# SEARCH FOR LONG-LIVED HEAVY PARTICLES

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The search technique which seems most likely to succeed is a straightforward beam survey using momentum analysis and velocity measurement in some Cerenkov counters. A beam survey which measures fluxes of known particles will be very valuable from a practical point of view and probably should be combined with the search for heavy particles. Unfortunately, it seems that the design requirements for the Cerenkov counter are somewhat different so probably the combining of the two tasks will be nothing more than putting the different counters in the same beam in tandem.

For a heavy-particle search the Cerenkov counter need not have terribly precise velocity discrimination since heavy particles will be moving slowly ($\beta \simeq 0.995$ for $\gamma = 10$). On the other hand, the light output should be high ($\sim 144$ photoelectrons) so that the counter is reasonably efficient for detection of particles with $1/3$ e and reasonably accurate in identification (from pulse height) of particles with $4/3$ e and $5/3$ e.

This requirement conflicts with precision velocity measurement since

$$N_{pe} \simeq 40 \text{ cm}^{-1} L \sin^2 \theta,$$

indicates that one should choose a large Cerenkov angle, $\theta$. And, on the other hand, the velocity precision is $\delta\beta/\beta = \tan \theta \delta\theta$. The angle accuracy is directly related to the angular acceptance and cannot be made significantly less than $10^{-4}$ radian because of diffraction in the optics.

We concentrate on the design of a counter suitable for a heavy-particle search. The problem is not hard and a possible combination of parameters for a DISC-type focusing counter is given in the table below.

Table I.

| | |
|---|---|
| Radiator Material | $CO_2$ |
| Radiator Length | 50 cm |
| Light Cone Angle | 20° |
| Focal Length | 100 cm |
| Light Cone Angle Band Width | 1.4 mrad |
| Index of Refraction | 1.065 |

The optical system of the DISC should be split into multiple rings so that several velocities can be searched simultaneously. This splitting system might be designed separately from the rest of the counter so that it could be used with a longer focal length and smaller Cerenkov angle in other experiments.

Some kinematical facts about this experiment are summarized in Fig. 1. The smooth curves are the kinematic limit for production of a particle, q, with mass $M_q$ and momentum $P_{qlab}$ in the reaction

$$p + p \rightarrow p + p + q + \bar{q}.$$

They are labelled with the incident proton energy. The right-most curve is obtained assuming 1 GeV/c Fermi momentum for the target proton. The straight lines are lines of constant p/m or velocity in the lab. One channel of the Cerenkov counter specified in Table I would respond to particles between the lines labelled 9.5 and 10.

The largest $M_q$ is obtained at a momentum of ~ 90 GeV/c. If we are looking for 1/3 e particles, the beam must be capable of transporting 270 GeV/c.

Using a thin-lens approximation we can sketch the design of a beam transport with 25 m focal length, $3 \times 10^{-6}$ sr (see Fig. 2). The beam out of the quadrupoles is sent through a momentum spectrometer and through two DISC counters. The counter array and spectrometer that are proposed here are considerably less complicated than was used by Dorfan et al.[1] We cannot use time of flight since our velocities are much closer. There should be guard counters at strategic planes along the beam.

The rejection ratio of a single DISC is reputed to be $10^{-6}$. If the DISC counters are placed reasonably far apart, the false counts are uncorrelated and the joint rejection will be $\sim 10^{-11}$.

The actual sensitivity for 1/3 e particles will depend on details of background since there are no particles at all in the beam with momentum 270 GeV/c.

The total length of this beam is 60 m. We are working with $p/m \simeq 10$, so decay in flight will cause an $e^{-1}$ loss for particles with a mean life $\tau_e = 20$ nsec.

If we tune the beam for 70 GeV/c we can, of course, look for heavy particles with the electronic charge. In this case, it is possible to estimate a background rate from the curves of Hagedorn and Ranft. We can expect $\sim 2 \times 10^{-4}$ particles/interacting proton (mostly protons).

The equipment needs of this experiment are as follows:

1. Beam-transport magnets with an aperture, total BL of all bending magnets = 50 Tesla-meters
2. 2 DISC counters as described above
3. A multi-dimension pulse height analyzer or equivalent small computer.
4. A few dozen scintillation counters and associated electronics.

In addition, there should be provided other DISCs for use in identification of $\pi$ and K mesons for beam survey.

## REFERENCE

[1] Dorfan, Eades, Lederman, Lee and Ting, Search for Massive Particle, Phys. Rev. Letters 14, 999 (1965).

## FIGURE CAPTIONS

Fig. 1. Kinematic limits for production of a hypothetical particle of mass $M_q$, including that for a target with Fermi momentum 1 GeV/c. The straight lines represent lines of given q/m in the laboratory.

Fig. 2. Design of beam for an experiment searching for heavy particle production.

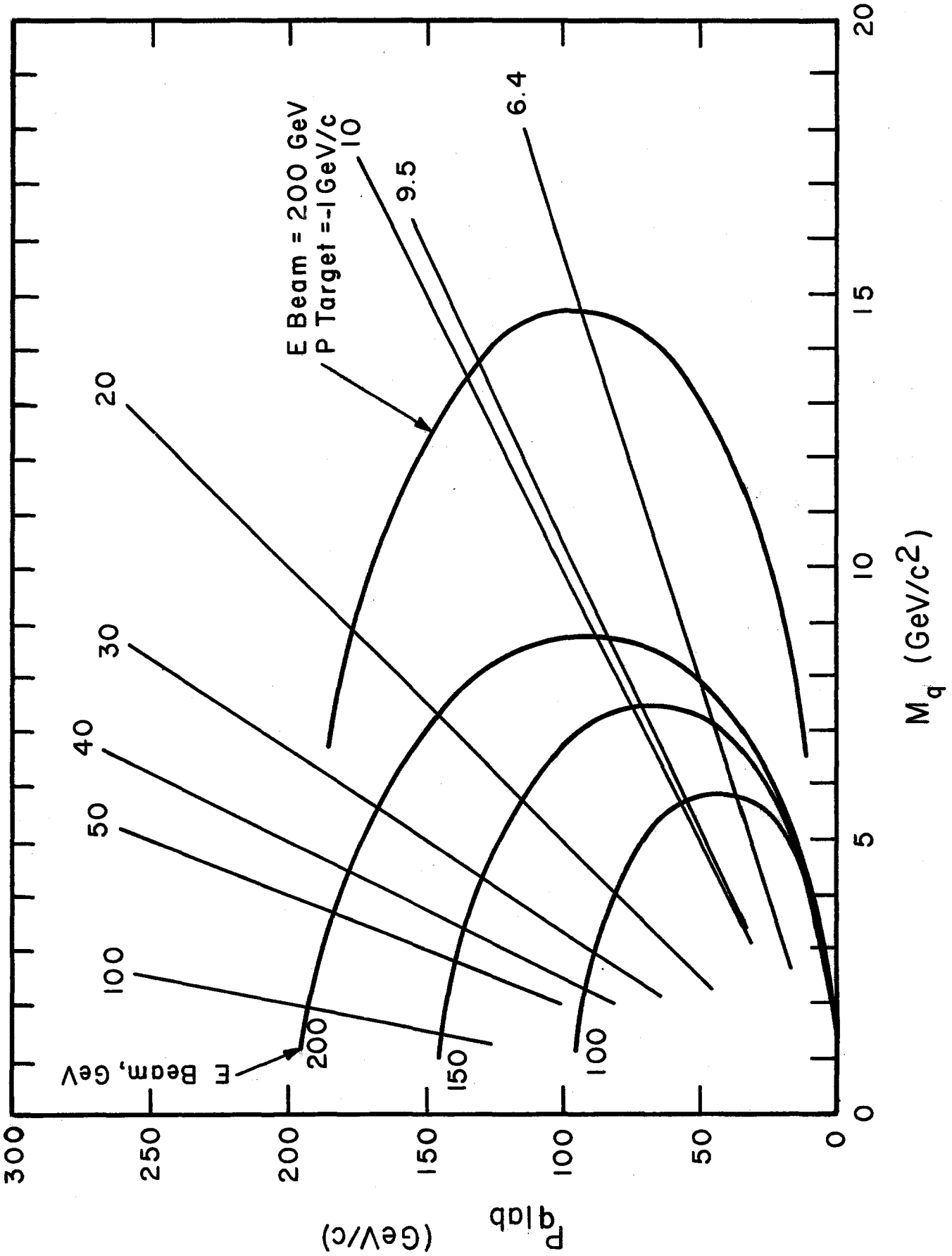
E Beam = 200 GeV
P Target =-1 GeV/c
10
9.5
6.4
20
30
40
50
100
E Beam, GeV
200
150
100
$P_{q\,lab}$ (GeV/c)
300
250
200
150
100
50
0
0
5
10
15
20
$M_q$ (GeV/$c^2$)

Fig. 1

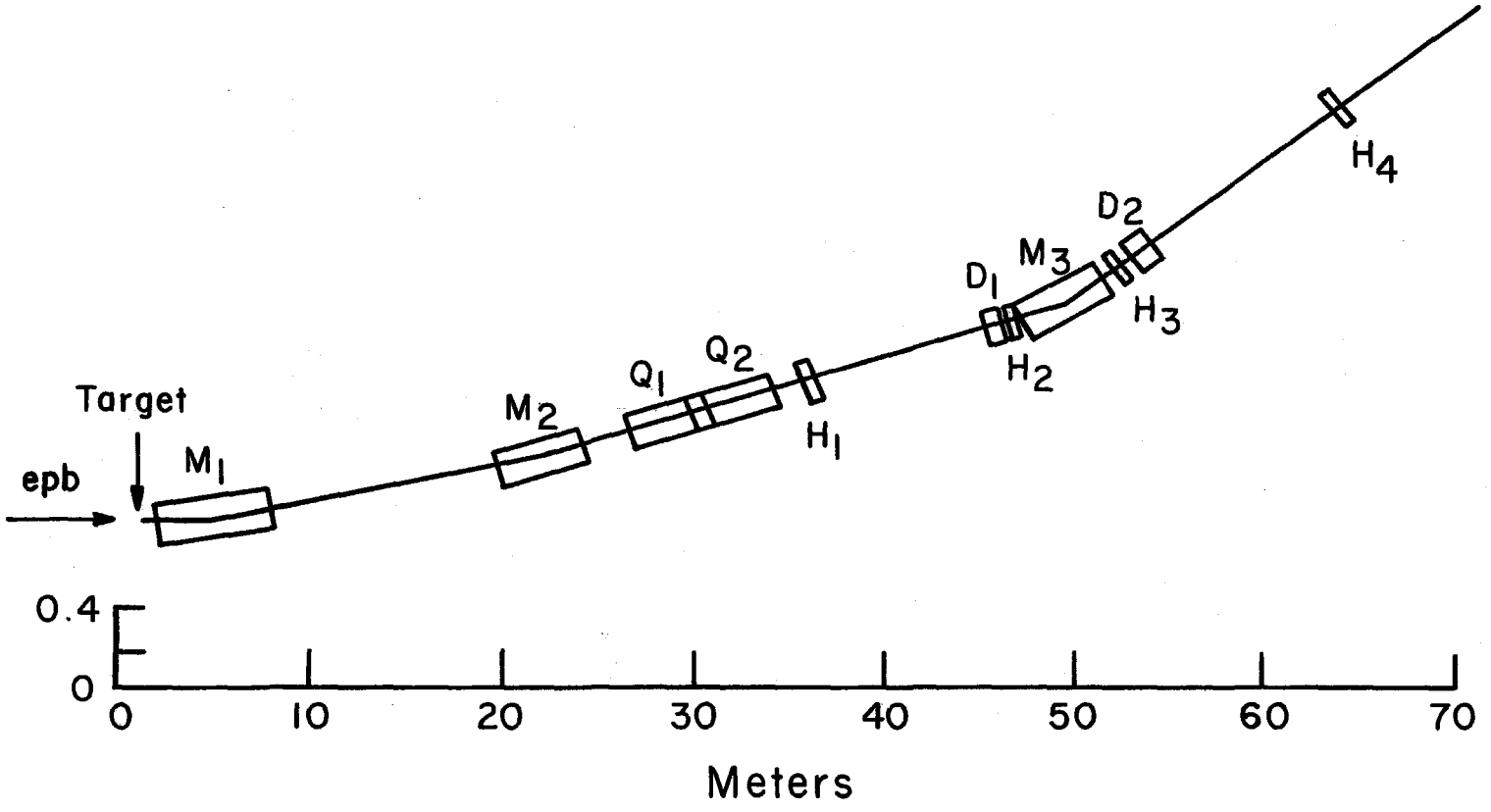
Target
epb
M1
M2
Q1
Q2
H1
D1
M3
H2
D2
H3
H4
0.4
0
0
10
20
30
40
50
60
70
Meters

Fig. 2