How Strange is the Proton?

G0 Experiment

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Approximately 100 Scientists from 18 Institutions

Caltech, Carnegie-Mellon, Grinnell, Hampton, Illinois, IPN Orsay, ISN Grenoble, Jefferson Lab, Kentucky, Louisiana Tech, Manitoba, Maryland, Massachusetts, New Mexico State, Northern British Columbia, TRIUMF, Virginia Tech, William & Mary, Winnipeg, Yerevan

Joint DOE and NSF Project with French (CNRS) and Canadian (NSERC) Contribution

The goal of the G0 experiment is to learn more about the quark substructure of protons and neutrons (nucleons). The experiment's focus is on the contribution of the strange quark to the electric and magnetic structure of nucleons.

The G0 experiment measures scattering caused when electrons strike protons. The experimental apparatus consists of a beam of polarized electrons from the Jefferson Lab accelerator, a liquid hydrogen target (protons), and a spectrometer to measure the scattered particles. The measurement is performed in two phases. In the first--the forward angle measurement--a proton recoiling from its interaction with an electron is bent in a magnetic field produced by the superconducting coils. Protons of different momenta bending by different amounts in the magnetic field strike the array of particle detectors in different places. The detectors consist of pairs of crescent-shaped pieces of a special plastic (called scintillator) which emits light when a particle passes through it. This phase has been run and the forward angle data is undergoing analysis. In the second phase—the backward angle measurement—the entire G0 assembly will be reversed relative to the beam. Scattered electrons from the beam striking the target will be measured, rather than the scattered target protons. The backward angle data is scheduled to begin collection in January 2005.

What makes G0 new and challenging is determining a very small, special piece of the overall interaction of electrons and protons. Because of the close relationship between the electromagnetic and weak interactions, it is interesting to compare these two interactions for nucleons. This comparison allows the isolation of the strange quark contribution. The electromagnetic interaction is well measured; this experiment is designed to measure the weak interaction. Observation of the weak interaction requires that an experiment be compared with its "mirror image". The mirror image is produced by reversing the beam polarization, i.e. changing the direction of the electron spins in the beam from parallel to anti-parallel relative to the direction of motion. The weak interaction effect is determined by measuring the difference in the number of scattered particles when the electron beam is polarized with electron spins parallel to the direction of travel as compared to anti-parallel. The relative difference of these numbers is very small—only a few parts in a million.

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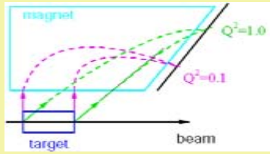
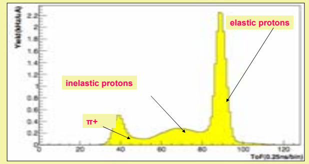
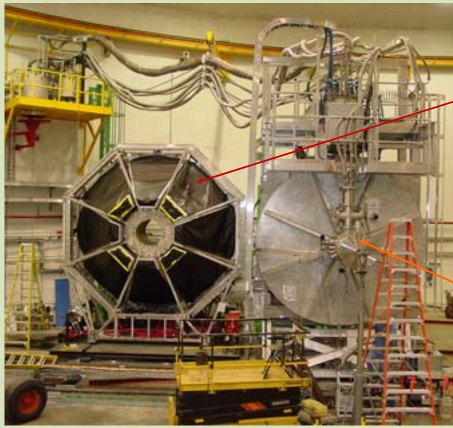
Forward Angle

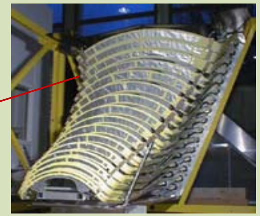
- •Detect scattered protons
- •Time-of-flight separates protons from pions
- •Superconducting toroidal magnet sorts protons by Q2
- •Segmented large area scintillation detector array
- •Custom and commercial high rate electronics
- •3 GeV polarized beam in 32 ns pulses
- •High power 20 cm liquid hydrogen target





Time of Flight





One octant scintillator array

20 cm liquid hydrogen (LH2) target

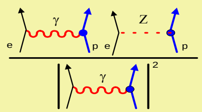
Formalism
Parity Violating Electron Scattering

Polarized electrons, unpolarized target

$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

$$= \left[\frac{-G_F Q^2}{4\pi\alpha\sqrt{2}}\right]\frac{A_E + A_M + A_A}{\sigma_p}$$

~ few parts per million



$$A_E = \varepsilon G_E^p G_E^Z$$

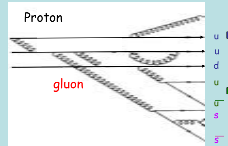
$$A_M = \tau G_M^p G_M^Z$$

$$A_A = -(1 - 4\sin^2\theta_W)\varepsilon' G_M^p G_A^e$$

Charge and magnetism distributions in proton:

$[G_E(p), G_E(n), G_E^Z(p)] \leftrightarrow$ [up, down, strange]

What role do strange quarks play in nucleon properties ?

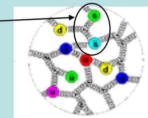


Valence quarks—determine properties such as charge

"Non-strange" sea (u, ū, d, d̄) quarks—don't change charge, but can contribute to rest energy, spin, etc.

"Strange" sea (s, s̄) quarks also contribute to rest energy and are much more massive than up and down quarks.

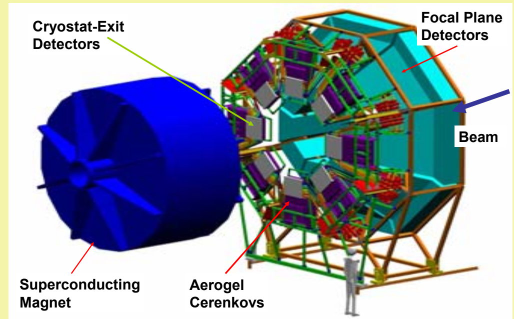
The G0 experiment probes strange quarks and antiquarks.

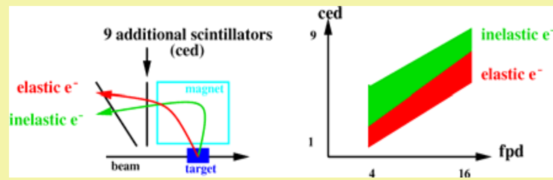


Main goal of G0:

To determine the contributions of the strange quark sea (s s̄) to the electro-magnetic properties of the nucleon ("strange form factors").

G0 BackAngle Configuration





G0 Expected Uncertainties