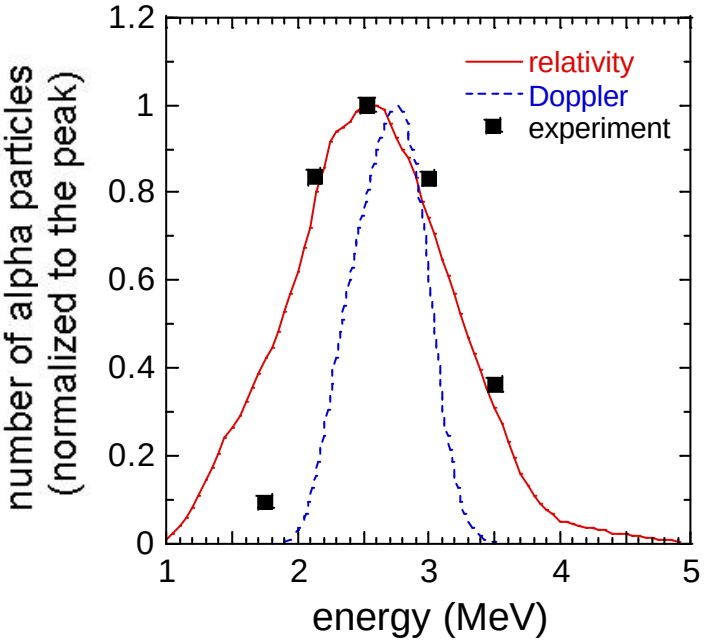
Plasma Study Shows Critical Role of Relativity in Dynamics of Low-Energy Alphas

Albert Einstein gave a famous equation, $E = mc^2$, in his theory of relativity, where $m = g\, m_0$ and m_0 is the rest mass. While $g - 1 << 1$, it becomes $E - m_0 c \cong \frac{1}{2} m v^2$, as in Newton mechanics. It is generally believed that the relativity is important when the kinetic energy is high (i.e., $g - 1$ is not small). K. R. Chen of Physics Department of National Cheng Kung University in Taiwan will report his results showing that the relativity plays a critical role in the dynamics of low-energy alpha particles (e.g., with the kinetic energy of 3.5 MeV corresponding to $g - 1 = 0.00093$) in magnetized plasmas. His results from Monte-Carlo and particle-in-cell simulations were compared with a recent tokamak experiment of Princeton Plasma Physics Laboratory. The alpha particles circulate the magnetic field with its cyclotron frequency inversely proportional to its mass. Because of the relativity, the frequency is not constant so that they resonant with the collective waves in the plasma and the slow ions. The resultant relativistic instability Chen proposed earlier is found to be crucial in shaping the birth and slowed-down spectrums. This effect has led to good agreement with both the spectral width and the energy of peak density obtained from the experimental measurement, as shown in the figure below.



The experimental data, and the calculated alpha energy spectrums based on the relativistic effect or the classical Doppler effect.

Plasma is among the earliest studied strongly coupled systems, as the development of modern physics has progressed from few body systems into many body systems in which strongly coupled effects dominate. Plasma physics research has laid the physics and mathematical foundation for studies of nonlinear phenomena in practically every field of modern physics, and has resulted in many critical applications. This study on the role of relativity for low-energy alphas adds one outstanding example of many fundamental phenomena in physics led by the studies of collective effects in plasmas.

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