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Detecting Particles: The Spark Chamber

Particle Physics Masterclass

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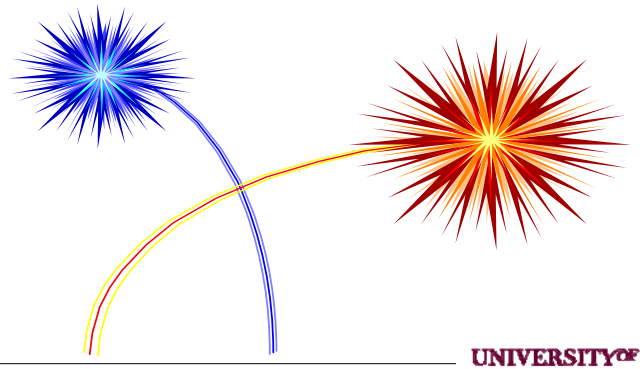
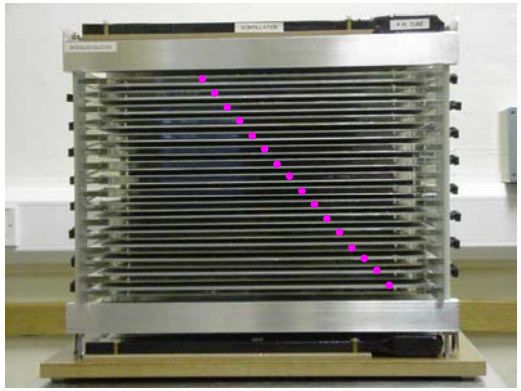
Particle Physics Detectors

- Normally, it is not possible to observe or feel individual particles
- Questions:-
  - How do we know they are there?
  - How do we learn more about their properties?
- Answer:-
  - By using particle detectors
- Many particle detectors have been developed to allow us to observe and study subatomic particles including the spark chamber

DEMONSTRATION 1



What you might see …



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What is the Spark Chamber detecting?

How does it work?

B

What does the Spark Chamber Detect (1)?

- The Spark Chamber detects Cosmic Rays
- Cosmic rays are particles which are all around us and, indeed, are going through us all the time
- Cosmic rays are the highest energy particles we observe in nature
  - typical energies between 10^6 and 10^{20}eV (10^{-13} and 10J): a cosmic ray of 10^{20}eV has an energy equivalent to a tennis ball travelling at 60mph!
- Cosmic rays move at very high speeds

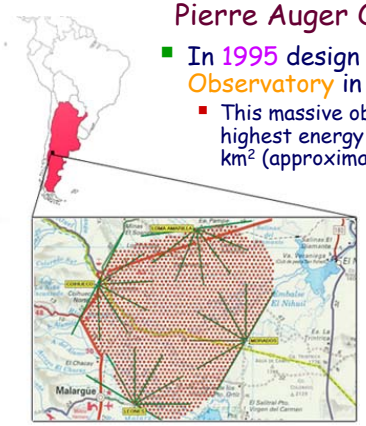
What does the Spark Chamber Detect (2)?

- Cosmic rays originate both within and outside of our galaxy
- Cosmic rays were particularly important to Particle Physics experiments before accelerator facilities had been developed …
- … However Particle Physicists today have a preference for accelerators as cosmic rays are very random and the highest energy cosmic rays are rare

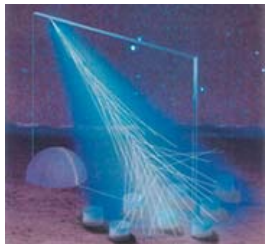
Brief History of Cosmic Rays (1)

- Cosmic rays were discovered in 1912 by Victor Hess who was in a balloon 5000m above the ground
- Observing cosmic rays in 1933, Carl Anderson discovered antimatter in the form of the positron
  - A positron is the same as an electron … but with a positive charge
- Following the discovery of the positron, other subatomic particles were discovered using cosmic rays including the muon, pion and kaon
- In 1993 a cosmic ray of 3×10^{20} eV was observed by the Fly's Eye experiment in Utah.
  - This is the highest energy cosmic ray ever detected and has an energy equivalent to a tennis ball travelling at 180 mph!

Brief History of Cosmic Rays (2): Pierre Auger Observatory



- In 1995 design studies for the Pierre Auger Observatory in Argentina, began.
  - This massive observatory aims to study the highest energy cosmic rays over an area of 3000 km^2 (approximately the area inside the M25!)



Source: www.pparc.ac.uk/frontiers (Issue 24)

Primary Cosmic Rays

- At their source cosmic rays are:
  - Ionised atomic nuclei
    - Atoms stripped of their outer electrons
  - Mainly Hydrogen and Helium nuclei
- They are known as primary cosmic rays

The Discrepancy

- Now, the number of cosmic rays observed on the Earth's surface can be many thousand per square metre per second
- And yet, on the Earth's surface it is unusual to encounter 'primary cosmic rays'
- Why the discrepancy?

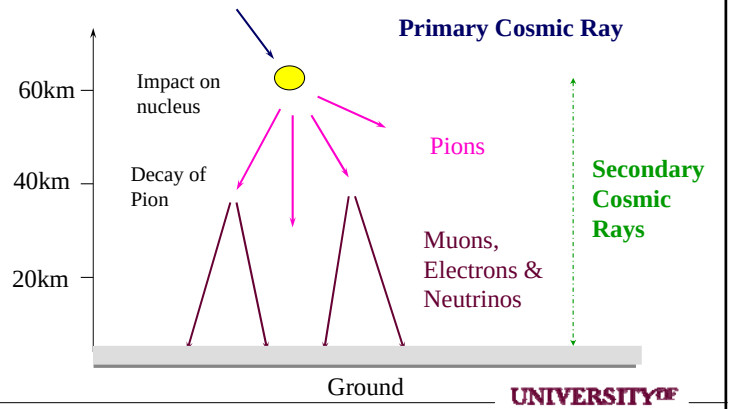
Secondary Cosmic Rays (1)

- Above the Earth's surface primary cosmic rays collide with air molecules producing an avalanche of secondary particles
- Each secondary having sufficient energy will create more secondaries
- The bigger the energy of the primary the bigger the size of the cosmic shower (also known as air shower)
- Pierre Auger discovered air showers of cosmic rays in 1938 by detecting particles (in the Alpes) arriving at the same time in two different detectors located many metres apart

Secondary Cosmic Rays (2)

- Secondary cosmic rays can include:
  - Neutrons and Protons
  - Mesons (including Pions)
  - Leptons (including Muons, Electrons and Neutrinos)
- It is mostly these secondary cosmic rays which the spark chamber detects, most of which are Muons

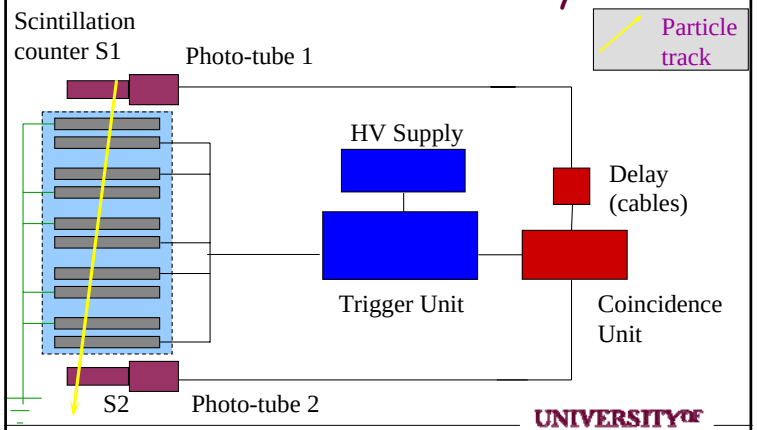
A Cosmic (Air) Shower



How can these cosmic showers occur?

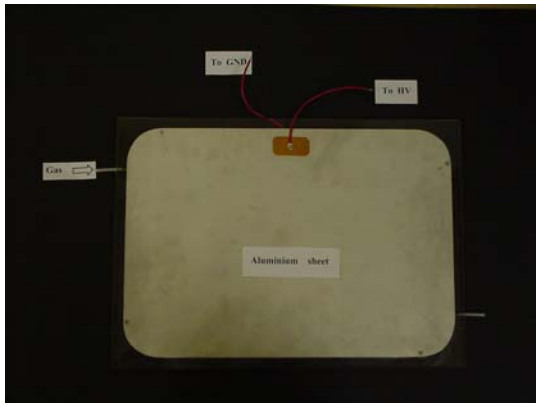
- In a similar way to accelerators, cosmic rays have been used as a lab for producing new particles.
- Using the relationship $E=mc^2$, Energy E from a primary cosmic ray can be converted to produce new particles

The Spark Chamber- How does it Detect the Cosmic Rays?

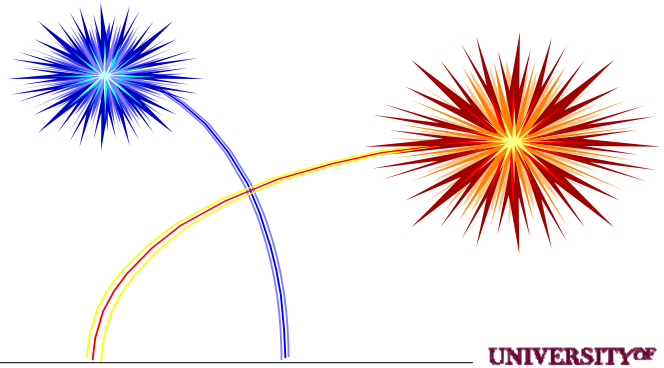


The Module (1)

The Module (2)



DEMONSTRATION 2



Summary

- Have seen the spark chamber demonstrated
- The spark chamber detects cosmic rays
- An insight into cosmic rays and their history has been given
- Have learnt how the spark chamber works
- The spark chamber is an example of a Particle Physics Detector
- Detectors are a common piece of apparatus used by Particle Physicists

Further Information

- See our Spark Chamber website for further information
  - www.ep.ph.bham.ac.uk/general/SparkChamber
- University of Birmingham Particle Physics Website
  - www.ep.ph.bham.ac.uk
- The Particle Physics Adventure
  - http://durpdg.dur.ac.uk/lbl/particleadventure
- The Pierre Auger Observatory
  - A.A. Watson, Cosmic Rays, Frontiers, 24 (2006)
  - www.auger.org