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A LARGE, WIDE-APERTURE CERENKOV HODOSCOPE*

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I. INTRODUCTION

A large-aperture Cerenkov chamber has been designed and constructed at SLAC for use in identifying particles in 1, 2 and 3 body final states. Though it is basically a threshold type counter, the optics is designed such that each of the eight 62.5×62.5 cm spherical mirrors reflects the Cerenkov light into a corresponding light horn and phototube (Figs. 1 and 2). Hence the counter may be used as a hodoscope of 8 Cerenkov cells which are optically independent. If the Cerenkov cone of a particle intersects only one mirror, it will be detected by a single phototube. The chamber may also be used as a single, large, uniformly efficient counter by summing the outputs of each of the phototubes.

II. DESCRIPTION

The basic design of the counter which operates at pressures between 0 and 45 PSIA is rather straightforward and was dictated by the desire to match its solid angle acceptance with that of the momentum analyzing magnet and the rest of the spectrometer system (e.g., spark chambers and trigger hodoscopes).[1] The entrance window (which is 2 mm thick Al) is $1 \text{ m} \times 2.5 \text{ m}$ and the minimum path length of radiator is 1.75 m. At the back of the counter there is a plane of mirrors covering a total area of $1.25 \text{ m} \times 2.5 \text{ m}$ and consisting of 8 square sections of spherical mirrors set edge to edge. Each of the upper four mirrors is inclined at an angle of 10° with respect to the horizontal so that it reflects light into one of the upper four light horns; similarly each of the lower mirrors was inclined to reflect light into one of the lower light horns. The horns are designed to accept all light rays which have an angle with respect to the axis of the horn that is less than a maximum cutoff angle of 25°.[2]

The light from each horn is then detected by a single photomultiplier tube (Amperex 58UVP) having a photocathode diameter of 110 mm.

To allow the maximum amount of information for use in identifying the particles, the individual pulse heights are recorded. The dynode signal from each phototube is integrated and the peak of the integrated pulse determined and converted to digital information by means of an analog-to-digital converter. In addition, the anode signals from all the phototubes are summed directly so that this hardware sum may be used for triggering if desired.

III. TESTING AND PERFORMANCE

The counter was tested using a pion beam at 8 and 5 GeV which when undeflected passed through the center of the Cerenkov chamber. Two bending magnets 10 m and 6.35 m upstream from the counter were used to deflect the beam vertically and horizontally towards various points on the mirror plane. In this way, it was verified that the efficiency of the counter to detect a particle was uniform for various particle trajectories. It was particularly important to check the regions at the edges of the mirrors where the Cerenkov light may be split two or even four ways and detected by separate phototubes. The uniformity was found to be very good. For example, Fig. 3 shows the pulse height spectrum obtained for two different incident trajectories of the pion beam (5 GeV) with a gas pressure of 22 PSIA Freon 12 in the counter. Note that although the Cerenkov light divides equally between two mirrors for the trajectory shown in Figs. 3a and 3b, the pulse height spectrum obtained by summing the outputs of the two phototubes, Fig. 3c, is essentially undegraded. The pulse height spectrum for the beam incident on the center of a mirror, Fig. 3d, was fit with a Poisson distribution $P(k) = \frac{m^k}{k!} e^{-m}$ to estimate the average number of photoelectrons, m. The best fit value of m was 11 which, when corrected for the statistics of the dynode multiplication, implies an average of 12-13 photoelectrons.

An 8 GeV/c pion beam was used to measure the efficiency of the counter as a function of the gas pressure for a typical trajectory, as shown in Fig. 4. The efficiency was decounters (two upstream and one downstream of the chamber) and a threshold gas Cerenkov counter set to count on π's with the fivefold rate which included the Cerenkov chamber. Th difference is plotted in Fig. 4; the maximum efficiency is 99.85 ± .1%. In addition, a seri of measurements were made without the beam Cerenkov. These measurements, also show in Fig. 4, illustrate that the chamber is capable of detecting a .1 - .2% contamination of K^- mesons in the beam.

The Cerenkov chamber has been used to separate K^+K^- states from $\pi^+\pi^-$ in the reactio

$$\pi^- p \rightarrow \pi^+\pi^- X^o$$
$$\rightarrow K^+K^- X^o$$

for a 15 GeV incident pion beam. The two charged particles are detected by the wire spark chamber spectrometer immediately upstream of the counter.[1] Figure 5 shows the total-pulse-height spectrum for those events where two oppositely charged particles were detected by the spectrometer and where either one or both of the particles entered the Cerenkov counter and had a momentum between 4 and 11 GeV. The gas pressure during the experiment was 18.4 PSIA. The separation between the events which have zero pulse height and the $\pi^+\pi^-$ events is clearly very good.[3] If only those events for which both particles entered the counter are considered, it is better still.

REFERENCES AND FOOTNOTES

1. Armstrong et al., "Wire Spark Chamber Spectrometer at SLAC," to be presented at Dubna Instr. Conference.

2. H. Hintergerger and R. Winston, Rev. Sci. Instr. 37, 1094 (1966).

3. The reason the events which produced no Cerenkov light fall at channel number 50 rather than at 0 is that the electronics was set to have a slightly positive pedestal. Th instability of this pedestal also explains the finite width of the spike.

FIGURE CAPTIONS

1. An artist's conception of the chamber showing particularly the optical arrangements.
2. A side view of the Cerenkov chamber.
3. The pulse height spectrum is shown for two different trajectories of the pion beam (5 GeV), as indicated by the inserts. The shaded region indicates for which mirror (phototube) the spectrum is plotted. Figures (a), (b), and (c) show for a trajectory which intersects the crack between two mirrors, the spectra of the two corresponding phototubes, both separately and summed together. The solid line in (d) is the best fit to a Poisson distribution. The small spike near the origin indicates the zero-pulse-height pedestal and consists largely of mistriggers.
4. A graph of 100% — EFFICIENCY versus pressure of Freon 12 for an 8 GeV pion beam. The insert indicates the trajectory of the pion beam with respect to the plane of mirrors. The measurements represented by the solid data points were made with a trigger which vetoed any K^- particles.
5. The distribution of the total pulse height from the Cerenkov chamber showing the clear separation of K^+K^- and $\pi^+\pi^-$ events. The events are from

$$\pi^- p \to \pi^+\pi^- X^o \quad \text{(15 GeV incident beam)}$$
$$\to K^+K^- X^o$$

where either one or both particles enters the chamber and has a momentum between 4 and 11 GeV.

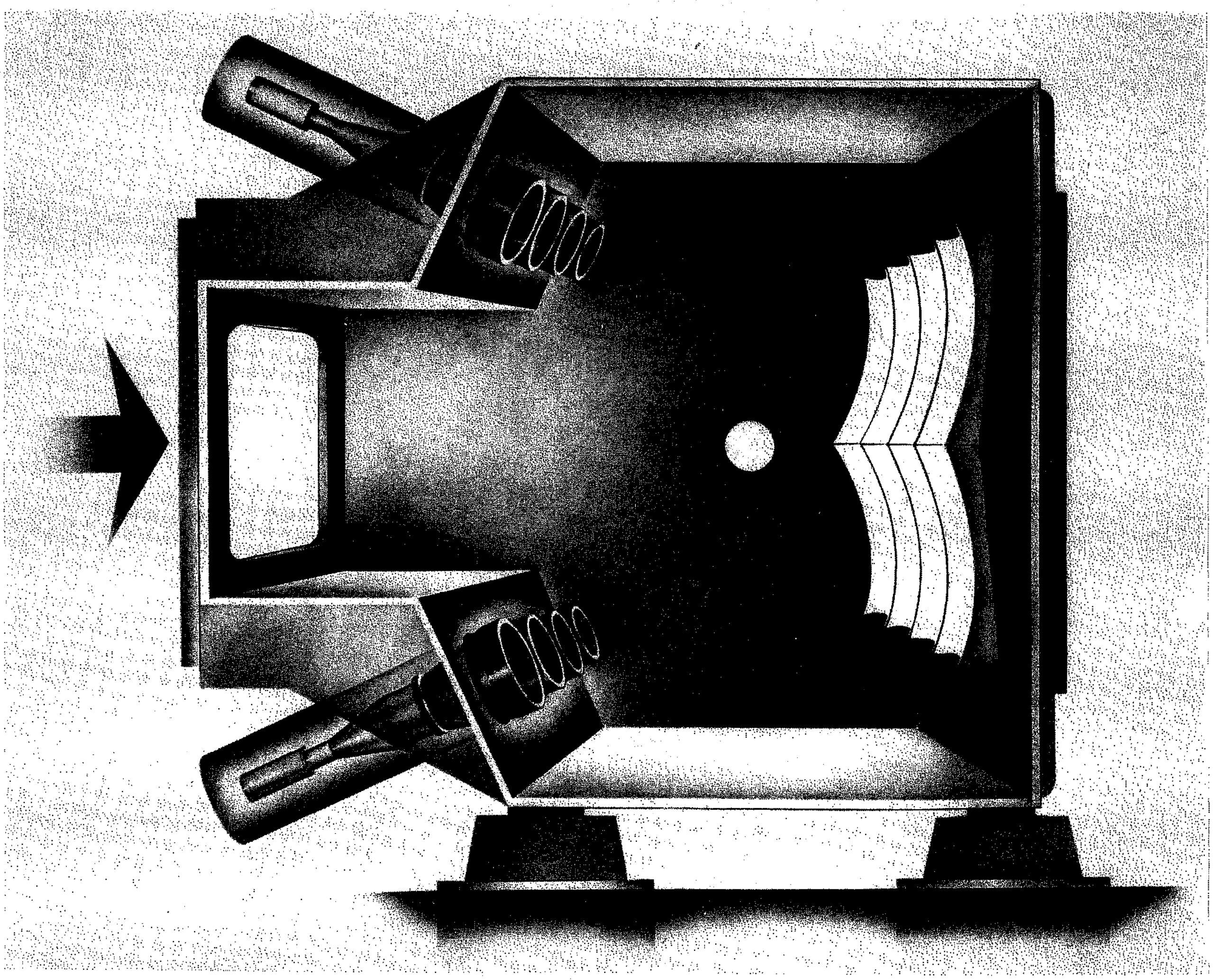

Fig. 1

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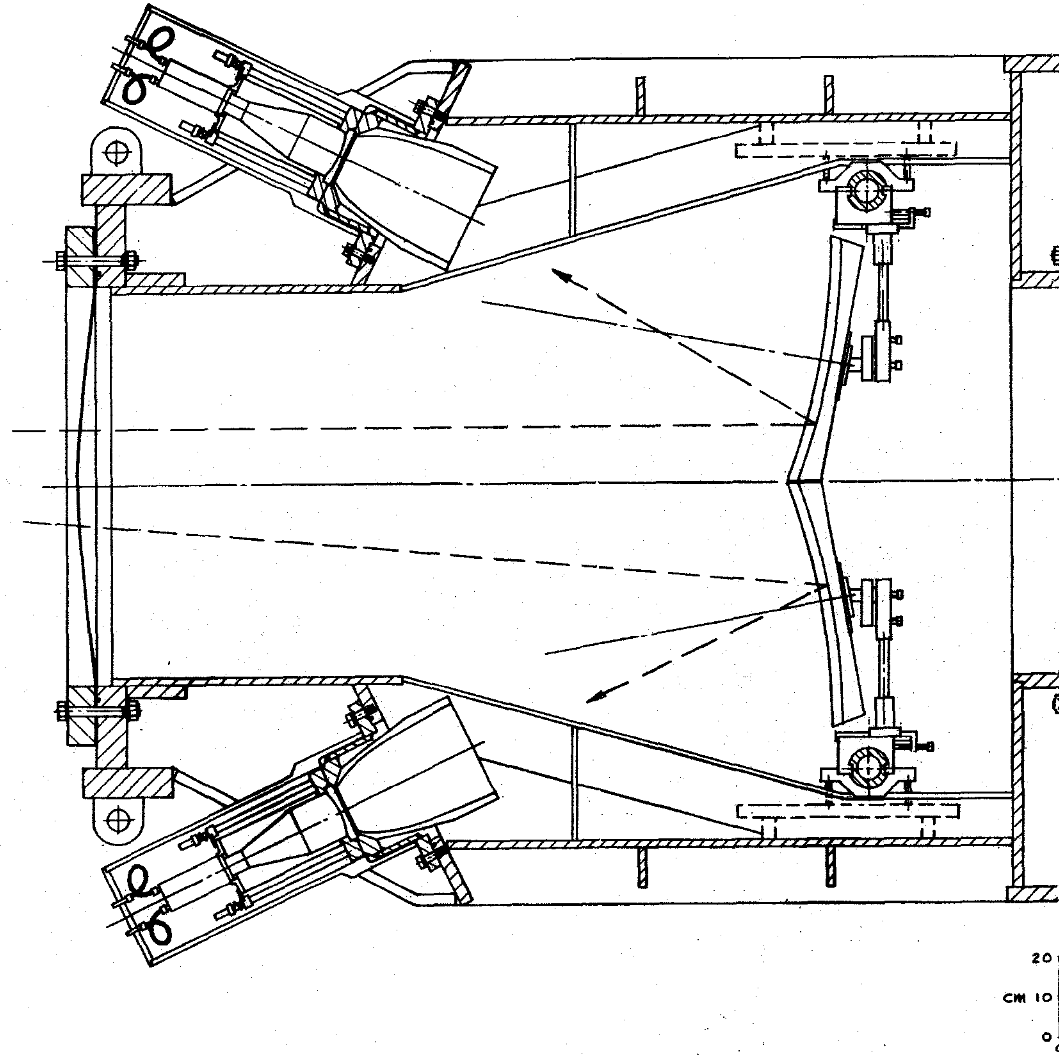
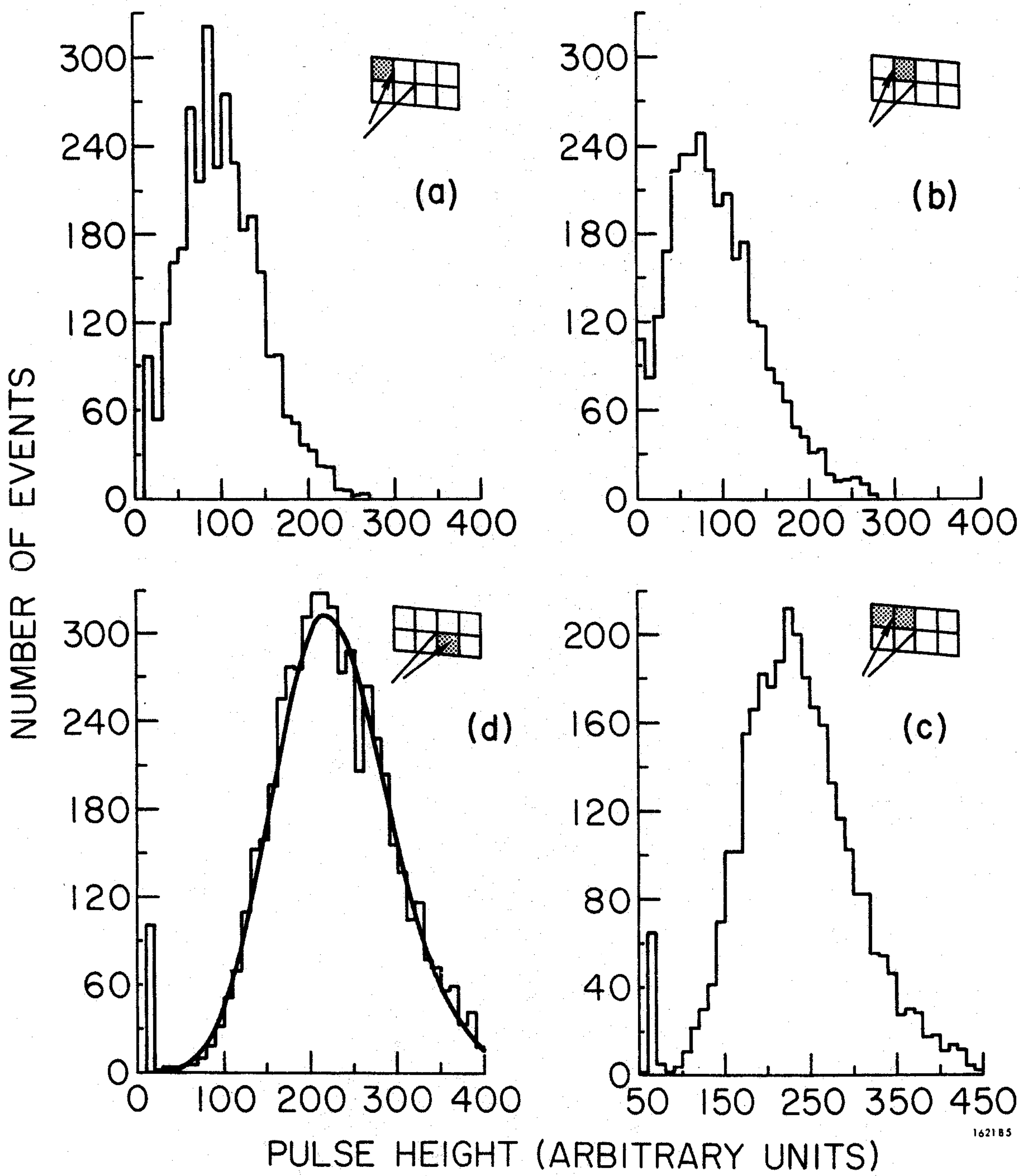
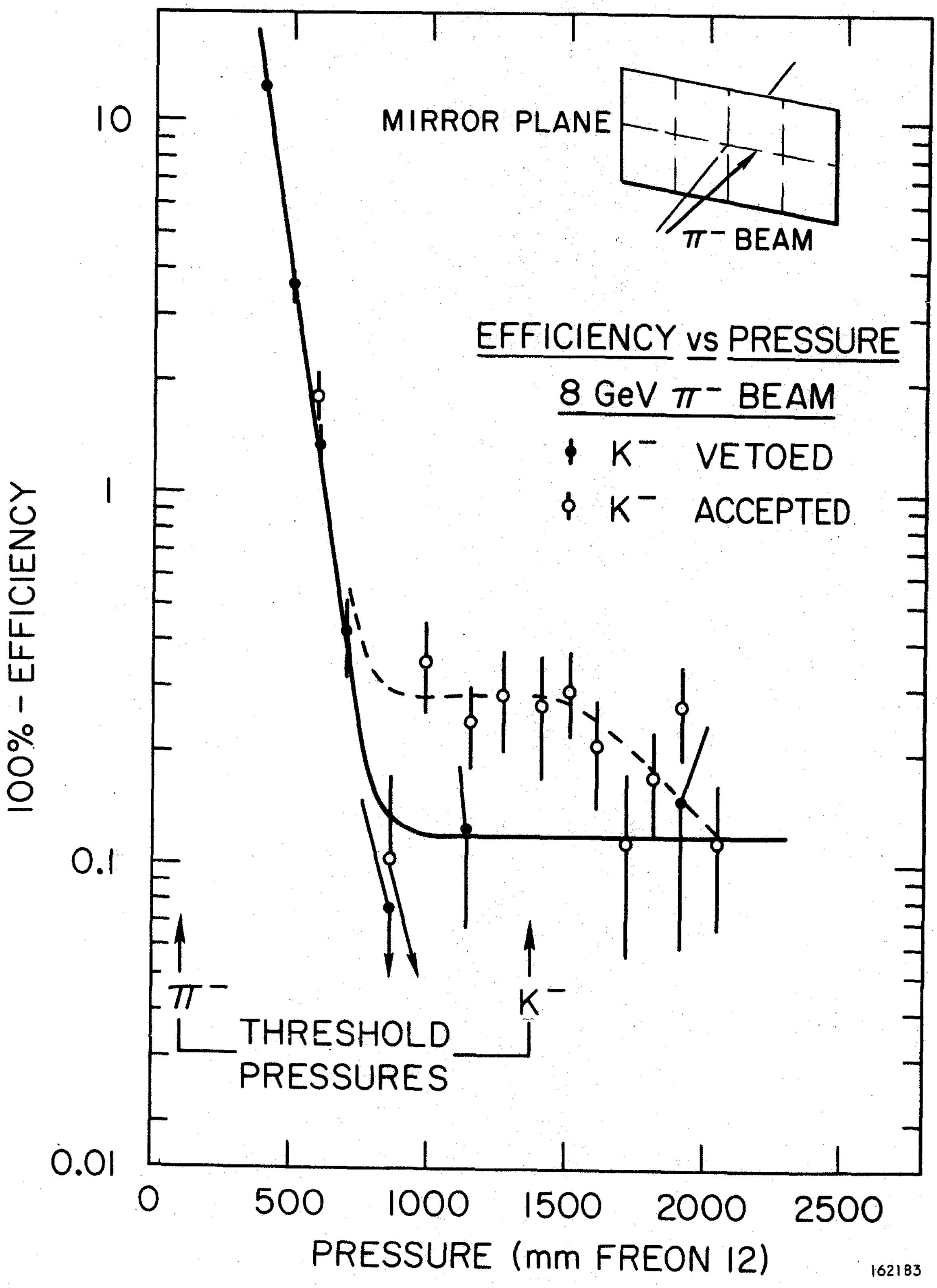


Fig. 2



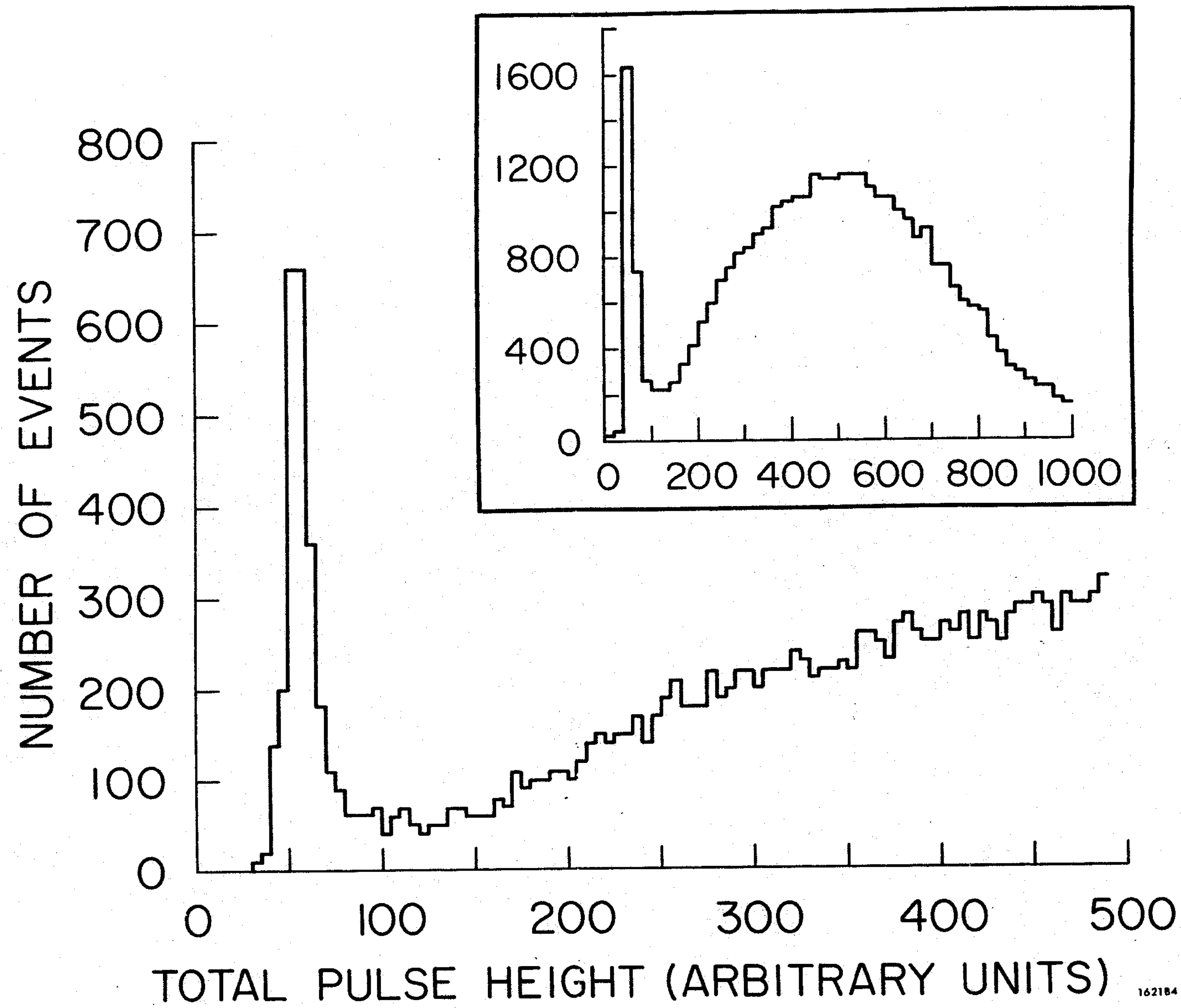
NUMBER OF EVENTS
PULSE HEIGHT (ARBITRARY UNITS)
(a)
(b)
(c)
(d)
0
60
120
180
240
300
200
160
80
40
100
400
50
150
250
350
450
162185

Fig. 3



MIRROR PLANE
π⁻ BEAM
EFFICIENCY vs PRESSURE
8 GeV π⁻ BEAM
K⁻ VETOED
K⁻ ACCEPTED
10
1
0.1
0.01
100% - EFFICIENCY
π⁻
K⁻
THRESHOLD
PRESSURES
0
500
1000
1500
2000
2500
PRESSURE (mm FREON 12)
1621B3

Fig. 4



800
700
600
500
400
300
200
100
0
NUMBER OF EVENTS
0
100
200
300
400
500
TOTAL PULSE HEIGHT (ARBITRARY UNITS)
1600
1200
800
400
0
0
200
400
600
800
1000
162184

Fig. 5