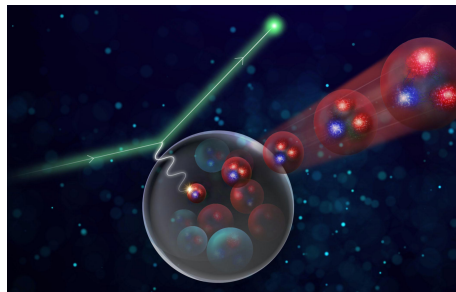


One of the essential tools for probing the structure of matter is scattering. Two sub-atomic particles collide and the properties of the debris tell us about the forces. In the figure an incident electron in green knocks a proton out of an atomic nucleus. The quarks making up the proton are visible. If we can select events that are elastic (no kinetic energy lost in the collision), then we can 'see' the internal structure of the nucleon.



What is the energy of the scattered electron in terms of the incident/beam energy of the electron and angle θ with respect to the beam direction?
How would you select these particles?

• QUARKS!!

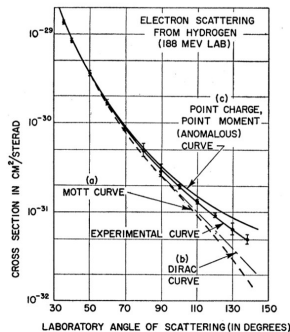


FIG. 5. Curve (a) shows the theoretical Mott curve for a spinless point proton. Curve (b) shows the theoretical curve for a point proton with the Dirac magnetic moment, curve (c) the theoretical curve for a point proton having the anomalous contribution in addition to the Dirac value of magnetic moment. The theoretical curves (b) and (c) are due to Rosenbluth.⁸ The experimental curve falls between curves (b) and (c). This deviation from the theoretical curves represents the effect of a form factor for the proton and indicates structure within the proton, or alternatively, a breakdown of the Coulomb law. The best fit indicates a size of 0.70×10^{-13} cm.

McAllister and Hofstadter, PR 102, 851 (1956)

- QUARKS!!
- MESONS!!

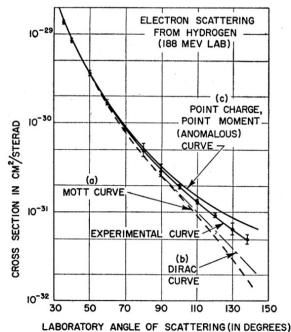


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- QUARKS!!
- MESONS!!
- GLUONS!!

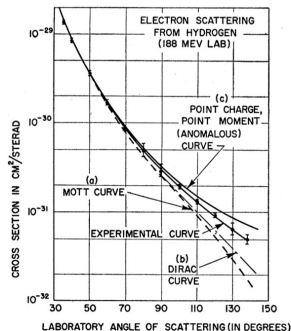


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- QUARKS!!
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- GLUONS!!



Robert Hofstadter, Nobel Prize 1961

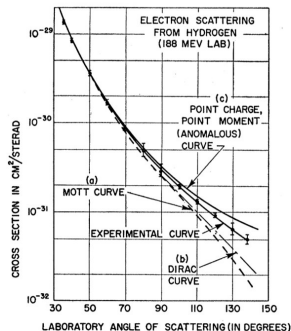


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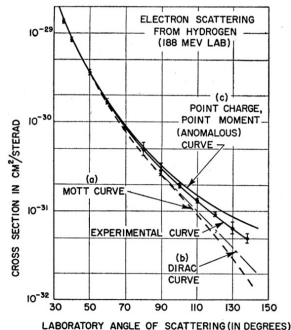


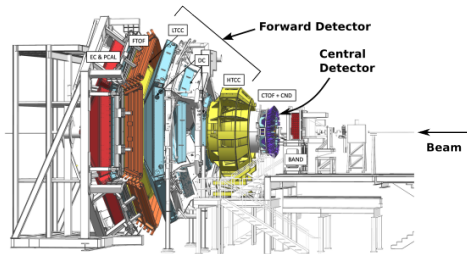
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McAllister and Hofstadter, PR 102, 851 (1956)



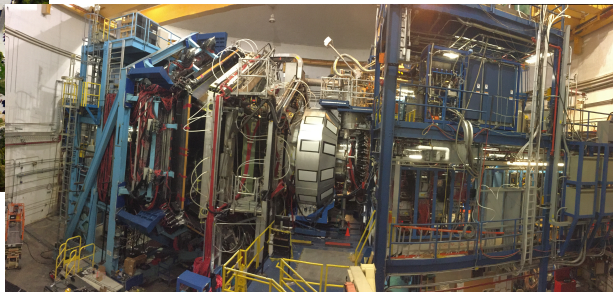
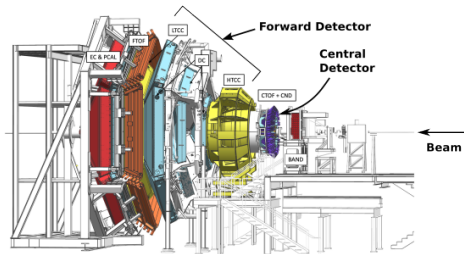


CLAS12 Detector



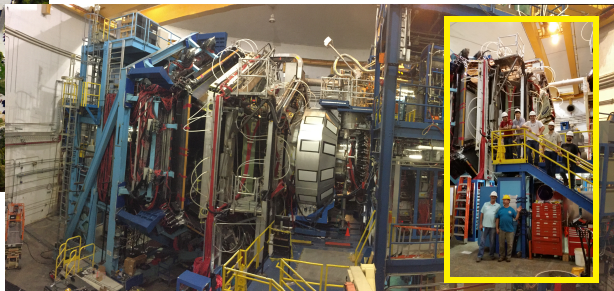
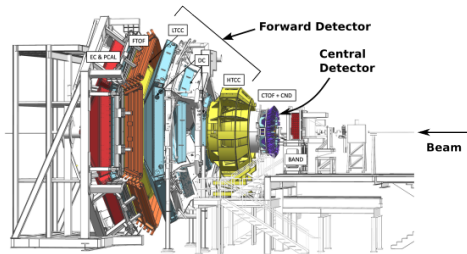


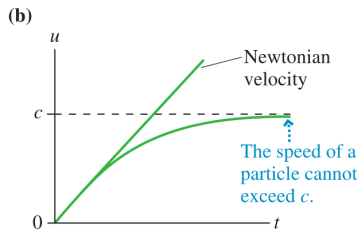
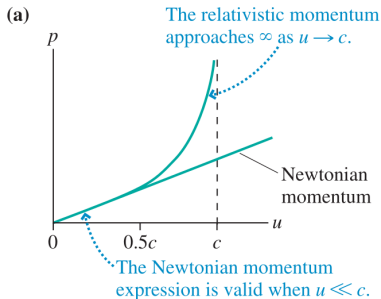
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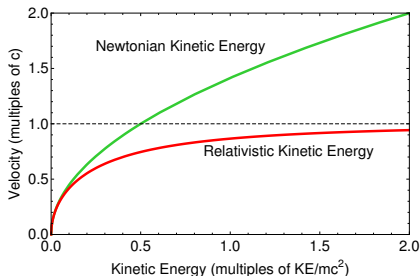


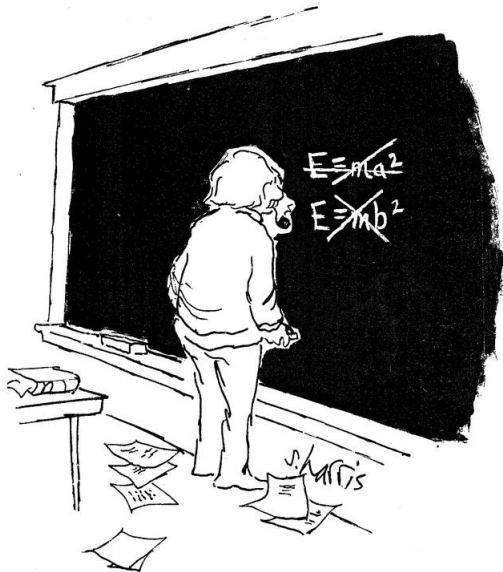
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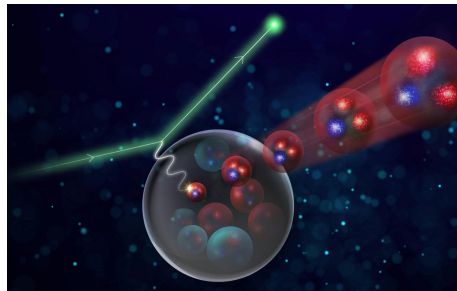


An electron is accelerated to an energy $E = 10.6 \text{ GeV}$ where $1 \text{ GeV} = 10^9 \text{ eV}$ at the Thomas Jefferson National Accelerator Facility in Newport News. What is the electron's speed and kinetic energy?

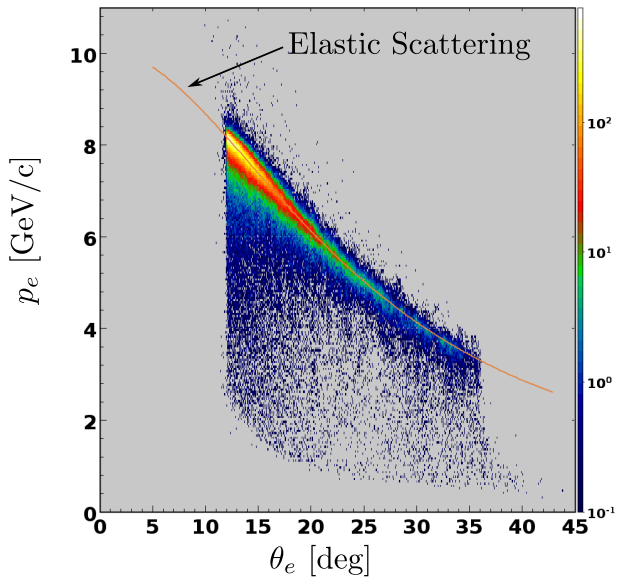




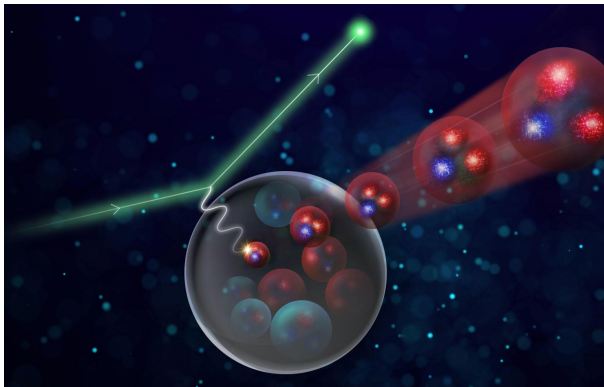
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What is the scattered electron energy in terms of the incident electron beam energy and the electron angle θ with respect to the beam direction? What is the energy of a scattered electron at $\theta = 10^\circ$? How would you select these particles?



What is the energy and angle of the scattered proton?



What We Get From Scattering Experiments 18

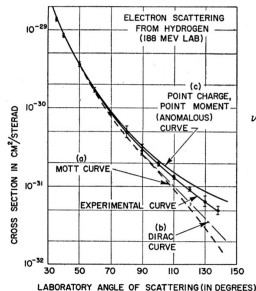
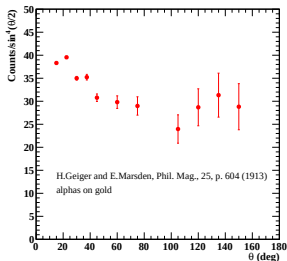


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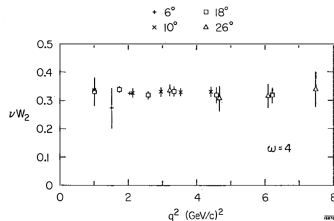


FIGURE 17. νW_2 for the proton as a function of q^2 for $W > 2$ GeV, at $\omega = 4$. Results from (7, 8, and 49).

$$E_{e'} = \frac{E_e}{1 + \frac{2E_e}{m_n} \sin^2 \left(\frac{\theta_e}{2} \right)}$$

$$p_{n'} = \frac{2m_n \cos \phi (1 + m_n/E_e)}{1 + \frac{m_n^2}{E_e^2} + \frac{2m_n}{E_e} - \cos^2 \phi}$$

