Today I am going to present a new proposal, measurement of GEp/GMp from elastic e−p scattering using polarized beam and a polarized target up to 3.5 GeV/c^2. Here is the outline of the talk.

First I will briefly review the motivation of this experiment. The proton form factors have been measured for more than 40 years, primarily by two experimental methods. I am sure you are all familier with these two plots. The first plot shows world data from the Rosenbluth method, in which the form factors are extracted using a linear fit of the reduced cross sections as a function of the photon polarization epsilon. In the second method, one measures the ratio of the transverse to longitudinal components of the polarization transfer of the recoil proton, which is proportional to GE/GM. Data from this method are shown in the bottom plot here. The polarization transfer data set very strong constraint on the theories. And as you can see, there is a significant disagreement between the two data sets in the high Q2 region.

So where the problem is? At the beginning, it has been questioned that there might be problem with the Rosenbluth data since we need to combine cross section results from different experiments and different facilities. However, preliminary results from a recent experiment in Hall A tend to confirm previous Rosenbluth results.

There could also be problem in the extraction of GE/GM from data. A possibl explanation is the two photon exchange effect. Here I list current understanding of this effect. Theoretically, calculations from several different models showed that the correction due to this effect is large for the Rosenbluth data than that for the polarization transfer results. Also, it has been found that the correction is large at small epsilon values, which corresponds to backward scatterings. However, so far theories on two photon exchange are far from complete, cannot explain the observed discrepancy, and need input from the data.

Experimentally, several measurements are being planned to study the two photon exchange. The first set of experiments is focused on measuring observables which are zero in the one photon exchange approximation. For example, the transverse target asymmetry, the normal component of the polarization transfer, and the transverse beam asymmetry. These experiments will certainly provide information on the two photon effect, and are very important to, for example, parity violation experiments. However, they will primarily study the imaginary part of the two photon exchange, while it is the real part of this effect which contributes to the discrepancy in proton form factor data. In other words, this kind of experiments cannot solve the problem here.

The second way to study the two photon exchange is to measure the non−linearity of the Rosenbluth plot. However, such measurement requires high precision on all data points in a wide range of epsilon and is experimentally very different. In addition, similar to the first sets of experiments, this kind of data will information only on the non−linear part of the two photon exchange effect, while such effect could also contribute linearly to the Rosenbluth plot. In other words, this kind of meausrement also cannot solve the proton discrepancy directly.

The only direct way of measuring the real part of the two photon exchange, in my view, is a precision measurement of the cross section ratio of the position and electron scatterings. For example, there is an LOI to this PAC to propose such measurments in Hall B. However, it requires new beam−line equipment and due to the low luminosity, the Q2 range is limited to one to 1.5 (GeV/c)^2, where the discrepancy in the proton data is not as significant.

Most likely, even with data from all experiments listed here, it is still necessary to use the discrepancy itself as an input for the calculation. Now it is necessary to ask some questions: is there any other unknown effect? And is it appropriate to say that the full discrepancy is coming from the two photon exchange?

Here is a review of the motivation that I just mentioned. Eventually, a measurement of GEp/GMp using a new method, which is completely independent from the first two, will not only help us to better understand the proton form factors, but is also nessacery for further study of the two photon exchange effect.

We propose here a measurement of GE/GM using polarized beam and a polarized prot

on target. The ratio GE/GM can be extracted from the measured elastic asymmetry from this equation. Here theta* and phi* are the polar and the azimuthal angles of the target spin. Since we will measure polarization observables, the effect of two photon exchange is supposed to be small. In addition the measurement will be preformed at small scattering angle, or large epsilon, hence the two photon correction should be even smaller. Compared to the polarization transfer method, we measure the polarization of initial protons instead of the recoil ones, hence the systematics will be completely different. The proposed measurement will provide the first GEp/GMp data from polarized target method at two Q2 point at 2.1 and 3.5 GeV/c^2, to a good precision.

Here is a list of the collaboration. We have strong support from the UVa group, who has extensive experience in performing polarized proton target experiments.

The experimental setup for this experiment is the following: We will use polarized electron beam. The UVa polarized proton target will be used in Hall C with its spin aligned at 139 degrees w.r.t. the beam line. The scattered electrons will be detected by the HMS. In addition to the measuremets at Q2=2.1 and 3.5, data will be taken at Q^2=0.6, where the GE/GM value from the two data sets still agree, as a cross check of the product of the beam and target polarizations and the target dilution factor. The slow rastering system and beam−line chicane will be used. I need to emphasize that this setup has been used in several experiments before.

We have also optimized the kinematics. The main constraint on the kinematics comes from the blocking of the target coils. Here is a schematic diagram to show the geometry of the coils. The target cell is in the center, and the Helmholtz coil pair is located from 48 to 73 degress on both sides of the field axis. The beam is rastered to 2cmin diameter, and there is a 5mm clearance between electrons and the coils. When choosing the kinematics, we need to make sure that the coils do not interfere with the beam and the scattered electrons.

Here what you see in the top panel are the total uncertainty on GE/GM as a function of the target spin orientation w.r.t. the beam line. The beam time used here are fixed to 46 and 246 hours, respectively. The red regions show the interference between the coils and the beam, and the blue shows interference between coils and outgoing electrons. Since rotating the target field needs at least one day, it is desired to perform the meausrements at all Q2 values at the same spin direction. We therefore choose the 139 degrees, shown by the two red stars in this figure. Then we fix the target spin at this angle, and varies the beam energy. We find that the GE/GM uncertainty decreases continuously as we use higher energy. Hence we propose to use 6 GeV beam. However, as you can see that the uncertainty almost flattens out here, so any value above 5.5 GeV is acceptable. This will make the scheduling much easier.

The data analysis is pretty straightforward. We correct the observed asymmetry by the beam and target polarizations, and the target dilution factor. Because the nitrogens in NH3 are slightly polarized, a small corredition for the nitrogen asymmetry will be applied. The target dilution comes mainly from the quasi−elastic events from unpolarized materials in the target. For example the nitrogen in NH3, the Al windows and the NMR coil in the cell. We have simulated the quasi−elastic scattering using SIMC and found that the dilution factor is close to 50% for all kinematics. From previous experiments, this factor can be measured to 2.5%.

The kinematics for the proposed measurment are shown in this table. The beam energies and the HMS settings are highlighted in the top. The asymmetries at these kinematics have high sensitivity to the GE/GM ratio. For example, we calculate the expected asymmetries using two GE/GM values from Bosted fit and the polarization transfer fit. For the highest Q2 point, they different by 27%, or about five sigma, compared to the expected uncertainty on the asymmetry.

In this table we give all major error sources. The systematic errors on GE/GM are dominated by the target polarization and the dilution factor. And the total uncertainties on GE/GM comes about equally from statistical and systematic uncertainties.

The measurement at Q^2=0.6 will check the product of beam and target polarizations and dilution factor to 4.4% level.

This table summarizes our beam time request. We ask for 334 PAC hours for data taking and 120 calendar hours overhead time for beam pass change, configuration change and target study. The total beam time needed is 17 days. We also need to mention that if this experiment is scheduled before or after the approved SANE experiment, then no addition time will be needed for target installation.

This figure shows the expected results, along Rosenbluth data and the poalrization transfer data. The black curve gives the Bosted fit, and the Purple curve is a global fit to the Rosenbluth data. The expected uncertainties on muGE/GM are 0.057 and 0.074, for Q2=2.1 and 3.5, respectively.

As I said that the systematic errotrs are dominated by the uncertainties in the target polarization and the dilution factor. I need to mentioned that the values used in the proposal are quite conservative. With dedicated work, it is possible to reduce the error on these two quantities from 2.5% to 2%. If this is the case, then the final uncertainties on GE/GM ratio will be 0.052 and 0.069, as shown by the black points here.

Next, I would like to address some of the questions, including questions from the PAC reviewers of this proposal. First, we have carefully compared sevearl different experimental designs. For example, the single−arm proton detection and the coincidence method. The advantage of the proton method is that there is less dilution effect because only the protons in the nitrogen will contribute to the quasi−elastic events. However, with the same solid angle acceptance, the rate is lower than electron detection and the beam time request will be longer. In addition we will also have confusion from the pi0 production background.

For the coincidence measurement, the advantage is that there is almost no dilution from quasi−elastic events. However, the only way to perform coincidence measurments is to use HMS for the proton and a calorimeter for the electrons. Again, the proton rate will be low and longer beam time will be needed. Also, to avoid the blocking of both the outgoing electrons and the protons, there will be very strong constraint on the beam energy.

We also compared the proposed method with that in PR01−105, which proposed to meausre the ratio of transverse and longitudinal asymmetries. For their case, the dominant systematic errors will cancel. But for this case, a precision measurement of the ratio AT/AL is needed, and as you can see that the error in AT will be magnified by 1/AL, which means higher statistics is required. We find that the beam time request using this method is also much longer than what we proposed.

The last one, LOI 04−001, which proposed to use polarized 3He as an effective poalrized proton target, is worse than our proposal in f.o.m by a factor of two.

In one word, the proposed method will use the least resources to achieve the best results.

As I mentioned, that this is not the first time a polarized target measurement is proposed to the PAC. Now let’s see what was the PAC report on proposal 01−105. Here we see that "

The last questions I would like to address is: Since we will have more meausrements on the GEp/GMp ratio in the near future, why is the proposed measurment so important? Our answer is: the real proton form factor is still unknown, and for any unknown physics quantities, we should measure it to as high precision as possible, and using as many methods as possible. I can also give some examples: for the form factor ratio of the proton, the single−arm proton measurement was proposed, which in principle should give the same results as the single−electron measurement. That was experiment E01−001. For the deuteron elastic form factor A(Q), an experiement was proposed to solve the observed 8% discrepancy between the Mainz and the Saclay data. That is E02−005. The last one, for the neutron form factor GEn, measurements using a recoil polarimeter and using polarized targets were both proposed. The Q2 ranges of these experiments are similar,and they again in principle should give the same results. In addition, for the polarized target method, we have experiments using ND3 target in Hall C, and an experiment using pol3He target in Hall A.

In summary, we ask for 17 days beam time in Hall C. The proposed measurement will provide the first results of G_E^p/G_M^p from polarized target method and logical step in the scientific program to understand the proton form factors.