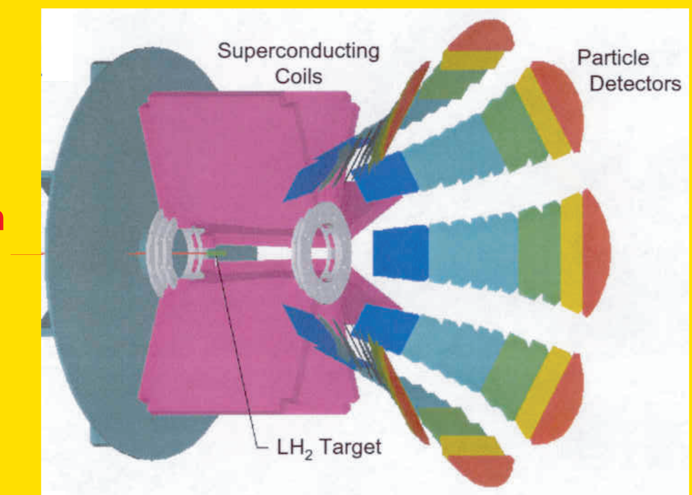
Study Strange Quarks in the Proton

G0 Experiment

Electron Beam



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Phil Roos (U. Maryland)

Approximately 100 Scientists from 18 Institutions

Caltech, Carnegie-Mellon, 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, Yerevan

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

The goal of the G0 experiment is to learn more about the quark substructure of protons and neutrons (nucleons). Our interest is in the distributions of charge and magnetization in the nucleon and how it is built up out of the different types of quarks. We are particularly interested in whether these distributions have any contribution from strange quarks, as this type exists only "virtually" in nucleons as the result of the quantum mechanical interplay between mass and energy.

The G0 experiment measures the scattering of electrons by protons. The apparatus consists of the beam of polarized electrons from the Jefferson Lab accelerator, a liquid hydrogen target that provides the protons for the scattering and a spectrometer to measure the scattering products. The actual measurement will be performed in two phases. In the first, a proton recoiling from its interaction with an electron will be bent in the magnetic field produced by the superconducting coils according to its speed (momentum). Protons of different momenta bending by different amounts in the magnetic field, will strike the array of particle detectors in different places. These detectors consist of pairs of crescent-shaped pieces of a special plastic (called scintillator), which emits light when a particle such as a proton passes through it. In the second phase the whole apparatus will be reversed relative to the beam direction and scattered electrons rather than protons will be detected.

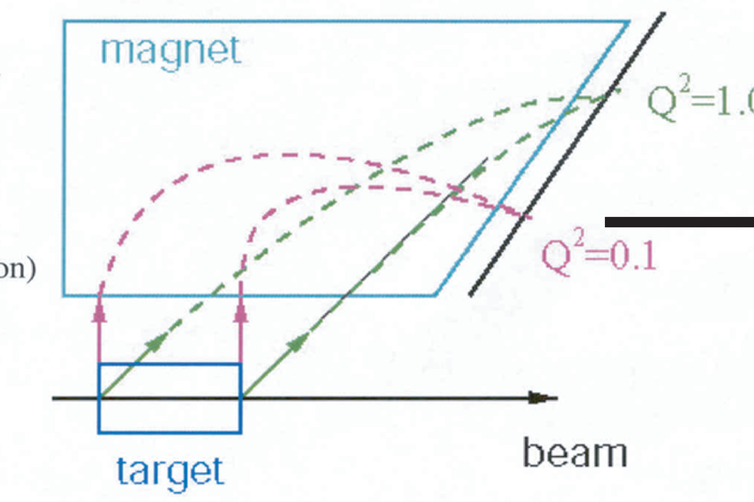
The particular feature of the experiment that makes it both new and challenging is that it will determine a very small, special piece of the overall interaction of electrons and protons. Because of the close relationship between the electromagnetic and weak interactions, it is interesting to compare these two interactions for nucleons. This comparison will allow us to isolate 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 we compare and experiment and 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 to its direction of motion. The weak interaction effect is therefore determined by measuring the difference in the number of scattered protons when the electron beam is polarized with electron spins parallel to their direction of travel as compared to anti-parallel. The relative difference of these numbers is very small - only a few parts in a million. The G0 experiment is carefully designed to reduce to acceptable level false signals that could mimic the physics effect we are interested in.

Parity-Violating Electron Scattering from Hydrogen

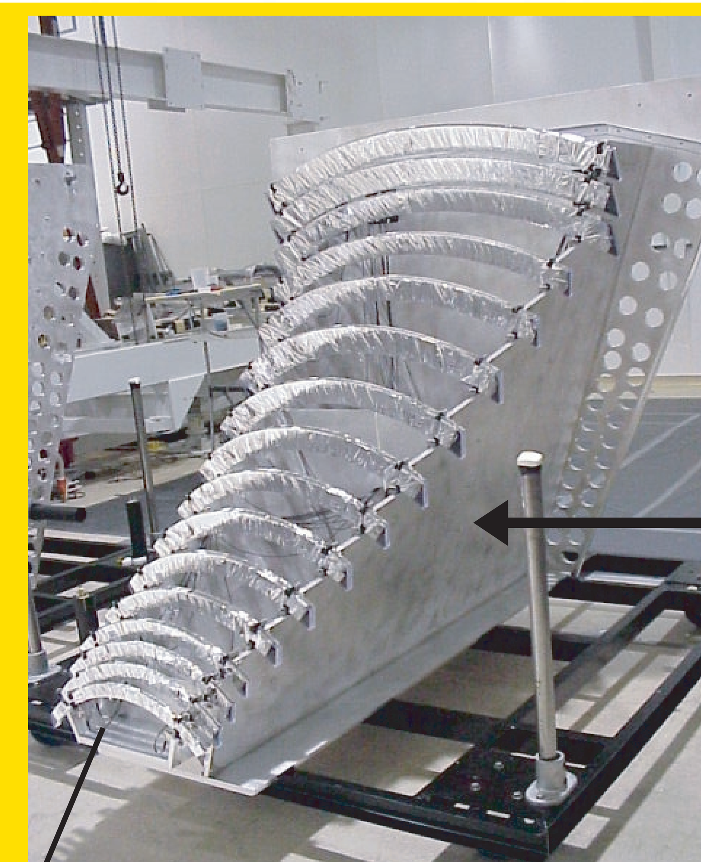
High Statistics
- $\Delta A \approx 2.5\times10^{-7} \Rightarrow 10^{13}$ counts
- Large acceptance, Q^2, $\Delta\Omega$
- Long targets, 20 cm LH_2
- Good resolution ($1\% < \Delta Q^2/Q^2 < 10\%$)
- Simple Detectors (no trajectory construction)

Low Instrumental Uncertainties
- $\Delta A \approx 2.5\times10^{-7}$ or $\approx 5\%$ of A
- Target B=0, Iron Free
- Axial Symmetry $\Rightarrow$ checks

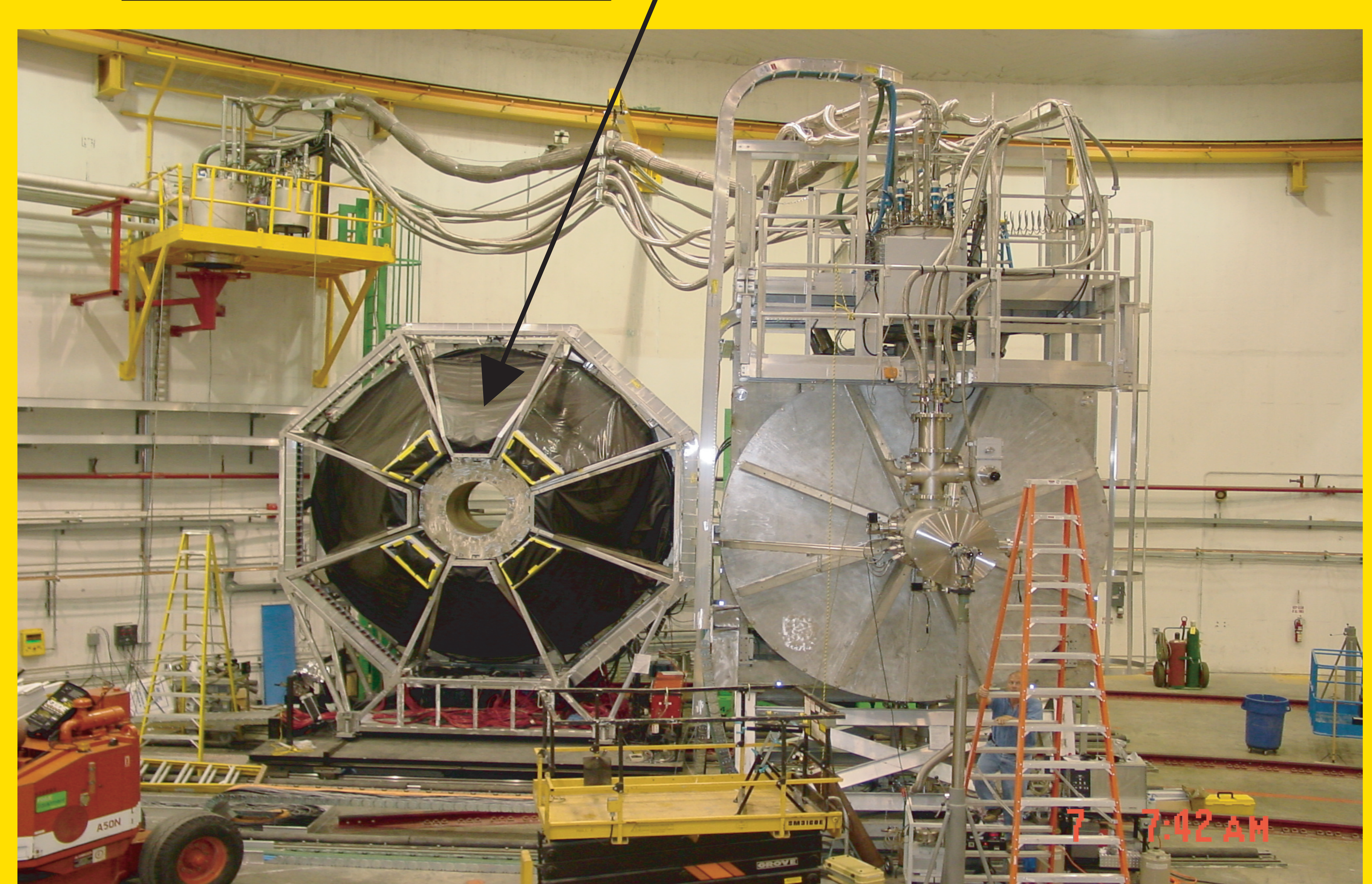
Background Rejection
- Counting (not integrating)
- TOF (<1 ns resolution)
- Detector Coincidence



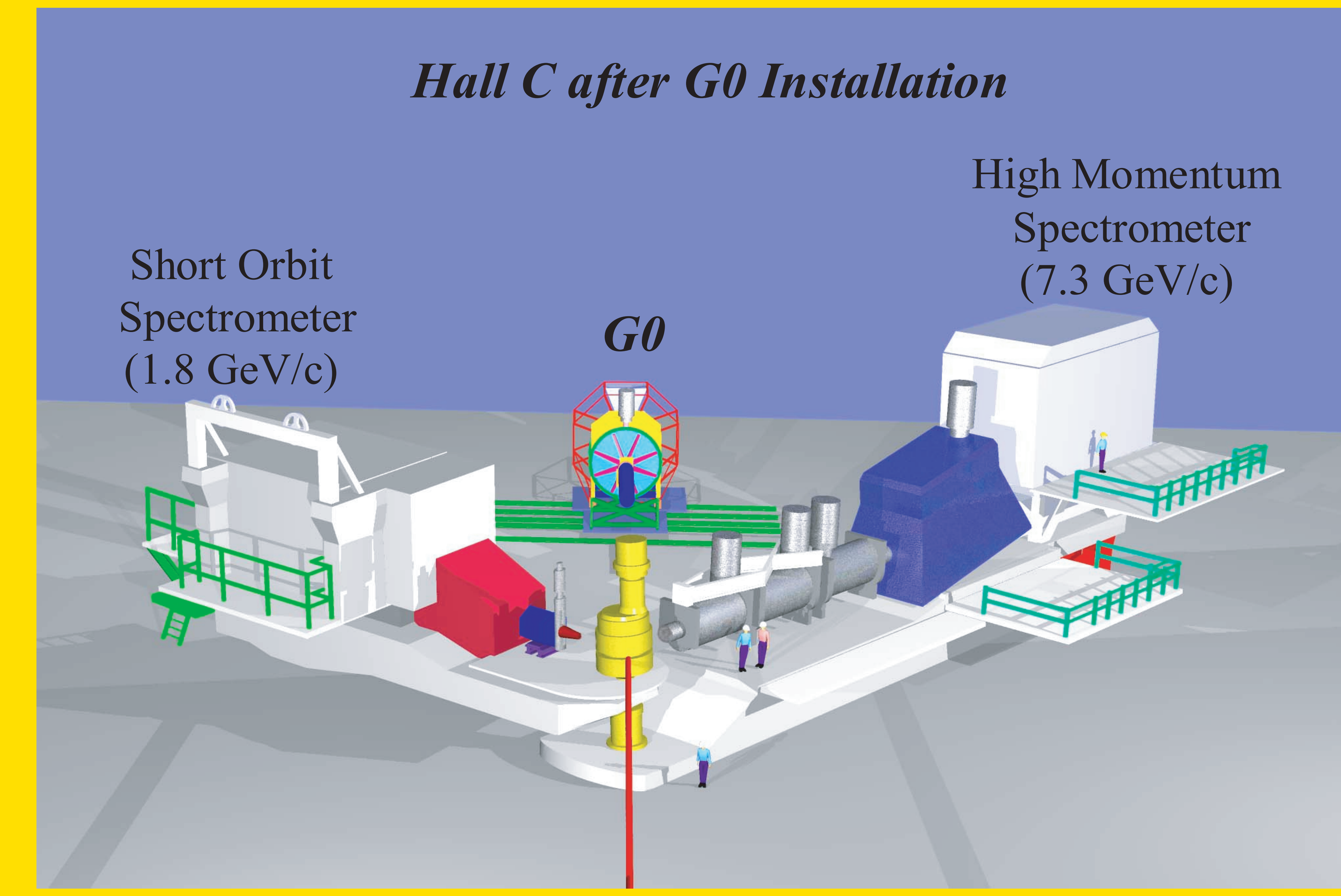
This diagram illustrates the trajectory of the Scattered protons in the magnetic field to the Focal plane detectors.



These photographs show the construction of the North American octants in the cleanroom during the summer of 2000. Each octant consists of 16 scintillator pairs, with 4 photomultiplier tubes per pair.

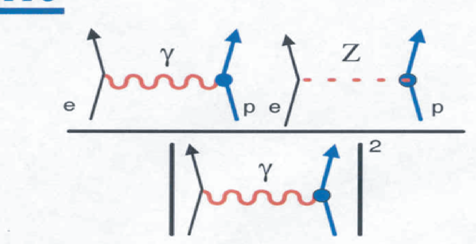


The G^0 Experimental Assembly in Hall C



Formalism

$$A=\frac{\sigma_R-\sigma_L}{\sigma_R+\sigma_L}=\left[\frac{-G_F Q^2}{4\pi\alpha\sqrt{2}}\right]\frac{A_E+A_M+A_A}{2\sigma_{unpol}}$$



polarized electrons, unpolarized target

$$A_E=\varepsilon(\theta)G_E^Z(Q^2)G_E^\gamma(Q^2)$$
$$A_M=\tau(Q^2)G_M^Z(Q^2)G_M^\gamma(Q^2)$$
$$A_A=-(1-4\sin^2\theta_W)\varepsilon' G_A^e(Q^2)G_M^\gamma(Q^2)$$

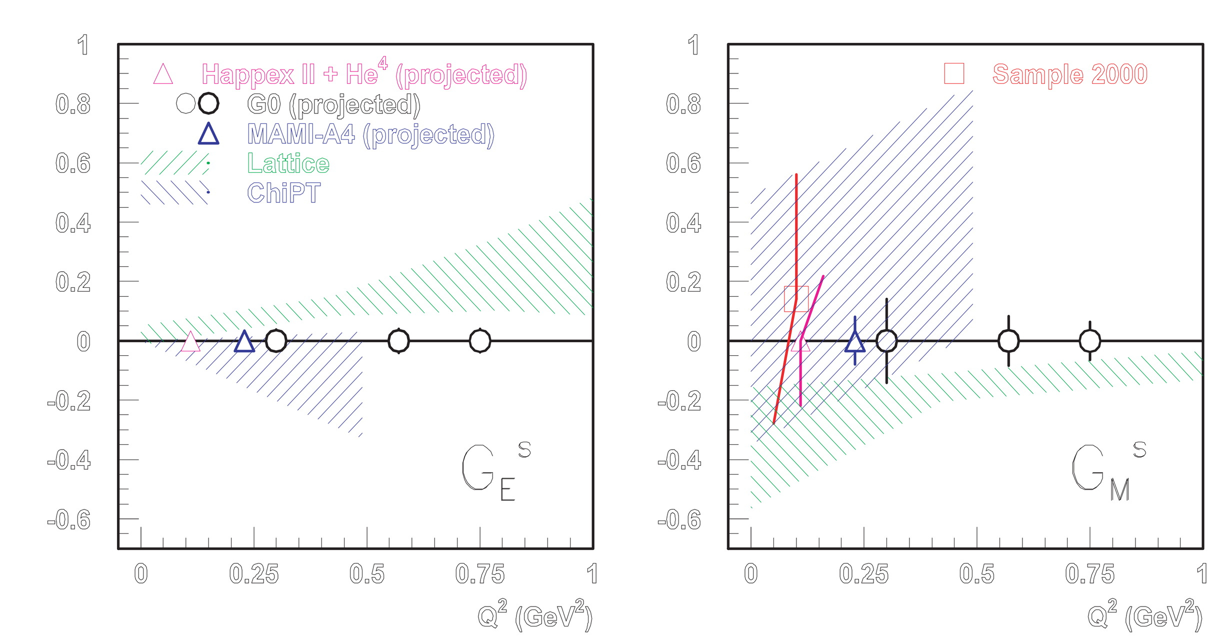
neutral weak form factors contain explicit contributions from strange sea

$$G_{E,M}^Z=(1-4\sin^2\theta_W)(1+R_V^p)G_{E,M}^p-(1+R_V^n)G_{E,M}^n-G_{E,M}^s$$
$$G_A^e=-G_A+\Delta s+\eta F_A+R^e$$

$$\eta=\frac{8\pi\alpha\sqrt{2}}{1-4\sin^2\theta_W}=3.45$$

axial f.f. has uncertain anapole + radiative corrections

G0 Projections



G^S_E, G^S_M and G^e_A separated over range $Q^2 \sim 0.1$-$1.0 (GeV/c)^2$