UNIVERSITÀ DEGLI STUDI FIRENZE

INFN FIRENZE

Muon Radiographic

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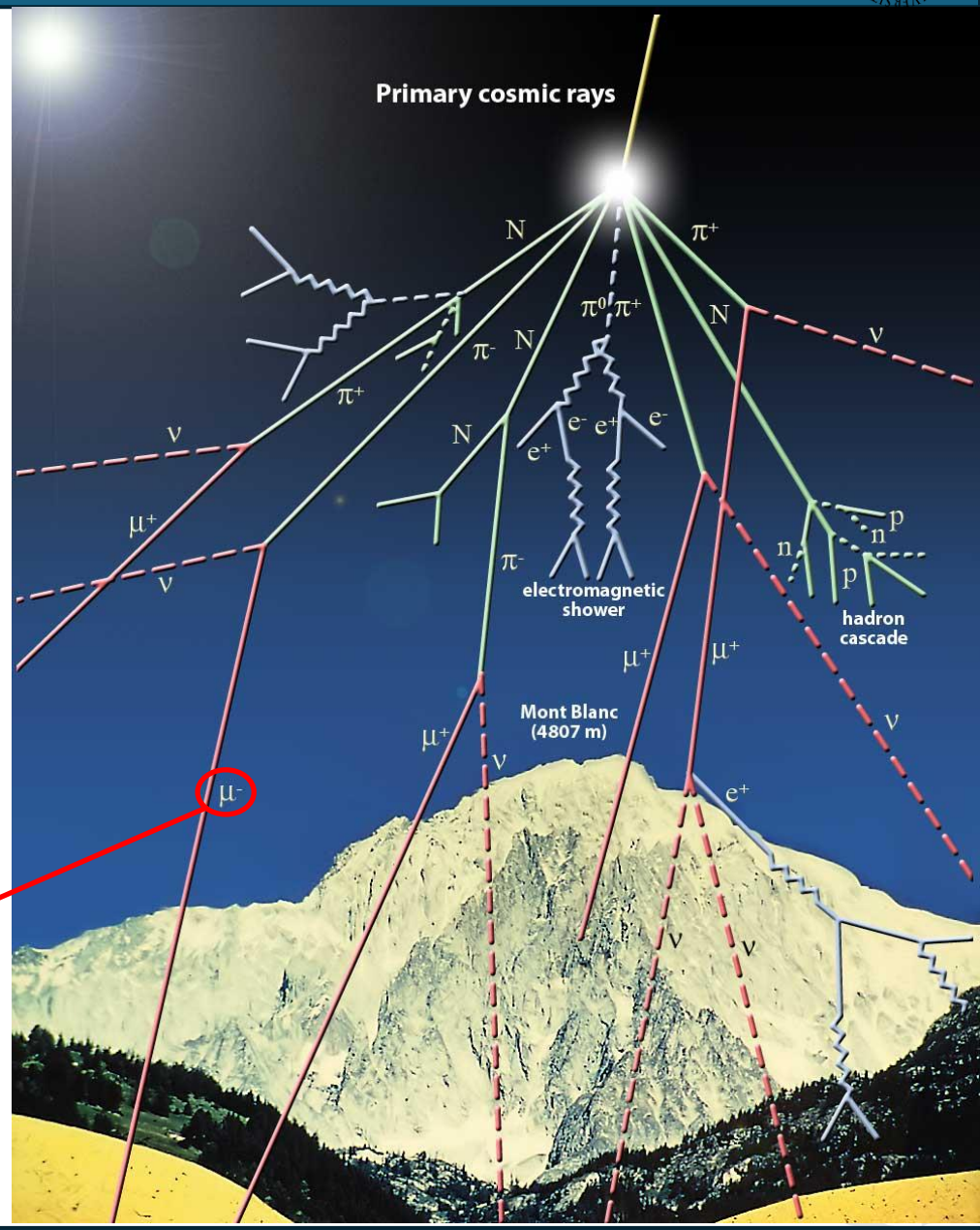
Cosmic Rays

- Cosmic rays are divided into primary and secondary:
  - The primaries impact the atmosphere from space and originate mainly from outside the solar system:
    - 98% nuclei:
      - 87% p
      - 12% He
      - 1% other nuclei
    - 2% e^+ and e^-
  - Secondaries are produced by the interaction of primaries with nuclei in the atmosphere:
    - X-ray, neutrons, mesons (such as pions and kaons), electrons and muons.

- $m_\mu \sim 105\text{MeV}/c^2 \sim 200\, m_e$
- High penetrating power in the matter
- Most abundant particles on the ground



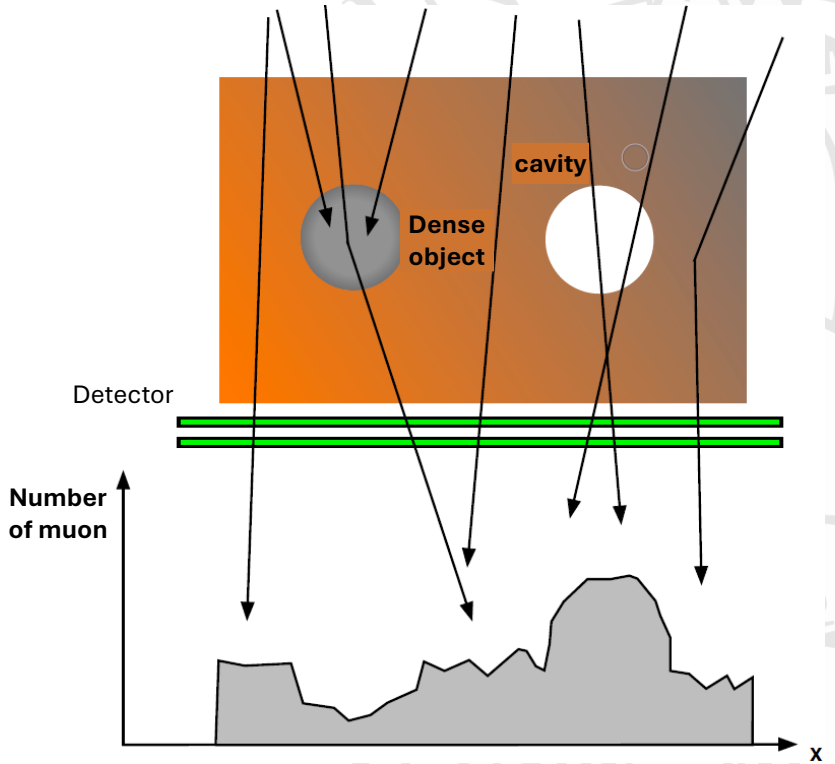
Muon Radiography

- The muon radiography technique exploits the penetration capacity of muons present in cosmic rays to make radiography of very large targets.

- This technique bases its operation on the energy loss of muons when they pass through a dense body.

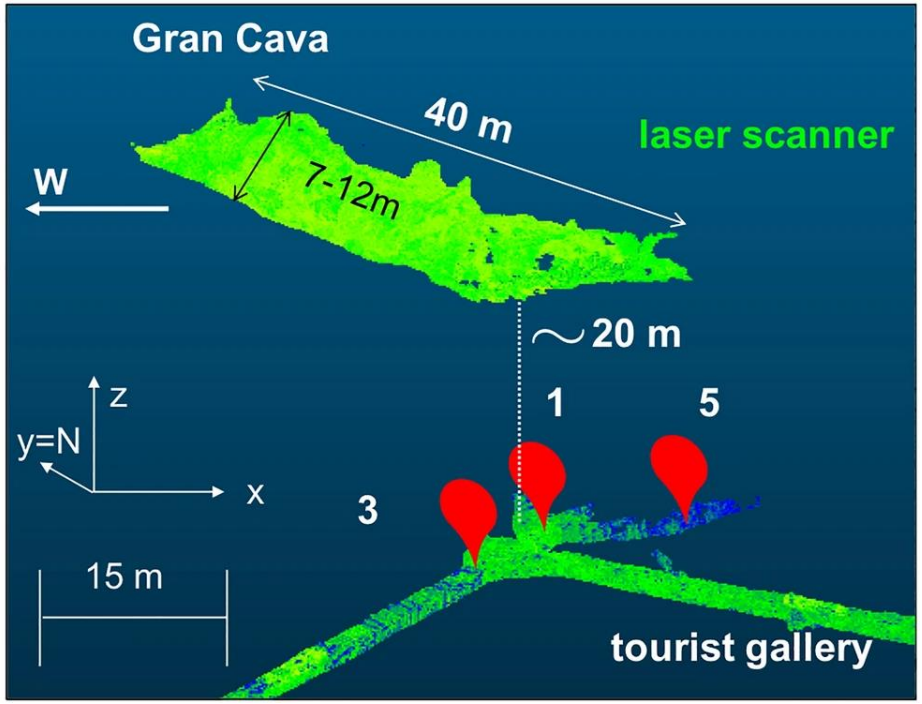
- Since muons are less likely to interact, stop and decay in low density matter than in high density matter, a larger number of muons will travel through the low density regions of target objects in comparison to higher density regions.

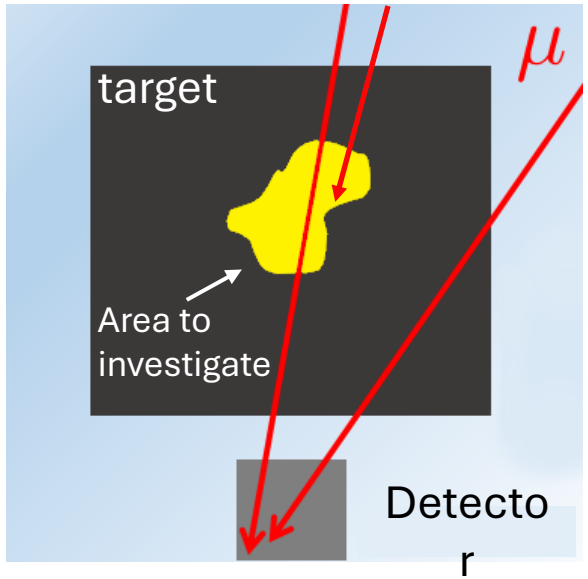
- Muography is a non-invasive technique and exploits natural radiation present on the entire surface of the earth.

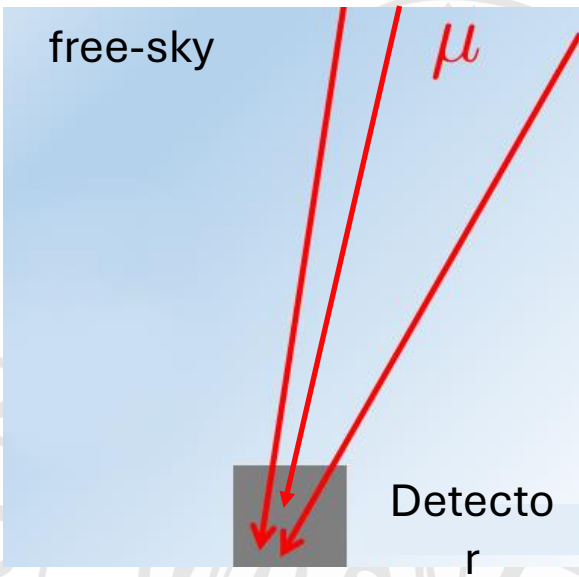


Muon Transmission technique

1. Observing the number of counts in the presence of the target ($N_{target}(\theta, \varphi)$).
2. Observing the number of counts without the target ($N_{target}(\theta, \varphi)$), also called Free-Sky configuration.
3. Compare the measured transmission with that expected at a fixed density.







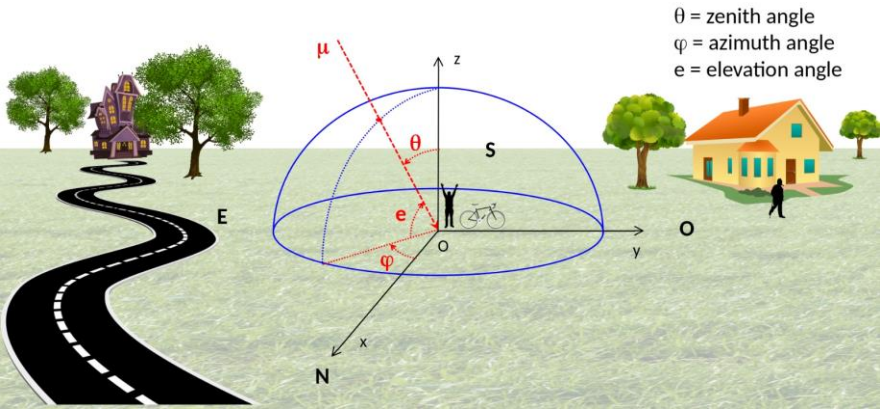
$$T_{measured} = \frac{N_{target}(\theta, \varphi)}{N_{free-sky}(\theta, \varphi)} \cdot \frac{t_{free-sky}}{t_{target}}$$

$$T_{relative} = \frac{T_{measured}}{T_{expected}}$$

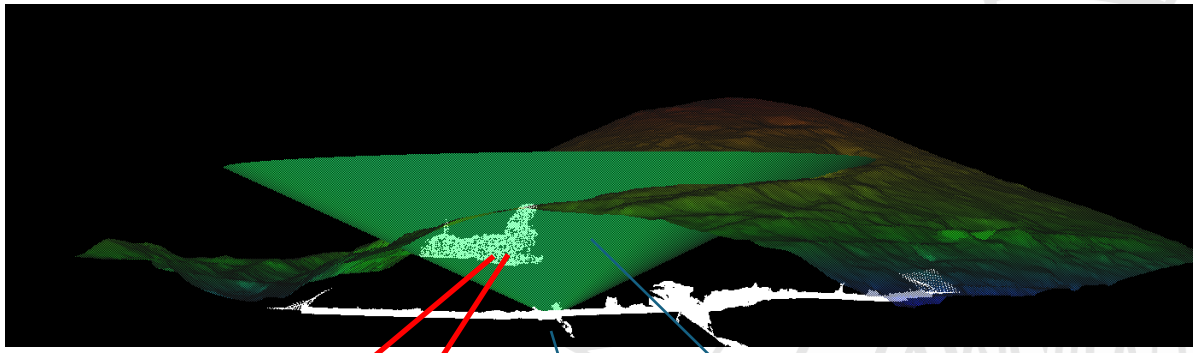
- > 1 Cavity?
- <1 Dense Object?
- =1 Match with simulation

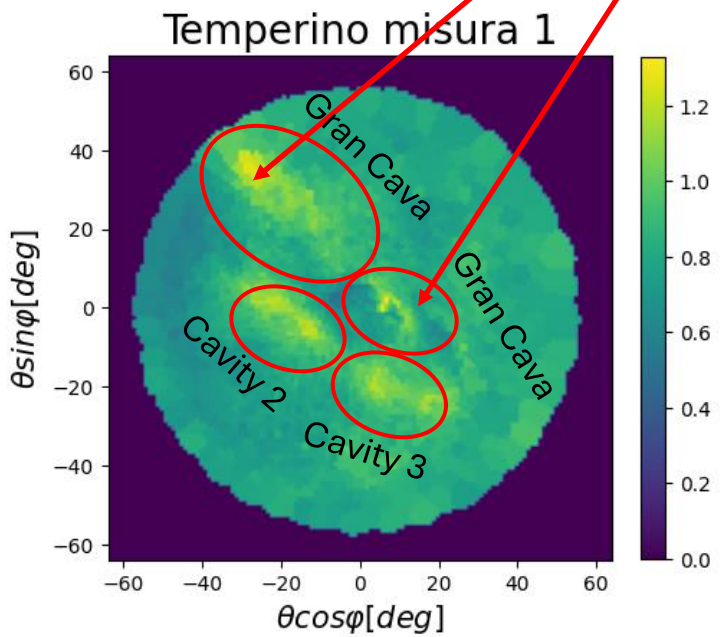
Temperino

- MIMA detector was positioned inside the mine with a vertical orientation, namely at $\theta = 0^{\circ}$
- Brighter areas = Higher relative transmission: region with a lower density than expected.
- Darker areas = Lower relative transmission: regions with a higher density than expected.



Our aim is to create a neural network that can predict and segment these cavities.

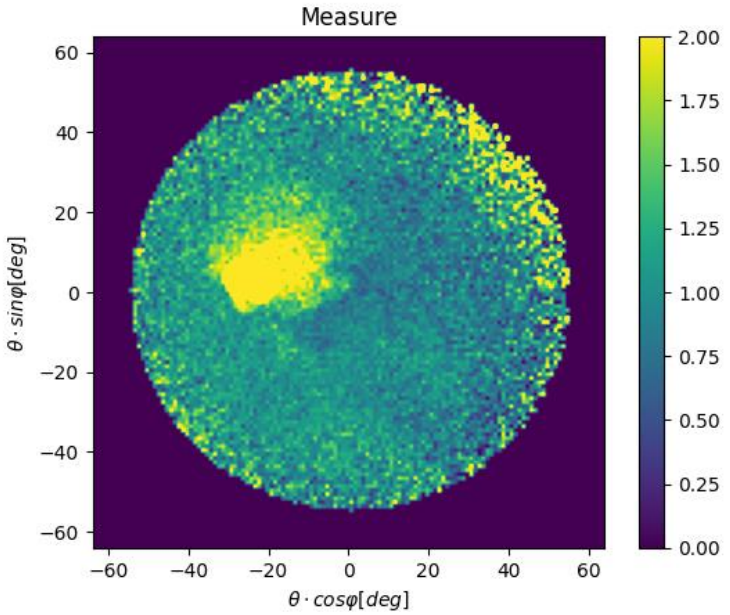


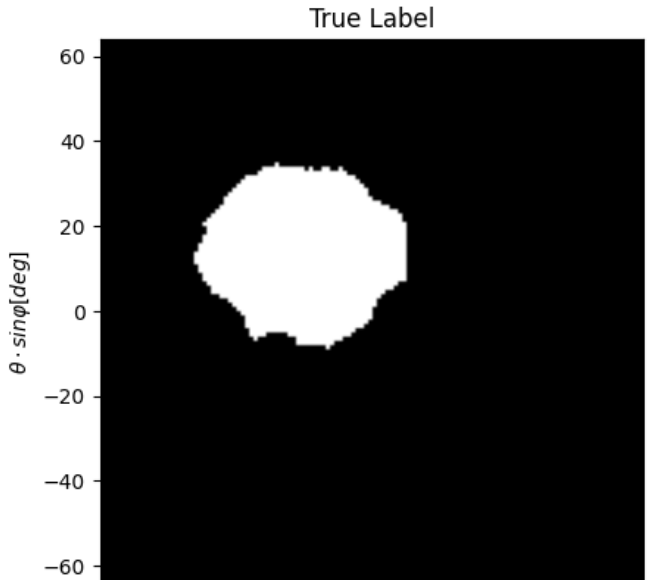


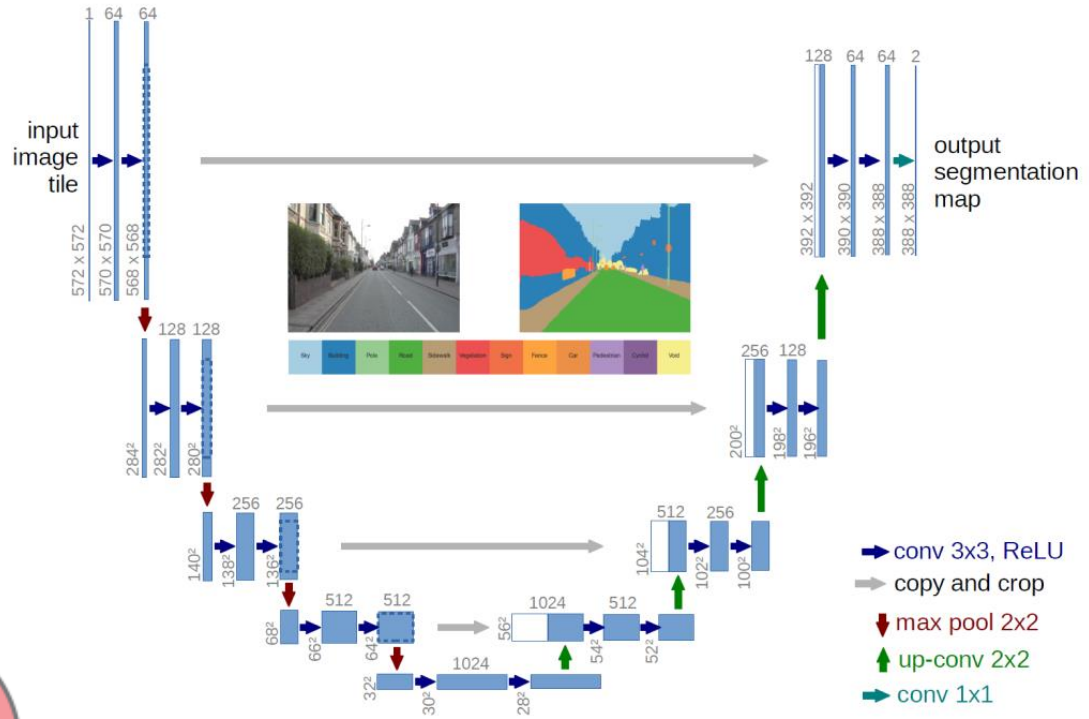
Acceptance Cone

MIMA Measuring Point

UNet

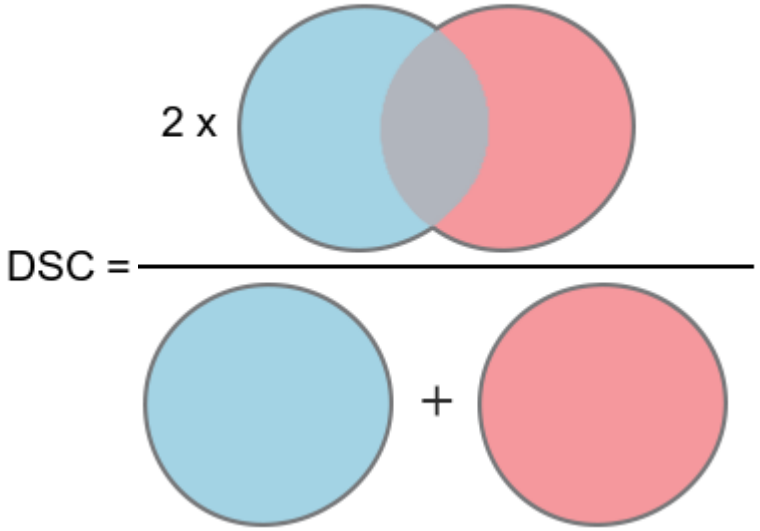






Dataset:

- 32592 training
- 8148 validation
- 686 test



Loss = 1 -DSC

UNet Results