Global Analysis of the Neutron Magnetic Form Factor

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Abstract

Protons and neutrons, the nucleons, are made up of smaller particles called quarks. Nucleons have three valence quarks, which are the dominant contributors to its properties, as well as sea quarks (quark-antiquark pairs) and gluons. The distribution of the charge and magnetization of these particles is described by the electric and magnetic form factors. These form factors can be measured with scattering experiments since they directly affect the particle's cross section. Neutron form factors are tricky to measure because a pure neutron target will decay very fast and is not viable for experiments. Instead, targets like ^{2}H and ^{3}H are used. However, the proton in these targets introduces large uncertainties. New data for the neutron magnetic form factor has been found using a method that uses mirror nuclei ^{3}H and ^{3}He and relies on canceling uncertainties in the ratio of cross sections of both nuclei. With this new data, we create a new global fit of the neutron magnetic form factor that agrees with both the new and old data.

Background

- Electric and magnetic form factors directly affect the cross section of the particle, so the form factors can be measured with scattering experiments.
  - In most experiments measuring neutron form factors, an electron is accelerated to high energies, typically measured in GeV.
  - When the electron collides with the target, it exchanges some momentum. This momentum transfer is referred to as Q^2.

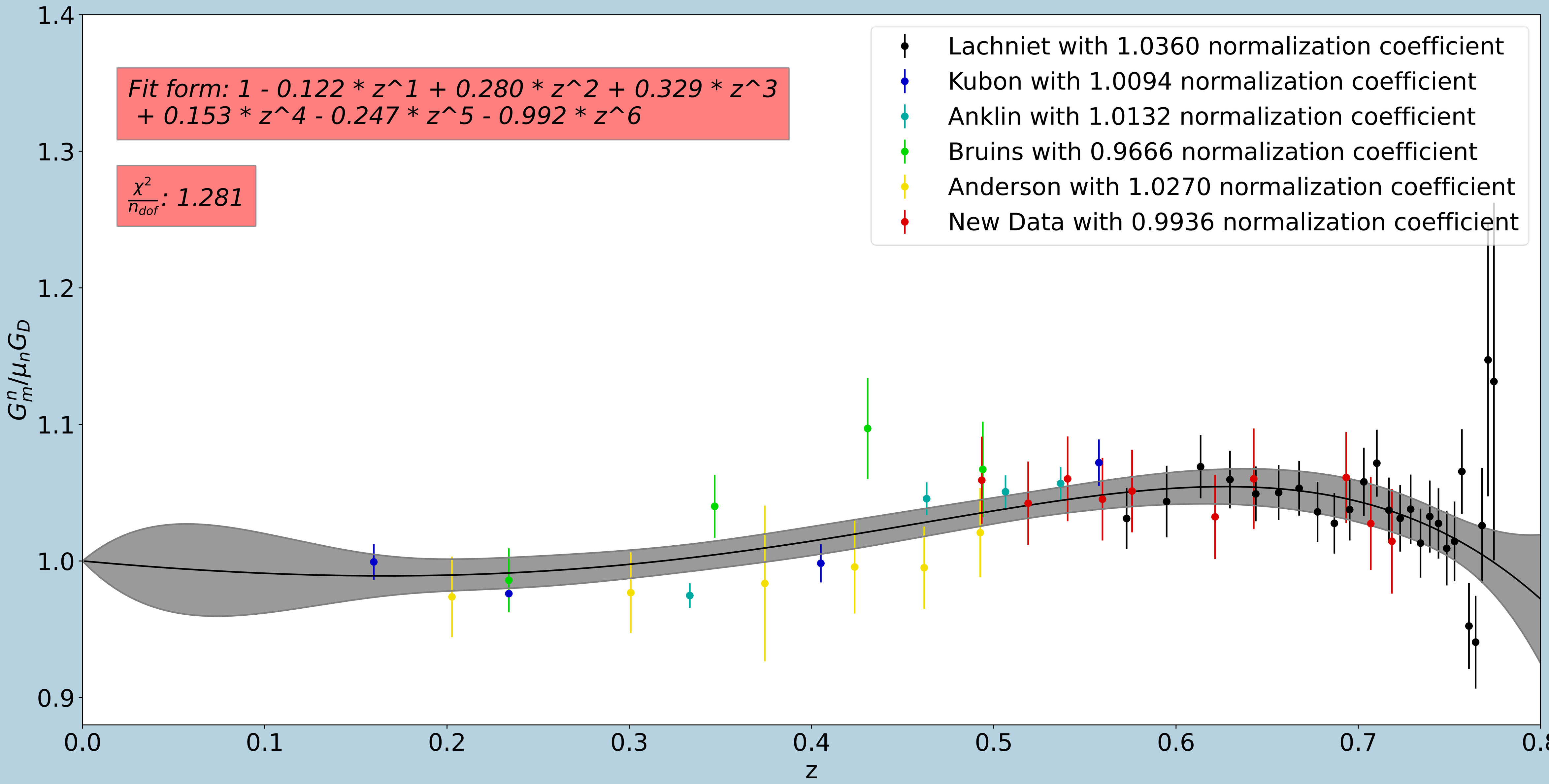
- To measure the neutron form factors, the electron would have to scatter off a neutron target. However, a pure neutron target is not viable as a target due to the short neutron lifetime.
- Instead, the neutron form factors are often measured using light targets like ^{2}H or ^{3}H.

- Previous measurements of neutron form factors had to account for the effects of the proton, resulting in relatively large uncertainties.
- New data for the neutron magnetic form factor has been found using a new method that uses mirror nuclei ^{3}H and ^{3}He.
  - This new data relies on cancelling uncertainties in the ratio of cross-sections of both nuclei.

By combining this new data with old data, we can create a new global fit of the neutron magnetic form factor that is more accurate.

Graph of Fit

Figure 1: Graph of a 6th order polynomial on z transformed data. The black line is the resulting fit of the data, with the form and χ^2 test shown in the red box. χ^2/n_{dof} is close to one, which indicates a strong fit. The shaded region shows the uncertainty of the fit. The normalization coefficients shown in the legend represent how much each $G^n_m/\mu_n G_D$ data point in each data set have been shifted as a part of the fitting process. Note that the number of parameters used for the fit is not yet finalized.



Methods

With the new data, a new global fit can be made for the neutron magnetic form factor that is more accurate than previous global fits. The least squares routine was used to find parameters that fit a polynomial of form

$$f(z) = \sum_{i=0}^{n} a_i z^i$$

Where z is a transform of the momentum transfer Q^2 found with

$$z(t, t_{cut}, t_0) = \frac{\sqrt{t_{cut} - t} - \sqrt{t_{cut} - t_0}}{\sqrt{t_{cut} - t} + \sqrt{t_{cut} - t_0}}$$

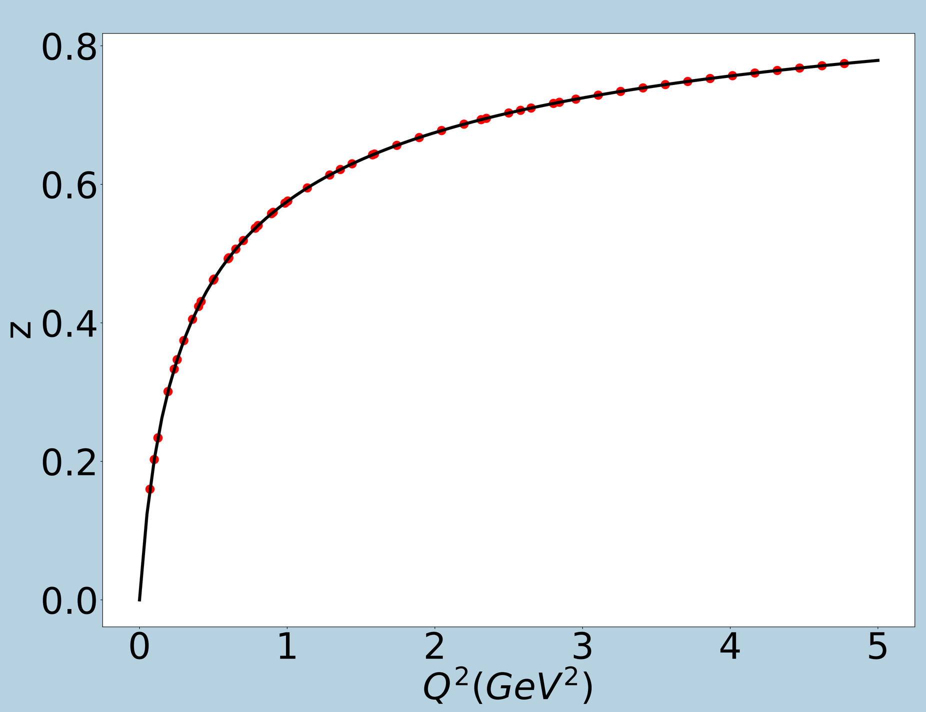
$t = -Q^2$

$t_{cut} = 4m_\pi^2$

In our case, $t_0 = 0$

The z transform allows us to place bounds on the parameters of the fit such that larger order parameters have a smaller impact

Figure 2: Graph of z transform used in the fit. The black line shows the transform for any point between 0 and 5 GeV^2, and the red points represent the actual data points that are being transformed.



Conclusion

The neutron magnetic form factor describes the distribution of magnetization within the neutron. A greater understanding of this distribution will better inform us of the interior properties of the neutron, and a more accurate fit of the form factor could support new theory on it.

Future Work

- Fit uncertainty gets large in extrapolated regions (low z, high z)
- Finalize number of parameters and data sets
- Finalize individual data set uncertainties (for normalization purposes)

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