Ultra High Energy Cosmic Ray Detector

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Abstract

A new inexpensive ultra high energy cosmic ray detector is proposed which uses existing cosmic ray monitors of the world wide neutron monitor network. These super neutron monitor (NM-64) stations are in operation since the early sixties and many of them record continuously galactic cosmic rays. With fast electronics and accurate timing based on GPS we can record the count rate with high time resolution in many stations. If a beam of many ultra high energy cosmic ray particles arrives from a very distant exotic source produces a number of extensive air showers which will be recorded by some or all the cosmic ray stations members of this universal detector. Our goal is to understanding the origin of the highest energy cosmic ray particles in the Universe.

1 Introduction

It is believed that very high energy cosmic ray particles extend to ultra high energies (Sigl, 2001) possibly going beyond 10^{22} eV. Several measurements indicate the existence of very high energy cosmic rays. It is long since the existence of 100,000 to 100,000,000 TeV cosmic rays has been discussed by Diakonov et al (1978) . The distribution of extensive air showers produced by cosmic rays above $10^{19}eV$ as measured by water-Cerenkov detectors at Haverah Park by Coy et al (1997) and See et al (1971) together with Monte Carlo simulations of shower development give more confidence that ultra high energy cosmic rays exist and that large scale experiments as the Auger project have a promising future. For an Overview of the Pierre Auger Observatory Project see Nitz (1998). The Pierre Auger Project is an international effort for a study of cosmic rays at very high energies with two air shower detectors, one in the Northern Hemisphere and the other in the Southern Hemisphere. Each installation will consist of an array of 1600 particle detectors spread over 3000 square km with solid angle acceptance of 2 sterads suitable for cosmic ray air showers. Each installation will also have an atmospheric fluorescence detector viewing the volume above the surface array. The Pierre Auger project is expected to measure the direction, energy, and mass composition of 60 events per year with energy of 10^{20} eV and about 6000 events per year above 10^{19} eV. Mantsch (1996) describe the Pierre Auger project goals. A good test for the Auger project has been proposed by Anchordoqui et al (2001) based on a Cen A model of highest energy cosmic rays.

European institutions are planing to further exploit the principle of stereoscopic observation of gamma-ray induced air showers as they have done so successfully with HEGRA with a technique which permits to do very high energy astronomy. They plan a next generation instrument H.E.S.S. (High Energy Stereoscopic System), which they construct in the Khomas Highland of Namibia (Steenkamp, 2000). The origin of Cosmological Gamma-Ray Bursts suggest the existence of very promising ultra high energy cosmic ray sources (Miralda-Escude and Waxman, 1996).

Aharonian et al (2001) propose a new design and discuss the performance of a powerful ground-based astronomical stereoscopic array of several large imaging atmospheric Cherenkov telescopes (IACTs) with a 5 GeV energy threshold, which

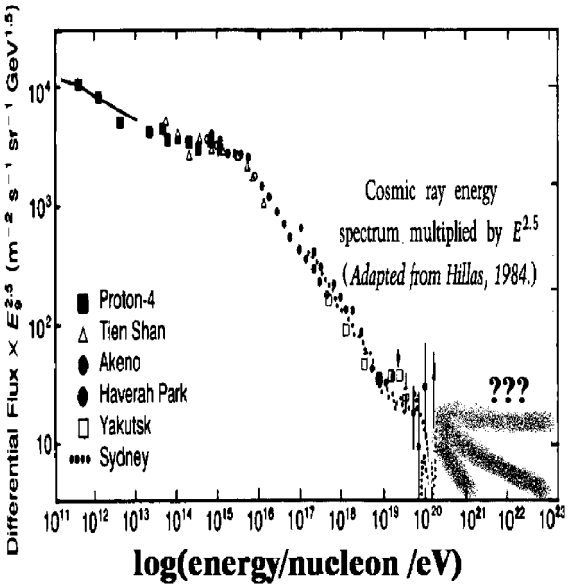

Figure 1. The spectrun of ultra high energy cosmic rays, adapted from Hillas, 1984

they plan to establish at an altitude of 5 km. This system is designed to study the sky in gamma rays at energies from 5 to 100 GeV. This instrument will be suitable to detect the standard EGRET gamma-ray sources with spectra beyond several GeV.

A novel design based on a Maximum-energy Auger (AIR)-shower satellite (MASS / AIRWATCH) is conceived (see Takahashi et al, 1996). The design will permit observation from space of the high energy cosmic rays hopefully above 10^{20} eV with a new concept detector observatory. The system is composed of segmented lenses and mirrors in combination with an array of 10^6 pixels to detect fluorescent light from high energy cosmic ray cascades in the Earth's atmosphere. The field-of-view of MASS could be extended to about 1000 km^2 so that more than 1000 events per year could be observed above 10^{20} eV and possibly up to 10^{22} eV. This space born detector would be suitable of observing events at all angles with very good spatial and temporal resolution.

It is believed that the Southern Hemisphere Pierre Auger Observatory might provide a decisive test for extragalactic models of the origin of the ultra-high energy cosmic rays (Romero et al 1996). The ultra-high energy cosmic rays recently detected by several air shower experiments have extragalactic origin. It is believed that some of the nearest active galaxies such as Centaurus A are possibly sources of very energetic particles coming at the Earth. Radio observations help to estimate the energy of the protons accelerated by strong shock waves. The galactic coordinates of such particles with energies up to 10^{21} eV are estimated to be $l = 310^o$ and $b = 20^o$.

The discovery of the very high energy cosmic rays 10^{20} eV with the Fly's Eye (Bird et al, 1993) and AGASA experiments make all future very high energy cosmic rays very promising (Hayashida, 1994 and Teshima, 1998). Bai and Lee (2001) investigated the long-term variability of Cen A and predict that in the near future this very interesting cosmic ray source will possibly undergo an outburst. The jet of M87 and Mrk 501, as well as other AGN jets are also very promising extremely energetic cosmic sources.

We believe that additionally to experiments such as the 10 m CANGAROO and the very extensive HESS facility. Such interesting sources which will provide new insite to ultra high energy phenomena and these will also be detectable by the proposed Universal Cosmic ray detector we propose here.

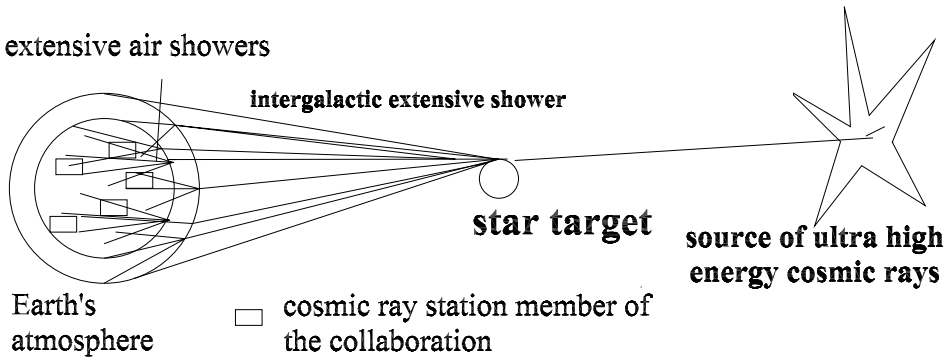

Figure 2. The concept of ultra high energy cosmic-ray detector

2 Proposal for the new inexpensive new generation instrument for Ultra High Energy Cosmic rays

We intent to use the existing network of super neutron monitor stations which cover all the Earth to construct an inexpensive ultra high energy cosmic ray universal detector. The system is feasible, inexpensive, the largest possible on Earth, it uses existing cosmic ray stations with fast electronics and recording system with very accurate timing. The system of the proposed *Universal Cosmic Ray Detector* has an area which covers all the Earth, much larger than any other system anticipated up to now. The super neutron monitor (NM-64) stations are in operation since the early sixties and most of them record continuously galactic cosmic rays. It is very easy to use fast electronics and to introduce accurate timing based on GPS. With tis system we can record the count rate with very accurate timing and high resolution. Such a system is capable to detect almost simultaneous arrival of cosmic ray particles in cosmic ray stations which are members of the collaboration.

We assume that it is possible that ultra high energy cosmic ray particles exist in the Universe. When such a particle hits a distant target, e.g. the atmosphere of a star in another galaxy, or any other target, it is possible to produce a beam of secondary but still very high energy cosmic rays. If such a beam of many ultra high energy cosmic ray particles arrives at the Earth from a very distant exotic source produces a number of extensive air showers in the atmosphere of the Earth. These extensive air showers consist of particles which will be recorded by some or all the cosmic ray stations members of this universal detector. Our goal is to detect for the first time these ultra high energy cosmic rays and understanding the origin of the highest energy cosmic ray particles in the Universe.

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