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MEMORANDUM

To/A: Members of the SPSC

From/De: A. Staude, Bologna-CERN-Dubna-Munich-Saclay collaboration (NA4)

Subject/: Concerne Measurement of the influence of nuclear matter on deep inelastic structure functions (EMC effect) in Period 5/1983.

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1. INTRODUCTION

The European Muon Collaboration (EMC) has observed a discrepancy between the nucleon structure functions F_2 measured on iron and deuterium targets [1]. The size and x dependence of the effect cannot be explained in terms of the familiar Fermi motion smearing. This result implies that in deep inelastic scattering the current does not only probe the structure of the nucleon but also the effects of the nuclear environment which embeds the nucleon. Therefore, the conventional interpretation of structure functions measured with complex nuclei, both with μ and ν beams, becomes somewhat questionable.

The effect has recently been confirmed by a reanalysis of the old SLAC deep inelastic scattering data, albeit in a different Q^2 and x range [2].

The EMC has measured the effect with good statistical accuracy but rather large systematic errors; for a linear parametrization of the effect, $F_2(Fe)/F_2(D_2) = a + bx$, their result on the slope parameter is $b = -0.52 \pm 0.04$ (stat.) ± 0.21 (syst.) [1]. We propose to measure the same effect with smaller statistical errors and substantially improved systematic accuracy, and also to extend this measurement to a new target not investigated so far (nitrogen). The experiment can be carried out with the NA4 apparatus in its present configuration and without disrupting the approved running schedule of the experiment.

2. APPARATUS, DATA TAKING, AND STATISTICAL ERRORS

In its present configuration the NA4 apparatus (Fig. 1) consists in the upstream part of two external targets followed by a system of seven hexagonal MWPC with three-coordinate readout. Downstream of this set-up there are eight toroidal iron magnets equipped with MWPC's and scintillation trigger counters (supermodules) which constitute part of the original NA4 spectrometer [3] and which also serve to momentum analyze muons scattered off the front targets. The first five supermodules contain target sections which, together with the two upstream targets, form a target 35 m long in total which can be filled with liquid hydrogen, deuterium or nitrogen.

We intend to replace the target section in supermodule 3 by an iron target and to take data with separate fills of D_2 and N_2 in the remaining targets. In this way, we can measure the effect in the three ratios $F_2(Fe)/F_2(D_2)$, $F_2(Fe)/F_2(N_2)$ and $F_2(N_2)/F_2(D_2)$, the first two from simultaneous measurements and the last one from separate measurements with identical target configurations.

The acceptance of the spectrometer is essentially constant along the target from supermodule 1 to 4. Thus the position of the iron target minimizes both the reliance on Monte-Carlo corrections for the acceptance and the influence of the heavy material on the measurement with the downstream liquid targets. The length of the iron (75 cm) is chosen to have about twice the integrated density of the D_2 in supermodules 1 to 4. This represents a compromise between statistical accuracy and degradation of beam quality.

The measurement can be carried out parasitically to NA9 data taking with 280 GeV muons. In order to minimize the risk of losing the deuterium it is best to perform the experiment during period 5 where power failures are least likely to occur and where the target operations group will have its full manpower available.

Assuming an intensity of 10^7 μ/spill, as it has been used by NA9 in 1982, and an overall data taking efficiency of 70% we expect the event statistics shown in Table I for a total of 50 days of running.

The sharing of the running time between deuterium and nitrogen has been chosen to yield similar statistical errors on the three structure function ratios. The simultaneous measurements [$F_2(Fe)/F_2(D_2)$, $F_2(Fe)/F_2(N_2)$] are restricted to the kinematical domain $Q^2 > 40$ GeV^2, $0.15 < x < 0.7$, while the measurement of $F_2(N_2)/F_2(D_2)$ extends over the wider range $Q^2 > 25$ GeV^2, $0.05 < x < 0.7$ using the data from the external targets. The expected results from these measurements are given in fig. 2 together with the published EMC points. As shown in fig. 3, the data can also be used to investigate the dependence of the effect on Q^2.

3. SYSTEMATIC ERRORS

The scenario of data taking permits a good control of the systematic errors since the structure function ratios are determined either from simultaneous measurements or from data sets which have identical target configurations. These have in common the iron data which can then be used as a monitor of the experimental conditions.

In the case of simultaneous measurements the systematic errors on setting of the spectrometer field, setting of the beam momentum spectrometer magnets, beam divergence and relative flux normalization are completely negligible. For separate measurements, we have shown in our measurement of the charge asymmetry [4] that these systematic errors can be controlled to a level that makes their effects negligible in the present experiment.

Other sources of potential systematic errors inherent in this measurement are:

a) Imperfect corrections for resolution smearing: Monte-Carlo calculations show that if the data are not corrected at all for spectrometer resolution, the size of the structure function ratio is affected by $\sim 40\%$ for $x > 0.5$. A conservative estimate of 15% accuracy for the smearing corrections leads to a systematic error of the slope parameter $\Delta b \simeq 0.015$.

b) Mutual contamination of D_2 and F_2 data samples by imperfect vertex resolution: Monte-Carlo studies show that they can be limited to $\lesssim 1\%$ each with appropriate cuts and that the remaining background can be corrected for. We will check the Monte-Carlo simulation by measuring this background directly in short dedicated runs, taking data with only the D_2 or iron target respectively.

c) Relative luminosity calibration: apart from errors in counting the incoming muon flux, this is affected by beam losses from the target due to beam divergence and multiple scattering and by uncertainties in the subtraction of background from the liquid target vessel. The size of all these effects was evaluated by Monte-Carlo calculations and their uncertainty found to be 1%.

In total, we expect a systematic error $\Delta b = 0.025$ on the slope parameter of the structure function ratios.

4. CONCLUSIONS

We can measure the EMC effect for the three target combinations Fe/D_2, N_2/D_2 and Fe/N_2 in the kinematic domain $Q^2 > 40$ GeV^2, $0.15 < x < 0.7$ (Fe/D_2, Fe/N_2) and $Q^2 > 25$ GeV^2, $0.05 < x < 0.7$ (N_2/D_2) with about a factor 2 reduction in the statistical and a factor 8 in the systematic error with respect to the EMC published result. The small normalisation errors will allow us to give a good measurement of the structure function differences

$$F_2(Fe) - F_2(D_2), \quad F_2(Fe) - F_2(N_2)$$

(fig. 4) which are expected to be important for a theoretical interpretation of the effect [5].

A more extensive investigation of the Q^2 dependence of the effect could be carried out at a later date in dedicated runs with lower beam energies and higher beam intensity.

REFERENCES

[1] EMC, J.J. Aubert et al., Phys. Lett. 123B (1983) 275.

[2] A. Bodek et al., Univ. of Rochester preprint UR841/COO-3065-348 and SLAC-PUB-3041.

[3] D. Bollini et al., Nucl. Instr. Meth. 204 (1983) 333.

[4] A. Argento et al., Phys. Lett. 120B (1983) 245.

[5] R.L. Jaffe, Phys. Rev. Lett. 50 (1983) 228.

FIGURE CAPTIONS

Fig. 1 Schematic view of the spectrometer.

Fig. 2 Expected results for the structure function ratios $F_2(N_2)/F_2(D_2)$ and $F_2(Fe)/F_2(D_2)$ compared to the published EMC data. Only statistical errors are shown. For the ratio $F_2(Fe)/F_2(N_2)$ we expect the same errors as for $F_2(Fe)/F_2(D_2)$ when determined from the simultaneous measurement only. These errors decrease by 25% when including the data from the Fe/D_2 run into the Fe/N_2 ratio.

Fig. 3 Expected errors for the Q^2 dependence of the $F_2(N_2)/F_2(D_2)$ ratio in bins of x.

Fig. 4 Expected results for the structure function difference $F_2(N_2)-F_2(D_2)$. The errors include the uncertainties of the relative normalisation and of the acceptance and resolution smearing.

TABLE I

Targets		Running time (Days)	Events (after cuts) x 10^{-3}				
Front, SM1,2,4	SM3		Deuterium		Nitrogen		Iron
			Front	SM 1,2,4	Front	SM 1,2,4	
Deuterium	Iron	26	145	116	-	-	288
Deuterium	empty	10	16	13	-	-	-
empty	Iron		-	-	-	-	40
empty	empty		-	-	-	-	-
Nitrogen	Iron	13	-	-	355	283	144

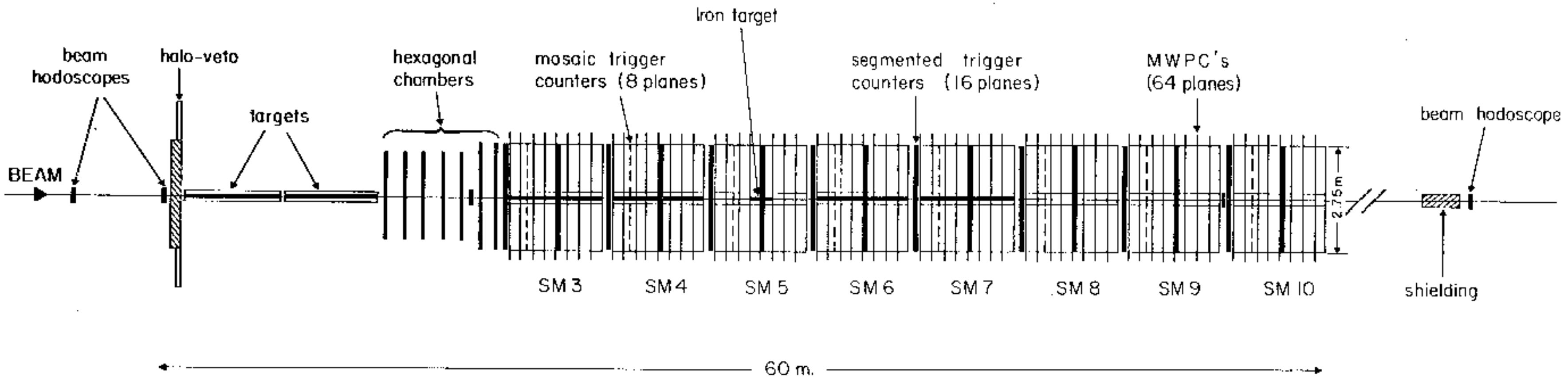
beam hodoscopes
halo-veto
targets
hexagonal chambers
mosaic trigger counters (8 planes)
Iron target
segmented trigger counters (16 planes)
MWPC's (64 planes)
beam hodoscope
BEAM
SM 3
SM 4
SM 5
SM 6
SM 7
SM 8
SM 9
SM 10
2.75 m
shielding
60 m.

FIG. 1

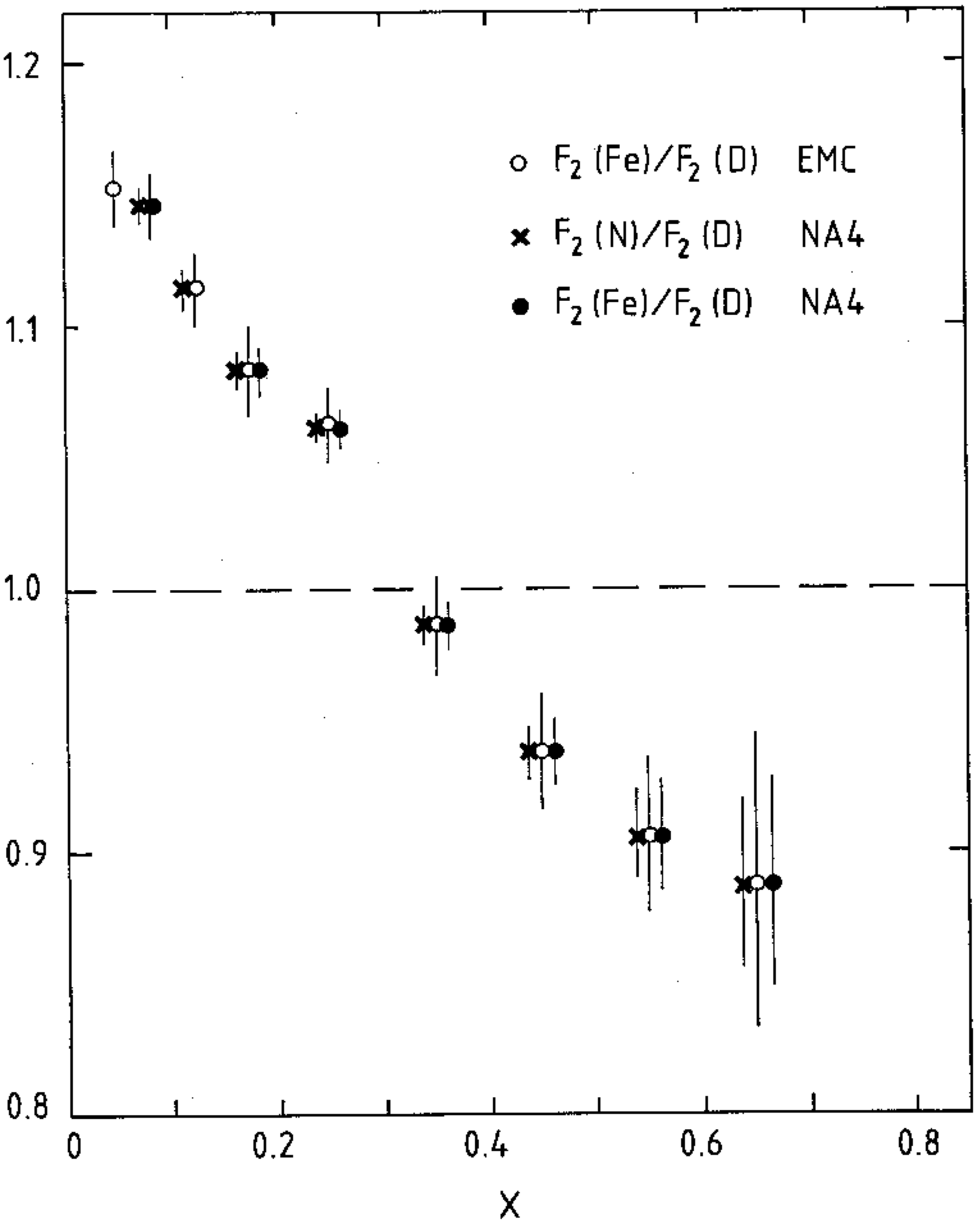

FIG. 2

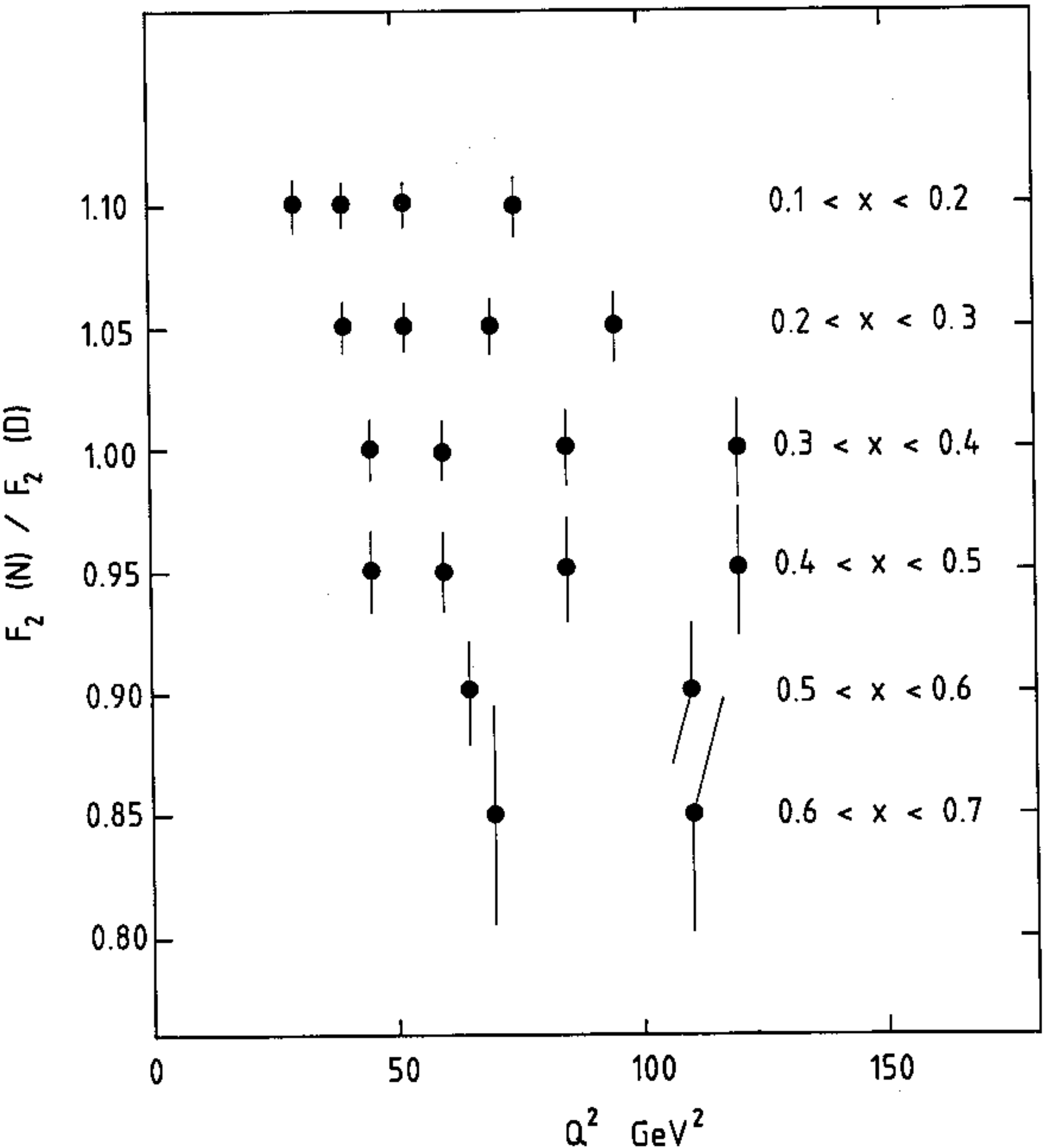
1.10
1.05
1.00
0.95
0.90
0.85
0.80
F2 (N) / F2 (D)
0
50
100
150
Q² GeV²
0.1 < x < 0.2
0.2 < x < 0.3
0.3 < x < 0.4
0.4 < x < 0.5
0.5 < x < 0.6
0.6 < x < 0.7

FIG. 3

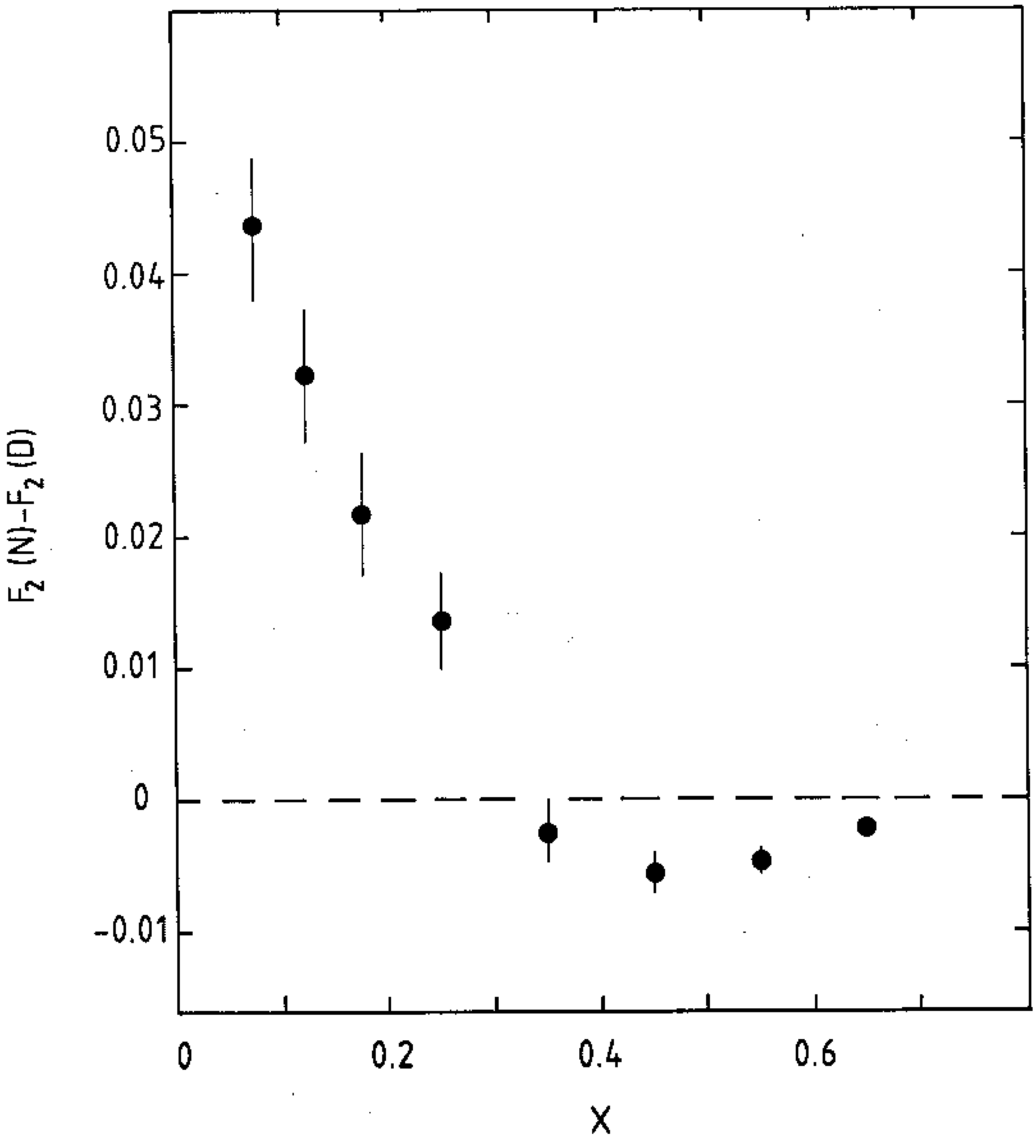

FIG. 4