International Particle Physics Outreach Group

Working group
OUTREACH of APPLICATION FOR SOCIETY
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Searching for hidden cavities inside the Sun pyramid in Mexico.

When the Aztecs stumbled upon the valley of Mexico near present-day Mexico City in the 14th century, the sight before them must have been nothing short of astonishing. Spread out was an expansive, uninhabited city adorned with majestic monuments, leading the tribe to believe they had discovered a sacred place, the very site where the gods crafted the Universe. Thus, they bestowed upon it the name Teotihuacan, meaning "The City of the Gods."

Teotihuacan became the sixth largest city in the world, only behind places like Rome, Constantinople and Alexandria. Two of the most representative monuments of the city are the pyramids of the Sun and the Moon -- so called by the Aztecs, their original name is unknown. In particular, the colossal pyramid of the Sun is the third largest in the world by its volume. Even for today's tourists, the views presented by these monuments are astonishing.

Fig 1. The Sun pyramid is the third largest pyramid in the world (figure taken from wikipedia https://es.wikipedia.org/wiki/Pir%C3%A1mide_del_Sol).

Over the years, archaeologists have meticulously studied Teotihuacan, dating its origins to around 200 BC and uncovering its transformation into one of the ancient world's most populous cities, hosting a population of at least 100,000 [1]. Yet, amid these discoveries, one enigma persists from the Aztec era: the whereabouts of the ancient rulers of Teotihuacan. Since the pyramids of Egypt served as a tomb for the pharaohs, a valid question arises: could the pyramid of the Sun be a tomb of the leaders of Teotihuacan? However, there is no obvious visible evidence of this.

This idea was reinforced when in 1971, at the foot of the pyramid of the Sun, a seven-meter-deep well, filled with gravel stones, was discovered. When removing this material, an ancient staircase appeared that led to a tunnel located just below the pyramid. About 100 meters long, the tunnel ends in a set of chambers located almost in the center of the pyramid. This tunnel and the fact that the pyramid of the Sun was not built in different stages are mysteries that archaeologists are intrigued to decipher.

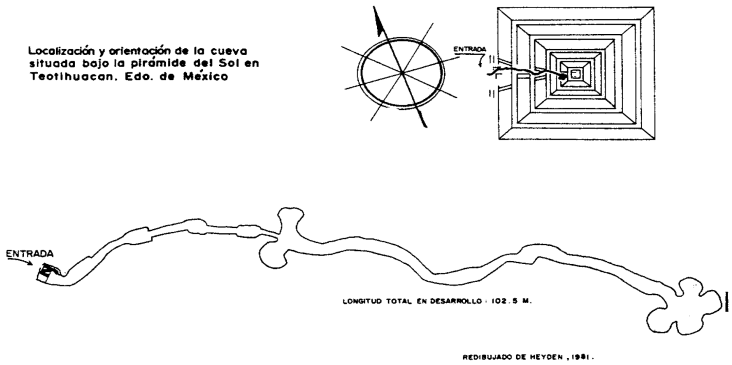

Fig 2. Scheme of the tunnel that runs beneath the pyramid of the Sun. The cave at the end of the tunnel has four cavities that have been associated with the underworld of Aztec mythology

Looking inside a pyramid?

To unravel the mysteries concealed within the pyramid of the Sun, a group of archeologists and physicists from the National Autonomous University of Mexico (UNAM) embarked on a project with the aim to use elementary particles to look inside the pyramid (muography) [2,3]. Setting aside their lab coats, the researchers donned boots and helmets and made use of muons to tackle the mystery. Muons are subatomic particles that constantly bombard the Earth's surface (link). Employing a technique called muography (muon tomography), these researchers aimed to peer inside the ancient structure in the hope of revealing its secrets.

To know more about the principles of myography and other applications check the related IPPOG article.

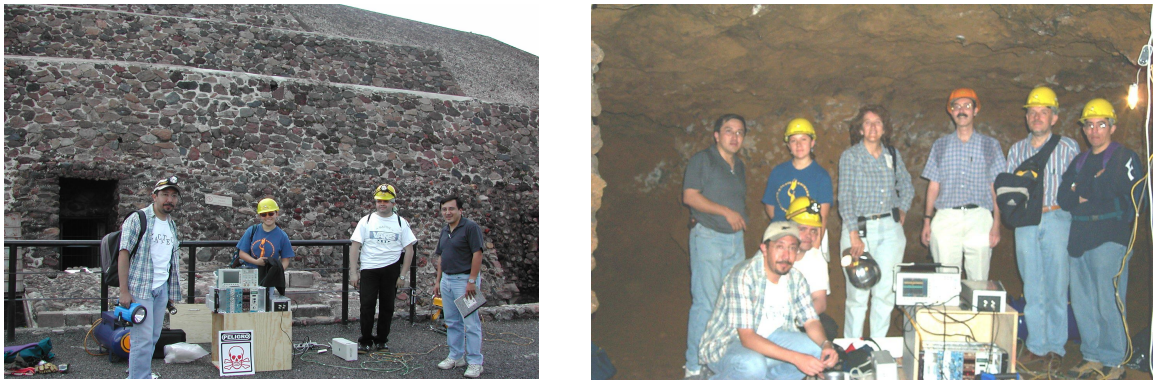

Fig 3. First excursion into the cave to measure muons: Outside the tunnel (left) inside the tunnel (right). UNAM students actively participated in this attractive project.

Despite the strategic location of the cavity, 8 meters underneath the pyramid, positioned close to its center, it was far from an ideal setting for a physics experiment. Access to the chamber is through a small hatch at the pyramid's base, leading to a narrow, irregular tunnel that descends into total darkness. In addition, high humidity, close to 100% and temperatures around 25 Celsius degrees make a harsh environment for any scientific equipment, not to speak about the scientists. Going through the tunnel proved challenging; at times, researchers had to bend and crouch down in order to go ahead. The team had to overcome many logistical challenges, such as extending the power from an electrical grid located about 2 km away, using cables threaded through pipes all the way to the pyramid.

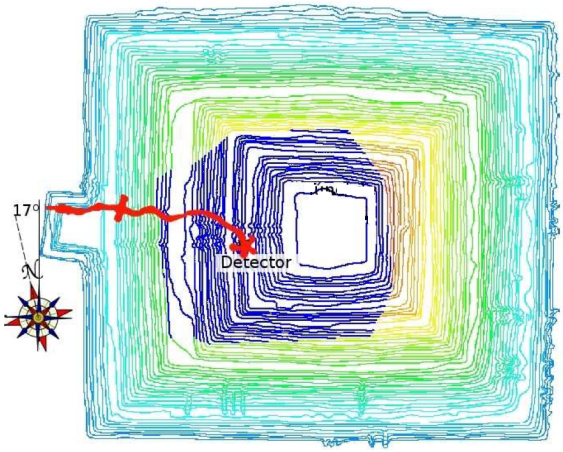

Fig 3: (Left) Entrance to the tunnel, 60 cm wide by 90 cm high, quite a challenge to get all the equipment through such a narrow door. (Right) Topographical representation of the pyramid, different colors show different heights and show the tunnel that runs underneath.

A long way to the measurements

The muon detector took the form of an array of rectangular multi-wire chambers. Because small droplets of water tended to condense on the internal rock walls of the cave, it was crucial to build a shed and to design the detectors with robustness to withstand these conditions. This ensured that the damp conditions would not affect their functionality. But, the detector, with a volume of 1.5 m^3, could not fit through the tunnel in its original form. Consequently, a custom-built approach was adopted: the smaller components of the detector were transported individually and then assembled inside the cave in the compact shed. To overcome the problem of reduced oxygen content towards the end of the tunnel, the team installed two fans to circulate fresh air throughout the passage. To ensure safety, carbon-dioxide monitors and oxygen tanks were strategically placed in critical areas. This planning and innovative problem-solving enabled the team to carry out their experiment in a space that, while not designed for such endeavors, yielded valuable insights.

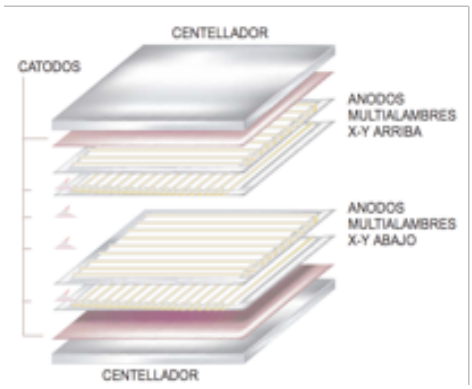

Fig. 5. (Right) The muon tracker at UNAM laboratories with a readout system. (Left) Schematic view of the muon tracker.

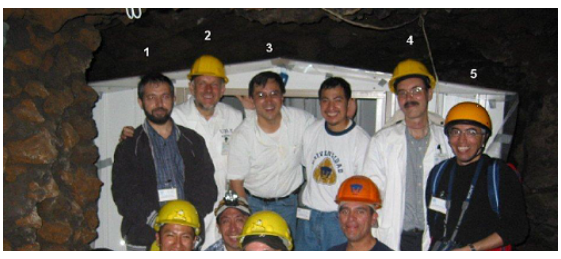

Fig 6. (Left) walking into the tunnel. (Rigth) Setting up the detector. At the back the shed is visible. The crew (back row) Varlen Grabsky, Arturo Menchaca, Ruben Alfaro, Rodolfo Herrera, Ernesto Belmont, Arnufo Martínez. They were also (front row) Azucena Cervantes, Juan Manuel Lopez, Emilio Arrtieta, Martín Duarte.

Do the muons reveal secrets?

The measurements did not allow a firm conclusion. Thus, the possibility of a tomb can neither be confirmed nor ruled out. Furthermore, one has to take into account that burials in Teotihuacan used materials similar to those of the pyramid itself. These characteristics effectively hide any discernible trace of a tomb. Nevertheless, the muon tomography revealed that there is a sector in the southern part of the pyramid that is less dense than the rest of the monument. Now it is the turn of archaeologists to come into the game[4].

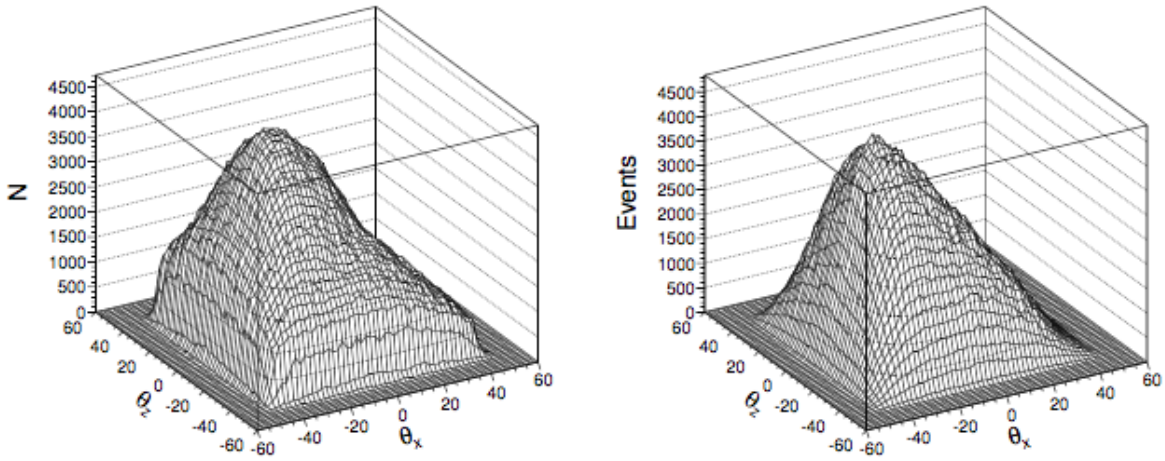

Fig. 7:(Right) Simulation and (left) reconstruction from the muon detector [5]

Connection to IPPOG

The author, Ruben Alfaro is an IPPOG member and he was deeply involved in the construction and installation of the detector in the tunnel. Besides, Cosmic Rays have played an important role in developing Physics in Mexico. Concurrently Mexico hosts one of the most important detectors of Cosmic Gamma Rays, The High Altitude Water Cherenkov observatory.

References

[1] https://patrimoniomundialmexico.inah.gob.mx/publico/lista_detalle.php?idLista=MTU=

[2] https://www.nature.com/articles/s43586-023-00270-7

[3] https://www.sciencedirect.com/science/article/pii/S0012825221003433#bb0465

[4] https://www.jornada.com.mx/2014/02/21/ciencias/a02n1cie

[5] S. Aguilar et al., Proceedings of the 33th International Cosmic Ray Conference, 2013-0364.