Detection methods for the Cherenkov Telescope Array at very-short exposure times

Ambra Di Piano,[a,*] **Andrea Bulgarelli,**[a] **Valentina Fioretti,**[a] **Leonardo Baroncelli,**[a] **Nicolò Parmiggiani,**[a] **Francesco Longo,**[b,c] **Antonio Stamerra,**[d] **Alicia López-Oramas,**[e,f] **Giulia Stratta**[a,g] **and Giovanni De Cesare**[a] **for the CTA Consortium**

[a] *INAF - Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, Italy*

[b] *Università degli Studi di Trieste, Italy*

[c] *INFN Sezione di Trieste, Italy*

[d] *INAF - Osservatorio Astronomico di Roma, Italy*

[e] *Instituto de Astrofisica de Canarias, La Laguna, Spain*

[f] *Departamento de Astrofisica, Universidad de La Laguna, Spain*

[g] *INFN, Sezione di Firenze, Italy*

E-mail: ambra.dipiano@inaf.it

The Cherenkov Telescope Array (CTA) will be the next generation ground-based observatory for very-high-energy (VHE) gamma-ray astronomy, with the deployment of tens of highly sensitive and fast-reacting Cherenkov telescopes. It will cover a wide energy range (20 GeV - 300 TeV) with unprecedented sensitivity. To maximize the scientific return, the observatory will be provided with an online software system that will perform the first analysis of scientific data in real-time. This study investigates the precision and accuracy of available science tools and analysis techniques for the short-term detection of gamma-ray sources, in terms of sky localization, detection significance and, if significant detection is achieved, a first estimation of the integral photon flux. The scope is to evaluate the feasibility of the algorithms' implementation in the real-time analysis of CTA. In this contribution we present a general overview of the methods and some of the results for the test case of the short-term detection of a gamma-ray burst afterglow, as the VHE counterpart of a gravitational wave event.

---

*Presenter

1. Introduction

The Cherenkov Telescope Array (CTA) will be the next generation of Imaging Atmospheric Cherenkov Telescopes (IACTs) and the largest ground-based gamma-ray detection observatory of the next decade. IACTs operate by observing the Cherenkov radiation induced by the Extensive Air Showers (EAS) produced during the interaction of very-high energy photons with the atmosphere. Data from an array of such telescopes is usually stereoscopically combined to improve the energy and direction reconstruction of the incident gamma-rays. With dozens of telescopes deployed among two observation sites (in the northern and southern hemispheres), CTA will observe the gamma-ray sky with high energy resolution and unprecedented sensitivity over a broad energy range (20 GeV - 300 TeV). High angular resolution ($\lesssim 0.05°$ at $E \geq 1$ TeV) will enable detailed imaging and precise morphology, and a large field of view (up to $\sim 8.8°$ in diameter) will provide exceptional survey capabilities [1]. The arrays will couple large effective area with fast slewing capability and unprecedented sensitivity, making CTA a crucial instrument for the future of groud-based gamma-ray astronomy. To maximize the scientific return, the observatory will be provided with an online automated Science Alert Generation (SAG) system [2] as part of the Array Control and Data Acquisition System [3]. The SAG will send and receive alerts on transients and variable phenomena (like gamma-ray bursts, active galactic nuclei, gamma-ray binaries, and any serendipitous source) in real-time. The SAG will also provide low-level Cherenkov data reconstruction, data quality monitoring and science monitoring during observations. The system is required to search for transient phenomena on multiple timescales (from 10 seconds to 30 minutes) in the field of view, and to issue candidate science alerts with a latency lower than 20 seconds after data acquisition. The sensitivity of the scientific analysis in real-time is nonetheless required to be not worse than half of the sensitivity of the final processing pipelines. Although challenging, these requirements will make the SAG a key system in multi-messenger (MM) and multi-wavelength (MWL) astronomy. Two science tools are available to the community for the analysis of CTA data, ctools [4, 5] and gammapy [6, 7]. Additionally, an aperture photometry tool [8] is being developed for the real-time analysis of CTA. To characterize the precision and accuracy of the tools for the detection of candidate sources at the very short exposure (up to 100 s), we inject a simulated observation (comprising gamma-ray photons as well as a diffuse background component due to cosmic ray residuals) and perform a search in the field of view to localize the source. If a candidate is found, we evaluate the significance of the detection and estimate the integrated flux.

1.1 Aperture photometry

The standard on/off analysis for Cherenkov observation includes different approaches to aperture photometry, of which we implement the reflection method.[1] The on/off technique is based on the extraction of fundamental photometric qualities from a photon list, as the number of photons from a defined region. Conventionally, the aperture (on region) is the region centered on the source itself and is used to count the on-source photons (N_{on}). To estimate the background with the reflection method, one or more off regions with the same characteristic of the aperture (radius and offset from the center of the field of view) are defined and used to count the off-source photons

---

[1]We use ctools version 1.7.3, gammapy version 0.18.2 and a photometry tool (version 0.1.0) in development for the SAG.

(N_{off}). The photon excess is computed as $N_{\text{S}} = N_{\text{on}} - \alpha N_{\text{off}}$, where α is the background scaling factor:

$$\alpha = \frac{A_{\text{on}} \cdot t_{\text{on}} \cdot k_{\text{on}}}{A_{\text{off}} \cdot t_{\text{off}} \cdot k_{\text{off}}}, \tag{1}$$

where A is the effective area, t the exposure, and k the size of the region. The reflection method allows to define on and off regions in the same observation, reducing eq (1) to $\alpha = 1/N_{\text{reg}}$, with N_{reg} the number of off regions (an example is shown in figure 1). The significance is then computed via the analytic Li and Ma [9] formula:

$$S = \sqrt{2} \left\{ N_{\text{on}} \ln \left[\frac{1 + \alpha}{\alpha} \left(\frac{N_{\text{on}}}{N_{\text{on}} + N_{\text{off}}} \right) \right] + N_{\text{off}} \ln \left[(1 + \alpha) \left(\frac{N_{\text{off}}}{N_{\text{on}} + N_{\text{off}}} \right) \right] \right\}^{1/2}. \tag{2}$$

1.2 Full field-of-view maximum likelihood

Alternatively to the standard on/off analysis, we implement an unbinned full field-of-view analysis[2] for the significance evaluation of the detected candidate. The analysis performs a maximum likelihood fit using the Poisson formula for maximum likelihood estimation (MLE) given the reconstructed direction $\vec{p}\,'$, the measured energy E' and the trigger time t'.

$$- \ln L(M) = e(M) - \sum_{\text{k}} \ln P(\boldsymbol{p}'_{\text{k}}, E'_{\text{k}}, t'_{\text{k}} | M), \tag{3}$$

where the maximum likelihood function $L(M)$ describes the probability of the collected data during the observation to be drawn from a particular model M, P is the probability density conditioned to a given model M at each event k, and e represent the total number of predicted events expected to occur given the model M. The source model comprises of two components: a simple power law spectral model and a point-like source spatial model with extension determined by the Point Spread Function (PSF) of the detector. The background rate is provided by the Instrument Response Functions (IRF) as function of off-axis angle and energy. By convolution with the IRF, the maximum likelihood fit adjusts a subset of parameters in order to find the values that best represent the measured data. The detection significance of the source model is described by a Test Statistic (TS) value:

$$TS = 2(\ln L(M_{\text{s}} + M_{\text{b}}) - \ln L(M_{\text{b}})), \tag{4}$$

where $\ln L(M_{\text{s}} + M_{\text{b}})$ is the log-likelihood value obtained when fitting the source and the background together to the data, and $\ln L(M_{\text{b}})$ is the log-likelihood value obtained when fitting only the background model to the data. The number n of degrees of freedom (dof) of the analysis is the number of free parameters in the source model. In this study, the pipeline is run at $n = 1$, with the coordinates and spectral index of the candidate's model fixed, and the power law normalization free. For $n = 1$ dof, we verified that the relation $\sigma \approx \sqrt{TS}$ holds also for very-short exposure times (down to 1 s).

---

[2]We use ctools version 1.7.3; a binned 3d analysis is being developed with the use of gammapy.
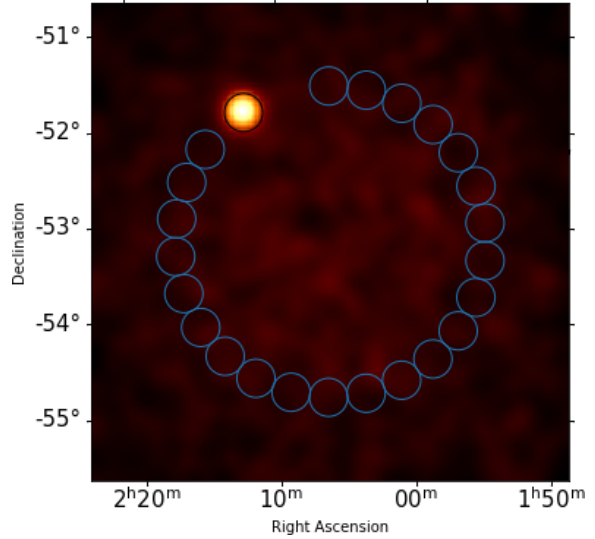
2. Application to a BNS merger

In this contribution, we focus on the SAG short-term reaction to an external alert. Specifically, the application of a short gamma-ray burst afterglow search as counterpart of a gravitational wave event [10]. The goal is to verify the agreement between analyses performed with the same techniques implemented by different science tools, and to constrain the accuracy and precision that can be expected at very-short exposure times for an online automated analysis. We exploited the GW COSMoS catalogue [11, 12], a public database of simulated BNS mergers providing the GW signals as detected by the network formed with Advanced LIGO and Advanced Virgo [13]. Each GW detection comes with a sky localization probability map, for given distance and inclination of the orbital plane of the BNS. To simulate the electromagnetic counterpart of a BNS merger, we use the associated afterglow template that provides the

Figure 1: Example of on source and off source regions defined on a count map with the reflection method, using 0.2° region radius and 1.638° offset. The areas adjacent to the on regions can be skipped to avoid contamination for the estimation of the background.

high energy emission [14, 15] given the GRB energy, redshift and viewing angle. The intrinsic spectral model is a simple power law, with normalization varying throughout the temporal evolution. We select a BNS merger with localization uncertainty comparable to the CTA field of view, located at a redshift of 0.097. The electromagnetic counterpart is at 1.638° off-axis angle from the peak of the sky localization probability map (R.A. = 31.582 and DEC. = -53.211 degrees) that we set as pointing coordinates. The isotropic energy of the counterpart is $E_{iso} = 1.48 \cdot 10^{51}$ erg, with intrinsic spectral shape of a simple power law of photon index -2.1 and normalization varying from $2.45 \cdot 10^{-7}$ to $3.1 \cdot 10^{-15}$ (ph cm^{-2} s^{-1} GeV^{-1}) in its temporal evolution. We add an exponential cut off to the intrinsic source spectral model, to account for the Extra-galactic Background Light absorption as $F^{ebl}(E) = F(E) \cdot e^{-\tau(E)}$, where $\tau(E)$ is the optical depth value from Ref. [16].
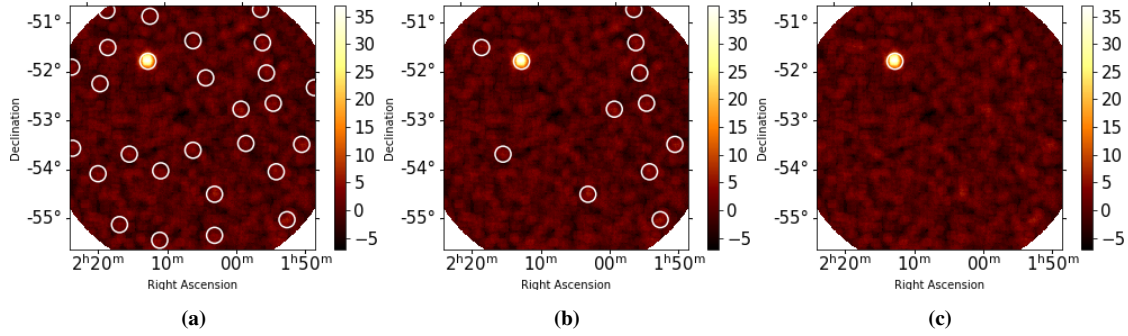
3. Source localization

The analysis takes a simulated photon list as input, with given configuration for the energy range, time interval, region of interest, and Instrument Response Function[3] for the analysis. The sky localization of the candidate source is performed in the field of view of the observation. We assume an extra-galactic scenario, therefore the background is mostly due to cosmic ray induced events that survive the gamma-ray selection criteria during the Cherenkov reconstruction. We perform a peak search to localize the coordinates of hot-spots with significance above a given acceptance threshold, selecting the most significant as the candidate source. The algorithm accepts exclusion regions to

---

[3]https://www.cta-observatory.org/science/cta-performance/

(a)   **(b)**   **(c)**

Figure 2: Source localization of a simulated gamma-ray burst afterglow ($E_{iso} = 1.48 \cdot 10^{51}$ erg at $z = 0.097$) using gammapy, in the energy range 40 GeV - 150 TeV using the 30 minutes CTA South IRF at 40° of zenith angle. The panels show a TS map with the number and position of hot-spots localized by the peak-search algorithm in a 10 s time window, requiring a significance threshold of (a) 3σ, (b) 5σ, and (c) 8σ.

mask known sources in the field of view. Figure 2 is an example of source localization in a 10 s time window, with different significance acceptance thresholds. At the very short exposure time, the background fluctuation becomes relevant due to the low counting rate and several hot spots are therefore detected. We evaluate the localization accuracy as the peak value of a Rayleigh distribution describing the on-sky distance between the detected and true coordinates of the source, whilst the precision is given by the R_{68} containment radius of 10^3 Monte Carlo realizations of the same source event. While the sigma acceptance threshold has no impact on either accuracy and precision of the localization, parameters such as the pixel size of the sky map required to run the peak-search do.

In figure 3 we present an example of the on-sky distance distribution at increasing exposure time (from 10 to 100 s) using a pixel size of 0.02° and 0.05° with respect to the difference in computational time required to complete the task. A finer spatial binning results in better accuracy and precision by a factor of 2, with little to no impact on the computational time required to complete the task (~ 0.001 s).
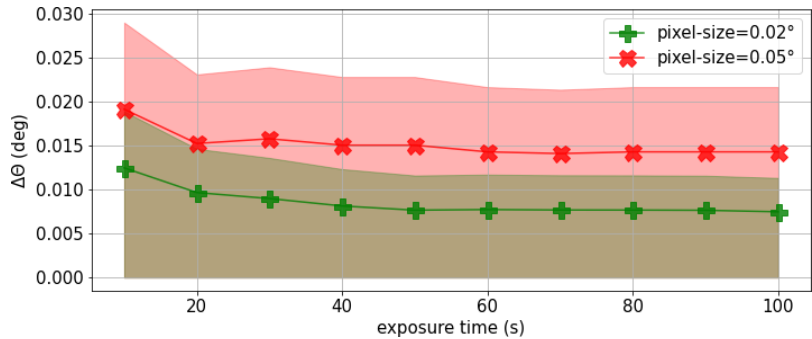
Figure 3: Comparison between the accuracy and precision of the source localization with pixel size of 0.02° (green plus markers) and 0.05° (red cross symbols) using ctools, in the energy range 40 GeV - 150 TeV using the 30 minutes CTA South IRF at 40° of zenith angle. The panel shows the peak on-sky distance ($\Delta\Theta$) between the true and detected coordinates of the source, with relative R_{68} containment radius (shaded areas).

4. Significance and flux estimation

In figure 4 we present lightcurves and detection significance with 10 s time windows, computed with a maximum likelihood analysis implemented with ctools, and the on/off reflection analysis

(a)
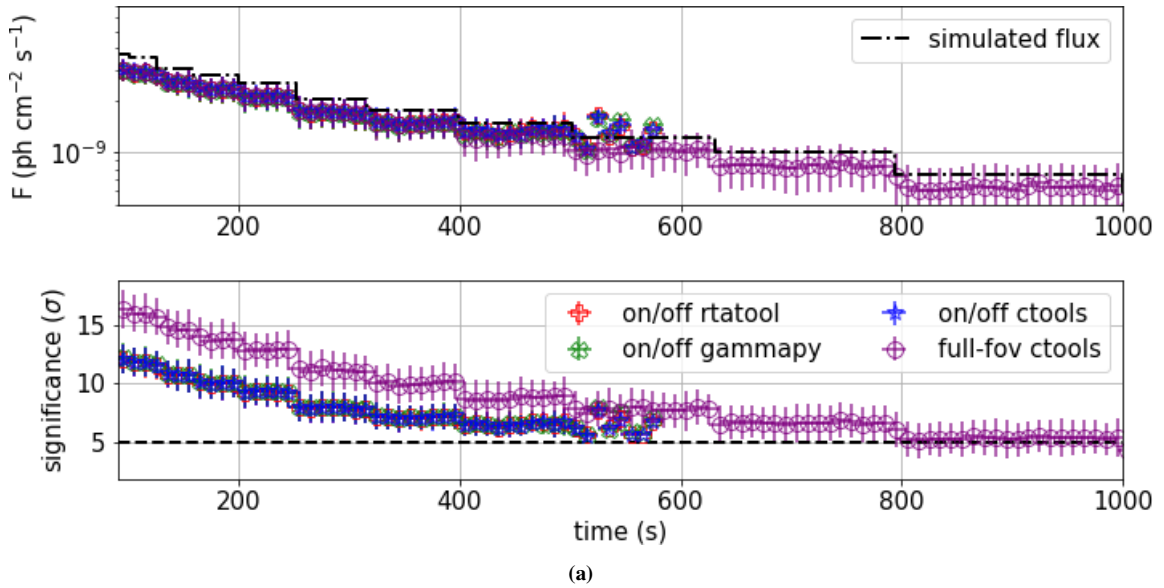
Figure 4: Lightcurves of a gamma-ray burst afterglow with 10 s of time window, computed with a full field-of-view maximum likelihood analysis (purple circles) and standard on/off analysis (red crosses, green exes ad blue stars) implemented by different science tools, in the energy range 40 GeV - 150 TeV using the 30 minutes CTA South IRF at 40° of zenith angle. The top panel shows the temporal evolution of the flux (the simulated flux is represented by the dashed line), and the bottom panel provides the significance of each detection. The lightcurves last for as long the significance is above 5σ.

implemented with ctools, gammapy and the real-time photometry tool [8].

The choice of the photon index introduces the largest uncertainty in the flux estimation, due to the EBL absorption becoming increasingly relevant at higher energies. For the flux computation a simple power law with photon index -2.4 has been assumed as spectral model for the source, while the simulated model is a cutoff power law with spectral index -2.1. Due to the wide energy range and the EBL absorption not taken into account, the model assumed for reconstruction of the flux introduces a bias. Figure 5
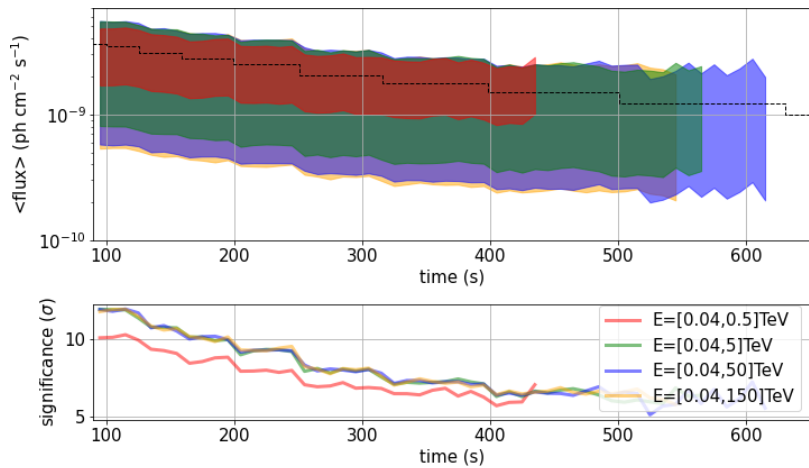
Figure 5: Impact of the choice of the photon index in the flux estimation with the SAG photometry tool, for given analysis configuration. The lightcurves have 10 s time windows. In the top panel the flux interval (shaded area) is computed with photon indexes between -1.5 and -3 for different energy ranges, compared to the simulated lightcurve (lines) using the 30 minutes CTA South IRF at 40° of zenith angle. In the bottom panel the significance is provided. The lightcurves last as long as the significance is above 5σ.

shows the integrated flux intervals computed with photon index between -1.5 and -3 for several energy ranges. The smallest energy range (0.04-0.5 TeV) improves the accuracy of the flux estimate but causes a loss in detection significance due to the reduced counting rate.

5. Summary

We have developed an automated pipeline that handles the analysis of CTA data with different techniques and science tools, to investigate their implementation in an online real-time analysis context. We used ctools and gammapy software packages as well as a photometry tool developed for the real-time analysis. Since with CTA we will be able to produce significant observation at very short exposure time, we focus on the characterization of the short-term reaction of the SAG up to 100 s where statistics is limiting. We verify that the same methods implemented in different science tools agrees under the same assumptions. Given a test case, we find that a finer binning (0.02 deg in pixel size) of the sky map produces a factor 2 more accurate and precise localization of the source with respect to a larger binning (0.05 deg) with negligible loss in terms of computational speed (~ 0.001 s). We compare the source detection significance of different techniques (a full field-of-view maximum likelihood and on/off reflection) and the estimation of the integrated photon flux. The full field-of-view analysis technique is more sensitive than the standard on/off analysis, although the two methods have proven to converge when assuming equal assumptions for the background estimation [17]. The standard on/off analysis, though, is computationally faster and provides the significance of a detection independently from model assumptions (i.e. the photon index) and fitting procedure. Due to the assumption of a simple power law spectral model, the impact of an arbitrary fixed photon index causes large uncertainties in the flux estimation mostly due to the EBL absorption that becomes increasingly relevant at higher energies. Future studies will investigate either an optimized choice of photon index (i.e., based on the energy range of the observation, knowledge of the source spectral shape and redshift), improvements on model assumptions or higher degrees of freedom analysis.

Acknowledgements

References

[1] CTA Consortium. *Science with the Cherenkov Telescope Array*. 2019.

[2] A. Bulgarelli et al. The Science Alert Generation system of the Cherenkov Telescope Array Observatory. In *37th International Cosmic Ray Conference (ICRC2021)*, International Cosmic Ray Conference, 2021.

---

[4]http://www.cta-observatory.org/science/cta-performance/
[5]https://www.gammapy.org

[3] I. Oya et al. The Array Control and Data Acquisition System of the Cherenkov Telescope Array. In *17th International Conference on Accelerator and Large Experimental Physics Control Systems*, page WEMPR005, New York, United States, October 2019.

[4] J. Knödlseder et al. ctools: Cherenkov Telescope Science Analysis Software, January 2016.

[5] J. Knödlseder et al. GammaLib and ctools. A software framework for the analysis of astronomical gamma-ray data. *Astronomy and Astrophysics*, 593:A1, August 2016.

[6] C. Deil et al. Gammapy - A prototype for the CTA science tools. In *35th International Cosmic Ray Conference (ICRC2017)*, volume 301 of *International Cosmic Ray Conference*, page 766, January 2017.

[7] C. Nigro et al. Towards open and reproducible multi-instrument analysis in gamma-ray astronomy. *Astronomy and Astrophysics*, 625:A10, May 2019.

[8] Simone Tampieri. Real time aperture photometry with cherenkov telescope array. *Master Thesis*, March 2020.

[9] T. P. Li and Y. Q. Ma. Analysis methods for results in gamma-ray astronomy. *The Astrophysical Journal*, 272:317–324, September 1983.

[10] B. Patricelli et al. Searching for very-high-energy electromagnetic counterparts to gravitational-wave events with the Cherenkov Telescope Array. In *37th International Cosmic Ray Conference (ICRC2021)*, International Cosmic Ray Conference, 2021.

[11] B. Patricelli et al. Searching for gamma-ray counterparts to gravitational waves from merging binary neutron stars with the Cherenkov Telescope Array. *Journal of Cosmology and Astroparticle Physics*, 2018(5):056, May 2018.

[12] Barbara Patricelli et al. GW COSMoS: Gravitational Wave COmpact binary SysteM Simulations., 2018.

[13] B. P. Abbott et al. Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO, Advanced Virgo and KAGRA. *Living Rev. Rel.*, 21(1):3, 2018.

[14] L. Nava et al. Clustering of LAT light curves: a clue to the origin of high-energy emission in gamma-ray bursts. *Monthly Notices of the RAS*, 443(4):3578–3585, October 2014.

[15] Lara Nava. High-energy emission from gamma-ray bursts. *International Journal of Modern Physics D*, 27(13):1842003, January 2018.

[16] Rudy C. Gilmore et al. Semi-analytic modelling of the extragalactic background light and consequences for extragalactic gamma-ray spectra. *Monthly Notices of the RAS*, 422(4):3189–3207, June 2012.

[17] V. Fioretti et al. The Cherenkov Telescope Array sensitivity to the transient sky. In *36th International Cosmic Ray Conference (ICRC2019)*, volume 36 of *International Cosmic Ray Conference*, page 673, July 2019.

The Cherenkov Telescope Array Consortium July 2021 Authors

H. Abdalla[1], H. Abe[2], S. Abe[2], A. Abusleme[3], F. Acero[4], A. Acharyya[5], V. Acín Portella[6], K. Ackley[7], R. Adam[8], C. Adams[9], S.S. Adhikari[10], I. Aguado-Ruesga[11], I. Agudo[12], R. Aguilera[13], A. Aguirre-Santaella[14], F. Aharonian[15], A. Alberdi[12], R. Alfaro[16], J. Alfaro[3], C. Alispach[17], R. Aloisio[18], R. Alves Batista[19], J.-P. Amans[20], L. Amati[21], E. Amato[22], L. Ambrogi[18], G. Ambrosi[23], M. Ambrosio[24], R. Ammendola[25], J. Anderson[26], M. Anduze[8], E.O. Angüner[27], L.A. Antonelli[28], V. Antonuccio[29], P. Antoranz[30], R. Anutarawiramkul[31], J. Aragunde Gutierrez[32], C. Aramo[24], A. Araudo[33,34], M. Araya[35], A. Arbet-Engels[36], C. Arcaro[1], V. Arendt[37], C. Armand[38], T. Armstrong[27], F. Arqueros[11], L. Arrabito[39], B. Arsioli[40], M. Artero[41], K. Asano[2], Y. Ascasíbar[14], J. Aschersleben[42], M. Ashley[43], P. Attinà[44], P. Aubert[45], C. B. Singh[19], D. Baack[46], A. Babic[47], M. Backes[48], V. Baena[13], S. Bajtlik[49], A. Baktash[50], C. Balazs[7], M. Balbo[38], O. Ballester[41], J. Ballet[4], B. Balmaverde[44], A. Bamba[51], R. Bandiera[22], A. Baquero Larriva[11], P. Barai[19], C. Barbier[45], V. Barbosa Martins[52], M. Barcelo[53], M. Barkov[54], M. Barnard[1], L. Baroncelli[21], U. Barres de Almeida[40], J.A. Barrio[11], D. Bastieri[55], P.I. Batista[52], I. Batkovic[55], C. Bauer[53], R. Bautista-González[56], J. Baxter[2], U. Becciani[29], J. Becerra González[32], Y. Becherini[57], G. Beck[58], J. Becker Tjus[59], W. Bednarek[60], A. Belfiore[61], L. Bellizzi[62], R. Belmont[4], W. Benbow[63], D. Berge[52], E. Bernardini[52], M.I. Bernardos[55], K. Bernlöhr[53], A. Berti[64], M. Berton[65], B. Bertucci[23], V. Beshley[66], N. Bhatt[67], S. Bhattacharyya[67], W. Bhattacharyya[52], S. Bhattacharyya[68], B. Bi[69], G. Bicknell[70], N. Biederbeck[46], C. Bigongiari[28], A. Biland[36], R. Bird[71], E. Bissaldi[72], J. Biteau[73], M. Bitossi[74], O. Blanch[41], M. Blank[50], J. Blazek[33], J. Bobin[75], C. Boccato[76], F. Bocchino[77], C. Boehm[78], M. Bohacova[33], C. Boisson[20], J. Boix[41], J.-P. Bolle[52], J. Bolmont[79], G. Bonanno[29], C. Bonavolontà[24], L. Bonneau Arbeletche[80], G. Bonnoli[12], P. Bordas[81], J. Borkowski[49], S. Bórquez[35], R. Bose[82], D. Bose[83], Z. Bosnjak[47], E. Bottacini[55], M. Böttcher[1], M.T. Botticella[84], C. Boutonnet[85], F. Bouyjou[75], V. Bozhilov[86], E. Bozzo[38], L. Brahimi[39], C. Braiding[43], S. Brau-Nogué[87], S. Breen[78], J. Bregeon[39], M. Breuhaus[53], A. Brill[9], W. Brisken[88], E. Brocato[28], A.M. Brown[5], K. Brügge[46], P. Brun[89], P. Brun[39], F. Brun[89], L. Brunetti[45], G. Brunetti[90], P. Bruno[29], A. Bruno[91], A. Bruzzese[6], N. Bucciantini[22], J. Buckley[82], R. Bühler[52], A. Bulgarelli[21], T. Bulik[92], M. Bünning[52], M. Bunse[46], M. Burton[93], A. Burtovoi[76], M. Buscemi[94], S. Buschjäger[46], G. Busetto[55], J. Buss[46], K. Byrum[26], A. Caccianiga[95], F. Cadoux[17], A. Calanducci[29], C. Calderón[3], J. Calvo Tovar[32], R. Cameron[96], P. Campaña[35], R. Canestrari[91], F. Cangemi[79], B. Cantlay[31], M. Capalbi[91], M. Capasso[9], M. Cappi[21], A. Caproni[97], R. Capuzzo-Dolcetta[28], P. Caraveo[61], V. Cárdenas[98], L. Cardiel[41], M. Cardillo[99], C. Carlile[100], S. Caroff[45], R. Carosi[74], A. Carosi[17], E. Carquín[35], M. Carrère[39], J.-M. Casandjian[4], S. Casanova[101,53], E. Cascone[84], F. Cassol[27], A.J. Castro-Tirado[12], F. Catalani[102], O. Catalano[91], D. Cauz[103], A. Ceccanti[64], C. Celestino Silva[80], S. Celli[18], K. Cerny[104], M. Cerruti[85], E. Chabanne[45], P. Chadwick[5], Y. Chai[105], P. Chambery[106], C. Champion[85], S. Chandra[1], S. Chaty[4], A. Chen[58], K. Cheng[2], M. Chernyakova[107], G. Chiaro[61], A. Chiavassa[64,108], M. Chikawa[2], V.R. Chitnis[109], J. Chudoba[33], L. Chytka[104], S. Cikota[47], A. Circiello[24,110], P. Clark[5], M. Çolak[41], E. Colombo[32], J. Colome[13], S. Colonges[85], A. Comastri[21], A. Compagnino[91], V. Conforti[21], E. Congiu[95], R. Coniglione[94], J. Conrad[111], F. Conte[53], J.L. Contreras[11], P. Coppi[112], R. Cornat[8], J. Coronado-Blazquez[14], J. Cortina[113], A. Costa[29], H. Costantini[27], G. Cotter[114], B. Courty[85], S. Covino[95], S. Crestan[61], P. Cristofari[20], R. Crocker[70], J. Croston[115], K. Cubuk[93], O. Cuevas[98], X. Cui[2], G. Cusumano[91], S. Cutini[23], A. D'Aì[91], G. D'Amico[116], F. D'Ammando[90], P. D'Avanzo[95], P. Da Vela[74], M. Dadina[21], S. Dai[117], M. Dalchenko[17], M. Dall' Ora[84], M.K. Daniel[63], J. Dauguet[85], I. Davids[48], J. Davies[114], B. Dawson[118], A. De Angelis[55], A.E. de Araújo Carvalho[40], M. de Bony de Lavergne[45], V. De Caprio[84], G. De Cesare[21], F. De Frondat[20], E.M. de Gouveia Dal Pino[19], I. de la Calle[11], B. De Lotto[103], A. De Luca[61], D. De Martino[84], R.M. de Menezes[19], M. de Naurois[8], E. de Oña Wilhelmi[13], F. De Palma[64], F. De Persio[119], N. de Simone[52], V. de Souza[80], M. Del Santo[91], M.V. del Valle[19], E. Delagnes[75], G. Deleglise[45], M. Delfino Reznicek[6], C. Delgado[113], A.G. Delgado Giler[80], J. Delgado Mengual[6], R. Della Ceca[95], M. Della Valle[84], D. della Volpe[17], D. Depaoli[64,108], D. Depouez[27], J. Devin[85], T. Di Girolamo[24,110], C. Di Giulio[25], A. Di Piano[21], F. Di Pierro[64], L. Di Venere[120], C. Díaz[113], C. Díaz-Bahamondes[3], C. Dib[35], S. Diebold[69], S. Digel[96], R. Dima[55], A. Djannati-Ataï[85], J. Djuvsland[116], A. Dmytriiev[20], K. Docher[9], A. Domínguez[11], D. Dominis Prester[121], A. Donath[53], A. Donini[41], D. Dorner[122], M. Doro[55], R.d.C. dos Anjos[123], J.-L. Dournaux[20], T. Downes[107], G. Drake[26], H. Drass[3], D. Dravins[100], C. Duangchan[31], A. Duara[124], G. Dubus[125], L. Ducci[69], C. Duffy[124], D. Dumora[106], K. Dundas Morå[111], A. Durkalec[126], V.V. Dwarkadas[127], J. Ebr[33], C. Eckner[45], J. Eder[105], A. Ederoclite[19], E. Edy[8], K. Egberts[128], S. Einecke[118], J. Eisch[129], C. Eleftheriadis[130], D. Elsässer[46], G. Emery[17], D. Emmanoulopoulos[115], J.-P. Ernenwein[27], M. Errando[82], P. Escarate[35], J. Escudero[12], C. Espinoza[3], S. Ettori[21], A. Eungwanichayapant[31], P. Evans[124], C. Evoli[18], M. Fairbairn[131], D. Falceta-Goncalves[132], A. Falcone[133], V. Fallah Ramazani[65], R. Falomo[76], K. Farakos[134], G. Fasola[20], A. Fattorini[46], Y. Favre[17], R. Fedora[135], E. Fedorova[136], S. Fegan[8], K. Feijen[118], Q. Feng[9], G. Ferrand[54], G. Ferrara[94], O. Ferreira[8], M. Fesquet[75], E. Fiandrini[23], A. Fiasson[45], M. Filipovic[117], D. Fink[105], J.P. Finley[137], V. Fioretti[21],

D.F.G. Fiorillo[24,110], M. Fiorini[61], S. Flis[52], H. Flores[20], L. Foffano[17], C. Föhr[53], M.V. Fonseca[11], L. Font[138], G. Fontaine[8], O. Fornieri[52], P. Fortin[63], L. Fortson[88], N. Fouque[45], A. Fournier[106], B. Fraga[40], A. Franceschini[76], F.J. Franco[30], A. Franco Ordovas[32], L. Freixas Coromina[113], L. Fresnillo[30], C. Fruck[105], D. Fugazza[95], Y. Fujikawa[139], Y. Fujita[2], S. Fukami[2], Y. Fukazawa[140], Y. Fukui[141], D. Fulla[52], S. Funk[142], A. Furniss[143], O. Gabella[39], S. Gabici[85], D. Gaggero[14], G. Galanti[61], G. Galaz[3], P. Galdemard[144], Y. Gallant[39], D. Galloway[7], S. Gallozzi[28], V. Gammaldi[14], R. Garcia[41], E. Garcia[45], E. García[13], R. Garcia López[32], M. Garczarczyk[52], F. Gargano[120], C. Gargano[91], S. Garozzo[29], D. Gascon[81], T. Gasparetto[145], D. Gasparrini[25], H. Gasparyan[52], M. Gaug[138], N. Geffroy[45], A. Gent[146], S. Germani[76], L. Gesa[13], A. Ghalumyan[147], A. Ghedina[148], G. Ghirlanda[95], F. Gianotti[21], S. Giarrusso[91], M. Giarrusso[94], G. Giavitto[52], B. Giebels[8], N. Giglietto[72], V. Gika[134], F. Gillardo[45], R. Gimenes[19], F. Giordano[149], G. Giovannini[90], E. Giro[76], M. Giroletti[90], A. Giuliani[61], L. Giunti[85], M. Gjaja[9], J.-F. Glicenstein[89], P. Gliwny[60], N. Godinovic[150], H. Göksu[53], P. Goldoni[85], J.L. Gómez[12], G. Gómez-Vargas[3], M.M. González[16], J.M. González[151], K.S. Gothe[109], D. Götz[4], J. Goulart Coelho[123], K. Gourgouliatos[5], T. Grabarczyk[152], R. Graciani[81], P. Grandi[21], G. Grasseau[8], D. Grasso[74], A.J. Green[78], D. Green[105], J. Green[28], T. Greenshaw[153], I. Grenier[4], P. Grespan[55], A. Grillo[29], M.-H. Grondin[106], J. Grube[131], V. Guarino[26], B. Guest[37], O. Gueta[52], M. Gündüz[59], S. Gunji[154], A. Gusdorf[20], G. Gyuk[155], J. Hackfeld[59], D. Hadasch[2], J. Haga[139], L. Hagge[52], A. Hahn[105], J.E. Hajlaoui[85], H. Hakobyan[35], A. Halim[89], P. Hamal[33], W. Hanlon[63], S. Hara[156], Y. Harada[157], M.J. Hardcastle[158], M. Harvey[5], K. Hashiyama[2], T. Hassan Collado[113], T. Haubold[105], A. Haupt[52], U.A. Hautmann[159], M. Havelka[33], K. Hayashi[141], K. Hayashi[160], M. Hayashida[161], H. He[54], L. Heckmann[105], M. Heller[17], J.C. Helo[35], F. Henault[125], G. Henri[125], G. Hermann[53], R. Hermel[45], S. Hernández Cadena[16], J. Herrera Llorente[32], A. Herrero[32], O. Hervet[143], J. Hinton[53], A. Hiramatsu[157], N. Hiroshima[54], K. Hirotani[2], B. Hnatyk[136], R. Hnatyk[136], J.K. Hoang[11], D. Hoffmann[27], W. Hofmann[53], C. Hoischen[128], J. Holder[162], M. Holler[163], B. Hona[164], D. Horan[8], J. Hörandel[165], D. Horns[50], P. Horvath[104], J. Houles[27], T. Hovatta[65], M. Hrabovsky[104], D. Hrupec[166], Y. Huang[135], J.-M. Huet[20], G. Hughes[159], D. Hui[2], G. Hull[73], T.B. Humensky[9], M. Hütten[105], R. Iaria[77], M. Iarlori[18], J.M. Illa[41], R. Imazawa[140], D. Impiombato[91], T. Inada[2], F. Incardona[29], A. Ingallinera[29], Y. Inome[2], S. Inoue[54], T. Inoue[141], Y. Inoue[167], A. Insolia[120,94], F. Iocco[24,110], K. Ioka[168], M. Ionica[23], M. Iori[119], S. Iovenitti[95], A. Iriarte[16], K. Ishio[105], W. Ishizaki[168], Y. Iwamura[2], C. Jablonski[105], J. Jacquemier[45], M. Jacquemont[45], M. Jamrozy[169], P. Janecek[33], F. Jankowsky[170], A. Jardin-Blicq[31], C. Jarnot[87], P. Jean[87], I. Jiménez Martínez[113], W. Jin[171], L. Jocou[125], N. Jordana[172], M. Josselin[73], L. Jouvin[41], I. Jung-Richardt[142], F.J.P.A. Junqueira[19], C. Juramy-Gilles[79], J. Jurysek[38], P. Kaaret[173], L.H.S. Kadowaki[19], M. Kagaya[2], O. Kalekin[142], R. Kankanyan[53], D. Kantzas[174], V. Karas[34], A. Karastergiou[114], S. Karkar[79], E. Kasai[48], J. Kasperek[175], H. Katagiri[176], J. Kataoka[177], K. Katarzyński[178], S. Katsuda[179], U. Katz[142], N. Kawanaka[180], D. Kazanas[130], D. Kerszberg[41], B. Khélifi[85], M.C. Kherlakian[52], T.P. Kian[181], D.B. Kieda[164], T. Kihm[53], S. Kim[3], S. Kimeswenger[163], S. Kisaka[140], R. Kissmann[163], R. Kleijwegt[135], T. Kleiner[52], G. Kluge[10], W. Kluźniak[49], J. Knapp[52], J. Knödlseder[87], A. Kobakhidze[78], Y. Kobayashi[2], B. Koch[3], J. Kocot[152], K. Kohri[182], K. Kokkotas[69], N. Komin[58], A. Kong[2], K. Kosack[4], G. Kowal[132], F. Krack[52], M. Krause[52], F. Krennrich[129], M. Krumholz[70], H. Kubo[180], V. Kudryavtsev[183], S. Kunwar[53], Y. Kuroda[139], J. Kushida[157], P. Kushwaha[19], A. La Barbera[91], N. La Palombara[61], V. La Parola[91], G. La Rosa[91], R. Lahmann[142], G. Lamanna[45], A. Lamastra[28], M. Landoni[95], D. Landriu[4], R.G. Lang[80], J. Lapington[124], P. Laporte[20], P. Lason[152], J. Lasuik[37], J. Lazendic-Galloway[7], T. Le Flour[45], P. Le Sidaner[20], S. Leach[124], A. Leckngam[31], S.-H. Lee[180], W.H. Lee[16], S. Lee[118], M.A. Leigui de Oliveira[184], A. Lemière[85], M. Lemoine-Goumard[106], J.-P. Lenain[79], F. Leone[94,185], V. Leray[8], G. Leto[29], F. Leuschner[69], C. Levy[79,20], R. Lindemann[52], E. Lindfors[65], L. Linhoff[46], I. Liodakis[65], A. Lipniacka[116], S. Lloyd[5], M. Lobo[113], T. Lohse[186], S. Lombardi[28], F. Longo[145], A. Lopez[32], M. López[11], R. López-Coto[55], S. Loporchio[149], F. Louis[75], M. Louys[20], F. Lucarelli[28], D. Lucchesi[55], H. Ludwig Boudi[39], P.L. Luque-Escamilla[56], E. Lyard[38], M.C. Maccarone[91], T. Maccarone[187], E. Mach[101], A.J. Maciejewski[188], J. Mackey[15], G.M. Madejski[96], P. Maeght[39], C. Maggio[138], G. Maier[52], A. Majczyna[126], P. Majumdar[83,2], M. Makariev[189], M. Mallamaci[55], R. Malta Nunes de Almeida[184], S. Maltezos[134], D. Malyshev[142], D. Malyshev[69], D. Mandat[33], G. Maneva[189], M. Manganaro[121], G. Manicò[94], P. Manigot[8], K. Mannheim[122], N. Maragos[134], D. Marano[29], M. Marconi[84], A. Marcowith[39], M. Marculewicz[190], B. Marčun[68], J. Marín[98], N. Marinello[55], P. Marinos[118], M. Mariotti[55], S. Markoff[174], P. Marquez[41], G. Marsella[94], J. Martí[56], J.-M. Martin[20], P. Martin[87], O. Martinez[30], M. Martínez[41], G. Martínez[113], O. Martínez[41], H. Martínez-Huerta[80], C. Marty[87], R. Marx[53], N. Masetti[21,151], P. Massimino[29], A. Mastichiadis[191], H. Matsumoto[167], N. Matthews[164], G. Maurin[45], W. Max-Moerbeck[192], N. Maxted[43], D. Mazin[2,105], M.N. Mazziotta[120], S.M. Mazzola[77], J.D. Mbarubucyeye[52], L. Mc Comb[5], I. McHardy[115], S. McKeague[107], S. McMuldroch[63], E. Medina[64], D. Medina Miranda[17], A. Melandri[95], C. Melioli[19], D. Melkumyan[52], S. Menchiari[62], S. Mender[46], S. Mereghetti[61], G. Merino Arévalo[6], E. Mestre[13], J.-L. Meunier[79], T. Meures[135], M. Meyer[142], S. Micanovic[121], M. Miceli[77], M. Michailidis[69], J. Michałowski[101],

T. Miener[11], I. Mievre[45], J. Miller[35], I.A. Minaya[153], T. Mineo[91], M. Minev[189], J.M. Miranda[30], R. Mirzoyan[105], A. Mitchell[36], T. Mizuno[193], B. Mode[135], R. Moderski[49], L. Mohrmann[142], E. Molina[81], E. Molinari[148], T. Montaruli[17], I. Monteiro[45], C. Moore[124], A. Moralejo[41], D. Morcuende-Parrilla[11], E. Moretti[41], L. Morganti[64], K. Mori[194], P. Moriarty[15], K. Morik[46], G. Morlino[22], P. Morris[114], A. Morselli[25], K. Mosshammer[52], P. Moya[192], R. Mukherjee[9], J. Muller[8], C. Mundell[172], J. Mundet[41], T. Murach[52], A. Muraczewski[49], H. Muraishi[195], K. Murase[2], I. Musella[84], A. Musumarra[120], A. Nagai[17], N. Nagar[196], S. Nagataki[54], T. Naito[156], T. Nakamori[154], K. Nakashima[142], K. Nakayama[51], N. Nakhjiri[13], G. Naletto[55], D. Naumann[52], L. Nava[95], R. Navarro[174], M.A. Nawaz[132], H. Ndiyavala[1], D. Neise[36], L. Nellen[16], R. Nemmen[19], M. Newbold[164], N. Neyroud[45], K. Ngernphat[31], T. Nguyen Trung[73], L. Nicastro[21], L. Nickel[46], J. Niemiec[101], D. Nieto[11], M. Nievas[32], C. Nigro[41], M. Nikołajuk[190], D. Ninci[41], K. Nishijima[157], K. Noda[2], Y. Nogami[176], S. Nolan[5], R. Nomura[2], R. Norris[117], D. Nosek[197], M. Nöthe[46], B. Novosyadlyj[198], V. Novotny[197], S. Nozaki[180], F. Nunio[144], P. O'Brien[124], K. Obara[176], R. Oger[85], Y. Ohira[51], M. Ohishi[2], S. Ohm[52], Y. Ohtani[2], T. Oka[180], N. Okazaki, A. Okumura[139,199], J.-F. Olive[87], C. Oliver[30], G. Olivera[52], B. Olmi[22], R.A. Ong[71], M. Orienti[90], R. Orito[200], M. Orlandini[21], S. Orlando[77], E. Orlando[145], J.P. Osborne[124], M. Ostrowski[169], N. Otte[146], E. Ovcharov[86], E. Owen[2], I. Oya[159], A. Ozieblo[152], M. Padovani[22], I. Pagano[29], A. Pagliaro[91], A. Paizis[61], M. Palatiello[145], M. Palatka[33], E. Palazzi[21], J.-L. Panazol[45], D. Paneque[105], B. Panes[3], S. Panny[163], F.R. Pantaleo[72], M. Panter[53], R. Paoletti[62], M. Paolillo[24,110], A. Papitto[28], A. Paravac[122], J.M. Paredes[81], G. Pareschi[95], N. Park[127], N. Parmiggiani[21], R.D. Parsons[186], P. Paśko[201], S. Patel[52], B. Patricelli[28], G. Pauletta[103], L. Pavletić[121], S. Pavy[8], A. Pe'er[105], M. Pech[33], M. Pecimotika[121], M.G. Pellegriti[120], P. Peñil Del Campo[11], M. Penno[52], A. Pepato[55], S. Perard[106], C. Perennes[55], G. Peres[77], M. Peresano[4], A. Pérez-Aguilera[11], J. Pérez-Romero[14], M.A. Pérez-Torres[12], M. Perri[28], M. Persic[103], S. Petrera[18], P.-O. Petrucci[125], O. Petruk[66], B. Peyaud[89], K. Pfrang[52], E. Pian[21], G. Piano[99], P. Piatteli[94], E. Pietropaolo[18], R. Pillera[149], B. Pilszyk[101], D. Pimentel[202], F. Pintore[91], C. Pio García[41], G. Pirola[64], F. Piron[39], A. Pisarski[190], S. Pita[85], M. Pohl[128], V. Poireau[45], P. Poledrelli[159], A. Pollo[126], M. Polo[113], C. Pongkitivanichkul[31], J. Porthault[144], J. Powell[171], D. Pozo[98], R.R. Prado[52], E. Prandini[55], P. Prasit[31], J. Prast[45], K. Pressard[73], G. Principe[90], C. Priyadarshi[41], N. Produit[38], D. Prokhorov[174], H. Prokoph[52], H. Prouza[33], H. Przybilski[101], E. Pueschel[52], G. Pühlhofer[69], I. Puljak[150], M.L. Pumo[94], M. Punch[85,57], F. Queiroz[203], J. Quinn[204], A. Quirrenbach[170], S. Rainò[149], P.J. Rajda[175], R. Rando[55], S. Razzaque[205], E. Rebert[20], S. Recchia[85], P. Reichherzer[59], O. Reimer[163], A. Reimer[163], A. Reisenegger[3,206], Q. Remy[53], M. Renaud[39], T. Reposeur[106], B. Reville[53], J.-M. Reymond[75], J. Reynolds[15], W. Rhode[46], D. Ribeiro[9], M. Ribó[81], G. Richards[162], T. Richtler[196], J. Rico[41], F. Rieger[53], L. Riitano[135], V. Ripepi[84], M. Riquelme[192], D. Riquelme[35], S. Rivoire[39], V. Rizi[18], E. Roache[63], B. Röben[159], M. Roche[106], J. Rodriguez[4], G. Rodriguez Fernandez[25], J.C. Rodriguez Ramirez[19], J.J. Rodríguez Vázquez[113], F. Roepke[170], G. Rojas[207], L. Romanato[55], P. Romano[95], G. Romeo[29], F. Romero Lobato[11], C. Romoli[53], M. Roncadelli[103], S. Ronda[30], J. Rosado[11], A. Rosales de Leon[5], G. Rowell[118], B. Rudak[49], A. Rugliancich[74], J.E. Ruíz del Mazo[12], W. Rujopakarn[31], C. Rulten[5], C. Russell[3], F. Russo[21], I. Sadeh[52], E. Sæther Hatlen[10], S. Safi-Harb[37], L. Saha[11], P. Saha[208], V. Sahakian[147], S. Sailer[53], T. Saito[2], N. Sakaki[54], S. Sakurai[2], F. Salesa Greus[101], G. Salina[25], H. Salzmann[69], D. Sanchez[45], M. Sánchez-Conde[14], H. Sandaker[10], A. Sandoval[16], P. Sangiorgi[91], M. Sanguillon[39], H. Sano[2], M. Santander[171], A. Santangelo[69], E.M. Santos[202], R. Santos-Lima[19], A. Sanuy[81], L. Sapozhnikov[96], T. Saric[150], S. Sarkar[114], H. Sasaki[157], N. Sasaki[179], K. Satalecka[52], Y. Sato[209], F.G. Saturni[28], M. Sawada[54], U. Sawangwit[31], J. Schaefer[142], A. Scherer[3], J. Scherpenberg[105], P. Schipani[84], B. Schleicher[122], J. Schmoll[5], M. Schneider[143], H. Schoorlemmer[53], P. Schovanek[33], F. Schussler[89], B. Schwab[142], U. Schwanke[186], J. Schwarz[95], T. Schweizer[105], E. Sciacca[29], S. Scuderi[61], M. Seglar Arroyo[45], A. Segreto[91], I. Seitenzahl[43], D. Semikoz[85], O. Sergijenko[136], J.E. Serna Franco[16], M. Servillat[20], K. Seweryn[201], V. Sguera[21], A. Shalchi[37], R.Y. Shang[71], P. Sharma[73], R.C. Shellard[40], L. Sidoli[61], J. Sieiro[81], H. Siejkowski[152], J. Silk[114], A. Sillanpää[65], B.B. Singh[109], K.K. Singh[210], A. Sinha[39], C. Siqueira[80], G. Sironi[95], J. Sitarek[60], P. Sizun[75], V. Sliusar[38], A. Slowikowska[178], D. Sobczyńska[60], R.W. Sobrinho[184], H. Sol[20], G. Sottile[91], H. Spackman[114], A. Specovius[142], S. Spencer[114], G. Spengler[186], D. Spiga[95], A. Spolon[55], W. Springer[164], A. Stamerra[28], S. Stanič[68], R. Starling[124], Ł. Stawarz[169], R. Steenkamp[48], S. Stefanik[197], C. Stegmann[128], A. Steiner[52], S. Steinmassl[53], C. Stella[103], C. Steppa[128], R. Sternberger[52], M. Sterzel[152], C. Stevens[135], B. Stevenson[71], T. Stolarczyk[4], G. Stratta[21], U. Straumann[208], J. Striškovic[166], M. Strzys[2], R. Stuik[174], M. Suchenek[211], Y. Suda[140], Y. Sunada[179], T. Suomijarvi[73], T. Suric[212], P. Sutcliffe[153], H. Suzuki[213], P. Świerk[101], T. Szepieniec[152], A. Tacchini[21], K. Tachihara[141], G. Tagliaferri[95], H. Tajima[139], N. Tajima[2], D. Tak[52], K. Takahashi[214], H. Takahashi[140], M. Takahashi[2], M. Takahashi[2], J. Takata[2], R. Takeishi[2], T. Tam[2], M. Tanaka[182], T. Tanaka[213], S. Tanaka[209], D. Tateishi[179], M. Tavani[99], F. Tavecchio[95], T. Tavernier[89], L. Taylor[135], A. Taylor[52], L.A. Tejedor[11], P. Temnikov[189], Y. Terada[179], K. Terauchi[180], J.C. Terrazas[192], R. Terrier[85], T. Terzic[121], M. Teshima[105,2], V. Testa[28], D. Thibaut[85], F. Thocquenne[75], W. Tian[2], L. Tibaldo[87], A. Tiengo[215], D. Tiziani[142],

M. Tluczykont[50], C.J. Todero Peixoto[102], F. Tokanai[154], K. Toma[160], L. Tomankova[142], J. Tomastik[104], D. Tonev[189], M. Tornikoski[216], D.F. Torres[13], E. Torresi[21], G. Tosti[95], L. Tosti[23], T. Totani[51], N. Tothill[117], F. Toussenel[79], G. Tovmassian[16], P. Travnicek[33], C. Trichard[8], M. Trifoglio[21], A. Trois[95], S. Truzzi[62], A. Tsiahina[87], T. Tsuru[180], B. Turk[45], A. Tutone[91], Y. Uchiyama[161], G. Umana[29], P. Utayarat[31], L. Vaclavek[104], M. Vacula[104], V. Vagelli[23,217], F. Vagnetti[25], F. Vakili[218], J.A. Valdivia[192], M. Valentino[24], A. Valio[19], B. Vallage[89], P. Vallania[44,64], J.V. Valverde Quispe[8], A.M. Van den Berg[42], W. van Driel[20], C. van Eldik[142], C. van Rensburg[1], B. van Soelen[210], J. Vandenbroucke[135], J. Vanderwalt[1], G. Vasileiadis[39], V. Vassiliev[71], M. Vázquez Acosta[32], M. Vecchi[42], A. Vega[98], J. Veh[142], P. Veitch[118], P. Venault[75], C. Venter[1], S. Ventura[62], S. Vercellone[95], S. Vergani[20], V. Verguilov[189], G. Verna[27], S. Vernetto[44,64], V. Verzi[25], G.P. Vettolani[90], C. Veyssiere[144], I. Viale[55], A. Viana[80], N. Viaux[35], J. Vicha[33], J. Vignatti[35], C.F. Vigorito[64,108], J. Villanueva[98], J. Vink[174], V. Vitale[23], V. Vittorini[99], V. Vodeb[68], H. Voelk[53], N. Vogel[142], V. Voisin[79], S. Vorobiov[68], I. Vovk[2], M. Vrastil[33], T. Vuillaume[45], S.J. Wagner[170], R. Wagner[105], P. Wagner[52], K. Wakazono[139], S.P. Wakely[127], R. Walter[38], M. Ward[5], D. Warren[54], J. Watson[52], N. Webb[87], M. Wechakama[31], P. Wegner[52], A. Weinstein[129], C. Weniger[174], F. Werner[53], H. Wetteskind[105], M. White[118], R. White[53], A. Wierzcholska[101], S. Wiesand[52], R. Wijers[174], M. Wilkinson[124], M. Will[105], D.A. Williams[143], J. Williams[124], T. Williamson[162], A. Wolter[95], Y.W. Wong[142], M. Wood[96], C. Wunderlich[62], T. Yamamoto[213], H. Yamamoto[141], Y. Yamane[141], R. Yamazaki[209], S. Yanagita[176], L. Yang[205], S. Yoo[180], T. Yoshida[176], T. Yoshikoshi[2], P. Yu[71], P. Yu[85], A. Yusafzai[59], M. Zacharias[20], G. Zaharijas[68], B. Zaldivar[14], L. Zampieri[76], R. Zanmar Sanchez[29], D. Zaric[150], M. Zavrtanik[68], D. Zavrtanik[68], A.A. Zdziarski[49], A. Zech[20], H. Zechlin[64], A. Zenin[139], A. Zerwekh[35], V.I. Zhdanov[136], K. Ziętara[169], A. Zink[142], J. Ziółkowski[49], V. Zitelli[21], M. Živec[68], A. Zmija[142]

1 : Centre for Space Research, North-West University, Potchefstroom, 2520, South Africa

2 : Institute for Cosmic Ray Research, University of Tokyo, 5-1-5, Kashiwa-no-ha, Kashiwa, Chiba 277-8582, Japan

3 : Pontificia Universidad Católica de Chile, Av. Libertador Bernardo O'Higgins 340, Santiago, Chile

4 : AIM, CEA, CNRS, Université Paris-Saclay, Université Paris Diderot, Sorbonne Paris Cité, CEA Paris-Saclay, IRFU/DAp, Bat 709, Orme des Merisiers, 91191 Gif-sur-Yvette, France

5 : Centre for Advanced Instrumentation, Dept. of Physics, Durham University, South Road, Durham DH1 3LE, United Kingdom

6 : Port d'Informació Científica, Edifici D, Carrer de l'Albareda, 08193 Bellaterrra (Cerdanyola del Vallès), Spain

7 : School of Physics and Astronomy, Monash University, Melbourne, Victoria 3800, Australia

8 : Laboratoire Leprince-Ringuet, École Polytechnique (UMR 7638, CNRS/IN2P3, Institut Polytechnique de Paris), 91128 Palaiseau, France

9 : Department of Physics, Columbia University, 538 West 120th Street, New York, NY 10027, USA

10 : University of Oslo, Department of Physics, Sem Saelandsvei 24 - PO Box 1048 Blindern, N-0316 Oslo, Norway

11 : EMFTEL department and IPARCOS, Universidad Complutense de Madrid, 28040 Madrid, Spain

12 : Instituto de Astrofísica de Andalucía-CSIC, Glorieta de la Astronomía s/n, 18008, Granada, Spain

13 : Institute of Space Sciences (ICE-CSIC), and Institut d'Estudis Espacials de Catalunya (IEEC), and Institució Catalana de Recerca I Estudis Avançats (ICREA), Campus UAB, Carrer de Can Magrans, s/n 08193 Cerdanyola del Vallés, Spain

14 : Instituto de Física Teórica UAM/CSIC and Departamento de Física Teórica, Universidad Autónoma de Madrid, c/ Nicolás Cabrera 13-15, Campus de Cantoblanco UAM, 28049 Madrid, Spain

15 : Dublin Institute for Advanced Studies, 31 Fitzwilliam Place, Dublin 2, Ireland

16 : Universidad Nacional Autónoma de México, Delegación Coyoacán, 04510 Ciudad de México, Mexico

17 : University of Geneva - Département de physique nucléaire et corpusculaire, 24 rue du Général-Dufour, 1211 Genève 4, Switzerland

18 : INFN Dipartimento di Scienze Fisiche e Chimiche - Università degli Studi dell'Aquila and Gran Sasso Science Institute, Via Vetoio 1, Viale Crispi 7, 67100 L'Aquila, Italy

19 : Instituto de Astronomia, Geofísico, e Ciências Atmosféricas - Universidade de São Paulo, Cidade Universitária, R. do Matão, 1226, CEP 05508-090, São Paulo, SP, Brazil

20 : LUTH, GEPI and LERMA, Observatoire de Paris, CNRS, PSL University, 5 place Jules Janssen, 92190, Meudon, France

21 : INAF - Osservatorio di Astrofisica e Scienza dello spazio di Bologna, Via Piero Gobetti 93/3, 40129 Bologna, Italy

22 : INAF - Osservatorio Astrofisico di Arcetri, Largo E. Fermi, 5 - 50125 Firenze, Italy

23 : INFN Sezione di Perugia and Università degli Studi di Perugia, Via A. Pascoli, 06123 Perugia, Italy

24 : INFN Sezione di Napoli, Via Cintia, ed. G, 80126 Napoli, Italy

12

25 : INFN Sezione di Roma Tor Vergata, Via della Ricerca Scientifica 1, 00133 Rome, Italy

26 : Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439, USA

27 : Aix-Marseille Université, CNRS/IN2P3, CPPM, 163 Avenue de Luminy, 13288 Marseille cedex 09, France

28 : INAF - Osservatorio Astronomico di Roma, Via di Frascati 33, 00040, Monteporzio Catone, Italy

29 : INAF - Osservatorio Astrofisico di Catania, Via S. Sofia, 78, 95123 Catania, Italy

30 : Grupo de Electronica, Universidad Complutense de Madrid, Av. Complutense s/n, 28040 Madrid, Spain

31 : National Astronomical Research Institute of Thailand, 191 Huay Kaew Rd., Suthep, Muang, Chiang Mai, 50200, Thailand

32 : Instituto de Astrofísica de Canarias and Departamento de Astrofísica, Universidad de La Laguna, La Laguna, Tenerife, Spain

33 : FZU - Institute of Physics of the Czech Academy of Sciences, Na Slovance 1999/2, 182 21 Praha 8, Czech Republic

34 : Astronomical Institute of the Czech Academy of Sciences, Bocni II 1401 - 14100 Prague, Czech Republic

35 : CCTVal, Universidad Técnica Federico Santa María, Avenida España 1680, Valparaíso, Chile

36 : ETH Zurich, Institute for Particle Physics, Schafmattstr. 20, CH-8093 Zurich, Switzerland

37 : The University of Manitoba, Dept of Physics and Astronomy, Winnipeg, Manitoba R3T 2N2, Canada

38 : Department of Astronomy, University of Geneva, Chemin d'Ecogia 16, CH-1290 Versoix, Switzerland

39 : Laboratoire Univers et Particules de Montpellier, Université de Montpellier, CNRS/IN2P3, CC 72, Place Eugène Bataillon, F-34095 Montpellier Cedex 5, France

40 : Centro Brasileiro de Pesquisas Físicas, Rua Xavier Sigaud 150, RJ 22290-180, Rio de Janeiro, Brazil

41 : Institut de Fisica d'Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Campus UAB, 08193 Bellaterra (Barcelona), Spain

42 : University of Groningen, KVI - Center for Advanced Radiation Technology, Zernikelaan 25, 9747 AA Groningen, The Netherlands

43 : School of Physics, University of New South Wales, Sydney NSW 2052, Australia

44 : INAF - Osservatorio Astrofisico di Torino, Strada Osservatorio 20, 10025 Pino Torinese (TO), Italy

45 : Univ. Savoie Mont Blanc, CNRS, Laboratoire d'Annecy de Physique des Particules - IN2P3, 74000 Annecy, France

46 : Department of Physics, TU Dortmund University, Otto-Hahn-Str. 4, 44221 Dortmund, Germany

47 : University of Zagreb, Faculty of electrical engineering and computing, Unska 3, 10000 Zagreb, Croatia

48 : University of Namibia, Department of Physics, 340 Mandume Ndemufayo Ave., Pioneerspark, Windhoek, Namibia

49 : Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, ul. Bartycka 18, 00-716 Warsaw, Poland

50 : Universität Hamburg, Institut für Experimentalphysik, Luruper Chaussee 149, 22761 Hamburg, Germany

51 : Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

52 : Deutsches Elektronen-Synchrotron, Platanenallee 6, 15738 Zeuthen, Germany

53 : Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

54 : RIKEN, Institute of Physical and Chemical Research, 2-1 Hirosawa, Wako, Saitama, 351-0198, Japan

55 : INFN Sezione di Padova and Università degli Studi di Padova, Via Marzolo 8, 35131 Padova, Italy

56 : Escuela Politécnica Superior de Jaén, Universidad de Jaén, Campus Las Lagunillas s/n, Edif. A3, 23071 Jaén, Spain

57 : Department of Physics and Electrical Engineering, Linnaeus University, 351 95 Växjö, Sweden

58 : University of the Witwatersrand, 1 Jan Smuts Avenue, Braamfontein, 2000 Johannesburg, South Africa

59 : Institut für Theoretische Physik, Lehrstuhl IV: Plasma-Astroteilchenphysik, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany

60 : Faculty of Physics and Applied Computer Science, University of Lódź, ul. Pomorska 149-153, 90-236 Lódź, Poland

61 : INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica di Milano, Via A. Corti 12, 20133 Milano, Italy

62 : INFN and Università degli Studi di Siena, Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente (DSFTA), Sezione di Fisica, Via Roma 56, 53100 Siena, Italy

63 : Center for Astrophysics | Harvard & Smithsonian, 60 Garden St, Cambridge, MA 02180, USA

64 : INFN Sezione di Torino, Via P. Giuria 1, 10125 Torino, Italy

65 : Finnish Centre for Astronomy with ESO, University of Turku, Finland, FI-20014 University of Turku, Finland

66 : Pidstryhach Institute for Applied Problems in Mechanics and Mathematics NASU, 3B Naukova Street, Lviv, 79060, Ukraine

67 : Bhabha Atomic Research Centre, Trombay, Mumbai 400085, India

68 : Center for Astrophysics and Cosmology, University of Nova Gorica, Vipavska 11c, 5270 Ajdovščina, Slovenia

PoS(ICRC2021)694

69 : Institut für Astronomie und Astrophysik, Universität Tübingen, Sand 1, 72076 Tübingen, Germany

70 : Research School of Astronomy and Astrophysics, Australian National University, Canberra ACT 0200, Australia

71 : Department of Physics and Astronomy, University of California, Los Angeles, CA 90095, USA

72 : INFN Sezione di Bari and Politecnico di Bari, via Orabona 4, 70124 Bari, Italy

73 : Laboratoire de Physique des 2 infinis, Irene Joliot-Curie,IN2P3/CNRS, Université Paris-Saclay, Université de Paris, 15 rue Georges Clemenceau, 91406 Orsay, Cedex, France

74 : INFN Sezione di Pisa, Largo Pontecorvo 3, 56217 Pisa, Italy

75 : IRFU/DEDIP, CEA, Université Paris-Saclay, Bat 141, 91191 Gif-sur-Yvette, France

76 : INAF - Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, 35122 Padova, Italy

77 : INAF - Osservatorio Astronomico di Palermo "G.S. Vaiana", Piazza del Parlamento 1, 90134 Palermo, Italy

78 : School of Physics, University of Sydney, Sydney NSW 2006, Australia

79 : Sorbonne Université, Université Paris Diderot, Sorbonne Paris Cité, CNRS/IN2P3, Laboratoire de Physique Nucléaire et de Hautes Energies, LPNHE, 4 Place Jussieu, F-75005 Paris, France

80 : Instituto de Física de São Carlos, Universidade de São Paulo, Av. Trabalhador São-carlense, 400 - CEP 13566-590, São Carlos, SP, Brazil

81 : Departament de Física Quàntica i Astrofísica, Institut de Ciències del Cosmos, Universitat de Barcelona, IEEC-UB, Martí i Franquès, 1, 08028, Barcelona, Spain

82 : Department of Physics, Washington University, St. Louis, MO 63130, USA

83 : Saha Institute of Nuclear Physics, Bidhannagar, Kolkata-700 064, India

84 : INAF - Osservatorio Astronomico di Capodimonte, Via Salita Moiariello 16, 80131 Napoli, Italy

85 : Université de Paris, CNRS, Astroparticule et Cosmologie, 10, rue Alice Domon et Léonie Duquet, 75013 Paris Cedex 13, France

86 : Astronomy Department of Faculty of Physics, Sofia University, 5 James Bourchier Str., 1164 Sofia, Bulgaria

87 : Institut de Recherche en Astrophysique et Planétologie, CNRS-INSU, Université Paul Sabatier, 9 avenue Colonel Roche, BP 44346, 31028 Toulouse Cedex 4, France

88 : School of Physics and Astronomy, University of Minnesota, 116 Church Street S.E. Minneapolis, Minnesota 55455-0112, USA

89 : IRFU, CEA, Université Paris-Saclay, Bât 141, 91191 Gif-sur-Yvette, France

90 : INAF - Istituto di Radioastronomia, Via Gobetti 101, 40129 Bologna, Italy

91 : INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo, Via U. La Malfa 153, 90146 Palermo, Italy

92 : Astronomical Observatory, Department of Physics, University of Warsaw, Aleje Ujazdowskie 4, 00478 Warsaw, Poland

93 : Armagh Observatory and Planetarium, College Hill, Armagh BT61 9DG, United Kingdom

94 : INFN Sezione di Catania, Via S. Sofia 64, 95123 Catania, Italy

95 : INAF - Osservatorio Astronomico di Brera, Via Brera 28, 20121 Milano, Italy

96 : Kavli Institute for Particle Astrophysics and Cosmology, Department of Physics and SLAC National Accelerator Laboratory, Stanford University, 2575 Sand Hill Road, Menlo Park, CA 94025, USA

97 : Universidade Cruzeiro do Sul, Núcleo de Astrofísica Teórica (NAT/UCS), Rua Galvão Bueno 8687, Bloco B, sala 16, Libertade 01506-000 - São Paulo, Brazil

98 : Universidad de Valparaíso, Blanco 951, Valparaiso, Chile

99 : INAF - Istituto di Astrofisica e Planetologia Spaziali (IAPS), Via del Fosso del Cavaliere 100, 00133 Roma, Italy

100 : Lund Observatory, Lund University, Box 43, SE-22100 Lund, Sweden

101 : The Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, ul. Radzikowskiego 152, 31-342 Cracow, Poland

102 : Escola de Engenharia de Lorena, Universidade de São Paulo, Área I - Estrada Municipal do Campinho, s/n°, CEP 12602-810, Pte. Nova, Lorena, Brazil

103 : INFN Sezione di Trieste and Università degli Studi di Udine, Via delle Scienze 208, 33100 Udine, Italy

104 : Palacky University Olomouc, Faculty of Science, RCPTM, 17. listopadu 1192/12, 771 46 Olomouc, Czech Republic

105 : Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München, Germany

106 : CENBG, Univ. Bordeaux, CNRS-IN2P3, UMR 5797, 19 Chemin du Solarium, CS 10120, F-33175 Gradignan Cedex, France

107 : Dublin City University, Glasnevin, Dublin 9, Ireland

108 : Dipartimento di Fisica - Universitá degli Studi di Torino, Via Pietro Giuria 1 - 10125 Torino, Italy

109 : Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Mumbai 400005, India

110 : Universitá degli Studi di Napoli "Federico II" - Dipartimento di Fisica "E. Pancini", Complesso universitario di Monte Sant'Angelo, Via Cintia - 80126 Napoli, Italy

111 : Oskar Klein Centre, Department of Physics, University of Stockholm, Albanova, SE-10691, Sweden

112 : Yale University, Department of Physics and Astronomy, 260 Whitney Avenue, New Haven, CT 06520-8101, USA

113 : CIEMAT, Avda. Complutense 40, 28040 Madrid, Spain

114 : University of Oxford, Department of Physics, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, United Kingdom

115 : School of Physics & Astronomy, University of Southampton, University Road, Southampton SO17 1BJ, United Kingdom

116 : Department of Physics and Technology, University of Bergen, Museplass 1, 5007 Bergen, Norway

117 : Western Sydney University, Locked Bag 1797, Penrith, NSW 2751, Australia

118 : School of Physical Sciences, University of Adelaide, Adelaide SA 5005, Australia

119 : INFN Sezione di Roma La Sapienza, P.le Aldo Moro, 2 - 00185 Roma, Italy

120 : INFN Sezione di Bari, via Orabona 4, 70126 Bari, Italy

121 : University of Rijeka, Department of Physics, Radmile Matejcic 2, 51000 Rijeka, Croatia

122 : Institute for Theoretical Physics and Astrophysics, Universität Würzburg, Campus Hubland Nord, Emil-Fischer-Str. 31, 97074 Würzburg, Germany

123 : Universidade Federal Do Paraná - Setor Palotina, Departamento de Engenharias e Exatas, Rua Pioneiro, 2153, Jardim Dallas, CEP: 85950-000 Palotina, Paraná, Brazil

124 : Dept. of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH, United Kingdom

125 : Univ. Grenoble Alpes, CNRS, IPAG, 414 rue de la Piscine, Domaine Universitaire, 38041 Grenoble Cedex 9, France

126 : National Centre for nuclear research (Narodowe Centrum Badań Jądrowych), Ul. Andrzeja Sołtana7, 05-400 Otwock, Świerk, Poland

127 : Enrico Fermi Institute, University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637, USA

128 : Institut für Physik & Astronomie, Universität Potsdam, Karl-Liebknecht-Strasse 24/25, 14476 Potsdam, Germany

129 : Department of Physics and Astronomy, Iowa State University, Zaffarano Hall, Ames, IA 50011-3160, USA

130 : School of Physics, Aristotle University, Thessaloniki, 54124 Thessaloniki, Greece

131 : King's College London, Strand, London, WC2R 2LS, United Kingdom

132 : Escola de Artes, Ciências e Humanidades, Universidade de São Paulo, Rua Arlindo Bettio, CEP 03828-000, 1000 São Paulo, Brazil

133 : Dept. of Astronomy & Astrophysics, Pennsylvania State University, University Park, PA 16802, USA

134 : National Technical University of Athens, Department of Physics, Zografos 9, 15780 Athens, Greece

135 : University of Wisconsin, Madison, 500 Lincoln Drive, Madison, WI, 53706, USA

136 : Astronomical Observatory of Taras Shevchenko National University of Kyiv, 3 Observatorna Street, Kyiv, 04053, Ukraine

137 : Department of Physics, Purdue University, West Lafayette, IN 47907, USA

138 : Unitat de Física de les Radiacions, Departament de Física, and CERES-IEEC, Universitat Autònoma de Barcelona, Edifici C3, Campus UAB, 08193 Bellaterra, Spain

139 : Institute for Space-Earth Environmental Research, Nagoya University, Chikusa-ku, Nagoya 464-8601, Japan

140 : Department of Physical Science, Hiroshima University, Higashi-Hiroshima, Hiroshima 739-8526, Japan

141 : Department of Physics, Nagoya University, Chikusa-ku, Nagoya, 464-8602, Japan

142 : Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics (ECAP), Erwin-Rommel-Str. 1, 91058 Erlangen, Germany

143 : Santa Cruz Institute for Particle Physics and Department of Physics, University of California, Santa Cruz, 1156 High Street, Santa Cruz, CA 95064, USA

144 : IRFU / DIS, CEA, Université de Paris-Saclay, Bat 123, 91191 Gif-sur-Yvette, France

145 : INFN Sezione di Trieste and Università degli Studi di Trieste, Via Valerio 2 I, 34127 Trieste, Italy

146 : School of Physics & Center for Relativistic Astrophysics, Georgia Institute of Technology, 837 State Street, Atlanta, Georgia, 30332-0430, USA

147 : Alikhanyan National Science Laboratory, Yerevan Physics Institute, 2 Alikhanyan Brothers St., 0036, Yerevan, Armenia

148 : INAF - Telescopio Nazionale Galileo, Roche de los Muchachos Astronomical Observatory, 38787 Garafia, TF, Italy

149 : INFN Sezione di Bari and Università degli Studi di Bari, via Orabona 4, 70124 Bari, Italy

150 : University of Split - FESB, R. Boskovica 32, 21 000 Split, Croatia

151 : Universidad Andres Bello, República 252, Santiago, Chile

152 : Academic Computer Centre CYFRONET AGH, ul. Nawojki 11, 30-950 Cracow, Poland

153 : University of Liverpool, Oliver Lodge Laboratory, Liverpool L69 7ZE, United Kingdom

154 : Department of Physics, Yamagata University, Yamagata, Yamagata 990-8560, Japan

155 : Astronomy Department, Adler Planetarium and Astronomy Museum, Chicago, IL 60605, USA

156 : Faculty of Management Information, Yamanashi-Gakuin University, Kofu, Yamanashi 400-8575, Japan

157 : Department of Physics, Tokai University, 4-1-1, Kita-Kaname, Hiratsuka, Kanagawa 259-1292, Japan

158 : Centre for Astrophysics Research, Science & Technology Research Institute, University of Hertfordshire, College Lane, Hertfordshire AL10 9AB, United Kingdom

159 : Cherenkov Telescope Array Observatory, Saupfercheckweg 1, 69117 Heidelberg, Germany

160 : Tohoku University, Astronomical Institute, Aobaku, Sendai 980-8578, Japan

161 : Department of Physics, Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima-ku, Tokyo, Japan

162 : Department of Physics and Astronomy and the Bartol Research Institute, University of Delaware, Newark, DE 19716, USA

163 : Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Technikerstr. 25/8, 6020 Innsbruck, Austria

164 : Department of Physics and Astronomy, University of Utah, Salt Lake City, UT 84112-0830, USA

165 : IMAPP, Radboud University Nijmegen, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands

166 : Josip Juraj Strossmayer University of Osijek, Trg Ljudevita Gaja 6, 31000 Osijek, Croatia

167 : Department of Earth and Space Science, Graduate School of Science, Osaka University, Toyonaka 560-0043, Japan

168 : Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto 606-8502, Japan

169 : Astronomical Observatory, Jagiellonian University, ul. Orla 171, 30-244 Cracow, Poland

170 : Landessternwarte, Zentrum für Astronomie der Universität Heidelberg, Königstuhl 12, 69117 Heidelberg, Germany

171 : University of Alabama, Tuscaloosa, Department of Physics and Astronomy, Gallalee Hall, Box 870324 Tuscaloosa, AL 35487-0324, USA

172 : Department of Physics, University of Bath, Claverton Down, Bath BA2 7AY, United Kingdom

173 : University of Iowa, Department of Physics and Astronomy, Van Allen Hall, Iowa City, IA 52242, USA

174 : Anton Pannekoek Institute/GRAPPA, University of Amsterdam, Science Park 904 1098 XH Amsterdam, The Netherlands

175 : Faculty of Computer Science, Electronics and Telecommunications, AGH University of Science and Technology, Kraków, al. Mickiewicza 30, 30-059 Cracow, Poland

176 : Faculty of Science, Ibaraki University, Mito, Ibaraki, 310-8512, Japan

177 : Faculty of Science and Engineering, Waseda University, Shinjuku, Tokyo 169-8555, Japan

178 : Institute of Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Toruń, ul. Grudziądzka 5, 87-100 Toruń, Poland

179 : Graduate School of Science and Engineering, Saitama University, 255 Simo-Ohkubo, Sakura-ku, Saitama city, Saitama 338-8570, Japan

180 : Division of Physics and Astronomy, Graduate School of Science, Kyoto University, Sakyo-ku, Kyoto, 606-8502, Japan

181 : Centre for Quantum Technologies, National University Singapore, Block S15, 3 Science Drive 2, Singapore 117543, Singapore

182 : Institute of Particle and Nuclear Studies, KEK (High Energy Accelerator Research Organization), 1-1 Oho, Tsukuba, 305-0801, Japan

183 : Department of Physics and Astronomy, University of Sheffield, Hounsfield Road, Sheffield S3 7RH, United Kingdom

16

184 : Centro de Ciências Naturais e Humanas, Universidade Federal do ABC, Av. dos Estados, 5001, CEP: 09.210-580, Santo André - SP, Brazil

185 : Dipartimento di Fisica e Astronomia, Sezione Astrofisica, Universitá di Catania, Via S. Sofia 78, I-95123 Catania, Italy

186 : Department of Physics, Humboldt University Berlin, Newtonstr. 15, 12489 Berlin, Germany

187 : Texas Tech University, 2500 Broadway, Lubbock, Texas 79409-1035, USA

188 : University of Zielona Góra, ul. Licealna 9, 65-417 Zielona Góra, Poland

189 : Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 72 boul. Tsarigradsko chaussee, 1784 Sofia, Bulgaria

190 : University of Białystok, Faculty of Physics, ul. K. Ciołkowskiego 1L, 15-254 Białystok, Poland

191 : Faculty of Physics, National and Kapodestrian University of Athens, Panepistimiopolis, 15771 Ilissia, Athens, Greece

192 : Universidad de Chile, Av. Libertador Bernardo O'Higgins 1058, Santiago, Chile

193 : Hiroshima Astrophysical Science Center, Hiroshima University, Higashi-Hiroshima, Hiroshima 739-8526, Japan

194 : Department of Applied Physics, University of Miyazaki, 1-1 Gakuen Kibana-dai Nishi, Miyazaki, 889-2192, Japan

195 : School of Allied Health Sciences, Kitasato University, Sagamihara, Kanagawa 228-8555, Japan

196 : Departamento de Astronomía, Universidad de Concepción, Barrio Universitario S/N, Concepción, Chile

197 : Charles University, Institute of Particle & Nuclear Physics, V Holešovičkách 2, 180 00 Prague 8, Czech Republic

198 : Astronomical Observatory of Ivan Franko National University of Lviv, 8 Kyryla i Mephodia Street, Lviv, 79005, Ukraine

199 : Kobayashi-Maskawa Institute (KMI) for the Origin of Particles and the Universe, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan

200 : Graduate School of Technology, Industrial and Social Sciences, Tokushima University, Tokushima 770-8506, Japan

201 : Space Research Centre, Polish Academy of Sciences, ul. Bartycka 18A, 00-716 Warsaw, Poland

202 : Instituto de Física - Universidade de São Paulo, Rua do Matão Travessa R Nr.187 CEP 05508-090 Cidade Universitária, São Paulo, Brazil

203 : International Institute of Physics at the Federal University of Rio Grande do Norte, Campus Universitário, Lagoa Nova CEP 59078-970 Rio Grande do Norte, Brazil

204 : University College Dublin, Belfield, Dublin 4, Ireland

205 : Centre for Astro-Particle Physics (CAPP) and Department of Physics, University of Johannesburg, PO Box 524, Auckland Park 2006, South Africa

206 : Departamento de Física, Facultad de Ciencias Básicas, Universidad Metropolitana de Ciencias de la Educación, Santiago, Chile

207 : Núcleo de Formação de Professores - Universidade Federal de São Carlos, Rodovia Washington Luís, km 235 CEP 13565-905 - SP-310 São Carlos - São Paulo, Brazil

208 : Physik-Institut, Universität Zürich, Winterthurerstrasse 190, 8057 Zürich, Switzerland

209 : Department of Physical Sciences, Aoyama Gakuin University, Fuchinobe, Sagamihara, Kanagawa, 252-5258, Japan

210 : University of the Free State, Nelson Mandela Avenue, Bloemfontein, 9300, South Africa

211 : Faculty of Electronics and Information, Warsaw University of Technology, ul. Nowowiejska 15/19, 00-665 Warsaw, Poland

212 : Rudjer Boskovic Institute, Bijenicka 54, 10 000 Zagreb, Croatia

213 : Department of Physics, Konan University, Kobe, Hyogo, 658-8501, Japan

214 : Kumamoto University, 2-39-1 Kurokami, Kumamoto, 860-8555, Japan

215 : University School for Advanced Studies IUSS Pavia, Palazzo del Broletto, Piazza della Vittoria 15, 27100 Pavia, Italy

216 : Aalto University, Otakaari 1, 00076 Aalto, Finland

217 : Agenzia Spaziale Italiana (ASI), 00133 Roma, Italy

218 : Observatoire de la Cote d'Azur, Boulevard de l'Observatoire CS34229, 06304 Nice Cedex 4, Franc