**IT-16-P-1553** Rutherford scattering of electron vortices

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Vortex beams have been met with great interest in various fields like optics, telecommunication, acoustics, and more recently in electron microscopy. Recently, techniques for the manipulation of the electron wave's phase have received a boost. Electron vortex beams show promise as a new tool to detect material properties at the nanoscale in a novel way. One feature which might contribute is the additional magnetic moment induced by a vortex electron's orbital angular momentum (OAM).

Theoretically, various studies have been done describing free space electron vortices and how they behave in electromagnetic fields. Relativistic aspects and the electron spin coupling to the OAM have also been considered. On the other hand, basic scattering theory with electron vortex beams has not yet been fully understood, and that is why elastic scattering of an electron vortex beam on a screened Coulomb potential is considered here. This work introduces the incoming beam's OAM (and associated transverse momentum) into the first Born approximation of quantum scattering theory. The influence of a beam's OAM and corresponding spatial shape on the elastic scattering amplitude has been analyzed using the derived analytical formula.

Using the results here, we can propose scattering experiments in which high values of transverse momentum of the initial beam expose these novel features, proving the treatment here lives up to its intent: generalize plane wave scattering to cylindrically symmetric beams, including those with OAM. With this result established, more complicated scattering amplitudes can be calculated, leading to a complete electron vortex scattering theory.

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Fig. 1: Schematic of the convergent beam scattering experiment. The relation of the transverse momenta and the aperture dimensions is shown, and an on-axis pinhole detector is shown.

Fig. 2: Transverse wave functions for the Bessel, aperture far field, and Laguerre-Gaussian beams. They all contain a first order vortex. The Laguerre-Gaussian has two intensity lobes (n=2), clearly showing the strongest localization of the three in the transverse plane.

Fig. 3: Elastic Coulomb scattering amplitude for fixed transverse momentum, and several values of OAM.

Fig. 4: Zeroth order elastic scattering amplitude for several values of the transverse momentum. The limit to the plane wave result is clearly visible.