CEBAF Program Advisory Committee Six (PAC6) Proposal Cover Sheet

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Proposal Title

Electric Form Factor of the Proton by Recoil Polarization

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1989-14 Electric Form Factor of the Proton by Recoil Polarization

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By: gp

THE HALL A COLLABORATION

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Case Western Reserve & LANL, George Washington University,

University of Georgia, Indiana University Cyclotron Facility,

Kent State University, University of Maryland,

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Williamsburg, April 5, 1993

1 Introduction

This is a resubmission of proposal 89-14 which was first presented to PAC 4, and given a "conditionally approved" status in 1989. The questions raised by the committee at the time can be paraphrased as follows:

a) how can the polarimeter (systematic intrinsic) asymmetry be measured, and how does it affect the uncertainty of the results?

b) what is the impact on the results of pions generated in the carbon analyzer?

c) the proposed results are only a factor 2 to 3 improvement over the SLAC/NPAS experiment NE-11; can they be improved further?

The answers to points a) and b) were evident to us at the time of the first submission, but we did apparently not succeed in convincing the committee that we had satisfactory answers or remedy. Since 1989 we have continued our efforts to determine proton analyzing powers of a similar polarimeter (POMME at Saturne) over the proton energy range relevant for experiment 89-14. This was particularly important because our original performance estimates at the time were based on a Monte Carlo (MC) simulation of such analyzing powers with a very thin data base for the pC analyzing power. We now have data up to 2.4 GeV and the numbers in the original proposal are vindicated. We also hope that higher electron polarizations will be possible at CEBAF in the near future; therefore we present estimated performances for beam helicity h=0.4 and 0.8. Since first submission it became increasingly evident to us that this experiment was going to provide the only on site calibration of the polarimeter analyzing power. As the experiment measures two components of the polarization simultaneously, two independent quantities can be obtained from these two polarization components: these will be the G_{Ep}/G_{Mp} ratio, which is the primary scientific goal of this experiment, and the graphite analyzing power A_c, giving us a calibration of the polarimeter at the same time. We do not see at this time that any other polarization experiment at CEBAF will achieve better absolute accuracy than provided by the results of the present experiment for A_c. The only possible alternative is to use pp scattering. This could be done with a hydrogen target instead of the graphite in the polarimeter, probably covering a small area of the focal plane for practical reasons; but at energies larger than 1 GeV the pp polarization data base is very uncertain at best.

Anticipating the content of the present proposal we state that the ratio G_{Ep}/G_{Mp} will be determined in this experiment INDEPENDENTLY OF ANY CALIBRATION OF THE POLARIMETER ANALYZING POWER OR MEASUREMENT OF THE BEAM POLARIZATION. The determination of A_c is thus a byproduct of the experiment, not a necessary ingredient.

2 Physics interest of measuring G_{Ep}

To the extent that the data base for G_{Mp} has now reached better levels of accuracy, this experiment will in fact obtain G_{Ep} from the measured ratio G_{Ep}/G_{Mp}, combined with the world data base for G_{Mp}. The understanding of the structure of the nucleon is of fundamental importance; ultimately such an understanding is necessary to a first principle description of the nuclear force. The distribution of charge and currents inside the nucleon is best revealed by the electromagnetic probe, through the interaction of the virtual photon with the quark constituents of the nucleon. Experiments are proposed at CEBAF to characterize how the nuclear medium affects the structure of bound nucleons: deformation, swelling, or other modifications of the charge and current distribution, or of underlying quark structure. The G_E/G_M ratio for the (e,e'p) reaction on a complex nucleus is a sensitive probe of such effects. But a precise knowledge of its Q^2 behavior for the free nucleon is a prerequisite for such experiments.

At the present time neither elastic form factors of the neutron are adequately determined experimentally; in particular G_{En} is poorly defined at any Q^2; but even for the proton the electric form factor is not well determined experimentally beyond $Q^2=1$ GeV^2.

Elastic ep differential cross sections have been measured by Arnold et al[1] up to four-momentum squared $Q^2 \approx 31$ GeV^2. However, the separate determination of G_{Ep} from a cross section measurement, by the Rosenbluth separation technique, becomes more and more difficult with increasing Q^2 because of the increasing dominance of the magnetic term. An important step was achieved by Janssens et al[2] when they isolated G_{Ep} by Rosenbluth separation, up to the Q^2-value of 0.86 GeV^2, although with relatively large error bars. More recently, Walker et al[3] (SLAC experiment E140) separated both G_{Ep} and G_{Mp} up to Q^2 = 3 GeV^2 with error bars for G_{Mp} smaller than 3% and error bars for G_{Ep} between 7 and 14%. Finally, the results of experiment

NE-11 have given yet the smallest error bars for G_{Ep} (Bosted et al[4]); they extend to $Q^2=8.83$ GeV^2, with error bars smaller than 2.5% for G_{Mp}, and error bars between 5 and 23% at 6 GeV^2, reaching 50% at 8.83 GeV^2. All data for $Q^2 \geq 0.15$ GeV^2 are shown in figure 1 for G_{Ep}, and in figure 2 for G_{Mp}. As is now common, both figures show the form factors divided by the dipole form factors:

$$G_{E_D}=\frac{1}{(1+\frac{0.71}{Q^2})^2} \qquad G_{M_D}=\mu_p\, G_{E_D} \qquad (1)$$

In fig. 1 we observe that error bars for G_{Ep} from ref. 4 reach ±8% at 3 GeV^2. However, there is no internal consistency between the 3 experiments which reach or exceed 3 GeV^2: Bartel et al[5] (DESY, 1972) shown as triangles, ref.3 (SLAC,1989) shown as open circles, and ref.4 (SLAC, 1992) shown as open squares. The G_{Ep} results from ref. 3 show a form factor ratio increasing with Q^2, in complete disagreement with the older data of ref. 5, which also reach $Q^2=3$ GeV^2 and suggested a decrease of the ratio to the dipole form factor. The latest data of ref. 4 disagree with both, indicating a constant ratio up to $Q^2=5$ GeV^2. This less than satisfactory situation illustrates the difficulty in separating G_{Ep} from cross section data, by the Rosenbluth separation method; at the risk of becoming unpopular, we would submit that the electric form factor of the proton is known at the present to ±20% above 2-3 GeV^2 if one takes into consideration the actual scatter of the data from these 3 experiments. The present experimental situation for G_{Ep} does strongly suggest that a new and independent technique should be used, and the recoil polarization technique proposed here is just the right one to resolve this ambiguity. The projected error bars we propose to obtain in this experiment up to $Q^2=4.5$ GeV^2 are in the range 1 to 2.5% if h=0.8 (and are shown as filled squares in figure 1), 1.5 to 4.5% with h=0.4. The systematics will be much better controlled because a measurement of G_{Ep}/G_{Mp} at a given Q^2 consists of a <u>simultaneous</u> determination of the transverse and longitudinal polarization components of the proton polarization.

3 Theoretical Predictions

Form factors of the nucleon have been calculated within the framework of either the vector meson dominance model (VMD), or QCD based quark models. The VMD calculations have given predictions which for G_{Ep} tend to decrease below G_D with increasing Q^2. Examples of such calculations are seen in fig. 3 taken from ref. 4. Most recent work with the VMD is from Gari and Krumpelman[6], were other refs. can be found. A prediction by Radyushkin[7] based on QCD sum rule and assuming quark-hadron duality is also shown in fig. 3. There are a number of perturbative QCD predictions inspired by the pioneering work of Brodsky and coworkers[8]. However, the applicability of PQCD is strongly denied by Isgur and Llewellyn Smith[9], who argue that non-perturbative (or soft) effects must be dominant, and in fact are sufficient to "explain" the nucleon form factors. The Bonn group (Pfeil et al[10]) has made quark model predictions based on the Isgur Karl[11] baryonic wave function; however their range of applicability is below $Q^2=2$ GeV^2. As we have suggested in the previous part, the present day G_{Ep} data base is inconsistent; we can expect future interesting theoretical developments once the ambiguities in the data have been removed.

It is not yet obvious that the quark structure of the hadrons play a detectable role in the intermediate range of four-momentum transfers $1 < Q^2 < 6$ GeV^2, which is the domain of standard nuclear physics. The kind and quality of data we propose to obtain in the present proposal will establish the features of the structure of the nucleon which are fundamental for an understanding of the structure of the nucleus.

4 The recoil polarization method

Instead of using the Rosenbluth separation technique we are proposing to measure the electric form factor G_{Ep} by measuring the interference term $G_{Ep}G_{Mp}$ directly. As discussed in detail by Arnold, Carlson and Gross[12], this can be done with longitudinally polarized electrons and either using a polarized target or by measuring the sideways polarization P_t of the recoil proton. The main advantage of the polarization method is that it requires no change of energy or angle: for each Q^2 a single measurement of the azimuthal distribution of the protons diffused in a secondary scatterer determines simultaneously both P_t and P_l, the sideways and longitudinal components of the recoil proton polarization. According to ref. 12, P_t and P_l are given by:

$$P_t = \frac{-2\sqrt{\tau(1+\tau)}\; G_{Ep}\; G_{Mp}\; \tan(\frac{\theta_e}{2})}{I_0} \qquad (2)$$

$$P_l = \frac{\frac{E_e + E'_e}{M}\sqrt{\tau(1+\tau)}\; G^2_{Mp}\; \tan^2(\frac{\theta_e}{2})}{I_0} \qquad (3)$$

where

$$I_0 = \{\, G^2_E(Q^2) + \tau\; G^2_M\; [1 + 2(1+\tau)\; \tan^2(\frac{\theta_e}{2})] \,\} \qquad (4)$$

The first experiment measuring recoil polarization has been done at Bates in $^2H(\vec{e},e'\vec{n})$, to obtain the electric form factor of the neutron (88-05[13]). An experiment to measure the form factors of the free proton and of the proton in the deuteron is planned for Bates in 1993 (88-21[14]); it will be a first exploration of medium effects in the deuteron measuring the G_{Ep}/G_{Mp} ratio at small Q^2-values. A new focal plane polarimeter for OHIPS, has recently been built by a U. of Virginia, MIT and William and Mary collaboration; it has been calibrated at IUCF in Feb. 1993. A continuation of the Bates $^2H(e,e'p)$ experiment at CEBAF is approved (89-28[15]).

With the 4 GeV polarized beam at CEBAF, G_{Ep} of the free proton can be measured by the recoil polarization technique out to 4.5 GeV^2. An extension to 6 GeV^2 will become possible with a future increase of the beam energy to 6 GeV, without restriction from the 4 GeV/c limit of the spectrometers in hall A.

The coincidence experiment proposed here requires that the hadron arm be equipped with a focal plane polarimeter (FPP) with good performance up to 3.2 GeV/c (2.4 GeV); the second phase would require an extension of the performance range of the polarimeter to 4 GeV/c (3.2 GeV). With the support of NSF[16], and in collaboration with the Rutgers group, we are presently building the tracking detectors of the FPP to be installed in the hadron arm in hall A (see more in part 6).

With a focal plane polarimeter one measures the azimuthal angular distribution after a second scattering in a carbon block; this distribution has the form:

$$N(\theta,\phi) = N(h=0,\theta)\ \{1+h\ A_C\ (\theta)[P_t'\ \sin\phi\ +\ P_n'\ \cos\phi]\} \qquad (5)$$

where h is the electron beam helicity

N(h=0,θ) the rate for unpolarized beam,

θ, ϕ are the polar and azimuthal angles after second scattering

P_t' and P_n' the transverse and normal components of the polarization at the analyzer

$A_c(\theta)$ the analyzing power of analyzer (graphite).

The relation between polarizations at the graphite (primed) and at the (hydrogen) target (unprimed) are:

$$P_t' = P_t \qquad P_n' = P_l \sin\chi + P_n \cos\chi \qquad (6)$$

where P_t, P_l and P_n are the transverse, longitudinal and normal polarization components at the target, and χ is the spin precession angle in the spectrometer.

If the normal component of the polarization is negligible, as is the case in the present reaction, then the measured quantities are the amplitudes:

$$a(\theta) = h\ A_c(\theta)\ P_t \qquad b(\theta) = h\ A_c(\theta)\ P_l\ \sin\chi \qquad (7)$$

which are obtained by Fourier analysis of the ϕ-distribution, formula (5); the analysis is to be done for a number of scattering angle bins. Then the ratio G_{Ep}/G_{Mp} can be obtained directly for each scattering angle from the measured quantities a(θ) and b(θ), as follows, using formula (2), (3) and (7):

$$\frac{G_{Ep}}{G_{Mp}} = -\frac{a(\theta)}{2b(\theta)} \frac{(E_e+E_e')}{M} \sin\chi \tan(\frac{\theta_e}{2}) \qquad (8)$$

showing the important point that the ratio G_{Ep}/G_{Mp} is independent of both A_c, the analyzing power of graphite, and h, the polarization of the beam. The final result will be obtained by averaging over the θ-bins. However, these final results are also independent of A_c and h.

The same measured quantities a and b (from (7)) can be used to calculate a second independent variable, the analyzing power of the polarimeter, A_c as follows:

$$A_c = \frac{b\,\{(\frac{a}{2b})^2 (\frac{E_e+E_e'}{M})^2 \sin^2\chi + \tau\,[\cot^2(\theta_e)+2(1+\tau)]\}}{h\,(\frac{E_e+E_e'}{M})\sqrt{\tau(1+\tau)}\,\sin\chi} \qquad (9)$$

5 Polarimeter characteristics

Even though the simultaneous measurement of the sideways and longitudinal components of the proton polarization determines G_{Ep} independently of the analyzing power A_c and usable fraction f in the polarimeter, the statistical uncertainty on G_{Ep} depends directly upon optimalization of these two numbers. In fact it is $A^2_c f$ which should be as large as possible. The only one parameter available, if graphite is chosen as the scatterer in the polarimeter, is the thickness of the scatterer, d. Recent work at Saturne (Punjabi et al.[18]) indicates that at energies larger than 800 MeV the optimum target thickness is ≥ 30 cm (density 1.7 gcm^{-2} or greater). The data base relevant for the present proposal is shown in figure 3, where a 9-parameter fit of the data from 800 MeV to 2400 MeV is shown.

A collaboration involving Rutgers and William and Mary has received an instrumentation grant from NSF to build a focal plane polarimeter (FPP) in the hadron arm; collaborators at Norfolk State U. (V.P. and students) and University of Georgia are also involved in the construction which started in Sept. 1992. Installation of the FPP is expected in the Spring of 1995, at the same time as the Focal Plane Detectors. The characteristic of this polarimeter are such that the whole focal plane of the HRS will be covered, and that scattering angles up to 20° in the graphite will be fully accepted for all trajectories; furthermore up to 60 cm of graphite, in slabs of thickness between 2 and 32 cm will allow to maintain optimum "figure of merit" for all points up to 2.4 GeV proton energy. Extrapolation of the calibration data base to 3.2 GeV let one expect a value of A_c falling to 75% of the 2.4 GeV value.

6 Proposed measurements, error and rates estimates, time request

The anticipated results of this experiment at the 9 kinematics proposed are in table 1: Q^2 is changed between 0.5 and 4.5 GeV^2, in steps of 0.5 GeV^2. The total uncertainties in table 1 are calculated for h=0.4 and 0.8, with formula:

$$\frac{\Delta G_{E_p}}{G_{E_p}} = \sqrt{(\frac{\Delta a}{a})^2 + (\frac{\Delta b}{b})^2 + (\frac{\Delta \sin\chi}{\sin\chi})^2 + (\frac{\Delta G_{M_p}}{G_{M_p}})^2} \qquad (10)$$

where the statistical uncertainties on a and b, the amplitudes from the Fourier analysis, are given by:

$$\Delta a(\theta) = \Delta b(\theta) = \sqrt{\frac{2}{fN_p(\theta)}} \qquad (11)$$

where f $N_p(\theta)$ is the number of usable events within a given θ-bin.

The relative uncertainty on G_{Ep} does directly depend on h, f and A_c, but these need to be known only to the precision one requires on the uncertainty ΔG_{Ep}, rather than G_{Ep} itself. Note that the uncertainty in G_{Mp}, according to ref. 4, is between 0.7% and 1.5% over the range of Q^2-values proposed here. Additional sources of error from uncertainties in the measurement of θ_e and E', which determine Q^2 have also been included. Error in table 1 use $\Delta(\sin\chi)/\sin\chi$ values evaluated with MCEEP[17] for nominal position resolution in the focal plane drift chambers, and including multiple scattering of the outgoing proton in the target and chambers. The uncertainty at the larger Q^2 points are mostly statistical. and thus scale like $h\sqrt{L}$, L the luminosity. Radiation corrections will be necessary to obtain the correct value of Q^2. The beam on target times in this table have been corrected for radiation.

Asymmetries in the polarimeter, may come from edge effects and anisotropies in the detection efficiency. The former are eliminated by the usual cone test. Switching of the beam helicity sign will allow a determination of the polarimeter asymmetry because the normal polarization component P_n is ≈ 0 in elastic ep; number of events $N_+(\theta,\phi)$ and $N_-(\theta,\phi)$ corresponding to beam helicities $h>0$ and $h<0$ will be measured:

$$N_+(\theta,\phi) = N(h{=}0,\theta)\ \{1 + (a+a_i)\sin\phi + (b+b_i)\cos\phi\}$$
$$N_-(\theta,\phi) = N(h{=}0,\theta)\ \{1 + (-a+a_i)\sin\phi + (-b+b_i)\cos\phi\} \qquad (12)$$
$$N_+ - N_- \rightarrow a\ ,\ b$$
$$N_+ + N_- \rightarrow a_i\ ,\ b_i$$

where a_i and b_i are the instrumental asymmetries (and therefore independent of h); of course the determination of a_i and b_i requires monitoring of the number of particles in each spin state, and of their average polarization.

The choice of electron beam energies and scattering angles is guided by the wish to maximize $P_t^2 d\sigma/d\Omega_e$, which will give the smallest statistical error bar in a given time (first 2 terms in (10)). However, the maximum of this function, evaluated by assuming that both the electric- and the magnetic form factors have the dipole form, is fairly wide, thus allowing selection of beam energies in multiple of the acceleration per turn, 800 MeV; other choices of energies and angles for the same Q^2-values are possible. **Also in table 1 is the estimated total uncertainties on the calibration of the FPP, $\Delta A_c/A_c$, which will be obtained simultaneously with the form factor measurement.**

Kinematical information, including cross sections in the dipole approximation, can be found in table 2.

The expected polarizations calculated in the dipole approximation, and event rates in the focal plane, as well as the precession angles χ are shown in table 3; also in this table are the average analyzing power A_c and fractions of usable events, f, in the polarimeter based on the calibration of the polarimeter POMME[18] at Saturne. Radiation corrections affect mainly the determination of Q^2. Higher order, spin dependent radiation corrections are expected to be small[19] and calculable. As we measure both P_t and P_l, the only other contributions to the total uncertainty on G_{Ep} besides statistics are the uncertainties on the G_{Mp} values which are taken from ref. 4. The rates are arbitrarily limited to about 2500 s^{-1}, by decreasing the beam intensity when needed. A liquid hydrogen target with a useful length of 10 cm (0.7 gcm^{-2}) is assumed. The intensity for most of the points is 100 μA (see foot notes at bottom of table 3).

This experiment requires two fully operational spectrometers and in addition the polarimeter; consequently, the preparation of this experiment will have to be closely coordinated with the commissioning of the 2 spectrometers; it is difficult to evaluate separately the setup time required by this experiment. Part of this setup time would have to include preliminary tests of the polarimeter. This experiment will calibrate the polarimeter with a precision of 1-4% for future use in other experiments; all uncertainty estimates are reliable because they are based on the POMME calibrations[18].

Finally table 4 shows singles rates obtained with the codes of Lightbody and O'Connell[20]. Coincidence events with a pion in the final state never enter into the experimental acceptance of the detectors. The contribution of pions to the singles proton rates remains always small. Accidental events are not a problem.

The total time requested according to the information in table 3 is 1344 hours with h=0.4, and 1280 hours should h=0.8 become available with the same luminosity.

Conclusion

We are proposing to measure the elastic electric form factor of the proton, G_{Ep}, at four-momentum transfers squared Q^2 between 0.5 and 4.5 GeV^2 in steps of 0.5 GeV^2. The total error bars are predicted to be between 134% at the lowest Q^2 and 4.4% at the highest, with beam helicity h=0.4; they would become 0.9% and 2.4%, respectively, should h=0.8 with 100μA become possible. G_{Ep} will be obtained from the polarization of the recoil proton from:

$$G_{Ep} = -(a/2b)\, G_{Mp}\, ((E+E')/M) \sin\chi \tan(\theta_e/2)$$

where a and b are the two Fourier components of the ϕ-distribution after a second scattering in a focal plane polarimeter under construction for the hadron arm in hall A.

The advantage of this method over the Rosenbluth separation method, is that, for a given Q^2, it requires a polarization measurement at a single beam energy and angle θ_e, whereas the separation technique typically requires 3 to 5 energies and angles. At Q^2=4.5 GeV^2 the error bars anticipated (systematics included) are 3-4 times smaller than expected from the latest SLAC separation data already with h=0.4. **In addition, this experiment will calibrate the analyzing power of the polarimeter at 9 proton energies.**

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Table 1

Kinematics at which G_{Ep} will be measured, and anticipated total uncertainties assuming beam helicities of 0.4 and 0.8, in specified amount of time

E_e	Q^2	h = 0.4		h = 0.8		$\Delta A_c/A_c$
GeV	GeV^2	$\Delta G_E/G_E$	hours	$\Delta G_E/G_E$	hours	
0.8	0.50	0.014	5	0.009	5	0.011
1.6	1.00	0.013	8	0.009	8	0.011
1.6	1.50	0.016	31	0.011	30	0.013
2.4	2.02	0.033	53	0.022	50	0.020
3.2	2.45	0.028	80	0.018	50	0.016
4.0	3.06	0.033	77	0.022	77	0.018
4.0	3.45	0.035	134	0.019	120	0.033
4.0	4.00	0.040	296	0.023	280	0.039
4.0	4.50	0.044	660	0.024	660	0.045
	total hours		1344		1280	
with 6 GeV beam						
5.25	5.00			0.023	400	
6.0	6.00			0.028	800	

Table 2

Kinematical information

E_e	Q^2	E_e'	$\theta_{e'}$	T_p	p	θ_p	$d\sigma/d\Omega_e$
GeV	GeV^2	GeV	°	GeV	GeV/c	°	cm^2/sr
with a maximum beam energy of 4 GeV							
0.80	0.50	0.53	65	0.26	0.752	40.3	$1.4.10^{-32}$
1.60	1.00	1.07	45	0.53	1.13	41.7	$5.2.10^{-33}$
1.60	1.49	0.81	65	0.79	1.46	30.1	$5.4.10^{-34}$
2.40	2.02	1.32	47	1.08	1.78	32.9	$3.9.10^{-34}$
3.20	2.45	1.90	37	1.30	2.04	34.1	$3.4.10^{-34}$
4.00	3.06	2.37	33	1.63	2.39	32.7	$1.8.10^{-34}$
4.00	3.47	2.15	37	1.85	2.62	29.6	$7.9.10^{-35}$
4.00	4.01	1.86	43	2.14	2.93	25.7	$2.7.10^{-35}$
4.00	4.53	1.59	50	2.41	3.22	22.2	$1.1.10^{-35}$
with a maximum beam energy of 6 GeV							
5.25	5.0	2.61	35	2.60	3.45	26.0	$1.8.10^{-35}$
6.00	6.0	2.78	35	3.20	4.05	23.0	$7.1.10^{-36}$

Table 3

Dipole approximation polarizations and expected data rates

E_e	Q^2	P_t	P_l	A_c	f	rate sec^{-1}	$\chi^{\$\$}$
0.80	0.50	-.46	.59	.50	.10	2472*	104°
1.60	1.00	-.33	.55	.33	.16	2770&	127°
1.60	1.50	-.34	.78	.24	.18	1150$	149°
2.45	1.99	-.28	.67	.20	.20	980$	163°#
3.20	2.45	-.25	.64	.16	.25	724$	202°##
4.00	3.06	-.21	.59	.13	.33	384$	232°##
4.00	3.47	-.22	.66	.11	.41	168$	239°
4.00	4.00	-.22	.75	.10	.44	58$	264°
4.00	4.53	-.21	.82	.10	.47	23&	288°
--------with a beam energy of 6 GeV:							
5.25	5.00	-.19.	.69	4.0	.47	38	307.4°
6.0	6.00	-.18	.73	3.5	.47	15	335.4°

* beam intensity reduced to 8 μA

& intensity reduced to 25 μA

$ intensity 100 μA on 10 cm LH_2 target (0.7 gcm^{-2}), luminosity $L=2.66*10^{38}$, $\Delta\Omega = 8$ msr

$$ result from MCEEP, centroid of distribution

hadron spectrometer tuned to -2%, ## tuned to +2%.

Singles rates and accidentals

(for a few kinematics only)

E_e	Q^2	$d\sigma/d\Omega(e,e')$	$d\sigma/d\Omega(e,p)$	e-rate	p-rate	π^+/p	real over random
GeV	GeV^2	cm^2/sr	cm^2/sr	s^{-1}	s^{-1}	%	
1.60	1.5	1.1^{-33}	4.6^{-32}	1155	$4.9.10^4$	0	2070[$]
3.2	2.5	3.4^{-34}	5.9^{-32}	714	$1.2.10^5$	0	800
4.0	3.5	8.1^{-35}	6.2^{-32}	172	$1.3.10^5$	4	750
4.0	4.5	2.1^{-35}	7.8^{-32}	44	$1.6.10^5$	10	288

[$] this point with 25 μA, all others with 100 μA.

Figure caption

Figure 1 All Rosenbluth separation data for G_{Ep}, shown as the ratio to the dipole formula.

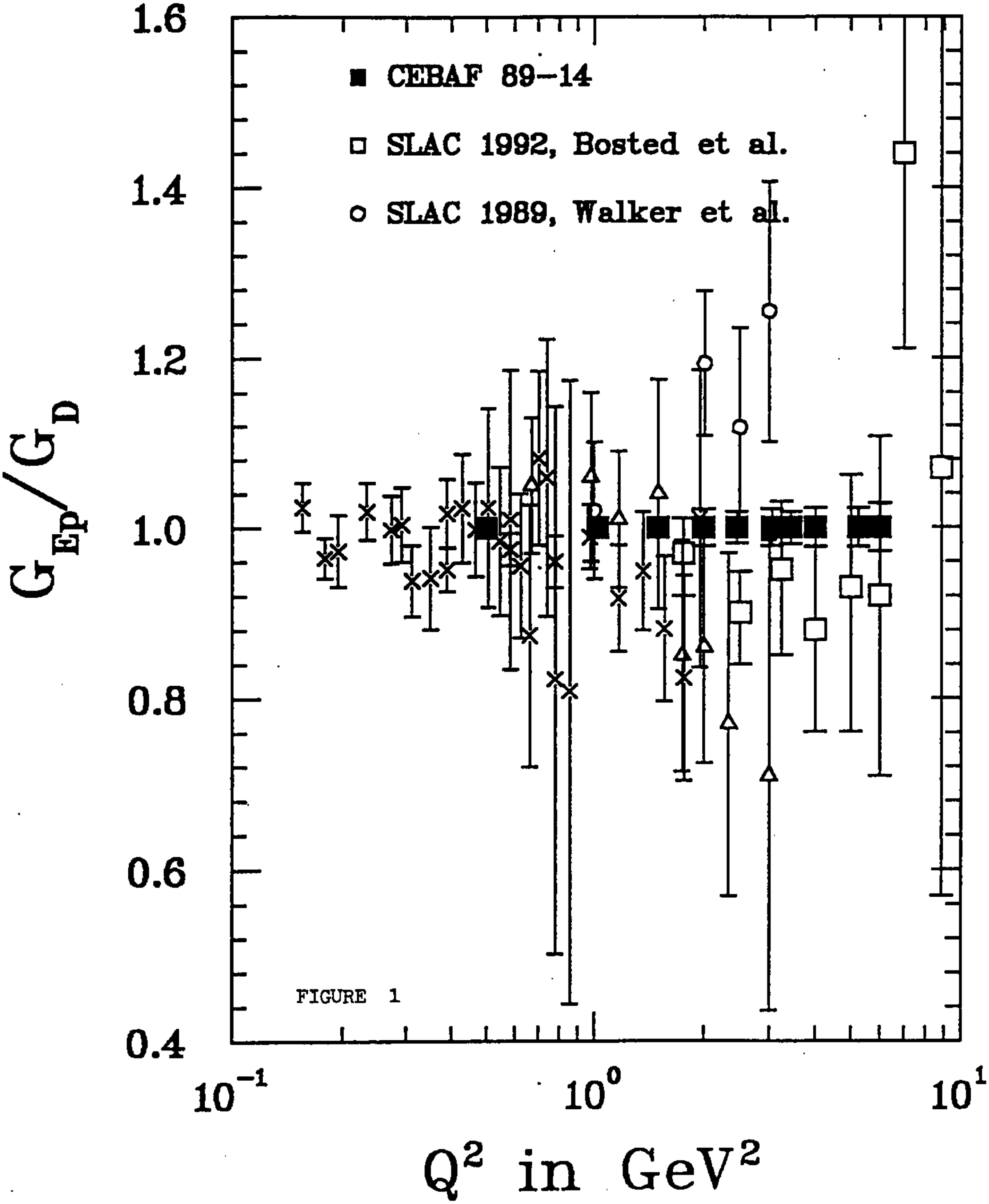
Figure 2 Compilation of existing data for G_{Mp}, shown as the ratio to the dipole formula.

Figure 3 Theoretical predictions for G_{Ep} and G_{Mp}, taken from ref. 3.

Figure 4 All polarimeter calibration data presently available between 800 and 2400 MeV proton energy, from various calibration runs at SATURNE, and 9-parameter fit; the graphite thickness was 31.2 cm.

Figure 5 Distribution of proton precession angles at the polarimeter for 4 Q^2-values (0.5, 1.0, 1.5 and 2 GeV^2), as obtained from MCEEP.

Figure 5 Expected resolution in precession angle for nominal spacial resolution of focal plane chambers, including scattering in the target, as obtained with MCEEP for above kinematics.



gep slac log 3/22/93

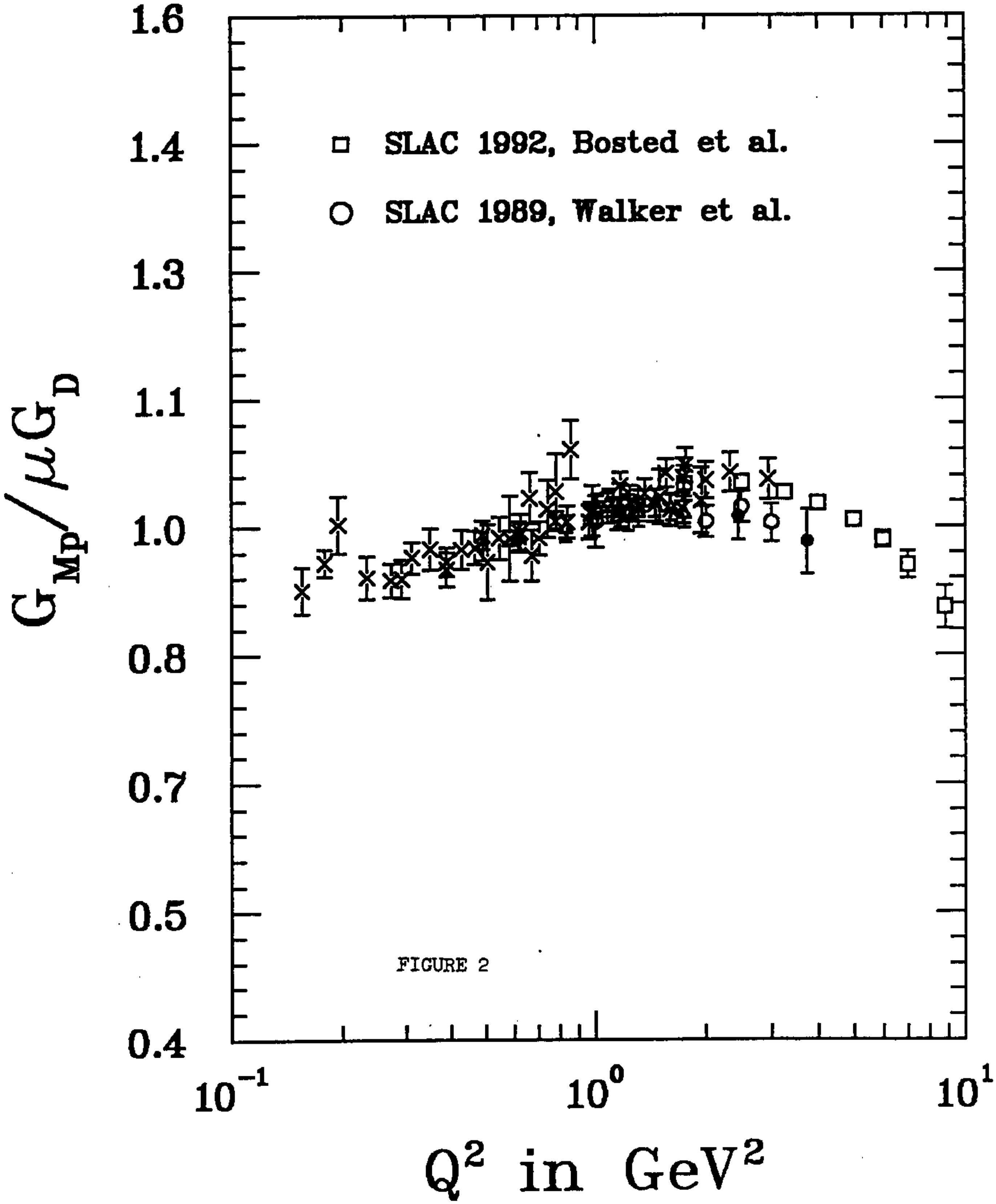


FIGURE 2

gmp slac log 3/22/93

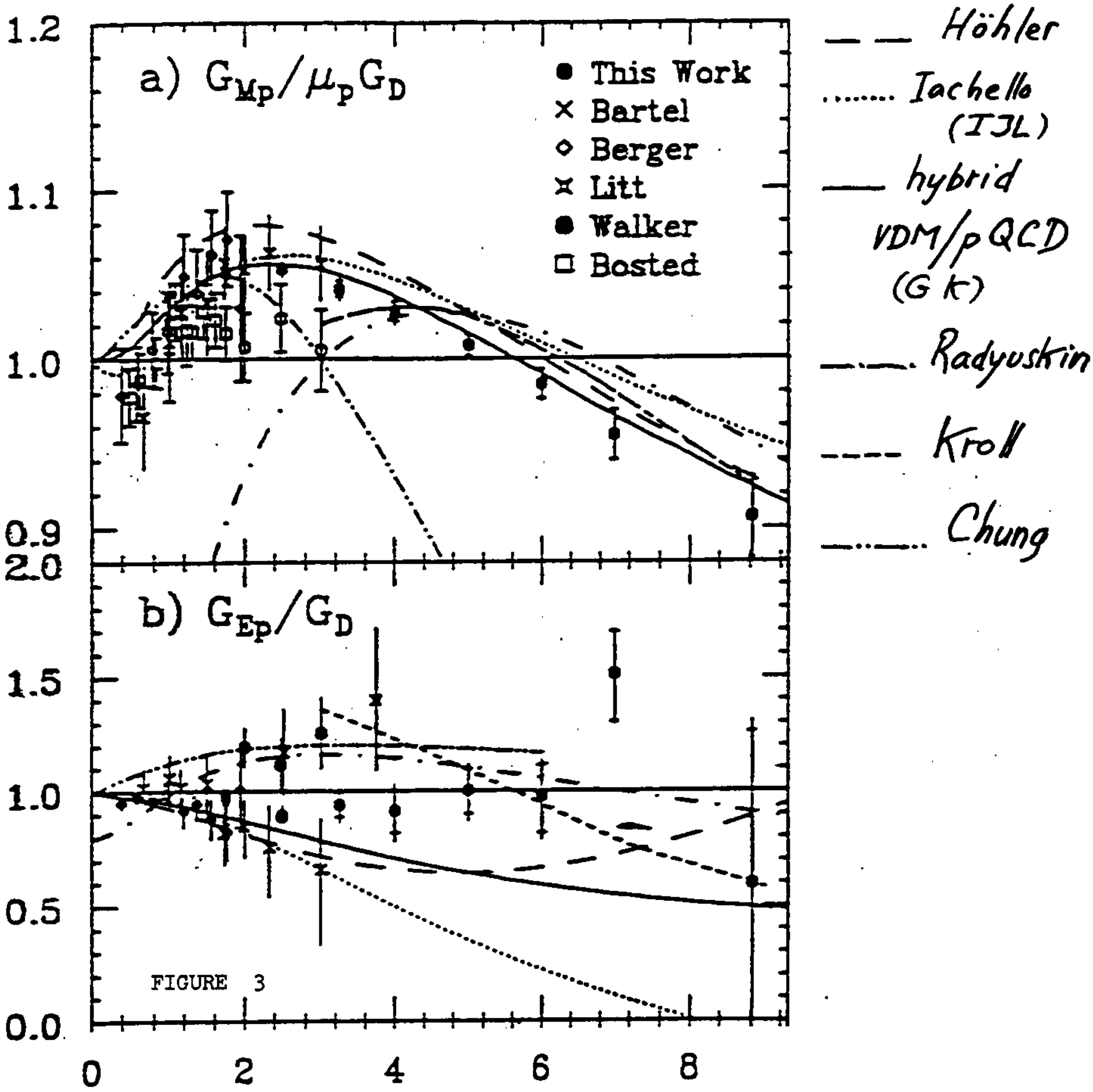
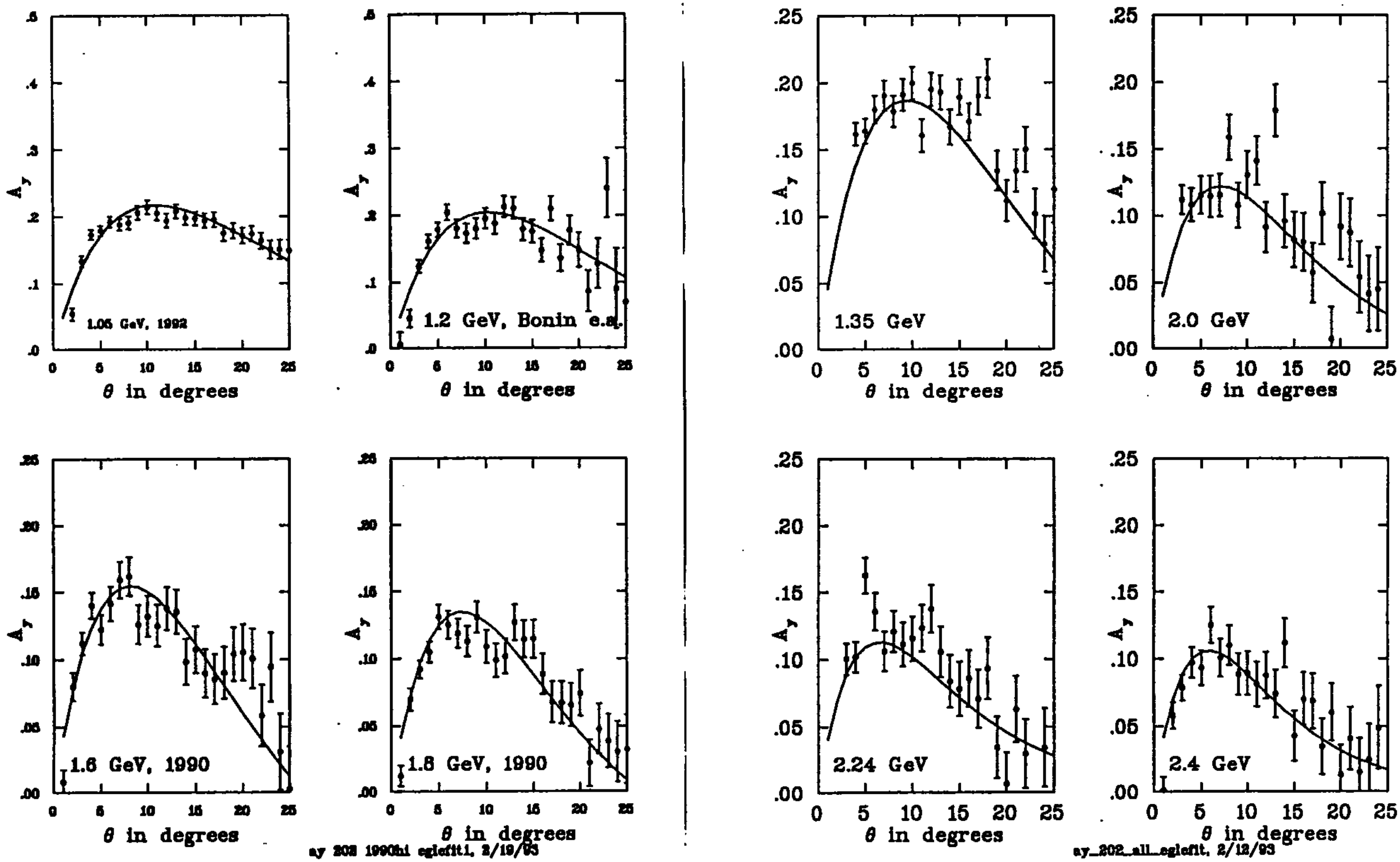

a) $G_{Mp}/\mu_p G_D$
This Work
Bartel
Berger
Litt
Walker
Bosted
Höhler
Iachello (IJL)
hybrid VDM/pQCD (GK)
Radyuskin
Kroll
Chung
b) G_{Ep}/G_D
1.2
1.1
1.0
0.9
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8

FIGURE 3



1.05 GeV, 1992
1.2 GeV, Bonin e.a.
1.35 GeV
2.0 GeV
1.6 GeV, 1990
1.8 GeV, 1990
2.24 GeV
2.4 GeV
A_y
θ in degrees
ay 202 1990hi eglefit1, 2/19/93
ay_202_all_eglefit, 2/12/93

FIGURE 4

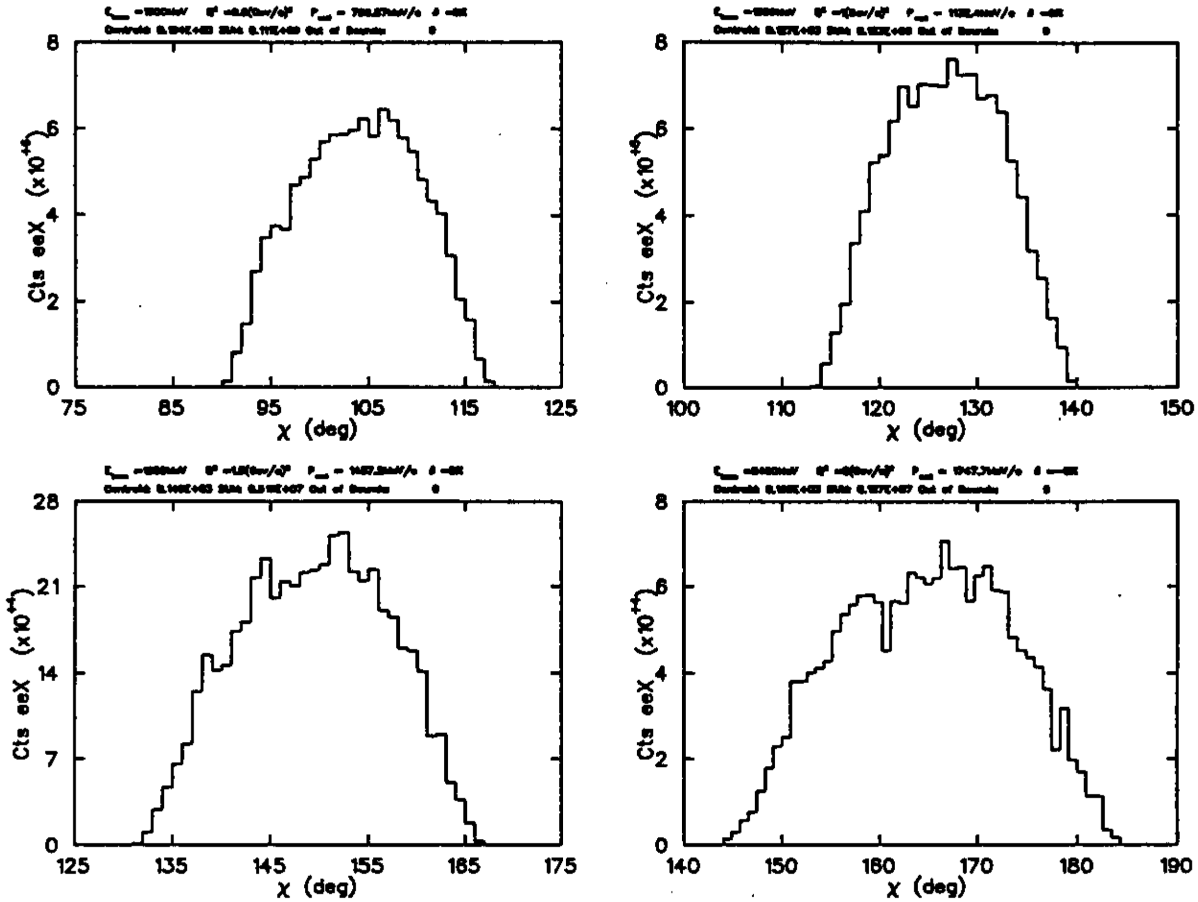
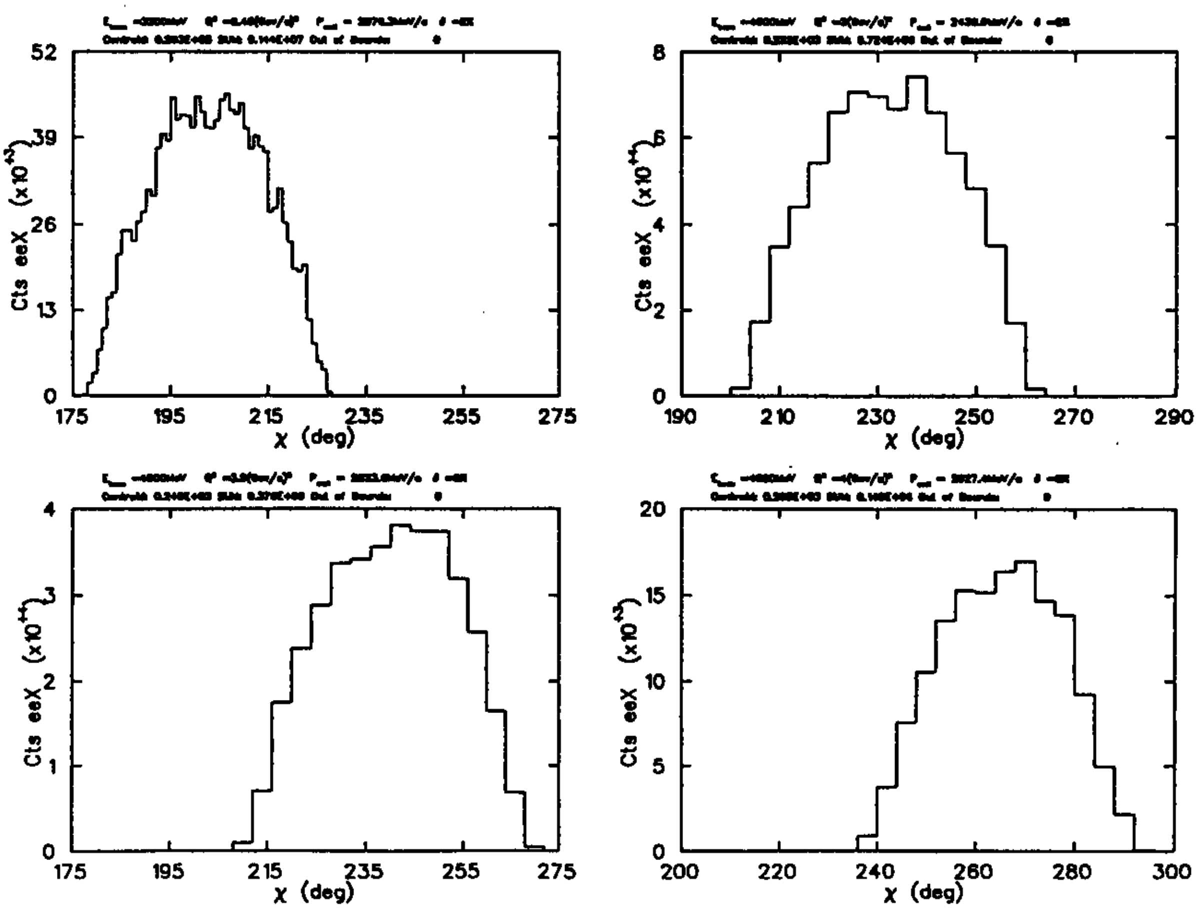


FIGURE 5



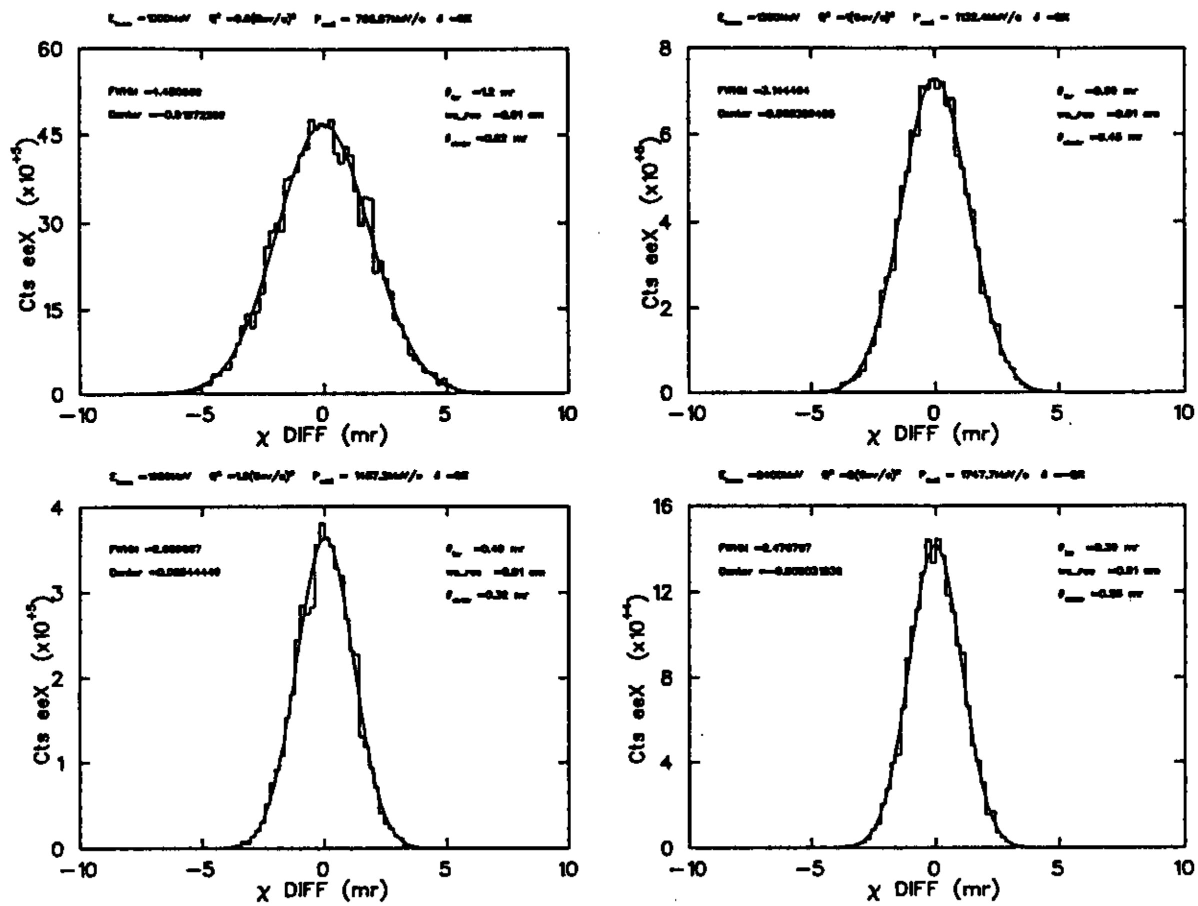
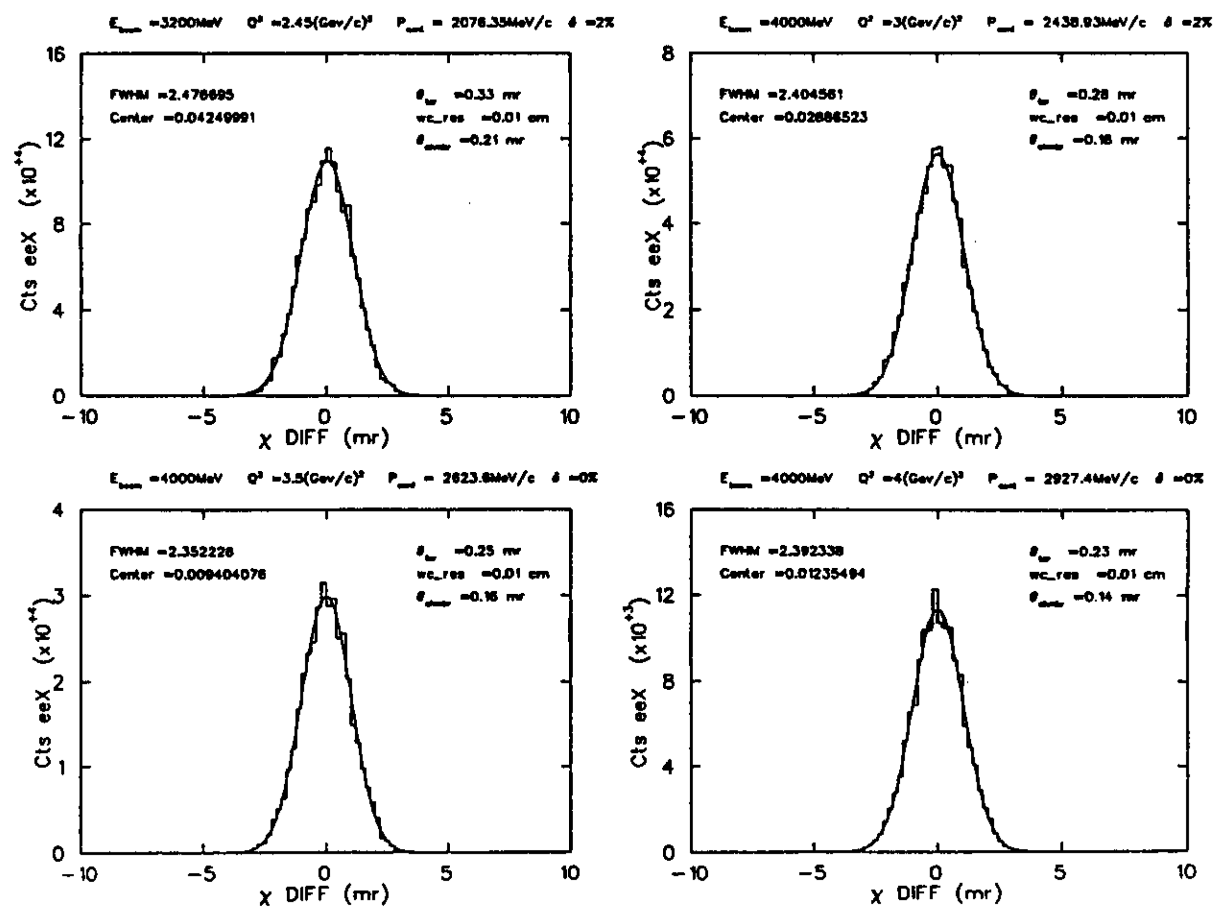

Cts eeX (x10^+5)
χ DIFF (mr)
Cts eeX (x10^+5)
χ DIFF (mr)
Cts eeX (x10^+5)
χ DIFF (mr)
Cts eeX (x10^+4)
χ DIFF (mr)

FIGURE 6


E_beam =3200MeV Q² =2.45(Gev/c)² P_cent = 2076.35MeV/c δ =2%
FWHM =2.476695
Center =0.04249991
θ_tgt =0.33 mr
wc_res =0.01 cm
=0.21 mr
Cts eeX (x10^+4)
χ DIFF (mr)
E_beam =4000MeV Q² =3(Gev/c)² P_cent = 2438.93MeV/c δ =2%
FWHM =2.404561
Center =0.02886523
θ_tgt =0.28 mr
wc_res =0.01 cm
=0.18 mr
Cts eeX (x10^+4)
χ DIFF (mr)
E_beam =4000MeV Q² =3.5(Gev/c)² P_cent = 2623.6MeV/c δ =0%
FWHM =2.352226
Center =0.009404076
θ_tgt =0.25 mr
wc_res =0.01 cm
=0.16 mr
Cts eeX (x10^+4)
χ DIFF (mr)
E_beam =4000MeV Q² =4(Gev/c)² P_cent = 2927.4MeV/c δ =0%
FWHM =2.392338
Center =0.01235494
θ_tgt =0.23 mr
wc_res =0.01 cm
=0.14 mr
Cts eeX (x10^+3)
χ DIFF (mr)