a,89b], B.S. Acharya [164a,164b], L. Adamczyk [37], D.L. Adams [24], T.N. Addy [56], J. Adelman [176], S. Adomeit [98], P. Adragna [75], T. Adye [129], S. Aefsky [22], J.A. Aguilar-Saavedra [124b,a], M. Aharrouche [81], S.P. Ahlen [21], F. Ahles [48], A. Ahmad [148], M. Ahsan [40], G. Aielli [133a,133b], T. Akdogan [18a], T.P.A. Åkesson [79], G. Akimoto [155], A.V. Akimov [94], A. Akiyama [66], M.S. Alam [1], M.A. Alam [76], J. Albert [169], S. Albrand [55], M. Aleksa [29], I.N. Aleksandrov [64], F. Alessandria [89a], C. Alexa [25a], G. Alexander [153], G. Alexandre [49], T. Alexopoulos [9], M. Alhroob [164a,164c], M. Aliev [15], G. Alimonti [89a], J. Alison [120], B.M.M. Allbrooke [17], P.P. Allport [73], S.E. Allwood-Spiers [53], J. Almond [82], A. Aloisio [102a,102b], R. Alon [172], A. Alonso [79], B. Alvarez Gonzalez [88], M.G. Alviggi [102a,102b], K. Amako [65], C. Amelung [22], V.V. Ammosov [128], A. Amorim [124a,b], N. Amram [153], C. Anastopoulos [29], L.S. Ancu [16], N. Andari [115], T. Andeen [34], C.F. Anders [20], G. Anders [58a], K.J. Anderson [30], A. Andreazza [89a,89b], V. Andrei [58a], X.S. Anduaga [70], A. Angerami [34], F. Anghinolfi [29], A. Anisenkov [107], N. Anjos [124a], A. Annovi [47], A. Antonaki [8], M. Antonelli [47], A. Antonov [96], J. Antos [144b], F. Anulli [132a], S. Aoun [83], L. Aperio Bella [4], R. Apolle [118,c], G. Arabidze [88], I. Aracena [143], Y. Arai [65], A.T.H. Arce [44], S. Arfaoui [148], J.-F. Arguin [14], E. Arik [18a,*], M. Arik [18a], A.J. Armbruster [87], O. Arnaez [81], V. Arnal [80], C. Arnault [115], A. Artamonov [95], G. Artoni [132a,132b], D. Arutinov [20], S. Asai [155], R. Asfandiyarov [173], S. Ask [27], B. Åsman [146a,146b], L. Asquith [5], K. Assamagan [24], A. Astbury [169], B. Aubert [4], E. Auge [115], K. Augsten [127], M. Aurousseau [145a], G. Avolio [163], R. Avramidou [9], D. Axen [168], G. Azuelos [93,d], Y. Azuma [155], M.A. Baak [29], G. Baccaglioni [89a], C. Bacci [134a,134b], A.M. Bach [14], H. Bachacou [136], K. Bachas [29], M. Backes [49], M. Backhaus [20], E. Badescu [25a], P. Bagnaia [132a,132b], S. Bahinipati [2], Y. Bai [32a], D.C. Bailey [158], T. Bain [158], J.T. Baines [129], O.K. Baker [176], M.D. Baker [24], S. Baker [77], E. Banas [38], P. Banerjee [93], Sw. Banerjee [173], D. Banfi [29], A. Bangert [150], V. Bansal [169], H.S. Bansil [17], L. Barak [172], S.P. Baranov [94], A. Barbaro Galtieri [14], T. Barber [48], E.L. Barberio [86], D. Barberis [50a,50b], M. Barbero [20], D.Y. Bardin [64], T. Barillari [99], M. Barisonzi [175], T. Barklow [143], N. Barlow [27], B.M. Barnett [129], R.M. Barnett [14], A. Baroncelli [134a], G. Barone [49], A.J. Barr [118], F. Barreiro [80], J. Barreiro Guimarães da Costa [57], P. Barrillon [115], R. Bartoldus [143], A.E. Barton [71], V. Bartsch [149], R.L. Bates [53], L. Batkova [144a], J.R. Batley [27], A. Battaglia [16], M. Battistin [29], F. Bauer [136], H.S. Bawa [143,e], S. Beale [98], T. Beau [78], P.H. Beauchemin [161], R. Beccherle [50a], P. Bechtle [20], H.P. Beck [16], S. Becker [98], M. Beckingham [138], K.H. Becks [175], A.J. Beddall [18c], A. Beddall [18c], S. Bedikian [176], V.A. Bednyakov [64], C.P. Bee [83], M. Begel [24], S. Behar Harpaz [152], P.K. Behera [62], M. Beimforde [99], C. Belanger-Champagne [85], P.J. Bell [49], W.H. Bell [49], G. Bella [153], L. Bellagamba [19a], F. Bellina [29], M. Bellomo [29], A. Belloni [57], O. Beloborodova [107,f], K. Belotskiy [96], O. Beltramello [29], O. Benary [153], D. Benchekroun [135a], K. Bendtz [146a,146b], N. Benekos [165], Y. Benhammou [153], E. Benhar Noccioli [49], J.A. Benitez Garcia [159b], D.P. Benjamin [44], M. Benoit [115], J.R. Bensinger [22], K. Benslama [130], S. Bentvelsen [105], D. Berge [29], E. Bergeaas Kuutmann [41], N. Berger [4], F. Berghaus [169], E. Berglund [105], J. Beringer [14], P. Bernat [77], R. Bernhard [48], C. Bernius [24], T. Berry [76], C. Bertella [83], A. Bertin [19a,19b], F. Bertolucci [122a,122b], M.I. Besana [89a,89b], N. Besson [136], S. Bethke [99], W. Bhimji [45], R.M. Bianchi [29], M. Bianco [72a,72b], O. Biebel [98], S.P. Bieniek [77], K. Bierwagen [54], J. Biesiada [14], M. Biglietti [134a], H. Bilokon [47], M. Bindi [19a,19b], S. Binet [115], A. Bingul [18c], C. Bini [132a,132b], C. Biscarat [178], U. Bitenc [48], K.M. Black [21], R.E. Blair [5], J.-B. Blanchard [136], G. Blanchot [29], T. Blazek [144a], C. Blocker [22], J. Blocki [38], A. Blondel [49], W. Blum [81], U. Blumenschein [54], G.J. Bobbink [105], V.B. Bobrovnikov [107], S.S. Bocchetta [79], A. Bocci [44], C.R. Boddy [118], M. Boehler [41], J. Boek [175], N. Boelaert [35], J.A. Bogaerts [29], A. Bogdanchikov [107], A. Bogouch [90,*], C. Bohm [146a], J. Bohm [125], V. Boisvert [76], T. Bold [37], V. Boldea [25a], N.M. Bolnet [136], M. Bomben [78], M. Bona [75], M. Bondioli [163],

M. Boonekamp [136], C.N. Booth [139], S. Bordoni [78], C. Borer [16], A. Borisov [128], G. Borissov [71], I. Borjanovic [12a], M. Borri [82], S. Borroni [87], V. Bortolotto [134a,134b], K. Bos [105], D. Boscherini [19a], M. Bosman [11], H. Boterenbrood [105], D. Botterill [129], J. Bouchami [93], J. Boudreau [123], E.V. Bouhova-Thacker [71], D. Boumediene [33], C. Bourdarios [115], N. Bousson [83], A. Boveia [30], J. Boyd [29], I.R. Boyko [64], N.I. Bozhko [128], I. Bozovic-Jelisavcic [12b], J. Bracinik [17], P. Branchini [134a], A. Brandt [7], G. Brandt [118], O. Brandt [54], U. Bratzler [156], B. Brau [84], J.E. Brau [114], H.M. Braun [175], B. Brelier [158], J. Bremer [29], K. Brendlinger [120], R. Brenner [166], S. Bressler [172], D. Britton [53], F.M. Brochu [27], I. Brock [20], R. Brock [88], E. Brodet [153], F. Broggi [89a], C. Bromberg [88], J. Bronner [99], G. Brooijmans [34], W.K. Brooks [31b], G. Brown [82], H. Brown [7], P.A. Bruckman de Renstrom [38], D. Bruncko [144b], R. Bruneliere [48], S. Brunet [60], A. Bruni [19a], G. Bruni [19a], M. Bruschi [19a], T. Buanes [13], Q. Buat [55], F. Bucci [49], J. Buchanan [118], P. Buchholz [141], R.M. Buckingham [118], A.G. Buckley [45], S.I. Buda [25a], I.A. Budagov [64], B. Budick [108], V. Büscher [81], L. Bugge [117], O. Bulekov [96], A.C. Bundock [73], M. Bunse [42], T. Buran [117], H. Burckhart [29], S. Burdin [73], T. Burgess [13], S. Burke [129], E. Busato [33], P. Bussey [53], C.P. Buszello [166], B. Butler [143], J.M. Butler [21], C.M. Buttar [53], J.M. Butterworth [77], W. Buttinger [27], S. Cabrera Urbán [167], D. Caforio [19a,19b], O. Cakir [3a], P. Calafiura [14], G. Calderini [78], P. Calfayan [98], R. Calkins [106], L.P. Caloba [23a], R. Caloi [132a,132b], D. Calvet [33], S. Calvet [33], R. Camacho Toro [33], P. Camarri [133a,133b], D. Cameron [117], L.M. Caminada [14], S. Campana [29], M. Campanelli [77], V. Canale [102a,102b], F. Canelli [30,g], A. Canepa [159a], J. Cantero [80], L. Capasso [102a,102b], M.D.M. Capeans Garrido [29], I. Caprini [25a], M. Caprini [25a], D. Capriotti [99], M. Capua [36a,36b], R. Caputo [81], R. Cardarelli [133a], T. Carli [29], G. Carlino [102a], L. Carminati [89a,89b], B. Caron [85], S. Caron [104], E. Carquin [31b], G.D. Carrillo Montoya [173], A.A. Carter [75], J.R. Carter [27], J. Carvalho [124a,h], D. Casadei [108], M.P. Casado [11], M. Cascella [122a,122b], C. Caso [50a,50b,*], A.M. Castaneda Hernandez [173,i], E. Castaneda-Miranda [173], V. Castillo Gimenez [167], N.F. Castro [124a], G. Cataldi [72a], P. Catastini [57], A. Catinaccio [29], J.R. Catmore [29], A. Cattai [29], G. Cattani [133a,133b], S. Caughron [88], P. Cavalleri [78], D. Cavalli [89a], M. Cavalli-Sforza [11], V. Cavasinni [122a,122b], F. Ceradini [134a,134b], A.S. Cerqueira [23b], A. Cerri [29], L. Cerrito [75], F. Cerutti [47], S.A. Cetin [18b], A. Chafaq [135a], D. Chakraborty [106], I. Chalupkova [126], K. Chan [2], B. Chapleau [85], J.D. Chapman [27], J.W. Chapman [87], E. Chareyre [78], D.G. Charlton [17], V. Chavda [82], C.A. Chavez Barajas [29], S. Cheatham [85], S. Chekanov [5], S.V. Chekulaev [159a], G.A. Chelkov [64], M.A. Chelstowska [104], C. Chen [63], H. Chen [24], S. Chen [32c], X. Chen [173], A. Cheplakov [64], R. Cherkaoui El Moursli [135e], V. Chernyatin [24], E. Cheu [6], S.L. Cheung [158], L. Chevalier [136], G. Chiefari [102a,102b], L. Chikovani [51a], J.T. Childers [29], A. Chilingarov [71], G. Chiodini [72a], A.S. Chisholm [17], R.T. Chislett [77], M.V. Chizhov [64], G. Choudalakis [30], S. Chouridou [137], I.A. Christidi [77], A. Christov [48], D. Chromek-Burckhart [29], M.L. Chu [151], J. Chudoba [125], G. Ciapetti [132a,132b], A.K. Ciftci [3a], R. Ciftci [3a], D. Cinca [33], V. Cindro [74], C. Ciocca [19a], A. Ciocio [14], M. Cirilli [87], M. Citterio [89a], M. Ciubancan [25a], A. Clark [49], P.J. Clark [45], W. Cleland [123], J.C. Clemens [83], B. Clement [55], C. Clement [146a,146b], Y. Coadou [83], M. Cobal [164a,164c], A. Coccaro [138], J. Cochran [63], P. Coe [118], J.G. Cogan [143], J. Coggeshall [165], E. Cogneras [178], J. Colas [4], A.P. Colijn [105], N.J. Collins [17], C. Collins-Tooth [53], J. Collot [55], G. Colon [84], P. Conde Muiño [124a], E. Coniavitis [118], M.C. Conidi [11], S.M. Consonni [89a,89b], V. Consorti [48], S. Constantinescu [25a], C. Conta [119a,119b], G. Conti [57], F. Conventi [102a,j], M. Cooke [14], B.D. Cooper [77], A.M. Cooper-Sarkar [118], K. Copic [14], T. Cornelissen [175], M. Corradi [19a], F. Corriveau [85,k], A. Cortes-Gonzalez [165], G. Cortiana [99], G. Costa [89a], M.J. Costa [167], D. Costanzo [139], T. Costin [30], D. Côté [29], L. Courneyea [169], G. Cowan [76], C. Cowden [27], B.E. Cox [82], K. Cranmer [108], F. Crescioli [122a,122b], M. Cristinziani [20], G. Crosetti [36a,36b], R. Crupi [72a,72b], S. Crépé-Renaudin [55], C.-M. Cuciuc [25a], C. Cuenca Almenar [176], T. Cuhadar Donszelmann [139], M. Curatolo [47], C.J. Curtis [17], C. Cuthbert [150], P. Cwetanski [60], H. Czirr [141], P. Czodrowski [43], Z. Czyczula [176], S. D'Auria [53], M. D'Onofrio [73], A. D'Orazio [132a,132b], C. Da Via [82], W. Dabrowski [37], A. Dafinca [118], T. Dai [87], C. Dallapiccola [84], M. Dam [35], M. Dameri [50a,50b], D.S. Damiani [137], H.O. Danielsson [29], V. Dao [49], G. Darbo [50a], G.L. Darlea [25b], W. Davey [20], T. Davidek [126], N. Davidson [86], R. Davidson [71], E. Davies [118,c], M. Davies [93], A.R. Davison [77], Y. Davygora [58a], E. Dawe [142], I. Dawson [139], R.K. Daya-Ishmukhametova [22], K. De [7], R. de Asmundis [102a], S. De Castro [19a,19b], S. De Cecco [78], J. de Graat [98], N. De Groot [104], P. de Jong [105], C. De La Taille [115], H. De la Torre [80], F. De Lorenzi [63], L. de Mora [71], L. De Nooij [105], D. De Pedis [132a], A. De Salvo [132a], U. De Sanctis [164a,164c], A. De Santo [149], J.B. De Vivie De Regie [115], G. De Zorzi [132a,132b], W.J. Dearnaley [71], R. Debbe [24], C. Debenedetti [45], B. Dechenaux [55], D.V. Dedovich [64], J. Degenhardt [120], C. Del Papa [164a,164c], J. Del Peso [80], T. Del Prete [122a,122b], T. Delemontex [55], M. Deliyergiyev [74], A. Dell'Acqua [29], L. Dell'Asta [21],

M. Della Pietra [102a,j], D. della Volpe [102a,102b], M. Delmastro [4], P.A. Delsart [55], C. Deluca [148], S. Demers [176], M. Demichev [64], B. Demirkoz [11,l], J. Deng [163], S.P. Denisov [128], D. Derendarz [38], J.E. Derkaoui [135d], F. Derue [78], P. Dervan [73], K. Desch [20], E. Devetak [148], P.O. Deviveiros [105], A. Dewhurst [129], B. DeWilde [148], S. Dhaliwal [158], R. Dhullipudi [24,m], A. Di Ciaccio [133a,133b], L. Di Ciaccio [4], A. Di Girolamo [29], B. Di Girolamo [29], S. Di Luise [134a,134b], A. Di Mattia [173], B. Di Micco [29], R. Di Nardo [47], A. Di Simone [133a,133b], R. Di Sipio [19a,19b], M.A. Diaz [31a], F. Diblen [18c], E.B. Diehl [87], J. Dietrich [41], T.A. Dietzsch [58a], S. Diglio [86], K. Dindar Yagci [39], J. Dingfelder [20], C. Dionisi [132a,132b], P. Dita [25a], S. Dita [25a], F. Dittus [29], F. Djama [83], T. Djobava [51b], M.A.B. do Vale [23c], A. Do Valle Wemans [124a,n], T.K.O. Doan [4], M. Dobbs [85], R. Dobinson [29,*], D. Dobos [29], E. 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Emeliyanov [129], R. Engelmann [148], A. Engl [98], B. Epp [61], A. Eppig [87], J. Erdmann [54], A. Ereditato [16], D. Eriksson [146a], J. Ernst [1], M. Ernst [24], J. Ernwein [136], D. Errede [165], S. Errede [165], E. Ertel [81], M. Escalier [115], C. Escobar [123], X. Espinal Curull [11], B. Esposito [47], F. Etienne [83], A.I. Etienvre [136], E. Etzion [153], D. Evangelakou [54], H. Evans [60], L. Fabbri [19a,19b], C. Fabre [29], R.M. Fakhrutdinov [128], S. Falciano [132a], Y. Fang [173], M. Fanti [89a,89b], A. Farbin [7], A. Farilla [134a], J. Farley [148], T. Farooque [158], S. Farrell [163], S.M. Farrington [118], P. Farthouat [29], P. Fassnacht [29], D. Fassouliotis [8], B. Fatholahzadeh [158], A. Favareto [89a,89b], L. Fayard [115], S. Fazio [36a,36b], R. Febbraro [33], P. Federic [144a], O.L. Fedin [121], W. Fedorko [88], M. Fehling-Kaschek [48], L. Feligioni [83], D. Fellmann [5], C. Feng [32d], E.J. Feng [30], A.B. Fenyuk [128], J. Ferencei [144b], W. Fernando [5], S. Ferrag [53], J. Ferrando [53], V. Ferrara [41], A. Ferrari [166], P. Ferrari [105], R. Ferrari [119a], D.E. Ferreira de Lima [53], A. Ferrer [167], D. Ferrere [49], C. Ferretti [87], A. Ferretto Parodi [50a,50b], M. Fiascaris [30], F. Fiedler [81], A. Filipčič [74], F. Filthaut [104], M. Fincke-Keeler [169], M.C.N. Fiolhais [124a,h], L. Fiorini [167], A. Firan [39], G. Fischer [41], M.J. Fisher [109], M. Flechl [48], I. Fleck [141], J. Fleckner [81], P. Fleischmann [174], S. Fleischmann [175], T. Flick [175], A. Floderus [79], L.R. Flores Castillo [173], M.J. Flowerdew [99], T. Fonseca Martin [16], A. Formica [136], A. Forti [82], D. Fortin [159a], D. Fournier [115], H. Fox [71], P. Francavilla [11], S. Franchino [119a,119b], D. Francis [29], T. Frank [172], M. Franklin [57], S. Franz [29], M. Fraternali [119a,119b], S. Fratina [120], S.T. French [27], C. Friedrich [41], F. Friedrich [43], R. Froeschl [29], D. Froidevaux [29], J.A. Frost [27], C. Fukunaga [156], E. Fullana Torregrosa [29], B.G. Fulsom [143], J. Fuster [167], C. Gabaldon [29], O. Gabizon [172], T. Gadfort [24], S. Gadomski [49], G. Gagliardi [50a,50b], P. Gagnon [60], C. Galea [98], E.J. Gallas [118], V. Gallo [16], B.J. Gallop [129], P. Gallus [125], K.K. Gan [109], Y.S. Gao [143,e], A. Gaponenko [14], F. Garberson [176], M. Garcia-Sciveres [14], C. García [167], J.E. García Navarro [167], R.W. Gardner [30], N. Garelli [29], H. Garitaonandia [105], V. Garonne [29], J. Garvey [17], C. Gatti [47], G. Gaudio [119a], B. Gaur [141], L. Gauthier [136], P. Gauzzi [132a,132b], I.L. Gavrilenko [94], C. Gay [168], G. Gaycken [20], E.N. Gazis [9], P. Ge [32d], Z. Gecse [168], C.N.P. Gee [129], D.A.A. Geerts [105], Ch. Geich-Gimbel [20], K. Gellerstedt [146a,146b], C. Gemme [50a], A. Gemmell [53], M.H. Genest [55], S. Gentile [132a,132b], M. George [54], S. George [76], P. Gerlach [175], A. Gershon [153], C. Geweniger [58a], H. Ghazlane [135b], N. Ghodbane [33], B. Giacobbe [19a], S. Giagu [132a,132b], V. Giakoumopoulou [8], V. Giangiobbe [11], F. Gianotti [29], B. Gibbard [24], A. Gibson [158], S.M. Gibson [29], D. Gillberg [28], A.R. Gillman [129], D.M. Gingrich [2,d], J. Ginzburg [153], N. Giokaris [8], M.P. Giordani [164c], R. Giordano [102a,102b], F.M. Giorgi [15], P. Giovannini [99], P.F. Giraud [136], D. Giugni [89a], M. Giunta [93], P. Giusti [19a], B.K. Gjelsten [117], L.K. Gladilin [97], C. Glasman [80], J. Glatzer [48], A. Glazov [41], K.W. Glitza [175], G.L. Glonti [64], J.R. Goddard [75], J. Godfrey [142], J. Godlewski [29], M. Goebel [41], T. Göpfert [43], C. Goeringer [81], C. Gössling [42], T. Göttfert [99], S. Goldfarb [87], T. Golling [176], A. Gomes [124a,b], L.S. Gomez Fajardo [41], R. Gonçalo [76], J. Goncalves Pinto Firmino Da Costa [41], L. Gonella [20], S. Gonzalez [173], S. González de la Hoz [167], G. Gonzalez Parra [11], M.L. Gonzalez Silva [26], S. Gonzalez-Sevilla [49], J.J. Goodson [148], L. Goossens [29], P.A. Gorbounov [95], H.A. Gordon [24], I. Gorelov [103], G. Gorfine [175], B. Gorini [29], E. Gorini [72a,72b], A. Gorišek [74], E. Gornicki [38], B. Gosdzik [41], A.T. Goshaw [5], M. Gosselink [105], M.I. Gostkin [64], I. Gough Eschrich [163], M. Gouighri [135a], D. Goujdami [135c], M.P. Goulette [49], A.G. Goussiou [138], C. Goy [4], S. Gozpinar [22], I. Grabowska-Bold [37], P. Grafström [29], K-J. Grahn [41], F. Grancagnolo [72a], S. Grancagnolo [15], V. Grassi [148], V. Gratchev [121], N. Grau [34], H.M. Gray [29], J.A. Gray [148], E. Graziani [134a], O.G. Grebenyuk [121], T. Greenshaw [73], Z.D. Greenwood [24,m], K. Gregersen [35], I.M. Gregor [41], P. Grenier [143], J. Griffiths [138], N. Grigalashvili [64], A.A. Grillo [137], S. Grinstein [11], Y.V. Grishkevich [97], J.-F. Grivaz [115], E. Gross [172], J. Grosse-Knetter [54], J. Groth-Jensen [172], K. Grybel [141], D. Guest [176], C. Guicheney [33], A. Guida [72a,72b], S. Guindon [54], H. Guler [85,p], J. Gunther [125], B. Guo [158], J. Guo [34], V.N. Gushchin [128], P. Gutierrez [111], N. Guttman [153], O. Gutzwiller [173], C. Guyot [136], C. Gwenlan [118], C.B. Gwilliam [73], A. Haas [143], S. Haas [29], C. Haber [14], H.K. Hadavand [39], D.R. Hadley [17], P. Haefner [99], F. Hahn [29], S. Haider [29], Z. Hajduk [38], H. Hakobyan [177], D. Hall [118], J. Haller [54], K. Hamacher [175], P. Hamal [113], M. Hamer [54], A. Hamilton [145b,q], S. Hamilton [161], L. Han [32b], K. Hanagaki [116], K. Hanawa [160], M. Hance [14], C. Handel [81], P. Hanke [58a], J.R. Hansen [35], J.B. Hansen [35], J.D. Hansen [35], P.H. Hansen [35], P. Hansson [143], K. Hara [160], G.A. Hare [137], T. Harenberg [175], S. Harkusha [90], D. Harper [87], R.D. Harrington [45], O.M. Harris [138], K. Harrison [17], J. Hartert [48], F. Hartjes [105], T. Haruyama [65], A. Harvey [56], S. Hasegawa [101], Y. Hasegawa [140], S. Hassani [136], S. Haug [16], M. Hauschild [29], R. Hauser [88], M. Havranek [20], C.M. Hawkes [17], R.J. Hawkings [29], A.D. Hawkins [79], D. Hawkins [163], T. Hayakawa [66], T. Hayashi [160], D. Hayden [76], H.S. Hayward [73], S.J. Haywood [129], M. He [32d], S.J. Head [17], V. Hedberg [79], L. Heelan [7], S. Heim [88], B. Heinemann [14], S. Heisterkamp [35], L. Helary [4], C. Heller [98], M. Heller [29], S. Hellman [146a,146b], D. Hellmich [20], C. Helsens [11], R.C.W. Henderson [71], M. Henke [58a], A. Henrichs [54], A.M. Henriques Correia [29], S. Henrot-Versille [115], F. Henry-Couannier [83], C. Hensel [54], T. Henß [175], C.M. Hernandez [7], Y. Hernández Jiménez [167], R. Herrberg [15], G. Herten [48], R. Hertenberger [98], L. Hervas [29], G.G. Hesketh [77], N.P. Hessey [105], E. Higón-Rodriguez [167], J.C. Hill [27], K.H. Hiller [41], S. Hillert [20], S.J. Hillier [17], I. Hinchliffe [14], E. Hines [120], M. Hirose [116], F. Hirsch [42], D. Hirschbuehl [175], J. Hobbs [148], N. Hod [153], M.C. Hodgkinson [139], P. Hodgson [139], A. Hoecker [29], M.R. Hoeferkamp [103], J. Hoffman [39], D. Hoffmann [83], M. 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Ishmukhametov [39], C. Issever [118], S. Istin [18a], A.V. Ivashin [128], W. Iwanski [38], H. Iwasaki [65], J.M. Izen [40], V. Izzo [102a], B. Jackson [120], J.N. Jackson [73], P. Jackson [143], M.R. Jaekel [29], V. Jain [60], K. Jakobs [48], S. Jakobsen [35], J. Jakubek [127], D.K. Jana [111], E. Jansen [77], H. Jansen [29], A. Jantsch [99], M. Janus [48], G. Jarlskog [79], L. Jeanty [57], I. Jen-La Plante [30], P. Jenni [29], A. Jeremie [4], P. Jež [35], S. Jézéquel [4], M.K. Jha [19a], H. Ji [173], W. Ji [81], J. Jia [148], Y. Jiang [32b], M. Jimenez Belenguer [41], S. Jin [32a], O. Jinnouchi [157], M.D. Joergensen [35], D. Joffe [39], L.G. Johansen [13], M. Johansen [146a,146b], K.E. Johansson [146a], P. Johansson [139], S. Johnert [41], K.A. Johns [6], K. Jon-And [146a,146b], G. Jones [118], R.W.L. Jones [71], T.J. Jones [73], C. Joram [29], P.M. Jorge [124a], K.D. Joshi [82], J. Jovicevic [147], T. Jovin [12b], X. Ju [173], C.A. Jung [42], R.M. Jungst [29], V. Juranek [125], P. Jussel [61], A. Juste Rozas [11], S. Kabana [16], M. Kaci [167], A. Kaczmarska [38], P. Kadlecik [35], M. Kado [115], H. Kagan [109], M. Kagan [57], E. Kajomovitz [152], S. Kalinin [175], L.V. Kalinovskaya [64], S. Kama [39], N. Kanaya [155], M. Kaneda [29], S. Kaneti [27], T. Kanno [157], V.A. Kantserov [96], J. Kanzaki [65], B. Kaplan [176], A. Kapliy [30], J. Kaplon [29], D. Kar [53], M. Karagounis [20], K. Karakostas [9], M. Karnevskiy [41], V. Kartvelishvili [71], A.N. Karyukhin [128], L. Kashif [173], G. Kasieczka [58b], R.D. Kass [109], A. Kastanas [13], M. Kataoka [4], Y. Kataoka [155], E. Katsoufis [9], J. Katzy [41], V. Kaushik [6], K. Kawagoe [69], T. Kawamoto [155], G. Kawamura [81], M.S. Kayl [105], V.A. Kazanin [107], M.Y. Kazarinov [64], R. Keeler [169], R. Kehoe [39], M. Keil [54], G.D. Kekelidze [64], J.S. Keller [138], J. Kennedy [98], M. Kenyon [53], O. Kepka [125], N. Kerschen [29], B.P. Kerševan [74], S. Kersten [175], K. Kessoku [155], J. Keung [158], F. 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Koperny [37], K. Korcyl [38], K. Kordas [154], A. Korn [118], A. Korol [107], I. Korolkov [11], E.V. Korolkova [139], V.A. Korotkov [128], O. Kortner [99], S. Kortner [99], V.V. Kostyukhin [20], S. Kotov [99], V.M. Kotov [64], A. Kotwal [44], C. Kourkoumelis [8], V. Kouskoura [154], A. Koutsman [159a], R. Kowalewski [169], T.Z. Kowalski [37], W. Kozanecki [136], A.S. Kozhin [128], V. Kral [127], V.A. Kramarenko [97], G. Kramberger [74], M.W. Krasny [78], A. Krasznahorkay [108], J. Kraus [88], J.K. Kraus [20], F. Krejci [127], J. Kretzschmar [73], N. Krieger [54], P. Krieger [158], K. Kroeninger [54], H. Kroha [99], J. Kroll [120], J. Kroseberg [20], J. Krstic [12a], U. Kruchonak [64], H. Krüger [20], T. Kruker [16], N. Krumnack [63], Z.V. Krumshteyn [64], A. Kruth [20], T. Kubota [86], S. Kuday [3a], S. Kuehn [48], A. Kugel [58c], T. Kuhl [41], D. Kuhn [61], V. Kukhtin [64], Y. Kulchitsky [90], S. Kuleshov [31b], C. Kummer [98], M. Kuna [78], J. Kunkle [120], A. Kupco [125], H. Kurashige [66], M. Kurata [160], Y.A. Kurochkin [90], V. Kus [125], E.S. Kuwertz [147], M. Kuze [157], J. Kvita [142], R. Kwee [15], A. La Rosa [49], L. La Rotonda [36a,36b], L. Labarga [80], J. Labbe [4], S. Lablak [135a], C. Lacasta [167], F. Lacava [132a,132b], H. Lacker [15], D. Lacour [78], V.R. Lacuesta [167], E. Ladygin [64], R. Lafaye [4], B. Laforge [78], T. Lagouri [80], S. Lai [48], E. Laisne [55], M. Lamanna [29], L. Lambourne [77], C.L. Lampen [6], W. Lampl [6], E. Lancon [136], U. Landgraf [48], M.P.J. Landon [75], J.L. Lane [82], C. Lange [41], A.J. Lankford [163], F. Lanni [24], K. Lantzsch [175], S. Laplace [78], C. Lapoire [20], J.F. Laporte [136], T. Lari [89a], A. Larner [118], M. Lassnig [29], P. Laurelli [47], V. Lavorini [36a,36b], W. Lavrijsen [14], P. Laycock [73], O. Le Dortz [78], E. Le Guirriec [83], C. Le Maner [158], E. Le Menedeu [11], T. LeCompte [5], F. Ledroit-Guillon [55], H. Lee [105], J.S.H. Lee [116], S.C. Lee [151], L. Lee [176], M. Lefebvre [169], M. Legendre [136], B.C. LeGeyt [120], F. Legger [98], C. Leggett [14], M. Lehmacher [20], G. Lehmann Miotto [29], X. Lei [6], M.A.L. Leite [23d], R. Leitner [126], D. Lellouch [172], B. Lemmer [54], V. Lendermann [58a], K.J.C. Leney [145b], T. Lenz [105], G. Lenzen [175], B. Lenzi [29], K. Leonhardt [43], S. Leontsinis [9], F. Lepold [58a], C. Leroy [93], J-R. Lessard [169], C.G. Lester [27], C.M. Lester [120], J. Levêque [4], D. Levin [87], L.J. Levinson [172], A. Lewis [118], G.H. Lewis [108], A.M. Leyko [20], M. Leyton [15], B. Li [83], H. Li [173,u], S. Li [32b,v], X. Li [87], Z. Liang [118,w], H. Liao [33], B. Liberti [133a], P. Lichard [29], M. Lichtnecker [98], K. Lie [165], W. Liebig [13], C. Limbach [20], A. Limosani [86], M. Limper [62], S.C. Lin [151,x], F. Linde [105], J.T. Linnemann [88], E. Lipeles [120], A. Lipniacka [13], T.M. Liss [165], D. Lissauer [24], A. Lister [49], A.M. Litke [137], C. Liu [28], D. Liu [151], H. Liu [87], J.B. Liu [87], M. Liu [32b], Y. Liu [32b], M. Livan [119a,119b], S.S.A. Livermore [118], A. Lleres [55], J. Llorente Merino [80], S.L. Lloyd [75], E. Lobodzinska [41], P. Loch [6], W.S. Lockman [137], T. Loddenkoetter [20], F.K. Loebinger [82], A. Loginov [176], C.W. Loh [168], T. Lohse [15], K. Lohwasser [48], M. Lokajicek [125], V.P. Lombardo [4], R.E. Long [71], L. Lopes [124a], D. Lopez Mateos [57], J. Lorenz [98], N. Lorenzo Martinez [115], M. Losada [162], P. Loscutoff [14], F. Lo Sterzo [132a,132b], M.J. Losty [159a], X. Lou [40], A. Lounis [115], K.F. Loureiro [162], J. Love [21], P.A. Love [71], A.J. Lowe [143,e], F. Lu [32a], H.J. Lubatti [138], C. Luci [132a,132b], A. Lucotte [55], A. Ludwig [43], D. Ludwig [41], I. Ludwig [48], J. Ludwig [48], F. Luehring [60], G. Luijckx [105], W. Lukas [61], D. Lumb [48], L. Luminari [132a], E. Lund [117], B. Lund-Jensen [147], B. Lundberg [79], J. Lundberg [146a,146b], J. Lundquist [35], M. Lungwitz [81], D. Lynn [24], J. Lys [14], E. Lytken [79], H. 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Poblaguev [24], S. Poddar [58a], F. Podlyski [33], L. Poggioli [115], T. Poghosyan [20], M. Pohl [49], F. Polci [55], G. Polesello [119a], A. Policicchio [36a,36b], A. Polini [19a], J. Poll [75], V. Polychronakos [24], D.M. Pomarede [136], D. Pomeroy [22], K. Pommès [29], L. Pontecorvo [132a], B.G. Pope [88], G.A. Popeneciu [25a], D.S. Popovic [12a], A. Poppleton [29], X. Portell Bueso [29], G.E. Pospelov [99], S. Pospisil [127], I.N. Potrap [99], C.J. Potter [149], C.T. Potter [114], G. Poulard [29], J. Poveda [173], V. Pozdnyakov [64], R. Prabhu [77], P. Pralavorio [83], A. Pranko [14], S. Prasad [29], R. Pravahan [24], S. Prell [63], K. Pretzl [16], D. Price [60], J. Price [73], L.E. Price [5], D. Prieur [123], M. Primavera [72a], K. Prokofiev [108], F. Prokoshin [31b], S. Protopopescu [24], J. Proudfoot [5], X. Prudent [43], M. Przybycien [37], H. Przysiezniak [4], S. Psoroulas [20], E. Ptacek [114], E. Pueschel [84], J. Purdham [87], M. Purohit [24,ac], P. Puzo [115], Y. 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Spigo [29], F. Spila [132a,132b], R. Spiwoks [29], M. Spousta [126], T. Spreitzer [158], B. Spurlock [7], R.D. St. Denis [53], J. Stahlman [120], R. Stamen [58a], E. Stanecka [38], R.W. Stanek [5], C. Stanescu [134a], M. Stanescu-Bellu [41], S. Stapnes [117], E.A. Starchenko [128], J. Stark [55], P. Staroba [125], P. Starovoitov [41], A. Staude [98], P. Stavina [144a], G. Steele [53], P. Steinbach [43], P. Steinberg [24], I. Stekl [127], B. Stelzer [142], H.J. Stelzer [88], O. Stelzer-Chilton [159a], H. Stenzel [52], S. Stern [99], G.A. Stewart [29], J.A. Stillings [20], M.C. Stockton [85], K. Stoerig [48], G. Stoicea [25a], S. Stonjek [99], P. Strachota [126], A.R. Stradling [7], A. Straessner [43], J. Strandberg [147], S. Strandberg [146a,146b], A. Strandlie [117], M. Strang [109], E. Strauss [143], M. Strauss [111], P. Strizenec [144b], R. Ströhmer [174], D.M. Strom [114], J.A. Strong [76,∗], R. Stroynowski [39], J. Strube [129], B. Stugu [13], I. Stumer [24,∗], J. Stupak [148], P. Sturm [175], N.A. Styles [41], D.A. Soh [151,w], D. Su [143], HS. Subramania [2], A. Succurro [11], Y. Sugaya [116], C. Suhr [106], K. Suita [66], M. Suk [126], V.V. Sulin [94], S. Sultansoy [3d], T. Sumida [67], X. Sun [55], J.E. Sundermann [48], K. Suruliz [139], G. Susinno [36a,36b], M.R. Sutton [149], Y. Suzuki [65], Y. Suzuki [66], M. Svatos [125], S. Swedish [168], I. Sykora [144a], T. Sykora [126], J. Sánchez [167], D. Ta [105], K. Tackmann [41], A. Taffard [163], R. Tafirout [159a], N. Taiblum [153], Y. Takahashi [101], H. Takai [24], R. Takashima [68], H. Takeda [66], T. Takeshita [140], Y. Takubo [65], M. Talby [83], A. Talyshev [107,f], M.C. Tamsett [24], J. Tanaka [155], R. Tanaka [115], S. Tanaka [131], S. Tanaka [65], A.J. Tanasijczuk [142], K. Tani [66], N. Tannoury [83], S. Tapprogge [81], D. Tardif [158], S. Tarem [152], F. Tarrade [28], G.F. Tartarelli [89a], P. Tas [126], M. Tasevsky [125], E. Tassi [36a,36b], M. Tatarkhanov [14], Y. Tayalati [135d], C. Taylor [77], F.E. Taylor [92], G.N. Taylor [86], W. Taylor [159b], M. Teinturier [115], M. Teixeira Dias Castanheira [75], P. Teixeira-Dias [76], K.K. Temming [48], H. Ten Kate [29], P.K. Teng [151], S. Terada [65], K. Terashi [155], J. Terron [80], M. Testa [47], R.J. Teuscher [158,k], J. Therhaag [20], T. Theveneaux-Pelzer [78], M. Thioye [176], S. Thoma [48], J.P. Thomas [17], E.N. Thompson [34], P.D. Thompson [17], P.D. Thompson [158], A.S. Thompson [53], L.A. Thomsen [35], E. Thomson [120], M. Thomson [27], R.P. Thun [87], F. Tian [34], M.J. Tibbetts [14], T. Tic [125], V.O. Tikhomirov [94], Y.A. Tikhonov [107,f], S. Timoshenko [96], P. Tipton [176], F.J. Tique Aires Viegas [29], S. Tisserant [83], T. Todorov [4], S. Todorova-Nova [161], B. Toggerson [163], J. Tojo [69], S. Tokár [144a], K. Tokunaga [66], K. Tokushuku [65], K. Tollefson [88], M. Tomoto [101], L. Tompkins [30], K. Toms [103], A. Tonoyan [13], C. Topfel [16], N.D. Topilin [64], I. Torchiani [29], E. Torrence [114], H. Torres [78], E. Torró Pastor [167], J. Toth [83,ad], F. Touchard [83], D.R. Tovey [139], T. Trefzger [174], L. Tremblet [29], A. Tricoli [29], I.M. Trigger [159a], S. Trincaz-Duvoid [78], M.F. Tripiana [70], W. Trischuk [158], B. Trocmé [55], C. Troncon [89a], M. Trottier-McDonald [142], M. Trzebinski [38], A. Trzupek [38], C. Tsarouchas [29], J.C-L. Tseng [118], M. Tsiakiris [105], P.V. Tsiareshka [90], D. Tsionou [4,ah], G. Tsipolitis [9], V. Tsiskaridze [48], E.G. Tskhadadze [51a], I.I. Tsukerman [95], V. Tsulaia [14], J.-W. Tsung [20], S. Tsuno [65], D. Tsybychev [148], A. Tua [139], A. Tudorache [25a], V. Tudorache [25a], J.M. Tuggle [30], M. Turala [38], D. Turecek [127], I. Turk Cakir [3e], E. Turlay [105], R. Turra [89a,89b], P.M. Tuts [34], A. Tykhonov [74], M. Tylmad [146a,146b], M. Tyndel [129], G. Tzanakos [8], K. Uchida [20], I. Ueda [155], R. Ueno [28], M. Ugland [13], M. Uhlenbrock [20], M. Uhrmacher [54], F. Ukegawa [160], G. Unal [29], A. Undrus [24], G. Unel [163], Y. Unno [65], D. Urbaniec [34], G. Usai [7], M. Uslenghi [119a,119b], L. Vacavant [83], V. Vacek [127], B. Vachon [85], S. Vahsen [14], J. Valenta [125], P. Valente [132a], S. Valentinetti [19a,19b], S. Valkar [126], E. Valladolid Gallego [167], S. Vallecorsa [152], J.A. Valls Ferrer [167], H. van der Graaf [105], E. van der Kraaij [105], R. Van Der Leeuw [105], E. van der Poel [105], D. van der Ster [29], N. van Eldik [29], P. van Gemmeren [5], I. van Vulpen [105], M. Vanadia [99], W. Vandelli [29], A. Vaniachine [5], P. Vankov [41], F. Vannucci [78], R. Vari [132a], T. Varol [84], D. Varouchas [14], A. Vartapetian [7], K.E. Varvell [150], V.I. Vassilakopoulos [56], F. Vazeille [33], T. Vazquez Schroeder [54], G. Vegni [89a,89b], J.J. Veillet [115], F. Veloso [124a], R. Veness [29], S. Veneziano [132a], A. Ventura [72a,72b], D. Ventura [84], M. Venturi [48], N. Venturi [158], V. Vercesi [119a], M. Verducci [138], W. Verkerke [105], J.C. Vermeulen [105], A. Vest [43], M.C. Vetterli [142,d], I. Vichou [165], T. Vickey [145b,ai], O.E. Vickey Boeriu [145b], G.H.A. Viehhauser [118], S. Viel [168], M. Villa [19a,19b], M. Villaplana Perez [167], E. Vilucchi [47], M.G. Vincter [28], E. Vinek [29], V.B. Vinogradov [64], M. Virchaux [136,∗], J. Virzi [14], O. Vitells [172], M. Viti [41], I. Vivarelli [48], F. Vives Vaque [2], S. Vlachos [9], D. Vladoiu [98], M. Vlasak [127], A. Vogel [20], P. Vokac [127], G. Volpi [47], M. Volpi [86], G. Volpini [89a], H. von der Schmitt [99], J. von Loeben [99], H. von Radziewski [48], E. von Toerne [20], V. Vorobel [126], V. Vorwerk [11], M. Vos [167], R. Voss [29], T.T. Voss [175], J.H. Vossebeld [73], N. Vranjes [136], M. Vranjes Milosavljevic [105], V. Vrba [125], M. Vreeswijk [105], T. Vu Anh [48], R. Vuillermet [29], I. Vukotic [115], W. Wagner [175], P. Wagner [120], H. Wahlen [175], S. Wahrmund [43], J. Wakabayashi [101], S. Walch [87], J. Walder [71], R. Walker [98], W. Walkowiak [141], R. Wall [176], P. Waller [73], C. Wang [44], H. Wang [173], H. Wang [32b,aj], J. Wang [151], J. Wang [55], R. Wang [103], S.M. Wang [151], T. Wang [20], A. Warburton [85], C.P. Ward [27], M. Warsinsky [48], A. Washbrook [45], C. Wasicki [41], P.M. Watkins [17], A.T. Watson [17], I.J. Watson [150], M.F. Watson [17], G. Watts [138], S. Watts [82], A.T. Waugh [150], B.M. Waugh [77], M. Weber [129], M.S. Weber [16], P. Weber [54], A.R. Weidberg [118], P. Weigell [99], J. Weingarten [54], C. Weiser [48], H. Wellenstein [22], P.S. Wells [29], T. Wenaus [24], D. Wendland [15], Z. Weng [151,w], T. Wengler [29], S. Wenig [29], N. Wermes [20], M. Werner [48], P. Werner [29], M. Werth [163], M. Wessels [58a], J. Wetter [161], C. Weydert [55], K. Whalen [28], S.J. Wheeler-Ellis [163], A. White [7], M.J. White [86], S. White [122a,122b], S.R. Whitehead [118], D. Whiteson [163], D. Whittington [60], F. Wicek [115], D. Wicke [175], F.J. Wickens [129], W. Wiedenmann [173], M. Wielers [129], P. Wienemann [20], C. Wiglesworth [75], L.A.M. Wiik-Fuchs [48], P.A. Wijeratne [77], A. Wildauer [167], M.A. Wildt [41,s], I. Wilhelm [126], H.G. Wilkens [29], J.Z. Will [98], E. Williams [34], H.H. Williams [120], W. Willis [34], S. Willocq [84], J.A. Wilson [17], M.G. Wilson [143], A. Wilson [87], I. Wingerter-Seez [4], S. Winkelmann [48], F. Winklmeier [29], M. Wittgen [143], M.W. Wolter [38], H. Wolters [124a,h], W.C. Wong [40], G. Wooden [87], B.K. Wosiek [38], J. Wotschack [29], M.J. Woudstra [82], K.W. Wozniak [38], K. Wraight [53], C. Wright [53], M. Wright [53], B. Wrona [73], S.L. Wu [173], X. Wu [49], Y. Wu [32b,ak], E. Wulf [34], B.M. Wynne [45], S. Xella [35], M. Xiao [136], S. Xie [48], C. Xu [32b,z], D. Xu [139], B. Yabsley [150], S. Yacoob [145b], M. Yamada [65], H. Yamaguchi [155], A. Yamamoto [65], K. Yamamoto [63], S. Yamamoto [155], T. Yamamura [155], T. Yamanaka [155], J. Yamaoka [44], T. Yamazaki [155], Y. Yamazaki [66], Z. Yan [21], H. Yang [87], U.K. Yang [82], Y. Yang [60], Z. Yang [146a,146b], S. Yanush [91], L. Yao [32a], Y. Yao [14], Y. Yasu [65], G.V. Ybeles Smit [130], J. Ye [39], S. Ye [24], M. Yilmaz [3c], R. Yoosoofmiya [123], K. Yorita [171], R. Yoshida [5], C. Young [143], C.J. Young [118], S. Youssef [21], D. Yu [24], J. Yu [7], J. Yu [112], L. Yuan [66], A. Yurkewicz [106], B. Zabinski [38], R. Zaidan [62], A.M. Zaitsev [128], Z. Zajacova [29], L. Zanello [132a,132b], A. Zaytsev [107], C. Zeitnitz [175], M. Zeman [125], A. Zemla [38], C. Zendler [20], O. Zenin [128], T. Ženiš [144a], Z. Zinonos [122a,122b], S. Zenz [14], D. Zerwas [115], G. Zevi della Porta [57], Z. Zhan [32d], D. Zhang [32b,aj], H. Zhang [88], J. Zhang [5], X. Zhang [32d], Z. Zhang [115], L. Zhao [108], T. Zhao [138], Z. Zhao [32b], A. Zhemchugov [64], J. Zhong [118], B. Zhou [87], N. Zhou [163], Y. Zhou [151], C.G. Zhu [32d], H. Zhu [41], J. Zhu [87], Y. Zhu [32b], X. Zhuang [98], V. Zhuravlov [99], D. Zieminska [60], R. Zimmermann [20], S. Zimmermann [20], S. Zimmermann [48], M. Ziolkowski [141], R. Zitoun [4], L. Živković [34], V.V. Zmouchko [128,∗], G. Zobernig [173], A. Zoccoli [19a,19b], M. zur Nedden [15], V. Zutshi [106], L. Zwalinski [29]

[1] *University at Albany, Albany NY, United States*
[2] *Department of Physics, University of Alberta, Edmonton AB, Canada*
[3] [(a)] *Department of Physics, Ankara University, Ankara;* [(b)] *Department of Physics, Dumlupinar University, Kutahya;* [(c)] *Department of Physics, Gazi University, Ankara;* [(d)] *Division of Physics, TOBB University of Economics and Technology, Ankara;* [(e)] *Turkish Atomic Energy Authority, Ankara, Turkey*
[4] *LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France*
[5] *High Energy Physics Division, Argonne National Laboratory, Argonne IL, United States*
[6] *Department of Physics, University of Arizona, Tucson AZ, United States*
[7] *Department of Physics, The University of Texas at Arlington, Arlington TX, United States*
[8] *Physics Department, University of Athens, Athens, Greece*
[9] *Physics Department, National Technical University of Athens, Zografou, Greece*
[10] *Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[11] *Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona and ICREA, Barcelona, Spain*
[12] [(a)] *Institute of Physics, University of Belgrade, Belgrade;* [(b)] *Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia*
[13] *Department for Physics and Technology, University of Bergen, Bergen, Norway*
[14] *Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley CA, United States*

[15] Department of Physics, Humboldt University, Berlin, Germany
[16] Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland
[17] School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom
[18] [(a)] Department of Physics, Bogazici University, Istanbul; [(b)] Division of Physics, Dogus University, Istanbul; [(c)] Department of Physics Engineering, Gaziantep University, Gaziantep; [(d)] Department of Physics, Istanbul Technical University, Istanbul, Turkey
[19] [(a)] INFN Sezione di Bologna; [(b)] Dipartimento di Fisica, Università di Bologna, Bologna, Italy
[20] Physikalisches Institut, University of Bonn, Bonn, Germany
[21] Department of Physics, Boston University, Boston MA, United States
[22] Department of Physics, Brandeis University, Waltham MA, United States
[23] [(a)] Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro; [(b)] Federal University of Juiz de Fora (UFJF), Juiz de Fora; [(c)] Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei; [(d)] Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil
[24] Physics Department, Brookhaven National Laboratory, Upton NY, United States
[25] [(a)] National Institute of Physics and Nuclear Engineering, Bucharest; [(b)] University Politehnica Bucharest, Bucharest; [(c)] West University in Timisoara, Timisoara, Romania
[26] Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina
[27] Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
[28] Department of Physics, Carleton University, Ottawa ON, Canada
[29] CERN, Geneva, Switzerland
[30] Enrico Fermi Institute, University of Chicago, Chicago IL, United States
[31] [(a)] Departamento de Fisica, Pontificia Universidad Católica de Chile, Santiago; [(b)] Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
[32] [(a)] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing; [(b)] Department of Modern Physics, University of Science and Technology of China, Anhui; [(c)] Department of Physics, Nanjing University, Jiangsu; [(d)] School of Physics, Shandong University, Shandong, China
[33] Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Aubiere Cedex, France
[34] Nevis Laboratory, Columbia University, Irvington NY, United States
[35] Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
[36] [(a)] INFN Gruppo Collegato di Cosenza; [(b)] Dipartimento di Fisica, Università della Calabria, Arcavata di Rende, Italy
[37] AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
[38] The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
[39] Physics Department, Southern Methodist University, Dallas TX, United States
[40] Physics Department, University of Texas at Dallas, Richardson TX, United States
[41] DESY, Hamburg and Zeuthen, Germany
[42] Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
[43] Institut für Kern- und Teilchenphysik, Technical University Dresden, Dresden, Germany
[44] Department of Physics, Duke University, Durham NC, United States
[45] SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[46] Fachhochschule Wiener Neustadt, Johannes Gutenbergstrasse 3 2700 Wiener Neustadt, Austria
[47] INFN Laboratori Nazionali di Frascati, Frascati, Italy
[48] Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg i.Br., Germany
[49] Section de Physique, Université de Genève, Geneva, Switzerland
[50] [(a)] INFN Sezione di Genova; [(b)] Dipartimento di Fisica, Università di Genova, Genova, Italy
[51] [(a)] E. Andronikashvili Institute of Physics, Tbilisi State University, Tbilisi; [(b)] High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
[52] II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[53] SUPA, School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[54] II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
[55] Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier and CNRS/IN2P3 and Institut National Polytechnique de Grenoble, Grenoble, France
[56] Department of Physics, Hampton University, Hampton VA, United States
[57] Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States
[58] [(a)] Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg; [(b)] Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg; [(c)] ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
[59] Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
[60] Department of Physics, Indiana University, Bloomington IN, United States
[61] Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
[62] University of Iowa, Iowa City IA, United States
[63] Department of Physics and Astronomy, Iowa State University, Ames IA, United States
[64] Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
[65] KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[66] Graduate School of Science, Kobe University, Kobe, Japan
[67] Faculty of Science, Kyoto University, Kyoto, Japan
[68] Kyoto University of Education, Kyoto, Japan
[69] Department of Physics, Kyushu University, Fukuoka, Japan
[70] Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
[71] Physics Department, Lancaster University, Lancaster, United Kingdom
[72] [(a)] INFN Sezione di Lecce; [(b)] Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
[73] Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
[74] Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
[75] School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
[76] Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
[77] Department of Physics and Astronomy, University College London, London, United Kingdom
[78] Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
[79] Fysiska institutionen, Lunds universitet, Lund, Sweden
[80] Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain
[81] Institut für Physik, Universität Mainz, Mainz, Germany
[82] School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[83] CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
[84] Department of Physics, University of Massachusetts, Amherst MA, United States
[85] Department of Physics, McGill University, Montreal QC, Canada
[86] School of Physics, University of Melbourne, Victoria, Australia
[87] Department of Physics, The University of Michigan, Ann Arbor MI, United States
[88] Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States
[89] [(a)] INFN Sezione di Milano; [(b)] Dipartimento di Fisica, Università di Milano, Milano, Italy

[90] B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus
[91] National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Belarus
[92] Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States
[93] Group of Particle Physics, University of Montreal, Montreal QC, Canada
[94] P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
[95] Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
[96] Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia
[97] Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
[98] Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
[99] Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
[100] Nagasaki Institute of Applied Science, Nagasaki, Japan
[101] Graduate School of Science, Nagoya University, Nagoya, Japan
[102] [(a)] INFN Sezione di Napoli; [(b)] Dipartimento di Scienze Fisiche, Università di Napoli, Napoli, Italy
[103] Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, United States
[104] Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
[105] Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
[106] Department of Physics, Northern Illinois University, DeKalb IL, United States
[107] Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
[108] Department of Physics, New York University, New York NY, United States
[109] Ohio State University, Columbus OH, United States
[110] Faculty of Science, Okayama University, Okayama, Japan
[111] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States
[112] Department of Physics, Oklahoma State University, Stillwater OK, United States
[113] Palacký University, RCPTM, Olomouc, Czech Republic
[114] Center for High Energy Physics, University of Oregon, Eugene OR, United States
[115] LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
[116] Graduate School of Science, Osaka University, Osaka, Japan
[117] Department of Physics, University of Oslo, Oslo, Norway
[118] Department of Physics, Oxford University, Oxford, United Kingdom
[119] [(a)] INFN Sezione di Pavia; [(b)] Dipartimento di Fisica, Università di Pavia, Pavia, Italy
[120] Department of Physics, University of Pennsylvania, Philadelphia PA, United States
[121] Petersburg Nuclear Physics Institute, Gatchina, Russia
[122] [(a)] INFN Sezione di Pisa; [(b)] Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
[123] Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, United States
[124] [(a)] Laboratorio de Instrumentacao e Fisica Experimental de Particulas, LIP, Lisboa, Portugal; [(b)] Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
[125] Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
[126] Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic
[127] Czech Technical University in Prague, Praha, Czech Republic
[128] State Research Center Institute for High Energy Physics, Protvino, Russia
[129] Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
[130] Physics Department, University of Regina, Regina SK, Canada
[131] Ritsumeikan University, Kusatsu, Shiga, Japan
[132] [(a)] INFN Sezione di Roma I; [(b)] Dipartimento di Fisica, Università La Sapienza, Roma, Italy
[133] [(a)] INFN Sezione di Roma Tor Vergata; [(b)] Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
[134] [(a)] INFN Sezione di Roma Tre; [(b)] Dipartimento di Fisica, Università Roma Tre, Roma, Italy
[135] [(a)] Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies, Université Hassan II, Casablanca; [(b)] Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat; [(c)] Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech; [(d)] Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; [(e)] Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco
[136] DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France
[137] Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, United States
[138] Department of Physics, University of Washington, Seattle WA, United States
[139] Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
[140] Department of Physics, Shinshu University, Nagano, Japan
[141] Fachbereich Physik, Universität Siegen, Siegen, Germany
[142] Department of Physics, Simon Fraser University, Burnaby BC, Canada
[143] SLAC National Accelerator Laboratory, Stanford CA, United States
[144] [(a)] Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; [(b)] Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
[145] [(a)] Department of Physics, University of Johannesburg, Johannesburg; [(b)] School of Physics, University of the Witwatersrand, Johannesburg, South Africa
[146] [(a)] Department of Physics, Stockholm University; [(b)] The Oskar Klein Centre, Stockholm, Sweden
[147] Physics Department, Royal Institute of Technology, Stockholm, Sweden
[148] Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, United States
[149] Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
[150] School of Physics, University of Sydney, Sydney, Australia
[151] Institute of Physics, Academia Sinica, Taipei, Taiwan
[152] Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
[153] Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
[154] Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[155] International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
[156] Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
[157] Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
[158] Department of Physics, University of Toronto, Toronto ON, Canada
[159] [(a)] TRIUMF, Vancouver BC; [(b)] Department of Physics and Astronomy, York University, Toronto ON, Canada
[160] Institute of Pure and Applied Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8571, Japan
[161] Science and Technology Center, Tufts University, Medford MA, United States
[162] Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
[163] Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States
[164] [(a)] INFN Gruppo Collegato di Udine; [(b)] ICTP, Trieste; [(c)] Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy

[165] Department of Physics, University of Illinois, Urbana IL, United States
[166] Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
[167] Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
[168] Department of Physics, University of British Columbia, Vancouver BC, Canada
[169] Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada
[170] Department of Physics, University of Warwick, Coventry, United Kingdom
[171] Waseda University, Tokyo, Japan
[172] Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
[173] Department of Physics, University of Wisconsin, Madison WI, United States
[174] Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
[175] Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
[176] Department of Physics, Yale University, New Haven CT, United States
[177] Yerevan Physics Institute, Yerevan, Armenia
[178] Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France

[a] Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas, LIP, Lisboa, Portugal.
[b] Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal.
[c] Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
[d] Also at TRIUMF, Vancouver BC, Canada.
[e] Also at Department of Physics, California State University, Fresno CA, United States.
[f] Also at Novosibirsk State University, Novosibirsk, Russia.
[g] Also at Fermilab, Batavia IL, United States.
[h] Also at Department of Physics, University of Coimbra, Coimbra, Portugal.
[i] Also at Department of Physics, UASLP, San Luis Potosi, Mexico.
[j] Also at Università di Napoli Parthenope, Napoli, Italy.
[k] Also at Institute of Particle Physics (IPP), Canada.
[l] Also at Department of Physics, Middle East Technical University, Ankara, Turkey.
[m] Also at Louisiana Tech University, Ruston LA, United States.
[n] Also at Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal.
[o] Also at Department of Physics and Astronomy, University College London, London, United Kingdom.
[p] Also at Group of Particle Physics, University of Montreal, Montreal QC, Canada.
[q] Also at Department of Physics, University of Cape Town, Cape Town, South Africa.
[r] Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[s] Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.
[t] Also at Manhattan College, New York NY, United States.
[u] Also at School of Physics, Shandong University, Shandong, China.
[v] Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[w] Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China.
[x] Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
[y] Also at Dipartimento di Fisica, Università La Sapienza, Roma, Italy.
[z] Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat a l'Energie Atomique), Gif-sur-Yvette, France.
[aa] Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[ab] Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal.
[ac] Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States.
[ad] Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
[ae] Also at California Institute of Technology, Pasadena CA, United States.
[af] Also at Institute of Physics, Jagiellonian University, Krakow, Poland.
[ag] Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France.
[ah] Also at Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom.
[ai] Also at Department of Physics, Oxford University, Oxford, United Kingdom.
[aj] Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[ak] Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States.
[*] Deceased.