Proposals for Initial Electron Scattering Experiments Using the SLAC Spectrometer Facilities

W. K. H. Panofsky, D. H. Coward, H. DeStaebler, J. Litt, L. W. Mo and R. E. Taylor, (SLAC), J. I. Friedman, H. W. Kendall and L. Van Speybroeck, (MIT), C. Peck and J. Pine, (CIT)

Proposal No. 4 actually comprises three separate but related experiments. These experiments acted as a shakedown of the spectrometers for scattering experiments and provide a general survey of the basic cross sections which will be useful for future proposals. They also furnished a relatively straightforward way to check out and debug the rather complex data recording system.

4a. Electron-Proton Elastic Scattering

Summary

Studies of electron-proton scattering[1] have been previously carried out at linear accelerators and electron synchrotrons in order to obtain information about the structure of the proton. Because of limitations in energy and beam intensities these measurements were able to determine separately the electric and magnetic form factors of the proton, G_E and G_M, only up to squared four-momentum transfers, q^2, of about 2 $(BeV/c)^2$. CEA experiments at higher q^2 values have placed a limit of about 0.04 on G_E, and G_M has been determined to an accuracy of about 0.02.[1] Utilizing the higher intensities and energies available at SLAC, we expect to extend considerably the measurements of the form factors to higher four-momentum transfers. The maximum value of four momentum transfer available at SLAC is about 37 $(BeV/c)^2$ corresponding to an incident energy of 20 BeV. Since the form factors decrease rapidly as q^2 increases, the range over which these measurements can be extended depends critically on the detailed behavior of the form factors. It is useful to list some of the questions of interest that can be investigated by extending the measurements to higher q^2:

(1) Existence of a nucleon core.
(2) Validity of the pole description of nucleon form factors.
(3) Validity of the Wu and Yang form factor,[2] that $G \sim e^{-|q|/0.6}$.
(4) Hypothesis of Drell[3] that $G > e^{-|q|/2M}$.
(5) Hypothesis of Sachs[4] that $G_E = G_M$ at large q^2.
(6) Hypothesis that $F_2(q^2)$ and $F_1(q^2)/q^2$ asymptotically approach zero as q^2 becomes large.[5]

Aside from shedding light on the validity of the above hypotheses, determinations of the detailed behavior of the proton form factors at large q^2 will provide very valuable constraints and guide posts to any future theory of the nucleon and its interactions with other particles.

Received: 4 January 1966
Approved: 13 February 1966, 50 hrs parasite/150 hrs prime time
Approved: 20 May 1967, 250 hr extension

Supplement No. 1 to Proposal 4a.

DATE: 28 October 1966

TO : M. Sands

FROM : J. Litt and R. E. Taylor

SUBJECT: SLAC Proposal No. 4-a.

We have reviewed this proposal in the light of the P.A.C. allocation of 150 hours of data collection time, and the new cross sections available from DESY. Fig. 1 shows the presently available data from all sources, for momentum transfers $q^2 \geq 1.1$ (BeV/c)^2, and the projected data which would be made available after 120 hours of actual data taking. The diameter of the open circles are proportional to the cross sectional errors of the previous measurements. Measurements of form factors exist up to $q^2 = \sim 10$(BeV/c)^2 for G_M and ~ 4 (BeV/c)^2 for G_E. The data can be fitted by:

$$G_E = \frac{G_M}{\mu} = \left(\frac{1}{1 + \frac{q^2}{0.71}} \right)^2 \qquad (1)$$

This expression lowers the predicted cross sections at high values of q^2 used in the preparation of the original proposal. A new proposed run program is shown in Table 1 using rates calculated from equation 1, and realistic beam intensities based on present machine performance. The errors given for G_E^2 in the original proposal were incorrect, and the values in the table are considerably less favorable. The lower predicted cross sections increase the running time required to obtain data at high q^2 points. In figure 1, we have shown as solid circles the data which might be obtained with the present run program, with counting statistics again indicated by the diameter of the circles. Out of 150 hours of scheduled time it is unlikely that we will be able to obtain 120 hours of actual counting since there are many changes in parameters to be made, and target-empty runs at each point. It will probably turn out that the higher q^2 points will receive even less time than indicated in the table.

We would like to request that this experiment be continued into the next scheduling period with an allocation of 250 hours of running time. This should allow us to cover most of the high q^2 points which were originally proposed, although the errors will be somewhat larger than anticipated if the present expression for the cross section is substantially correct.

The run program proposed in this letter is to some extent predicated on the assumption that e-p elastic scattering will continue beyond the presently allocated 150 hours. The program proposed is a part of a systematic study of the process from the lowest convenient q^2, overlapping as much of the present data as possible, to the point when diminishing counting rates will limit the experiment. If the assumption of a continuing program is incorrect, the program should probably be reconsidered to include more high q^2 points at lower accuracy.

JL:RET:as
attachments: Figure 1
Table 1

TABLE 1: NEW PROPOSED RUN PROGRAM

q^2 $(BeV/c)^2$	Angles to be Measured (degrees).	Total Data Collection Time (hrs)	Predicted Range of Rates	Counting Statistics Error in $\frac{d\sigma}{d\Omega}$	Values of the Form Factors (using eq. 1) and the Estimated(**) Errors from Experiment 4a.		
					G_M^2	G_E^2	ΔG_E
2.0	15,26,34,40,45	5	3/sec (reduced intensity)	1%	$3.66 \cdot 10^{-2} \pm 2\%$	$4.70 \cdot 10^{-3} \pm 15\%$	$\pm 5.1 \cdot 10^{-3}$
4.0		8	3/sec→ 16/min.	2%	$4.06 \cdot 10^{-3} \pm 7\%$	$5.20 \cdot 10^{-4} \pm 84\%$	$\pm 9.7 \cdot 10^{-3}$
6.0	18,30,39,45	14	30/min→ 2/min	3%	$9.80 \cdot 10^{-4} \pm 11\%$	$1.26 \cdot 10^{-4} \pm 210\%$	$\pm 1.2 \cdot 10^{-2}$
8.0		38	8/min→ 35/hr	4%	$3.43 \cdot 10^{-4} \pm 12\%$	$4.40 \cdot 10^{-5} \pm 312\%$	$\pm 1.0 \cdot 10^{-2}$
10.0	18,28,35	36	2/min→ 18/hr	5%	$1.51 \cdot 10^{-4} \pm 20\%$	$1.93 \cdot 10^{-5} \pm 615\%$	$\pm 1.4 \cdot 10^{-2}$
~14-16	20	20	~6/hr	~10%	$\sim 10^{-5} \sim \pm 5\%$*	- - - -	- - -

(**) These errors have been calculated by the method outlined in the original proposal.

* This single error in G_M^2 assumes the value of G_E to be 0 or $\frac{G_M}{\mu}$.

Supplement No. 1 to Proposal 4a.

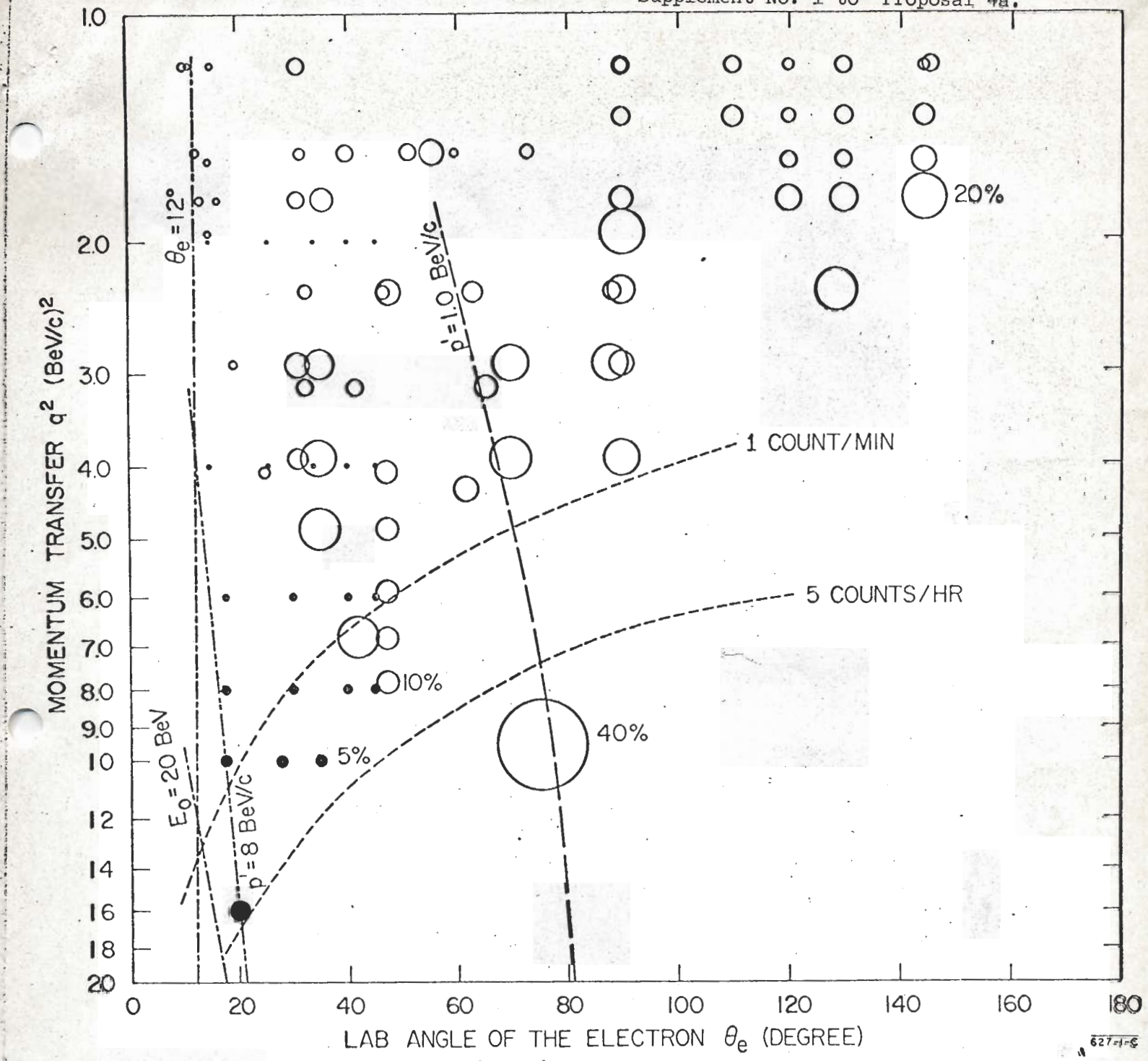

Fig. 1--Presently available e-p elastic scattering data for momentum transfers $q^2 \geq 1.1$ (BeV/c)^2 are shown as open circles whose diameters are proportional to the errors in the cross section measurements. The solid circles show the data which might be obtained in the present run program of experiment 4a. The count rate curves are drawn for an incident beam of 1.0×10^{13} electrons/sec, 20-cm-long liquid hydrogen target and a solid angle of 0.65 msr. The curves of p' indicate the limits of scattered momentum when using the 8 BeV spectrometer.

Date	Shift	Sched. Hours	Charged Hours	Lost Time Hours: P.S. Failure	Target Failure	Comp. Failure	Faraday cup-out	Drive Line Failure	Main Booster Failure		Misc. Accel. Failure

Recapitulation

		Percent
Charged Hours	347.9	51.2%
Lost Time Hours		
Power Supply Failure	28.90	4.3
Target Failure	19.75	2.9
Install & Charge Target	28.55	4.2
Install Faraday cup ↓	5.00	0.7
change Spectro meter	0.75	0.1
Drive Line Failure	140.50	20.6
Main Booster Failure	4.00	0.6
Energy Change & Tune-up	51.65	7.6
Radiation Check	1.50	0.2
Vacuum Failure	22.50	3.3
Misc. Accel & BSY Failure	29.00	4.3
Total Lost Time	332.1	48.8%
Total Manned Hours	680.0	100.0%

Computer Failure (Included in Charged Hours) 6.0

↓ Faraday cup troubles (a 10 hr) in addition
that problem was used during the time

E-4a

				Lost Time Hours									
Date	Shift	Sched. Hours	Charged Hours	P.S. Failure	Target Failure	Komp. Failure	Faraday cup-out	Misc. Exper. Equip	Drive Line Failure	Main Booster Failure	Energy Change and Tune-up	Misc. Accel. Failure	
Apr 3	3	8.0	2.0		6.0								
✓ 4	1	8.0	4.0	4.0									
✓ 4	2	8.0	1.25		6.75		↑						
✓ 4	3	8.0	1.3	2.7	4.0								
✓ 5	1	8.0	7.5				FARADAY CUP REMOVED					0.5	
✓ 5	2	8.0	6.0	1.0								1.0	
✓ 5	3	8.0	4.5	2.5								1.0	
✓ 6	1	8.0	4.0							4.0			
✓ 6	2	8.0	8.0										
✓ 6	3	8.0	8.0										
✓ 7	1	8.0	4.0		Change Target 4.0								
✓ 7	2	8.0	3.0				Install Faraday Cup 5.0						
✓ 7	3	8.0	6.0								2.0		
✓ 8	1	8.0	3.5	4.0							0.5	.25	
✓ 8	2	8.0	5.75	2.0									Radiation Check 1.5
✓ 8	3	8.0	2.5					Change Spectrometer .75				4.0	
✓ 9	1	8.0	7.25										
✓ 9	2	8.0	6.5								1.5		
✓ 9	3	8.0	5.75			⟨2.5⟩					1.0	1.75	
✓ 10	1	8.0	5.5			⟨2.5⟩					0.5	2.0	
✓ 10	2	8.0	4.0									4.0 Vac. Leak BSF	
✓ 10	3	8.0	-0-									8.0 Vac. Leak BSF	
✓ 11	1	8.0	1.5									6.5	
✓ 11	2	8.0	7.0			⟨0.5⟩						1.0	
✓ 11	3	8.0	6.5								1.5		
✓ 12	1	8.0	5.75								2.25		
✓ 12	2	8.0	5.25			⟨0.5⟩					2.75		
Total		216.0	125.8	16.2	Failure 16.75 Install 4.0	⟨6.0⟩	5.0	.75		4.0	12.0	30.0	1.5

E-4a

Date	Shift	Sched. Hours	Charged Hours	Lost Time Hours: P.S. Failure	Target Failure	Compt. Failure	Faraday Cup-out	Misc. Expmt. Equip	Drive Line Failure	Main Booster Failure	Energy Change and Tune-up	Misc. Accel. Failure
Apr 17	3	8.0	-0-						8.0			
✓ 18	1	8.0	-0-						8.0			
✓ 18	2	8.0	-0-						8.0			
✓ 18	3	8.0	-0-						8.0			
✓ 19	1	8.0	-0-						8.0			
✓ 19	2	8.0	-0-						8.0			
✓ 19	3	8.0	-0-						8.0			
✓ 20	1	8.0	-0-						8.0			
✓ 20	2	8.0	-0-						8.0			
✓ 20	3	8.0	-0-						8.0			
✓ 21	1	8.0	-0-						8.0			
✓ 21	2	8.0	-0-						8.0			
✓ 21	3	8.0	-0-						8.0			
✓ 22	1	8.0	-0-						8.0			
✓ 22	2	8.0	-0-						8.0			
✓ 22	3	8.0	-0-						8.0			
✓ 23	1	8.0	-0-						8.0			
✓ 23	2	8.0	6.7									1.3
✓ 23	3	8.0	6.5								1.5	
✓ 24	1	8.0	-0-						4.5		3.5	
✓ 24	2	8.0	3.0								3.0	2.0
✓ 24	3	8.0	6.0								1.0	1.0
✓ 25	1	8.0	7.25	0.25								0.5
✓ 25	2	8.0	6.0	0.5							1.5	
✓ 25	3	8.0	6.5								1.5	
✓ 26	1	8.0	7.0	0.75								0.25
✓ 26	2	8.0	5.75	0.25							0.5	1.5
✓ 26	3	8.0	6.0								1.3	0.7
Total		224.0	60.7	1.75					140.5		13.8	7.25

E-4a

Date	Shift	Sched. Hours	Charged Hours	Lost Time Hours: R.S. Failure	Target Failure	Comput. Failure	Faraday Cup-out	Misc. Upper Equip.	Drive Line Failure	Main Booster Failure	Energy Change and Tune-up	Misc. Accel. Failure
Apr 30	3	8.0	-0-		Install Target 8.0							
May 1	1	5.0	3.75		Install Target 4.25							
✓ 1	2	8.0	3.0		Change Target 4.3							0.7
✓ 1	3	8.0	-0-		Install Target 8.0							
✓ 2	1	8.0	6.0		1.0						0.5	0.5
✓ 2	2	8.0	4.0								3.0	1.0
✓ 2	3	8.0	7.25								0.75	
✓ 3	1	8.0	7.75		0.25							
✓ 3	2	8.0	7.25	0.25								0.5
✓ 3	3	8.0	7.0								1.0	
✓ 4	1	8.0	5.75								2.25	
✓ 4	2	8.0	7.0								1.0	
✓ 4	3	8.0	4.0								4.0	
✓ 5	1	8.0	6.0								2.0	
✓ 5	2	8.0	1.0	5.0							2.0	
✓ 5	3	8.0	4.5	3.5								
✓ 6	1	8.0	5.5								2.5	
✓ 6	2	8.0	-0-									Vacuum Leak 8.0
✓ 6	3	8.0	5.0	1.75								1.75
✓ 7	1	8.0	7.0								1.0	
✓ 7	2	8.0	5.2								2.8	
✓ 7	3	8.0	7.75								0.25	
✓ 8	1	8.0	6.7								1.0	0.3
✓ 8	2	8.0	7.75									0.25
✓ 8	3	8.0	7.0	0.75								0.75
✓ 9	1	8.0	8.0									
✓ 9	2	8.0	6.5	0.2							1.3	
✓ 9	3	8.0	5.75		1.75						0.5	
✓ 10	1	8.0	8.0									
✓ 10	2	8.0	7.0									1.0
Total		240.0	161.4	10.95	Failure 3.0 Install 2.55						25.85	14.25