# Performance of the Tibet-III Air Shower Array

**The Tibet AS$\gamma$ Collaboration**
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**Abstract:** The Tibet-III air shower array (36900 m$^2$) has been successfully operating at Yangbajing (4300 m a.s.l.), China. The threshold energy of observed air shower is estimated to be 1.5 TeV and 1.0 TeV for protons and gamma rays, respectively. The angular resolution is estimated to be $0.95^\circ \pm 0.01^\circ$ around 3 TeV using a Monte Carlo simulation. This angular resolution is well confirmed by the cosmic-ray shadow by the Moon observed during 83.0-day live time.

## 1. Introduction

A collaboration experiment on cosmic-ray physics between Japan and China has been successfully continued at Yangbajing (90.°522E, 30.°102N; 4300 m above sea level) since 1990 when it succeeded in detecting cosmic ray showers around 10 TeV with an angular resolution better than 1 degree[1][2]. On the basis of this experiment, the Tibet air shower array has been gradually expanded and its photosensitive coverage was improved to increase the sensitivity to detecting cosmic-ray showers with energy as low as possible.

The Tibet-III air shower array (Tibet III), was enlarged from 22050 m$^2$ to 36900 m$^2$ in fall, 2002 to detect cosmic-ray showers in the multi-TeV region with

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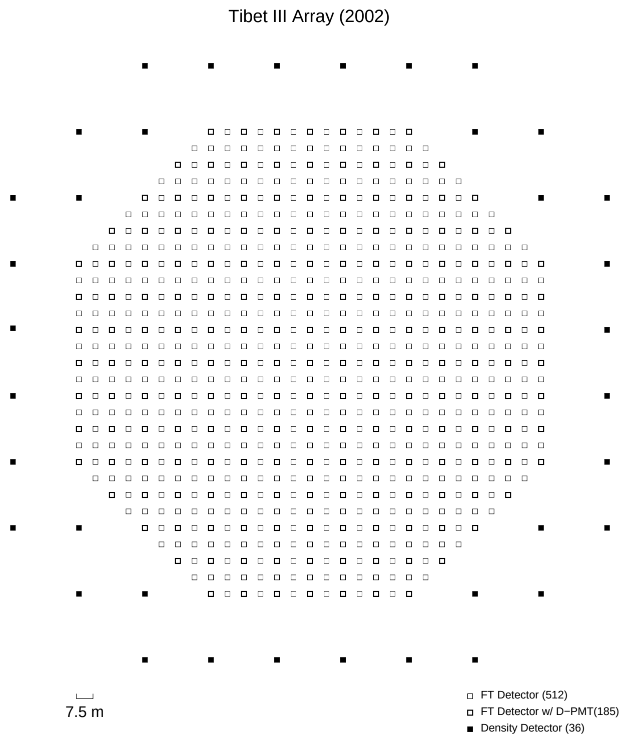


**Fig. 1.** The Tibet Air Shower Array in 2002.

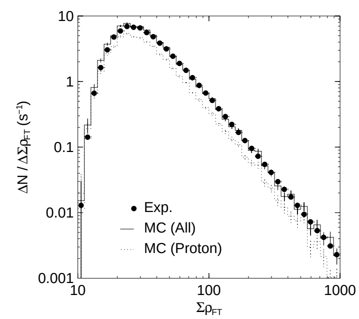


**Fig. 2.** $\sum \rho_{\rm FT}$ spectrum. Closed circles show experimental data. Solid lines show the MC simulation and dashed lines extract its proton component.

higher good statistics. We report the performance of this new array based on a Monte Carlo (MC) simulation.

## 2. Present status of Tibet III

The Tibet-III air shower array (36900 m$^2$) is composed of 697 fast-timing (FT) detectors and 36 density (D) detectors (Fig. 1) and has been in operation since November 2002, with the present configuration. Each FT detector equipped with a plastic scintillator plate of 70.7 cm × 70.7 cm × 3 cm thickness and with a 2 inch photomultiplier tube, is deployed at a lattice of 7.5 m spacing. Currently, the trigger pulse is formed when 4 units or more among all FT detectors, give a signal of 0.6 particles or more. The present trigger rate is 1430 events/s, and the dead time is estimated to be 11.5%. The stored event rate amounts to about 25 GB/day, and 2-day data fill a tape. Details of Tibet III are described elsewhere[3].

## 3. Performance of Tibet III

A MC simulation was done to estimate the performance of Tibet III. The Corsika Ver. 6.004 code[4] was used for calculating the development of air showers in the atmosphere, and the Epics uv7.24 code[5] was used for simulating the

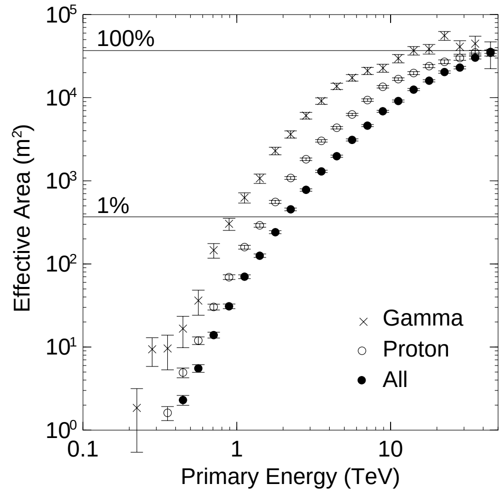


**Fig. 3.** Effective area. Closed circles show the MC results plotted as a function of primary energy per particle.

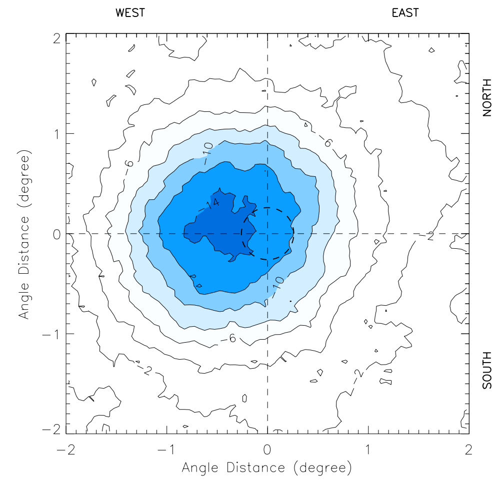


**Fig. 4.** Moon shadow observed by Tibet III 83.0-day data.

detector response. A primary cosmic-ray flux model, based on direct observation data, was employed[6][7][8]. Primary particles were thrown isotropically within the zenith angle 0° to 60° on the top of the atmosphere, and generated air showers were collected within the circle of the radius 300 m from the center of the array. We used the experimental data obtained on February 27th, 2003 to compare it with the MC simulation. This is a typical run of Tibet III, corresponding to 1.63-hour live time. The event selection was done by imposing the following three conditions on both of the simulation and experimental data: (1) Each of any four detectors should record a signal of more than 1.25 particles; (2) estimated core location should be inside of the array; and (3) estimated zenith angle of the incident direction should be less than 40°. After data processing and quality cuts, $1.57 \times 10^4$ and $1.75 \times 10^6$ events survived for the simulation and experimental data, respectively.

A distribution of the sum of shower particle densities, $\sum \rho_{\rm FT}$, of 697 FT-detectors is shown in Fig. 2. The simulation and the experimental results are in good agreement for $10 < \sum \rho_{\rm FT} < 1000$. The integral event rates in this region are calculated to be $304.9 \pm 2.4$ events/s and $297.5 \pm 0.2$ events/s for the simulation and the experimental data, respectively, demonstrating good agreement between them. The systematic error in the size scale is estimated to be less than 10% level, assuming a ±30% normalization uncertainty for the absolute flux of primary cosmic rays.

Figure 3 shows an effective area of Tibet III as a function of $\sum \rho_{\rm FT}$. The threshold energy, as defined so that the effective area becomes 1% of the geometrical area (36900 m$^2$), is 1.5 TeV and 1.0 TeV for protons and gamma rays, respectively.

The systematic pointing error and angular resolution of Tibet III can be estimated by observing the Moon's shadow in cosmic rays flux. Primary charged particles are bent by the geomagnetic field before reaching the Earth[2]. Figure 4 shows the Moon's shadow observed with Tibet III for 83.0-day live time during the period from November 18th, 2002 through April 17th, 2003. The maximum deficit depth is estimated to be $\sim 15\sigma$. Here, we define the angular resolution of Tibet III as the radius of a circle in which 50% of shower events coming from a point source are contained. The angular resolution of Tibet III is estimated to be $0.92° \pm 0.04°$ by the sharpness of the shadow. The angular resolution for all the events with $\sum \rho_{\rm FT} > 10$ is also estimated to be $0.95° \pm 0.01°$ by the MC simulation, reproducing the data quite well. The center position of Moon's shadow should also shift westward from the true position due to the geomagnetic field. As seen in Fig. 4, the center of the Moon's shadow is observed at the position deviating to the west by $\sim 0.3°$. This displacement is consistent with the expected deviation. The shadow center deviation $< 0.1°$ in the north-south direction indicates that the possible systematic pointing error of Tibet III is $< 0.1°$, since the geomagnetic field at Yangbajing does not affect the shadow in the north-south direction.

## 4. Summary

The new Tibet-III air shower array has been successfully operating at Yangbajing since November 2002. We estimated the performance of this array using a Monte Carlo simulation. The threshold energies for detecting proton-induced showers and gamma-induced ones are estimated to be 1.5 TeV and 1.0 TeV, respectively. The angular resolution is estimated to be $0.95° \pm 0.01°$ in the energy region around 3 TeV (mode energy of all selected events). This angular resolution is well confirmed by the observed Moon's shadow.

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