

# MUON TOMOGRAPHY FOR UNDERGROUND GEOLOGICAL SURVEYS

ONGOING APPLICATION AT THE LOUSAL MINE ( PORTUGAL )

**PEDRO TEIXEIRA**

IN COLLABORATION WITH LOUMU TEAM

**FCT** Fundação  
para a Ciência  
e a Tecnologia



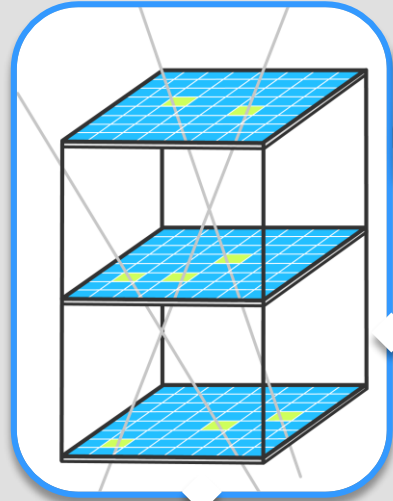
LABORATÓRIO DE INSTRUMENTAÇÃO  
E FÍSICA EXPERIMENTAL DE PARTÍCULAS  
*partículas e tecnologia*



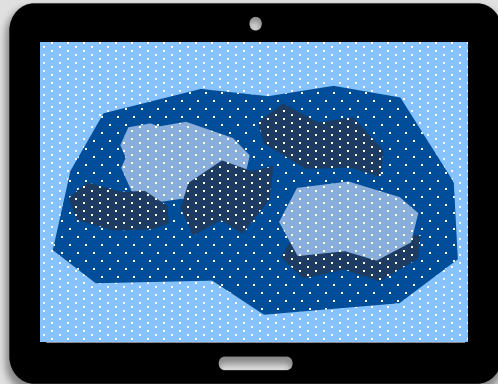
UNIVERSIDADE  
DE ÉVORA



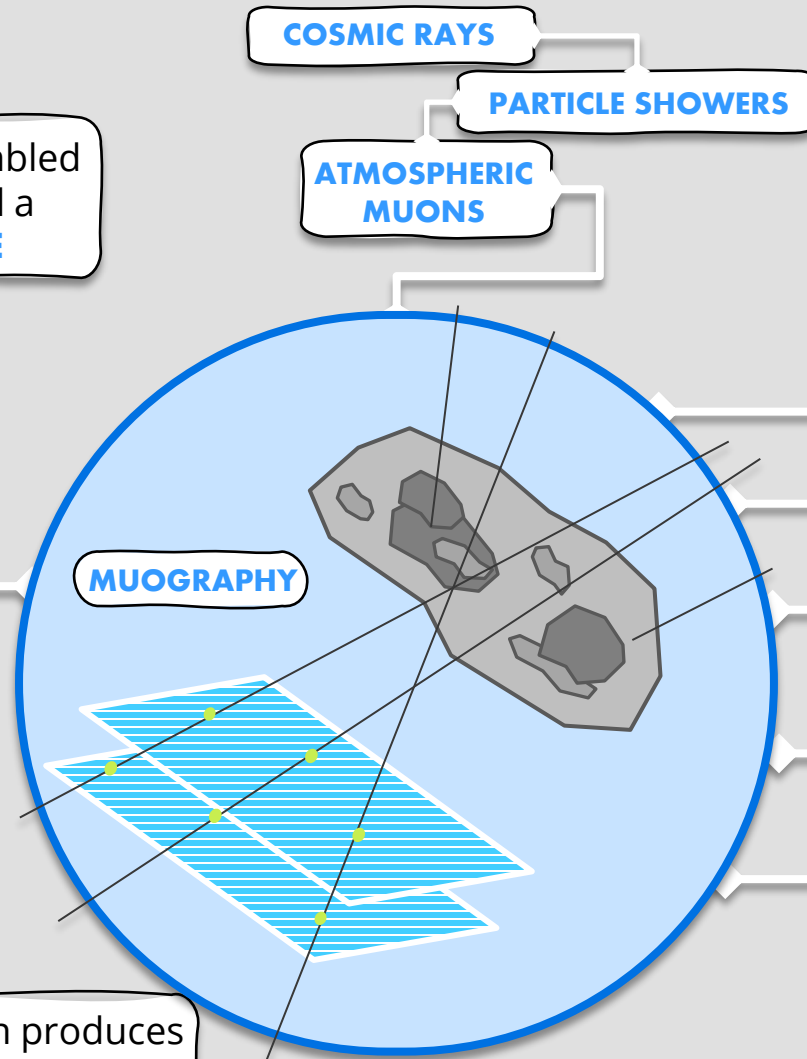
# MUOGRAPHY BASICS



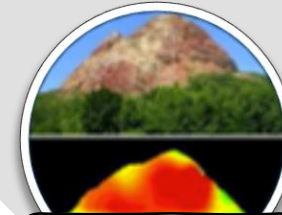
Muon detectors assembled in a structure called a **MUON TELESCOPE**



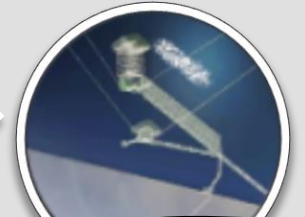
The observation produces images like "muon radiographs" called **MUOGRAPHS**



## APPLICATIONS IN DIFFERENT FIELDS



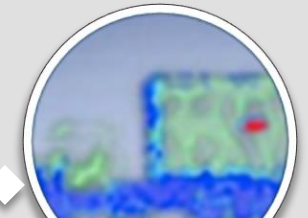
**GEOSCIENCES**



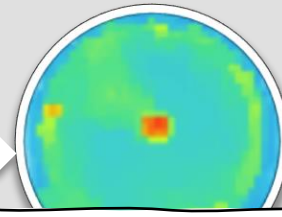
**ARCHAEOLOGY**



**CIVIL ENGINEERING**



**CARGO SURVEILLANCE**

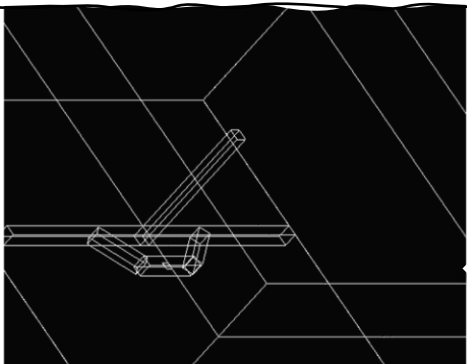


**NUCLEAR REACTOR AND WASTE CONTROL**



# LOUMU PROJECT

## SIMULATIONS AND TOOLS



LABORATÓRIO DE INSTRUMENTAÇÃO  
E FÍSICA EXPERIMENTAL DE PARTÍCULAS  
*partículas e tecnologia*

# LoμMμ

SCIENCE WITH  
COSMIC MUONS  
AT THE LOUSAL MINE



Instituto de Ciências da Terra  
Institute of Earth Sciences



UNIVERSIDADE  
DE ÉVORA

Centro  
Ciência Viva  
do Lousal  
MinadeCiência



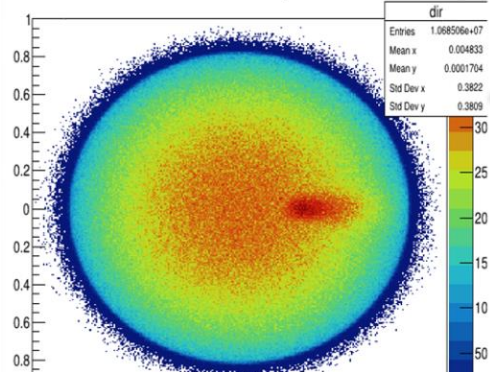
## MUOGRAPHY AND TELESCOPES



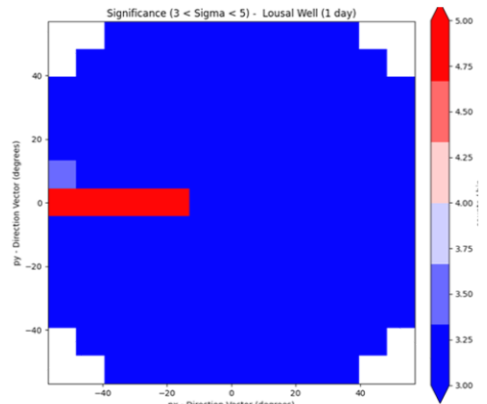
## GEOPHYSICAL WORK



Direction Map

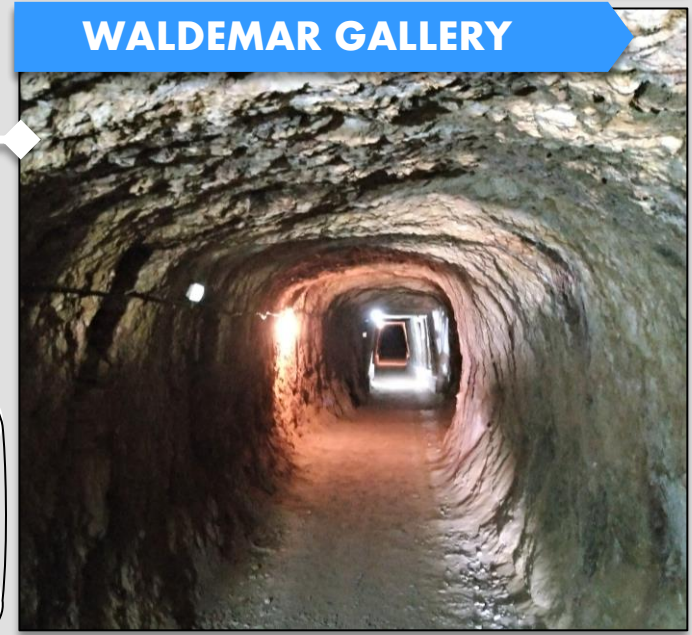
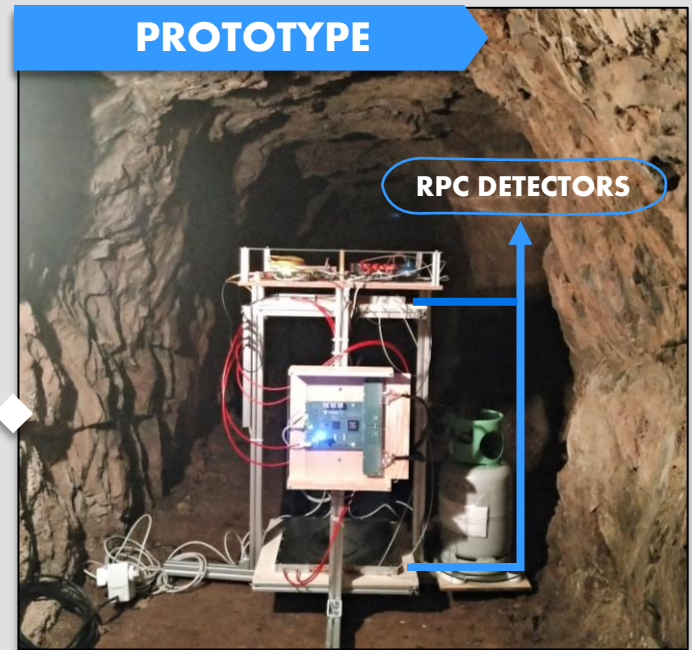
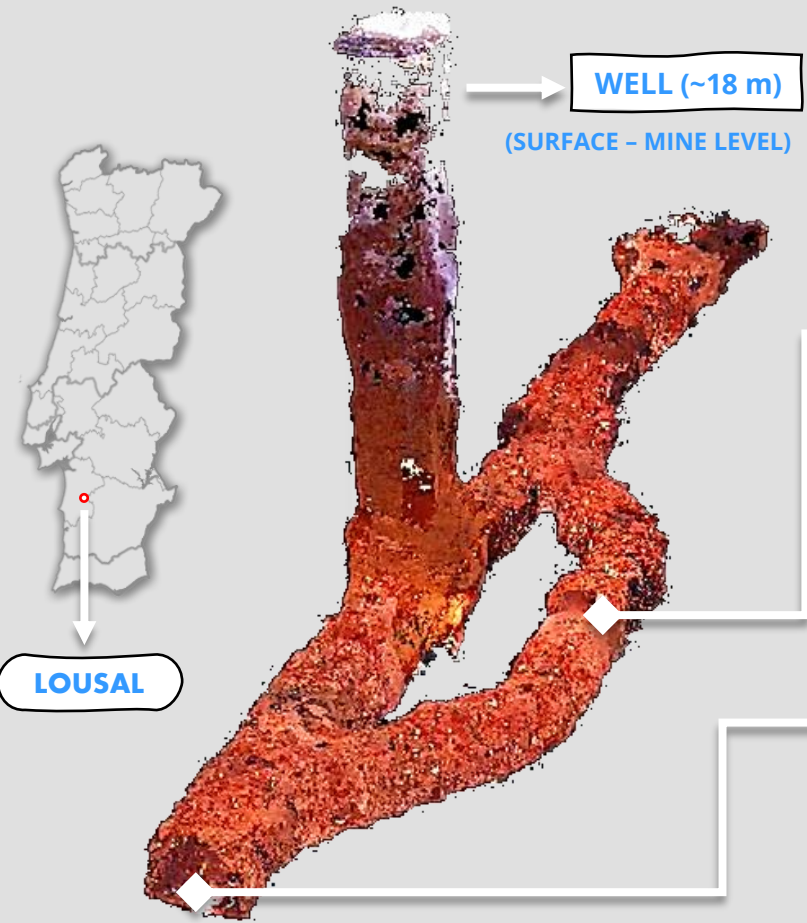
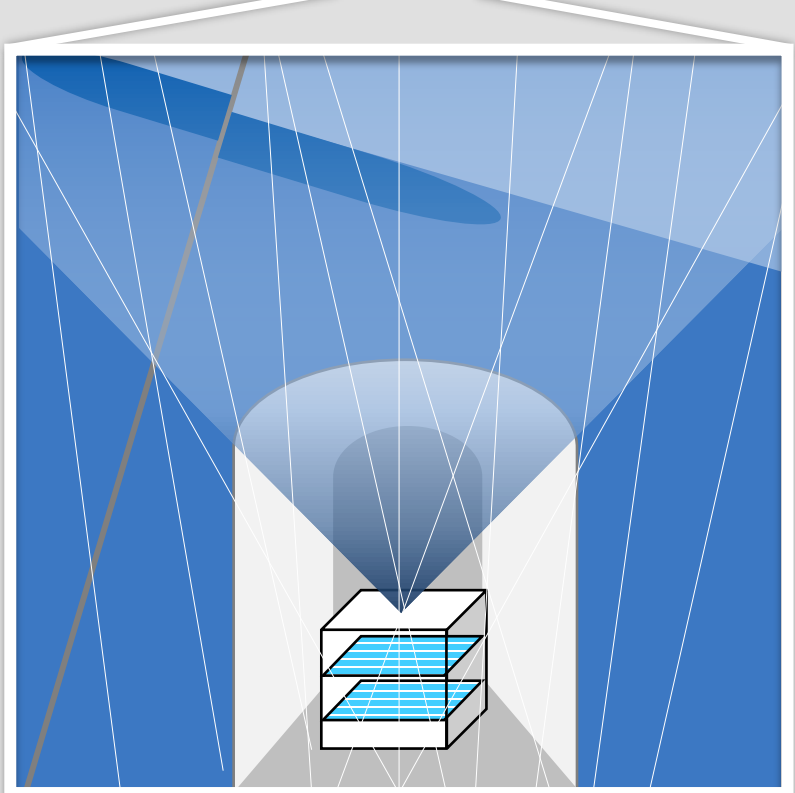
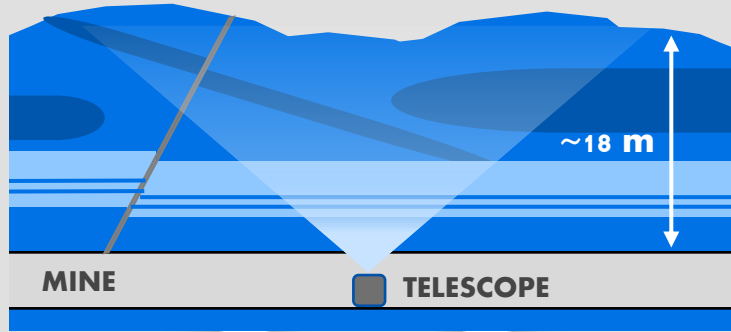


Significance ( $3 < \Sigma < 5$ ) - Lousal Well (1 day)





# UNDERGROUND MUOGRAPHY - LOUSAL MINE



**OBJECTIVE:** to do a geological survey of the terrain between the telescope and the surface and improve the existing information with new data while testing the performance of the telescope

# WORK PROGRESSION

## STANDARD TECHNIQUES

### PHOTOGRAMMETRY



+

### GPR



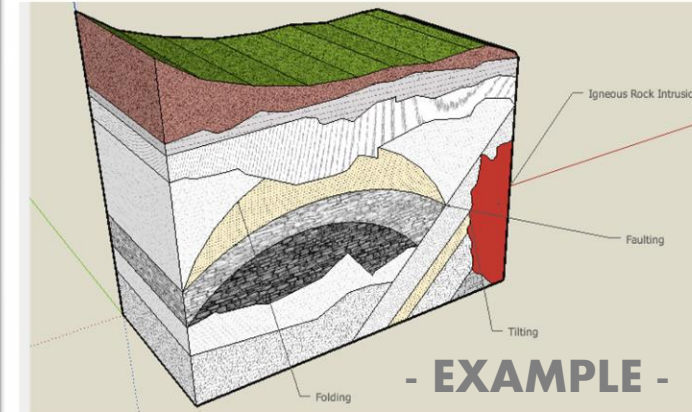
+

### SEISMIC REFRACTION



=

## REFERENCE GEOLOGICAL MODEL



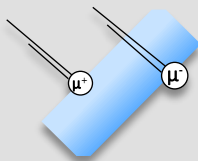
## FOCUS TECHNIQUE

### MUOGRAPHY

SIMULATIONS

ANALYSIS TOOLS

TELESCOPE



$$\phi \propto \frac{1}{\rho}$$

$$g \propto \rho$$



## JOINT INVERSION

### MUOGRAPHY

+

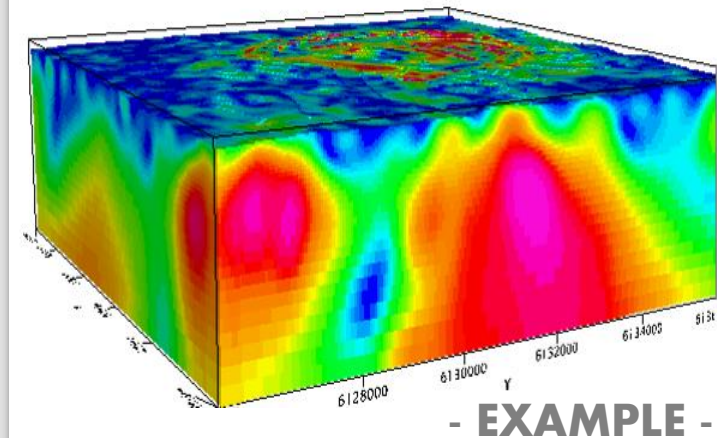
### GRAVIMETRY

=

obtains the density through the attenuation of the muon flux

obtains the density through the strength of the gravitational field

## RECONSTRUCTED 3D DENSITY MODEL





# THANK YOU!



LABORATÓRIO DE INSTRUMENTAÇÃO  
E FÍSICA EXPERIMENTAL DE PARTÍCULAS  
*partículas e tecnologia*



UNIVERSIDADE  
DE ÉVORA



Instituto de Ciências da Terra  
Institute of Earth Sciences



Centro  
Ciência Viva  
do Lousal  
MinadeCiência

# FCT

Fundação  
para a Ciência  
e a Tecnologia

IDPASC-FCT: PD/BD/150490/2019

## LOUSAL MINE

