

Search for same-sign top-quark pair production at $\sqrt{s} = 7$ TeV and limits on flavour changing neutral currents in the top sector

The CMS collaboration

ABSTRACT: An inclusive search for same-sign top-quark pair production in pp collisions at $\sqrt{s} = 7$ TeV is performed using a data sample recorded with the CMS detector in 2010, corresponding to an integrated luminosity of 35 pb^{-1} . This analysis is motivated by recent studies of $p\bar{p} \rightarrow t\bar{t}$ reporting mass-dependent forward-backward asymmetries larger than expected from the standard model. These asymmetries could be due to Flavor Changing Neutral Currents (FCNC) in the top sector induced by t -channel exchange of a massive neutral vector boson (Z'). Models with such a Z' also predict enhancement of same-sign top-pair production in pp or $p\bar{p}$ collisions. Limits are set as a function of the Z' mass and its couplings to u and t quarks. These limits disfavour the FCNC interpretation of the Tevatron results.

KEYWORDS: Hadron-Hadron Scattering

ARXIV EPRINT: [1106.2142](https://arxiv.org/abs/1106.2142)

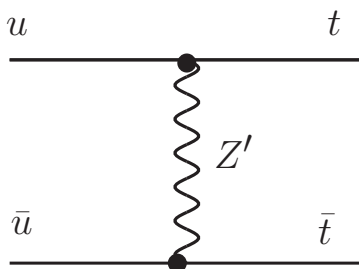


Figure 1. Diagram for $t\bar{t}$ production induced by t -channel Z' exchange, which can generate a forward-backward asymmetry.

The Compact Muon Solenoid (CMS) Collaboration recently published a search for new physics in events with same-sign isolated dileptons, jets, and \cancel{E}_T [1]. The results of that search are recast in this short Letter to set constraints on the production of same-sign top-quark pairs at the Large Hadron Collider (LHC). This effort is motivated by the recent Tevatron measurements of the forward-backward $t\bar{t}$ asymmetry (A_{FB}) which deviates from the standard model (SM) expectations [2–4]. Many of the attempts put forth [5–25] to explain this asymmetry invoke Flavour Changing Neutral Currents (FCNC) in the top-quark sector [5] mediated by the t -channel exchange of a new massive Z' boson, as shown in figure 1. It has also been suggested [19, 22–25] that the anomalous dijet invariant mass distribution recently reported by the CDF collaboration in $p\bar{p} \rightarrow W + 2$ jets [26] could be evidence for such a boson.

The same type of interaction would also give rise to same-sign top-quark pair production, as illustrated in figure 2. In this case, the initial state involves two u quarks. Because of the large valence quark parton density of the proton, the tt production cross section at the Large Hadron Collider (LHC) could then be large enough to be observable with a modest amount of integrated luminosity. This motivates the search described in this Letter.

For concreteness, we consider the model of ref. [10]. The relevant u - t - Z' interaction term in the Lagrangian is

$$\mathcal{L} = g_W \bar{u} \gamma^\mu (f_L P_L + f_R P_R) t Z'_\mu + \text{h.c.}, \tag{1}$$

where g_W is the weak coupling strength, and P_L and P_R are the left-handed and right-handed projection operators. The left-handed coupling is set to $f_L = 0$, because of the B_d - \bar{B}_d mixing constraint [27]. The right-handed coupling f_R and the Z' mass ($M_{Z'}$) are the free parameters of the model. Within this model there is a narrow range of parameter space consistent with the Tevatron measurements of $\sigma(p\bar{p} \rightarrow t\bar{t})$ and A_{FB} , which is not excluded by direct searches for same-sign top-quark pairs [10].

We search for $pp \rightarrow tt$ or $pp \rightarrow ttj$ using a data sample corresponding to an integrated luminosity of 35 pb^{-1} , collected at a centre-of-mass energy of 7 TeV in 2010 by the CMS experiment [28] at the LHC. We concentrate on the final state where both top quarks decay as $t \rightarrow Wb$ followed by $W \rightarrow \ell\nu$, where $\ell = e$ or μ . Thus, the final state of interest contains

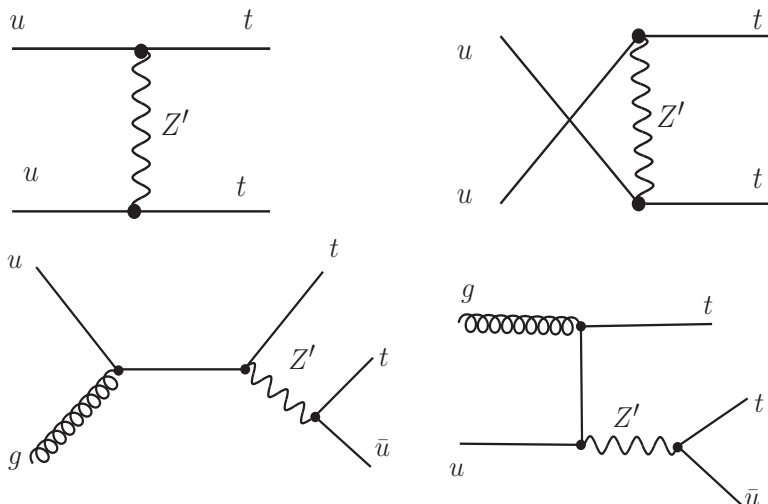


Figure 2. Diagrams for tt and ttj production in the presence of a Z' .

two high transverse momentum (p_T) isolated positive leptons (e^+ or μ^+), two or more jets, and missing transverse energy (\cancel{E}_T) from two neutrinos.

The result presented here is based on an already published search for new physics in events with same-sign isolated dileptons, jets, and \cancel{E}_T [1]. In that search we presented event yields and background expectations for a number of event selections sensitive to different possible new physics contributions. We observed no excess of events for any of the event selections, and we established 95% confidence level (CL) upper limits on non-standard model event yields.

We now reinterpret the results of ref. [1] in terms of the model of eq. (1). We start from the “baseline event selection” defined in [1]. Briefly, this selection consisted of two same-sign isolated leptons of $p_T > 10$ GeV, one of which must have $p_T > 20$ GeV, at least two jets of $p_T > 30$ GeV and $\cancel{E}_T > 20$ (30) GeV for $e\mu$ ($\mu\mu$ or ee). Leptons and jets were reconstructed in the pseudorapidity ranges $|\eta| < 2.4$ and $|\eta| < 2.5$, respectively. Three events passed these requirements, with an expected background of 3.4 ± 1.8 .

For the purpose of the tt search, the baseline event selection is modified by raising the transverse momentum threshold on the lowest p_T lepton from 10 to 20 GeV, since leptons from $t \rightarrow Wb$, $W \rightarrow \ell\nu$ tend to have high p_T . In addition, we demand that both leptons be positive since we are searching for $pp \rightarrow tt$ and not $pp \rightarrow t\bar{t}$. These changes are expected to reduce the background by more than a factor of two.

These requirements select 2 events, while the background expectation is 0.9 ± 0.6 events. The main background contribution is attributed to $t\bar{t}$ events with one lepton from W decay and one “fake” lepton, i.e. a lepton from heavy flavour decay, an electron from unidentified photon conversion, or a muon from meson decays in flight and other processes. This background is estimated in a data-driven way from studies of the sample of events selected with looser lepton isolation and identification requirements. More details on the event selection and the background estimation can be found in ref. [1].

Source	ee	$\mu\mu$	$e\mu$	all
Lepton selection	11.8%	10.6%	10.8%	10.7%
Energy scale	8%	8%	8%	8%
ISR/FSR and PDF	3%	3%	3%	3%
Total without luminosity	14.6%	13.6%	13.8	13.7%
Integrated luminosity	4%	4%	4%	4%
Total	15%	14%	14%	14%

Table 1. Fractional systematic uncertainties on the $pp \rightarrow tt(j)$ signal selection efficiency. ISR/FSR denote initial and final state radiation.

As a cross-check, we repeat the analysis with the same kinematic selection, but requiring the two leptons to be negative. No events in the data satisfy these requirements, in agreement with the charge-symmetric background expectation of 0.9 ± 0.6 events.

There is no statistically significant excess of tt candidate events over the background prediction. We thus proceed to set limits on the parameters of the Lagrangian of eq. (1). The ingredients for this calculation are the observed (2) and expected (0.9 ± 0.6) number of events, the cross section for $pp \rightarrow tt(j)$ as a function of f_R and $M_{Z'}$, the efficiency of the event selection, the integrated luminosity, and all associated uncertainties.

We used the external model interface in the MADGRAPH [29] event generator to calculate at the leading order (LO) the $tt + ttj$ cross section as a function of f_R and $M_{Z'}$. In this calculation we used the CTEQ6L [30] parton distribution functions (PDFs), fixed the top quark mass M_{top} to be 172.5 GeV, and set the renormalization and factorization scales to be $\mu = M_{top}$.

MADGRAPH was also used to generate $pp \rightarrow tt$ and $pp \rightarrow ttj$ events according to the diagrams of figure 2. These events were then processed by PYTHIA [31] for parton showering, followed by the CMS parametrized event simulation, and the same chain of reconstruction and analysis programs used for collision data. The event selection efficiency, including all relevant branching ratios, is $(0.95 \pm 0.13)\%$, independent of Z' mass. Note that the branching ratio for $tt \rightarrow \ell\nu b\ell\nu b$ ($\ell = e, \mu$) is 4.54% [32], but our selection is also sensitive to leptons from tau decays. The fractional systematic uncertainty on the event selection efficiencies was calculated as in ref. [1], and its components are summarized in table 1.

We compute the upper limits using a Bayesian method [32]. We assume a flat prior for the signal strength and a log-normal distribution for the nuisance parameters. The 95% CL upper limit on the number of signal events is 5.7 using a 14% uncertainty on the signal efficiency (table 1). The expected upper limit is $4.4^{+1.4}_{-1.3}$ events. The limit on the cross section is $\sigma(pp \rightarrow tt(j)) < 17.0$ pb at 95% CL. As a cross-check, we also calculate the upper limit on the number of events using the hybrid frequentist-Bayesian CL_s approach [33]. With this method we find an upper limit of 5.6 events, which demonstrates the insensitivity of our results to the details of the statistical analysis.

Using the LO cross section as computed in MADGRAPH, we turn the limit on the number of events into an exclusion region in the f_R - $M_{Z'}$ plane as shown in figure 3. The region of parameter space consistent with the Tevatron A_{FB} [10] is disfavoured by this analysis.

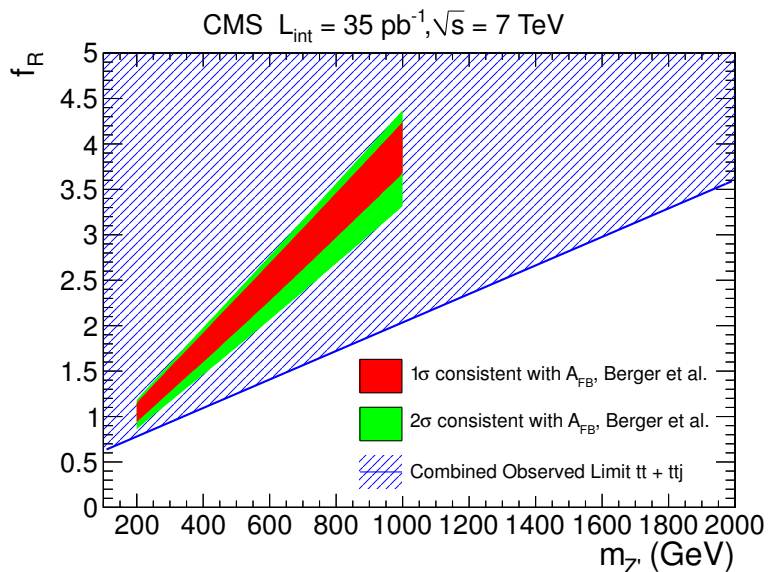


Figure 3. The shaded area is the exclusion region at 95% CL as a function of Z' mass and right handed couplings f_R (see the Lagrangian of eq. (1)). We also show the region of parameter space consistent with the Tevatron measurements of A_{FB} and $\sigma(t\bar{t})$ as inferred in ref. [10].

The Lagrangian of eq. (1) has two parameters, $M_{Z'}$ and f_R . At very large values of $M_{Z'}$ this lagrangian becomes equivalent to $\mathcal{L} = -\frac{1}{2} \frac{C_{RR}}{\Lambda^2} [\bar{u}_R \gamma^\mu t_R] [\bar{u}_R \gamma_\mu t_R] + \text{h.c.}$ [34, 35], with $\frac{C_{RR}}{\Lambda^2} = \frac{2g_W^2 f_R^2}{M_{Z'}^2}$. Using the f_R limit calculated at $M_{Z'} = 2 \text{ TeV}$, which is the highest value of the Z' -mass considered in our analysis, we set a limit $\frac{C_{RR}}{\Lambda^2} < 2.7 \text{ TeV}^{-2}$ at 95% confidence level. This bound is more stringent than that recently reported by CDF: $\frac{C_{RR}}{\Lambda^2} < 3.7 \text{ TeV}^{-2}$ [36].

In summary, we have established a limit on $t\bar{t}$ production in pp collisions at $\sqrt{s} = 7 \text{ TeV}$, based on a search for same-sign dileptons. Our bound can be used to test models of new physics with massive Z' bosons that have been proposed to explain the Tevatron measurements of the $p\bar{p} \rightarrow t\bar{t}$ forward-backward asymmetry. Our result disfavors this FCNC interpretation.

Acknowledgments

We thank Johan Alwall, Ed Berger, Qing-Hong Cao, Chuan-Ren Chen, Chong-Sheng Li and Hao Zhang for discussions and help in implementing the Z' model in MADGRAPH/MADEVENT. We wish to congratulate our colleagues in the CERN accelerator departments for the excellent performance of the LHC machine. We thank the technical and administrative staff at CERN and other CMS institutes, and acknowledge support from: FMSR (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MES (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIEN-CIAS (Colombia); MSES (Croatia); RPF (Cyprus); Academy of Sciences and NICPB (Es-

tonia); Academy of Finland, ME, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NKTH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); NRF and WCU (Korea); LAS (Lithuania); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); PAEC (Pakistan); SCSR (Poland); FCT (Portugal); JINR (Armenia, Belarus, Georgia, Ukraine, Uzbekistan); MST and MAE (Russia); MSTD (Serbia); MICINN and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); TUBITAK and TAEK (Turkey); STFC (United Kingdom); DOE and NSF (USA).

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] CMS collaboration, S. Chatrchyan et al., *Search for new physics with same-sign isolated dilepton events with jets and missing transverse energy at the LHC*, *JHEP* **06** (2011) 077 [[arXiv:1104.3168](#)] [[SPIRES](#)].
- [2] D0 collaboration, V.M. Abazov et al., *First measurement of the forward-backward charge asymmetry in top quark pair production*, *Phys. Rev. Lett.* **100** (2008) 142002 [[arXiv:0712.0851](#)] [[SPIRES](#)].
- [3] CDF collaboration, T. Aaltonen et al., *Forward-backward asymmetry in top quark production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV*, *Phys. Rev. Lett.* **101** (2008) 202001 [[arXiv:0806.2472](#)] [[SPIRES](#)].
- [4] CDF collaboration, T. Aaltonen et al., *Evidence for a mass dependent forward-backward asymmetry in top quark pair production*, *Phys. Rev. D* **83** (2011) 112003 [[arXiv:1101.0034](#)] [[SPIRES](#)].
- [5] S. Jung, H. Murayama, A. Pierce and J.D. Wells, *Top quark forward-backward asymmetry from new t -channel physics*, *Phys. Rev. D* **81** (2010) 015004 [[arXiv:0907.4112](#)] [[SPIRES](#)].
- [6] D.-W. Jung, P. Ko and J.S. Lee, *Longitudinal top polarization as a probe of a possible origin of forward-backward asymmetry of the top quark at the Tevatron*, *Phys. Lett. B* **701** (2011) 248 [[arXiv:1011.5976](#)] [[SPIRES](#)].
- [7] D. Choudhury, R.M. Godbole, S.D. Rindani and P. Saha, *Top polarization, forward-backward asymmetry and new physics*, [arXiv:1012.4750](#) [[SPIRES](#)].
- [8] K. Cheung and T.-C. Yuan, *Top quark forward-backward asymmetry in the large invariant mass region*, *Phys. Rev. D* **83** (2011) 074006 [[arXiv:1101.1445](#)] [[SPIRES](#)].
- [9] J. Cao, L. Wang, L. Wu and J.M. Yang, *Top quark forward-backward asymmetry, FCNC decays and like-sign pair production as a joint probe of new physics*, [arXiv:1101.4456](#) [[SPIRES](#)].
- [10] E.L. Berger, Q.-H. Cao, C.-R. Chen, C.S. Li and H. Zhang, *Top quark forward-backward asymmetry and same-sign top quark pairs*, *Phys. Rev. Lett.* **106** (2011) 201801 [[arXiv:1101.5625](#)] [[SPIRES](#)].

- [11] Y. Bai, J.L. Hewett, J. Kaplan and T.G. Rizzo, *LHC predictions from a Tevatron anomaly in the top quark forward-backward asymmetry*, *JHEP* **03** (2011) 003 [[arXiv:1101.5203](#)] [[SPIRES](#)].
- [12] J. Shelton and K.M. Zurek, *A theory for maximal flavor violation*, *Phys. Rev. D* **83** (2011) 091701 [[arXiv:1101.5392](#)] [[SPIRES](#)].
- [13] V. Barger, W.-Y. Keung and C.-T. Yu, *Tevatron asymmetry of tops in a W', Z' model*, *Phys. Lett. B* **698** (2011) 243 [[arXiv:1102.0279](#)] [[SPIRES](#)].
- [14] B. Bhattacharjee, S.S. Biswal and D. Ghosh, *Top quark forward-backward asymmetry at Tevatron and its implications at the LHC*, *Phys. Rev. D* **83** (2011) 091501 [[arXiv:1102.0545](#)] [[SPIRES](#)].
- [15] K. Blum et al., *Implications of the CDF $t\bar{t}$ forward-backward asymmetry for boosted top physics*, [arXiv:1102.3133](#) [[SPIRES](#)].
- [16] B. Grinstein, A.L. Kagan, M. Trott and J. Zupan, *Forward-backward asymmetry in $t\bar{t}$ production from flavour symmetries*, *Phys. Rev. Lett.* **107** (2011) 012002 [[arXiv:1102.3374](#)] [[SPIRES](#)].
- [17] K.M. Patel and P. Sharma, *Forward-backward asymmetry in top quark production from light colored scalars in SO(10) model*, *JHEP* **04** (2011) 085 [[arXiv:1102.4736](#)] [[SPIRES](#)].
- [18] M.I. Gresham, I.-W. Kim and K.M. Zurek, *On models of new physics for the tevatron top A_{FB}* , *Phys. Rev. D* **83** (2011) 114027 [[arXiv:1103.3501](#)] [[SPIRES](#)].
- [19] M.R. Buckley, D. Hooper, J. Kopp and E. Neil, *Light Z' bosons at the Tevatron*, *Phys. Rev. D* **83** (2011) 115013 [[arXiv:1103.6035](#)] [[SPIRES](#)].
- [20] Z. Ligeti, G.M. Tavares and M. Schmaltz, *Explaining the $t\bar{t}$ forward-backward asymmetry without dijet or flavor anomalies*, *JHEP* **06** (2011) 109 [[arXiv:1103.2757](#)] [[SPIRES](#)].
- [21] J.A. Aguilar-Saavedra and M. Pérez-Victoria, *Probing the Tevatron $t\bar{t}$ asymmetry at LHC*, *JHEP* **05** (2011) 034 [[arXiv:1103.2765](#)] [[SPIRES](#)].
- [22] S. Jung, A. Pierce and J.D. Wells, *Top quark asymmetry and dijet resonances*, [arXiv:1104.3139](#) [[SPIRES](#)].
- [23] D.-W. Jung, P. Ko and J.S. Lee, *A possible common origin of the top forward-backward asymmetry and the CDF dijet resonance*, [arXiv:1104.4443](#) [[SPIRES](#)].
- [24] P.J. Fox, J. Liu, D. Tucker-Smith and N. Weiner, *An effective Z'* , [arXiv:1104.4127](#) [[SPIRES](#)].
- [25] K. Cheung and J. Song, *Baryonic Z' explanation for the CDF Wjj excess*, *Phys. Rev. Lett.* **106** (2011) 211803 [[arXiv:1104.1375](#)] [[SPIRES](#)].
- [26] CDF collaboration, T. Aaltonen et al., *Invariant mass distribution of jet pairs produced in association with a W boson in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV*, *Phys. Rev. Lett.* **106** (2011) 171801 [[arXiv:1104.0699](#)] [[SPIRES](#)].
- [27] Q.-H. Cao, D. McKeen, J.L. Rosner, G. Shaughnessy and C.E.M. Wagner, *Forward-backward asymmetry of top quark pair production*, *Phys. Rev. D* **81** (2010) 114004 [[arXiv:1003.3461](#)] [[SPIRES](#)].
- [28] CMS collaboration, S. Chatrchyan et al., *The CMS experiment at the CERN LHC*, 2008 *JINST* **3** S08004 [[SPIRES](#)].

- [29] J. Alwall et al., *MadGraph/MadEvent v4: the new web generation*, *JHEP* **09** (2007) 028 [[arXiv:0706.2334](#)] [[SPIRES](#)].
- [30] J. Pumplin et al., *New generation of parton distributions with uncertainties from global QCD analysis*, *JHEP* **07** (2002) 012 [[hep-ph/0201195](#)] [[SPIRES](#)].
- [31] T. Sjöstrand, S. Mrenna and P.Z. Skands, *PYTHIA 6.4 physics and manual*, *JHEP* **05** (2006) 026 [[hep-ph/0603175](#)] [[SPIRES](#)].
- [32] PARTICLE DATA GROUP collaboration, K. Nakamura et al., *Review of particle physics*, *J. Phys. G* **37** (2010) 075021 [[SPIRES](#)].
- [33] A. Read, *Modified frequentist analysis of search results (the CLs method)*, [CERN-OPEN-2000-005](#) (2000).
- [34] D.-W. Jung, P. Ko, J.S. Lee and S.-h. Nam, *Model independent analysis of the forward-backward asymmetry of top quark production at the Tevatron*, *Phys. Lett. B* **691** (2010) 238 [[arXiv:0912.1105](#)] [[SPIRES](#)].
- [35] J.A. Aguilar-Saavedra, *Effective four-fermion operators in top physics: a roadmap*, *Nucl. Phys. B* **843** (2011) 638 [[arXiv:1008.3562](#)] [[SPIRES](#)].
- [36] CDF collaboration, *Search for like-sign top quark pair production at CDF with 6.1 fb^{-1}* , [CDF/PHYS/EXO/PUBLIC/10466](#) (2011).

The CMS collaboration**Yerevan Physics Institute, Yerevan, Armenia**

S. Chatrchyan, V. Khachatryan, A.M. Sirunyan, A. Tumasyan

Institut für Hochenergiephysik der OeAW, Wien, Austria

W. Adam, T. Bergauer, M. Dragicevic, J. Erö, C. Fabjan, M. Friedl, R. Frühwirth, V.M. Ghete, J. Hammer¹, S. Häsnel, M. Hoch, N. Hörmann, J. Hrubec, M. Jeitler, W. Kiesenhofer, M. Krammer, D. Liko, I. Mikulec, M. Pernicka, B. Rahbaran, H. Rohringer, R. Schöfbeck, J. Strauss, A. Taurok, F. Teischinger, P. Wagner, W. Waltenberger, G. Walzel, E. Widl, C.-E. Wulz

National Centre for Particle and High Energy Physics, Minsk, Belarus

V. Mossolov, N. Shumeiko, J. Suarez Gonzalez

Universiteit Antwerpen, Antwerpen, Belgium

S. Bansal, L. Benucci, E.A. De Wolf, X. Janssen, T. Maes, L. Mucibello, S. Ochesanu, B. Roland, R. Rougny, M. Selvaggi, H. Van Haevermaet, P. Van Mechelen, N. Van Remortel

Vrije Universiteit Brussel, Brussel, Belgium

F. Blekman, S. Blyweert, J. D'Hondt, O. Devroede, R. Gonzalez Suarez, A. Kalogeropoulos, M. Maes, W. Van Doninck, P. Van Mulders, G.P. Van Onsem, I. Vilella

Université Libre de Bruxelles, Bruxelles, Belgium

O. Charaf, B. Clerbaux, G. De Lentdecker, V. Dero, A.P.R. Gay, G.H. Hammad, T. Hreus, P.E. Marage, A. Raval, L. Thomas, C. Vander Velde, P. Vanlaer

Ghent University, Ghent, Belgium

V. Adler, A. Cimmino, S. Costantini, M. Grunewald, B. Klein, J. Lellouch, A. Marinov, J. Mccartin, D. Ryckbosch, F. Thyssen, M. Tytgat, L. Vanelderen, P. Verwilligen, S. Walsh, N. Zaganidis

Université Catholique de Louvain, Louvain-la-Neuve, Belgium

S. Basegmez, G. Bruno, J. Caudron, L. Ceard, E. Cortina Gil, J. De Favereau De Jeneret, C. Delaere, D. Favart, A. Giammanco, G. Grégoire, J. Hollar, V. Lemaitre, J. Liao, O. Militaru, C. Nuttens, S. Oryn, D. Pagano, A. Pin, K. Piotrkowski, N. Schul

Université de Mons, Mons, Belgium

N. Bely, T. Caebergs, E. Daubie

Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil

G.A. Alves, L. Brito, D. De Jesus Damiao, M.E. Pol, M.H.G. Souza

Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

W.L. Aldá Júnior, W. Carvalho, E.M. Da Costa, C. De Oliveira Martins, S. Fonseca De Souza, L. Mundim, H. Nogima, V. Oguri, W.L. Prado Da Silva, A. Santoro, S.M. Silva Do Amaral, A. Sznajder

Instituto de Fisica Teorica, Universidade Estadual Paulista, Sao Paulo, Brazil

C.A. Bernardes², F.A. Dias, T.R. Fernandez Perez Tomei, E. M. Gregores², C. Lagana, F. Marinho, P.G. Mercadante², S.F. Novaes, Sandra S. Padula

Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria

N. Darmenov¹, V. Genchev¹, P. Iaydjiev¹, S. Piperov, M. Rodozov, S. Stoykova, G. Sultanov, V. Tcholakov, R. Trayanov

University of Sofia, Sofia, Bulgaria

A. Dimitrov, R. Hadjiiska, A. Karadzhinova, V. Kozhuharov, L. Litov, M. Mateev, B. Pavlov, P. Petkov

Institute of High Energy Physics, Beijing, China

J.G. Bian, G.M. Chen, H.S. Chen, C.H. Jiang, D. Liang, S. Liang, X. Meng, J. Tao, J. Wang, J. Wang, X. Wang, Z. Wang, H. Xiao, M. Xu, J. Zang, Z. Zhang

State Key Lab. of Nucl. Phys. and Tech., Peking University, Beijing, China

Y. Ban, S. Guo, Y. Guo, W. Li, Y. Mao, S.J. Qian, H. Teng, B. Zhu, W. Zou

Universidad de Los Andes, Bogota, Colombia

A. Cabrera, B. Gomez Moreno, A.A. Ocampo Rios, A.F. Osorio Oliveros, J.C. Sanabria

Technical University of Split, Split, Croatia

N. Godinovic, D. Lelas, K. Lelas, R. Plestina³, D. Polic, I. Puljak

University of Split, Split, Croatia

Z. Antunovic, M. Dzelalija

Institute Rudjer Boskovic, Zagreb, Croatia

V. Brigljevic, S. Duric, K. Kadija, S. Morovic

University of Cyprus, Nicosia, Cyprus

A. Attikis, M. Galanti, J. Mousa, C. Nicolaou, F. Ptochos, P.A. Razis

Charles University, Prague, Czech Republic

M. Finger, M. Finger Jr.

**Academy of Scientific Research and Technology of the Arab Republic of Egypt,
Egyptian Network of High Energy Physics, Cairo, Egypt**

Y. Assran⁴, A. Ellithi Kamel, S. Khalil⁵, M.A. Mahmoud⁶

National Institute of Chemical Physics and Biophysics, Tallinn, Estonia

A. Hektor, M. Kadastik, M. Müntel, M. Raidal, L. Rebane, A. Tiko

Department of Physics, University of Helsinki, Helsinki, Finland

V. Azzolini, P. Eerola, G. Fedi

Helsinki Institute of Physics, Helsinki, Finland

S. Czellar, J. Härkönen, A. Heikkinen, V. Karimäki, R. Kinnunen, M.J. Kortelainen, T. Lampén, K. Lassila-Perini, S. Lehti, T. Lindén, P. Luukka, T. Mäenpää, E. Tuominen, J. Tuominiemi, E. Tuovinen, D. Ungaro, L. Wendland

Lappeenranta University of Technology, Lappeenranta, Finland

K. Banzuzi, A. Karjalainen, A. Korpela, T. Tuuva

**Laboratoire d'Annecy-le-Vieux de Physique des Particules, IN2P3-CNRS,
Annecy-le-Vieux, France**

D. Sillou

DSM/IRFU, CEA/Saclay, Gif-sur-Yvette, France

M. Besancon, S. Choudhury, M. Dejardin, D. Denegri, B. Fabbro, J.L. Faure, F. Ferri, S. Ganjour, F.X. Gentit, A. Givernaud, P. Gras, G. Hamel de Monchenault, P. Jarry, E. Locci, J. Malcles, M. Marionneau, L. Millischer, J. Rander, A. Rosowsky, I. Shreyber, M. Titov, P. Verrecchia

**Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau,
France**

S. Baffioni, F. Beaudette, L. Benhabib, L. Bianchini, M. Bluj⁷, C. Broutin, P. Busson, C. Charlot, T. Dahms, L. Dobrzynski, S. Elgammal, R. Granier de Cassagnac, M. Hagnauer, P. Miné, C. Mironov, C. Ochando, P. Paganini, D. Sabes, R. Salerno, Y. Sirois, C. Thiebaux, B. Wyslouch⁸, A. Zabi

**Institut Pluridisciplinaire Hubert Curien, Université de Strasbourg, Université
de Haute Alsace Mulhouse, CNRS/IN2P3, Strasbourg, France**

J.-L. Agram⁹, J. Andrea, D. Bloch, D. Bodin, J.-M. Brom, M. Cardaci, E.C. Chabert, C. Collard, E. Conte⁹, F. Drouhin⁹, C. Ferro, J.-C. Fontaine⁹, D. Gelé, U. Goerlach, S. Greder, P. Juillot, M. Karim⁹, A.-C. Le Bihan, Y. Mikami, P. Van Hove

Centre de Calcul de l'Institut National de Physique Nucleaire et de Physique des Particules (IN2P3), Villeurbanne, France

F. Fassi, D. Mercier

Université de Lyon, Université Claude Bernard Lyon 1, CNRS-IN2P3, Institut de Physique Nucléaire de Lyon, Villeurbanne, France

C. Baty, S. Beauceron, N. Beaupere, M. Bedjidian, O. Bondu, G. Boudoul, D. Boumediene, H. Brun, J. Chasserat, R. Chierici, D. Contardo, P. Depasse, H. El Mamouni, J. Fay, S. Gascon, B. Ille, T. Kurca, T. Le Grand, M. Lethuillier, L. Mirabito, S. Perries, V. Sordini, S. Tosi, Y. Tschudi, P. Verdier

Institute of High Energy Physics and Informatization, Tbilisi State University, Tbilisi, Georgia

D. Lomidze

RWTH Aachen University, I. Physikalisches Institut, Aachen, Germany

G. Anagnostou, S. Beranek, M. Edelhoff, L. Feld, N. Heracleous, O. Hindrichs, R. Jussen, K. Klein, J. Merz, N. Mohr, A. Ostapchuk, A. Perieanu, F. Raupach, J. Sammet, S. Schael, D. Sprenger, H. Weber, M. Weber, B. Wittmer

RWTH Aachen University, III. Physikalisches Institut A, Aachen, Germany

M. Ata, E. Dietz-Laursonn, M. Erdmann, T. Hebbeker, C. Heidemann, A. Hinzmann, K. Hoepfner, T. Klimkovich, D. Klingebiel, P. Kreuzer, D. Lanske[†], J. Lingemann, C. Magass, M. Merschmeyer, A. Meyer, P. Papacz, H. Pieta, H. Reithler, S.A. Schmitz, L. Sonnenschein, J. Steggemann, D. Teyssier

RWTH Aachen University, III. Physikalisches Institut B, Aachen, Germany

M. Bontenackels, M. Davids, M. Duda, G. Flügge, H. Geenen, M. Giffels, W. Haj Ahmad, D. Heydhausen, F. Hoehle, B. Kargoll, T. Kress, Y. Kuessel, A. Linn, A. Nowack, L. Perchalla, O. Pooth, J. Rennefeld, P. Sauerland, A. Stahl, M. Thomas, D. Tornier, M.H. Zoeller

Deutsches Elektronen-Synchrotron, Hamburg, Germany

M. Aldaya Martin, W. Behrenhoff, U. Behrens, M. Bergholz¹⁰, A. Bethani, K. Borrás, A. Cakir, A. Campbell, E. Castro, D. Dammann, G. Eckerlin, D. Eckstein, A. Flossdorf, G. Flucke, A. Geiser, J. Hauk, H. Jung¹, M. Kasemann, I. Katkov¹¹, P. Katsas, C. Kleinwort, H. Kluge, A. Knutsson, M. Krämer, D. Krücker, E. Kuznetsova, W. Lange, W. Lohmann¹⁰, R. Mankel, M. Marienfeld, I.-A. Melzer-Pellmann, A.B. Meyer, J. Mnich, A. Mussgiller, J. Olzem, A. Petrukhin, D. Pitzl, A. Raspereza, M. Rosin, R. Schmidt¹⁰, T. Schoerner-Sadenius, N. Sen, A. Spiridonov, M. Stein, J. Tomaszewska, R. Walsh, C. Wissing

University of Hamburg, Hamburg, Germany

C. Autermann, V. Blobel, S. Bobrovskiy, J. Draeger, H. Enderle, U. Gebbert, M. Görner, T. Hermanns, K. Kaschube, G. Kaussen, H. Kirschenmann, R. Klanner, J. Lange, B. Mura, S. Naumann-Emme, F. Nowak, N. Pietsch, C. Sander, H. Schettler, P. Schleper, E. Schlieckau, M. Schröder, T. Schum, H. Stadie, G. Steinbrück, J. Thomsen

Institut für Experimentelle Kernphysik, Karlsruhe, Germany

C. Barth, J. Bauer, J. Berger, V. Buege, T. Chwalek, W. De Boer, A. Dierlamm, G. Dirkes, M. Feindt, J. Gruschke, C. Hackstein, F. Hartmann, M. Heinrich, H. Held, K.H. Hoffmann, S. Honc, J.R. Komaragiri, T. Kuhr, D. Martschei, S. Mueller, Th. Müller, M. Niegel, O. Oberst, A. Oehler, J. Ott, T. Peiffer, G. Quast, K. Rabbertz, F. Ratnikova, N. Ratnikova, M. Renz, C. Saout, A. Scheurer, P. Schieferdecker, F.-P. Schilling, G. Schott, H.J. Simonis, F.M. Stober, D. Troendle, J. Wagner-Kuhr, T. Weiler, M. Zeise, V. Zhukov¹¹, E.B. Ziebarth

Institute of Nuclear Physics "Demokritos", Aghia Paraskevi, Greece

G. Daskalakis, T. Geralis, S. Kesisoglou, A. Kyriakis, D. Loukas, I. Manolakos, A. Markou, C. Markou, C. Mavrommatis, E. Ntomari, E. Petrakou

University of Athens, Athens, Greece

L. Gouskos, T.J. Mertzimekis, A. Panagiotou, N. Saoulidou, E. Stiliaris

University of Ioánnina, Ioánnina, Greece

I. Evangelou, C. Foudas, P. Kokkas, N. Manthos, I. Papadopoulos, V. Patras, F.A. Triantis

KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary

A. Aranyi, G. Bencze, L. Boldizsar, C. Hajdu¹, P. Hidas, D. Horvath¹², A. Kapusi, K. Krajczar¹³, F. Sikler¹, G.I. Veres¹³, G. Vesztergombi¹³

Institute of Nuclear Research ATOMKI, Debrecen, Hungary

N. Beni, J. Molnar, J. Palinkas, Z. Szillasi, V. Veszpremi

University of Debrecen, Debrecen, Hungary

P. Raics, Z.L. Trocsanyi, B. Ujvari

Panjab University, Chandigarh, India

S.B. Beri, V. Bhatnagar, N. Dhingra, R. Gupta, M. Jindal, M. Kaur, J.M. Kohli, M.Z. Mehta, N. Nishu, L.K. Saini, A. Sharma, A.P. Singh, J. Singh, S.P. Singh

University of Delhi, Delhi, India

S. Ahuja, B.C. Choudhary, P. Gupta, S. Jain, A. Kumar, A. Kumar, M. Naimuddin, K. Ranjan, R.K. Shivpuri

Saha Institute of Nuclear Physics, Kolkata, India

S. Banerjee, S. Bhattacharya, S. Dutta, B. Gomber, S. Jain, R. Khurana, S. Sarkar

Bhabha Atomic Research Centre, Mumbai, India

R.K. Choudhury, D. Dutta, S. Kailas, V. Kumar, P. Mehta, A.K. Mohanty¹, L.M. Pant, P. Shukla

Tata Institute of Fundamental Research - EHEP, Mumbai, India

T. Aziz, M. Guchait¹⁴, A. Gurtu, M. Maity¹⁵, D. Majumder, G. Majumder, K. Mazumdar, G.B. Mohanty, A. Saha, K. Sudhakar, N. Wickramage

Tata Institute of Fundamental Research - HECR, Mumbai, India

S. Banerjee, S. Dugad, N.K. Mondal

Institute for Research and Fundamental Sciences (IPM), Tehran, Iran

H. Arfaei, H. Bakhshiansohi¹⁶, S.M. Etesami, A. Fahim¹⁶, M. Hashemi, H. Hesari, A. Jafari¹⁶, M. Khakzad, A. Mohammadi¹⁷, M. Mohammadi Najafabadi, S. Paktinat Mehdiabadi, B. Safarzadeh, M. Zeinali¹⁸

INFN Sezione di Bari ^a, Università di Bari ^b, Politecnico di Bari ^c, Bari, Italy

M. Abbrescia^{a,b}, L. Barbone^{a,b}, C. Calabria^{a,b}, A. Colaleo^a, D. Creanza^{a,c}, N. De Filippis^{a,c,1}, M. De Palma^{a,b}, L. Fiore^a, G. Iaselli^{a,c}, L. Lusito^{a,b}, G. Maggi^{a,c}, M. Maggi^a, N. Manna^{a,b}, B. Marangelli^{a,b}, S. My^{a,c}, S. Nuzzo^{a,b}, N. Pacifico^{a,b}, G.A. Pierro^a, A. Pompili^{a,b}, G. Pugliese^{a,c}, F. Romano^{a,c}, G. Roselli^{a,b}, G. Selvaggi^{a,b}, L. Silvestris^a, R. Trentadue^a, S. Tupputi^{a,b}, G. Zito^a

INFN Sezione di Bologna ^a, Università di Bologna ^b, Bologna, Italy

G. Abbiendi^a, A.C. Benvenuti^a, D. Bonacorsi^a, S. Braibant-Giacomelli^{a,b}, L. Brigliadori^a, P. Capiluppi^{a,b}, A. Castro^{a,b}, F.R. Cavallo^a, M. Cuffiani^{a,b}, G.M. Dallavalle^a, F. Fabbri^a, A. Fanfani^{a,b}, D. Fasanella^a, P. Giacomelli^a, M. Giunta^a, C. Grandi^a, S. Marcellini^a, G. Masetti^b, M. Meneghelli^{a,b}, A. Montanari^a, F.L. Navarria^{a,b}, F. Odorici^a, A. Perrotta^a, F. Primavera^a, A.M. Rossi^{a,b}, T. Rovelli^{a,b}, G. Siroli^{a,b}, R. Travaglini^{a,b}

INFN Sezione di Catania ^a, Università di Catania ^b, Catania, Italy

S. Albergo^{a,b}, G. Cappello^{a,b}, M. Chiorboli^{a,b,1}, S. Costa^{a,b}, R. Potenza^{a,b}, A. Tricomi^{a,b}, C. Tuve^{a,b}

INFN Sezione di Firenze ^a, Università di Firenze ^b, Firenze, Italy

G. Barbagli^a, V. Ciulli^{a,b}, C. Civinini^a, R. D'Alessandro^{a,b}, E. Focardi^{a,b}, S. Frosali^{a,b}, E. Gallo^a, S. Gonzi^{a,b}, P. Lenzi^{a,b}, M. Meschini^a, S. Paoletti^a, G. Sguazzoni^a, A. Tropiano^{a,1}

INFN Laboratori Nazionali di Frascati, Frascati, ItalyL. Benussi, S. Bianco, S. Colafranceschi¹⁹, F. Fabbri, D. Piccolo**INFN Sezione di Genova, Genova, Italy**

P. Fabbriatore, R. Musenich

INFN Sezione di Milano-Bicocca ^a, Università di Milano-Bicocca ^b, Milano, ItalyA. Benaglia^{a,b}, F. De Guio^{a,b,1}, L. Di Matteo^{a,b}, S. Gennai¹, A. Ghezzi^{a,b}, S. Malvezzi^a, A. Martelli^{a,b}, A. Massironi^{a,b}, D. Menasce^a, L. Moroni^a, M. Paganoni^{a,b}, D. Pedrini^a, S. Ragazzi^{a,b}, N. Redaelli^a, S. Sala^a, T. Tabarelli de Fatis^{a,b}**INFN Sezione di Napoli ^a, Università di Napoli "Federico II" ^b, Napoli, Italy**S. Buontempo^a, C.A. Carrillo Montoya^{a,1}, N. Cavallo^{a,20}, A. De Cosa^{a,b}, F. Fabozzi^{a,20}, A.O.M. Iorio^{a,1}, L. Lista^a, M. Merola^{a,b}, P. Paolucci^a**INFN Sezione di Padova ^a, Università di Padova ^b, Università di Trento (Trento) ^c, Padova, Italy**P. Azzi^a, N. Bacchetta^a, P. Bellan^{a,b}, D. Bisello^{a,b}, A. Branca^a, R. Carlin^{a,b}, P. Checchia^a, T. Dorigo^a, U. Dosselli^a, F. Fanzago^a, F. Gasparini^{a,b}, U. Gasparini^{a,b}, A. Gozzelino, S. Lacaprara^{a,21}, I. Lazzizzera^{a,c}, M. Margoni^{a,b}, M. Mazzucato^a, A.T. Meneguzzo^{a,b}, M. Nespolo^{a,1}, L. Perrozzi^{a,1}, N. Pozzobon^{a,b}, P. Ronchese^{a,b}, F. Simonetto^{a,b}, E. Torassa^a, M. Tosi^{a,b}, S. Vanini^{a,b}, P. Zotto^{a,b}, G. Zumerle^{a,b}**INFN Sezione di Pavia ^a, Università di Pavia ^b, Pavia, Italy**P. Baesso^{a,b}, U. Berzano^a, S.P. Ratti^{a,b}, C. Riccardi^{a,b}, P. Torre^{a,b}, P. Vitulo^{a,b}, C. Viviani^{a,b}**INFN Sezione di Perugia ^a, Università di Perugia ^b, Perugia, Italy**M. Biasini^{a,b}, G.M. Bilei^a, B. Caponeri^{a,b}, L. Fanò^{a,b}, P. Lariccia^{a,b}, A. Lucaroni^{a,b,1}, G. Mantovani^{a,b}, M. Menichelli^a, A. Nappi^{a,b}, F. Romeo^{a,b}, A. Santocchia^{a,b}, S. Taroni^{a,b,1}, M. Valdata^{a,b}**INFN Sezione di Pisa ^a, Università di Pisa ^b, Scuola Normale Superiore di Pisa ^c, Pisa, Italy**P. Azzurri^{a,c}, G. Bagliesi^a, J. Bernardini^{a,b}, T. Boccali^{a,1}, G. Broccolo^{a,c}, R. Castaldi^a, R.T. D'Agnolo^{a,c}, R. Dell'Orso^a, F. Fiori^{a,b}, L. Foà^{a,c}, A. Giassi^a, A. Kraan^a, F. Ligabue^{a,c}, T. Lomtadze^a, L. Martini^{a,22}, A. Messineo^{a,b}, F. Palla^a, F. Palmonari, G. Segneri^a, A.T. Serban^a, P. Spagnolo^a, R. Tenchini^a, G. Tonelli^{a,b,1}, A. Venturi^{a,1}, P.G. Verdini^a

INFN Sezione di Roma ^a, Università di Roma "La Sapienza" ^b, Roma, Italy

L. Barone^{a,b}, F. Cavallari^a, D. Del Re^{a,b}, E. Di Marco^{a,b}, M. Diemoz^a, D. Franci^{a,b},
M. Grassi^{a,1}, E. Longo^{a,b}, P. Meridiani, S. Nourbakhsh^a, G. Organtini^{a,b}, F. Pandolfi^{a,b,1},
R. Paramatti^a, S. Rahatlou^{a,b}, C. Rovelli¹

INFN Sezione di Torino ^a, Università di Torino ^b, Università del Piemonte Orientale (Novara) ^c, Torino, Italy

N. Amapane^{a,b}, R. Arcidiacono^{a,c}, S. Argiro^{a,b}, M. Arneodo^{a,c}, C. Biino^a, C. Botta^{a,b,1},
N. Cartiglia^a, R. Castello^{a,b}, M. Costa^{a,b}, N. Demaria^a, A. Graziano^{a,b,1}, C. Mariotti^a,
M. Marone^{a,b}, S. Maselli^a, E. Migliore^{a,b}, G. Mila^{a,b}, V. Monaco^{a,b}, M. Musich^{a,b},
M.M. Obertino^{a,c}, N. Pastrone^a, M. Pelliccioni^{a,b}, A. Potenza^{a,b}, A. Romero^{a,b},
M. Ruspa^{a,c}, R. Sacchi^{a,b}, V. Sola^{a,b}, A. Solano^{a,b}, A. Staiano^a, A. Vilela Pereira^a

INFN Sezione di Trieste ^a, Università di Trieste ^b, Trieste, Italy

S. Belforte^a, F. Cossutti^a, G. Della Ricca^{a,b}, B. Gobbo^a, D. Montanino^{a,b}, A. Penzo^a

Kangwon National University, Chunchon, Korea

S.G. Heo, S.K. Nam

Kyungpook National University, Daegu, Korea

S. Chang, J. Chung, D.H. Kim, G.N. Kim, J.E. Kim, D.J. Kong, H. Park, S.R. Ro,
D.C. Son, T. Son

Chonnam National University, Institute for Universe and Elementary Particles, Kwangju, Korea

Zero Kim, J.Y. Kim, S. Song

Korea University, Seoul, Korea

S. Choi, B. Hong, M. Jo, H. Kim, J.H. Kim, T.J. Kim, K.S. Lee, D.H. Moon, S.K. Park,
K.S. Sim

University of Seoul, Seoul, Korea

M. Choi, S. Kang, H. Kim, C. Park, I.C. Park, S. Park, G. Ryu

Sungkyunkwan University, Suwon, Korea

Y. Choi, Y.K. Choi, J. Goh, M.S. Kim, B. Lee, J. Lee, S. Lee, H. Seo, I. Yu

Vilnius University, Vilnius, Lithuania

M.J. Bilinskas, I. Grigelionis, M. Janulis, D. Martisiute, P. Petrov, T. Sabonis

Centro de Investigacion y de Estudios Avanzados del IPN, Mexico City, Mexico

H. Castilla-Valdez, E. De La Cruz-Burelo, I. Heredia-de La Cruz, R. Lopez-Fernandez,
R. Magaña Villalba, A. Sánchez-Hernández, L.M. Villasenor-Cendejas

Universidad Iberoamericana, Mexico City, Mexico

S. Carrillo Moreno, F. Vazquez Valencia

Benemerita Universidad Autonoma de Puebla, Puebla, Mexico

H.A. Salazar Ibarguen

Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico

E. Casimiro Linares, A. Morelos Pineda, M.A. Reyes-Santos

University of Auckland, Auckland, New Zealand

D. Krofcheck, J. Tam

University of Canterbury, Christchurch, New Zealand

P.H. Butler, R. Doesburg, H. Silverwood

National Centre for Physics, Quaid-I-Azam University, Islamabad, Pakistan

M. Ahmad, I. Ahmed, M.I. Asghar, H.R. Hoorani, W.A. Khan, T. Khurshid, S. Qazi

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland

G. Brona, M. Cwiok, W. Dominik, K. Doroba, A. Kalinowski, M. Konecki, J. Krolikowski

Soltan Institute for Nuclear Studies, Warsaw, Poland

T. Frueboes, R. Gokieli, M. Górski, M. Kazana, K. Nawrocki, K. Romanowska-Rybinska, M. Szleper, G. Wrochna, P. Zalewski

Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal

N. Almeida, P. Bargassa, A. David, P. Faccioli, P.G. Ferreira Parracho, M. Gallinaro¹, P. Musella, A. Nayak, J. Pela¹, P.Q. Ribeiro, J. Seixas, J. Varela

Joint Institute for Nuclear Research, Dubna, Russia

S. Afanasiev, I. Belotelov, I. Golutvin, A. Kamenev, V. Karjavin, G. Kozlov, A. Lanev, P. Moisenz, V. Palichik, V. Perelygin, M. Savina, S. Shmatov, V. Smirnov, A. Volodko, A. Zarubin

Petersburg Nuclear Physics Institute, Gatchina (St Petersburg), Russia

V. Golovtsov, Y. Ivanov, V. Kim, P. Levchenko, V. Murzin, V. Oreshkin, I. Smirnov, V. Sulimov, L. Uvarov, S. Vavilov, A. Vorobyev, An. Vorobyev

Institute for Nuclear Research, Moscow, Russia

Yu. Andreev, A. Dermenev, S. Gninenko, N. Golubev, M. Kirsanov, N. Krasnikov,
V. Matveev, A. Pashenkov, A. Toropin, S. Troitsky

Institute for Theoretical and Experimental Physics, Moscow, Russia

V. Epshteyn, V. Gavrilov, V. Kaftanov[†], M. Kossov¹, A. Krokhotin, N. Lychkovskaya,
V. Popov, G. Safronov, S. Semenov, V. Stolin, E. Vlasov, A. Zhokin

Moscow State University, Moscow, Russia

E. Boos, M. Dubinin²³, L. Dudko, A. Ershov, A. Gribushin, O. Kodolova, I. Lokhtin,
A. Markina, S. Obraztsov, M. Perfilov, S. Petrushanko, L. Sarycheva, V. Savrin, A. Snigirev

P.N. Lebedev Physical Institute, Moscow, Russia

V. Andreev, M. Azarkin, I. Dremin, M. Kirakosyan, A. Leonidov, S.V. Rusakov, A. Vinogradov

State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, Russia

I. Azhgirey, I. Bayshev, S. Bitioukov, V. Grishin¹, V. Kachanov, D. Konstantinov,
A. Korablev, V. Krychkin, V. Petrov, R. Ryutin, A. Sobol, L. Tourtchanovitch, S. Troshin,
N. Tyurin, A. Uzunian, A. Volkov

University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia

P. Adzic²⁴, M. Djordjevic, D. Krpic²⁴, J. Milosevic

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain

M. Aguilar-Benitez, J. Alcaraz Maestre, P. Arce, C. Battilana, E. Calvo, M. Cepeda,
M. Cerrada, M. Chamizo Llatas, N. Colino, B. De La Cruz, A. Delgado Peris, C. Diez Pardos,
D. Domínguez Vázquez, C. Fernandez Bedoya, J.P. Fernández Ramos, A. Ferrando,
J. Flix, M.C. Fouz, P. Garcia-Abia, O. Gonzalez Lopez, S. Goy Lopez, J.M. Hernandez,
M.I. Josa, G. Merino, J. Puerta Pelayo, I. Redondo, L. Romero, J. Santaolalla, M.S. Soares,
C. Willmott

Universidad Autónoma de Madrid, Madrid, Spain

C. Albajar, G. Codispoti, J.F. de Trocóniz

Universidad de Oviedo, Oviedo, Spain

J. Cuevas, J. Fernandez Menendez, S. Folgueras, I. Gonzalez Caballero, L. Lloret Iglesias,
J.M. Vizán García

Instituto de Física de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain

J.A. Brochero Cifuentes, I.J. Cabrillo, A. Calderon, S.H. Chuang, J. Duarte Campderros, M. Felcini²⁵, M. Fernandez, G. Gomez, J. Gonzalez Sanchez, C. Jorda, P. Lobelle Pardo, A. Lopez Virto, J. Marco, R. Marco, C. Martinez Rivero, F. Matorras, F.J. Munoz Sanchez, J. Piedra Gomez²⁶, T. Rodrigo, A.Y. Rodríguez-Marrero, A. Ruiz-Jimeno, L. Scodellaro, M. Sobron Sanudo, I. Vila, R. Vilar Cortabitarte

CERN, European Organization for Nuclear Research, Geneva, Switzerland

D. Abbaneo, E. Auffray, G. Auzinger, P. Baillon, A.H. Ball, D. Barney, A.J. Bell²⁷, D. Benedetti, C. Bernet³, W. Bialas, P. Bloch, A. Bocci, S. Bolognesi, M. Bona, H. Breuker, K. Bunkowski, T. Camporesi, G. Cerminara, T. Christiansen, J.A. Coarasa Perez, B. Curé, D. D'Enterria, A. De Roeck, S. Di Guida, N. Dupont-Sagorin, A. Elliott-Peisert, B. Frisch, W. Funk, A. Gaddi, G. Georgiou, H. Gerwig, D. Gigi, K. Gill, D. Giordano, F. Glege, R. Gomez-Reino Garrido, M. Gouzevitch, P. Govoni, S. Gowdy, L. Guiducci, M. Hansen, C. Hartl, J. Harvey, J. Hegeman, B. Hegner, H.F. Hoffmann, A. Honma, V. Innocente, P. Janot, K. Kaadze, E. Karavakis, P. Lecoq, C. Lourenço, T. Mäki, M. Malberti, L. Malgeri, M. Mannelli, L. Masetti, A. Maurisset, F. Meijers, S. Mersi, E. Meschi, R. Moser, M.U. Mozer, M. Mulders, E. Nesvold¹, M. Nguyen, T. Orimoto, L. Orsini, E. Palencia Cortezon, E. Perez, A. Petrilli, A. Pfeiffer, M. Pierini, M. Pimiä, D. Piparo, G. Polese, A. Racz, W. Reece, J. Rodrigues Antunes, G. Rolandi²⁸, T. Rommerskirchen, M. Rovere, H. Sakulin, C. Schäfer, C. Schwick, I. Segoni, A. Sharma, P. Siegrist, M. Simon, P. Sphicas²⁹, M. Spiropulu²³, M. Stoye, P. Tropea, A. Tsirou, P. Vichoudis, M. Voutilainen, W.D. Zeuner

Paul Scherrer Institut, Villigen, Switzerland

W. Bertl, K. Deiters, W. Erdmann, K. Gabathuler, R. Horisberger, Q. Ingram, H.C. Kaestli, S. König, D. Kotlinski, U. Langenegger, F. Meier, D. Renker, T. Rohe, J. Sibille³⁰, A. Starodumov³¹

Institute for Particle Physics, ETH Zurich, Zurich, Switzerland

L. Bäni, P. Bortignon, L. Caminada³², B. Casal, N. Chanon, Z. Chen, S. Cittolin, G. Dissertori, M. Dittmar, J. Eugster, K. Freudenreich, C. Grab, W. Hintz, P. Lecomte, W. Lusterhmann, C. Marchica³², P. Martinez Ruiz del Arbol, P. Milenovic³³, F. Moortgat, C. Nägeli³², P. Nef, F. Nessi-Tedaldi, L. Pape, F. Pauss, T. Punz, A. Rizzi, F.J. Ronga, M. Rossini, L. Sala, A.K. Sanchez, M.-C. Sawley, B. Stieger, L. Tauscher[†], A. Thea, K. Theofilatos, D. Treille, C. Urscheler, R. Wallny, M. Weber, L. Wehrli, J. Weng

Universität Zürich, Zurich, Switzerland

E. Aguilo, C. AMSler, V. Chiochia, S. De Visscher, C. Favaro, M. Ivova Rikova, B. Millan Mejias, P. Otiougova, P. Robmann, A. Schmidt, H. Snoek

National Central University, Chung-Li, Taiwan

Y.H. Chang, K.H. Chen, C.M. Kuo, S.W. Li, W. Lin, Z.K. Liu, Y.J. Lu, D. Mekterovic, R. Volpe, J.H. Wu, S.S. Yu

National Taiwan University (NTU), Taipei, Taiwan

P. Bartalini, P. Chang, Y.H. Chang, Y.W. Chang, Y. Chao, K.F. Chen, W.-S. Hou, Y. Hsiung, K.Y. Kao, Y.J. Lei, R.-S. Lu, J.G. Shiu, Y.M. Tzeng, M. Wang

Cukurova University, Adana, Turkey

A. Adiguzel, M.N. Bakirci³⁴, S. Cerci³⁵, C. Dozen, I. Dumanoglu, E. Eskut, S. Girgis, G. Gokbulut, I. Hos, E.E. Kangal, A. Kayis Topaksu, G. Onengut, K. Ozdemir, S. Ozturk³⁶, A. Polatoz, K. Sogut³⁷, D. Sunar Cerci³⁵, B. Tali³⁵, H. Topakli³⁴, D. Uzun, L.N. Vergili, M. Vergili

Middle East Technical University, Physics Department, Ankara, Turkey

I.V. Akin, T. Aliev, B. Bilin, S. Bilmis, M. Deniz, H. Gamsizkan, A.M. Guler, K. Ocalan, A. Ozpineci, M. Serin, R. Sever, U.E. Surat, E. Yildirim, M. Zeyrek

Bogazici University, Istanbul, Turkey

M. Deliomeroğlu, D. Demir³⁸, E. Gülmez, B. Isildak, M. Kaya³⁹, O. Kaya³⁹, M. Özbek, S. Ozkorucuklu⁴⁰, N. Sonmez⁴¹

National Scientific Center, Kharkov Institute of Physics and Technology, Kharkov, Ukraine

L. Levchuk

University of Bristol, Bristol, United Kingdom

F. Bostock, J.J. Brooke, T.L. Cheng, E. Clement, D. Cussans, R. Frazier, J. Goldstein, M. Grimes, D. Hartley, G.P. Heath, H.F. Heath, L. Kreczko, S. Metson, D.M. Newbold⁴², K. Nirunpong, A. Poll, S. Senkin, V.J. Smith

Rutherford Appleton Laboratory, Didcot, United Kingdom

L. Basso⁴³, K.W. Bell, A. Belyaev⁴³, C. Brew, R.M. Brown, B. Camanzi, D.J.A. Cockerill, J.A. Coughlan, K. Harder, S. Harper, J. Jackson, B.W. Kennedy, E. Olaiya, D. Petyt, B.C. Radburn-Smith, C.H. Shepherd-Themistocleous, I.R. Tomalin, W.J. Womersley, S.D. Worm

Imperial College, London, United Kingdom

R. Bainbridge, G. Ball, J. Ballin, R. Beuselinck, O. Buchmuller, D. Colling, N. Cripps, M. Cutajar, G. Davies, M. Della Negra, W. Ferguson, J. Fulcher, D. Futyan, A. Gilbert, A. Guneratne Bryer, G. Hall, Z. Hatherell, J. Hays, G. Iles, M. Jarvis, G. Karapostoli, L. Lyons, B.C. MacEvoy, A.-M. Magnan, J. Marrouche, B. Mathias, R. Nandi, J. Nash,

A. Nikitenko³¹, A. Papageorgiou, M. Pesaresi, K. Petridis, M. Pioppi⁴⁴, D.M. Raymond, S. Rogerson, N. Rompotis, A. Rose, M.J. Ryan, C. Seez, P. Sharp, A. Sparrow, A. Tapper, S. Tourneur, M. Vazquez Acosta, T. Virdee, S. Wakefield, N. Wardle, D. Wardrope, T. Whyntie

Brunel University, Uxbridge, United Kingdom

M. Barrett, M. Chadwick, J.E. Cole, P.R. Hobson, A. Khan, P. Kyberd, D. Leslie, W. Martin, I.D. Reid, L. Teodorescu

Baylor University, Waco, USA

K. Hatakeyama, H. Liu

The University of Alabama, Tuscaloosa, USA

C. Henderson

Boston University, Boston, USA

T. Bose, E. Carrera Jarrin, C. Fantasia, A. Heister, J. St. John, P. Lawson, D. Lazic, J. Rohlf, D. Sperka, L. Sulak

Brown University, Providence, USA

A. Avetisyan, S. Bhattacharya, J.P. Chou, D. Cutts, A. Ferapontov, U. Heintz, S. Jabeen, G. Kukartsev, G. Landsberg, M. Luk, M. Narain, D. Nguyen, M. Segala, T. Sinthuprasith, T. Speer, K.V. Tsang

University of California, Davis, Davis, USA

R. Breedon, G. Breto, M. Calderon De La Barca Sanchez, S. Chauhan, M. Chertok, J. Conway, P.T. Cox, J. Dolen, R. Erbacher, E. Friis, W. Ko, A. Kopecky, R. Lander, H. Liu, S. Maruyama, T. Miceli, M. Nikolic, D. Pellett, J. Robles, S. Salur, T. Schwarz, M. Searle, J. Smith, M. Squires, M. Tripathi, R. Vasquez Sierra, C. Veelken

University of California, Los Angeles, Los Angeles, USA

V. Andreev, K. Arisaka, D. Cline, R. Cousins, A. Deisher, J. Duris, S. Erhan, C. Farrell, J. Hauser, M. Ignatenko, C. Jarvis, C. Plager, G. Rakness, P. Schlein[†], J. Tucker, V. Valuev

University of California, Riverside, Riverside, USA

J. Babb, A. Chandra, R. Clare, J. Ellison, J.W. Gary, F. Giordano, G. Hanson, G.Y. Jeng, S.C. Kao, F. Liu, H. Liu, O.R. Long, A. Luthra, H. Nguyen, B.C. Shen[†], R. Stringer, J. Sturdy, S. Sumowidagdo, R. Wilken, S. Wimpenny

University of California, San Diego, La Jolla, USA

W. Andrews, J.G. Branson, G.B. Cerati, D. Evans, F. Golf, A. Holzner, R. Kelley, M. Lebourgeois, J. Letts, B. Mangano, S. Padhi, C. Palmer, G. Petrucciani, H. Pi, M. Pieri, R. Ranieri, M. Sani, V. Sharma, S. Simon, E. Sudano, M. Tadel, Y. Tu, A. Vartak, S. Wasserbaech⁴⁵, F. Würthwein, A. Yagil, J. Yoo

University of California, Santa Barbara, Santa Barbara, USA

D. Barge, R. Bellan, C. Campagnari, M. D'Alfonso, T. Danielson, K. Flowers, P. Geffert, J. Incandela, C. Justus, P. Kalavase, S.A. Koay, D. Kovalskyi, V. Krutelyov, S. Lowette, N. Mccoll, V. Pavlunin, F. Rebassoo, J. Ribnik, J. Richman, R. Rossin, D. Stuart, W. To, J.R. Vlimant

California Institute of Technology, Pasadena, USA

A. Apresyan, A. Bornheim, J. Bunn, Y. Chen, M. Gataullin, Y. Ma, A. Mott, H.B. Newman, C. Rogan, K. Shin, V. Timciuc, P. Traczyk, J. Veverka, R. Wilkinson, Y. Yang, R.Y. Zhu

Carnegie Mellon University, Pittsburgh, USA

B. Akgun, R. Carroll, T. Ferguson, Y. Iiyama, D.W. Jang, S.Y. Jun, Y.F. Liu, M. Paulini, J. Russ, H. Vogel, I. Vorobiev

University of Colorado at Boulder, Boulder, USA

J.P. Cumalat, M.E. Dinardo, B.R. Drell, C.J. Edelmaier, W.T. Ford, A. Gaz, B. Heyburn, E. Luiggi Lopez, U. Nauenberg, J.G. Smith, K. Stenson, K.A. Ulmer, S.R. Wagner, S.L. Zang

Cornell University, Ithaca, USA

L. Agostino, J. Alexander, A. Chatterjee, N. Eggert, L.K. Gibbons, B. Heltsley, K. Henriksson, W. Hopkins, A. Khukhunaishvili, B. Kreis, G. Nicolas Kaufman, J.R. Patterson, D. Puigh, A. Ryd, M. Saelim, E. Salvati, X. Shi, W. Sun, W.D. Teo, J. Thom, J. Thompson, J. Vaughan, Y. Weng, L. Winstrom, P. Wittich

Fairfield University, Fairfield, USA

A. Biselli, G. Cirino, D. Winn

Fermi National Accelerator Laboratory, Batavia, USA

S. Abdullin, M. Albrow, J. Anderson, G. Apollinari, M. Atac, J.A. Bakken, L.A.T. Bauerdick, A. Beretvas, J. Berryhill, P.C. Bhat, I. Bloch, F. Borchering, K. Burkett, J.N. Butler, V. Chetluru, H.W.K. Cheung, F. Chlebana, S. Cihangir, W. Cooper, D.P. Eartly, V.D. Elvira, S. Esen, I. Fisk, J. Freeman, Y. Gao, E. Gottschalk, D. Green, K. Gunthoti, O. Gutsche, J. Hanlon, R.M. Harris, J. Hirschauer, B. Hooberman, H. Jensen, M. Johnson, U. Joshi, R. Khatiwada, B. Klima, K. Kousouris, S. Kunori, S. Kwan, C. Leonidopoulos, P. Limon, D. Lincoln, R. Lipton, J. Lykken, K. Maeshima, J.M. Marraffino, D. Mason, P. McBride, T. Miao, K. Mishra, S. Mrenna, Y. Musienko⁴⁶, C. Newman-Holmes, V. O'Dell, J. Pivarski, R. Pordes, O. Prokofyev, E. Sexton-Kennedy, S. Sharma, W.J. Spalding, L. Spiegel, P. Tan, L. Taylor, S. Tkaczyk, L. Uplegger, E.W. Vaandering, R. Vidal, J. Whitmore, W. Wu, F. Yang, F. Yumiceva, J.C. Yun

University of Florida, Gainesville, USA

D. Acosta, P. Avery, D. Bourilkov, M. Chen, S. Das, M. De Gruttola, G.P. Di Giovanni, D. Dobur, A. Drozdetskiy, R.D. Field, M. Fisher, Y. Fu, I.K. Furic, J. Gartner, J. Hugon, B. Kim, J. Konigsberg, A. Korytov, A. Kropivnitskaya, T. Kypreos, J.F. Low, K. Matchev, G. Mitselmakher, L. Muniz, C. Prescott, R. Remington, A. Rinkevicius, M. Schmitt, B. Scurlock, P. Sellers, N. Skhirtladze, M. Snowball, D. Wang, J. Yelton, M. Zakaria

Florida International University, Miami, USA

V. Gaultney, L.M. Lebolo, S. Linn, P. Markowitz, G. Martinez, J.L. Rodriguez

Florida State University, Tallahassee, USA

T. Adams, A. Askew, J. Bochenek, J. Chen, B. Diamond, S.V. Gleyzer, J. Haas, S. Hagopian, V. Hagopian, M. Jenkins, K.F. Johnson, H. Prosper, L. Quertenmont, S. Sekmen, V. Veeraraghavan

Florida Institute of Technology, Melbourne, USA

M.M. Baarmand, B. Dorney, S. Guragain, M. Hohlmann, H. Kalakhety, I. Vodopyanov

University of Illinois at Chicago (UIC), Chicago, USA

M.R. Adams, I.M. Anghel, L. Apanasevich, Y. Bai, V.E. Bazterra, R.R. Betts, J. Callner, R. Cavanaugh, C. Dragoiu, L. Gauthier, C.E. Gerber, D.J. Hofman, S. Khalatyan, G.J. Kunde⁴⁷, F. Lacroix, M. Malek, C. O'Brien, C. Silkworth, C. Silvestre, A. Smoron, D. Strom, N. Varelas

The University of Iowa, Iowa City, USA

U. Akgun, E.A. Albayrak, B. Bilki, W. Clarida, F. Duru, C.K. Lae, E. McCliment, J.-P. Merlo, H. Mermerkaya⁴⁸, A. Mestvirishvili, A. Moeller, J. Nachtman, C.R. Newsom, E. Norbeck, J. Olson, Y. Onel, F. Ozok, S. Sen, J. Wetzell, T. Yetkin, K. Yi

Johns Hopkins University, Baltimore, USA

B.A. Barnett, B. Blumenfeld, A. Bonato, C. Eskew, D. Fehling, G. Giurciu, A.V. Gritsan, Z.J. Guo, G. Hu, P. Maksimovic, S. Rappoccio, M. Swartz, N.V. Tran, A. Whitbeck

The University of Kansas, Lawrence, USA

P. Baringer, A. Bean, G. Benelli, O. Grachov, R.P. Kenny Iii, M. Murray, D. Noonan, S. Sanders, J.S. Wood, V. Zhukova

Kansas State University, Manhattan, USA

A.f. Barfuss, T. Bolton, I. Chakaberia, A. Ivanov, S. Khalil, M. Makouski, Y. Maravin, S. Shrestha, I. Svintradze, Z. Wan

Lawrence Livermore National Laboratory, Livermore, USA

J. Gronberg, D. Lange, D. Wright

University of Maryland, College Park, USA

A. Baden, M. Boutemeur, S.C. Eno, D. Ferencek, J.A. Gomez, N.J. Hadley, R.G. Kellogg, M. Kirn, Y. Lu, A.C. Mignerey, K. Rossato, P. Rumerio, F. Santanastasio, A. Skuja, J. Temple, M.B. Tonjes, S.C. Tonwar, E. Twedt

Massachusetts Institute of Technology, Cambridge, USA

B. Alver, G. Bauer, J. Bendavid, W. Busza, E. Butz, I.A. Cali, M. Chan, V. Dutta, P. Everaerts, G. Gomez Ceballos, M. Goncharov, K.A. Hahn, P. Harris, Y. Kim, M. Klute, Y.-J. Lee, W. Li, C. Loizides, P.D. Luckey, T. Ma, S. Nahn, C. Paus, D. Ralph, C. Roland, G. Roland, M. Rudolph, G.S.F. Stephans, F. Stöckli, K. Sumorok, K. Sung, D. Velicanu, E.A. Wenger, R. Wolf, S. Xie, M. Yang, Y. Yilmaz, A.S. Yoon, M. Zanetti

University of Minnesota, Minneapolis, USA

S.I. Cooper, P. Cushman, B. Dahmes, A. De Benedetti, P.R. Duderø, G. Franzoni, A. Gude, J. Haupt, K. Klapoetke, Y. Kubota, J. Mans, N. Pastika, V. Rekovic, R. Rusack, M. Sasseville, A. Singovsky, N. Tambe

University of Mississippi, University, USA

L.M. Cremaldi, R. Godang, R. Kroeger, L. Perera, R. Rahmat, D.A. Sanders, D. Summers

University of Nebraska-Lincoln, Lincoln, USA

K. Bloom, S. Bose, J. Butt, D.R. Claes, A. Dominguez, M. Eads, P. Jindal, J. Keller, T. Kelly, I. Kravchenko, J. Lazo-Flores, H. Malbouisson, S. Malik, G.R. Snow

State University of New York at Buffalo, Buffalo, USA

U. Baur, A. Godshalk, I. Iashvili, S. Jain, A. Kharchilava, A. Kumar, S.P. Shipkowski, K. Smith

Northeastern University, Boston, USA

G. Alverson, E. Barberis, D. Baumgartel, O. Boeriu, M. Chasco, S. Reucroft, J. Swain, D. Trocino, D. Wood, J. Zhang

Northwestern University, Evanston, USA

A. Anastassov, A. Kubik, N. Odell, R.A. Ofierzynski, B. Pollack, A. Pozdnyakov, M. Schmitt, S. Stoynev, M. Velasco, S. Won

University of Notre Dame, Notre Dame, USA

L. Antonelli, D. Berry, A. Brinkerhoff, M. Hildreth, C. Jessop, D.J. Karmgard, J. Kolb, T. Kolberg, K. Lannon, W. Luo, S. Lynch, N. Marinelli, D.M. Morse, T. Pearson, R. Ruchti, J. Slaunwhite, N. Valls, M. Wayne, J. Ziegler

The Ohio State University, Columbus, USA

B. Bylsma, L.S. Durkin, J. Gu, C. Hill, P. Killewald, K. Kotov, T.Y. Ling, M. Rodenburg, C. Vuosalo, G. Williams

Princeton University, Princeton, USA

N. Adam, E. Berry, P. Elmer, D. Gerbaudo, V. Halyo, P. Hebda, A. Hunt, J. Jones, E. Laird, D. Lopes Pegna, D. Marlow, T. Medvedeva, M. Mooney, J. Olsen, P. Piroué, X. Quan, B. Safdi, H. Saka, D. Stickland, C. Tully, J.S. Werner, A. Zuranski

University of Puerto Rico, Mayaguez, USA

J.G. Acosta, X.T. Huang, A. Lopez, H. Mendez, S. Oliveros, J.E. Ramirez Vargas, A. Zatserklyaniy

Purdue University, West Lafayette, USA

E. Alagoz, V.E. Barnes, G. Bolla, L. Borrello, D. Bortoletto, M. De Mattia, A. Everett, A.F. Garfinkel, L. Gutay, Z. Hu, M. Jones, O. Koybasi, M. Kress, A.T. Laasanen, N. Leonardo, C. Liu, V. Maroussov, P. Merkel, D.H. Miller, N. Neumeister, I. Shipsey, D. Silvers, A. Svyatkovskiy, H.D. Yoo, J. Zablocki, Y. Zheng

Purdue University Calumet, Hammond, USA

N. Parashar

Rice University, Houston, USA

A. Adair, C. Boulahouache, K.M. Ecklund, F.J.M. Geurts, B.P. Padley, R. Redjimi, J. Roberts, J. Zabel

University of Rochester, Rochester, USA

B. Betchart, A. Bodek, Y.S. Chung, R. Covarelli, P. de Barbaro, R. Demina, Y. Eshaq, H. Flacher, A. Garcia-Bellido, P. Goldenzweig, Y. Gotra, J. Han, A. Harel, D.C. Miner, D. Orbaker, G. Petrillo, W. Sakumoto, D. Vishnevskiy, M. Zielinski

The Rockefeller University, New York, USA

A. Bhatti, R. Ciesielski, L. Demortier, K. Goulios, G. Lungu, S. Malik, C. Mesropian

Rutgers, the State University of New Jersey, Piscataway, USA

O. Atramentov, A. Barker, D. Duggan, Y. Gershtein, R. Gray, E. Halkiadakis, D. Hidas, D. Hits, A. Lath, S. Panwalkar, R. Patel, K. Rose, S. Schnetzer, S. Somalwar, R. Stone, S. Thomas

University of Tennessee, Knoxville, USA

G. Cerizza, M. Hollingsworth, S. Spanier, Z.C. Yang, A. York

Texas A&M University, College Station, USA

R. Eusebi, W. Flanagan, J. Gilmore, A. Gurrola, T. Kamon, V. Khotilovich, R. Montalvo, I. Osipenkov, Y. Pakhotin, A. Safonov, S. Sengupta, A. Tatarinov, D. Toback, M. Weinberger

Texas Tech University, Lubbock, USA

N. Akchurin, C. Bardak, J. Damgov, C. Jeong, K. Kovitanggoon, S.W. Lee, T. Libeiro, P. Mane, Y. Roh, A. Sill, I. Volobouev, R. Wigmans, E. Yazgan

Vanderbilt University, Nashville, USA

E. Appelt, E. Brownson, D. Engh, C. Florez, W. Gabella, M. Issah, W. Johns, P. Kurt, C. Maguire, A. Melo, P. Sheldon, B. Snook, S. Tuo, J. Velkovska

University of Virginia, Charlottesville, USA

M.W. Arenton, M. Balazs, S. Boutle, B. Cox, B. Francis, J. Goodell, R. Hirosky, A. Ledovskoy, C. Lin, C. Neu, R. Yohay

Wayne State University, Detroit, USA

S. Gollapinni, R. Harr, P.E. Karchin, P. Lamichhane, M. Mattson, C. Milstène, A. Sakharov

University of Wisconsin, Madison, USA

M. Anderson, M. Bachtis, J.N. Bellinger, D. Carlsmith, S. Dasu, J. Efron, L. Gray, K.S. Grogg, M. Grothe, R. Hall-Wilton, M. Herndon, A. Hervé, P. Klabbbers, J. Klukas, A. Lanaro, C. Lazaridis, J. Leonard, R. Loveless, A. Mohapatra, I. Ojalvo, D. Reeder, I. Ross, A. Savin, W.H. Smith, J. Swanson, M. Weinberg

†: Deceased

- 1: Also at CERN, European Organization for Nuclear Research, Geneva, Switzerland
- 2: Also at Universidade Federal do ABC, Santo Andre, Brazil
- 3: Also at Laboratoire Leprince-Ringuet, Ecole Polytechnique, IN2P3-CNRS, Palaiseau, France
- 4: Also at Suez Canal University, Suez, Egypt
- 5: Also at British University, Cairo, Egypt
- 6: Also at Fayoum University, El-Fayoum, Egypt
- 7: Also at Soltan Institute for Nuclear Studies, Warsaw, Poland
- 8: Also at Massachusetts Institute of Technology, Cambridge, USA
- 9: Also at Université de Haute-Alsace, Mulhouse, France
- 10: Also at Brandenburg University of Technology, Cottbus, Germany
- 11: Also at Moscow State University, Moscow, Russia
- 12: Also at Institute of Nuclear Research ATOMKI, Debrecen, Hungary
- 13: Also at Eötvös Loránd University, Budapest, Hungary
- 14: Also at Tata Institute of Fundamental Research - HECR, Mumbai, India
- 15: Also at University of Visva-Bharati, Santiniketan, India
- 16: Also at Sharif University of Technology, Tehran, Iran

- 17: Also at Shiraz University, Shiraz, Iran
- 18: Also at Isfahan University of Technology, Isfahan, Iran
- 19: Also at Facoltà Ingegneria Università di Roma "La Sapienza", Roma, Italy
- 20: Also at Università della Basilicata, Potenza, Italy
- 21: Also at Laboratori Nazionali di Legnaro dell' INFN, Legnaro, Italy
- 22: Also at Università degli studi di Siena, Siena, Italy
- 23: Also at California Institute of Technology, Pasadena, USA
- 24: Also at Faculty of Physics of University of Belgrade, Belgrade, Serbia
- 25: Also at University of California, Los Angeles, Los Angeles, USA
- 26: Also at University of Florida, Gainesville, USA
- 27: Also at Université de Genève, Geneva, Switzerland
- 28: Also at Scuola Normale e Sezione dell' INFN, Pisa, Italy
- 29: Also at University of Athens, Athens, Greece
- 30: Also at The University of Kansas, Lawrence, USA
- 31: Also at Institute for Theoretical and Experimental Physics, Moscow, Russia
- 32: Also at Paul Scherrer Institut, Villigen, Switzerland
- 33: Also at University of Belgrade, Faculty of Physics and Vinca Institute of Nuclear Sciences, Belgrade, Serbia
- 34: Also at Gaziosmanpasa University, Tokat, Turkey
- 35: Also at Adiyaman University, Adiyaman, Turkey
- 36: Also at The University of Iowa, Iowa City, USA
- 37: Also at Mersin University, Mersin, Turkey
- 38: Also at Izmir Institute of Technology, Izmir, Turkey
- 39: Also at Kafkas University, Kars, Turkey
- 40: Also at Suleyman Demirel University, Isparta, Turkey
- 41: Also at Ege University, Izmir, Turkey
- 42: Also at Rutherford Appleton Laboratory, Didcot, United Kingdom
- 43: Also at School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom
- 44: Also at INFN Sezione di Perugia; Università di Perugia, Perugia, Italy
- 45: Also at Utah Valley University, Orem, USA
- 46: Also at Institute for Nuclear Research, Moscow, Russia
- 47: Also at Los Alamos National Laboratory, Los Alamos, USA
- 48: Also at Erzincan University, Erzincan, Turkey