Rayos Cósmicos:
La Sublime utilidad de la "ciencia inútil"

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Octubre 2021

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Me he robado el título
y lo ejemplifico con los rayos cósmicos

https://www.youtube.com/watch?v=f6hdgSqAcOY

Hoy mas que nunca nuestro futuro está en manos de la ciencia inútil

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Pero ya alguien lo había dicho casi igual

Harpers, issue 179, June/November 1939

https://www.ias.edu/sites/default/files/library/UsefulnessHarpers.pdf

THE USE

Is it not a curious fact tha
steeped in irrational ha
threaten civilization itself
women—old and young—c
selves wholly or partly fro
current of daily life to devo
to the cultivation of beauty,

Abraham Flexner

From Wikipedia, the free encyclopedia

Abraham Flexner (November 13, 1866 – September 21, 1959) was an American educator, best known for his role in the 20th century reform of medical and higher education in the United States and Canada.[1]

After founding and directing a college-preparatory school in his hometown of Louisville, Kentucky, Flexner published a critical assessment of the state of the American educational system in 1908 titled *The American College: A Criticism*. His work attracted the Carnegie Foundation to commission an in-depth evaluation into 155 medical schools in the US and Canada.[2] It was his resultant self-titled *Flexner Report*, published in 1910, that sparked the reform of medical education in the United States and Canada.[1] Flexner was also a founder of the Institute for Advanced Study in Princeton, which brought together some of the greatest minds in history to collaborate on intellectual discovery and research.[2]

Abraham Flexner

Flexner circa 1910

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Agenda

Desarrollo de Capacidades

Introito:

Astropartículas en un píldora

Acto Primero:

Rayos Cósmicos y tripulaciones

Acto Segundo

MuTe:

Un telescopio de muones y los volcanes

Acto Tercero

De rayos, explosivos y otros demonios

Básico

Aplicado

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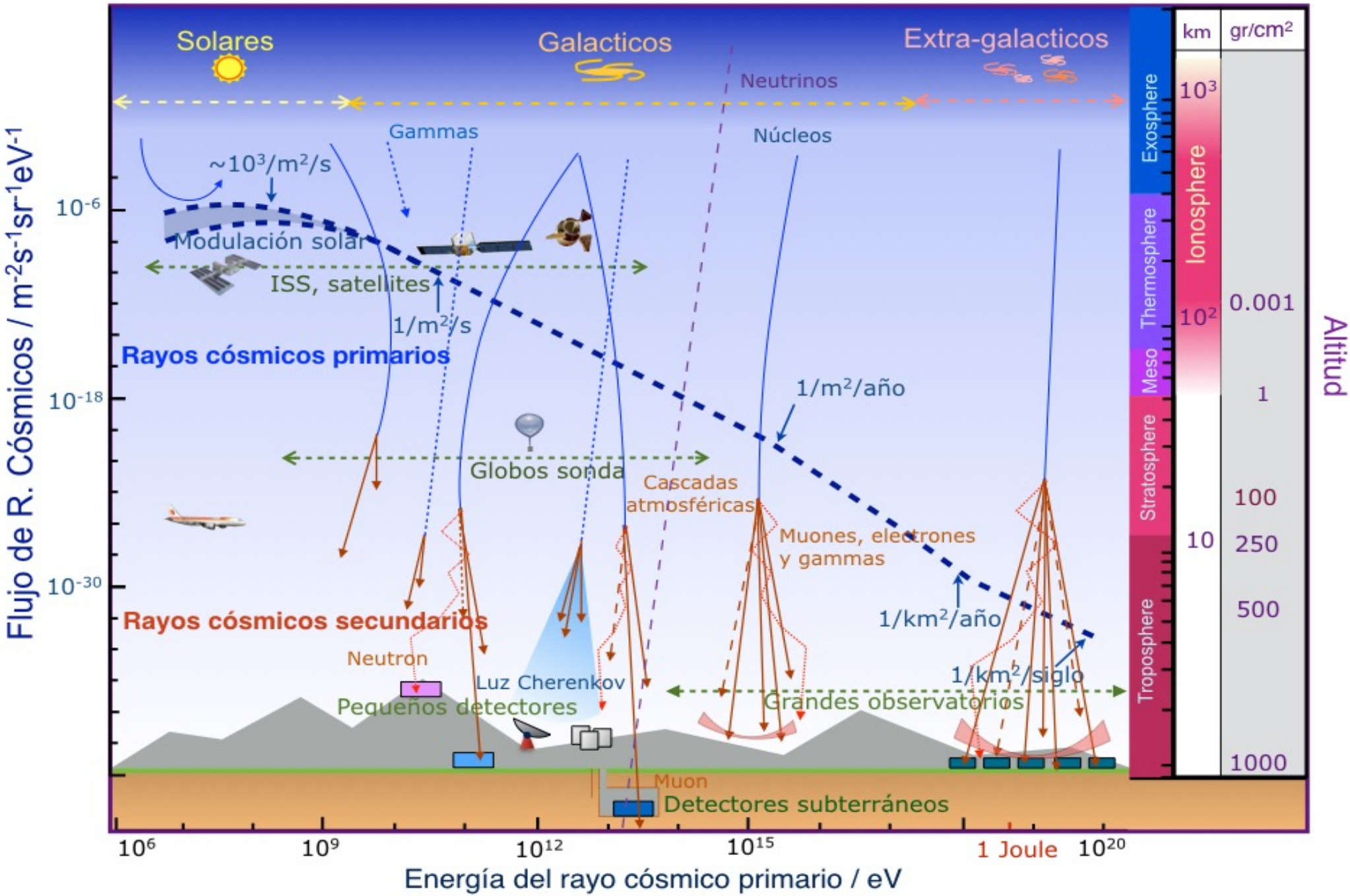
Introito

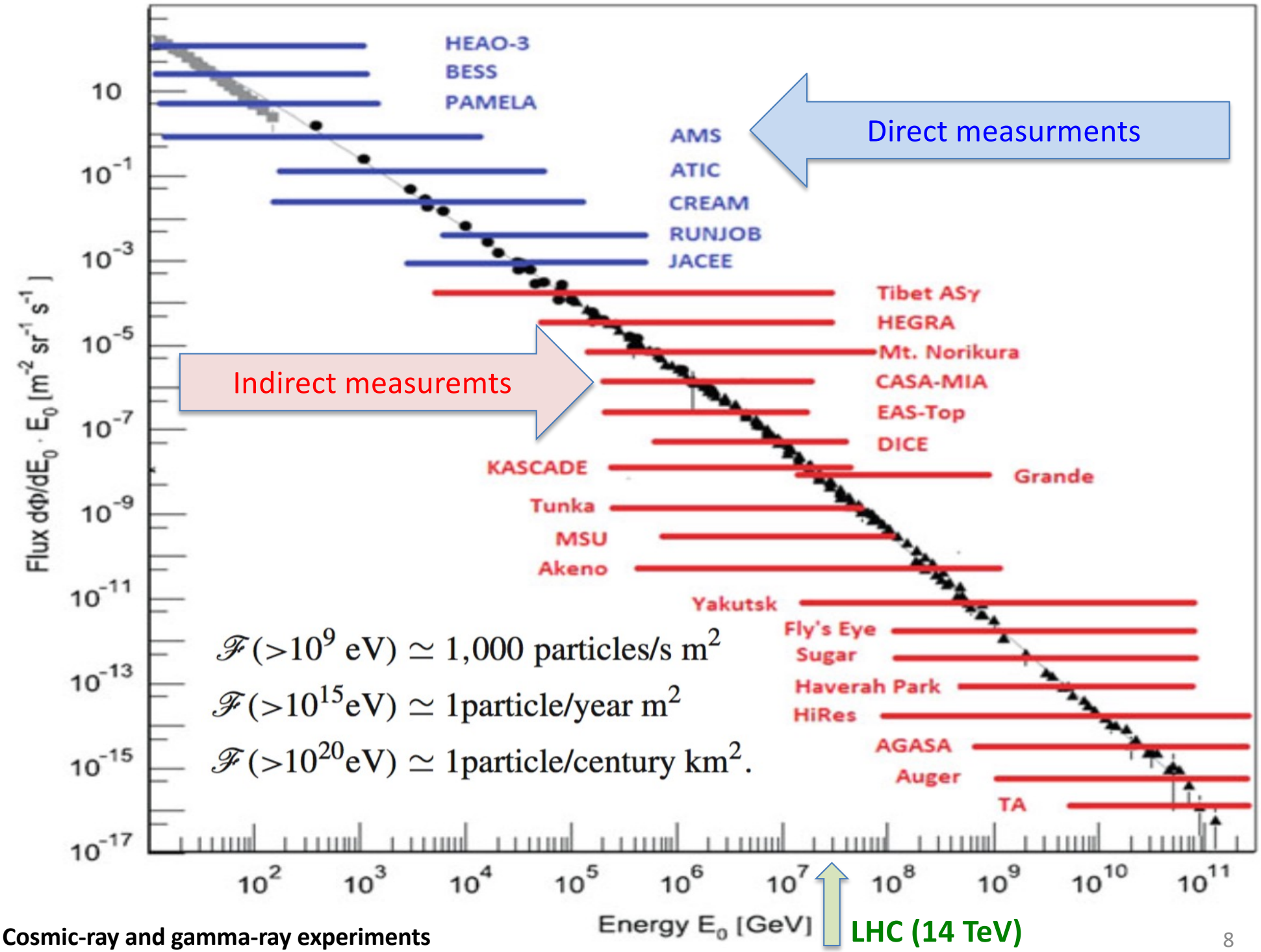
ASTOPARTÍCULAS EN UNA PÍLDORA



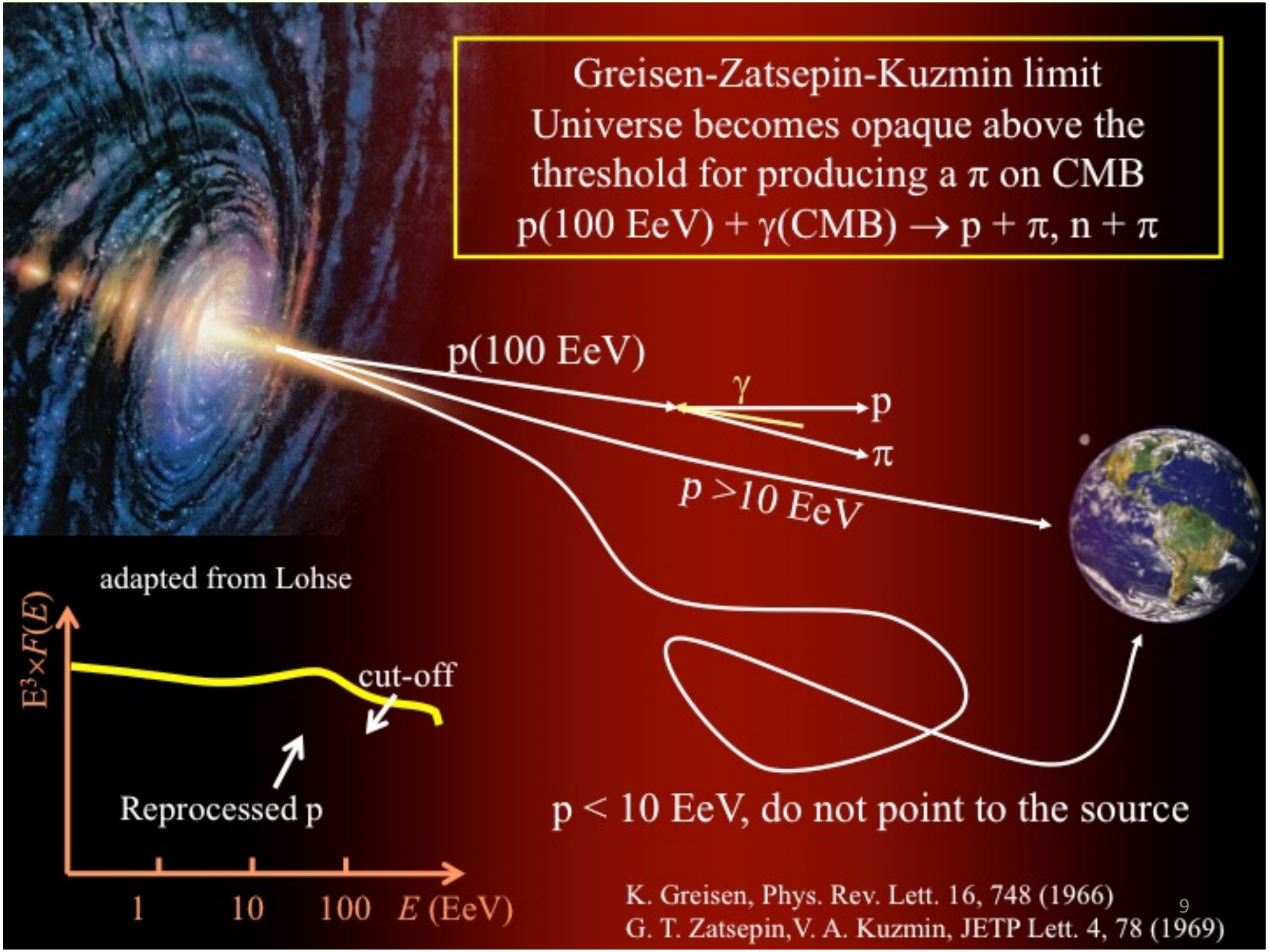
Los rayos cósmicos: una nueva ventana al universo

A. Ferriz Mas, *Universidad de Vigo e IAA/CSIC* y J. A. Garzón-Heydt, *Universidad de Santiago de Compostela*

http://revista.iaa.es/content/los-rayos-cósmicos-una-nueva-ventana-al-universo

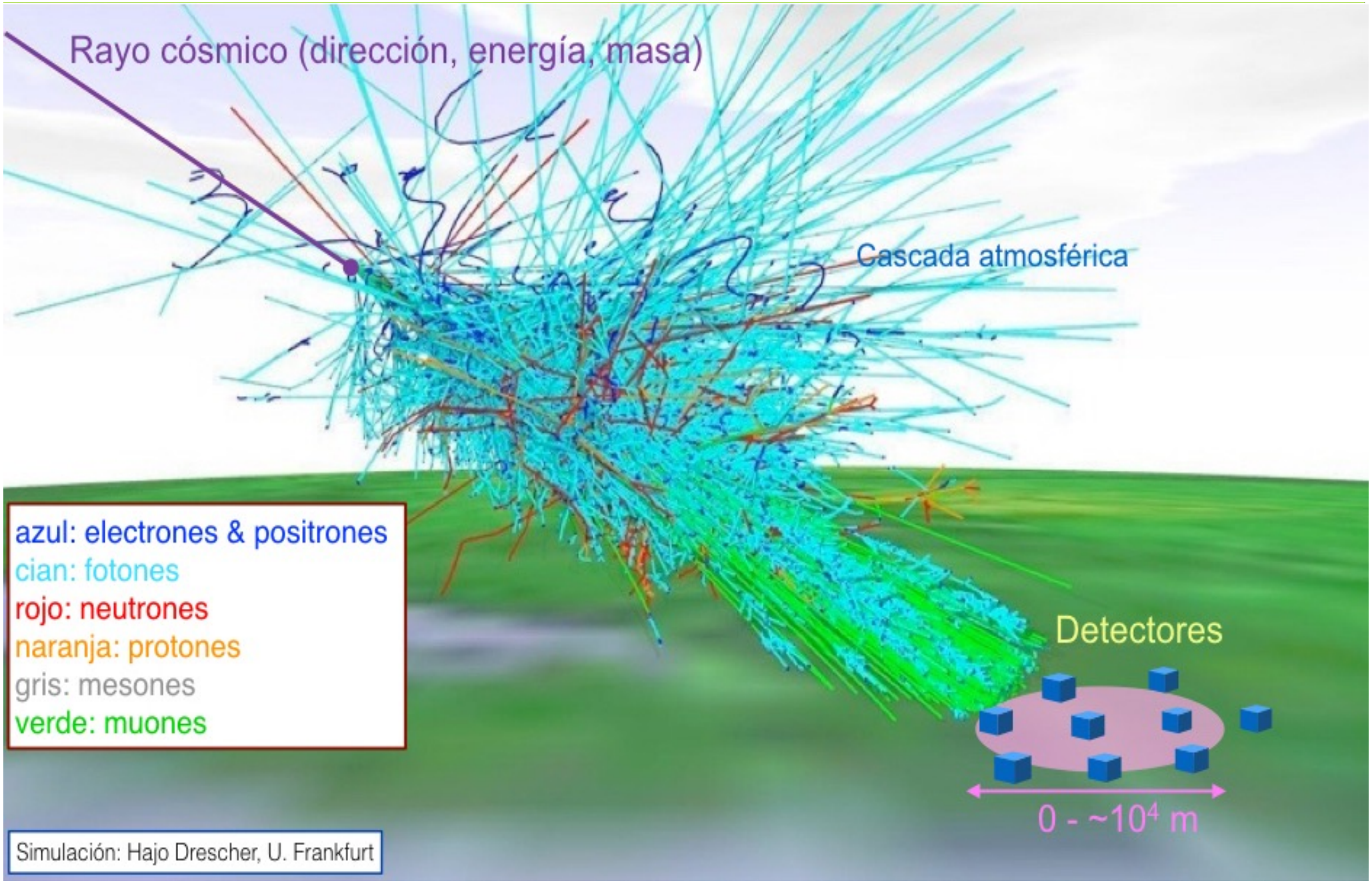


Cosmic-ray and gamma-ray experiments
https://www.mpi-hd.mpg.de/hfm/CosmicRay/CosmicRaySites.html#space


Greisen-Zatsepin-Kuzmin limit
Universe becomes opaque above the threshold for producing a π on CMB
p(100 EeV) + γ(CMB) → p + π, n + π
p(100 EeV)
γ
p
π
p >10 EeV
adapted from Lohse
E³×F(E)
cut-off
Reprocessed p
1
10
100
E (EeV)
p < 10 EeV, do not point to the source
K. Greisen, Phys. Rev. Lett. 16, 748 (1966)
G. T. Zatsepin,V. A. Kuzmin, JETP Lett. 4, 78 (1969)

Air Showers

All those... moments will be lost in time, like tears... in rain.
replicante Roy Batty
- R. Hauer
Blade Runner (1982)



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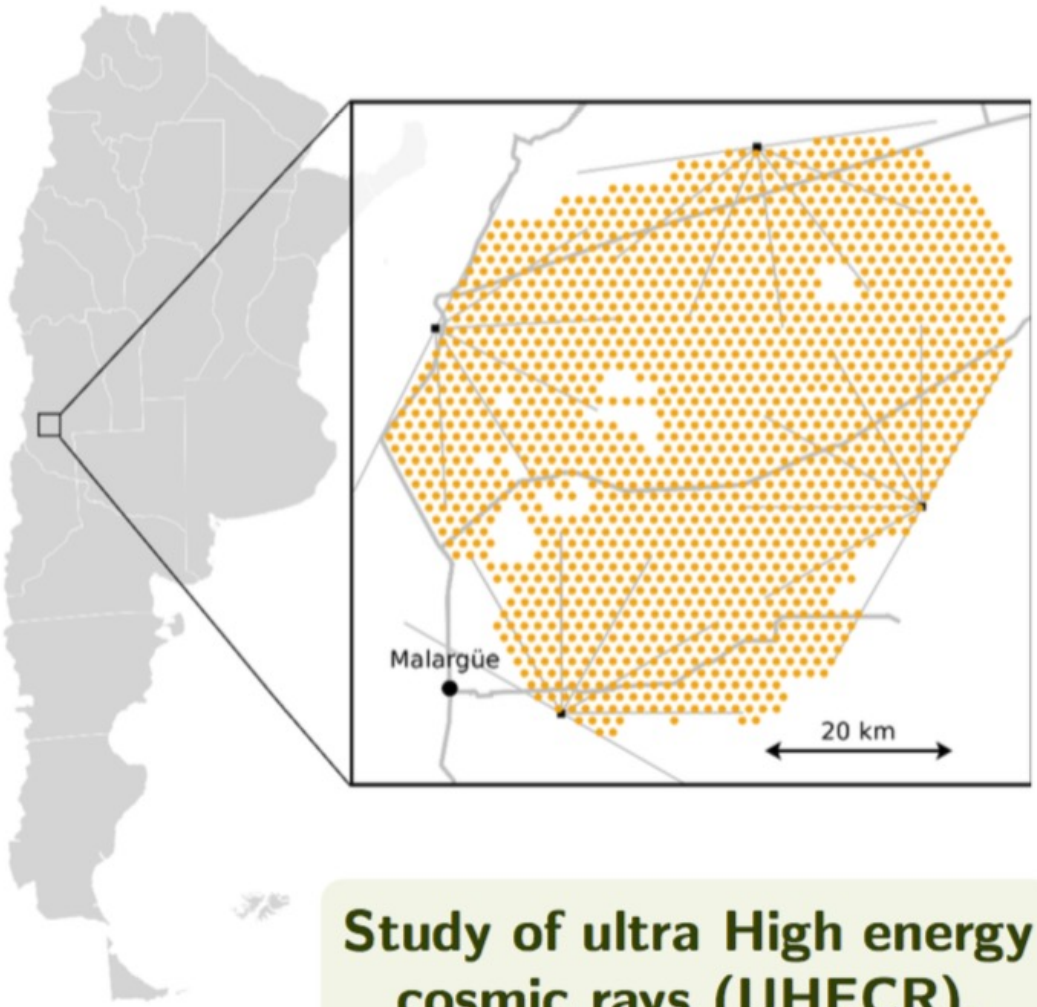
The Pierre Auger Observatory

A theory is something nobody believes, except the person who made it.
An experiment is something everybody believes, except the person who made it.
- attributed to Albert Einstein

The Pierre Auger Observatory

J. Abraham et al., NIM A523:1-2(2004)50



Location

- Pampa Amarilla, Malarge, Argentina
- 69,3° W, 35,3° S
- 1400 m a.s.l., $X_d \simeq 870\,\mathrm{g\,cm^{-2}}$
- 3000 $\mathrm{km^2}$ of surface

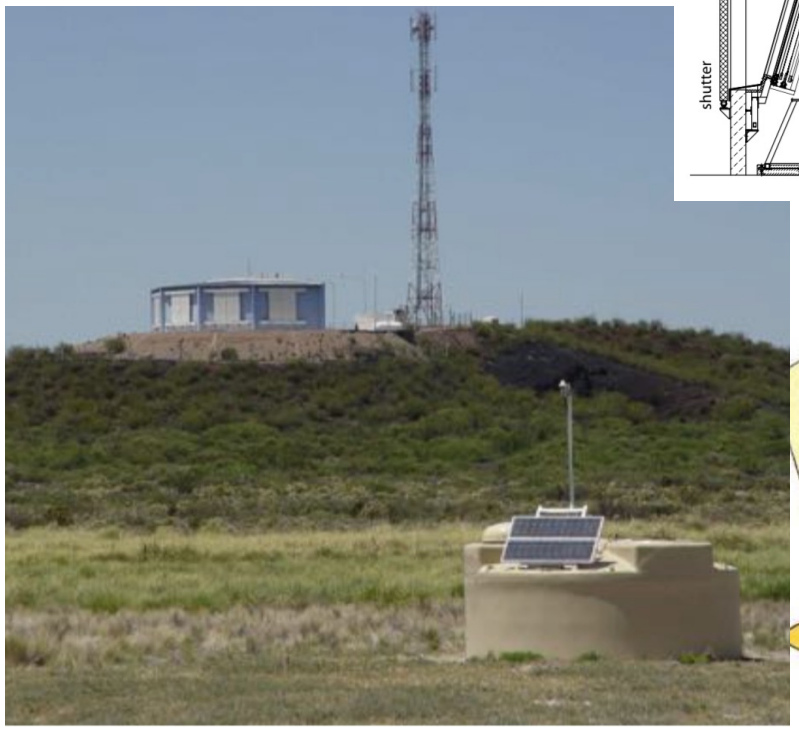
Study of ultra High energy cosmic rays (UHECR),
$E_p \geq 10^{18}\,\mathrm{eV} \equiv 1\,\mathrm{EeV}$

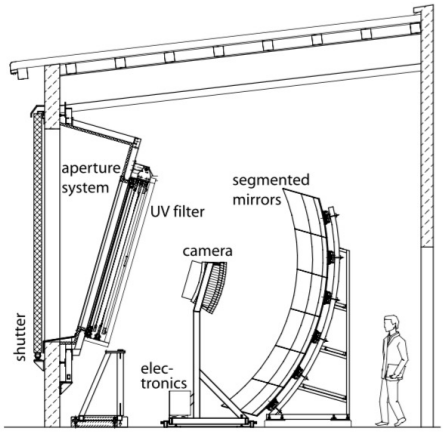
Surface detector: SD

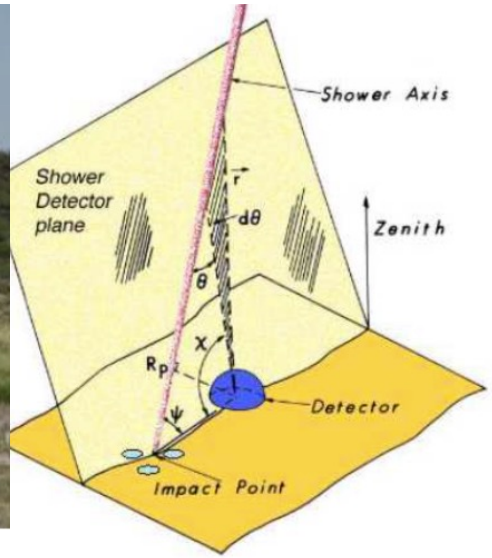
1660 Water Cherenkov detector in a triangular grid of 1500 m in a 3000 km^2 area

The Pierre Auger Observatory

Concept

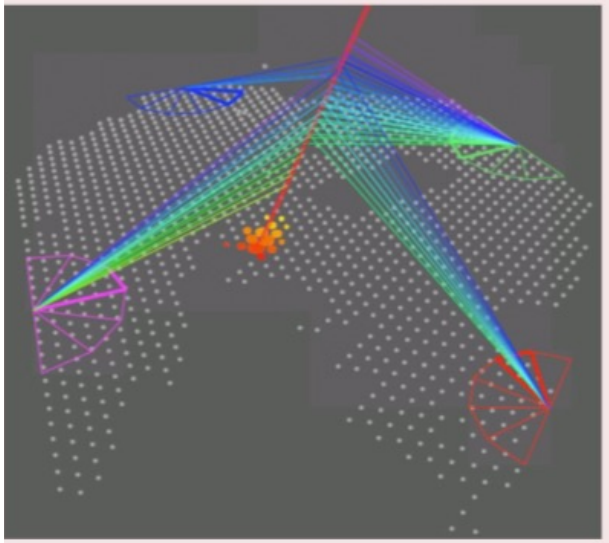




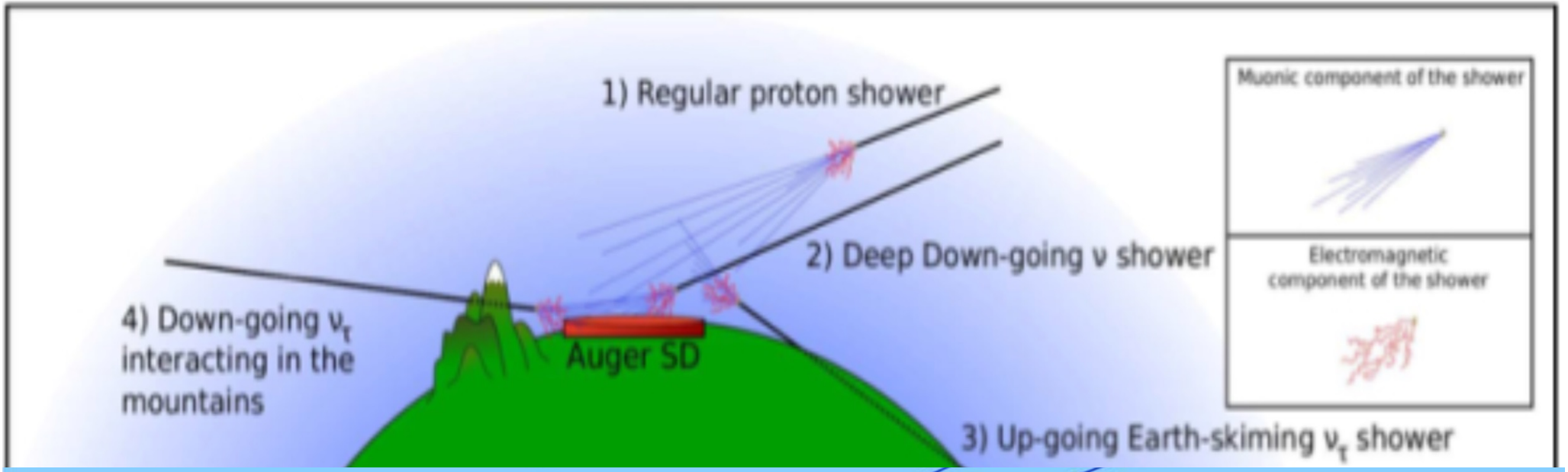


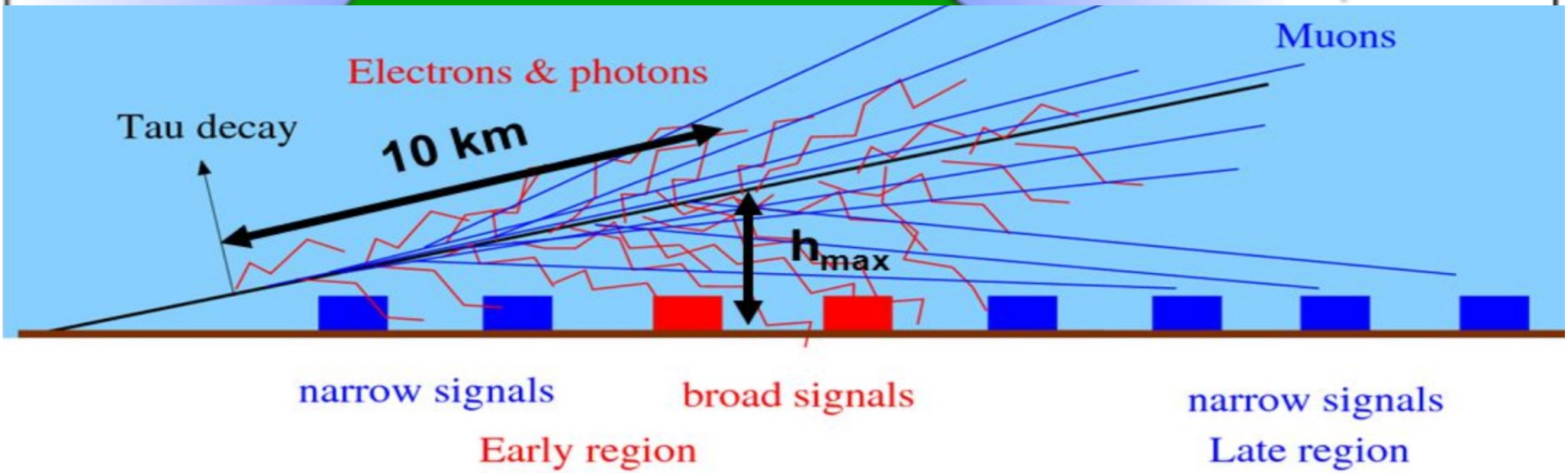
Hybrid detection

- Surface detector (**SD**)
  - **Transversal development**
  - **1660 water Cherenkov detectors**
  - **Triangular grid of** 750 **and** 1500 **m**
- Fluorescence detector (**FD**)
  - **Longitudinal development**
  - **4 sites surrounding the SD**
  - **27 fluorescence telescopes**



Neutrinos from WCD signal

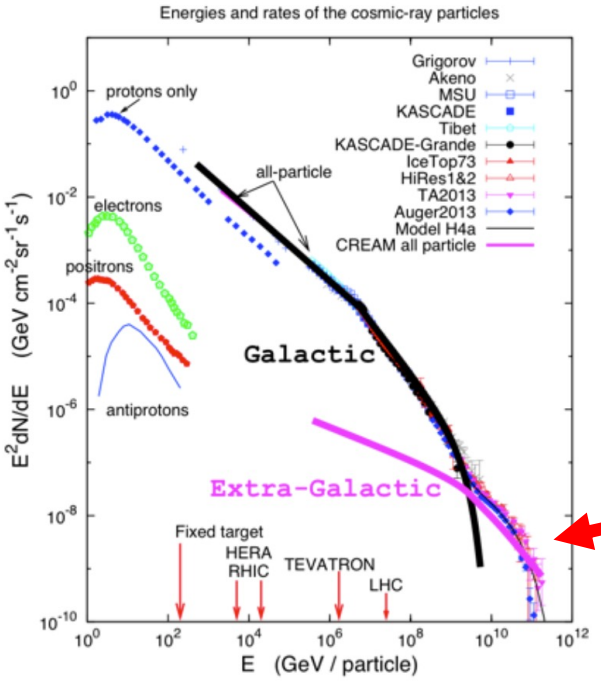




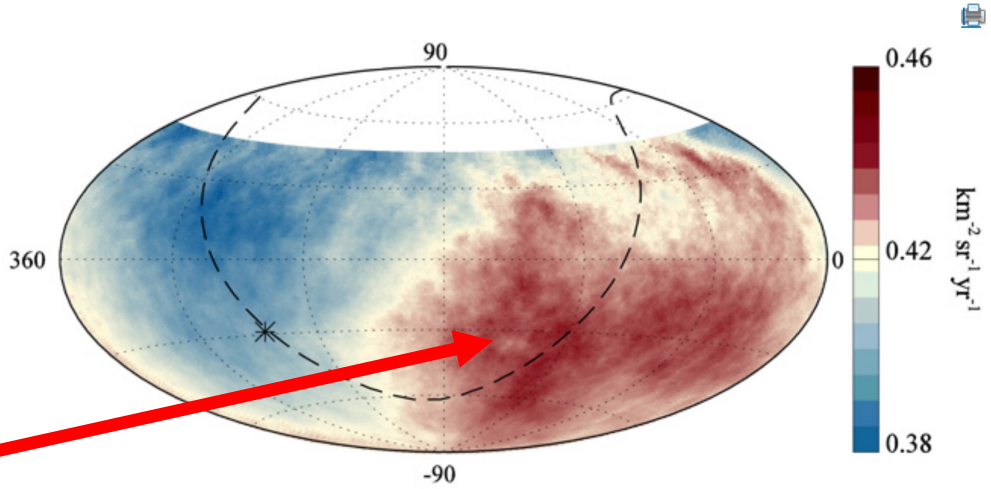
Abbot, B. P., Abbot, T. D., Acernese, F., & André, M. (2017). Multi-messenger observations of a binary neutron star merger. *Astrophysical Journal Letters*, *848*.

Auger: Scientific Results

physicsworld TOP 10 BREAKTHROUGH 2017



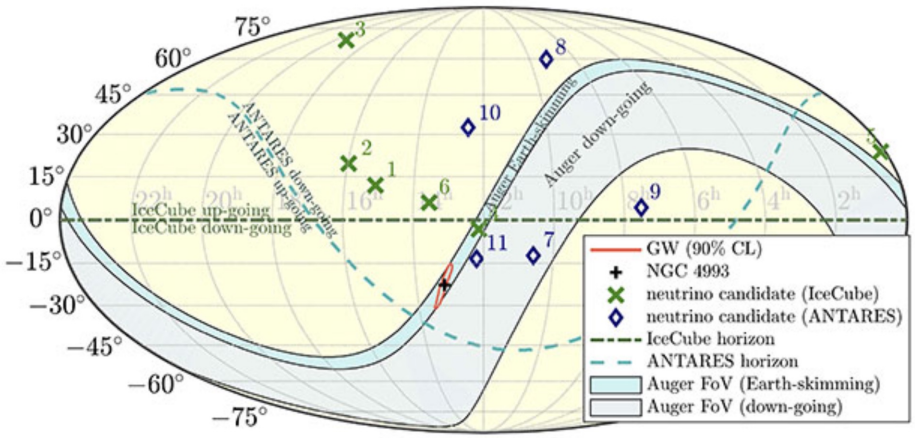
50 year-old mystery has been solved



Ever since the existence of cosmic rays with individual energies of several Joules was established in the 1960s, speculation has raged as to whether cosmic particles of mean energy of 2 Joules are created in our Milky Way or in distant extragalactic objects.

The anisotropy indicates an extragalactic origin for these ultra-high energy particles.

Pierre Auger Collaboration, 2017. Observation of a large-scale anisotropy in the arrival directions of cosmic rays above 8× 1018 eV. *Science*, *357*(6357), pp.1266-1270. ArXiv 1709.07321

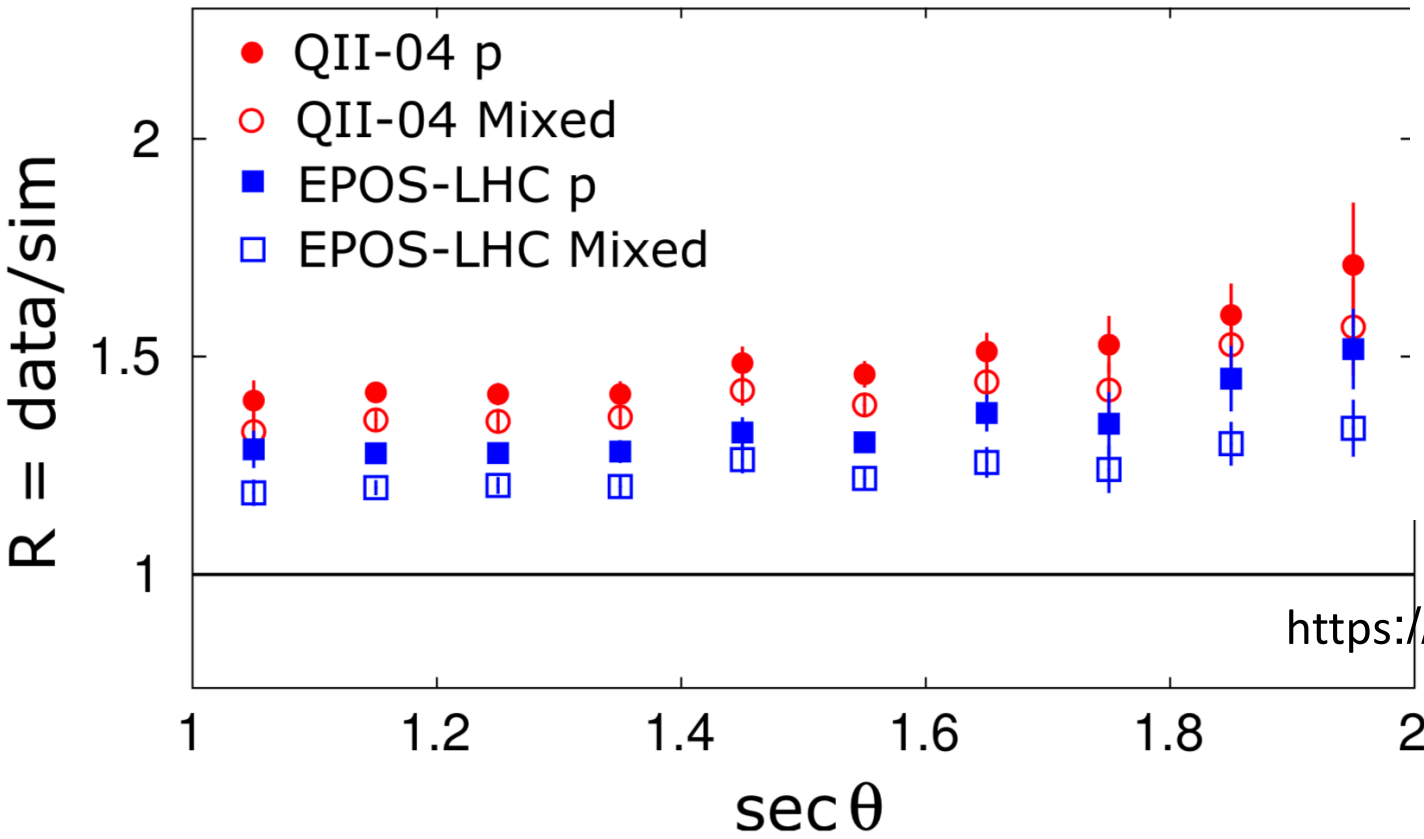


Detection of GW170817: No associated neutrino events in a time window within 500 seconds (and up to 14 days after) around the detection. In agreement with Antares and IceCube

Multi-messenger Observations of a Binary Neutron Star Merger (2017) *Astrophysical Journal Letters*, *848*.

Ultrahigh-energy neutrino follow-up of gravitational wave events GW150914 and GW151226 with the Pierre Auger Observatory (2016) *Physical Review D, 94(12), 122007.*

Auger: Scientific Results



***) 33% more muons were detected than predicted by the "EPOS-LHC" model**
***) 61% more were detected than predicted by the "QGSJet-II-04" model.**

https://arxiv.org/abs/1610.08509

The Auger collaboration can extend its analysis outside the narrow energy range to look for an energy dependence of the discrepancy, which would provide a clue to its origin. For a complementary test, they could also analyze other observables that are sensitive to hadronic interactions, such as the height at which muons are produced.

https://physics.aps.org/articles/v9/125

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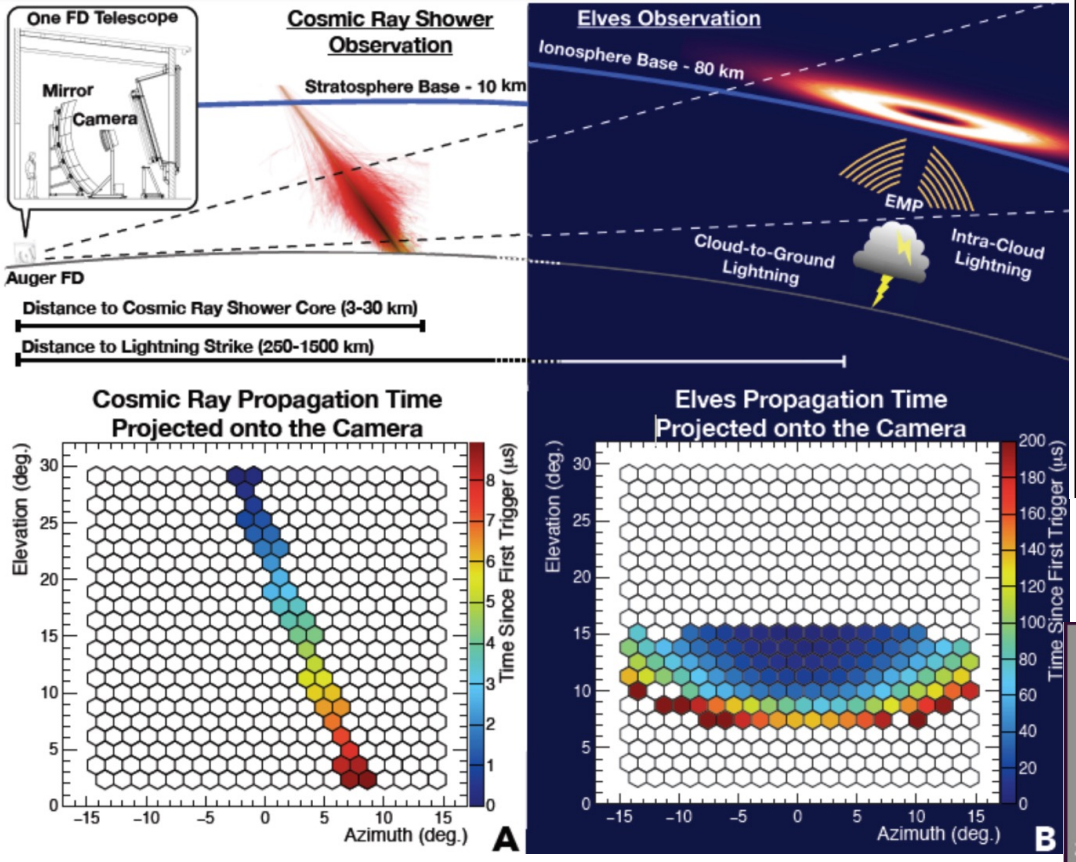
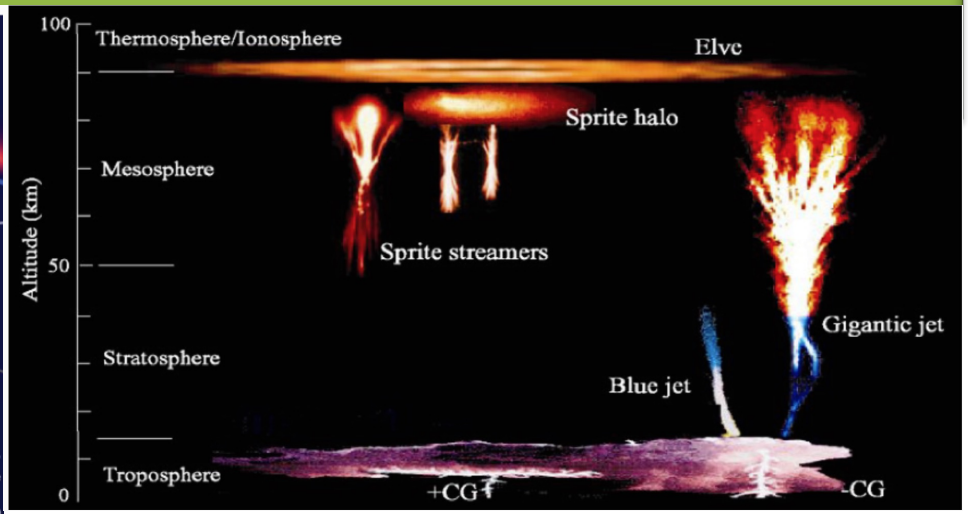
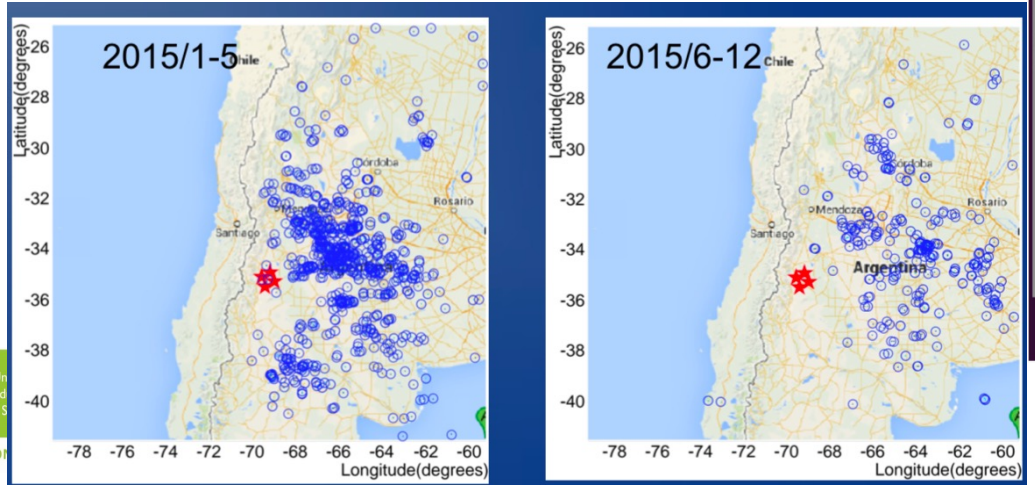
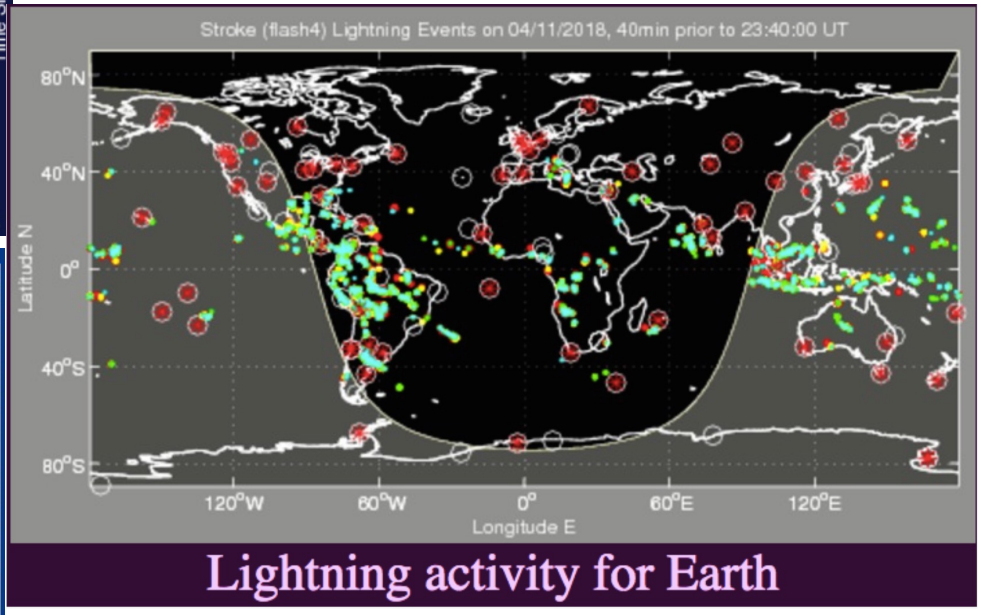
ELVES at the Pierre Auger Observatory









Lightning activity for Earth

Acto Primero

EL CLIMA ESPACIAL Y LAS TRIPULACIONES

The LAGO Space Weather Program

via Solar modulation of low energy cosmic rays

Connections

CR Flux	$\xrightarrow{\text{Solar Activity}}$	Modulated flux
Modulated flux	$\xrightarrow{\text{Geomagnetic field}}$	Primaries
Primaries	$\xrightarrow{\text{Atmospheric conditions}}$	Secondary particles
Secondary particles	$\xrightarrow{\text{Detector response}}$	**Signals**

Synergy

Flux variation of signals at detector level $\Leftrightarrow$ Solar Activity

- Asorey, H. et al (2015) "The LAGO space weather program: Directional geomagnetic effects, background fluence calculations and multi-spectral data analysis, PoS(ICRC2015) 142.
- Asorey, H., et al (2018). Preliminary results from the Latin American Giant Observatory space weather simulation chain. Space Weather, 16, 461–475.

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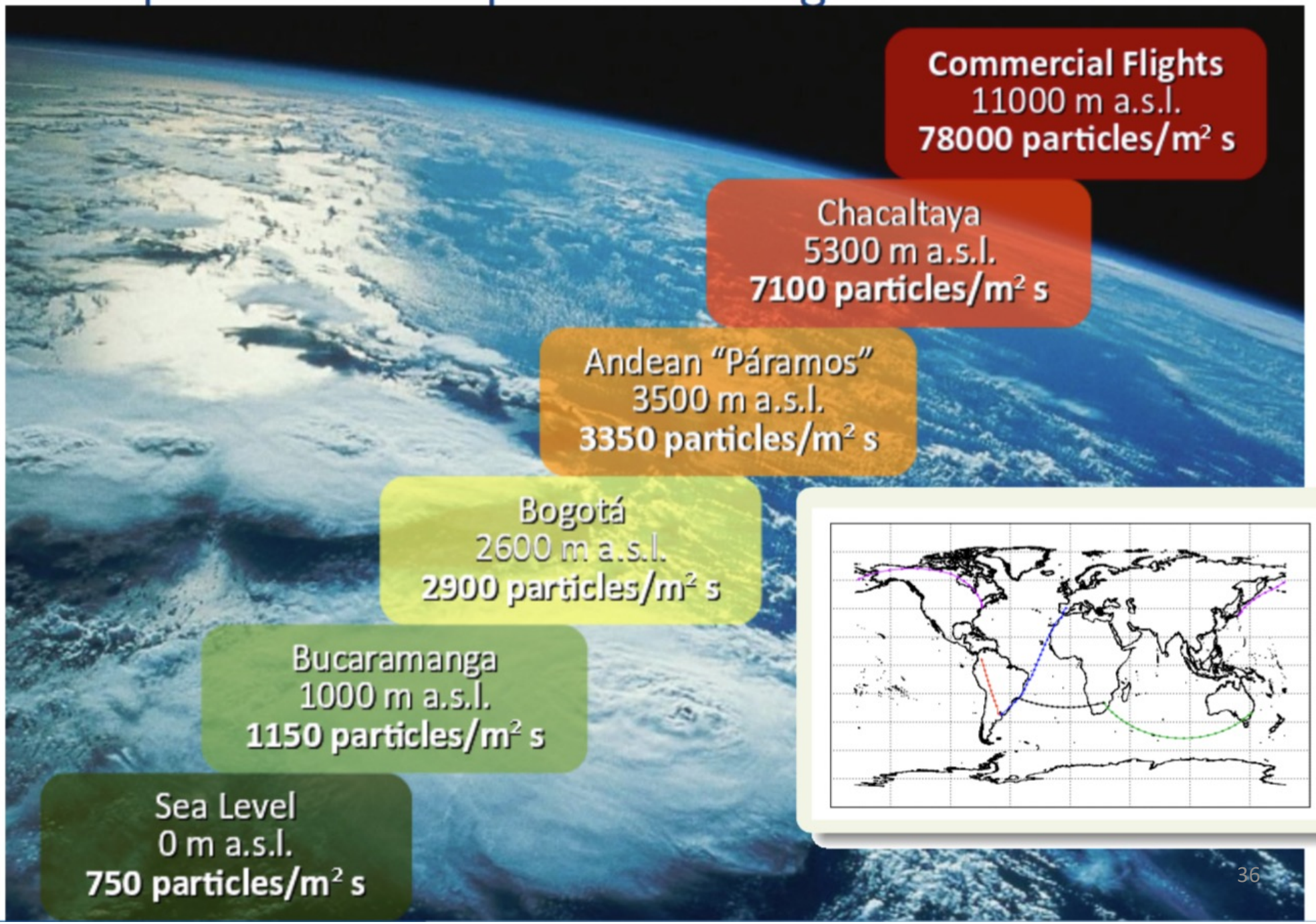
Atmospheric reaction produces background radiation



The LAGO Space Weather Program

via Solar modulation of low energy cosmic rays and biological impact

Connections

CR Flux	$\xrightarrow{\text{Solar Activity}}$	Modulated flux
Modulated flux	$\xrightarrow{\text{Geomagnetic field}}$	Primaries
Primaries	$\xrightarrow{\text{Atmospheric conditions}}$	Secondary particles
Secondary particles	$\xrightarrow{\text{Tissue Damage}}$	**Damage**

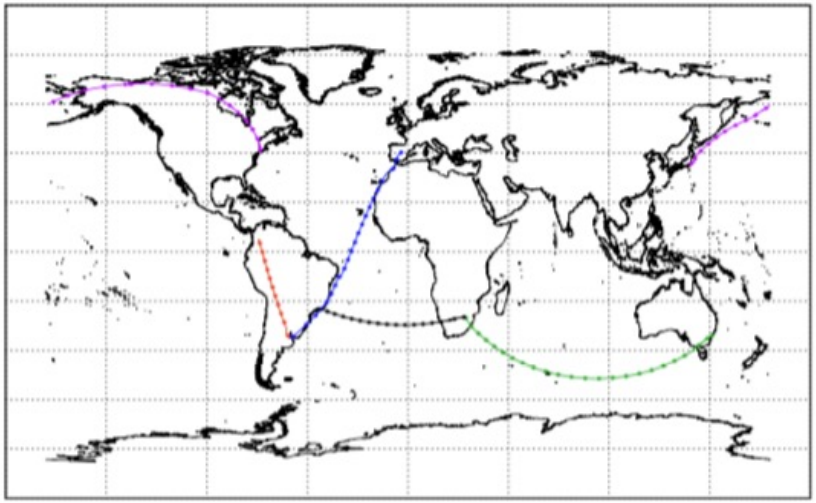
Synergy

Flux variation at the airline route $\Leftrightarrow$ Solar Activity

Pinilla, Sergio, Hernan Asorey, and Luis A. Núñez. "Cosmic Rays Induced Background Radiation on Board of Commercial Flights." *Nuclear and Particle Physics Proceedings* 267 (2015): 418-420.

Radiation flux and comercial flights

Particle flux



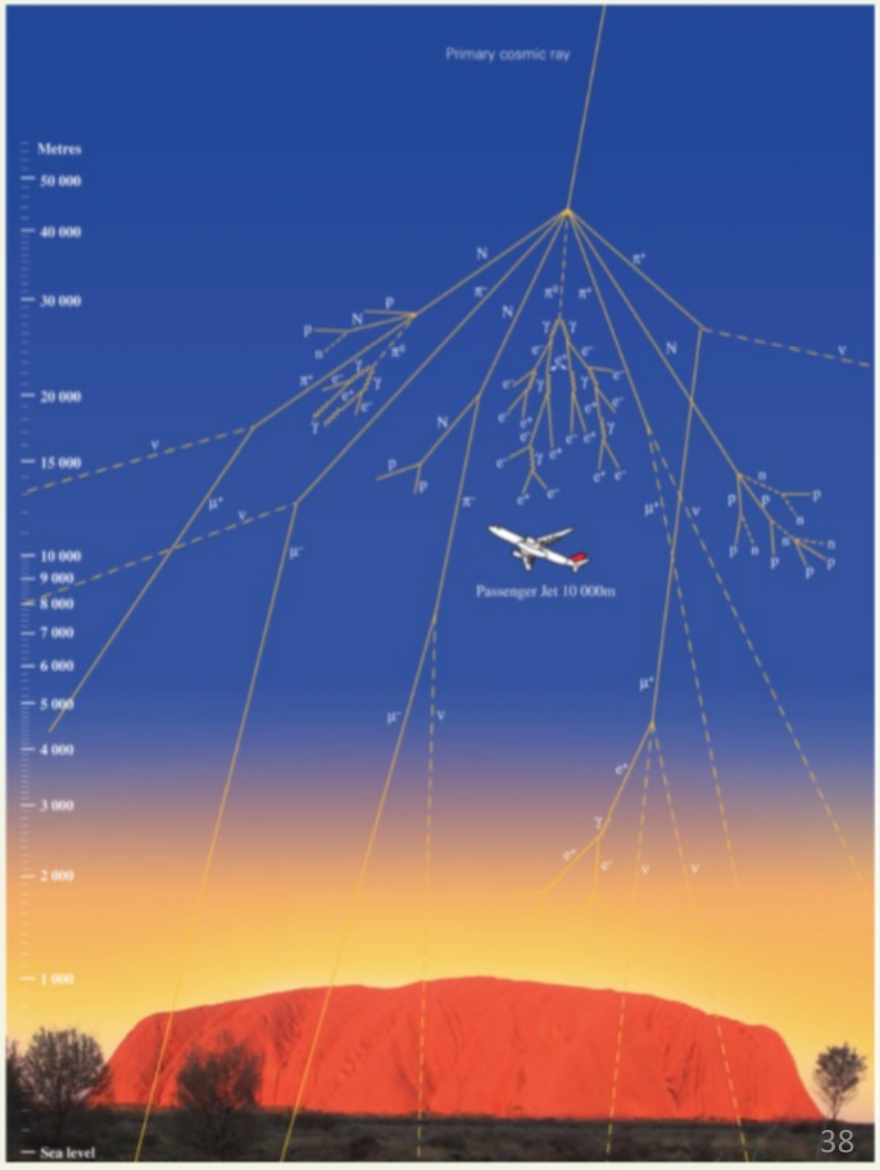
$$\%F_N = \frac{N_{\text{con CG}}}{N_{\text{sin CG}}} \times 100\,\%. \qquad (9)$$

Ruta	γ	e^+	e^-	μ^+	μ^-	n^0	p^+	Otros	Total
BOG-BUE	55.9	59.6	59.0	60.0	63.6	17.5	21.5	59.7	52.0
BUE-MAD	57.0	60.6	60.1	61.2	64.7	18.8	22.8	60.6	53.1
JNB-SYD	93.3	94.3	94.1	95.8	96.7	79.9	82.5	94.9	91.9
NYC-TYO	91.0	92.1	91.9	93.1	94.2	78.2	80.4	92.4	89.7
SAO-JNB	71.6	74.7	74.1	77.3	80.6	33.5	38.4	73.7	67.7

$$d_N = \frac{N_{\text{ruta}} - N_{\text{BGA}}}{N_{\text{BGA}}} \qquad (10)$$

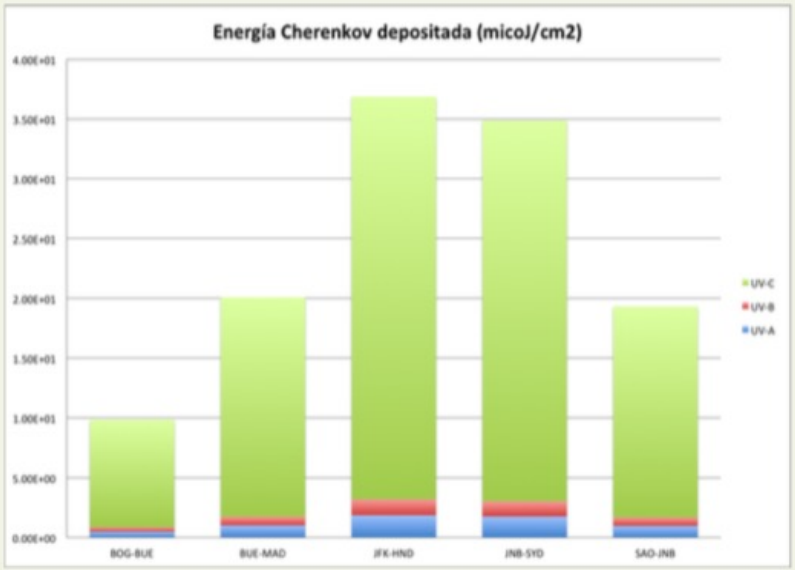
Ruta	γ	e^+	e^-	μ^+	μ^-	n^0	p^+	Otros	Total
BOG-BUE	55.5	56.0	56.2	3.5	3.9	84.6	165.8	122.6	46.1
BUE-MAD	56.6	57.0	57.3	3.6	4.0	90.7	175.9	124.6	47.1
JNB-SYD	93.3	89.3	90.3	6.2	6.5	388.7	638.0	195.6	82.2
NYC-TYO	91.0	87.2	88.1	6.1	6.3	380.6	621.9	190.4	80.2
SAO-JNB	71.3	70.5	70.8	4.9	5.3	162.7	296.6	151.7	60.3

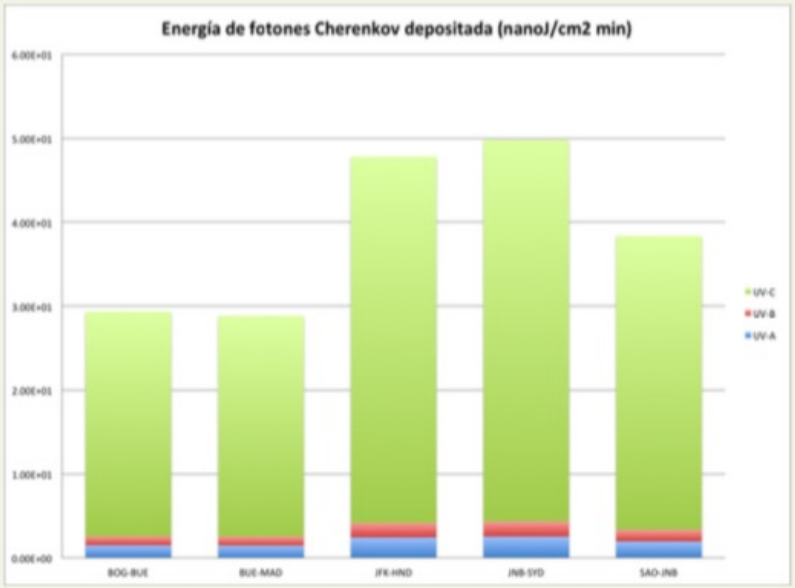
Particles and comercial flight



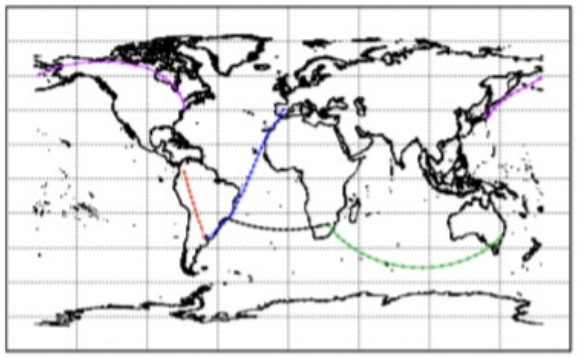
Energy Deposited

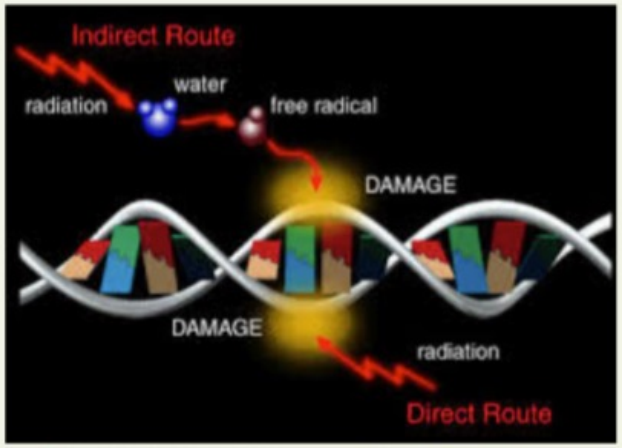
Cherenkov Energy

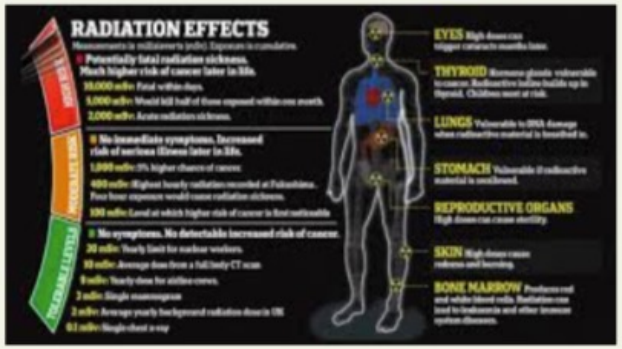


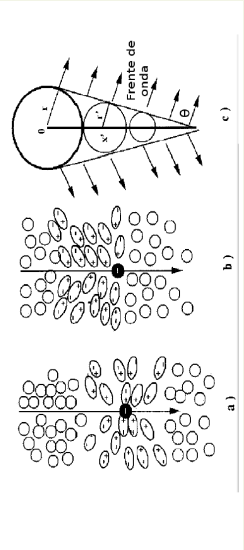


Bioeffects and comercial flights









Acto Segundo

MUTE UNA SOPA DE MUONES PARA VER VOLCANES

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rsta.royalsocietypublishing.org Phil. Trans. R. Soc. A 377: 20180049

Figure 3. Schematic infographic illustrating the different applications of muography, courtesy of Lynkeos Technology Ltd.

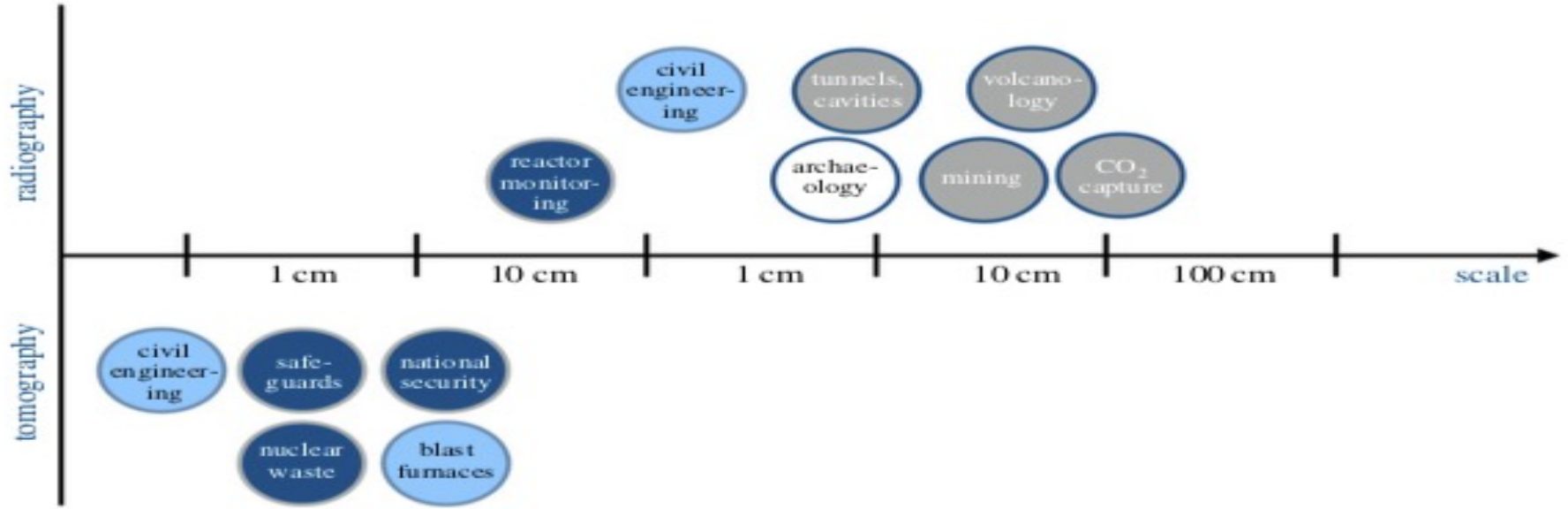
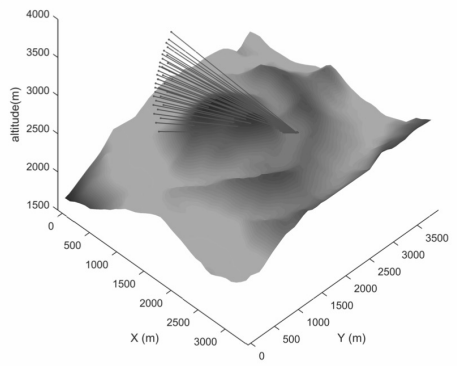
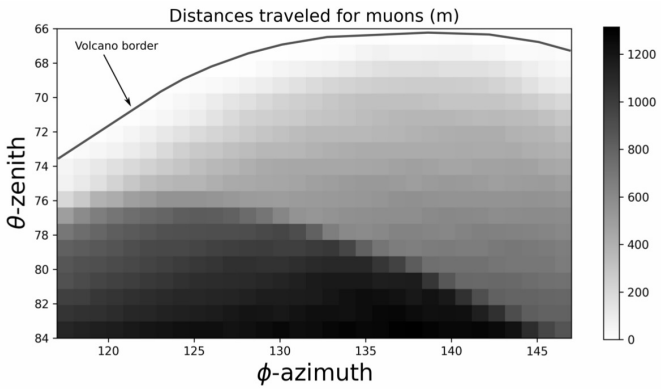


Figure 4. Typical scale of muon radiography and tomography applications, with civil engineering applications in light blue, nuclear safety and security applications in dark blue and geoscience applications in grey. (Online version in colour.)





13 volcanoes analysed
Complies: Cerro Machín

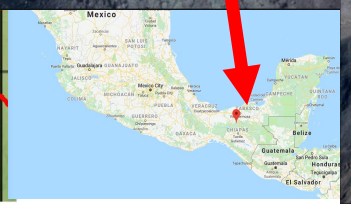
Volcano	Criterion 1:	Criterion 2:	Criterion 3:
Azufral	N	Y	N
Cerro Negro*	Y	Y	N
Chiles*	Y	Y	N
Cumbal	N	Y	N
Dona Juana	N	Y	N
Galeras	Y	N	Y
Machín	**Y**	**Y**	**Y**
Nevado del Huila	N	Y	N
Nevado del Ruíz	N	Y	Y
Nevado Santa Isabel	N	Y	Y
Nevado del Tolima	N	N	Y
Puracé	N	Y	Y
Sotará	N	Y	N

- At the observational level, is the volcano base width less than 1,500 m?
- Are there tentative observation points where the surrounding topography does not affect the target?
- Are the sites accessible and secure?

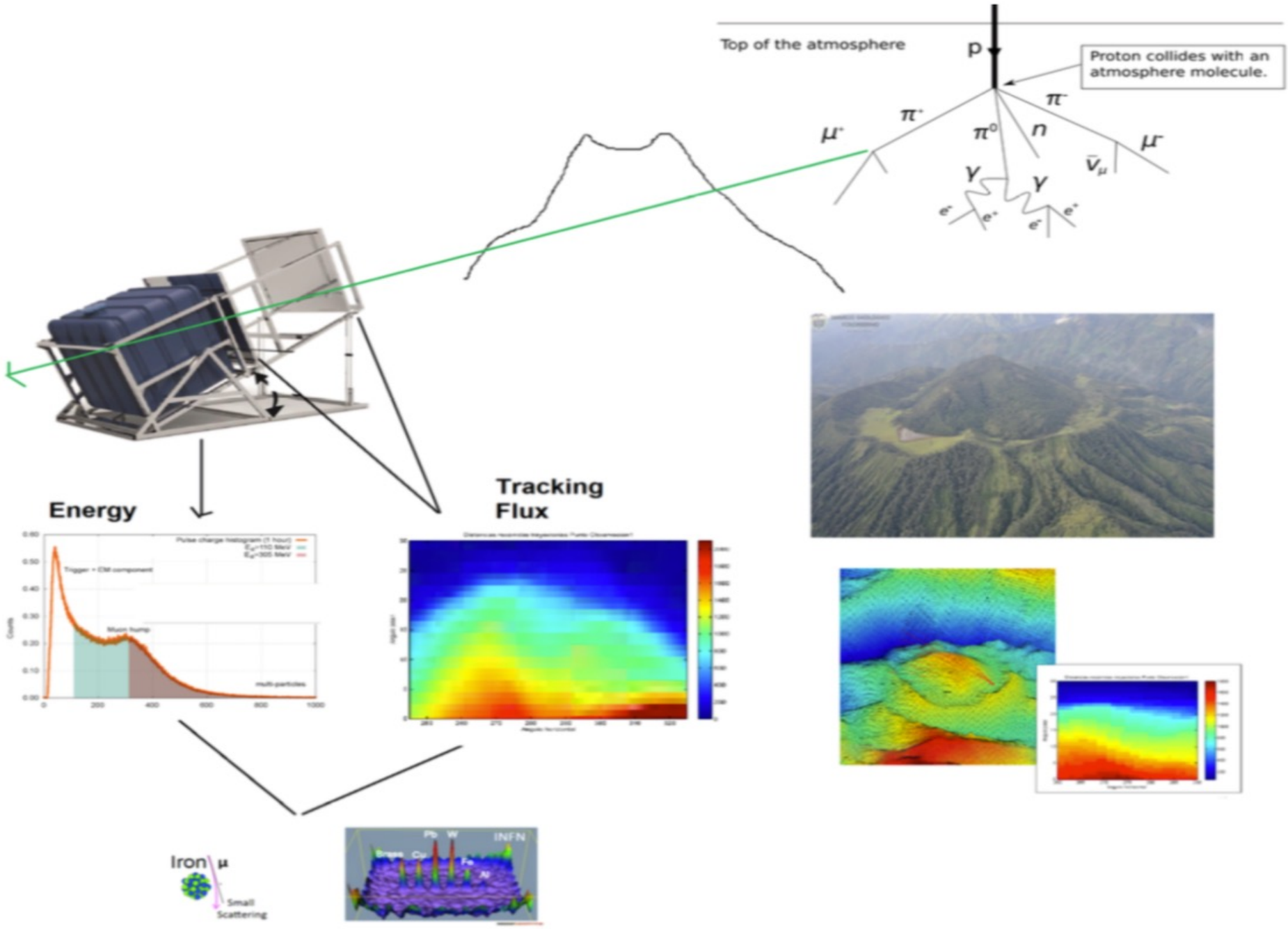
Vesga-Ramírez, A.; Sierra-Porta, D.; Pena-Rodriguez, J.; Sanabria-Gomez, J. D.; Valencia-Otero, M.; Sarmiento-Cano, C.; Suarez-Duran, M.; Asorey, H.; Nunez, L. A.
(2017). Muon Tomography sites for Colombia volcanoes. *arXiv preprint arXiv:1705.09884*.

Colombian Volcanoes

Cerro Machin Volcano

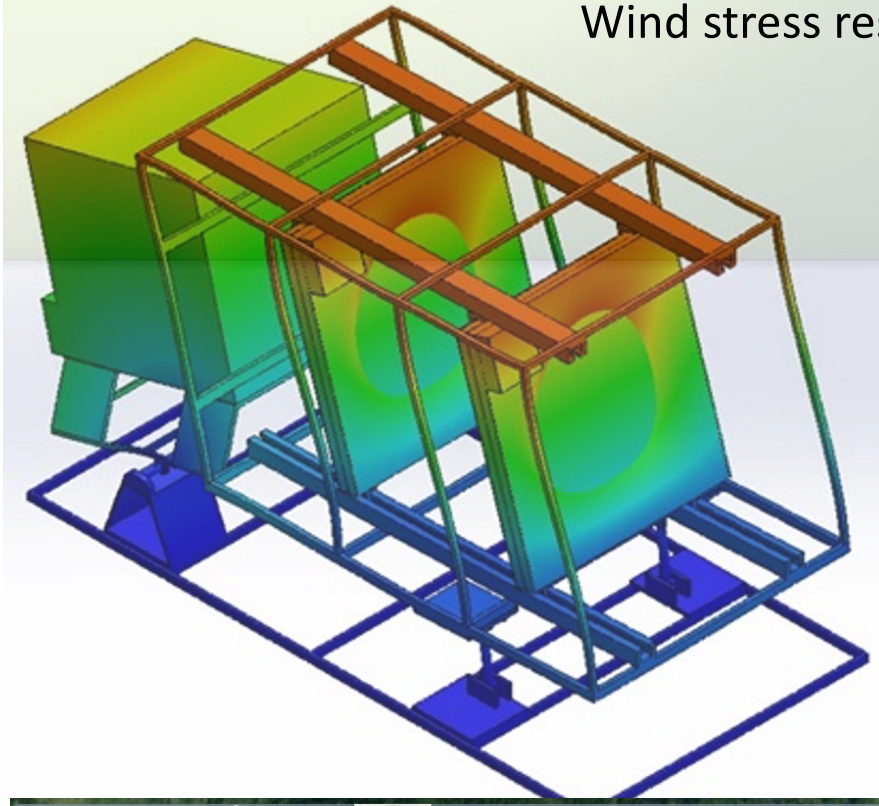


Chichonal or Chichón (Mx)
The most deadly eruption of the century (1982)



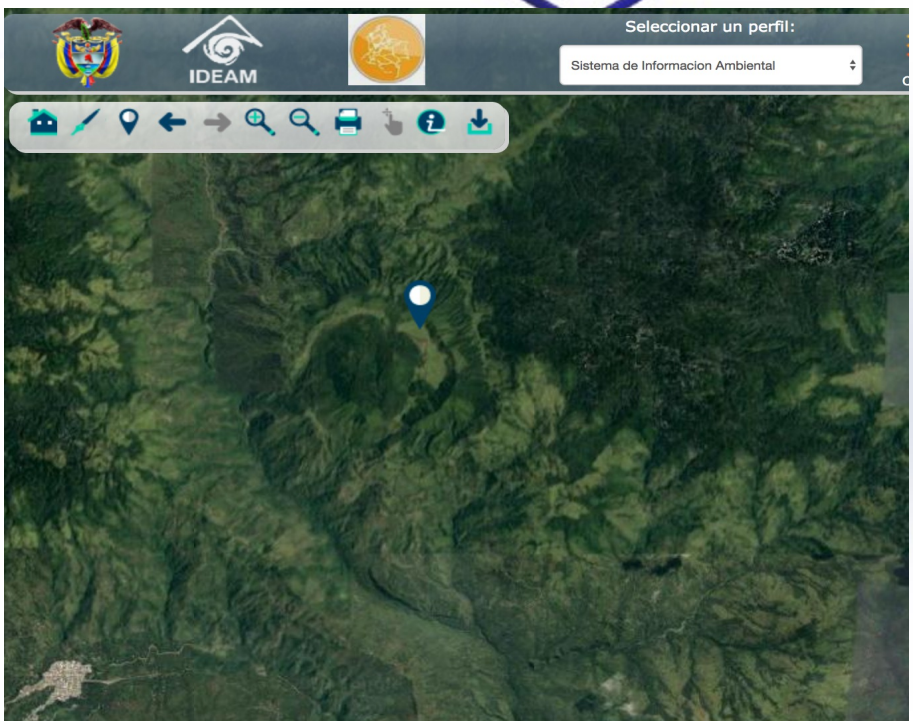
Cosmic Ray Flux →Heliosphere Modulated Flux → Magnetosphere →
$\cdots \rightarrow$ Primaries →Atmosphere Secondaries → Detector response → Signals

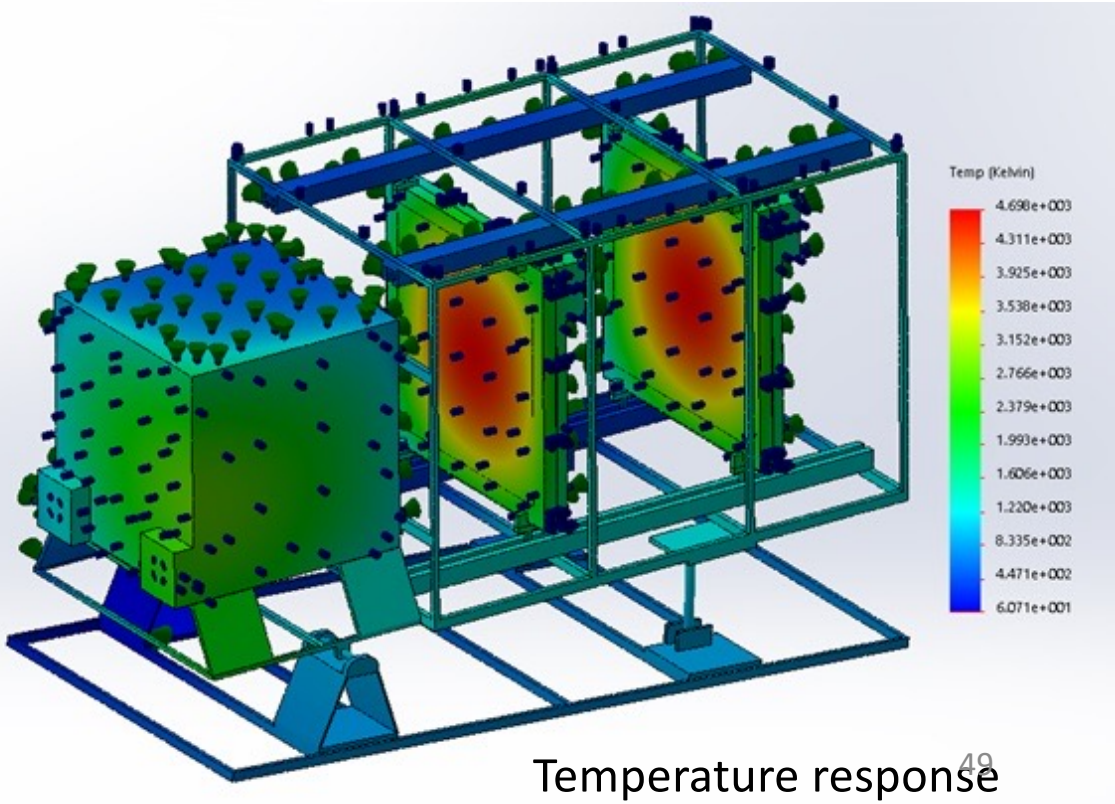
Wind stress response



Instrument response To climate variables

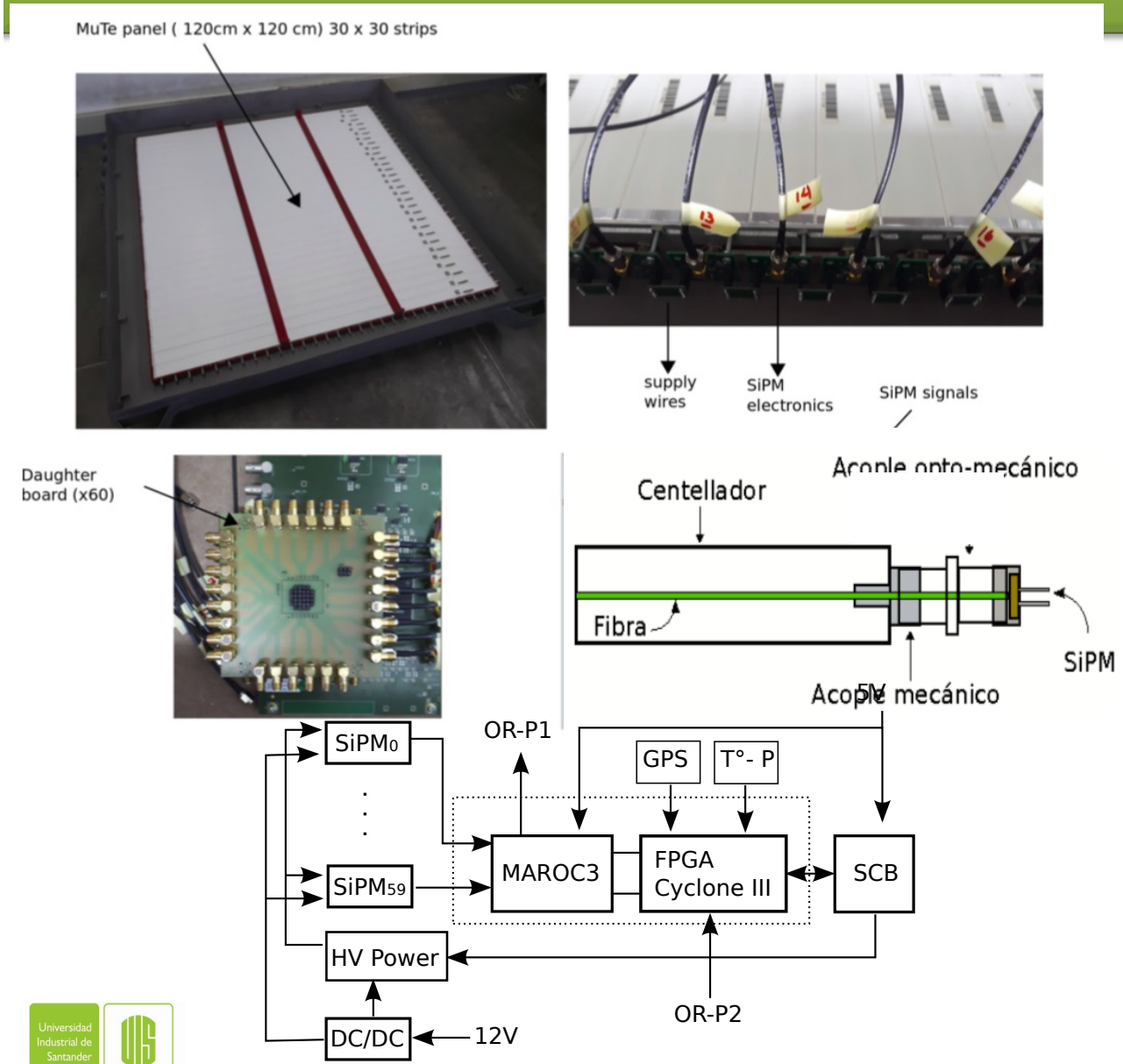
Peña-Rodríguez, J., et al. (2020). **Design and construction of MuTe: a hybrid Muon Telescope to study Colombian Volcanoes**. Journal of Instrumentation 15 (09), P09006.

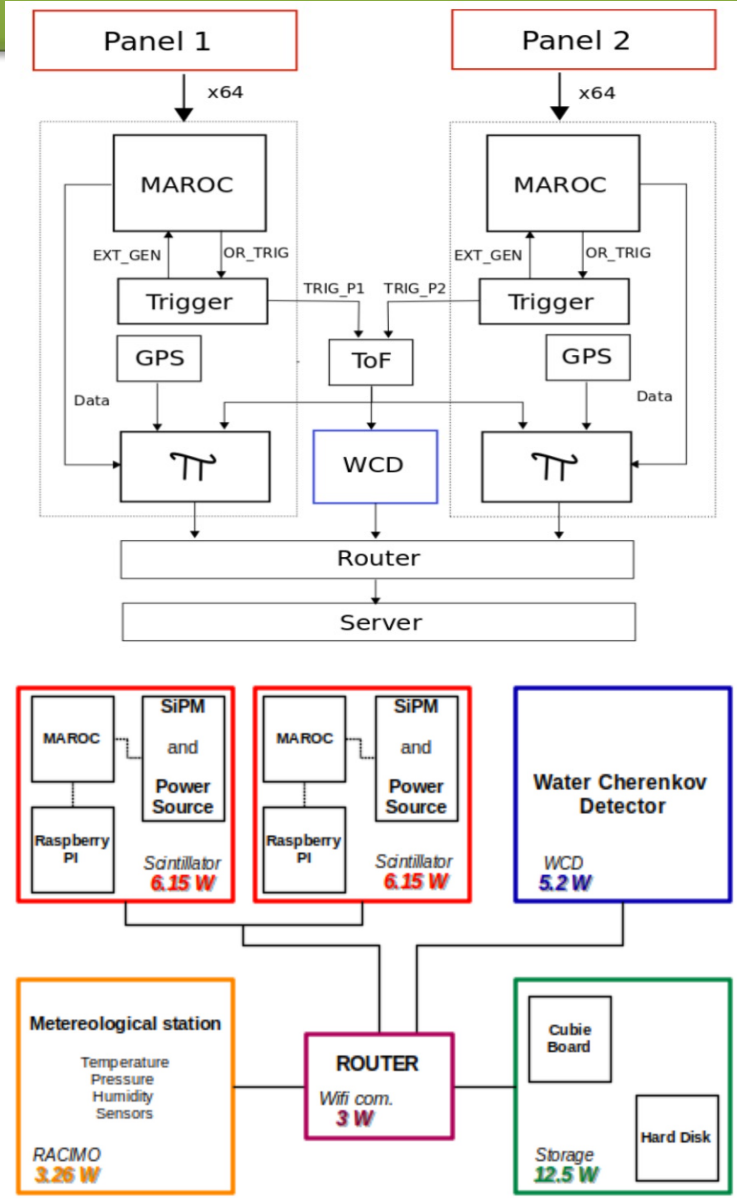




Temperature response

MuTe electronics





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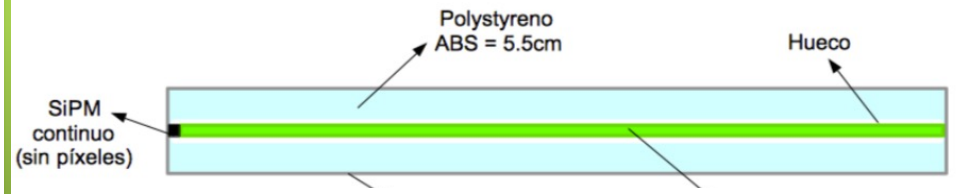
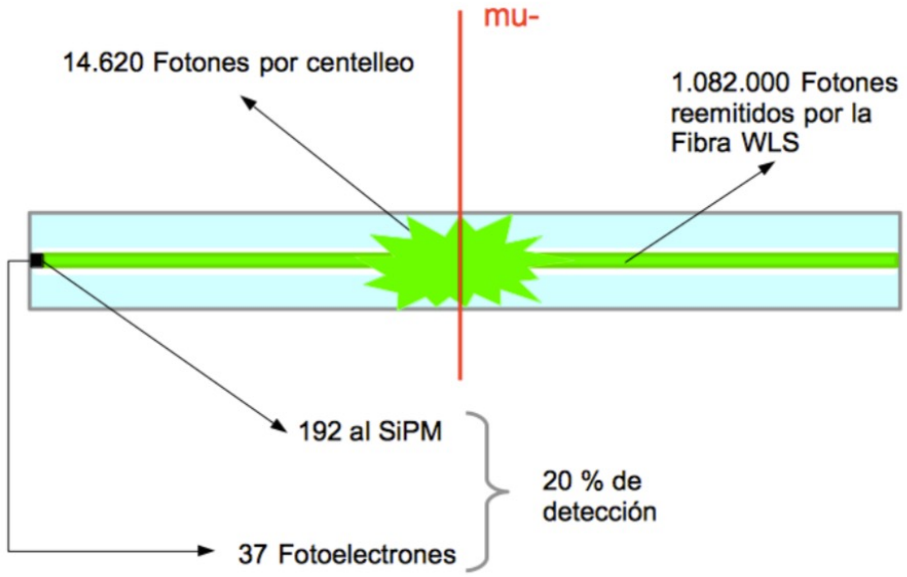
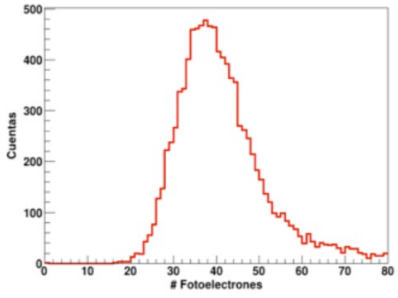
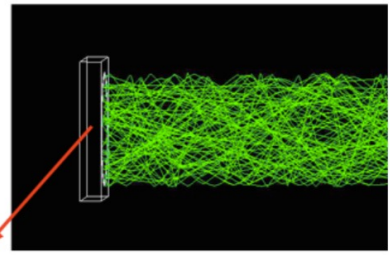
Peña-Rodríguez, J., Pisco-Guabave, J., Sierra-Porta, D., Suárez-Durán, M., Arenas-Flórez, M., Pérez-Archila, L. M., ... & Núñez, L. A. (2020). Design and construction of MuTe: a hybrid Muon Telescope to study Colombian Volcanoes. *arXiv preprint arXiv:2004.09364*.

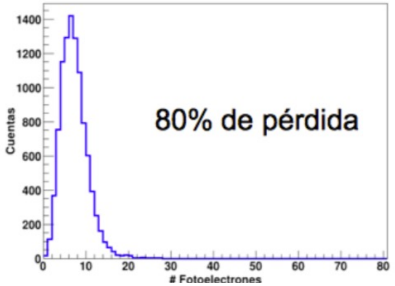


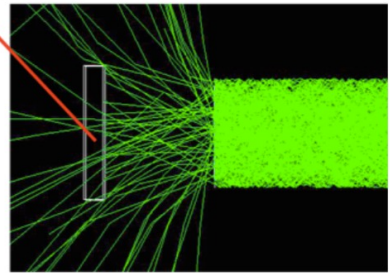




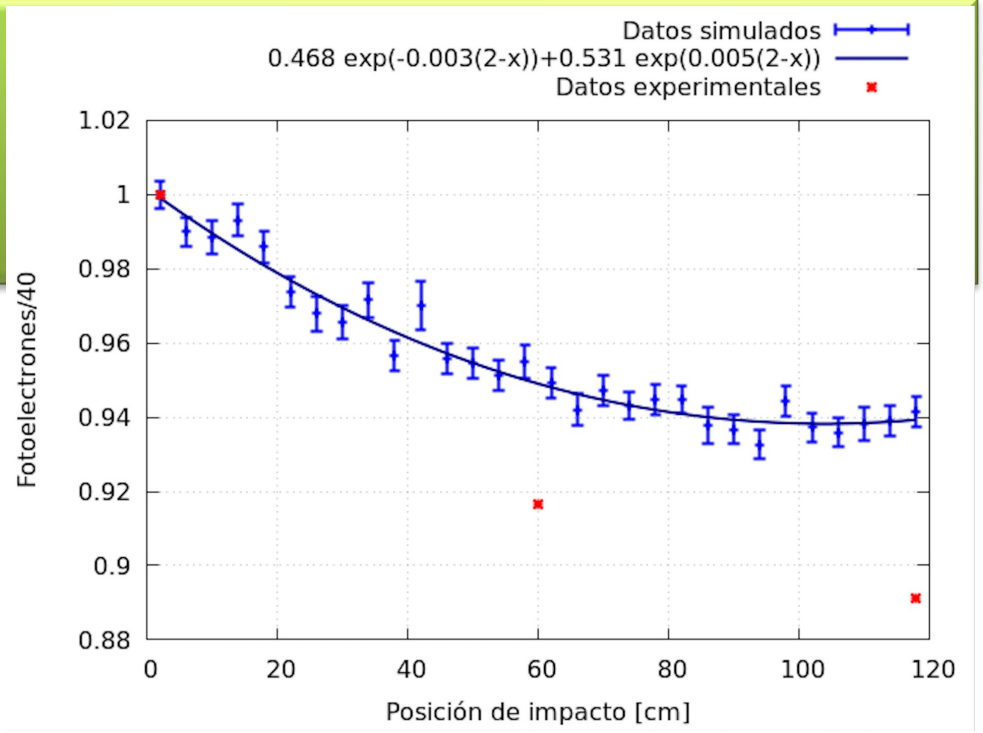


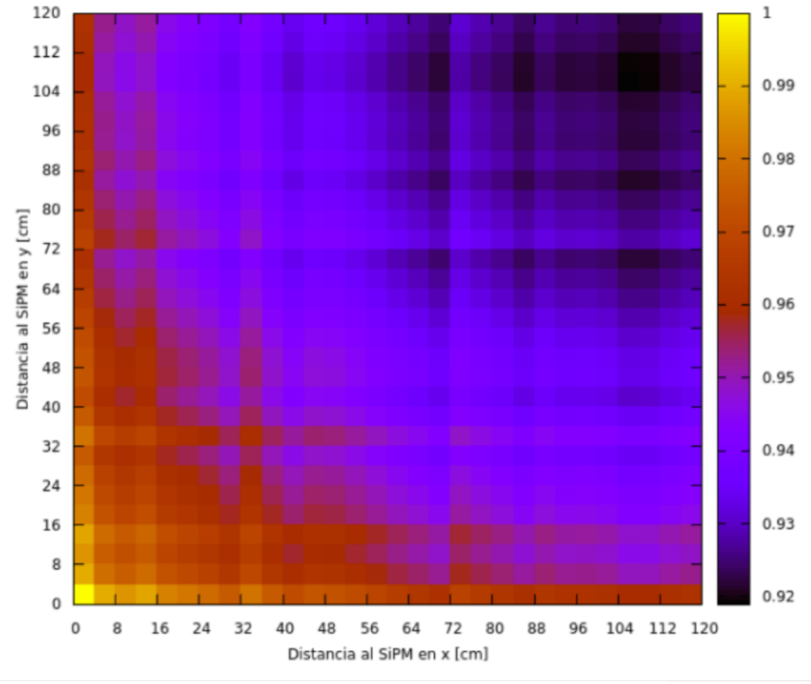
SiPM





Geant4 Simulations

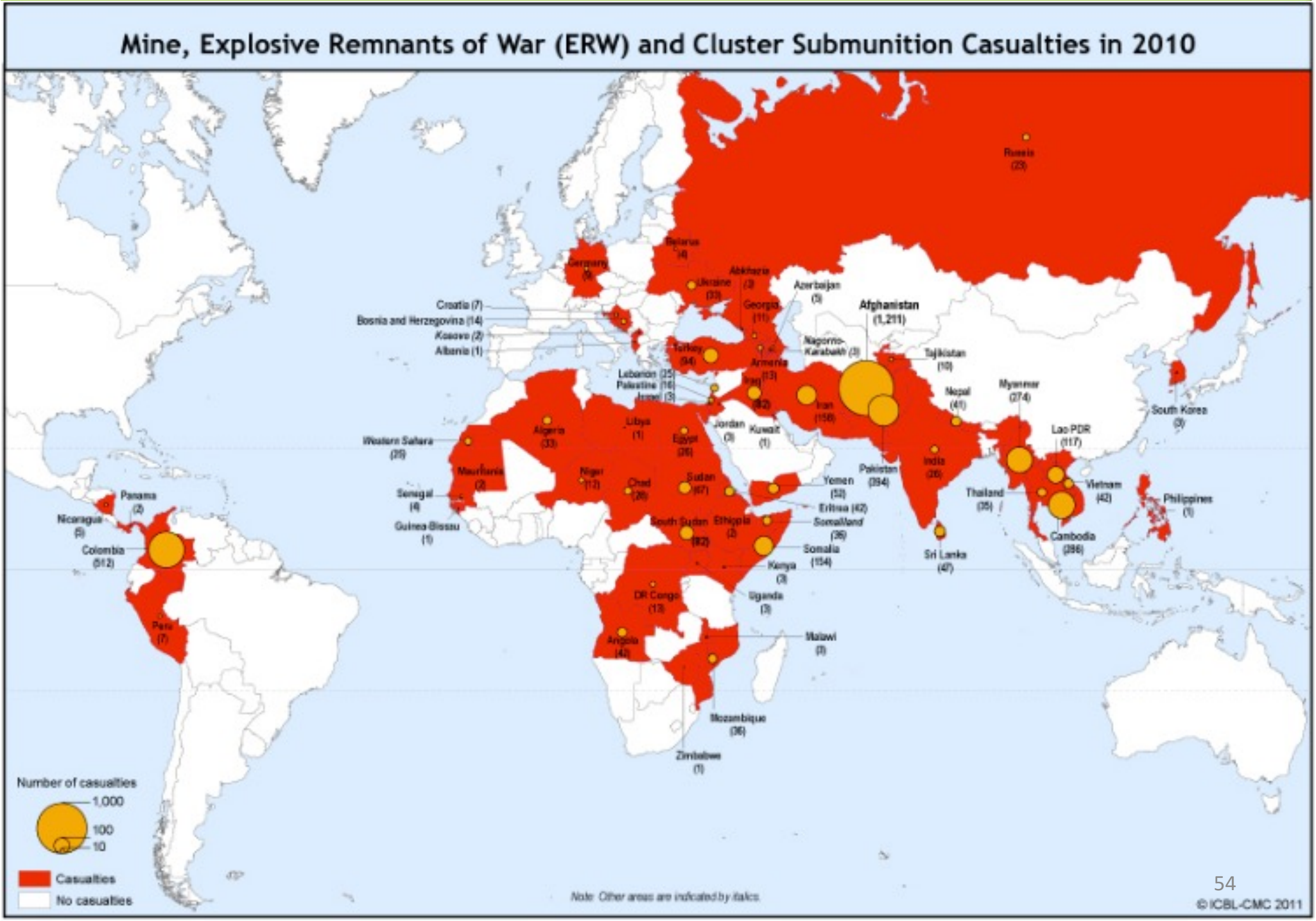




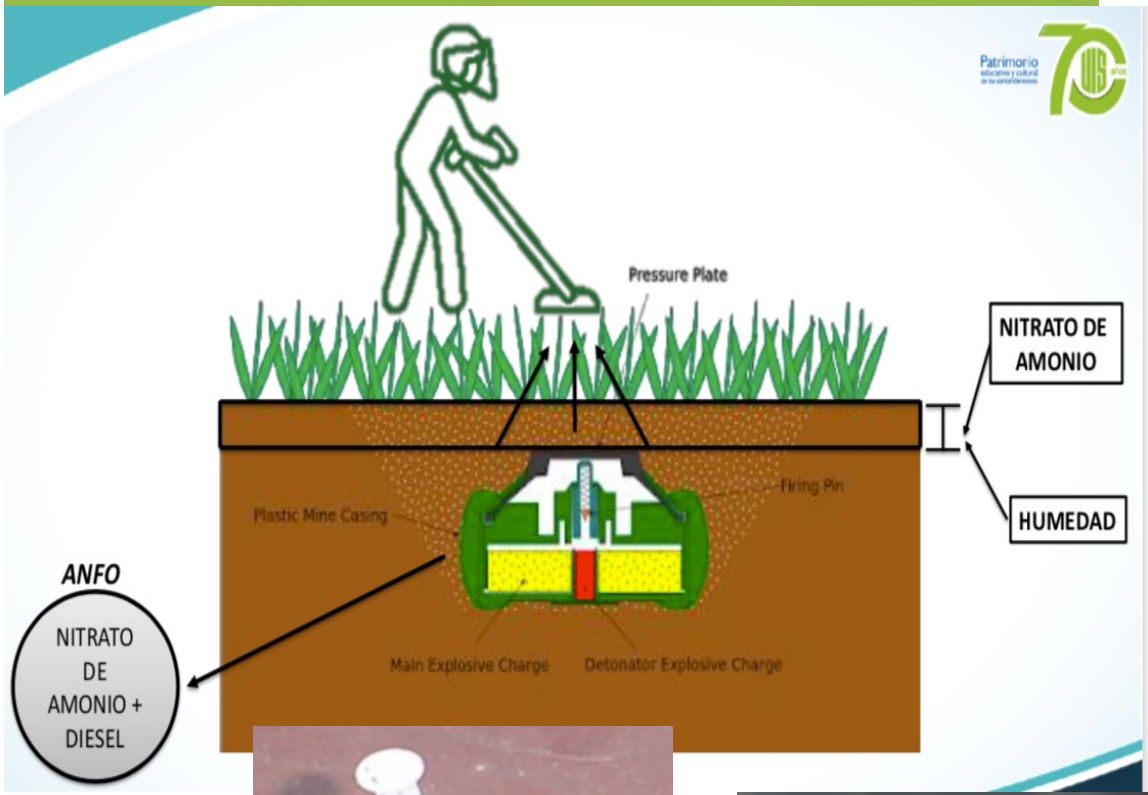
Vásquez-Ramírez, A., Suárez-Durán, M., Jaimes-Motta, A., Calderón-Ardila, R., Peña-Rodríguez, J., Sánchez-Villafrades, J., ... & Núñez, L. A. (2019). Simulated Response of MuTe, a Hybrid Muon Telescope. Journal of Instrumentation 15 (08), P08004.

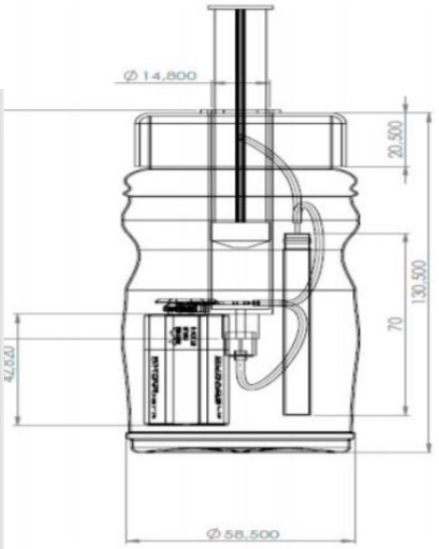
Acto Tercero

DE EXPLOSIVOS Y OTROS DEMONIOS


Mine, Explosive Remnants of War (ERW) and Cluster Submunition Casualties in 2010
Russia (23)
Belarus (4)
Germany (9)
Ukraine (33)
Abkhazia (3)
Azerbaijan (5)
Georgia (11)
Afghanistan (1,211)
Croatia (7)
Bosnia and Herzegovina (14)
Kosovo (2)
Albania (1)
Turkey (34)
Nagorno-Karabakh (3)
Tajikistan (10)
Armenia (13)
Lebanon (25)
Palestine (16)
Israel (3)
Iraq (82)
Iran (158)
Nepal (41)
Myanmar (274)
South Korea (3)
Jordan (3)
Kuwait (1)
Libya (1)
Egypt (26)
Algeria (33)
Western Sahara (26)
Mauritania (2)
Niger (13)
Chad (26)
Sudan (67)
Senegal (4)
Guinea Bissau (1)
South Sudan (82)
Ethiopia (2)
Yemen (52)
Eritrea (42)
Somaliland (36)
Somalia (154)
Kenya (3)
Uganda (3)
DR Congo (13)
Angola (42)
Malawi (3)
Mozambique (36)
Zimbabwe (1)
Pakistan (394)
India (26)
Sri Lanka (47)
Thailand (35)
Lao PDR (117)
Vietnam (42)
Cambodia (286)
Philippines (1)
Panama (2)
Nicaragua (5)
Colombia (512)
Peru (7)
Number of casualties
1,000
100
10
Casualties
No casualties
Note: Other areas are indicated by italics.
© ICBL-CMC 2011

Geometría IED





Fabricación:

Autodenominado Farc y Eln.

Información general :

- Contenedor plástico
- 58.50 mm de ancho, 130.50 mm de alto
- 450 g de peso aproximado.
- Espoleta que emplea una jeringa
- Rojo o pintado color verde oliva.
- Detonador Eléctrico

Activación:

- Presión: 5 kg Aproximadamente

. E. Posconflicto, "TIPOS DE MINAS ANTIPERSONAL EN COLOMBIA," 2011.

Predator: "If it bleeds, we can kill it" Quote Off Extravaganza!

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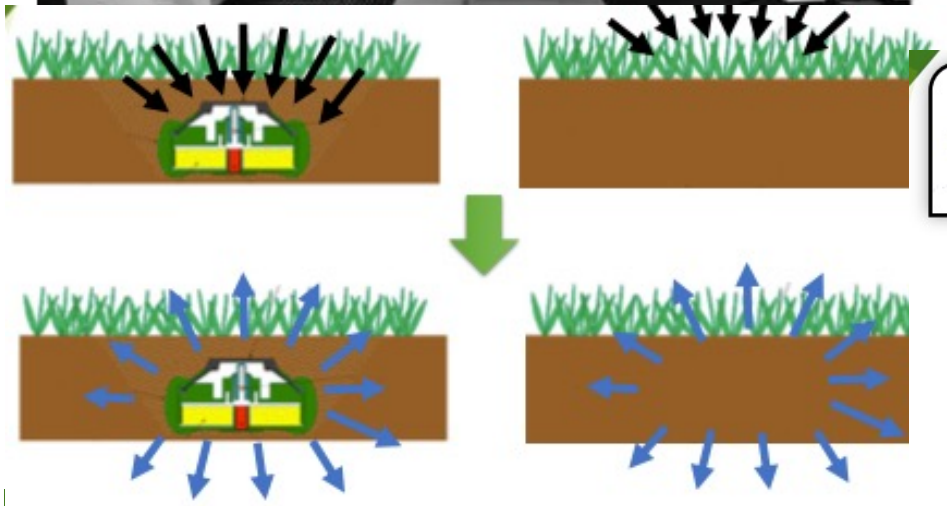
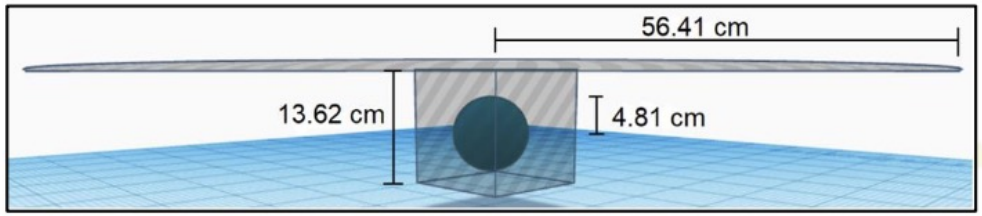
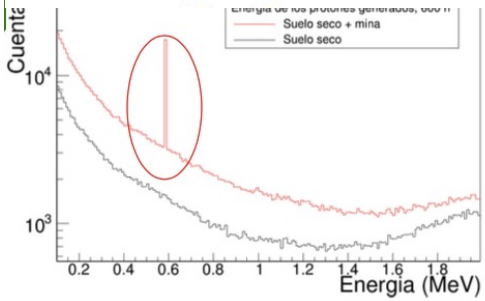
It bleeds

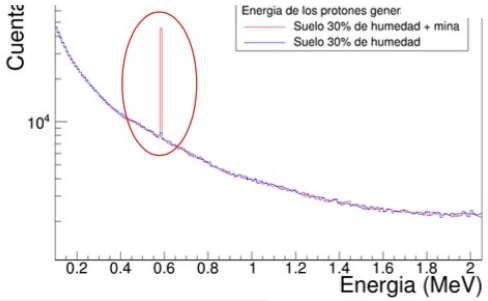


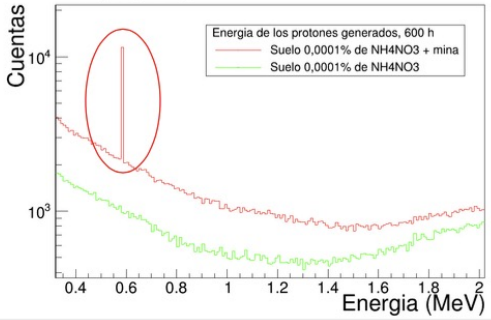
Tomado de: https://geant4.web.cern.ch/

Variables introducidas:
- Elementos químicos
- Fracción porcentual
- Densidad
- Dimensiones de la geometría
- Tipo de partículas
- Cantidad y energía de partículas
- Paquete de física

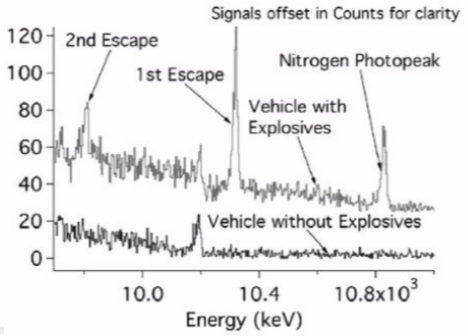


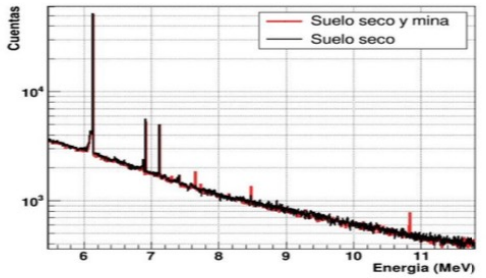


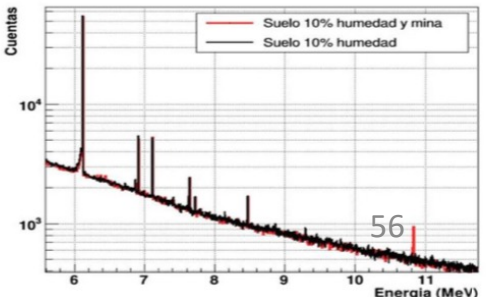




COMPARACIÓN



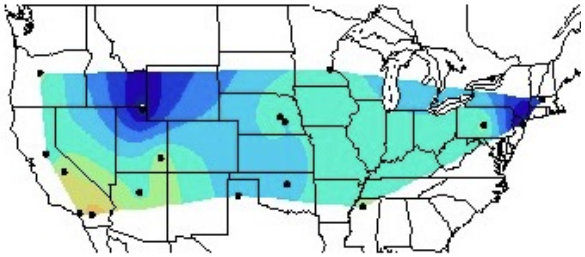


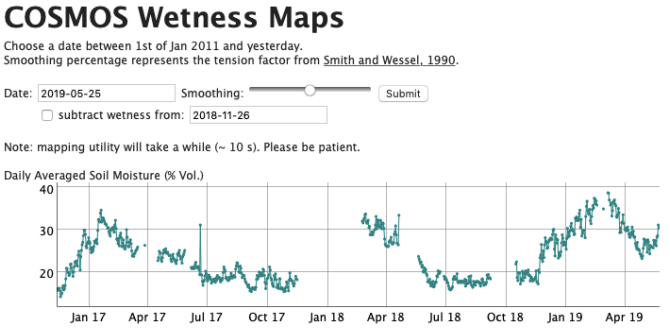


Vásquez-Ramírez, A. et al (2021).PoS(ICRC2021) 480.

COSMOS

Cosmic-ray Soil Moisture Observing System





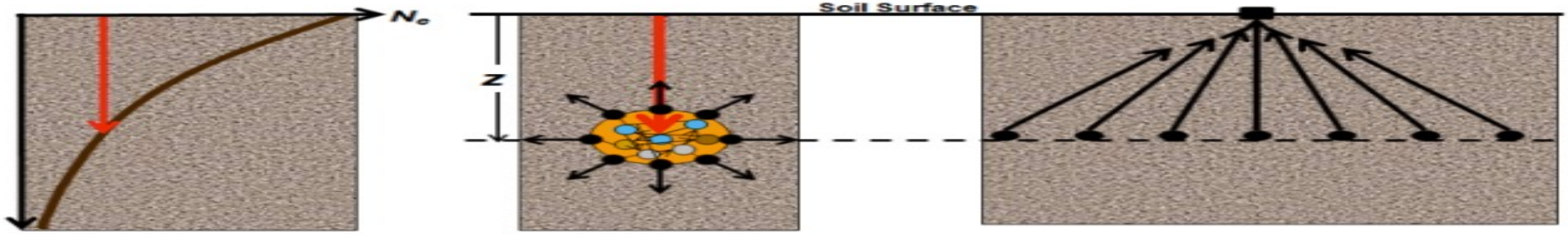
COSMOS probes measure soil moisture at the horizontal scale of hectometers and depths of decimeters using cosmogenic neutrons.

COsmic-ray Soil Moisture Interaction Code (COSMIC)

Date: August 2013

The COsmic-ray Soil Moisture Interaction Code (COSMIC) is a simple, physically based and analytic model used for data assimilation applications of cosmic-ray soil moisture sensors. The model includes simple descriptions of (a) degradation of the incoming high-energy neutron flux with soil depth, (b) creation of fast neutrons at each depth in the soil, and (c) scattering of the resulting fast neutrons before they reach the soil surface, all of which processes may have parameterized dependency on the chemistry and moisture content of the soil (see below).

The three physical processes represented in the COSMIC that control the above ground fast neutron count rate.



(a) Exponential reduction in the number of high energy neutrons with depth

(b) Isotropic creation of fast neutrons from high energy neutrons at level *z*

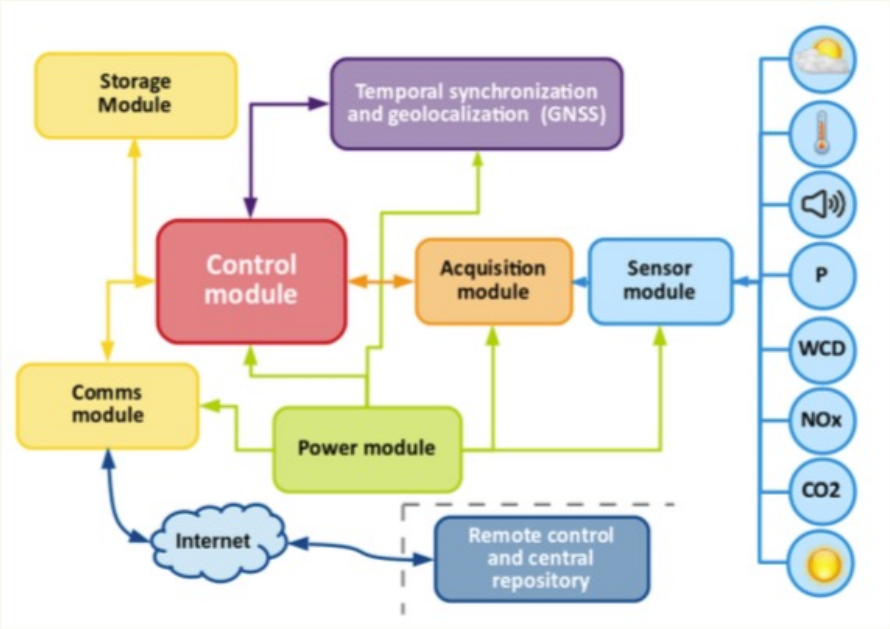
(c) Reduction in the number of fast neutrons created in the plane at level *z* before their surface measurement

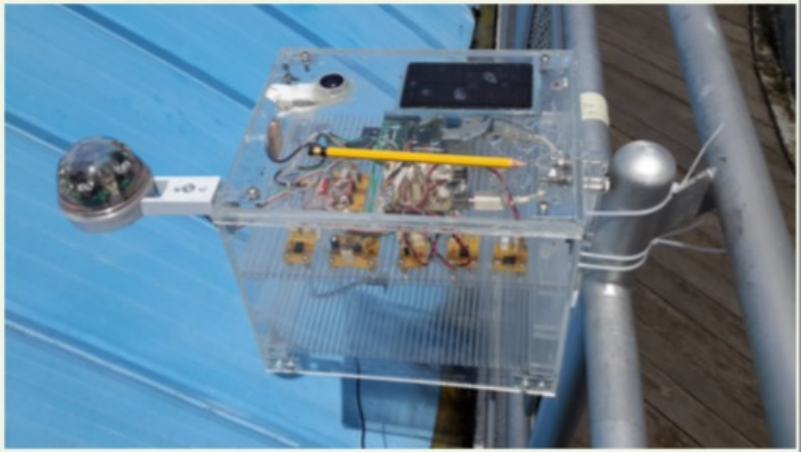
high energy neutrons → fast neutrons

Rayos Cósmicos y agricultura de precisión

Our new station: the smart LAGO-WCD

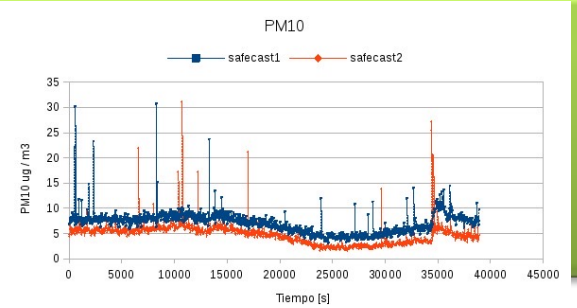
RACIMO: Red Ambiental Cludadana de MOnitoreo

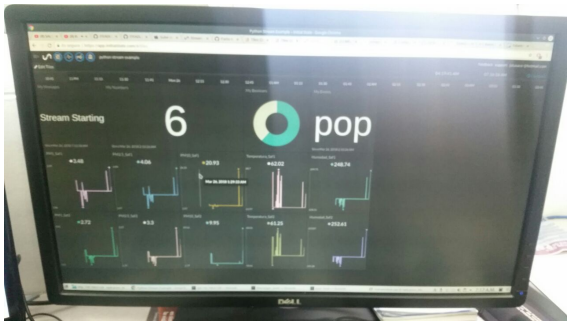


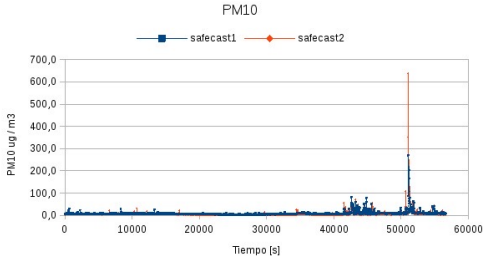


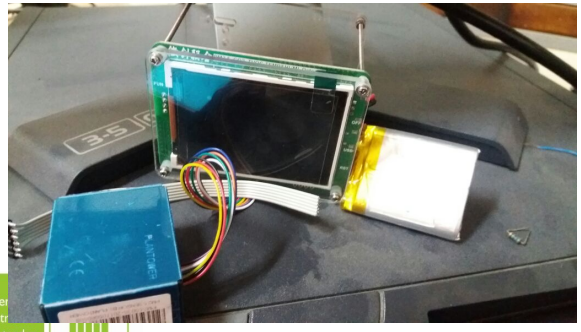
Control and Acquistion Station → Environment (including WCD)

- Sensors: Arduino-One&shield + environmental sensors (P, T, CO_2, NO_x, radiance, illuminance, noise)
- Control (SBC Raspberry Pi): data conformation, pre-processing and station control
- Power: 15 W solar panel and batteries
- GNSS: geo-localization and time synchronization
- Comms: support standard protocols: WiFi, GPRS (2.5G-3G-3.5G), 4G-LTE









RA
Ci
Mo

Red Ambiental Ciudadana de Monitoreo

MPSIG

Alcaldía Municipal de Floridablanca

MUNICIPIO DE BUCARAMANGA

ÁREA METROPOLITANA DE BUCARAMANGA
BUCARAMANGA - FLORIDABLANCA - GIRÓN - PIEDECUESTA

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Citizen science particle pollution monitoring network

RACIMO evolution at glance ~6years City/Rural

Funding & strategic alliances

2014
RACIMO

5 secondary schools Bucaramanga
Impacting **48 students 9 teachers**

2018
RACIMO-Air

8 secondary schools Metro-Bucaramanga
Impacting **83 students 12 teachers**

2019 EVA
MakeSense

2020
AstroPáramo

3 secondary rural schools
Impacting **21 students 3 teachers**

2021
AstroAndes

Rising awareness Open Science
Empowering Citizen gathering and understanding environmental data

2018 AstroParamo

We use Astrobiology and Climate Change Physics to convince ourselves that the Earth is a very special world in our Galaxy that we must preserve.

https://halley.uis.edu.co/astroparamo/

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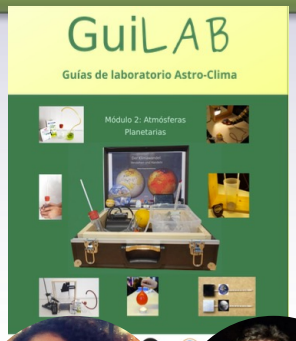
2020 Astropáramo



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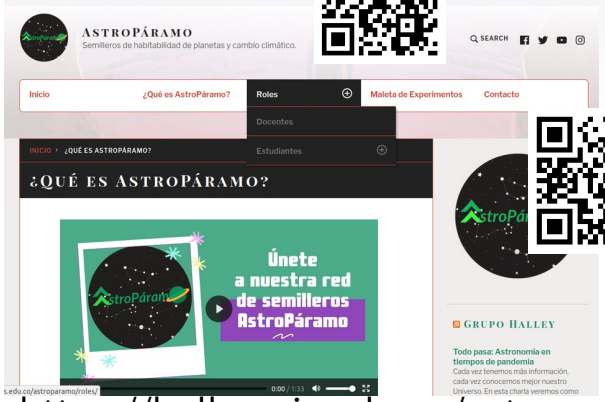
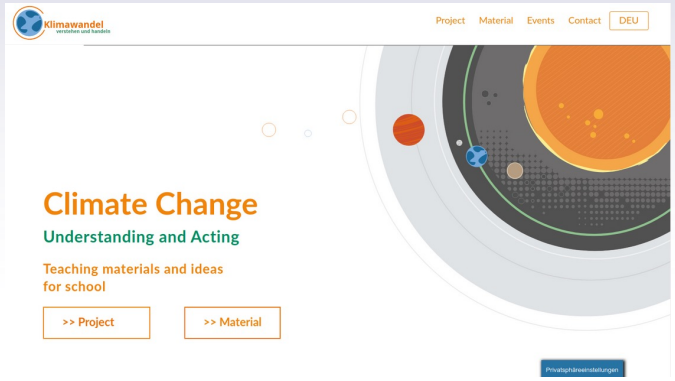
Open Accesss Open Data

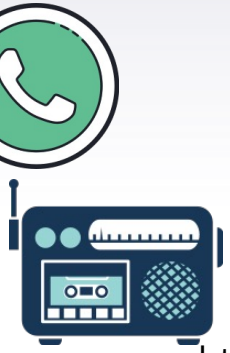
WEB



https://hallev.uis.edu.co/astroparamo

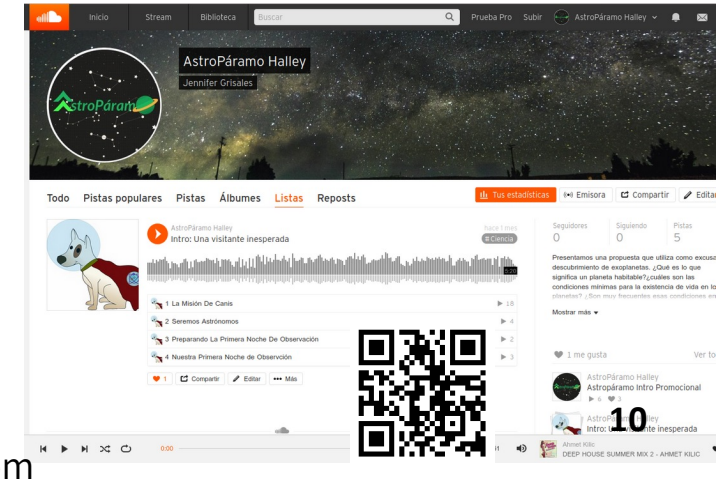
https://klimawandel-schule.de/

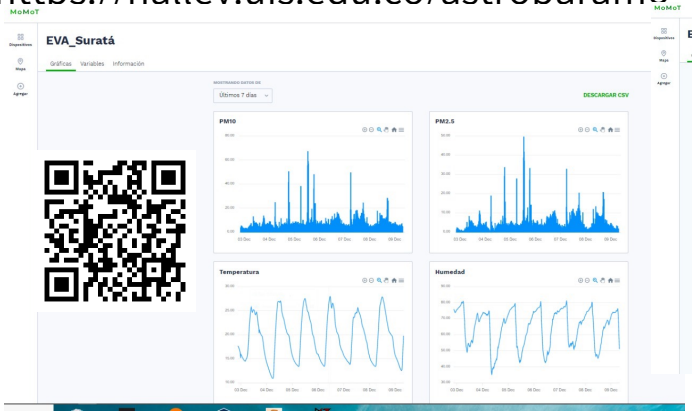


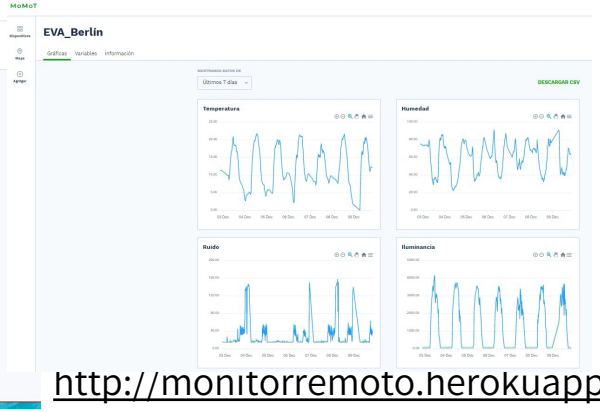


https://soundcloud.com/astro-paramo-358723547

PODCAST







http://monitorremoto.herokuapp.com

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LET IT BE


Rayo cósmico
Núcleo atmosférico
Componente electromagnética
Componente hadrónica
Componente muónica
Neutrinos
That's all Folks!

Gracias