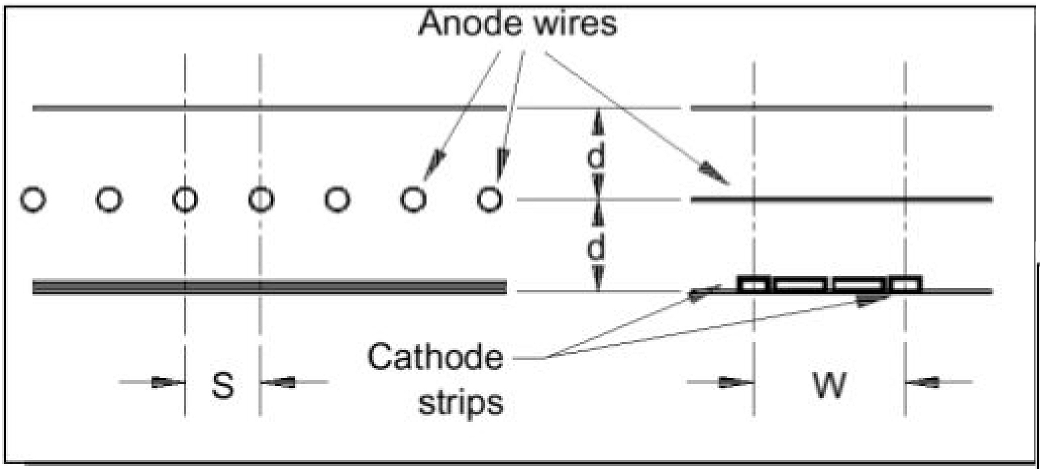
Back to the Detectors

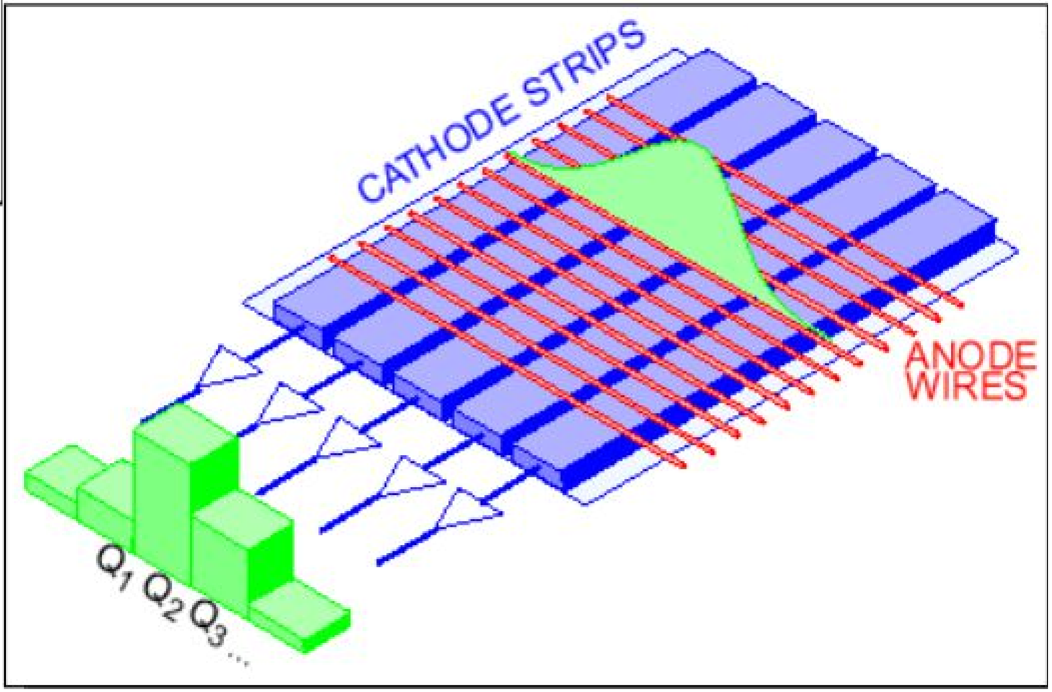
Detectors(Gaseous)

CSC: Cathode Strip Chamber

- Determine muon position by interpolating the charge on 3 to 5 adjacent strips
- Precision (x-) strip pitch ~ 5.6 mm
- Measure Q1, Q2, Q3... with 150:1 SNR to get σx ~ 60 μm.
- Second set of y-strips measure transverse
- coordinate to ~ 1 cm.
- Position accuracy unaffected by gas gain or drift time variations



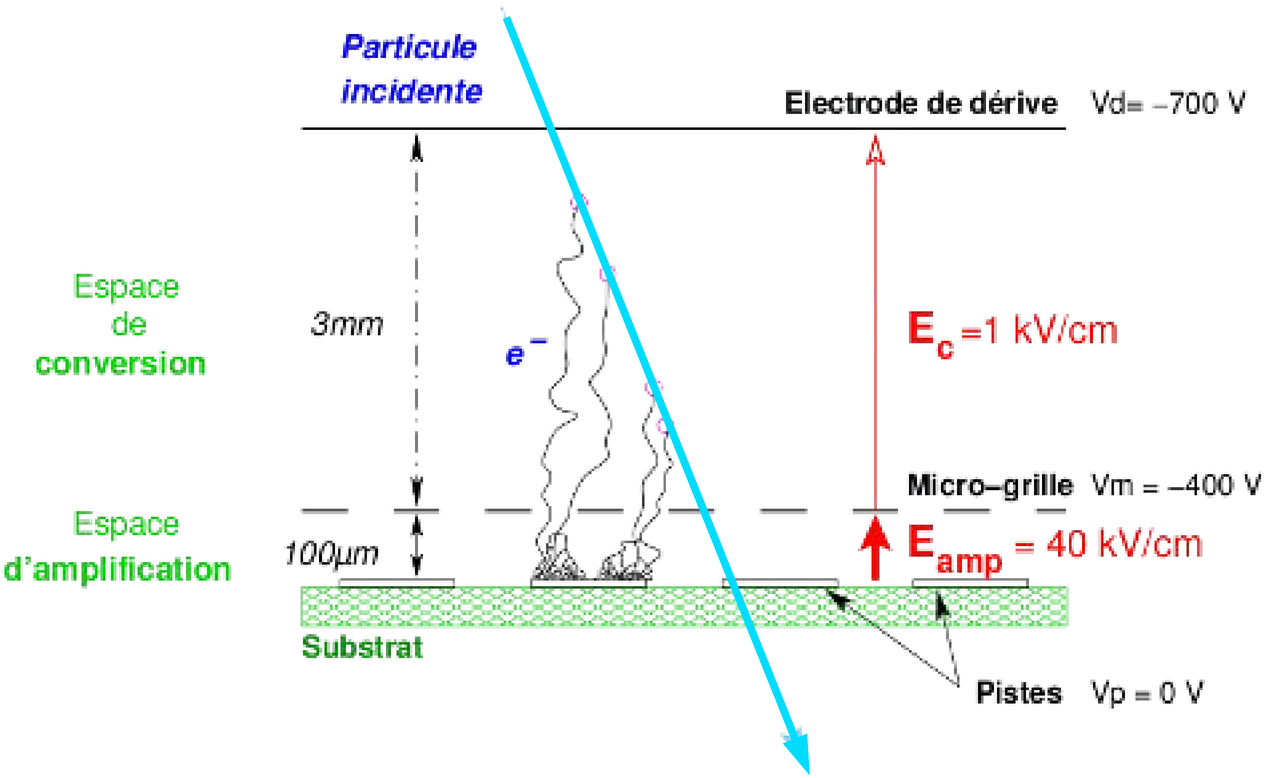
S = 2.54 mm W = 5.60 mm

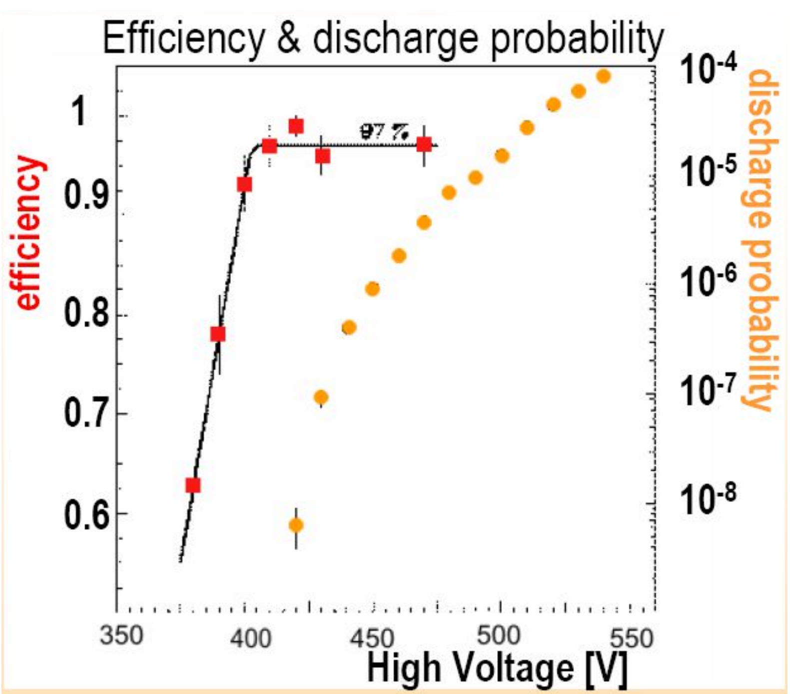


Detectors(Gaseous)

Micro-Megas

- Giomataris I. et al., NIMA 376 (1996) 29
- Capable of operating at very high rates
- Work in magnetic fields
- Radiation hard and age well.
- Shape and readout segmentation can be adapted to the needs
- Parallel plate structures with straight-forward field shapes.
- Work at very low HV (thin amplification gap)
- Industrially produced

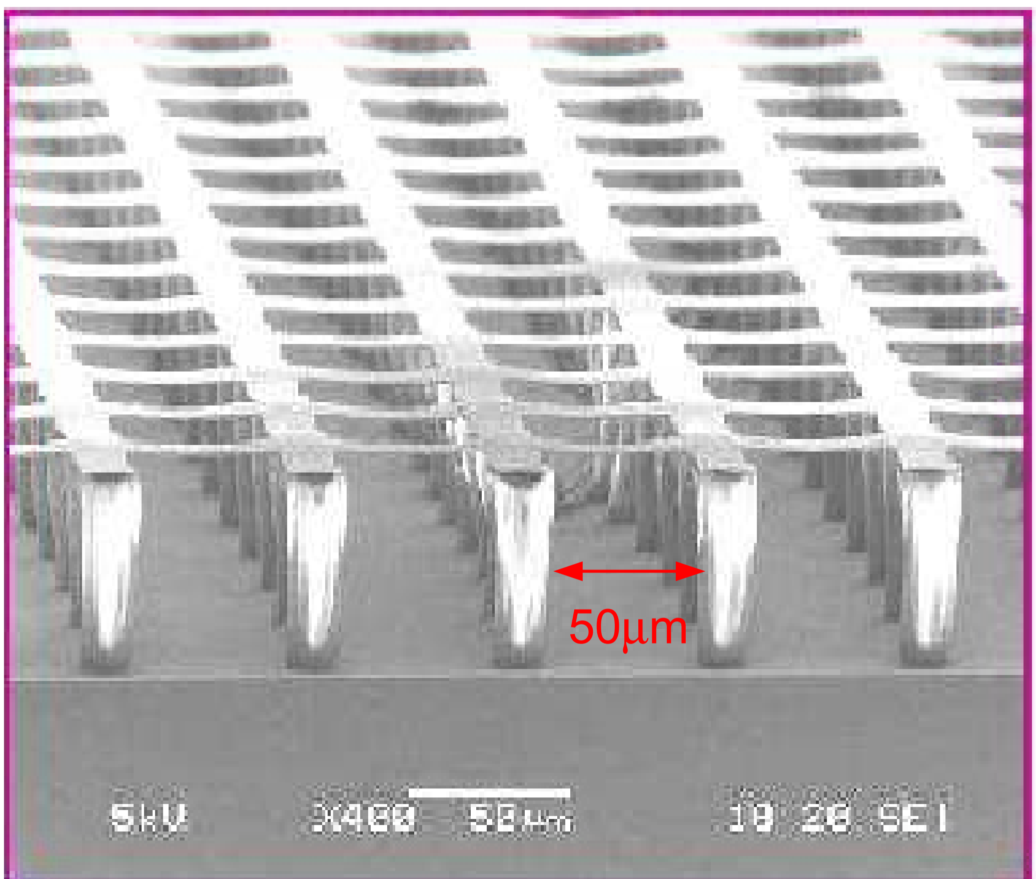


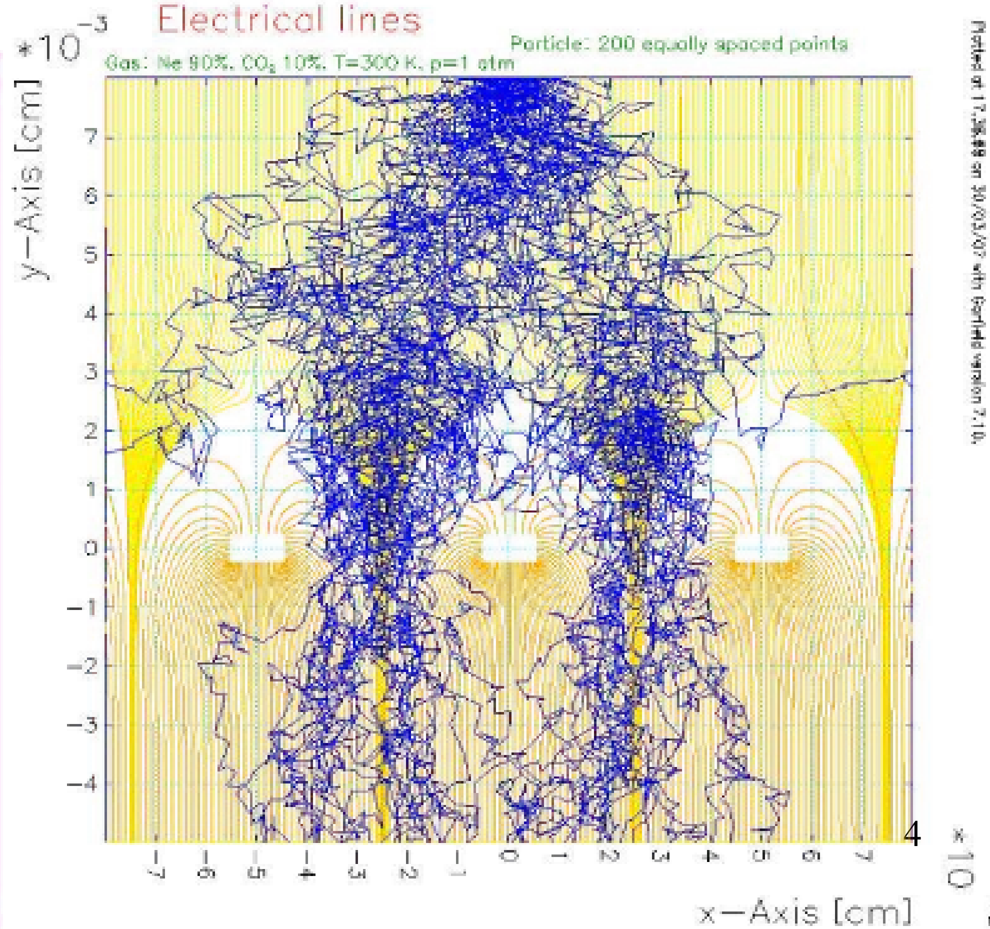


Detectors(Gaseous)

Micro-Megas

- Capable of operating at very high rates
- Work in magnetic fields
- Radiation hard and age well.
- Shape and readout segmentation can be adapted to the needs
- Parallel plate structures with straight-forward field shapes.
- Work at very low HV (thin amplification gap)
- Industrially produced

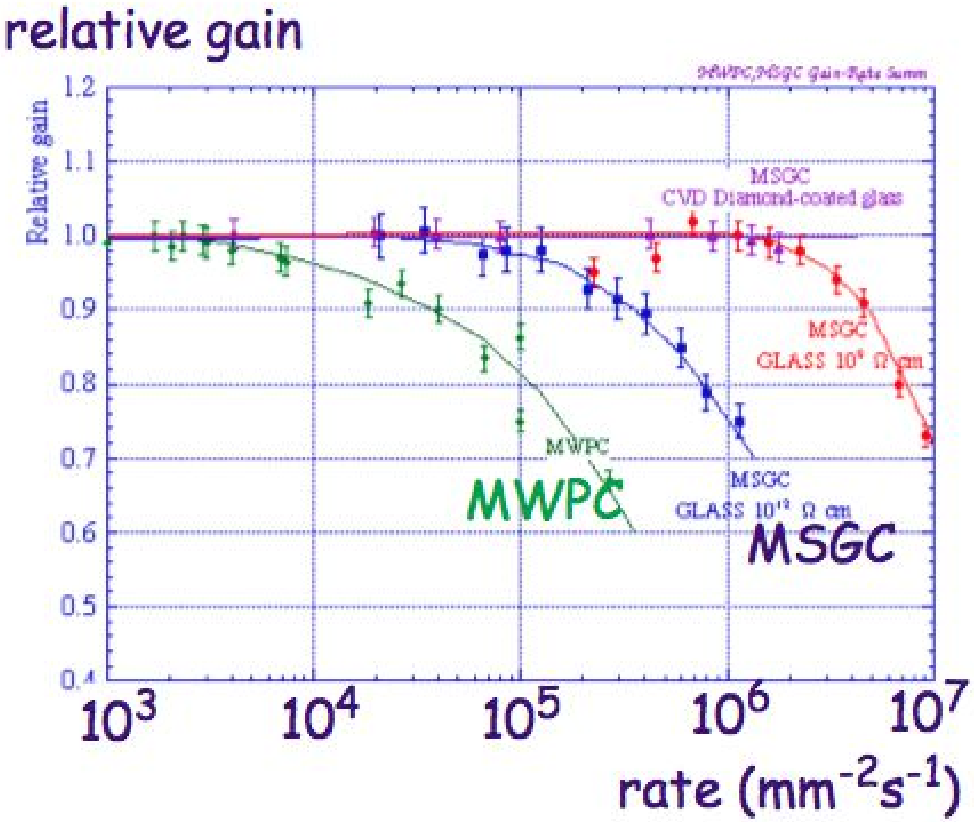


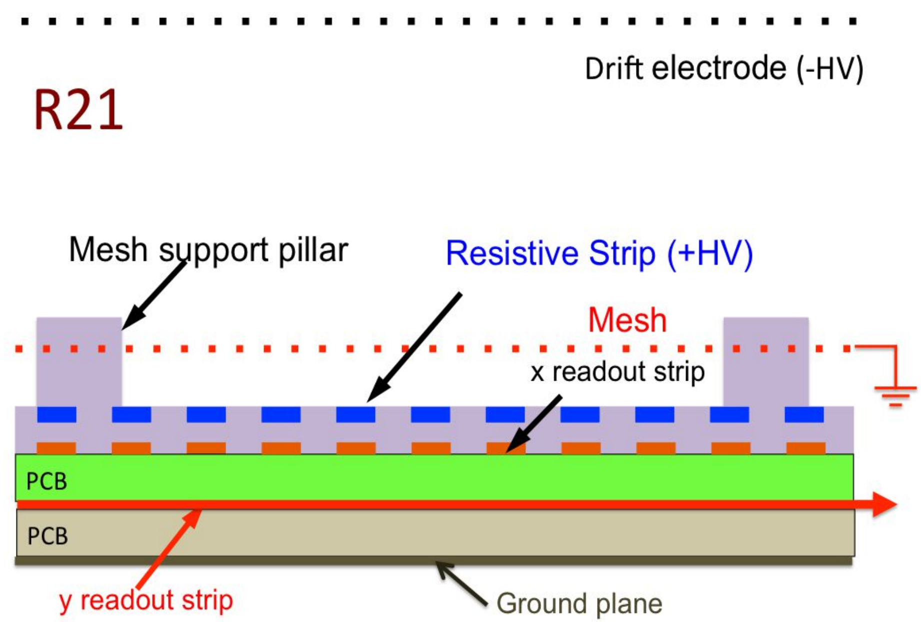


Detectors(Gaseous)

Micro-Megas

- Capable of operating at very high rates
  - Short ion evacuation path => high rate capability
- Very precise readout structures produced using PCB technology (lithography)
- Very good spatial resolution
- Improvement (add of a layer of resistive strips above the readout structure:
  Spark tolerant without degrading their performance
  T. Alexopoulos et al., NIMA 640 (2011) 110-118





Interlude

Muography

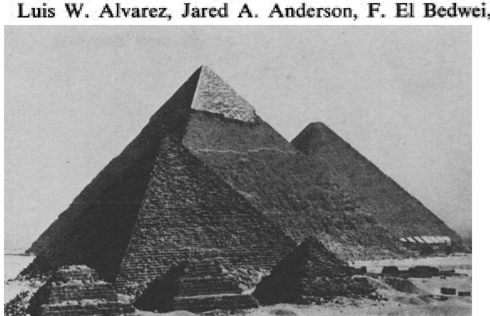
Muography

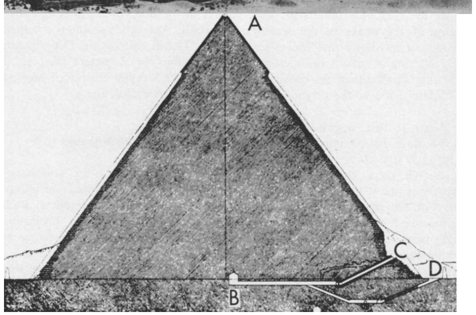
- the probability of muon absorption is proportional to the density
  Muon flux → density map
- Use cosmic muons to analyse Archaeology,Volcanology, buildings structure,...

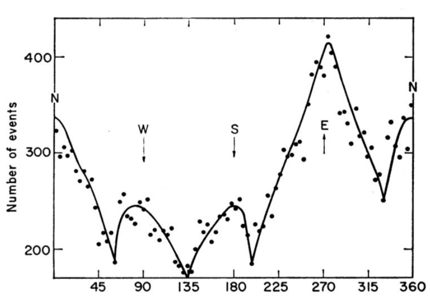
Search for Hidden Chambers in the Pyramids

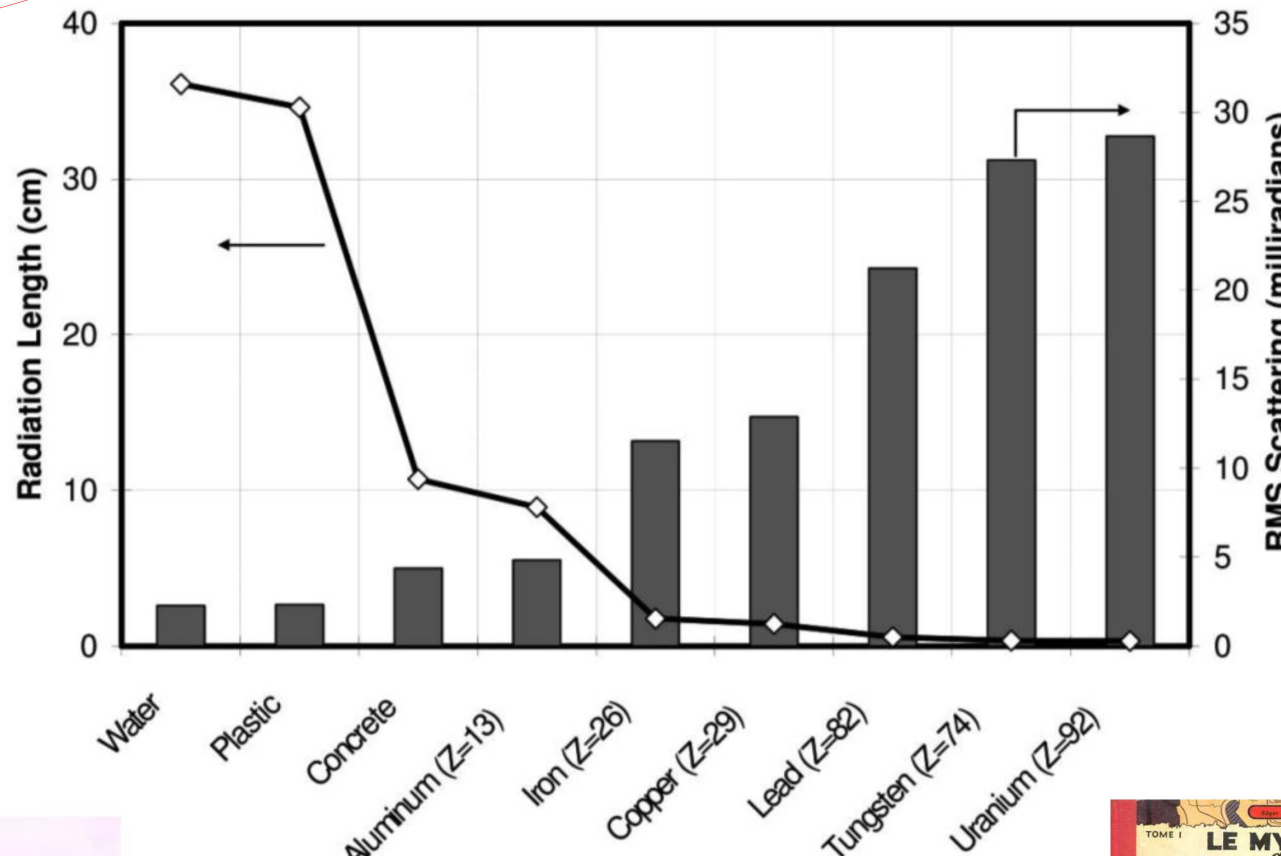
The structure of the Second Pyramid of Giza is determined by cosmic-ray absorption.

Luis W. Alvarez, Jared A. Anderson, F. El Bedwei,

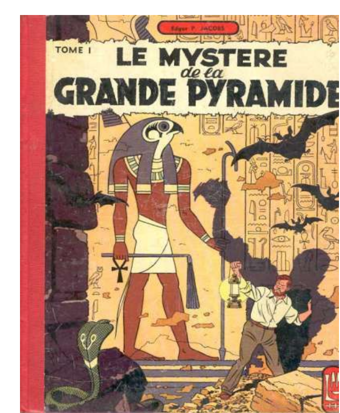






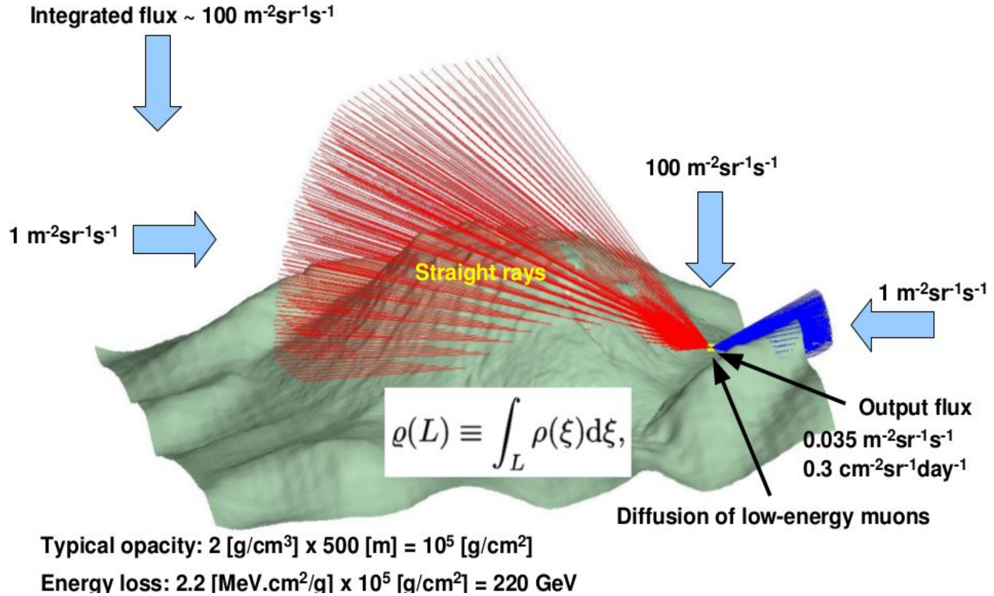


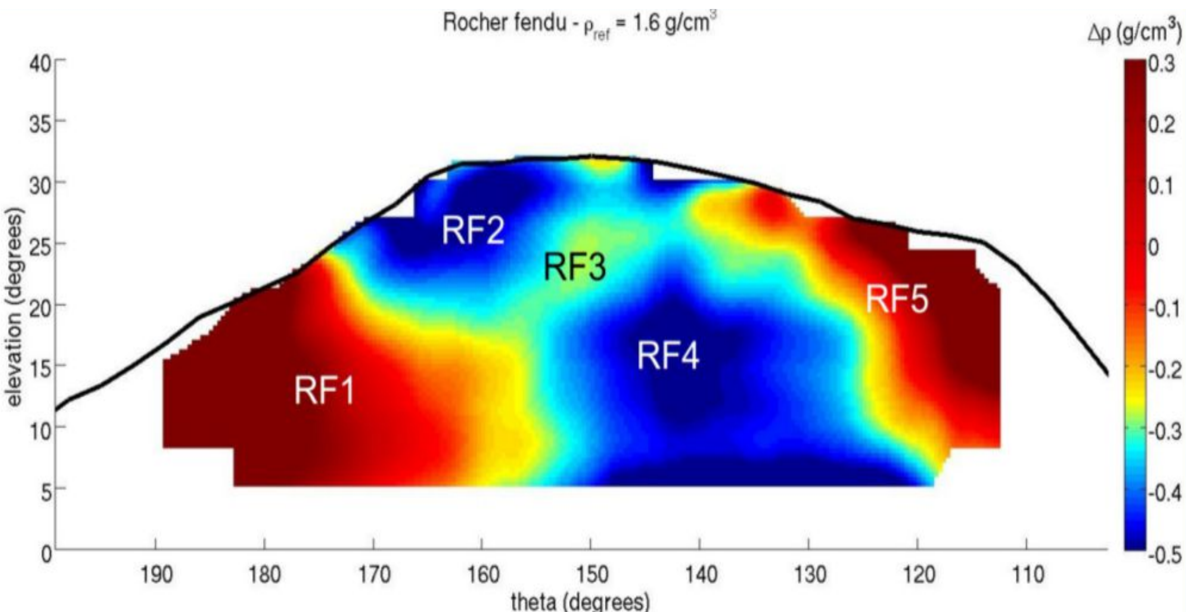
Hidden room in the pyramid? →



Muography

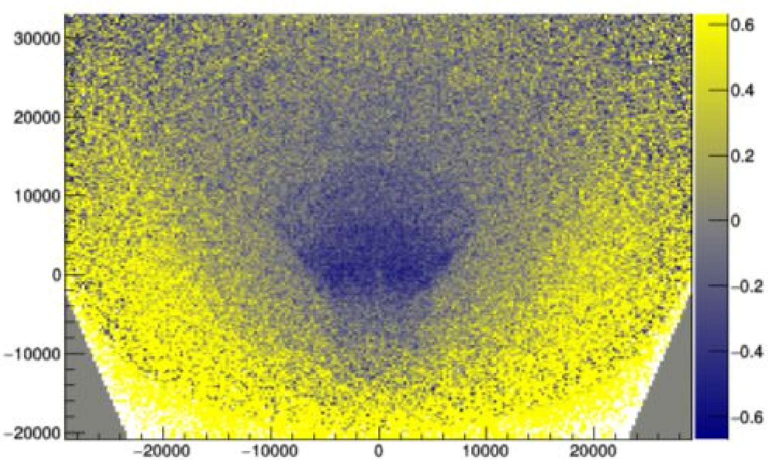
- the probability of muon absorption is proportional to the density
  Muon flux → density map
- Use cosmic muons to analyse Archaeology, Volcanology, buildings structure,...

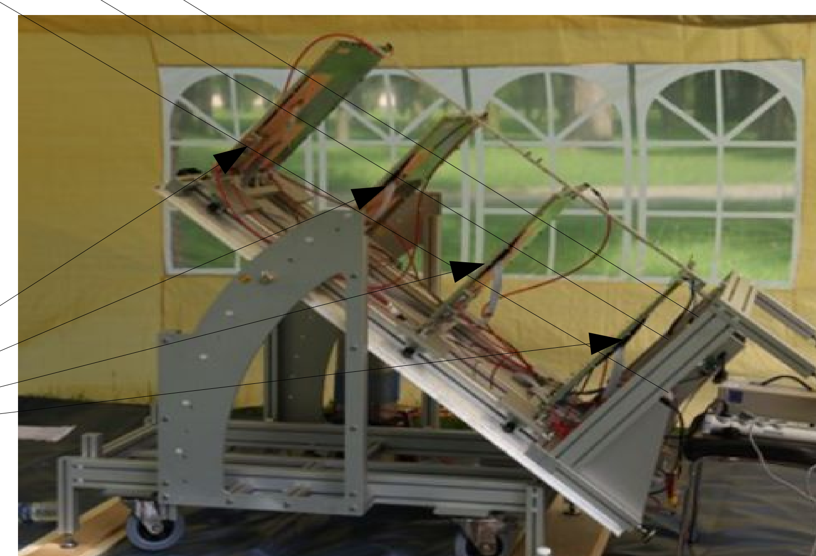




Muography

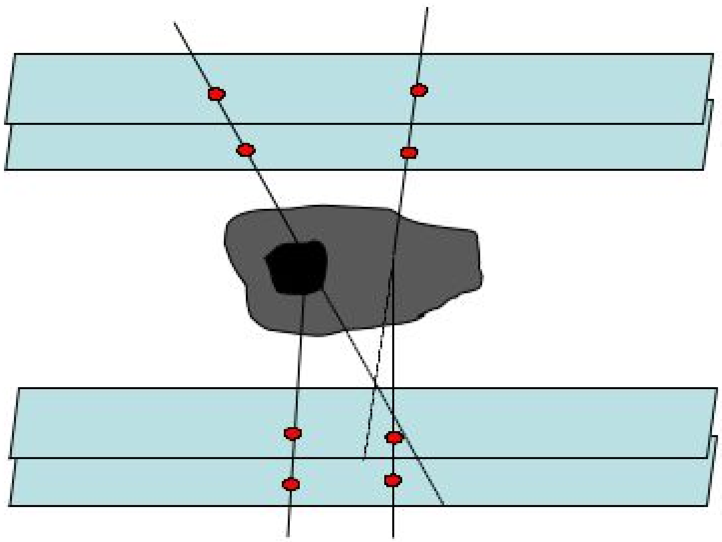
- the probability of muon absorption is proportional to the density
  Muon flux → density map
- Use cosmic muons to analyse Archaeology,Volcanology, buildings structure,...

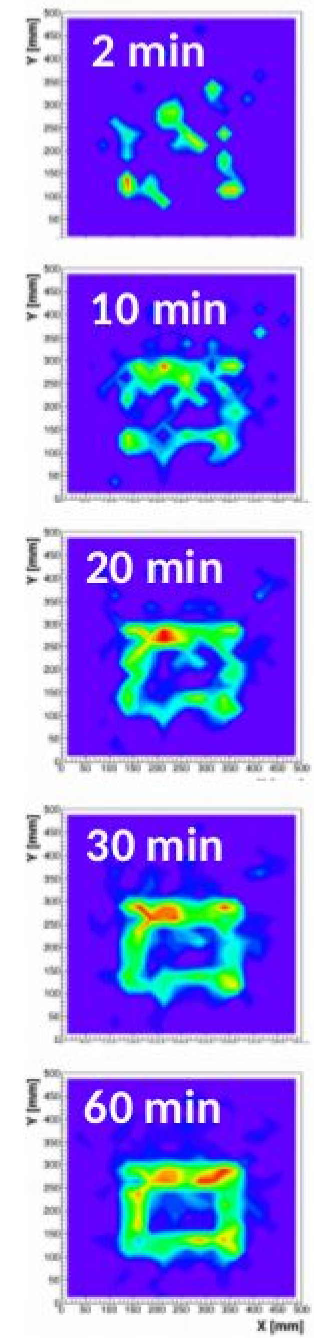




Muography

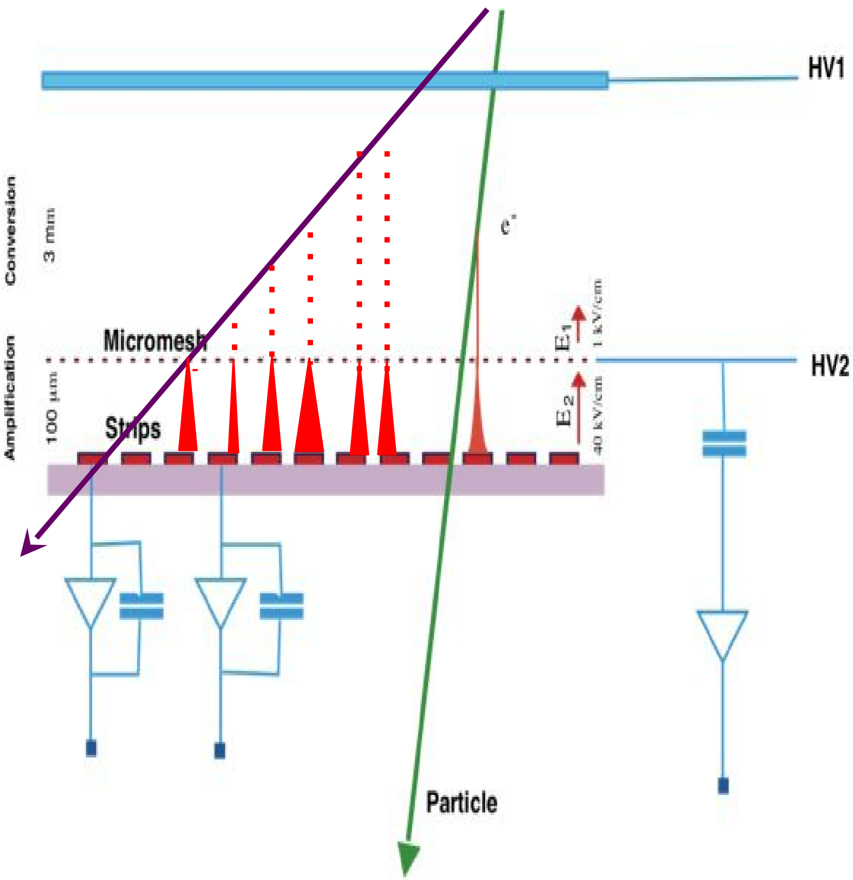
- Use cosmic muons to analyse truck, container....
- Multiple diffusion:
  - 2 detectors: deviation angle
  - fast (~mn), 3D,

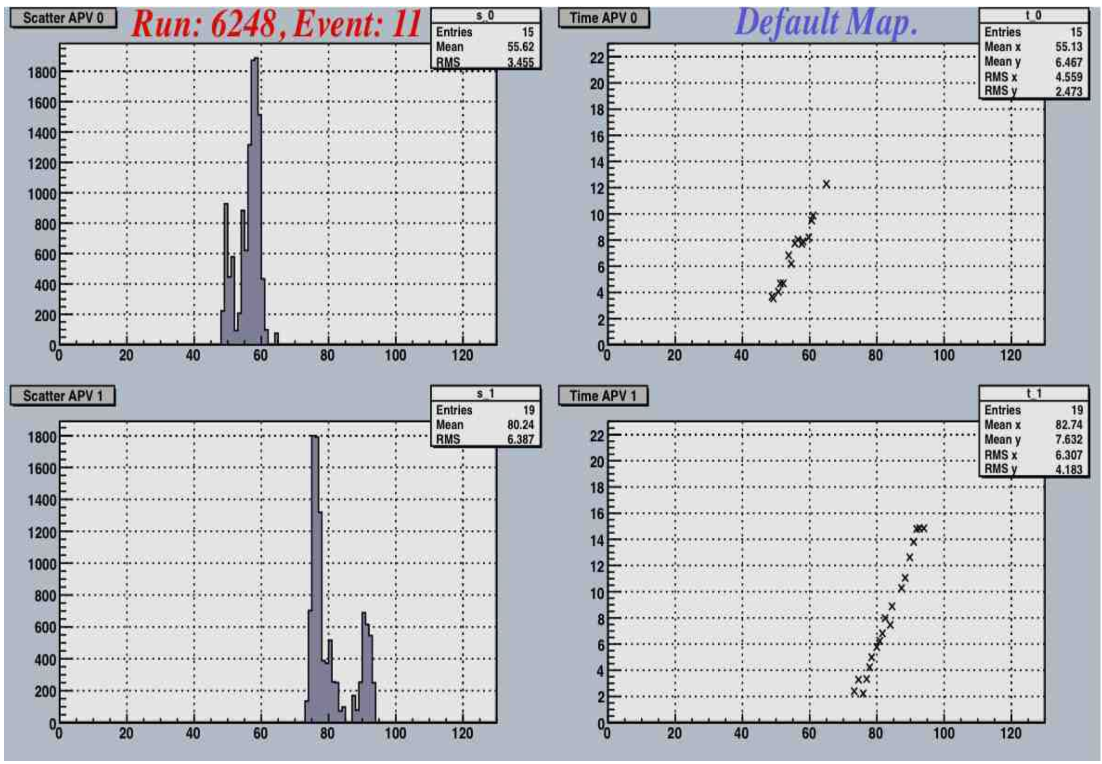




Micro-Megas: µTPC!!!!

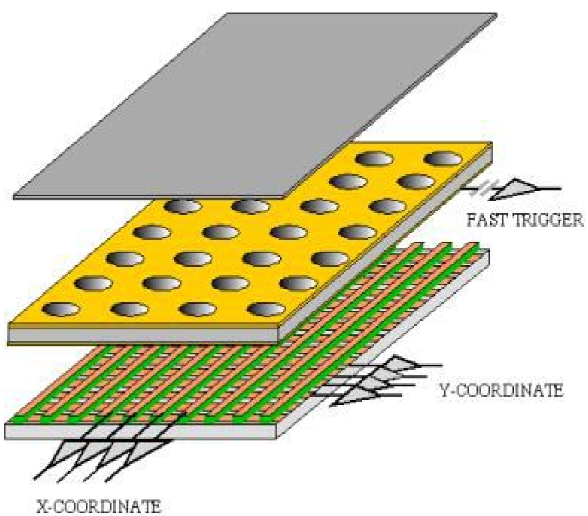
- ”Wide” drift region (typically a few mm)
- Electric field of 100–1000 V/cm
- 100 µm amplification gap with high electrical field (40–50 kV/cm)
  - a factor Em/Ed≈70–100 is required for full mesh transparency for electrons
- Drift velocities of 5 cm/µs (or 20 ns/mm) electrons need 100 ns for a 5 mm gap
- Adding the time arrival of the signals => TPC-like
- Track vectors for inclined tracks

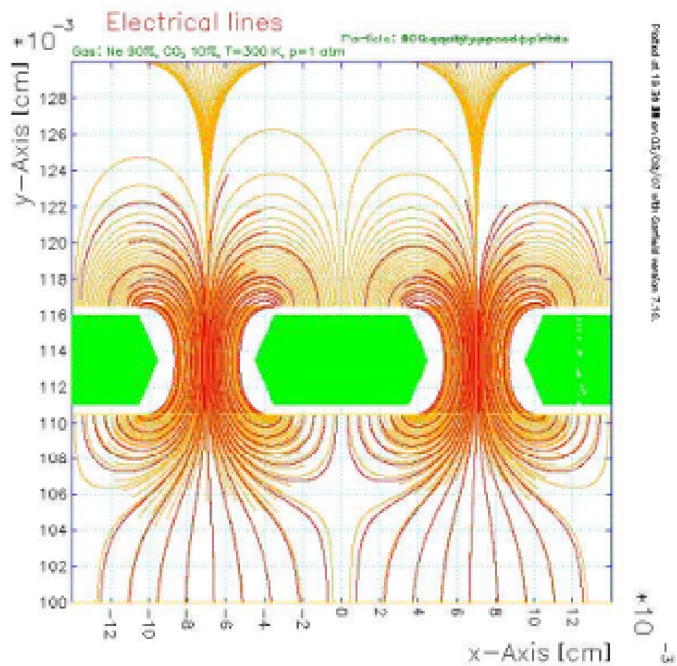


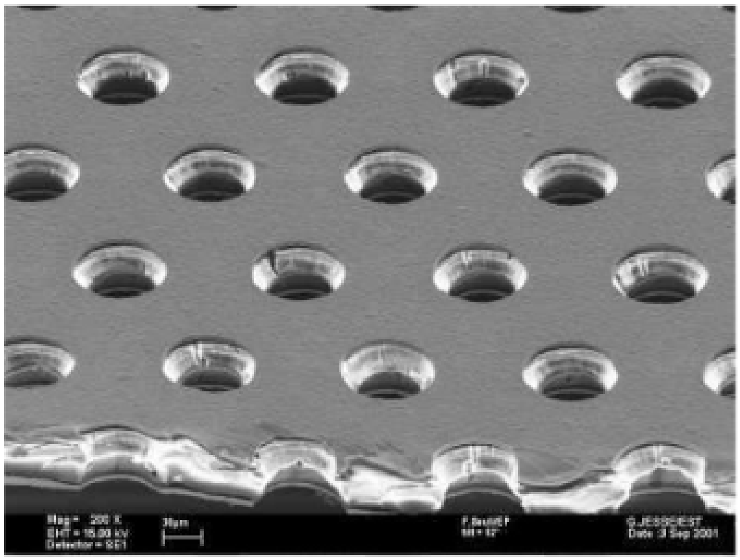


GEM: Gas Electron Multiplier

- F. Sauli at CERN, (R. Bouclier et al., NIM A 396 (1997) 50).
- Parallel plate structure with perforated Cu-clad Kapton foils.
- By applying a potential between conducting foil surfaces a strong electric field develops inside the holes
- Electron multiplication takes place in the field inside the holes
- Hole diameters are 70–120 μm
- Kapton foils are about 50 μm thick

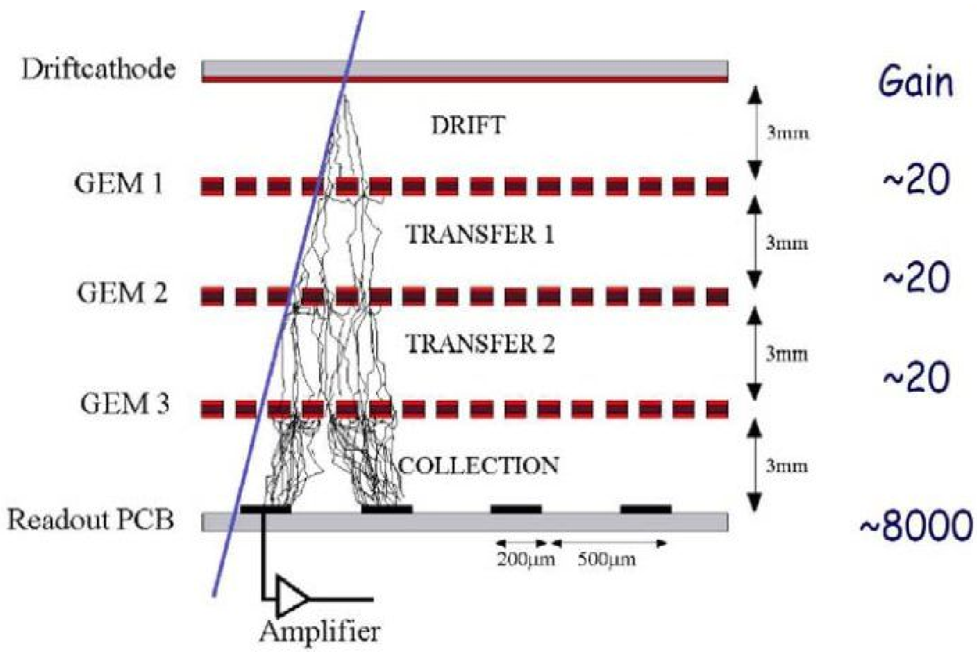


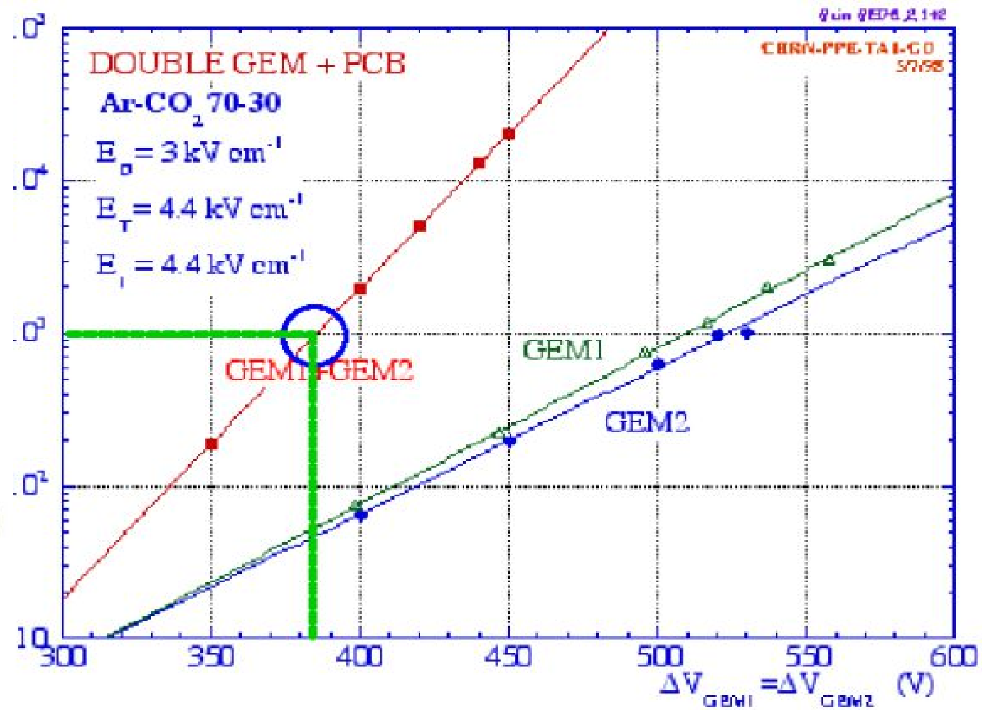




GEM: Gas Electron Multiplier

- Triple GEM
- Lower voltage for the same gain
- Less spark



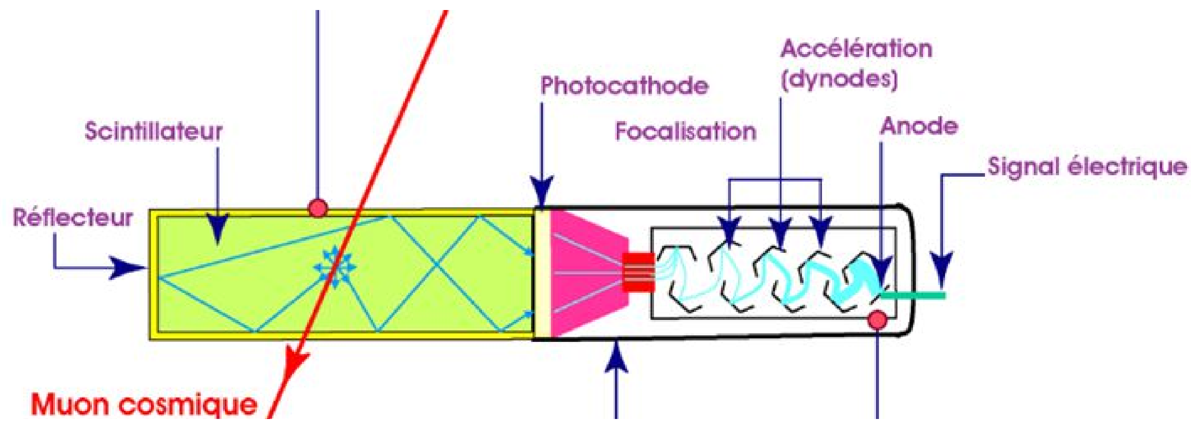


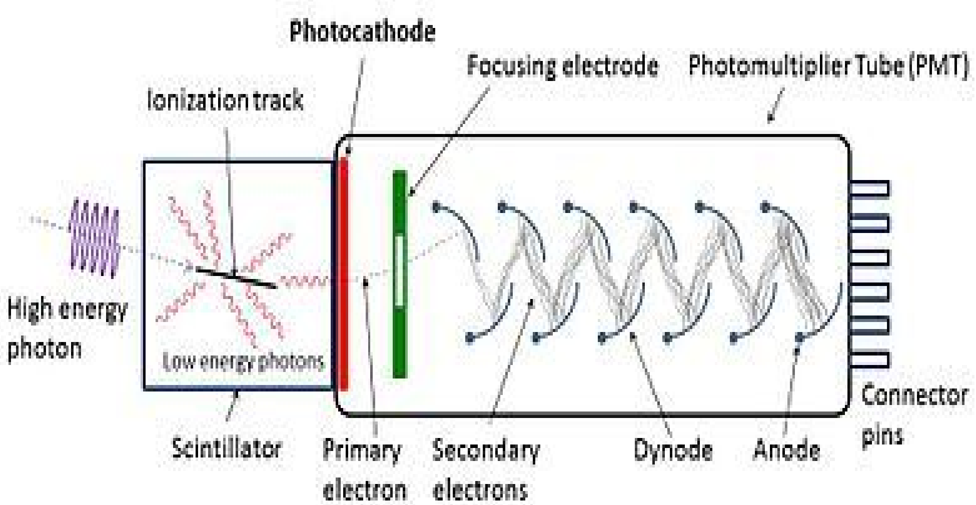
Detectors(Solid)

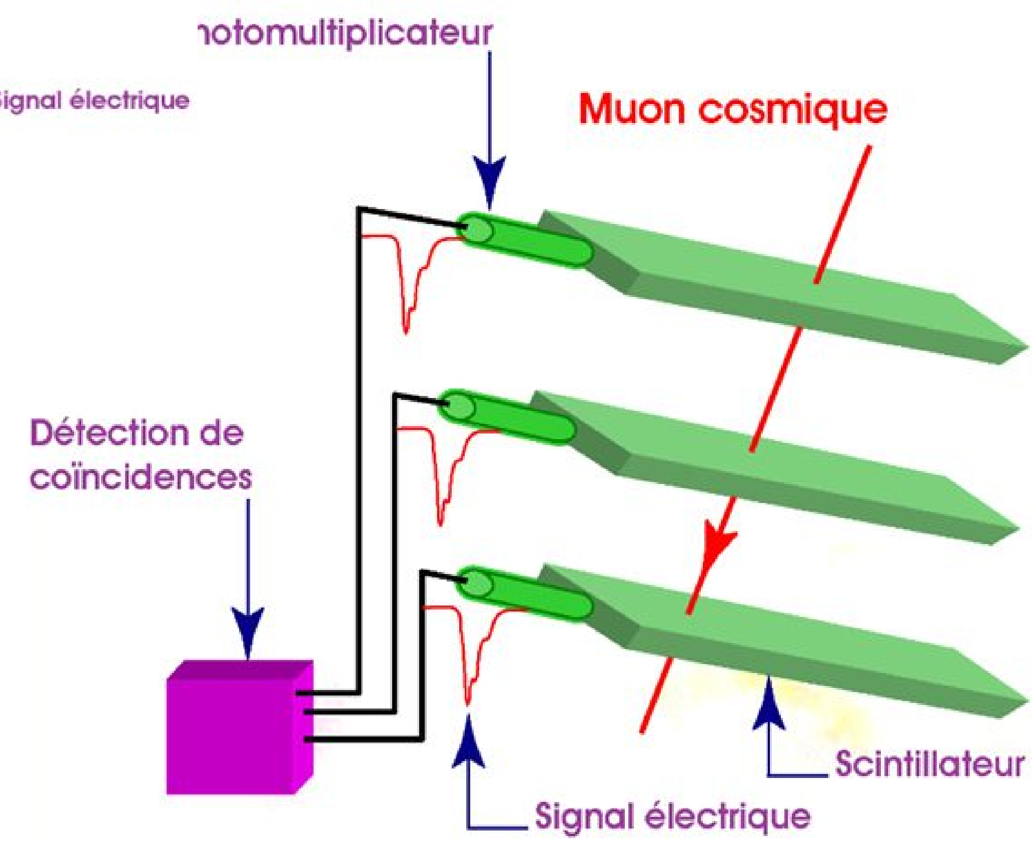
Detectors(Solid)

Scintillator

- Scintillation: atoms are excited by a muon
- Atoms are emitting photons which are detected by the photomultiplier.
- The scintillator is plastic (made from organic matter).



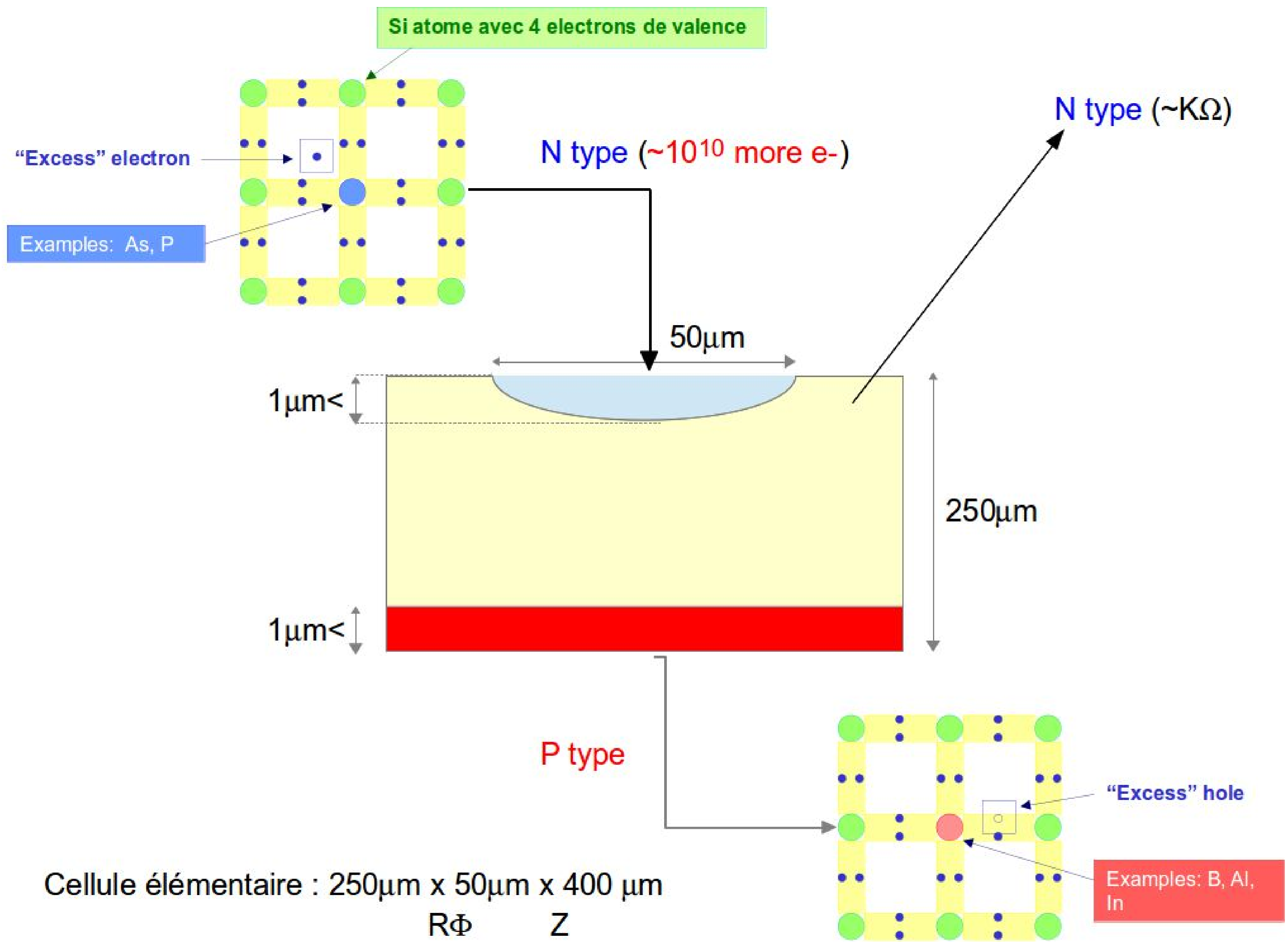




Detectors(Solid)

Silicon: Pixel

- Elementary cell

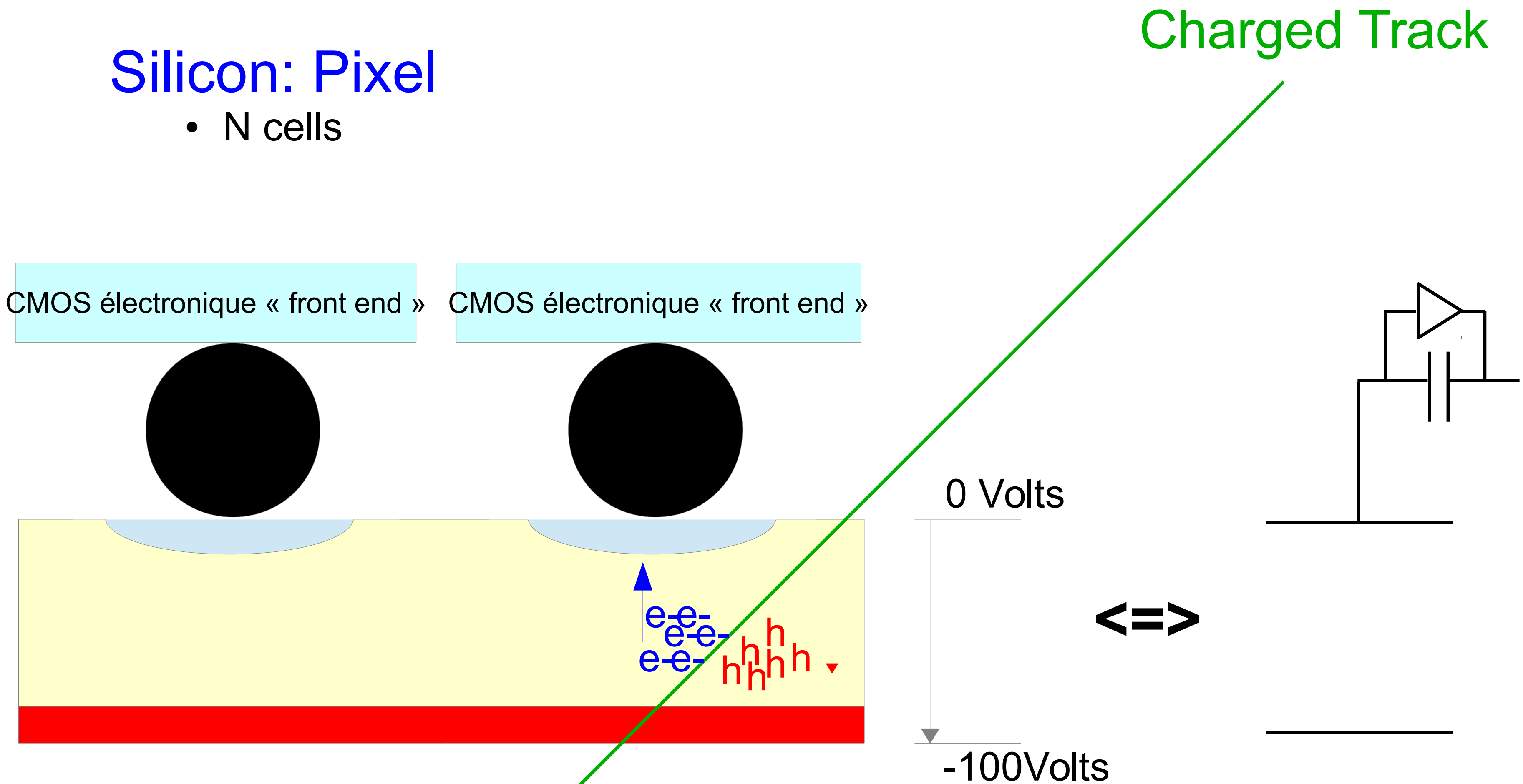


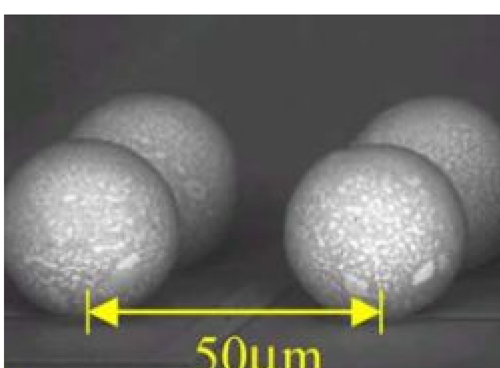
Cellule élémentaire : 250µm x 50µm x 400 µm
RΦ Z

Detectors(Solid)

Silicon: Pixel

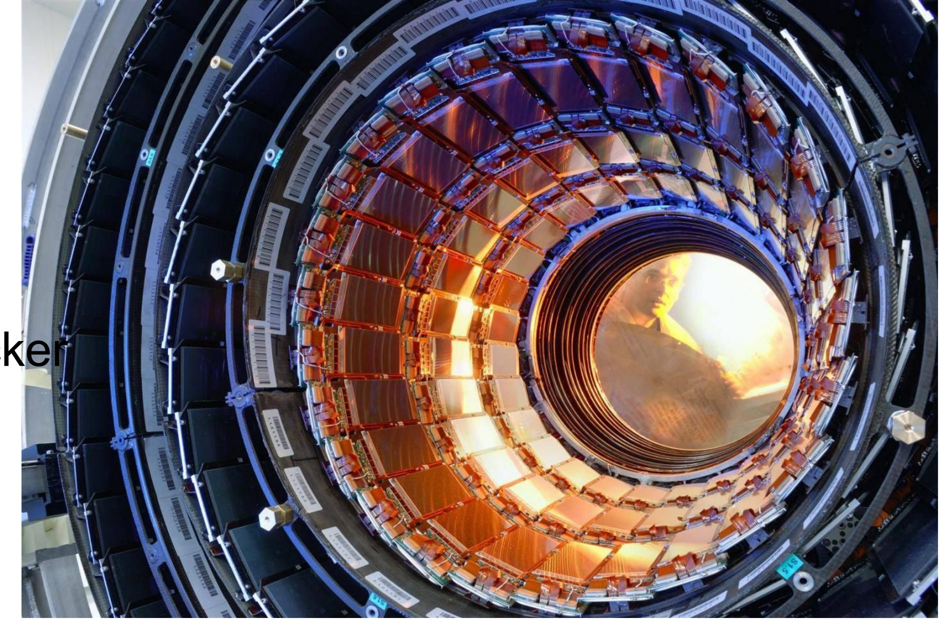
- N cells





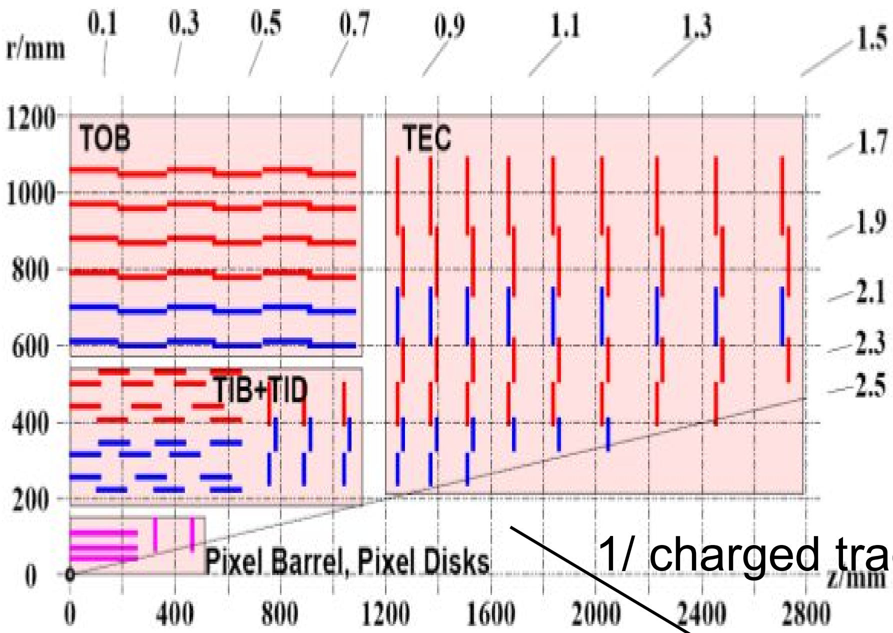
- ~20000 electrons per track
- Times electron collection ~ 5ns

Detectors(Solid)



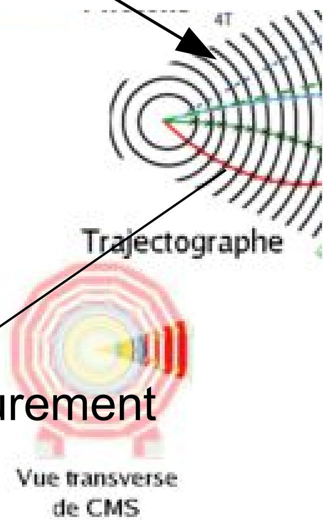
Silicon Tracker: CMS

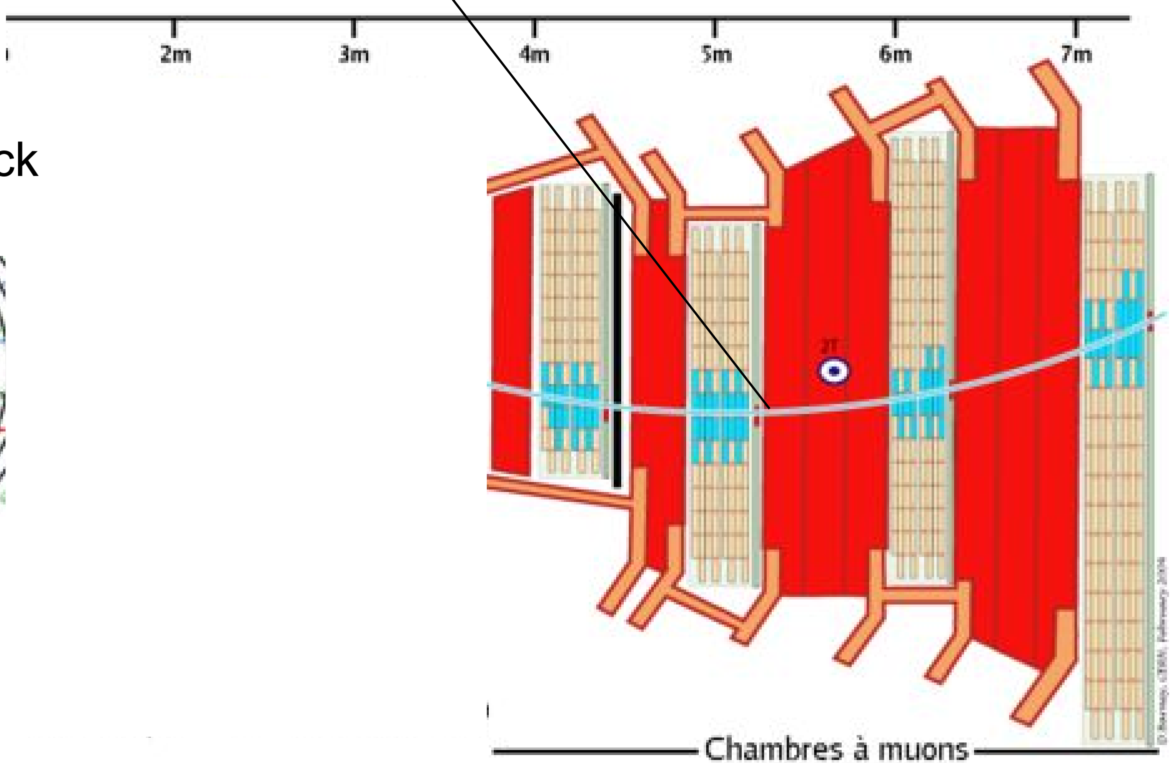
- 11 layers
- 200 m^2 of active silicon for CMS tracker



2/ Muon confirmation

1/ charged track





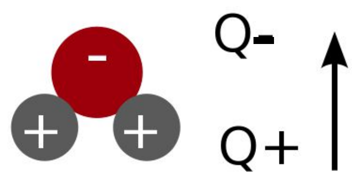
3/ Muon momentum measurement

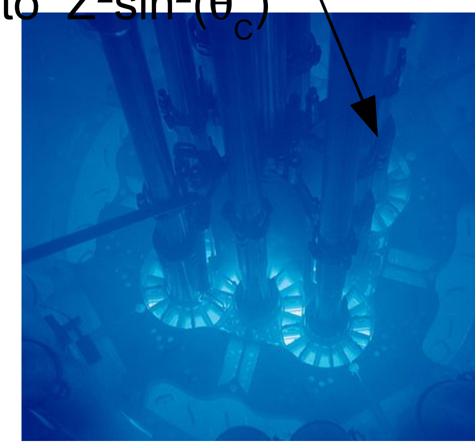
Detectors(Liquid)

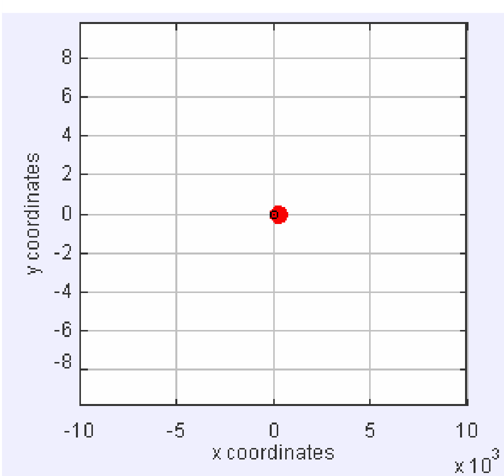
Detectors(Liquid)

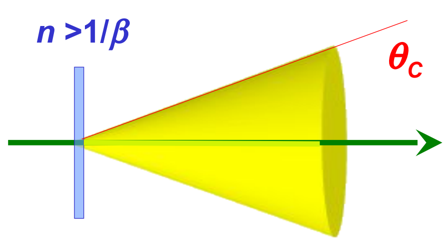
Cherenkov radiation: Photo Multiplier (PM)

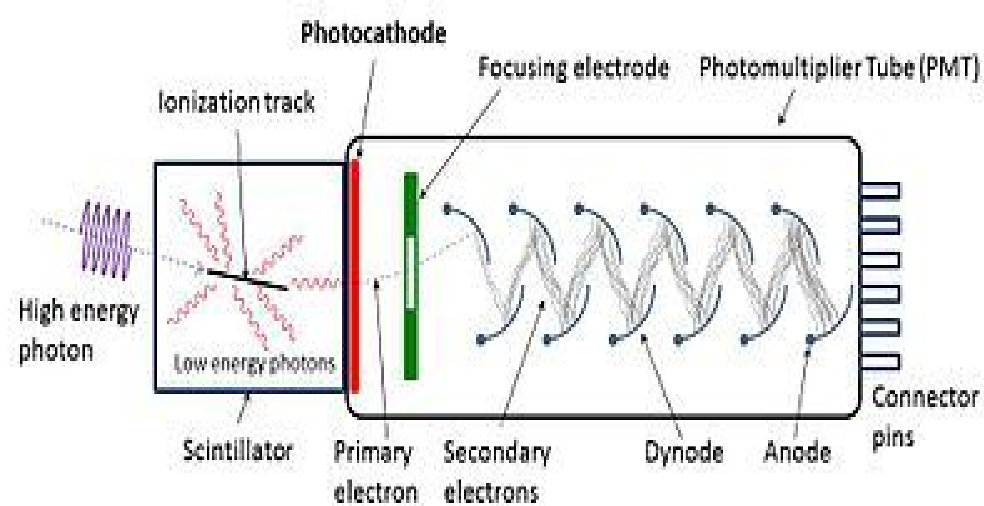
- Relativistic charged particles through a medium of refractive index $n > 1 / \beta$
- Relativistic means that the particle moves faster than the light in the medium
- Cherenkov radiation is tangent to a cone θ_C around the trace: $\cos(\theta_C) = 1 / n\beta$
  - Radiation is due to the polarization of the medium and a dynamic variation of the dipole moment of the molecules of the medium (ie water)
  - Number of photons (Frank-Tamm) is proportional to $Z^2\sin^2(\theta_C)$







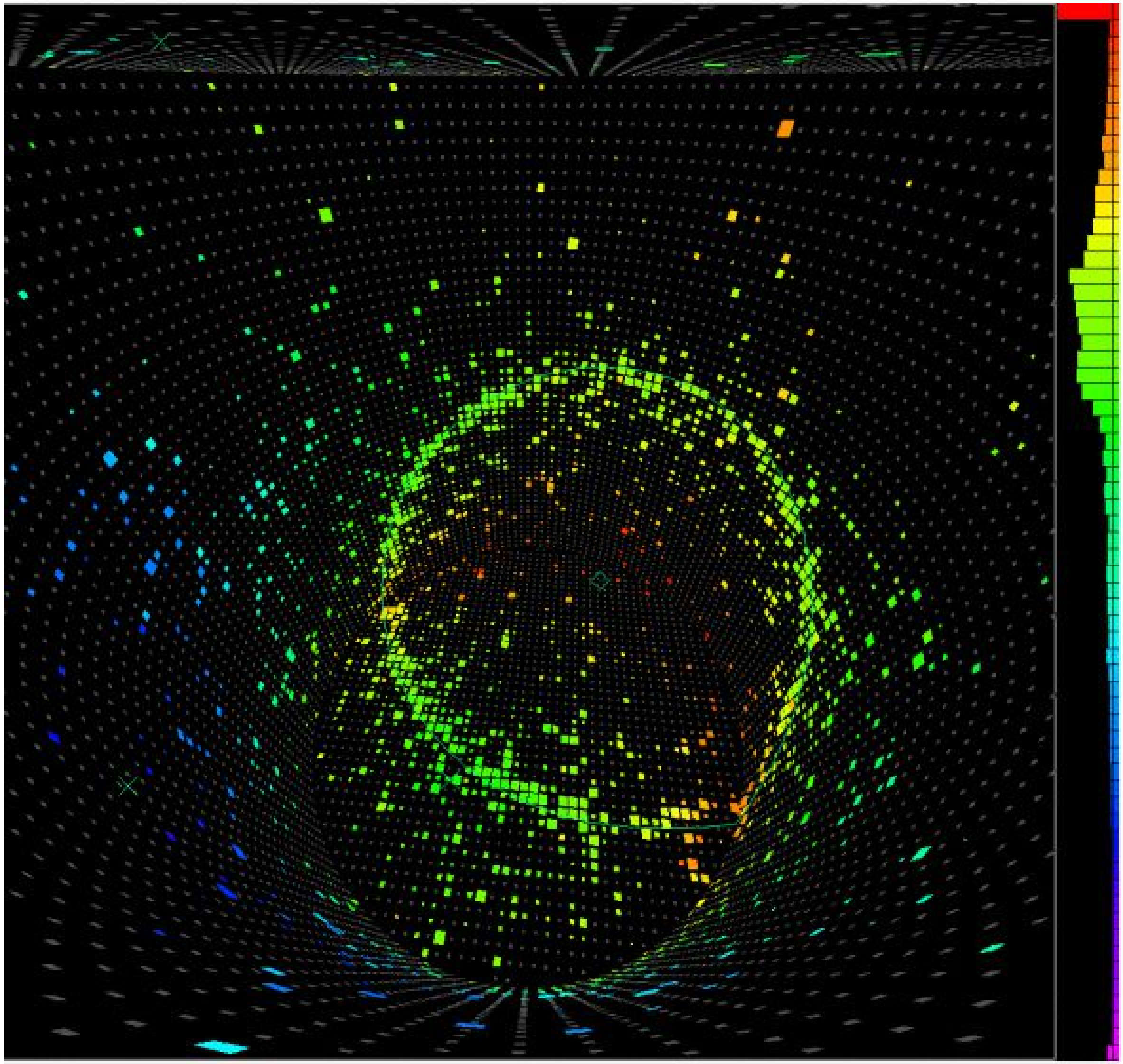




Detectors(Liquid)

Photo Multiplier: Cherenkov radiation

- Mini-Boon

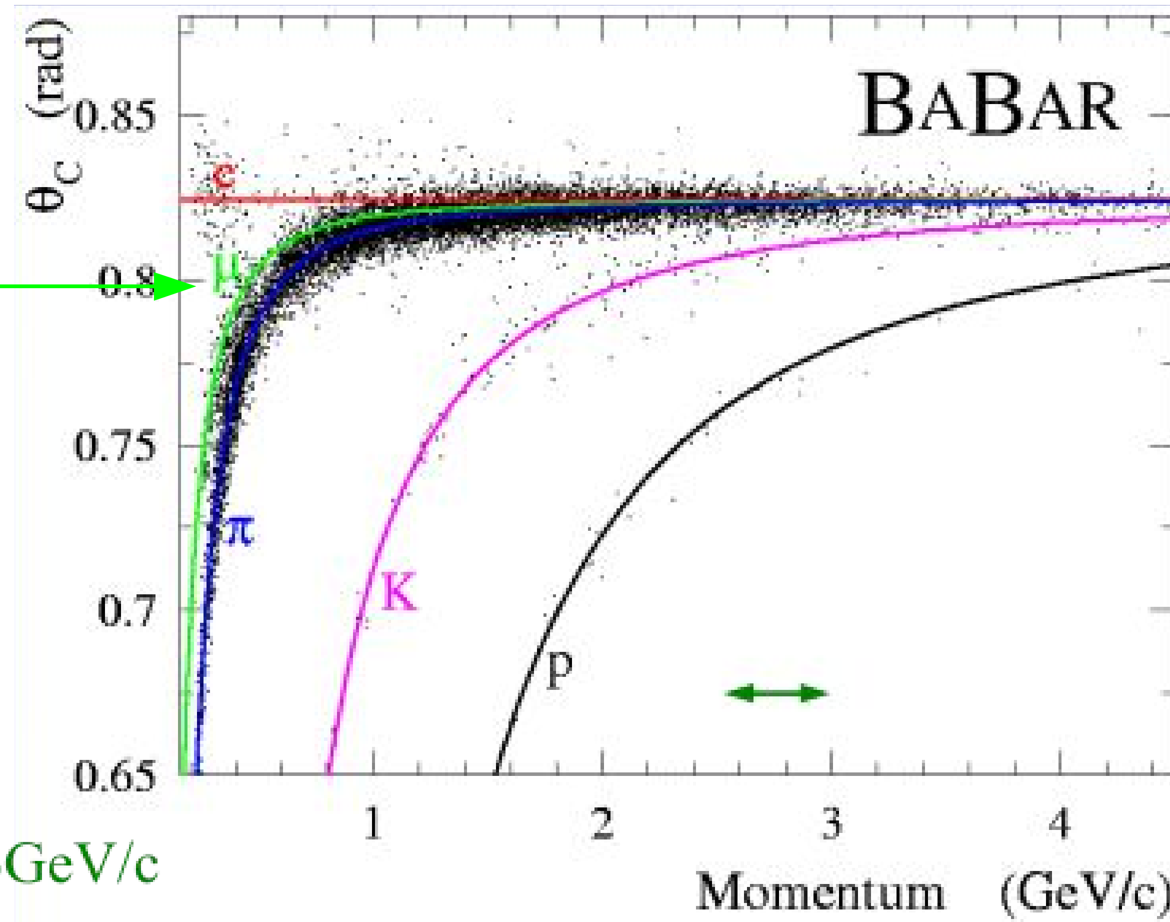


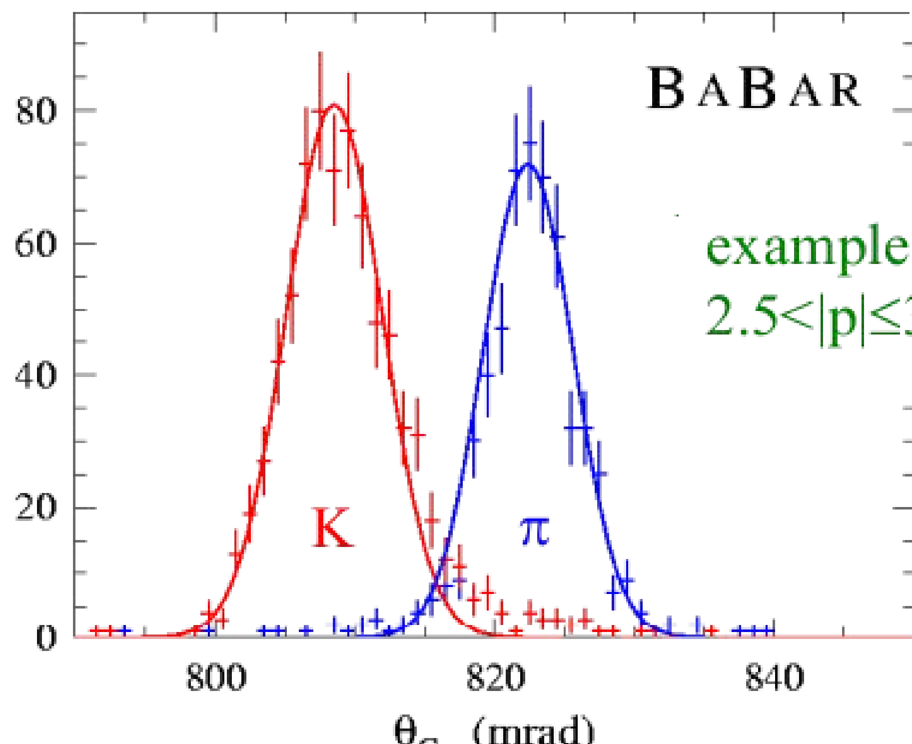
Detectors(Liquid)

Photo Multiplier: Cherenkov radiation

- Babar identification

Muon



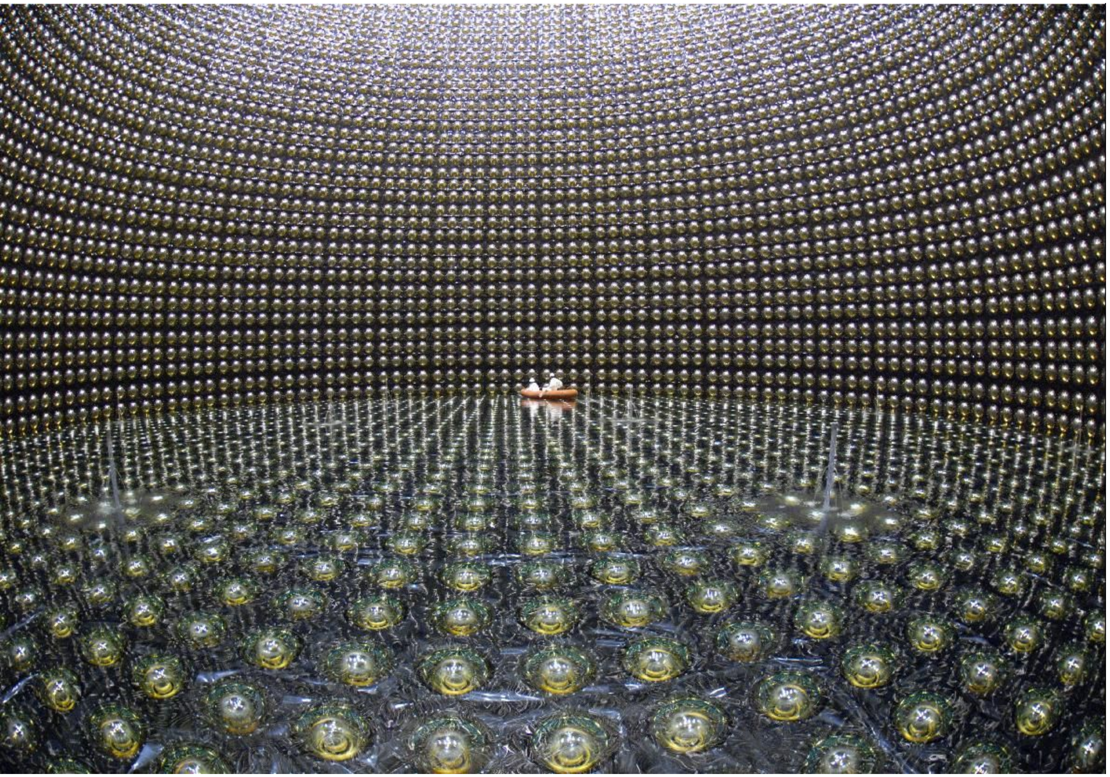


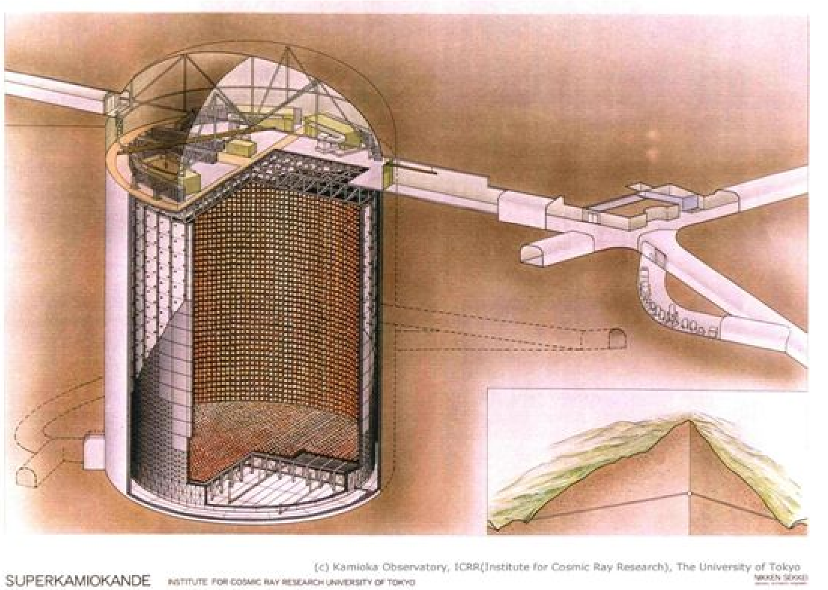
example:
$2.5<|p|\leq 3$GeV/c

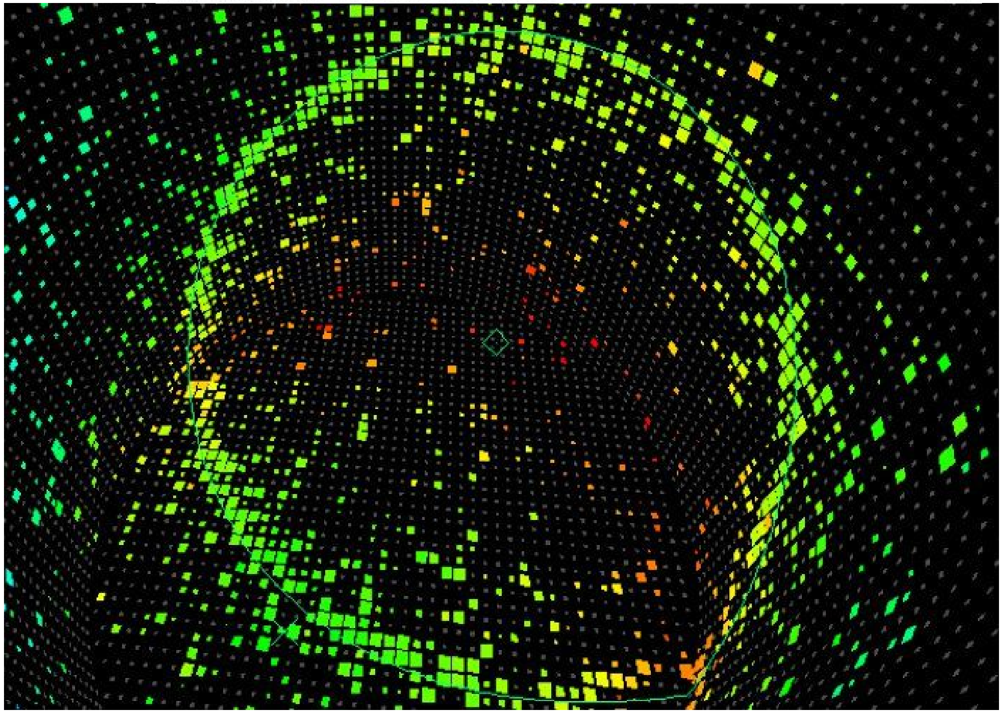
Detectors(Liquid)

Photo Multiplier: Cherenkov radiation

- T2K





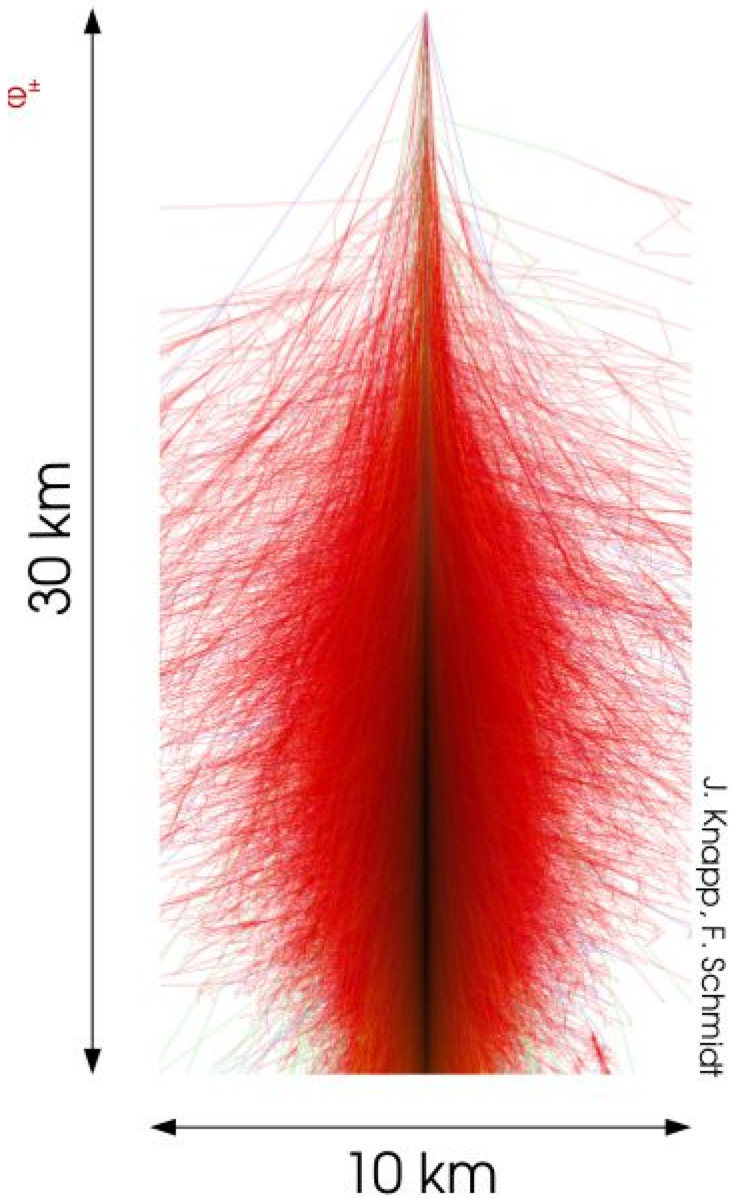


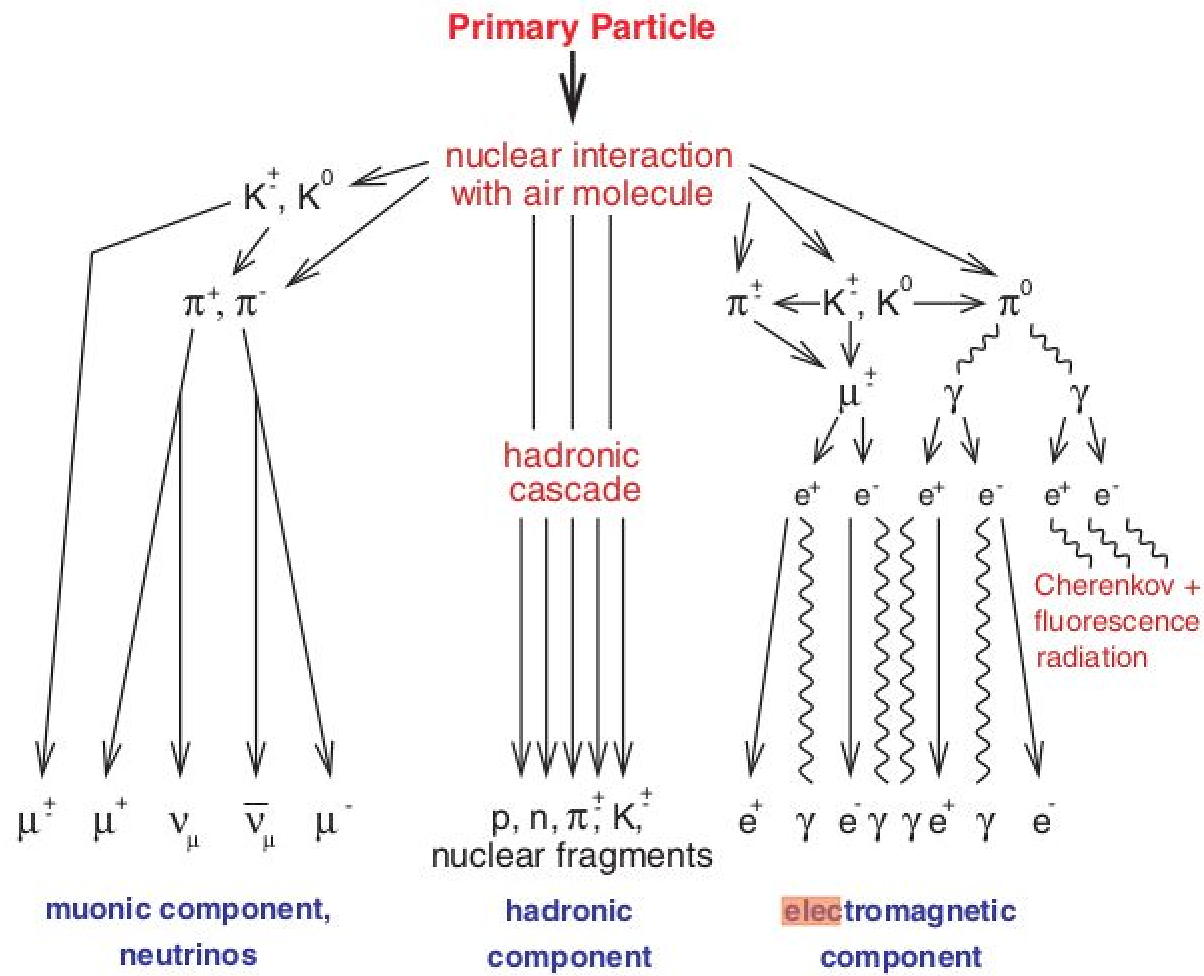
Detectors(Liquid)

Francois Montanet
Experimental astroparticle physics

Photo Multiplier: Cherenkov radiation

- Back to Cosmics



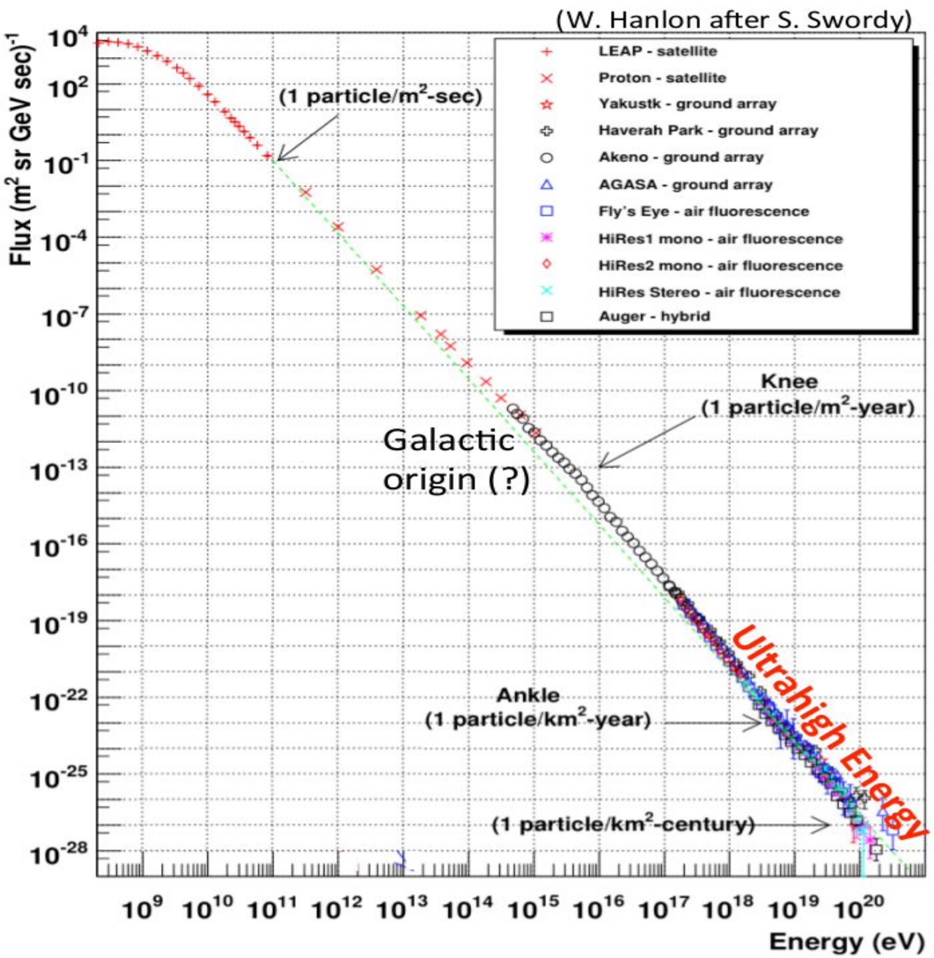


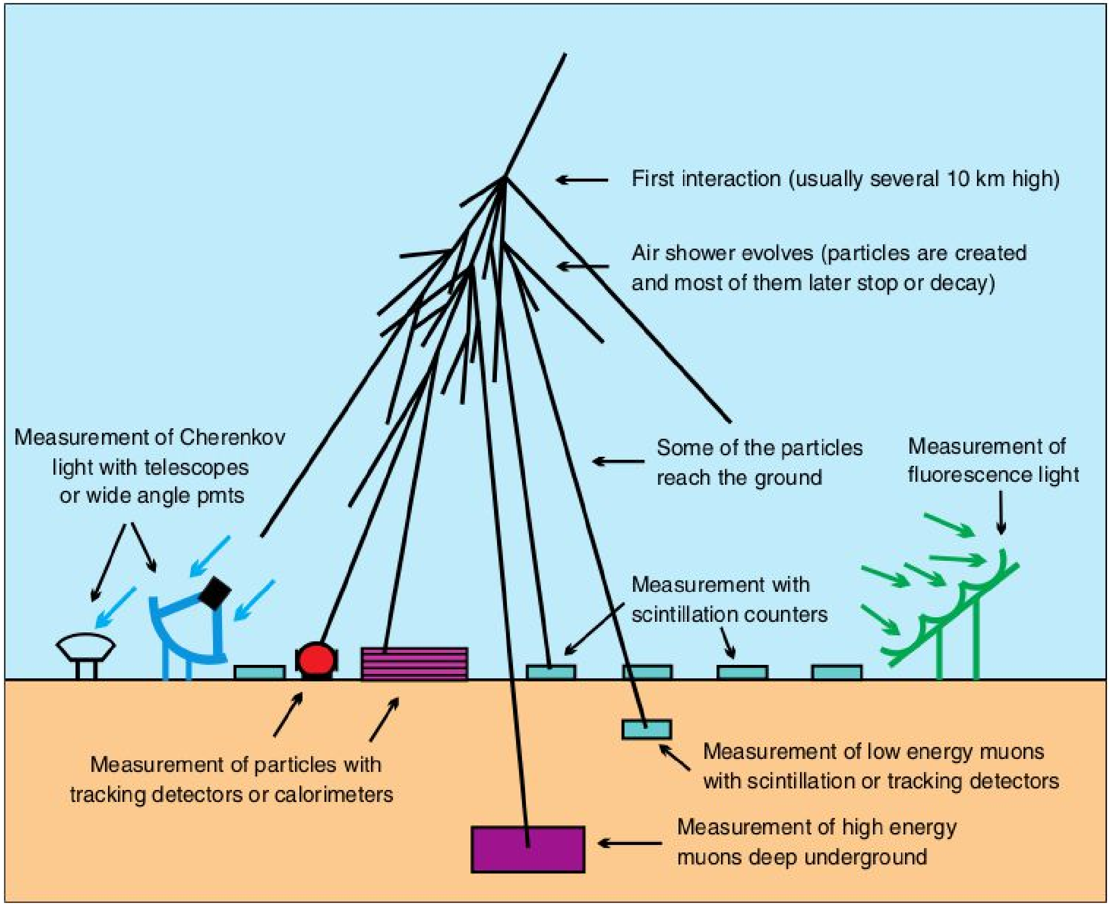
Detectors(Liquid)

Francois Montanet
Experimental Astroparticle Physics

Photo Multiplier: Cherenkov radiation

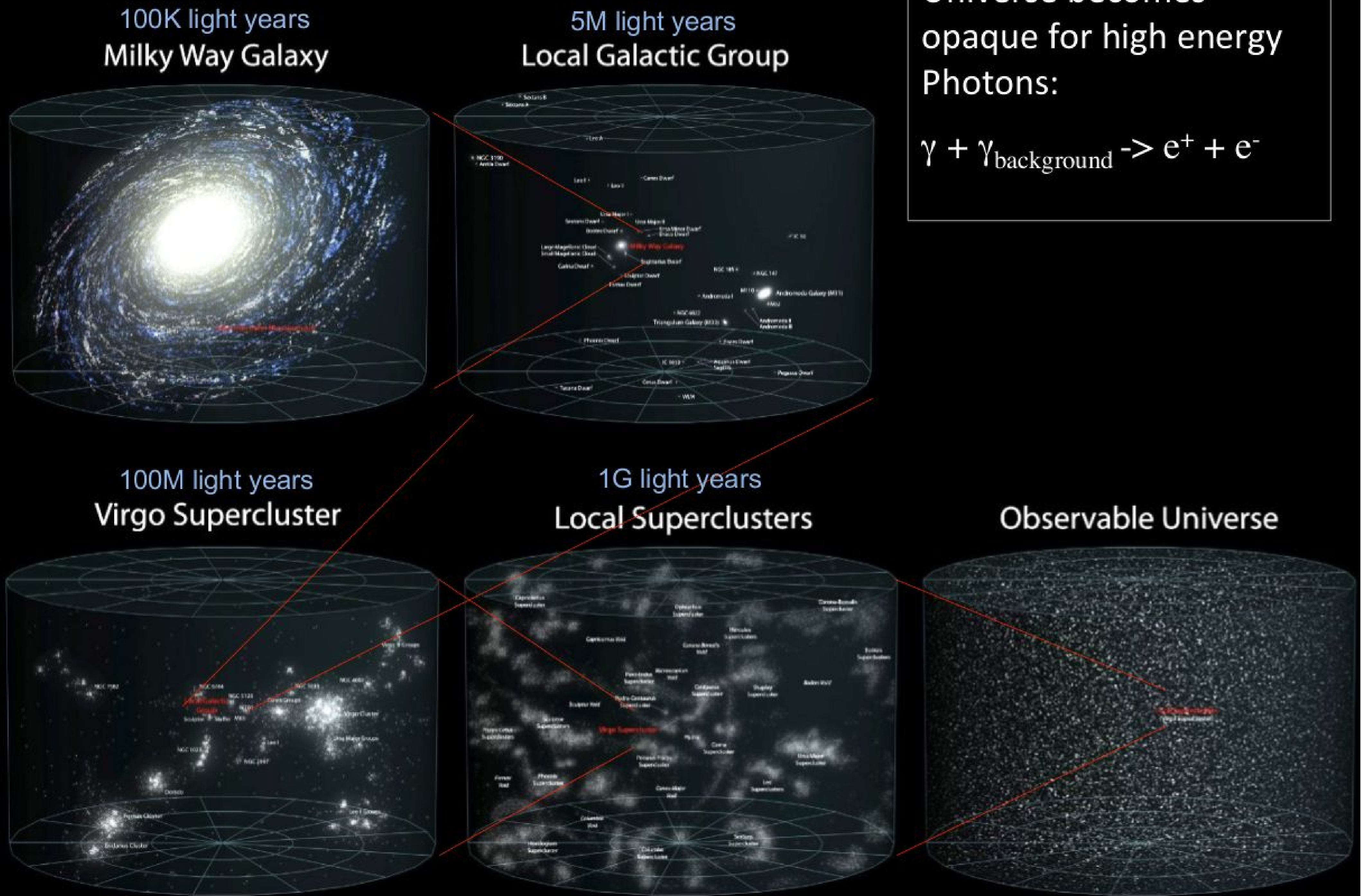
- Back to Cosmics

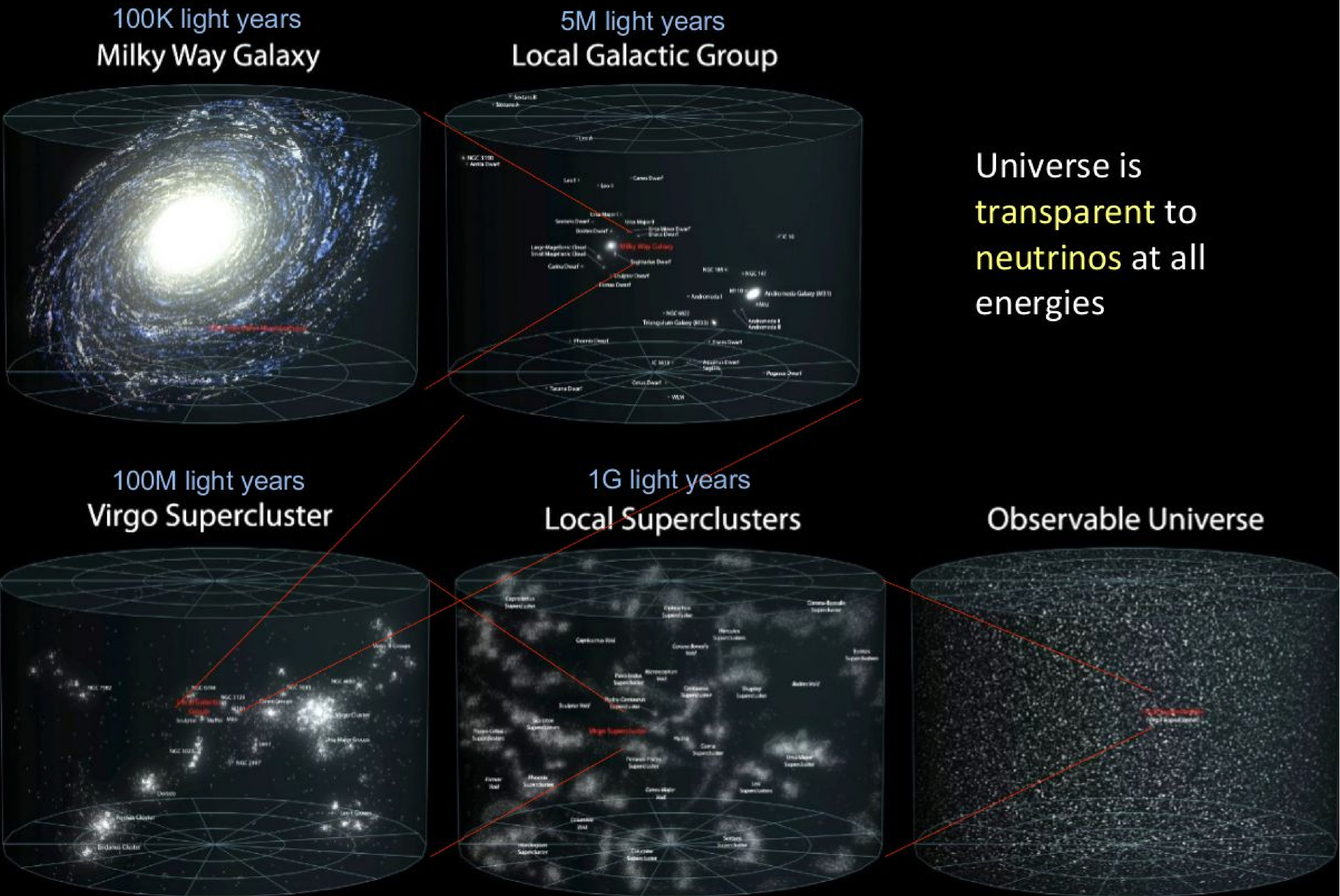




Universe becomes opaque for high energy Photons:

$\gamma + \gamma_{background} \rightarrow e^+ + e^-$

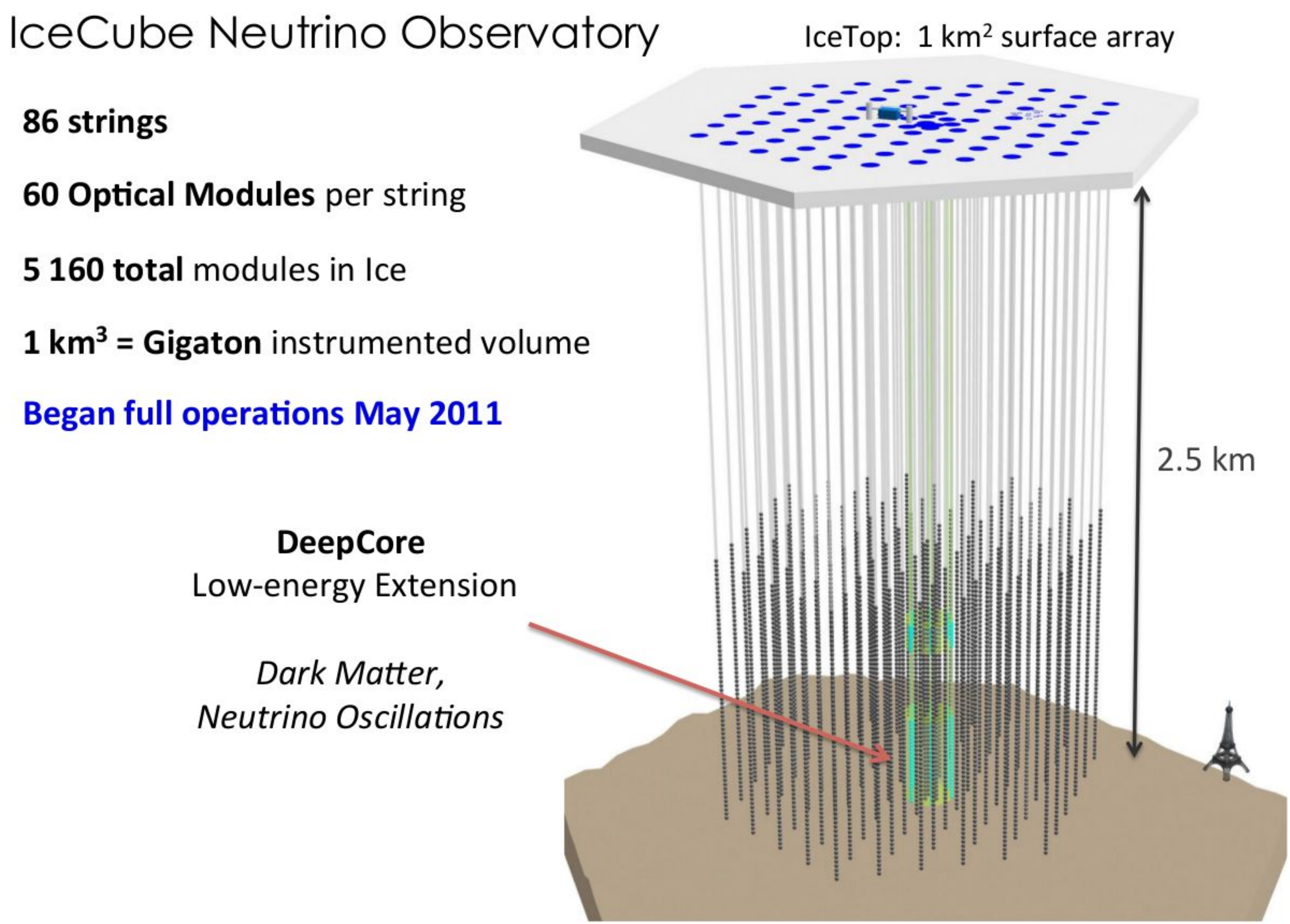


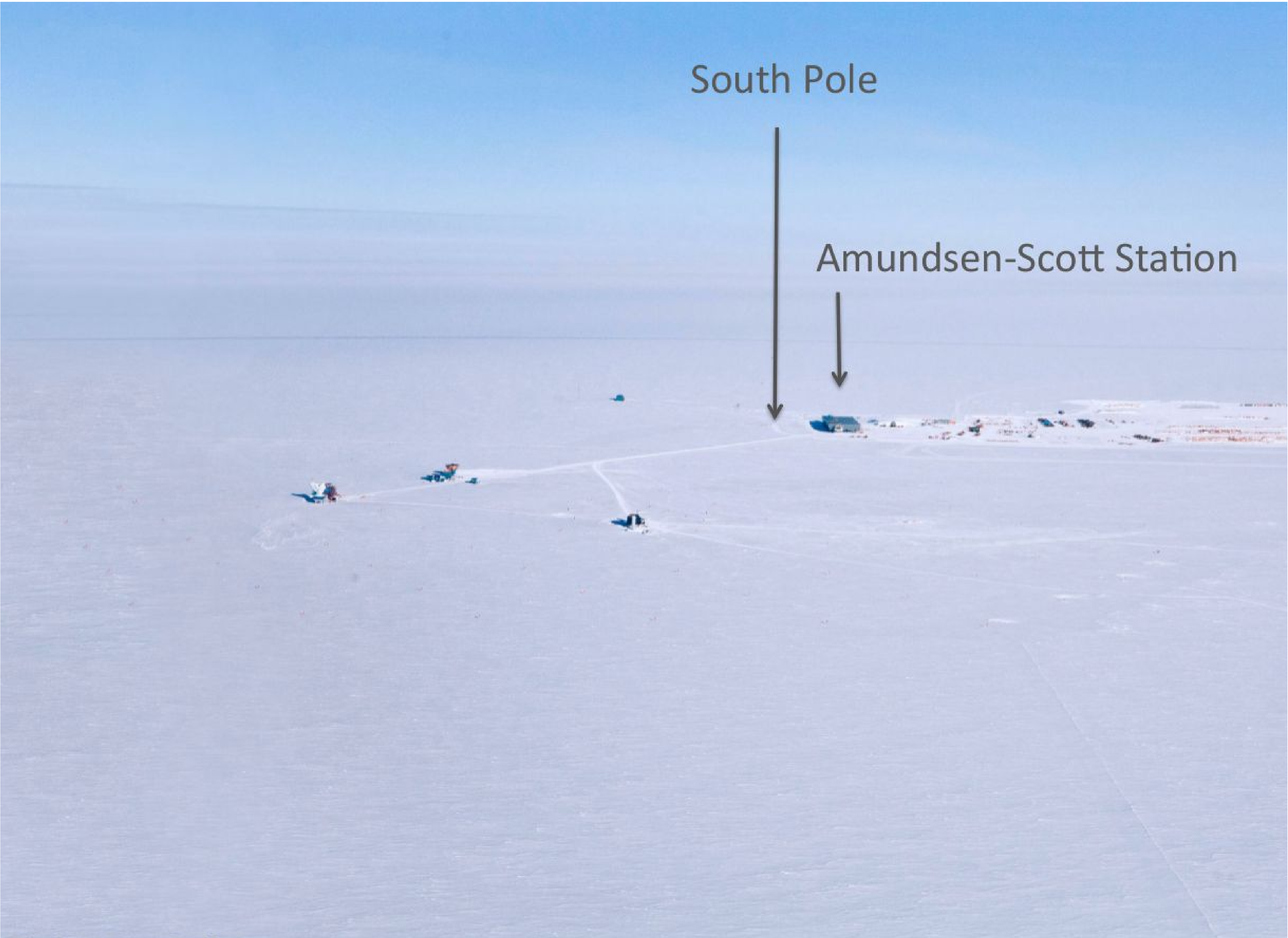

100K light years
Milky Way Galaxy
5M light years
Local Galactic Group
Universe is transparent to neutrinos at all energies
100M light years
Virgo Supercluster
1G light years
Local Superclusters
Observable Universe

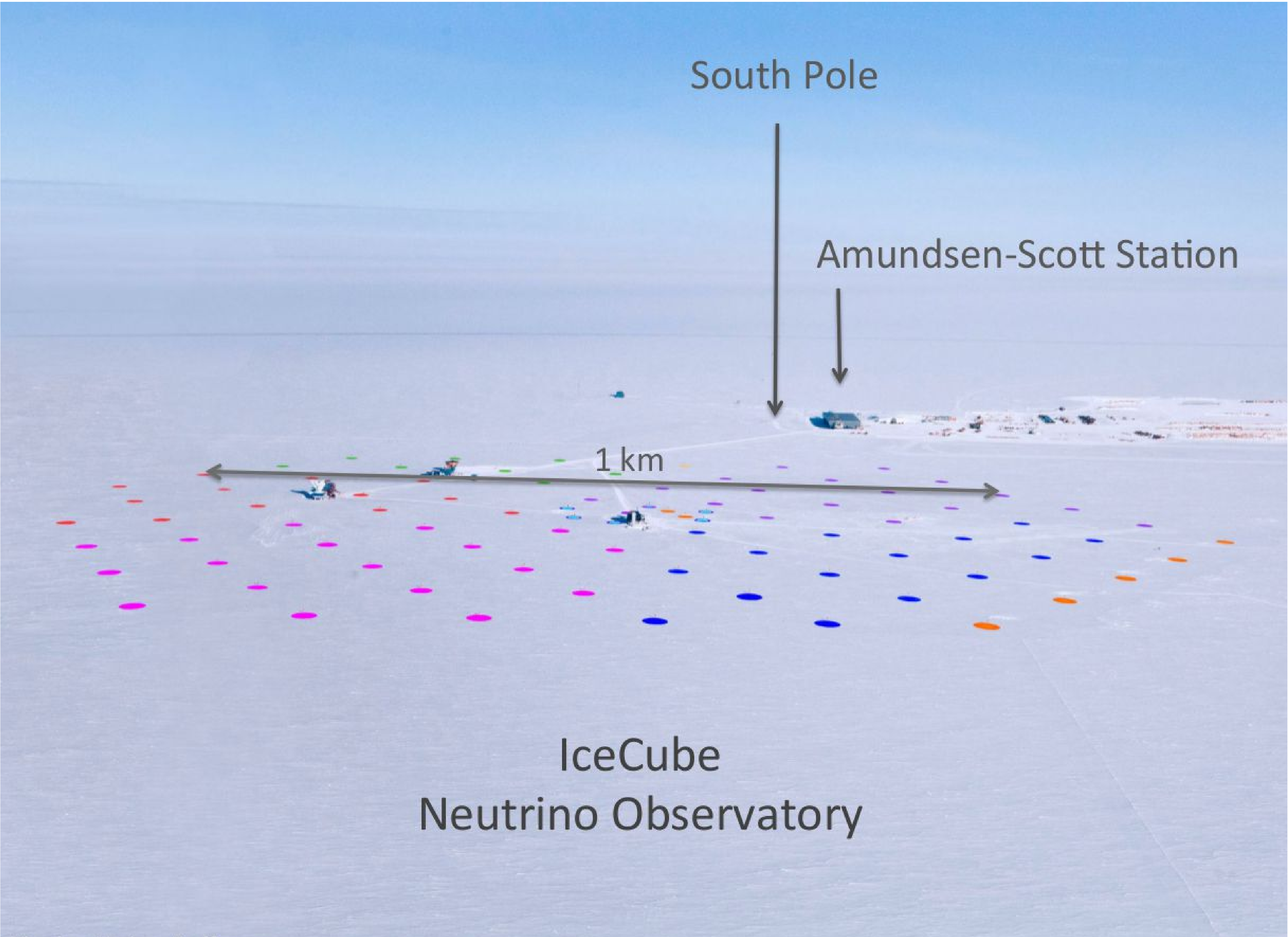
Detectors(Liquid)

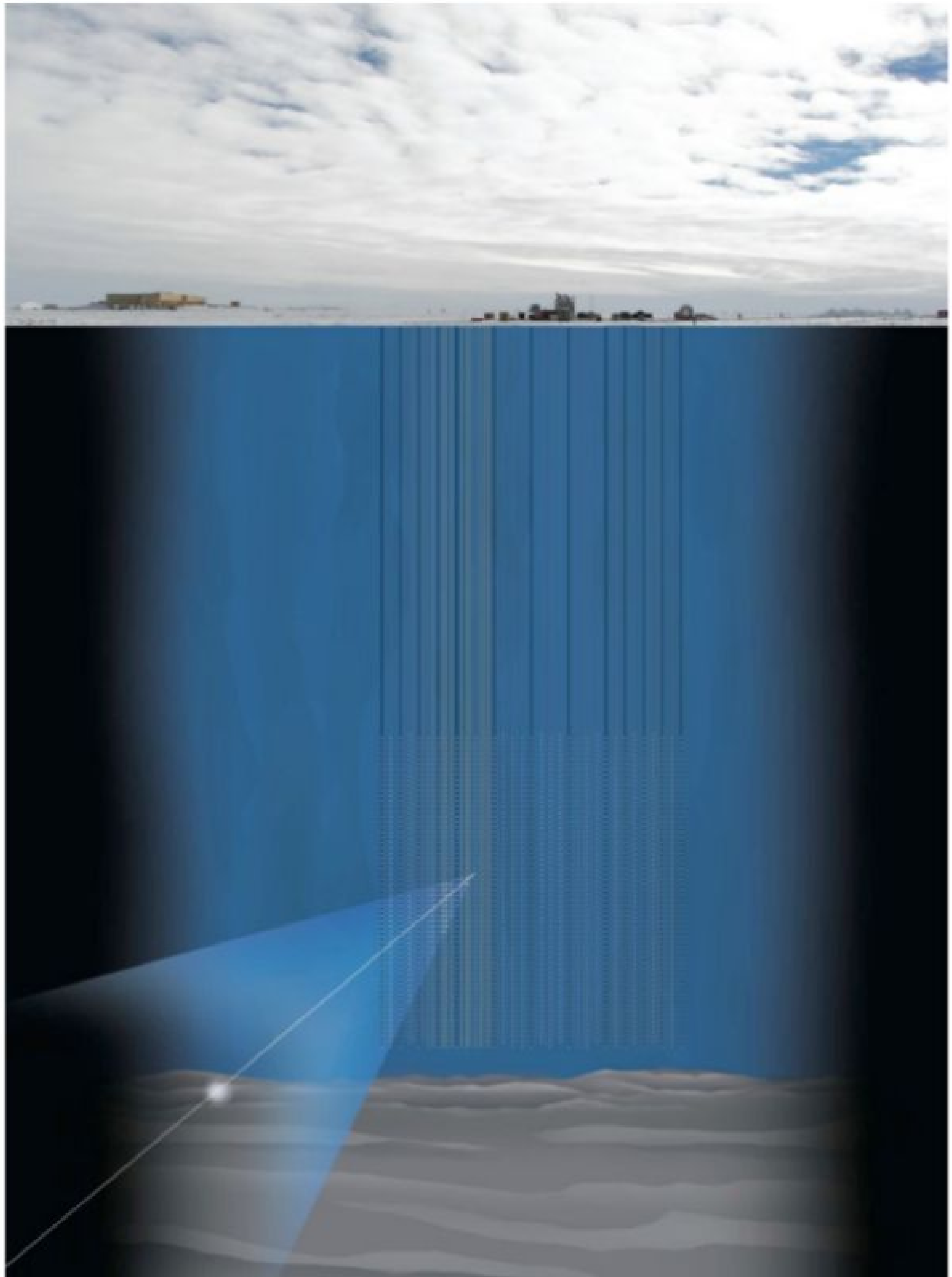
Photo Multiplier: Cherenkov radiation

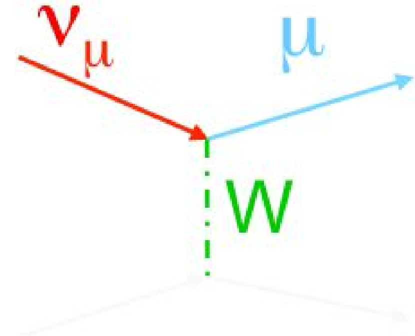
- The muon is detected via Cherenkov radiation in the water or ice



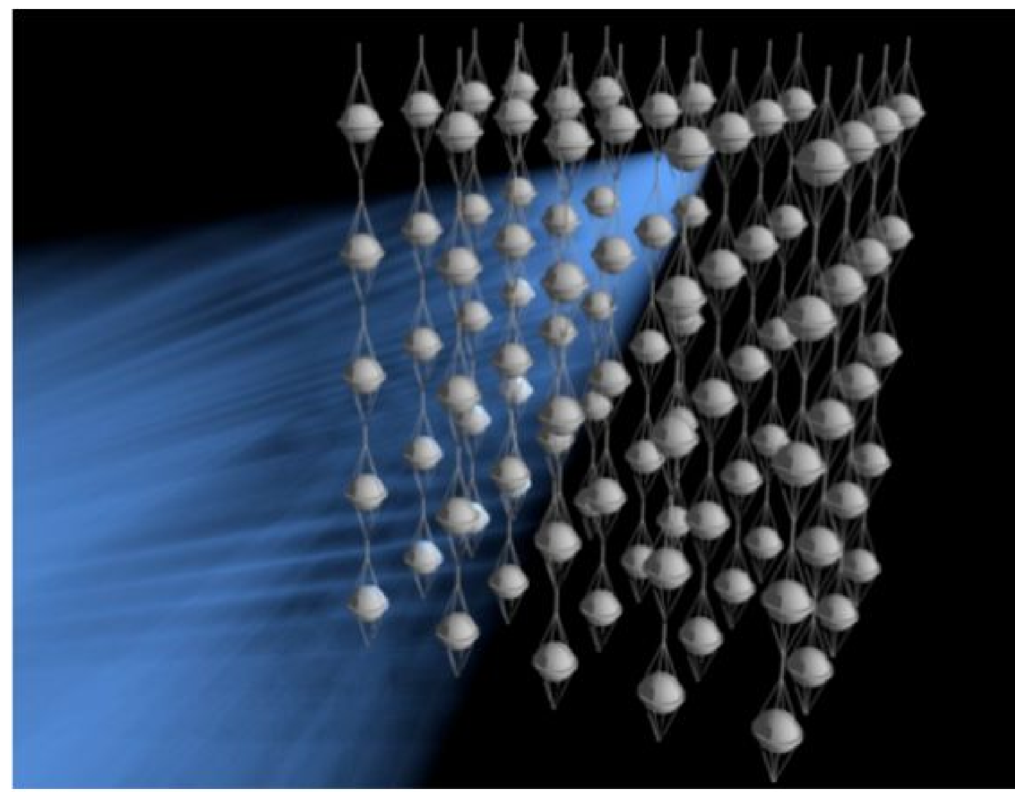

South Pole
Amundsen-Scott Station

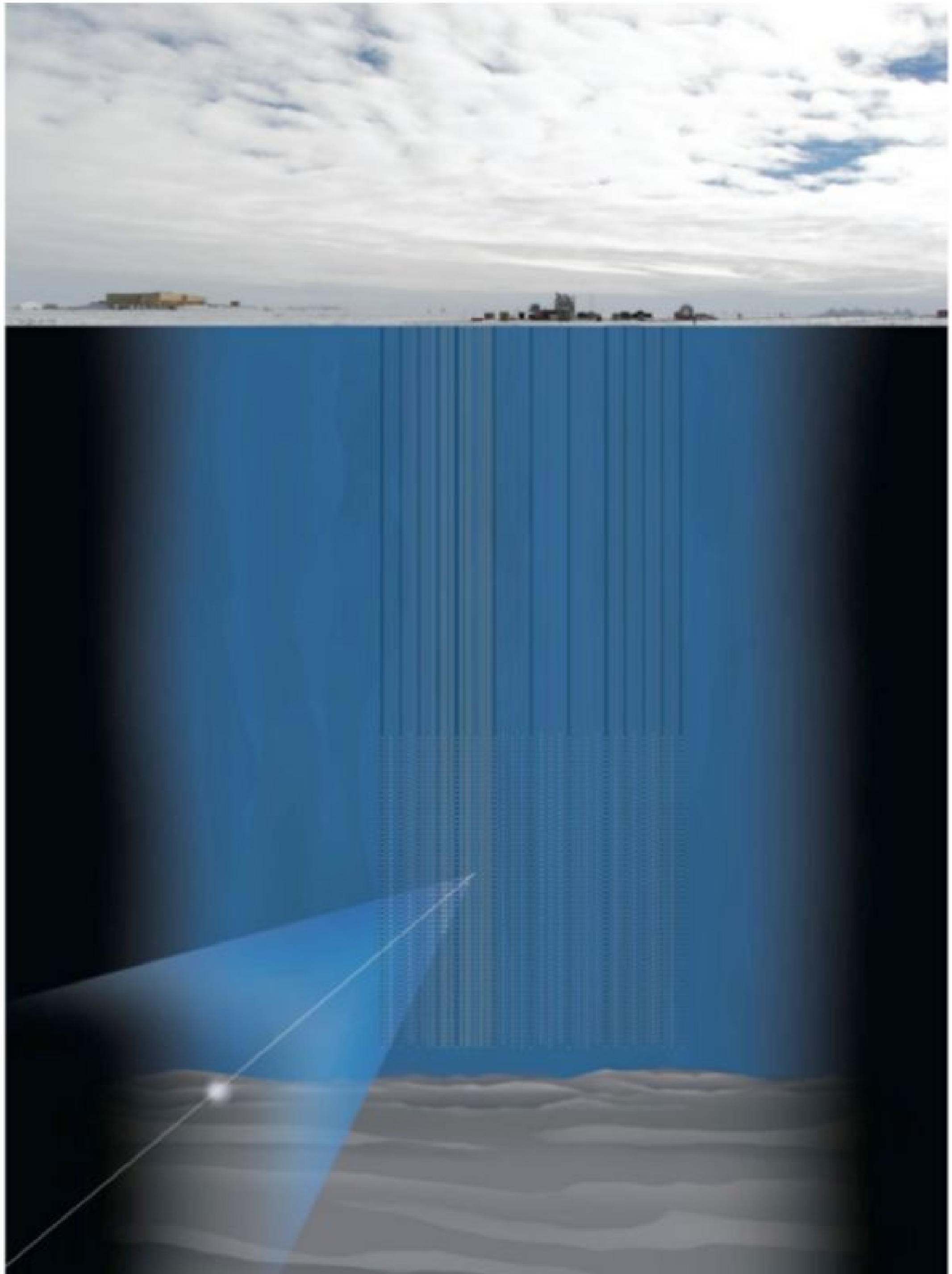

South Pole
Amundsen-Scott Station
1 km
IceCube
Neutrino Observatory

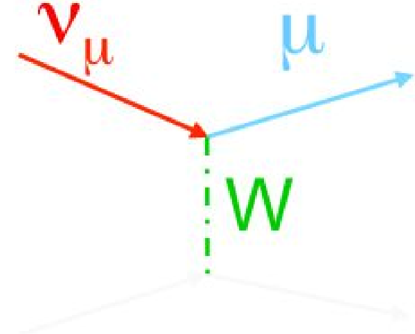


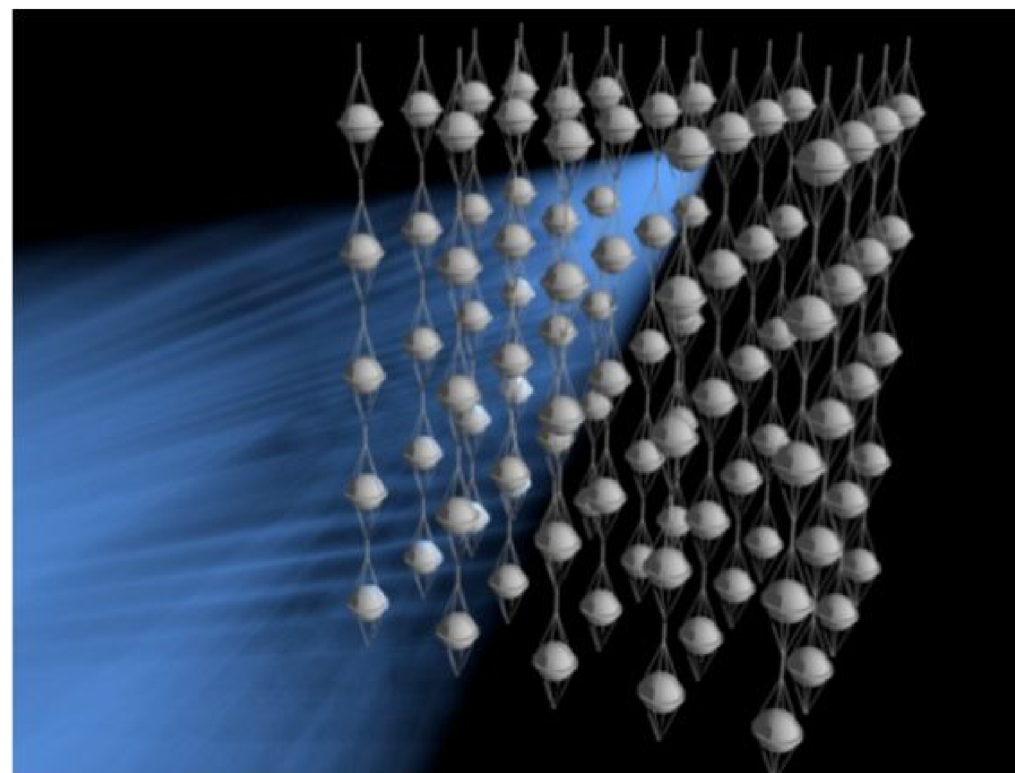


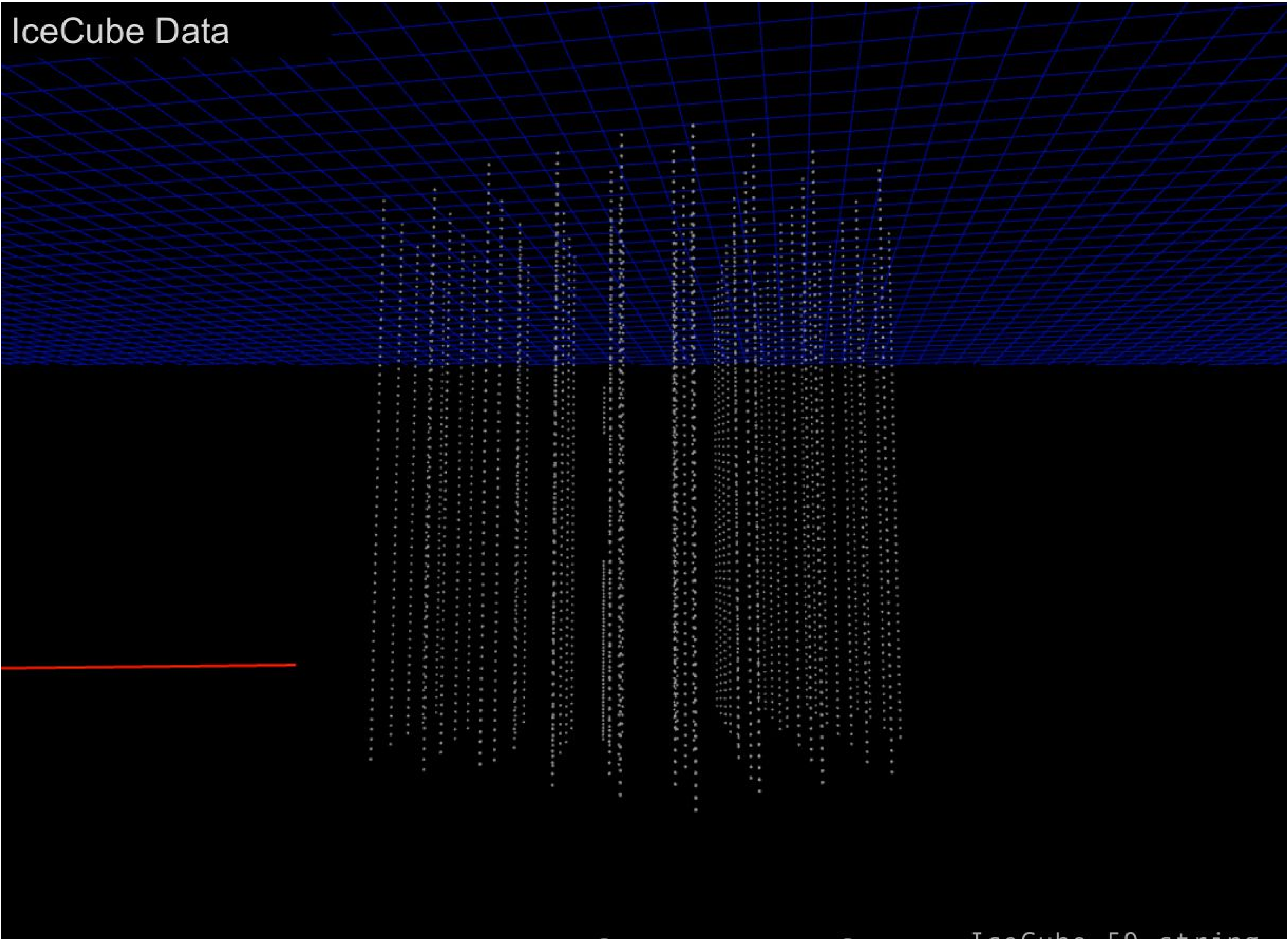
ν_μ
μ
W

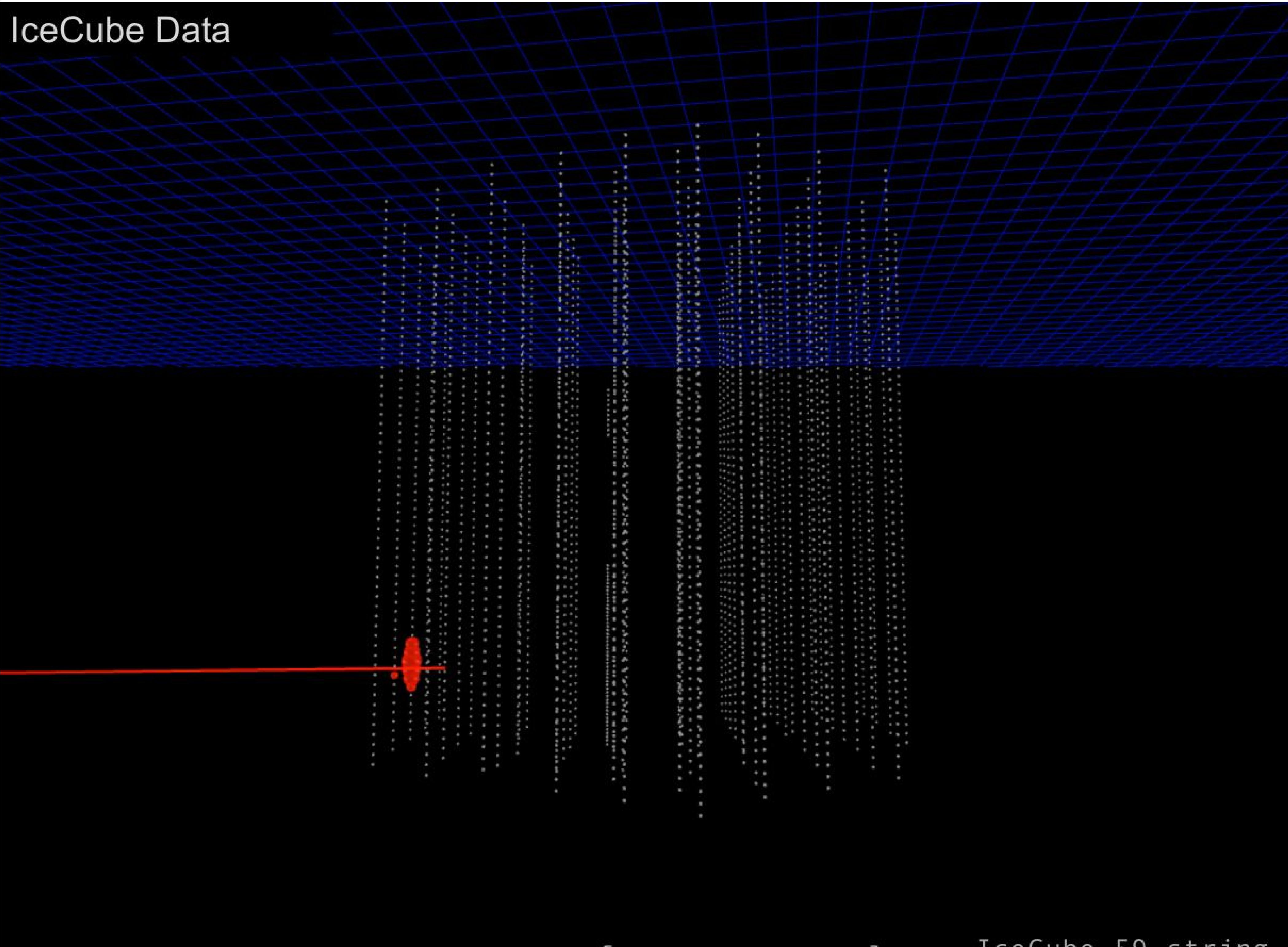


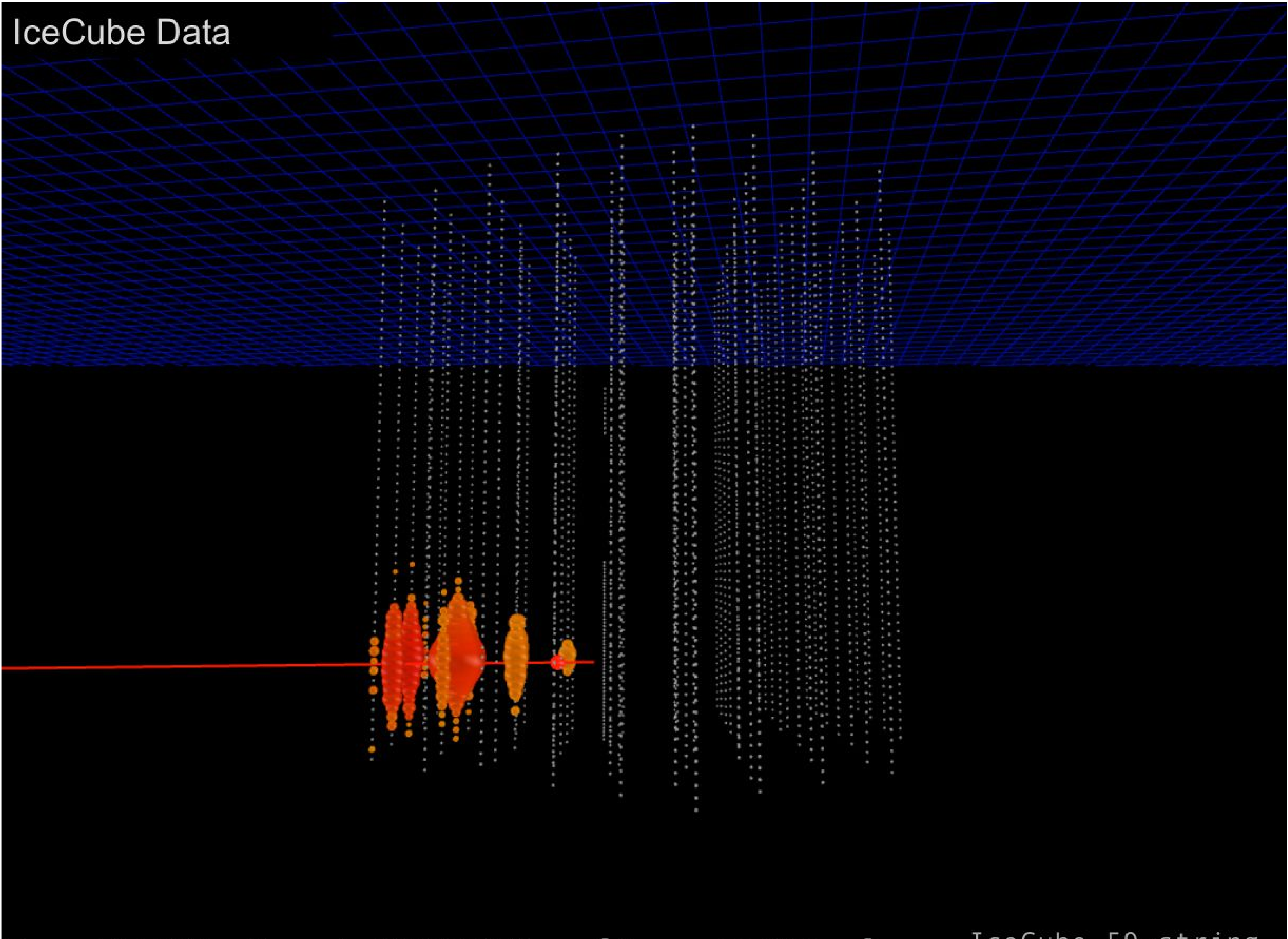


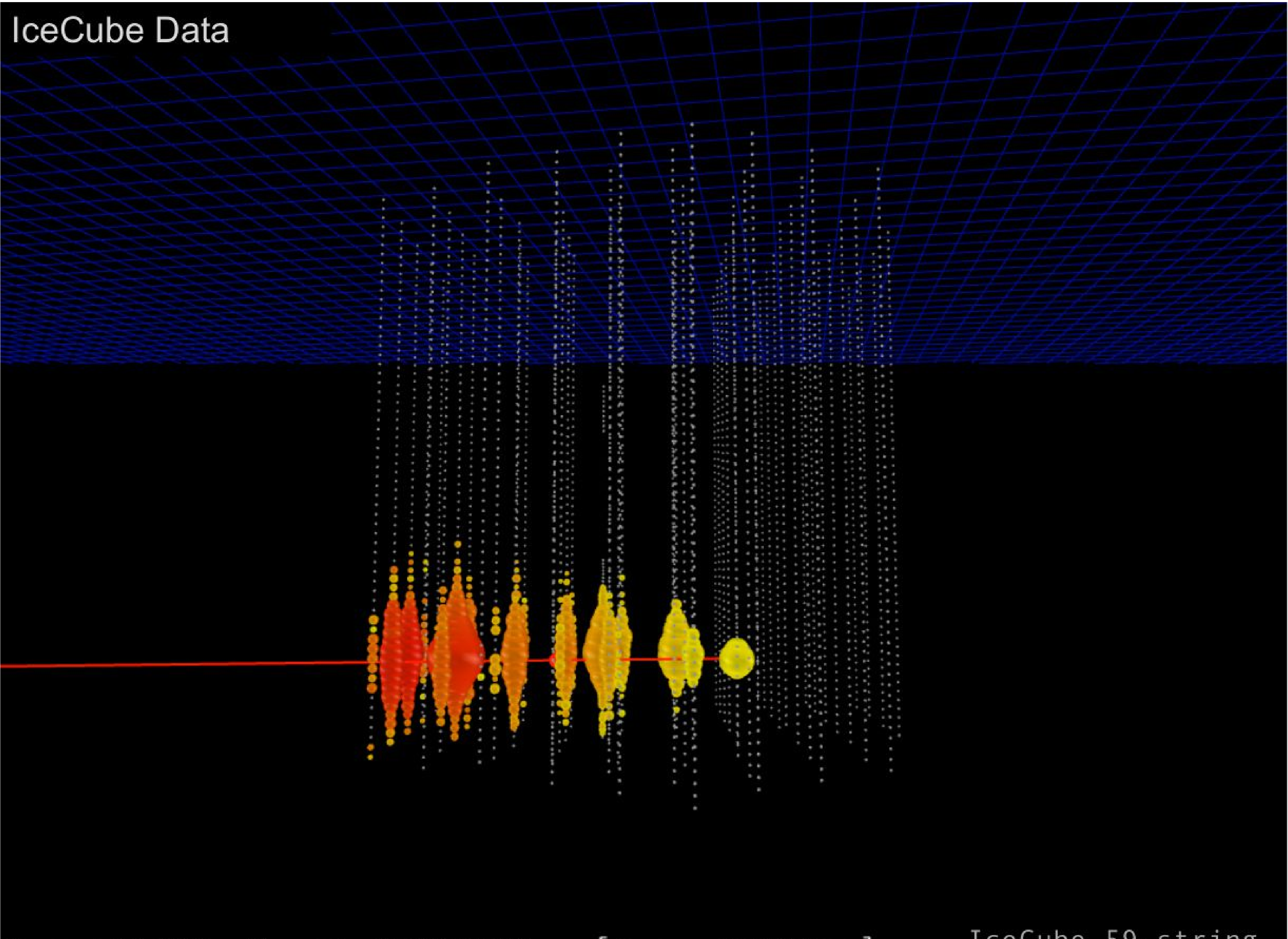

νμ
μ
W

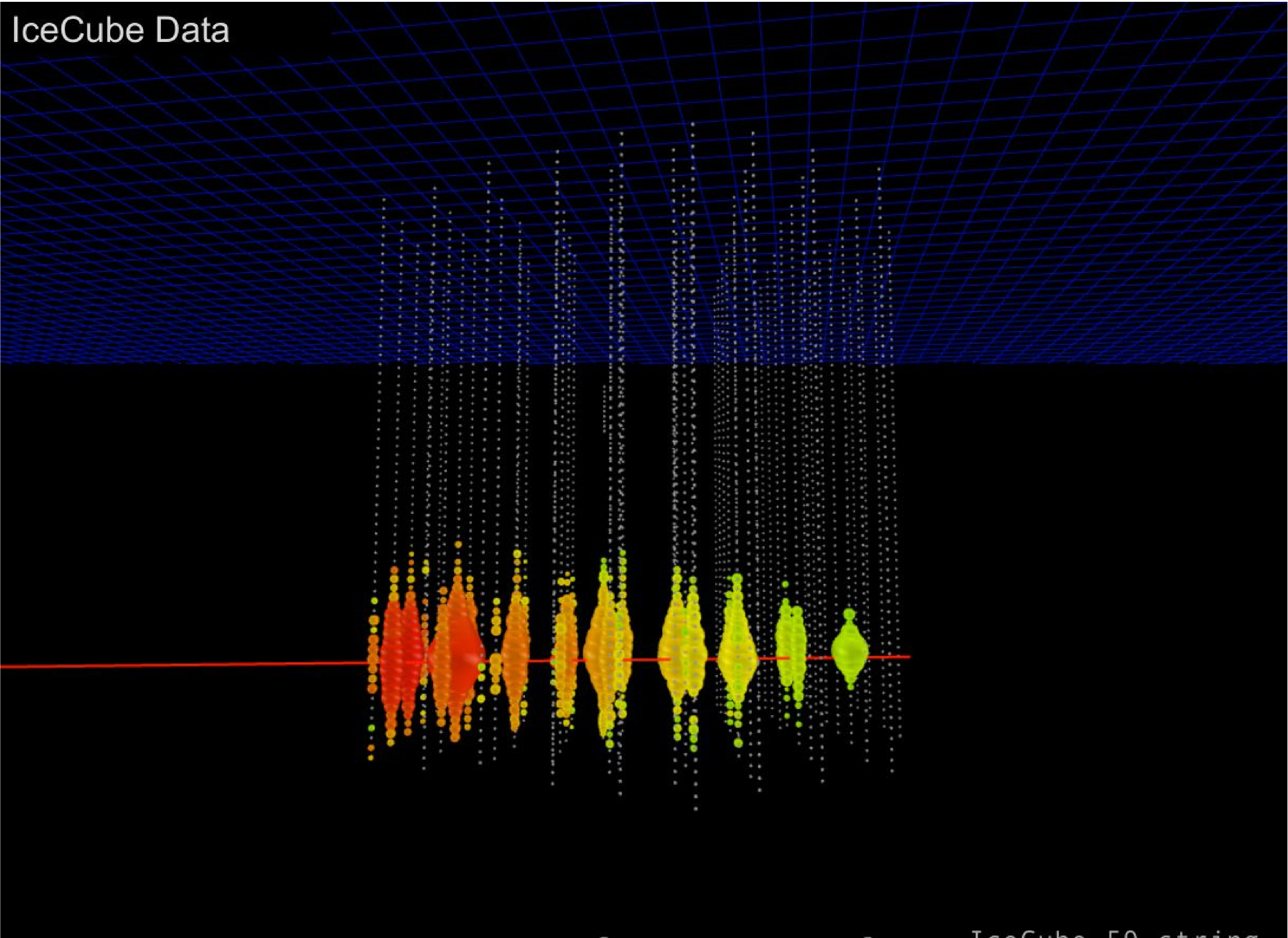


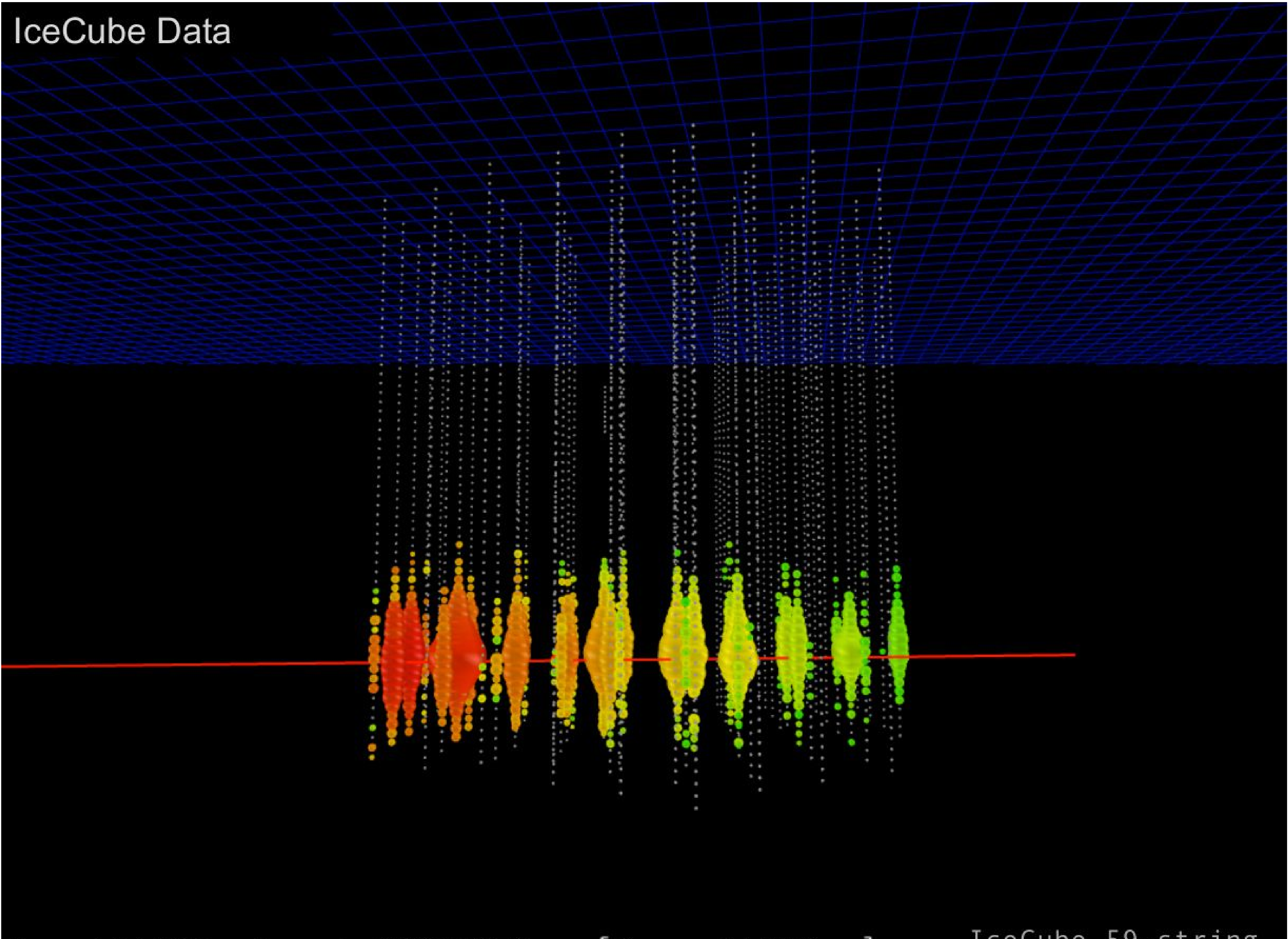

IceCube Data


IceCube Data


IceCube Data


IceCube Data

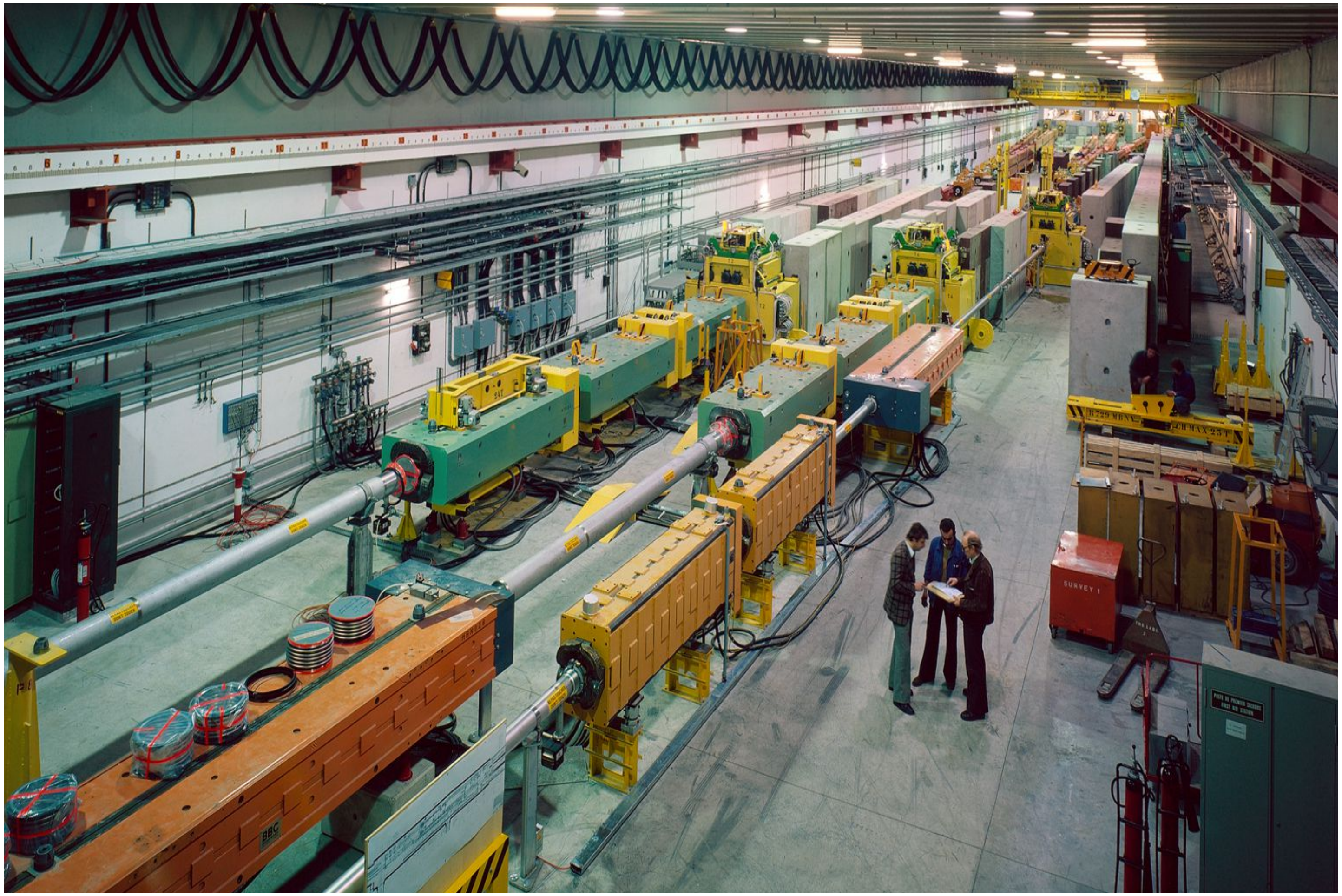

IceCube Data


IceCube Data

Muon

Beam

- In accelerators muons are abundantly produced in hadronic interactions
  - $pp \rightarrow \pi + \ldots$ and $\pi \rightarrow \mu \nu_{\mu}$
- Today muon beams are available at many places in Europe, Asia, and America.
- High energy muon beams, e.g., at CERN SPS, FNAL
- Low/medium energy: PSI, TRIUMF, Los Alamos, BNL, DUBNA, RAL, …



Muon

Muon cooling for a Higgs Factory at CERN ?

New boson sparks call for 'Higgs factory'

physicsworld.com
BEST SPECIALIST SITE FOR JOURNALISM 2011

Jul 5, 2012 15 comments

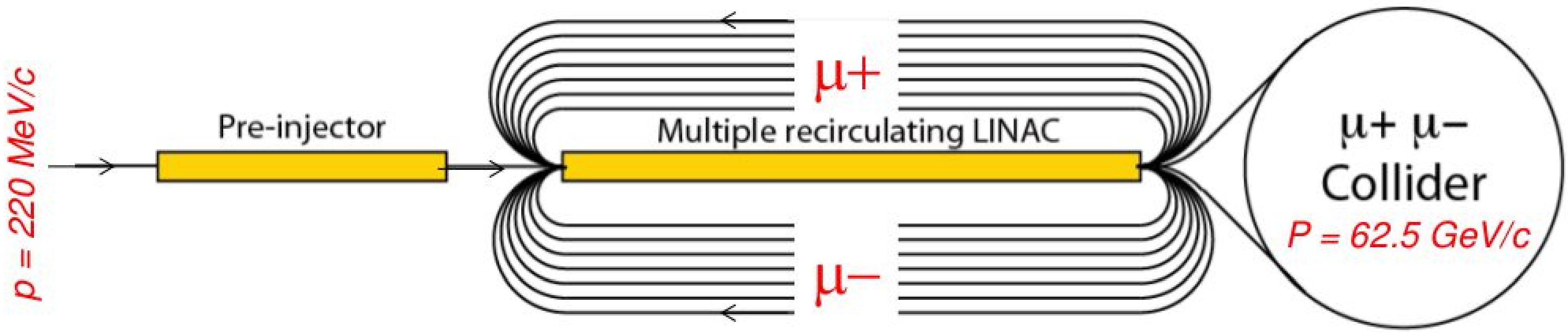
Former CERN boss Carlo Rubbia wants a muon collider

CERN's discovery of a new fundamental particle – most likely a Higgs boson – was barely hours old when physicists speaking at this year's Lindau Nobel Laureate Meeting in Germany argued the case for a new facility to measure its properties in detail. Speaking out in favour of a new machine was former CERN boss Carlo Rubbia, who shared the 1984 Nobel Prize for Physics for the discovery of the W and Z bosons. "The technology is there to construct a Higgs factory," he claimed. "You don't need €10bn; it could be done relatively cheaply.

"With a Higgs of 125 GeV we need only a modest machine, perhaps not a large linear collider." Rubbia points out that muons colliding at a combined energy of roughly 125 GeV would suffice – just over half the energy of LEP and requiring a machine with a much smaller radius.

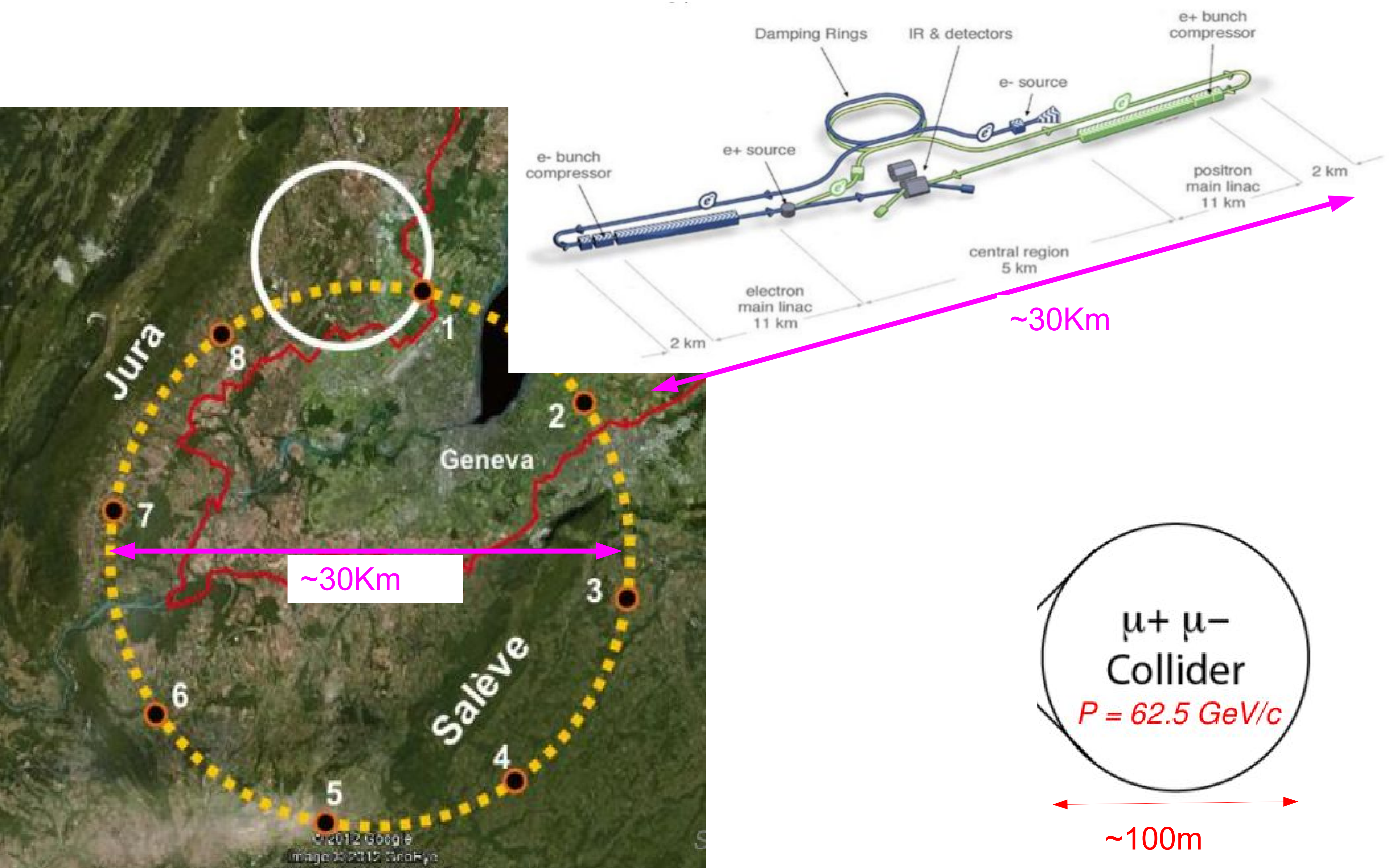
Muon

Muon cooling for a Higgs Factory at CERN ?



Muon

Muon cooling for a Higgs Factory at CERN ?



Summary

- Muon is an elementary particle describe by the SM
  - All its parameters are well known
  - Some tension on g_μ-2 (3.6 sigma)
  - Muons is used in many domain: Astrophysics, particle physics
    - Atmospheric showers, Trigger, Veto,...
- Muon detection
  - started with cloud chambers and Geiger-Müller
  - Detection mechanism always the same: Ionisation
  - The main break-through in tracking detectors: MWPC
  - Spark chambers parallel-plate chambers has lead to RPCs and now MPGDs*
  - MPDGs are probably the new generation of muon detectors being robust
  - GEM, MicroMegas,THGEM...
    - Radiation hard and showing no signs of ageing
    - High rates
    - Excellent spatial resolution
    - Fast (trigger)
- Muo-graphy
- Future: Muon collider?

*Micro Pattern Gas Detectors