física extrema para enfermedades extremas

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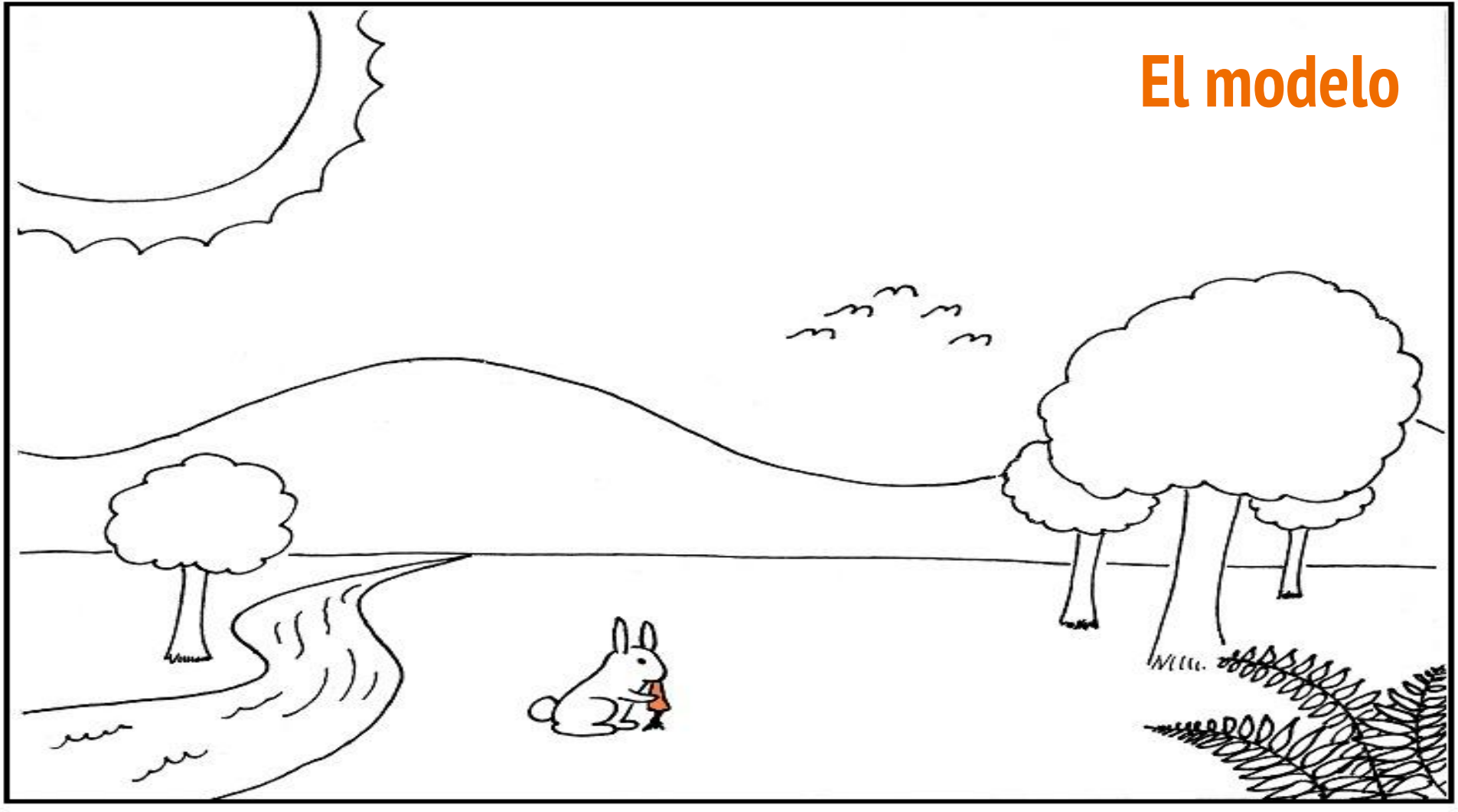
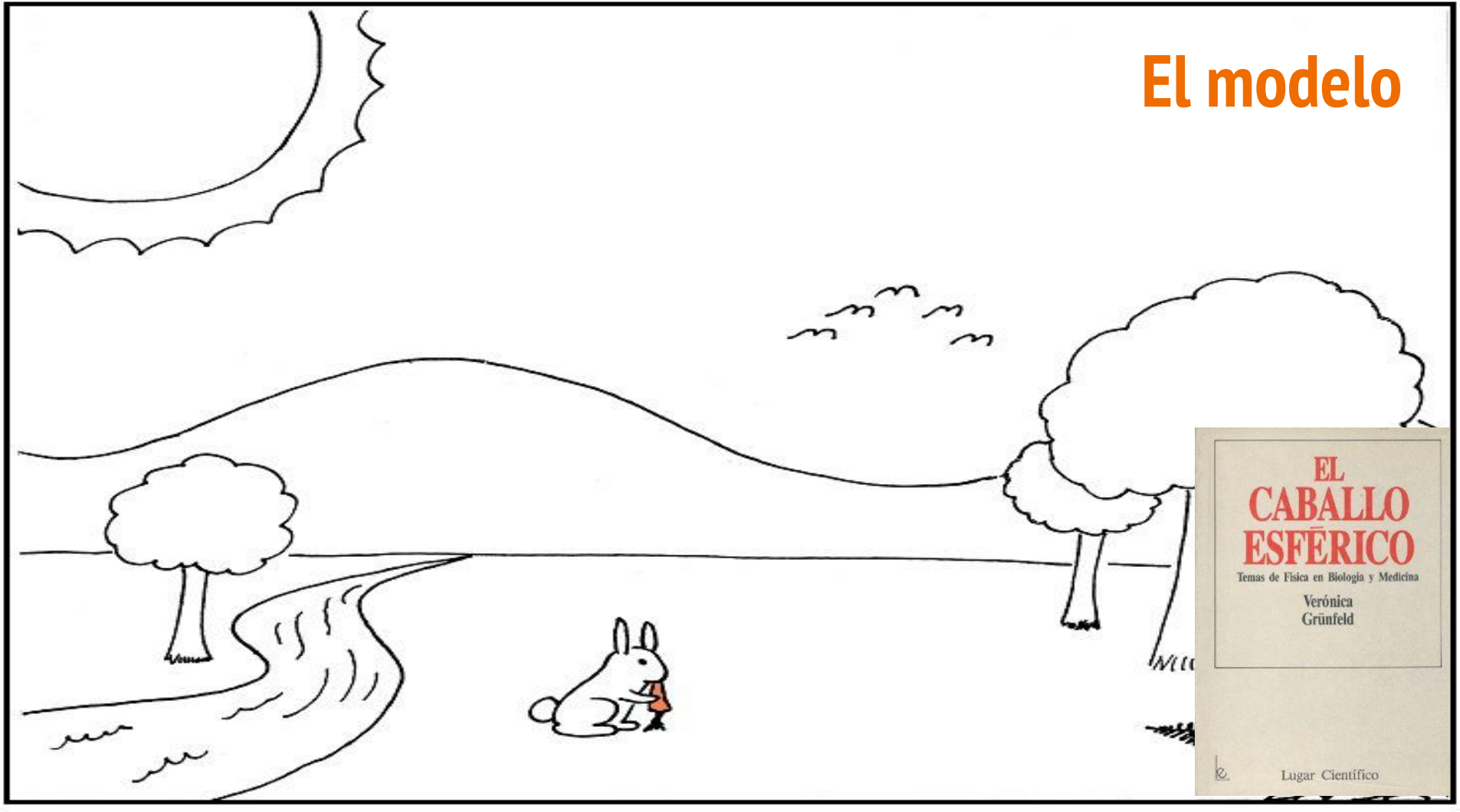
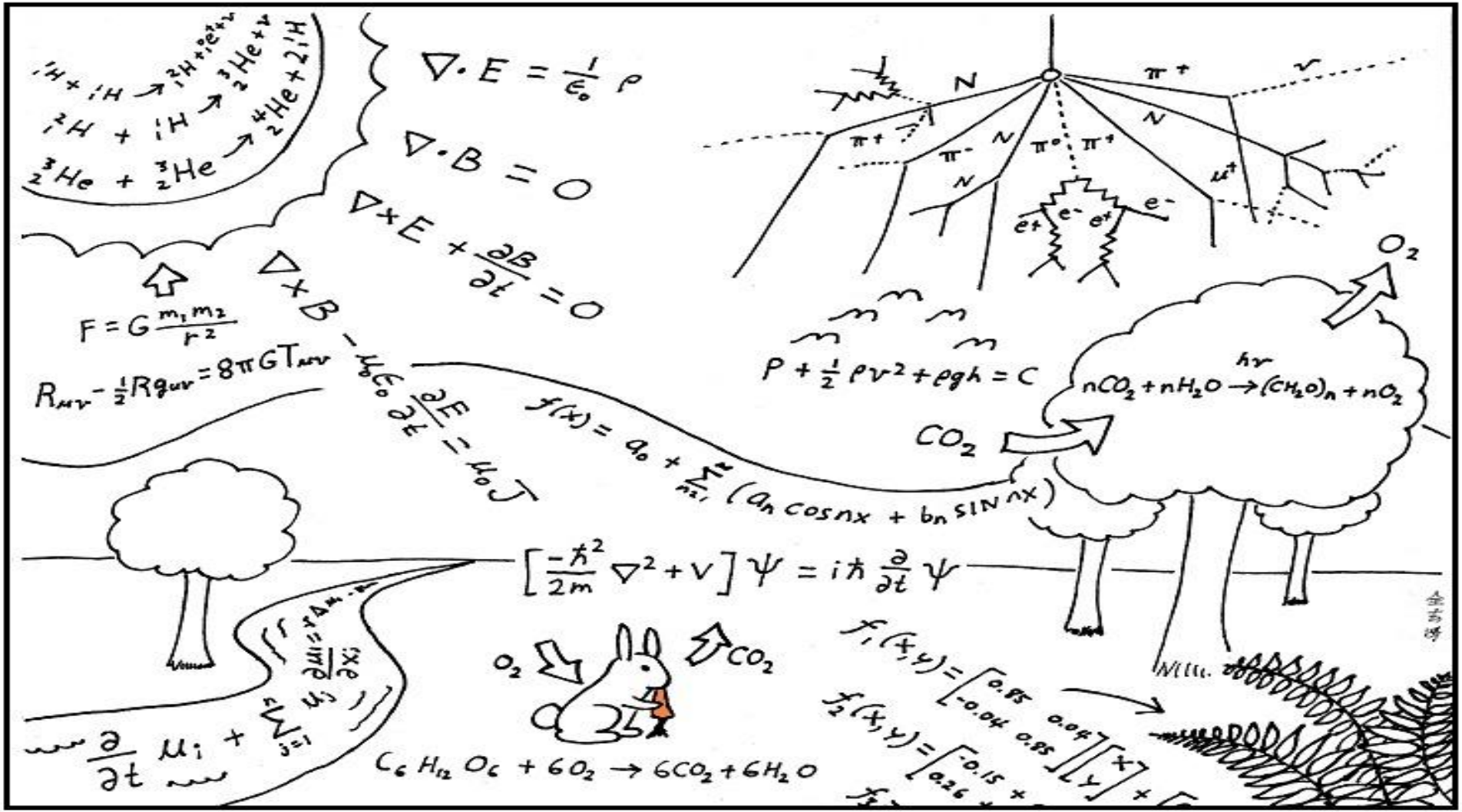
El modelo



El modelo



EL
CABALLO
ESFÉRICO
Temas de Física en Biología y Medicina
Verónica
Grünfeld
Lugar Científico


$^1H + {}^1H \rightarrow {}^2_1H + {}^0_1e + \nu$
$^2_1H + {}^1H \rightarrow {}^3_2He + \nu$
$^3_2He + {}^3_2He \rightarrow {}^4_2He + 2\,{}^1_1H$
$\nabla \cdot E = \frac{1}{\epsilon_0}\rho$
$\nabla \cdot B = 0$
$\nabla \times E + \frac{\partial B}{\partial t} = 0$
$F = G\frac{m_1 m_2}{r^2}$
$\nabla \times B - \mu_0\epsilon_0\frac{\partial E}{\partial t} = \mu_0 J$
$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = 8\pi G T_{\mu\nu}$
$P + \frac{1}{2}\rho v^2 + \rho g h = C$
$n CO_2 + n H_2O \xrightarrow{h\nu} (CH_2O)_n + n O_2$
CO_2
O_2
$f(x) = a_0 + \sum_{n=1}^{\infty}(a_n \cos nx + b_n \sin nx)$
$\left[\frac{-\hbar^2}{2m}\nabla^2 + V\right]\psi = i\hbar\frac{\partial}{\partial t}\psi$
O_2
CO_2
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
$\frac{\partial}{\partial t}\mu_i + \sum_{j=1}^{n} u_j \frac{\partial \mu_i}{\partial x_j} = r\Delta\mu_i - \frac{\mu_i}{\tau}$
$f_1(x,y) = \begin{bmatrix} 0.85 & 0.04 \\ -0.04 & 0.85 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \\ \end{bmatrix}$
$f_2(x,y) = \begin{bmatrix} -0.15 & \\ 0.26 & \end{bmatrix} \times$
N
π^+
π^-
π^0
μ^+
e^+
e^-
ν


sepa física y sea el alma de las fiestas

The extreme Universe

Cosmic Rays or 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"

Physikalische Zeitschrift, 13, 1084 (1912)
Victor Hess, Nobel Prize in Physics, 1936

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"They are particles, being mostly atomic nuclei, that originate outside the Solar System reaching the Earth or its close environment. From now, CR or GCR (galactic origin)"

from my lectures, no nobel prize, neither in physics nor literature

CR Spectrum

Power-law spectrum, spectral index depending on primary energy E_p and composition (identified by atomic number Z_p)

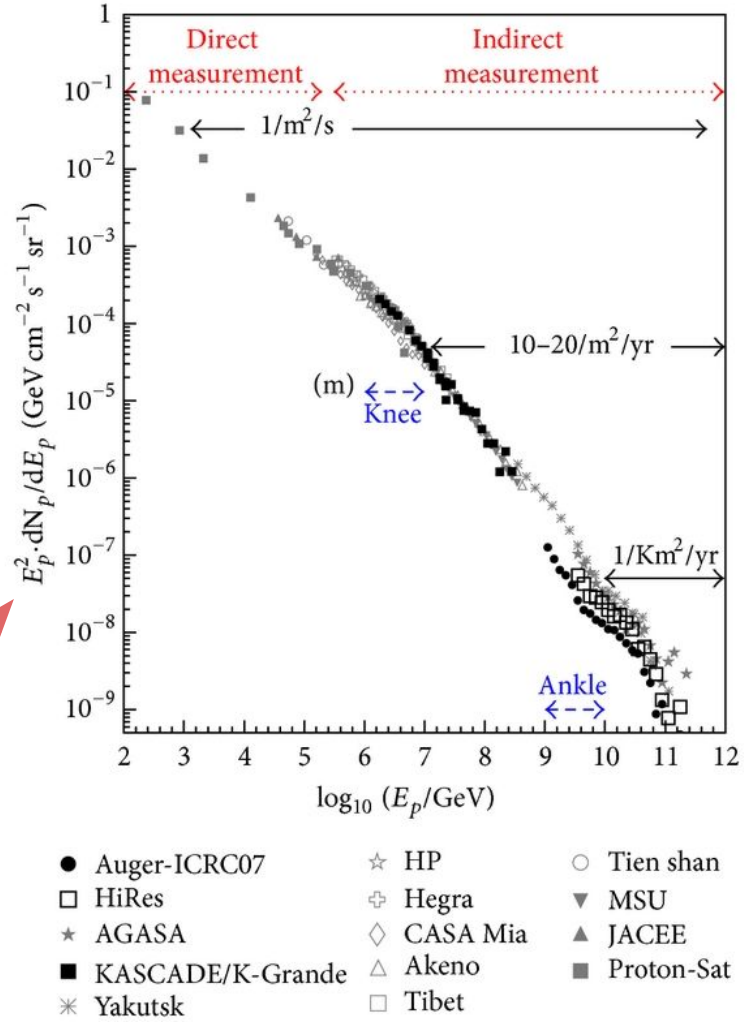
$$j(E_p) = j_0(E_p, Z_p) E^{\alpha(E_p, Z_p)}$$

but…..

$$\alpha \simeq -3$$

in a wide range of energies

$$j(E_p) \times E_p^2$$



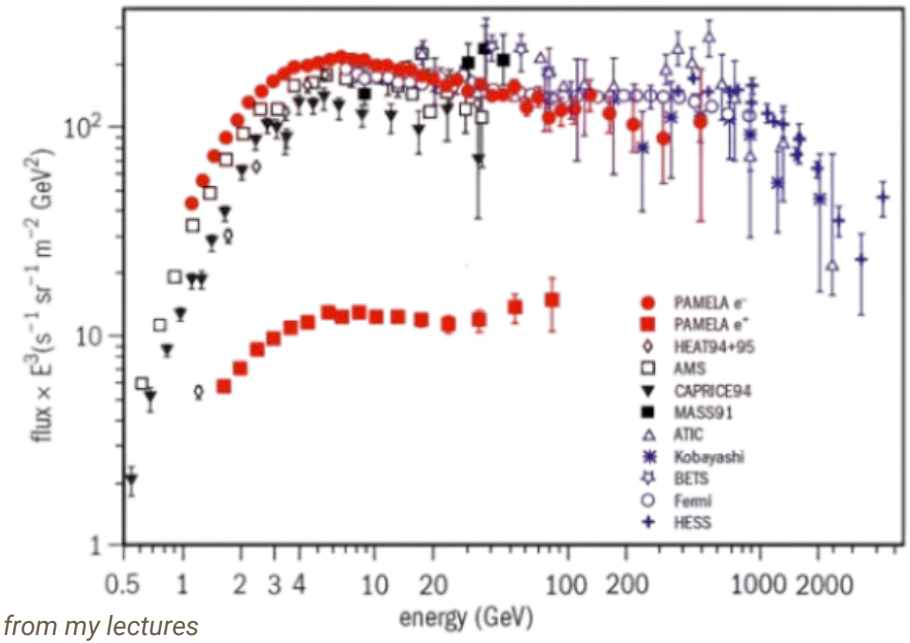
from my lectures

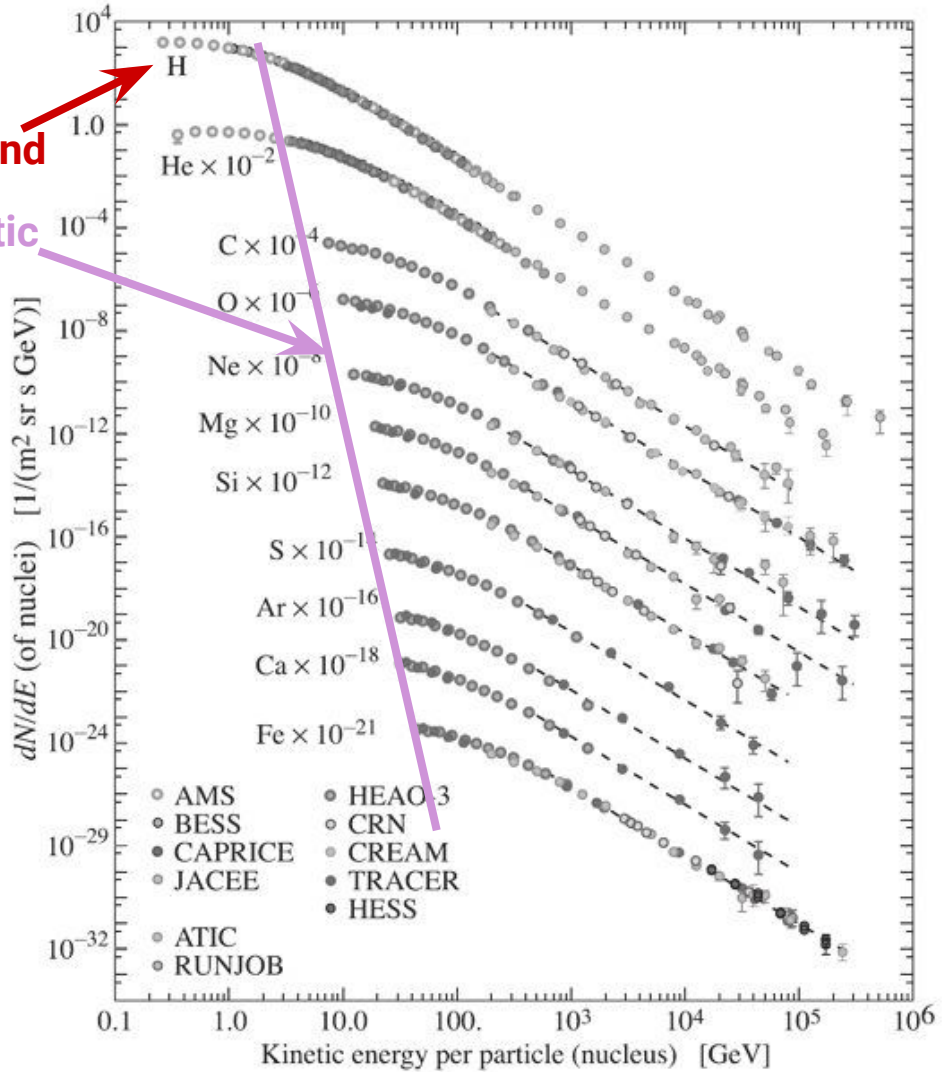
CR Spectrum

In the range of energies of interest for this talk

Solar wind

Geo-Helio magnetic effects

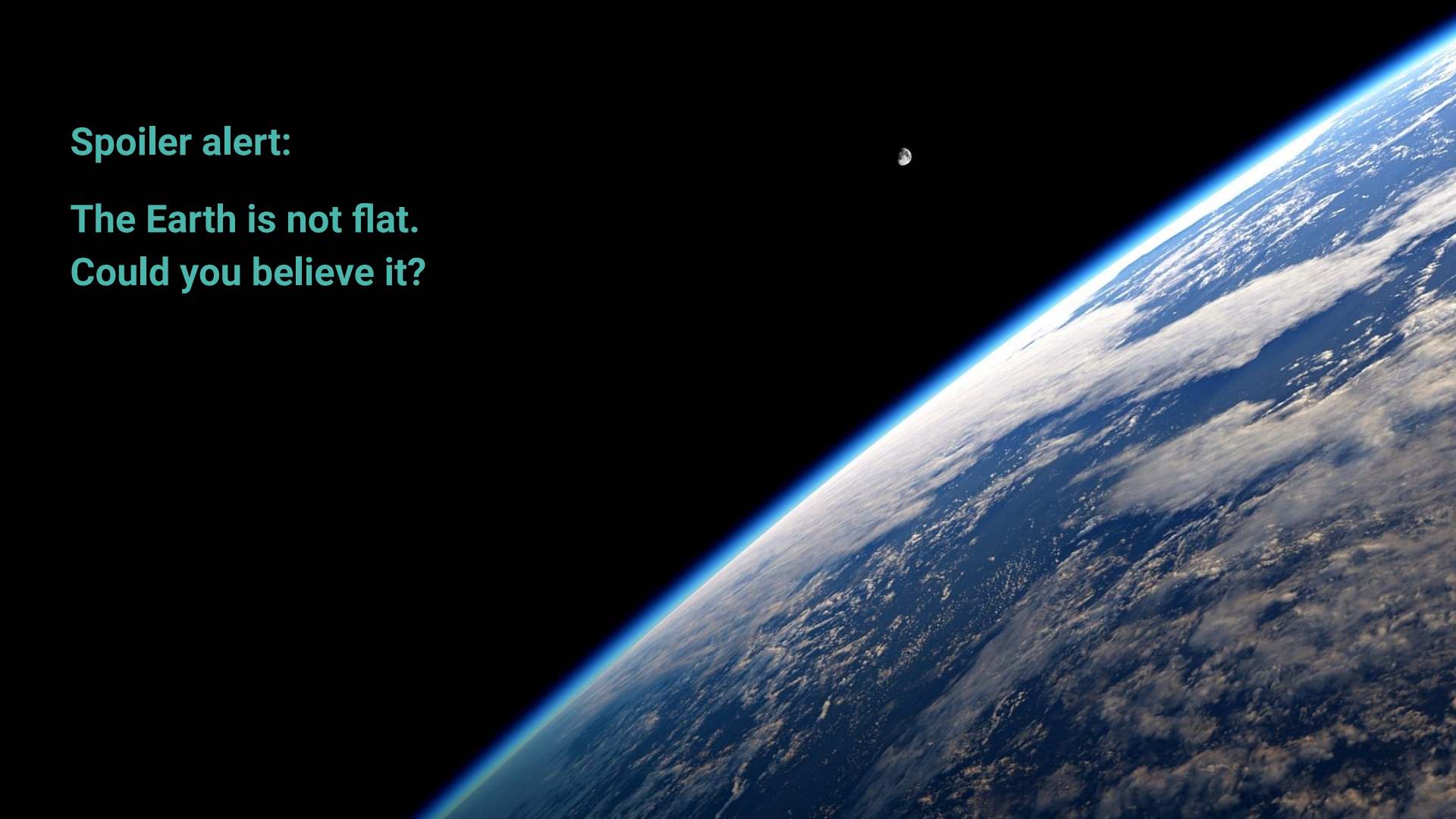




from my lectures

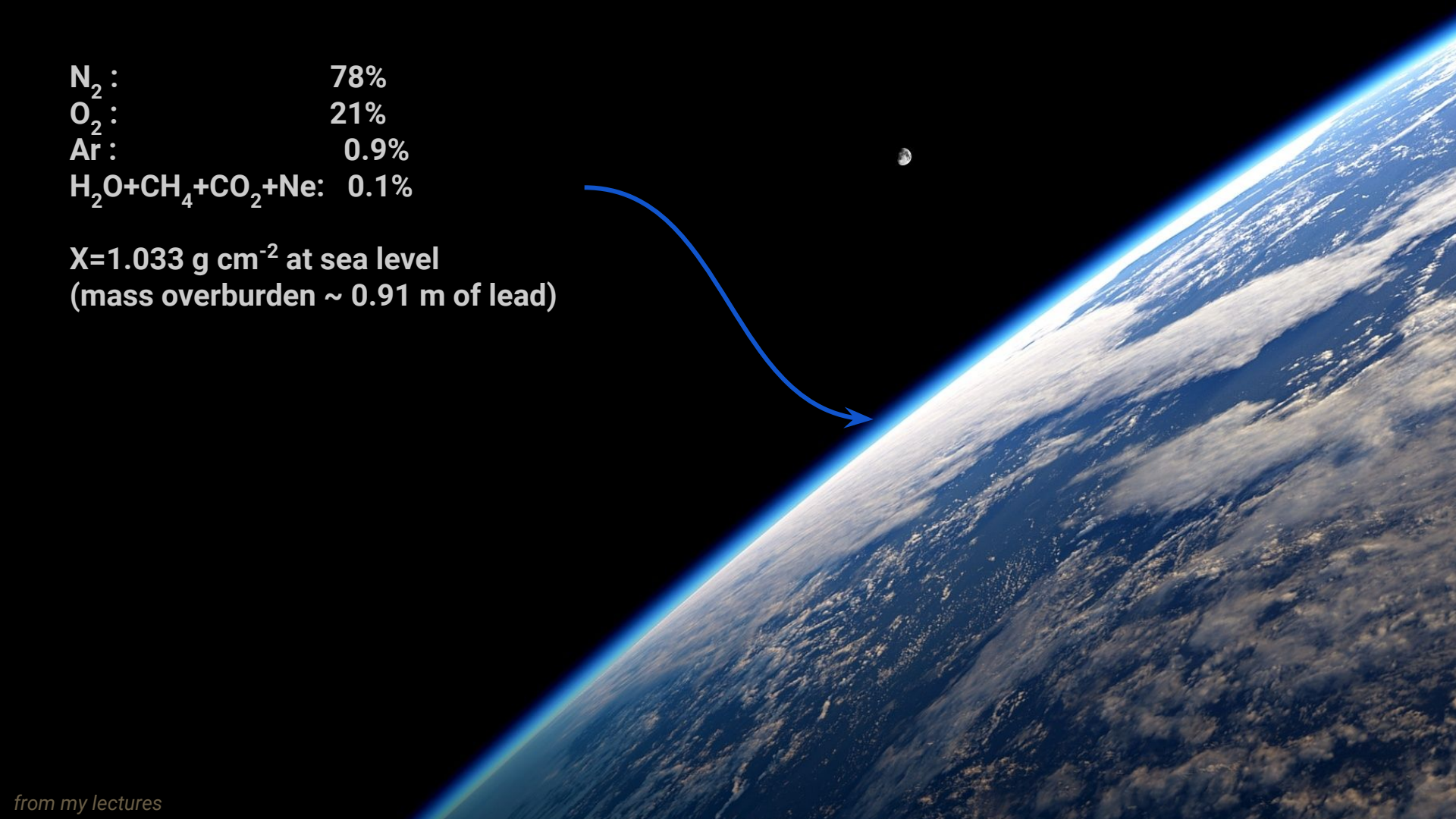
Spoiler alert:

The Earth is not flat.
Could you believe it?

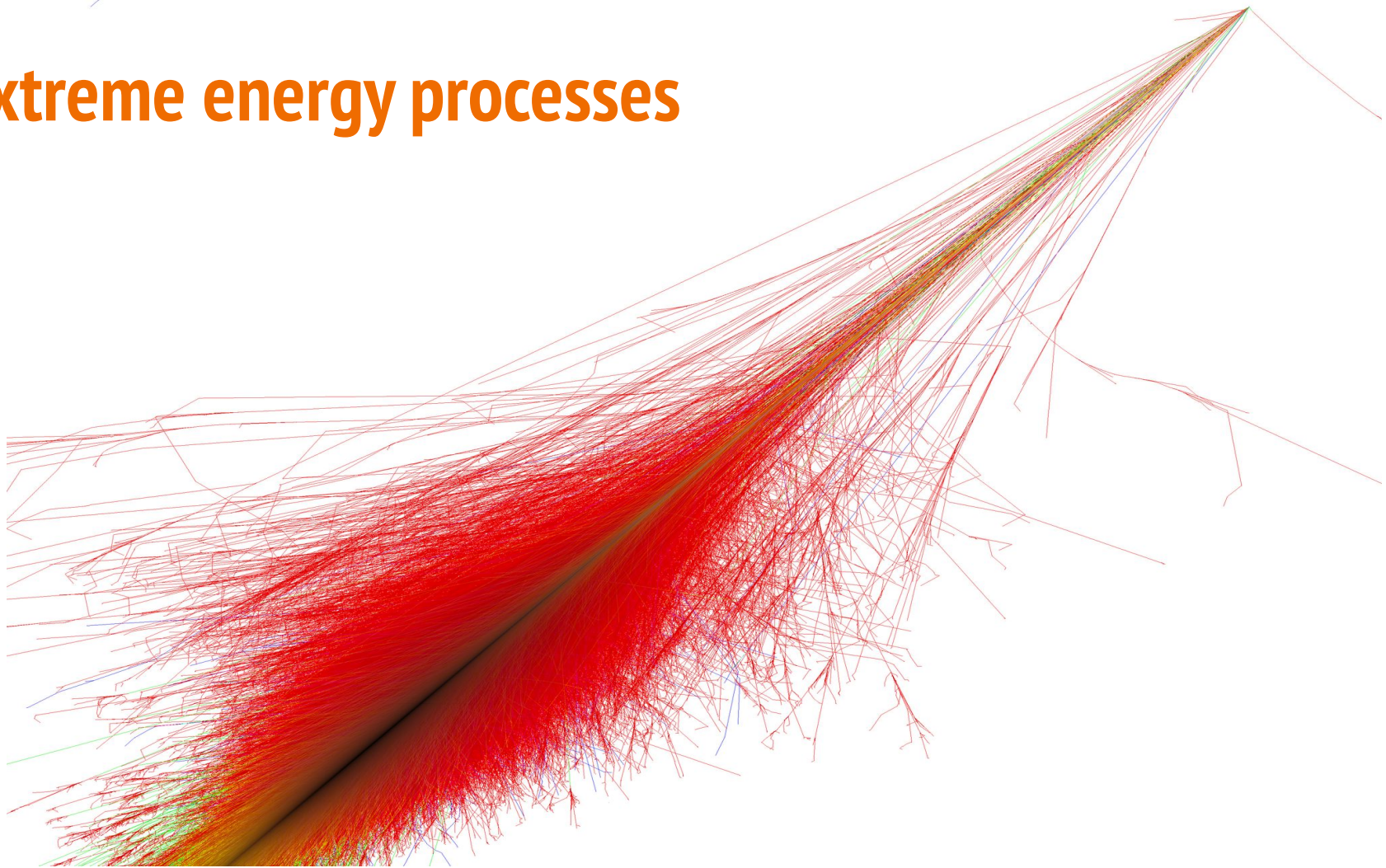


N_2 : 78%
O_2 : 21%
Ar : 0.9%
$H_2O+CH_4+CO_2+Ne$: 0.1%

$X=1.033$ g cm^{-2} at sea level
(mass overburden ~ 0.91 m of lead)



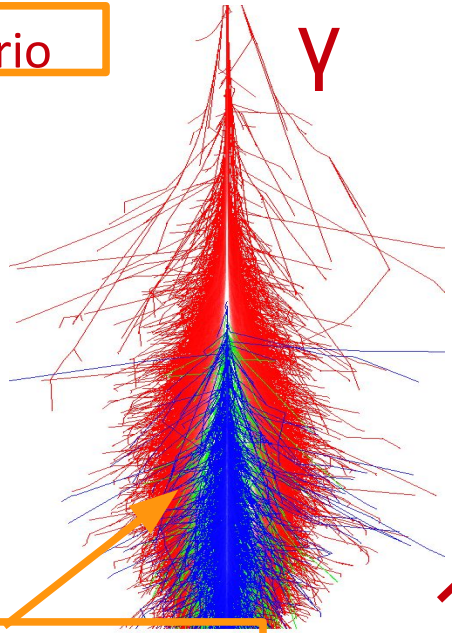
Extreme energy processes

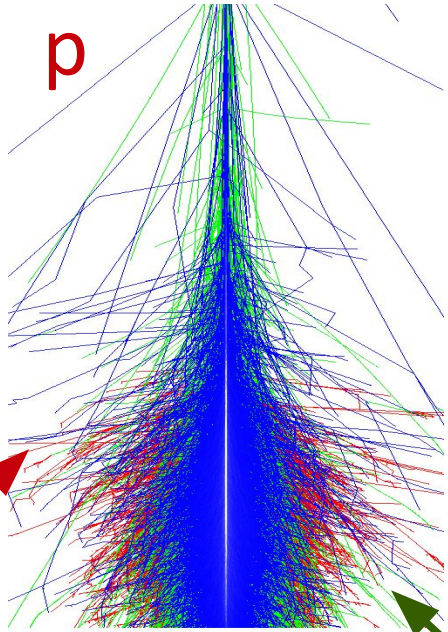


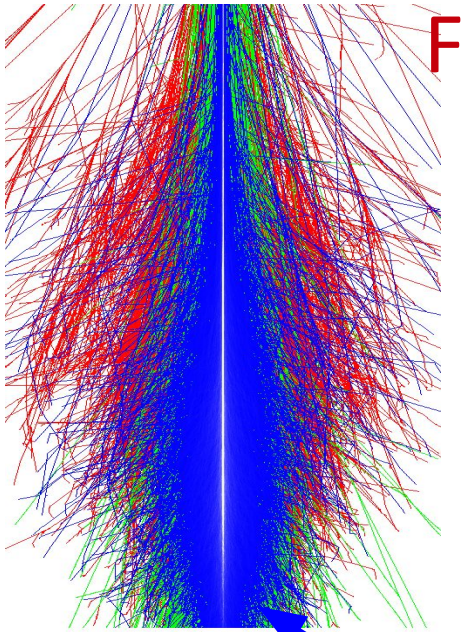
Extensive Air Showers

E=5x10^{14} eV

Primario







Secondaries

em

mu

hd

EAS development depend on primary composition

Extreme detectors for the extreme Universe

The Surface Detector of the Pierre Auger Observatory
~ (50x60) km = 3000 km² of instrumented area
1660 Water Cherenkov detectors
27 Fluorescence detectors

1500 m

eme Universe

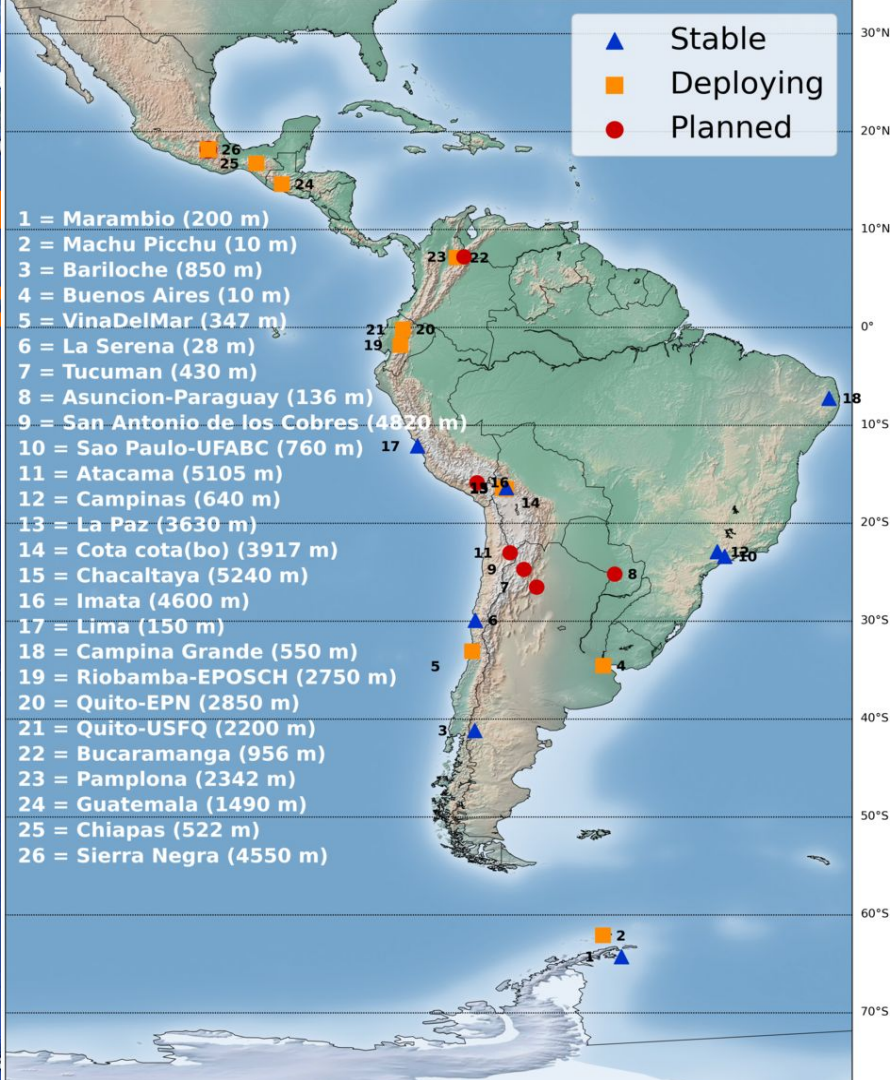
The Sur
Pierre A
~ (50x6
instrum
1660 W
detecto
27 Fluo

LAGO: The Latin American Giant Observatory
Extreme collaborations for build extreme detectors

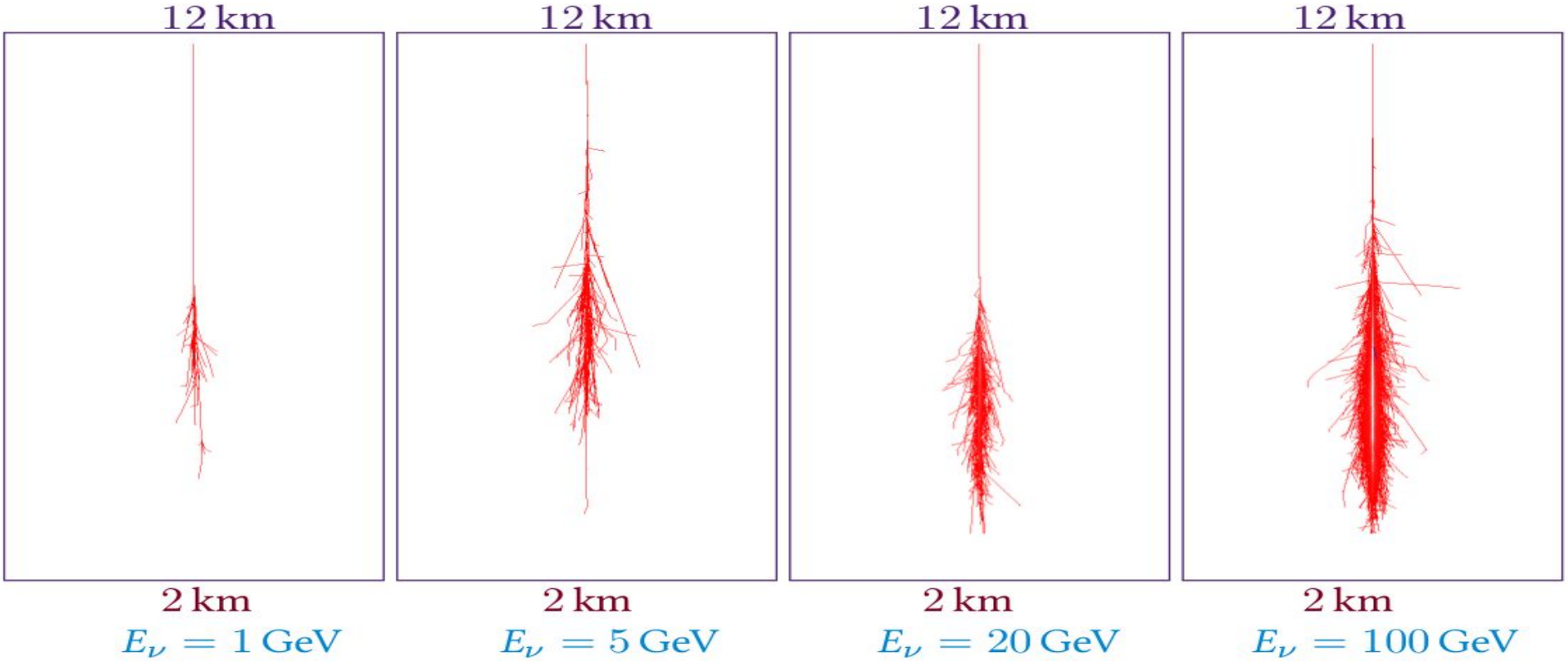
- 11 iberoamerican countries
- The LAGO Collaboration, +100 scientists from Iberoamerica (mostly LA)
- A giant WCD array at continental scale, from México to Antarctica

LAGO: The Latin American Giant Ob
Extreme collaborations for build ex

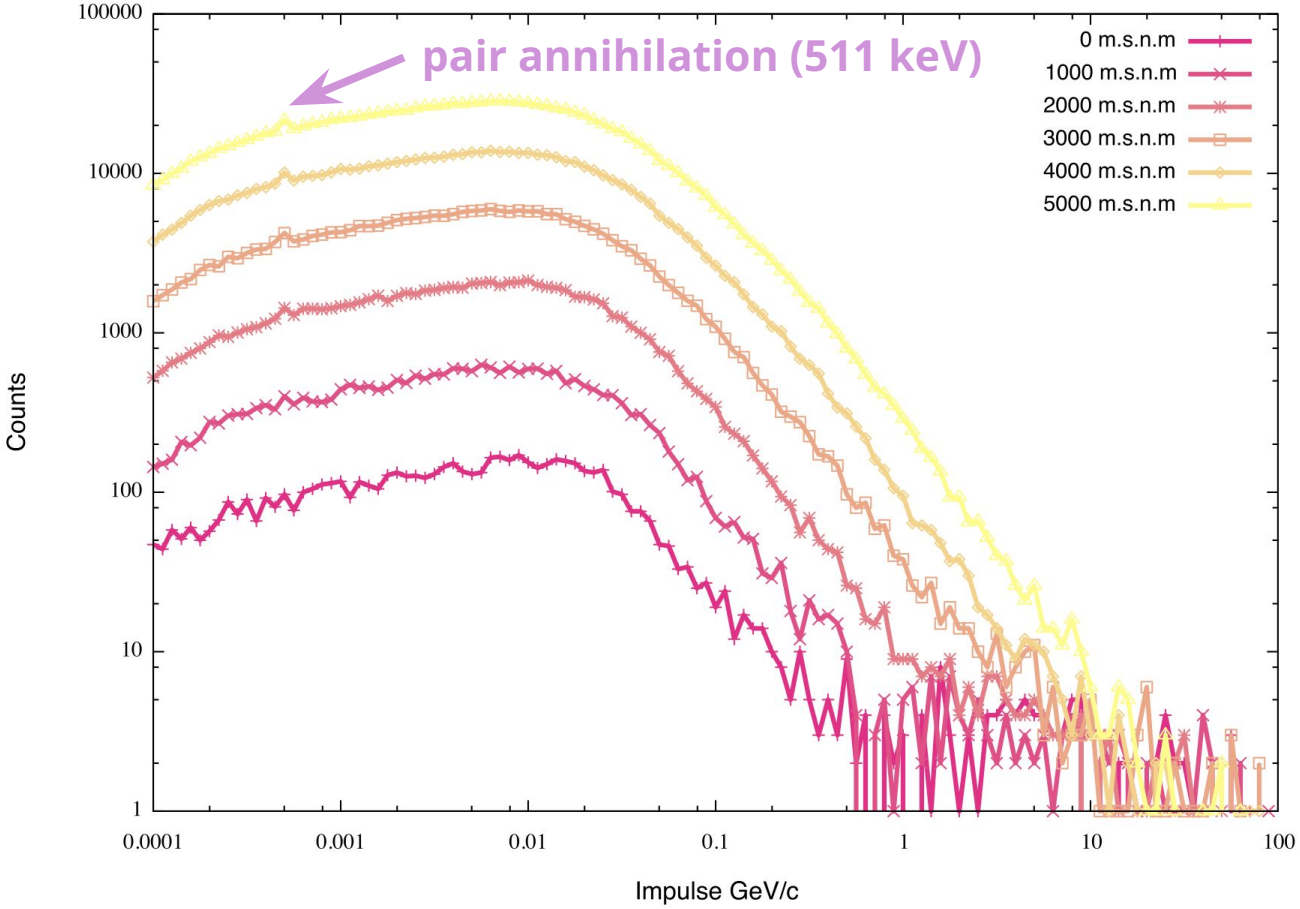
- 11 iberoamerican countries
- The LAGO Collaboration, +100 scientists from Iberoamerica (mostly LA)
- A giant WCD array at continental scale, from México to Antarctica + Spain (soon)



Altitude effect: atmospheric absorption

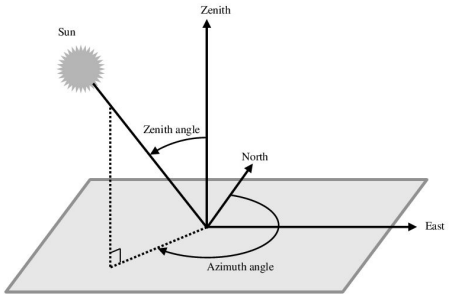


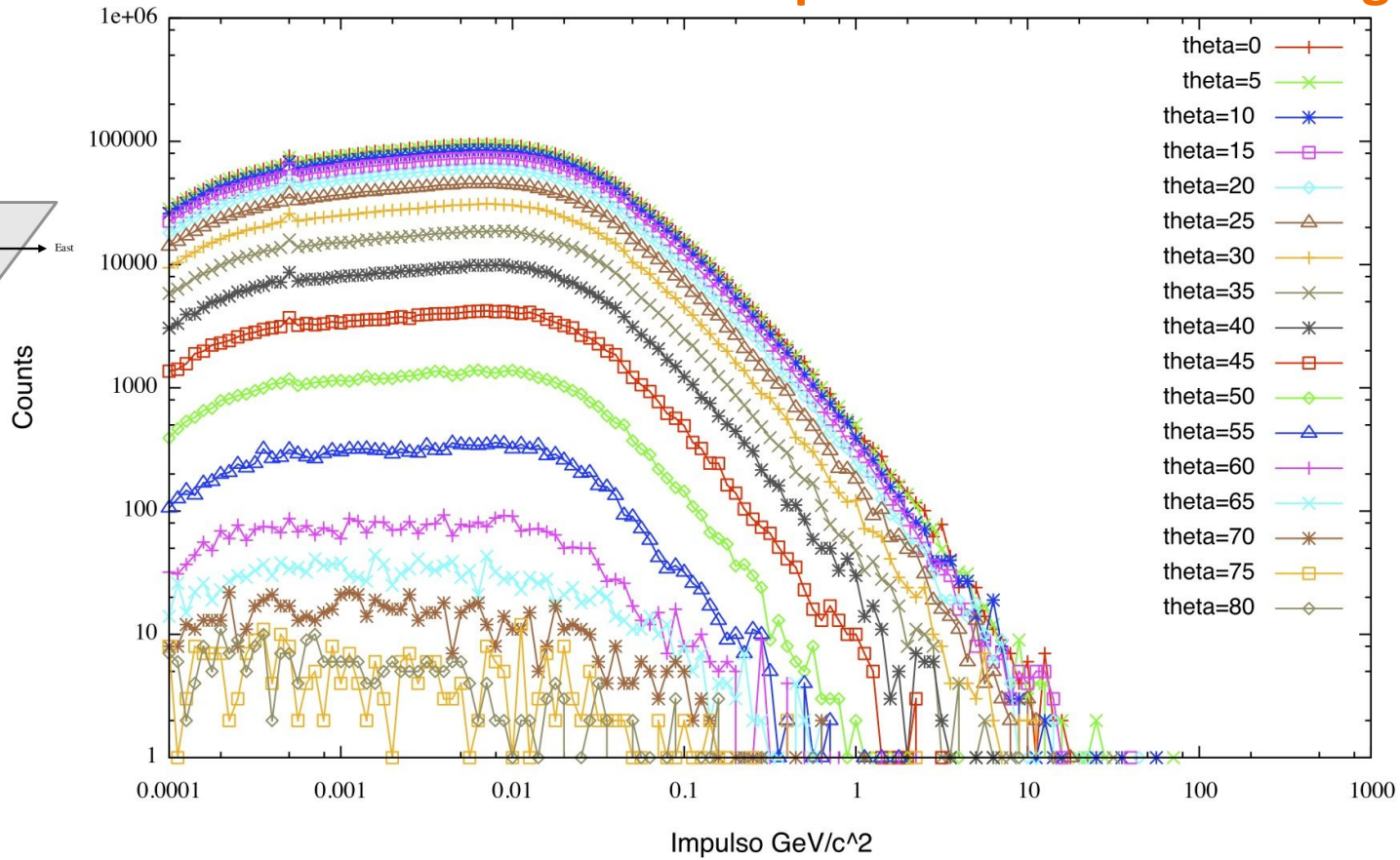
Atmospheric effect: altitude



C. Sarmiento-Cano, et al. (ICRC2021), DOI:10.22323/1.395.0929

Atmospheric effect: zenith angle

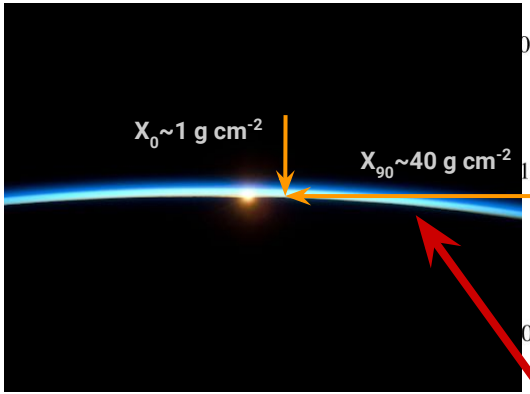


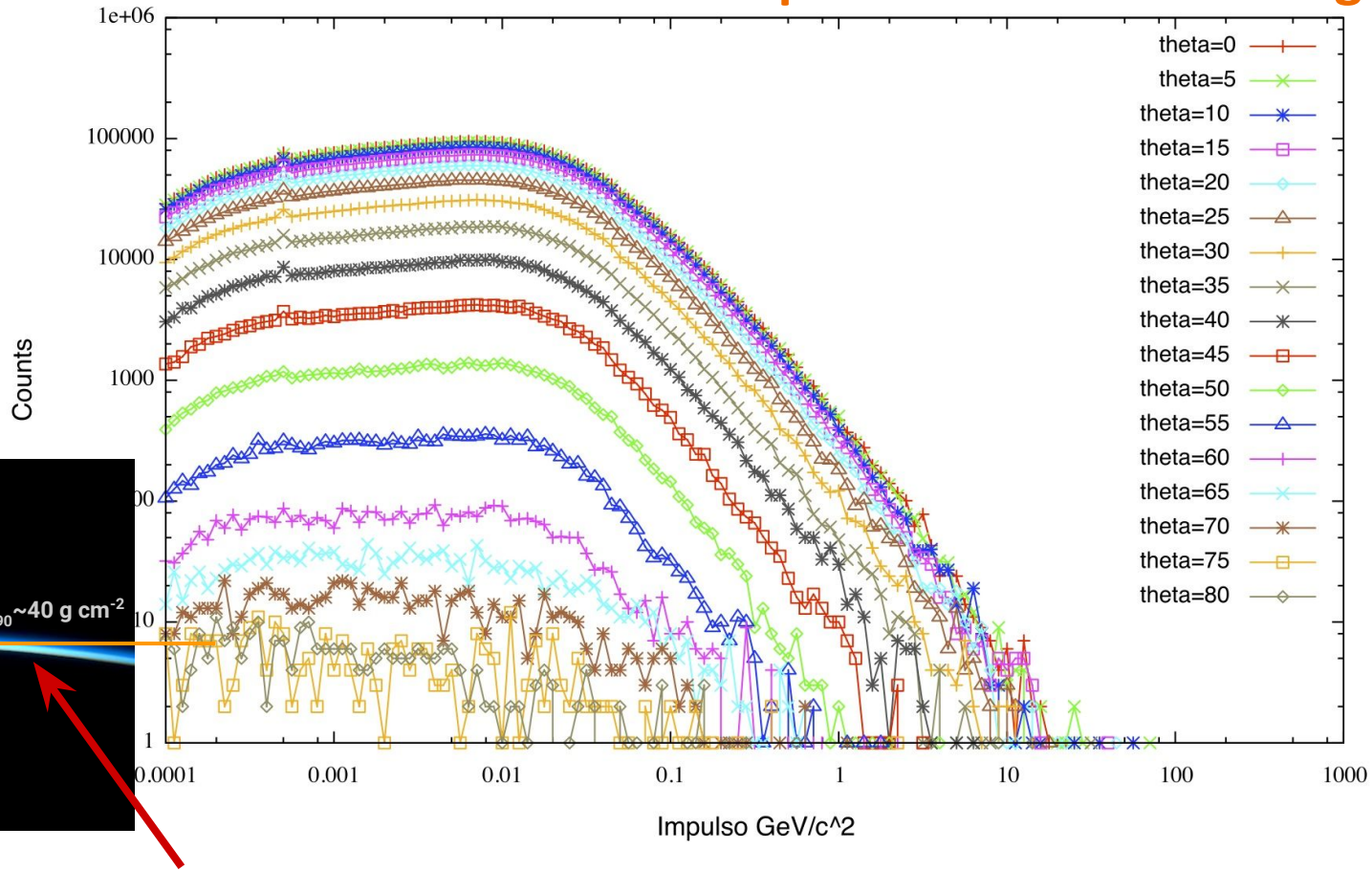


from my lectures

Atmospheric effect: zenith angle

Not obvious take-home message: **the atmosphere is curved, and therefore the Earth is curve**



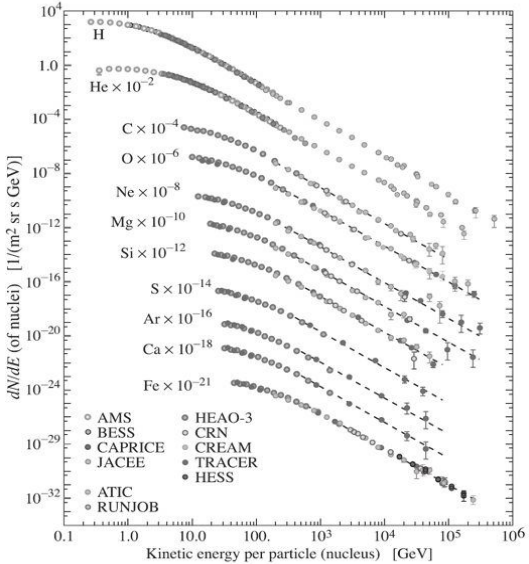


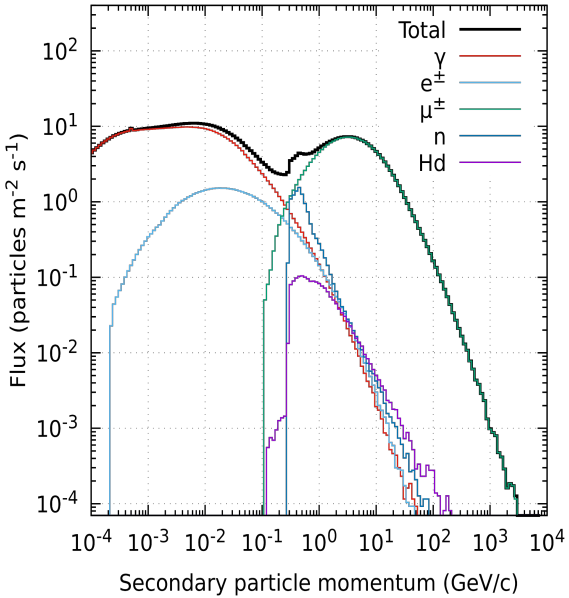
from my lectures

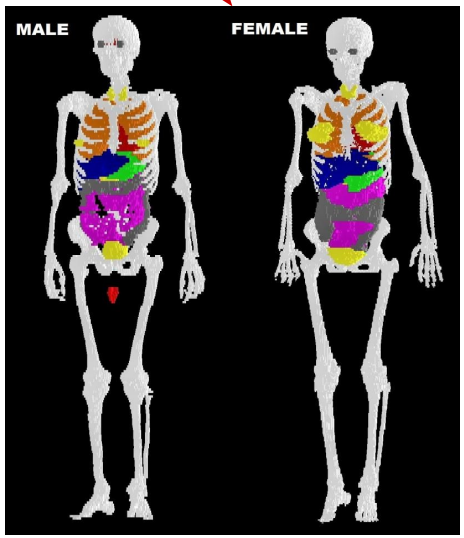
Extreme simulations for extreme phenomena

GCRFlux —Heliosphere→ Modulated Flux —Magnetosphere→ Primaries → · · ·

· · · → Primaries —Atmosphere→ Secondaries —Detector→ Signals.

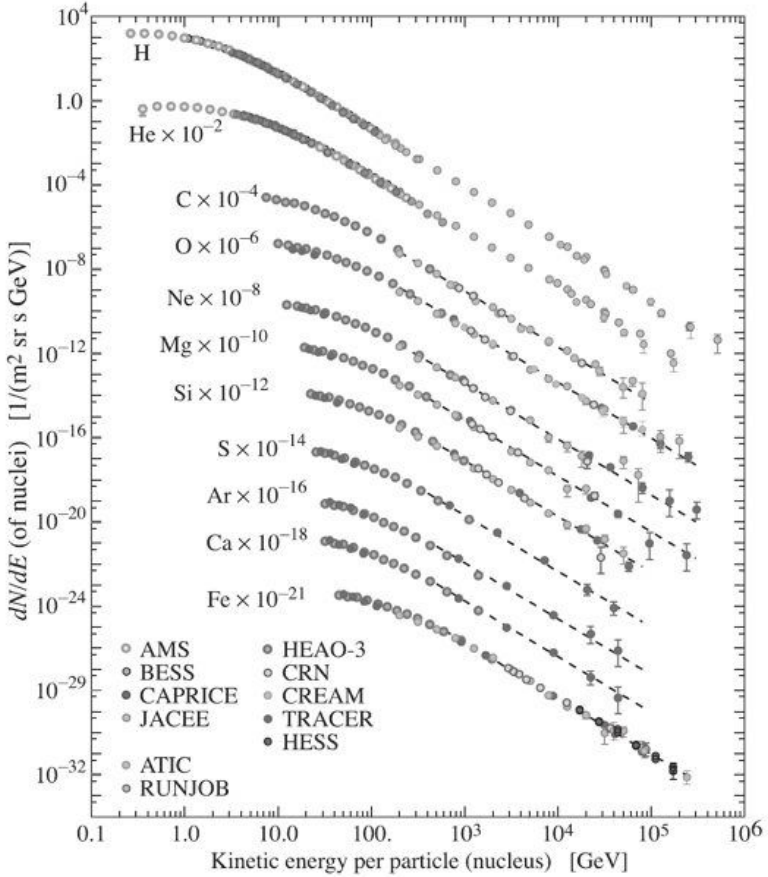






HA, et al., COLAGE 2021, and HA et al., Adv. Space Res., in preparation

primary flux integration



For each primary, we need to integrate its spectrum to get the expected (Poissonian) number of primaries at the top of the atmosphere

$$N_{t,S} = \int_t \int_S \int_\Omega \int_{E_p} j_0(E_p, Z_p)^{\alpha(E_p,Z_p)}\, dt\, dS\, d\Omega\, dE$$

We integrate:

full spectra, $1 < Z < 26$

hemisphere, $0 \leq \theta \leq \pi/2, -\pi \leq \phi \leq \pi$

energy range, $(R_C \times Z_p) < E/GeV < 10^{15}$

(R_C is the local, time-dependent, geomagnetic rigidity cut-off)

*M. Suárez-Durán, **HA** and LA Núñez, Space Weather, (2018), DOI:10.1002/2017SW001774*

Earth Magnetic Field (EMF)

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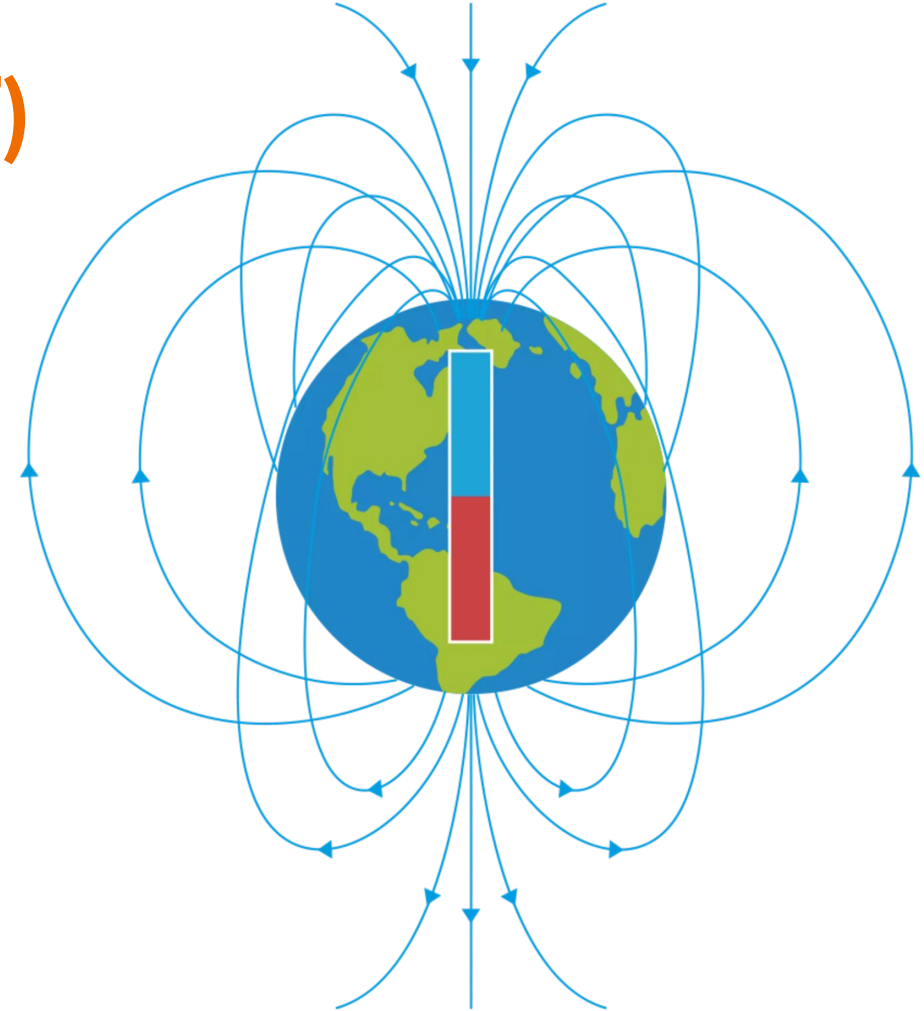
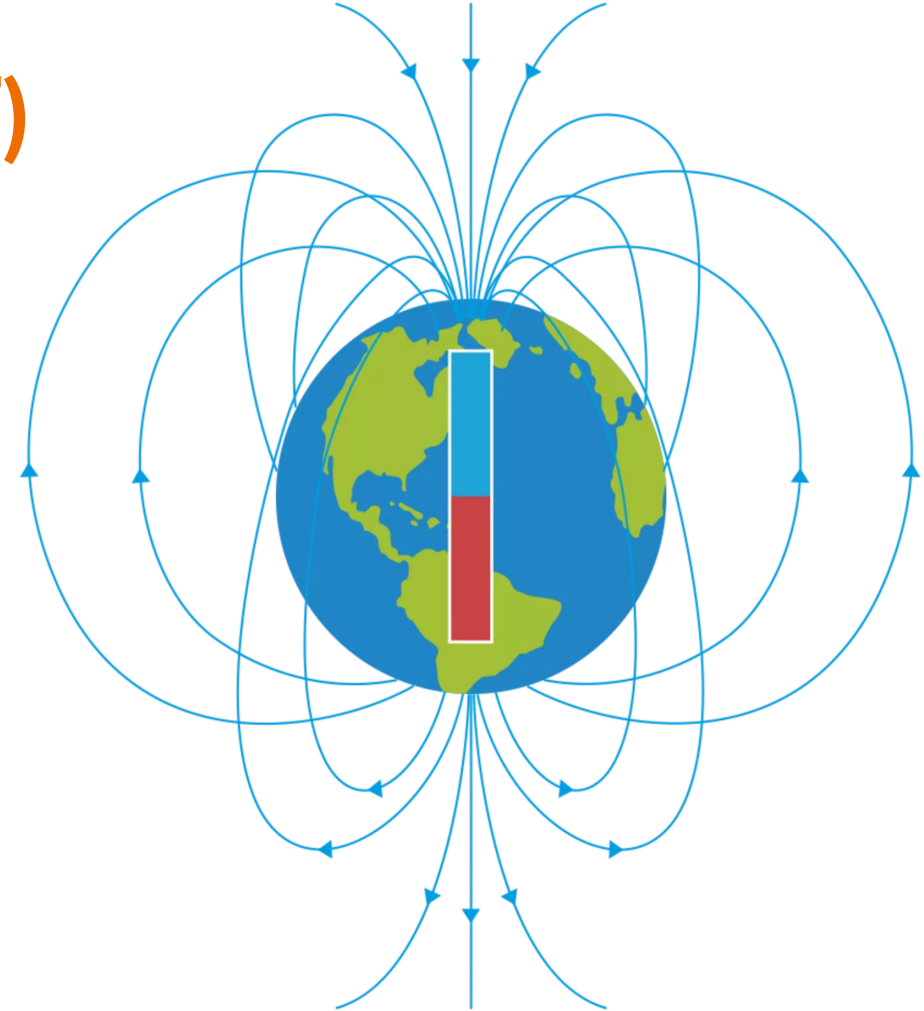
Spoilers alert:



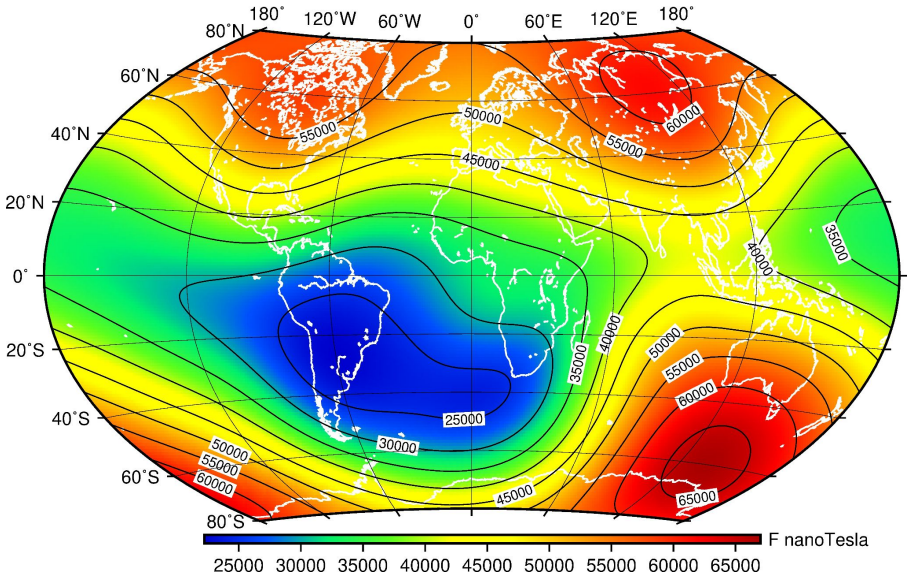
Earth Magnetic Field (EMF)

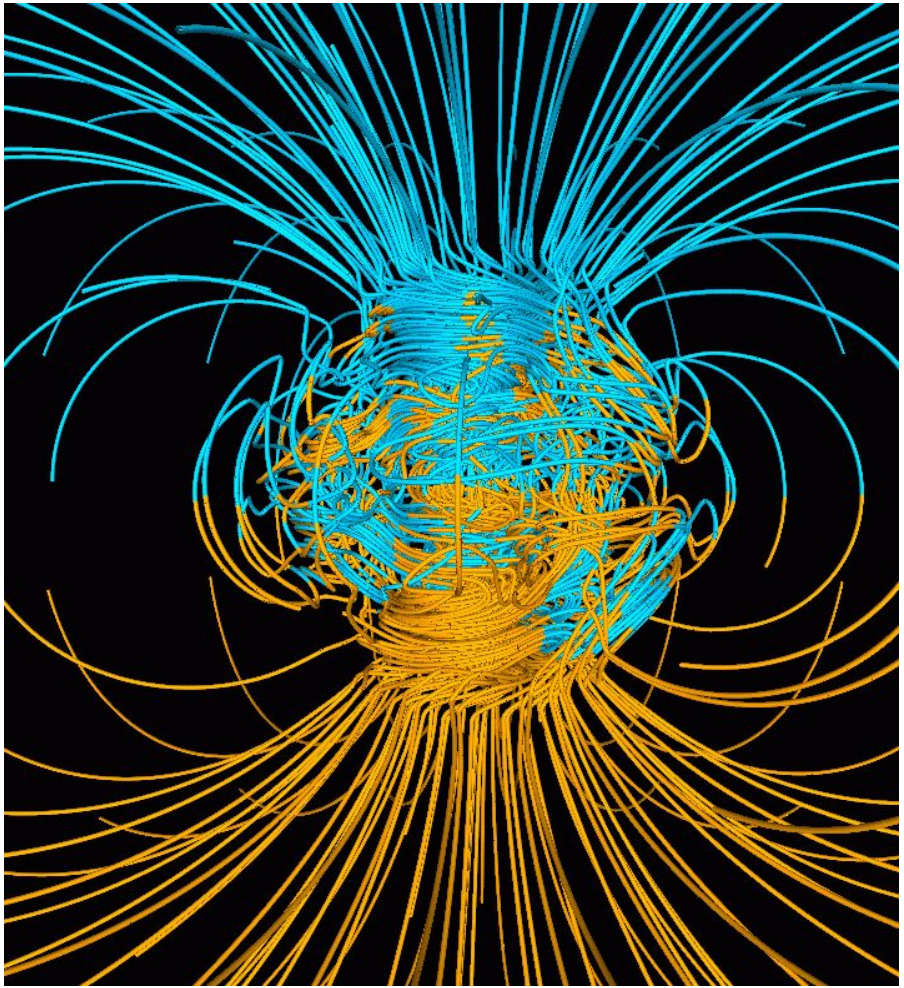
Spoilers alert:

Earth is not flat, vaccines work and this is not the real Earth Magnetic Field



extreme EMF

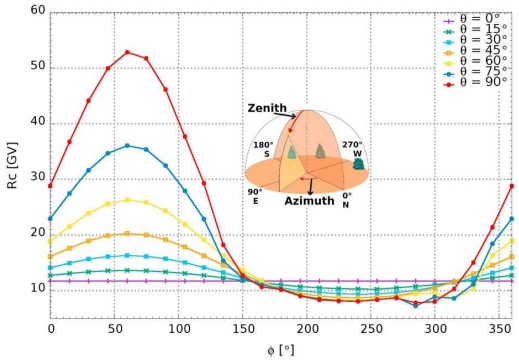


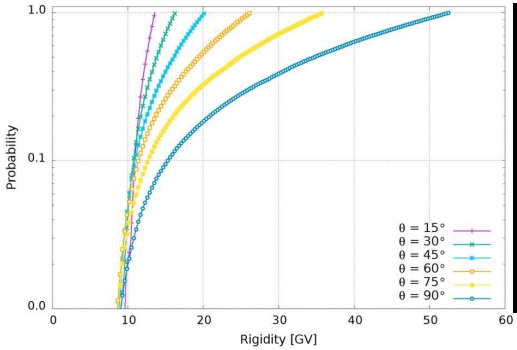


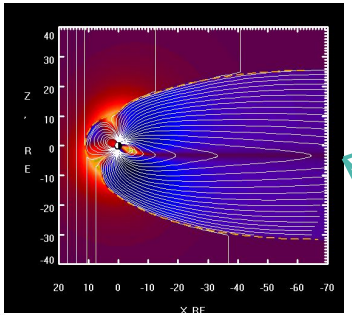
IGRF-13 Geomagnetic model
Total intensity field as for Jan 2020

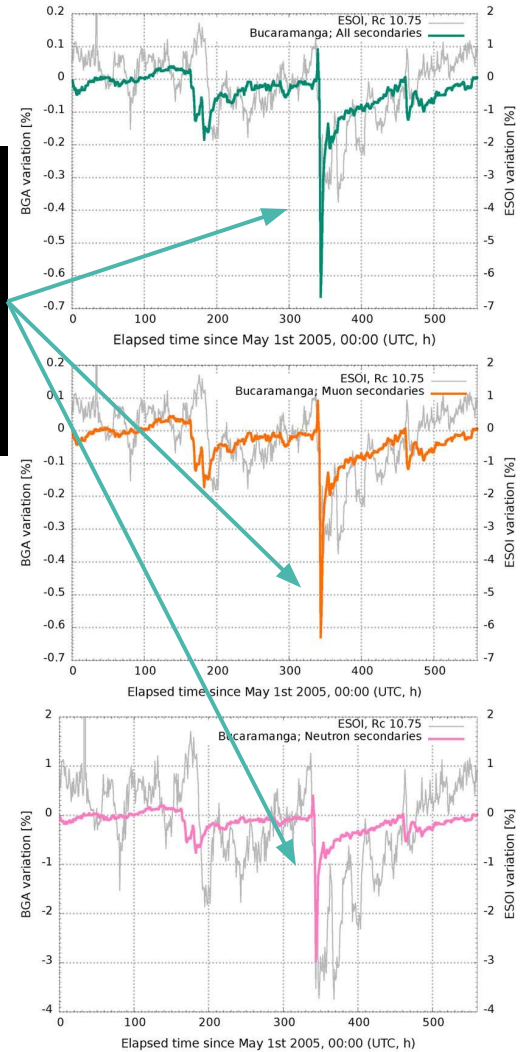
Multipole expansion up to l=13

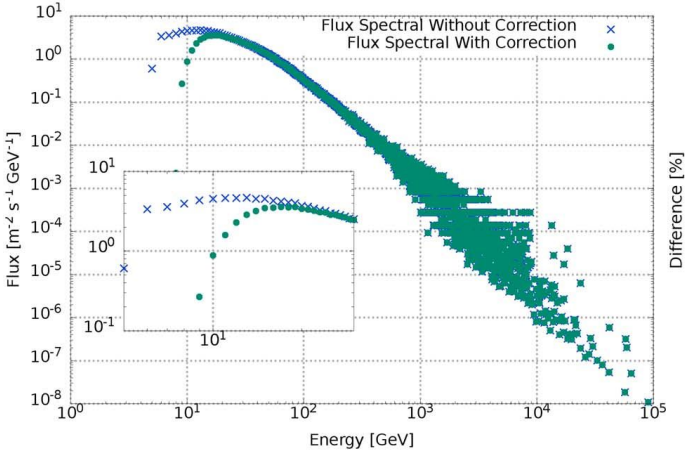
time-dependent local geomagnetic effects

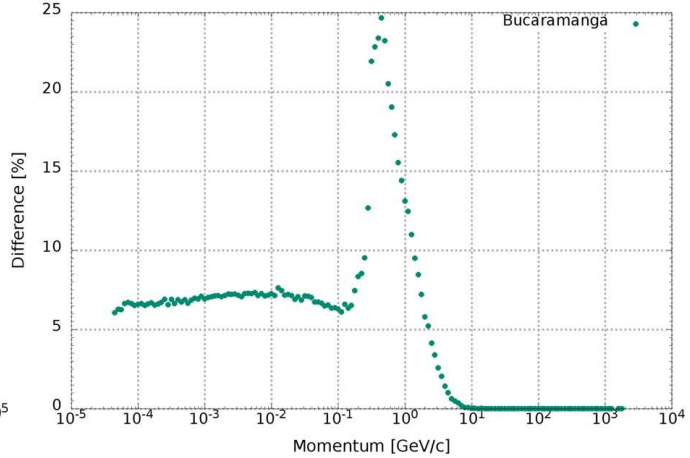








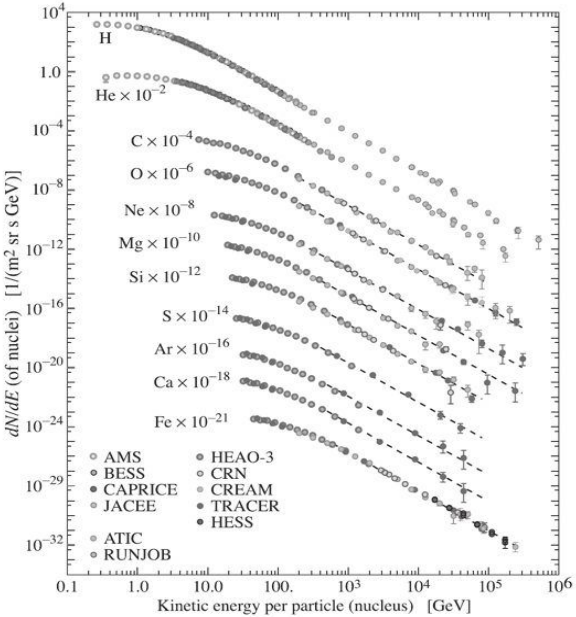


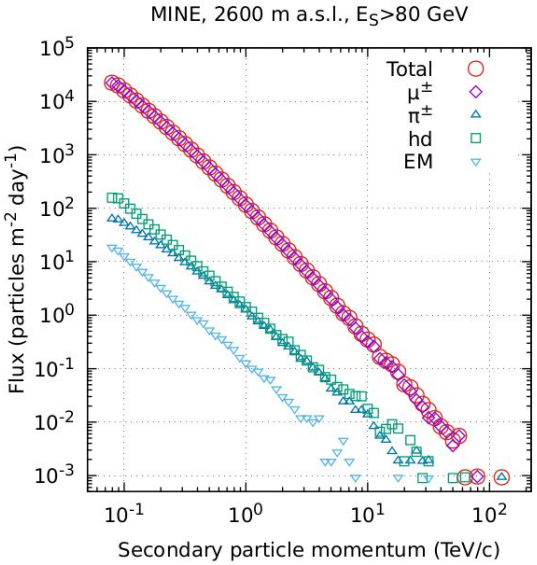


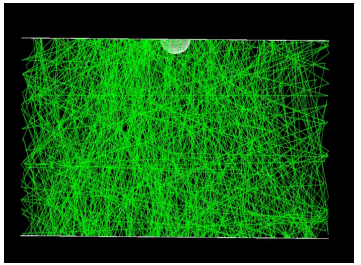
*M. Suárez-Durán, **HA** and LA Núñez, Space Weather, (2018), DOI:10.1002/2017SW001774*

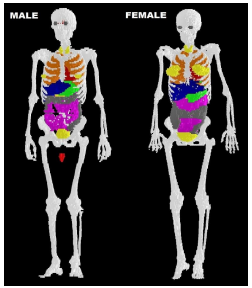
ARTI: The LAGO Simulation framework

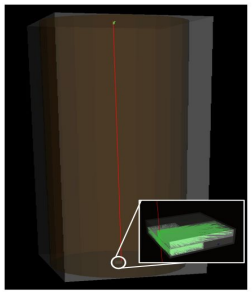
GCR Flux → (Heliosphere) → **Modulated Flux** → (Magnetosphere) → **Primaries** → (Atmosphere) → **Secondaries** → (Detector) → **Signals or Doses**









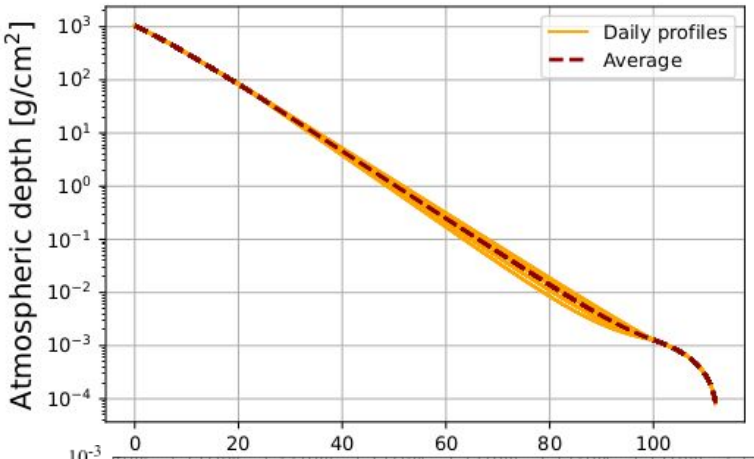


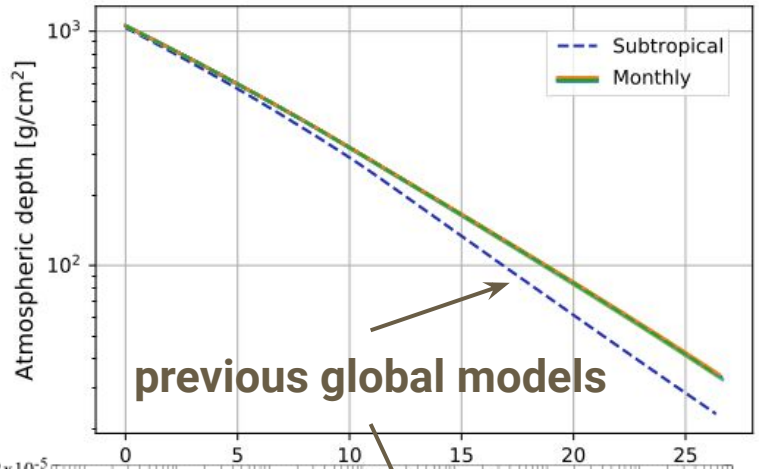
ARTI + CORSIKA | **ARTI** | **ARTI + MEIGA (Geant4)**

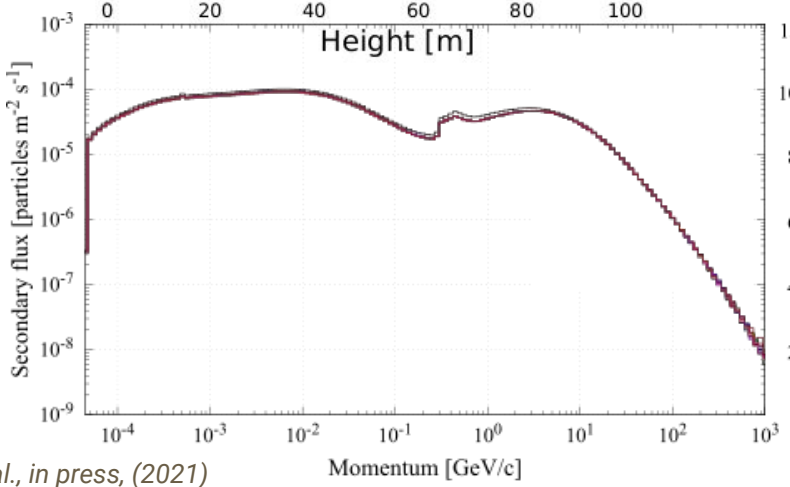
C. Sarmiento Cano et al., Eur. Phys. J. C (2022) 82: 1019 - https://doi.org/10.1140/epjc/s10052-022-10883-z

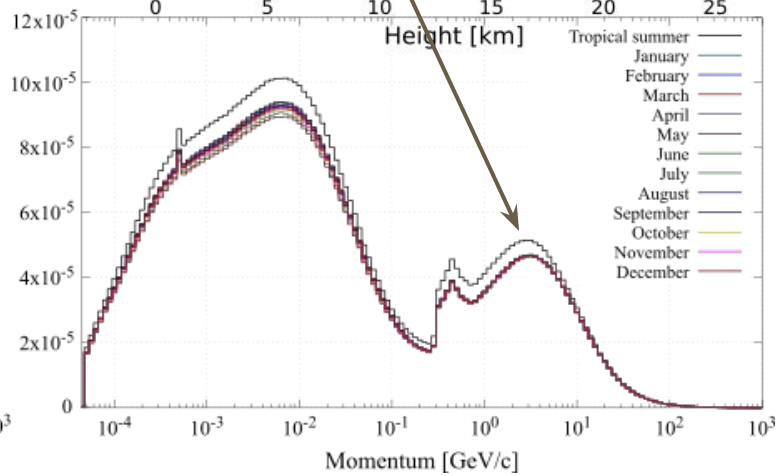
local atmospheric effects

Monthly-averaged or instantaneous local atmospheric profiles from GDAS



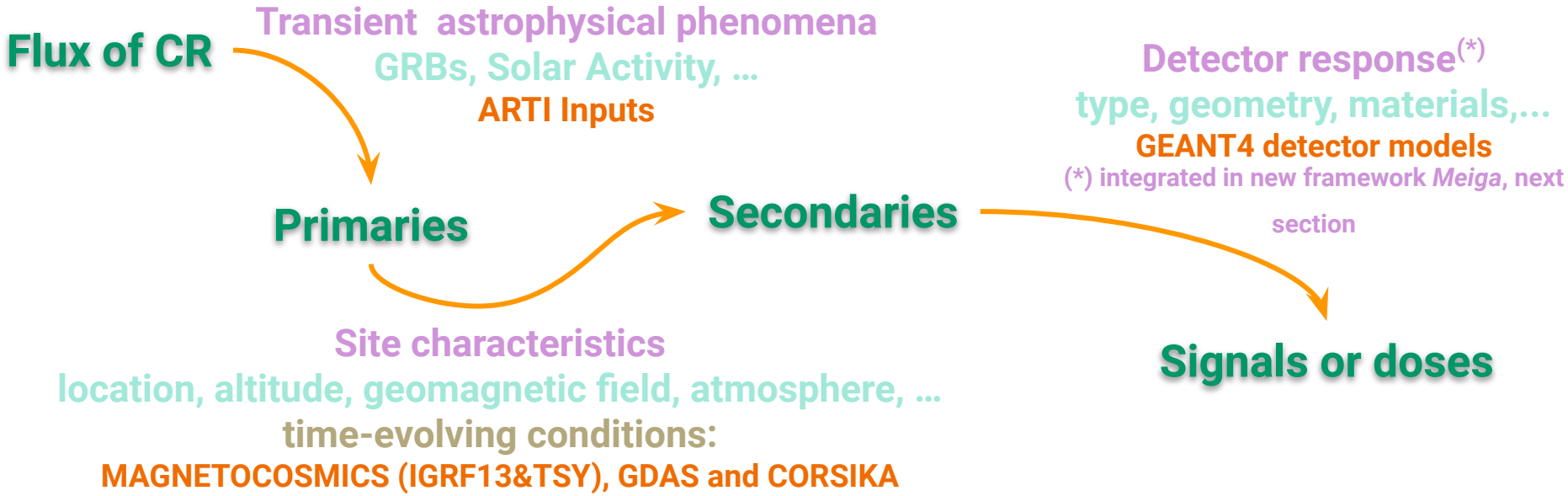






J. Grisales et al., in press, (2021)

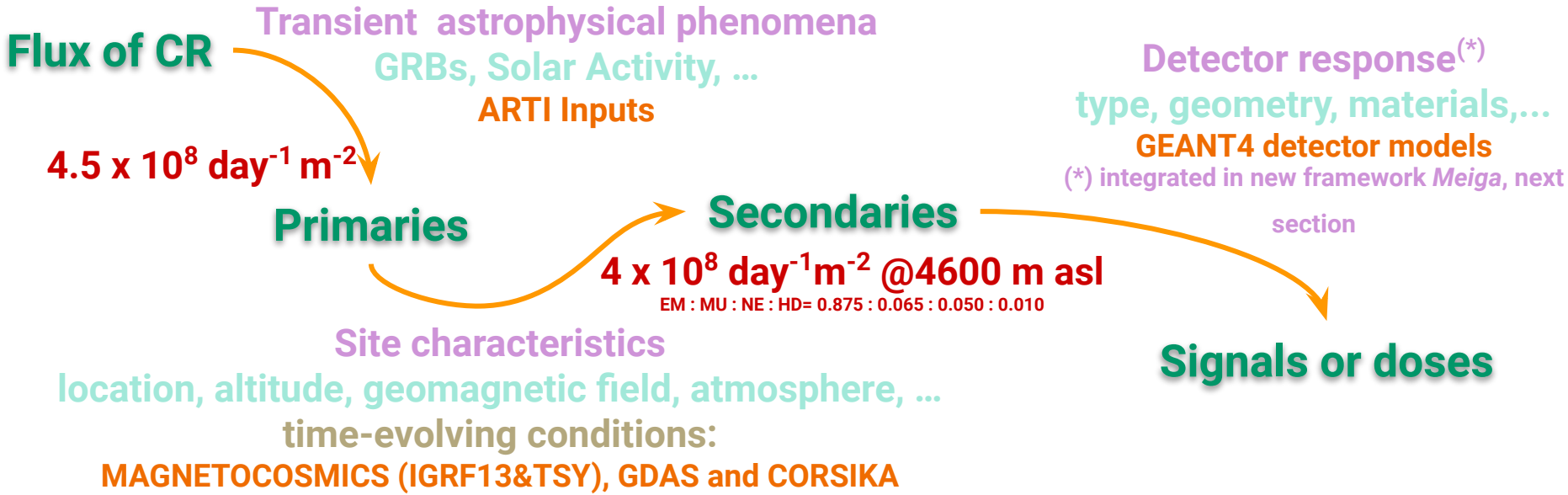
ARTI, our secondary flux simulation framework



ARTI inputs → **S0: raw Corsika** → **S1: secondaries** → **S2: signals**

*C. Sarmiento-Cano et al. (2019), DOI:10.22323/1.358.0412; **HA** et al., in preparation*

ARTI, our secondary flux simulation framework



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EOSC-Synergy

European Open Science Cloud expanding the capacity and capabilities of EOSC by leveraging the experience, effort and resources of national publicly-funded digital infrastructures

Main objectives of our Tematic Service: To produce standardized computational mechanisms and tools for

- production of simulated data (ARTI)
- curation and analysis (ANNA) of measured and simulated data
- feasibility for Geant4 applications on medicine and geophysics

- **Enable open data and open science standards**
  - FAIR principles: Findable, Accessible, Interoperable, Re-usable data
- **Enable data and resources long-term sustainability**

The FAIR paradigm

Findability

discoverable, identifiable and locatable by means of a standard identification mechanism

PiD, Metadata

Accessibility

always available and obtainable; even if the data is restricted, the metadata is open

Cloud storage

Interoperability

syntactically parseable and semantically understandable, allowing data exchange and reuse

Vocabulary

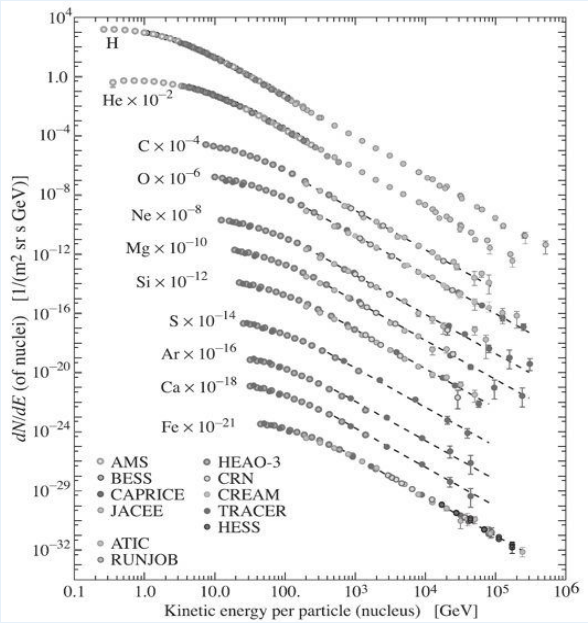
Reusability

described and shared with the least restrictive licences, allowing the widest reuse possible

Harversters, copyleft

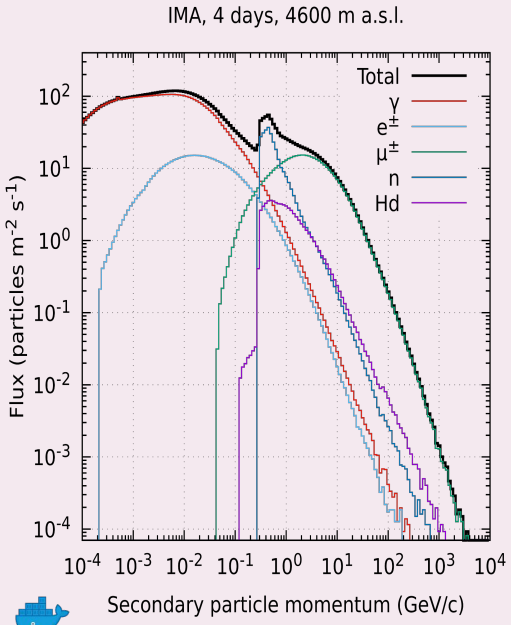
Standardizing: data-sets & encapsulates pipeline steps

GCR Flux → (Heliosphere) → Modulated Flux → (Magnetosphere) → **Primaries (S0)**



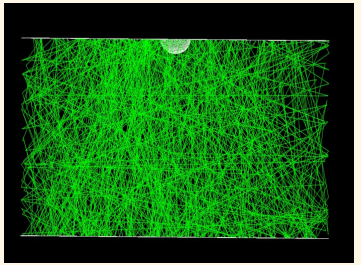
docker **onedataSim-S0**

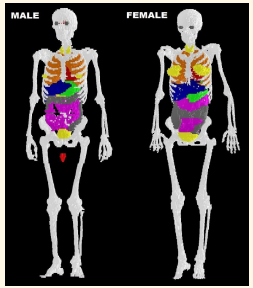
Atmosphere → **Secondaries (S1)**

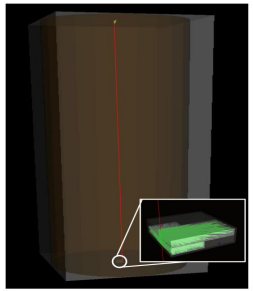


docker **onedataSim-S1**

Detector → **Signals or Doses (S2)**







docker **onedataSim-S2**

A. J. Rubio- Montero et al., PoS ICRC2021 261, 2021

Extreme infrastructures for extreme simulations

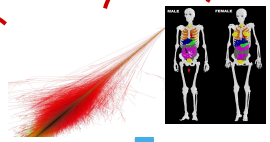
HPC provider assigns cloud resources to EOSC:
n Nodes, *r* GB/TB of RAM, *d* TB local storage

Infrastructure Manager

web-based service with templates for distributing all the available resources in virtual clusters. Installs OS, in our case, ubuntu 20.04 + slurm manager

docker containers with our codes are deployed from docker HUB in the virtual cluster

virtual cluster



FAIR: catalogs are findable, accessible, interoperable and reusable

Results are stored at cloud-based storage services. Access trough personal tokens

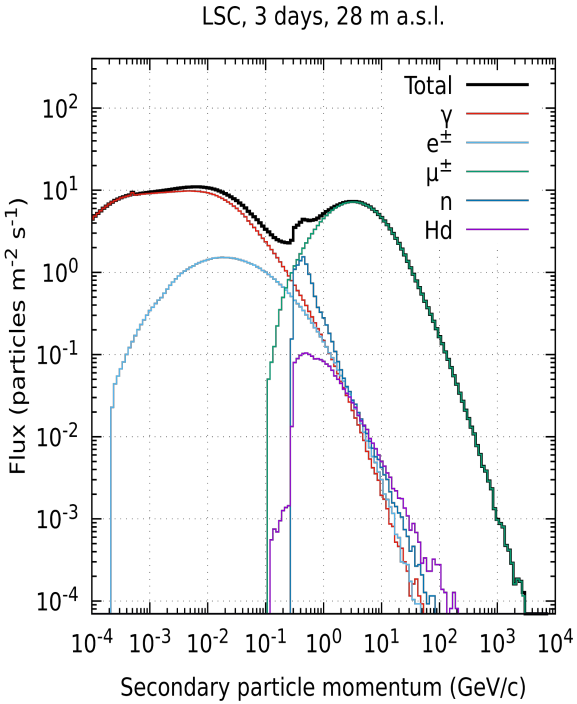
PID (Persistent IDentifiers) are assigned for each data catalog

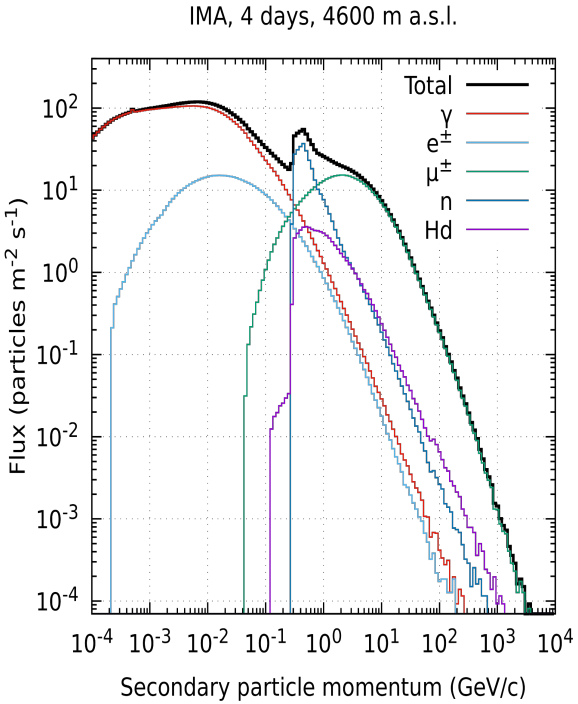
AR Rubio-Montero et al. (WSC-2021), IEEE, accepted

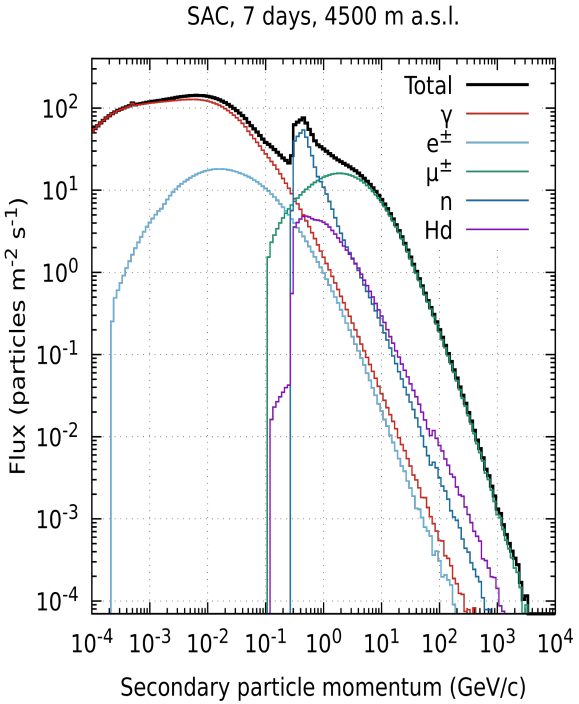
New detectors, integrated dose and better shieldings for HPC computer facilities

Detailed flux of of secondary particles at any location around the World.

Normalised secondary particle flux at different sites in LA







JA Rubio-Montero et al (ICRC 2021) DOI:10.22323/1.395.0261

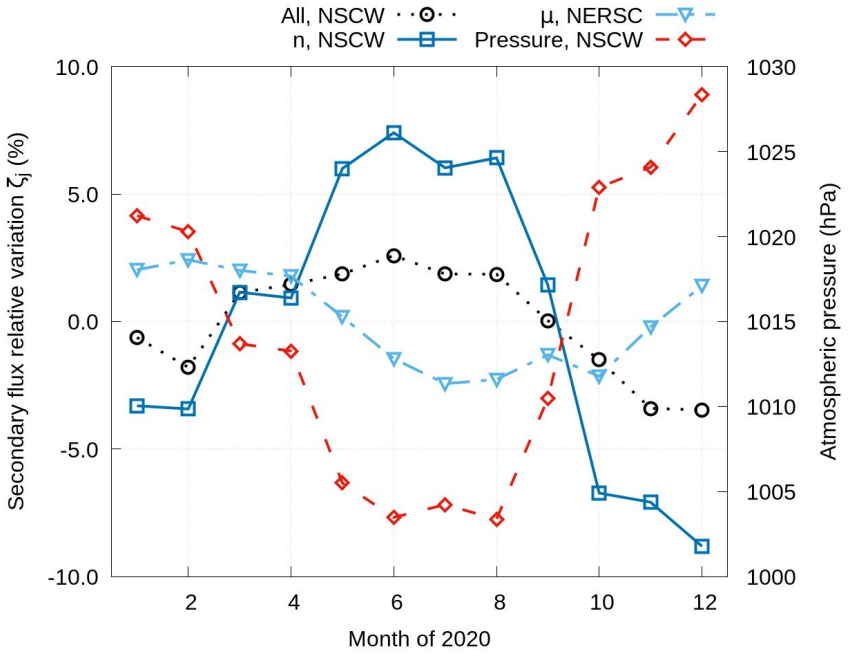
Extreme calculations for the extreme computers: the dawn of the Exascale

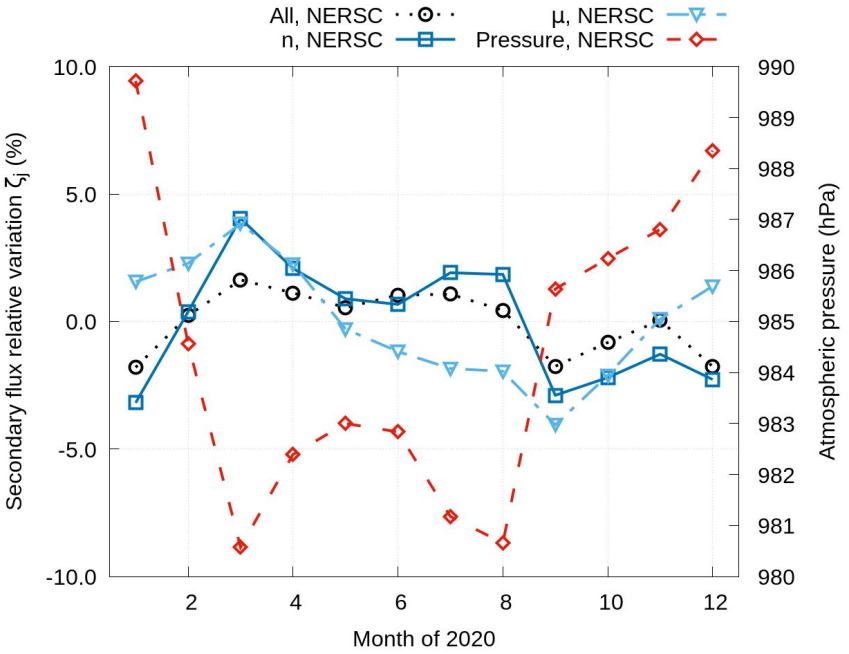
23 new exascale supercomputing centres are being built around the World

High- and low-energy neutrons are one of the main sources of Silent (undetected) Errors

H. Asorey and R. Mayo-García, J. Supercomputing 2022, https://doi.org/10.1007/s11227-022-04981-8

Seasonal variations and real atmospheric effects on HE neutrons

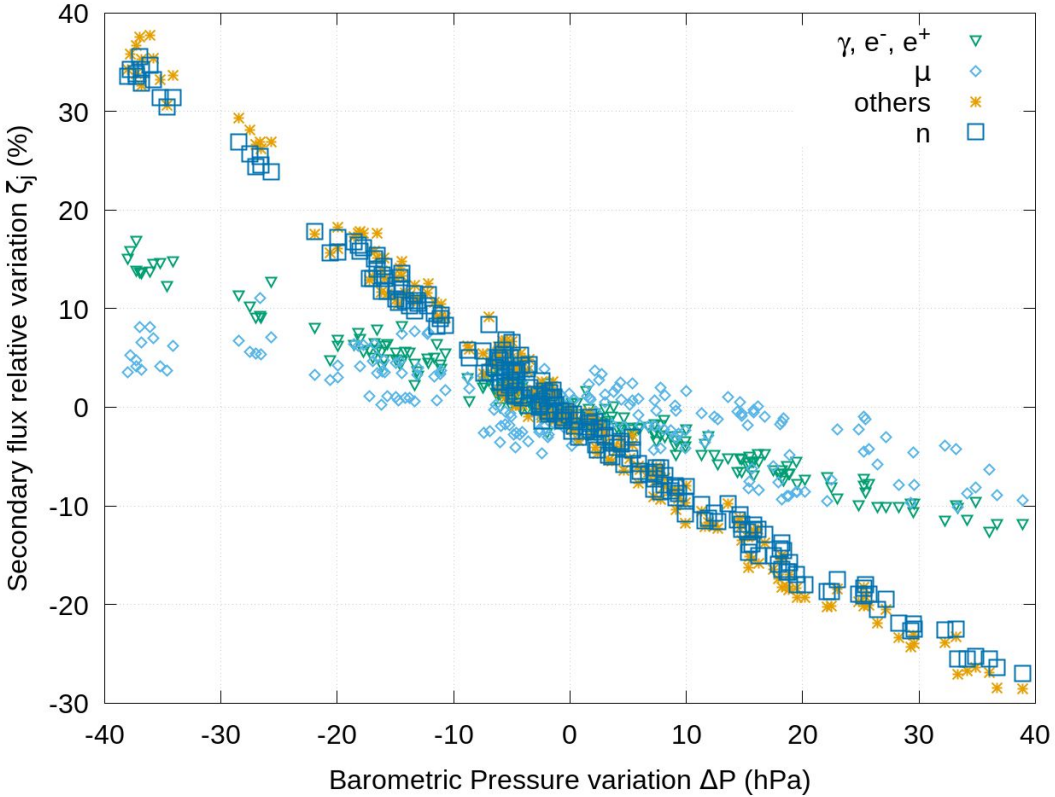




For each centre, real GDAS atmospheric profiles and geomagnetic conditions were extracted and relative variations were computed

H. Asorey and R. Mayo-García, J. Supercomputing 2022, https://doi.org/10.1007/s11227-022-04981-8

Barometric coefficients β and Failure in Time rates at each site



- Atmospheric impact depends on secondary particle type
- neutrons are the most affected
- Barometric coefficients β were calculated for each site
- From β and averaged values at each site is it possible to calculate the failure-in-time rates:

$$\mathrm{FIT}_{\mathrm{err}}(t) = 10^5 \, \sigma_{\mathrm{err}} \, \overline{\Xi_i} \left[1 + \beta_i \left(P(t) - \overline{P} \right) \right]$$

- And then, the expected MTBF (mean time between failures):

$$\mathrm{MTBF}_{\mathrm{err}}(t) = \frac{10^9}{\mathrm{FIT}_{\mathrm{err}}(t)} \mathrm{hours}$$

During a thunderstorm, ΔP~-5 hPa, and so, at, e.g., Titan, silent errors MTBF ~1 day

H. Asorey and R. Mayo-García, J. Supercomputing 2022, https://doi.org/10.1007/s11227-022-04981-8

Extreme detectors for extreme objects

- **Situation:**
  I want to look inside my arm
- **Solution 1:**

Extreme detectors for extreme objects

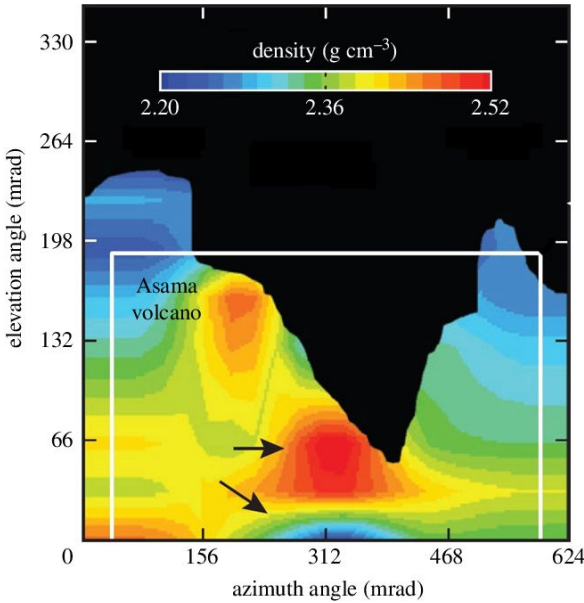
- **Situation:**
  I want to look inside my arm
- **Solution 1:**

- **Solution 2:**
  - Use ionizing radiation (X-Ray)
  - X-Ray absortion depends on density and atomic number of the medium
  - So, use a sensitive detector to (indirectly) measure the density (and materials)


Pyroclastic flows normally travel to distances of 5 to 10 kilometres
GVM

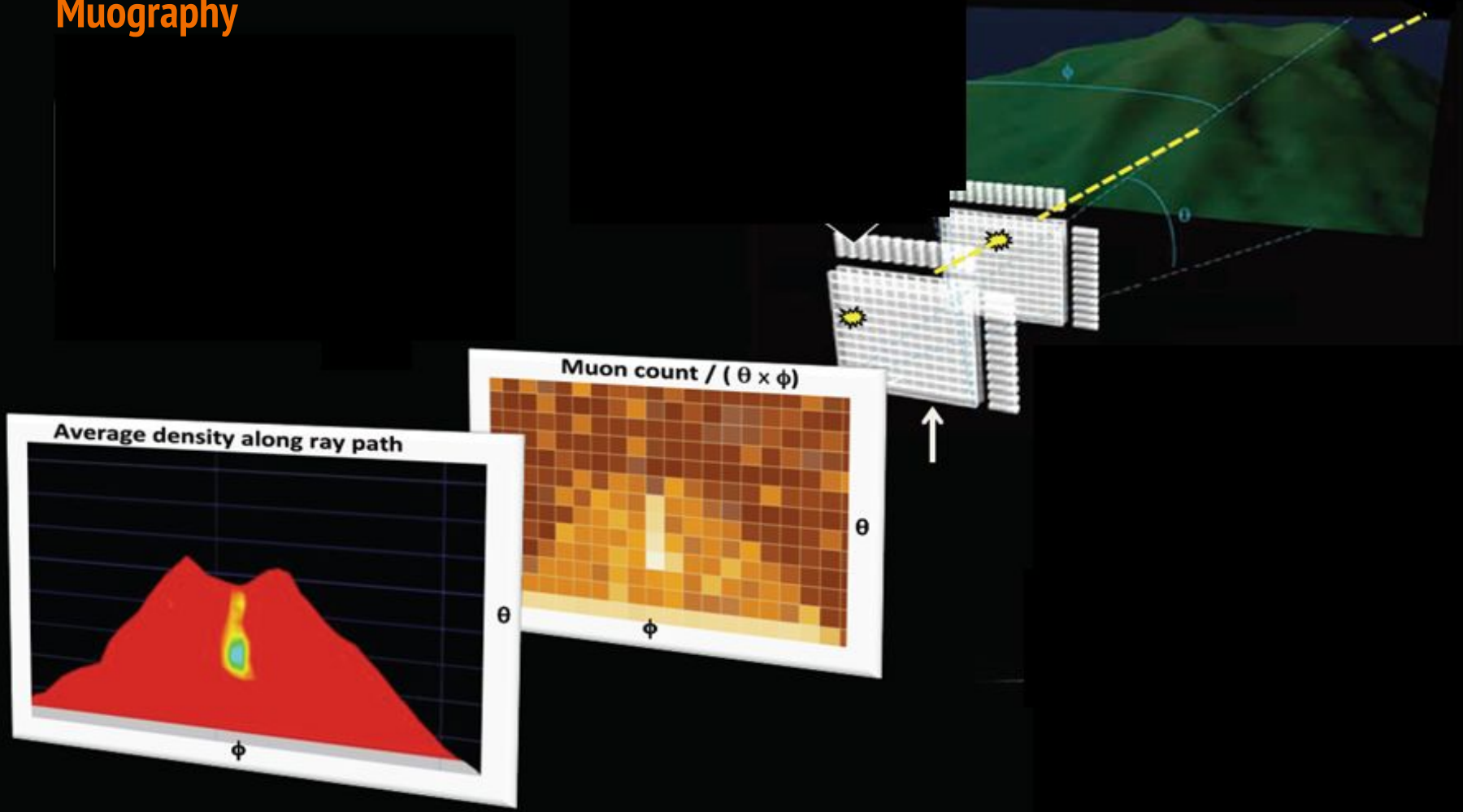
Muography, how to

- Start with an object with an unknown density profile
  - … measure the directional muon flux through this object
  - … and compare with the muon reference flux
  - → **you get the directional opacity of this object [g/cm²]**
- Additionally…
  - … obtain the external geometry of the object
  - → **and calculate the directional interaction distance [cm]**
- Finally, from…
  - directional opacity
  - directional interaction distances
- **→ get internal density profile along muon propagation direction**

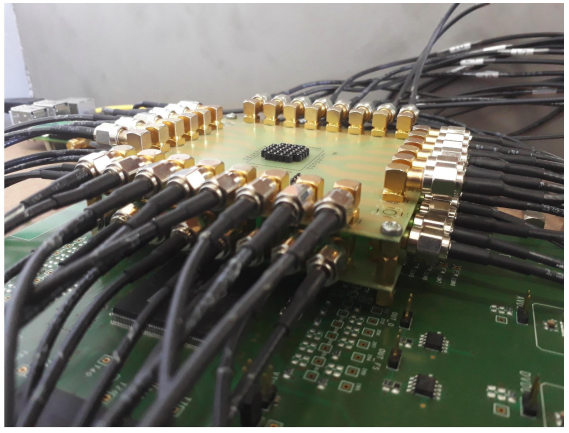


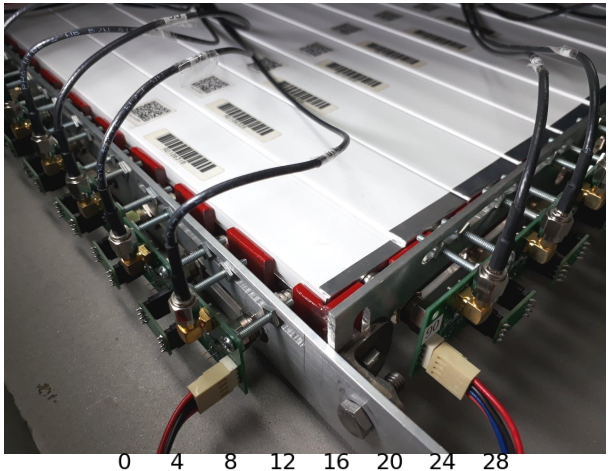
$$\varrho(L) \equiv \int_L \rho(\xi)\,\mathrm{d}\xi,$$

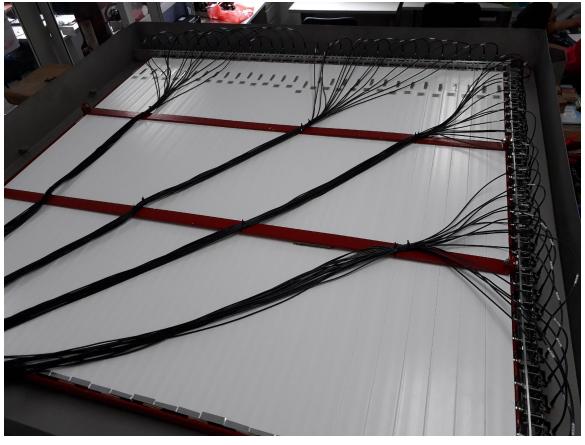
Muography

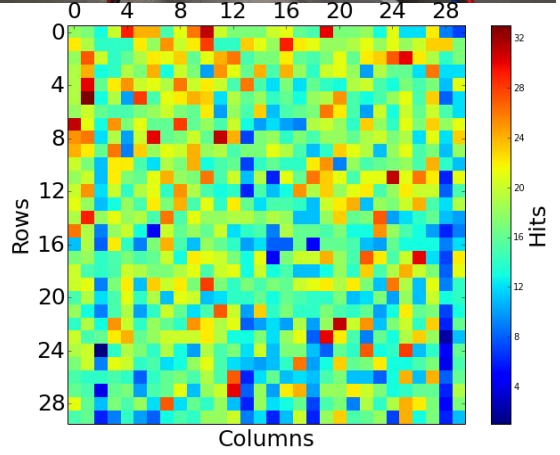


Extreme electronics for extreme measurements

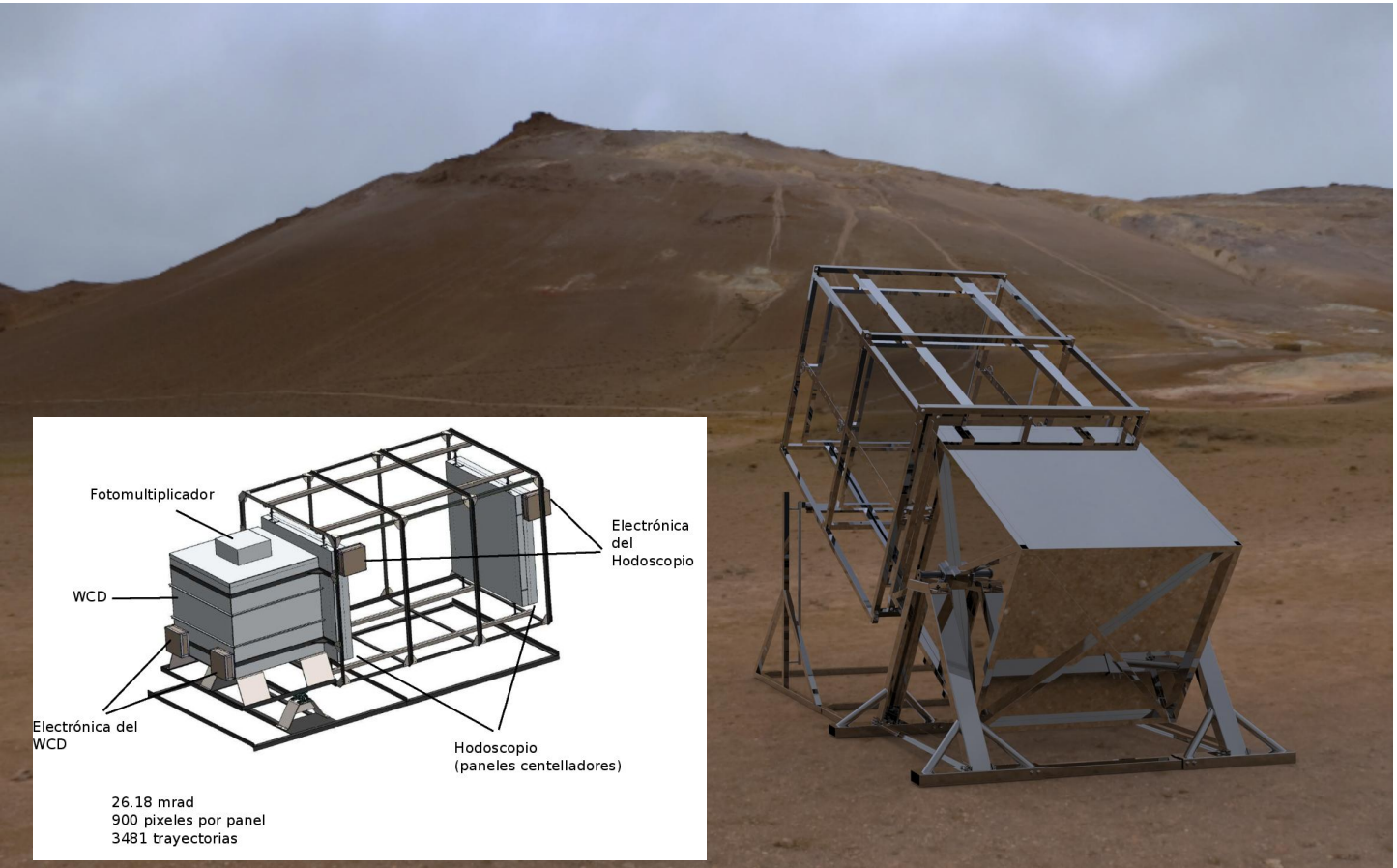






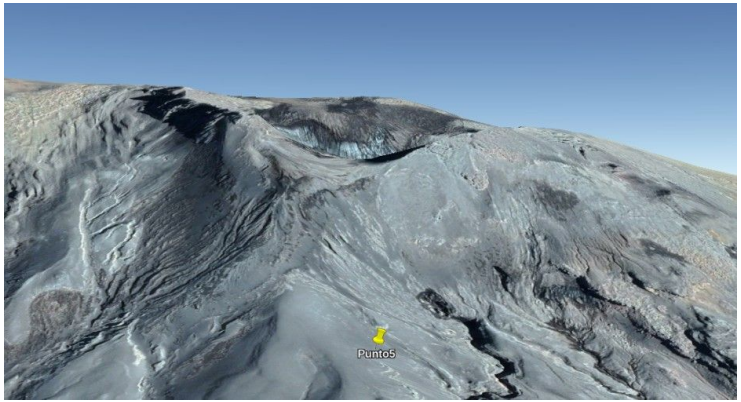


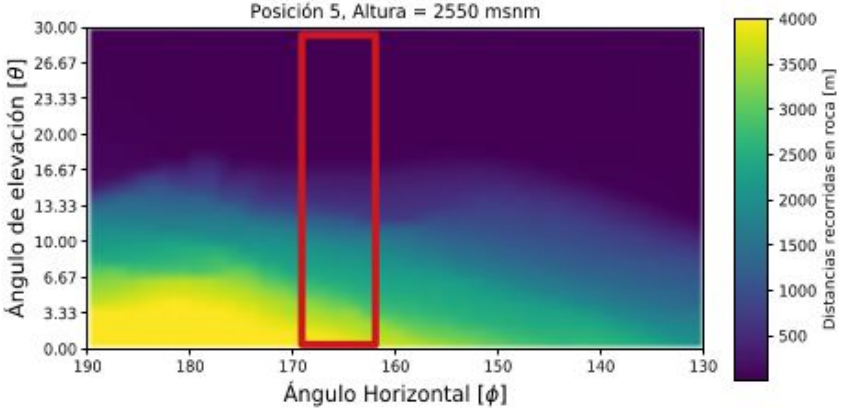
MuTe, the Muon Telescope

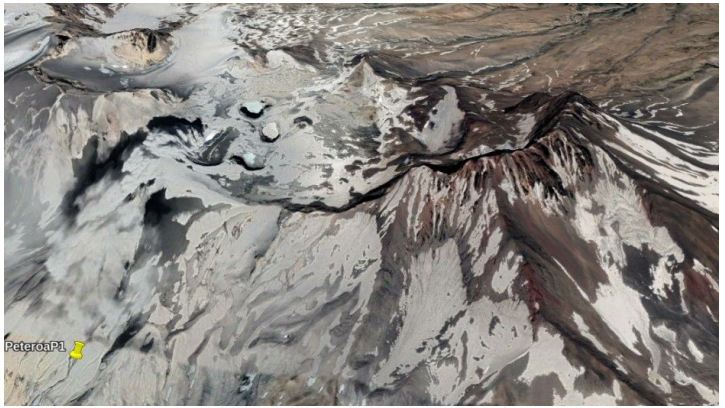


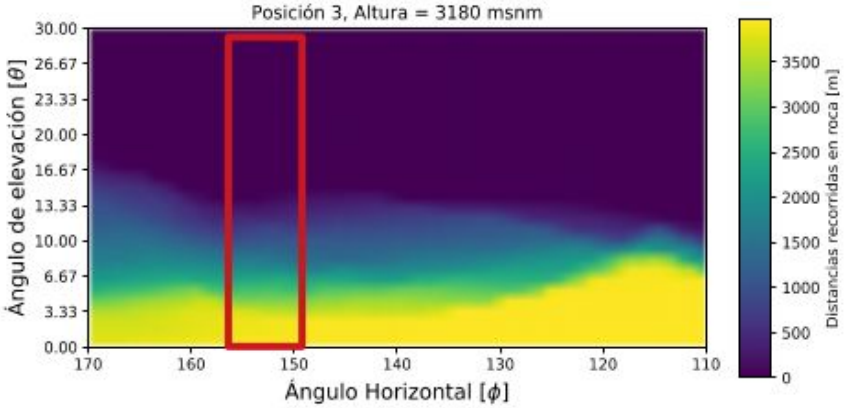
26.18 mrad
900 pixeles por panel
3481 trayectorias

Two possible volcanic targets in Argentina
Copahue and Planchón-Peteroa

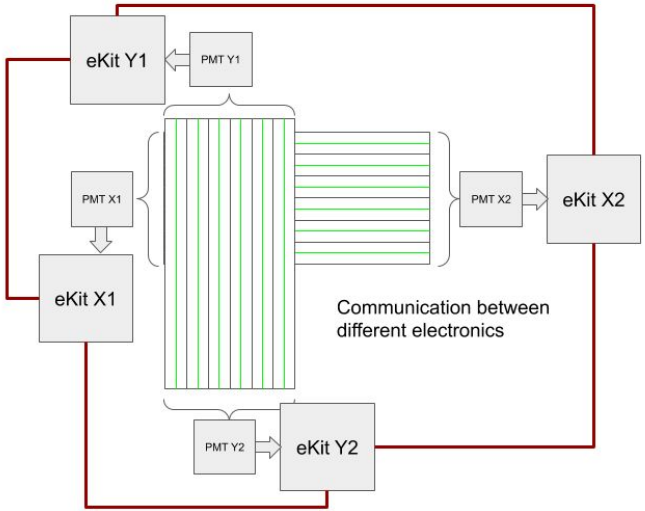


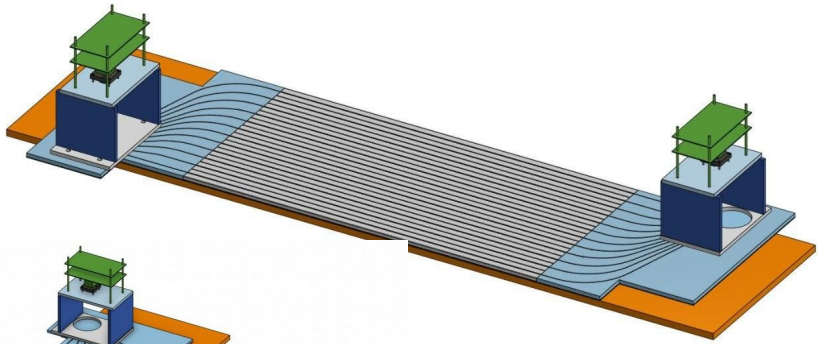


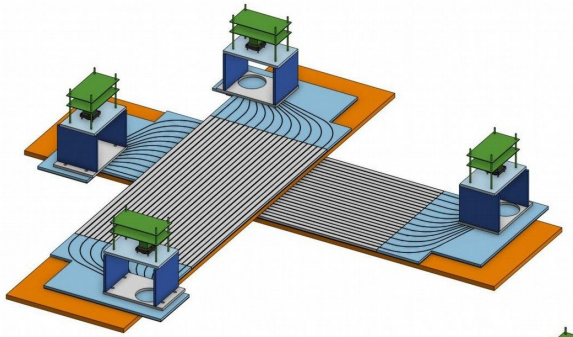


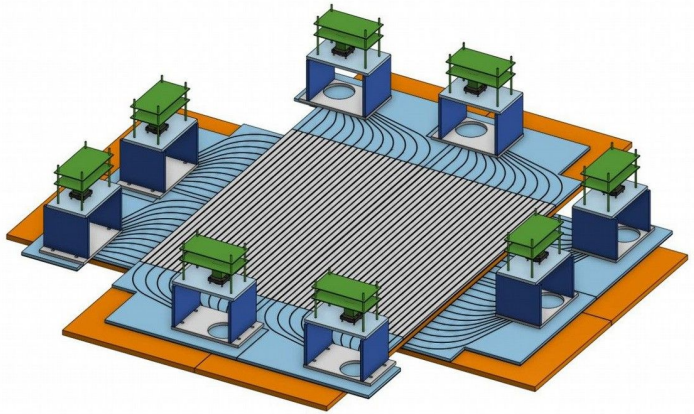


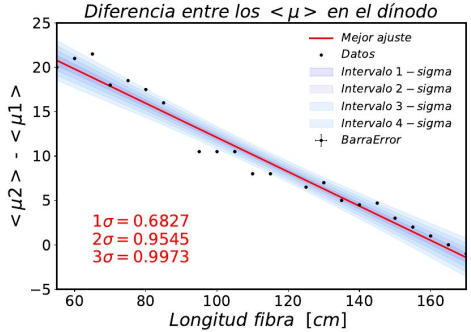
Our modular design

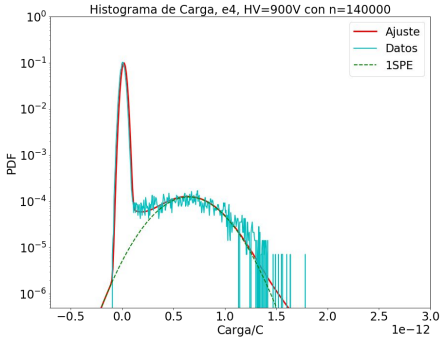






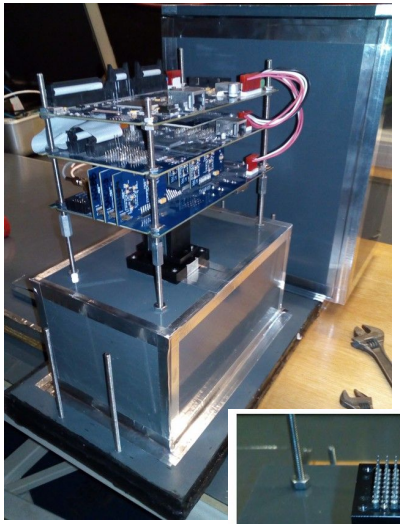


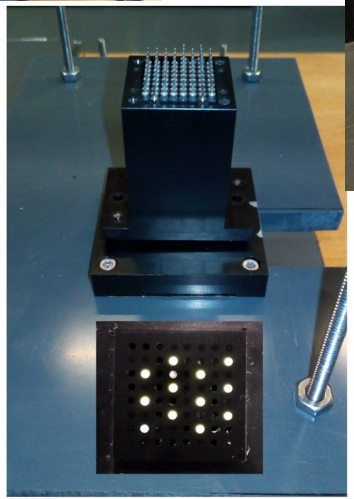


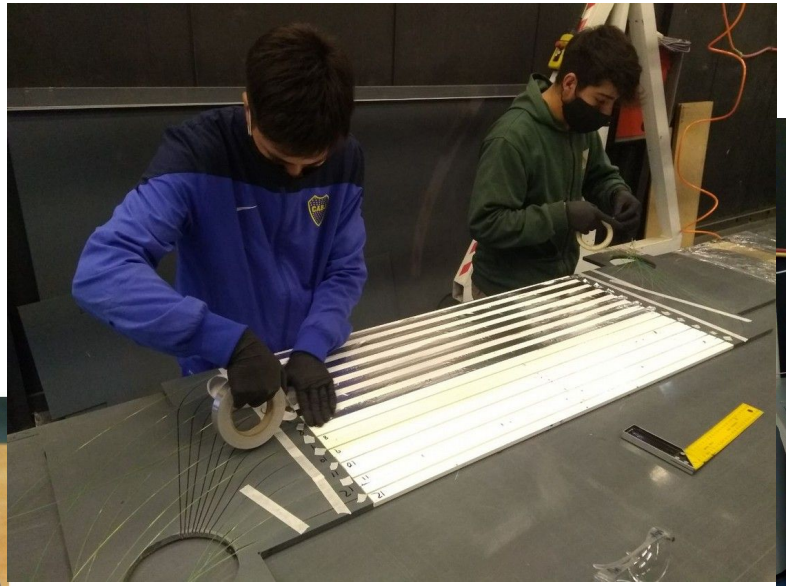


R. Calderón-Ardila et al, JINST, submitted

First functional prototype (Jul 2021)

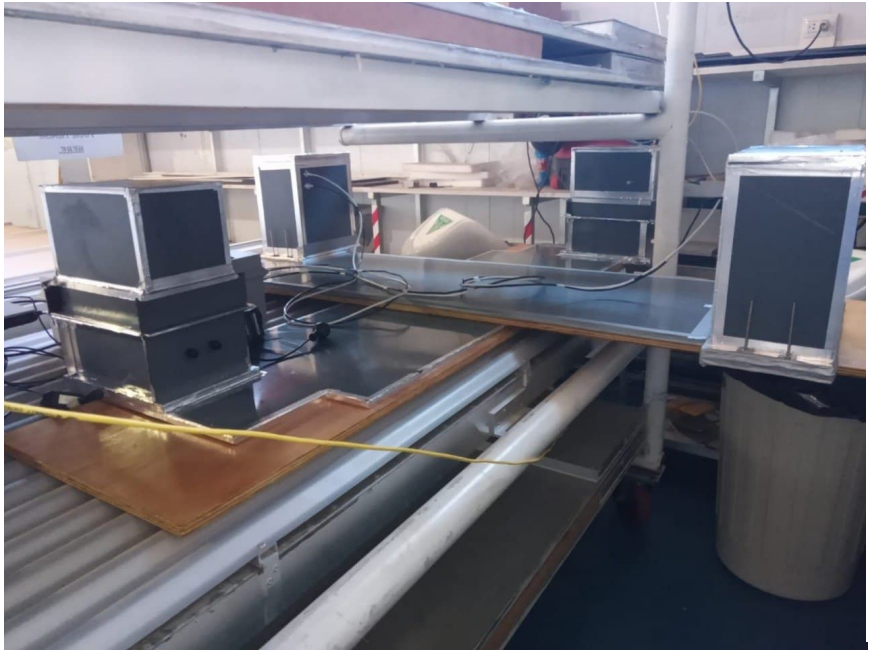


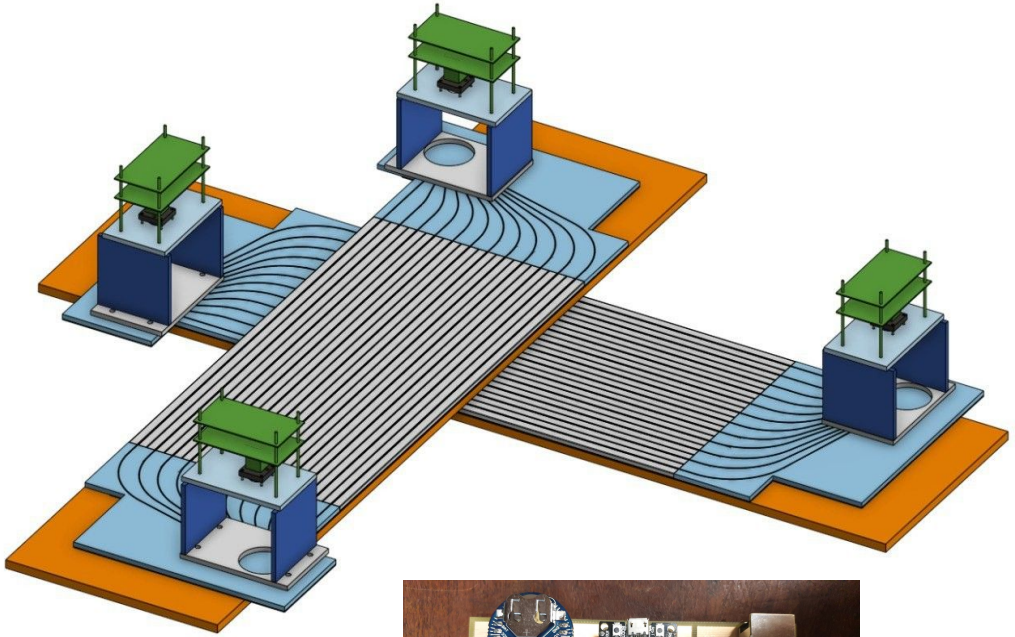




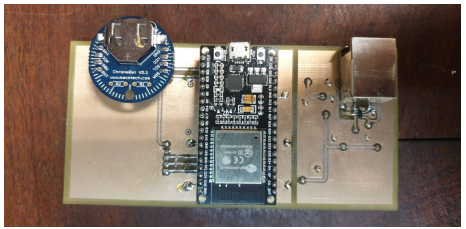
Technology transference from Astroparticle detection to volcanic assessment risks

Modular assembly, calibration, testing and coincidence detection

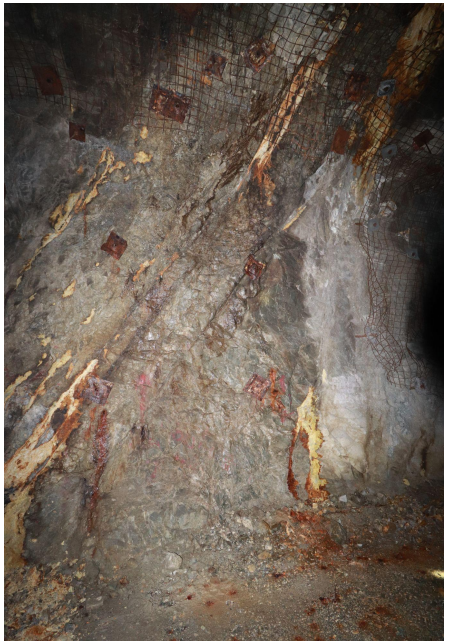




ESP32-based synchronism electronics



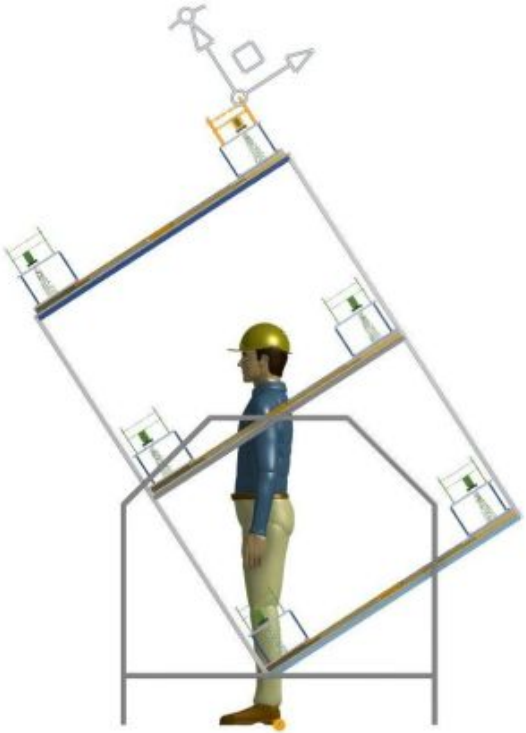
Mining prospecting applications

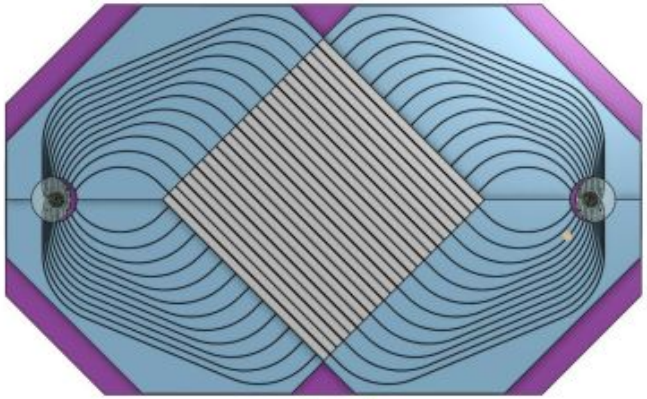


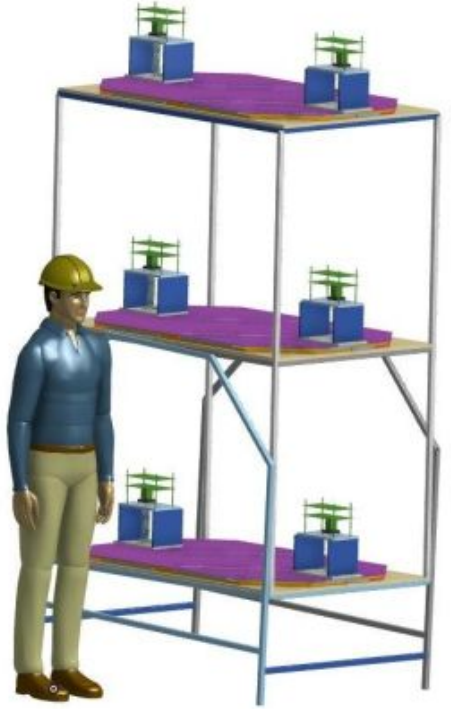
$$\sigma_\mu \propto \langle \rho \rangle \times Z_{\text{eff}}^2$$

Enhanced determination of density contrasts between rocks and ore veins (iron, gold, silver, uranium, ...) due to different muon-absorption cross-section

New detector optimized for underground measurement

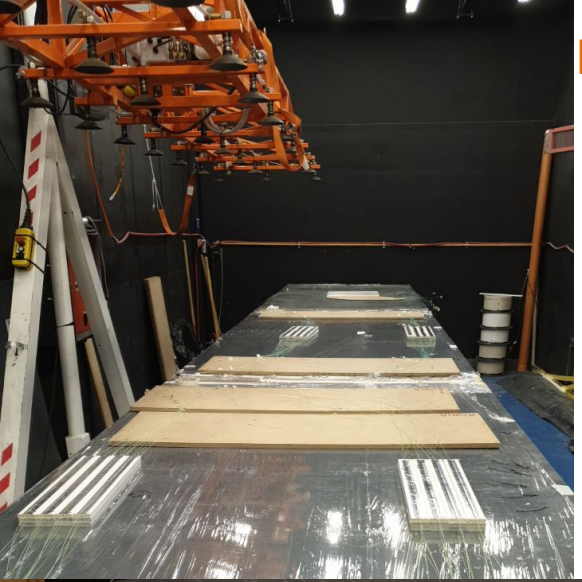


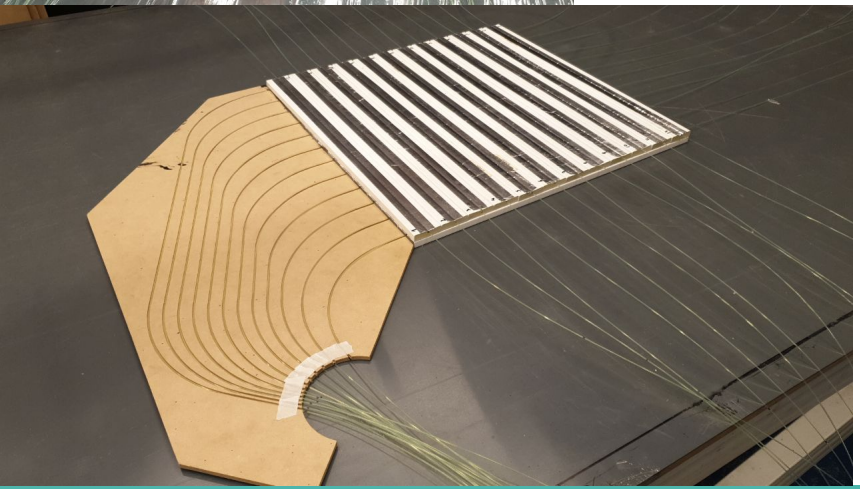


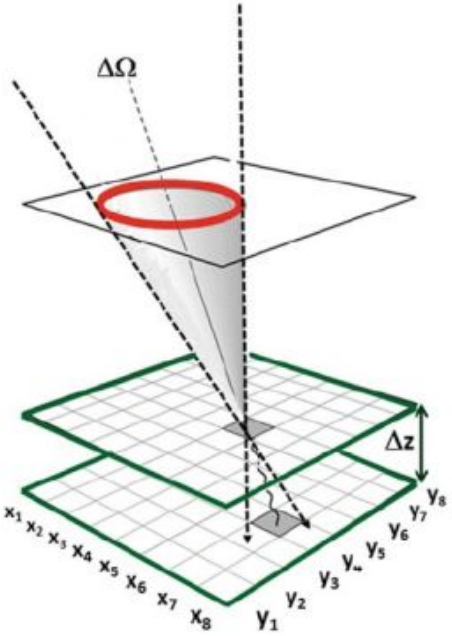


C. Ardila et al, JAIS 2022, https://doi.org/10.31526/jais.2022.300

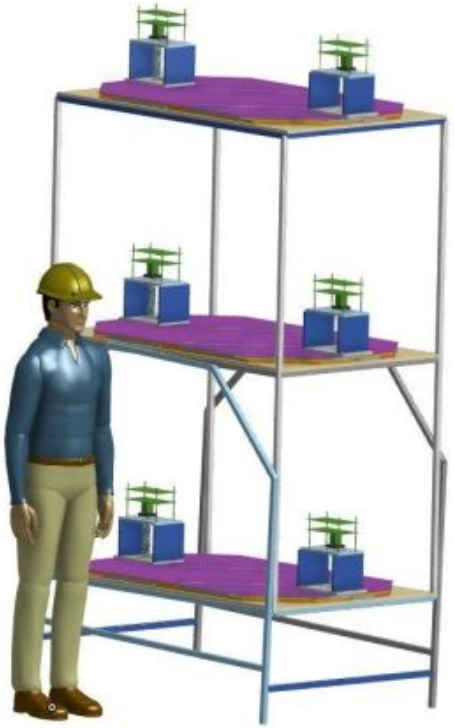
Detector aperture depends on the detection panels separation



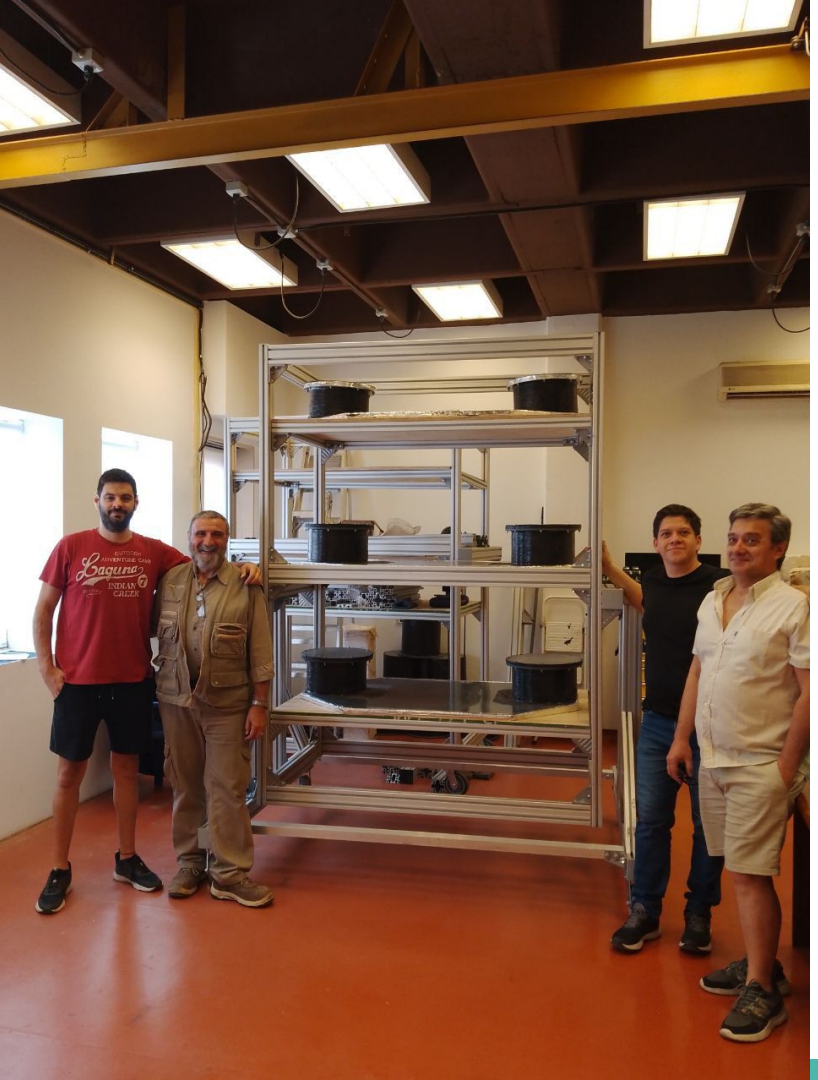




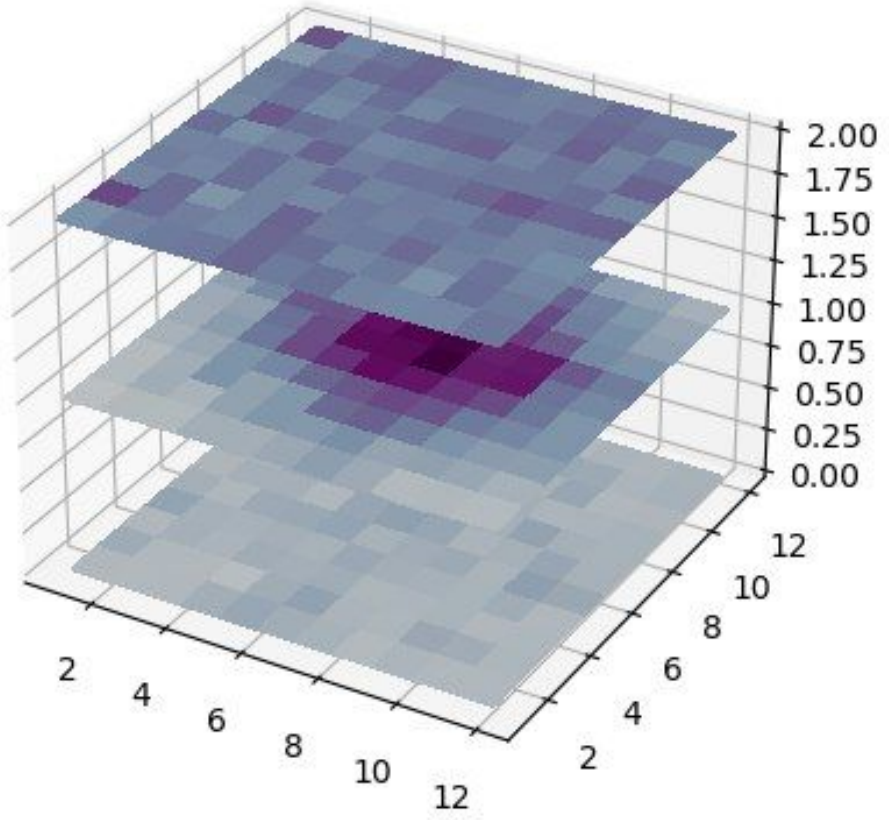
$$N(\varrho) = \Delta T \times T \times I(\varrho)$$



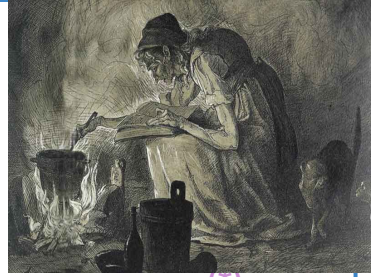
C. Ardila et al, JAIS 2022, https://doi.org/10.31526/jais.2022.300



Calibration and first target measurements currently underway



Extreme simulations for extreme objects
Meiga, the sorceress (work in progress)



Flux of CR

Transient astrophysical phenomena
GRBs, Solar Activity, ...
ARTI Inputs

Primaries

Secondaries

Site characteristics
location, altitude, geomagnetic field, atmosphere, ...
time-evolving conditions:
MAGNETOCOSMICS (IGRF13&TSY), GDAS and CORSIKA

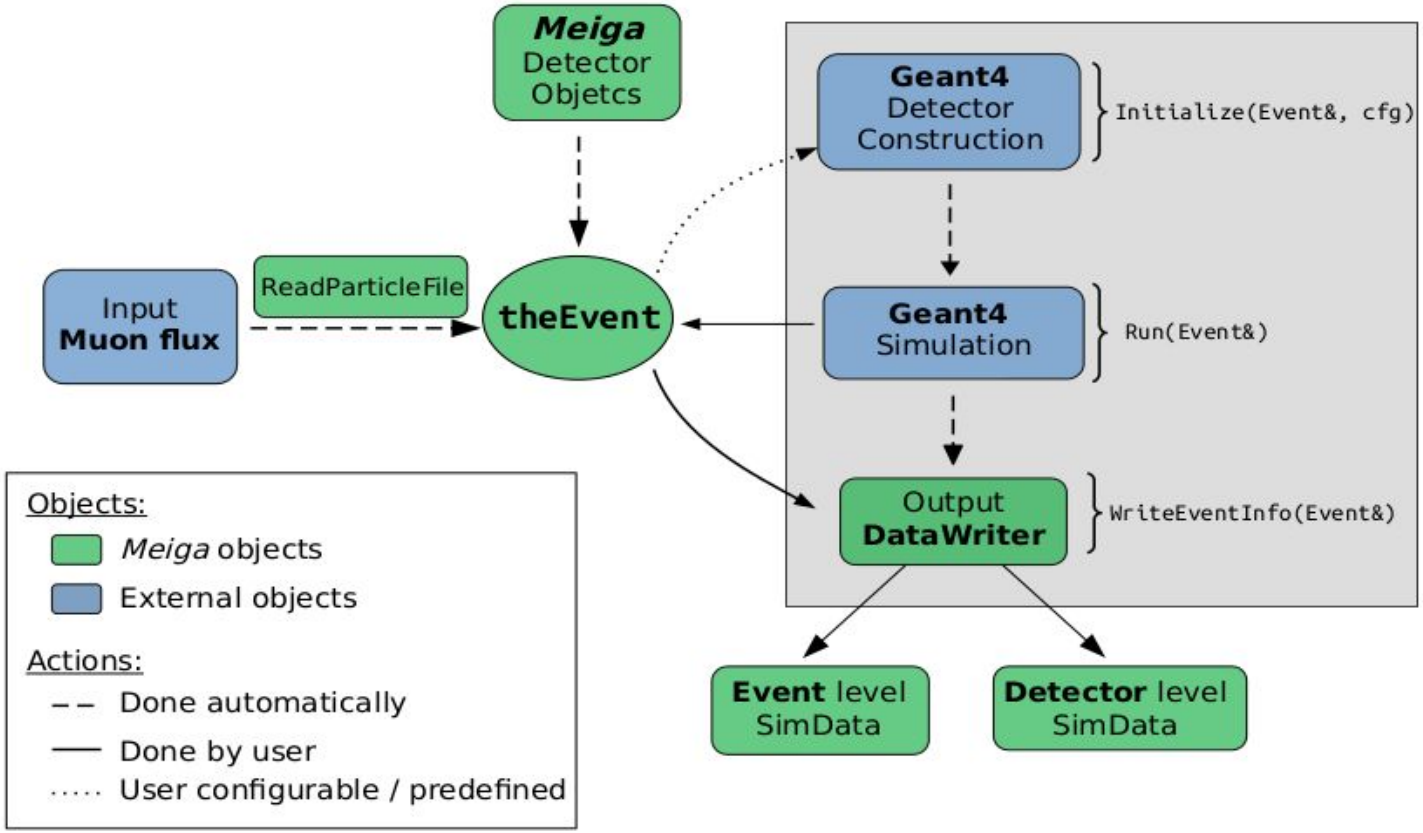
Detector response(*)
type, geometry, materials,...
GEANT4 detector models
(*) integrated in new framework *Meiga*, next section

Signals or doses

ARTI inputs → S0: raw Corsika → S1: secondaries → **S2: doses**

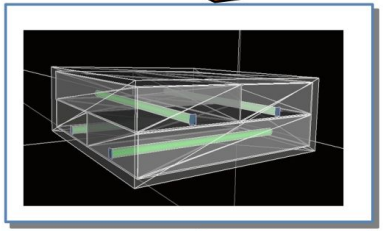
A. Taboada et al, JAIS 2022, https://doi.org/10.31526/jais.2022.266

Meiga workflow



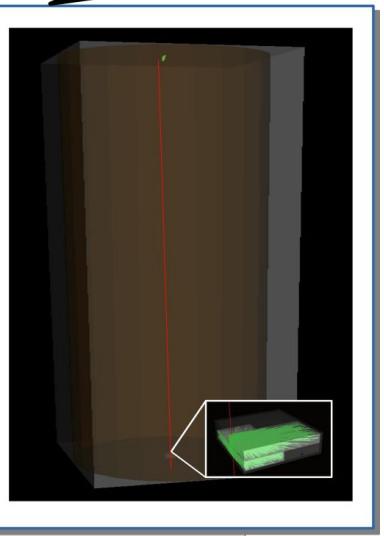
A. Taboada et al, JAIS 2022, https://doi.org/10.31526/jais.2022.266

Workflow



Meiga Detector Objetcs

Geant4 Detector Construction



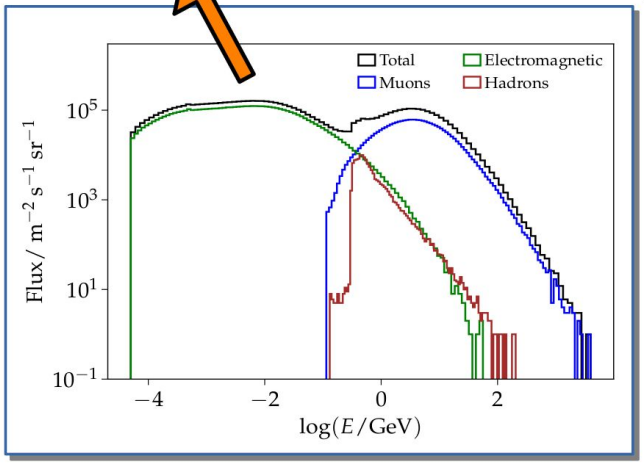
Input **Muon flux**

ReadParticleFile

theEvent

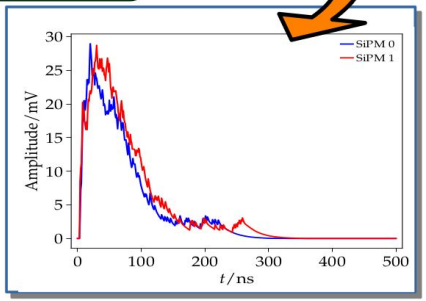
Geant4 Simulation

Output **DataWriter**

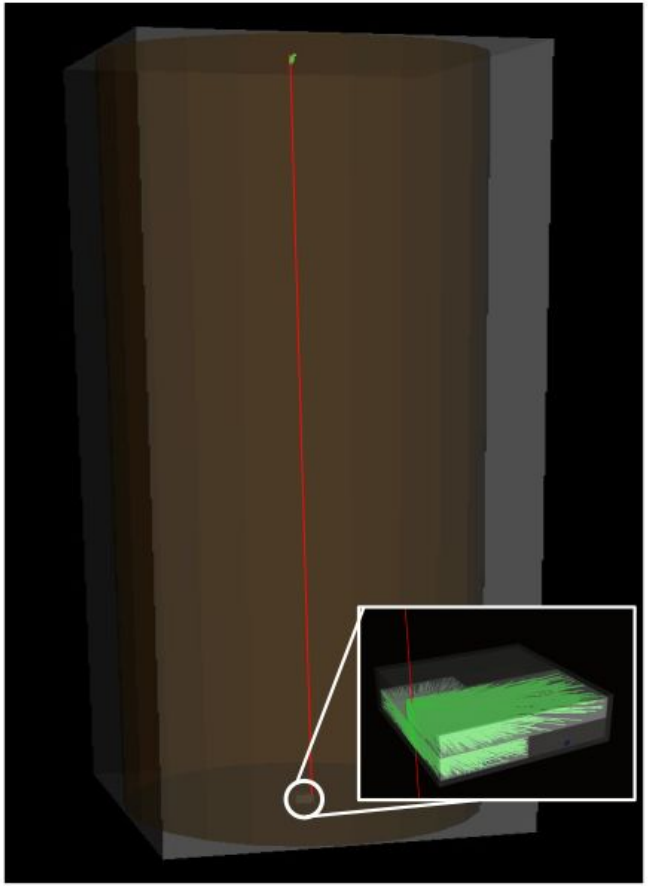


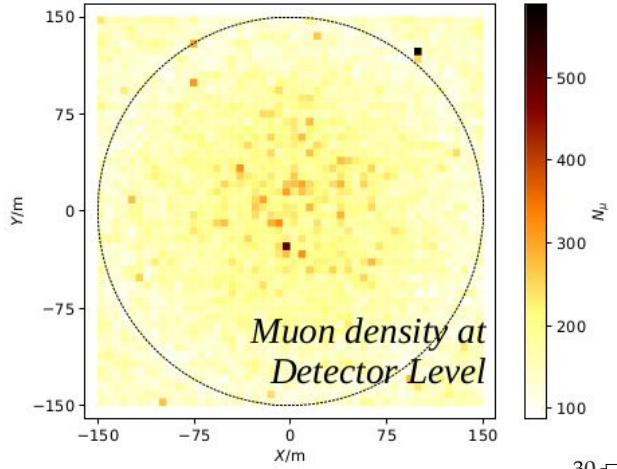
Event level SimData

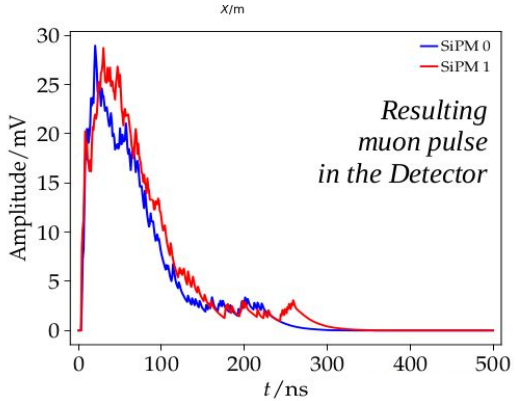
Detector level SimData



First test: propagation through 500m of rock impinging on Modulus



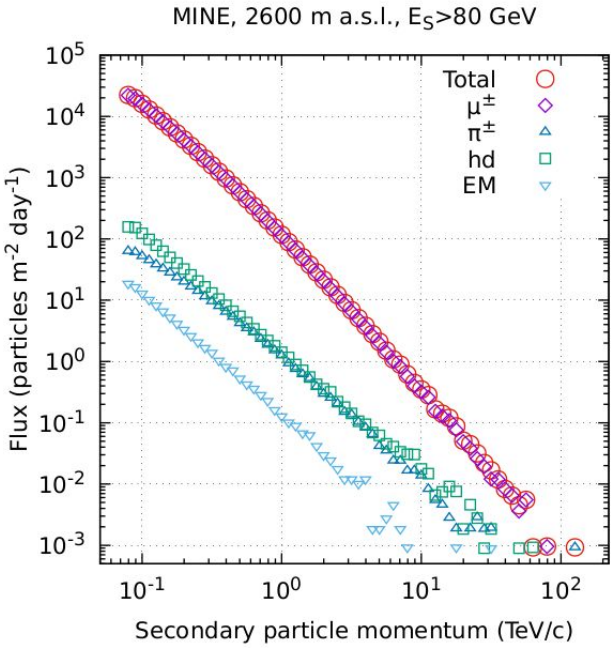




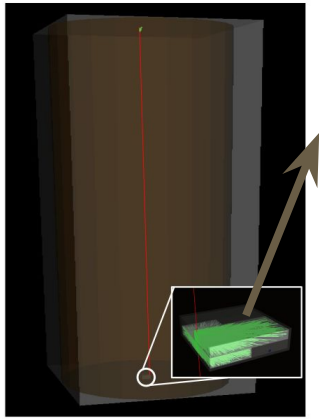
A. Taboada et al, JAIS 2022, https://doi.org/10.31526/jais.2022.266

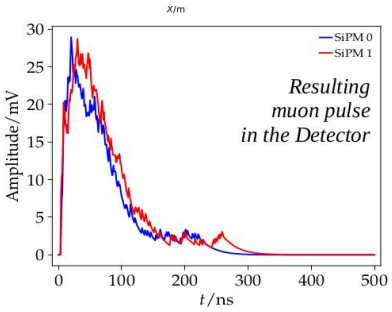
High-energy flux propagation through 500m of rock impinging on an underground detector

OneDataSim@cloud

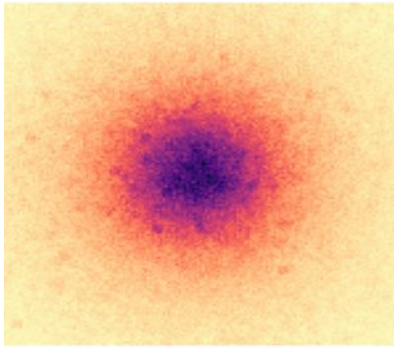


MEIGA@hpc

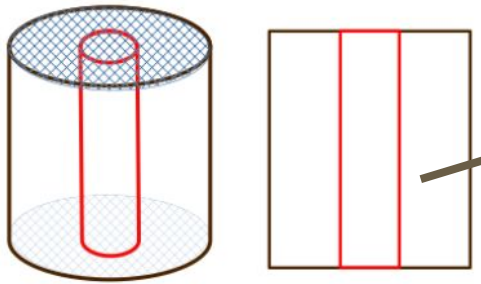


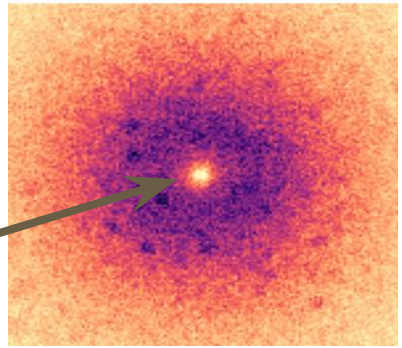


Expected detector response



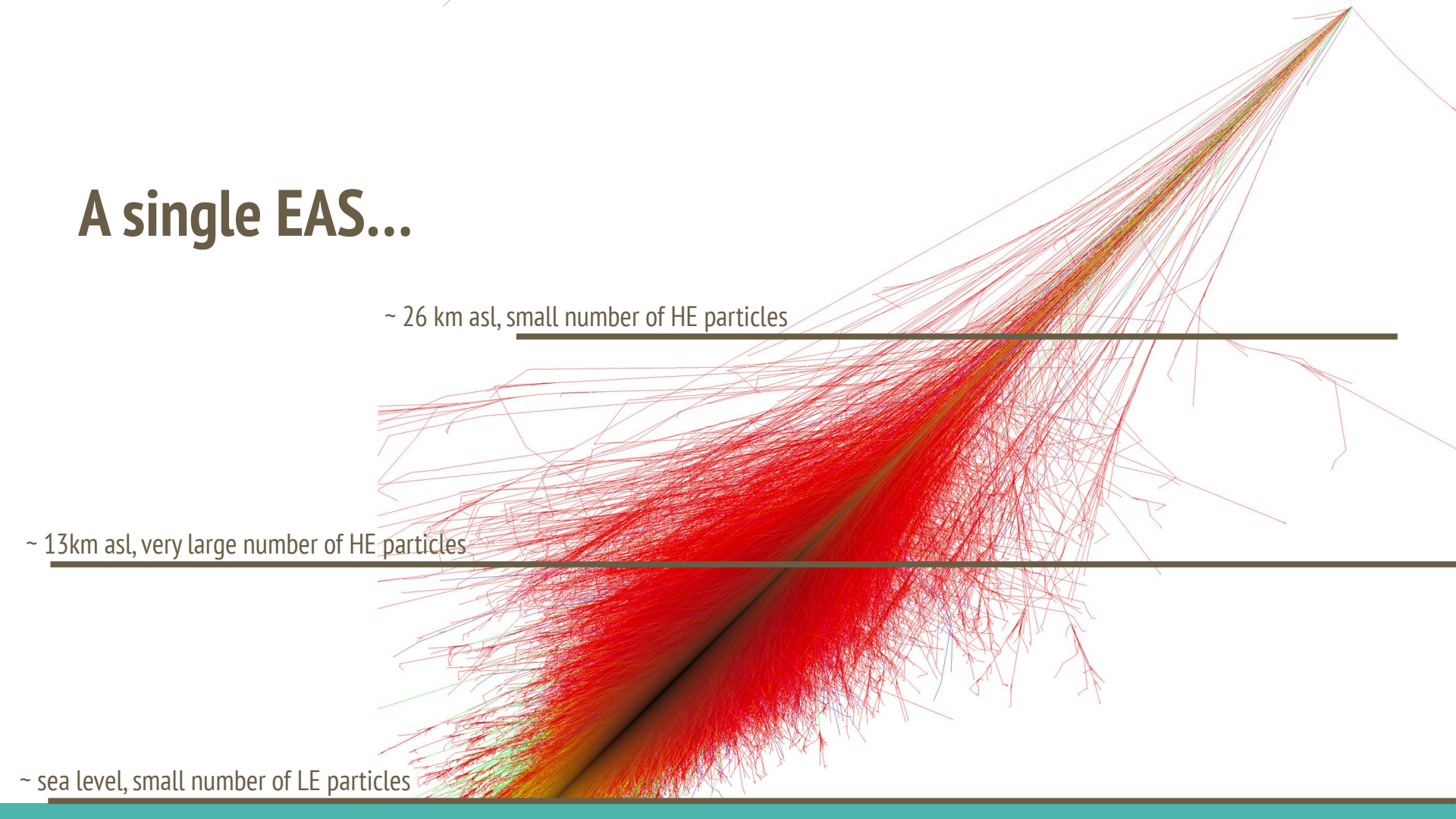
Example: change in density profile

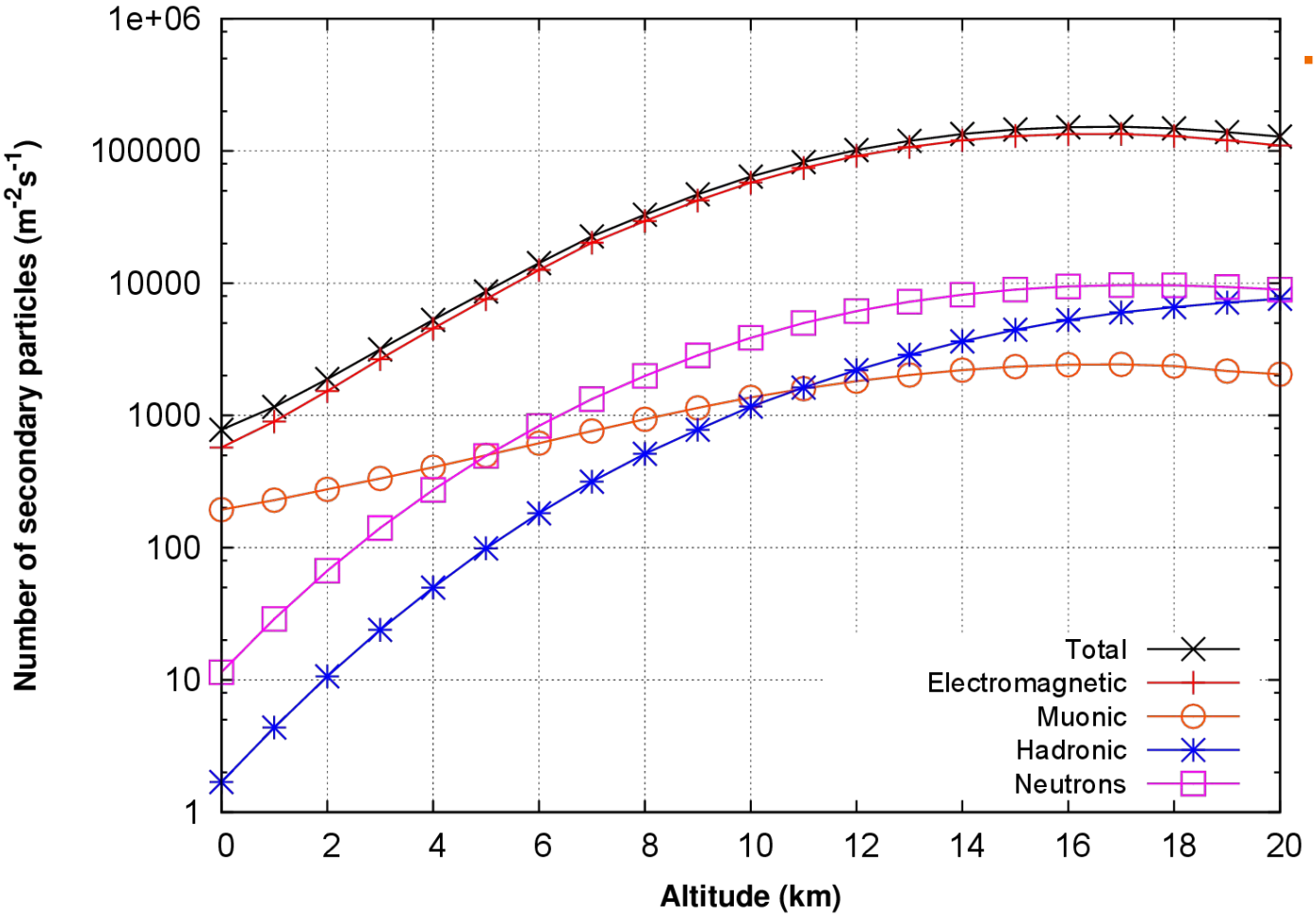




A. Taboada et al, JAIS 2022, https://doi.org/10.31526/jais.2022.266

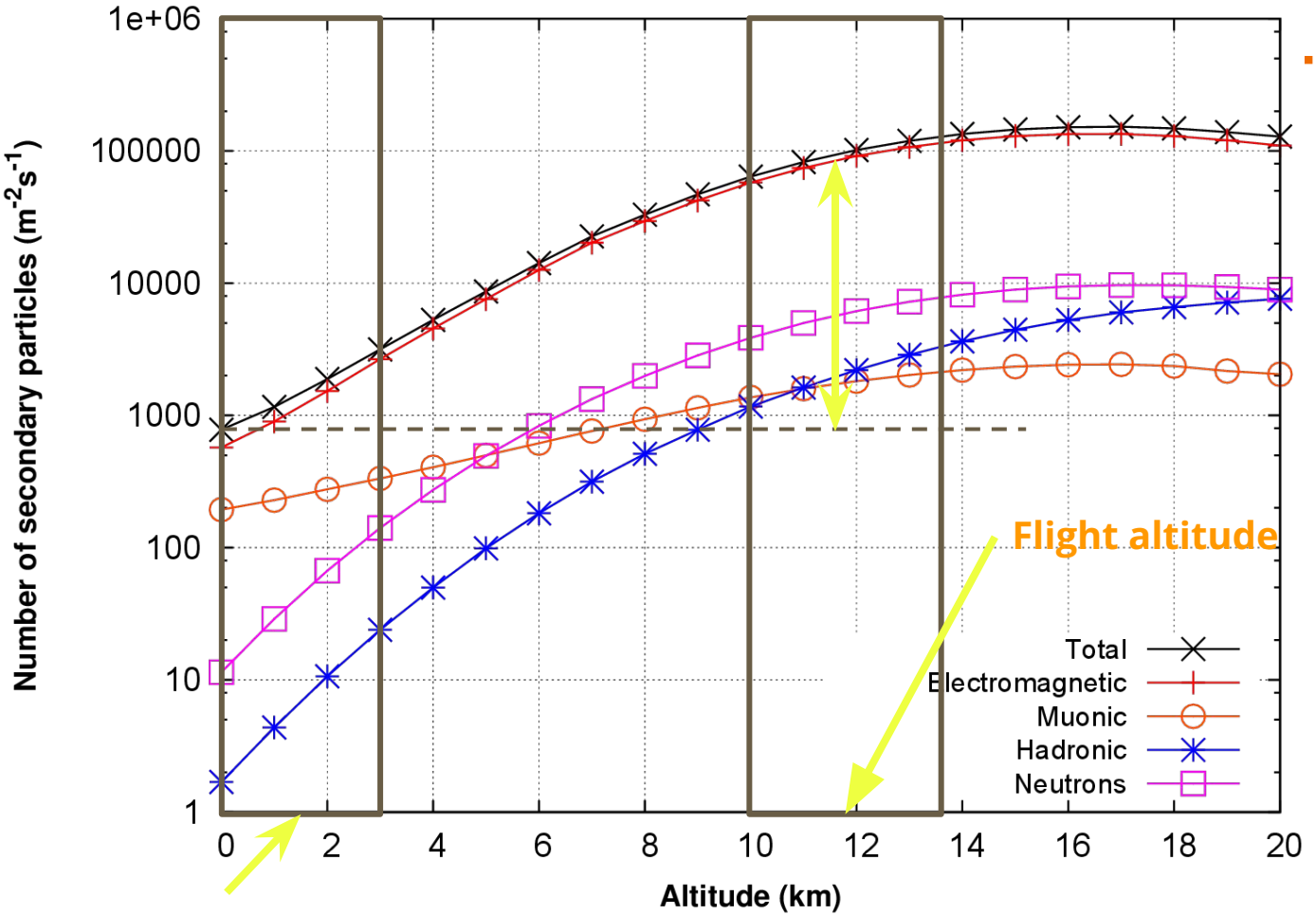
A single EAS...


~ 26 km asl, small number of HE particles
~ 13km asl, very large number of HE particles
~ sea level, small number of LE particles



… but 10^5 $s^{-1}m^{-2}$

H.A. and L. Núñez, AIP Conference Proceedings 1693, 060008 (2015); https://doi.org/10.1063/1.4937213

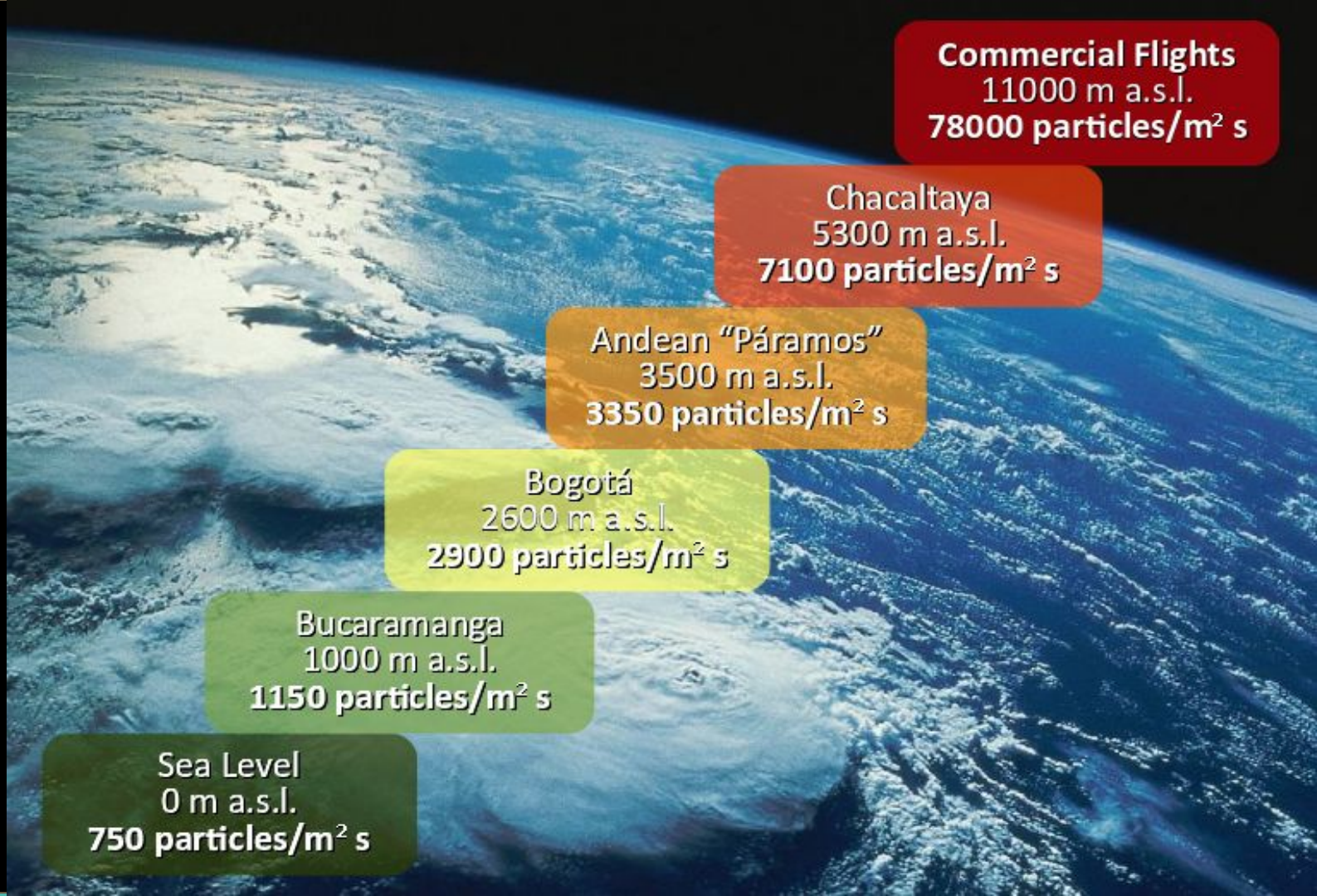


… but 10^5 $s^{-1}m^{-2}$

99% of world population

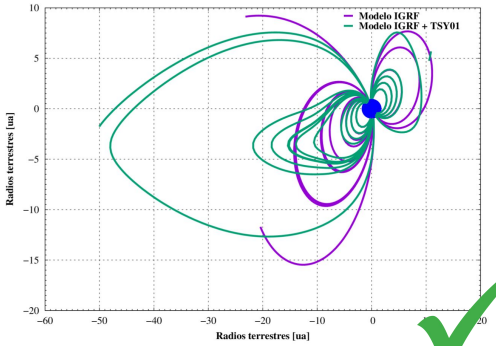
H.A. and L. Núñez, AIP Conference Proceedings 1693, 060008 (2015); https://doi.org/10.1063/1.4937213

Atmospheric reaction to CR + natural radioactivity are the main sources of background radiation

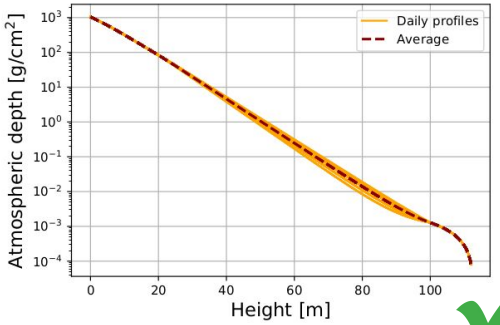


ACORDE: Application COde for the Radiation Dose Estimation

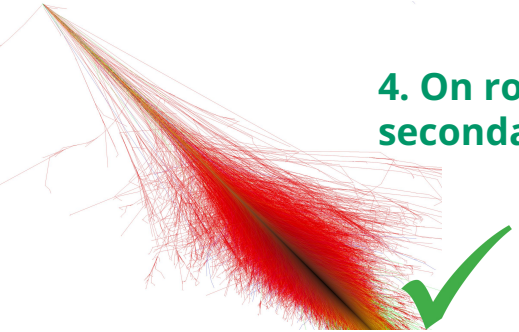
1. Segmentation of real flight paths from public databases



2. On route real-time geomagnetic field condition (IGRF13+TSY01)



3. On route GDAS atmospheric profiles

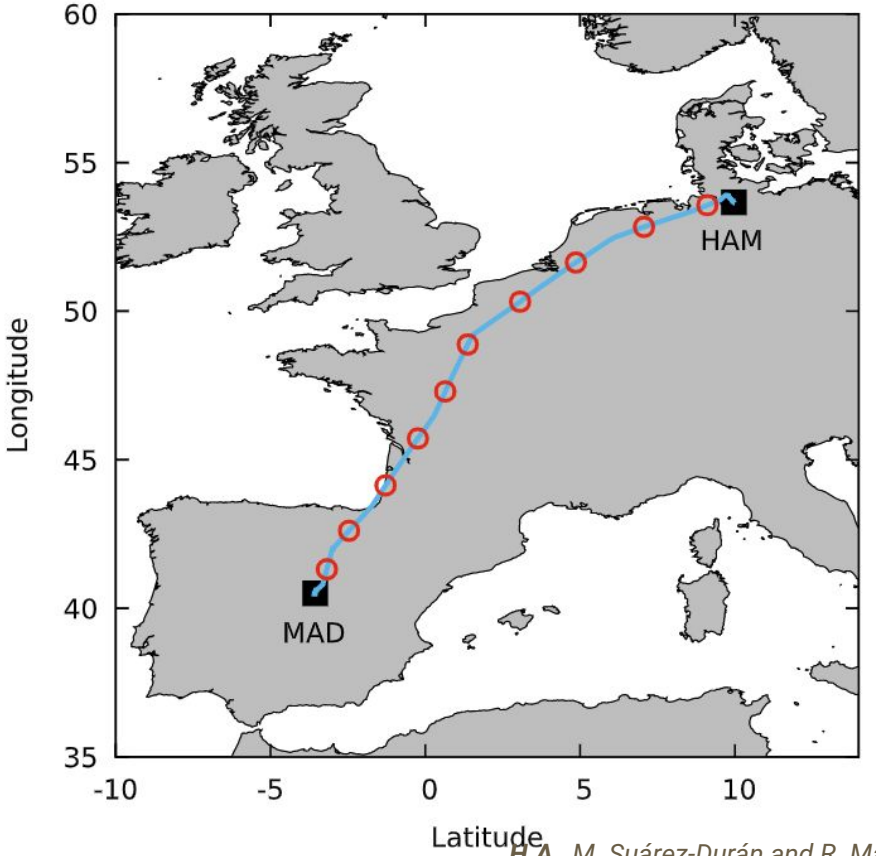


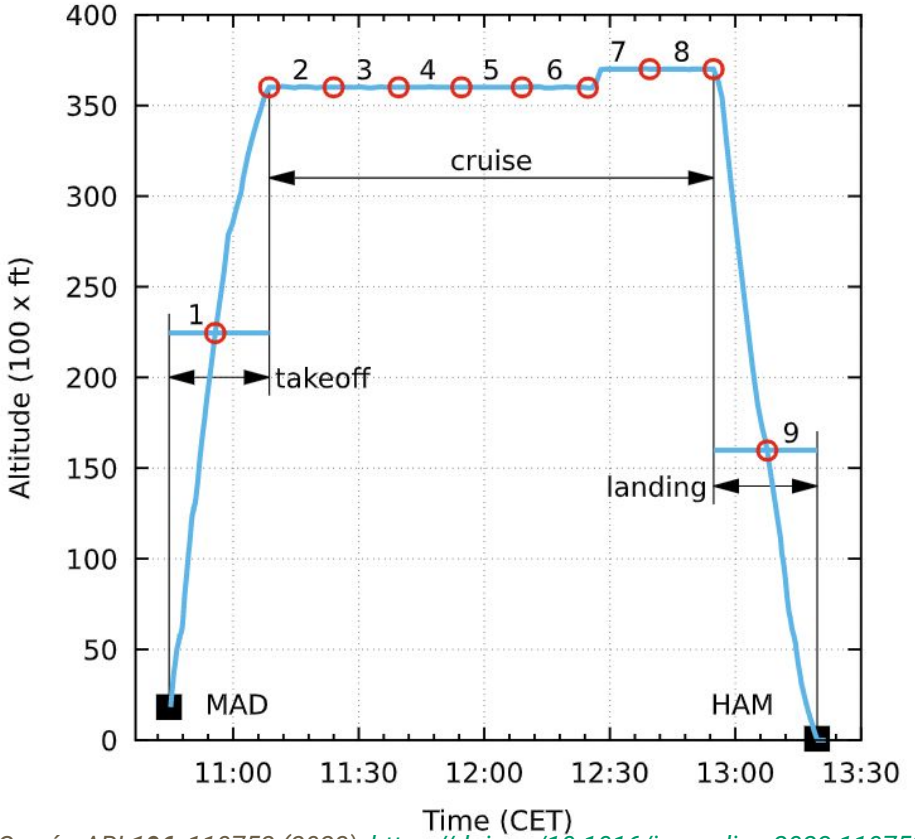
4. On route integrated secondary particles flux

5. Effective dose calculation from Geant4 plane model and human phantoms

***H.A.**, M. Suárez-Durán and R. Mayo-García, ARI **196**, 110752 (2023), https://doi.org/10.1016/j.apradiso.2023.110752*

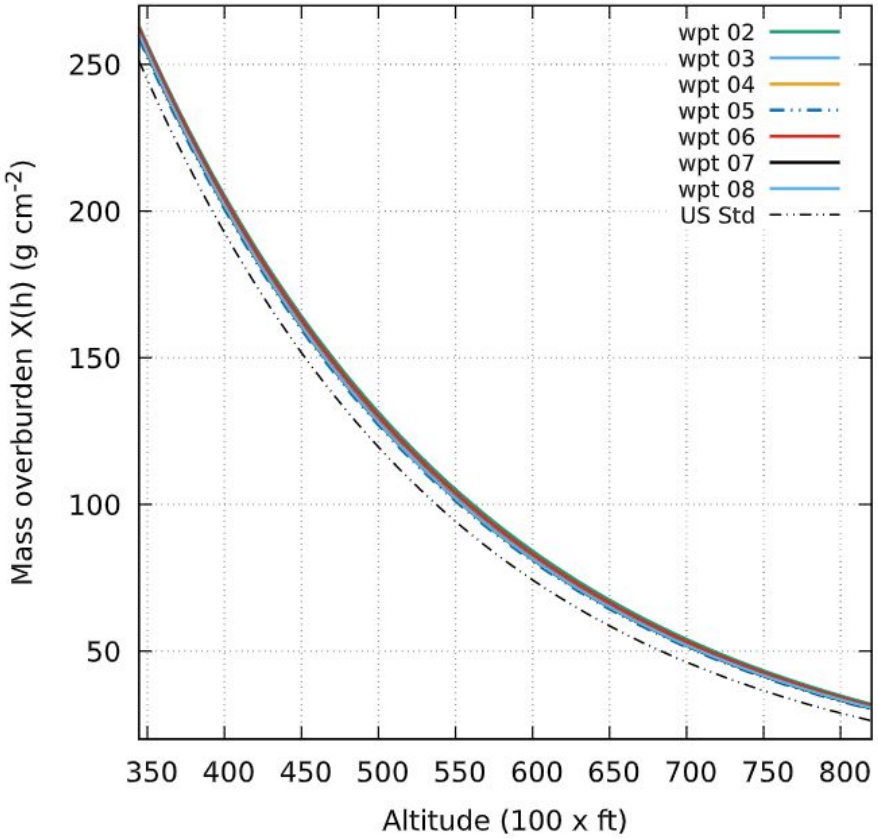
IB3270 MAD-HAM

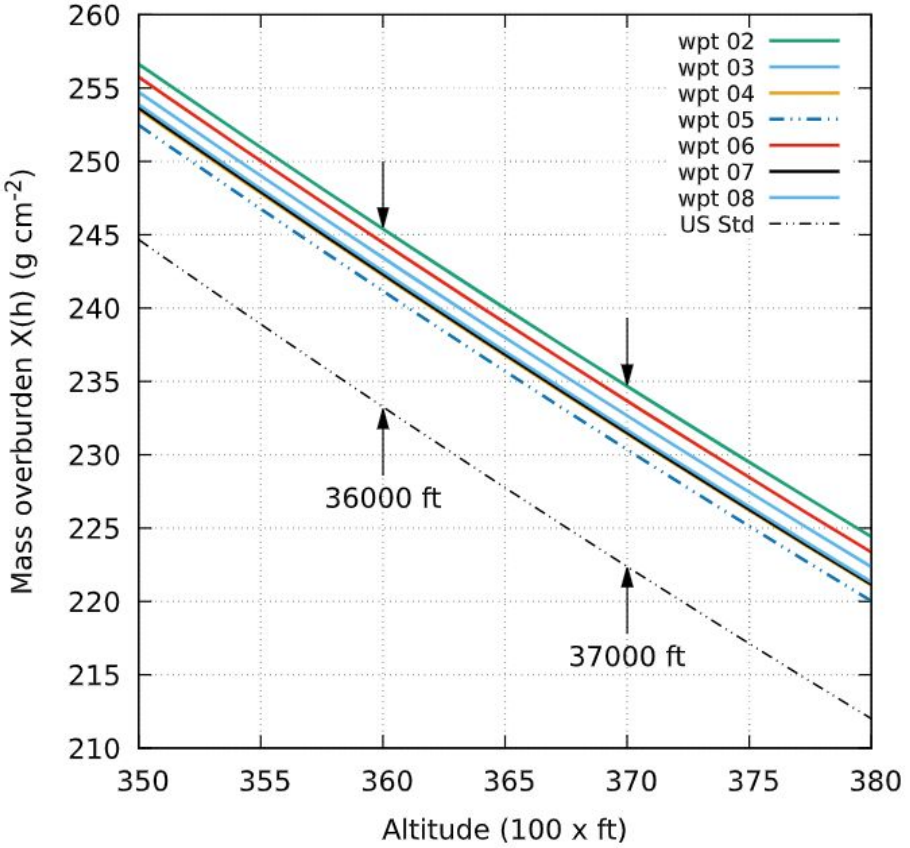




*H.A., M. Suárez-Durán and R. Mayo-García, ARI **196**, 110752 (2023), https://doi.org/10.1016/j.apradiso.2023.110752*

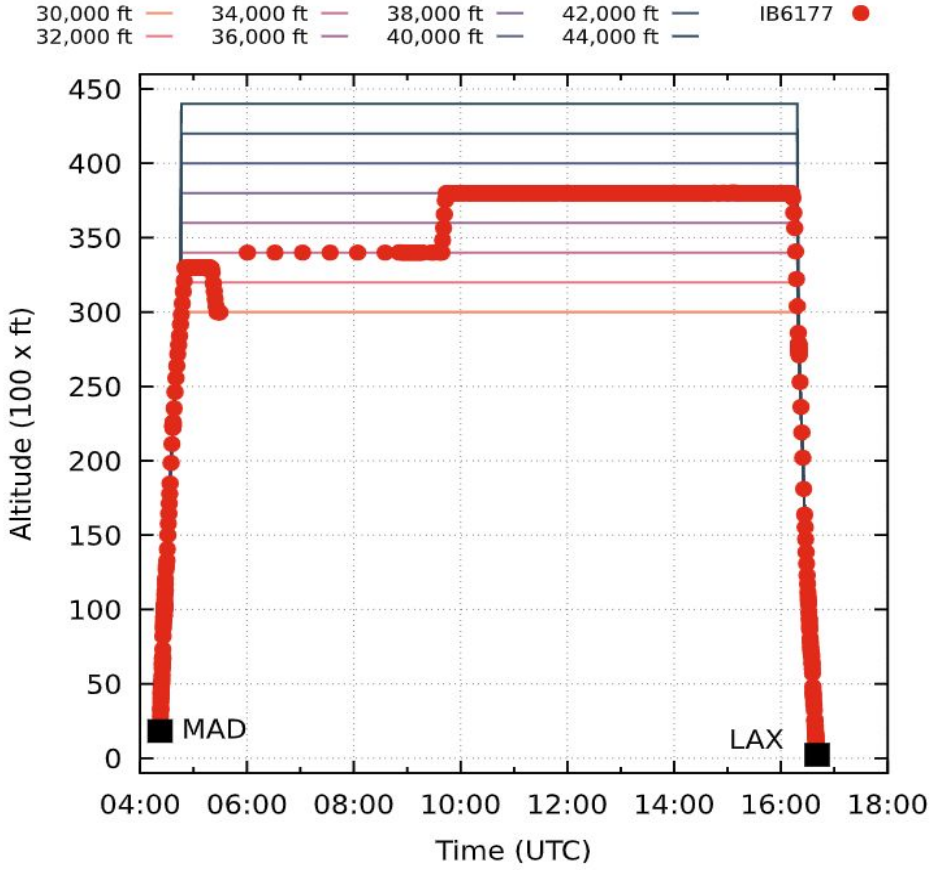
Real instantaneous atmospheres from GDAS

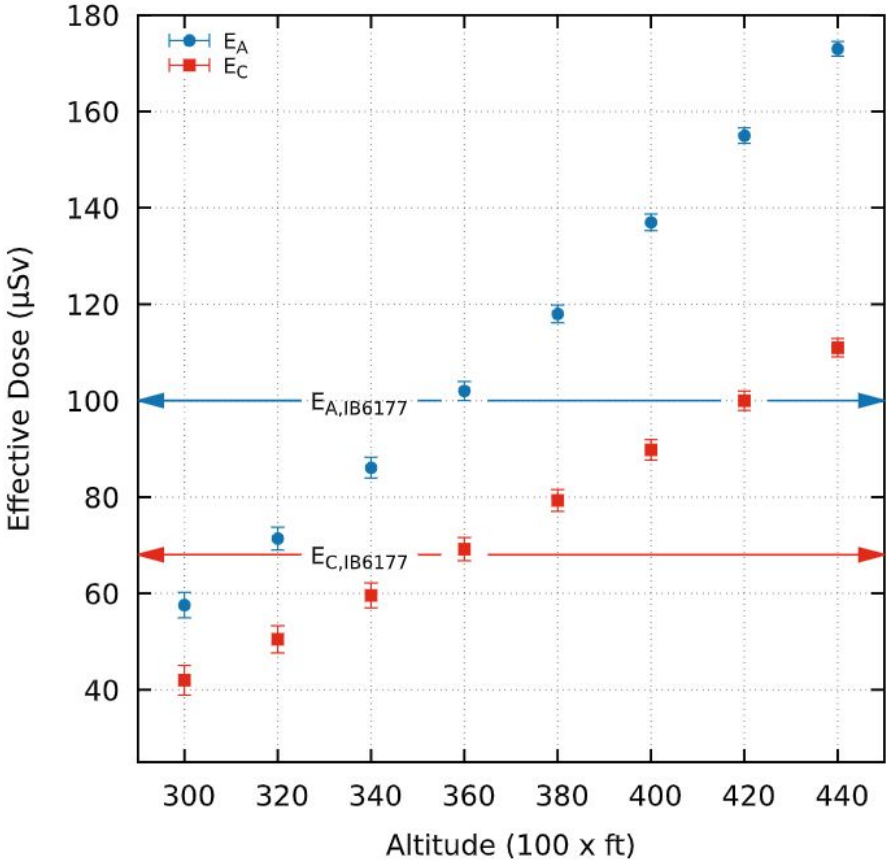




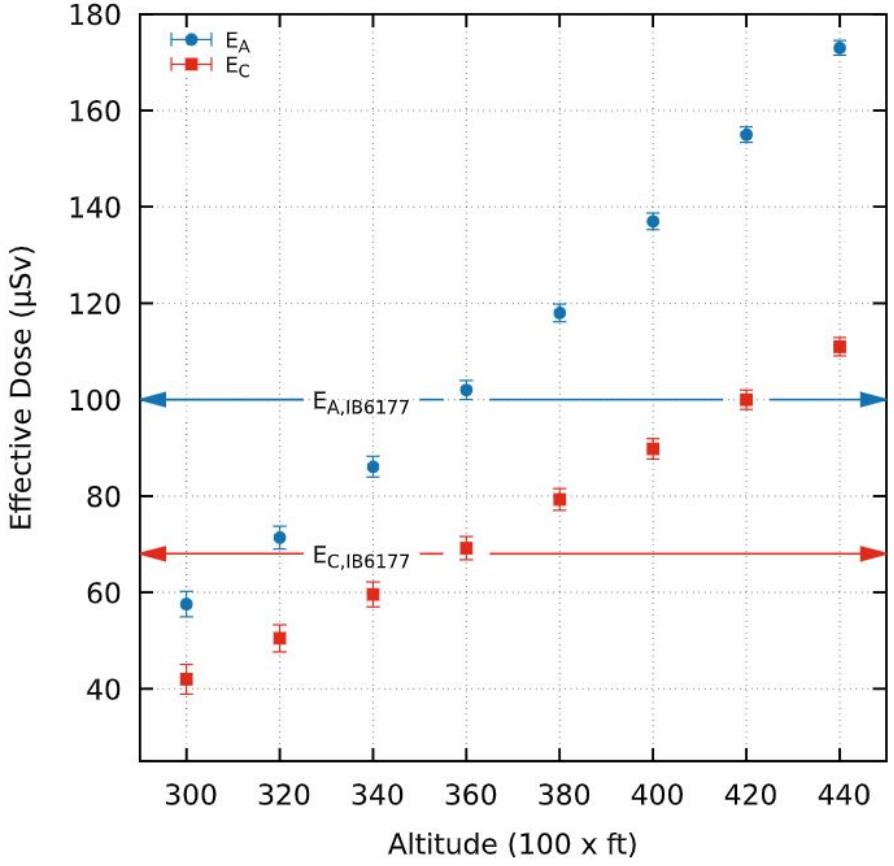
H.A., *M. Suárez-Durán and R. Mayo-García, ARI* ***196****, 110752 (2023),* https://doi.org/10.1016/j.apradiso.2023.110752

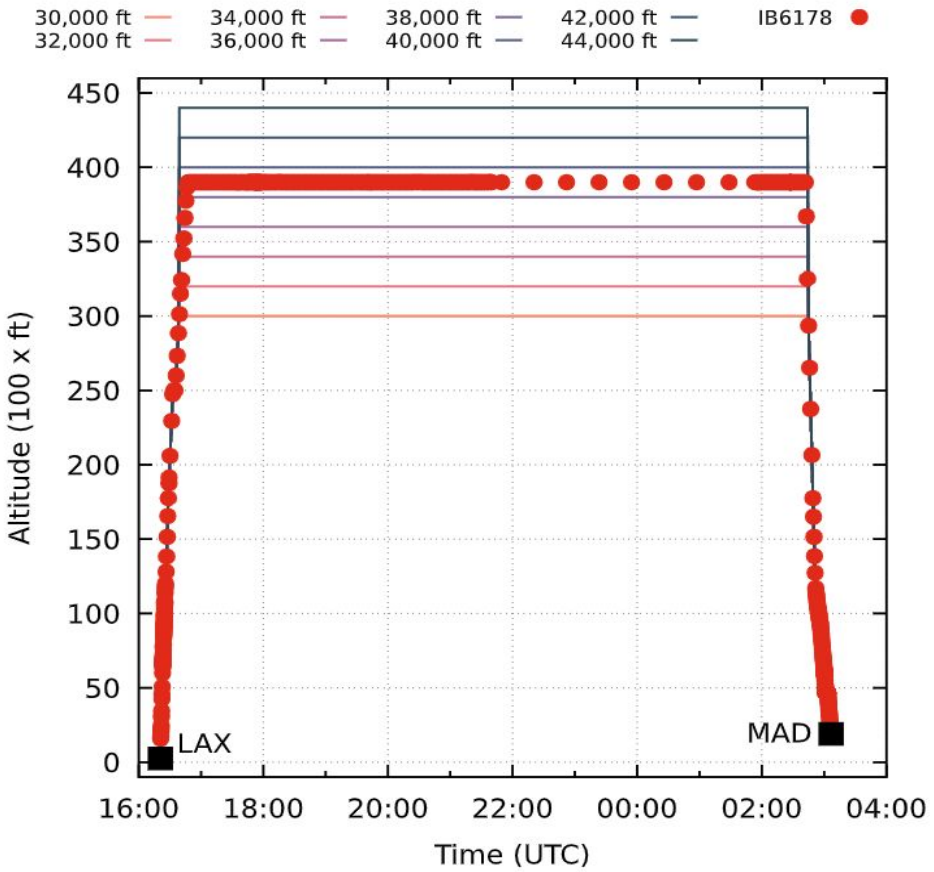
Altitude effect on total dose, IB6177 MAD-LAX



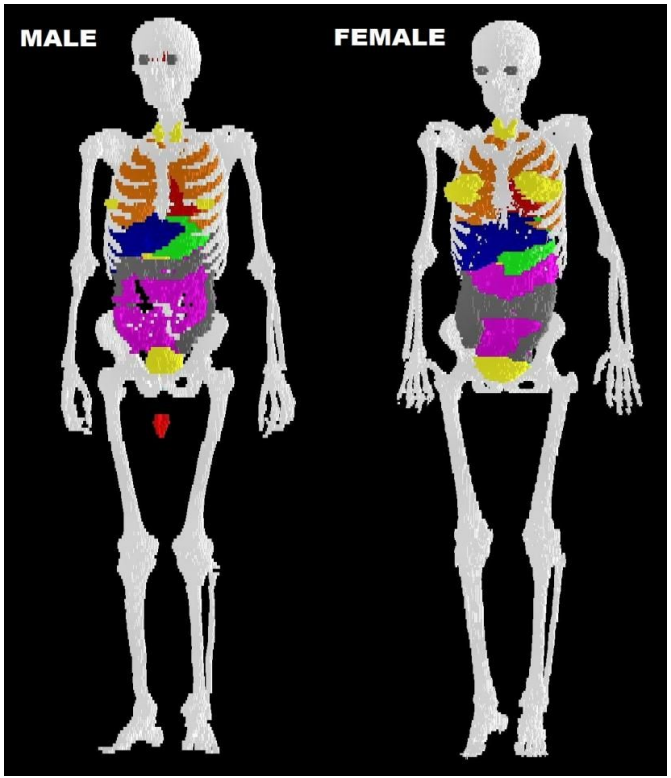


Altitude effect on total dose, IB6178 LAX-MAD





Effective dose based on ICRP110 anthropomorphic phantoms
Human phantoma exposed to flight level expected background



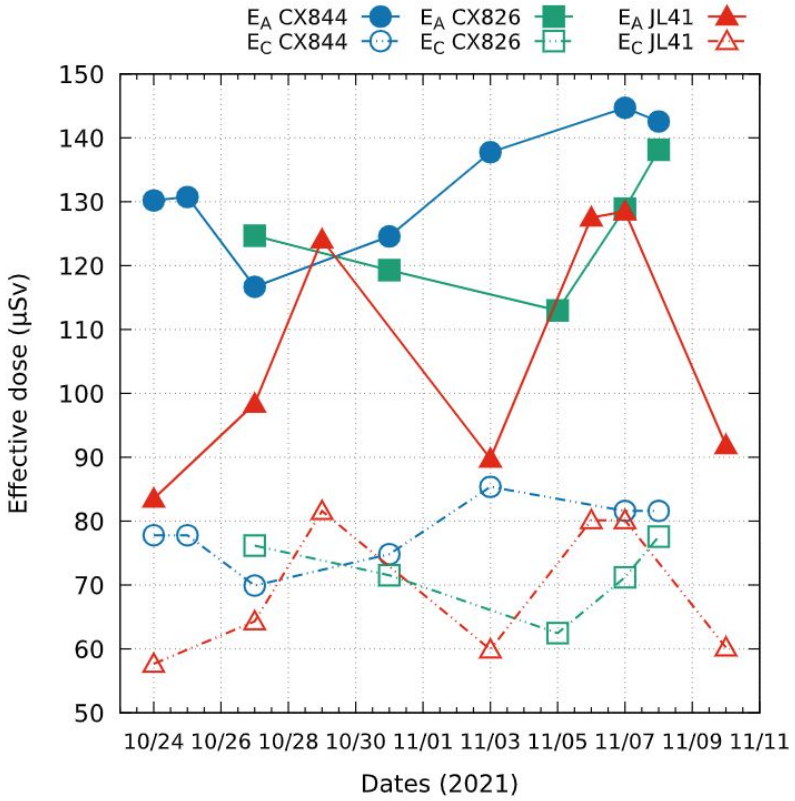

```
==========================
[...]

Doses deposited into:

Dose in Left Lung :
 Muons = 241.194 picoGy  rms = 21.3391 picoGy
 EM = 27.5122 picoGy  rms = 5.44075 picoGy
 Neutrons = 145.664 picoGy  rms = 23.9125 picoGy
 Protons = 2.59971 picoGy  rms = 0.876751 picoGy

[...]

Dose in Body =
 Muons = 419.479 picoGy  rms = 0.181504 picoGy
 EM = 42.3128 picoGy  rms = 0.0700462 picoGy
 Neutrons = 44.4889 picoGy  rms = 0.178061 picoGy
 Protons = 24.442 picoGy  rms = 0.151958 picoGy
```

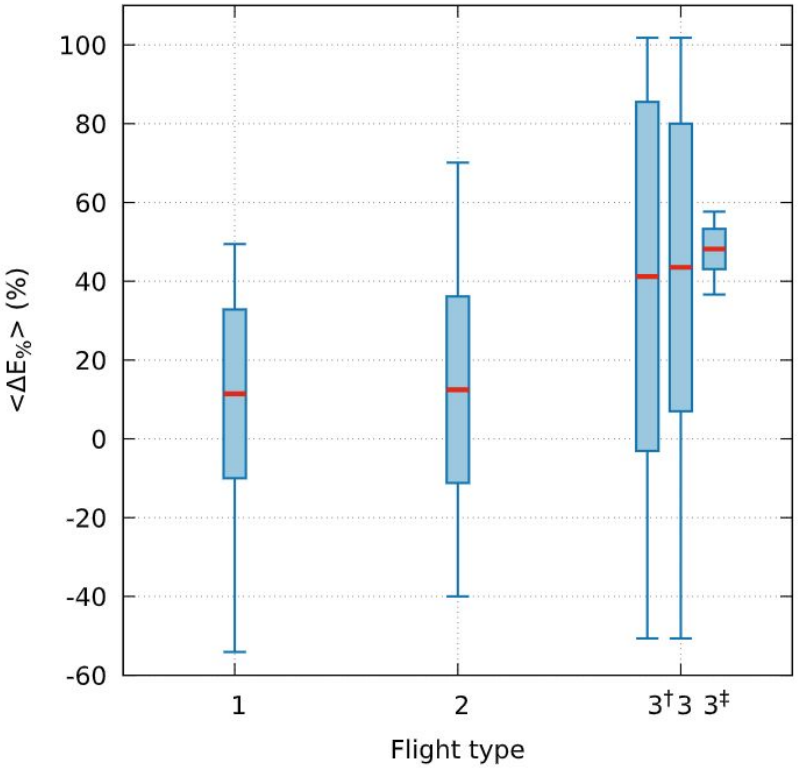
First results compatible with standard calculation methods but … spoiler alert: systematics observed for long flights, t>5h: +50% (!!!)

Typical calculation times at cloud: 8 hour·proc / 1 flight hour

*H.A., M. Suárez-Durán and R. Mayo-García, ARI **196**, 110752 (2023), https://doi.org/10.1016/j.apradiso.2023.110752 - O. Núñez-Chongo, H.A., et al, WSC'23*

Forbush decreases and Acorde - Cari7A difference





ACORDE

→Self-managed high-performance local and cloud computing

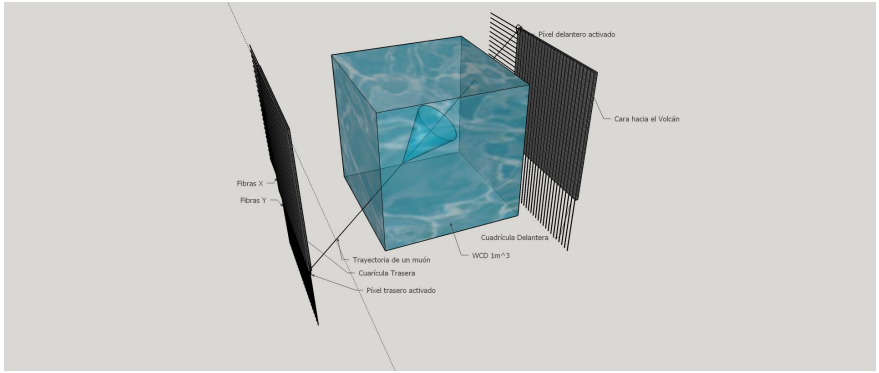
→ Cloud based dosimetry calculations in Geant4 (ICRC 110 phantoma implementation, with applications in radiotherapy)

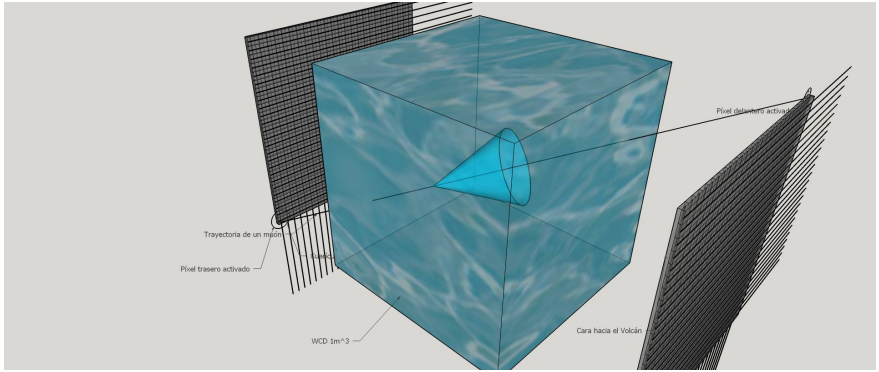
→ Software as a Service (SaaS) capable implementation

→ Work in progress: results stored in a blockchain, improved fuselage effect, including cabin luggage, …

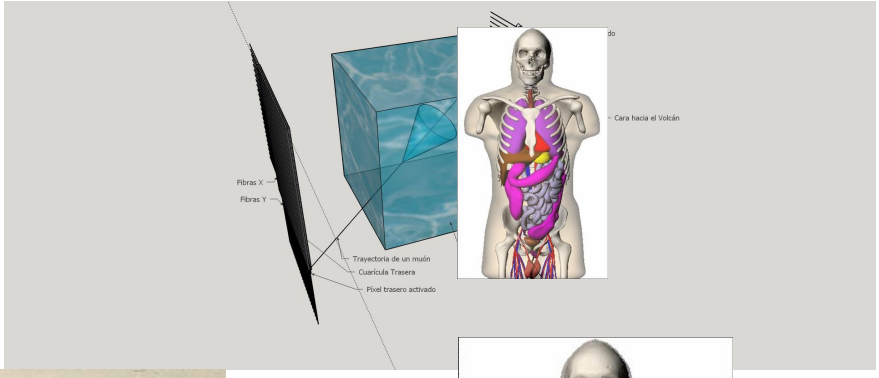
H.A., M. Suárez-Durán and R. Mayo-García, ARI **196**, 110752 (2023), https://doi.org/10.1016/j.apradiso.2023.110752

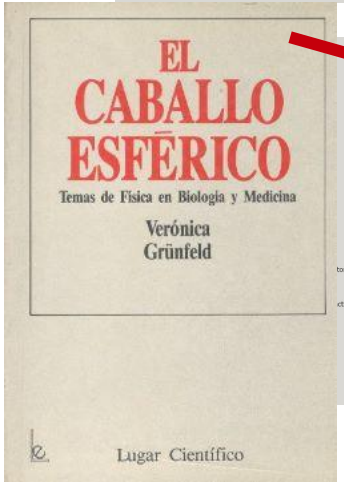
Extreme ideas for extreme diagnostics

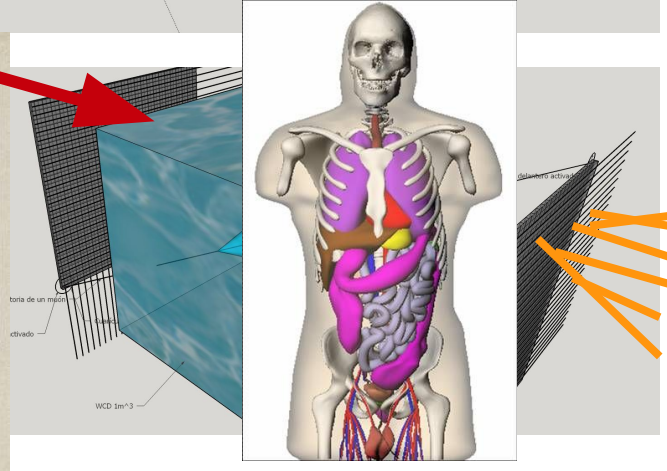




CTRL-H: water -> salty water && scintillator -> aSi



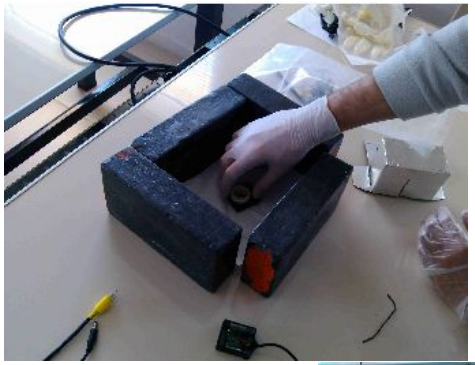


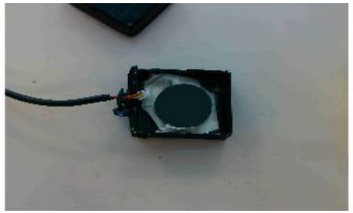


Extreme sensors for extreme environments: CMOS for high-dose environments

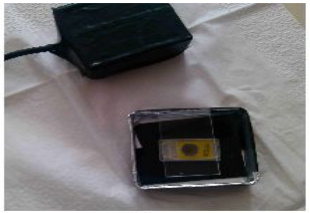
"COTS" CMOS technology:

- β, γ ^{137}Cs
- X-ray ^{55}Fe
- β ^{152}Eu
- γ ^{60}Co, ^{133}Ba
- α, γ ^{241}Am and ^{235}U





^{235}U



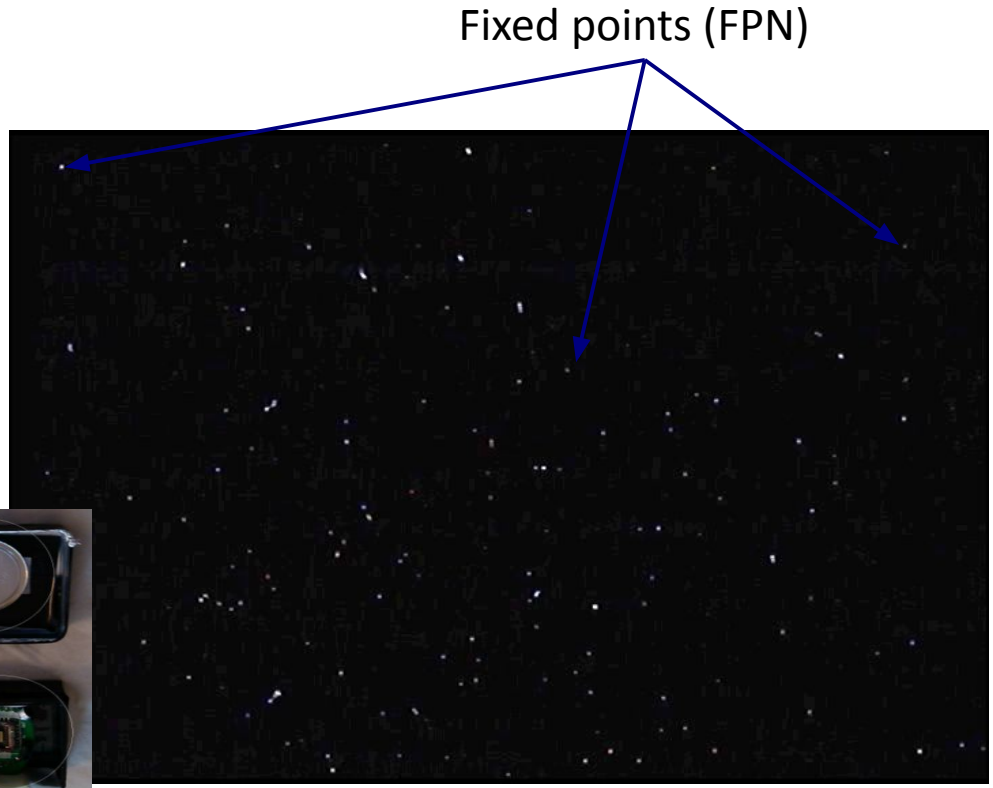
^{137}Cs

^{60}Co

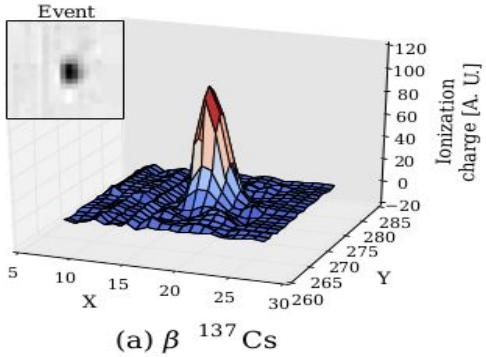
^{241}Am (con blindaje)

Ionizing particle detection using CMOS

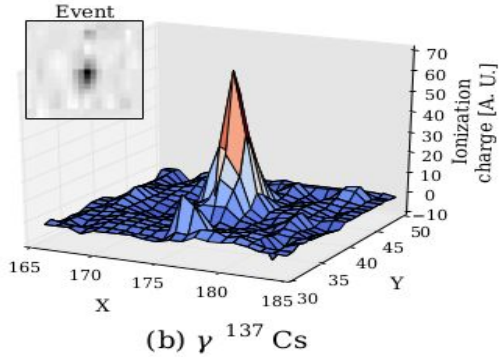
We can see
1- Events
2- Fixed points
3- Non zero Background (average dark current)



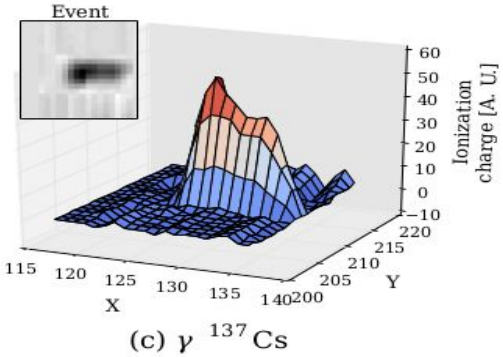
Particle response and identification



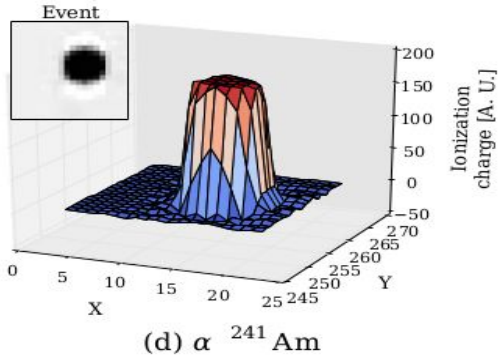
(a) β ^{137}Cs



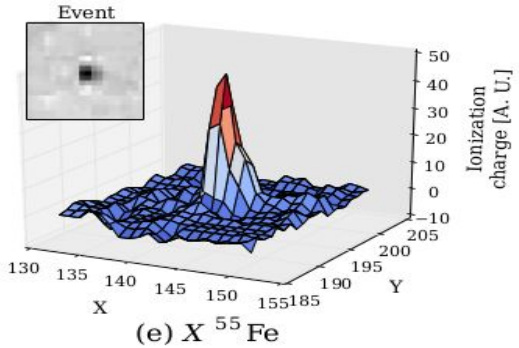
(b) γ ^{137}Cs



(c) γ ^{137}Cs



(d) α ^{241}Am

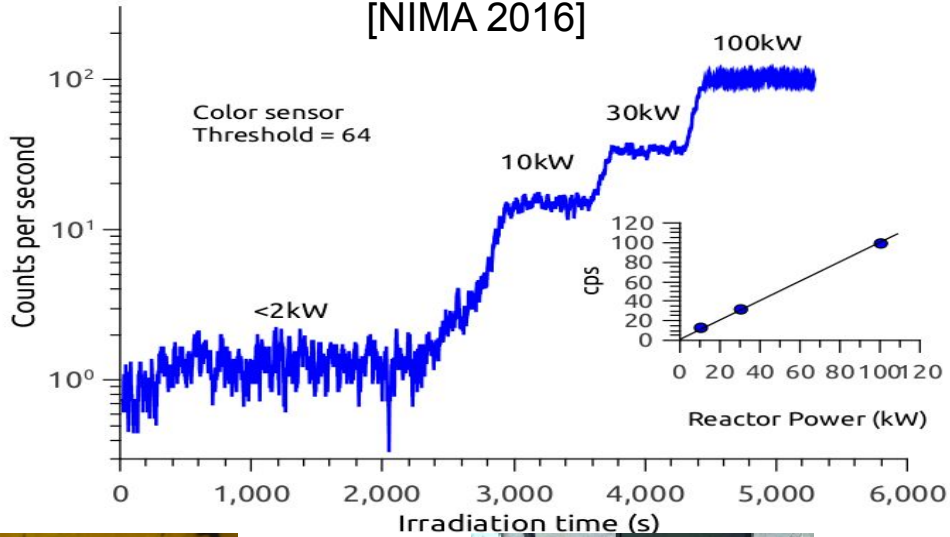


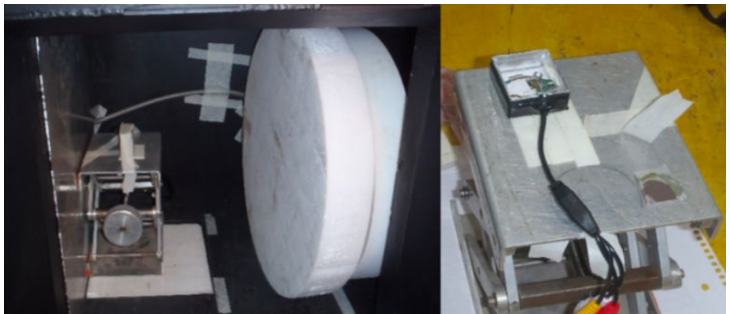
(e) X ^{55}Fe

Pérez, M. et al, JINST 2-s2.0-85112518794, https://doi.org/10.1088/1748-0221/16/08/p08008

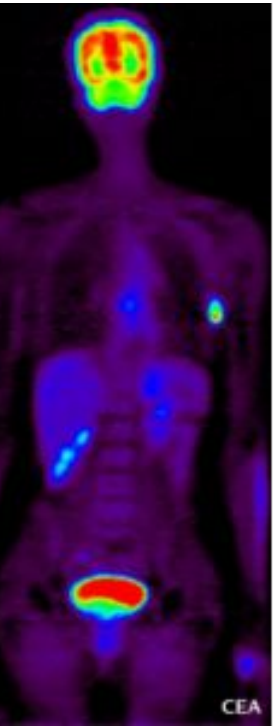
Neutron detection using conversion layers at RA-6

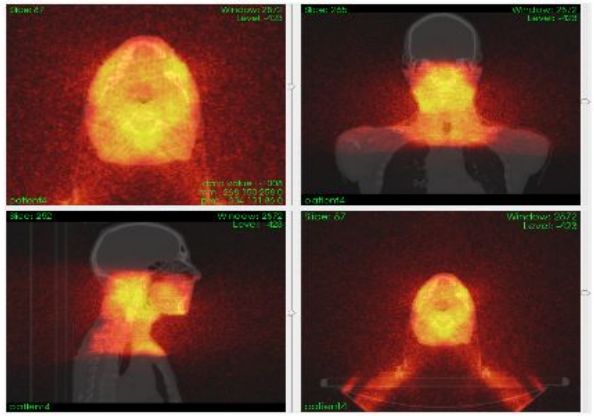
[NIMA 2016]





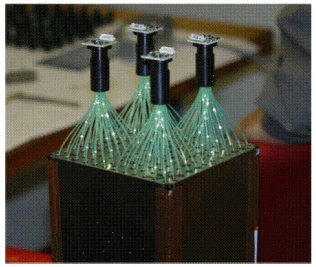
Extreme developments for extreme diagnostics

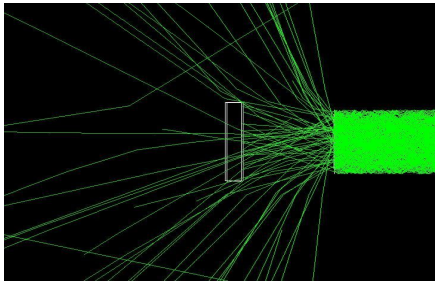


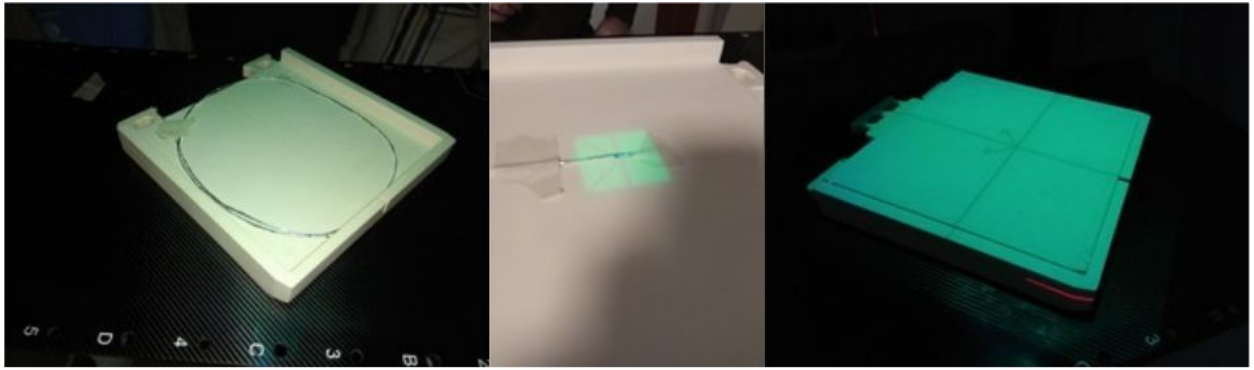


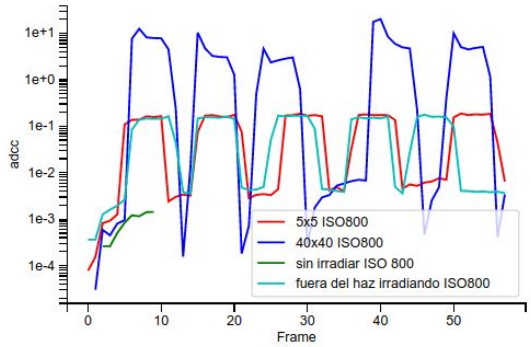
Combining MuTe&AMIGA Technology + MuTe-like TOF (~ps) proposal for a new Positron Emission Tomography (PET) scanner

RT beam characterization using WLS scintillator optical fibers & PiCam

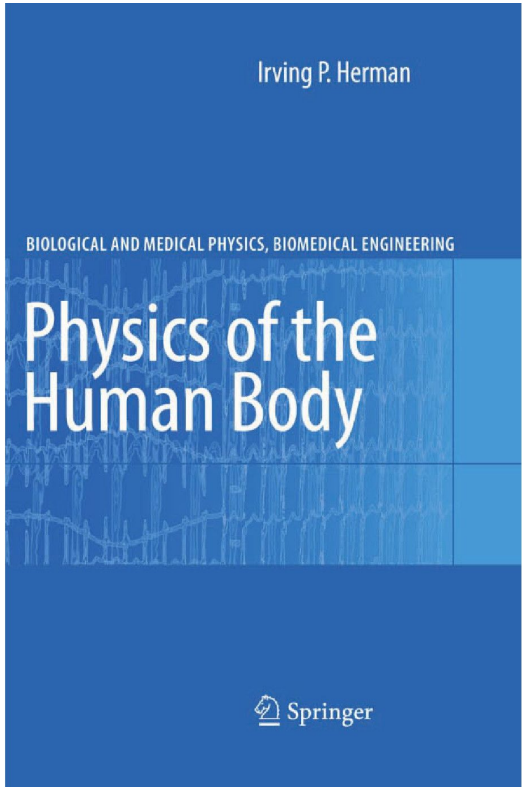








Extreme questions for extreme diseases



- “Gran parte del problema que tenemos en comprender especialistas en cualquier campo es entender su jerga, no sus ideas. Esto es particularmente cierto para la medicina.”
- **A veces tenemos respuestas pero desconocemos las preguntas que se podrían contestar**

Extreme questions for extreme diseases

Extreme questions for extreme diseases

¿Podemos nosotros (las o los ……..……) ayudar a personas que realmente están padeciendo enfermedades muy serias?

Extreme questions for extreme diseases

¿Podemos nosotros (las o los ……..……) ayudar a personas que realmente están padeciendo enfermedades muy serias?

¡Si!

Extreme questions for extreme diseases

¿Podemos nosotros (las o los ……..……) ayudar a personas que realmente están padeciendo enfermedades muy serias?

¡Si!

Vamos a hacerlo juntos…