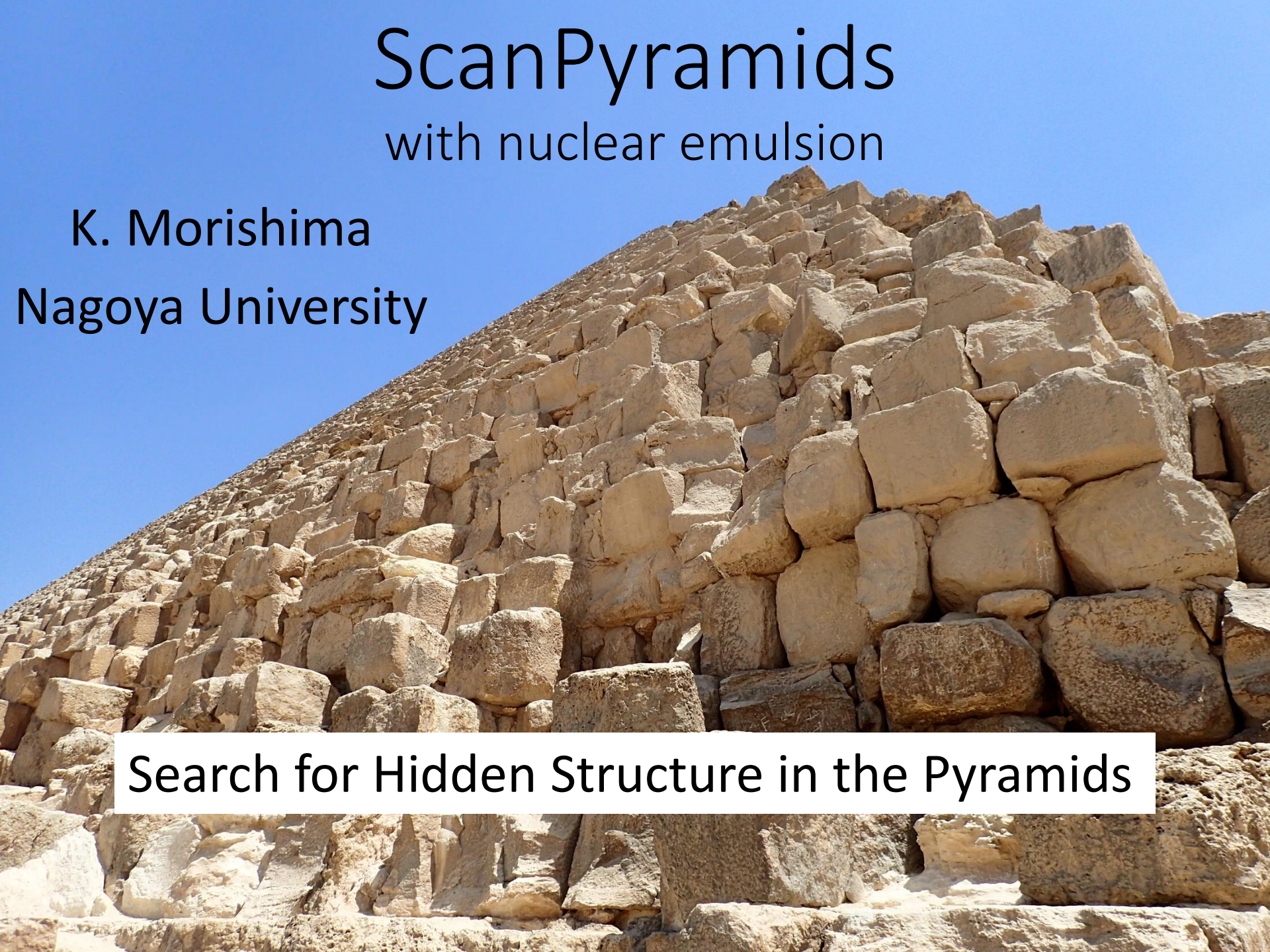
ScanPyramids

with nuclear emulsion

K. Morishima

Nagoya University



Search for Hidden Structure in the Pyramids

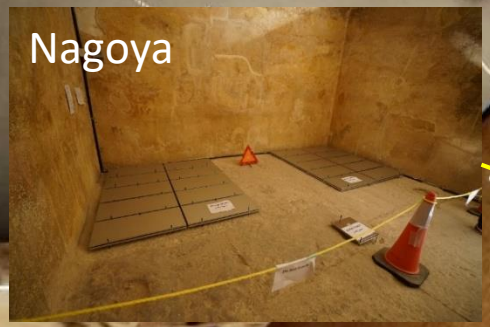
ScanPyramids

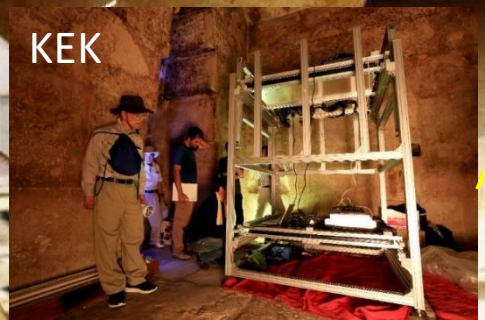
international scientific project

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

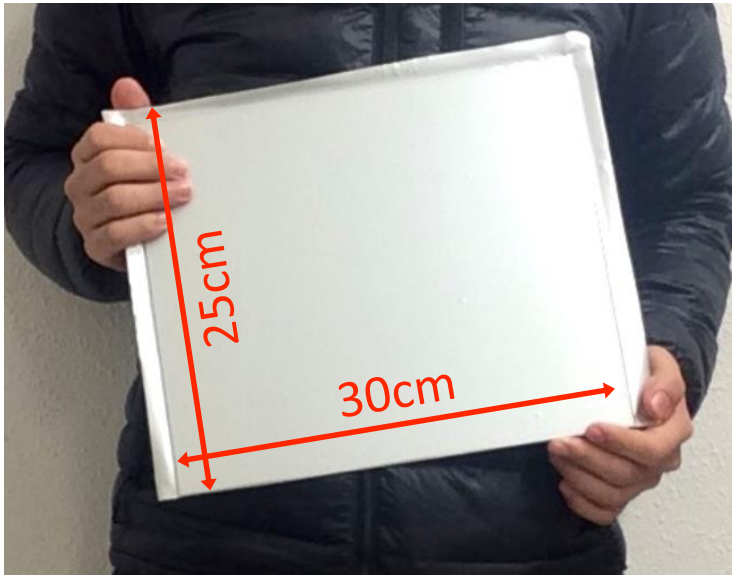
Non-destractive Imaging Technologies

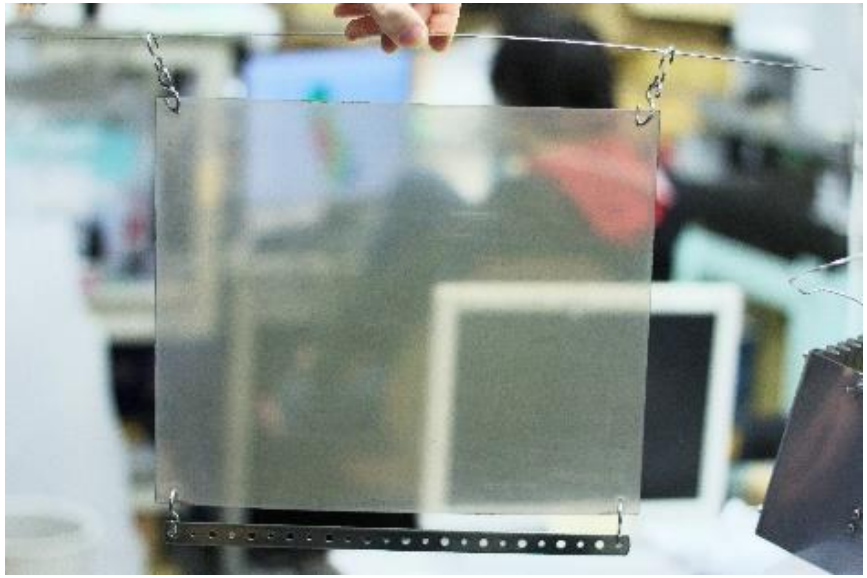
- Muon Radiography : Nagoya University, KEK, CEA
- Infrared imaging : Laval University
- Laser 3D reconstruction : Iconem





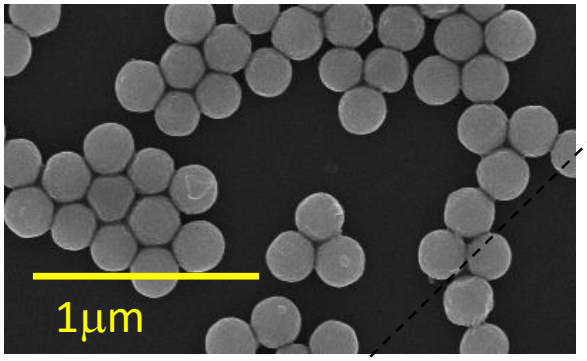
Nuclear emulsion

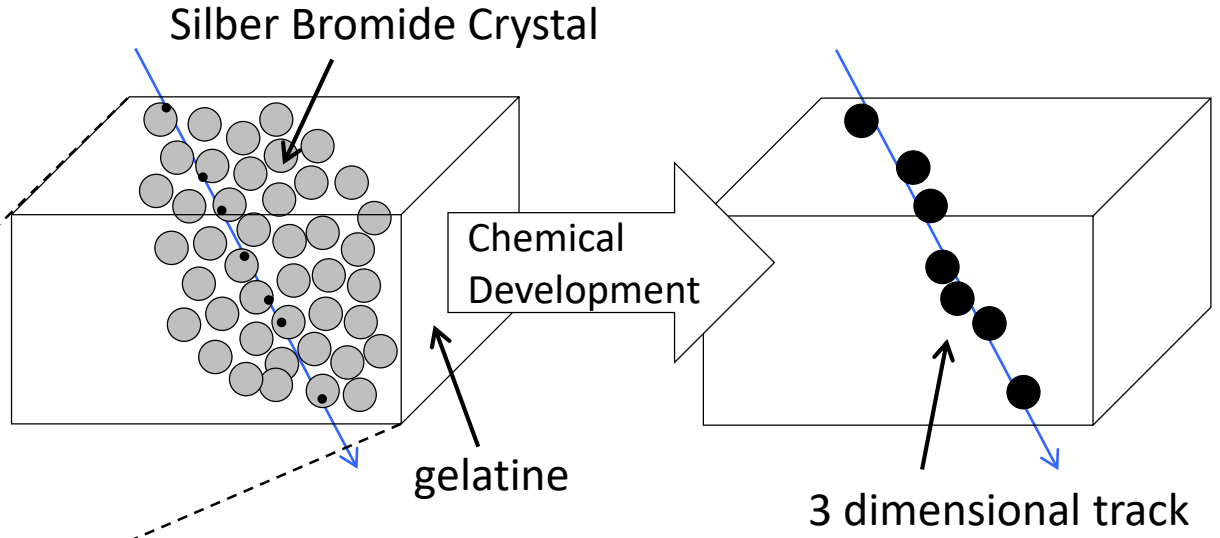




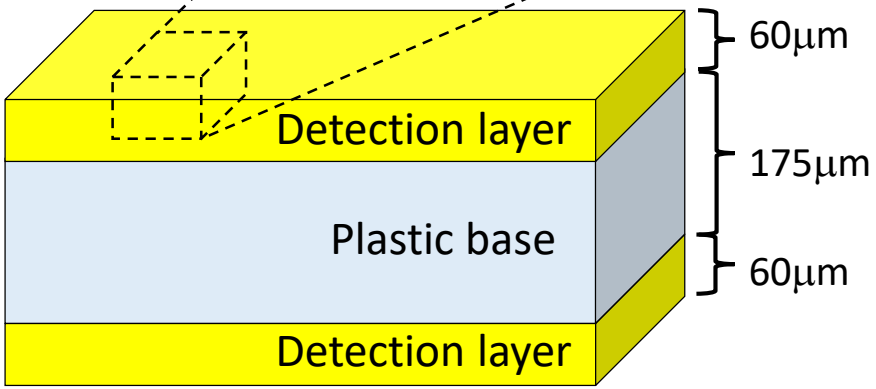
Nuclear emulsion

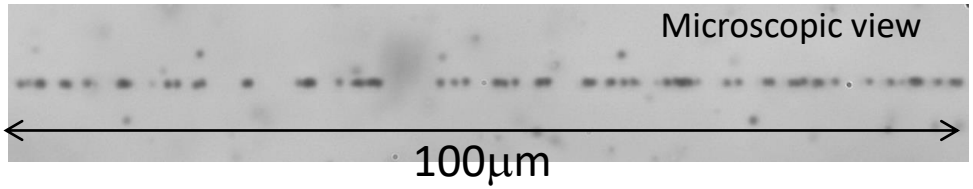
Visualization of trajectories of charged particles in three dimension





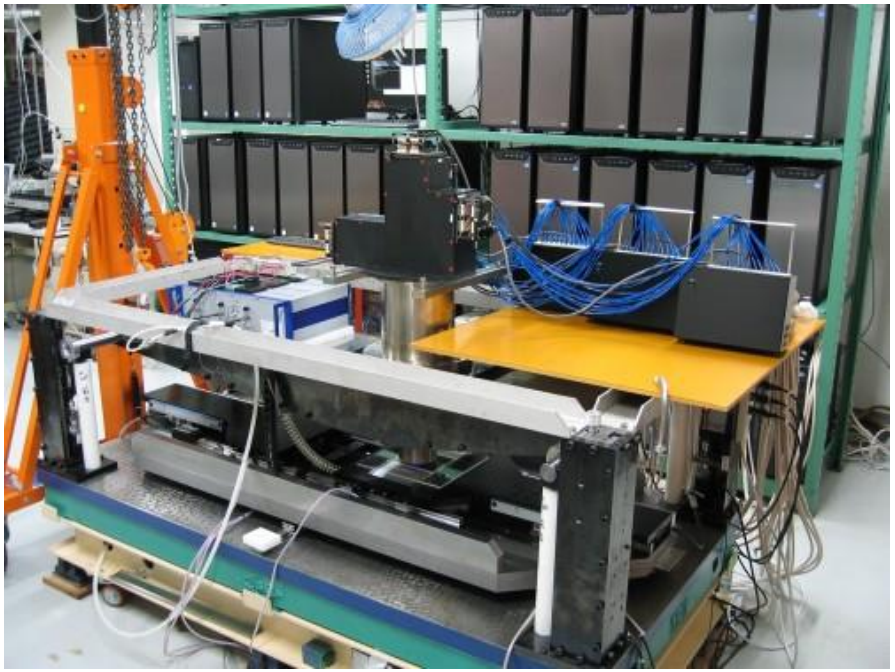
High spatial resolution (< 1μm)

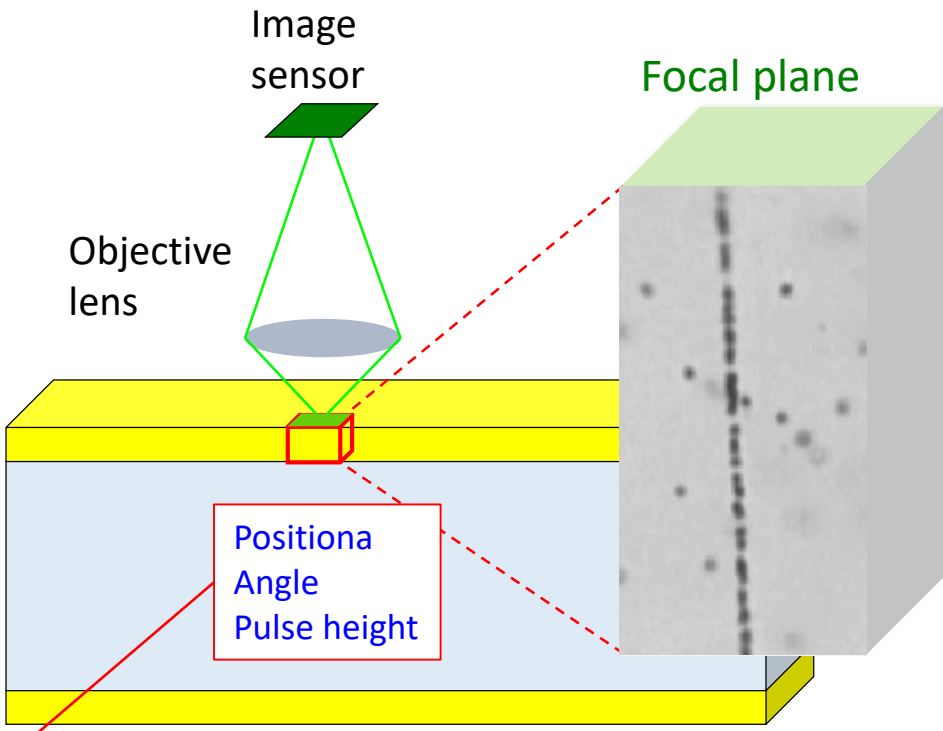


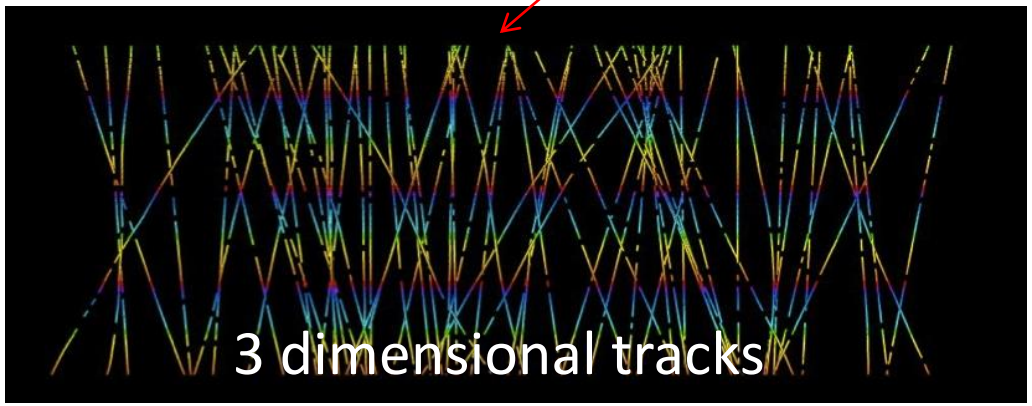


- Sensitive to Minimum Ionizing Particles
- No need of power supply
- thin and light weight
- high resolution and Large field of view

Emulsion Scanning System







Overview of measurement flow with nuclear emulsion

Nagoya University

Egypt

Pyramid

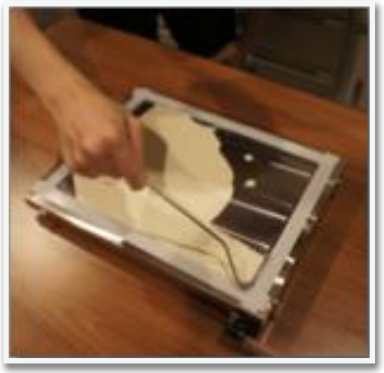
Development lab. Cairo

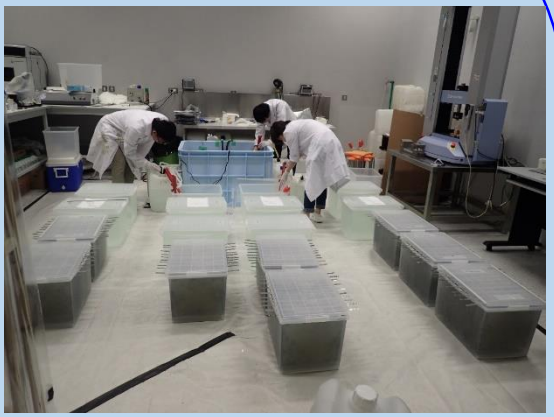
Air transportation

Production of Films

Installation, Observation, Collection

Development

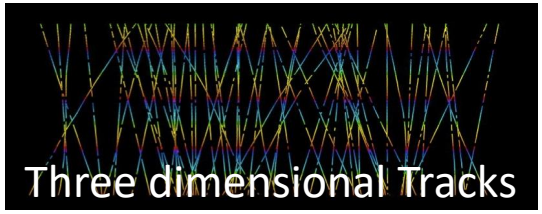


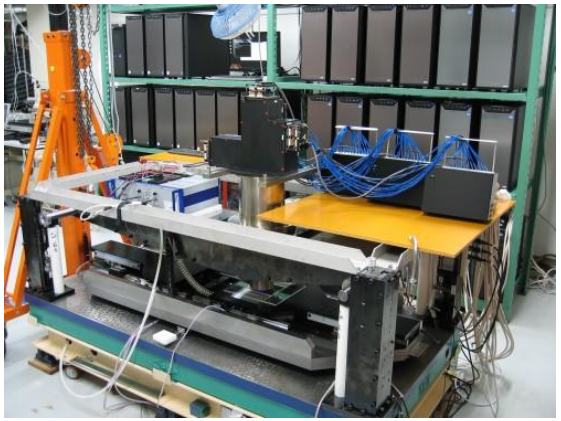


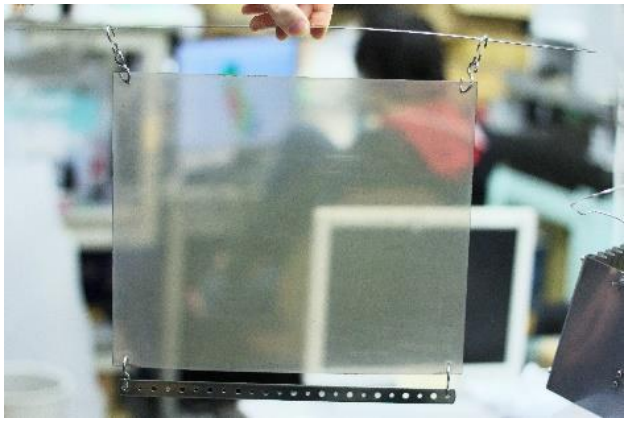
Scanning

Cleaning

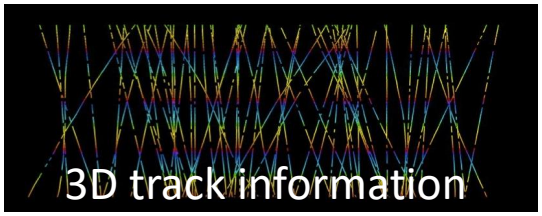
Reconstructed Data



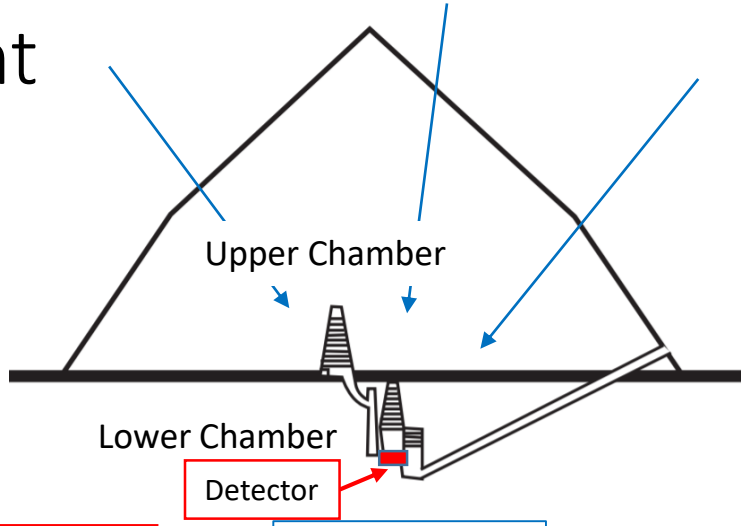




Imaging of upper chamber of Bent Pyramid with nuclear emulsion

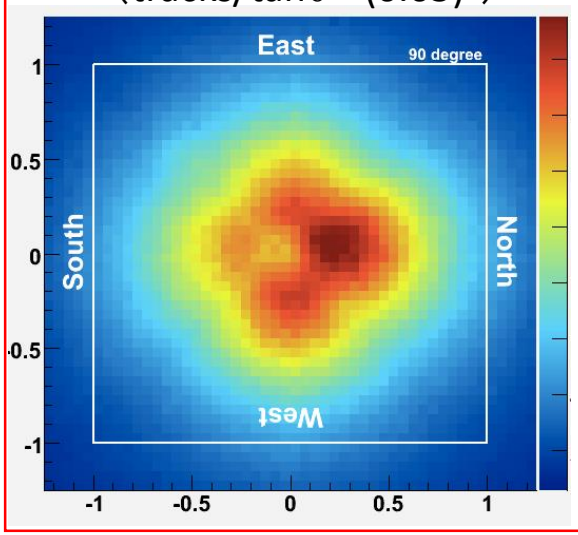


Observation Condition
Date : 40days
Detector Area : $3m^2$

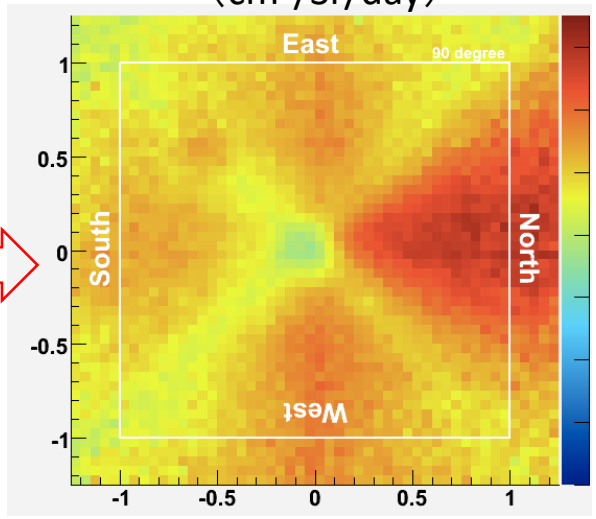


Data

Angular distribution of detected muons
(tracks/$\tan\theta^2=(0.05)^2$)

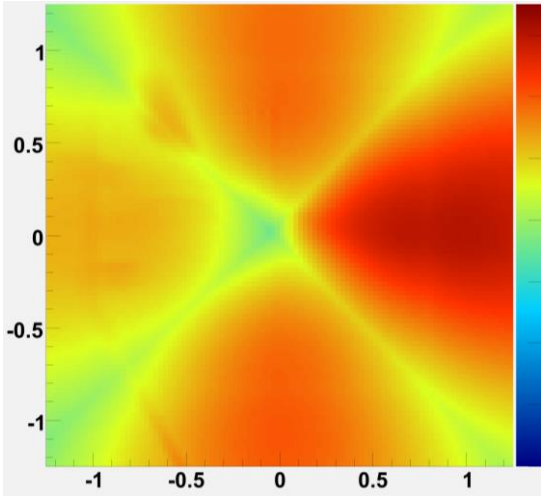


Angular distribution of Muon flux
(cm^2/Sr/day)



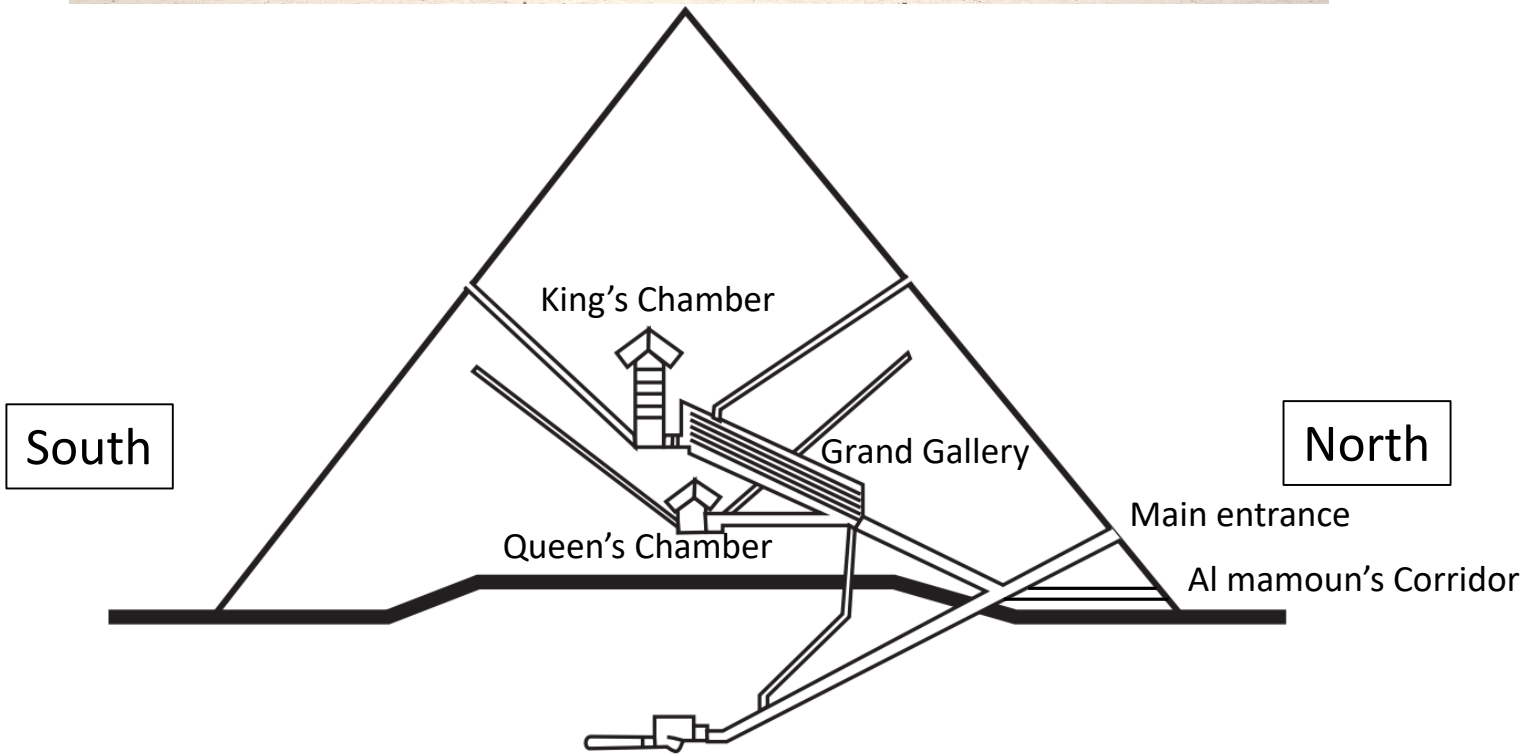
Simulation

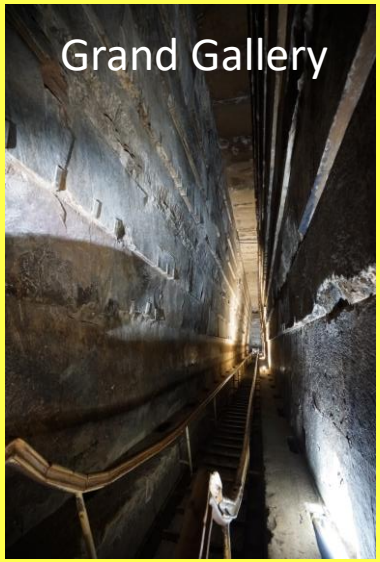
Muon flux
(Miyake)

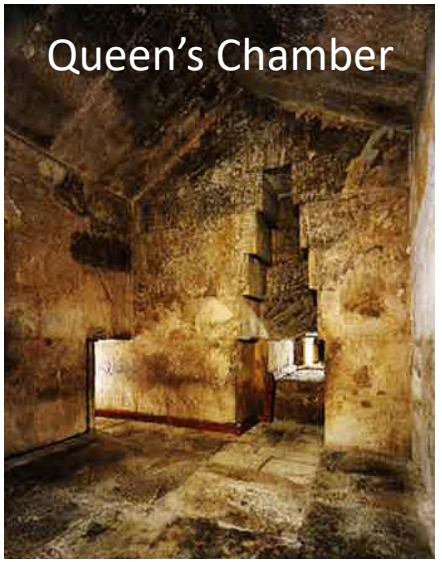


First validation of the capability of imaging of inner structure of pyramid

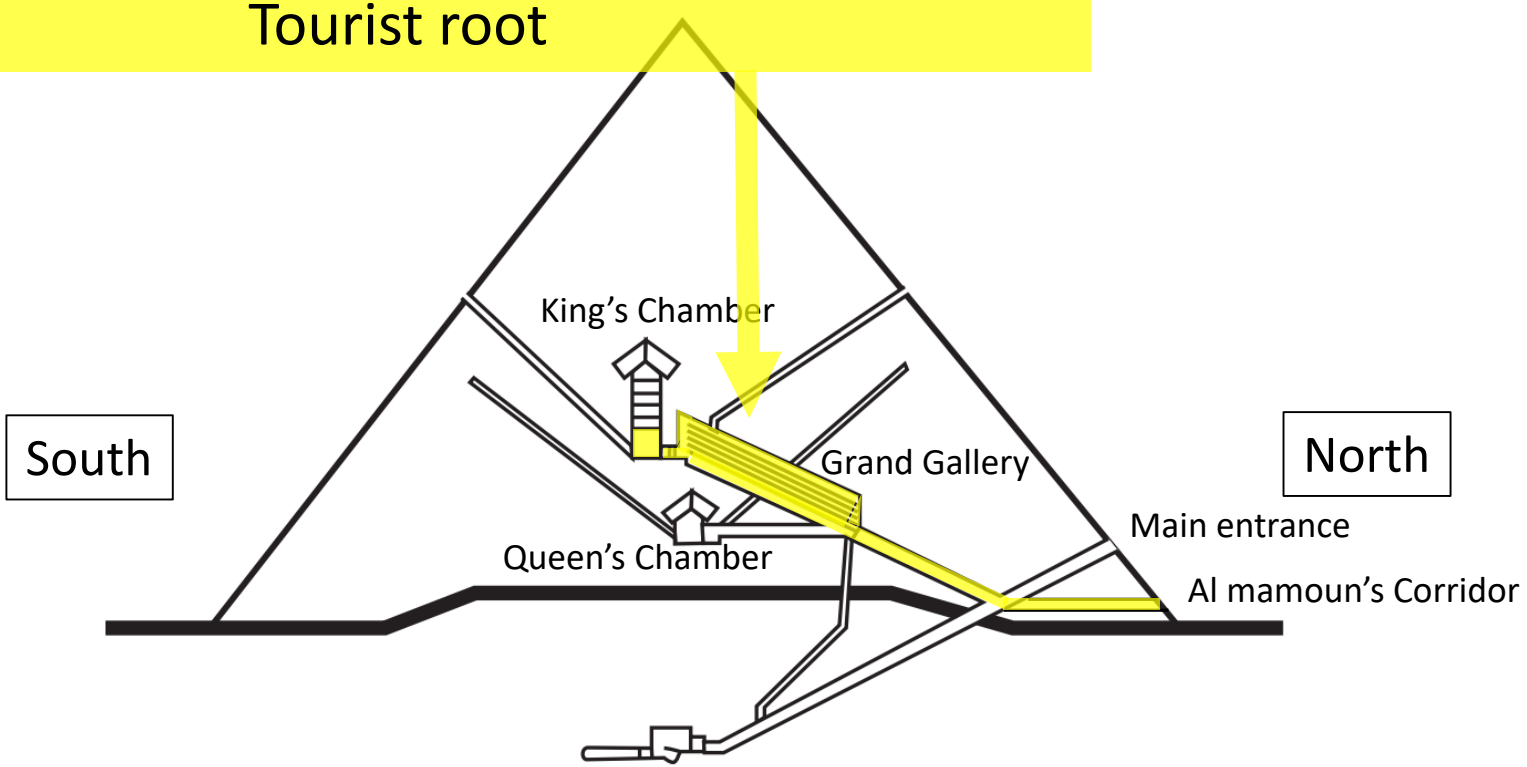
Khufu’s Pyramid

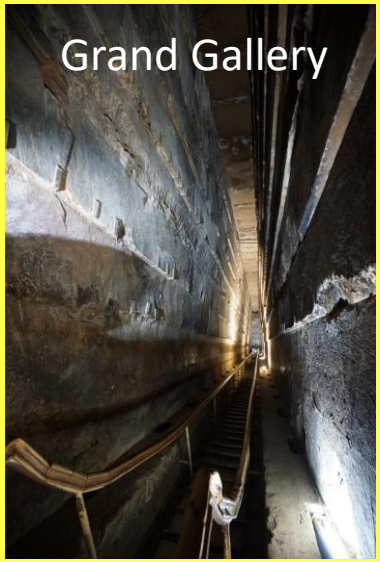


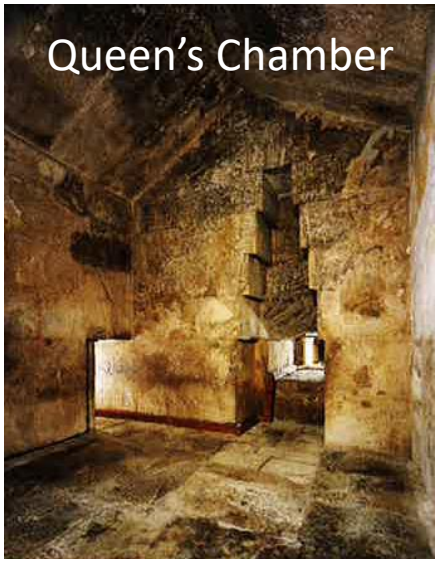




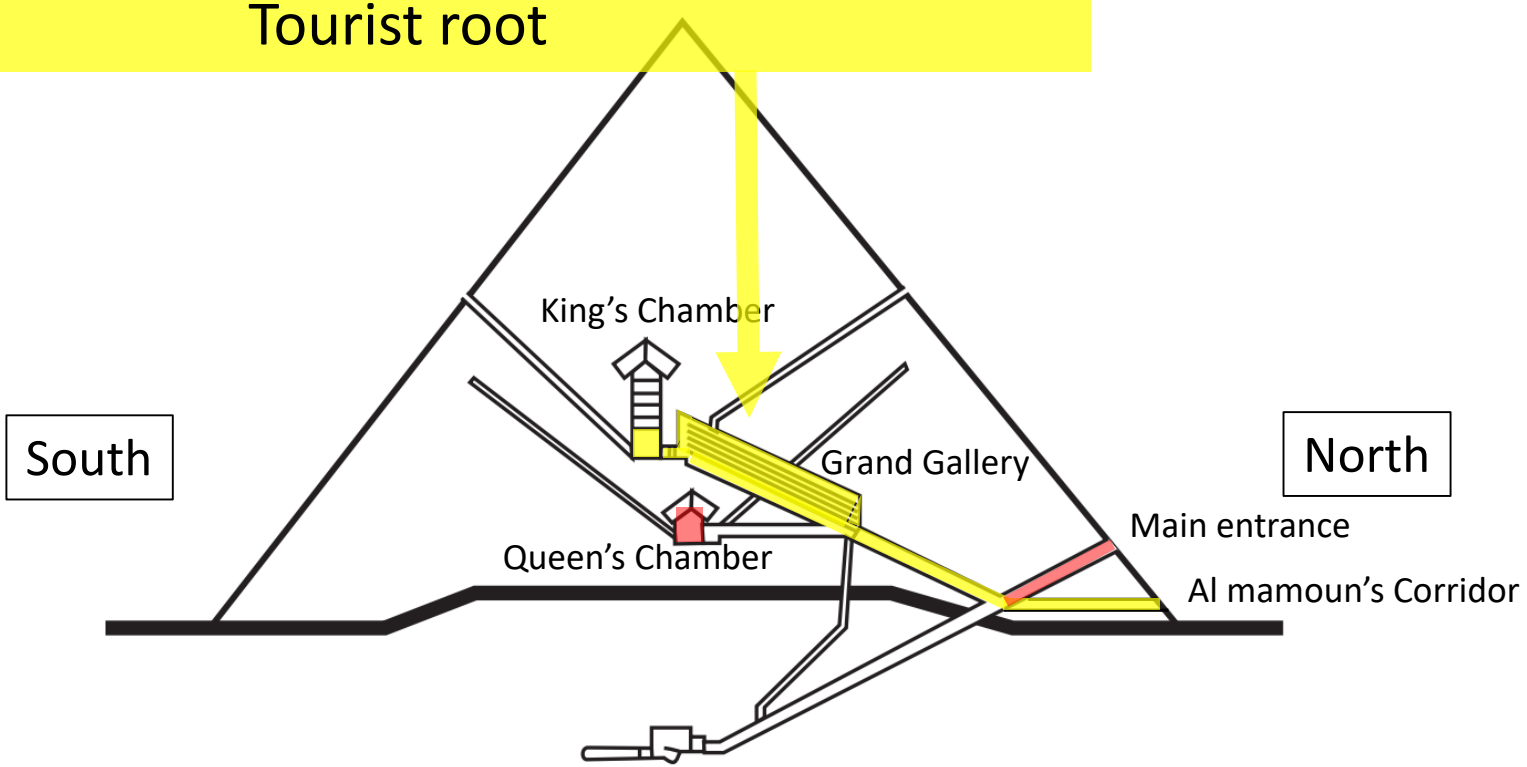
Tourist root



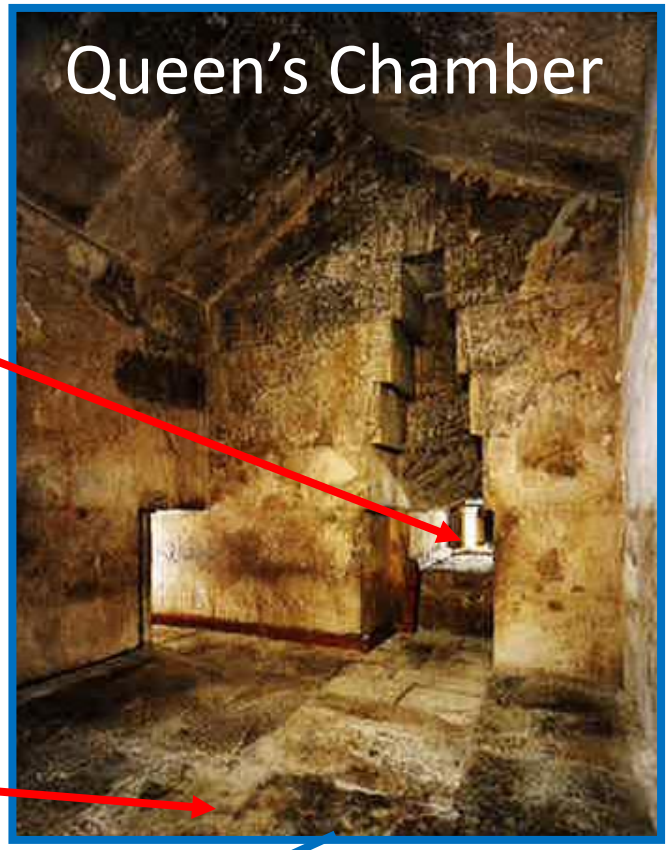




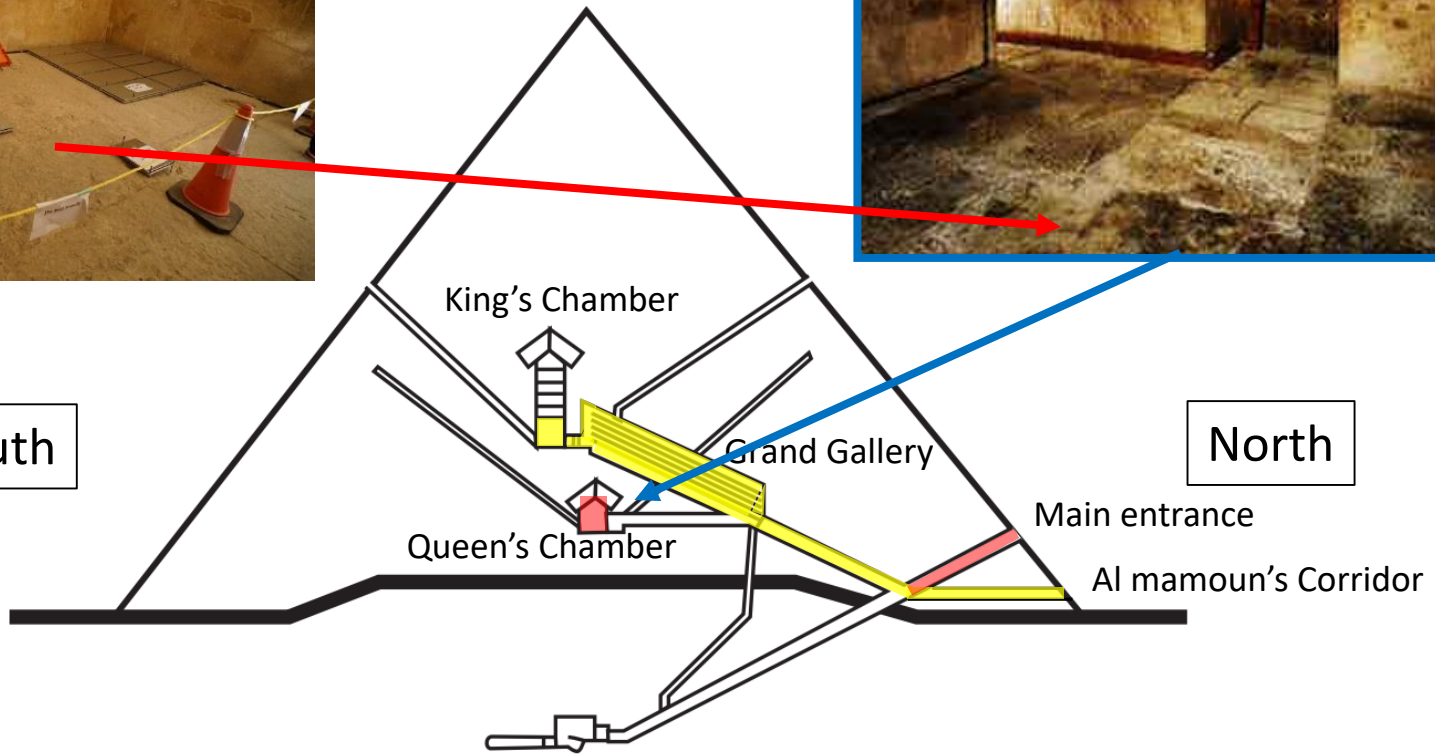
Tourist root



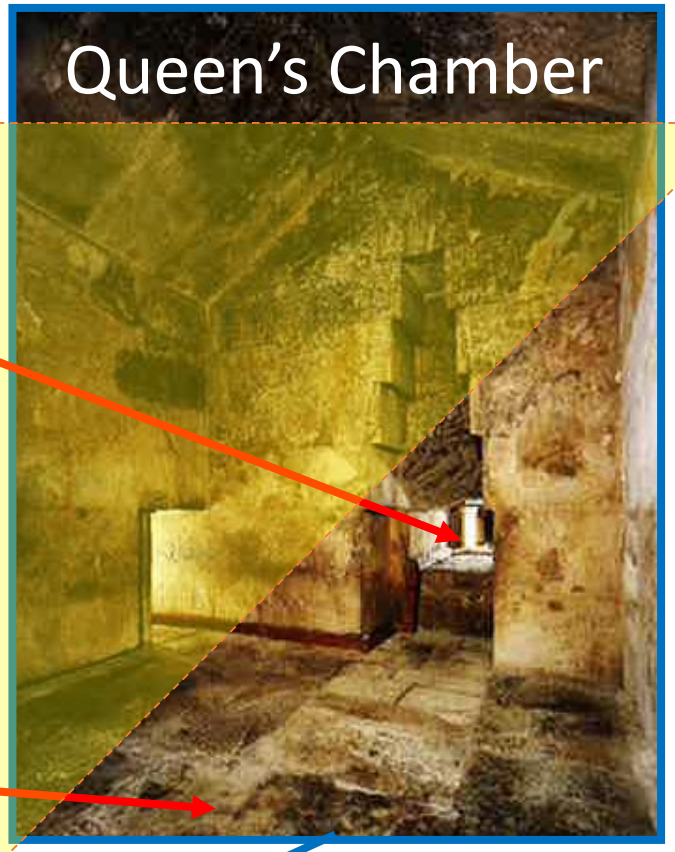

Inside Corridor

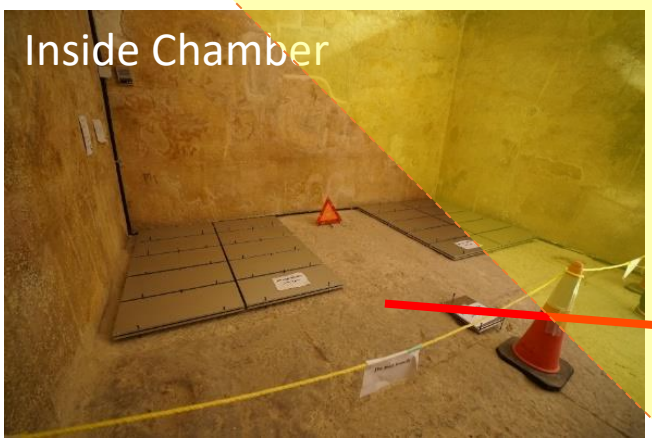

Queen's Chamber

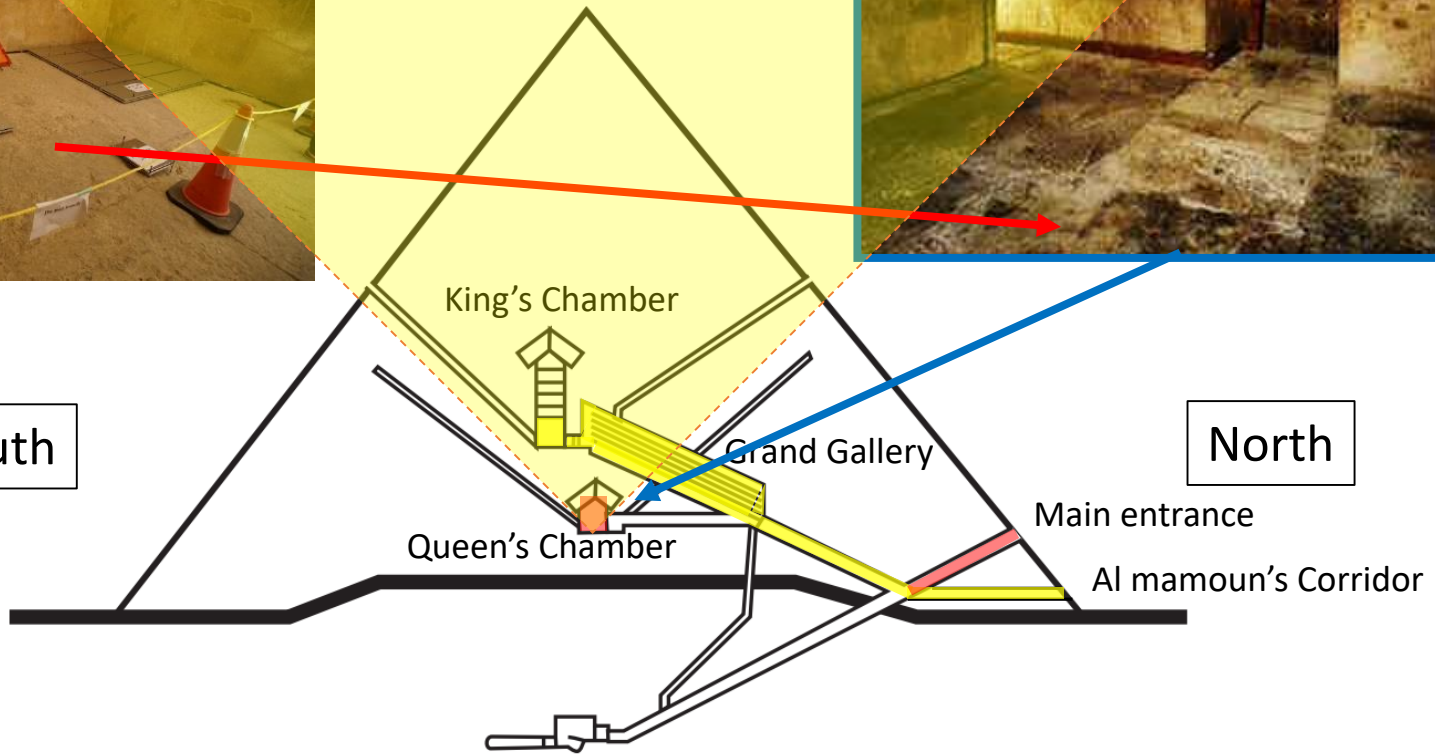

Inside Chamber


King's Chamber
South
Grand Gallery
North
Main entrance
Queen's Chamber
Al mamoun's Corridor

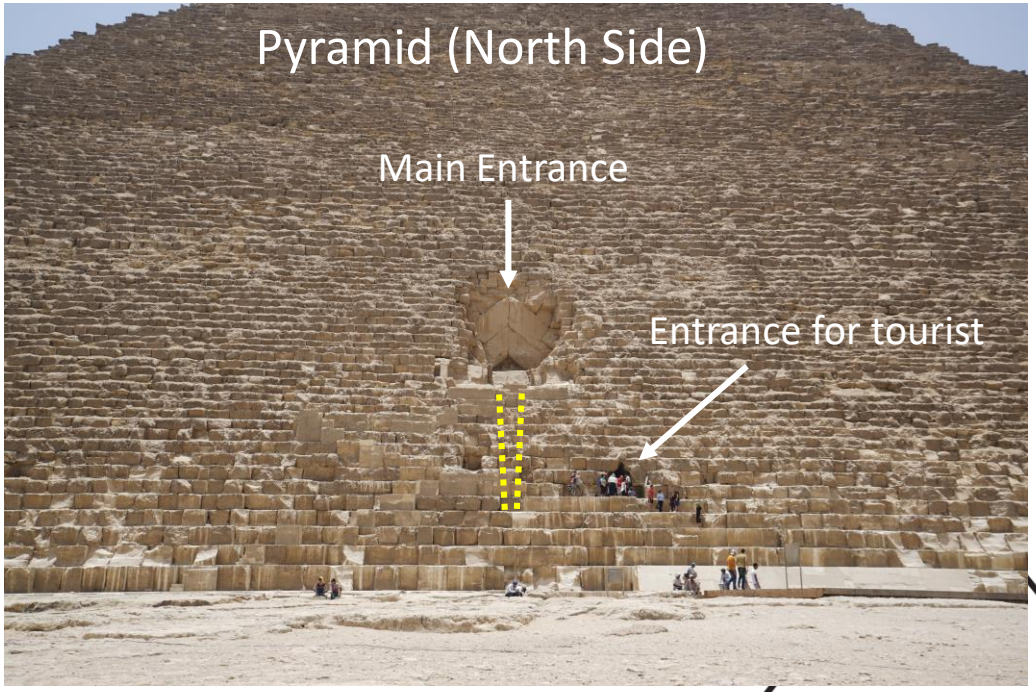

Inside Corridor


Queen's Chamber


Inside Chamber


King's Chamber
South
Grand Gallery
North
Main entrance
Queen's Chamber
Al mamoun's Corridor

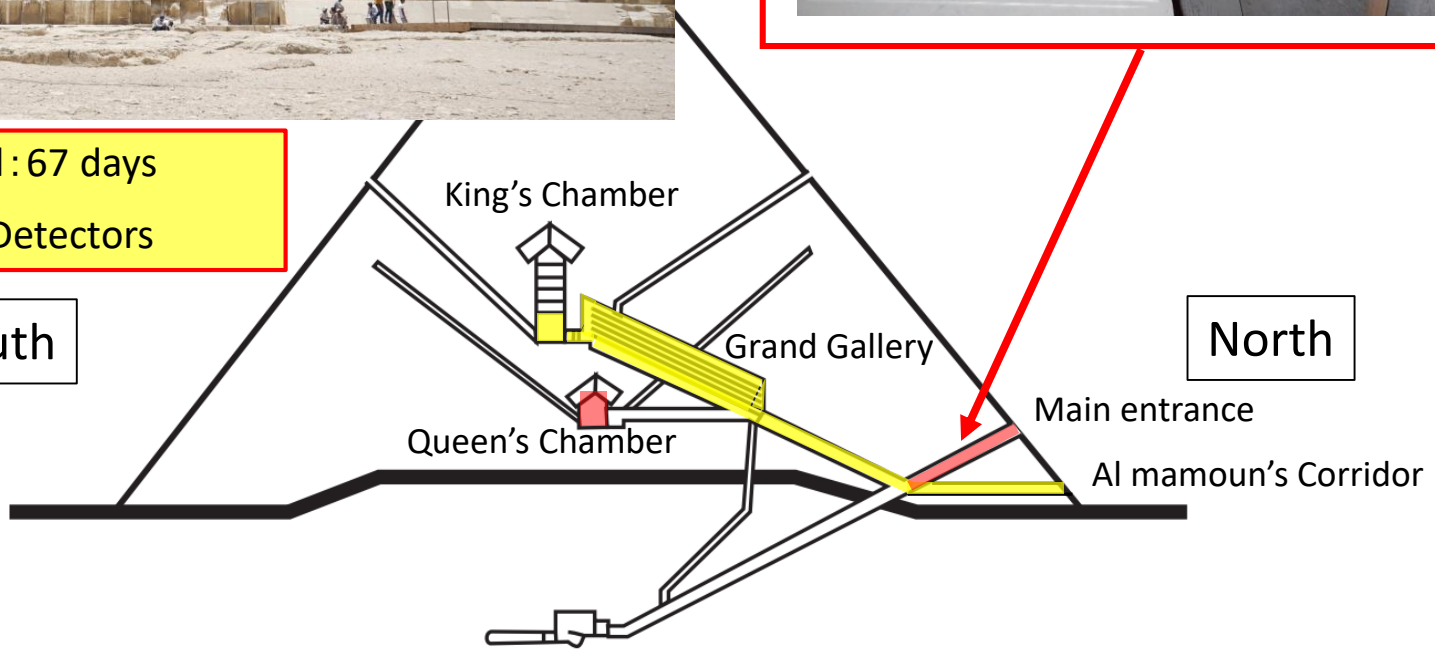
Observation from the Descending Corridor



Descending Corridor

Observation period : 67 days

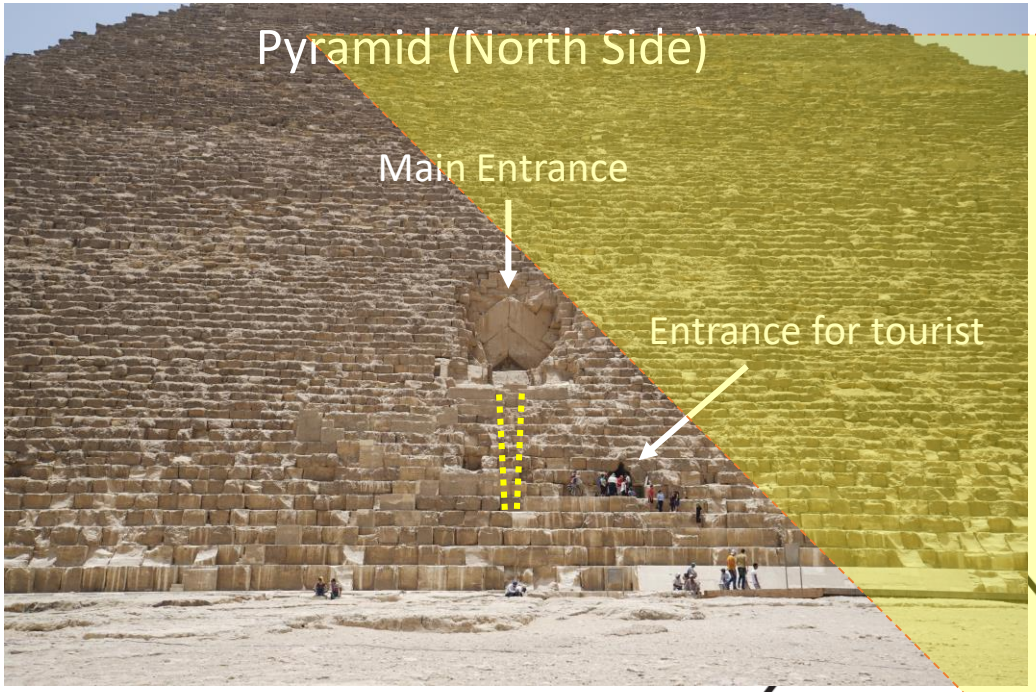
Area : 0.075m^2 x 3Detectors



South

North

Observation from the Descending Corridor



Descending Corridor

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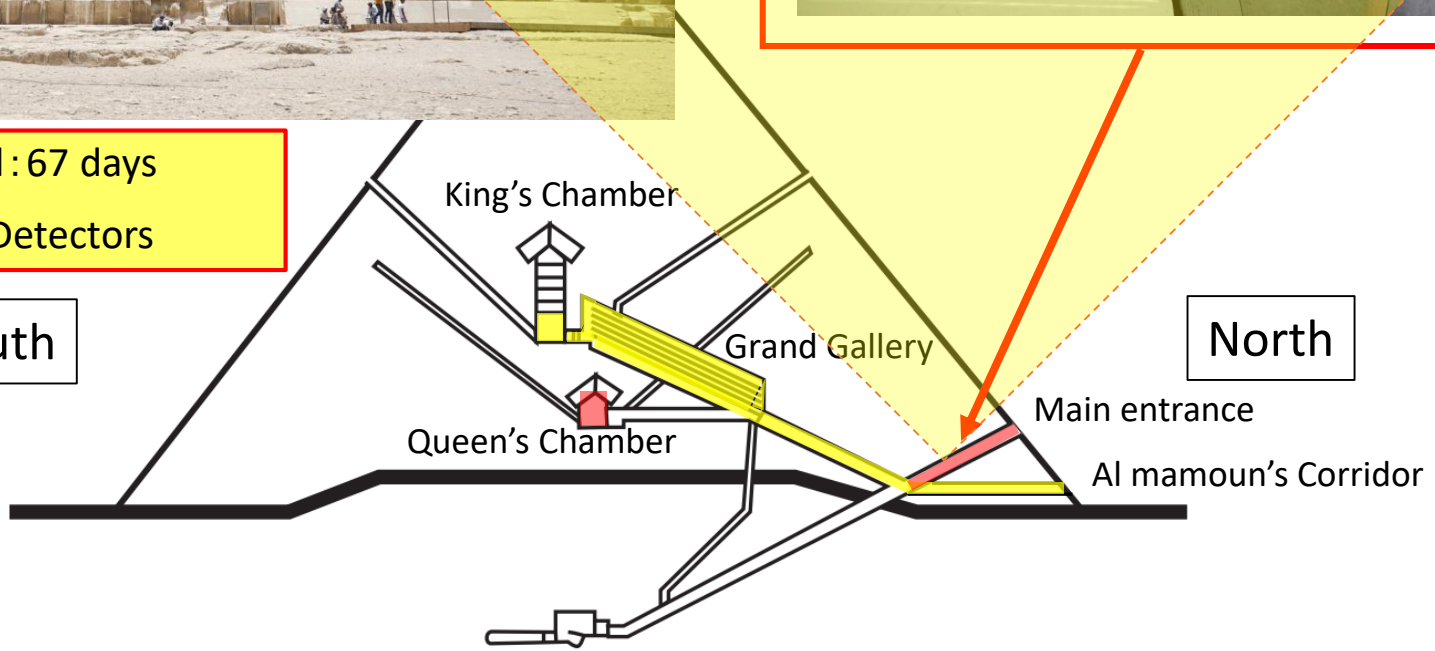
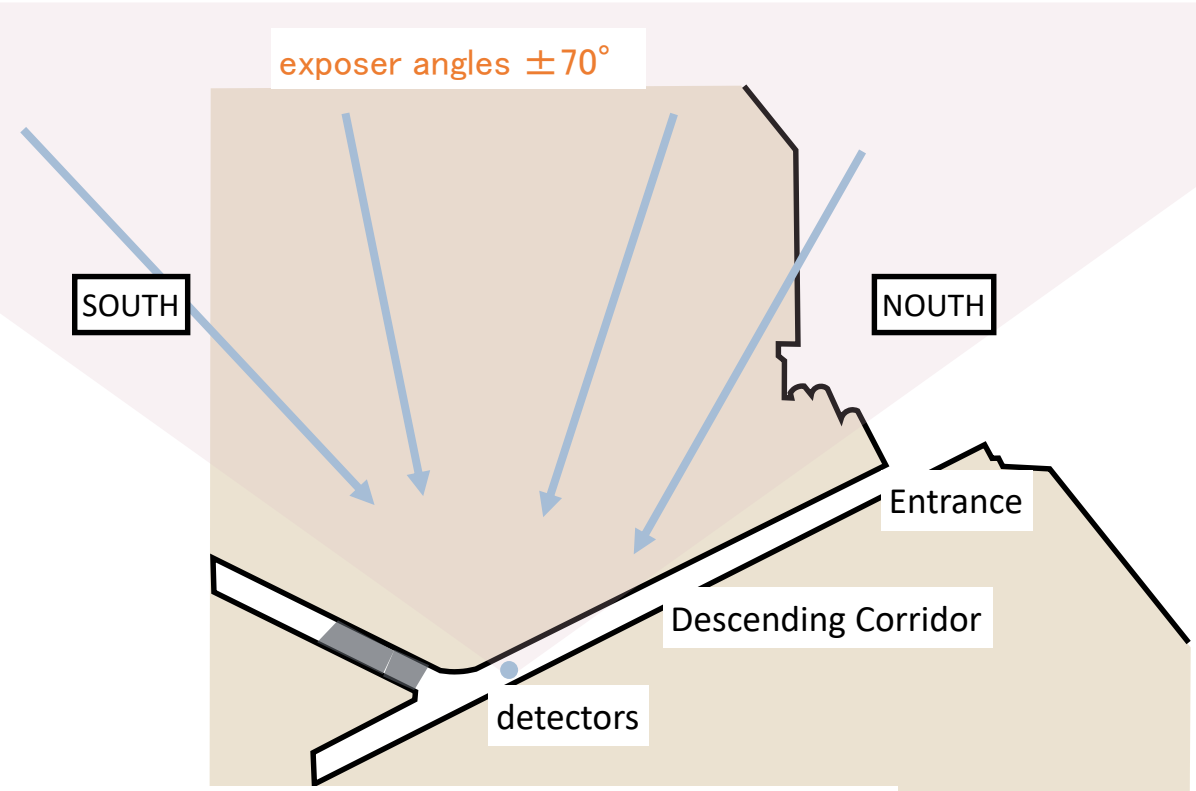


South

North

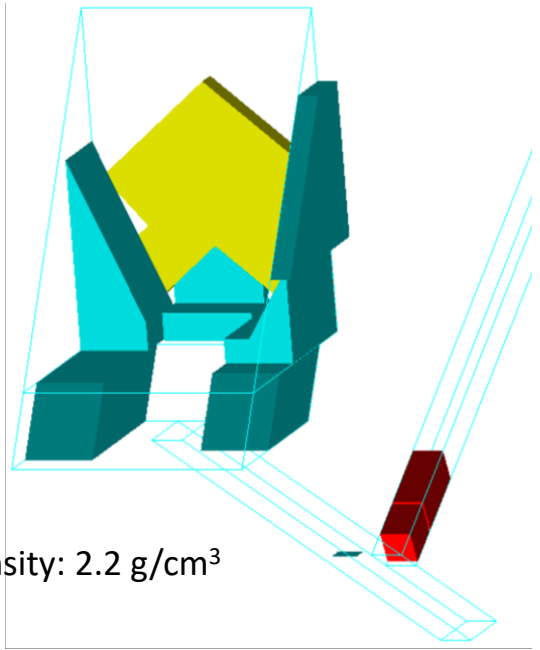
Development of cosmic-ray radiography simulator using Geant4



Exposer muons 3×10^9 (>5GeV, $10 m^2$, 100days)
Processing time is 24 hours

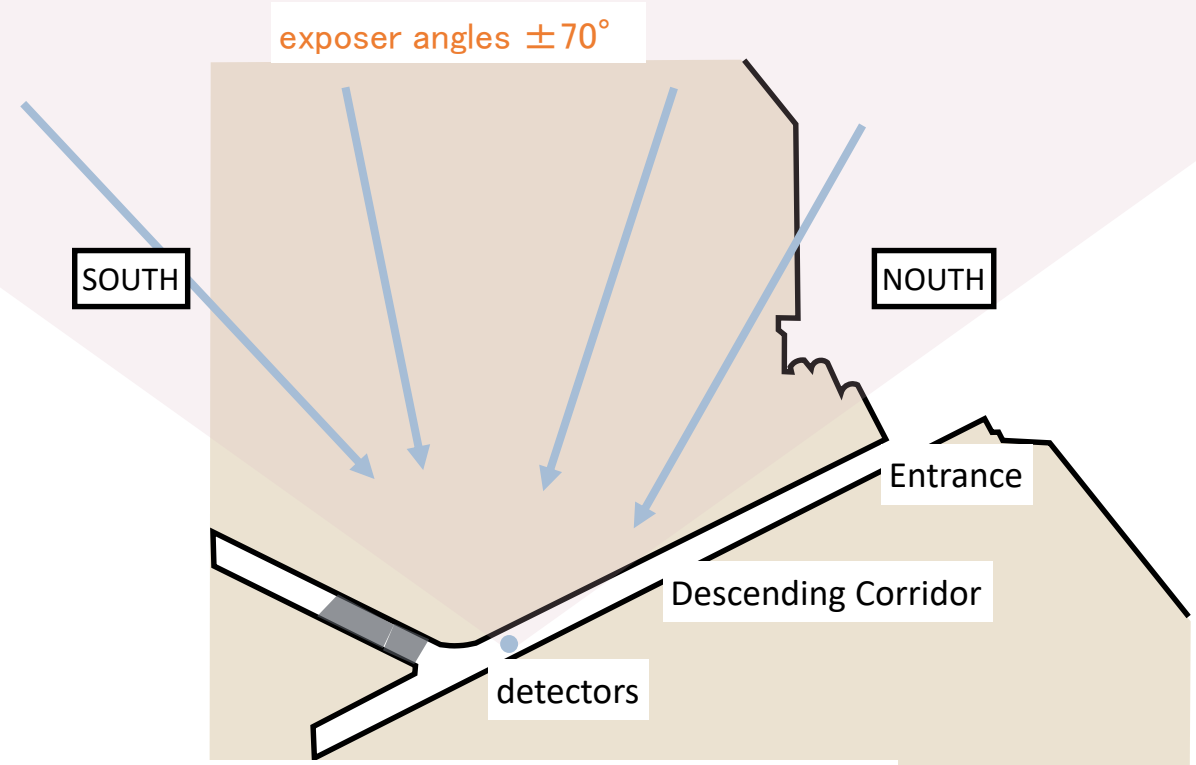
maximum statistics : 300days

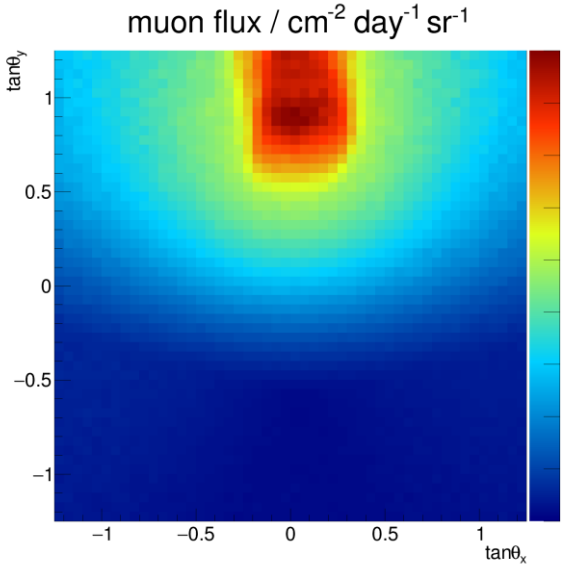
simply 3D model of Khufu's entrance



Assuming stone density: 2.2 g/cm^3

Development of cosmic-ray radiography simulator using Geant4





Exposer muons 3×10^9 (>5GeV, $10m^2$, 100days)
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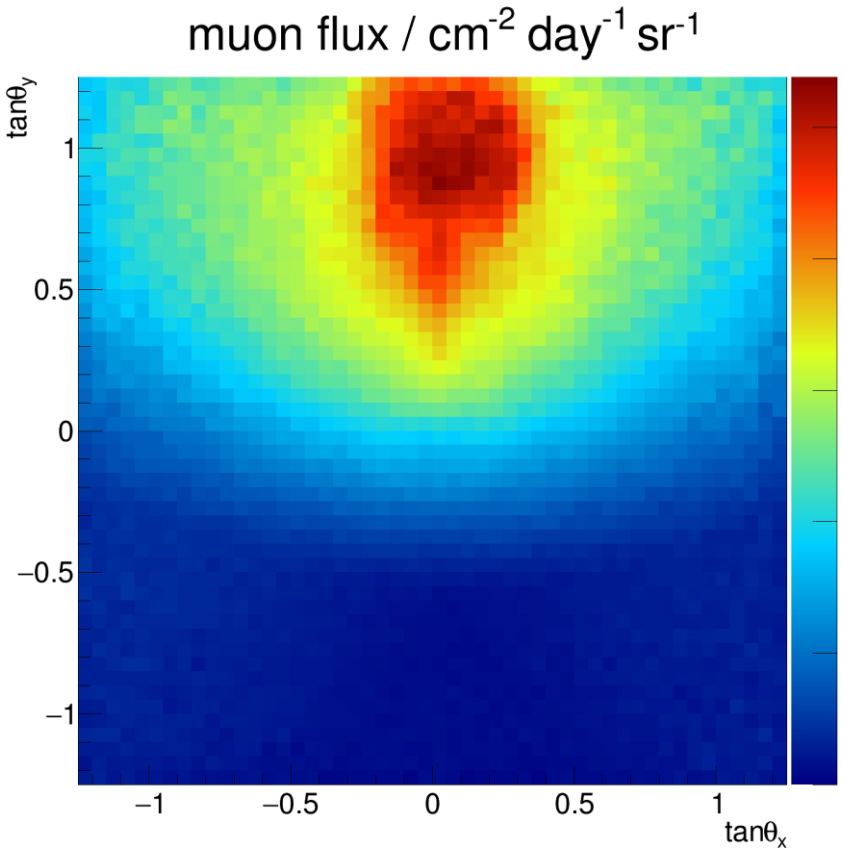
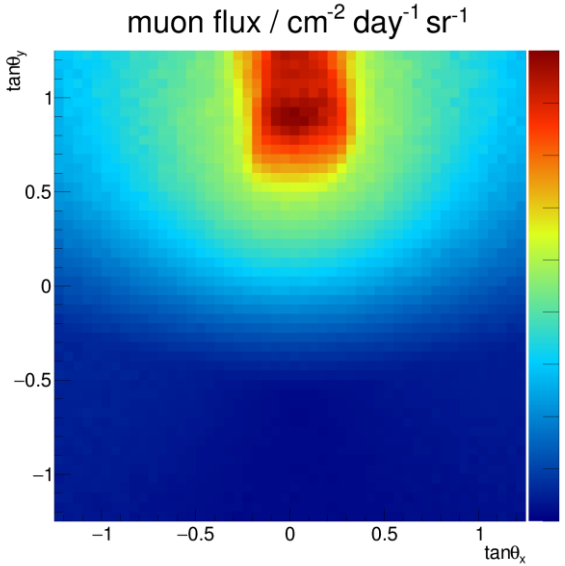
Assuming stone density: 2.2 g/cm^3

Result





Assuming stone density: 2.2 g/cm^3

Muon excess region compared with simulation was observed !

Image of discovered space behind the north face

The precise size, shape and exact position of this space is now under future investigation

Conclusions

- Scan Pyramids are international project
  - Japan, French, Canada and Egypt
  - Muon radiography plays an important role in the project

- Measurement of bent pyramid was successfully conducted by using nuclear emulsion
  - Upper chamber was clearly imaged (New unknown big space was not found)

- We discovered new space behind the north face of the Khufu's pyramid.
  - Additional measurement for tomographic analysis
  - Analysis of detector installed in the Queen's chamber