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PROPOSAL TO LEPC

INSTALLATION OF A PAIR SPECTROMETER IN LEP STRAIGHT SECTION 1

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A PROPOSAL TO SEARCH FOR HIGHLY IONIZING PARTICLES IN e^+e^- COLLISIONS AT LEP USING MODAL.

(MOnopole Detector At Lep)

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SUMMARY

The experiment proposed here is designed to search for highly ionizing particles such as the monopole and the dyon. The Dirac monopole [1] was first hypothesized by Dirac in 1931; and the dyon[4], hypothesized by Schwinger in 1968. The magnetic charge of the monopole is generally agreed to be $g_0=ne/2\alpha=n68.5e$, where $n>1$ and an integer. The mass of the classical monopole was first estimated by Dirac to be approximately 0.5 GeV [1]. However, the presently predicted mass of the monopole ranges from around 10 GeV [2] to the huge value of 10^{16} GeV [3]. On the assumption that monopole-antimonopole pairs are produced via a virtual-photon intermediate state, and have a mass in the range 0-100 GeV, a direct search for Dirac monopoles using e^+e^- annihilation carries a distinct cross sectional advantage over a search using hadron colliders.

The proposed detector, called **MODAL**, is formed from lexan/CR-39 dielectric track detector modules, arranged in a polyhedral configuration ouside of the vacuum pipe and around the intersection region, as shown in figure(1). Etchable track detectors are more sensitive to particles at normal incidence, the size and shape of the detector was chosen with this fact in mind to allow for maximum acceptance for monopoles which leave the beam pipe.These dielectric track detectors will enable us to detect particles with magnetic charge $20e<g_d<<200e$, or electric charge $3<Z<180.$ The passage of a highly ionizing particle through a dielectric track detector is revealed as a cone shaped pit when the surface of the plastic sheet is etched in a controlled manner. The depth of the etched pits is an increasing function of Z/β, where Z is the electric charge, and $\beta=v/c$. Such a detector is passive, and does not require electronic readout or a gas supply.

The previous limits for direct searches for Dirac monopoles are shown in figure(2) and figure (3). Above 23 GeV LEP could easily set the world's best limit, in the event of a null signal. The naive cross section for monopole production is of the order $R=1$; but, as there is no definite theoretical prediction for this cross section in e^+e^- collisions, one requires as much luminosity as possible. The minimum luminosity that we estimate will be needed to make a contribution to the world data on this subject, at LEP energies, is quite modest, i.e, an integrated luminosity of 10^{35} cm^{-2}, or a 12 day run at an average luminosity of 10^{29} $cm^{-2}\,s^{-1}$ (at the I5 intersection point). It should be noted that we would require some work on the beampipe in the intersection region.

It is proposed that the detector described above be installed around the beam pipe in a previously unused intersection region of LEP, presumably I5. Obviously collisions in the intersection region would have to be initiated. Access would not be required for the period of the run, neither will any electrical or gas systems. Although there is no luminosity monitor available for this intersection region, the luminosity can be estimated to the order of 20% [13].

The operation of two extra intersection regions (I1 & I5) would only noticeably reduce the luminosity for the other LEP experiments if the machine were being operated at high liminosity nearthe beam-beam limit. We request some beam development time to ascertain if it is possible to bring beams into collision in IP1 and IP5 without degrading the physics operation for the other LEP

experiments. A memorandum of understanding for the execution of experiment MODAL detailing the agreement between CERN and the MODAL collaboration relating to matters financial, managerial and organizational is on file with the CERN management.

Depending on positive results from the beam collision test at I5 we request that the experiment proper be allowed to run in early1990. We ask this for two reasons. Firstly, we need a relatively simple modification to the beampipe at the I5 intersection region, this work could only be completed in the, at least, four week shutdown expected for the winter of 1989/1990. The LEP machine group would also need a few months to prepare the necessary hardware modifications. Secondly, a second approved experiment (Diambini et al) at I1 will require beam at this time. Beam alignment problems, if any, in the I5 and I1 intersection regions will presumably have been cured and also the operation of two intersection regions, rather than one, yield less of a luminosity penalty.

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Introduction.

Many kinds of highly ionizing particles have been hypothesized but the hypothetical entity which has received the most theoretical and experimental attention is the magnetic monopole. The classical monopole was first introduced by Dirac in 1931 to symmetrize Maxwell's equations and explain the quantisation of electric charge. The magnetic charge of the monopole is generally agreed to be $g_d=ne/2\alpha= n68.5e$, where $n>1$ and an integer. If the elementary charge is that of an electron then $n=1$. If a free quark exists, then the elementary charge is that of the quark. Thus, one would have a magnetic charge three times larger. The mass of classical monopole was first predicted by Dirac to be approximately 0.5 GeV [1]. However, the present predicted mass of the monopole ranges from around 10 GeV [2] to the huge value of 10^{16} GeV [3]. Other highly ionizing particles have been hypothesized, such as the dyon [4] with both electric and magnetic charge.

Assuming that monopole-antimonopole pairs are produced via a virtual-photon intermediate state, and have a mass in the range 0 - 100 GeV, a direct search using e^+e^- annihilation carries a definite cross-sectional advantage over a search in hadron colliders, since for pp colisions the cross-section for massive virtual-photon production falls exponentially with rising mass. **A direct search minimizes assumptions made about the behaviour of monopoles in matter, and about the nature of the particle.** In the case of LEP1 we are sensitive to particles with masses up to around 50 GeV. For LEP2 the maximum mass particle that could be detected would be around 100 GeV. An experiment at LEP with an integrated minimum luminosity of 10^{35} cm^{-2} would, in the event of a null observation, clearly give the world's best direct limit on the existence of Dirac monopoles heavier than about 22 GeV/c^2.

The results of previous searches are given in figure (2) and figure (3). Previously, monopole searches at CERN have been performed using hadron colliders. The results from the ISR (ISR75) are given in figure (2). The most recent monopole search at CERN was performed using the proton-antiproton collider[5]. In this case plastic track etch detectors were deployed inside the vacuum pipe, immediately around the vacuum pipe, and around the central detector of UA1. No monopole candidates were observed and therefore a lower cross-section limit was placed on monopole production via the "Drell Yang" process: qq->monopole antimonopole. These cross-section limits, given as a function of monopole mass, are shown in figure(3). The most recent search at an electron-positron collider was performed at KEK [12]. The corresponding limits derived from a null observation are shown in figure(2).

Ionization, Bremssrahlung and Multiple Scattering of Dirac Monopoles.

The ionization loss of magnetically charged particles with matter, where the monopole is relativistic, is given by [6]:

$$dE/dx = [\, g_d^2 \beta^2 / e^2] (dE/dx)_{BB} \qquad (1)$$

where, dE/dx_{BB} is the energy loss for a unit electric charge from the conventional Bethe Bloch formula.

In passing through matter, a monopole may be expected to emit bremmstrahlung. Following semi-classical arguments from Reference [1] the energy radiated by a monopole of mass m is given by [7]:

$$dE/dx_{rad} = -[g_d^4\beta^4/e^4].[m_e/m]^2dx/X_o \qquad (2)$$

where, m_e is the electron mass and X_o is the radiation length of the material. The severe dependence on g_d is somewhat alleviated by the fact that for the monopole masses we are considering m_e/m is very much less than 1.

A calculation of the cross-section for magnetically charged particles [8] suggests the following form for the multiple scattering of the monopole:

$$<\Phi^2>_m = [g_d^2\beta^2/e^2]<\Phi^2>_{e=1} \qquad (3)$$

where $<\Phi^2>_{e=1}$ is the mean square deflection for a unit electric charge.

The Detector (MODAL).

The proposed detector, which has been given the acronym **MODAL**, is an assembly of lexan and CR-39 dielectric track detectors which can detect particles with magnetic charge $20e<g_d<200e$ or electric charge $3<Z<180$ The detector consists of interleaved sheets of Lexan, of thickness 125 μm, and CR-39, of thickness 500 μm, arranged in stacks. Each lexan/CR39 stack is deployed in a polyhedral configuration that surrounds the intersection region, as shown in figure (1). This shape was chosen to maximize the probability of a track from the intersection region traversing the detector as near to normal incidence as possible. Since it is well known that etchable track detectors are more sensitive to particles at normal incidence. A set of holes will be drilled in each sheet to allow alignment between individual sheets to <100μm. A similar detector was used for monopole searches at PEP [9] and KEK [10].

The passage of a highly ionizing particle through a dielectric track detector is revealed as a cone-shaped pit when the surface of the plastic sheet is etched in a controlled manner using hot concentrated sodium hydoxide solution. The depth of the etched pits is an increasing function of the parameter Z/β, where Z is the electric charge and $\beta = v/c$. The trajectory of a highly ionizing particle can be traced by having a number of layers of dielectric detectors. In the accelerator environment the vast majority of particles have $Z/\beta \cong 1$. However, Lexan records only tracks with $Z/\beta > 70$ (60 for sensitised lexan[11]); CR39 is sensitive to particles with a $Z/\beta > 15$. Consequently, the normal interaction products in an e^+e^- interaction would not be recorded in the dielectric track detectors.

The Location of the Experiment.

It is proposed that the the detector described above be placed in one of the unused intersection regions of LEP. In order to obtain collisions at this point the electrostatic separators would have to be turned off. It is assumed that in order to preserve the "symmetry" in the LEP ring, the partnering intersection region (I1) would be treated in a similar manner. The lexan element of the proposed dielectric track detector can tolerate an integrated radiation dose of more than 100 Mrad. Unfortunately, CR-39, because of its sensitivity, can only withstand radiation doses of less than a few megarads. However, it is extremely unlikely that radiation damage to the proposed detector will be an issue during the lifetime of the proposed experiment.

Luminosity Requirements.

Previous limits obtained in the search for the Dirac monopole are shown in figure (2). The variable R in figure (2) is the cross section for the production of charge g_d monopoles normalized to the μ pair cross section multiplied by $(gd/e)^2$. Naively, one would expect R to be of the order of one (gd is assumed here to be 86.5e, or one dirac magnetic charge). The only direct limits on monopole production, with mass above around 22 GeV, are from a search at FNAL[12] and from the CERN proton-antiproton collider [5]. At LEP we should be able to push the search to a maximum monopole mass of just under the LEP beam energy. The proton-antproton collider limits are not very stringent: the least we should be able to do is to push the search down to below $\log_{10}(R)=0$. However, it would be preferable to push the search below the indirect limit found from an analysis of cosmic ray data [13].

To achieve the limit of $\log_{10}(R)=0$ we would require an integrated luminosity of around 10^{33} cm^{-2} or an average luminosity of at least10^{27} cm^{-2} s^{-1} for 10 days. We feel **an integrated luminosity of 10^{35} cm^{-2}, or a 12 day run with an average luminosity of 10^{29} cm^{-2} s^{-1} (at I5) would make the LEP limit clearly the best direct limit on the existence of the Dirac monopole, with mass above 22 GeV.** To better the indirect cosmic ray limit, we would need an integrated luminosity of at least approximately **10^{38}** cm^{-2}.

Experimental Requirements.

We request the following resources from CERN in order to undertake the proposed experiment:

a) Some beam development time during the initial stages of LEP running (in 1989) in order to ascertain the problems with clashing beams at I5.

b) We request that a simple modification be made to the beampipe at the I5 intersection region in the shutdown of LEP expected for early 1990. The modifications we request are given in more detail below.

c) We request that the physics run proper take place early in 1990, after the shutdown. This would enable us to benefit from the modified beampipe. Also, Diambrini et al are approved to run at I1 at this time, two additional intersection points, rather than one, give rise to less of a luminosity penalty. In order that this experimental programme can proceed any problems found by the LEP beam physicists with the use of the intersection regions I1 and I5 at LEP during early LEP running will have to have been solved. This is more likely to be the case in early 1990 than in 1989.

Modifications Required to the Beampipe at I5.

The beampipe that is presently in place at I5 is an circular tube with a wall thickness of 2mm and diameter 16 cm. There is also a vacuum valve placed exactly at the intersection point of I5. This valve would have to be moved in order that our detector can be installed. Discussions with G. Von Holtey, O. Grobner and C. Hauviller of the LEP machine group indicate that the single valve now in place could be moved, and the vacuum vessel in at I5 modified, in order to leave a clear section of thin walled beampipe around which our detector can be mounted. **This section of unobstructed beampipe would also allow the I5 intersection region to be used for future physics experiments.**

A Dirac monopole with magnetic charge g_d will lose around 5 GeV when traversing, at normal incidence, a 3mm thick piece of aluminium pipe. Consequently a thin walled beampipe is important in order to maximize the acceptance of monopoles as well as to reduce background in the plastic detector. We therefore request that when the beampipe modifications are made the replacement section is 0.4mm thick, thin ribbed, circular cross-section aluminium beampipe with radius 16 cm. This particular choice of beampipe was made after discussions with O. Grobner of the LEP machine group. The design we have choosen is the thinnest walled beampipe with which the LEP machine group are comfortable. C. Hauviller has has indicated that the construction of the beampipe will take a few months.

Division of work within the collaboration.

There are at present six physicists collaborating in this proposed experiment. The Bologna group lead by Professor Giacomelli have extensive facilities for etching dielectric track detectors, they would etch and analyse some fraction of the exposed plastic. Professor Kinoshita (plus student) from Harvard will provide the detector shown in figure (1). This detector exists and will be moved from KEK prior to the experiment, if approved.Harvard will also be involved in the etching and analysis of the exposed plastic. Dr Pinfold besides initiating the experimental proposal is organizing the experiment from his base at CERN. In view of the relative simplicity of this experiment no other support from within the collaboration is required.

Conclusion.

The importance of finding a Dirac monopole is obvious. As the cross section for monopole production at electron positron colliders is not known, although there are naive theoretical estimates, the more luminosity one has for the search the better. Ideally, we would have enough luminosity to push the search below the indirect limit derived from cosmic ray data. But, this would require an integrated luminosity exceeding 10^{38} cm^{-2}, and this is likely to reduce significantly the luminosity available to the other LEP experiments. **However, the non-observation of a signal at LEP with a minimum integrated luminosity of approximately 10^{35} cm^{-2} would enable us to put the best directly measured limit in the world on the existence of the Dirac monopole, with a mass exceeding approximately 22 GeV/c^2.**

A search for monopoles using track-etch detectors, as described above, minimises the assumptions that one has to make about the interaction of the monopole with the detector and could provide the most direct evidence for monopoles. As the detector described above is extremely simple and the analysis techniques required to extract the data well understood, it should be possible to analyse results quickly. In the event of a signal the conventional detectors at LEP such as OPAL (which is equipped with track-etch detectors) can be utilized to check the result either by looking for particles with large energy loss, or by searching for particles with strange trajectories in their magnetic field.

Memorandum of Understanding for the Execution of Experiment Modal.

A memorandum detailing the agreement between CERN and the MODAL collaboration relating to matters financial, managerial and organizational is on file with the CERN management.

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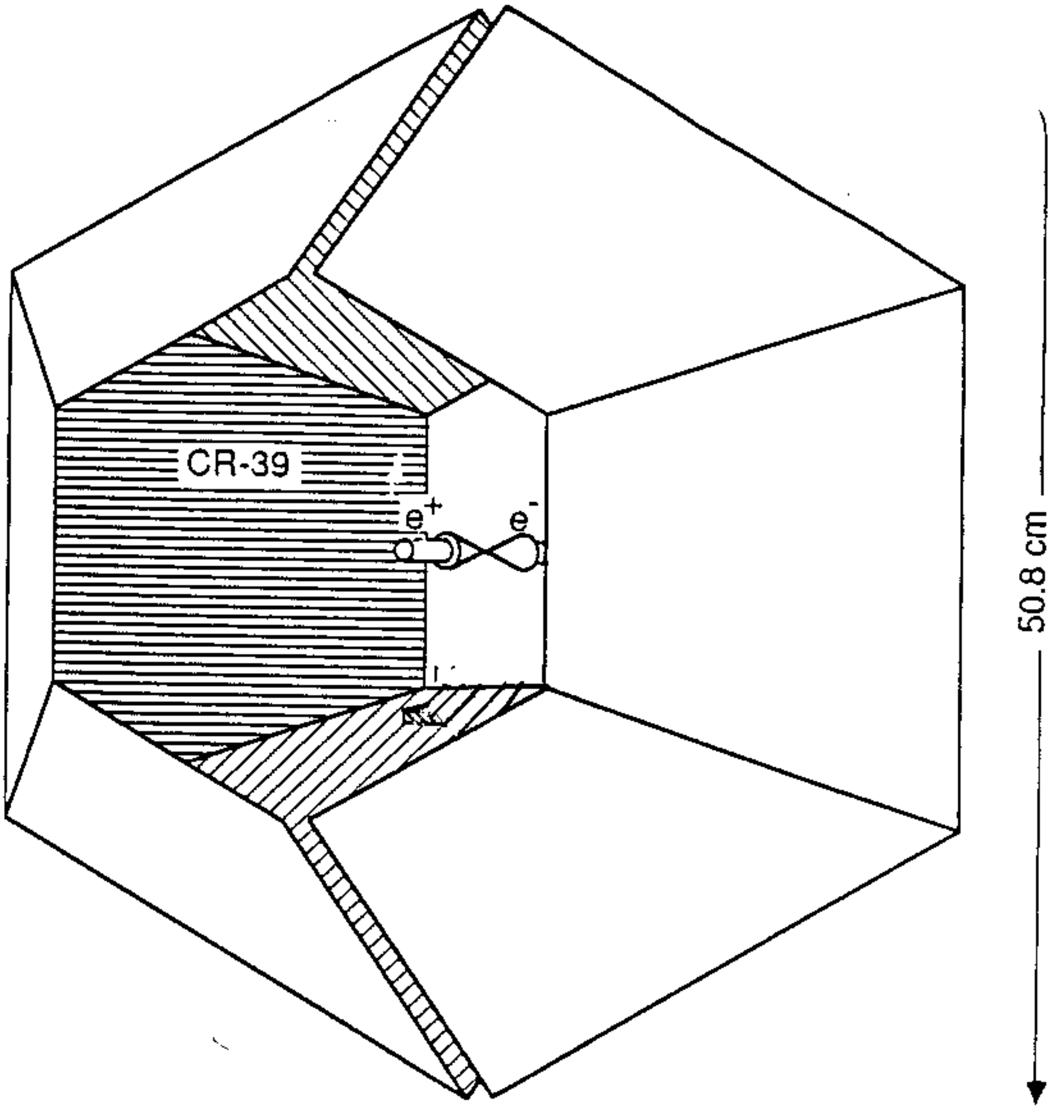

Figure (1) Schematic representation of detector configuration.

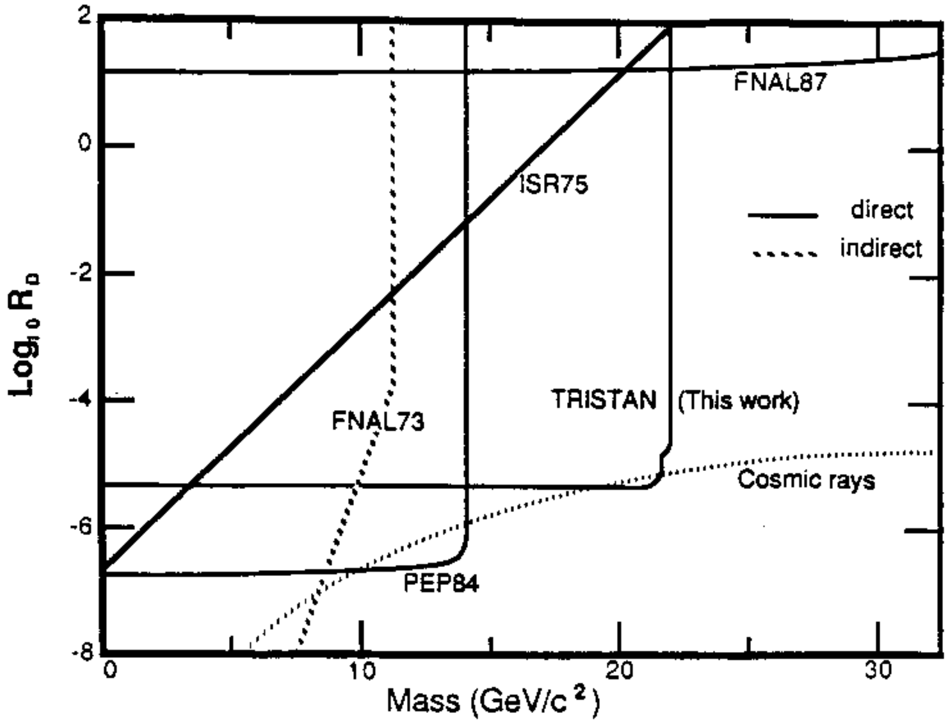

Figure (2) Limit at 95% confidence on the ratio $R=\sigma_{lim}(m)/[(\sigma_{\mu\mu'}).(g_d/e)^2]$ for isotropic exclusive production of monopole-antimonopole pairs. Shown, are the results of the most restrictive accelerator searches [5], and from cosmic rays [9]

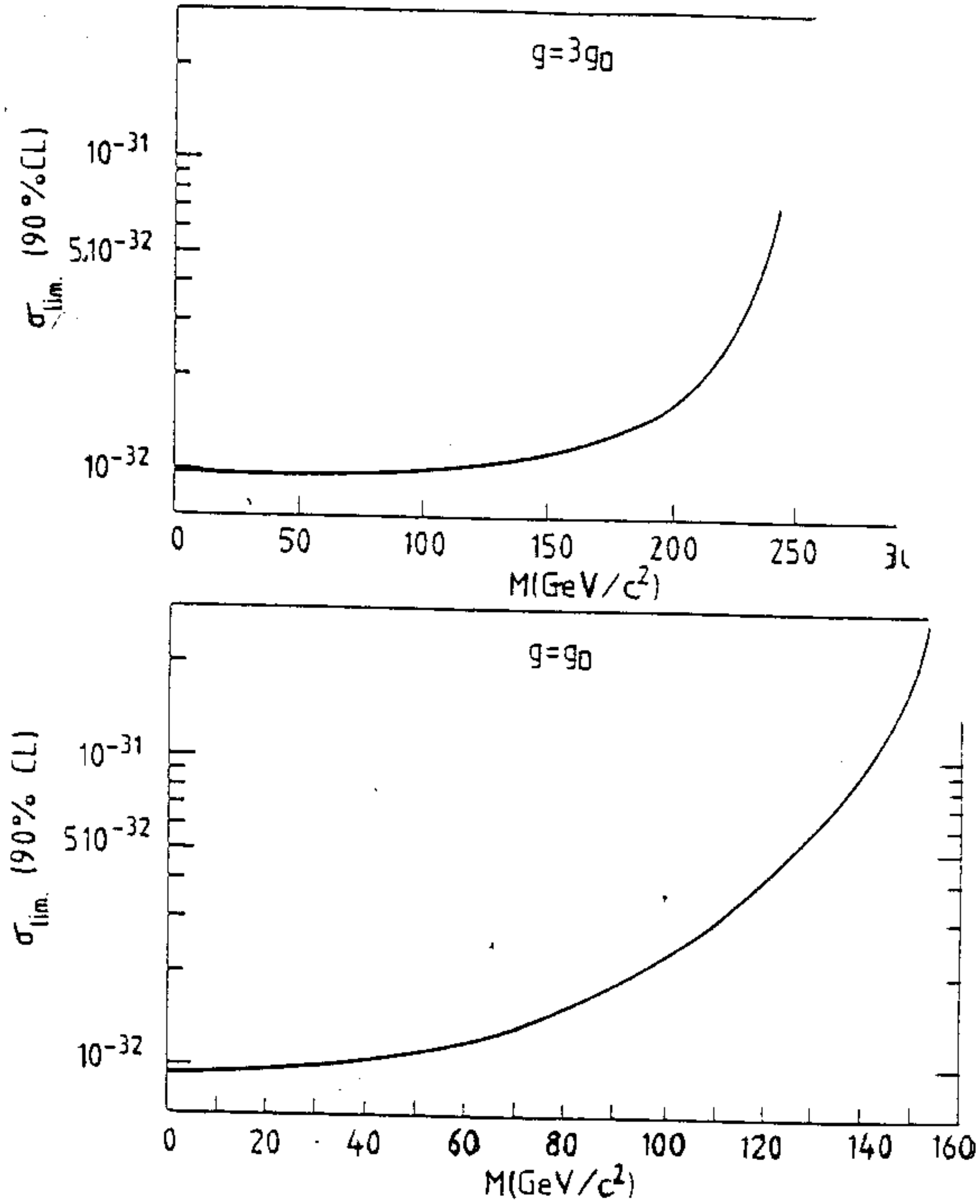

Figure (3) Limits on direct monopole production from the CERN proton-antiproton collider [5].

ABSTRACT

We propose that a simple pair spectrometer based on existing equipment be installed in LEP straight section 1. This will allow a precise measurement of the scattering of the LEP beam off the thermal photons in the beam pipe, as well as a measurement of the energy spectrum of the back-scattered photons from the laser polarimeter.

1. INTRODUCTION

Straight section 1 of LEP has been equipped with the diagnostic apparatus necessary for the operation of the machine. The pulsed laser used in the measurement of the beam polarization is brought into collision with the electron beam at this point, and suitable windows exist for the detection of the back-scattered γ-rays. The spatial distribution of the back-scattered γ's is at present measured with a segmented silicon detector.

The availability of the 20×50 mm^2 thin window at QL13 makes it possible to detect γ-rays produced over the entire 500 m straight section. These γ's are principally due to bremsstrahlung from the residual gas in the beam pipe. They are produced with an opening angle $1/\gamma$ ($\gamma \equiv E_e/m$) and therefore their angular distribution is determined completely by the angular divergence of the electron orbits.

In addition to the bremsstrahlung γ's, the dominant contribution at energies $E_\gamma \lesssim 5$ GeV comes from the scattering of the LEP beam off the thermal photons in the beam pipe [1]. Results from a preliminary measurement of this effect are discussed in the following section. However, to improve on these results and to achieve a precise determination of the energy distribution of the scattered thermal photons it is necessary to use the proposed pair spectrometer. The spectrometer can also be used to measure the energy spectrum of the back-scattered photons from the laser polarimeter.

The preliminary measurements reported below were made with a single Pb-glass block. This method, while simple, cannot be used during normal LEP operations because of the high probability for multiple hits in the detector. Furthermore, the intense synchrotron radiation in the median plane makes it necessary to shield the Pb-glass block, thus deteriorating the resolution at low energy.

These problems are absent from the pair spectrometer, where the rate of γ-conversions is controlled by the radiator thickness and the detectors are outside the median plane.

2. PRELIMINARY RESULTS ON THERMAL PHOTON SCATTERING [2]

The LEP beam pipe is to a good approximation a black body and therefore the photon density in the pipe has a Planck spectrum with $T = 300$ K. As the beam travels through the pipe it scatters on the thermal photons and boosts them to energies of a few GeV. At a beam energy $E_e = 45.6$ GeV, the rate of back-scattered thermal photons for momenta $E_\gamma \lesssim 5$ GeV exceeds the beam-gas bremsstrahlung rate (evaluated at a residual pressure of 2×10^{-10} Torr). Figure 1 shows the calculated rate of thermal photon scattering for incident beam energies $E_e = 45.6$ and 20 GeV; the bremsstrahlung contribution, which is almost energy independent, is also indicated. The rate of γ-rays reaching the detector, as obtained from a Monte Carlo simulation using the actual orbit in the straight section [3], is 0.70 of the results shown in Fig. 1. The length of straight section contributing to the production of high-energy γ-rays is of order $\ell = 500$ m.

A preliminary measurement of the γ-spectrum in LEP straight section 1 was made this spring by using a single Pb-glass block. The location of the detector is shown in Fig. 2a; it is 45 m downstream from the exit window at QL13. The counter is a $15 \times 15 \times 40$ cm^3 SF5 Pb-glass block viewed by a single photomultiplier [4]. The data were recorded by an integrating ADC [LeCroy QVT], and by using suitable attenuators it was possible to cover the dynamic range from 1 to 50 GeV. To suppress the synchrotron radiation, the counter was surrounded by 2 cm of Pb. This shielding degrades the resolution at low energy; the resolution, as calculated by the EGS III program [5], was $\Delta E/E = 0.27$ at $E = 0.2$ GeV, 0.10 at $E = 1$ GeV, and ~ 0.06 for $E > 3$ GeV. The detector was calibrated by using cosmic-ray muons on the surface, whilst in the tunnel the end-point of the bremsstrahlung spectrum could be used.

To avoid pile-up of events, the data were obtained with a single electron bunch, yielding a current of $\sim 60\ \mu$A. This has the further advantage of improved vacuum in the straight section. The spectra obtained at beam energies E_e = 20 and 45.6 GeV are shown in Fig. 3; here the 45.6 GeV data have been renormalized by a factor of 4.7 to be brought into agreement with the 20 GeV data [6]. For $E_\gamma > 10$ GeV, the data fit the $1/E_\gamma$ bremsstrahlung spectrum well, and one deduces that the average pressure was $P = 1.5 \times 10^{-10}$ Torr. Although the exact pressure over the entire straight section is not known, the deduced value is within the expected range. Measurements of the bremsstrahlung spectrum, with higher machine currents, give consistent results for the beam-pipe pressure.

In Fig. 4 we show the low-energy part of the spectrum for beam energies E_0 = 20 GeV (Fig. 4a) and E_0 = 45.6 GeV (Fig. 4b). There is a clear difference between the two spectra, whereas the bremsstrahlung contribution is almost energy-independent. In both figures the dotted curve is the bremsstrahlung contribution as obtained by fitting the data for $E_\gamma > 10$ GeV; the solid curve is the sum of the bremsstrahlung and of the calculated contribution from the thermal photon scattering. The latter includes the 0.70 acceptance correction but has *not* been normalized. There is good qualitative agreement between the 45.6 GeV data and the prediction. In particular, in the region $E_\gamma \approx 1$–2 GeV the effect is extremely large, a factor of 10 in excess of the bremsstrahlung yield. There is also agreement for the 20 GeV data even though, as predicted, in this case the thermal photon contribution is very much suppressed in the range of our measurements.

Since LEP is the only accelerator where thermal photon scattering can be observed, we believe that it is of interest to study this effect quantitatively. This is not possible with the data in hand or with the present detector. On the other hand, we expect that with the pair spectrometer we will achieve a measurement at the 2% absolute level. Such accuracy makes it possible to set meaningful limits on models of 'stochastic electrodynamics' [7], since the data probe the high-energy tail of the Planck distribution.

Secondary goals are a precise measurement of the beam-gas bremsstrahlung spectrum and a study of the tails of the beam by the use of the wire scanner. The proposed set-up is compatible with the operation of the laser polarimeter. The most important aspect of the pair spectrometer is that the energy distribution of the γ-rays originating in the straight section can be measured *completely parasitically*, without making any demands on normal LEP operation.

3. THE PAIR SPECTROMETER

The pair spectrometer uses as a converter the 2 mm aluminium window, giving a minimum conversion rate of 2.2%. The analysing element is a cobalt-samarium permanent magnet, 40 cm long with a 0.3 T field, dispersing in the vertical direction. The magnet is available and will be located outside the beam vacuum along the external photon line next to quadrupole QL14 (see Fig. 2b). The electron beam is fully shielded from the dipole field. The detector configuration is shown in Fig. 5. Each arm contains 18 Pb-glass crystals, of 4×4 cm^2 frontal area and 40 cm length [8]; they are arranged in a 12 cm wide by 24 cm high array. From the distribution of the shower over the array elements, we expect a spatial resolution of Δy = 0.5 cm, whilst the energy resolution is of order $\Delta E/E = 0.06/\sqrt{E}$ (for fully contained showers).

The acceptance of the spectrometer is a function of the distance of the detector from the magnet centre. The acceptance for two typical distances, ℓ = 4 m and 10 m, is shown in Fig. 6. The corresponding resolution in the pair energy is $\Delta E_\gamma/E_\gamma = 0.04\,E_\gamma$ and $0.01\,E_\gamma$, respectively, with E_γ in GeV. The detector arms can be retracted vertically to protect the Pb-glass from the median-plane radiation and to adjust the upper limit of the acceptance. The lower limit is best set by longitudinal motion (along the photon line) of the detector. After three months with our Pb-glass block in operation in the tunnel, there is no visible change in the transparency of the glass. We have, however, observed a loss of gain during this period, and we are making a further investigation.

The Pb-glass blocks are read out individually by CAMAC ADCs when triggered by two scintillators. To avoid long (and expensive) cable runs, data acquisition and HV are controlled locally by a MAC II computer placed next to the crate in the tunnel. A second MAC II in the optical laboratory can then control the local computer by means of a single coaxial cable. The schematic for the electronics is shown in Fig. 7. For a machine current of 1.5 mA per beam, the rate of γ's with $E_\gamma > 1$ GeV is ~ 20 kHz; given the 2% conversion rate and the detector acceptance, the trigger rate is $f_{trig} < 140$ Hz. This rate can be accepted by the electronics with little dead-time, since a complete event can be read out in 10 ms. Thus in one hour a 256-channel spectrum can be obtained with a 3% statistical accuracy. This relatively high data-rate allows for consistency checks and for understanding the systematic effects.

The resolution of the pair spectrometer can be greatly improved by the addition of a position-sensitive detector (i.e. one or more drift chamber planes) to measure the vertical coordinate of the impact points. In this configuration, one can also use the spectrometer to measure the energy spectrum of the back-scattered photons from the laser polarimeter. The design intensity of the laser is such that ~ 10^3 photons are scattered per pulse [9]. Thus a calorimetric measurement is not practical since it responds to the total energy, all the photons arriving within a few nanoseconds. On the other hand, the low conversion rate combined with the spectral dispersion introduced by the spectrometer makes possible the measurement of the converted electron (positron) spectrum. From that spectrum the primary γ-ray spectrum can then be reconstructed.

4. INSTALLATION AND SCHEDULE

The magnet and detector can be ready for installation during the winter 1990 shutdown of LEP. The only requirements from CERN are the remote-controlled support for the two spectrometer arms and a motorized converter of variable thickness. No cabling is required, because the remote control of our data-acquisition system utilizes existing cables. The use of Pb glass in the tunnel does not give rise to any safety hazards. Our experience with the operation of the polarimeter [10] has accustomed us to having limited access to our apparatus.

It should be possible to complete the measurements and check the results in three months of normal LEP running.

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[7] F. Cardone, On a possible measurement of the zero-point radiation contribution to Planck's distribution, private communication, 1989, and submitted to Physics Letters B.
See also T.H. Boyer, Phys. Rev. **D29** (1984) 1096.

[8] On loan from the Kurchatov Inst. of Atomic Energy group, participating in Experiment WA80.

[9] Up to 50 back-scattered photons in a single pulse have already been observed.

[10] M. Placidi and R. Rosmanith, Nucl. Instrum. Methods **A274** (1989) 79.

Figure captions

Fig. 1 Calculated rates for thermal photon scattering at 20 GeV (diamonds) and 45.6 GeV (squares). The continuous curve is the bremsstrahlung rate for $P = 2 \times 10^{-10}$ Torr.

Fig. 2 Location of a) the detector and b) the analysing magnet in LEP straight section 1.

Fig. 3 The γ-ray spectrum at 20 and 45.6 GeV. Note the cut-off of the bremsstrahlung contribution at the beam energy.

Fig. 4 The low-energy part of the γ-ray spectrum a) at 20 GeV and b) at 45.6 GeV. The dashed curve is the bremsstahlung contribution and the solid curve is the sum of the bremsstrahlung and thermal photon scattering contributions.

Fig. 5 The layout of the pair spectrometer detector.

Fig. 6 Acceptance of the pair spectrometer for distances $\ell = 4$ m (squares) and 10 m (diamonds).

Fig. 7 Schematic of the detector readout system.

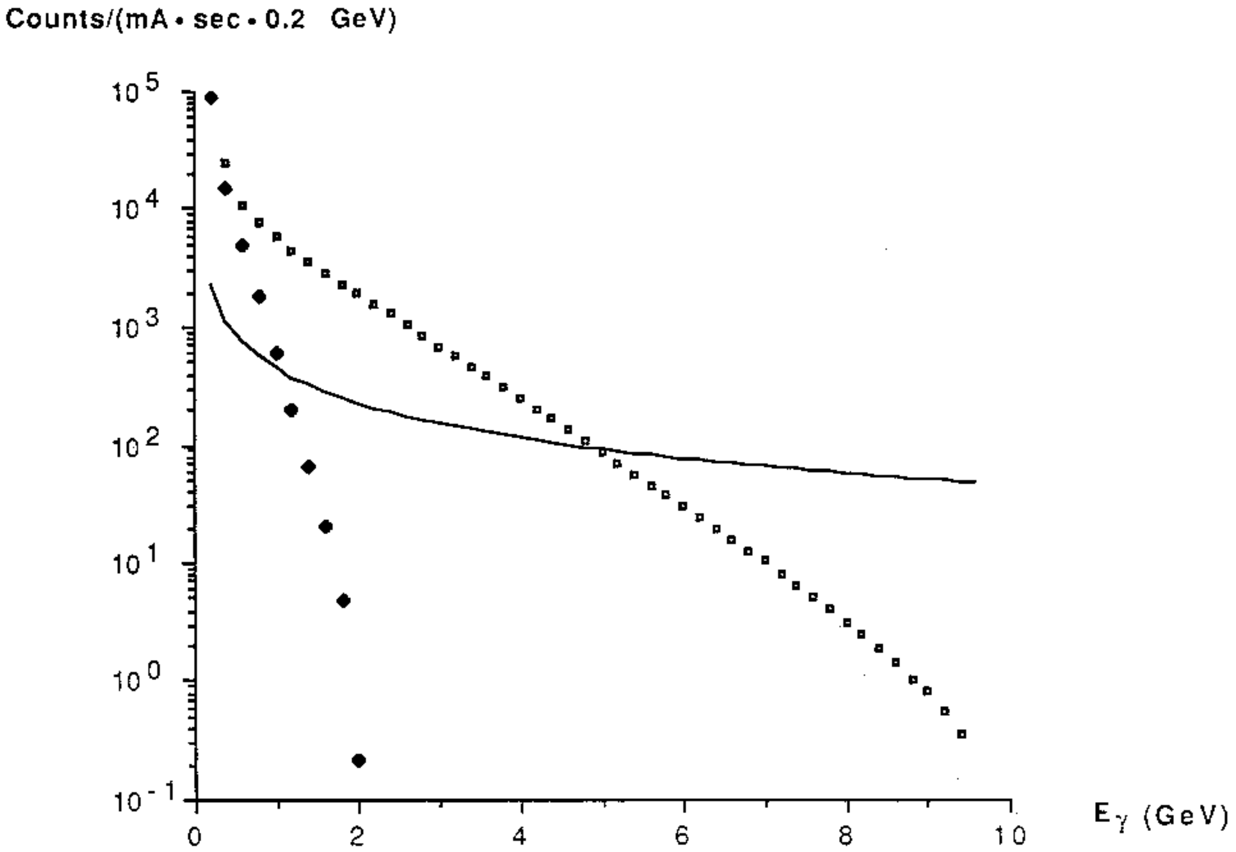
Counts/(mA • sec • 0.2 GeV)
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
0
2
4
6
8
10
E_γ (GeV)

Fig. 1

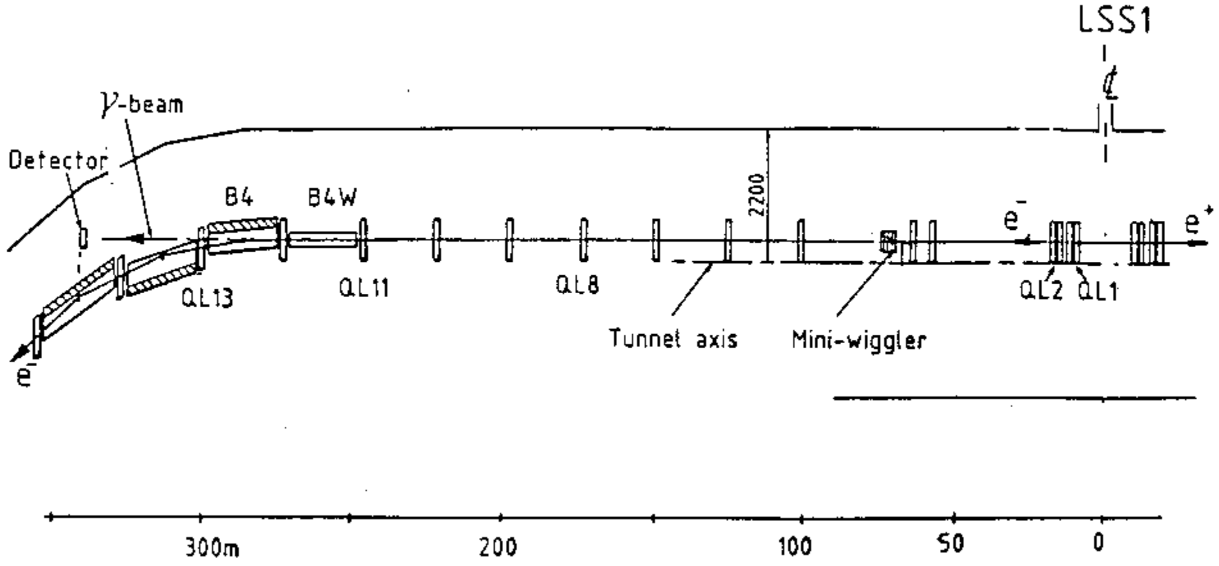
LSS1
℄
γ-beam
Detector
B4
B4W
2200
e^-
e^+
QL13
QL11
QL8
Tunnel axis
Mini-wiggler
QL2
QL1
e^-
300m
200
100
50
0

Fig. 2a

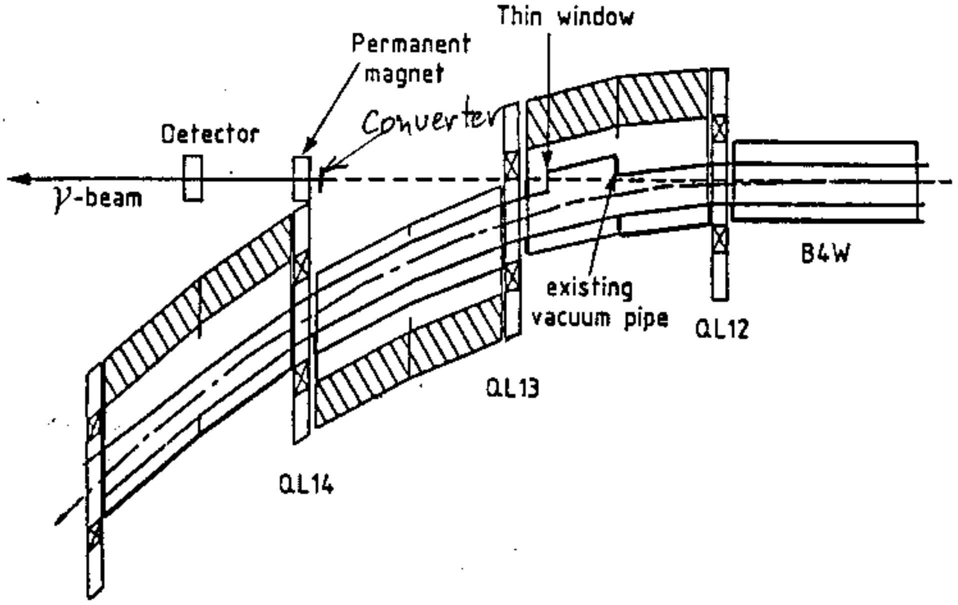
Thin window
Permanent magnet
Converter
Detector
γ-beam
B4W
existing vacuum pipe
QL12
QL13
QL14

Fig. 2b

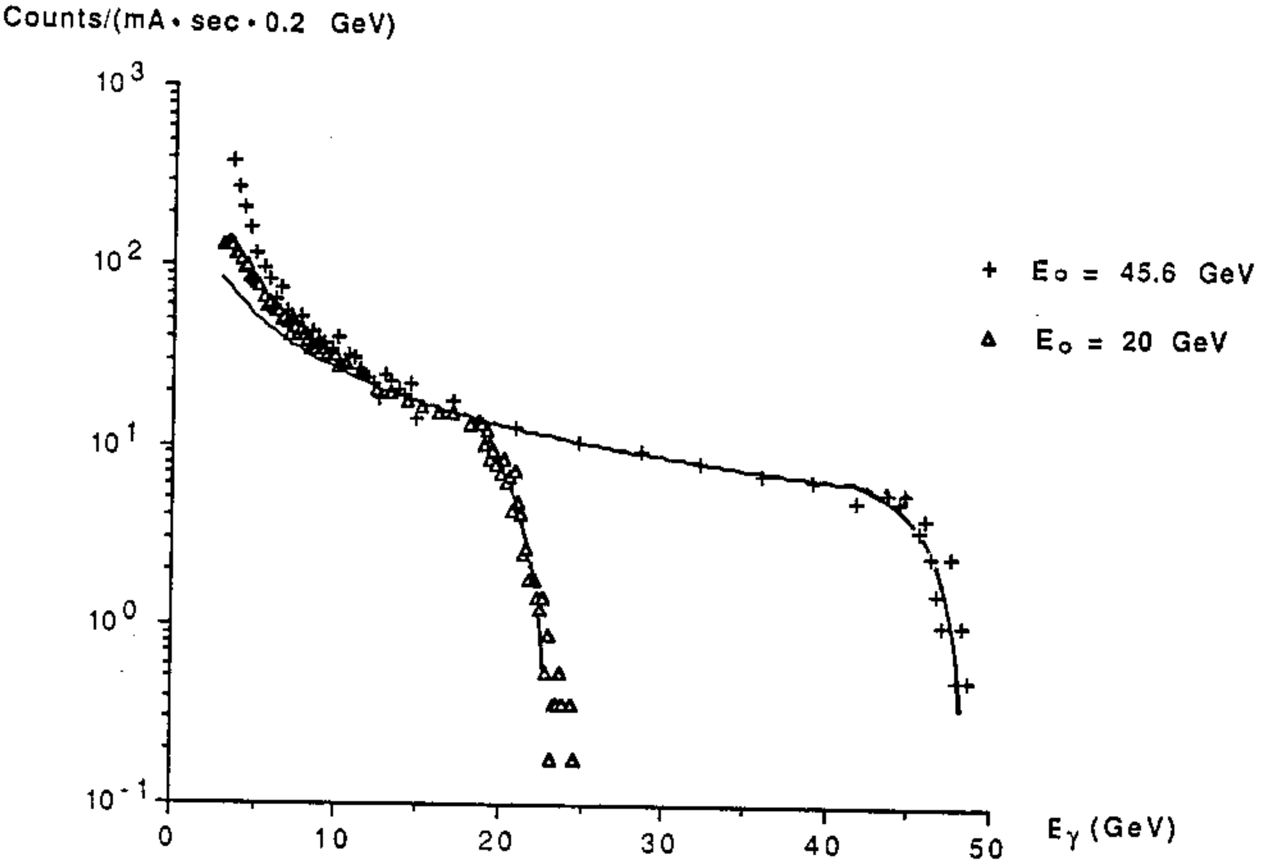
Counts/(mA • sec • 0.2 GeV)
10^3
10^2
10^1
10^0
10^{-1}
0
10
20
30
40
50
E_γ (GeV)
+ E_o = 45.6 GeV
Δ E_o = 20 GeV

Fig. 3

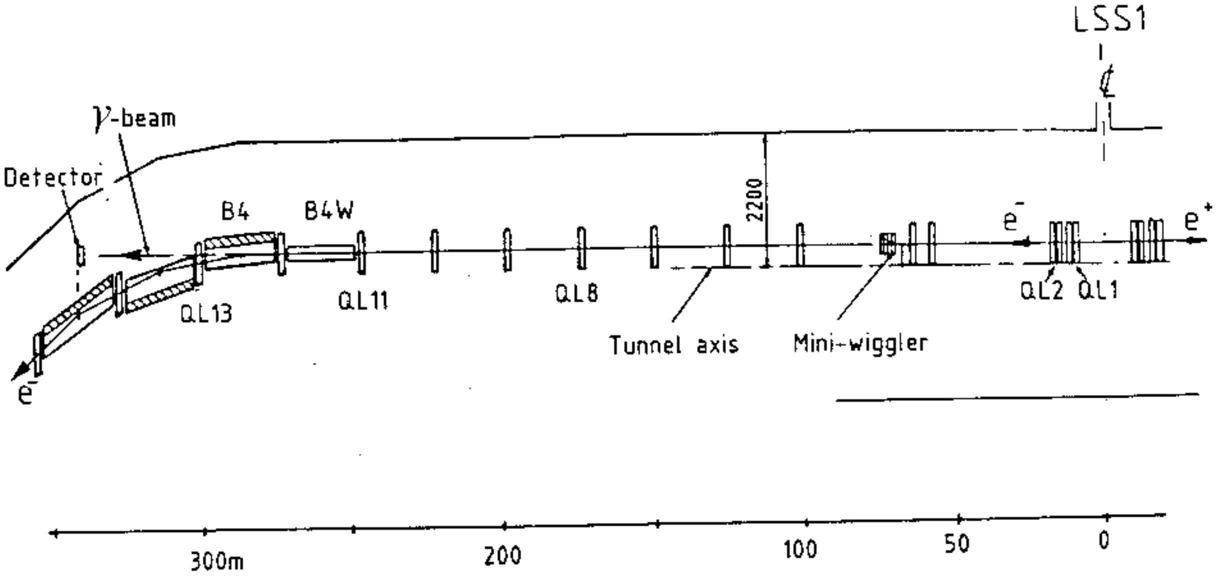
LSS1
γ-beam
Detector
B4
B4W
2200
e⁻
e⁺
QL13
QL11
QL8
QL2
QL1
Tunnel axis
Mini-wiggler
e⁻
300m
200
100
50
0

Fig. 2a

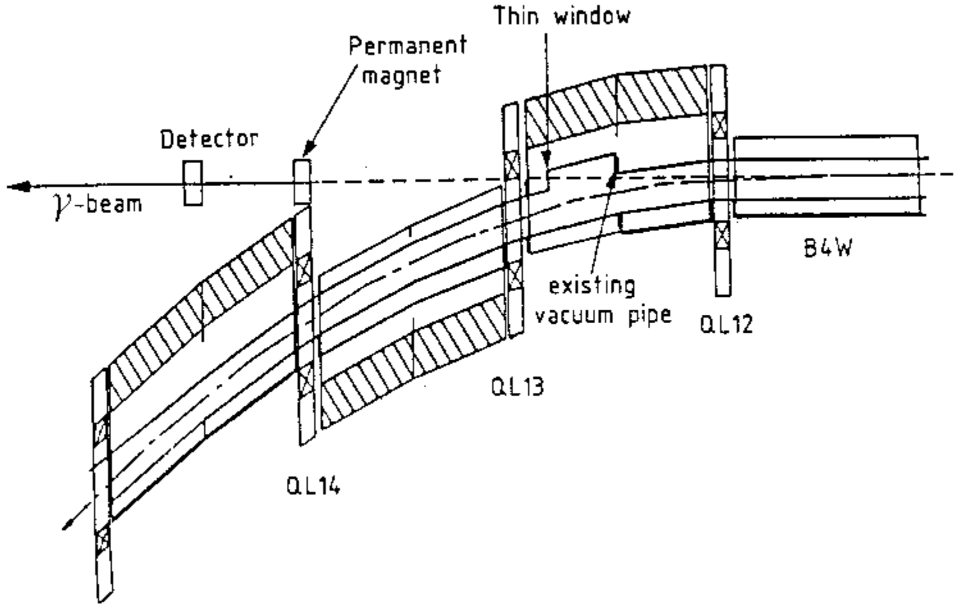
Thin window
Permanent magnet
Detector
γ-beam
existing vacuum pipe
B4W
QL12
QL13
QL14

Fig. 2b

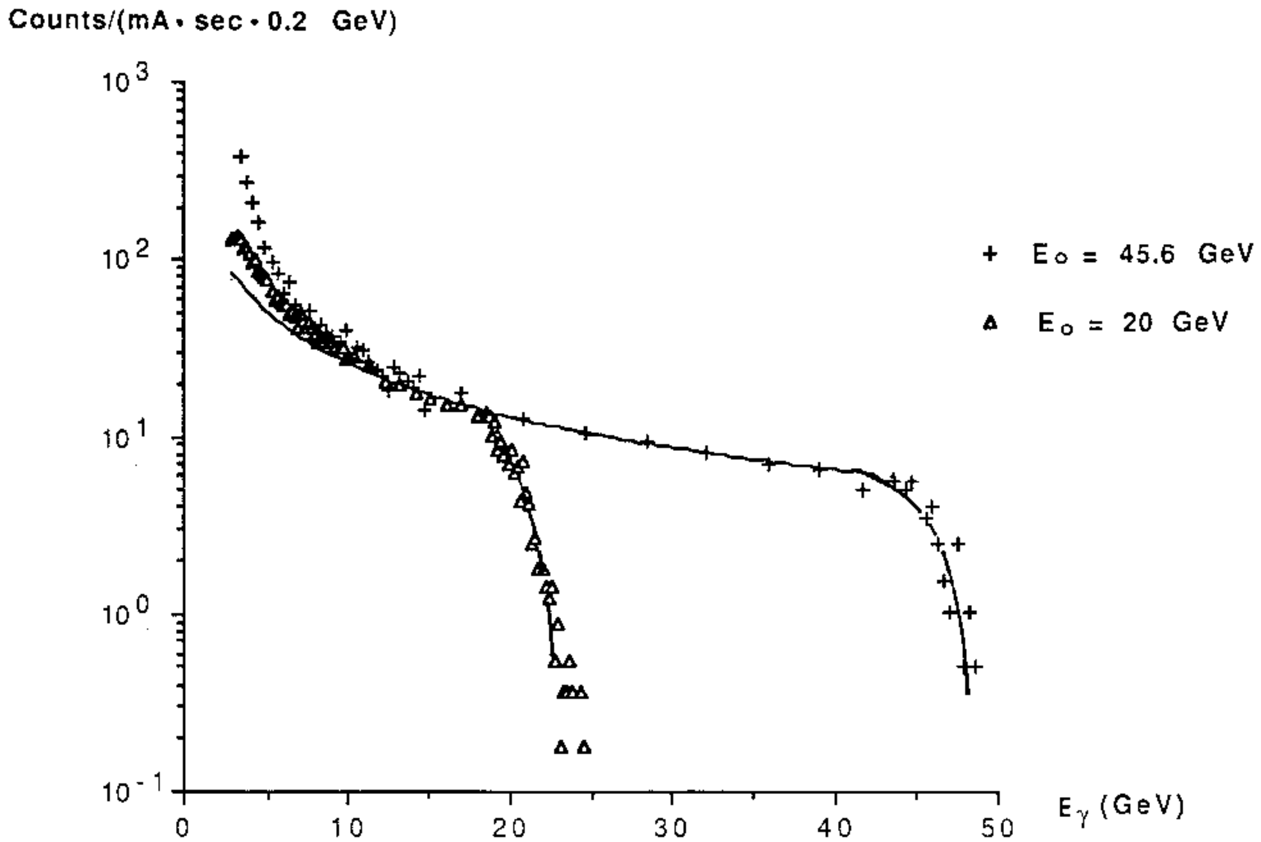
Counts/(mA • sec • 0.2 GeV)
10^3
10^2
10^1
10^0
10^{-1}
0
10
20
30
40
50
E_γ (GeV)
+ E_o = 45.6 GeV
Δ E_o = 20 GeV

Fig. 3

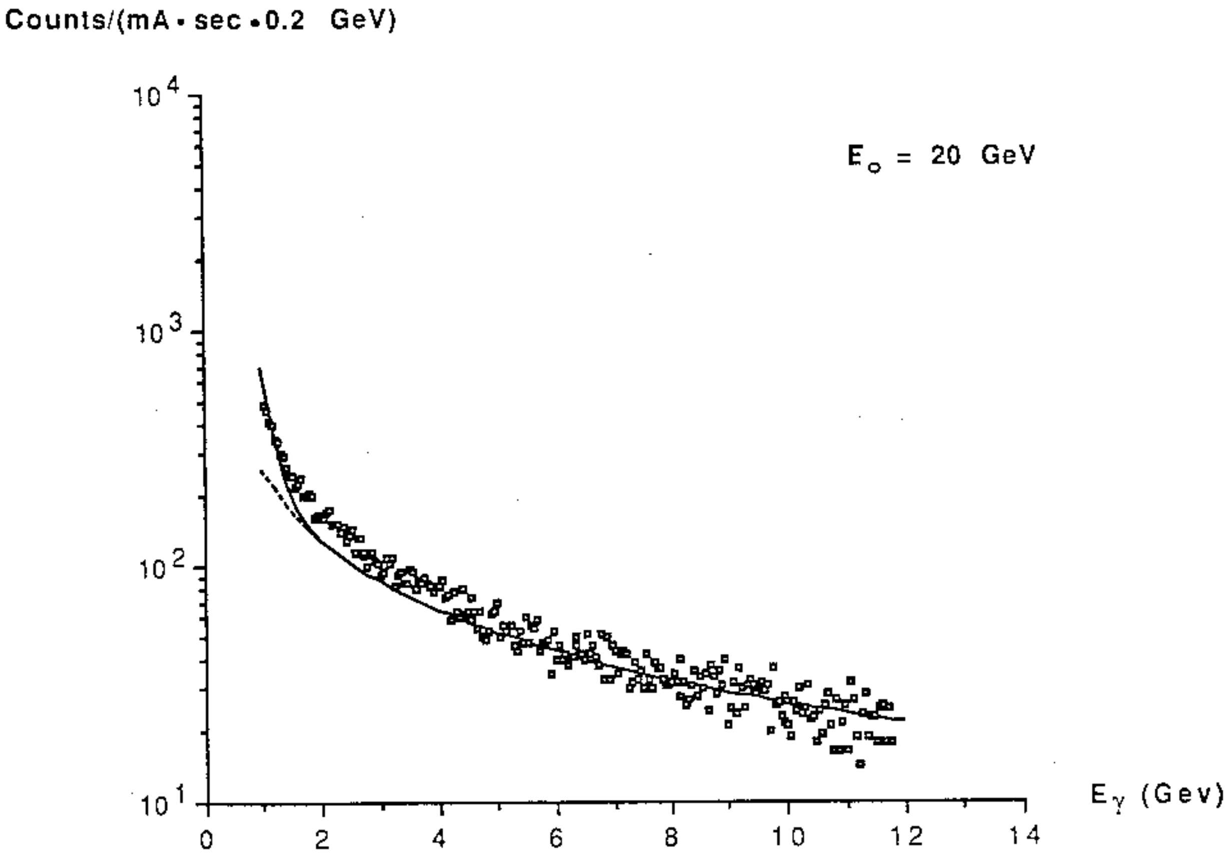
Counts/(mA • sec • 0.2 GeV)
10^4
10^3
10^2
10^1
E_o = 20 GeV
0
2
4
6
8
10
12
14
E_γ (Gev)

Fig. 4a

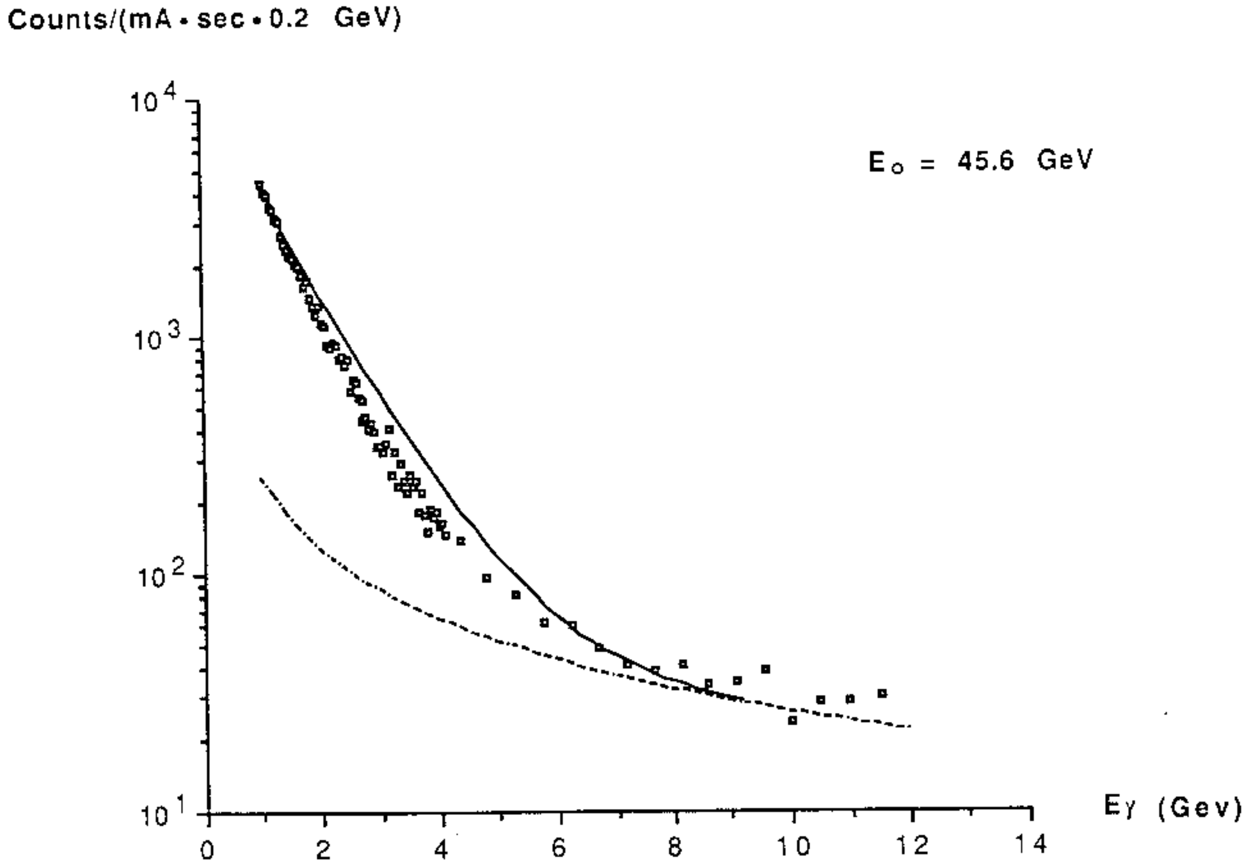
Counts/(mA • sec • 0.2 GeV)
10^4
10^3
10^2
10^1
E_o = 45.6 GeV
0
2
4
6
8
10
12
14
E_γ (Gev)

Fig. 4b

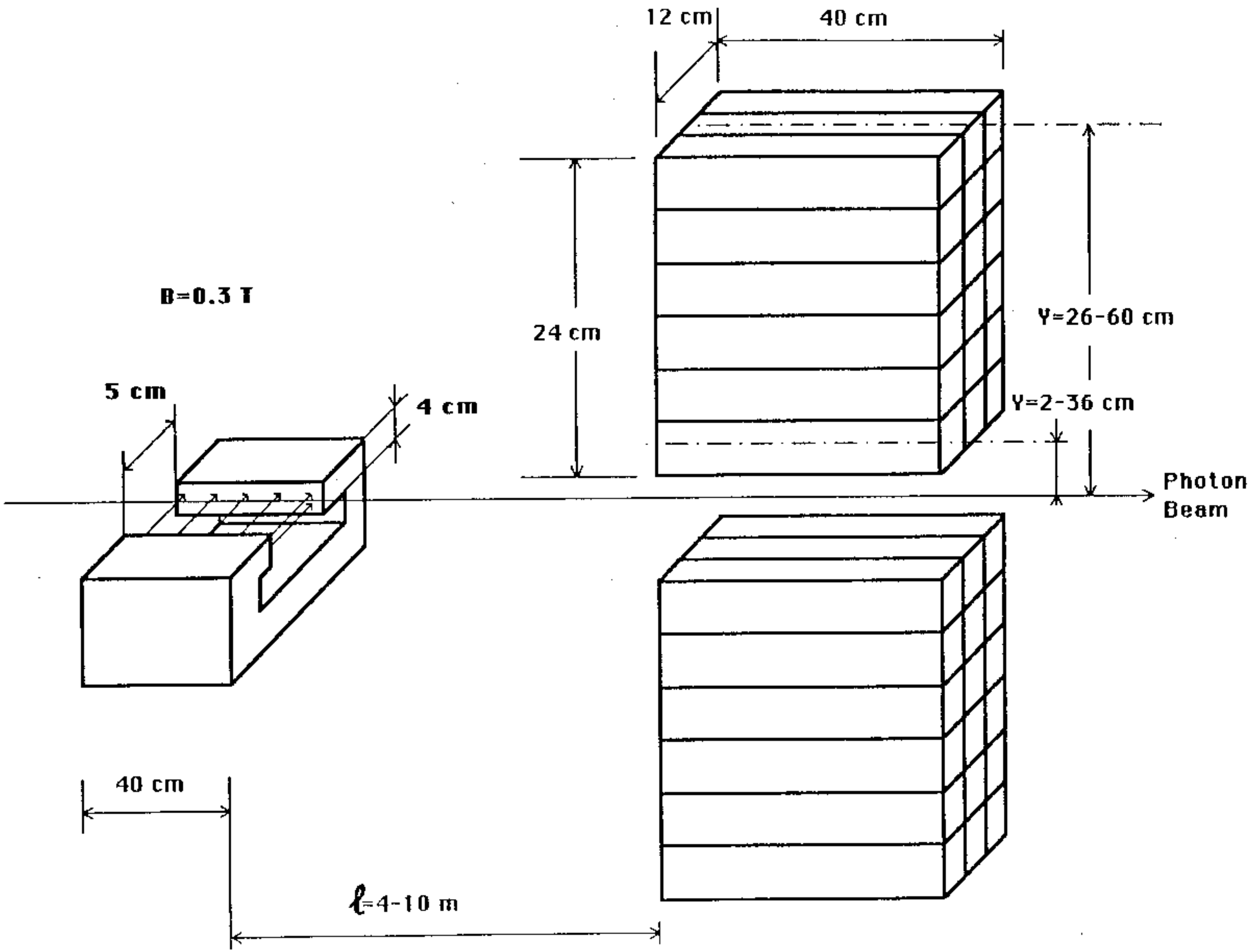
12 cm
40 cm
B=0.3 T
24 cm
Y=26-60 cm
5 cm
4 cm
Y=2-36 cm
Photon
Beam
40 cm
ℓ=4-10 m

Fig. 5

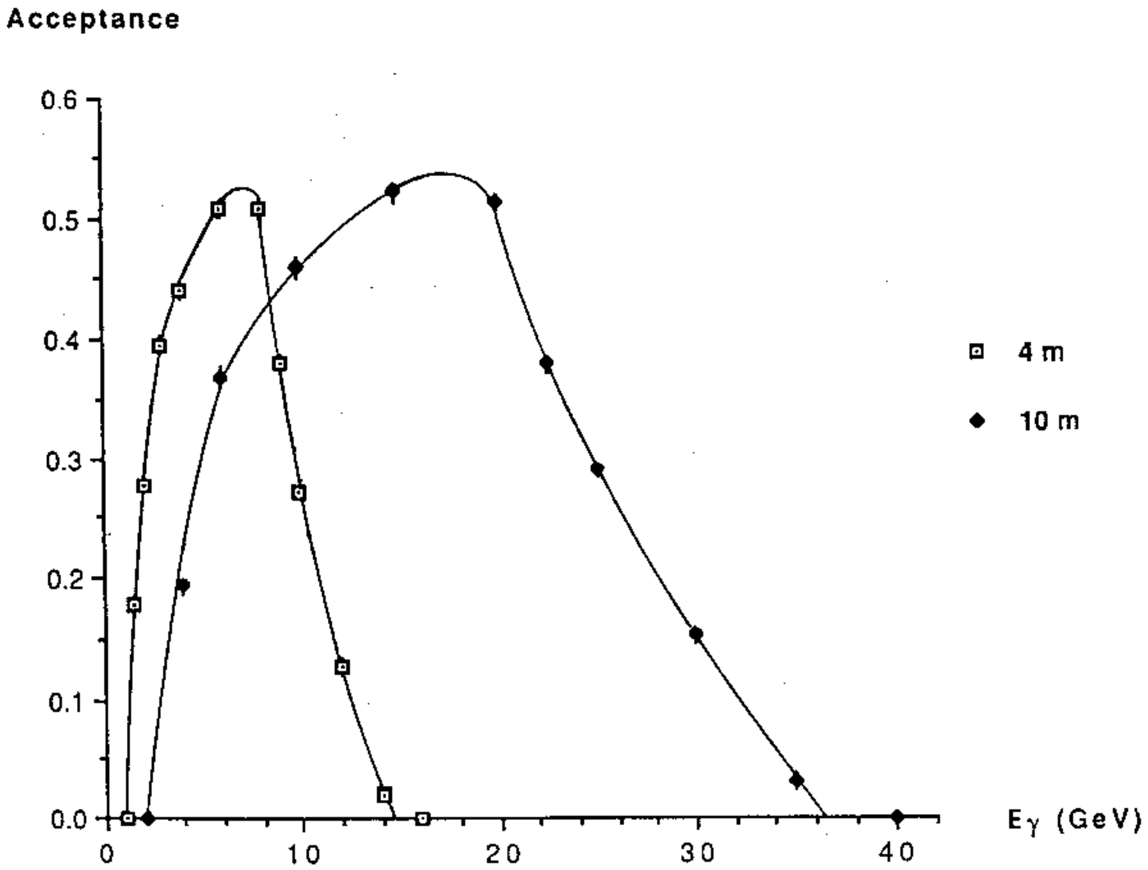

Fig. 6

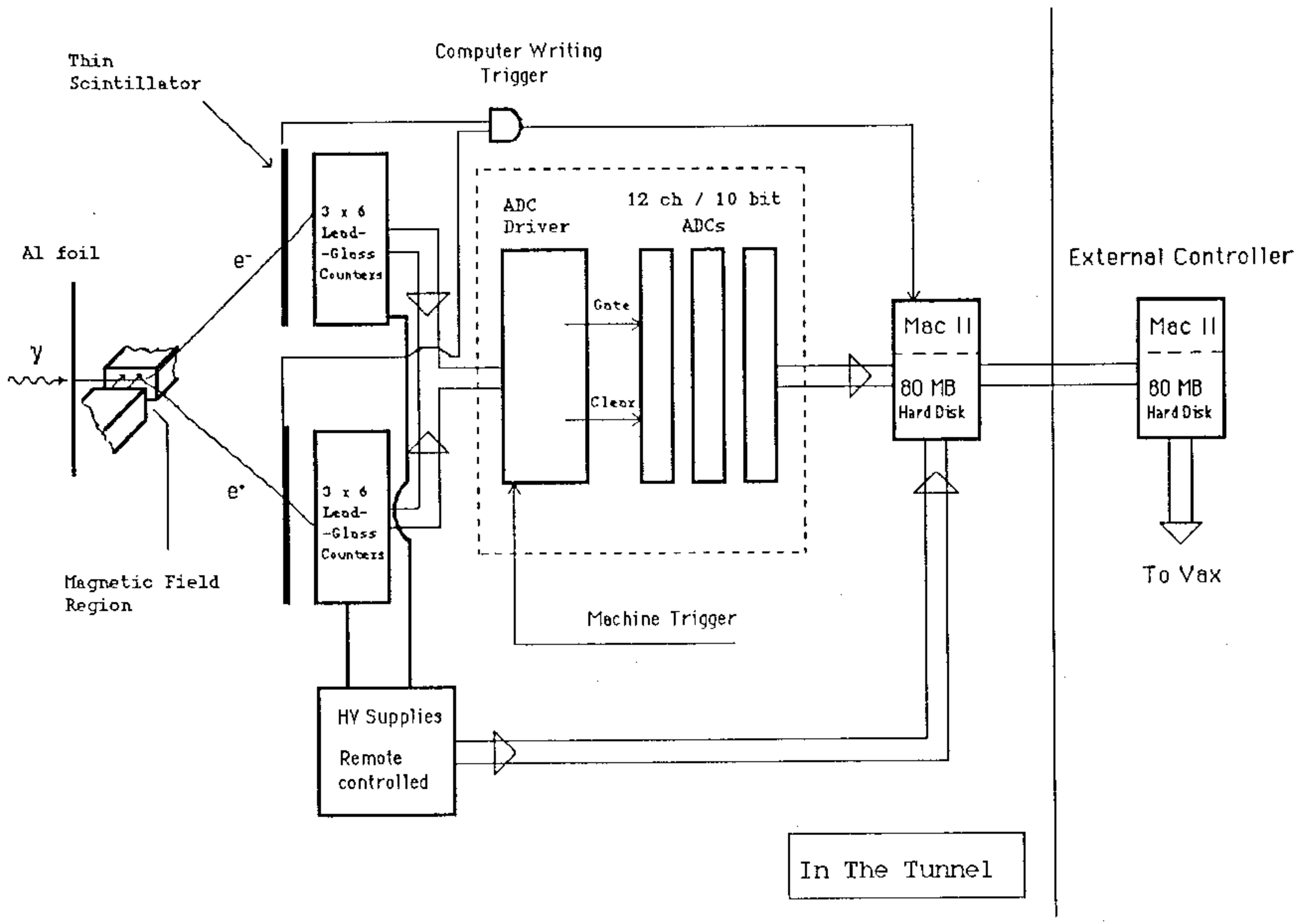
Thin
Scintillator
Computer Writing
Trigger
Al foil
γ
e-
e+
3 x 6
Lead-
-Glass
Counters
3 x 6
Lead-
-Glass
Counters
Magnetic Field
Region
ADC
Driver
12 ch / 10 bit
ADCs
Gate
Clear
Machine Trigger
HV Supplies
Remote
controlled
Mac II
80 MB
Hard Disk
External Controller
Mac II
80 MB
Hard Disk
To Vax
In The Tunnel

Fig. 7