ISAPP 2003

Madonna di Campiglio – July 14-19, 2003

Observations of cosmic rays

Tiina Suomijärvi
Institut de Physique Nucléaire
Université Paris XI-Orsay, IN2P3/CNRS
France

Why to Study Cosmic Rays ?

✓Cosmic rays span over an enormous range of energies, up to 10^{20} eV

✓They are abundant and serve an important role in the energy balance of galaxy. Their energy density 1 eVcm^{-3} is comparable to that contained in the galactic magnetic field or in the cosmic microwave background.

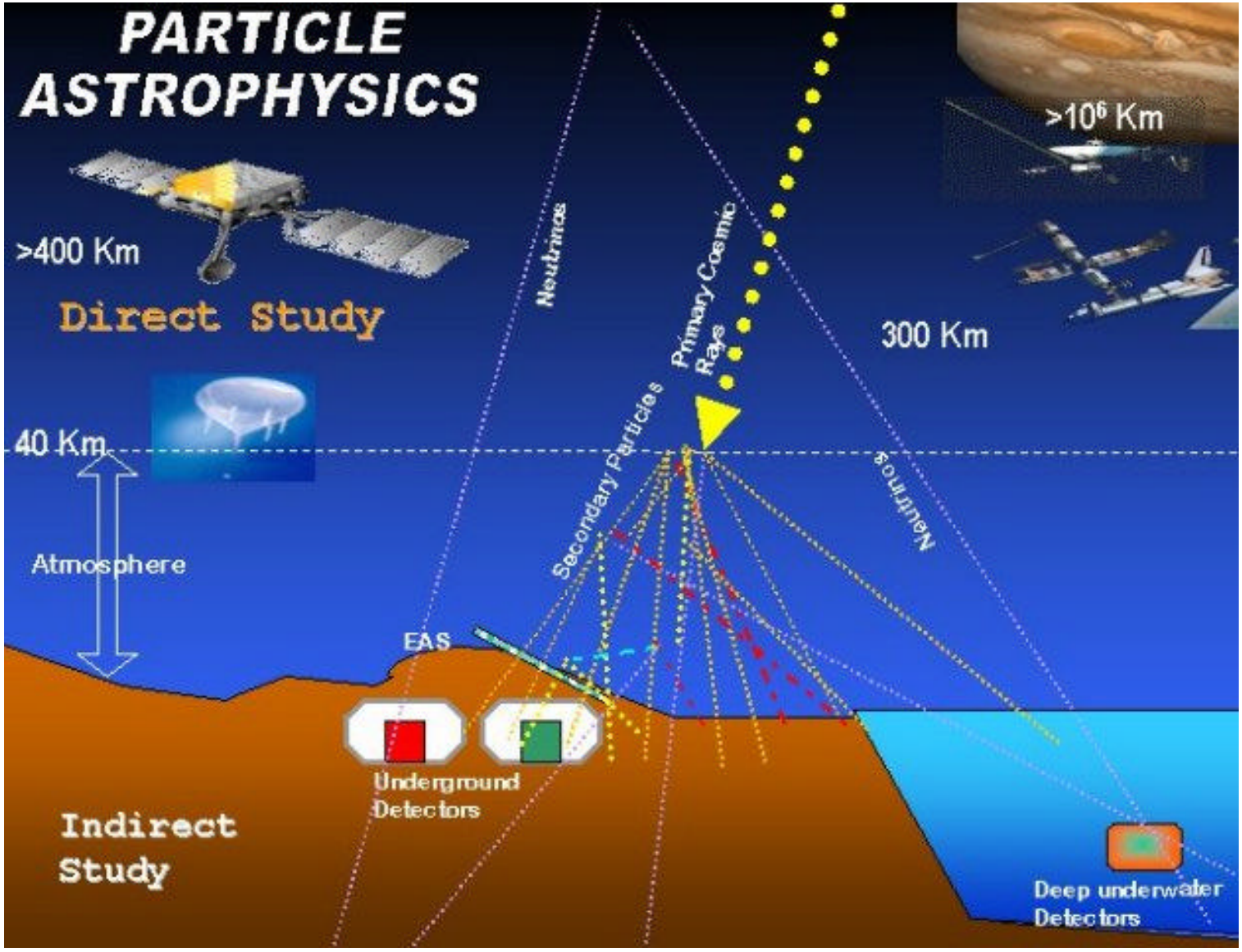
✓They are evidence of powerful astrophysical accelerators and can be used to study these accelerators

✓They propagate through universe and can give information on properties of cosmic environment (magnetic fields, matter densities…)

✓Their chemical composition, modulated by propagation, reflects the nucleosynthetic processes occurring at their origin and can also be used to measure age of astrophysical objects

✓They can be used to study the validity of physical laws in extreme conditions

✓They can be messengers of « new physics » or yet unknown particles


PARTICLE
ASTROPHYSICS
>400 Km
Direct Study
Neutrinos
Primary Cosmic Rays
>10⁶ Km
300 Km
40 Km
Atmosphere
Secondary Particles
Neutrinos
EAS
Underground Detectors
Indirect Study
Deep underwater Detectors

Outline

- A Brief History of Cosmic Ray Physics
- Air Shower Detection Techniques
- Examples of Air Shower Detectors
- Balloon and Satellite Experiments
- Radiodetection
- Neutrino detection by telescopes and horizontal air showers

ISAPP 2003

Observations of Cosmic Rays

- A Brief History of Cosmic Ray Physics

A Brief History of Cosmic Ray Physics

Great Triumphs of 19th Century

J.C. Maxwell

H.R. Hertz

Unification of electricity and magnetism
Maxwell 1864

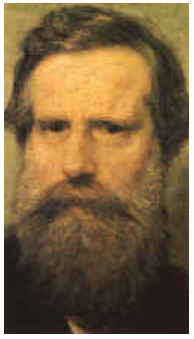
20 years later experiments of Hertz confirmed that the light is a form of electromagnetic radiation

Experiments in Electricity and Magnetism

Conduction of electricity through gases:
Good vacuum tubes and high voltages between the positive and negative electrodes

1879 : Crookes tube

Discovery of cathode rays



Crookes

1897 : Thomson measured the charge to mass ratio of cathode rays by deflection the radiation by crossed electric and magnetic fields: Discovery of the first sub-atomic particle, electron

Thomson

New Discoveries

1895 Röntgen discovered X-rays: Photographic plates left close to Crookes tubes were darkened

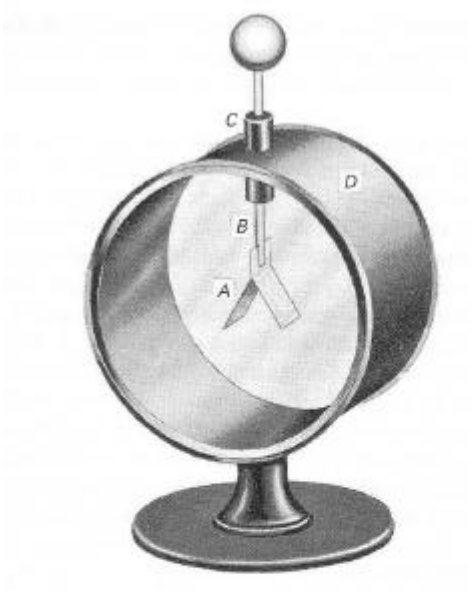
Search for other sources of X-ray emission

1896 Becquerel discovered natural radioactivity by studying uranium samples

1898-1900 Rutherford, P. et M. Curie and Villard understood that there were several types of radioactivity: α, β, γ

The Discovery of Cosmic Rays

Early experiments in radioactivity used electroscope

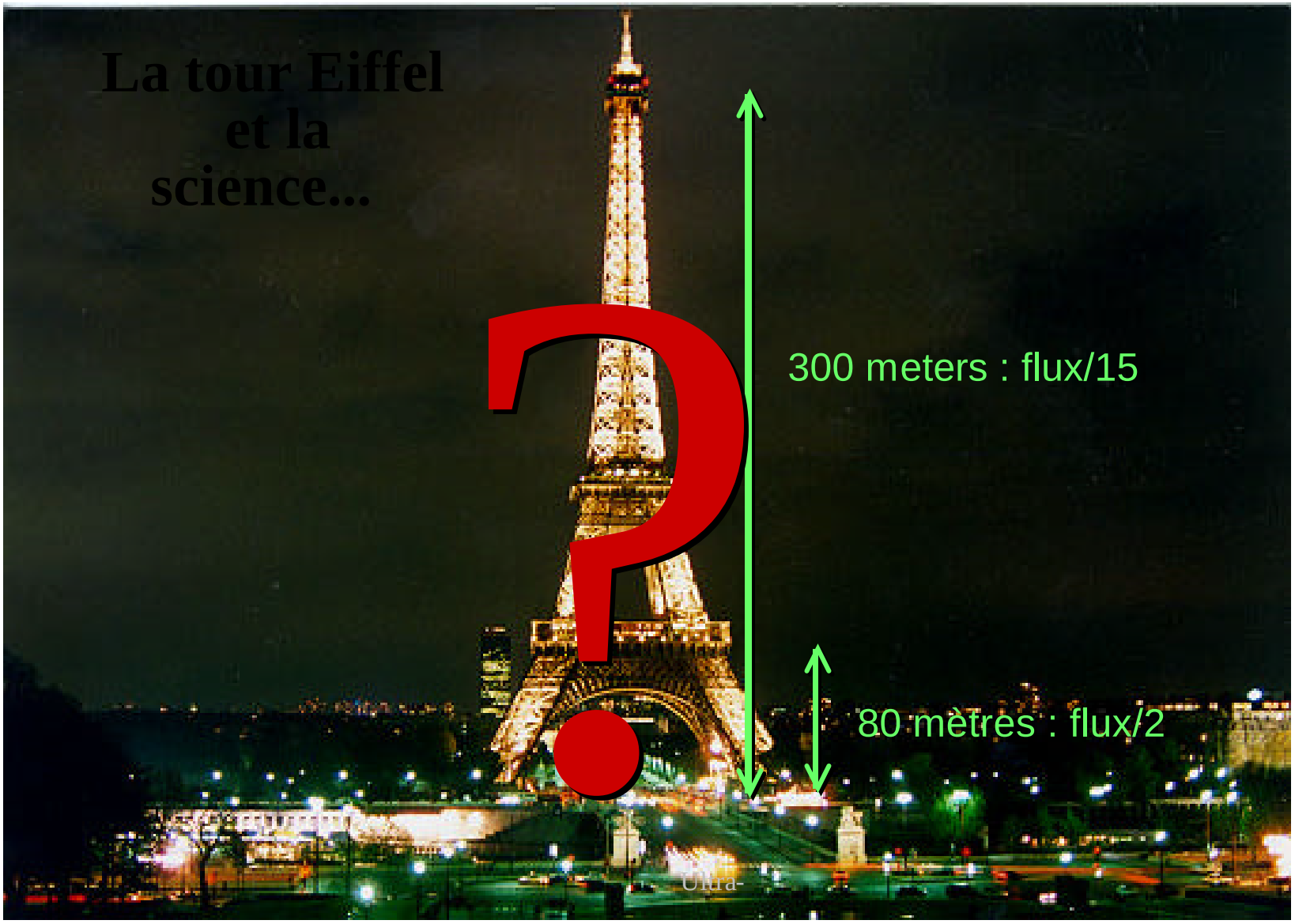


✓When electroscope is charged, the leaves (A) are pushed apart
✓The ionisation of the gas inside discharge the electroscope and the leaves move towards each other
✓The rate at which the leaves came together measured the amount of ionisation

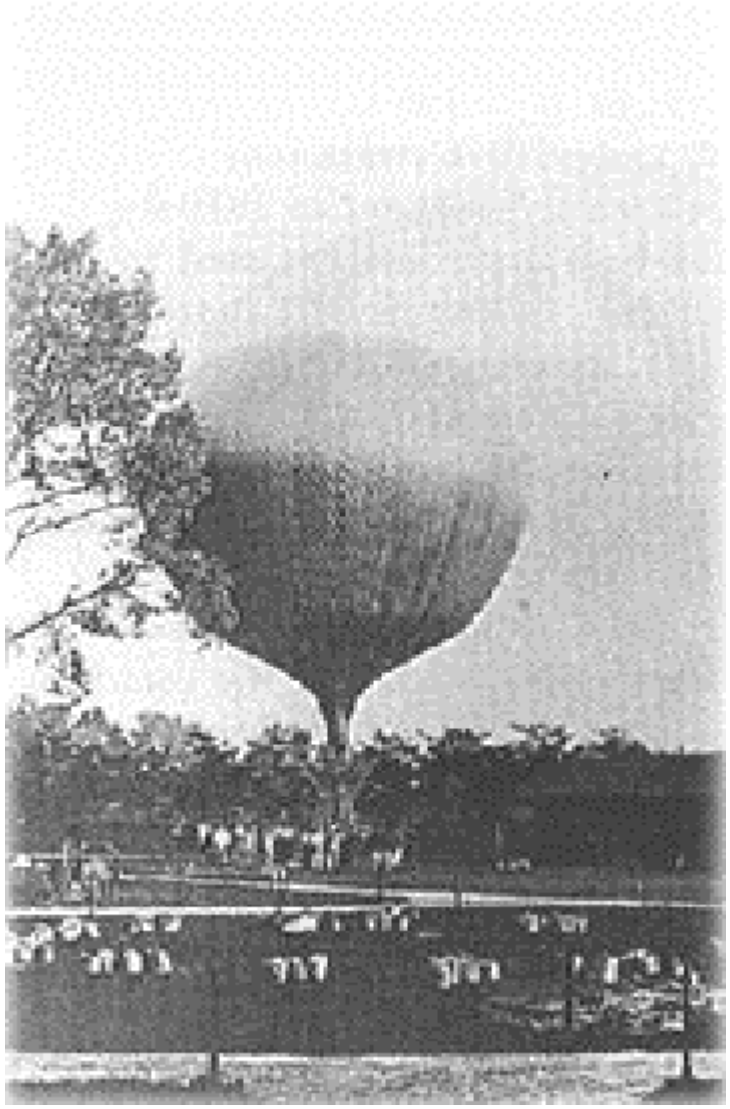
Spontaneous discharge of the electroscope !

✓1901 Wilson observes that the discharge is identical on the ground and in a tunnel
✓Rutherford shows that this is due to the natural radioactivity
✓1910 Father Théodore Wulf (jesuite, amatory physicists) conducted experiments on top of the Eiffel tower

Eiffel Tower and the Science



Up to the Sky



1912 and 1913 : Hess and Kolhörster made manned balloon flights to measure the ionisation of the atmosphere with increasing altitude

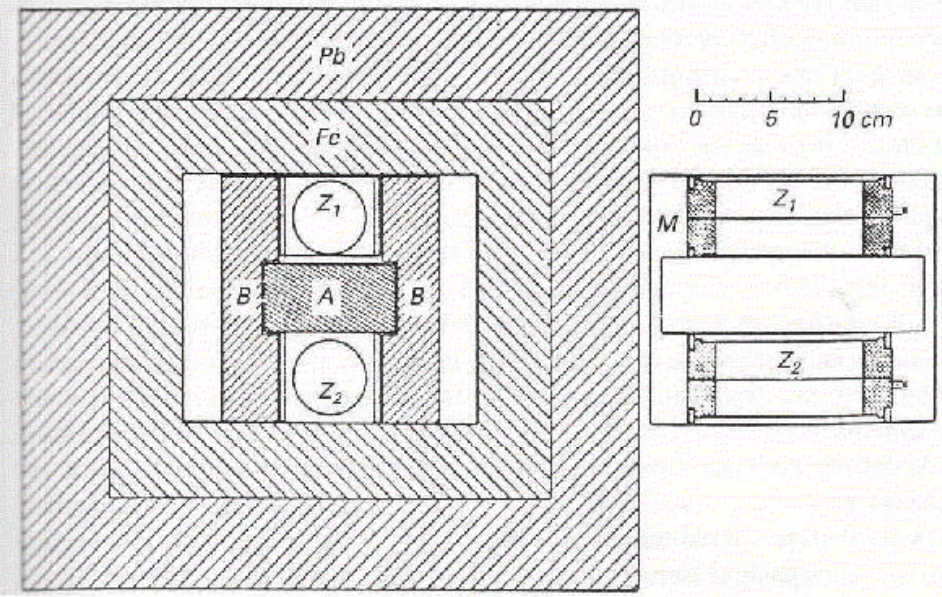
Average ionisation increase with increasing altitude

Source of the ionisation must be located above the earth's atmosphere !

Counting Improves

1929 Geiger-Müller detector was invented

Fast response time allow to count individual cosmic rays and also to determine precisely their arrival time

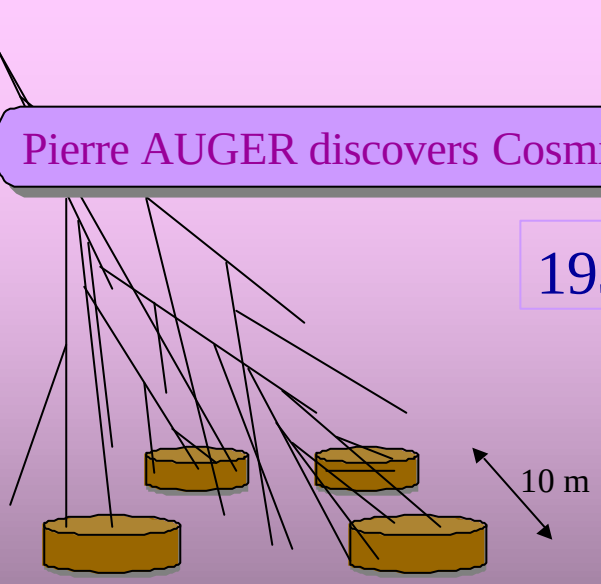


1929 Bothe and Kolhörster performed the first coincidence experiment by using two counters one placed above the other and introducing thick absorber between the two

Coincident events indicated that the cosmic rays were charged, very penetrating particle (gamma rays were stopped in the absorber)

Towards Extreme Energies

Pierre AUGER discovers Cosmic Ray showers



1938

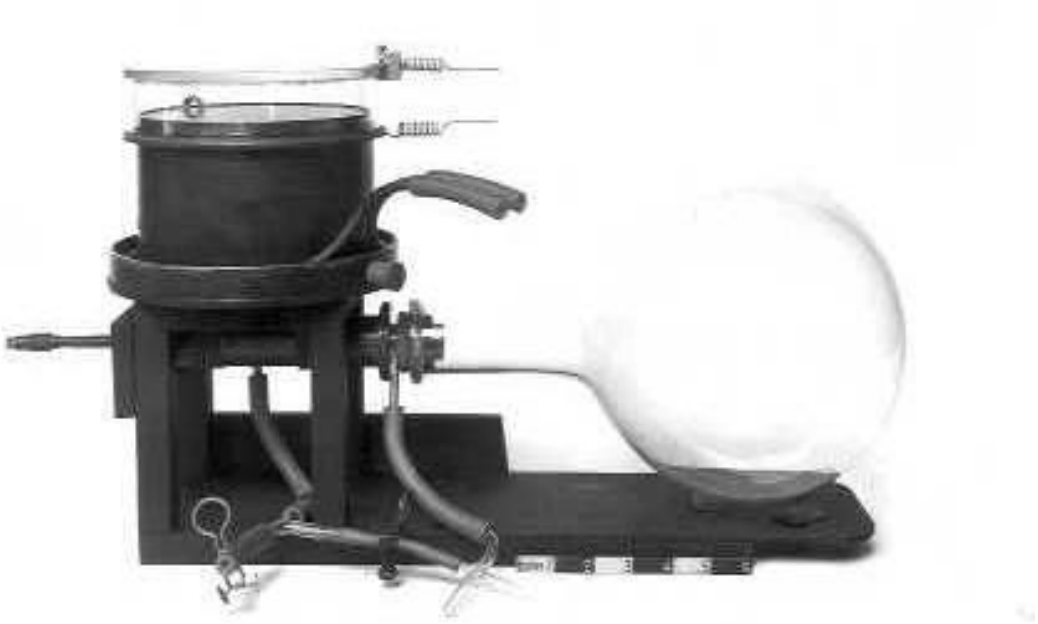
Two particle detectors positioned high in the Alps signaled arrival of particles at exactly the same time

$E > 10^{15}$ eV (!)

Cosmic Rays and the Discovery of Elementary Particles

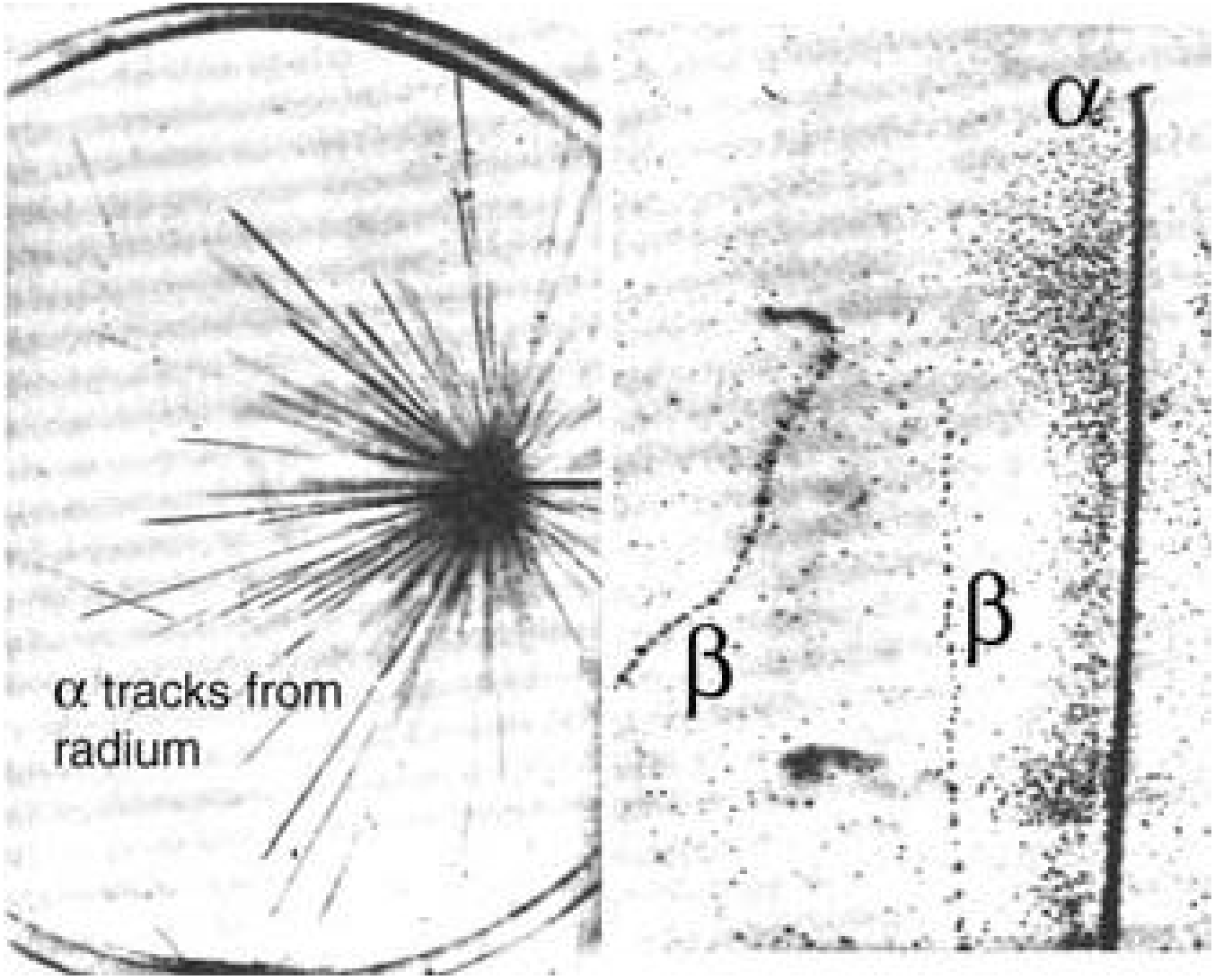
C.T.R. Wilson

Invention of cloud chamber



Fast expansion of gas in order to decrease temperature and over saturate the gas
Condensation of drops on the ions produced by particles

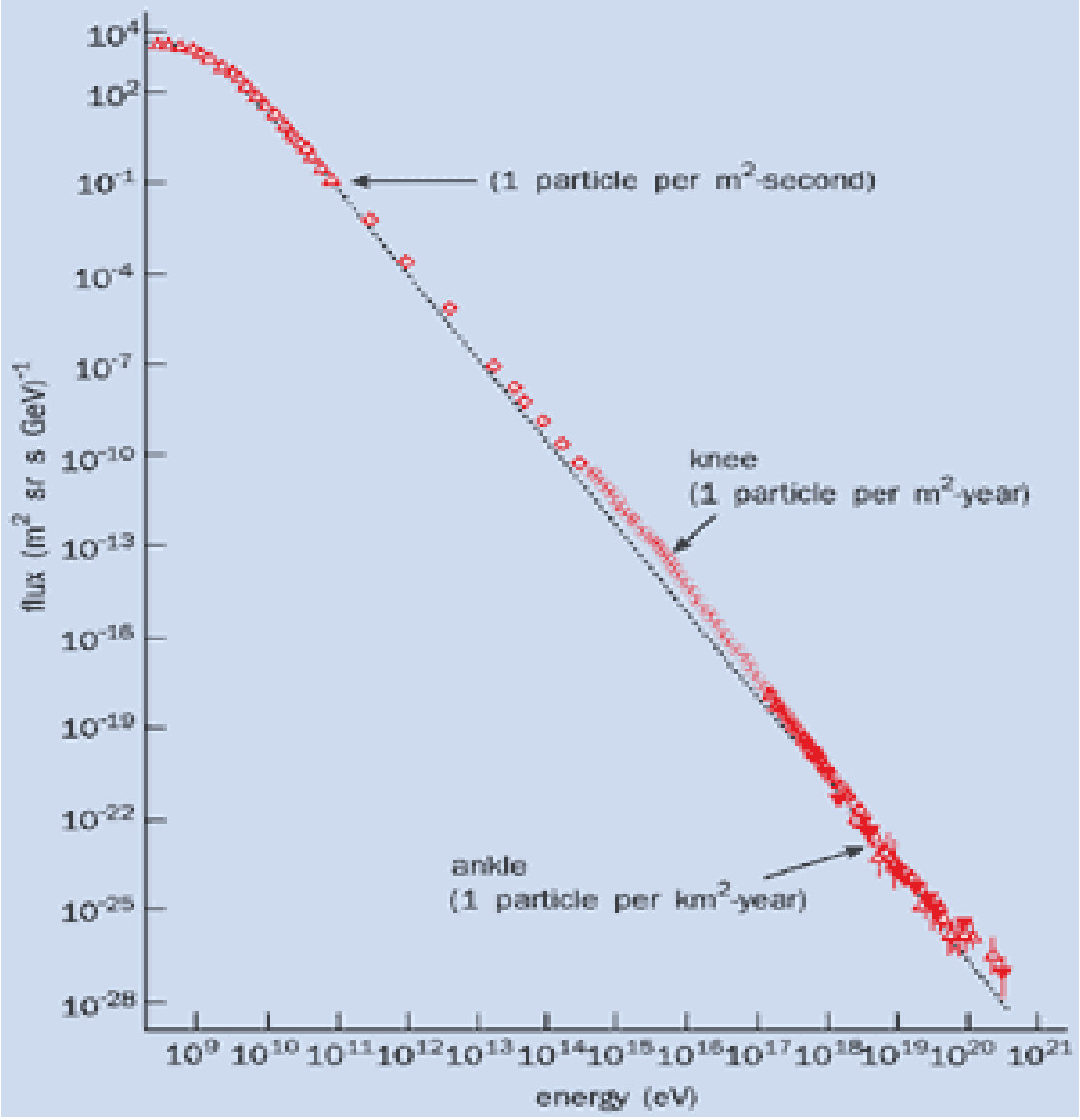
Ionisation tracks



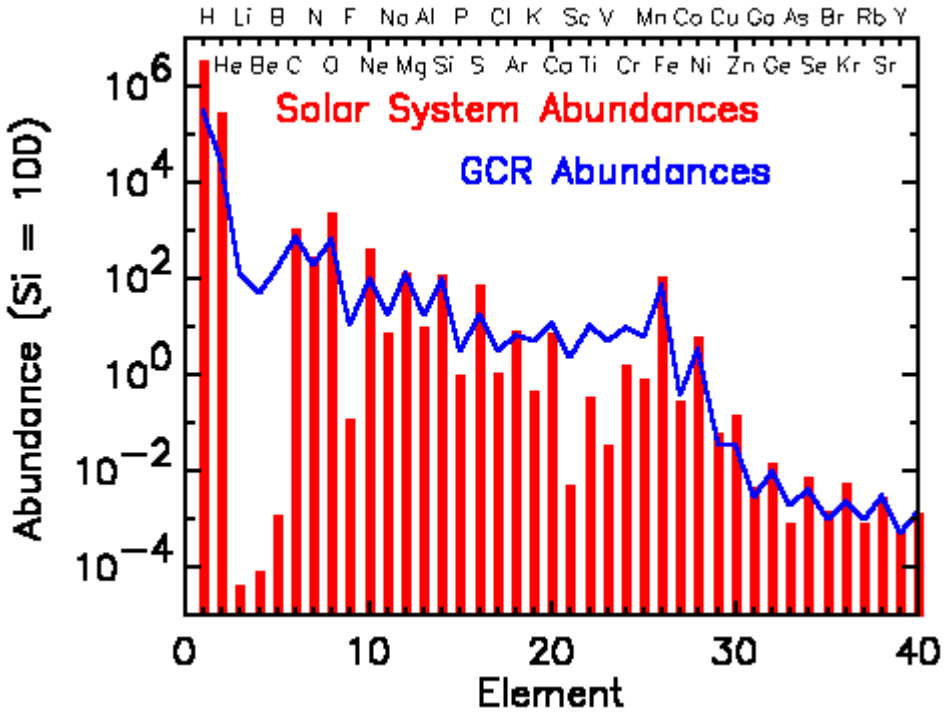
The Beginning of Particle Physics !

1932	◆ Positon ⇒ antimatter!
1936	◆ Muon
1947	◆ Pions : π^0, π^+, π^-
1949	◆ Kaons (K)
1949	◆ Lambda (Λ)
1952	◆ Xi (Ξ)
1953	◆ Sigma (Σ)

Cosmic Ray Energy Spectrum



Cosmic Ray Composition



- Composition (at ~GeV):

  85% H (p)

  12% He (α)

  1% heavier nuclei

  2% $e^{\pm}$ ($\geq$90% e^-)

  10^{-5}-10^{-4} antiprotons.