



João Espadanal

Curriculum Vitae

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Education

PhD degree: in Physics (2011 – 2015), Instituto Superior Técnico, Lisbon, Portugal.
Researcher at LIP (Laboratório de Instrumentação e Física Experimental de Partículas).
Dissertation: [Study of the longitudinal and transverse cosmic ray shower profiles at the Pierre Auger Observatory](#)
Research field: cosmic rays, high energy physics
Classification: Pass with distinction

M.Sc. degree: in Physics Engineering (2008 – 2010), Instituto Superior Técnico, Lisbon, Portugal.
Thesis: Studies of the non-standard extensive air showers events and development of new analysis to constrain hadronic models using simulated longitudinal light profiles.
Classification: 18/20

B.Sc. degree: in Physics Engineering (2005 - 2008), Instituto Superior Técnico, Lisbon, Portugal.
Classification: 16/20

High school: Escola Secundária Pública Hortênsia de Castro, Vila Viçosa, Portugal
High school in scientific group (classification 19/20)

Grants

- ❖ PostDoc grant from LIP, in 2015.
- ❖ PhD grant from FCT, 2010, Fundação para a Ciência e a Tecnologia
- ❖ Research grant at LIP in the Pierre Auger Observatory project for my Master, in 2009.
- ❖ Student grant from Calouste Gulbenkian Foundation, from 2001 to 2009.

Brief description and Research interests

I'm currently working at LIP (Laboratório de Instrumentação e Física Experimental de Partículas), in Lisbon, as part of the Pierre Auger Collaboration. My work is integrated in a large particle physics collaboration, where I developed strong computational and teamwork skills. At Auger, I'm involved on both Surface Detectors and Fluorescence Detectors, using offline tools for the analysis. I generated simulations with CONEX and CORSIKA programs using the most recent hadronic models (in which I also modified CORSIKA program). I've created and modified simulation modules in the Auger framework. From the academic point of view, I have a

background in particle physics and have also taught at the university (for which I won a Diploma of Excellence).

Current results in ultra-high energy cosmic rays show that the LHC tuned hadronic models cannot describe consistently at the same time the electromagnetic and muonic component of an extensive air shower. It is considered that the problem comes from the muon sector, so I changed muon characteristics such as energy production, pt and positions to find out if the effects that could explain the differences in the data. I'm also involved in the Auger data analysis for the recovery of the number of muons.

In detail, I developed a 3D simulation for the fluorescence and direct Cherenkov emission of cosmic ray extensive air showers, using CORSIKA as a generator program. I also worked on the surface detector within the upgrade proposals (in the MARTA project). We tried to develop ways to disentangle the electromagnetic and muonic signals on the surface. I studied the effect of using the electromagnetic signal to calibrate the SD energy. I tried new analysis approaches, such as obtaining the longitudinal electromagnetic Xmax using the ground signal, or considering the average LDFs to study the composition and problems within the hadronic models.

I also did field work for the collaboration: two FD shifts and one Roving Laser. In the FD shift, the aim was to monitor the FD data taking, including LIDAR radars and atmospheric monitoring. In the Roving Laser, a laser was used to calibrate the telescopes in different positions along the observatory.

Apart from the data analysis and software development, I am also interested in hadronic physics (which are closely related to Auger particle physics), as well as more theoretical work like UHE cosmic rays models for the spectrum with composition, neutrino physics and connections to dark matter.

Research

Publications

Spirens: <https://inspirehep.net/author/profile/J.Espadanal.1>

Google Scholar: <http://scholar.google.com.ar/citations?user=QU5LMyQAAAAJ&hl=en>

ORCID: <http://orcid.org/0000-0002-1301-8061>

Full list of publications and talks in the end.

Selected publications:

- [1] J. Espadanal, L. Cazon and R. Conceição. "Sensitivity of EAS measurements to the energy spectrum of muons". Submitted to Astrophysical journal. [arXiv:1607.06760](https://arxiv.org/abs/1607.06760).
- [2] J. Espadanal. "Measurement of the Muon Content of EAS with the Pierre Auger Observatory". In: Proceedings, 30th International Workshop on High Energy Physics: Particle and Astroparticle Physics, Gravitation and Cosmology: Predictions, Observations and New Projects (IHEP 2014). 2015, pp. 287-292. [doi:10.1142/9789814689304_0045](https://doi.org/10.1142/9789814689304_0045). [arXiv:1505.05527](https://arxiv.org/abs/1505.05527).
- [3] A. Aab et al. "Muons in air showers at the Pierre Auger Observatory: Mean number in highly inclined events". In: Phys. Rev. D91.3 (2015). [Erratum: [Phys. Rev. D91, no. 5, 059901 \(2015\)](https://doi.org/10.1103/PhysRevD.91.032003)], p. 032003. [doi:10.1103/PhysRevD.91.032003](https://doi.org/10.1103/PhysRevD.91.032003). [arXiv:1408.1421](https://arxiv.org/abs/1408.1421).
- [4] A. Aab et al. "Muons in air showers at the Pierre Auger Observatory: Measurement of atmospheric production depth". In: Phys. Rev. D90.1 (2014). [Erratum: Phys. Rev. D92, no. 1, 019903 (2015)], p. 012012.
- [5] A. Aab et al. "Depth of maximum of air-shower profiles at the Pierre Auger Observatory. I. Measurements at energies above $10^{17.8}$ eV". In: Phys. Rev. D90.12 (2014), p. 122005. [doi:10.1103/PhysRevD.90.122005](https://doi.org/10.1103/PhysRevD.90.122005). [arXiv:1409.4809](https://arxiv.org/abs/1409.4809).

Auger Internal Notes (GAP Notes)

- ❖ J. Espadanal, S. Andringa, P. Gonçalves, M. Pimenta, "Electromagnetic Xmax from SD signals with an upgraded SD", GAP-Note 2016-002.
- ❖ J. Espadanal, S. Andringa, P. Gonçalves, M. Pimenta, "Average slope of SD LDFs for the QGSJet-II model", GAP-Note 2016-003.

- ❖ The MARTA teams, “MARTA (Muon Auger RPC for the Tank Array) Design Report”, GAP-Note 2013-020.
- ❖ J. Espadanal, M. Pimenta, P. Gonçalves, S. Andringa, “SD Energy Calibration based on the Electromagnetic Signal”, Pierre Auger GAP-Note 2013-054.
- ❖ J. Espadanal, P. Gonçalves, M. Pimenta, “3D simulation of EAS for the FD: validation with a fluorescence rich data sample”, Pierre Auger GAP-Note 2012-039.

PhD Schools

21 January to 2 February 2013	Third IDPASC School in Santiago de Compostela, Spain (approved in examination).
24 to 26 June 2012	Auger Software Tutorial, Prague.
23 January to 3 February 2012	Second IDPASC School, Udine, Italy (approved in examination)
14 to 18th December 2011	IDPASC Dark Matter School, Évora, Portugal (approved in examination)
24 to 28th October 2011	Statistic Course held at LIP, Lisbon (approved in examination)
06 to 09th September 2011	Higgs IDPASC School in Foz do Arelho
13 to 19th December 2010	First IDPASC School in Sesimbra (approved in examination)
02 to 06th September 2008	4th School of Astrophysics and Gravitation in Instituto Superior Técnico

Experience

I’ve done research at LIP and gave classes at Instituto Superior Técnico. In 2013, I also did volunteering work in CAIS. I started a small business with my mother and I did other courses.

- ❖ In 2014/2015 I was the student representative in LIP.

Teaching

- ❖ Electromagnetism and Optics (year 2014/2015 - 1st Semester), Problem classes (average 50 students per class) for Civil Engineering and Mining and Geological Engineering.
 - ❖ Thermodynamics and the Structure of Matter (2nd Semester – 2013/2014), Problems classes for Civil Engineering and Mining and Geological Engineering.
 - ❖ Electromagnetism and Optics (year 2013/2014 - 1st Semester), Problem classes for Civil Engineering and Mining and Geological Engineering.
 - ❖ Mechanics and Waves (2nd Semester - 2012/2013), laboratories for:
 - Information Systems and Computer Engineering, and Mining and Geological Engineering;
 - Materials Engineering, Environmental Engineering, Chemical Engineering and Biological Engineering. IST.
 - ❖ Electromagnetism and Optics (year 2012/2013 - 1st Semester), Problems classes for Integrated Master (MSc) in Electrical and Computer Engineering, IST.
- ➔ In 2014 I won a Diploma of Excellence for teaching.

Volunteering

- ❖ In CAIS February-July 2013, and GASTagus (<http://www.gastagus.org>), December 2012 to March 2013. I helped the CAIS magazine project where homeless and temporary disfavored sell copies of the magazine for self-sustainment, promotion reintegration.

Entrepreneur

- ❖ In 2015, I started a small business with my mother called LICOREIRA DA VILLA. It produces and sells traditional gourmet products from my birthplace, namely traditional liquors, jellies, jams, Açordas, Dry fruits and others, see www.licoreiradavilla.pt or <https://www.facebook.com/licoreira/>.

Additional Observations

Professional Skills

Programming	C, C++, Shell script, HTML, PHP, CSS, XML, LaTeX, little JavaScript
Applications	CORSIKA, CONEX, ROOT, Mathematica, Origin, MS Office.
Operating systems	Linux, Windows.
Languages	Portuguese (mother tongue), Good knowledge of English and Spanish

Other Activities

Sports: Swimming, running, fitness, football (but I'm not that good).

Cultural Interests: Reading, music, cinema, history and travelling, learning more about new cultures.

Work Style

Willing to perform basic tasks and move on to solve complex problems.

Able to learn new knowledge and adapt to new environment quickly.

Strong independence work style and excellent teamwork skills.

Well-organized and passionate.

Other Courses and Formations?

- ❖ Oral Presentation, 4h formation for professors, in Instituto Superior Técnico, 2013.
- ❖ Conflict management, 6h formation for professors, in Instituto Superior Técnico, 2013.
- ❖ Online Course at Coursera: Organizational Analysis (A+), on 2012, Stanford University, by Prof. Daniel A. McFarland.
- ❖ Monitoring and correction of written tests of the regional physics Olympiads (25 April 2010)
- ❖ Challenge 2 Learn 2010, Tagus Park, Instituto Superior Técnico (management challenge).
- ❖ Global Management Challenge 2009.
- ❖ Challenge 2 Learn 2009, Tagus Park, Instituto Superior Técnico (management challenge).
- ❖ Writing Course in El Corte Inglés, November-December 2009.
- ❖ Participation in the program of Mentorado do NAPE in Instituto Superior Técnico September de 2009 (mentoring program for college freshmen).

Cover Letter

As a graduate from the Instituto Superior Técnico with a strong particle physics background, and by working in a large physics collaboration (specifically, the Pierre Auger Observatory) at the Lisbon LIP group, I feel that I am an excellent fit for the postdoc position. As a PhD student, I've worked on data analysis at the Pierre Auger Observatory, on both Surface Detectors and Fluorescence Detectors, using offline tools and became a proficient about these two detection techniques. I generated simulations with CONEX and CORSIKA programs, using the most recent hadronic models, having changed the latter during my research. I've also created and modified simulation modules in the Auger framework. Therefore, I'm very familiar to general simulation procedures in bash, xml and C++ modules. Moreover, at my university, I had courses on quantum field theory and particles physics, being a good asset for the CMS data analysis.

Next, I will describe my work in detail. Recent results in ultra-high energy cosmic rays show that the LHC tuned hadronic models cannot describe consistently the electromagnetic and muonic component of an extensive air shower at the same time. It is considered that the problem comes from the muon sector. So, in order to find out if the effects that could explain the differences in the data, I changed the simulation muon characteristics such as energy production, pt and production coordinates. I'm also involved in the Auger data analysis for the recovery of the number of muons.

I also developed a 3D simulation for the fluorescence and direct Cherenkov emission of cosmic ray extensive air showers. At very high energies, it is not feasible to use the CORSIKA generator to simulate the Cherenkov emissions since it is computationally too heavy. So, I developed a framework that uses relevant 3D information from CORSIKA and uses it to simulate the light emissions (in a dedicated module inside the Auger offline or independently). With this framework, it is possible to simulate the Cherenkov emission in an event-by-event basis and use it at Auger or other Cherenkov detectors.

Moreover, the muon content is correlated with the energy calibration. So, we have worked on a way to disentangle the electromagnetic and the muonic signal (in a future upgrade or new projects). I studied the effect of using the electromagnetic signal to calibrate the SD energy. I tried new analysis approaches, such as obtaining the longitudinal electromagnetic Xmax using the ground signal, or considering the average LDFs to study the composition and problems within the hadronic models.

I also did field work for the collaboration: two FD shifts and one Roving Laser. In the FD shift, the aim was to monitor the FD data taking, including LIDAR radars and atmospheric monitoring. In the Roving Laser, a laser was used to calibrate the telescopes in different positions along the observatory.

I'm very interested in hadronic physics, the properties of the quark gluon plasma and forward physics, all very important to Auger, and that being the main reason why I chose this experiment. I have worked with Sibyll, QGSjet and EPOS models. During my graduation I was also attracted to Higgs mechanism, SUSY theories, Higgs doublets and lepton mixing. Since my bachelor, after visiting CERN in 2006, that my wish to work there, but after running a different path. Now its the time to jump to another particle physics experiment which would greatly enrich my experience. Cosmic ray models share some variable definitions with particle accelerator physics and, in general, are quite related. Nevertheless I'm committed to quickly learn the CMS framework software.

I taught at the university (IST) for 5 semesters. In 2014 I won a Diploma of Excellence in teaching and I'm prepared to help in student supervision. I'm applying to this postdoc grant because it will allow me to further develop my capabilities while inserted in a large collaboration, with the opportunity to gain new contacts, essential to my career future. I plan to participate actively in research seminars, and get a lot of work done! I look forward to work and discuss within a new environment and culture and interact with the many other postdocs at Brown University.

I look forward to hearing from you soon.

Best Regards

João Espadanal

List of Publications

Spires: <https://inspirehep.net/author/profile/J.Espadanal.1>

Google Scholar: <http://scholar.google.com.ar/citations?user=QU5LMYQAAAAJ&hl=en>

Talks

28 th June 2016	“Sensitivity of EAS measurements to the energy spectrum of muons”, Auger Analysis Meeting 2016, Karlsruhe, Germany.
2 nd June 2016	“Constraints of hadronic interactions in extensive air showers with the Pierre Auger Observatory”, 14th International Workshop on Meson Production, Properties and Interaction, KRAKÓW, POLAND.
24 th July 2015	“Cosmic Rays Anisotropies and Point Sources at Pierre Auger Observatory”, XXV Encontro Nacional de Astronomia e Astrofísica (ENAA), Instituto Superior Técnico, Portugal.
4 th September 2014	“Recent results of the Pierre Auger Observatory”, 19 ^a Conferência Nacional de Física, Instituto Superior Técnico, Portugal.
27 th June 2014	“Measurement of the Muon content of EAS with the Pierre Auger Observatory”, XXX-th International Workshop on High Energy Physics, Protvino, Russia.
22 nd March 2014	“Studies at Pierre Auger Observatory”, Jornadas do LIP 2014, Pavilhão do Conhecimento, Lisboa.
29 th October 2013	“Update on SD Energy Calibration based on the electromagnetic Signal”, 4 th MARTA Progress Meeting, Lisbon.
1 st June 2013	“SD Energy Calibration based on the electromagnetic Signal: GAP 2013-054”, 3 rd MARTA Progress Meeting, Lisbon.
12 th October 2012:	Presentation: “3D simulation Of Extensive Air Showers at Pierre Auger Observatory”, 1st PhD Student Workshop, Coimbra.
20 th June 2012:	Presentation: “Study of Cherenkov Rich Events with the 3D simulation”, Auger Analysis Meeting 2012, Prague.
23 rd April 2012:	Presentation: “Light Studies and exotics events at Pierre Auger Observatory” in Jornadas do LIP 2012, Lisbon, Portugal.
13 th November 2011	Presentation: “3D simulation of EAS for the FD: validation with a fluorescence rich data sample” in Auger Collaboration Meeting November 2011, Malargüe, Argentina.
21 st June 2011	Presentation “Understanding FD data and 3D simulation event by event” in Auger Analysis Meeting 2011, Santiago de Compostela.
7 th March 2010	Presentation “How strange are standard events?” in Auger Collaboration Meeting March 2010, Malargüe, Argentina.

Auger Internal Notes ([GAP Notes](#))

- ❖ L. Cazon, F. Diogo, R. Conceicao, S. Andringa, J. Espadanal, M. Pimenta, “*dlnA/dlogE from hadronic-type and EM-type cascade observables*”, GAP-Note 2016-022.
- ❖ J. Espadanal, S. Andringa, P. Gonçalves, M. Pimenta, “*Electromagnetic Xmax from SD signals with an upgraded SD*”, GAP-Note 2016-002.
- ❖ J. Espadanal, S. Andringa, P. Gonçalves, M. Pimenta, “*Average slope of SD LDFs for the QGSJet-II model*”, GAP-Note 2016-003.
- ❖ J. Espadanal, “*Study of the longitudinal and transverse cosmic ray shower profiles at the Pierre Auger Observatory*”, GAP-Note 2015-079.
- ❖ The MARTA teams, “*MARTA (Muon Auger RPC for the Tank Array) Design Report*”, GAP-Note 2013-020.
- ❖ J. Espadanal, M. Pimenta, P. Gonçalves, S. Andringa, “*SD Energy Calibration based on the Electromagnetic Signal*”, Pierre Auger GAP-Note 2013-054.
- ❖ J. Espadanal, P. Gonçalves, M. Pimenta, “*3D simulation of EAS for the FD: validation with a fluorescence rich data sample*”, Pierre Auger GAP-Note 2012-039.

Proceedings

- [1] J. C. Espadanal. “Constraints of hadronic interactions in extensive air showers with the Pierre Auger Observatory”, Proceedings, 14th International Workshop on Meson Production, Properties and Interaction (MESON2016), to be published in EPJ Web of Conferences, 2016.

- [2] J. C. Espadanal. "Measurement of the Muon Content of EAS with the Pierre Auger Observatory". In: Proceedings, 30th International Workshop on High Energy Physics: Particle and Astroparticle Physics, Gravitation and Cosmology: Predictions, Observations and New Projects (IHEP 2014). 2015, pp. 287-292. [doi:10.1142/9789814689304_0045](https://doi.org/10.1142/9789814689304_0045). [arXiv:1505.05527](https://arxiv.org/abs/1505.05527).

List of Publications

- [1]- J. Espadanal, L. Cazon and R. Conceição. "Sensitivity of EAS measurements to the energy spectrum of muons". Submitted to Astrophysical journal. [arXiv:1607.06760](https://arxiv.org/abs/1607.06760).
- [2]- A. Aab et al. "Ultrahigh-energy neutrino follow-up of Gravitational Wave events GW150914 and GW151226 with the Pierre Auger Observatory", (2016) [arXiv:1608.07378](https://arxiv.org/abs/1608.07378).
- [3]- A. Aab et al. "Measurement of the Radiation Energy in the Radio Signal of Extensive Air Showers as a Universal Estimator of Cosmic-Ray Energy", Phys. Rev. Lett. 116 24 (2016), p 241101. [Doi: 10.1103/PhysRevLett.116.241101](https://doi.org/10.1103/PhysRevLett.116.241101) [arxiv: 1605.02564](https://arxiv.org/abs/1605.02564).
- [4]- A. Aab et al. "The Pierre Auger Observatory Upgrade – Preliminary Design Report", (2016) [arXiv:1604.03637](https://arxiv.org/abs/1604.03637).
- [5]- A. Aab et al. "Azimuthal Asymmetry in the Risetime of the Surface Detector Signals of the Pierre Auger Observatory". In: Phys Rev. D93 7 (2016), p 072006. [doi: 10.1103/PhysRevD.93.072006](https://doi.org/10.1103/PhysRevD.93.072006) [arXiv: 1604.00978](https://arxiv.org/abs/1604.00978).
- [6]- A. Aab et al. "Prototype muon detectors for the AMIGA component of the Pierre Auger Observatory", In: JINST 11 02 (2016), p P02012. [Doi: 10.1088/1748-0221/11/02/P02012](https://doi.org/10.1088/1748-0221/11/02/P02012) [arxiv:1605.01625](https://arxiv.org/abs/1605.01625)
- [7]- A. Aab et al. "Nanosecond-level time synchronization of autonomous radio detector stations for extensive air showers". In: JINST 11 01 (2016), p. P01018. [doi: 10.1088/1748-0221/11/01/P01018](https://doi.org/10.1088/1748-0221/11/01/P01018) [arXiv:1512.02216](https://arxiv.org/abs/1512.02216).
- [8]- M. G. Aartsen et al. "Search for correlations between the arrival directions of IceCube neutrino events and ultrahigh-energy cosmic rays detected by the Pierre Auger Observatory and the Telescope Array". In: JCAP 1601 (2016), p. 037. [doi: 10.1088/1475-7516/2016/01/037](https://doi.org/10.1088/1475-7516/2016/01/037) [arXiv:1511.09408](https://arxiv.org/abs/1511.09408).
- [9]- M. G. Aartsen et al. "The IceCube Neutrino Observatory, the Pierre Auger Observatory and the Telescope Array: Joint Contribution to the 34th International Cosmic Ray Conference (ICRC 2015)". FERMILAB-CONF-15-494-AD-AE-CD-TD (2015). [arXiv:1511.02109](https://arxiv.org/abs/1511.02109).
- [10]- R. U. Abbasi et al. "Pierre Auger Observatory and Telescope Array: Joint Contributions to the 34th International Cosmic Ray Conference (ICRC 2015)". FERMILAB-CONF-15-495-AD-AE-CD-TD (2015). [arXiv:1511.02103](https://arxiv.org/abs/1511.02103).
- [11]- A. Aab et al. "The Pierre Auger Observatory: Contributions to the 34th International Cosmic Ray Conference (ICRC 2015)". FERMILAB-CONF-15-396-AD-AE-CD-TD (2015). [arXiv:1509.03732](https://arxiv.org/abs/1509.03732).
- [12]- A. Aab et al. "Energy Estimation of Cosmic Rays with the Engineering Radio Array of the Pierre Auger Observatory". In: Submitted to: Phys. Rev. D (2015). [arXiv:1508.04267](https://arxiv.org/abs/1508.04267).
- [13]- A. Aab et al. "Improved limit to the diffuse flux of ultrahigh energy neutrinos from the Pierre Auger Observatory". In: Phys. Rev. D91.9 (2015), p. 092008. [doi:10.1103/PhysRevD.91.092008](https://doi.org/10.1103/PhysRevD.91.092008). [arXiv:1504.05397](https://arxiv.org/abs/1504.05397).
- [14]- A. Aab et al. "Measurement of the cosmic ray spectrum above 4×10^{18} eV using inclined events detected with the Pierre Auger Observatory". In: JCAP 1508 (2015), p. 049. [doi:10.1088/1475-7516/2015/08/049](https://doi.org/10.1088/1475-7516/2015/08/049). [arXiv:1503.07786](https://arxiv.org/abs/1503.07786).
- [15]- A. Aab et al. "The Pierre Auger Cosmic Ray Observatory". In: Nucl. Instrum. Meth. A798 (2015), pp. 172-213. [doi: 10.1016/j.nima.2015.06.058](https://doi.org/10.1016/j.nima.2015.06.058). [arXiv:1502.01323](https://arxiv.org/abs/1502.01323).
- [16]- A. Aab et al. "Large Scale Distribution of Ultra High Energy Cosmic Rays Detected at the Pierre Auger Observatory With Zenith Angles up to 80". In: Astrophys. J. 802.2 (2015), p. 111. [doi: 10.1088/0004-637X/802/2/111](https://doi.org/10.1088/0004-637X/802/2/111). [arxiv:1411.6953](https://arxiv.org/abs/1411.6953).
- [17]- A. Aab et al. "Searches for Anisotropies in the Arrival Directions of the Highest Energy Cosmic Rays Detected by the Pierre Auger Observatory". In: Astrophys. J. 804.1 (2015), p. 15. [doi:10.1088/0004-637X/804/1/15](https://doi.org/10.1088/0004-637X/804/1/15). [arXiv:1411.6111](https://arxiv.org/abs/1411.6111).
- [18]- A. Aab et al. "Search for patterns by combining cosmic-ray energy and arrival directions at the Pierre Auger Observatory". In: Eur. Phys. J. C75.6 (2015), p. 269. [doi:10.1140/epjc/s10052-015-3471-0](https://doi.org/10.1140/epjc/s10052-015-3471-0). [arXiv:1410.0515](https://arxiv.org/abs/1410.0515).
- [19]- A. Aab et al. "Depth of maximum of air-shower profiles at the Pierre Auger Observatory. II. Composition implications". In: Phys. Rev. D90.12 (2014), p. 122006. [doi:10.1103/PhysRevD.90.122006](https://doi.org/10.1103/PhysRevD.90.122006). [arXiv:1409.5083](https://arxiv.org/abs/1409.5083).
- [20]- A. Aab et al. "Depth of maximum of air-shower profiles at the Pierre Auger Observatory. I. Measurements at energies above $10^{17.8}$ eV". In: Phys. Rev. D90.12 (2014), p. 122005. [doi:10.1103/PhysRevD.90.122005](https://doi.org/10.1103/PhysRevD.90.122005). [arXiv:1409.4809](https://arxiv.org/abs/1409.4809).
- [21]- A. Aab et al. "Searches for Large-Scale Anisotropy in the Arrival Directions of Cosmic Rays Detected above Energy of 10^{19} eV at the Pierre Auger Observatory and the Telescope Array". In: Astrophys. J. 794.2 (2014), p. 172. [doi:10.1088/0004-637X/794/2/172](https://doi.org/10.1088/0004-637X/794/2/172). [arXiv:1409.3128](https://arxiv.org/abs/1409.3128).

- [22]- A. Aab et al. "Muons in air showers at the Pierre Auger Observatory: Mean number in highly inclined events". In: Phys. Rev. D91.3 (2015).
[Erratum: [Phys. Rev. D91, no. 5, 059901 \(2015\)](#)], p. 032003. [doi:10.1103/PhysRevD.91.032003](#). [arXiv:1408.1421](#).
- [23]- A. Aab et al. "Muons in air showers at the Pierre Auger Observatory: Measurement of atmospheric production depth". In: Phys. Rev. D90.1 (2014). [Erratum: Phys. Rev. D92, no. 1, 019903 (2015)], p. 012012.
[doi:10.1103/PhysRevD.92.019903](#), [10.1103/PhysRevD.90.012012](#), [10.1103/PhysRevD.90.039904](#).
[arXiv:1407.5919](#).
- [24]- A. Aab et al. "Reconstruction of inclined air showers detected with the Pierre Auger Observatory". In: JCAP 1408.08 (2014), p. 019.
[doi:10.1088/1475-7516/2014/08/019](#). [arXiv:1407.3214](#).
- [25]- A. Aab et al. "A Targeted Search for Point Sources of EeV Neutrons". In: Astrophys. J. 789 (2014), p. L34.
[doi:10.1088/2041-8205/789/2/L34](#). [arXiv:1406.4038](#).
- [26]- A. Aab et al. "A search for point sources of EeV photons". In: Astrophys. J. 789.2 (2014), p. 160.
[doi:10.1088/0004-637X/789/2/160](#). [arXiv:1406.2912](#).
- [27]- A. Aab et al. "Origin of atmospheric aerosols at the Pierre Auger Observatory using studies of air mass trajectories in South America". In: Atmos. Res. 149 (2014), pp. 120-135.
[doi:10.1016/j.atmosres.2014.05.021](#). [arXiv:1405.7551](#).
- [28]- A. Aab et al. "Probing the radio emission from air showers with polarization measurements". In: Phys. Rev. D89.5 (2014), p. 052002.
[doi:10.1103/PhysRevD.89.052002](#). [arXiv:1402.3677](#).
- [29]- A. Aab et al. "Highlights from the Pierre Auger Observatory". In: Braz. J. Phys. 44 (2014), pp. 560-570.
[doi:10.1007/s13538-014-0218-6](#). [arXiv:1310.4620](#).
- [30]- P. Abreu et al. "Identifying Clouds over the Pierre Auger Observatory using Infrared Satellite Data". In: Astropart. Phys. 50-52 (2013), pp. 92-101.
[doi:10.1016/j.astropartphys.2013.09.004](#). [arXiv:1310.1641](#).
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