

P. Abreu<sup>1,2</sup>, A. Albert<sup>3</sup>, R. Alfaro<sup>4</sup>, A. Alfonso<sup>5</sup>, C. Álvarez<sup>6</sup>, Q. An<sup>7</sup>, E. O. Angüner<sup>8</sup>, C. Arcaro<sup>9</sup>, R. Arceo<sup>6</sup>, S. Arias<sup>10</sup>, H. Arnaldj<sup>11</sup>, P. Assis<sup>1,2</sup>, H. A. Ayala Solares<sup>12</sup>, A. Bakalova<sup>13</sup>, U. Barres de Almeida<sup>14,15</sup>, I. Batković<sup>9,16</sup>, J. Bazo<sup>17</sup>, J. Bellido<sup>18,19</sup>, E. Belmont<sup>4</sup>, S. Y. BenZvi<sup>20</sup>, A. Bernal<sup>21</sup>, W. Bian<sup>22</sup>, C. Bigongiari<sup>23</sup>, E. Bottacini<sup>9,16</sup>, P. Brogueira<sup>1,2</sup>, T. Bulik<sup>24</sup>, G. Busetto<sup>9,16</sup>, K. S. Caballero-Mora<sup>6</sup>, P. Camarri<sup>25,26</sup>, S. Campos<sup>27</sup>, W. Cao<sup>7</sup>, Z. Cao<sup>7</sup>, Z. Cao<sup>28</sup>, T. Capistrán<sup>21</sup>, M. Cardillo<sup>23</sup>, E. Carquin<sup>29</sup>, A. Carramiñana<sup>30</sup>, C. Castromonte<sup>31</sup>, J. Chang<sup>28</sup>, O. Chaparro<sup>\*</sup>, S. Chen<sup>22</sup>, M. Chianese<sup>32,33</sup>, A. Chiavassa<sup>34,35</sup>, L. Chytka<sup>13</sup>, R. Colallillo<sup>32,33</sup>, R. Conceição<sup>1,2</sup>, G. Consolati<sup>36,38</sup>, R. Cordero<sup>38</sup>, P. J. Costa<sup>1,2</sup>, J. Cotzomi<sup>39</sup>, S. Dasso<sup>40</sup>, A. De Angelis<sup>9,16</sup>, H. de León Hidalgo<sup>6</sup>, P. Desiati<sup>41</sup>, F. Di Pierro<sup>35</sup>, G. Di Sciascio<sup>25</sup>, J. C. Díaz Vélez<sup>41</sup>, C. Dib<sup>29</sup>, B. Dingus<sup>3</sup>, J. Djvuksland<sup>42</sup>, C. Dobrigkeit<sup>43</sup>, L. M. Domingues Mendes<sup>1,44</sup>, T. Dorigo<sup>9</sup>, M. Doró<sup>9,16</sup>, A. C. dos Reis<sup>14</sup>, M. Du Vernois<sup>41</sup>, M. Echiburú<sup>5</sup>, D. Elsaesser<sup>45</sup>, K. Engel<sup>2,46</sup>, T. Ergin<sup>47</sup>, F. Espinoza<sup>5</sup>, K. Fang<sup>41</sup>, F. Farfán Carreras<sup>48</sup>, A. Fazzi<sup>37,49</sup>, C. Feng<sup>50</sup>, M. Feroci<sup>23</sup>, N. Fraija<sup>21</sup>, S. Fraija<sup>21</sup>, A. Franceschini<sup>16</sup>, G. F. Franco<sup>14</sup>, S. Funk<sup>51</sup>, S. Garcia<sup>10</sup>, J. A. García-González<sup>52</sup>, F. Garfias<sup>21</sup>, G. Giacinti<sup>22</sup>, L. Gibilisco<sup>1,2</sup>, J. Glombitza<sup>51</sup>, H. Goksu<sup>42</sup>, G. Gong<sup>53</sup>, B. S. González<sup>1,2</sup>, M. M. Gonzalez<sup>21</sup>, J. Goodman<sup>46</sup>, M. Gu<sup>28</sup>, F. Guarino<sup>32,33</sup>, S. Gupta<sup>54</sup>, F. Haist<sup>42</sup>, H. Hakobyan<sup>29</sup>, G. Han<sup>55</sup>, P. Hansen<sup>56</sup>, J. P. Harding<sup>3</sup>, J. Helo<sup>5</sup>, I. Herzog<sup>57</sup>, J. Hinton<sup>42</sup>, K. Hu<sup>50</sup>, D. Huang<sup>46</sup>, P. Huentemeyer<sup>58</sup>, F. Hueyotl-Zahuantitla<sup>6</sup>, A. Insolia<sup>59</sup>, A. Iriarte<sup>21</sup>, J. Isaković<sup>60</sup>, V. Joshi<sup>51</sup>, J. Juryšek<sup>13</sup>, S. Kaci<sup>22</sup>, D. Kieda<sup>61</sup>, F. La Monaca<sup>23</sup>, G. La Mura<sup>1,62</sup>, R. G. Lang<sup>51</sup>, J. S. Lapington<sup>63</sup>, R. Laspiur<sup>27</sup>, L. Lavitola<sup>33</sup>, J. Lee<sup>64</sup>, F. Leitl<sup>51</sup>, L. Lessio<sup>23</sup>, C. Li<sup>28</sup>, J. Li<sup>7</sup>, K. Li<sup>28</sup>, T. Li<sup>22</sup>, B. Liberti<sup>25,26</sup>, S. Lin<sup>65</sup>, D. Liu<sup>50</sup>, J. Liu<sup>28</sup>, R. Liu<sup>66</sup>, F. Longo<sup>67,68</sup>, Y. Luo<sup>22</sup>, J. Lv<sup>69</sup>, E. Macerata<sup>37,49</sup>, K. Malone<sup>3</sup>, D. Mandat<sup>13</sup>, M. Manganaro<sup>60</sup>, M. Mariani<sup>37,49</sup>, A. Mariuzzi<sup>56</sup>, M. Mariotti<sup>9,16</sup>, T. Marrodan<sup>42</sup>, J. Martínez-Castro<sup>70</sup>, H. Martínez-Huerta<sup>71</sup>, S. Medina<sup>5</sup>, D. Melo<sup>72</sup>, L. F. Mendes<sup>2</sup>, E. Meza<sup>73,74</sup>, D. Miceli<sup>9</sup>, S. Miozzi<sup>25</sup>, A. Mitchell<sup>51</sup>, A. Molinario<sup>35,75</sup>, O. G. Morales-Olivares<sup>6</sup>, E. Moreno<sup>39</sup>, A. Morselli<sup>25,26</sup>, E. Mossini<sup>37,49</sup>, M. Mostafá<sup>12</sup>, F. Muleri<sup>23</sup>, F. Nardi<sup>9,16</sup>, A. Negro<sup>34,35</sup>, L. Nellen<sup>76</sup>, V. Novotny<sup>13</sup>, L. Olivera-Nieto<sup>42</sup>, E. Orlando<sup>67,68</sup>, M. Osorio<sup>21</sup>, L. Otiniano<sup>74</sup>, M. Peresano<sup>34,35</sup>, G. Piano<sup>23</sup>, A. Pichel<sup>40</sup>, M. Pihet<sup>9,16</sup>, M. Pimenta<sup>1,2</sup>, E. Prandini<sup>9,16</sup>, J. Qin<sup>7</sup>, E. Quispe<sup>1</sup>, S. Rainò<sup>77</sup>, E. Rangel<sup>21</sup>, L. Recabarren<sup>9,16</sup>, A. Reisenegger<sup>54</sup>, H. X. Ren<sup>42</sup>, F. Rescic<sup>60</sup>, B. Reville<sup>42</sup>, C. D. Rho<sup>78</sup>, M. Riquelme<sup>79</sup>, G. Rodriguez Fernandez<sup>25</sup>, Y. Roh<sup>64</sup>, G. E. Romero<sup>48</sup>, F. F. Rosales-Ortega<sup>30</sup>, B. Rossi<sup>33</sup>, A. C. Rovero<sup>40</sup>, A. Ruina<sup>9</sup>, E. Ruiz-Velasco<sup>42</sup>, G. Salazar<sup>27</sup>, J. Samanes<sup>74</sup>, F. Sanchez<sup>72</sup>, A. Sandoval<sup>4</sup>, M. Santander<sup>80</sup>, R. Santonicio<sup>25,26</sup>, G. L. P. Santos<sup>14</sup>, D. Sartirana<sup>35</sup>, N. Saviano<sup>32,33</sup>, M. Schneider<sup>46</sup>, M. Schneider<sup>51</sup>, H. Schoorlemmer<sup>81</sup>, J. Serna-Franco<sup>4</sup>, V. Serrano<sup>27</sup>, A. Smith<sup>46</sup>, Y. Son<sup>64</sup>, O. Soto<sup>5</sup>, R. W. Springer<sup>61</sup>, J. Stewart<sup>63</sup>, L. A. Stuaní<sup>82</sup>, H. Sun<sup>50</sup>, R. Tang<sup>22</sup>, Z. Tang<sup>7</sup>, S. Tapia<sup>29</sup>, M. Tavani<sup>23</sup>, T. Terzić<sup>60</sup>, K. Tollefson<sup>57</sup>, B. Tomé<sup>1,2</sup>, I. Torres<sup>30</sup>, R. Torres-Escobedo<sup>22</sup>, G. C. Trinchero<sup>35,75</sup>, R. Turner<sup>58</sup>, P. Ulloa<sup>5</sup>, L. Valore<sup>32,33</sup>, C. van Eldik<sup>51</sup>, I. D. Vergara Quispe<sup>56</sup>, A. Viana<sup>83</sup>, J. Vícha<sup>13</sup>, C. F. Vigorito<sup>34,35</sup>, V. Vittorini<sup>23</sup>, B. Wang<sup>50</sup>, J. Wang<sup>42</sup>, L. Wang<sup>28</sup>, X. Wang<sup>58</sup>, X. Wang<sup>66</sup>, X. Wang<sup>84</sup>, Z. Wang<sup>22</sup>, M. Waqas<sup>32,33</sup>, I. J. Watson<sup>64</sup>, F. Werner<sup>42</sup>, R. White<sup>42</sup>, C. Wiebusch<sup>85</sup>, E. J. Willox<sup>46</sup>, F. Wohlleben<sup>42</sup>, S. Wu<sup>28</sup>, S. Xi<sup>28</sup>, G. Xiao<sup>28</sup>, L. Yang<sup>65</sup>, R. Yang<sup>7</sup>, R. Yanyachi<sup>18</sup>, Z. Yao<sup>28</sup>, D. Zavrtnik<sup>86</sup>, H. Zhang<sup>22</sup>, H. Zhang<sup>66</sup>, S. Zhang<sup>87</sup>, X. Zhang<sup>28</sup>, Y. Zhang<sup>68</sup>, J. Zhao<sup>28</sup>, L. Zhao<sup>7</sup>, H. Zhou<sup>22</sup>, C. Zhu<sup>50</sup>, P. Zhu<sup>88</sup>, and X. Zuo<sup>28</sup>

<sup>1</sup>Laboratório de Instrumentação de Física Experimental de Partículas - LIP, Av. Prof. Gama Pinto, 2, 1649-003 Lisboa, Portugal

<sup>2</sup>Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal

<sup>3</sup>Physics Division, Los Alamos National Laboratory, Los Alamos, NM, USA

<sup>4</sup>Instituto de Física, Universidad Nacional Autónoma de México, Circuito de la Investigación Científica, C.U., A. Postal 70-364, 04510 Cd. de México, México

- <sup>5</sup>Universidad de La Serena, Chile
- <sup>6</sup>Facultad de Ciencias en Física y Matemáticas, Universidad Autónoma de Chiapas, C. P. 29050, Tuxtla Gutiérrez, Chiapas, México
- <sup>7</sup>School of physical science, University of Science and Technology of China, 96 Jinzhai Road, Hefei, Anhui 230026, China
- <sup>8</sup>TÜBİTAK Research Institute for Fundamental Sciences, 41470 Gebze, Turkey
- <sup>9</sup>INFN - Sezione di Padova, I-35131, Padova, Italy
- <sup>10</sup>Universidad Nacional de San Antonio Abad del Cusco, Av. de la Cultura, Nro. 733, Cusco - Perú
- <sup>11</sup>Centro Atómico Bariloche (CNEA-CONICET-IB/UNCuyo), Av. E. Bustillo 9500, (8400) San Carlos de Bariloche, Rio Negro, Argentina
- <sup>12</sup>Department of Physics, Pennsylvania State University, University Park, PA, USA
- <sup>13</sup>Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic
- <sup>14</sup>Centro Brasileiro de Pesquisas Físicas (CBPF), Rua Dr. Xavier Sigaud 150, 22290-180 Rio de Janeiro, Brasil
- <sup>15</sup>Universidade de São Paulo, Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Departamento de Astronomia, Rua do Matão 1226, 05508-090 São Paulo, Brasil
- <sup>16</sup>Università di Padova, I-35131, Padova, Italy
- <sup>17</sup>Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel, 15088, Lima, Perú
- <sup>18</sup>Universidad Nacional de San Agustín de Arequipa, Santa Catalina Nro. 117. Arequipa
- <sup>19</sup>University of Adelaide, Adelaide, S.A., Australia
- <sup>20</sup>Department of Physics and Astronomy, University of Rochester, Rochester, NY, USA
- <sup>21</sup>Instituto de Astronomía, Universidad Nacional Autónoma de México, Circuito Exterior, C.U., A. Postal 70-264, 04510 Cd. de México, México
- <sup>22</sup>Tsung-Dao Lee Institute & School of Physics and Astronomy, Shanghai Jiao Tong University, 520 Shengrong Road, Shanghai 201210, China
- <sup>23</sup>Istituto Nazionale Di Astrofisica (INAF), Roma, Italy
- <sup>24</sup>Astronomical Observatory Warsaw University, 00-478 Warsaw, Poland
- <sup>25</sup>INFN, Roma Tor Vergata, Italy
- <sup>26</sup>Department of Physics, University of Roma Tor Vergata, Viale della Ricerca Scientifica 1, I-00133 Roma, Italy
- <sup>27</sup>Facultad de Ciencias Exactas, Universidad Nacional de Salta, Avda. Bolivia 5150, A4408FVY, Salta, Argentina
- <sup>28</sup>Institute of High Energy Physics, Chinese Academy of Science, 19B Yuquan Road, Shijingshan District, Beijing 100049, China
- <sup>29</sup>CCTVal, Universidad Tecnica Federico Santa Maria, Chile
- <sup>30</sup>Instituto Nacional de Astrofísica, Óptica y Electrónica, Puebla, Mexico
- <sup>31</sup>Universidad Nacional de Ingeniería, Av. Túpac Amaru 210 - Rímac. Apartado 1301, Lima Perú
- <sup>32</sup>Università di Napoli "Federico II", Dipartimento di Fisica "Ettore Pancini", Napoli, Italy
- <sup>33</sup>INFN, Sezione di Napoli, Napoli, Italy
- <sup>34</sup>Università degli Studi di Torino, I-10125 Torino, Italy
- <sup>35</sup>INFN, Sezione di Torino, Torino, Italy
- <sup>36</sup>Politecnico di Milano, Dipartimento di Scienze e Tecnologie Aerospaziali, Milano, Italy
- <sup>37</sup>INFN, sezione di Milano, Milano, Italy
- <sup>38</sup>Departamento de Física, Universidad de Santiago de Chile, Chile
- <sup>39</sup>Facultad de Ciencias Físico Matemáticas, Benemérita Universidad Autónoma de Puebla, Av. San Claudio y 18 Sur, Ciudad Universitaria 72570, Puebla, Mexico.
- <sup>40</sup>Instituto de Astronomía y Física del Espacio (IAFE (CONICET-UBA)), Ciudad Universitaria, CABA, Argentina
- <sup>41</sup>Department of Physics, University of Wisconsin-Madison, Madison, WI, USA
- <sup>42</sup>Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany
- <sup>43</sup>Departamento de Raios Cósmicos e Cronologia, Instituto de Física "Gleb Wataghin", Universidade Estadual de Campinas, C.P. 6165, 13083-970 Campinas, Brasil
- <sup>44</sup>Centro Federal de Educação Tecnológica Celso Suckow da Fonseca (CEFET), Rio de Janeiro, Brasil
- <sup>45</sup>Technische Universität Dortmund, D-44221 Dortmund, Germany
- <sup>46</sup>Department of Physics, University of Maryland, College Park, MD, USA

- <sup>47</sup>Middle East Technical University, Northern Cyprus Campus, 99738 Kalkanli via Mersin 10, Turkey
- <sup>48</sup>Instituto Argentino de Radioastronomía (CONICET, CIC, UNLP), Camino Gral. Belgrano Km 40, Berazategui, Argentina
- <sup>49</sup>Politecnico di Milano, Dipartimento di Energia, Milano, Italy
- <sup>50</sup>Key Laboratory of Particle Physics and Particle Irradiation (MOE), Institute of Frontier and Interdisciplinary Science, Shandong University, Qingdao, Shandong 266237, China
- <sup>51</sup>Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Str. 2, D 91058 Erlangen, Germany
- <sup>52</sup>Tecnologico de Monterrey, Escuela de Ingeniería y Ciencias, Ave. Eugenio Garza Sada 2501, Monterrey, N.L., Mexico, 64849
- <sup>53</sup>Dept. of Engineering Physics, Tsinghua University, 1 Tsinghua Yuan, Haidian District, Beijing 100084, China
- <sup>54</sup>Departamento de Física, Facultad de Ciencias Básicas, Universidad Metropolitana de Ciencias de la Educación, Av. José Pedro Alessandri 774, Ñuñoa, Chile
- <sup>55</sup>School of Mechanical Engineering and Electronic Information, China University of Geosciences, Wuhan, Hubei 430074, China
- <sup>56</sup>IFLP, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
- <sup>57</sup>Department of Physics and Astronomy, Michigan State University, East Lansing, MI, USA
- <sup>58</sup>Michigan Technological University, Houghton, Michigan, 49931, USA
- <sup>59</sup>Università di Catania, Catania, Italy
- <sup>60</sup>University of Rijeka, Faculty of Physics, 51000 Rijeka, Croatia
- <sup>61</sup>Department of Physics and Astronomy, University of Utah, Salt Lake City, UT, USA
- <sup>62</sup>INAF - Osservatorio Astronomico di Cagliari, Via della Scienza 5, 09047 Selargius, Italy
- <sup>63</sup>University of Leicester, School of Physics and Astronomy, University Road, Leicester, LE1 7RH, United Kingdom
- <sup>64</sup>University of Seoul, Seoul, Rep. of Korea
- <sup>65</sup>School of Physics and Astronomy, Sun Yat-sen University, Zhuhai, Guangdong 519082, China
- <sup>66</sup>School of Astronomy and Space Science, Nanjing University, Xianlin Avenue 163, Qixia District, Nanjing, Jiangsu 210023, China
- <sup>67</sup>Dipartimento di Fisica, Università degli Studi di Trieste, via Valerio 2, I-34127 Trieste, Italy
- <sup>68</sup>INFN - Sezione di Trieste, via Valerio 2, I-34127 Trieste, Italy
- <sup>69</sup>Aerospace Information Research Institute, Chinese Academy of Science, 9 Dengzhuang South Road, Haidian District, Beijing 100094, China
- <sup>70</sup>Centro de Investigación en Computación, Instituto Politécnico Nacional, Ciudad de México, Mexico
- <sup>71</sup>Departamento de Física y Matemáticas, Universidad de Monterrey, Av. Morones Prieto 4500, 66238, San Pedro Garza García NL, México
- <sup>72</sup>Instituto de Tecnologías en Detección y Astropartículas (CNEA, CONICET, UNSAM), Buenos Aires, Argentina
- <sup>73</sup>Comisión Nacional de Investigación y Desarrollo Aeroespacial, Calle Luis Felipe Villarán 1069, 15046, Lima, Perú
- <sup>74</sup>Universidad Nacional de Moquegua, Calle Ancash S/N, 18001, Moquegua, Perú
- <sup>75</sup>Instituto Nazionale Di Astrofisica (INAF), Torino, Italy
- <sup>76</sup>Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Circuito Exterior, C.U., A. Postal 70-543, 04510 Cd. de México, México
- <sup>77</sup>Università degli Studi di Bari Aldo Moro, Italy
- <sup>78</sup>Department of Physics, Sungkyunkwan University, Suwon, South Korea
- <sup>79</sup>Universidad de Chile, Chile
- <sup>80</sup>Department of Physics and Astronomy, University of Alabama, Tuscaloosa, Alabama, 35487, USA
- <sup>81</sup>IMAPP, Radboud University Nijmegen, Nijmegen, The Netherlands
- <sup>82</sup>Unidade Acadêmica de Física, Universidade Federal de Campina Grande, Av. Aprígio Veloso 882, CY2, 58.429-900 Campina Grande, Brasil
- <sup>83</sup>Instituto de Física de São Carlos, Universidade de São Paulo, Av. Trabalhador São-carlense 400, São Carlos, Brasil

<sup>84</sup>School of Integrated Circuit, Ludong University, 186 Hongqi Middle Road, Zhifu District, Yantai, Shandong, China

<sup>85</sup>III. Physics Institute A, RWTH Aachen University, Templergraben 56, D-52062 Aachen, Germany

<sup>86</sup>Center for Astrophysics and Cosmology (CAC), University of Nova Gorica, Nova Gorica, Slovenia

<sup>87</sup>College of Engineering, Hebei Normal University, 20 South Second Ring East Road, Shijiazhuang, Hebei, China

<sup>88</sup>School of mechanical engineering, University of Science and Technology Beijing, 30 Xueyuan Road, Haidian District, Beijing 100083, China

September, 2023

## Acknowledgments

The SWGO Collaboration acknowledges the support from the agencies and organizations listed here:

<https://www.swgo.org/SWGOWiki/doku.php?id=acknowledgements> and the support from UNAM DGAPA-PAPIIT project number IG101323; ANID PIA/APOYO AFB220004; GACR 23-05827S; FCT, under project PTDC/FIS-PAR/4300/2020; FAPERJ Thematic Grant E-26/211.342/2021; ANID/fondo 2022 quimal/Quimal220008; FONDECYT project 1201582; Center for Astrophysics and Associated Technologies (CATA; ANID Basal project FB210003).