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Marmet P & Kerwin L. An improved electrostatic electron selector.
Can. J. Phys. 38:787-96, 1960.
[Centre de Recherches en Physique, Université Laval, Quebec, Canada]

The paper describes an electrostatic electron source giving an energy spread of less than 40 meV that can be operated at an energy as low as 0.5 eV. The best performance obtained previously had been a resolution of 300 meV usable above 7 eV. This instrument led to new discoveries. [The *SCI*® indicates that this paper has been cited in over 215 publications.]

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Long before 1960 it became clear that a monoenergetic electron beam source was needed to study the excitation and ionization mechanisms of atoms and molecules. At that time, electron-scattering experiments and angular correlations with monoenergetic beams were practically unknown. Furthermore, it was impossible then to generate a beam of monochromatic electrons having a continuously adjustable energy covering the range from below 1 eV up to 100 eV. Consequently, things such as the electronic states of negatively charged atoms and molecules, predicted by James Franck as early as 1921,[1] were unknown.

Around 1950 Larkin Kerwin, then professor in the Physics Department at Laval University, was working with his graduate students and developed the idea of constructing the first low-energy cylindrical velocity analyser. His collaborator, E.M. Clarke, developed the first idea, as reported in his PhD thesis in 1954 and published in the *Canadian Journal of Physics*.[2] Later, from 1957 to 1960, Paul Marmet, a new member of the group, made new observations on the behaviour of low-energy electron beams at surfaces that enabled him to build the final instrument described in this paper.

Until 1960 it was not realized that the electron optics developed in 1929 by A.Ll. Hughes and J.H. McMillen[3] would not work in a straightforward way for electron beams at very low energy (below 1 eV). After such a preliminary observation, we aimed to explain this anomaly and to overcome it. There was a preconceived idea that the resolution of an electron beam was limited almost solely by the space charge within the instrument. Of course, the space charge problem exists, but after making many attempts, our experiments indicated that surface phenomena (related to surface charging) due to adsorbed gases were rendering surfaces highly reflective to very slow electrons. Unfortunately, after an initial successful experiment, we had to exercise our patience for a few more months before we could verify the result because the first working apparatus was completely destroyed by fire in 1959.

After the instrument was reconstructed, the high reflectivity of slow electrons at most surfaces was confirmed. We then realized how important this phenomenon was for the quality of the electron beam. As described in the paper, a special geometry had to be found to avoid these reflected electrons.

The instrument is still used today in many laboratories; the authors and others have improved the resolution by greater than another factor of five, following recent technological improvements in materials.

Immediately after its development in 1960, the instrument was widely used for studying electron scattering, leading immediately to several new discoveries.[4] After visiting our laboratory early in 1960 (before the paper was published), George J. Schulz discovered over the next three years, with the help of this new instrument, enhanced vibrational excitation in nitrogen[5] and the first Feshbach resonance in helium.[6] Before the paper's publication, the instrument was also inspected by R.L. Conrod of the Massachusetts Institute of Technology. A review article describing some of the discoveries made primarily by using this instrument appeared in *Physics Today*.[4]

After more than a quarter of a century, new geometries and magnetic analysers have been introduced in order to produce monoenergetic electron beams in new experimental conditions, but the electron selector using the original design with minor modifications is still among the most popular in use today.

[See reference 7 for a recent paper citing this field.]

1. **Franck J & Grotrian W.** Bemerkungen über angeregte Atome (Excited atoms). *Z. Phys.* 4:89-99, 1921.
2. **Clarke E M.** Ionization probability curves using an electron selector: results on N_2^+, N^+, Xe^{++} . *Can. J. Phys.* 32:764-74, 1954. (Cited 95 times since 1955.)
3. **Hughes A Ll & McMillen J H.** Re-focussing of electron paths in a radial electrostatic field. *Phys. Rev.* 34:291-5, 1929. (Cited 160 times since 1955.)
4. **Biondi M A, Herzenberg A & Kuyatt C E.** Resonances in atoms and molecules. *Phys. Today* 32(10):44-9, 1979.
5. **Schulz G J.** Vibrational excitation of L-N_2 by electron impact. *The Second International Conference of the Physics of Electronic and Atomic Collisions*, 12-15 June 1961, Boulder, CO. New York: Benjamin, 1961.
6. ———. Resonance in the elastic scattering of electrons in helium. *Phys. Rev. Lett.* 10:104-5, 1963. (Cited 110 times.)
7. **Drouhin H J & Eminyan M.** Simple concepts in the measurement of the energy distribution and spin polarization of an electron beam. *Rev. Sci. Instr.* 57:1052-60, 1986.