Multiple scattering of slow muons in an electron gas

Claudio Archubi* [1], Diego Arbó* , and Nestor R. Arista†

* Instituto de Astronomía y Física del Espacio, Universidad de Buenos Aires, Ciudad Universitaria, 1428 Buenos Aires, Argentina
† División Colisiones Atómicas, Centro Atómico Bariloche, 8400 S. C. Bariloche, Argentina,

Synopsis We have performed a study of velocity threshold effects in the angular dispersion of slow muons in an electron gas using different dielectric models and a non-linear model to represent metals and band-gap materials.

With the advent of low energy muon beams capable of stopping in thin layers of crystalline material it becomes important to know the depth distribution of these muons in order to properly interpret muon spin rotation experiments. These experiments are performed to learn more about the surrounding dipole contributions and the nature of local magnetic field distribution of a crystalline sample. Recent computational simulations [1] conclude that channeling conditions may increment the penetration depth, but these simulations do not take into account the importance of the multiple scattering of the projectile with the electrons of the channel.

In a previous work [2] we developed a formalism based on the theory of multiple scattering and the calculus of the elastic scattering cross section for a dielectric model. Using this formalism, we aim here to describe the behaviour of the half width of the angular dispersion of muons with a material characterized in terms of different dielectric approaches which represent the cases of metals (Lindhard free electron gas model), semiconductors and insulators (Levine and Louie model [3] and Brandt and Reinheimer model [4] for systems with an energy band gap Eg). However, at low velocities non-linear effects become important. So we have incorporated the results using the non-linear approach [2], which applies also in the cases of very strong screening and large scattering amplitudes, and reduces to the linear treatment when the magnitude of the perturbation is small. The non-linear approach is based on transport cross section calculations according to quantum scattering theory.

Figure 1 shows the results for the half width $\alpha_{1/2}$ of the angular dispersion as a function of the projectile velocity for two different cases. For velocities lower than 1 a.u. the dispersion becomes important as the half width raises to several degrees, increasing the probability of dechanneling. However, in insulators and semiconductors this effect is attenuated by the sudden decreasing of the dispersion near the velocity threshold.

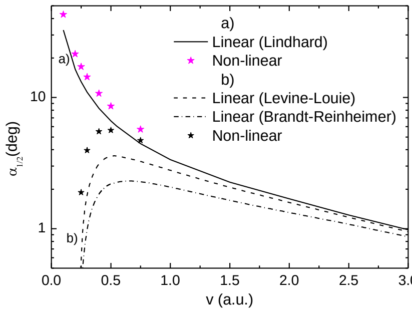

Figure 1. Muons traversing an electron gas target of width 800 a.u. with r_s.=1.5 a.u. for two cases: a) Eg=0 eV (Lindhard dielectric model and non-linear model) , b) Eg=14 eV (Levine and Louie and Brandt-Reinheimer dielectric models and non-linear model) The velocity threshold for this case is v=0.21 a.u.

References

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[1] E-mail: archubi@iafe.uba.ar