

# CATACOSMIC-BOX

Ricerca di un'eventuale correlazione tra muoni e radon

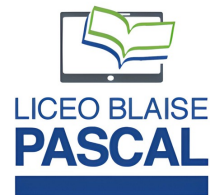
May 24, 2023

Liceo Blaise Pascal, Pomezia (RM)

Speakers:

Giuseppe Roberto 5C

Francesca Sabato 4L



MUSEO  
STORICO DELLA FISICA  
E  
CENTRO  
STUDI E RICERCHE  
ENRICO FERMI





# WHERE DID WE LEAVE OFF?

Last year, using our Cosmic Box, we took the following readings:



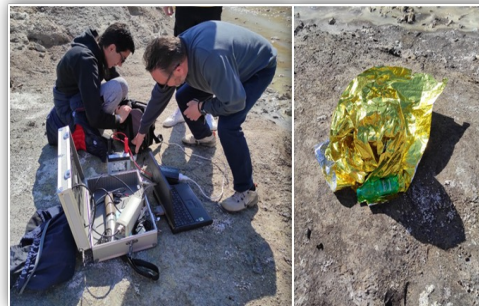
*At different altitudes*



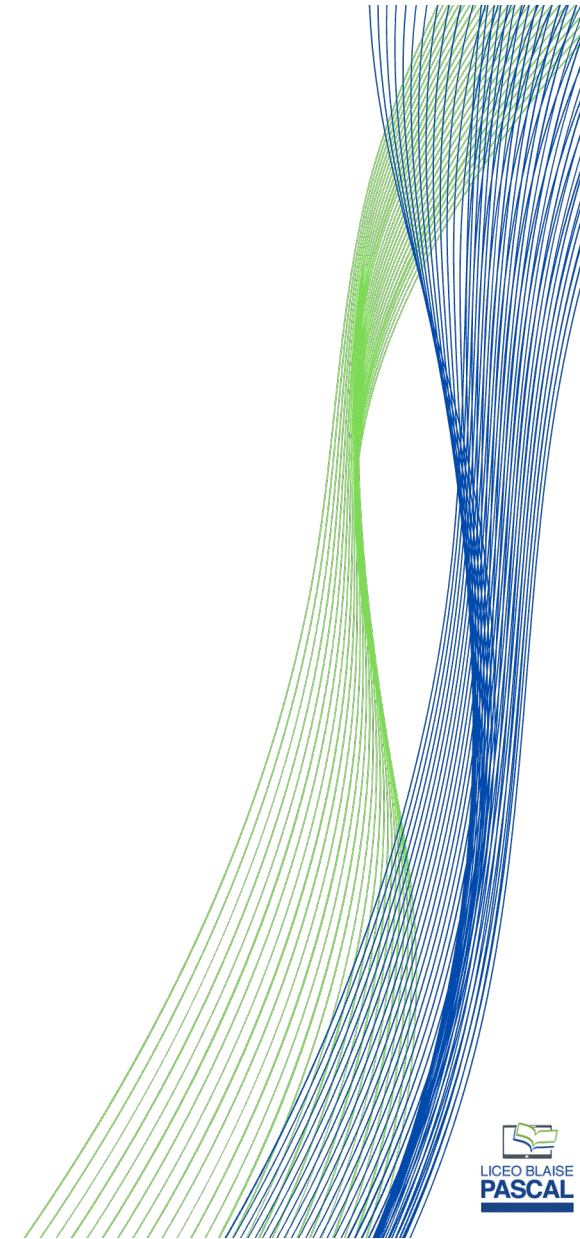
*For the consistency*



*At different angles*

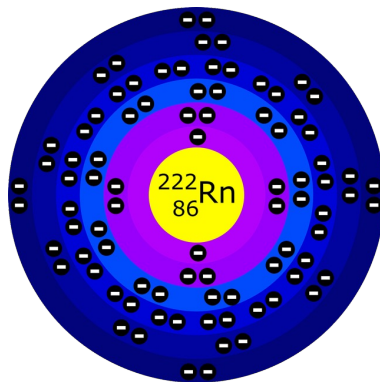


*In relation with gamma rays*

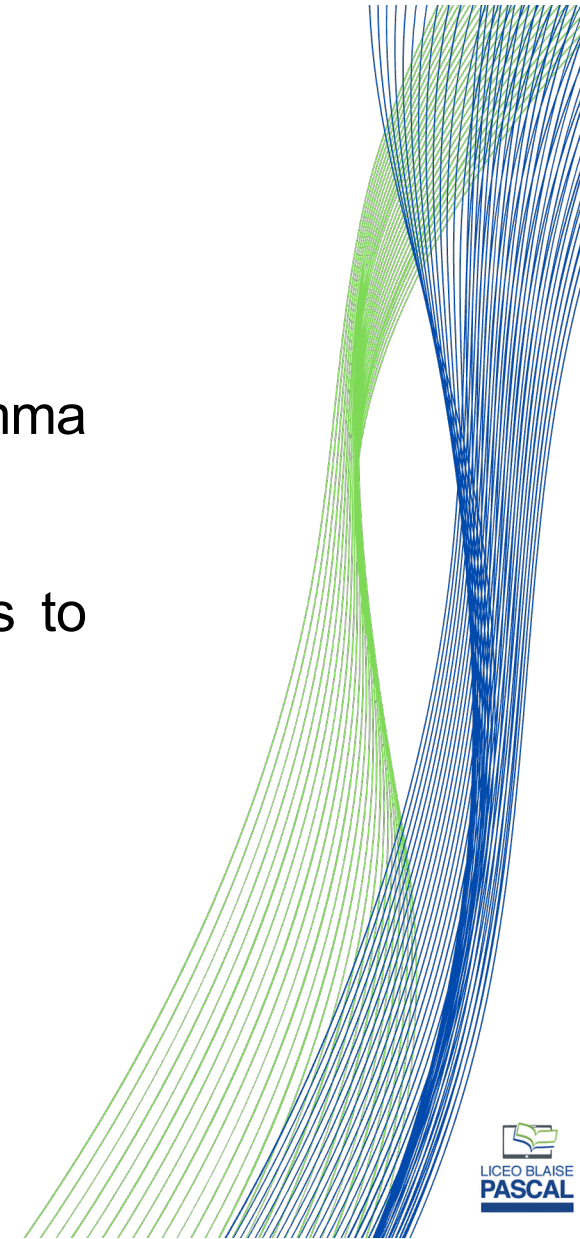
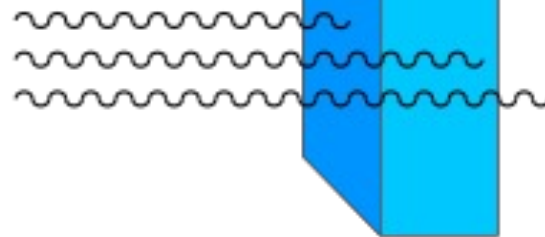


# OUR NEW PROJECT

- Measurements taken at different altitudes.
- Additional measurements to compare muon flux and gamma rays.
- Measurements taken in radon-rich closed environments to try finding a correlation with the muon flux readings.



$\gamma$



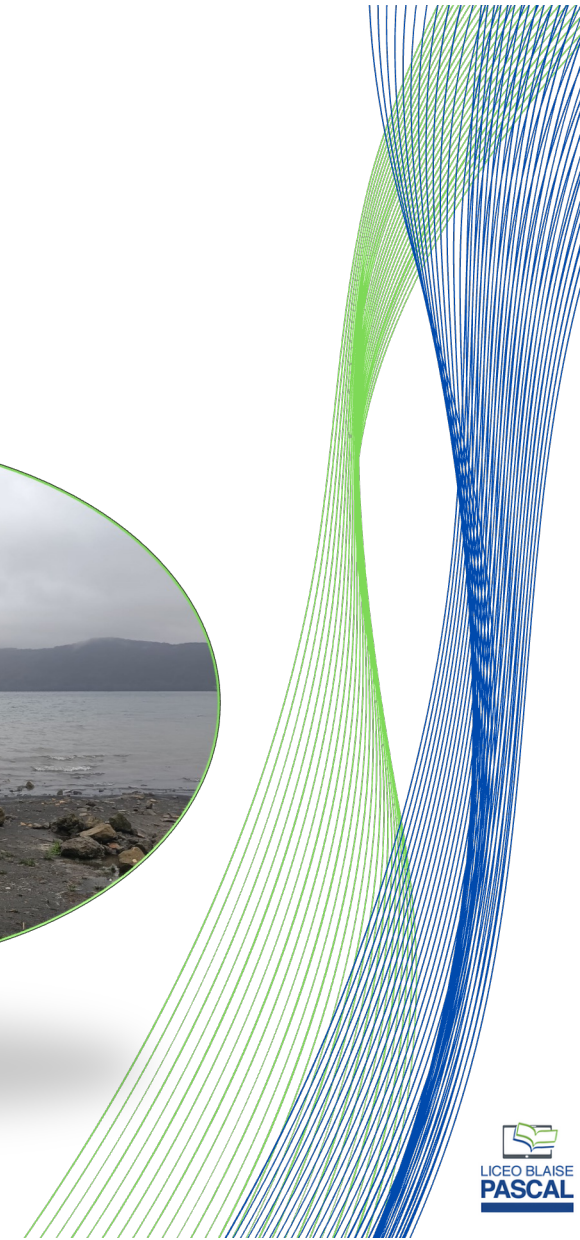
# PLACES OF THE MEASUREMENTS



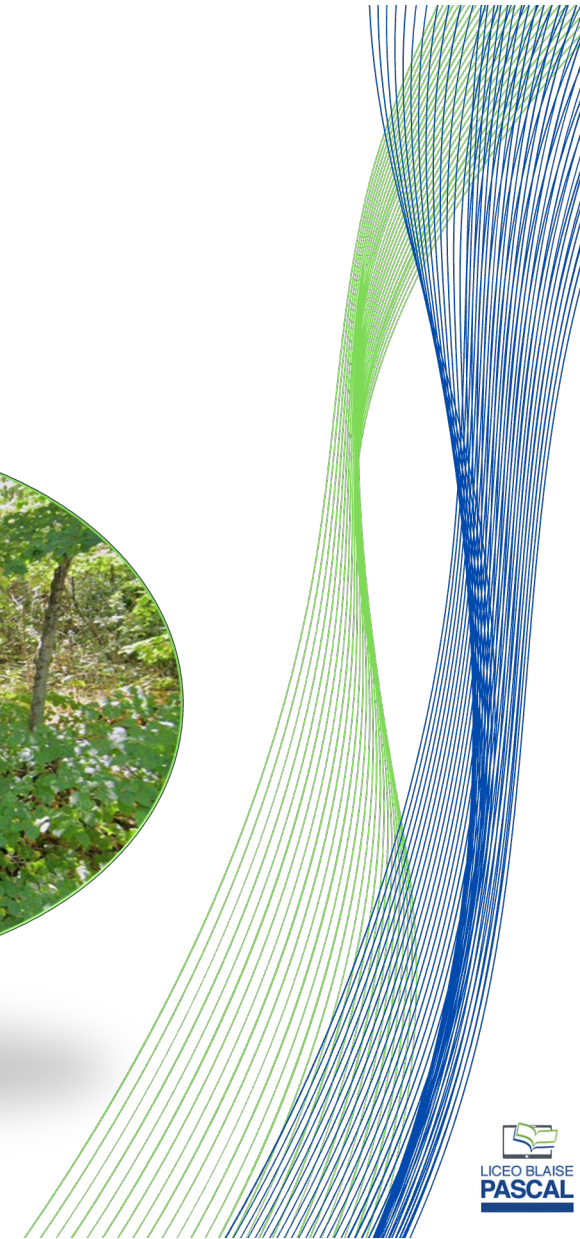
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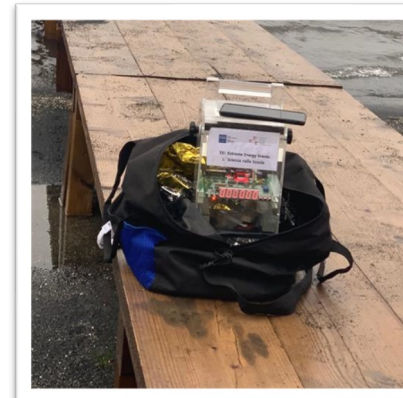
# OUR EQUIPMENT

The measurements were carried out using our **Cosmic Box**, a portable particles detector with an acceptance angle of  $46.69^\circ$  ( $46^\circ 41' 24''$ ), equipped with two chambers with scintillators (dimensions  $0.15 \text{ m} \times 0.15 \text{ m} \times 0.01 \text{ m}$ ) placed parallel at a distance of  $0.20 \text{ m}$ .

The gamma ray values were measured with a **portable gamma spectrometer**, consisting of a NaI(Tl) solid scintillator and a photomultiplier directly interfaced to the NaI(Tl) crystal.

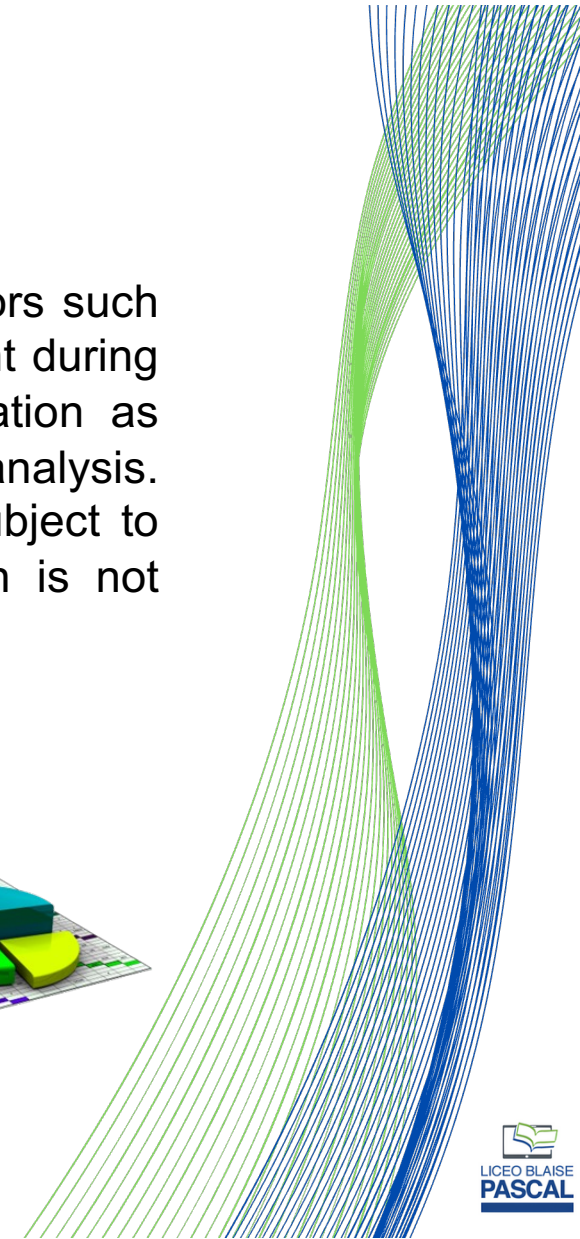
Apart from being able to provide the absolute value of measured gamma rays, the detector is also capable of differentiating the radionuclide emitter of the recorded gamma rays based on the energy of the latter.

The instrument was made available to us by a professor of our school, **Geologist Giuseppe Antonino Di Lisa**, who contributed in carrying out the measurements of gamma rays.



# MEASUREMENTS

The measurements carried out are conditioned by environmental factors such as **temperature** and **pressure** which have not been taken into account during the execution but which will, in any case, be taken into consideration as possible causes of variations in the measurements during our analysis. Furthermore, it should be remembered that each measurement is subject to **statistical fluctuations**, that are variations in the muon rate which is not always constant.



# MEASUREMENTS AT DIFFERENT ALTITUDES

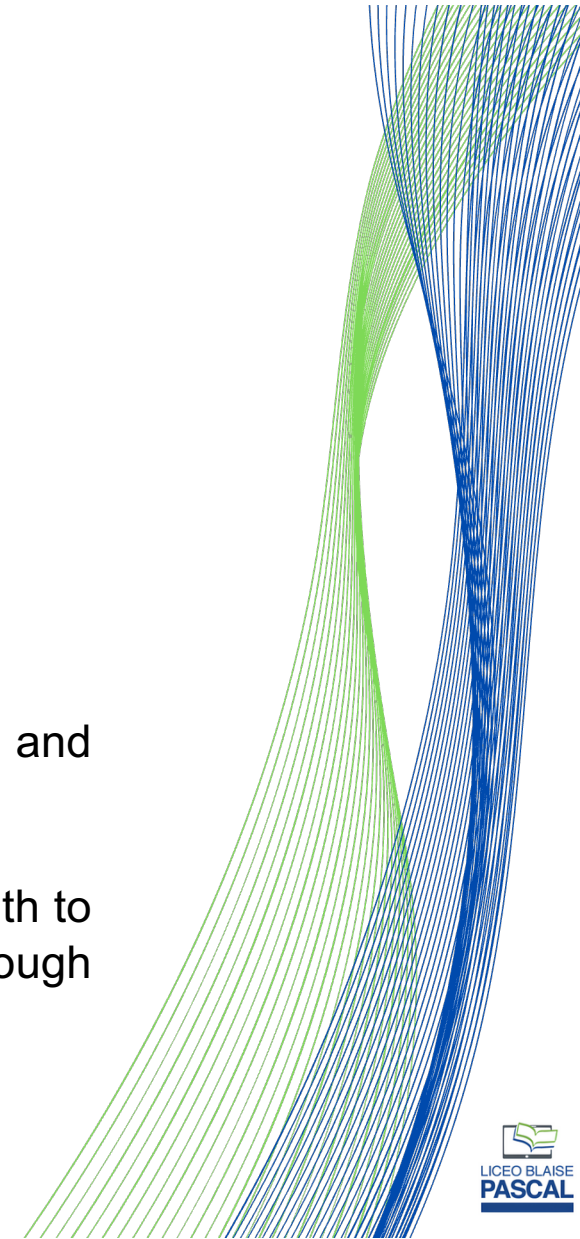
The measurements were carried out in 4 different volcanic locations:

- Catacombe di Albano;
- Lago di Albano;
- Campi di Annibale;
- Pozzo delle Barozze.

The **range of altitudes** studied goes from **293 to 680 m.a.s.l.**

Each measurement was done with the CB perpendicular to the ground and the exposition time was of **10 min.**

We expect higher values at greater altitudes because, with a shorter path to travel, particles have a lower probability to decay before passing through our CB.



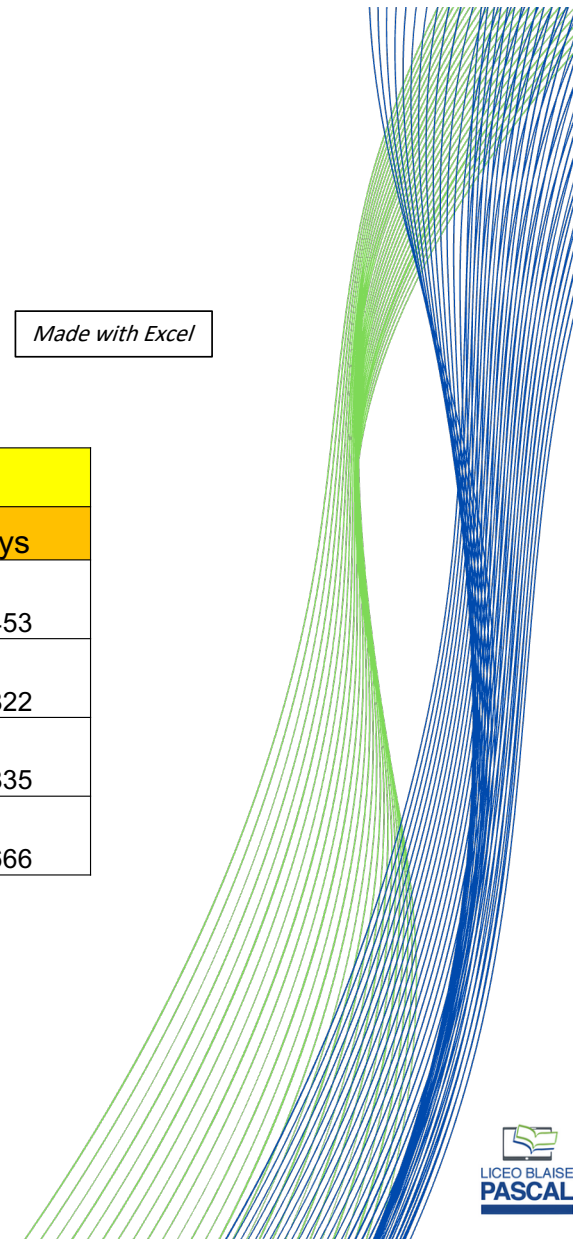
# MEASUREMENTS AT DIFFERENT ALTITUDES

Made with Excel

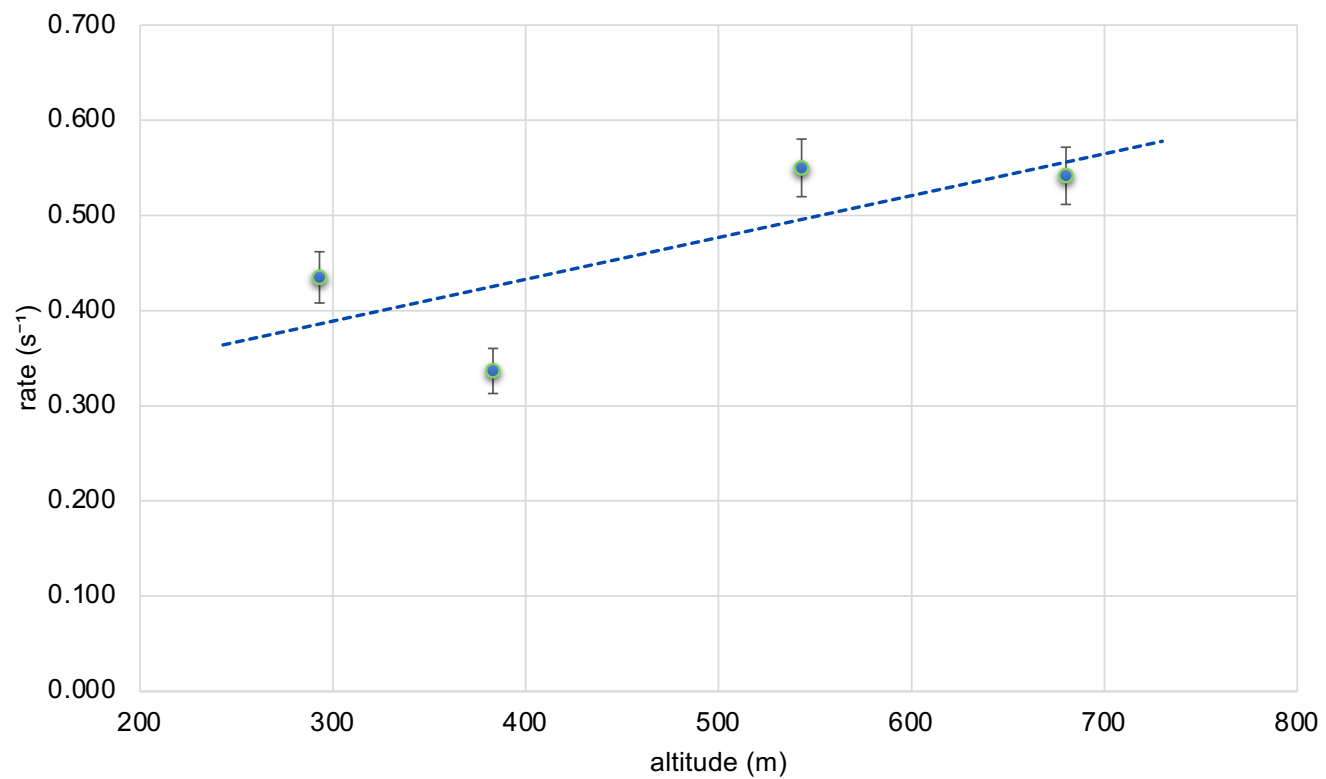
Measurements 17/01/2023						
	n°events	error	rate (s <sup>-1</sup> )	error	altitude (m)	γ rays
Catacombe Albano Esterno	202	14	0.337	0.024	383	262453
Campi di Annibale	325	18	0.542	0.030	680	178822
Lago di Albano	261	16	0.435	0.027	293	322835
Pozzo delle Barozze	330	18	0.550	0.030	543	198666

$$\text{Counts Error} = \sqrt{n}$$

$$\text{Rate} = \frac{\text{events}}{s}$$

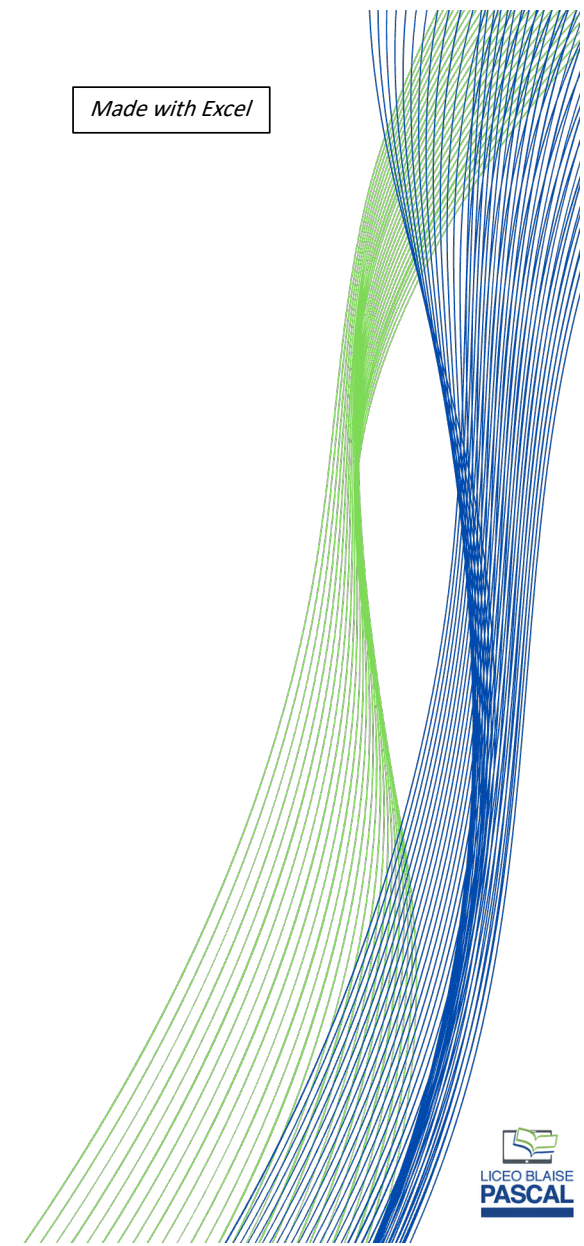


# Measurements Rate-Altitude



$y = 0.00044x + 0.25727$  → Percentage change = 0.044%/m

Made with Excel



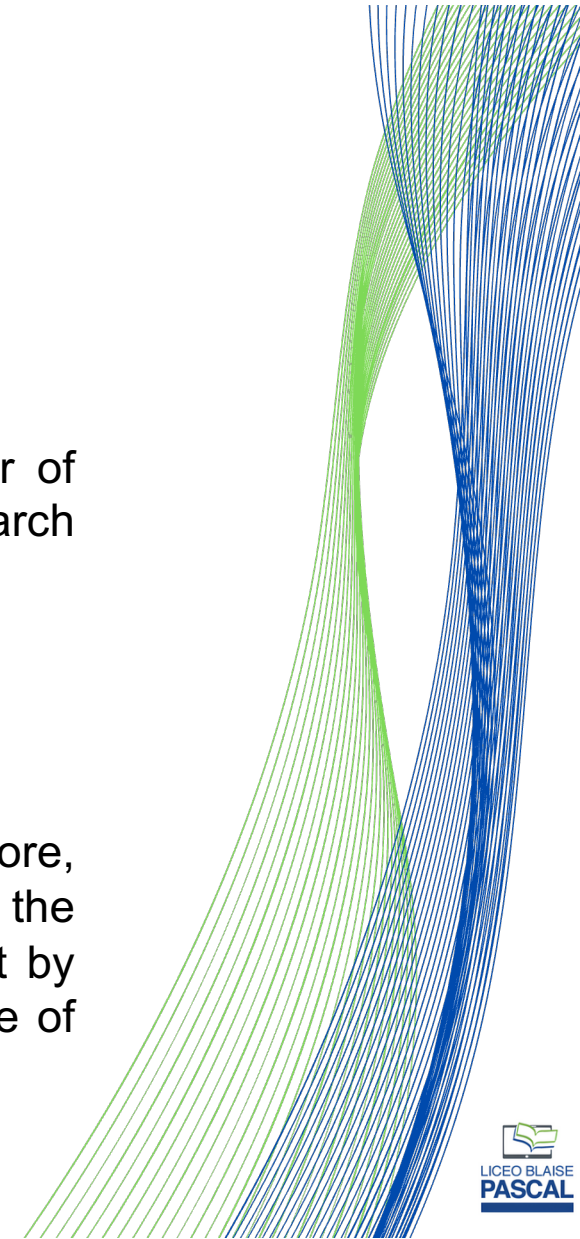
# DISCUSSION

An **increase** in flow is observed at **higher altitudes**.  
This behavior mirrors our theoretical expectation.

The obtained linear fit shows a **percentage increase** in the number of counts of **0.044%/m**. This data can be compared with other research published regarding this topic, that show percentage changes of:

- 0.025%/m [1]
- 0.037%/m [2]
- 0.018%/m [3]

Our result is greater than all those taken as an example and, therefore, probably inaccurate. Taking into account this result, we underline that the data we have collected is not numerous and, therefore, we think that by increasing the statistics our values could very well fall within the range of values measured by other experiments.



# MEASUREMENTS IN RELATION WITH $\gamma$ RAYS

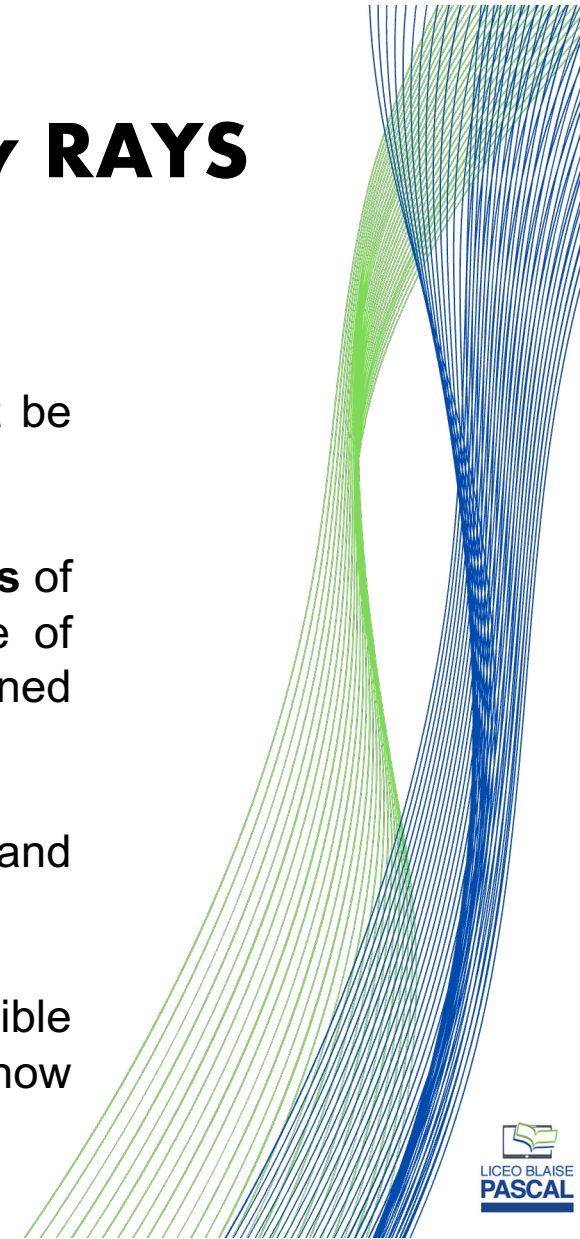
The measurements are the same as in the previous analysis.

The locations of the measurements, being at different altitudes, can't be used for a direct comparison with the concentration of gamma rays.

To overcome this problem we have carried out a **normalization process** of the data collected. In this way, despite still having a certain degree of uncertainty, we were able to compare at least broadly the data obtained with the concentrations of gamma rays.

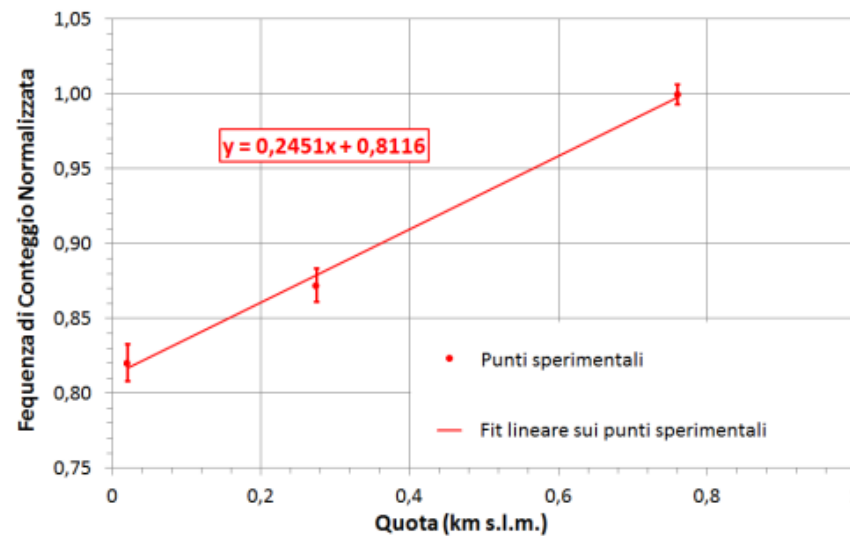
Each measurement was done with the CB perpendicular to the ground and the exposition time was of **10 min**.

Last year we had already carried out measurements in search of a possible correlation between muon flux and gamma rays. Those data did not show any type of correlation between the quantities analysed.

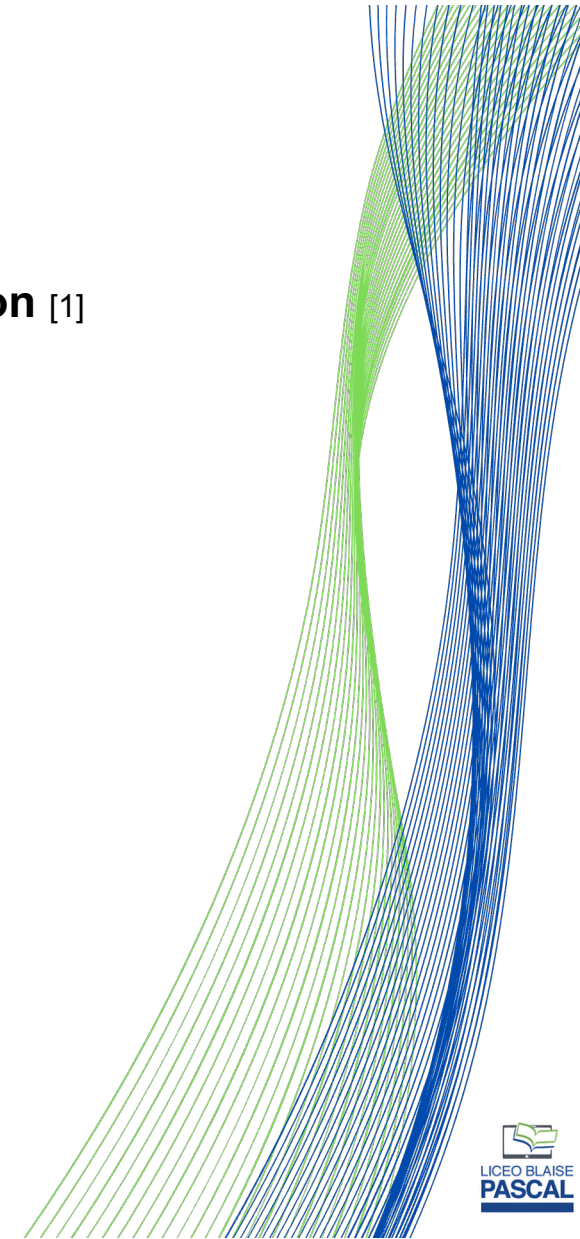


# PROCESS OF NORMALISATION

To normalize the data, the **analysis** carried out by the **EEE collaboration** [1] with a **percentage change of 0.025%/m** was taken as a reference.



The data were normalized to an **altitude of 0 m.a.s.l.**

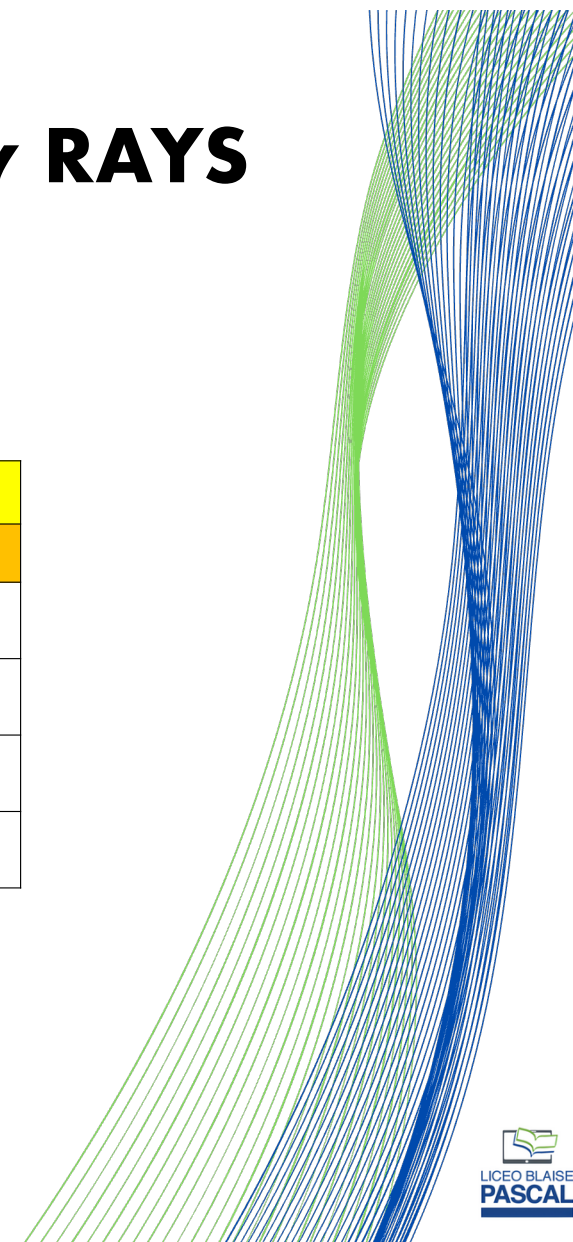




# MEASUREMENTS IN RELATION WITH $\gamma$ RAYS

Normalised Results					
	n°events	error	rate (s <sup>-1</sup> )	error	$\gamma$ rays
Catacombe Albano (outside)	183	17	0.304	0.028	262453
Campi di Annibale	270	20	0.450	0.034	178822
Lago di Albano	242	20	0.403	0.033	322835
Pozzo delle Barozze	285	21	0.475	0.036	198666

$$\text{Normalised Counts} = \text{Counts}(1 - h \cdot 0.025\%/m)$$



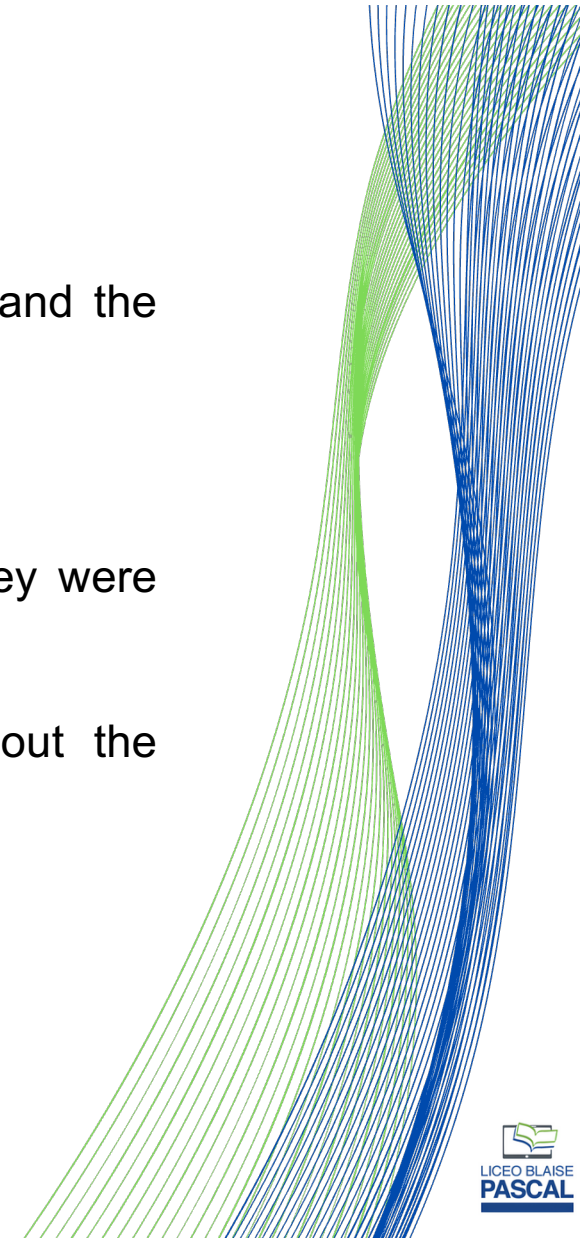
# DISCUSSION

There appears to be **no correlation** between the number of counts and the concentration of gamma rays.

These data confirm the analysis carried out last year.

However, these data are subject to a high level of uncertainty as they were obtained through a normalization process.

Despite that, they still contribute to increasing the information about the possible relationship between muon flux and gamma rays.



# CATACOMBE DI SAN SENATORE: HISTORY

The cemetery complex, **near the church of Santa Maria della Stella, opposite the tomb of the Orazi and Curiazi**, is one of the most important suburban catacombs in Rome.

The catacomb, **used for burial from the end of the 3rd to the 5th century**, was still considered a pilgrimage destination in the 7th century and **continued to be frequented until the 9th century**, as a sanctuary for the martyrs buried here.

**It was rediscovered in 1671. In 1989**, following a landslide in front of the access to the catacomb, **a new and systematic investigation was undertaken** by the Pontifical Commission for Sacred Archaeology.

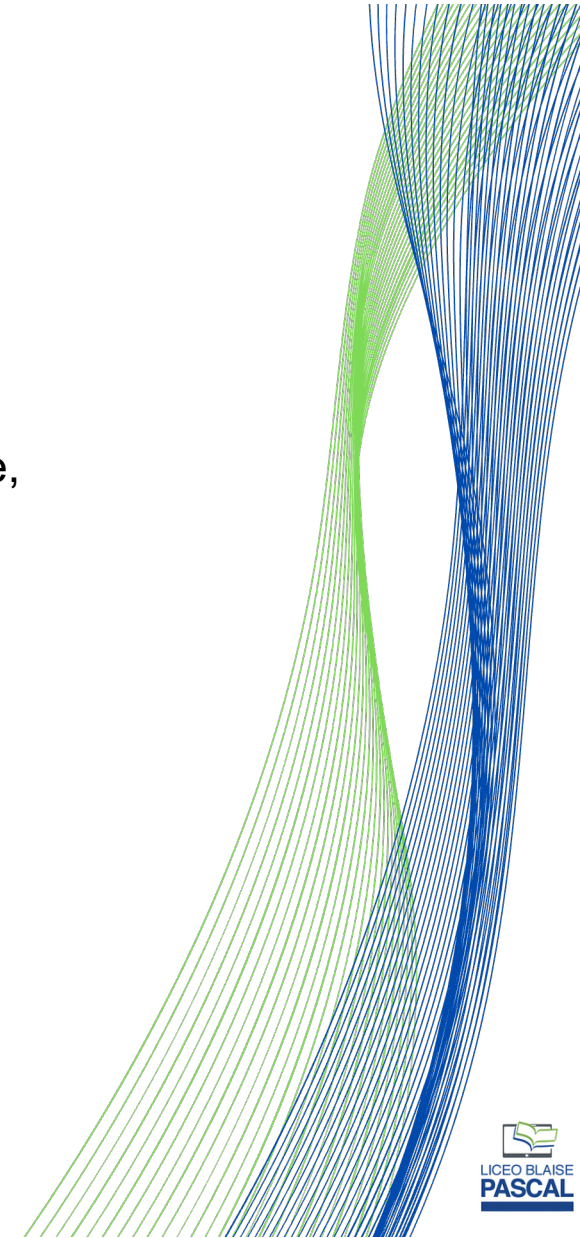
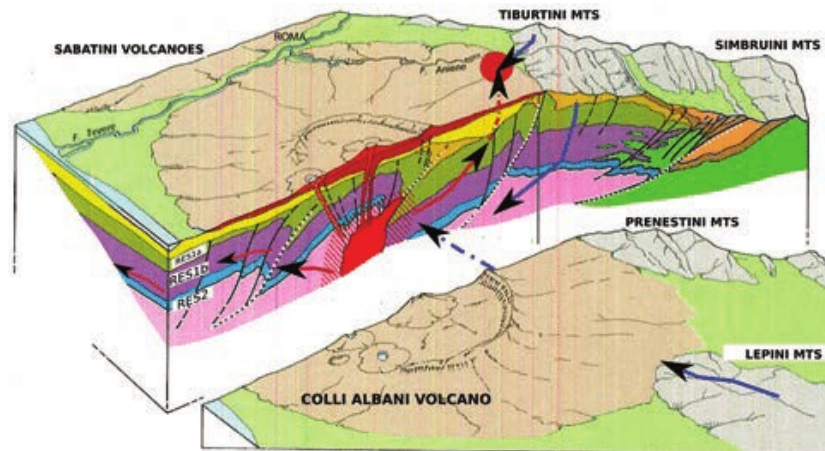


# CATACOMBE DI SAN SENATORE: GEOLOGY

The Catacombs of San Senatore are located in a **volcanic area**.

The soil covering them is mainly composed of:

- **pozzolana** (consisting of reactive silicon dioxide, aluminum oxide, and to a lesser extent iron oxide);
- **tuff**;
- **granite**;
- **lava**.



# CATACOMBE DI SAN SENATORE: MEASUREMENTS

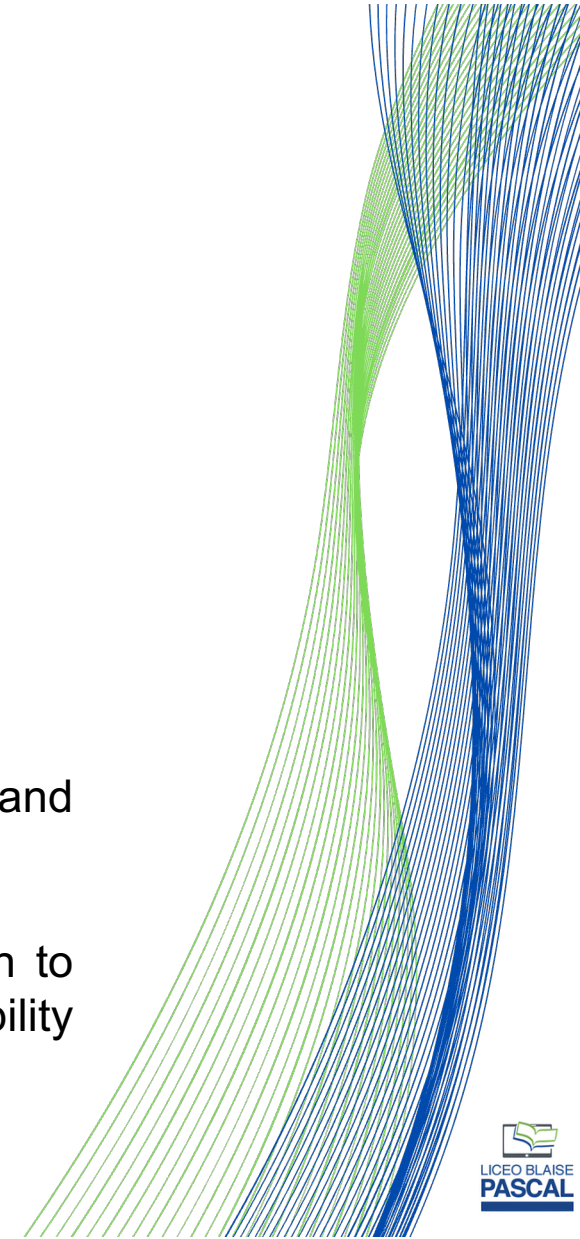
The measurements were taken into 5 different environments:

- outside the catacombs
- in the apse room (under an opening)
- in the apse room
- in a corridor
- in an inner room of the catacombs

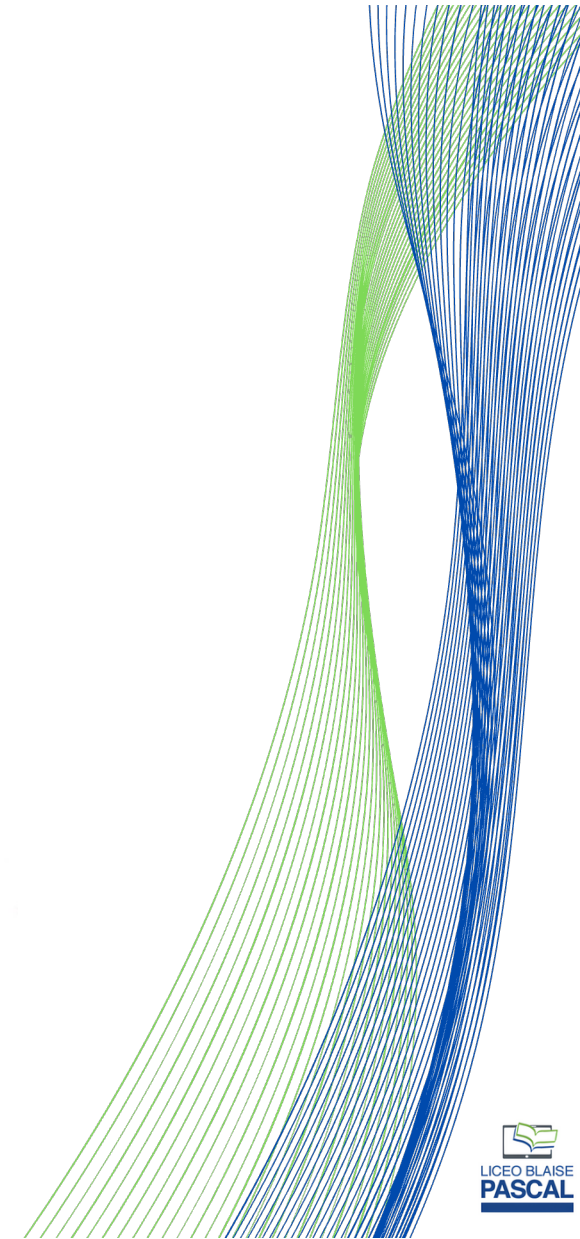
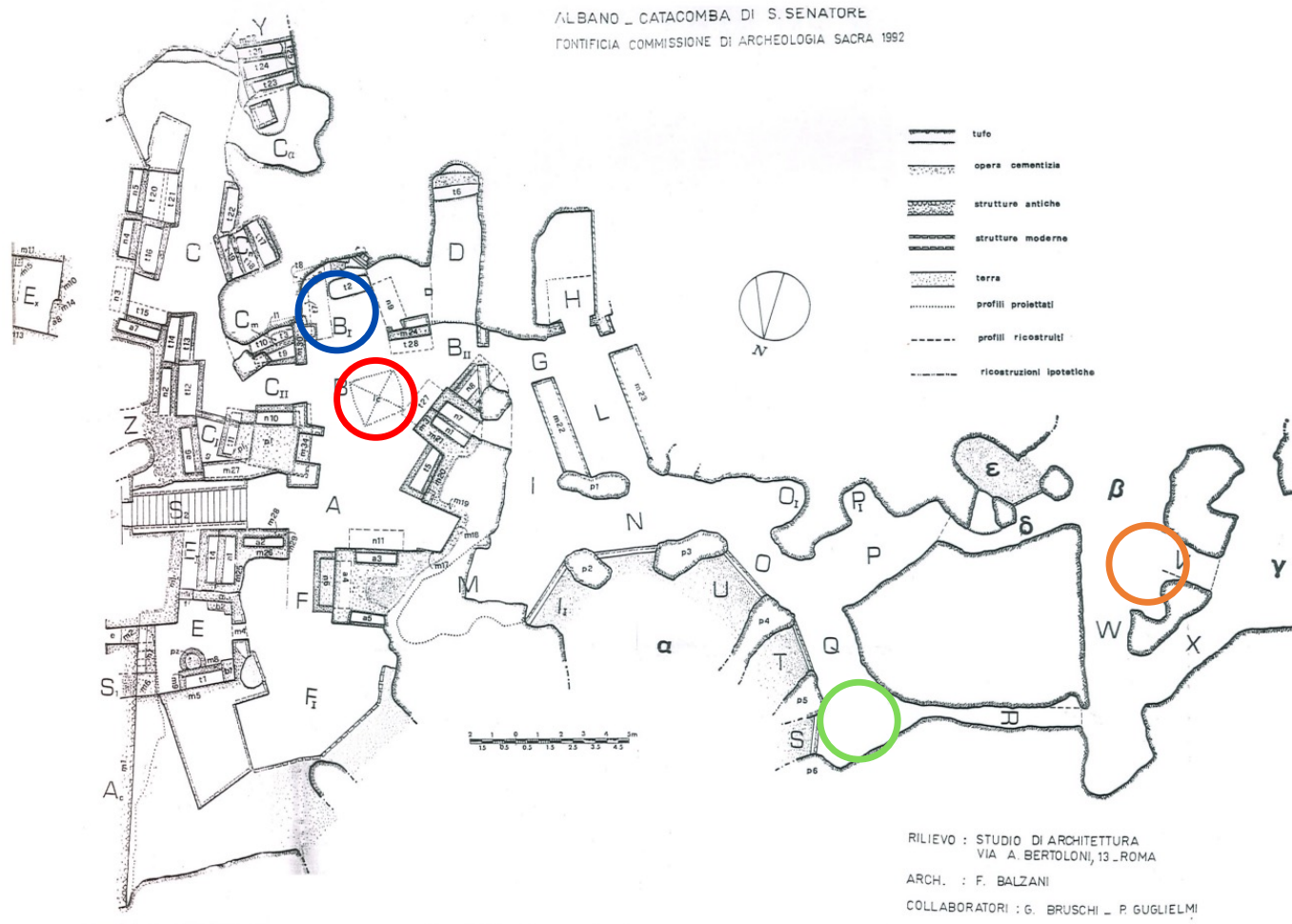
The measurements vary in the **depth range from 0m to -11m.**

Each measurement was done with the CB perpendicular to the ground and the exposition time was of **10 min.**

We expect lower values at greater depth because, with a longer path to travel and more matter to pass through, particles have a higher probability to decay before passing through our CB.



# CATACOMBE DI SAN SENATORE: MAP



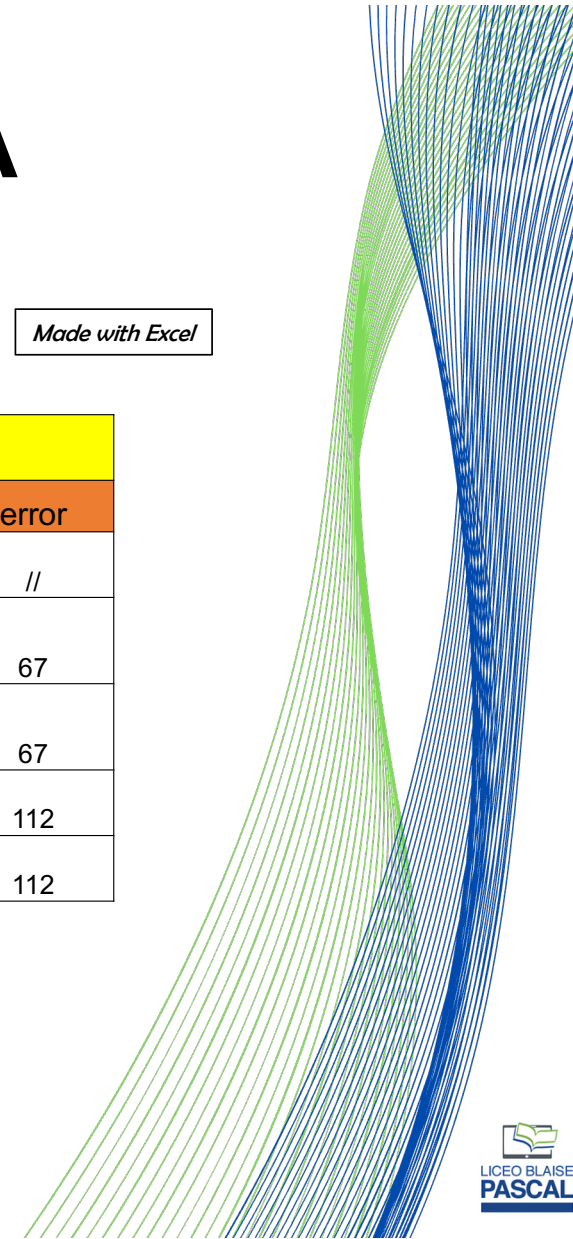
# CATACOMBE DI SAN SENATORE: DATA

Made with Excel

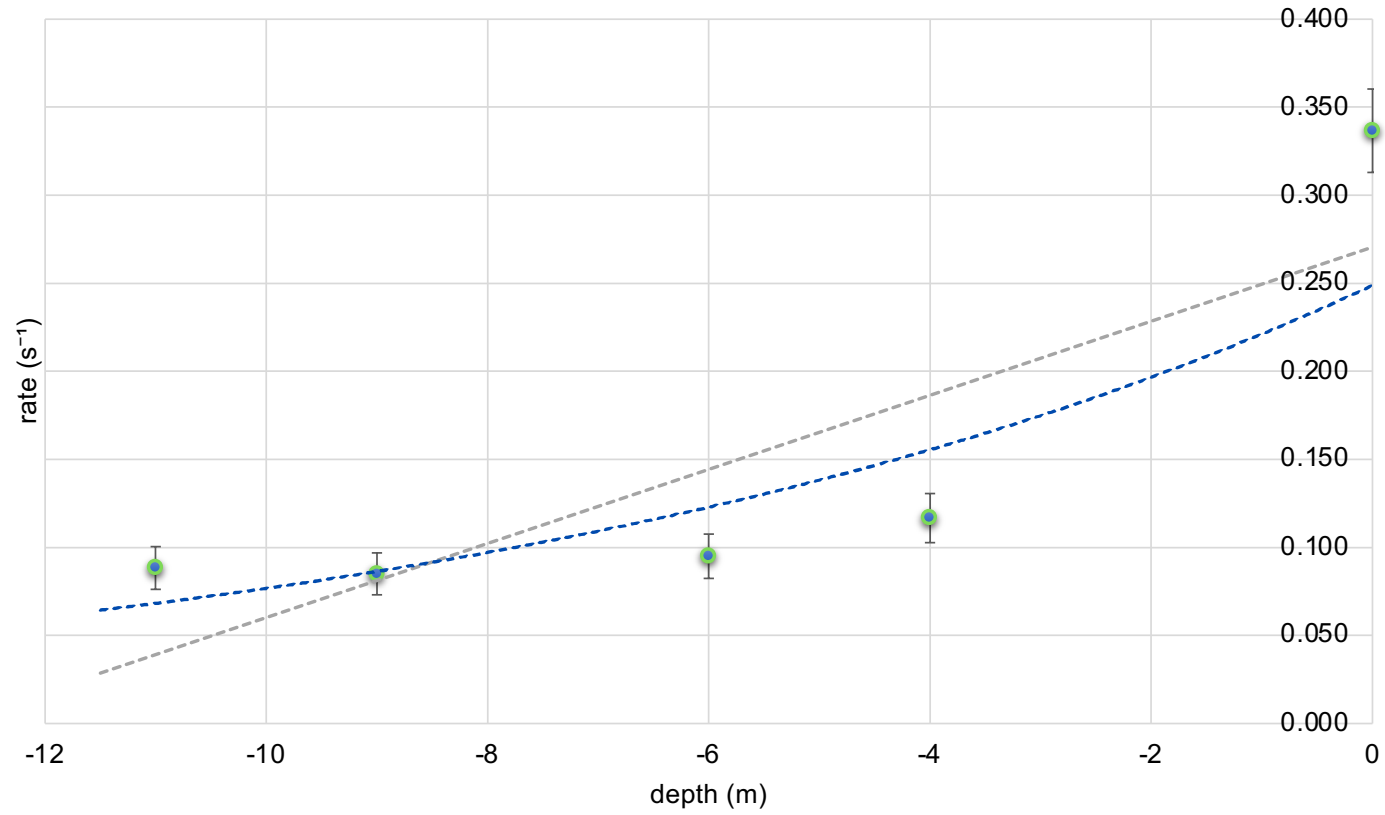
Measurements at the Catacombe of San Senatore								
	n°events	error	rate (s <sup>-1</sup> )	error	depth (m)	γ rays	Bq/m <sup>3</sup>	error
Outside	202	14	0.337	0.024	0	262453	//	//
Apse room (under an opening)	70	8	0.117	0.014	-4	498499	3025	67
Apse room	57	8	0.095	0.013	-6	498499	3025	67
Corridor	51	7	0.085	0.012	-9	//	3379	112
Inner room	53	7	0.088	0.012	-11	716033	3114	112

$$\text{Counts Error} = \sqrt{n}$$

$$\text{Rate} = \frac{\text{events}}{s}$$



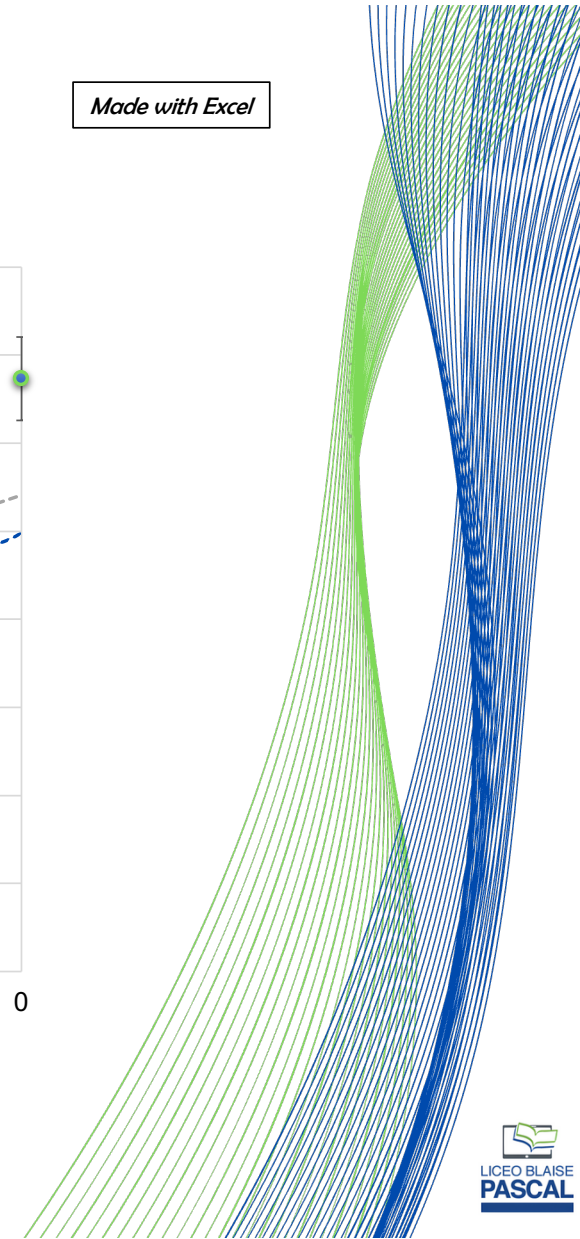
# Catacombe di San Senatore: Rate-Depth



Made with Excel

$$y = 0.021x + 0.2705$$

$$y = 0.2488e^{0.1176x}$$





# DISCUSSION

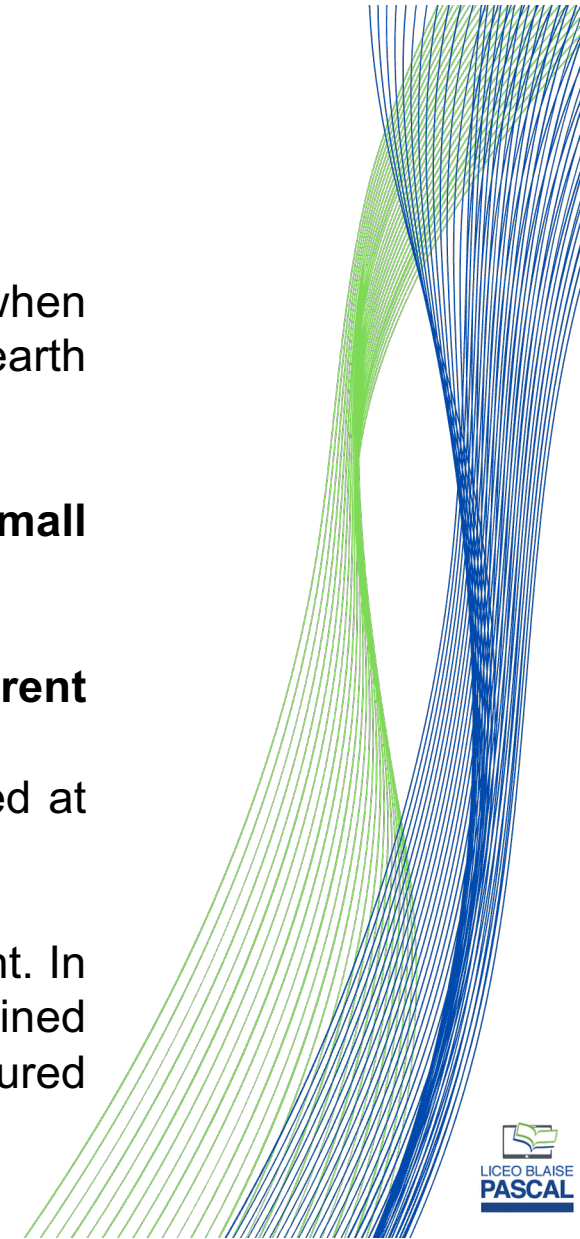
From the data collected we can observe a **decrease** in the readings when **underground**. This behavior is expected and due to the layer of earth which shields part of the cosmic rays.

Furthermore, from the data collected, there appear to be only **small variations in the interval (-6m;-11m)**.

We believe that this condition may be caused by the **different concentrations of radon** in the measurement locations.

Bringing up a meaningful example: the **minimum** reading was obtained at **-9m** in correspondence with the **maximum radon value (3379 Bq/m<sup>3</sup>)**.

However, the data collected is **insufficient** to prove our hypothesis right. In fact, the apparent inconsistencies with the theory can also be explained taking into consideration the **statistical fluctuations** to which the measured muon flux is subject.



# REFERENCES

[1] [https://www.iisfermi.edu.it/index.php?option=com\\_attachments&task=download&id=2034](https://www.iisfermi.edu.it/index.php?option=com_attachments&task=download&id=2034)

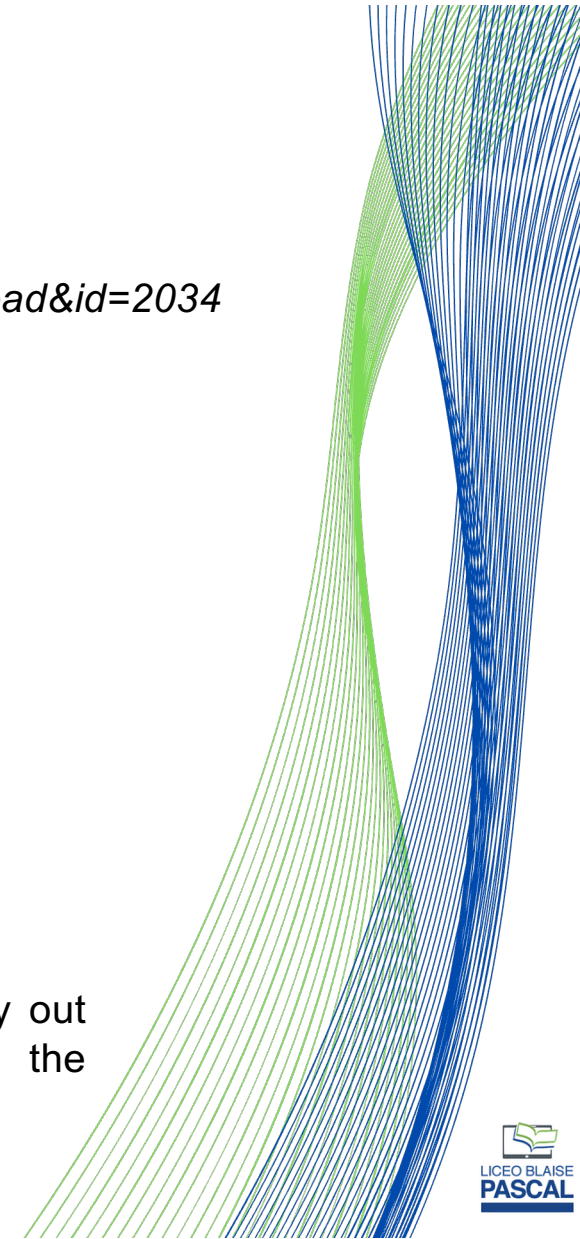
[2] <https://indico.cern.ch/event/596002/contributions/2463935/>

[3] F. Blanco, P. La Rocca and F. Riggi, Eur. J. Phys., 30 (2009) 685.

# ACKNOWLEDGMENTS

We would like to thank:

- the **EEE Collaboration** for giving us the opportunity to use the Cosmic Box;
- **our professors** for accompanying us during the measurements;
- the **director of the Catacombe di San Senatore** for allowing us to carry out measurements in this place and for providing us with data about the concentration of radon.



# END OF PRESENTATI ON

**Speakers:**

**Giuseppe Roberto 5C**

**Francesca Sabato 4L**

**Liceo Blaise Pascal, Pomezia (RM)**