OLYMPUS

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Theory

- In theory, if we know everything about the proton, we should be able to obtain an analytic expression for the form factors.
- Advances in lattice QCD techniques are getting us closer and closer to this goal, and results are expected in the foreseeable future...
- In the meantime, however, theories can’t help much.

Polarised Scattering

- The factors $G_E$ and $G_M$ can also be determined by performing scattering experiments using polarised particles.
- For example when polarised electrons are scattered off unpolarised protons, polarisation transfer occurs to the proton with two components — parallel ($P$) and perpendicular ($P')$ to the proton momentum in the scattering plane. In fact:

$$G_E = \frac{P}{P'} \frac{(E + E')}{(E - E') \tan \frac{q}{2}}$$

- Similarly, carrying out $e^- p$ scattering with spins aligned and anti-aligned and measuring the difference in cross sections (the scattering asymmetry) allows us to determine the form factors.

- A crucial aspect of these experiments is that they only occur when a single photon is transferred in the interaction.

Results

Current data indicates that both electric and magnetic form factors have the same dipole distributions. $G_E/G_M = \frac{G_E}{G_M} = 1$.

Such form factors indicate that charge is concentrated in the centre of the proton, and decreases exponentially.

Practical Details

- Measurements of this kind have already been made, but at low energy (~500 MeV) and with poor precision. The aim of OLYMPUS is to make measurements in the 2 GeV range with 1% precision.

- Getting the Particles -
  The experiment will use the DORIS storage ring at DESY in Hamburg, Germany. Because (1) it can be used to store both $e^-$ and $e^+$ at high energies and (2) the beams can be switched from $e^-$ to $e^+$ in under an hour. The experiment would involve installing an unpolarised hydrogen gas target at the storage ring.

- Detecting the Particles -
  The experiment will use the BLAST (Bates Large Angle Scattering) detector from the MIT-Bates accelerator. It is optimally designed for 1-2 GeV elastic ep scattering because of its toroidal shape (the beam can be located in the centre of the detector) and its drift chambers. Only problem—it’s over 3700 miles away!

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Experiments

- A crucial assumption in deriving the Rosenbluth formula was that the Born approximation applied (i.e. only one photon was involved in the interaction).
- Polarisation transfer only occurs in one-photon processes, and does not rely on this approximation.
- The idea is that the cross-section measurements are polluted by second-order interactions. These render the resulting form-factors meaningless, because the entire (already doubtful) interpretation of these measurements as Fourier transforms of the charge distribution relies heavily on the assumptions that only single-photon processes are involved.