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PROPOSAL

SEARCH FOR HEAVY, PENETRATING AND LONG-LIVED PARTICLES IN THE NA3 SPECTROMETER

Ph. Charpentier, J.F. Detoeuf
CEN, Saclay, France

M. Hansroul, A. Michelini
CERN, Geneva, Switzerland

M. Crozon, P. Delpierre, P. Espigat, A. Tilquin
Collège de France, Paris, France

J. Badier, J. Bourotte
Ecole Polytechnique, Palaiseau, France

C. Bemporad, A.M. Cnops, G.R. Giannini, P. Lariccia
Dipartimento di Fisica, Università di Pisa, Italy
and INFN, Pisa, Italy

J. Boucrot, O. Callot
Laboratoire de l'Accélérateur linéaire, Orsay, France

J.K. Walker*
Fermilab, Batavia, Illinois (United States)

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INTRODUCTION

We propose a sensitive search for decays of long-lived, penetrating and heavy particles produced at the SPS. We intend to use the well understood and powerful NA3 spectrometer, in beam dump configuration. We will be able to detect hadronic, leptonic and semi-leptonic decays of neutral and/or charged particles emerging from the dump. The experiment would be sensitive to lifetimes from 10^{-10} to several 10^{-8}s, and to masses from some hundreds of MeV/c^2 to 5-6 GeV/c^2. Only new particles with relatively low nuclear interaction cross sections (10 millibarns or less) can be detected since they have to punch through the dump.

Many new particles are predicted either by gauge theories, or by competing models. Some of them, like Higgs bosons or axions, should interact weakly; others as gluinos or supersymmetric hadrons should interact strongly. Unfortunately the theory is in general unable to predict the mass and the lifetime of these particles.

Upper limits on the existence of such new particles have been set, either at e^+e^- colliders (up to 42 GeV/c^2 in the center of mass), or from fixed target experiments [1]. The latter have looked either at very short lifetimes ($< 10^{-12}$s, emulsion experiments) or at interactions or decays of neutrino-like particles in neutrino beam lines (with in general a small geometrical acceptance) : the detectors are several tens or hundreds of meters from a dump where intense proton beams - up to 10^{13}/pulse - are absorbed. The proposed experiment will be very different, and complementary, since it uses high energy incoming pions and has a large acceptance (typically 30% for particles decaying just behind a dump). It will be able, after a modest running time, to give limits at the picobarn level on the cross section times branching ratio for the hadronic production of particles in a mass and lifetime region where present limits are loose or missing.

1. PHYSICS OBJECTIVES

The proposed experiment will be able to detect hadronic as well as leptonic final states and thus will be sensitive to all reasonable decays of unknown particles into charged hadrons and/or leptons. This kind of search using experimental conditions which have never been used up to now, has its own justification, and does not have to be supported by detailed theoretical predictions. However we give in the following sections some indications on new states predicted by recent theories, which could be searched for in the present experiment. These indications are not exhaustive; attention is drawn to the fact that most expectations are far from being precise, proliferation of models being encouraged by the present status of experimental constraints [1].

1.1 Strongly Interacting New Particles

1.1.1 Introduction

In the case of strongly interacting new particles, a problem comes from the small probability of emerging from the dump. However, a general guess can be made, which is model-independent since it comes from experiment. It is well known that one can describe the nuclear cross-section of hadrons using an additive model and assigning for u and d quarks a nuclear cross section around 12 millibarns, for the strange quark 4.5 mb and for the charmed quark 1 mb. Thus, the phenomenological nuclear interaction cross section of quarks decreases quickly as their mass increases. One may therefore expect a low cross section for massive new states, giving a good transmission probability through the dump for masses above ∿ 1 GeV/c^2.

Going to existing predictions, it seems that the best candidate which can be searched for in the proposed experiment is the gluino predicted by supersymmetry.

1.1.2 Supersymmetry and new supersymmetric particles

In supersymmetric theories (SUSY), a lot of new particles are predicted. Their mass scale is rather arbitary; however in most models the SUSY partners of electrons and quarks are expected to be heavy (order of magnitude 10 to 100 GeV), whereas the SUSY partners of the photon and gluon are predicted to be "light" (less than 10 GeV). Electron-positron colliders are well adapted to search for selectrons and squarks, and have already given lower limits on their masses ($>$ 20 GeV/c^2). Fixed target experiments are better adapted to gluino searches, as gluinos are expected to be produced via gluon-gluon fusion.

1.1.3 Gluinos : states and production

The gluino is generally supposed to be confined into stable hadrons [2] often termed "R-hadrons". A lot of combinations are predicted, some of them are neutral like "glueballons" $\tilde{g}\tilde{g}$, "glueballinos" $\tilde{g}g$ and "hybrinos" $\tilde{g}\, q\bar{q}$; the "hybrinos" may of course carry electric charges. With probably the exception of the $\tilde{g}\tilde{g}$ state, all other combinations should be long-lived [3] with a mass slightly greater than the mass of the "naked" gluino : $m_R \sim m_{\tilde{g}} + 0.5$ GeV [3].

The production is expected to proceed via gluon fusion, with a cross section which should be quite large, due to a color factor of order 10 with respect to quark-antiquark production at the same Q^2. Thus at SPS energies the production cross section of massive gluinos around 2 GeV could be of the order of 100 microbarns, since $D\bar{D}$ production is estimated around 20 μb from 350 GeV/c π^- mesons [4].

However R-hadrons are expected to interact strongly with matter, with color factor enhancement with respect to quarks. Thus their interacting cross section may be substantial, of the order of 10 mb or more, even taking into account the effect discussed in section 1.1.1 for high masses.

1.1.4 Existing limits on gluinos

The experimental situation has been reviewed by Dawson et al. [5] and is summarized on Figs. 2 and 3. The existing experimental limits come either from direct search of long lived ($\tau > 10^{-8}$s), or short lived ($< 10^{-12}$s) particles in hadronic interactions, or from indirect evidence in neutrino beam dump experiments for $\tau < 10^{-10}$s. In all cases the limits are slightly model-dependent; for instance the limits from CHARM or Fermilab [6] neutrino beam dump experiments use the following relation between the gluino lifetime and mass [7] :

$$t = 0.8 \times 10^{-6} \left(\frac{m_\mu}{m_{\tilde{g}}}\right)^5 \left(\frac{m_{\tilde{q}}}{m_w}\right)^4 \text{ sec}$$

where $m_{\tilde{q}}$ is the mass of the lightest supersymmetric partner to the quarks,

The present experiment will be sensitive precisely to the lifetime region where no experimental limits are available. Even a negative result would thus exclude experimentally gluinos with $m_{\tilde{g}} < 6$ GeV/c²

1.2 Weakly Interacting New Particles

Such particles, if they exist, are of particular interest for the proposed experiment since they go through a beam dump with a very small interaction probability. Many states of this kind are predicted either in the standard model, or in more speculative theories :

1.2.1 Higgs and technipions

In the minimum Weinberg-Salam model, a single neutral Higgs boson H^0 is predicted; in more complicated models several neutral H^0 and even charged bosons $H^\pm$ are predicted. Higgs bosons are expected to decay into the heaviest available particle; thus their lifetime is not expected to be very long : if q is the heaviest available quark :

$$\Gamma(H^0 \rightarrow q\bar{q}) \sim \frac{1}{8\pi} G_F m_q^2 m_{H^0}$$

Higgs masses are completely unknown : the upper bounds $m_H < 0$ (1 TeV) opens quite a large field of investigations since the lower bounds of the minimal model ($m_H \geqslant 10$ GeV/c²) vanishes either if the top quark mass is sufficiently massive, or if a theory with several Higgs is considered [8].

If neutral Higgs bosons happened to have the right lifetime and mass, they should appear in the present experiment as a $\mu^+\mu^-$ pair if $M_H{}^0 < 300$ MeV, $\pi^+\pi^-$ if $0.3 < M_H{}^0 < 1$ GeV/c², a K^+K^- pair if $1 < M_H{}^0 \leqslant 3.7$ GeV/c² and a $D\bar{D}$ pair above 3.7 GeV/c² [9].

Technicolour models are alternative solutions to the gauge symmetry breaking problem : symmetry is broken dynamically and many new scalar particles appear as Nambu-Goldstone bosons, which behave in many aspects like Higgs bosons [8]. Some of these new particles, the technipions

$P^{0,3}$ and $P^{\pm}$, are predicted to be not too heavy : $m > 3$ GeV/c² for the $P^{0,3}$ and $m \sim 15$ GeV/c² for the $P^{\pm}$. However unsuccessful $P^{\pm}$ searches at PETRA and PEP rule out $m < 15$ GeV/c². On the other hand, the existence of the light colorless $P^{0,3}$ technipions is not yet excluded by present experimental results. They should be detectable in our experiment by $\mu^+\mu^-$ or hadronic decay.

1.2.2 Heavy axions

The standard and very light Peccei-Quinn axion [10], decaying into a photon pair, is now clearly excluded by experiment. However, many axion-like particles have been predicted, as a new class of particles. Their masses and lifetimes are quite arbitary; depending on their mass M_x they should decay either into e^+e^- pair if $M_x < 200$ MeV/c², into a $\mu^+\mu^-$ pair if $0.2\ M_x < 1$ GeV/c², and into a pair of hadron jets above 1 GeV/c². The proposed experiment is very well adapted to search for this kind of particle. Present limits on these axions may be parametrized as a function of the axion mass M_x, and of the decay parameter F_x defined by

$$\Gamma(x \to \ell^+\ell^-) = \frac{1}{8\pi}\frac{m_\ell^2}{F_x^2} M_x \qquad \text{where } \ell = e \text{ or } \mu$$

and are displayed on Fig. 1.

These limits have been compiled by J.D. Bjorken who has initiated an experimental search at the Tevatron [11], which will be sensitive to $M_x < 1$ GeV/c² and $10^5 < F_x < 10^7$ GeV and will be able to detect rather long-lived axions ($\tau > 10^{-8}$s). Our experiment, by looking directly to axion decays with $10^{-10}\text{s} < \tau < 10^{-8}\text{s}$, will have access to the unexplored regions 1 GeV < $M_x < 5$ or 6 GeV/c² and $F_x < 10^4$. It should be noted that the signature of such a particle is particularly clean : a peak in the invariant mass distribution of the observed decay products of the axion.

1.2.3 Other predictions

In some supersymmetric models appears a new gauge boson of spin 1, called the U-boson [12]. It is the SUSY partner of the Goldstone boson; its mass and lifetime are not predicted by theory. It would appear in many aspects like an axion, and thus may be added to the weakly interacting particles considered above.

To summarize the above considerations, present models and experimental limits do not exclude the existence of a new particle in the domain where the proposed experiment is sensitive. As any such discovery would profoundly influence the direction of physics, this search seems worthwhile to do. Even in the case of negative results, the great sensitivity of the experiment will put stringent limits and will give additional constraints to theorists, in particular concerning gluinos and related R-hadrons.

2. THE EXPERIMENTAL SET-UP

The experimental set-up is given in Fig. 4. It consists of the NA3 spectrometer in its beam dump configuration, with some modifications in the forward arm. The incoming beam is absorbed in the dump and penetrating particles may emerge from it, in a relatively clean environment. The particles may then decay in a vacuum tank, which is followed by the spectrometer.

2.1 The Beam

We propose to use the ordinary secondary H8 pion beam, which can provide π^- mesons up to 350 GeV/c with intensities above 10^6/pulse (it is possible to have primary 450 GeV/c protons in our beam line, but this would prevent all other experiments in the North Area from running). With 10^{12} protons at 450 GeV/c on the primary target, one obtains about 10^7 300 GeV/c π^- mesons in the H8 beam line. The smaller center-of-mass energy (23.7 GeV, instead of 29 GeV for 450 GeV/c protons), is compensated in part by the fact that π^- induced cross sections of massive particles are higher than from protons. If a new heavy particle is produced from quark-antiquark annihilation, we benefit from the presence of valence antiquarks in the pion (this gives for instance a factor $\sim$ 100 in the Υ production cross section at 280 GeV/c). If the production occurs from gluon fusion, the harder gluon structure function in the pion enhances the cross section, which gives for instance a factor 2 for the J/ψ production.

2.2 The Dump

The existing dump, which was used for the dimuon experiment, is made of stainless steel with a central tungsten conical plug (with 20 mrad aperture) to efficiently absorb the beam. From our previous experiment, we estimate that its length cannot be lower than 200 cm for 300 GeV/c incoming particles : this gives 1% probability of charged particles punch-through, 1/5 of which are forward energetic particles with $P > 10$ GeV/c and $\theta_{lab} <$ 20 mrad. From the same previous studies we know that a substancial flux of slow neutrons (10% of the incoming flux) emerges from the dump and gives an important background in chambers and hodoscopes.

The length of the dump may be easily varied in 20 cm steps; the maximum available length is 340 cm. Such a length has been successfully used in the dimuon experiment to handle an intense 400 GeV/c proton beam up to 1.5 10^9/second.

In the following we will refer to "standard running conditions" for 10^7 incoming π^- mesons per SPS pulse, hitting a dump 200 cm long, and the operation of the NA3 magnet at one-half of its maximum field (8 kgauss instead of 16).

2.3 The Decay Space

In order to be sure that we eventually observe a decay of some new particle, and not the interaction of a punch through energetic hadron in air or helium, we propose to have a vacuum tank in the decay space. We intend to use an available cylindrical tank 1.8 m long and 1.5 m diameter. It will be equipped with Aluminium end plates 10 mm thick, with a central thinner window (30 cm diameter, 1 mm Aluminium thickness); this will reduce the interactions of energic punch-through particles which might dangerously increase the trigger rate.

2.4 New Hodoscopes T1, T2

The new hodoscopes T1 and T2 have to be built; they will be used for triggering and will be placed just before and after the decay space.

a) A small (64 x 64 cm) T1 hodoscope, just before the decay space, consists of 4 layers of 8 strips, alternatively horizontal and vertical (Fig. 5). Strip-to-strip narrow coincidences (5 to 10 nanoseconds width) are performed for both horizontal and vertical layers to eliminate random triggering from slow neutrons, which in "standard conditions" will give a counting rate of the order of several 10^5 Hz in each strip*).

b) A T2 hodoscope, 1 x 1 m^2, situated at the entrance of the magnet, consists of 2 layers of 8 horizontal strips, each strip being divided horizontally in two parts. As for the T1, strip-to-strip narrow coincidences are performed.

2.5 The Spectrometer

Behind the T2 hodoscope, the other elements of the existing NA3 set-up remain unchanged; they have been described in detail in ref. [13]. The electromagnetic calorimeter, with its position measuring device (Shower chamber in Fig. 1) allows the identification of electrons, and also, if necessary, of photons above 1 GeV. The T3 hodoscope, being behind an iron wall 1.8 m thick, allows a clean muon signature. The proposed configuration gives a momentum resolution $\Delta p/p \sim 10^{-3}p$ (p in GeV/c) on charged particles.

3. TRIGGER AND EVENT SELECTION

3.1 Trigger

We propose a three-level trigger which uses both existing NA3 facilities, and the new hodoscopes T1 and T2 described above. All the notations used below are given in Fig. 4.

i) Pretrigger : two kinds of pretrigger can be envisaged :

- a "neutral" pretigger given by the coincidence $T0.\overline{T1}.T2.\overline{H}$, where $\overline{H}$ ensures the absence of any halo particle by a veto counter H mounted upstream of the beam absorber, and T0 the presence of a beam particle (T0 is in fact mainly used for giving a precise timing to the pretrigger).
- a "charged" pretrigger $T0.T2.\overline{H}.[T1 = 1].[\gamma 3\overline{T3} \geqslant 1]$.

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*) The boundaries of the horizontal and vertical strips are slightly shifted in respect to each other such that at most one of the double hodoscopes can be fired by any charged particle.

The condition [T1 = 1] (only 1 strip hit in each of the T1 hodoscopes) reduces background from low-energy showers emerging from the dump. If necessary, we can veto the large pulses due to a shower in a single strip of T1, in order to enforce the condition "only one charged particle". The condition $[\gamma 3\overline{T3} \geqslant 1]$ uses the third part, $\gamma 3$, of the electromagnetic calorimeter as a 40 strips hodoscope tuned to detect minimum ionising particles, and the corresponding strips of the T3 hodoscope which performs a muon veto signature. This condition vetoes triggers from beam particle punch-through (there is a gap in γ_3 in the horizontal plane), and events with only muons from vector meson decays, by ensuring the presence of at least one charged hadron in the back of the spectrometer.

ii) Hardware trigger : it is performed using multiplicity conditions on the events, which are achieved with two devices :

- a fast on-line counting of the number of wire clusters, NCH3, in two planes of the CH3 chamber; this can be done with fast ECL electronics and would be available about 100 nsec after the pretrigger.
- a veto, $\overline{\text{OVFL}}$, on high multiplicity events which were clearly seen in the dimuon experiment as coming from showers escaping from the dump, or created in the magnet iron yokes. This veto may be done from NCH3, or from the number of strips fired in the first part (γ_1) of the electromagnetic calorimeter.

Then for neutral particles we would have

$$\text{Trigger} = \text{neutral pretrigger} \times [\text{NCH3} \geqslant 2] \times \overline{\text{OVFL}}$$

and for charged particles

$$\text{Trigger} = \text{charged pretrigger} \times [\text{NCH3} \geqslant 3] \times \overline{\text{OVFL}}$$

iii) Software trigger : two existing powerful on-line processors can be used as a third level trigger before writing the events on tape :

- The hardware processor "MORPION" which reconstructs on-line all horizontal or vertical straight line projections of particle trajectories in chambers CH4 - CH5 - CH6, and works since 4 years.

- The emulator 168/E which is successfully working in the present Direct Photon experiment and is able to fully reconstruct the straight lines and even the full tracks in all the spectrometer for simple events, before writing them on tape. As the average multiplicity is expected to be around 2 to 3 particles in the proposed experiment, this processor should be extremely powerful to reject fake events.

The proposed trigger allows to detect all long-lived and penetrating particles giving at least two charged particles (which may be hadrons or leptons).

3.2 Data acquisition and off-line processing

All the existing on-line acquisition system and off-line analysis programs may be immediately applied to the proposed experiment. In order to obtain the most powerful reconstruction of events, minor modifications must be done in the pattern recognition and momentum calculation of tracks not coming from the beam region. The new trigger is very easy to incorporate in the NA3 simulation program using GEANT package.

3.3 Event Reconstruction and Data Processing

3.3.1 The charged particle multiplicity for the decay of the searched "new particle" is expected to be like in the NA3 dimuon experiment, i.e. 2 or 3. Hence pattern recognition and track recognition will be as powerful (98% efficiency) and as fast (20 ms of CYBER 875 CP time) as in the dimuon experiment.

From present performances the vertex resolution for reconstructed events is expected to be about 2 mm transverse and 2 cm longitudinal for parent masses above 1 GeV/c². Thus decays in the vacuum tank will be clearly distinguished from interactions in T1 and T2 hodoscopes, or in the end plates of the tank.

Due to the vacuum tank, the only background to the detection of new particles decays will be the decay of known, long-lived hadrons punching through the dump, i.e. essentially K^0_S and K^0_L. The K^0_S signal is easily distinguished from its reconstructed mass; the K^0_L will give either $\pi\mu\nu$ or

$\pi e \nu$ decays with known ratio, or $\pi^+\pi^-\pi^0$ decays where the $\pi^+\pi^-$ system has a low invariant mass. In any case, high-mass (> 500 MeV/c^2) hadronic decays, or any dilepton decay will give a clean signature of a new particle.

3.3.2 Data processing :

It can be expected, as was the case in the dimuon experiment, that data processing will be fast; a response on the existence or on the absence of a new particle should be obtained within a few months after data taking.

4. RATES AND SENSITIVITY

4.1 Trigger rate

The event rate from the searched new particles is of course impossible to estimate, and surely very low. The trigger will be given by various mechanisms coming from the punch-through particles. All numbers given below refer to the "standard running conditions" defined in 2.2.

4.1.1 Random triggers

Random pretriggers from slow neutron background will be lowered by narrow coincidences (5 to 10 nanoseconds) between corresponding strips in T1 and T2 hodoscopes, to the level of at most 10^2/s.

Random "charged" pretriggers will occur from the occurence of simultaneous outgoing of 2 or more charged particles from the dump. From Monte Carlo simulations this pretrigger rate may be several 10^3 per burst, but at the trigger level the condition NCH3 $\geqslant 3$ reduces the rate to some tens/burst; then a simple check on the multiplicity in the CH1 chamber will eliminate completely these events before writing on tape.

4.1.2 Interactions of punch-through particles

They will give the main contribution to the trigger rate, since we have a probability of $\sim 10^{-3}$ to have, behind a 200 cm dump, a charged hadron with $P > 10$ GeV/c. Interacting with the matter of T1 or T2 hodoscopes, or with the windows of the vacuum tank, such hadrons will give unwanted triggers. Reliable estimations cannot be done for fast outgoing neutrons or K^0, which are not simulated in available hadronic shower programs. Assuming that their rate is comparable to charged outgoing hadrons we find a trigger rate of a few tens per burst in "standard conditions".

4.1.3 Decays of punch-through particles.

They will come essentially from punch-through K^0_s or K^0_L originating either from beam primary interaction, or from any step of hadronic showers in the dump. The resulting K^0 spectrum and rate behind the dump is unknown. Estimations from primary production only will give a marginal trigger rate (less than 0.05 per burst) but in a 10 days running period they will give approximately 3000 $K^0_s \rightarrow \pi^+\pi^-$ decays. These events will be very useful to check the event reconstruction and the signature procedure of the searched new particle. The trigger rate from decays of K^0 originating from the hadronic showers cannot be reliably calculated; assuming arbitrarily the same spectrum as for charged outgoing particles will give about 10 triggers/burst from K^0_s decay and less than 1 from K^0_L.

4.1.4 Running strategy

In conclusion, the total trigger rate cannot be reliably calculated due to the lack of knowledge of energetic neutral hadrons behind a dump. Reasonable assumptions give a hardware trigger rate which should be managed by the NA3 data acquisition system, which is able to handle up to 300 triggers per burst (before the so-called "software trigger").

In case of rate problems several parameters may be adjusted to give, as a compromise, an acceptable rate :

- the dump length may be increased, which is of no importance for detecting weakly interacting particles, but lowers the probability of observing strongly interacting ones

- the trigger constraints may be more selective and exclude, for instance the whole "charged trigger", since we have seen in section 1 that most interesting predicted new particles are neutral.

- the magnetic field may be increased up to its maximum value, sweeping away all charged particles of $P < 3.5$ GeV/c, but decreasing the acceptance to low mass new particles.

- the beam flux may be reduced.

Clearly the running conditions will have to be tuned with the whole set-up.

4.2 Sensitivity of the Experiment

As it is impossible to give expected "new particles" rates, we will give indications on the sensitivity corresponding to weakly interacting particles. We assume that we will cut events with a reconstructed vertex within ± 10 cm of the window of the vacuum tank; taking into account the window sagitta, this gives a true decay space 150 cm long, situated 250 cm from the production region.

We will consider for instance the detection of an axion-like particle of mass Mx < 5 GeV, produced either at $x_F = 0$ or, like the J/ψ at the same energy, at $x_F = 0.15$, Table 1 gives, for lifetimes between 10^{-10} to 10^{-8}s, the observed fraction of such particles decaying in the 150 cm free space.

The acceptance for a $\mu^+\mu^-$ decay where both muons are identified in the set-up is given in Fig. 6 as a function of M_x and x_F*). As in "standard conditions" in 10 effective days the integrated luminosity is ∿ 10^{38} cm^{-2}, these values allow to give in Table 2 the 90% CL limits obtained on the production of such axion-like objects, if no event is seen. One can see that in the most favourable conditions, limits as low as 0.3 picobarns per nucleon can be given on $B\sigma$.

Concerning strongly interacting particles such as R-hadrons, the experiment will be able to see them only if their punch-through probability is substancial. For instance, assuming $B\sigma \sim 100$ nanobarns and no gluino seen would imply, in the most favourable (m, x_F) region, a transmission probability through the dump lower than 3 10^{-6}, which is lower than the value for K^0.

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*) The curves of Fig.6 are obtained assuming an axion production with $< P_T > = 300$ MeV/c. The acceptance increases strongly for $M_X < 1$ GeV/c^2, if higher $< P_T >$ values are allowed.

In conclusion, due to its very good acceptance for high masses, the experiment will be very sensitive; even if no new particle is seen, it will give very stringent limits on their production. The sensitivity is of the order of 1 picobarn (on Bσ) for weakly interacting particles, and allows detecting gluino-like particles even if they interact as strongly as the K^0.

SCHEDULE AND BEAM REQUESTS

As the spectrometer is already working, and the dump exists from previous runs, the only necessary new devices are T1, T2 and the wire cluster counting electronics for CH3. All these new devices are cheap (about 30 KSF) and simple to build, and may be ready for June 1984.

Hence we propose running a 10 days test with a π^- beam at 300 GeV/c in July 1984. If this test is successful, a 17-days SPS period of data taking at the end of 1984 fixed target period will provide a very significant amount of data. The analysis of events will be quite fast and simple. We expect to be able, at the end of 84, to conclude if there is indication of some new particle, and in this case beam time may be requested at the very beginning of the 1985 SPS fixed target period.

REFERENCES

[1] A review of recent search for "new particles" is given in S. Yamada - DESY Internal Report 83-100, Nov. 1983.

[2] G.R. Farrar and P. Fayet, Phys. Lett. 76B (1978) 575.

[3] M. Chanowitz and S. Sharp, Phys. Lett. 126B (1983) 225.
D.V. Nanopoulos, S. Ono and T. Yanagida, Preprint CERN TH 3724, September 1983).

[4] M. Aguilar-Benitez et al., (LEBC-EHS Collaboration), Phys. Lett. 135B (1984) 237.

[5] S. Dawson. E. Eichten and C. Quigg, Preprint LBL-16540, 1983.

[6] F. Bergsma et al., Phys. Lett. 121B (1983) 429.
R.C. Ball et al., Preprint UMHE 83-13 (Fermilab Experiment E 613)

[7] G.L. Kane and J.P. Leveille, Phys. Lett. 112B (1981) 319.

[8] For a recent review on "new spectroscopy" see J. Ellis, Preprint CERN TH 3747, October 1983.

[9] Detailed expectations on Higgs decays are given for instance in G. Barbiellini et al., DESY 79/27, May 1979.

[10] R.D. Peccei and H.R. Quinn, Phys. Rev. D16 (1977) 1791.

[11] L.W. Mo et al., Fermilab Proposal E635 (1981); addendum given in May 1982.

[12] P. Fayet, Nucl. Phys. B187 (1981) 184.

[13] J. Badier et al., Nucl. Inst. and Methods 175 (1980) 319.

TABLE 1

Probability (in %) of observing in the free space volume the decay of a particle with specified x_F, mass and lifetime.

Lifetime τ	$x_F = 0$ all masses	$x_F = 0.15$ M = 1 GeV	M = 3 GeV	M = 5 GeV
10^{-10}s	0.13	11.4	2.0	0.8
10^{-9}s	16.9	8.3	13.9	15.2
10^{-8}s	3.6	1.0	2.1	2.6

TABLE 2

Sensitivity of the proposed experiment to axion-like particles decaying into a muon pair. The numbers are 90% CL upper limits on the production cross section times branching ratio, Bσ, in picobarns per nucleon. A linear dependence of the cross section with the target atomic number has been assumed.

Lifetime τ	$x_F = 0$ M = 1 GeV	 M = 5 GeV	$x_F = 0.15$ M = 1 GeV	 M = 5 GeV
10^{-10}s	87	35	0.7	6
10^{-9}s	0.7	0.3	1.0	0.3
10^{-8}s	3.5	1.3	8.0	1.7

FIGURE CAPTIONS

Fig. 1 Limits at 90% confidence level on the existence of axions, from J.D. Bjorken compilation [4]. M_x is the axion mass and Fx the decay parameter.

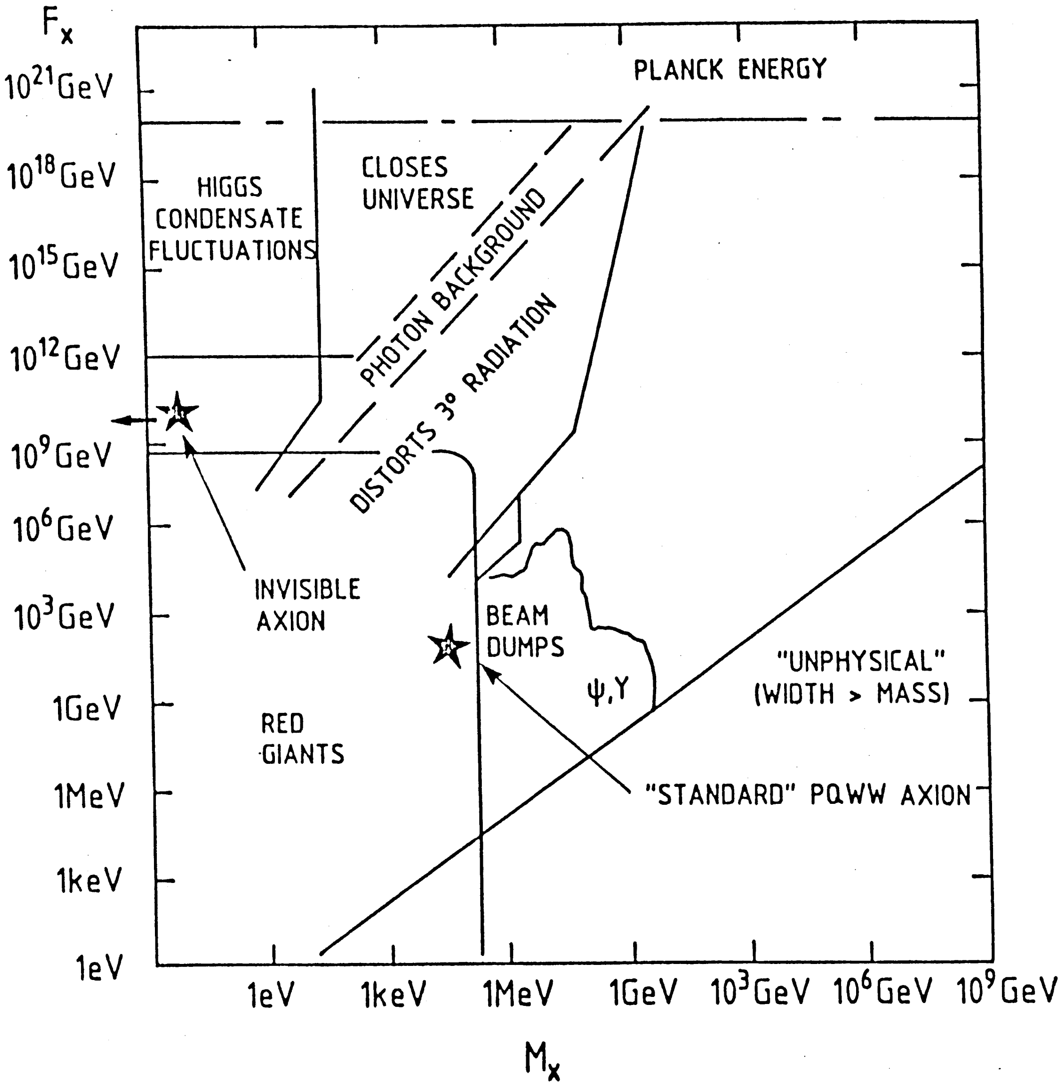
Fig. 2 Existing experimental limits on gluinos in the $M_{\tilde{g}}$, $m_{\tilde{q}}$ plane.

Fig. 3 Existing experimental limits on gluinos in the $m_{\tilde{g}}$, $t_{\tilde{g}}$ plane.

Fig. 4 Proposed layout of the NA3 spectrometer.

Fig. 5 The T1 hodoscope.

Fig. 6 a) Efficiency of the proposed set-up to detect axion-like massive particles decaying into a muon pair, at $x_F = 0.15$
b) Same efficiency, given as a function of x_F for M = 1 and M = 5 GeV/c^2. The axion is assumed to be produced with $< P_T > = 300$ MeV/c.



F$_x$
10^{21}GeV
10^{18}GeV
10^{15}GeV
10^{12}GeV
10^{9}GeV
10^{6}GeV
10^{3}GeV
1GeV
1MeV
1keV
1eV
PLANCK ENERGY
HIGGS CONDENSATE FLUCTUATIONS
CLOSES UNIVERSE
PHOTON BACKGROUND
DISTORTS 3° RADIATION
INVISIBLE AXION
RED GIANTS
BEAM DUMPS
ψ,Υ
"UNPHYSICAL" (WIDTH > MASS)
"STANDARD" PQWW AXION
1eV
1keV
1MeV
1GeV
10^{3}GeV
10^{6}GeV
10^{9}GeV
M$_x$

Fig. 1

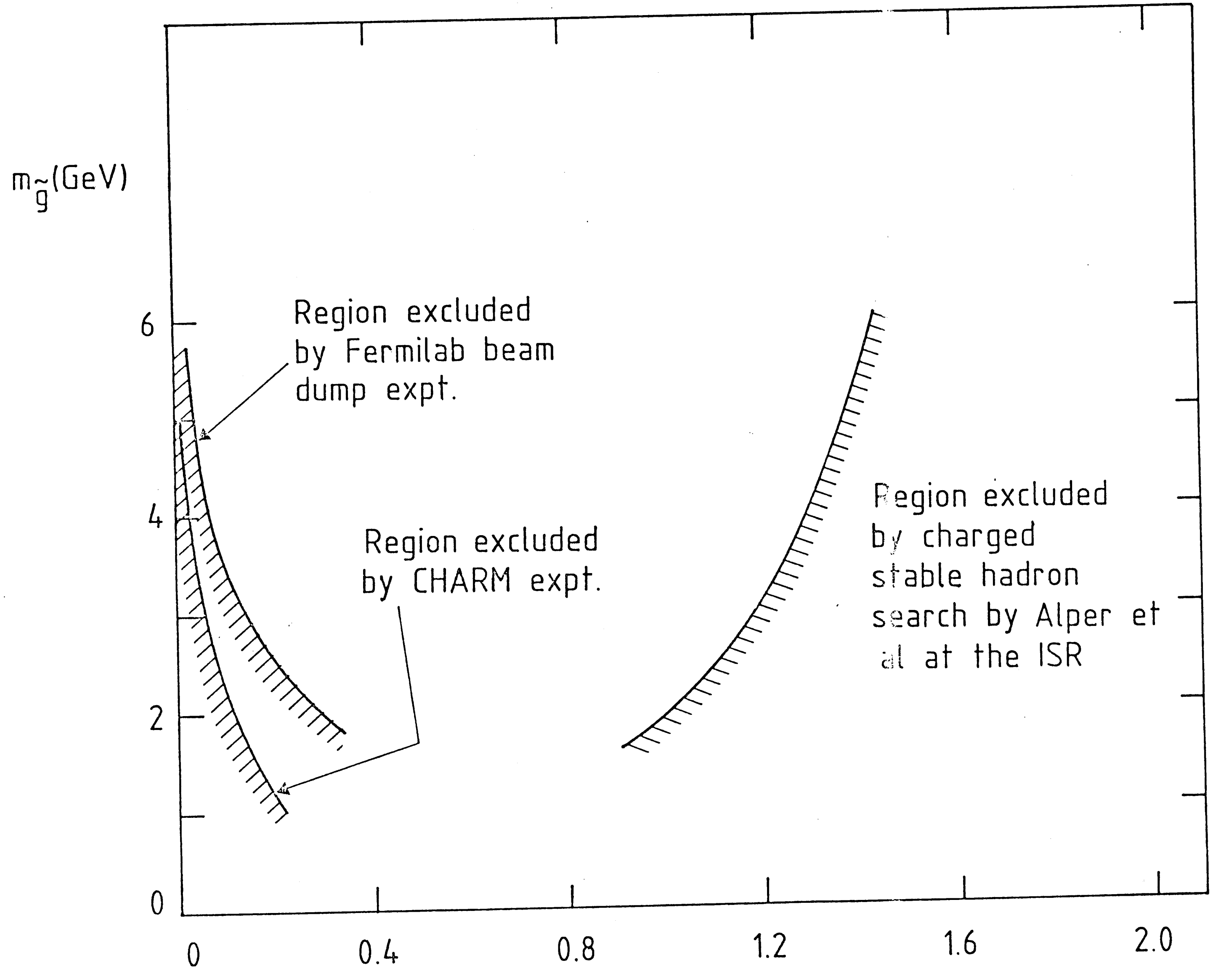

$m_{\tilde{g}}$(GeV)
6
4
2
0
0
0.4
0.8
1.2
1.6
2.0
$m_{\tilde{q}}$ (TeV)
Region excluded by Fermilab beam dump expt.
Region excluded by CHARM expt.
Region excluded by charged stable hadron search by Alper et al at the ISR

FIG. 2

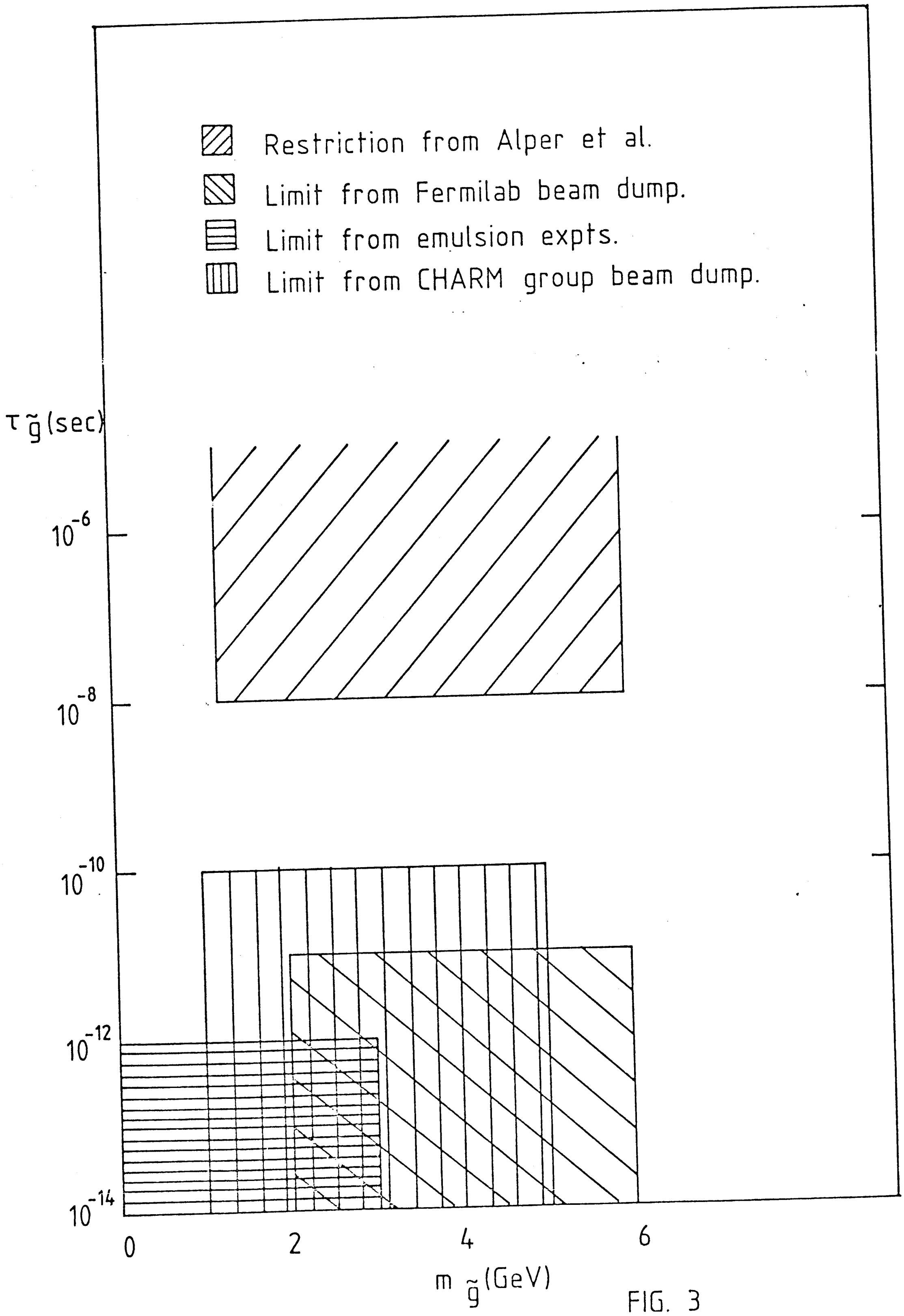

▨ Restriction from Alper et al.
▧ Limit from Fermilab beam dump.
▤ Limit from emulsion expts.
▥ Limit from CHARM group beam dump.
τ g̃ (sec)
10^-6
10^-8
10^-10
10^-12
10^-14
0
2
4
6
m g̃ (GeV)

FIG. 3

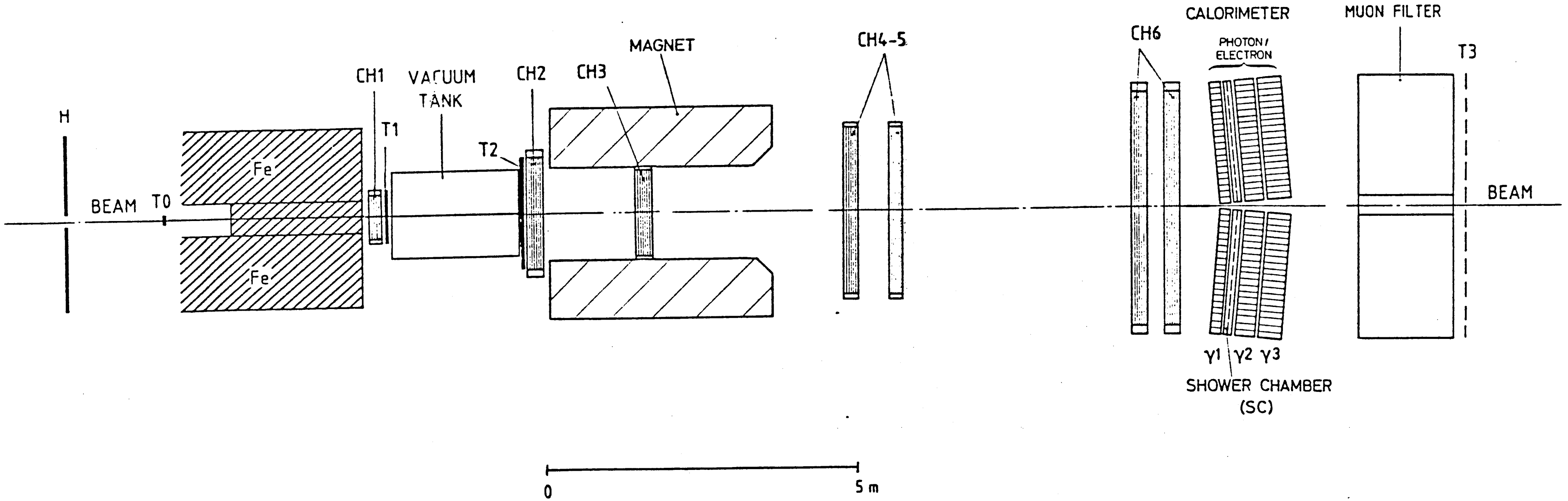

H
BEAM
T0
Fe
Fe
CH1
VACUUM TANK
T1
T2
CH2
CH3
MAGNET
CH4-5
CH6
CALORIMETER
PHOTON/ ELECTRON
γ1 γ2 γ3
SHOWER CHAMBER (SC)
MUON FILTER
T3
BEAM
0
5 m

Fig. 4

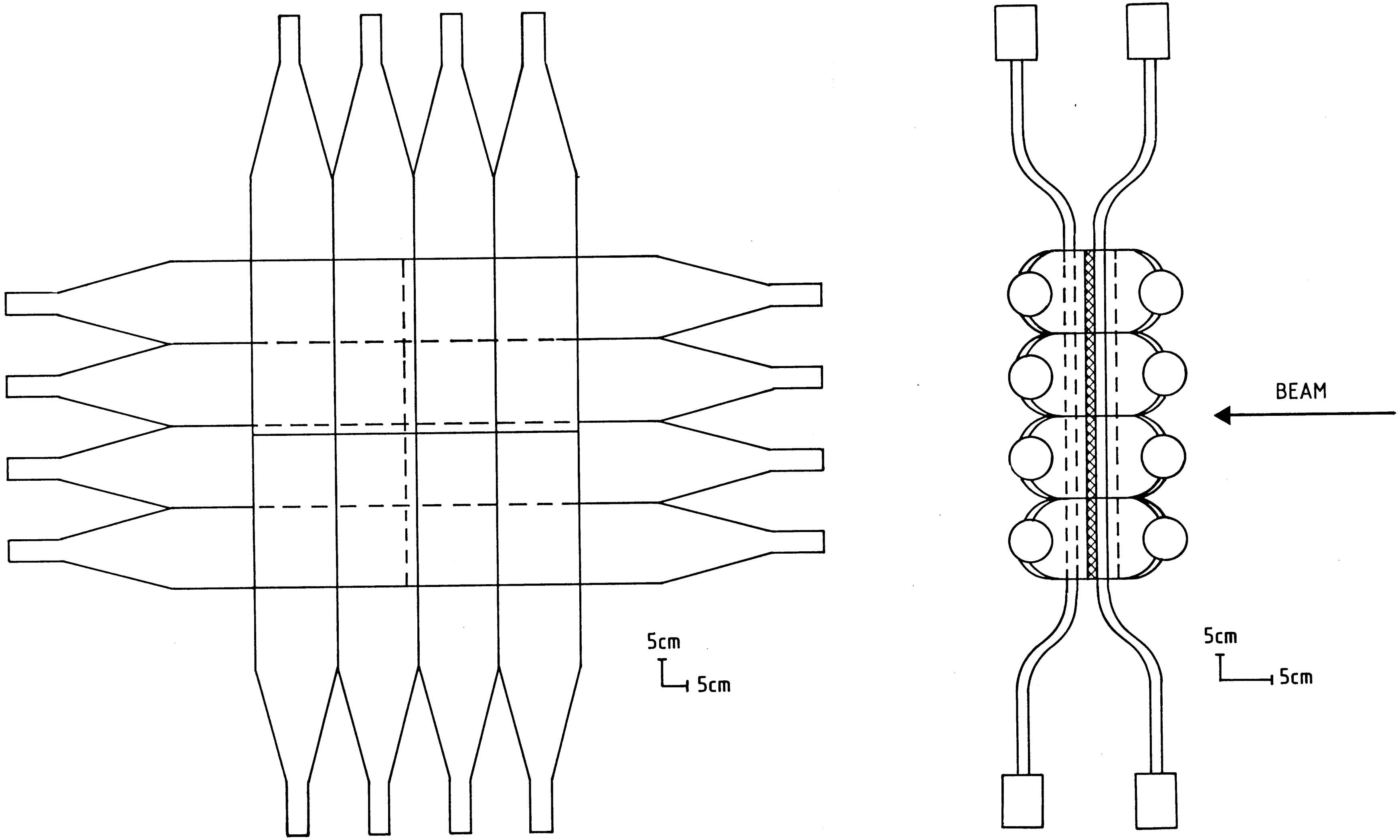


Fig. 5

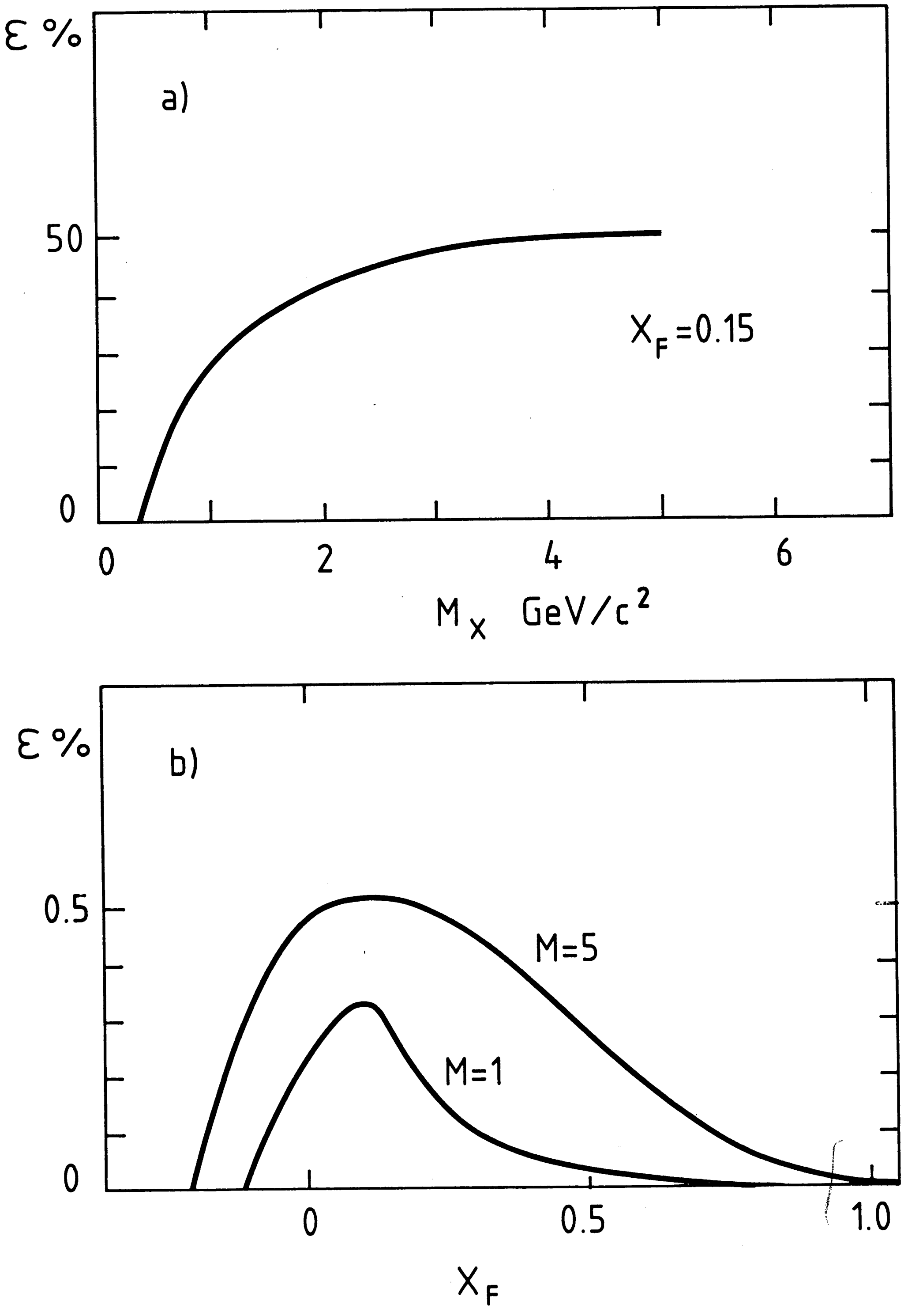


Fig. 6