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Abstract. This experiment demonstrates detection of cosmic ray tracks by using scintillating fiber planes and multi-anode photomultipliers (MA-PMTs). In a laboratory like this, cosmic rays provide a natural source of high-energy charged particles which can be detected with high efficiency and with nanosecond time resolution.

INTRODUCTION

The scintillating fibers and photomultipliers (PMTs) were used earlier in a Fermilab experiment, APEX, for searching for anti-proton decay. The amplifiers and the scintillating fiber plane couplings were improved for this laboratory experiment.

The majority of the cosmic particles are muons which are mainly from the decay products of charged pions. The mean lifetime of the pions (π^+, π^-) at rest is around 26ns, and they decay into muons and neutrinos 99.987% of the time. Depending on the relativistic γ factor, this lifetime can be much longer. The positively charged muons, μ^+, decay into a positron and a neutrino. The muon lifetime at rest is around 2.2μs. Again, this time can be longer depending on the relativistic γ factor.

We expect the largest cosmic particle flux to reach the earth's surface from the zenith (directly overhead). Tracks from this direction travel through a thinner layer of atmosphere, and so less are absorbed by atmospheric nitrogen and oxygen. When one does this experiment, one will see the display of the charged cosmic ray particle tracks together with their angular distribution after some time (Fig. 1).

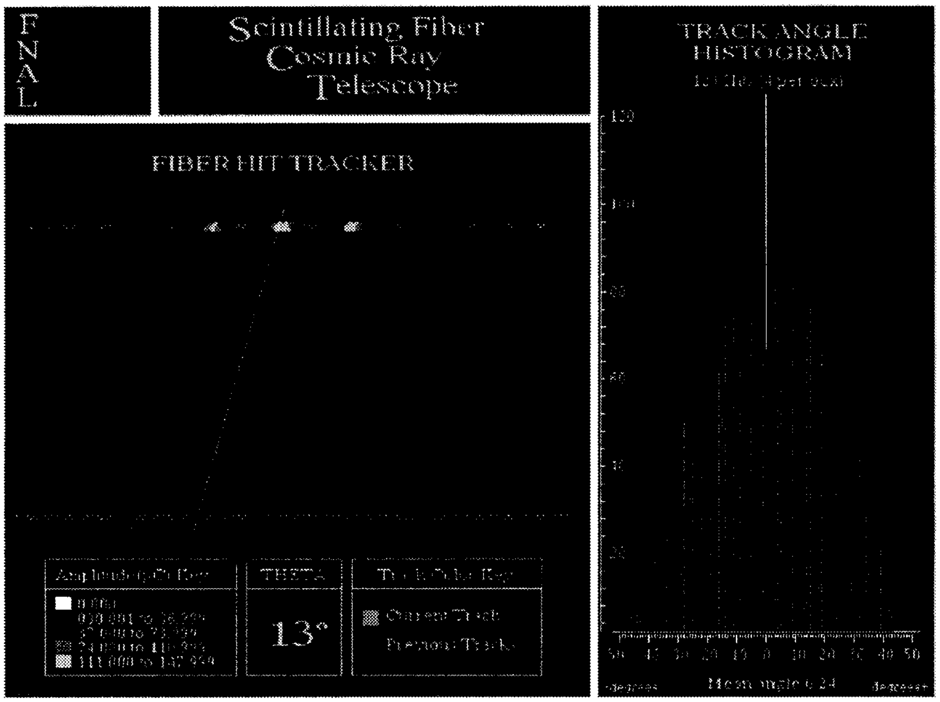

FIGURE 1. Screen display from the cosmic ray telescope.

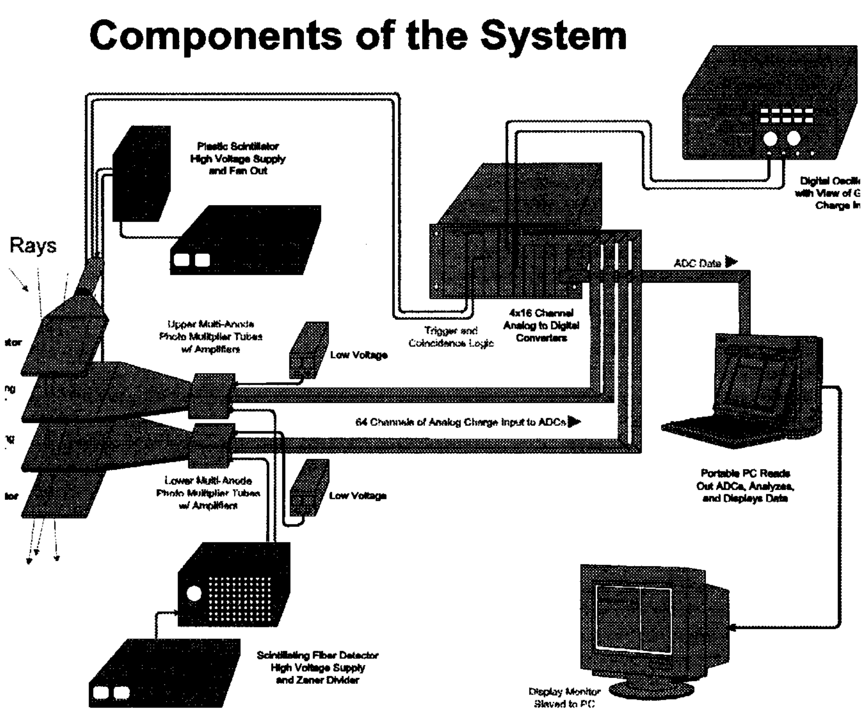

FIGURE 2. Block diagram of the apparatus.

DESCRIPTION

Figure 2 shows the experimental arrangement as a block diagram. The cosmic particles are selected at the given solid angle by a pair of plastic scintillators arranged as a telescope. We use the discriminated signals from these scintillators to provide a trigger to the CAMAC read-out system. Outputs of the discriminators are put through a coincidence module to provide a gate to the LeCroy FERA Analog to Digital Converters (ADCs). The fibers inside each detector are arranged in two layers of staggered rows which are composed of 2mm, singly clad BICRON fibers (Fig. 3). There are 192 fibers in each detector. The fibers are butted onto the face of the MA-PMTs in an 8 by 24 grid. Each fiber is aligned with the matrix of eight strips and 24 wire anodes inside the MA-PMT (Fig. 4). The signals from the 32 anode outputs for each MA-PMT are amplified before being digitized by the ADCs. This reduces the (8+24=) 32 anode signals in each detector. A program running in the PC detects the gate generated by the scintillators, and reads the ADCs. It then decodes the 64 ADC values to reconstruct the hit pattern of the 384 fibers. When studying the display, one should note that often more than one fiber is lit. Sometime this is due to cosmic ray showers where a particle has interacted with the ceiling of the building and produced many secondaries. The most common cause of the multiplier hits in a single fiber plane is due to cross-talk in the MA-PMT. Each wire and strip receives as much as 20% from the charge of its two neighbors. Cross-talk between adjacent wires will appear as hits on neighboring fibers on the event display. Cross-talk between adjacent strips will appear as hits on every eighth fiber.

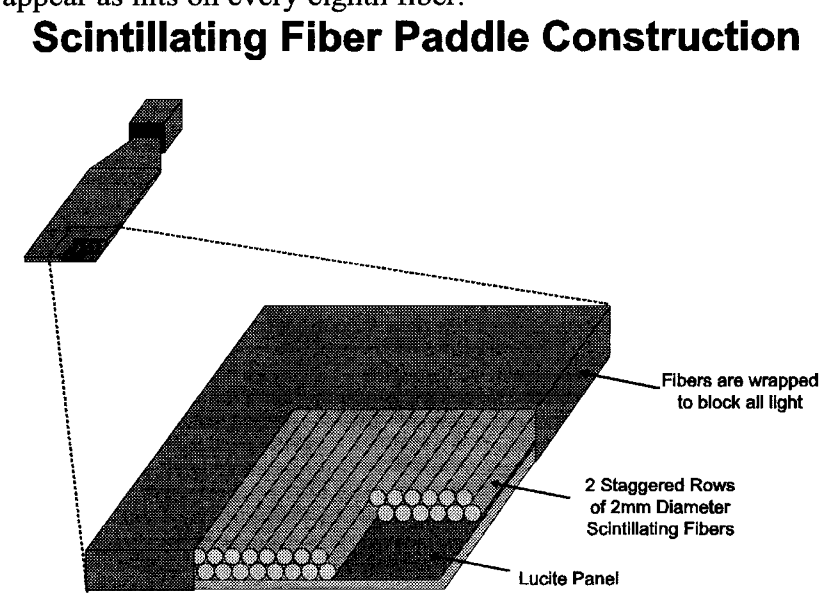

FIGURE 3. Arrangement of fibers in the detector.

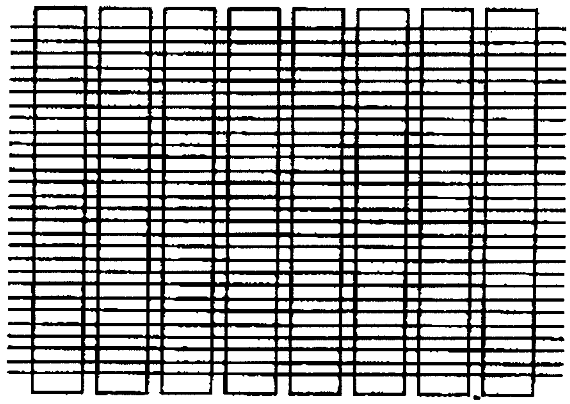

FIGURE 4. Arrangement of 24 wires and 8 strips in MA-PMT.

MATERIALS AND EQUIPMENT

- Butyl PBD and POPOP scintillating fiber planes. The core of the fiber's base material is polystyrene and the clad material is poly-methyl-metacrylate (PMMA), trade name is *Lucite.*
- 64 channels of LeCroy 4300 CAMAC-FERA ADCs.
- Two Hamamatsu R4135 multi-wire anode PMTs.
- Two RCA 8575 PMTs.
- Bias power supplies for the amplifiers on the R4135 signals.
- Portable CAMAC crate with two CAMAC-to-NIM converters for trigger logic.
- LeCroy 4222 gate generator for pedestals.
- LeCroy 622 coincidence unit and LeCroy 621L discriminator unit for trigger logic.
- 100MHz Pentium PC with DSP602 ISA-CAMAC crate interface.

OPERATING INSTRUCTIONS FOR THE SFCRT

Starting Data Taking

1. Turn on the computer.
2. When the computer requests a password, hit CANCEL.
3. Turn on CAMAC crate and power supplies.

4. Attach lemo cable from 4222 OUT1 to the GAI input of the 4301 (for pedestal gate).
5. On the Windows95 screen, there is an icon for the SFCRT. Double-click it. The introductory screen will be displayed while 100 pedestals are taken and the averages downloaded to the 4300s.
6. When the screen changes to the data-taking view (Fig. 1), disconnect the lemo cable from the 4301 GAI input and connect the lemo cable from the 622 OUT to the 4301 GAI input. The system can now trigger on the plastic scintillator coincidence.
7. Hit ENTER to start data-taking.

Getting a Screendump of the Display

Press ALT-PRINT SCREEN. This will save the screen in the computer's paste buffer as a bitmap image. You can then start the PAINT utility that comes with Windows95. Select the PASTE option under the edit window, and the image will appear on the screen. At this point you can save the image to a file or to a printer.

Switch Settings

1. DSP controller: On-line/off-line switch is set to "on-line".
2. Lambda low voltage power supplies for the amplifiers: Both set to "7V".
3. 622 QUAD coincidence module: And/or switch set to "and".

CAUTION: HV supplies must be powered up and down in correct sequence and at correct values. Please do not attempt to change HV setting unless authorized.

4. Fiber detector HV power supply: Set to "NEG 1300V".
5. Fiber detector HV zener divider (COW): Channel 1 peg inserted in the "500 NEG" HV hole. (One detector runs at 1300V; the other at 900V.)
6. Plastic trigger scintillator power supply: Set to "NEG 1700V". Both run at -1700V.
7. Use channels 2 and 3 of the plastic scintillator COW. (Channel 1 is stuck at 100.)

Cabling Hook-up for the SFCRT

Lemo Connections

1. DSP CAMAC controller REQUEST: Set to "GRANT IN".
2. TOP PMT gate to 1st section IN of 621L.

3. BOTTOM PMT gate to 2nd section IN of 621L.
4. Output (lower left) of 1st section of 621L to In of 1st section of 622.
5. Output (lower left) of 2nd section of 621L to the other In of 1st section of 622.
6. Out of 1st section of 622 to IN of 3rd section of 621L.
7. During data taking: OUT of 3rd section of 621L to GAI input of 4301.
8. During pedestal calculation (on start-up): OUT1 of 422 to GAI input of 4301.

Twist-n-flat Cables

1. Cable 1 tube 4 bottom 34-pin connector to 4300 (slot 20) 34-pin connector IN. Pin 1 marking on header up.
2. Cable 2 tube 4 top 34-pin connector to 4300 (slot 21) 34-pin connector IN. Pin 1 marking on header up.
3. Cable 3 tube 4 bottom 34-pin connector to 4300 (slot 22) 34-pin connector IN. Pin 1 marking on header up.
4. Cable 4 tube 4 top 34-pin connector to 4300 (slot 23) 34-pin connector IN. Pin 1 marking on header up.

High Voltage Cables (Red Cables)

CAUTION: HV supplies must be powered up and down in correct sequence and at correct values. Please do not attempt to change HV setting unless authorized.

1. From tube 4 detector to PG1 input of MA-PMT COW (-900V).
2. From tube 9 detector to PG2 input of MA-PMT COW (-1300V).
3. From HV output of model 1570 HV supply to -HV input of COW.
4. From top gate paddle to regulating HV fan-out panel input (3rd from top).
5. From bottom gate paddle to regulating HV fan-out front panel input (2nd from top).
6. From rear connector of 415B to NEGATIVE input of regulating HV fan-out.