Facultad de Ciencias Físico Matemáticas BUAP

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Study of East-West asymmetry of Cosmic rays at Puebla by MACARIO detector

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Centro Interdisciplinario de Investigación y Enseñanza de la Ciencia

Ciencia y Tecnología
Secretaría de Ciencia, Humanidades, Tecnología e Innovación

Cosmic rays (CRs)

- Cosmic rays are high energetic charged particles hitting continuously the Earth at a rate about 10’000 particles by square meter by second at energies of 1 GeV.

- The number of particles quickly reduce as the energy increases, particles with energy above 10^{19} eV arrives at a rate about one particle by square kilometer by year.

Grieder, P., 2011. Extensive Air Showers: High Energy Phenomena and Astrophysical Aspects - A Tutorial, Reference Manual and Data Book. Springer Berlin Heidelberg.

CRs ENERGY SPECTRUM

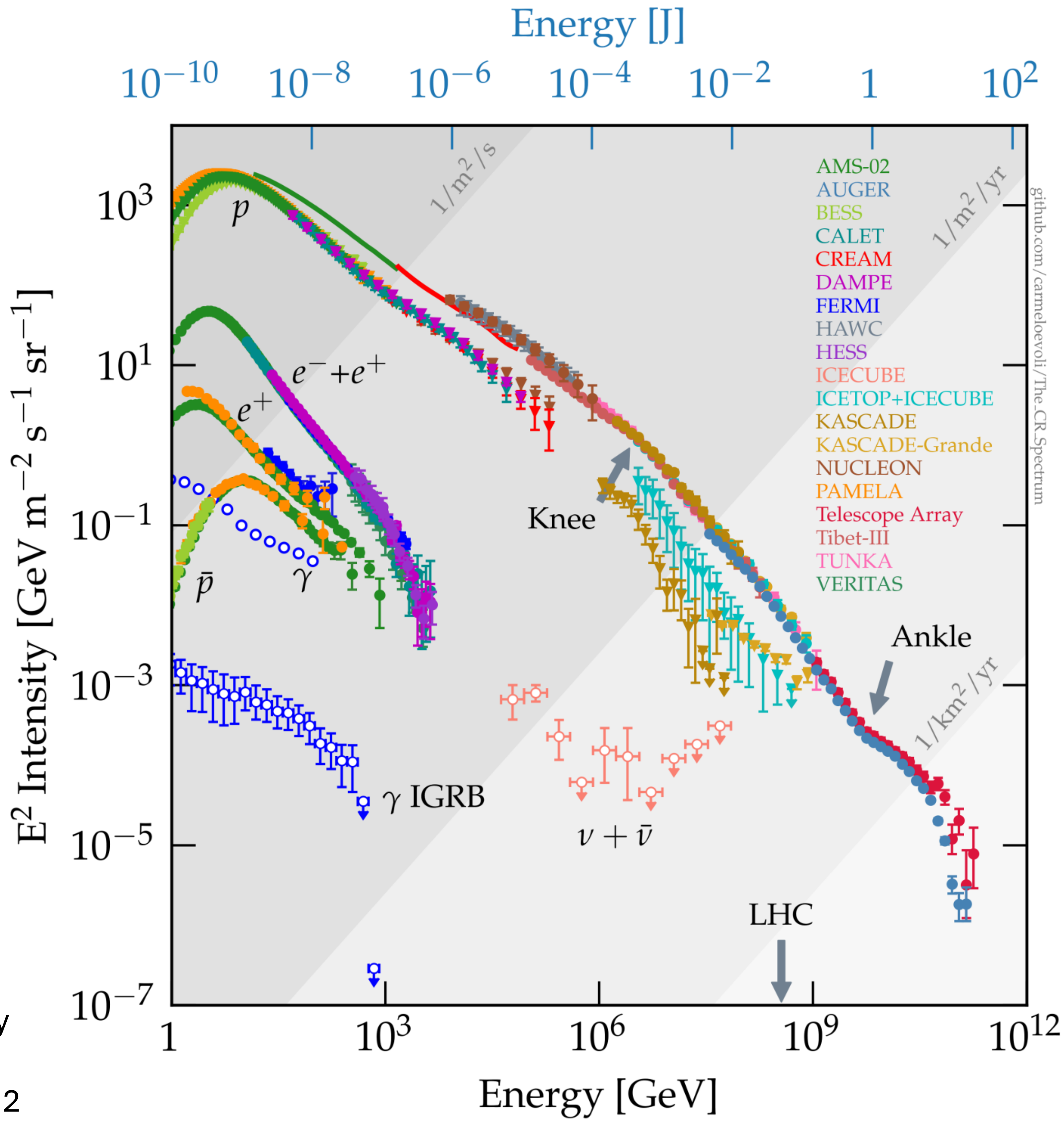


Figure 1. Global cosmic rays energy spectrum.

Evoli, C. (2020). The Cosmic-Ray Energy Spectrum. Zenodo. https://doi.org/10.5281/zenodo.7948212

EAS

An extensive air shower (EAS) takes place when a primary cosmic ray hit an air molecule on top of the atmosphere, generating a violent collision.
The fragments hit more air molecules since the energy of the original particle spread over millions of particles arriving the Earth's surface.

Studying EAS give us information about their development and energy of the primary particle.

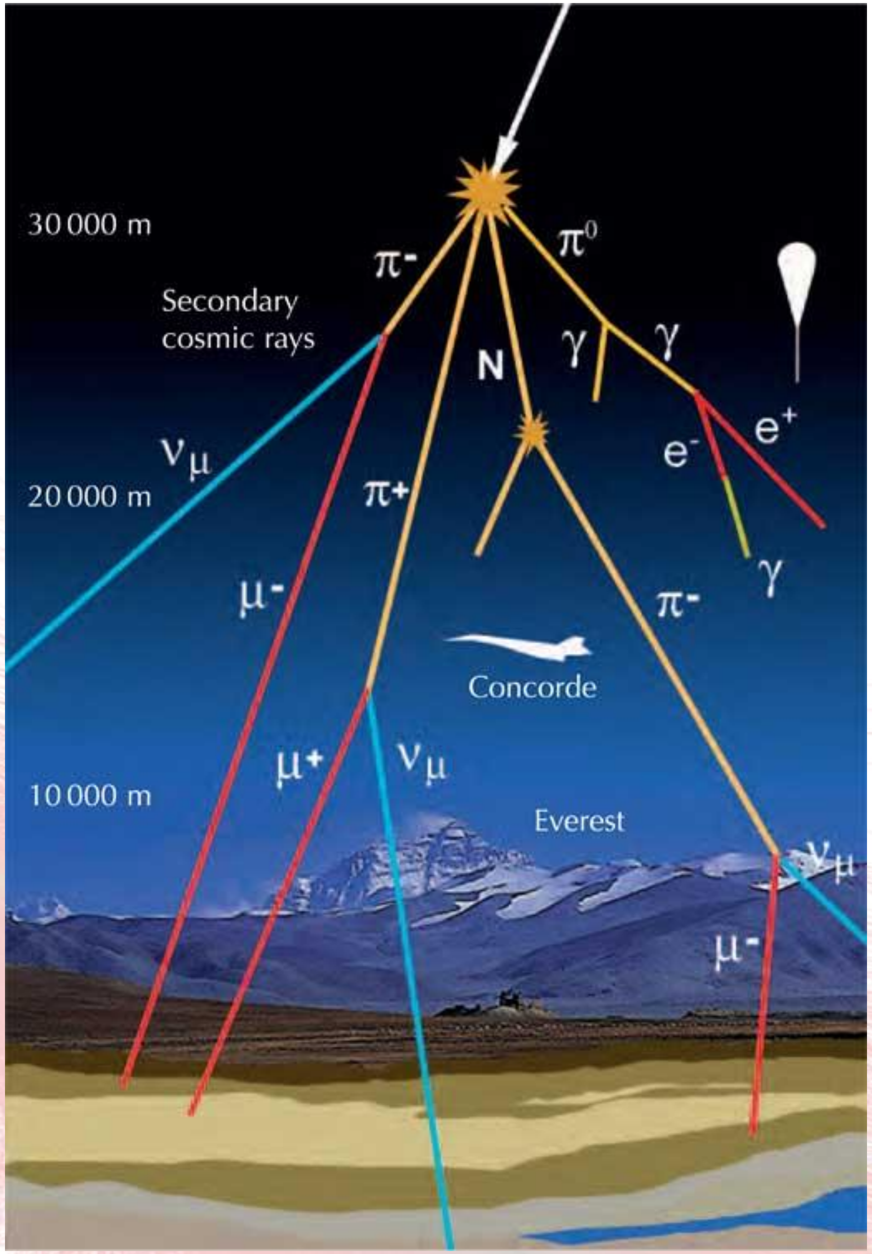


Figure 2. Schematic illustration of EAS development.

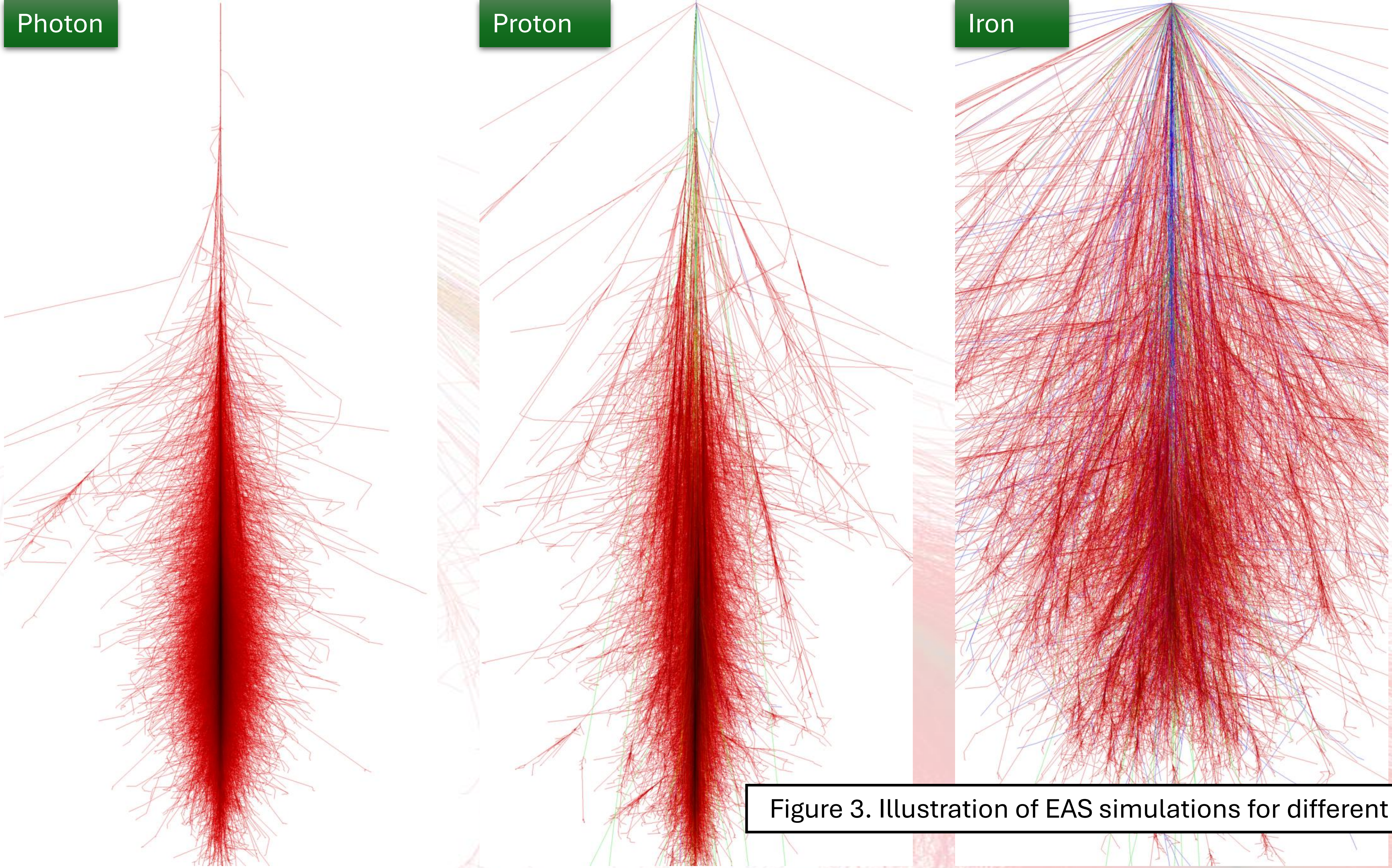


Figure 3. Illustration of EAS simulations for different primaries CRs.

F. Schmidt, J. Knapp, "CORSIKA Shower Images", 2005, https://www-zeuthen.desy.de/~jknapp/fs/showerimages.html

East-West asymmetry

- In the 1930's G. Lemaitre and S. Vallarta wrote a series of papers explaining the latitude and azimuth effects discovered by Clay and Compton: the cosmic rays are affected by geomagnetic filed and can be charged particles.
- S. Vallarta convinced to A. Compton to make measurements in Mexico to test their predictions.

Figure 4. George Lemaitre and Manuel Sandoval Vallarta in 1938.

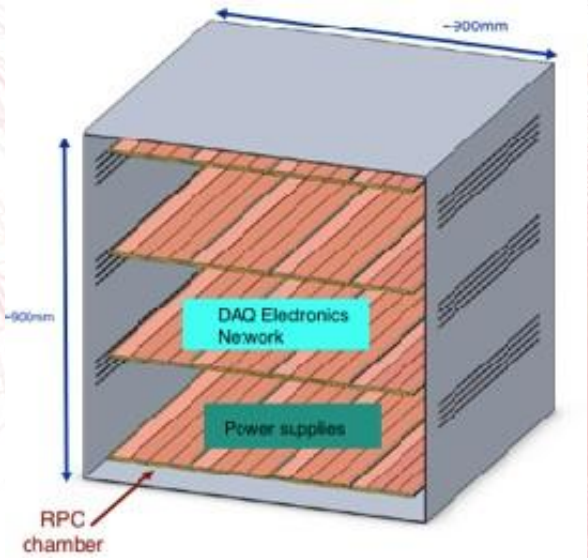
Pérez-Peraza, J. (2009). Reminiscences of cosmic ray research in Mexico. Advances in Space Research, 44(10), 1215–1220. https://doi.org/10.1016/j.asr.2008.11.031

- Compton sent his student Luis W. Alvarez to conduct the experiments in the mountains around Mexico city.
- They measured the cosmic ray intensity by varying the orientation of the detector.
- Compton and Alvarez determinedd an excess of about 10 % in the intensity deviations to the west, implying that cosmic radiation consisted principally of protons.

Pérez-Peraza, J. (2009). Reminiscences of cosmic ray research in Mexico. Advances in Space Research, 44(10), 1215–1220. https://doi.org/10.1016/j.asr.2008.11.031

Trasgo-like detector

TRASGO (Goblin): TRAck reconStructinG bOx



Initiative from the Institute of High Energy (IGFAE) from Santiago de Compostela University, Spain

- ✓ High granularity tracking detector
- ✓ Good temporal resolution
- ✓ Sensitive to bunches of particles (clusters)
- ✓ Muon / Electron sensitive (software separation)
- ✓ Rough estimation of electron and gamma energy

Figure 5. Illustration of a TRASGO and Trasgo detector

MiniTrasgo

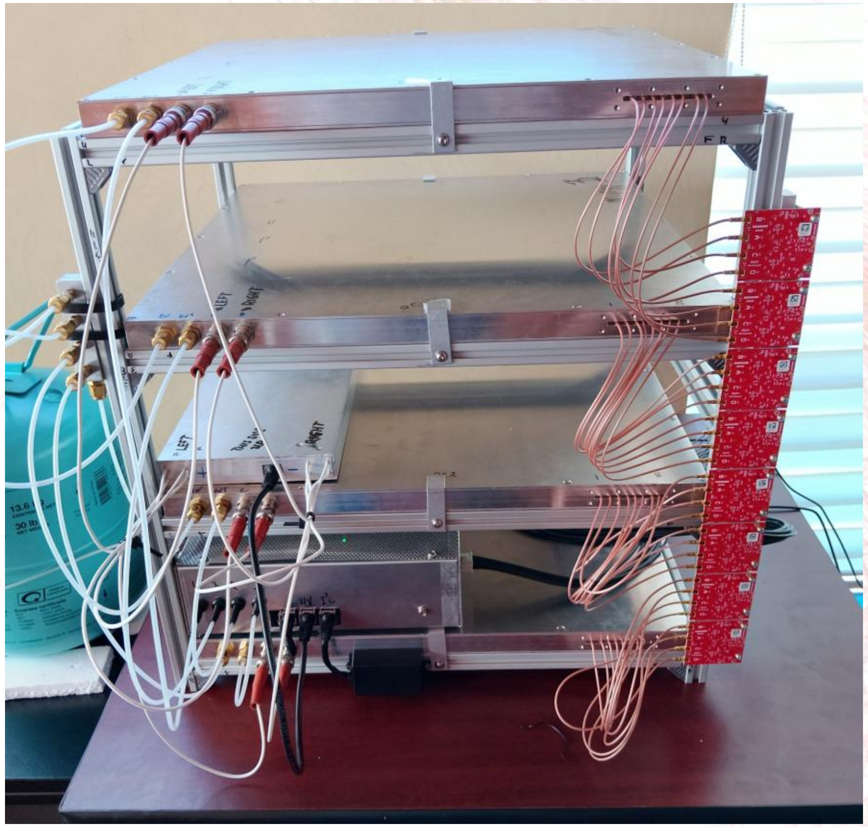


Figure 6. MiniTrasgo detector

Main features:
Effective Surface: 0.1 m^2
Number of Channels: 32
Angular resolution: ~3°
Mean rate: 9 Hz

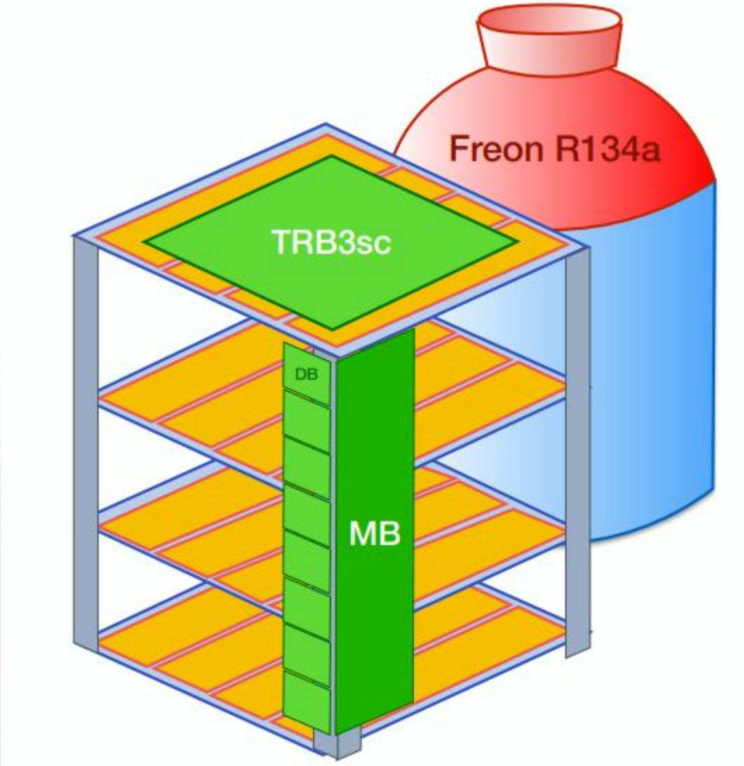
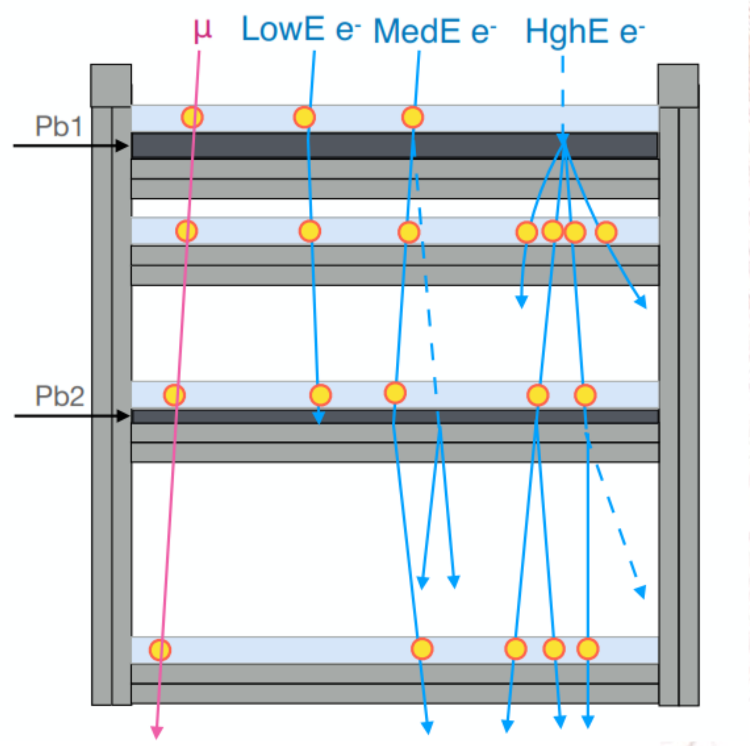


Figure 7. Cartoon of a MiniTrasgo detector, electronics and Gas Freon.

Detection by resistive plate chambers (RPCs)



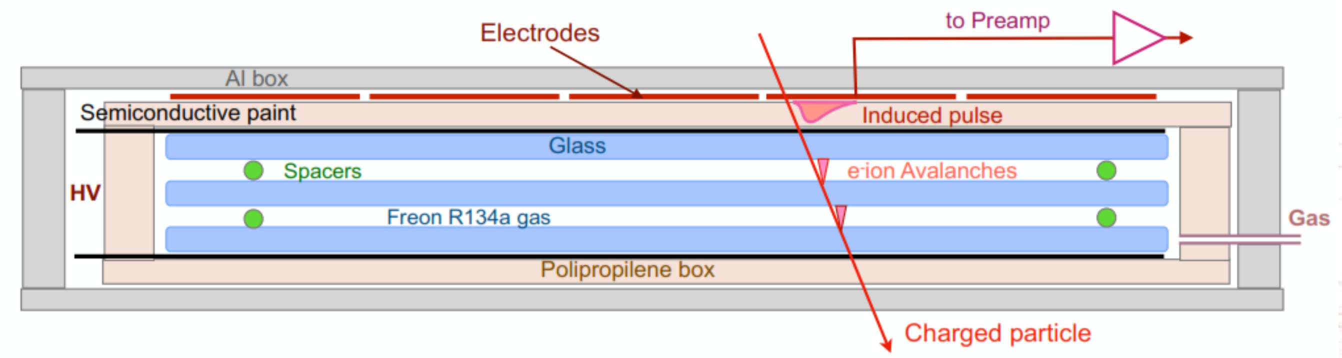


Figure 8: Left: design of a miniTrasgo detector, showing the particles produced by muons and electrons of different energies. Right: RPC side view.

MACARIO detector at CIIEC (BUAP)

Figure 9. MACARIO detector layout during data adquisition for this work.

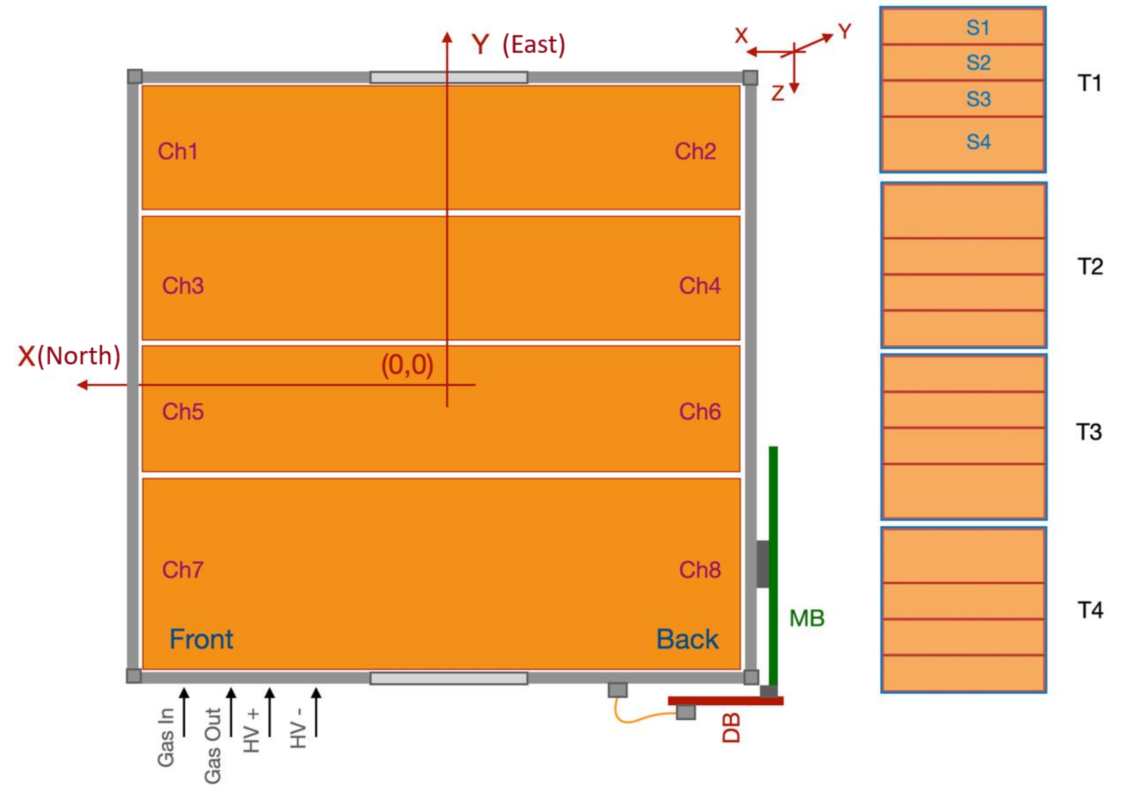
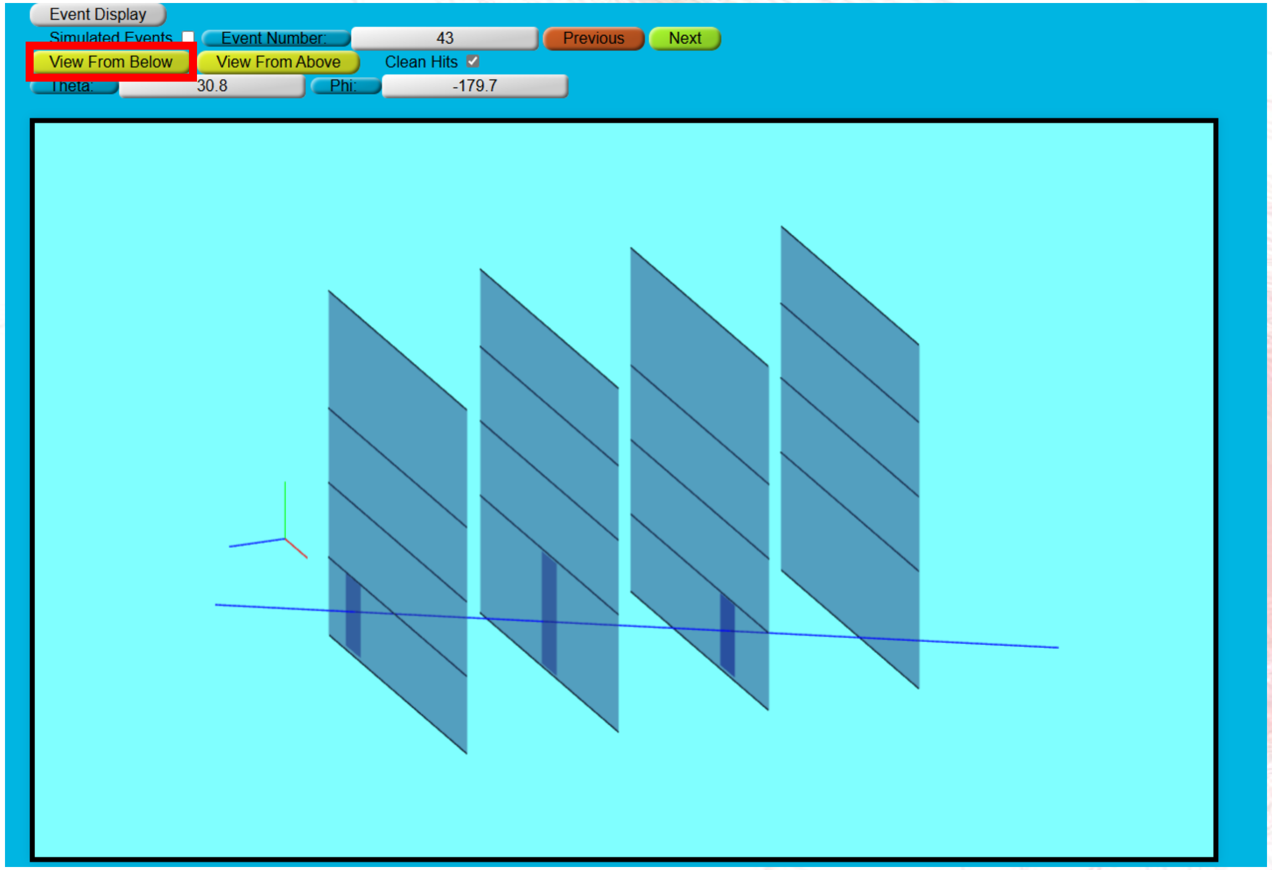
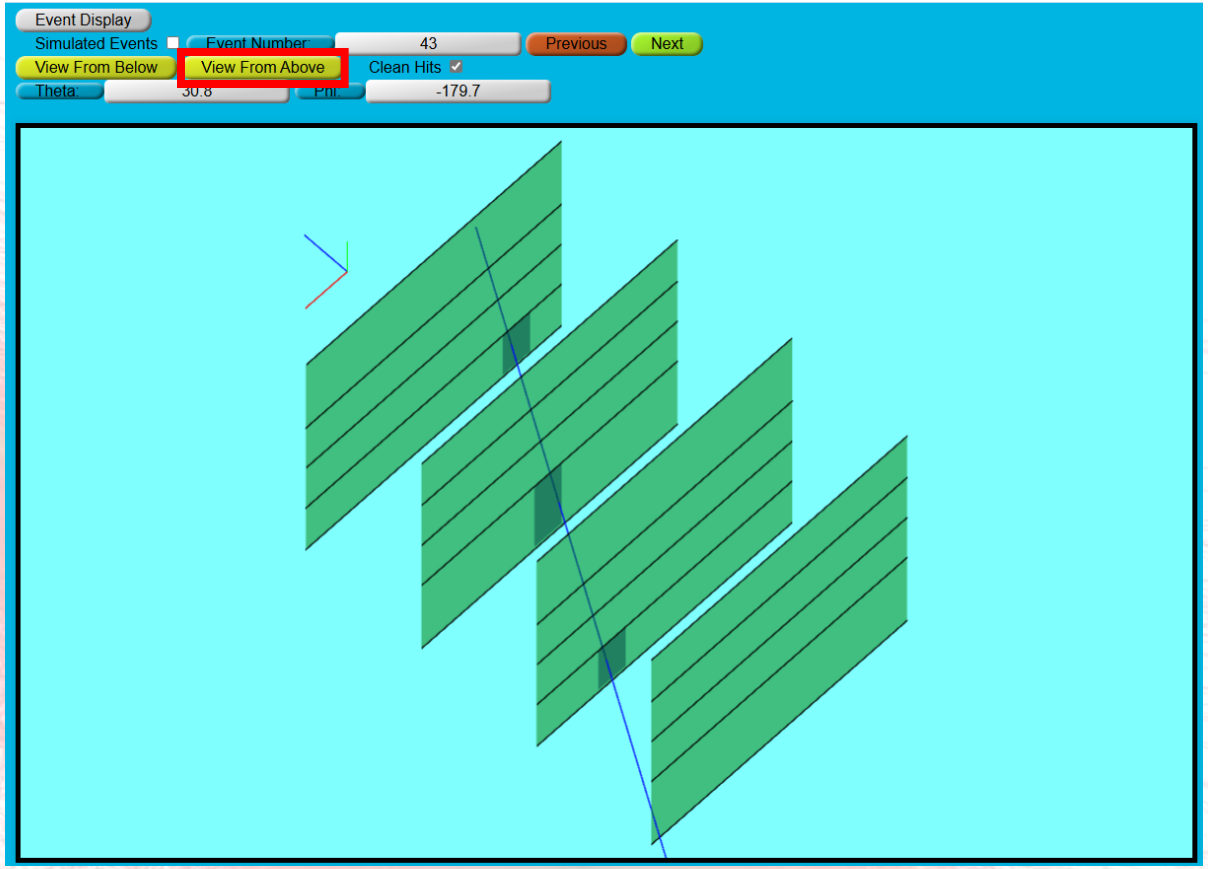


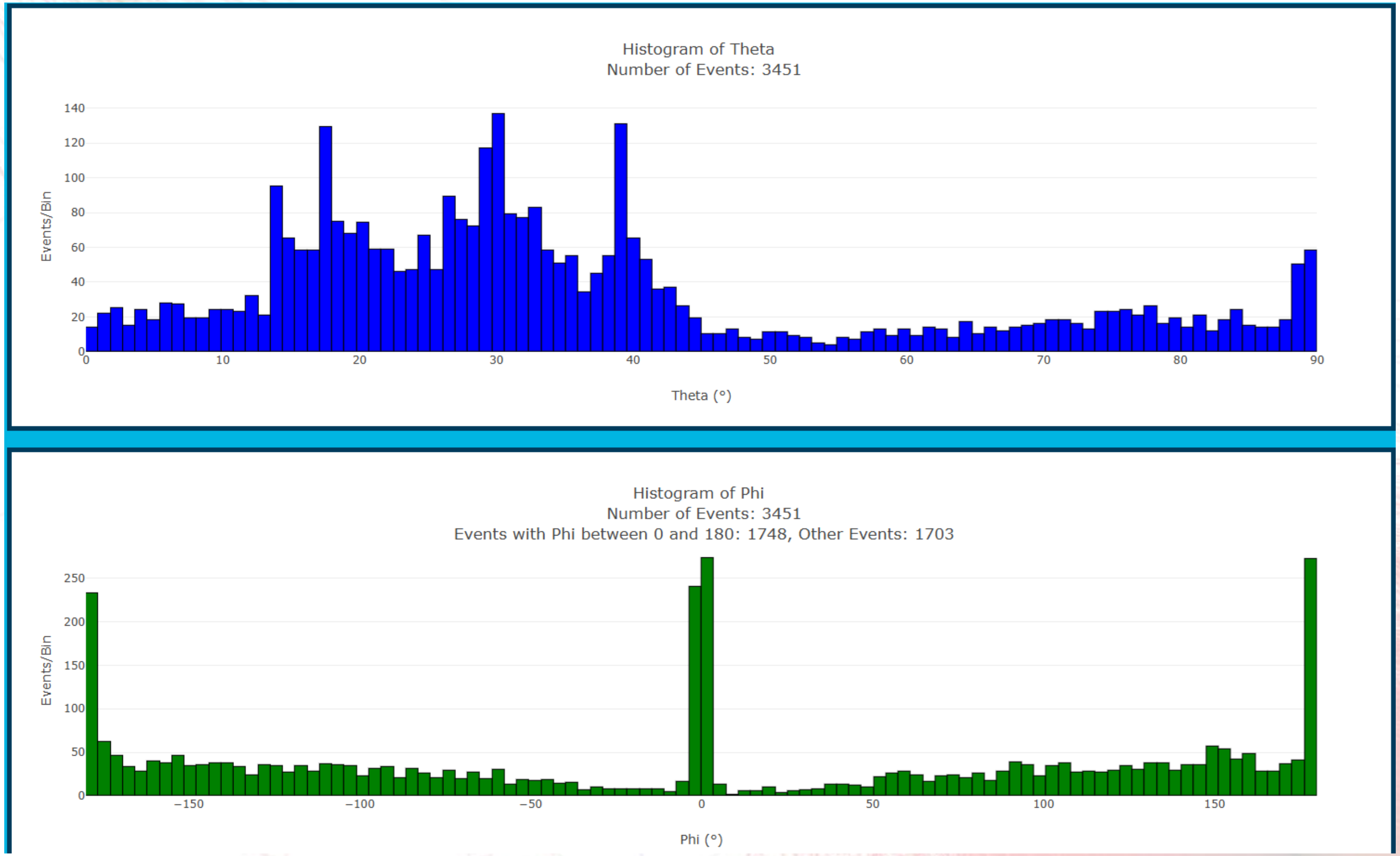
Figure 10. Strips orientation for this work

Data analysis by event display





Angular distributions



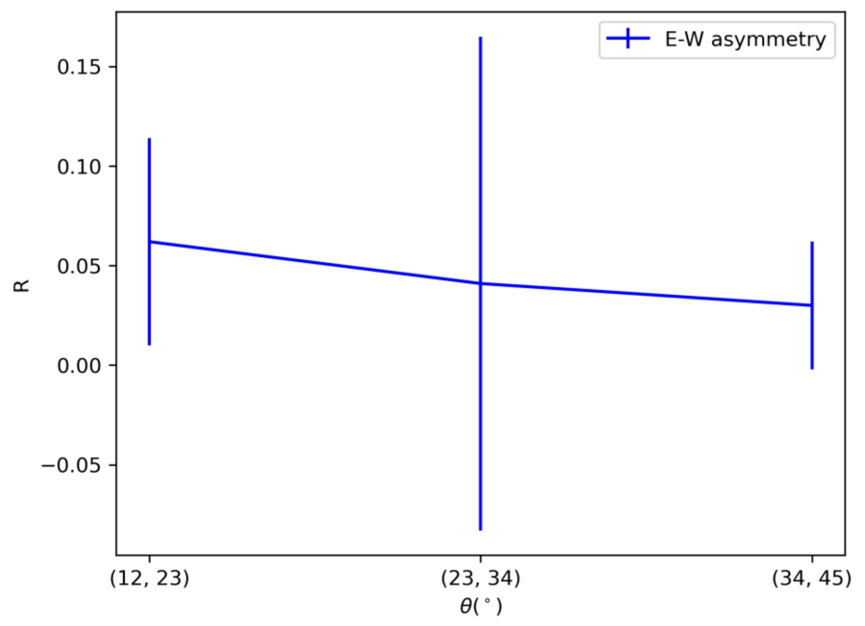
Results on East-West asymmetry (Puebla)

- Typically the asymmetry factor is expressed as:

$$R = 2 * (I_{west} - I_{east})/(I_{west} + I_{east})$$

- Considering the data measured on different days around the same time we get the next results:

Zn	(12°, 23°)	(23°, 34°)	(34°, 45°)
R	0.062 ± 0.052	0.041 ± 0.124	0.030 ± 0.032



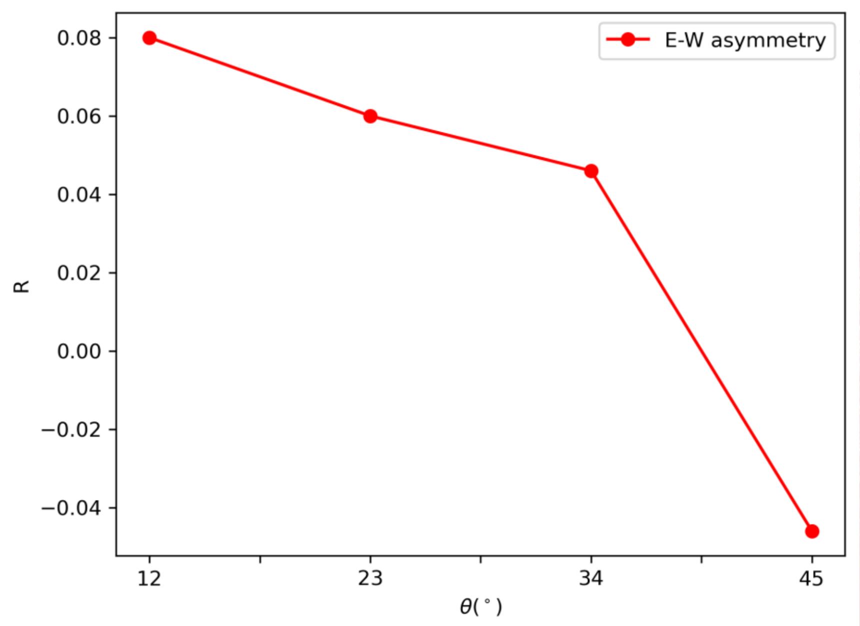
CORSIKA simulations

- Primary proton
- 250’000 showers per run
- Fixed energies: 10, 100, 400, 1’000 GeV
- Zenith angles: 12, 23, 34, 45 °
- Observation level: 2’100 m
- Geographic location: latitude 18.99 N, longitude 98.19 W
- Magnetic field: Bx → 27.08 μT, Bz → 28.64 μT
- Cut-off rigidity (Puebla): ~7.5 GV

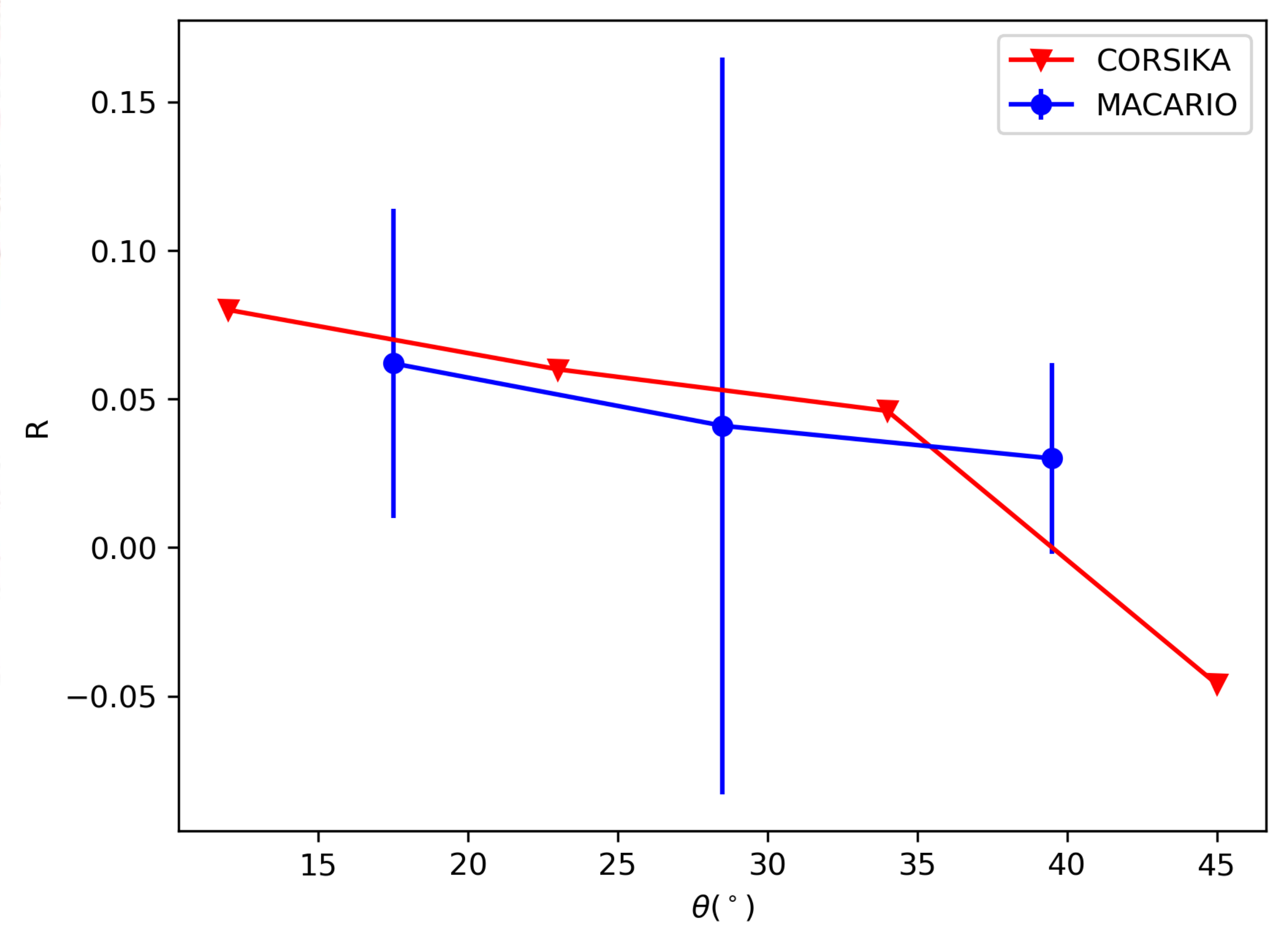
Results for simulations

- For low energies (10, 100 GeV) there is not an asimmetry due to geomagnetic cut-off rigidity.
- For high energy (1’000 GeV) there is not asymmetry because the geomagnetic field can not deviate the particles anymore.
- In the middle range (400 GeV) we found an asymmetry.

Zn	12°	23°	34°	45°
R	0.08	0.06	0.046	-0.46

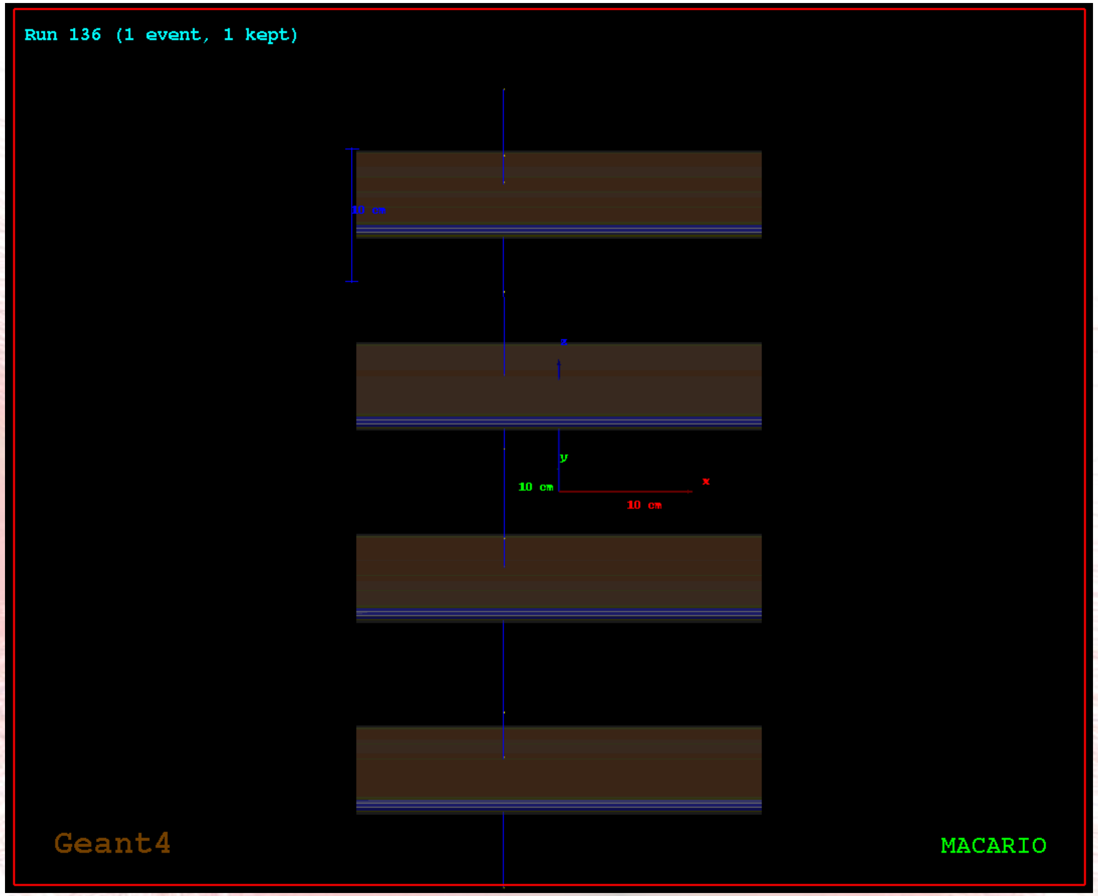


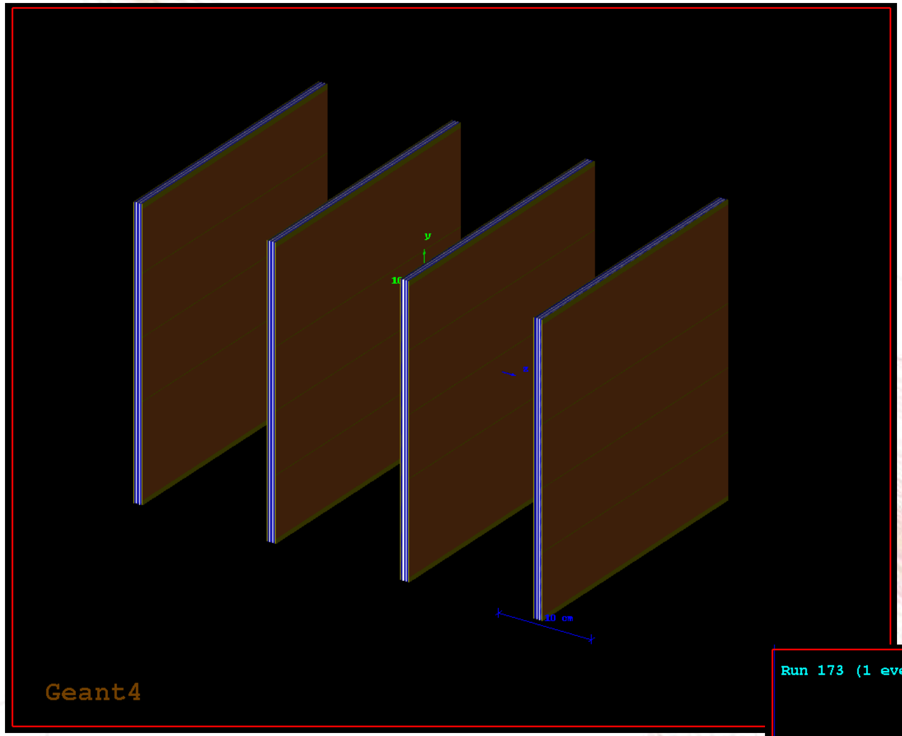
Comparison of measurements and simulation

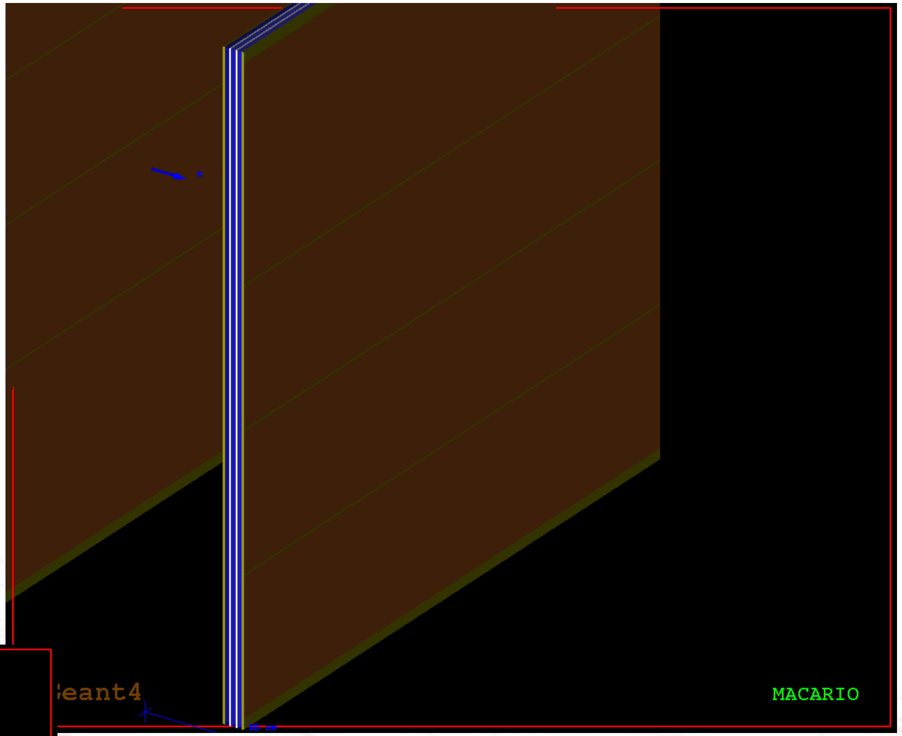


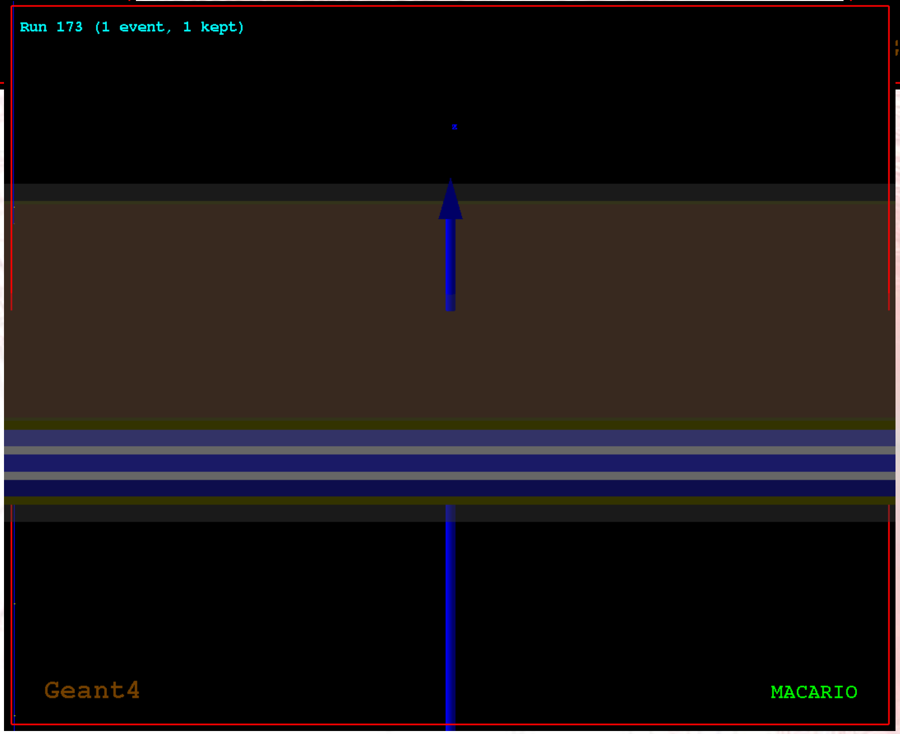
Ongoing work

- Detector response with GEANT4 simulations
- Particles produced by different incident particles (μ^-, e^-)
- Track topologies
- Incident particles injected based on CORSIKA simulations results

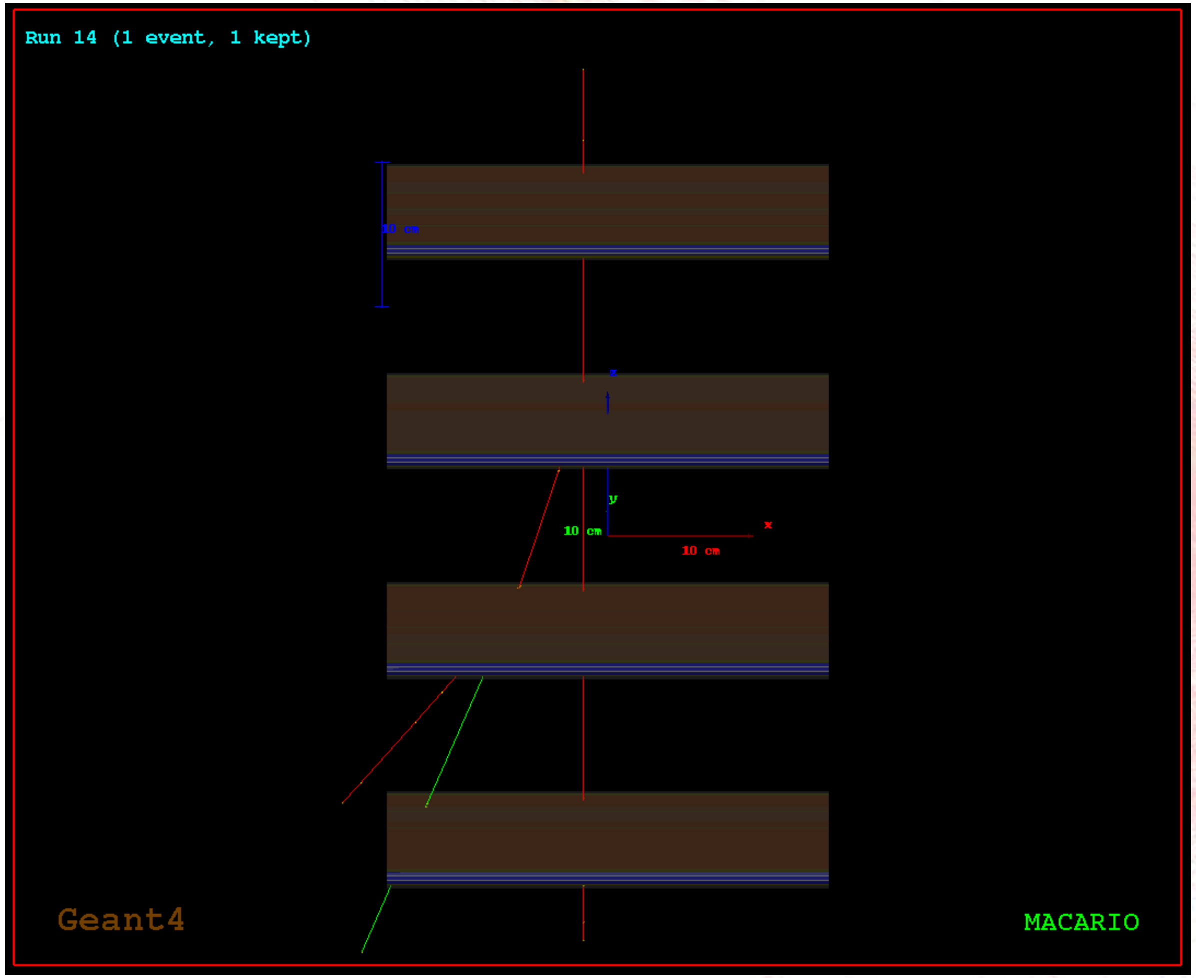



Geant4

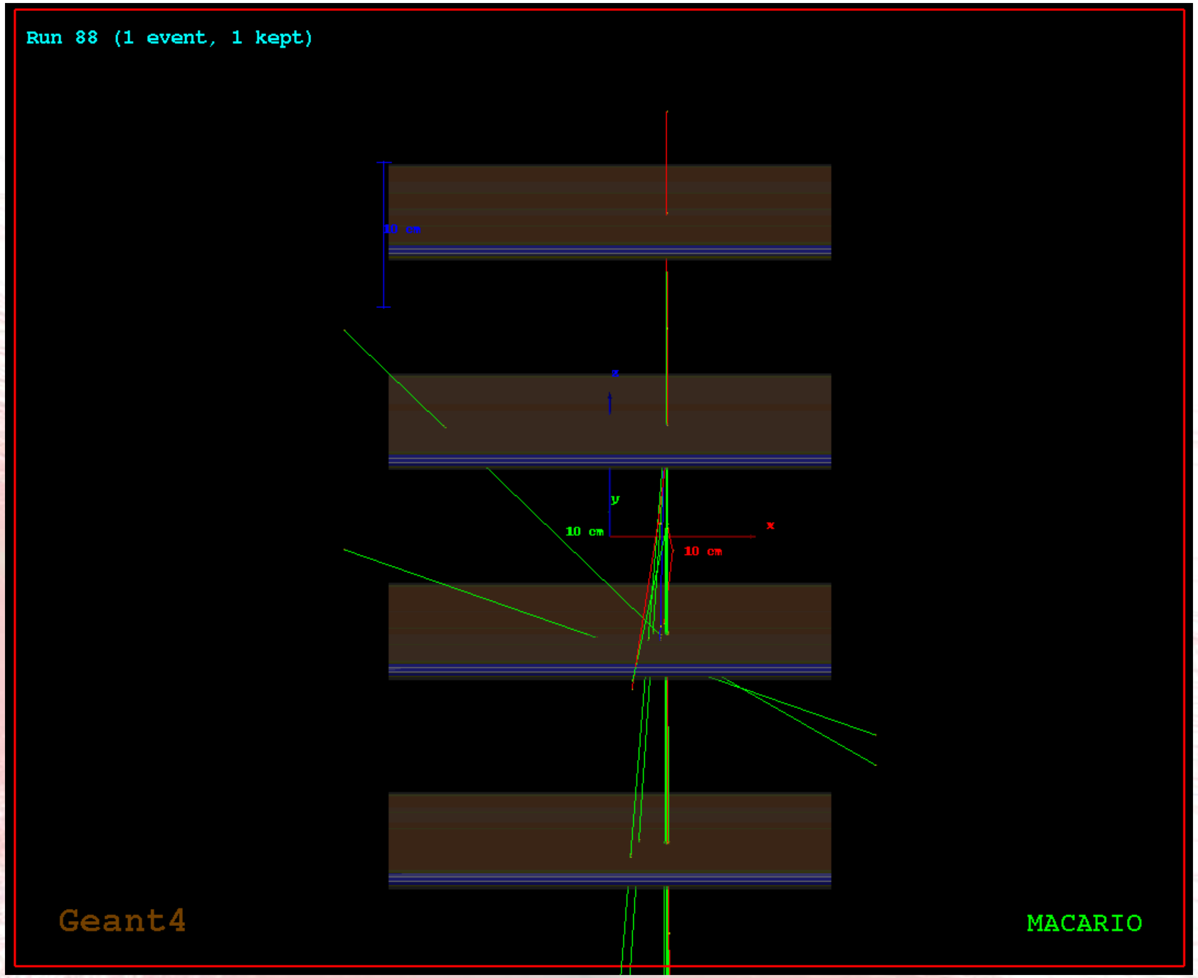

MACARIO


Run 173 (1 event, 1 kept)
Geant4
MACARIO

Vertical muon of 4 GeV

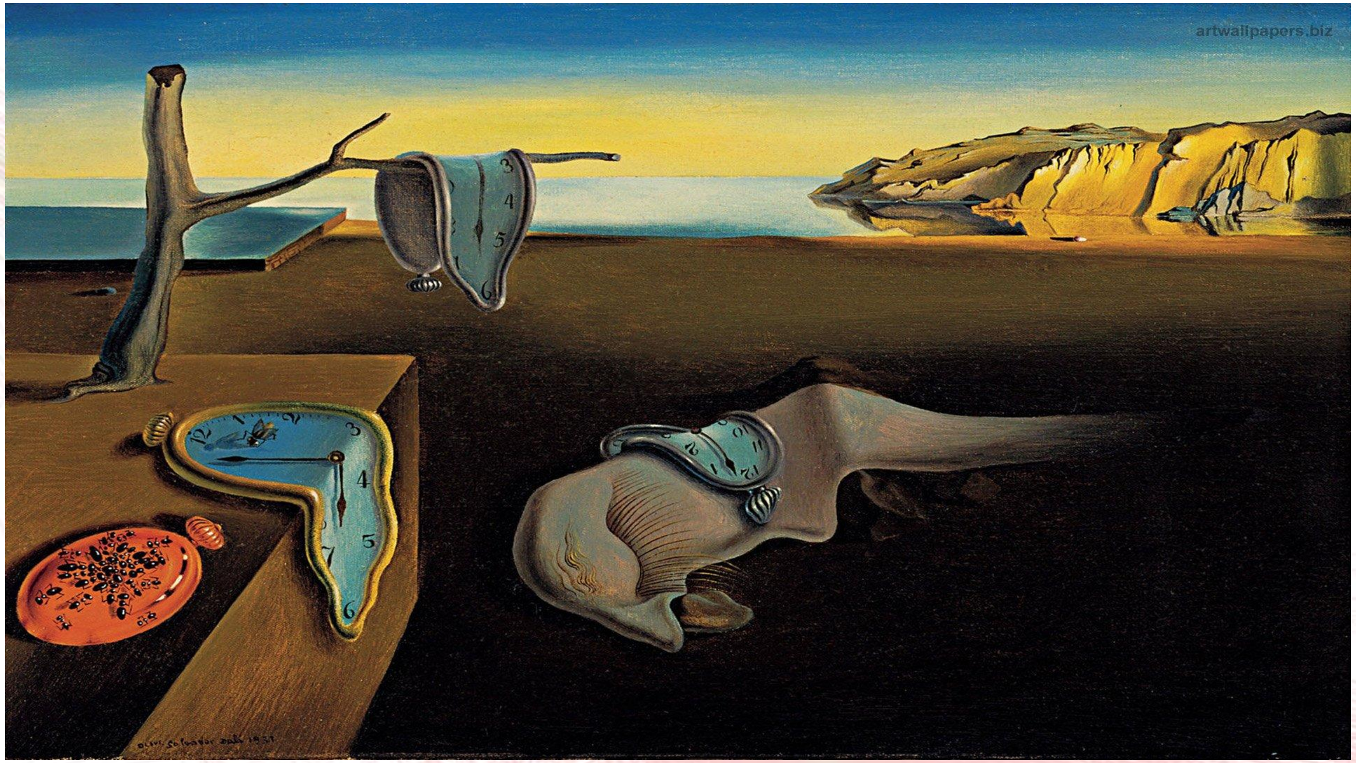


Vertical electron of 4 GeV



Conclusions

- The study of East-West asymmetry is a fundamental phenomenon which happens in every place of the world but depends on the latitude and altitude.
- MACARIO detector is very useful for training students who are starting to get involved in astroparticle and particle physics.
- The technology employed on MACARIO is like the instrumentation of bigger particle physics projects and familiarize with it allows to gain experience on the high energy physics area.
- Due to compact size the Trasgo-like detectors are suitable for education and outreach activities.



Thanks for your time

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Backup slides

A historical second measurement of East-West asymmetry

- In 1940, under the guidance of Alfredo Baños, the Young students Fernando Alba Andrade and Manuel I. Perrusquia constructed a rotaiting rail system of Geiger counters to measure cosmic ray intensity as a function of time at azimuth and zenith angles.

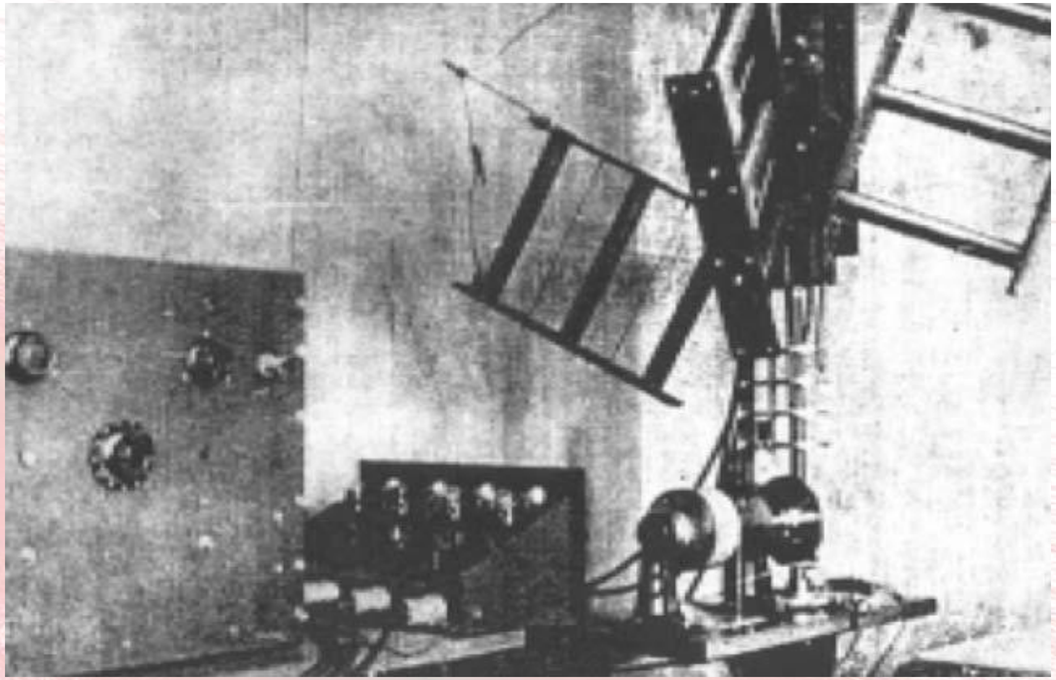


Figure 11. First Mexican cosmic ray detector placed on the roof of the Mining Palace in 1941.

PHYSICAL REVIEW VOLUME 71, NUMBER 7 APRIL 1, 1947

The Determination of the Sign and the Energy Spectrum of Primary Cosmic Radiation*

M. S. VALLARTA, M. L. PERUSQUÍA,** AND J. DE OYARZÁBAL
Instituto de Física, Universidad de México, México, D. F.

(Received November 19, 1946)

An experiment is reported in this paper for the measurement of the complete azimuthal effect. This experiment was performed in Mexico City (geomagnetic latitude 29°, altitude 2242 m above sea level) for constant zenith angles 20°, 40°, and 60°. A characteristic feature is that the length of the atmospheric path is constant, hence the assumption is made that the number of secondaries detected by the cosmic-ray telescope is a measure of the number of primaries. The analysis yields an energy spectrum of the primary radiation of the form $K/E^{1.45}$ (E=energy, K=constant). There is no evidence of negative primary particles. The results are subject to revision because the penumbra bands at this latitude are only imperfectly known, and also because of the resolving power of our present apparatus. The possibility of a bright line spectrum, or of such a spectrum superimposed on a continuous distribution, is not ruled out. The possibility of negative primaries is excluded within the limits of experimental error. The spectrum obtained from our experimental data agrees completely with that determined from the experiment of Gill, carried out at Lahore, Punjab, India. The result is valid in the energy range from about 350 to 600 millistörmers, or 6 to 21 Bev if the primaries are protons.

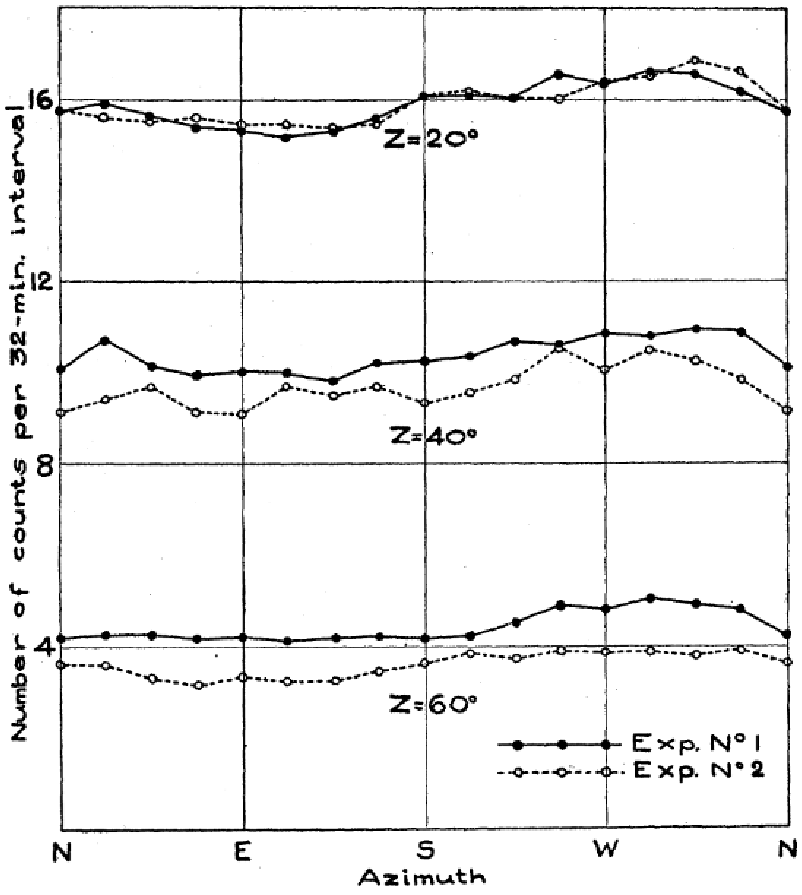
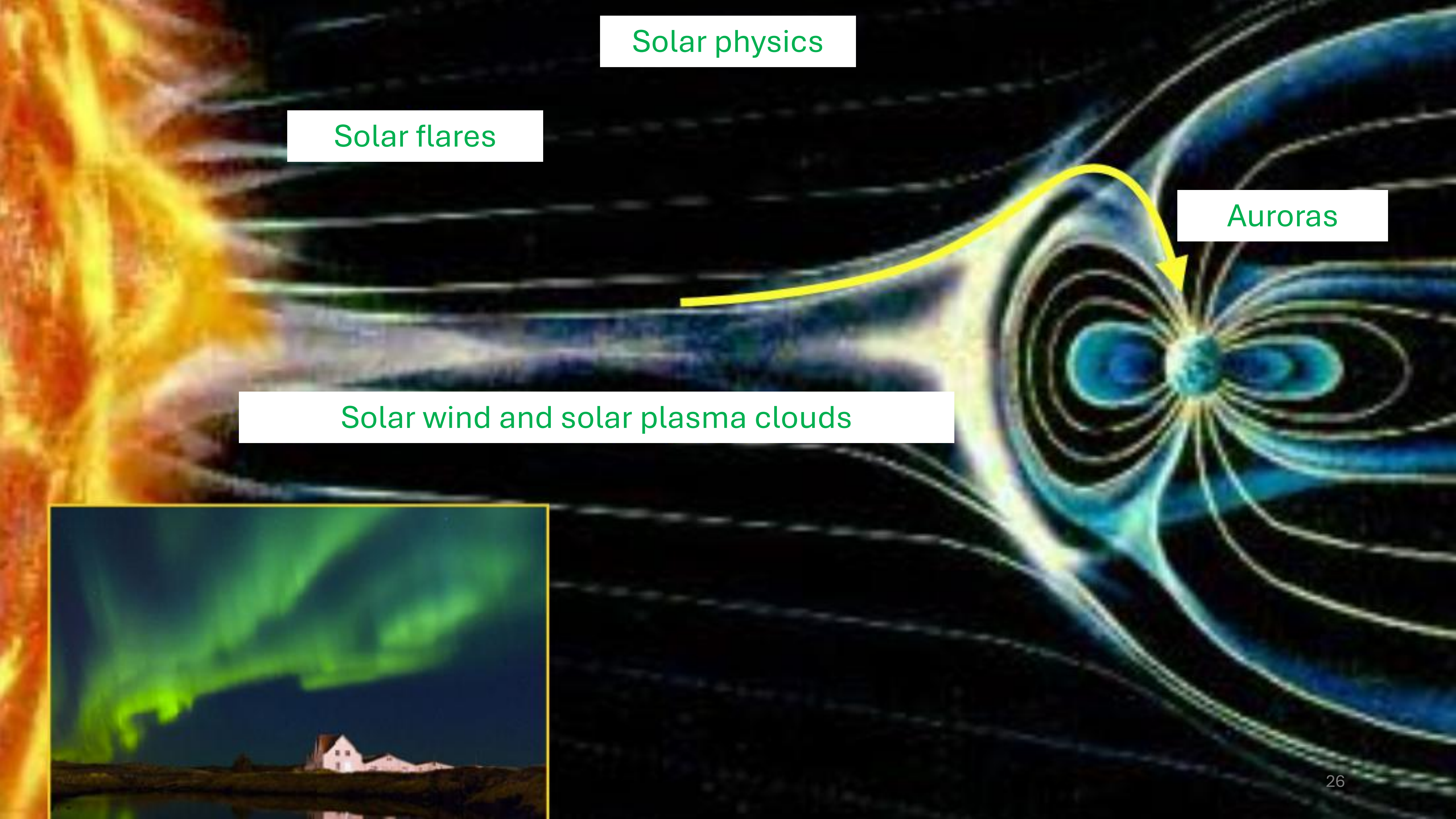


FIG. 1. The experimental azimuthal effect.


Solar physics
Solar flares
Auroras
Solar wind and solar plasma clouds

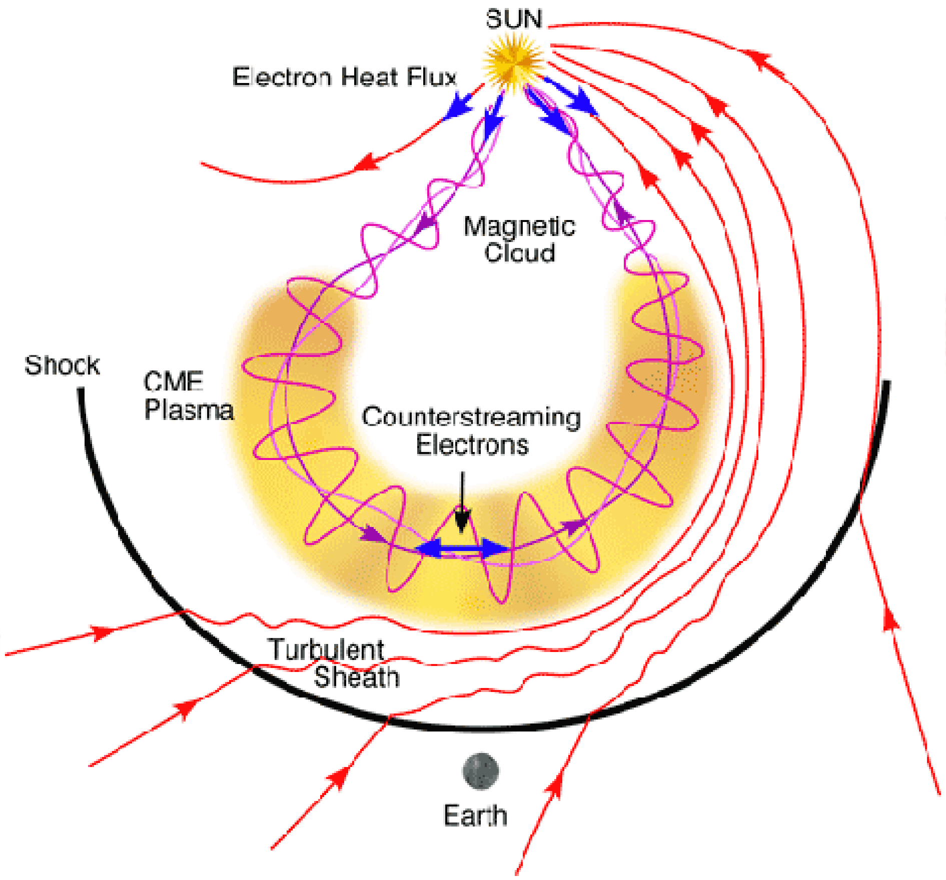
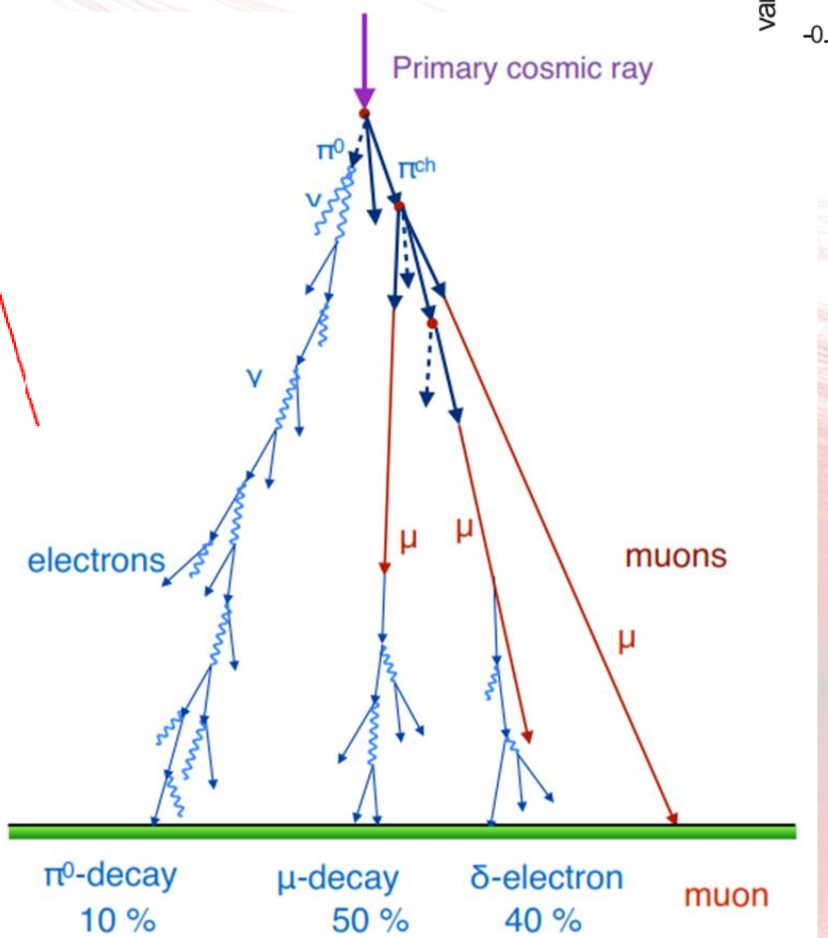


Figura 12. Escheme of cosmic rays propagation towards the Earth.

Figura 13. Muons and electrons origin



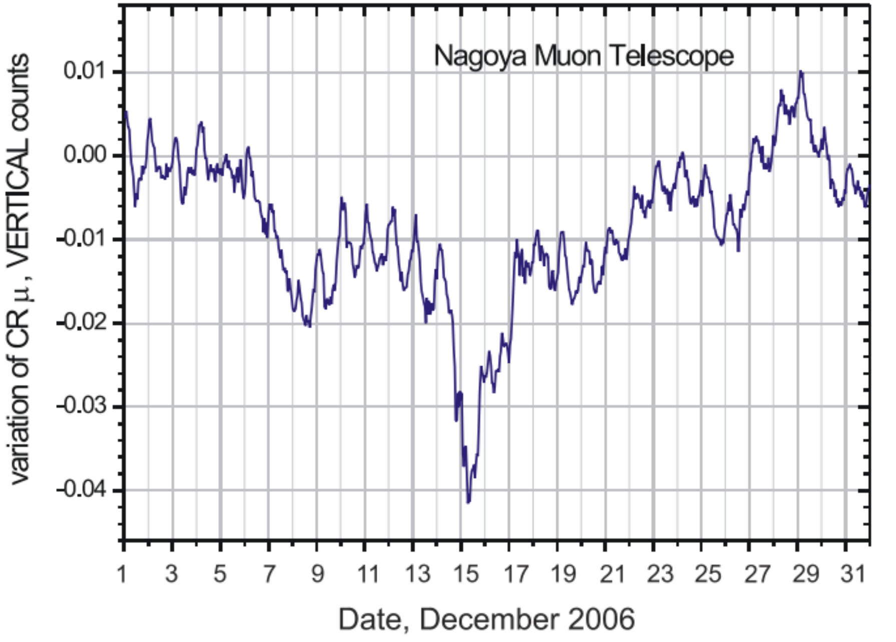


Figura 14. Forbush decrease.

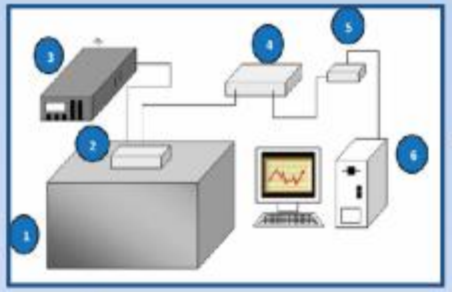
Angelov, I., Malamova, E., & Stamenov, J. (2009). The Forbush decrease after the GLE on 13 December 2006 detected by the muon telescope at BEO - Moussala.

Main effects of the atmosphere as extenuating

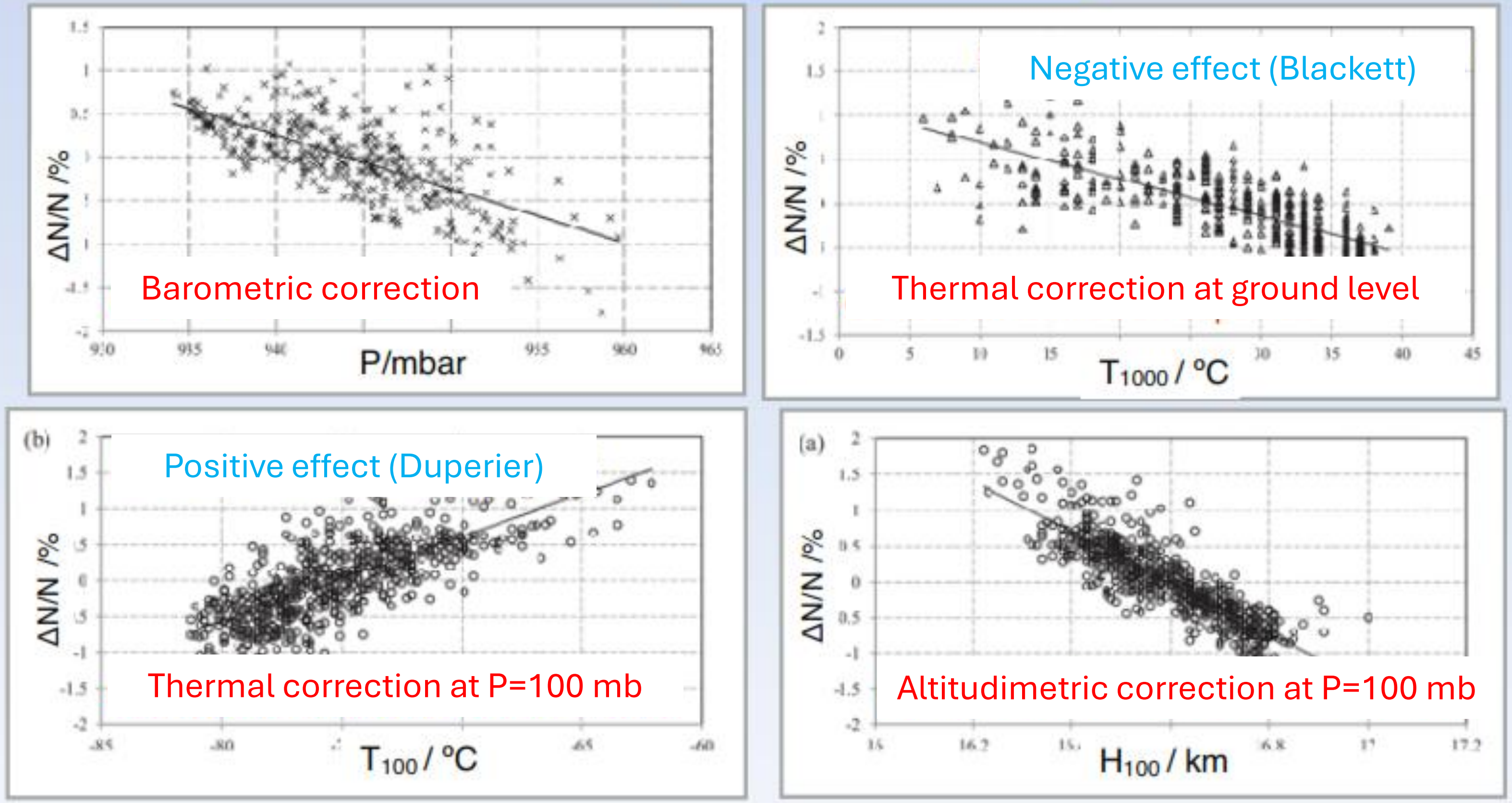
The influence of several atmospheric variables on cosmic ray muons observed by KACST detector

A. Maghrabi, M. Almutairi (2018)

1m2 scintillator + 1 PMT + 200g/cm2 concrete (3 X_0)



1	Muon Box	4	Amplifier
2	PMT Base and Preamp	5	ADC
3	HV Power Supplier	6	Data Acquisition Board



Atmospheric temperature corrections attempts

THE TEMPERATURE EFFECT IN SECONDARY COSMIC RAYS (MUONS) OBSERVED AT THE GROUND: ANALYSIS OF THE GLOBAL MUON DETECTOR NETWORK DATA

R. R. S. de Mendonça[1], C. R. Braga[1], E. Echer[1], A. Dal Lago[1], K. Munakata[2], T. Kuwabara[3], M. Kozai[4], C. Kato[2], M. Rockenbach[1], N. J. Schuch[1], H. K. Al Jassar[4], M. M. Sharma[4], M. Tokumaru[5], M. L. Duldig[6], J. E. Humble[6],

The Astrophysical Journal, 830:88 (25pp), 2016 October 20

4.1. The Atmospheric Expansion (ATE) Method — C. altitudimétrica

$$\Delta I_T = \alpha_{\mathrm{ATE}} * \Delta H[p], \quad p = 100\ \mathrm{hPa}$$

4.2. The Ground (GRD) Method — P. Blackett

$$\Delta I_T = \alpha_{\mathrm{GRD}} * \Delta T[h_{\mathrm{GRD}}]$$

4.3. The MMP Method — A. Duperier

$$\Delta I_T = \alpha_{\mathrm{MMP}} * \Delta T[h_{\mathrm{MMP}}]$$

4.4. The GRD, ATE and MMP Method Combinations (GRD+MMP and ATE+MMP)

$$\Delta I_T = \sigma_{\mathrm{ATE}} * \Delta H[p] + \sigma_{\mathrm{MMP}} * \Delta T[h_{\mathrm{MMP}}] \quad (5)$$

$$\Delta I_T = \sigma_{\mathrm{GRD}} * \Delta T[h_{\mathrm{GRD}}] + \sigma_{\mathrm{MMP}} * \Delta T[h_{\mathrm{MMP}}]$$

4.5. The Theoretical (THR) Method and its Variation (THR-L) — L. Dorman

$$\Delta I_T = \int_0^{x_{\mathrm{GRD}}} \alpha_{\mathrm{THR}}[x] * \Delta T[x] * dx$$

$$x[h] = \int_h^{\infty} \rho[h]dh, \quad \rho[h] = \frac{P[h]}{T[h]} * \frac{M_{\mathrm{Mol}}}{R}$$

4.6. The Mass Weighted (MSS) Method — V.M. Dvornikov

$$\Delta I_T = \alpha_{\mathrm{MSS}} * \Delta T_{\mathrm{MSS}}$$

$$T_{\mathrm{MSS}} = \sum_{i=0}^{n} w[h_i] * T[h_i], \quad w[h_i] = \frac{x[h_i] - x[h_{i+1}]}{x[h_0]}$$

4.7. The Effective Temperature (EFF) Method and its Variation (EFF-M) — P.H. Barrett

$$\Delta I_T = \alpha_{\mathrm{EFF}} * \Delta T_{\mathrm{EFF}} \quad (13)$$

$$T_{\mathrm{EFF}} = \frac{\int_0^{x_{\mathrm{GRD}}} \omega[x] * T[x]\,dx}{\int_0^{x_{\mathrm{GRD}}} \omega[x]\,dx}, \quad \omega[x] = \frac{1}{x} * \left(e^{-\frac{x}{\Lambda_\pi}} - e^{-\frac{x}{\Lambda_N}}\right) \quad (14)$$

Cosmic rays as temperature probe

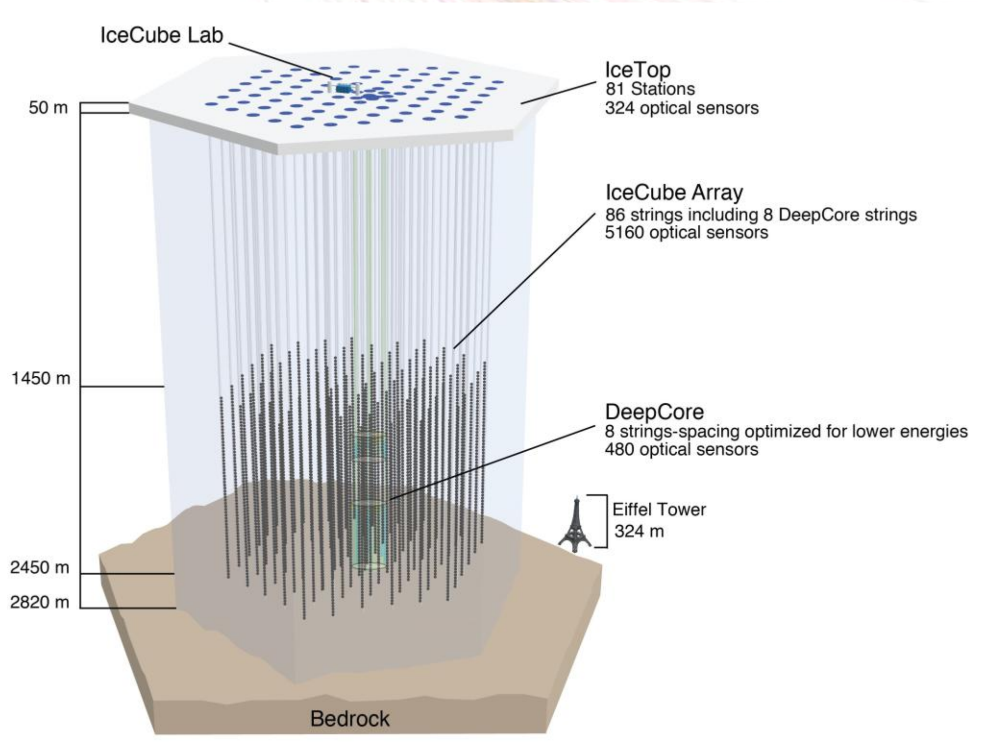


Figura 15. IceCube observatory at south pole.

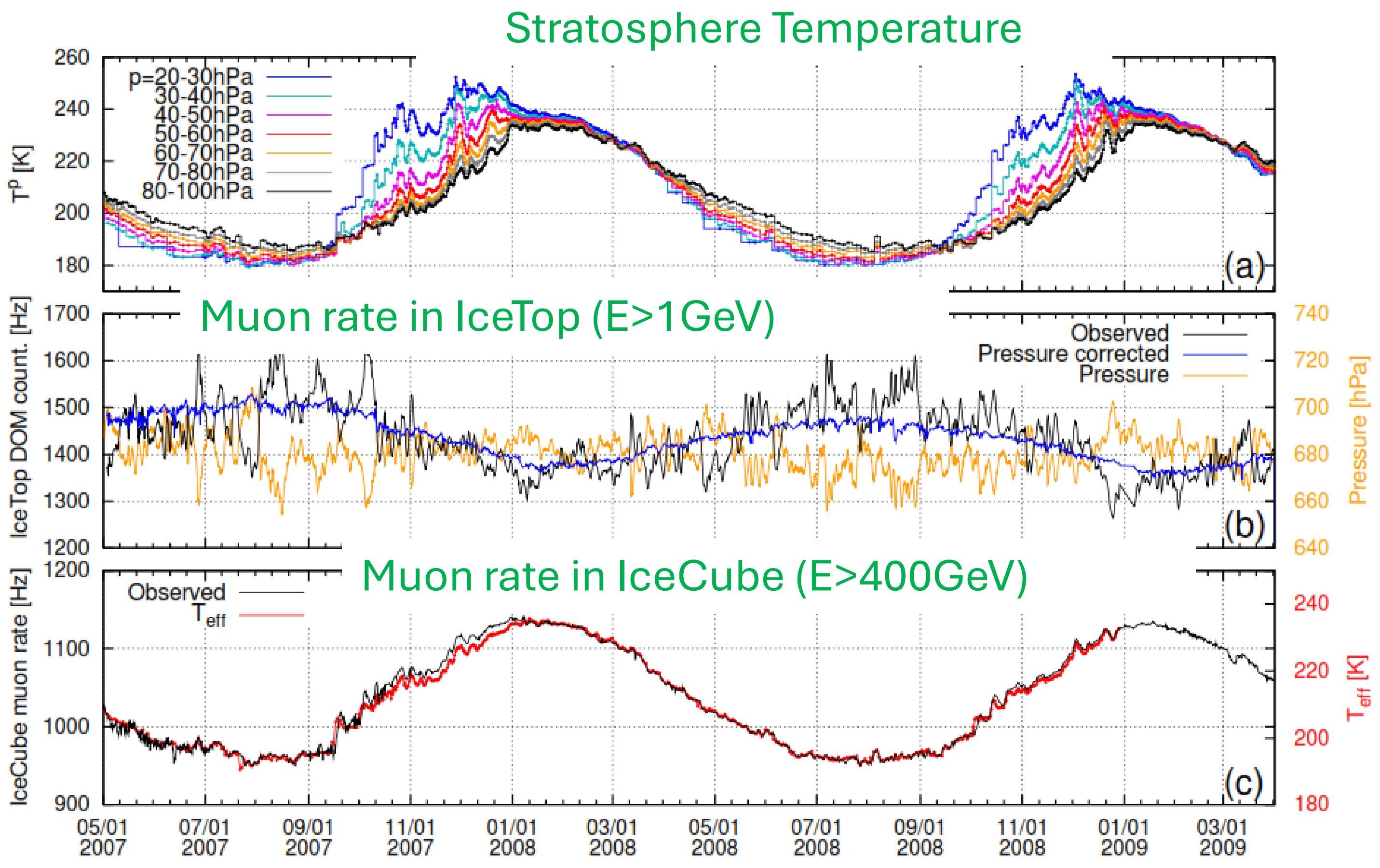


Figure 16. Temporal evolution of temperature and muon rates detected from 2007 till 2009.

https://icecube.wisc.edu/gallery/detector/#modulagallery-7032-9784

Tilav, S., Desiati, P., Kuwabara, T., et. al (2009). Atmospheric variations as observed by IceCube.