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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  - X-rays (1885)
- Henri Becquerel
  - Radioactivity of Uranium salts (1886)
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  - X-rays (1885)
- Henri Becquerel
  - Radioactivity of Uranium salts (1886)
- Ernest Rutherford
  - 'Discovery' and naming of $\alpha$, $\beta$, and $\gamma$-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

Hajo Drescher, Frankfurt U.

time = -1000 µs
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 with 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
• 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

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

Puy-de-dôme in Clermont-Ferrand, France (ToMuVol project)
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
• Lot of research done

• Lot of research still being done

• Still lots of open questions

• What’s this got to do with you…?
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 – School Detector

Build your own detector

And place it on top of the roof of the school
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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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 Mediterranean 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
Gerasimova-Zatsepin effect

Two showers, correlated in time and space