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PROPOSAL TO MEASURE THE A-DEPENDENCE OF DEEP INELASTIC ELECTRON SCATTERING FROM NUCLEI

Submitted by

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ABSTRACT

We propose to compare deep inelastic electron scattering from a variety of nuclei. Measurements would be made using ten nuclear targets from deuterium to gold. The kinematics covered would include a range in the scaling variable x from 0.1 to 0.7, and a range in momentum transfer, Q^2, from 1.3 to 15 GeV^2. The experiment would use the 8-GeV spectrometer in End Station A to detect scattered electrons. Because the spectrometer is currently set up and working, the only major new piece of equipment required would be the target assembly. The experiment could measure approximately 20 kinematic points in 100 hours of beam time at 180 pps. We believe that we could be ready to begin data taking by May 15, 1983.

I. MOTIVATION

A significant difference between the cross-section per nucleon for deep inelastic lepton scattering from iron and that from deuterium has recently been observed by the European Muon Collaboration in muon scattering[1] and confirmed by a Rochester-SLAC-MIT group in electron scattering[2] (see fig. 1). Because these effects are observed in kinematic regions where shadowing and Fermi-momentum smearing are not expected to be large, a likely explanation is that the distribution functions of quarks within nucleons are significantly altered by the presence of nearby nucleons. While some explanations along this line have been advanced[3], the result has largely taken the high energy physics community by surprise. Such an effect has important experimental consequences in interpreting the present body of deep inelastic scattering data, which relies heavily on the use of nuclear targets. Furthermore, if the interpretation of the results as a distortion of the quark distribution functions proves to be correct, then the effect is important as a basic physics question in both quantum chromodynamics and nuclear physics. It is therefore important that experimental data be obtained covering a range of nuclei in order to gain insight into this effect.

II. THE EXPERIMENT

A. Apparatus

The experiment would use the SLAC 8-GeV spectrometer in its present configuration to identify and track scattered electrons. The detectors in the spectrometer consist of a gas Cerenkov counter and a two-layer lead-glass total absorption counter for electron identification, and a 10-plane proportional wire chamber system for kinematic reconstruction. The detector system has a larger acceptance and improved particle indentification and tracking compared to systems previously used in the 8-GeV spectrometer.

The target assembly would include a liquid deuterium cell, a high pressure helium gas cell at liquid hydrogen temperature, two dummy cells for the deuterium and helium empty target subtraction, and a number of solid targets. The cycling of targets would be computer- controlled in order to maximize data taking efficiency.

Electron beams through $\pm 0.5\,\%$ slits, varying in energy from 6 to 21 GeV and in intensity from 1 to 40 mAmp, would be monitored using the standard End Station A toroids for intensity measurement. The 1.6-GeV spectrometer, detecting scattered protons at high counting rate, would be used as a relative luminosity monitor, in order to monitor density changes and detect potential boiling problems in the deuterium target.

B. Target Selection

In order to determine the nature of the observed effect, even if only qualitatively, one would like to perform measurements on targets covering a wide range in binding energy per nucleon (see fig. 2), nuclear density (see fig. 3), surface to volume ratio, and atomic number.

A tentative list of targets to be used is given in Table I. The following considerations were used in the selection of targets:

1. The deuterium target would be used as a reference for all other targets because the deuteron is the simplest nucleus containing both a proton and a neutron. Since the ratio of deuterium to hydrogen cross-sections has been measured extensively, the use of a hydrogen target is unnecessary.
2. The comparison of deuterium to helium is of particular interest, since, in the absence of nuclear effects, their cross-sections should differ by a factor of two. However, the difference in nuclear density and binding energy per nucleon is significantly larger than can be obtained for any other nuclei closely spaced in atomic number.
3. As can be seen from fig. 2, the curve of binding energy per nucleon *vs* atomic number peaks roughly at iron. It is therefore important to study nuclei of atomic number both higher and lower than iron in order to distinguish between effects which depend upon binding energy and those which depend upon surface to volume ratio. Iron itself is of additional interest since a large number of deep inelastic scattering experiments use iron targets.
4. Where possible, nuclei have been chosen for which nuclear charge densities are known from low energy elastic form factor measurements.
5. Solid targets have been limited to elements of relatively high melting point, for which densities can be reliably determined, and which can be fabricated into mechanically sound self-supporting structures.
6. In order to minimize differences from target to target due to radiative corrections, one would like to use targets of the same thickness in radiation lengths. However, this would result in very thin targets for the high Z elements, making their thickness difficult to measure and resulting in significantly lower event rates. We therefore would propose to have two aluminum targets of different thickness for use as a transfer standard between 2% and 6% radiation length targets.

C. Selection of Kinematic Points

A tentative list of kinematic points to be covered is given in Table II and is shown schematically in fig. 4. Electron cross-sections have been obtained from existing deuterium data[4], and pion rates have been estimated using inclusive pion photoproduction data[5]. The running times quoted assume a repetition rate of 180 pps, and would provide approximately 1% statistical uncertainties in the measurements for each target and kinematic point. The quoted running times include the time required for empty target and positron background runs as well as overhead required in changing targets, spectrometer momentum, and spectrometer angle. Of the total 100 hours requested, 30 hours have been alloted to allow for contingencies and high repetition rate tests. No inflation factor has been included to allow for accelerator down time, energy changes, current changes, or reduced repetition rate.

The following considerations have been used in the selection of kinematic points:

1. The points selected give reasonable coverage of the x and Q^2 range available subject to constraints of beam energy, avoidance of the resonance region, and of low counting rate at high Q^2.
2. For three points in x and Q^2, data would be taken at two different angles in order to detect any dramatic target-dependent effects in the ratio of longitudinal to transverse photon cross-sections, R. These measurements would provide a statistical uncertainty of less than 0.1 in R. Note that from target to target most of the systematic uncertainties involved in the measurement of R remain the same.

3. Kinematic points were chosen at six discrete beam energies in order to minimize the number of energy changes required.

4. Where necessary, beam currents have been limited to maintain electron counting rates at less than one half per pulse and pion rates at less than one per pulse.

5. Not all targets would be run at all kinematic points. In Table II running times are calculated assuming that all targets would be run for the points labelled "All"; carbon, calcium, and silver targets would be omited for the points labelled "Most"; and only deuterium and aluminum targets would be used for the points labelled "Minimum".

III. REQUEST TO THE LABORATORY

We request the equivalent of 100 hours of beam time at 180 pps to perform the experiment. Additionally, approximately one week of running at low repetition rate would be required for checkout.

Because the requirements for this experiment are very similar to those of the presently running experiment E-136, the only major piece of new equipment required would be the target assembly. We believe that such a target could be operational by May 15 of this year. Both the 8-GeV and 1.6-GeV spectrometers were in use during this experimental cycle in the same configuration as would be used for the proposed experiment. The software required for the two experiments is also very similar. Hence the proposed experiment could be mounted with only minor changes to the existing software and electronics. Because of the timeliness of the experiment, and because it can be carried out in a short amount of time, we request that the experiment begin in May or as soon as is practical.

IV. REFERENCES

1. J. J. Aubert et al., CERN-EP/83-14 (submitted to Physics Letters).
2. A. Bodek, et al., SLAC-PUB-3041, University of Rochester Preprint UR 841 (submitted to Phys. Rev. Letters).
3. R. L. Jaffe, Phys. Rev. Letters 50 , 228 (1983).
4. A. Bodek, thesis, MIT (1972, unpublished).
5. D. E. Wiser, thesis, University of Wisconsin (1977, unpublished).
6. R. Evans, *The Atomic Nucleus,* McGraw-Hill, New York (1955).

V. FIGURE CAPTIONS

1. Ratio of Iron to deuterium cross-section per nucleon *vs* x (corrected for neutron to proton ratio). The solid curve shows the effect expected as a result of Fermi-momentum smearing. The data are from refs 1 and 2, and the figure is taken from ref. 2.
2. Nuclear binding energy per nucleon as a function of atomic number[6].
3. Nuclear charge density of selected nuclei determined from elastic scattering.
4. Proposed kinematic points in x and Q^2. The solid lines show the kinematic limitations of beam energy and fixed missing mass.

Table I. Proposed Targets

Nucleus	t (g/cm^2)	t (cm)	Rad Length (%)
^{2}H	2.5	15.5	2
^{4}He	1.9	20.0	2
^{9}Be	1.3	0.71	2
^{12}C	0.85	0.47	2
^{27}Al	0.48	0.18	2
^{27}Al	1.45	0.54	6
^{40}Ca	0.98	0.63	6
^{56}Fe	0.86	0.10	6
^{107}Ag	0.56	0.051	6
^{197}Au	0.39	0.020	6

Table II. Kinematics and Rates for Proposed Kinematic Points

Q^2 (GeV^2)	X	E (GeV)	E' (GeV)	θ (deg)	W^2 (GeV^2)	$d\sigma/d\Omega dp$ (nb/GeV·sr)	Rate/ gm/cm^2 / 10^{15} e	π/e Ratio	Tgt Set	I (mA)	Time (hrs @ 180 pps)
1.28	.1	9.4	2.579	13.195	12.4	27.7	2754	40	Min	0.4	5.1
2	.2	9.4	4.071	13.127	8.9	25.0	3920	3	Most	5	1.1
2	.3	7.4	3.847	15.231	5.6	26.1	3885	0.8	Most	2	2.4
2	.4	7.4	4.736	13.721	3.9	38.8	7077	0.1	Most	2	1.4
2	.5	7.4	5.268	13.005	2.9	43.9	8917	0.02	Most	2	1.1
5	.2	18.5	5.178	13.119	20.9	3.46	691	12.5	All	6	6.0
5	.3	11.9	3.018	21.503	12.6	1.60	186	20	Min	10	3.7
5	.3	15.2	6.318	13.102	12.6	4.86	1184	0.8	All	17	1.5
5	.4	11.9	5.239	16.281	8.4	3.22	650	0.6	All	20	2.2
5	.5	7.4	2.071	33.188	5.9	.593	47	14.5	Min	> 20	5.7
5	.5	11.9	6.571	14.527	5.9	3.78	956	0.07	All	20	1.7
5	.6	11.9	7.459	13.630	4.2	3.37	968	0.01	All	20	1.7
5	.7	7.4	3.594	25.043	3.0	.570	79	0.3	Min	> 20	3.3
5	.7	11.9	8.094	13.083	3.0	2.45	765	0.005	All	20	1.9
10	.4	21.2	7.878	14.055	15.9	.96	291	0.6	Most	40	2.0
10	.5	18.5	7.842	15.086	10.9	.70	211	0.1	Most	40	2.2
10	.6	15.2	6.318	18.569	7.6	.31	75	0.1	All	40	8.9
10	.7	15.2	7.587	16.933	5.2	.22	65	0.08	Min	40	2.1
10	.8	15.2	8.539	15.955	3.4	.12	39	0.009	Min	40	3.5
15	.6	21.2	7.878	17.236	10.9	.14	43	0.04	All	40	14.3
											71
								Contingency and high rep-rate tests			29
										Total Hours	100

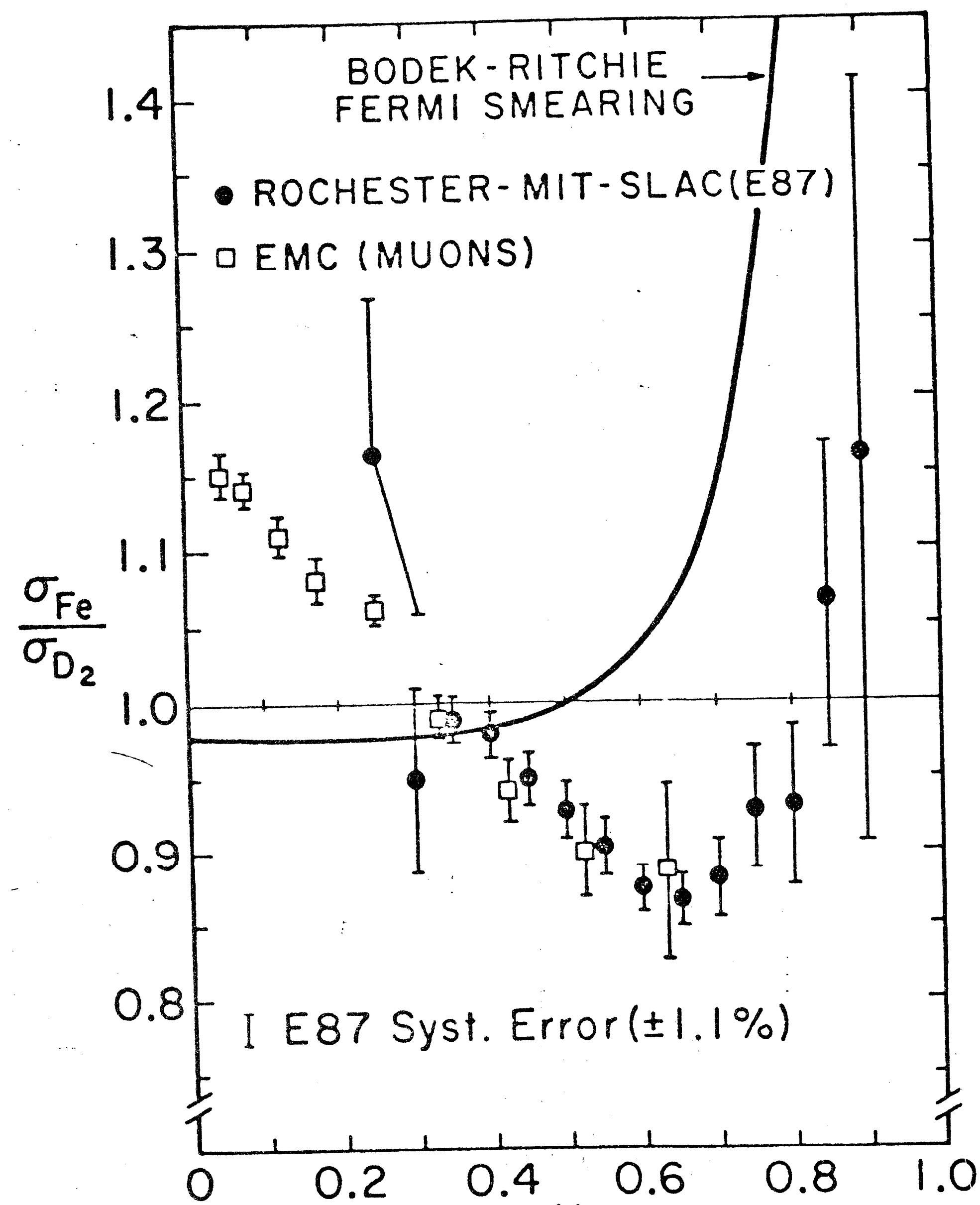
BODEK-RITCHIE FERMI SMEARING
ROCHESTER-MIT-SLAC(E87)
EMC (MUONS)
E87 Syst. Error(±1.1%)
1.4
1.3
1.2
1.1
1.0
0.9
0.8
σFe/σD2
0
0.2
0.4
0.6
0.8
1.0
X

Fig. 1

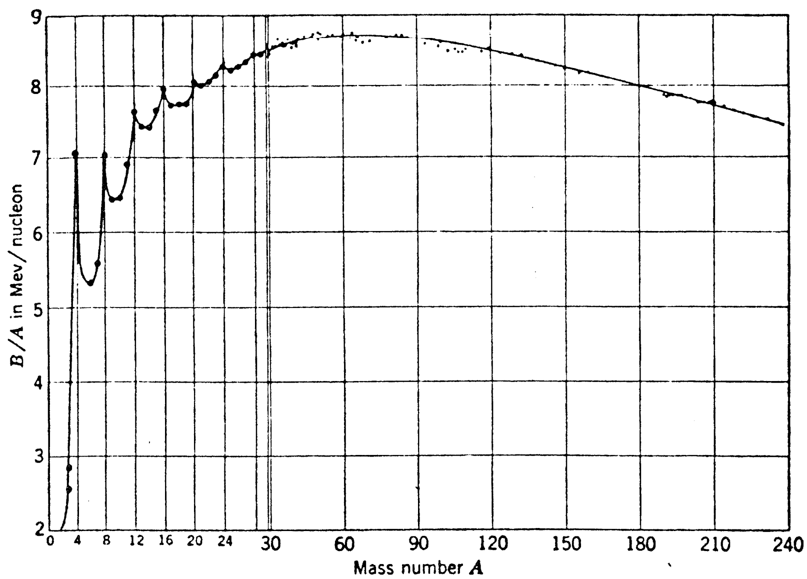
B/A in Mev / nucleon
Mass number A
9
8
7
6
5
4
3
2
0
4
8
12
16
20
24
30
60
90
120
150
180
210
240

FIG. 2

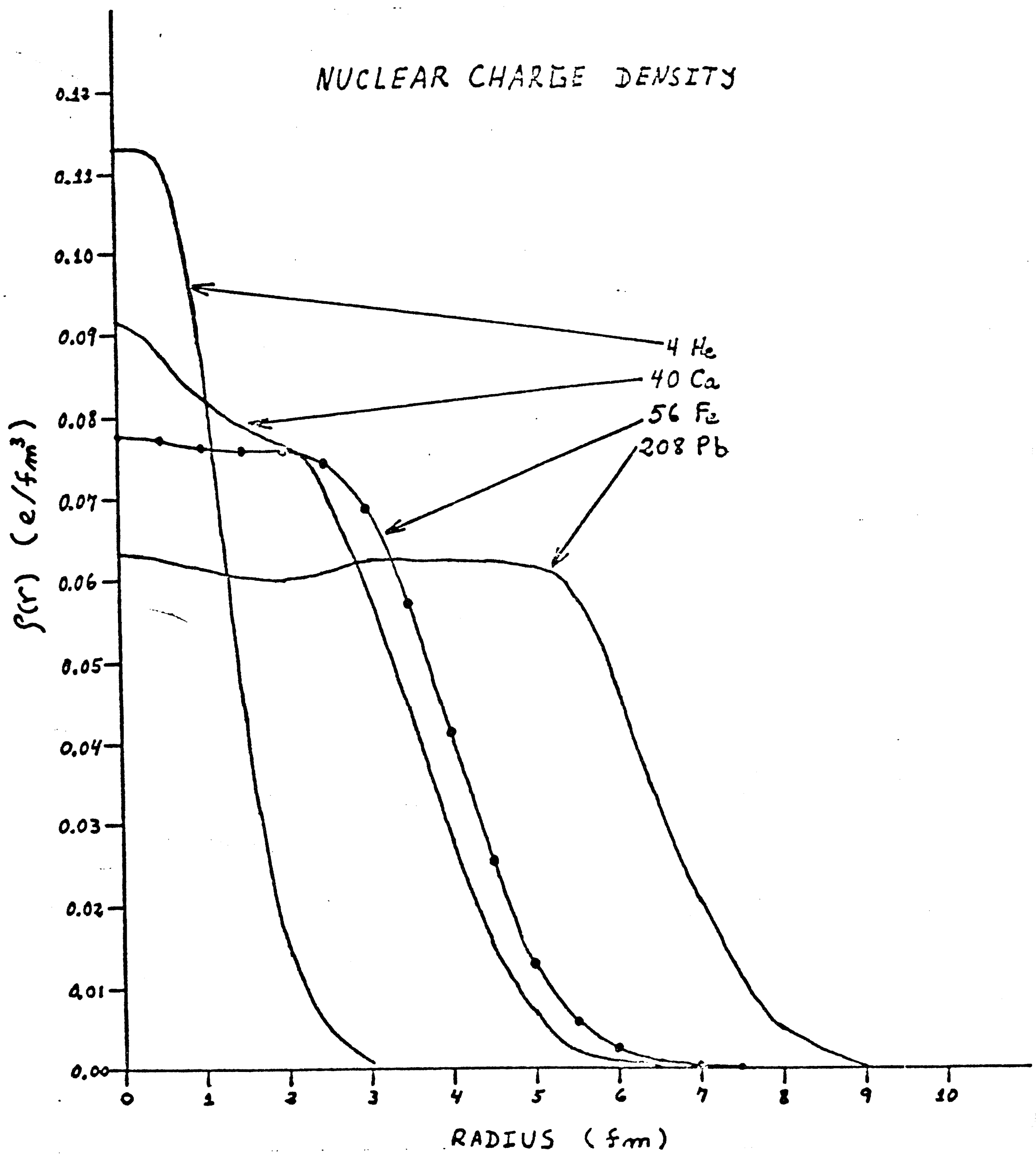
NUCLEAR CHARGE DENSITY
ρ(r) (e/fm³)
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
4 He
40 Ca
56 Fe
208 Pb
0
1
2
3
4
5
6
7
8
9
10
RADIUS (fm)

Fig. 3

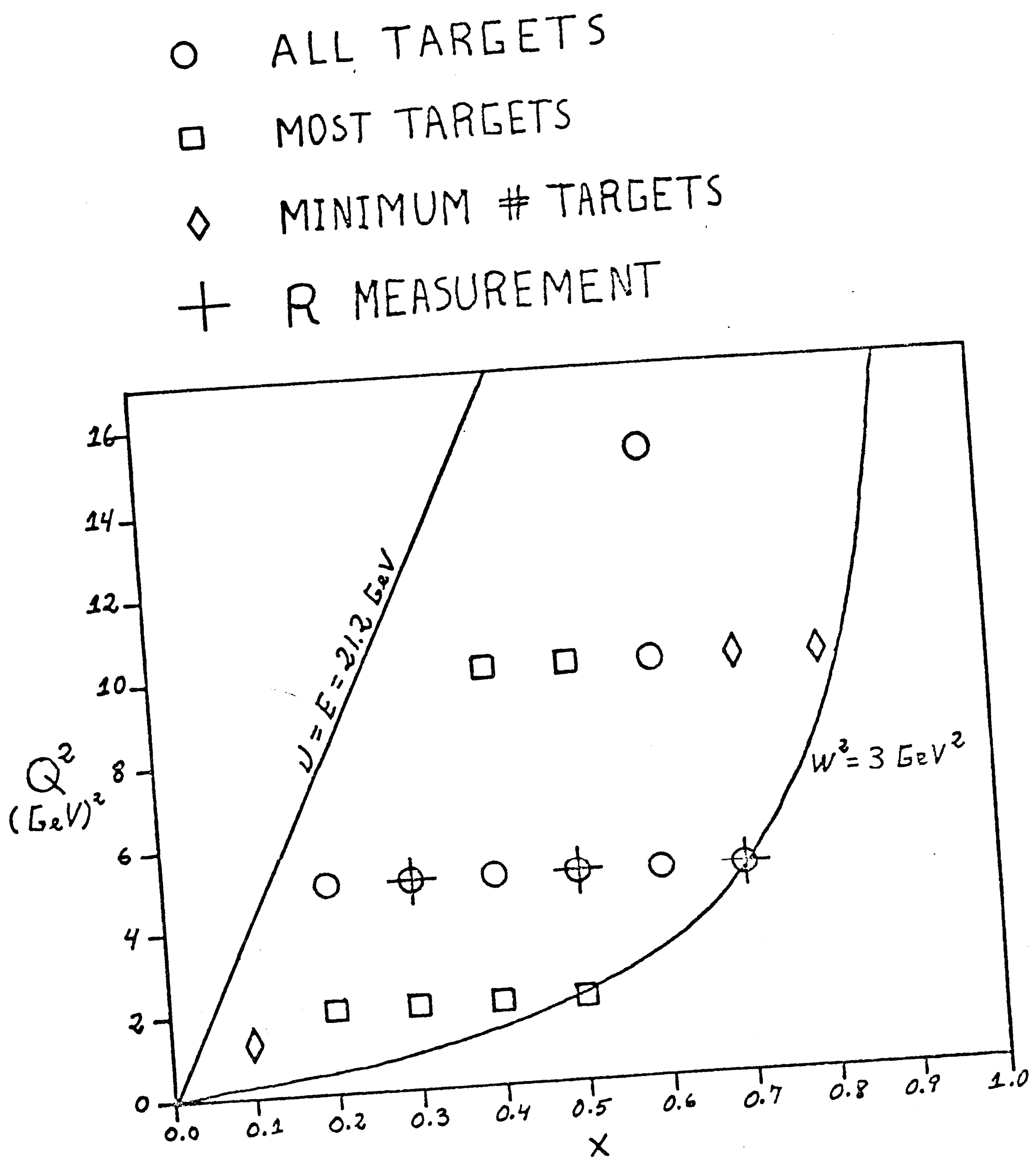
○ ALL TARGETS
□ MOST TARGETS
◊ MINIMUM # TARGETS
+ R MEASUREMENT
ν = E = 21.2 GeV
W² = 3 GeV²
Q²
(GeV)²
0
2
4
6
8
10
12
14
16
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
X

Fig. 4