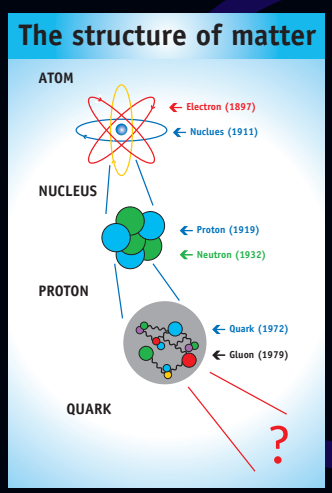
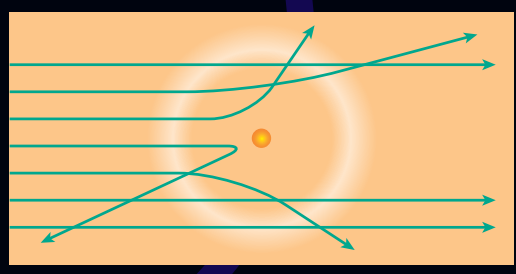
INSIDE THE PROTON



In Manchester in 1908 Hans Geiger and Ernest Marsden discovered that energetic alpha particles from a radioactive source could bounce back from a thin gold foil. Ernest Rutherford realised that this meant that the positive charge in the atom must be concentrated in a tiny central nucleus.



"It was as if you had fired a 15" shell at tissue paper and it had bounced right back." Rutherford.

Courtesy Stanford Linear Accelerator Center

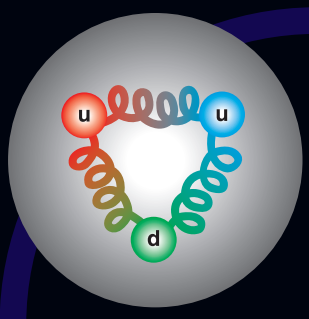
In 1969 at the Stanford Linear Accelerator Center (SLAC) in California, a team of physicists discovered that high energy electrons could be deflected through large angles by the single protons in the atomic nuclei in liquid hydrogen. This was evidence for elementary charged particles - quarks - *inside* the proton.

de Broglie's equation

Wavelength → $\lambda = \frac{h}{p}$ ← Momentum

h is Planck's constant

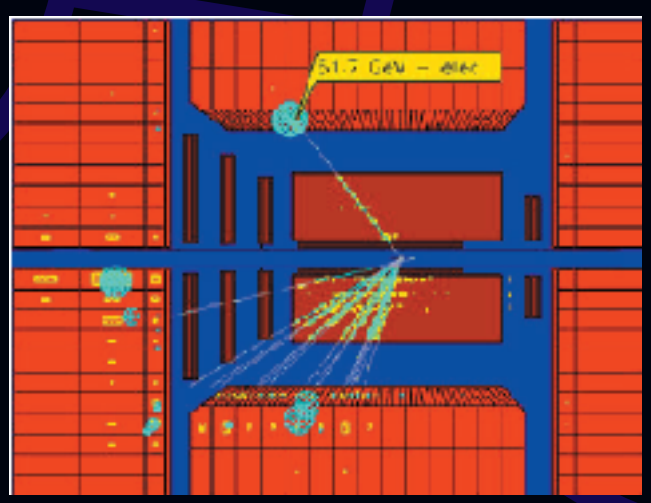
Quantum theory tells us that particles behave like waves, and the higher the energy and momentum, the shorter the wavelength. This means that higher energy (momentum) particles can probe shorter distances. At SLAC the electrons had enough energy to probe *deep* inside the protons. Also, there was enough energy to disrupt the proton and make new particles: the collisions were *inelastic*. This process is called deep inelastic scattering.



Quarks were hypothesised in 1964 by Murray Gell-Mann, who predicted that the proton contains three quarks: two "up" quarks with charge +2/3, and one "down" quark with charge -1/3 giving a total of 1 for the proton. This structure was confirmed in the experiments at SLAC. We know now that the quarks are held together by the strong force, which acts through the "exchange" of particles called gluons.

Source: DESY Hamburg.

Physicists at Oxford work on the ZEUS experiment at HERA, which continues to study the deep inelestic scattering of electrons from protons. They have discovered that at the very small distances they probe, the proton contains many gluons.



Since 1991, physicists have been probing the proton at even shorter distances (wavelengths ~ 10^{-18} m) in high energy electron-proton collisions at the Hadron Electron Ring Accelerator (HERA) at the DESY laboratory in Hamburg.

If you want to know more about Physics at Oxford see the web:
http://www.physics.ox.ac.uk/

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