Charlie's Contributions to the Hall A Experimental Program

The advent of high polarization, high current and long lifetime electron sources have opened the doors for a variety of experiments which, just ten years ago were not feasible. Charlie Sinclair and his group at Jefferson Lab have been in the forefront of those changes.

Back in 1997, when the first polarized beam experiment in Hall A (E89-033, "Measurement of Recoil Polarization in the $^{16}O(e,e'p)$ Reaction with 2.4 GeV Electrons") was to take place, the requested beam parameters of 50 μA and 30% beam polarization looked more like a dream in the sky. The rumor mill was busy reminding us of the tortuous paths followed by many other labs to obtain a polarized beam of much less intensity, polarization and that, in many cases, required so much attention that the beam seemed to be mostly off than on. Yet, there was a glimpse of hope. Already Charlie and his group had managed to deliver a continuous unpolarized electron beam which, at least for those of us accustomed to pulsed accelerators with beam spots of several millimeters (on a good day), large beam halos and low average current, was of unprecedented quality and intensity. The day of E89-033 came and Charlie and his group showed us that a new chapter of "routine" experimental techniques had been opened: the use of polarized electron beams, recoil polarimeters and polarized targets.

With the availability of reliable polarized beam, the physics payback for Jefferson Lab has been substantial. In the case of Hall A, a few examples are measurement of the strangeness form factor of the nucleon via parity violation (see below), $N \rightarrow \Delta$ transition form factors, helicity conservation in deuteron photodesintegration, measurement of the proton elastic form factor ratio G_p^e/G_p^m, several experiments making use of polarized beam - polarized ^3He target (see below) and, the study of nuclear wavefunctions for several nuclei.

Without the tenacious efforts of Chralie, the spin physics program in Hall A would not have materialized. The Hall A community is grateful to Charlie for a job well done.

Parity Violation Program

The polarized beam development at Jefferson Lab was of vital importance to the Hall A Proton Parity Experiment (HAPPEX) and has paved the way for future parity experiments at Jefferson Lab. Parity experiments use the weak interaction as a complementary probe of nucleon or nuclear structure. The weak interaction is observable through an interference of the electromagnetic amplitude with the parity violating Z^0 boson amplitude giving rise to an asymmetry $A = (\sigma_R - \sigma_L)/(\sigma_R + \sigma_L)$, where $R(L)$ denote right(left) handed longitudinally polarized electrons. These asymmetries are typically 0.1 to 1 ppm and the measurements require exquisite control of helicity correlated systematics. The physics accessed by parity experiments include the measurements of the strangeness electric and magnetic form factors G_E^s and G_M^s and measurements of neutron rms radii R_n in nuclei; HAPPEX was primarily sensitive to G_E^s.

The parity experiments generally have enjoyed a very favorable scientific rating by Program Advisory Committees, and Jefferson Lab appears to be one of the best places in the world to perform them, in large part because of the highly reliable, high intensity, low emittance beam with excellent control of systematics. More than any other part of the experimental program, parity experiments involve the entire laboratory. At the injector, one must very cleanly reverse the longitudinal helicity state of the beam. The reversals must be uncoupled to other parameters that affect the measurements. Many other difficult problems potentially affect these experiments, including electronics pickup of helicity signals, cross talk between the beams of different halls, noise on the laser, and the effect of the analyzing power of strained GaAs crystal.

Charlie Sinclair and his team in the accelerator division have understood the requirements of the experiments and and have worked diligently to solve the technical problems. During HAPPEX, a feedback loop controlled the helicity correlated charge asymmetry to an average level of less than 1 ppm, which was sufficient to maintain small systematics in other parameters that affect the cross section, such as energy or position. In addition, using air corrector coils in the beam line and an energy vernier, the experimenters modulated the position, angle, and energy of the beam to measure the apparatus response and possible corrections to residual systematics. The helicity correlated beam position differences averaged to less than 10 nanometers, and the corrections were 20 times smaller than the statistical error. In the future, to achieve higher accuracies than HAPPEX will require reduction of helicity correlated position differences either using a feedback system or perhaps a beam tune with improved betatron matching.

Polarized ^{3}He Program

The excellent performance of the Jefferson Lab polarized source has been a crucial factor in the success of the Hall A polarized ^{3}He program. The polarized ^{3}He program is mostly concentrated to study the neutron spin structure with a polarized ^{3}He target and polarized electron beam. The polarized ^{3}He target was built by a collaboration from Caltech, University of Clermont-Ferrand, Jefferson Lab, University of Kentucky, MIT, Princeton University, Temple University, University of Virginia and College of William and Mary. The first round of running of the polarized ^{3}He program was from September 1998 to February 1999 for two experiments. The first one was measurements of generalized GDH sum to study the link between GDH sum rule and the Bjorken sum rule[1]. The experiment was aiming to understand the transition region from incoherent parton (quark-gluon) picture to coherent hadron (nucleon-meson) picture. The second experiment measured the spin asymmetry in the quasielastic region and extracted the neutron magnetic form factor G_m^n[2]. Both experiments were successful, thanks to the excellent performance of the polarized source and the polarized ^{3}He target. The JLab polarized source together with the polarized ^{3}He target provide the world highest polarized luminosity of 10^{36} particles/sec/cm^2. They make precision measurements of the neutron spin structure become possible. The first experiment have extracted final results on the generalized GDH sum as well as spin structure functions in the resonance region. These results have been presented in several conferences[1] and will be submitted to Physical Review Letter shortly. The second experiment extracted G_m^n and also studied nuclear physics effect in the threshold region. The results have been published in two Physical Review Letters[2].

The second round running of the polarized ^{3}He program was in the summer of 2001 for about 4 months. Two experiments were successfully completed. The first one is a precision measurement of the spin asymmetry A_1^n in the valence quark (high x) region[3]. The experiment will test fundamental predictions by pQCD and by valence quark models. The second is a precision measurement of the second spin structure function g_2^n to study quark-gluon correlations[4]. The polarized source had an outstanding performance during the experiments. Average polarization of the beam reached over 80%. Beam current was at 10-15 μA. Beam conditions were very stable. To be able to precisely measure small physics asymmetries, the charge asymmetry from the source has to be kept to very small. The source group worked hard to satisfy our stringent requirement and had the charge asymmetry kept below 200 ppm most of the time. Together with the outstanding performance of the polarized ^{3}He target, the second round of experiments improved the systematic precision to better than 10^{-4} level, reached and exceeded the proposed physics goals.

References

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[2] JLab E95-001, Spokespersons, H, Gao and O. Hansen; W. Xu, *et al.*, Phys. Rev. Lett. 85, 2900 (2000); F. Xiong, *et al.*, accepted to be published in Phys. Rev. Lett. (2001).

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[4] JLab E97-103, Spokespersons, T. Averett and W. Korsch.