



William N. Lennard, or “Willy” to his friends, is recognized internationally as an experimental innovator in ion beam physics through the impact of research spanning almost 40 years. His careful and thorough methodology has resulted in a plethora of published work that reveals an impressive breadth of knowledge and technical skills, covering investigations with beams of electrons, positrons, light and heavy ions at both low and high velocities and neutrons. He has published results detailing the behavior of Si, Ge and CsI(Tl) charged particle detectors, Si X-ray detectors and channel plates - relating to radiation detection and spectrometry of charged particles and photons (visible, X and  $\gamma$ ).

Born in Toronto, Canada, Lennard earned his B.A.Sc. in engineering science at the University of Toronto in 1969 and then enrolled in an experimental physics (PhD 1974) program at Caltech. Lennard worked with Ward Whaling’s research group using beam-foil spectroscopy with Ni ion beams to investigate the solar abundance of Ni. In Whaling’s research group, students were expected to keep their electrostatic accelerators in good working order. In 1974, a move to the Chalk River Nuclear Laboratories (CRNL, part of the Atomic Energy of Canada Ltd.) saw the beginning of a lifelong inspirational collaboration (and friendship) forged with Ian V. Mitchell, who served as a constant reminder that in science as in life – the high road is the *only* road. Many investigations followed, initially in the field of inner-shell excitation in heavy ion-atom collisions, which was at that time accommodated by molecular orbital promotion theory. In the 1970s, the use of the CRNL 2 MV Pelletron, 2.5 MV Van de Graaff and MP Tandem accelerators produced novel results to explain K-shell X-ray yields observed for both gaseous and solid targets in near-symmetric ion-atom collisions, including “Double K-Vacancy Sharing in Ion-Atom Collisions” [IEEE Trans. Nucl. Sci. NS-26 (1979) 997]. Lennard was one of the first experimentalists to recognize the intrinsic accuracy of theoretical cross sections for  $^1\text{H}$  and  $^4\text{He}$ -induced K-excitation, which were subsequently used to measure the “Absolute Photopeak Efficiency for a Si(Li) Detector: 0.52-8.04 keV” in a seminal publication [Nucl. Instr. and Meth. 166 (1979) 521].

The 1980s brought links with the CRNL nuclear physicists, particularly D. Ward, G.C. Ball and T.K. Alexander, and an intense period of measurement of low energy stopping powers using time-of-flight methods. With the onset of a 2-year visit by H. Geissel (GSI, Germany), the search for a *universal* stopping power prescription was expanded to include energy loss straggling and angular/charge state distributions. Using the same experimental equipment, Lennard found an empirical relationship to explain the “Non-Linear Response of Si Detectors for Low-Z Ions” [Nucl. Instr. and Meth. in Phys. Res. A 248 (1986) 454] that has always been experimentally confirmed but for which no adequate theoretical explanation has yet been posited.

The demise of some areas of basic research at CRNL in 1986 brought a refreshing change of scenery as several scientists moved en bloc to the University of Western Ontario (London, Ontario, Canada), together with the Van de Graaff accelerator, followed soon after by the acquisition of a 1.7 MV High Current Tandem for heavy ions. Initially, Lennard moved to ion-induced Auger electron spectroscopy together with positron-induced inner-shell excitation studies using a novel technique whereby the Au window of the Si(Li) X-ray detector served as a target for “Observation of the Difference Between  $e^-e^-$  and  $e^+e^-$  Interactions” [Phys. Rev. Lett. 61 (1988) 2428]. Funding realities now dictated an emphasis on ion beam analysis studies relevant to materials composition and structure studies – a burgeoning field in several international laboratories and of vital importance to several key industries. Close collaborations ensued with L.C. Feldman and M.L. Green (Bell Labs/Lucent) relating to ultrathin silicon oxynitride gate dielectric materials where trace nitrogen contamination was an issue. Lennard and Len Feldman developed an ultrasensitive nuclear reaction technique that enabled depth profiling via step-etching for sub-monolayer  $^{14}\text{N}$  concentrations using the  $^{14}\text{N}(d,\alpha)^{12}\text{C}$  reaction [Appl. Phys. Lett. 64 (1994) 3473] that remains the ‘gold standard’ for quantitative  $^{14}\text{N}$  analysis to this day. Lennard was somewhat concerned that the ion beam research field was becoming too applications-oriented, and succeeded in organizing the “Atomic Collisions in Solids” conference in London, Canada, in 1993 to maintain the ties of his group to the basic ion-atom collision phenomena.

It was during this period that Lennard, Ian Mitchell and John Davies were persuaded to put together an informative chapter in the new Ion Beam Handbook dealing with “Pitfalls of Ion Beam Analysis” (Materials Research Society, 1995) which pointed out several subtle issues that could materially impact the quantitative accuracy of charged particle induced ion beam analysis techniques. This article, reflecting almost 100 years of ion beam knowledge, which the three authors together had amassed, still serves as an enduring ‘bible’ to new students and researchers in many laboratories.

With the help of students, Lennard succeeded in solving a problem that the PIXE pundits asserted was not possible - “SPIX: A New Technique for Quantitative Surface Spectroscopy Applied to S/InP(001)” [Appl. Surf. Sci. 103 (1996) 289] - whereby a single monolayer of sulphur was quantitatively measured on an InP substrate using a modest resolution Si(Li) X-ray detector through an innovative geometrical setup.

There were always opportunities to solve problems, and the so-called RUMP puzzle was a particularly stubborn one that had plagued elastic scattering measurements for Si-based materials for some time. “Improved Stoichiometry Measurements Using  $^4\text{He}$  Elastic Backscattering: Experiment and Simulation” [Nucl. Instr. and Meth. in Phys. Res. B152 (1999) 370] clarified this enigma, and Lennard and his student, Chris McNorgan, produced user-friendly elastic scattering simulation programs which are still distributed gratis at his website.

Lennard has been continuously supported by NSERC (Canada) with an individual research grant since 1987 and has co-authored over 175 scientific articles since 1972. During the period of 1996-2006, Lennard served as Chairman of the Board of Directors for IsoTrace – Ted Litherland’s AMS laboratory located at Lennard’s alma mater. Lennard has always believed in the important role of serendipity in his own research endeavors, but probably his peers would suggest that careful and thorough measurement practices – not just good luck - lay at the root of all his innovative works. Lennard semi-retired in 2006 due to health issues; he continues with a reduced research program focusing on thin film growth and serves as a valuable mentor for many graduate students.

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