EDUCATIONAL OUTREACH ACTIVITIES ON COSMIC RAYS: INVESTIGATE THE CORRELATION BETWEEN MUON COUNTS AND ATMOSPHERIC PARAMETERS

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TAUP, 30/08/2023

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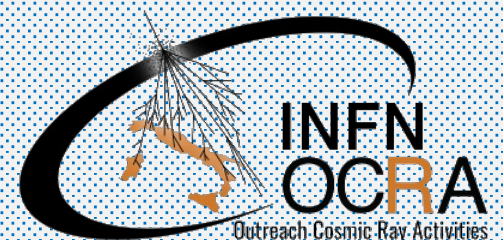
OCRA

- **Outreach Cosmic Ray Activities (OCRA)** is a national outreach project born in 2018 of the Istituto Nazionale di Fisica Nucleare (INFN)

- Build a national framework for the INFN public engagement activities in the field of cosmic ray physics (24 INFN divisions and laboratories all over Italy involved)

- **Activities**:
  - Core activity: **International Cosmic Day (ICD)** worldwide yearly outreach event organized by DESY (https://icd.desy.de/) for high-school students (presentation of the cosmic-ray physics background and local activities; hands-on measurements on cosmic ray flux)

  - Local or national activities (OCRA summer camp, local workshop and tutorships, online laboratories, European Researchers' Night, **Pathways for Transversal Competences and Orientation (PCTO)** activities for high school students)

ICD and PCTO activities in Padova

- During **ICD** group of scientists, teachers, and students meet for one day to learn about cosmic rays and perform an experiment with atmospheric muons (the zenith angle distribution of atmospheric muons)

- Activities are performed using the data collected by a **muon telescope** hosted in the Laboratori Nazionali di Legnaro (LNL)

- The department of Physics and Astronomy at the University of Padova offers a **PCTO project** for students from high-school in collaboration with INFN Padova focused on cosmic rays analysis
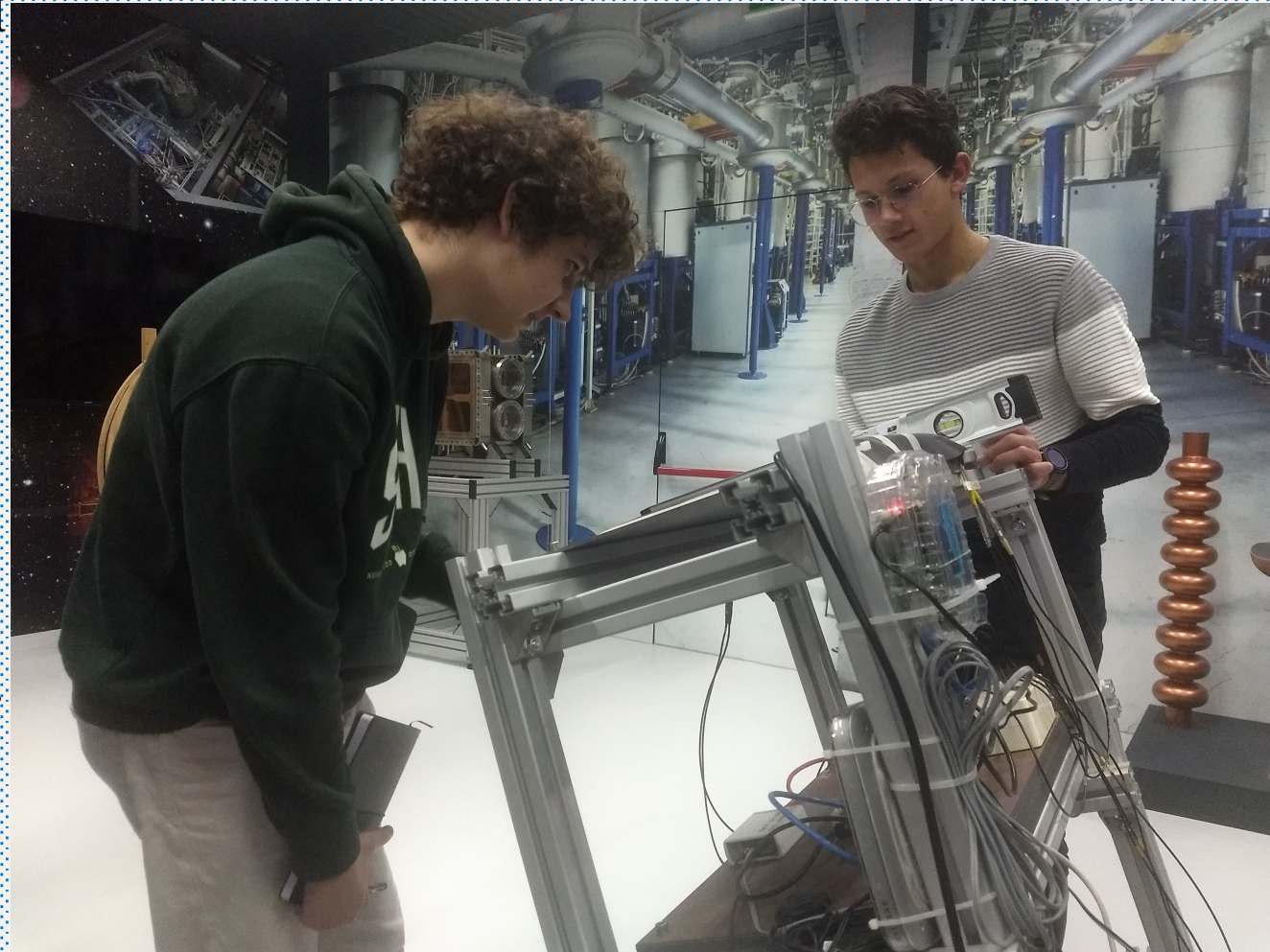

Courtesy of S.Hemmer

Hadronic cascade and muons

Credit: CERN
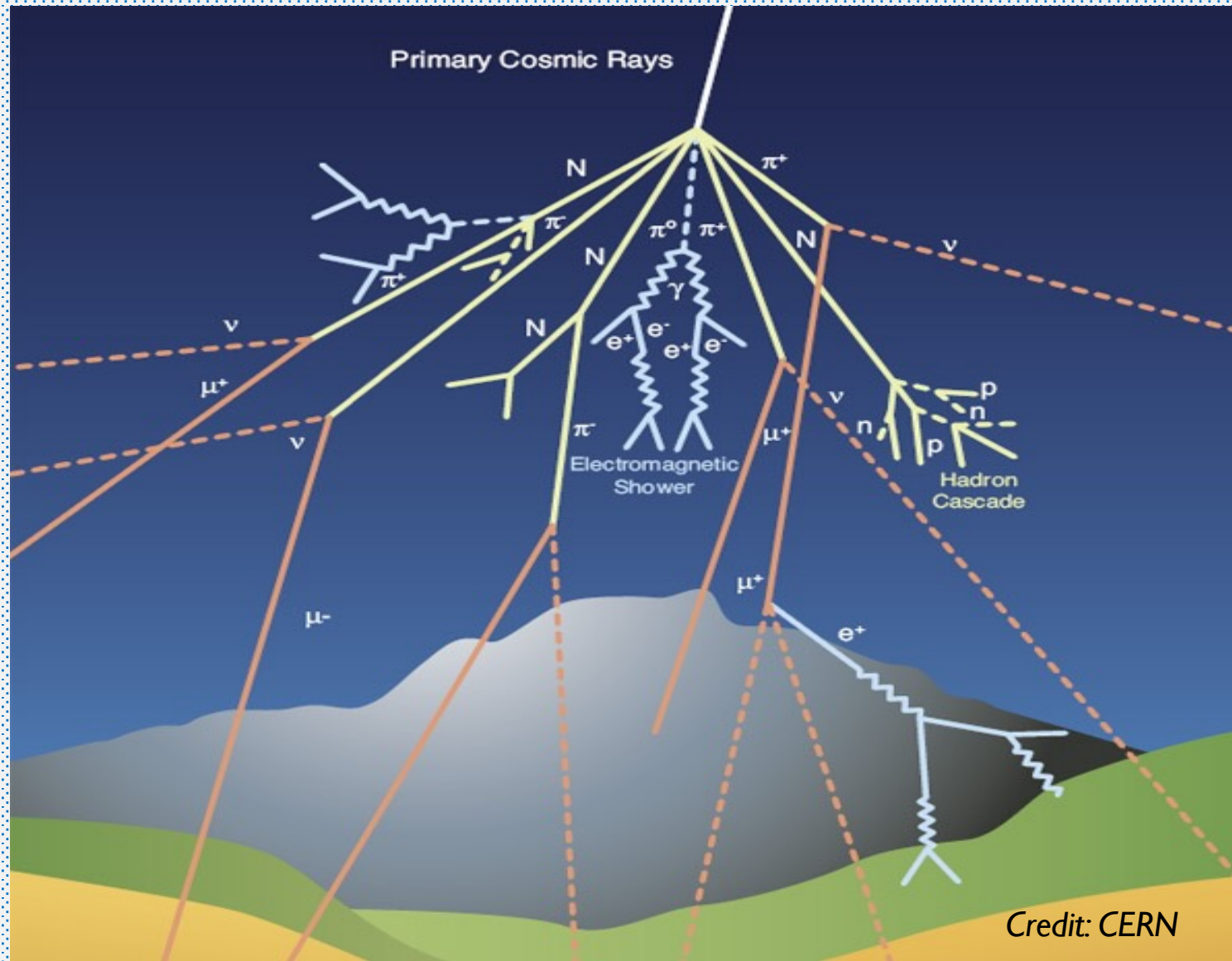
Muon counts and atmospheric parameters

- Muon flux at the Earth surface is influenced by atmospherical properties:
  - Pressure dependence (1920s): absorption, decay and generation effect
  - Temperature dependence (1930s): decay of muons and pions
  - Other effects involved (Humidity, Gravitational effects, see Dorman, 2004)
  - Only a few contributions on the topic (Catanach, 2011; Savic, 2016; Maghrabi, 2017; Gorzkiewicz, 2021)
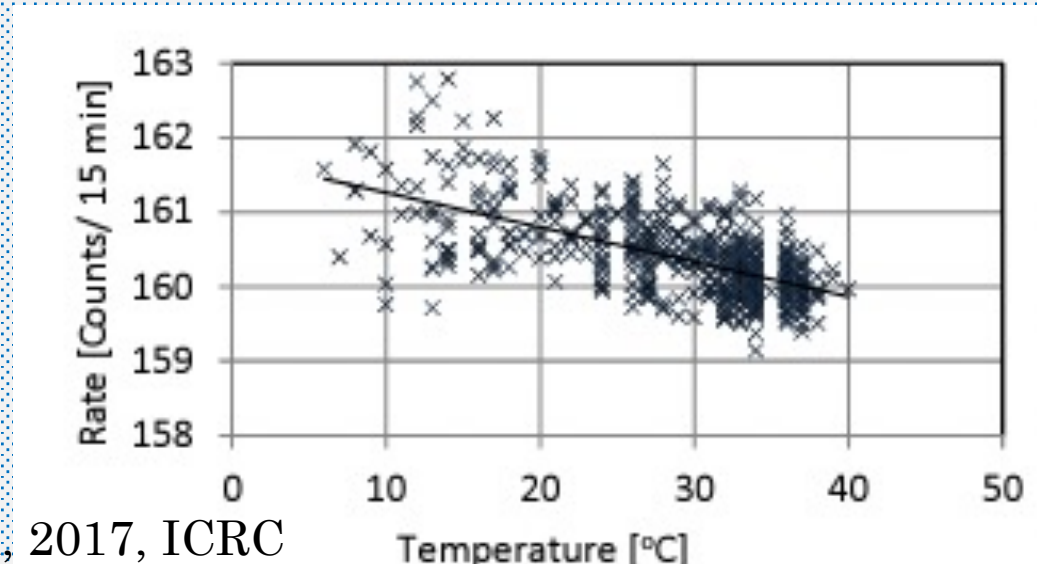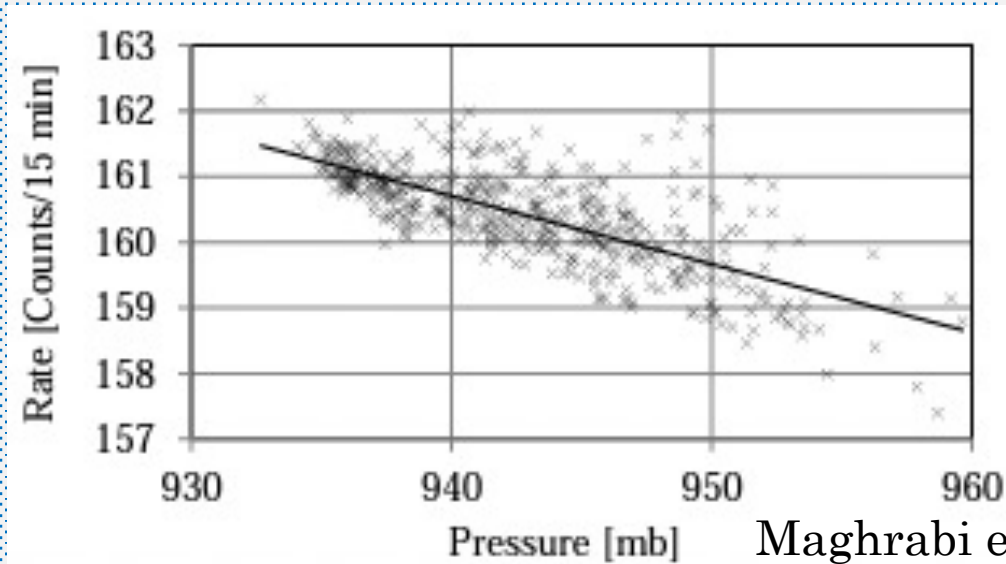
Maghrabi et al, 2017, ICRC

Activities performed by students

Goal: Investigate relationship between mount counts and atmospheric parameters using the data from the LNL muon telescope

- Three high-school students have been involved in the PCTO activities: **V. Di Toro, C. Degasperi, E. Premrù**

- Activities have been supervised by M.Doro, D.Miceli and E.Prandini

- Final report written together with the students on the activities performed

Courtesy of S.Hemmer

Activities performed by students

PCTO activities:

- Learning basics of:
  - code-programming (Python)
  - data analysis
  - graphical outputting of a research
  - science report writing

- The approach was '*problem-solving*' with development of the code done by the students in collaboration with us

Courtesy of S.Hemmer

The '*homemade*' muon telescope in LNL

- Two plastic scintillators slabs 2 with silicon photomultipliers (SiPM) at a distance of 1 m each other and a Pb shield between the scintillators to filter lower energy particles

- A counter of coincidences linked to the scintillators with a counter circuit mounted on a programmable custom board

- Recorder programmed to reset every minute, and transmit the data through a USB serial link

- Data collected online: http://www2.lnl.infn.it/~canella/COSMIC/WWW2/DatiGiornalieri/2022-11-15.dat

- **Setup for datataking**: telescope in fixed position with slabs inclined of 45° (Jan-Feb 2022) or in horizontal position (Jul 2022- Apr 2023)
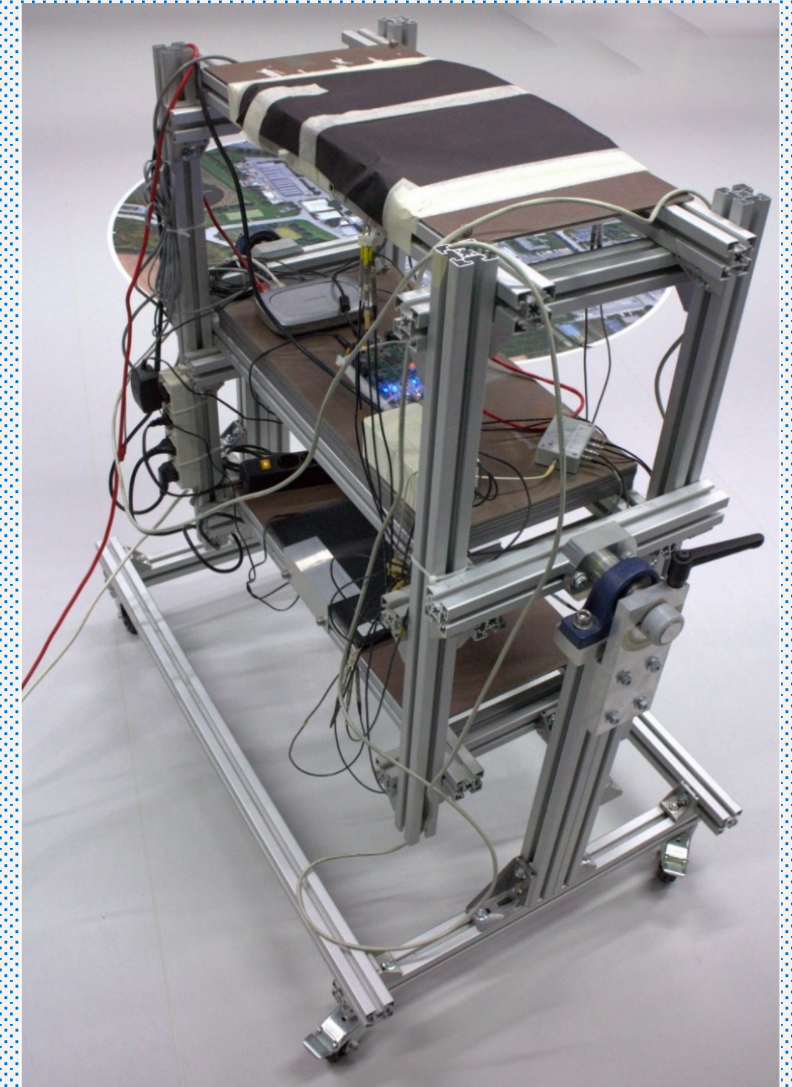
Data collected by the muon telescope

Time	Daily Counter	Single SiPM counts				Coincidences	P	T
00:00:29	0	176601	110260	237073	149663	86	1020	18.3
00:01:34	1	176618	109740	236730	149983	89	1020	18.2
00:02:34	2	176806	110035	237307	149778	82	1020	18.3
00:03:34	3	176685	109742	237873	148893	70	1020	18.3
00:04:34	4	176807	110205	238307	149252	93	1020	18.3
00:05:34	5	177220	109665	238170	149813	84	1020	18.3
00:06:34	6	177687	110058	236919	149451	82	1020	18.3
00:07:34	7	178002	109881	237586	150010	84	1020	18.3
00:08:34	8	176569	110308	238367	148927	92	1020	18.3
00:09:34	9	176722	110308	236754	149024	89	1020	18.3
00:10:34	10	177082	109828	237009	149676	97	1020	18.2
00:11:34	11	176460	111140	237700	149858	94	1020	18.2
00:12:34	12	176695	110950	237459	149102	73	1020	18.3
00:13:34	13	177204	110857	238012	149281	89	1020	18.2
00:14:34	14	176076	110209	236727	149087	71	1020	18.3
00:15:34	15	177183	111121	237425	149045	79	1020	18.2
00:16:34	16	176868	110119	237322	149086	62	1020	18.2
00:17:34	17	176720	110487	236895	148537	92	1020	18.2
00:18:34	18	176693	110596	236749	149181	67	1020	18.2
00:19:34	19	175998	109962	236484	148507	93	1020	18.2
00:20:34	20	175913	110802	238166	148384	88	1020	18.2
00:21:34	21	177010	111153	236683	148629	81	1020	18.2
00:22:34	22	176535	111095	236907	149366	84	1020	18.3

Scripts for data analysis on the Gitlab repo of the project


```
muon_counts_pressure_plot.ipynb          265.26 KiB

In [1]:    # List of imports
           import matplotlib.pyplot as plt
           import numpy as np
           import urllib # Serve per leggere il fil
           from datetime import datetime # Serve pe
           from astropy.time import Time
           import pandas as pd
           from matplotlib.ticker import MaxNLocato

           # A basic design setting
           plt.rcParams["figure.figsize"] = (10,10)

In [73]:   base_url = "http://www2.lnl.infn.it/~canella/COSMIC/WWW2/DatiGiorn
           start_date = datetime.date(2022, 7, 15)
           end_date = datetime.date(2023, 5, 31)
           delta = datetime.timedelta(days=1)
           excluded_start_date = datetime.date(2022, 11, 16)
           excluded_end_date = datetime.date(2022, 11, 27)
           excluded_start_date2 = datetime.date(2023, 3, 11)
           excluded_end_date2 = datetime.date(2023, 3, 12)
           days = []
```

μ **muon_barometer** 🔒
Project ID: 32896866 · Leave project

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-○- 61 Commits   ⅄ 1 Branch   ⊘ 0 Tags   ⊟ 22.8 MiB Project Storage

updated
Michele Doro authored 1 month ago   5d3815ac

main ∨   muon_barometer /   + ∨   History   Find file   Edit ∨   ⬇ ∨   Clone ∨

📄 README   ⊞ Add LICENSE   ⊞ Add CHANGELOG   ⊞ Add CONTRIBUTING   ⊞ Add Kubernetes cluster   ⊞ Set up CI/CD   ⊞ Add Wiki

⚙ Configure Integrations

🗖 **Look for temperature data (and humidity) close to Legnaro**
#12 · created 5 months ago by Michele Doro

🗖 **Temporal distribution of counts at fixed pressure**
#11 · created 5 months ago by Michele Doro

🗖 **Daily counts plot at fixed pressure**
#10 · created 5 months ago by Michele Doro   📅 Mar 10, 2023

🗖 **Monthly pressure-counts plots**
#9 · created 5 months ago by Michele Doro   📅 Mar 9, 2023

🗖 **File format has changed**
#8 · created 6 months ago by Michele Doro   📅 Feb 24, 2023

Results: anticorrelation between muon counts and atmospheric pressure

- Data recorded between 2022-01-28 and 2022-02-08

- Significant anticorrelation between average muon counts and pressure values (Pearson index = -0.885)

28/01-08/02 - Correlation:-0.885
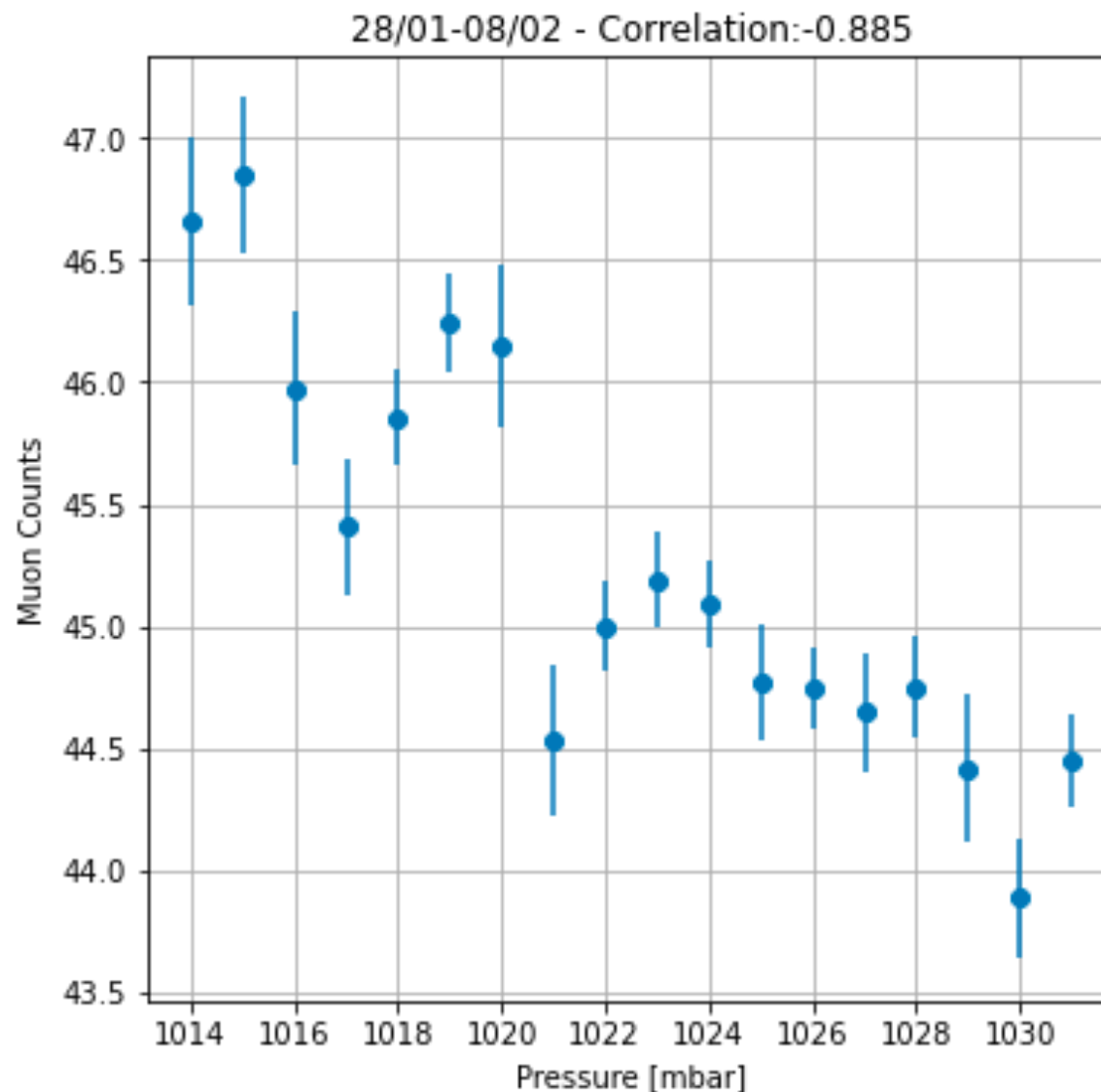
Results: anticorrelation between muon counts and atmospheric pressure

Results have been published in the LNL annual report 2021
(https://www1.lnl.infn.it/~annrep/read_ar/2021/index.htm)

First Results on the Anticorrelation Between Muon Counts and Atmospheric Pressure at the International Cosmic Day Muon Telescope at the LNL

V. Di Toro[1], D. Miceli[2,4], S. Canella[3], A. Dainelli[3], F, Dal Corso[4], M. Doro[2,4], A. Ruzzon[3], C. Arcaro[4], S. Hemmer[4], R. Lopez Coto[4], E. Prandini[2,4], R. Rando[2,4,5], I. Viale[2,3]
for the OCRA collaboration

[1] Liceo Classico Tito Livio, Riviera Tito Livio, (Padova), Italy . [2] Dipartimento di Fisica e Astronomia, Università di Padova, Padova, Italy. [3] INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy . [4] INFN, Sezione di Padova, Padova, Italy. [5] Centro di Ateneo di Studi e Attività Spaziali, Università di Padova, Padova, Italy.

ABSTRACT

The LNL hosts a muon telescope (Figure 1) mostly used for outreach purposes and especially for the International Cosmic Day (ICD), an event organized by DESY which sees several institutes around the world perform in parallel cosmic ray measurements together with high-school students.

It is well known that local atmospheric parameters affect the muon rate. In this contribution, we investigate the anticorrelation between muon counts and atmospheric pressure as measured with the muon telescopes in Jan-Feb 2022. A significant anticorrelation is found. Further analyses with a larger datasample will allow us to improve the

between the two variables: as the detector is tilted toward the horizontal position, the amount of muon coincidences diminishes following a $\cos^2$ law reaching a minimum when the scintillator plates are vertical. Following the ICD experience, it was decided to offer the participants the possibility of taking part to other projects that revolve the theme of cosmic rays analysis by creating booklets that describe the personal take of each participant on the event and this project involved one of them as a PCTO (soft skill training for high school students that offers the chance to broaden the students' knowledge and view on a specific profession).

Results: anticorrelation between muon counts and atmospheric pressure

- Enlarged dataset: from 2022-07 to 2023-04

- Anticorrelation is still present (Pearson index = -0.916)

- Effects of other variables (temperature, humidity) may affect the result?

Muon counts vs Pressure - Correlation:-0.916+/-0.070
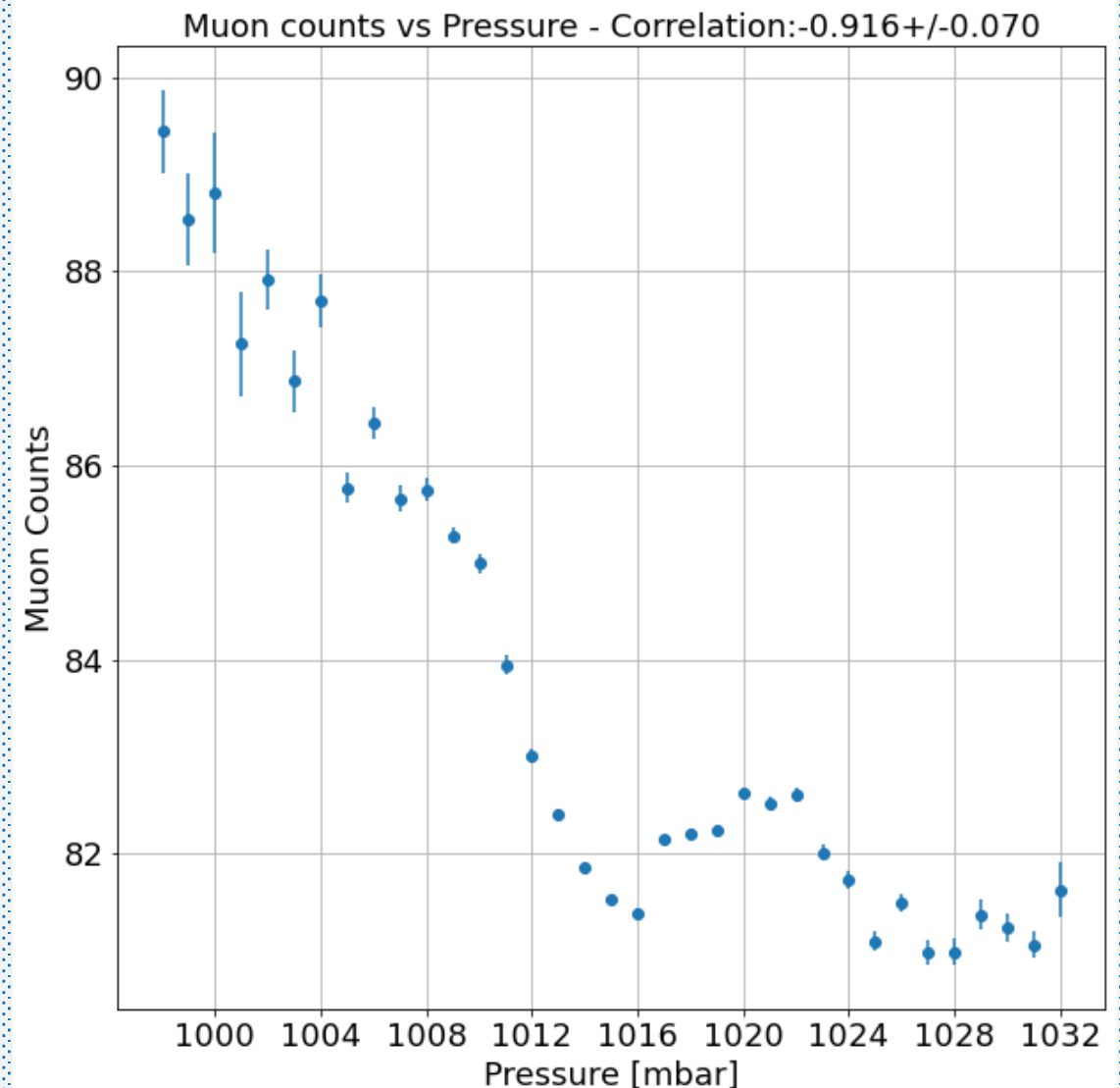
Results: monthly average muon counts over atmospheric pressure

- Average muon count at different pressure for each month from July 2022 up to April 2023

- Anticorrelation is stable over different months

- Pressure variation is different from month to month

- Muon count is affected by winter-summer conditions
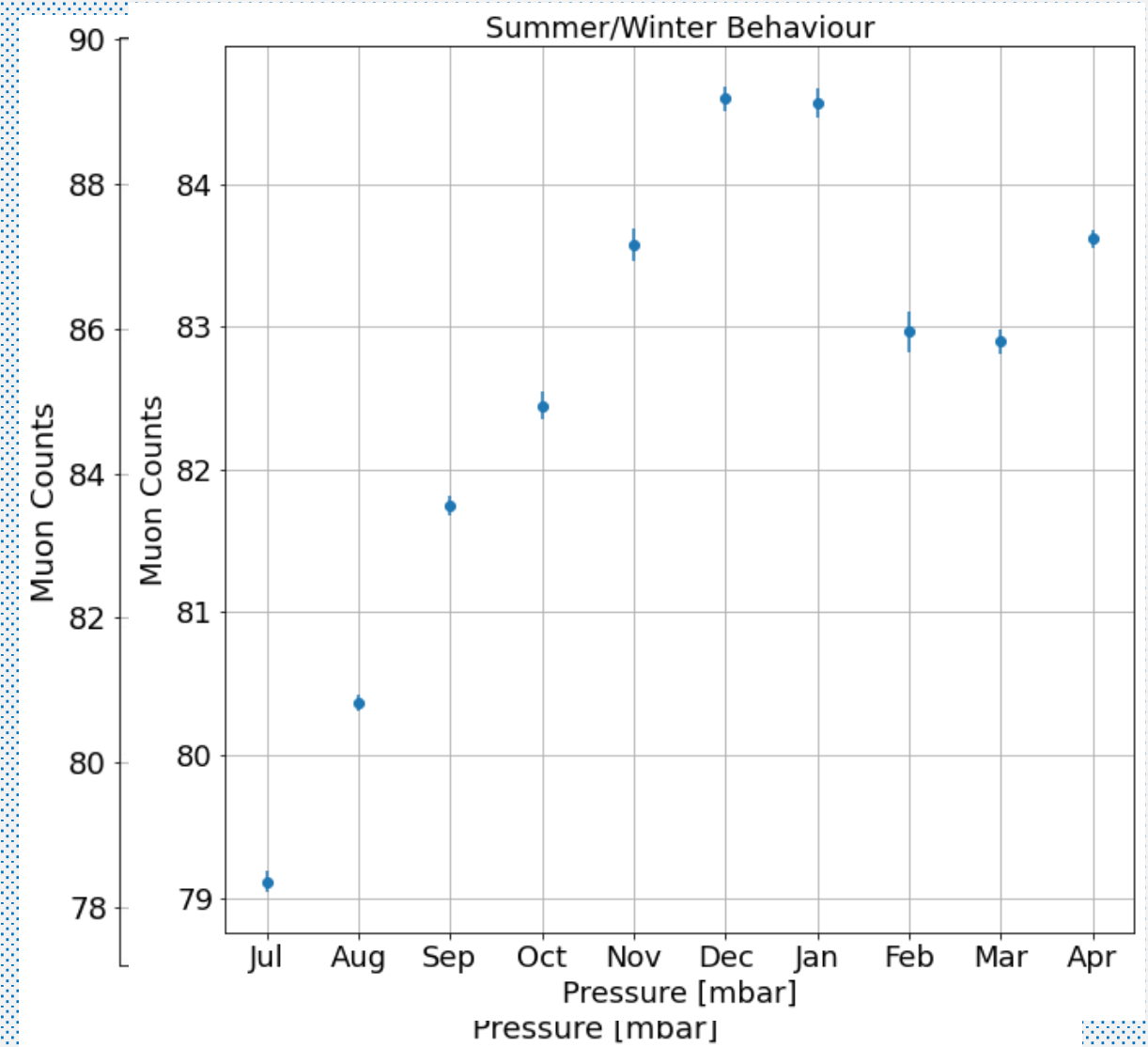
Results: Relation between INFN pressure data and ARPAV public data

$$P_{INFN}(true) = 350 + 0.657\, P_{INFN}$$
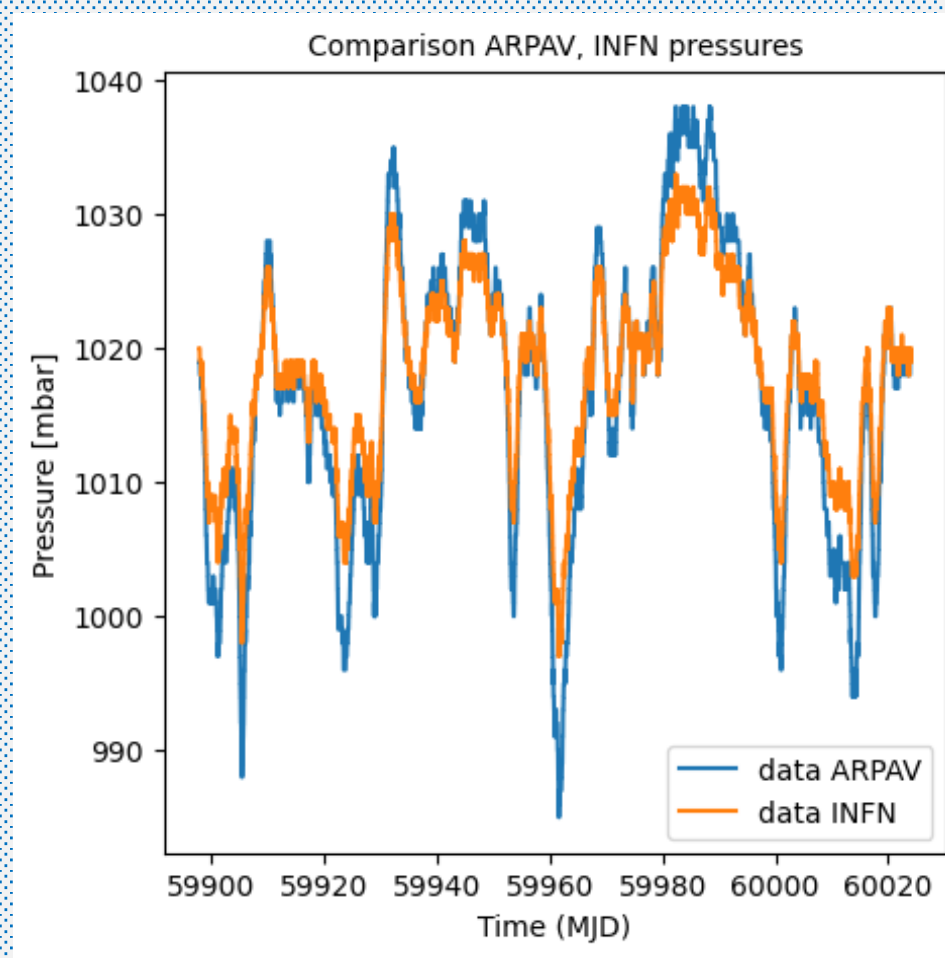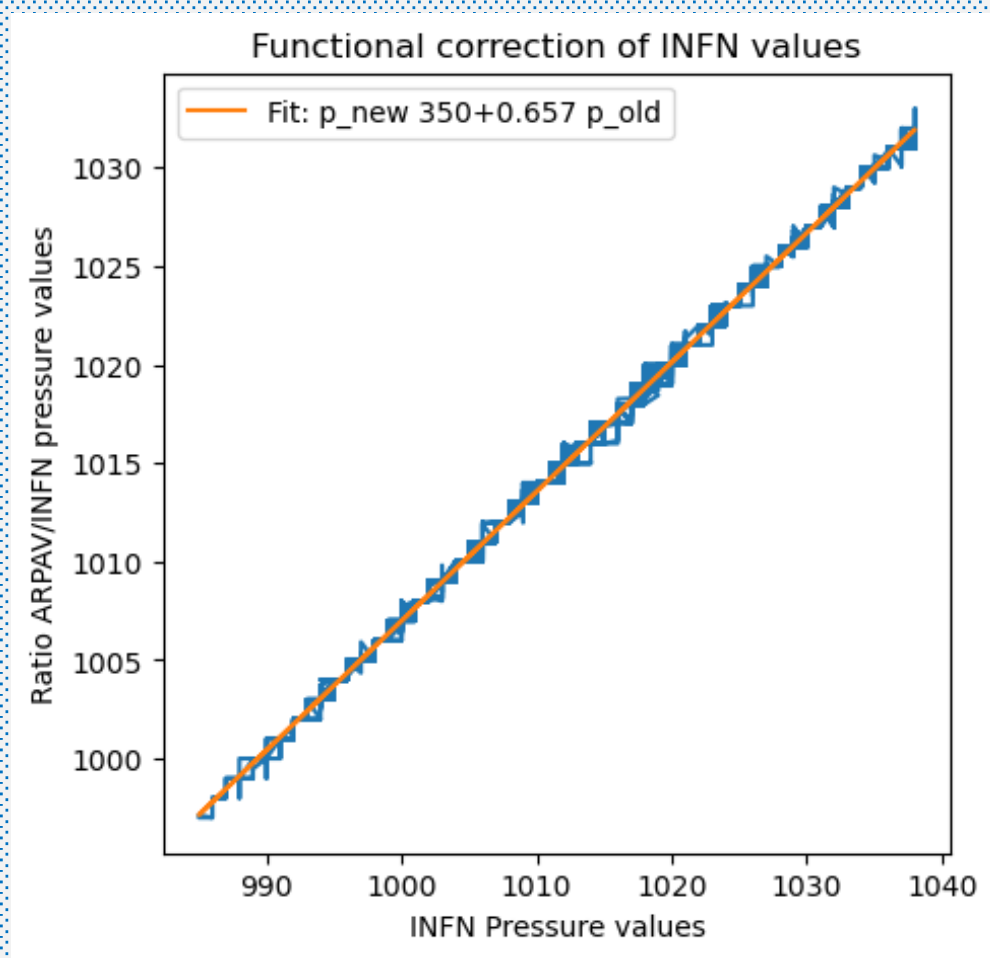
Conclusions

- OCRA and educational outreach activities are growing every year; Students reports indicate high level of satisfaction of the activities proposed

- Students were able to work in close contact with INFN and University researchers; learn the activities involved in the life of a researcher; participate to a project including data analysis and interpretation of scientific results

Conclusions

- Valuable scientific result: **strong anticorrelation between muon counts and pressure found and published!**

- Effects of other atmospheric variables (temperature, humidity) or the East-West effect can be investigated

- A new muon telescope (Cosmic Hunter developed by CAEN group) have been bought and will be used for ICD 2023 and possible future PCTO activities

Conclusions
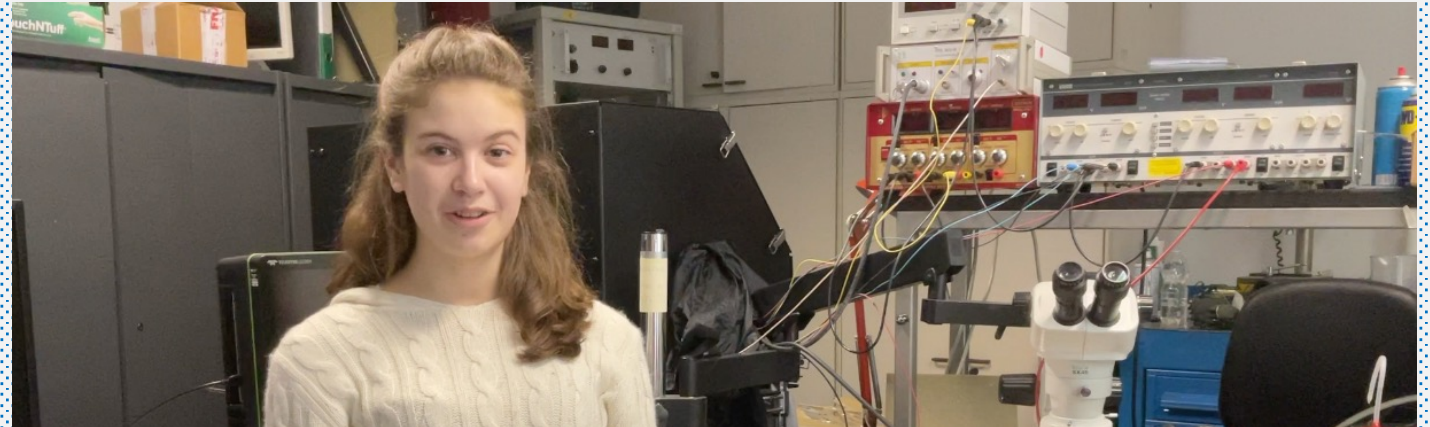
V. Di Toro

WHAT DID WE FIND OUT?

In conclusion, the most important lesson I have learned from my wonderful experience at the INFN labs during the International Cosmic Day was to truly experience the reality of scientific research, even just for a day: this project, in fact, showed me what defines a great researcher, which is the ability to have a clear understanding of the variables at play, how the experimental machine interacts with them and, most of all, being capable of asking the right questions. Moreover, this event gave me an insight into the complexity of conducting an experiment, which can involve people with very different skills that are all necessary for the interpretation of the experiment: programmers capable of analysing the data, engineers who can project the most efficient machine, etc. However, the greatest gift that I have received from this opportunity was the chance to realise, in such a confusing world, that there is something that I can love unconditionally: the purity of the scientific approach to reality