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COMMENTS ON SUBSTITUTING A STREAMER CHAMBER FOR THE BUBBLE CHAMBER IN THE HYBRID BUBBLE-CHAMBER-SPARK-CHAMBER DETECTOR PROPOSED BY FIELDS ET AL.

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Introduction

This report is a discussion of how a streamer chamber might replace the bubble chamber in the proposed hybrid chamber-spectrometer system.

Motivation

T. Fields, A. Roberts, D. Sinclair, J. Vandervelde, and T. G. Walker (A. 3-68-12) proposed a detector system for studying multiparticle final states in reactions occurring with primary beams of momenta up to 200 GeV/c. The limitation on rates of events analyzed is the rate of which the bubble chamber can be pulsed and the number of beam particles that can be sent through the chamber without undue confusion.

First we shall discuss the number of beam particles per picture. Experiments with adequate statistics to resolve resonances and to measure their production and decay angular distributions involve analyzing over 100,000 events per experiment. This number is so large that some form of automatic measuring operation is needed and all current versions (SMP, HPD, Spiral Reader, Polly, and PEPR) do not work well with more than 8-10 beam tracks per picture, particularly at high energies.

So this seems like a reasonable limit to beam tracks per picture.

Then taking the hoped-for cycle rate of 10 per second for the bubble chamber and a fiducial length of 60 cm for useable interactions, there will be 5-6 events per second for a 24-mb cross section. Pictures triggered on lower cross-section reactions would be less frequent. The streamer chamber offers an opportunity to increase the total rate of events by a factor of 2 to 3 and to photograph only events selected by a triggering system. Its thin walls simplify the problem of detecting π^o's. Several arrangements are considered.

Design Considerations

1. The error in measuring momentum in a chamber is given by:

$$(\Delta p)^2 = \left(\frac{0.57\,p}{\beta H\sqrt{X_o \ell_c}}\right)^2 + \left(\frac{2.7 \times 10^2 p^2 \delta_c}{H\ell_c^{\,2}}\right)^2 ,$$

where p is in GeV/c,

H is the magnetic field of the chamber in kG,

X_o is radiation length of the chamber fluid in meters,

ℓ_c is the track length of the particle in the chamber,

δ_c is the setting error of track measurements in the chamber in meters,

β is v/c for the particle.

(Note: for neon at NTP, X_o = 610 meters)

For δ_c we take 3×10^{-4} m in probably unwarranted optimism. Odian finds he must use 5.6×10^{-4} m to get a flat probability distribution in his 2-m streamer chamber.

2.
$$(\Delta p_\perp)^2 \approx (p\Delta\theta)^2 + (\theta\Delta p)^2$$
$$= \left(\delta p \frac{\delta_c}{\ell_c}\right)^2 + \left(\frac{p_\perp}{p_\parallel}\Delta p\right)^2 .$$

(same units)

We are going to need $\Delta p \approx 0.1$ for the highest momentum tracks, and for those $p_\perp/p_\parallel << 1$, so the second term is negligible.

3. Lateral deflection of a particle in the chamber due to the magnetic field:

$$y_m = \frac{1.5 \times 10^{-2} H \ell_c^2}{p} .$$

(same units)

This quantity determines the width of the chamber. The width is determined by y_m for the highest momenta particles to be analyzed in the chamber because by the time lower momenta tracks have been deflected by a distance y_m their momentum can be determined satisfactorily.

4. Aperture of spectrometer magnets.

I shall use the values given by Fields et al., but I shall scale them inversely proportional to the minimum momentum the spectrometer must analyze.

A Direct Substitution of a Streamer Chamber for the Bubble Chamber

The two criteria that fixed the bubble-chamber dimensions and field were that $\Delta p \leq 0.1$ BeV/c and $p\Delta\theta \leq 0.02$ for 5 GeV/c secondaries.

For a streamer chamber, the multiple-scattering contribution to the momentum error is negligible at high momenta, so $\Delta p \sim \delta_c / H\ell_c^2$. The setting error taken was 94×10^{-6} m for the bubble chamber, and H = 40 kG. For the streamer chamber $\delta_c = (300\text{-}600) \times 10^{-6}$ meters, so for the same field

$$\ell_c = 0.5 \text{ m} \times \left(\sqrt{\frac{300}{94}} \text{ to } \sqrt{\frac{600}{94}} \right)$$

$$= 0.9 \text{ m to } 1.3 \text{ m}.$$

If the streamer chamber has a mylar tube of 10 atmosphere hydrogen running through the NTP neon and the interaction length desired were 0.7 m, the streamer chamber would have to be 1.6 to 2.0 m in length.

Notice that if you hold $H\ell_c^2$ constant, the measurement error and the required width of the chamber stay constant. Then if you cut H from 40 kG to 20 kG, ℓ_c only has to be increased by 1.4. Since the cost of big magnets is roughly proportional to H × volume = H × ht × width × $2\ell_c$, it looks cheaper to build a 20-kG magnet with

$$L = 0.7 + 1.4\ (0.9 \text{ to } 1.3)$$

$$= 1.96 \text{ to } 2.5 \text{ meters}.$$

Rates

The streamer chamber could be triggered with a beam particle anti-coincidence trigger. For this type of triggering, the limit of 10-20 events per second set by the camera advance rate could be achieved with 10^4 beam particles per second in a 10 atmosphere, 1 cm^2 tube with a fiducial length of 0.7 m. The limit on event rates for selectively triggered reactions with $\sigma < \sigma_{TOT}$ would be set by the background of undesired tracks in the chamber. If we assume that the memory time for old tracks is 20 μsec and that we would not tolerate more than two "old" events in the same picture as the selected event, then the limit on beam-particle flux is 10^8/sec. With this flux, events with cross sections of $\sigma \geq 2\mu b$ could be photographed at 10/sec. Events with smaller cross sections could be obtained at proportionately lower rates.

Alternatively, it would be possible to trigger the chamber on selected beam particles using Cerenkov counters. Again the selected events could be down by a factor of 10^4 from the background events without too much confusion from "old" tracks.

Conclusion on Direct Substitution

A streamer chamber with one atmosphere of neon, a 10-atmosphere gaseous hydrogen target tube of mylar 1 cm^2 in area, with setting errors of 600 microns could be substituted for the bubble chamber in the proposed hybrid system. With a 40-kG field the chamber should be 2.0-m long, with 20 kG--2.5 m. If the measuring error could be reduced to 300 microns, the length of the chamber could be reduced to 1.6 or 2.0 m respectively. A side benefit of reducing the measuring error and thus the chamber length is that the magnetic deflection of the tracks would be smaller and the horizontal dimension of the downstream spectrometer magnets could be made smaller.

Streamer Chamber if a 100 kG 2.0-m Diameter Magnet Were Available

If it were possible to build a 100-kG magnet 2 m in diameter for a streamer chamber, then the momenta of particles of momenta up to 30 GeV/c could be measured adequately in the chamber, and the first downstream spectrometer would be unnecessary. The chamber would need to be only 30 cm wide. Measurements of angles would not be improved by the increased field, so angles of high-momentum secondaries would have to be measured in the downstream spark chambers.

Downstream Streamer Chamber

Consider a detector system with the streamer chamber in a magnet followed by 2 downstream spectrometers. If the space between the magnet chamber and the first downstream spectrometer magnet (about 2.5 m) were filled with a streamer chamber, several advantages would accrue:

1. The decay vertex of fast unstable secondaries, Λ, k^o, Σ^-, Σ^+, could be located and the decay particles traced into the magnet for subsequent location and identification.

2. Tracing secondary tracks through the fringe field and down into the first spectrometer magnet would be simplified. Since the multiplicity of charged secondaries at these energies is expected to be around 6-10, this capability would be a distinct advantage.

The operational cost of this addition would be the extra film and its processing and the measurement of the pictures. The 2.5-m section could be photographed in two views or 35 mm film with a demagnification of 20 without loss of resolution, so each event would use 25 cm of extra 35mm film (film and processing about 5¢ per foot).

A Speculation

One step beyond the idea of the last section leads to the following possibility. If a streamer chamber 7.5 m long × 1 m wide were placed in a 20-kG magnet, tracks of momenta up to 35 GeV/c could be analyzed for momentum and angle, Λ, k^o, $\Sigma^{\pm}$ decays for particles up to 35 GeV/c would be seen, and the intermediate spectrometer could be eliminated (see Summer Study Report A. 3-63-13). Secondaries could be traced far enough to simplify their identification in the high-momentum spectrometer.

Troubles

At the present time, streamer chambers have problems. Steeply dipping tracks tend to flash and obscure their region of the chamber. The light level is so low that wide-aperture lenses and fast, grainy film has to be used. The resultant images are not of sufficient quality to be measured on contemporary automatic measuring machines.

Neutral-Pion Detection

A significant advantage of the streamer chambers over the bubble chamber is that the thin walls make it possible to get the photons from π^o decay out of the chamber into shower detectors. If the streamer chamber is in a magnet, it becomes difficult and/or expensive to cover the faces normal to the magnetic field. Kruse has suggested two possible methods of solving this problem, shown in Figs. 1 and 2. Both of these methods require expensive increases in magnet gap.

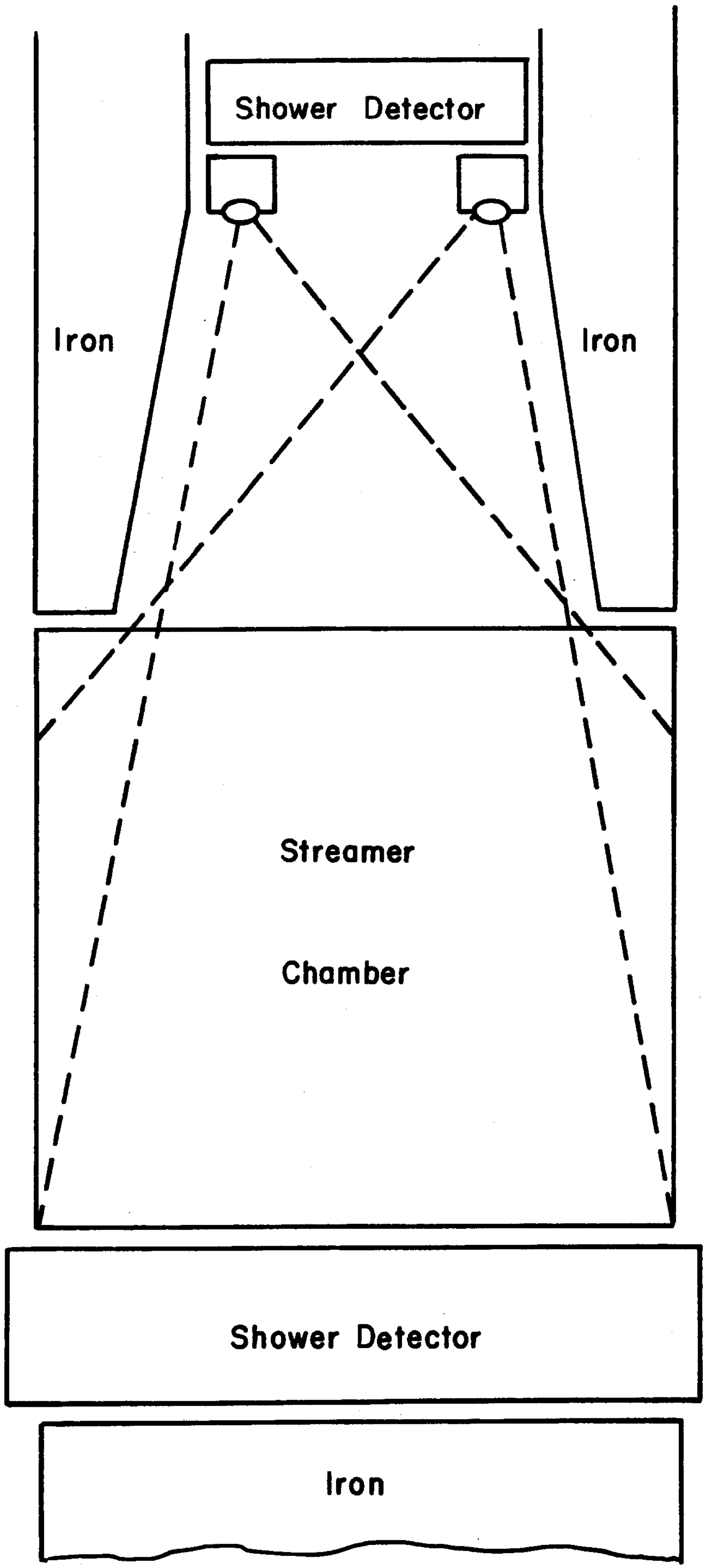

Fig. 1. Large streamer-chamber system (elevation view) showing how shower detectors might be accommodated.

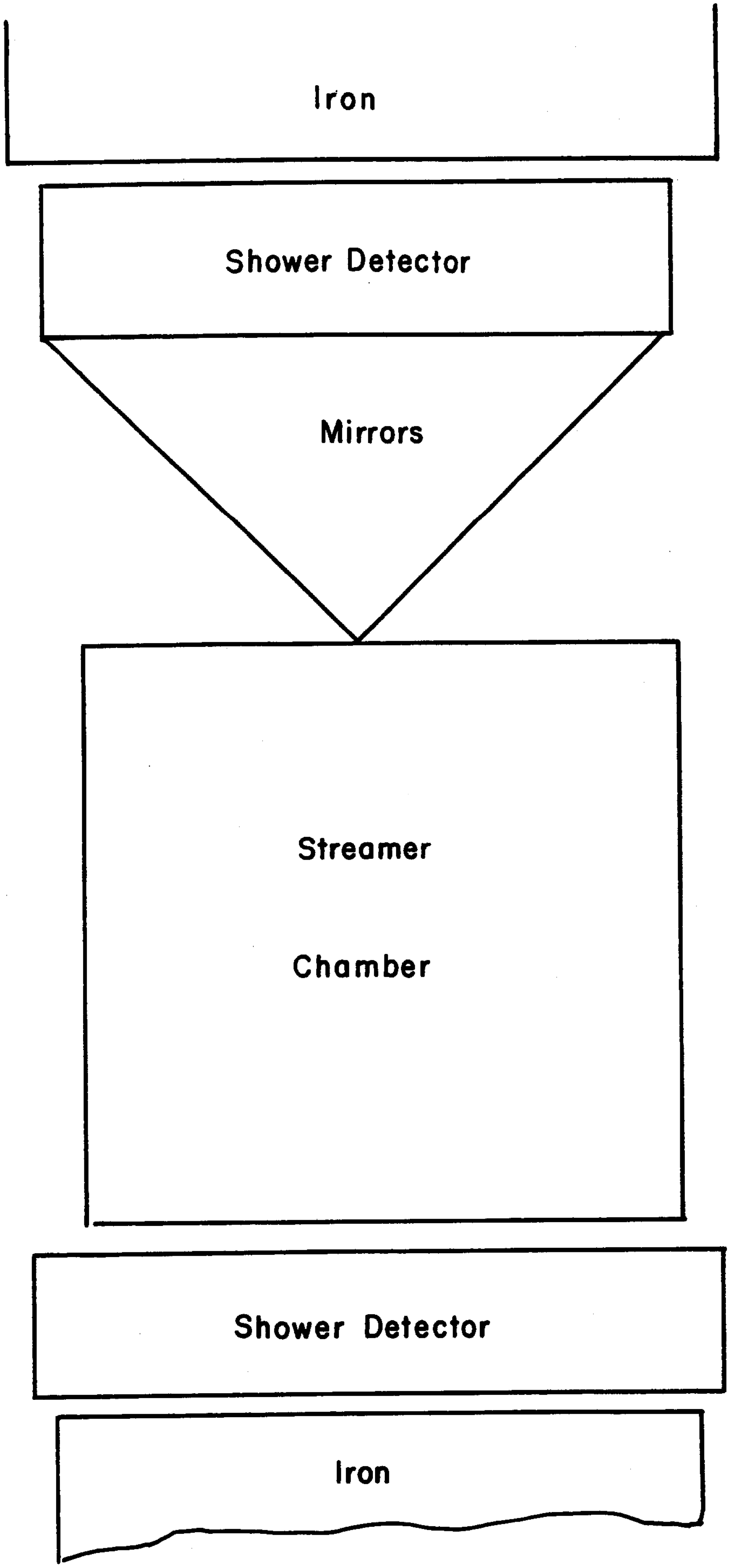

Fig. 2. Alternative procedure for using shower detectors.