Auger project technical note — Optimum latitude for the Auger Observatories to achieve all sky coverage

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Abstract

The latitude of the sites chosen for the Auger observatories in the northern and southern hemispheres determines the declination distribution of the EAS that will be recorded, and hence the effectiveness with which an all-sky survey of the arrival direction distribution may be performed. A simple calculation is presented which confirms that latitudes of approximately $\pm 35^\circ$ N and S will give near uniform exposure for the proposed water Čerenkov arrays.

1 Introduction

Water Čerenkov detectors are currently the technology of choice for the Auger ground arrays (AGA) [1]. A principal advantage of a giant airshower array composed of deep water detectors is that the energy of cosmic ray primaries required to trigger the system is only weakly dependent on the zenith angle of incidence. This is very different than for an equivalent array composed of thin (scintillator) detectors, and is due the combination of several effects:

- The response of a deep, massive particle detector to the penetrating (GeV) shower muons is large per particle compared to that produced by the more numerous but softer electromagnetic particles (MeV).

- The lateral distribution of muons is flatter, and at large distances from the shower core (~ 1 km) the muonic signal comes to dominate.
- The attenuation rate of shower muons passing through the atmosphere is slower than for the electromagnetic particles.
- Inclined showers produce elliptical footprints at ground level increasing the number of detectors at a given perpendicular distance to the shower axis.

It is believed that guided by modern Monte Carlo calculations we will be able to reconstruct and use EAS events recorded by the Auger water Čerenkov arrays incident at zenith angles of up to 60°. This will result in a viewing cone of π steradians ie. more than twice the observing power of an equivalent thin detector array limited to a 45° cone opening angle. It is probable that water detectors are intrinsically cheaper per 10 m^2 unit than scintillator and other thin detector types. However, on the basis of the above argument they could actually be up to twice as expensive and still form a more cost effective EAS observatory.

There is an additional reason why deep detectors are to be prefered from a physics/financial point of view. A key goal of the Auger project is to carry out an "all-sky survey" at the very highest cosmic ray energies, performing cluster searching and large scale anisotropy scans over the complete celestial sphere. This paper demonstrates that twin arrays able to view EAS out to zenith angles of 60° provide near uniform exposure when located at latitudes of $\approx \pm 35°$ north and south. To obtain similar coverage using thin detectors three arrays would be required.

2 Calculation technique

The calculation technique used in this paper is to determine the declination distribution that would be observed experimentally if the incoming cosmic rays were perfectly isotropic. Any deviation from uniform intensity per unit solid angle is then non-ideal behavior for a detector system. Under the above assumption the zenith angle distribution of EAS cores impacting within a given ground area is $\propto \cos\theta \sin\theta$. The solid angle viewed rises as $\sin\theta$ and the array projected area falls as $\cos\theta$. In fact even for an array as large as the proposed Auger instruments ($\approx$ 50 km across) the effective projected area

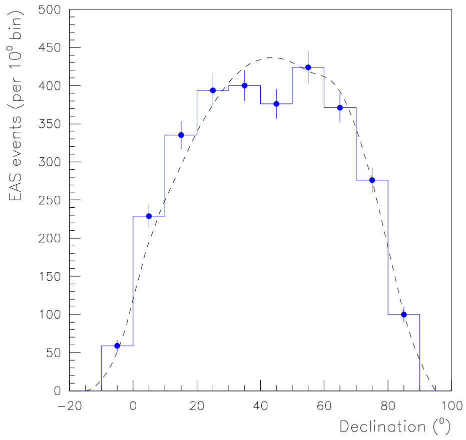

Figure 1: Comparison of calculated and measured EAS declination distributions. The dashed line is the result of calculation for a water Čerenkov array at latitude 54° north. The solid histogram is data from the Haverah Park experiment (2964 events with $\theta < 60°$ and $E > 4$ EeV).

will fall a little faster than $\cos\theta$ due to the increasing fraction of showers whose elliptical footprints extend too close to the array boundary to allow confident reconstruction.

A large sample of random (θ, ϕ) pairs was generated according to the above rule, and requiring $\theta < 60°$. The equivalent declination angle was then calculated for each "event" on the basis of an assumed array latitude. The predicted declination distribution for an array operating at 54° north is presented in figure 1, together with the observed distribution as measured by the Haverah Park experiment [2]. The agreement between the two curves gives confidence that this very simple calculation procedure is sound. (It is also clear that there isn't huge anisotropy in the energy regime displayed!)

3 Optimum array latitude

Sets of 10^5 "events" were generated assuming arrays at latitudes of ± 25, 30, 35 and 40° north and south. (Each equivalent to the total number of showers that will be collected during the projected 20 year lifetime of the Auger experiment!) The result are shown in figure 2. The behavior of an ideal detector under these conditions is also shown. Figure 3 displays the ratio of these two curves. It is seen that arrays at latitudes between 30 and 40° north and south would be acceptable, with 35° being close to optimal.

4 conclusions

A very simple calculation has been shown to reproduce rather well the experimentally observed declination distribution of the Haverah Park water Čerenkov array. The same procedure indicates that the proposed Auger arrays should be sited as close to latitudes $\pm 35°$ north and south as is possible given the many other practical considerations.

References

[1] The Auger Collaboration, *Design Report* (August 1995).

[2] , *Catalogue of Highest Energy Cosmic Rays 1: Volcano Ranch and Haverah Park*, ed by M. Wada, World Data Center C2 for Cosmic Rays, Institute of Physical and Chemical Research, Itabashi, Tokyo, Japan, (1980).

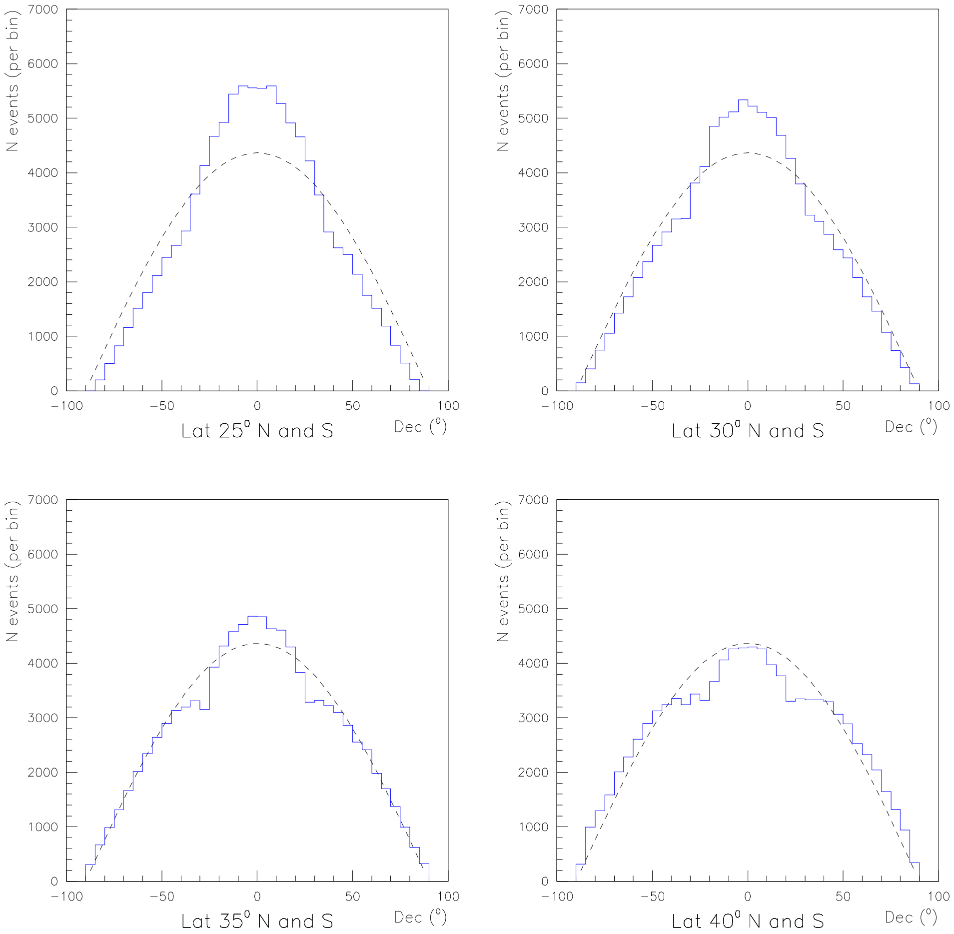

Figure 2: Calculated arrival direction distributions for twin arrays at four latitudes, assuming isotropic incoming cosmic rays. In each case the solid histogram is the calculation result and the dashed line indicates sin(Dec); the available solid angle.

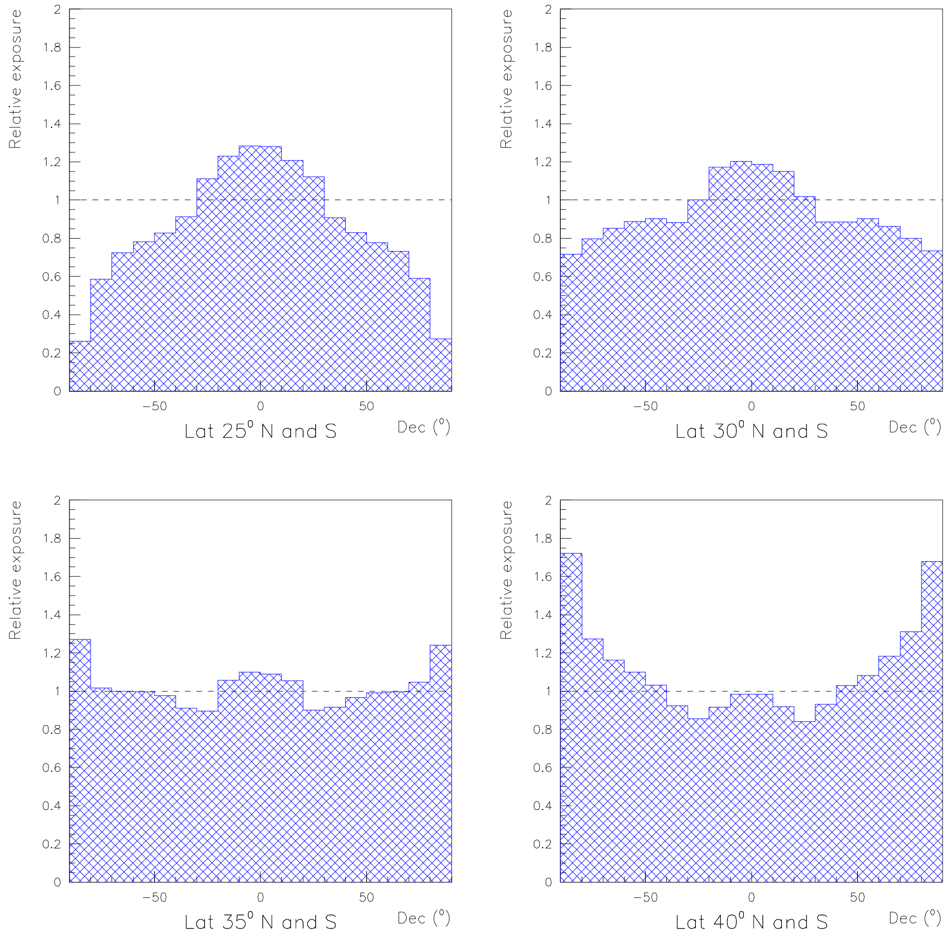

Figure 3: Ratio of calculated arrival direction distribution to the available solid angle. This figure redisplays the same information as shown in figure 2.