(2)

AFOSR-TR- 92 0684

MERGED BEAM STUDIES OF LASER STIMULATED RADIATIVE RECOMBINATION.

Final ~~3rd~~ Technical Report

31 May 1992

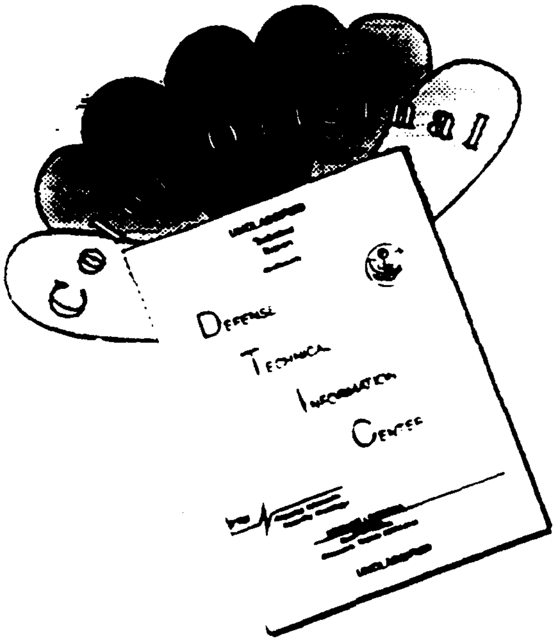
Prepared by:

J.B.A. Mitchell

PHYSICS

The University of Western Ontario

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF COLOR PAGES WHICH DO NOT REPRODUCE LEGIBLY ON BLACK AND WHITE MICROFICHE.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR
6a. NAME OF PERFORMING ORGANIZATION The University of Western Ontario 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Same as 8a
6c. ADDRESS (City, State, and ZIP Code) Department of Physics London, Ontario, Canada N6A3K7	7b. ADDRESS (City, State, and ZIP Code) Same as 8c
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR 8b. OFFICE SYMBOL (If applicable) NE	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR-89-0327
8c. ADDRESS (City, State, and ZIP Code) Bolling AFB DC20332-6448	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 61102F PROJECT NO. 2301 TASK NO. A4 WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

Merged Beam Studies of Laser Stimulated Radiative Recombination

12. PERSONAL AUTHOR(S) Mitchell

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 6/91 to 5/92	31 May 1992	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A brief description is given of a multi-pass cavity assembly, installed recently in the merged beams apparatus. Results for the recombination of molecular ions to give neutrals in specific principal quantum number states are presented.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Kelley	22b. TELEPHONE (Include Area Code) 202-767-4908 22c. OFFICE SYMBOL NE

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

INTRODUCTION

In the previous phase of this contract, stimulated radiative recombination of electrons and protons in the presence of an infra-red photon field was successfully demonstrated. Not only was this measurement of particular significance for demonstrating a new atomic process but it also demonstrated the extremely high energy resolution (0.5 meV) capabilities of the merged beams technique. Our aim is now to examine the stimulated recombination process in more detail, to study the relation between gain and laser power, to look for saturation effects and to measure cross sections for radiative recombination to individual n states. To this end we have implemented two modifications to our apparatus. We have installed and tested a new twin field-ionizer system and have developed a multi-pass cavity to increase the illumination of the interaction region by the laser beam. These modifications are discussed in more detail below.

TWIN FIELD-IONIZER SYSTEM

The new experimental arrangement is illustrated schematically in figure 1. Two new field ionizers, arranged in series, have been installed in place of the single ionizer used in the previous measurement. These ionizers have larger apertures (2.5 mm) and makes collimation easier and also allows the dissociative recombination of molecular species to be examined. The products of this reaction fly apart from each other and so a larger aperture is required so that they are not lost on the front faces of the ionizers.

The method of measuring recombination to individual n states is as follows. The first ionizer is set to ionizer all levels greater than a given state, designated n_c. Detector 1 measures recombination to states with $n>n_c$. All atoms surviving passage through this

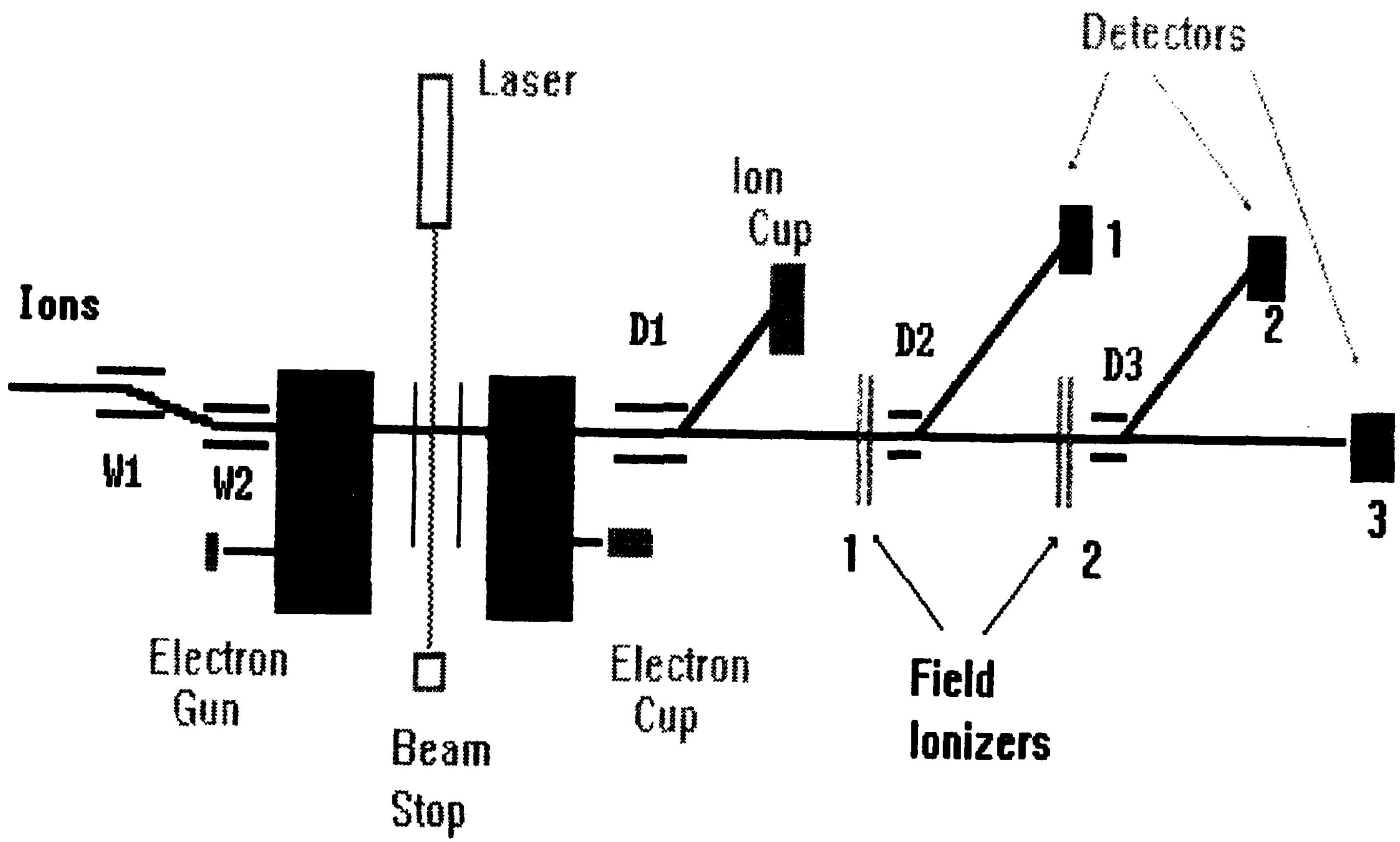


Figure 1.
Merged Beams Apparatus.
Schematic Diagram.

device, will have states $n \leq n_c$ populated. The next ionizer field is set to ionize all atoms with $n \geq n_c$. In the absence of repopulation (Morgan et al 1974), only atoms with $n = n_c$ are in this group. Hence the signal measured in detector 2 is that for the recombination to the n_c state. Detector 3 measures recombination to states with $n < n_c$. Dissociative recombination of molecular ions has a much larger cross section that recombination of atomic ions and sc it was decided to test the system by examining the recombination of H_2^+. For ground vibrational state H_2^+ ions, the only exothermic exit channel is that leading to $H(1s)+H(n=2)$. When produced in a conventional ion source operating with moderate pressures of pure hydrogen gas, however, H_2^+ is formed with all 19 available vibrational levels populated. This means that final channels with n states up to the ionization limit are accessible. In our apparatus, the primary ion beam must be deflected into a Faraday cup before the detection of the neutrals is performed. This is accomplished using an electric field of 6kV/cm and this field is sufficient to ionize all neutrals with $n \geq 20$. All neutrals detected therefore have n values less than 20.

Figure 2 shows the cross sections for the reaction

$$e + H_2^+ \rightarrow H(1s)+H(nl)$$

for $n \leq 20$, $n \leq 10$ and $10 < n < 20$.

Figures 3 show the measured signal in detector 1, as a function of the electric field applied to ionizer 1. At the highest field, all H atoms with $n > 10$ are ionized. As the field is decreased, atoms with $n=11$ can no longer be ionized and the signal in detector 1 decreases so that the signal vs field plot displays a downward step. Further decrease of the field produces another step as states with $n=12$ can no longer be ionized. For higher n levels, the steps are too small to be seen and the curve displays a continuous

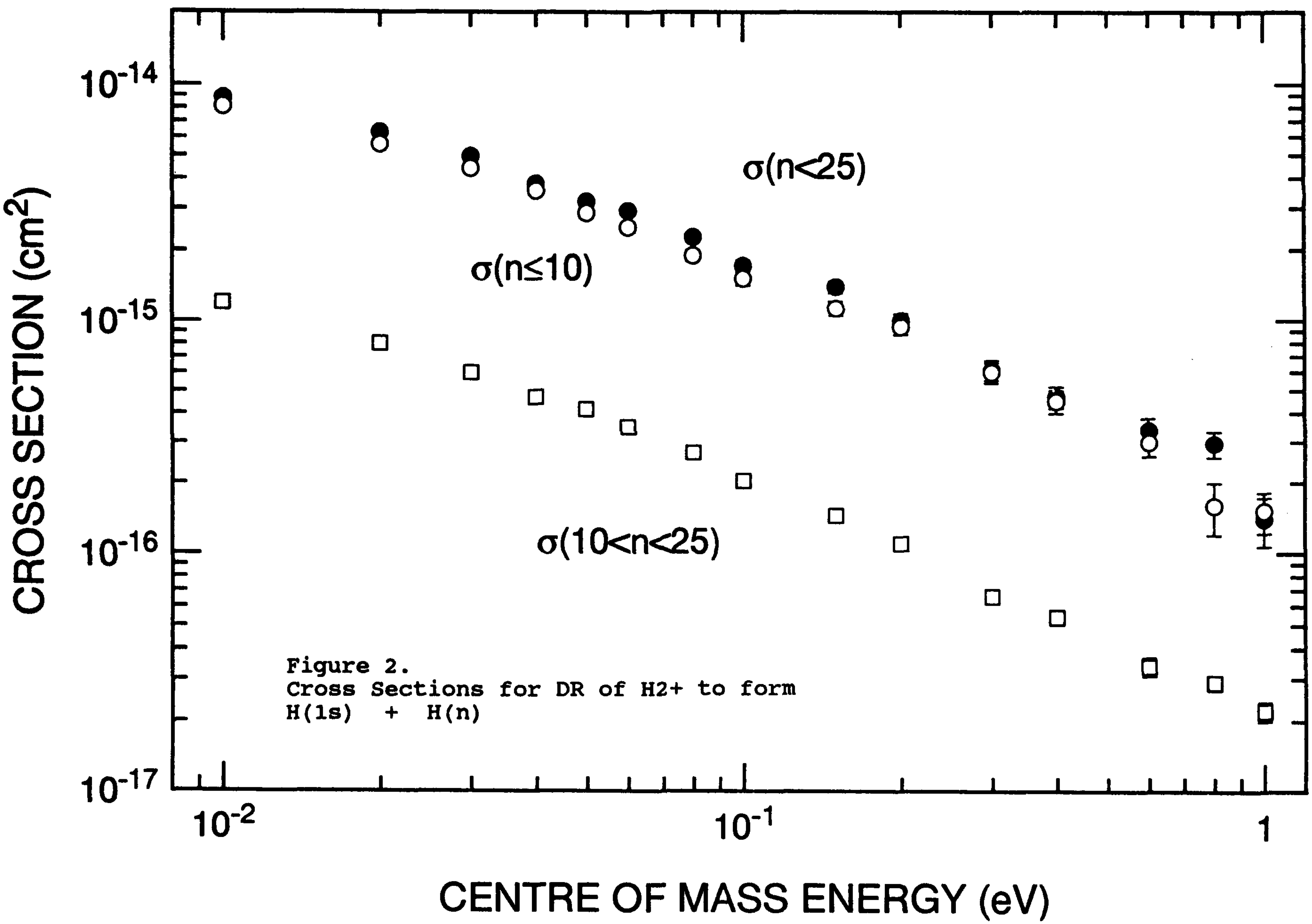


Figure 2.
Cross Sections for DR of H2+ to form
H(1s) + H(n)

05-29-92
b:h2result.plt

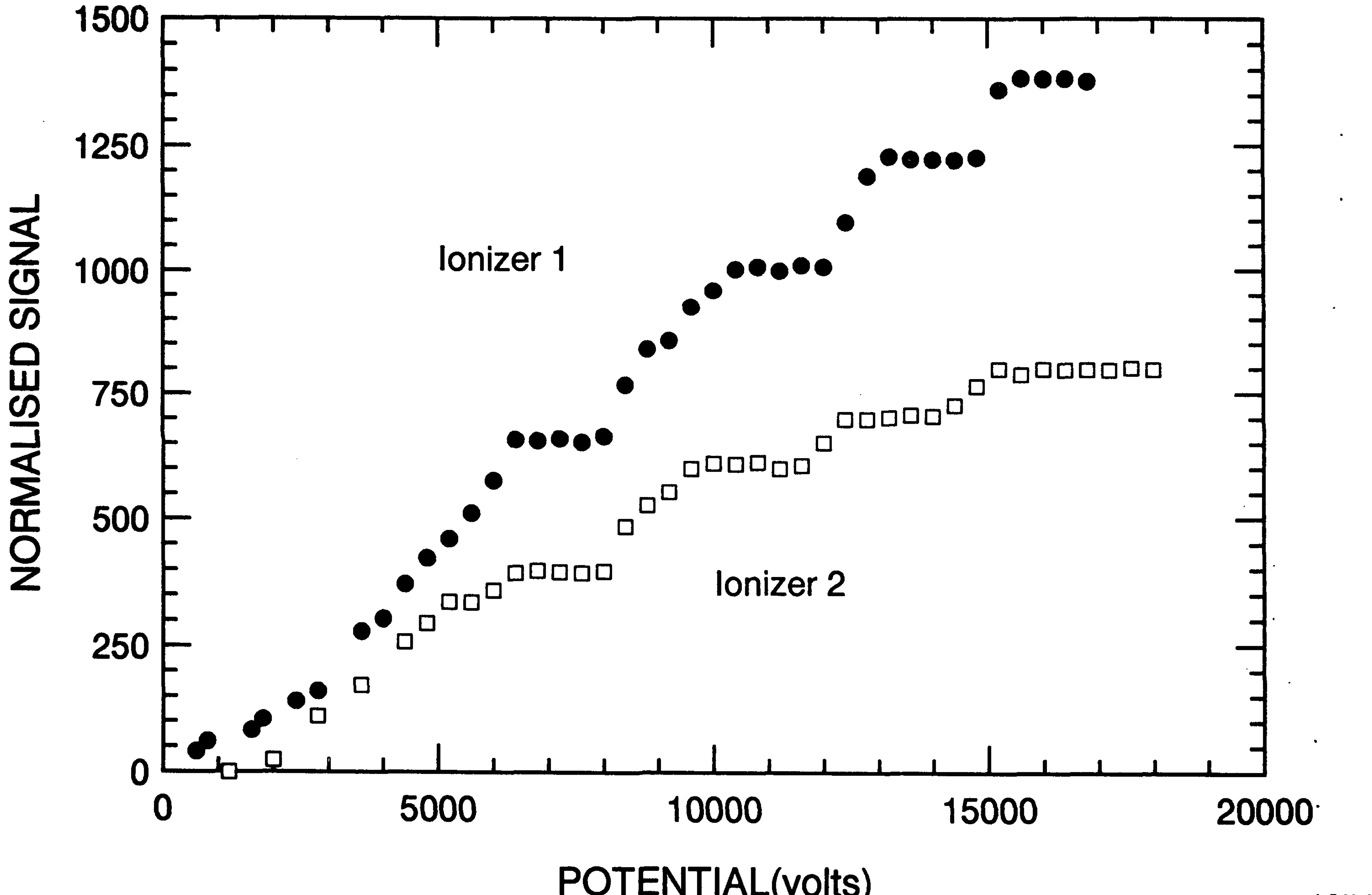

1500
1250
1000
750
500
250
0
NORMALISED SIGNAL
Ionizer 1
Ionizer 2
0
5000
10000
15000
20000
POTENTIAL(volts)
b:field.plt
05-29-92

Figure 3.

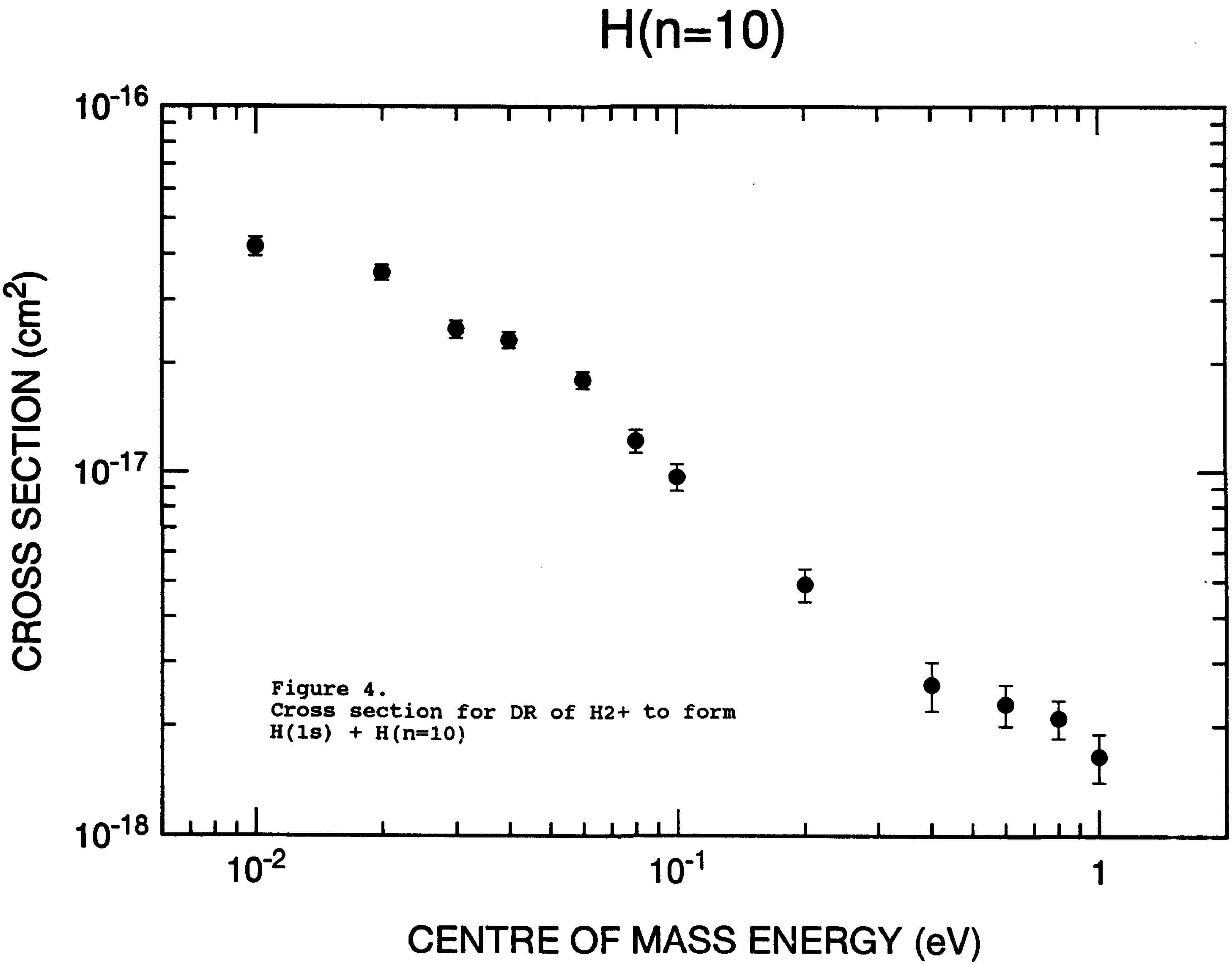


Figure 4.
Cross section for DR of H2+ to form
H(1s) + H(n=10)

05-29-92
b:h10.plt
05-29-92
B:H10.DAT

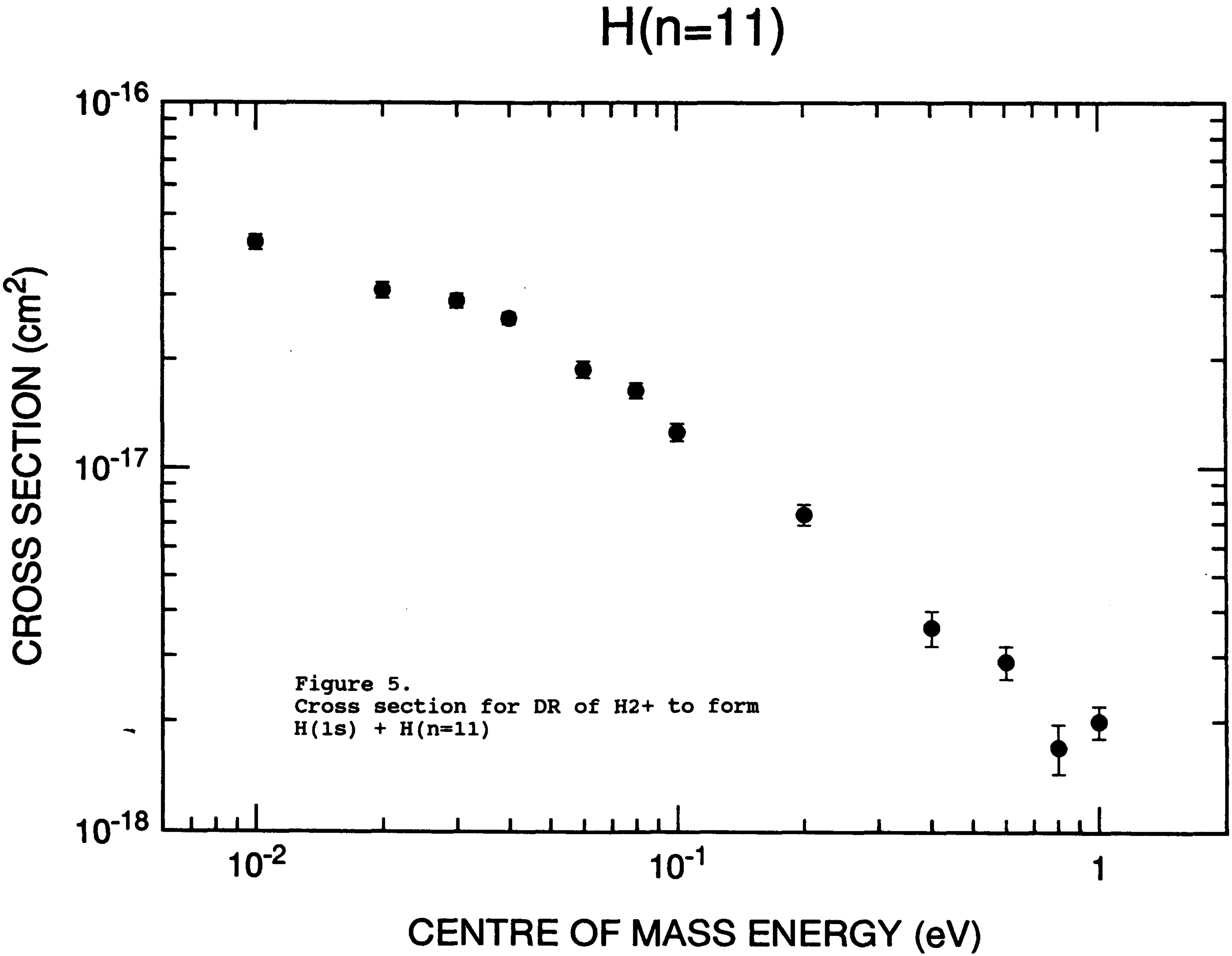


Figure 5.
Cross section for DR of H2+ to form
H(1s) + H(n=11)

05-29-92
b:h11.plt
05-29-92
B:H11.DAT

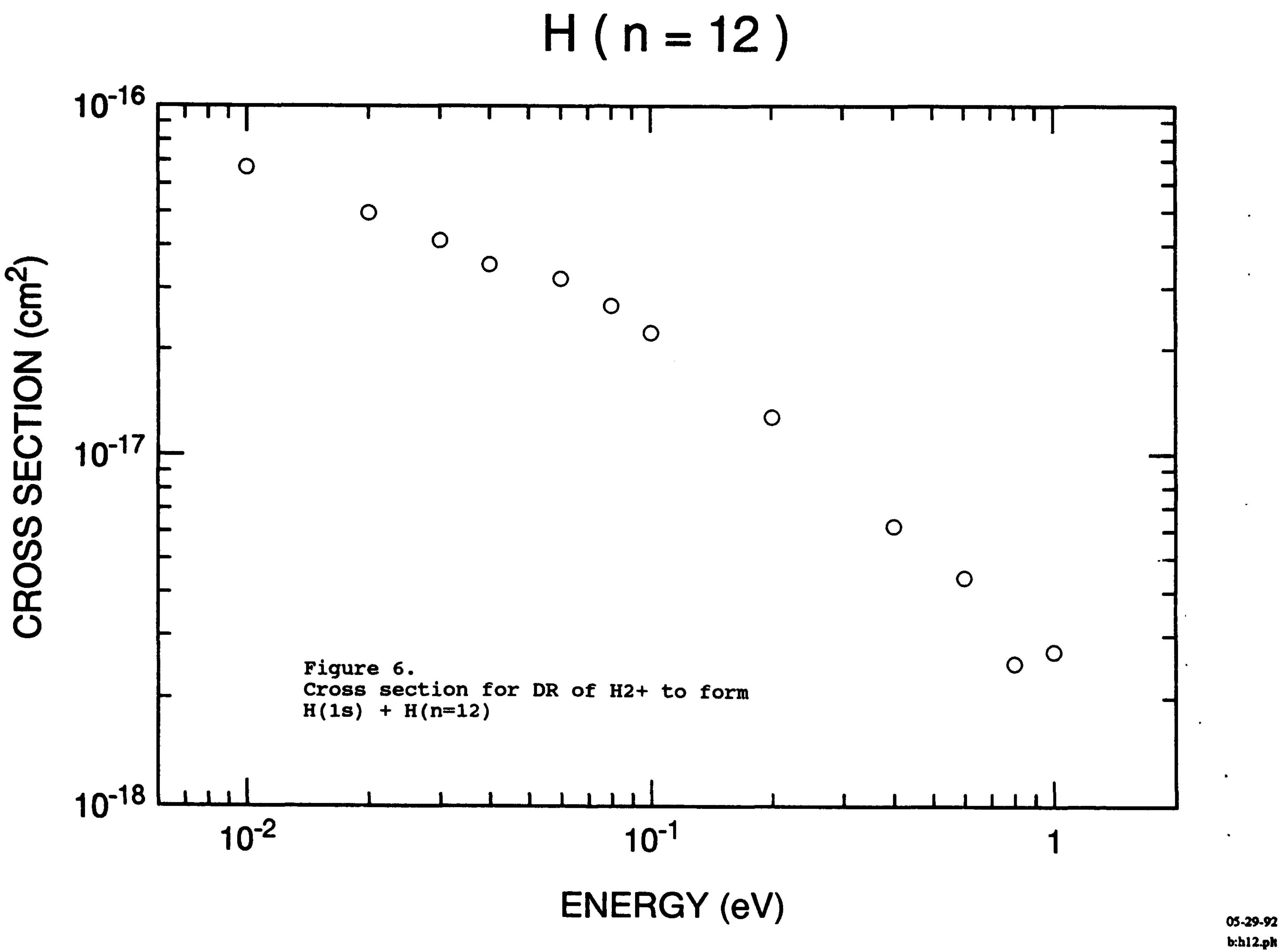


Figure 6.
Cross section for DR of H2+ to form
H(1s) + H(n=12)

downward slope. Figure 3 shows the same curve for ionizer 2, (with ionizer 1 at zero field). It is seen that the steps appear at the same voltages. As described above, the use of two ionizers in series allows the recombination to a single n value to be determined and this is illustrated in figure 4, 5 and 6 for $n=10$, $n=11$ and $n=12$ respectively. These measurements are presented here in so far as they are relevant to the testing of the apparatus. They are of course important in their own right and a paper is in preparation discussing their implication to our understanding of the dissociative recombination process.

MULTI-PASS CAVITY

The most important limitation to our previous measurement of stimulated radiative recombination was the fact that the laser beam only intersected the interaction region over a distance of about 1.5 mm. This is to be compared with the overall length of 86 mm. An obvious suggestion would be to have the laser beam pass co-linearly through the region. Since this would involve passing the beam through the small apertures of the field ionizers with the subsequent risk of severe damage to these devices, this option is therefore not practical. An alternative scheme is to zig-zag the laser beam across the intersection region and this approach has been adopted. The multi-pass cavity, needed to accomplish this has been constructed and tested and is shown in figures 7 and 8. It incorporates gold coated, stainless steel mirrors and in tests it has been found that between 10 and 20 passes can be achieved. This will produce stimulated recombination

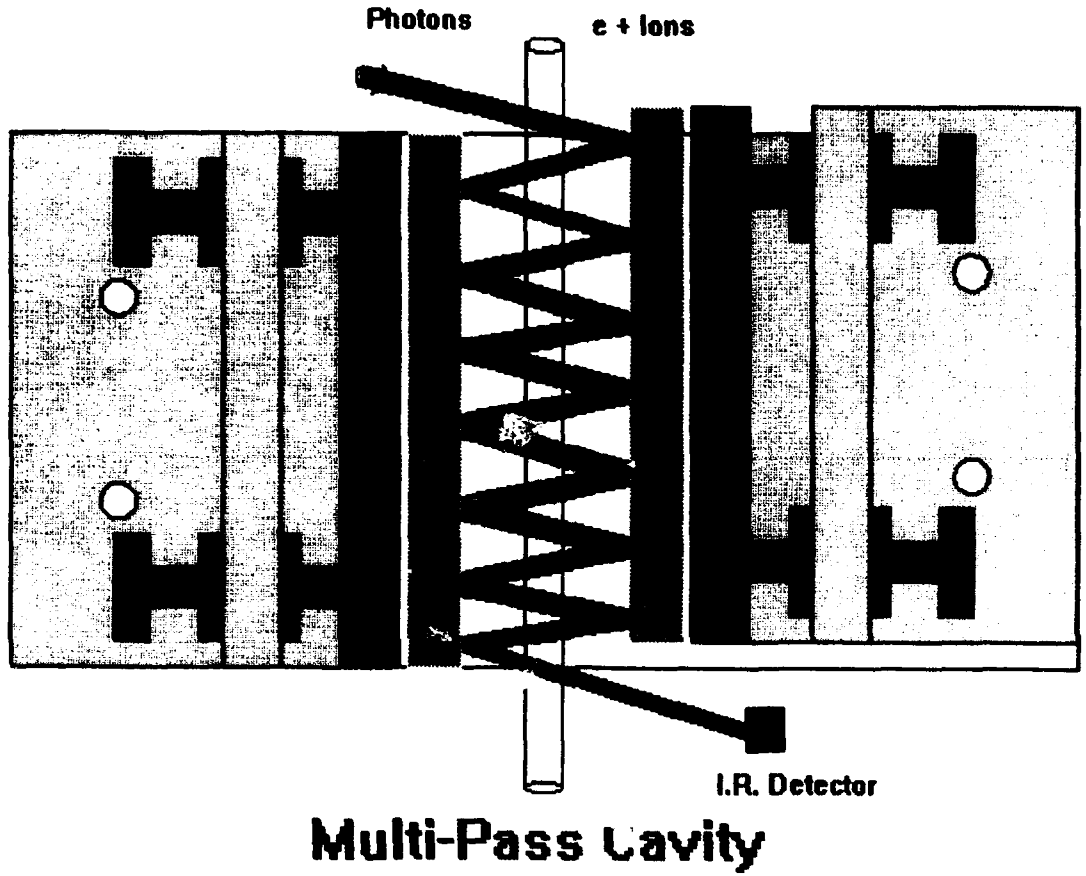


Figure 7.
Multi-Pass Cavity
Plan View.

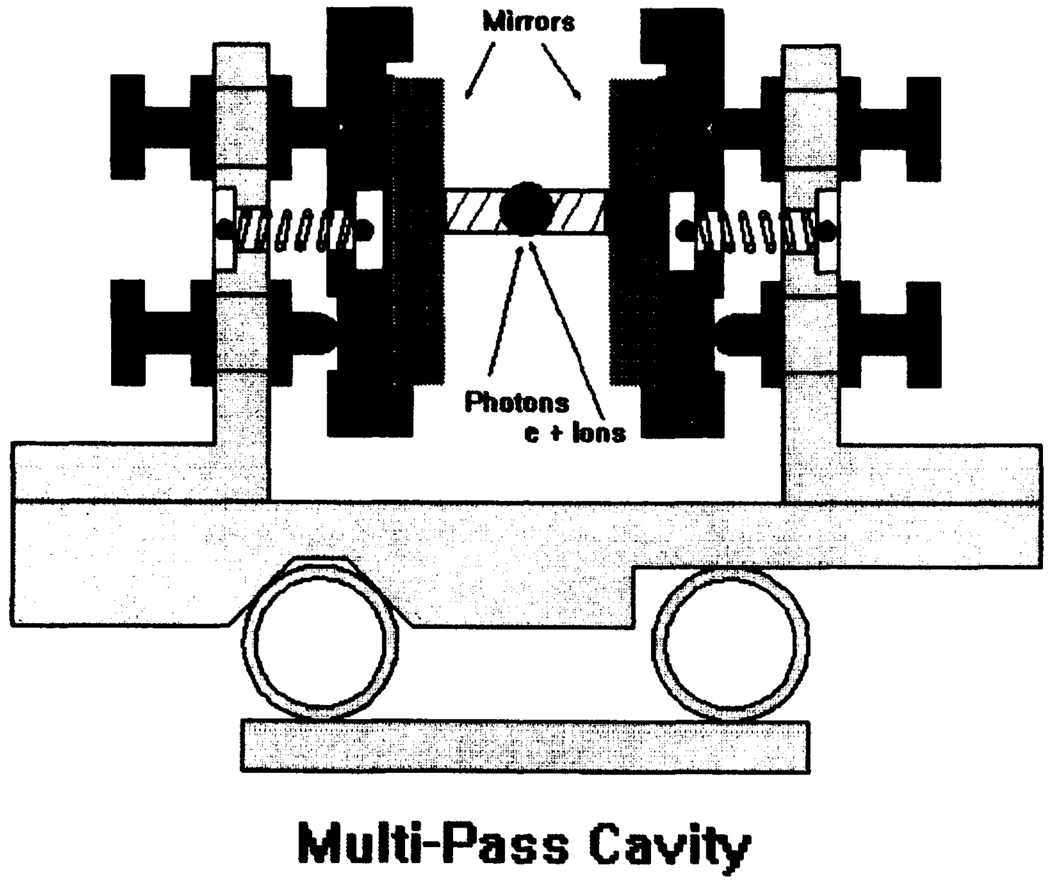


Figure 8.
Multi-Pass Cavity
End View

signals that are 10 to 20 times larger than in the previous experiment and so make it much more convenient to study the details of the process. It will also allow us to vary the laser power and to determine its relationship with the gain in the cross section due to the laser stimulation.

Installation of the multi-pass cavity will be performed during the summer of 1992 and initial experiments will commence in the fall.

REFERENCES

Yousif, F.B., Van der Donk, P.J.T., Kucherovsky, Z., Reis, J.,Brannen, E., Mitchell, J.B.A. and Morgan, T.J. (1991) Phys.Rev.Lett. **67**, 26.

Morgan, T.J., Barnett, C.F., Ray, J.A. and Russek, A. (1974) Phys. Rev. A. **20**, 1062.