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Measurements of Scattering Processes in

Negative Ion - Atom Collisions

Technical Progress Report

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I. Introduction

This report describes the progress made on the research objectives during the past three years of the grant. This research project is designed to study various scattering processes which occur in H^- collisions with atomic (specifically, noble gas and atomic hydrogen) targets in the intermediate energy region. These processes include: elastic scattering, single- and double-electron detachment, and target excitation/ionization. For the elastic and target inelastic processes where H^- is scattered intact, the experimental technique of Ion Energy-Loss Spectroscopy (IELS) will be employed to identify the final target state(s). In most of the above processes, cross sections are unknown both experimentally and theoretically. The measurements will provide total cross sections (TCS) initially, and once the angular positioning apparatus is installed, will provide angular differential cross sections (ADCS). This research project has resulted in 2 refereed publications [1,2], 3 submitted manuscripts to refereed journals [3-5], 3 papers presented at international conferences [6-8], and 5 papers presented at national or regional meetings [9-13] in the past three years. This research is being performed on the facility shown in Figure 1.

II. Completed Projects Contained in the Proposal

The initial experiments conducted on the UT-Negative Ion Accelerator concentrated on single- and double-electron detachment studies. The major findings from these completed experiments are summarized below and more complete discussions of the experiments are given in the manuscripts submitted for publication covering those particular aspects of this research project. Briefly, the present single- and double-electron detachment data were obtained by measuring the scattered ions in shielded Faraday cups located on the two 30° magnet ports. A secondary electron emission detector/Faraday cup was placed on the zero-degree magnet port in order to detect H^0 resulting from single detachment collisions. This results in the detection of all three beam charge (H^+, H^0, and H^-) components, and permits the simultaneous measurements of single- and double-electron detachment processes.

The scattered beam fraction F_i ($i = -1, 0, 1$) was obtained by dividing each scattered beam

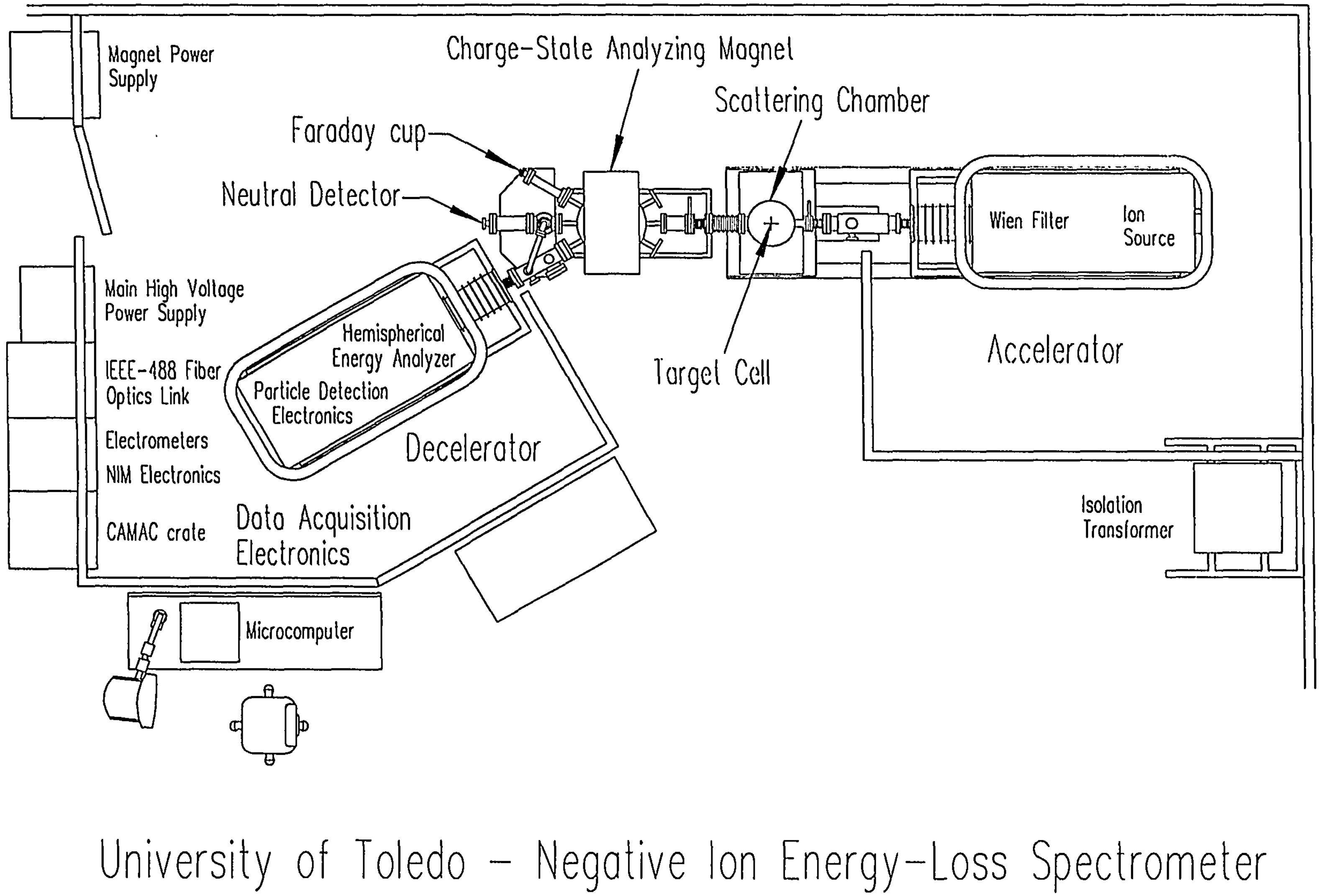

Figure 1: The UT - Negative Ion Energy-Loss Spectrometer

component current by the incident H^- ion beam current. The F_i growth/decrease was measured as a function of target thickness ($\pi = nl$) in order to obtain growth/attenuation curves from which total cross sections were obtained. In the target thickness determinations, n is the target number density and l is the interaction length. The data contained a small but non-negligible quadratic term for basically all target thicknesses employed in the measurements. For this reason, the data were fit to second-order polynomials in target thickness and the total cross sections were obtained from the coefficient of the linear term.

A) Single Electron Detachment Cross Section Measurements in H^- + Helium, Neon, and Argon Collisions

Single electron detachment total cross section measurements for H^- + (He, Ne, and Ar) collisions are complete and a manuscript has been submitted for publication [3]. The scattered atomic hydrogen beam fraction solution from the rate equations is:

$$F_0(\pi) = \sigma_{-1,0}\pi + \frac{1}{2}[\sigma_{-1,1}\sigma_{1,0} - \sigma_{-1,0}(\sigma_{-1,0} + \sigma_{-1,1} + \sigma_{0,1} + \sigma_{0,-1})]\pi^2 + \dots \quad . \tag{1}$$

The measured F_0 growth curves relied on the knowledge of the *true* atomic hydrogen beam current. This was accomplished by measuring all three charge-state components of the scattered beams, thus allowing a systematic check on the data and permitting absolute measurements of the single detachment total cross sections which are free of normalization to other experiments or theories. This experimental technique compares favorably to those employed for the single detachment cross section measurements previously reported in the literature. The present results are shown in Figure 2, where it is seen that the present results are generally higher than the existing ones in the literature. One explanation for this discrepancy rests in the negative quadratic coefficient given in Equation 1. For this reason, linear fits to the experimental data would necessarily produce cross section values that underestimate the true cross sections.

B) Double Electron Detachment Cross Section Measurements in H^- + Helium, Neon, and Argon Collisions

Double electron detachment total cross section measurements for H^- + (He, Ne, and Ar) collisions are complete and a manuscript has been submitted for publication [5]. The scattered

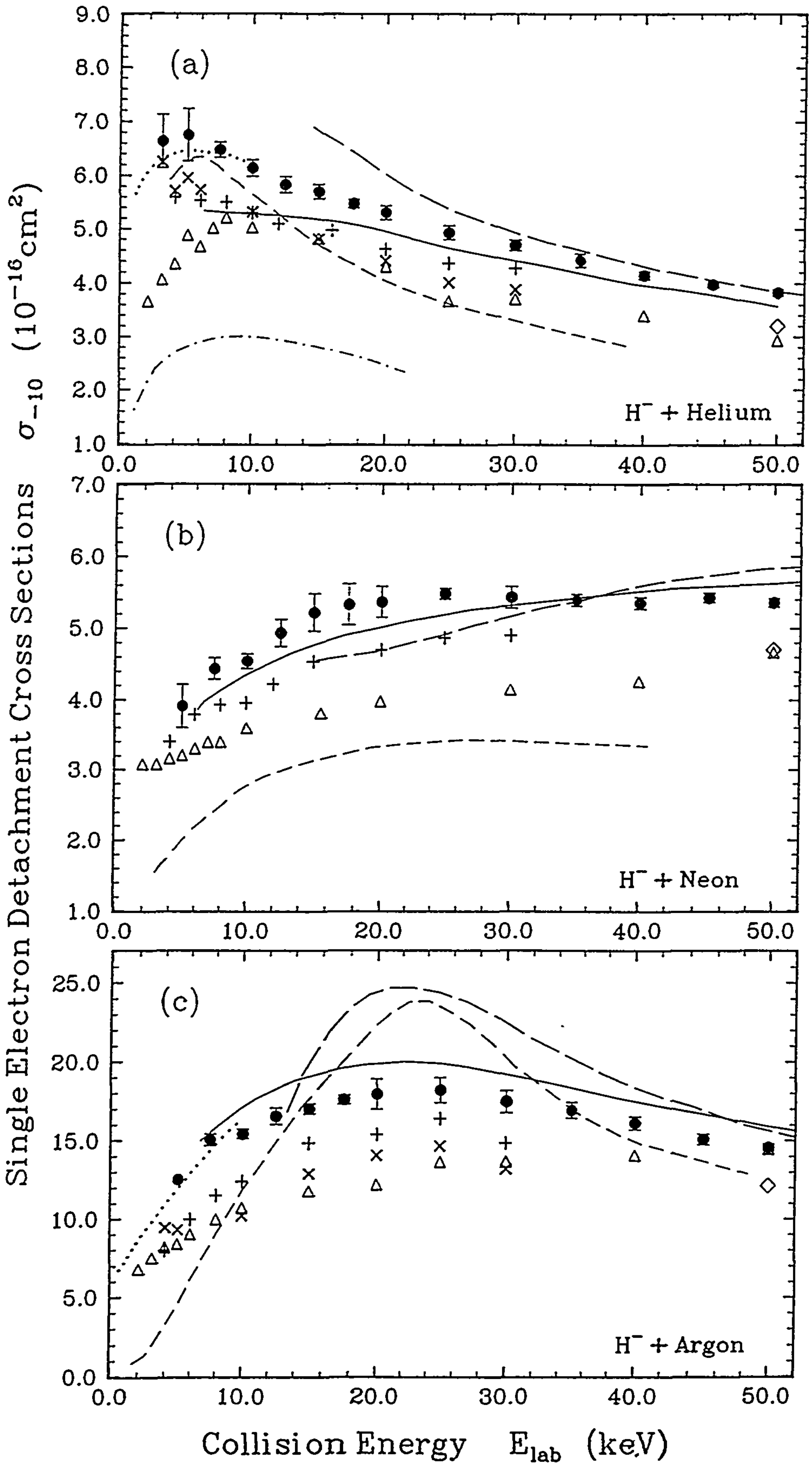

Figure 2: Present Single Electron Detachment Total Cross Sections

proton beam fraction solution from the rate equations is:

$$F_1(\pi) = \sigma_{-1,1}\pi + \frac{1}{2}[\sigma_{-1,0}\sigma_{0,1} - \sigma_{-1,1}(\sigma_{-1,0} + \sigma_{-1,1} + \sigma_{1,0} + \sigma_{1,-1})]\pi^2 + \dots \quad . \tag{2}$$

The measured F_1 growth curves relied on the direct measurements of the scattered proton beam and the incident H^- beam. This technique is relatively standard and because both scattered beams are ion beams, the absolute magnitudes of the growth curves are obtained more easily than in the case of single detachment. The present results are shown in Figure 3, where it is seen that the present results are only slightly smaller than the existing cross sections in the literature for helium targets, but disagree in the cases of the other two target species. In the case of neon targets, one explanation for this discrepancy rests in the positive quadratic coefficient given in Equation 2. For this reason, linear fits to the experimental data would necessarily produce cross section values that overestimate the true cross sections. Because each of the previous researchers presumably employed a consistent analysis method to all three target species, we do not have an explanation at present for the discrepancy in the case of argon targets.

C) Curvature Measurements in H^- + Helium, Neon, and Argon Collisions

In the course of the electron detachment studies, it was found that the scattered beam growth curves contained slight curvatures which were well described by quadratic functions. The quadratic coefficients arise from multiple scattering of the projectile beam as it traverses the target gas. Even though the projectile beam is initially purely H^-, charge-changing collisions will produce non-negligible fractions of H^o and H^+ ion beams. Because of this, the scattered beam fraction rate equations must include contributions from secondary processes and not just from the primary process. The correct solutions to the scattered beam rate equations are given in Equations 1 and 2 above for the atomic hydrogen and proton beam fractions, respectively.

The scattered beam fractions growths and/or attenuations were measured as a function of target thickness and to our knowledge, this is the first time that a systematic study [4] was made of the curvature in the growth curves for these collisional systems. The present experimental technique permitted the absolute measurements of the curvature in the scattered beam growth curves. The measured quadratic coefficients for helium targets are shown in Figure 4 along with

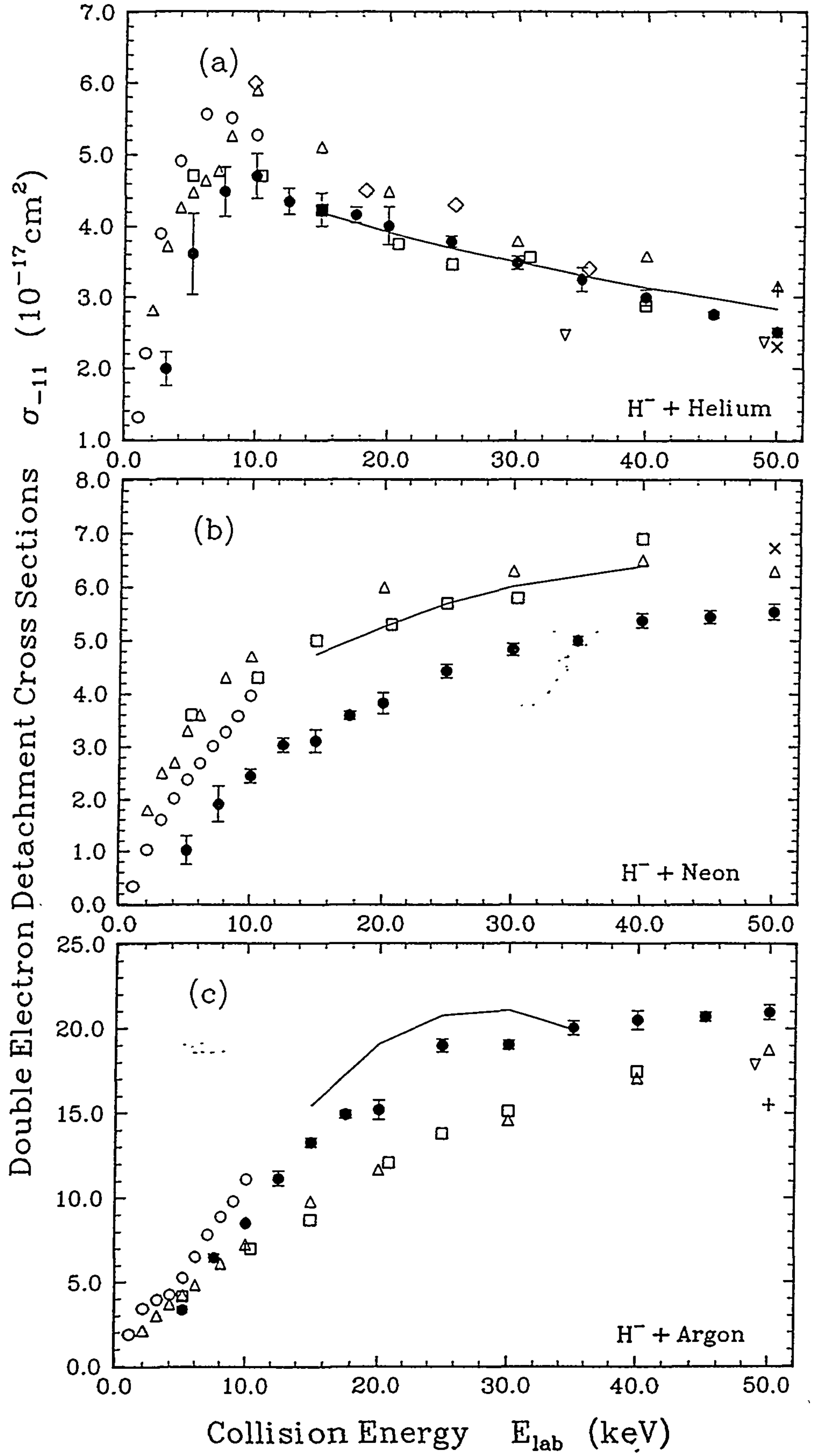

Figure 3: Present Double Electron Detachment Total Cross Sections

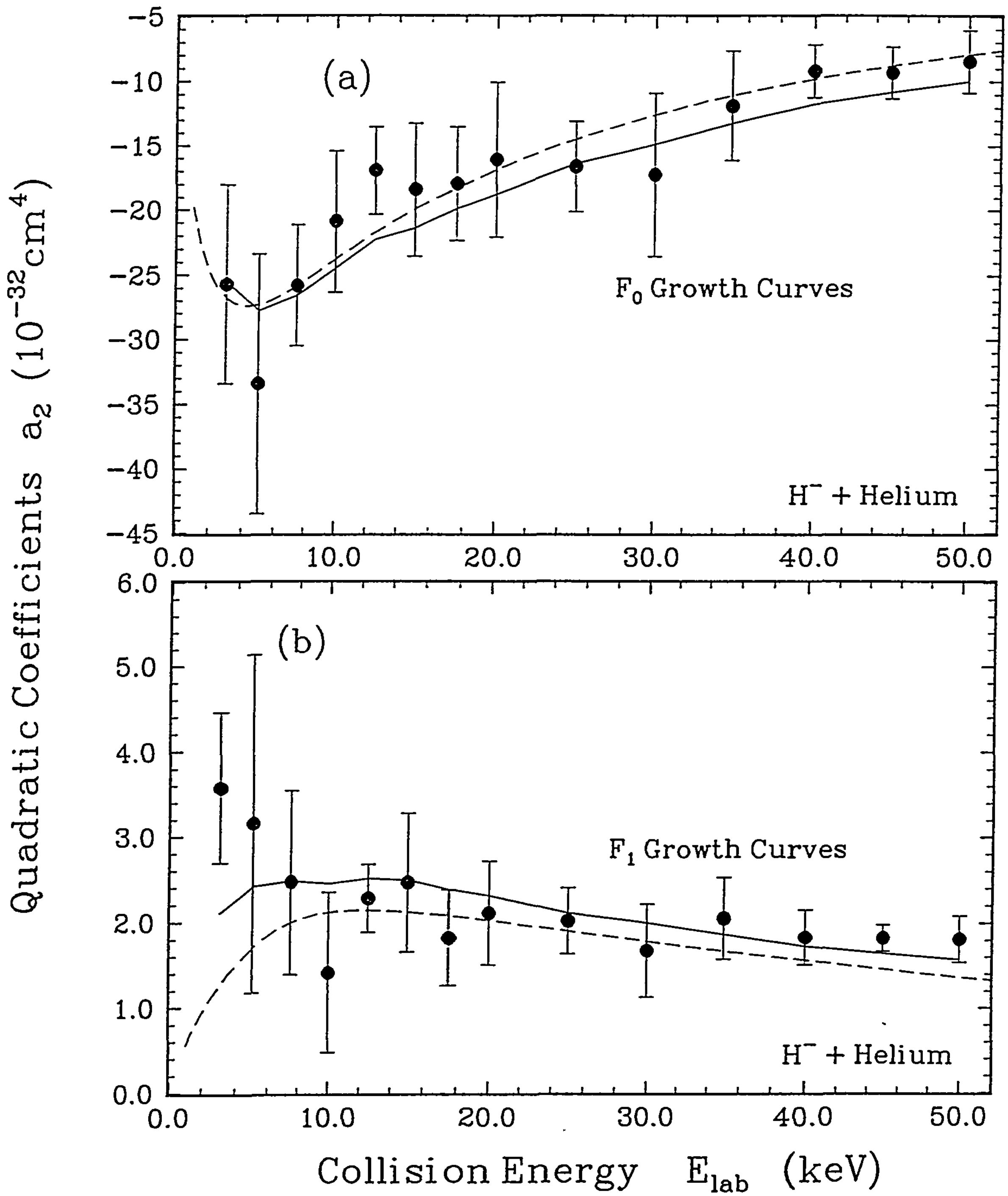

Figure 4: Present Quadratic Coefficients of the F_0 and F_1 Scattered Beam Growth Curves for H^- Impact on Helium Targets.

the expected quadratic coefficients as given in Equations 1 and 2. The recommended fits to the total cross section data from ORNL-6086 Compilation are used to generate the expected quadratic coefficients shown as the dashed curves in this figure, whereas the present single- or double-detachment cross sections are used in place of the ORNL-6086 recommended total cross sections to generate the solid curves. We have obtained similar results for neon and argon targets and these results have been submitted for publication [4]. As seen in Figure 4, the expected quadratic coefficients for helium targets are in general agreement with the measured quadratic coefficients. In the case of neon targets, a 20% decrease in σ_{01} considerably improves the agreement for both F_0 and F_1 growth curves. The situation is more complicated for argon targets, since no single cross section adjustment satisfactorily improves the agreements for both F_0 and F_1 growth curves simultaneously.

III. Completed Projects in Addition to those Contained in the Proposal

A. Secondary Emission Yields for H° Atoms Incident on Copper

In the present experimental arrangement, the sum of all three, simultaneously-detected, scattered, hydrogen beam (H^+, H^o, and H^-) components adds up to a constant, (i.e., is independent of target thickness). Therefore

$$I^-(\pi_1) + I^o(\pi_1) + I^+(\pi_1) = I^-(\pi_2) + I^o(\pi_2) + I^+(\pi_2) \qquad (3)$$

where π_i is the target thickness at target density n_i and I^j (j = -1, 0, 1) are the various charge-state, scattered beam currents. A benefit of this experimental technique is the measurement of the yield, γ, of secondary, negatively-charged particles resulting from the impact of energetic H^o atoms striking a copper surface. The yield γ is given by

$$\gamma = \frac{[S^o(\pi_2) - S^o(\pi_1)]}{[I^-(\pi_1) - I^-(\pi_2)] + [I^+(\pi_1) - I^+(\pi_2)]} \qquad \text{where } I^o(\pi) \equiv S^o(\pi)/\gamma \qquad (4)$$

where S^o is the measured positive current, which is related to the neutral H^o atom current I^o. The results of fast H^o atoms produced from H^- + He collisions striking a Cu target at an angle of 30° to the normal were obtained from the data and have been published [1]. We noticed essentially no significant difference in γ using neon and argon targets, however a very slight increase in γ is observed with helium targets. This may be the result of the different, relative populations of $H^0(2s)$ in the H^0 beam due to collisions with the different target gas species.

B) Single- and Double-Electron Detachment Cross Section Measurements in $H^- + CH_4$ Collisions

We finished a study of single- and double-electron detachment in collisions of H^- with methane during this grant period. The present data were obtained by the same experimental technique that was employed for the noble gas target studies. All three, scattered hydrogen beam (H^+, H^0, and H^-) components were simultaneously detected, thereby absolute measurements of single- and double-electron detachment total cross sections (TCS) were performed. The present data for single- and double-electron detachment are shown in Figure 5. These results will be submitted for publication during this grant period.

IV. Current Areas of Research

A) Target Inelastic Total Cross Section Measurements

The acquisition of energy-loss spectra from ion-atom collisions is a very powerful experimental technique (IELS) which permits state-resolved, absolute, elastic and target excitation and ionization measurements. This series of experiments is one of the main motivations behind the construction of this facility. The apparatus is designed so that the total cross sections for target excitation and ionization can be obtained by a careful analysis of the signal intensities in the energy-loss spectra. The chosen experimental technique has the advantage that the total cross sections are obtained from measured quantities and the ratio of the scattered H^- ion beam at different energy-loss locations. As such, the deduced cross sections are absolute and free of normalization to other data or calculations. In addition to the total cross sections for discrete target state excitation, the energy-loss differential cross sections ($\partial\sigma/\partial\xi$) can be obtained for target ionization processes without modification of the initial configuration of the apparatus. These experiments are currently in progress on the accelerator and results are expected during this grant period. Additional information on the IELS technique is contained in the IV.C. Apparatus

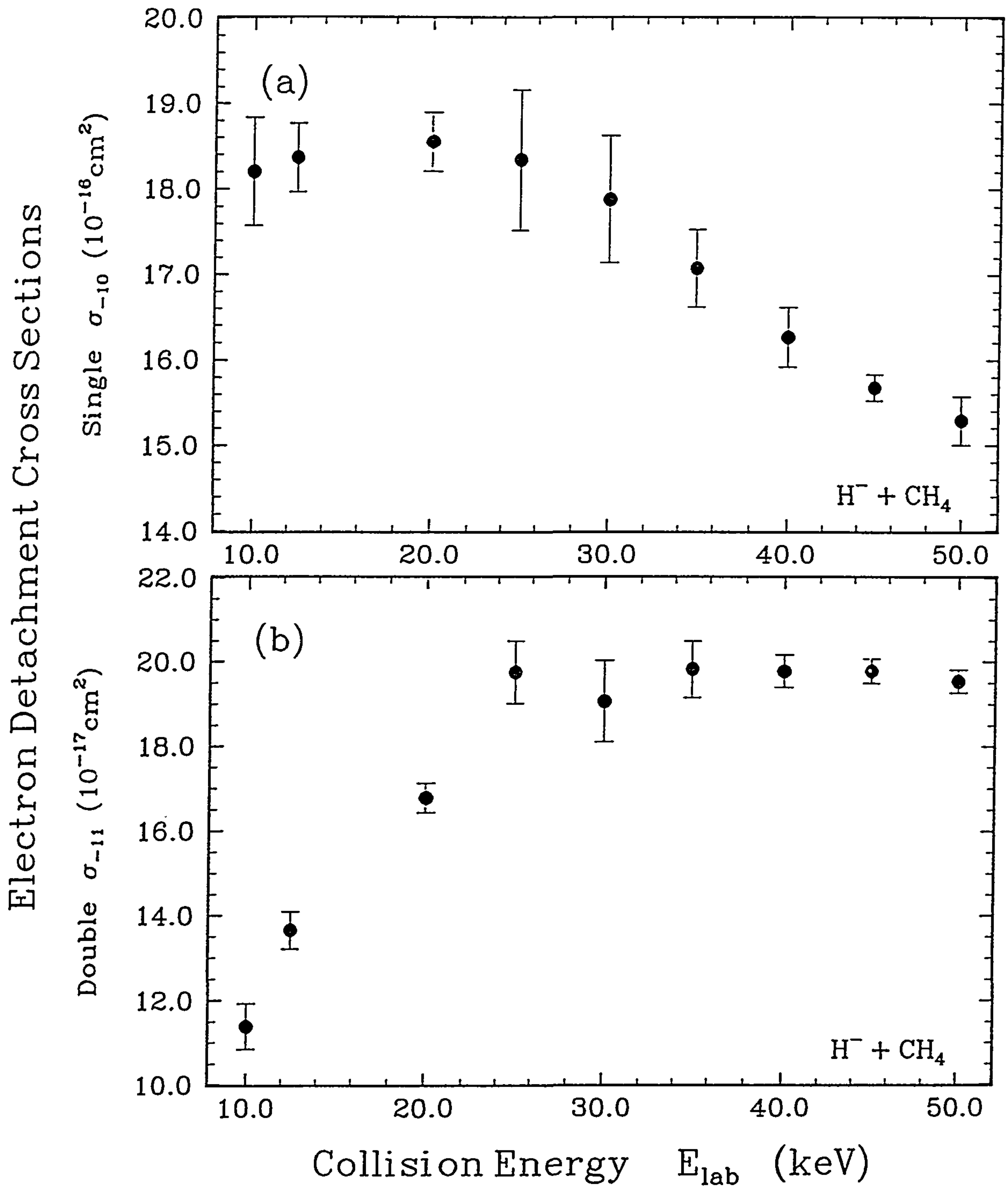

Figure 5: Present Single- and Double-Electron Detachment Total Cross Sections for $H^- + CH_4$ Collisions.

Modifications and Status section of this report.

B) Angular Differential Cross Section Measurements

The main goal of the apparatus is the measurement of cross sections that are differential in scattering angle (ADCS). The ADCS are valuable tests of our understanding of the important processes inherent in energetic ion-atom collisions. The angular and energy-loss capability of the apparatus will permit measuring the "true" elastic differential cross sections. Three teams of students and faculty mentors have performed the design studies necessary for the angular motion of the accelerator. Two of the teams, consisting of faculty members and senior undergraduate students in the UT Department of Mechanical Engineering, have produced the design and mechanical analyses of the angular components. A three-dimensional drawing of the undercarriage design is given in Figure 6. The undercarriage is the platform upon which the accelerator will ride and will be an integral component in the scattering angle determination. The angular components are being assembled and tested, then will await a convenient time for installation. This installation, which is tentatively scheduled for the Summer or Fall 1995, will occur only after the total cross section measurements are complete. It is estimated that the modifications will require approximately two to three months before the initial angular data can be acquired.

C) Apparatus Modifications and Status

Ion Energy-Loss Spectroscopy (IELS)

We have completed the installation of the components necessary for performing the energy-loss measurements. Because of the complexity of the project, four students were involved in various aspects of the project during this three year period. A schematic drawing of the implementation of IELS on the apparatus is shown in Figure 7. During the Summer 1993, Mr. Murray Henderson wrote the apparatus control and data acquisition program (CADAC) to acquire energy-loss spectra. This program is in excess of 2,000 lines of code and a block diagram of CADAC is given in Figure 8. Also during 1993, Mr. William Mitchell worked on ion beam elements to transport the ion beam into the energy analyzer. Mr. Travis Monson and Mr. Robert Csortos worked on implementing the energy analyzer system and electronics in the decelerator.

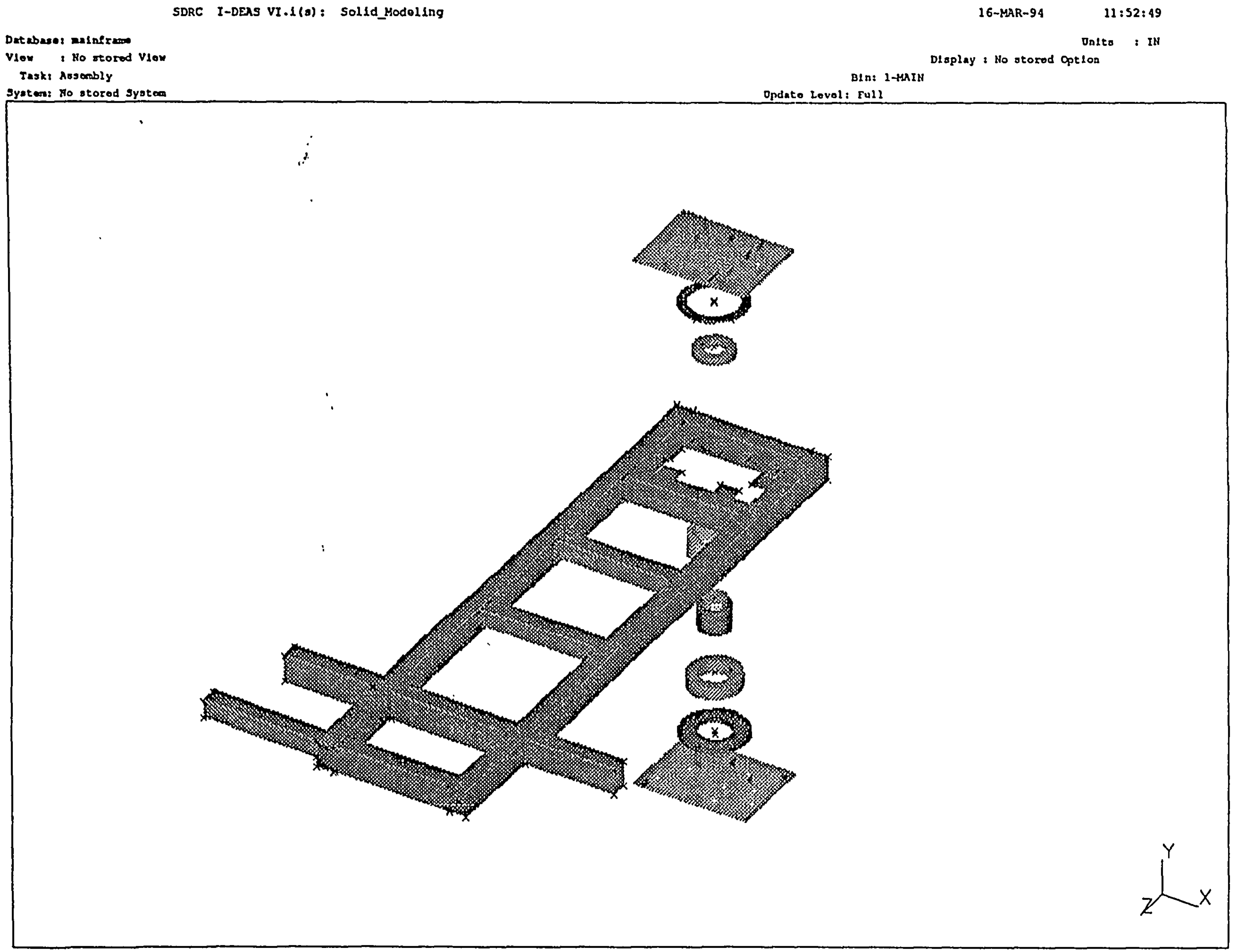

Figure 6: 3-D Drawing of the Accelerator Undercarriage

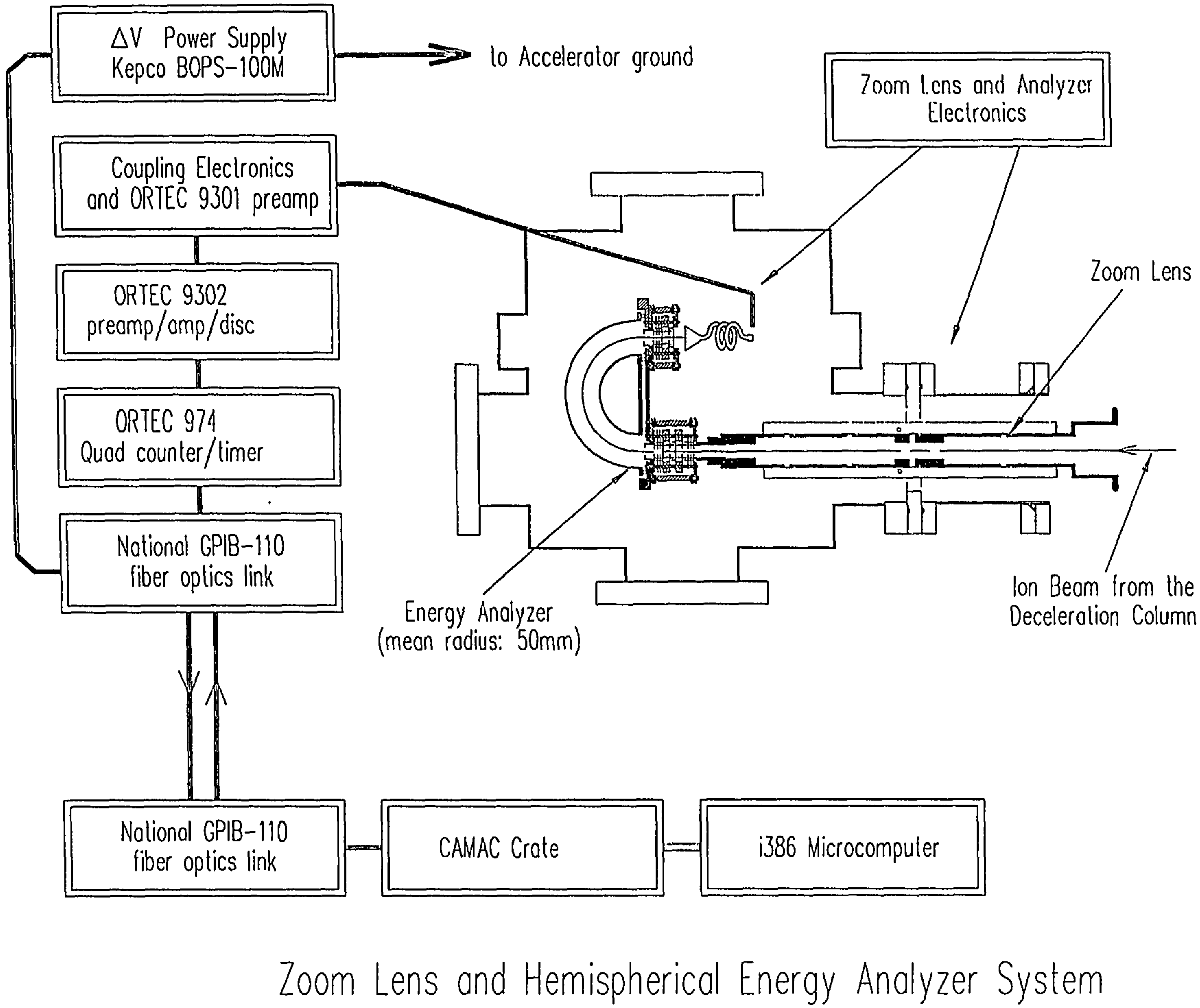

Figure 7: Schematic Drawing of the IELS System on UT-NIELS

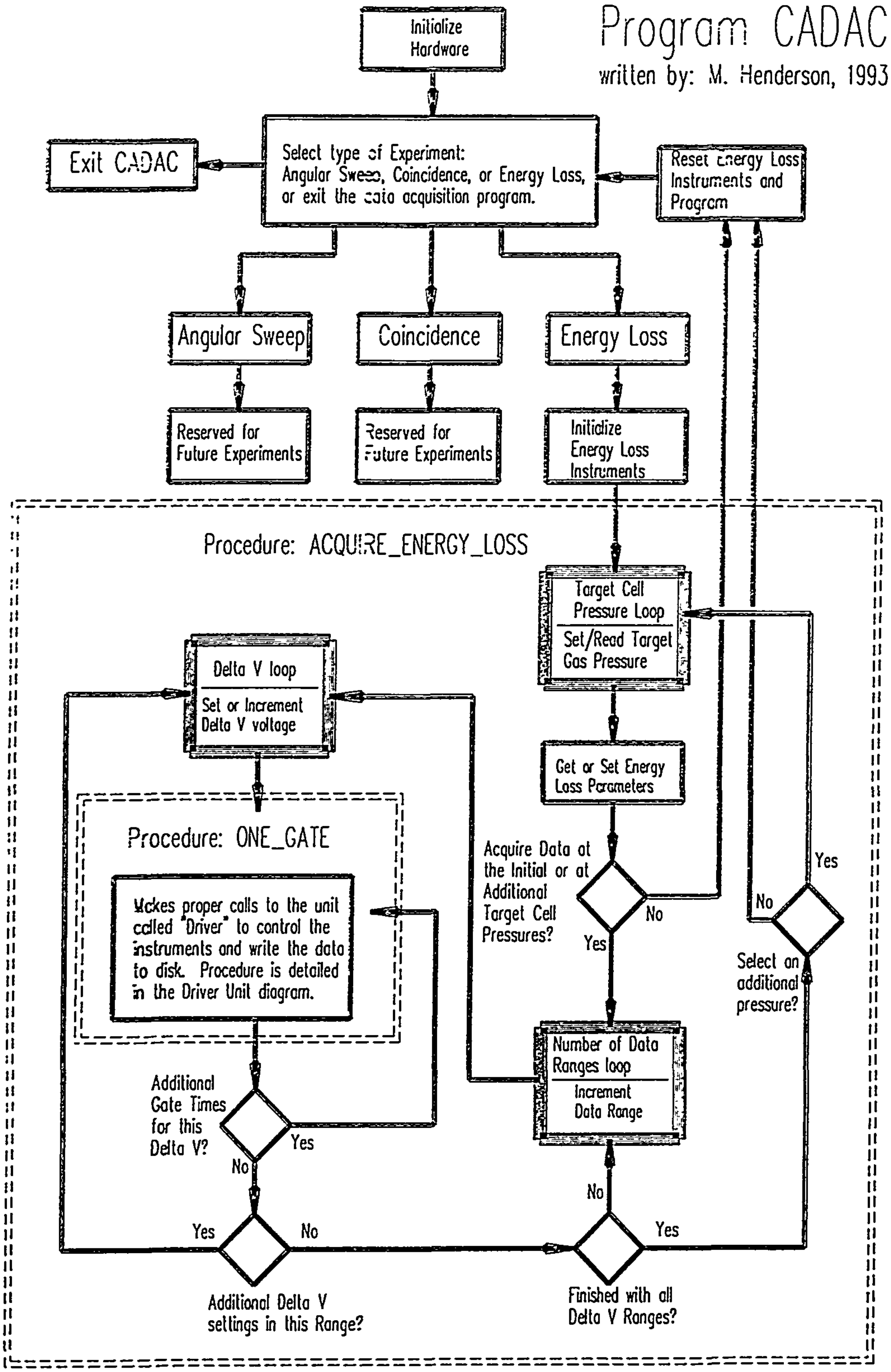

Figure 8: Computer Flow Diagram of the Data Acquisition Program CADAC

The installation of the energy analyzer-zoom lens assembly in the decelerator is complete and presently in operation, thus allowing energy-loss spectra to be obtained.

Collision Energy Upgrade

The main high voltage power supply is scheduled to be replaced with one capable of reaching 100 kV. UT-NIELS was designed to readily accommodate this voltage, so this upgrade should proceed quickly after receipt of the power supply in October 1994. The main reason for the long acquisition time is the severe constraint on the voltage ripple specification that will be necessary for future experiments after the energy-loss measurements. One advantage for the extended energy range is that it will extend our measurements further into the impulsive energy regime. In addition, this upgrade will allow another, independent measurement in the energy region where previous experiments are in disagreement concerning a secondary peak in the H^- + He double-electron detachment total cross sections.

Atomic Hydrogen Targets

Once target inelastic processes have been measured for noble gas targets, the next step would be H^- scattering from atomic hydrogen targets. This is the fundamental negative ion - atom collisional system, so understanding the scattering processes in it is of great importance. Atomic hydrogen requires the design and fabrication of a high temperature target cell, which formed the Senior Thesis of Mr. Michael Rosendaul. A prototype unit was completed in the Fall 1991 and was described in the previous Three Year Progress Report (DOE/ER/13971--7). It is currently awaiting completion of the noble gas scattering experiments, prior to installation. The target number density will not be known directly, so a normalization of the total cross sections can be made by using protons as the projectile and comparing with existing measurements. The present apparatus is capable of accelerating protons with only straightforward changes in the various potentials. If H^- scatters at large impact parameters as a structureless particle, comparisons of the various scattering processes by H^- and proton impact would be very interesting.

V. Support of Students and Scientists

The training of young physicists is vital in order to adequately meet the energy challenges of tomorrow. This research project has been a source of involvement for many young scientists -- from the undergraduate students to graduate students to postdocs to faculty collaborators at undergraduate institutions. A summary of their involvement is given below and in Figure 9.

PROFESSIONAL SCIENTISTS

Dr. James Allen joined the project as a Postdoctoral Research Associate in January 1990 and stayed through August 1992. His main contributions were in the initial operation of the facility and in the detachment studies. A collaboration continues to exist with Prof. David Seely, Physics Department, Albion College, Albion, Michigan. Prof. Seely is experienced in IELS and in coincidence studies.

GRADUATE STUDENTS

Xiaodong Fang, "*Total Cross Sections for Single– and Double–Electron Detachment in 3 – 50 keV* H^- *+ He Collisions*," (M.S. – Physics, December 1992.)

Rasa Matulioniene, "*Excitation of Helium States in Intermediate Energy* H^- *+ Helium Collisions*," (M.S. – Physics, in progress.)

Yushan Lu, "*Detachment into Excited* H^0 *States*," (M.S. – Physics, in progress.)

UNDERGRADUATE SENIOR RESEARCH PROJECT:

Yaser Alhendi (B.S.E.P. – 1993), "*Negative Ion Accelerator Angular Positioning System*," Engineering Physics Senior Project (1992 – 1993).

UNDERGRADUATE SUMMER RESEARCH PROJECTS:

Travis Monson, "*Using Energy-Loss Spectroscopy to Study Negative Ion - Atom Collisions*," Gustavus Adolphus College, Saint Peter, Minnesota, (1992).

Murray Henderson, "*Computer Programming and Control of the Ion Energy-loss Experiments on the Negative Ion Accelerator*," Albion College, Albion, Michigan, (1993).

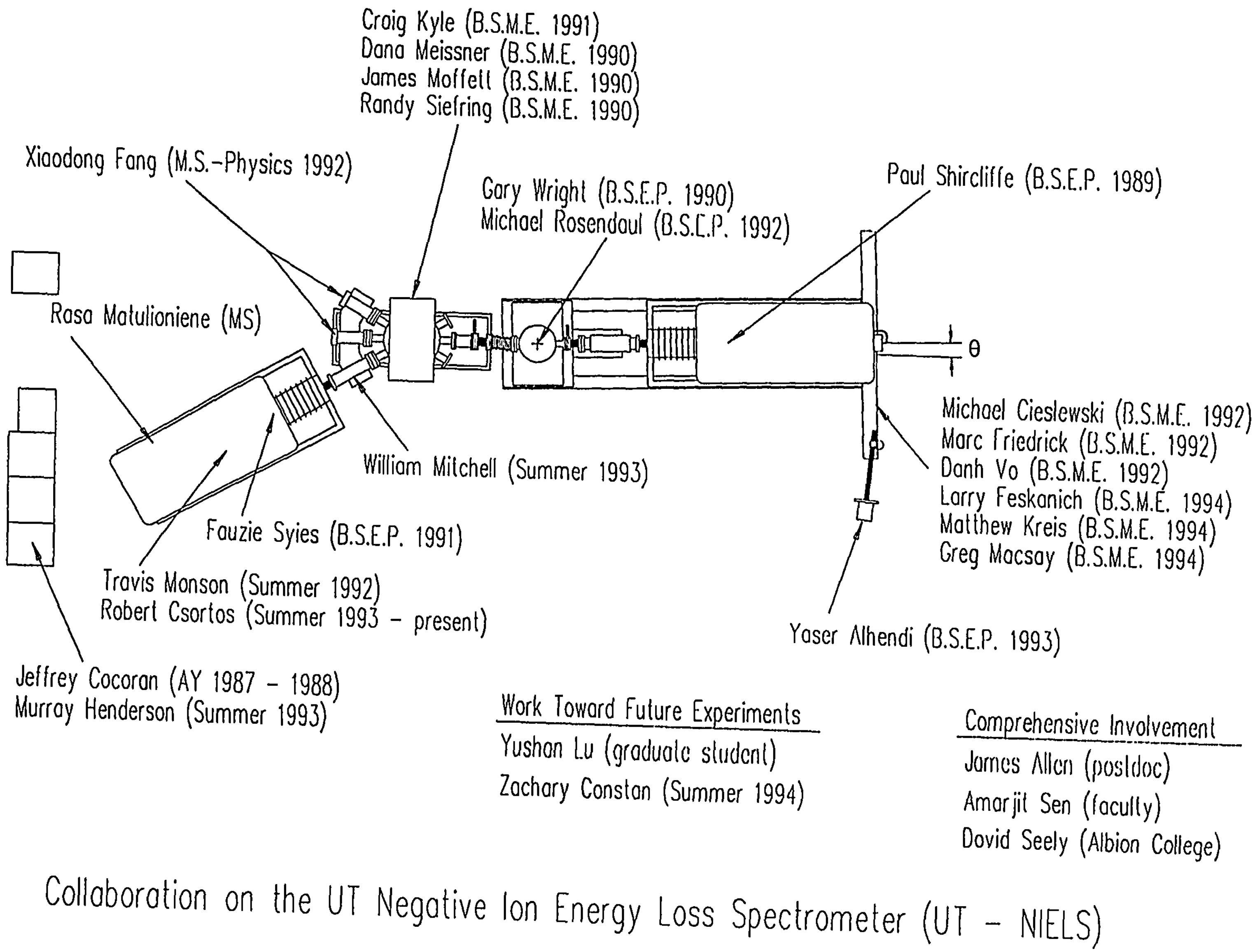

Figure 9: Students and Collaborators Associated with Their Area of Contribution to UT-NIELS

William Mitchell, "*Ion Beam Transport Elements on the Negative Ion Accelerator*," Harvey Mudd College, Claremont, California, (1993).

Robert Csortos, "*Implementation of the Hemispherical Energy Analyzer on the Negative Ion Accelerator*," University of Toledo, (1993).

Zachary Constan, "*Calculation of Atomic Beam Flow in Long Tubes*," Albion College, Albion, Michigan, (1994).

UNDERGRADUATE SENIOR PROJECTS: In collaboration with the U.T. Department of Mechanical Engineering:

Michael Cieslewski (B.S.M.E. – 1992), Marc Friedrick (B.S.M.E. – 1992), Danh Vo (B.S.M.E. – 1992), "*Undercarriage for the Negative Ion Accelerator*," Mechanical Engineering Senior Synthesis Project, (1991 – 1992).

(Marc won first place in the 1992 UT–ASME Student Design Award Competition for his work on this project.)

Lawrence Feskanich (B.S.M.E. – 1994), Matthew Kreis (B.S.M.E. – 1994), Gregory Macsay (B.S.M.E. – 1994),"*Undercarriage for the Negative Ion Accelerator II*," Mechanical Engineering Senior Synthesis Project, (1993 – 1994).

VI. Summary

The initial measurements taken on the apparatus occurred in this three year reporting period. These measurements have been valuable in determining the absolute values and shapes of the single- and double-electron detachment total cross sections in the intermediate energy region for H^- collisions with noble gas targets. The accuracies of the present cross sections compare favorably with those in the literature. In the course of the detachment measurements, slight curvatures were observed in the growth curves for tenuous target thicknesses. These curvatures can be explained by the secondary, charge-changing processes. As such, indirect tests were made of the other, significant cross sections in the H^q + noble gas collision systems. To our knowledge, this is the first time that a consistency check of this type has been conducted for this fundamental, atomic collision system.

Progress toward the ion energy-loss spectroscopy measurements has been steady and those measurements are currently under investigation on the facility. The design and a large fraction of the construction has been completed on the angular motion capability of the accelerator. It is anticipated that angular differential cross sections will be obtained during the next three year reporting period.

VII. Publications: Abstracts and Papers (09/1991 - 12/1994)

Refereed Publications

1. J. S. Allen, X. D. Fang, and T. J. Kvale, "*Secondary Emission Yields for 3 − 50 keV H^0 Atoms Striking a Copper Target,*" Nucl. Instrum. and Meth. B79, 106 (1993).

2. R. R. Haar, D. J. Beideck, L. J. Curtis, T. J. Kvale, A. Sen, R. M. Schectman, and B. Stevens, "*The Toledo Heavy Ion Accelerator,*" Nucl. Instrum. and Meth. B79, 746 (1993).

3. T. J. Kvale, J. S. Allen, X. D. Fang, A. Sen, and R. Matulioniene, "*Single Electron Detachment Cross Sections for 5- to 50-keV H^- Ions Incident on Helium, Neon, and Argon Atoms,*" Physical Review A, 1994 (submitted).

4. T. J. Kvale, J. S. Allen, A. Sen, X. D. Fang, and R. Matulioniene, "*Curvature in the Scattered Beam Growth Curves in H^- + (He, Ne, and Ar) Collisions,*" Physical Review A, 1994 (submitted).

5. J. S. Allen, X. D. Fang, A. Sen, R. Matulioniene, and T. J. Kvale, "*Double Electron Detachment Cross Sections in Intermediate Energy H^- + Noble Gas Collisions,*" Physical Review A, 1994 (submitted).

Conference Abstracts

XII International Conference on the Application of Accelerators in Research and Industry-Denton, TX, November 1992.

6. J. S. Allen, X. D. Fang, and T. J. Kvale, "*Secondary Electron Emission Coefficients for 3− to 50−keV H^0 Atoms Striking a Beveled Copper Target,*" Book of Contributed Abstracts, p. 35.

7. T. J. Kvale, J. S. Allen, and X. D. Fang, "*An Apparatus for the Measurement of Scattering Processes in Intermediate Energy H^- Ion − Atom Collisions,*" Book of Contributed Abstracts, p. 39.

XVIII International Conference on the Physics of Electronic and Atomic Collisions, Århus, Denmark, July 1993.

8. T. J. Kvale, A. Sen, X. D. Fang, and R. Matulioniene, "*Total Cross Sections for Double−Electron Detachment in Intermediate Energy H^- + Noble Gas Collisions,*" Abstracts of Contributed Papers, p. 526 (1993).

Division of Atomic. Molecular, and Optical Physics of the APS: DAMOP - Chicago, May 1992

9. J. S. Allen, X. D. Fang, and T.J. Kvale, "*Single–Electron Detachment Cross Sections for 3 – 50 keV H^- Ions Incident on He Atoms*," Bull. Am. Phys. Soc. 37, 1115 (1992).

10. T. J. Kvale, J. S. Allen, and X. D. Fang, "*Absolute Total Cross Section Measurements of Double Electron Detachment in H^- + Helium Collisions at Intermediate Energies*," Bull. Am. Phys. Soc. 37, 1115 (1992).

Ohio Section of the American Physical Society

11. J. S. Allen, X. D. Fang, and T. J. Kvale, "*Double–Electron Detachment Cross Sections for 5 – 45 keV H^- Ions Incident on He Atoms*," Bull. Am. Phys. Soc. 37, 1879 (1992).

Division of Atomic. Molecular, and Optical Physics of the APS: DAMOP - Reno, May 1993

12. T. J. Kvale, A. Sen, X. D. Fang, and R. Matulioniene, "*Total Cross Sections for Double–Electron Detachment in Intermediate Energy H^- + Neon Collisions*," Bull. Am. Phys. Soc. 38 1131 (1993).

13. T.J. Kvale, A. Sen, R. Matulioniene, and X. D. Fang, "*Single–Electron Detachment Cross Sections in H^- + Ar Collisions in 5 – 50 keV*," Bull. Am. Phys. Soc. 38, 1131 (1993).

Abstract Submitted for the
Twelfth International Conference
on the Application of
Accelerators in Research and Industry

November 2 - 5, 1992
Meeting Date

Suggested title of session
in which paper should be placed:
Accelerator Technology, Ion-Surface Interactions

Physics and Astronomy
Classification Scheme
Number: 79.20.Nc

Secondary Electron Emission Coefficients for 3- to 50-keV H^o Atoms Striking a Beveled Copper Target*, J.S. ALLEN, X.D. FANG, and T.J. KVALE, Dept. of Physics and Astronomy, The Univ. of Toledo. By measuring all three charged-particle fractions emerging from energetic (3 - 50 keV) collisions of H^- with helium, the secondary electron emission (SEE) coefficients γ were determined for H^o striking a copper surface inclined 60° to the ion beam. The electrons were accelerated from the copper target to a shielded cylinder surrounding the target by a weak electric field. The current to the copper target was then measured simultaneous with the H^- and H^+ ion currents. The coefficient measurements are absolute and free of normalization to other experiments or theories. The SEE coefficients rise monotonically from $\gamma \cong 1.6\ e^-/H^o$ atom at 3 keV to $\gamma \cong 4.0\ e^-/H^o$ atom at 50 keV.

* Supported in part by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Dept. of Energy, under grant no. DE-FG05-88ER13971.

(XX) Prefer Poster Session

Submitted by

Signature of APS Member

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Toledo, OH 43606

Abstract Submitted for the
Twelfth International Conference
on the Application of
Accelerators in Research and Industry
November 2 - 5, 1992
Meeting Date

Suggested title of session
in which paper should be placed:
Experimental Techniques - Apparatus

Physics and Astronomy
Classification Scheme
Number: 35.80.+s, 34.70.+e

An Apparatus for the Measurement of Scattering Processes in Intermediate Energy H^- Ion - Atom Collisions*, T.J. KVALE, J.S. ALLEN, and X.D. FANG, Dept. of Physics and Astronomy, The Univ. of Toledo. The apparatus at the Univ. of Toledo, which is designed for the measurement of scattering processes in intermediate energy H^- ion - atom collisions, is described in this paper. This apparatus is capable of detecting all three charged-particle fractions emerging from energetic (3 - 50 keV) collisions of H^- ions with atoms. This permits the simultaneous measurement of total single- (SED) and double- (DED) electron detachment cross sections. The capabilities of the apparatus are currently being extended to permit an energy analysis of the scattered H^- ions. These modifications will allow the measurement of target inelastic processes in which H^- ions scatter intact, as well as the other charge-changing processes described above.

* Supported in part by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Dept. of Energy, under grant no. DE-FG05-88ER13971.

(XX) Prefer Poster Session

Submitted by

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Total Cross Sections for Double-Electron Detachment in Intermediate Energy $H^- +$ Noble Gas Collisions*

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The University of Toledo, Toledo, Ohio 43606 USA.

Total cross sections for the double-electron detachment ($\sigma_{-1,1}$) in collisions between H^- and the noble gases of He, Ne, and Ar have been measured in the collisional energy range from 5- to 50-keV. The present results for the double-electron ($\sigma_{-1,1}$) detachment are shown in Figure 1. The measurements are absolute, and free of normalization to other measurements or theories. A well-collimated H^- ion beam is directed into a static target gas cell and the various charge-state scattered beam components, i.e, H^0, H^+ and H^- are magnetically analyzed and measured simultaneously. The H^+ and H^- components are directed into shielded Faraday cups and measured by separate digital electrometers. The H^0 atom beam is directed into a secondary-electron-emission detector (neutral detector) and measured independently. The double-electron detachment cross sections are determined by a quadratic least squares fit of the H^+ fraction as a function of the target thickness in the growth curve analysis of the data. The double-electron detachment cross sections for $H^- +$ (Ne and Ar) increase monotonically with energy in the range 5- to 50-keV, with the main difference being that the Ar cross sections are about a factor of four larger than the Ne cross sections. This contrasts with the double-electron detachment cross section curve for helium targets, which contains a distinct maximum at a collisional energy of about 10 keV. The present measurements will be compared to previous measurements and calculations.

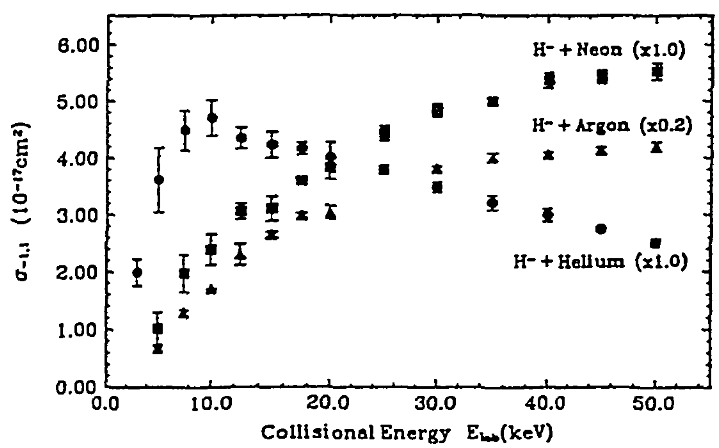

Figure 1.

* Supported in part by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy, under grant DE-FG05-88ER13971.

Session title:
Ion-Atom Collisions

Abstract Submitted
for the DAMOP meeting of the
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May 20-22, 1992

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Single-Electron Detachment Cross Sections for 3-50 keV H^- Ions Incident on He Atoms.* J. S. ALLEN, X. D. FANG, and T. J. KVALE, University of Toledo.--Absolute measurements of the total cross section for single-electron detachment from the H^- ion in collisions between 3-50 keV H^- ions and He atoms are reported. The cross sections are determined from simultaneous measurements of the attenuation of the incident H^- ion beam in He gas and the rate of growth of the H^0 atom and H^+ ion components of the beam. The single detachment cross section has a broad maximum of 6.0×10^{-16} cm^2 in the energy range from 3 keV to 10 keV and decreases gradually to a value of 3.8×10^{-16} cm^2 at 50 keV. We compare the present measurements with previous measurements of the single detachment cross sections reported in the literature.

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(X) Prefer Poster Session

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Ion - Atom Collisions, Experimental

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Absolute Total Cross Section Measurements of Double Electron Detachment in H^- + Helium Collisions at Intermediate Energies.* T.J. KVALE, J.S. ALLEN, and X.D. FANG, Dept. of Physics and Astronomy, The University of Toledo. --- Absolute total cross sections (TCS) have been measured of double electron detachment for H^- incident on helium for impact energies of 3.0 - 50.0 keV. The TCS exhibit a maximum of 4.87×10^{-17} cm^2 at 10.0 keV. At impact energies less than 10 keV, the TCS decreases monotonically to 1.92×10^{-17} cm^2 at 3.0 keV. The TCS values in this energy region are consistently lower than Williams [1], but display a similar energy dependence. For impact energies greater than 10.0 keV, the TCS again decreases to 2.38×10^{-17} cm^2 at 50.0 keV. In this energy region, the present data compare favorably with Fogel, et al. [2].

*Supported by a grant from the U.S. Dept. of Energy, Division of Chemical Sciences, DE-FG05-88ER13971.

[1] J.F. Williams, Phys. Rev. 154, 9 (1967).
[2] Ia. M. Fogel, V.A. Ankudinov, and R.E. Slabospitskii, Sov. Phys. JETP 5, 382 (1957).

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Double-Electron Detachment Cross Sections for 5-45 keV H^- Ions Incident on He Atoms.* J. S. ALLEN, X. D. FANG, and T. J. KVALE, University of Toledo. --We report absolute measurements of double-electron detachment cross sections for 5-45 keV H^- ions incident on He atoms. The measurements are made using a new negative-ion accelerator at the University of Toledo. The cross sections are determined by measuring the rate of growth of the H^+ ion current exiting a He target, as a function of increasing He target density. The cross section increases from a value of 4.0×10^{-17} cm^2 at an impact energy of 5 keV to a value of 5.3×10^{-17} cm^2 at 12.5 keV. Above 12.5 keV, the cross section falls to a value of 3.6×10^{-17} cm^2 at 45 keV. Our values of the cross section are compared with previous measurements of the double-electron detachment cross section for H^- ions incident on He atoms.[1,2]

*Supported in part by US DOE Grant DE-FG05-88ER13971

[1] J. F. Williams, Phys. Rev. 154, 9(1967).
[2] Ia. M. Fogel, V. A. Ankudinov, and R. E. Slabospitskii, Sov. Phys. JETP 5, 382(1957).

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Total Cross Sections for Double-Electron Detachment in Intermediate Energy H^- + Neon Collisions.* T.J. Kvale, A. Sen, X. Fang and R. Matulioniene, Department of Physics and Astronomy, The University of Toledo, Toledo, Ohio 43606. Absolute total cross sections for the double electron detachment ($\sigma_{-1,1}$) in collisions between H^- and Ne have been measured in the 5 - 50 keV energy range. A well-collimated H^- ion beam is directed into a static neon gas cell and the beam components of the collision products (i.e, H^0, H^+ and H^-) are magnetically analyzed and directed into appropriately-biased Faraday cups for detection. The cross sections are determined by a quadratic least squares fit of the H^+ fraction as a function of the target thickness in the growth curve analysis of the data. The double-electron detachment cross sections increase monotonically with impact energy over the energy region covered in this experiment. The values of $\sigma_{-1,1}$ range from 1.02 x 10^{-17}cm^2 at 5.0 keV to 5.54 x 10^{-17}cm^2 at 50 keV.

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Single-Electron Detachment Cross Sections in H^- + Ar Collisions in 5 – 50 keV.* T.J. Kvale, A. Sen, R. Matulioniene and X. Fang, Department of Physics and Astronomy, The University of Toledo, Toledo, Ohio 43606. Measurements of absolute cross sections for the single electron detachment ($\sigma_{-1,0}$) in collisions between H^- and Ar in the energy range 5 – 50 keV are reported. A well-collimated H^- ion beam is directed toward an Ar gas target and all three of the exiting scattered beam components (i.e, H^0, H^+ and H^-) are measured simultaneously. Using the closure relation among the collision beam components, (H^0, H^- and H^+) the neutral detection efficiencies are determined at each energy and thereby we are able to report absolute single detachment cross sections. The single detachment cross sections $\sigma_{-1,0}$ exhibit a broad maximum with a value of 1.78 x 10^{-15} cm^2 at an impact energy of 25 keV.

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