101 Years of Cosmic Radiation Research

University of Bristol Masterclass 2013

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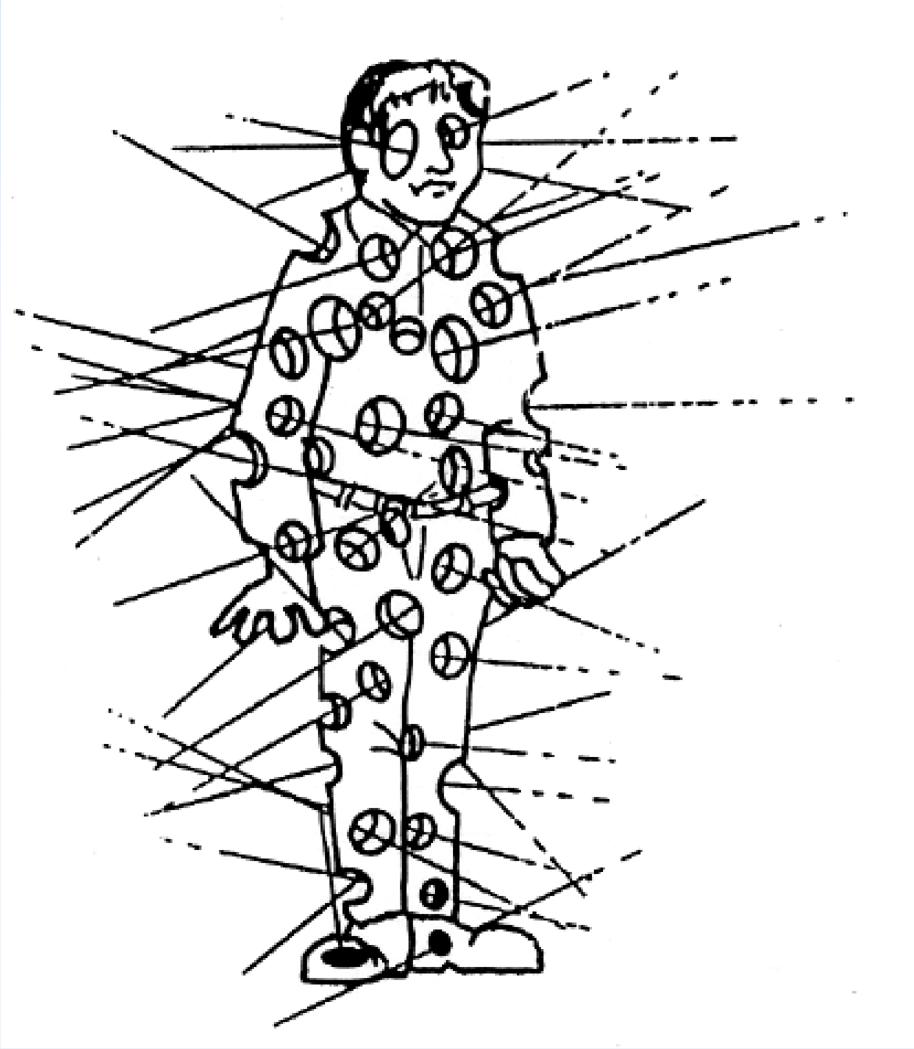
(with thanks to Kaj Schadenberg and Cristina Carloganu)

What is Radiation?



Early research (up to ~1930)

- Wilhelm Röntgen
  - X-rays (1885)

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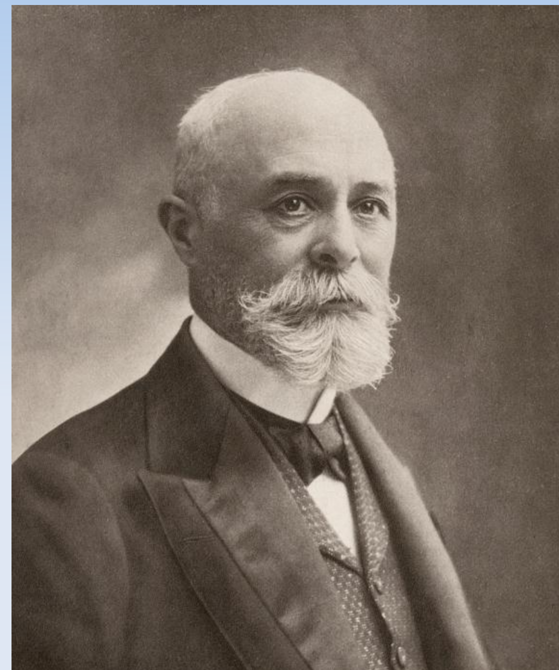
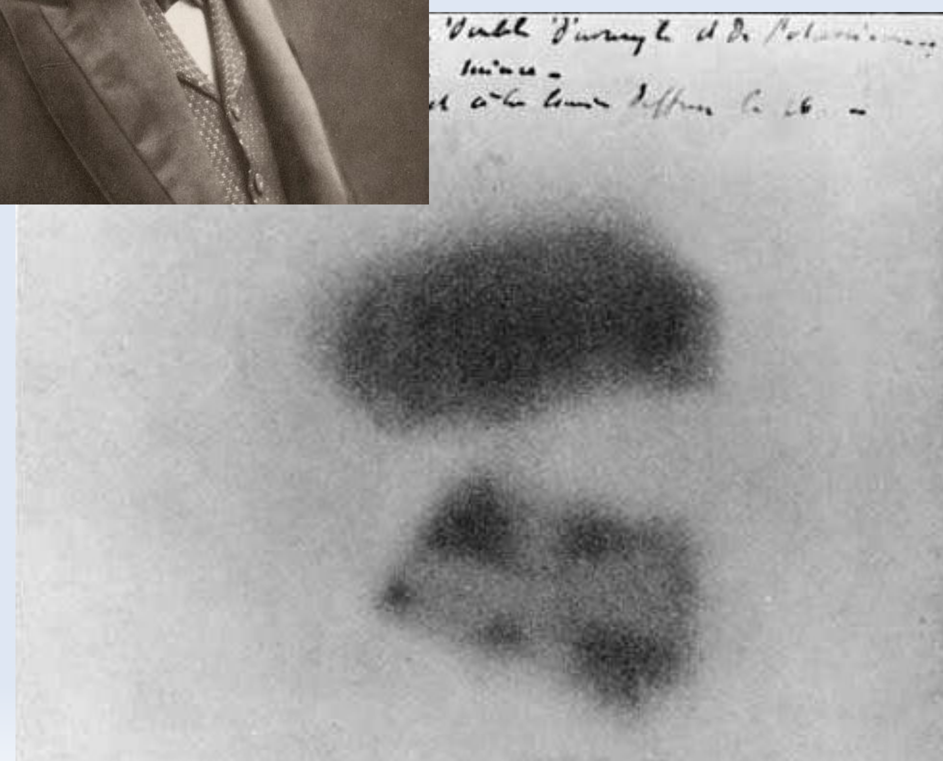
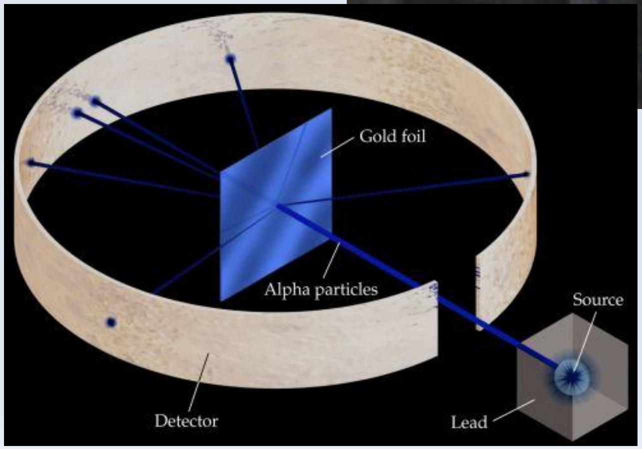
  - Radioactivity of Uranium salts (1886)





Early research (up to ~1930)

- Wilhelm Röntgen
  - X-rays (1885)
- Henri Becquerel
  - Radioactivity of Uranium salts (1886)
- Ernest Rutherford
  - 'Discovery' and naming of α, β, and γ-radiation (1899)



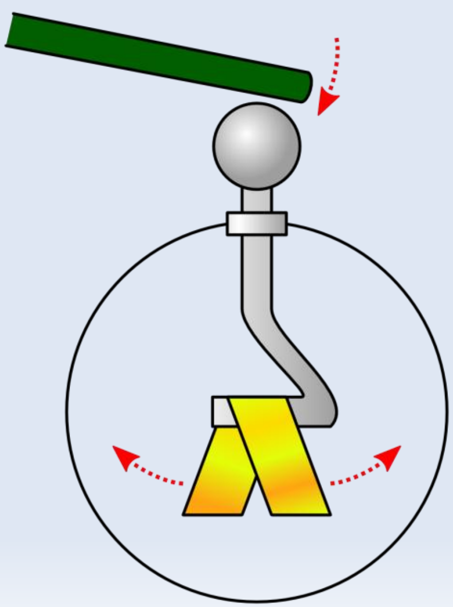
Early measurements of Radiation

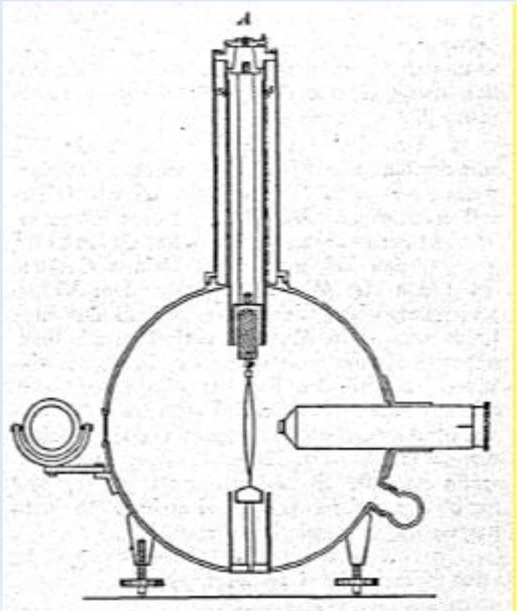
- Photographic paper
- Phosphorescent or fluorescent materials
- Ionisation chambers

Origins of Radiation

Measurements of atmospheric radiation

- Wulf (1868-1946)
- Hess (1883-1964)
- Millikan (1868-1953)

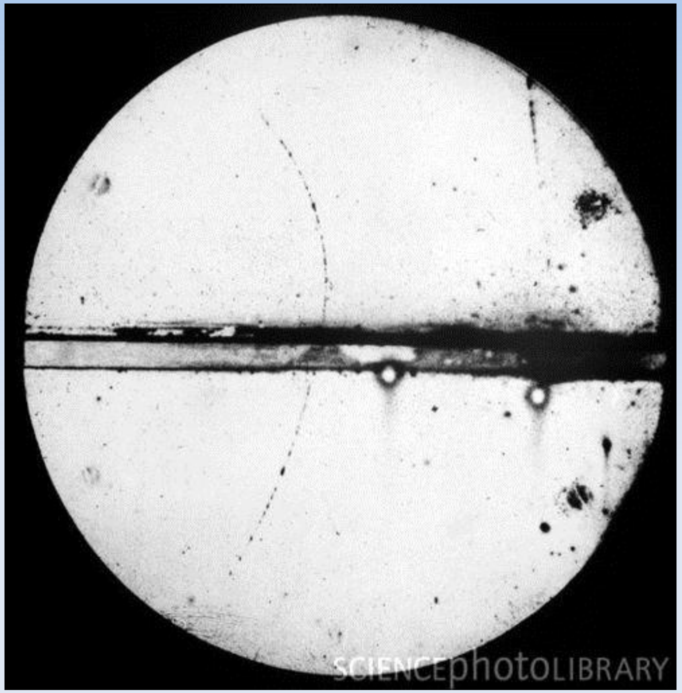


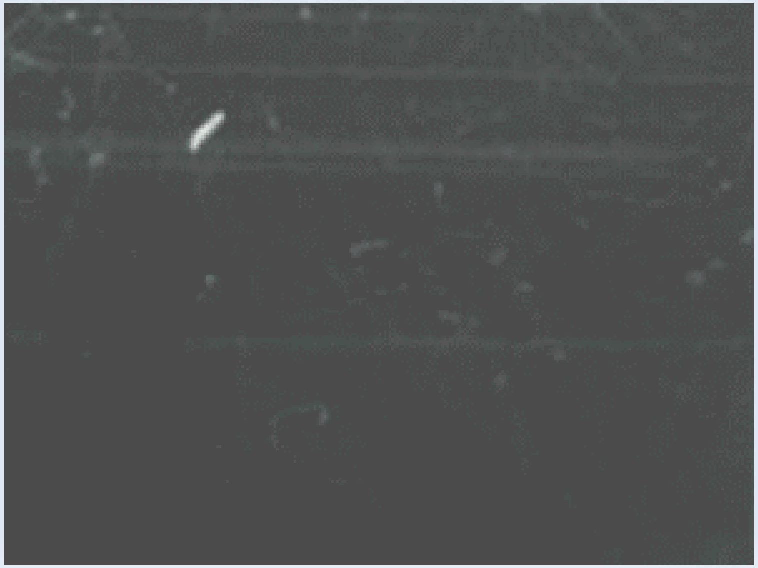


Cosmic Air Showers

Measurement devices

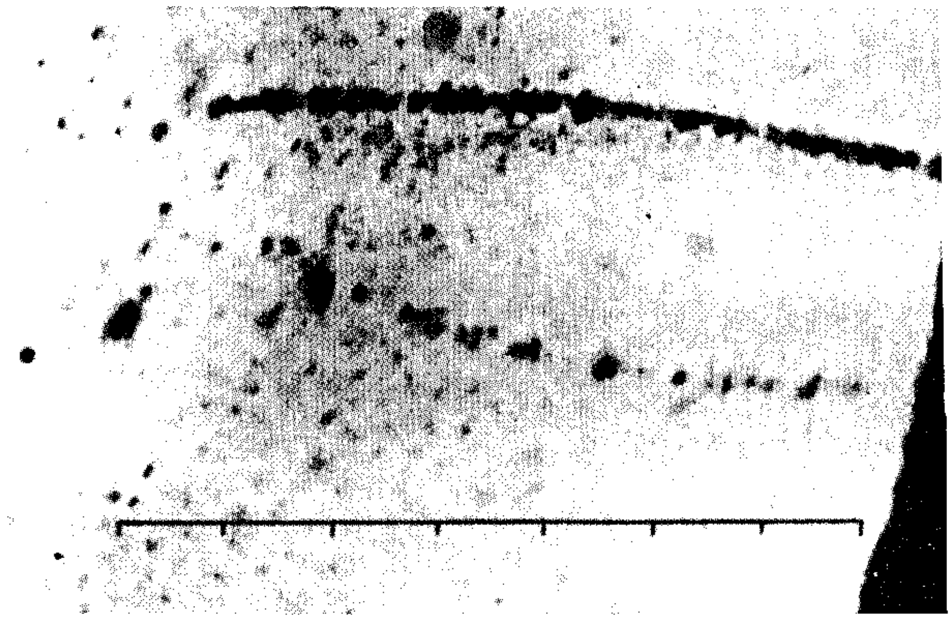
- Cloud chamber
- Geiger counter
- Bubble chamber
- Nuclear emulsion





Early particle physics (~1930-1960)

- Study of air showers crucial for particle physics
  - Use photographic emulsions
  - Discovery of
    - Positron
    - Muon
    - Mesons



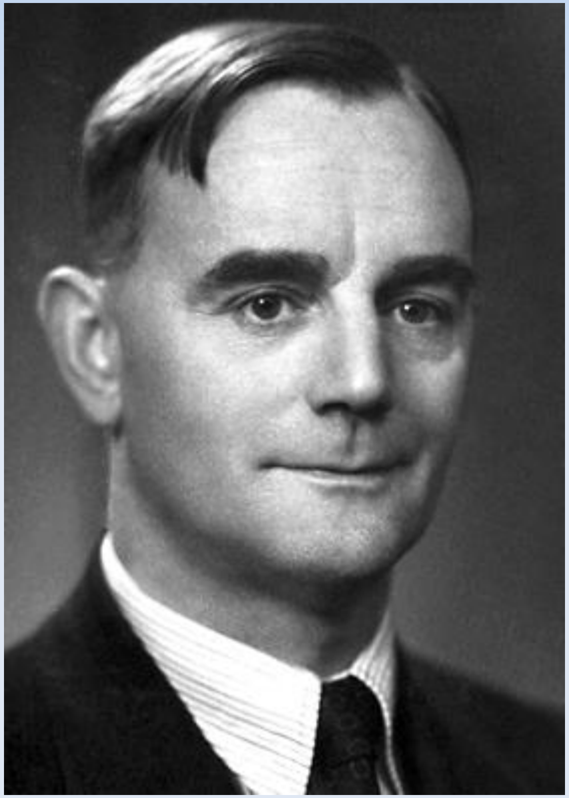
"The other double trace of the same type (figure 5) shows closely together the thin trace of an electron of 37 MeV, and a much more strongly ionizing positive particle whith a much larger bending radius. The nature of this particle is unknown; for a proton it does not ionize enough and for a positive electron the ionization is too strong. The present double trace is probably a segment from a "shower" of particles as they have been observed by Blackett and Occhialini, i.e. the result of a nuclear explosion".

Kunze, P., Z. Phys. 83, (1933) 1

Early particle physics (~1930-1960)

- 1946 discovery of pion (pi-meson)

C.F. Powell of Bristol University

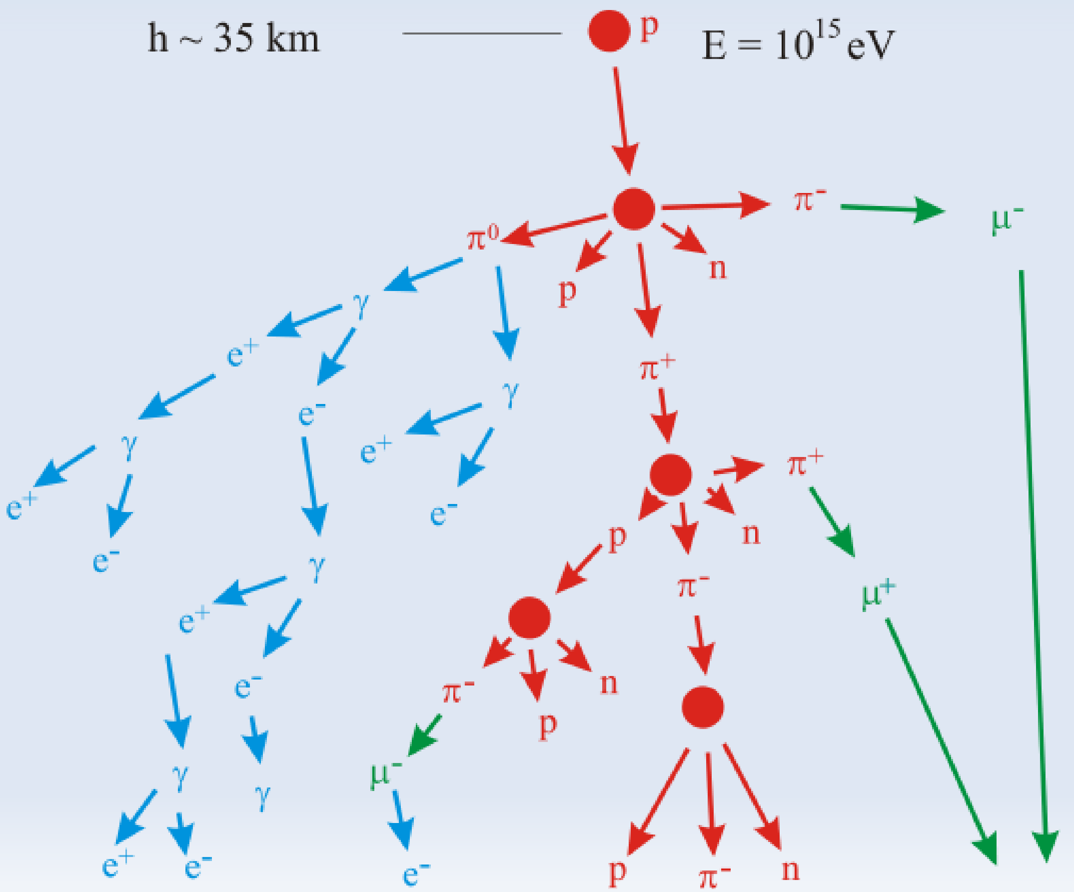


  - Balloon experiments
  - Experiments on mountains

Nobel prize in 1950

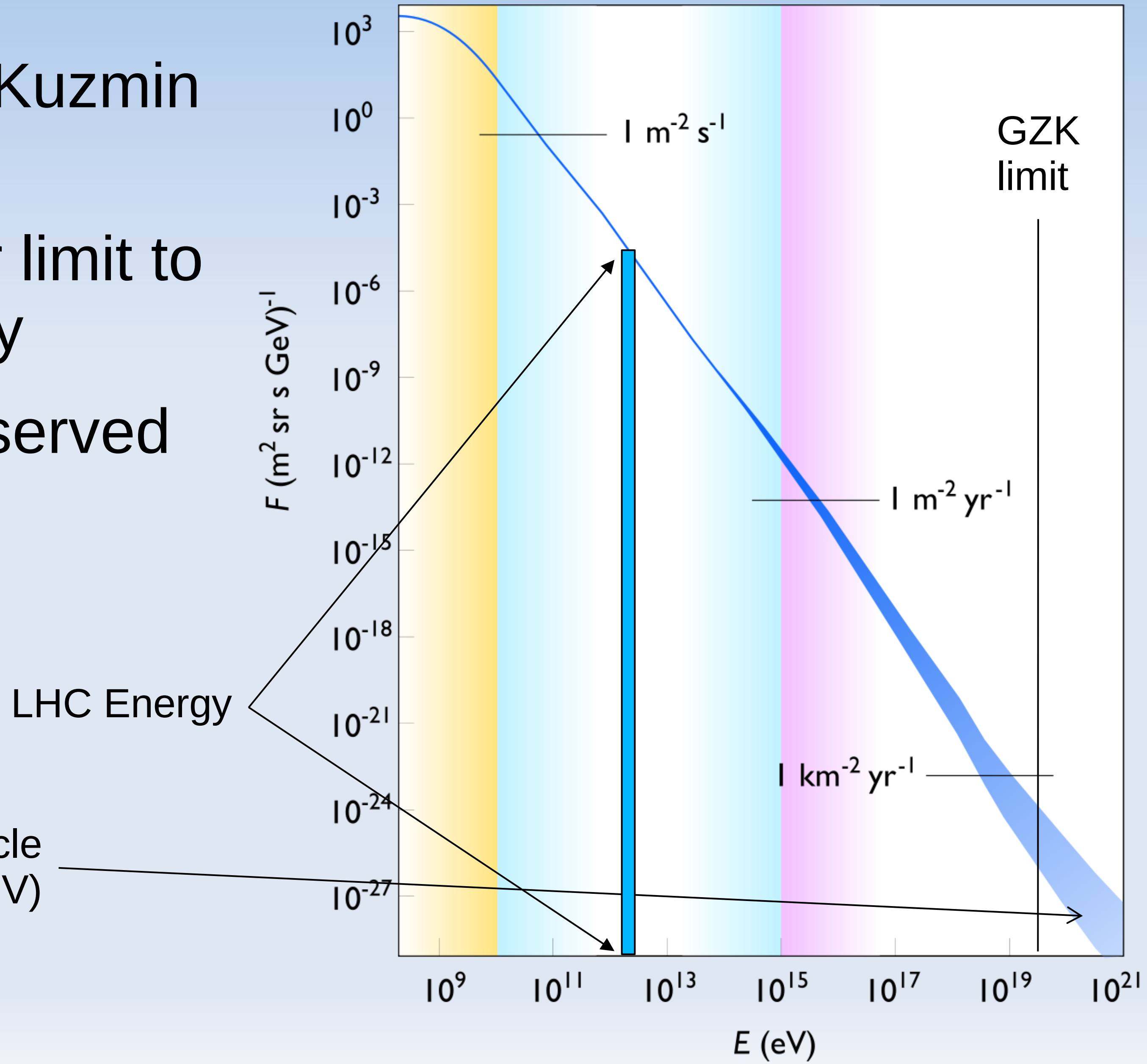
Summary Cosmic Rays

- ‘Primary’ particle hits atmosphere
- Primaries can be protons, nuclei, electrons, photons
- New particles created in interaction (usually pions)
- New particles unstable: decay into further particles
- Cascade of interactions and decays



Remaining Fundamental Questions

- Greisen–Zatsepin–Kuzmin limit
  - Theoretical upper limit to cosmic ray energy
  - Violations are observed
- Origin of radiation?

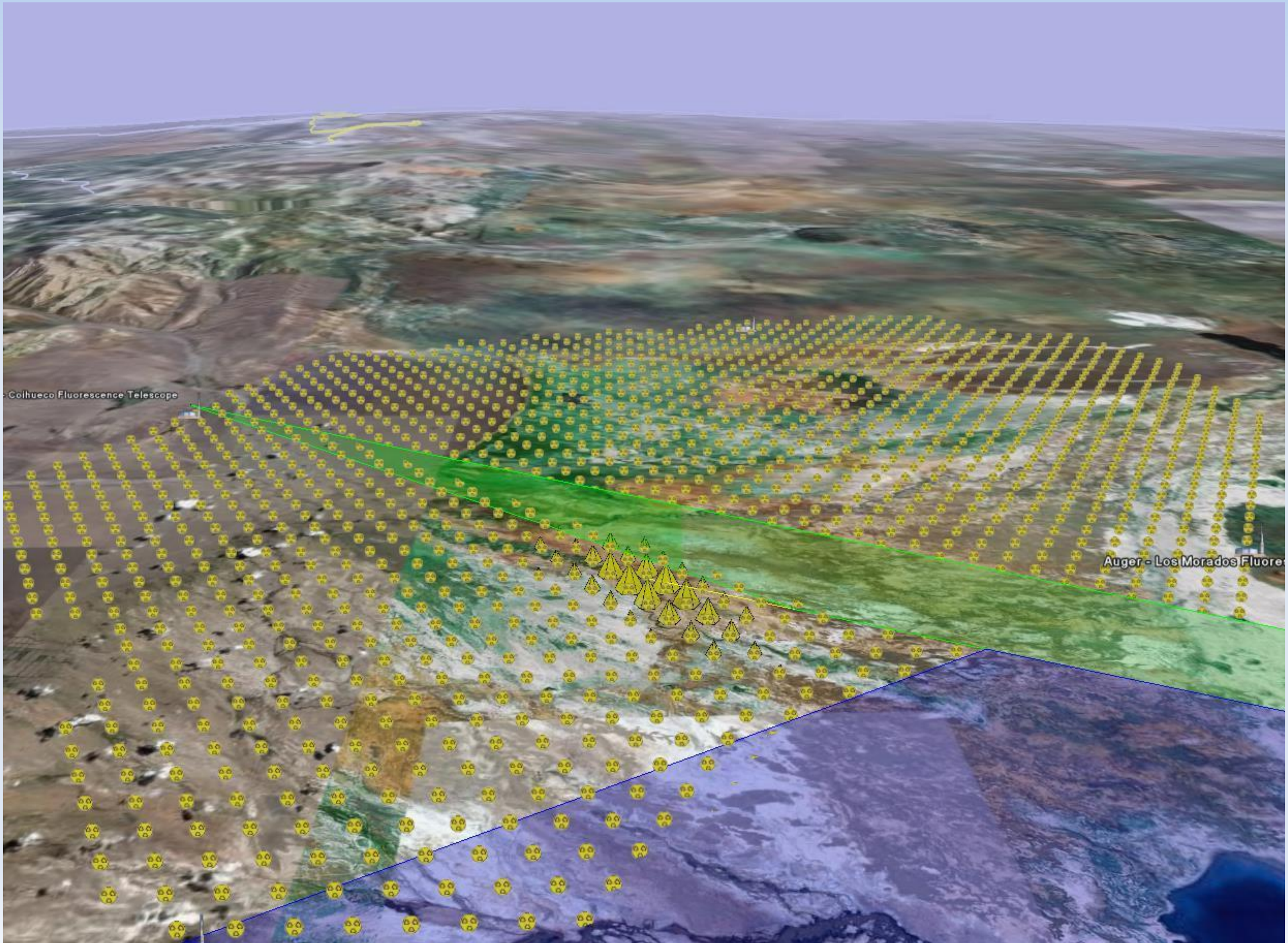


Large arrays – Pierre Auger

- Pampa Amarilla plain Argentina
- 1604 detectors
- 3000 km²

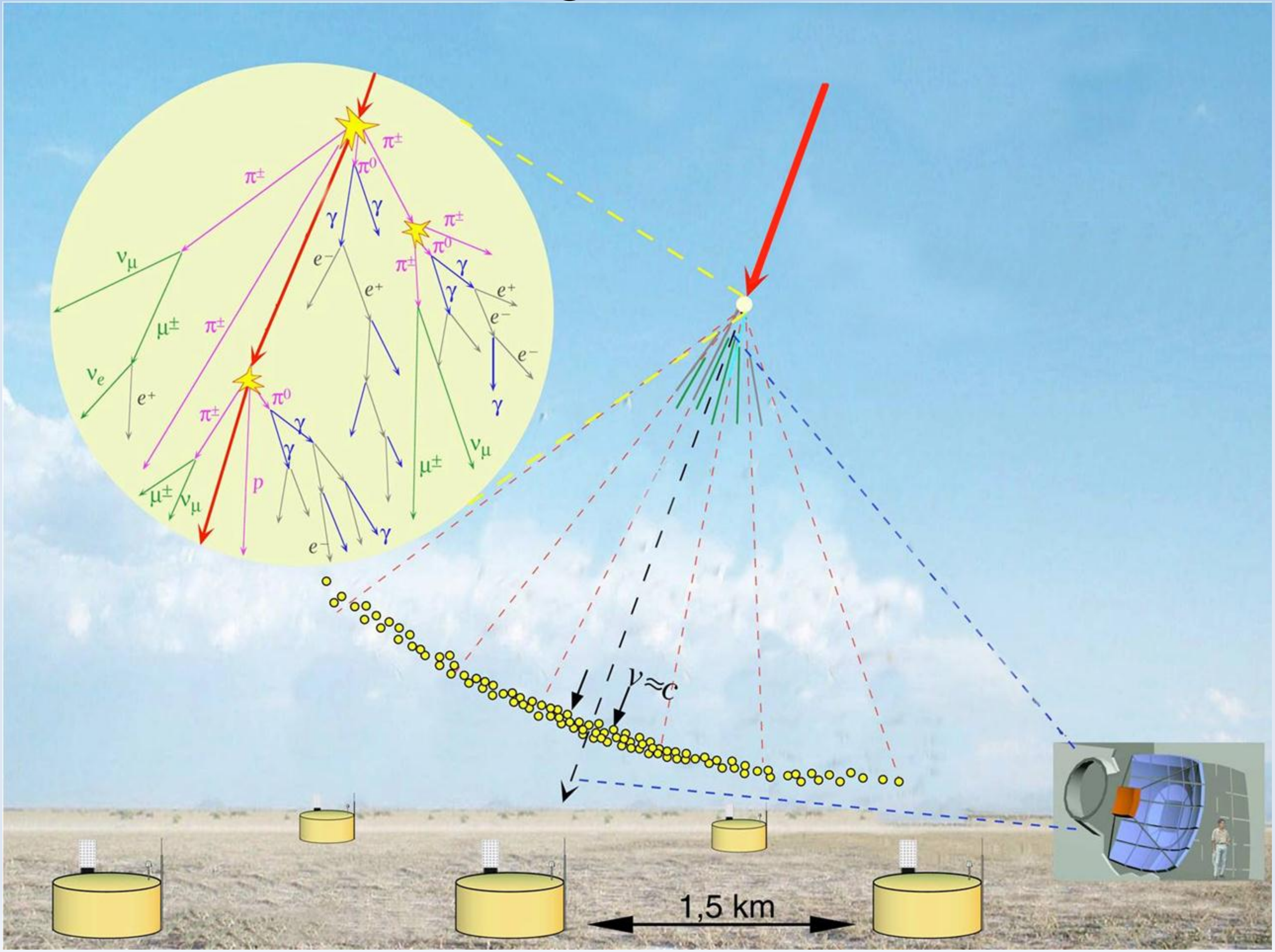
Large arrays – Pierre Auger

1600 detectors spread across plains

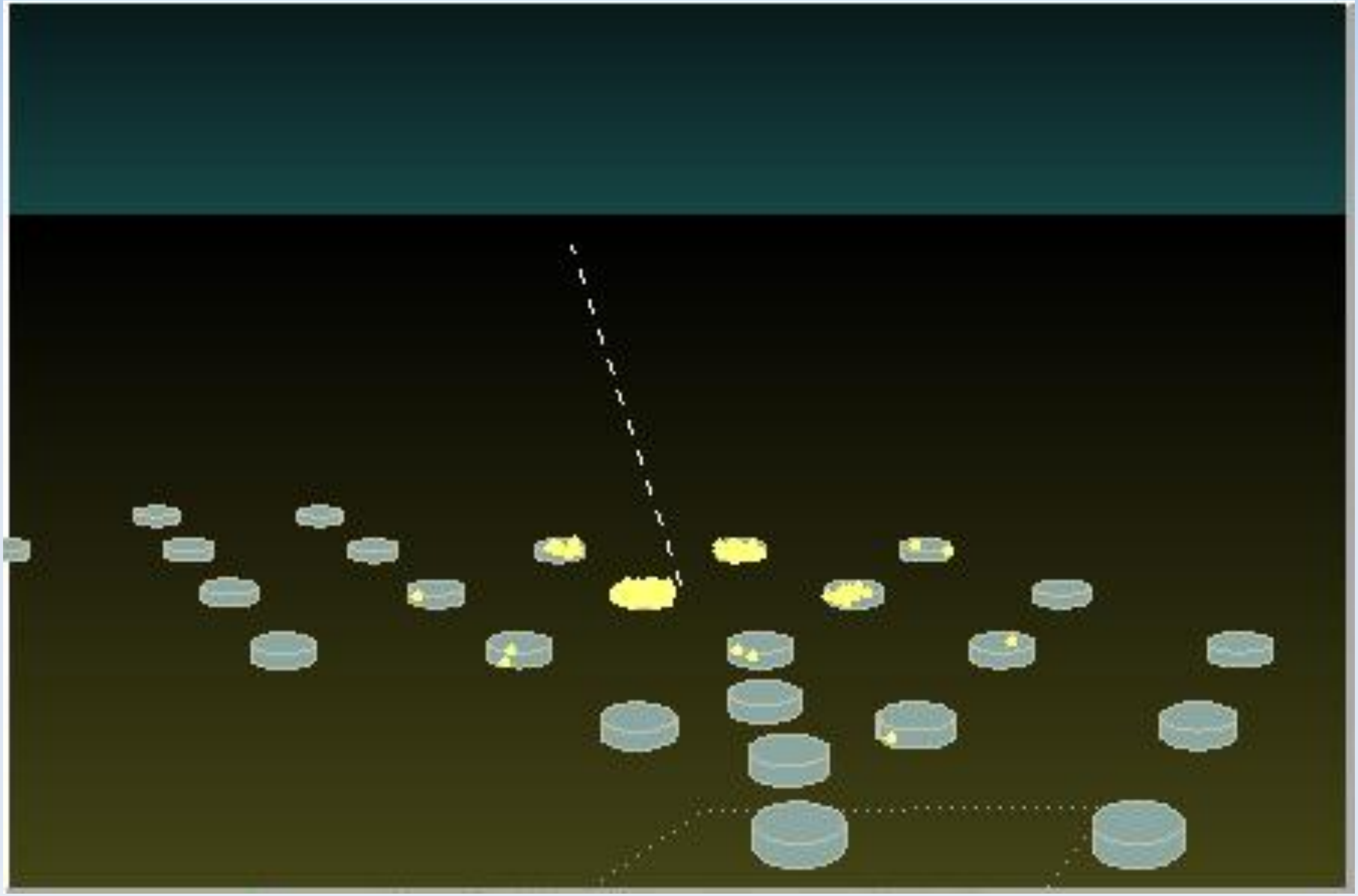


Large arrays – Pierre Auger

Detecting Air Showers



Large arrays – Pierre Auger

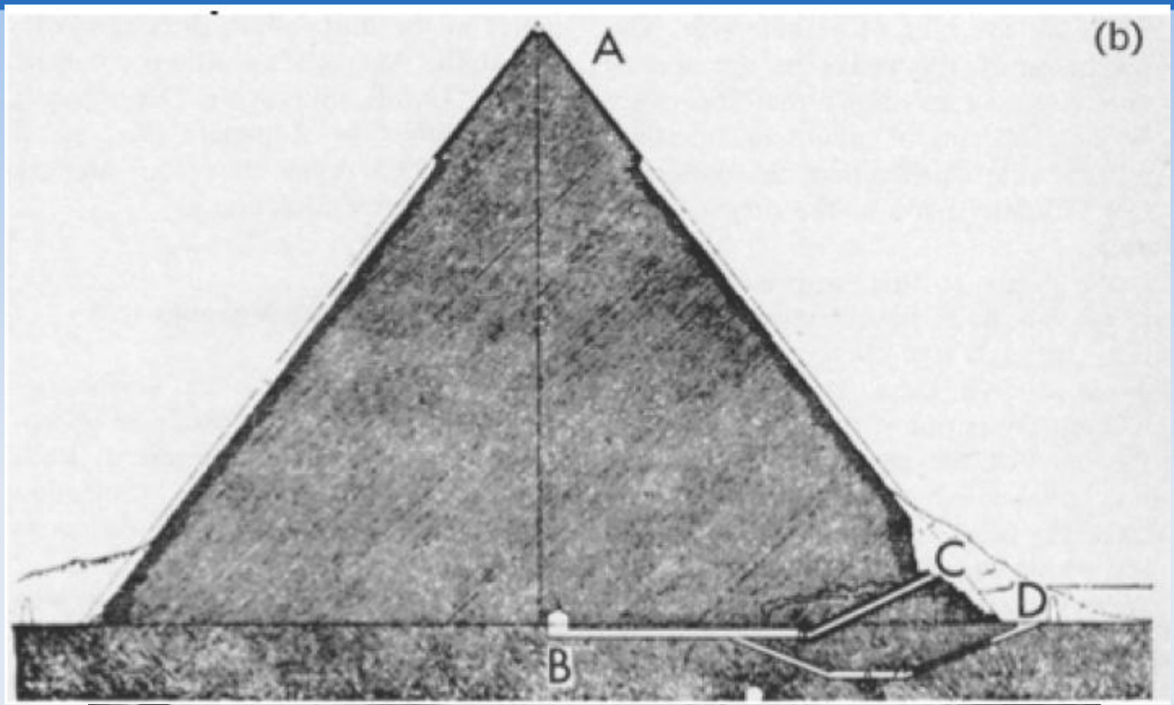


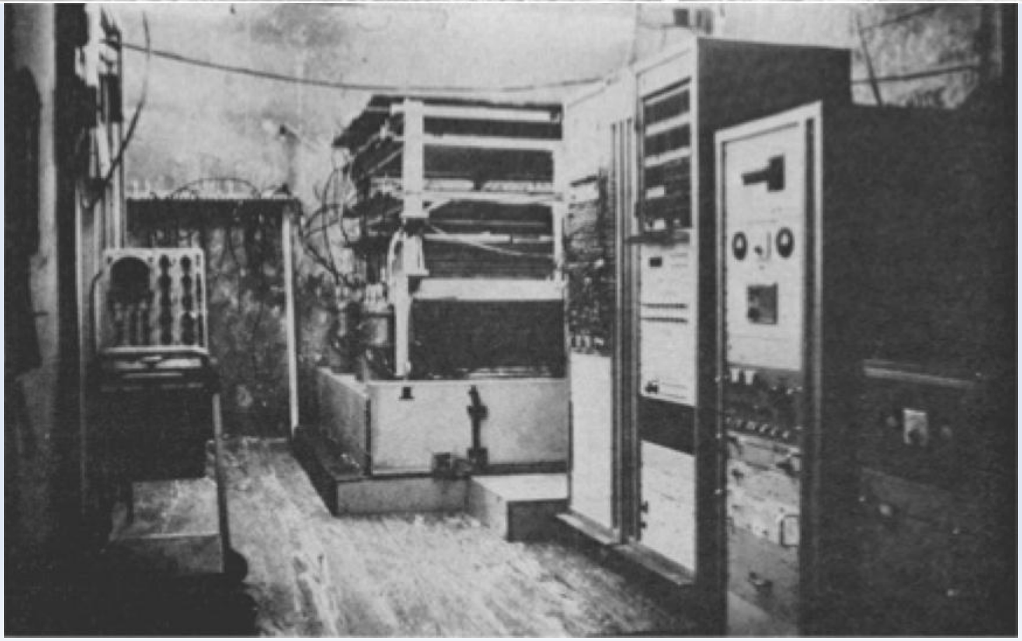
Research & Use

- So far, saw research into cosmic rays
- But cosmic rays are useful in their own right:
  - Highly penetrating
  - Abundant and free
  - Mostly charged (so easy to measure)
- Can use cosmic rays to scan and image things too large for conventional scanners

Chephren Pyramid

Pyramid Scanning (~1970)

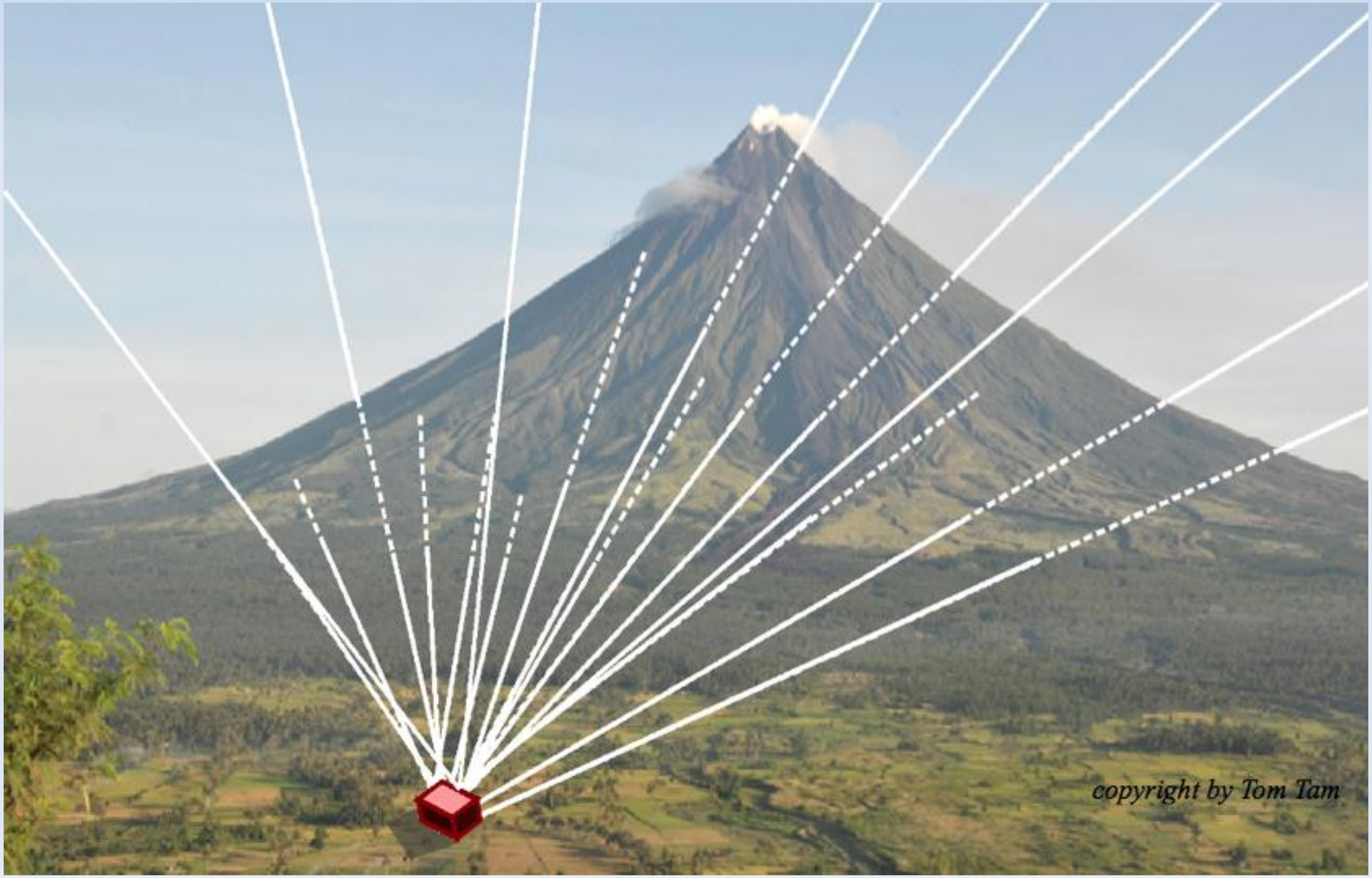




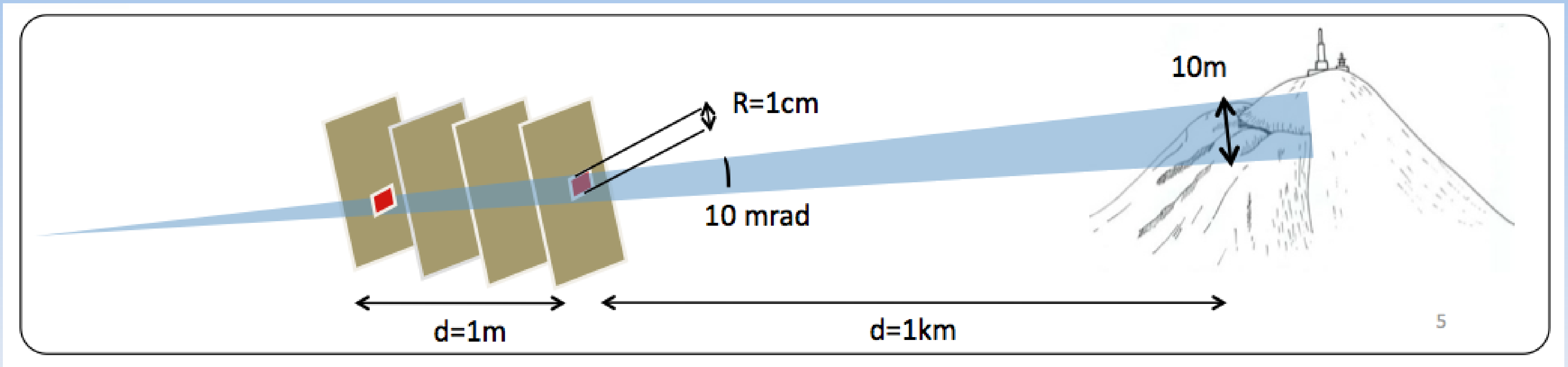
- Luis Alvarez (1970): *Are there undiscovered chambers in the Chephren pyramid?*
- Investigate with cosmic rays
- Detector installed in chamber at the bottom (B)
- Results compared to what would have been expected from a hidden chamber
- Ultimately, hidden chamber was ruled out

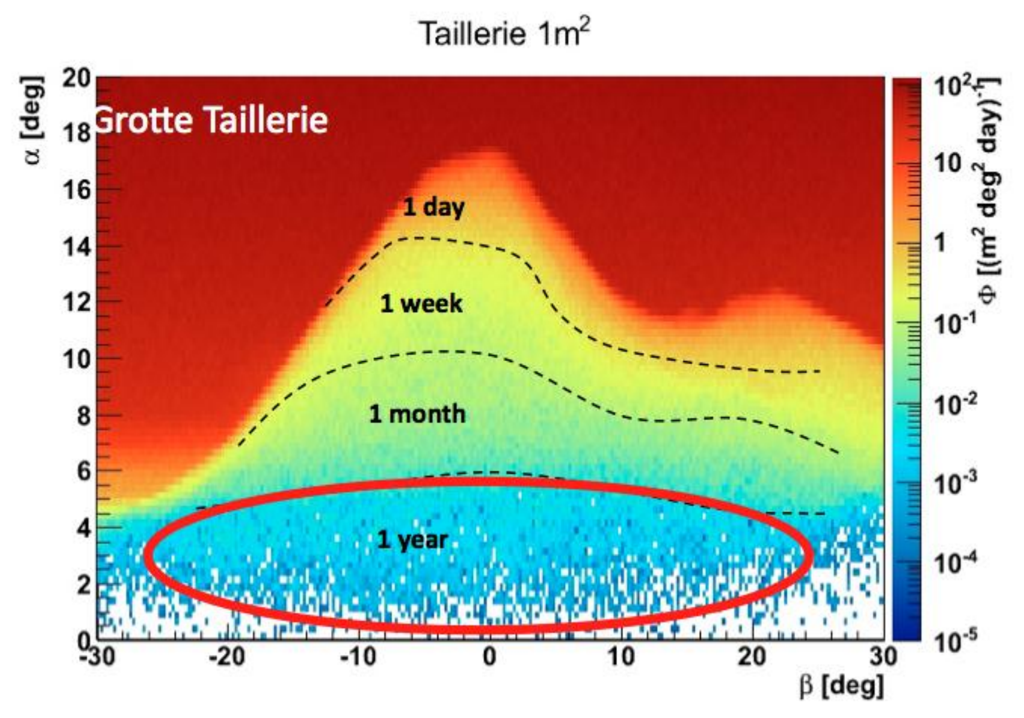
Volcano Radiography

- Internal structure of volcanoes not very well known
- Use cosmic rays to do radiographical scanning



Volcano Radiography

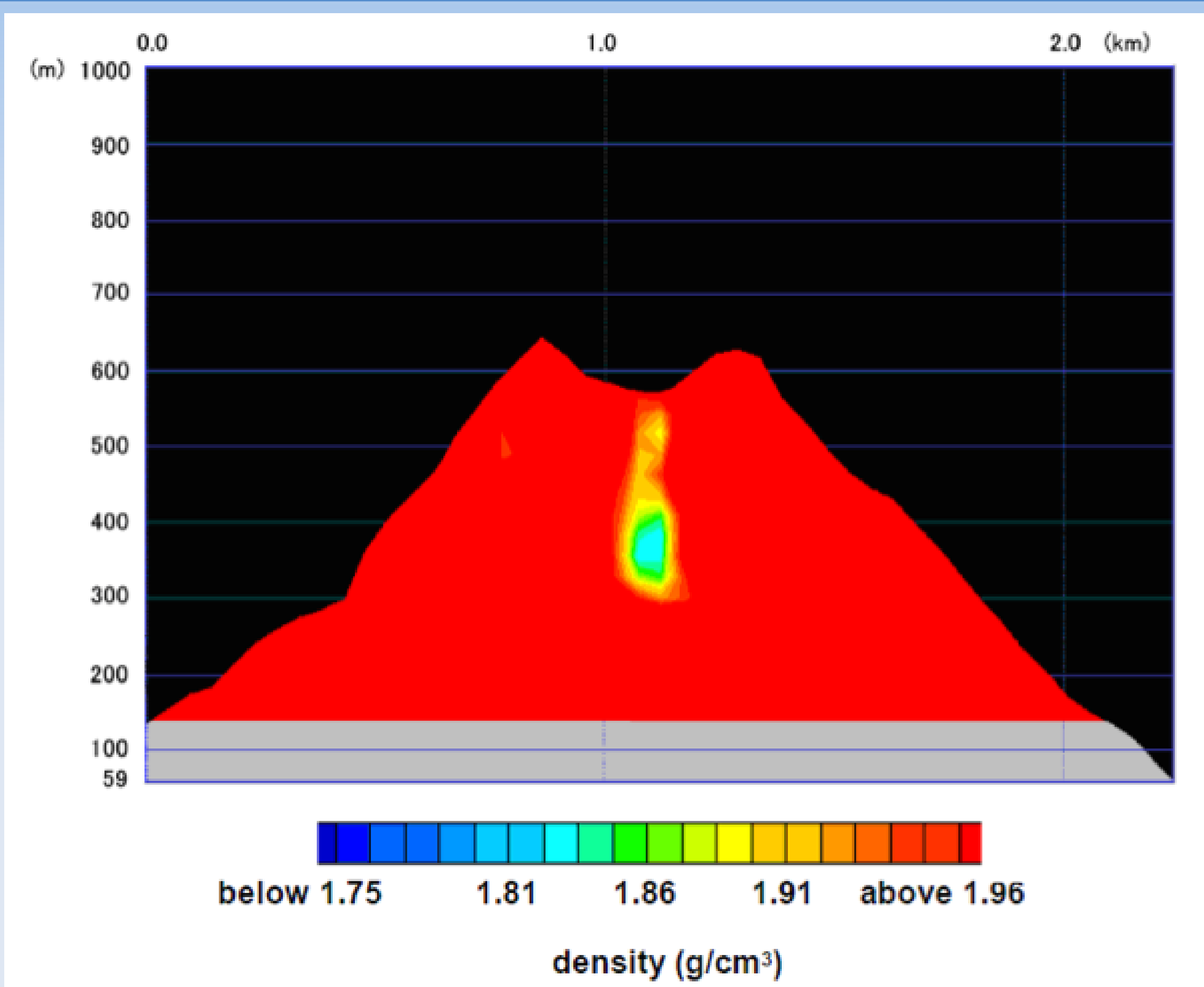


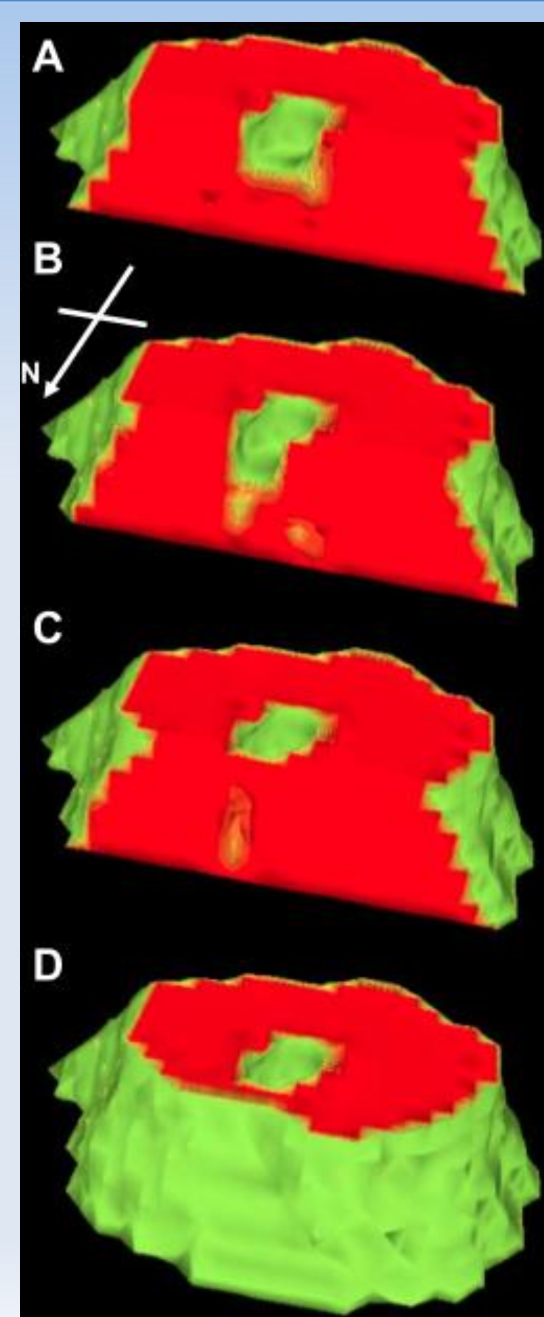


Puy-de-dôme in Clermont-Ferrand, France
(ToMuVol project)

- Measure cosmic ray flux through volcano
- Obtain 2D density map
- Lots of data needed
- Then again, geologists have time…

Volcano Radiography





Mt. Iwatodake, Japan (Tanaka et al.)

National Security

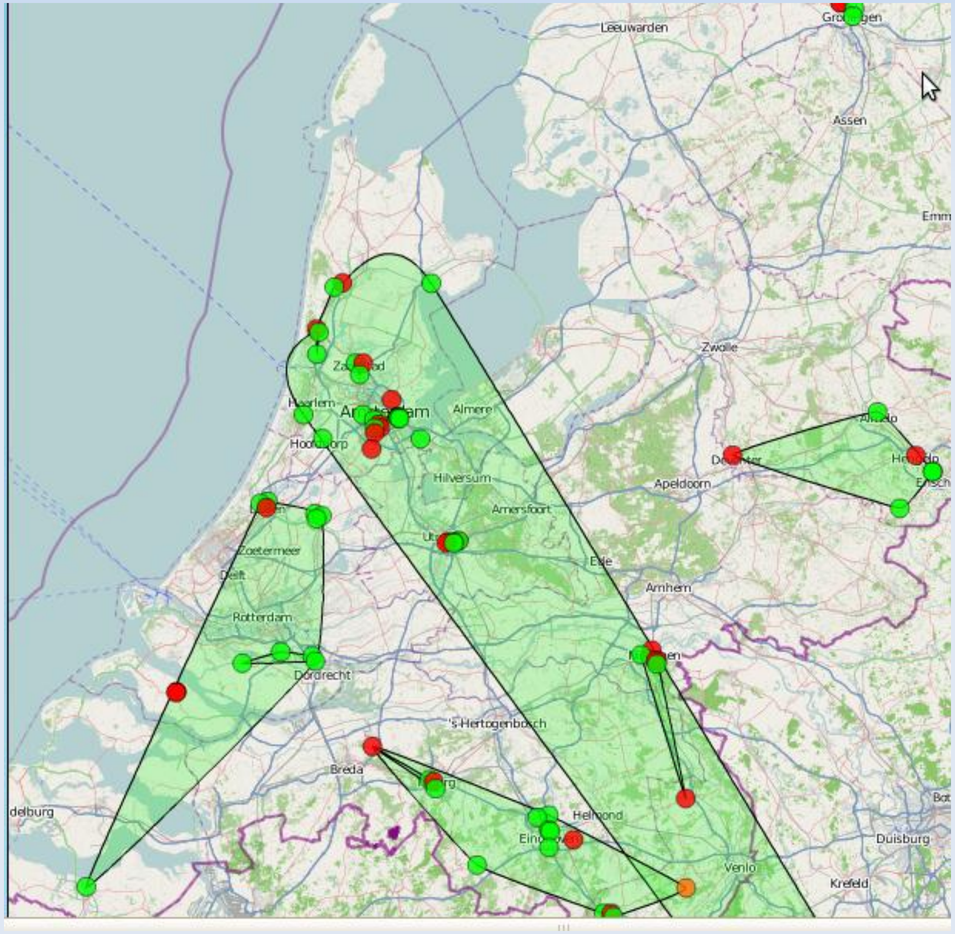
- Safety of cargo an issue
- Nuclear material could be smuggled
- Many scanning methods (X-ray, neutrons, etc.)
- But generally expensive, and may introduce radiation
- Alternative: cosmic rays

Research & You

- Lot of research done
- Lot of research still being done
- Still lots of open questions
- What’s this got to do with you…?

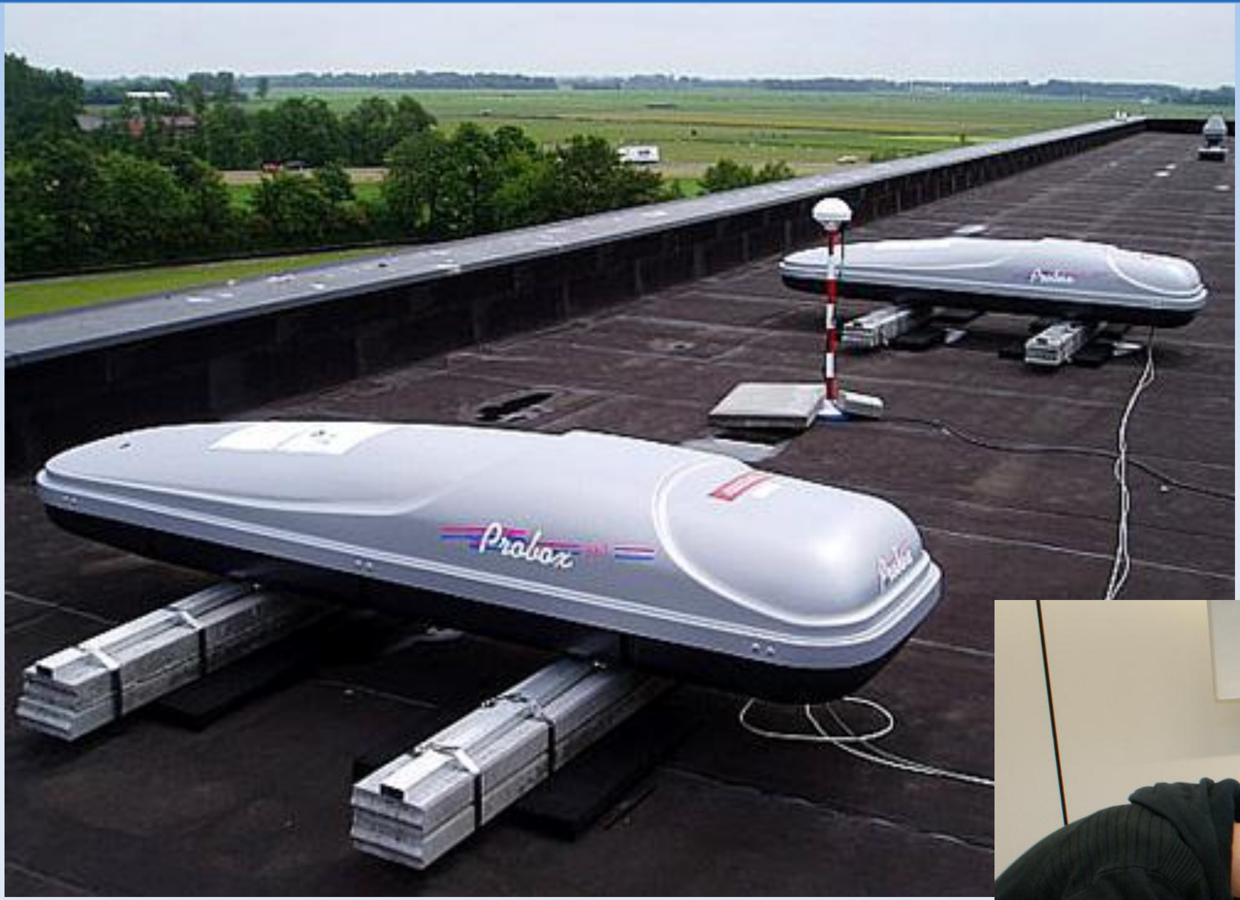
Sparse Array – Large Area

- HiSPARC project
  - High School Project on Astrophysics Research with Cosmics
  - Idea: make large grid of cosmic ray detectors on schools
  - You build your own detectors
  - Measure data and exchange with others
  - Exists for >10 years
  - International: 110+ detectors in the Netherlands, also in Denmark, Vietnam, Kenya…

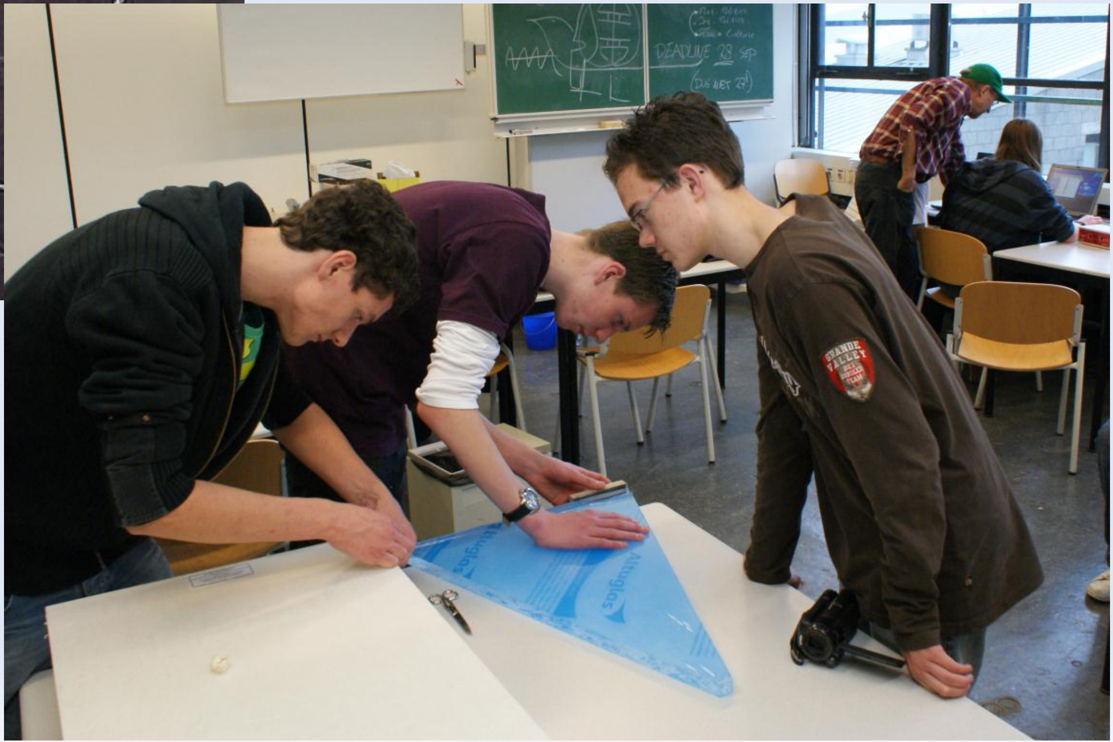


HiSPARC in the Netherlands

HiSPARC – School Detector



Build your own detector



And place it on top of the
roof of the school

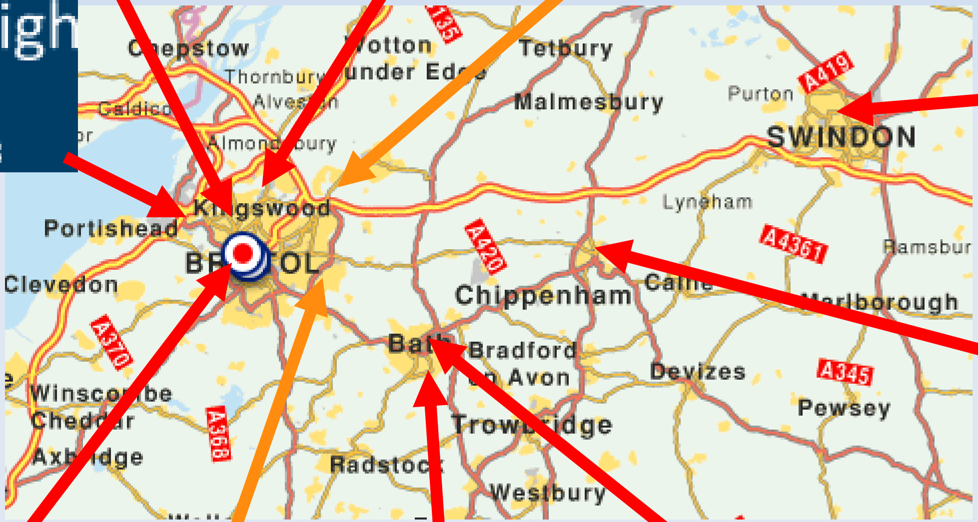
HiSPARC Bristol Network

The Red Maids' School

sgs
South Gloucestershire and Stroud College

Clifton High School
Boys and girls 4-18

New College Swindon



Sheldon School

Bristol Grammar School

HS

Beechen Cliff School

The Royal High School Bath

HiSPARC Research Questions

- Upper limit energy
- Shower distribution and direction
- Weather effects
  - Air pressure
  - Clouds
  - Lightning
  - ...
- Long-range correlations between showers (Gerasimova-Zatsepin effect)

HiSPARC Bristol

- HiSPARC Bristol up and running
- Looking for new members
- Need you to help us do research
- Get involved
  - Talk to your teacher
  - Talk to us

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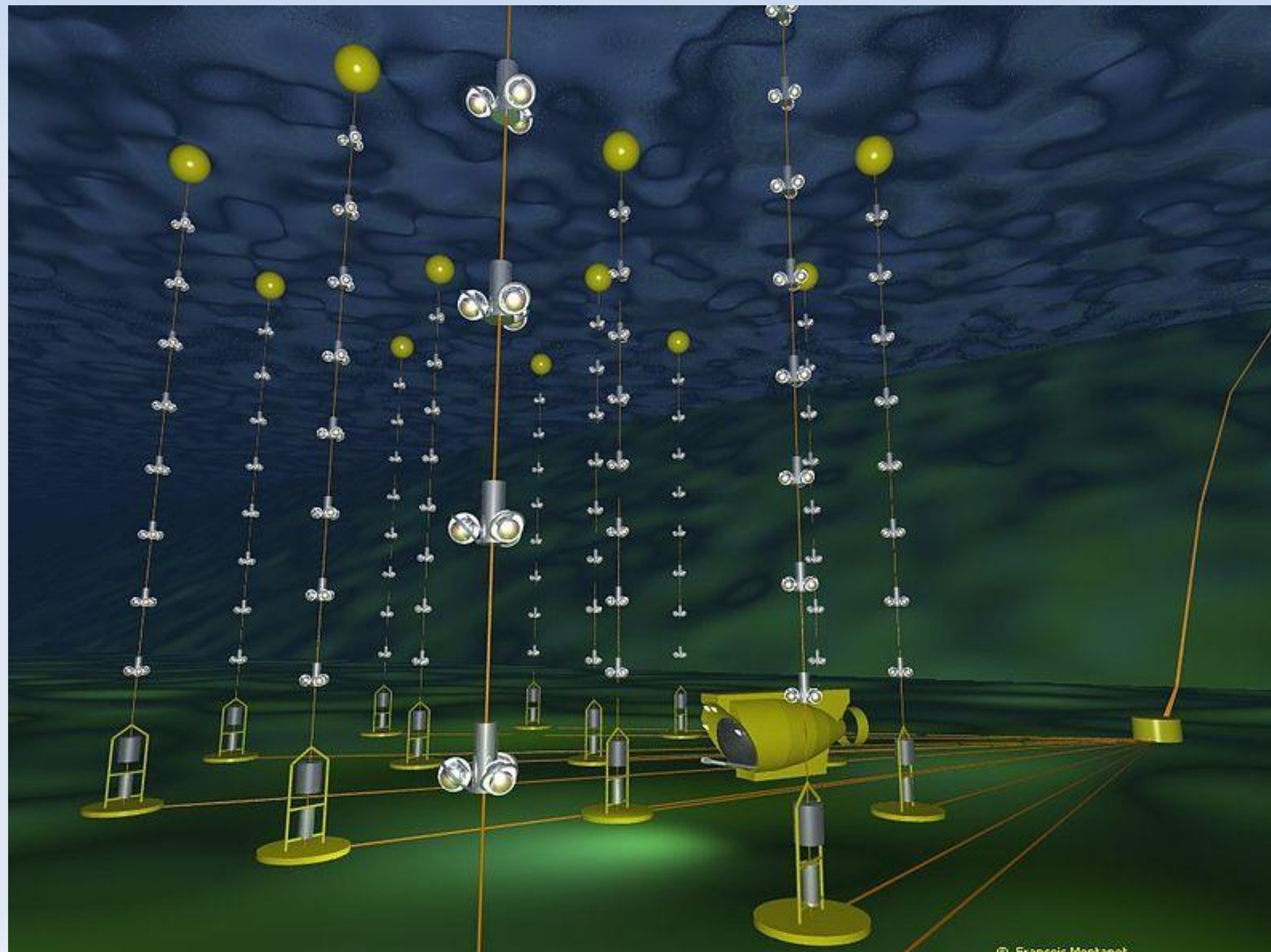
Backup Slides

Free Ions in Air

- Charles Coulomb
  - A electrically charged body, placed outdoors (in free air), will gradually lose its charge (1785)
- Joseph J. Thompson
  - Research of electrical conductivity of gasses (1880)

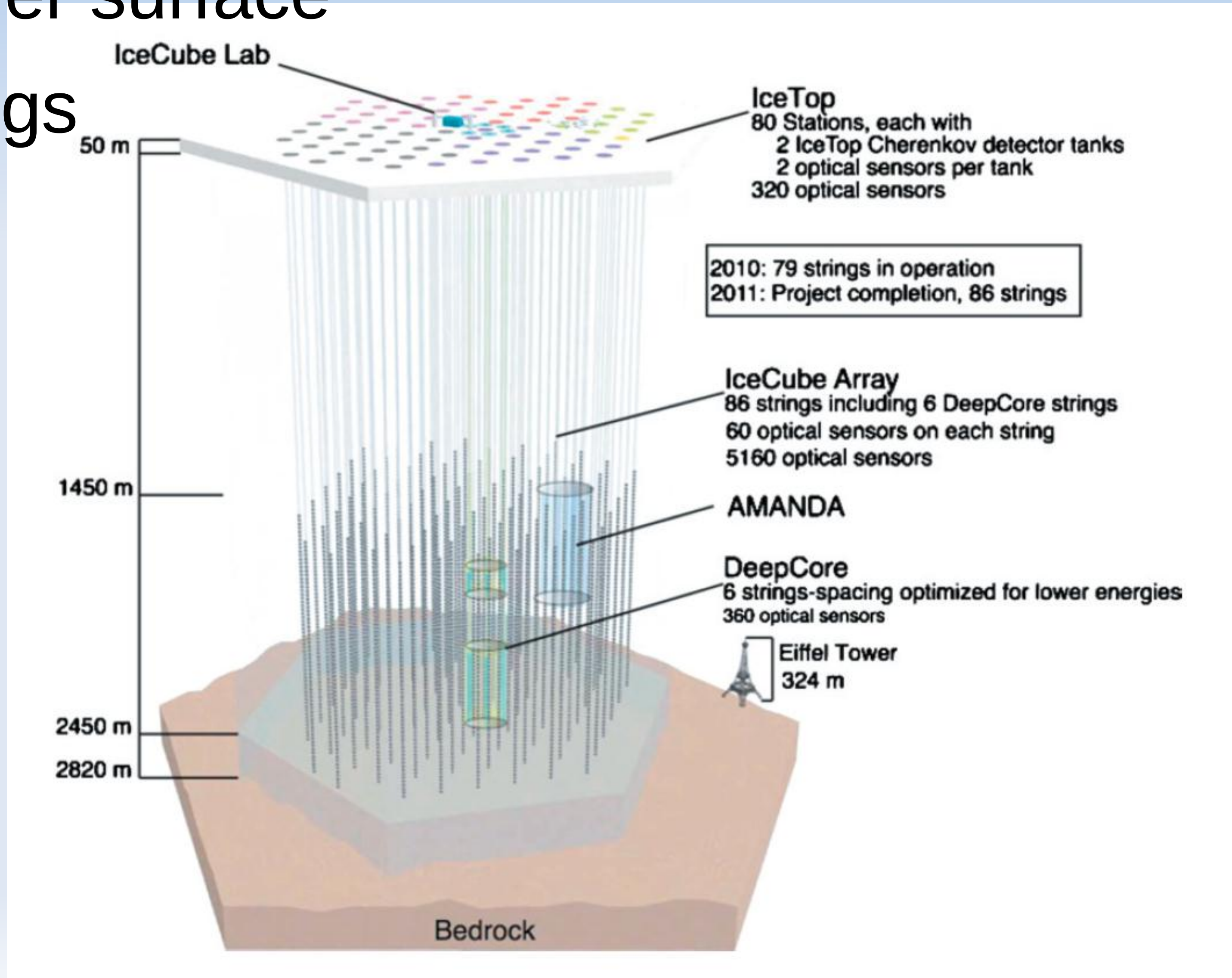
Large arrays - ANTARES

- 2.5 km under Mediterrenean sea (near Toulon)
- 1 km³ array
- 900 detectors



Large arrays - IceCube

- Amundsen-Scott South Pole Station
- 1.5 - 2.5 km under surface
- 86 detector strings
- 5160 sensors



Current research question

Gerasimova-Zatsepin effect

- Two showers, correlated in time and space