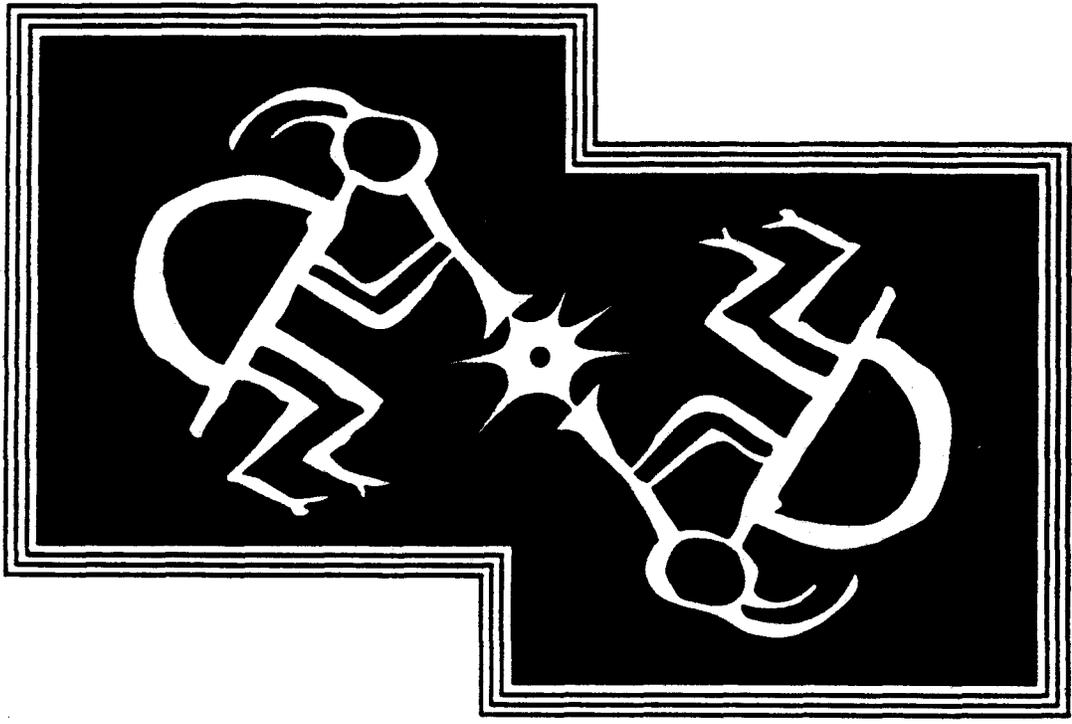


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SSC-E010017

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TEXAS NATIONAL RESEARCH
LABORATORY COMMISSION
Research and Development Program



RELATIVISTIC ATOMIC PHYSICS
AT THE SSC

A Proposal from
The University of New Mexico, Albuquerque, New Mexico

FACE PAGE

Texas National Research Laboratory Commission

Research and Development Program

Please Type the Following Information

(A separate Face Page is required for each member of a consortia proposal)

1. TITLE OF PROPOSED RESEARCH

Relativistic Atomic Physics at the SSC

2. I.R.S. ENTITY IDENTIFICATION OF PROPOSER

85-6000-642

3. SOCIAL SECURITY NUMBER OR FEDERAL I.D. OF PROPOSER

85-6000-642

4. REQUESTED AWARD AMOUNT

\$272,000 (first year)

5. DURATION OF THE ENTIRE PROJECT PERIOD

1/1/91

12/31/95

Mo. Day Yr.

Mo. Day Yr.

8. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR NAME, TITLE, ADDRESS AND PHONE NUMBER

Dr. Howard C. Bryant
Professor of Physics
Physics & Astronomy
The University of New Mexico
Albuquerque, NM 87131
(505) 277-3044

9. NAME, AND ADDRESS OF INSTITUTION CERTIFYING PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR NAME, TITLE AND PHONE NUMBER

Ann Powell
Director of Research Administration
102 Scholes Hall
The University of New Mexico
Albuquerque, NM 87131
(505) 277-2256

SIGNATURE OF PRINCIPAL INVESTIGATOR PROGRAM DIRECTOR

HC Bryant

WARRANTY ASSURANCE: I agree to accept responsibility for the scientific content of the proposal and to provide the required program reports. I am aware a claim as a result of the submission. My signature of false information is a criminal offense.

SIGNATURE OF INSTITUTION CERTIFYING PRINCIPAL INVESTIGATOR PROGRAM DIRECTOR

Ann Powell

CERTIFICATION & ACCEPTANCE: I certify that the statements herein are true and accurate to the best of my knowledge and accept the obligation to comply with Commission rules and procedures. I am aware a claim as a result of the submission. My signature of false information is a criminal offense.

FOR INTERNAL USE ONLY

Agreed and Accepted:
TEXAS NATIONAL RESEARCH LABORATORY COMMISSION

By: _____

Title: _____

Date: _____



The University of New Mexico

Department of Physics and Astronomy

Albuquerque, NM 87131

(505) 277-2616

FAX: (505) 277-1520

e-mail: panda8@carina.unm.edu

January 28, 1991

Dr. Neil V. Baggett
Program Advisory Committee, SSC
2550 Beckleymeade Avenue
Dallas, TX 75232

Dear Dr. Baggett,

This is a letter of intent to inform the PAC that we plan to submit a proposal at the appropriate time to do atomic physics on the H^- Linac of the SSC. The subject of our work will be the experimental study of structures in the H^- system.

We feel that it is essential that you be aware of the following three points:

1) The high-quality H^- beam at the Linac will offer a unique opportunity to study the dynamics of the two electron system. The existence of a bound H^- ion as well as structures in its continuum is entirely due to electron correlations; a study of these states is an important and exciting field in atomic physics. The use of currently-available lasers and the relativistic Doppler shift will allow us to access states far into the vacuum ultraviolet with very good precision. Multiphoton techniques that we have recently developed at LAMPF will also be used. We emphasize that fundamental atomic physics could well be the first results issuing from the SSC, before the main rings are commissioned.

2) The colliding laser beam- H^- beam technique seems to be one of the best, probably the best, ways of monitoring the phase space of an H^- beam. The experience and techniques we have developed at LAMPF should benefit the consistent production of a high quality beam for injection into the booster. We would like very much to be of assistance and hope that our help would compensate for any distractions that an atomic physics experiment at the SSC Linac might cause.

3) Time is of the essence. In order to do atomic physics and laser diagnostics on the H^- beam, appropriate access to the beam line must be provided. Retrofitting could be expensive and unacceptable. Therefore it is important to make decisions on our proposal before the final linac design solidifies.

I am attaching a copy of our proposal for funding for this work to the Texas National Research Laboratory Commission (TNRL # 010), for your information. The names of other proposal participants can be found on page 2 of the proposal.

We would appreciate any guidelines you can provide for the submission of a scientific proposal.

Sincerely yours,

A handwritten signature in black ink that reads "Howard". The signature is written in a cursive style with a large, prominent 'H'.

Howard C. Bryant
Professor of Physics

HCB:de

cc: Roy F. Schwitters, Director SSC
Edward C. Bingler, Executive Director, TNRLC
J. V. Martinez, DOE
Robert Diebold, DOE
Jerry Watson, SSC Linac Division
Don Edwards, SSC Linac Division

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I. EXECUTIVE SUMMARY

The first results from the SSC could well be major advances in fundamental atomic physics, rather than in fundamental particles, simply because the linac accelerating H^- up to relativistic velocities will come on line about 5 years before two 20 TeV protons will have close encounters of any kind. In its own way, a high quality, intense, beam of H^- ions with energies of the order of a GeV is just as unique in the physical world as is the beam of ultra high energy protons being produced by the big ring. Both beams allow us to make observations at the frontiers of human knowledge; in the linac case, the unique probes available would allow us to open a new window on the one- and two-electron atom and, as well, investigate the isotropy of space-time with precision in a rest frame moving near the speed of light.

This proposal is asking for support to prepare for an optimum and intelligent use of the H^- beam. Thought must go into how atomic physics measurements could be made, for example, using laser probes at the linac, and how one could make a high quality beam of H^+ atoms prepared by photodetachment to be in a unique quantum state. Conversely, equipment could be developed, using known atomic beam techniques, to monitor and tailor the beam being injected into the ring structures. A cadre of scientists familiar with relativistic atomic beam physics must be built up.

We therefore propose that the group centered at the University of New Mexico presently working on relativistic atomic beam physics at LAMPF be strengthened and given the wider mandate to prepare for the SSC linac. We are asking for support for visitors from other institutions to come work with us on linac-related physics, and we are asking for more support of the real future of this field, the post docs and students.

In addition to support for people, we request a relatively modest equipment budget principally to acquire appropriate lasers, optics and high speed electronics for data acquisition for first use at LAMPF and finally at the SSC. Insofar as it is appropriate, the

UNM atomic physics group would participate in the outreach and other activities of the New Mexico Center for Particle Physics, which is being proposed in a separate document.

The research program of our group at UNM is presently supported as follows:

\$110,000/per year	U.S. Department of Energy, Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research
\$ 12,813/per year	NSF (U.S.—Hungary Exchange)

Our group has been receiving an average of 3 or 4 weeks of machine time at LAMPF per year as well as year-round access to LANL facilities including laboratory and office space.

We are requesting support of \$272,000 per year for the next five years from the Texas Commission, to complement our current support and to expand our level of effort in the direction of the SSC linac.

II. LIST OF PARTICIPATING SCIENTISTS AND INSTITUTIONAL AFFILIATIONS

1. Senior Scientists

As the atomic physics capabilities at the SSC are developed and recognised we expect the group at UNM and our collaborators will grow. At this point, we list those who are presently engaged in relativistic atomic beam work at LAMPF or who have expressed strong interest in joining this effort (marked with *).

Experimentalists

Dr. H.C. Bryant, The University of New Mexico

Dr. J.B. Donahue, LANL

Dr. C.R. Quick, Jr. LANL

Dr. Stanley Cohen, LANL

Dr. Joe Tiee, LANL

Dr. W.W. Smith, The University of Connecticut

* Dr. J.E. Stewart, Western Washington University

* Dr. M. Lubell, City College of New York

Dr. K. Rozsa, Hungarian Academy of Sciences

Dr. H. Sharifian, Cal State Long Beach

Dr. R.A. Reeder, University of New Mexico

Theorists

Dr. Jack McIver, University of New Mexico

Dr. Wilhelm Becker, University of New Mexico

Dr. Janos Bergou, Hunter College, CUNY, New York

Dr. Peter Kalman, Technical University, Budapest, Hungary

2. Graduate Students (UNM)

Experimental

Amir Mohagheghi (now post doc)

Chen Yau Tang

Monica Halka

Edward MacKerrow

Robert Pastel

Robert Giannelli

Theoretical

Steve Long

Li-E Li

III. GENERAL BACKGROUND

The advent of the SSC machine is widely expected to give a strong impetus to high energy particle physics in the U.S. What may not, however, have been recognized is that the new facility could also mean a major advance for an emerging branch of atomic physics

involving the study of atoms and ions moving at near luminal velocities: high energy atomic physics.

Since the late seventies¹, work has been going on at the 800 MeV linear accelerator (LAMPF) at Los Alamos using laser beams and other probes, such as strong fields and thin foils, to study the structure and electromagnetic interactions of the simplest of atomic systems H^+ and H^- . The basic idea is to take advantage of the relativistic kinematics of an atom moving with a large β (at 800 MeV, $v/c = 0.84$) to Doppler-shift beams from ordinary pulsed lasers into the vacuum ultraviolet, corresponding to excitation energies of the neutral hydrogen atom and its negative ion. Enormous electric fields can be induced in the atom's frame using modest laboratory magnets. Recently, continuously tunable, intense beams from the CO_2 laser have been used to study for the first time multiphoton processes in the H^- ion.

To give a clearer idea of the power of relativistic kinematics in laser-ion beam studies, consider the relativistic Doppler formula

$$E = \gamma E_L (1 + \beta \cos \alpha).$$

Here the center-of-mass photon energy, E , is given in terms of its laboratory energy E_L , with α being the angle between the laser beam and the particle beam, such that for head-on collisions $\alpha=0$. At 800 MeV, since $\gamma=1.853$ and $\beta=.842$, one can continuously tune a fixed-frequency laser through the range

$$0.29 E_L \leq E \leq 3.4 E_L.$$

Furthermore the laser intensity, I , in the center of mass (Watts/cm²) is related to the lab intensity, I_L , by the square of the Doppler factor. That is,

$$I = \gamma^2 (1 + \beta \cos \alpha)^2 I_L,$$

so that one can get an intensity gain at $\alpha=0$ of 11.65!

Finally, the barycentric electric field E produced by a transverse laboratory magnetic field B is given, in S.I. units, by

$$E = \gamma \beta c B,$$

so that a 1 Tesla lab field can result in a center of mass electric field of 4.7 MV/cm.

Before the development of relativistic beam techniques, the resonance structure of the H^- ion in the vacuum ultraviolet was essentially unknown except for a few electron-hydrogen scattering measurements. With our new methods we were able to demonstrate a rich structure of doubly-excited resonances in H^- and to study their behavior in electric and magnetic fields. We were also able to do similar studies on the low-lying states of H^+ . Precision checks on the isotropy of space-time are also possible using our technique.

In this proposal we are asking for support to increase our present level of effort to allow us to participate in the planning of the SSC linac facility and to gear up for state of the art experiments in the atomic beam at the SSC. The work already done and being planned for LAMPF may be regarded as prelude to the eventual flowering of these endeavors at the SSC, with the help of a strong group in high energy atomic physics at the University of New Mexico.

IV. PROJECT DESCRIPTION

1. Diagnostics, Monitoring and Tailoring for the H^- Linac at the SSC

The use of lasers to probe relativistic atomic beams, developed at LAMPF over the past twelve years, can be applied to the diagnosis, monitoring, and tailoring of the H^- linac beam at the SSC. The basic idea is to direct a laser beam at the H^- beam so that its Doppler-shifted frequency is centered on a well-defined feature in the absorption spectrum. This feature could be the well-known Feshbach resonance in H^- , for example, at an excitation energy of 10.926 eV, whose intrinsic width is some 30 microvolts, or it could be a hydrogen resonance line excited by a 2-step process in which the H^- is first photodetached using a precursor infrared beam and the ground-state H^+ is then excited. Even a three-step process might be contemplated, in which the complication of 3 separate laser beams might be exchanged for higher resolution and more convenient laboratory wave

lengths as well as a higher signal-to-noise ratio. By selective photodetachment or excitation, small regions of the overall phase space could be studied.

The energy resolution in the center of mass of a system moving at βc in a beam whose momentum dispersion is $\delta p/p$, and where the rms angular uncertainty is $\delta\alpha$, is given by

$$\frac{\delta E}{E} = \left\{ \left(\frac{\delta E_L}{E_L} \right)^2 + \left(\frac{\beta \sin \alpha}{1 + \beta \cos \alpha} \right)^2 (\delta\alpha)^2 + \left(\frac{\beta^2 + \beta \cos \alpha}{1 + \beta \cos \alpha} \right)^2 \left(\frac{\delta p}{p} \right)^2 \right\}^{\frac{1}{2}}$$

Let us assume now for example that the laboratory energy resolution of the laser line is negligibly narrow, so that $\delta E_L/E_L \rightarrow 0$, and that we are exciting the 1P Feshbach resonance at 10.926 eV just below the threshold for $\gamma + H^- \rightarrow H^*(2) + e$. By using a fixed-frequency laser, the observed angular width of the resonance would reflect both the angular uncertainty $\delta\alpha$ and the momentum spread $\delta p/p$ of the beam. At LAMPF $\delta\alpha$ can be as low as 10 microradians and $\delta p/p$ about 10^{-4} .

If it were possible to operate near $\cos \alpha = -\beta$ (the "magic angle"), sensitivity to $\delta p/p$ would disappear.

If it were possible to operate near $\alpha = 0$, sensitivity to $\delta\alpha$ would disappear.³

If we wished to monitor both variables at once we would have to use one of the hydrogen lines, by first photodetaching (to either the ground state or an excited state) and then exciting the line. The use of such a technique is described in a publication of our group.⁴

In Figure 1 we show as an example the laboratory intersection angle α required to excite the Feshbach resonance below $n=2$ in H^- using garden-variety pulsed lasers. The use of pulsed lasers gives a large signal to noise ratio. The availability of a tunable laser in the lab with sufficient intensity would be a great boon for this work because it would allow for continuous monitoring. A uv laser that could operate essentially CW while the H^- beam were present for example is a hollow cathode Cu^+ laser which would offer unique possibilities: 1) Several uv lines together very near to the 4th YAG line (259.06, 259.90

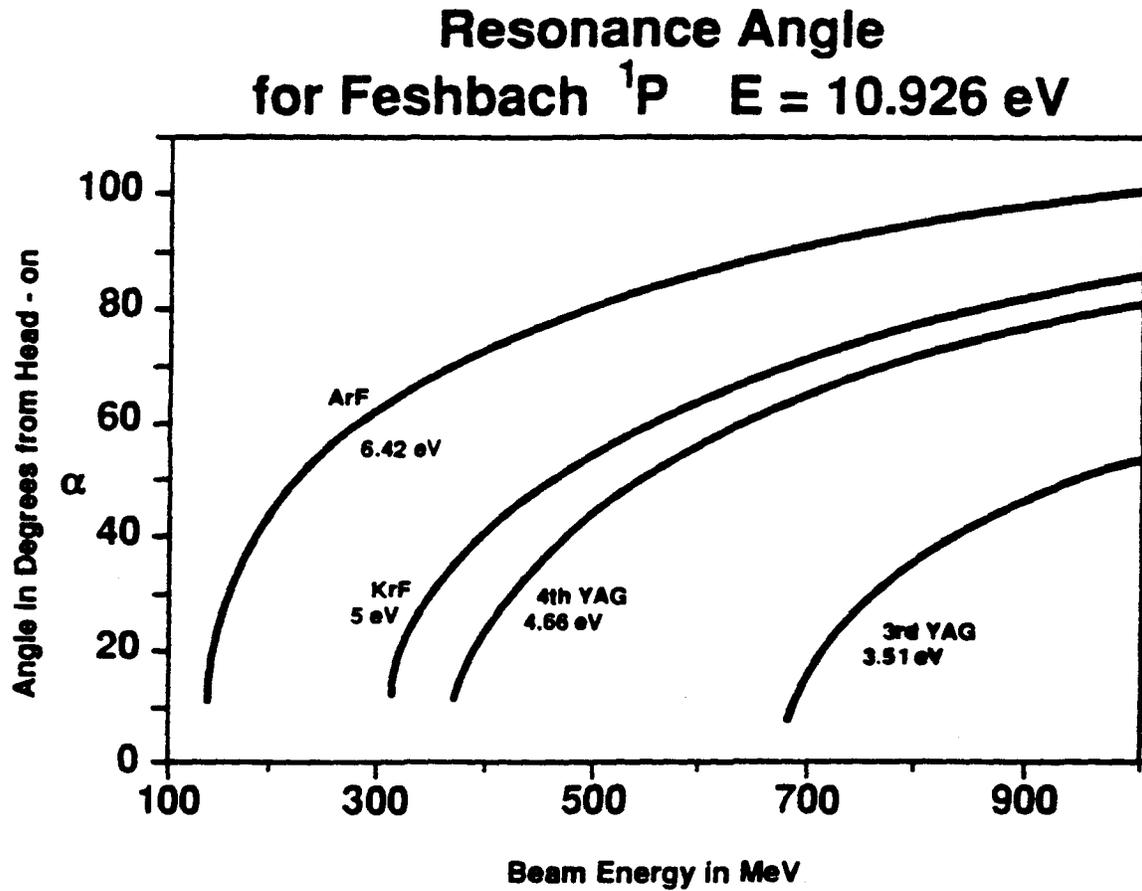


Fig. 1.

Angle of excitation of the Feshbach resonance at 10.926 eV as a function of H^- kinetic energy for several "garden-variety" laser lines of high intensity.

and 260.03 nm) would allow step-wise tuning. 2) Single mode operation with 10–15 MHz FWHM. 3) A long laser pulse that overlaps the beam pulse. 4) The excellent beam quality of the CW gas laser. On the other hand, no commercial model of such a laser has been made. Research is going on to develop such a laser in the framework of the NSF–Hungarian Academy of Sciences cooperation (Károly Rózsa). The feasibility of such a laser for the SSC should be investigated.

In order to permit flexibility in monitoring the linac beam as it is accelerated one should contemplate the provision of space between accelerating sections to insert laser beams with precision optics so that the angle α may be altered at will with high resolution. The resulting electrons could be bent out of the beam at any point into a detector with a weak magnetic field. By operating near 90° and focusing the laser beam with a cylindrical lens in the transverse direction, one could examine separately small subsets of the larger diameter beam. Also one could monochromatize by photodetaching only those ions within a prescribed momentum bite.

We believe these techniques are quite promising and powerful. There are also many variations that could be studied to find the optimum arrangement for a given application. Therefore, at this point, it is important to design the space around the linear accelerator in such a way as to allow laser access to it. Equipment we are developing for use at LAMPF could be transferred over to experiments at the SSC linac.

Further development of appropriate laser systems would also be called for.

2. Atomic Physics Research

In addition to the diagnostics and other applications described above, it appears that unique basic atomic physics could also be performed at the SSC linac. Among the reasons why such work is so exciting, we can list

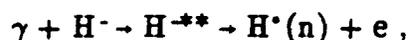
- A much more intense (milli- rather than pico-amps!), better quality beam with possibly a higher kinetic energy than the LAMPF beam (800 MeV). Even at 600 MeV, the beam would be very attractive.

- A chance to develop an atomic physics facility from scratch rather than retrofitting it to an existing accelerator where compromises must be made, as was the case at LAMPF. With very little additional cost in the initial stages atomic physics experimental space and facilities can be accommodated, which later on would be extremely expensive to build into the system.
- More visibility and support both technically and financially, since it would be part of a "flagship of American science".

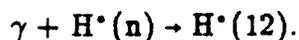
Of course, in the study of something as rich in phenomena as atomic physics, many new and unexpected ideas will undoubtedly arise, but we can only plan based on what we already know. Therefore we sketch below some of the kinds of physics one could do using the H⁻ beam at the SSC.

a) High Resolution Spectroscopy of H⁻

Recently¹ we have been able to study the highly correlated, doubly-excited states in H⁻ by first exciting them through the process



with subsequent motional field stripping of H^{*}(n) in an appropriately-chosen magnetic field. A dissertation written on this work won the Louis Rosen prize for the best done at LAMPF in the past year⁵. The cases for which n = 4,5,6 and 7 were studied. See Fig. 2. With better signal-to-noise, the levels studied could be pushed up to much higher n's so that the systematics could be established. We could achieve a much clearer signal by introducing a second laser beam, rather than the stripping field, to label the final H^{*} state, through, for example, its promotion to a higher n state, which could be unambiguously identified in an electron spectrometer e.g.



We demonstrated a "proof-of-principle" for this technique in a short experimental run at LAMPF in August 1990 (unpublished). And we obtained interesting data on the n=2 channel in a run October 3-11, 1990.

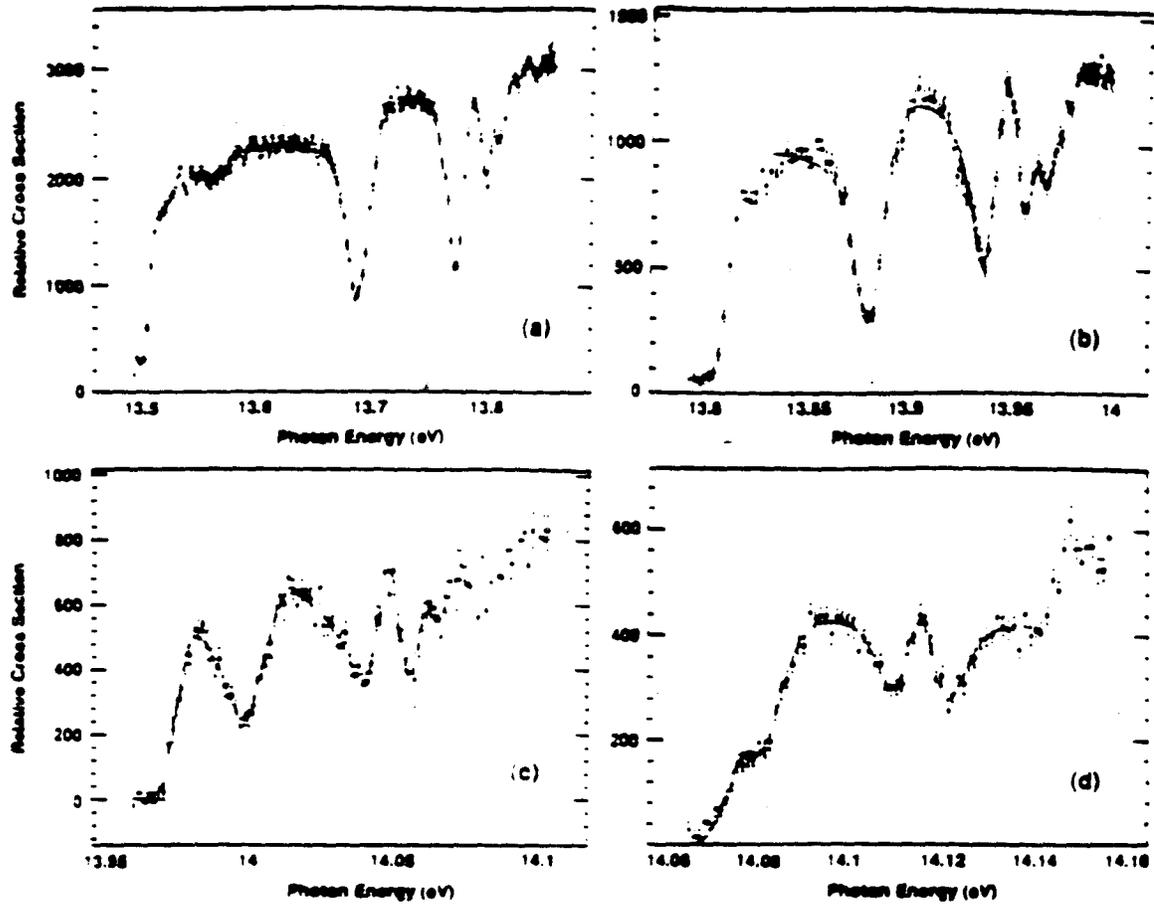


Fig. 2. High-lying resonances in the $1P$ continuum of H^- . The energies of these resonances can be fitted to a remarkably simple formula reminiscent of that of Balmer for neutral hydrogen.

By the application of external fields to the interaction region or by multiphoton excitation, a thorough picture of the resonance structure of H^- could be mapped out.

b) Multiphoton Studies

Currently our experimental program includes the study of multiphoton detachment of H^- using a CO_2 laser beam. Preliminary results are already available,⁶ and work is continuing. With the CO_2 beam, with a lab photon energy of 0.117 eV, at 1000 MeV we should be able to study detachment with photon numbers ranging from 2 to 24.

Because of the fundamental simplicity of the atomic system involved, along with the interesting complication of 2 electrons, these measurements merit precision work, for which conditions such as laser intensity and focal spot are carefully controlled.

This work is likely to continue to excite high interest for many years.

c) Strong-field effects

Our studies of H^- in strong electric fields have yielded surprises⁷ and such work should continue. A near-luminal H^- ion moving through a modest laboratory magnetic field experiences enormous electric fields in its barycentric frame yet is essentially undeflected because of its high magnetic rigidity.

d) Passage through thin foils and channeling

A recent Ph.D. dissertation⁸ in our group was written on the study of the excitation of $H^*(n)$ by the passage of H^- through carbon foils ranging in thickness from 20 $\mu g/cm^2$ to 300 $\mu g/cm^2$. In this case the foil delivers an intense perturbation to the H^- ion for times of the order of a femtosecond.

Further studies are contemplated⁹ using very thin oriented crystals of Si or sapphire (Al_2O_3) in which channeling may be expected to occur for intact atomic systems. Such work may have practical applications.

e) Searches for a preferred frame

Tests of special relativity based on the exquisitely well-known energy levels of atomic hydrogen can be contemplated for a high quality 1000 MeV H^- beam. At LAMPF we have checked the Doppler formula to the 36th power of β .¹⁰ Conditions for such tests would be unique for the SSC.

3. Program

Our research plan for the next five years has two main components:

A) Collaboration with SSC linac personnel in the design and testing of laser-based diagnostic and experimental atomic beam facilities.

B) Continued experimental and theoretical work in basic atomic beam physics both at LAMPF and in our laboratories on the UNM campus.

The level of effort required for the work at the SSC site depends on the needs of the linac personnel,² with whom only preliminary contact has been made. However, we believe our experience at LAMPF could be quite useful, and that the experiments developed at LAMPF could be transferred to the SSC and performed with significantly higher precision. We therefore anticipate that over the years there will be considerable travel of faculty and students between Albuquerque and Dallas. If a viable atomic physics facility is to be prepared at the SSC, planning must begin immediately. As our experience at LAMPF has shown, the retrofitting of experimental layouts to beam lines is expensive, and unfortunate compromises may have to be made.

The crystal ball is much less cloudy concerning continued experimental work at LAMPF. The present lines of research outlined above could profitably be followed for many more years. In particular we are enthusiastic about the new physics one can learn from multiphoton interactions with H^- and H^+ . A very intriguing branch of the multiphoton work is the study of the channeling of atoms through thin crystals. We will

submit a proposal to the LAMPF PAC for beam prepared by photodetaching H^- which could be used for such channeling measurements.

On campus we propose to continue the development of an experiment to look for optical harmonics generated from a dense H^- beam by a high-powered TEA CO_2 laser. The source of H^- is a surface source we have acquired and are refurbishing from Los Alamos and the CO_2 laser is a gift from the Sandia National Laboratory. We are presently exploring the spectra of laser-induced sparks in hydrogen gas.

4. Staffing

With the help of the Texas Commission we plan to add a post doctoral research associate, a technician and three graduate students to our group. To facilitate collaboration with other universities and research institutes, we plan to have a regular visitor as well. Funding is also requested for summer internships for undergraduates and secretarial help. A longer term goal (two year time scale) is to add another faculty person in this field.

5. Education

Our principal missions at the University of New Mexico are education and research, and in the atomic beam work these two mesh neatly together. So far 8 students have received Ph.D.'s for their work with us on atomic physics at LAMPF and 4 more are in the pipeline. With the help of the Texas Commission more students will be able to participate in these studies.

TEXAS NATIONAL RESEARCH LABORATORY COMMISSION

Research and Development Program

(See Summary of Direct Costs and Indirect Costs)

Form RFD-100

The University of New Mexico

ORGANIZATION

H. C. Bryant

PRINCIPAL INVESTIGATOR (P.I.)
PROJECT DIRECTOR (P.D.)

PERIOD COVERED
10/1/90
12/31/91

FOR COMMISSION USE ONLY
PROPOSAL NO.
AWARD NO.

A. SENIOR PERSONNEL (PI/D, FACULTY AND OTHER SENIOR ASSOCIATES)	FUNDED PERSONS	FUNDS REQUESTED BY APPLICANT
P.I. 1/3 time/academic year, 1.5 mo/summer	1.5	30,500
1 Visitor (s)	11	35,000
1		
1		
1		
1. TOTAL SENIOR PERSONNEL		65,500
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)		
1.1 POST DOCTORAL ASSOCIATES	12	30,000
1.2 OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12 Technician	33,000
1.3 GRADUATE STUDENTS	36	36,000
1.4 UNDERGRADUATE STUDENTS	6	6,000
1.5 SECRETARIAL-CLERICAL	6	9,203
1.6 OTHER		
TOTAL SALARIES AND WAGES (A + B)		179,703
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 20%		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)		215,644
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM ON SEPARATE PAGE)		
TOTAL EQUIPMENT		98,900
E. TRAVEL: 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)		
1 FOREIGN		2,000
F. OTHER DIRECT COSTS		
1 MATERIALS AND SUPPLIES		20,000
2 PUBLICATION COST PAGE CHARGES		1,000
3 CONSULTANT SERVICES		
4 COMPUTER (ADP) SERVICES		5,000
5 CONTRACTS AND SUBGRANTS		
6 OTHER Equipment maintenance		1,456
TOTAL OTHER DIRECT COSTS		25,456
G. TOTAL DIRECT COSTS (A THROUGH F)		350,000
H. APPLICANT'S COST SHARING		78,000
I. TOTAL AMOUNT OF THIS REQUEST (ITEM G LESS ITEM H)		272,000
P.I/D TYPED NAME	Howard C. Bryant, P.I.	DATE 10/25/90
P.I/D SIGNATURE	<i>H.C. Bryant</i>	
INST. R/P TYPED NAME	Ann Powell, Director of Research Administration	DATE 10/26/90
INST. R/P SIGNATURE	<i>Ann Powell</i>	

Budget Information Document (Page
TEXAS NATIONAL RESEARCH LABORATORY COMMISSION
Research and Development Program

(See General and Subgrant and Instrumentation)

The University of New Mexico

Please Print or Type

ORGANIZATION
H. C. Bryant
PRINCIPAL INVESTIGATOR (PI)
PROJECT DIRECTOR (P.D.)

PI JOB NUMBER
171791
PI YEAR
12/31/95
TO

FDS COMMISSION USE ONLY
PERSONAL NO.
AGENCY NO.

A. SENIOR PERSONNEL (PI/PI, FACULTY AND OTHER SENIOR ASSOCIATES)	FUNDED PERSONNEL	FUNDS REQUESTED BY APPLICANT
1. P.I.	22.5	168,532
2. Visitor(s)	55	193,397
3.		
4.		
6.1. TOTAL SENIOR PERSONNEL	77.5	361,929
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)		
1.1. POST DOCTORAL ASSOCIATE	60	165,769
1.2. OTHER PROFESSIONALS (TECHNICAL, PROGRAMMER, ETC.)	60	182,346
1.3. GRADUATE STUDENTS	180	198,922
1.4. UNDERGRADUATE STUDENTS	30	33,154
1.5. SECRETARIAL/CLERICAL	30	50,852
6.1. OTHER		
TOTAL SALARIES AND WAGES (A + B)		992,972
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)		198,597
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)		1,191,569
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM ON SEPARATE PAGE)		
TOTAL EQUIPMENT		365,923
E. TRAVEL: 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)		44,000
2. FOREIGN		11,000
F. OTHER DIRECT COSTS		
1. MATERIALS AND SUPPLIES		108,036
2. PUBLICATION COST PAGE CHARGES		5,402
3. CONSULTANT SERVICES		
4. COMPUTER (ADPP) SERVICES		16,205
5. CONTRACTS AND SUBGRANTS		
6. OTHER Equipment maintenance		7,865
TOTAL OTHER DIRECT COSTS		137,508
G. TOTAL DIRECT COSTS (A THROUGH F)		1,750,000
H. APPLICANT'S COST SHARING		390,000
I. TOTAL AMOUNT OF THIS REQUEST (ITEM G LESS ITEM H)		1,360,000
PI/PI TYPED NAME H. C. Bryant		DATE 10/25/90
PI/PI SIGNATURE <i>HCBryant</i>		
PI/PI TYPED NAME Ann Powell		DATE 10/26/90
PI/PI SIGNATURE <i>Ann Powell</i>		

BUDGET INFORMATION DOCUMENT (PAGE 2)

Texas National Research Laboratory Commission

Research and Development Program

Summary By Budget Period*

Please Print or Type

Categories	Budget Period 1	Budget Period 2	Budget Period 3	Budget Period 4	Budget Period 5	Budget Periods 1-5	Total Project Period
A. Senior Personnel Totals	65,500	68,775	72,214	75,824	79,616	361,929	361,929
B. Other Personnel Totals	114,203	119,913	125,909	132,909	138,814	631,043	631,043
C. Fringe Benefit Totals	35,944	37,738	39,625	41,606	43,687	198,597	198,597
Total of A, B & C	215,644	226,426	237,748	249,634	249,117	,191,569	,191,569
D. Equipment	98,900	86,345	76,340	59,397	44,941	365,923	365,923
E. Travel							
1. Domestic	8,000	8,400	8,800	9,200	9,600	44,000	44,000
2. Foreign	2,000	2,100	2,200	2,300	2,400	11,000	11,000
F. Other Direct Costs	25,456	26,729	24,912	29,469	30,942	137,508	137,508
G. Total Direct Costs (Item A through Item F)	350,000	350,000	350,000	350,000	350,000	1,750,000	1,750,000
H. Applicant's Cost-Sharing	78,000	78,000	78,000	78,000	78,000	390,000	390,000
I. Total Amount of Request (Item G. Less Item H.)	272,000	272,000	272,000	272,000	272,000	1,360,000	1,360,000
Duration of Budget Period	<u>1/1/91</u> Mo/Day/Yr to <u>12/31/91</u> Mo/Day/Yr	<u>1/1/92</u> Mo/Day/Yr to <u>12/31/92</u> Mo/Day/Yr	<u>1/1/93</u> Mo/Day/Yr to <u>12/31/93</u> Mo/Day/Yr	<u>1/1/94</u> Mo/Day/Yr to <u>12/31/94</u> Mo/Day/Yr	<u>1/1/95</u> Mo/Day/Yr to <u>12/31/95</u> Mo/Day/Yr	<u>1/1/91</u> Mo/Day/Yr to <u>12/31/95</u> Mo/Day/Yr	<u>1/1/91</u> Mo/Day/Yr to <u>12/31/95</u> Mo/Day/Yr

PI/PD TYPED NAME & SIGNATURE: H. C. Bryant

H.C. Bryant

DATE: 10/25/90

INST. REP. TYPED NAME & SIGNATURE: Ann Powell

Ann Powell

DATE: 10/25/90

BUDGET INFORMATION DOCUMENT (PAGE 4)

Texas National Research Laboratory Commission

Research and Development Program

Summary By Participant for Total Project Period

Please Print or Type

Categories	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participants 1-5	All Participants Total
A. Senior Personnel Totals	361,929						361,929
B. Other Personnel Totals	631,043						631,043
C. Fringe Benefit Totals	198,597						198,597
Total of A, B & C	1,191,569						1,191,569
D. Equipment	365,923						365,923
E. Travel							
1. Domestic	44,000						44,000
2. Foreign	11,000						11,000
F. Other Direct Costs	137,508						137,508
G. Total Direct Costs (Item A through Item F)	1,750,000						1,750,000
H. Applicant's Cost-Sharing	390,000						390,000
I. Total Amount of Request (Item G. Less Item H.)	1,360,000						1,360,000
Duration of Project Involvement	1/1/91 Mo/Day/Yr to 12/31/95 Mo/Day/Yr	Mo/Day/Yr to Mo/Day/Yr	Mo/Day/Yr to Mo/Day/Yr	Mo/Day/Yr to Mo/Day/Yr	Mo/Day/Yr to Mo/Day/Yr	Mo/Day/Yr to Mo/Day/Yr	1/1/91 Mo/Day/Yr to 12/31/95 Mo/Day/Yr
PI/PD TYPED NAME & SIGNATURE: <i>H. C. Bryant</i>							DATE: <i>10/25/90</i>
INST. REP. TYPED NAME & SIGNATURE: <i>Ann</i>							DATE: <i>10/25/90</i>

VI. STATEMENT CONCERNING MATCHING FUNDS

The University of New Mexico will share the first year costs of this proposal as follows:

One-third released time for Professor Bryant during academic year @ \$65,000/9 months	\$ 21,667
One-half stipend(s) for visitor(s)	17,500
One-half FTE secretarial-clerical	9,203
One-half stipend for three graduate students for 12 months @12,000	18,000
Tuition for 3 graduate students assumed to be non-resident @\$2,488	7,464
Travel	4,166
	<hr/>
Total	\$ 78,000

A similar matching of funding will be available for subsequent years of the successful proposal.

VII. DESCRIPTION AND JUSTIFICATION OF MAJOR ITEMS OF EQUIPMENT

1. Major Equipment for the first three years

First Year

GCR-3-30	High Power Scientific Pulsed Nd:YAG Laser, 750 mJ at 1064 nm Diffraction coupled output (30 Hz)	\$ 62,500
HG-2C	High Efficiency Harmonic Generator, Angle Tuned and Temperature Stabilized with SHG Type II, THG, and FHG KD*P Crystals	7,200
PHS-1F	Spectrally pure separation of Harmonics (includes PB-2 Prism) for use with all Harmonics	8,200
Model 6300	Injection seeder providing transform-limited pulses	21,000
Total		<u>\$ 98,900</u>

Second Year

PDL-3	Broadly tunable, high efficiency Nd:YAG pumped dye laser, up to 30% conversion efficiency (includes oscillator and amplifier, TSC-2 dye circulator .07 cm ⁻¹ line width)	29,925
MCI-2	RS232 Interface for Computer Controlling of Dye Scanning Motor	2,700
PRA-1	Preamplifier Assembly for higher efficiency with UV pumped and IR dyes	1,950
RS-1	Extremely wide range Raman Shifter	8,800
WEX-1D	Wavelength extension system for difference frequency mixing to produce wavelengths between 1500 and 4500 nm	29,000
	High speed electronics and optical components	13,970
Total		<u>\$ 86,345</u>

Third Year		
TEA-840/1	CO ₂ Lasser, 10 pps @3.5 J. Line tuned (capable of operation at up to 50 pps with reduced energy)	36,000
	Line tuning optics set for TEA-840 laser. Includes multimode output coupler, wavelength tuning attachment, cavity extension and master diffraction grating.	10,000
	CO ₂ unstable resonator output coupler	1,200
	RAL 20/106(4) 20 bit hollow shaft angular encoder RMS error 1.4 arc sec	29,140
	Total	<u>76,340</u>

2. Justification

The Need for a Better Laser System

Relativistic atomic beam work at LAMPF was strengthened greatly in 1987 by the completion of HIRAB (High Resolution Atomic Beam) facility, a dedicated experimental area, built to receive a specially-designed low-divergence H⁻ beam. This area, with its world-class beam line, was made possible by the requirements of SDI, but now is available for work of more general interest. We are anxious to put this beam to scientific use by continuing our studies of both H⁻ and H⁺ atoms in strong fields, taking advantage of the unique possibilities present when the ion velocity is near that of light. Most of our work in earlier years has been done using first a DCR1 and then a DCR2 laser, with considerable success. Our present request for a GCR3 laser ("DC" stands for "diffraction-coupled" and "GC" stands for "Gaussian-coupled"), the state of the art, seems to be a reasonable and conservative upgrade in our laser facility to match the upgrade of the laboratory, which, incidentally included the replacement of our PDP11 by a MicroVax for data acquisition. We know that we were able to get good data with the DCR2; thus, we expect that we will get even better data ("better" means more reproducible, with smaller systematic effects and over a larger range of photon energies) with the GCR3 system, which will also allow us

to take data at least 3 times faster since its repetition rate is 30 rather than 10 pps, the repetition rate of our DCR2. Taking data faster means that the statistical uncertainties can be reduced. The LAMPF accelerator produces macropulses at the rate of 120 Hz. The dye laser which can be pumped by the CGR3 gives us for the first time the opportunity to sit at a constant angle (normally this would be the "magic" or "Doppler-free" angle where to first order the energy resolution does not depend on the momentum spread $\Delta p/p$) and tune through a wavelength range. This option would be especially valuable in making a high resolution study of the magnetic substates produced in H^+ 's emerging from a thin stripper foil, and for the examination of final states of the decay of doubly excited H^{**} following laser excitation.

The CO_2 laser component of our laser system would vastly improve our ability to do multiphoton studies and would also be very helpful in examining final state hydrogen levels.

More Details

In order to demonstrate more clearly the need for the new laser system, let us consider as an example one of our proposed experiments in more detail, namely, the study of the photoproduction and decay modes of high-lying doubly-excited resonances in the H^- . To be specific, let us consider the simplest case in which the resonance is excited by a single photon. Kinematically, the decay modes can include photon emission to lower-lying resonances or the ground state, presumably rare, and, much more often, the decay into various states of hydrogen plus an electron. This study would require two pulsed laser beams crossing at well-defined and measured angles (using our proposed encoder as well as our present one), with the H^- beam. The relative timing would have to be good to a few nanoseconds which would be no problem if both beams were derived from the GCR3 system. The use of the CO_2 laser beam of pulse duration of 100 ns and jitter of 15 ns is also feasible. One would wish to examine many cases, extending to as high an energy as

possible, in order to establish the systematics and the behavior as one approaches the two electron continuum.

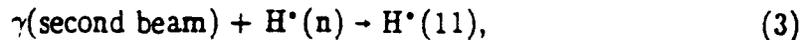
The excitation of H^{**} would be by use of the 4th harmonic of the YAG on an 800 MeV beam which would allow the production of states approaching the two-electron threshold at 14.35 eV. At a short distance downstream from the production point, the beam would be probed with a second laser beam to determine the hydrogenic states produced in the decay. The idea here, for example, would be to promote lower hydrogenic states to $n=11$. The resulting $H^*(11)$ would be selectively ionized and its electron detected in a down stream magnetic spectrometer. One therefore has



followed by autoionization,



followed by



followed by



and



Because of the large energies, processes 4 and 5 have essentially 100% efficiency. Since the cross section for process 3 is known very well, the branching ratio for process 2 can be determined. The yield from process 3 as a function of the angle of the first laser beam determines both the energy and the width of the resonance being produced in process 1. Let us consider an H^{**} resonance whose energy exceeds that of $H^*(9) + e$. From Table 1 below, one can see that in order to cover the range of n from 1 to 9 for process 3, we would have to use both the YAG 1st and 4th and a CO_2 laser.

Table 1. Probes for hydrogen state, below $n=10$.

Decay State	Transition Energy (eV)	Laser Beam	Intersection angle (degs.)
H ⁺ (1)	13.492	YAG 4th	47.9
2	3.289	YAG 1st	50.8°
3	1.399		114.5
4	0.738		141.3
5	0.4317		161.7
6	0.2654	CO ₂ 10.6 μ	73.7
7	0.1652		105.9
8	0.1001		129.4
9	0.0555		151.8

To compare data-taking rates between the present and proposed laser systems, see Table 2 below.

Table 2. Data Rates

Data Set	Present	Proposed	Ratio
$1 \leq n \leq 5$	10 Hz	30 Hz	3
$6 \leq n \leq 9$	0.5 Hz	10 Hz	20

STATEMENT OF CURRENT AND PENDING SUPPORT

Work on the atomic physics of the H⁻ ion has been funded at UNM by the DOE since 1977 in the amount \$1,307,041. In addition, LANL provided UNM with a contract of \$377,309 for related beam-sensing work relevant to SDI neutral beam concerns. We received a grant of \$2,000 from the NSF to support a workshop on the H⁻ in January 1989 and we have currently in force a grant of \$38,438 to support collaboration between UNM and the Hungarian Academy of Sciences to work on the H⁻ project.

Our current grants are

U.S. DOE, Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research \$330,000 covering period 2/1/90 – 1/31/93

NSF 38,438 covering period 5/15/89 – 10/31/92

Pending: None other than this proposal.

ASSURANCE OF COMPLIANCE

Texas National Research Laboratory Commission

Research and Development Program

Nondiscrimination in Texas National Research Laboratory Commission Programs

The University of New Mexico (Hereinafter called the "Applicant") HEREBY AGREES to comply with Title VI of the Civil Rights Act of 1964 (Pub. L. 88-352), Section 16 of the Federal Energy Administration Act of 1974 (Pub. L. 93-275), Section 401 of the Energy Reorganization Act of 1974 (Pub. L. 93-438), Title IX of the Education Amendments of 1972, as amended, (Pub. L. 92-318, Pub. L. 93-568, and Pub. L. 94-482), Section 504 of the Rehabilitation Act of 1973 (Pub. L. 93-112), the Age Discrimination Act of 1975 (Pub. L. 94-135), Title VIII of the Civil Rights Act of 1968 (Pub. L. 90-284), the Department of Energy Organization Act of 1977 (Pub. L. 95-91), and the Energy Conservation and Production Act of 1976, as amended, (Pub. L. 94-385). In accordance with the above laws and regulations issued pursuant thereto, the Applicant agrees to ensure that no person in the United States shall, on the ground of race, color, national origin, sex, age, or handicap, be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity in which the Applicant receives assistance from the Texas National Research Laboratory Commission (Hereinafter called the "Commission").

Applicability and Period of Obligation

In the case of any service, financial aid, covered employment, equipment, property, or structure provided, leased, or improved with assistance extended to the Applicant by the Commission, this assurance obligates the Applicant for the period during which assistance is extended. In the case of any transfer of such service, financial aid, equipment, property, or structure, this assurance obligates the transferee for the period during which assistance is extended. If any personal property is so provided, this assurance obligates the Applicant for the period during which it retains ownership or possession of the property. In all other cases, this assurance obligates the Applicant for the period during which the assistance is extended to the Applicant by the Commission.

Employment Practices

Where a primary objective of the assistance is to provide employment or where the Applicant's employment practices affect the delivery of services in programs or activities resulting from assistance extended by the Commission, the Applicant agrees not to discriminate on the ground of race, color, national origin, sex, age, or handicap, in its employment practices. Such employment practices may include, but are not limited to, recruitment, recruitment advertising, hiring, layoff or termination, promotion, demotion, transfer, rates of pay, training and participation in upward mobility programs, or other forms of compensation and use of facilities.

Subrecipient Assurance

The Applicant shall require any individual, organization, or other entity with whom it subcontracts, subgrants, or subleases for the purpose of providing any service, financial aid, equipment, property, or structure to comply with laws cited above. To this end, the subrecipient shall be required to sign a written assurance form; however, the obligation of both recipient and subrecipient to ensure compliance is not relieved by the collection or submission of written assurance forms.

Data Collection and Access to Records

The Applicant agrees to compile and maintain information pertaining to programs or activities developed as a result of the Applicant's receipt of assistance from the Commission. Such information shall include, but is not limited to, the following: (1) the manner in which services are or will be provided and related data necessary for determining whether any persons are or will be denied such services on the basis of prohibited discrimination; (2) the population eligible to be served by race, color, national origin, sex, age and handicap; (3) data regarding covered employment including use or planned use of bilingual public contact employees serving beneficiaries of the program where necessary to permit effective participation by beneficiaries unable to speak or understand English; (4) the location of existing or proposed facilities connected with the program and related information adequate for determining whether the location has or will have the effect of unnecessarily denying access to any person on the basis of prohibited discrimination; (5) the present or proposed membership by race, color, national origin, sex, age and handicap, in any planning or advisory body which is an integral part of the program; and (6) any additional written data determined by the Commission to be relevant to its obligation to assure compliance by recipients with laws cited in the first paragraph of this assurance.

The Applicant agrees to submit requested data to the Commission regarding programs and activities developed by the Applicant from the use of assistance funds extended by the Commission. Facilities of the Applicant (including the physical plants, buildings, or other structures) and all records, books, accounts, and other sources of information pertinent to the Applicant's compliance with the civil rights laws shall be made available for inspection during normal business hours on request of an officer or employee of the Commission specifically authorized to make such inspections.

This assurance is given in consideration of and for the purpose of obtaining grants or other assistance extended after the date hereto, to the Applicant by the Commission. The Applicant recognizes and agrees that such assistance will be extended in reliance upon the representations and agreements made in this assurance and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant, its successors, transferees, and assignees, as well as the person whose signature appears below and who is authorized to sign this assurance on behalf of the Applicant.

10/29/90

(Date)

The Board of Regents of the
University of New Mexico

Dept. of Physics and Astronomy
(Name of Applicant)

Office of Research Administration

Scholes Hall, Room 102

Albuquerque, NM 87131

(Address)

Ann Powell

(Authorized Official)

(505) 277-2256

(Applicant's Telephone Number)

BIOGRAPHICAL SKETCH

Howard Carnes Bryant

Born: July 9, 1933, Fresno, California

Married: Mona Jordan, 1960

Children: Matthew, Clifford and Susannah

Education:

Public Schools, California and Mississippi

B.A. University of California, Berkeley, 1955 ($\phi\beta\kappa$)

M.S. University of Michigan, Ann Arbor, 1957

Ph.D. University of Michigan, Ann Arbor, 1960

Foreign Languages:

Spanish, German and French (reading).

Positions Held:

Professor of Physics, The University of New Mexico, 1971–present.

Fulbright Guest Professor, Institut fur Atomphysik, Universitat Innsbruck, Austria, 1982–1983.

Science Research Council Senior Visiting Research Fellow, Queen Mary College, University of London and the Rutherford Laboratory, 1975–1976.

Consultant: Los Alamos National Laboratory, 1961–present.

Staff Member, Stanford Linear Accelerator Center, Stanford, California, 1967–1969.

Associate Professor, the University of New Mexico, 1965–1971.

Assistant Professor, the University of New Mexico, 1960–1965.

Professional Organizations:

American Physical Society (Fellow, 1980)

Optical Society of America

American Association of Physics Teachers

Areas of Specialization:

Atomic Physics, Optics, Elementary Particles and Solar Energy.

Research Contracts and Grants:

Sandia Corporation	
#53-2290 7/64-6/65	\$14,296
#53-2290 7/65-6/66	\$15,297
#53-4757 7/66-6/67	\$17,933
New Mexico Water Resources Research Institute	
OWRR-A-014 7/67-6/68	\$ 8,340
National Science Foundation	
GP20197 9/61-10/72	\$19,800
Energy Research and Development Administration (ERDA)	
(with B.D. Dieterle, C.P. Leavitt, and D.M. Wolfe)	
E(29-2)-3347 7/73-12/76	\$320,228
New Mexico State Board of Education and Finance	
BEF-161 7/75-9/76	\$19,897
New Mexico Energy Institute	
ERB-76-202 9/76-1/77	\$10,000
Department of Energy	
DE-ASO4-77CS33977 4/77-6/81	\$155,952
Department of Energy	
DE-ASO4-77ERO3998 6/77-11/86	\$747,041
New Mexico Energy Research and Development Institute	
2-73-4102 8/84-9/86	\$ 23,470
Los Alamos National Laboratory	
"Resonant Absorption Beam Sensing Techniques,"	
8/18/86- 9/30/89	\$377,309
Department of Energy Grant	
DE-FG0-87ERB746 7/20/87-1/31/90	\$230,000
National Science Foundation	
"U.S. - Hungary Research on Relativistic H-Beam Interaction	
with External Fields and Matter (Physics)".	
5/15/89 - 10/31/92	\$ 38,438
National Science Foundation	
"H- Summit Meeting: Albuquerque, NM; January 1990	
(Physics)" [PHY-9000 942]	
1/1/90 - 12/31/90	\$ 2,000
Department of Energy	
DE-FG 04-87 AL 13746, Amd. No. A003	
"Relativistic Atomic Beam Spectroscopy II"	
2/1/90 - 1/31/93	\$330,000

PUBLICATIONS

Refereed Journal Articles

- "Direct Proof of θ_1 Neutral Decay," *Phys. Rev. Letters* **3**, 51 (1959). Co-authors: J. L. Brown, R. A. Burnstein, D. A. Glaser, R. Hartung, J. A. Kadyk, J. D. Van Putten, D. Sinclair, G. H. Trilling, J. C. VanderVelde.
- "Neutral Branching Ratios of Λ^0 and K^0 Particles," *Phys. Rev. Letters* **3**, 563 (1959). Co-authors: J. L. Brown, R. A. Burnstein, D. A. Glaser, R. Hartung, J. A. Kadyk, J. D. Van Putten, D. Sinclair, G. H. Trilling, J. C. VanderVelde.
- "Properties of Neutral Strange Particles Produced in a Xenon Bubble Chamber," *Il Nuovo Cimento* **19**, 1155-1170 (1961). Co-authors: J. L. Brown, R. A. Burnstein, D. A. Glaser, R. Hartung, J. A. Kadyk, J. D. Van Putten, D. Sinclair, G. H. Trilling, J. C. VanderVelde.
- "Heat Waves and Angstrom's Method," *Am. J. Phys.* **31**, 325 (1963).
- "(He^3, n) Reactions on Various Light Nuclei," *Nuclear Physics*, **53**, pp. 97-112 (1964). Co-authors: W. T. Leland, E. R. Flynn, J. G. Beery.
- "High-Efficiency Solid State Neutron Telescope for 15-35 MeV Neutrons," *Rev. Sci. Instruments* **37**, 215 (1966). Co-author: E. R. Flynn.
- "Mie Theory and the Glory," *J. Opt. Soc. Am.* **56**, 1529 (1966). Co-author: A. J. Cox.
- "Direct Observation of Surface Waves on Water Droplets," *J. Opt. Soc. Am.* **56**, 1635 (1966). Co-author: T. S. Fahlen.
- "Spin Correlation in Proton-Proton Scattering at 27 MeV," *Phys. Rev.* **155**, 1438 (1967). Co-authors: N. Jarmie, J. E. Brolley, H. Kruse, R. Smythe.
- "Monte Carlo Simulation of a Proton-Proton Spin Correlation Experiment," *Phys. Rev.* **155**, 1444 (1967). Co-author: Nelson Jarmie.
- "Detection of Surface Waves at a Plane Air-Water Interface," *J. Opt. Soc. Am.*, **57**, 430 (1967). Co-author: Benjamin W. Woodward.
- "The Mossbauer Effect with Sinusoidal Doppler Shift," *Amer. J. Phys.* **35**, 1159 (1967).
- "Surface-Wave Phenomena at Liquid-Air Interfaces," *J. Opt. Soc. Am.* **58**, 283 (1968). Co-author: R. H. Dungan.
- "Nuclear Glory Scattering," *Annals of Phys.* **4**, 127/140 (1968). Co-author: Nelson Jarmie.
- "Optical Backscattering from Single Water Droplets," *J. Opt. Soc. Am.* **58**, 304/1671E (1968). Co-author: T. S. Fahlen.
- "Precision Measurements of Water Droplet Evaporation Rates," *J. App. Opt.* **7**, 883-890 (1968). Co-authors: P. S. Ro and T. S. Fahlen.
- "Surface-Wave Description of $\pi^+ p$ Backward Scattering," *Phys. Rev.* **186**, 1488 (1969).

"Muon-Proton Inelastic Scattering, $|q^2|$ less than $1.2 (\text{GeV}/c)^2$," Phys. Rev. Letters 23, 1187 (1969). Co-authors: B. D. Dieterle, T. J. Braunstein, J. Cox, W. L. Lakin, F. Martin, W. T. Toner, M. L. Perl, T. F. Zipf.

"Muon-Proton Inelastic Scattering and Vector Dominance," Phys. Rev. Letters 23, 1191 (1969). Co-authors: B. D. Dieterle, T. J. Braunstein, J. Cox, W. L. Lakin, F. Martin, W. T. Toner, M. L. Perl, T. F. Zipf.

"Experimental Determination of the Inelastic Neutron Form Factor by Scattering of 12 GeV Muons on Hydrogen, Carbon and Copper," Phys. Rev. Letters 26, 34 (1971). Co-authors: W. L. Lakin, T. J. Braunstein, J. Cox, B. D. Dieterle, M. L. Perl, W. T. Toner, T. F. Zipf.

"Comparison of Muon-Proton and Electron-Proton Deep Inelastic Scattering," Phys. Letters 36B, No. 3, 251 (1971). Co-authors: W. T. Toner, T. J. Braunstein, W. L. Lakin, F. Martin, M. L. Perl, T. F. Zipf, B. D. Dieterle.

"Production of Pulsed Particle Beams by Photodetachment of H^- ," Phys. Rev. Letters 27, 1628 (1971). Co-authors: P. A. Lovoi and G. G. Ohlsen.

"Lateral Waves on a Plane Air-Water Interface," J. Opt. Soc. Am. 63, 1009 (1973) 5 pages.

"Precision Measurement of n-p Charge-Exchange Cross Section at 647 MeV," Physical Review Letters 36, 497 (1976). Co-authors: M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, R. A. Kenefick, L. C. Northcliffe, B. E. Bonner, J. E. Simmons, C. W. Bjork, P. J. Riley, C. G. Cassapakis, B. D. Dieterle, C. P. Leavitt, D. M. Wolfe, D. W. Werren.

"Neutron Spectra at 0° from p-p and p-d collisions at 647 and 800 MeV Incident Energies," Physics Letters, 63B, 31 (1976). Co-authors: C. W. Bjork, P. J. Riley, B. E. Bonner, J. E. Simmons, K. D. Williamson, Jr., M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, R. A. Kenefick, L. C. Northcliffe, C. G. Cassapakis, B. D. Dieterle, C. P. Leavitt, D. M. Wolfe, D. W. Werren.

"Neutron Spectra at 0° from (p,n) Reactions on ^9Be , ^{12}C , and ^{27}Al at 647 and 800 MeV," Physics Letters 63B, 35 (1976). Co-authors: C. G. Cassapakis, B. D. Dieterle, C. P. Leavitt, D. M. Wolfe, B. E. Bonner, J. E. Simmons, C. W. Bjork, P. J. Riley, M. L. Evans, G. Glass, J. C. Hiebert, M. Jain, R. A. Kenefick, L. C. Northcliffe, D. W. Werren.

"A Solar Pond for London?", co-author, Ian Colbeck, Solar Energy 19, 321 (1977).

"Observation of Resonances Near 11 eV in the Photodetachment Cross Section of the H^- Ion," Phys. Rev. Letters 38, 228 (1977). H. C. Bryant, B. D. Dieterle, J. Donahue, H. Sharifian, H. Tootoonchi, D. M. Wolfe, P. A. M. Gram, M. A. Yates-Williams.

"Optical Transforms of the Alphabet," The Physics Teacher 15, 301 (1977). Co-authors: H. Sharifian, H. Tootoonchi, J. D. Seagrave.

"Effect of an Electric Field upon Resonances in the H^- Ion," Phys. Rev. Lett. 40, 107 (1978). H. C. Bryant, P. A. M. Gram, J. C. Pratt, M. A. Yates-Williams, J. Donahue, H. Sharifian, H. Tootoonchi.

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Observation of Excited H⁺ 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.

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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.

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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 Lagrigna 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."

Series of 3 Lectures given at the 1989 Los Alamos Theoretical Atomic Physics Summer School, July 18, 19, 20, 1989:

1. What good is relativity?
2. The Structure of the H⁻ Ion.
4. Effects of Fields.

ν Seminar, "Observations of atoms in strong fields", UNM, 20 September 1989.

Colloquium: Hungarian Academy of Sciences, Budapest. October 25, 1989, 2 pm. "An Atomic Interferometer".

Colloquium: Institute of Nuclear Research "Atomki" Debrecen, Hungary, October 26, 2:00 pm "An Atomic Interferometer".

"Concluding Remarks", H⁻ Workshop, Albuquerque, NM, January 9, 10, 11, 1990. (Organizer) on January 11, 1990.

Colloquium: Department of Physics, University of Wyoming, Laramie "Recent advances in the Physics of the H⁻ Ion", February 27, 1990.

Lecture: Institut für Experimentalphysik, Technische Universität Graz, Petersgasse 16, "Experiments with 800 MeV H⁻ Ions", June 22, 1990, 3:30 pm.

Seminar: Tungstam Factory, Budapest, "Atomic Physics at the Linear Accelerator at Los Alamos", June 6, 1990, 10:00 am.

Colloquium: University of Szeged, Szeged, Hungary. "The Physics of the H⁻ Ion". June 7, 1990.

Radio Talk Show: Magyar Radio, Budapest, "Science in America" broadcast 6/17/90 and 6/19/90.

Journal Club: Discussion of D.J. Pegg, et al., "Partial cross sections for the photodetachment of metastable He⁻", Phys. Rev. Letters 64, 278 (90), Feb. 20, 1990, 12:30.

Series of 3 lectures given at the 1990 Los Alamos Theoretical Atomic Physics Summer School, July 24, 26, 27, 1990. Essentially a repeat of those given in 1989.

Appendix 2

References

1. H.C. Bryant et al., Phys. Rev. Letters 38, 228 (1977). The latest publication of our group is P.G. Harris, et al., Phys. Rev. Letters, 65, 309 (1990).
2. G.E. Jamieson and G. Leifeste, private communication. J. Watson, "The SSC Linac", Invited paper. 1990 Linear Accelerator Conference, Albuquerque, NM Sept. 10-14, 1990.
3. D.B. Holtkamp and C.R. Quick, Nuclear Instruments and Methods in Physics Research , A287, 348 (1990).
4. P.G. Harris et al., Nuclear Instruments and Methods. A292, 254 (1990).
5. P.G. Harris, Ph.D. Dissertation May 1990, UNM "Observation of High-Lying Resonances in the H⁻ Ion" (LA-11843-T).
6. C.Y. Tang et al., Phys. Rev. A 39, 6068 (1989). H.C. Bryant et al., International Conference on Multiphoton Processes (Invited Paper) Paris, September 24-28 (1990).
7. H.C. Bryant et al., Phys. Rev. Letters 58, 2412 (1987).
8. A.H. Mohagheghi, Ph.D. Dissertation May 1990, UNM "Interaction of Relativistic H⁻ Ions with Thin Foils" (to be published as a LA report).
9. Károly Rózsa, a collaborator from the Hungarian Academy of Sciences, has been investigating the manufacture of oriented crystal foils of submicron thickness.
10. D.W. MacArthur et al., Phys. Rev. Letters 56, 282 (1986).

Appendix 3

Existing Facilities

On the UNM campus our group has two large general purpose laboratories and a class 100 laminar down-flow clean room. The department has a well-equipped machine shop with three machinists.

At LAMPF we have been allocated adequate office space for at least 6 people, and we are the sole users of the High Resolution Atomic Beam (HIRAB) facility, a dedicated experimental area built to receive a specially-designed low-divergence H^- beam. Laser-ion beam studies are performed on a 4-foot thick isolation slab embedded in the floor along the beam line. The heart of our data acquisition system is a microvax computer. At present we have 2 CO_2 lasers, 1 DCR2 YAG laser, 1 DCR1 YAG laser, and a Lambda Physik excimer laser system. The YAG lasers as well as the CO_2 lasers need to be upgraded to higher rep rate and power. The DCR1 laser is presently inoperable, having been cannibalized for parts for the DCR2. The DCR2, in view of its age and infirmities, is marginal for use in long accelerator runs.