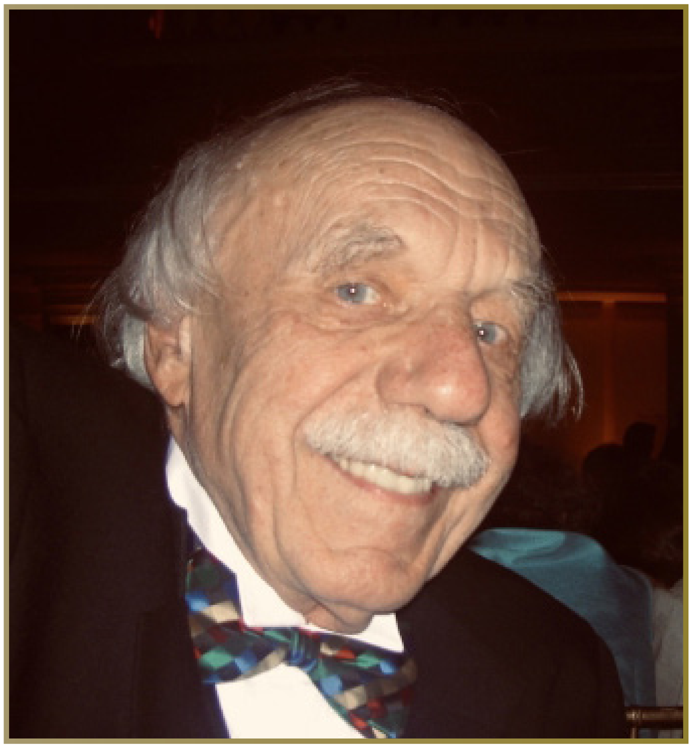
BIOGRAPHICAL MEMOIRS

Willy Haeberli

June 17, 1925–October 4, 2021
Elected to the NAS, 2002

A Biographical Memoir by Richard Milner and Erhard Steffens



Willy Haeberli was a remarkable physicist who in the mid-twentieth century initiated the field of experimental spin polarization physics. He developed both polarized sources and targets that are used worldwide in fundamental subatomic physics research on the largest particle accelerators. Haeberli's research was characterized by the originality of his experiments, his generous and genial collaboration, his outstanding mentoring of young colleagues, and the great care he took in establishing definitive scientific conclusions.

Early Life

Willy Haeberli was born in Zürich, Switzerland, on June 17, 1925, to Paul and Clara Haeberli. The family moved to Basel when he was only a year or two old, and he grew up in the St. Johann district of Basel, located on a bend of the Rhine River. As he noted in an oral history conducted for the American Institute of Physics (AIP) by David Zierler in 2020,

> "My parents grew up in a small farm village in the center of Switzerland, a little village of maybe 600 people near the city of Solothurn, Switzerland. In that city, my grandfather was not a farmer, but rather he was in charge of running a small steam engine train from Solothurn to a nearby city of Biel, about forty miles away. It was a very simple train, just back and forth, and he was running the steam engine. That's where both of my parents grew up, in that place. My mother, who grew up in the same village, often told me how she was crying for several days, because as a young woman, after eight years of elementary school, she was not allowed to go to school anymore, which she would have loved to do. Instead, she took an apprenticeship as a seamstress. So, that's the professional background of my parents."[1]

During World War II, Willy attended the Gymnasium of Mathematics and Natural Science in Basel, which in Switzerland is required for entering a university. He received advanced instruction in calculus, physics, chemistry, French, and English, and by then he already knew that he was going to be a physicist. In his AIP interview, he said: "As soon as I learned about physics in physics class, I just knew that was what I was going to do." In 1943, he was drafted into the Swiss Army and served as a Funker (radioman) at the Bülach training camp, near Zürich.

Willy entered the University of Basel in 1944, towards the end of the war, and received his Ph.D. in 1952 under the supervision of Paul Huber, with a thesis entitled "The Ionization of Gas Mixtures by α-Particles from a Radioactive Source." Willy used alpha particles from the decay of polonium-210 to measure the energy required to ionize gas molecules. Upon completion of his Ph.D., he had postdoc offers from Stanford University and the University of Wisconsin-Madison. Encouraged by Huber and drawn to the lakes, he chose to go to Madison because of its existing accelerators and experienced nuclear physics faculty, including Heinz Barschall, Ray Herb, and Hugh Richards. His principal research focus was to understand the internal structure of atomic nuclei by shattering them with accelerated fast particles and detecting the debris that came out; or as he described it, to learn "how the nucleus rings."

At this time, little was understood about the origin of spin in nuclei or how the forces between protons and neutrons inside nuclei depend on spin.[2] It was known that there was a "spin-orbit" interaction, but it was poorly understood. Willy realized that beams of spin-polarized particles (with their spins pointing in the same direction) were essential to experimentally study the spin-orbit force.

Late in 1953, Willy arranged for his fiancée, Heidi Speiser, to travel by boat to the United States from her home in Basel so they could marry in Madison. After two years as a postdoc at Madison, Willy was required to leave, and so he spent two years at Duke University in Durham, North Carolina, as a research scientist. Heidi and Willy had their firstborn son while in Durham. At Duke, Willy carried out his first polarization experiment, which was a measurement of the nuclear reaction: carbon-12 + deuteron → nitrogen-13 + neutron. The counting rates were extremely low and the unwanted backgrounds were problematic. Willy recalled, "That was absolutely the hardest experiment I had ever attempted."

The Early Madison Years

In 1956, Willy and Heidi returned to Madison, and Willy joined the faculty and would remain there until his retirement in 2005. In the 1950s, activities were underway in Germany, Switzerland, and the United States to develop sources of polarized particles to study the spin structure of nuclei. In 1959, Madison acquired a Tandem Van de Graaff accelerator. In 1960, the first international symposium on the subject, Polarization Phenomena in Nuclear Physics, took place in Basel. By 1964, Willy and his colleagues were able to produce relatively low intensity beams of polarized nuclei to be injected into the Tandem accelerator.[3] The following year, they successfully accelerated the polarized ions using a foil stripper to invert their charge in the center of the Tandem accelerator.[4] By 1967, they used the new polarized beams to take important data on stripping reactions that provided unprecedented insight into the spin-orbit interaction.[5] Willy and his group installed the first Lamb-shift polarized source on an accelerator and subsequently produced the first purely vector- and tensor-polarized deuteron beams.[6]

Tom Clegg worked with Willy's group as a postdoc in the years from 1965 to 1968. He recalls:

> "Just before Willy left in late May 1966 to spend two summer months in Basel, he placed orders on a Saturday morning for $30K in new equipment. For perspective, that's at least $250K in today's dollars! He challenged me to work while he was away with a team of several students to assemble all that hardware into an entirely new type of polarized ion source. Overly optimistic, I naively agreed to finish the task 'before the snow falls.' On the day in late October when the first flakes appeared, Willy came into the lab holding a snow shovel with a sign taped to its handle, 'Tom. It snowed today!' With his often humorous encouragement, we all thrived. Willy was an enormously clever, inventive physicist. I was extremely fortunate to have him so long as wise mentor, insightful teacher, and dear friend."

By 1970, Willy Haeberli had established a world-leading center for spin polarization in nuclear physics at Madison. A group from Rice University brought an optically pumped, polarized He-3 target to Madison, and the group carried out the first experiment with polarized proton beam scattering from polarized He-3. Willy published the seminal review article on polarized sources,[7] often referred to colloquially by workers in the field as "the bible," and he and Heinz Barschall hosted the 1970 conference Polarization Phenomena in Nuclear Reactions at Madison from August 31 to September 4, 1970. The conference was intended to showcase the unique Madison laboratories with their impressive array of state-of-the-art polarization technology.

The Sterling Hall Bombing

Unfortunately, Willy's research was violently, although temporarily, interrupted by the 1970 bombing of Sterling Hall.[8] The bomb—one of the last gasps of the anti-Vietnam War protests—was set off in the early morning of August 24, exactly one week before the Madison nuclear physicists were to host the large international symposium *Polarization Phenomena in Nuclear Physics.* The perpetrators stated that their goal was the destruction of the Army Mathematical Research Center (AMRC), which occupied the second, third and fourth floors of one wing of Sterling Hall. They filled a stolen van with ammonium nitrate and fuel oil, parked it on a ramp leading down to the loading dock, and exploded it near the

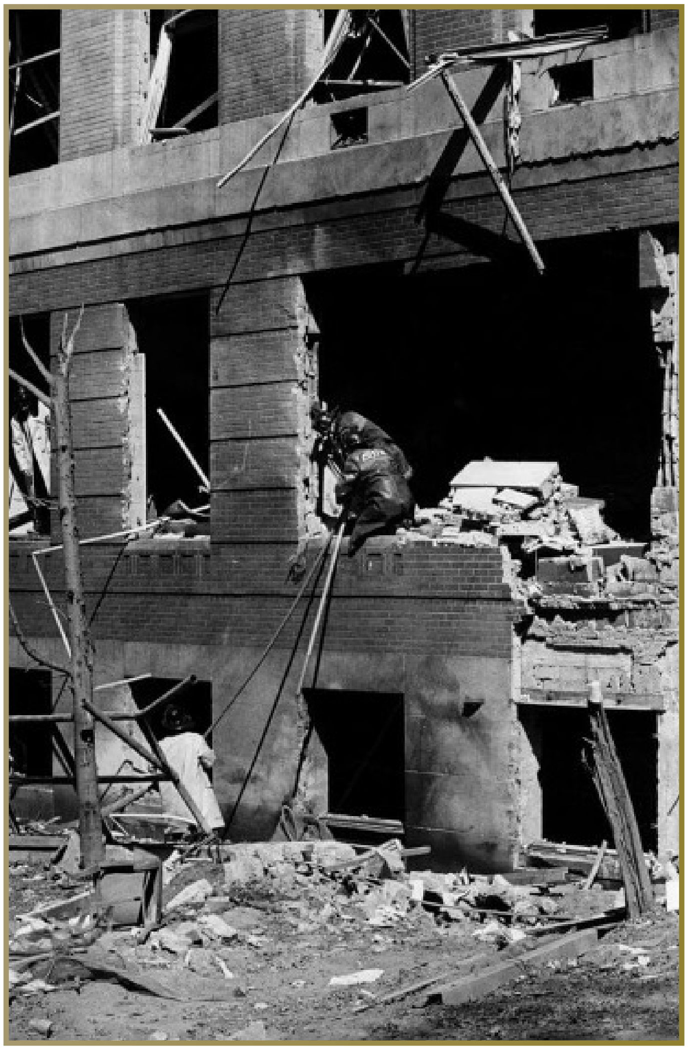


Figure 1 The ruins in the immediate aftermath of the 1970 bombing of the first-floor Sterling Hall office that housed several of Willy's graduate students. (Source: S. Vigdor)

entrance to the basement vault containing the Tandem Van de Graaff accelerator. The AMRC suffered little damage and relocated its offices to another building on campus within a week of the bombing. It was the basement laboratories and first-floor nuclear physics offices in that wing of Sterling Hall that bore the greatest brunt of the blast (see photo in Fig. 1). One postdoctoral researcher in low-temperature physics was killed by the blast, and a nuclear physics graduate student, a postdoc, and a security officer were injured. All of them had been working in Sterling Hall in the early hours of that morning. Three of the perpetrators were apprehended within several years, but the fourth has eluded capture for more than fifty years.

Willy's leadership was key to the resiliency of the nuclear physics group. He made sure that the symposium was carried off without a hitch. He kept the nuclear physics faculty together. He organized a small army of graduate students, postdocs, and technicians into teams that worked three shifts a day for several months to repair the damage to the Van de Graaff laboratory. They replaced the accelerating tubes, refurbished the vacuum, rebuilt the ion sources, replaced a number of auxiliary systems with equipment donated by other nuclear physics research laboratories worldwide, and cleaned up the massive debris left by the bombing. Beam was re-accelerated in the Tandem before the end of 1970, and the Tandem-based research program was restarted during the first half of 1971. The blast had destroyed a number of the logbooks and magnetic tapes containing data for various graduate student thesis projects. But Willy oversaw the redistribution of surviving data among his students and redefined thesis projects so that none of his ten Ph.D. students at the time of the bombing ended up suffering more than about a year's delay in attaining their degrees. Willy's own research program remained mostly focused at the Tandem for the ensuing decade, but during that time he also became heavily involved with the ETH Zürich group in the proton-proton parity violation experiment at the Swiss Institute for Nuclear Research. Fig. 2 is a photo of Willy's group in Madison in 1972, happy after the research lab was rebuilt and again carrying out frontier research.

Erhard Steffens well remembers his first encounter with Willy, in the years after the bombing. In 1973, Dieter Fick (University of Erlangen-Nürnberg) organized a conference, "Polarization Nuclear Physics," that celebrated the seventieth birthday of spin physics pioneer Rudolf Fleischmann.[9] The event took place at Ebermannstadt, a rural town near Erlangen, with sixty-two participants, including many well-known experts in the field. Steffens took part as a

Figure 2 Front row (left to right): Haeberli graduate students Bob Rathmell, Norm Rohrig, and John Lohr. Second row: Graduate student Dave Kocher; Tandem operator Pat Ferrara; Willy; graduate student Bob Goddard; former postdoc Gian-Reto Plattner (seated at right). Third row: Postdoc Paul Quin (seated); graduate students Steve Vigdor, Bob Cadmus, Ed Stephenson; Postdoc Hans-Otto Meyer; graduate students Jim Tyler and Lynn Knutson. Standing in back: Postdocs John Duder and Hank Liers. (Source: H.-O. Meyer and S. Vigdor)

Hamburg graduate student and member of a group working on spin polarized lithium beams. There, he met Willy—one of the most famous attendees—for the first time, and the meeting was the starting point of a lifelong friendship. With his casual wear and long hair, Willy contrasted very much with the German professors in suits and ties. He even took off his sandals when it was hot and walked barefoot down the main street of Ebermannstadt, to the astonishment of the young participants and local people.

Proton-Proton Parity Violation Experiment

Weak interactions in the nucleon-nucleon system have long been of fundamental interest. For example, the proton-proton weak interaction is the primary route for energy production in the Sun. In the 1970s, electroweak unification was a principal focus, and the Swiss theorist Markus Simonius initiated and led an experiment at the laboratory of the Swiss Institute for Nuclear Research (now known as the Paul Scherrer Institute) in Villigen, Switzerland, to measure the parity-violating asymmetry in proton-proton scattering at 45 MeV incident energy. Willy Haeberli played a central role in this experiment. In particular, he was an important mentor to the junior members of the group and a leader in devising the auxiliary measurements needed for precise control of systematic errors. To attain the necessary precision of better than 10^{-7}, about 10^{16} events were required, which had the consequence necessitating integrating detectors. The circulating gas target operated at a pressure of 100 atmospheres to maximize the collision luminosity and to minimize heating effects.

The experiment continued in a number of phases for over a decade and reported the total nuclear parity non-conserved analyzing power at 45 MeV of

$$A^{tot}(45.0\ \text{MeV}) = -(1.50 \pm 0.22) \times 10^{-7}.$$

The agreement with the theoretical expectation (in both magnitude and sign) is excellent and confirms the important role of the nonfactorization contributions to the weak vector meson exchange couplings. It is the most accurate measurement of parity violation in hadronic interactions to date.[10]

Polarized Gas Targets

Until about 1980, Willy's research program was focused on developing and utilizing beams of spin polarized ions. He also returned to his old but untested idea that he had proposed at the 1965 meeting on polarization in Karlsruhe. The basic idea was to send an ion beam through a storage vessel with a Teflon wall coating, like the storage bulb in Norman Ramsey's hydrogen maser. The polarized atoms bump around and serve as targets more than once. The idea was noted with interest at that time, but there were no storage rings of sufficient circulating beam current to allow such a gaseous polarized target to be used effectively. Around 1980, a strong research program at CERN developed antiproton storage rings that led to the discovery of the Intermediate Vector Bosons Z^0 and $W^{\pm}$, earning Carlo Rubbia and Simon Van der Meer the Nobel Prize in Physics in 1984. Subsequently, several low-energy storage rings were built, with which gas targets could be used. This combination of storage ring and target comes close to realizing the ideal experimental configuration of a pure target with high spin polarization.

More than ten years after his proposal, Willy assembled a group of talented students and set up a test experiment at the Madison tandem accelerator, built with used parts, to confirm his 1965 proposal. At the 1980 Santa Fe polarization conference, he reported that, despite an average of 900 wall collisions per atom, their polarization was practically unchanged compared with the injected atomic beam. This result paved the way towards pure gas targets of high polarization. Later, Willy pointed out that, instead of a vessel, a T-shaped tubular structure with a straight beam tube and a sideways injection tube leading to the center gives the highest increase of target (areal) density, when using such a storage cell, compared with a free atomic beam. The gain can be up to a factor of several hundred. For a complete polarized target, an atomic beam source (ABS) of polarized atoms is required, injected into the storage cell.

Spin polarized storage cell targets were developed for different experiments, such as

- PINTEX at the IUCF Cooler Ring at Indiana University, built by the Wisconsin group[11];
- FILTEX at the Heidelberg Test Storage Ring by a Heidelberg-Madison-Marburg-Munich collaboration[12] (see Fig. 3); and
- HERMES at the HERA 30 GeV electron storage ring at DESY, Hamburg. The hydrogen and deuterium target was built by a big group, including FILTEX plus Erlangen. A target of polarized ^{3}He gas, built by MIT and Caltech, was also successfully operated at HERMES[13];
- BLAST at the MIT-Bates South Hall Ring used an 850 MeV, 200 mA polarized electron beam by an MIT-Madison collaboration; the charge distribution of the neutron and the tensor structure of the deuteron were simultaneously measured using a polarized deuterium target that cycled through the three magnetic substates.[14]

Figure 3 Members of the FILTEX team at the control panel of the MPI-Heidelberg MP-Tandem and storage ring TSR, celebrating successful results in 1993. In front: E. Steffens and K. Zapfe; first row standing, from right: Z. Moroz and W. Haeberli, left: M. Grieser (TSR-expert), back row, right: D. Fick. (Source: MPI-K)

Another research highlight of Willy's group, led by Tom Wise and Alex Nass, shown with Willy in Fig. 4, was the development of a freepolarized hydrogen-jet of known polarization and highest density, crossed with the energetic proton beams of RHIC-Spin (Brookhaven National Laboratory, New York). Proton-proton scattering from this target in the Coulomb-nuclear interference region serves as an absolute proton beam polarization calibration and tremendously improved the accuracy of the RHIC-spin experiments.[15] All of these experiments led to novel results with unprecedented precision. Further, a promising storage cell target is currently under study using a 7 TeV proton beam of the 14 TeV proton collider LHC, CERN, Geneva, developed by the LHC-spin study group.[16] Willy followed its progress until mid-2021 with interest.

Willy had a particular style and approach to experimental nuclear physics. As he noted in his oral history interview:

> "After we established these methods, a whole industry developed where some laboratories did nothing but these experiments, on and on for years and years. That was never my style.... When a method was well established, I would turn to some new idea."

Willy was a part of the fourteen-member committee chaired by Herman Feshbach that met from July 30 to August 4, 1979, at Orleans, Massachusetts, to formulate the first "Long Range Plan for Nuclear Science" at the request of the U.S. Department of Energy and National Science Foundation. This initiative became a regular long-term planning exercise that was repeated in 1983, again with Willy's participation, and in 1989, 1996, 2002, 2007, 2015, and 2023. The effort has been essential to the growth and vitality of U.S. nuclear science.

Willy was the Raymond G. Herb Professor of Physics and a Steenbock Professor at the University of Wisconsin-Madison. He was a world-class experimental nuclear physicist whose research focused on studying spin effects in nuclear processes and in fundamental interactions. His technical innovations transformed this field. In 1979, the American Physical Society awarded the Tom W. Bonner Prize in Nuclear Physics to Willy Haeberli and Roy Middleton for their "unusual contributions to the development and use of ion sources for charged particle accelerators in both basic physics and applied fields." The polarized internal targets Willy developed fueled novel and important experiments in storage rings worldwide. In 1988, he was elected to the American Academy of Arts and Sciences; in 2002 he was elected to the National Academy of Sciences.

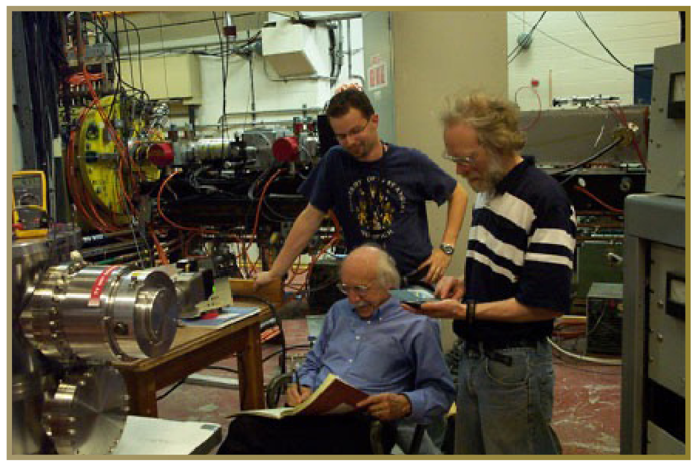


Figure 4 Willy Haeberli, from the University of Wisconsin-Madison, one of the fathers of the polarized hydrogen and deuterium target, with colleagues Tom Wise (right, Wisconsin) and Alex Nass (left, Juelich). (Source: W. Haeberli)

Physics in the Arts

In addition to his scientific achievements, Willy was an accomplished teacher. He taught physics courses at Madison for forty-nine years. In particular, he had a major impact on the popular course Physics 109: Physics in the Arts, which was initially developed by Ugo Camerini. Physics in the Arts has been offered successfully and continuously since 1969 and has been emulated by numerous universities across the country. In his last five years before retiring, he co-taught the course with Pupa Gilbert. After he retired, Gilbert convinced him to co-author the textbook *Physics in the Arts,* and it was reprinted in 2011.[17] The book was translated into Chinese and published by Tsinghua University Press in 2011.

Personal Life

Willy and his first wife Heidi together had three children, Martin, Paul, and Frances. Heidi Speiser-Haeberli passed away on May 7, 2010. Their children enjoyed their dad's fervent passion for cooking and entertaining, hiking, sailing, canoeing, and family picnics that often included physics colleagues and students. As a father and grandfather, Willy was always challenging his offspring with physics and science questions, particularly at the dinner table, and he enjoyed collaborating with family on puzzles and games. Throughout his life, he loved telling stories and jokes.

Willy married his second wife, Gabriele S. Haberland, in 1992. As a couple, Gabriele and Willy were art collectors and patrons of the arts in Madison, particularly of the Madison Museum of Contemporary Art, the Chazen Museum, and Tandem Press. After Gabriele's death in 2017, Willy honored her by establishing programs in her name to support exhibitions, publications, graduate students, and conservation in the Madison area.

Willy Haeberli passed away in Madison, Wisconsin, on October 4, 2021. He is survived by his older sister, Edith Hess in Switzerland, and in the United States by his three children and four grandchildren.

References

1 Willy Haeberli, interview by David Zierler, 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.

2 Milner, R. G. 2013. A short history of spin. In: *Proceedings of the XVth International Workshop on Polarized Sources, Targets, and Polarimetry,* Charlottesville, Virginia, September 9–13.

3 Gruebler, W.,W. Haeberli, and P. Schwandt. 1964. Production of a beam of polarized negative hydrogen ion. *Phys. Rev. Lett.* 12:L595–L597.

4 Haeberli, W., W. Gruebler, P. Extermann, and P. Schwandt. 1965. Acceleration of polarized protons and deuterons in a Tandem accelerator. *Phys. Rev. Lett.* 15:L267–L268.

5 Yule, T. J., and W. Haeberli. 1967. Use of polarized deuterons to determine the total angular momentum transfer in stripping reactions. *Phys. Rev. Lett.* 19:L756–L759.

6 Clegg, T. B., G. R. Plattner, L. G. Keller, and W. Haeberli. 1967. Description of a Lamb-shift polarized ion source installed on a Tandem accelerator. *Nucl. Instr. Meth.* A 57:167–170.

7 Haeberli, W. 1967. Sources of polarized ions. *Ann. Rev. Nucl. Part. Sci.* 17:373–426.

8 The account of the Sterling Hall bombing was provided by Steven Vigdor.

9 Fick, D. 1974. *Polarization Nuclear Physics,* Proceedings of a Meeting held at Ebermannstadt October 1–5, 1973. Lecture Notes in Physics 30. Berlin: Springer-Verlag.

10 Kistryn, S., et al. 1987. Precision measurement of parity nonconservation in proton-proton scattering at 45 MeV. *Phys. Rev. Lett.* 58:L1616–1619.

11 Meyer, H.-O., et al. 1998. Dependence of pp->pp pi0 near threshold on the spin of the colliding nucleons. *Phys. Rev. Lett.* 81:L3096–3107.

12 Rathmann, F., et al. 1993. New method to polarize protons in a storage ring and implications to polarize antiprotons. *Phys. Rev. Lett.* 71:1379–1382.

13 Milner, R, and E. Steffens. 2021. *The HERMES Experiment: A Personal Story.* Singapore: World Scientific.

14 Hasell, D. K., et al. 2011. Spin-Dependent Electron Scattering from Polarized Protons and Deuterons with the BLAST Experiment at MIT-Bates. *Ann. Rev. Nucl. Part. Sci.* 61:409–433.

15 Zelenski, A., et al. 2005. Absolute polarized H-jet polarimeter development, for RHIC. *Nucl. Instr. Meth. A.* 536:248–254.

16 Di Nezza, P., et al. 2021. The LHCspin project. *Proceedings for the XXVIII International Workshop on Deep-Inelastic Scattering and Related Subjects*, Stony Brook University, New York, USA, 12-16 April 2021.

17 Pupa, G., and W. Haeberli. 2008. *Physics in the Arts.* Amsterdam: Elsevier.

Selected Bibliography

1964 With W. Gruebler and P. Schwandt. Production of a beam of polarized negative hydrogen ion. *Phys. Rev. Lett.* 12:L595–L597.

1965 With W. Gruebler, P. Extermann, and P. Schwandt. Acceleration of polarized protons and deuterons in a Tandem accelerator. *Phys. Rev. Lett.* 15:L267–L268.

1967 With T. J. Yule. Use of polarized deuterons to determine the total angular momentum transfer in stripping reactions. *Phys. Rev. Lett.* 19:L756–L759.

With T. B. Clegg, G. R. Plattner, and L. G. Keller. Description of a Lamb-shift polarized ion source installed on a Tandem accelerator. *Nucl. Instr. and Meth.* A 57:167–170.

Sources of polarized ions. *Ann. Rev. Nucl.* and *Part. Sci.* 17:373–426.

1973 With L. D. Knutson, E. J. Stephenson, and N. Rohrig. Observation of the deuteron D-state effects in (d,p) reactions. *Phys. Rev. Lett.* 31:L392–L395.

1987 With S. Kistryn et al. Precision measurement of parity nonconservation in proton-proton scattering at 45 MeV. *Phys. Rev. Lett.* 58:L1616–L1619.

1993 With F. Rathmann et al. New method to polarize protons in a storage ring and implications to polarize antiprotons. *Phys. Rev. Lett.* 71:L1379–L1382.

1998 With H.-O. Meyer et al. Dependence of pp->pp pi0 near threshold on the spin of the colliding nucleons. *Phys. Rev. Lett.* 81:L3096–L3107.

2001 With A. Airapetian et al. Measurement of the beam-spin azimuthal asymmetry associated with deeply virtual compton scattering. *Phys. Rev. Lett.* 87:L182001.

2003 With E. Steffens. Polarized gas targets. *Rep. Prog. Phys.* 66:1887–1935.

Selected Bibliography (cont.)

2006 With M. Bai et al. Polarized proton collisions at 205 GeV at RHIC. *Phys. Rev. Lett.* 96:L174801.

2007 With C. B. Crawford et al. Measurement of the proton's electric to magnetic form factor ratio from $^1\vec{H}(\vec{e}, e'p)$. *Phys. Rev. Lett.* 98:L052301.