

RELATIVISTIC ATOMIC BEAM SPECTROSCOPY II

Introduction

The negative ion of hydrogen is one of the simplest 3 body atomic systems. Understanding its spectroscopy is important to fusion research, astrophysics and accelerator physics, and of course the H^- system has great intrinsic scientific interest as a prototypical atom and an atomic "laboratory". The techniques we have developed for the experimental study of atoms moving near the speed of light have been productive. Table 1 displays a list of milestones: publications illustrating our progress.

Table 1: Guide to Relativistic Atomic Beam Work at LAMPE

- 1976 "Observation of Resonances near 11 eV in the Photodetachment Cross Section of the H^- Ion," H.C. Bryant et al., Physical Review Letters 38, 228 (77).
- 1977 "Effect of an Electric Field upon Resonances in the H^- Ion," P.A.M. Gram et al., Physical Review Letters 40, 107(78).
- 1979 "Observation of Narrow Resonances in the H^- Photodetachment Cross Section near the $n=3$ Threshold," M.E.Hamm et al, Physical Rev. Letters 43 1715(79).
- 1982 "Observation of Two-Electron Photoionization of the H^- Ion near Threshold," J.B. Donahue et al., Physical Review Letters 48, 1538(82).
- 1983 "Effects of Strong Fields on Resonant Structures in H^- Photodetachment," H.C. Bryant et al., Physical Review 27, 2889(83).
- 1984 "Shape Resonances in the Hydrogen Stark Effect in Fields up to 3 MV/cm," T. Bergeman et al., Physical Review Letters 53, 775 (1984).
- 1985 "Energy Measurement of the Lowest $1p^0$ Feshbach Resonance in H^- ," D.W. MacArthur et al., Physical Review Letters A32, 1921 (1985).
- 1986 "Test of the Special Relativistic Doppler Formula for $\beta=0.84$," D.W. MacArthur et al., Physical Review Letters 56, 282 (1986).
- 1987 "Observation of Motional-Field-Induced Ripples in the Photodetachment Cross Section of H^- ," H.C. Bryant et al, Physical Review Letters 58, 2412 (1987).
- 1988 "Effects of Electric Fields on the Photodetachment Cross Section of the H^- Ion near Threshold," J.E. Stewart et al., Physical Review A38, 5628 (1988).
- 1989 "Observation of Multiphoton Detachment of the H^- Ion," C.Y. Tang et al., Phys. Rev. A, A39, 6068 (1989).

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In this proposal we request continuing support for experimental studies of the H^- system principally conducted at the 800 MeV linear accelerator at Los Alamos. Four experiments are currently approved for beam time and operational support, by the LAMPF program committee, with available beam time presently totalling over 1,000 hours. Each of the four experiments, summarized in Table 2, focuses on a different aspect of the physics of the H^- ion, and each requires different laser and running conditions.

Table 2			
Current HIRAB Experiments			
Expt.	Title	Status	Available Time*
1075	"Photodetachment of H^- near threshold in an electric field"	250 hrs. @ B+ priority	97.4
1076	"Interaction of relativistic H^- ions with matter"	400 hrs. @ B priority	300
1121	"High excitations and double charge escape in the negative hydrogen ion"	360 hrs. @ A- priority	360
1127	"Multiphoton detachment of electrons from the H^- ion"	300 hrs. @ A priority	300
Total		1310	1057.4
*As of June 1, 1989			

The Physics

A. Photodetachment in an Electric Field

The phenomenon of the detachment of an electron from an H^- in polarized light in the presence of a static electric field, producing a series of ripples in the cross section¹, has, as recently emphasized by Fabrikant² and Gao & Starace³, not yet been fully explored. In the presence of strong fields or high photon energies, when the residual atom is left excited, there is the possibility of rescattering by the detached electron as it revisits its parent atom after being "reflected" by the electric field, in which it finds itself. This rescattering should result in an experimentally significant modification in the form of the modulations in the cross section. For the experimental cases we have so far examined such rescattering is not important. According to Fabrikant, the fields at which such effects should be prominent start at around 1 MV/cm.

Under the constraints imposed by using relativistic beams, there are two approaches to experimental observations of this phenomenon. First, one can use a quasi c.w. laser beam in the motional field produced from a dc electromagnet, or, second, one can use a pulsed laser beam with a pulsed magnet both of which are synchronized to overlap a 0.25 nsec beam pulse. Our best data so far, in the lower field case, have been obtained using a non-Q switched YAG. Therefore, we are planning on performing the measurements in a large electromagnet ("PAN"), which we have identified at LAMPF, bringing the ion beam in and out of the strong field region using a magnetically-shielded tube. (5000 Gauss yields a motional electric field of 2.3 MV/cm for an 800 MeV H^- ion). Accelerator time and support for this experiment is available under LAMPF expt. 1075.

B. Atoms in a Matter Field

There is more work to be done in the experimental investigation of relativistic hydrogen beams traversing thin foils. For relatively low energy hydrogen beams traversing thin foils, surface effects seem to play an important role.⁴ Our preliminary results,⁵ on the other hand, seem to indicate that the relative abundances of excited states depend on foil thickness. The hope is that the scattering of a hydrogen atom from bulk matter in the relativistic regime is, in a sense, simpler than the scattering from individual atoms just as for example the traversal of light through a transparent medium does not require detailed consideration of individual interactions.

One can make the analogy between the traversal of hydrogen atoms in a foil and that of their passage through a microwave cavity such as in the experiments of Bayfield⁶ and of Koch⁷. These beautiful experiments seem to have established that "quantum chaos" is present in such an interaction.

In the relativistic-beams-through-foils case we have much stronger electric fields interacting with the atom at a very high frequency for a very short time. For example, with a 100 nm thick carbon foil, traversed by a hydrogen atom of $\beta = .84$ (800 MeV), where the average electric field felt by the atom is of the order of 10^{10} V/cm, carbon atoms are encountered at the rate of 10^{17} Hz and the "matter field" pulse lasts only some 0.3 femtoseconds. As has already been demonstrated, a sizeable fraction of hydrogen atoms subjected to this ordeal survive intact. The distribution of the emerging hydrogen atom population in excited states will be the object of our further investigation.

In our work so far we have studied the state distributions by selectively field-ionizing the emerging beam and by subjecting it to laser probes in which low-lying states are excited to states which may be field-ionized.

The very exciting possibility of observing long-lived foil-produced doubly excited H⁻ states using this technique has also occurred to us and it would come as a by-product of this

approved experiment. By slightly altering the trajectories of these states with a weak electric field we should be able to separate the signature of their decays from those of the highly excited neutral hydrogens with which they are produced when an H^- beam traverses a thin foil.

Accelerator time and support for this experiment is available under LAMPF expt 1076.

C. Doubly Highly Excited States and the 2e Continuum

Work is currently underway in the study of the process in which a single photon impinging on an H^- ion results in double detachment. A preliminary result obtained several years ago has been reported.⁸ This work breaks into two equally interesting endeavors: study of the signal and study of the background. More so than in most experiments, understanding the background is absolutely essential to understanding the signal and, in a sense, the signal and background are just different aspects of the same underlying process. The signal is

$$\gamma + H^- \rightarrow p + 2e$$

and the background

$$\gamma + H^- \rightarrow H^{\circ}(n) + e$$

with $H^{\circ}(n) + \text{motional field} \rightarrow p + e$.

Since the proton, which is the signature of the signal, must be magnetically deflected from the H^- beam in order to be detected, the motional field is an essential ingredient of the experiment and thus the background process is always with us. We thus must understand it in order to extrapolate to the zero field limit.

When the photon energy drops below the two electron threshold, the background is of course still present, with an interesting complication. Then, competing with the direct channel, is the process

$$\gamma + H^- \rightarrow H^{-**} \rightarrow H^{\circ}(n) + e,$$

followed by $H^{\circ}(n) + \text{motional field} \rightarrow p + e.$

Thus by triggering on protons in particular motional fields we can study the very high-lying doubly-excited states⁸ of H^- .

Accelerator time and support for this experiment is available under LAMPF expt. 1121.

D. Multiphoton Photodetachment of H^-

During the summer of 1989 we are conducting a preliminary experimental study of H^- in an intense CO_2 laser beam¹⁰. Because of the relativistic conditions, the photons from the 10.6μ line of CO_2 range in energy in the H^- center of mass from some 34 meV to 400 meV, depending on the intersection angle. Thus with a 800 MeV beam, one can study multiphoton detachment of H^- requiring from 2 up to 22 photons. So far we have been impressed by the difficulty of these measurements. We have definitely observed multiphoton detachment events, ranging in multiplicity from 2 to about 8, but maintaining a properly-characterized interaction region is quite difficult. Essentially we are exploring the multiphoton phenomenon in a full three dimensional parameter space--photon energy, photon density, and applied electric field. We should be able to observe "above threshold detachment", ATI, in the H^- system by observing the transverse spread in the electron beam ejected from the H^- beam by light polarized perpendicular to the scattering plane.

Accelerator time and support for this experiment is available under LAMPF expt. 1127.

A thorough discussion of the experimental details can be found in the original LAMPF proposals, which we attach.

Experimental Facilities

A. HIRAB (High Resolution Atomic Beam)

A new experimental hall, the HIRAB facility, has been appended to the External Proton Beam (EPB) area at LAMPF, providing a large vibration-free environment in which high precision measurements of relativistic H^- and H^+ beams can be undertaken. (See Figure 1.) An H^- beam of remarkably high quality is brought through two interaction regions and finally into a large beam stop. In order to reduce disturbances to a level commensurate with resolutions in the few microvolt range, beam line experiments in HIRAB are mounted on a concrete slab of dimensions 35' x 20' x 4', resting on sand and recompacted fill, loosely-coupled to the surrounding structures. Clean-room conditions to insure that the laser optics are dust free are unfortunately still not available, but we expect an improved air filtering system will be installed later this year. When the beam is not being used a moveable upstream beam stop can be inserted allowing access to the apparatus in the HIRAB building, in order that the fine tuning, so important to precision experiments, can be performed carefully without the extreme time pressure normally associated with beam line work. HIRAB is a national facility open to outside users.

Since the H^- beam is prepared as a horizontal ribbon (2 mm x 5 mm) with the minimum angular divergence in the vertical direction, our scattering chamber has been redesigned. The angular divergence of the beam can be a few microradians; consequently, the angular precision of the laser-beam positioning optics as well as the angle encoder will also be upgraded. The laser beam will have to be expanded along the beam direction to bring its divergence down to match that of the particle beam.

B. Lasers and Scattering Chambers

In order to accomplish the measurements planned for this period, we will bring three different laser beams to bear on the H^- beam: CO_2 (10.6 μ), Yag (1st and 4th harmonics,

1.06 μ and 266 nm), and ArF (193 nm). For these we need three separate set-ups along the beam line, but we believe now that two scattering chambers will suffice, as will be made clear as we discuss each of these requirements in order.

CO₂: The CO₂ laser will be used for the multiphoton ionization (MPI) studies of H⁻ as outlined in LAMPF proposal 1127. We demonstrated in September, 1988, that the MPI process can be observed with a CO₂ oscillator/amplifier combination, using a modified version of our original scattering chamber.¹⁰ In order to make a proper study of the MPI process, including above-threshold ionization (ATI), a larger chamber is under construction which can accommodate a polarizer and electrostatic plates, with a 17 bit angular encoder on the optical "spider" (rotating mirror arrangement to change the angle between the laser beam and the H⁻ beam). Special attention must be paid to the problem of lining up the beams and characterizing the overlap region. Copper mirrors, NaCl vacuum windows and ZnSe lenses will be required.

YAG: The fourth harmonic of this Q-switched laser will be used for our planned studies of high excitations and double charge escape from the H⁻, as presented in LAMPF proposal 1121. This second-generation experiment in our program at LAMPF requires state-of-the-art angular resolution and much care with beam characterization and linearity of the scintillation counters over a large dynamic range. We have revamped our existing belt-driven spectrometer-scattering chamber for this use, including provision for application of a 60 kV/cm field over the interaction region and the accommodation of larger optics.

We also propose to use this set up to study ripples induced in the threshold photodetachment cross section by a large magnetic field using the large C magnet "PAN" and a modification to the scattering chamber. For these measurements, the fundamental of the YAG will be used, not Q-switched if the beam line vacuum is adequate. This set up will also be compatible with studies of foil-produced H⁰ states. Our data-taking rate (and

hence ultimate statistical variance) could be increased by a factor of 3 if we had a Quanta-Ray DCR-3 (30 pps) laser rather than our present DCR-2 (10 pps). A request for funds to buy such a laser has been submitted separately.

ArF: The ArF (Lambda Physik EMG150 excimer) laser will be used to study the two-electron ionization continuum of H- up to a Doppler-shifted center of mass photon energy of almost 22 eV, as proposed in experiment 1121. The detection system will be essentially the same as for the YAG portion of the measurement, but a different scattering chamber will be necessary. Our present thinking is that we may be able to use the CO₂ scattering chamber with appropriate changes in the optics to accommodate the much different wavelengths (from 10.6 μ to 193 nm). For these wavelengths, transmitting optics (windows, lenses) require CaF₂. The EMG1509 laser at present for ArF operation requires frequent (every 15 minutes) cycling of the toxic gas. For efficient use at HIRAB, we will have to design and build a gas handling system so that this process can occur continuously. We will rely very heavily on our LANL collaborators for help with this.

Personnel

Our work on the relativistic H⁻ beam is a joint venture. Presently our principal collaborators are Joey Donahue, Bob Quick and Stan Cohen at LANL, Win Smith at U. Conn and Jim Stewart from Western Washington University. Recently, we began a three year collaborative arrangement with Hungarian Academy of Sciences Budapest with the help of NSF's US-Eastern Europe Cooperative Science Program. This will provide for interchanges between UNM personnel and Hungarian physicists. The principal Hungarian physicists involved are Janos Bergou, a theorist, and Karoly Rozsa, an experimentalist. The UNM group presently consists of, in addition to Howard Bryant, a postdoctoral associate, Hossein Toutounchi, and three graduate students, Philip Harris, Amir Mohagheghi and

Chen Yau Tang. In the summer of 1989 we were joined by a temporary post doc from Long Beach State, Hassan Sharifian. In our budget for the next three years, we anticipate keeping our level of effort at UNM about the same, with the exception of the addition of a full-time technician. The addition of a technician to our group has been long overdue--the equipment we are using has become too complicated to be maintained by overworked graduate students. The details of holding a competent laboratory together require a technician's full attention and continuity. UNM has a strong theory group in quantum optics under the leadership of Marlon Scully and we anticipate further help in the MPI work from Wilhelm Becker and Jack McIver.

Workshop

We are thinking of having a workshop just preceding the beginning of the period covered by this proposal. No funding has been requested from the DOE.

Dates: January 9, 10, 11, 1990
Location: UNM campus, Physics Lecture Hall
Title: "Workshop on the Spectroscopy of H"
Number of Participants: ~ 75
Registration Fee: \$40

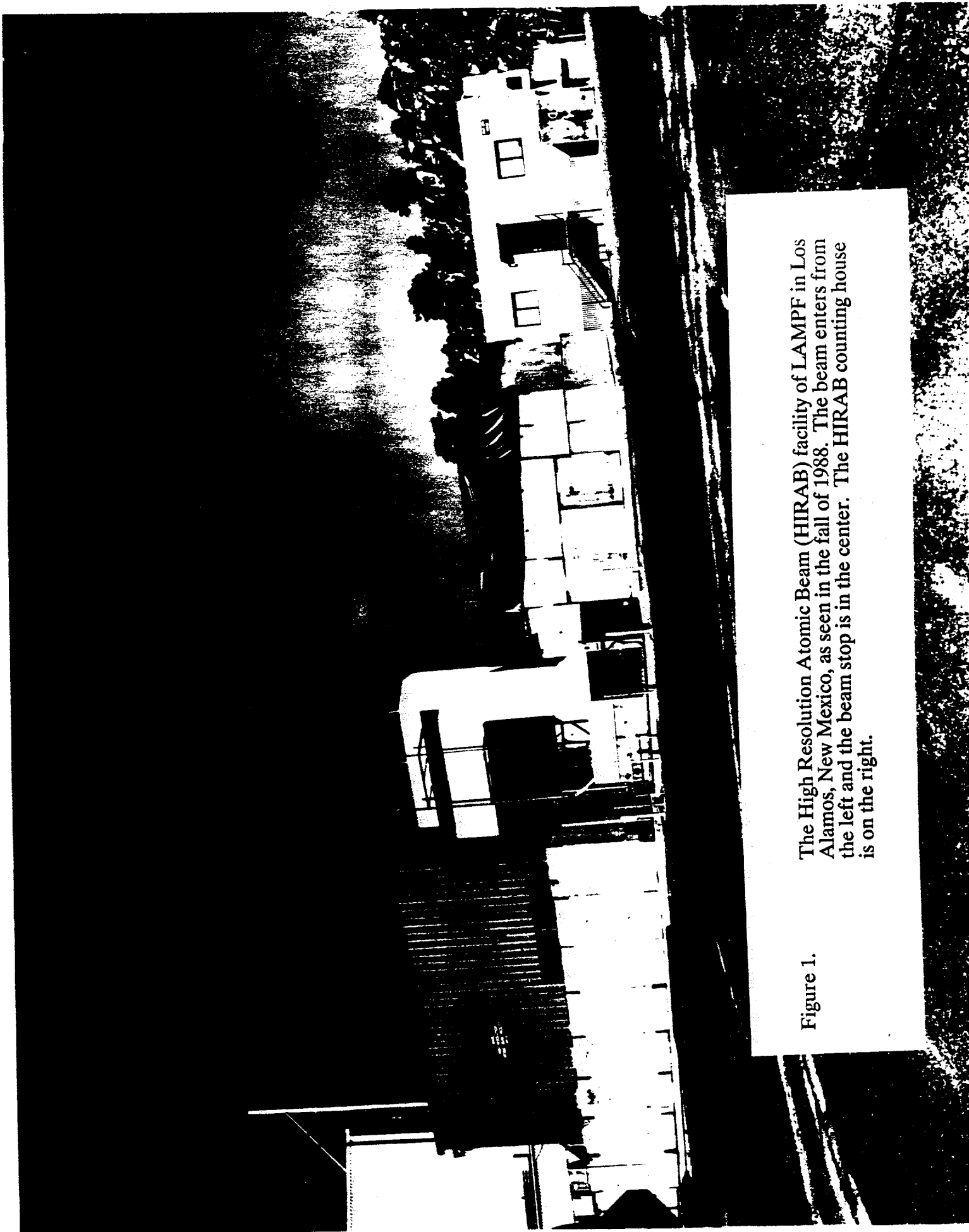
Since UNM will not yet be in session, the physics lecture hall which seats 300 people will be free and local eating establishments will be uncrowded. Accomodation in the best local hotels can be had for \$35/night, and on down.

We would have long sessions, probably all day and evening on Tuesday, January 9, and Thursday, January 11, with only a morning session on Wednesday, January 10. In the afternoon we would bus everyone up to Los Alamos where they could tour the lab or go skiing. It may be we would want to keep the entire day free and expand into Friday. On Wednesday evening we would have a banquet in Santa Fe (Rancho Encantado?) and invite a speaker on some Southwestern topic. No invitations have as yet been issued.

*Budget info. removed.
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The High Resolution Atomic Beam (HIRAB) facility of LAMPF in Los Alamos, New Mexico, as seen in the fall of 1988. The beam enters from the left and the beam stop is in the center. The HIRAB counting house is on the right.

Figure 1.

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"An Atomic Interferometer," H. C. Bryant. Contributed paper to Atomic Spectra and Collisions in External Fields II, Royal Holloway and Bedford New College, Egham Hill, Egham, Surrey, TW200EX, UK, 30-32 July 1987.

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"Observation of Excited H_o Atoms Produced by Relativistic H^- Ions in Carbon and Formvar Foils" A.H. Mohagheghi, H. C. Bryant, P. G. Harris, C. Y. Tang, C. R. Quick, S. Cohen, R. A. Reeder, W. W. Smith, J. E. Stewart. XVI International Conference on the Physics of Electronic and Atomic Collisions 26 July - 1 Aug, 1989, NY, NY.

TECHNICAL REPORTS

"A Monte Carlo Calculation of the neutron Detection Efficiency of a Hydrogen Bubble Chamber," Los Alamos Scientific Laboratory Report. Lams-2764 (1962).
Co-author: J. K. Wooten.

"A Monte Carlo Simulation of a Proton-Proton Spin Correlation Experiment," Los Alamos Scientific Laboratory Report, LA-3558, UC-34, PHYSICS, TID-4500, 17 October 1966, 45 pages. Co-author: Nelson Jarmie.

"A Study of the Glory," Final Report to the Sandia Corporation, Contract No. 53-4757 6/1967 by Howard C. Bryant.

Research Project Technical Completion Report to the Water Resources Research Institute, New Mexico State University, 20 June 1968. H. C. Bryant.

"Surface-Wave Description of π^+p Backward Scattering," SLAC-PUB-608.

"A Multiwire Proportional Chamber Spectrometer for Nucleon-Nucleon Experiments', LA-5396-MS Informal Report UC-34c issued October 1973. Los Alamos Scientific Laboratory. Co-authors: D. W. Werren, L. M. Fox, C. W. Bjork, S. Cohen, J. E. Simmons, C. G. Cassapakis, D. M. Wolfe, D. Brown, C. Pacheco, B. E. Bonner, F. D. Newcom, D. B. Dieterle, J. C. Hiebert.

UNM Salt Gradient Solar Pond Research Reports (1982)

- 82/1 "Transmittance in a NaCl Solar Pond," R. Almanza and H. C. Bryant.
- 82/2 "Oscillatory motions in the nonconvective layer of a solar pond," R. Almanza and H. C. Bryant.
- 82/3 Solar pond as a source for a flash evaporation chamber," R. Almanza and H. C. Bryant.
- 82/4 "Transmittance Measurements in the KNO₃ Solar Pond," R. Almanza and H. C. Bryant.
- 82/5 "Recent work on salt-gradient ponds at UNM," H. C. Bryant, A. L. Salamah, R. Almanza and H. Fang.
- 82/6 "A colloidal solar pond," H. C. Bryant.
- 82/7 "Atomic Physics with Relativistic Beams 1984" C. J. Harvey and H. C. Bryant
Abstract for Atomic Physics Program Contractor's Workshop, U. S. DOE May 13-14, 1985 (page 68), University of North Carolina, Chapel Hill.
- "The Hybrid Salt Gradient Pond — From NaCl to KNO₃," Final Technical Report to the New Mexico Research and Development Institute. November 1986 (100 pages).

POPULAR ARTICLES

- "The Fisheye Pinhole Camera," contribution to Physics Demonstration Experiments, page 1040-1041, (1970). Edited by Harry F. Meiners, The Ronald Press Co., New York. Library of Congress No. 69-14674.
- "The Glory," Scientific American, July 1974, p. 60-71. Co-author: Nelson Jarmie.
- "Quarking on the Berkshire Downs," European Science Notes, Office of Naval Research, London, ESN-30-10, 31 Oct. 1976, 469-472.
- "Atomic Physics with Relativistic Beams" in Physics News in 1978 published by the American Institute of Physics, New York, 1978 (distributed by Public Relations Division, A.I.P.).
- "A Brief Report on the 'Physics of the H⁻ Ion' Workshop," Honglie Fang and H. C. Bryant, submitted to Acta Optica Sinica.

RECENT TALKS AND COLLOQUIA

"Inaccessible Energy" and "Solar Ponds", two talks presented at the Ganado Energy Forum, College of Ganado, Arizona, April 10-12, 1980.

"Why the Sea is Boiling Hot: Salt Gradient Solar Ponds," Sandia Colloquium, Sandia Laboratories, Albuquerque, NM, Oct. 15, 1980.

"Relativistic Beams", joint Department of Physics-JILA colloquium, U. of Colorado, Boulder, CO., Fall 1980.

"Atomic Physics with Relativistic Beams" and "Why the Sea is Boiling Hot: Salt Gradient Solar Ponds", two colloquia presented at the Department of Physics and College of Engineering, The University of Wyoming, Laramie, WY., Feb. 10, 1981.

" H^- in Strong Electric Fields: Experimental Results", one hour lecture at workshop "The Physics of the H^- Ion", Los Alamos, NM, Nov. 12-13, 1981.

Talk and demonstration on solar ponds to students from Aztec Elementary School, Aztec, New Mexico, May 7, 1982 (at UNM).

Colloquium: Institut fur Atomphysik, U. Innsbruck "Atomic Physics Near C," Oct. 7, 1982.

Lecture Series U. Innsbruck: 7 lectures "Photoelectric Processes in Simple Atoms," Fall 1982.

Lecture Series U. Innsbruck: 5 lectures "The Vector Potential and the Origin of Forces," Fall 1982.

Colloquium: Max-Planck-Institut fur Quanten Optik, Garching, West Germany, Dec. 8, 1982. "Experimental Spectroscopic Studies of the H^- Ion at Relativistic Velocities."

Lecture at the American Studies Seminar for Austrian University Students: "American Society in a Changing World," organized by the Austrian-American Educational Commission (Fulbright Commission) "The Energy Crisis" Schloss Kassegg, Styria, Austria, Nov. 17, 1982.

Colloquium for the Institut fur Experimental Physik, Canisianum, U. of Innsbruck, Innsbruck, Austria, March 10, 1983, "Outdoor drifttube: the physics of the salt-gradient solar pond."

Colloquium for the Physics Department, University of Kragujevac, Kragujevac, Yugoslavia, March 31, 1983, "The origin of the electromagnetic force."

Colloquium for the Physics Department, University of Belgrade, Belgrade, Yugoslavia, April 1, 1983, "Atomic Physics near the speed of light."

Colloquium for the Institut fur Experimental Physik, University of Freiburg, Germany, April 23, 1983, "Atomic Physics near the speed of light."

Seminar for the Physics Department at the Universite Degli Studi, Povo, Trient, Italy, May 7, 1983, "Atomic Physics near the speed of light."

Seminar for Atomic Physics Institute, Orsay, Universite Paris-Sud, May 25, 1983, "Atomic Physics near the speed of light."

Seminar for visiting engineers from Jordan (Royal Scientific Society, Jordan) at Physics and Astronomy building, UNM, Sept. 25, 1983, "The future for salt gradient solar ponds."

Talk to Prof. Gross's class ME 425: (visitors from U. of Khartoum, Sudan), Nov. 29, 1983, "Salt Gradient Solar Ponds."

Colloquium for UNM Physics and Astronomy Department, March 2, 1984, "Atomic Spectroscopy Near the Speed of Light".

Talk to Harvena Richter and Fred Strum's, "Creative Principles in Arts and Sciences" English 411/511, "Light and Color", March 20, 1984, UNM.

"Atomic Physics with Relativistic Beams" talk to Physics Division (1 hour), Los Alamos National Lab, MP 215, Nov. 8, 1984.

Colloquium for UNM Physics and Astronomy Department, January 25, 1985 "Progress in Understanding Simple Atoms".

Talk to "La Vida Llena" 10501 Lagrinda de Oro, Albuquerque, Feb. 21, 1985, 7 p.m., "The Glory".

30th Annual Faculty Research Lecture, April 1, 1985, Physics Lecture Hall, 8 p.m. "A Physicist's Journal: from the Glory to the Two-electron Ion".

"Physics with relativistic beams", Talk to Amer. Phys. Soc. SDI Study Committee 11:30-12:00 May 24, 1985 at AT Div. Los Alamos National Lab, Los Alamos, N. M. TA-53, MPF-6, Room 302.

Sandia Colloquium, Sandia National Laboratory, Albuquerque, N.M., 9-10 a.m. 13 Sept 1985, "Tweedle Dee and Tweedle Dum near the Speed of Light", (on film, transcript also available).

Seminar, Los Alamos National Laboratory, Conference Room TA3, Bldg. 215, Rm 281, 1 pm, July 16, 1986, "Photodetachment Study of H^- ions at Relativistic Velocities."

Colloquium, Dept. of Physics and Atmospheric Science, Drexel University, Philadelphia, 1 pm, May 4, 1987, Disque Hall, Room 12-919, "Experimental Verifications of Special Relativity."

Bag Lunch Seminar, MP Division Auditorium, 12 noon June 8, 1987, "A New Test of Special Relativity."

Seminar, "Relativity Tests at LAMPF" Rutherford Laboratory, Chilton, Didcot England 29 July 1987.

Talk, "Photon Interactions with H^- ," Los Alamos National Lab, TA 35-127, A101, 2:30 PM, Feb. 3, 1988.

Series of 5 Lectures given at The Los Alamos Summer School in Atomic Physics: July 25-29, 1988: 10:30-12 UNM Campus, Los Alamos

1. What good is relativity?
2. The Structure of the H^- Ion.
3. Photodetachment of H^- .
4. Effects of Fields: The Tale of Two Resonances.
5. The Atomic Interferometer and Beam Me Up, Scotty!

Colloquium, Dept. of Physics and JILA, University of Colorado, Boulder, CO, Oct 5, 1988, "Atomic Physics Near the Speed of Light."

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