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CERENKOV COUNTERS AT ISABELLE+

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The following is a brief summary of our study of Cerenkov counters for ISABELLE. This study was certainly not exhaustive and was meant primarily to suggest future detector development.

The most simple Cerenkov counters that can be used are threshold counters where the light is focussed on phototubes. A likely application of these devices at ISABELLE will occur in large-angle, small-aperture magnetic spectrometers for the measurement of particle yields at large p_T. Three threshold counters, such as those used in a Fermilab experiment,[1] will provide complete π-K-p separation in the range from 7-20 GeV/c. This p_T range is well matched to the expected luminosity and particle yields at ISABELLE. The use of standard threshold Cerenkov counters in other application appears less attractive. For example, at small angles where particle momenta extend to 400 GeV/c very long counters are required since their length scales with the square

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1. D. Bintinger, R.A. Lundy, D.D. Yovanovitch, C.W. Akerlof, P. Alley, D. Koltick, R.L. Loveless, D.I. Meyer, R. Thun, W.R. Ditzler, D.A. Finley, F.J. Loeffler, E.I. Shibata, and K.C. Stanfield, Phys. Rev. Lett. 37, 732 (1976).

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of the momentum. Another example is a large-aperture spectrometer where the requirements of good segmentation and likely pressurization of counters present formidable mechanical problems. A more extensive discussion of standard Cerenkov techniques for ISABELLE is given in a separate paper by K. Foley.[4]

More compact and powerful Cerenkov counter systems than those outlined above can be achieved if the Cerenkov angle defined by $\cos \theta = 1/n\beta$ is measured. Particle identification by this technique requires correlatable measurements of charged particle tracks, momenta, and associated Cerenkov radiation. Detectors with such a capability have been suggested by Seguinot and Ypsilantis[2] based on photoionizing devices (to be discussed below) and by Kostoulas and collaborators[3] who propose the use of image intensifiers and CCD arrays. In the latter scheme, Cerenkov light generated in freon 12 or SF_6 is focussed on an image intensifier with a gain of 10^4-10^5. Light from the fast phosphor output of the intensifier is then refocussed on a CCD array which employs, for the sake of high-rate operations, two parallel outputs per cell which are cleared alternately with a frequency of 0.5 MHz. With this system 2σ π-K separation is expected between 5 and 65 GeV and K-p separation between 10 and 100 GeV.

As stated above, Seguinot and Ypsilantis have suggested a Cerenkov counter where the radiation is detected by a photoionizing

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[2] J. Seguinot and T. Ypsilantis, Nucl. Instr. Meth. 142, 377 (1977).

[3] Fermilab Proposal 556.

[4] K.J. Foley, "'Conventional' Cerenkov Counters at Isabelle", these proceedings.

device. In this scheme the radiator is a spherical shell of inner and outer radius R/2 and R respectively, with the inner surface being the window of the photoionization detector. If the particles come from a point source then the Cerenkov light is focussed by the spherical mirror (radius-R) into a ring at the window of the photoionization detector. The photoelectrons are detected by needles run as Geiger counters.

We believe that the significance for ISABELLE of the Seguinot and Ypsilantis approach lies more in the general nature of the technique than in the specific features of their proposal. The significant idea is to detect ultraviolet Cerenkov light by photoionization and gas multiplication of the resultant electron. The potential advantages of such Cerenkov counters are very attractive. They include:

1) Improved photon statistics because of higher quantum efficiency and possibly broader frequency acceptance. This allows a reduction in Cerenkov counter dimensions which is clearly important for many ISABELLE detector configurations.
2) Detection of Cerenkov light with high spatial resolution because of the use of relatively cheap wire amplification systems. The measurement of particle velocities by the determination of Cerenkov angles is thus made feasible.
3) Operation of threshold counters in high magnetic fields. Wire-based amplification systems operate in much higher fields than do phototubes.

4. Ease of segmentation of large aperture threshold Cerenkov counters.

For successful application of this idea we need a Cerenkov media transparent to the far ultraviolet, a good ultraviolet window, a photoionizing gas with high ultraviolet absorption, and a readout system. There is a need for a considerable amount of research and development work before we can have practical components, as is indicated in the following brief discussion of the present state of the individual components. Very few Cerenkov media are known to be suitable for these detectors. Most substances (including air and water vapor!) are opaque in the far ultraviolet. The inert elements are transparent as is N_2. For argon and N_2 at STP, $n-1 \approx 56 \times 10^{-5}$ at around 10 eV. It should be noted that dispersion which has not been well measured or understood in the vacuum ultraviolet region, must be carefully considered in the design of a Cerenkov counter. We therefore recommend a program to study these materials and search for and catalog other Cerenkov media, in order to more fully exploit the photoionizing Cerenkov counter.

Presently used window materials are LiF, MgF_2 and plastic films. LiF has the highest known transmission cutoff at 11.8 eV. Although it is sensitive to moisture and becomes opaque under intense ionizing radiation, LiF could be a practical window because the transmission properties can be restored by baking (which could even be done in situ). MgF_2 is much more resistant to moisture and radiation and still has a high cutoff energy at

10.8 eV. Very thin films of plastic have been used and may prove useful for reasonably sized counters. Because of the short range of the photons in the ionizing gas it is necessary to have the cathode plane very close to the window. This requirement and the difficulty of making large windows out of any of the previously mentioned materials dictates that new construction techniques or new materials be developed. One suggestion is to deposit or grow window material on a wire mesh that would serve as the cathode; it remains to be seen if good optical properties can be obtained this way.

The photoionizing gas must have several properties. It must be a good proportional counter gas with the usual quenching ability and it must of course have a large ionization cross section for ultraviolet light. Seguinot and Ypsilantis have shown that an argon-CO_2 mixture doped with benzene satisfies these requirements. Benzene has a photoionization threshold of 9.2 eV. A number of organic substances (see Bibliography and Fig. 1) are known to have thresholds appreciably below this (down to about 6 eV). A major effort should be made to study their feasibility in photoionizing detectors since the number of Cerenkov photons available for detection is proportional to the frequency interval between ionization threshold and window cutoff.

If one is only interested in having one dimensional readout of the photon position (such as in a threshold counter), one can use standard multiwire proportional chamber techniques to detect the photoelectron. If two dimensional information is required (such as to determine the Cerenkov angle) then techniques such as charge division, delay line readout of induced cathode signals, or readout of individual cathode pads might be used. These techniques suffer from disadvantages such as poor time resolution, poor two electron resolution and high expense. The suggestion by J. Seguinot and T. Ypsilantis of using many small Geiger cells with needles is appealing but it has proven difficult to construct a large array of needles with a uniform plateau. Also the electron collection efficiency of simple needle arrays is low (∿ 10%) and some focussing structure must be developed to get high efficiency. Another way to have two dimensional readout is the suggestion of Leith and collaborators to use a segmented anode wire readout in which the PWC anode is made in short lengths mounted on a printed circuit, each length being read out individually. This idea requires further investigation to see if large chambers can be built that are stable and reasonable in cost.

In summary we would like to emphasize the need for a substantial research effort to be mounted in order to insure that Cerenkov counters utilizing photoionization are fully exploited. In the hope of stimulating interest in this topic we are including a Bibliography of relevant literature. We would like to thank N. Kublin for her extensive help in the preparation of the Bibliography.

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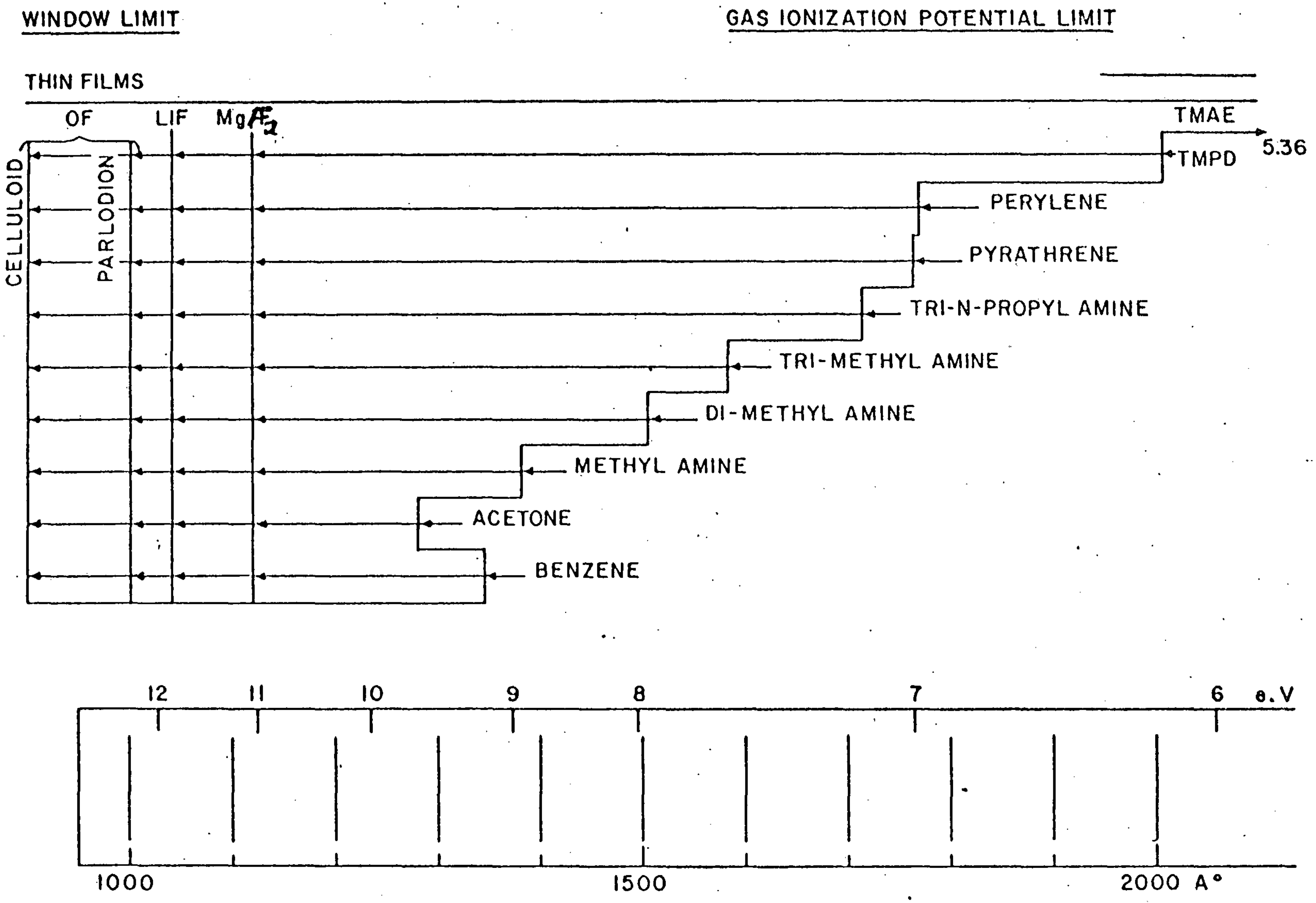
FIGURE CAPTION

Fig. 1 Ionization potential limit of various gases and ultraviolet transmission cutoff of window materials.


WINDOW LIMIT
GAS IONIZATION POTENTIAL LIMIT
THIN FILMS
OF
LIF
MgF_2
CELLULOID
PARLODION
TMAE
5.36
TMPD
PERYLENE
PYRATHRENE
TRI-N-PROPYL AMINE
TRI-METHYL AMINE
DI-METHYL AMINE
METHYL AMINE
ACETONE
BENZENE
12
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