DETECTOR DEVELOPMENT SUMMARY **

E.D. Platner, BNL

H.H. Williams, University of Pennsylvania

Ninety of the 1978 ISABELLE Summer Study participants showed special interest in detector development. This topic was divided into five subgroups, which were characterized by type of detector. Table 1 shows the organization and the names of those who participated.

DRIFT AND PROPORTIONAL CHAMBERS

The subgroup on drift and proportional chambers systematically studied the performance of drift PWCs that may be expected in the high flux environment at ISABELLE; particular effort was devoted to evaluating whether one could simultaneously obtain the desired performance in terms of (1) chamber lifetime, (2) absence of space-charge effects, (3) position resolution, (4) particle identification via dE/dx measurements, (5) double-pulse resolution, and (6) three-dimensional readout. A few of the particularly interesting conclusions are the following.

Chamber Lifetime

Real progress was made in this area since an experiment was actually carried out during the Summer Study; small cylindrical proportional counters filled with different gases were exposed to a high intensity ^{56}Fe source, and the output current and pulse-height distribution were monitored as a function of time. The very encouraging conclusion is that for a chamber filled with Ar, C_4H_{10} (30%), and methylal gas, one can expect the lifetime of the chamber, τ , to satisfy $\eta Q_0 > 3 \times 10^{19}$ per mm where η = charged particle rate per mm of wire length and Q_0 = mean charge per avalanche. If one assumes a chamber with a 1-cm drift cell, $Q_0 = 2 \times 10^5$, and ISABELLE operating at a luminosity $L = 5 \times 10^{32}$, the approximate lifetime as a function of radial distance from the beam is 3 yr for $r = 2$ cm and 75 yr for $r = 10$ cm. However, one word of caution is needed because the proportional counters tested had solid metal cathodes; it is important that the test be repeated with wire cathodes.

Position Resolution

Assuming the noise and risetime specifications for two currently popular amplifiers, we estimated that for $Q_0 = 2 \times 10^5$ one could obtain a time resolution of 2 nsec, and hence a position resolution transverse to the wire of $\sim 100 \mu\text{m}$. For $Q_0 \sim 5 \times 10^5$, however, the estimated position resolution is already degraded to 200 to 300 μm . Similarly, the position resolution along the length of the wire (l) was estimated to be $\Delta l/l \sim 1\%$ for charge

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MASTER

Table 1
Organization and Contributors

Proportional Wire and Drift Chambers

M. Atac	R. Stump
H.B. Jensen	Y. Teramoto *
A. Kanofsky	A.H. Walenta
S.J. Lindenbaum	R. Weinstein
H. Okuno	C.D. Wheeler
P. Rehak	S. White
B. Sadoulet	

Cerenkov Detectors

V. Ashford *	I. Kostoulas
A. Etkin	R. Lanou
A. Honma	T. Watts

Calorimetry

A. Erwin	A.L. Sessoms
H. Gorden	S.D. Smith *
P. Limon	G.J. Tarnopolsky
J.A.J. Matthews	

Hodoscopes and Microchannel Plates

J. Alspector *	I. Kostoulas
S. Borenstein	T.Y. Ling
R. DiNardo	R.B. Palmer
S. Dhawan	R.C. Strand
V. Flaminio	F. Takasaki
G. Kalbfleisch	A.V. Tollestrup

Triggering

G. Abshire	A. Lesnik
J.H. Christenson	G. Moneti
D. Cutts	G.R. Morris
C.T. Day	R.J. Plano
J. Dorfan	M.S.Z. Rabin
B.G. Gibbard	A.L. Read
D.A. Jensen	M. Sakitt *
R.A. Johnson	J. Sculli
L.E. Kirsch	J.A. Thompson
P.F.M. Koehler	E. Willen
K. Kondo	

* Subgroup Chairman.

division and $\Delta l/l \sim 0.15\%$ for delay-line readout, assuming $Q_0 \sim 2 \times 10^8$. This resolution is estimated to degrade as $1/Q_0$ which again implies that it will not be feasible to operate at significantly lower charge per avalanche.

Cathode strip readout, where the charge induced on several strips is encoded, can provide a position resolution of 0.3 mm for an avalanche size of 2×10^8 electrons. One can thus obtain three-projection stereo of a single avalanche with cathode strips at two different angles to the anode readout.

dE/dx Measurements and Particle Identification

Considerable effort was applied to the problem of particle identification by ionization measurements. Perhaps the most interesting development is the prospect of improving dE/dx resolution by either counting the avalanches or at least encoding the time development of the charge collection. It is anticipated that improvement by a factor of $\sqrt{2}$ to 2 may be realized over the more conventional methods in which the total charge is integrated. Unless this potential factor of 2 improvement in dE/dx resolution can be realized, serious compromises between momentum resolution and particle identification are required because of the substantial multiple scattering in the gas.

CERENKOV COUNTERS

The subgroup on Cerenkov counters studied several approaches to particle identification using Cerenkov radiation. One approach is to use conventional threshold Cerenkov counters to distinguish π , K, and p in the range 0.5 to 60 GeV/c. The counter would contain eight different radiators and extend 8 m from the interaction region. To enable it to handle the expected event rates and to distinguish the 20 or so particles per event, each layer would be segmented into 10^4 cells. The mechanical difficulty of supporting 10^5 cells over a radius of 8 m is enormous if not insurmountable. A possible solution to this dilemma using photoionization detectors is discussed.

A second approach to particle identification considered is the spherical imaging Cerenkov counter. If the photon detector had a position resolution < 0.5 mm, it would have 4π coverage and resolve π/K between 6 and 75 GeV/c, provided, of course, that other detectors measured each particle's momentum. A PWC photoionization detector is, in principle, capable of such resolution; however, difficulties remain in finding suitable materials for the barrier window separating the radiator and detector gases. More work is also required to develop gas mixtures having broader photoionization spectra for the PWCs. Also discussed in this connection is the use of photosensitive CCDs, possibly coupled to image intensifiers. Two other detector methods, both of which require considerable development but offer promise, are microchannel plates with multi-anode readout and arrays of avalanche photodiodes.

In Appendix D-I, two examples of possible experimental halls for ISABELLE are given to compare the various Cerenkov techniques. In Appendix D-II, recent developments in microchannel plates are reviewed.

CALORIMETRY

It is certain that calorimetry will play an important role in most of the intersecting areas at ISABELLE, and the calorimetry subgroup focussed its attention on which types of calorimeters will be most suitable for a range of applications. Fe, Pb, and U calorimeters were compared with several ionization detection methods; liquid argon, scintillator, and MWPC were considered. Both the resolution and the shape of the resolution function were studied. A particular question raised during the 1977 Summer Study was whether uranium-scintillator calorimeters were feasible; work performed since that time indicates that the answer is definitely YES. No new information on the resolution obtainable with a U calorimeter was available but existing measurements indicate that it is about twice as good as that of a comparable Fe calorimeter. It was found that careful comparisons of the resolution are difficult because (1) there are no data on the performance of U calorimeters at high energy and (2) data on the performance of Fe calorimeters with thin plates (2 to 3 mm) are sparse, and the few measurements that have been made are not consistent with one another.

Existing data indicate that the resolution obtainable with MWPC sampling is ~50% worse than that obtained with scintillator for electromagnetic showers and probably worse by a similar factor for hadronic showers. However, comparison is again made difficult by the limited number of measurements available with thin-plate calorimeters.

Another important point was raised: that the effective time resolution of the three different sampling techniques is not well understood. Liquid argon is limited to a resolution of 100 to 150 nsec both by the charge collection time and by problems of inductance. Somewhat surprising, however, is that the time resolution of existing scintillator calorimeters is also ~100 nsec. In principle, these can be made significantly faster, but further study is required to determine just how much of an improvement can be made. The time resolution obtainable with MWPC sampling also needs to be determined.

Several new ideas were presented. One suggestion was to combine scintillator and Cerenkov plastic in Fe multiplate calorimeters to help distinguish the electromagnetic component. Another idea was to make use of the Fe poles and flux return of magnets as calorimeters by inserting proportional tubes to measure ionization. Another suggestion was to use APDs to detect wavelength-shifted light from scintillators; this raises the prospect of fine segmentation with compact light detectors that are not adversely affected by the presence of magnetic fields.

HODOSCOPES AND MICROCHANNEL PLATE DETECTORS

The subgroup on hodoscopes and microchannel plate detectors studied several approaches to charged particle detection with scintillating materials and a variety of light detectors. Scintillating optical fibers appear to have considerable merit because of their inherent high event rate capability along with potentially excellent time resolution. They also offer good spatial resolution ≤ 0.4 mm. Several spatial configurations of multilayer film hodoscopes are presented, including applications in the axial-field magnet spectrometer, the lepton detector, the wide-angle spectrometer, and a small-angle scattering detector. One difficulty yet to be overcome is shortness of lifetime due to radiation damage. Acrylic scintillators are significantly damaged at 10^5 rads, which is substantially lower than the levels that damage PWCs. Other problems with fiber optic hodoscopes are excessive γ conversions and multiple scattering due to the substantial material presented by the detector. In both cases a reasonable detector configuration of future hodoscopes compared with a similar array of PWCs would have ~ 10 times as much radiation length.

Secondary emission devices were studied to assess their merit for use in ISABELLE detectors. It has been shown that 10 to 20- μ m thick layers of KCl can yield a time resolution of 0.25 ns. This type of detector also holds promise for measuring ionization in the relativistic rise region, at least to $p/mc \sim 2000$. In addition, the detector seems to withstand radiation up to 10^{18} particles/cm², showing a resistance higher by many orders of magnitude than that of acrylic scintillators. One difficulty that may limit this application of secondary emission detectors is their susceptibility to even weak magnetic fields.

Two types of light detection are discussed. (1) The report on the current status of microchannel plate tubes indicates progress in one area that formerly limited the usefulness of these devices, i.e., improving the lifetime by the use of electrostatic focusing and the inclusion of an ion pump and getter. (2) The avalanche photodiode (APD) is a solid state light detector that has been under development by industry for many years for its application in optical communication. Shifting its photon response to the ultraviolet can make it useful in high energy physics experiments. In some ways the APD is superior to photomultiplier tubes because of its immunity to magnetic fields, small size (making it applicable to film scintillators), low power, insensitivity to overload, and high quantum efficiency. On the other hand APDs are extremely expensive per unit detector area, and their requirement for high-speed low-noise amplifiers increases their cost. However, there is hope for the future, since the history of the semiconductor industry has consistently shown great cost reduction once a device gets into large-scale production. Another possible approach is the cold APD, which can deliver large-amplitude subnanosecond resolving pulses that do not require amplification and have a single-photon detection efficiency of 50%.

TRIGGERING

The triggering subgroup studied the problems of event selection in the high rate environment expected at ISABELLE. They divided into three sections. The first studied general triggering strategies and problems, taking as examples an axial-field magnet and a large dipole detector. They attempted to give a more general description of multilevel processing and looked for constraints imposed on the earliest level of processing. The second section considered the triggering problems that occur in the first 200 ns. They developed a formalism to calculate system deadtime in a multilevel system and suggested means for limiting system deadtime to the first level of triggering. The third section studied fast processing, including methods of rapidly calculating parameters such as angles and momenta for later use in the processing. They also studied the types of pipelines necessary after reduction of the initial rate by one or two orders of magnitude by the fast trigger.

CONCLUSION

This year's Summer Study brought great enthusiasm to the problems of detector development. In past years the especially difficult problem of detecting and identifying particles in the high multiplicity and high event rate environment anticipated at ISABELLE had at times seemed nearly impossible to solve. Very significant progress has been made during the year on a number of questions raised last summer. This summer again a number of specific areas needing continued research and development became apparent. Among these are (1) further measurements on the lifetime, pulse-height resolution, and position resolution of multiwire proportional drift chambers (particularly at high rates); (2) energy and timing resolution of thin-plate calorimeters, particularly uranium plate with scintillator sampling and iron plate with both scintillator and MWPC sampling; (3) photoionization detectors, image intensifiers, and new types of transition radiators; (4) scintillating optical fibers, avalanche photodiodes, secondary emission devices, and microchannel plates; and, perhaps most important, (5) triggering and hardware processors.

Finally, we note that, while in the eyes of impatient physicists ISABELLE may occasionally seem distant, only 3 to 4 years remain for new technologies to be proven if they are to be included in the first round of ISABELLE experiments.