

**PRESENTATION DAY
CREF ACTIVITIES
FOR THE SCIENTIFIC COUNCIL
AND THE INTERNAL EVALUATION COMMITTEE**

- Short Introduction
- Network restart & data taking
- Polar activities at Ny-Ålesund (Svalbard)
- OvEEErland 2025: latitude campaign on the road
- Ongoing analyses and key results
- R&D: gas recirculation and Transportable Tracking Telescope (TTT)
- Publications + outreach + 2026 roadmap

The Extreme Energy Events Project is a Centro Fermi & INFN Experiment with dual role

- Cosmic ray experiment: detection and study of cosmic rays at ground
- Scientific Education: involve high school students in all the phases of the experiment

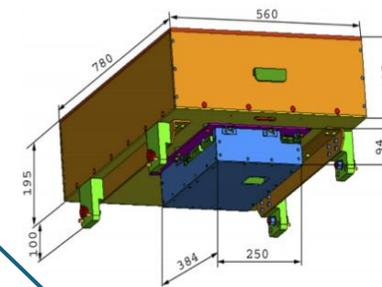
Today it is constituted by a network of 50 muon tracking telescopes installed inside Italian high schools, INFN laboratories, Centro Fermi and CERN.

Many other High Schools participating without telescopes

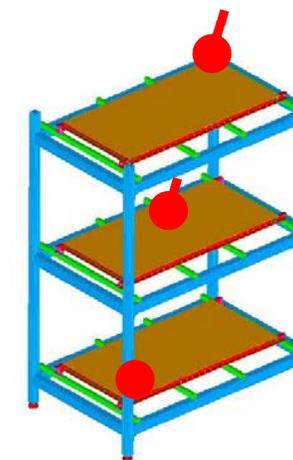
Hundreds of students working in the EEE experiment each year!



POLA-R detectors



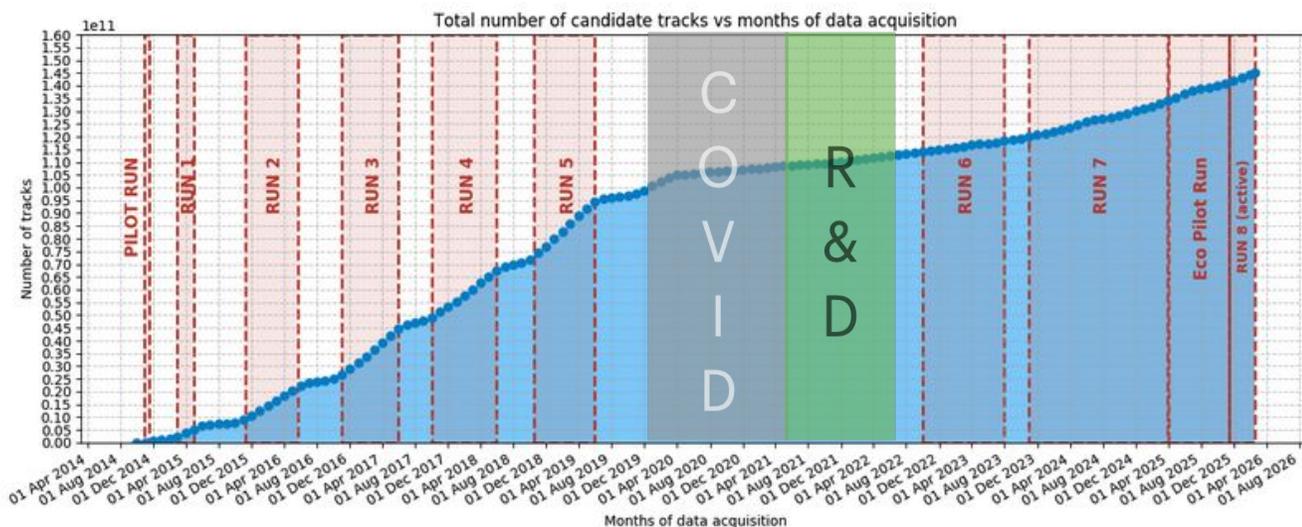
MRPC detectors



- 46 telescopes restarted* (36 schools, 10 labs)

*= new eco-friendly gas mixture □ Restart actions: eco-gas replacement, leak tests, electronics/hardware checks

- Eco-Pilot RUN (Spring 2025): ~25 telescopes
- RUN 8 started 14 Nov 2025 (Dec 2025: 32 telescopes taking data)
- Weekly online meetings for operations and data-taking coordination

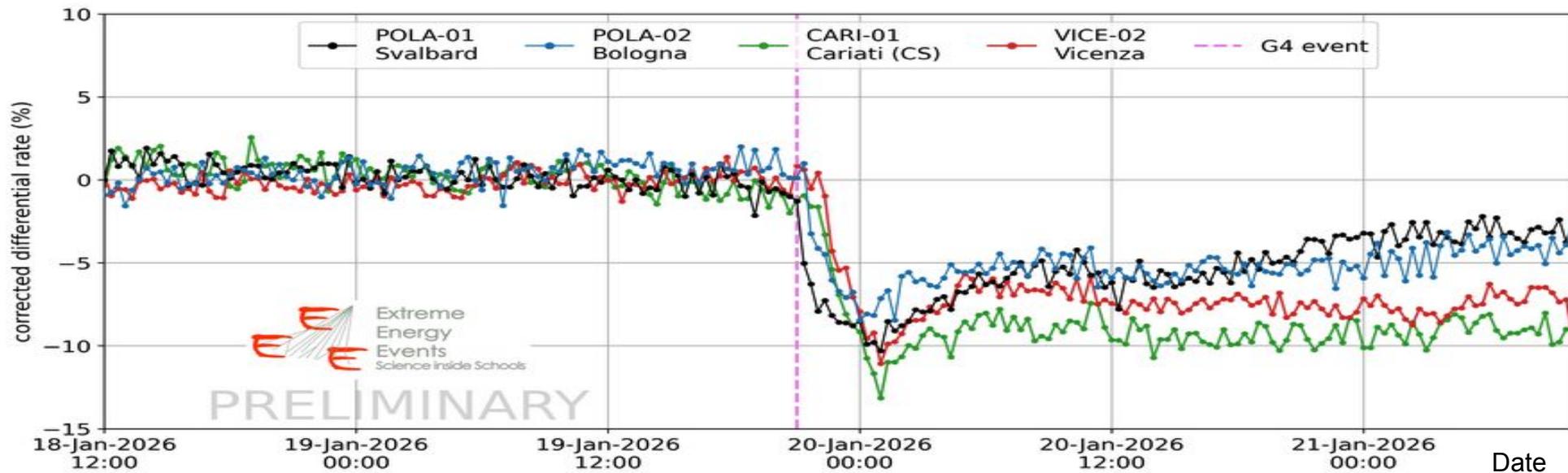


Total number of candidate tracks ($X^2 < 10$) in the database: 145119377333

OpenData DB



- Mid-January 2026 -> one of the most intense solar storms in decades
- A strong solar flare on 18 Jan (~17:00 UTC) triggered a coronal mass ejection (CME) that reached Earth on 19 Jan at an estimated ~1700 km/s,
- The event produced a pronounced Forbush decrease
- The EEE (Extreme Energy Events) collaboration detected the effect promptly using scintillator POLA-R telescopes and MRPC telescopes
- After atmospheric-pressure correction, the differential rate shows a large variation (~10%), and a multi-latitude, multi-detector combined analysis is ongoing



Detailed
analysis
ongoing

Differential cosmic-ray rate (%): POLA-01 (Svalbard), POLA-02 (Bologna), CARI-02 (Cariati), VICE-02 (Vicenza); dashed line marks the estimated onset (~21:00 UTC) of the Forbush variation

- 4 POLA-R detectors complement the MRPC telescope network
- POLA-01/03/04 operate at Ny-Ålesund since 2019
- POLA-02 used for latitude campaigns (Vespucci 2022, OvEEErland 2025)

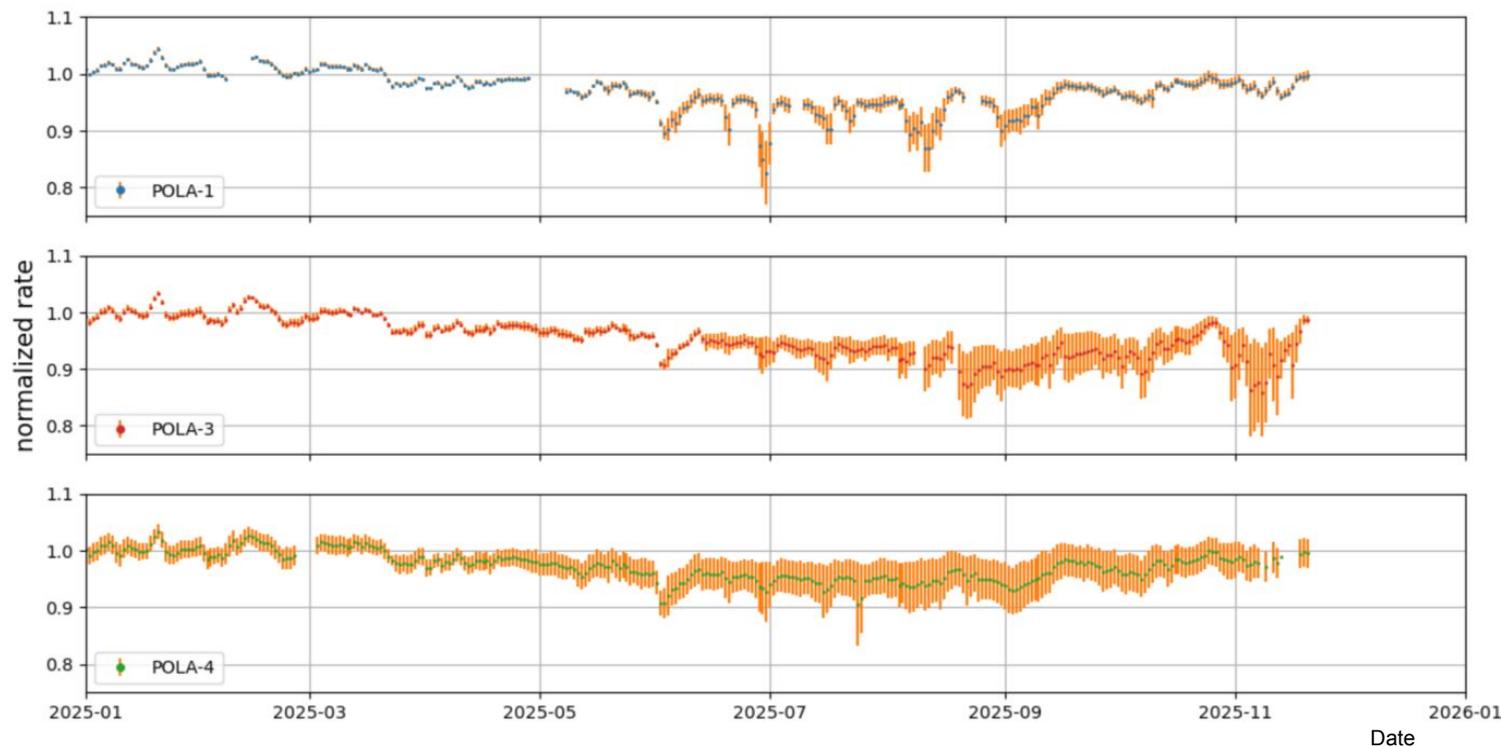


Ny-Ålesund (Svalbard): operations and data quality (2025)

Maintenance mission 12-19 May 2025 (cleaning, batteries, SD cards)

Interruptions mainly due to GPS / power; mostly recovered remotely

Increasing systematic uncertainty trend : recalibration and repositioning planned this year



- Land expedition Bologna → Tromsø: ~8200 km across 6 countries
- Latitude coverage: 44.5-70.0°N
- Scientific + outreach stops (Germany, Norway)



Bologna
Munich
Bamberg
Leipzig
Wildau
Wildau
Rostok
Rostok
Helsingborg
Goteborg
Oslo

Oslo
Elverum
Atna
Tynset
Ulsberg
Trondheim
Trondheim
Snåsa
Trofors
Mo i Rana
Fauske
Narvik
Olsborg
Tromsø

Tromsø
Narvik
Kiruna
Luleå
Umeå
Sundsvall
Stockholm
Jönköping
Helsingborg
Copenhagen
Køge
Kiel
Hamburg

Hamburg
Braunschweig
Gottingen
Fulda
Schwabach
Rosenheim
Innsbruck (Steinach)
Bolzano
Bologna



Marco G.



Daniele



Eirik (Oslo)



Akiesieniia



Carmelo



James (Oslo)



Paola



Marco P.



Francesco N.

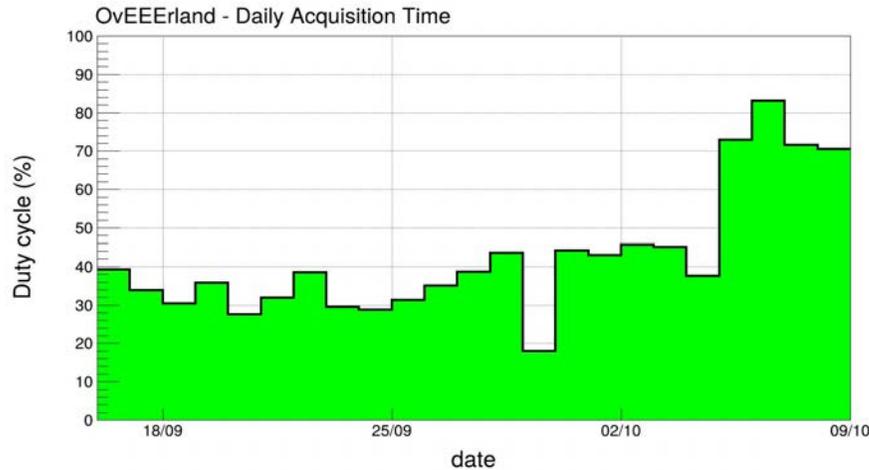


Alessandro



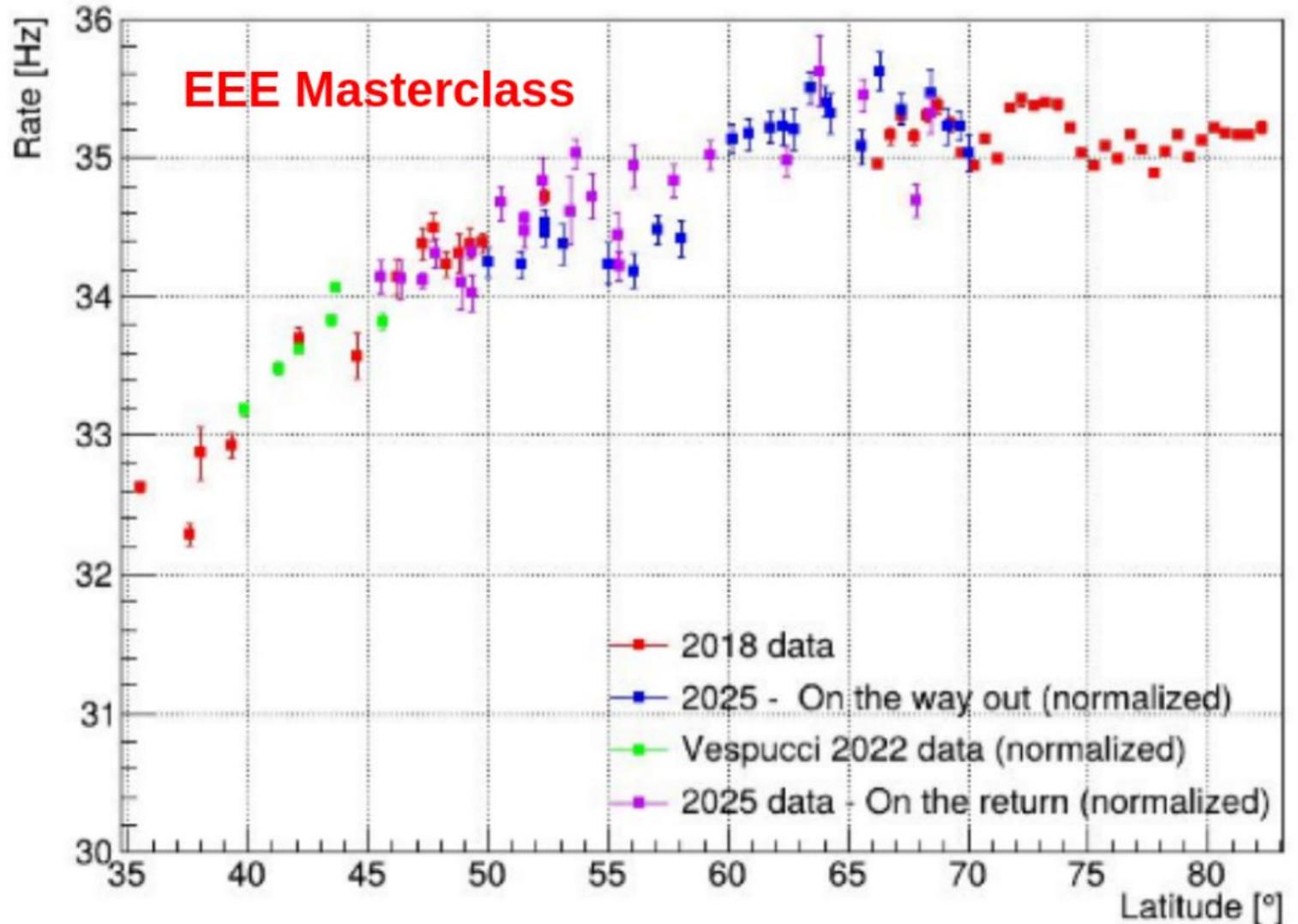
Fabrizio

- Campaign completed after 23 days of data taking



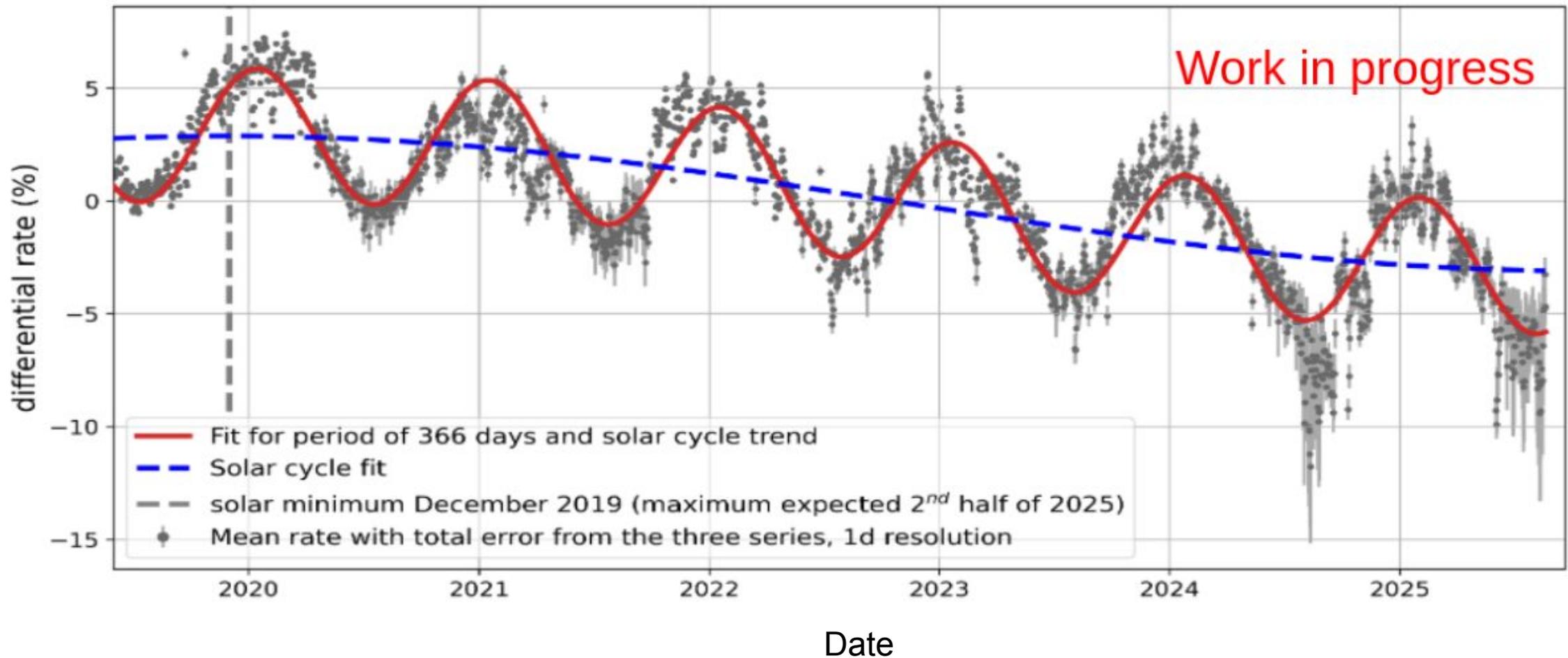
- New points extend flux-vs-latitude dataset
- First analysis by EEE students during Nov 2025 masterclass (Rome)

Corrected Rate vs Latitude - Normalized



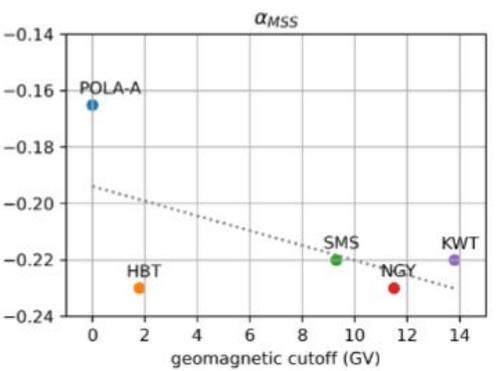
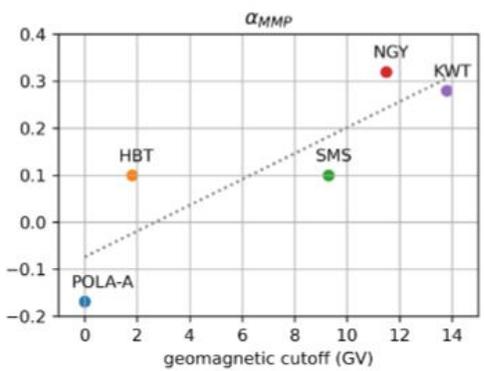
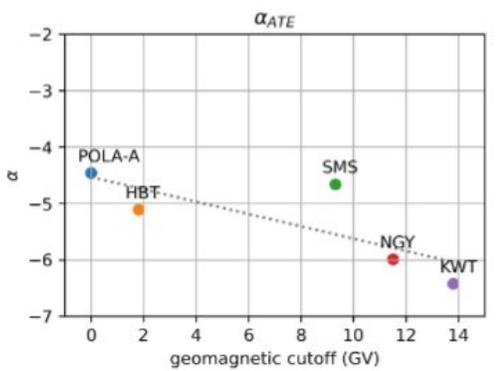
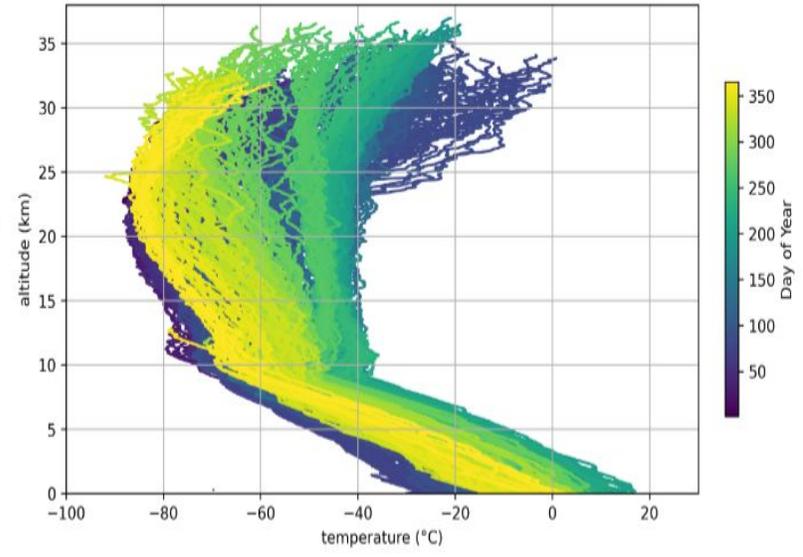
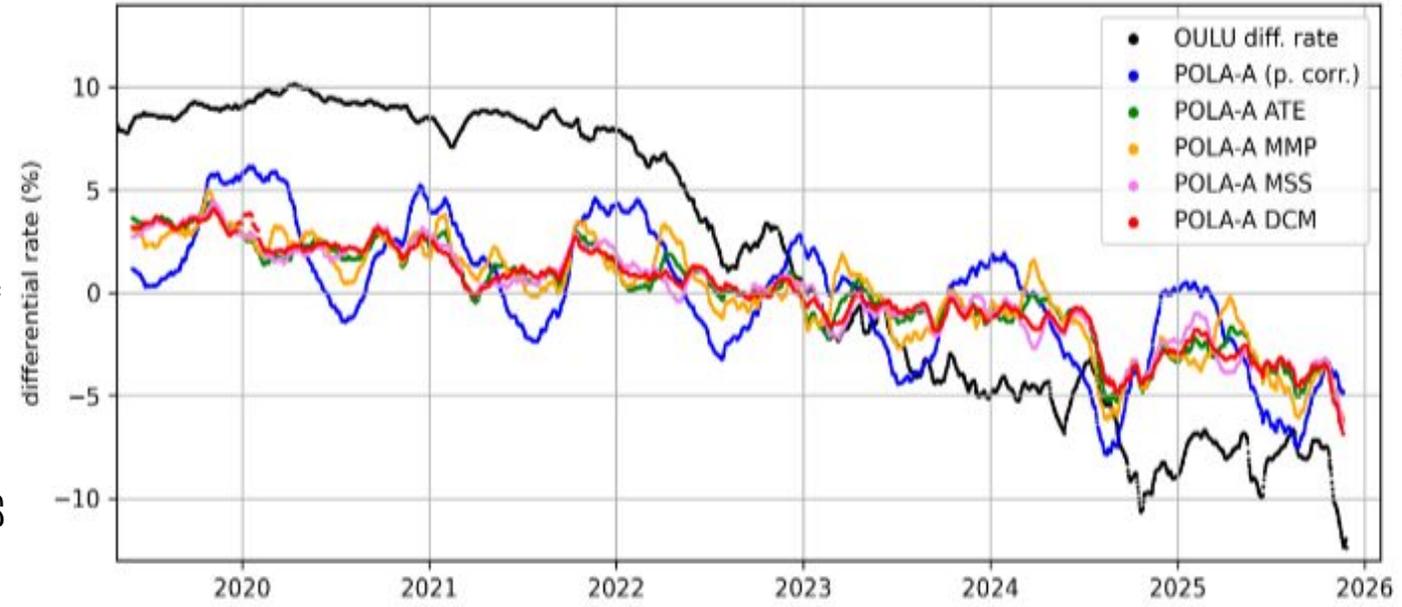
- Periodicities at very high latitude (POLA-R 2019-2025)
- Atmospheric temperature effects
- Diurnal modulation at large latitudes
- Flux vs latitude (2018-2025 missions)
- Forbush decrease (2024-2026) quantitative study of the effect vs latitude.
- Muon-rate DB for students; efficiency studies; upgoing muons

- Six years of continuous POLA-R data (2019-2025)
- Clear annual modulation and solar-cycle contribution
- Manuscript submitted: cosmic-ray rate at 78.9°N (EPJ C) (interaction with referees ongoing)



- Annual modulation correlated with atmospheric temperature profile
- TMSS mass-weighted method used for correlation studies
- **Draft in circulation in the Collaboration (advanced stage)**

Remove the temperature dependent contribution, to further examine the properties of the residual muon rate and its remaining periodic features

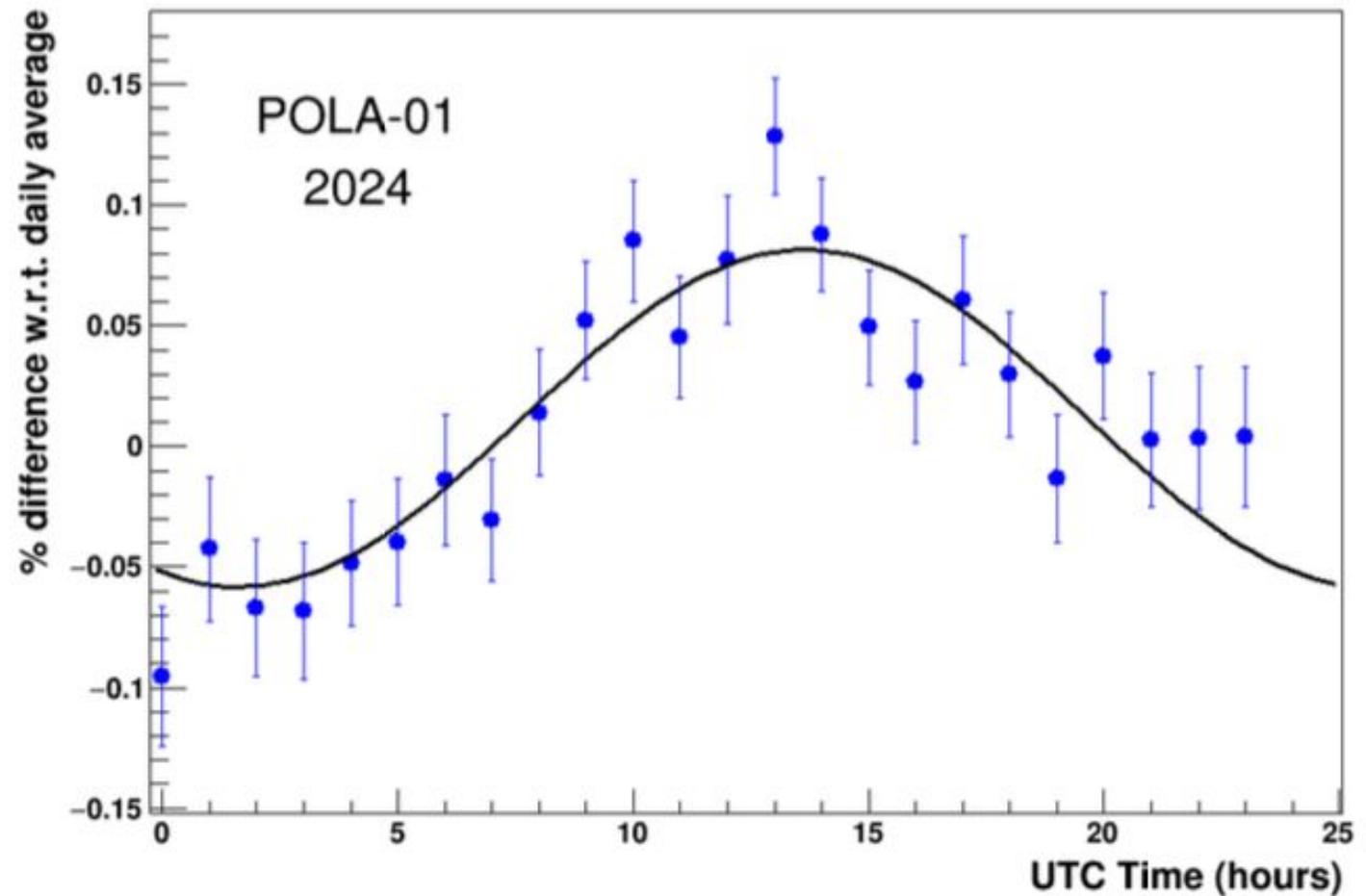


Comparison with other experiments at different latitudes of the correlation coefficients between rate and temperature in these three models

- Observed diurnal modulation integrating one year of data (example: 2024)
- Amplitude typically 0.1-0.3%; long-term phase trends enable solar-cycle studies
- **Draft in circulation in the Collaboration (advanced stage)**

Measurements of the diurnal modulation carried out at polar latitudes with both neutron and muon detectors are not common;

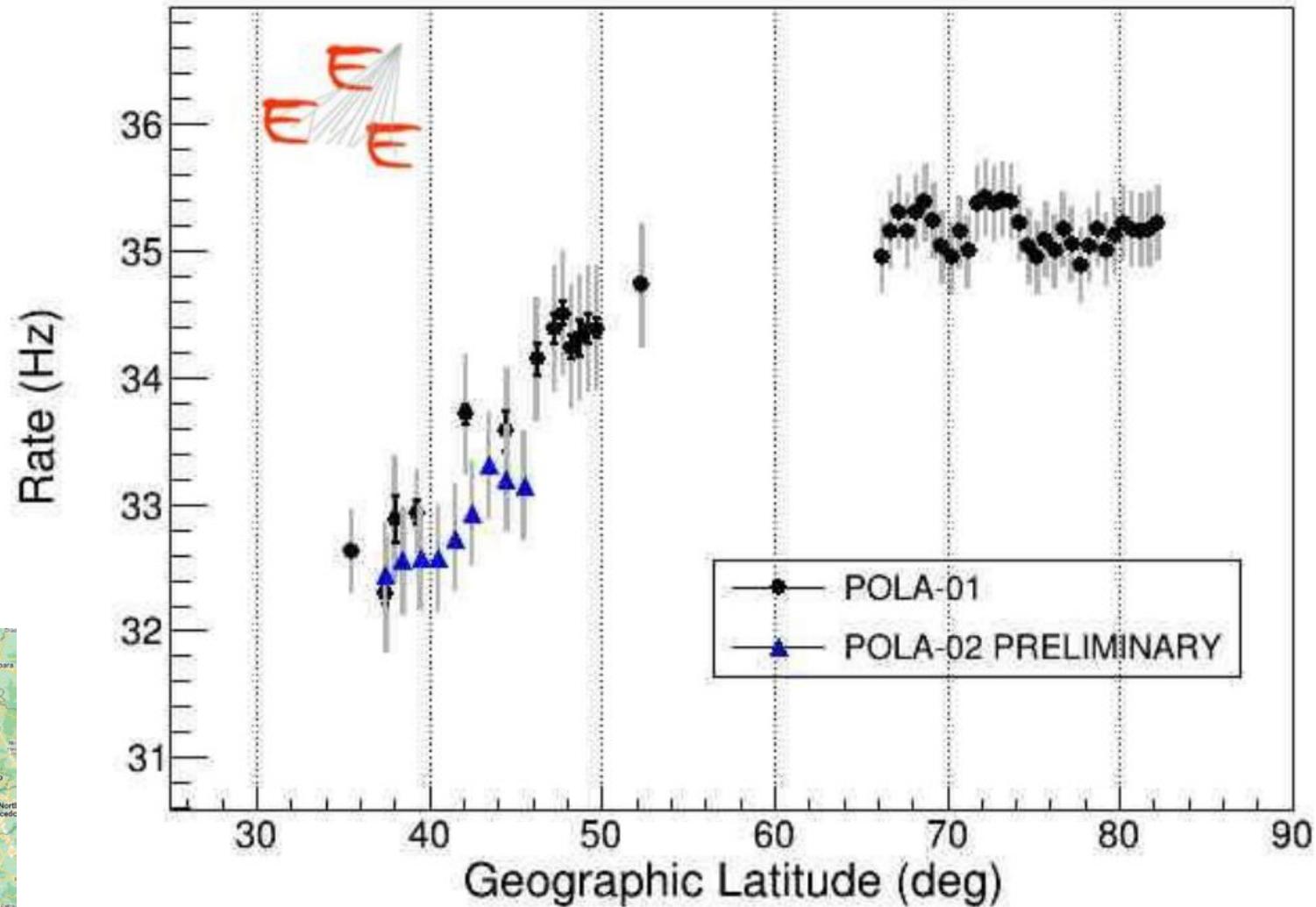
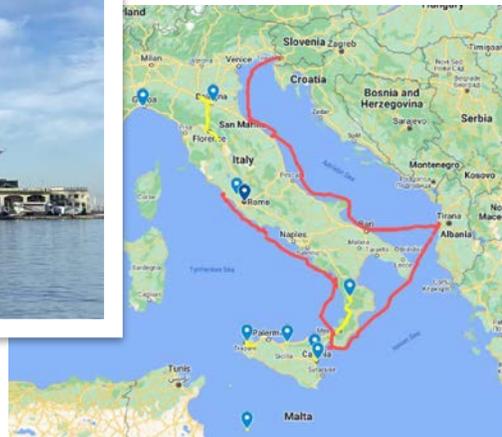
- quantitative comparison with the data collected by the Barentsburg Neutron Monitor,
- amplitude of the anisotropy for muons is smaller, at least by a factor 2, than for neutrons
- trend of the phase over the last years was similar both for muons and neutron



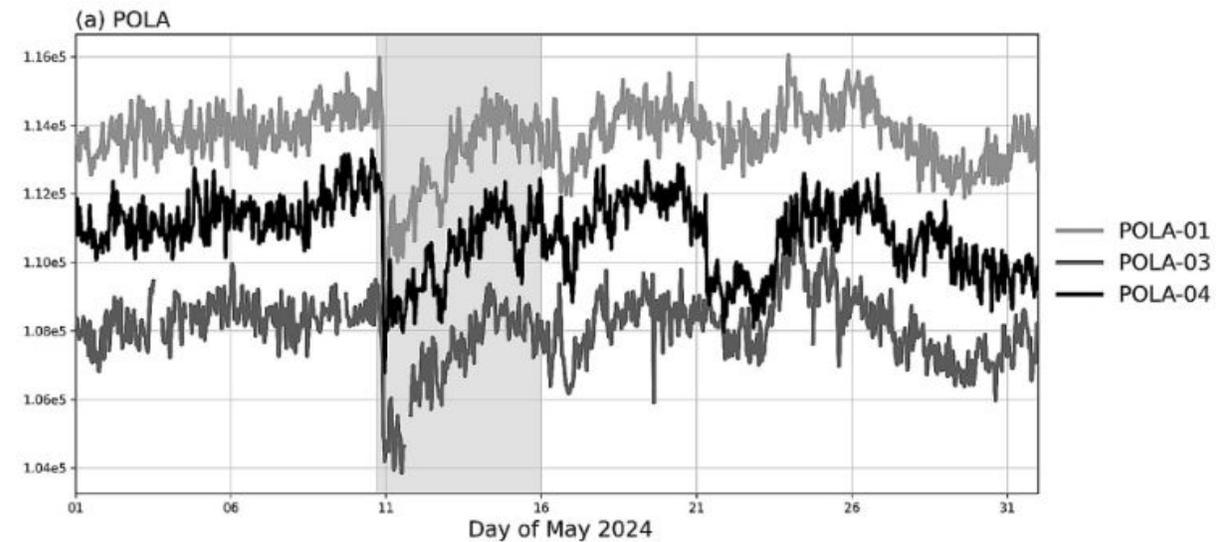
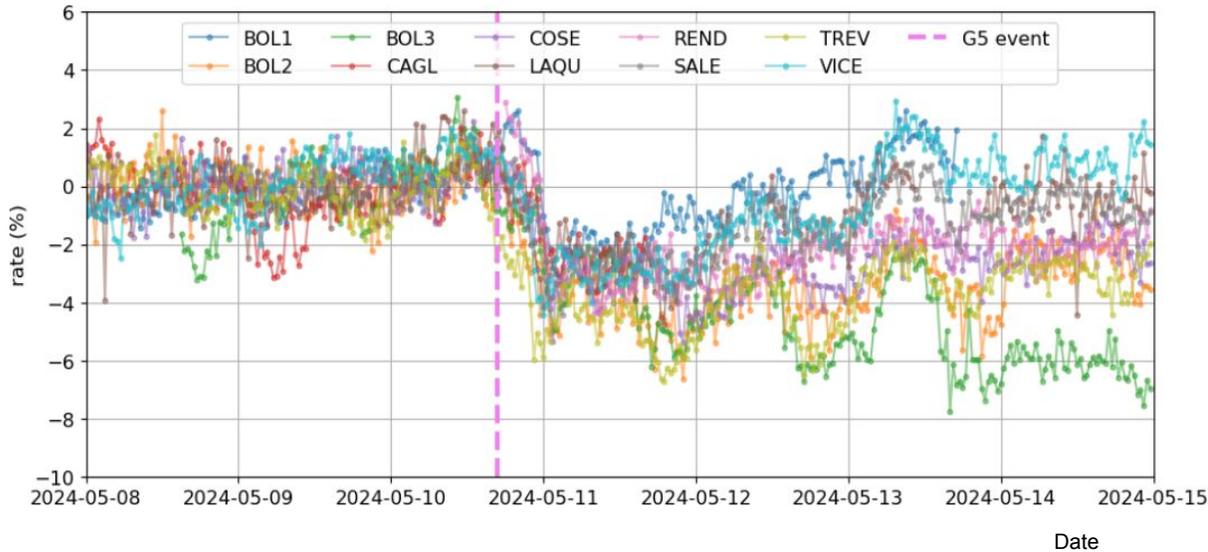
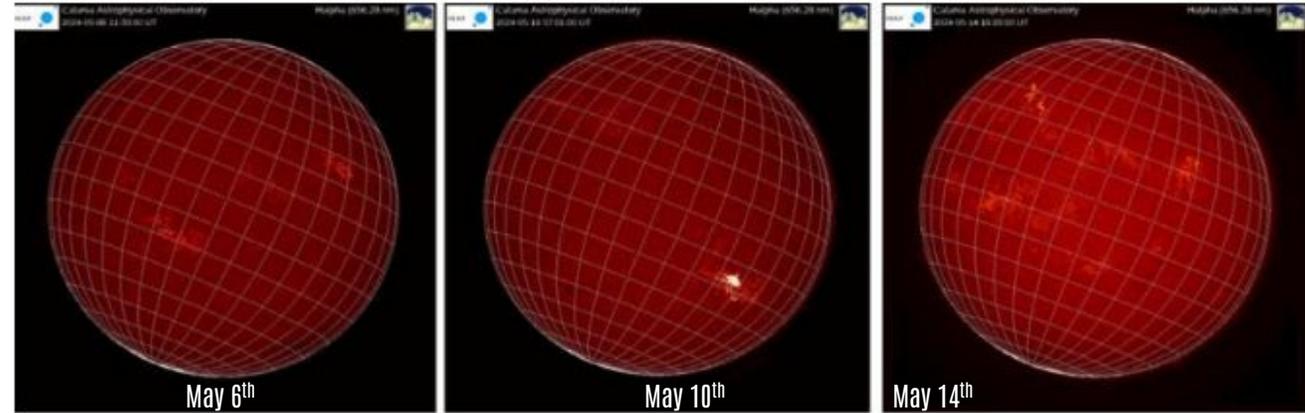
Sea-level secondary flux as a function of latitude

Vespucci 2022 data combined with 2018-2019 and 1c campaigns

Preliminary results presented at ICRC 2025 (PoS(ICRC2025)1245)



- Observed by MRPC telescopes in Italy and POLA-R at Svalbard
- POLA-R data: Published results (Advances in Space Research, 2025) in collaboration with BSS and CRNS at Ny Ålesund
- MRPC data: Paper accepted by EPJP
- BRAND NEW Ongoing analysis: Forbush amplitude vs latitude



- ✓ **Detector studies: POLA-R efficiency & stability**
 - Detailed response/efficiency studies to correct small rate variations
 - Preparatory work for a long-term muon flux monitoring database

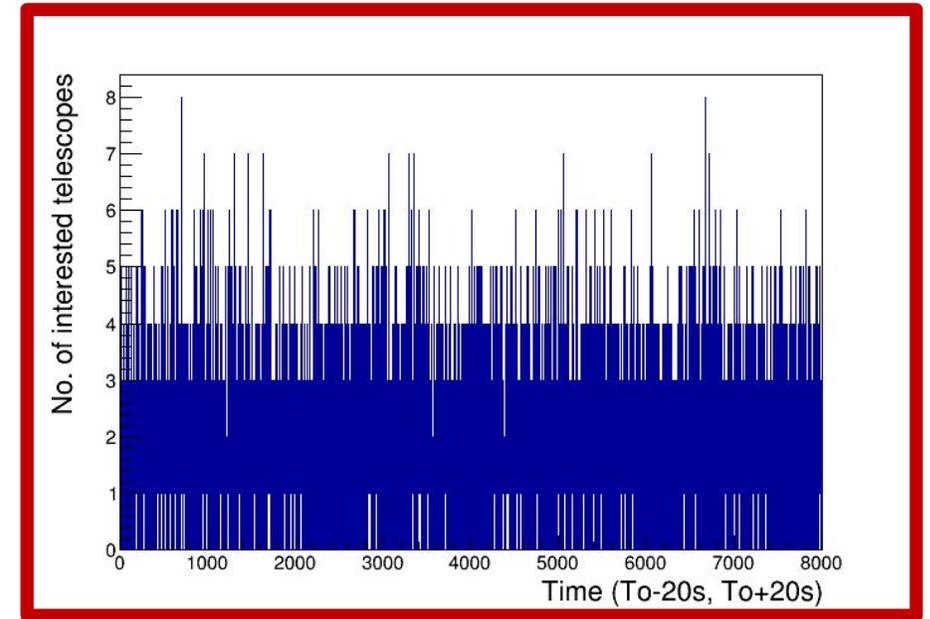
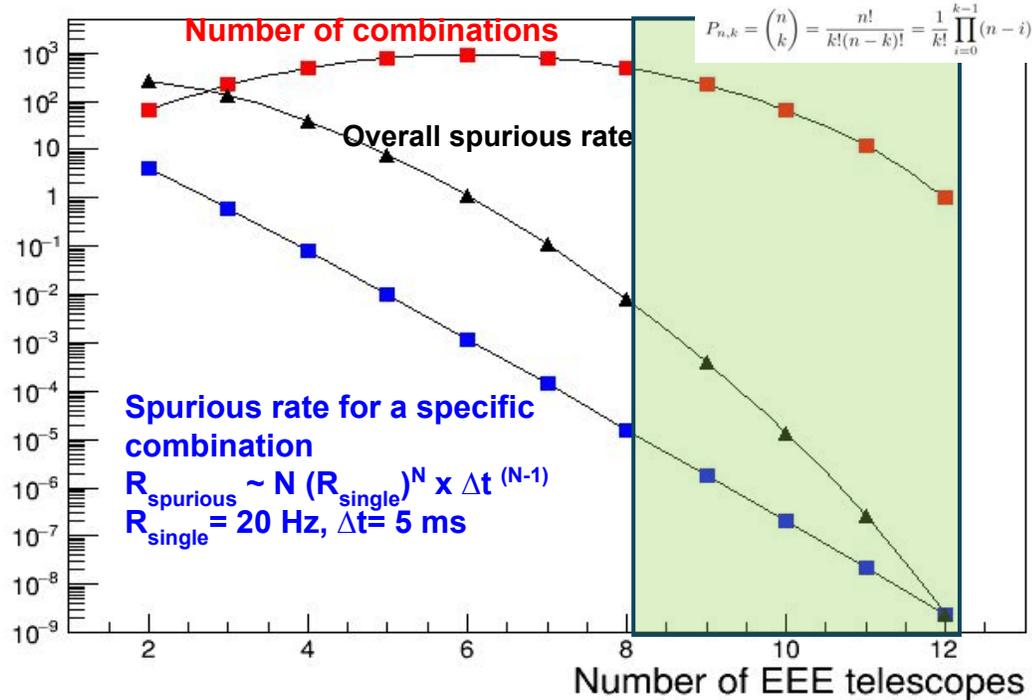
- ✓ **Muon-rate database (DB) for students**
 - DB under implementation to track muon flux across the EEE network
 - First step: authenticated access for students
 - Prototype expected in middle 2026

- ✓ **Feasibility: upgoing events in EEE data**
 - Directionality capability exploited to search for upgoing candidates
 - Background rejection (muon decay electrons) under study
 - Target sample: ~140 billion downgoing events collected since 2014

On Sept. 22, 2017 at 20:54:30,43 UTC time a high energy (290 TeV) neutrino event was observed by the IceCube km³ neutrino Observatory

What to search for: coincident events between several EEE telescopes in a coincidence time window Δt around the time of the physics event of interest

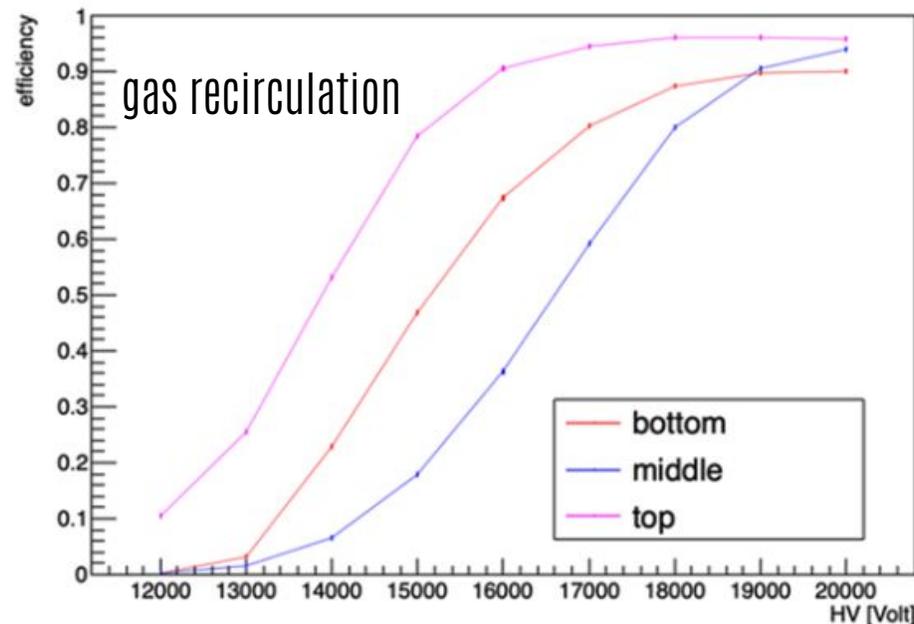
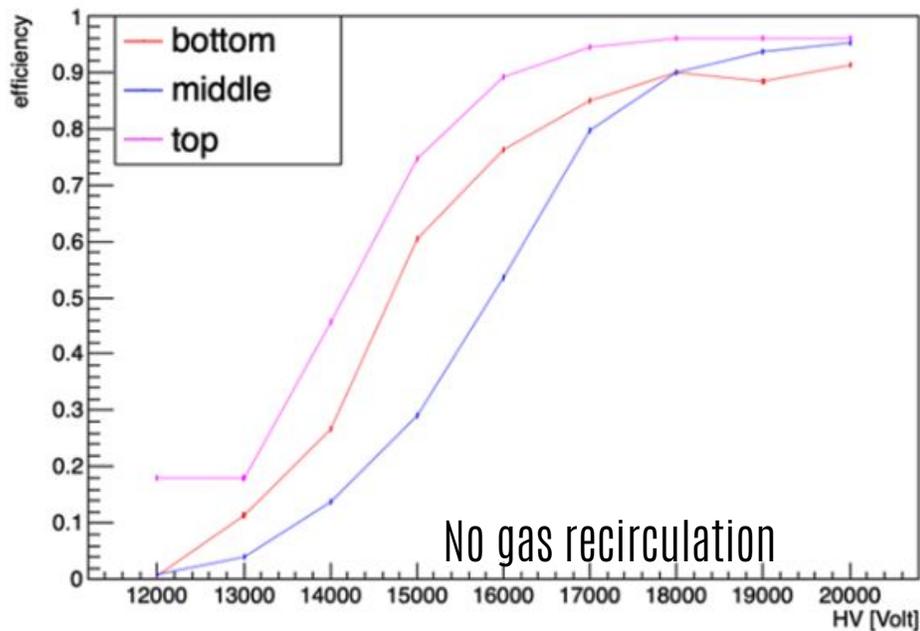
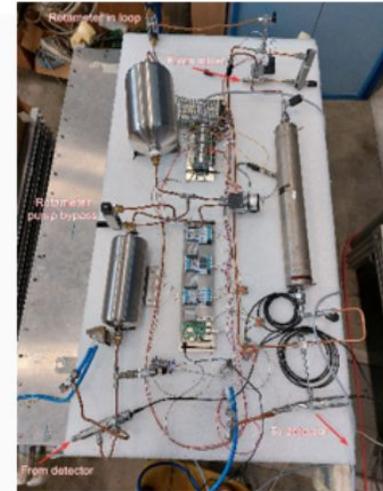
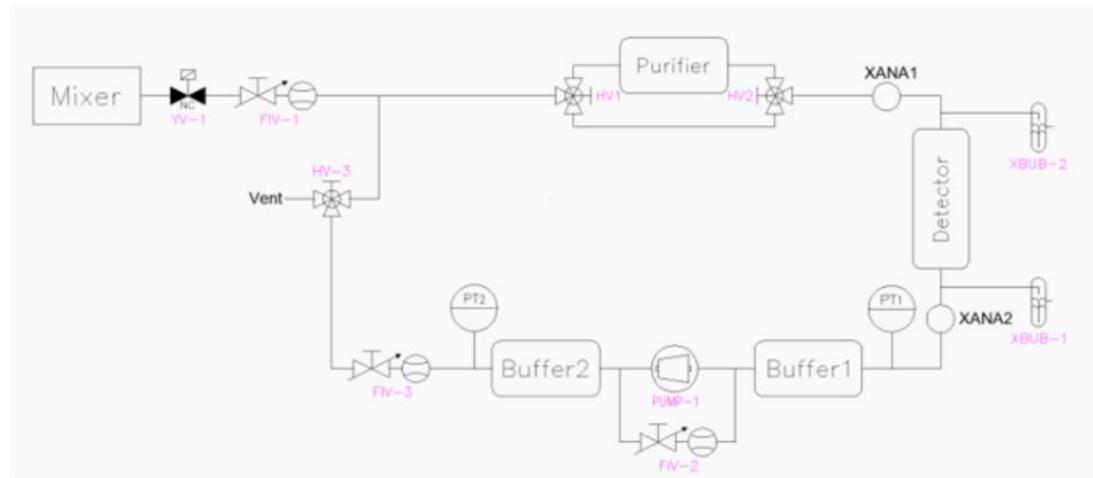
- careful analysis of number of telescopes
- Define Δt for coincidence search and the time window around event (physics case)
- Evaluate expected spurious coincidences (example the 2017 neutrino event in IceCube \square 12 active telescopes: 0 events with 9 tel. in coincidence and 2 with 8 tel. (0.3 expected))



Take-home message: telescopes need to stay on!

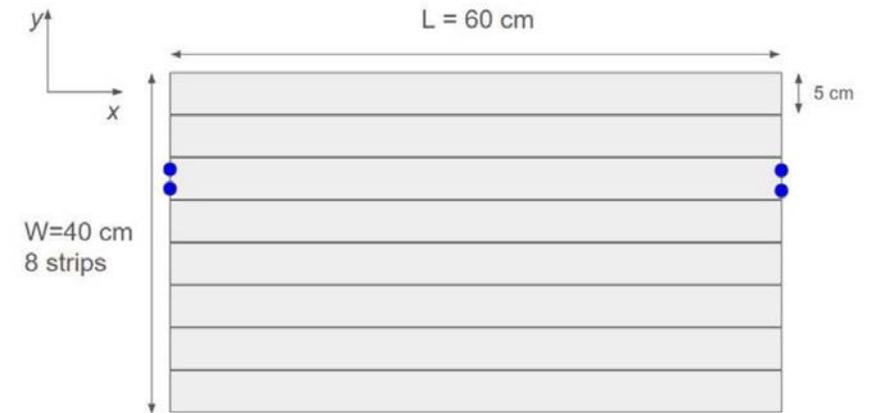
- **Gas recirculation system**
- **New Transportable Tracking Telescope (TTT) development**

- Goal: reduce gas consumption (~1 L/h baseline)
- Circuit designed with CERN Gas Group; humidity issues mitigated
- Engineering toward a compact transportable module



- Performance in agreement with standard operation
- **0.23 l/h flux (factor 4 reduction of the gas consumption)**
- Long-term stability tests ongoing

- Portable detector with tracking capability
- Scintillator bars $5 \times 60 \text{ cm}^2$ with 4 SiPM readout (two per side)
- Position estimate: segmentation (y) + time difference (x)

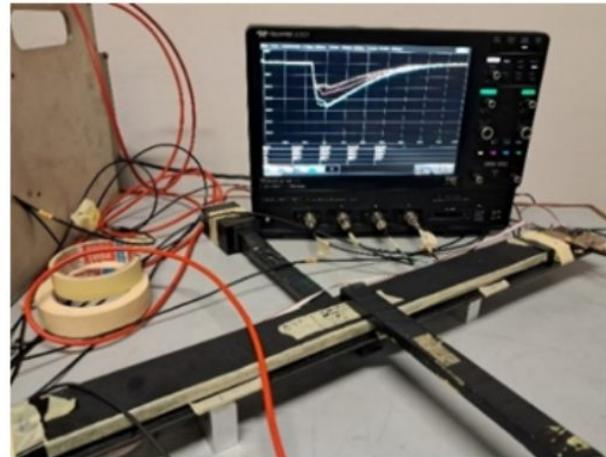


2 Prototype bars instrumented

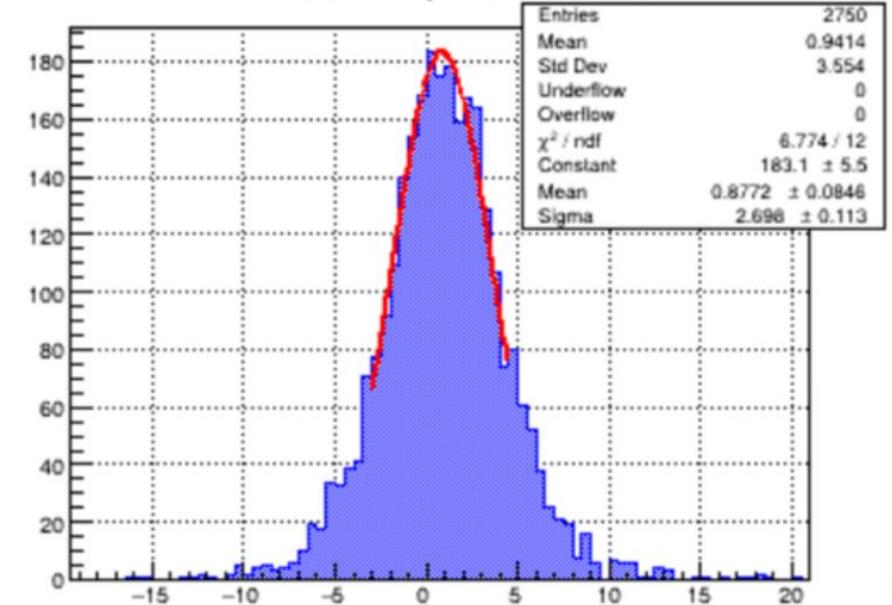
97% of triggered muons give signal on all 4 SiPMs

Preliminary spatial resolution from timing difference demonstrated

Preliminary study on readout electronics (commercial CAEN FERS5202)



reconstruct x position minifx



Published manuscript 2025:

The EEE Collaboration, **Bringing Science in the Heart of the Young - The Extreme Energy Events Project (2004-2024)**, *Giornale di Fisica Supplemento* Vol.65, S3(2024)1-192

F.Riggi et al. (EEE Collaboration), **High latitude observation of the Forbush decrease during the May 2024 solar storms with muon and neutron detectors on Svalbard**, *Advances in Space Research* (2025), 76(2025), pp.1225-1239

F.Riggi and C.Ripoli, **Bringing science in the hear of the young, a two-decades long fruitful collaboration**, *Nuovo Saggiatore* (2025), 41(2025)64

C.Ripoli et al. (EEE Collaboration), **Recent outreach activities of the EEE Project**, *Proceedings of the CRIS-MAC Conference*, IOP Conf.Series, 3053(2025)012042

O.Pinazza et al. (EEE Collaboration), **Annual quasiperiodicity in muon rate observed by PolarQuEEEst detectors at 79 N**, *Proceedings of the CRIS-MAC Conference*, IOP Conf. Series, 3053(2025)012003

M.Abbrescia et al. (EEE Collaboration), **Measurement of the muon flux in the tunnels of Doss Trento hill**, *Nuclear Instruments and Methods A1072*(2025)170163

- O.Pinazza et al., **High latitude muon and neutron observation of the Forbush decrease during the May 2024 solar storm**, POS(ICRC2025)1356

- P.La Rocca et al., **Measurement campaigns of the cosmic ray flux at different latitudes within the Extreme Energy Events Project**, POS(ICRC2025)1245

- F.Nozzoli et al., **Characterization of the Piedicastello Tunnels as a Potential Underground Laboratory for Astroparticle Physics in Trento**, POS(ICRC2025)509

Manuscripts / drafts (submitted or internal):

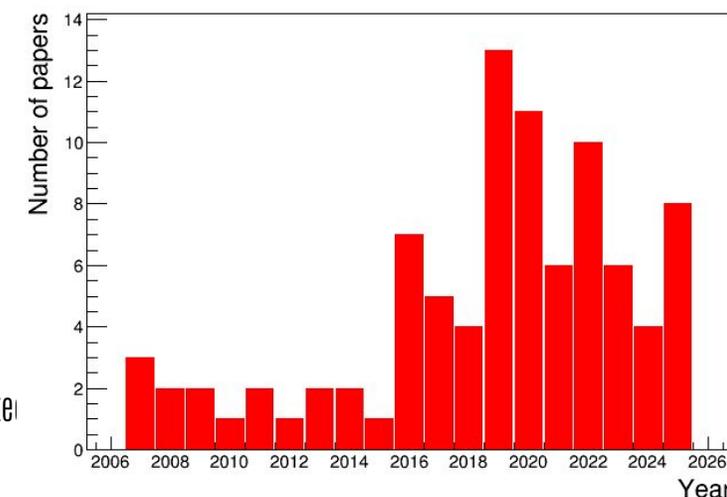
Observation of Forbush events with the EEE detectors operated with an eco-friendly gas mixture, accepted for publication on EPJP

Measurement of the cosmic-ray rate over the period 2019-2025 at very high latitude (78.9°N), submitted to EPJ-C

Atmospheric effects on cosmic-ray muon rate at high latitude (78.9°N), circulating

Investigation of the diurnal variation of cosmic rays at large latitudes by the detectors of the Extreme Energy Events Project", circulating

(Timing performance of the Multigap Resistive Plate Chambers for the cosmic ray telescopes of the EEE Project Proceedings of FATA2025), submitted



- Monthly Run Coordination Meetings: average 200 connections, ~600 students involved
- General EEE Meeting in Rome: 26 schools, 65 students, 29 teachers
- Participation in the International Cosmic Day (DESY)
- Three contests: Cosmic Box, Eco-Pilot Run, Eco-Logo
- International live calls with schools and CERN
- New social media management: weekly series “The mysteries of cosmic rays”
- 3 outreach events during the OvEEErland mission (Vildau, Oslo, Trondheim)

Meeting Generale del Progetto EEE - Extreme Energy Events



The Extreme Energy Events (EEE) Project - "Science in Schools" is an experiment for measuring and studying Cosmic Rays at ground level, featuring an innovative and impactful program for promoting scientific culture.

Strongly supported by CREF since the very beginning today is financed by CREF and INFN and many other institutions are involved: CERN, University Physics Depts, Majorana Center, SIF, INGV, CNR, INRIM).

What next in Short/Medium/Long Term

- 2026: consolidate RUN 8 & complete restart of remaining telescopes
 - finalize key analyses and submit papers
 - Conclude the R&D on gas recirculation system
 - Complete R&D on the trasportable tracking telescope
 - Deliver muon-rate DB prototype (AI in the game?);
- > EEE will continue the monitoring of the CR flux (and ready for Long distance Correlation studies or multi messenger Events)

Thank you for your attention!

EXTRA

>60 scientists from CREF

INFN - Bari, Bologna, Cagliari, Catania, Lecce, LNF,
LNGS, LNL, Genova, Pisa, Torino

University of Bari, Bologna, Cagliari, della Calabria,
Catania, Messina, Pisa, del Salento, Salerno, Siena,
Politecnico di Torino, Trento and CERN

80 Italian High Schools

M. Abbrescia^{a,b} C. Avanzini^{c,d} L. Baldini^{c,d} R. Baldini Ferroli^e G. Batignani^{c,d} M. Battaglieri^f S. Boi^{g,h} E. Bossini^{d,1} F. Carnesecchiⁱ F. Cavazza^j C. Cicalò^h L. Cifarelli^{k,j} F. Coccetti^l E. Coccia^m A. Corvagliaⁿ D. De Gruttola^{o,p} S. De Pasquale^{o,p} L. Galante^q M. Garbini^{l,j} I. Gnesi^{l,r} F. Gramegna^w S. Grazzi^{s,f} D. Hatzifotiadou^{j,i} P. La Rocca^{t,u} Z. Liu^v G. Mandaglio^{s,u} A. Margotti^j G. Maron^w M. N. Mazziotta^b A. Mulliri^{g,h} R. Nania^j F. Noferini^j F. Nozzoli^x F. Palmonari^{k,j} M. Panareo^{y,n} M. P. Panettaⁿ R. Paoletti^{z,d} C. Pellegrino^{aa} L. Perasso^f O. Pinazza^j C. Pintoⁱ S. Pisano^{l,e} F. Riggi^{t,u} G. Righini^{ab} C. Ripoli^{o,p} M. Rizzi^b G. Sartorelli^{k,j} E. Scapparone^j M. Schioppa^{ac,r} G. Scioli^{k,j} A. Scribano^{z,d} M. Selvi^j M. Taiuti^{ad,f} G. Terreni^d A. Trifirò^{s,u} M. Trimarchi^{s,u} C. Vistoli^{aa} L. Votano^{ae} M. C. S. Williams^{i,v} A. Zichichi^{l,k,j,i,v} R. Zuyeuski^{v,i}

A large effort since the beginning to involve scientific Institutions: CERN, INFN, University Physics Depts, Majorana Center, SIF, INGV, CNR, INRIM

October 2020: INFN-Centro Fermi agreement signed to share contributions from the two Institutions for equipment, consumables, personnel, travel and meeting organization, fellowship

**Project Responsible @ CREF
and Spokesperson**



MARCO GARBINI



FABRIZIO COCCETTI



SILVIA PISANO



KRISTIAN PISCICCHIA



MARTA PEPE



JACOPO SIGNORINI



FRANCESCO FURFARI

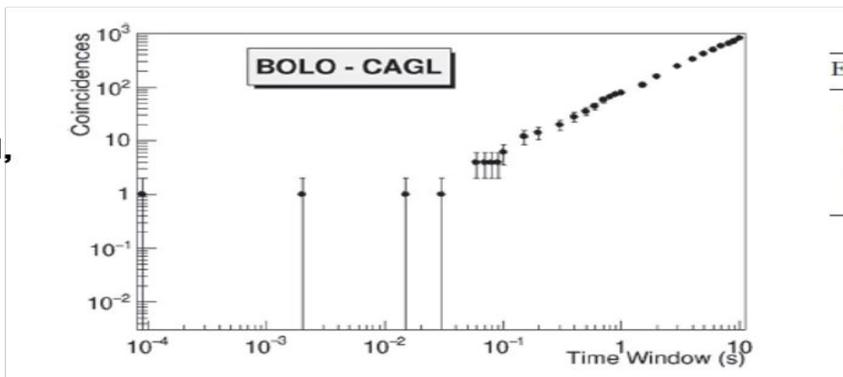


FRANCESCO BUCCHERI

And others actually...

Strategy 1

M. Abbrescia et al, Eur. Phys. J. Plus (2018) 133: 34

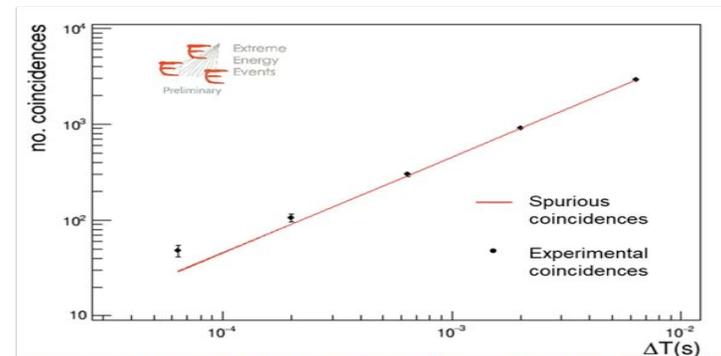
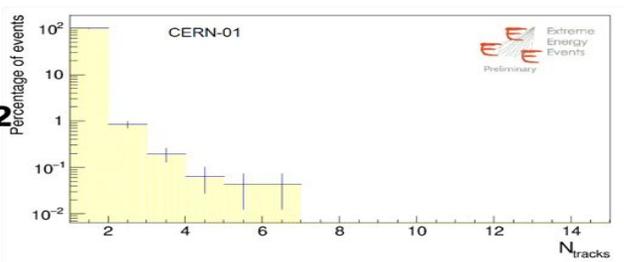


Event	EEE pairs	Distance (km)	Δt (μs)	ϑ_{rel} (deg)	Expected events	p -value
(A)	BOLO-CAGL	614	86	27.1	0.0069 ± 0.0002	0.007
(B)	BOLO-LAQU	290	740	9.1	0.014 ± 0.001	0.014
(C)	CATA-TORI	1040	88	9.2	0.0265 ± 0.0005	0.026
(D)	GROS-TORI	377	297	14.4	0.032 ± 0.001	0.031
(E)	CERN-CATA	1200	248	9.3	0.049 ± 0.001	0.048

5 candidate events with low p-value
A clear evidence for long distance correlations needs higher statistics.

Strategy 2

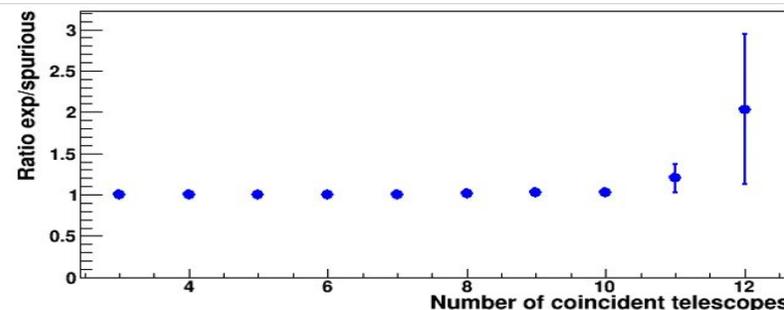
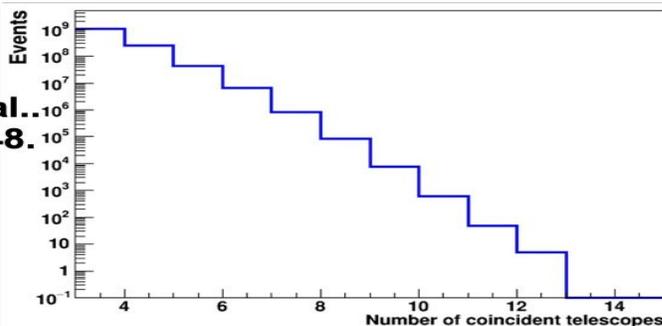
P. La Rocca et al., PoS(ICRC2021)292



A slight excess found for multitrack-multitrack coincidence events below 100 μs

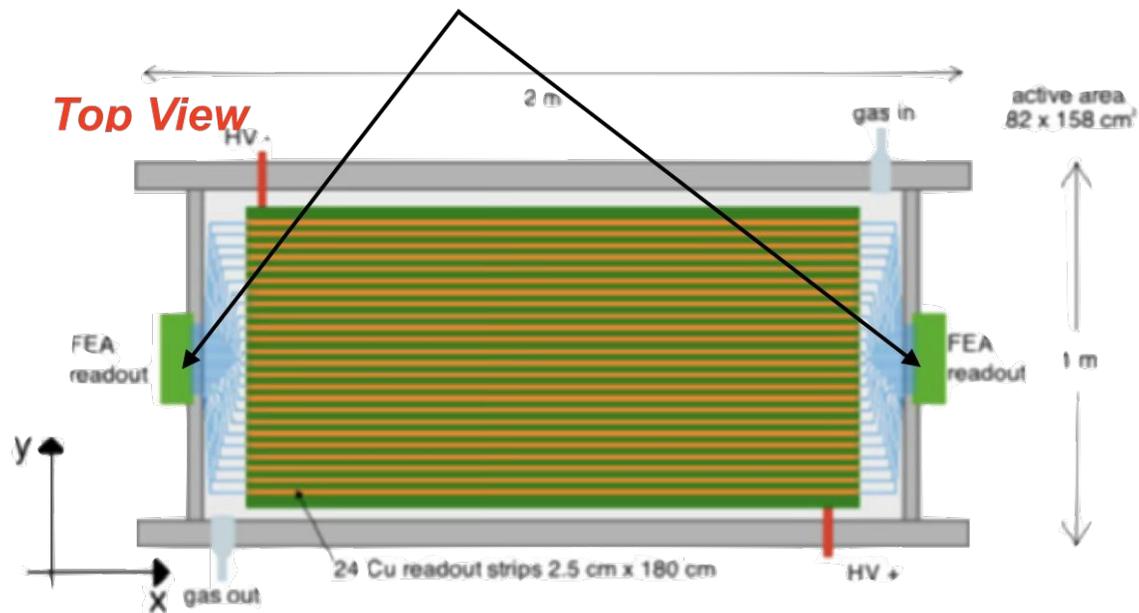
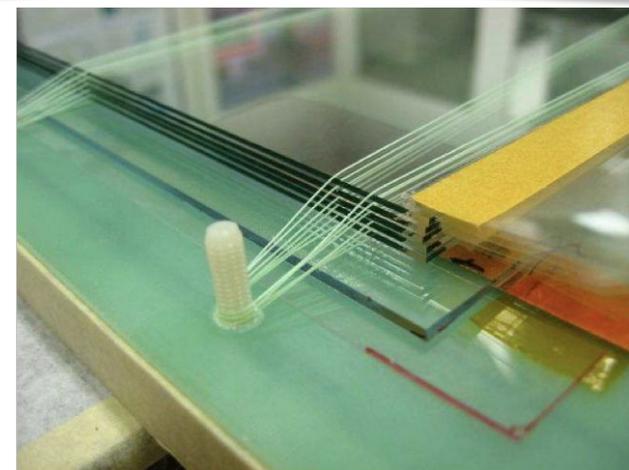
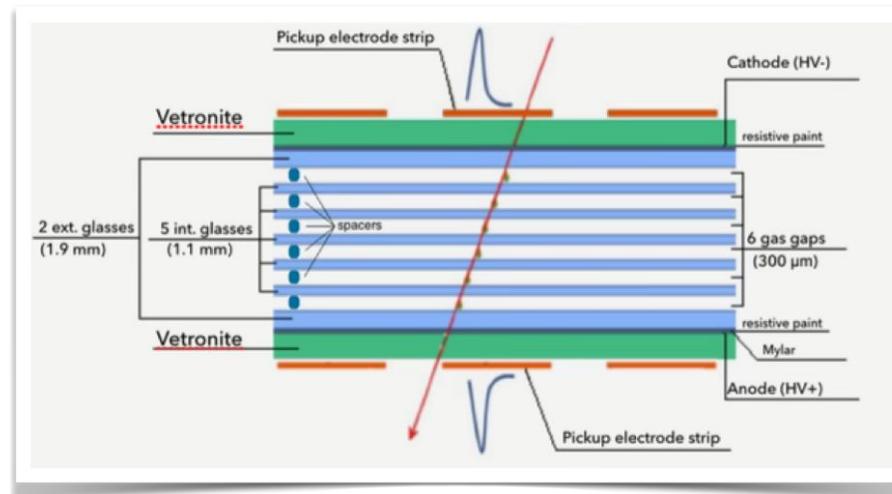
Strategy 3

M. Abbrescia et al., J 2021, 4, 838–848.



A slight excess over random background found for events with >10 telescopes in coincidence

- Wide area ($\sim 2 \text{ m}^2$) MRPC
- 6, 300 ($250 \mu\text{m}$) thick, gas gaps
- 1.9 mm thick glass plates used as electrodes (resistive paint)
- 1.1 mm thick glass plates floating
- Fishing line as spacer
- 24 readout copper strips (both anodic and cathodic)
- Till 2019 operated with 98%-2% r134a-SF₆ (streamer free operation) gas mixture, then...we will see later
- $\sim 20 \text{ kV}$ ($\pm 10 \text{ kV}$). DC/DC converters close to the detector to avoid HV cables in schools
- NINO based FE cards



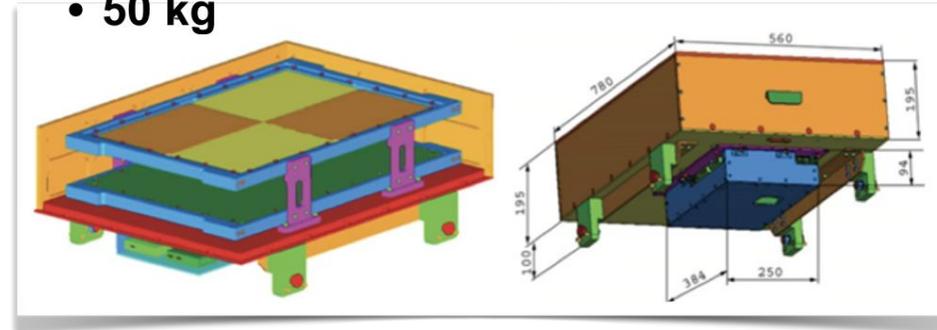
X coordinates by signal arrival time difference
Y strip with signal

-The Polar Quest 2018 mission was a scientific multidisciplinary exploration of Svalbard archipelago.

-The EEE Project contribute to the mission with a cosmic ray detector, POLA-R, to observe Cosmic Rays at very high latitude.

-3 POLA-R detectors were assembled at CERN by high school students: POLA-01, installed on Nanuq sailboat, POLA-02 installed in a Norwegian high school (Nesodden) and POLA-03 installed in an Italian high school (Bra)

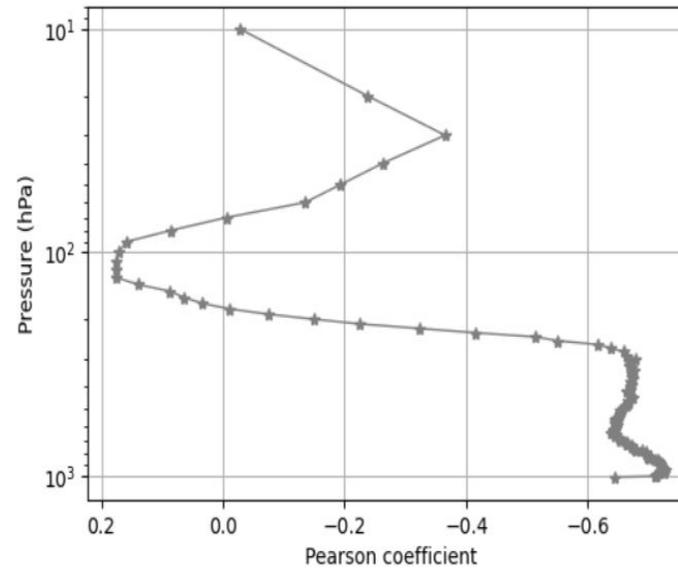
- 2 Plastic scintillator planes
- distance between planes: 11 cm
- 4 Tiles for each plane: 30 cm x 20 cm
- 2 SiPMs per tile (16 SiPMs in total)
- 15 Watts power consumption
- 50 kg



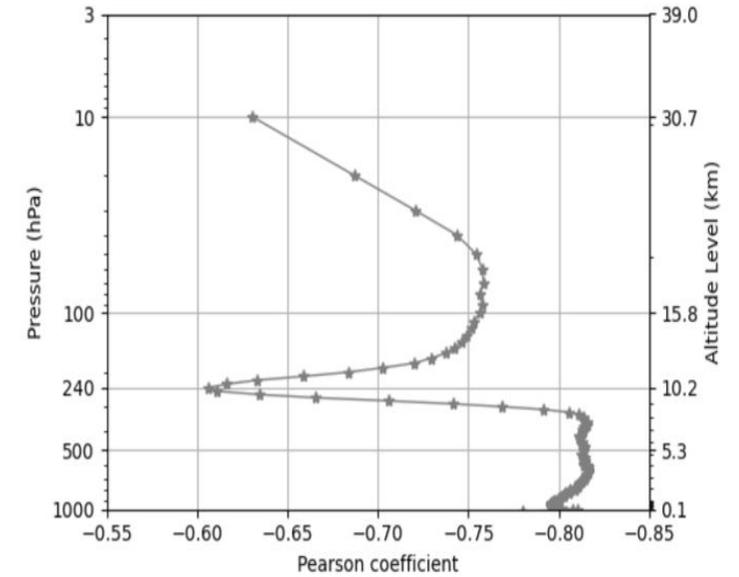
Measurement of the correlation between the rate (pressure-corrected) and the pressure at different altitudes.

new way of analyzing the data that would make it possible to understand how the different layers of the atmosphere influence the rate at two different latitudes

Bologna



Svalbard



We use questionnaires to evaluate the EEE Project impact.

80 schools (about 8000 **secondary high schools in Italy**, ~ 1%)

→ **Indicative survey result (2022-2025): ~60% of EEE student participants chose a STEM degree program (but great dispersion of data)**

Observations on the results of the questionnaires completed by the students who participated in the projects; It is confirmed that:

- laboratory-based teaching is effective both in learning processes and in fostering inclusion;
- physics is perceived as a subject rooted in our everyday life and useful for shaping future, informed citizens;
- students gained hands-on awareness of the importance of teamwork and of collaborations between schools and research and/or university institutions;
- there is a significant reduction in many misconceptions about physics that are detrimental to university orientation;
- interpersonal relationships with classmates and teachers improved.

The interviewed students expressed their wish to take part in similar experiences again, and a significant proportion believes that their experience with cosmic rays will be useful for their future studies, regardless of the university path they choose, and that it greatly increased their interest in physics.