Relativistic Dispersion Relation for Electrons

University of Chicago, July 14–16, 2017

(This is ONE of the THREE experiments that each participant is to perform.)

Mentor

David McCowan completed his B.S. in 2007 at Ohio University, then continued at the University of Chicago where he received an M.S. in 2008 and a Ph.D. in 2014 based on research in liquid-to-glass transition theory. Since 2015, he has been an Assistant in the Instructional Laboratories of the Department of Physics at the University of Chicago developing, maintaining, and implementing introductory and advanced experiments for both undergraduate and graduate students. During this time, David has worked with his colleagues on several projects including incorporating python scripting into the advanced labs curriculum, developing an online wiki of the lab manual and supplementary material, and revamping the graduate experimental lab course structure.

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Direct tests of special relativity are rare in the undergraduate laboratory as they often require large and expensive particle accelerators. In this experiment, we will use a gamma detection technique to measure both the kinetic energy and momentum of electrons produced during Compton scattering. In addition to “discovering” the energy-momentum dispersion relation for electrons, we will measure the electron’s rest mass and compare this value to literature.

The apparatus: High purity germanium gamma detector in liquid nitrogen, NIM bin with high voltage power supply and amplifier, oscilloscope, pulse height analyzer, and computer. Gamma sources not shown. (Click on photo for a higher resolution view.)

Skills that will be acquired include: understanding nuclear decay schemes; the acquisition and interpretation of gamma spectra from a germanium gamma detector, and the interpretation of data using non-relativistic and relativistic models.

This experiment takes one of the three days. This day will be used to learn the physics of the detection process, calibrating the detection system, gathering gamma spectra, interpreting the spectra and extracting the energy-momentum relation for free electrons. Use will be made of nuclear decay schemes, gamma sources, a germanium gamma detector, scope, pulse height analyzer and related software. Plots will be made to reveal relativistic behavior.

Participants should bring a lab notebook. A laptop computer would be useful but is not required.

Instruction will be given on proper use of radioactive sources, liquid nitrogen and high voltage power supply.

The cost to implement the experiment is roughly $15,000, or somewhat less if purchased used.

Please note that the Jonathan F. Reichert Foundation has established a grant program (ALPhA webpage; Foundation website) to help purchase apparatus used in Laboratory Immersions. Limitations and exlusions apply, but generally speaking the foundation may support up to 40% of the cost of the required equipment.