



UvA-DARE (Digital Academic Repository)

Search for new phenomena in final states with large jet multiplicities and missing transverse momentum using $\sqrt{s} = 7$ TeV pp collisions with the ATLAS detector

Aad, G.; et al., [Unknown]; Bentvelsen, S.; Bobbink, G.J.; Bos, K.; Boterenbrood, H.; Colijn, A.P.; Daum, C.; de Jong, P.; de Nooij, L.; Doxiadis, A.D.; Ferrari, P.; Garitaonandia, H.; Geerts, D.A.A.; Gosselink, M.; Hartjes, F.; Igonkina, O.; Hesse, N.P.; Kayl, M.S.; Klous, S.; Kluit, P.; Koffeman, E.; Koutsman, A.; Lee, H.; Lenz, T.; Linde, F.; Luijckx, G.; Massaro, G.; Mechnich, J.; Mussche, I.; Ottersbach, J.P.; Reichold, A.; Rijpstra, M.; Ruckstuhl, N.; Snuverink, J.; Ta, D.; Tsiakiris, M.; Turlay, E.; van der Graaf, H.; van der Kraaij, E.; van der Leeuw, R.; van der Poel, E.; van Kesteren, Z.; van Vulpen, I.; Verkerke, W.; Vermeulen, J.C.; Vranjes Milosavljevic, M.; Vreeswijk, M.

DOI

[10.1007/JHEP11\(2011\)099](https://doi.org/10.1007/JHEP11(2011)099)

Publication date

2011

Document Version

Final published version

Published in

The Journal of High Energy Physics

[Link to publication](#)

Citation for published version (APA):

Aad, G., et al., U., Bentvelsen, S., Bobbink, G. J., Bos, K., Boterenbrood, H., Colijn, A. P., Daum, C., de Jong, P., de Nooij, L., Doxiadis, A. D., Ferrari, P., Garitaonandia, H., Geerts, D. A. A., Gosselink, M., Hartjes, F., Igonkina, O., Hesse, N. P., Kayl, M. S., ... Vreeswijk, M. (2011). Search for new phenomena in final states with large jet multiplicities and missing transverse momentum using $\sqrt{s} = 7$ TeV pp collisions with the ATLAS detector. *The Journal of High Energy Physics*, 2011(11), [99]. [https://doi.org/10.1007/JHEP11\(2011\)099](https://doi.org/10.1007/JHEP11(2011)099)

General rights

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Search for new phenomena in final states with large jet multiplicities and missing transverse momentum using $\sqrt{s} = 7$ TeV pp collisions with the ATLAS detector

The ATLAS Collaboration

ABSTRACT: Results are presented of a search for any particle(s) decaying to six or more jets in association with missing transverse momentum. The search is performed using 1.34 fb^{-1} of $\sqrt{s} = 7$ TeV proton-proton collisions recorded by the ATLAS detector during 2011. Data-driven techniques are used to determine the backgrounds in kinematic regions that require at least six, seven or eight jets, well beyond the multiplicities required in previous analyses. No evidence is found for physics beyond the Standard Model. The results are interpreted in the context of a supersymmetry model (MSUGRA/CMSSM) where they extend previous constraints.

KEYWORDS: Hadron-Hadron Scattering

Contents

1	Introduction	1
2	The ATLAS detector and data samples	2
3	Object reconstruction	2
4	Event selection	3
5	Backgrounds, simulation and normalisation	4
6	Systematic uncertainties	8
7	Results, interpretation and limits	9
8	Summary	11

1 Introduction

Many extensions of the Standard Model predict the existence of TeV-scale states that rapidly decay to a large number of strongly interacting particles in association with one or more stable, weakly interacting particles. If such states are kinematically accessible with the proton-proton collisions at the LHC [1], they will be characterised by events with many hadronic jets with unbalanced momenta in the plane perpendicular to the beams due to the unobserved weakly interacting particles.

The most sensitive direct searches [2–8] have been previously performed at the LHC by the ATLAS and CMS collaborations in selections requiring jets and missing transverse momentum ($E_{\text{T}}^{\text{miss}}$). These analyses required a varying number of jets from as few as one [4, 7, 8], to as many as ≥ 4 [5].

The delivery of a large ($> \text{fb}^{-1}$) integrated luminosity makes it possible to extend those searches to final states with at least six, seven or even eight jets. Selecting events with larger jet multiplicities provides increased sensitivity to models that predict many-body decays or sequential cascade decays to many strongly interacting particles. Such models include supersymmetric [9–17] (SUSY) models that have gluinos with masses near the TeV scale and relatively heavy squarks.

Standard Model predictions must be determined with particular care for large jet multiplicities. The background from multi-jet events, in which the momentum imbalance results from jet mismeasurement, is evaluated using entirely data-driven methods. Electroweak and top contributions are obtained from a mixture of control measurements, and

transfer factors calculated from sophisticated multi-leg Monte Carlo simulations [18–21]. A detailed description of the background determination can be found in section 5.

Events containing high transverse momentum (p_T) electrons or muons are vetoed in order to reduce backgrounds from (semi-leptonically) decaying top quarks or W bosons. Other complementary searches have been performed by the ATLAS collaboration in final states with E_T^{miss} and lower jet multiplicity requirements [2, 4, 5], in conjunction with b -jet tagging [3], hard electrons and/or muons [22–24] or photons [25].

While the results are presented in the context of MSUGRA/CMSSM [26–31], the analysis is sensitive to any new states that decay into large numbers of jets in association with weakly interacting particles which escape the detector unseen.

2 The ATLAS detector and data samples

The ATLAS experiment [32] is a multipurpose particle physics detector with a forward-backward symmetric cylindrical geometry and nearly 4π coverage in solid angle.¹ The layout of the detector is dominated by four superconducting magnet systems, which comprise a thin solenoid surrounding inner tracking detectors and a barrel and two end-cap toroids supporting a large muon tracker. The calorimeters are of particular importance to this analysis. In the pseudorapidity region $|\eta| < 3.2$, high-granularity liquid-argon (LAr) electromagnetic (EM) sampling calorimeters are used. An iron-scintillator tile calorimeter provides hadronic coverage for $|\eta| < 1.7$. The end-cap and forward regions, spanning $1.5 < |\eta| < 4.9$, are instrumented with LAr calorimetry for both EM and hadronic measurements.

The data sample used in this analysis was taken during the first half of 2011 with the LHC operating at a centre-of-mass energy of $\sqrt{s} = 7$ TeV. Application of beam, detector and data-quality requirements resulted in an integrated luminosity of $1.34 \pm 0.05 \text{ fb}^{-1}$. The analysis makes use of dedicated multi-jet triggers, the details of which changed during the data-taking period as a consequence of increasing LHC luminosity. In all cases the trigger efficiency was greater than 95% for events with either at least four jets with $p_T > 80$ GeV, or at least five jets with $p_T > 55$ GeV.

3 Object reconstruction

The definitions of jets, leptons (e and μ) and missing transverse momentum follow closely those of previous ATLAS searches [5, 24].

Jet candidates are reconstructed using the anti- k_t jet clustering algorithm [33, 34] with distance parameter 0.4. The inputs to this algorithm are clusters of calorimeter cells [35] seeded by those with energy significantly above the measured noise. Jet momenta are constructed by performing a four-vector sum over these topological clusters of calorimeter cells, treating each as an (E, \vec{p}) four-vector with zero mass. These jets are corrected for the

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

effects of calorimeter non-compensation and inhomogeneities by using p_T - and η -dependent calibration factors based on Monte Carlo (MC) simulations validated with extensive test-beam and collision-data studies [36]. Only jet candidates with $p_T > 20$ GeV and $|\eta| < 4.9$ are retained. During the data-taking period, a localized electronics failure in the LAr barrel calorimeter created an electronically dead region in the second and third calorimeter layers, approximately 1.4×0.2 in $\Delta\eta \times \Delta\phi$, in which on average 30% of incident jet energy is lost. The impact on reconstruction efficiency for $p_T > 20$ GeV jets is found to be negligible. Since the energy response for jets in the problematic region is underestimated due to this extra dead area, a correction factor is applied to the jet transverse momenta. Events are rejected if the correction applied to any jet candidate provides a contribution to E_T^{miss} that is greater than both 10 GeV and $0.1 E_T^{\text{miss}}$. When identification of jets containing heavy flavour quarks is required, either to make measurements in control regions or for cross checks, a tagging algorithm exploiting both impact parameter and secondary vertex information is used [37].

Electron candidates are required to have $p_T > 20$ GeV and $|\eta| < 2.47$, to pass the ‘medium’ electron shower shape and track selection criteria of ref. [38], and to be outside problematic regions of the calorimeter. Muon candidates are required to have $p_T > 10$ GeV and $|\eta| < 2.4$.²

The measurement of the missing transverse momentum two-vector \vec{P}_T^{miss} (and its magnitude E_T^{miss}) is then based on the transverse momenta of all electron and muon candidates, all jets which are not also electron candidates with $|\eta| < 4.5$, and all calorimeter clusters with $|\eta| < 4.5$ not associated to such objects.

Following the steps above, overlaps between candidate jets with $|\eta| < 2.8$ and leptons are resolved as follows. First, any such jet candidate lying within a distance $\Delta R < 0.2$ of an electron is discarded, where $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$. Then any lepton candidate remaining within a distance $\Delta R = 0.4$ of such a jet candidate is discarded. Thereafter, all jet candidates with $|\eta| > 2.8$ are discarded, and the remaining electron, muon and jet candidates are retained as reconstructed objects.

4 Event selection

Following the object reconstruction described in section 3, events are discarded if any electrons or muons remain, or if they contain any jet failing quality selection criteria designed to suppress detector noise and non-collision backgrounds [39], or if they lack a reconstructed primary vertex with five or more associated tracks.

Four different signal regions (SRs) are defined as shown in table 1. The use of multiple signal regions provides sensitivity in different areas of the MSUGRA/CMSSM plane. Furthermore, the complementarity of the selections may be enhanced in new models not

²When defining control regions that require the presence of one or more leptons, additional requirements are applied. Electrons must pass the ‘tight’ selection criteria of ref. [38], and the sum Σ of the transverse momentum of tracks within a cone of $\Delta R = 0.2$ around the electron must satisfy $\Sigma/p_T(e) < 0.1$. Muons must have longitudinal and transverse impact parameters within 1 mm and 0.2 mm of the primary vertex, respectively, and must have $\Sigma < 1.8$ GeV.

Signal region	7j55	8j55	6j80	7j80
Jet p_T	$> 55 \text{ GeV}$		$> 80 \text{ GeV}$	
Jet $ \eta $	< 2.8			
ΔR_{jj}	> 0.6 for any pair of jets			
Number of jets	≥ 7	≥ 8	≥ 6	≥ 7
$E_T^{\text{miss}}/\sqrt{H_T}$	$> 3.5 \text{ GeV}^{1/2}$			

Table 1. Definitions of the four signal regions.

explicitly considered here. The combinations of jet multiplicities and p_T thresholds are chosen such that all four SRs have trigger efficiencies in excess of 95% and acceptances greater than 2% - 3% for kinematically accessible MSUGRA/CMSSM models. Differences caused by jet merging and splitting between the offline and online selections can lead to trigger inefficiencies. A separation of $\Delta R_{jj} > 0.6$ between all jets with p_T above the threshold for the SR is required to maintain acceptable trigger efficiency.

The final selection variable is $E_T^{\text{miss}}/\sqrt{H_T}$, the ratio of magnitude of the missing transverse momentum to the square root of the scalar sum H_T of transverse momenta of all jets with $p_T > 40 \text{ GeV}$ and $|\eta| < 2.8$. This ratio provides a measure of the size of the missing transverse momentum relative to the resolution due to stochastic variations in the measured jet energies.

5 Backgrounds, simulation and normalisation

Standard Model processes contribute to the event counts in the signal regions. The dominant backgrounds are multi-jet production, including those from purely strong interaction processes and fully hadronic decays of $t\bar{t}$; semi- and fully-leptonic decays of $t\bar{t}$; and leptonically-decaying W or Z bosons produced in association with jets. Non-fully-hadronic top, and W and Z are collectively referred to as ‘leptonic’ backgrounds, and can contribute to the signal regions when no e or μ leptons are produced (for example $Z \rightarrow \nu\nu$ or hadronic $W \rightarrow \tau\nu$ decays) or when they are produced but out of acceptance or not reconstructed. Contributions from the hadronic decays of W and Z bosons are negligible.

The selection cuts were chosen such that the background from the multi-jet processes can be determined from supporting measurements. In events dominated by jet activity, the ATLAS E_T^{miss} resolution is approximately proportional to $\sqrt{H_T}$. The ratio $E_T^{\text{miss}}/\sqrt{H_T}$ is therefore almost invariant under changes in the jet multiplicity N_{jet} , as will be shown later.

The shape of the $E_T^{\text{miss}}/\sqrt{H_T}$ distribution for the multi-jet background is therefore determined from data using control regions CR with smaller jet multiplicities than the SRs. The control regions are assumed to be dominated by Standard Model processes, an assumption that is corroborated by the agreement of multi-jet cross section measurements with up to six jets [40] with Standard Model predictions. The signal ‘contamination’ contributes less than 1% to the higher multiplicity CRs for relevant, unexcluded MSUGRA/CMSSM points. The basic shape of the $E_T^{\text{miss}}/\sqrt{H_T}$ distribution is encapsulated in transfer factors

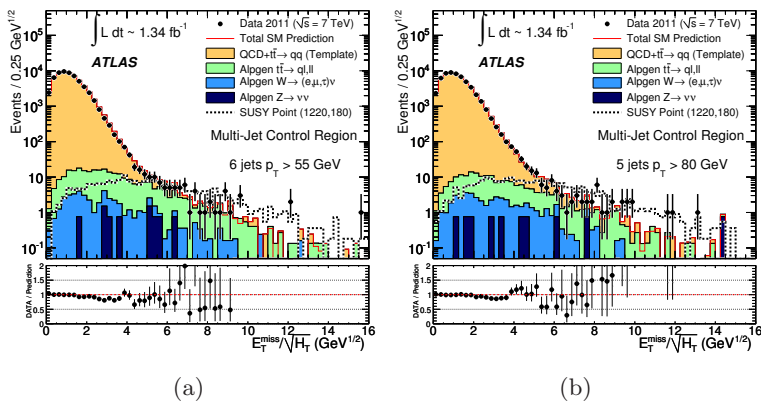


Figure 1. The distribution of the variable $E_T^{\text{miss}}/\sqrt{H_T}$ for control regions requiring (a) exactly six jets with $p_T > 55$ GeV or (b) exactly five jets with $p_T > 80$ GeV. Overlaid are templates taken from selections requiring (a) exactly five jets with $p_T > 55$ GeV or (b) exactly four jets with $p_T > 80$ GeV. These templates are normalised to the data in the region with $E_T^{\text{miss}}/\sqrt{H_T} < 1.5$. The background estimation includes the ALPGEN Monte-Carlo prediction for the ‘leptonic’ Standard Model backgrounds. For illustrative purposes the plots also contain the distribution expected for an example MSUGRA/CMSSM point with $m_0 = 1220$ GeV and $m_{1/2} = 180$ GeV. In all ratio plots (lower), in regions with very low numbers of events, some points may lie off the shown range and for bins with no observed events no ratio is shown. For $t\bar{t}$ backgrounds the labels ‘qq’ and ‘ql,ll’ represent fully hadronic and non-fully-hadronic decays respectively.

$T_{j,p}$, defined to be the ratio of the number of events in the control region, $\text{CR}_{j,p}^+$, with a certain number, j , of jets above a p_T threshold p and $E_T^{\text{miss}}/\sqrt{H_T} > 3.5\text{GeV}^{1/2}$ to the number in the control region, $\text{CR}_{j,p}^-$, with the same j, p and $E_T^{\text{miss}}/\sqrt{H_T} < 1.5\text{GeV}^{1/2}$. The $T_{j,p}$ are calculated after subtracting the predicted contributions of the ‘leptonic’ backgrounds from the measured counts. The signal region prediction is found by applying a $T_{j,p}$, with the same p as the signal region and $j = 5$ when $p = 55$ GeV and $j = 4$ when $p = 80$ GeV, to the number of events (after subtracting the expected contribution from ‘leptonic’ background sources) satisfying signal region multiplicity requirements but with $E_T^{\text{miss}}/\sqrt{H_T} < 1.5\text{GeV}^{1/2}$.

The validity of the assumption of $E_T^{\text{miss}}/\sqrt{H_T}$ invariance has been tested with data, using a series of additional CRs with either smaller jet multiplicities than the SRs, or at smaller values of $E_T^{\text{miss}}/\sqrt{H_T}$ (between $1.5\text{GeV}^{1/2}$ and $3.0\text{GeV}^{1/2}$) or both. Templates are formed from data selections with lower values of N_{jet} and correcting for ‘leptonic’ contamination. After scaling by the appropriate normalisation the shapes of the $E_T^{\text{miss}}/\sqrt{H_T}$ distributions in these CRs are found to be well described by these templates (see figures 1 and 2 for examples). The numbers of events in each of six different CRs are found to be correctly predicted to within $\sim 10\% - 20\%$. The residual differences are included in the systematic uncertainty associated with the method.

The backgrounds from multi-jet processes are cross checked using another data-driven technique [2, 5] which smears the energies of individual jets from low- E_T^{miss} multi-jet ‘seed’ events in data. Separate smearing functions are defined for b -tagged and non- b -tagged

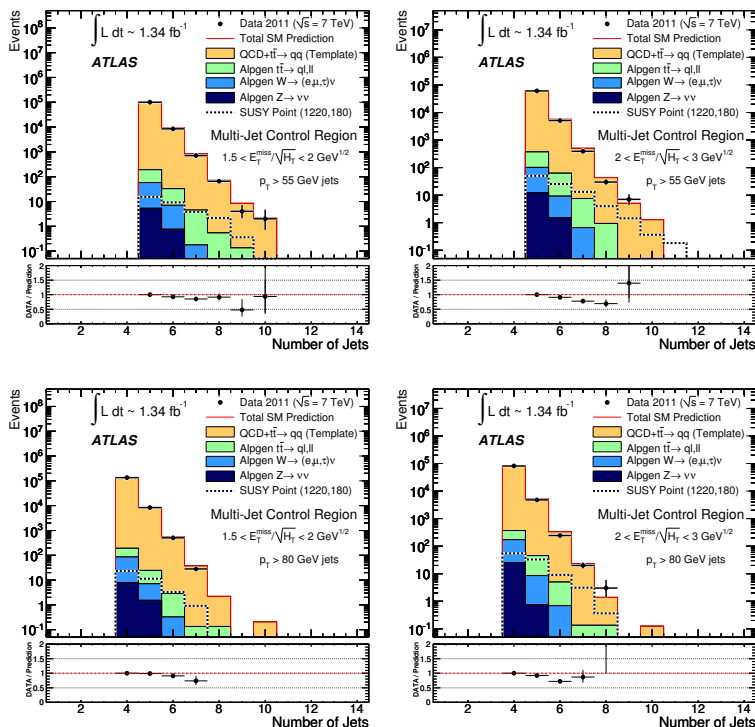


Figure 2. Observed and predicted jet multiplicity distributions for jets with $p_T > 55$ GeV (upper) and with $p_T > 80$ GeV (lower) in four example control regions defined by $1.5 \text{ GeV}^{1/2} < E_T^{\text{miss}}/\sqrt{H_T} < 2 \text{ GeV}^{1/2}$ (left) and $2 \text{ GeV}^{1/2} < E_T^{\text{miss}}/\sqrt{H_T} < 3 \text{ GeV}^{1/2}$ (right). Overlaid are templates taken from selections requiring $E_T^{\text{miss}}/\sqrt{H_T} < 1.5 \text{ GeV}^{1/2}$ which are normalised to the data in the lowest jet multiplicity bin shown. The background estimation includes the ALPGEN Monte-Carlo prediction for the ‘leptonic’ Standard Model backgrounds. For illustrative purposes the plots also contain the distribution expected for an example MSUGRA/CMSSM point with $m_0 = 1220$ GeV and $m_{1/2} = 180$ GeV.

jets, with each modelling both the Gaussian core and the non-Gaussian tail of the jet response. The functions are based on simulations and are verified with data in three-jet control regions in which the \vec{P}_T^{miss} can be associated with the fluctuation of a particular jet. The agreement between the two methods is satisfactory within uncertainties, and so the prediction used in what follows is that based on $E_T^{\text{miss}}/\sqrt{H_T}$ shape invariance.

Monte Carlo simulations are used to determine the transfer factors used to estimate the ‘leptonic’ Standard Model backgrounds, and to assess sensitivity to specific SUSY signal models. When used for ‘leptonic’ background estimation, the resulting transfer factors connect CRs and SRs with similar selection requirements. Theoretical uncertainties, including those arising from the use of Leading Order (LO) generators, are therefore reduced. All Monte Carlo samples employ a GEANT4 [41] based detector simulation [42], and are reconstructed with the same algorithms as the data. The simulations include the effects of multiple proton-proton interactions per bunch crossing.

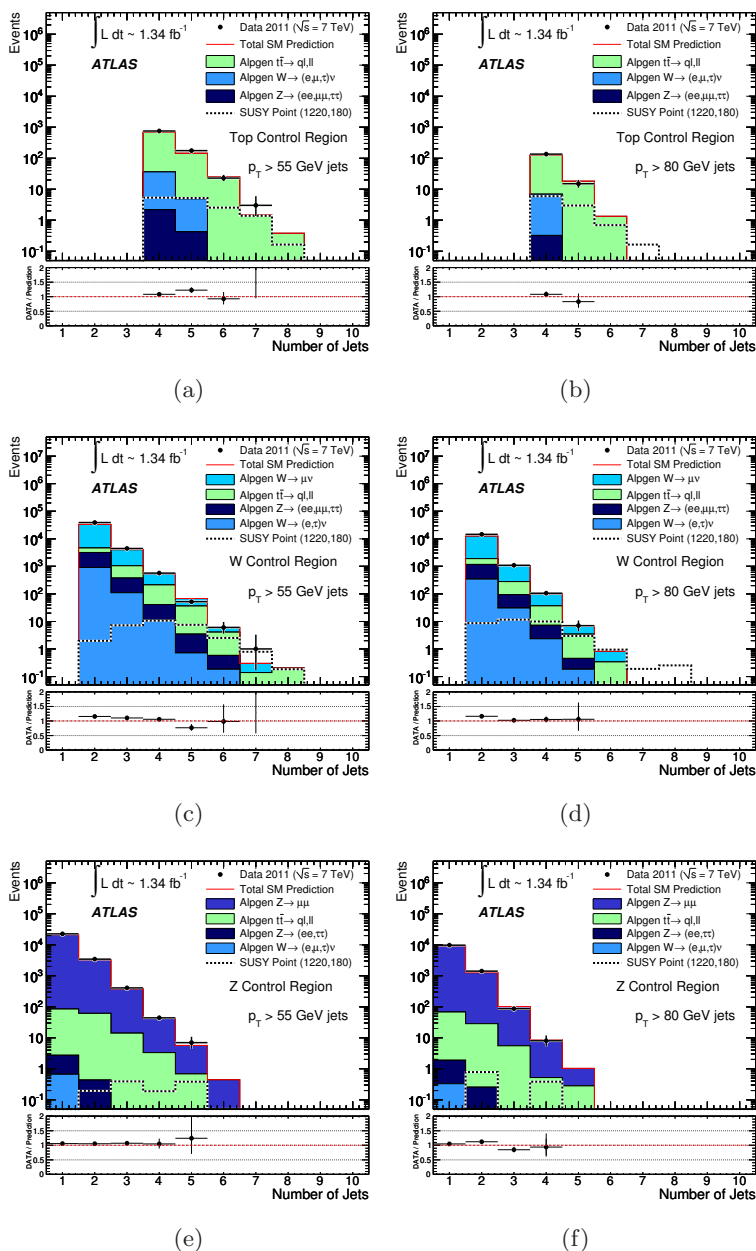


Figure 3. The multiplicity of jets with $p_T > 55$ GeV (left) or $p_T > 80$ GeV (right) for events in various control regions. Top row: top-quark enhanced control regions requiring at least one b -tagged jet, a single isolated muon with $p_T > 20$ GeV and $|\eta| < 2.4$ and $40 < m_T < 100$ GeV. Middle row: W -boson enhanced region (as for top, but with b -jet veto). Bottom row: $Z \rightarrow \mu\mu$ enhanced region.

To estimate the contribution from ‘leptonic’ $t\bar{t}$ events, control regions are defined with exactly one $p_T > 20$ GeV muon, transverse mass³ in the range $40 \text{ GeV} < m_T(\mu, \vec{P}_T^{\text{miss}}) < 100 \text{ GeV}$, and at least one b -tagged jet. The jet multiplicity distributions for this initial

³The transverse mass is defined by $m_T^2(a, b) = m_a^2 + m_b^2 + 2(E_T^{(a)} E_T^{(b)} - \vec{p}_T^{(a)} \cdot \vec{p}_T^{(b)})$, where $E_T^2 = p_T^2 + m^2$. The massless representation is used for \vec{P}_T^{miss} .

control selection are shown in figures 3(a) and 3(b). The control regions, $CR_{j,p}^{t\bar{t}}$, are then formed by including the leptons in the jet multiplicity, j , and requiring $E_T^{\text{miss}}/\sqrt{H_T} > 3.5 \text{ GeV}^{1/2}$. The contribution in each SR is calculated from the corresponding $CR_{j,p}^{t\bar{t}}$ (with the same j, p) in each case using a transfer factor evaluated using ALPGEN [18] v2.13 $t\bar{t}$ Monte Carlo, the PDF set CTEQ6L1 [43] and up to three (and as a cross check, up to five) additional outgoing partons in the matrix elements. Parton showering, fragmentation and hadronization for all ALPGEN samples is performed with HERWIG [44, 45], while JIMMY [46] is used to simulate the underlying event.

The vector boson processes $Z \rightarrow \nu\nu$ and $W \rightarrow \ell\nu$ provide small contributions to the signal regions when produced in association with jets. The $W \rightarrow \ell\nu + \text{jets}$ background is evaluated using an ALPGEN-based simulation with up to five additional partons in the matrix elements. Control regions are defined with selections similar to the $CR_{j,p}^{t\bar{t}}$ but with a b -jet veto to reduce contamination from $t\bar{t}$. The jet multiplicity distributions for the W -enhanced selection can be found in figures 3(c) and 3(d).

The $Z \rightarrow \nu\nu + \text{jets}$ background is calculated using an ALPGEN-based simulation with up to five additional partons in the matrix elements. There are sufficient $Z \rightarrow \mu^+ \mu^-$ events in data to verify the Monte Carlo predictions for multiplicities in the range $1 \leq N_{\text{jet}} \leq 5$ (figures 3(e) and 3(f)). The ratio of cross sections $R_n \equiv \frac{\sigma(V+(n+1)\text{jets})}{\sigma(V+n\text{jets})}$ is found, both in simulations and in data, to be nearly constant.⁴ The values of R_n for $N_{\text{jet}} \in \{5, 6, 7\}$ have been cross checked against SHERPA [19–21] with COMIX [53] and agreement found at the 20% level.

Backgrounds from other sources such as single top or diboson production, which have been evaluated using Monte Carlo simulations, and those from non-collision sources are found to be negligible.

MSUGRA/CMSSM particle spectra and decay modes are calculated with ISAJET [54] v7.75. Samples are generated with HERWIG++ [55] v2.4.2. The cross sections are normalised using the next-to-leading-order predictions of PROSPINO [56] v2.1.

6 Systematic uncertainties

Systematic uncertainties arise through the imperfect modelling of the multi-jet $E_T^{\text{miss}}/\sqrt{H_T}$ distribution, the use of MC-derived transfer factors relating observations in the control regions to ‘leptonic’ background expectations in the signal regions, and from the calculation of the SUSY signal.

For the multi-jet contribution, systematic uncertainties are determined to account for the residual dependence of the $E_T^{\text{miss}}/\sqrt{H_T}$ distribution on N_{jet} (as described in section 5), the fraction of jets containing b quarks and the response in problematic areas of the calorimeter. A special study performed to quantify the effect of the dead area of the calorimeter found that after applying the correction-based veto described in section 3 the uncertainty is less than 5%.

Jets containing heavy flavour (b and c) quarks can include neutrinos and hence have broader resolution functions. The size of the systematic uncertainty resulting from heavy

⁴See also ref. [47–52].

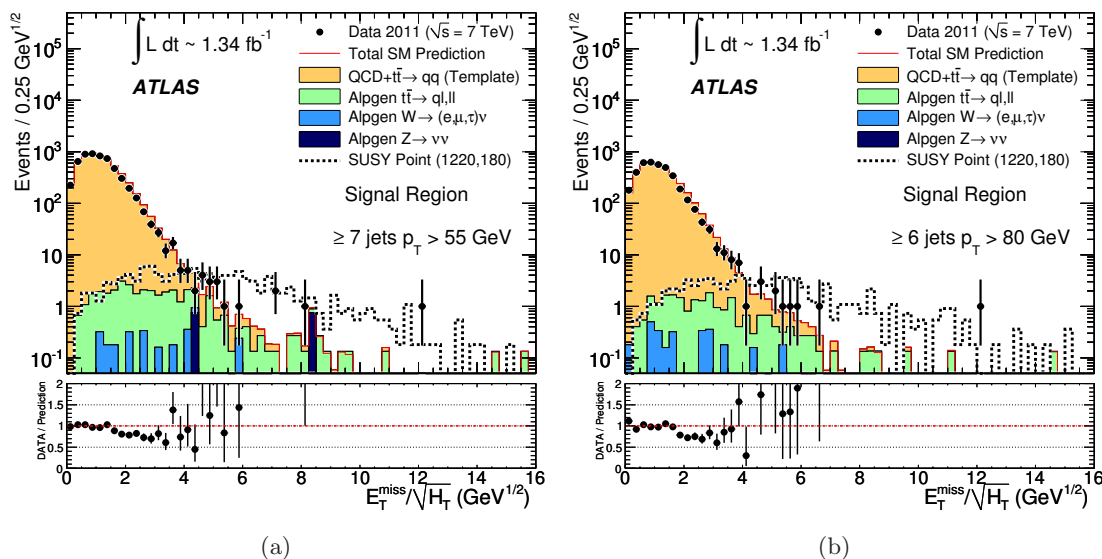


Figure 4. The distribution of the variable $E_T^{\text{miss}}/\sqrt{H_T}$ for events with (a) seven or more jets with $p_T > 55$ GeV or (b) six or more jets with $p_T > 80$ GeV. Overlaid are the hadronic background templates plus the ALPGEN Monte-Carlo prediction for the ‘leptonic’ Standard Model backgrounds. For illustrative purposes the plots also contain the distribution expected for an example MSUGRA/CMSSM point with $m_0 = 1220$ GeV and $m_{1/2} = 180$ GeV.

flavour (b -jet) contributions, including those from fully-hadronic $t\bar{t}$, is determined as follows. Separate values of T are calculated for events with at least one b jet and for non- b -tagged sub-samples, and their individual contributions to the SRs are determined. The differences with respect to the flavour-blind determination actually used are 8% – 15% depending on SR, and are included as a systematic uncertainty.

The transfer factors calculated for the ‘leptonic’ backgrounds have systematic uncertainties due to the finite number of Monte Carlo events generated, the jet energy scale, the jet energy resolution, the lepton identification efficiency, the b -tag efficiency, and the effect of multiple proton-proton interactions per bunch crossing.

Theoretical uncertainties on the SUSY signal were estimated from variation of the factorisation and renormalisation scales in PROSPINO between half and twice the mean outgoing sparticle mass and by considering the PDF uncertainties provided by CTEQ6.6 [57]. Uncertainties were calculated for individual production processes (e.g. $q\bar{q}$, $\tilde{g}\tilde{g}$, etc.) and are typically 30% – 40% for models in the vicinity of the limits expected to be set by this analysis. For the signal samples, the combined experimental systematic uncertainties from jet energy scale, resolution, and cleaning are typically 15% – 20%. The 3.7% luminosity uncertainty [58, 59] is included but is negligible.

7 Results, interpretation and limits

The measured $E_T^{\text{miss}}/\sqrt{H_T}$ distributions for two of the signal regions are shown in figure 4 prior to the final $E_T^{\text{miss}}/\sqrt{H_T} > 3.5$ GeV $^{1/2}$ requirement. The number of observed events

Signal region	7j55	8j55	6j80	7j80
Multi-jets	26 ± 5.2	2.3 ± 0.7	19 ± 4	1.3 ± 0.4
$t\bar{t} \rightarrow q\ell, \ell\ell$	10.8 ± 6.7	$0^{+4.3}$	6.0 ± 4.6	$0^{+0.13}$
W + jets	0.95 ± 0.45	$0^{+0.13}$	0.34 ± 0.24	$0^{+0.13}$
Z + jets	$1.5^{+1.8}_{-1.5}$	$0^{+0.75}$	$0^{+0.75}$	$0^{+0.75}$
Total Standard Model	39 ± 9	$2.3^{+4.4}_{-0.7}$	26 ± 6	$1.3^{+0.9}_{-0.4}$
Data	45	4	26	3
$N_{\text{BSM,max}}^{95\%}$	26.0	11.2	16.3	6.0
$\sigma_{\text{BSM,max}}^{95\%} \times \epsilon / \text{fb}$	19.4	8.4	12.2	4.5
p_{SM}	0.30	0.36	0.49	0.16

Table 2. Results for each of the four signal regions for 1.34 fb^{-1} . The expected number of Standard Model events are given for each of the following sources: multi-jet (including fully hadronic $t\bar{t}$), semi- and fully-leptonic top combined, and W and Z bosons (separately) in association with jets, as well as the total Standard Model expectation. Where small event counts in control regions have not made it possible to determine a central value for the expectation, an asymmetric bound is given instead. The number of observed events is also shown. The final three rows show the statistical quantities described in the text.

for each of the signal regions is shown in table 2. The Standard Model expectations are also shown, together with their combined statistical and systematic uncertainties. The data are found to be in good agreement with the background model and no excess is observed. table 2 shows the 95% confidence level upper bound $N_{\text{BSM,max}}^{95\%}$ on the number of events originating from sources other than the Standard Model, the corresponding upper limit $\sigma_{\text{BSM,max}}^{95\%} \times \epsilon$ on the cross section times efficiency within acceptance (which equals the limit on the observed number of signal events divided by the luminosity) and the p -value for the Standard Model-only hypothesis (p_{SM}).

An interpretation of these results is presented in figure 5 as a 95% confidence level exclusion region in the $\tan\beta = 10$, $A_0 = 0$, $\mu > 0$ slice of MSUGRA/CMSSM.⁵ Data from the four SRs are used to set the limits, taking the SR with the best expected limit at each point in parameter space. The limit for each SR is obtained by comparing the observed event count with that expected from Standard Model background plus SUSY signal processes, taking into account uncertainties in the expectation including those which are correlated between signal and background (for instance jet energy scale uncertainties). The exclusion regions are obtained using the CL_s prescription [60]. Acceptance times efficiency values are tabulated for typical points elsewhere [61].

⁵A particular MSUGRA/CMSSM model point is specified by five parameters: the universal scalar mass m_0 , the universal gaugino mass $m_{1/2}$, the universal trilinear scalar coupling A_0 , the ratio of the vacuum expectation values of the two Higgs fields $\tan\beta$, and the sign of the higgsino mass parameter μ .

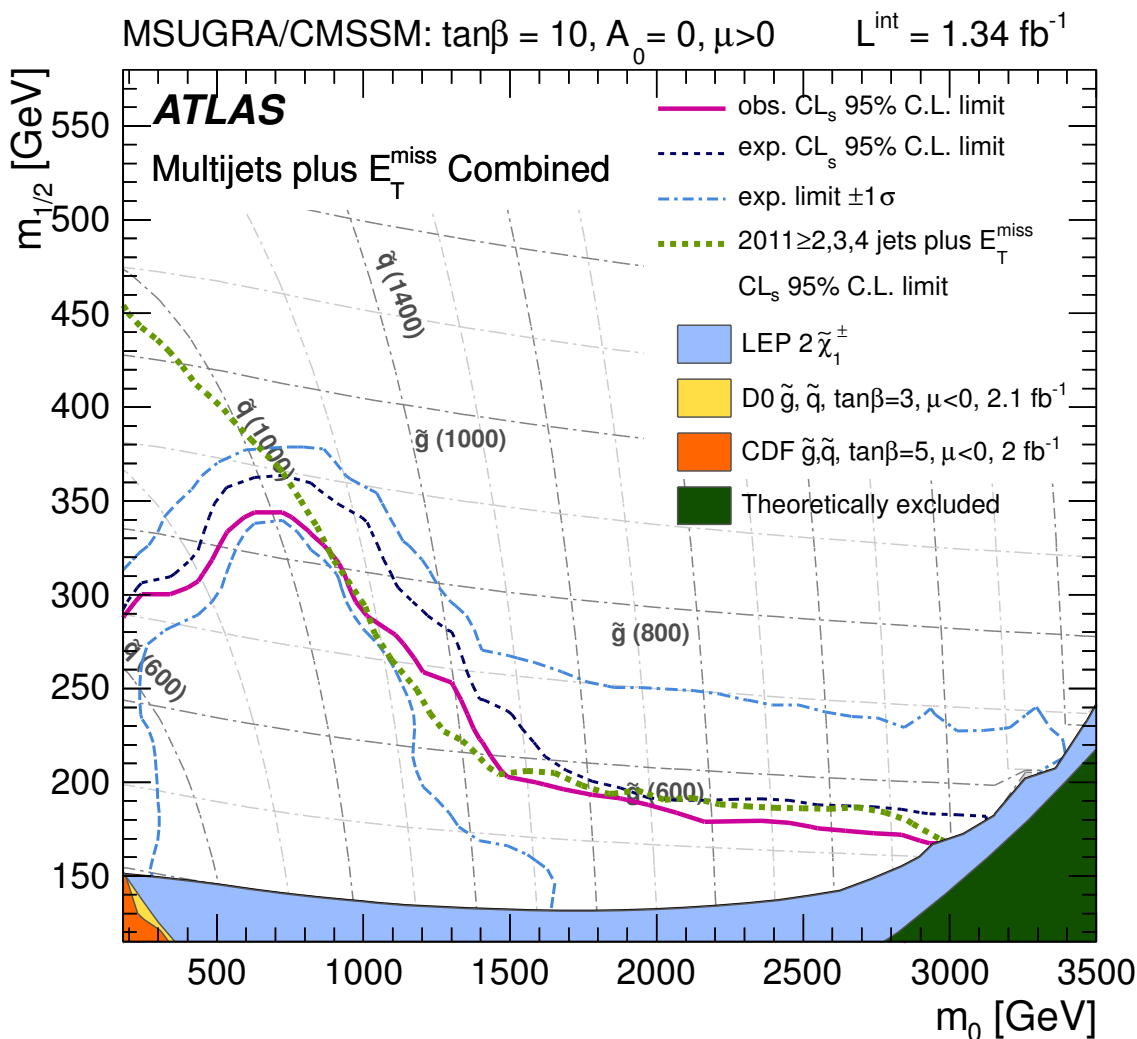


Figure 5. Combined exclusion bounds in the $\tan\beta = 10, A_0 = 0, \mu > 0$ slice of the MSUGRA/CMSSM space. Gluinos with masses below 520 GeV, and gluinos with masses below 680 GeV under the assumption that $m_{\text{squark}} = 2 \times m_{\text{gluino}}$ are excluded at the 95% confidence level. Limits from individual SRs can be found elsewhere [61]. Recent limits from ATLAS [5], as well as previous limits from D0 and CDF [62–65] and LEP [66, 67] are also shown.

8 Summary

A search for new phenomena has been performed using events containing missing transverse momentum and much larger jet multiplicities than have been previously considered, up to eight or more jets. The dominant Standard Model background contributions have been determined from the data themselves. The sub-dominant ‘leptonic’ backgrounds are measured using multiple control regions together with Monte Carlo transfer factors.

No evidence for physics beyond the Standard Model has been observed in a data sample from early 2011 corresponding to an integrated luminosity of 1.34 fb^{-1} . Limits are set on MSUGRA/CMSSM models excluding at the 95% confidence level gluinos with masses below 520 GeV, and gluinos with masses below 680 GeV under the assumption that $m_{\text{squark}} = 2 \times m_{\text{gluino}}$. This result extends those set by previous ATLAS analyses.

Acknowledgments

We wish to thank CERN for the efficient commissioning and operation of the LHC during this data-taking period as well as the support staff from our institutions without whom ATLAS could not be operated efficiently.

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; ARTEMIS, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNAS, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America.

The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

Open Access. This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.

References

- [1] L. Evans and P. Bryant, *LHC machine*, 2008 *JINST* **3** S08001 [[INSPIRE](#)].
- [2] ATLAS COLLABORATION, *Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions*, *Phys. Lett. B* **701** (2011) 186 [[arXiv:1102.5290](#)] [[INSPIRE](#)].
- [3] ATLAS COLLABORATION, *Search for supersymmetry in pp collisions at $\sqrt{s} = 7$ TeV in final states with missing transverse momentum and b-jets*, *Phys. Lett. B* **701** (2011) 398 [[arXiv:1103.4344](#)] [[INSPIRE](#)].

- [4] ATLAS COLLABORATION, *Search for new phenomena with the monojet and missing transverse momentum signature using the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions*, *Phys. Lett. B* **705** (2011) 294 [[arXiv:1106.5327](#)] [[INSPIRE](#)].
- [5] ATLAS COLLABORATION, *Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions*, [arXiv:1109.6572](#) [Submitted to *Phys. Lett. B*] [[INSPIRE](#)].
- [6] CMS COLLABORATION, *Search for new physics with jets and missing transverse momentum in pp collisions at $\sqrt{s} = 7$ TeV*, [arXiv:1106.4503](#) [[INSPIRE](#)].
- [7] CMS COLLABORATION, *Inclusive search for squarks and gluinos in pp collisions at $\sqrt{s} = 7$ TeV*, [arXiv:1107.1279](#) [[INSPIRE](#)].
- [8] CMS COLLABORATION, *Search for new physics with a mono-jet and missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV*, [arXiv:1106.4775](#) [[INSPIRE](#)].
- [9] Y. Golfand and E. Likhtman, *Extension of the algebra of Poincaré group generators and violation of p invariance*, *JETP Lett.* **13** (1971) 323 [http://www.jetpletters.ac.ru/ps/1584/article_24309.shtml] [[INSPIRE](#)].
- [10] A. Neveu and J. Schwarz, *Factorizable dual model of pions*, *Nucl. Phys. B* **31** (1971) 86 [[INSPIRE](#)].
- [11] A. Neveu and J. Schwarz, *Quark model of dual pions*, *Phys. Rev. D* **4** (1971) 1109 [[INSPIRE](#)].
- [12] P. Ramond, *Dual theory for free fermions*, *Phys. Rev. D* **3** (1971) 2415 [[INSPIRE](#)].
- [13] D. Volkov and V. Akulov, *Is the neutrino a Goldstone particle?*, *Phys. Lett. B* **46** (1973) 109 [[INSPIRE](#)].
- [14] J. Wess and B. Zumino, *A Lagrangian model invariant under supergauge transformations*, *Phys. Lett. B* **49** (1974) 52 [[INSPIRE](#)].
- [15] J. Wess and B. Zumino, *Supergauge transformations in four-dimensions*, *Nucl. Phys. B* **70** (1974) 39 [[INSPIRE](#)].
- [16] P. Fayet, *Spontaneously broken supersymmetric theories of weak, electromagnetic and strong interactions*, *Phys. Lett. B* **69** (1977) 489 [[INSPIRE](#)].
- [17] G.R. Farrar and P. Fayet, *Phenomenology of the production, decay and detection of new hadronic states associated with supersymmetry*, *Phys. Lett. B* **76** (1978) 575 [[INSPIRE](#)].
- [18] M.L. Mangano, M. Moretti, F. Piccinini, R. Pittau and A.D. Polosa, *ALPGEN, a generator for hard multiparton processes in hadronic collisions*, *JHEP* **07** (2003) 001 [[hep-ph/0206293](#)] [[INSPIRE](#)].
- [19] T. Gleisberg, S. Hoeche, F. Krauss, M. Schonherr, S. Schumann, et al., *Event generation with SHERPA 1.1*, *JHEP* **02** (2009) 007 [[arXiv:0811.4622](#)] [[INSPIRE](#)].
- [20] S. Schumann and F. Krauss, *A parton shower algorithm based on Catani-Seymour dipole factorisation*, *JHEP* **03** (2008) 038 [[arXiv:0709.1027](#)] [[INSPIRE](#)].
- [21] S. Hoeche, F. Krauss, S. Schumann and F. Siegert, *QCD matrix elements and truncated showers*, *JHEP* **05** (2009) 053 [[arXiv:0903.1219](#)] [[INSPIRE](#)].
- [22] ATLAS COLLABORATION, *Search for supersymmetry using final states with one lepton, jets and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7$ TeV pp*, *Phys. Rev. Lett.* **106** (2011) 131802 [[arXiv:1102.2357](#)] [[INSPIRE](#)].

- [23] ATLAS COLLABORATION, *Search for an excess of events with an identical flavour lepton pair and significant missing transverse momentum in $\sqrt{s} = 7$ TeV proton-proton collisions with the ATLAS detector*, *Eur. Phys. J. C* **71** (2011) 1647 [[arXiv:1103.6208](#)] [[INSPIRE](#)].
- [24] ATLAS COLLABORATION, *Search for supersymmetry in final states with jets, missing transverse momentum and one isolated lepton in $\sqrt{s} = 7$ TeV pp collisions using 1fb^{-1} of ATLAS data*, *Phys. Rev. D* (2011) [[arXiv:1109.6606](#)] [[INSPIRE](#)].
- [25] ATLAS COLLABORATION, *Search for diphoton events with large missing transverse energy with 36pb^{-1} of 7 TeV proton-proton collision data with the ATLAS detector*, *Eur. Phys. J. C* **71** (2011) 1744 [[arXiv:1107.0561](#)] [[INSPIRE](#)].
- [26] A.H. Chamseddine, R.L. Arnowitt and P. Nath, *Locally supersymmetric grand unification*, *Phys. Rev. Lett.* **49** (1982) 970 [[INSPIRE](#)].
- [27] R. Barbieri, S. Ferrara and C.A. Savoy, *Gauge models with spontaneously broken local supersymmetry*, *Phys. Lett. B* **119** (1982) 343 [[INSPIRE](#)].
- [28] L.E. Ibáñez, *Locally supersymmetric SU(5) grand unification*, *Phys. Lett. B* **118** (1982) 73 [[INSPIRE](#)].
- [29] L.J. Hall, J.D. Lykken and S. Weinberg, *Supergravity as the messenger of supersymmetry breaking*, *Phys. Rev. D* **27** (1983) 2359 [[INSPIRE](#)].
- [30] N. Ohta, *Grand unified theories based on local supersymmetry*, *Prog. Theor. Phys.* **70** (1983) 542 [[INSPIRE](#)].
- [31] G.L. Kane, C.F. Kolda, L. Roszkowski and J.D. Wells, *Study of constrained minimal supersymmetry*, *Phys. Rev. D* **49** (1994) 6173 [[hep-ph/9312272](#)] [[INSPIRE](#)].
- [32] ATLAS COLLABORATION, *The ATLAS experiment at the CERN Large Hadron Collider*, 2008 *JINST* **3** S08003 [[INSPIRE](#)].
- [33] M. Cacciari, G.P. Salam and G. Soyez, *The anti- k_t jet clustering algorithm*, *JHEP* **04** (2008) 063 [[arXiv:0802.1189](#)] [[INSPIRE](#)].
- [34] M. Cacciari and G.P. Salam, *Dispelling the N^3 myth for the k_t jet-finder*, *Phys. Lett. B* **641** (2006) 57 [[hep-ph/0512210](#)] [[INSPIRE](#)].
- [35] W. Lampl et al., *Calorimeter clustering algorithms: description and performance*, *ATL-LARG-PUB-2008-002* (2008).
- [36] ATLAS COLLABORATION, *Jet energy scale and its systematic uncertainty for jets produced in proton-proton collisions at $\sqrt{s} = 7$ TeV and measured with the ATLAS detector*, *ATLAS-CONF-2010-056* (2010).
- [37] ATLAS COLLABORATION, *Commissioning of the ATLAS high-performance b-tagging algorithms in the 7 TeV collision data*, *ATLAS-CONF-2011-102* (2011).
- [38] ATLAS COLLABORATION, *Measurement of the $W \rightarrow l\nu$ and $Z/\gamma^* \rightarrow ll$ production cross sections in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, *JHEP* **12** (2010) 060 [[arXiv:1010.2130](#)] [[INSPIRE](#)].
- [39] 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).

- [40] ATLAS COLLABORATION, *Measurement of multi-jet cross sections in proton-proton collisions at a 7 TeV center-of-mass energy*, [arXiv:1107.2092](#) [Submitted to *Eur. Phys. J. C*] [[INSPIRE](#)].
- [41] GEANT4 COLLABORATION, *GEANT4: a simulation toolkit*, *Nucl. Instrum. Meth. A* **506** (2003) 250 [[INSPIRE](#)].
- [42] ATLAS COLLABORATION, *The ATLAS simulation infrastructure*, *Eur. Phys. J. C* **70** (2010) 823 [[arXiv:1005.4568](#)] [[INSPIRE](#)].
- [43] J. Pumplin, D. Stump, J. Huston, H. Lai, P.M. Nadolsky, et al., *New generation of parton distributions with uncertainties from global QCD analysis*, *JHEP* **07** (2002) 012 [[hep-ph/0201195](#)] [[INSPIRE](#)].
- [44] G. Corcella, I. Knowles, G. Marchesini, S. Moretti, K. Odagiri, et al., *HERWIG 6: an event generator for hadron emission reactions with interfering gluons (including supersymmetric processes)*, *JHEP* **01** (2001) 010 [[hep-ph/0011363](#)] [[INSPIRE](#)].
- [45] G. Corcella, I. Knowles, G. Marchesini, S. Moretti, K. Odagiri, et al., *HERWIG 6.5 release note*, [hep-ph/0210213](#) [[INSPIRE](#)].
- [46] J. Butterworth, J.R. Forshaw and M. Seymour, *Multiparton interactions in photoproduction at HERA*, *Z. Phys. C* **72** (1996) 637 [[hep-ph/9601371](#)] [[INSPIRE](#)].
- [47] S. Ellis, R. Kleiss and W. Stirling, *W's, Z's and jets*, *Phys. Lett. B* **154** (1985) 435 [[INSPIRE](#)].
- [48] F.A. Berends, W. Giele, H. Kuijf, R. Kleiss and W. Stirling, *Multi - jet production in W Z events at $p\bar{p}$ colliders*, *Phys. Lett. B* **224** (1989) 237 [[INSPIRE](#)].
- [49] C. Berger, Z. Bern, L.J. Dixon, F. Febres Cordero, D. Forde, et al., *Vector boson + jets with Blackhat and SHERPA*, *Nucl. Phys. Proc. Suppl.* **205-206** (2010) 92 [[arXiv:1005.3728](#)] [[INSPIRE](#)].
- [50] D0 COLLABORATION, *$t\bar{t}$ production cross-section in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV*, *Phys. Rev. D* **67** (2003) 012004 [[hep-ex/0205019](#)] [[INSPIRE](#)].
- [51] CDF COLLABORATION, W. Wagner, *Top quark cross-section measurements at the Tevatron*, *Eur. Phys. J. C* **33** (2004) S238 [[hep-ex/0312008](#)] [[INSPIRE](#)].
- [52] ATLAS COLLABORATION, *Measurement of the production cross section for W-bosons in association with jets in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, *Phys. Lett. B* **698** (2011) 325 [[arXiv:1012.5382](#)] [[INSPIRE](#)].
- [53] T. Gleisberg and S. Hoeche, *Comix, a new matrix element generator*, *JHEP* **12** (2008) 039 [[arXiv:0808.3674](#)] [[INSPIRE](#)].
- [54] F.E. Paige, S.D. Protopopescu, H. Baer and X. Tata, *ISAJET 7.69: a Monte Carlo event generator for pp, $p\bar{p}$ and e^+e^- reactions*, [hep-ph/0312045](#) [[INSPIRE](#)].
- [55] M. Bahr, S. Gieseke, M. Gigg, D. Grellscheid, K. Hamilton, et al., *HERWIG++ physics and manual*, *Eur. Phys. J. C* **58** (2008) 639 [[arXiv:0803.0883](#)] [[INSPIRE](#)].
- [56] W. Beenakker, R. Hopker, M. Spira and P. Zerwas, *Squark and gluino production at hadron colliders*, *Nucl. Phys. B* **492** (1997) 51 [[hep-ph/9610490](#)] [[INSPIRE](#)].
- [57] P.M. Nadolsky, H.-L. Lai, Q.-H. Cao, J. Huston, J. Pumplin, et al., *Implications of CTEQ global analysis for collider observables*, *Phys. Rev. D* **78** (2008) 013004 [[arXiv:0802.0007](#)] [[INSPIRE](#)].

- [58] ATLAS COLLABORATION, *Luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector in 2011*, [ATLAS-CONF-2011-116](#) (2011).
- [59] ATLAS COLLABORATION, *Luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector at the LHC*, *Eur. Phys. J. C* **71** (2011) 1630 [[arXiv:1101.2185](#)] [[INSPIRE](#)].
- [60] A.Read, *Presentation of search results: the CLs technique*, *J. Phys. G: Nucl. Part. Phys.* **28** (2002) 2693.
- [61] *A set of tables for acceptance times efficiency values are available at the Durham HepData repository*, <http://hepdata.cedar.ac.uk/view/red4931>.
- [62] D0 COLLABORATION, *Search for squarks and gluinos in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV*, *Phys. Rev. Lett.* **75** (1995) 618 [[INSPIRE](#)].
- [63] CDF COLLABORATION, *Search for gluinos and scalar quarks in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV using the missing energy plus multijets signature*, *Phys. Rev. Lett.* **88** (2002) 041801 [[hep-ex/0106001](#)] [[INSPIRE](#)].
- [64] CDF COLLABORATION, *Inclusive search for squark and gluino production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV*, *Phys. Rev. Lett.* **102** (2009) 121801 [[arXiv:0811.2512](#)] [[INSPIRE](#)].
- [65] D0 COLLABORATION, *Search for squarks and gluinos in events with jets and missing transverse energy using 2.1fb^{-1} of $p\bar{p}$ collision data at $\sqrt{s} = 1.96$ TeV*, *Phys. Lett. B* **660** (2008) 449 [[arXiv:0712.3805](#)] [[INSPIRE](#)].
- [66] LEP SUSY WORKING GROUP (ALEPH, DELPHI, L3, OPAL), *Combined LEP chargino results, up to 208 GeV*, [LEPSUSYWG/01-03.1](#), http://lepsusy.web.cern.ch/lepsusy/www/inos_moriond01/charginos_pub.html.
- [67] LEP SUSY WORKING GROUP (ALEPH, DELPHI, L3, OPAL), *Combined LEP selectron/smuon/stau results, 183-208 GeV*, [LEPSUSYWG/04-01.1](#), http://lepsusy.web.cern.ch/lepsusy/www/sleptons_summer04/slep_final.html.

The ATLAS collaboration

G. Aad⁴⁸, B. Abbott¹¹¹, J. Abdallah¹¹, A.A. Abdelalim⁴⁹, A. Abdesselam¹¹⁸, O. Abidinov¹⁰, B. Abi¹¹², M. Abolins⁸⁸, H. Abramowicz¹⁵³, H. Abreu¹¹⁵, E. Acerbi^{89a,89b}, B.S. Acharya^{164a,164b}, D.L. Adams²⁴, T.N. Addy⁵⁶, J. Adelman¹⁷⁵, M. Aderholz⁹⁹, S. Adomeit⁹⁸, P. Adragna⁷⁵, T. Adye¹²⁹, S. Aefsky²², J.A. Aguilar-Saavedra^{124b,a}, M. Aharrouche⁸¹, S.P. Ahlen²¹, F. Ahles⁴⁸, A. Ahmad¹⁴⁸, M. Ahsan⁴⁰, G. Aielli^{133a,133b}, T. Akdogan^{18a}, T.P.A. Åkesson⁷⁹, G. Akimoto¹⁵⁵, A.V. Akimov⁹⁴, A. Akiyama⁶⁷, M.S. Alam¹, M.A. Alam⁷⁶, J. Albert¹⁶⁹, S. Albrand⁵⁵, M. Aleksa²⁹, I.N. Aleksandrov⁶⁵, F. Alessandria^{89a}, C. Alexa^{25a}, G. Alexander¹⁵³, G. Alexandre⁴⁹, T. Alexopoulos⁹, M. Alhroob²⁰, M. Aliev¹⁵, G. Alimonti^{89a}, J. Alison¹²⁰, M. Aliyev¹⁰, P.P. Allport⁷³, S.E. Allwood-Spiers⁵³, J. Almond⁸², A. Aloisio^{102a,102b}, R. Alon¹⁷¹, A. Alonso⁷⁹, M.G. Alviggi^{102a,102b}, K. Amako⁶⁶, P. Amaral²⁹, C. Amelung²², V.V. Ammosov¹²⁸, A. Amorim^{124a,b}, G. Amorós¹⁶⁷, N. Amram¹⁵³, C. Anastopoulos²⁹, L.S. Ancu¹⁶, N. Andari¹¹⁵, T. Andeen³⁴, C.F. Anders²⁰, G. Anders^{58a}, K.J. Anderson³⁰,

A. Andreazza^{89a,89b}, V. Andrei^{58a}, M-L. Andrieux⁵⁵, X.S. Anduaga⁷⁰, A. Angerami³⁴, F. Anghinolfi²⁹, N. Anjos^{124a}, A. Annovi⁴⁷, A. Antonaki⁸, M. Antonelli⁴⁷, A. Antonov⁹⁶, J. Antos^{144b}, F. Anulli^{132a}, S. Aoun⁸³, L. Aperio Bella⁴, R. Apolle^{118,c}, G. Arabidze⁸⁸, I. Aracena¹⁴³, Y. Arai⁶⁶, A.T.H. Arce⁴⁴, J.P. Archambault²⁸, S. Arfaoui^{29,d}, J-F. Arguin¹⁴, E. Arik^{18a,*}, M. Arik^{18a}, A.J. Armbruster⁸⁷, O. Arnaez⁸¹, C. Arnault¹¹⁵, A. Artamonov⁹⁵, G. Artoni^{132a,132b}, D. Arutinov²⁰, S. Asai¹⁵⁵, R. Asfandiyarov¹⁷², S. Ask²⁷, B. Åsman^{146a,146b}, L. Asquith⁵, K. Assamagan²⁴, A. Astbury¹⁶⁹, A. Astvatsatourov⁵², G. Atoian¹⁷⁵, B. Aubert⁴, E. Auge¹¹⁵, K. Augsten¹²⁷, M. Auresseau^{145a}, N. Austin⁷³, G. Avolio¹⁶³, R. Avramidou⁹, D. Axen¹⁶⁸, C. Ay⁵⁴, G. Azuelos^{93,e}, Y. Azuma¹⁵⁵, M.A. Baak²⁹, G. Baccaglioni^{89a}, C. Bacci^{134a,134b}, A.M. Bach¹⁴, H. Bachacou¹³⁶, K. Bachas²⁹, G. Bachy²⁹, M. Backes⁴⁹, M. Backhaus²⁰, E. Badescu^{25a}, P. Bagnaia^{132a,132b}, S. Bahinipati², Y. Bai^{32a}, D.C. Bailey¹⁵⁸, T. Bain¹⁵⁸, J.T. Baines¹²⁹, O.K. Baker¹⁷⁵, M.D. Baker²⁴, S. Baker⁷⁷, E. Banas³⁸, P. Banerjee⁹³, Sw. Banerjee¹⁷², D. Banfi²⁹, A. Bangert¹³⁷, V. Bansal¹⁶⁹, H.S. Bansil¹⁷, L. Barak¹⁷¹, S.P. Baranov⁹⁴, A. Barashkou⁶⁵, A. Barbaro Galtieri¹⁴, T. Barber²⁷, E.L. Barberio⁸⁶, D. Barberis^{50a,50b}, M. Barbero²⁰, D.Y. Bardin⁶⁵, T. Barillari⁹⁹, M. Barisonzi¹⁷⁴, T. Barklow¹⁴³, N. Barlow²⁷, B.M. Barnett¹²⁹, R.M. Barnett¹⁴, A. Baroncelli^{134a}, G. Barone⁴⁹, A.J. Barr¹¹⁸, F. Barreiro⁸⁰, J. Barreiro Guimarães da Costa⁵⁷, P. Barrillon¹¹⁵, R. Bartoldus¹⁴³, A.E. Barton⁷¹, D. Bartsch²⁰, V. Bartsch¹⁴⁹, R.L. Bates⁵³, L. Batkova^{144a}, J.R. Batley²⁷, A. Battaglia¹⁶, M. Battistin²⁹, G. Battistoni^{89a}, F. Bauer¹³⁶, H.S. Bawa^{143,f}, B. Beare¹⁵⁸, T. Beau⁷⁸, P.H. Beauchemin¹¹⁸, R. Beccherle^{50a}, P. Bechtel⁴¹, H.P. Beck¹⁶, S. Becker⁹⁸, M. Beckingham¹³⁸, K.H. Becks¹⁷⁴, A.J. Beddall^{18c}, A. Beddall^{18c}, S. Bedikian¹⁷⁵, V.A. Bednyakov⁶⁵, C.P. Bee⁸³, M. Begel²⁴, S. Behar Harpaz¹⁵², P.K. Behera⁶³, M. Beimforde⁹⁹, C. Belanger-Champagne⁸⁵, P.J. Bell⁴⁹, W.H. Bell⁴⁹, G. Bella¹⁵³, L. Bellagamba^{19a}, F. Bellina²⁹, M. Bellomo²⁹, A. Belloni⁵⁷, O. Beloborodova¹⁰⁷, K. Belotskiy⁹⁶, O. Beltramello²⁹, S. Ben Ami¹⁵², O. Benary¹⁵³, D. Benchekroun^{135a}, C. Benchouk⁸³, M. Bendel⁸¹, N. Benekos¹⁶⁵, Y. Benhammou¹⁵³, D.P. Benjamin⁴⁴, M. Benoit¹¹⁵, J.R. Bensinger²², K. Benslama¹³⁰, S. Bentvelsen¹⁰⁵, D. Berge²⁹, E. Bergeaas Kuutmann⁴¹, N. Berger⁴, F. Berghaus¹⁶⁹, E. Berglund⁴⁹, J. Beringer¹⁴, K. Bernardet⁸³, P. Bernat⁷⁷, R. Bernhard⁴⁸, C. Bernius²⁴, T. Berry⁷⁶, A. Bertin^{19a,19b}, F. Bertinelli²⁹, F. Bertolucci^{122a,122b}, M.I. Besana^{89a,89b}, N. Besson¹³⁶, S. Bethke⁹⁹, W. Bhimji⁴⁵, R.M. Bianchi²⁹, M. Bianco^{72a,72b}, O. Biebel⁹⁸, S.P. Bieniek⁷⁷, K. Bierwagen⁵⁴, J. Biesiada¹⁴, M. Biglietti^{134a,134b}, H. Bilokon⁴⁷, M. Bindi^{19a,19b}, S. Binet¹¹⁵, A. Bingul^{18c}, C. Bini^{132a,132b}, C. Biscarat¹⁷⁷, U. Bitenc⁴⁸, K.M. Black²¹, R.E. Blair⁵, J.-B. Blanchard¹¹⁵, G. Blanchot²⁹, T. Blazek^{144a}, C. Blocker²², J. Blocki³⁸, A. Blondel⁴⁹, W. Blum⁸¹, U. Blumenschein⁵⁴, G.J. Bobbink¹⁰⁵, V.B. Bobrovnikov¹⁰⁷, S.S. Bocchetta⁷⁹, A. Bocci⁴⁴, C.R. Boddy¹¹⁸, M. Boehler⁴¹, J. Boek¹⁷⁴, N. Boelaert³⁵, S. Böser⁷⁷, J.A. Bogaerts²⁹, A. Bogdanchikov¹⁰⁷, A. Bogouch^{90,*}, C. Boehm^{146a}, V. Boisvert⁷⁶, T. Bold³⁷, V. Boldea^{25a}, N.M. Bolnet¹³⁶, M. Bona⁷⁵, V.G. Bondarenko⁹⁶, M. Bondioli¹⁶³, M. Boonekamp¹³⁶, G. Boorman⁷⁶, C.N. Booth¹³⁹, S. Bordini⁷⁸, C. Borer¹⁶, A. Borisov¹²⁸, G. Borisso⁷¹, I. Borjanovic^{12a}, S. Borroni⁸⁷, K. Bos¹⁰⁵, D. Boscherini^{19a}, M. Bosman¹¹, H. Boterenbrood¹⁰⁵, D. Botterill¹²⁹, J. Bouchami⁹³, J. Boudreau¹²³, E.V. Bouhova-Thacker⁷¹,

C. Bourdarios¹¹⁵, N. Bousson⁸³, A. Boveia³⁰, J. Boyd²⁹, I.R. Boyko⁶⁵, N.I. Bozhko¹²⁸,
 I. Bozovic-Jelisavcic^{12b}, J. Bracinik¹⁷, A. Braem²⁹, P. Branchini^{134a},
 G.W. Brandenburg⁵⁷, A. Brandt⁷, G. Brandt¹⁵, O. Brandt⁵⁴, U. Bratzler¹⁵⁶, B. Brau⁸⁴,
 J.E. Brau¹¹⁴, H.M. Braun¹⁷⁴, B. Brelief¹⁵⁸, J. Bremer²⁹, R. Brenner¹⁶⁶, S. Bressler¹⁵²,
 D. Breton¹¹⁵, D. Britton⁵³, F.M. Brochu²⁷, I. Brock²⁰, R. Brock⁸⁸, T.J. Brodbeck⁷¹,
 E. Brodet¹⁵³, F. Broggi^{89a}, C. Bromberg⁸⁸, G. Brooijmans³⁴, W.K. Brooks^{31b},
 G. Brown⁸², H. Brown⁷, P.A. Bruckman de Renstrom³⁸, D. Bruncko^{144b}, R. Bruneliere⁴⁸,
 S. Brunet⁶¹, A. Bruni^{19a}, G. Bruni^{19a}, M. Bruschi^{19a}, T. Buanes¹³, F. Bucci⁴⁹,
 J. Buchanan¹¹⁸, N.J. Buchanan², P. Buchholz¹⁴¹, R.M. Buckingham¹¹⁸, A.G. Buckley⁴⁵,
 S.I. Buda^{25a}, I.A. Budagov⁶⁵, B. Budick¹⁰⁸, V. Büscher⁸¹, L. Bugge¹¹⁷, D. Buirra-Clark¹¹⁸,
 O. Bulekov⁹⁶, M. Bunse⁴², T. Buran¹¹⁷, H. Burckhart²⁹, S. Burdin⁷³, T. Burgess¹³,
 S. Burke¹²⁹, E. Busato³³, P. Bussey⁵³, C.P. Buszello¹⁶⁶, F. Butin²⁹, B. Butler¹⁴³,
 J.M. Butler²¹, C.M. Buttar⁵³, J.M. Butterworth⁷⁷, W. Buttinger²⁷, S. Cabrera Urbán¹⁶⁷,
 D. Caforio^{19a,19b}, O. Cakir^{3a}, P. Calafiura¹⁴, G. Calderini⁷⁸, P. Calfayan⁹⁸, R. Calkins¹⁰⁶,
 L.P. Caloba^{23a}, R. Caloi^{132a,132b}, D. Calvet³³, S. Calvet³³, R. Camacho Toro³³,
 P. Camarri^{133a,133b}, M. Cambiaghi^{119a,119b}, D. Cameron¹¹⁷, S. Campana²⁹,
 M. Campanelli⁷⁷, V. Canale^{102a,102b}, F. Canelli^{30,g}, A. Canepa^{159a}, J. Cantero⁸⁰,
 L. Capasso^{102a,102b}, M.D.M. Capeans Garrido²⁹, I. Caprini^{25a}, M. Caprini^{25a},
 D. Capriotti⁹⁹, M. Capua^{36a,36b}, R. Caputo¹⁴⁸, R. Cardarelli^{133a}, T. Carli²⁹,
 G. Carlino^{102a}, L. Carminati^{89a,89b}, B. Caron^{159a}, S. Caron⁴⁸, G.D. Carrillo Montoya¹⁷²,
 A.A. Carter⁷⁵, J.R. Carter²⁷, J. Carvalho^{124a,h}, D. Casadei¹⁰⁸, M.P. Casado¹¹,
 M. Cascella^{122a,122b}, C. Caso^{50a,50b,*}, A.M. Castaneda Hernandez¹⁷²,
 E. Castaneda-Miranda¹⁷², V. Castillo Gimenez¹⁶⁷, N.F. Castro^{124a}, G. Cataldi^{72a},
 F. Cataneo²⁹, A. Catinaccio²⁹, J.R. Catmore⁷¹, A. Cattai²⁹, G. Cattani^{133a,133b},
 S. Caughron⁸⁸, D. Cauz^{164a,164c}, P. Cavalleri⁷⁸, D. Cavalli^{89a}, M. Cavalli-Sforza¹¹,
 V. Cavasinni^{122a,122b}, F. Ceradini^{134a,134b}, A.S. Cerqueira^{23a}, A. Cerri²⁹, L. Cerrito⁷⁵,
 F. Cerutti⁴⁷, S.A. Cetin^{18b}, F. Cevenini^{102a,102b}, A. Chafaq^{135a}, D. Chakraborty¹⁰⁶,
 K. Chan², B. Chapleau⁸⁵, J.D. Chapman²⁷, J.W. Chapman⁸⁷, E. Chareyre⁷⁸,
 D.G. Charlton¹⁷, V. Chavda⁸², C.A. Chavez Barajas²⁹, S. Cheatham⁸⁵, S. Chekanov⁵,
 S.V. Chekulaev^{159a}, G.A. Chelkov⁶⁵, M.A. Chelstowska¹⁰⁴, C. Chen⁶⁴, H. Chen²⁴,
 S. Chen^{32c}, T. Chen^{32c}, X. Chen¹⁷², S. Cheng^{32a}, A. Cheplakov⁶⁵, V.F. Chepurinov⁶⁵,
 R. Cherkaoui El Moursli^{135e}, V. Chernyatin²⁴, E. Cheu⁶, S.L. Cheung¹⁵⁸, L. Chevalier¹³⁶,
 G. Chiefari^{102a,102b}, L. Chikovani^{51a}, J.T. Childers^{58a}, A. Chilingarov⁷¹, G. Chiodini^{72a},
 M.V. Chizhov⁶⁵, G. Choudalakis³⁰, S. Chouridou¹³⁷, I.A. Christidi⁷⁷, A. Christov⁴⁸,
 D. Chromek-Burckhart²⁹, M.L. Chu¹⁵¹, J. Chudoba¹²⁵, G. Ciapetti^{132a,132b}, K. Ciba³⁷,
 A.K. Ciftci^{3a}, R. Ciftci^{3a}, D. Cinca³³, V. Cindro⁷⁴, M.D. Ciobotaru¹⁶³, C. Ciocca^{19a},
 A. Ciochio¹⁴, M. Cirilli⁸⁷, M. Ciubancan^{25a}, A. Clark⁴⁹, P.J. Clark⁴⁵, W. Cleland¹²³,
 J.C. Clemens⁸³, B. Clement⁵⁵, C. Clement^{146a,146b}, R.W. Clift¹²⁹, Y. Coadou⁸³,
 M. Cokal^{164a,164c}, A. Coccaro^{50a,50b}, J. Cochran⁶⁴, P. Coe¹¹⁸, J.G. Cogan¹⁴³,
 J. Coggeshall¹⁶⁵, E. Cogneras¹⁷⁷, C.D. Cojocaru²⁸, J. Colas⁴, A.P. Colijn¹⁰⁵,
 C. Collard¹¹⁵, N.J. Collins¹⁷, C. Collins-Tooth⁵³, J. Collot⁵⁵, G. Colon⁸⁴, P. Conde
 Muiño^{124a}, E. Coniavitis¹¹⁸, M.C. Conidi¹¹, M. Consonni¹⁰⁴, V. Consorti⁴⁸,
 S. Constantinescu^{25a}, C. Conta^{119a,119b}, F. Conventi^{102a,i}, J. Cook²⁹, M. Cooke¹⁴,

B.D. Cooper⁷⁷, A.M. Cooper-Sarkar¹¹⁸, N.J. Cooper-Smith⁷⁶, K. Copic³⁴,
 T. Cornelissen¹⁷⁴, M. Corradi^{19a}, F. Corriveau^{85,j}, A. Cortes-Gonzalez¹⁶⁵, G. Cortiana⁹⁹,
 G. Costa^{89a}, M.J. Costa¹⁶⁷, D. Costanzo¹³⁹, T. Costin³⁰, D. Côte²⁹, L. Courneyea¹⁶⁹,
 G. Cowan⁷⁶, C. Cowden²⁷, B.E. Cox⁸², K. Cranmer¹⁰⁸, F. Crescioli^{122a,122b},
 M. Cristinziani²⁰, G. Crosetti^{36a,36b}, R. Crupi^{72a,72b}, S. Crépe-Renaudin⁵⁵,
 C.-M. Cuciuc^{25a}, C. Cuenca Almenar¹⁷⁵, T. Cuhadar Donszelmann¹³⁹, M. Curatolo⁴⁷,
 C.J. Curtis¹⁷, P. Cwetanski⁶¹, H. Czirr¹⁴¹, Z. Czyczula¹⁷⁵, S. D’Auria⁵³, M. D’Onofrio⁷³,
 A. D’Orazio^{132a,132b}, P.V.M. Da Silva^{23a}, C. Da Via⁸², W. Dabrowski³⁷, T. Dai⁸⁷,
 C. Dallapiccola⁸⁴, M. Dam³⁵, M. Dameri^{50a,50b}, D.S. Damiani¹³⁷, H.O. Danielsson²⁹,
 D. Dannheim⁹⁹, V. Dao⁴⁹, G. Darbo^{50a}, G.L. Darlea^{25b}, C. Daum¹⁰⁵, W. Davey⁸⁶,
 T. Davidek¹²⁶, N. Davidson⁸⁶, R. Davidson⁷¹, E. Davies^{118,c}, M. Davies⁹³,
 A.R. Davison⁷⁷, Y. Davygora^{58a}, E. Dawe¹⁴², I. Dawson¹³⁹, J.W. Dawson^{5,*},
 R.K. Daya³⁹, K. De⁷, R. de Asmundis^{102a}, S. De Castro^{19a,19b},
 P.E. De Castro Faria Salgado²⁴, S. De Cecco⁷⁸, J. de Graat⁹⁸, N. De Groot¹⁰⁴,
 P. de Jong¹⁰⁵, C. De La Taille¹¹⁵, H. De la Torre⁸⁰, B. De Lotto^{164a,164c}, L. De Mora⁷¹,
 L. De Nooij¹⁰⁵, D. De Pedis^{132a}, A. De Salvo^{132a}, U. De Sanctis^{164a,164c}, A. De Santo¹⁴⁹,
 J.B. De Vivie De Regie¹¹⁵, S. Dean⁷⁷, R. Debbé²⁴, D.V. Dedovich⁶⁵, J. Degenhardt¹²⁰,
 M. Dehchar¹¹⁸, C. Del Papa^{164a,164c}, J. Del Peso⁸⁰, T. Del Prete^{122a,122b},
 M. Deliyergiyev⁷⁴, A. Dell’Acqua²⁹, L. Dell’Asta^{89a,89b}, M. Della Pietra^{102a,i},
 D. della Volpe^{102a,102b}, M. Delmastro²⁹, N. Delruelle²⁹, P.A. Delsart⁵⁵, C. Deluca¹⁴⁸,
 S. Demers¹⁷⁵, M. Demichev⁶⁵, B. Demirköz^{11,k}, J. Deng¹⁶³, S.P. Denisov¹²⁸,
 D. Derendarz³⁸, J.E. Derkaoui^{135d}, F. Derue⁷⁸, P. Dervan⁷³, K. Desch²⁰, E. Devetak¹⁴⁸,
 P.O. Deviveiros¹⁵⁸, A. Dewhurst¹²⁹, B. DeWilde¹⁴⁸, S. Dhaliwal¹⁵⁸, R. Dhullipudi^{24,l},
 A. Di Ciaccio^{133a,133b}, L. Di Ciaccio⁴, A. Di Girolamo²⁹, B. Di Girolamo²⁹,
 S. Di Luise^{134a,134b}, A. Di Mattia¹⁷², B. Di Micco²⁹, R. Di Nardo^{133a,133b},
 A. Di Simone^{133a,133b}, R. Di Sipio^{19a,19b}, M.A. Diaz^{31a}, F. Diblen^{18c}, E.B. Diehl⁸⁷,
 J. Dietrich⁴¹, T.A. Dietzsch^{58a}, S. Diglio¹¹⁵, K. Dindar Yagci³⁹, J. Dingfelder²⁰,
 C. Dionisi^{132a,132b}, P. Dita^{25a}, S. Dita^{25a}, F. Dittus²⁹, F. Djama⁸³, T. Djobava^{51b},
 M.A.B. do Vale^{23a}, A. Do Valle Wemans^{124a}, T.K.O. Doan⁴, M. Dobbs⁸⁵,
 R. Dobinson^{29,*}, D. Dobos²⁹, E. Dobson²⁹, M. Dobson¹⁶³, J. Dodd³⁴, C. Doglioni¹¹⁸,
 T. Doherty⁵³, Y. Doi^{66,*}, J. Dolejsi¹²⁶, I. Dolenc⁷⁴, Z. Dolezal¹²⁶, B.A. Dolgoshein^{96,*},
 T. Dohmae¹⁵⁵, M. Donadelli^{23d}, M. Donega¹²⁰, J. Donini⁵⁵, J. Dopke²⁹, A. Doria^{102a},
 A. Dos Anjos¹⁷², M. Dosit¹¹, A. Dotti^{122a,122b}, M.T. Dova⁷⁰, J.D. Dowell¹⁷,
 A.D. Doxiadis¹⁰⁵, A.T. Doyle⁵³, Z. Drasal¹²⁶, J. Drees¹⁷⁴, N. Dressnandt¹²⁰,
 H. Drevermann²⁹, C. Driouichi³⁵, M. Dris⁹, J. Dubbert⁹⁹, S. Dube¹⁴, E. Duchovni¹⁷¹,
 G. Duckeck⁹⁸, A. Dudarev²⁹, F. Dudziak⁶⁴, M. Dührssen²⁹, I.P. Duerdoth⁸²,
 L. Dufflot¹¹⁵, M-A. Dufour⁸⁵, M. Dunford²⁹, H. Duran Yildiz^{3b}, R. Duxfield¹³⁹,
 M. Dwuznik³⁷, F. Dydak²⁹, M. Düren⁵², W.L. Ebenstein⁴⁴, J. Ebke⁹⁸, S. Eckert⁴⁸,
 S. Eckweiler⁸¹, K. Edmonds⁸¹, C.A. Edwards⁷⁶, N.C. Edwards⁵³, W. Ehrenfeld⁴¹,
 T. Ehrich⁹⁹, T. Eifert²⁹, G. Eigen¹³, K. Einsweiler¹⁴, E. Eisenhandler⁷⁵, T. Ekelof¹⁶⁶,
 M. El Kacimi^{135c}, M. Ellert¹⁶⁶, S. Elles⁴, F. Ellinghaus⁸¹, K. Ellis⁷⁵, N. Ellis²⁹,
 J. Elmsheuser⁹⁸, M. Elsing²⁹, D. Emelianov¹²⁹, R. Engelmann¹⁴⁸, A. Engl⁹⁸, B. Epp⁶²,
 A. Eppig⁸⁷, J. Erdmann⁵⁴, A. Ereditato¹⁶, D. Eriksson^{146a}, J. Ernst¹, M. Ernst²⁴,

J. Ernwein¹³⁶, D. Errede¹⁶⁵, S. Errede¹⁶⁵, E. Ertel⁸¹, M. Escalier¹¹⁵, C. Escobar¹²³,
 X. Espinal Curull¹¹, B. Esposito⁴⁷, F. Etienne⁸³, A.I. Etievre¹³⁶, E. Etzion¹⁵³,
 D. Evangelakou⁵⁴, H. Evans⁶¹, L. Fabbri^{19a,19b}, C. Fabre²⁹, R.M. Fakhrutdinov¹²⁸,
 S. Falciano^{132a}, Y. Fang¹⁷², M. Fanti^{89a,89b}, A. Farbin⁷, A. Farilla^{134a}, J. Farley¹⁴⁸,
 T. Farooque¹⁵⁸, S.M. Farrington¹¹⁸, P. Farthouat²⁹, P. Fassnacht²⁹, D. Fassouliotis⁸,
 B. Fatholahzadeh¹⁵⁸, A. Favareto^{89a,89b}, L. Fayard¹¹⁵, S. Fazio^{36a,36b}, R. Febbraro³³,
 P. Federic^{144a}, O.L. Fedin¹²¹, W. Fedorko⁸⁸, M. Fehling-Kaschek⁴⁸, L. Feligioni⁸³,
 C. Feng^{32d}, E.J. Feng³⁰, A.B. Fenyuk¹²⁸, J. Ferencei^{144b}, J. Ferland⁹³, W. Fernando¹⁰⁹,
 S. Ferrag⁵³, J. Ferrando⁵³, V. Ferrara⁴¹, A. Ferrari¹⁶⁶, P. Ferrari¹⁰⁵, R. Ferrari^{119a},
 A. Ferrer¹⁶⁷, M.L. Ferrer⁴⁷, D. Ferrere⁴⁹, C. Ferretti⁸⁷, A. Ferretto Parodi^{50a,50b},
 M. Fiascaris³⁰, F. Fiedler⁸¹, A. Filipčić⁷⁴, A. Filippas⁹, F. Filthaut¹⁰⁴,
 M. Fincke-Keeler¹⁶⁹, M.C.N. Fiolhais^{124a,h}, L. Fiorini¹⁶⁷, A. Firan³⁹, G. Fischer⁴¹,
 P. Fischer²⁰, M.J. Fisher¹⁰⁹, M. Flechl⁴⁸, I. Fleck¹⁴¹, J. Fleckner⁸¹, P. Fleischmann¹⁷³,
 S. Fleischmann¹⁷⁴, T. Flick¹⁷⁴, L.R. Flores Castillo¹⁷², M.J. Flowerdew⁹⁹, M. Fokitis⁹,
 T. Fonseca Martin¹⁶, D.A. Forbush¹³⁸, A. Formica¹³⁶, A. Forti⁸², D. Fortin^{159a},
 J.M. Foster⁸², D. Fournier¹¹⁵, A. Foussat²⁹, A.J. Fowler⁴⁴, K. Fowler¹³⁷, H. Fox⁷¹,
 P. Francavilla^{122a,122b}, S. Franchino^{119a,119b}, D. Francis²⁹, T. Frank¹⁷¹, M. Franklin⁵⁷,
 S. Franz²⁹, M. Fraternali^{119a,119b}, S. Fratina¹²⁰, S.T. French²⁷, F. Friedrich⁴³,
 R. Froeschl²⁹, D. Froidevaux²⁹, J.A. Frost²⁷, C. Fukunaga¹⁵⁶, E. Fullana Torregrosa²⁹,
 J. Fuster¹⁶⁷, C. Gabaldon²⁹, O. Gabizon¹⁷¹, T. Gadfort²⁴, S. Gadomski⁴⁹,
 G. Gagliardi^{50a,50b}, P. Gagnon⁶¹, C. Galea⁹⁸, E.J. Gallas¹¹⁸, V. Gallo¹⁶, B.J. Gallop¹²⁹,
 P. Gallus¹²⁵, E. Galyaev⁴⁰, K.K. Gan¹⁰⁹, Y.S. Gao^{143,f}, V.A. Gapienko¹²⁸,
 A. Gaponenko¹⁴, F. Garbersson¹⁷⁵, M. Garcia-Sciveres¹⁴, C. García¹⁶⁷, J.E. García
 Navarro⁴⁹, R.W. Gardner³⁰, N. Garelli²⁹, H. Garitaonandia¹⁰⁵, V. Garonne²⁹,
 J. Garvey¹⁷, C. Gatti⁴⁷, G. Gaudio^{119a}, O. Gaumer⁴⁹, B. Gaur¹⁴¹, L. Gauthier¹³⁶,
 I.L. Gavrilenko⁹⁴, C. Gay¹⁶⁸, G. Gaycken²⁰, J-C. Gayde²⁹, E.N. Gazis⁹, P. Ge^{32d},
 C.N.P. Gee¹²⁹, D.A.A. Geerts¹⁰⁵, Ch. Geich-Gimbel²⁰, K. Gellerstedt^{146a,146b},
 C. Gemme^{50a}, A. Gemmell⁵³, M.H. Genest⁹⁸, S. Gentile^{132a,132b}, M. George⁵⁴,
 S. George⁷⁶, P. Gerlach¹⁷⁴, A. Gershon¹⁵³, C. Geweniger^{58a}, H. Ghazlane^{135b}, P. Ghez⁴,
 N. Ghodbane³³, B. Giacobbe^{19a}, S. Giagu^{132a,132b}, V. Giakoumopoulou⁸,
 V. Giangiobbe^{122a,122b}, F. Gianotti²⁹, B. Gibbard²⁴, A. Gibson¹⁵⁸, S.M. Gibson²⁹,
 L.M. Gilbert¹¹⁸, V. Gilevsky⁹¹, D. Gillberg²⁸, A.R. Gillman¹²⁹, D.M. Gingrich^{2,e},
 J. Ginzburg¹⁵³, N. Giokaris⁸, M.P. Giordani^{164c}, R. Giordano^{102a,102b}, F.M. Giorgi¹⁵,
 P. Giovannini⁹⁹, P.F. Giraud¹³⁶, D. Giugni^{89a}, M. Giunta⁹³, P. Giusti^{19a},
 B.K. Gjelsten¹¹⁷, L.K. Gladilin⁹⁷, C. Glasman⁸⁰, J. Glatzer⁴⁸, A. Glazov⁴¹,
 K.W. Glitza¹⁷⁴, G.L. Glonti⁶⁵, J. Godfrey¹⁴², J. Godlewski²⁹, M. Goebel⁴¹, T. Göpfert⁴³,
 C. Goeringer⁸¹, C. Gössling⁴², T. Göttfert⁹⁹, S. Goldfarb⁸⁷, T. Golling¹⁷⁵,
 S.N. Golovnia¹²⁸, A. Gomes^{124a,b}, L.S. Gomez Fajardo⁴¹, R. Gonçalo⁷⁶,
 J. Goncalves Pinto Firmino Da Costa⁴¹, L. Gonella²⁰, A. Gonidec²⁹, S. Gonzalez¹⁷²,
 S. González de la Hoz¹⁶⁷, M.L. Gonzalez Silva²⁶, S. Gonzalez-Sevilla⁴⁹, J.J. Goodson¹⁴⁸,
 L. Goossens²⁹, P.A. Gorbounov⁹⁵, H.A. Gordon²⁴, I. Gorelov¹⁰³, G. Gorfine¹⁷⁴,
 B. Gorini²⁹, E. Gorini^{72a,72b}, A. Gorišek⁷⁴, E. Gornicki³⁸, S.A. Gorokhov¹²⁸,
 V.N. Goryachev¹²⁸, B. Gosdzik⁴¹, M. Gosselink¹⁰⁵, M.I. Gostkin⁶⁵, I. Gough Eschrich¹⁶³,

M. Gouighri^{135a}, D. Goujdami^{135c}, M.P. Goulette⁴⁹, A.G. Goussiou¹³⁸, C. Goy⁴,
 I. Grabowska-Bold^{163,m}, P. Grafström²⁹, K-J. Grahn⁴¹, F. Grancagnolo^{72a},
 S. Grancagnolo¹⁵, V. Grassi¹⁴⁸, V. Gratchev¹²¹, N. Grau³⁴, H.M. Gray²⁹, J.A. Gray¹⁴⁸,
 E. Graziani^{134a}, O.G. Grebenyuk¹²¹, D. Greenfield¹²⁹, T. Greenshaw⁷³,
 Z.D. Greenwood^{24,l}, K. Gregersen³⁵, I.M. Gregor⁴¹, P. Grenier¹⁴³, J. Griffiths¹³⁸,
 N. Grigalashvili⁶⁵, A.A. Grillo¹³⁷, S. Grinstein¹¹, Y.V. Grishkevich⁹⁷, J.-F. Grivaz¹¹⁵,
 M. Groh⁹⁹, E. Gross¹⁷¹, J. Grosse-Knetter⁵⁴, J. Groth-Jensen¹⁷¹, K. Grybel¹⁴¹,
 V.J. Guarino⁵, D. Guest¹⁷⁵, C. Guicheney³³, A. Guida^{72a,72b}, T. Guillemin⁴,
 S. Guindon⁵⁴, H. Guler^{85,n}, J. Gunther¹²⁵, B. Guo¹⁵⁸, J. Guo³⁴, A. Gupta³⁰,
 Y. Gusakov⁶⁵, V.N. Gushchin¹²⁸, A. Gutierrez⁹³, P. Gutierrez¹¹¹, N. Guttman¹⁵³,
 O. Gutzwiller¹⁷², C. Guyot¹³⁶, C. Gwenlan¹¹⁸, C.B. Gwilliam⁷³, A. Haas¹⁴³, S. Haas²⁹,
 C. Haber¹⁴, R. Hackenburg²⁴, H.K. Hadavand³⁹, D.R. Hadley¹⁷, P. Haefner⁹⁹, F. Hahn²⁹,
 S. Haider²⁹, Z. Hajduk³⁸, H. Hakobyan¹⁷⁶, J. Haller⁵⁴, K. Hamacher¹⁷⁴, P. Hamal¹¹³,
 M. Hamer⁵⁴, A. Hamilton⁴⁹, S. Hamilton¹⁶¹, H. Han^{32a}, L. Han^{32b}, K. Hanagaki¹¹⁶,
 M. Hance¹⁴, C. Handel⁸¹, P. Hanke^{58a}, J.R. Hansen³⁵, J.B. Hansen³⁵, J.D. Hansen³⁵,
 P.H. Hansen³⁵, P. Hansson¹⁴³, K. Hara¹⁶⁰, G.A. Hare¹³⁷, T. Harenberg¹⁷⁴, S. Harkusha⁹⁰,
 D. Harper⁸⁷, R.D. Harrington⁴⁵, O.M. Harris¹³⁸, K. Harrison¹⁷, J. Hartert⁴⁸,
 F. Hartjes¹⁰⁵, T. Haruyama⁶⁶, A. Harvey⁵⁶, S. Hasegawa¹⁰¹, Y. Hasegawa¹⁴⁰,
 S. Hassani¹³⁶, M. Hatch²⁹, D. Hauff⁹⁹, S. Haug¹⁶, M. Hauschild²⁹, R. Hauser⁸⁸,
 M. Havranek²⁰, B.M. Hawes¹¹⁸, C.M. Hawkes¹⁷, R.J. Hawkings²⁹, D. Hawkins¹⁶³,
 T. Hayakawa⁶⁷, T. Hayashi¹⁶⁰, D. Hayden⁷⁶, H.S. Hayward⁷³, S.J. Haywood¹²⁹,
 E. Hazen²¹, M. He^{32d}, S.J. Head¹⁷, V. Hedberg⁷⁹, L. Heelan⁷, S. Heim⁸⁸,
 B. Heinemann¹⁴, S. Heisterkamp³⁵, L. Helary⁴, S. Hellman^{146a,146b}, D. Hellmich²⁰,
 C. Hensens¹¹, R.C.W. Henderson⁷¹, M. Henke^{58a}, A. Henrichs⁵⁴,
 A.M. Henriques Correia²⁹, S. Henrot-Versille¹¹⁵, F. Henry-Couannier⁸³, C. Hensel⁵⁴,
 T. Henß¹⁷⁴, C.M. Hernandez⁷, Y. Hernández Jiménez¹⁶⁷, R. Herrberg¹⁵,
 A.D. Hershenhorn¹⁵², G. Herten⁴⁸, R. Hertenberger⁹⁸, L. Hervas²⁹, N.P. Hessey¹⁰⁵,
 A. Hidvegi^{146a}, E. Higón-Rodríguez¹⁶⁷, D. Hill^{5,*}, J.C. Hill²⁷, N. Hill⁵, K.H. Hiller⁴¹,
 S. Hillert²⁰, S.J. Hillier¹⁷, I. Hinchliffe¹⁴, E. Hines¹²⁰, M. Hirose¹¹⁶, F. Hirsch⁴²,
 D. Hirschbuehl¹⁷⁴, J. Hobbs¹⁴⁸, N. Hod¹⁵³, M.C. Hodgkinson¹³⁹, P. Hodgson¹³⁹,
 A. Hoecker²⁹, M.R. Hoferkamp¹⁰³, J. Hoffman³⁹, D. Hoffmann⁸³, M. Hohlfeld⁸¹,
 M. Holder¹⁴¹, S.O. Holmgren^{146a}, T. Holy¹²⁷, J.L. Holzbauer⁸⁸, Y. Homma⁶⁷,
 T.M. Hong¹²⁰, L. Hooft van Huysduynen¹⁰⁸, T. Horazdovsky¹²⁷, C. Horn¹⁴³, S. Horner⁴⁸,
 K. Horton¹¹⁸, J-Y. Hostachy⁵⁵, S. Hou¹⁵¹, M.A. Houlden⁷³, A. Hoummada^{135a},
 J. Howarth⁸², D.F. Howell¹¹⁸, I. Hristova¹⁵, J. Hrivnac¹¹⁵, I. Hruska¹²⁵, T. Hryn'ova⁴,
 P.J. Hsu⁸¹, S.-C. Hsu¹⁴, G.S. Huang¹¹¹, Z. Hubacek¹²⁷, F. Hubaut⁸³, F. Huegging²⁰,
 T.B. Huffman¹¹⁸, E.W. Hughes³⁴, G. Hughes⁷¹, R.E. Hughes-Jones⁸², M. Huhtinen²⁹,
 P. Hurst⁵⁷, M. Hurwitz¹⁴, U. Husemann⁴¹, N. Huseynov^{65,o}, J. Huston⁸⁸, J. Huth⁵⁷,
 G. Iacobucci⁴⁹, G. Iakovidis⁹, M. Ibbotson⁸², I. Ibragimov¹⁴¹, R. Ichimiya⁶⁷,
 L. Iconomidou-Fayard¹¹⁵, J. Idarraga¹¹⁵, P. Iengo^{102a,102b}, O. Igonkina¹⁰⁵, Y. Ikegami⁶⁶,
 M. Ikeno⁶⁶, Y. Ilchenko³⁹, D. Iliadis¹⁵⁴, D. Imbault⁷⁸, M. Imori¹⁵⁵, T. Ince²⁰,
 J. Inigo-Golfin²⁹, P. Ioannou⁸, M. Iodice^{134a}, A. Irlles Quiles¹⁶⁷, A. Ishikawa⁶⁷,
 M. Ishino⁶⁸, R. Ishmukhametov³⁹, C. Issever¹¹⁸, S. Istin^{18a}, A.V. Ivashin¹²⁸,

W. Iwanski³⁸, H. Iwasaki⁶⁶, J.M. Izen⁴⁰, V. Izzo^{102a}, B. Jackson¹²⁰, J.N. Jackson⁷³,
 P. Jackson¹⁴³, M.R. Jaekel²⁹, V. Jain⁶¹, K. Jakobs⁴⁸, S. Jakobsen³⁵, J. Jakubek¹²⁷,
 D.K. Jana¹¹¹, E. Jankowski¹⁵⁸, E. Jansen⁷⁷, A. Jantsch⁹⁹, M. Janus²⁰, G. Jarlskog⁷⁹,
 L. Jeanty⁵⁷, K. Jelen³⁷, I. Jen-La Plante³⁰, P. Jenni²⁹, A. Jeremie⁴, P. Jež³⁵, S. Jézéquel⁴,
 M.K. Jha^{19a}, H. Ji¹⁷², W. Ji⁸¹, J. Jia¹⁴⁸, Y. Jiang^{32b}, M. Jimenez Belenguer⁴¹, G. Jin^{32b},
 S. Jin^{32a}, O. Jinnouchi¹⁵⁷, M.D. Joergensen³⁵, D. Joffe³⁹, L.G. Johansen¹³,
 M. Johansen^{146a,146b}, K.E. Johansson^{146a}, P. Johansson¹³⁹, S. Johnert⁴¹, K.A. Johns⁶,
 K. Jon-And^{146a,146b}, G. Jones⁸², R.W.L. Jones⁷¹, T.W. Jones⁷⁷, T.J. Jones⁷³,
 O. Jonsson²⁹, C. Joram²⁹, P.M. Jorge^{124a,b}, J. Joseph¹⁴, T. Jovin^{12b}, X. Ju¹³⁰,
 C.A. Jung⁴², V. Juranek¹²⁵, P. Jussel⁶², A. Juste Rozas¹¹, V.V. Kabachenko¹²⁸,
 S. Kabana¹⁶, M. Kaci¹⁶⁷, A. Kaczmarska³⁸, P. Kadlecik³⁵, M. Kado¹¹⁵, H. Kagan¹⁰⁹,
 M. Kagan⁵⁷, S. Kaiser⁹⁹, E. Kajomovitz¹⁵², S. Kalinin¹⁷⁴, L.V. Kalinovskaya⁶⁵,
 S. Kama³⁹, N. Kanaya¹⁵⁵, M. Kaneda²⁹, T. Kanno¹⁵⁷, V.A. Kantserov⁹⁶, J. Kanzaki⁶⁶,
 B. Kaplan¹⁷⁵, A. Kapliy³⁰, J. Kaplon²⁹, D. Kar⁴³, M. Karagoz¹¹⁸, M. Karnevskiy⁴¹,
 K. Karr⁵, V. Kartvelishvili⁷¹, A.N. Karyukhin¹²⁸, L. Kashif¹⁷², G. Kasieczka^{58b},
 A. Kasmi³⁹, R.D. Kass¹⁰⁹, A. Kastanas¹³, M. Kataoka⁴, Y. Kataoka¹⁵⁵, E. Katsoufis⁹,
 J. Katzy⁴¹, V. Kaushik⁶, K. Kawagoe⁶⁷, T. Kawamoto¹⁵⁵, G. Kawamura⁸¹, M.S. Kayl¹⁰⁵,
 V.A. Kazanin¹⁰⁷, M.Y. Kazarinov⁶⁵, J.R. Keates⁸², R. Keeler¹⁶⁹, R. Kehoe³⁹, M. Keil⁵⁴,
 G.D. Kekelidze⁶⁵, M. Kelly⁸², J. Kennedy⁹⁸, C.J. Kenney¹⁴³, M. Kenyon⁵³, O. Kepka¹²⁵,
 N. Kerschen²⁹, B.P. Kerševan⁷⁴, S. Kersten¹⁷⁴, K. Kessoku¹⁵⁵, J. Keung¹⁵⁸,
 M. Khakzad²⁸, F. Khalil-zada¹⁰, H. Khandanyan¹⁶⁵, A. Khanov¹¹², D. Kharchenko⁶⁵,
 A. Khodinov⁹⁶, A.G. Kholodenko¹²⁸, A. Khomich^{58a}, T.J. Kho²⁷, G. Khoriali²⁰,
 A. Khoroshilov¹⁷⁴, N. Khovanskiy⁶⁵, V. Khovanskiy⁹⁵, E. Khramov⁶⁵, J. Khubua^{51b},
 H. Kim⁷, M.S. Kim², P.C. Kim¹⁴³, S.H. Kim¹⁶⁰, N. Kimura¹⁷⁰, O. Kind¹⁵, B.T. King⁷³,
 M. King⁶⁷, R.S.B. King¹¹⁸, J. Kirk¹²⁹, L.E. Kirsch²², A.E. Kiryunin⁹⁹, T. Kishimoto⁶⁷,
 D. Kisielewska³⁷, T. Kittelmann¹²³, A.M. Kiver¹²⁸, E. Kladiva^{144b},
 J. Klaiber-Lodewigs⁴², M. Klein⁷³, U. Klein⁷³, K. Kleinknecht⁸¹, M. Klemetti⁸⁵,
 A. Klier¹⁷¹, A. Klimentov²⁴, R. Klingenberg⁴², E.B. Klinkby³⁵, T. Klioutchnikova²⁹,
 P.F. Klok¹⁰⁴, S. Klous¹⁰⁵, E.-E. Kluge^{58a}, T. Kluge⁷³, P. Kluit¹⁰⁵, S. Kluth⁹⁹,
 N.S. Knecht¹⁵⁸, E. Kneringer⁶², J. Knobloch²⁹, E.B.F.G. Knoops⁸³, A. Knue⁵⁴,
 B.R. Ko⁴⁴, T. Kobayashi¹⁵⁵, M. Kobel⁴³, M. Kocian¹⁴³, A. Kocnar¹¹³, P. Kodys¹²⁶,
 K. Köneke²⁹, A.C. König¹⁰⁴, S. Koenig⁸¹, L. Köpke⁸¹, F. Koetsveld¹⁰⁴, P. Koevesarki²⁰,
 T. Koffas²⁸, E. Koffeman¹⁰⁵, F. Kohn⁵⁴, Z. Kohout¹²⁷, T. Kohriki⁶⁶, T. Koi¹⁴³,
 T. Kokott²⁰, G.M. Kolachev¹⁰⁷, H. Kolanoski¹⁵, V. Kolesnikov⁶⁵, I. Koletsou^{89a},
 J. Koll⁸⁸, D. Kollar²⁹, M. Kollefrath⁴⁸, S.D. Kolya⁸², A.A. Komar⁹⁴, Y. Komori¹⁵⁵,
 T. Kondo⁶⁶, T. Kono^{41,p}, A.I. Kononov⁴⁸, R. Konoplich^{108,q}, N. Konstantinidis⁷⁷,
 A. Kootz¹⁷⁴, S. Koperny³⁷, S.V. Kopikov¹²⁸, K. Korcyl³⁸, K. Kordas¹⁵⁴, V. Koreshev¹²⁸,
 A. Korn¹¹⁸, A. Korol¹⁰⁷, I. Korolkov¹¹, E.V. Korolkova¹³⁹, V.A. Korotkov¹²⁸,
 O. Kortner⁹⁹, S. Kortner⁹⁹, V.V. Kostyukhin²⁰, M.J. Kotamäki²⁹, S. Kotov⁹⁹,
 V.M. Kotov⁶⁵, A. Kotwal⁴⁴, C. Kourkoumelis⁸, V. Kouskoura¹⁵⁴, A. Koutsman¹⁰⁵,
 R. Kowalewski¹⁶⁹, T.Z. Kowalski³⁷, W. Kozanecki¹³⁶, A.S. Kozhin¹²⁸, V. Kral¹²⁷,
 V.A. Kramarenko⁹⁷, G. Kramberger⁷⁴, M.W. Krasny⁷⁸, A. Krasznahorkay¹⁰⁸, J. Kraus⁸⁸,
 J.K. Kraus²⁰, A. Kreisel¹⁵³, F. Krejci¹²⁷, J. Kretzschmar⁷³, N. Krieger⁵⁴, P. Krieger¹⁵⁸,

K. Kroeninger⁵⁴, H. Kroha⁹⁹, J. Kroll¹²⁰, J. Kroseberg²⁰, J. Krstic^{12a}, U. Kruchonak⁶⁵,
 H. Krüger²⁰, T. Kruker¹⁶, Z.V. Krumshteyn⁶⁵, A. Kruth²⁰, T. Kubota⁸⁶, S. Kuehn⁴⁸,
 A. Kugel^{58c}, T. Kuhl⁴¹, D. Kuhn⁶², V. Kukhtin⁶⁵, Y. Kulchitsky⁹⁰, S. Kuleshov^{31b},
 C. Kummer⁹⁸, M. Kuna⁷⁸, N. Kundu¹¹⁸, J. Kunkle¹²⁰, A. Kupco¹²⁵, H. Kurashige⁶⁷,
 M. Kurata¹⁶⁰, Y.A. Kurochkin⁹⁰, V. Kus¹²⁵, M. Kuze¹⁵⁷, J. Kvita²⁹, R. Kwee¹⁵,
 A. La Rosa¹⁷², L. La Rotonda^{36a,36b}, L. Labarga⁸⁰, J. Labbe⁴, S. Lablak^{135a},
 C. Lacasta¹⁶⁷, F. Lacava^{132a,132b}, H. Lacker¹⁵, D. Lacour⁷⁸, V.R. Lacuesta¹⁶⁷,
 E. Ladygin⁶⁵, R. Lafaye⁴, B. Laforge⁷⁸, T. Lagouri⁸⁰, S. Lai⁴⁸, E. Laisne⁵⁵,
 M. Lamanna²⁹, C.L. Lampen⁶, W. Lampl⁶, E. Lancon¹³⁶, U. Landgraf⁴⁸,
 M.P.J. Landon⁷⁵, H. Landsman¹⁵², J.L. Lane⁸², C. Lange⁴¹, A.J. Lankford¹⁶³, F. Lanni²⁴,
 K. Lantzschi¹⁷⁴, S. Laplace⁷⁸, C. Lapoire²⁰, J.F. Laporte¹³⁶, T. Lari^{89a}, A.V. Larionov¹²⁸,
 A. Larner¹¹⁸, C. Lasseur²⁹, M. Lassnig²⁹, P. Laurelli⁴⁷, W. Lavrijsen¹⁴, P. Laycock⁷³,
 A.B. Lazarev⁶⁵, O. Le Dortz⁷⁸, E. Le Guirriec⁸³, C. Le Maner¹⁵⁸, E. Le Menedeu¹³⁶,
 C. Lebel⁹³, T. LeCompte⁵, F. Ledroit-Guillon⁵⁵, H. Lee¹⁰⁵, J.S.H. Lee¹¹⁶, S.C. Lee¹⁵¹,
 L. Lee¹⁷⁵, M. Lefebvre¹⁶⁹, M. Legendre¹³⁶, A. Leger⁴⁹, B.C. LeGeyt¹²⁰, F. Legger⁹⁸,
 C. Leggett¹⁴, M. Lehmacher²⁰, G. Lehmann Miotto²⁹, X. Lei⁶, M.A.L. Leite^{23d},
 R. Leitner¹²⁶, D. Lellouch¹⁷¹, M. Leltchouk³⁴, B. Lemmer⁵⁴, V. Lendermann^{58a},
 K.J.C. Leney^{145b}, T. Lenz¹⁰⁵, G. Lenzen¹⁷⁴, B. Lenzi²⁹, K. Leonhardt⁴³, S. Leontsinis⁹,
 C. Leroy⁹³, J-R. Lessard¹⁶⁹, J. Lesser^{146a}, C.G. Lester²⁷, A. Leung Fook Cheong¹⁷²,
 J. Levêque⁴, D. Levin⁸⁷, L.J. Levinson¹⁷¹, M.S. Levitski¹²⁸, A. Lewis¹¹⁸, G.H. Lewis¹⁰⁸,
 A.M. Leyko²⁰, M. Leyton¹⁵, B. Li⁸³, H. Li¹⁷², S. Li^{32b,d}, X. Li⁸⁷, Z. Liang³⁹, Z. Liang^{118,r},
 H. Liao³³, B. Liberti^{133a}, P. Lichard²⁹, M. Lichtnecker⁹⁸, K. Lie¹⁶⁵, W. Liebig¹³,
 R. Lifshitz¹⁵², J.N. Lilley¹⁷, C. Limbach²⁰, A. Limosani⁸⁶, M. Limper⁶³, S.C. Lin^{151,s},
 F. Linde¹⁰⁵, J.T. Linnemann⁸⁸, E. Lipeles¹²⁰, L. Lipinsky¹²⁵, A. Lipniacka¹³,
 T.M. Liss¹⁶⁵, D. Lissauer²⁴, A. Lister⁴⁹, A.M. Litke¹³⁷, C. Liu²⁸, D. Liu^{151,t}, H. Liu⁸⁷,
 J.B. Liu⁸⁷, M. Liu^{32b}, S. Liu², Y. Liu^{32b}, M. Livan^{119a,119b}, S.S.A. Livermore¹¹⁸,
 A. Lleres⁵⁵, J. Llorente Merino⁸⁰, S.L. Lloyd⁷⁵, E. Lobodzinska⁴¹, P. Loch⁶,
 W.S. Lockman¹³⁷, T. Loddenkoetter²⁰, F.K. Loebinger⁸², A. Loginov¹⁷⁵, C.W. Loh¹⁶⁸,
 T. Lohse¹⁵, K. Lohwasser⁴⁸, M. Lokajicek¹²⁵, J. Loken¹¹⁸, V.P. Lombardo⁴, R.E. Long⁷¹,
 L. Lopes^{124a,b}, D. Lopez Mateos⁵⁷, M. Losada¹⁶², P. Loscutoff¹⁴, F. Lo Sterzo^{132a,132b},
 M.J. Losty^{159a}, X. Lou⁴⁰, A. Lounis¹¹⁵, K.F. Loureiro¹⁶², J. Love²¹, P.A. Love⁷¹,
 A.J. Lowe^{143,f}, F. Lu^{32a}, H.J. Lubatti¹³⁸, C. Luci^{132a,132b}, A. Lucotte⁵⁵, A. Ludwig⁴³,
 D. Ludwig⁴¹, I. Ludwig⁴⁸, J. Ludwig⁴⁸, F. Luehring⁶¹, G. Luijckx¹⁰⁵, D. Lumb⁴⁸,
 L. Luminari^{132a}, E. Lund¹¹⁷, B. Lund-Jensen¹⁴⁷, B. Lundberg⁷⁹, J. Lundberg^{146a,146b},
 J. Lundquist³⁵, M. Lungwitz⁸¹, A. Lupi^{122a,122b}, G. Lutz⁹⁹, D. Lynn²⁴, J. Lys¹⁴,
 E. Lytken⁷⁹, H. Ma²⁴, L.L. Ma¹⁷², J.A. Macana Goia⁹³, G. Maccarrone⁴⁷,
 A. Macchiolo⁹⁹, B. Maček⁷⁴, J. Machado Miguens^{124a}, R. Mackeprang³⁵, R.J. Madaras¹⁴,
 W.F. Mader⁴³, R. Maenner^{58c}, T. Maeno²⁴, P. Mättig¹⁷⁴, S. Mättig⁴¹, L. Magnoni²⁹,
 E. Magradze⁵⁴, Y. Mahalalel¹⁵³, K. Mahboubi⁴⁸, G. Mahout¹⁷, C. Maiani^{132a,132b},
 C. Maidantchik^{23a}, A. Maio^{124a,b}, S. Majewski²⁴, Y. Makida⁶⁶, N. Makovec¹¹⁵, P. Mal¹³⁶,
 Pa. Malecki³⁸, P. Malecki³⁸, V.P. Maleev¹²¹, F. Malek⁵⁵, U. Mallik⁶³, D. Malon⁵,
 C. Malone¹⁴³, S. Maltezos⁹, V. Malyshev¹⁰⁷, S. Malyukov²⁹, R. Mameghani⁹⁸,
 J. Mamuzic^{12b}, A. Manabe⁶⁶, L. Mandelli^{89a}, I. Mandić⁷⁴, R. Mandrysch¹⁵,

J. Maneira^{124a}, P.S. Mangear⁸⁸, I.D. Manjavidze⁶⁵, A. Mann⁵⁴, P.M. Manning¹³⁷,
A. Manousakis-Katsikakis⁸, B. Mansoulie¹³⁶, A. Manz⁹⁹, A. Mapelli²⁹, L. Mapelli²⁹,
L. March⁸⁰, J.F. Marchand²⁹, F. Marchese^{133a,133b}, G. Marchiori⁷⁸, M. Marcisovsky¹²⁵,
A. Marin^{21,*}, C.P. Marino¹⁶⁹, F. Marroquim^{23a}, R. Marshall⁸², Z. Marshall²⁹,
F.K. Martens¹⁵⁸, S. Marti-Garcia¹⁶⁷, A.J. Martin¹⁷⁵, B. Martin²⁹, B. Martin⁸⁸,
F.F. Martin¹²⁰, J.P. Martin⁹³, Ph. Martin⁵⁵, T.A. Martin¹⁷, V.J. Martin⁴⁵,
B. Martin dit Latour⁴⁹, S. Martin-Haugh¹⁴⁹, M. Martinez¹¹, V. Martinez Outschoorn⁵⁷,
A.C. Martyniuk⁸², M. Marx⁸², F. Marzano^{132a}, A. Marzin¹¹¹, L. Masetti⁸¹,
T. Mashimo¹⁵⁵, R. Mashinistov⁹⁴, J. Masik⁸², A.L. Maslennikov¹⁰⁷, I. Massa^{19a,19b},
G. Massaro¹⁰⁵, N. Massol⁴, P. Mastrandrea^{132a,132b}, A. Mastroberardino^{36a,36b},
T. Masubuchi¹⁵⁵, M. Mathes²⁰, P. Matricon¹¹⁵, H. Matsumoto¹⁵⁵, H. Matsunaga¹⁵⁵,
T. Matsushita⁶⁷, C. Mattravers^{118,c}, J.M. Maugain²⁹, S.J. Maxfield⁷³, D.A. Maximov¹⁰⁷,
E.N. May⁵, A. Mayne¹³⁹, R. Mazini¹⁵¹, M. Mazur²⁰, M. Mazzanti^{89a}, E. Mazzoni^{122a,122b},
S.P. Mc Kee⁸⁷, A. McCarn¹⁶⁵, R.L. McCarthy¹⁴⁸, T.G. McCarthy²⁸, N.A. McCubbin¹²⁹,
K.W. McFarlane⁵⁶, J.A. Mcfayden¹³⁹, H. McGlone⁵³, G. Mchedlidze^{51b}, R.A. McLaren²⁹,
T. McLaughlan¹⁷, S.J. McMahan¹²⁹, R.A. McPherson^{169,j}, A. Meade⁸⁴, J. Mechnich¹⁰⁵,
M. Mechtel¹⁷⁴, M. Medinnis⁴¹, R. Meera-Lebbai¹¹¹, T. Meguro¹¹⁶, R. Mehdiyev⁹³,
S. Mehlhase³⁵, A. Mehta⁷³, K. Meier^{58a}, J. Meinhardt⁴⁸, B. Meirose⁷⁹, C. Melachrinou³⁰,
B.R. Mellado Garcia¹⁷², L. Mendoza Navas¹⁶², Z. Meng^{151,t}, A. Mengarelli^{19a,19b},
S. Menke⁹⁹, C. Menot²⁹, E. Meoni¹¹, K.M. Mercurio⁵⁷, P. Mermod¹¹⁸, L. Merola^{102a,102b},
C. Meroni^{89a}, F.S. Merritt³⁰, A. Messina²⁹, J. Metcalfe¹⁰³, A.S. Mete⁶⁴, C. Meyer⁸¹,
J-P. Meyer¹³⁶, J. Meyer¹⁷³, J. Meyer⁵⁴, T.C. Meyer²⁹, W.T. Meyer⁶⁴, J. Miao^{32d},
S. Michal²⁹, L. Micu^{25a}, R.P. Middleton¹²⁹, P. Miele²⁹, S. Migas⁷³, L. Mijović⁴¹,
G. Mikenberg¹⁷¹, M. Mikestikova¹²⁵, M. Mikuz⁷⁴, D.W. Miller³⁰, R.J. Miller⁸⁸,
W.J. Mills¹⁶⁸, C. Mills⁵⁷, A. Milov¹⁷¹, D.A. Milstead^{146a,146b}, D. Milstein¹⁷¹,
A.A. Minaenko¹²⁸, M. Miñano¹⁶⁷, I.A. Minashvili⁶⁵, A.I. Mincer¹⁰⁸, B. Mindur³⁷,
M. Mineev⁶⁵, Y. Ming¹³⁰, L.M. Mir¹¹, G. Mirabelli^{132a}, L. Miralles Verge¹¹,
A. Misiejuk⁷⁶, J. Mitrevski¹³⁷, G.Y. Mitrofanov¹²⁸, V.A. Mitsou¹⁶⁷, S. Mitsui⁶⁶,
P.S. Miyagawa¹³⁹, K. Miyazaki⁶⁷, J.U. Mjörnmark⁷⁹, T. Moa^{146a,146b}, P. Mockett¹³⁸,
S. Moed⁵⁷, V. Moeller²⁷, K. Mönig⁴¹, N. Möser²⁰, S. Mohapatra¹⁴⁸, W. Mohr⁴⁸,
S. Mohrdieck-Möck⁹⁹, A.M. Moisseev^{128,*}, R. Moles-Valls¹⁶⁷, J. Molina-Perez²⁹,
J. Monk⁷⁷, E. Monnier⁸³, S. Montesano^{89a,89b}, F. Monticelli⁷⁰, S. Monzani^{19a,19b},
R.W. Moore², G.F. Moorhead⁸⁶, C. Mora Herrera⁴⁹, A. Moraes⁵³, N. Morange¹³⁶,
J. Morel⁵⁴, G. Morello^{36a,36b}, D. Moreno⁸¹, M. Moreno Llácer¹⁶⁷, P. Morettini^{50a},
M. Morii⁵⁷, J. Morin⁷⁵, A.K. Morley²⁹, G. Mornacchi²⁹, S.V. Morozov⁹⁶, J.D. Morris⁷⁵,
L. Morvaj¹⁰¹, H.G. Moser⁹⁹, M. Mosidze^{51b}, J. Moss¹⁰⁹, R. Mount¹⁴³, E. Mountricha¹³⁶,
S.V. Mouraviev⁹⁴, E.J.W. Moyses⁸⁴, M. Mudrinic^{12b}, F. Mueller^{58a}, J. Mueller¹²³,
K. Mueller²⁰, T.A. Müller⁹⁸, D. Muenstermann²⁹, A. Muir¹⁶⁸, Y. Munwes¹⁵³,
W.J. Murray¹²⁹, I. Mussche¹⁰⁵, E. Musto^{102a,102b}, A.G. Myagkov¹²⁸, M. Myska¹²⁵,
J. Nadal¹¹, K. Nagai¹⁶⁰, K. Nagano⁶⁶, Y. Nagasaka⁶⁰, A.M. Nairz²⁹, Y. Nakahama²⁹,
K. Nakamura¹⁵⁵, T. Nakamura¹⁵⁵, I. Nakano¹¹⁰, G. Nanava²⁰, A. Napier¹⁶¹, M. Nash^{77,c},
N.R. Nation²¹, T. Nattermann²⁰, T. Naumann⁴¹, G. Navarro¹⁶², H.A. Neal⁸⁷, E. Nebot⁸⁰,
P.Yu. Nechaeva⁹⁴, A. Negri^{119a,119b}, G. Negri²⁹, S. Nektarijevic⁴⁹, A. Nelson¹⁶³,

S. Nelson¹⁴³, T.K. Nelson¹⁴³, S. Nemecek¹²⁵, P. Nemethy¹⁰⁸, A.A. Nepomuceno^{23a},
M. Nessi^{29,u}, S.Y. Nesterov¹²¹, M.S. Neubauer¹⁶⁵, A. Neusiedl⁸¹, R.M. Neves¹⁰⁸,
P. Nevski²⁴, P.R. Newman¹⁷, V. Nguyen Thi Hong¹³⁶, R.B. Nickerson¹¹⁸,
R. Nicolaidou¹³⁶, L. Nicolas¹³⁹, B. Nicquevert²⁹, F. Niedercorn¹¹⁵, J. Nielsen¹³⁷,
T. Niinikoski²⁹, N. Nikiforou³⁴, A. Nikiforov¹⁵, V. Nikolaenko¹²⁸, K. Nikolaev⁶⁵,
I. Nikolic-Audit⁷⁸, K. Nikolics⁴⁹, K. Nikolopoulos²⁴, H. Nilsen⁴⁸, P. Nilsson⁷,
Y. Ninomiya¹⁵⁵, A. Nisati^{132a}, T. Nishiyama⁶⁷, R. Nisius⁹⁹, L. Nodulman⁵,
M. Nomachi¹¹⁶, I. Nomidis¹⁵⁴, M. Nordberg²⁹, B. Nordkvist^{146a,146b}, P.R. Norton¹²⁹,
J. Novakova¹²⁶, M. Nozaki⁶⁶, L. Nozka¹¹³, I.M. Nugent^{159a}, A.-E. Nuncio-Quiroz²⁰,
G. Nunes Hanninger⁸⁶, T. Nunnemann⁹⁸, E. Nurse⁷⁷, T. Nyman²⁹, B.J. O'Brien⁴⁵,
S.W. O'Neale^{17,*}, D.C. O'Neil¹⁴², V. O'Shea⁵³, F.G. Oakham^{28,e}, H. Oberlack⁹⁹,
J. Ocariz⁷⁸, A. Ochi⁶⁷, S. Oda¹⁵⁵, S. Odaka⁶⁶, J. Odier⁸³, H. Ogren⁶¹, A. Oh⁸²,
S.H. Oh⁴⁴, C.C. Ohm^{146a,146b}, T. Ohshima¹⁰¹, H. Ohshita¹⁴⁰, T. Ohsugi⁵⁹, S. Okada⁶⁷,
H. Okawa¹⁶³, Y. Okumura¹⁰¹, T. Okuyama¹⁵⁵, M. Olcese^{50a}, A.G. Olchevski⁶⁵,
M. Oliveira^{124a,h}, D. Oliveira Damazio²⁴, E. Oliver Garcia¹⁶⁷, D. Olivito¹²⁰,
A. Olszewski³⁸, J. Olszowska³⁸, C. Omachi⁶⁷, A. Onofre^{124a,v}, P.U.E. Onyisi³⁰,
C.J. Oram^{159a}, M.J. Oreglia³⁰, Y. Oren¹⁵³, D. Orestano^{134a,134b}, I. Orlov¹⁰⁷,
C. Oropeza Barrera⁵³, R.S. Orr¹⁵⁸, B. Osculati^{50a,50b}, R. Ospanov¹²⁰, C. Osuna¹¹,
G. Otero y Garzon²⁶, J.P. Ottersbach¹⁰⁵, M. Ouchrif^{135d}, F. Ould-Saada¹¹⁷, A. Ouraou¹³⁶,
Q. Ouyang^{32a}, M. Owen⁸², S. Owen¹³⁹, V.E. Ozcan^{18a}, N. Ozturk⁷, A. Pacheco Pages¹¹,
C. Padilla Aranda¹¹, S. Pagan Griso¹⁴, E. Paganis¹³⁹, F. Paige²⁴, K. Pajchel¹¹⁷,
G. Palacino^{159b}, C.P. Palestini⁶, S. Palestini²⁹, D. Pallin³³, A. Palma^{124a,b}, J.D. Palmer¹⁷,
Y.B. Pan¹⁷², E. Panagiotopoulou⁹, B. Panes^{31a}, N. Panikashvili⁸⁷, S. Panitkin²⁴,
D. Pantea^{25a}, M. Panuskova¹²⁵, V. Paolone¹²³, A. Papadelis^{146a}, Th.D. Papadopoulou⁹,
A. Paramonov⁵, W. Park^{24,w}, M.A. Parker²⁷, F. Parodi^{50a,50b}, J.A. Parsons³⁴,
U. Parzefall⁴⁸, E. Pasqualucci^{132a}, A. Passeri^{134a}, F. Pastore^{134a,134b}, Fr. Pastore⁷⁶,
G. Pásztor^{49,x}, S. Patariaia¹⁷⁴, N. Patel¹⁵⁰, J.R. Pater⁸², S. Patricelli^{102a,102b}, T. Pauly²⁹,
M. Pecsý^{144a}, M.I. Pedraza Morales¹⁷², S.V. Peleganchuk¹⁰⁷, H. Peng^{32b}, R. Pengo²⁹,
A. Penson³⁴, J. Penwell⁶¹, M. Perantoni^{23a}, K. Perez^{34,y}, T. Perez Cavalcanti⁴¹,
E. Perez Codina¹¹, M.T. Pérez García-Estañ¹⁶⁷, V. Perez Reale³⁴, L. Perini^{89a,89b},
H. Pernegger²⁹, R. Perrino^{72a}, P. Perrodo⁴, S. Persebe^{3a}, V.D. Peshekhonov⁶⁵,
B.A. Petersen²⁹, J. Petersen²⁹, T.C. Petersen³⁵, E. Petit⁸³, A. Petridis¹⁵⁴, C. Petridou¹⁵⁴,
E. Petrolo^{132a}, F. Petrucci^{134a,134b}, D. Petschull⁴¹, M. Petteni¹⁴², R. Pezoa^{31b}, A. Phan⁸⁶,
A.W. Phillips²⁷, P.W. Phillips¹²⁹, G. Piacquadio²⁹, E. Piccaro⁷⁵, M. Piccinini^{19a,19b},
S.M. Piec⁴¹, R. Piegai²⁶, J.E. Pilcher³⁰, A.D. Pilkington⁸², J. Pina^{124a,b},
M. Pinamonti^{164a,164c}, A. Pinder¹¹⁸, J.L. Pinfold², J. Ping^{32c}, B. Pinto^{124a,b}, O. Pirotte²⁹,
C. Pizio^{89a,89b}, R. Placakyte⁴¹, M. Plamondon¹⁶⁹, M.-A. Pleier²⁴, A.V. Pleskach¹²⁸,
A. Poblaguev²⁴, S. Poddar^{58a}, F. Podlyski³³, L. Poggioli¹¹⁵, T. Poghosyan²⁰, M. Pohl⁴⁹,
F. Polci⁵⁵, G. Polesello^{119a}, A. Policicchio¹³⁸, A. Polini^{19a}, J. Poll⁷⁵, V. Polychronakos²⁴,
D.M. Pomarede¹³⁶, D. Pomeroy²², K. Pommès²⁹, L. Pontecorvo^{132a}, B.G. Pope⁸⁸,
G.A. Popeneciu^{25a}, D.S. Popovic^{12a}, A. Poppleton²⁹, X. Portell Bueso²⁹, C. Posch²¹,
G.E. Pospelov⁹⁹, S. Pospisil¹²⁷, I.N. Potrap⁹⁹, C.J. Potter¹⁴⁹, C.T. Potter¹¹⁴,
G. Poulard²⁹, J. Poveda¹⁷², R. Prabhu⁷⁷, P. Pralavorio⁸³, S. Prasad⁵⁷, R. Pravahan⁷,

S. Prell⁶⁴, K. Pretzl¹⁶, L. Pribyl²⁹, D. Price⁶¹, L.E. Price⁵, M.J. Price²⁹, P.M. Prichard⁷³, D. Prieur¹²³, M. Primavera^{72a}, K. Prokofiev¹⁰⁸, F. Prokoshin^{31b}, S. Protopopescu²⁴, J. Proudfoot⁵, X. Prudent⁴³, H. Przysiezniak⁴, S. Psoroulas²⁰, E. Ptacek¹¹⁴, E. Pueschel⁸⁴, J. Purdham⁸⁷, M. Purohit^{24,w}, P. Puze¹¹⁵, Y. Pylypchenko¹¹⁷, J. Qian⁸⁷, Z. Qian⁸³, Z. Qin⁴¹, A. Quadt⁵⁴, D.R. Quarrie¹⁴, W.B. Quayle¹⁷², F. Quinonez^{31a}, M. Raas¹⁰⁴, V. Radescu^{58b}, B. Radics²⁰, T. Rador^{18a}, F. Ragusa^{89a,89b}, G. Rahal¹⁷⁷, A.M. Rahimi¹⁰⁹, D. Rahm²⁴, S. Rajagopalan²⁴, M. Rammensee⁴⁸, M. Rammes¹⁴¹, M. Ramstedt^{146a,146b}, A.S. Randle-Conde³⁹, K. Randrianarivony²⁸, P.N. Ratoff⁷¹, F. Rauscher⁹⁸, E. Rauter⁹⁹, M. Raymond²⁹, A.L. Read¹¹⁷, D.M. Rebutzi^{119a,119b}, A. Redelbach¹⁷³, G. Redlinger²⁴, R. Reece¹²⁰, K. Reeves⁴⁰, A. Reichold¹⁰⁵, E. Reinherz-Aronis¹⁵³, A. Reinsch¹¹⁴, I. Reisinger⁴², D. Reljic^{12a}, C. Rembser²⁹, Z.L. Ren¹⁵¹, A. Renaud¹¹⁵, P. Renkel³⁹, M. Rescigno^{132a}, S. Resconi^{89a}, B. Resende¹³⁶, P. Reznicek⁹⁸, R. Rezvani¹⁵⁸, A. Richards⁷⁷, R. Richter⁹⁹, E. Richter-Was^{4,z}, M. Ridel⁷⁸, M. Rijpstra¹⁰⁵, M. Rijssenbeek¹⁴⁸, A. Rimoldi^{119a,119b}, L. Rinaldi^{19a}, R.R. Rios³⁹, I. Riu¹¹, G. Rivoltella^{89a,89b}, F. Rizatdinova¹¹², E. Rizvi⁷⁵, S.H. Robertson^{85,j}, A. Robichaud-Veronneau¹¹⁸, D. Robinson²⁷, J.E.M. Robinson⁷⁷, M. Robinson¹¹⁴, A. Robson⁵³, J.G. Rocha de Lima¹⁰⁶, C. Roda^{122a,122b}, D. Roda Dos Santos²⁹, S. Rodier⁸⁰, D. Rodriguez¹⁶², A. Roe⁵⁴, S. Roe²⁹, O. Røhne¹¹⁷, V. Rojo¹, S. Rolli¹⁶¹, A. Romaniouk⁹⁶, M. Romano^{19a,19b}, V.M. Romanov⁶⁵, G. Romeo²⁶, L. Roos⁷⁸, E. Ros¹⁶⁷, S. Rosati^{132a,132b}, K. Rosbach⁴⁹, A. Rose¹⁴⁹, M. Rose⁷⁶, G.A. Rosenbaum¹⁵⁸, E.I. Rosenberg⁶⁴, P.L. Rosendahl¹³, O. Rosenthal¹⁴¹, L. Rossetti⁴⁹, V. Rossetti¹¹, E. Rossi^{132a,132b}, L.P. Rossi^{50a}, M. Rotaru^{25a}, I. Roth¹⁷¹, J. Rothberg¹³⁸, D. Rousseau¹¹⁵, C.R. Royon¹³⁶, A. Rozanov⁸³, Y. Rozen¹⁵², X. Ruan¹¹⁵, I. Rubinskiy⁴¹, B. Ruckert⁹⁸, N. Ruckstuhl¹⁰⁵, V.I. Rud⁹⁷, C. Rudolph⁴³, G. Rudolph⁶², F. Rühr⁶, F. Ruggieri^{134a,134b}, A. Ruiz-Martinez⁶⁴, V. Rumiantsev^{91,*}, L. Romyantsev⁶⁵, K. Runge⁴⁸, O. Runolfsson²⁰, Z. Rurikova⁴⁸, N.A. Rusakovich⁶⁵, D.R. Rust⁶¹, J.P. Rutherford⁶, C. Ruwiedel¹⁴, P. Ruzicka¹²⁵, Y.F. Ryabov¹²¹, V. Ryadovikov¹²⁸, P. Ryan⁸⁸, M. Rybar¹²⁶, G. Rybkin¹¹⁵, N.C. Ryder¹¹⁸, S. Rzaeva¹⁰, A.F. Saavedra¹⁵⁰, I. Sadeh¹⁵³, H.F.W. Sadrozinski¹³⁷, R. Sadykov⁶⁵, F. Safai Tehrani^{132a,132b}, H. Sakamoto¹⁵⁵, G. Salamanna⁷⁵, A. Salamon^{133a}, M. Saleem¹¹¹, D. Salihagic⁹⁹, A. Salnikov¹⁴³, J. Salt¹⁶⁷, B.M. Salvachua Ferrando⁵, D. Salvatore^{36a,36b}, F. Salvatore¹⁴⁹, A. Salvucci¹⁰⁴, A. Salzburger²⁹, D. Sampsonidis¹⁵⁴, B.H. Samset¹¹⁷, A. Sanchez^{102a,102b}, H. Sandaker¹³, H.G. Sander⁸¹, M.P. Sanders⁹⁸, M. Sandhoff¹⁷⁴, T. Sandoval²⁷, C. Sandoval¹⁶², R. Sandstroem⁹⁹, S. Sandvoss¹⁷⁴, D.P.C. Sankey¹²⁹, A. Sansoni⁴⁷, C. Santamarina Rios⁸⁵, C. Santoni³³, R. Santonicio^{133a,133b}, H. Santos^{124a}, J.G. Saraiva^{124a,b}, T. Sarangi¹⁷², E. Sarkisyan-Grinbaum⁷, F. Sarri^{122a,122b}, G. Sartisohn¹⁷⁴, O. Sasaki⁶⁶, T. Sasaki⁶⁶, N. Sasao⁶⁸, I. Satsounkevitch⁹⁰, G. Sauvage⁴, E. Sauvan⁴, J.B. Sauvan¹¹⁵, P. Savard^{158,e}, V. Savinov¹²³, D.O. Savu²⁹, L. Sawyer^{24,l}, D.H. Saxon⁵³, L.P. Says³³, C. Sbarra^{19a}, A. Sbrizzi^{19a,19b}, O. Scallon⁹³, D.A. Scannicchio¹⁶³, J. Schaarschmidt¹¹⁵, P. Schacht⁹⁹, U. Schäfer⁸¹, S. Schaepe²⁰, S. Schaetzel^{58b}, A.C. Schaffer¹¹⁵, D. Schaile⁹⁸, R.D. Schamberger¹⁴⁸, A.G. Schamov¹⁰⁷, V. Scharf^{58a}, V.A. Schegelsky¹²¹, D. Scheirich⁸⁷, M. Schernau¹⁶³, M.I. Scherzer¹⁴, C. Schiavi^{50a,50b}, J. Schieck⁹⁸, M. Schioppa^{36a,36b}, S. Schlenker²⁹, J.L. Schlereth⁵, E. Schmidt⁴⁸, K. Schmieden²⁰, C. Schmitt⁸¹,

S. Schmitt^{58b}, M. Schmitz²⁰, A. Schöning^{58b}, M. Schott²⁹, D. Schouten^{159a},
 J. Schovancova¹²⁵, M. Schram⁸⁵, C. Schroeder⁸¹, N. Schroer^{58c}, S. Schuh²⁹, G. Schuler²⁹,
 J. Schultes¹⁷⁴, H.-C. Schultz-Coulon^{58a}, H. Schulz¹⁵, J.W. Schumacher²⁰,
 M. Schumacher⁴⁸, B.A. Schumm¹³⁷, Ph. Schune¹³⁶, C. Schwanenberger⁸²,
 A. Schwartzman¹⁴³, Ph. Schwemling⁷⁸, R. Schwienhorst⁸⁸, R. Schwierz⁴³,
 J. Schwindling¹³⁶, T. Schwindt²⁰, W.G. Scott¹²⁹, J. Searcy¹¹⁴, G. Sedov⁴¹, E. Sedykh¹²¹,
 E. Segura¹¹, S.C. Seidel¹⁰³, A. Seiden¹³⁷, F. Seifert⁴³, J.M. Seixas^{23a}, G. Sekhniaidze^{102a},
 D.M. Seliverstov¹²¹, B. Sellden^{146a}, G. Sellers⁷³, M. Seman^{144b}, N. Semprini-Cesari^{19a,19b},
 C. Serfon⁹⁸, L. Serin¹¹⁵, R. Seuster⁹⁹, H. Severini¹¹¹, M.E. Sevier⁸⁶, A. Sfyrla²⁹,
 E. Shabalina⁵⁴, M. Shamim¹¹⁴, L.Y. Shan^{32a}, J.T. Shank²¹, Q.T. Shao⁸⁶, M. Shapiro¹⁴,
 P.B. Shatalov⁹⁵, L. Shaver⁶, K. Shaw^{164a,164c}, D. Sherman¹⁷⁵, P. Sherwood⁷⁷,
 A. Shibata¹⁰⁸, H. Shichi¹⁰¹, S. Shimizu²⁹, M. Shimojima¹⁰⁰, T. Shin⁵⁶, A. Shmeleva⁹⁴,
 M.J. Shochet³⁰, D. Short¹¹⁸, M.A. Shupe⁶, P. Sicho¹²⁵, A. Sidoti^{132a,132b}, A. Siebel¹⁷⁴,
 F. Siegert⁴⁸, Dj. Sijacki^{12a}, O. Silbert¹⁷¹, J. Silva^{124a,b}, Y. Silver¹⁵³, D. Silverstein¹⁴³,
 S.B. Silverstein^{146a}, V. Simak¹²⁷, O. Simard¹³⁶, Lj. Simic^{12a}, S. Simion¹¹⁵, B. Simmons⁷⁷,
 M. Simonyan³⁵, P. Sinervo¹⁵⁸, N.B. Sinev¹¹⁴, V. Sipica¹⁴¹, G. Siragusa¹⁷³, A. Sircar²⁴,
 A.N. Sisakyan⁶⁵, S.Yu. Sivoklokov⁹⁷, J. Sjölin^{146a,146b}, T.B. Sjursen¹³, L.A. Skinnari¹⁴,
 H.P. Skottowe⁵⁷, K. Skovpen¹⁰⁷, P. Skubic¹¹¹, N. Skvorodnev²², M. Slater¹⁷,
 T. Slavicek¹²⁷, K. Sliwa¹⁶¹, J. Sloper²⁹, V. Smakhtin¹⁷¹, S.Yu. Smirnov⁹⁶,
 L.N. Smirnova⁹⁷, O. Smirnova⁷⁹, B.C. Smith⁵⁷, D. Smith¹⁴³, K.M. Smith⁵³,
 M. Smizanska⁷¹, K. Smolek¹²⁷, A.A. Snesarev⁹⁴, S.W. Snow⁸², J. Snow¹¹¹,
 J. Snuverink¹⁰⁵, S. Snyder²⁴, M. Soares^{124a}, R. Sobie^{169,j}, J. Sodomka¹²⁷, A. Soffer¹⁵³,
 C.A. Solans¹⁶⁷, M. Solar¹²⁷, J. Solc¹²⁷, E. Soldatov⁹⁶, U. Soldevila¹⁶⁷,
 E. Solfaroli Camillocci^{132a,132b}, A.A. Solodkov¹²⁸, O.V. Solovyanov¹²⁸, J. Sondericker²⁴,
 N. Soni², V. Sopko¹²⁷, B. Sopko¹²⁷, M. Sosebee⁷, R. Soualah^{164a,164c}, A. Soukharev¹⁰⁷,
 S. Spagnolo^{72a,72b}, F. Spanò⁷⁶, R. Spighi^{19a}, G. Spigo²⁹, F. Spila^{132a,132b}, E. Spiriti^{134a},
 R. Spiwoks²⁹, M. Spousta¹²⁶, T. Spreitzer¹⁵⁸, B. Spurlock⁷, R.D. St. Denis⁵³, T. Stahl¹⁴¹,
 J. Stahlman¹²⁰, R. Stamen^{58a}, E. Stanecka²⁹, R.W. Stanek⁵, C. Stanescu^{134a},
 S. Stapnes¹¹⁷, E.A. Starchenko¹²⁸, J. Stark⁵⁵, P. Staroba¹²⁵, P. Starovoitov⁹¹,
 A. Staude⁹⁸, P. Stavina^{144a}, G. Stavropoulos¹⁴, G. Steele⁵³, P. Steinbach⁴³,
 P. Steinberg²⁴, I. Stekl¹²⁷, B. Stelzer¹⁴², H.J. Stelzer⁸⁸, O. Stelzer-Chilton^{159a},
 H. Stenzel⁵², K. Stevenson⁷⁵, G.A. Stewart²⁹, J.A. Stillings²⁰, T. Stockmanns²⁰,
 M.C. Stockton²⁹, K. Stoerig⁴⁸, G. Stoicea^{25a}, S. Stonjek⁹⁹, P. Strachota¹²⁶,
 A.R. Stradling⁷, A. Straessner⁴³, J. Strandberg¹⁴⁷, S. Strandberg^{146a,146b}, A. Strandlie¹¹⁷,
 M. Strang¹⁰⁹, E. Strauss¹⁴³, M. Strauss¹¹¹, P. Strizenecek^{144b}, R. Ströhmer¹⁷³,
 D.M. Strom¹¹⁴, J.A. Strong^{76,*}, R. Stroynowski³⁹, J. Strube¹²⁹, B. Stugu¹³, I. Stumer^{24,*},
 J. Stupak¹⁴⁸, P. Sturm¹⁷⁴, D.A. Soh^{151,r}, D. Su¹⁴³, H.S. Subramania², A. Succurro¹¹,
 Y. Sugaya¹¹⁶, T. Sugimoto¹⁰¹, C. Suhr¹⁰⁶, K. Suita⁶⁷, M. Suk¹²⁶, V.V. Sulin⁹⁴,
 S. Sultansoy^{3d}, T. Sumida²⁹, X. Sun⁵⁵, J.E. Sundermann⁴⁸, K. Suruliz¹³⁹, S. Sushkov¹¹,
 G. Susinno^{36a,36b}, M.R. Sutton¹⁴⁹, Y. Suzuki⁶⁶, Y. Suzuki⁶⁷, M. Svatos¹²⁵,
 Yu.M. Sviridov¹²⁸, S. Swedish¹⁶⁸, I. Sykora^{144a}, T. Sykora¹²⁶, B. Szeless²⁹, J. Sánchez¹⁶⁷,
 D. Ta¹⁰⁵, K. Tackmann⁴¹, A. Taffard¹⁶³, R. Tafirout^{159a}, N. Taiblum¹⁵³, Y. Takahashi¹⁰¹,
 H. Takai²⁴, R. Takashima⁶⁹, H. Takeda⁶⁷, T. Takeshita¹⁴⁰, M. Talby⁸³, A. Talyshev¹⁰⁷,

M.C. Tamsett²⁴, J. Tanaka¹⁵⁵, R. Tanaka¹¹⁵, S. Tanaka¹³¹, S. Tanaka⁶⁶, Y. Tanaka¹⁰⁰,
 K. Tani⁶⁷, N. Tannoury⁸³, G.P. Tappern²⁹, S. Tapprogge⁸¹, D. Tardif¹⁵⁸, S. Tarem¹⁵²,
 F. Tarrade²⁸, G.F. Tartarelli^{89a}, P. Tas¹²⁶, M. Tasevsky¹²⁵, E. Tassi^{36a,36b},
 M. Tatarkhanov¹⁴, Y. Tayalati^{135d}, C. Taylor⁷⁷, F.E. Taylor⁹², G.N. Taylor⁸⁶,
 W. Taylor^{159b}, M. Teinturier¹¹⁵, M. Teixeira Dias Castanheira⁷⁵, P. Teixeira-Dias⁷⁶,
 K.K. Temming⁴⁸, H. Ten Kate²⁹, P.K. Teng¹⁵¹, S. Terada⁶⁶, K. Terashi¹⁵⁵, J. Terron⁸⁰,
 M. Terwort^{41,p}, M. Testa⁴⁷, R.J. Teuscher^{158,j}, J. Thadome¹⁷⁴, J. Therhaag²⁰,
 T. Theveneaux-Pelzer⁷⁸, M. Thioye¹⁷⁵, S. Thoma⁴⁸, J.P. Thomas¹⁷, E.N. Thompson³⁴,
 P.D. Thompson¹⁷, P.D. Thompson¹⁵⁸, A.S. Thompson⁵³, E. Thomson¹²⁰, M. Thomson²⁷,
 R.P. Thun⁸⁷, F. Tian³⁴, T. Tic¹²⁵, V.O. Tikhomirov⁹⁴, Y.A. Tikhonov¹⁰⁷,
 C.J.W.P. Timmermans¹⁰⁴, P. Tipton¹⁷⁵, F.J. Tique Aires Viegas²⁹, S. Tisserant⁸³,
 J. Tobias⁴⁸, B. Toczec³⁷, T. Todorov⁴, S. Todorova-Nova¹⁶¹, B. Toggerson¹⁶³, J. Tojo⁶⁶,
 S. Tokár^{144a}, K. Tokunaga⁶⁷, K. Tokushuku⁶⁶, K. Tollefson⁸⁸, M. Tomoto¹⁰¹,
 L. Tompkins¹⁴, K. Toms¹⁰³, G. Tong^{32a}, A. Tonoyan¹³, C. Topfel¹⁶, N.D. Topilin⁶⁵,
 I. Torchiani²⁹, E. Torrence¹¹⁴, H. Torres⁷⁸, E. Torr o Pastor¹⁶⁷, J. Toth^{83,x}, F. Touchard⁸³,
 D.R. Tovey¹³⁹, D. Traynor⁷⁵, T. Trefzger¹⁷³, L. Tremblet²⁹, A. Tricoli²⁹, I.M. Trigger^{159a},
 S. Trincaz-Duvoid⁷⁸, T.N. Trinh⁷⁸, M.F. Tripiana⁷⁰, W. Trischuk¹⁵⁸, A. Trivedi^{24,w},
 B. Trocme⁵⁵, C. Troncon^{89a}, M. Trottier-McDonald¹⁴², A. Trzupek³⁸, C. Tsarouchas²⁹,
 J.C-L. Tseng¹¹⁸, M. Tsiakiris¹⁰⁵, P.V. Tsiarehka⁹⁰, D. Tsiou⁴, G. Tsipolitis⁹,
 V. Tsiskaridze⁴⁸, E.G. Tskhadadze^{51a}, I.I. Tsukerman⁹⁵, V. Tsulaia¹⁴, J.-W. Tsung²⁰,
 S. Tsuno⁶⁶, D. Tsybychev¹⁴⁸, A. Tua¹³⁹, A. Tudorache^{25a}, V. Tudorache^{25a},
 J.M. Tuggle³⁰, M. Turala³⁸, D. Turecek¹²⁷, I. Turk Cakir^{3e}, E. Turlay¹⁰⁵, R. Turra^{89a,89b},
 P.M. Tuts³⁴, A. Tykhonov⁷⁴, M. Tylmad^{146a,146b}, M. Tyndel¹²⁹, H. Tyrva inen²⁹,
 G. Tzanakos⁸, K. Uchida²⁰, I. Ueda¹⁵⁵, R. Ueno²⁸, M. Ugland¹³, M. Uhlenbrock²⁰,
 M. Uhrmacher⁵⁴, F. Ukegawa¹⁶⁰, G. Unal²⁹, D.G. Underwood⁵, A. Undrus²⁴, G. Unel¹⁶³,
 Y. Unno⁶⁶, D. Urbaniec³⁴, E. Urkovsky¹⁵³, P. Urrejola^{31a}, G. Usai⁷, M. Uslenghi^{119a,119b},
 L. Vacavant⁸³, V. Vacek¹²⁷, B. Vachon⁸⁵, S. Vahsen¹⁴, J. Valenta¹²⁵, P. Valente^{132a},
 S. Valentinetti^{19a,19b}, S. Valkar¹²⁶, E. Valladolid Gallego¹⁶⁷, S. Vallecorsa¹⁵²,
 J.A. Valls Ferrer¹⁶⁷, H. van der Graaf¹⁰⁵, E. van der Kraaij¹⁰⁵, R. Van Der Leeuw¹⁰⁵,
 E. van der Poel¹⁰⁵, D. van der Ster²⁹, N. van Eldik⁸⁴, P. van Gemmeren⁵,
 Z. van Kesteren¹⁰⁵, I. van Vulpen¹⁰⁵, M. Vanadia⁹⁹, W. Vandelli²⁹, G. Vandoni²⁹,
 A. Vaniachine⁵, P. Vankov⁴¹, F. Vannucci⁷⁸, F. Varela Rodriguez²⁹, R. Vari^{132a},
 D. Varouchas¹⁴, A. Vartapetian⁷, K.E. Varvell¹⁵⁰, V.I. Vassilakopoulos⁵⁶, F. Vazeille³³,
 G. Vegni^{89a,89b}, J.J. Veillet¹¹⁵, C. Vellidis⁸, F. Veloso^{124a}, R. Veness²⁹, S. Veneziano^{132a},
 A. Ventura^{72a,72b}, D. Ventura¹³⁸, M. Venturi⁴⁸, N. Venturi¹⁶, V. Vercesi^{119a},
 M. Verducci¹³⁸, W. Verkerke¹⁰⁵, J.C. Vermeulen¹⁰⁵, A. Vest⁴³, M.C. Vetterli^{142,e},
 I. Vichou¹⁶⁵, T. Vickey^{145b,aa}, O.E. Vickey Boeriu^{145b}, G.H.A. Viehhauser¹¹⁸, S. Viel¹⁶⁸,
 M. Villa^{19a,19b}, M. Villaplana Perez¹⁶⁷, E. Vilucchi⁴⁷, M.G. Vincter²⁸, E. Vinek²⁹,
 V.B. Vinogradov⁶⁵, M. Virchaux^{136,*}, J. Virzi¹⁴, O. Vitells¹⁷¹, M. Viti⁴¹, I. Vivarelli⁴⁸,
 F. Vives Vaque², S. Vlachos⁹, D. Vladoiu⁹⁸, M. Vlasak¹²⁷, N. Vlasov²⁰, A. Vogel²⁰,
 P. Vokac¹²⁷, G. Volpi⁴⁷, M. Volpi⁸⁶, G. Volpini^{89a}, H. von der Schmitt⁹⁹, J. von Loeben⁹⁹,
 H. von Radziewski⁴⁸, E. von Toerne²⁰, V. Vorobel¹²⁶, A.P. Vorobiev¹²⁸, V. Vorwerk¹¹,
 M. Vos¹⁶⁷, R. Voss²⁹, T.T. Voss¹⁷⁴, J.H. Vosseveld⁷³, N. Vranjes^{12a},

M. Vranjes Milosavljevic¹⁰⁵, V. Vrba¹²⁵, M. Vreeswijk¹⁰⁵, T. Vu Anh⁸¹, R. Vuillermet²⁹, I. Vukotic¹¹⁵, W. Wagner¹⁷⁴, P. Wagner¹²⁰, H. Wahlen¹⁷⁴, J. Wakabayashi¹⁰¹, J. Walbersloh⁴², S. Walch⁸⁷, J. Walder⁷¹, R. Walker⁹⁸, W. Walkowiak¹⁴¹, R. Wall¹⁷⁵, P. Waller⁷³, C. Wang⁴⁴, H. Wang¹⁷², H. Wang^{32b,ab}, J. Wang¹⁵¹, J. Wang^{32d}, J.C. Wang¹³⁸, R. Wang¹⁰³, S.M. Wang¹⁵¹, A. Warburton⁸⁵, C.P. Ward²⁷, M. Warsinsky⁴⁸, P.M. Watkins¹⁷, A.T. Watson¹⁷, M.F. Watson¹⁷, G. Watts¹³⁸, S. Watts⁸², A.T. Waugh¹⁵⁰, B.M. Waugh⁷⁷, J. Weber⁴², M. Weber¹²⁹, M.S. Weber¹⁶, P. Weber⁵⁴, A.R. Weidberg¹¹⁸, P. Weigell⁹⁹, J. Weingarten⁵⁴, C. Weiser⁴⁸, H. Wellenstein²², P.S. Wells²⁹, M. Wen⁴⁷, T. Wenaus²⁴, S. Wendler¹²³, Z. Weng^{151,r}, T. Wengler²⁹, S. Wenig²⁹, N. Wermes²⁰, M. Werner⁴⁸, P. Werner²⁹, M. Werth¹⁶³, M. Wessels^{58a}, C. Weydert⁵⁵, K. Whalen²⁸, S.J. Wheeler-Ellis¹⁶³, S.P. Whitaker²¹, A. White⁷, M.J. White⁸⁶, S.R. Whitehead¹¹⁸, D. Whiteson¹⁶³, D. Whittington⁶¹, F. Wicke¹¹⁵, D. Wicke¹⁷⁴, F.J. Wickens¹²⁹, W. Wiedenmann¹⁷², M. Wielers¹²⁹, P. Wienemann²⁰, C. Wiglesworth⁷⁵, L.A.M. Wiik⁴⁸, P.A. Wijeratne⁷⁷, A. Wildauer¹⁶⁷, M.A. Wildt^{41,p}, I. Wilhelm¹²⁶, H.G. Wilkens²⁹, J.Z. Will⁹⁸, E. Williams³⁴, H.H. Williams¹²⁰, W. Willis³⁴, S. Willocq⁸⁴, J.A. Wilson¹⁷, M.G. Wilson¹⁴³, A. Wilson⁸⁷, I. Wingerter-Seez⁴, S. Winkelmann⁴⁸, F. Winklmeier²⁹, M. Wittgen¹⁴³, M.W. Wolter³⁸, H. Wolters^{124a,h}, W.C. Wong⁴⁰, G. Wooden⁸⁷, B.K. Wosiek³⁸, J. Wotschack²⁹, M.J. Woudstra⁸⁴, K. Wraight⁵³, C. Wright⁵³, M. Wright⁵³, B. Wrona⁷³, S.L. Wu¹⁷², X. Wu⁴⁹, Y. Wu^{32b,ac}, E. Wulf³⁴, R. Wunstorff⁴², B.M. Wynne⁴⁵, L. Xaplanteris⁹, S. Xella³⁵, S. Xie⁴⁸, Y. Xie^{32a}, C. Xu^{32b,ad}, D. Xu¹³⁹, G. Xu^{32a}, B. Yabsley¹⁵⁰, S. Yacoob^{145b}, M. Yamada⁶⁶, H. Yamaguchi¹⁵⁵, A. Yamamoto⁶⁶, K. Yamamoto⁶⁴, S. Yamamoto¹⁵⁵, T. Yamamura¹⁵⁵, T. Yamanaka¹⁵⁵, J. Yamaoka⁴⁴, T. Yamazaki¹⁵⁵, Y. Yamazaki⁶⁷, Z. Yan²¹, H. Yang⁸⁷, U.K. Yang⁸², Y. Yang⁶¹, Y. Yang^{32a}, Z. Yang^{146a,146b}, S. Yanush⁹¹, Y. Yao¹⁴, Y. Yasu⁶⁶, G.V. Ybeles Smit¹³⁰, J. Ye³⁹, S. Ye²⁴, M. Yilmaz^{3c}, R. Yoosoofmiya¹²³, K. Yorita¹⁷⁰, R. Yoshida⁵, C. Young¹⁴³, C.J. Young¹¹⁸, S. Youssef²¹, D. Yu²⁴, J. Yu⁷, J. Yu¹¹², L. Yuan^{32a,ae}, A. Yurkewicz¹⁴⁸, V.G. Zaets¹²⁸, R. Zaidan⁶³, A.M. Zaitsev¹²⁸, Z. Zajacova²⁹, Yo.K. Zalite¹²¹, L. Zanello^{132a,132b}, P. Zarzhitsky³⁹, A. Zaytsev¹⁰⁷, C. Zeitnitz¹⁷⁴, M. Zeller¹⁷⁵, M. Zeman¹²⁵, A. Zemla³⁸, C. Zender²⁰, O. Zenin¹²⁸, T. Ženiš^{144a}, Z. Zenonos^{122a,122b}, S. Zenz¹⁴, D. Zerwas¹¹⁵, G. Zevi della Porta⁵⁷, Z. Zhan^{32d}, D. Zhang^{32b,ab}, H. Zhang⁸⁸, J. Zhang⁵, X. Zhang^{32d}, Z. Zhang¹¹⁵, L. Zhao¹⁰⁸, T. Zhao¹³⁸, Z. Zhao^{32b}, A. Zhemchugov⁶⁵, S. Zheng^{32a}, J. Zhong^{151,af}, B. Zhou⁸⁷, N. Zhou¹⁶³, Y. Zhou¹⁵¹, C.G. Zhu^{32d}, H. Zhu⁴¹, J. Zhu⁸⁷, Y. Zhu^{32b}, X. Zhuang⁹⁸, V. Zhuravlov⁹⁹, D. Ziemska⁶¹, R. Zimmermann²⁰, S. Zimmermann²⁰, S. Zimmermann⁴⁸, M. Ziolkowski¹⁴¹, R. Zitoun⁴, L. Živković³⁴, V.V. Zmouchko^{128,*}, G. Zobernig¹⁷², A. Zoccoli^{19a,19b}, Y. Zolnierowski⁴, A. Zsenei²⁹, M. zur Nedden¹⁵, V. Zutshi¹⁰⁶, L. Zwalinski²⁹.

¹ University at Albany, Albany NY, United States of America

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 of America
- ⁶ Department of Physics, University of Arizona, Tucson AZ, United States of America
- ⁷ Department of Physics, The University of Texas at Arlington, Arlington TX, United States of America
- 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, 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 of America
- 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 of America
- ²² Department of Physics, Brandeis University, Waltham MA, United States of America
- 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 of America
- 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 of America

- 31 (a)Departamento de Física, 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)High Energy Physics Group, 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 of America
- 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 Faculty of Physics and Applied Computer Science, AGH-University of Science and Technology, 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 of America
- 40 Physics Department, University of Texas at Dallas, Richardson TX, United States of America
- 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 of America
- 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, Georgian Academy of Sciences, 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 of America
- ⁵⁷ Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States of America
- 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 Science, Hiroshima University, Hiroshima, Japan
- ⁶⁰ Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
- ⁶¹ Department of Physics, Indiana University, Bloomington IN, United States of America
- ⁶² Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
- ⁶³ University of Iowa, Iowa City IA, United States of America
- ⁶⁴ Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America
- ⁶⁵ Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
- ⁶⁶ KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
- ⁶⁷ Graduate School of Science, Kobe University, Kobe, Japan
- ⁶⁸ Faculty of Science, Kyoto University, Kyoto, Japan
- ⁶⁹ Kyoto University of Education, Kyoto, 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 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 Department of Physics, 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 Física Teórica C-15, Universidad Autónoma 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 of

America

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 of America

⁸⁸ Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America

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, Republic of Belarus

⁹¹ National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus

⁹² Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States of America

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 of America

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 of America

¹⁰⁷ Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia

¹⁰⁸ Department of Physics, New York University, New York NY, United States of America

¹⁰⁹ Ohio State University, Columbus OH, United States of America

¹¹⁰ Faculty of Science, Okayama University, Okayama, Japan

¹¹¹ Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States of America

¹¹² Department of Physics, Oklahoma State University, Stillwater OK, United States of America

- 113 Palacký University, RCPTM, Olomouc, Czech Republic
- 114 Center for High Energy Physics, University of Oregon, Eugene OR, United States of America
- 115 LAL, Univ. 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 Nucleare e Teorica, Università di Pavia, Pavia, Italy
- 120 Department of Physics, University of Pennsylvania, Philadelphia PA, United States of America
- 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 of America
- 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)Université Cadi Ayyad, Faculté des sciences Semlalia Département de Physique, B.P. 2390 Marrakech 40000; ^(d)Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; ^(e)Faculté des Sciences, Université Mohammed V, 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 of America
- ¹³⁸ Department of Physics, University of Washington, Seattle WA, United States of America
- 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 of America
- 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 Department of Physics and Astronomy, Stony Brook University, Stony Brook NY, United States of America
- 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 Inst. 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, Ibaraki, Japan
- ¹⁶¹ Science and Technology Center, Tufts University, Medford MA, United States of America
- ¹⁶² Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia
- ¹⁶³ Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States of America
- ¹⁶⁴ ^(a)INFN Gruppo Collegato di Udine; ^(b)ICTP, Trieste; ^(c)Dipartimento di Fisica,

Università di Udine, Udine, Italy

¹⁶⁵ Department of Physics, University of Illinois, Urbana IL, United States of America

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 Waseda University, Tokyo, Japan

¹⁷¹ Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel

¹⁷² Department of Physics, University of Wisconsin, Madison WI, United States of America

¹⁷³ Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany

¹⁷⁴ Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany

¹⁷⁵ Department of Physics, Yale University, New Haven CT, United States of America

¹⁷⁶ Yerevan Physics Institute, Yerevan, Armenia

¹⁷⁷ Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France

^a Also at Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa, Portugal

^b Also at Faculdade de Ciências and CFNUL, Universidade de Lisboa, Lisboa, Portugal

^c Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom

^d Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France

^e Also at TRIUMF, Vancouver BC, Canada

^f Also at Department of Physics, California State University, Fresno CA, United States of America

^g Also at Fermilab, Batavia IL, United States of America

^h Also at Department of Physics, University of Coimbra, Coimbra, Portugal

ⁱ Also at Università di Napoli Parthenope, Napoli, Italy

^j Also at Institute of Particle Physics (IPP), Canada

^k Also at Department of Physics, Middle East Technical University, Ankara, Turkey

^l Also at Louisiana Tech University, Ruston LA, United States of America

^m Also at Faculty of Physics and Applied Computer Science, AGH-University of Science and Technology, Krakow, Poland

ⁿ Also at Group of Particle Physics, University of Montreal, Montreal QC, Canada

^o Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan

^p Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany

^q Also at Manhattan College, New York NY, United States of America

^r Also at School of Physics and Engineering, Sun Yat-sen University, Guanzhou, China

^s Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica,

Taipei, Taiwan

^t Also at High Energy Physics Group, Shandong University, Shandong, China

^u Also at Section de Physique, Université de Genève, Geneva, Switzerland

^v Also at Departamento de Física, Universidade de Minho, Braga, Portugal

^w Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America

^x Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary

^y Also at California Institute of Technology, Pasadena CA, United States of America

^z Also at Institute of Physics, Jagiellonian University, Krakow, Poland

^{aa} Also at Department of Physics, Oxford University, Oxford, United Kingdom

^{ab} Also at Institute of Physics, Academia Sinica, Taipei, Taiwan

^{ac} Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States of America

^{ad} Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique), Gif-sur-Yvette, France

^{ae} Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France

^{af} Also at Department of Physics, Nanjing University, Jiangsu, China

* Deceased