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COUNTER DATA RECORDING FOR ANALYSIS BY COMPUTERS

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June 12, 1962

Counter Data Recording for Analysis By Computers

by

C. E. Wiegand

Great amounts of data are coming from experiments with large accelerators. The sorting and analysis of these data are formidable problems. This is true whether the experiment involves a bubble chamber, an array of scintillation counters, or a spark chamber.

For many years our group at Berkeley has worked primarily with counters. Our experiments have gone through a process of evolution from a few gas ionization counters to an array of more than 100 scintillation counters. The amount of data that these counters give out has incrased even more than their numbers because the rate of counting has also greatly increased. I hasten to say though, that the importance of the experimental results has, alas, not always increased in the same proportion! It became evident that automatic recording and analysis was a necessity. Fortunately the electronic computers have appeared on the scene and we can use them to help us.

I thought it might be of interest to the delegates to this conference to hear how we manage an experiment involving a large array of counter elements. I will not discuss the electronics in detail but rather tell the techniques of how we apply the apparatus to an experiment.

We have used automatic data processing equipment in two experiments. The first experiment, the one for which this system was originally designed, was a study of the interactions of π-mesons with π-mesons. The second experiment is still in progress and is the detection of a very rare disintegration scheme--the so-called beta decay of π^+ mesons.

In order to understand the experiment we shall have to consider some particle physics. Pions are unstable particles. They decay in an average time of 25 nsec. Ordinarily a positively charged pion decays into a positively charged μ-meson (muon) and a neutrino. However a positive pion can break up in at least two other ways. It can decay into a positron and a neutrino. This happens once in about 8000 decays; it was predicted theoretically and measured in a beautiful experiment at the CERN Synchrocyclotron. It can also decay, according to prediction, into a neutral pion, a positron, and a neutrino, but with much less probability. It is expected that this process will occur only about once in every 10^8 decays. This is the experiment we are working on now; I will use it as the illustration of the method of using automatic data storage and a computer.

Fig 1. (SLIDE) shows a schematic illustration of the radiations resulting from the special decay scheme and how we can place counters to detect them.

We stop 10^5 sec pions in the stopper. Let us consider one pion that will oblige us by being the one in 10^8 that will decay in the special way. This pion will come to rest in the stopping counter in about 10^{-11} sec. It waits 25 nsec, then decays to a π^o, e^+, and . Instantaneously the π^o disintegrates into two γ-rays of 70 Mev each and they are colinear in space. The positron is emitted at the time of decay. It travels a few cm in the stopper counter and annihilates with an atomic electron into two more γ-rays of 1/2 Mev each. Again the annihilation γ-rays are colinear in space. The neutrino is undetectable.

In order to have reasonably high efficiency, the region in spcae where the pions stop must be surrounded by counters. We have done this by placing 36 counters around the stopper as illustrated in Fig. 2 (SLIDE). Also surrounding the stopper are ten thin scintillation counters to indicate when charged particles enter the γ-ray detectors because this could be a confusing background. We have a total of 46 counter elements and we wish to detect the passage of colinear rays originating in the stopper. This is where the data storage system and computer enter the picture.

The data recording system was developed and built at Berkeley in 1959 and 1960 by a group of engineers under the direction of Dick Mack and Fred Kirsten. It is described in detail in the Journal of Nuclear Instruments and Methods. The apparatus consists of 180 parallel input channels (Fig. 3). (SLIDE) We can ask it to interrogate the inputs to determine whether or not pulses are present. The time resolution is such that we can require the pulses to arrive at the input within a time interval of about 10 nsec. If a pulse is outside this interval it will be rejected. This gives us 2^{180} possible combinations--a large number even for the astronomers. After the interval of interrogation the input information is transferred to a ferrite core memory. When the memory is full the machine takes time out (20 msec) to transfer the data to a magnetic tape. The purpose of the temporary storage is to allow a regulated flow of information to the tape. The data is placed onto the magnetic tape in a pattern that is suitable for digestion by an IBM 709 type computer. Each input channel is assigned a definite location in the pattern of information. For example channel number one is the first position in the first character, etc.

Before we can proceed, we must have a program of instructions for the computer. This is a major part of the project and must be considered in the schedule of cost and the time of preparation of the experiment. Sometimes the computer program is called the "software". This is to distinguish it from the experimental apparatus called the "hardware". The computer program will include instructions for all the data tabulations and computations that the experimenter needs. In the particulár experiment we are discussing the operation is principally that of sorting and tabulating. (In the experiment on pion-pion interactions the computer calculated kinematics relations which, of course, was much more complicated.)

Now to accomplish the wedding of the computer system to the counter array we need only to connect the outputs of the elements of the array to the data storage inputs. Another branch of electronic circuitry advises the storage system when to expect an event. In our illustration this would be a few nsec after a pion came to rest in the stopper and other appropriate conditions were fulfilled.

Suppose we operate the apparatus for a test of its performance. We can vary some of the conditions of the array. For example, we can increase the sensitivity of the counters or change the time of interrogation with respect to the time pions stop. We need only to transfer our reel of tape and program of instructions to the input readers of the computer. In a few minutes we have a tabulation of the performance of the counter array. For each counter we can plot curves of rate versus sensitivity and rate versus time. We can tell if certain counters need more or less sensitivity or longer or shorter cables in their signal lines.

In an actual attempt to detect the beta decays of pions, we would ask the computer to list those events in which the radiation was neutral and colinear through the stopper. We would also ask it to list events in which the rays were not colinear. This would help us to decide whether the events were real or accidental.

I hope that this semi-technical description will start some thought by those experimenters who are planning complicated counter experiments. The apparatus can be more or less elaborate according to the experiments. At least I can say that for us it is a practical system of experimentation.

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(3) R. Larsen, R. Bacastow, T. Elioff, C. Wiegand, and T. Ypsilantis. Postdeadline Paper, Washington Meeting of the American Physical Society, April 23, 1962.

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Figure Captions

Fig. 1. Schematic illustration of pion beta decay and a detection scheme.

Fig. 2. Diagram of the counter array for pion beta decay experiment.

Fig. 3. Schematic diagram of the data recording system and its relation to a counter array.

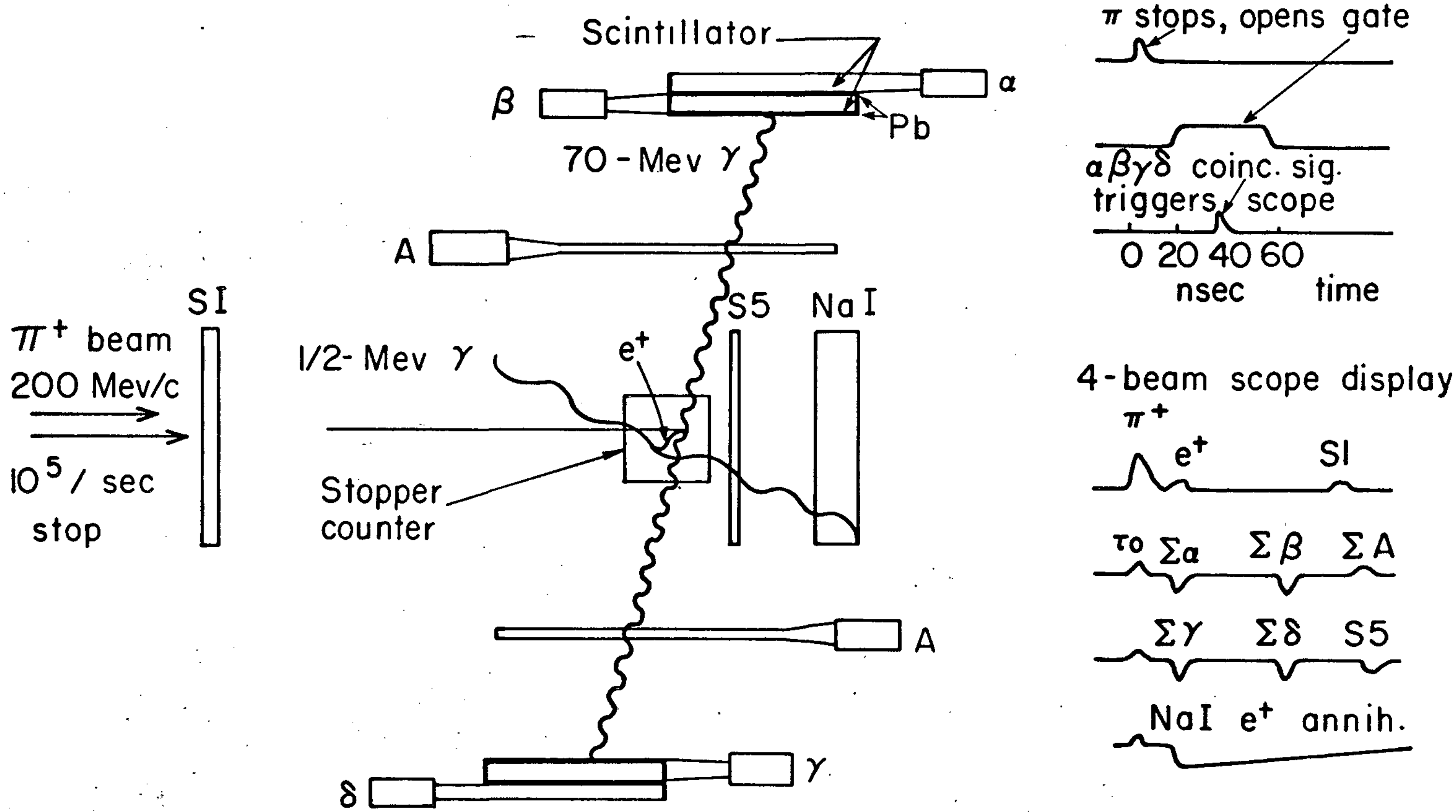

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Fig. 1.

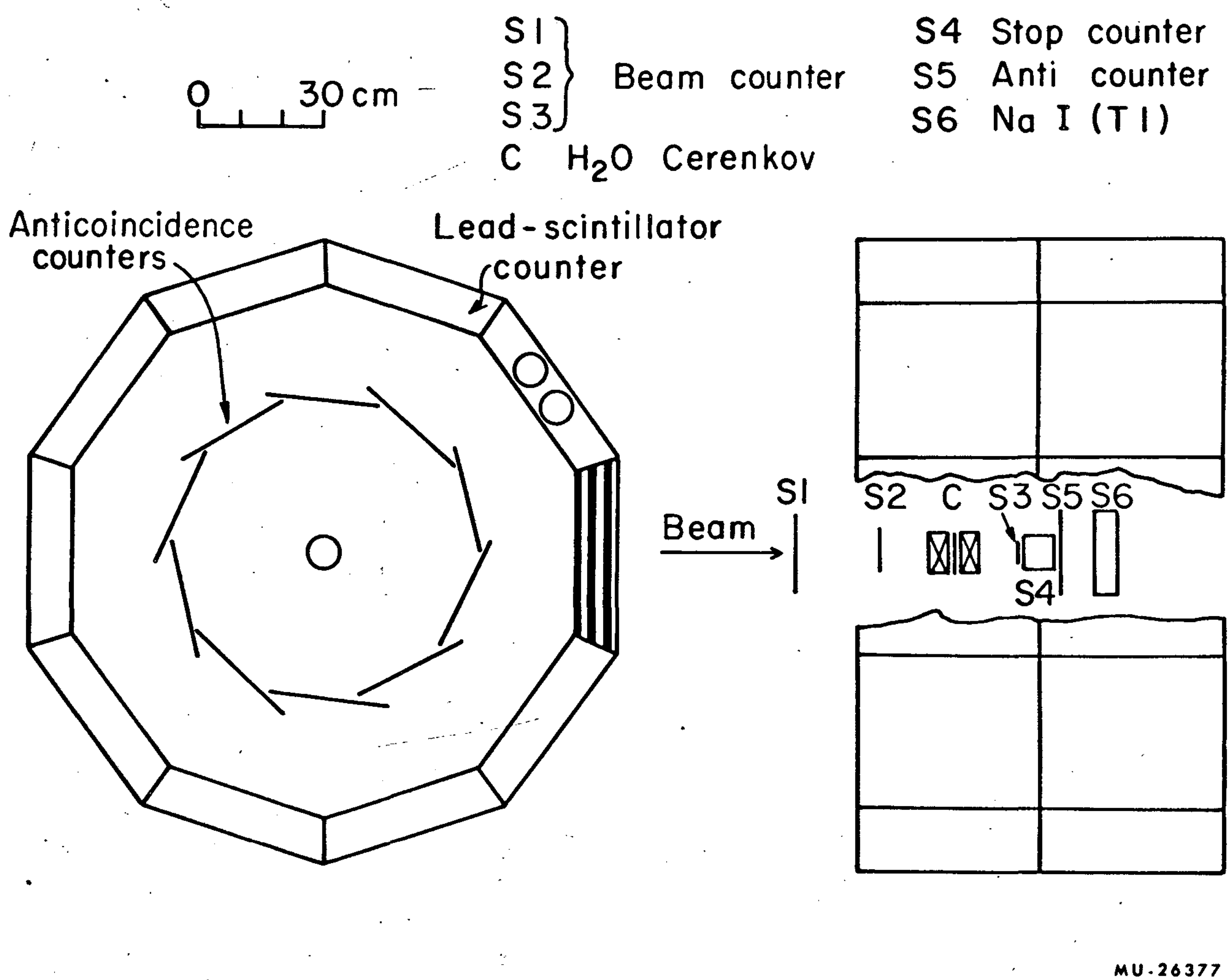
0 30 cm
S1
S2
S3
Beam counter
C H_2O Cerenkov
S4 Stop counter
S5 Anti counter
S6 Na I (Tl)
Anticoincidence counters
Lead-scintillator counter
Beam
S1
S2
C
S3
S5
S6
S4
MU-26377

Fig. 2.

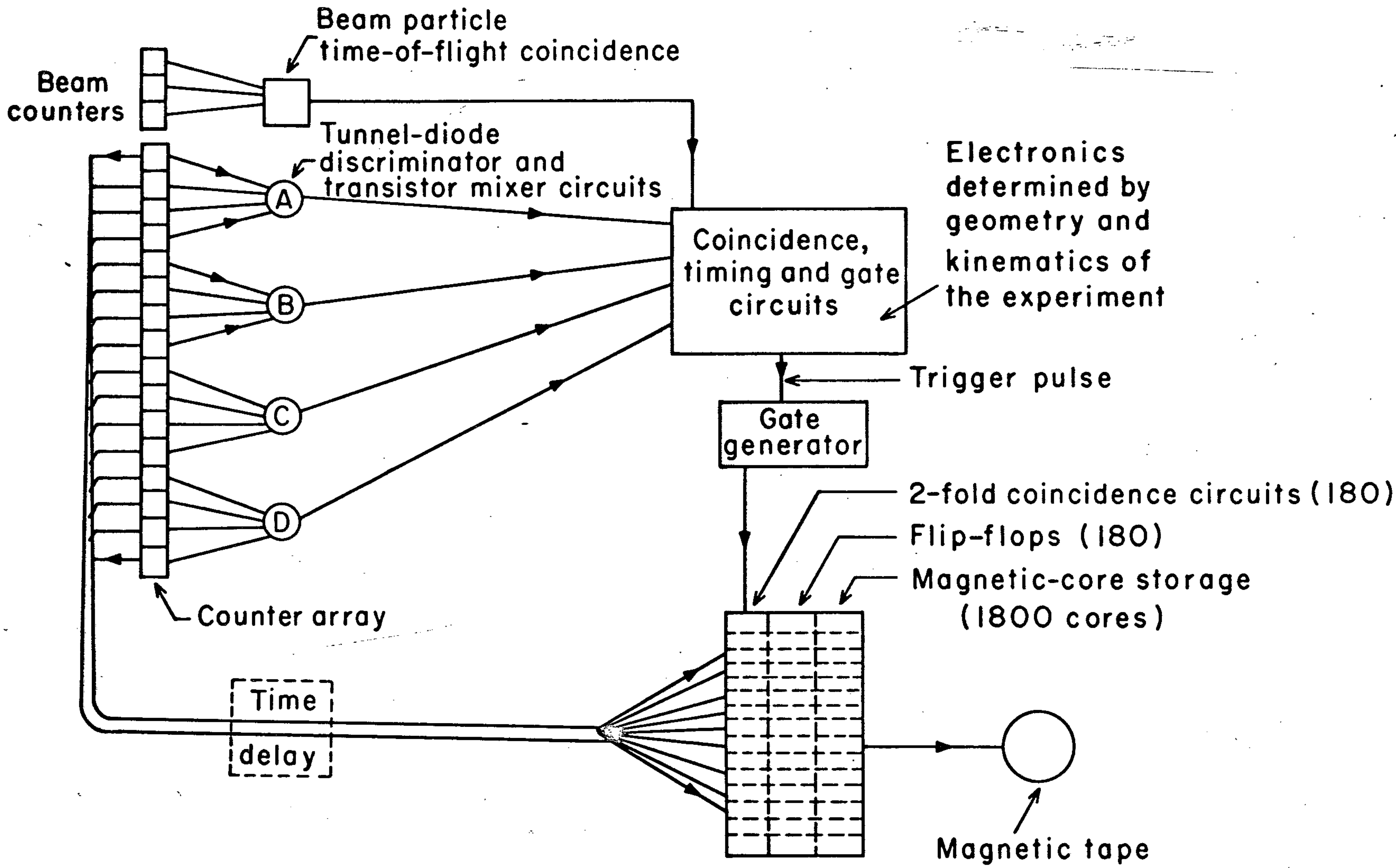

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Fig. 3.