Semi-Annual Status Report

NASA Grant NSG 7386

LABORATORY STUDIES OF ATOMIC COLLISION PROCESSES OF IMPORTANCE IN PLANETARY ATMOSPHERES

R.F. Stebbings and Ken Smith
Rice University

Period ending 31 August, 1984

During the six-month period ending on 31 August, 1984, the research supported under NSG 7386 has included:

1. Measurement of differential cross sections for atomic and molecular collisions relevant to analysis and modeling of data from NASA Missions Pioneer 11, Pioneer 12, Voyager 1, and Voyager 2.
2. Analysis of measured differential cross section results to provide scattering data in forms that are easy to apply to atmospheric modeling work.
3. Analysis of the data to give basic information on the molecular potentials involved in the scattering process.
4. Development and initial use of apparatus to study dissociative processes in neutral molecules.

Differential cross sections

Using the apparatus shown in Figure 1, we have measured differential cross sections for H, He, H^+, and He^+ projectiles colliding with H_2, N_2, O_2, and He. This work is still in progress with new reactant species which will include S, S^+, S^{++}, O, O^+, and O^{++}. These studies employ position-sensitive detectors (PSD's) to provide simultaneous measurement of all scattered particles, and the research program covers investigation of differential cross sections for total angular scattering, charge transfer, stripping, and other inelastic collisions. All of these processes can be studied with the same basic apparatus, but minor modifications in the equipment details and in the data acquisition programs and techniques are required for investigation of each individual process.

• Differential cross sections for angular scattering

In this series of experiments, we have measured total differential cross sections for neutral (and some ionic) species scattering from atmospheric gases. Preliminary results have been presented in seminars and conference papers by the investigators, and the first paper reporting these results will be submitted for publication in December, 1984. Figures 2-13 give examples of the data produced, showing differential cross sections for scattering of neutral species. Compared to more traditional techniques, the application of PSD's in this work provides for a substantial increase in data-acquisition rates. During the last six months, both the apparatus and the programs for data acquisition and analysis have been refined so that data can be taken and quickly reduced to give differential cross section information.

• Charge transfer

The NASA missions to Jupiter have shown that the region of Io's orbit contains both a plasma torus of oxygen and sulfur ions, and substantial concentrations of atomic oxygen, atomic sulfur, and alkalai metal vapor. Recent modeling studies indicate that charge transfer and other atomic collision processes act to couple Jupiter's magnetosphere to the neutral gas cloud near Io's orbit. Several Jovian moons have substantial atmospheres, all of which interact by charge transfer with the hot ions in Jupiter's magnetosphere. In addition, data from Voyager show that Saturn has a

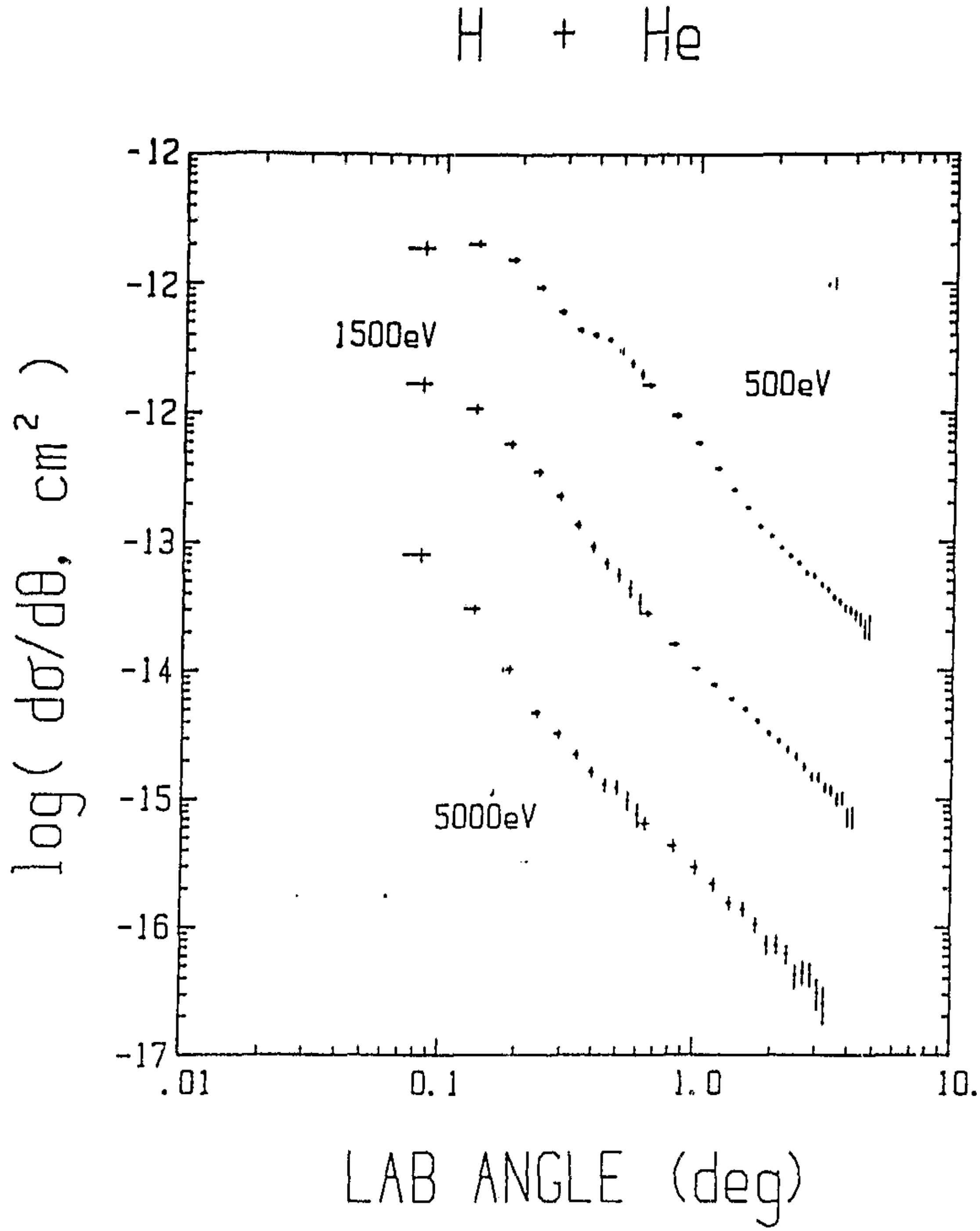

FIGURE 6 DIFFERENTIAL CROSS SECTIONS FOR COLLISIONS OF HYDROGEN WITH HELIUM.

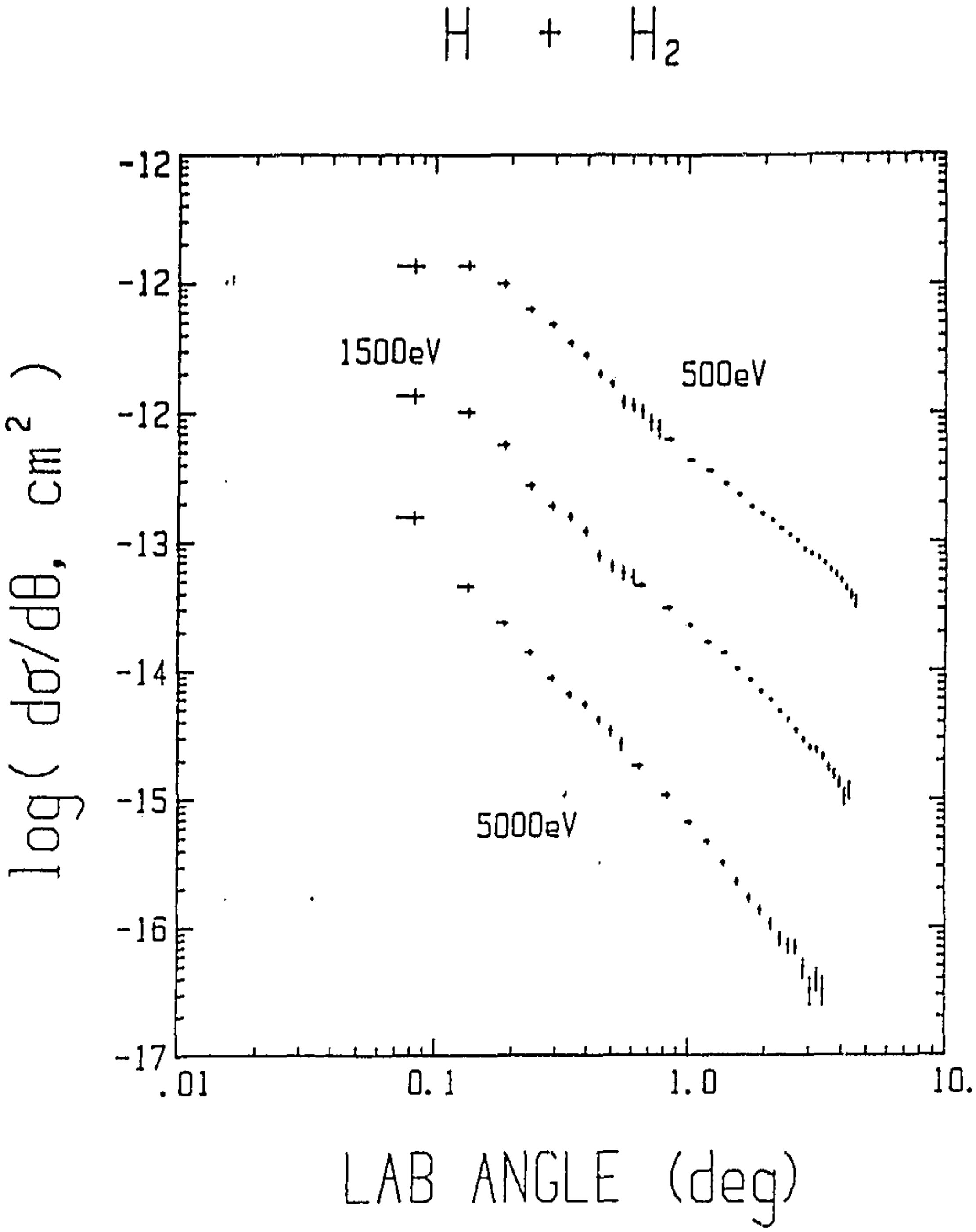

FIGURE 7 DIFFERENTIAL CROSS SECTIONS FOR COLLISIONS OF HYDROGEN WITH MOLECULAR HYDROGEN.

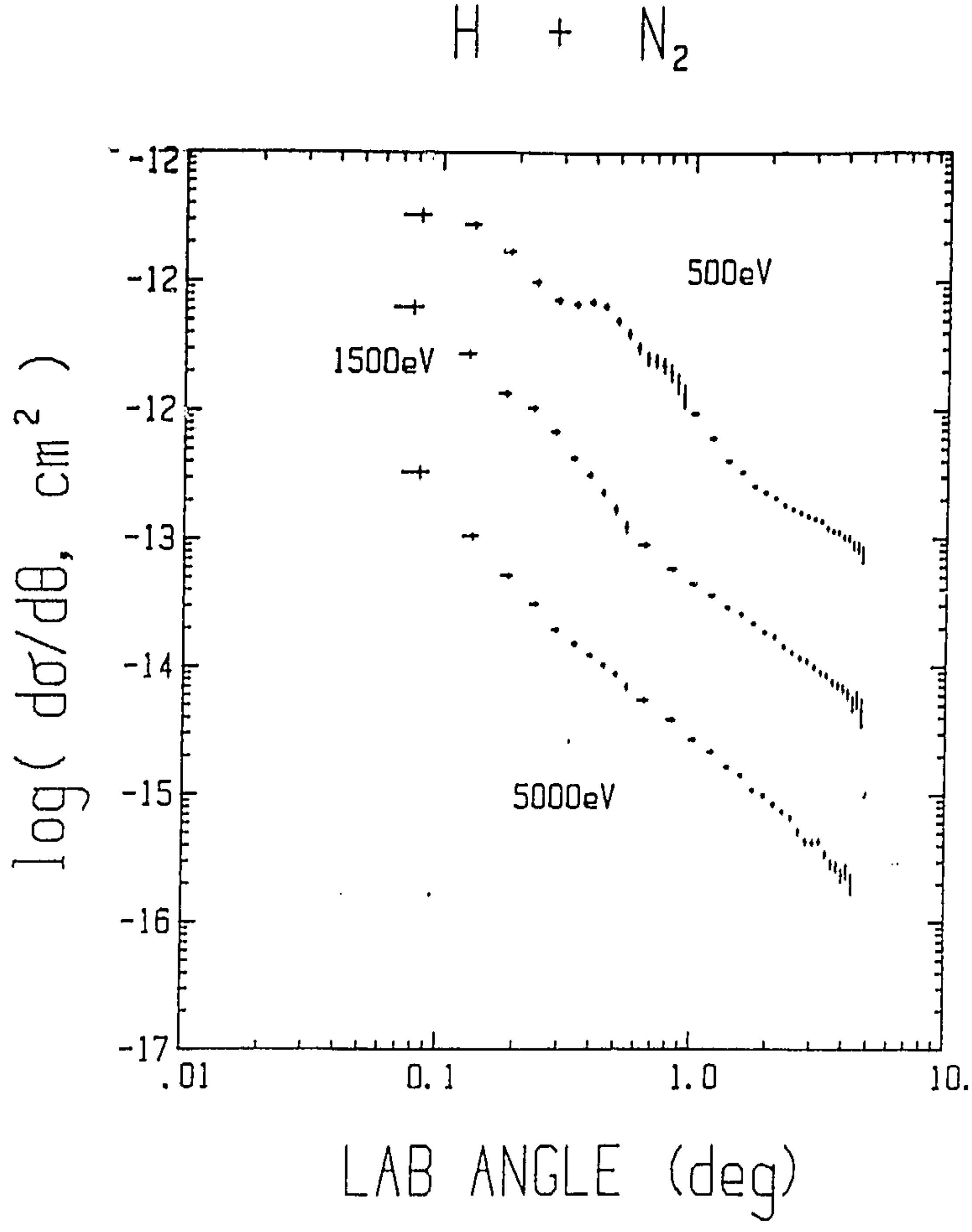

FIGURE 8 DIFFERENTIAL CROSS SECTIONS FOR COLLISIONS OF HYDROGEN WITH MOLECULAR NITROGEN.

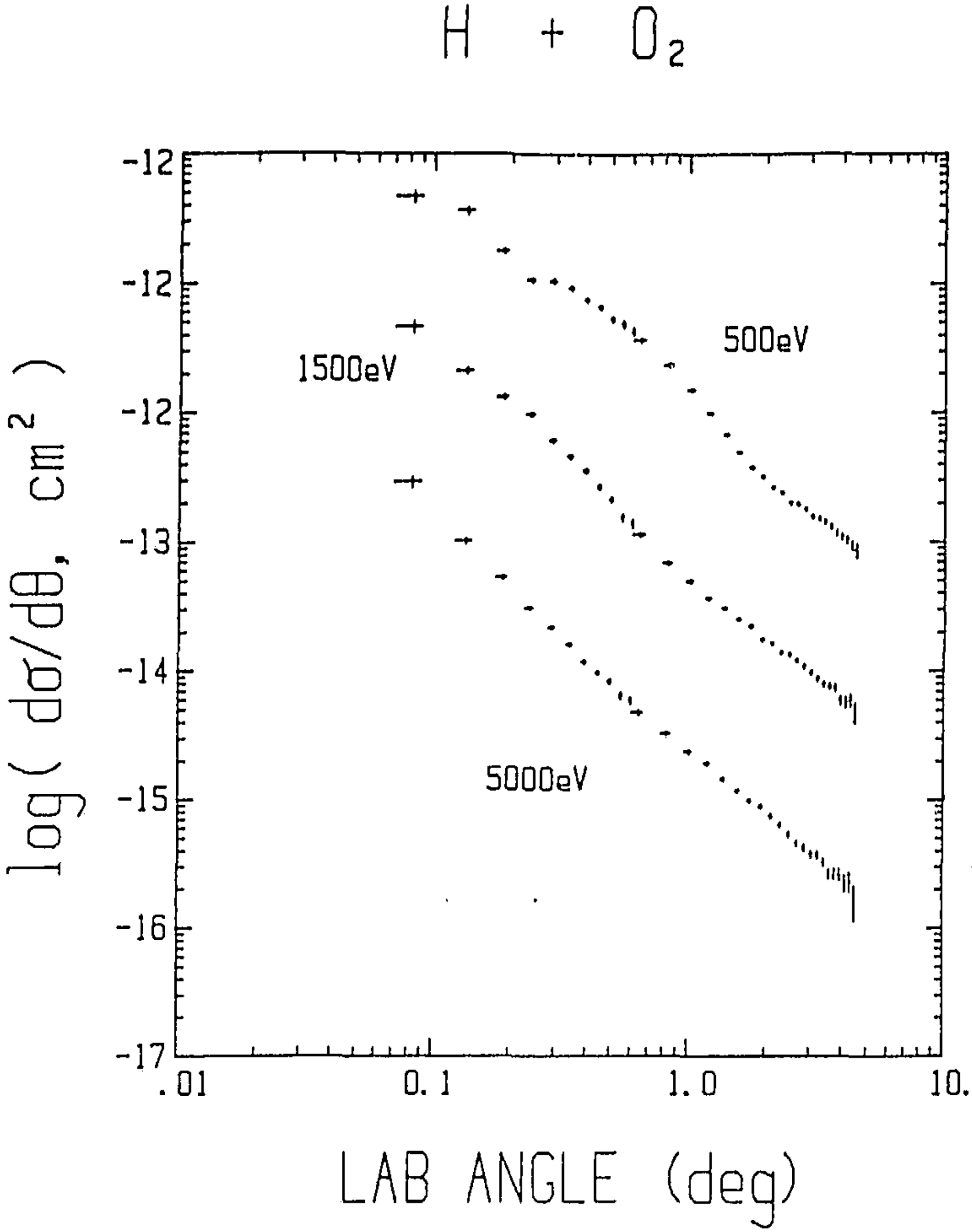

FIGURE 9 DIFFERENTIAL CROSS SECTIONS FOR COLLISIONS OF HYDROGEN WITH MOLECULAR OXYGEN

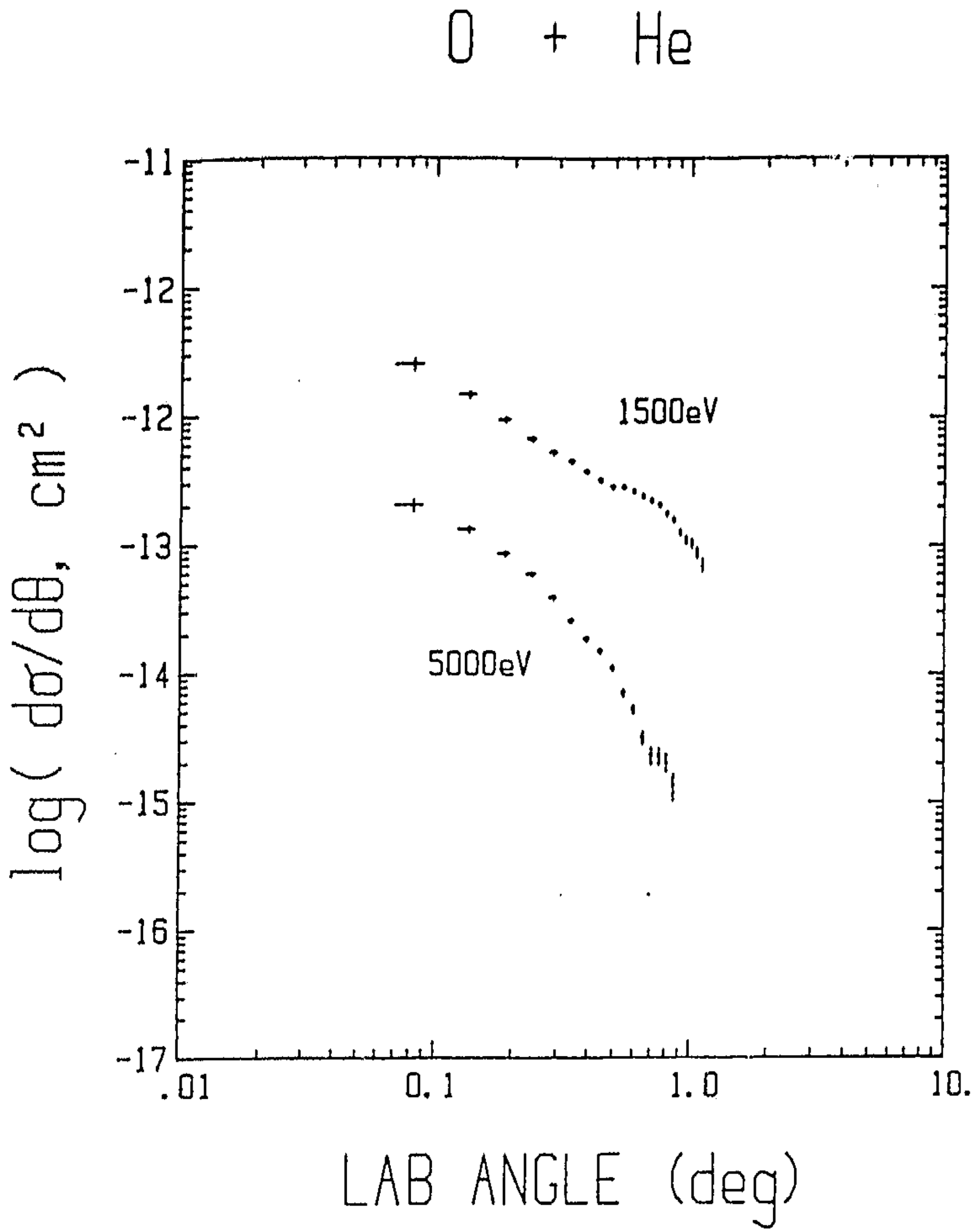

FIGURE 10 DIFFERENTIAL CROSS SECTIONS FOR COLLISIONS OF OXYGEN WITH HELIUM.

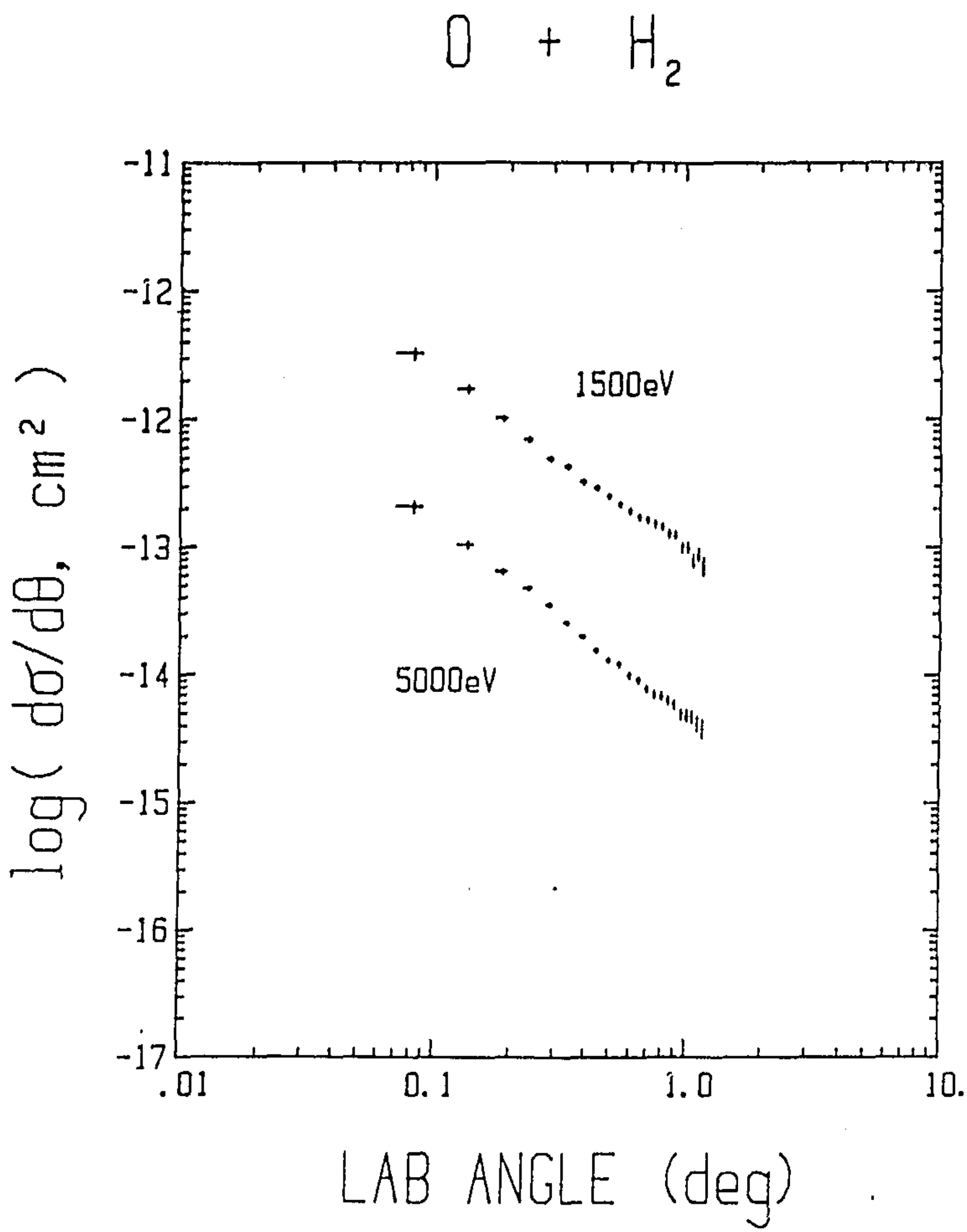

FIGURE 11 DIFFERENTIAL CROSS SECTIONS FOR COLLISIONS OF OXYGEN WITH MOLECULAR HYDROGEN.

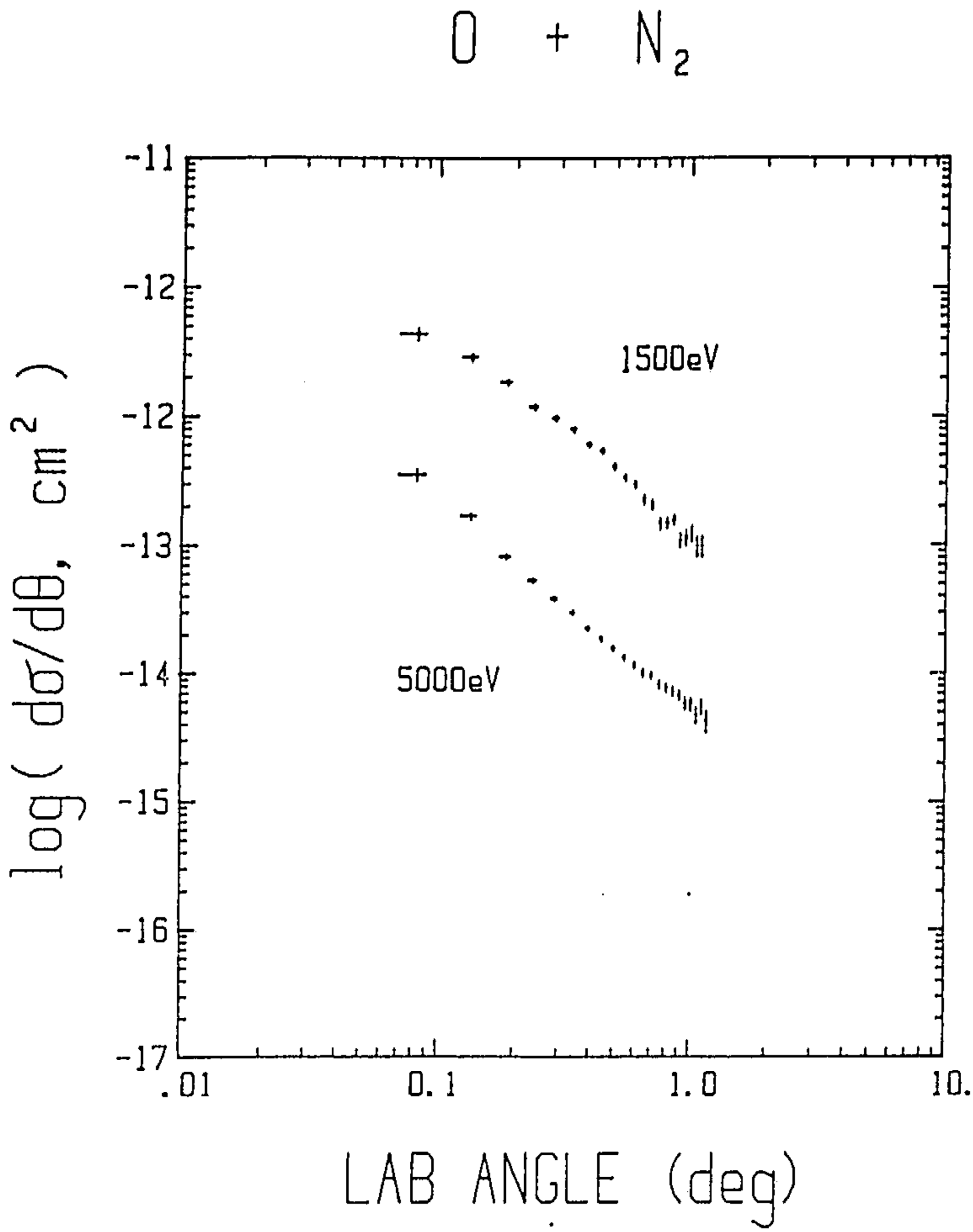

FIGURE 12 DIFFERENTIAL CROSS SECTIONS FOR COLLISIONS OF OXYGEN WITH MOLECULAR NITROGEN.

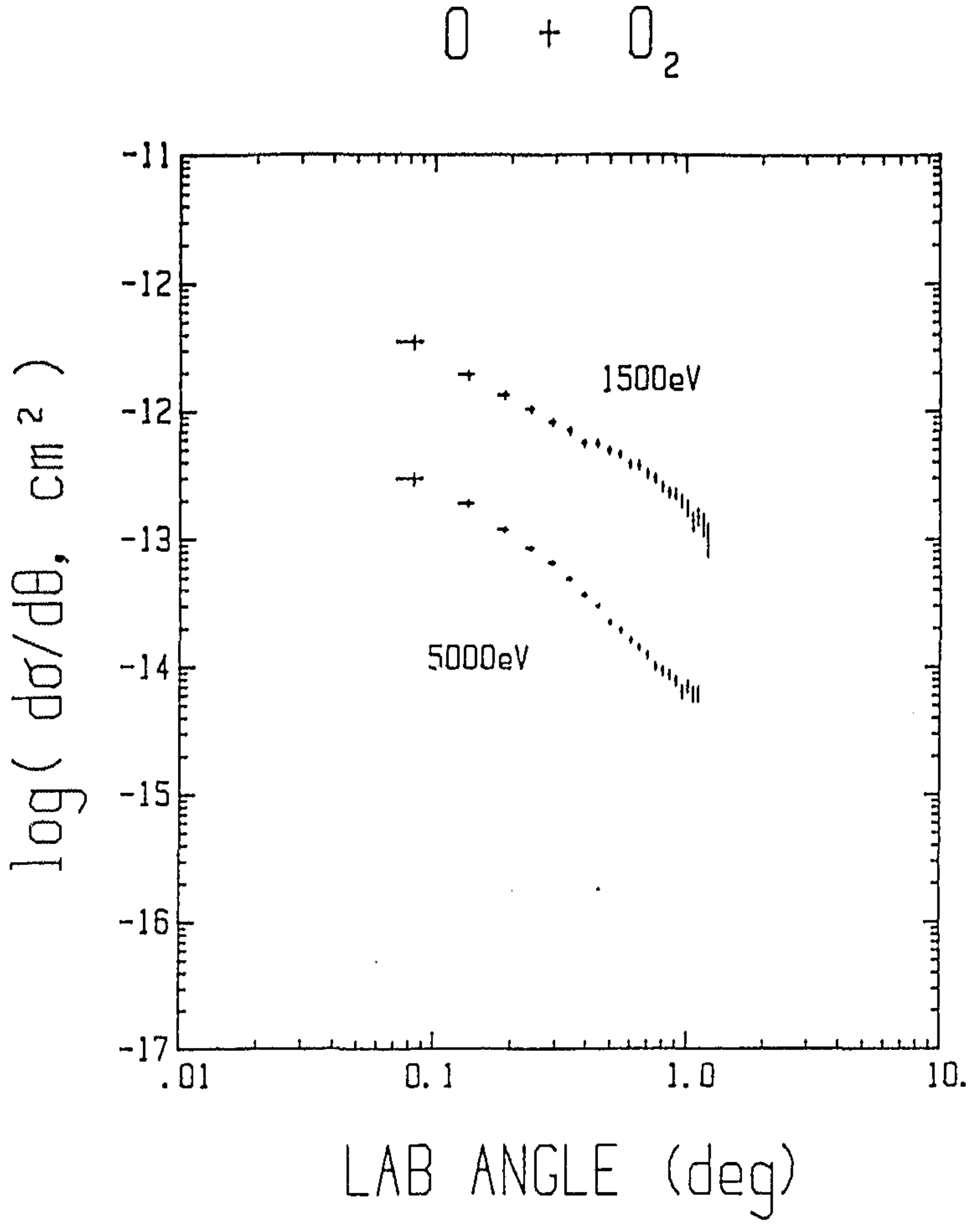

FIGURE 13 DIFFERENTIAL CROSS SECTIONS FOR COLLISIONS OF OXYGEN WITH MOLECULAR OXYGEN.

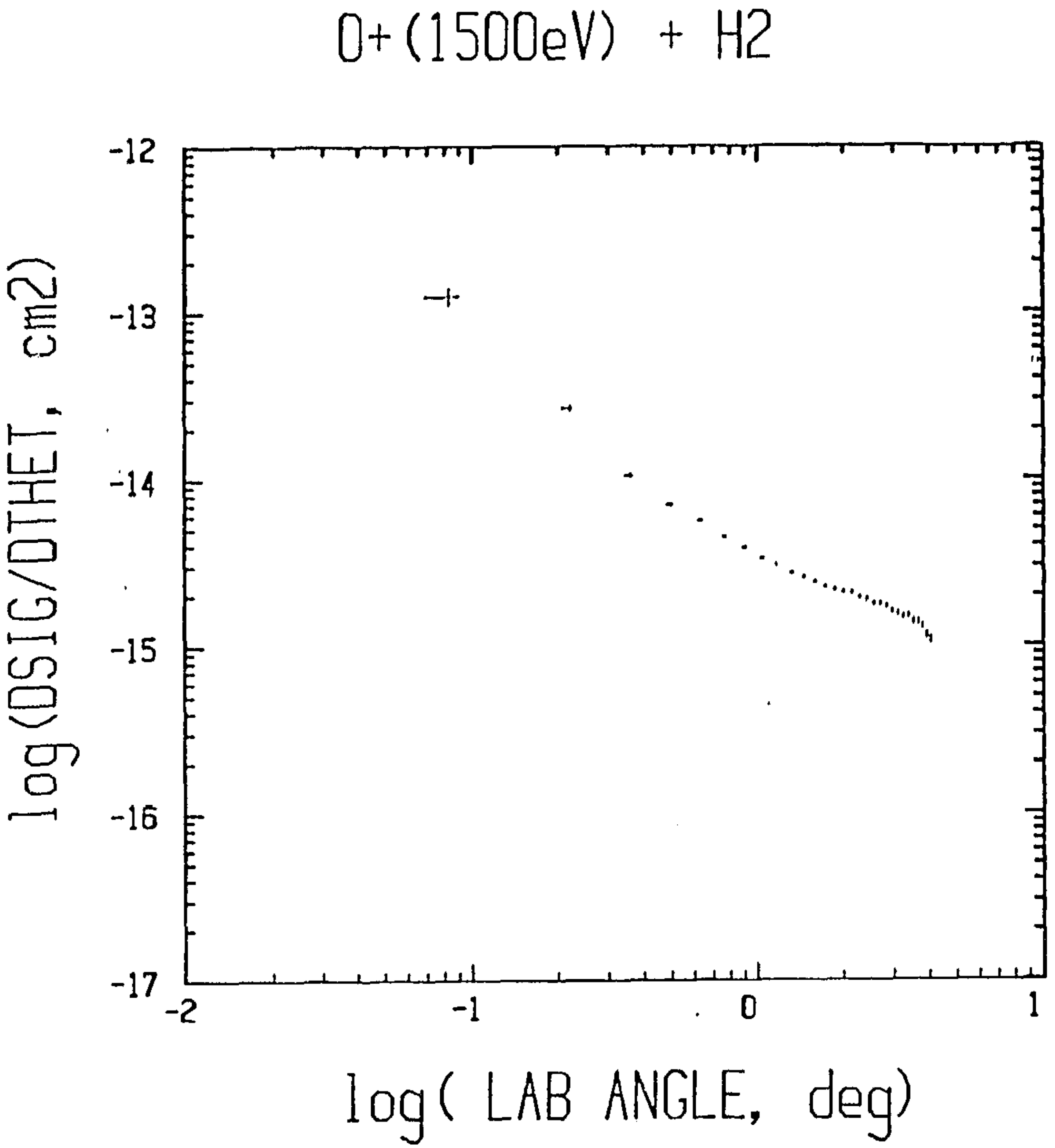

FIGURE 14 DIFFERENTIAL CROSS SECTION FOR CHARGE TRANSFER OF 1500 eV O^+ IONS IN H_2.

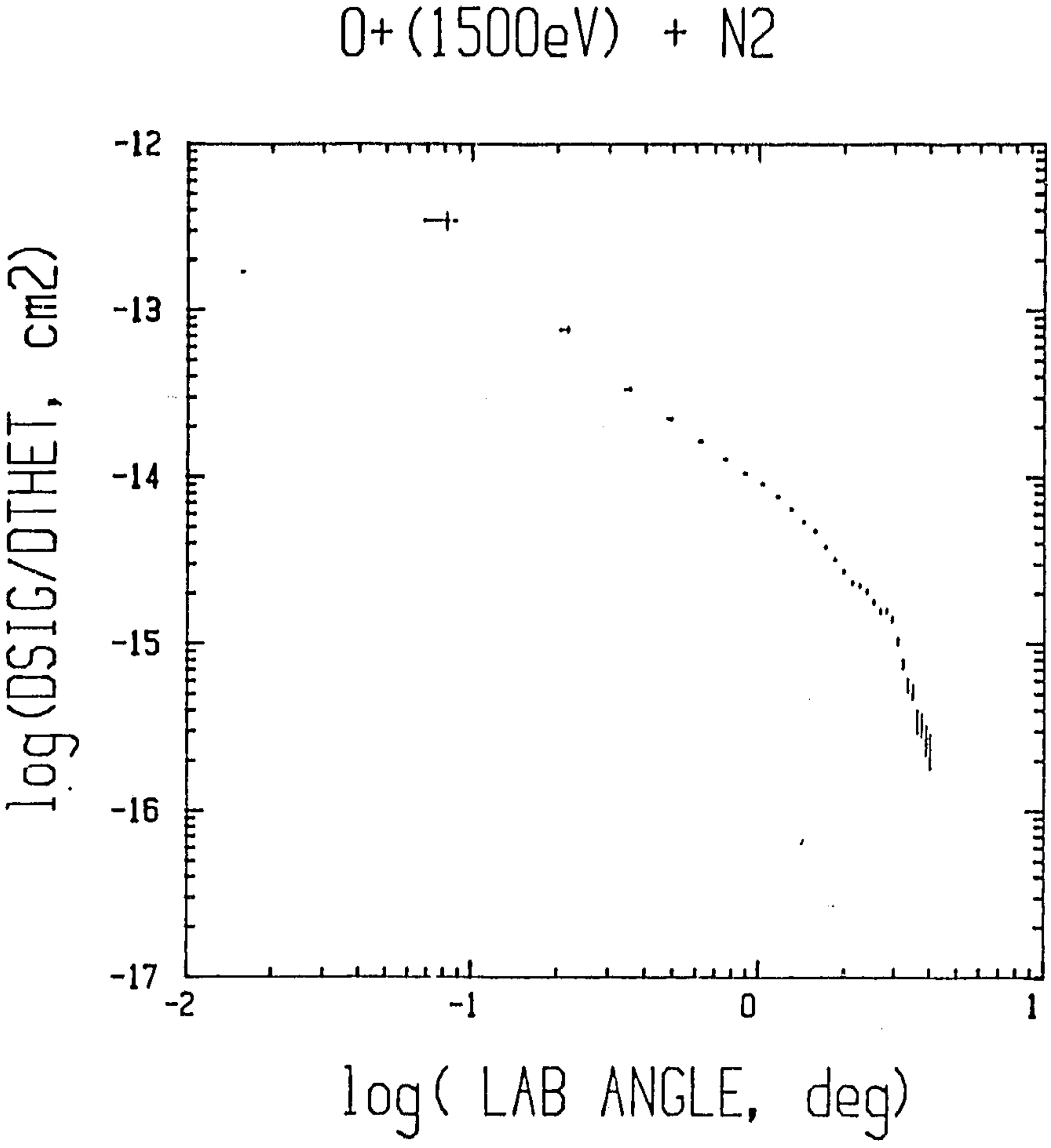

FIGURE 15 DIFFERENTIAL CROSS SECTION FOR CHARGE TRANSFER OF 1500 eV O^+ IONS IN N_2.

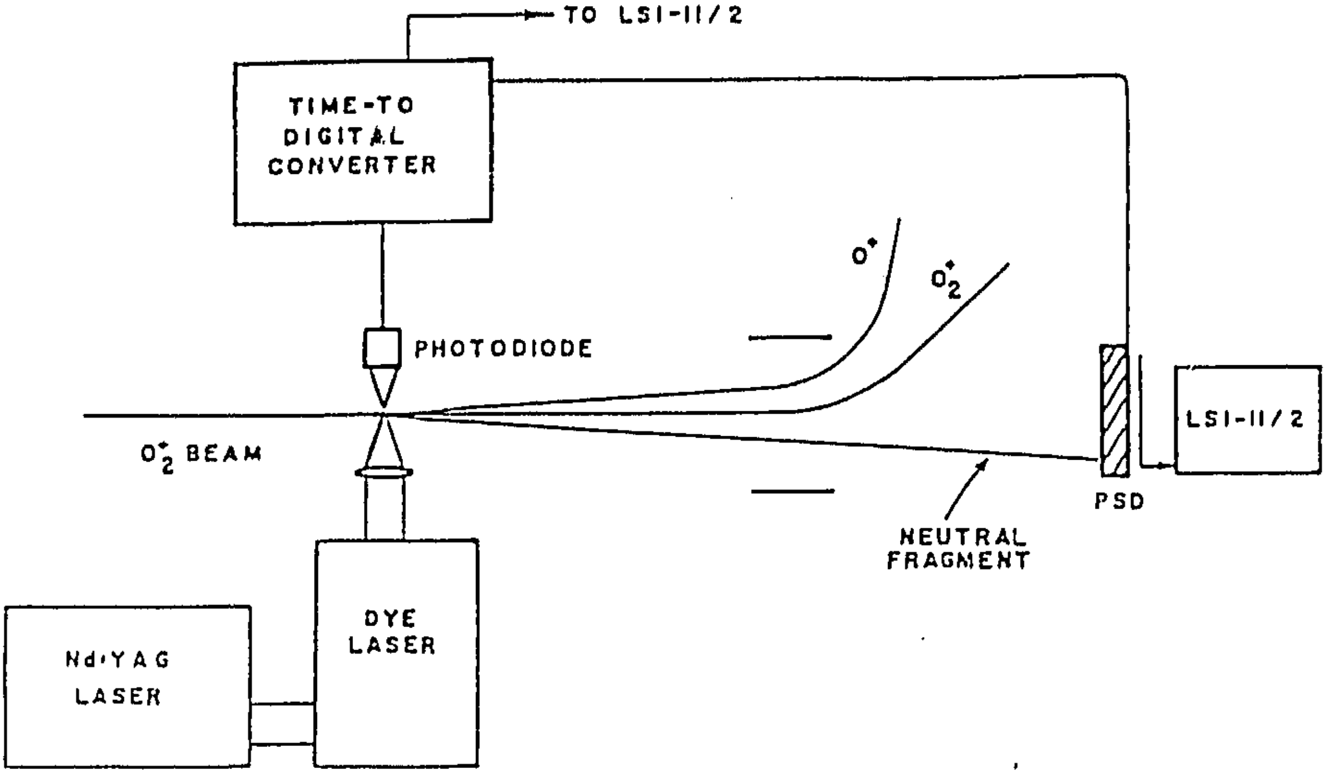

FIGURE 16 APPARATUS TO SHOW FEASIBILITY OF PHOTOFRAGMENT SPECTROSCOPY BY TIME-AND-POSITION-SENSITIVE DETECTION OF NEUTRAL ATOMS.

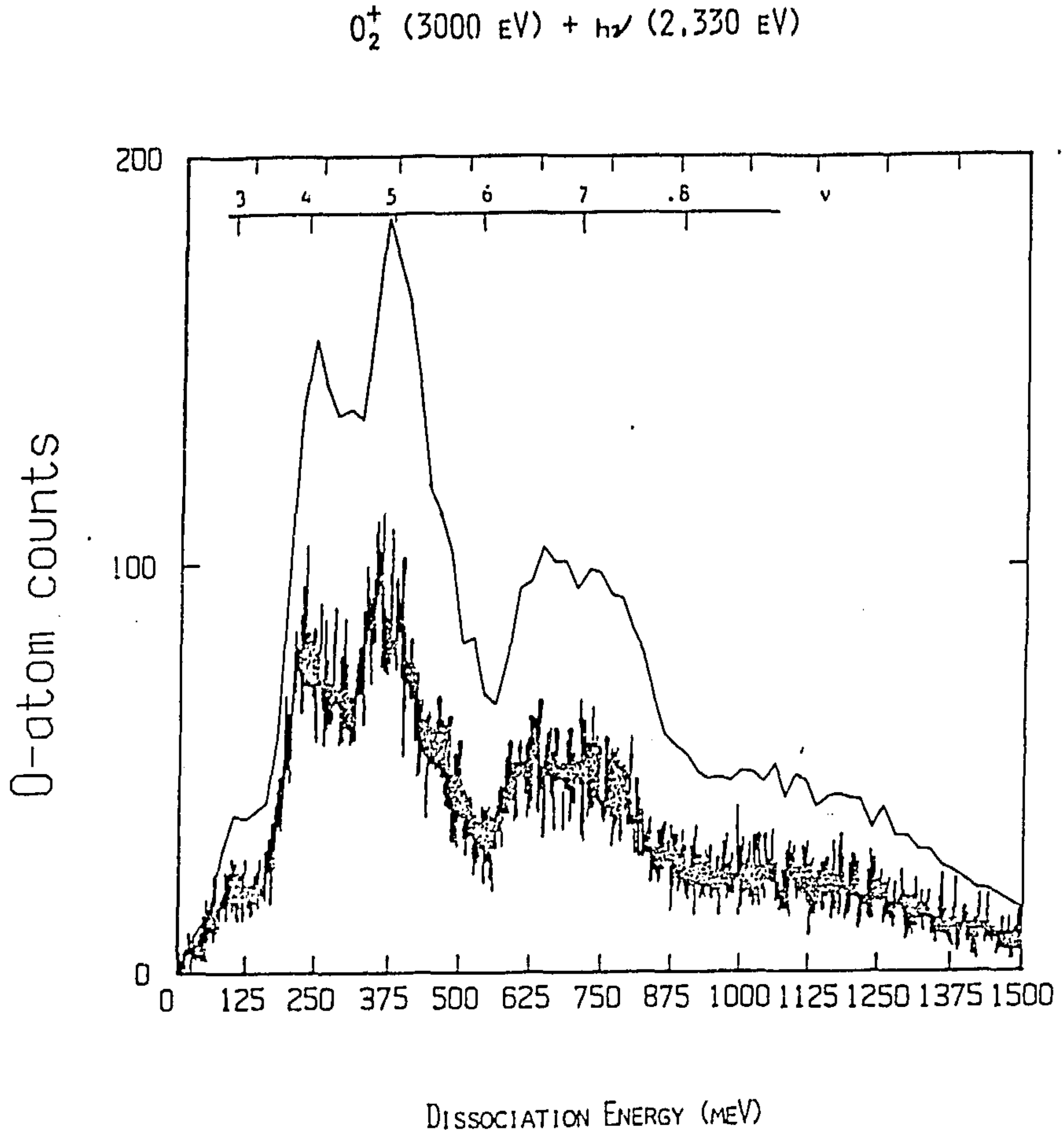

FIGURE 17 SEPARATION ENERGY OF PHOTOFRAGMENTS IN DISSOCIATION OF $O_2^+(a^4\Pi_u)$. BOTH CURVES REPRESENT THE SAME DATA. FOR THE UPPER CURVE, THE DATA ARE SORTED INTO 20meV-WIDE BINS, WHILE FOR THE LOWER CURVE THE BINS ARE 1meV WIDE. THE PEAKS IN THE DATA CORRESPOND TO DISSOCIATION OF DIFFERENT VIBRATIONAL LEVELS NUMBERED ON THE BAR AT THE TOP OF THE FIGURE.

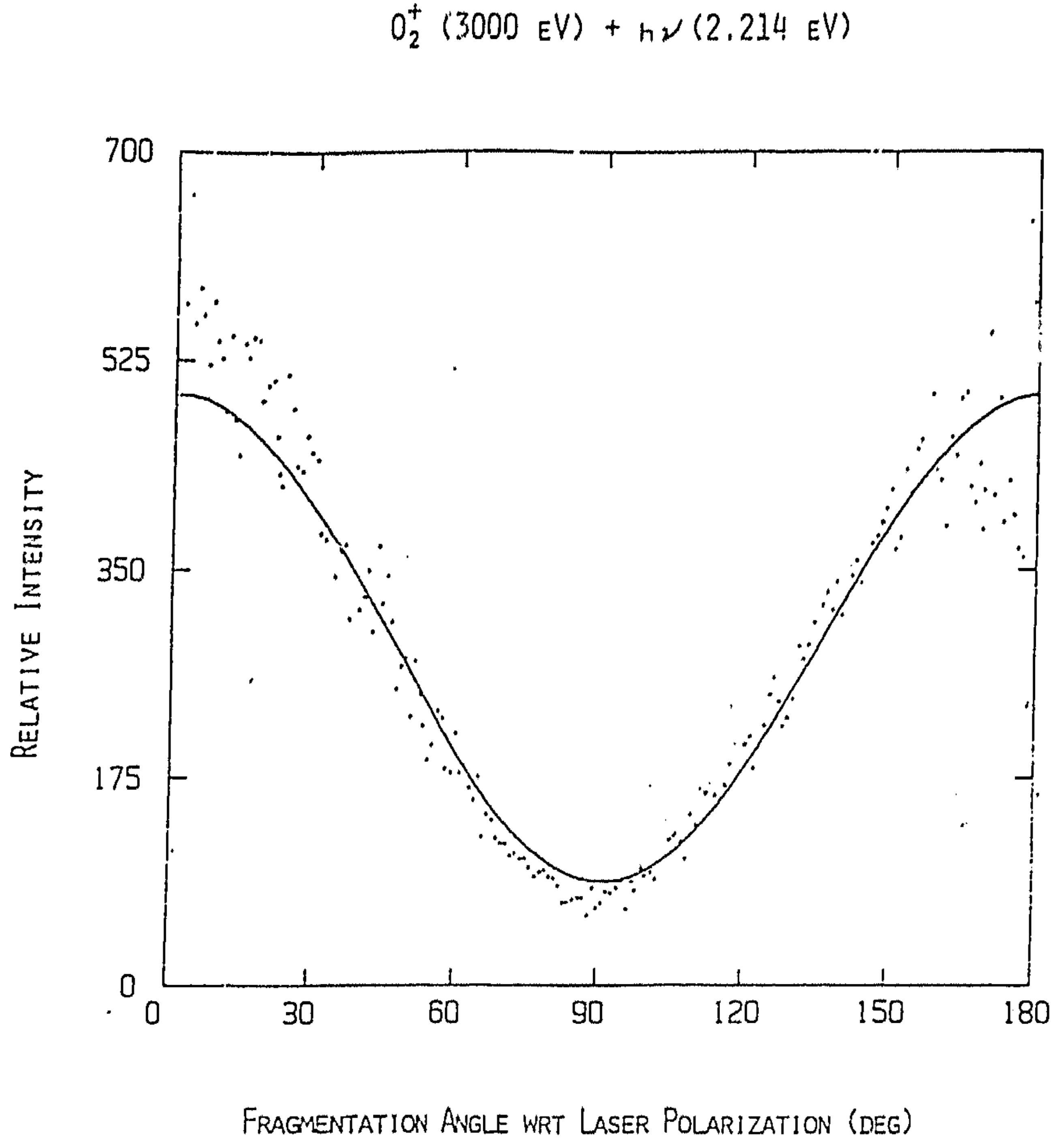

FIGURE 18 AVERAGE ANGULAR DISTRIBUTION OF THE DISSOCIATION VELOCITY VECTOR FOR PHOTODISSOCIATION OF $O_2^+(a^4\Pi_u)$ BY 2.214 eV PHOTONS.

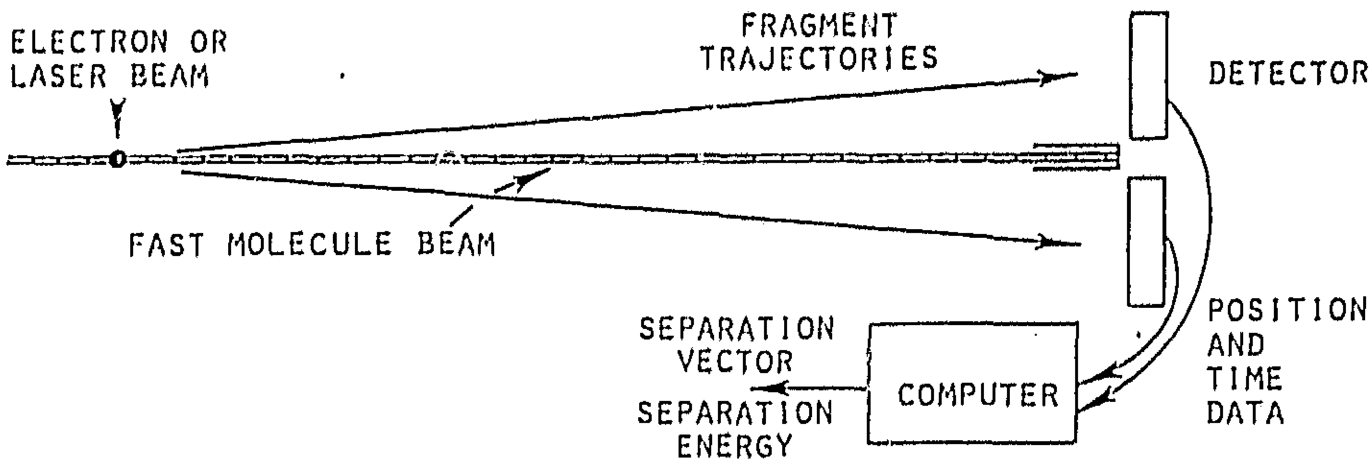

FIGURE 19 2-DETECTOR APPARATUS FOR DISSOCIATIVE PROCESS STUDIES.