Fermilab Proposal 702

A Search for Particles with Anomalous Values of $^M/_q$ and Extremly Short Interaction Lengths

(A revision of P-607)

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ABSTRACT

A quark search based on the hypothesis that quarks interact very strongly with conventional matter is proposed at the CØ internal target area. The high luminosity ($\gtrsim 10^{30}$ cm^{-2}) combined with a low areal density target ($\lesssim .005$ gm/cm^2) which is only possible with an internal target provides a unique arrangement to search for such particles. A spectrometer will be used to measure charge X momentum which when combined with a time-of-flight measurement yields a value of the mass to charge ratio. This ratio in conjunction with a low resolution energy measurement will uniquely single out the presence of anomalous particles which may very well be quarks.

Objectives:

As the community at large is well aware[1] quarks have yet to be found as isolated energetic particles. It is the purpose of this proposed experiment to find such particles which may have eluded investigators until now because these entities allegedly interact with such strength that they normally would not exit the target from whence they were created. Here we describe an arrangement which has sufficient luminosity to probe for very small production cross sections ($\sim 10^{-32}$ cm^2) while at the same time has an unusually vacuous transit region preceding the particle detection apparatus. The total area density prior to the detectors will be kept below .005 gm/cm^2. The detectors will be thin solid-state Si strips, a technology which is presently coming of age and is potentially capable of spatial resolution equal to about 100 μ. A momentum spectrometer having such a detector will, in conjunction with time-of-flight measurements, be capable of a high resolution $\left(\frac{M}{q}\right)^2$ search. The parameters of the setup will be ideally suited for the detection of a particle with charge ± 1/3 e and mass in the region .5 to .55 GeV/c^2 ($\left(\frac{M}{q}\right)^2$ between 2.25 and 2.72).* A mass equal to $\sim$ 540 MeV/c^2 has been suggested for the strange quark and antiquark. Nuclides such as $^7B_4$ also are in this range. However, the kinetic energy of these nuclides in the momentum region to be explored will be at least a factor of five more than the entity having mass $\sim$ 500 MeV and ± 1/3 e charge. A crude energy measurement will enable the $\left(\frac{M}{q}\right)^2$ search to seek out anomalous type particles over the $\left(\frac{M}{q}\right)^2$ range 1.5 to 3 with relatively small background from conventional particles and nuclides.

Particles which interact with unusually large cross sections have been reported in cosmic ray studies[2] and recently in heavy ion collisions.[3] It will be an easy matter in the proposed setup to establish their existence should they

* Units for $\left({}^{M}/_{q}\right)^2$ are $GeV/(c^2e)$.

be produced at a reasonable rate. Since the region between target and detector will be a vacuum, the insertion of thin foils of various thicknesses will demonstrate the existence of such strongly interacting objects.

A comprehensive review of quark searches up to 1977[4] indicates the lack of success of such endeavors. Of about eighty such experiments, only three have made any claim toward the detection of fractionally charged particles, and of these three only one[5] seems to have followed up with continued success. Even if quarks should exist in stable matter as is presently claimed[5] it has yet to be demonstrated that isolated energetic quarks can be produced. Should quarks somehow become isolated despite confinement restrictions, they are still most likely going to hadronize and lose their kinetic energy to conventional particles. Therefore, it is more likely that stationary quarks be found than energetic ones, which can hadronize and lose their energy to pions. However, in the present experiment the quark kinetic energy will at times be below pion production threshold (140 MeV for an infinite mass target). Hence, if quarks are to be found in stable matter, they should be detected at low enough energies provided care is taken to avoid interactions with matter once they are produced.

<u>Experimental Procedure</u>

The technique underlying this experiment has been presented in the original proposal and spelled out in greater detail in an addendum (9/78) both of which are attached in the appendix. Several modifications and additions are presented here.

The Cϕ internal target area will still be available, it is assumed, in the near and distant future. As has already been mentioned (appendix) the spectrometer in this area would be used to momentum analyze particles scattered ($\sim 33.5^{\circ}$) from an internal target. Originally this target was to be a gas jet, but it is felt that a rotating Be wire filament target would be adequate. Both the gas jet and the wire filament approaches have been used with success.[6] Each has its advantages. The gas jet of hydrogen provides a target free of nuclides except perhaps $^{2}H_{1}$ (deuterium), but a 20 μ Be filament has about ten times the luminosity of a gas jet and is considerably easier to maintain. To eliminate the backgrounds created by nuclides produced in Be, a minimum energy measurement has been added to the proposed momentum and time-of-flight measurements. This energy measurement will also extend significantly the $\left(\frac{M}{q}\right)^2$ range of sensitivity to anomalous particle production. It can easily be done with detectors outside the vacuum chamber of the spectrometer, where in fact, the possibility of quark-like particles to appear is highly unlikely if they interact very strongly. A scintillator, absorber wire chamber arrangement similar to that shown in Fig. II.2 of the P607 addendum is envisioned and shown in Fig. III.1.

The high charge and large mass of the nuclides guarantee very large values of dE/dx (∿ 60 to 100 MeV/gm) and make it very easy to see these particles in both scintillators and wire chambers. In Table III.1 we show the kinetic energies and β for the particles and nuclides of interest for three different spectrometer momentum values 1, 2 and 2.5 GeV/c. One sees that nuclides having $\left(\frac{M}{q}\right)^2$ values near 2.5 all have energy greater than 500 MeV and, therefore, should penetrate at least 5 gm/cm^2 and give rather large pulse heights in all the scintillators and PWC's traversed. In contrast, the s type quarks which have considerably smaller energy at each spectrometer momentum setting will have little or no chance of depositing energy in the back end of the detector array. Should the presumed strongly interacting quark not stop in the Si detector, it would convert most of its energy to a low energy pion and low energy nucleons in the thin scintillator. As a result, the thin scintillator would exhibit a large pulse while the subsequent 1/2" thick scintillator would have a considerably smaller pulse. It is events like these which would be candidates for anomalous particles. Of course, a negative particle search avoids any problem with nuclides, and half our time will be devoted to negative particles. The important point is that heavy nuclides are easily eliminated since they are so much more energetic than the quarks. The use of a 100 μ resolution silicon strip detector improves the $\left(\frac{M}{q}\right)^2$ resolution but the main purpose for this type of detector here is to avoid the possibility of very large dE/dx effects in scintillators which cause loss of light production and could inhibit detection of these supposedly very strongly interacting particles. However, the time-of-flight measurement will require that the 1/8" scintillator register unless the timing resolution of the strip detector can be improved to the 1 nsec level.

The time-of-flight measurement will use the RF structure (buckets) with a signal from the machine to mark time module 18.8 nsec. The 1/8" scintillator pulse should provide better than 1 nsec timing resolution and provided events are restricted to that portion of the ramp ($\lesssim$ 60 GeV) where the bucket width remains narrower than a nanosecond, we should have the resolution in $\left(\frac{M}{q}\right)^2$ given in Table II.1 of the addendum. Another illustration of this resolution is shown in Fig. III.2 which is a spectrometer momentum versus T_{rf} (time-of-flight with respect to RF) plot for several particles and values of $\left(\frac{M}{q}\right)^2$ as well as for the s type quark.

It can be ascertained from Fig. III.2 and Table III.1 that provided a crude energy measurement is made, there is good separation between an s type quark and any conventional particle or long-lived nuclide. The energy discrimination for particles having $\left(\frac{M}{q}\right)^2 \approx 2.63$ needs to have a rejection ratio of ~100 to 1 to be equivalent to that obtained by the $\left(\frac{M}{q}\right)^2$ separation between the s quark and $^2H_1$ (deuterium) since their separation is ~3 standard deviations in Fig. III.2.

Rates

The signal rate estimated in the addendum should be modified by two factors: 1) the use of wire filament target, and 2) the number of circulations per ramp for which bucket width is less than 1 nanosecond. These factors are respectively 10 and 0.44, or a net factor of 4.4, which would result in ~500 s type quarks per day given the assumptions of the P607 addendum.

The background with a filament target will be higher than that with the gas jet, but because most of this increase in background will be light nuclides, energy discrimination should neutralize the effect on this measurement. Clearly better timing resolution will improve the $\left(\frac{M}{q}\right)^2$ resolution which will in turn decrease background effects, and much effort is called for in this direction. The possibilities for better timing resolution using time pick off techniques in the Si strip detector exist provided the rates in these detectors can be kept in the kilohertz region. However, whether 1 nsec resolution in this particular configuration can be attained has yet to be established. Investigation along these lines is presently underway.

Running Time and other Requests

Here the requests are the same as in the addendum, and the earliest we could start on this experiment would be in the Fall of 1981, although we prefer to have until the Spring of 1982. In the meantime, we are collaborating in the analysis of E-629 and the tentative preparations for P695 and P645. Two of us, D. A. Garelick and M. J. Glaubman, will be able to participate full time for six months starting March 1982, since we will be free of our teaching obligations.

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   B. Judek, Proc. XIV Int. Cosmic Ray Conf. 7 2349 (1975).
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Table III.1

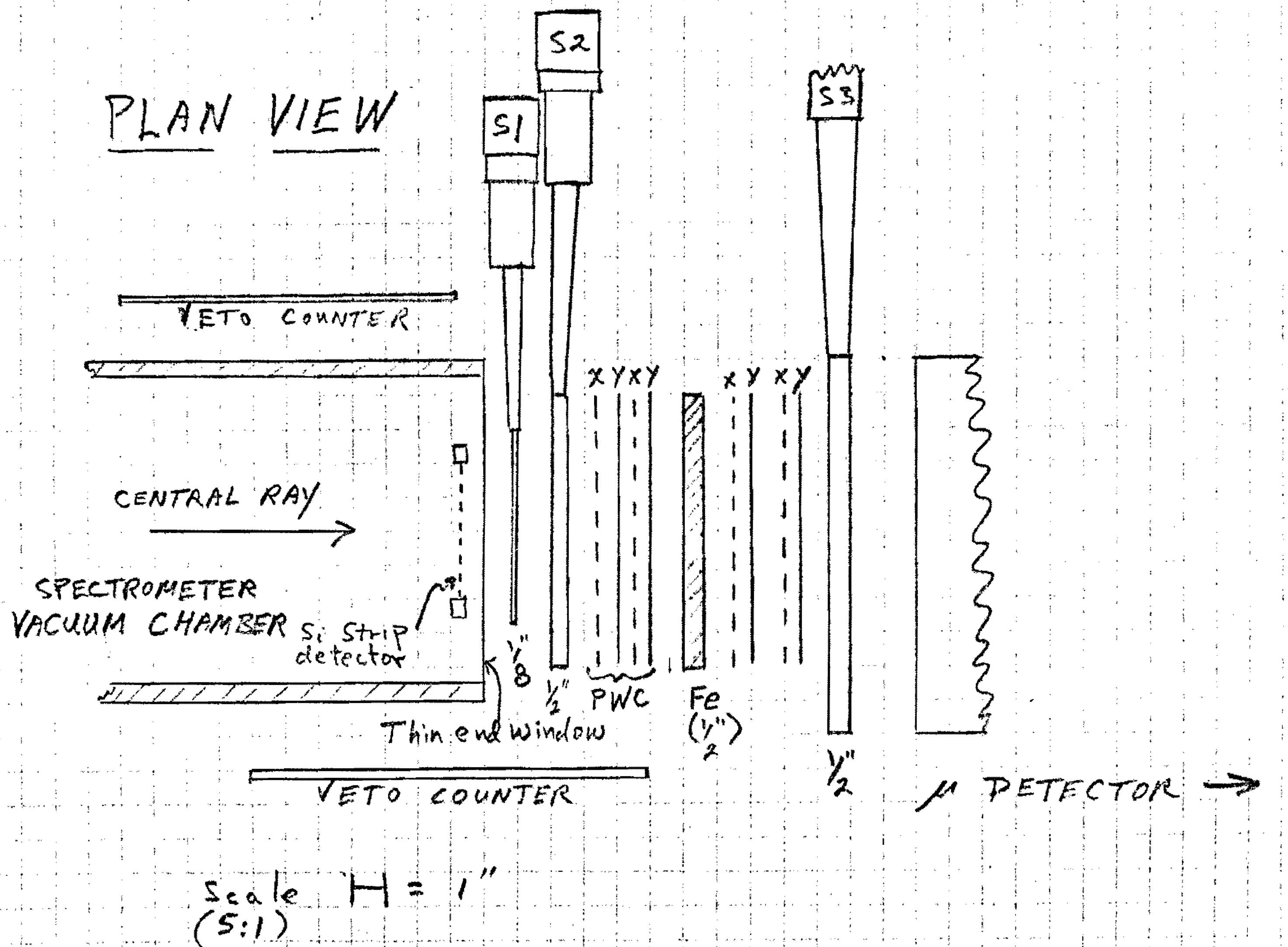
Particle	charge (e)	mass* (GeV/c^2)	τ	$(M/q)^2$ (GeV/$c^2 e$)	$P_1 = 1$ GeV/c T (GeV)	β	$P_1 = 2$ GeV/c T (GeV)	β	$P_1 = 2.5$ GeV/c T (GeV)	β
u quark	2/3	.336?	?	.254	.41	.89	1.04	.97	1.36	.98
d "	1/3	.336?	?	1.016	.14	.70	.41	.89	.56	.56
s "	1/3	.540?	?	2.63	.09	.53	.32	.78	.45	.84
c "	2/3	1.50?	?	5.07	.14	.41	.51	.66	.74	.74
π	1	.140	2.6×10^{-8}	.02	.87	.99	1.86	.998	2.36	~1
K	1	.494	1.2×10^{-8}	.244	.62	.90	1.57	.97	2.05	.98
P	1	.938	∞	.882	.43	.73	1.27	.91	1.73	.94
Nuclide										
^2H	1	1.88	∞	3.52	.25	.47	.87	.73	1.25	.80
^3H	1	2.80	12y	7.88	.17	.34	.64	.58	.96	.67
^3He	2	2.80	∞	1.95	.64	.58	2.08	.82	2.93	.87
^4He	2	3.73	∞	3.46	.50	.47	1.74	.73	2.51	.80
^5He	2	4.66	~0	—	—	—	—	—	—	—
^6He	2	5.59	.8s	7.82	.35	.34	1.28	.58	1.91	.67
^8He	2	7.46	.12s	13.9	.26	.26	1.00	.47	1.52	.56
^5Li	3	4.66	10^{-21}s	2.42	.88	.54	2.94	.79	4.17	.85
^6Li	3	5.59	∞	3.47	.75	.47	2.61	.73	3.76	.80
^7Li	3	6.52	∞	4.74	.66	.41	2.34	.68	3.42	.75
^8Li	3	7.46	.85s	6.18	.58	.37	2.11	.63	3.12	.71
^9Li	3	8.39	.175s	7.82	.52	.34	1.93	.58	2.86	.67
^7Be	4	6.52	53d	2.67	1.13	.52	3.80	.78	5.42	.84
^8Be	4	7.46	10^{-16}s	3.48	1.00	.47	3.48	.73	5.02	.80
^9Be	4	8.39	∞	4.40	.91	.43	3.20	.69	4.66	.77
^{10}Be	4	9.32	~∞	5.43	.822	.39	2.96	.65	4.35	.73
^8B	5	7.46	.77s	2.22	1.52	.56	5.02	.80	7.10	.86
^9B	5	8.39	~10^{-18}s	2.81	1.38	.51	4.66	.77	6.67	.83
^{10}B	5	9.32	∞	3.47	1.26	.47	4.35	.73	6.27	.80
^9C	6	8.39	.13s	1.94	1.93	.58	6.25	.82	8.80	.87
^{10}C	6	9.32	19s	2.41	1.76	.54	5.87	.79	8.34	.85
^{11}C	6	10.25	20m	2.96	1.63	.51	5.53	.76	7.92	.83

*Nuclide masses estimated from $E_{binding} \sim 6$ MeV/nucleon
i.e. $M(A) = A * .932$ GeV/c^2

Figure Captions

III. 1) Detectors at the end of the spectrometer. Veto counters will be placed along sides where possible. The Si strip detector will be mounted as close to the end window as possible and the 1/8" scintillator follows the window as close as is reasonable.

III. 2) A somewhat busy representation of what one would see in P_1, T_{rf} space if no energy discrimination were made. The lines connecting the loci for $^2H_1$ and $(^M/_q)^2 = 6$ indicate a region occupied by several nuclides, $^7Li_3$, $^9Be_4$ and $^{10}Be_4$ and demonstrate the importance of energy discrimination, especially for $P_1 < 2$ GeV/c. The regions marked along one of the s loci indicate where intended spectrometer settings would overlap these loci. The spectrometer monentum, P_1, is the monemtum deduced from the bend angle for a charge equal to e. The first 20 nsec region of the plot is not completely filled in so that the first loci of π, K, P and s are clearly visible.



FOCAL PLANE DETECTOR

Fig. III.1

LOCI of VARIOUS PARTICLES and $(M/q)^2$ VALUES IN P_1, T_{rf} SPACE

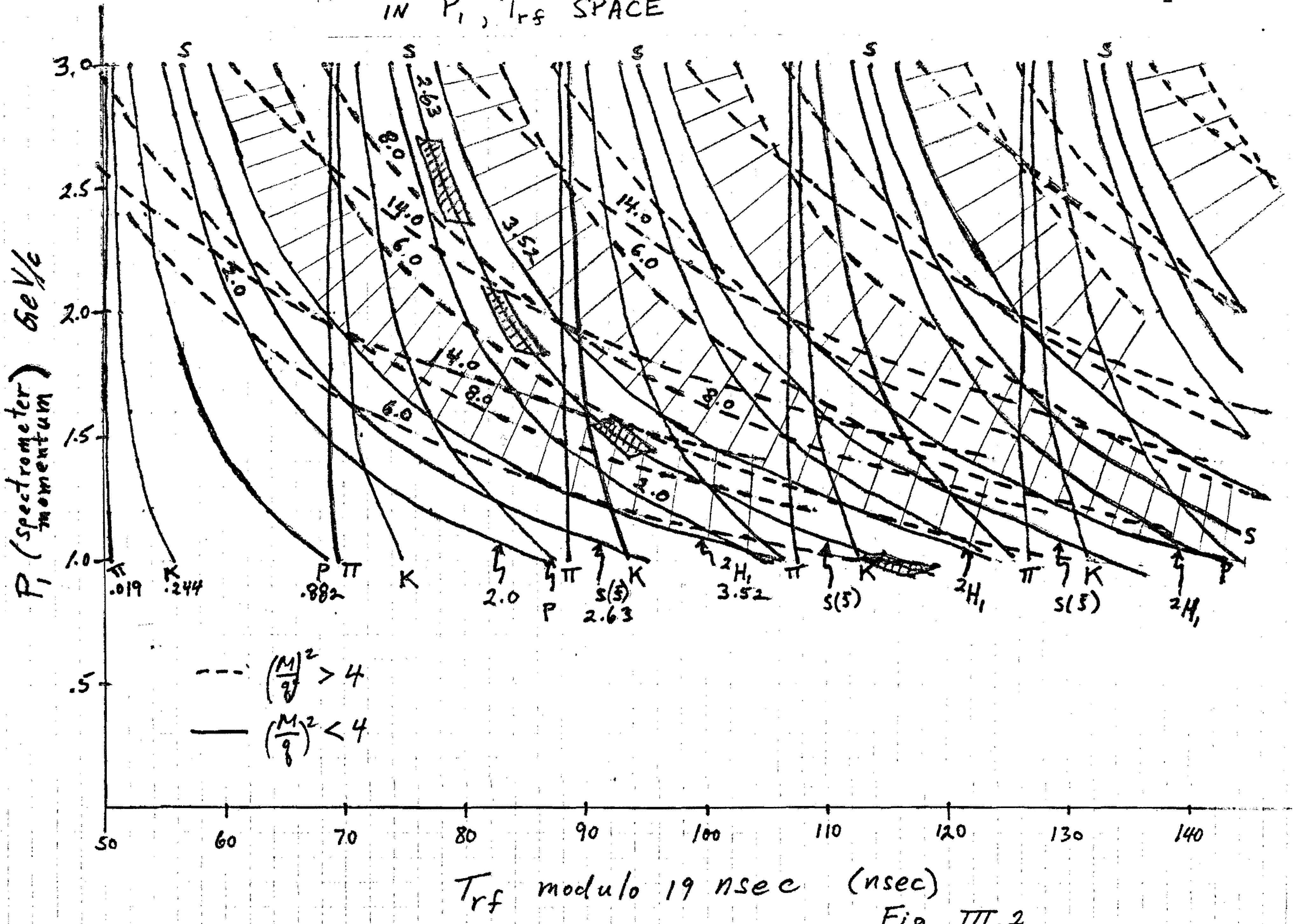


Fig. III.2

Appendix

1. Original P607 proposal
2. Addendum to P607

Proposal to Search for Particles which have an Anomolous Interaction with Normal Matter

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(submitted: June 13, 1978)

Abstract

The CØ (Internal Target Area) magnetic spectrometer will be used to search for particles which have an anomolously high interaction with normal matter. (Quarks may be such particles.) The apparatus will measure charge to mass ratio (q/m) for particles produced in interactions of the accelerator beam with a warm hydrogen gas jet. The total material from production point to the end of the detector will be significantly less than 5×10^{-2} grms/cm^2, making it possible to detect for the first time these anomolous particles. An exploratory experiment of one week set up time and 100 hours of running is requested.

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Introduction

We are proposing an exploratory experiment to test the hypothesis that there exist particles with an anomolously high interaction with matter. (Quarks may be such particles.)[1] We will measure charge to mass ratio (q/m) for particles produced in interactions of the accelerator beam with the warm gas jet. The total material (production to end of the detector) will be kept to a minimum ($\ll 10^{-1}$ grms/cm^2). We believe that such particles would have escaped detection in all previous particle search experiments.

Our approach is strictly empirical and based on the conviction that all possible types of particle searches should be carried out, especially those which require a small effort.

The significance of a positive result cannot be overemphasized and we urge Fermilab to give special attention to this proposal.

Apparatus

We propose to use the E-198/E-552 warm gas jet target spectrometer system which one of us (R.R.) is very familiar with. We would extend the main ring vacuum from where it currently ends on the spectrometer to behind the dipole, as shown in Fig. 1. Outside the thin vacuum window there would be a single hodoscope made of twelve 6" strips of plastic scintillator 1/8" deep and 1/2" wide readout at both ends behind these would be a large counter covering the area of the hodoscope. (The hodoscope would be surrounded by counters so that we may separate real events from background radiation from the main ring.) We will place a thin berylium foil that can be remotely flipped in and out of the path between the target and the dipole.

Our trigger will be either a coincidence between one of the hodoscope elements and the plastic counter directly behind it, or singles in the hodoscope and we will read out all the other counters.

Experimental Method

The method we propose to use is to determine the value of q/m using information from the magnet and time of flight.

The measurement of p/q will be done by placing a collimator in the dipole bore upstream of the field with a slit width of 2" and detecting the bent particle with the hodoscope plane. This method will give a measurement of p/q to 7% (f.w.).

Time of flight will be measured by the hodoscope and the beam bunch time. This will of course give a T.O.F. modulo 18.8 ns, the bunch separation. Before the bunch spreader is turned on at 60 GeV the bunch half-width is 0.5 ns, after that it increases to 2 ns. Since time resolution is essential to this measurement, we will work below 60 GeV.

Resolution

The relation between q/m and momentum and velocity is given by

$$m/q = p\sqrt{1/v^2 - 1/c^2}$$

Converting to units of time in nanoseconds and the flight path d in feet gives

$$m/q = p\sqrt{t^2/d^2 - 1}$$

From this the resolution in m/q can be found:

$$\delta(m/q) = \left\{m^2(\delta p/p)^2 + p^2/d^2\ (p^2/m^2 + 1)\ \delta t^2\right\}^{1/2}$$

Fig. 2 shows plots of the resolution for different particle types. The increase for the high recoil momentum is caused by the onset of relativistic effects. We will look at particles with a recoil momenta of 0.5 GeV and be sensitive to the regions of m/q of <80, 180 -- 420, 580 -- 850. (MeV/electron charge)

Rates

With the spectrometer set at 35° and the magnet set for unitary charged particles with a recoil momentum of 0.5 GeV, we will be sensitive to particles with an x_r of $(= p^*/p^*_{max})$ of 0.3, giving a counting rate of $\sim 10^3\ \pi$'s /ramp. The sensitivity of the experiment is limited by this pion background and the unknown machine background. We expect to be able to see effects at the 1% of the π level, which will make us sensitive to cross-sections of the order $10\mu b$. The actual limit of sensitivity will depend on how well we do the timing and how well we can eliminate the background radiation, which can only be determined by doing the experiment.

Requests

We intend to keep this exploratory experiment as simple as possible. We have chosen not to use the superconducting quadrupole doublet so that the liquid helium required to run the experiment can be produced by a single liquefier.

We are requesting 200 hours setup and run time. Our requests from the laboratory are for $5K. to make the necessary vacuum extensions and device to flip the foil in and out, $35 K. of PREP electronics and $5 K. of CDC time.

Scheduling

None of us have any commitments to running experiments for the next nine months. It would take one month to prepare for this experiment and it could be set up in one three day shutdown period, and completed in two weeks. It is feasible that we can complete this experiment by the August shut-down of 1978, and not interfere with the preparations for E591 which begin during that shutdown.

References

1. D. Garelick, "A New Idea for Searching for Free Quarks", Northeastern University preprint, NUB 2503, Oct., 1976.

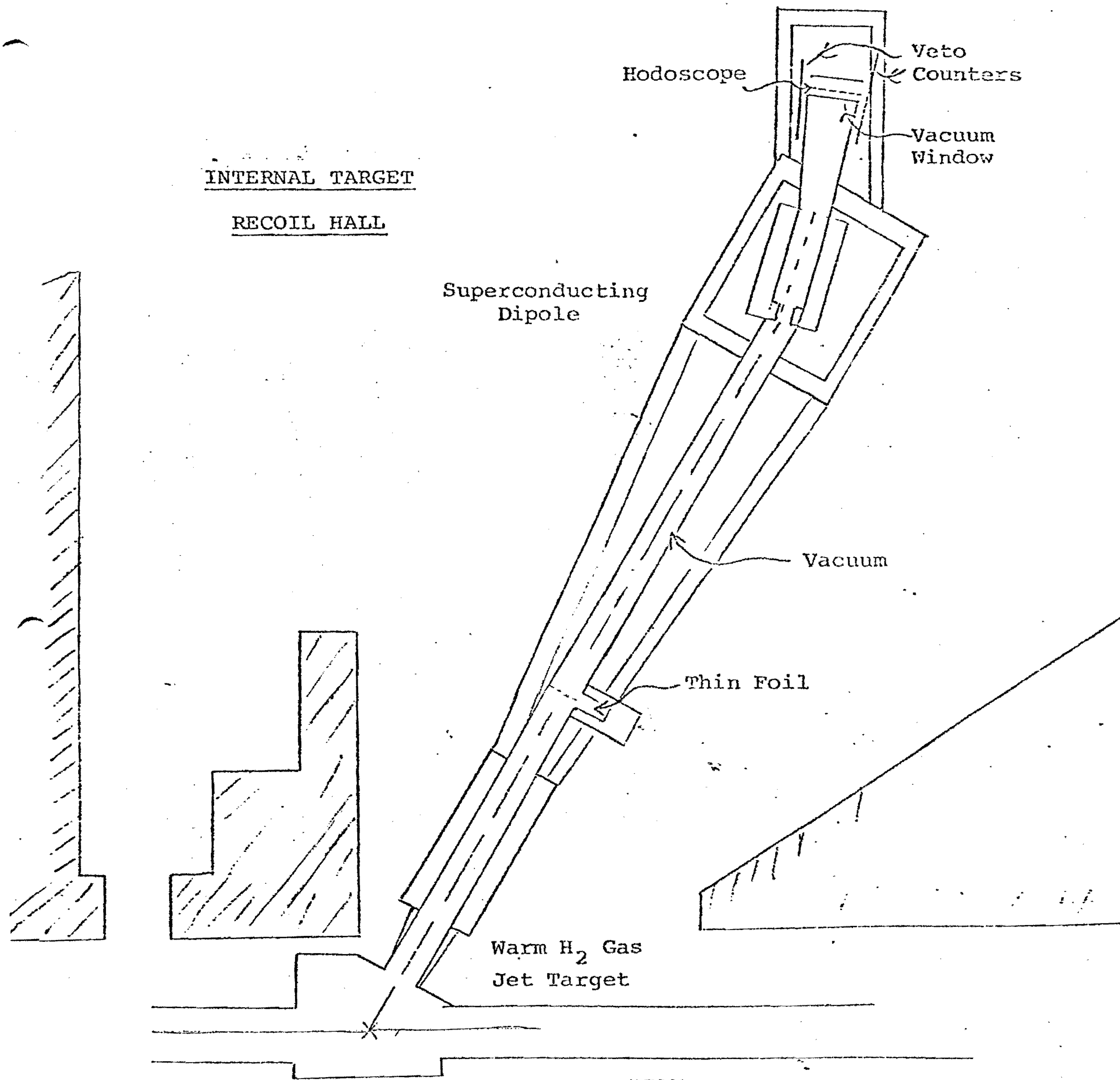
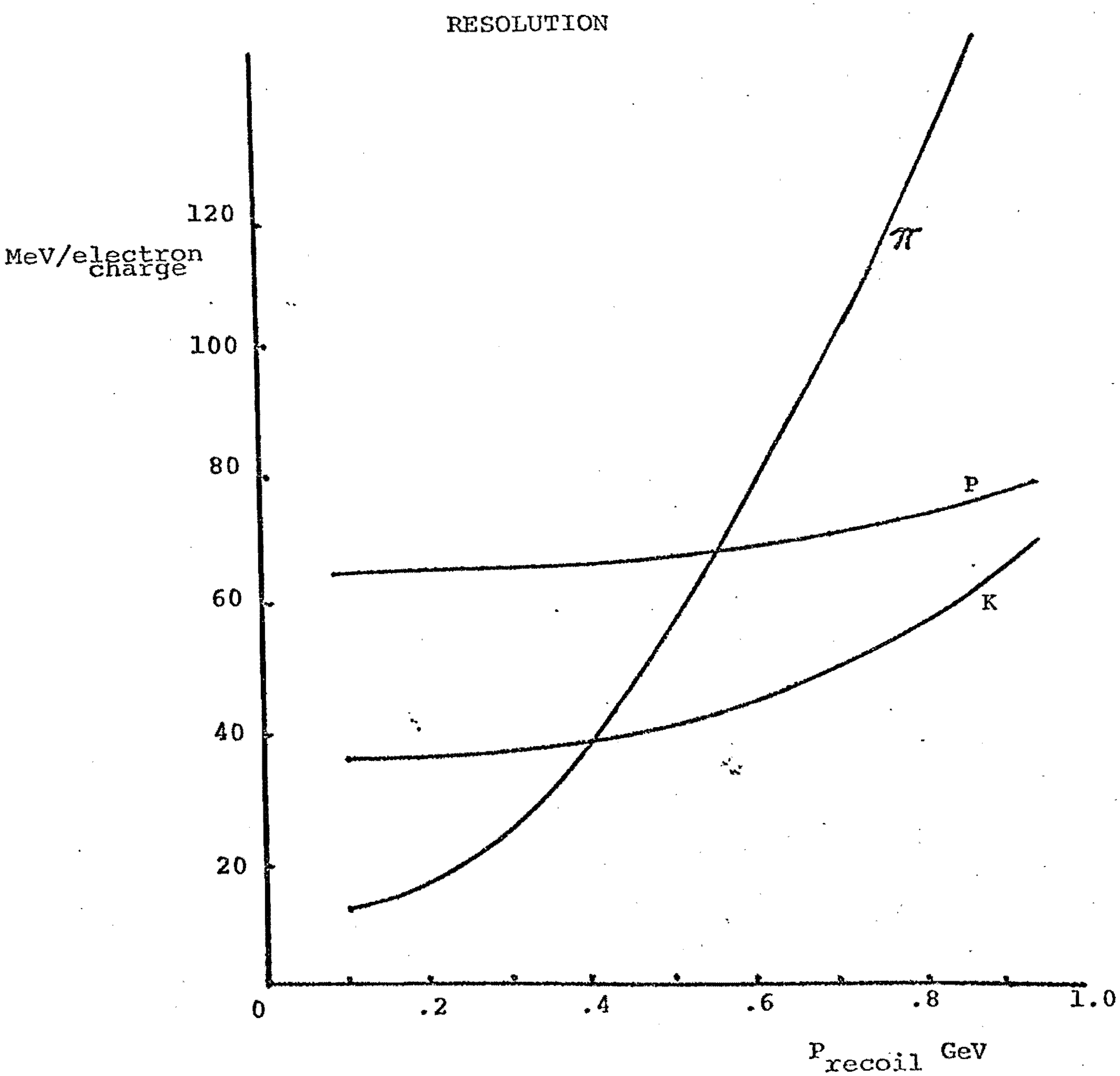


Figure (1) Experimental layout for proposed experiment.



RESOLUTION
MeV/electron charge
120
100
80
60
40
20
0
.2
.4
.6
.8
1.0
π
P
K
P_{recoil} GeV

Fig. 2

Addendum to Proposal P607

(9/78)

Proposal to Search for Particles which have an Anomalous Interaction with Normal Matter

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Introduction

The purpose of this addendum is to indicate our current plans and thoughts concerning P607. This addendum also contains some detailed calculations not presented in the original proposal. It is divided into the following sections:

I: The $(M/Q)^2$ Spectrum

II: Details of the Apparatus

A) Layout and $(M/Q)^2$ Resolution

B) Backgrounds and Additional Quark Signatures

III: The Sensitivity of P607

IV: Running time and other requests

I. The $(M/Q)^2$ Spectrum

In order to identify various particles detected by the P607 apparatus, we plan to plot the number of events versus $(M/Q)^2$. The reasons for this choice are apparent if one considers the experimental resolution in this quantity, $(M/Q)^2$. The relationship between $(M/Q)^2$ and the quantities determined by the apparatus can be found in the following manner.

$$\text{I)} \quad \theta_B = \frac{C_o QB}{p}$$

$$\text{II)} \quad p = \frac{M\,(v/c)}{\sqrt{1 - (v/c)^2}}$$

where: θ_B is the angle of bend;

Q is the particle's charge;

B the magnetic field;

p the particle's momentum;

C_o the constant relating θ_B, Q, B, p;

M is the particle's mass;

v is the particle's velocity; and

c is the velocity of light.

For the revised P607 apparatus (see section IIA) θ_B is determined by the point of intersection of the accelerator beam with the gas jet and the position of the hodoscope counter hit by the particle. v/c is determined by measuring the time-of-flight between an accelerator r.f. bunch and the time at which the hodoscope counter is hit.

Combining I) and II) gives:

$$\text{III)} \quad \frac{Q}{M} = \frac{\theta_B}{C_o B} \frac{(v/c)}{\sqrt{1 - (v/c)^2}} = \frac{1}{p_1} \frac{(v/c)}{\sqrt{1 - (v/c)^2}}$$

where p_1 is the momentum that a charge Q = 1 particle would have in order to be bent through an angle θ_B. From III) we get

$$\left(\frac{M}{Q}\right)^2 = p_1^2 \left[\frac{1 - (v/c)^2}{(v/c)^2} \right]$$

$$\left(\frac{M}{Q}\right)^2 = p_1^2 \left[(c/v)^2 - 1 \right] .$$

Also $$c/v = \frac{c}{(L/t)} = \frac{t}{(L/c)} = \frac{t}{t_o}$$

where t is the time of flight, and L is the distance from the production point to the hodoscope counter. t_o is the time light would take to travel the distance L. Therefore:

$$\left(\frac{M}{Q}\right)^2 = p_1^2 \left[\left(\frac{t}{t_o}\right)^2 - 1 \right]$$

and the resolution in $(M/Q)^2 \equiv \delta(M/Q)^2$ is:

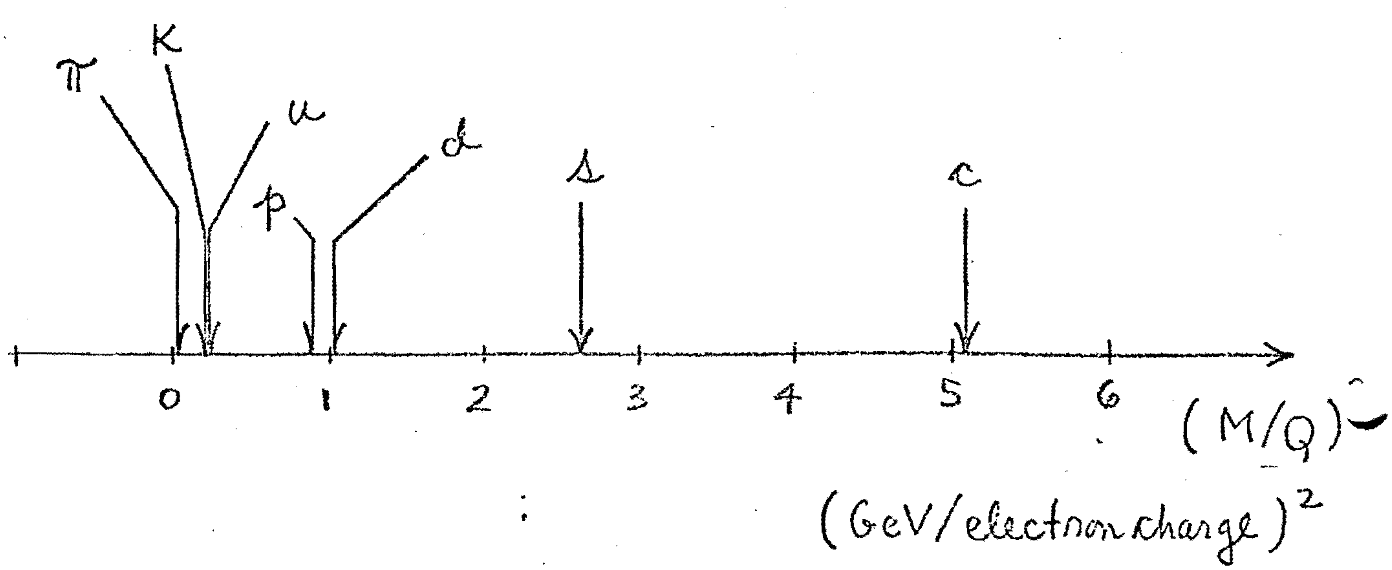
$$\delta[(M/Q)^2] = 2p_1^2 \sqrt{[(t/t_o)^2 - 1]^2\left[\frac{dp_1}{p_1}\right]^2 + [(\frac{t}{t_o})\ (\frac{\delta t}{t_o})]^2}$$

In order to evaluate the P607 apparatus, we assume the following "standard" quark charges and masses.[1]

Table I.1

Particle	Q Charge	M Mass (GeV)	$(M/Q)^2$ (GeV/electron charge)^2
u quarks	2/3	.336	.254
d quarks	1/3	.336	1.016
s quarks	1/3	.540	2.627
c quarks	2/3	1.5	5.073
π	1	.140	.020
K	1	.494	.244
p	1	.939	.882

Fig. I.1 $(M/Q)^2$ values for quarks and known particles



II. Details of the Apparatus

A) Layout and $(M/Q)^2$ Resolution

The layout of the P607 apparatus is shown in Figs. II.1-2. This layout differs from that of the original P607 proposal in that a quadrupole doublet has been added to the spectrometer. In this configuration the spectrometer is a standard point-to-point focusing spectrometer. The length of the spectrometer is determined by the need for good fractional ($\delta t/t$) time-of-flight measurements. The location of the quads is a compromise between the conflicting need for a large angular acceptance and the need for a small spatial magnification. In order to make the detector elements small, we have chosen a $\sim$ 1:1, object: image magnification. The effective object size at C0 is $[\sim 1\text{cm(H)}]\text{x}[\sim .5\text{cm(V)}](\text{FWHM})^2$. Since the spectrometer bends horizontally, the first quad, Q_1, is set to defocus horizontally and focus vertically in order to minimize the horizontal magnification. The actual magnifications are .9(H) and 1.1(V) and the distance from the dipole bend plane to the detector is L_B = 19 ft.

We have chosen the hodoscope element size to be 1.0 in (H) x .5 in.(V) and there will be 7 elements in the hodoscope. This arrangement gives an angular acceptance of

$$\Delta\Omega = 24 \text{ mrad (H)} \times 29 \text{ mrad (V)}$$
$$= 700\mu \text{ strad},$$

and a momentum acceptance of

$$\Delta p/p = 6\%.$$

The momentum resolution for the system is $\delta p/p$ = 1% (FWHM) and the time of flight resolution is δt = 1 nsec (FWHM). The resolutions in the quantity $(M/Q)^2$ and the time of flights for two settings of the spectrometer central momentum are given in Table II.1.

B) Backgrounds and Additional Quark Signatures

In order to help separate the quark signal from possibly large backgrounds from conventional particles traversing the spectrometer and from general room background, the focal plane detector shown in Fig. II.2 will be used. Some important features of this detector are:

1. The scintillator of each hodoscope element will be viewed by two phototubes in order to minimize the effect of phototube noise. These scintillators will be mounted in the vacuum chamber so that particles do not have to traverse material other than the gas of the jet before entering the scintillation material.
2. The pulse heights and timing information from all phototubes will be digitized for each event.
3. DEDX counters and the proportional chambers (PC's) will be used to help reject standard particles (π's, K's, p's) which should give "normal" pulse heights in the DEDX counters and straight tracks in the PC's.
4. To help identify cases in which an $\bar{s}$ anti-quark stops in the first .1 gm/cm^2 of material of the detector and combines with a u quark to form a K^+ meson, we will look for a muon track in the PC's indicative of $K_{\mu 2}$ and $K_{\mu 3}$ decays.

In addition, any quark signal is expected to be removed by insertion of the .1 gm/cm^2 Al foil across the spectrometer aperture. This foil will be moved in and out of the spectrometer aperture on a machine pulse-to-pulse basis.

III. The Sensitivity of P607

A measure of the sensitivity of P607 is given by the number of π^+'s that will be detected. The π^+ counting rate is given by:

$$\#\pi^+/\text{ramp} = \frac{d\sigma}{dxdp_\perp} \Delta x \Delta p_\perp (\#\text{protons/cm}^2)\Big|_{\text{tgt}} (\#\text{protons/ramp})\Big|_{\text{beam}} \left(\frac{\Delta\theta_v}{2\pi \sin\theta_H}\right)$$

$$(\#\text{protons/cm}^2)\Big|_{\text{tgt}} = (10^{-7}\ \text{gm/cm}^2)(6\text{x}10^{23}\ \text{protons/gm})$$

$$= 6\text{x}10^{16}\ \text{protons/cm}^2$$

for a 1 second jet pulse:

$$(\#\text{protons/ramp})\Big|_{\text{beam}} = (2\text{x}10^{13}\ \text{protons/pulse})(5\text{x}10^{4}\ \text{circulations/ramp})$$

$$= 10^{18}(\text{protons/ramp}).$$

For a spectrometer setting of $\theta_H = 33.5^\circ$ and $p_1 = 2$ GeV, $\Delta\theta_H = 24$ mrad, $\Delta\theta_v = 29$ mrad, $\Delta p = .12$ GeV; $\Delta x \Delta p_\perp \simeq 10^{-3}$ GeV, $X \simeq .35$ and $P_\perp \simeq 1.1$ GeV, and $\frac{\Delta\theta_v}{2\pi\sin\theta_H} = 8.4\text{x}10^{-3}$ rad.

The results of E118 suggest:

$$\frac{d^2\sigma}{dxdp_\perp} \simeq 750\ \frac{P_\perp}{X}(1 - X)^4\ e^{-6P_\perp}(\text{mb/GeV})$$

or: $$\frac{d^2\sigma}{dxdp_\perp} \cong .6\ \text{mb/GeV for } x = .35,\ p_\perp = 1.1\ \text{GeV}.$$

Thus:

$$\#_{\pi^+}/\text{ramp} \simeq (.6\times10^{-27})(10^{-3})(6\times10^{16})(10^{18})(8.4\times10^{-3})$$

$$\simeq 300/\text{ramp}$$

or $\#_{\pi^+}/\text{day} \simeq 2\times10^6/\text{day}$ (for 1 ramp/12 sec).

This corresponds to approximately 2×10^5 K^+'s produced at the target. If $\bar{s}$ quarks are produced with the same x and $p_\perp$ behavior as π^+ then an $\bar{s}$ abundance of one in 6×10^6 π^+ produced at the target will give a signal of $\sim 10^2$ $\bar{s}$ events per day.

Most probably, the sensitivity levels achieved will be determined by the actual background levels encountered in the experiment which are unknown at this time.

IV. Running Time and Other Requests

As indicated in the Spectrometer Layout, Fig. II.1, P607 will require that the magnetic elements of the existing C0 spectrometer be repositioned. We will not change spectrometer angles during P607 so that the spectrometer elements can be set directly on the floor.

The experimenters will supply the detector and its small vacuum chamber. We expect Fermilab to supply and maintain the gas jet and the remainder of the spectrometer system such as, vac. parts, lqd. He, and the assembly to pulse the Al foil in and out of the spectrometer aperture.

We anticipate that it will take approximately 3 months for us to build and debug the apparatus and require approximately 4 weeks (~ 400 hours) of accelerator time to complete the experiment. We estimate that it will require approximately one week to reconfigure the spectrometer and one week to install the detectors.

A modest amount of PREP electronics and off-line computing will also be required.

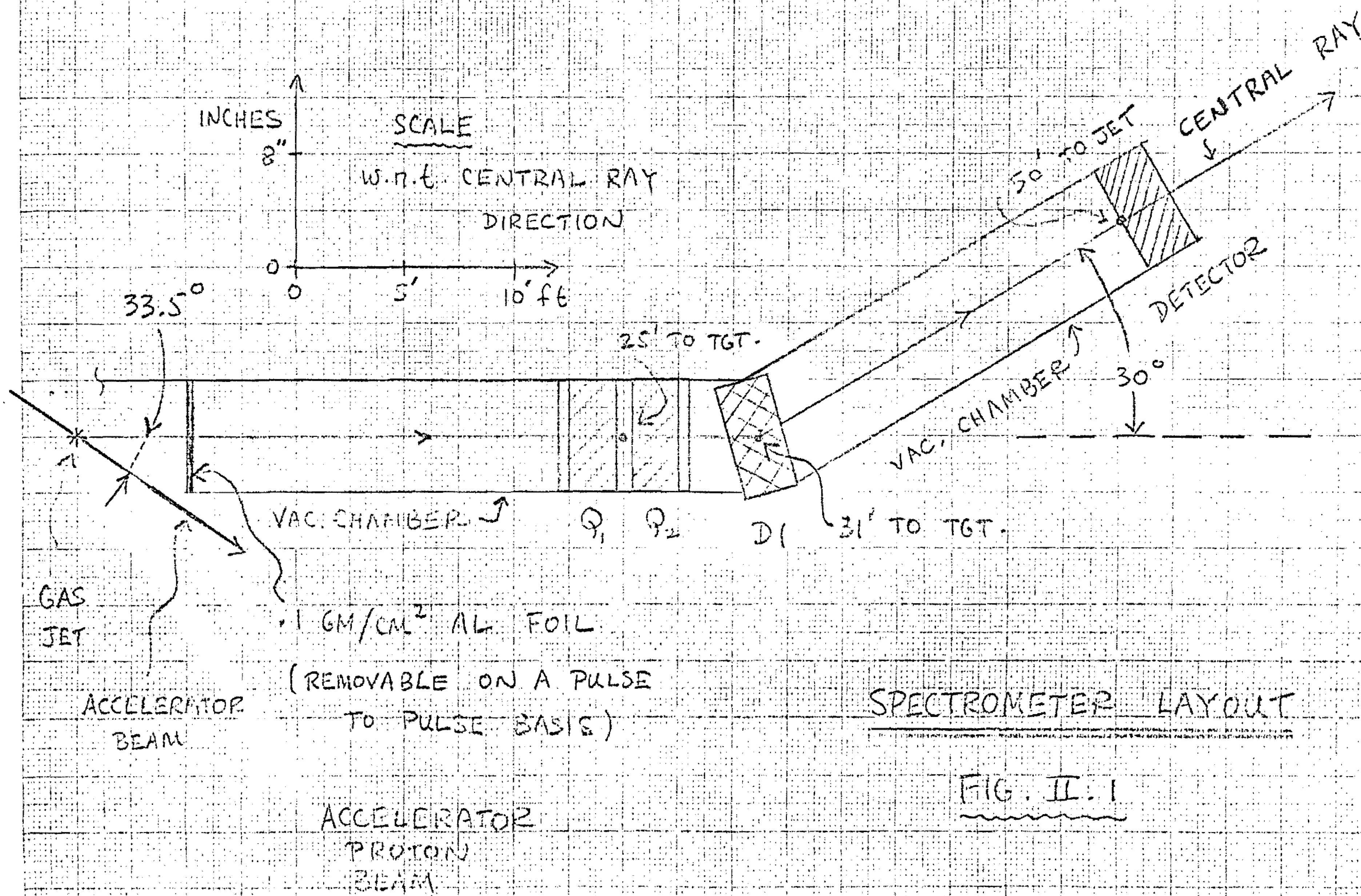
Our present best estimate is that we will be able to begin taking data for this experiment in April 1979. Until April 1979 our major effort will be the analysis of E439.

Reference

1. A. De Rujula, H. Georgi, S. L. Glashow, Phys. Rev. D12, 147 (1975) and references cited therein.

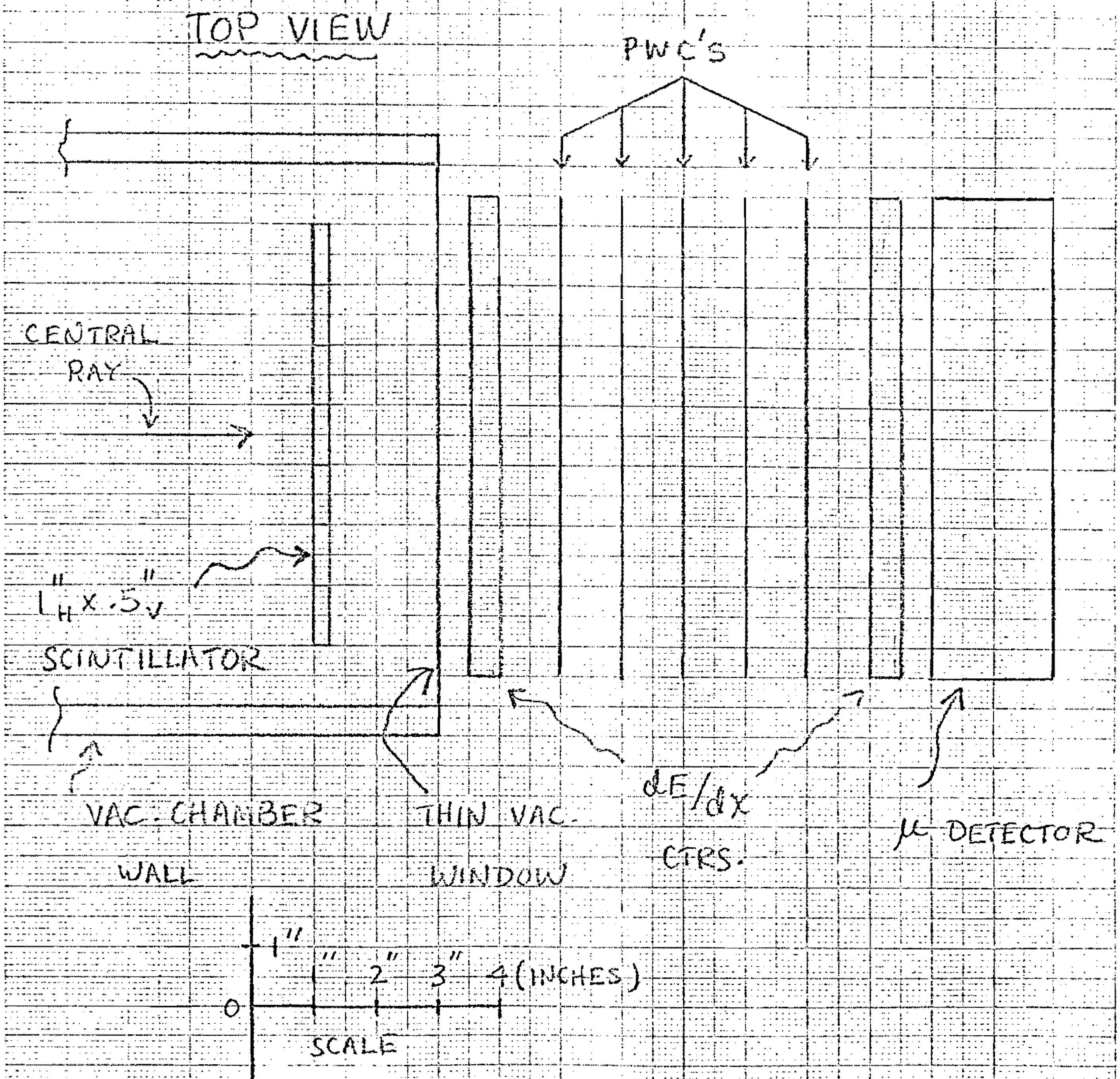
Table II.1. $(M/Q)^2$ Resolutions and Flight Times. (Assumed masses and charges are given in Table I.1.) e = one electron charge.

particle	$(M/Q)^2$ (GeV^2/e^2)	P_1 = 2 GeV $\delta(M/Q)^2$ (GeV^2/e^2)	P_1 = 2 GeV t (nsec)	P_1 = 1 GeV $\delta(M/Q)^2$ (GeV^2/e^2)	P_1 = 1 GeV t (nsec)
u	.254	.17	51.56	.05	55.99
d	1.016	.18	55.99	.06	71.00
s	2.627	.21	64.36	.09	95.22
c	5.073	.26	75.30	.14	123.21
π	.020	.16	50.12	.04	50.48
K	.244	.16	51.50	.05	55.77
p	.882	.18	55.24	.06	68.59



SPECTROMETER LAYOUT

FIG. II.1



FOCAL PLANE DETECTOR
(SKETCH)

FIG. II. 2