Compton Scattering

In 1923, the particle-like nature of photons was confirmed via an experiment that measured the wavelength (and thus the frequency and thus the energy) of scattered light as a function of scattering angle. In classical theory, the electromagnetic wave would scatter just as a water wave around an island, changing it’s direction and intensity, but not it’s wavelength. Compton’s experimental setup and data are shown below.

Now, given that the mass of a photon is zero (because of relativity and since its velocity is c), and the equation for the total relativistic energy: $E^2 = c^2 p^2 + (m_0 c^2)^2$, this leads us to the relation that for a photon, $p = E/c = h \nu/c$, or $p = h/\lambda$. Assuming that the photons are scattering off the electrons in the scattering material (since the results were independent of material), then one can write down the relativistic equations for energy and momentum conservation we can determine the change in wavelength for a scattered photon with scattering angle $\theta$:

$$\Delta \lambda = \frac{h}{m_e c} (1 - \cos \theta)$$

This equation accounts for the shifted peak precisely. The stationary peak is accounted for by assuming scattering off the entire atom (or a deeply bound electron), which means that the mass in the above formula is several thousand times larger and hence the shift in wavelength is negligible. This was considered irrefutable proof of the particle nature of photons.