THE G^0 EXPERIMENT : MEASUREMENTS OF THE STRANGE FORM FACTORS OF THE PROTON.

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In the G^0 experiment, parity violation asymmetries in elastic electron scattering from the nucleon will be measured. The primary purpose of the experiment is to separate the s quark contributions ($G_E^s(Q^2)$) and ($G_M^s(Q^2)$) from the overall charge and magnetization densities of the proton. With this aim in view, a dedicated apparatus has been constructed and is currently being installed at JLab / Hall C.

Parity violation in elastic electron scattering arises through the interference of Z^0 and the γ exchange. The relative asymmetry of the reaction for the two helicity states of the beam, can be expressed as[1] :

$$A = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\,\frac{\varepsilon G_E^\gamma G_E^Z + \tau G_M^\gamma G_M^Z - (1-4\sin^2\theta_W)\varepsilon' G_M^\gamma G_A^e}{\varepsilon (G_E^\gamma)^2 + \tau (G_M^\gamma)^2} \tag{1}$$

where : G_E^γ and G_M^γ are the proton electro-magnetic form-factors, G_E^Z and G_M^Z are the proton weak form-factors and G_A^e is the axial form-factor of the nucleon[2]. The measurements of G_E^Z, G_M^Z and G_A^e combined with the knowledge of the electro-magnetic form-factors of the proton and the neutron, allows one to extract the s quark contribution (G_E^s and G_M^s) to the overall nucleon structure. In this decomposition, one need only to assume charge symmetry between the proton and neutron[1] and SU(3). As a result, one can express the measured asymmetry directly in terms of strange form-factors :

$$A = \eta + \xi G_E^s + \chi G_M^s + \phi G_A^e \tag{2}$$

where η is the asymmetry completly known if neutron and proton form factors are known. For the G^0 experiment, η ranges between -1 and -35 $\times 10^{-6}$.

1 The G^0 program relative to other parity violation experiments.

Three asymmetry measurements are necessary to extract G_E^Z, G_M^Z and G_A^e without any other experimental assumptions. Table 1 shows, for experiments measuring the strange form-factors, the kinematics used to provide the necessary experimental data. Most measure asymmetries at a given angle from two

Experiment	Target	θ_e (deg.)	Q^2 (GeV^2)	Observables
SAMPLE [3]	p	146	0.1	$G_M^s = 0.14 \pm 0.29 \pm 0.31$
(MIT-Bates)	d	146	0.1	$G_A^e = 0.22 \pm 0.45 \pm 0.39$
HAPPEX[4]	p	12.3	0.47	$G_E^s + 0.392 G_M^s =$
(JLab)				$0.025 \pm 0.020 \pm 0.014$
SAMPLE'01	d	146	0.04	$G_M^s + 3.8 G_A^e$
HAPPEX II	p	6	0.1	$G_E^s + 0.1 G_M^s$
	He[4]	6	0.1	G_E^s
PV-A4	p	35	0.23	$G_E^s + 0.2 G_M^s$
(MAMI)	p	35	0.1	$G_E^s + 0.1 G_M^s$
	p	7	0.1 ... 1.0	
G^0	p	110	0.3, 0.5, 0.8	G_E^s , G_M^s, G_A^e
(JLab)	d	110	0.3, 0.5, 0.8	

Table 1. Scope of the experiments measuring the strange form-factors.

different targets (like SAMPLE or HAPPEX II), then they utilize kinematic suppression of one of the observables (resp. G_E^s or G_A^e). The G^0 program[5] is the only one planned which will completely separate G_E^Z, G_M^Z and G_A^e. Asymmetries are measured with hydrogen target at forward (7°) and hydrogen and deuterium targets at backward (110°) electron angles. Moreover, the complete G^0 experiment will measure the evolution of those observables for three different momentum transfers Q^2. Figure 1 shows the expected total errors of the G^0 measurements compared to the predictions of two different models : Chiral Perturbation Theory[6] and Lattice QCD[7]. Note that though both models computations actually agree[a] with the zero-compatible results of the published SAMPLE and HAPPEX experiments, they predict non-zero individual values for G_E^s and G_M^s. Also, note that given the precision of the experiment, the G^0 data points will be sensitive to the Q^2 evolution such as the ones predicted by those models. The projected errors presented here include the statistical accuracy of the measurements ($\frac{\Delta A}{A} = 5\%$), the systematic precision, as well as the knowledge of the electro-magnetic form-factors of the proton and the neutron. Though the G^0 collaboration has designed a specific apparatus of large solid angle (0.5-0.9 str), able to handle a large luminosity (2×10^{38} cm^{-2} s^{-1}), the G^0 overall errors are dominated by statistics .

[a]Note that the Chiral model actually uses the SAMPLE and the HAPPEX results to fix two of its perturbative constants.

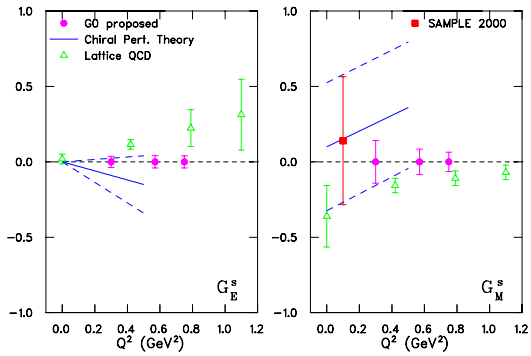

Figure 1. The projected errors of the G^0 measurements compared to two different models.

2 The G^0 experimental technique.

The G^0 experiment will use a 40μA beam with 70% polarization hitting a long cryogenic target (0.2 cm). A special purpose, super-conducting toroidal spectrometer, with azimuthally symmetric angular acceptance has been constructed. In the forward angle mode (see sketch in figure 2), individual particles will be counted in a set of 16 pairs of scintillators per octant placed in the focal plane. Each scintillator pair provides one bin in Q^2. The bending angle is 35° and collimators protect the detectors from direct view of the beam. In the first part of the experiment, the protons recoiling from *ep* scattering at a fixed incident electron beam of 3 GeV will be detected at $\theta_p = 70^o \pm 10^o$ for Q^2 ranging from 0.1 to 1.0 GeV^2. Time of flight measurement over a 32 ns window will be used to supplement momentum selection by the spectrometer and separate elastic from inelastic contributions. For this purpose, the beam will be pulsed at 31.25 MHz, although usually CEBAF operates at 499 MHz. Custom time-encoding electronics allow readout of high rates of the order of 2 MHz per scintillator pair.

In a second part of experiment, the full detector will be rotated back-to-front in order to detect electrons at backward angles ($\theta_e = 111^o \pm 10^o$), giving a comfortable lever arm for a Rosenbluth separation. In this configuration, each incident beam energy (0.4, 0.6 and 0.8 GeV) will correspond to a given Q^2 (resp. 0.3, 0.5 and 0.8 GeV^2). An additional scintillator hodoscope will allow kinematic separation of elastic and inelastic electrons. Inelastic asymmetries will measure the weak neutral transition current in the region of the Δ-resonance[8]. In order to separate the axial form-factor G_A^e, data will be taken with proton and deuterium targets. For the deuterium measurements, aerogel Cerenkov counters will provide π/e separation.

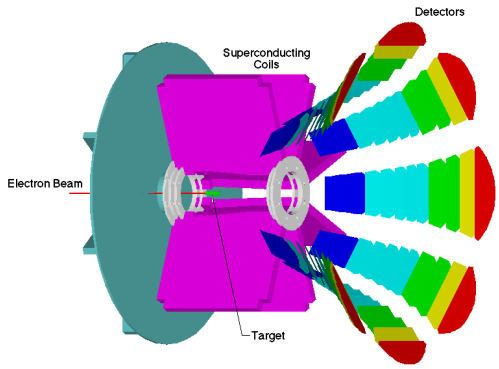

Figure 2. Sketch of the G^0 apparatus in the forward configuration. The recoil particles are deflected by the magnet toward 8 focal plane detectors called octants.

3 Conclusion.

The G^0 experiment is currently undergoing installation in Hall C at JLab. All components (magnet, target, detectors and electronics) of the apparatus have been completed by an international (North American and French) collaboration of 80 physicists and are mounted on the beamline. Commissioning of the apparatus will take place between October and December 2002. The schedule for the different phases of the G^0 experiment will be interleaved with other experiments using the standard Hall C apparatus.
By performing a complete separation of G_E^s, G_M^s and G_A^e, the G^0 experiment will enlarge the extent of existing data on the strange quark content of the nucleon. Moreover, the complete G^0 experiment will measure the evolution of these form-factors for Q^2 ranging from 0.3 to 0.8 GeV^2.

References

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