

Muography in the University and in the Museum

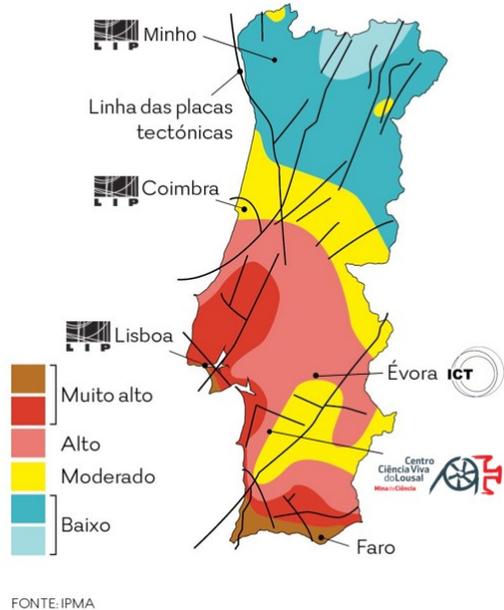
Muography 2021
November, Ghent



Sofia Andringa, sofia@lip.pt
for the LouMu collaboration

LouMu project & team

RISCO SÍSMICO EM PORTUGAL



the national ciência viva network gathers 21 open science centers

w/ the Mine of Science @ Lousal

LouMu
 Science with Cosmic Muons at the Lousal Mine

Centro Ciência Viva do Lousal
 Universidade IP-ÉVOORA
 ICT Instituto de Ciências da Terra
 LIP LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
 FCT Fundação para a Ciência e a Tecnologia

LouMu is a scientific research project combining particle physics and geophysics in order to map large geological structures, using the Muon Tomography technique.

The partners in the project are LIP – Laboratory for Instrumentation and Experimental Particle Physics, the Institute of Earth Sciences of the University of Évora, and the Mine of Science – Lousal Ciência Viva Science Centre.



Planet Earth is constantly being struck by particles coming from space, known as cosmic rays.

As they collide with atoms in the atmosphere, a shower of new particles is created. Among them are muons, particles that can reach the surface of the Earth and pass through rocks.

Taking into account the number of muons that reach us, it is possible to figure out the different densities in the interior of rocks. In this way, the Invisible becomes visible.

This is a Muography: like a radiography, but with muons.

In the Lousal Mine a muon detector is installed which, in combination with other geophysical techniques, will enable the Muon Tomography, three dimensional information, to let us better understand the interior of the mine and of other geological structures.

For more information:

<https://pages.lip.pt/LouMu>

<https://lousal.cienciaviva.pt>

contact to schedule visits:

info@lousal.cienciaviva.pt

Muons are particles similar to electrons, but more able to pass through matter.

Residue Plate Chamber (RPC) detectors contain a gas that is ionized by the passage of electrically charged particles, like muons. They allow us to know with precision the crossing point of each muon.

The Muon Tomography provides an image with information about the interior of the structure traversed by the muons.

the LouMu RPCs

spin-off from R&D for the
Pierre Auger Observatory



not just the detectors

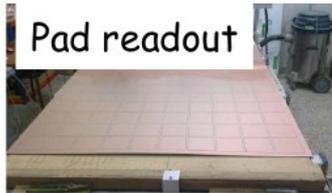
also

simulation/analyses tools
& even outreach efforts

LIP R&D in RPCs for different applications

1. high resolution TOF trackers
2. high resolution PET imaging
3. epi-thermal neutron detection
4. **cosmic ray experiments**

- > automatic adjustment for environmental conditions
- > low maintenance & low consumption
 - fed by solar powered stations
 - 4 cc/min of R-124a gas
- > 64 channels read by MAROC-3

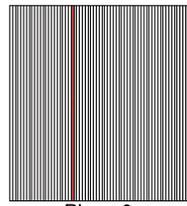


LouMu will test new readout segmentation

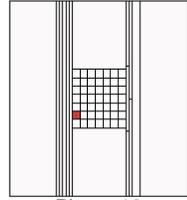
- *much smaller pads and guard rings*
- *different lengths and widths of strips*
- *some analyses tools and methods*

the LouMu detector

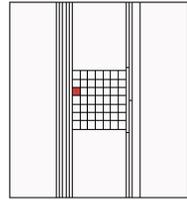
a $(1\text{ m})^3$ telescope with
4 planes of low power,
low gas flux RPCs



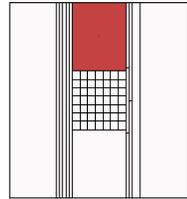
Plano 0



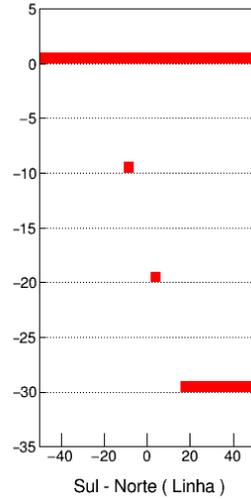
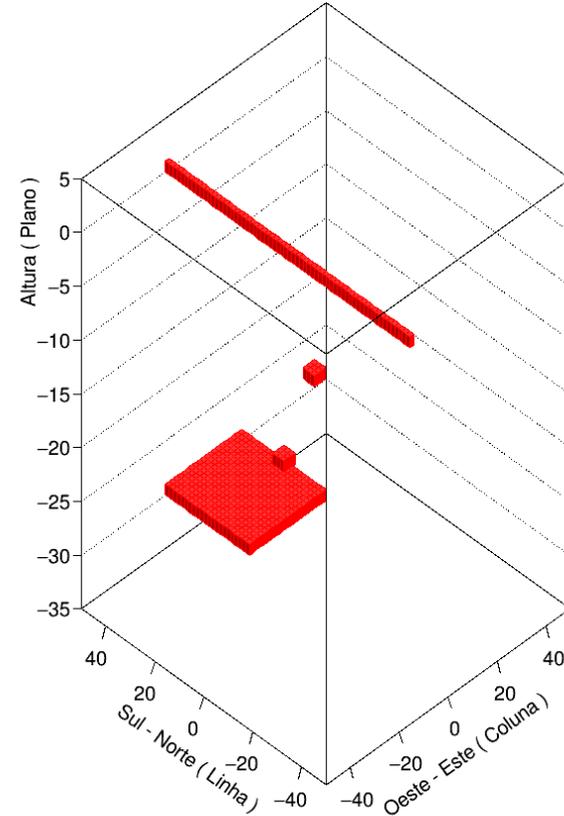
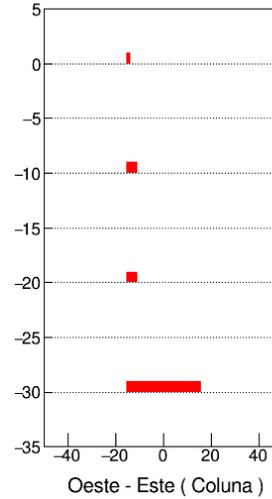
Plano -10



Plano -20



Plano -30

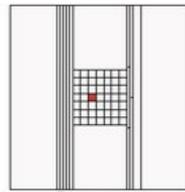
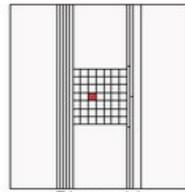
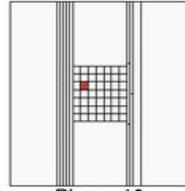
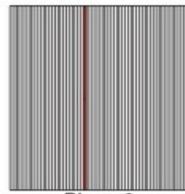


inner region with $(4\text{ cm})^2$ pads for high resolution images

extra area with strips of different widths (for R&D tests)

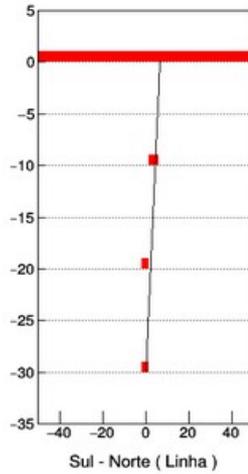
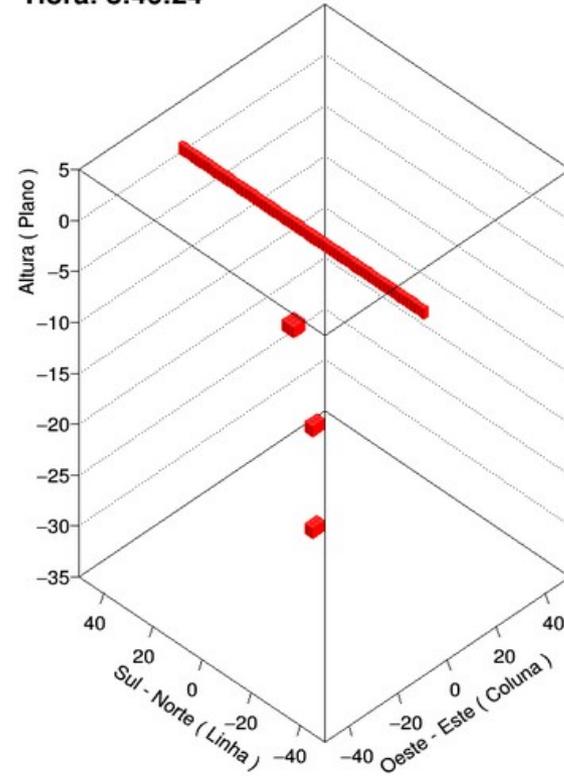
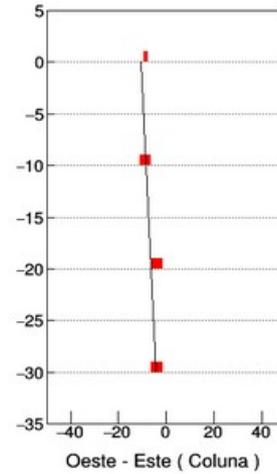
the LouMu detector

a $(1\text{ m})^3$ telescope with
4 planes of low power,
low gas flux RPCs



Data: 23/11/2021

Hora: 8:46:24



inner region with $(4\text{cm})^2$ pads for high resolution images
extra area with strips of different widths (for R&D tests)

In the University



ESTÁGIOS
DE VERÃO LIP

JULHO – SETEMBRO

TOMOGRAFIA MUÓNICA

PARA ESTUDANTES DE
FÍSICA
GEOFÍSICA
GEOLOGIA
ENGENHARIA

DEMUSAR RAIOS CÓSICOS PARA
EXPLORAR ESTRUTURAS GEOLÓGICAS,
CONSTRUÇÕES HUMANAS E A MINA DO LOUSAL

www.lip.pt/estagios-de-verao
CONTACTO: muom-info@lip.pt

Uma colaboração de

LABORATÓRIO DE INVESTIMENTOS E FORMAÇÃO EXPERIMENTAL DE PARTÍCULAS FOTÓNICAS E GEOLÓGICAS
UNIVERSIDADE DE ÉVORA
Centro Ciência Viva do Lousal
Município de Évora

Muography of a building (M)
Muography on Earth and Mars (L)
RPC calibration for muography (C)
Sensitivity of muon telescope (L)
Muography optimization (M)

Student prizes in U. Minho!

A block model for simulation and reconstruction

1. open air muon flux – simple parametrization on zenith angle
more information needed for other applications

X

2. muon transmission – the product of simple exponentials per object
Geant4 to include scattering effects in the mine

X

3. detector response – position and direction efficiency measured from data
detector geometrical model, also RPC physics?

=

4. standardized maps – for our 7 x 7 CorePix pads, use just 13 x 13 directions
will be fun, to include different pixel shapes

Still many challenges ahead!

» extra information from position

» extra information from focusing

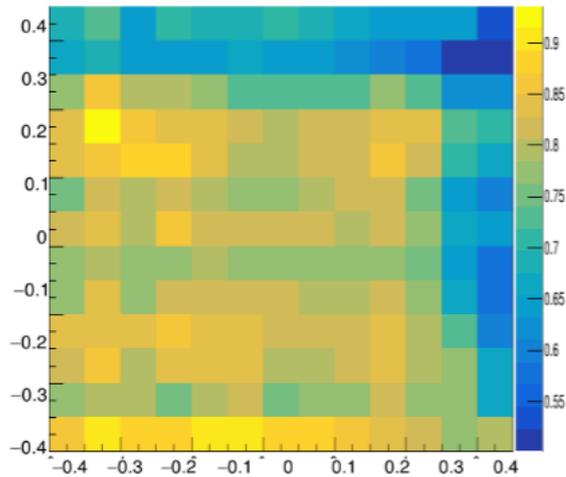
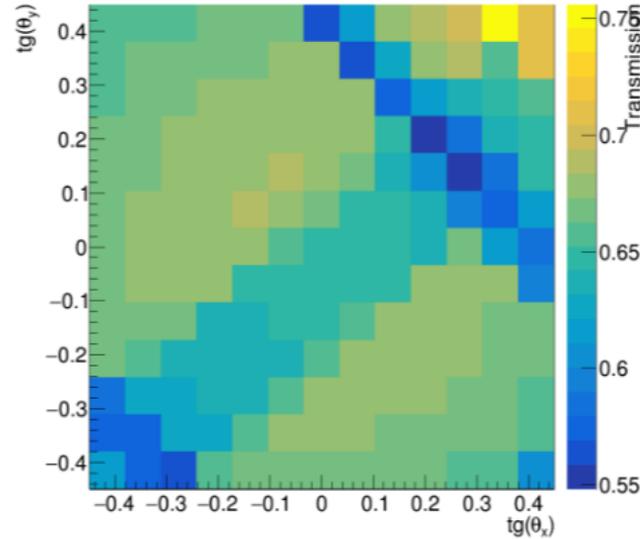
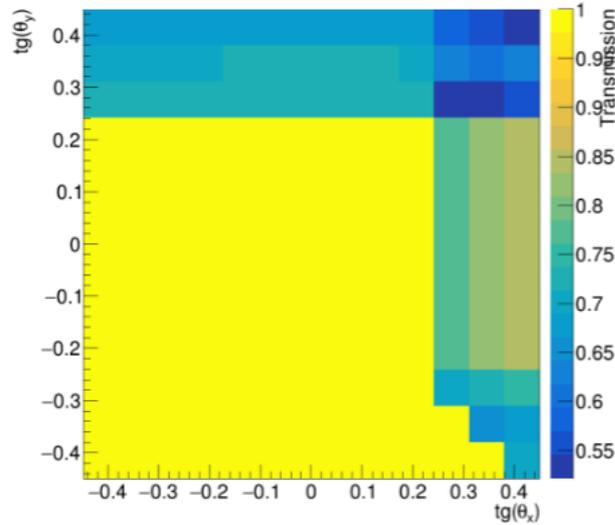
» 3D combination of muographies

Imaging the University

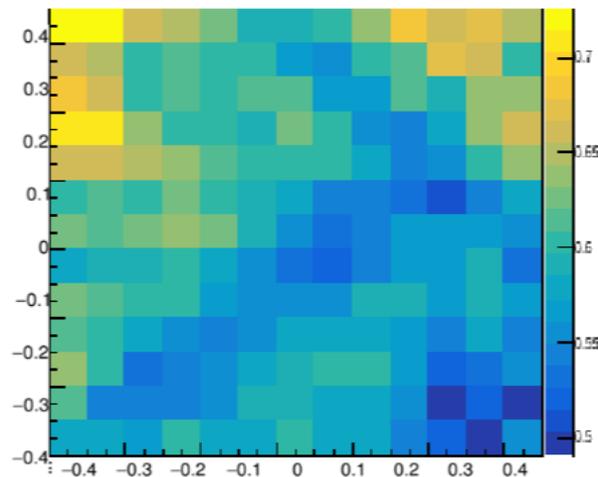
data driven approach
developed with students

**step by step
modelization**

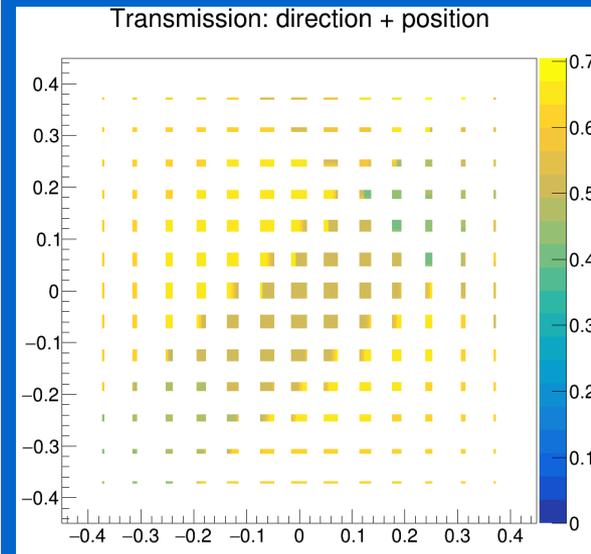
and surprises!



high contrast

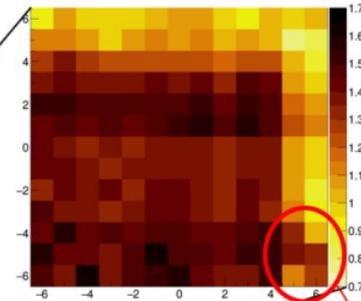
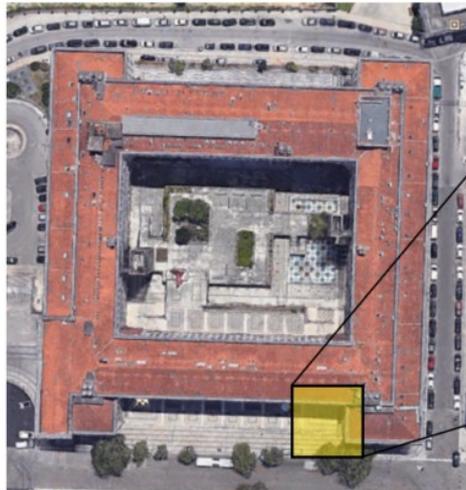


low contrast



Physics department of the Coimbra University

data Sept, 2020



ENTRADA
DO EDIFÍCIO



National Week of
Science and Technology
November 21-27, 2021

Feliz semana nacional da

Ciência e da Tecnologia!

Todos os anos, a Semana da C&T celebra-se em torno do dia 24 de Novembro, aniversário de Rómulo de Carvalho, que José Mariano Gago instituiu como Dia Nacional da Cultura Científica.



LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia



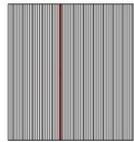


LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

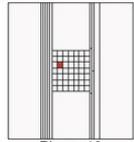
LouMu em Coimbra

Muografar o Departamento de Física

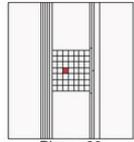
<https://pages.lip.pt/loumu>



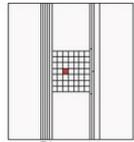
Plano 0



Plano -10



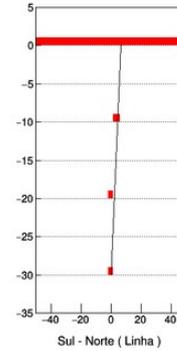
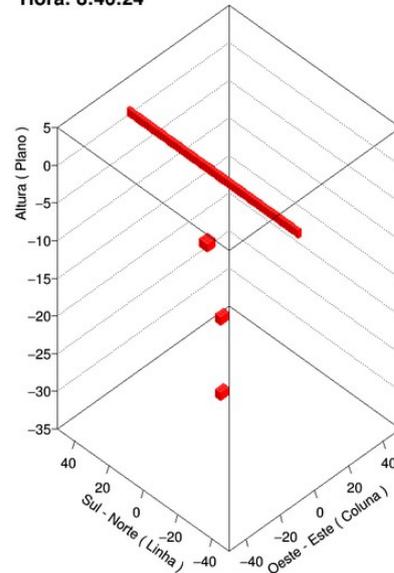
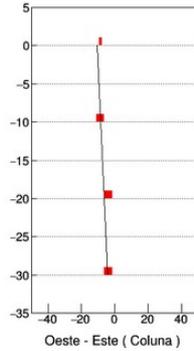
Plano -20



Plano -30

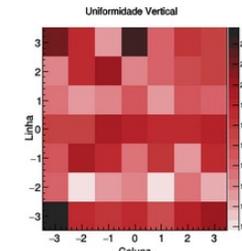
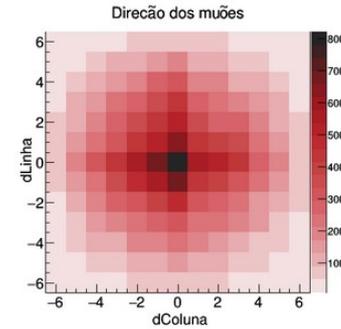
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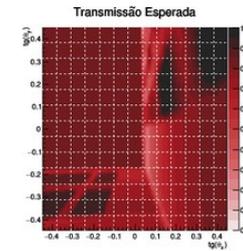
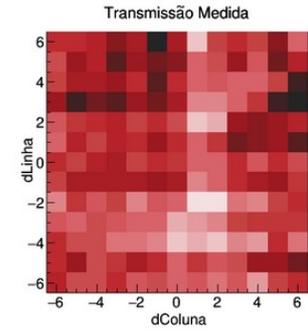
Mapas de Contagens

de 19/11 15:9 a 23/11 9:2



Análise da Muografia

comparando com fluxo ao ar livre



from the University

to high school

introduce different subjects and concepts

explore the data with some maths

to younger students

introduce different subjects and concepts

play with data more visually

a block model for simulation and reconstruction

1. open air muon flux

» astrophysics

» cosmic ray showers

2. muon transmission

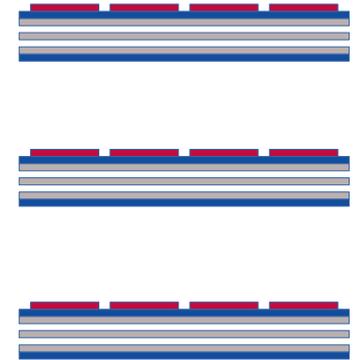
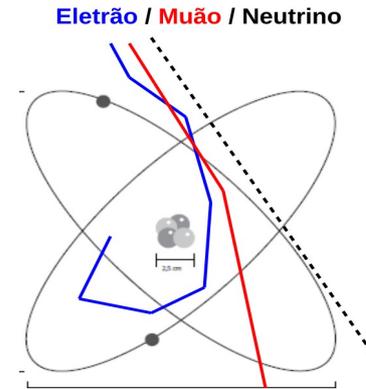
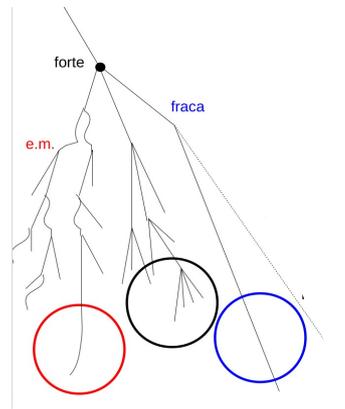
» geophysics

» particle interactions

3. detector response

» technology

» particle detection



4. standardized maps » challenge: how to analyse!

* construct maps by adding in lego pieces?

* will test ideas with teachers and students!

in the Museum

Mine of Science
part of Ciência Viva
National Network

@Lousal devoted to mining
and underground sciences

LouMu @ Lousal calendar

introduce muography
& particle physics topics

different ways of seeing
cosmic ray observatories
underground laboratories
neutrinos, dark matter...



Muões Cósicos na Mina do Lousal
Cosmic Muons at the Lousal Mine

Radiografia X-ray ≠ Muografia Muography ?

Os feixes de raios-X podem atravessar alguns centímetros de água, permitindo criar imagens dos contrastes de densidade do corpo humano.

X-ray photons can cross a few centimeters of water, allowing us to create images of density contrasts inside the human body.

Os muões podem atravessar quilómetros da crosta terrestre e, portanto, permitem criar muografias – imagens dos contrastes de densidade no interior de uma montanha.

Muons can cross kilometers of the Earth crust and thus allow to create muographies – images of density contrasts inside a mountain.

A Terra está sempre a ser atingida por partículas vindas do espaço, conhecidas como raios cósmicos. Quando os raios cósmicos chocam com os átomos da atmosfera, criam-se uma chuva de novas partículas, entre elas os muões, que são partículas elementares com carga elétrica, semelhantes aos elétrons dos átomos, mas com uma massa dez vezes vezes maior e um tempo de vida de microssegundos. Os muões conseguem penetrar a atmosfera, chegar à superfície e atravessar água e até rochas.

Earth is always being struck by particles from the outer space known as cosmic rays. When cosmic rays hit the atoms in the atmosphere a shower of new particles is created. Among these new particles are muons, electrically charged elementary particles similar to the electrons of atoms, but with a mass ten hundred times higher and a lifetime of microseconds. Muons can cross the atmosphere, enter the surface and cross water or even rock.

LouMu

Lousal é um projeto de investigação científica que junta física de partículas e geofísica para fazer o mapeamento de grandes estruturas geológicas em ambiente subterrâneo, usando a técnica de tomografia com muões.

The interior of a Gallery of the Lousal Mine, está instalado um telescópio de muões, que deteta a passagem de muões vindo de diferentes direções. Este telescópio cria muografias das rochas circundantes.

Estas muografias serão primeiro comparadas com o mapeamento já existente da mina e confrontadas com os resultados obtidos por métodos realizados por métodos geofísicos tradicionais.

Os dados de tomografia com muões serão combinados com os resultados dos métodos geofísicos, permitindo uma análise conjunta de qual resultará um mapa 3D mais preciso de geologia ambiente da Lousal.

Lousal is a science research project joining particle physics and geophysics to map large geological structures in an underground setting, using the muon tomography technique.

A muon telescope is installed in a Gallery of the Lousal Mine, detecting the passage of muons coming from different directions. This telescope creates muographies of the surrounding rocks.

These muographies will be first compared to the existing mapping of the mine, improved by new measurements using standard geophysical techniques.

The muon tomography data will be combined with the data acquired with other techniques, in a common analysis, to Lousal site.

FCT Fundação para a Ciência e a Tecnologia
CENTRO CIÊNCIAS DA TERRA E AMBIENTE
UNIVERSIDADE DE ÉVORA
FCT



MiniMu

Tested detector stability,
communications,
gas feeding and recovering

reaching out to visitors

the underground gallery
houses old mining equipment,
also a room for aging wine,
a working sismopgrapher,
a working muographer...



in the Museum

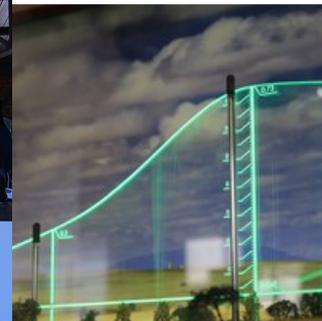
Above ground spaces include the old shower room houses, “the bath of science” with modules on mining, geology, biology, chemistry, physics

gravimetry + muography + cosmic rays + muon detectors

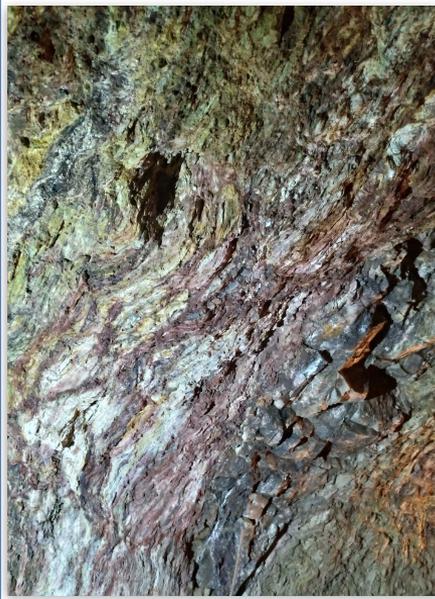
input from museum experts, LIP-ECO and school groups

return of the results

- add to Lousal information
- show & explain muography
- visits from possible users



geosciences as first real use case, online data taking and analyses



Outlook

Muography is a great tool for communication of particle physics

communication can help make muography a more standard tool

Muography in the university

gaining insight on the technique in a simple case
preparing the team for more complex analyses

making it understandable by school children
and as such also for possible end-users

Muography in the museum

an ideal test case for geophysical analyses
R&D and open-science in a public setting

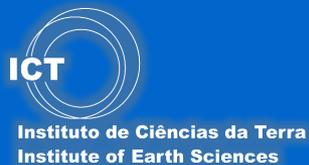
testing the scientific possibilities and limitations
both for the expected or unexpected users

Thank you for your attention!

More in
<https://pages.lip.pt/loumu/en>

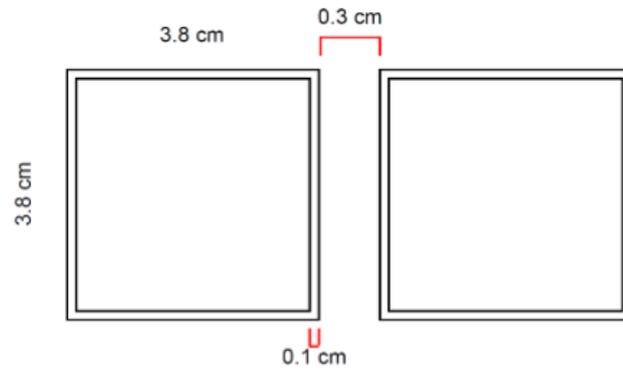
and/or visit us at Lousal!

Acknowledgments



EXPL/FIS-OUT/1185/2021

Backups



15	19	10	28	35	53	44
3	7	23	29	36	41	57
16	20	11	30	37	54	45
4	8	24	31	38	42	58
17	21	25	32	39	55	46
5	9	26	33	52	43	59
18	22	27	34	40	56	47

