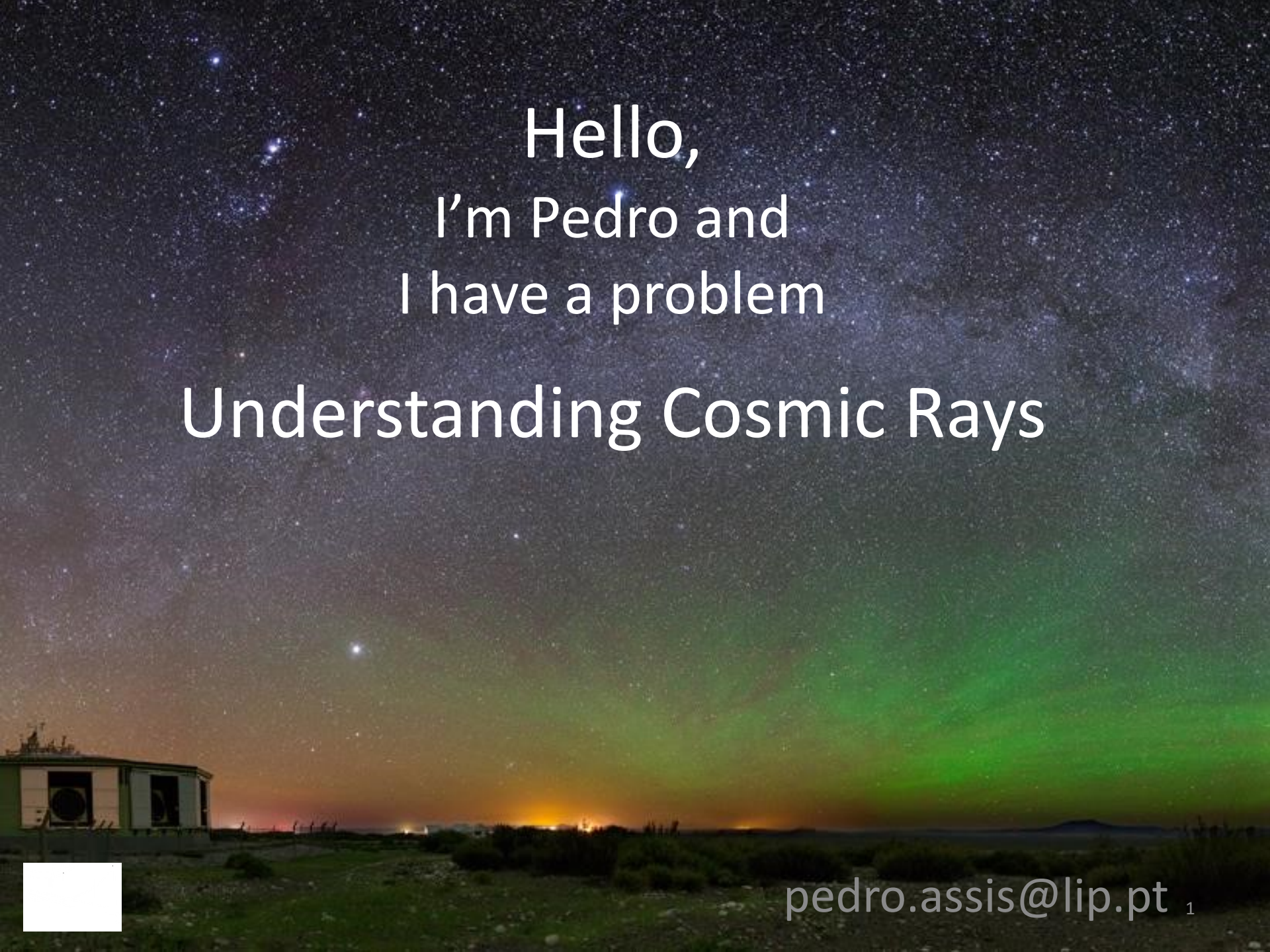
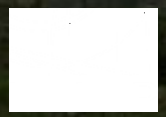


pedro.assis@lip.pt

Cosmic Rays
The history told by detectors



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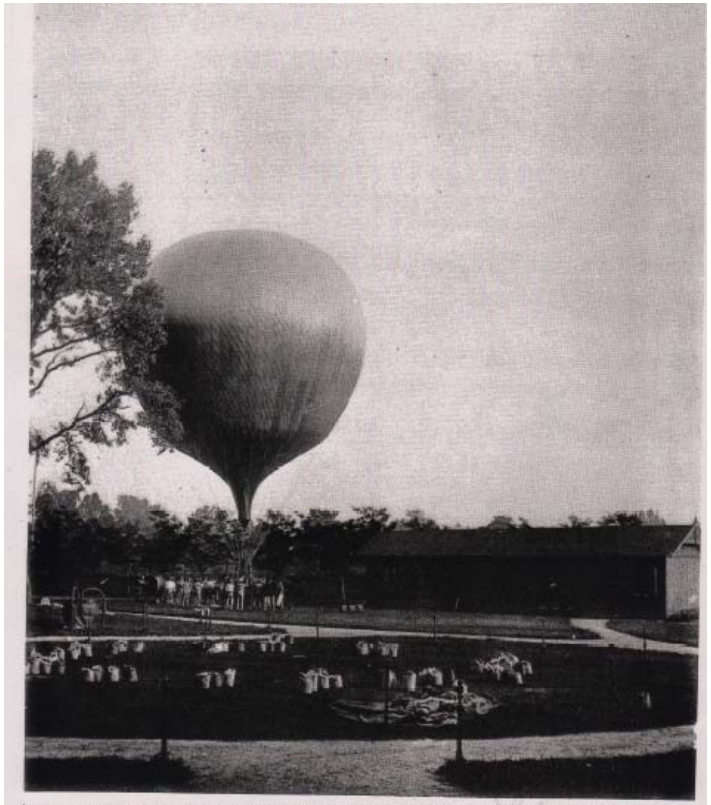
Cosmic Rays and the electrometer

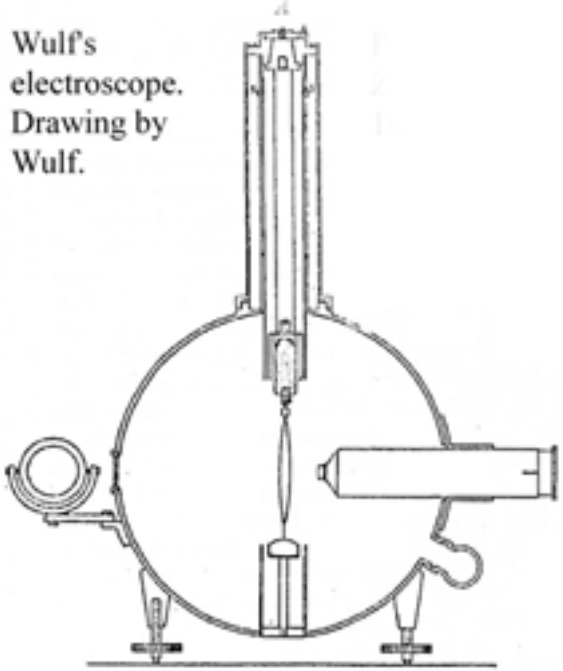
On the leakage of Electricity through dust-free air. By C. T. R. Wilson, M.A., Sidney Sussex College.

[*Read* 26 November 1900.]



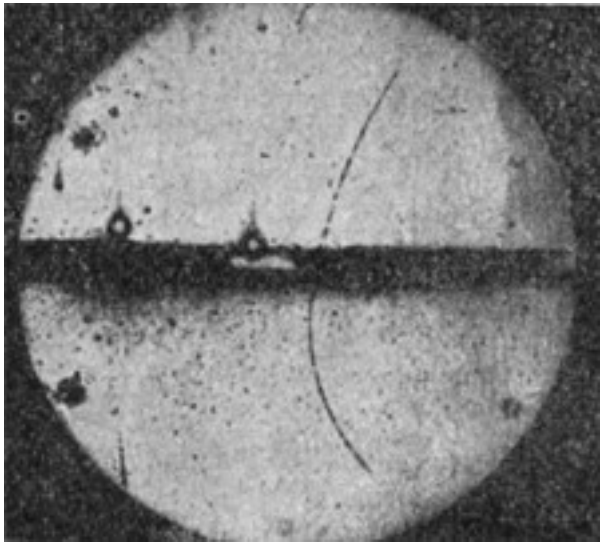
Aeronautisches Gelände im Wiener Prater, von dem aus V. F. Hess in den Jahren 1911/12 seine ersten Freiballon-Forschungsfahrten unternommen hatte. (Courtesy of Heeresgeschichtliche Museum, Vienna)

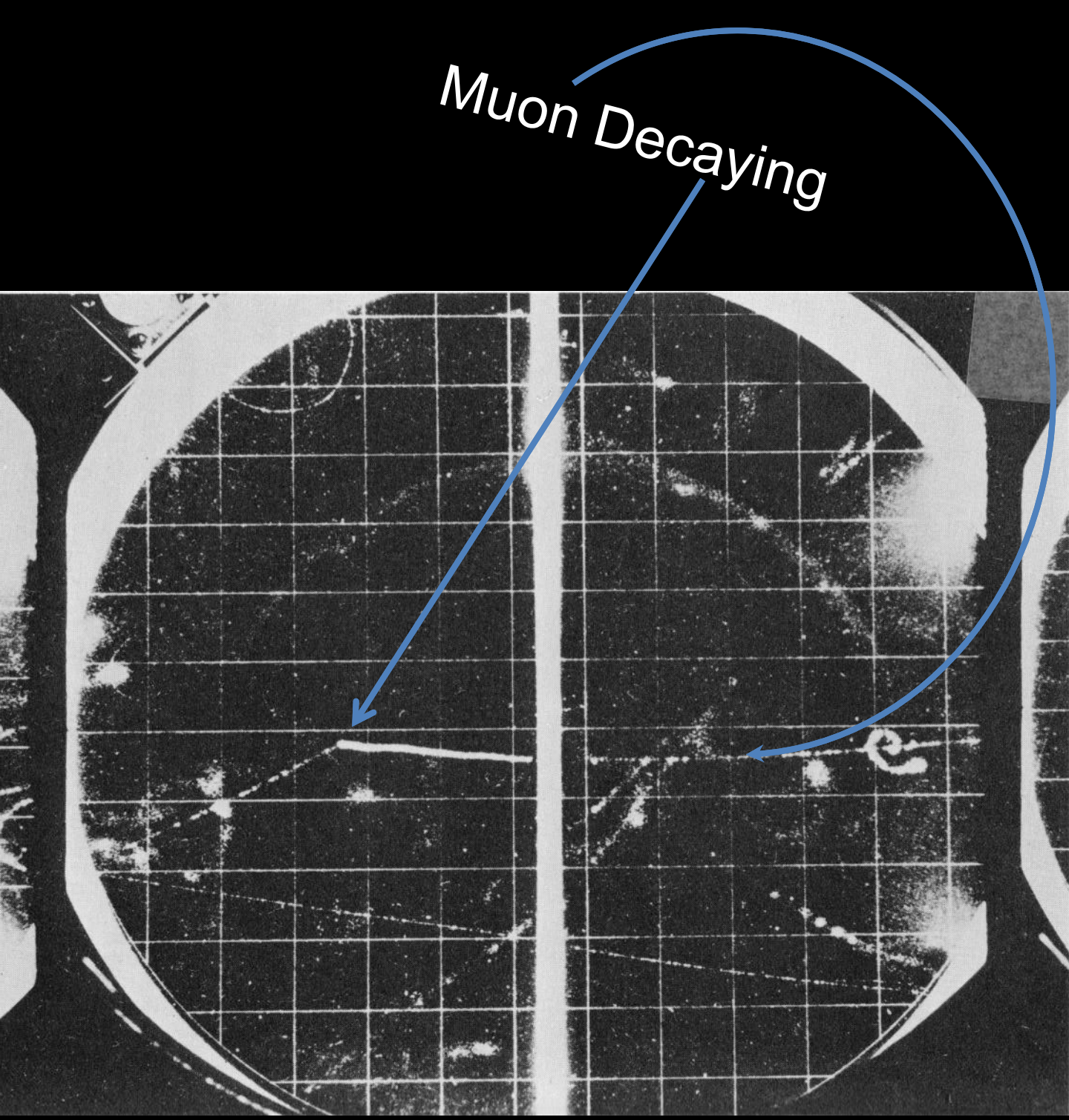
Hess bei Ballonlandung (1912).



Wulf's electroscope. Drawing by Wulf.

The Cloud Chamber




Muon Decaying

Particle Physics in a box

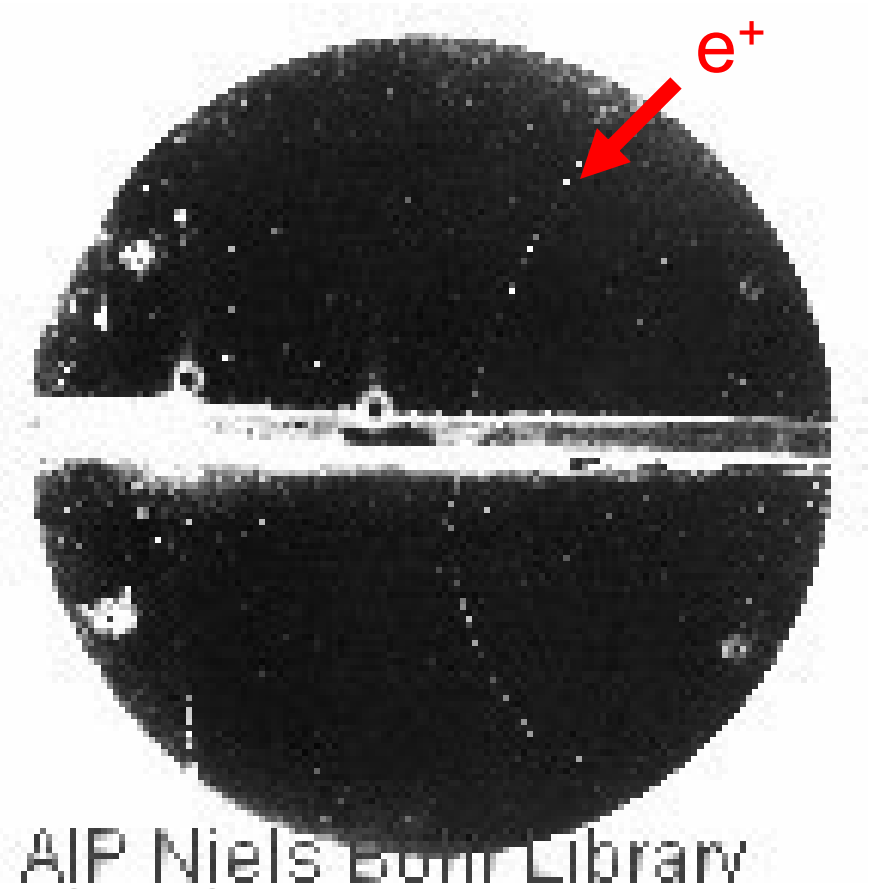
"seeing" particles

Positron (Anderson, 1932)

μ (Anderson,1937)

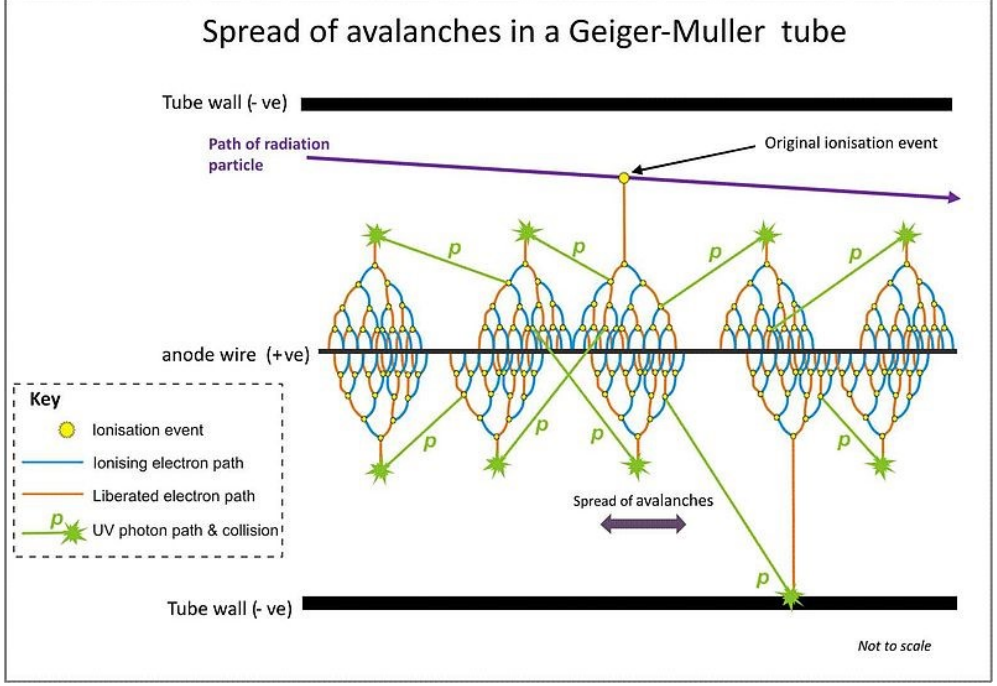
π (Latter, 1947)

50s: K, Λ, Σ, Ξ, Ω ...



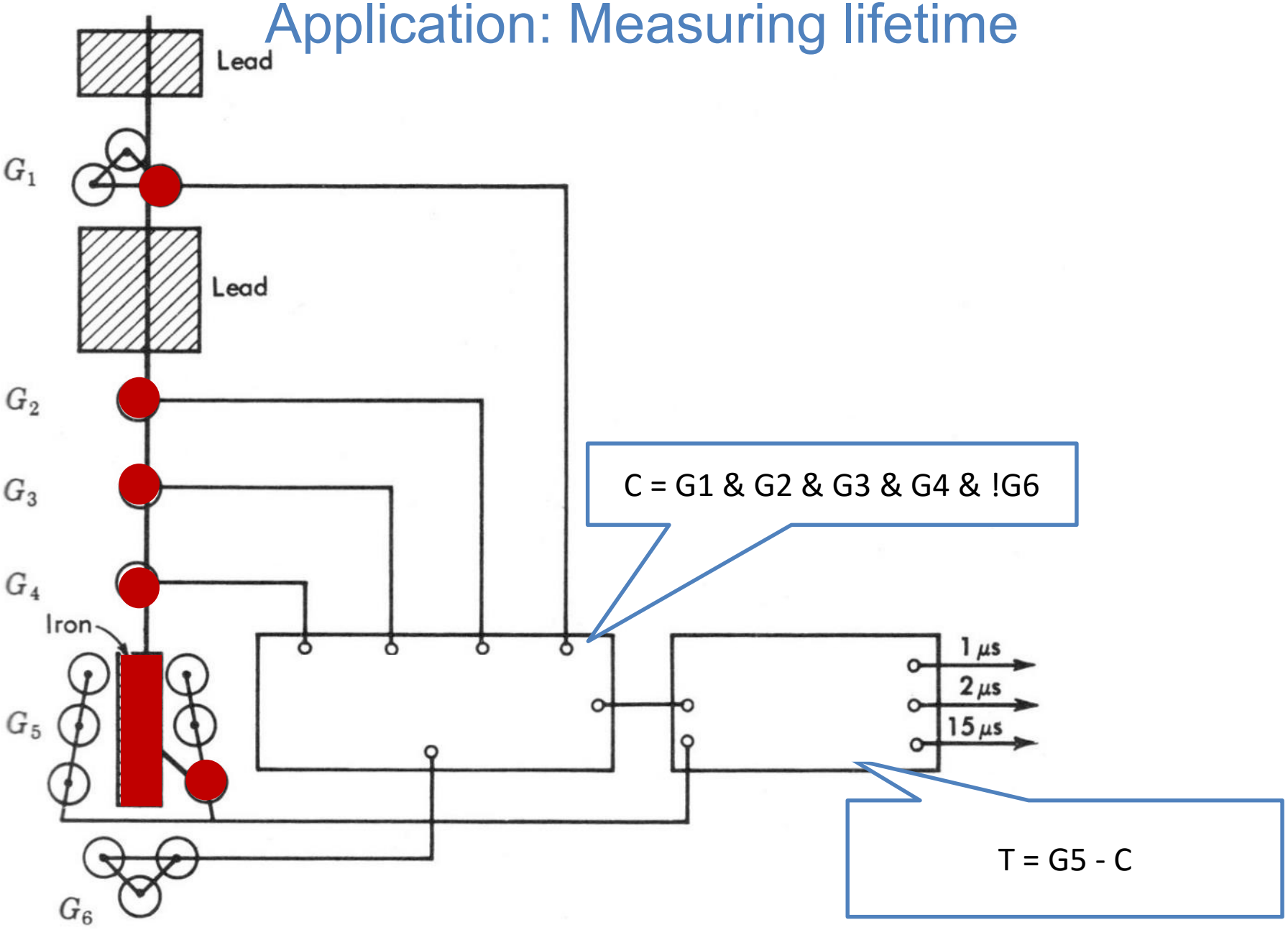
Cloud Chamber picture

The Geiger tube



Is there a particle?

Application: Measuring lifetime



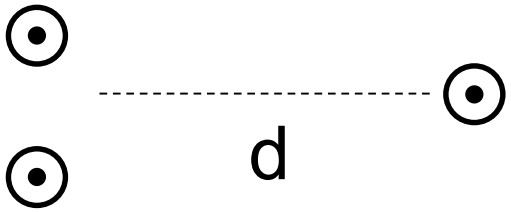
Application: Measure coincidence rate

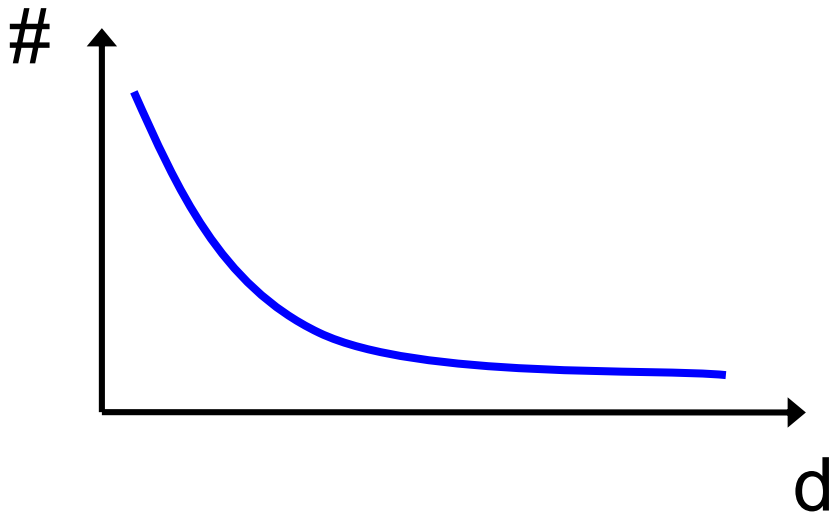
Pierre Auger

1938

Coincidencies!

Possible with “fast” electronics



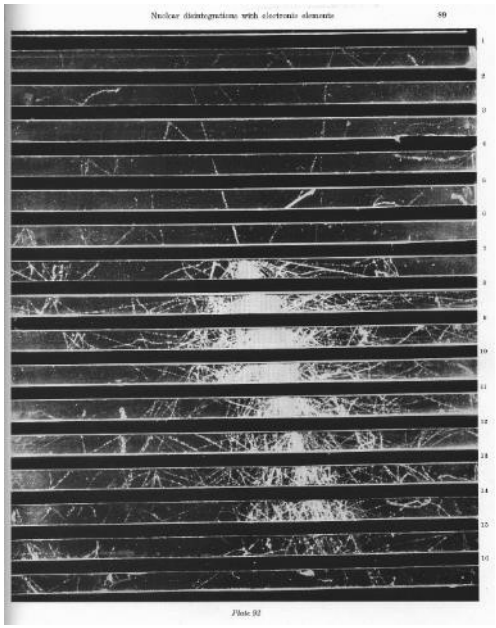


Coincidence definition depends on time resolution

Result: Air Showers

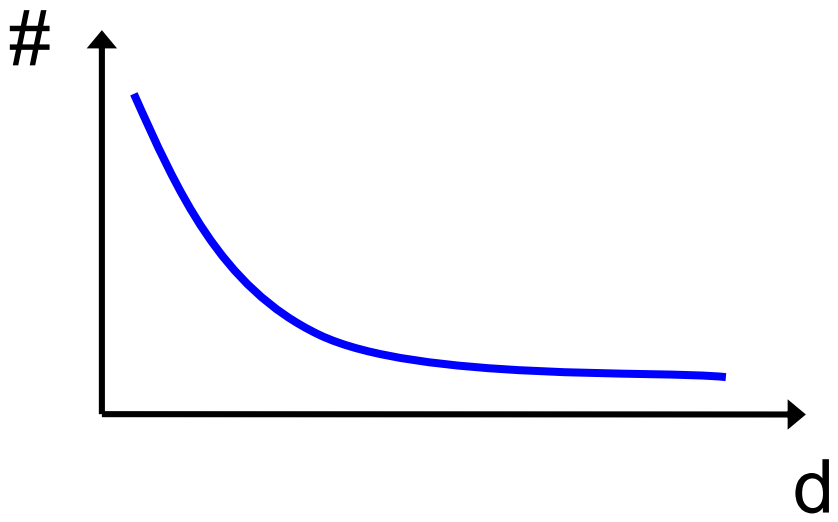
Pierre Auger

1938



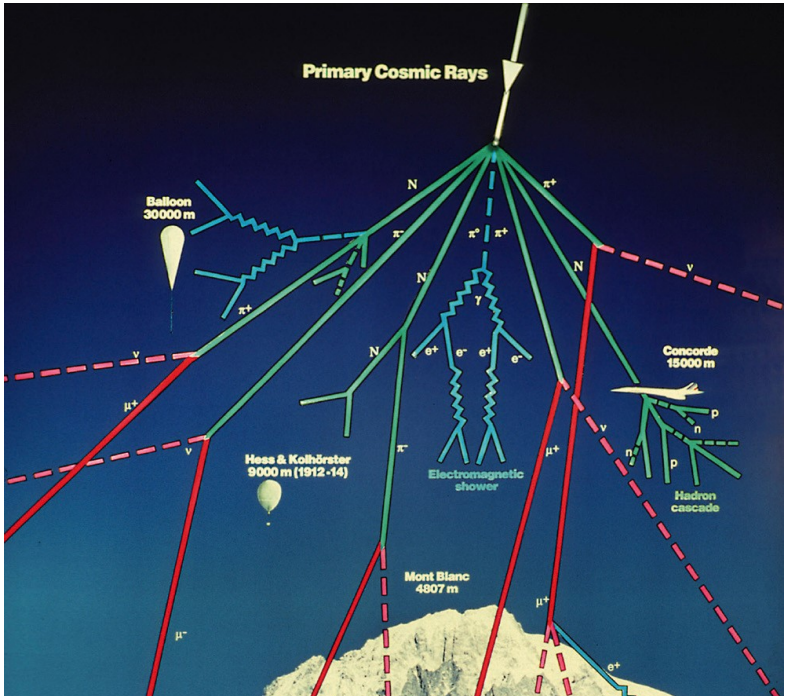
Coincidencies!

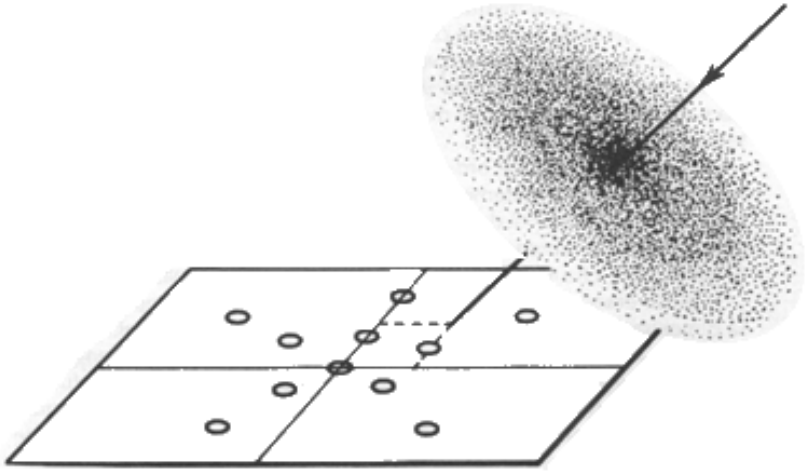
Possible with “fast” electronics



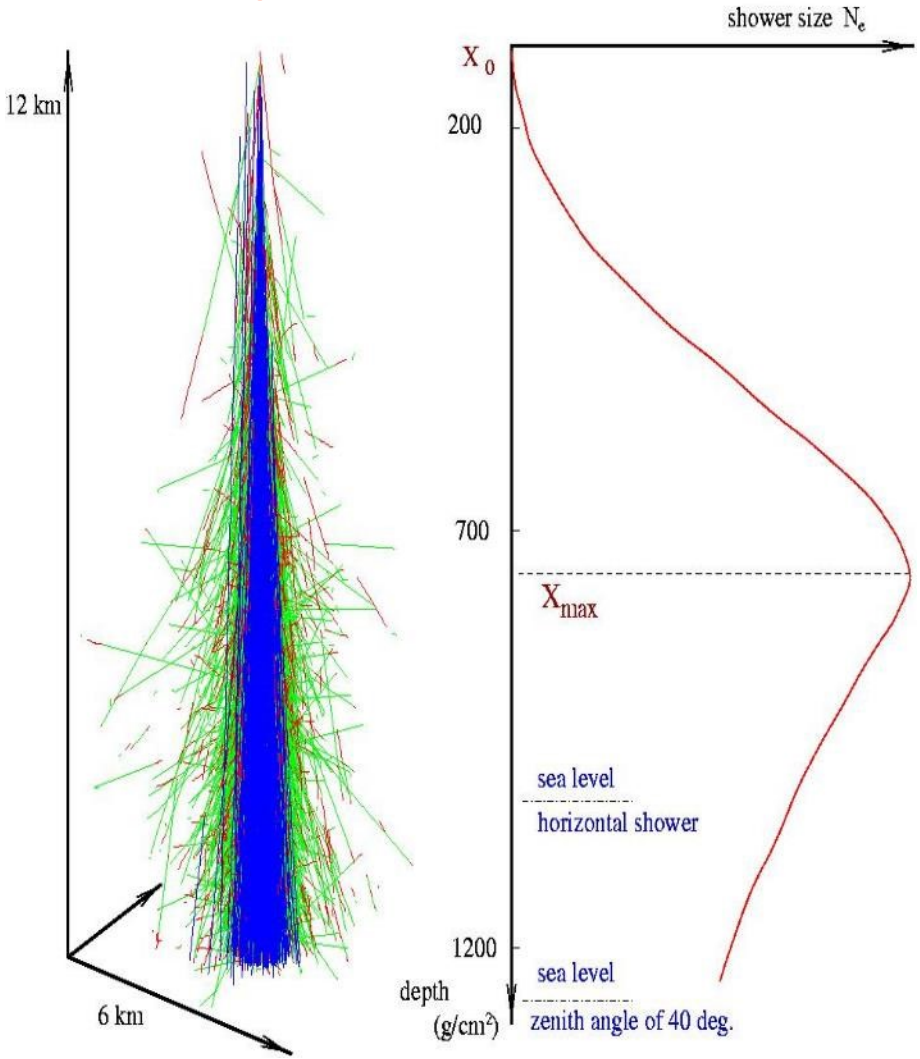
First estimates of the shower energy!

Extensive Air Showers (EAS)

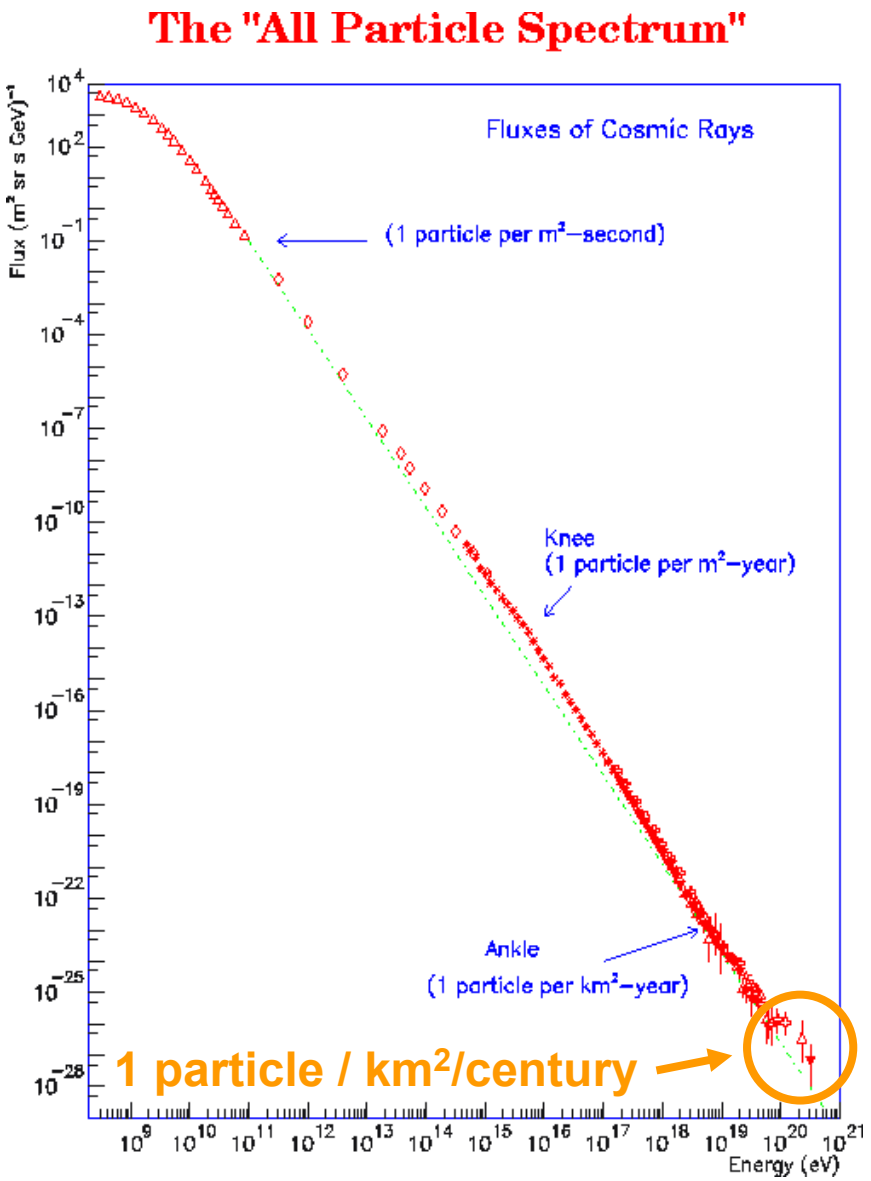




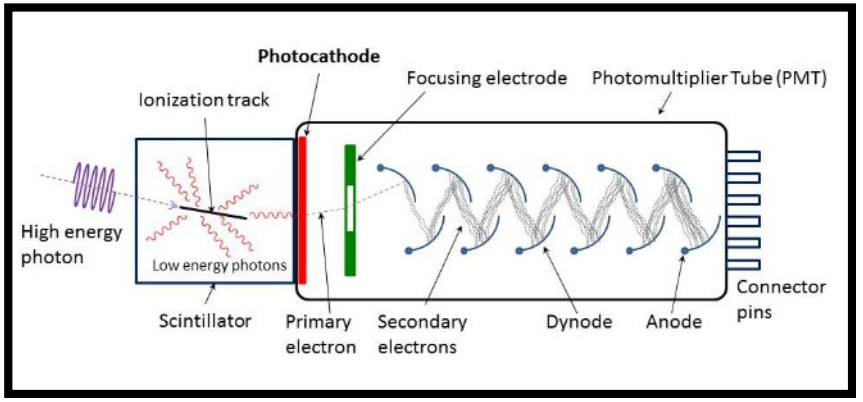
10^{19} eV

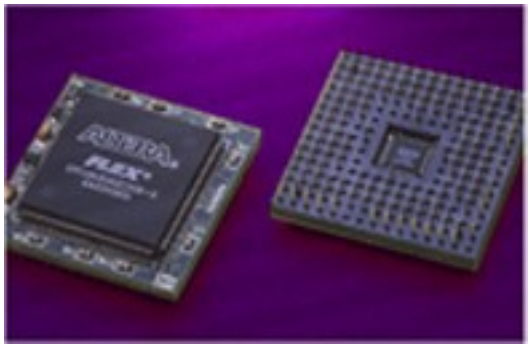


High Energy Cosmic Rays

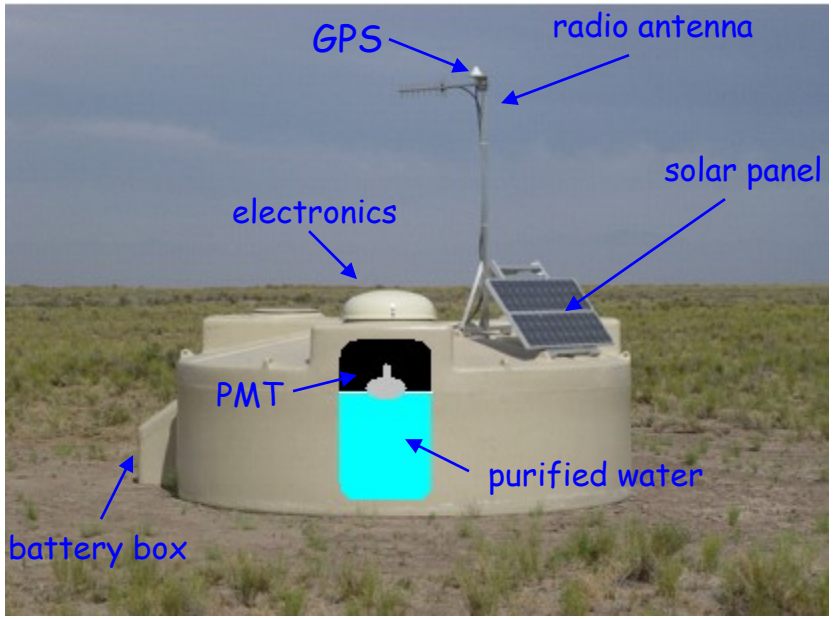


The PMT

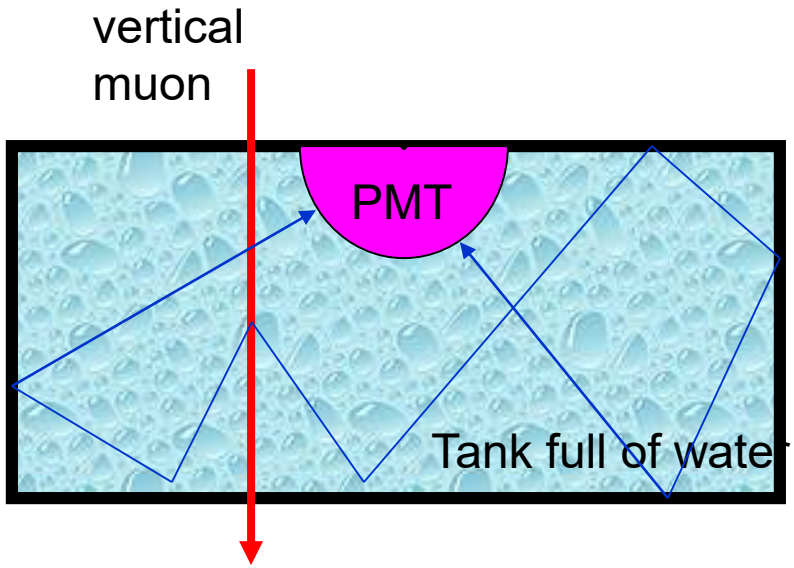

Photocathode
Focusing electrode
Photomultiplier Tube (PMT)
Ionization track
High energy photon
Low energy photons
Scintillator
Primary electron
Secondary electrons
Dynode
Anode
Connector pins



Application: Auger – Surface detector



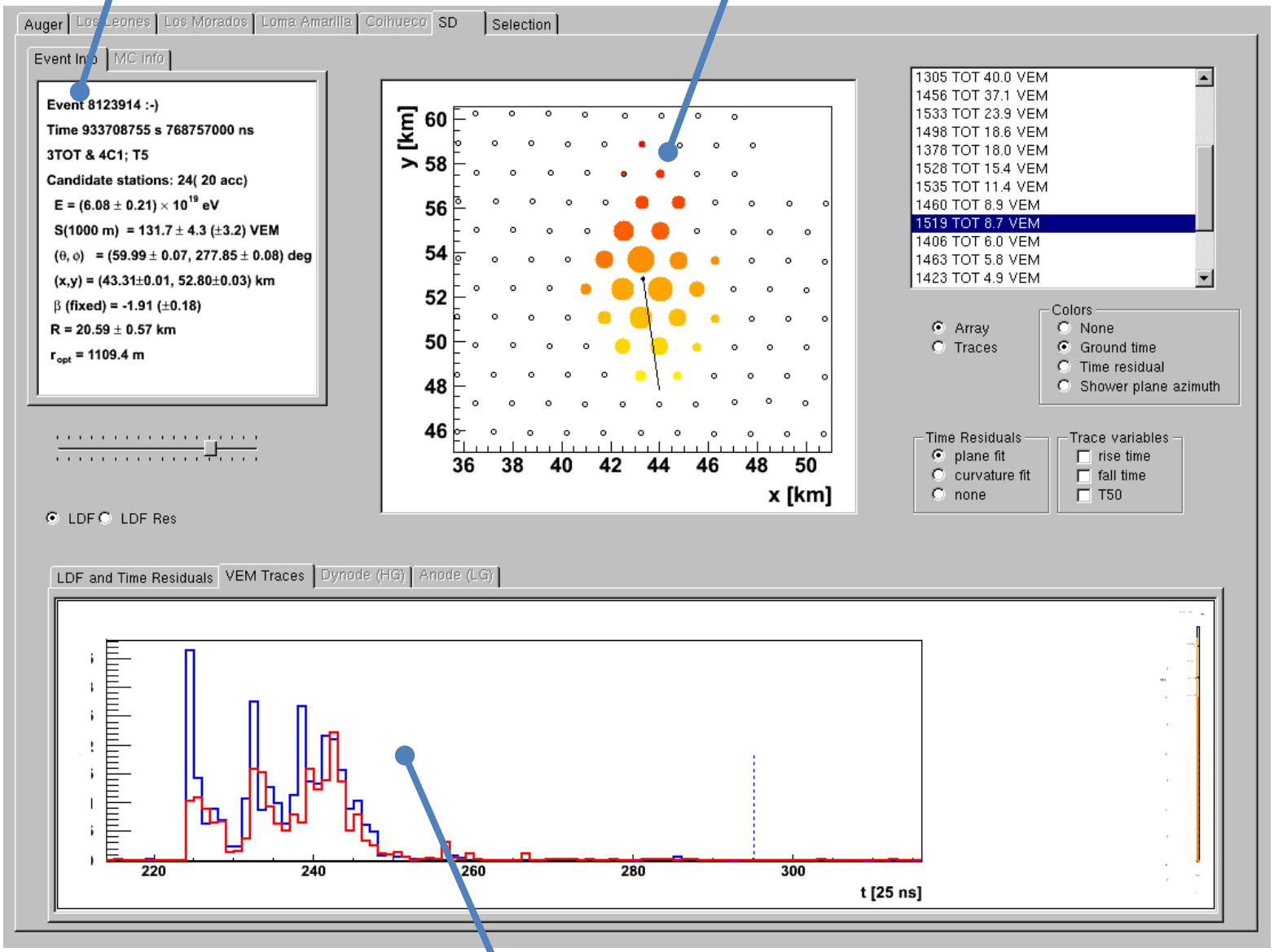
Signal → Number of Particles
Time → Direction



Signal is digitized with ADCs
40 MHz = 25 ns = 25 x 10^{-9} s
GPS synchronization ~ 10 ns
FPGA:
Digitalization
Triggers
Synchronization

Event reconstruction
Energy and direction

Size: Nº particles in tanks
Color: Time



Sinal recorded in 1 Tank

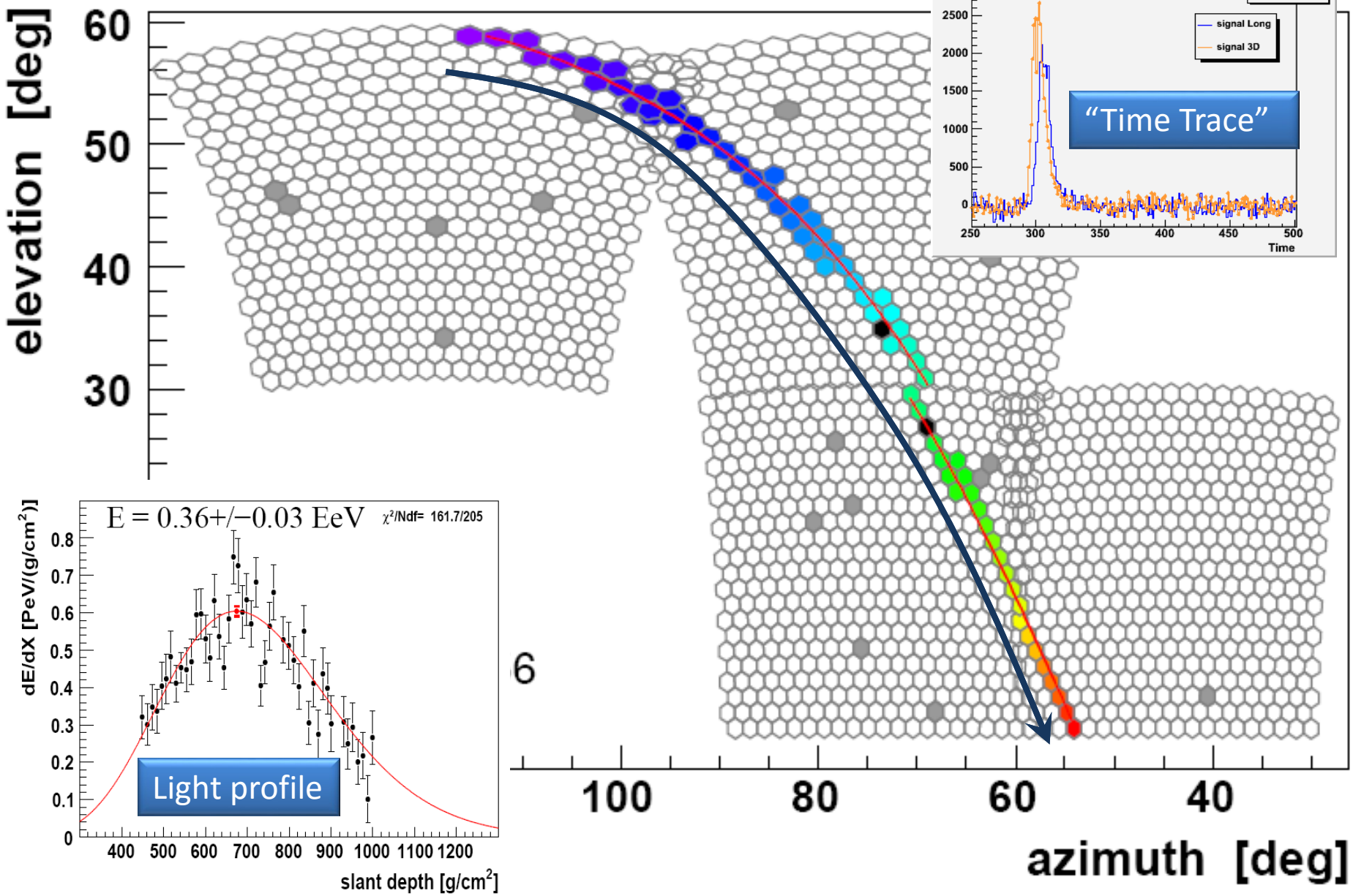
Application: Auger – Fluorescence detector

Signal → Number of Particles
Time & pixels → Direction
Signal vs time → Air shower profile

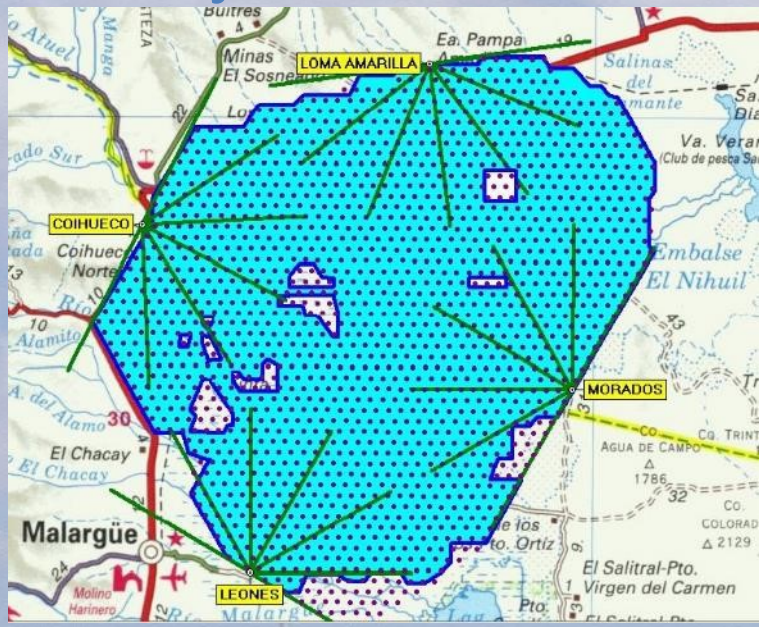
Signal is digitized with ADCs
10 MHz = 100 ns

FPGA:
Digitization
Triggers
Synchronization
Signals sent to PC

FD event


elevation [deg]
60
50
40
30
azimuth [deg]
100
80
60
40
6
Time trace (bkg subtracted)
HS3
Entries 186000
Mean 328.6
RMS 55.81
signal Long
signal 3D
Time
"Time Trace"
E = 0.36+/−0.03 EeV
χ²/Ndf= 161.7/205
dE/dX [PeV/(g/cm²)]
slant depth [g/cm²]
Light profile

Pierre Auger Observatory



Hybrid Detector

1600 Detectors

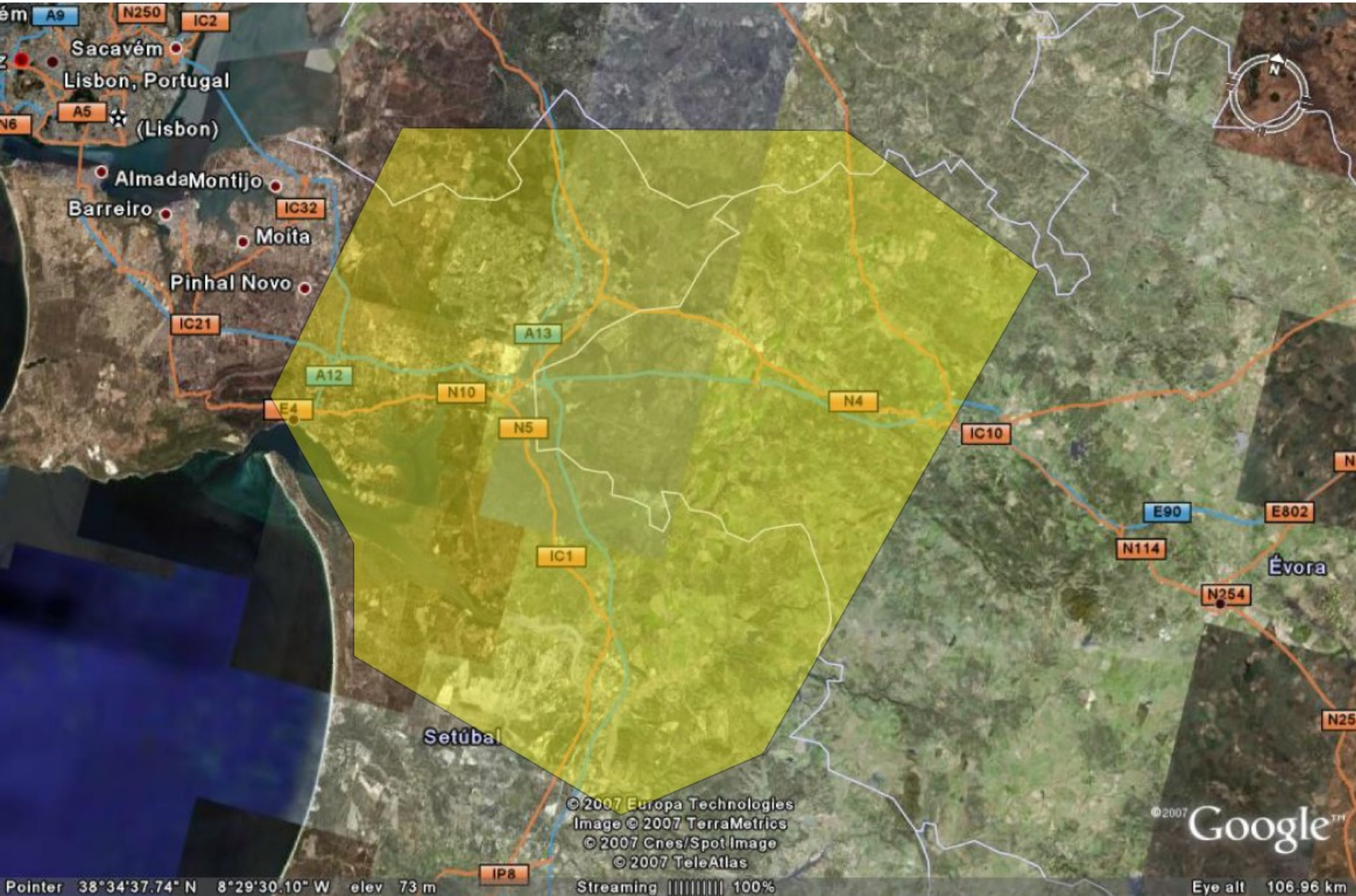
(Water tanks – Cherenkov)

In a 1500m grid

Covered area = 3000 km^2

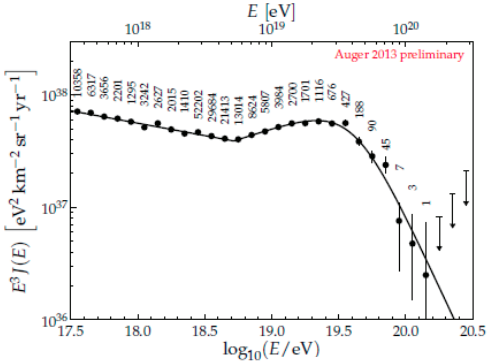
27 (24+3) fluorescence telescope

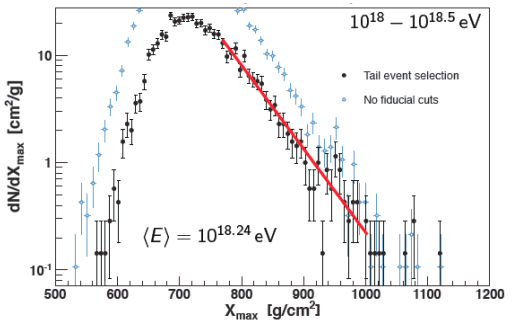
3 000 km^2


A9
N250
IC2
Sacavém
Lisbon, Portugal
A5
(Lisbon)
N6
Almada
Montijo
Barreiro
IC32
Moita
Pinhal Novo
IC21
A13
A12
N10
E4
N5
N4
IC10
E90
E802
N114
Évora
N254
IC1
Setúbal
IP8
© 2007 Europa Technologies
Image © 2007 TerraMetrics
© 2007 Cnes/Spot Image
© 2007 TeleAtlas
©2007 Google
Pointer 38°34'37.74" N 8°29'30.10" W elev 73 m
Streaming 100%
Eye alt 106.96 km

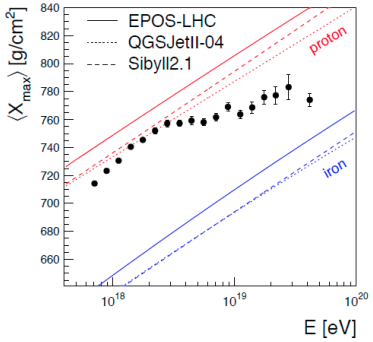
Results: Auger

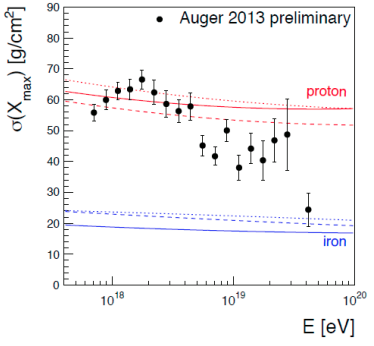
How Many?





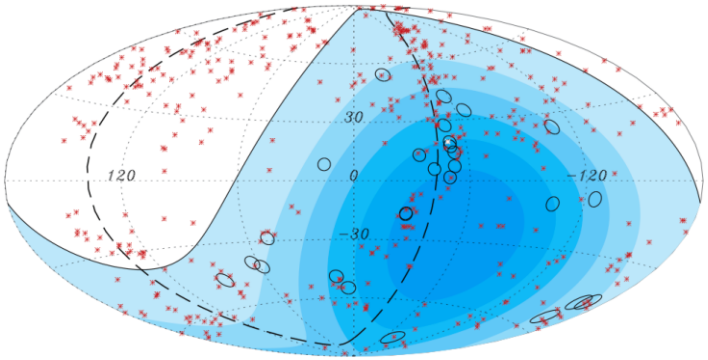
What is their nature?

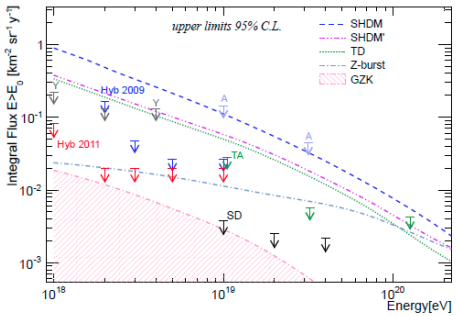


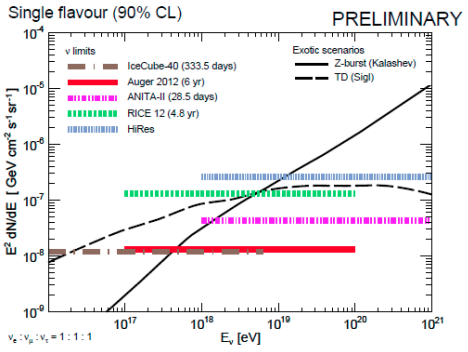


Where do they come from?

Are there companion particles? Neutrinos, Photons?







What, how, and why

Complete the puzzle

Composition change?

New Physics?

Why so much muons?

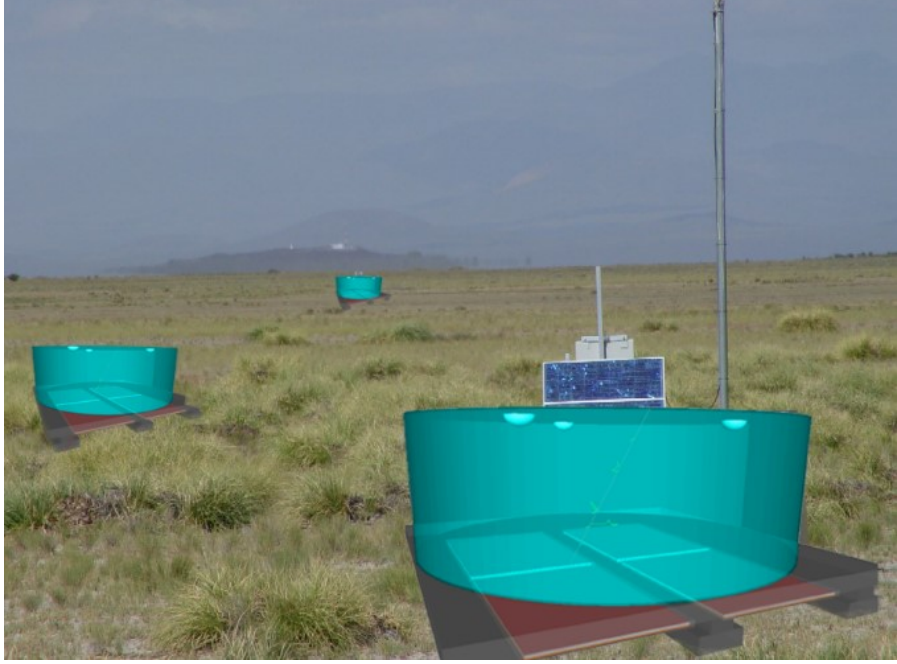
Measure the muons!!

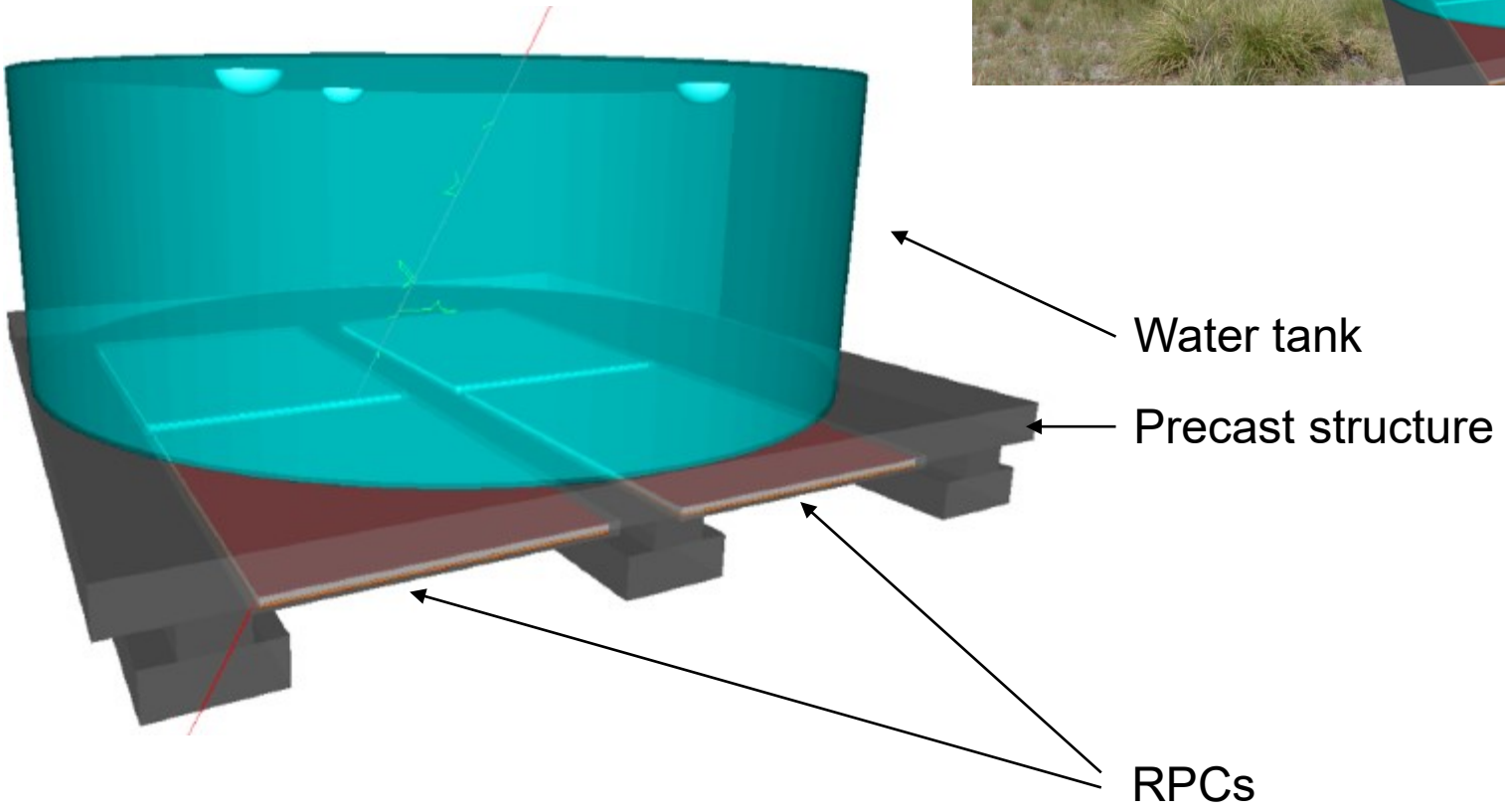
We need more precise measurements!!

Measuring Muons

A dedicated muon detector:
An array of particle detector installed beneath the tanks.

Cost-effective.

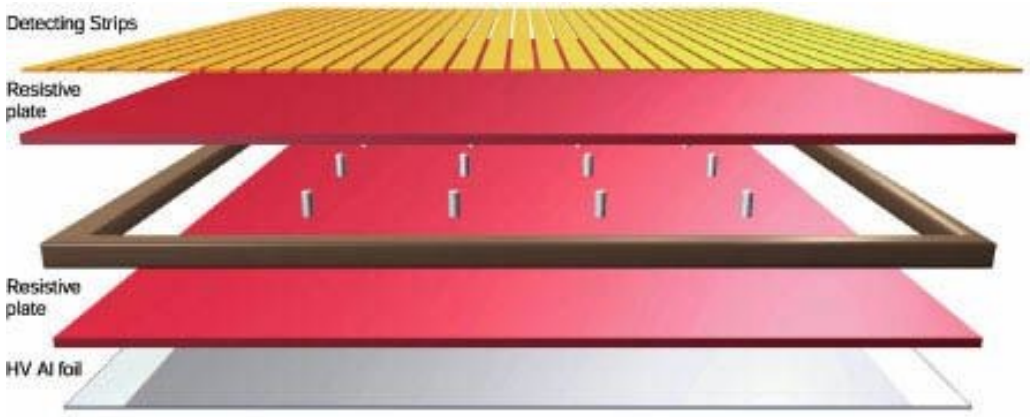




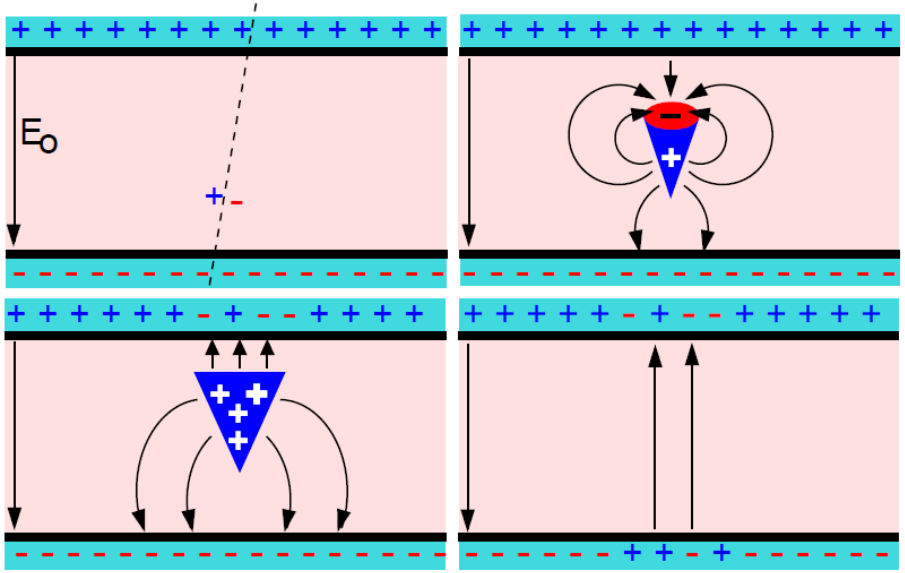
What is a RPC

Resistive Plate Chamber

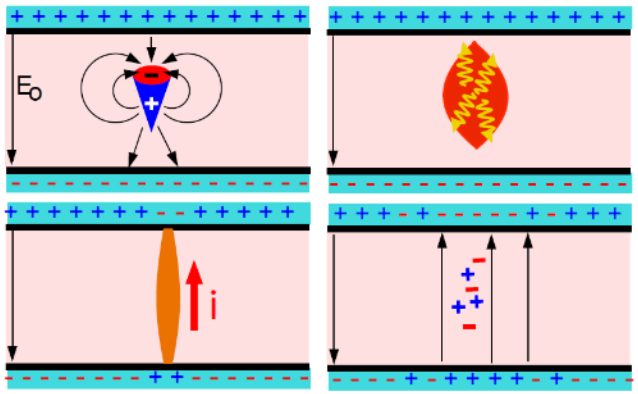
- Gaseous detector
- Planar geometry
- uniform electrical field imposed.
- High resistive plates in between the electrodes limit the avalanche current.
- Signal is picked up by the induction of the avalanche in the readout pads.



Avalanche mode



Streamer mode

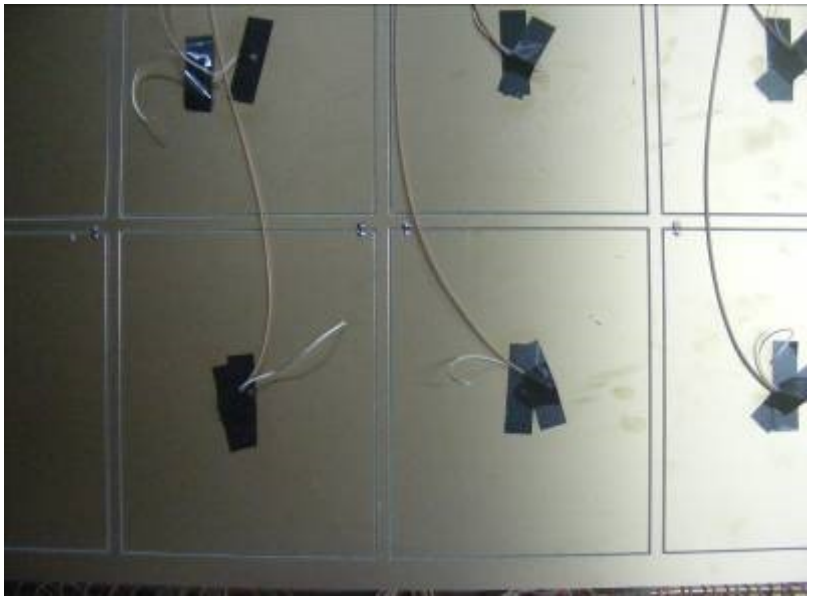


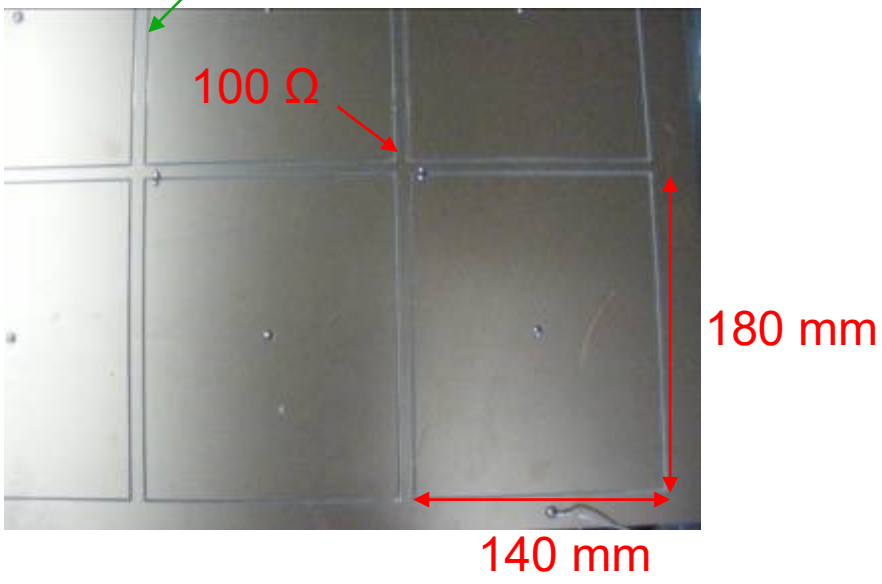
SIGNAL PICKUP MODULE

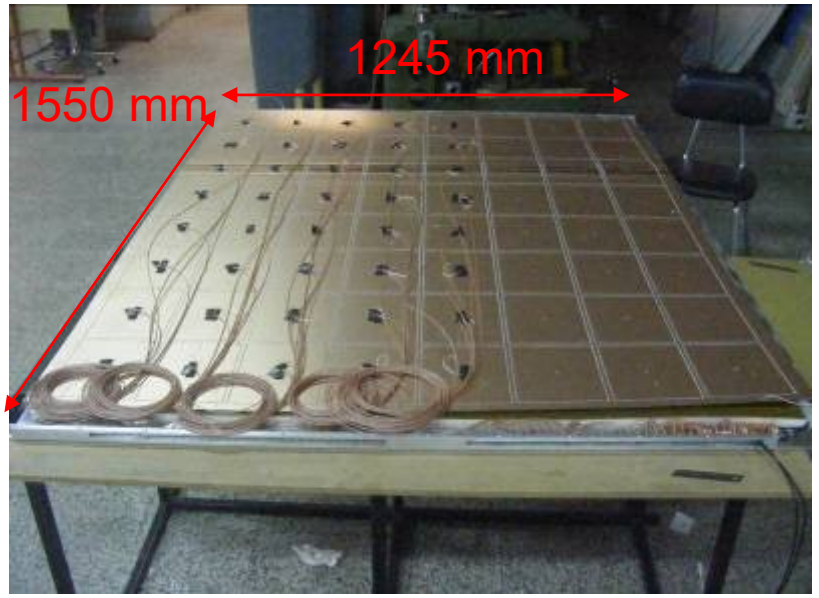
Total area 150x120 = 18000 cm^2

Area covered with pads, “efficient” area
64x18x14=16128 cm^2 ⇔ 90 % of the total area

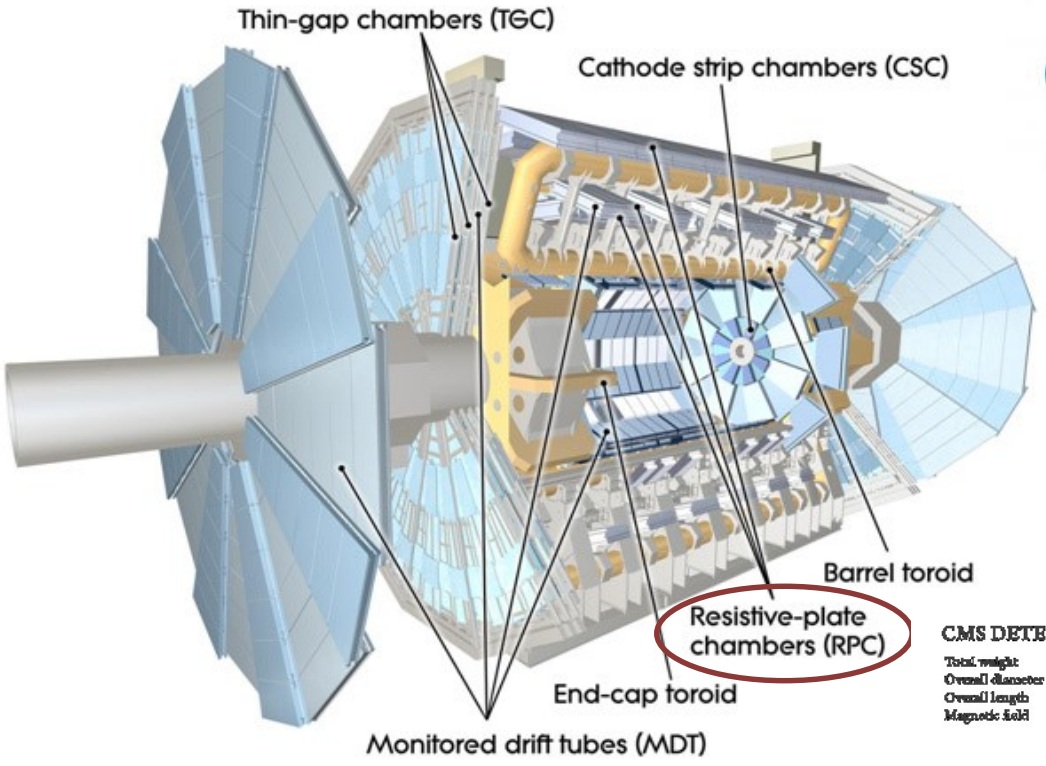
Area covered with guard rings,
18000 - 16128 = 1872 cm^2 ⇔
10 % of the total area



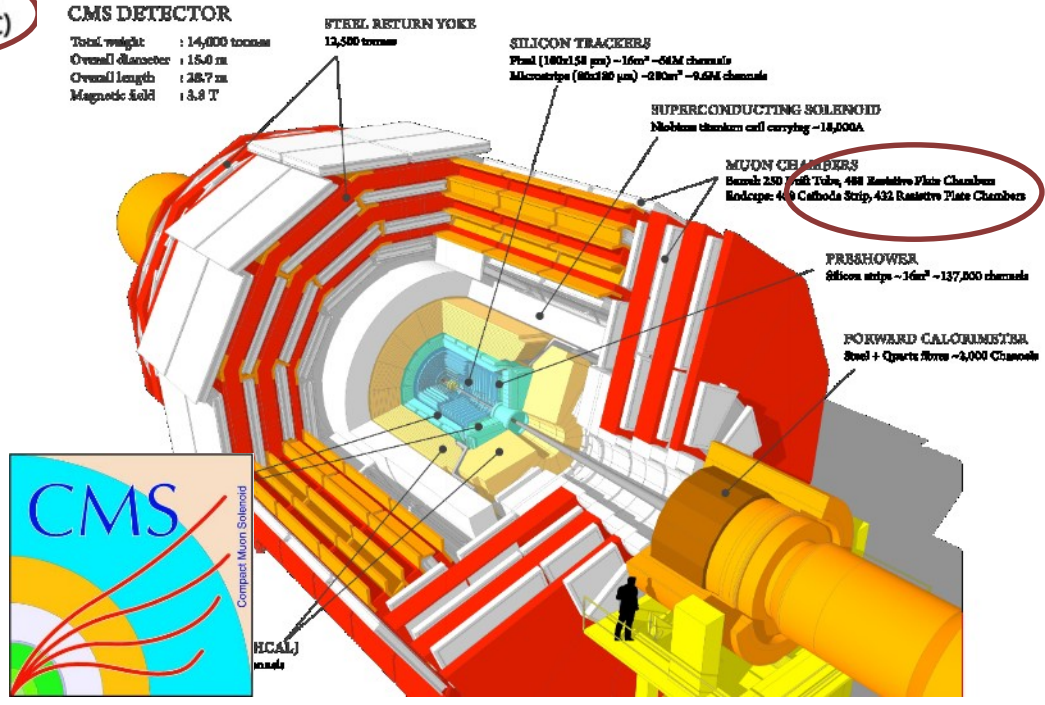




RPCs: a traditional detector in HEP



ATLAS EXPERIMENT



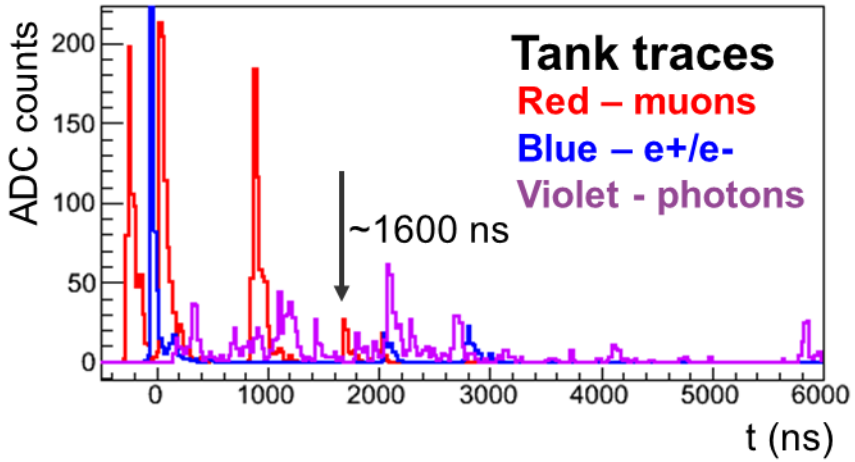
The challenge

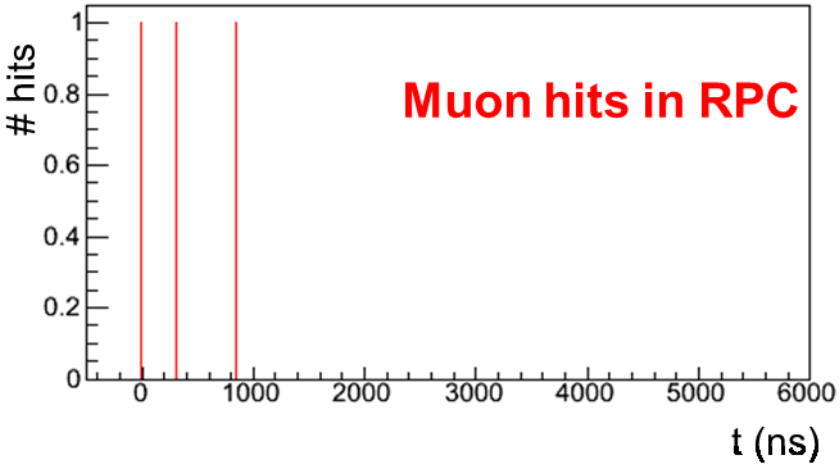
In a Cosmic Ray array the detectors must:

- Be standalone
- Have low power consumption
- Be cheap (cost-effective
- Acquire data at fast rates
- Precision timing!

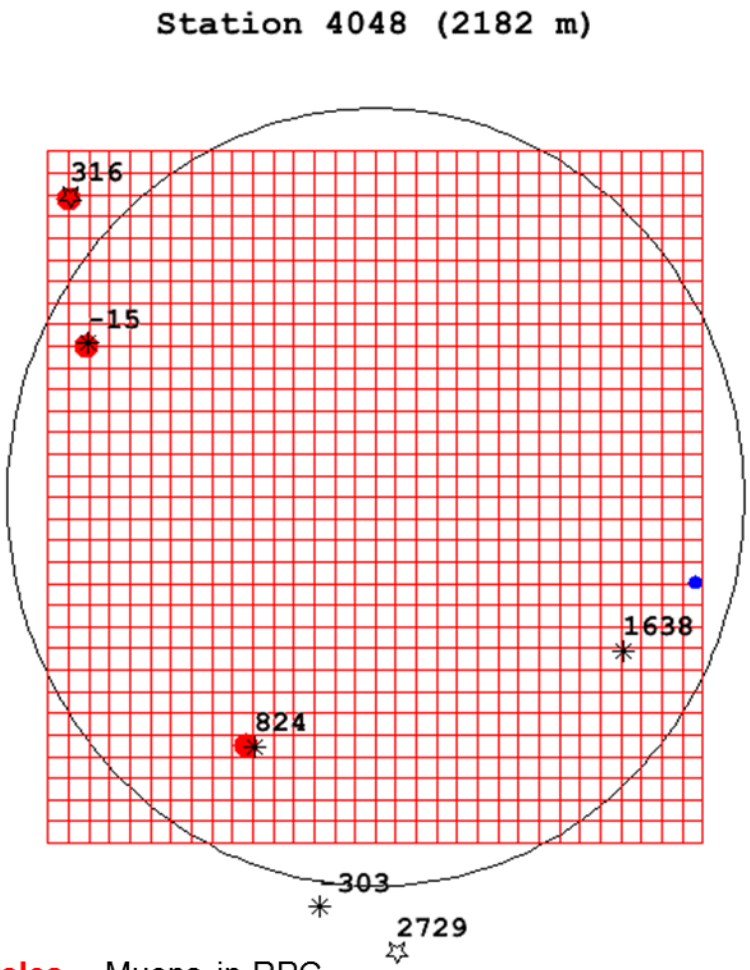
Expected results: Muon signals in tank vs RPC

proton, $10^{19.5}$ eV θ=40°





Only muon hits in RPC are shown.



Red circles – Muons in RPC

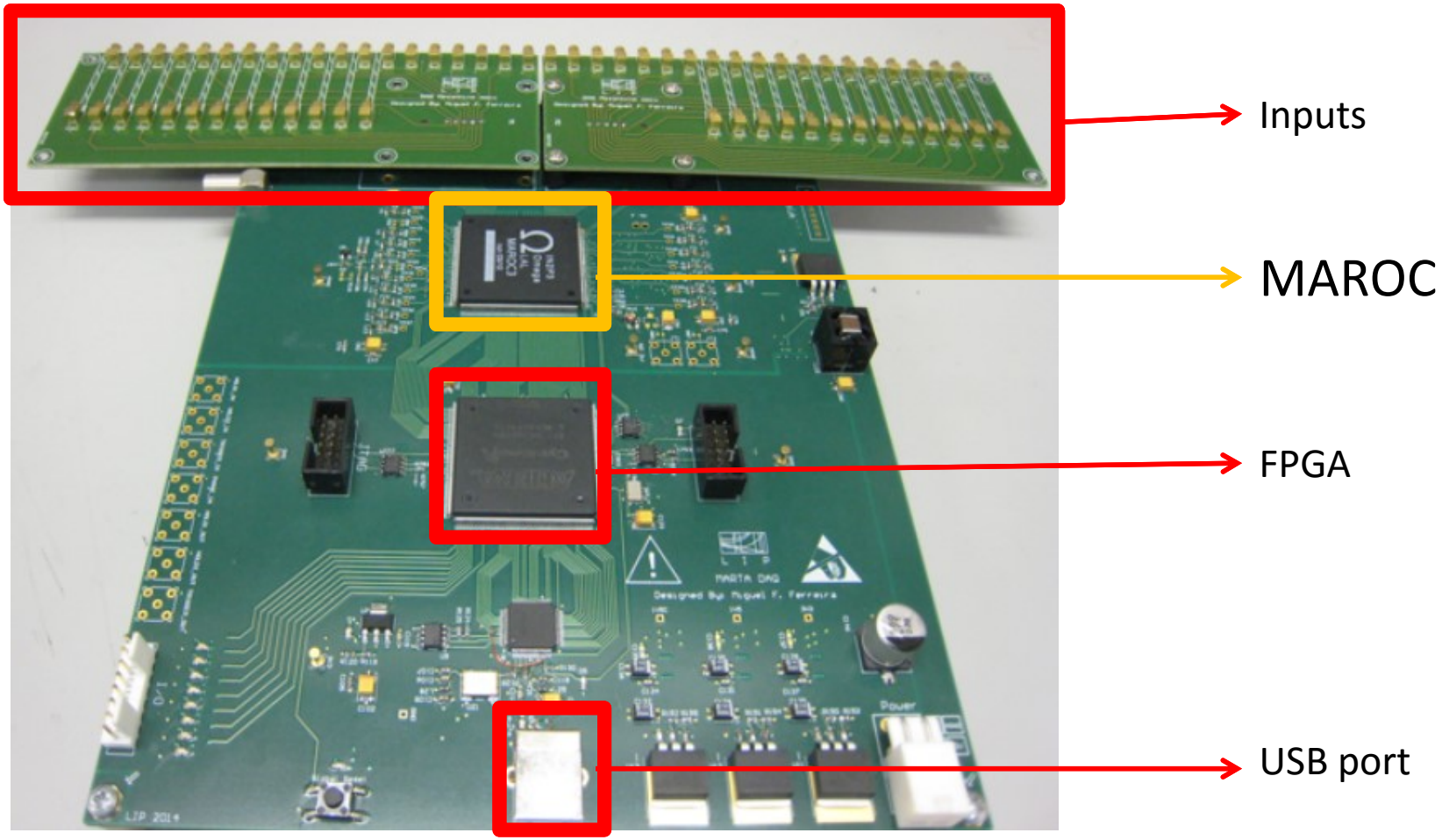
Blue circles - Electrons from shower e.m.

Asteriscs – Muons injected in tank, extrapolated to RPC plane

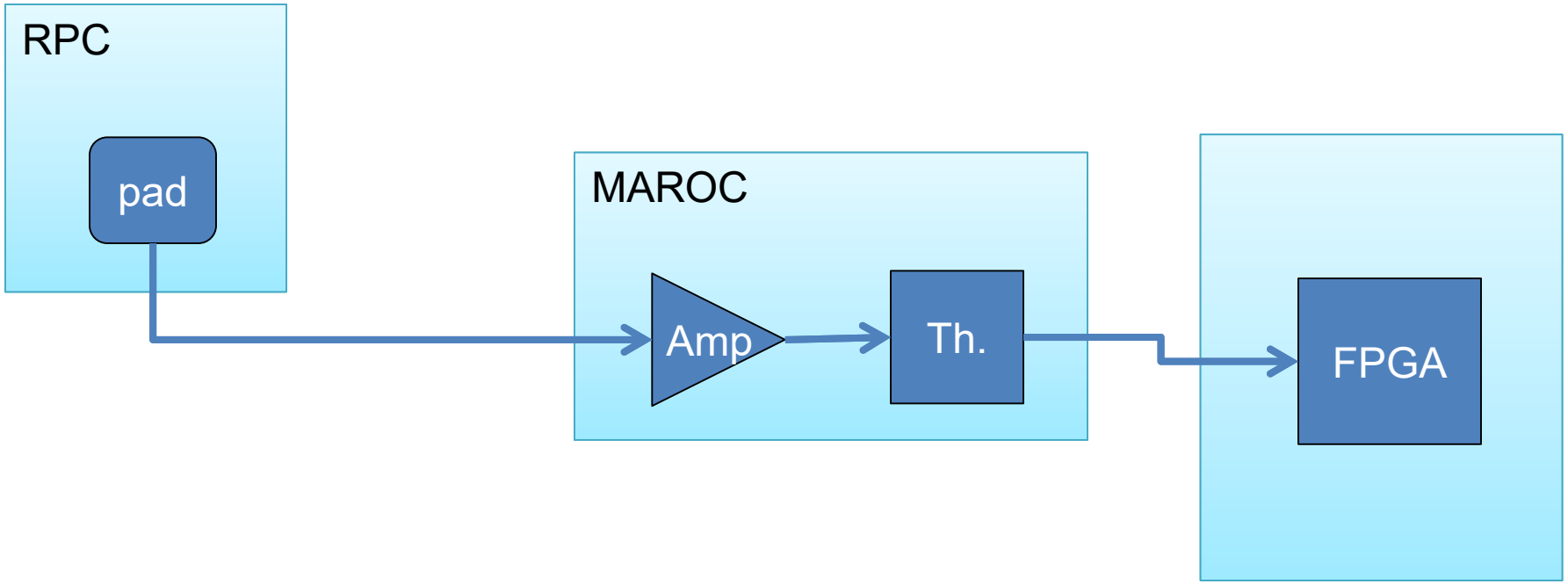
Stars - Muons injected below tank, extrapolated to RPC plane

Numbers – time (ns)

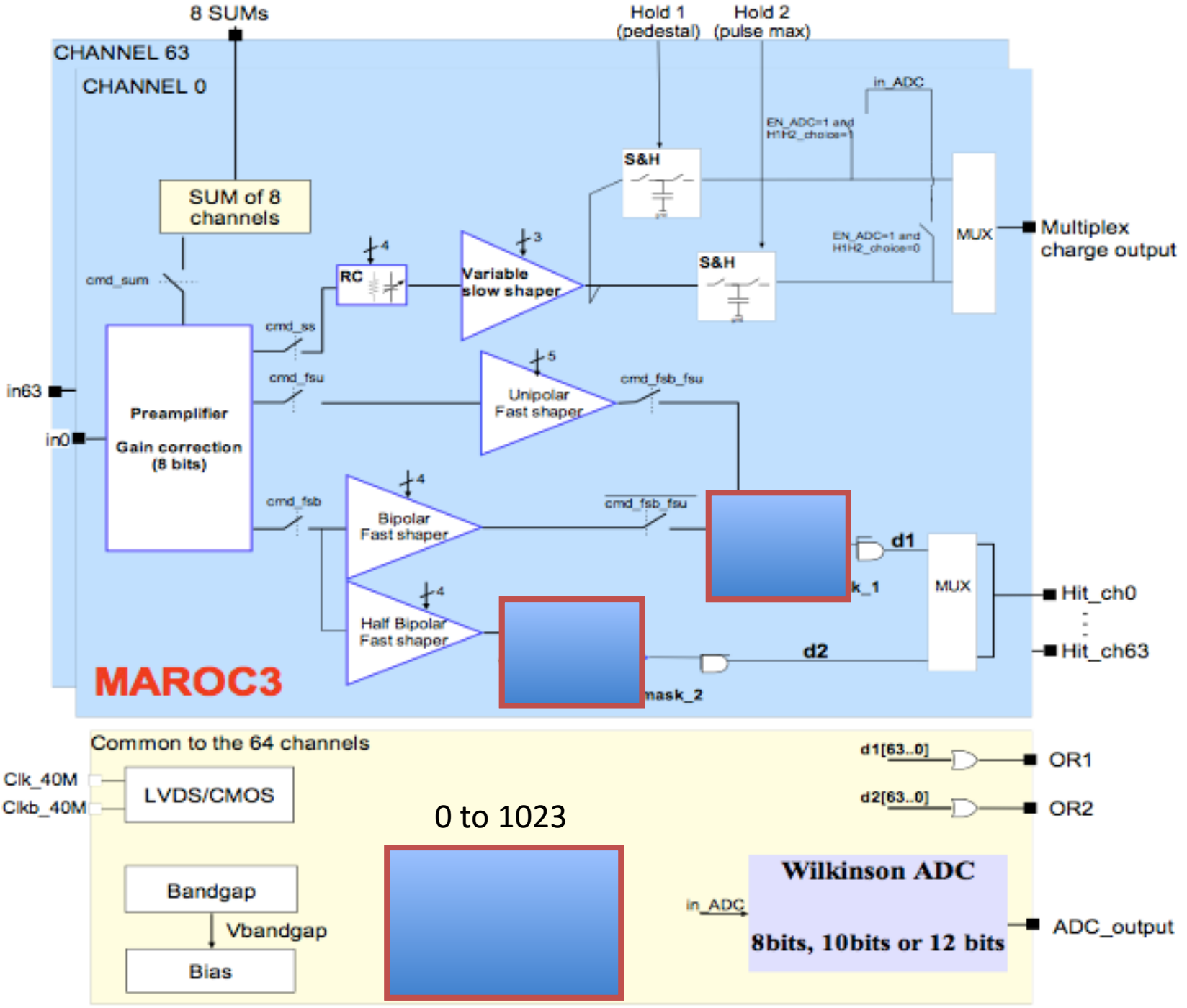
MARTA Readout System



RPC channel



The MAROC chip



MARTA @ Gianni's tank

RPC

Scint

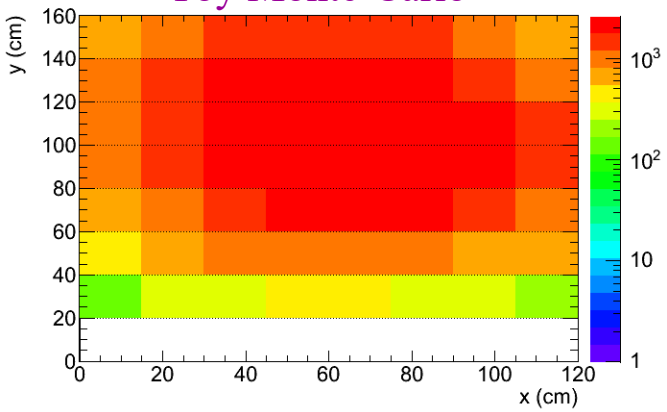
Scint

Tank

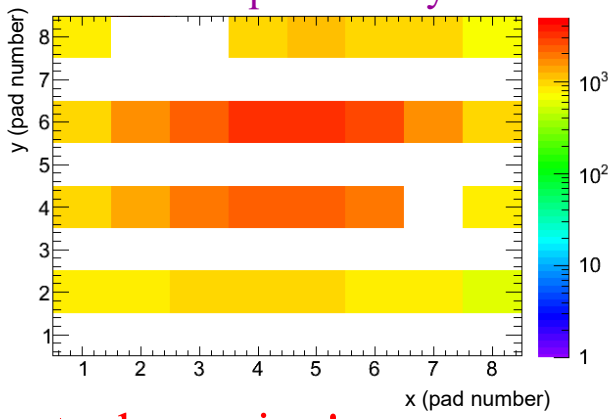
RPC

Events taken asking coincidence of scintillators:

Toy Monte-Carlo

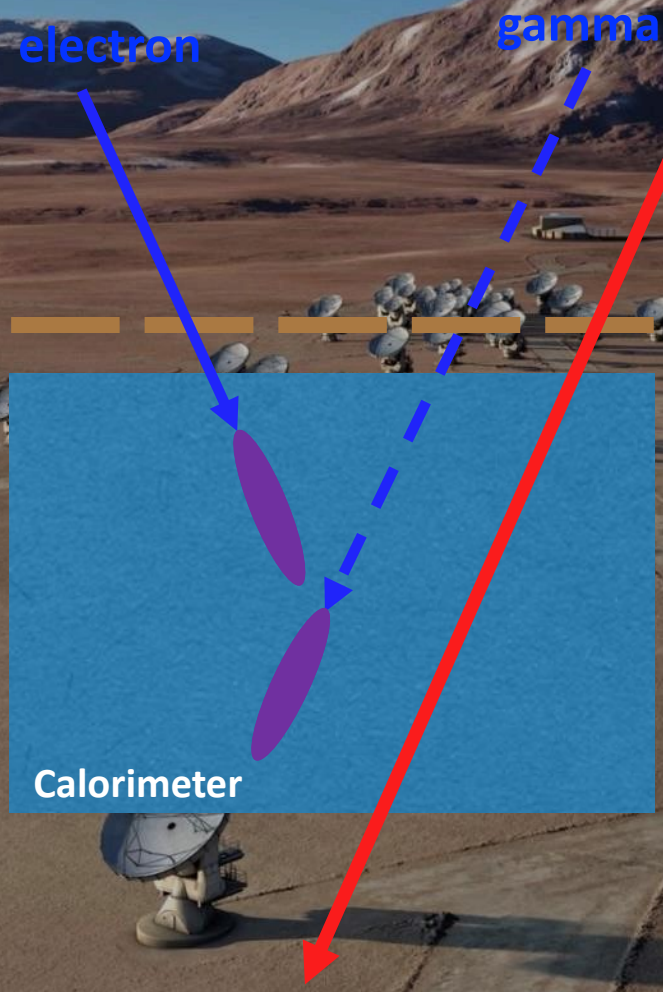


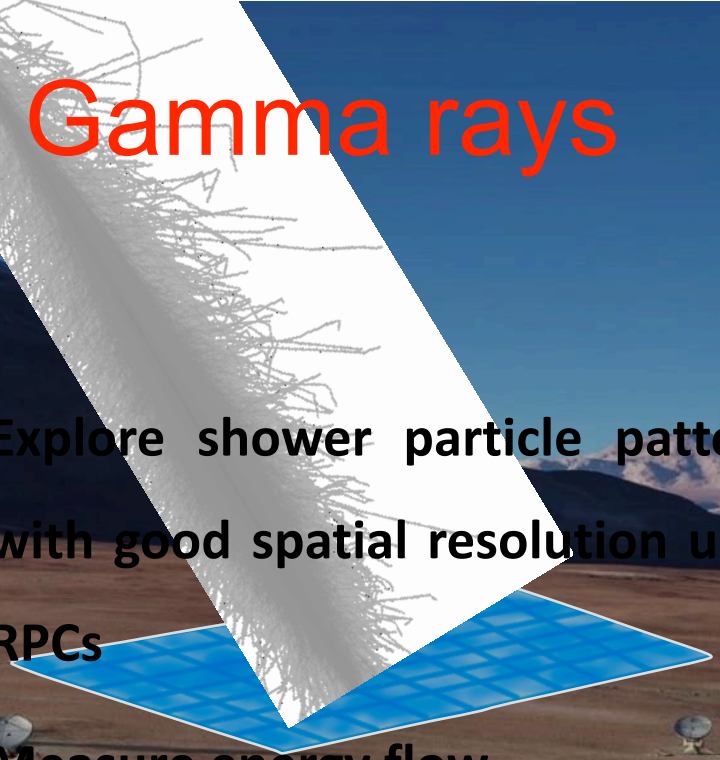
Data - preliminary



Acquisition with trigger from tank running!

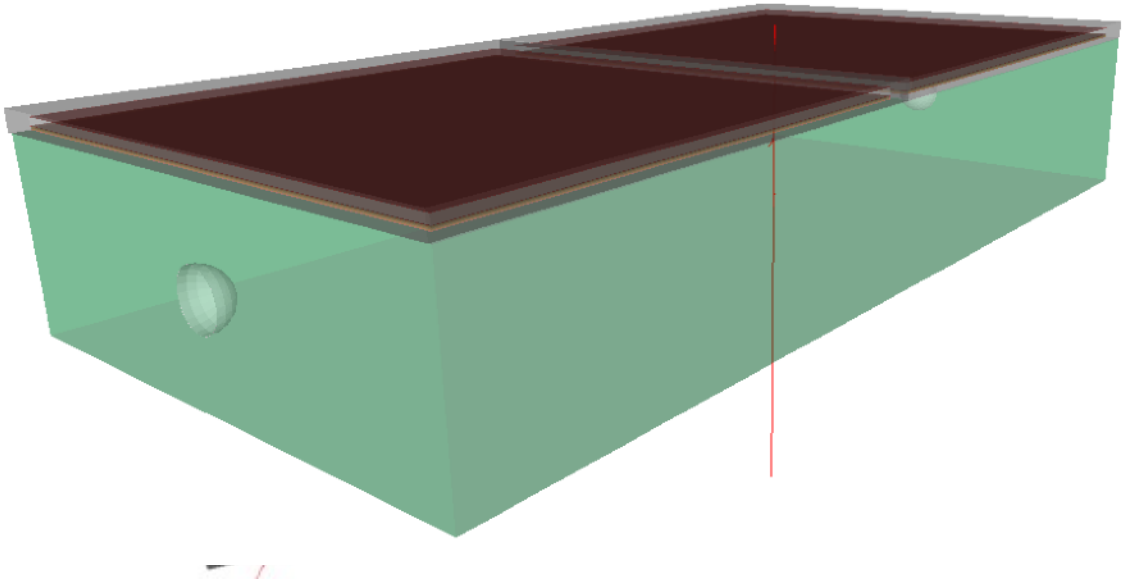
LATTES – study VHE Gamma rays





- Explore shower particle patterns with good spatial resolution using RPCs
- Measure energy flow
- Combined detection:
  - Sensitivity to low energy showers
  - Photon/proton discrimination
- @ ~ 5000 m a.s.l.

Lattes – the detector




Tank you