# Threshold Photoelectron Source for Ultra-Low-Energy Electron Collision Experiments

We have developed a new experimental technique for measuring the total cross section of ultra-low energy electron collisions with atoms and molecules utilizing synchrotron radiation. The present technique employs a combination of the penetrating field technique and the threshold photoionization of rare gas atoms using synchrotron radiation as an electron source in order to produce a high resolution electron beam at very low energy. The total cross sections for electron scattering from Kr in the energy range from 14 meV to 20 eV are obtained with the new technique. In addition, resonant structures in the total cross sections due to $Kr^-$ $(4p^5 5s^2\ ^2P_{3/2})$ and $Kr^-$ $(4p^5 5s^2\ ^2P_{1/2})$ Feshbach resonances are also observed for the first time.

The scattering of low-energy electrons by atoms and molecules has been the subject of extensive experimental and theoretical investigations. Cross-section data concerning electron-atom or -molecule scattering are of great importance in understanding the fundamental physics of electron collisions and applications such as electron-driven processes in the Earth and planetary phenomena, radiation chemistry, gaseous discharges, plasmas. When the collision energy becomes very low, say below 100 meV, the de Broglie wavelength of electrons becomes very much greater than the typical size of an atom or molecule, and in this fascinating area of "cold electron collisions," quantum effects dominate the outcome of the collisions. Up to now, most of the experimental studies on low-energy electron collisions in the gas phase have been performed with a technique using a hot-filament electron source followed by an electrostatic monochromator. An alternative method is through near-threshold photoionization of atoms by using a photoelectron source, first achieved by Gallagher and York [1]. Making use of this technique, Field, Ziesel and coworkers succeeded in measuring total cross section for electron scattering from various molecules in the cold electron collision regime [2]. One of the experimental difficulties of employing photoelectron sources is the tradeoff between the resolution and the intensity of the electron beam. The electric field applied across the photoionization region degrades the energy resolution of the electron beam. Therefore, it is necessary to narrow the size of the photon beam used for photoionization, but this reduces the intensity of the photon beam for ionization.

Recently, we presented a new method for producing an electron beam with very low energy for cold electron collision experiments by employing a threshold photoelectron source [3]. The method employs a combination of the penetrating field technique and the threshold photoionization of rare gas atoms using synchrotron radiation (SR) as an electron source in order to produce an ultra-low-energy electron beam. An overview of the experimental setup is shown in Fig. 1. The monochromatized SR from BL-20A tuned just at the first ionization threshold of Ar (15.760 eV) was focused on the center of the photoionization cell, which was filled with argon atoms. The threshold photoelectrons produced are extracted by the weak electrostatic field formed by the penetrating field technique and formed into a beam. By tuning the penetrating field, only very-low-energy photoelectrons can be extracted from the photoionization region and formed into the beam, while the energetic photoelectrons rapidly diverge. Therefore this technique produces a highly mono-energetic electron beam even if the bandwidth of the ionization radiation is wide. The technique also has an advantage of weakening the electrostatic field for collecting the photoelectrons in the photoionization region, allowing a fairly large size of photon beam. Thus, the new technique overcomes the tradeoff between the resolution and the intensity of the electron beam. The electron beam from the threshold photoelectron source is focused on the collision cell filled with target gas. The electrons passing through the cell without any collision with the target are detected by a channel electron multiplier (CEM). The counting rates of electrons detected in the presence and absence of target gas are converted to total cross section for electron scattering according to the attenuation law.

The total cross sections for electron scattering from Kr obtained in the energy range of 14 meV – 20 eV in the present experiment are shown in Fig. 2 together with the previous experimental and theoretical total cross sections. In Fig. 2, the well-known Ramsauer-Townsend minimum, which is the pure result of the quantum effect, is seen at around 0.7 eV and the cross section increases gradually, reaching a maximum at around 12 eV, and then decreases slowly with increasing electron energy. At around 10 eV, very sharp structures due to $Kr^-$ $(4p^5 5s^2\ ^2P_{3/2},\ ^2P_{1/2})$ Feshbach resonances are seen on the total cross section curve, as marked with a vertical arrow in the figure. Below the Ramsauer-Townsend minimum, the cross section increases rapidly with decreasing electron energy extending down to the energy range of the cold electron collision regime. In general, the present results agree with the reported experimental data, showing that the present apparatus is performing adequately and is a useful new tool for investigating the physics of cold electron collisions.

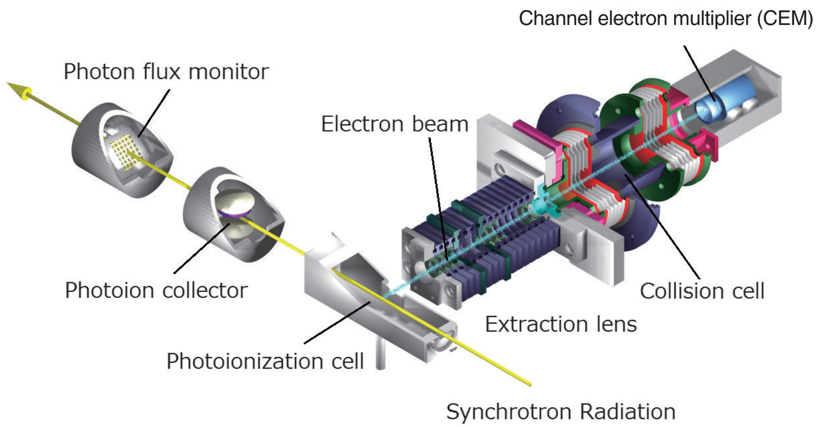


Figure 1
Schematic view of the experimental set-up. The system consists of an electron scattering apparatus with a photoionization cell, a photoion collector, and photon flux monitor of the monochromatized SR.

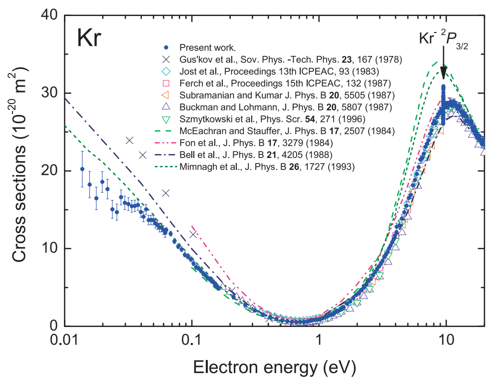


Figure 2
Total cross sections for electron scattering from krypton. The vertical arrow at around 10 eV shows the position of the structure due to $Kr^-$ $(4p^5 5s^2\ ^2P_{3/2})$ Feshbach resonance.

## REFERENCES

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## BEAMLINE

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