Ref.: CERN/SPSC-84-68
SPSC/M388
Date: September 4, 1984

M E M O R A N D U M

Copy to/Copie à:

To/A: The S P S C

From/De: The DUBNA group of the NA4 Collaboration*

Subject/: Concerne The decisive study of nuclear effects

1. INTRODUCTION

It is already well understood that the wavelength of the probe determines the level of structure that is being explored. So one can expect that a virtual photon with a mass much greater than that of a nucleon is unlikely to interact with nucleons of a nucleus as if they were free. Similarly, the Fermi-motion of nucleons in a nucleus is unlikely to affect quark-parton structure functions because it belongs to another level of structure.

It can be shown that if multiquark configurations exist in a nucleus then the structure function $F_2(x)$ for $x \gtrsim 0.4$ would behave as $a.\exp(-x/b)$ with $b \simeq 0.16$ [1]. This hypothese has been used in the processing of the data obtained by NA4 with muon energy 280 GeV on a carbon target [2]. The structure function reconstructed after smearing corrections and integrated over Q^2-range is shown in fig. 1. The experimental points can be very well fitted with an exponential $F_2(x) = a.\exp(-x/b)$ where $b = 0.14 \pm 0.01$ (stat.). Unfortunately systematic errors exceed statistical ones by factor of 3 or even more in the region $x \simeq 1$. This has considerably hindered the analysis.

---

* D.Yu. Bardin, J. Cvach, N.G. Fadeev, N.D. Gagunashvili, I.A. Golutvin, J. Hladky, V.Y. Karzhavin, M.Yu. Kazarinov, Yu.T. Kiryushin, V.S. Kisselev, V.G. Krivokhizhin, V.V. Kukhtin, W. Lohmann, J. Nemechek, P. Reimer, I.A. Savin, G.I. Smirnov, D.A. Smolin, J. Strachota, G. Sultanov, P. Todorov, A.G. Volodko, J. Veress and J. Zachek.

163M/ma

In 1982 the EMC has shown that the nuclear effects in structure functions of nucleons are rather strong even for $x < 1$. The most important factor was the evidence that Fermi-motion does not play any part in quark-parton structure functions [3]. These results were confirmed by SLAC and recently by NA4 measurements and initiated an avalanche of theoretical papers pretending to describe the observed effects.

The situation at present is as follows. There are numbers of theoretical models that satisfactorily describe the EMC effect using, at times, contradicting starting points. This can be explained on one hand by large experimental errors and, on the other hand, by the fact that many models give practically the same predictions in the region $0.1 < x < 0.6$ that is being explored experimentally. The data in the region of large x, on the contrary, are decisive for many theoretical approaches. Most promising among them appears to be the hypothesis of multiquark systems [4].

The NA4 spectrometer posses an important advantage as compared to other facilities operating at present. Its acceptance is unrestricted at large x-values and the luminosity allows one to obtain high statistics in a rather short period. Estimating the situation for the study of structure functions it seems unlikely that a new spectrometer is going to be constructed in the next few years that will provide high resolution measurements in the region $x \sim 1$ with high efficiency. The cost of a new set-up would be in the order of tens of millions of swiss francs. On the other hand, the NA4 spectrometer can be converted at a small cost into a set-up capable of providing $\sim (10 \div 15)\%$ resolution in $\Delta x/x$ in the region $x \simeq 1$ that is sufficient to resolve a number of problems important to the understanding of nuclear structure.

Now the possibility arises to improve our apparatus by the hadron calorimeter from NA3 (under CERN responsibility) and a few calorimeter modulus from EHS which both (NA3 and EHS) has resolution $\Delta\nu/\nu \simeq 0.8/\sqrt{\nu}$.

2. RESOLUTION OF THE NA4 SPECTROMETER IN THE REGION OF LARGE X

The measurement accuracy of the Bjorken variable $x = Q^2/2M\nu$ can be expressed in terms of known variables Q^2 and ν. For the present configuration of the NA4 $\Delta Q^2/Q^2 = 6 \div 9\%$. The parameter ν being determined by means of scattered muon momentum reconstruction, the resolution $\Delta\nu/\nu$ is worst in the region of small ν-values. This deteriorates considerably the resolution, particularly in the region $x \simeq 1$.

The addition of a hadron calorimeter increases considerably the resolution of the our set up in the region of small ν where $\Delta\nu/\nu$ is the poorest. Even a calorimeter with modest resolution is going to provide an effective resolution $\Delta\nu/\nu = (8\div15)\%$. The results of calculations of $\Delta x/x$ for the present NA4 configuration (open and black points) and also for the version with a calorimeter (crossed point) are shown in fig. 2. The calorimeter resolution has been calculated according $\Delta\nu/\nu = .8/\sqrt{\nu}$ and permits to reach $\Delta x/x \simeq (12 \div 15)\%$ independent of x.

As it has been mentioned above most of the theoretical models yield similar results in the region $x < 1$ and comparison in the region $x \gtrsim 1$ are difficult due to the large smearing effects. We have estimated a possibility to discriminate two similar prediction for the x-dependence of the structure function $F_2(x)$ using Monte-Carlo calculations. As the version for the structure functions we took $F_2 \sim (1-x)^3$ and $F_2 \sim \exp(-x/0.12)$. These parametrisations are close to those of experimentally determined in the region $x < 1$. The simulation has been performed both for the present configuration of the spectrometer and for the modified version that provided the resolution $\Delta x/x = 12\%$ independent of x. The results of simulation at $E = 200$ GeV are shown in fig. 3. This two hypotheses can be separated when the differences between event distributions uncorrected for resolution exceed by a factor of 3 the experimental errors in corresponding x-bins. For the version with a simple calorimeter ($\Delta x/x \sim (12\div15)\%$) this becomes possible already at $x = 0.9 \div 1.0$

3. MODIFICATION OF THE NA4-SPECTROMETER

At present there are available two operating hadron calorimeters which, in principle can be used for the NA-4 spectrometer. That is, the NA3 hadron calorimeter (fig. 5) and the spare blocks of the EHS hadron calorimeter [5] which both provide $\Delta\nu/\nu = 0.8/\sqrt{\nu}$.

A possible layout of the NA4 spectrometer modified by the installation of calorimeters is shown in fig. 4.

NA3 calorimeter can be installed in the place of supermodules 4 and 5 to provide high luminosity and have possibility to check A-dependence for nuclear structure function.

In the forward part of the spectrometer one can place 24 EHS modules around the deuterium targets. Such a configuration could provide possibilities of simultaneous measurements on D_2 and Fe (or other targets) and yield data on nuclear effect in the region $x \sim 1$.

The effective data taking could be achieved by triggering the spectrometer with events in the region $x > 0.5$. Estimated number of events accumulated in this rejgion at E = 200 GeV is shown (as example) in Table 1.

TABLE 1

Intensity	2.10^7	muon/burst
Time	25	days
Flux	$2.5 \cdot 10^{12}$	gated m
Events (x>0.5)	30K/Fe-target	1 meter (in front of NA3 Calorimeter)
	10K/D2	15 meters

For cross-checking we can put two D_2-targets in the second target region.

REFERENCES

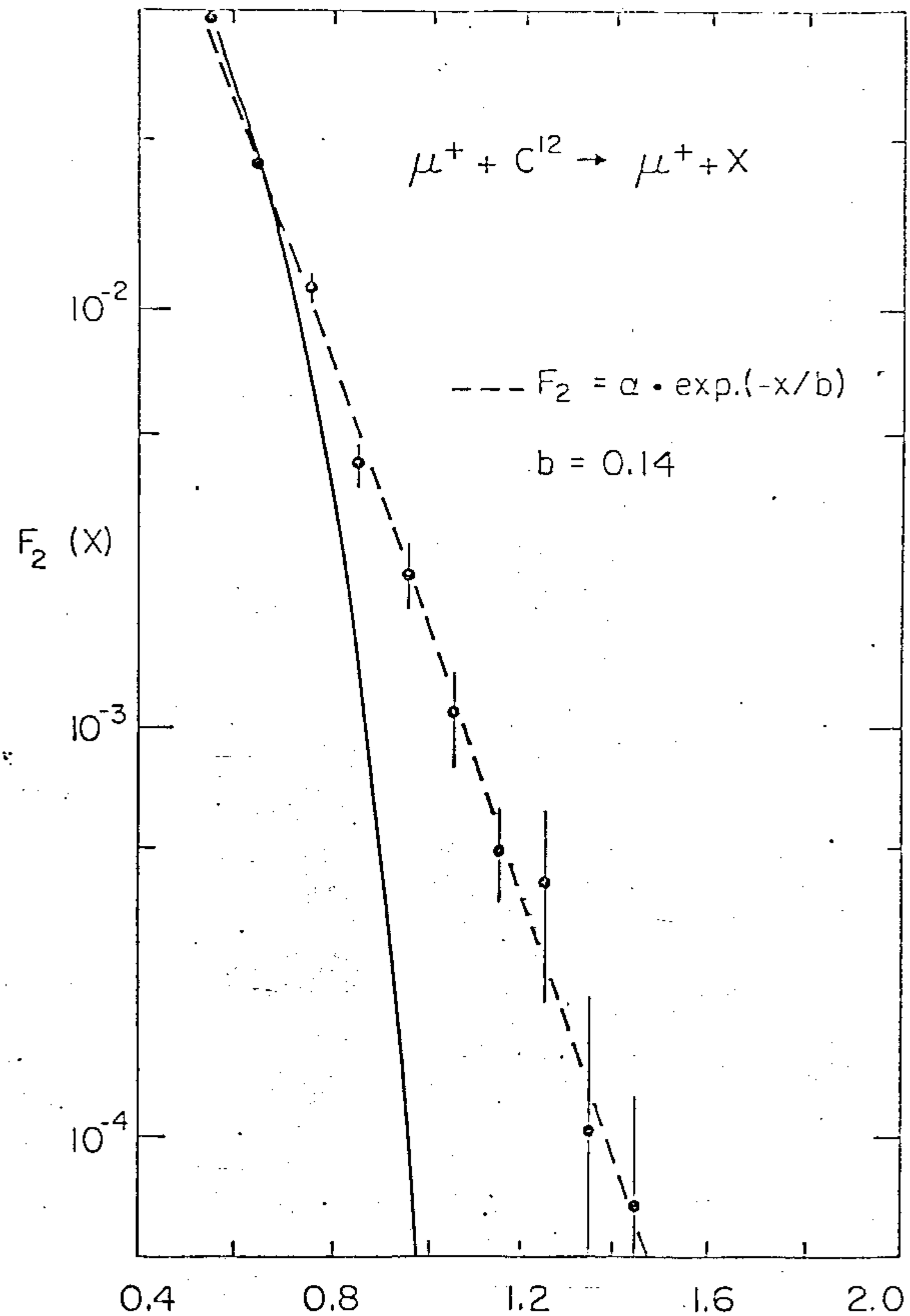
[1] A.M. Baldin, Particles and Nuclei, 8 (1977) 429;
Dubna preprint, JINR, E1-80-545 (1980).

[2] A. Argento et al. The report at the Conference on High Energy Phys. and Nuclear Structure, Versailles, 1981.

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

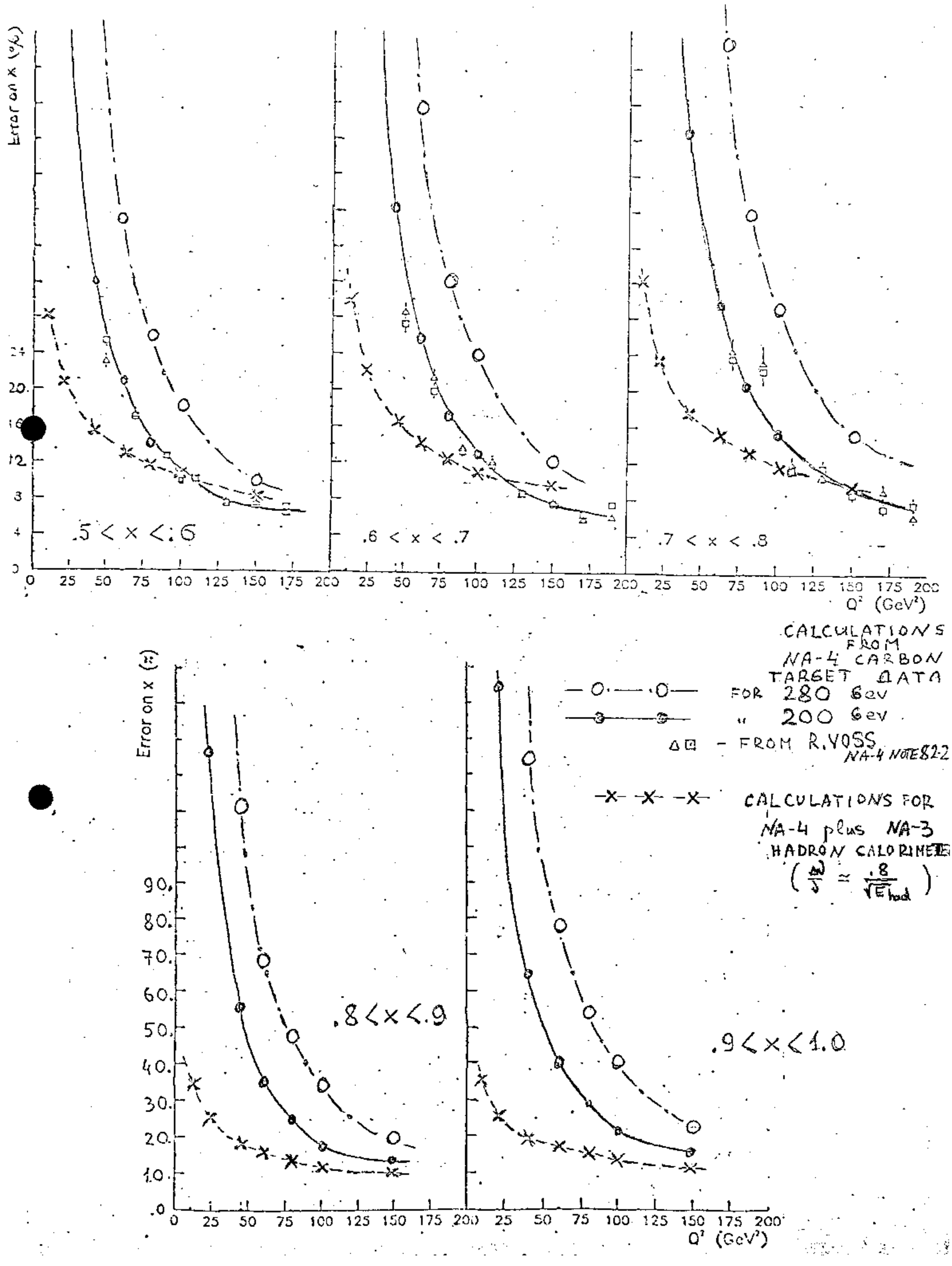
[4] L. Kondratjuk and M. Shamtikov, ITEP Preprint-13, (1984);
A.V. Efremov and E.A. Bondarchenko, Dubna preprint JINR, E2-84-124 (1984); M. Chemtob and R. Peschanski, Saclay preprint, SPhT-84-49 (1984).

[5] M. Boratav et al., IHEP preprint 83-12, (1983).

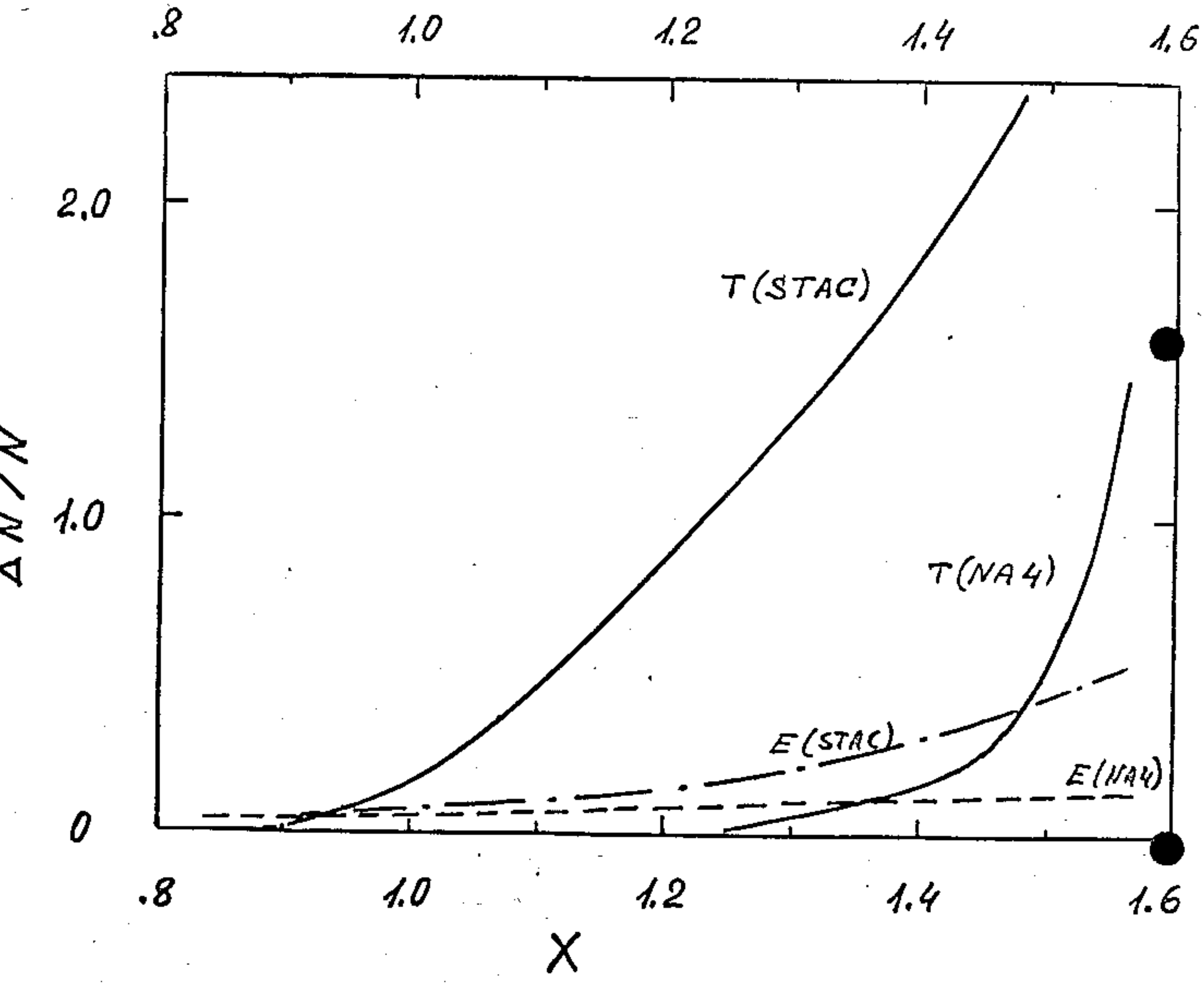


$\mu^+ + C^{12} \rightarrow \mu^+ + X$
$F_2 = a \cdot \exp.(-x/b)$
b = 0.14
F_2 (X)
10^{-2}
10^{-3}
10^{-4}
0.4
0.8
1.2
1.6
2.0
X

FIG. 1



Error on x (%)
.5 < x <.6
.6 < x < .7
.7 < x < .8
Q² (GeV²)
CALCULATIONS FROM NA-4 CARBON TARGET DATA
FOR 280 GeV
" 200 GeV
Δ□ - FROM R. VOSS NA-4 NOTE 82-2
CALCULATIONS FOR NA-4 plus NA-3 HADRON CALORIMETER
Error on x (%)
.8<x<.9
.9<x<1.0
Q² (GeV²)



T means that ΔN is from theories a, b

E statistical error – NA4 : observed in PAC·80 E=200

– STAC : estimated

a – $F_2 \sim \exp(-x/0.12)$

b – F_2 from EMC

NA-3
HADRON CALORIMETER

Sampling - 5 cm Fe
1 cm plexipop

Resolution

$$\frac{\Delta E_h}{E_h} \sim \frac{0.8}{\sqrt{E_h}}$$

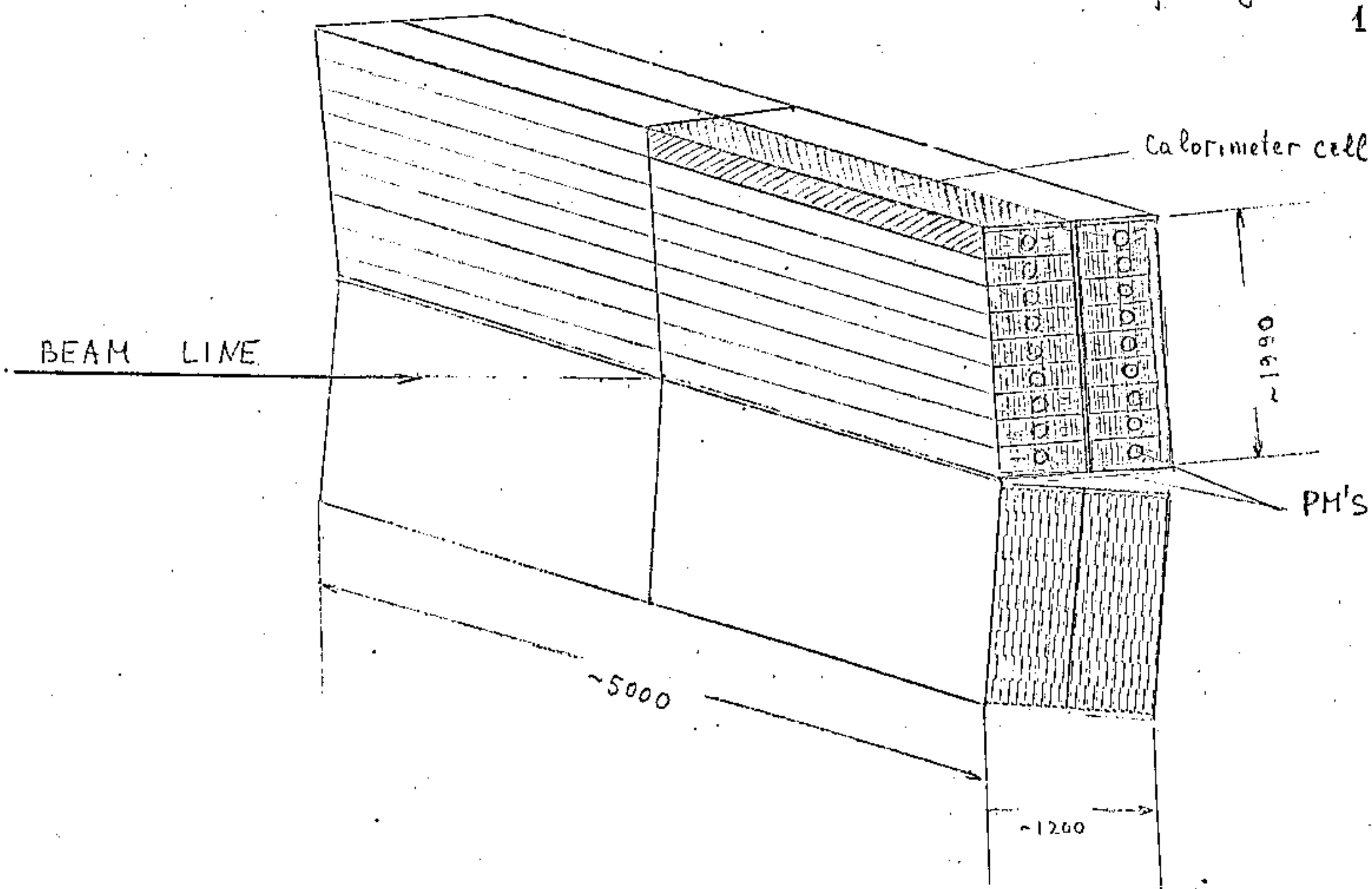


FIG. 4

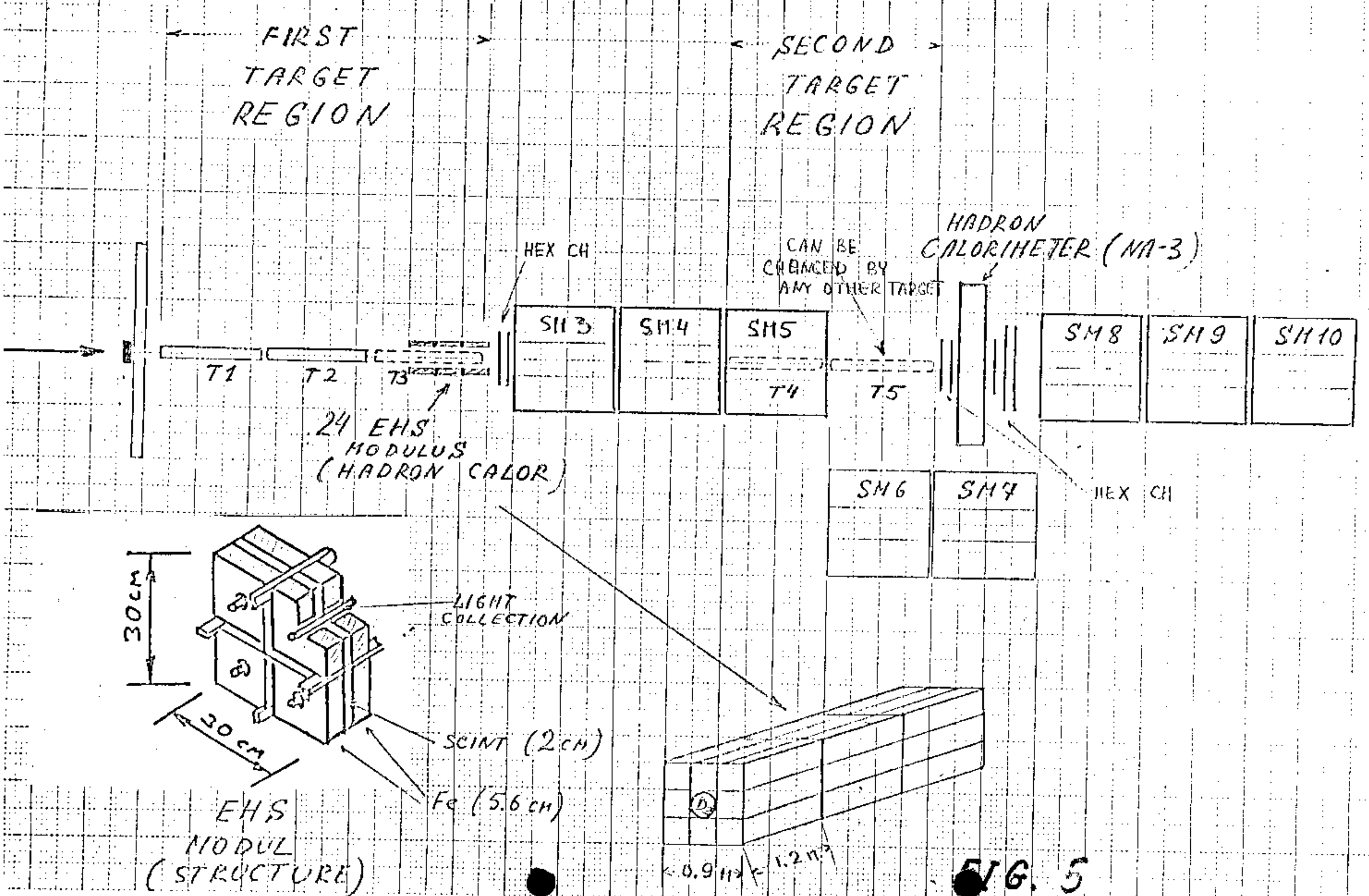

FIRST TARGET REGION
SECOND TARGET REGION
HEX CH
CAN BE CHANGED BY ANY OTHER TARGET
HADRON CALORIMETER (NA-3)
SM3
SM4
SM5
SM8
SM9
SM10
T1
T2
T3
T4
T5
24 EHS MODULUS (HADRON CALOR)
SM6
SM7
HEX CH
30CM
LIGHT COLLECTION
30 cm
SCINT (2 cm)
Fe (5.6 cm)
EHS MODUL (STRUCTURE)
0.9 m
1.2 m

FIG. 5