# Pyramids: a case study for muon tomography

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Not new !

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### Search for Hidden Chambers in the Pyramids

The structure of the Second Pyramid of Giza is determined by cosmic-ray absorption.

Luis W. Alvarez, Jared A. Anderson, F. El Bedwei, James Burkhard, Ahmed Fakhry, Adib Girgis, Amr Goneid, Fikhry Hassan, Dennis Iverson, Gerald Lynch, Zenab Miligy, Ali Hilmy Moussa, Mohammed-Sharkawi, Lauren Yazolino

### Why look for an extra room in Chephren's pyramid?

Pyramids are burial monuments. Real or symbolic? Most were looted

Some were never used (Snefru built at least three)

Some designs were adjusted, with several rooms

## Why look for an extra room in Chephren's pyramid?

Cheops' pyramid has several rooms and a complex design

# His son's is much simpler, with a single room

Could other rooms have been more successfully hidden?



### A conveniently located room in Khephren's pyramid



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#### Spark chambers...



Fig. 6 (left). The equipment in place in the Belzoni Chamber under the pyramid. Fig. 7 (right). The detection apparatus containing the spark chambers.



#### No extra room!

#### Raw data

Pyramid structure corrected



# Acceptance corrected

# Simulated room

Fig. 13. Scatter plots showing the three stages in the combined analytic and visual analysis of the data and a plot with a simulated chamber. (a) Simulated "x-ray photograph" of uncorrected data. (b) Data corrected for the geometrical acceptance of the apparatus. (c) Data corrected for pyramid structure as well as geometrical acceptance. (d) Same as (c) but with simulated chamber, as in Fig. 12.

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#### Complex building history

# Several rooms, several changes of design during the construction, no known room apparently used

Architectural hints point to the possibility of an extra room below the Queen chamber (reorganized flooring, side access — for portcullis? — reflexions seen in ground radar survey...)

Study by G. Dormion in 2004 — he successfully found two unknown chambers at Meidum with a similar analysis



First project: underground room, unfinished

Second project: burial room, the "Queen" room being ancillary — portcullis maneuvering

Third project: higher room ("King's room"), that would have less weight above — cf Dashur's failure

The King's room ceiling breaks : back to the second project, with access through the Queen's room floor.

#### An extra room ?

Below and to the West of the Queen chamber (~20 m above ground level, + relieving chamber above)



### Only two possible locations for a detector

Underground room — 72 m of 1.05 m x 1.20 m corridor to reach it

On the side of the pyramid, using grazing muons (like for a volcano...)

#### Muon tomography for Cheops?

TOMUVOL team simulation of a  $5m \ge 5m \ge 5m$  room Detector on the side



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Could confirm or rule out the existence of an extra room in Cheops' pyramid, next to the Queen chamber or elsewhere

A portable detector could be used on many pyramids Previously unknown chambers found in Meidum a few years ago Muon Maya project at UTexas (buried cylindrical detectors)

### Finding prehistoric painted caves?

# Known caves could have neighbours in the same mountain

More difficult modeling though...