INTENSE Meeting
Naples Secondment Update

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Promoter: Andrea Giammanco

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Naples Secondment

▶ **Institute :** TECNO IN, Naples, Italy
(Guilio Saracino's team at University of Naples Federico II)

▶ **Duration :** 8 days (Feb.02 – 09, 2020) and 22 days (Aug.28 – Sept.18, 2022)

Objectives

1. To get hands-on experience with the MURAVES instrumentation, hardware as well as the reconstruction software

2. To progress with the time of flight (ToF) analysis, working closely with the Naples group

MUon RAdiography of VESuvius (MURAVES)

MURAVES Detector

- Consists of **three** identical telescopes
- Each telescope is composed of four x-y layers of scintillators, with each individual plane containing 64 channels in total
- 4 available slots (3 in the forward-looking and 1 in the backward-looking mode)

- All three detectors (**NERO**, **ROSSO**, and **BLU**) already mounted at Mt. Vesuvius and are currently taking data
- Primary goals of the MURAVES experiment briefly summarized earlier by my promoter, Andrea Giammanco
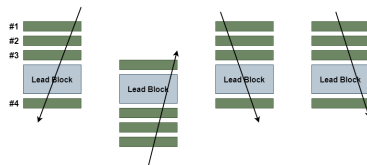
Schematic representation of four available slots
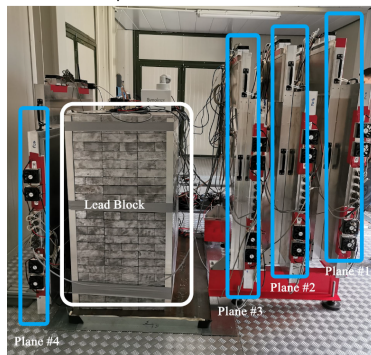
One of the MURAVES telescopes in forward-looking mode for Mt. Vesuvius data-taking.

Time of Flight (ToF) in absorption muography

▶ In high energy physics, ToF is typically used as a means to separate particles by mass

▶ For MURAVES, the detector is oriented quasi-horizontally so soft muons scattering off the ground behind the detector can enter from its rear

▶ These backward muons may even overwhelm the muons that carry information about the target and thus have to be rejected

▶ ToF of the detected muons between front and rear layer of the telescope can be used to reject these backward muon background
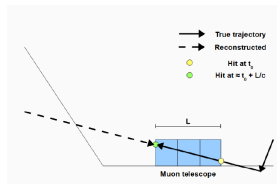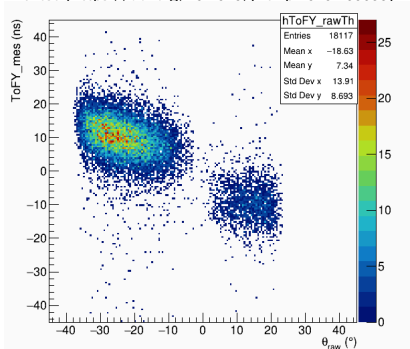

Figure illustrating backward muon – ToF to be used to reject these (https://doi.org/10.1016/j.revip.2020.100038)

ToF vs θ_{recons} – two represent forward and backward muons

Calibration of the electronics boards

Time Expansion Characterization of the boards for **Blu** telescope

- Each plane consists of two electronic boards (slave) handling 32 channels each
- Each layer consists of two planes (x and y views) so a total of 16 electronic boards
- Due to incorrect capacitance being used, the boards had to be refurbished and their time expansion (E) characterization had to be performed

$$t_{discharge} = E \cdot t_{charge} \qquad (1)$$

- A reference board with known time expansion characteristics and a master board were used to perform this study
- Stop trigger given by the master board
- Delays (correlated to the t_{charge}) were introduced from 2ns to 20ns and the subsequent $t_{discharge}$ were read out for each board

Slope = 7.305 ± 0.154

Slope = 7.264 ± 0.121

Discharge time (in TDC units)

Delay (ns)
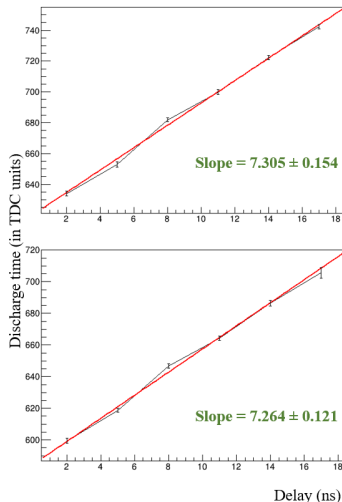
Time expansion characterization for boards 4 (top) and 13 (bottom) with the help of Luigi (Naples group).

Calibration of the electronics boards

| Board no.	E-factor (ns/TDC)	Intercept (ns)
0	7.21	558.1
1	6.87	532.5
2	6.73	494.7
3	7.11	549.9
4	7.26	620.2
5	6.99	565.3
6	7.35	651.3
7	7.33	594.3
8	7.99	620.5
9	7.30	578.8
10	6.95	564.1
11	7.37	655.0
12	7.18	571.6
13	7.30	584.5
14	7.05	566.5
15	7.45	659.1

Table: Summary of the calibration results for BLU boards

Detector Geometry
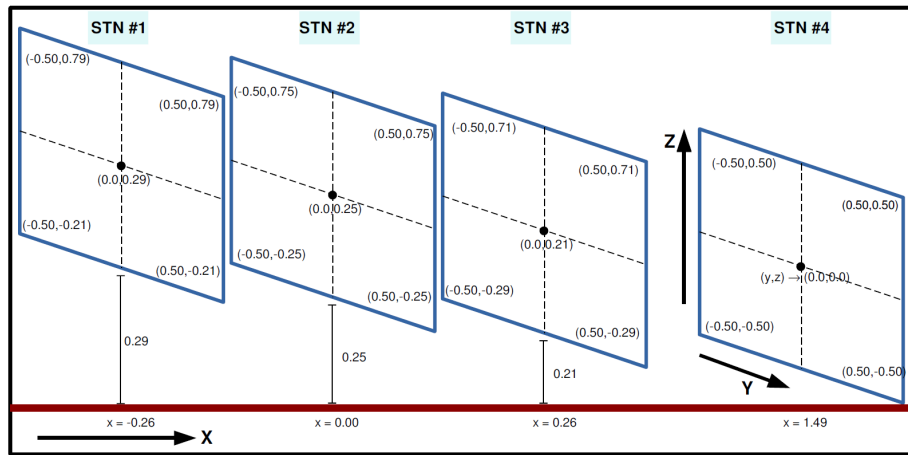
Figure: Based on detector geometry and the position of hits in Y and Z after track reconstruction, the expected time of flight (exp. ToF) can be calculated in an event-by-event basis

Expected Time of Flight
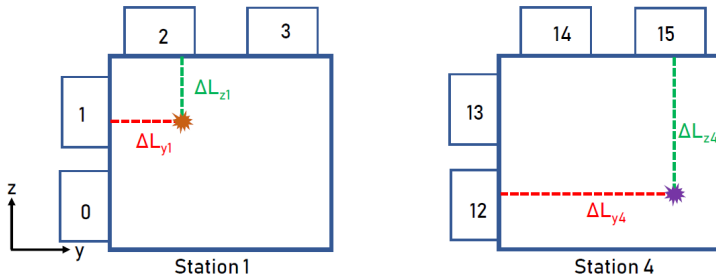

exp. ToF_1 (1X_3X)

expToF_XX_1	
Entries	174469
Mean	2.136
Std Dev	0.06393
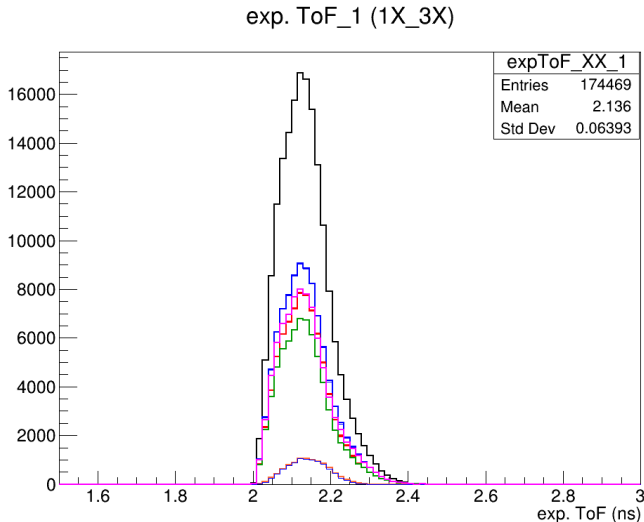
Figure: Expected ToF between stations 1 and 3 (colors represent various regions.) Average exp. ToF of 2.1 ns as expected.)

Measured Time of Flight
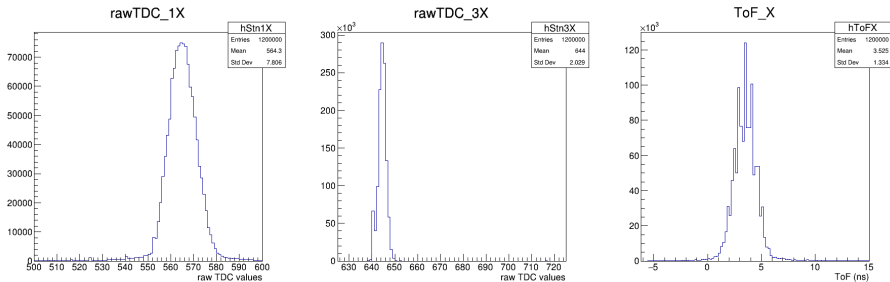
Fiber-delay addition:

For XX view :
$$ToF_X = \left(\frac{(T_{1X} - T_1^0)}{E_1} + \frac{\Delta L_{y1}}{\vartheta_{fiber}} \right) - \left(\frac{(T_{4X} - T_4^0)}{E_4} + \frac{\Delta L_{y4}}{\vartheta_{fiber}} \right)$$

For YY view :
$$ToF_Y = \left(\frac{(T_{1Y} - T_1^0)}{E_1} + \frac{\Delta L_{z1}}{\vartheta_{fiber}} \right) - \left(\frac{(T_{4Y} - T_4^0)}{E_4} + \frac{\Delta L_{z4}}{\vartheta_{fiber}} \right)$$

- Adjust the equations above accordingly for XY and YX views ToF (w/ delay) calculation.

Measured Time of Flight

- ▶ Test performed in the lab in Naples, using a fixed delay of 3.5 ns between stations 1 and 3

- ▶ raw TDC distribution in station 1 and 3 are shown

- ▶ Using equation in the previous slides, we were able to reproduce the correct measured time of flight distribution. This proves that ToF-based results can be performed with MURAVES data to reject soft-muon background.

Divide and Conquer

Example:

Station 1   Station 4
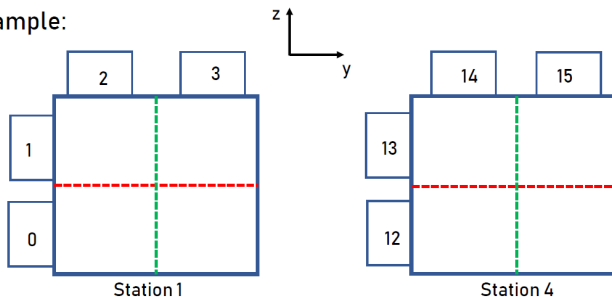
XX – boards	YY – boards	XY – boards	YX – boards
✓ 0-12	✓ 2-14	✓ 0-14	✓ 2-12
✓ 0-13	✓ 2-15	✓ 0-15	✓ 2-13
✓ 1-12	✓ 3-14	✓ 1-14	✓ 3-12
✓ 1-13	✓ 3-15	✓ 1-15	✓ 3-13

▶ Time of flight analysis dividing the detector active area into various regions to isolated two boards is currently underway

▶ The older calibration of NERO and ROSSO boards is incomplete so we plan to use the results from BLU to get all the missing calibration parameters for NERO and ROSSO boards

Summary

- ▶ Secondment with TECNO IN, Naples in collaboration with MURAVES team at University of Naples Federico II in 2020 and 2022
- ▶ First hand experience with MURAVES detectors setup and helped with the calibration of the electronic boards in BLU detector
- ▶ On the analysis side, a more general time of flight analysis for scint. based detectors is being developed
  - ▶ This work has been continued from Louvain-La-Neuve, Belgium, after the secondments
  - ▶ If we are able to obtain good results, ToF can also be used for "golden" muon track selection and for improving the current analysis framework
  - ▶ The analysis can also be adapted to other TECNO IN detectors
- ▶ More secondments expected in 2023!!