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Willy Haeberli's Early Resarch: Developing and Using Accelerated Spin-Polarized Beams

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Willy Haeberli, the University of Wisconsin Raymond G. Herb Professor of Physics Emeritus, passed away on October 4, 2021, at the age of 96. Willy trained generations of students, post-docs, and international collaborators in the intricacies of planning and making nuclear-spin-physics measurements. His insight guided our development of polarized ion sources and polarized targets, and their subsequent use in new, increasingly precise measurements of very small nuclear-spin-dependent effects. I was fortunate to work with Willy in the 1960s. His large Wisconsin research group's early successes were seeds that grew steadily over the next 50 years into his exceptionally rich nuclear polarization physics legacy.

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1. Introduction

Our field of nuclear spin physics recently lost a leading international experimental pioneer, Willy Haeberli of the University of Wisconsin. He was a faculty member there from 1956 until 2006. In honor of his long career of impactful nuclear spin physics leadership, Willy was elected to membership in the National Academy of Sciences in 2002.

Willy was revered by his many former graduate students and research collaborators. He guided groups that developed several types of early spin-polarized proton and deuteron ion sources of increasingly greater intensity. Their beams were often used for ground-breaking measurements. He later led widening groups of research colleagues in developing dense internal spin-polarized targets for fundamental experiments at several United States and European storage-ring accelerators.

In June 2022, the University of Wisconsin's Department of Physics held a memorial symposium in Madison to honor Willy. Its recorded talks are available[1]. Many speakers there chronicled his life and research contributions. Some outlined future spin physics program plans and ideas that are building on these intellectual contributions. Willy also was recognized there for developing and teaching, with Wisconsin faculty colleagues, a highly popular *Physics and the Arts* course and textbook for undergraduate non-science majors. Other speakers related their personal experiences with Willy and his wife, Gabriele Haberland, who together were notable art collectors and generous patrons of the arts in Madison.

The organizers of SPIN2023 suggested that I repeat here my Wisconsin symposium talk that was based largely on my experiences while working as a post-doc in Willy's research group. Many of my personal recollections of that time have since been included in an excellent memoir describing Willy's life and accomplishments, written by Richard Milner and Ehrhard Steffens[2]. An oral history interview with Willy for the Niels Bohr Library of the American Institute of Physics is also available[3]. This with the recorded Madison symposium talks and recent memoir provide a comprehensive perspective on Willy's life and legacy. Thus, I include here only a few additional personal recollections and stories.

1. My Reflections on Working with Willy

Willy conducted his very first nuclear polarization experiment here in Durham at Duke University. After completing his formal academic training in Basel and two years as a post-doc at Wisconsin, Willy spent 1954-56 working in Duke's recently established Nuclear Structure Laboratory. He used deuteron beam from Duke's 4 MV Van de Graaff accelerator for a double-scattering measurement of the nuclear polarization of outgoing neutrons from the $^{12}C(d,n)^{13}N$ reaction.

In spring 2021, when discussing his early Duke measurement, Willy told me he had never before undertaken such a hard experiment with such a dauntingly small signal-to-background event ratio. After completing the actual measurements, he left Duke in fall 1956 to return to Madison and join the Wisconsin faculty.

Willy as a young student and later when graduating from the University of Basel.

Willy and his early students there continued double-scattering polarization measurements for several years. Though they achieved good proton polarization measurements[4,5,6] in which experimental backgrounds were lower than those earlier at Duke, Willy also began developing Wisconsin's first ion source to produce and accelerate spin-polarized proton and deuteron beams[7].

I first met Willy on a February morning in 1963, when he handed me a stack of 3"x4" lantern slides for his invited talk[8] at the **International Conference on Fast Neutron Physics** being held on the Rice University campus in Houston, TX. As a 2nd-year physics graduate student there, I was assigned to project slides at that physics event during Rice's year-long semi-centennial celebration. Among Willy's

slides summarizing studies of neutron polarization from reactions were results of his earlier Duke measurements. His and other talks at that conference about nuclear polariation studies convinced me for my Ph.D to try my own measurement of the nuclear polarization in $^{12}C(p,p)^{12}C$ elastic scattering.

The double-scattering apparatus I designed and built at Rice for that thesis experiment was rudimentary[9], and my results were scientifically underwhelming. Thankfully they were deemed good enough for me to graduate. I was delighted a few weeks later to receive a Wisconsin post-doc offer and arrived in Madison in September 1965 firmly determined to learn more by working with Willy. Very soon I found out how really underwhelming my doctoral project's results had been! In Sterling Hall's basement using several picoamperes of polarizad proton beam from its polarized ion source and tandem Van de Graaff accelerator[7], I could have retaken ***all*** of my Rice Ph.D. thesis data ***in a single da***y with ***10 times better precision***!

Guided by Willy I began to learn how first to think carefully about the goal of a measurement, determine what was needed to make it possible, and then actually design, assemble, and test the hardware required. Research in Willy's group of 35 students and post-docs was truly invigorating! He had the gifted teacher's ability for providing his younger associates just enough independence and encouragement for them to learn, while supporting them if they stumbled. We learned quickly by working together, were forgiven for an occasional screw-up, and knew damn well not to do that same stupid thing again.

Attendance was required at Wisconsin's weekly evening nuclear group seminars. Faculty sat on the front row with post-docs and graduate students filling all seats behind. The faculty invited leading scientists to describe their recent work there, and in May 1966, Bailey Donally was the speaker. He described for us how one could use proton charge-exchange in cesium to make a beam of hydrogen atoms in the 2S metastable state and then use the Lamb-shift to manipulate their hyperfine state lifetimes to create a nuclear-spin-polarized atomic beam. Their subsequent charge-exchange in argon could then produce nuclear-spin-polarized H^- ions[10,11].

At lunch the next day Willy and I discussed building such an ion source. I immediately agreed to try, he ordered the equipment needed, and then left for the summer. Soon it was like Christmas! Boxes of vacuum pumps and power supplies arrived daily. Designing hardware, winding magnet coils in the student shop, and assembling everything into a working system were completely new experiences for me. Another post-doc, Reto Plattner, and I worked with four students to build that new ion source. In early April 1967, a group of Willy's students helped us roll our operating Lamb-Shift polarized source system carefully into the tandem accelerator vault and attach it to the accelerator. Two days later we accelerated 4 nanoamperes of polarized proton beam to target … 1000x greater intensity than from Willy prior polarized source!

Members of Willy's research group just after rolling the Lamb-Shift source into the tandem accelerator vault. At right behind the source, back row, leftt to right: Lynn Veeser, Robert Rathmell, Paul Bjorklhom; front row, John Lohr (behind chair of overhead crane), Lee Keller, Jerry Ellis; at left facing the camera, David Loyd, Reto Plattner, David Kocher; at far left, Tom Clegg.

In the following year many of us depicted here in the faded polaroid picture successfully took data using spin-polarized beams from the new ion source. After building, testing, and installing this source, writing the manuscript describing our system and results for publication was no smaller challenge … because Willy was a very demanding editor. His persistent critique lasted until I had a complete, clear, concise description of the experimental hardware and measurement[12] written "such that it can not be misunderstood."

In the following year while I was participating in several experiments using the higher intensity beams[13,14,15], Willy and I began designing a more refined, higher intensity version of the Lamb-Shift

source. I spent many hours bent over a big drafting table specifying components and creating part drawings. Willy consulted frequently, and signed all of the requird supply and equipment purchase orders. Money seemed not to be a concern. More vacuum chambers and magnet coils were built in the shop and new students were engaged to help with their assembly. I was also scheduling job interviews, and by June 1968, I had accepted an offer to join the physics faculty at UNC-Chapel Hill and continue my nuclear polarization physics research with faculty and students at the newly established Triangle Universities Nuclear Laboratory at Duke. I arrived here in September bringing with me a new wife and a set of plans for the improved Lamb-Shift source that she had helped me copy during the four days following our mid-August Sunday wedding. Willy invited us to stay on Thursday evening for a final dinner with him and his family. I very reluctantly declined, and we began our driving honeymoon trip to Chapel Hill instead.

It would be extremely difficult today to recreate the scientifically rich, educationally supportive, and socially warm environment that Willy and his faculty colleagues created in the 1960s at Wisconsin. When I arrived in Madison, I was not a fully trained experimental physicist. For three years, Willy was my guiding mentor and constant sounding board. He encouraged my best ideas. He often helped make them better. What finer educational opportunity could anyone want? I will forever be grateful.

References

[1] *Willy Haeberli Memorial Symposium, June 19-20, 2022*, https://www.physics.wisc.edu/haeberli-symposium/.

[2] Richard Milner and Erhard Steffens, *Willy Haeberli - A Biographical Memoir*, National Academy of Sciences (2023). https://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/haeberli-willy.pdf.

[3] David Zierler, *Interview of Willy Haeberli*, video conference, July 31, 2020, American Institute of Physics. Niels Bohr Library & Archives College Park, Maryland; https://www.aip.org/history-programs/niels-bohr- library/oral-histories/47243.

[4] R.L. Brown, W. Haeberli, *Polarization of Protons from the ^{3}He(d,p)^{4}He Reaction,* Phys Rev. 1**30** (1963) 1163.

[5] R. L. Brown, W. Haeberli, J. Saladin, *Polarization in the Scattering of Protons by α-particles*, Nucl. Phys. **47** (1963) 212. https://doi.org/10.1016/0029-5582%2863%2990866-6

[6] S.J. Moss, W. Haeberli, *The Polarization of Protons Scattered by Carbon* Nucl. Phys. **72** (1965) 417. DOI: 10.1016/0029-5582(65)90444-X

[7] W. Haeberli, W. Gruebler, P. Extermann, P. Schwandt, *Accceleration of Polarized Protons and Deuterons in a Tandem Accelerator*, Phys. Rev. Lett. **15** (1965) 267.

[8] W. Haeberli, *Study of Neutron Polarization from Reactions*, in proceedings of *Progress in Fast Neutron Physics*, Univ. of Chicago Press by William Marsh Rice University, (1965) 307.

[9] T.B. Clegg, A.C.L. Barnard, J.B. Swint, *New Polarimeter Designed for Use with Position-Sensitive Solid-State Detectors*, Bull. Am. Phys. Soc. 1**0** (l965) l56.

[10] B. Donally, T. Clapp, W. Sawyer, M. Schultz, *Metastable Hydrogen Atoms Produced in Charge Exchange*, Phys. Rev. Lett. **12** (1964) 502.

[11] W. Haeberli, *Sources of Polarized Ions*, Ann. Rev. of Nuclear Science, **17** (1967) 373.

[12] T.B. Clegg, G.R.Plattner, L.G. Keller, W. Haeberli, Description of a Lamb-Shift Polarized Ion Source Installed on a Tandem Accelerator, Nucl. Instr. Meth. **57** (1967) 167.

[13] D.H. McSherry, S.D. Baker, G.R. Plattner, T.B. Clegg, *Meaurement of Spin Correlation Effects in p-^{3}He Elastic Scattering at 8.8 MeV,* Nucl. Phys. A, 1**26** (1969) 233.

[14] G. R. Plattner, T.B. Clegg, L. G. Keller), Nucl. Phys, **A111** (1968) 481.

[15] P. Schwandt, T.B. Clegg, W. Haeberli). *Polarization and Phase Shifts for p-^{4}He Scattering Between 3 and 18 MeV*, Nuclear Physics **A163** (1971) 432.