16 September 2003
Dubna Spin2003
G. Bunce

Vernon Hughes: "to learn fundamental things"

1921--2003

A presentation in Vernon's words, attempting to capture his sense of seriousness, humor, and justice.

From "Various Researches in Physics" by VWH, in Annual Review of Nuclear and Particle Science 2000, 50:i-xxxvi (2000).

MY UNPRECOCIOUS ENTRY INTO PHYSICS

WORLD WAR II YEARS AND COLUMBIA GRADUATE SCHOOL

ATOMIC PHYSICS RESEARCH

MUONIUM

POLARIZED LEPTONS AT HIGH ENERGY

MUON g-2

AN ADMINISTRATIVE ADDENDUM

Grew up in NYC, brought up by his mother, Jean Parr Hughes (his memoir is dedicated to her).

School—small private school on upper west side

"idealistic and humanistic orientation"

Columbia College in pre-law

"I planned a pre-law course of study with the intention of going to law school and then eventually doing good things for the world."

"A pre-law course entitled "Analysis of the Written Word" was particularly stimulating and valuable with its emphasis on the exact meaning of the written word."

1st physics course in sophomore year (2nd year)

3rd year: majored in physics, graduated 1941

Caltech graduate school

"President Robert Milikan gave a spirited but not humble course on modern physics..."

Pearl Harbor bombed

MIT Rad Lab—radar 1941--1945

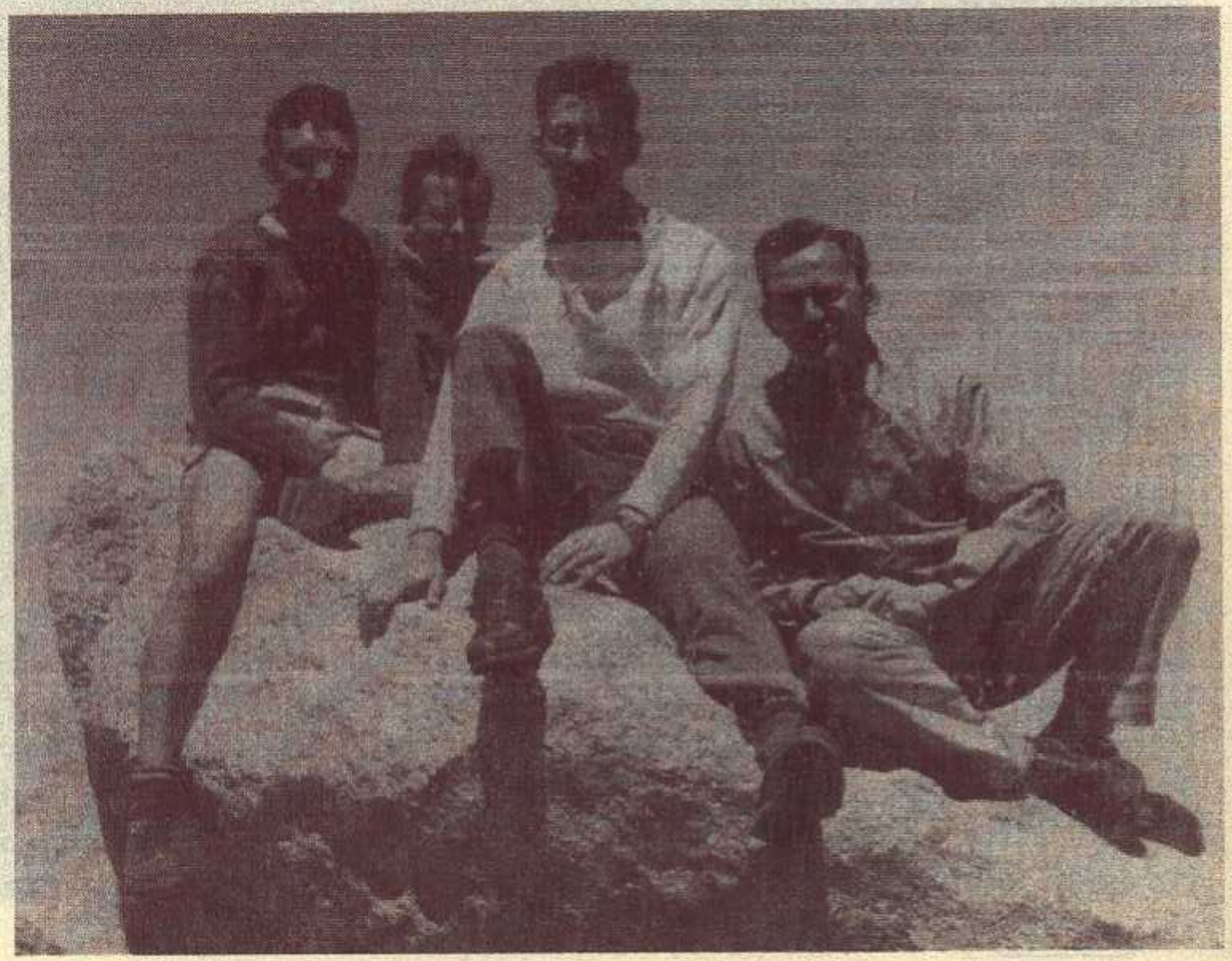


Figure 1 Four Caltech graduate students on Mt. San Gorgonio, 1941. *From left*: Vernon Hughes, Pief Panofsky, Bill Eberhardt, Ed Deeds.

1946: Columbia graduate school

QED, g-2 (electron), beta decay (Rabi, Lamb, Wu, ..)

Nuclear electric quadrupole moment from polarization of nuclear core by an outer nucleon

--thesis in molecular beams with Rabi

"I was particularly interested at the time in building an apparatus by myself from scratch."

"I then worked out the theory for this two-photon transition for our case. At that time at Columbia theoretical course work was extensive and one was expected to handle the theory relevant to one's experiments."

"As a teacher, I found Rabi most inspiring, helpful, encouraging, and basically sane."

--missed doing hyperfine structure of hydrogen for his thesis (led to first observation of a discrepancy with QED, before Lamb shift discovery)

"My thesis was certainly satisfying and instructive. And it contributed a bit of new knowledge."

"This experience did instill in me the firm view that, to learn fundamental things, it is best to study a simple system where the theory should be adequate."

Ph.D. 1950: "Launched with a Ph.D. in 1950..."

Yale in 1954

--helium research for 30 years, many "ppm" measurements

$\mu(^3He)/\mu(1H) = 0.761\ 812\ 37\ (46)$ (0.6 ppm)

"to provide a test of modern QED theory of the two-electron system"

--good agreement at ppm level

(e^+ -- e^-) positronium (1951—Deutsch, MIT)

--measured hyperfine interval with C.S. Wu to 3.6 ppm

--Wu et al. discover parity violation in 1957

--experiment to measure polarization of electron from ^{60}Co decay

"Furthermore, believing that polarized electron sources would prove useful generally in atomic and high-energy physics, I began to study methods of producing a beam of polarized electrons with reasonable intensity..."

--electronically polarized K beam (6-pole magnets), photo-ionize → polarized electrons (PEGGY)

--P=.8, 2×10^8 electrons in 1.5 μsec pulse

$\Delta\nu$ (Hz)

μ_μ/μ_p (ppm)

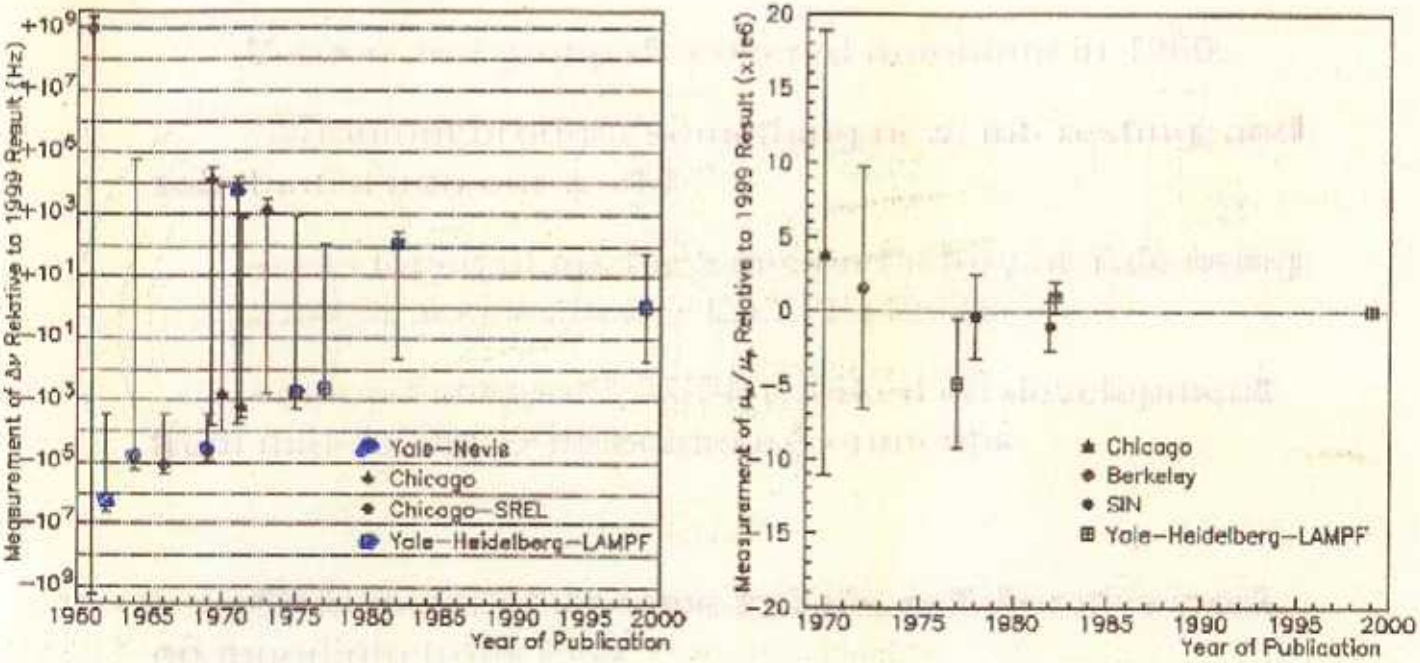


Figure 12 History of muonium $\Delta\nu$ and μ_μ/μ_p measurements.

(e^- -- μ^+): Muonium

--search started within weeks of parity violation discoveries (beta decay; $\pi \rightarrow \mu \rightarrow$ electron)

--tool to identify μ, spin state

1957—1960: a spin exchange between muonium and oxygen (an impurity in argon gas of apparatus) depolarized electrons

Vernon and group discovered muonium in 1960.

"Muonium brought something new, interesting, and substantial into our world."

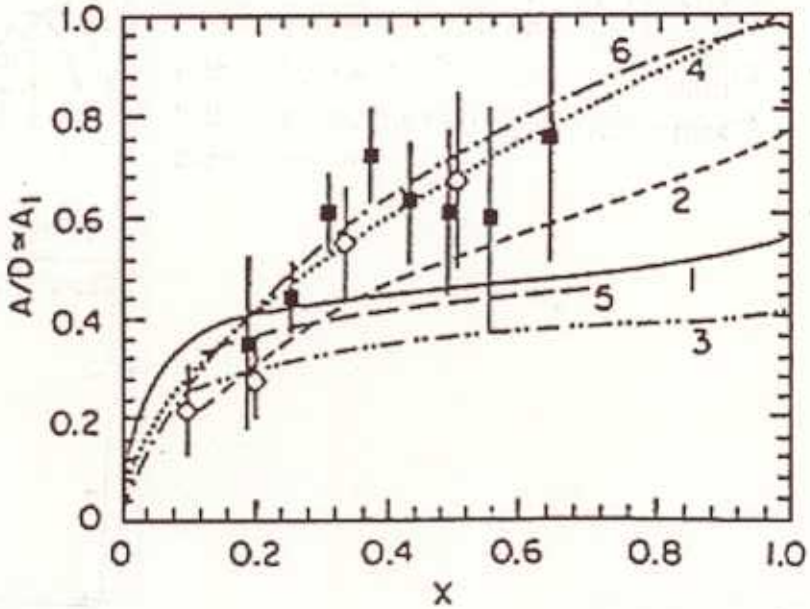
--developed plans for a meson factory at Yale using a linear accelerator → LAMPF (1972)

--muon facility at LAMPF (worked on development from mid-1960s) → muonium experiments

Gisbert zu Putlitz came to Yale, collaborative work on muonium from 1967

"Gisbert and I, as well as our families, have been close friends for over 30 years. Our collaboration and friendship have been among the better experiences in my life."

Figure 14 Experimental values A_1 compared with theories. (1) Symmetrical valence-quark model. (2) Current quarks. (3) Orbital angular momentum. (4) Unsymmetrical model (63). (5) MIT bag model. (6) Source theory. (See Reference 62 for references for theoretical curves.)



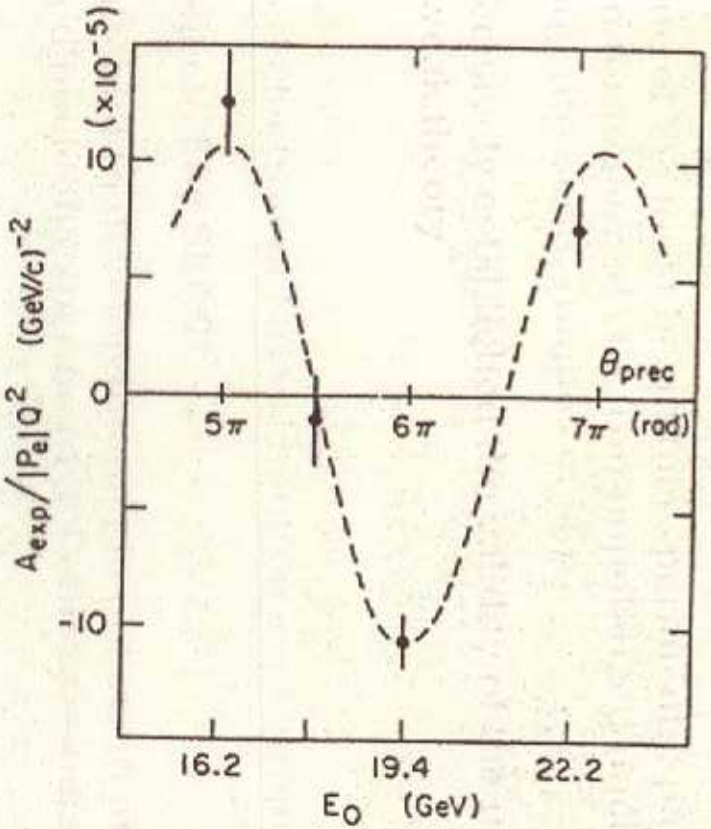


Figure 15 The experimental asymmetry shows the expected variation (dashed line) as the beam helicity changes as a function of beam energy due to the $g-2$ precession in the beam transport system. Only statistical errors are shown.

Polarized leptons at high energy

"A second area in which our Yale group was able to bring something new, interesting, and important into the world was high energy polarized lepton-nucleon scattering."

--1968: unpolarized e + p → quarks (SLAC-MIT)

--polarized proton structure function →polarizability contribution to hyperfine structure interval in hydrogen

--plan to do polarized electron-polarized proton scattering at SLAC (Yale polarized electron source, polarized target)

--first measurement of $A_1(p)$ confirms naïve quark model expectations

--one of the most beautiful experiments: parity violation for polarized electron-unpolarized nucleon scattering (Prescott, Hughes et al.)

"decisively established the validity of the unified electroweak theory"

Polarized electron-polarized neutron expt. proposed

--rejected by SLAC

--attempt to develop interest in polarized muon-polarized nucleon experiment at Fermilab—no success

EMC: polarized muon-polarized proton scattering

--Gabathuler, Sloan, Hughes et al.

--spin surprise/crisis/puzzle!

--experimenters focus on nuclear EMC effect

SMC: focus on polarized muon experiment

"Since NMC did not have anyone who had been active in the spin structure field (the British having left after EMC), it turned out that I became spokesman of SMC."

--beautiful results—Bjorken sum rule confirmed to 10%

"The large amount of data on spin structure functions obtained by SMC and by SLAC confirmed but did not resolve the spin puzzle. Interest has focused on the polarized gluon contribution to nucleon spin."

Next step: collide polarized electrons, polarized nucleons

--studies for polarized protons at HERA; later, studies for polarized electrons at RHIC

--Collaboration formed for polarized proton beam polarimetry for RHIC and future polarized HERA

RHIC Spin:

--Vernon first suggested to Ernest Courant to study whether acceleration of polarized protons in a strong-focusing accelerator would be possible

--the waveform digitizers from Yale (Satish Dhawan) are a crucial contribution to proton polarimetry

--Vernon never joined polarized proton-polarized proton collision physics. I believe he thought protons too complicated as a probe.

Muon g-2

"The anomalous magnetic moment or g-value of the muon, like that of the electron, is a fundamental quantity of great interest."

1979: 3rd CERN muon g-2 to 7 ppm (syst. error 1 ppm)

1978: "Muon g-2—the Last Word" R.W. Williams

--a challenge

1982: LAMPF II workshop (I_μ 100xCERN)

--considered mounting new g-2 experiment

→ AGS

"The value of the muon anomalous magnetic moment may be considered a sum rule of present physics. Any deviation of a_μ(experiment) from a_μ(theory) indicates physics beyond the standard model."

While writing paper showing a 2.5 sigma deviation (1999 BNL result):

"we are very lucky"

While preparing a press release:

"deviation can come from

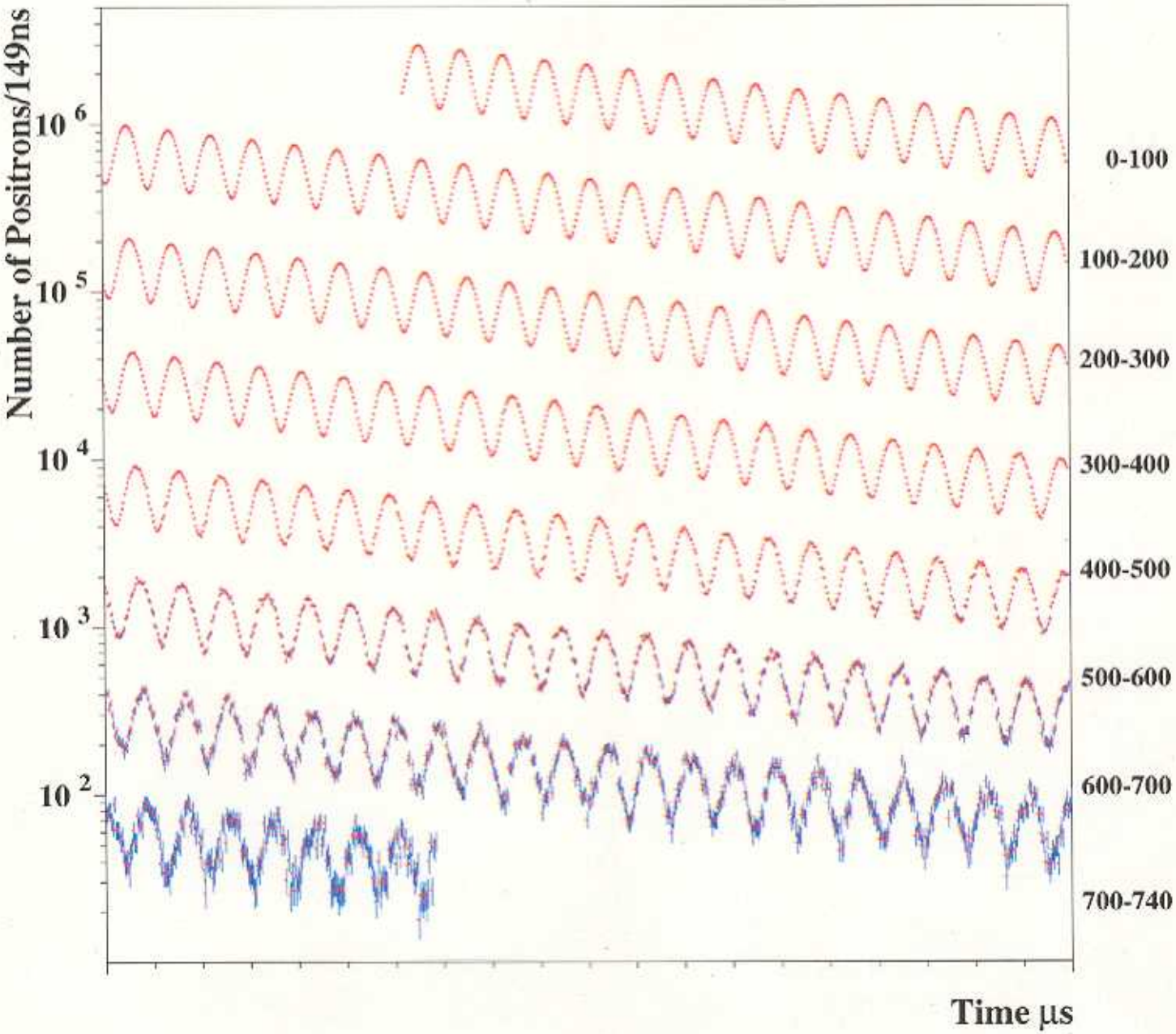
1) we are wrong

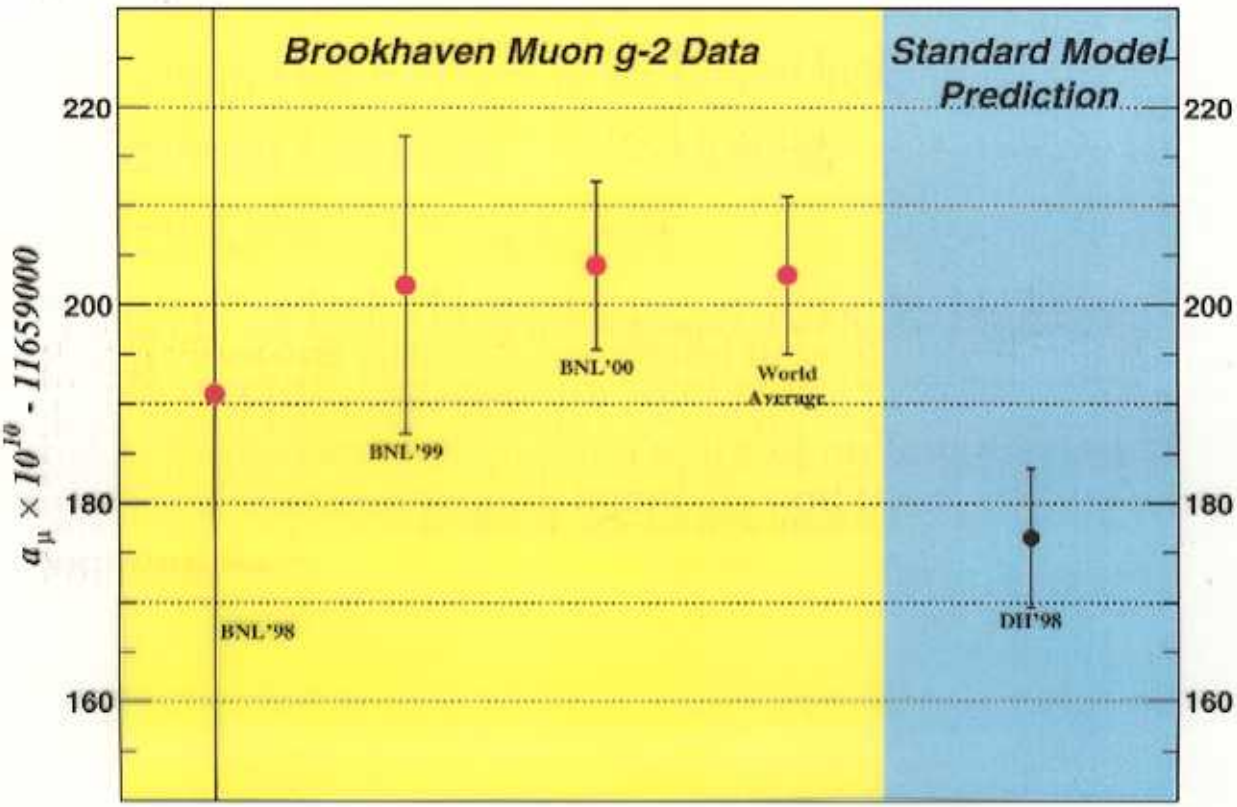
2) theory is wrong

3) new physics" (paraphrased)

The last result from the present BNL experiment should reach 0.5 ppm.

Muon g-2 Spin Precession
at BNL




Brookhaven Muon g-2 Data
Standard Model Prediction
$a_\mu \times 10^{10}$ - 11659000
220
200
180
160
BNL'98
BNL'99
BNL'00
World Average
DH'98

An Administrative Addendum

Associated Universities Incorporated (AUI) established BNL in 1947, Vernon was trustee from 1962.

AUI was removed from managing BNL in 1998 by the U.S. DOE

--High Flux Beam Reactor tritium leak

--about 1 exit sign worth of tritium

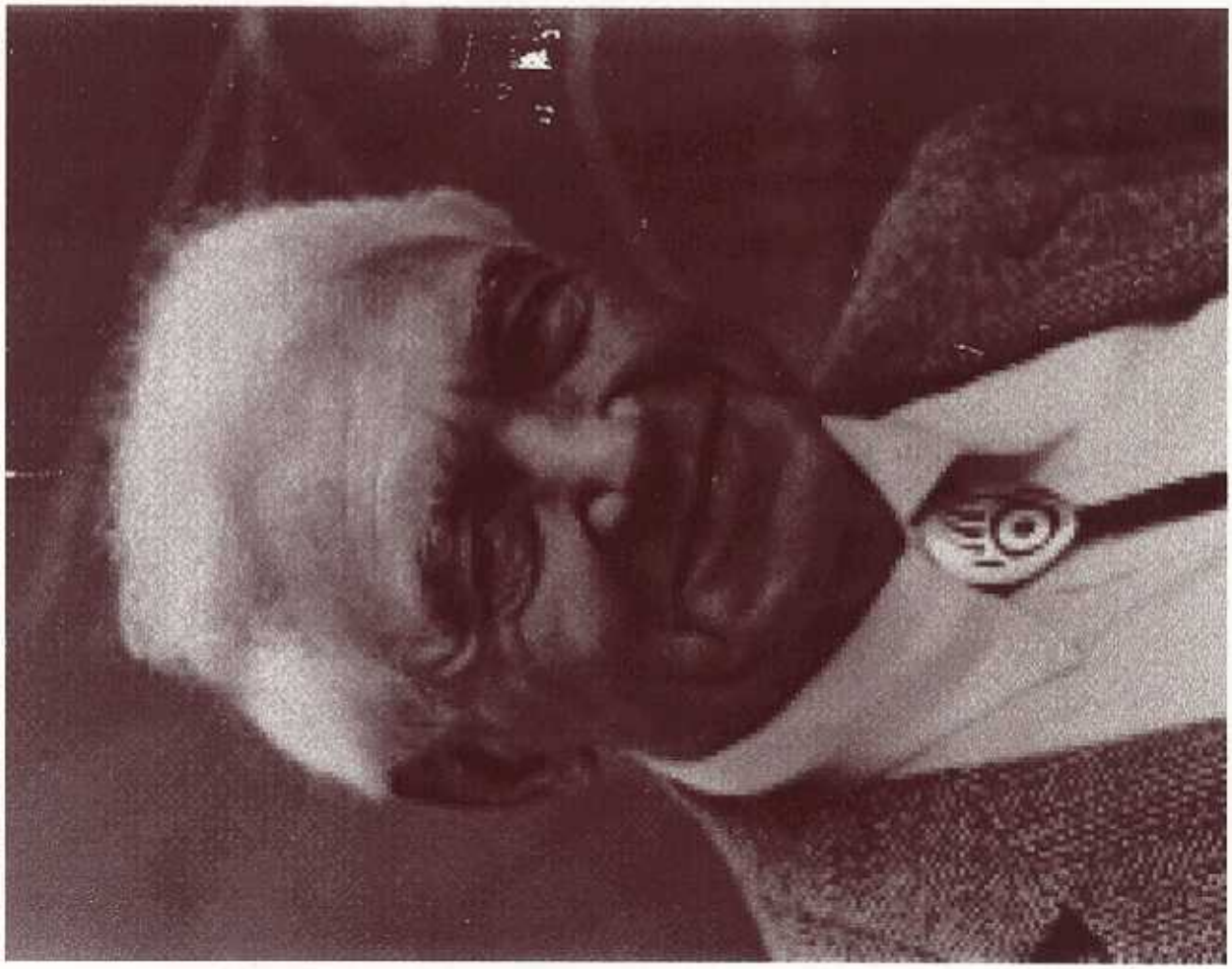
--not fought legally by AUI

"I regret this lack of legal response because I believe that a vigorous AUI defense could have clarified many aspects of the situation and would have been a positive move toward strengthening a spirit of mutual respect and trust between federal agencies and the scientific community."

From "A Festschrift in honor of Vernon W. Hughes"

edited by M.E. Zeller, World Scientific 1991

(on the occasion of Vernon's 70th birthday)

"Being descended from Iowa stock, which included an evangelical Methodist minister, I should probably have some moral, wise thoughts to offer. However, I don't have anything very original to say. Surely the important driving force for research is one's own interest in the topic. One shouldn't be too influenced by other people's opinions, or by current fads or speculations. I have found, on several occasions, progress in research has been slowed at least partly due to the injection of criteria extraneous to the research itself, e.g. consideration of credit to individuals, a teaching objective or some political funding matter. Effective collaboration in small or large groups requires the closest possible communication among their members and maximum input from everyone. I have derived great satisfaction from the warm human relationships with physicists with whom I have worked or shared common interests."

"I have felt for a long time, as I believe many of us do, that a particular importance of our profession is its international aspect. We have a rather unique opportunity, largely independent of politics, to communicate and work and to become friends with physicists from almost any country which has activity in our field. Our collaborations are not only a great professional and personal pleasure but also an important contribution to international understanding and peace."