Muon Radiography in the Egyptian Pyramids

K.Morishima Nagoya University

Khufu's Pyramid



Pyramids at Giza



Pyramids at Giza



Scan Pyramids

International Scientific Project

Organization : Egyptian Ministry of Antiquities, Cairo University and HIP institute Participating countries : Egypt, France, Canada and Japan

Non-destractive Imaging Technologies

Muon Radiography : Nagoya University, KEK, CEA

Infrared imaging : Laval UniversityLaser 3D reconstruction : Iconem



Targets

- Khufu's Pyramid
- Khafre's Pyramid
- Bent Pyramid
- Red Pyramid

Target Pyramids







Khufu's Pyramid Khafre's Pyramid

Red Pyramid Bent Pyramid

Bent Pyramid



Red Pyramid

Mit Rahine

Imaging of Pyramid



Imaging of Pyramid



Imaging of Pyramid



Nuclear emulsion



Nuclear Emulsion Film

Three dimensional Tracking Detector for charged particles



Sub-micrometric spatial Resolution in three dimension, detection in 4pi steradian
No electric power, light weight, thin, Water proof -> No limitation to installation place
Mass production -> Large area detector, multi target, multi position in parallel



Nuclear emulsion

Shielding package

After photographic development



Nuclear Emulsion Scanning System based on Optical microscope





Nuclear Emulsion Scanning System based on Optical microscope





Three Dimensional Track Reconstruction

Scanning System "Hyper Track Selector"



Measurement system of cosmic-ray muons



Digital data of three dimensional track



Khufu's Pyramid



















Nuclear Emulsions

8

B

Nuclear Emulsion Detector







Axis of Grand Gallery West **East** King's Chamber Grand Gallery Queen's Chamber

Cosmic-ray Image



West

Axis of Grand Gallery West **East** King's Chamber Grand Gallery Queen's Chamber

Cosmic-ray Image

Muon Flux (Red : Many $\leftarrow \rightarrow$ Blue : Few)



West



Cosmic-ray Image





Cosmic-ray Image



Cosmic-ray Image





Cosmic-ray Image





Cosmic-ray Image



Cosmic-ray Image



Cosmic-ray Image





Cosmic-ray Image





Cosmic-ray Image











Revealing precise three dimensional structure Measurement of density of Pyramid

New technology for archaeological heritage all over the world

Cosmic-ray Imaging

