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This Week's Citation Classic

Blaugrund A E. Notes on Doppler-shift lifetime measurements.
Nucl. Phys. 88:501-12, 1966.
[Argonne National Laboratory, Argonne, IL]

Using Lindhard's[1] atomic collision theory, the velocity and the average scattering angle of a nucleus slowing down in matter were calculated. It was shown that the effect of large angle scattering on the Doppler shift of gamma rays emitted during flight can be important and should be taken into account while deducing level lifetimes from the measured Doppler shifts. [The *SCI*®indicates that this paper has been cited in over 530 publications since 1966.]

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"During 1965, I was on a year's sabbatical leave from the Weizmann Institute, working at the Argonne National Laboratory. In my PhD research and during the postdoctoral period I had measured short lifetimes of excited states of nuclei using the microwave method which I had developed. This involved the use of fairly complex hardware which had taken a long time to build and to debug. Upon my arrival in Argonne I soon realized that if I wanted to accomplish anything during the short time available, I would have to stick to simple experiments. Measuring nuclear level lifetimes by the Doppler shift attenuation method[2] seemed just such an experiment. In this method the excited nucleus is produced in a nuclear reaction and in the process it acquires a high recoil velocity. The recoiling nucleus is slowed down and eventually stopped by the target or backing material. The slowing down time usually is of the order of 10^{-13}s-10^{-12}s. If the nucleus emits a gamma ray in a forward or backward direction before it stops, the energy of the gamma ray is Doppler shifted. A measurement of this Doppler shift, together with the knowledge of the angular distribution of the recoils and of the slowing down time, gives the lifetime of the level. All that is needed for such a measurement is a beam from an accelerator populating the required level in target nuclei and a high resolution Ge(Li) gamma ray spectrometer. Data on angular distributions of the recoiling nuclei necessary for the analysis can usually be found in the literature and the slowing down process had been treated numerous times in the past, both theoretically and experimentally.

"I got the experimental setup going and, together with a few colleagues, we started turning out raw data which looked great and promised, after analysis, to yield a host of new lifetimes. The analysis seemed straightforward and the available computer programmes were more than adequate for the necessary line shape fitting and unfolding. But at some point it struck me that a certain detail in the slowing down process had been overlooked. The energy loss of the recoiling nucleus is mostly due to collisions with electrons. Collisions with target nuclei contribute little to the slowing down process. However, in such collisions, especially with heavy nuclei, very large angle scattering may occur which could considerably reduce the Doppler shift of the emitted gamma ray or even reverse its sign. It seemed to me that in some cases this effect could significantly modify the lifetimes derived from our measurements.

"In between two scheduled runs on the accelerator I dug into the literature, and using the theory of atomic collisions of Lindhard *et al.*,[1] I set out to investigate the effect of large angle scattering on the Doppler shift. For once I did not need a laboratory to do my work. I spent long nights and weekends working at home. Needless to say, my family was not very pleased by this state of affairs, but I managed to appease them with promises of future picnic trips. When I finally succeeded in deriving expressions for the attenuated Doppler shift, which included the effect of large angle scattering, it became obvious that in some experiments this effect was indeed far from negligible.

"The then wide use of the Doppler shift method combined with the relative simplicity of the expressions which I had derived probably contributed to the widespread use and high citation of the formalism by the nuclear physics community.

"A fairly recent and comprehensive review of work in this field can be found in 'The measurement of the lifetimes of excited nuclear states.' "[3]

1. **Lindhard J, Scharff M & Schiøtt H E.** Range concepts and heavy ion ranges (notes on atomic collisions, II). *Mat. Fys. Medd. Dan. Vid. Selsk.* 33(14):3-42, 1963.
2. **Devons S, Manning G & Bunbury D St. P.** Measurement of γ-transition lifetimes by recoil methods. *Proc. Phys. Soc. A* 68:18-31, 1955.
3. **Nolan P J & Sharpey-Schafer J F.** The measurement of the lifetimes of excited nuclear states. *Rep. Progr. Phys.* 42:1-86, 1979.

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