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PROPOSAL FOR A SEARCH FOR DIRAC MAGNETIC MONOPOLES AT THE ISR WITH THE PLASTIC-DETECTOR TECHNIQUE

Rome-Saclay-Strasbourg Collaboration

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I. INTRODUCTION

We propose a search for monopoles in p-p interactions at ISR. The interest of this research is that we can now explore a much higher mass region than before with accelerators. This document replaces the preliminary proposals submitted by the Rome Group in July 1968 and March 1970, and by the Saclay Group in May 1969.

Methods aiming to detect tracks of poles just after production have given upper limits for the cross-section between $10^{-40} \div 10^{-36}$ cm^2 according to the value adopted for the mass;[1)] the upper limit established until now by methods based on the assumption that the poles remain bound in matter are much lower, as one can see from previous work[1)], and even lower according to the recent paper by Alvarez et al. on the search for monopoles in the lunar samples from Apollo 11 [2)].

The experiment we propose consists in the use of plastic sheets to detect tracks of magnetic poles. The reason for this choice is that with this technique we can give significant results without assumptions about the possibility of poles remaining bound in pieces of matter. In this way it can be complementary to the technique proposed by Alvarez, Eberhard and others. In fact, this technique allows the recognition of a single pole track over a background at least up to 10^{12} particles/cm^2; in addition, a pole track can be unambiguously recognized on the basis of its predicted electromagnetic properties ($g = n\frac{137}{2} e$), as no other track of similar ionization can be produced at the ISR.

2. PRINCIPLE OF THE EXPERIMENT

The present proposal consists in exposing layers of plastic inside the vacuum chamber in an intersection region of the ISR. The plastic will be convered with a 35 μm*) stainless-steel foil so that the pressure can be kept at 10^{-10} torr with only a slight increase in pumping capacity even if the temperature is brought occasionally up to 130°C.

The existing vacuum chambers can be used without major modifications.

The plastics will be in the form of sheets 200 μm thick cut in the most convenient form to fit inside the chamber; the number of sheets will be ~ 50,

*) The thickness of the foil is that used for the prototype ISR windows.

with some stainless-steel absorber in between, so that all the monopoles would be completely stopped within the stack.

If no monopole is observed after one year of exposure, an upper limit can be given for its production cross-section,

$$\sigma \simeq 10^{-38}\ \mathrm{cm}^2 ,$$

assuming for the luminosity

$$L = 4 \times 10^{30}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1} .$$

The background for 1 year ($\sim 3 \times 10^7$ sec) exposure has been evaluated as follows. It includes two contributions: the first one, due to the beam-beam interaction, has been evaluated by taking

$$10^5\ \frac{\text{interactions}}{\text{sec}} = 3 \times 10^{12}\ \frac{\text{interactions}}{\text{year}}$$

and a multiplicity of charged particles of about 12 [3].

The result is

$$4 \times 10^{13}\ \frac{\text{charged particles}}{\text{year}}\ (\text{over } 4\pi \text{ solid angle}).$$

The second contribution arises from the beam-residual gas interaction which is assumed to give[3]:

$$\frac{6 \times 10^3}{r}\ \text{particles/sec cm}^2 = \frac{1.8 \times 10^{11}}{r}\ \text{particles/year cm}^2 ,$$

where r is the distance from the beam. Taking the value $r = 10$ cm, one obtains in the worst case a flux of

$$\sim 10^{11}\ \frac{\text{charged particles}}{\text{year cm}^2} ,$$

which is considerably lower than the maximum flux of charged particles that a plastic can stand without being damaged ($> 10^{12}$ $\frac{\text{particles}}{\text{cm}^2}$). This justifies the choice of plastic sheets as detector.

3. MAIN FEATURES OF THE PLASTICS AS DETECTORS OF MONOPOLES

In this proposal we consider only two kinds of plastic but we are checking other types:

1) Makrofol E, which can be brought up to 150°C,
2) Nitrocellulose, which can be brought at least up to 100°C.

The final decision on the plastic to be used will be taken later, after discussion with ISR people and taking into account the results of experiments still in progress.

Fig. 1 shows the energy loss in Makrofol E as a function of the kinetic energy for monopoles of mass 1,... 20 m_p and for two values (n = 1,2) of the magnetic charge

$$g = n \frac{137}{2} e.$$

The curve have been calculated by means of the Tables of Benton and Henke[4], from which we have derived the energy loss for protons in Makrofol E $(\frac{dT}{dx})_p$.

The energy loss for monopoles of the same velocity is given by:

$$(\frac{dT}{dx})_g = (\frac{dT}{dx})_p \, n^2 \, (\frac{g}{e})^2 \, \beta^2 .$$

Since the tables mentioned above extend only up to 1.2 GeV, they have been extrapolated to higher energies assuming that for

$$T_p \geq 2 \text{ GeV} \quad \text{is} \quad (\frac{dT}{dx})_p = \text{const.} = 1.64 \text{ MeV/g/cm}^2 .$$

The range-energy curves have been obtained from the curves of Fig. 1 by integration, assuming

$$R = 0 \text{ for } T_g = 2 \text{ MeV},$$

and taking for the density of Makrofol E

$$\rho = 1.2 \text{ g/cm}^3 .$$

The results are shown in Fig. 2. The line becomes broken in the region of energies for which a monopole of charge n = 1 does not produce a detectable track. For n = 2 this does never happen. As the Nitrocellulose is more sensitive, it should be able to detect poles of any charge and energy.

It is well known that plastics are threshold detectors: we evaluate the detection threshold for monopoles with n = 1 (independently of the mass) on the basis of the theories on the response of the plastics to the ionization[5,6,7] and taking into account that Makrofol E has its threshold for relativistic ions of Z = 55 [8].

The results are shown in Fig. 3. For comparison we report in the same figure also the threshold of the Nitrocellulose we are using.

We note that even poles with the high value n = 6, $m \simeq 6$ GeV/c^2, as suggested by Schwinger[9], should be detected if produced with energies higher than ~ 5 GeV.

According to the experimental scheme indicated in Section 2, before entering the plastic, the monopoles have to cross a thin layer of metal; we have assumed 35 μm of stainless steel, corresponding, in stopping power, to ~ 150 μm of Makrofol E.

In order to evaluate the number of poles that would be lost for this reason, in Fig. 4 we report the momentum spectra of monopoles of different masses[10] (there is practically no difference between mg/mp = 5 and 1) produced in p-p collisions with a total energy in C.M.S. of 50 GeV. The dashed curves represent the fraction of the spectra we cannot detect (assuming n = 1 and in the rather pessimistic case of an angle of incidence of 60°), taking into account the thickness of the stainless steel layer and requiring the poles to penetrate a depth of at least 300 μm in plastic.

Table 1 summarizes some data for the use of plastics in this experiment.

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mg/mp	Pmax (GeV/c)	Rmax *) (mm)	P threshold **) (GeV/c)	P min (GeV/c) ***) θ=0° L=450µm	θ=30° L=520 µm	θ=60° L=900 µm
1 (n=1)	24.91	25	.14	.84	.93	1.34
3 (n=1)	24.70	24	.41	1.31	1.47	2.02
5 (n=1)	24.34	23	.69	1.58	1.76	2.45
10 (n=1)	22.75	18	1.44	2.04	2.27	3.10
15 (n=1)	19.98	13	2.13	2.38	2.61	3.55
20 (n=1)	15.38	8	2.82	2.61	2.88	3.99
1 (n=2)	24.91	6.5	-	2.20	2.47	3.82
3 (n=2)	24.70	6.3	-	3.07	3.40	4.97
5 (n=2)	24.34	6.	-	3.65	4.04	5.84
10 (n=2)	22.75	4.6	-	4.79	5.31	7.45
15 (n=2)	19.98	3.2	-	5.54	6.19	8.56
20 (n=2)	15.38	1.9	-	6.21	6.82	9.57

*) In Makrofol E.

**) In Makrofol E; the nitrocellulose is sensitive to poles of any momentum.

***) Corresponding to 35 µm stainless steel plus 300 µm plastic.

Table 1

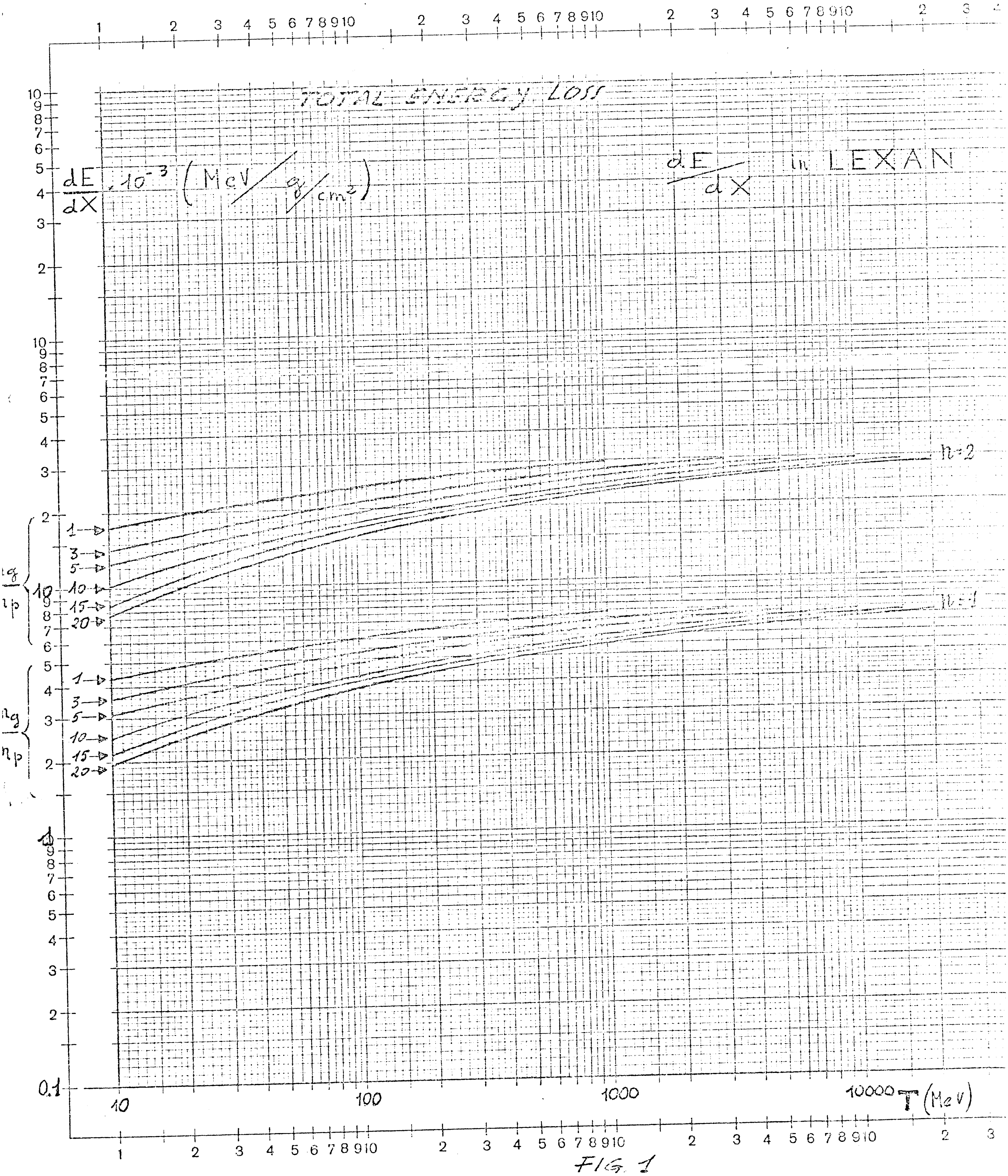
FIGURE CAPTIONS

Fig. 1 Total energy loss in Makrofol E for poles of different masses as function of the kinetic energy.

Fig. 2 Range-energy curves in Makrofol E for poles of different masses: the curves are broken where the track cannot be detected.

Fig. 3 Dosage of ionization energy of monopoles in Makrofol E (Nitrocellulose threshold for comparison).

Fig. 4 Momentum spectra of monopoles with n=1 produced in p-p interaction (total energy 50 GeV) according to their mass: all the spectra are normalized to 1. The curves are broken where the poles cannot cross more than 35 μm stainless steel and 300 μm plastic with an angle of incidence of 60°.



TOTAL ENERGY LOSS
dE/dX · 10⁻³ (MeV / g/cm²)
dE/dX in LEXAN
n=2
n=1
ng/np
1
3
5
10
15
20
10
100
1000
10000
T (MeV)
0.1

FIG. 1

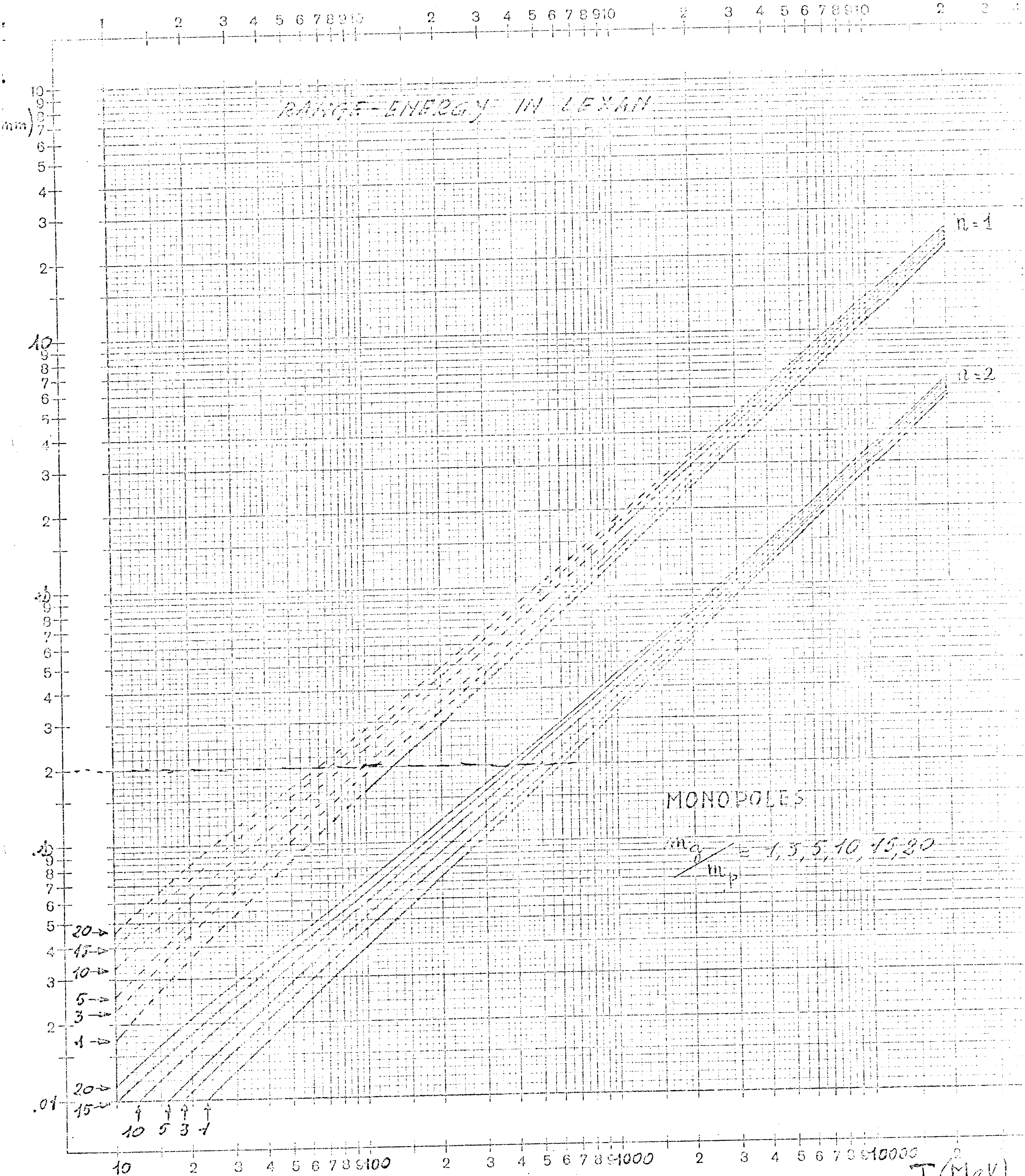

RANGE-ENERGY IN LEXAN
(mm)
n = 1
n = 2
MONOPOLES
m_g / m_p = 1, 3, 5, 10, 15, 20
T (MeV)

FIG. 2

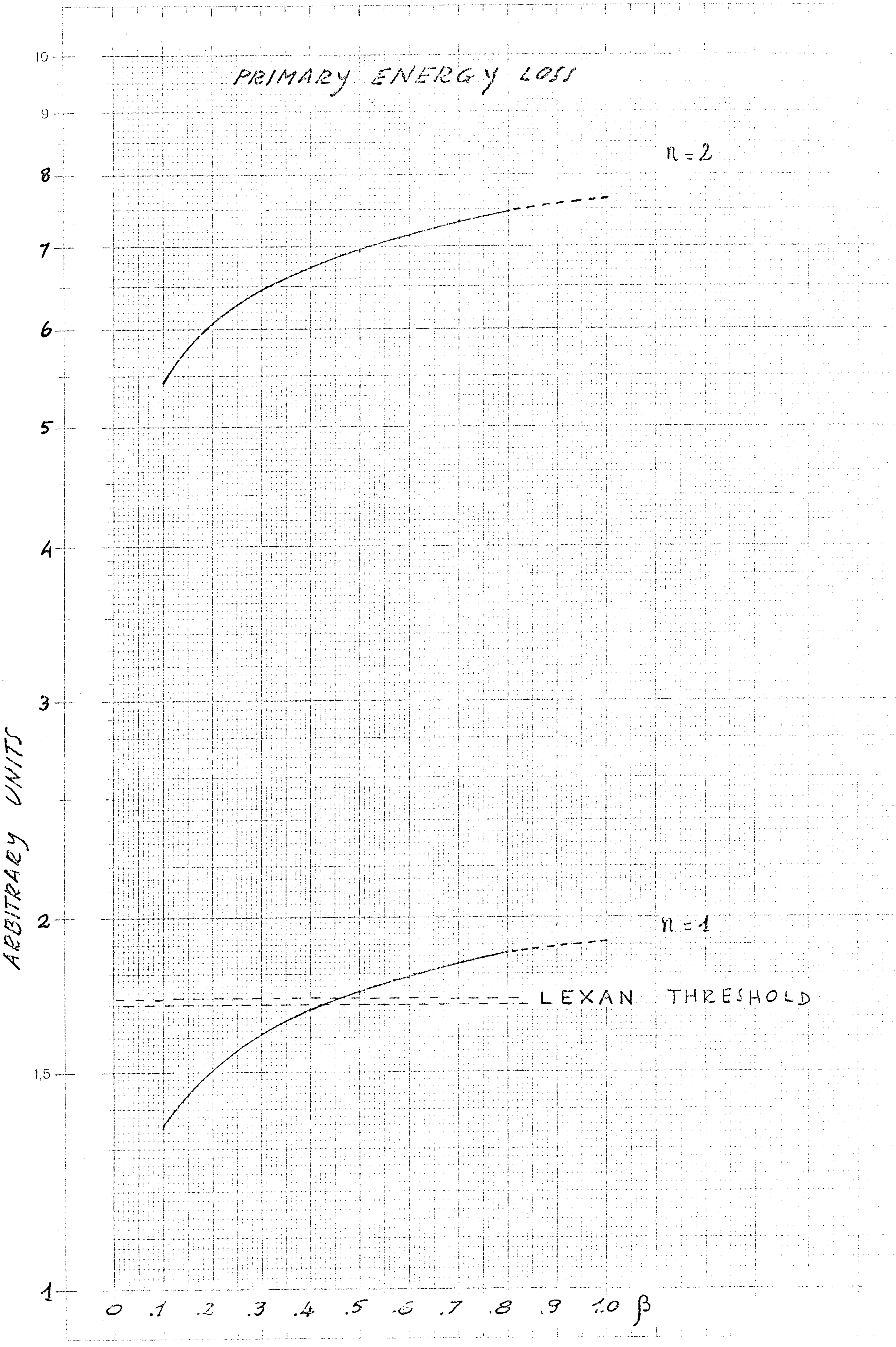

PRIMARY ENERGY LOSS
n = 2
n = 1
LEXAN THRESHOLD
ARBITRARY UNITS
10
9
8
7
6
5
4
3
2
1,5
1
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
β

FIG. 3

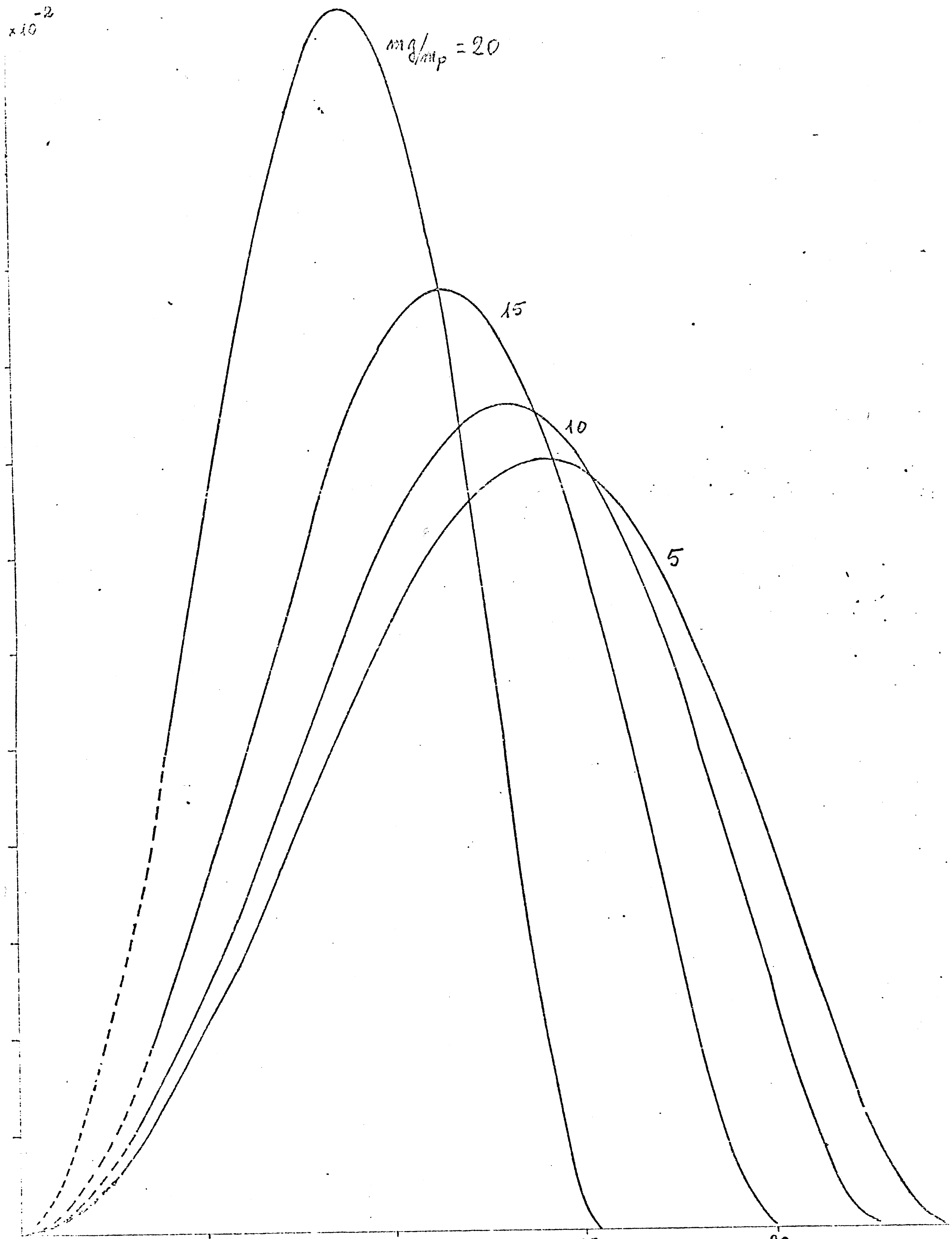


FIG. 4