PART-A

Chapter-2

A NEW EXPERIMENTAL SET UP FOR UHE GAMMA RAY OBSERVATION.

2.1 New data acquisition system:

The main purpose of new NBU EAS array used as telescope (see section-2.2) is to search for discrete point sources of ultra high energy cosmic gamma rays. For this a significant air shower statistics is required and hence data acquisition system should be such that the dead time of the system is small. Moreover in a number of EAS observations it has been found that EAS are coming within short interval of time (Klebesadel R. W. et al[1], Smith G.R. et al[2], Hillas A.M.[3]) similar to low energy gamma ray burst. To observe such phenomena , again data acquisition time need to be as small as possible. To minimise the data acquisition time , a new data acquisition system has been developed (Chakrabarti C. et al [4]) for the NBU EAS array.

In the original data acquisition system of the NBU EAS array (Basak D.K. et al[5]) a 32 channel multiplexed analog-to-digital converter (ADC) was used to digitise the analog pulse carrying the information of charged particle density in the EAS. In the new system , analog pulse heights are digitised simultaneously for all the 32 channels and these digitised density data are automatically recorded in an external 32-k byte RAM and subsequently stored into the Computer hard disk. Block diagram of the new data acquisition system is shown in fig.2.1a. The whole data acquisition system is divided into following units.

2.1.1. EAS selection system with master control unit (MCU):

The circuit that controls the selection of the detector pulses to produce a coincidence master pulse for the detection of arrival of air shower and also to send pulses at different units of the data handling system for storing different data, are termed as EAS selection system with master control unit (MCU). Block diagram of this unit is shown in fig. 2.1b. Operation of the system is detailed below.

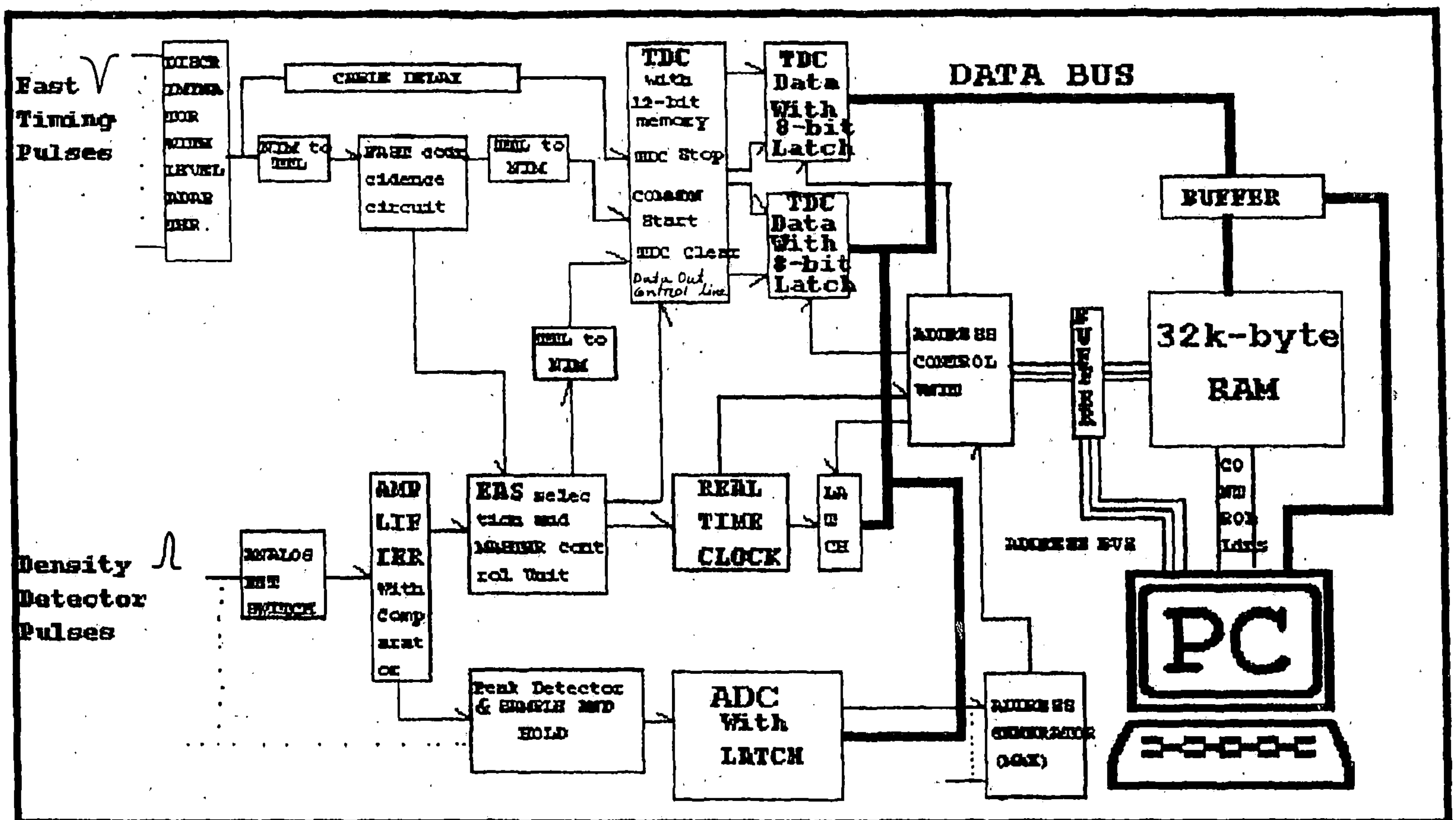

Fig.2.1a.
Block diagram of the new data acquisition system.

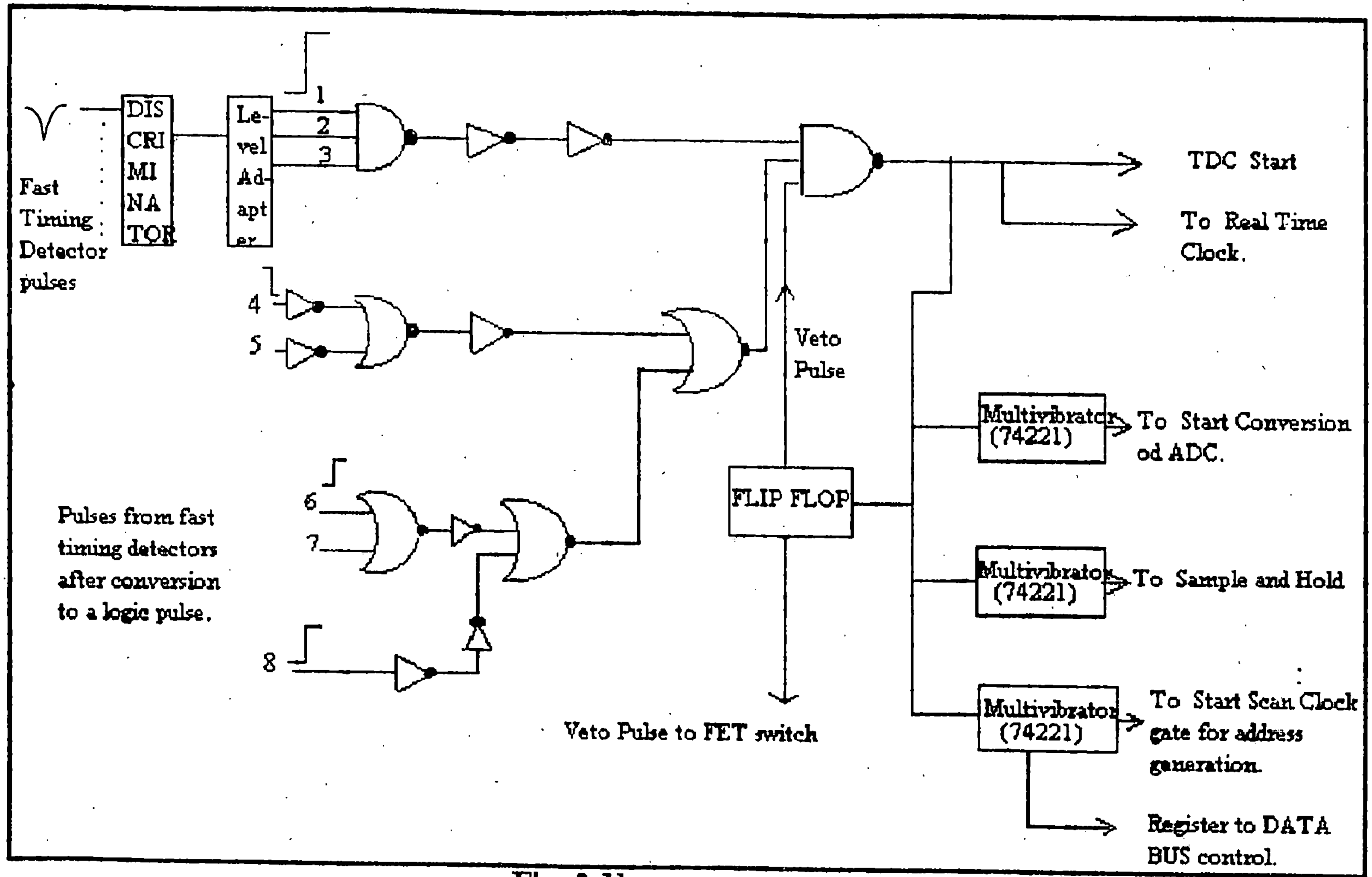

Fig. 2.1b.
EAS selection system with master control unit.

Fast timing detector pulses are discriminated through a Lecroy discriminator. Discriminated output is converted into TTL through Level Adapter of Lecroy for coincidence. Out of 8 fast timing detectors , we used three fixed and another one from remaining five for four fold coincidence pulse generation. The coincidence pulse is shaped through a Multivibrator (IC 74221). When coincidence pulse is generated ,it allows the arrival time data(fig.2.1e) to get stored into the register buffer (IC 74373) , starts TDC scan (fig.2.1f) and gives a hold command to the sample & hold (S/H)(fig.2.1c). At the same time, the coincidence pulse generates a veto pulse which is withdrawn after the completion of total data acquisition process. This pulse also disconnects all the ADC inputs (fig.2.1d) by means of a FET switch . The coincidence pulse also generates three other pulses . One is used to generate hold command for all the ADC channels(fig.2.1d) through multivibrator (IC 74123). Width of this pulse is 150 μs. Second pulse goes to ADC (fig.2.1d) for the digital conversion of analog pulse. Width of this pulse is 150 ns. The third pulse is used to open a gate so that all the data are stored into the memory by means of a scan counter generator(fig.2.1d). After storing all the data into the memory , a pulse is generated to withdraw the veto pulse so that the circuit is ready for next coincidence.

2.1.2 **Sample & Hold unit with input cut-off switch:**

Main purpose of this unit is the detection of each of the density detector pulse for monitoring during sampling and holding the peak of coincidence selected pulses and then feeding it to an ADC for scanning. Block diagram of this unit is shown in fig 2.1c. Principle of operation of the circuit is given below.

When pulses from density detectors come into this circuit, the hold capacitor for each channel is charged up at the peak voltage of the pulses. The voltage across the capacitor is retained for 4 μs and then allowed to discharge through a transistor switch for sampling. If a hold command from MCU comes within that 4μs, the hold capacitor is isolated from discharging for 150 μs. The output pulses from S/H are connected to the input of the ADC to scan the pulse heights. Until the conversion is complete, a FET switch is used to open the input lines of S/H.

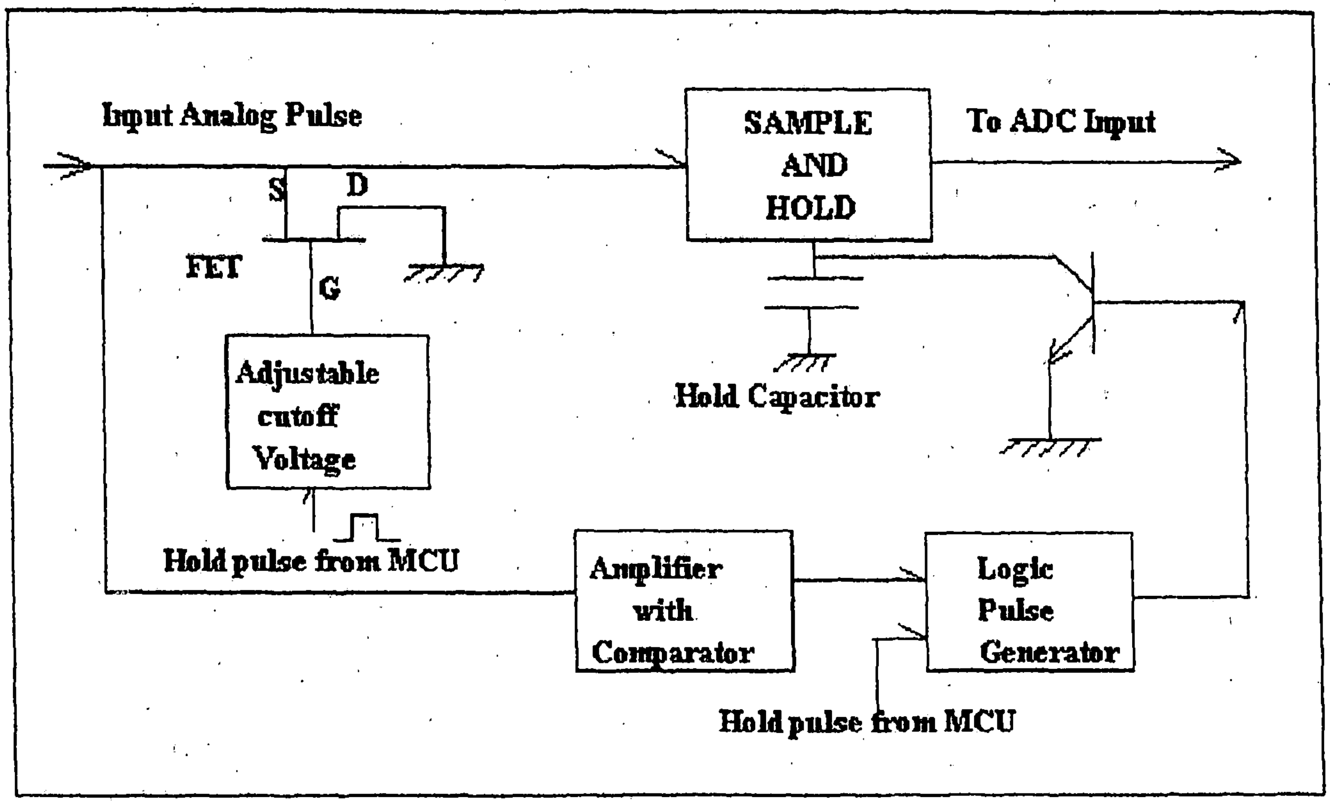

Fig.2.1c.

Sample and Hold with input cutoff switch.

2.1.3 **Pulse height conversion and data out unit:**

This unit digitise the analog pulses from S/H by ADC and lead out the data from ADC to the data bus. Fig 2.1d shows the block diagram of the conversion circuit. Here we use individual 8-bit ADC with latch for each of the 24 channels to store particle density data. Principle of operation of the circuit is described below.

When a start conversion pulse of width 150 ns is generated from MCU, a gate is opened for 100 μs to pass 500 kHz clock pulse for scanning the analog pulse by ADC. All the ADCs (IC 0809) digitise the analog pulses simultaneously and store until next start pulse comes. After storing all the data , a pulse comes from MCU to start a binary counter (IC 7490) for count '00 to 23' which is used to connect all the ADC outputs one after another to the data bus by a Multiplexer(IC 74154).

2.1.4 **Real time clock unit:**

This unit store the arrival time & date of individual shower event and also displays the time & date. Here 1 MHz crystal oscillator is used for the generation of pulses to control the whole data acquisition system and also keeps the data of actual time of arrival of individual showers. Block diagram of this unit is shown in fig. 2.1e. Operation of the unit is detailed below.

1 MHz oscillator pulse first is shaped into a square wave logic pulse. This pulse is divided by 10^6 to make 'second' pulse. This 'second pulse' is fed into a binary counter to store the data into the latch(IC74373) and the output of the binary counter is connected to a Binary to BCD converter (IC 7447) to display the second data by seven segment LED. 'Second pulse' is divided by 60 to make the 'minute pulse'. 'Minute pulse' is also displayed and latched similar way. The 'minute pulse' is divided by 60 to make 'hour pulse' and 'hour pulse' is divided by 24 to make 'day pulse'. The hour and day pulses are also displayed and latched. The time data can be adjusted to proper value through individual manual switches by means of a high frequency square wave pulse. When coincidence trigger pulse comes from MCU, all the binary data are stored into individual latches simultaneously. These latched data are stored into the external memory through data bus one after another by means of read out pulse .

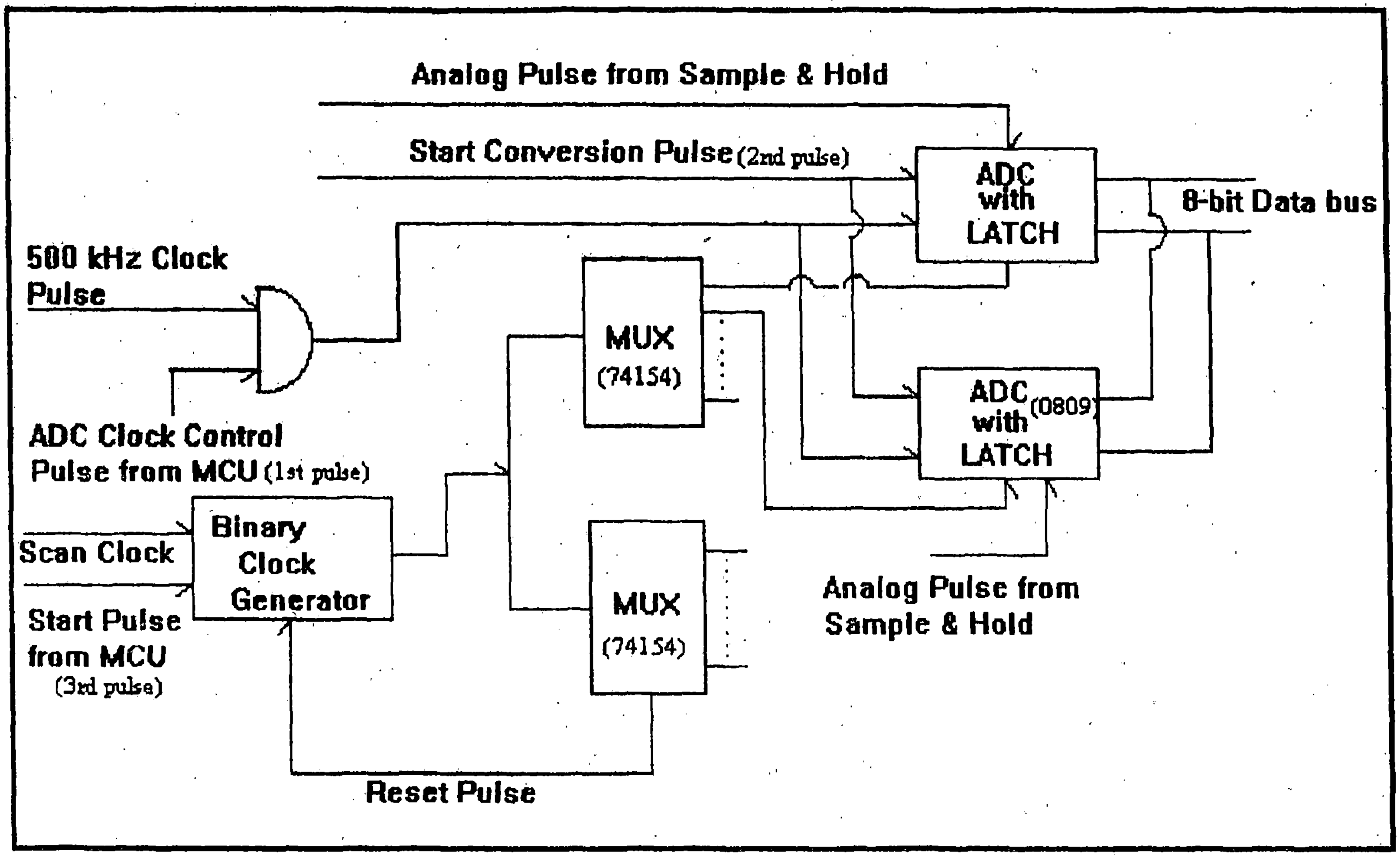

Fig.2.1d.
Pulse height conversion and data out unit.

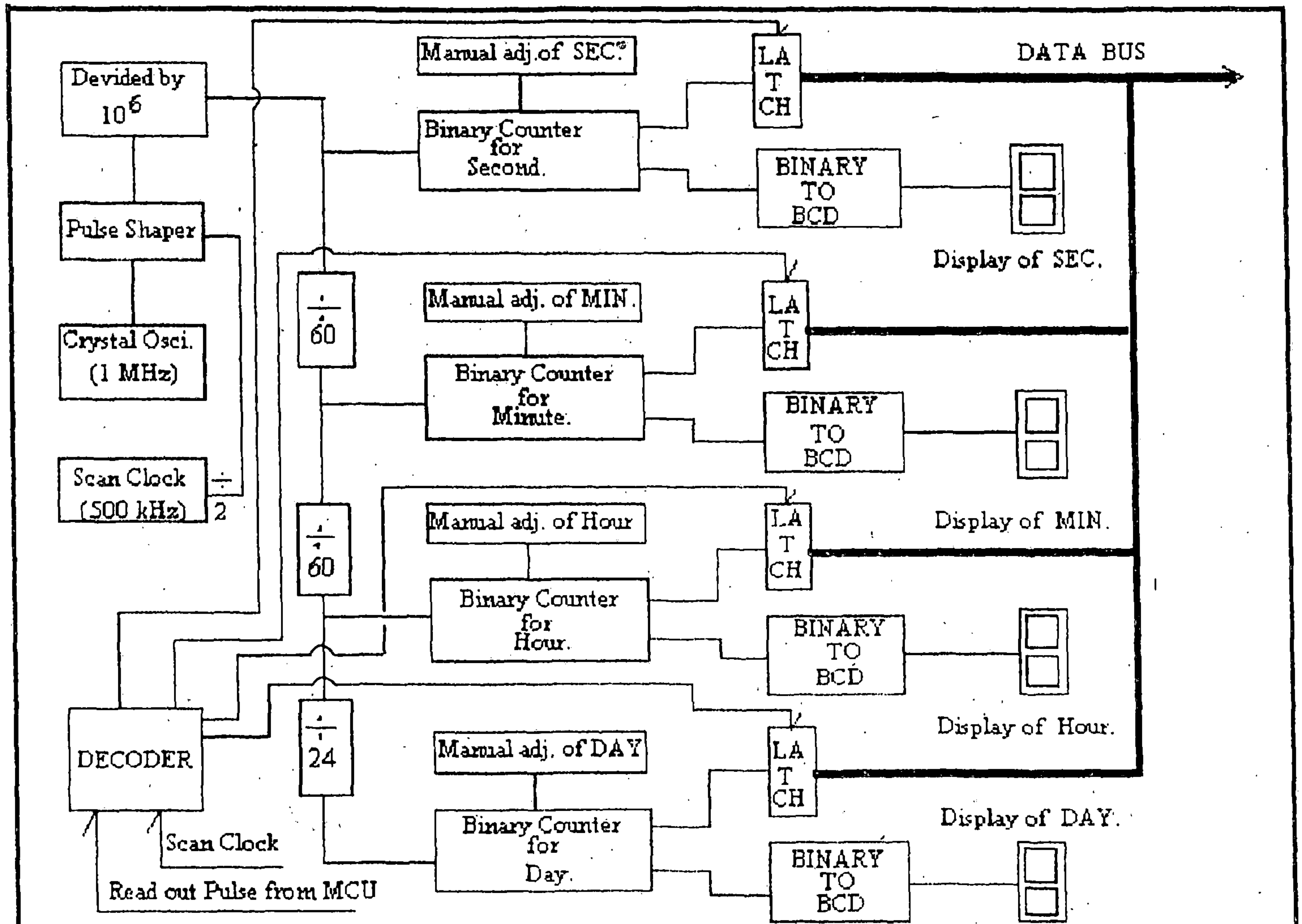

Fig.2.1e.. Block diagram of the Real Time Clock unit.

2.1.5. **Timing data conversion and storing unit:**

This unit converts relative time delay of the arrival of shower particles detected by different fast timing detectors into digital data and store these data into the memory for arrival direction measurement. The conversion and storing process is described below.

The output pulses of the fast timing detectors are given to a Lecroy fast discriminator (Lecroy Octal Discriminator 623B). The width of the discriminator output pulse is adjusted to 50 ns which ensure the coincidence. The bias of the discriminator is set at half particle pulse height level. The coincidence output pulse is used as the start pulse for the 8 channel Lecroy TDC modules (Lecroy 2228A) . Output of each discriminator channel is delayed by 172 feet RG174 cables and these delayed pulses give the individual TDC stop. The measured time interval is converted into a 11-bit digital number by means of a 20 MHz clock. The time-to-digital conversion is accomplished in two steps. A capacitor is charged up through constant current by common start pulse until individual stop pulse comes , and then analog-to-digital conversion is performed by Willkinson method. The final count is proportional to the time interval . These digital data are written to the register by sequential addressing and these registers store data until clear pulse comes. Maximum time required for storing the data is 100 μs.

After storing all the ADC data into the memory (IC-62256). a start pulse is generated for read out the TDC data and store into the memory. Block diagram of the circuit is shown in fig2.1f. Start pulse from MCU is fed into a Flip-Flop which generates some conditions so that data are out from TDC memory by 12-bit data bus. This pulse also opens a gate for address generation by means of a binary counter with 'scan clock'. A BCD counter is used to divide 'scan clock' into two. 1st 'scan clock' BCD output is used for two purposes- to read out the 12-bit data by two 8-bit latch, and to store one 8-bit data into the memory unit. Second 'scan clock' only stores the other 8-bit data into the memory. Thus, each channel of TDC data is stored by two 'scan clock' and it takes two bytes of external memory.

2.1.6. **Data storage system from RAM to hard disk :**

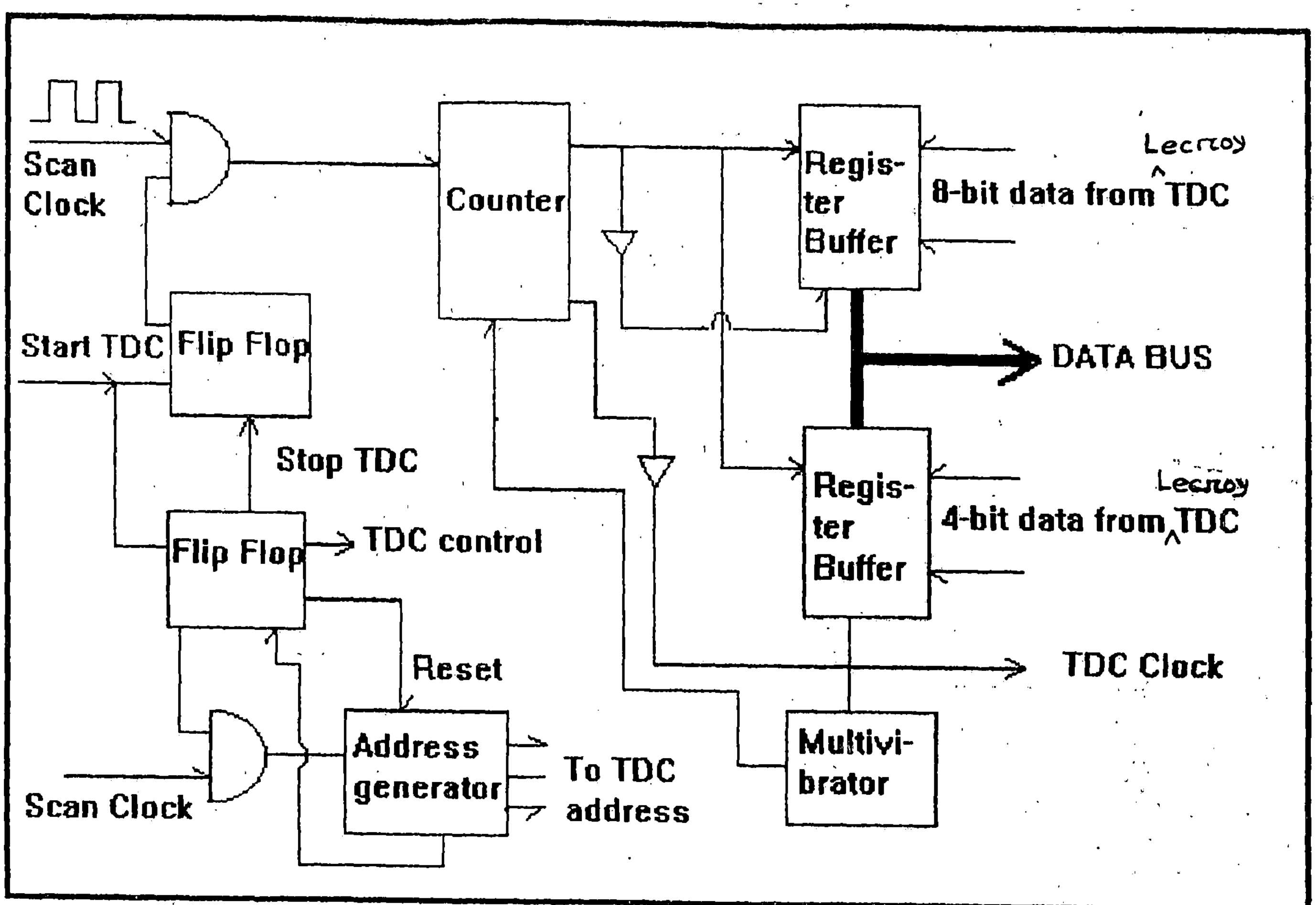

Fig.2.1f.
Timing data conversion and storing unit.

The external 32 k-byte RAM (IC 62256) has nearly 600 event data storing capacity. Hence after completion of nearly 600 event , we start transfer all the data into the hard disk from RAM by means of a Computer software. We have developed a Computer programme so that a parallel port is used to control all the data line and address line of the memory bank. Block diagram of the circuit is shown in fig 2.1g.

In the present system we have used 4 data line to collect data from RAM and 8 address line to generate address. We converting 8 address line to 15 address line by means of two 8-bit tri-state register (IC 74373) and 8 data line to 4 data line by means of two 4-bit tri-state register (IC 74173). This conversion was controlled by three lines from PC to 8 lines into the data handling system by 7447 decoder. In our Computer software , we first generate address from 0 to required number to bring out the data from RAM. As first address generates, it goes to address line of the RAM by the control of control lines. The control lines then generate a write command to RAM so that first data store into two 4-bit tri-state register . After storing this data , another two control commands generate, which are used to transfer both 4-bit data to the Computer and then for connecting them for actual data transfer. After completion of this cycle, we increase the address by one and repeat the cycle until all the data transfer to the hard disk.

2.2. The new NBU EAS telescope:

The design and construction of the new NBU EAS telescope have been made for the observation of several gamma ray sources e.g. Cygnus X-3, Hercules X-1, Crab nebula from a new site (latitude 26^{o} 42' N, longitude 88^{o} 21' E , atmospheric depth ~1000gm/cm^2). The telescope currently consists of 24 plastic scintillation detectors each of area 0.25 m^2 for the measurement of particle density of EAS at various points , 8 fast timing detectors for the determination of arrival direction of each shower event and two muon magnetic spectrogrphs of m.d.m. 500 GeV/c for the study of muon component of EAS. The layout of the telescope is based on the arrangement of scintillation detectors in a square array. The plan of the telescope is shown in fig.2.2a. The scintillation detectors covered an area of ~ 1450 m^2. The array is designed to observe showers of energies 10^{14}-10^{16} eV. Direction of the showers are obtained by relative time delay measured by the 8 fast timing detectors , four of them located near the centre of the array while the rest four are placed at

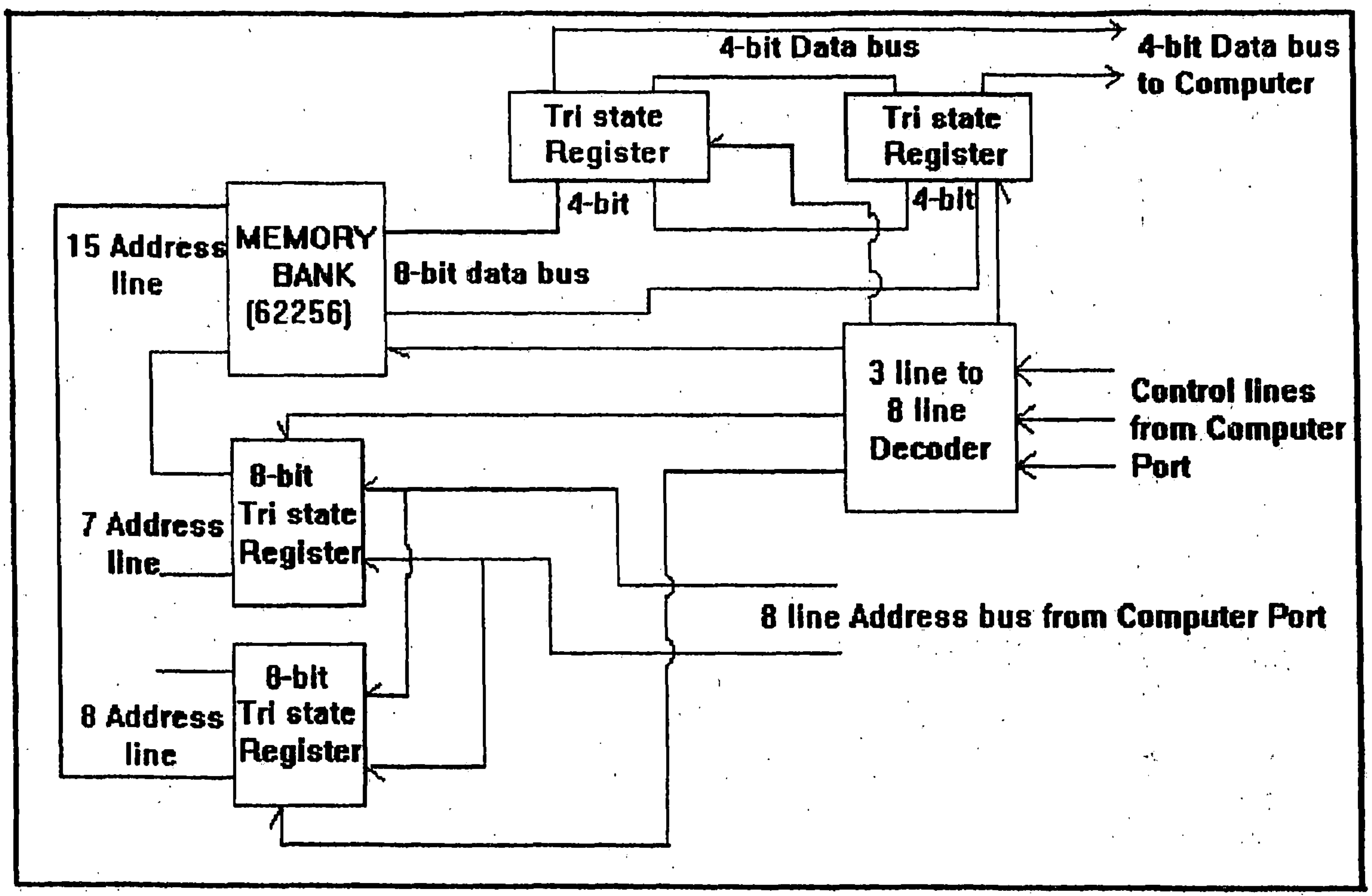

Fig.2.1g.
Data storage system from RAM to hard disk.

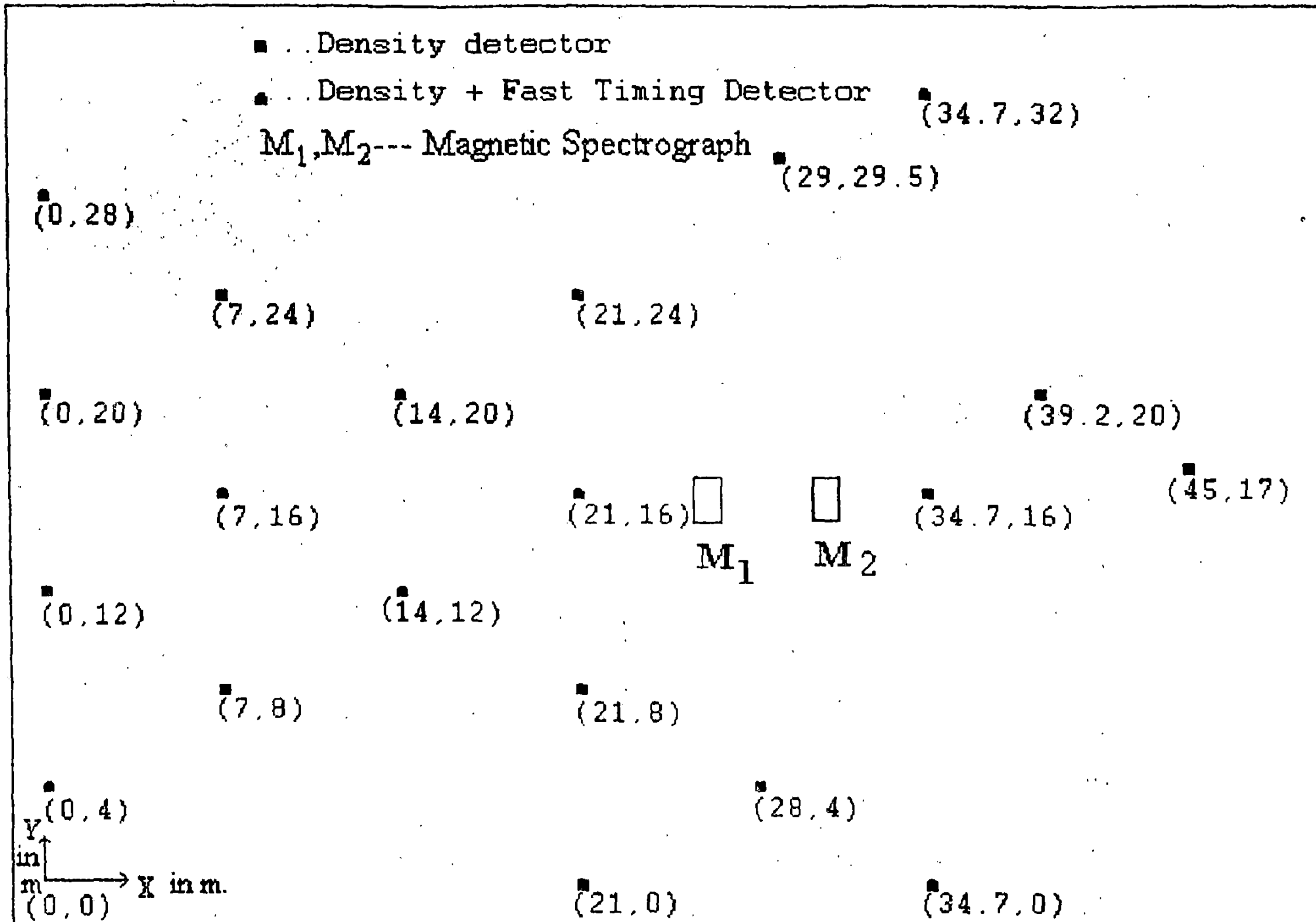

Fig.2.2a.
A schematic diagram of the NBU EAS Telescope

the four edges of the array. Two muon magnetic spectrographs each of area 0.5 m^2 are used for the study of muon component of EAS.

2.3. Electron density detector:

Each of 24 plastic scintillation detector is used as particle detector to obtain the density of the shower particles at various points of the array. All the detectors are made by plastic scintillator blocks each of size 50cmX50cmX5cm. The scintillator block is enclosed in a pyramidal light tight enclosure . The inner surfaces of the enclosure are painted by Titanium dioxide(TiO_2) which has a high light reflection efficiency. A Photomultiplier (Philips XP2050/Dumont 6364/RCA 5819) tube mounted at a vertical distance of about 39cm below to view the scintillator, forms the detector. The arrangement of a detector is shown in fig-2.3a. The photomultiplier tubes are operated in the voltage range 825-1325 Volt. The variation of the operating voltage of different photomultipliers are monitored to ensure that the single particle pulse height in different counters are nearly same. The pulses from all the photomultipliers are amplified by a pre-amplifier of gain 4.7 . The pulses from each detector (pre-amplifier output pulse) are sent to the central laboratory for the collection of data. The performance of each of the detectors was monitored during detector calibration by measuring single particle pulse heights. The variation of pulse height from the centre of the detector to its edge is within 9%.

2.4. Fast timing detector:

Fast timing detectors are used to get timing information of shower front. Eight fast timing detectors are operated in the new NBU EAS telescope. These detectors are exactly of the same structure as of the electron density detectors, only difference is, Philips fast photomultiplier tube (XP2020, rise time ~ 1.5ns) are used . These photomultiplier tubes are operated at negative voltages of 1900-2300 volt to minimise the noise generated from the high voltage power supply. Photomultiplier pulses are amplified by a pre-amplifier and then sent to the Lecroy TDC unit (fig.2.1f.) in the central laboratory for collection of timing information of incident shower front.

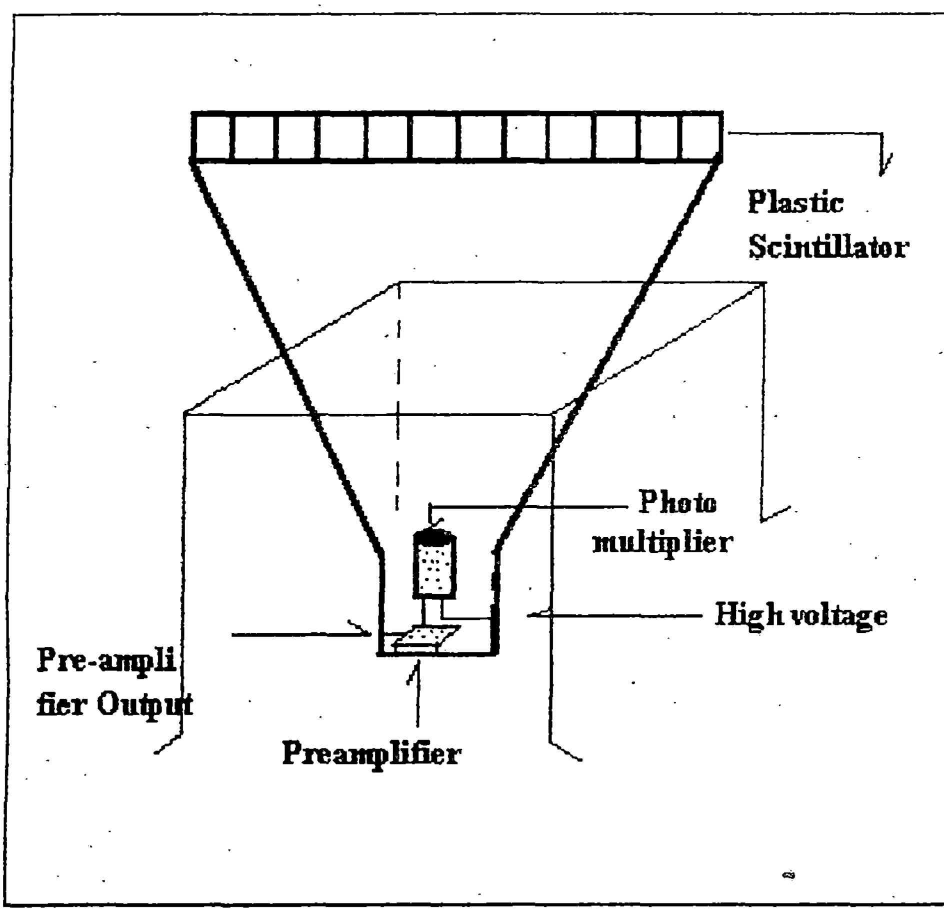

Fig.2.3a.
Electron Density Detector.

2.5. Magnetic spectrograph unit:

Two identical magnetic spectrograph units seperated by a distance of 4m are operated to study the muon component of EAS (Basak D.K. et al[6]) . Each spectrograph unit consists of a solid iron magnet in between four neon flash tube trays. Four cameras are used for recording muon track on flash tubes. The height of the electromagnet is 1m and the magnetic induction in iron is 16 K.Gauss. To remove the electromagnetic component of EAS , the spectrograph is shielded by concrete absorber. Additional lead absorber of about 5cm thick is placed above the top tray of neon flash tubes. Two spectrographs each with a lever arm of 6.3 meter were set up pointing to the zenith to collect muons above 2.5 GeV. in incident vertical showers. The accuracy of locating a muon trajectory is within ±0.14cm. The muon energy is estimated by deflection of a muon in the magnetic field.

2.6. Maintenance of the apparatus :

In order to maintain uniformity of response from scintillator , the performance of the linear amplifiers used for calibration and selection, are checked frequently. The count rate of pulses of each of the density and fast timing detectors are monitored daily . Checking of the data handling system also performed frequently.

2.7. Calibration of the read out system :

2.7.1. ADC and TDC calibration :

All the ADC's are Calibrated first using a standard DC source. In the next step, a square wave pulse generator of variable amplitude was used as a standard source. The width of the pulses were taken comparable with the output analog pulses of the density detectors. Fig. 2.7a shows an actual calibration curve of a particular ADC. From the calibration curve it is found that digitised output pulses are linear to the input voltage of ADC and the uncertainty in the conversion is within 0.39%.
The TDC s are calibrated using a standard Timer.

2.7.2 Density detector calibration :

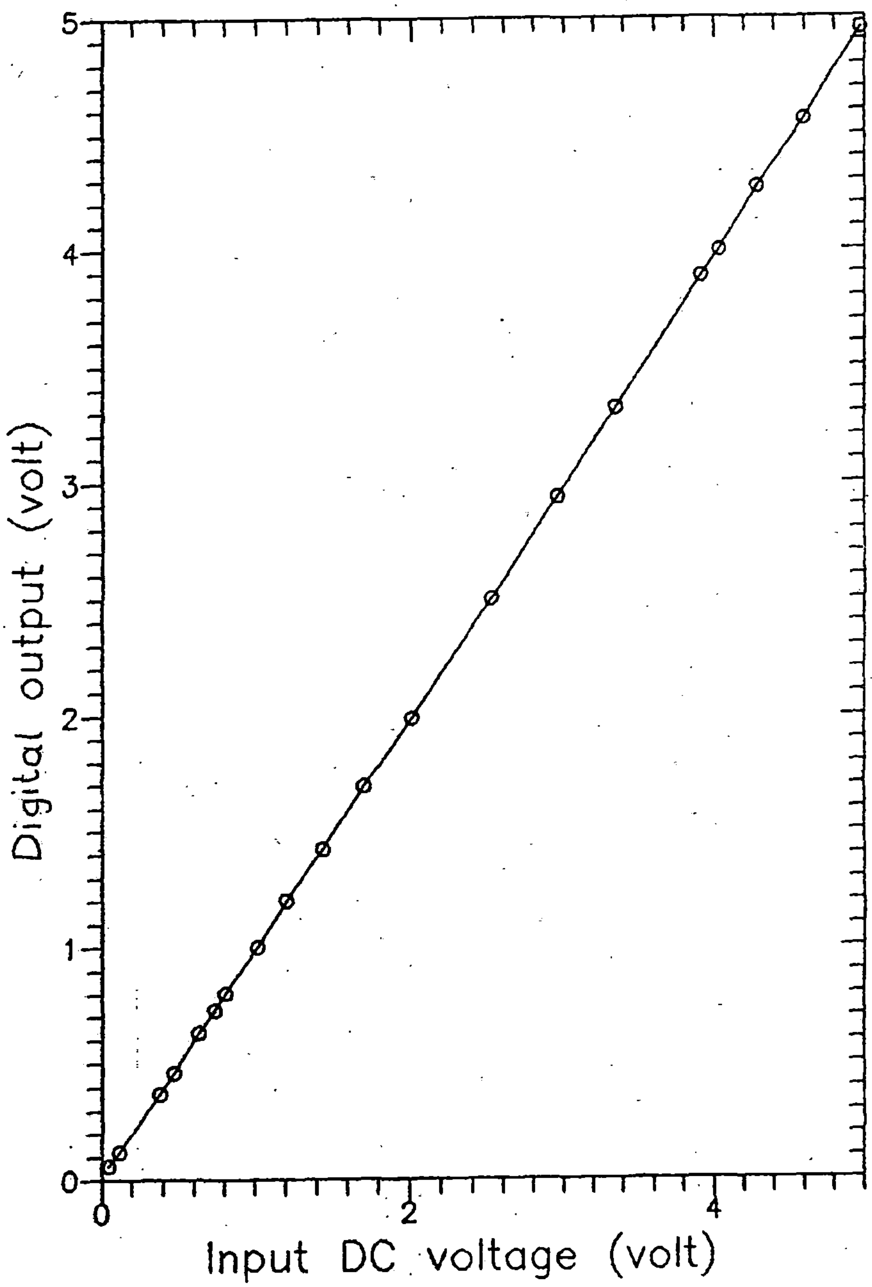

Fig.2.7a
Calibration curve of an ADC.

For the measurement of particle density , each density detector must be calibrated in terms of single particle pulse height. This was done by placing each density detector within a telescopic arrangement of three GM counters , two of which were placed above the detector with their axis mutually perpendicular to each other and the third GM counter was placed below the detector. The arrangement is shown in fig. 2.7b. For the measurement of pulse height , the coincidence pulse from the telescope is used to trigger the MCU of the data acquisition system and the output from the detector is connected to each of the channels of the pulse height measuring circuit one after another. Most coincidences correspond to single particle . Fig. 2.7c shows the single particle pulse height distribution of a particular detector. The full width at half maximum (FWHM) of single particle pulse height distribution for each of the channels is found to be within 27% of the average single particle pulse height of that channel. During the operation of the array , the differential pulse height spectrum for all the detectors has also been measured sequentially and from the pulse height spectrum , the average single particle pulse height was estimated.

2.7.3. Instrumental uncertainty in timing measurements :

For the observation of UHE point sources, an accurate determination of arrival angle of shower is necessary. The accuracy in arrival angle determination mainly depends on the capability of accurate measurement of the relative arrival times of the shower particles. The error in the relative arrival time measurement includes the instrumental uncertainty of the time measuring instruments. For an isolated fast timing detector, instrumental uncertainty is measured in the following way.

The fast timing detector under study is placed above another fast timing detector to form a telescope as shown in fig.2.7d. 2-fold coincidence is obtained by the detectors and the coincidence pulse starts the Lecroy TDC unit. Individual pulses of the two detectors are fed to discriminator and the discriminated output pulses pass with the same cable delay. These delayed pulses are used to stop the channels of the TDC. The distribution of the quantity $\delta = t_d - t_o + (d/c)$ is shown in fig. 2.7e ; where t_d is the time recorded by the detector under study when a particle passes through the telescope, t_o is the time recorded by the other detector for the same event, d is the vertical distance between the two detectors and c is the velocity of light.

Assuming that the distribution of δ is Gaussian , the standard deviation σ of the distribution gives the uncertainity in arrival time measurements and the uncertainity

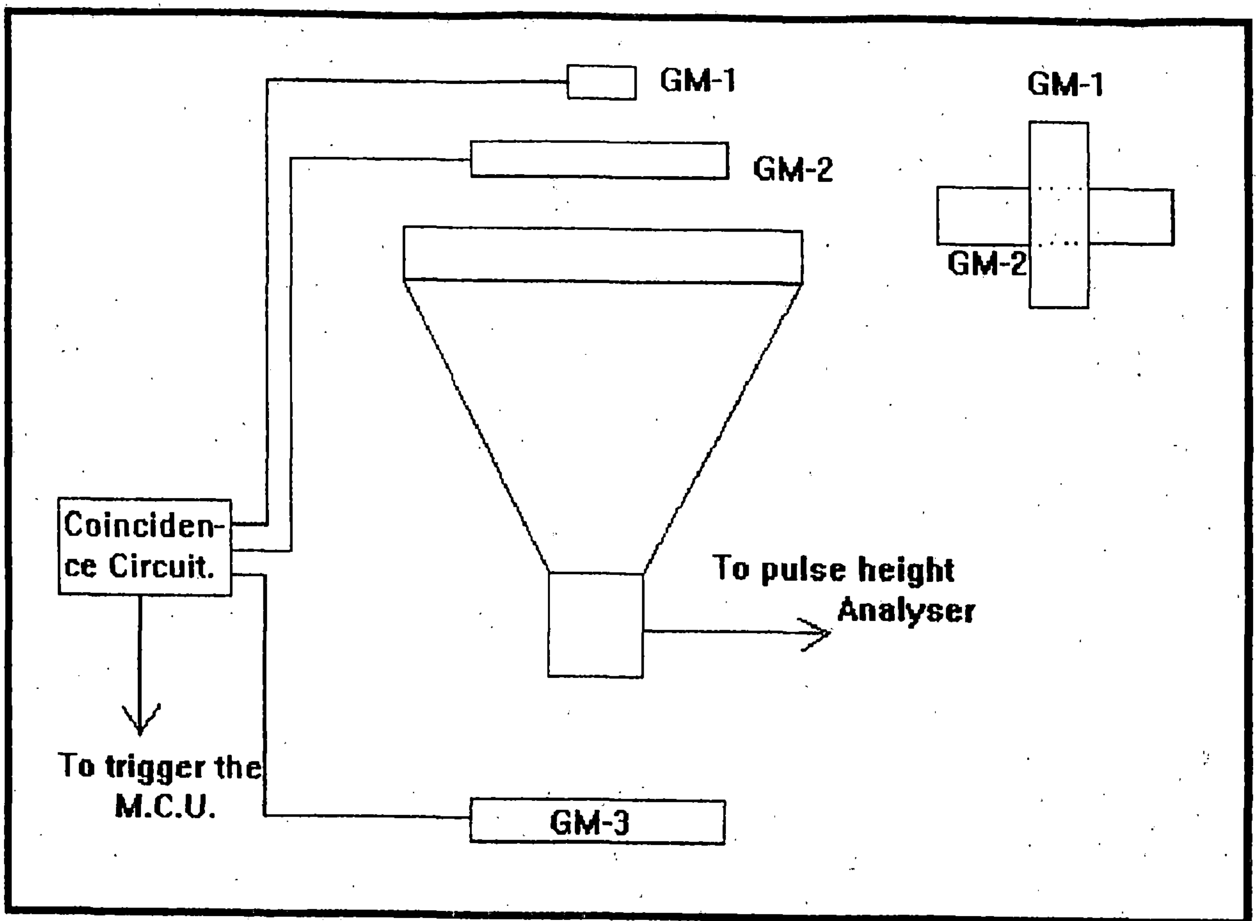

Fig.2.7b.

Arrangement for measuring single particle pulse height.

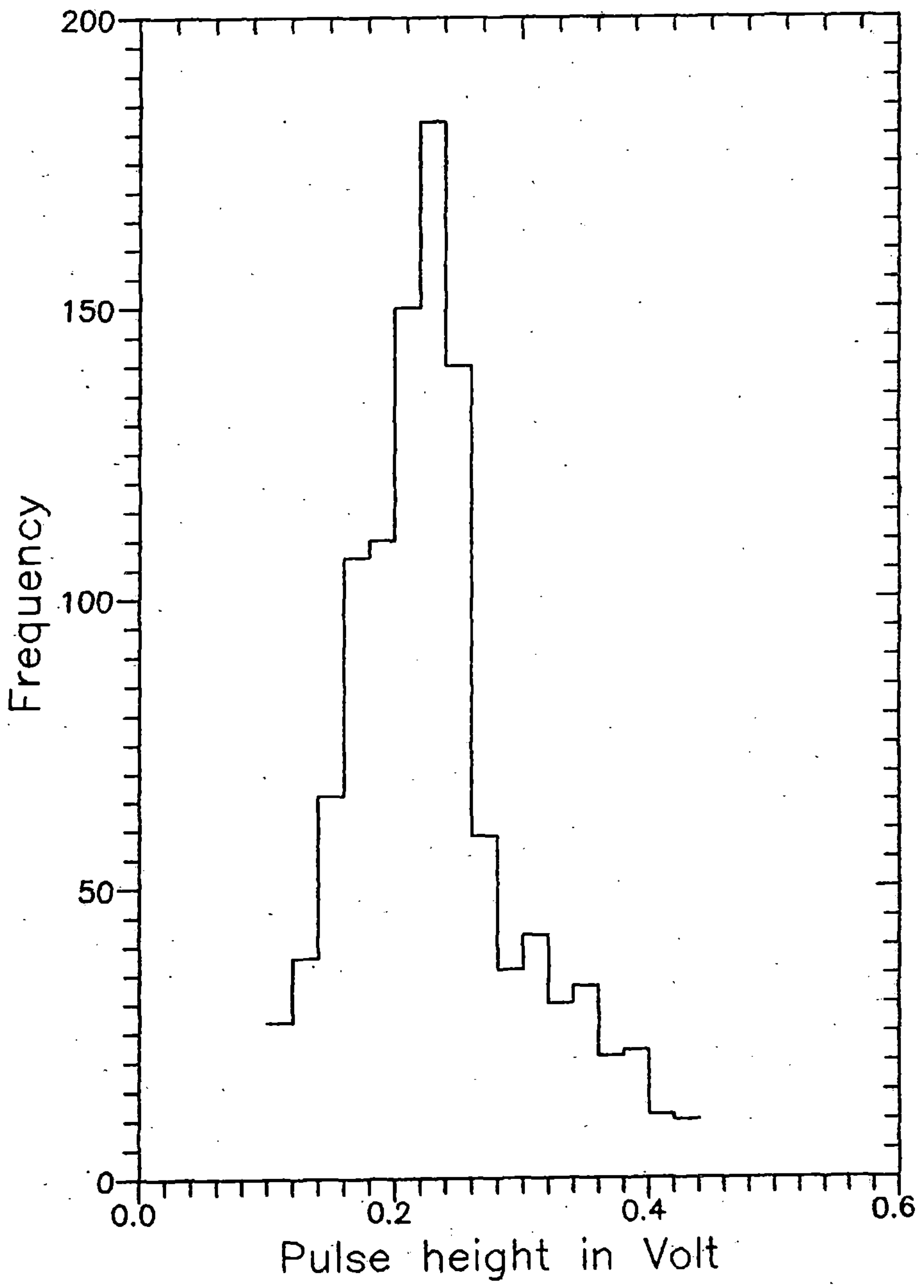

Fig.2.7c.
Single particle pulse height distribution for a particular detector.

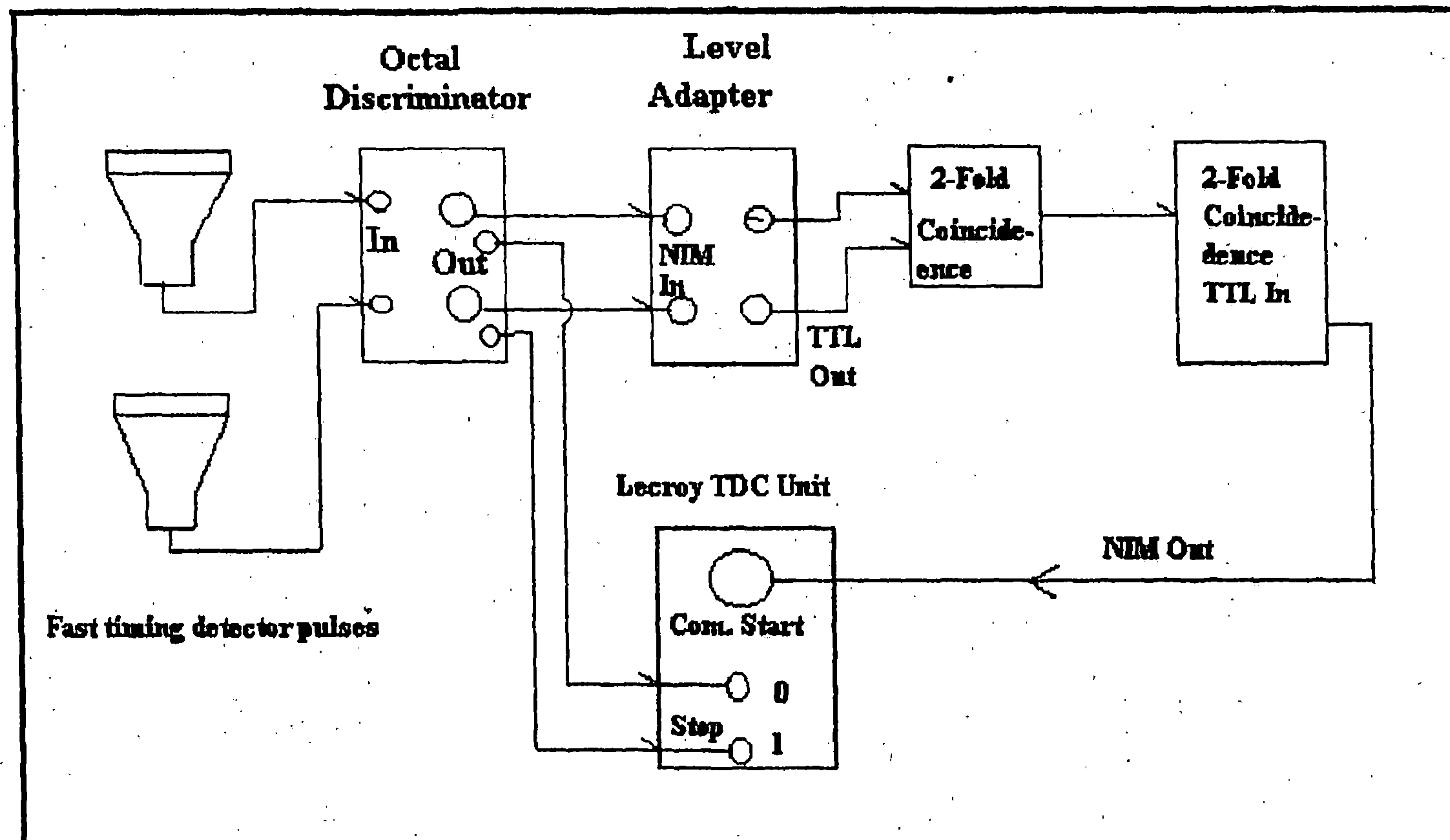

Fig.2.7d.

Experimental arrangement for instrumental uncertainty measurement.

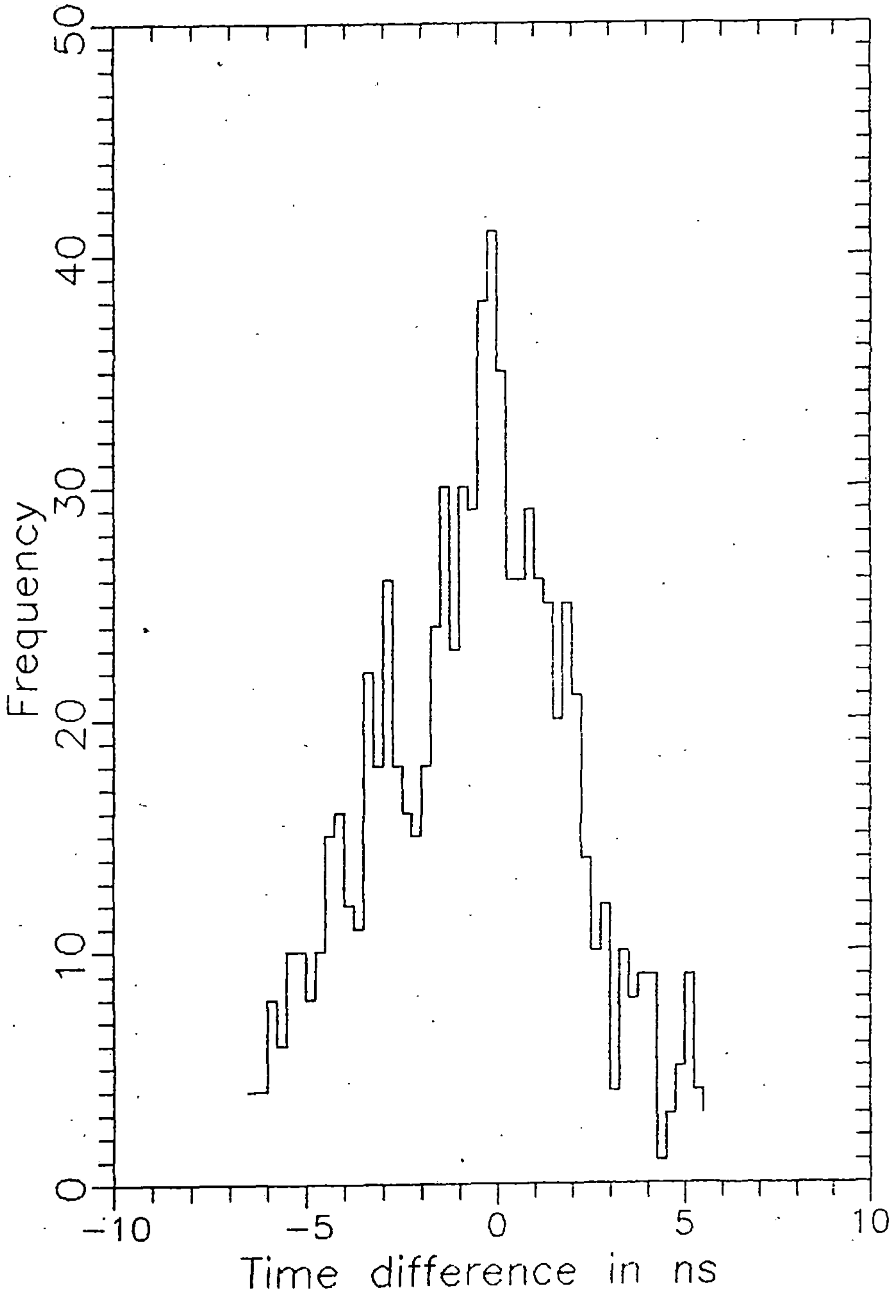

Fig.2.7e.
Instrumental uncertainty
in timing measurement.

in timing measurement for a single detector is found to be $\sigma/2^{0.5}$ which is (1.84 ± 0.05) nano second.

2.8. Discussion:

The new data acquisition system has a provision to extend the array by adding any number of detectors in the array to collect air shower data. In the present system, parallel processing technique is used instead of serial multiplexing technique so that the required time of data acquisition is less. It needs only one clock pulse time for one additional detector channel. The system does not require a dedicated Computer for the collection of air shower data. Only at the time of data transfer from external memory to the hard disk, the Computer is connected to the data acquisition system through a standard parallel port.