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BNL-23468

Conf-770753--1

"CONVENTIONAL" CERENKOV COUNTERS AT ISABELLE *

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One of the aims of the 1977 ISABELLE Summer Study was to define a R&D program to ensure that experiments at ISABELLE would be equipped with the best possible detectors. Since one area of discussion involved new ideas for reading out Cerenkov counters, it seemed appropriate that some thought be given to the design of Cerenkov counters using present-day techniques, if only to set a scale.[1] As an example of large area Cerenkov counters of limited depth I considered the six counters (three on each side of the intersection) proposed in the 1976 Summer Study for the Multiparticle Hadron Spectrometer: The setup is shown in Fig. 1.

In general, focussing Cerenkov counters cover large areas with relatively small angular acceptance for each mirror; light collecting cones of large angular acceptance but small area then transport the light to the photomultiplier tubes. In this case the angular spread of particles hitting a particular area is comparable to that of collector cones (± 20° is typical), so the use of a focussing mirror is not advantageous; I suggest instead the arrangement shown schematically in Fig. 2. A plane mirror assembly is used to reflect the light to collectors and so remove the photomultiplier tubes from the path of the particles; the plane mirrors are also pivoted to permit adjustment of the mean angle accepted by the counter as a function of

*Research carried out under the auspices of the United States Department of Energy under Contract No. EY-76-C-02-0016.

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position. The light collectors consist of compound parabolic cones as described by Winston and Hinterberger.[1] Hexagonal packing of intersecting cones will minimize the number of tubes used while providing continuous collection. Such a system is being built for use at the BNL Multiparticle Spectrometer, providing valuable experience in constructing large, inexpensive, light collecting arrays. The number of photomultiplier tubes needed to cover a given area is proportional to the square of the sine of the acceptance angle of each cone, which will be determined by the physics objective of the experiment - to set a scale, with an angular acceptance of ± 19° at any position an area 4 ft. x 12 ft. requires ≈ 160 2" tubes. Since the area covered by each tube is about 0.3 sq. ft., events with many particles in the counter can be analyzed - the area of the light cone is smaller than the collection area per tube, so determination of the Cerenkov angle for a single particle based on spatial distribution is not favored (pulse height information will be very useful). Because of the awkward shape of the counters I have limited myself to gas radiators at atmospheric pressure.

The principle of operation is to use two Cerenkov counters to separate pions, kaons and protons (or antiprotons) at a given momentum. One needs one counter in which pions count while kaons and protons don't and another in which pions and kaons count while protons don't. Leptons must be identified

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[1] H. Hinterberger and R. Winston, Review of Scientific Instruments 37, 1094 (1966).

separately. I considered the four gases, whose refractive index (Δn, actually) and thresholds are listed in Table I.

TABLE I

Gas	Δn	γ_t	P_t		
			π	K	P
Freon 114	12.5×10^{-4}	20	2.8	10	19
CO_2	4.5×10^{-4}	33	4.6	16.5	31
H_2	1.4×10^{-4}	60	8.4	30	56
He	3.5×10^{-5}	120	17	60	110

One can "tailor" the refractive indices by choosing other gases or by mixing; a factor of $\approx$ 3 to 4 in Δn for successive counters is appropriate. In calculating the number of photoelectrons to be expected, I used the formula:

$$\text{mean number of photoelectrons} = 150\ell \sin^2\theta$$

where ℓ is the length in cm and θ is the angle of the Cerenkov light. This can be achieved using photomultipliers with quartz windows and gallium phosphide dynodes or, more cheaply, by the use of wavelength shifters in front of ordinary bi-alkali photomultiplier tubes - note that this assumption is rather demanding on the quality of all reflective surfaces and optical contacts.

The mean number of Cerenkov photons emitted per unit length is proportional to the refractive index; since the longest counter shown in Fig. 1 is 3.3 m, the maximum efficiency obtainable ($\beta = 1$) with a He radiator is $\approx$ 97%. This is not adequate for good K-π separation. From the practical point of view I therefore considered counter 1 to have Freon, counter 2 to have CO_2 and counter 3 to have H_2. Table II lists the logic requirements and the momentum range covered by C1 + C2 and C2 + C3.

TABLE II

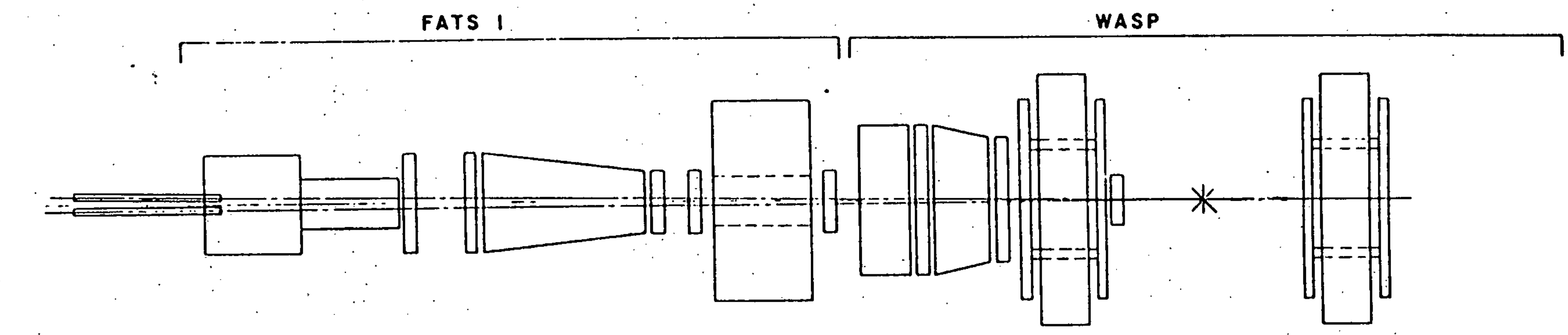
C1 + C2

Particle Selected	Logic	Momentum Range
pion	$C1 \cdot C2$	3-19 GeV/c
kaon	$C1 \cdot \overline{C2}$	11-19 GeV/c
proton	$\overline{C1} \cdot \overline{C2}$	11-19 GeV/c
C2 + C3		
pion	$C2 \cdot C3$	10-30 GeV/c
kaon	$C2 \cdot \overline{C3}$	19-30 GeV/c
proton	$\overline{C2} \cdot \overline{C3}$	19-30 GeV/c

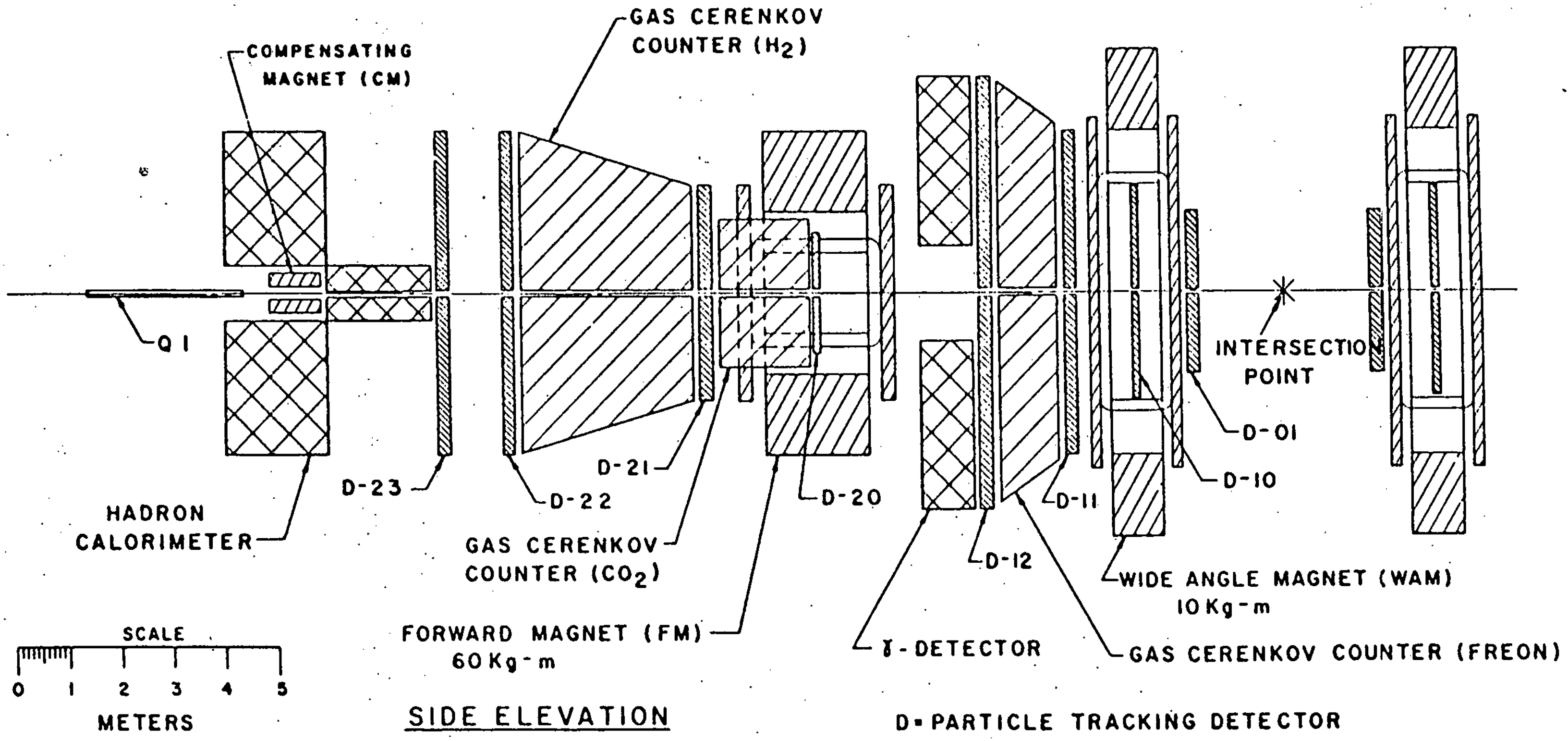
In addition, with an A/D converter for each photomultiplier tube one can use the pulse height information from counter 3 to extend the range of particle separation. By determining the number of photoelectrons one can separate pions from kaons even though both are above threshold. This technique will work up to $\approx$ 40 GeV/c. This principle will also be used in counter 2 to ensure good overlap of the momentum range selected by the two pairs of counters.

In summary, the three Cerenkov counters shown in the 1976 design of the Hadron Spectrometer can be used to identify particles in the range 10-40 GeV/c with pions separated from heavier particles down to $\approx$ 3 GeV/c.

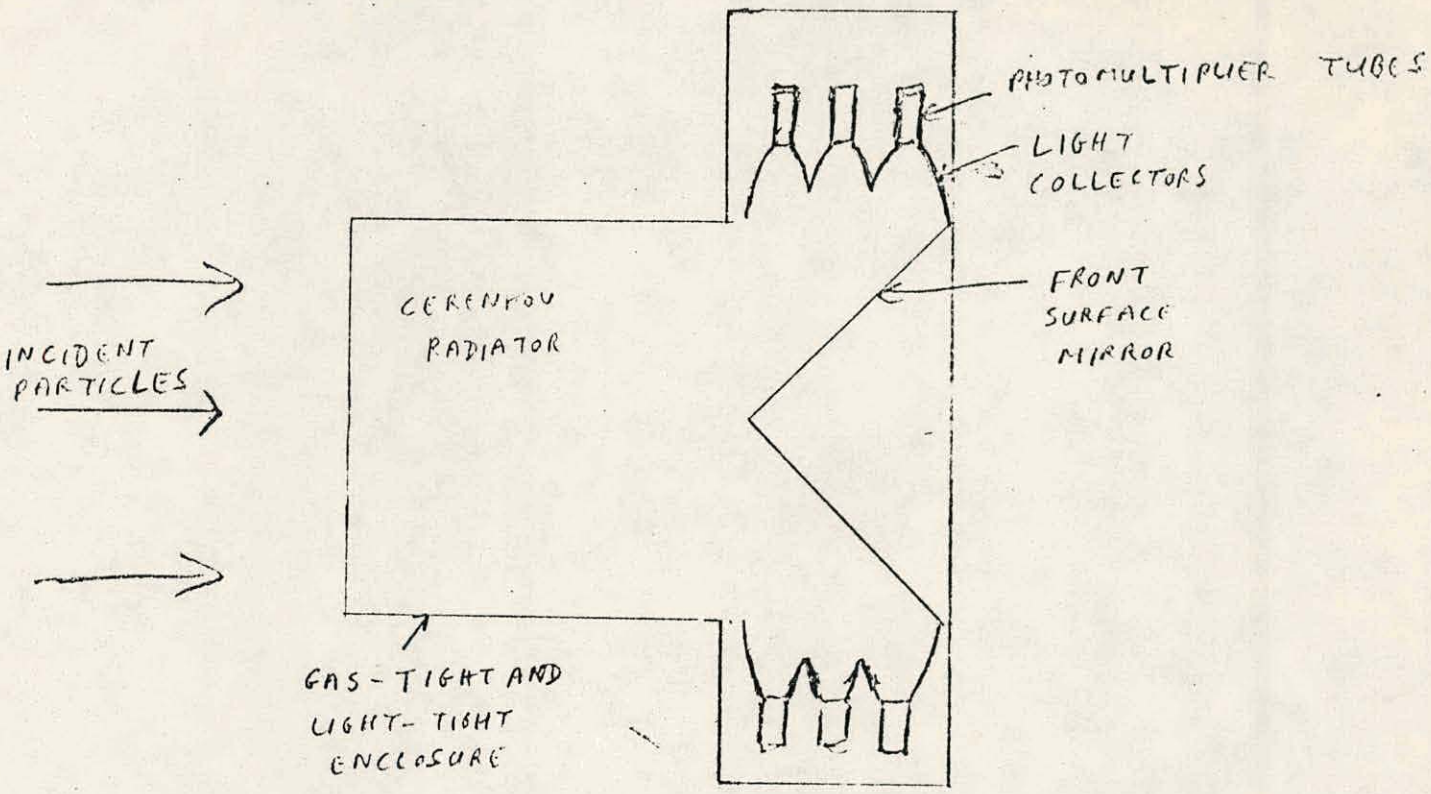
Since I anticipate a somewhat longer spectrometer for 400 x 400 GeV operations, I'd suggest doubling the length of the third counter to 6.6 m in order to extend the useful separated particle momentum to $\approx$ 60 GeV/c. The lengths of C1 and C2 are adequate to use with CO_2 and H_2 respectively, giving a total range of particle identification of 8 to $\approx$ 60 GeV/c with pions separated from heavier particles down to $\approx$ 5 GeV/c.



PLAN VIEW



SIDE ELEVATION



NOT TO SCALE

FIG 2 CAPTION A SIMPLE, LARGE APERTURE, THRESHOLD CERENKOV COUNTER