CHAPTER 6: CONCLUSION AND OUTLOOK

6.1 Conclusions

We see from Figure 5.14 that the one preliminary result - along with results from [Plaster et al., 2006] - suggests a departure from the Galster parametrization, and lie more in line with the Miller curve. Of course, these results are preliminary and the FSI calculations and other corrections due to nuclear effects may move the point around (by less than about one sigma), but still would remain at least three sigma away from the Galster fit\textsuperscript{1}. So we can say that the Galster parametrization does not work at higher $Q^2$. Although, a refit with different values for the parameters $A_\tau$ and $B_\tau$ might provide a better fit for the new data (Equation 1.49).

As for the theory models, the results definitely lay to rest some of them. The strongest theory contender is the full Miller calculation based on the cloudy bag model described in Section 1.3.3 [Miller, 2002, Miller, 2003]. The results will give us more insight into the sign of the charge distribution of the neutron core. Also, an as yet unpublished paper by [Miller et al., 2007] on the ratio of the proton form factors reveals that the magnetization density of the proton extends out further than the charge distribution, also contrary to the common belief to far. A similar analysis for the neutron should also be very interesting.

The pQCD curve, too, seems to fit the higher $Q^2$ points. The difference between the Miller curve and the pQCD prediction curve is quite large around this $Q^2$ region and beyond. Higher $Q^2$ results will either decide between these two curves, or open up the arena for other contestants.

Various other ongoing efforts to devise parametrization fits will have better data to play with. For example, Kelly’s parametrization for $G^n_E$ (Equation 1.50) used the Galster parametrization mainly due to lack of high quality data at high $Q^2$. Now the parametrization can be extended to $G^n_E$ as well. The BBBA form factor fits [Bradford et al., 2006] borrow Kelly’s parametrization and use additional conditions from duality to constrain $G^n_E$, again because of a lack of high quality data at high $Q^2$. Our results will set them on track for obtaining a good fit to $G^n_E$ too, hopefully without the additional duality conditions. It will also be interesting to see how the GPD limits will be affected by the results. Better phase-space pictures of the neutron will become available.

\textsuperscript{1}The error bars will decrease once all the systematic corrections are properly incorporated.
Interpreting the $G^n_E$ versus $Q^2$ data in terms of a physical charge density distribution, however, remains the arena of theory models. Whether we look at the neutron in physical space\(^2\) in the Breit frame, the infinite momentum frame, or any other (physically or mathematically) convenient frame that can be come up with, its Fourier transform into momentum space will have to agree with the data in Figure 5.14.

6.2 Future

There are quite a few experiments that are already approved at Jefferson Lab for measuring nucleon form factors at higher $Q^2$ and more precisely. These are mostly after the 12 GeV upgrade. A higher $Q^2$ experiment for $G^n_E$ is due to run in Hall C at Jefferson Lab. In small and steady steps, we inch towards better understanding of the neutron structure and a better understanding of our (visible matter) Universe.

\(^2\)To get a static distribution, the time component in coordinate 4-space should disappear. In 4-momentum space, this corresponds to zero energy transfer to the nucleon.