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A Proposal to Conduct a Quark Search at the Fermilab Collider

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Summary

We propose an experiment designed to search for free quarks produced in the interaction of colliding 1 TeV X 1 TeV protons with antiprotons at the D0 intersection of the Fermilab Collider. Assuming a canonical integrated luminosity of 10^{36} (e.g. 12 days running with a luminosity of 10^{30}), we expect to detect quarks if the production cross section is as large as $1.2 \cdot 10^{-35}$ cm^2. We would detect one quark in about 10^{10} regular charged particles emitted near 90° and we would detect a leakage from containment of $\approx 10^{-3}$ of color-neutral quark-antiquark pairs produced with an invariant mass of 100 GeV.

We plan to use a 2π detector, divided into 24 independent sectors, with all of the active elements scintillation counters. Quarks would be distinguished from other charged particles through their anomalously low energy loss in at least 8 scintillation counters which make up a sector. The detector, a variation of detectors used previously which have demonstrated a discrimination of quarks from singly charged particles near 10^{11}, is designed to have a discrimination of better than 10^{12} so that as few as three quarks should constitute a believable signal. The detector would be constructed so that set up and disassembly times in the D0 area would be only about one day. About 200 hours of beam time (or 8 days) would be required to complete set up and calibrations and about 500 hours (or 20 days) of data taking should be sufficient.

I Quark Production at the Fermilab Collider

1a) The Production of Quark-Antiquark Pairs

If the quark containment mechanism admits of small leaks, free quarks might be observed under certain conditions. Moreover, it is plausible that the leakage, if there is any leakage, will be very strongly energy dependent. In particular, we might expect that such leakage might be observed in measurements of quark-antiquark pairs produced with very large invariant masses. Such pairs, in general contained, will be produced at the Fermilab Collider with large cross sections which may be estimated intelligently. Knowing the production cross sections for massive quark pairs, measurements of the flux of free quarks defines a containment leakage ratio. A negative result will define a quantitative limit on the experimental measurement of containment for such high energy quark-antiquark pairs.

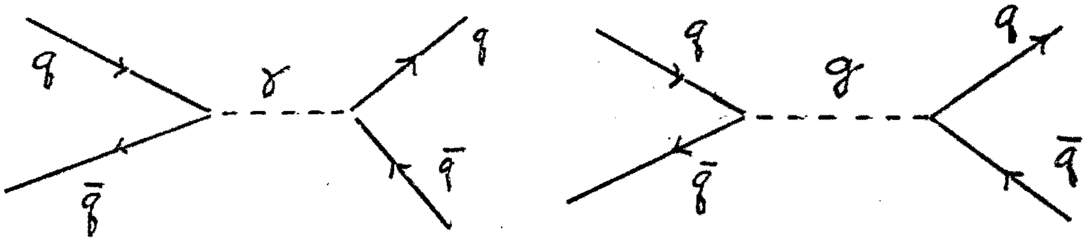


Fig. 1 a) Shows the Bethe-Heitler production of quark-antiquark pairs through the virtual photon produced in the course of annihilation of color and flavor neutral incident quark and antiquark. b) Shows the simililar production of pairs through an intermediate vector gluon.

To estimate the cross sections for the production of massive quark-antiquark pairs in nucleon-nucleon collisions, we first discuss the cross section for the production of quark-antiquark pairs through virtual photons produced in the collisions of the constituent quarks of the nucleons with the constituent anti-quarks of the antinucleons through a process such as that described by the diagram of Fig. 1a. We note that the anti-quark must match the quark in (anti-) flavor and color since the photon carries neither color nor flavor.

This cross section for the Bethe-Heitler production of pairs with an invariant mass M can be written as

$$\frac{d\sigma}{d\Omega} = \frac{\hbar^2}{4M^2c^2}\,\alpha^2(1 + \cos^2\theta)\cdot Q^2R \qquad (1)$$

$$\text{and} \quad \sigma = \frac{4\ \pi}{3}\,\frac{\hbar^2}{M^2c^2}\,\alpha^2Q^2R \qquad (2)$$

where Q is the charge of the incident quark, R is the usual ratio of hadron to lepton pair production in the parton model equal to 10/3 for the four light quarks and 5 for six flavors (we use 10/3 in these calculations considering then only the light quarks).

If we assume that intermediate gluons will act in a manner similar to that for intermediate photons, as shown by the diagram of Fig. 1b, we might expect a contribution from the strong interactions of the order of $(\alpha_s/\alpha)^2$ times the electromagnetic contribution where α_s is the effective quark-gluon coupling constant at the high energies and small distances relevant to the production of massive quark-antiquark pairs. We estimate the effective coupling using the relation,

$$\alpha_s \approx \frac{1}{(33-2f)/12\pi \ \ln(q^2/\Lambda^2)} \approx \frac{1}{(21/12\pi)\ \ln(M^2/m_\pi^2)} \qquad (3)$$

where $f=6$ is the number of quark flavors and Λ is a parameter taken from experiment. The form used here roughly fits the measured value of α_s of ≈ 0.5 at $M^2(\phi)$ and of ≈ 0.2 at $M^2(\Phi/J)$. With this formula, we estimate a coupling $\alpha_s \approx 0.13$ at $M = 100$ GeV and ≈ 0.11 at $M = 400$ GeV, ~~N~~noting that the coupling can be expected to decrease quite slowly with energy (i.e logarithmically). In our calculations, we use an estimate of the ratio of the strong and electromagnetic production, $(\alpha_s/\alpha)^2$ of 100.

We then estimate the cross section for the production of quark-antiquark pairs by the strong interaction of colliding quark and antiquark by the Bethe-Heitler formulae of Eq. 2 with α replaced by $\alpha_s \approx 10\alpha$ and taking $Q=1$ and $R=12$ (for the four flavors and and three colors of the light quarks).

Since the intermediate gluon can carry color (i.e. in non-Abelian QCD, the intermediate boson, the gluon, carries color-charge while in Abelian QED, the photon is electrically neutral), the quark and antiquark in Fig. 1b need not have matching color and anticolor. However, if the intermediate gluon is not neutral, the residual state of the proton plus antiproton minus quark and antiquark will not be color-neutral or a color singlet which may further restrict leakage. Hence, in our attempt to put the quark search on a semi-quantitative basis, we consider only pairs produced through color-neutral intermediate gluons on the basis that quark leakage through such transitions is likely to be dominant.

We know the energy and luminosity of the proton-antiproton system; we need the energy and luminosity of the quark-antiquark systems. Using the approximation, adequate for our purposes, that only the three constituent quarks (or anti-quarks) are relevant, for a proton-proton luminosity of L_p, the u-$\bar{u}$ luminosity is $4L_p$ and the d-$\bar{d}$ luminosity is L_p giving a total q-$\bar{q}$ luminosity of $5L_p$. This estimate is valid if we consider the production of quark-antiquark pairs through color-charged and color-neutral intermediate gluons. Accepting our restriction to color-neutral gluons, the effective fluxes are reduced by a factor of 9, hence, the effective color-neutral quark-antiquark luminosity is then 5/9 L.

Since each quark can be considered to be in motion with respect to the center-of-mass of the nucleon, in the laboratory system, the quark will carry different portions of the nucleon momentum at different times. At the time of collision, the momentum of a quark is then defined by a probability spectrum. Hence, the quark-antiquark total luminosity is spread about a spectrum of quark-antiquark center-of-mass energies, M. Moreover, the quarks carry only about one-half of the momentum (or energy) of the high energy proton -- the field (or gluons) carries the rest. Writing x as p_q/p_p, where p_q is the momentum of the quark (anti-quark) and p_p the proton (anti-proton) momentum, we take the momentum spectrum of any one quark as

$$\frac{dN}{dx} = 5\cdot(1 - x)^4 \qquad (4)$$

This description of the momentum spectrum of the quarks leads to a quark momentum distribution for the three quarks of the form

$$\frac{dp}{dx} = 3\cdot5\cdot x(1 - x)^4 \qquad (5)$$

where dp/dx is the fraction of the nucleon momentum carried by quarks with momenta x, per unit interval of x. Even as the integral of dN/dx = 1, for each quark, the integral of dp/dx (for three quarks) equals 0.5. The quantity dp/dx from this very simple model is compared with experimental determinations in Fig. 2. The fit is adequate for our estimates.

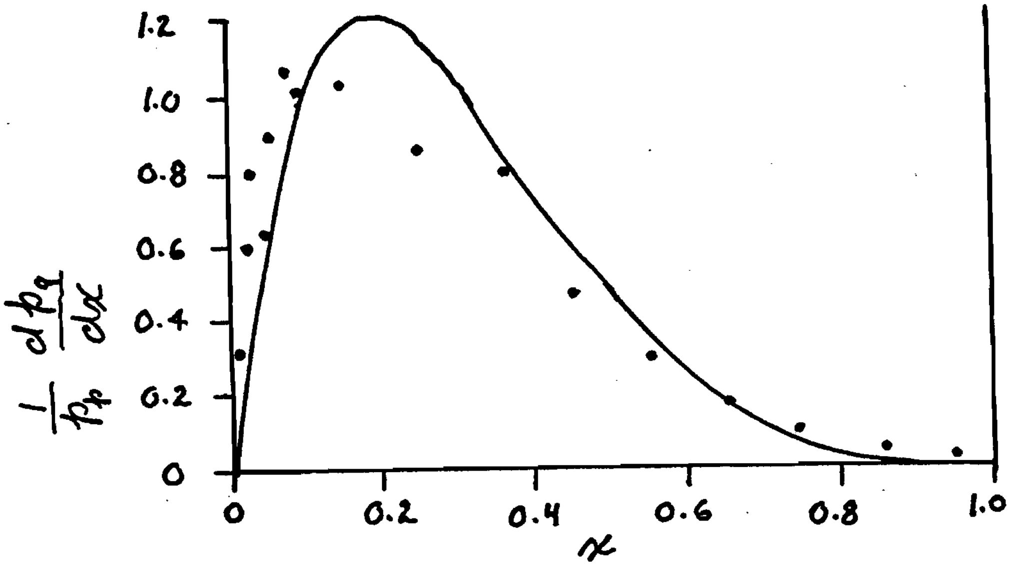


Fig. 2 The value of the fractional momentum contributed by quarks with a momentum of x, per unit interval of x, is plotted against x. The points show experimental results, the solid line the formula used here.

Knowing the momentum spectra of the colliding quarks and antiquarks and the quark-quark luminosity, it is easy to calculate dL/dM, the luminosity per unit of invariant mass. This calculation was conducted numerically using Monte Carlo techniques and the resultant differential luminosity is shown in Fig. 3 as a function of the proton-antiproton luminosity L_p where the quark-antiquark total luminosity is 5/9 L_p.

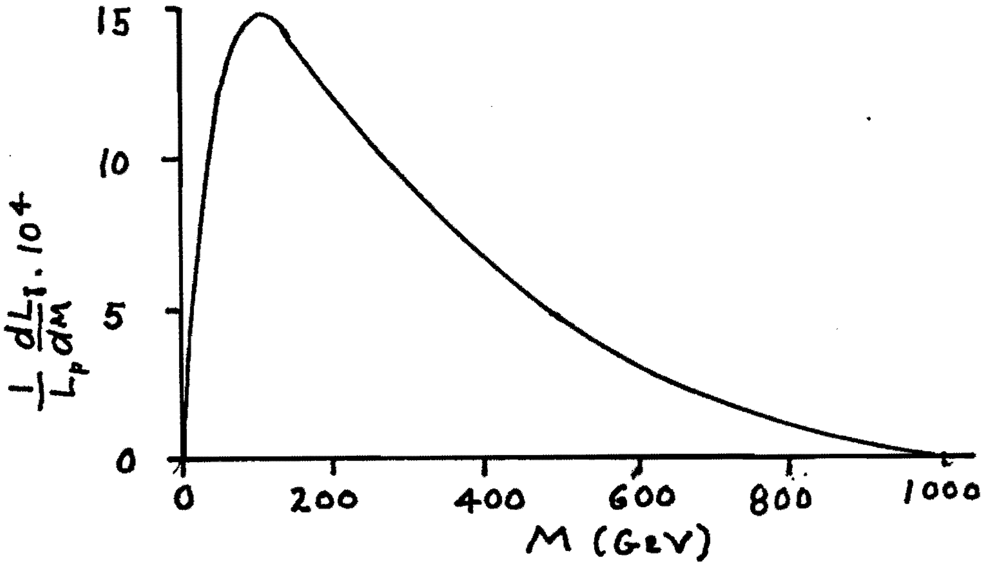


Fig. 3 The differential fractional luminosity of quark-antiquark pairs of invariant mass M. The quantity $(1/L_p)(dL_q/dM)$ is plotted against M measured in GeV.

Values of the modified Bethe-Heitler cross sections used as estimates of the strong interaction cross section, and the production rates in quark-pairs per second from a Fermilab Collider with a luminosity L_p of 10^{30} per second, are given in Table I.

Of course, in conventional views of containment, these quark pairs are manifest as hadron jets with no production of free quarks. Now with these numbers (or refined versions of these numbers) together with experimental results, one can determine the proportion (or a limit on that proportion) of the produced pairs which results in the "leakage" of free quarks. For example, a run of 300 hours at a canonical p-$\bar{p}$ luminosity, $L_p = 10^{30}$ cm^2 will produce 5000 color-neutral quark pairs with an invariant mass greater than 50 GeV and about 1000 pairs with invariant masses greater than 100 GeV. With a detection efficiency of 25% for free quarks, and assuming that 3 observed events constitutes a believable signal, the experiment is sensitive to a leakage of about 10^{-3} for invariant masses greater than 50 GeV and a leakage of $4\cdot10^{-3}$ for quark-antiquark pairs with invariant masses greater than 100 GeV. Quark-pairs with a retained total color charge will be produced with a frequency about nine times greater.

M(GeV)	$\frac{1}{L_p}\frac{dL_q}{dM}$	σ	$\frac{\sigma}{L_p}\frac{dL_q}{dM}$	$\int_M \frac{\sigma}{L_p}\frac{dL_q}{dM}\,dM$
25	$3.03\cdot10^{-4}$	$1.65\cdot10^{-31}$	$4.95\cdot10^{-35}$	$7.0\cdot10^{-33}$
50	$12.0\cdot10^{-4}$	$4.12\cdot10^{-32}$	$4.94\cdot10^{-35}$	$4.8\cdot10^{-33}$
100	$14.5\cdot10^{-4}$	$1.03\cdot10^{-32}$	$1.49\cdot10^{-35}$	$1.1\cdot10^{-33}$
150	$13.3\cdot10^{-4}$	$4.58\cdot10^{-33}$	$6.10\cdot10^{-36}$	$4.9\cdot10^{-34}$
200	$12.0\cdot10^{-4}$	$2.58\cdot10^{-33}$	$3.12\cdot10^{-36}$	$2.7\cdot10^{-34}$
300	$9.05\cdot10^{-4}$	$1.45\cdot10^{-33}$	$1.33\cdot10^{-34}$	$1.3\cdot10^{-34}$
500	$4.51\cdot10^{-4}$	$4.12\cdot10^{-34}$	$1.85\cdot10^{-37}$	$2.3\cdot10^{-35}$
700	$2.09\cdot10^{-4}$	$2.10\cdot10^{-34}$	$4.41\cdot10^{-38}$	$3.5\cdot10^{-36}$
900	$0.31\cdot10^{-4}$	$1.2\cdot10^{-34}$	$3.94\cdot10^{-39}$	

Table I Cross sections and fluxes for the production of massive quark-antiquark pairs in 1000 GeV X 1000GeV proton-antiproton collisions. The numbers in the last two columns can be multiplied by L_p, the proton-antiproton luminosity to determine the flux in pairs per second.

1b) Quark-Meson Correlations

It is assumed, implicitly, in the design of the experiment that free quarks will not be accompanied by another charged particle in their passage through a sector of the detector. If the quark charge were 1/3, the pulse height resulting from the passage of the quark and an accompanying singly charged particle through each scintillator making up the detector sector would be about 1.11 times the pulse height from a lone singly charged particle. If the quark charge were 2/3, the resultant normalized pulse height would be 1.44 for the two particles. It would probably be impossible to detect the existence of a charge 1/3 quark in the presence of a singly charged particle, exhibiting so small a pulse height anomaly, using the detector we propose and it would be difficult to identify rare quarks with a charge of 2/3 if they were accompanied by a singly charged particle.

Without a model of quark production, it is not possible to estimate the probability of another particle accompanying a quark. Since the individual sectors cover only 2% of the total solid angle, and that near 90°, we feel that we can neglect interference from the meson spray we can expect from the residual final state interactions after the production of a massive quark-antiquark pair. However, we must be more concerned over mesons which may be produced in the course of the stretching and breaking of the gluon field lines of force which define the confinement bond. Mesons produced in that way from the pair can be expected to travel in the direction of the escaping free quarks. In this view, we might expect that the quark would be a kind of leading particle of a meson jet. We consider this description qualitatively to gain some insight into the limitations imposed on the acceptances of the detector with finite segmentation in the face of such possible quark-meson production correlations.

The physics of jets is not now completely understood, but certain elements of the character of jets have emerged which have experimental and theoretical bases. We then consider that jets can be described as a set of particles emitted along a jet axis such that they are distributed on the average evenly in momentum space such that the mean gap between particles is one unit of rapidity. The particles will also have a distribution of transverse momenta relative to the jet axis such that the mean transverse momentum will be of the order of 0.5 GeV.

With this model, the magnitude of the quark-meson detection interference caused by meson-quark direction correlations depends strongly on the magnitude of the quark rapidity (and hence the mass of the free quark) and the quark-meson rapidity gap. We present a numerical model to better delineate the character of the problem. A 25 GeV quark with a mass equal to a spectroscopic light quark mass of 0.35 GeV will have a rapidity of of about 5. A pion with a rapidity of 4 will have an energy of about 3.7 GeV and will be produced at a mean angle with respect to the quark of about 0.15 radians. Since a sector subtends a least angle at the point of interaction of about 0.5 radians, we might expect that only a small fraction of the quarks would pass through the detector unaccompanied. If the rapidity gap were two units and the "next" pion had a rapidity of 3, the pion energy would be only about 1.4 GeV and travel at a mean angle of about 0.35 radians with respect to the quark. A much higher portion of such pions would miss the sector traversed by the quark. If the quark were heavier, the pion angles would be greater and, of course, if the quark-meson rapidity gaps were large, the pion angles would be greater.

We know little of the masses of free quarks (which need not be anything like the very small current algebra masses of the u- and d-quarks but might be nearly equal to or larger than the spectroscopic masses of the order of 350 MeV for these light quarks) nor can we have much insight into rapidity gaps between free quarks and mesons. However, the presumption which motivates this proposal to search for quarks at the Collider, is that quarks may be produced at very high energies much more freely than at lower energies. Since the quark only "sees" the rapidity gap between it and what mesons may be produced in the breaking of the gluon force lines, we suggest that any anomalous leakage in very high energy reactions will manifest itself in very large rapidity gaps between the free quarks and any accompanying particles. We then expect that accompanying mesons will be rare and slow and their mean transverse momentum with respect to the quark direction of the order of 0.5 GeV will usually carry them into a different detector sector than that which accepts the quark.

II Experimental Design and Procedures

2a) Detector Design

The diagram of Fig. 4 presents a schematic view of the basic assembly of the detector. The fundamental concept is similar to that which our group has used in a program of quark searches which has been conducted over the past 20 years. The quarks are to be identified by their characteristically small energy loss in passing through at least 8 of the 10 scintillation counters which make up each of the 24 scintillation counter sections; a charge e/3 quark (p/mc > 1.5) will lose 1/9 as much energy as a minimum singly charged particle and a charge 2/3 particle will lose 4/9 as much energy. We note that in the model of quark production we have discussed, we would expect that half of the quarks we might see would have a charge of 1/3 and half a charge of 2/3.

We also show, in the diagrams of Fig. 5 and Fig. 6, details of one of the 24 sections. The individual scintillation counters will be 1/2" thick from 6" to 8.5" wide, and 12" long. The 10 pieces of scintillator are arranged in sets of two in a package 2" thick as shown, where each scintillator is is viewed by a phototube through an air light pipe. The cross sectional dimensions of the scintillator are chosen to match the photocathode area of a 2" tube so as to maximize the collection of photoelectrons. With a reflector at the far end of the 12" long scintillator, the efficiency of a test counter was found to be constant to better than 10% over the scintillator area. With this design, maximizing light collection, we expect to receive 15 photoelectrons initiated by the passage of an e/3 quark -- and 60 for a 2e/3 quark.

Since the pulse height will vary as cosine of the angle between the track and the normal to the counter plane, and since the longitudinal position of the origin of an event is not well determined by the design of the crossing beams, it is necessary to make some measure of the angle of the particle trajectory. We do this by using two counters, each extending over 2/3 of the length of the section as shown in the diagram of Fig. 5, to define the entering position and exiting position of a particle of

Fig. 4 A schematic view of the detector assembly.

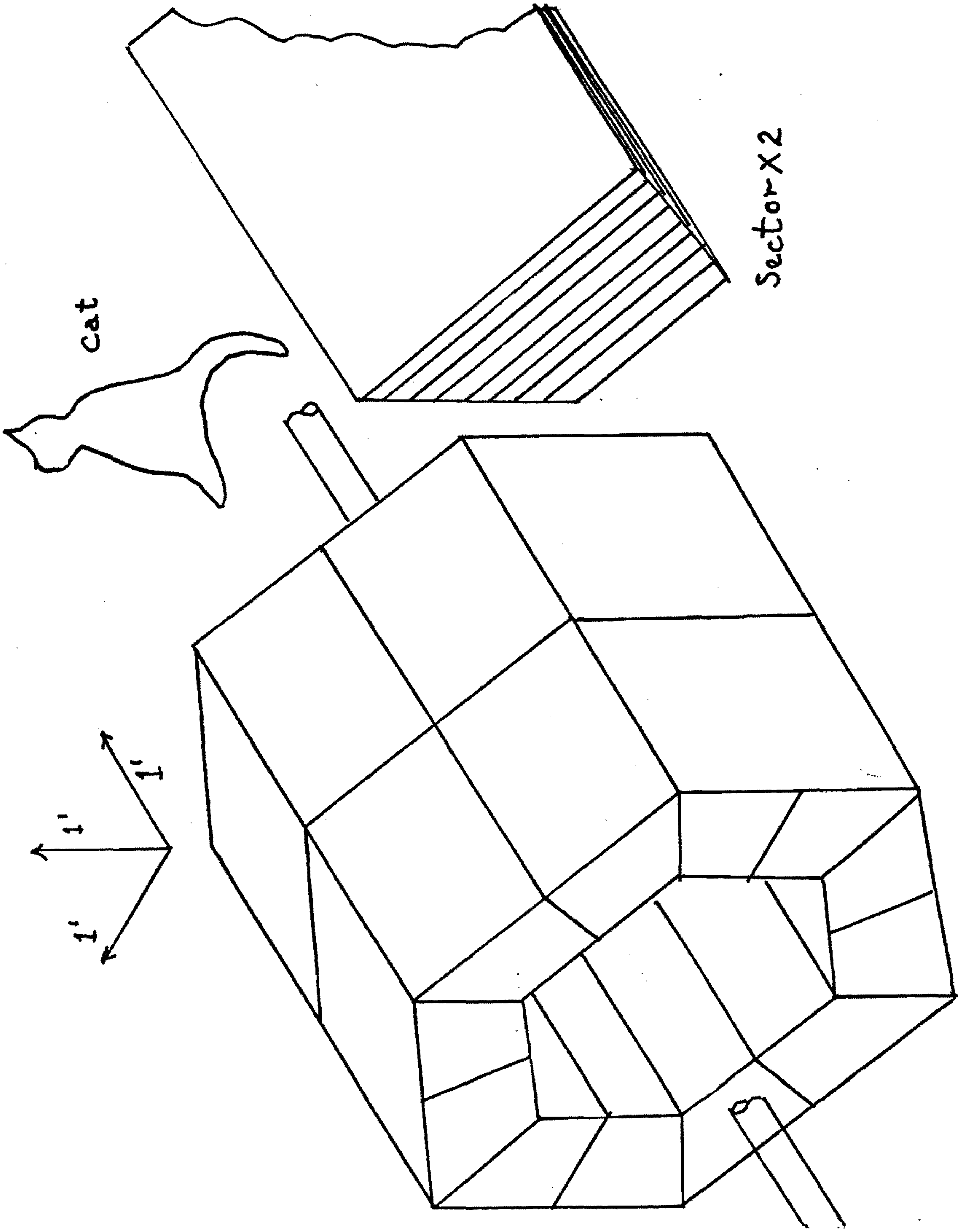


Fig. 5 A cross sectional view of one of the 24 sectors of the detector in a plane containing the beam line.

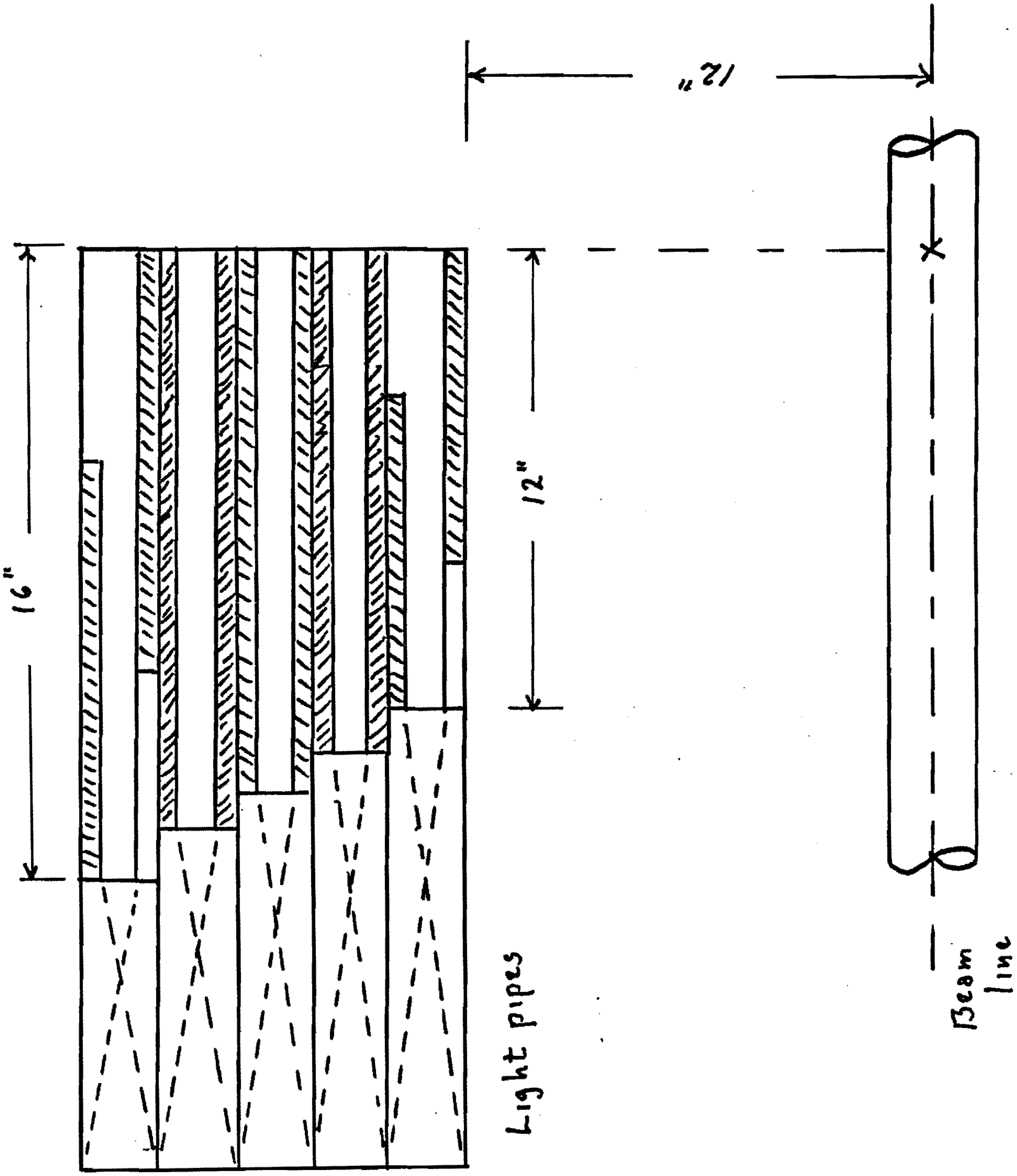


Fig. 6 A cross sectional view of a sector of the detector in a plane normal to the beam line.

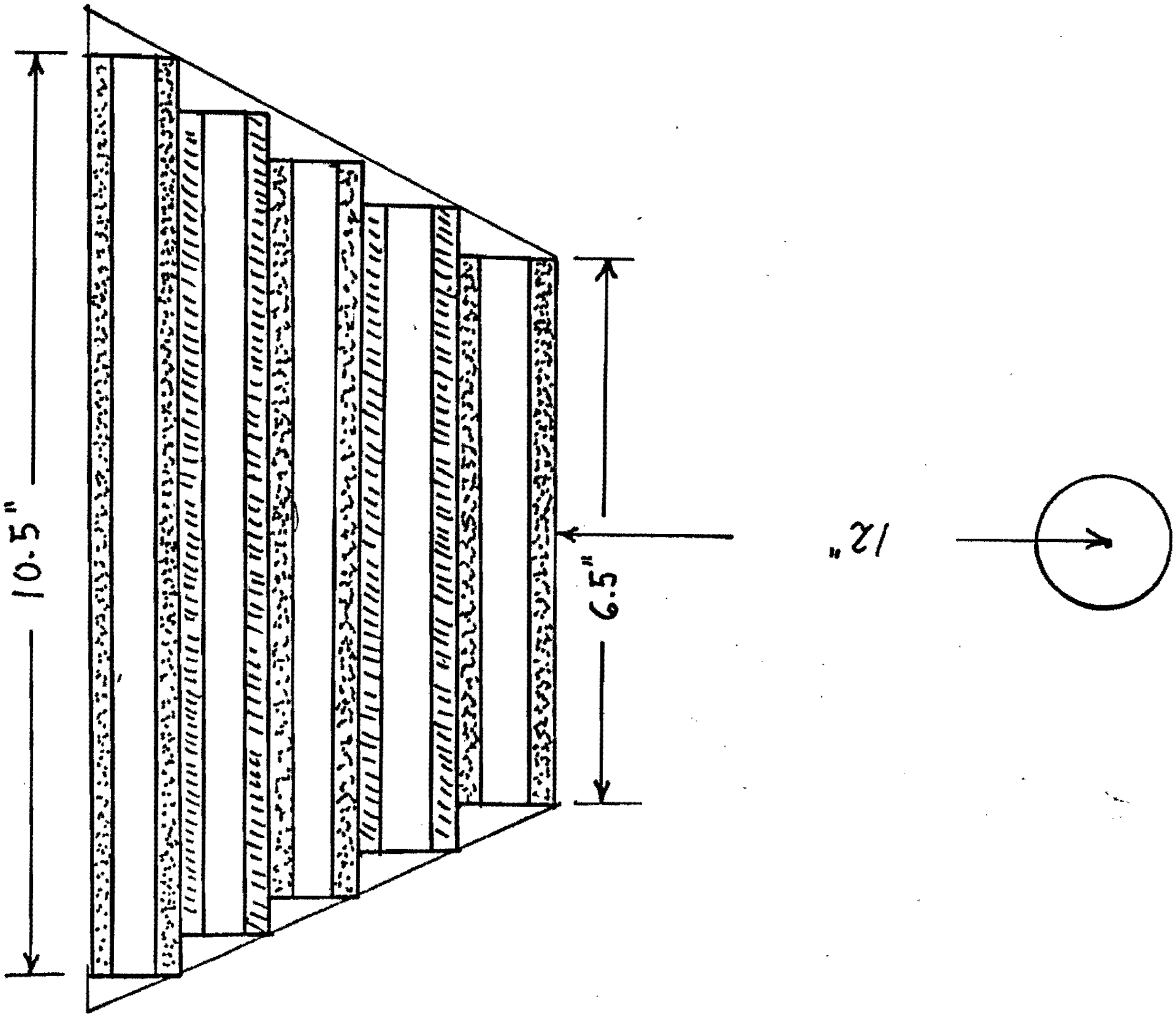
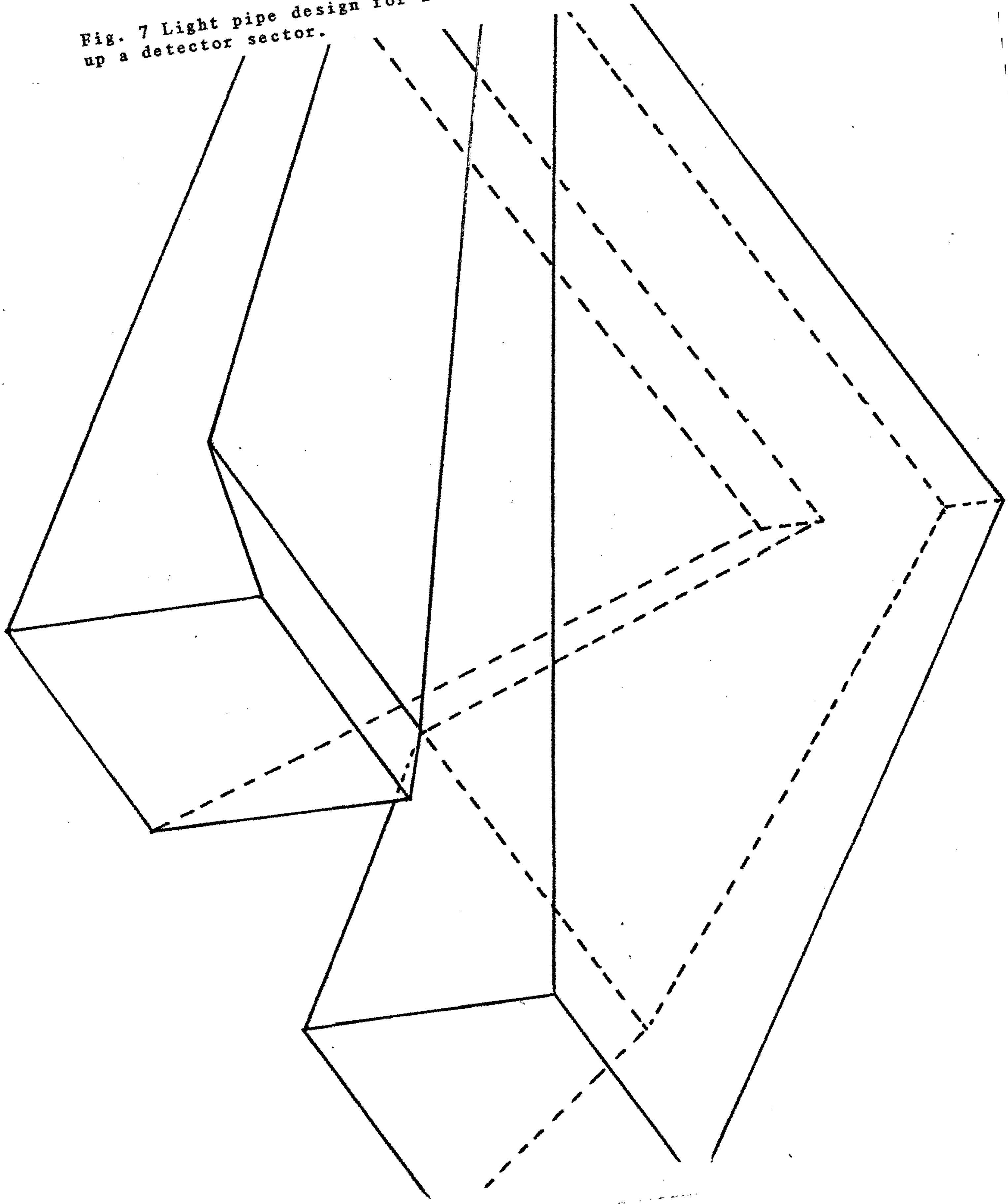


Fig. 7 Light pipe design for a two-scintillator package making up a detector sector.



interest within an uncertainty of ±2" or the angle of passage to an uncertainty of ±15°.

In order to be recorded, the quark must pass through btween 4" and 5" of scintillator depending upon the trajectory and the beam pipe. With packaging material, this will amount to less than 15 gm/cm^2. Hence, we implicitly assume that the quark mean-free-path in matter is not small compaired to that thickness. If the quark engages in any strong interaction with nucleons, a pulse height different than from a free quark will be produced eliminating that quark as a candidate.

With 240 separate counters packed into a small volume, careful packaging is important. The diagram of Fig. 7 shows the design of the light pipe for the two scintillators which make up a unit 2" thick. With the assembly of the 5 different units of two phototubes into a sector as defined by the diagrams, the acceptance of the whole set of counters is about 45% of the sphere or almost 2π steradians.

It is important to achieve high resolution in the pulse height determination inasmuch as the discrimination against backgrounds depends strongly on that resolution. Real events deposit very much the same energy in each scintillator, while the most serious backgrounds result from the chance juxtaposition in time and energy loss of small uncorrelated energy losses in each of the eight counters rom soft photon or slow neutron backgrounds.

With a luminosity of 10^{30} and a cross section of ≈ 70 mb, there will be about $7 \cdot 10^4$ interactions per second in the interaction region. The charged particle multiplicity will be of the order of 30 and the total hadron multiplicity will be about 50% larger giving a hadron production of the order of $3 \cdot 10^6$ particles per second. Since we are searching for quark pairs with large invariant masses, produced in their own center-of-mass system with an angular distribution described adequately by the relation $d\sigma/d\Omega \approx 1-\cos^2\theta$ where θ is the angle between the quark emission direction and the beam direction, such quarks will often be produced at large angles. From our Monte Carlo calculations, we found that for about 2/3 of the quark pairs produced with invariant masses greater than 25 GeV, the momentum of the pair, in the laboratory system, was less than their invariant mass; the pairs tend to be produced with small momenta in the laboratory system.

Our detector will cover about 2π sr from $\cos\theta = 0.5$ to $\cos\theta = -0.5$. Since we expect that the quark production will not be restricted nearly so strongly to small transverse momenta as hadron production in general, we estimate that the detector, centered at 90°, will accept about 25% of the quarks produced but less than 5% of other hadrons. Hence, in the angular interval covered by the detector, the hadron flux should not be large. [We note that the scaling of the inclusive invariant cross section $E\, d^3\sigma/dp^3$ suggests to us that there may be no more particles produced in this angular interval at Fermilab Collider energies than at lower energies.] Indeed, we estimate that only about two charged particles per interaction will pass through the counters giving a total rate of about $1.5 \cdot 10^5$ particles per second.

Even that moderate flux rate is operationally reduced further by the segmentation of the detector: our detector is to be made up of 24 essentially independent elements where the average rate in each will be hardly more than 6000 counts per second. The time structure of the beam will produce much higher instantaneous rates but these rates will still be very comfortably lower than the cpacity of the electronics. In 300 hours, a total of about $1.5 \cdot 11^{10}$ particles will pass through the whole detector -- or about $6 \cdot 10^{9}$ particles through each segment. Hence, if one quark is to be detected, the discrimination must be of the order of one in 10^{12}. In previous experiments we have demonstrated a discrimination near one in 10^{11} -- without reaching a discrimination limit. Since the background pulses in each counter which simulate the small energy loss of a quark are not correlated in energy and largely uncorrelated in time, the discrimination index is a nearly exponential function of the number and energy resolution of detector units and the design presented here, an extrapolation of previous designs, is meant to achieve a discrimination which is better than 10^{12}.

2b) Electronic Data Handling

The experiment will select events of interest through a hierarchy of acceptance criteria. Initially, events will be selected such that each of the eight elements of any one sector generates a pulse greater than 0.03 times minimum and less than 0.7 times minimum. This selection would be made through standard discriminator logic in no more than 10 nsec. Each such trigger, would initiate 6 bit A to D converters acting on each element of that sector (and, perhaps, other sectors) to record the pulse heights with a resolution of about 0.015 times minimum. We might use flash A to D detectors but most likely, simple sample and hold circuits transfering the information to slower A to D units will be a better choice. In either case, the time resolution of the measurement will be less than or of the order of 25 nsec. This information (i.e. 8 six-bit numbers) will be transfered to an on-line computer for further processing. However, if the trigger rate is too high, preprocessing in hard-wired logic can be accomplished within the framework of our FASTBUS data handling system to reduce the load on the computer.

At the on-line computer level, more sophisticated algorithms will then select as quark candidates only those events such that the normalized energy losses in each element of the triggered sector are about equal. Although, the raw data concerning each event transferred to the computer will be stored on magnetic tape, the experiment is envisioned as, essentially, an on-line experiment. With final results available immediately, subtle as well as egregious errors may be corrected in a timely manner as the experiment proceeds.

2c) Acceptance Criteria and Calibration Measures

Since real quarks are to be differentiated from backgrounds by the equality of the normalized pulses in each counter, it is important to establish the criteria for equality in a satisfactory manner. Too loose a criteria will admit excessive backgrounds, too selective a measure may throw out real events. We set the criteria by generating "fake" quark events regularly by measuring artificially produced "quarks" generated by charge one particles passing through the scintillators where masks in front of the phototubes pass 1/9 or 4/9 of the scintillator light. Such a simulation is nearly exact, fitting the Landau dispersion as well as the mean pulse height. The masks are to be put in at intervals throughout the experiment and the relevant parameters will be adjusted so as to accept the (pseudo) quarks with high efficiency and discrimination against backgrounds.

Our criteria for an interesting event will be set by the determination of an anomalous average charge q' for events such that the quantity X is less than some value X_0 where,

$$X = \sum_i (q_i - q')^2 / D_i^2(q_i), \quad i = 1,8 \tag{6}$$

where q_i is the pulse height in counter i, normalized so that a singly charged particle has a pulse height of one, q' is the average of the q_i, $D_i(q')$ is a measure of the resolution of the counter i for pulses with an amplitude q'. The factor X_0 is to be chosen so as to let a large portion (typically 90%) of real particles with a charge q'.

From an analysis of the sources of pulse height dispersion which should be important in this design together with our experience in similar measurements, we estimate that we should have a high efficiency for the detection of quarks and good rejection of backgrounds with settings of $D_i(q') \approx 0.1 \cdot \sqrt{q'}$ and $X_0 \approx 10$. Clearly Eq. 6 and the recipe for the recognition of an acceptable fit depend upon adequate determinations of the normalizations, the values of the functions $D_i(q')$, and the appropriate value of X_0. We set these criteria by measuring artificially produced quarks generated by charge-one particles passing through the scintillators where masks in front of the phototubes pass 1/9 or 4/9 of the scintillator light. The masks are to be put on at intervals throughout the experiment, through remotely triggered mechanisms, and the relevant parameters will be adjusted so as to accept the (pseudo) quarks with high efficiency.

In our previous experiments at accelerators and in using cosmic rays as a possible quark source, it was possible to change the masks manually without an excessive interuption of the experimental operation. We do not expect to have such access in the D0 region of the Collider and have designed mechanisms to allow remote changes of masks.

III Time Requests and Equipment Costs

Our considerable experience with this kind of experiment suggests to us that neither the installation of the equipment in the beam line nor the subsequent calibration and set up procedures will be difficult or time consuming. The apparatus will be constructed to that it can be assembled about the beam in a time of the order of one day. Disassembly and removal should be not take more than a few hours.

We would ask for about one chronological week with the beam running to check out operation, perform calibrations, and to make minor changes and repairs. Three weeks of running should be adequate for the measurements. As is the case for any such search experiment, it does not make sense to be preoccupied with limits; if the quarks are not found in three weeks, little will be gained by running for six weeks more. If time is available, short searches for charge 4/3 particles (giving 16/9 minimum pulse height) and pulse heights of 1.44 (representing a charge 2/3 quark and an accompanying particle, would be interesting. A week devoted to such studies -- including two days of set up -- should be sufficient.

The apparatus consists, basically, of 240 scintillation counters with each counter served by an A to D circuit and associated electronics. An accurate accounting of costs would result in a total of about $500,000 for the whole apparatus. Although we would plan to supply much of the apparatus from our own resources, we would ask Fermilab to provide phototubes and basic electronics, power supplies, a PDP-11/44 on-line computer, etc. All to be returned after the experiment. In short, we would ask Fermilab for the "loan" of about $50,000 worth of phototubes and about $200,000 worth of electronics and a small on-line computer.