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Publication Date

1962-06-05

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UCRL-10280

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California
Contract No. W-7405-eng-48

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Clyde Wiegand

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At the CERN Conference on High Energy Accelerators in 1959 I reported on the construction of a data storage system for counter arrays⁽¹⁾. At the time of the Berkeley Conference on Instrumentation for High Energy Physics in 1960 we had used the system in a preliminary experiment at the Bevatron⁽²⁾. In the 1960 experiment we recorded the data on paper tape. We soon realized that the paper tape system was too slow and unnecessarily inconvenient. For the complete experiment in 1961 we recorded directly on magnetic tape in a format acceptable to the IBM 709 computer⁽³⁾. We needed only to transfer the tapes from our recorder to the input readers of the 709 and in a few minutes we had a complete computation and summary of the experimental data. This experiment was on the pion-pion interactions.⁽⁴⁾ It involved the recording of data from one hundred and two scintillation counter elements. The system performed admirably with a very high degree of reliability.

Let us review briefly the salient features of the data acquisition system. It consists of two hundred and ten parallel input channels (Fig. 1). (SLIDE) The presence or absence of input pulses greater than 150 mv in amplitude can

be ascertained with a time resolution of about 10 nsec. The dead time between events is 40 μ sec. During this interval the input information is transferred to a buffer storage consisting of 2100 ferrite cores. After the acceptance of ten events the stored data is transferred to magnetic tape. The time to read the core memory and write the tape is 20 msec. This includes 10 msec to start and stop the tape transport. Along with the actual data of each event there is recorded on the tape an event serial number and six bits of fixed data commanded by manually operated switches. Also there are instructions to the computer for ends of records and ends of files. A continuous check on the operation of the system is provided by a reading head adjacent to the recording head. The first event out of each ten events recorded is fed back to the storage system where it is compared to the data that was originally stored.

In conclusion our experience has been that for experiments involving large numbers of counters, a data acquisition system working with a high speed computer is a practical combination.

In the time remaining I will reply to the question: What is new in counting techniques at Berkeley? Obviously I can only mention some of the work that is in progress, and trust that those experimenters who are interested can obtain further

information. I want to make it clear that I am speaking in the role of a rapporteur. Some of the work is unpublished and we are indebted to the investigators for this preview.

Quentin Kerns and his group have made many experiments on the performance of multiplier phototubes. Their measurements re-enforce the knowledge that our standard laboratory discriminator and coincidence circuits are not utilizing all the potentialities that photomultiplier pulses are capable of giving.

Recently two of Kern's engineers, Arthur Bjerke and Thomas Nunamaker,⁽⁵⁾ made some studies of the time resolution of typical counters in a beam of 200 Mev/c pions, muons, and electrons. The width of the time delay curves was about the same as those that have come out in CERN time-of-flight experiments for the last year or two. Both the CERN and Berkeley systems base their timing on the first "zero-crossing" of clipped photomultiplier pulses. I will describe some of the features of our system. Fig. 2 (SLIDE) shows the schematic circuit. The transformer, anode and dynode capacitances, and the resistors form an 80-Mc tuned circuit that is over-damped. This circuit produces the "zero-crossing" pulse. Signal current flows through the additional damping resistor (27 ohms) and into the tunnel diode. When the signal reaches a point slightly past zero the tunnel diode regenerates. The

regenerator pulse rises in 150 psec and is 3 nsec wide. The tunnel diode and differentiating capacitor (4 pF) are built into a 50 ohm coaxial housing and assembled to the phototube as shown in Fig. 3. (SLIDE) The differentiated pulse (300 psec width at half maximum) is carried to a remote counting station by high quality coaxial cable. Returning to Fig 2. we see that the signal enters an isolation stage and a restandarization circuit similar to the one at the base of the phototube. Another isolation stage passes the signal to a tunnel diode regenerator that comprises the coincidence circuit.

The performance of the system is indicated in Fig. 3 (SLIDE). These curves were taken by using a light pulser to activate a photomultiplier connected to one input channel of the coincidence circuit. The second coincidence input was fed by an electrical signal that came directly from the light pulse generator. These curves show the sharpness of the delay curve of one phototube for several values of incident light intensity per pulse. For example the slope is 125 psec per decade for 10^3 photoelectrons reaching the first dynode. Actual time of flight curves are shown in Fig. 4 (SLIDE). The flight path was 144 cm. There were other absorbers in the beam (in case you check the positions of the peaks for 200 Mev/c particles). The counting efficiency was about 70%.

From the light pulse measurements we would expect that

the resolution would have been better. However the scintillator decay time and losses in the light pipe are not included in the light pulser curves.

I think that you might be interested in a new light pulser that Quentin Kerns and Robert Tusting have developed. About two years ago Kerns, Cox and Innes ^{(6),(7)} introduced their light pulser that works by field emission of electrons to initiate a discharge in a hydrogen atmosphere. This light pulser has become an almost indispensable tool for experimenters at Berkeley who work with large counter arrays. With the system it is possible to adjust the timing of photomultiplier tubes to within one nsec. The discharge lamps are not intended to be stable with respect to the amount of light they emit although they can be used to compare the performance of photomultipliers and their associated circuitry.

Recently Kerns and his co-workers have produced a light source that is stable in light output. Although the rise time is not as rapid as that of the field emission discharge bulbs, it is adequate for the adjustment of many coincidence circuits. The time of rise of the new pulser is about 5 nsec. The bulb used is an argon lamp available in most electrical supply stores in the United States. It is a one-quarter watt argon lamp designated General Electric type AR 4. The arrangement is indicated in Fig. 5. (SLIDE). The lamp

must have a small direct current of about 1 microamp passing through it so that there will be an abundance of ions in the gas at the time the high voltage pulse is applied. The amount of background light emitted due to the idling current is negligibly small (about 10^{-4} of the actual pulsed light intensity). The light flash is produced by applying an electrical pulse to the lamp bulb of about 1500 volts for a duration of 5 to 10 nsec. Naturally the light output of the bulb is quite sensitive to the amplitude of the applied electrical pulse but it is not unmanageable. In a typical operating region of the voltage, the variation in light output is about three times the variation in applied pulse amplitude. Of course this calls for a stable electrical pulse but this is not difficult to achieve with today's circuit techniques. The quantity of light emitted in a single flash from a bulb that has been in continuous operation for several weeks amounts to about 10^7 photons. This includes all the wavelengths of light that are detected by a photomultiplier having S11 cathode sensitivity.

The light pulser that has been in operation over a period of several weeks has been constant in its light output to about 3 parts in 1000.

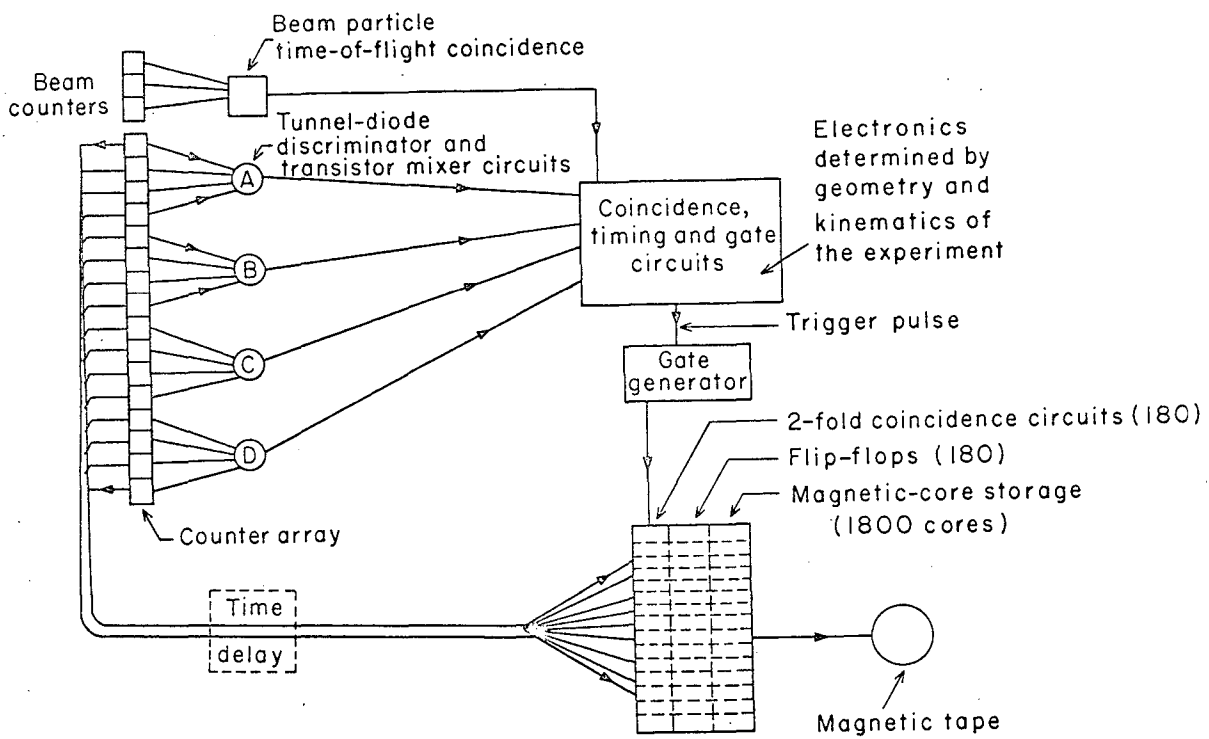
By employing test pulses and a feedback system to automatically adjust the supply voltages of the photomultipliers, a stable counting system has been assembled and used in an experiment at the Berkeley 184 inch cyclotron.

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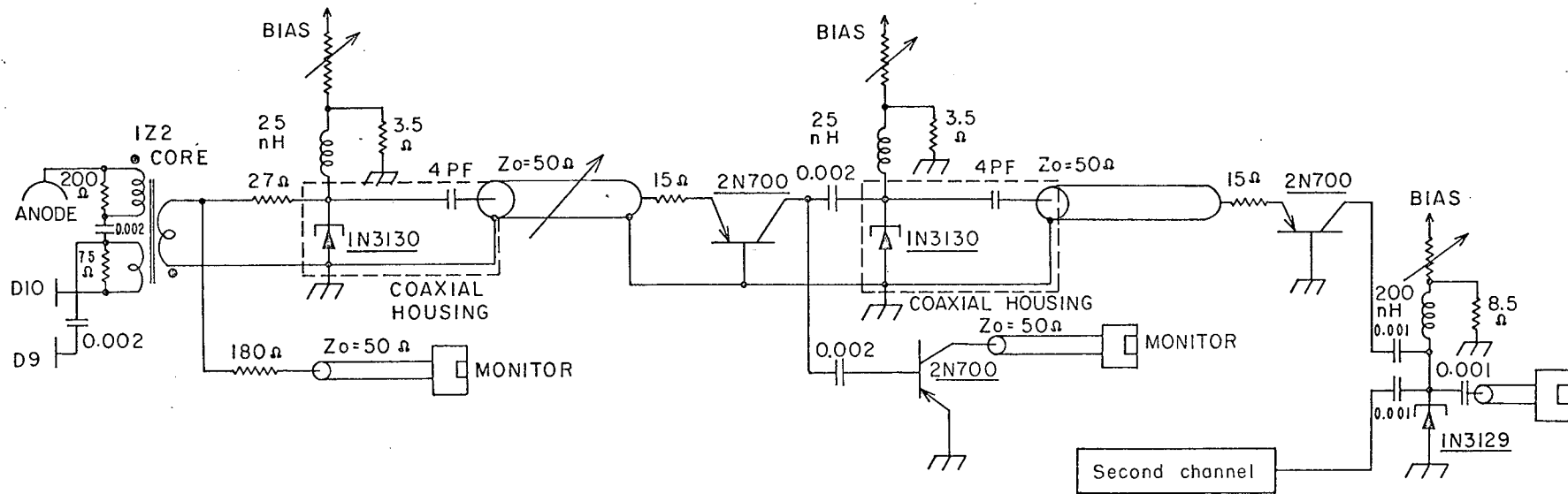
FIGURE CAPTIONS

- Fig. 1. Basic block diagram of the data recording system. The storage capacity has been increased to 2100 cores.
- Fig. 2. Schematic diagram of the standardizing circuits and coincidence circuits.
- Fig. 3. Views of the tube base assembly and the tunnel diode housing.
- Fig. 4. Photomultiplier coincidence counter versus time delay for several values of light incident intensity.
- Fig. 5. Time resolution of two counters in a beam of particles.
- Fig. 6. View of the argon lamp and associated components. Shown is the step up transformer that is driven from a 50 ohm cable.



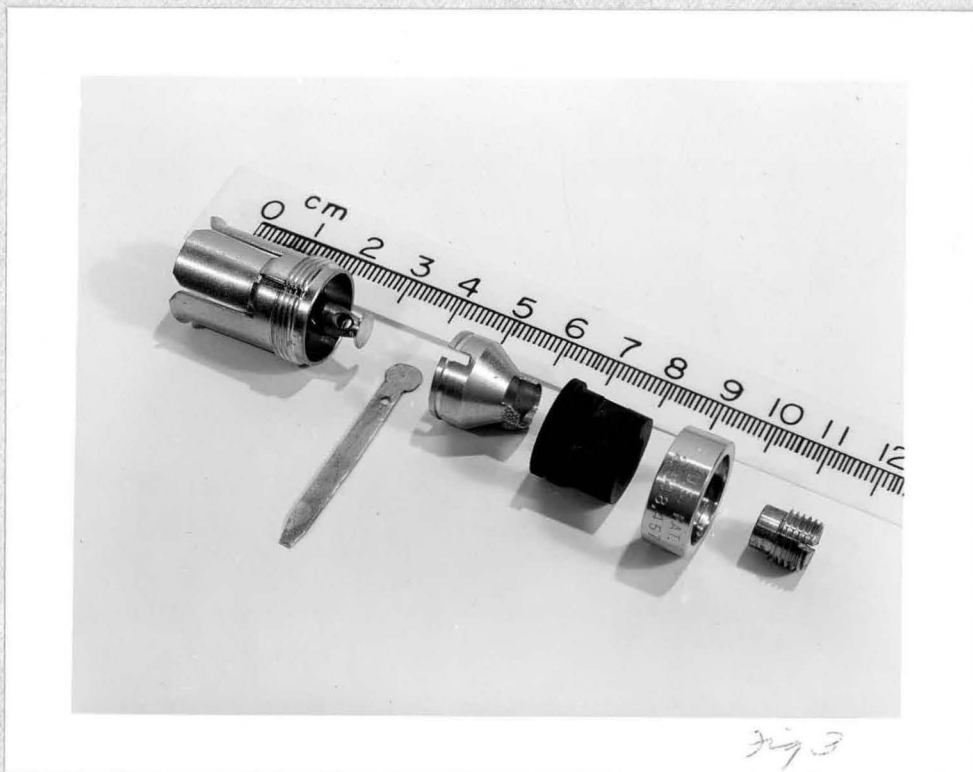
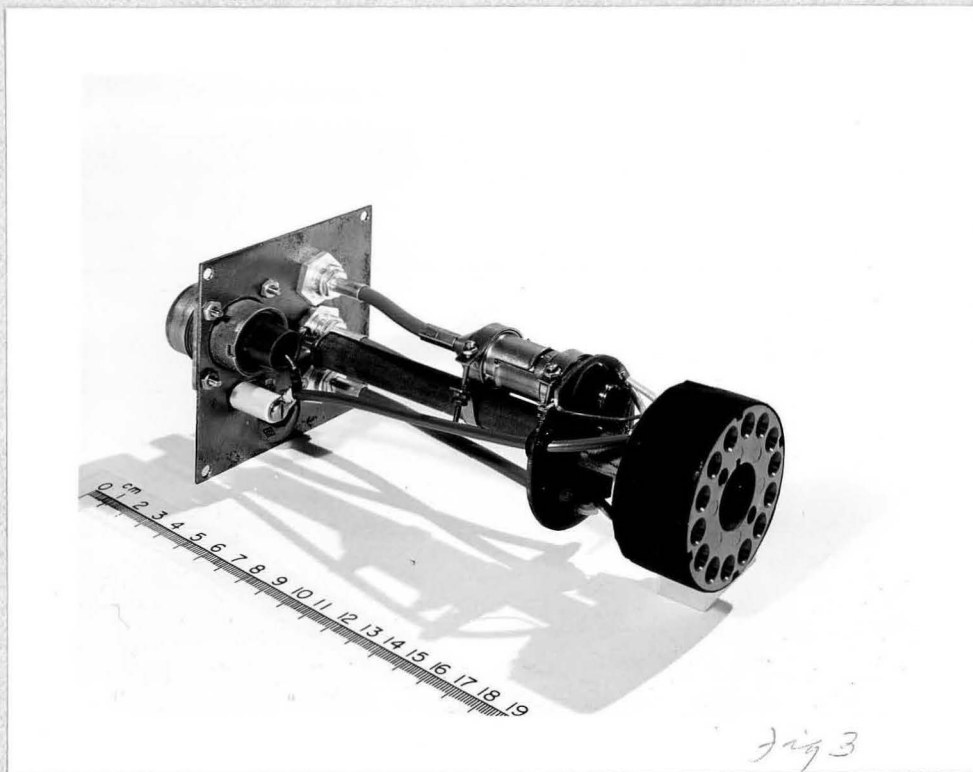
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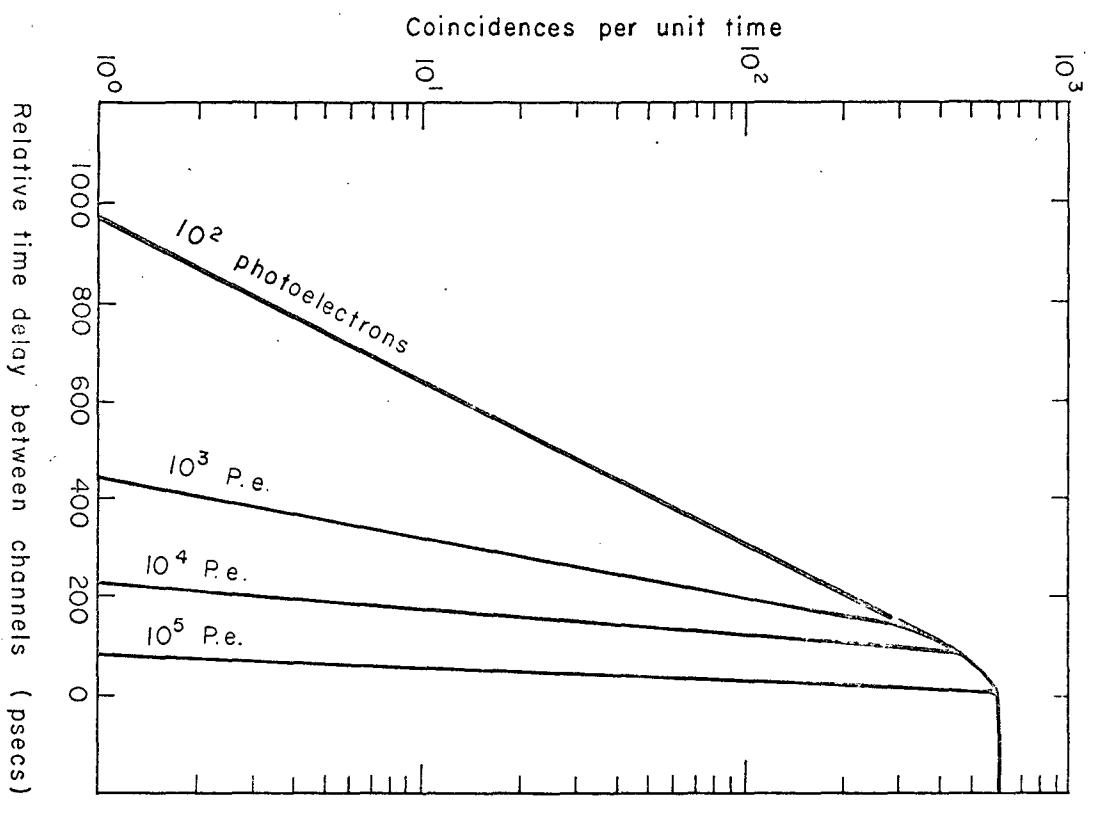
Fig 1



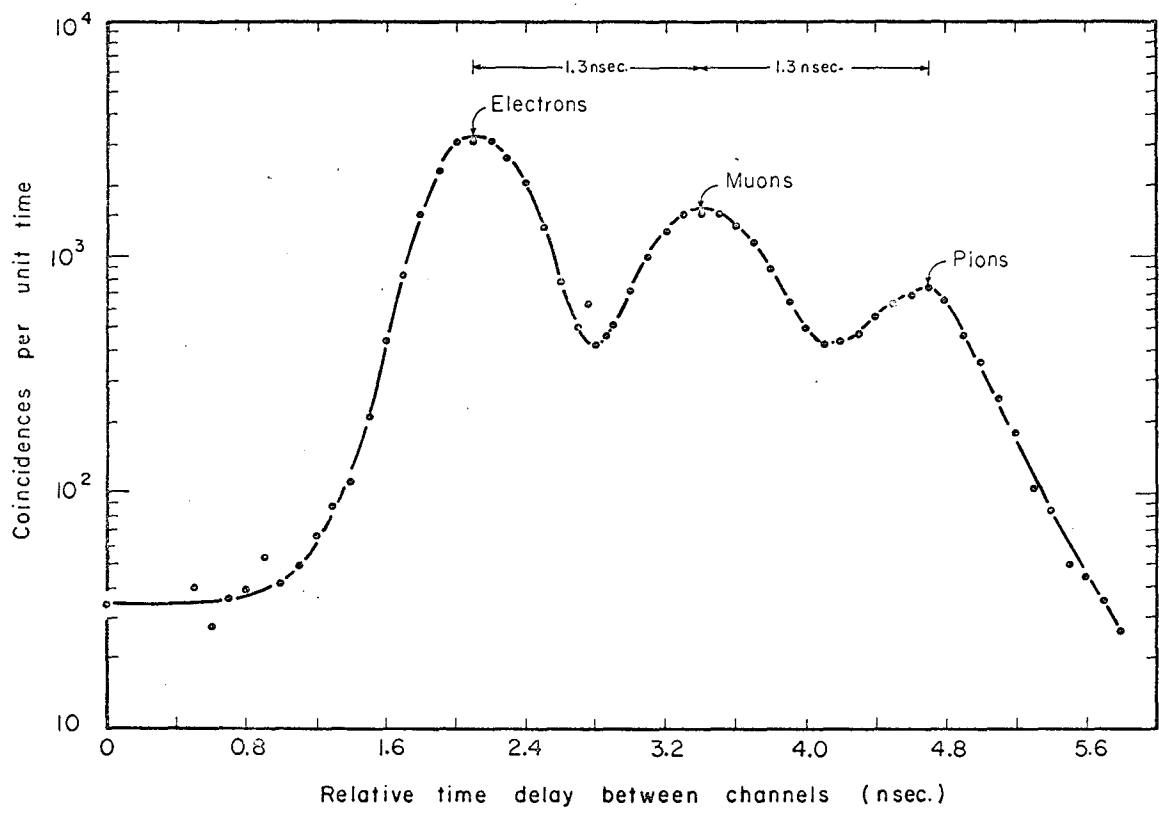
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Fig. 2





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Fig 15

MILLERS HALLS
EVERASE
COTTON CONTENT



Fig 6

