EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

PH I/COM-72/39

23 August 1972

PROPOSAL

STUDY OF THE REACTION $K^o_L p \to K^o_S p$ IN THE MOMENTUM INTERVAL $2 \leqslant p_{K^o_L} \leqslant 16$ GEV/C

P. Chavanon, M. Crozon, A. Diaczek, T. Leray,

P. Leruste, J.P. Mendiburu, J. Tocqueville, J. Valentin

Laboratoire de Physique atomique et moléculaire

Collège de France - PARIS - France.

G. Calvelli, S. Cittolin, F. Gasparini, S. Limentani,

P. Mittner, M. Posocco, L. Ventura, C. Voci

Istituto Nazionale di Fisica Nucleare - Sezione di Padova

Istituto di Fisica dell'Università - PADOVA, Italia

I - Introduction

Following our letter of intention, we present here a proposal to study the reaction $K^o_L p \rightarrow K^o_S p$ in the 2-16 GeV/c momentum range.

After discussing the physical interest of the measurement, we investigate the neutral beam characteristics and describe an apparatus that can be used to detect with sufficient accuracy and high statistics the proposed reaction. We make an estimate of 50 days of effective running time to collect about 160.000 events, according to predictable trigger rates. Eventually we analyse the support that our groups can receive from their home institutions and that required from CERN.

II - Physical interest and existing data.

In the reaction $K^o_L p \rightarrow K^o_S p$ the meson trajectories that are allowed to be exchanged in the t channel are only the C = -1, natural spin-parity ones (ρ, ω, ϕ). The ω trajectory contribution is expected to dominate over the ϕ , which is weakly coupled to the nucleon. On the other hand, for t = 0 the ρ residue is thought to be 4 to 5 times smaller[(1)] than the ω residue (SU_3 would give a factor of 3) : its contribution, relatively well known, is expected to be limited.

Altogether a study of the $K^o_L p \rightarrow K^o_S p$ process should determine the ω exchange in a unique way, analogous to that of πp charge exchange for the ρ . Furthermore, it should help complete the present knowledge of the K-nucleon high energy scattering amplitudes in a model-independent way, as obtained from $K^{\pm} p$ elastic scattering and polarization and $K^+ n$, $K^- p$ charge exchange and polarization.

The present bubble chamber data[(2)] on this reaction are quite poor (571 events, with $1.3 \leqslant p_{K^o_L} \leqslant 8.0$ GeV/c) and should hopefully be improved by about

(1) F.J. Gilman, P.R. 171, 1453 (1968)

(2) A.D. Brody et al., P.R.L. 26, 1050 (1971).

three orders of magnitude in statistics in the momentum range covered by the proposed experiment. Some of the existing results are shown in figure 2.1 ; they display the following features :

1) the cross section σ falls as p_{lab}^{-n} with $n = 2 \pm 0.2$;

2) the forward differential cross section $(d\sigma/dt)_{t=0}$ falls as P_{lab}^{-m} , with $m = 1.3 \pm 0.3$;

3) the average value of the phase of the forward amplitude is $\phi = 133° \pm 8°$, while the regeneration phase is $-43° \pm 8°$;

4) $d\sigma/dt$ displays a sharp forward peak, a shoulder around $t \simeq 0.5$ $(GeV/c)^2$ at the lowest momenta, and a rapid fall-off for $t \lesssim -1$ $(GeV/c)^2$.

Features 2) and 3) are consistent with a reggeized ω -exchange with an intercept $\alpha_\omega(0) \simeq 0.5$. The forward peak can be explained on the basis of a non-flip amplitude dominance over the spin-flip in the forward region.

There are however other structures that could be expected and are non clearly displayed : a dip at $t \simeq -0.16$ $(GeV/c)^2$, if the cross-over phenomenon is to be attributed to a zero in the ω trajectory, and a possible dip at $t \simeq -0.6$ $(GeV/c)^2$, whose size would indicate the relative magnitude of the ω and ρ spin-flip amplitudes.

III - Beam.

The neutral beam which is suitable for the proposed reaction has to satisfy two rather conflicting requirements : a sufficiently large number of K_L^o's to allow a reasonable trigger rate and a number of neutrons as low as possible to limit the noise level.

We have calculated the neutrons and K_L^o's fluxes from p-Cu interactions on the basis of the 1970 CERN report "Particle Spectra" (Grote-Hagedorn-Ranft). They are shown in figure 3.1 for an internal energy of 24 GeV. In figure 3.2

the K_L^o ' s spectra at 50 mrad are plotted, at production and at 30, 40, 50 meters from the target. The integrated spectra (number of particles at a fixed production angle) are shown in figure 3.3, as well as the ratio between K_L^o's (at 40m) and neutrons. In the same figure the scale on the right gives the absolute fluxes per burst, calculated on the assumptions that the number of interacting protons is 3.10^{11} and that the solid angle is $6.25.10^{-7}$ sterad ($10cm.^2$ at 40m).

A choice of a 50 mrad production angle practically maximizes the K_L^o/n ratio, still maintaining the high energy tail of the K_L^o's spectrum. It gives about $1.7.10^6$n/burst and about 8.10^4 K_L^o's/burst within the stated solid angle ; in these figures a reduction of the intensity by a factor 2/3 is included, due to a 5cm γ-ray lead absorber.

The above choice provides us a neutron flux not exceeding a tolerable maximum which should be about $2,10^6$n/burst. In a 25 cm long hydrogen target this flux gives rise to some 6.10^4 inelastic interactions per burst (400 msec), or 1 interaction per 7 μsec, thus avoiding saturation of the chambers by spurious tracks within the memory time ($\sim$ 2 μsec).

The absolute intensity should be regulated by a variable collimator and controlled by a variable beryllium absorber. The latter device allows an increase of the K_L^o/n ratio, due to the fact that on light nuclei $\sigma_{K_L^o} / \sigma_n \simeq 1/2$.

The geometry of the beam should be similar to that of the np $\rightarrow$ pn CERN-Karlsruhe experiment, which resulted in a low level halo. The elements of the beam were one "gross" fixed collimator, one "defining" variable collimator, one cleaning magnet, one "shadow" variable collimator, one cleaning magnet.

Our choice of 50 mrad rules out a South Hall solution, because of compatibility problems with other charged beams. In the East Hall a neutral beam can be accomodated in place of the existing P_8 beam : the length from the target to the end of the shielding is sufficient ($\sim$30m) and the available area is large enough for our apparatus. Otherwise, it can be envisaged to produce a neutral beam from the Ω target in the West Hall.

IV - Apparatus.

The set up to detect the proposed reaction is shown in figure 4.1 ; it consists essentially of a long forward spectrometer which measures the K_S^o (via its 2π decay) and of a wire chamber telescope which detects the recoil proton on one side of the target.

Along the beam, the liquid hydrogen target, 40cm.long, is followed by an anticounter rejecting all interactions with charged prongs in the forward direction, by a decay zone about 1.2m. long, and by the forward spectrometer. The magnet has an effective gap 1. 6m. wide, 1.0m. deep, 0.5m. high with a field of 1.3T ; the trajectory detection is accomplished with two sets of magnetostrictive wire chambers, before and after the magnet, each set consisting of nine gaps, 0.8x0.5 m^2 and 3.0 x 1.5 m^2.

The forward signature for the events satisfy the following requirements : no charged particles before the decay region (as pointed out before), two charged particles after the decay region, detected by two vertical hodoscopes, whose counters dimensions are 30x3x0.2 $cm.^3$ before and 80x10x0.5 $cm.^3$ after the magnet.

The recoil proton detector is designed to give the direction of the proton (with a threshold around 300 MeV/c, which corresponds to about $t = -0.09\ (GeV/c)^2$ in the whole range) and also information about the energy, at least for the slow recoils. The direction measurement is accomplished with four magnetostrictive wire chambers. The trigger signature requires only one charged particles in the two thin counter hodoscopes before and after the chambers. The energy information should be provided by a suitable analysis of the pulses from these counters.

All the solid angle around the target, with exception for the entrance, the forward region and the proton detector, is covered with plastic-lead sandwiches, to form a π^o shield. A similar disposition on the side of the first forward telescope shall help kill neutron stars and wide angle V^o decays. Finally, also the downstream hodoscope (after the magnet) is provided with a lead sheet to anticoincide events with forward going γ-rays.

In order to detect $K_L^o \to \mu \pi \nu$ decays (as coming from beam K_L^o's or elastically scattered ones), we have placed downstream the whole spectrometer a μ-detector, that is a concrete block followed by another counter array.

It has been pointed out before that the t cut is around $-0.09\ (GeV/c)^2$. We envisage however a special trigger, based on symmetric configuration for the very forward K_S^o's, without the proton information, but with the following characteristics :

a) quasi-horizontal decay plane

b) secondary pions trajectories converging after the magnet

c) one secondary pion on each side of the beam.

It is evident as well that a similar trigger has to be used to detect the monitor $K_L^o \to \mu \pi \nu$ decays of the beam.

V - Trigger rates.

The expected numbers of $K_L^o p \to K_S^o p$ events are calculated assuming that :

1) there are 3.10^{11} interacting protons and the acceptance is $6.25.10^{-7}$ sterad (as previously stated in the beam paragraph) ;

2) the cross section is the one published in reference and is given by the formula $\sigma = 1.65\ p^{-2,1}$ (p in GeV/c, σ in mbarn) ;

3) the hydrogen target length is t = 25 cm ; its center is at 40 m. from the copper target ;

4) the neutral beam is at 50 mrad with respect to the incident proton beam.

In the following table along with the intensities and the calculated cross sections, we give the quantity $R = n\sigma tF$, with $n = 4.22.10^{22}$ protons/cm. t = 25 cm and F a correction factor which takes into account the overall efficiency of the apparatus and the known branching ratio for the K^o_S decay into two charged pions. The number of events per burst and per day (one "day" = 2.10^4 bursts) are then given. The lower limit in p(2 GeV/c) is dictated by the fact that nearly all K^o_S below that value decay before the anticounter ; the upper limit (16 GeV/c) follows from the fact that the intensity becomes quite low.

VI - Background.

As stated before, we expect a trigger rate of about 0.2 triggers/burst for the reaction of interest $K^o_L p \rightarrow K^o_S\ p$. In order to evaluate the total trigger rate we have considered the following types of sources :

1) Two step neutron interactions : in the fist step the incoming neutron produces a charged particle in the proton arm (e.g. $np \rightarrow np$, $np \rightarrow np\pi^o$) ; in the second step the outgoing neutron produces a star in the decay region materials (counter walls, helium) or the γ's from the π^o produce electron pairs in the same region.

2) Accidental coincidences between $np \rightarrow np$ reaction and a star produced by another neutron in the decay region or a beam K^o_L decaying in the same region. Contributions from sources 1) and 2) should not exceed a few 10^{-2} triggers/b.

3) Three or four body np reactions with a forward produced V^{o} and a charged prong going sideways. The most effective source of such triggers is the reaction $np \rightarrow K^{o} \Lambda^{o} p$ with $K^{o} \rightarrow K^{o}_{L}$ and $\Lambda^{o} \rightarrow p\pi^{-}$, whose cross section is comparable to ours. However, a smaller geometrical acceptance and kinematical factors roughly compensate the amount by which the neutron flux exceed the K^{o}_{L} one, and therefore we expect a contribution of the order of 0.2 triggers/burst to the trigger rate.

Other neutron induced reactions we took under consideration are the following : $np \rightarrow npK^{o}\overline{K^{o}}$, $nnK^{+}\overline{K^{o}}$, $n\Lambda K^{o}\pi^{+}$, $nnK^{o}\overline{K^{o}}\pi^{+}$. Because of the higher multiplicities the geometrical acceptance is even smaller, while the cross sections are somewhat depressed with respect to the reaction under study. We conclude that the total rate for neutron reactions must be in the order of a few tenths triggers/burst.

As for K^{o}_{L} induced interactions, the following processes might generate triggering topologies.

4) $K^{o}_{L}p \rightarrow K^{o}\pi^{+}n$, $K^{o}\pi^{o}p$. While the total cross sections for such reactions are one order of magnitude larger than ours, only those events are likely to cause a trigger for which the final state pion and nucleon are produced as a baryon resonance. Cross sections for these events will be not larger than $\sim 100\ \mu b$; the geometrical acceptance is smaller by about a factor of 3, giving a contribution to the trigger rate again of the order of 0.1 triggers/burst. Kinematical computations indicate that the contamination from these events to our distributions is not likely to exceed 1 $^{o}/_{oo}$.

5) $K^{o}_{L}p \rightarrow K^{o}_{L}p$ with $K^{o}_{L} \rightarrow \mu\pi\nu$ and $e\pi\nu$ within the decay region. Events of these type contribute each about 1/3 of the trigger rate for $K^{o}_{L}p \rightarrow K^{o}_{S}p$.

$K^{o}_{\mu 3}$ decays are separated by means of the concrete absorber, whereas K^{o}_{e3} decays, due to the kinematical constraints, should not exceed a few percent.

As a conclusion, our trigger rate should not exceed about 1 - 2 triggers/burst, 10°/₀ of which correspond to good events.

VII - Beam monitoring.

In order to evaluate the cross sections with an accuracy comparable to the statistical errors of event counts, the beam spectrum and flux are to be measured to within a few percent. Therefore we plan to detect and measure a fraction of the $K^{o}_{L} \to \mu \pi \nu$ decays taking place in the decays region.

For a quick measurement and control of beam intensity a neutron-interaction counter telescope, downstream with respect to the detection apparatus, seems adequate.

Finally, as a check and possibly a normalization of our data, we plan to use the elastic scattering $K^{o}_{L} p \to K^{o}_{L} p$ followed by $K^{o}_{L} \to \mu \pi \nu$ decay within the decay region. The instrumental detection efficiency, apart from computable geometrical factor, should be the same as for the main process ; its cross section can be supposed fairly well known as calculated from other K-nucleon processes.

VIII - Supports.

A fair amount of the experimental setup already exists. The large forward spark chamber system is presently in use at Saturne for an experiment ; most of the on line data acquisition system comes from our last experiment. The other parts, essentially counters, fast electronics and the proton arm, will be built in the two laboratories.

With respect to CERN support, we shall require a hydrogen target (with reservoir and controls), usual beam facilities, according to the § 3 statements, and as far as possible, use of the existing neutron collimators. Also some access to CERN workshops will be needed. Room for assembling will be required starting from spring 1973 as well as some testing time in a parasitic charged beam. For computation 20 hours, 7600 CP time, would be useful. It is understood that a large amount of computations will be done on our institutions computers.

An AEG magnet would fit our spectrometer requirements. However, if the experiment is approved, we hope to get from Saturne the VENUS magnet, presently used by the College de France group.

IX - Time schedule.

We expect to be able to start assembling the apparatus on the beam by the end of summer 1973. As previously said, we shall require parasitic beam time in order to test the various components. The data taking could begin by the end of 1973 and continue during 1974.

We foresee that some time will be needed as soon as the beam is ready to explore its basic properties ; at least 10 days are then required for adjustement and various measurements concerning the apparatus. Finally about 50 days are needed for data collection, which would furnish about 150.000 events, taking account of empty target measurements, calibrations and apparatus fiability.

TRIGGER RATES TABLE FOR GOOD EVENTS

$P_{K^o_L}$	K^o_L/burst $(GeV/c)^{-1}$	σ μbarn	R.10^6	$(N_{ev}/\text{burst}).10^3$ $(GeV/c)^{-1}$	N_{ev}/day $(GeV/c)^{-1}$ (raw)	N_{ev}/50 days * $(GeV/c)^{-1}$
2	6375	385.0	7.15	45.58	912	30400
3	10375	172.0	5.81	60.28	1206	40200
4	11500	90.0	3.95	45.43	909	30300
5	10875	56.4	3.05	33.17	663	22100
6	9250	38.8	2.36	21.83	437	14600
7	7625	27.9	1.79	13.65	273	9100
8	6000	21.5	1.49	8.94	179	5950
9	4500	16.5	1.17	5.27	105	3500
10	3375	13.4	0.97	3.27	65	2200
11	2500	10.9	0.79	1.98	40	1350
12	1750	9.1	0.68	1.19	24	800
13	1250	7.8	0.58	0.73	15	500
14	750	6.6	0.48	0.36	7	250
15	500	5.6	0.41	0.21	4	150
16	250	4.8	0.35	0.09	1	30
<u>Totals</u>	76875 K^o_L/b			0.242 ev/b	4840 ev/day	161400 ev/50 days

* Taking account of safety factor.

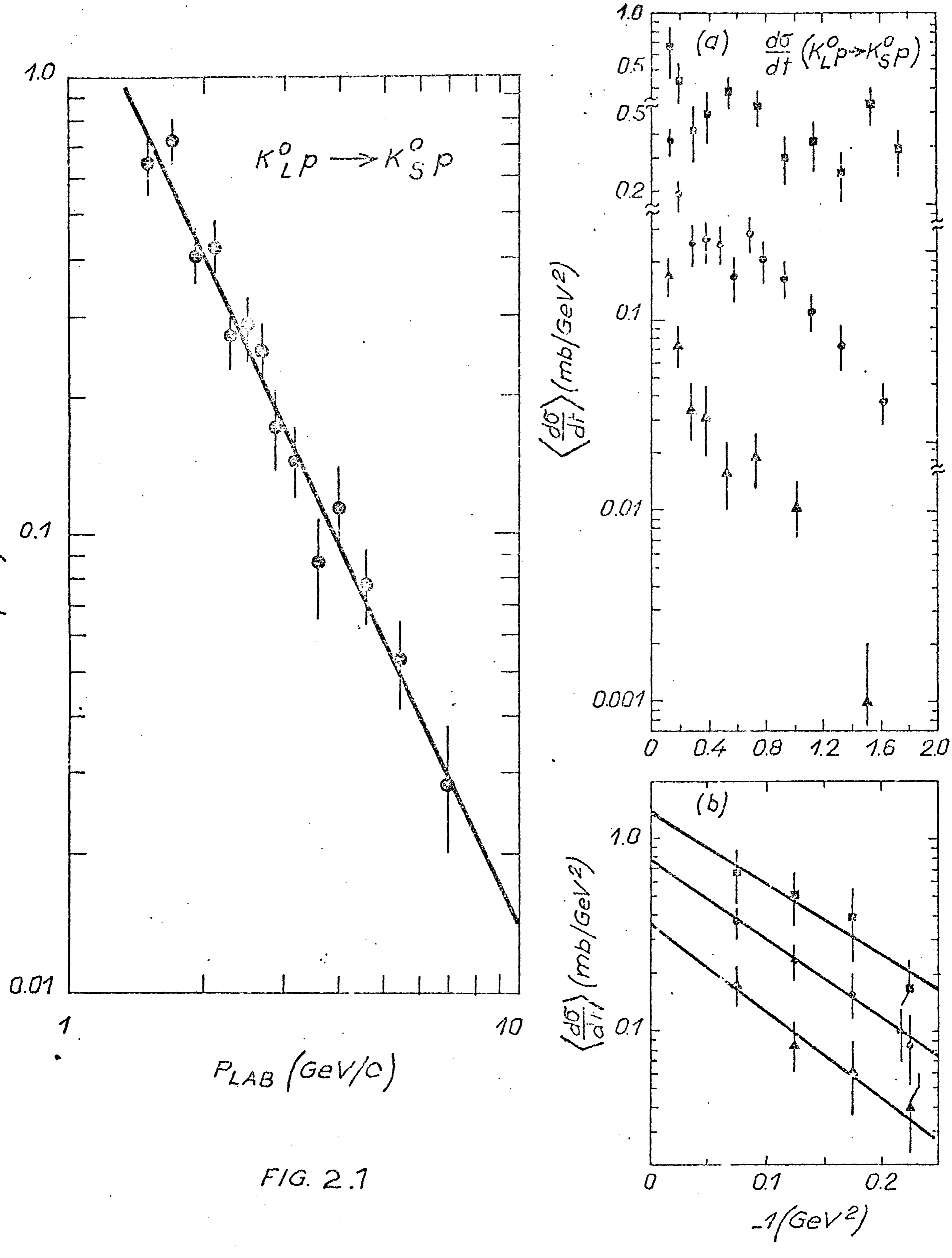
1.0
0.1
0.01
σ (mb)
1
10
P_{LAB} (GeV/c)
$K^o_L p \rightarrow K^o_S p$
(a)
$\frac{d\sigma}{dt}(K^o_L p \rightarrow K^o_S p)$
0.5
0.2
0.001
$\langle \frac{d\sigma}{dt} \rangle$ (mb/GeV²)
0
0.4
0.8
1.2
1.6
2.0
(b)
0.1
0.2
-t (GeV²)

FIG. 2.1

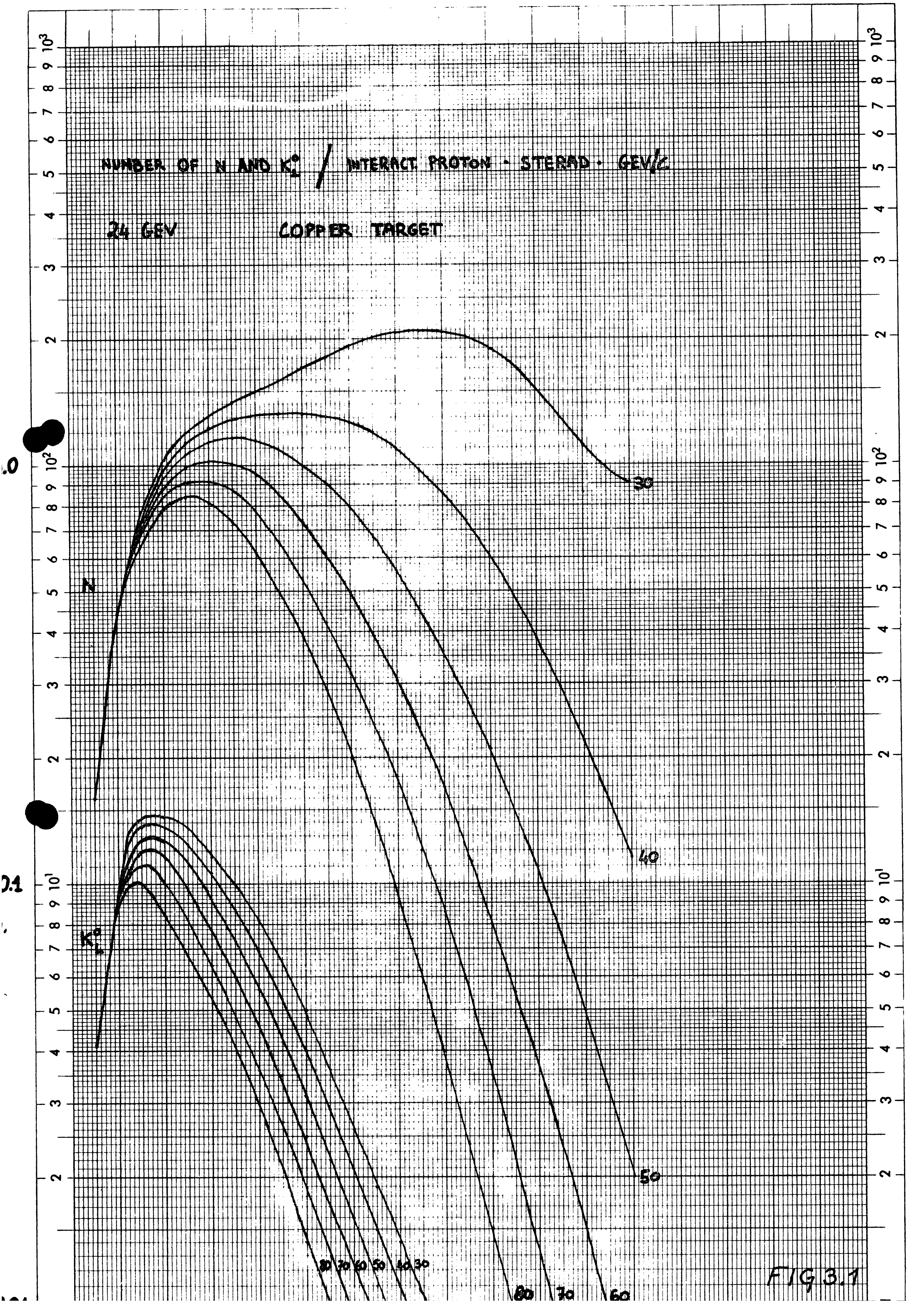
NUMBER OF N AND K_L^0 / INTERACT. PROTON · STERAD · GEV/C
24 GEV
COPPER TARGET
N
K_L^0
1.0
0.1
30
40
50
80 70 60 50 40 30
80
70
60

FIG 3.1

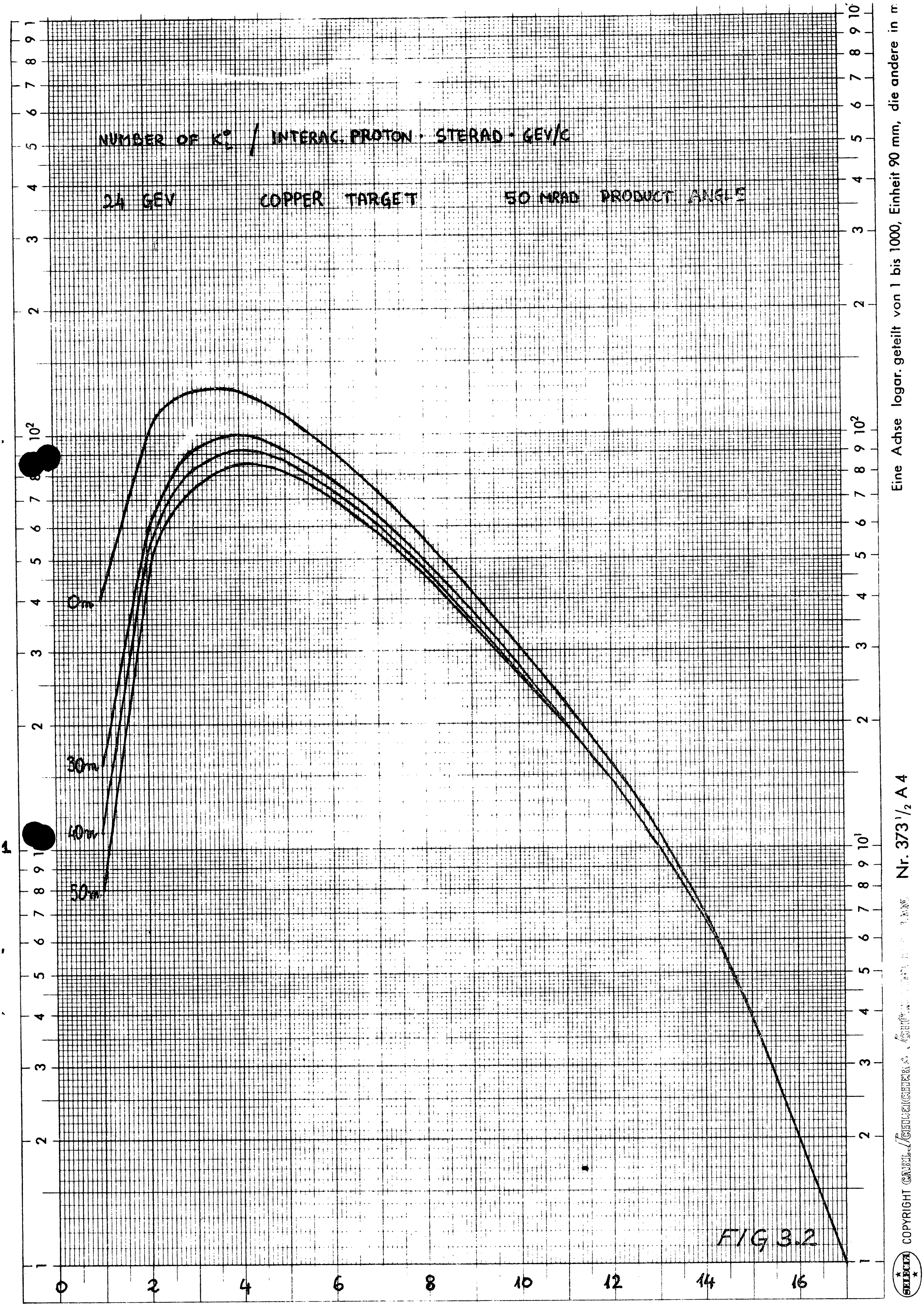
NUMBER OF K_L^0 / INTERAC. PROTON · STERAD · GEV/C
24 GEV
COPPER TARGET
50 MRAD PRODUCT ANGLE
0m
30m
40m
50m
0
2
4
6
8
10
12
14
16
Eine Achse logar. geteilt von 1 bis 1000, Einheit 90 mm, die andere in mm
Nr. 373 1/2 A 4
COPYRIGHT

FIG 3.2

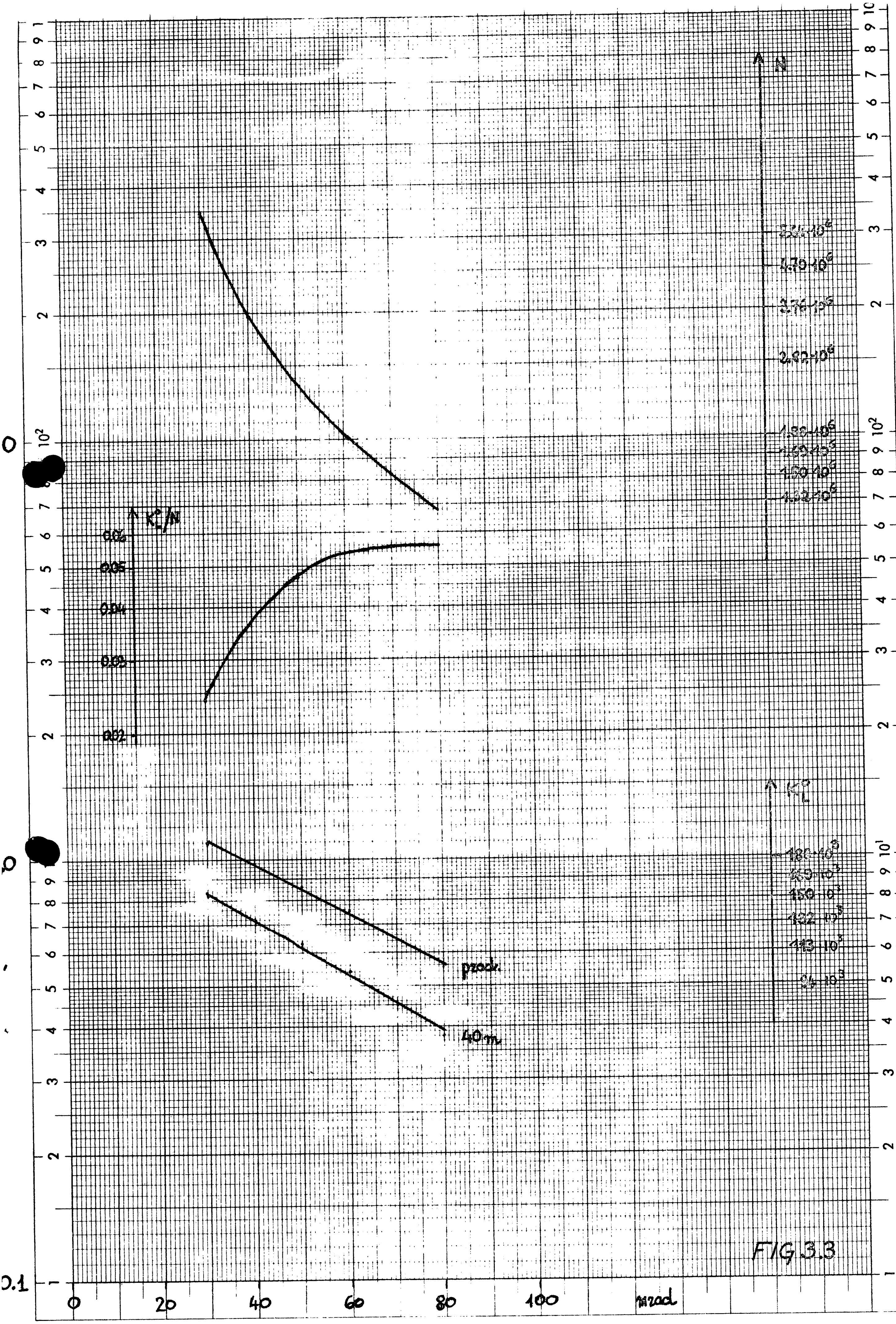

FIG 3.3

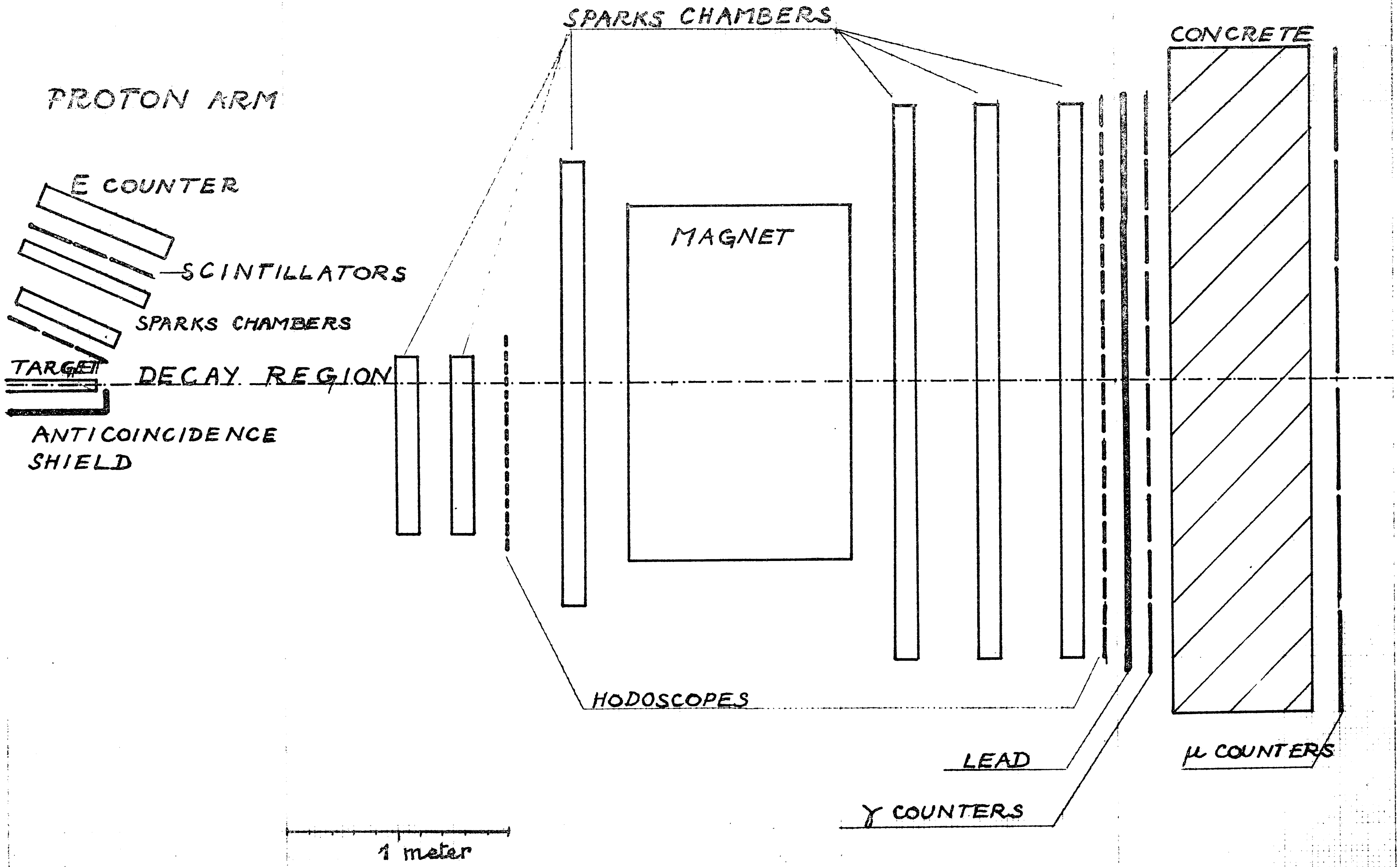
SPARKS CHAMBERS
CONCRETE
PROTON ARM
E COUNTER
SCINTILLATORS
SPARKS CHAMBERS
MAGNET
TARGET
DECAY REGION
ANTICOINCIDENCE SHIELD
HODOSCOPES
LEAD
μ COUNTERS
γ COUNTERS
1 meter

FIG 4.1