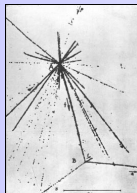


How to find a quark?

You need a little luck and a huge accelerator – a ring of several kilometres diameter, consuming electricity like a medium-size city.

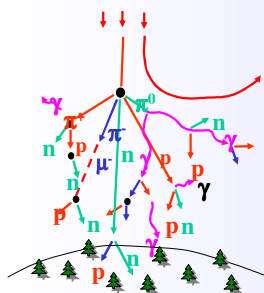
1, 2. The first pair – “up” and “down” are everywhere, being components of atomic nuclei



3. The lighter of the second pair, “strange” is a constituent of particles heavier than proton and neutron and observed in cosmic radiation in 40-ies. These strange particles can be captured atomic nuclei for a glimpse, before decaying. This picture shows a first noticed trace in the photographic emulsion of a decaying hyperonucleus.

M. Danysz and J. Pniewski, *J. Phil. Mag.* **44** (1953), 348

Cosmic rays



Cosmic rays

Cosmic rays were first found to be of extraterrestrial origin by Victor F. Hess (c.1912) when he recorded them with electrometers carried to high altitudes in balloons, an achievement for which he won the Nobel Prize in 1936. They were so named in 1925 by R. A. Millikan, who did extensive research on them.

Cosmic rays are mainly energetic protons, of 1 GeV energy, but not only.

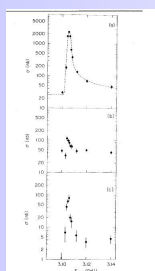


FIG. 1. From computer averaging for all widths between these limits, the J/ψ meson, and all ψ' , ψ'' , and ψ''' had states. The curve fits to the data points. The J/ψ meson is a bound state of charm quark and anti-charm quark. The energy levels are in MeV and the vertical axis is the number of events. The horizontal axis is the mass in GeV. The vertical axis is the number of events.

J.-E. Augustin et al., *Phys. Rev. Lett.* **33**, 1004-1006 (1974)

4. The “charm”, completing the second generation was subject to double hunting: in Brookhaven a narrow peak was observed at 3.1 GeV for electron- positron pairs production in $p+Be$ collisions, in Stanford vice-versa – a peak for hadron production in electron- positron annihilation; the papers were submitted with one day difference, the $c\bar{c}$ meson brings a double name J/ψ and the Noble prize was shared by both groups

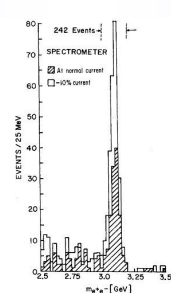
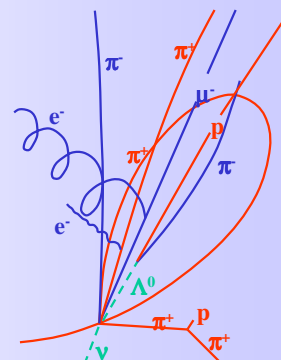


FIG. 2. Mass spectrum showing the existence of J/ψ . Results from two spectrometer settings are plotted showing that the peak is independent of spectrometer currents. The run at reduced current was taken two months later than the normal run.

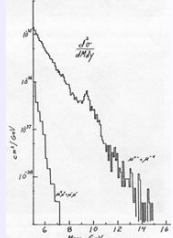
J.J. Aubert et al. *Phys. Rev. Lett.* **33**, 1404-1406 (1974)

Discovery of the Charmed Baryon

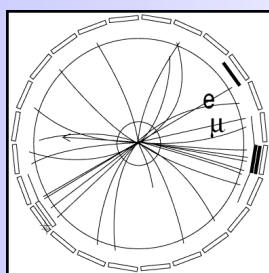
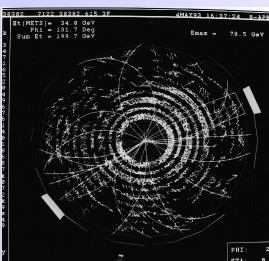
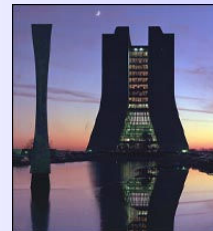
The photograph of the event in the Brookhaven 7-foot bubble chamber which led to the discovery of the charmed baryon (a three-quark particle) is shown. left. A neutrino enters the picture from below (dashed line) and collides with a proton in the chamber's liquid. The collision produces five charged particles--a negative muon, three positive pions, and a negative pion--and a neutral lambda. The lambda produces a characteristic 'V' when it decays into a proton and a pi-minus.



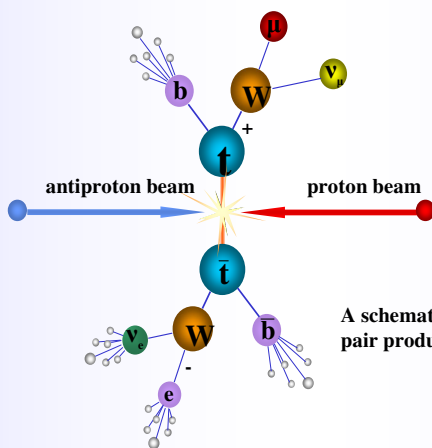
<http://www.bnl.gov/bnlweb/history/charmed.asp>



5. The third generation was first predicted theoretically by M. Kobayashi and T. Masakawa in 1974. The “bottom” quark called also “beauty” was observed in 1977 in FermiLab in production of muons from proton scattering on Cu or Pt, as a faint “bump” (Y - Upsilon meson $b\bar{b}$) at 9.5 GeV mass.

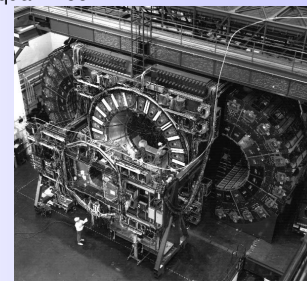


A computer simulation of a proton-antiproton collision. The tracks show the paths of different kinds of particles created in the collision.



A schematic of top-quark pair production

6. The last, “top” is so heavy (175 GeV) that becomes a father for generations of other particles – so called jets; its mass was predicted correctly by the theory and was measured with the best accuracy in the whole quark zoo.



Bigger and bigger machines are needed to find small quarks.

So if you have no money, or you do not believe in new quarks, you can find it always in the bakery shop in Trento, Italy.

