

Astroparticle initiatives @Eastern Colombia

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Universidad Industrial de Santander
Bucaramanga



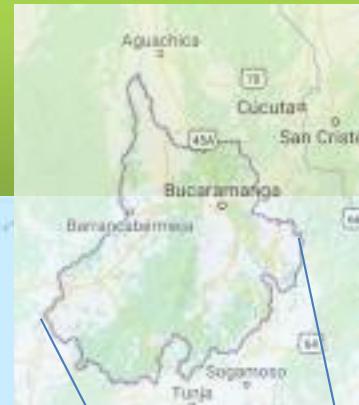
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Agenda

- Astroparticle/Air-showers in a nutshell
- LAGO: Latino American Giant Observatory
- Aerodosis: Cosmic Rays on aircraft
- MuTe: Muon Telescope for Colombian Volcanoes
- CosmoGeophysics @Pierre Auger Observatory
- PAS: Polo de Astronomía Social
- RACIMO: Red Ambiental Ciudadana de Monitoreo (Citizen Science Environmental Monitoring Network)

Capacity building

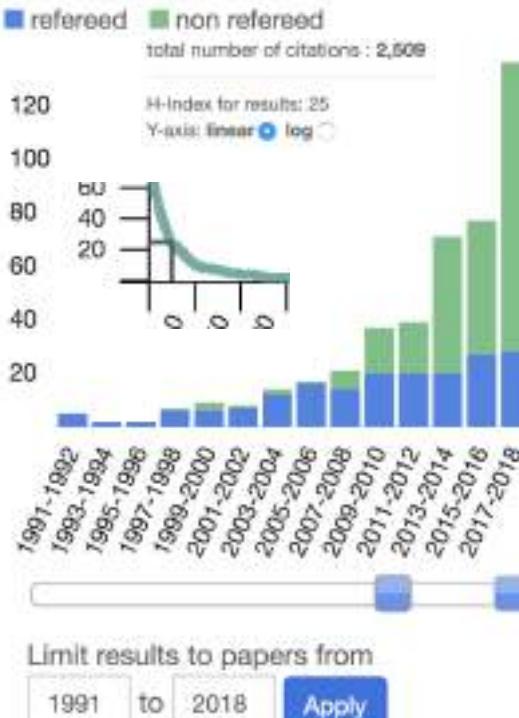
@Eastern Colombia



Ubicación de Santander en Colombia

UIS Faculty:
500 full time
500 part time equivalent

Academic programs:
43 undergraduate
113 graduate
48 master
10 PhD.



Limit results to papers from
1991 to 2018

Universidad Industrial de Santander



| | |
|-------------|---|
| Other name | UIS |
| Motto | Construimos Futuro ^[1] "Making our future" |
| Type | Public |
| Established | 1948 |
| Rector | Hernán Porras Díaz |
| Students | 22000 approx. (2010) |
| Location | Bucaramanga, Santander, Colombia |
| Campus | CUP 337,000 m ² (83 acres) Faculty of Health 9,500 m ² (2.3 acres) Bucarica Building Urban |
| Colors | Green and White |
| Website | www.uis.edu.co |



UIS:
No HEP or
Astroparticle
tradition
Still low impact
But we are working

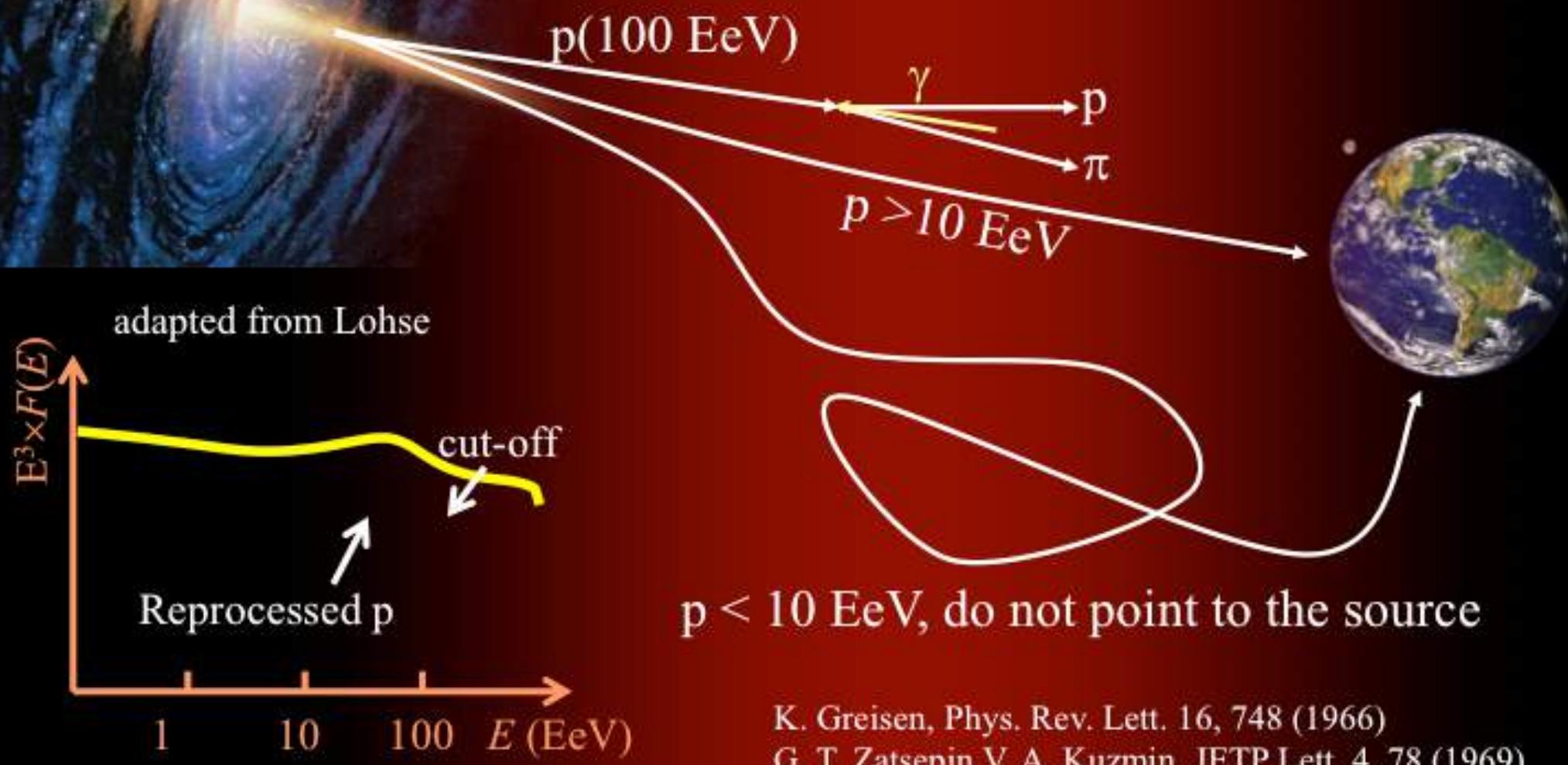
Astroparticles



The results of my observations are best explained by the assumption that a radiation of very great penetrating power enters our atmosphere from above.

- Victor Hess
Physikalische Zeitschrift (1912)

Greisen-Zatsepin-Kuzmin limit
Universe becomes opaque above the threshold for producing a π on CMB
 $p(100 \text{ EeV}) + \gamma(\text{CMB}) \rightarrow p + \pi, n + \pi$



K. Greisen, Phys. Rev. Lett. 16, 748 (1966)
G. T. Zatsepin, V. A. Kuzmin, JETP Lett. 4, 78 (1969)

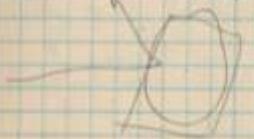
Fermi acceleration

Dec 4 1948

137

Theory of cosmic rays

a) Energy acquired in collisions against cosmic magnetic fields



Non relativistic case

MV^2

(M = mass of particle V = velocity of moving field)

(Proof) Head on collision gives energy gain

$$\frac{M}{2} (v + 2V)^2 - \frac{Mv^2}{2} = \frac{M}{2} (4vV + 4V^2) = M(2vV + 2V^2) \quad \text{Prob} = \frac{v+V}{2v}$$

Running after collision ($\text{prob} = \frac{v-V}{2v}$) gives energy gain
 $M(-2vV + 2V^2)$

Average gain order

MV^2

Relativistic order

$w\beta^2$

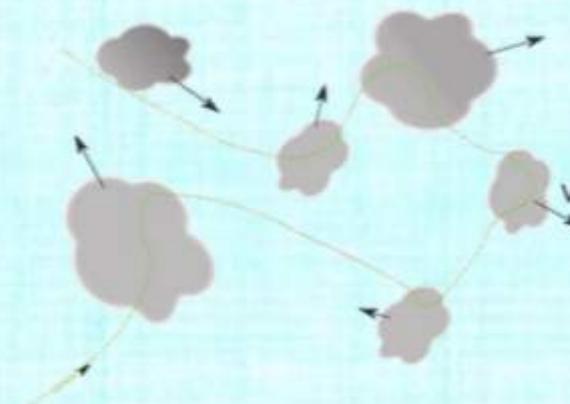
Published in E. Fermi Phys Rev 75 (1949) 1169

Charged particles are accelerated by collisions with “magnetic clouds”

Magnetic cloud = a region of several light years diameter of particle density higher than average containing irregular magnetic field

Head on collision accelerates, tail collision decelerates

The former is more likely because the probability is proportional to the relative velocity



Mechanism exists, but is not the most effective

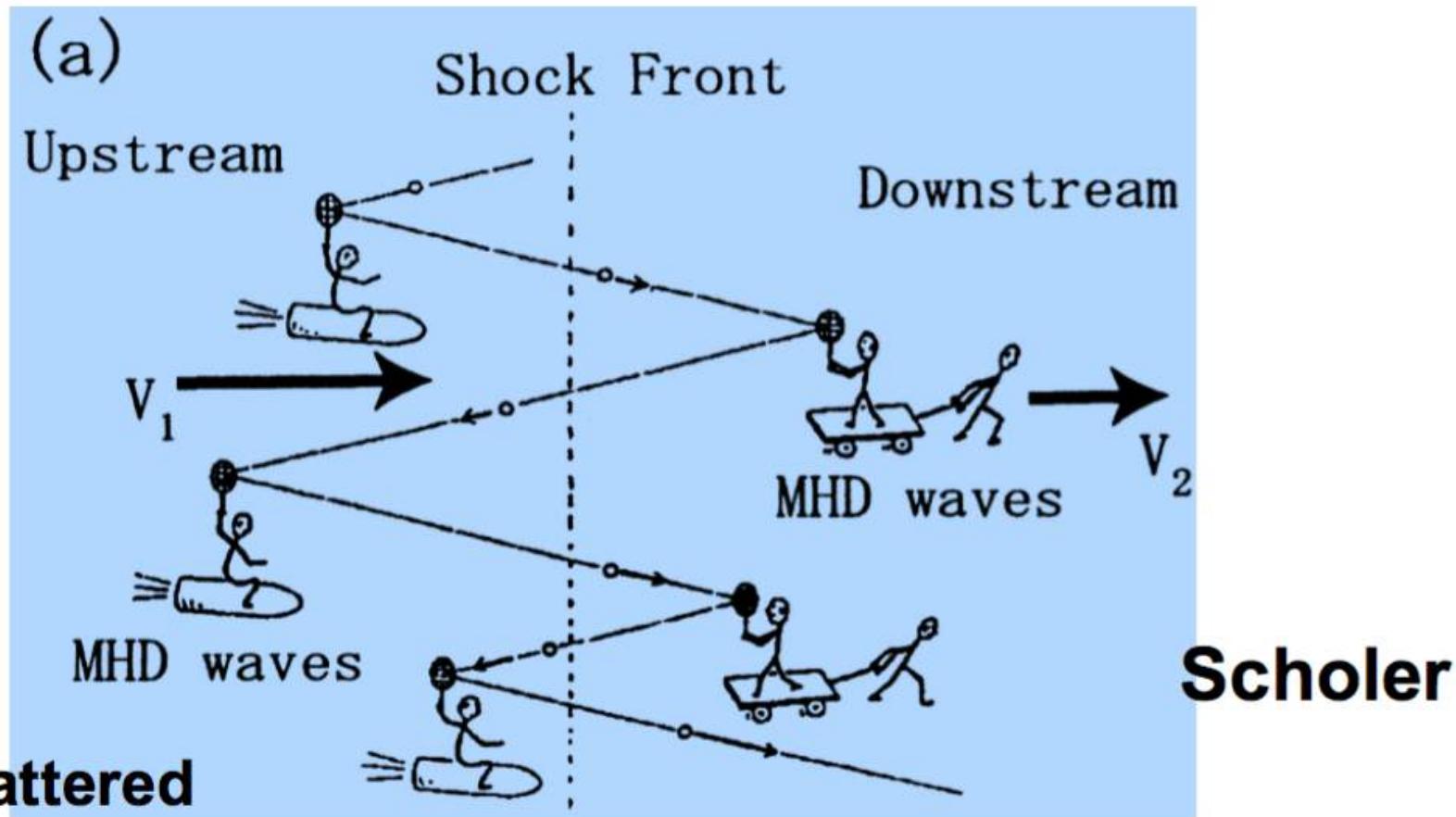
Fermi acceleration

The original model of Fermi is today known as **first order Fermi mechanism**



The **second order Fermi mechanism** was developed in 1977 by Krymsky in the URSS and Axford in the USA. It is similar, but much more effective. The accelerating object is the **expanding magnetic shock wave of a SN remnant**

Diffusive Shock Acceleration(DSA)

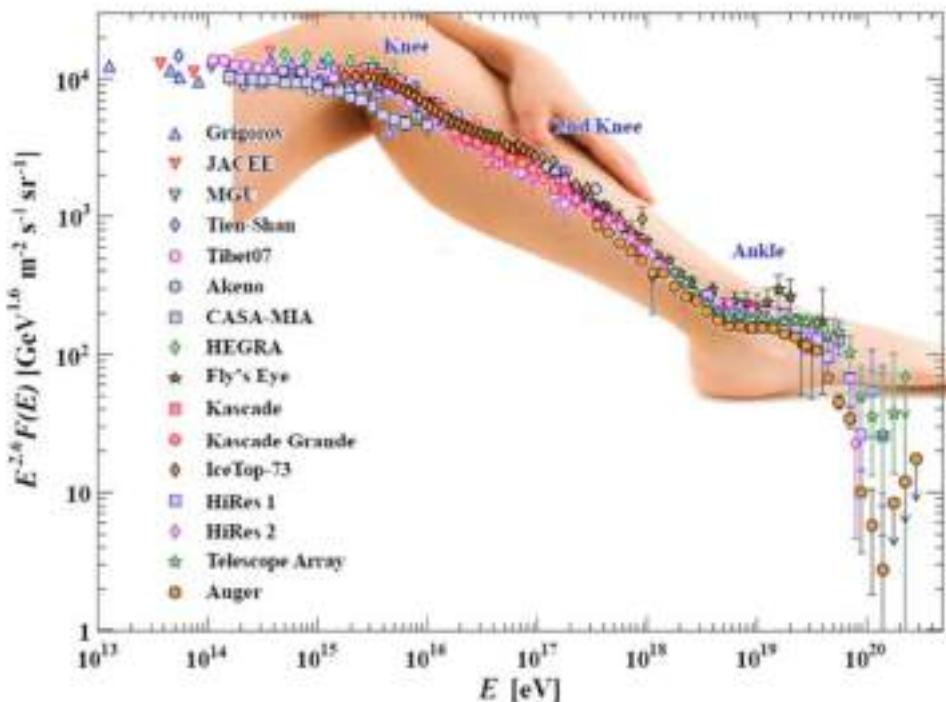


CRs are scattered
by MHD waves.

CRs excite
the MHD waves.

$$dN/dE \propto E^{-s} \quad s = \frac{u_1/u_2 + 2}{u_1/u_2 - 1} = 2$$

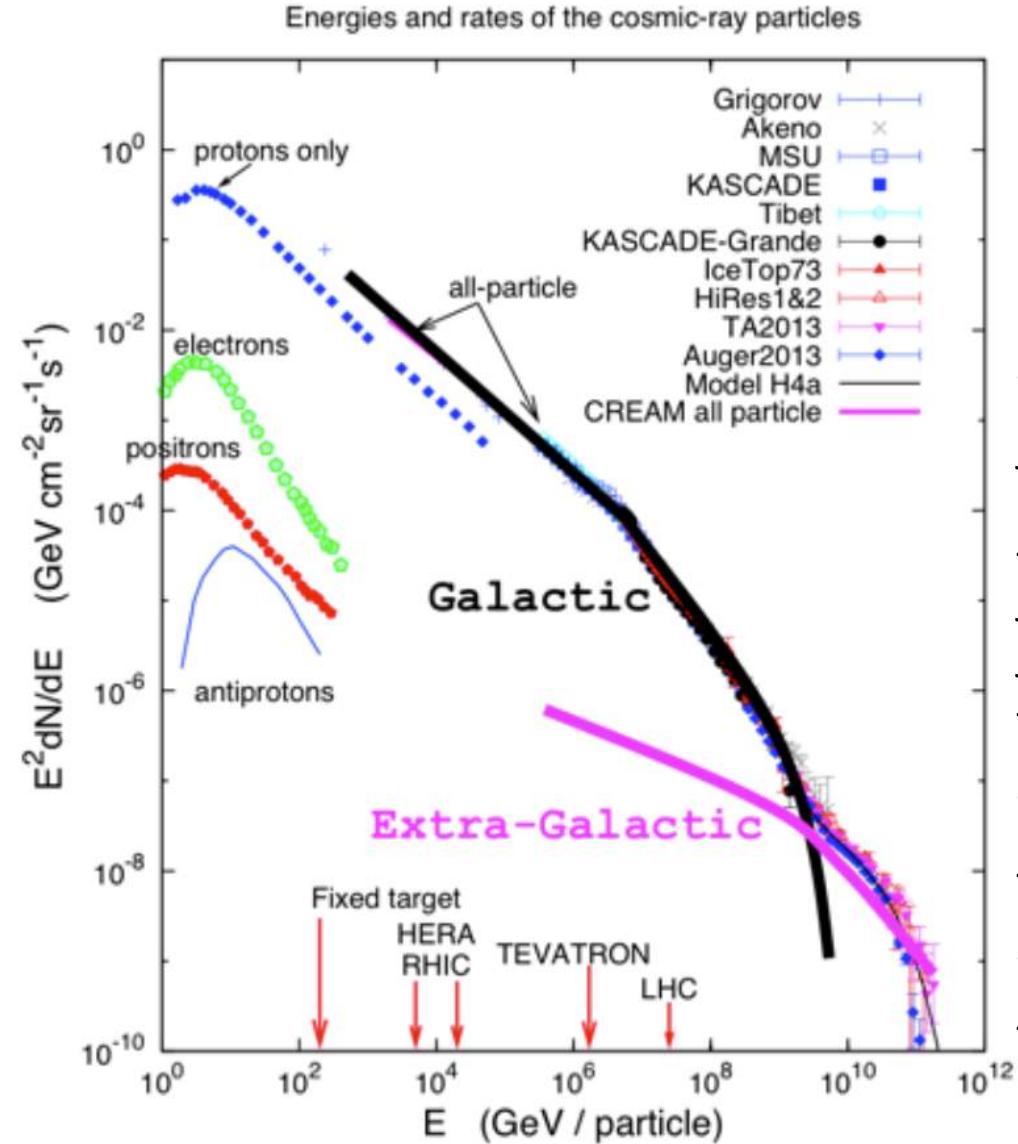
Axford 1977, Krymsky 1977, Blandford&Ostriker 1978, Bell 1978



- *) What is the composition in the knee region and how does it connect with direct measurements at lower energy?
- *) What is the cause of the hardening of the spectrum around 20 PeV?
- *) Where is the transition from Galactic to extra-galactic cosmic rays and how is it related to composition around the ankle?
- *) What is responsible for the apparent end of the spectrum around 100 EeV?



Gaisser, Thomas. "Challenges for cosmic-ray experiments." In *EPJ Web of Conferences*, vol. 145, p. 18003. EDP Sciences, 2017.



Cosmic Ray Spectrum

$$\left(\frac{dN}{dE_p} \right) \propto E_p^\alpha$$

Production

Acceleration and decay (K. Kotera et al, ARAA49:119(2011)53)

Acceleration: Fermi + diffusion

- First order: (SNR, $\beta_s \sim 0,03$):
 $\overline{\Delta E}/E \simeq \beta_s$

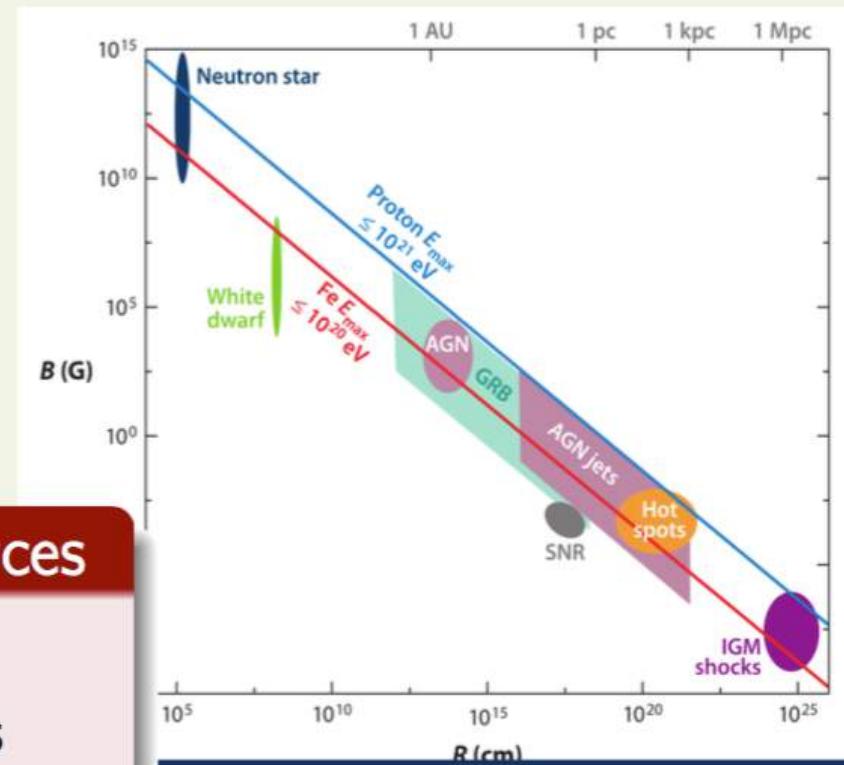
- Power law like spectrum:

$$\frac{dN}{dE_p} \propto E^\alpha \quad \alpha < -2$$

- Acceleration $E_{\text{mx}} \propto ZRB$

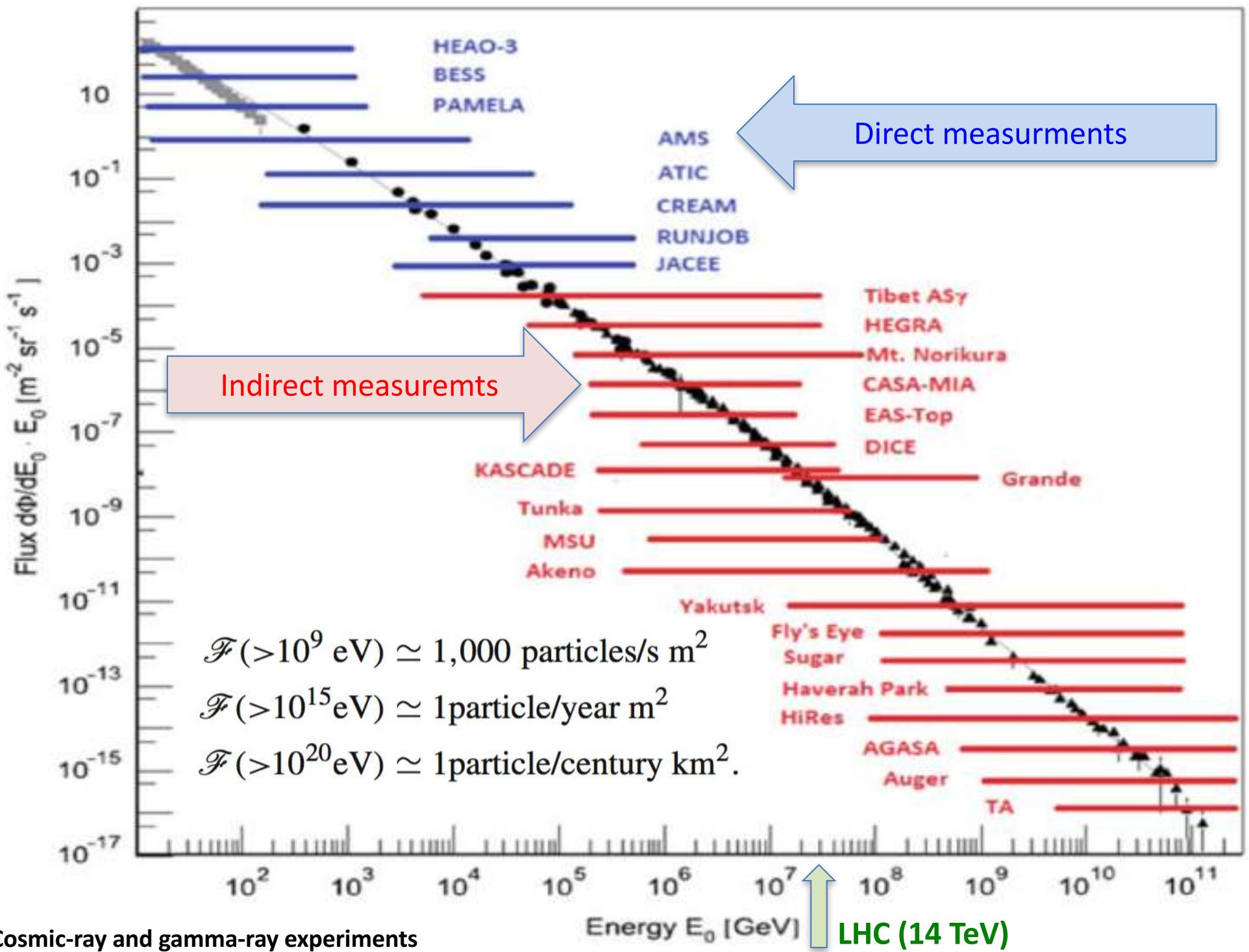
Possible sources

- AGN
- Magnetars
- GRBs



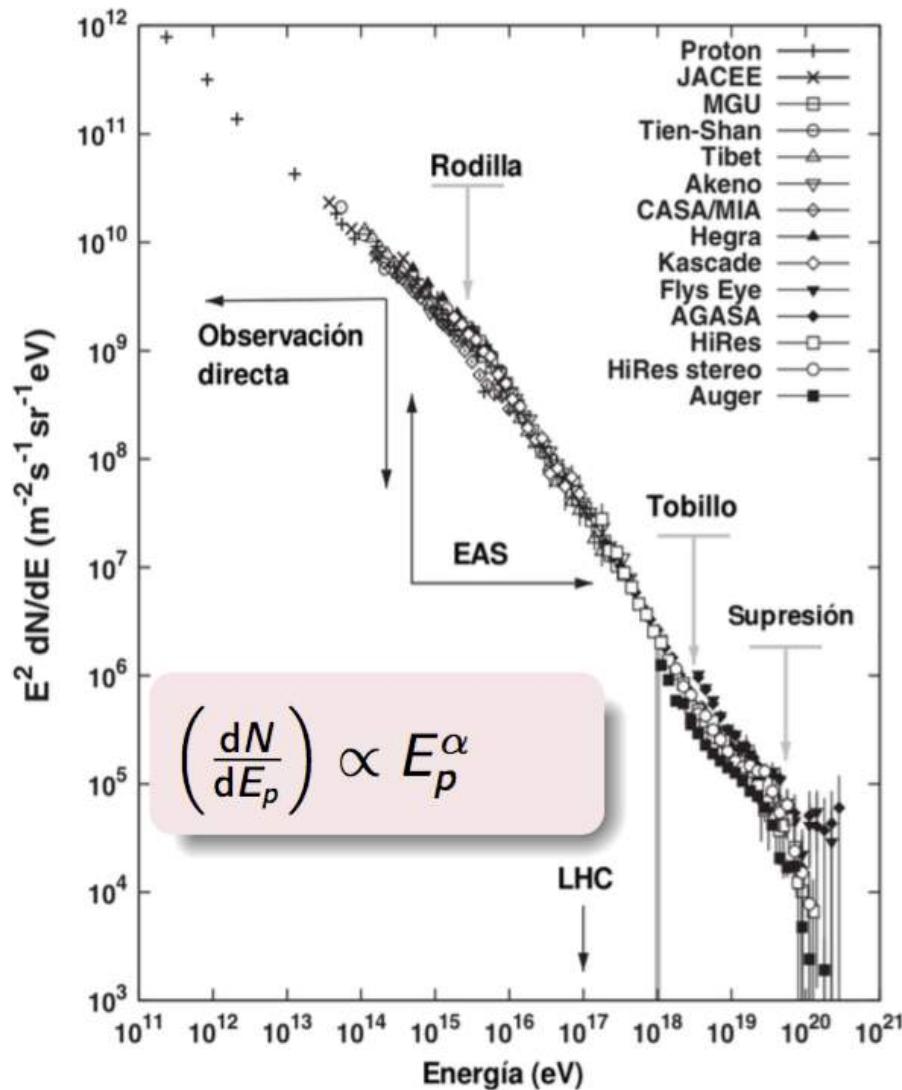
Decay

- Decay of supermassive particles X , $m_X \gtrsim 10^{21}$ eV
- All models predicts $n_\gamma \simeq n_\nu \gg n_{\text{nucleons}}$
- Predicted fluxes are inconsistent with UHECR observations of mass composition



Energy spectrum and composition

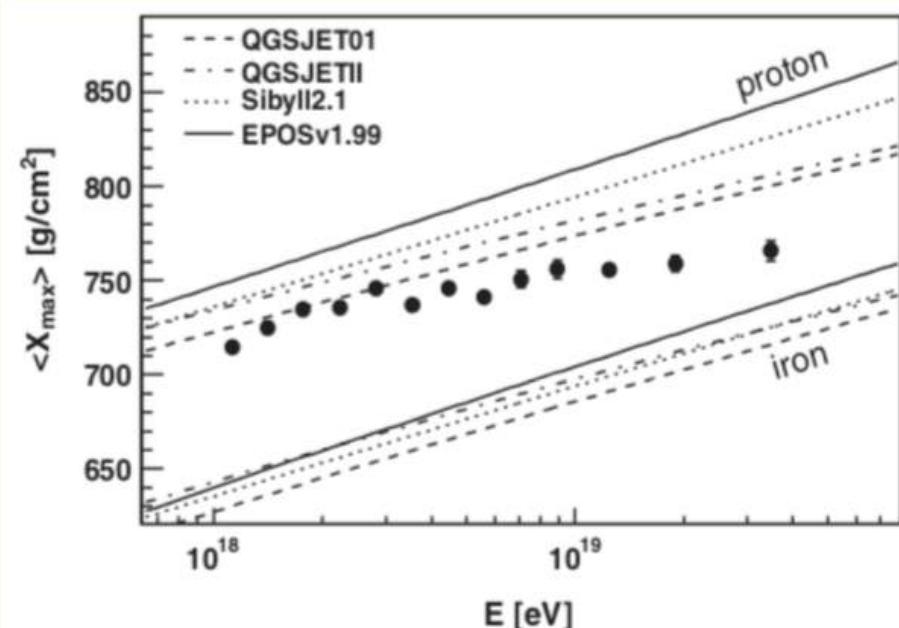
A. Letessier-Selvon & T. Stanev, Rev. Mod. Phys. 83:3(2011)907



Changes in α

- 1st knee: $10^{15.5}$ eV
- 2nd knee: $10^{16.9}$ eV $\rightarrow 10^{17.6}$ eV
- Ankle: $10^{18.6}$ eV
- Supression: $10^{19.4}$ eV

Composition



Changes in the slope α are linked to different physical phenomena

Air Showers

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

Extended Air Showers (EAS)

EAS Particle cascade that originates with the interaction of a CR with the atmosphere

- X Atmospheric depth (traversed mass)
- X_0 First interaction point
- N_{mx} Maximum number of particles in the shower: $N_{\text{mx}} \propto E_p$
- X_{mx} Maximum depth: $X_{\text{mx}} \propto \ln(E_p)$

EM

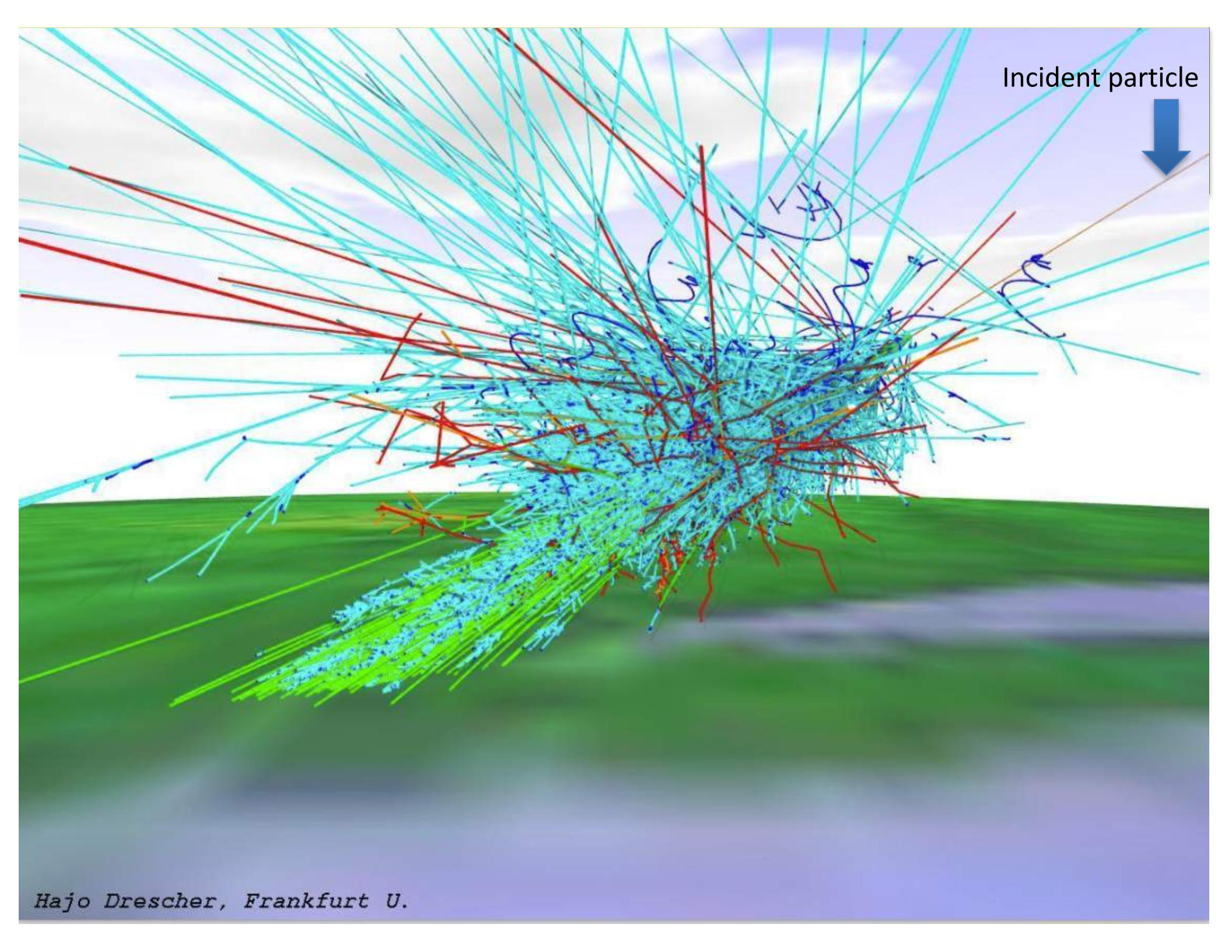
- Decay of π^0 : $\pi^0 \rightarrow \gamma\gamma$
 $\pi^0 \rightarrow \gamma e^+ e^-$
- Bethe-Heitler:
Bremsstrahlung:
 $e^\pm \xrightarrow{\frac{A}{Z}Y} e^\pm \gamma$
- Pair production:
 $\gamma \xrightarrow{\frac{A}{Z}Y} e^+ e^-$
- Dominates $N_{\text{mx}} \rightarrow X_{\text{mx}}$
- $E_{\text{EM}} = (80\% - 90\%)E_p$

Muonic

- Decay of K^\pm and π^\pm :
 $K^+ \rightarrow \mu^+ \nu_\mu$
 $K^+ \rightarrow \pi^+ \pi^0$
 $\pi^+ \rightarrow \mu^+ \nu_\mu$
- Radiative processes
 $\mu^\pm \xrightarrow{\frac{A}{Z}Y} \mu^\pm e^+ e^-$
 $\mu^\pm \xrightarrow{\frac{A}{Z}Y} \mu^\pm + \text{had}$
- $N_\mu \propto A^{0,1} E_p^{0,9}$

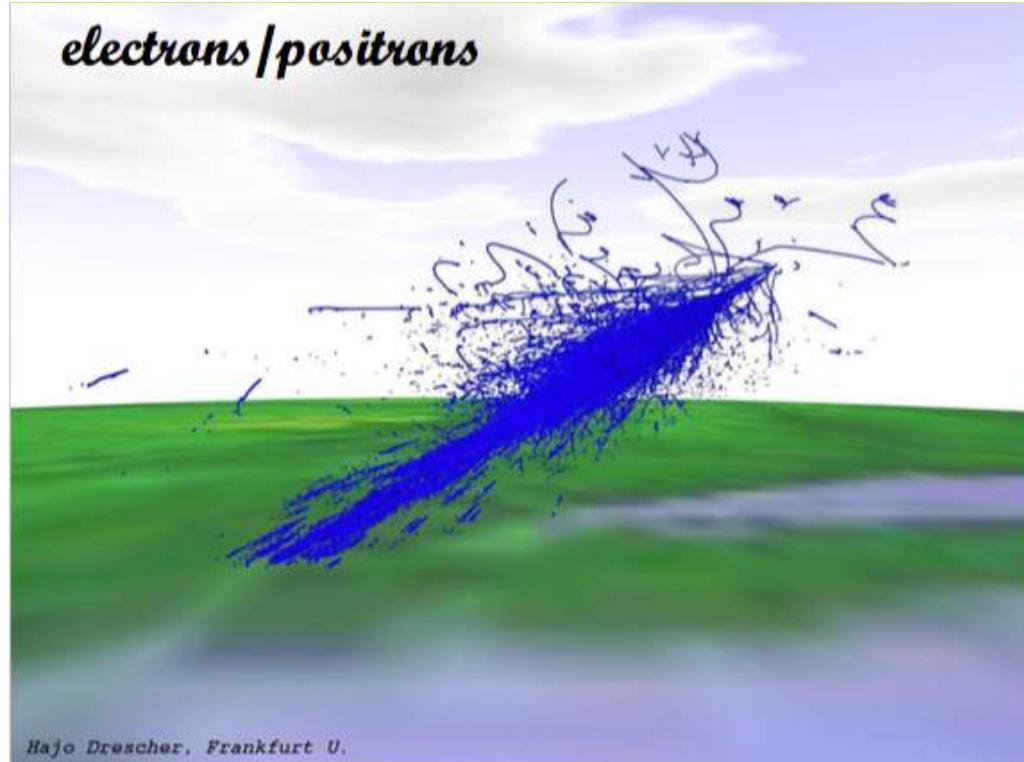
Hadronic

- Nuclear fragments
- p, n, π^\pm, K^\pm
- Charmed mesons
- *Leading particle effect*
- Concentrated in the axis shower
- $N_h \propto N_e^{0,95}$
- $N_h/N_e \sim 10^{-2} - 10^{-4}$

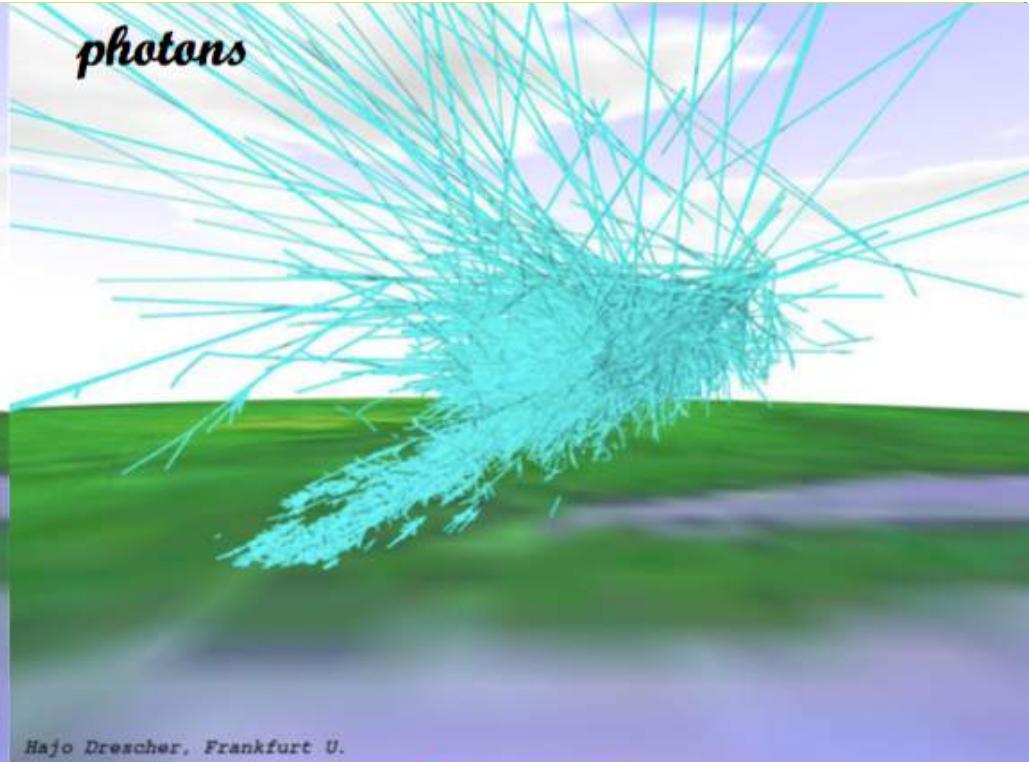


Incident particle

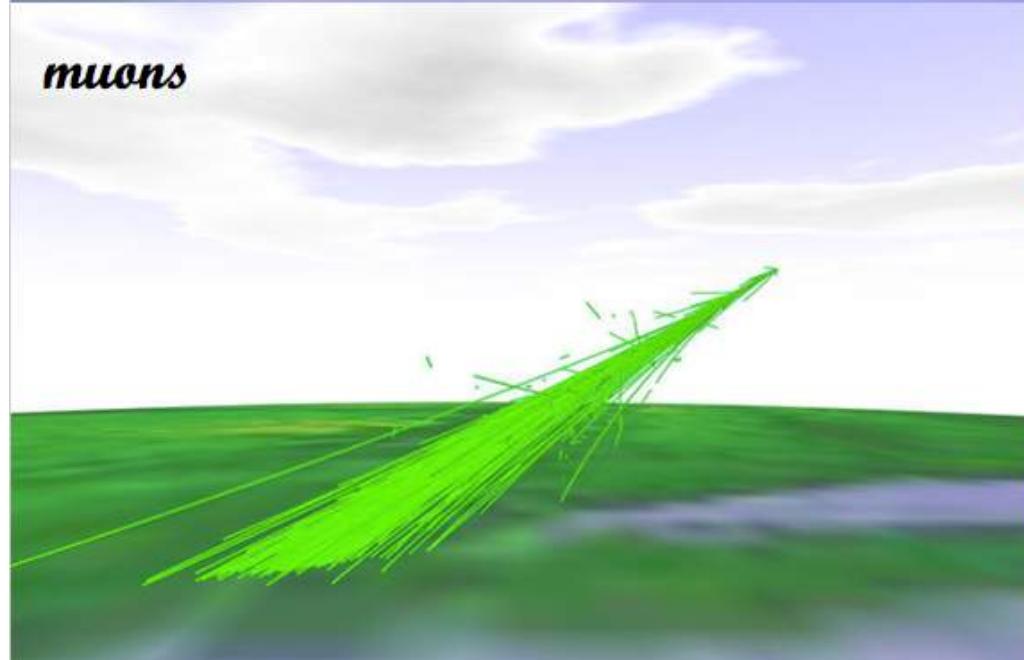
electrons/positrons



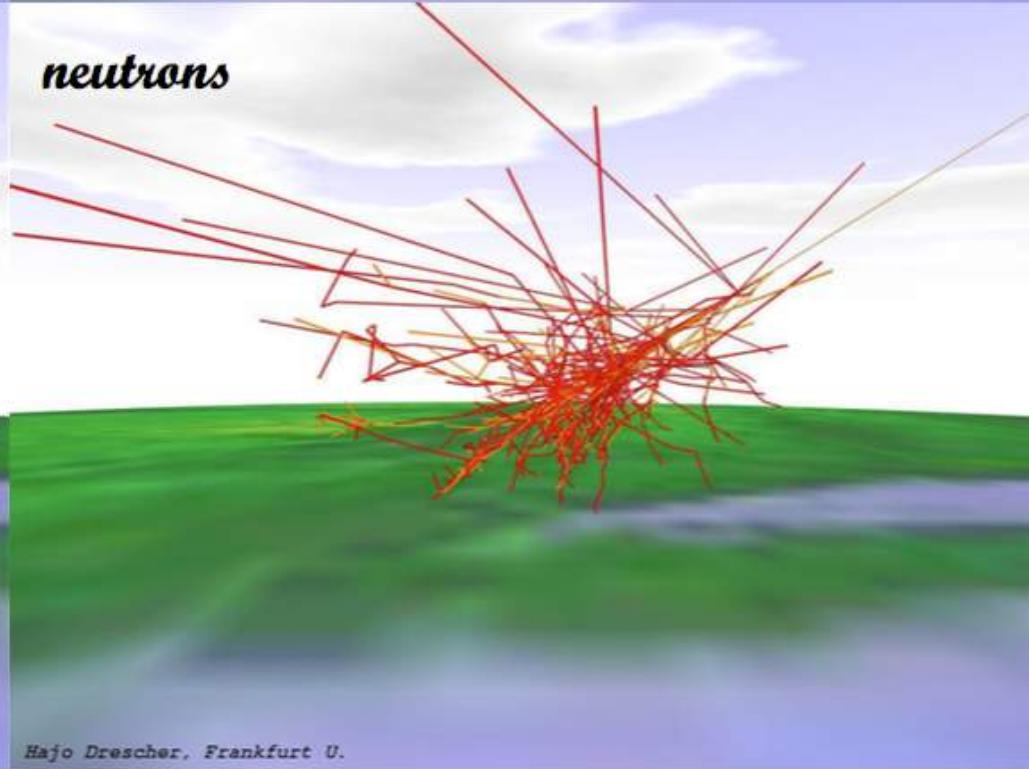
photons



muons



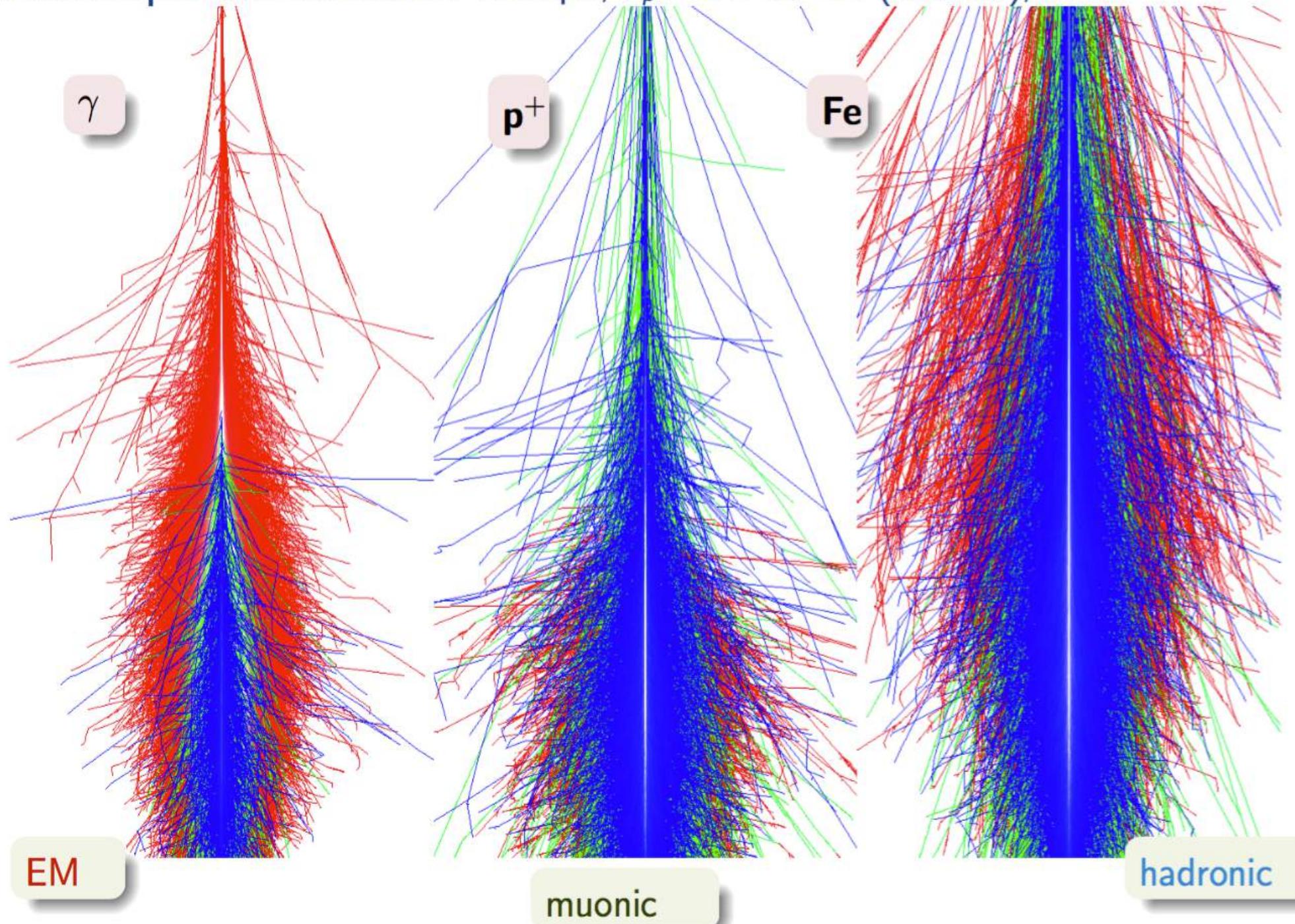
neutrons



Hajo Drescher, Frankfurt U.

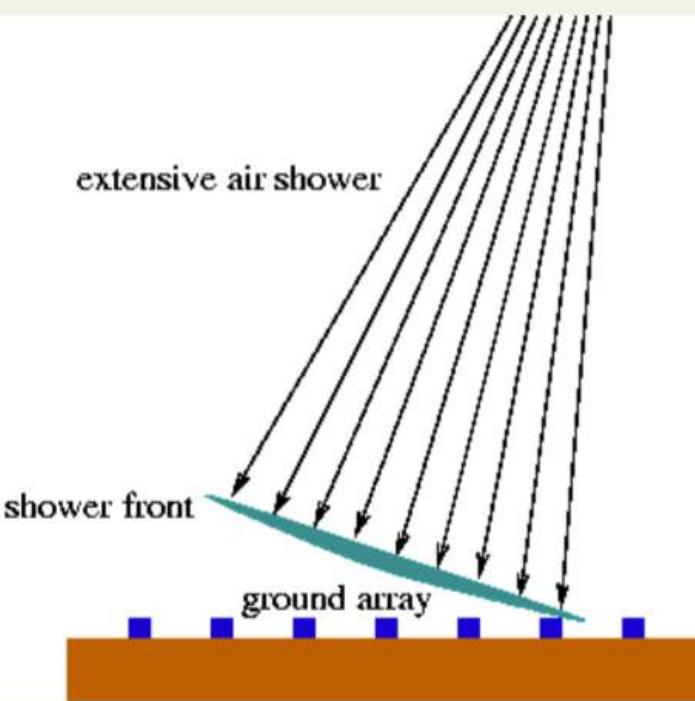
Hajo Drescher, Frankfurt U.

Atmospheric showers Example, $E_p = 5 \times 10^{14}$ eV (500 TeV), $\theta = 0^\circ$

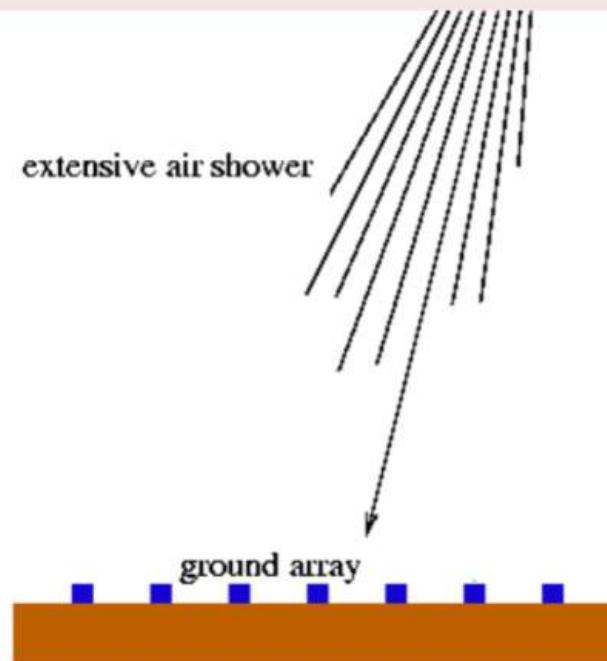


Detection techniques at ground level

Transversal sampling



Single particle technique (SPT)



- Reconstruction of shower parameters
- Excesses in the source direction
- High energy threshold

- No energy or direction reconstruction
- Searches of excesses in the counting rate
- Low energy thresholds

The Latin American Giant Observatory (LAGO) Project

A very long baseline “array” of water Cherenkov detectors (WCD)



- Sites at eight countries:
Argentina, Bolivia,
Colombia, Ecuador,
Guatemala, México, Perú &
Venezuela
- Two new detectors in Brazil
will be incorporated by ~~2016~~

operational

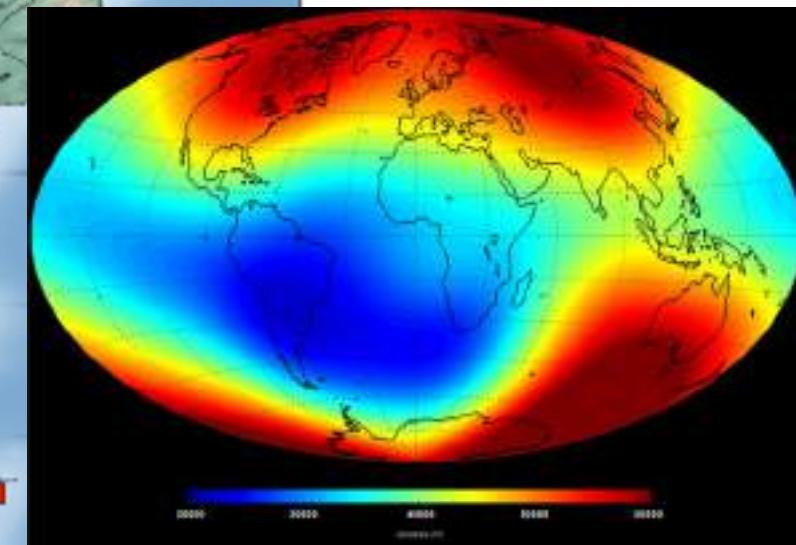
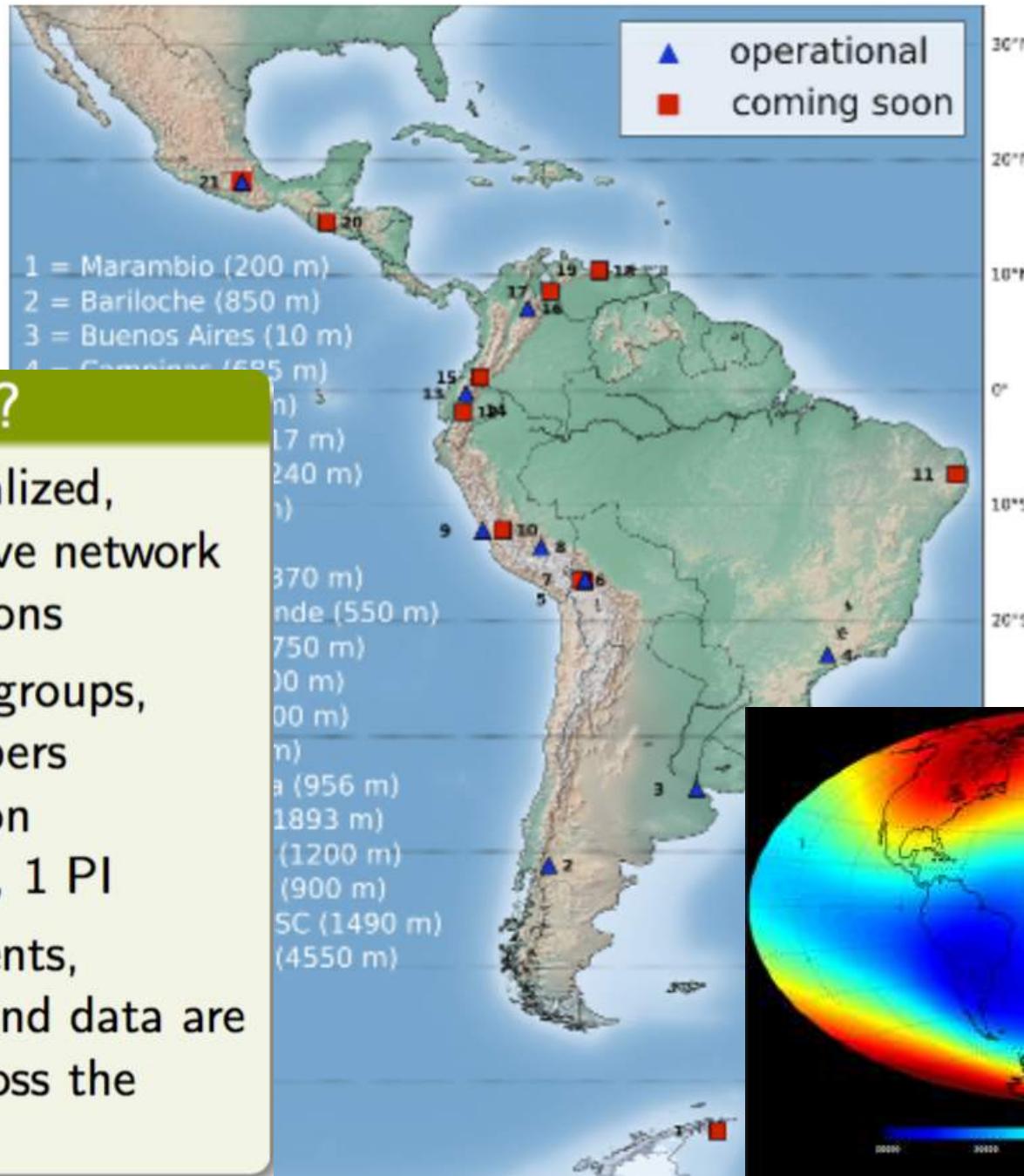
The LAGO Collaboration

- 80 members from 25 institutions at 10 LA countries
- **Scientific goals:**
 - ▶ Astroparticles up to the CR knee
 - ▶ Study transient and long term Space Weather phenomena through Solar modulation (SM) of Cosmic Rays (CR)
 - ▶ Measurements of background radiation at ground level
- **Academic goals:**
 - ▶ Train latin-american students in HEP and Astroparticle techniques
 - ▶ Build a Latin-American network of Astroparticle researchers

The Latin American astroparticle network

How it works?

- Non-centralized, collaborative network of institutions
- 3 working groups, 9+2 members coordination committee, 1 PI
- Developments, expertise and data are shared across the network



LAGO Programs

LAGO-Extreme Universe

- High energy astroparticles
- Towards CR knees region

LAGO-Space Weather

- Cosmic ray solar modulation
- Possible connections with physics of the atmosphere
- Background radiation at ground (and flight) level

WG1: Physics

S. Dasso (ARG)

LAGO-Virtual

- Acquire, produce, collect and preserve LAGO data

LAGO-Universities

- Astrophysics and particle physics in undergraduate courses
- Data analysis and statistic
- Muon decay
- Detector physics and interaction of radiation with matter
- Construction and characterization of particles detectors

WG2: Detectors

L. Otiniano (PER)

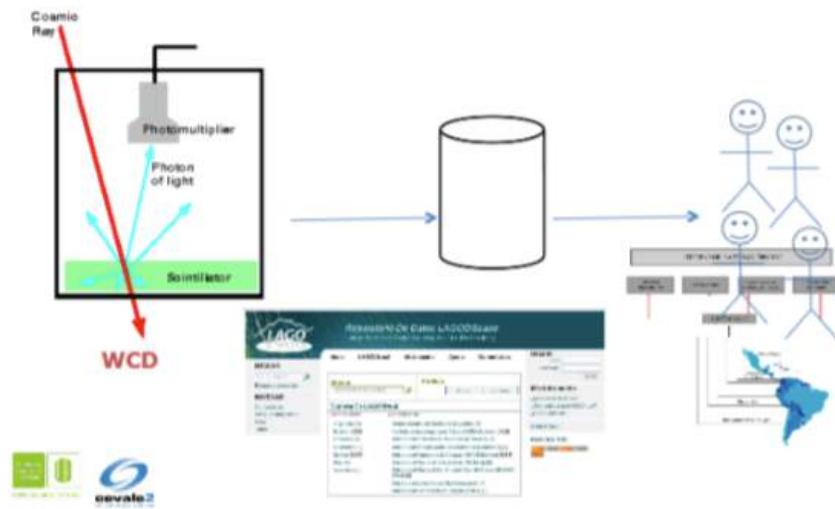
WG3: Data

L. A. Núñez (COL)

LAGO-Virtual: the Latin American astroparticle network

LAGO Data

- Two types of data: measured and simulated
- Measured data: 4 quality levels: raw data, preliminary, Data Quality & High Quality
- Massive data production: raw ($\sim 1 \text{ TiB year}^{-1} \text{ det}^{-1}$); sims ($\sim 3 \text{ TiB year}^{-1} \text{ site}^{-1}$)
- LAGO is an EU FP7 CHAIN-REDS case study: first data repository in LA
- LAGO data challenge: DART (Data Accessibility, Reproducibility and Trustworthiness) initiative
- Deploying LAGO-CORSIKA implementation on GRID



LAGO & RedCLARA

- Data repository located at UIS (BGA, Colombia)
- Data transfer from Sites to Repository using RedCLARA (where available)

Our detector: sWCD (Water Cherenkov Detector) *s* as in *smart*

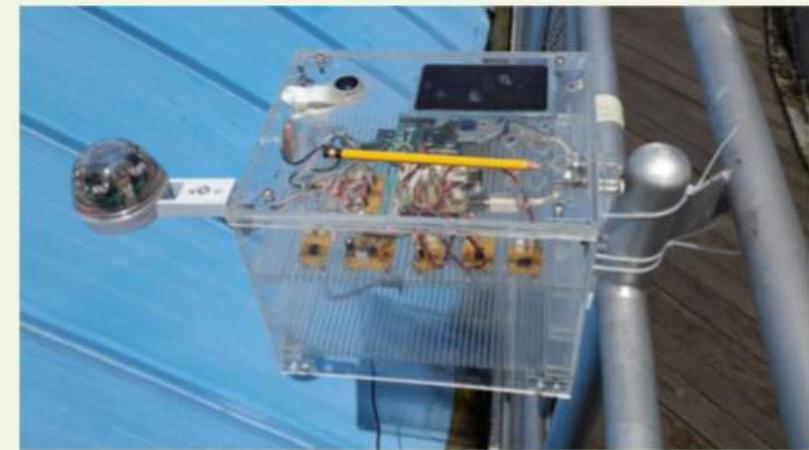
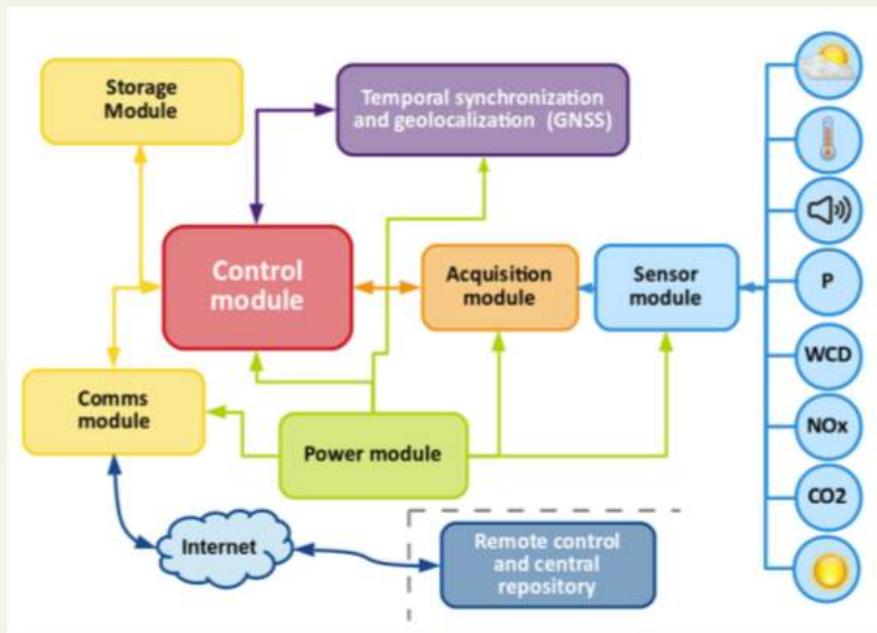
- Autonomous, reliable, simple and cheap detector
- Commercial tanks with $1,5 \text{ m}^2 - 10 \text{ m}^2$ of detection area filled with purified water
- Inner coating of Tyvek (UV diffusive and reflective fabric)
- PMT + Digitizer board (own design)
- FPGA + Raspberry Pi: detector control, telemetry, data acquisition and on board data pre-analysis (including machine learning techniques)



- Digitized signals by a 10-14 bits FADC at 40-100 MHz (10-25 ns)
- Temporal synchronization: GPS in PPS mode
- Station consumption: $\lesssim 8 \text{ W}$

Our new station: the smart LAGO-WCD

RACIMO: Red Ambiental Cludadana de MOnitoreo

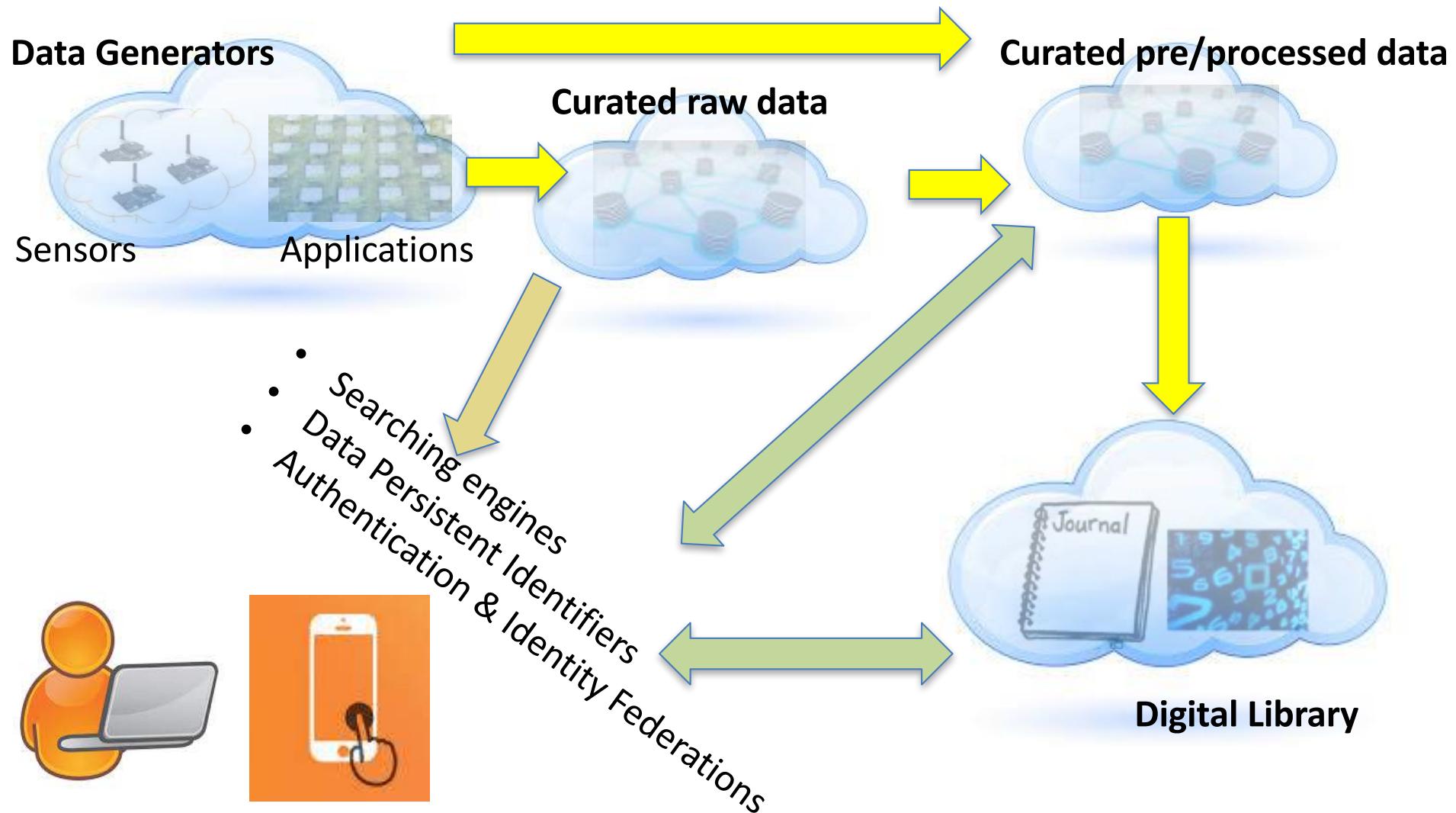


Control and Acquisition Station → Environment (including WCD)

- 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

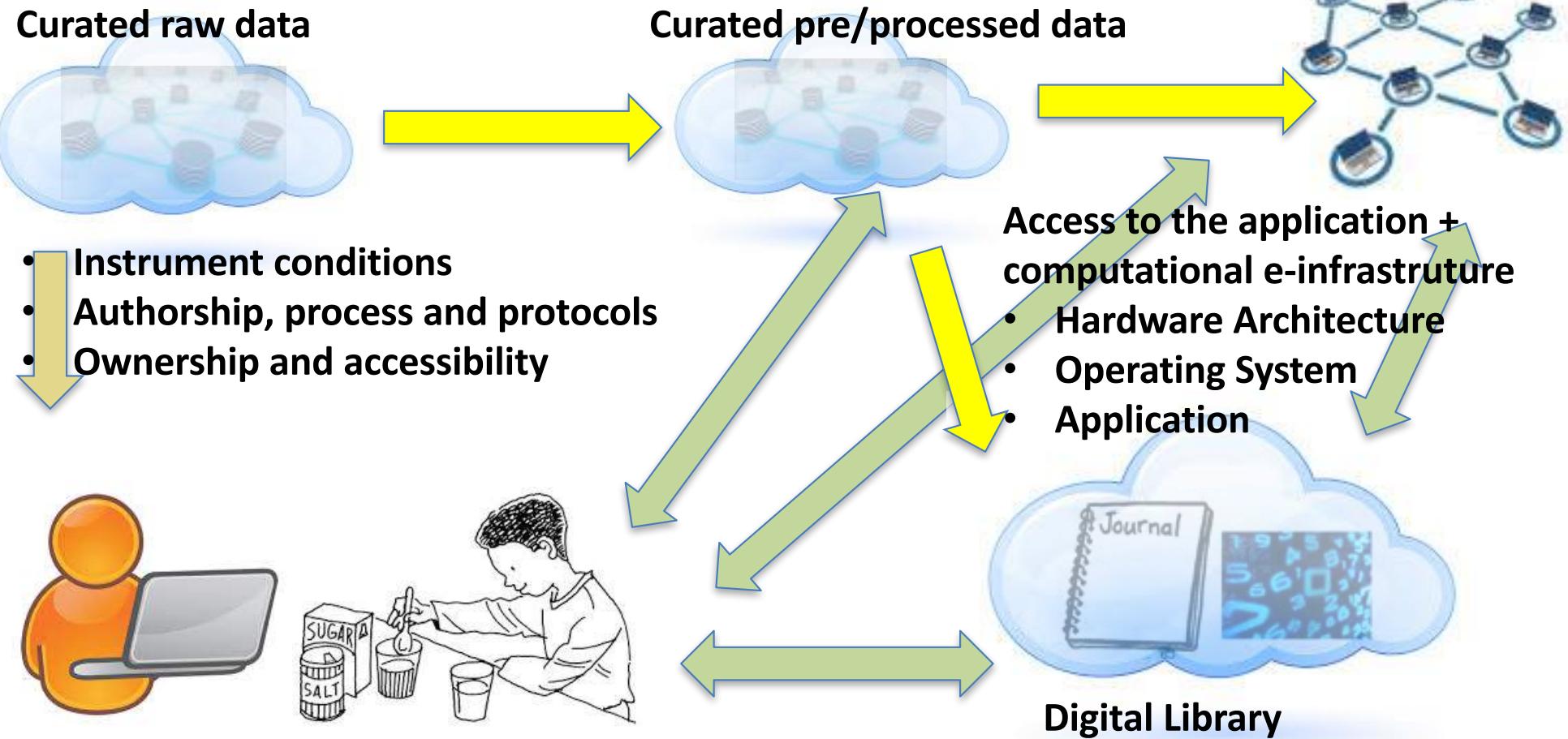
Accessibility

Data Accessibility, Reproducibility, and Trustworthiness

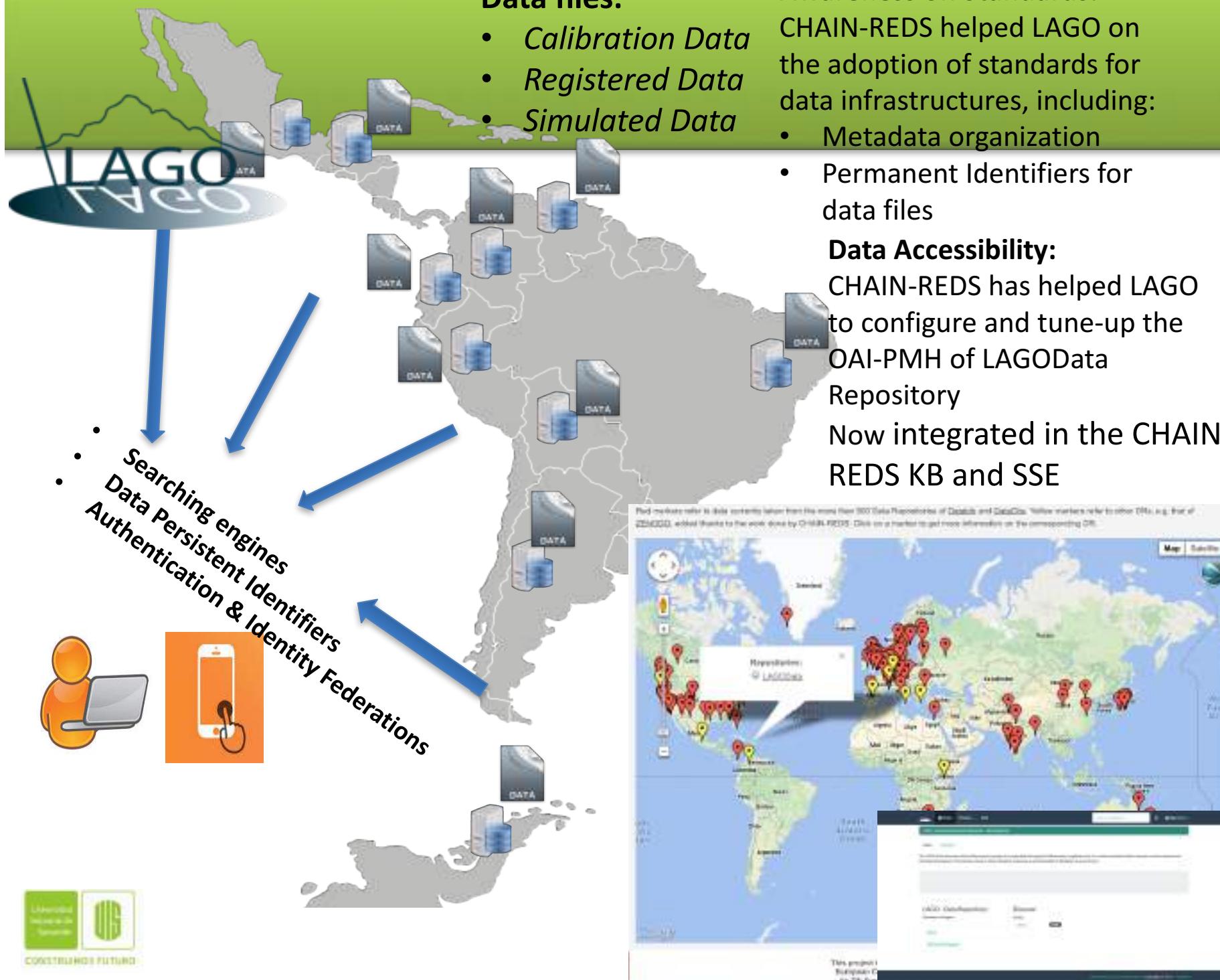


Reproducibility

Data
Accessibility,
Reproducibility, and
Trustworthiness



Asorey, H. Et al "Data accessibility, reproducibility and trustworthiness with Iago data repository" Proceedings of "The 34th International Cosmic Ray Conference, PoS(ICRC2015) 672, 2015



Data files:

- *Calibration Data*
 - *Registered Data*
 - *Simulated Data*

Awareness on Standards:

CHAIN-REDS helped LAGO on the adoption of standards for data infrastructures, including:

- Metadata organization
 - Permanent Identifiers for data files

Data Accessibility:

CHAIN-REDS has helped LAGO to configure and tune-up the OAI-PMH of LAGOData Repository

Now integrated in the CHAIN
REDS KB and SSE

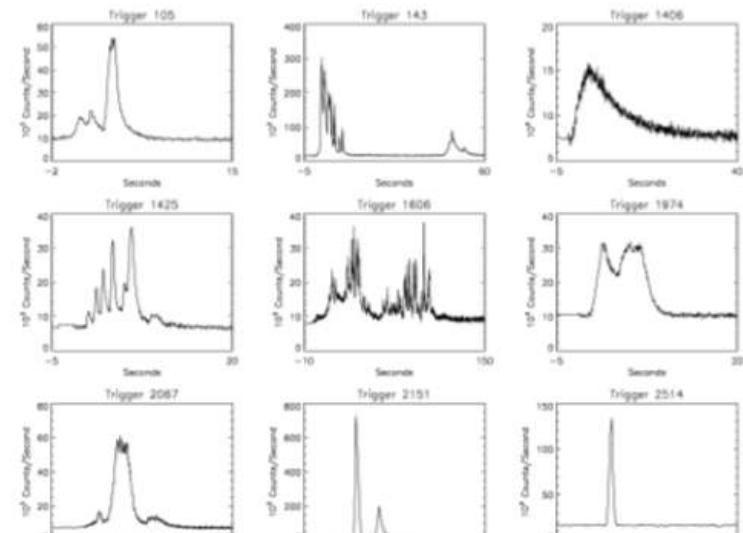
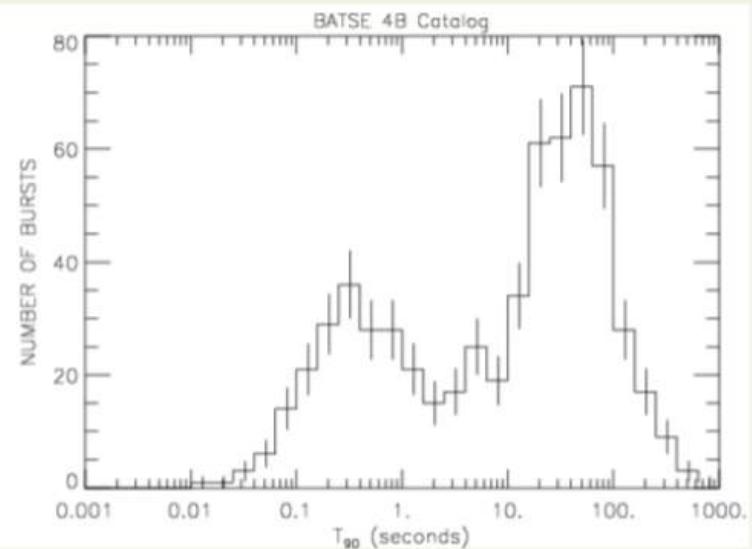


Rodriguez-Pascual, M., et al. "A resilient methodology for accessing and exploiting data and scientific codes on distributed environments." *Computational Science and Engineering (CSE), 2015 IEEE 18th International Conference on*. IEEE, 2015.

New LAGO High Energy program

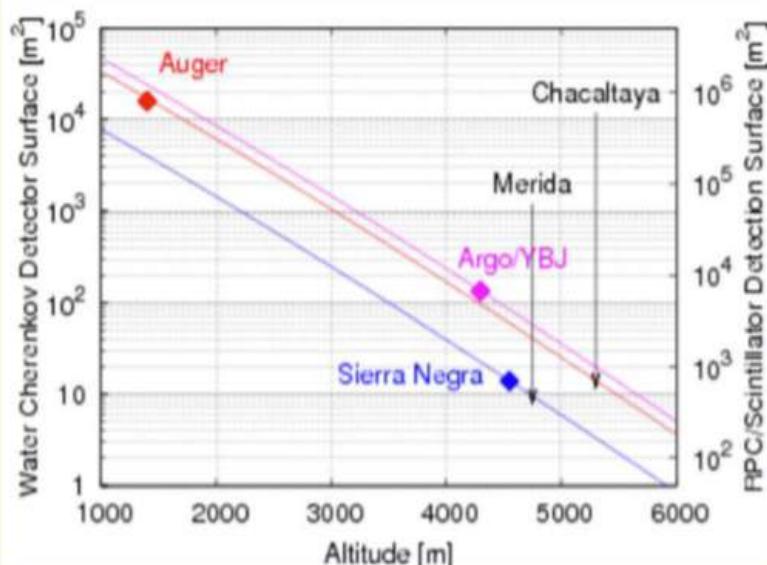
- New detectors at Sierra Negra: 4 segmented 40 m² WCD. Full operation in 2015.
- First SN WCD test and calibration (Aug/2014)
- Re-deploy detectors at Chacaltaya (Dec/2015)
- ~~Pico Espejo cable-way will be operative in 2017 (OCAM)~~
- Re-analysis of the full data set
- Building arrays at medium altitude sites ($h > 3000$ m a.s.l.)
- LAGO-GLORIA network: CR+Global warming at high altitude sites
- Signal time superposition analysis at Chacaltaya for Galactic Center studies
- Simulations of high energy showers (knee)

GRB light curve

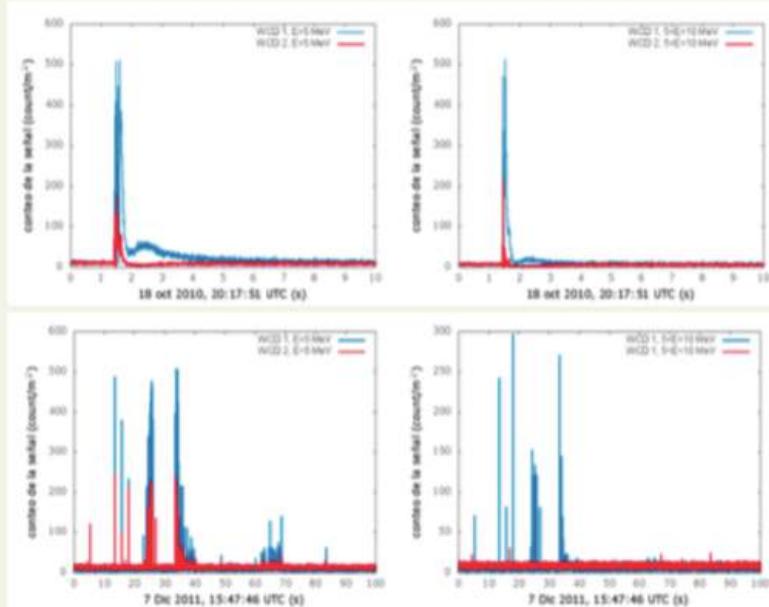


Chacaltaya Signal: 2 Gamma Ray Candidates

Altitude vs Surface



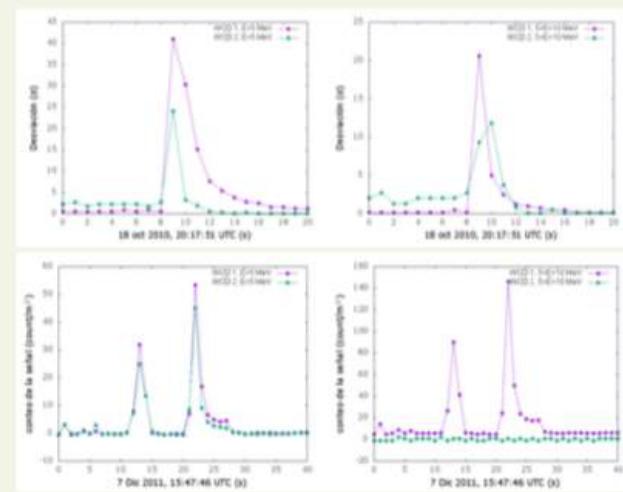
Candidates



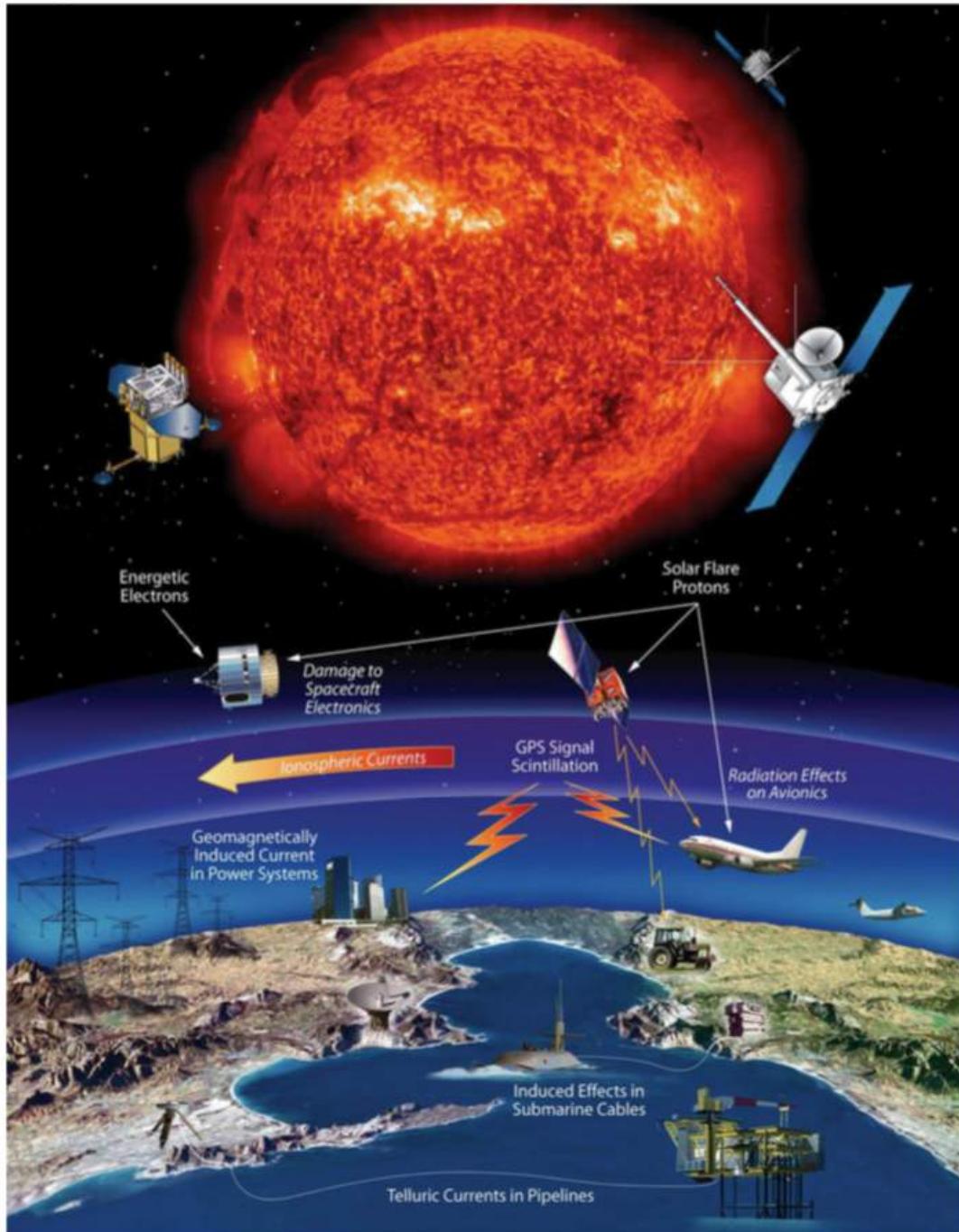
Chacaltaya Site



Deviations



Space Weather



Sun-Earth connection

- Dynamic conditions in the Earth outer space environment:
 - ▶ Disruption of electrical power grids
 - ▶ Contribute to the corrosion of long pipelines
 - ▶ HF radio communications and GPS interferences
 - ▶ Operational anomalies and damage or degradation of critical electronics on spacecraft, satellites and even on board of commercial airplanes

The LAGO Space Weather Program

via Solar modulation of low energy cosmic rays

Connections

CR Flux

Modulated flux

Primaries

Secondary particles

Solar Activity

Geomagnetic field

Atmospheric conditions

Detector response

Modulated flux

Primaries

Secondary particles

Signals

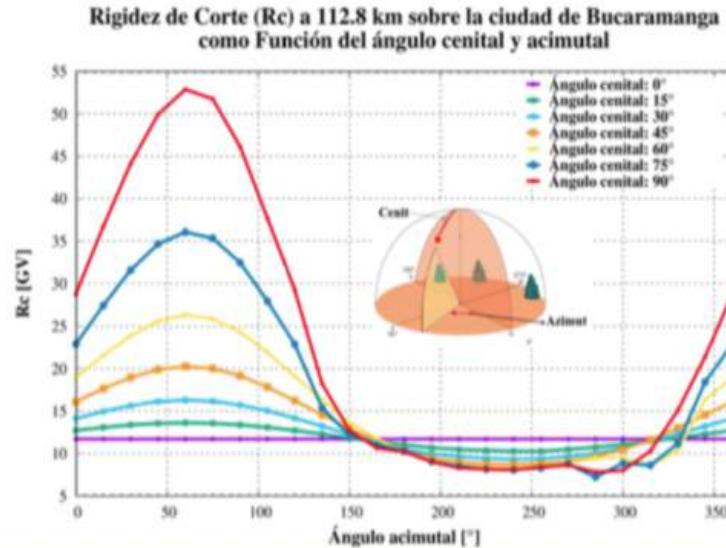
Synergy

Flux variation of signals at detector level \Leftrightarrow Solar Activity

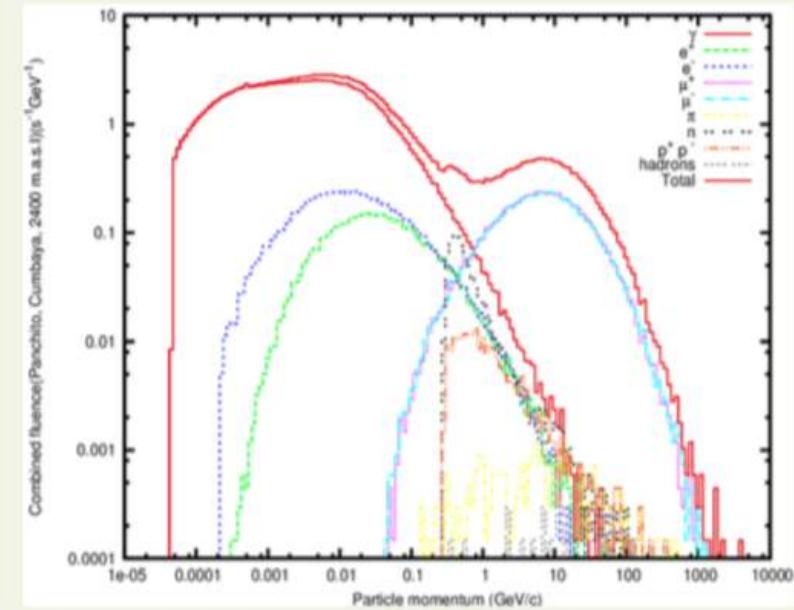
Asorey, H. Et al "The LAGO space weather program: Directional geomagnetic effects, background fluence calculations and multi-spectral data analysis" Proceedings of The 34th International Cosmic Ray Conference, PoS(ICRC2015) 142, 2015

Simulations

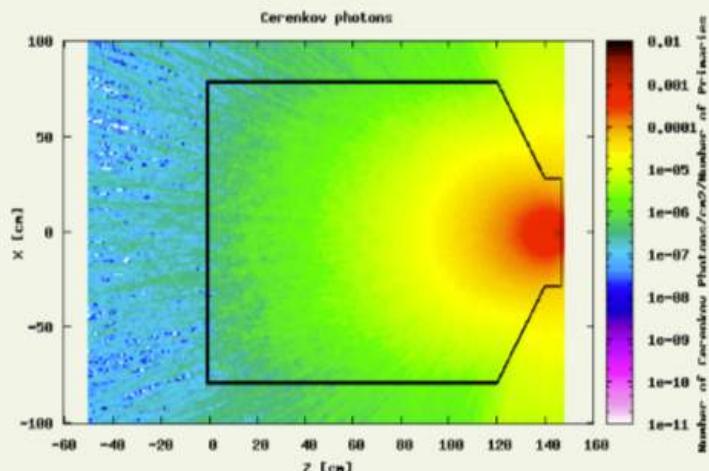
Geomagnetic effects



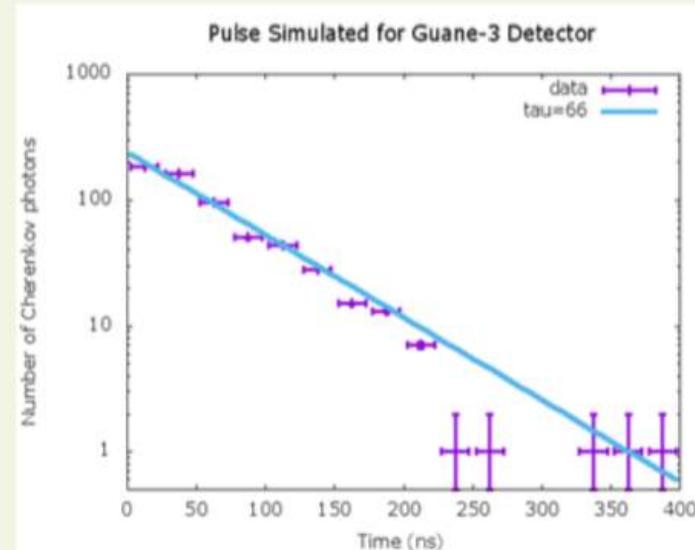
Site characterization



FLUKA WCD response



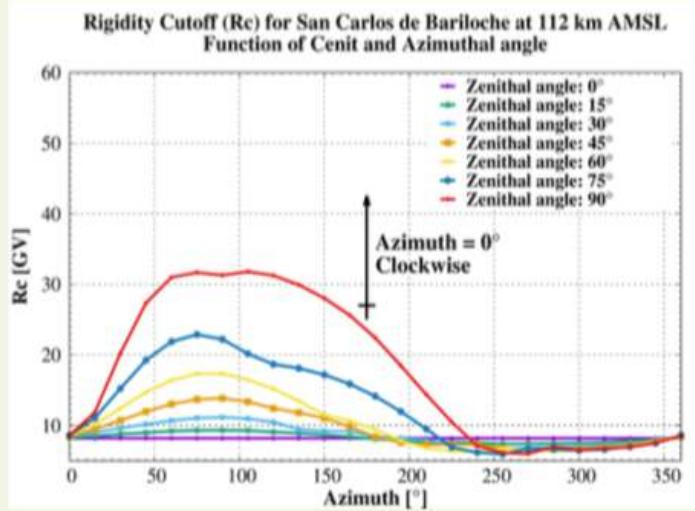
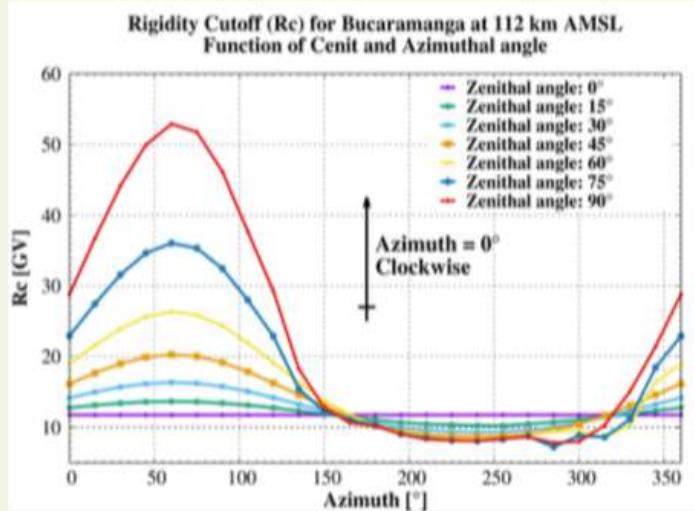
G4 full detector simulation



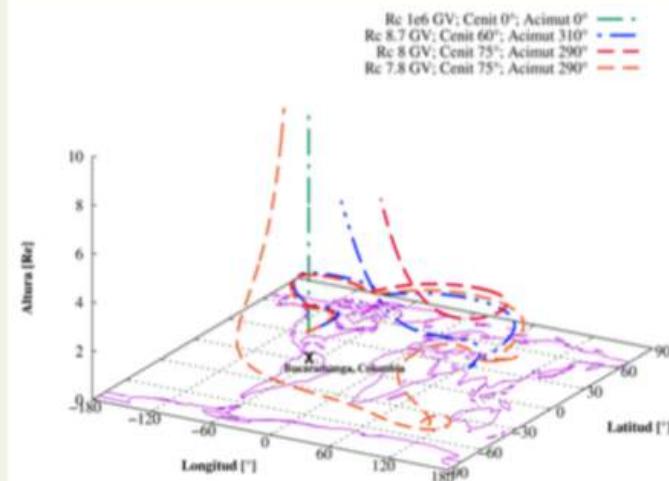
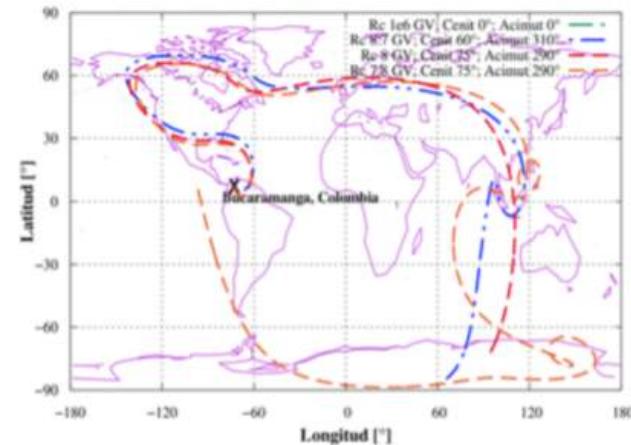
Magnetic Rigidity

$$\frac{dm\vec{v}}{dt} = \frac{eZ}{c} (\vec{v} \times \vec{B}) \rightarrow \frac{d\vec{l}_v}{ds} = \frac{eZ}{pc} (\vec{l}_v \times \vec{B}) \equiv \frac{1}{R_m} (\vec{l}_v \times \vec{B})$$

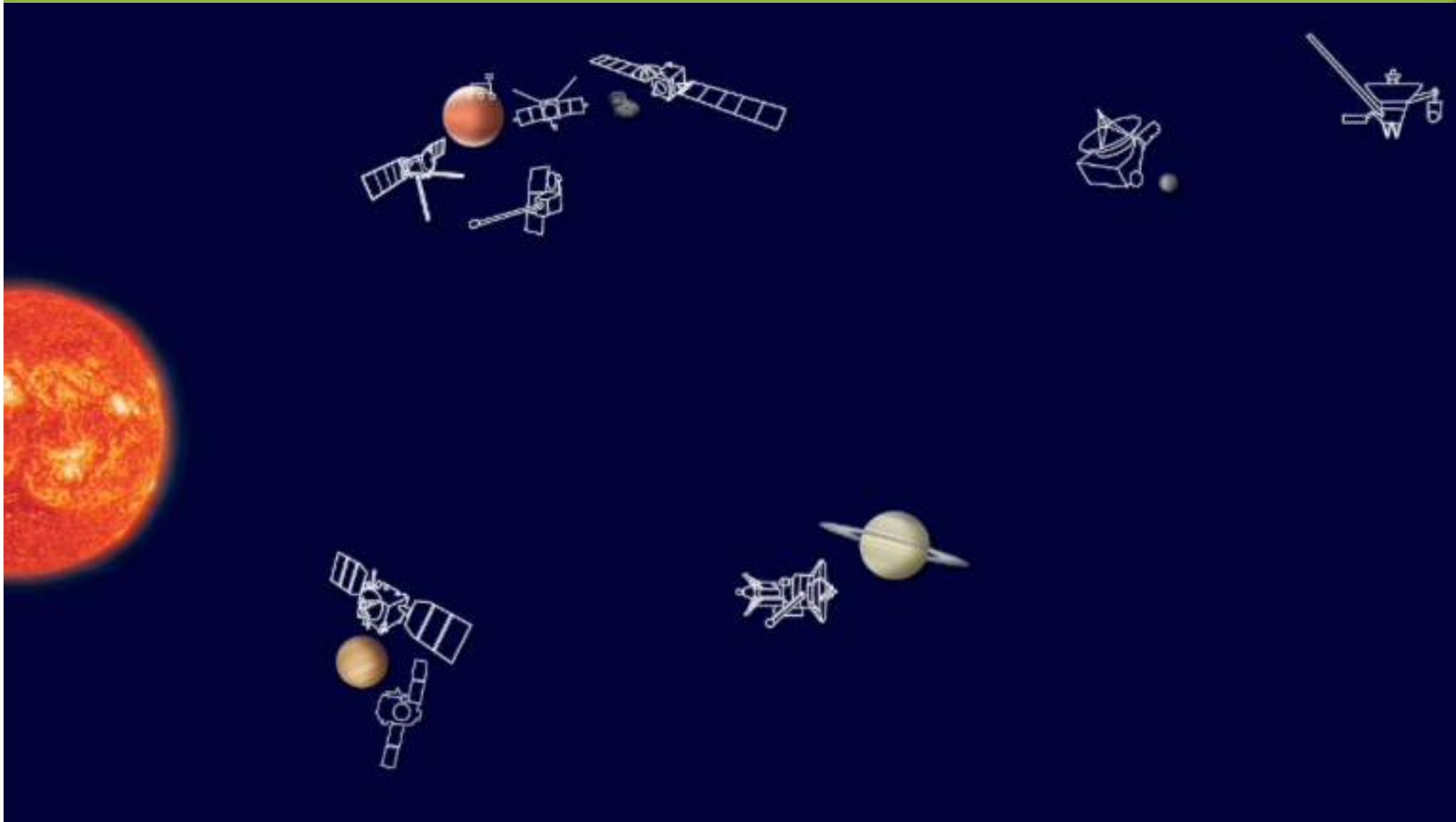
Secular R_C

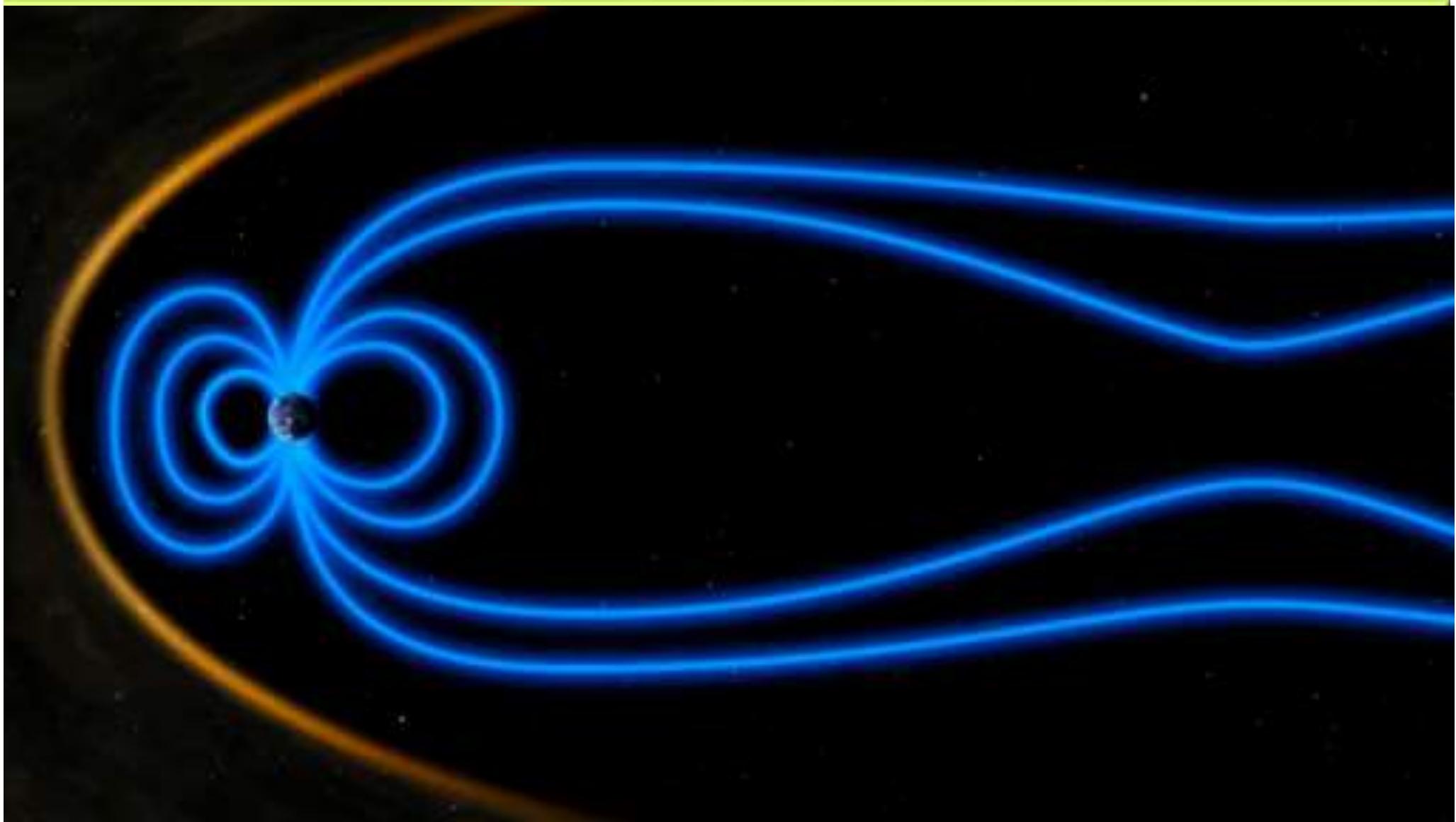


Particle Trajectories



Coronal Mass Ejection

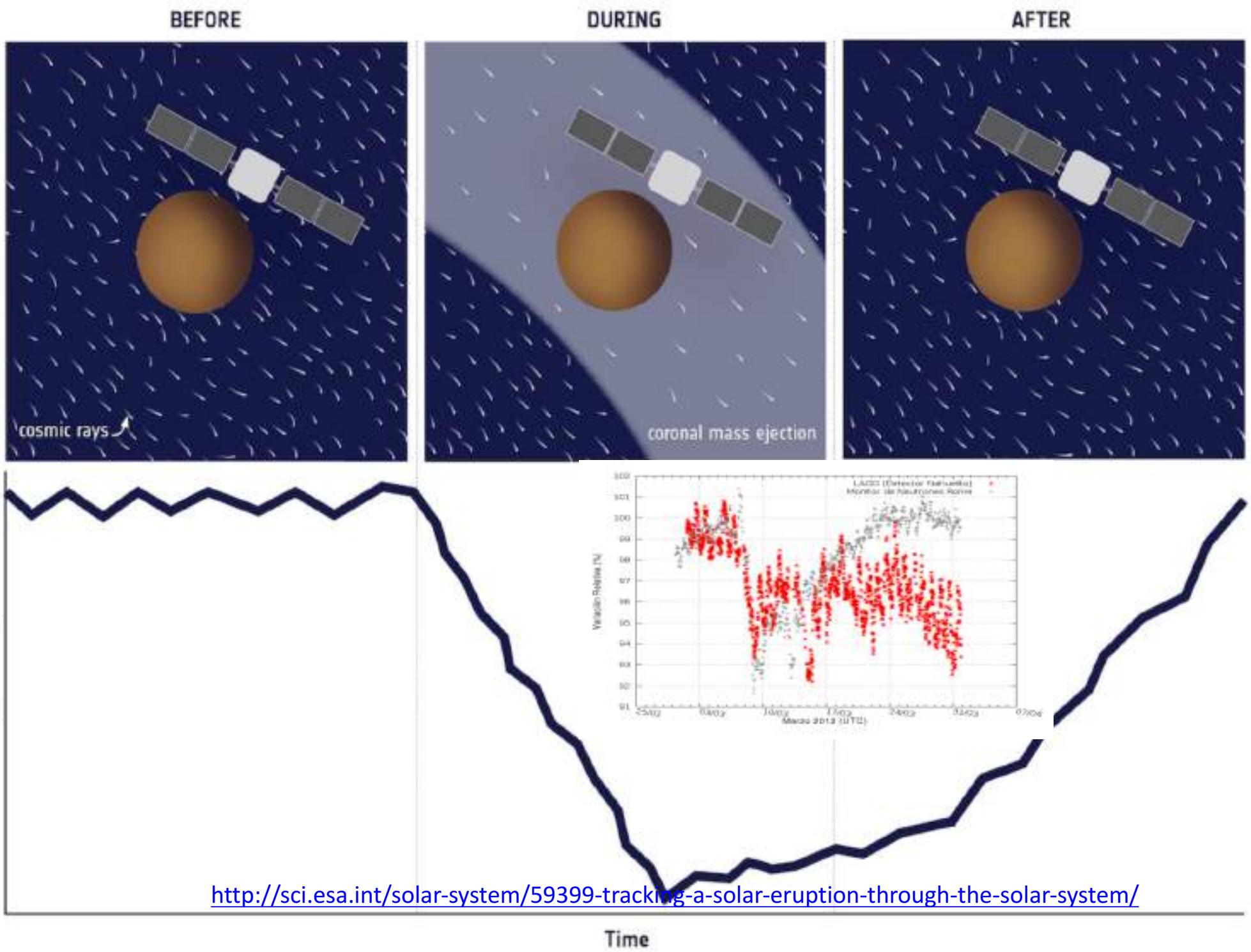




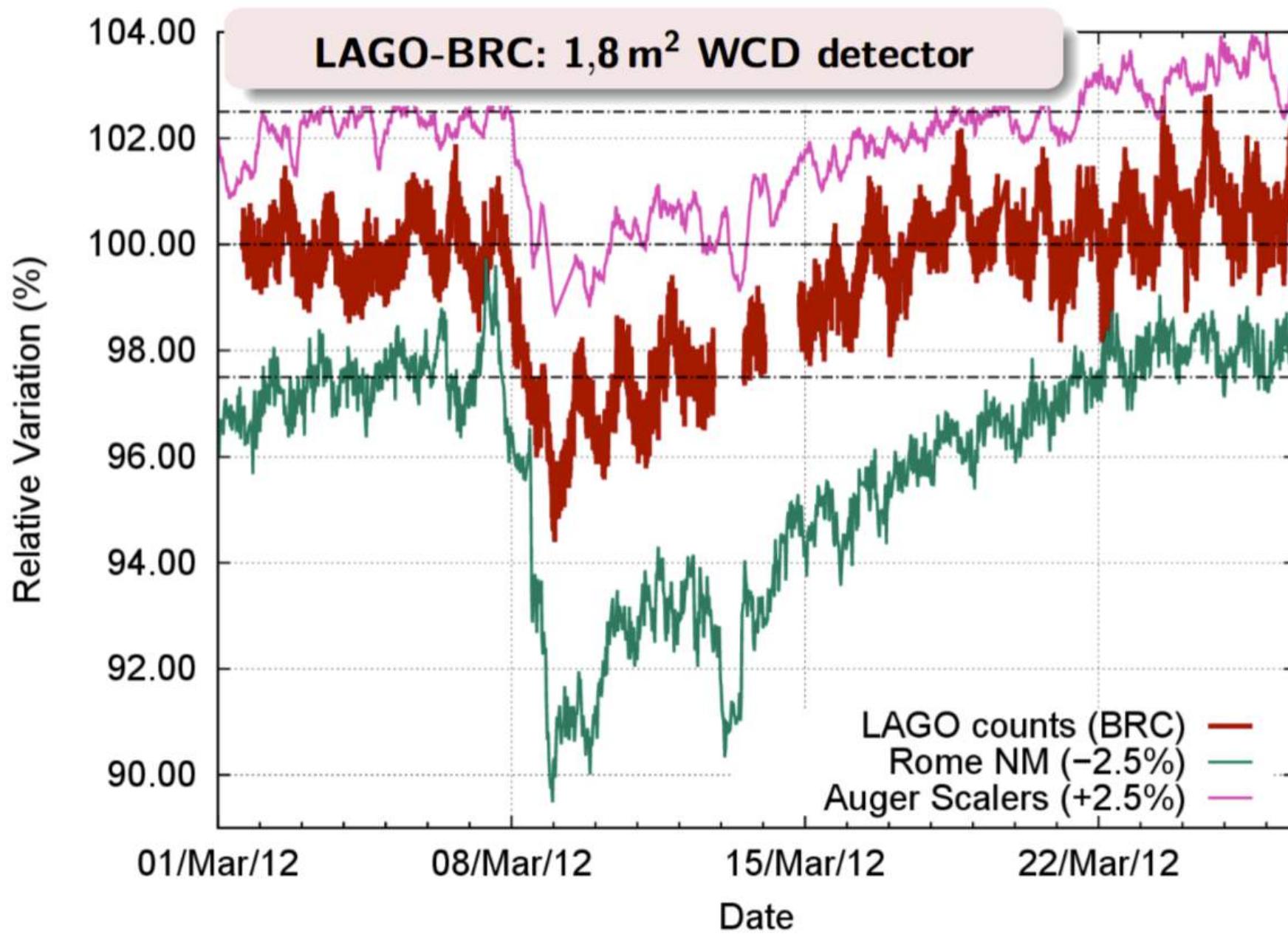
<http://sci.esa.int/cluster/51744-magnetic-reconnection-in-earth-s-magnetosphere/>

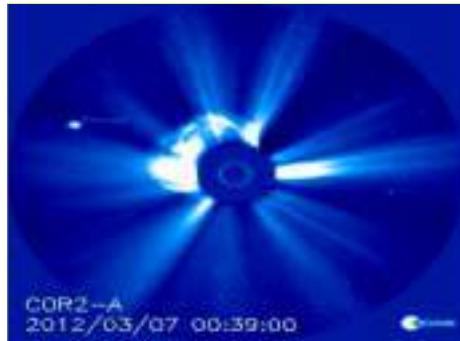


Geomagnetic reconnection

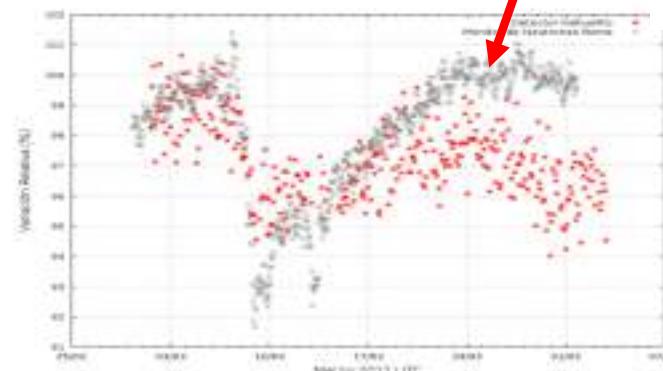
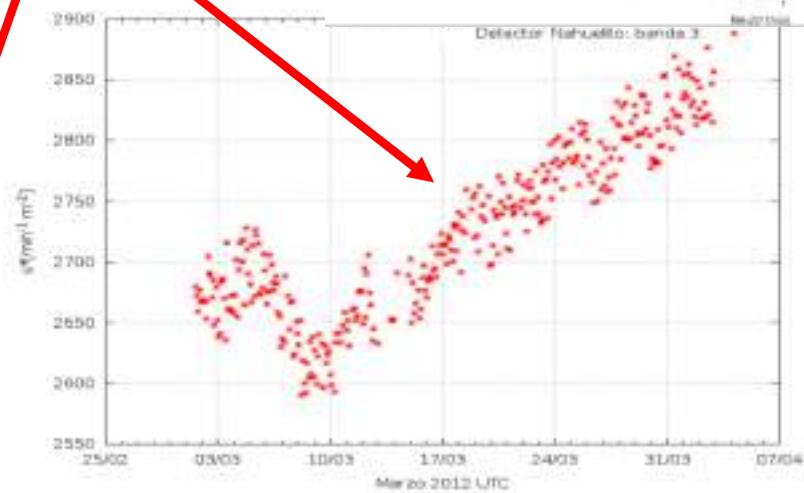
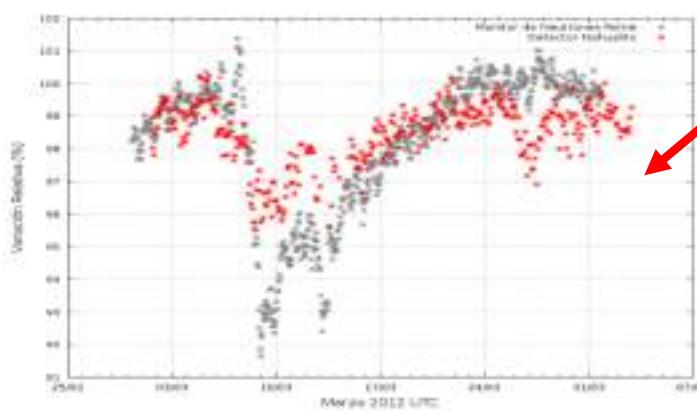
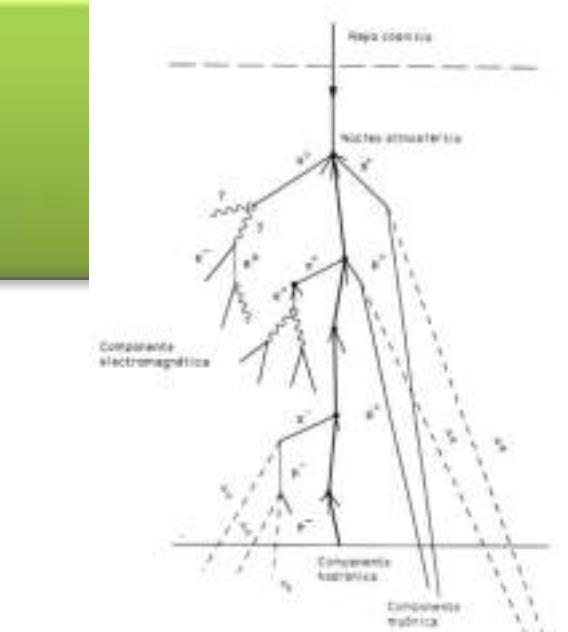
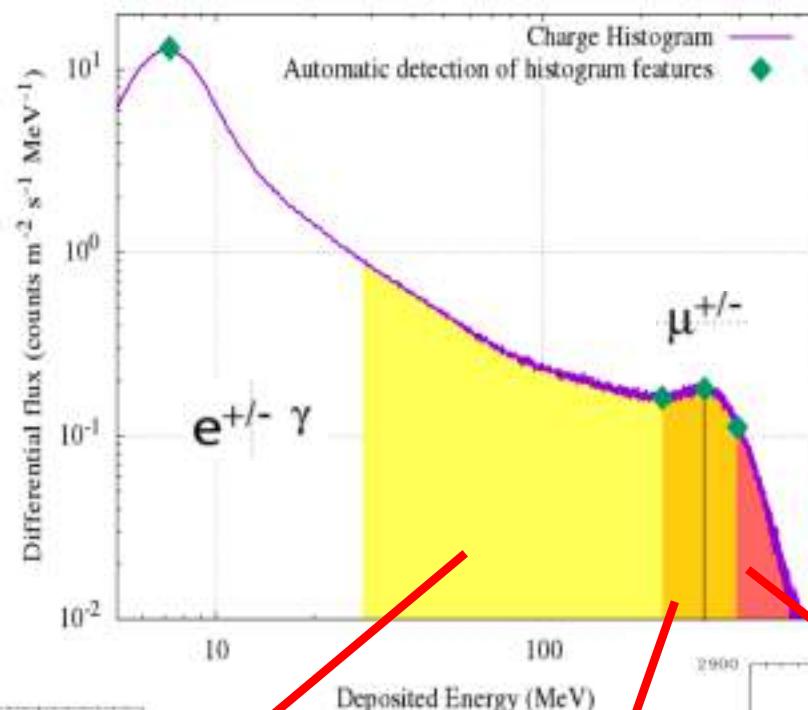


08/March/2012: Forbush event ← single LAGO detector





Forbush detection March 2012



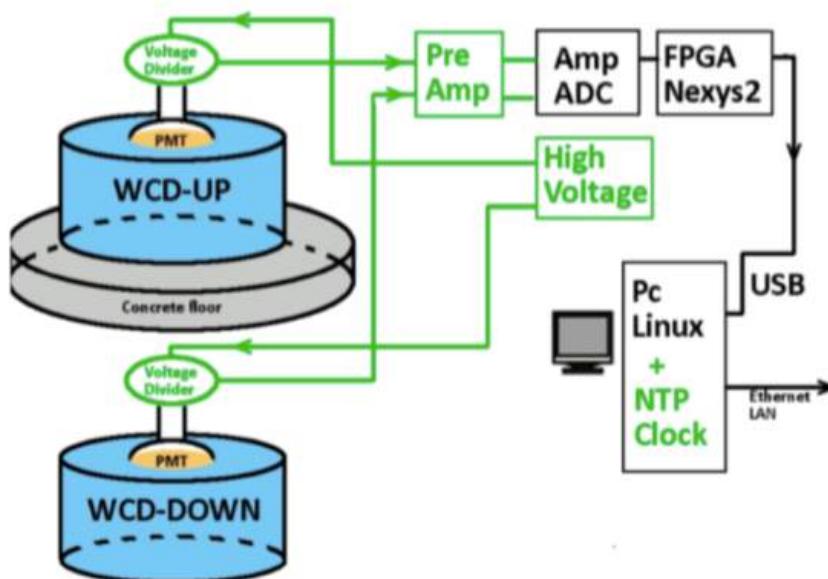
[The LAGO space weather program: Directional geomagnetic effects, background fluence calculations and multi-spectral data analysis H Asorey, S Dasso, LA Núñez, Y Pérez... - The 34th International Cosmic Ray Conference, vol ...](#), 2015



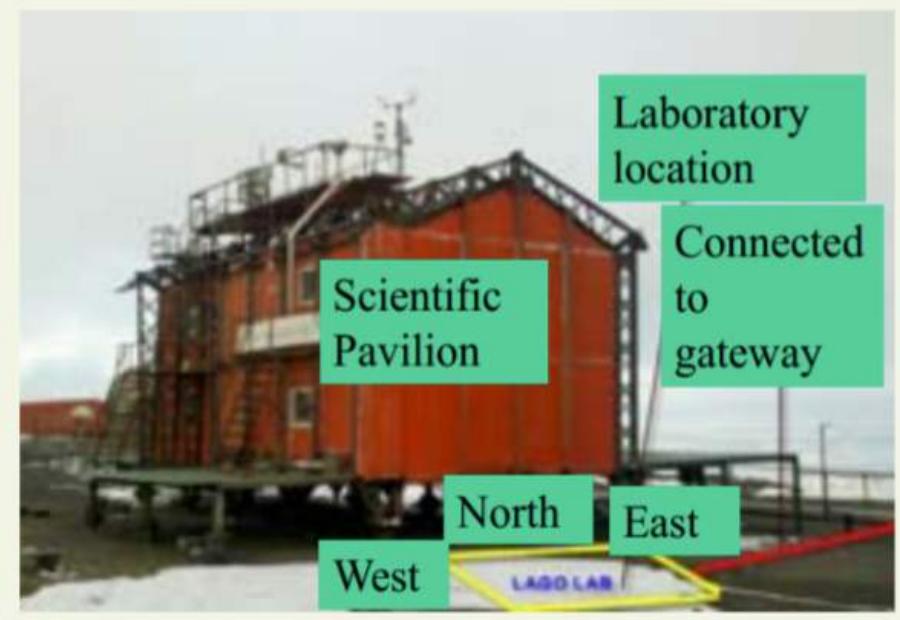
New Space Weather dedicated sites

The LIMA μ counter & First LAGO sWCD in the Antarctic Peninsula

Coincidences: Muon counter



2015: LAGO at Antarctica



The GUANE Array + The CONIDA Array

Towards Space Weather using small arrays of sWCD

Three 4 m² smart LAGO-WCD at the vertices of an equilateral triangle of 105 m side at Bucaramanga and Huancayo

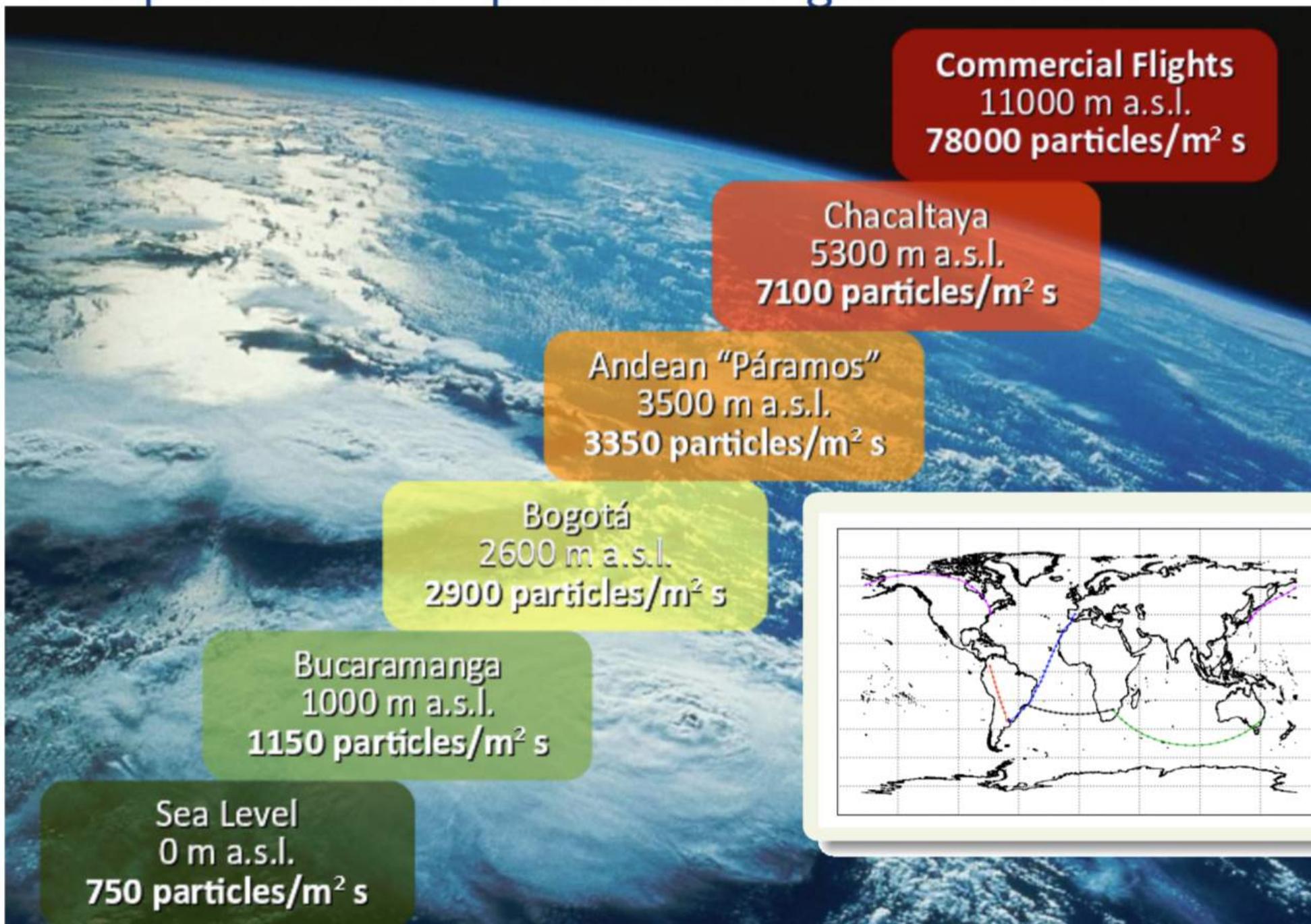


Arrays of WCD: towards detection of mid energy showers

Two detection modes:

- **Counting mode:** acquires individual pulses that satisfies trigger condition: amplitude, total charge or pulse shape
- **Shower mode:** Signal correlation in three detectors → extensive air showers: arrival direction and shower energy

Atmospheric reaction produces background radiation



The LAGO Space Weather Program

via Solar modulation of low energy cosmic rays and biological impact

Connections

CR Flux

Modulated flux

Primaries

Secondary particles

Solar Activity
→

Geomagnetic field
→

Atmospheric conditions
→

Tissue Damage
→

Modulated flux

Primaries

Secondary particles

Damage

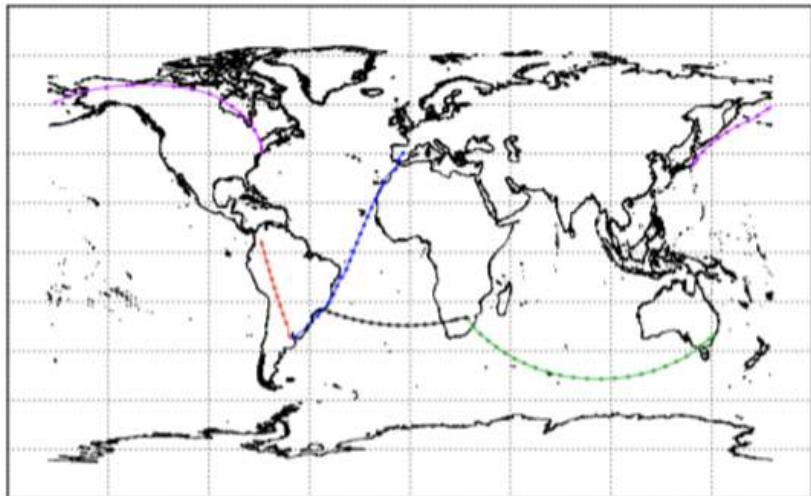
Synergy

Flux variation at the airline route ⇔ 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 commercial flights

Particle flux



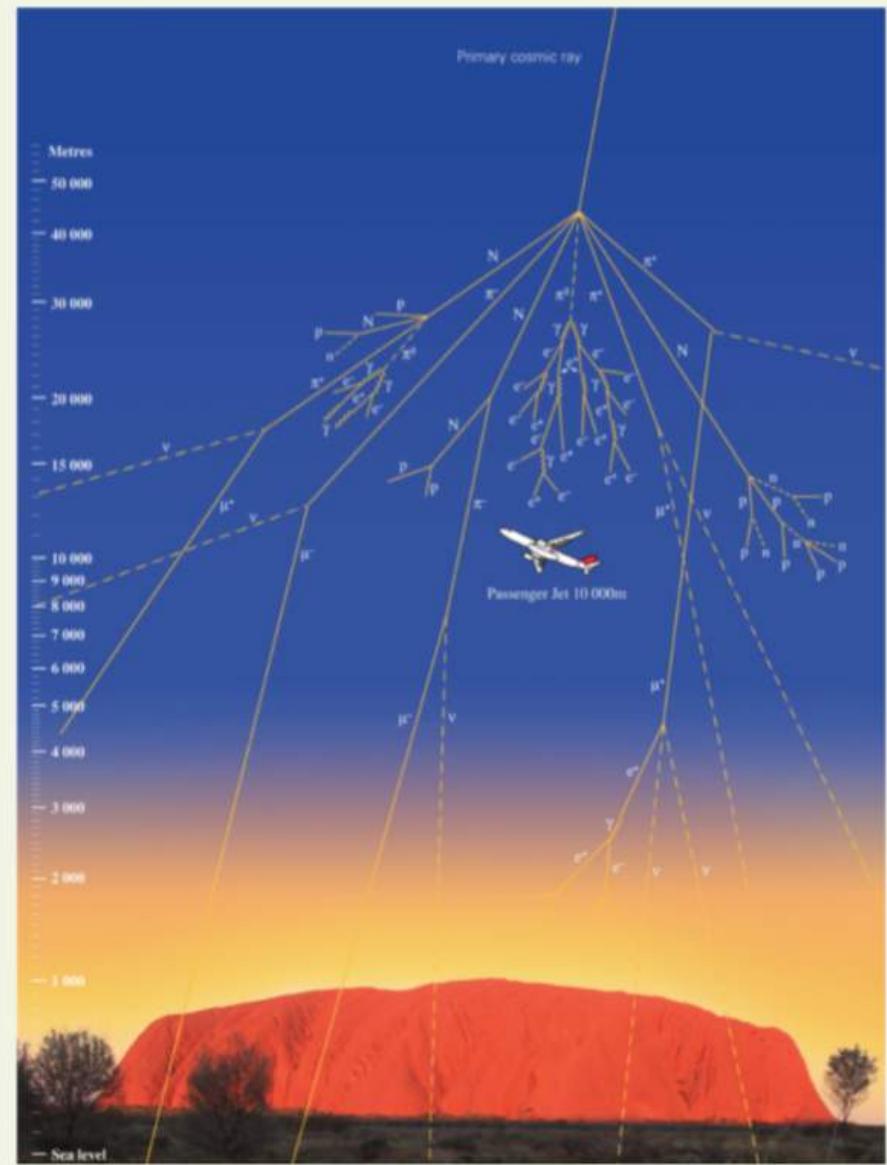
$$\%F_N = \frac{N_{\text{con CG}}}{N_{\text{sin CG}}} \times 100 \%. \quad (9)$$

| 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 |

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

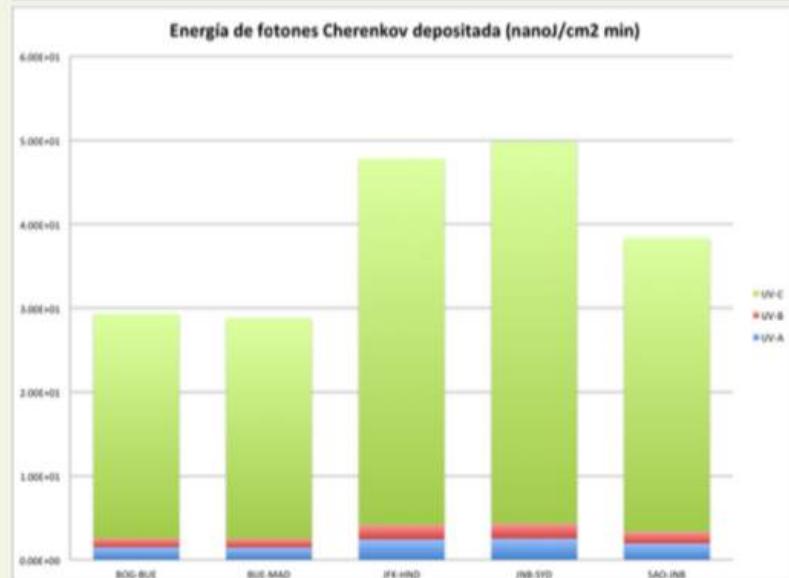
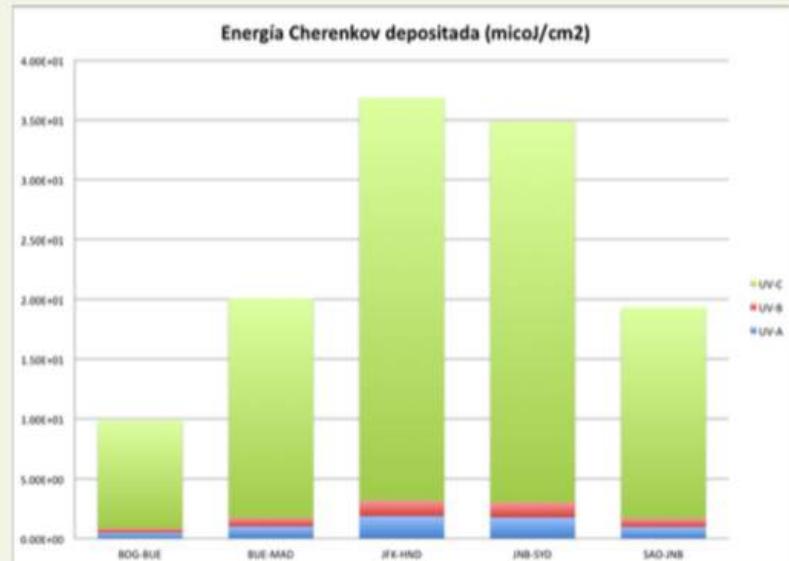
| Ruta | γ | e^+ | e^- | μ^+ | μ^- | n^0 | p^+ | Otros | Total |
|---------|----------|-------|-------|---------|---------|-------|-------|-------|-------|
| BOG-BUE | 55.5 | 56.0 | 56.2 | 3.5 | 3.9 | 84.6 | 165.8 | 122.6 | 46.1 |
| BUE-MAD | 56.6 | 57.0 | 57.3 | 3.6 | 4.0 | 90.7 | 175.9 | 124.6 | 47.1 |
| 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

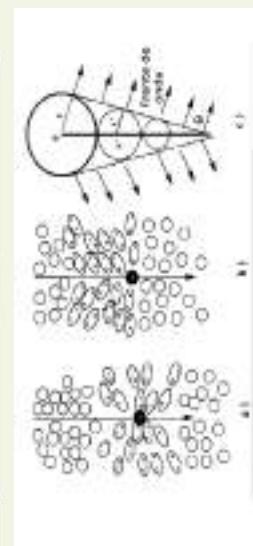
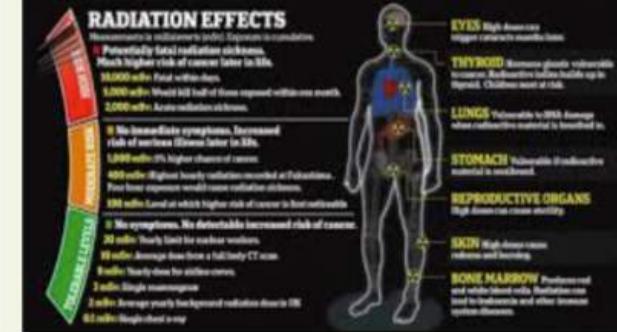
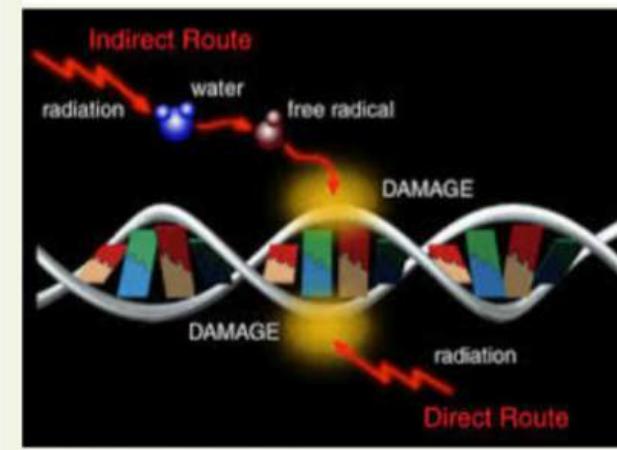
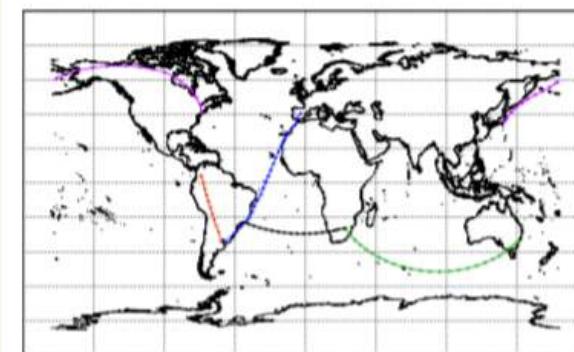


Energy Deposited

Cherenkov Energy



Bioeffects and commercial flights

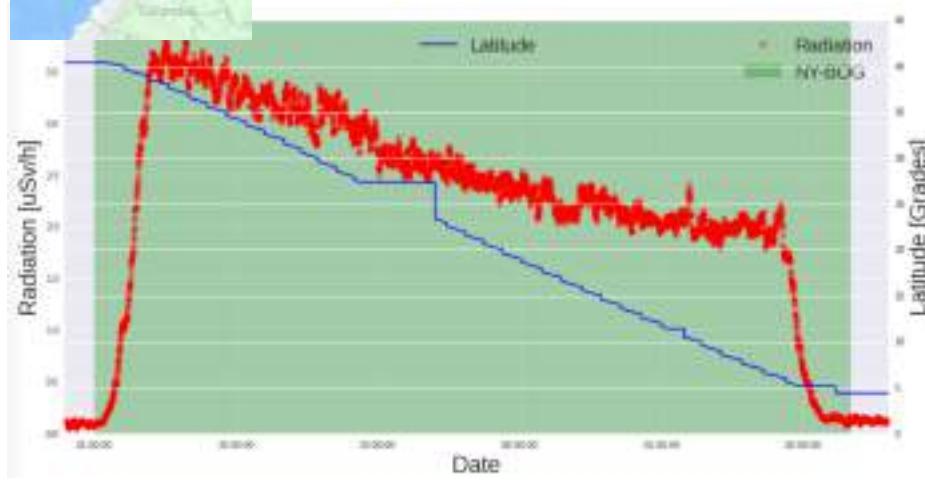




<https://blog.safecast.org/bgeigie-nano/>

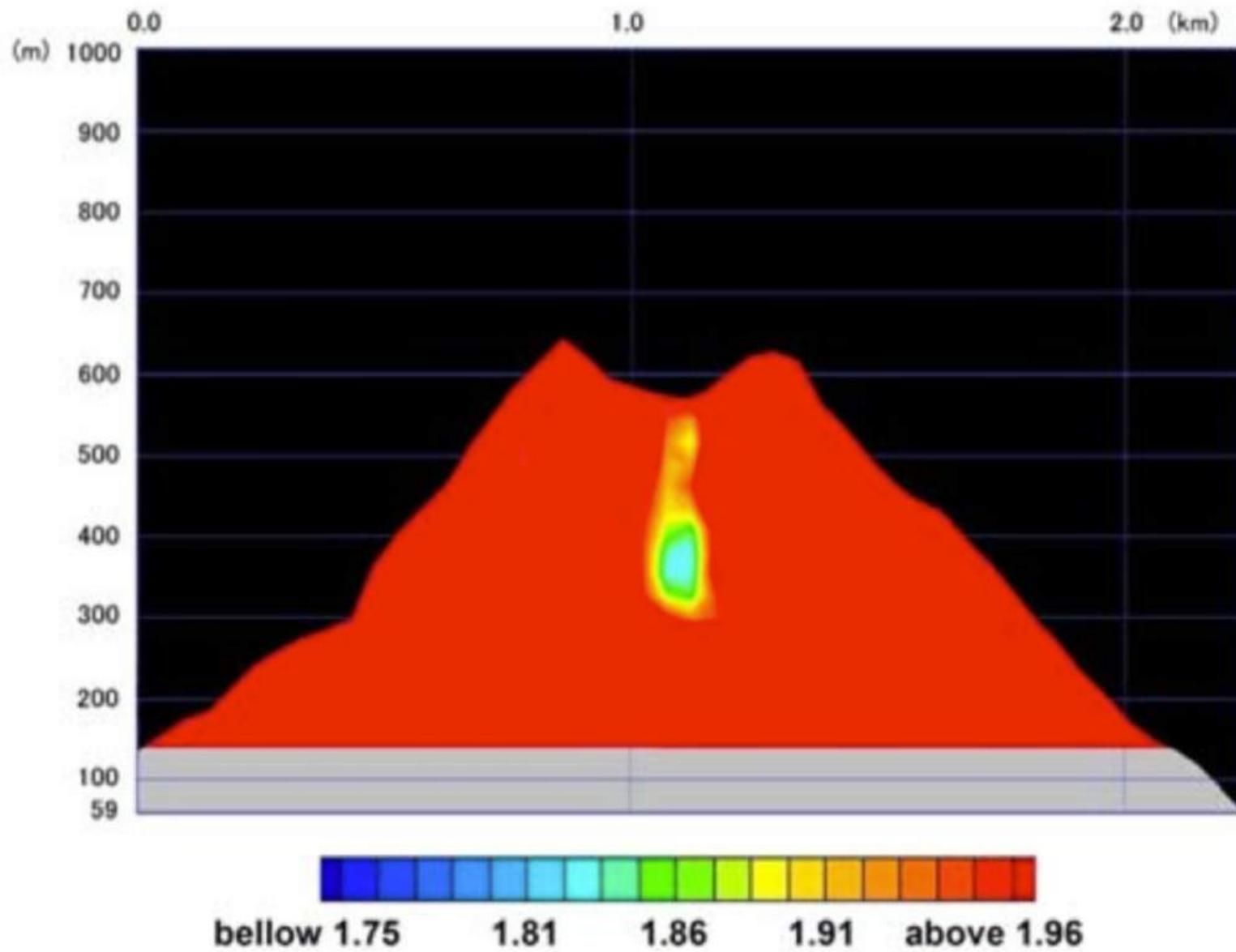
OPEN ENVIRONMENTAL DATA FOR EVERYONE

Safecast is a global volunteer-powered citizen science project working to empower people with data about their environment. We believe that having access to freely available open data is better for everyone. Everything we do is aimed at putting place-based data collection knowledge in the hands of people worldwide.

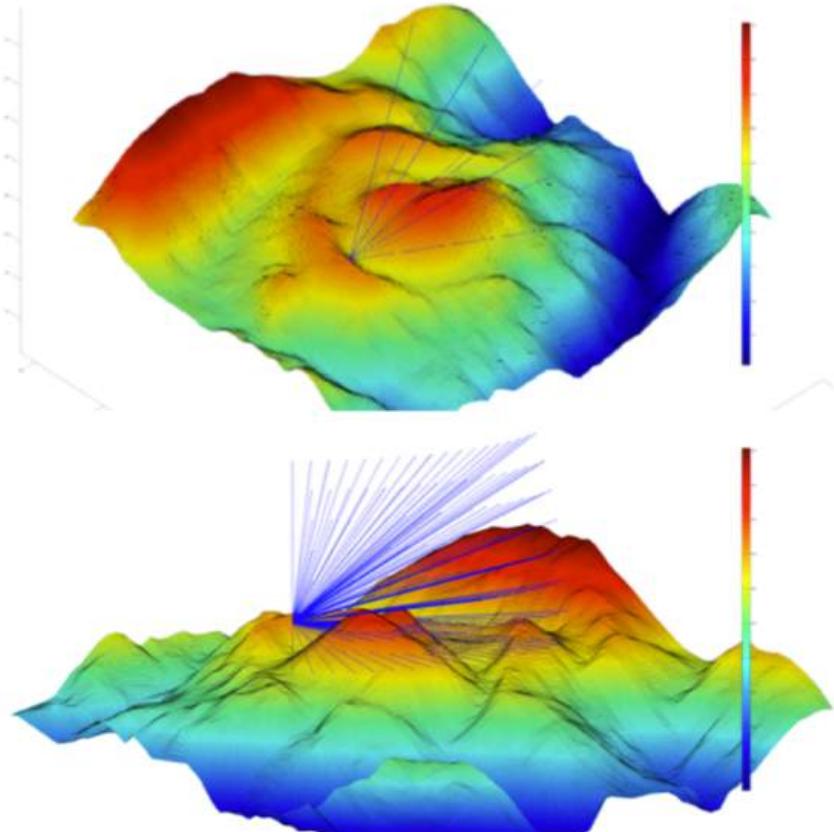
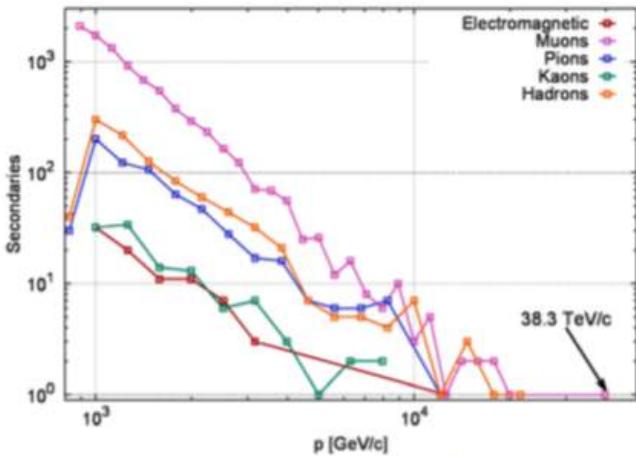


Volcanoes Muongraphy

Tanaka et al., Nature Comms 5 (2014) and refs



Volcanos Muongraphy

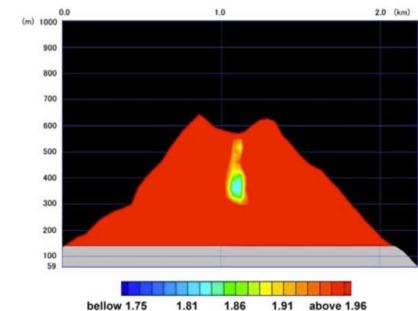


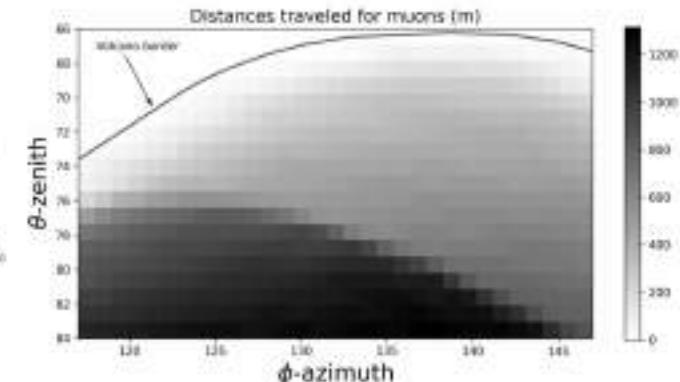
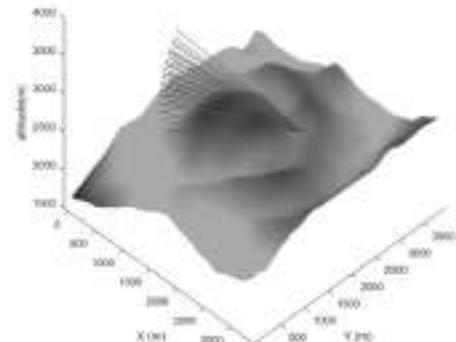
Muongraphy primer

- Muons: Very low stopping power:

$$\left(\frac{dE_\mu}{dX_{\text{std rock}}} \right) \simeq 6 \text{ MeV cm}^{-1}$$

- High energy atmospheric muons can penetrate hundreds of meters of rock
- From the known atmospheric muon flux and measured directional flux across the volcano → rock opacity
- From rock opacity and volcano and detector geometry → internal density profile
- Internal density profile → deep volcanic structures





13 volcanoes analysed Complies: Cerro Machín

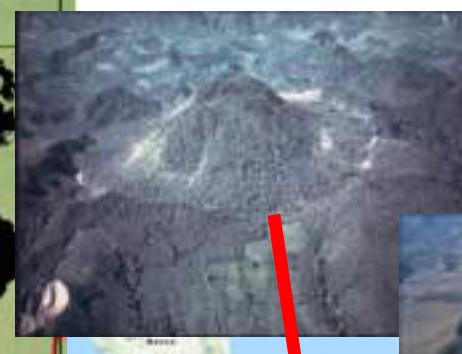
| Volcano | Criterion 1: | Criterion 2: | Criterion 3: |
|---------------------|--------------|--------------|--------------|
| Azufral | N | Y | N |
| Cerro Negro* | Y | Y | N |
| Chiles* | Y | Y | N |
| Cumbal | N | Y | N |
| Dona Juana | N | Y | N |
| Galeras | Y | N | Y |
| Machín | Y | Y | Y |
| Nevado del Huila | N | Y | N |
| Nevado del Ruiz | 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?

Colombian Volcanoes



Cerro Machin Volcano

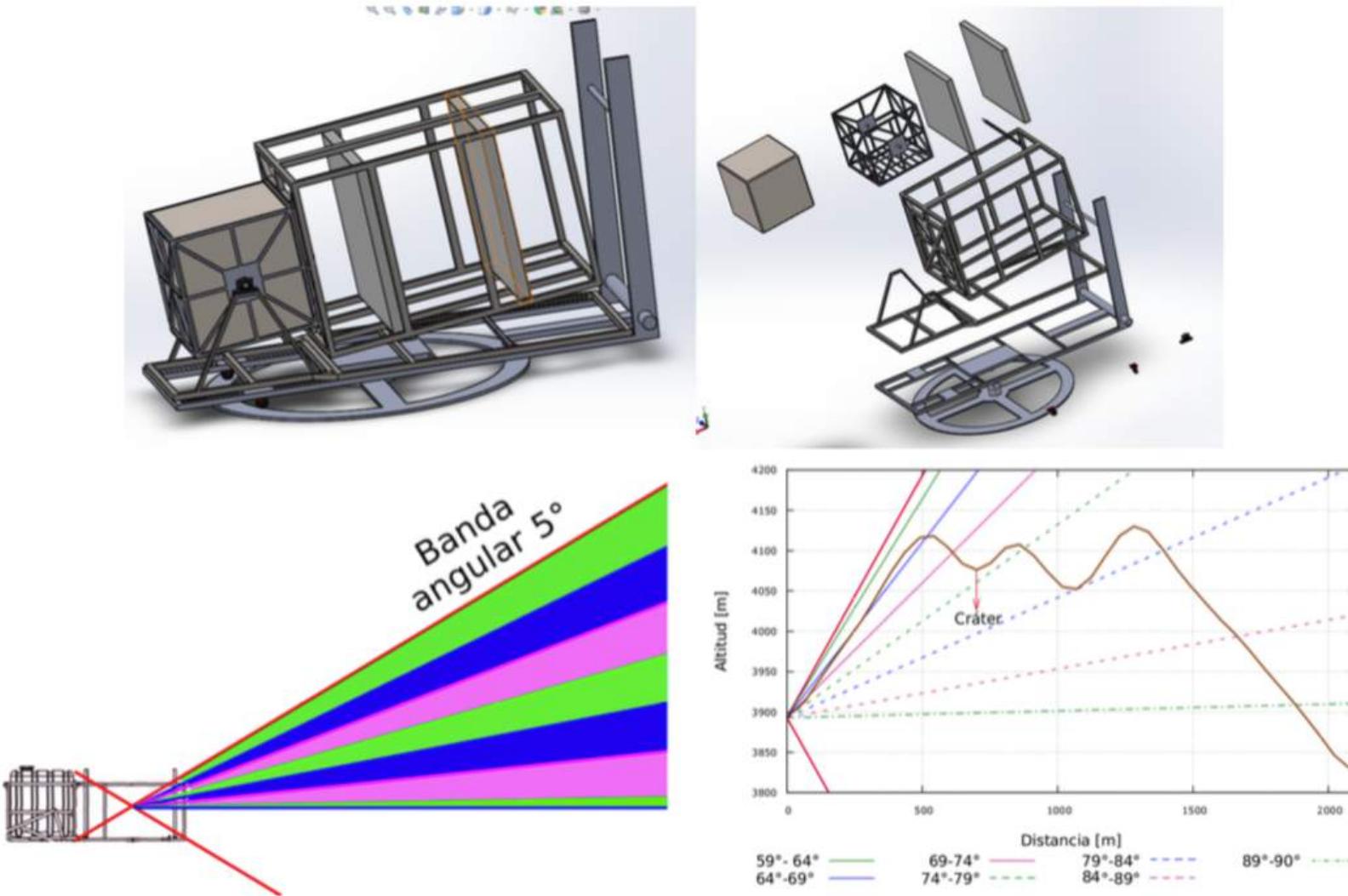


Chichonal or Chichón (Mx)
The most deadly eruption of the century
(1982)

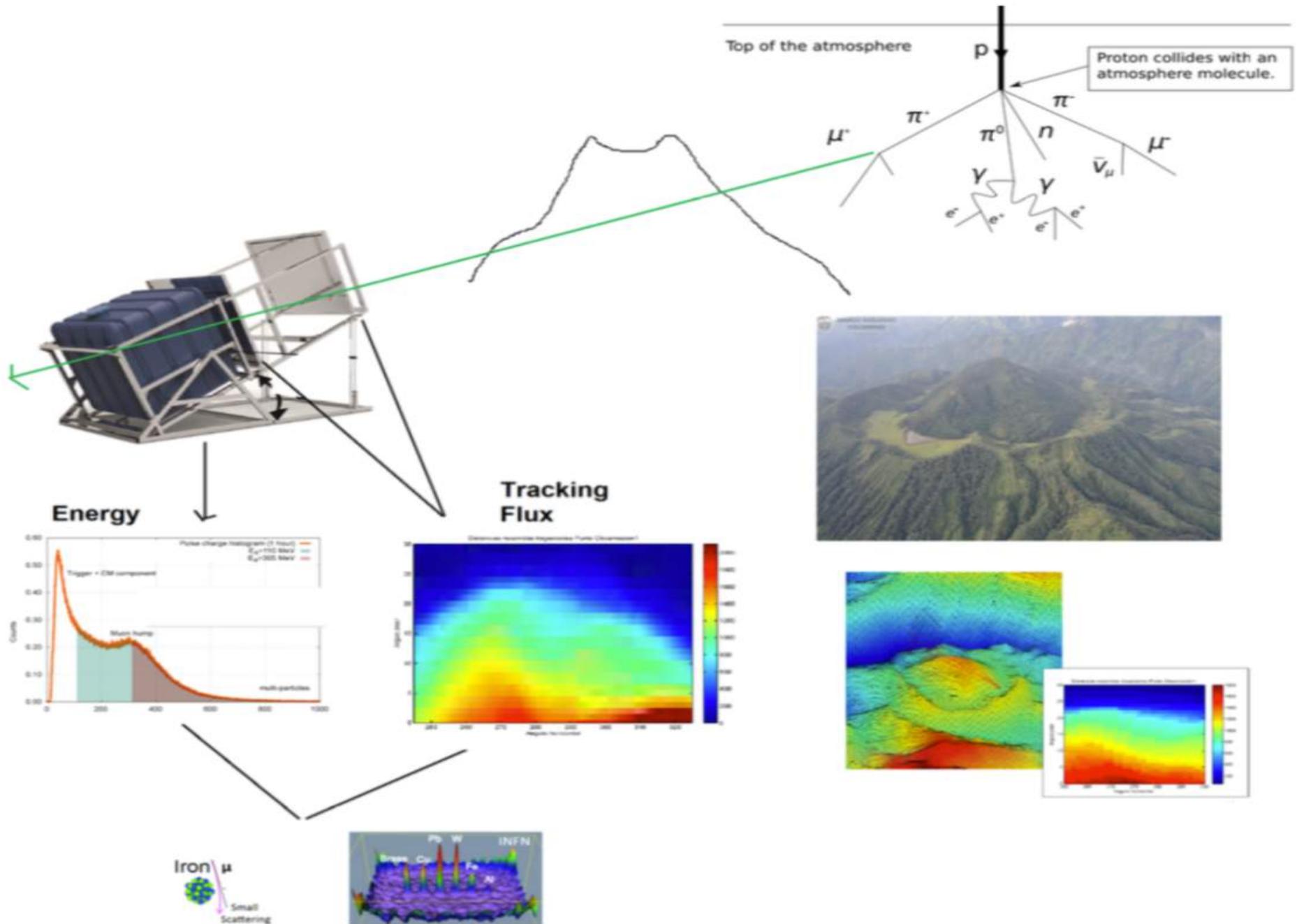


MuTe (Muon Telescope)

(30x30) pixels camera for high precision muon detection

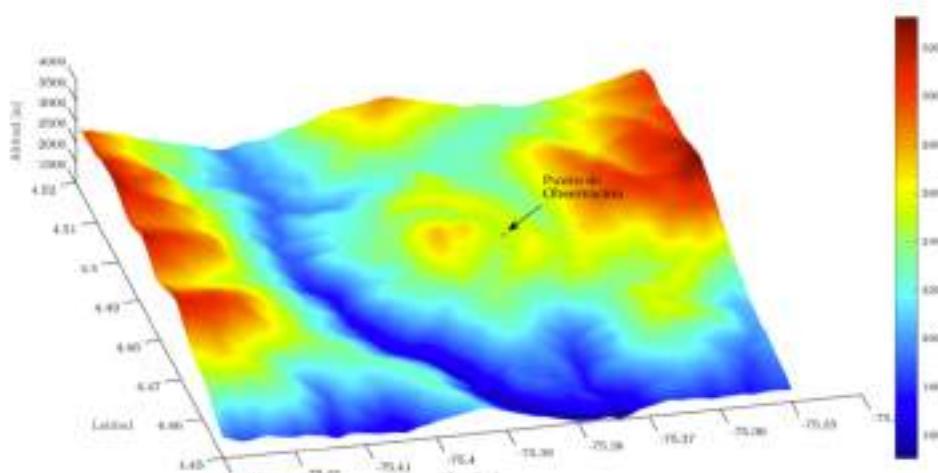


Joint effort from UIS (Col), UT (Col), SGC(Col), CONIDA(Per) and UNAM(Mex)



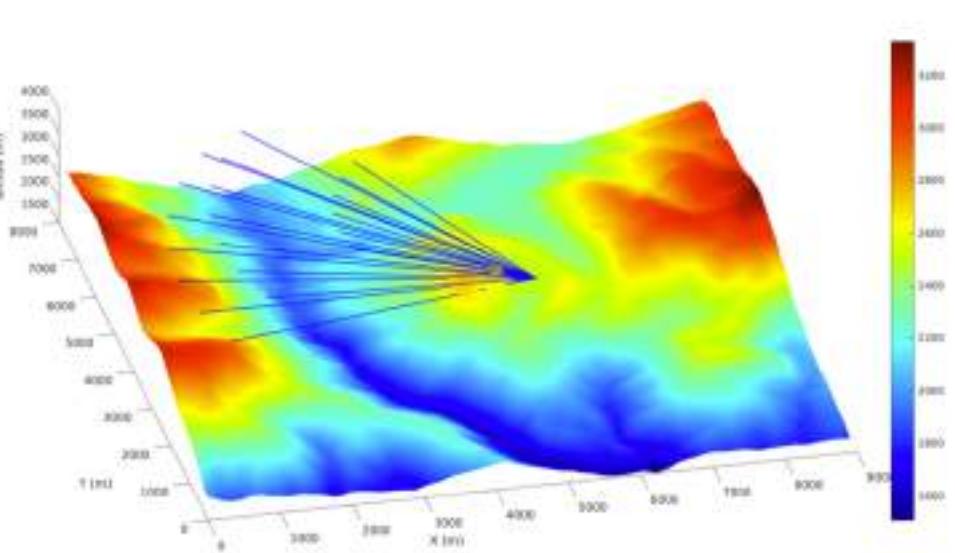
Cosmic Ray Flux → Heliosphere Modulated Flux → Magnetosphere → Signals.
 ... → Primaries → Atmosphere Secondaries → Detector response

Observation points at Cerro Machín

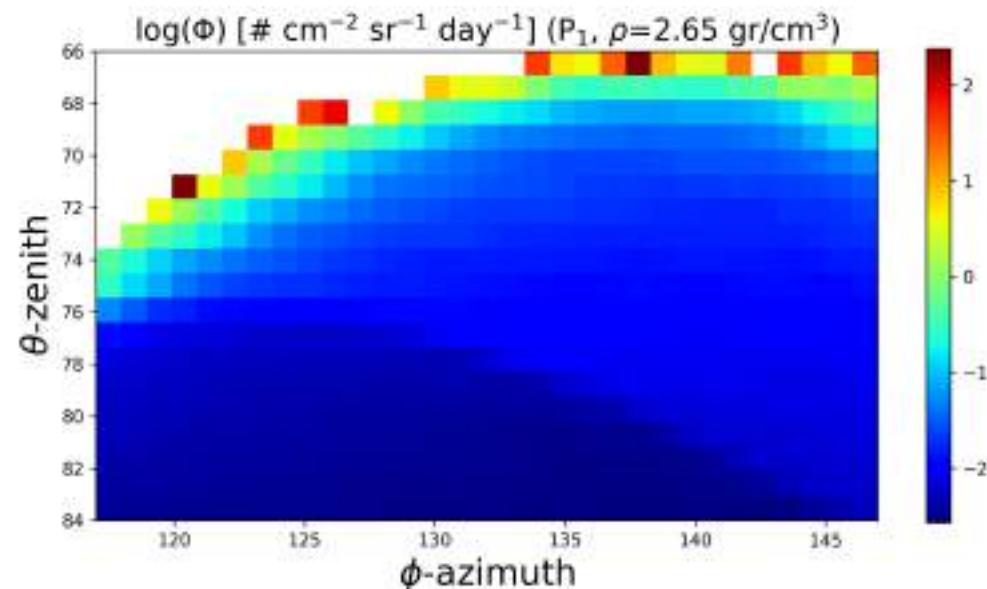


| Cerro Machín points | P ₁ | P ₂ | P ₃ | P ₄ |
|---------------------------------------|----------------|----------------|----------------|----------------|
| Latitude (°N) | 4.492 | 4.491 | 4.493 | 4.494 |
| Longitude (°W) | 75.381 | 75.380 | 75.392 | 75.388 |
| Distance to center of the edifice (m) | 836 | 946 | 762 | 730 |
| Maximum observed depth (m) | 208 | 228 | 250 | 190 |

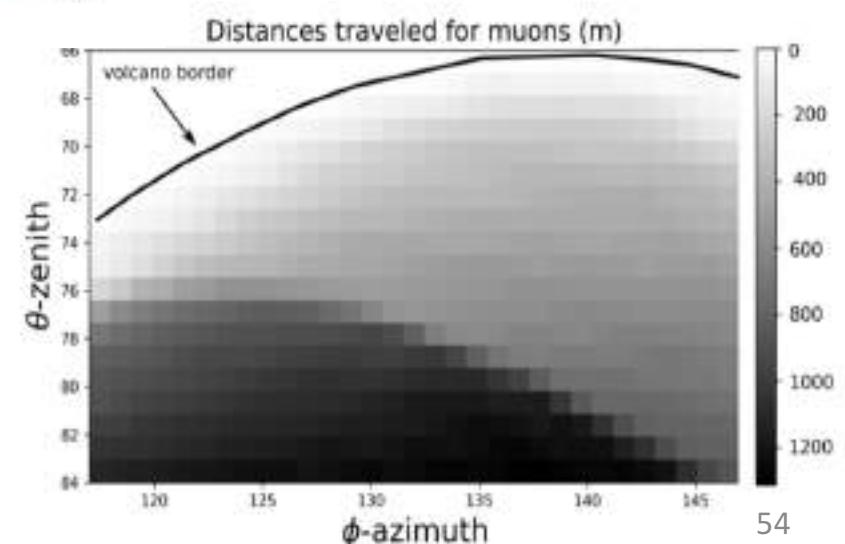
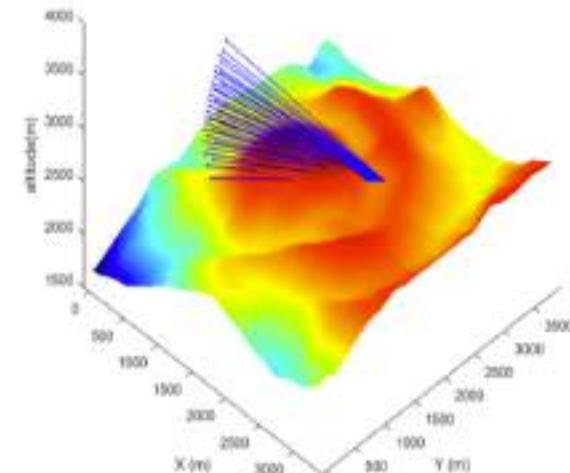
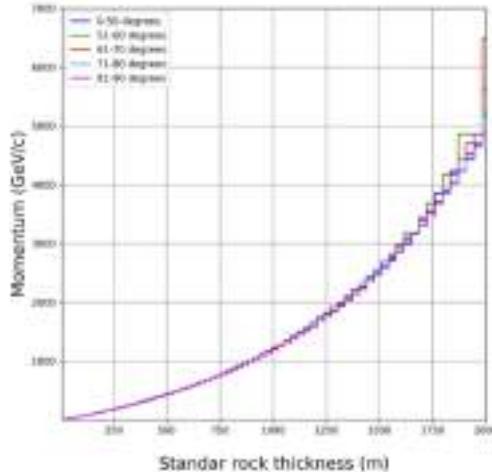
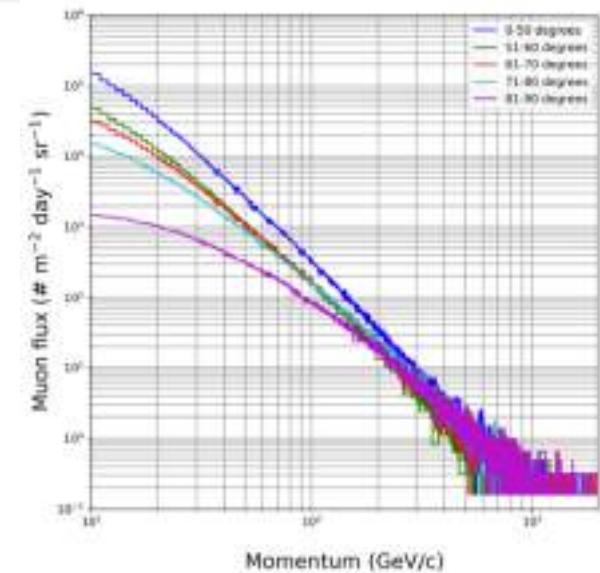
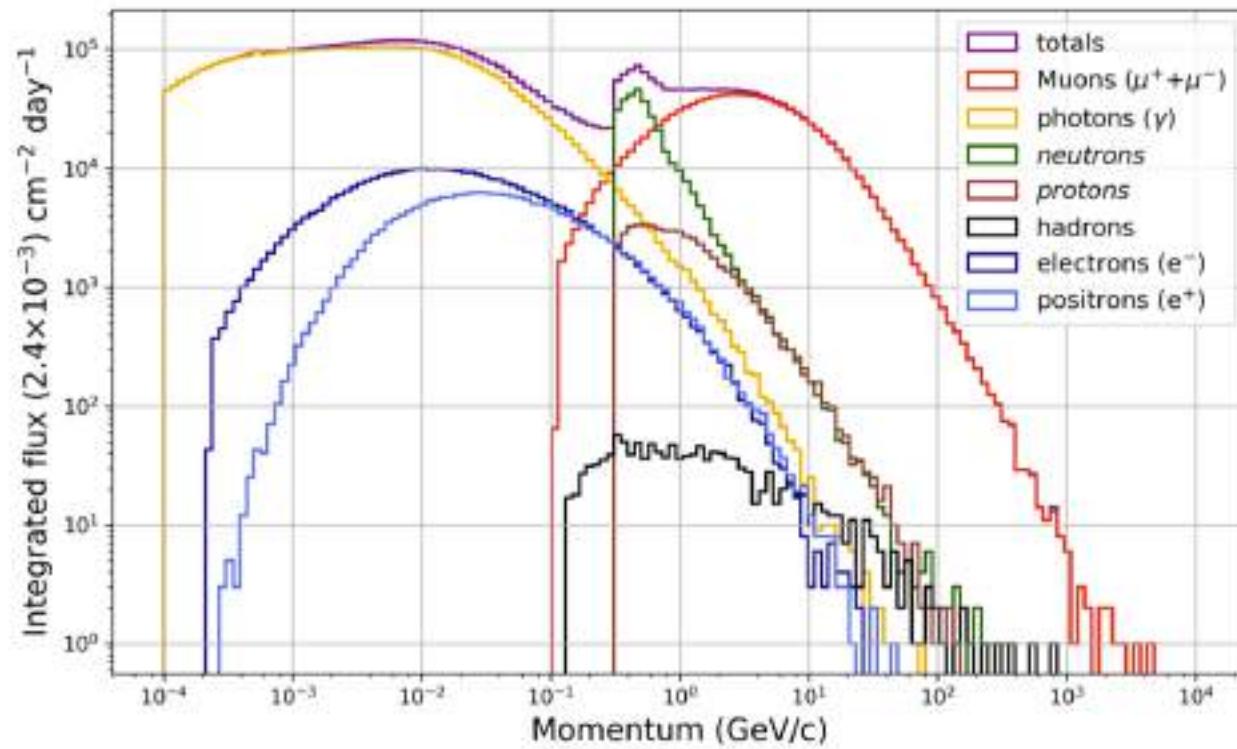
Table 2: Feasible observation points at Cerro Machín volcano ($4^{\circ}29'23.08''\text{N}$, $75^{\circ}23'15.39''\text{W}$) complying with the “thumb criteria” described in section 5.2. The maximum observed depth are those points where the emerging muon flux is less than 10^{-2} muons per cm^2 per day, corresponding to zenith angles $\theta \approx 82^\circ$.



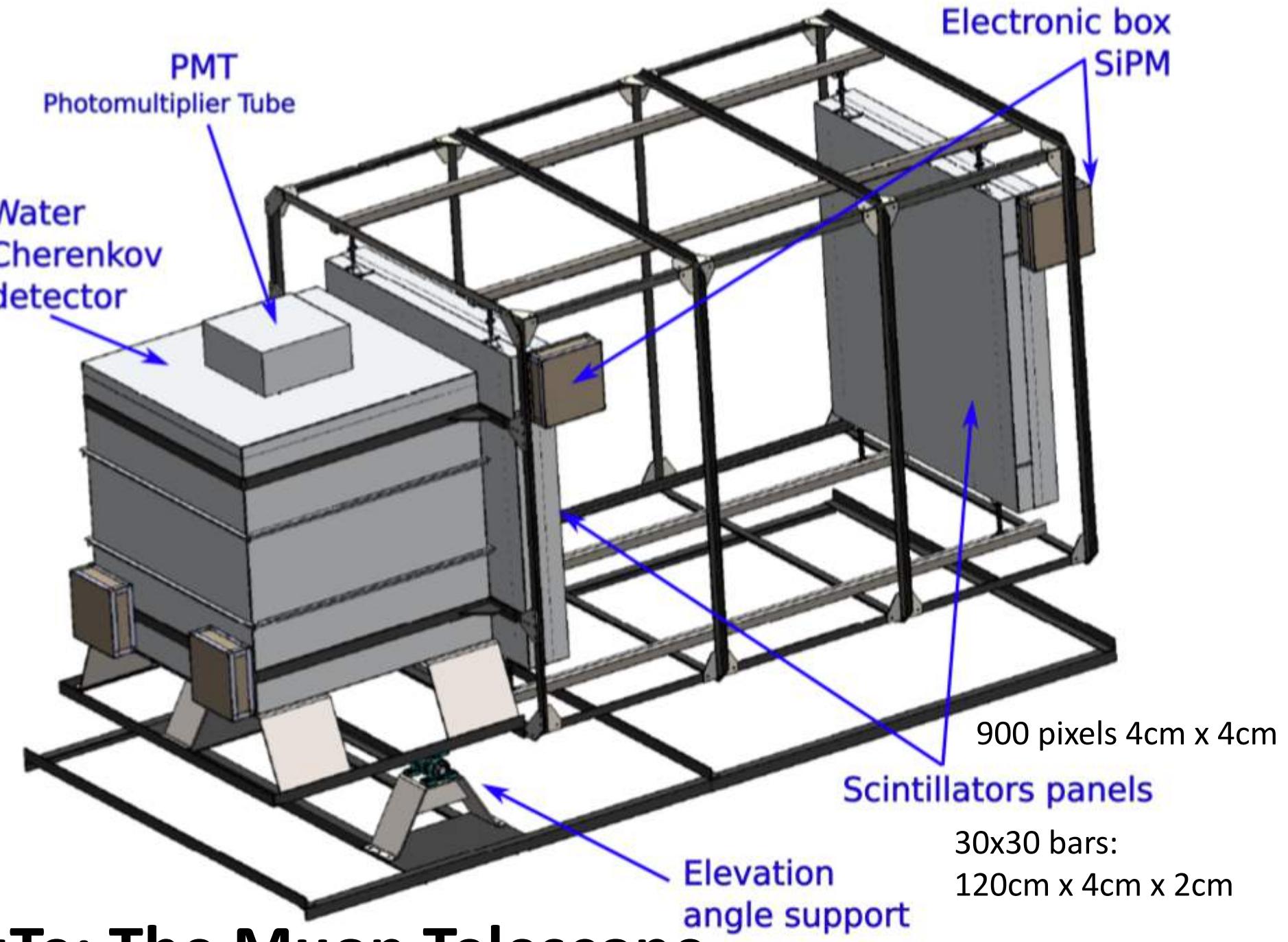
Simulated flux at observation points



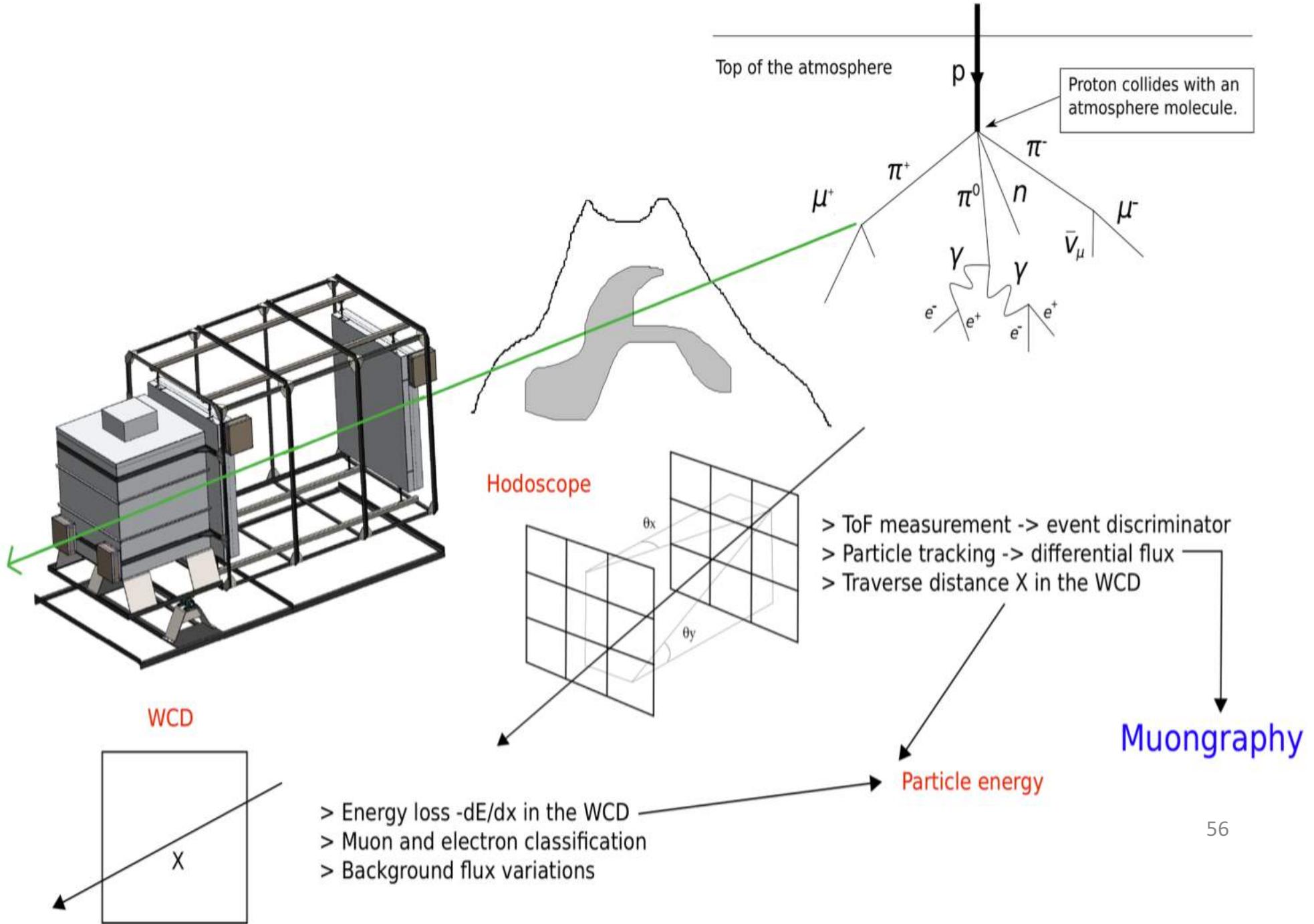
Particle/Muon flux at Cerro Machín



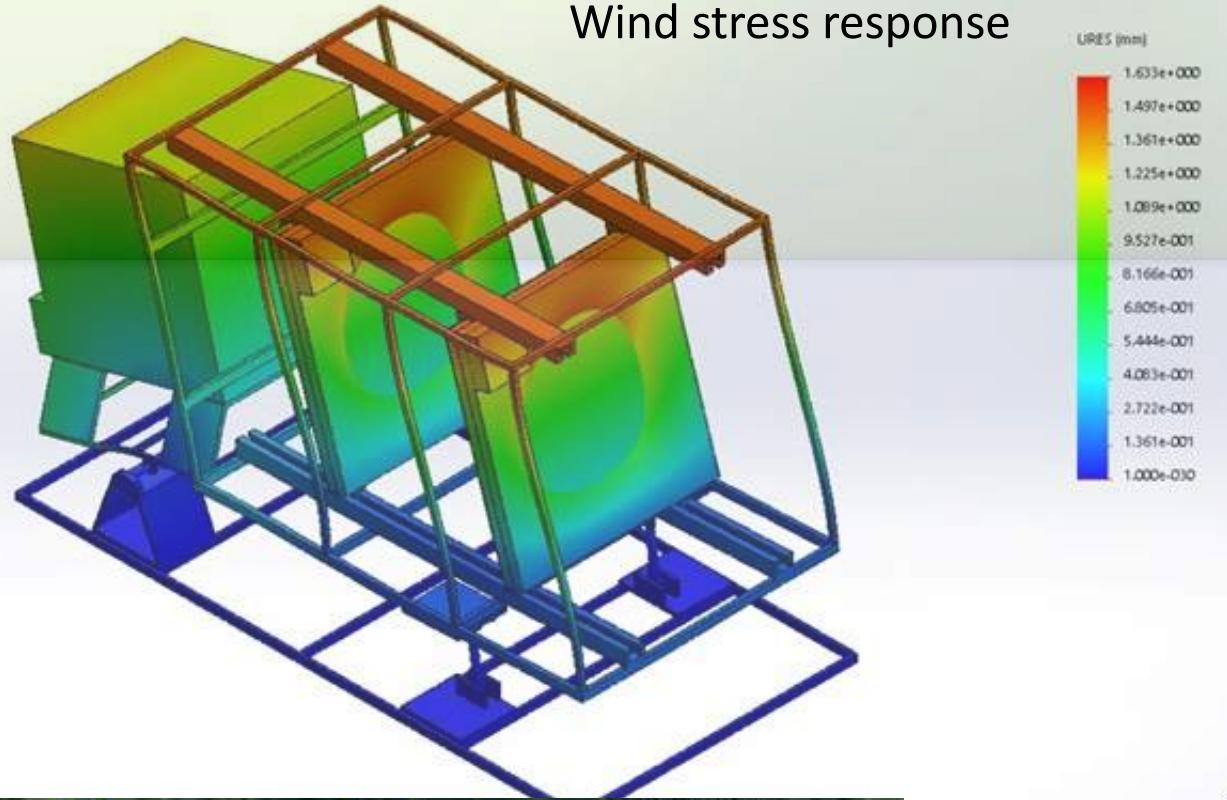
Ray tracing in muon trajectories



MuTe: The Muon Telescope



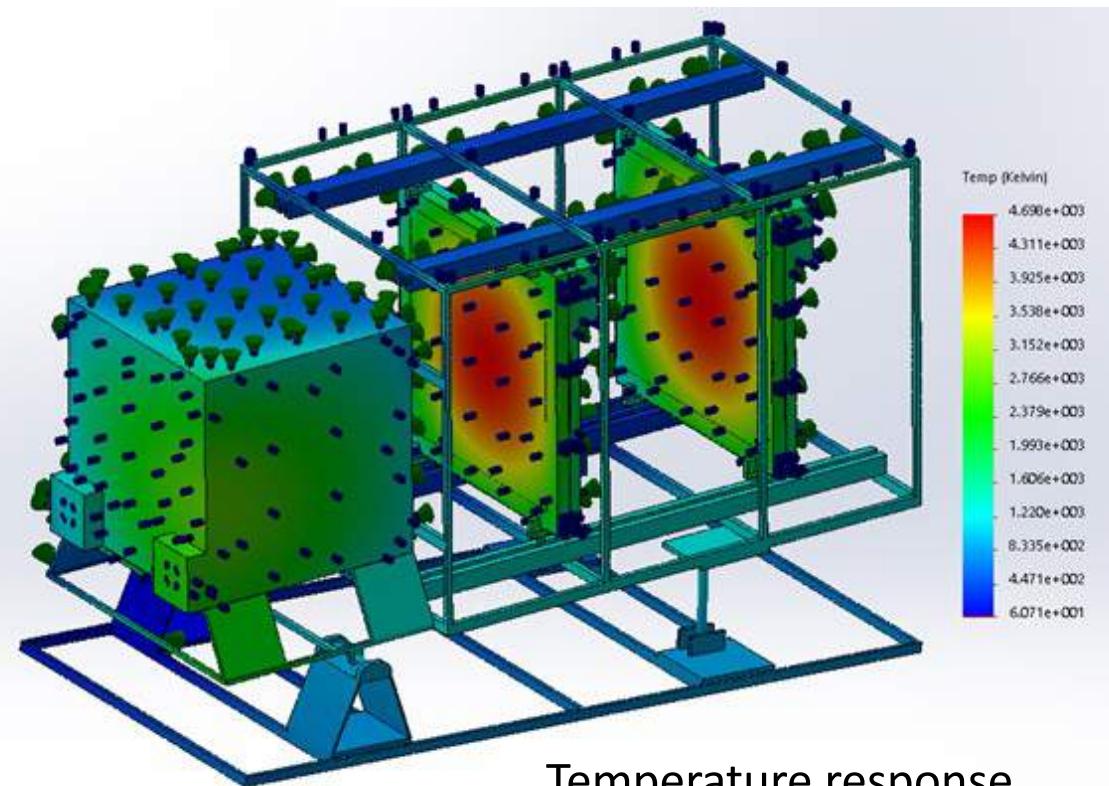
Wind stress response



URE5 (mm)

| |
|------------|
| 1.633e+000 |
| 1.497e+000 |
| 1.361e+000 |
| 1.225e+000 |
| 1.089e+000 |
| 9.527e-001 |
| 8.166e-001 |
| 6.805e-001 |
| 5.444e-001 |
| 4.083e-001 |
| 2.722e-001 |
| 1.361e-001 |
| 1.000e-030 |

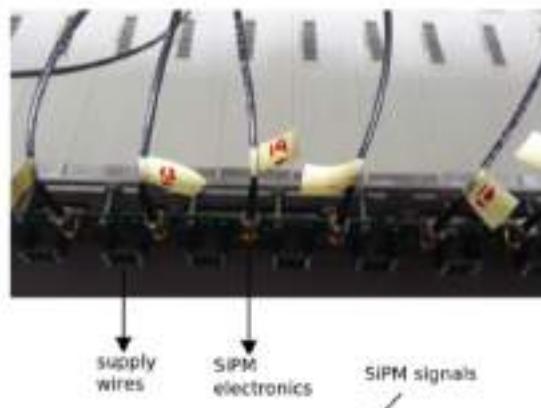
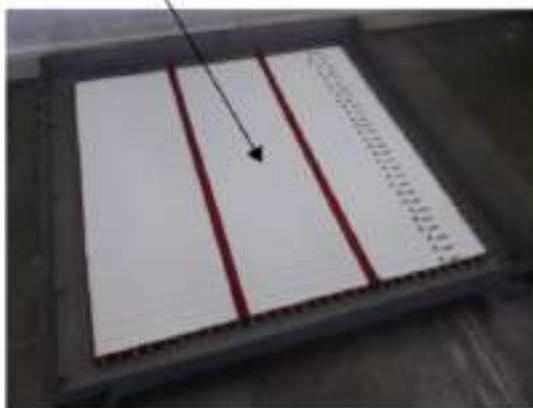
Instrument
To climate variables



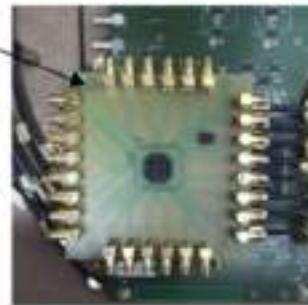
Temperature response

MuTe electronics

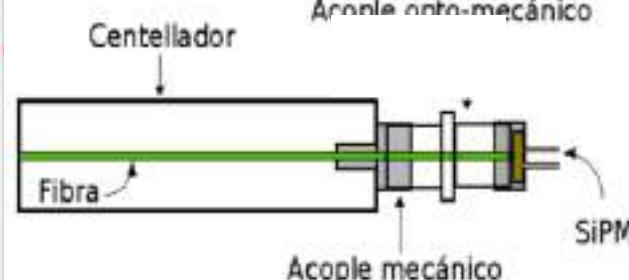
MuTe panel (120cm x 120 cm) 30 x 30 strips



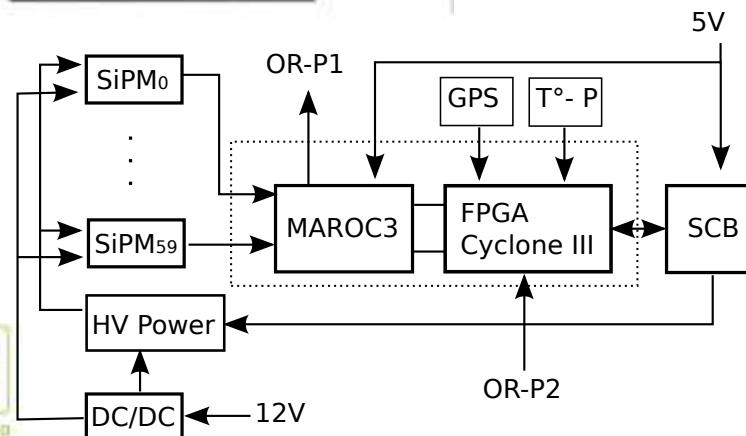
Daughter board (x60)



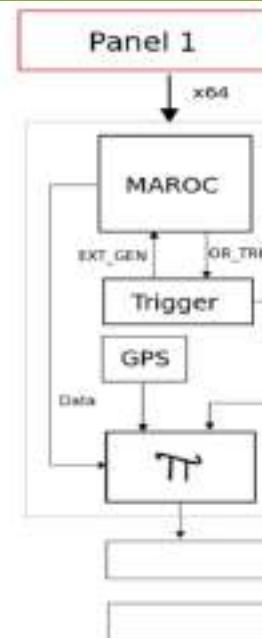
Centellador



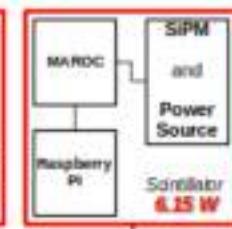
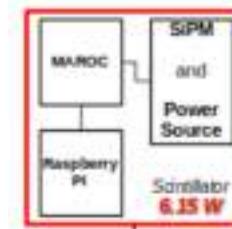
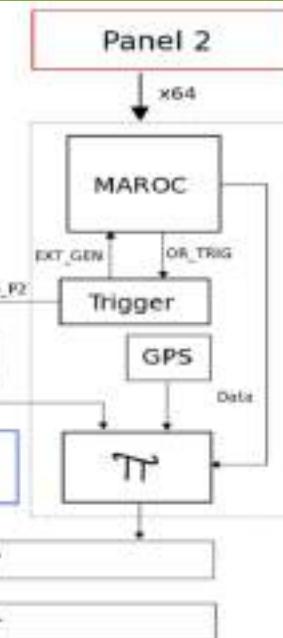
5V

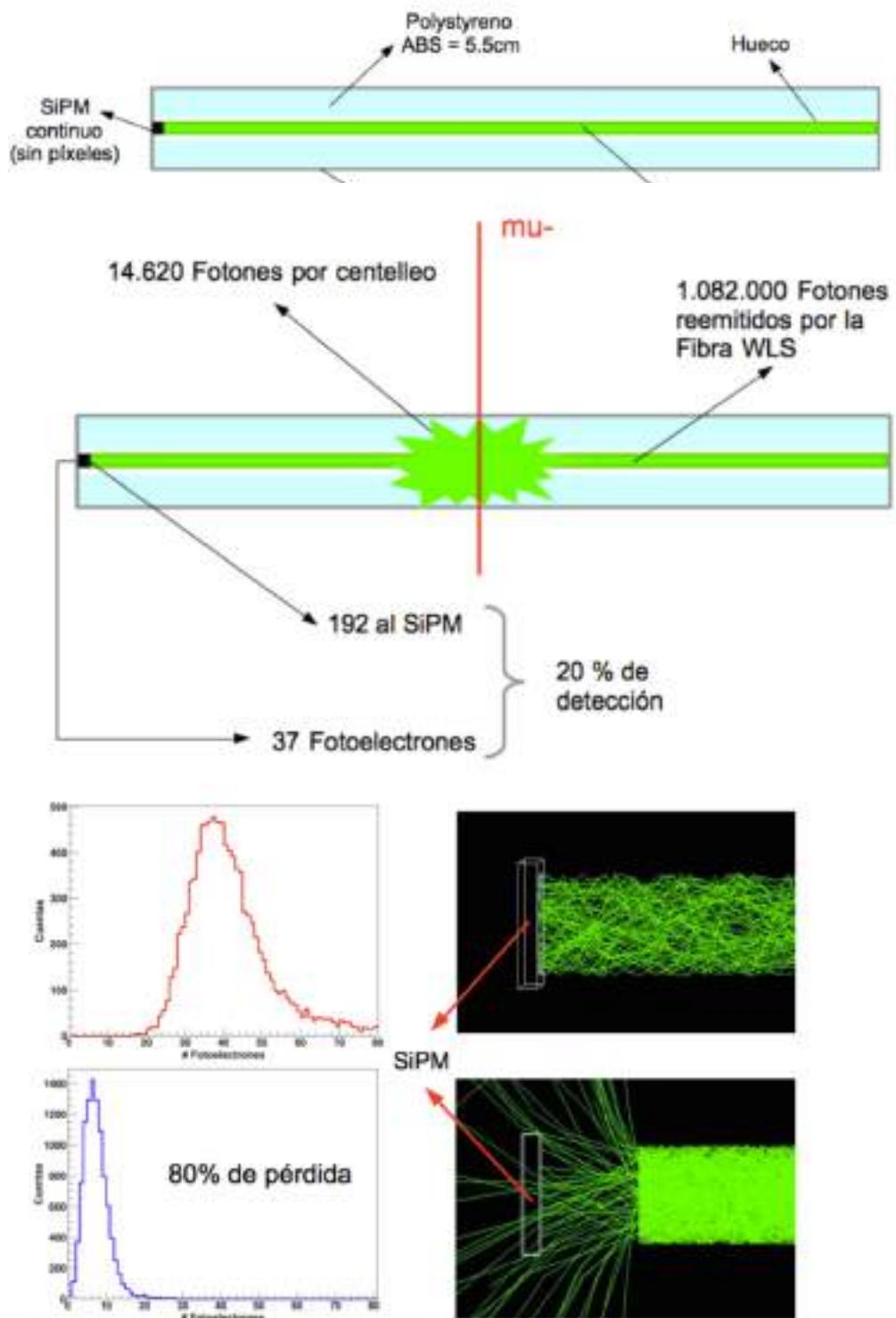


Panel 1

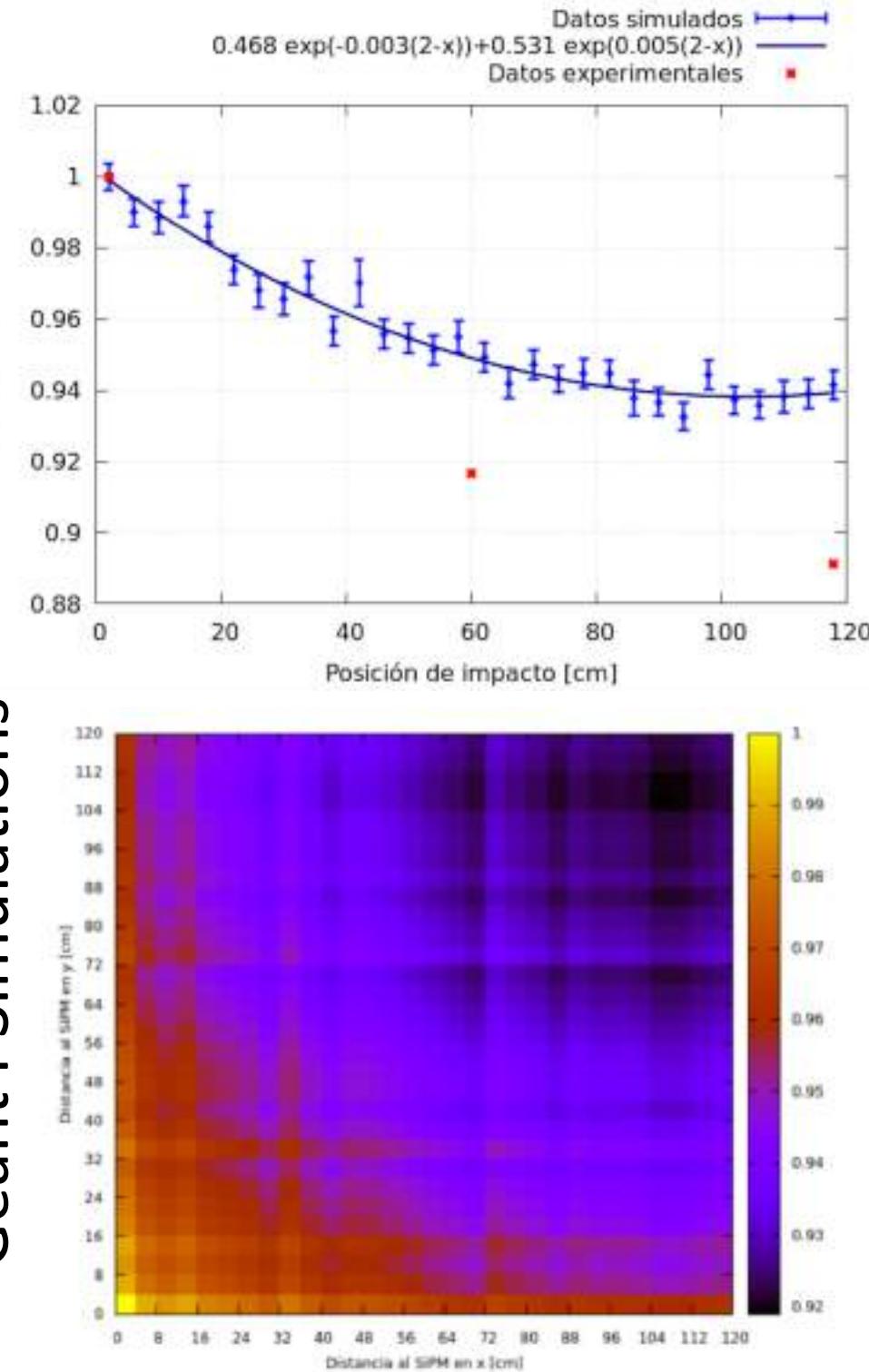


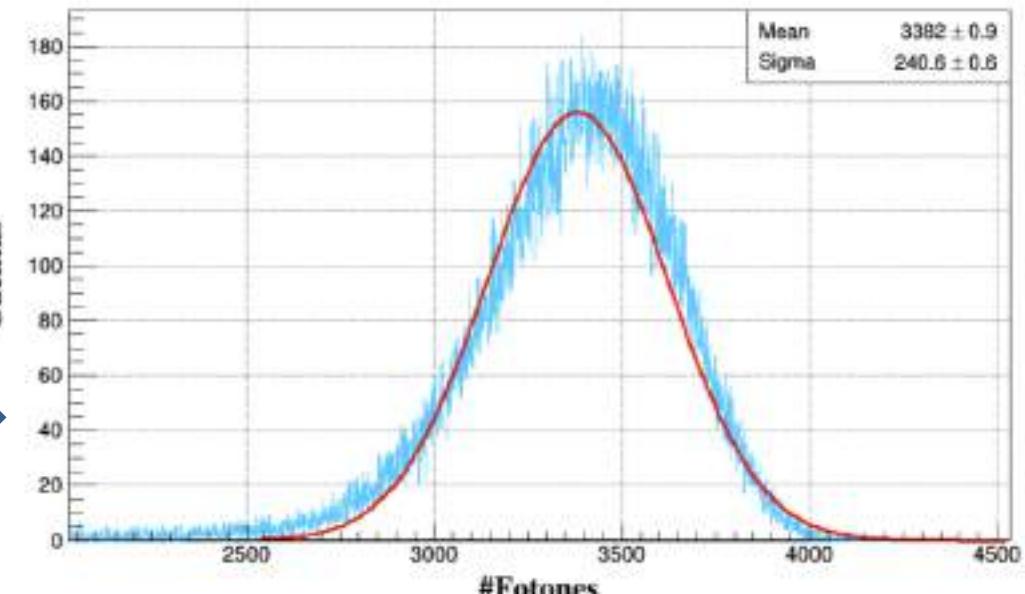
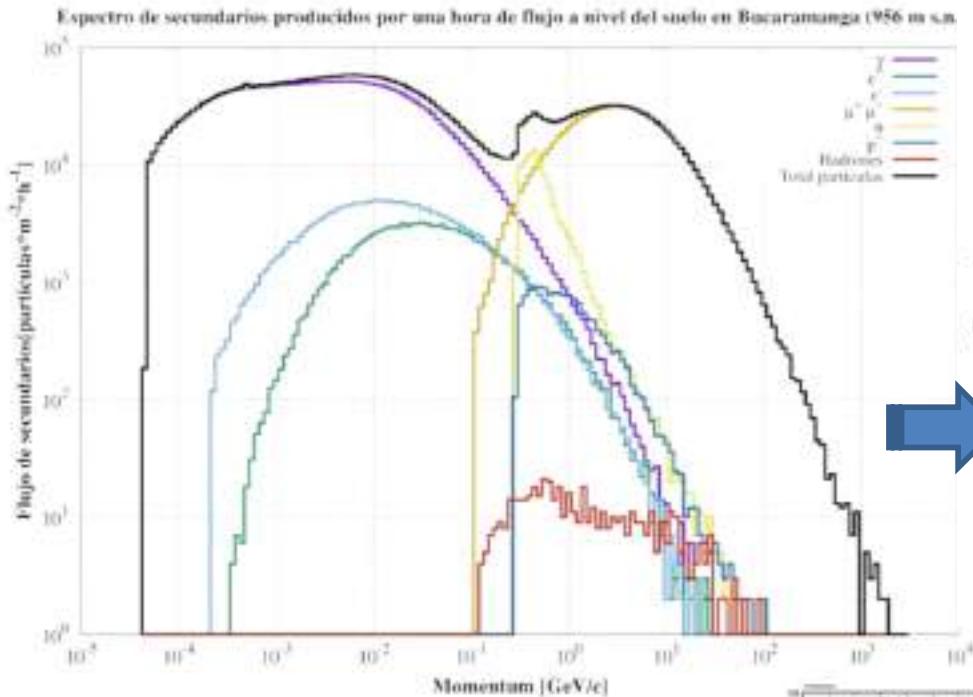
Panel 2





Geant4 Simulations

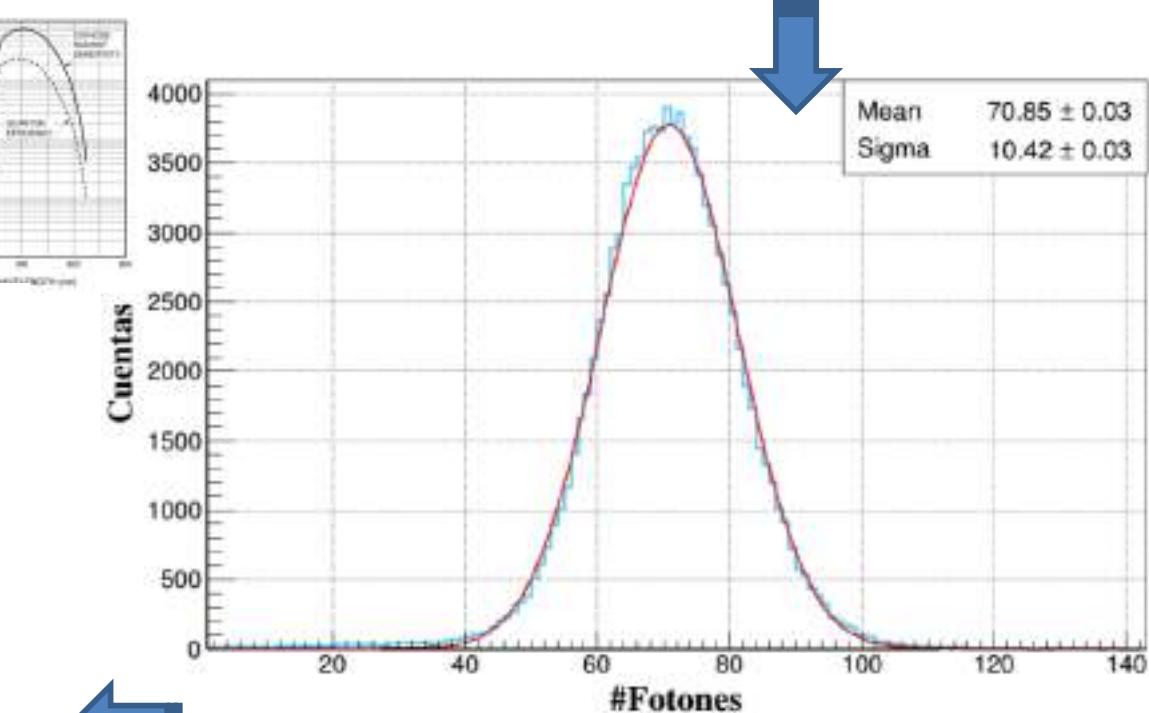
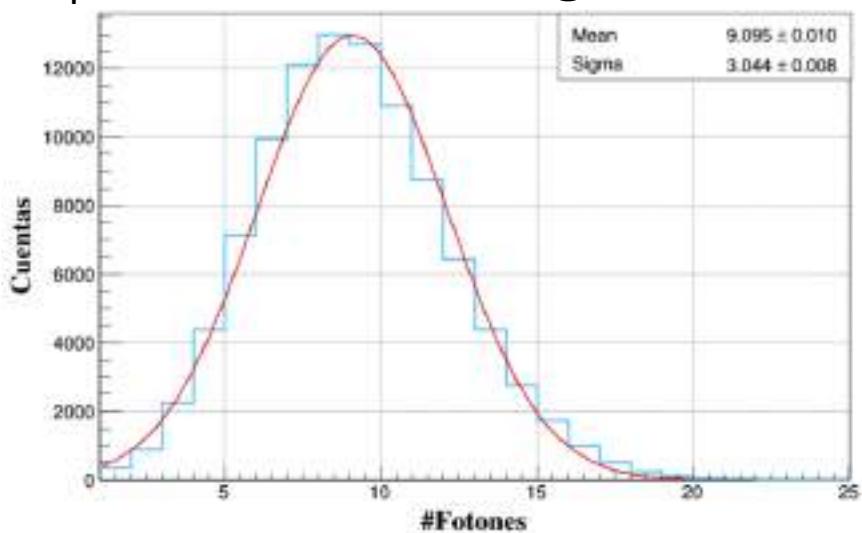




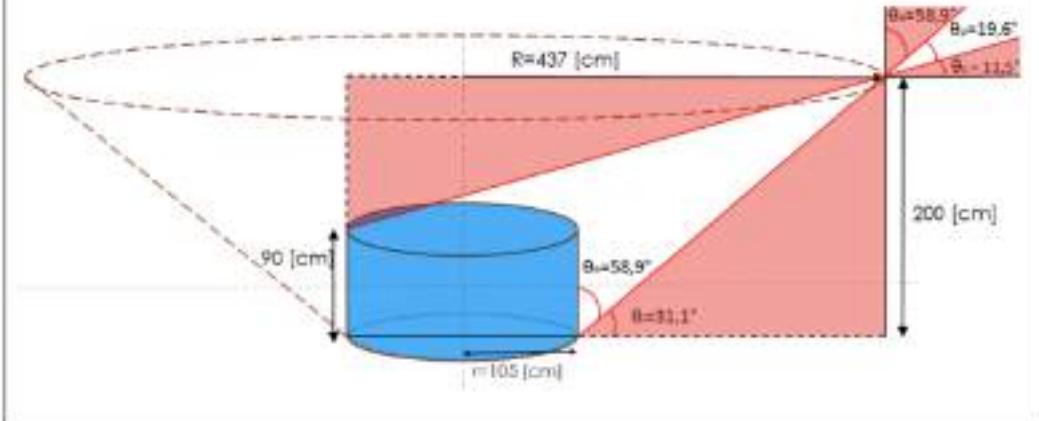
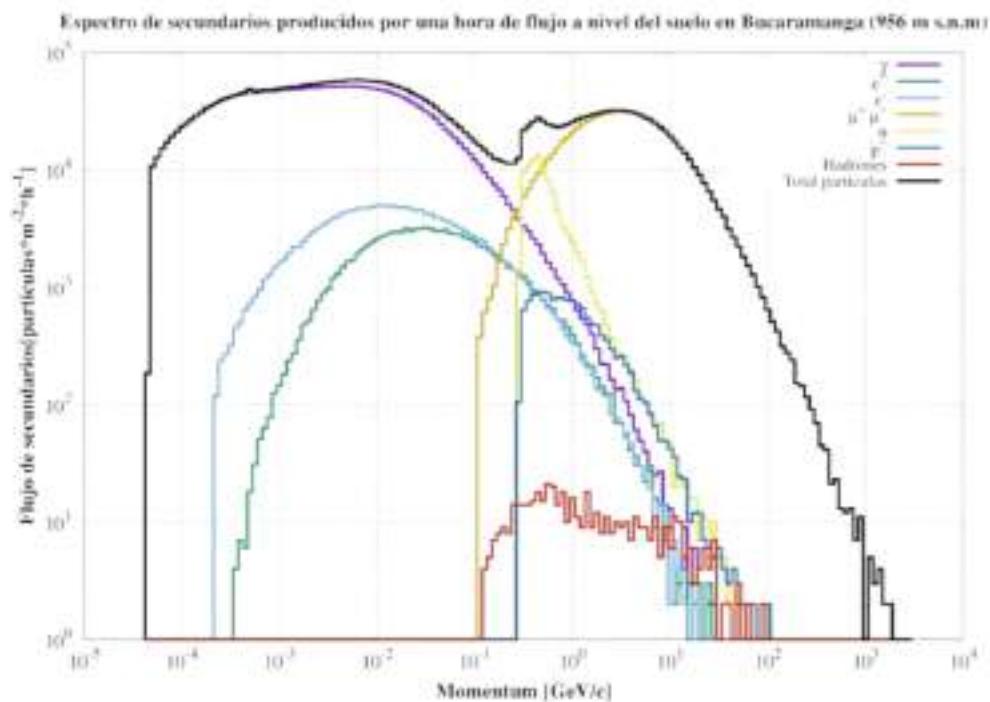
~3382 Cherenkov photons generated by 10^5 e^- 20Mev

Simulations chain for the efficiency of WCD

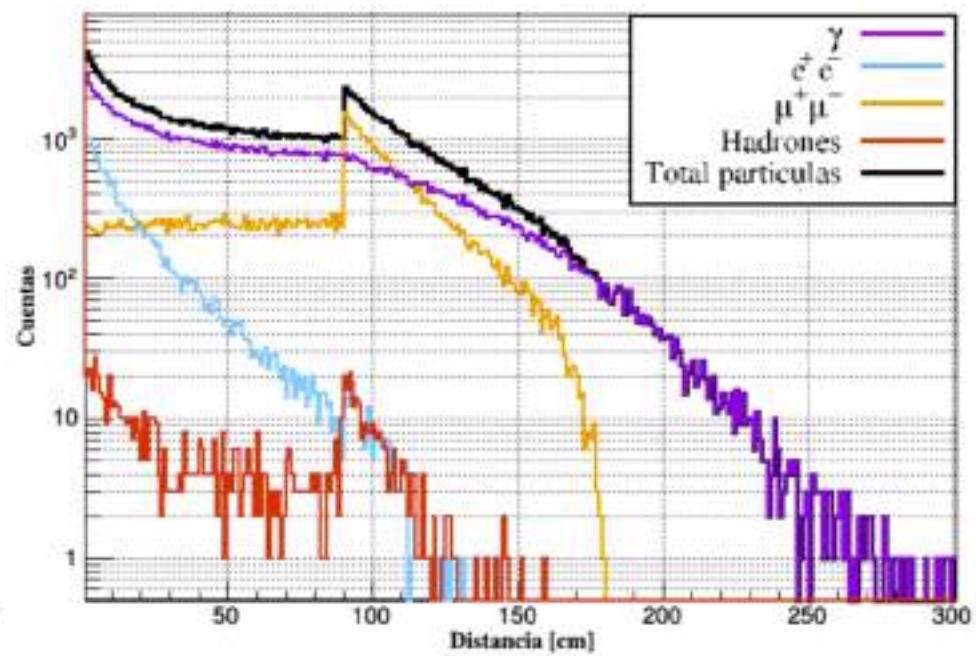
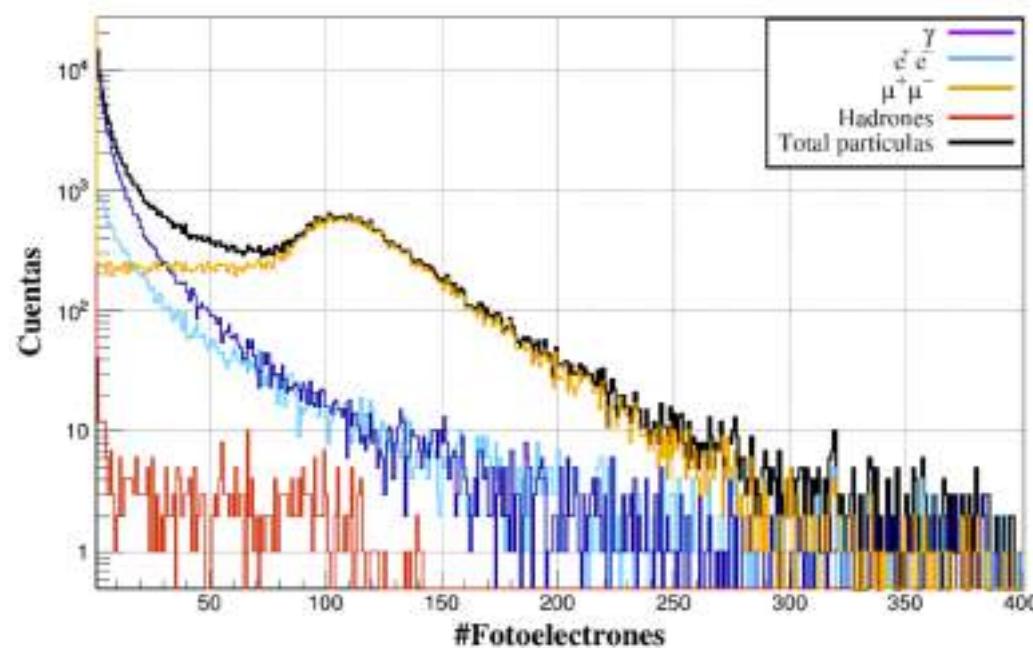
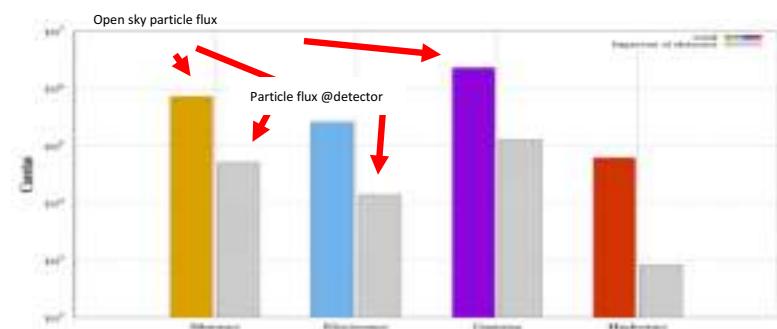
~6 photo-electrons detected @PMT

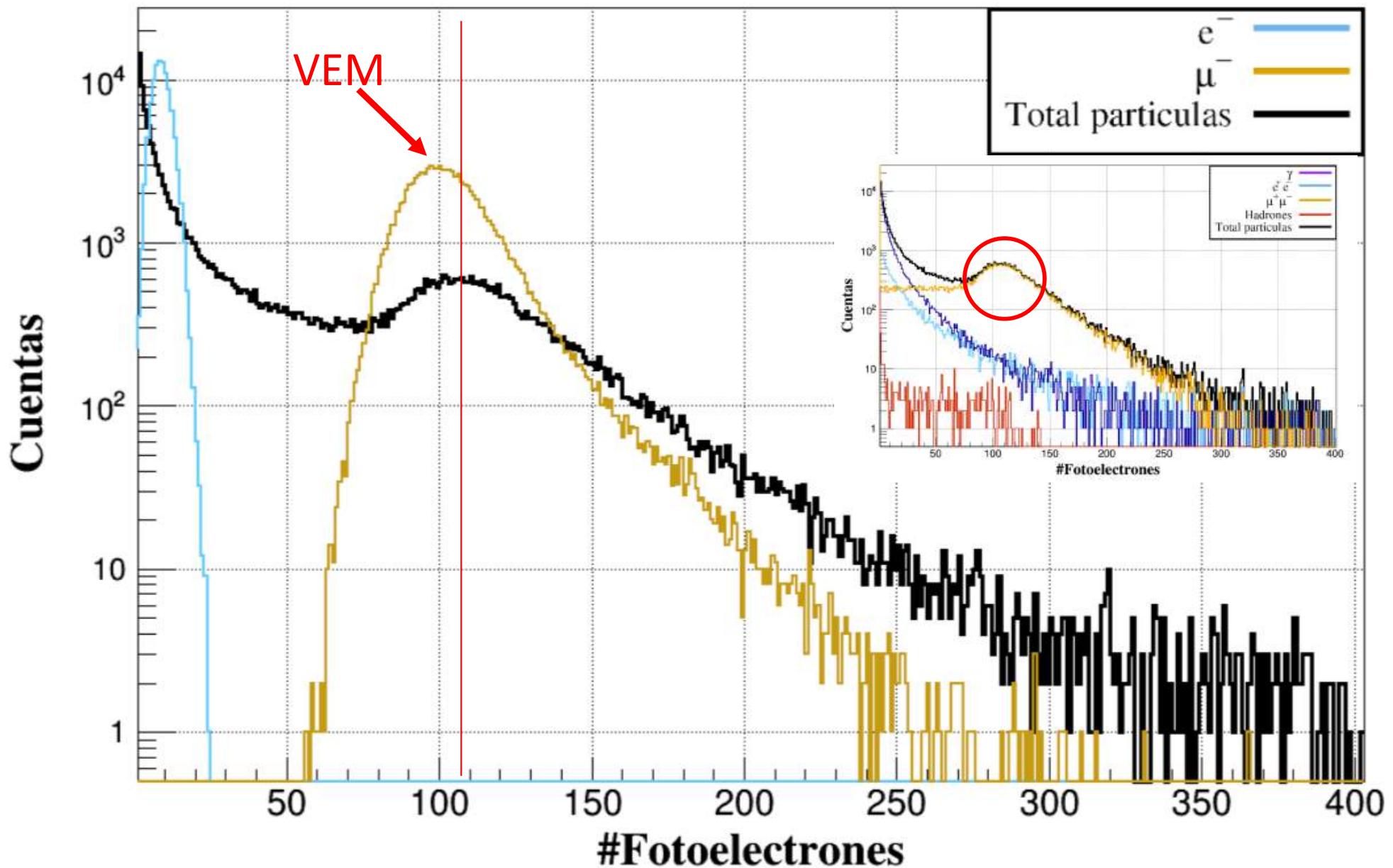


~70 Cherenkov photons impacting PMT

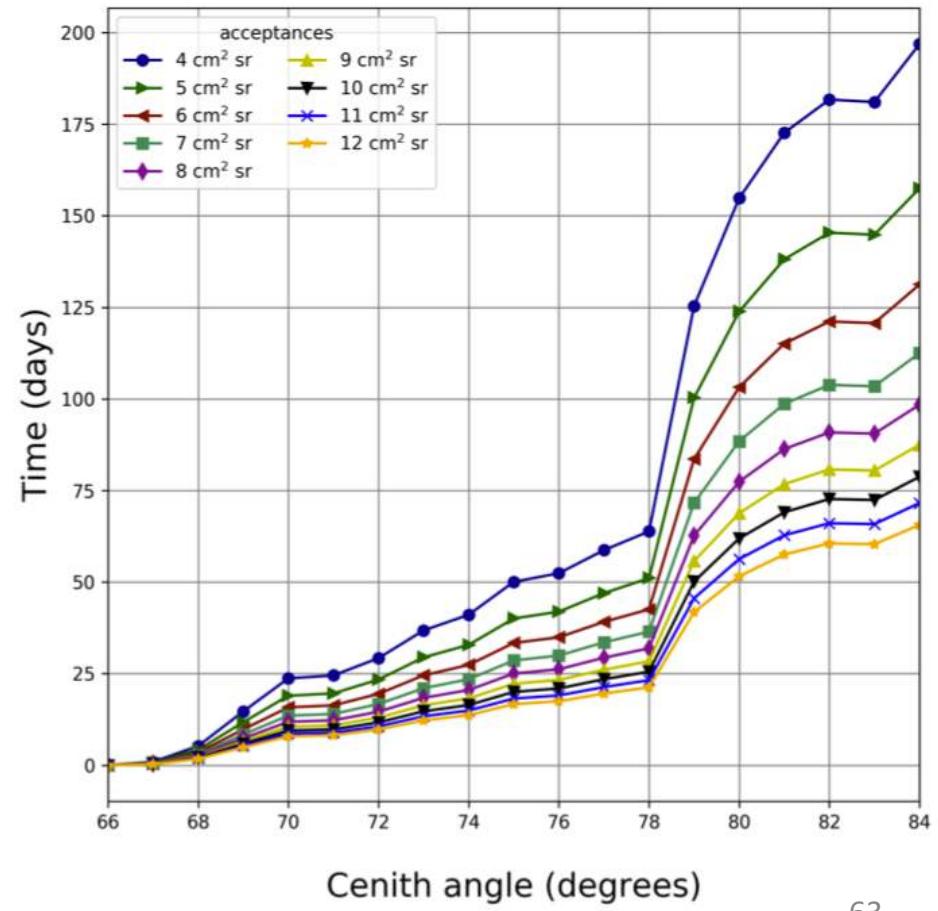
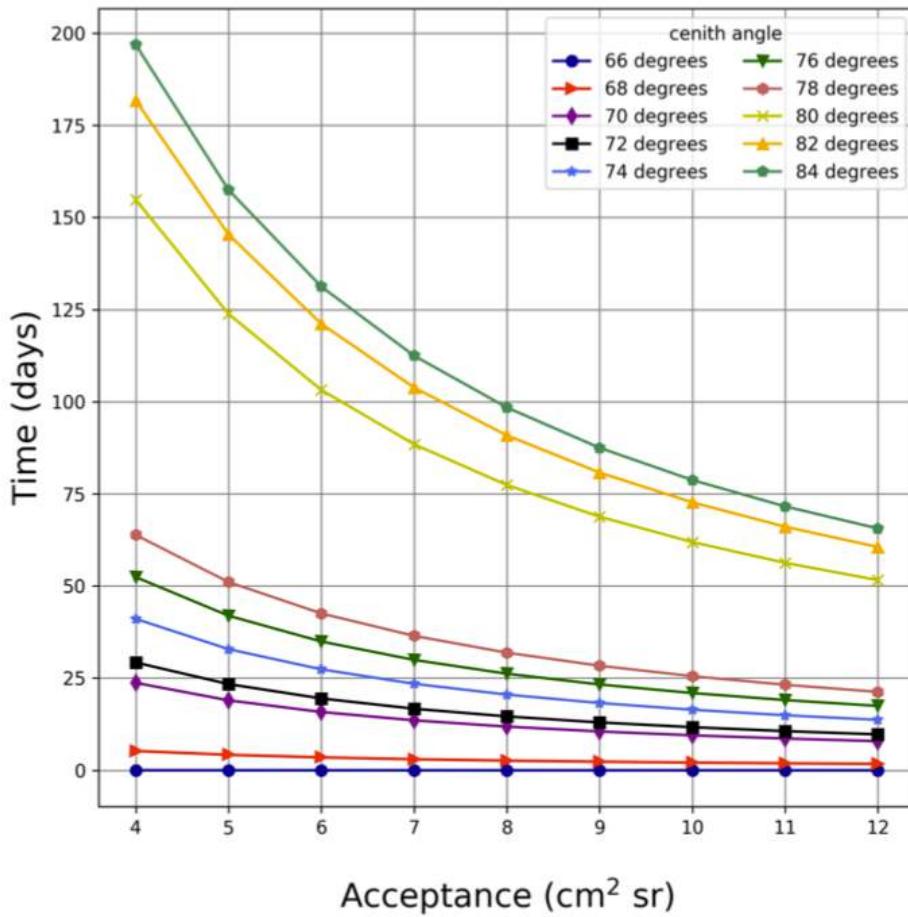


Total particle flux / Total foto-electron simulation





Time exposure for > 1000 events

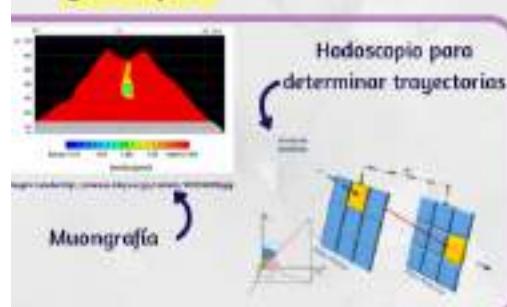


Diseño y construcción de un hodoscopio portátil de 9 pixeles para la caracterización de estructuras a partir del flujo de rayos cósmicos

H. Asorey[1], L. A. Núñez[2], K. J. Forero-Gutiérrez[3], J. L. Salamanca-Coy[3], J. Peña-Rodríguez[2].

[1] CIRQ, Universidad Industrial de Santander, Bucaramanga Colombia.

[2] IIEA, M. Centro Atómico Bariloche, C.C. de Bariloche, Argentina. [3] Escuela de Física, Universidad Industrial de Santander, [3] EDF, Universidad Industrial de Santander.

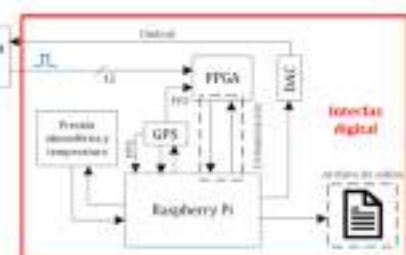
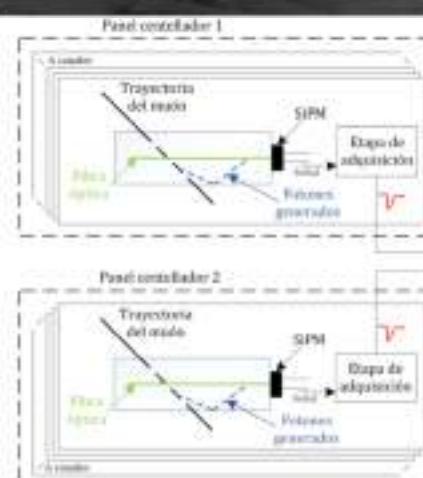
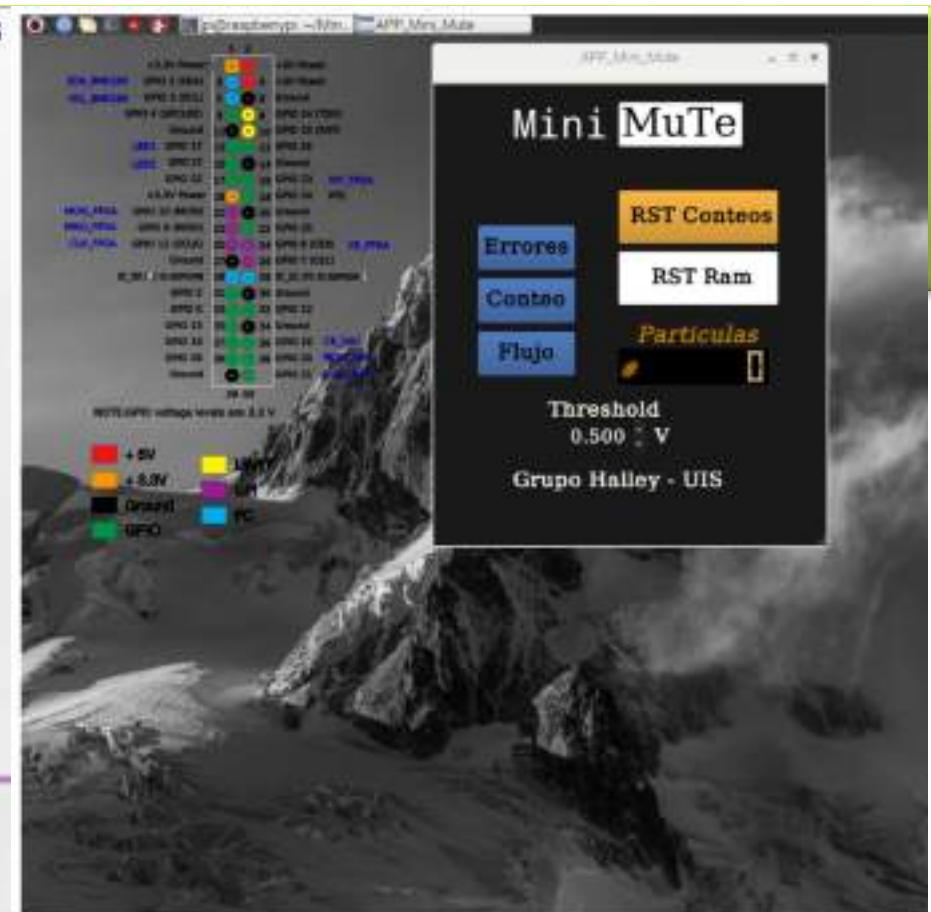


Resultados



Siguientes pasos

- Consolidar estructura mecánica para facilitar su transporte
- Validar instrumento con simulaciones
- Realizar muongrafía con el instrumento
- Estudiar comportamiento del instrumento en campo



Portable Hodoscope with local electronics

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

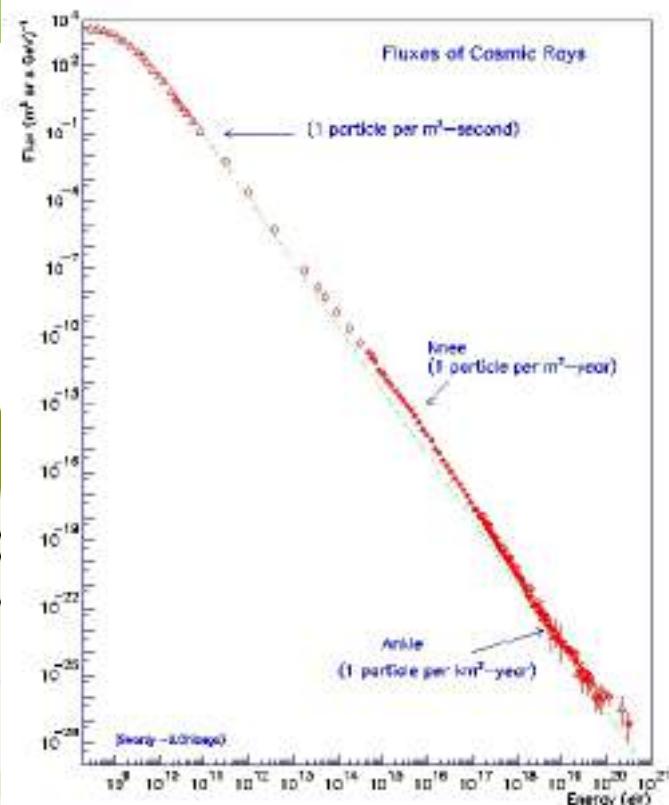
J. Abraham et al., NIM A523:1-2(2004)50



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

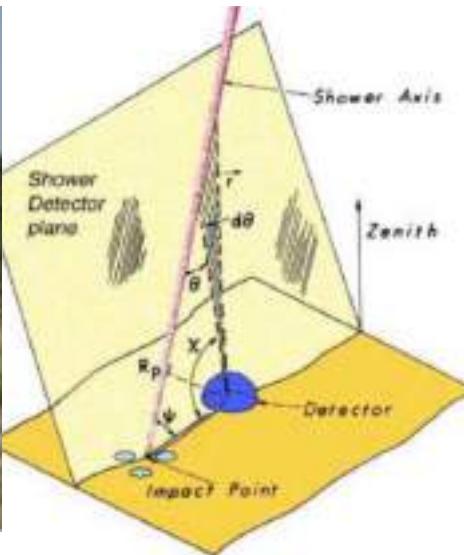
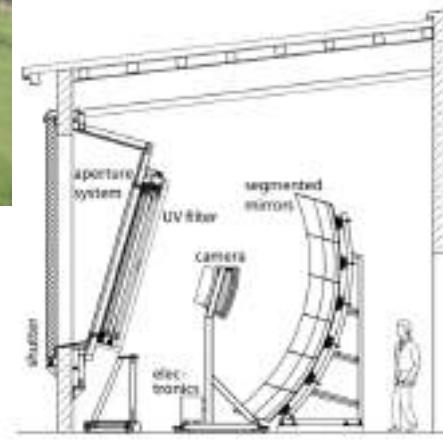
Location

- Pampas, Argentina
- 69.3°S
- 1400 m a.s.l.
- 3000 km² of surface



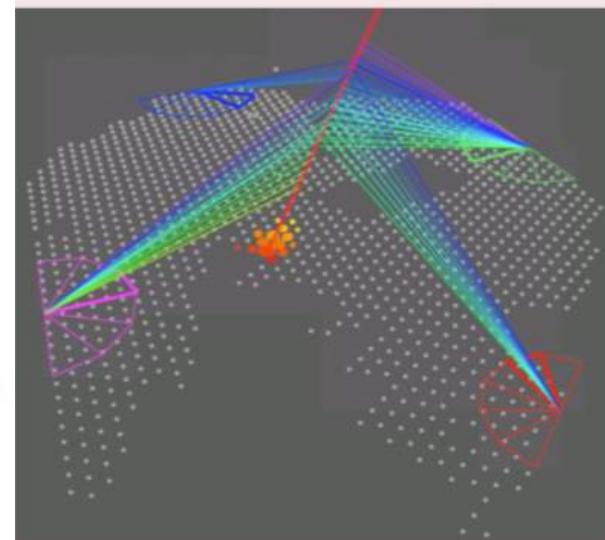
The Pierre Auger Observatory

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**



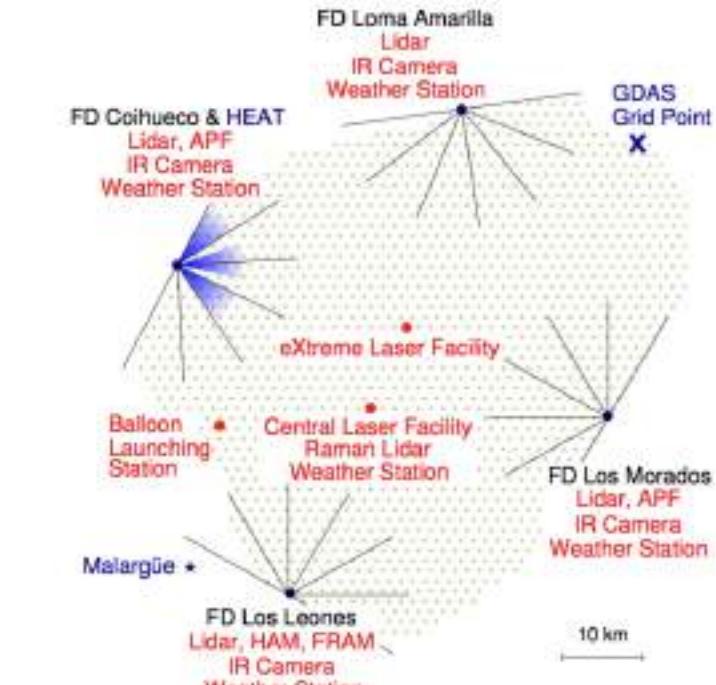
Surface detector: SD

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

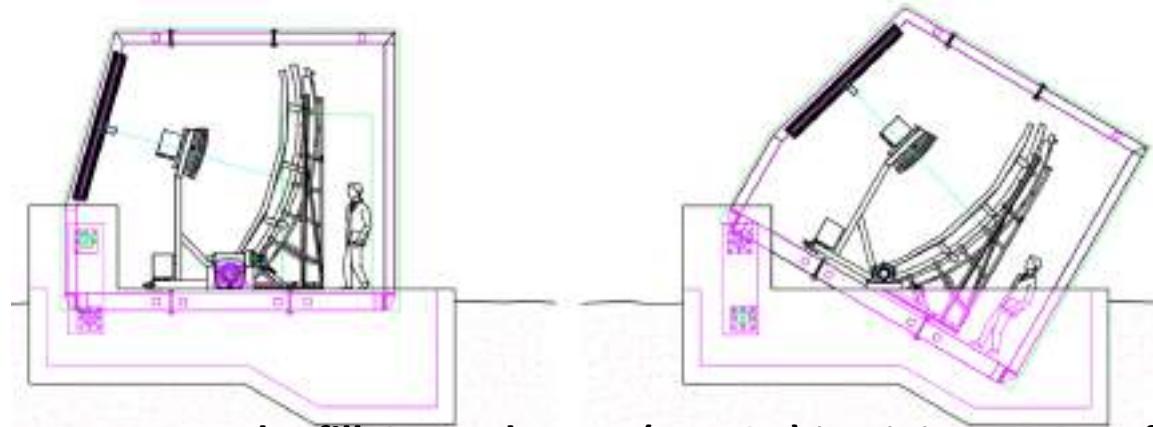


The Pierre Auger Observatory

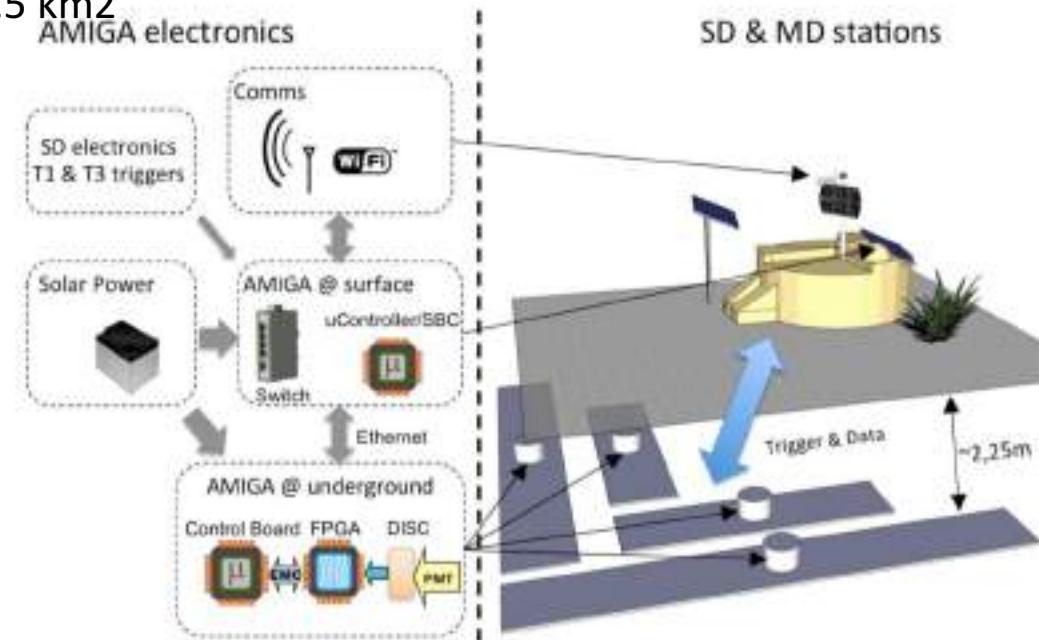
Enhancements



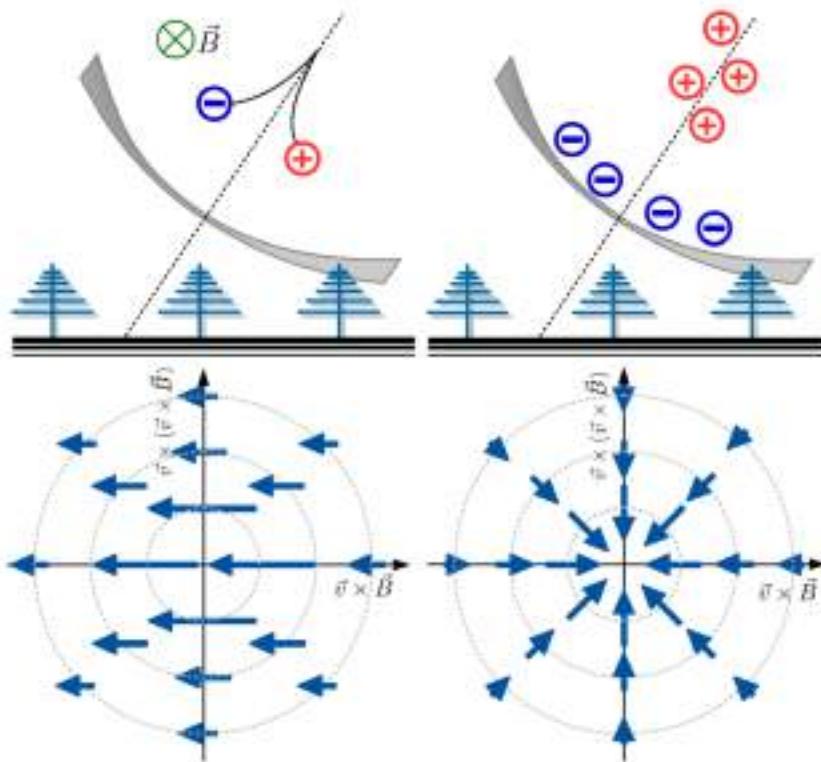
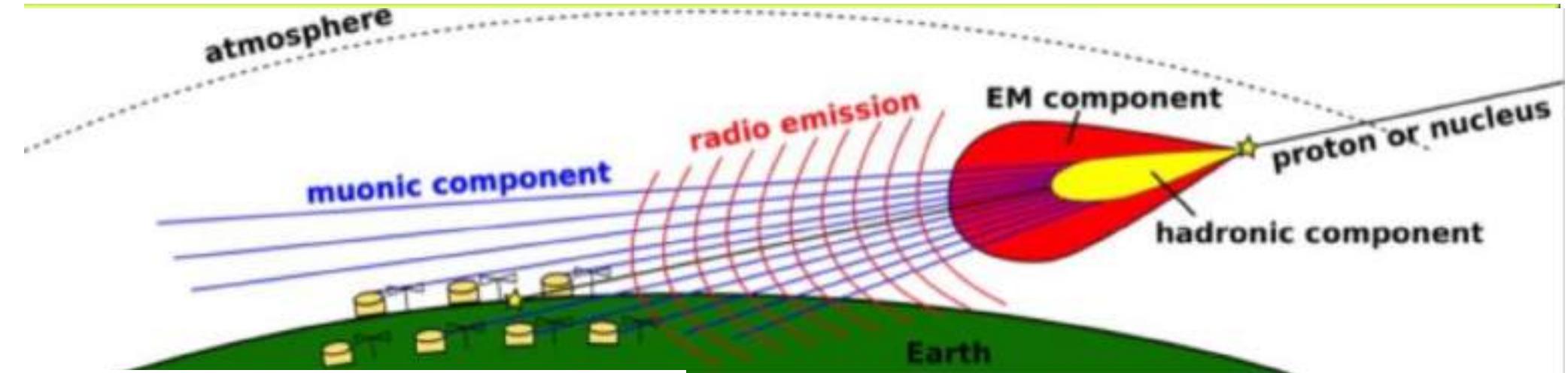
The HEAT telescopes were designed to cover the elevation range from 30° to 58° , which lies above the field of view of the other FD telescopes.



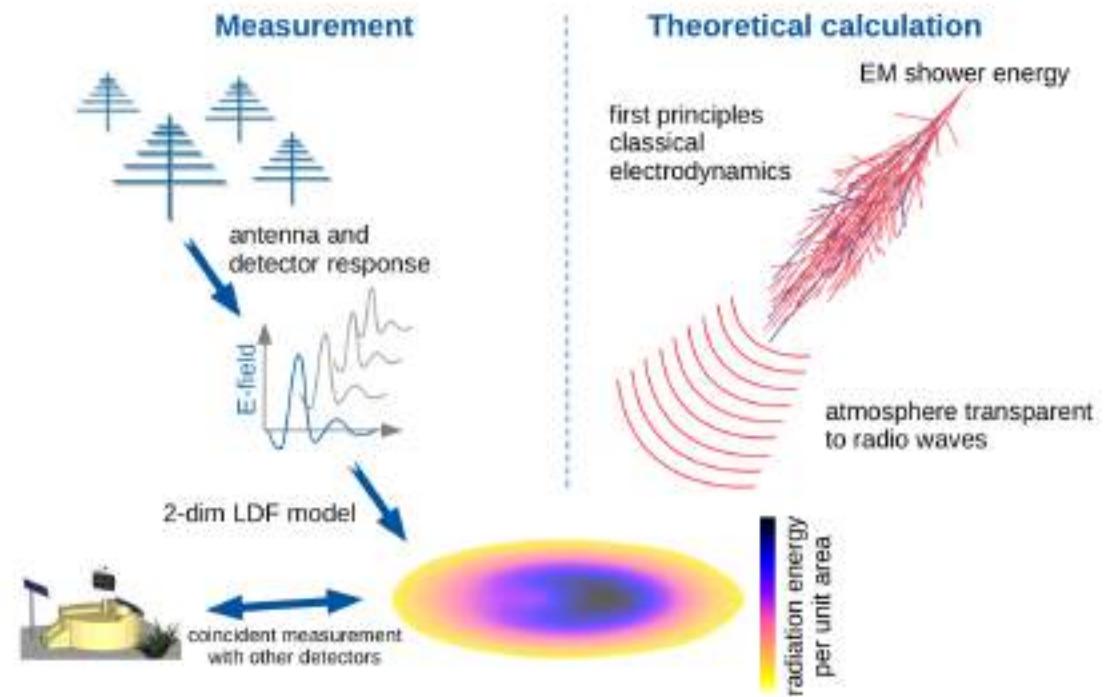
Auger Muon and Infill Ground Array (AMIGA) is a joint system of water-Cherenkov and buried scintillator detectors that spans an area of 23.5 km^2



Auger Engineering Radio Array AERA consists of 153 antenna stations at the Auger Infill array covering an area of $\approx 17 \text{ km}^2$



Different types of polarization

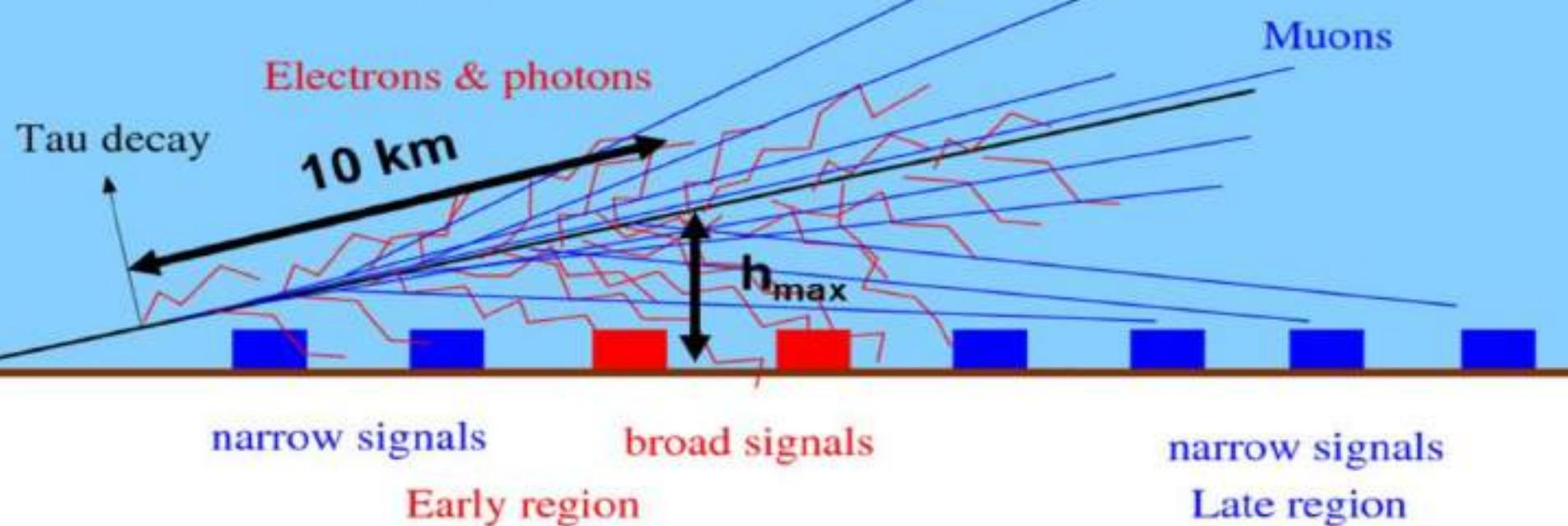
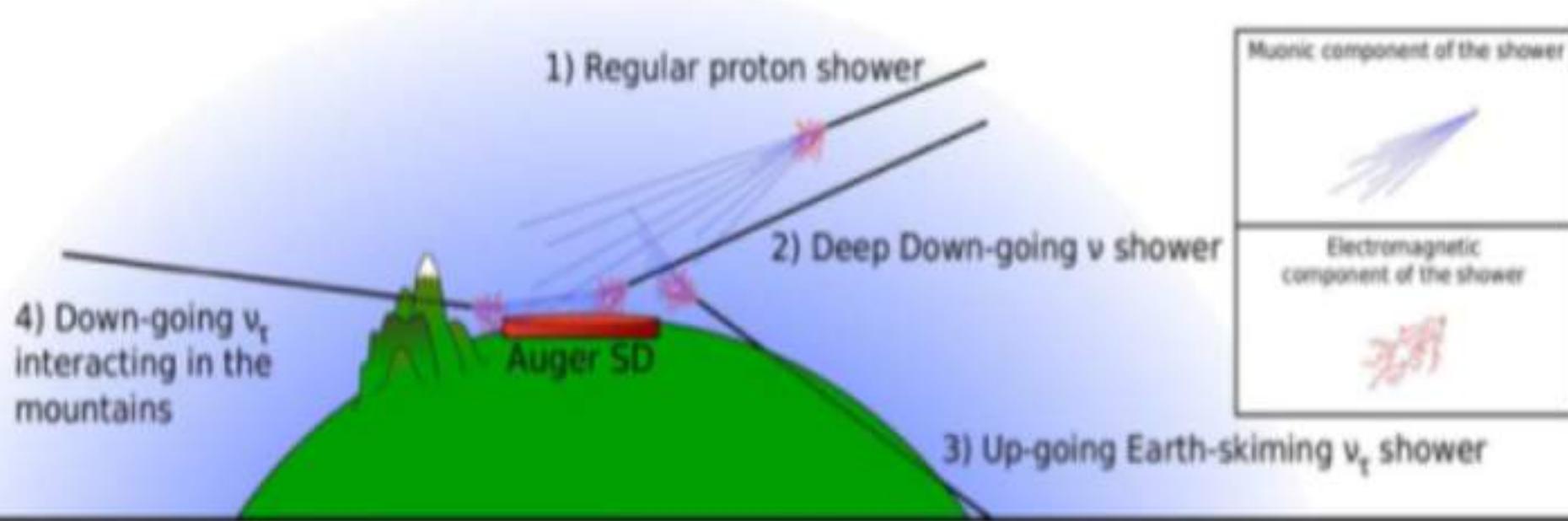


Need to be triggered by others detectors

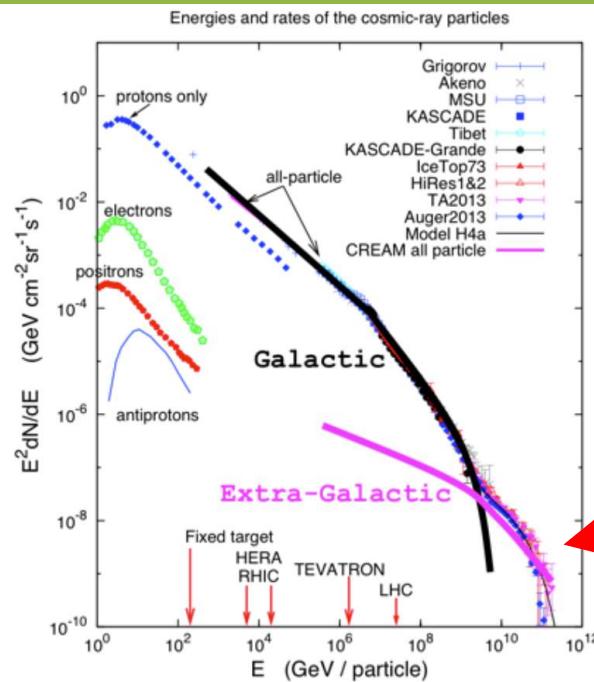
Glaser, C., 2017. A novel method for the absolute energy calibration of large-scale cosmic-ray detectors using radio emission of extensive air showers. *arXiv preprint 1706.01451*.

Huege, Tim. "Radio detection of cosmic ray air showers in the digital era." *Physics Reports* 620 (2016): 1-52. *arXiv preprint 1601.07426*

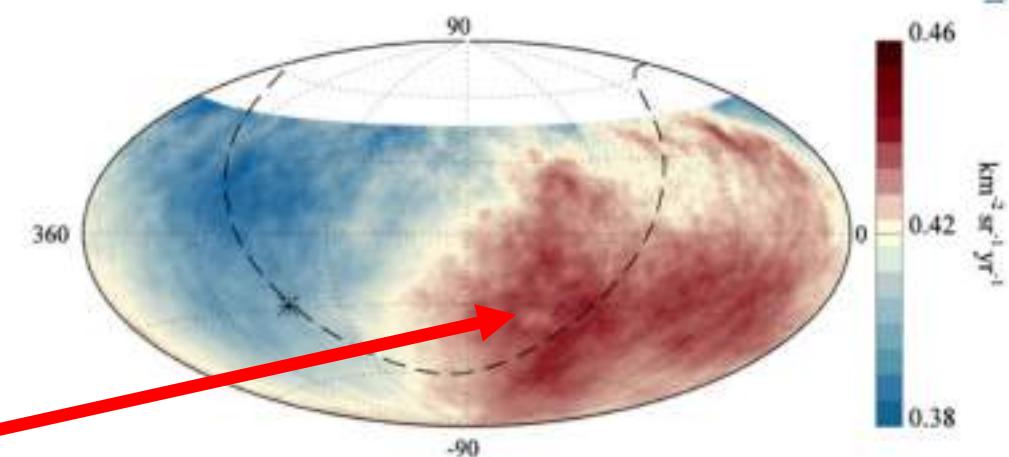
Neutrinos from WCD signal



Auger: Scientific Results



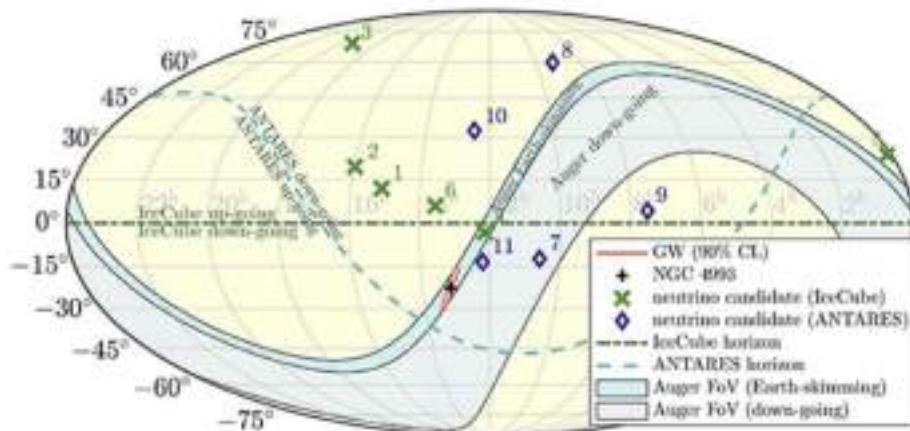
50 year-old mystery has been solved



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 8×10^{18} eV. *Science*, 357(6357), pp.1266-1270. ArXiv 1709.07321

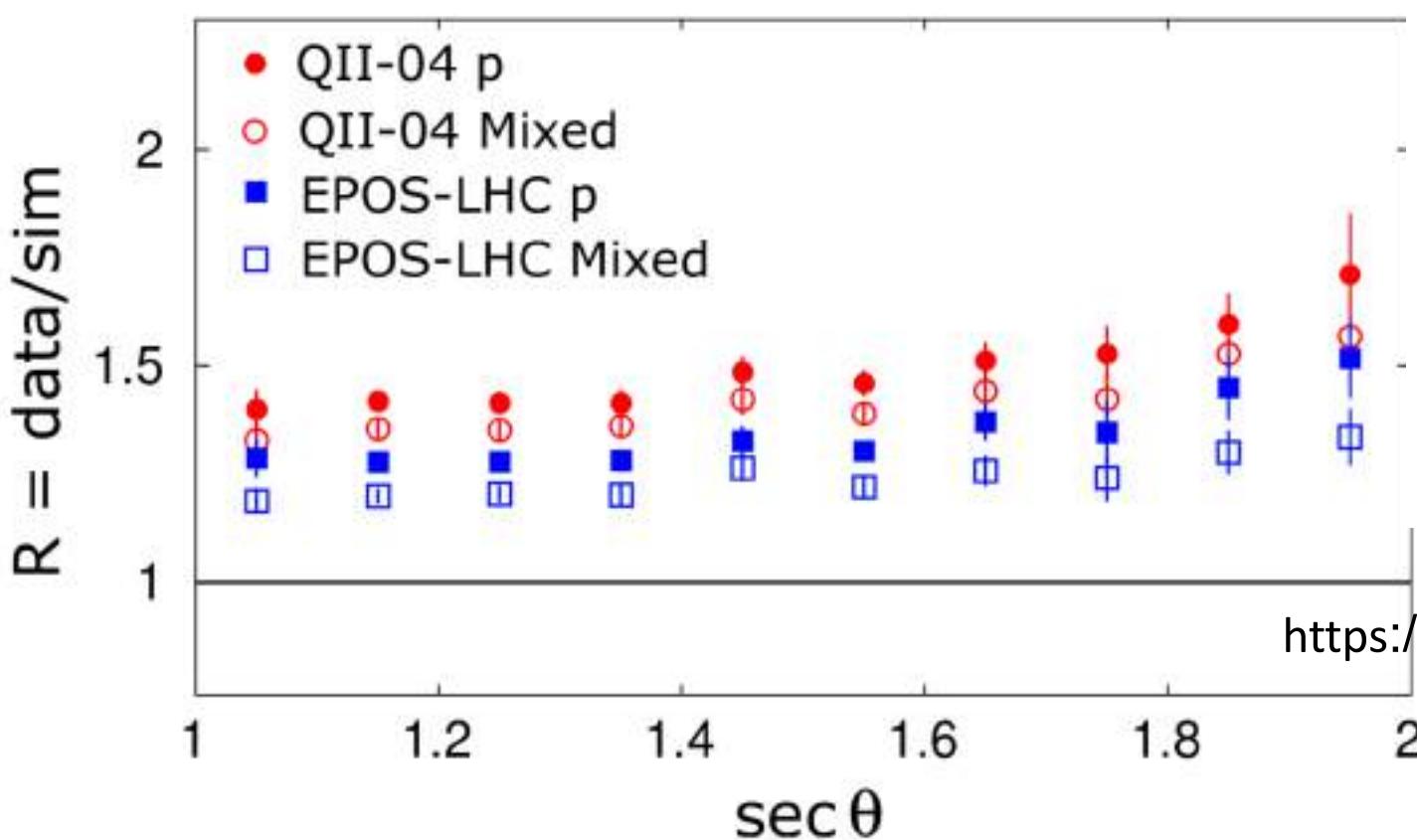


Detection of GW170817: No associated neutrino events in a time window within 500 seconds (and up to 14 days after) around the detection. In agreement with Antares and IceCube

Multi-messenger Observations of a Binary Neutron Star Merger
ArXiv 1710.05833

Ultrahigh-energy neutrino follow-up of gravitational wave events GW150914 and GW151226 with the Pierre Auger Observatory
ArXiv [1608.07378](#)

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>

**Performance and Science Coordination****L. Perrone, T. Suomijarvi****M. Unger, P. Ghia****G. Salina, B. Revenu, S. Maldera****Calibration Analysis:**

SD, FD, Radio, ...

V. Verzi, I. Valiño**Spectrum:**

SD, Hybrid, inclined, Radio, (incl. acceptances)

M. Mostafa, E. Moura Santos**Arrival directions:**

point sources, large-scale, multiplets, magnetic field effects, ...

J. Bellido, A. Yushkov**Composition:**

charged & neutral primaries mass estimators from FD, SD, Radio

L. Cazon, T. Pierog**Air shower physics:**

hadronic interactions and shower phenomenology, Askaryan, new physics, LIV, ...

S. Petrera, S. Mollerach**Cosmic ray phenomenology:**

CR sources, CR propagation, magnetic fields, ...

R. Mussa, H. Asorey**Cosmo-geophysics:**

atmospheric physics, solar-CRs, lightning, earthquakes...

L. Valore, B. Keilhauer**Atmospheric Conditions:**

atmospheric monitoring, atm. data-bases

P. Assis, C. Di Giulio**Operation / Long Term****Performance:**

SD, FD, Radio, ...

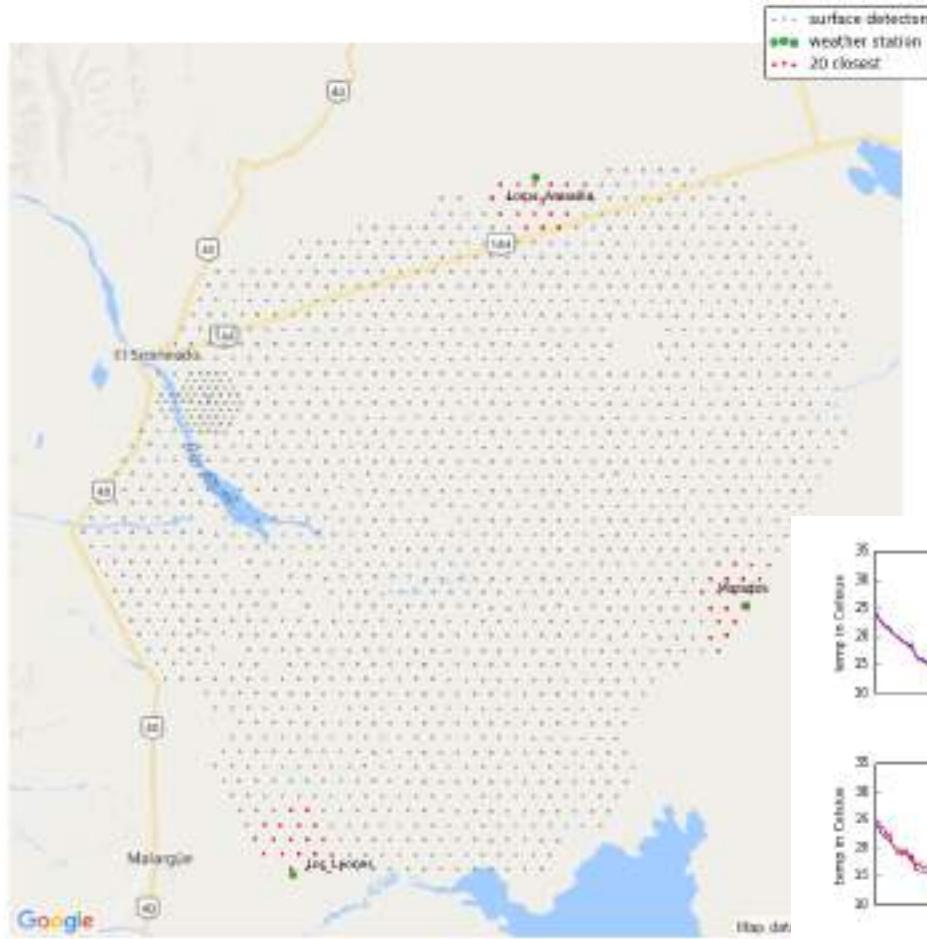
I. Lhenry-Yvon, M. Roth, B. Dawson**Analysis foundations:**SD/FD/ μ -detector/Radio reconstruction, E-scale, event selection, detector simulation...

We are here

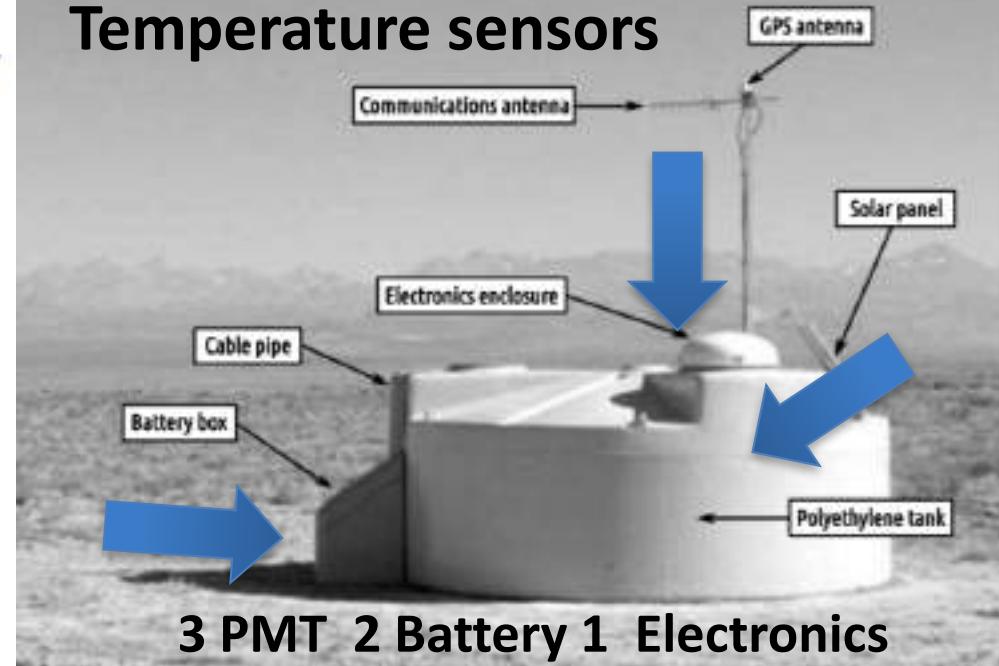


The Pierre Auger Observatory

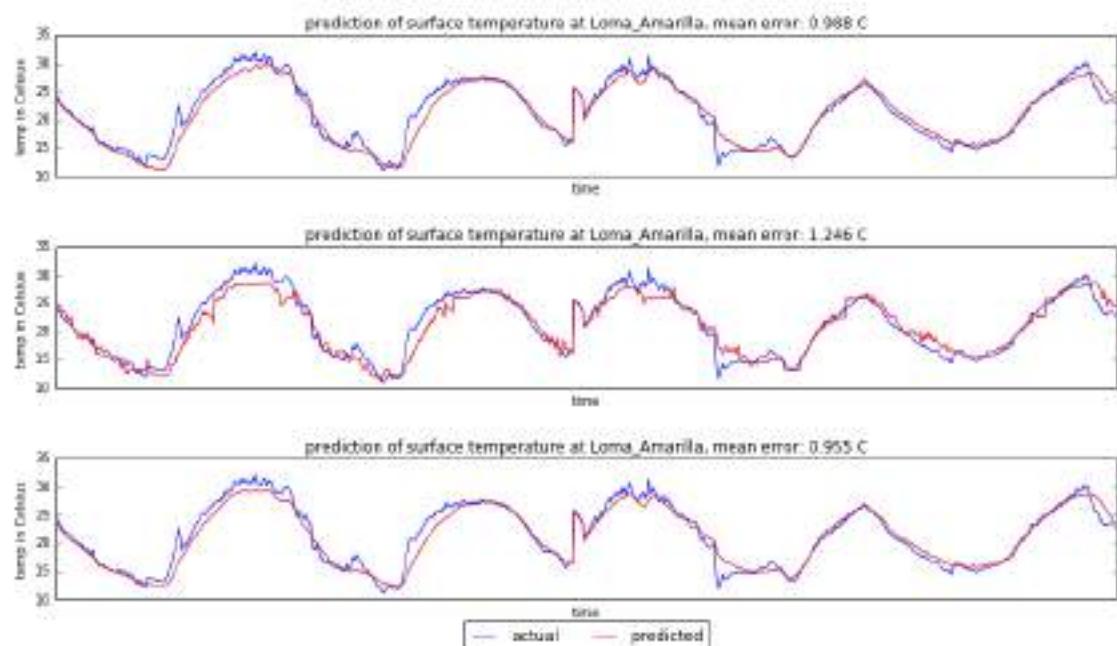
CosmoGeophysics Task Force



Temperature sensors



3 PMT 2 Battery 1 Electronics

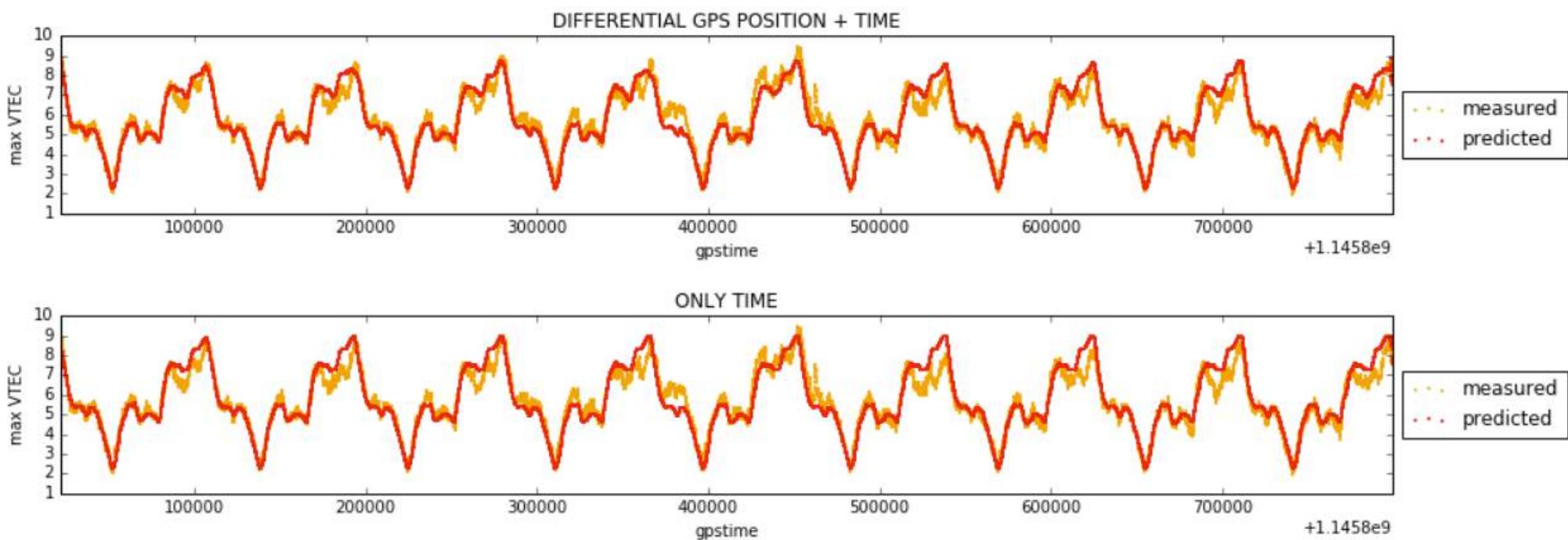
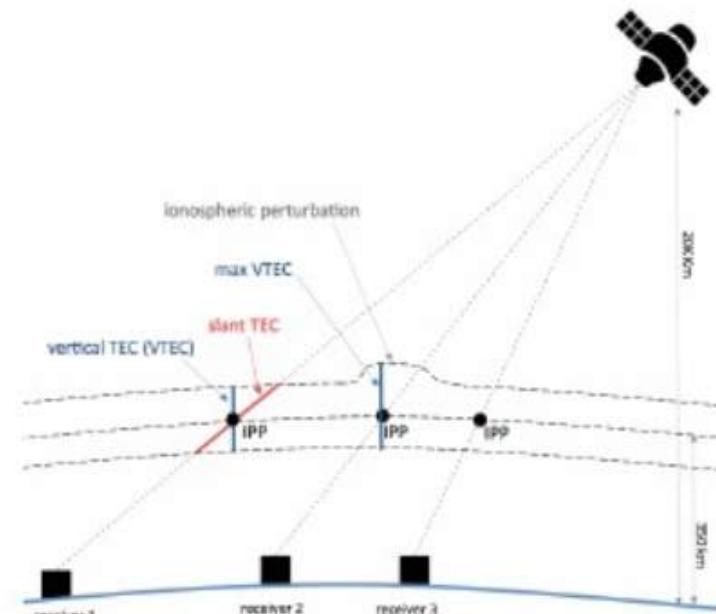
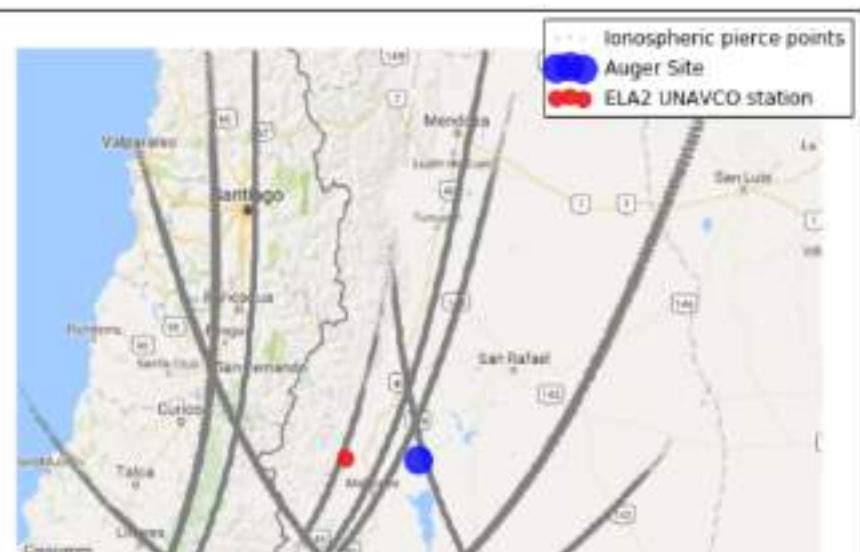


Prediction of environmental temperature
from internal temperature sensors

Estimating the ionospheric electron content from a single frequency GPS

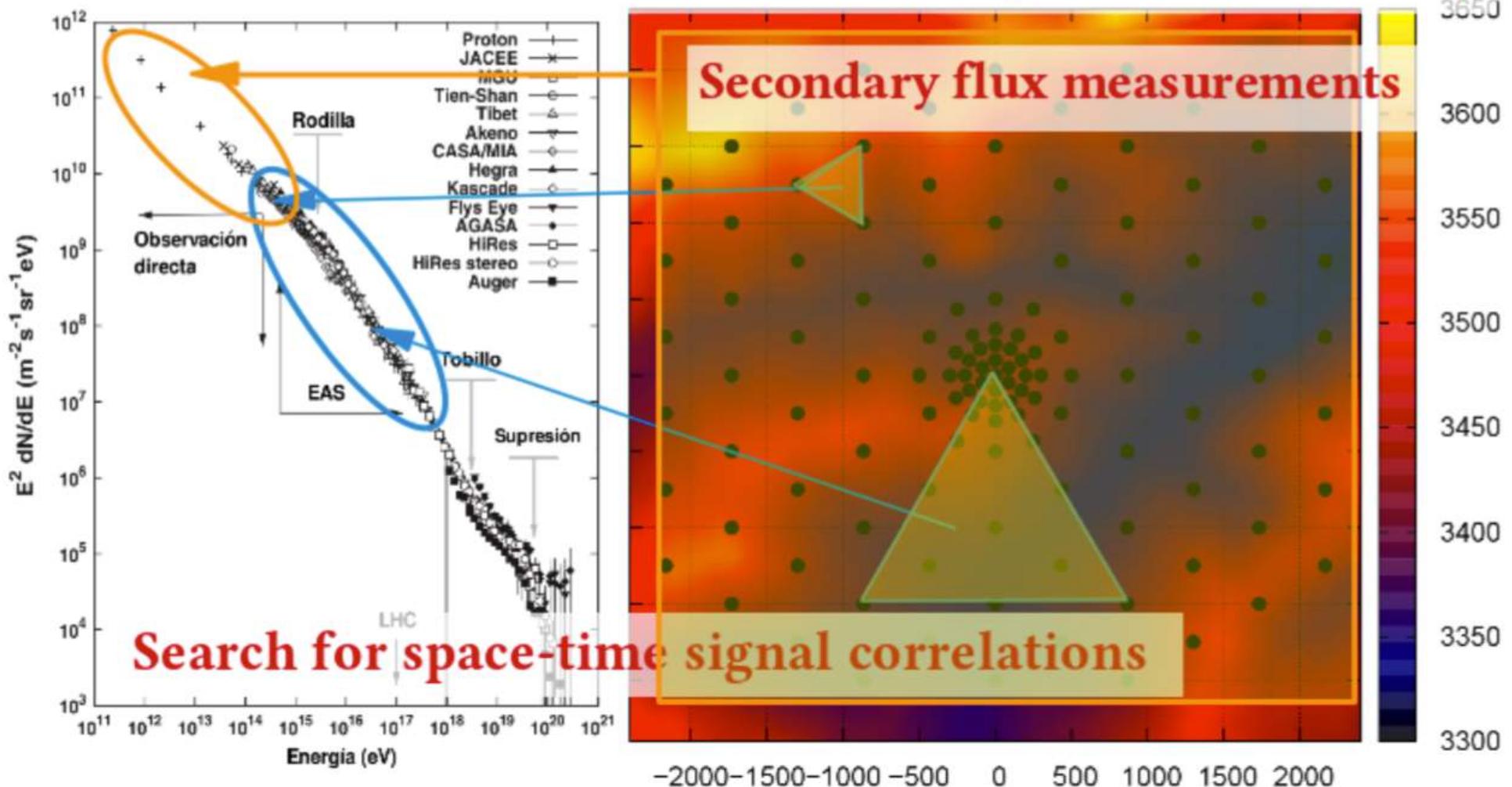
The Pierre Auger Observatory

CosmoGeophysics Task Force



OCoCo: Observatorio Colombiano de Rayos Cósmicos

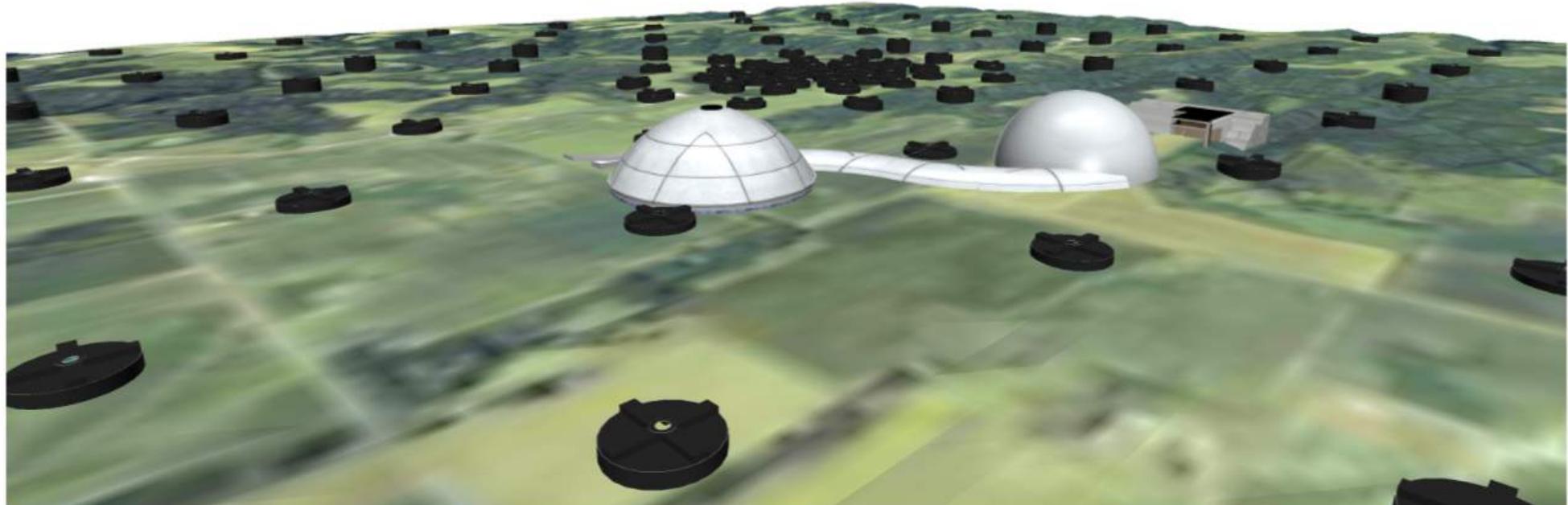
121 WCD on a triangular modular array



PAS: Polo de Astronomía Social

Main objectives

- To become a permanent link between Science and Society
- To build a world class centre in astrophysics and related sciences



“Society” Dome

- Planetary
- Convention center
- Data visualization

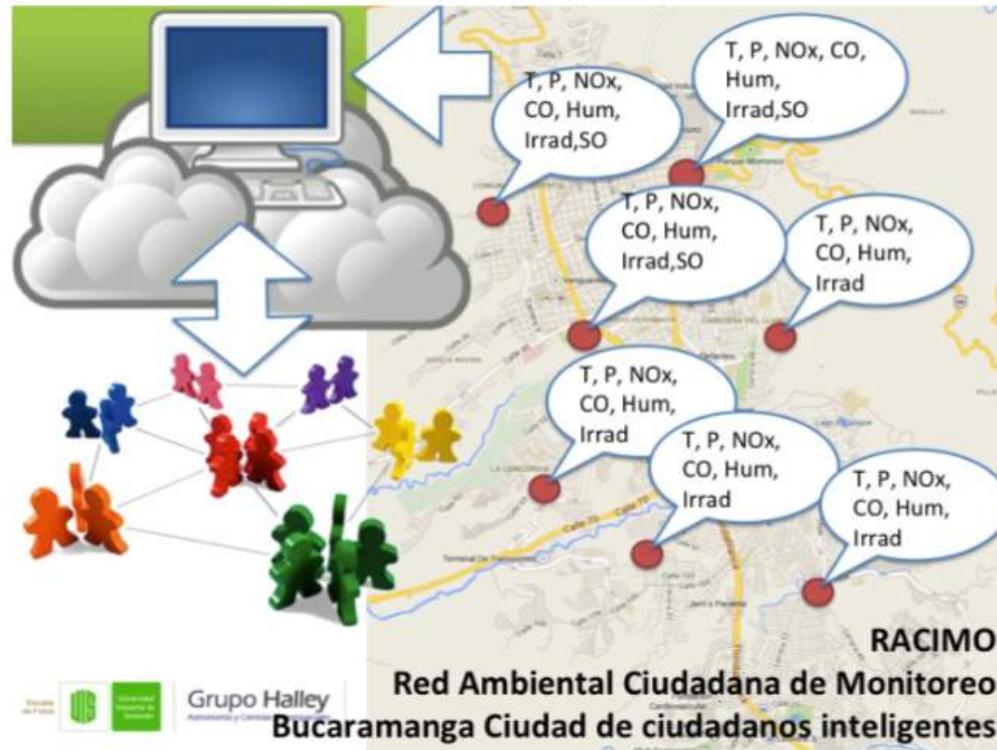


“Science” Dome

- 20" fully automated optical telescope
- control and data acquisition of the array
- labs and offices

Asorey, H., and L. A. Núñez. "The pas (polo de astronomia social) project." *Revista Mexicana de Astronomia y Astrofisica Conference Series*. Vol. 44. 2014.

Citizen Science Environmental Project



RED AMBIENTAL CIUDADANA DE MONITOREO (RACIMO)

COLEGIOS VINCULADOS

Cierre Ciclo

Cierre de ciclo

Cierre de ciclo

Nuevas formas de producir conocimiento por el cambio social

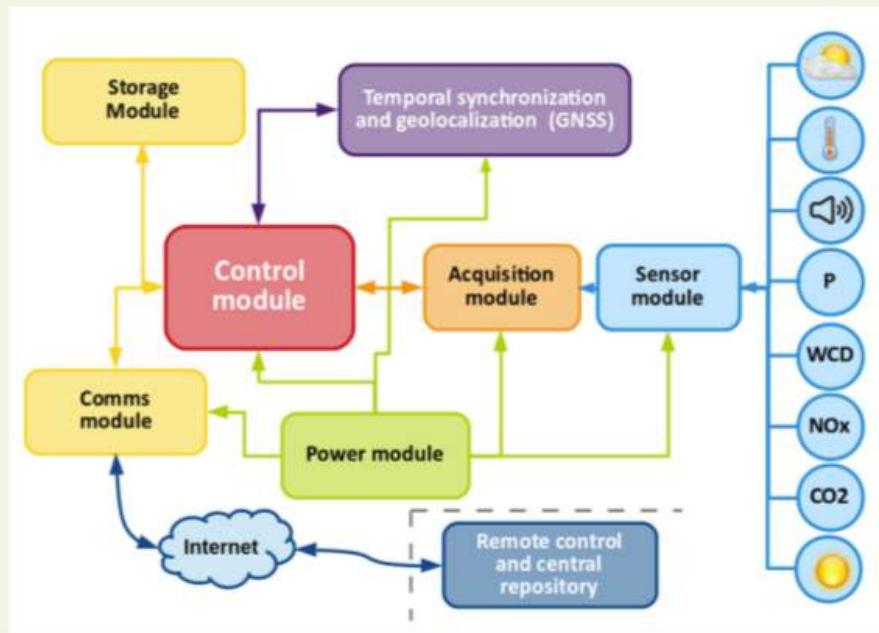
Generar una experiencia educativa bajo el paradigma de la ciencia abierta en colegios de la región, la cual pueda ser replicable para otras regiones del país y servir referencia nacional en iniciativas de Ciencia Ciudadana

Las Actividades

<http://halley.uis.edu.co/tierra/>

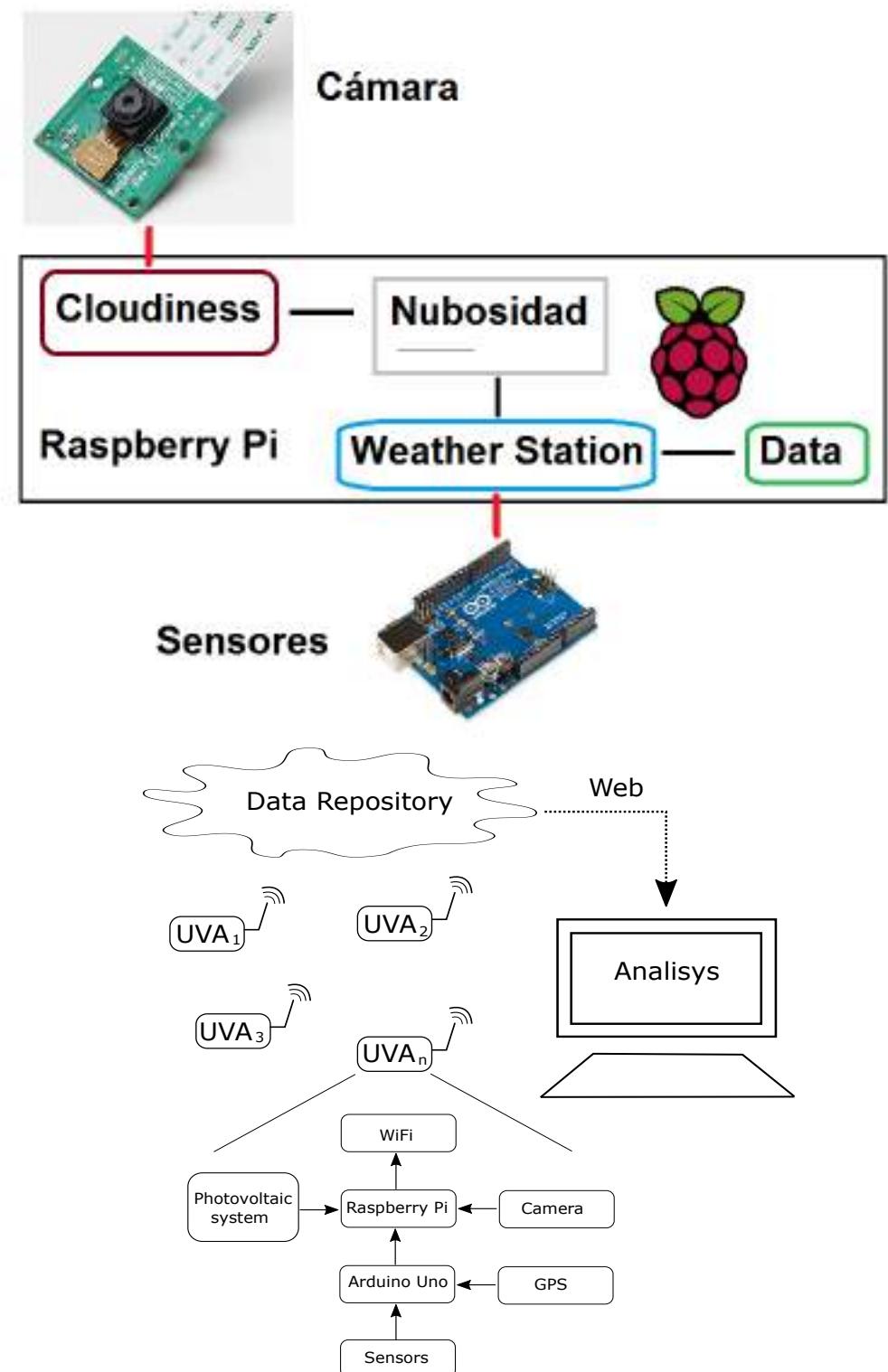
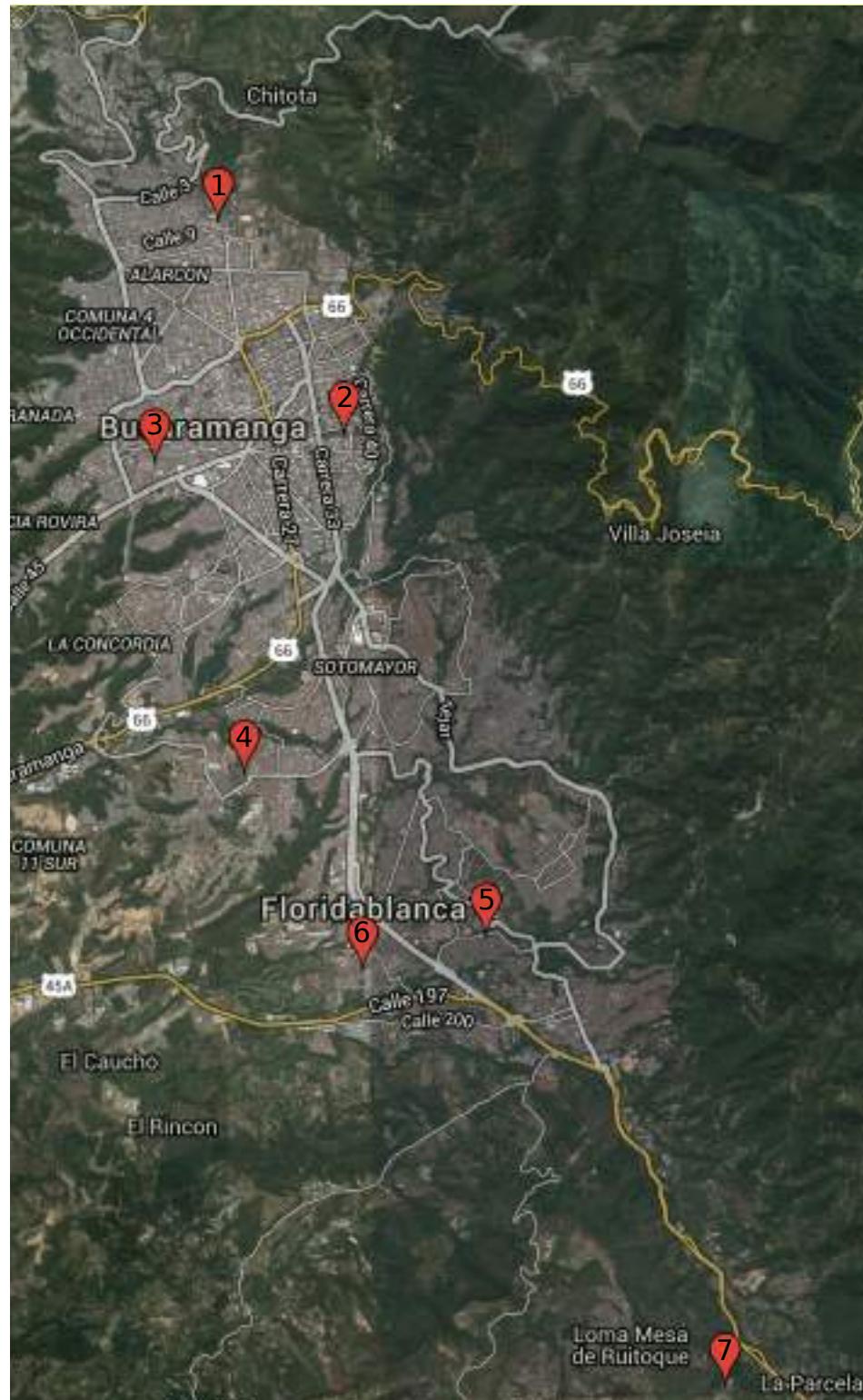
Our new station: the smart LAGO-WCD

RACIMO: Red Ambiental Cludadana de MOnitoreo



Control and Acquisition 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





Safecast is an international, volunteer-centered organization devoted to open citizen science for the environment. Safecast was established by Sean Bonner, Pieter Franken and Joi Ito shortly after the Fukushima Daiichi nuclear disaster in Japan, following the Tōhoku earthquake on 11 March 2011 and manages a global open data network for ionizing radiation monitoring.

The Safecast team, with help of International Medcom, Tokyo Hackerspace and other volunteers, has designed various devices for radiation mapping. These include the bGeigie and bGeigie Nano for mobile applications (carbone and walking measurements) as well as fixed stations called Pointcast.

All data are collected via the [Safecast API](#) and are presented on the publicly available interactive Safecast Tip Map.

<https://blog.safecast.org/2016/01/safecast-air-prototypes/>

Safecast Air Quality Discussion Shared publicly

30 of 125 topics (99+ unread) 9+

Do you have any calibration procedure? (2)

By Karen Forero - 2 posts - 4 views

Can't get the PM data CSV files. Error ID: c6e0a680. (2)

By Alberto Villa - 2 posts - 7 views

Back Online--Needed to restart once to eliminate high values. (4)

By Catherine Baldoni - 4 posts - 27 views

Huge bursts of PM10 values only. (1)

By Alberto Villa - 2 posts - 11 views

Again very high bursts of PM10 values, up to >6000 ug/m3. (1)

By Alberto Villa - 1 post - 13 views

I found some reasonably good air quality monitor

By Andrius - 2 posts - 23 views

Re: [Safecast-Air] Digest for safecast-air@googlegroups.com - 1 update in 1 topic

By Catherine Baldoni - 3 posts - 18 views

Is the site down? (5)

By James Potts - 5 posts - 23 views

Abnormally high PM values again (third case) - Again solved by vacuum cleaning the sensor. (1)

By Alberto Villa - 1 post - 11 views

Colorado beta site. (1)

By Zach Knapp - 11 posts - 34 views

Timestamp Weirdness. (7)

By ts...@kth.se - 7 posts - 17 views

Vacuum cleaning the air sensor stabilizes abnormal readings again. (3)

By Alberto Villa - 3 posts - 24 views

Some recent PM peaks explained (sensor OK). (2)

By Alberto Villa - 2 posts - 17 views



Features Business Explore Marketplace Pricing

This repository is... Issues

Sign In Sign Up

Safecast / Safecast-Air

0 Code

Issues (1)

Pull requests (3)

Projects (0)

Wiki

Insights

0 stars

4 forks

4

Views 4



Join GitHub today

GitHub is home to over 20 million developers working together to host and review code, manage projects, and build software together.

Sign Up

Repo for all things related to Safecast's air quality monitoring platform.

(1) 232 commits

3 branches

0 releases

0 contributors

Graph, master | Use pull request

b7aearunner Merge pull request #19 from Safecast/acc-wifi-image...

Latest commit: d4d1380 on Apr 8, 2017

8 commits

Update v4_code.tcl

2 years ago

6 merges

Merge /home/ethan/airmon/nanorc/Safecast-Air-Dev

a year ago

6 forches

Mount and Drilling Instructions for Target Case

a year ago

4 images

4.01 images for electronics assembly

a year ago

3 tests

Add esp8266 library for WiFi module. Modified: particulate_only

3 years ago

3 utility

Add python plotting script to utility sub-directory

3 years ago

2 gitignores

Add esp8266 library for WiFi module. Modified: particulate_only

a year ago

2 loggers

Added up-to-date versions of the documentation. Split into two files...

3 years ago

1 README.md

Update README.md

0 years ago

1 build_github

Modified particulate_only buildfile (removed p1-charger target) and added...

2 years ago

15 README.md

Safecast



Safecast Air

Documentation for Safecast's Air Quality Monitoring device and platform.

Purchase Kit or Parts

Kit

<https://shop.kitshub.com/products/safecast-air-quality-monitoring-kit-beta-version>

Parts

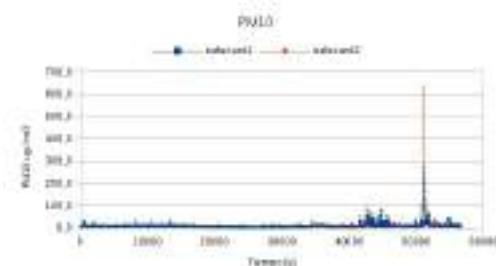
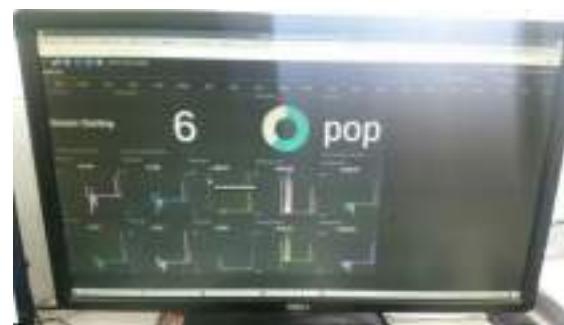
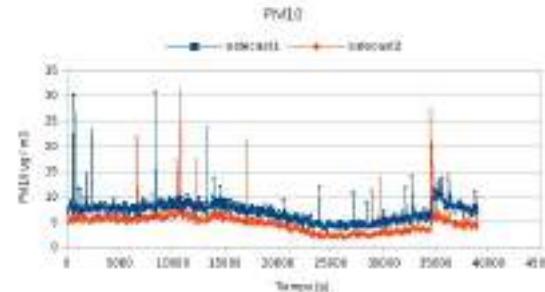
<https://github.com/Safecast/Safecast-Air/wiki/Assembly-Manual#parts>

Assembly Manual

<https://github.com/Safecast/Safecast-Air/wiki/Assembly-Manual>

Operation Manual

<https://github.com/Safecast/Safecast-Air/wiki/Operations-Manual>



Alcaldía Municipal
de Floridablanca



MUNICIPIO DE
BUCARAMANGA

ÁREA METROPOLITANA
DE BUCARAMANGA

BUCARAMANGA - FLORIDABLANCA - DÍON - PEDECUESTA



Universidad
Industrial de
Santander



UIS

Citizen science particle pollution monitoring network

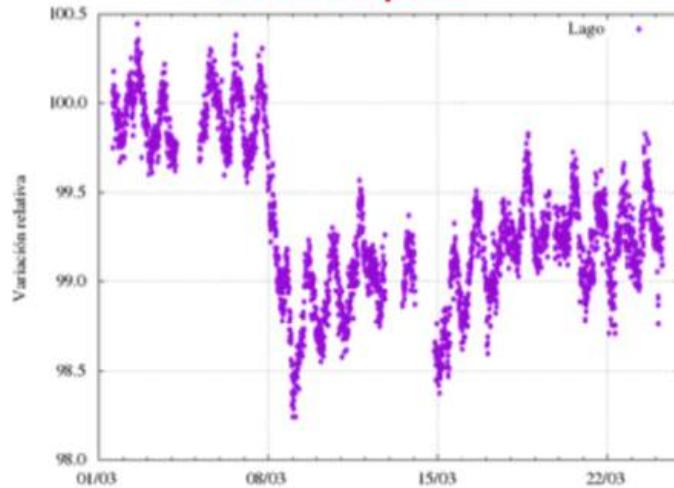


Red Ambiental
Ciudadana de
Monitoreo

Astroparticle Outreach



Introductory Physics Course 2014 at Universidad Industrial de Santander:
python + gnuplot + data analysis techniques

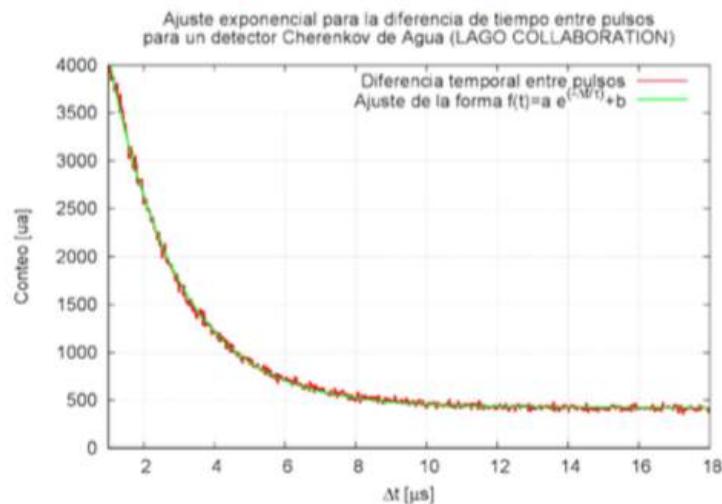


Asorey, H., L. A. Nunez, and C. Sarmiento-Cano. "Exposición Temprana de Nativos Digitales en Ambientes, Metodologías y Técnicas de Investigación en la Universidad."

Revista Brasileira de Ensino de Física, vol. 40, no 4, e5407 (2018)

Particle Physics or Experimental Physics courses at UIS (COL), Balseiro (ARG) and UCV (VEN):

Electroweak theory + python + data analysis techniques



$$\tau_\mu = (2020 \pm 0,1) \text{ ns}$$

$$\rightarrow g_w = \frac{m_W}{m_\mu \tau_\mu^{1/4}} \left(\frac{12 \hbar (8\pi)^3}{m_\mu c^2} \right)^{1/4}$$

$$g_w = 0,7 \pm 0,1$$



INTERNATIONAL MASTERCLASSES

hands on particle physics

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[Information for Teachers and Educators](#)
[Information for Institutes and Physicists](#)
[Schedule](#)
[Intl. Day of Women and Girls in Science](#)
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Participating Institutes

COLOMBIA **UIS**
[Universidad Industrial de Santander](#)
Institute


Carrera 27 con Calle 9, Barrio La Universidad

+57 7 6344000 ext. 2286

Research & Teaching

Our institute is placed in the Colombian northeast at Bucaramanga city. With the pass of the years we have established links between Colombian and Venezuelan scientists and so with scientists from the rest of the world.

Now we have participation in several world collaborations including the LAGO project (Gamma Ray Bursts detection), and the PIERRE AUGER ARRAY DETECTOR (Astrophysics). Also we have started to study the interior of volcanoes in Colombia with the NuTe (Muon Telescope) project and start making insights in Radiation Protection for Humans.

Right now we're working on a wide brand of subjects belonging to HEP theoretical and experimental, among them are:

- Elementary Particles
- Astroparticles
- Cosmic Rays
- Solar Physics
- Detectors and Data Acquisition
- Cosmology
- Physics Beyond the Standard Model
- General Relativity
- Astronomy
- Geophysics and Earth Sciences
- Medical Physics

Intense Outreach

ANGULAR DISTRIBUTION OF COSMIC RAYS

C. R. Casajal-Bohorquez, L. N. Martinez-Ramirez, D. Sierra-Porta, L. A. Núñez, R. Calderón-Ardila, J. Peña-Rodríguez,
Universidad Industrial de Santander, Colombia

INTERNATIONAL COSMIC DAY 2017

Abstract

In this study, the muon flux measurement was performed for different locations in Bucaramanga, Colombia (Universidad Industrial de Santander), at Escatambo, which is part of a international collaboration (www.esi.it) using scintillator plates coupled to silicon photomultipliers and connected to individual cosmic ray particles that are then analyzed by means of software. It is well known, in fact it is known that astroparticles exhibit modulation in the atmosphere, however, this modulation depends on several factors such as meteorological variables.

Experimental Setup

The study characterizes the muon flux response zenith angle of arrival into detector by observing the behavior of the frequency of counts. This is determined by the number of particles passing through the detector normalized with the product of acceptance and the time for collecting samples. The acceptance is characteristic of the detector, for this configuration is 116.7 sr cm^2 given that the distance between the two scintillator plates in this configuration is 56.6 cm . The detector used in the investigation can be seen in Figure 1.

Fig 1: Detector



The arrangement of the detector allowed the measurement of the zenith angle respect to the vertical axis over a range of 0 to 90 degrees. Resolution angle for samples is 5 degrees, a measurement time of approximately one hour.

Conclusions

The behavior of the muon flux is according to the detector and decreases with the increase of the zenith angle with the atmosphere, because most of these particles interact with other particles and electric fields.

ALL PARTICIPATING GROUPS



The google map shows the location of the registered participants.

INTERNATIONAL COSMIC DAY

Dear Young ICD Researchers,

Thank you for your participation and contribution to the 6th International Cosmic Day!

Over 1500 students, teachers and scientists in 69 groups from 12 countries have made this day possible.

Various cosmic particles constantly reach the Earth – particles that can provide insights into events happening in the depths of the universe. You – the ICD young researchers – studied cosmic rays for one day. For 24 hours around the globe, cosmic particles were at the center of interest. All over the world, we discussed questions like:

- What are cosmic particles?
- Where do they come from?
- How can they be measured?

You all have done your measurements very well. It is really great to see all the results, which show only small differences but many agreements.

We hope the International Cosmic Day gave you an insight into astroparticle physics – a young research field located at the interface between astrophysics, particle physics, astronomy and cosmology.

Maybe you have become interested and it opens a new window for you to explore the universe.

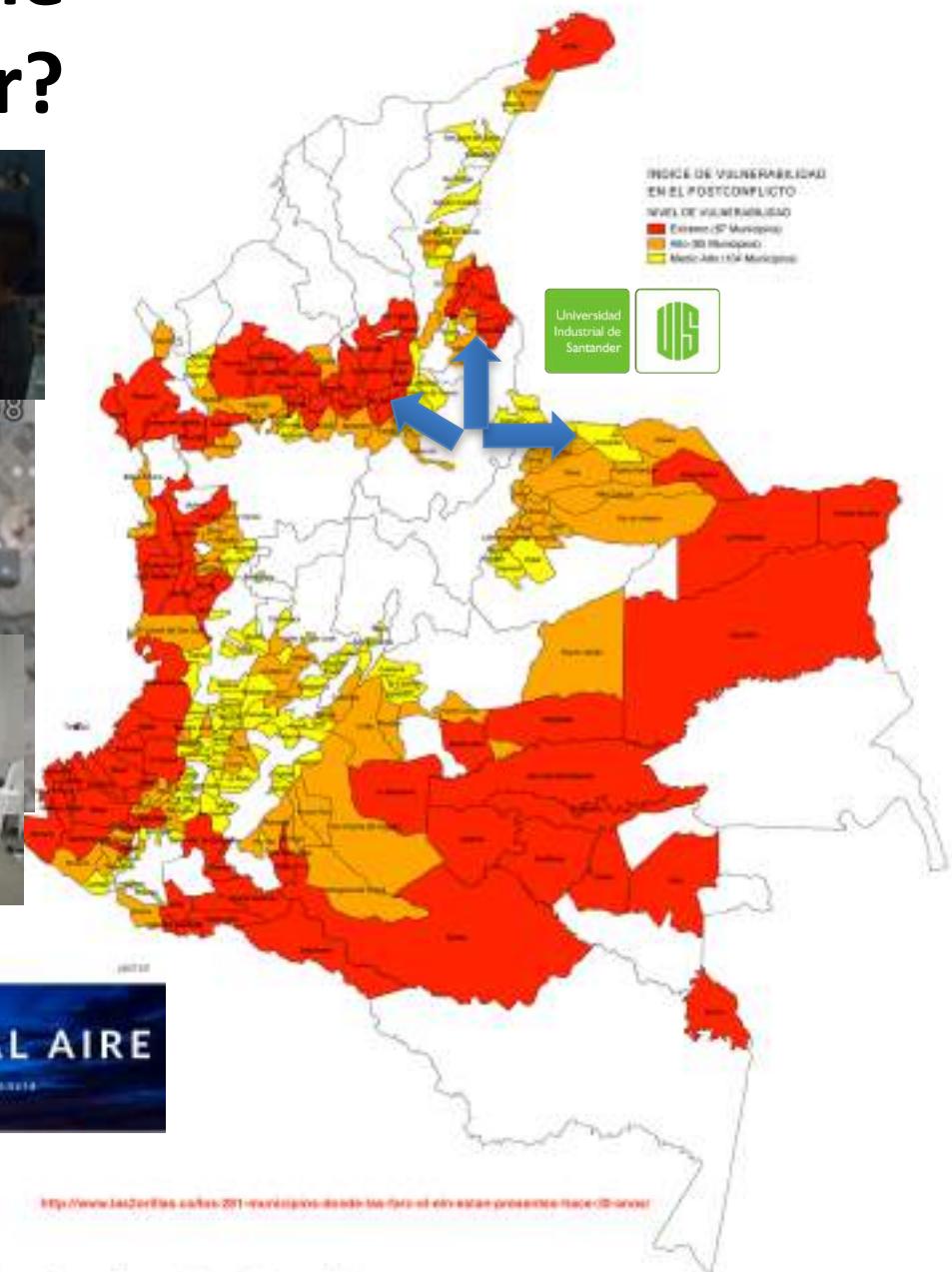
In this booklet you can find information about all participating groups, the results of their measurements and web links to more information about astroparticle physics.

USA
ITALY
CHINA
MEXICO
FRANCE
POLAND
REUNION
GEORGIA
GERMANY
COLOMBIA
NETHERLANDS
UNITED KINGDOM

Astroparticle Outreach to the Jungle: after 50 years of war?



| Nombre | Apellido | Edad | Sexo | Interés |
|--------|----------|------|--------|-------------|
| Diego | Perez | 20 | Hombre | Astrofísico |
| Diego | Perez | 20 | Hombre | Astrofísico |
| Diego | Perez | 20 | Hombre | Astrofísico |
| Diego | Perez | 20 | Hombre | Astrofísico |



<http://www.uis.edu.co/facultad-ciencias-naturales/estadisticas-matematicas/estadistica-aplicada-a-la-salud/>

100 200 300 400 Km

That's all folks!

Componente
electromagnética

Rayo cósmico

Núcleo atmosférico

π^0

π^+

γ
 γ

e^-

e^+

π^+

π^0

μ^-

μ^+

π^-

π^0

μ^-

μ^+

μ^-

μ^+

μ^-

μ^+

μ^-

μ^+

μ^-

μ^+

Componente
hadrónica

v_μ

Componente
muónica

v_e

Neutrinos

Gracias