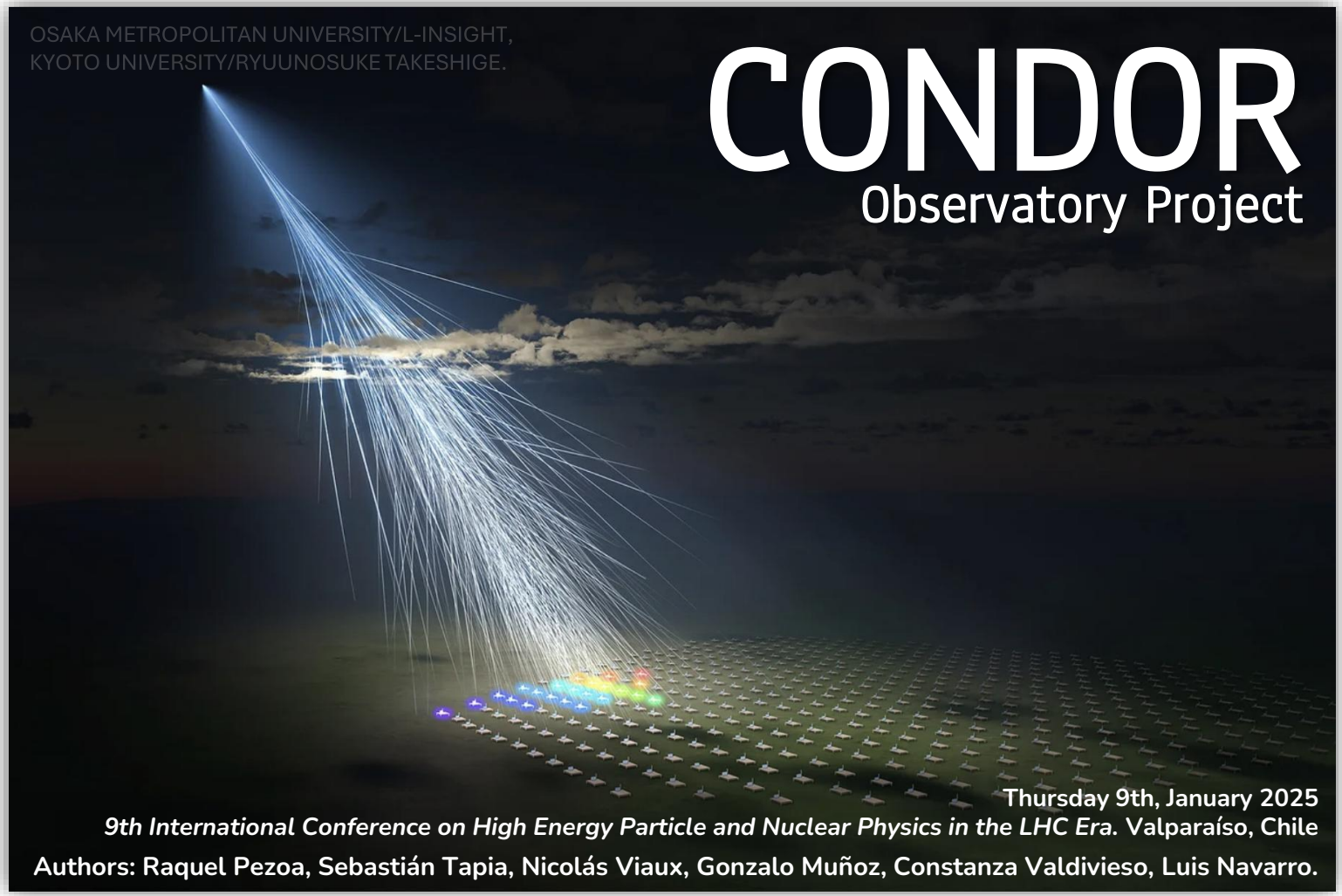

CONDOR

Observatory Project

CONDOR OBSERVATORY

UC RIVERSIDE

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CCTVal
CENTRO CIENTÍFICO TECNOLÓGICO DE VALPARAÍSO

Thursday 9th, January 2025

9th International Conference on High Energy Particle and Nuclear Physics in the LHC Era. Valparaíso, Chile

Authors: Raquel Pezoa, Sebastián Tapia, Nicolás Viaux, Gonzalo Muñoz, Constanza Valdivieso, Luis Navarro.

01

CONDOR Observatory

Technology, materials, detection, etc.

02

CORSIKA

Extensive air showers simulations and particles spatio-temporal distributions.

03

Machine Learning

Angular reconstruction and particles classification.

04

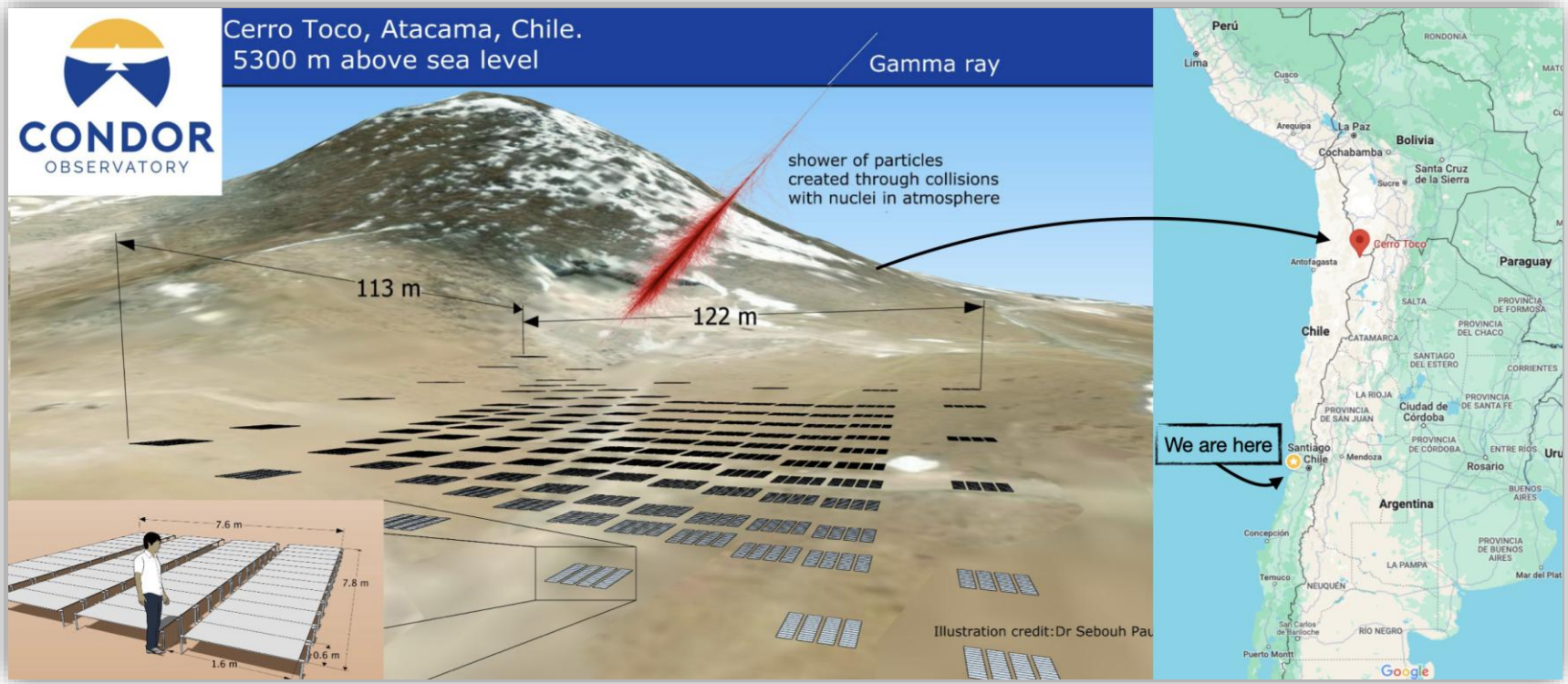
Current advances

On-site testing, data acquisition boards, simulations, predictions.

01

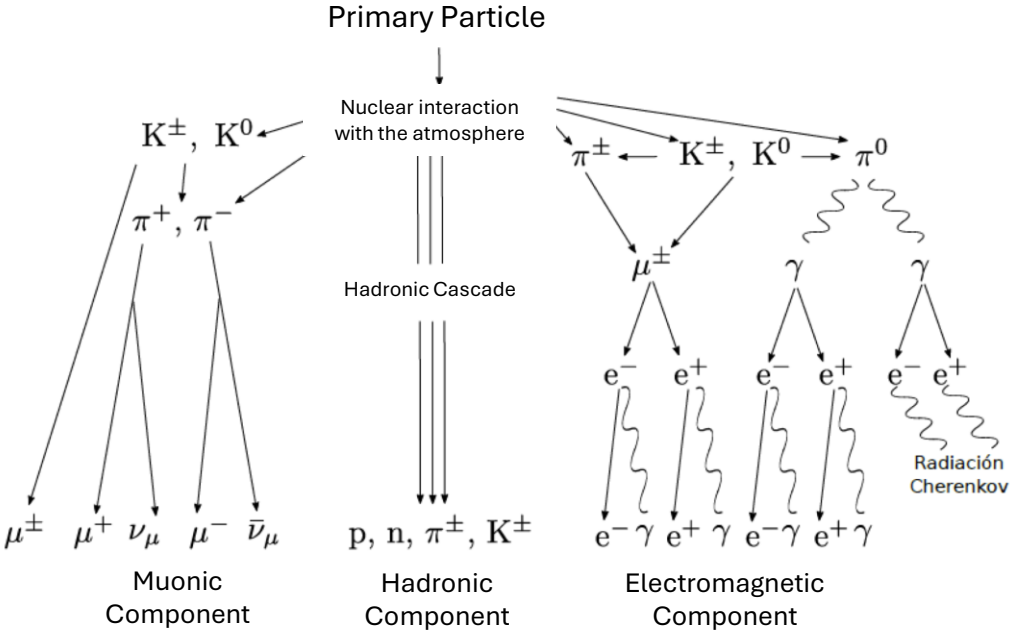
CONDOR: The world's highest-altitude observatory for cosmic and gamma rays.

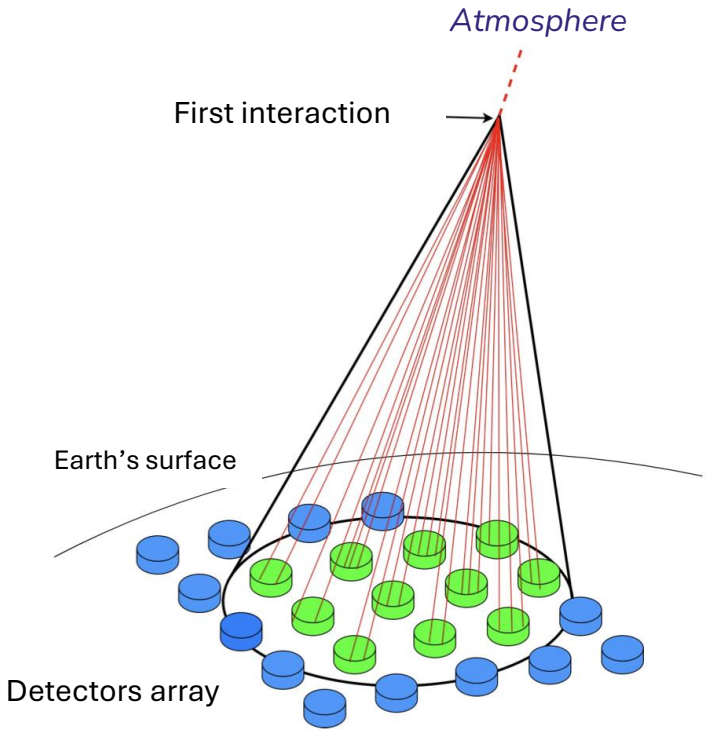
CONDOR (**CO**mpact **N**etwork of **D**etectors with **O**rbital **R**ange)



Cosmic and Gamma Rays

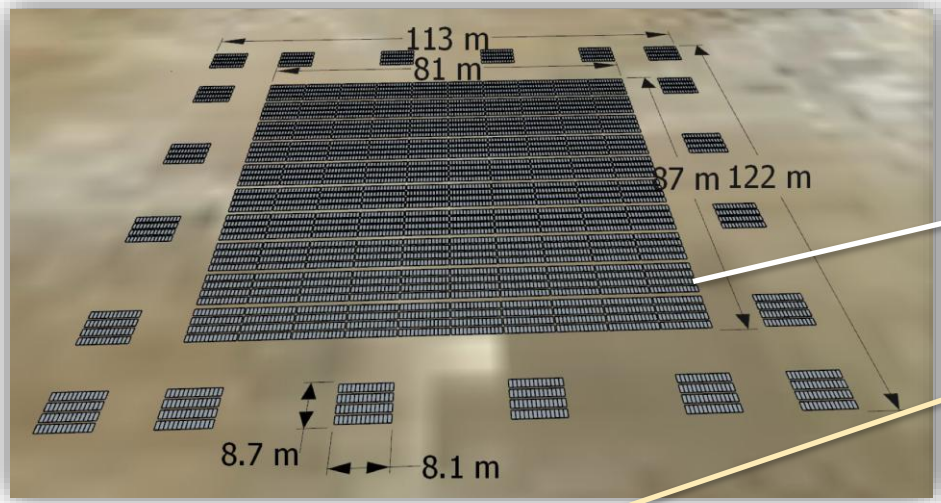
This rays interact with the atmosphere producing **particles showers**.



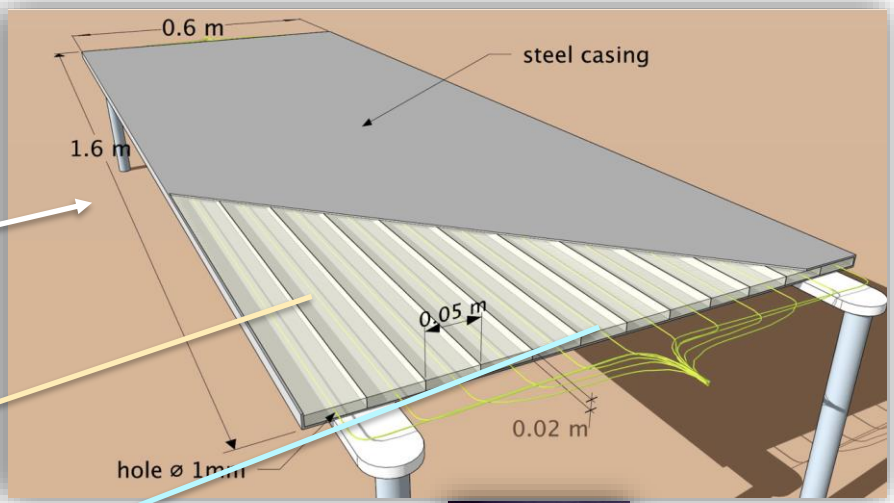


How do we detect Cosmic Rays?

Detectors Array



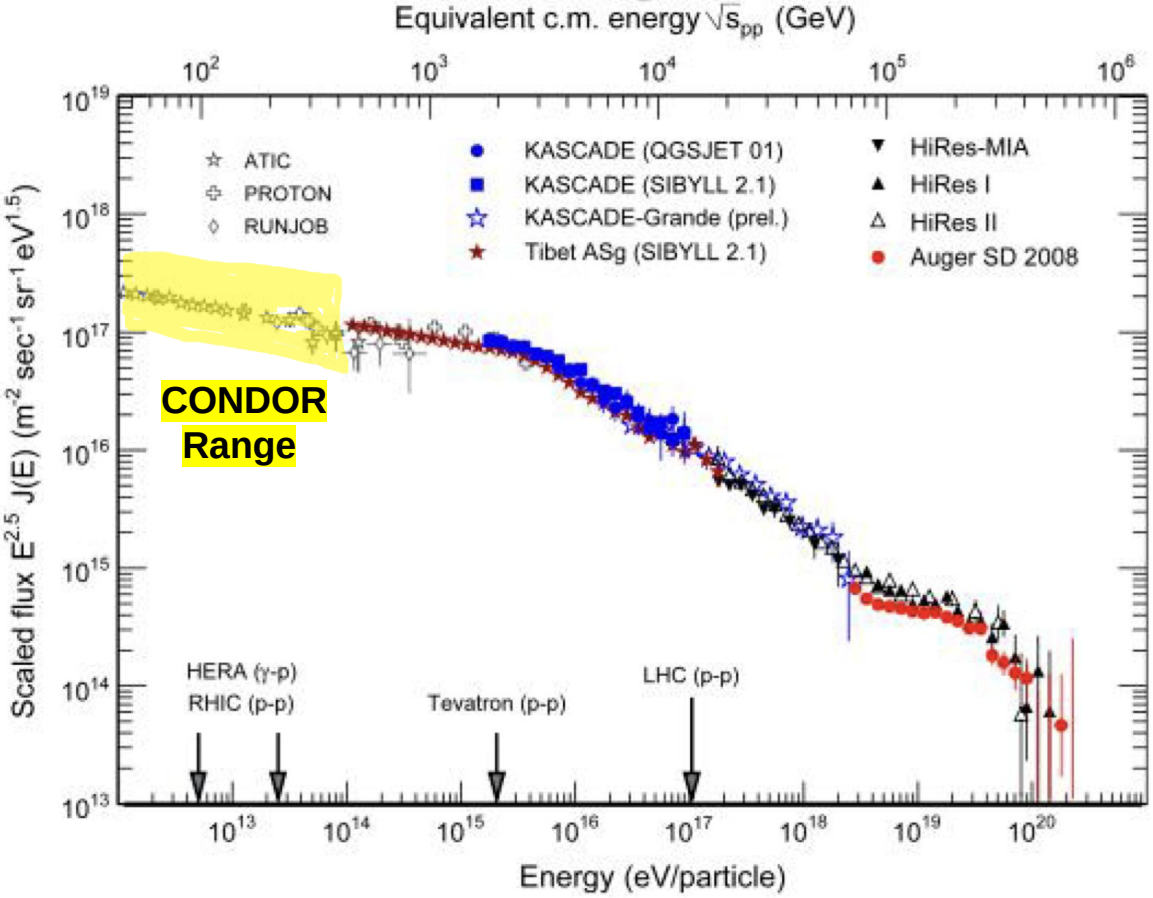
Detector module



Plastic Scintillator + Wave-length shifting fiber + Light sensors (**SiPM**)

CONDOR will consist of a total of 5200 detectors in the central array and 1040 in the peripheral array.

CONDOR Objectives



CONDOR will be a bridge between ground-based measurements and those made with satellites and balloons, opening a new window to study the universe and our sun.

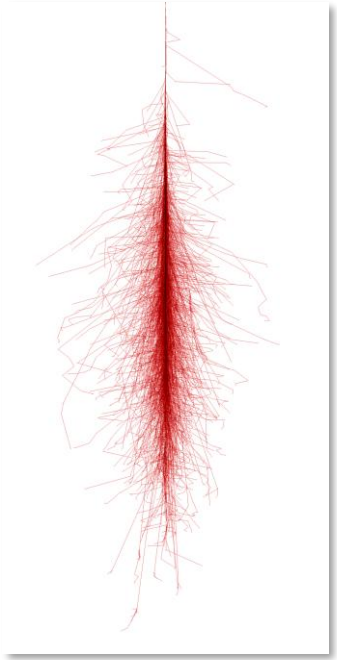
The scientific program of CONDOR includes:

- Gamma rays in the GeV-TeV scale, covering transient phenomena such as gamma-ray bursts.
- Solar astronomy with multiple probes.
- Beyond the Standard Model.

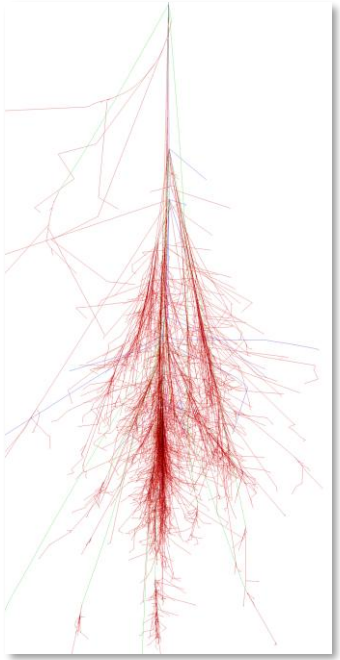
02 CORSIKA: A software for particles showers simulations

Extensive Air Showers (EAS) simulations

Detailed EAS simulations, with information on energy, spatial and temporal distribution of particles, etc. *https://www.iap.kit.edu/corsika.*

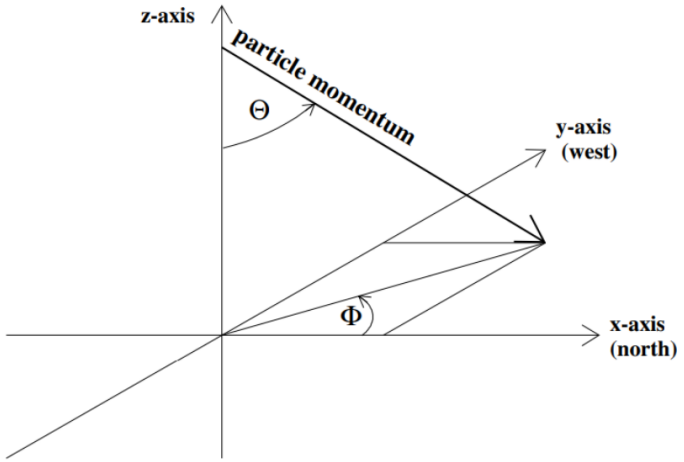


Gamma Ray
(50 GeV Photon)



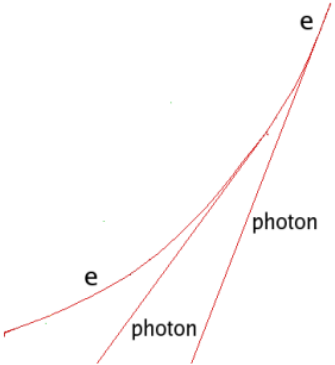
Cosmic Ray
(100 GeV Proton)

CORSIKA Reference System

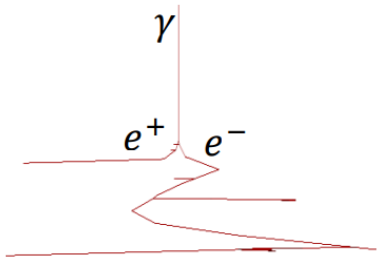


Some CORSIKA Particles Interactions

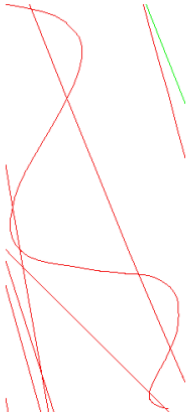
Bremmstrahlung



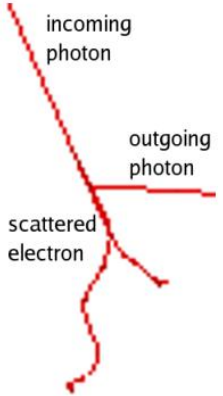
Pair Production



Magnetic Deflection



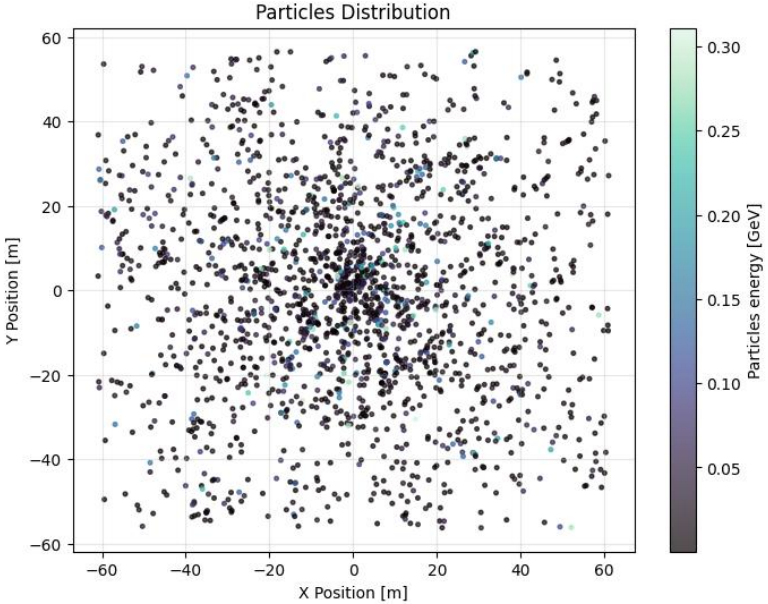
Compton Scattering



EAS Data

0° Zenith Angle 1E3 GeV Primary Photon

Particles Spatial Distributions

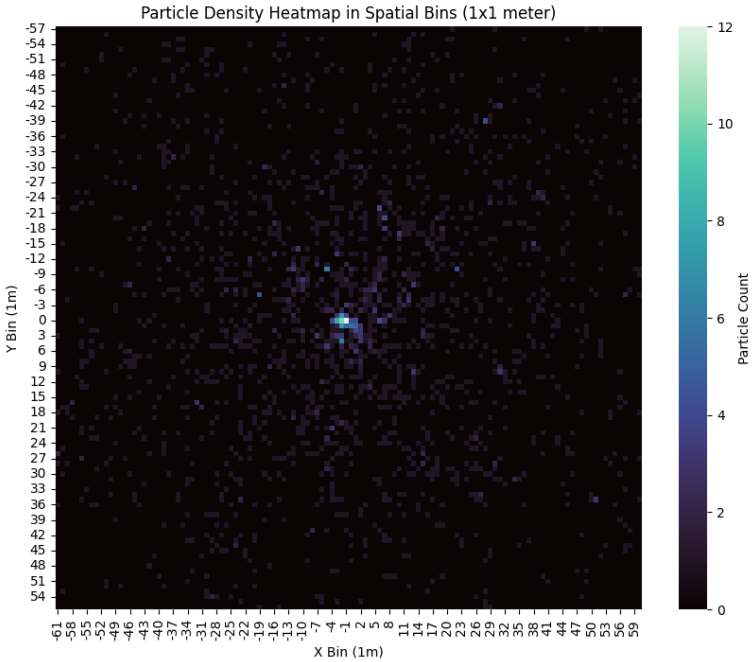


Limited at CONDOR's detector array

(*113 x 122 squared meters area*)

Particle spatial density

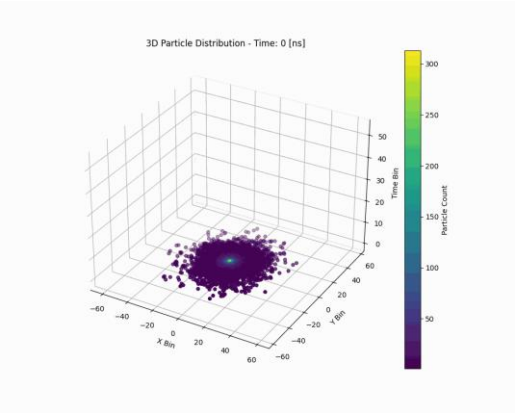
Particle "hits" per squared meter, time integrated

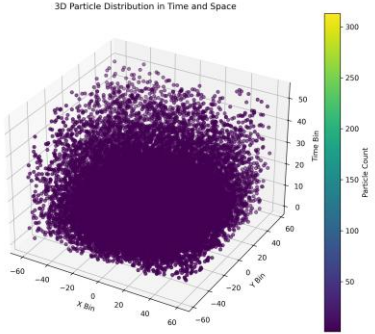


x_bin	y_bin	t_bin	particle_count
-2	-9	0	2
-22	-21	0	1
-22	-27	0	1
-13	-12	0	1
-1	-31	0	1
...	...	...	...
-33	-49	105	1
-6	9	107	1
36	-8	108	1
31	-40	109	1
-32	-34	110	1

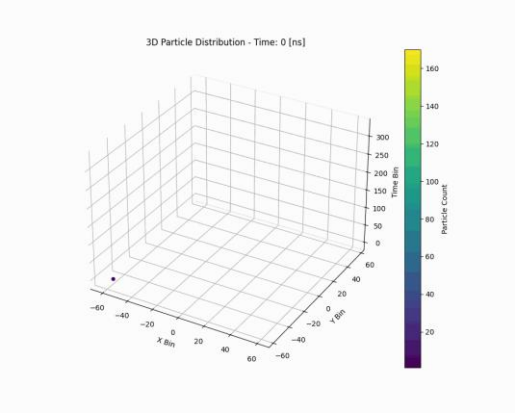
10^5 [GeV] Proton CR Spatio-Temporal Distributions

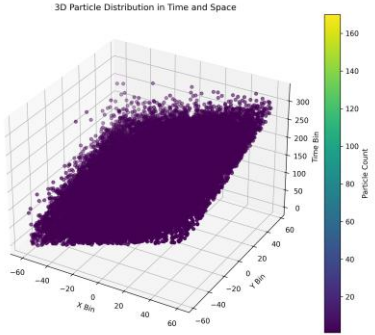
0°



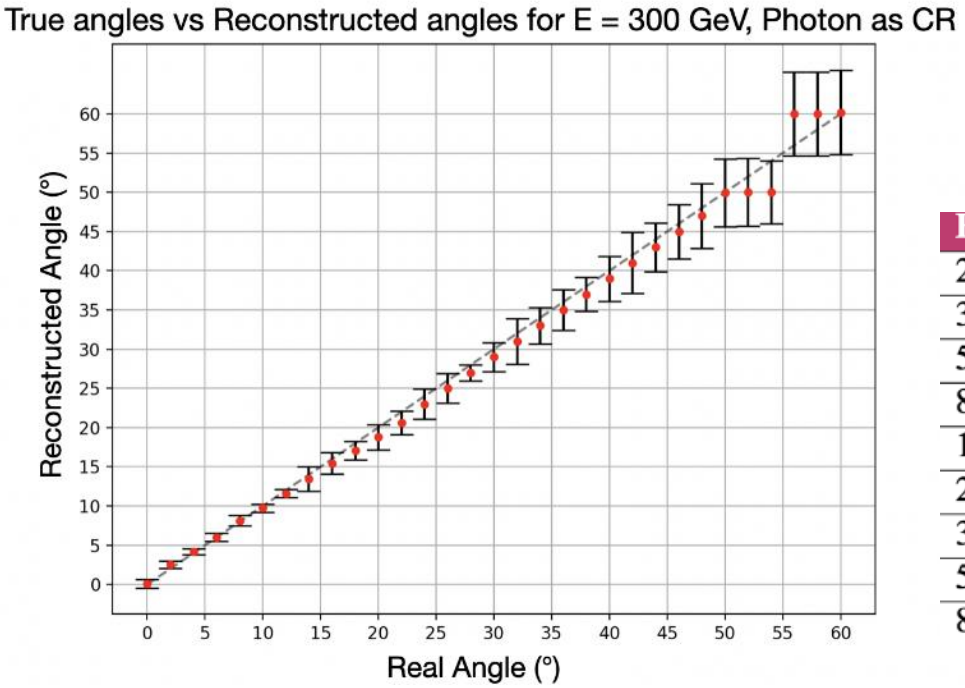


30°





Angular Reconstruction – Angle Fit



$$\theta = \arccos\left(\frac{\{\vec{n} \cdot \hat{z}\}}{|\vec{n}||\hat{z}|}\right)$$

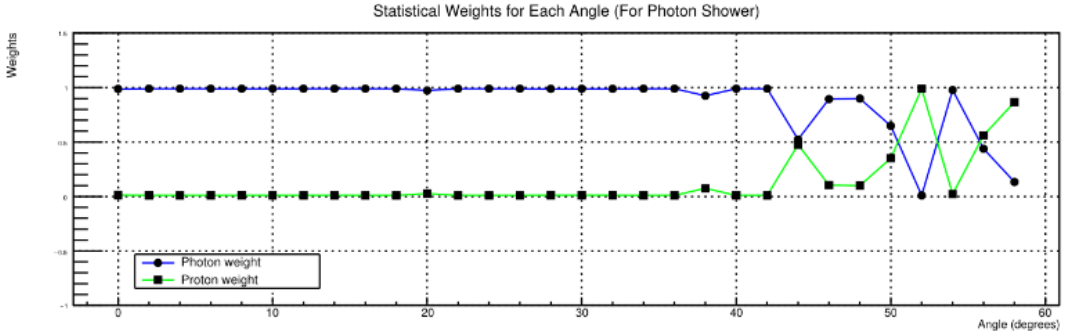
Energy (GeV)	Cosmic Ray Particle	1 error (°)
20	Photon	6.39
30	Photon	5.73
50	Photon	3.56
80	Photon	3.29
150	Photon	3.15
200	Photon	2.39
300	Photon	2.38
500	Photon	2.10
800	Photon	1.04

See "*Angle reconstruction for Cosmic Rays at CONDOR Observatory.*" by **Constanza Valdivieso**.

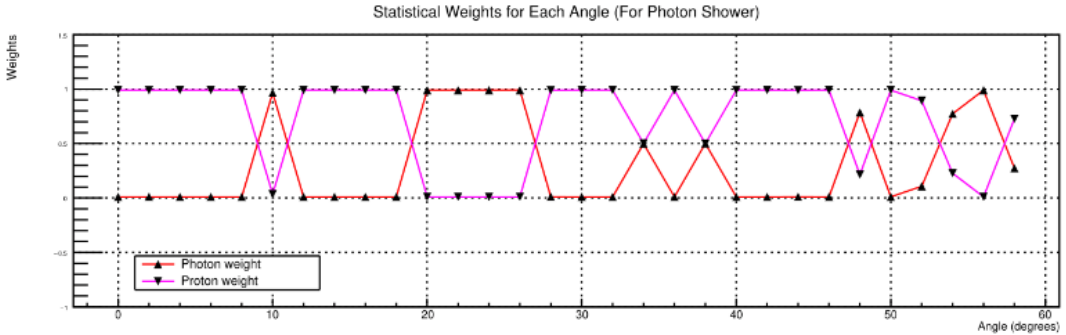
Particle Classification

High-statistics MonteCarlo algorithm tagger for classifying unknown showers at an energy of **300 GeV**.

Gamma Ray
Photon



Cosmic Ray
Proton



See "*Tagger System: Particle Identification for Cosmic Rays at the CONDOR Observatory.*" by **Gonzalo Muñoz.**

03 Machine Learning

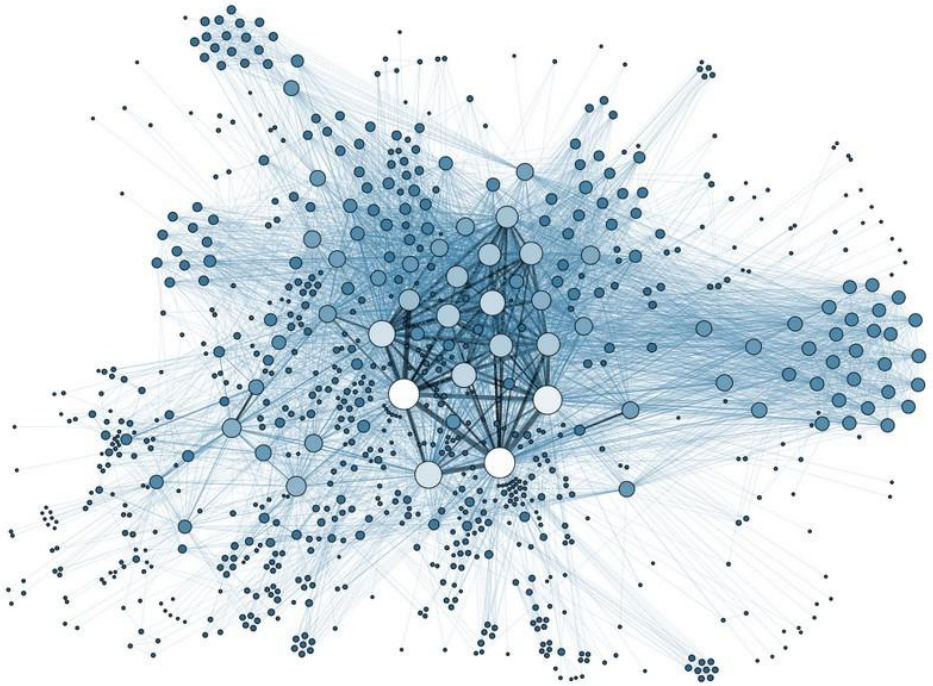
Angular Reconstruction.

Large amount of Particle Data

Complex data due to volume, complex characteristics

Complex algorithms are needed

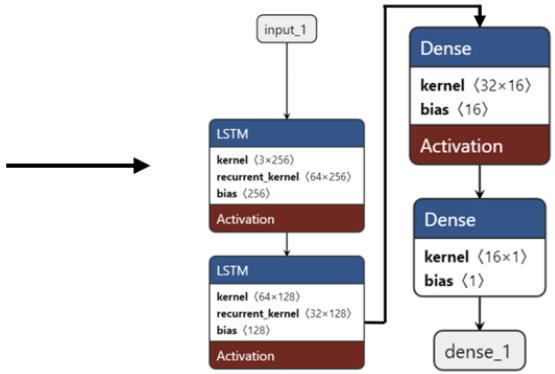
Machine Learning



Long Short-Term Memory (LSTM) Model

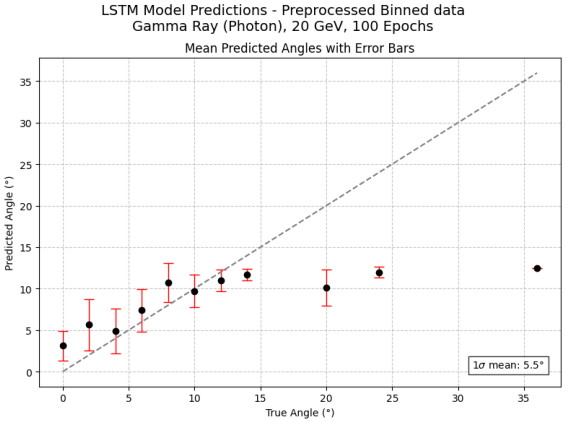
- Type of recurrent neural network (RNN) specifically designed to handle **sequential data** and learn **temporal** or **spatial** *patterns* within those sequences.
- Each sequence represents the behavior of particle showers over a specific **time window**.

Hyperparameter	Description	Values
time_steps	Number of time steps in each sequence	100
batch_size	Batch size used during training	32
epochs	Number of training epochs	100
LSTM_units	Number of units in the LSTM layers	[64, 32]
Dense_units	Number of neurons in dense layers	[16]
Activation	Activation functions used in the layers	ReLU, Linear
Loss	Loss function	Mean Squared Error
Optimizer	Optimizer used for training	Adam

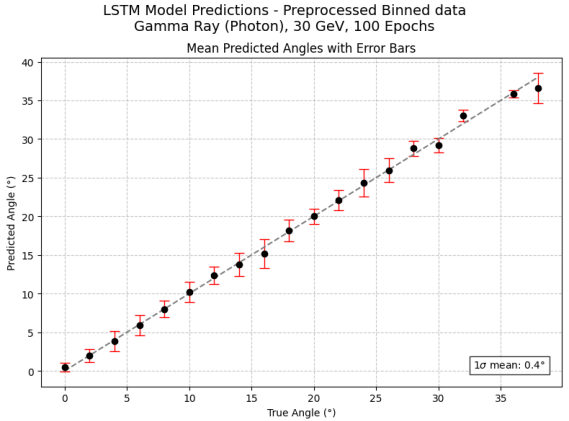


See "*Cosmic Ray Simulations for CONDOR Observatory and Angular Reconstruction via Machine Learning.*" by **Luis Navarro.**

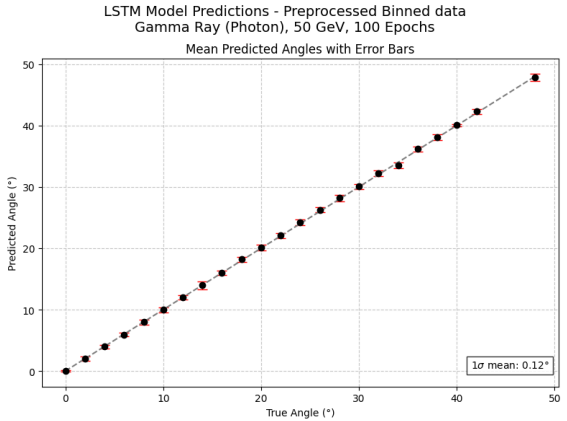
Angular Reconstruction – ML
(Photon – Gamma Ray)



20 [GeV]



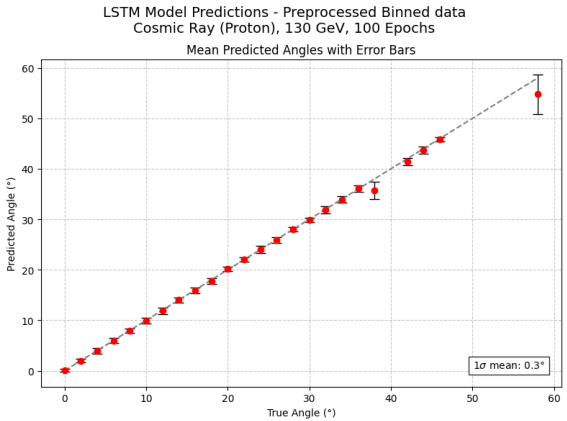
30 [GeV]



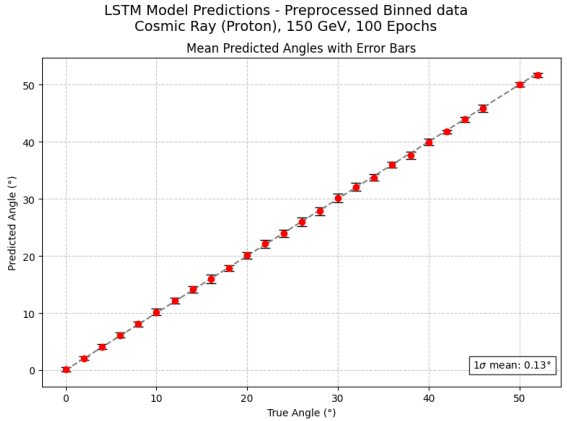
50 [GeV]

See "*Cosmic Ray Simulations for CONDOR Observatory and Angular Reconstruction via Machine Learning.*" by **Luis Navarro.**

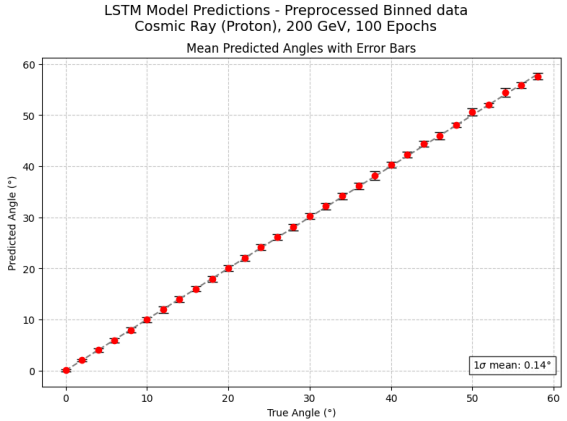
Angular Reconstruction – ML
(Proton – Cosmic Ray)



130 [GeV]



150 [GeV]

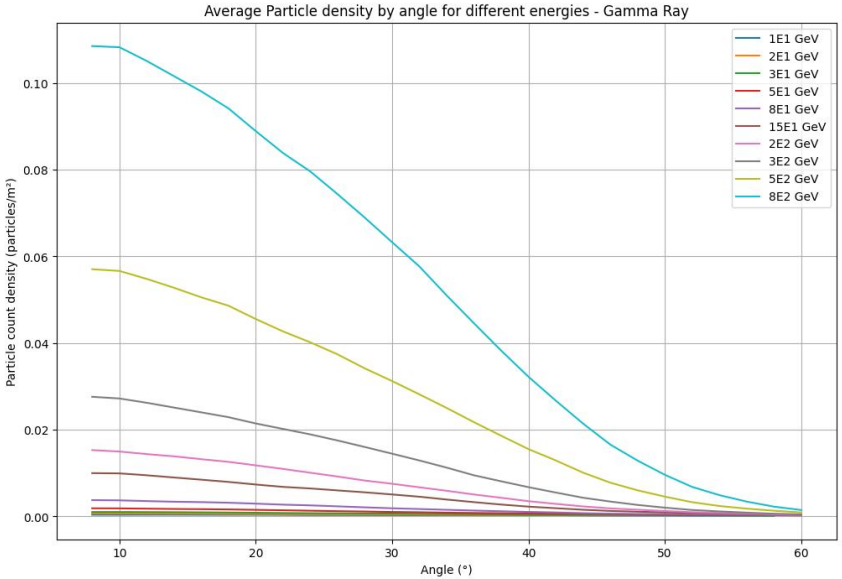


200 [GeV]

See "*Cosmic Ray Simulations for CONDOR Observatory and Angular Reconstruction via Machine Learning.*" by **Luis Navarro.**

Particle Density by angle per energy

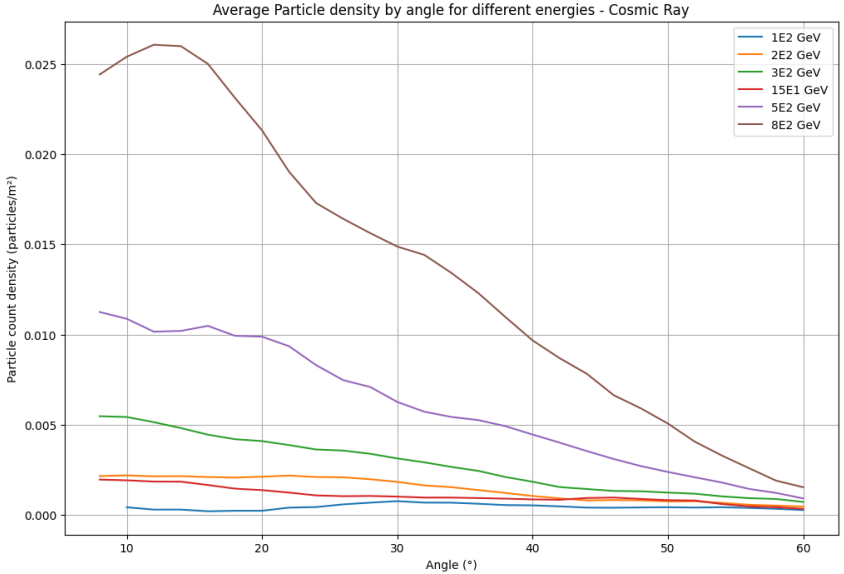
Gamma Ray – Primary Photon



Energy range: 10 - 800 [GeV]

Density range: 0.001 - 0.14 $\left[\frac{\text{particles}}{\text{m}^2}\right]$

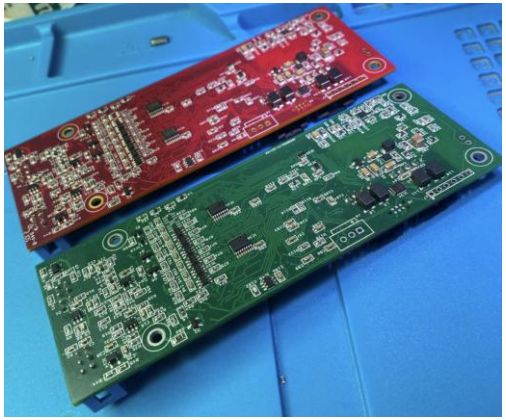
Cosmic Ray - Primary Proton



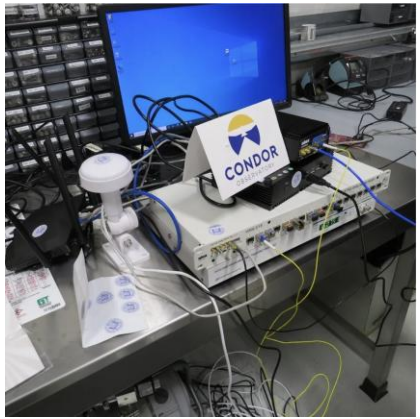
Energy range: 10 - 800 [GeV]

Density range: 0.0005 - 0.025 $\left[\frac{\text{particles}}{\text{m}^2}\right]$

Where are we now?

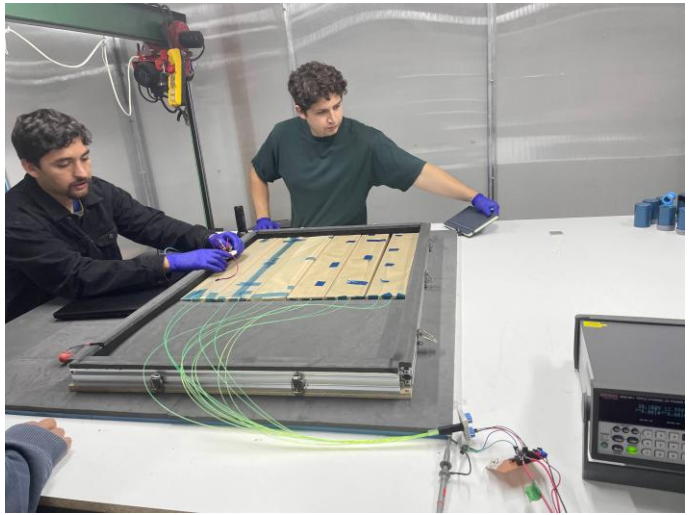


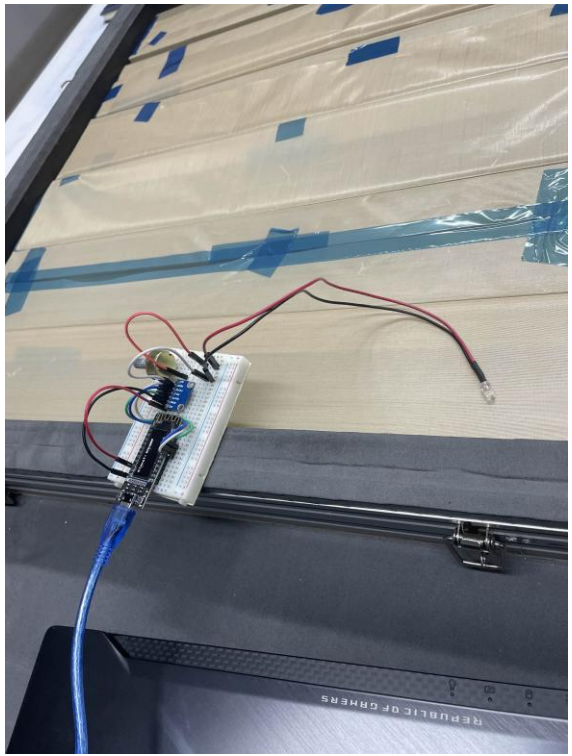
- Producing data acquisition board
- Synchronization studies
- More models, more predictions.

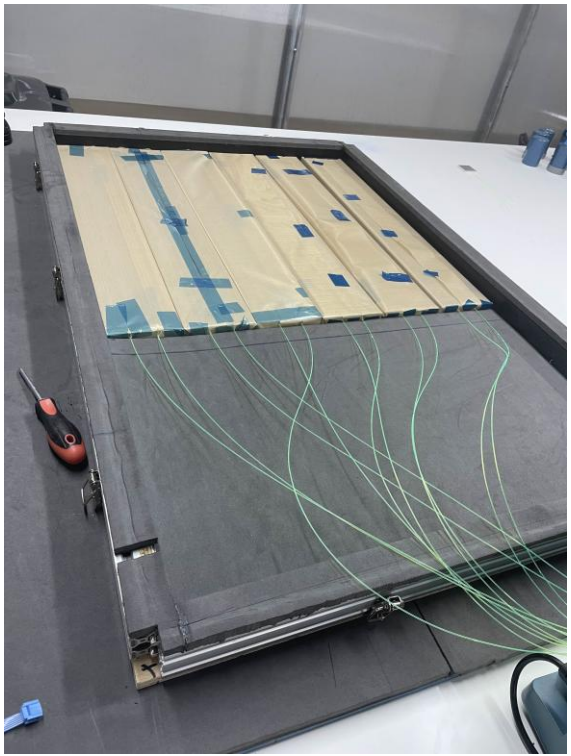


Where are we now?

- On-site testing (Cerro Toco, Atacama).
- Building module prototypes

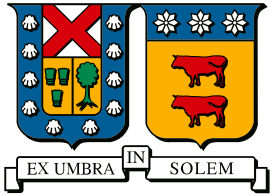






Thanks!

Questions?



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