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TEST OF A SINGLE VOLUME CERENKOV COUNTER/DRIFT CHAMBER DETECTOR*

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ABSTRACT

A prototype detector which utilizes a single gas volume for both a Cerenkov counter radiator and a drift chamber has been built and tested. Such a detector has practical use in high energy physics experiments which require both charged particle momentum measurement and particle identification. The advantage in using such a system is the reduction in size and cost of such a system as compared to the cost of a similar system which uses two distinct gas volumes for the Cerenkov radiator and the drift chamber.

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Most detectors currently in use at colliding beam machines or which are being considered for future colliding beam machines are general purpose, large solid angle multiparticle spectrometers. These detectors generally attempt to do charged particle tracking, calorimetry, and particle identification at some level. The ability to do all of these things well with a single detector is limited by the maximum reasonable size, complexity, and cost that a detector can have.

One method of obtaining particle identification is through detection of the Cerenkov radiation emitted by a charged particle passing through a medium with velocity greater than the speed of light in that medium. By varying the composition or pressure of the gas (in the case of gaseous Cerenkov counters) in the radiator, it is possible to separate electrons, pions, kaons, and protons over a wide range of momenta. Unfortunately, if a full-size Cerenkov radiator is desired in addition to a large central tracking chamber, the resulting detector can become very large and expensive.

Another drawback of a separated function detector such as this is the amount of material which separates the Cerenkov radiator volume from the interaction region. This results from the fact that the tracking chamber almost always precedes the Cerenkov radiator volume. This is particularly serious for applications involving electron identification as the photon conversion probability is proportional to the amount of material through which the photon passes. This produces a serious background for the direct-electron events of interest.

I have investigated the possibility of using a single gas volume for both the Cerenkov radiator and the tracking chamber. A combined

Cerenkov counter/drift chamber detector in which the field shaping and sense wires were strung through the radiator volume was built and tested. Such a detector solves the size problem and reduces the background problem discussed above. However, there are other problems which must be considered. A gas must be chosen that is satisfactory for both the tracking chamber and the Cerenkov counter application. A more serious problem is the scintillation in the gas due to the presence of the large electric fields which are required for charge multiplication. This scintillation has been studied in terms of its application to the detection of X-rays with good energy resolution [1]. For the application at hand, it is possibly a serious background. However, as discussed in this paper, it is possible to differentiate the Cerenkov signal from the scintillation background by means of timing.

A prototype detector, shown in Fig. 1, was constructed to test the feasibility of operating a combined Cerenkov counter/drift chamber detector and to determine the effects of the produced scintillation light on the ability to observe the Cerenkov radiation. The apparatus provides a radiator volume for the production of Cerenkov radiation with a length greater than one meter. Tests were made with vertical cosmic rays which traversed the entire volume as defined by scintillation counters above and below the detector. The optical system consists of a 5-inch 58DVP photomultiplier tube and a front-face reflecting mirror to reflect the Cerenkov light into the photomultiplier tube. The mirror has an SiO coating to reflect in the far UV. There is no window between the radiator volume and the tube face to reduce transmission efficiency.

Wires were strung across the radiator volume in a direction perpendicular to the plane of Fig. 1 to form four layers of six drift cells each. Each cell consists of a central sense (anode) wire surrounded by four field shaping wires. Adjacent cells share pairs of field wires. The dimensions of the drift cells are 0.75 in. × 0.75 in. and are 12 inches in length. The signal from each sense wire is carried via a 50Ω coaxial cable to a front-end circuit employing a LeCroy LD604 discriminator and preamplifier. Signals from all cells are OR'd together to provide a single signal to be used for timing purposes.

Figure 2 shows the time distribution of the signal observed by the 58DVP photomultiplier tube relative to the time of the cosmic ray trigger. (A standard single-hit time-to-amplitude converter was used for the measurement.) There was no high voltage on either the sense or the field shaping wires. The gas used was a 95% Ar-5% CO_2 mixture, slightly above atmospheric pressure. A narrow signal ($\sigma < 2$ ns), in time with the cosmic ray trigger, is observed with very little background. This signal is due to the Cerenkov radiation produced by the passage of cosmic rays.

Figure 3 shows the corresponding time distribution after application of -2300 V to the field shaping wires. (The voltage on the drift chamber wires was determined from a measurement of the drift chamber efficiency for tagged cosmic rays as a function of high voltage.) The in-time signal corresponding to the produced Cerenkov radiation is still clearly visible, but there is also a background which results from scintillation in the gas and extends for a few hundred nanoseconds past the in-time signal. This time span is consistent with the expected

200 - 300 ns maximum drift time in the cell. Within the statistical uncertainty of the measurement, there is no evidence for additional events produced within approximately 10 ns of the in-time signal when high voltage is applied to the chamber relative to the case when there is no applied high voltage. It should be noted that the time of only the first signal observed by the 58DVP after the cosmic ray start signal is measured. Thus, in cases where Cerenkov radiation is observed, no signal from possible scintillation light will be observed. However, since the observed Cerenkov rate is on the order of 7% (which is consistent with estimates based on a threshold at about 5 GeV/c for muons and taking into account inefficiencies in the system), this implies only a minor correction for events lost from the distribution.

Figure 4 shows the 58DVP time distribution relative to the time of the drift chamber anode signal. In order to eliminate ambiguous drift chamber signals, only one of the four drift cell layers was utilized. The correlation in time between the two signals is seen to be quite good. One expects approximately 10% of the events (i.e., those due to actual Cerenkov radiation) to be spread out over a few hundred nanoseconds at negative times. This is consistent with the observed tail for negative times.

The narrowness of this distribution compared to the distribution in Fig. 3 shows that the scintillation light is essentially all produced at the time that the electron reaches the anode wire. It is believed that the scintillation process is due to the radiative de-excitation of excited molecules [2]. Thus, one would expect the distribution to be exponential. The time distribution in Fig. 4 was fitted to an exponential e^{-at} convoluted with a Gaussian resolution function. The resolution function was included to account for time jitter in the electronics and variations in the time of molecular formation relative to the signal time on the anode wires. The best fit is shown as the dashed curve in Fig. 4. The fit gives a value for the slope of $a = 0.060 \pm 0.002\ ns^{-1}$ (statistical error only) and the resolution of the Gaussian as $\sigma = 3$ ns.

It is known that the scintillation yield in non-noble gases, for instance methane or nitrogen, is considerably lower than in argon for a given value of the high voltage [3]. Extensive tests were made with methane gas in the detector. Whereas the scintillation yield was found to be considerably lower with methane gas than with the Ar-CO_2 mixture at the high voltages used for the Ar-CO_2 tests, it was necessary to increase the high voltage considerably to get sufficient charge multiplication to observe signals on the drift chamber wires. At these higher voltages, the scintillation was found to be comparable to the scintillation in the Ar-CO_2 mixture at lower voltage. Thus, in terms of reducing scintillation, no advantage was found in using methane rather than Ar-CO_2.

Figure 5 shows the scintillation yield in both Ar-CO_2 and methane as a function of high voltage. These results cannot be compared directly to other results in the literature [3] as only one signal per cosmic ray crossing can be observed with this experimental setup (as discussed earlier). In addition, scintillation yield is measured in terms of number of coincidences in this experiment, rather than number of photons as is customary. A coincidence can result from detection of a few or many photons. Nevertheless, one observes that the yield increases sharply with high voltage. Thus, the scintillation yield can be minimized by running at the lowest possible voltage at which drift chamber efficiency is not compromised.

The usefulness of a combined Cerenkov counter/drift chamber detector, such as the one described here, depends on how well the Cerenkov signal can be separated from the scintillation background. A detector of this type which utilizes a fast photon detection system (e.g., photomultiplier tubes) should be able to do a reasonable job of separating the Cerenkov radiation from the scintillation background. However, if the application for which such a system is to be used does not permit the use of photomultiplier tubes, one may have difficulty in separating the signals by timing. For instance, a photoionization chamber [4] used for photon detection may have a resolution of as long as a few hundred nanoseconds. (The exact resolution depends on wire spacing, etc). Thus, the Cerenkov signal and the scintillation background would be smeared and overlap, making separation, and hence particle identification, impossible. (There is an additional uncertainty due to the fact that photomultiplier tubes are sensitive to a different part of the spectrum than photoionization devices. The effects of this difference have not been examined.) However, it should be possible to identify the Cerenkov signal, even if a photoionization technique is used for detecting the photons, by separating the anode sufficiently from the track trajectory so that the drift time is longer than the resolution of the photoionization device. Possible methods of accomplishing this include construction of detectors with very wide drift cells, or time-projection chambers with long drift distances to the endplates. Such detectors would only be insensitive to Cerenkov radiation very near the anodes.

One aspect of the scintillation light which has not been taken full advantage of is the fact that this light is radiated isotropically. With a sensitive detector with good spatial resolution, it might be fairly simple to separate clusters of photons resulting from Cerenkov radiation from the isotropic scintillation background. Another improvement can be made by using more sensitive preamplifiers on the chamber wires. This allows the detector to be run at lower voltages where the scintillation yield is considerably reduced.

To conclude, a chamber which makes use of a single volume for the Cerenkov radiator and the drift chamber was successfully tested. It appears likely that such a system can be used in a large scale detector to provide both charged particle tracking and particle identification. The savings in terms of size and cost over a standard, separated volume system could be considerable.

REFERENCES

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FIGURE CAPTIONS

Fig. 1. Schematic of the experimental apparatus.

Fig. 2. 58DVP time distribution relative to cosmic ray trigger with no high voltage on chamber.

Fig. 3. 58DVP time distribution relative to cosmic ray trigger with -2300V on field shaping wires.

Fig. 4. 58DVP time distribution relative to drift chamber signal.

Fig. 5. Scintillation yield as a function of chamber high voltage for Ar-CO_2 and methane.

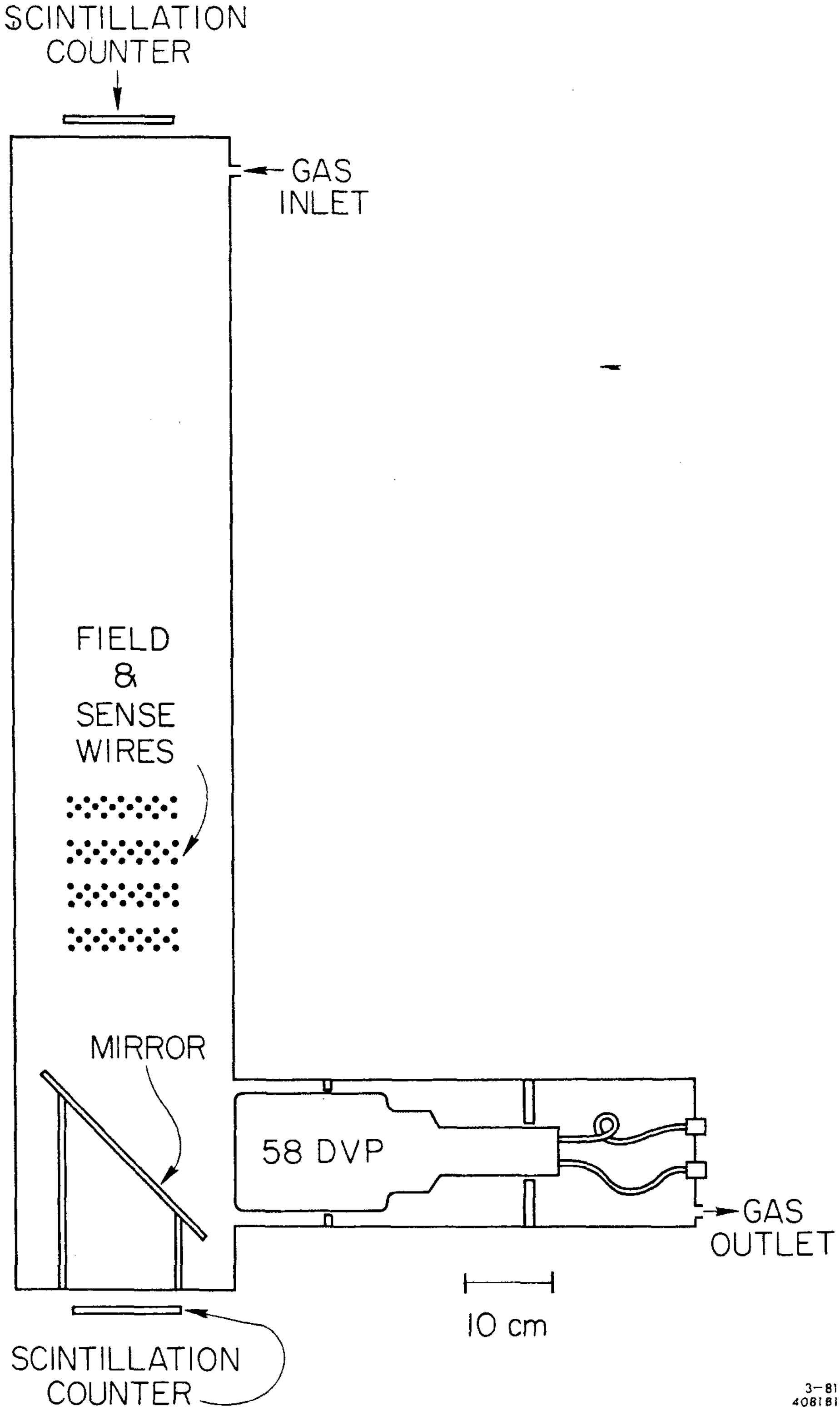
SCINTILLATION
COUNTER
GAS
INLET
FIELD
&
SENSE
WIRES
MIRROR
58 DVP
GAS
OUTLET
10 cm
SCINTILLATION
COUNTER
3-81
4081B1

Fig. 1

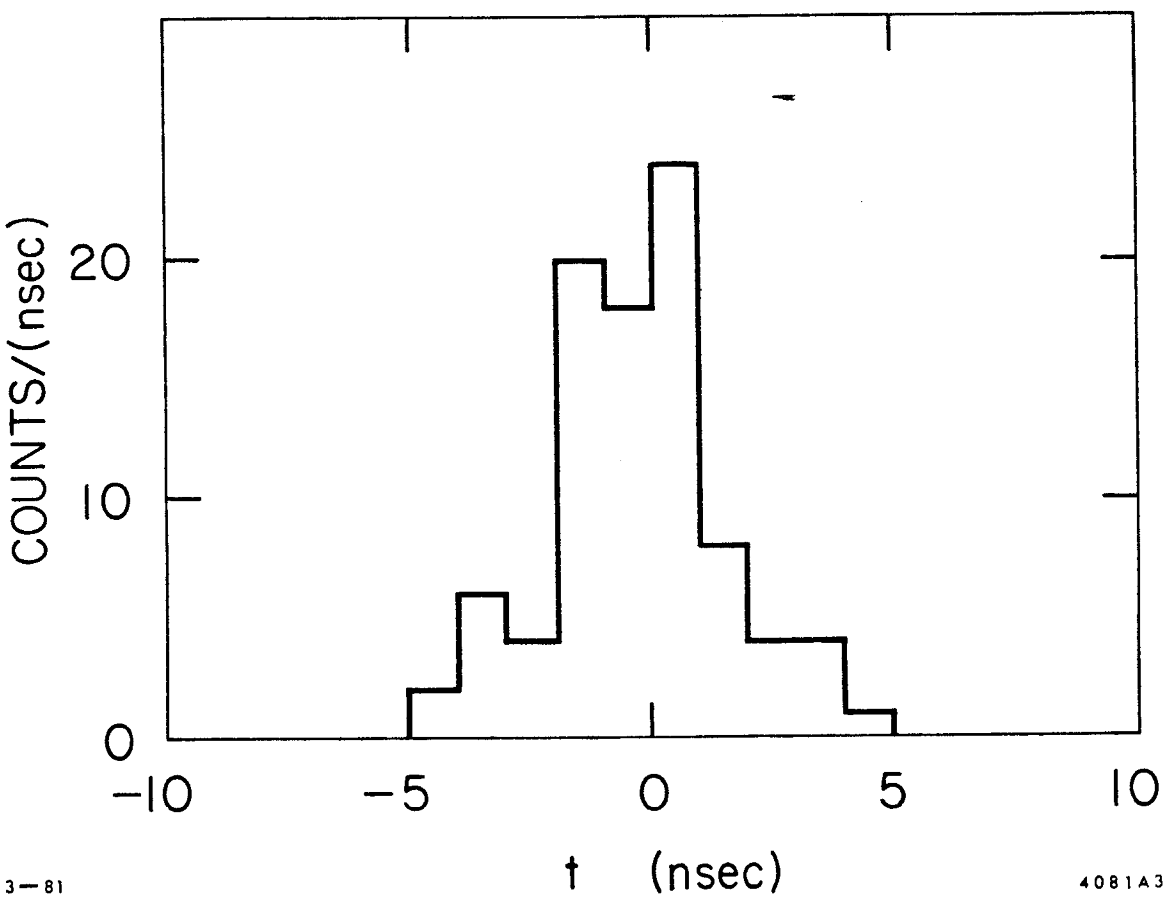

Fig. 2

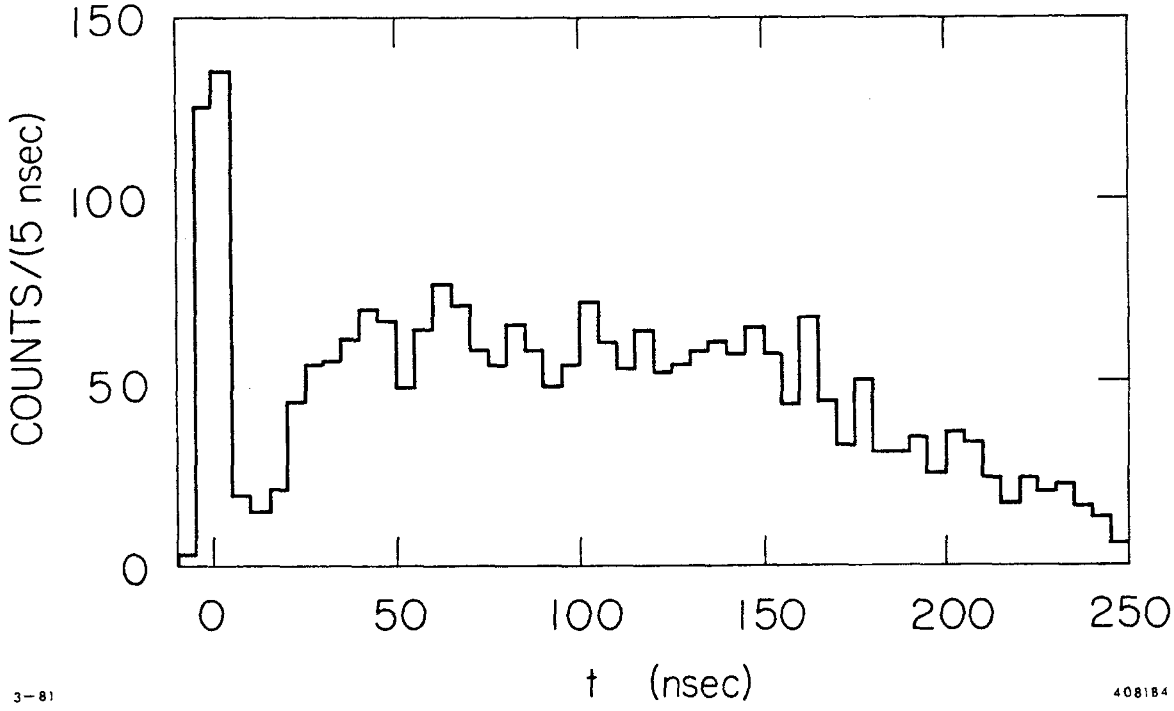

Fig. 3

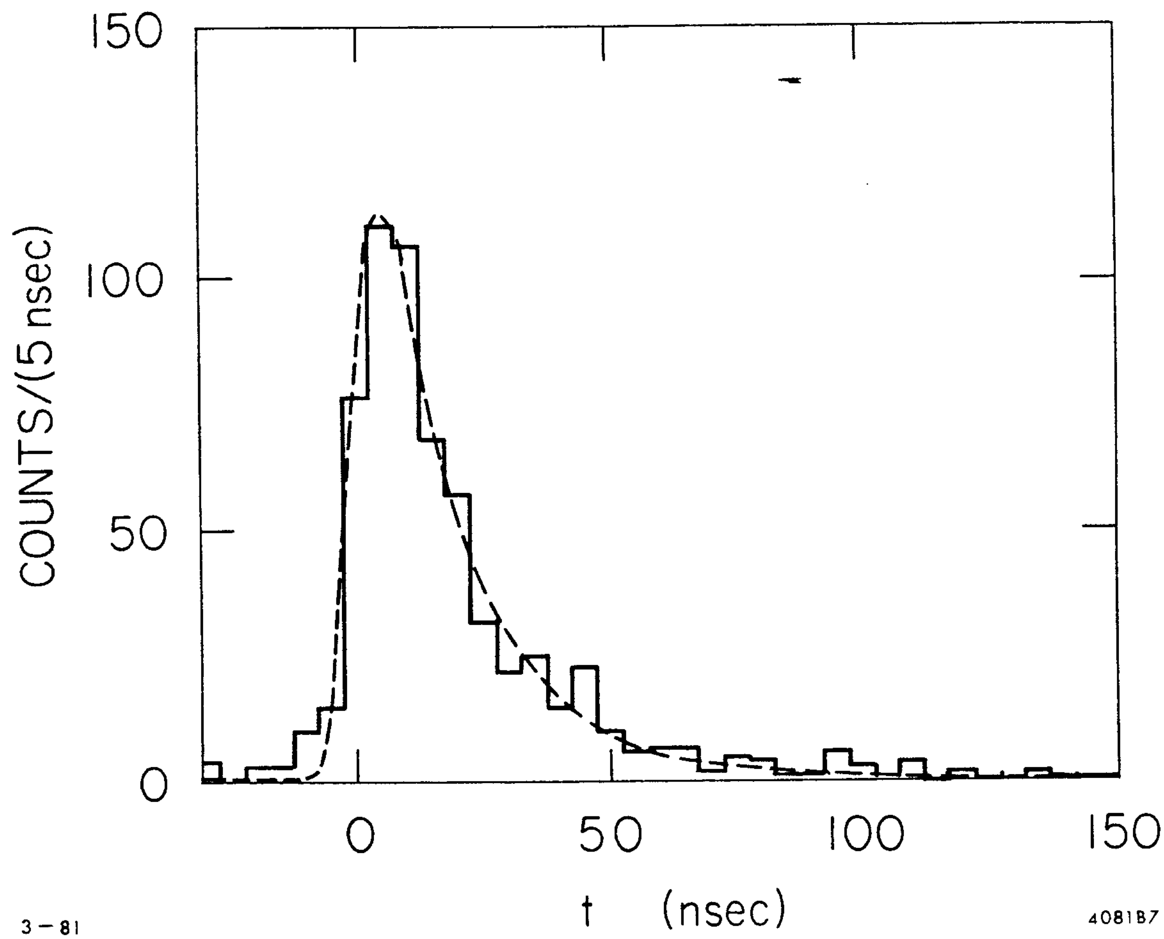

Fig. 4

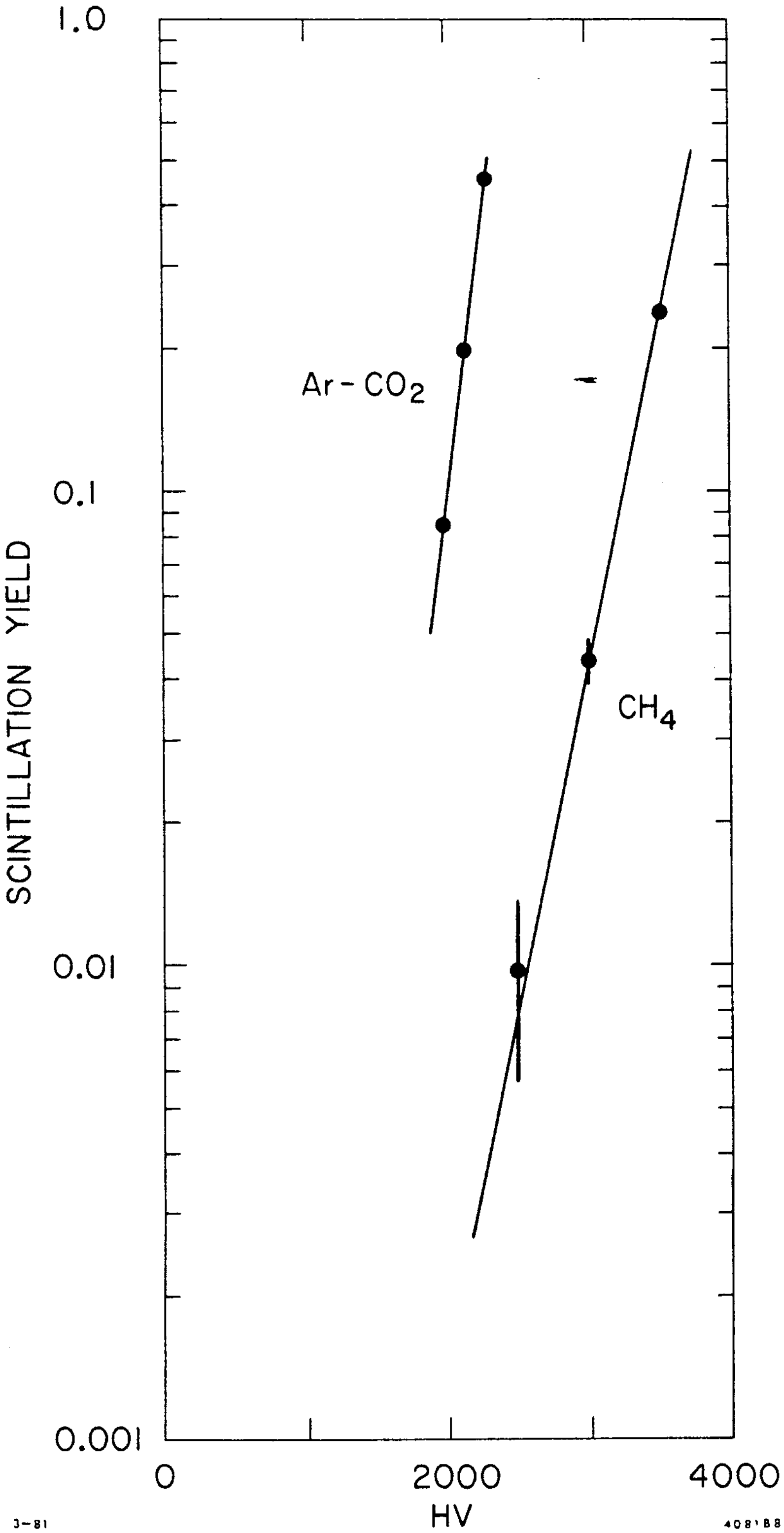
1.0
0.1
0.01
0.001
SCINTILLATION YIELD
Ar - CO_2
CH_4
0
2000
4000
HV
3-81
408188

Fig. 5