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The Spin Structure of the Neutron Determined Using a Polarized He-3 Target*

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Abstract

Described is a study of the internal spin structure of the neutron performed by measuring the asymmetry in spin-dependent deep inelastic scattering of polarized electrons from nuclear polarized ^{3}He. Stanford Linear Accelerator experiment E142's sample of 400 million scattering events collected at beam energies between 19 and 26 GeV led to the most precise measurement of a nucleon spin structure function to date.

The ^{3}He target represents a major advance in polarized target technology, using the technique of spin exchange with optically pumped rubidium vapor to produce a typical ^{3}He nuclear polarization of 34% in a 30 cm long target cell with a gas density of $2.3 \times 10^{20}\,\mathrm{cm}^{-3}$. The target polarization was measured to $\pm 7\%$ using an Adiabatic Fast Passage NMR system calibrated with the thermal equilibrium polarization of the protons in a sample of water. The relatively high polarization and target thickness were the result of the development of large volume glass target cells which had inherent nuclear spin relaxation times for the ^{3}He gas of as long as 70 hours. A target cell production procedure is presented which focuses on special glass blowing techniques to minimize surface interactions with the ^{3}He nuclei and careful gas purification and vacuum system procedures to reduce relaxation inducing impurities.

The spin structure function of the neutron g_1^n was determined over a range of the Bjorken scaling parameter $0.03 < x < 0.6$ with an average Q^2 of 2 $(\mathrm{GeV/c})^2$. The integral $\int_0^1 g_1^n(x)\,dx = -0.022 \pm 0.011$, combined with previous proton results provided the first significant experimental test of the fundamental Bjorken sum rule. Furthermore, this integral result together with the Ellis-Jaffe sum rule imply that the net polarization of the strange quark sea is consistent with zero and that the valence quarks contribute a total of about 60% of the nucleon spin. Although consistent with the standard theoretical picture of the nucleon, this result is contrary to the nucleon 'spin crisis' conclusions of previous proton spin structure results. However, this disagreement is less than 2σ of the combined experimental uncertainties.

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I begin by thanking my advisor, Gordon Cates, for allowing me an unusual level of freedom in working on my thesis, meanwhile having to run interference for me with the Particle Politicians. I did not make his job particularly easy. Among the Particle Politicians, I must thank the mild mannered Emlyn Hughes. He not only challenged the collaboration to do their best work, but his own drive kept the entire project moving forward, while preventing the run schedule from doing the same. Also among the E-142 collaborators, Jim Johnson was perhaps the most critical person to have working on the target project, Tim Chupp helped provide a concern for detail and Alan Thompson I thank for being himself.

During the early stages of my thesis, I am particularly indebted to Nate Newbury for his invaluable time, experience, and above all, patience in helping get me started. He was much more understanding than I deserved and I was very lucky to work with him even for a brief time. In the later stages, Krishna Kumar's arrival at Princeton was very fortuitous, providing an important and enthusiastic sounding board while I was working on the analysis and writing. Throughout the project, the glass working talent of Mike Souza was indispensible. Also, although I did not work closely with either Will Happer or Paul Souder during my thesis, no student can do an accelerator project from our group without being strongly influenced by these two persons.

As always, there is a large number of very competent students in the Atomic group which produce a synergistic environment for doing physics. Brain Saam, Paul Bogorad, and I have gone through the whole Princeton thing together, exchanging barbs, sports scores, political opinions, and even some physics along the way. These two, along with Bas Driehuys, are probably in some way responsible for any spark of intelligence which may appear in these pages. Beyond these three, with whom I have worked closely, there are also Mike Gatzke, Amy Barton, Carl Collins, Karen Sauer, Joel Ulm, Mike Romalis, and Jill McCracken who have influenced me during our

more brief overlaps in the group. What else can be said of all these Atomic students except, mmmooooooooo!

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I dedicate this thesis to the free minded, scientifically objective, un-'correct' thinkers of the world.

...Do not scornfully reject, before you have understood them, the gifts I have marshalled for you with zealous devotion. I will set out to discourse to you on the ultimate realities of heaven and the gods. I will reveal those atoms from which nature creates all things and increases and feeds them and into which, when they perish, nature again resolves them.

...[Superstition], this dread and darkness of the mind cannot be dispelled by the sunbeams, the shining shafts of day, but only by an understanding of the outward form and inner workings of nature.

-Titus Lucretius Carus, *The Nature of the Universe*, c. 50 B.C.

(tr. R.E. Latham)

...But the reward of a successful collaboration is a thing that cannot be produced by either of the parties working alone. It is akin to the benefits of sex with a partner, as opposed to [censored]. The latter is fun, but you show me anyone who has gotten a baby from playing with him or herself, and I'll show you an ugly baby, with just a whole bunch of knuckles.

- Harlan Ellison

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