Rutherford's incredible event

This is a passage from Ernest Rutherford's 1936 lecture, "The Development of the Theory of Atomic Structure."[1]

… I would like to use this example to show how you often stumble upon facts by accident. In the early days I had observed the scattering of α-particles, and Dr Geiger in my laboratory had examined it in detail. He found, in thin pieces of heavy metal, that the scattering was usually small, of the order of one degree. One day Geiger came to me and said, "Don't you think that young Marsden, whom I am training in radioactive methods, ought to begin a small research?" Now I had thought that too, so I said, "Why not let him see if any α-particles can be scattered through a large angle?" I may tell you in confidence that I did not believe that they would be, since we knew that the α-particle was a very fast massive particle, with a great deal of energy, and you could show that if the scattering was due to the accumulated effect of a number of small scatterings the chance of an α-particle's being scattered backwards was very small. Then I remember two or three days later Geiger coming to me in great excitement and saying, "We have been able to get some of the α-particles coming backwards…". It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you. On consideration I realized that this scattering backwards must be the result of a single collision, and when I made calculations I saw that it was impossible to get anything of that order of magnitude unless you took a system in which the greater part of the mass of the atom was concentrated in a minute nucleus. It was then that I had the idea of an atom with a minute massive centre carrying a charge.

[1] in *Background to Modern Science: Ten Lectures at Cambridge Arranged by the History of Science Committee, 1936*, ed. Joseph Needham and Walter Pagel (Macmillan, 1938), pp. 68–9.

What did Rutherford show?

At the turn of the century, there was little known about atoms except that they contained electrons. J.J. Thompson discovered the electron in 1897, and there was considerable speculation about where these negatively charged particles existed in nature. Matter is electrically neutral; some positive charge must balance the charge of the electron. One popular theory of the time was called the 'plum pudding model'. This model, invented by Thompson, envisioned matter made of atoms that were spheres of positive charge spiked with electrons throughout. Electrons were chunks of plum distributed through a positively charged sphere of pudding.

In 1911, Ernest Rutherford performed an experiment to test the plum pudding model. He fired energetic α [He2+] particles at a foil, and measured the deflection of the particles as they came out the other side. From this he could deduce information about the structure of the foil. To understand how this works, imagine shooting a rifle at a mound of loose snow: one expects some bullets to emerge from the opposite side with a slight deflection and a bit of energy loss depending on how regularly the pile is packed. One can deduce something about the internal structure of the mound if we know the difference between the initial (before it hits the pile) and final (after it emerges from the pile) trajectories of the bullet. If the mound were made of loose, powdery snow, the bullets would be deflected very little; if the bullets were deflected wildly, we might guess that there was a brick of hard material inside.

Rutherford expected all of the particles to be deflected just a bit as they passed through the plum pudding. He found that most of the α's he shot at the foil were not deflected at all. They passed through the foil and emerged undisturbed. Occasionally, however, particles were scattered at huge angles. While most of the α's were undisturbed, a few of them bounced back directly. Imagine if something like this happened at our mound of snow. We shoot bullets at the pile for days, and every round passes straight through, unperturbed – then a bullet hits the snow, reflects back, and splinters the gun's stock! Rutherford's result lead him to believe that most of the foil was made of empty space, but had extremely small, dense lumps of matter inside. No other model accounted for the occasional wide angle scattering of the α. With this experiment, Rutherford discovered the nucleus.[2]

2 http://www.physics.rutgers.edu/meis/Rutherford.htm