

# Recent results from EEE and PolarquEEEst

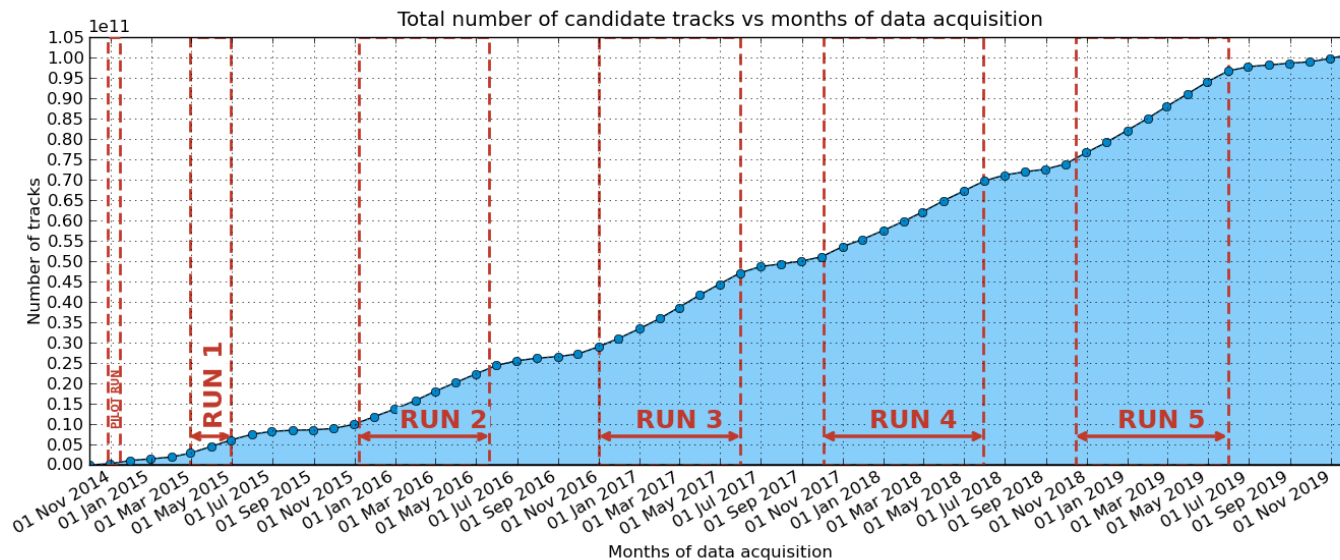
F. Noferini on behalf of the EEE Collaboration



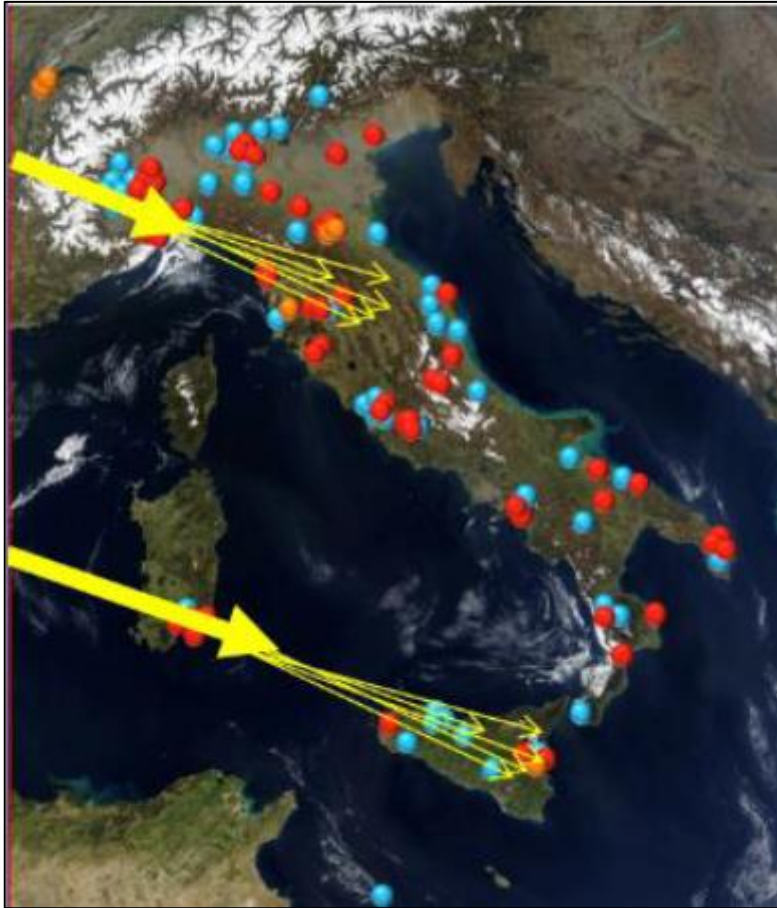
# Outline

Just a selection of recent results from EEE:

- Long distance correlations (past and future strategies)
- polarquEEEst 2018/2019 activity



# Long Distance Correlations (LDC)



## Possible physical mechanisms:

- Primaries from the same source (limited by the presence of magnetic fields)
- Interaction of a primary with the interstellar medium
- Photodisintegration of primary cosmic rays (nuclei) in the solar field (GZ effect)

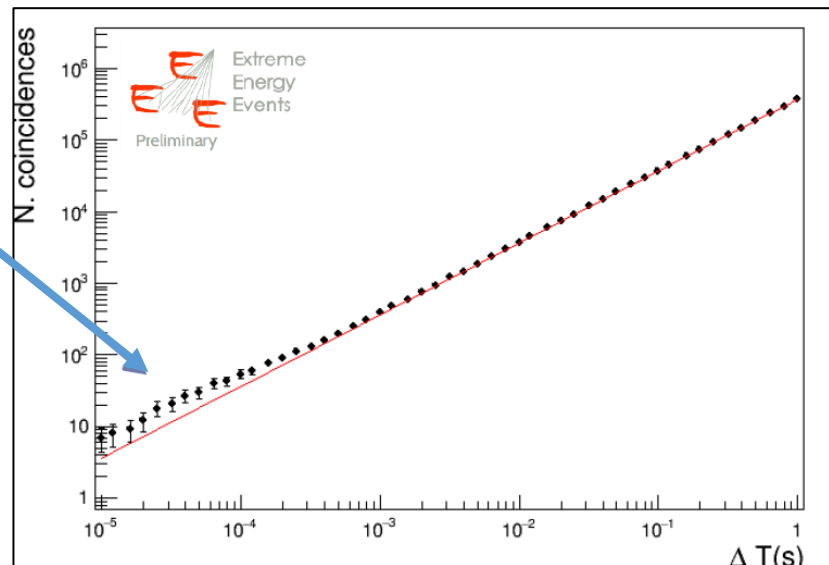
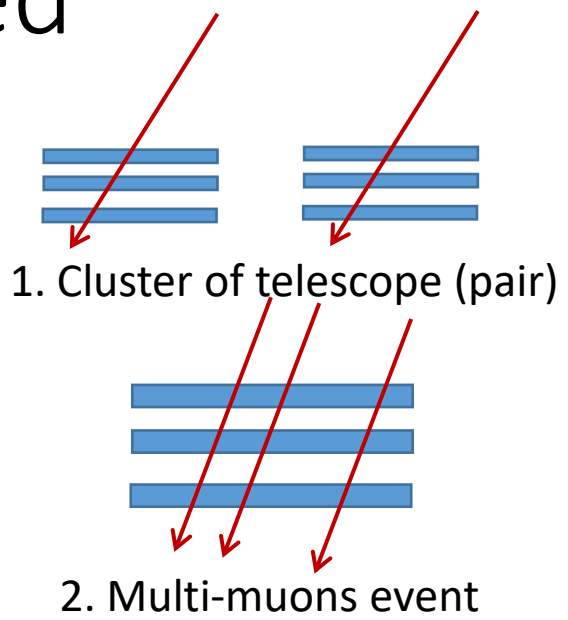
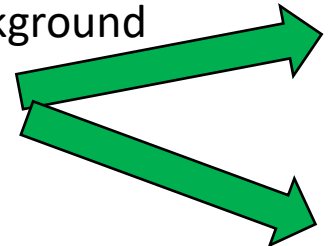
# Long Distance Correlation: different strategies

- 1. Selecting Extensive Air Shower (EAS) via coincidences between telescopes** in the same city and looking for EAS coincidences at very large distance (low background, limited number of telescopes pair)
- 2. Selecting EAS from multi-muon events with a single telescope** and looking for EAS coincidences at very large distance (background depending on the number of muons required, all telescopes available)
- 3. Looking for all possible coincidences with single muons at very large distance** (background is an issue)  
→ **multi-messenger** (triggered) analysis: external triggers allows to strongly reduce background!

So far we explore (1, published) and (2, preliminary results). (3) under investigation how to control background (e.g. by requiring  $N$ -telescopes  $> 2$ )

# LDC: (1) and (2) combined

- Rare events  $\rightarrow$  negligible combinatorial background
- Need of selective triggers: detection of EAS



Small excess of events  
observed for  $\Delta T < 10$  ms

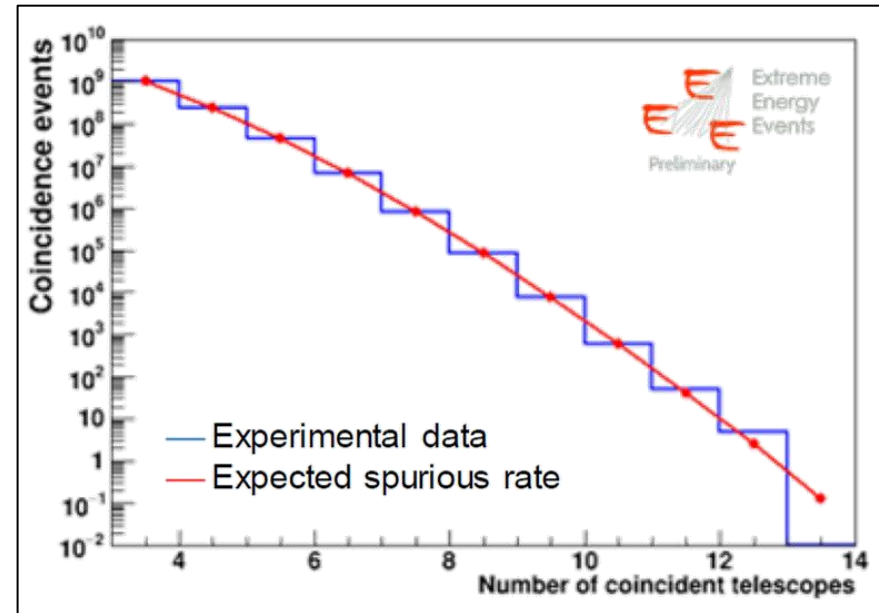
40 coincident events  
(background  $\sim 23.4$ )  
p-value  $\sim 0.001$

# LDC by correlating all muons (3)

## NEW APPROACH

- Consider all possible correlation between 2, 3, ..., N and look for events outside the expected spurious rate
- Integrate over long data taking (> months)
- So far we applied the procedure on the Run-5 data

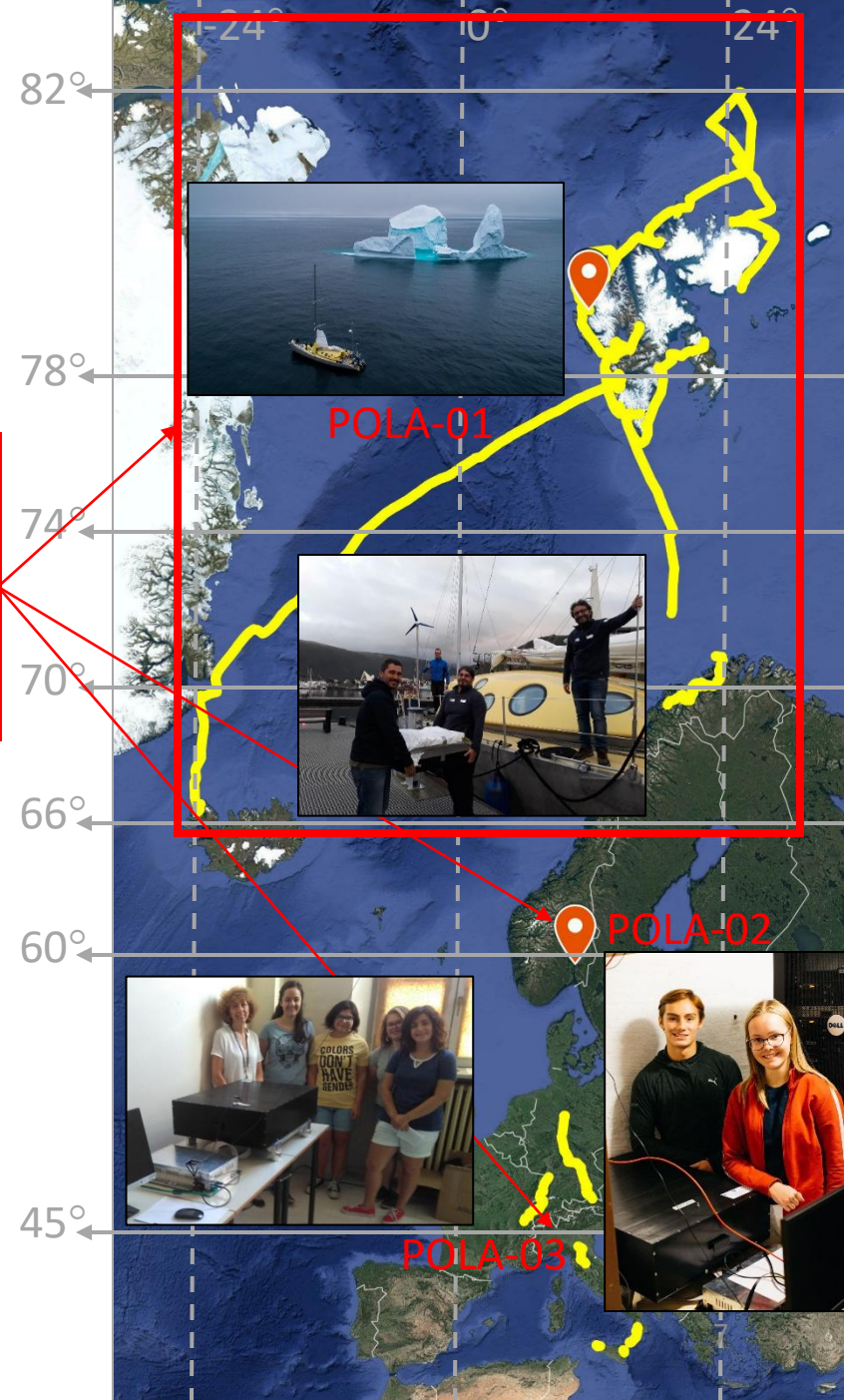
- A reasonable agreement observed between raw data and spurious expected trend over 9 order of magnitude
- An upper limit on the number of such events may be established



# PolarquEEEst trip

GOAL: Cosmic ray flux up to extreme latitude

- 2018 **PolarquEEEst2018**
  - 3 detectors (POLA-01, POLA-02, POLA-03)
  - PolarquEEEst2018 → expedition with Nanuq boat (July-September) + 2 telescopes at fixed latitude (Bra(TO), Nessoden(Norvegia))
- 2019
  - (Dec 18 – Apr 19) → measurements at several latitudes (Italy, Germany, CERN)
  - A 4° detector built (POLA-04)
  - (PolarquEEEst2019) → 3 detectors installed in Ny Ålesund (Svaldbard)



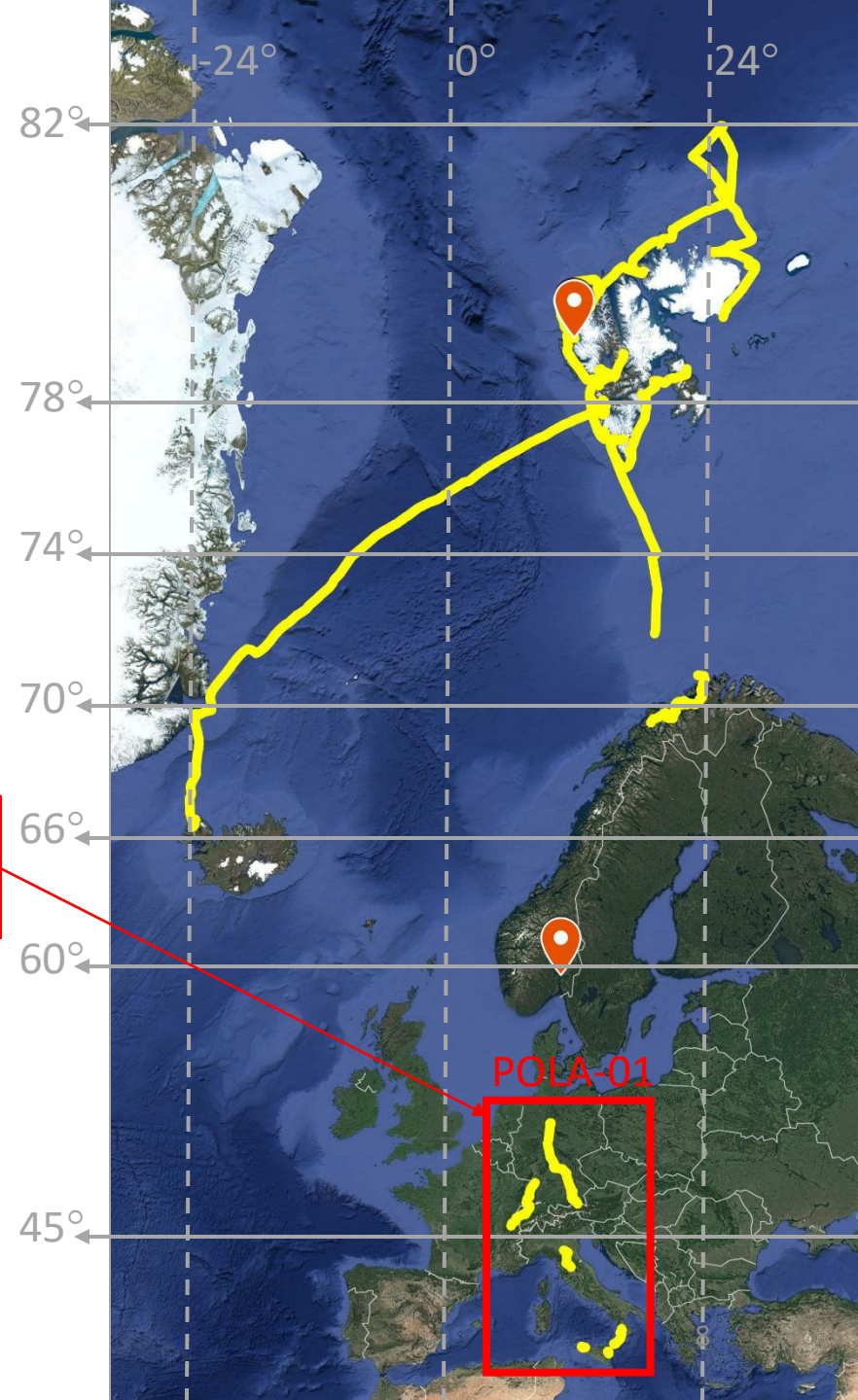
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- 2019 **Verso PolarquEEEst2019**
  - (Dec 18 – Apr 19) → measurements at several latitudes (Italy, Germany, CERN)
  - A 4<sup>th</sup> detector built (POLA-04)
  - (PolarquEEEst2019) → 3 detectors installed in Ny Ålesund (Svaldbard)



POLA-01

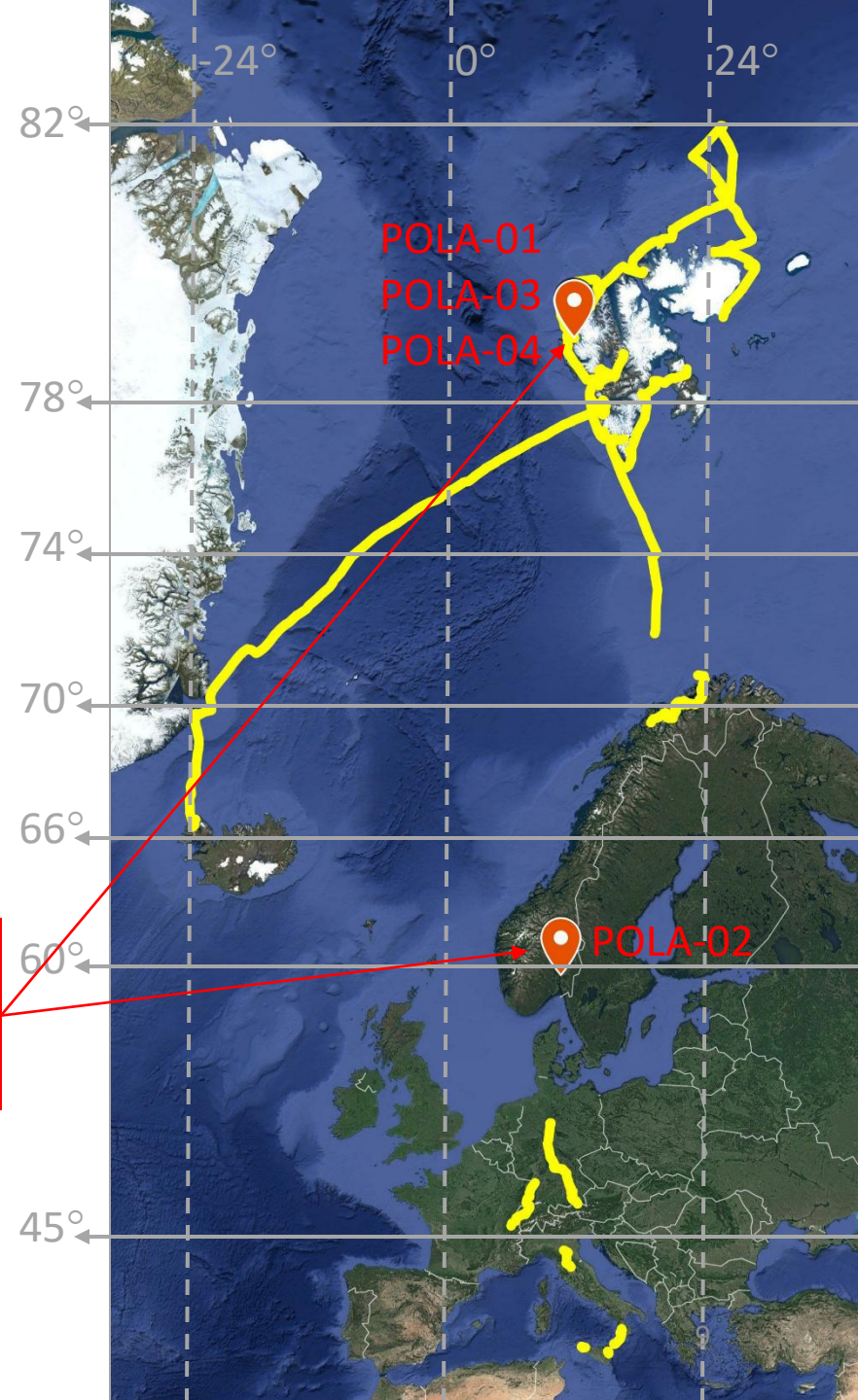


# PolarquEEEst trip

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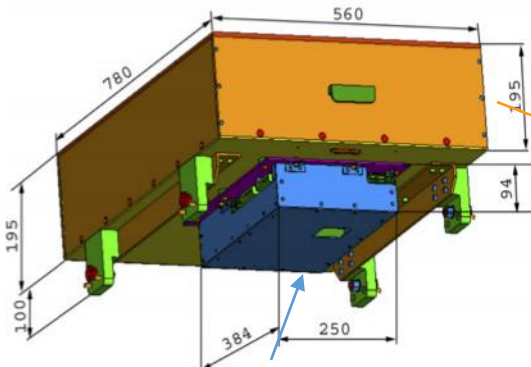
- 2018
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PolarquEEEst2019

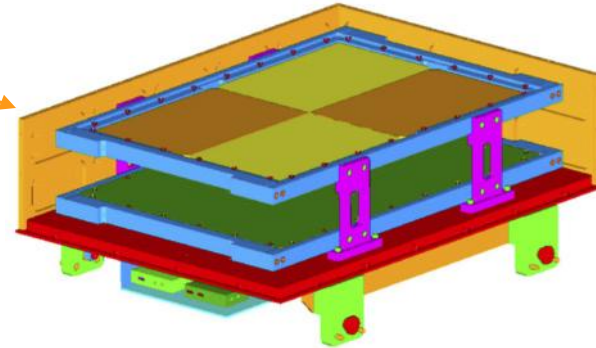


# The detector

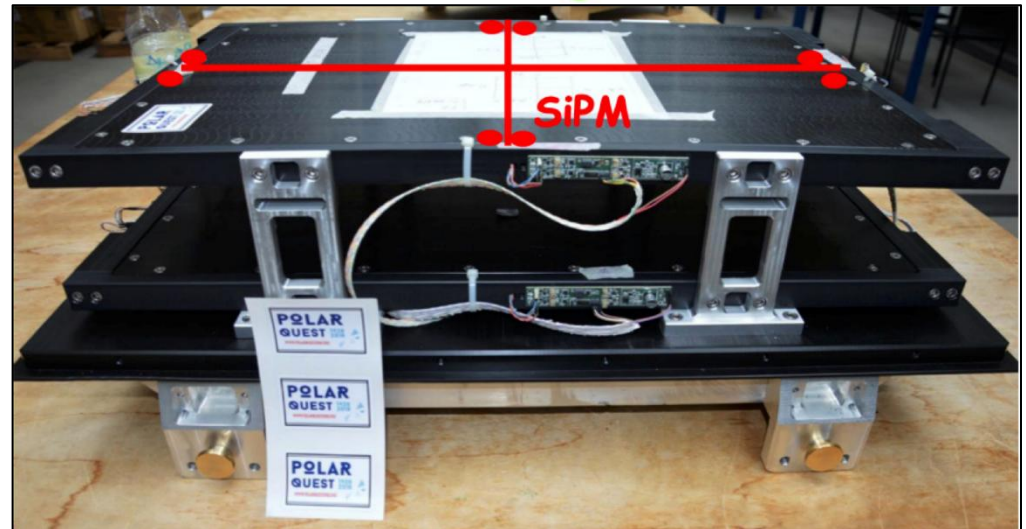
- 2 scintillator planes
- Plane distance = 11 cm
- 4 + 4 tiles: 30 x 20 cm<sup>2</sup>
- 2 SiPM per tile
- Efficiency > 96%
- Trigger condition: signal coincidence in both planes (at least 3 SiPM in total)



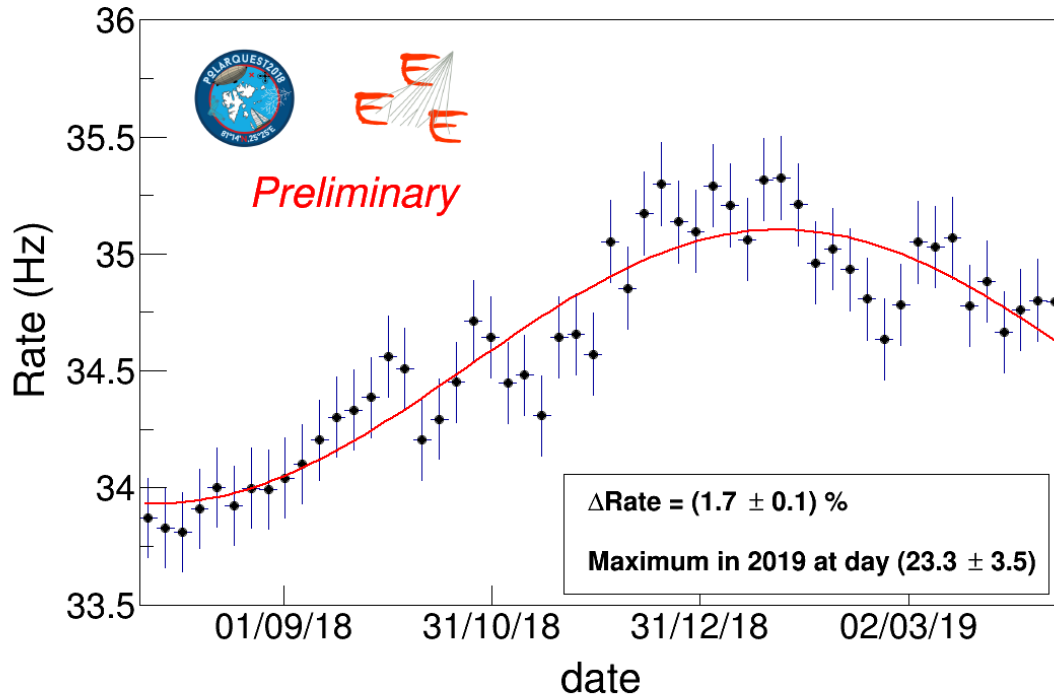
Electronic box



Students (Italy, Switzerland and Norway) at CERN



# Seasonal effect



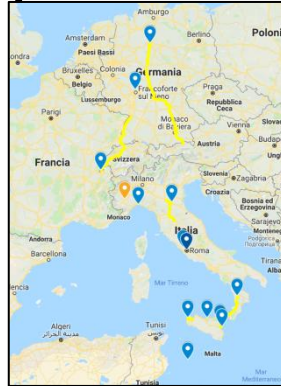
Flux at ground as measured by POLA-02 and POLA-03 (combined) vs time

2% variation along the year (seasonal effect) → consistent with previous measurements [\*].

Minimum during summer period due to temperature increase in atmosphere → volume increase → Secondaries (pion) produced at higher altitude → Muon decay favored (no effect observed with *neutron monitor*).

[\*] R. R. S. de Mendonca, The Astrophysical Journal, 830:88

# POLA-01 trip in Italy/Germany



Our stops:

- Bologna
- Vigna di Valle
- Erice
- Catania

POLA-01 on Etna



POLA-01 in Cosenza



POLA-01 in Lampedusa



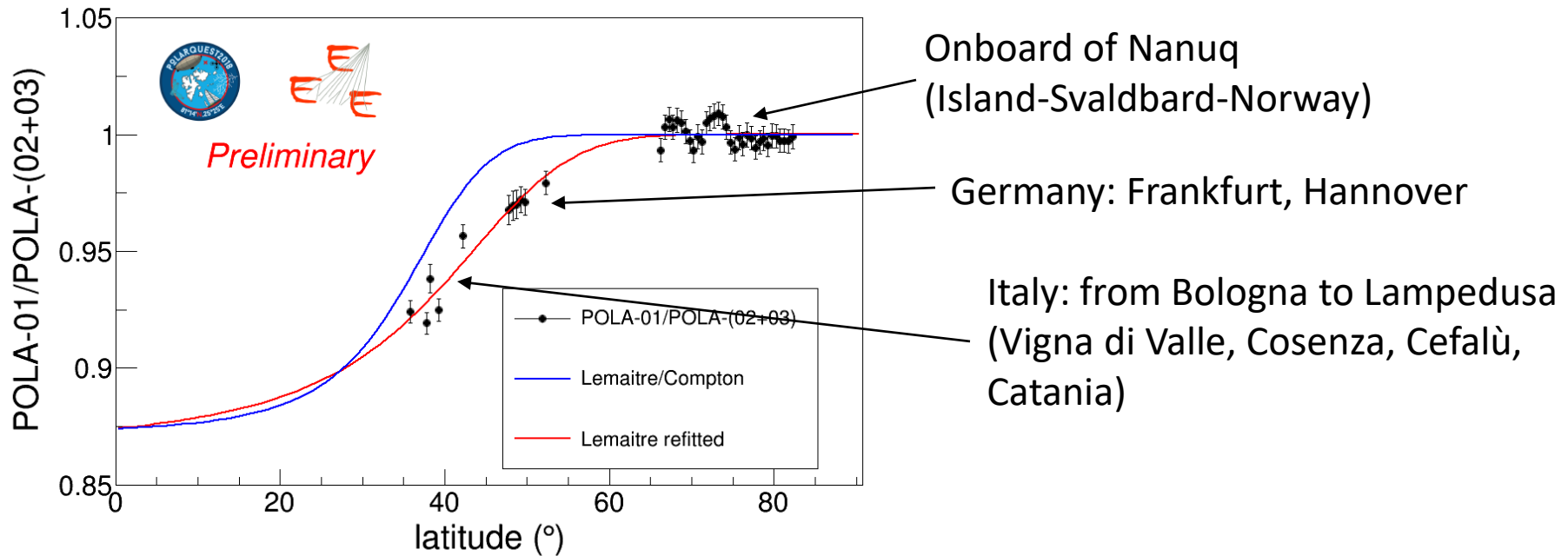
POLA-01 in Cefalù



Germany: Frankfurt, Hannover



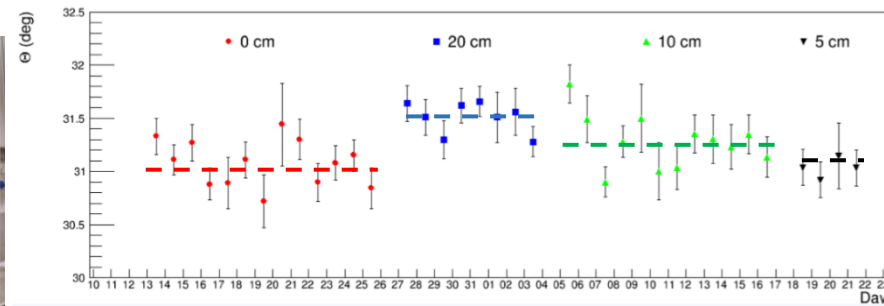
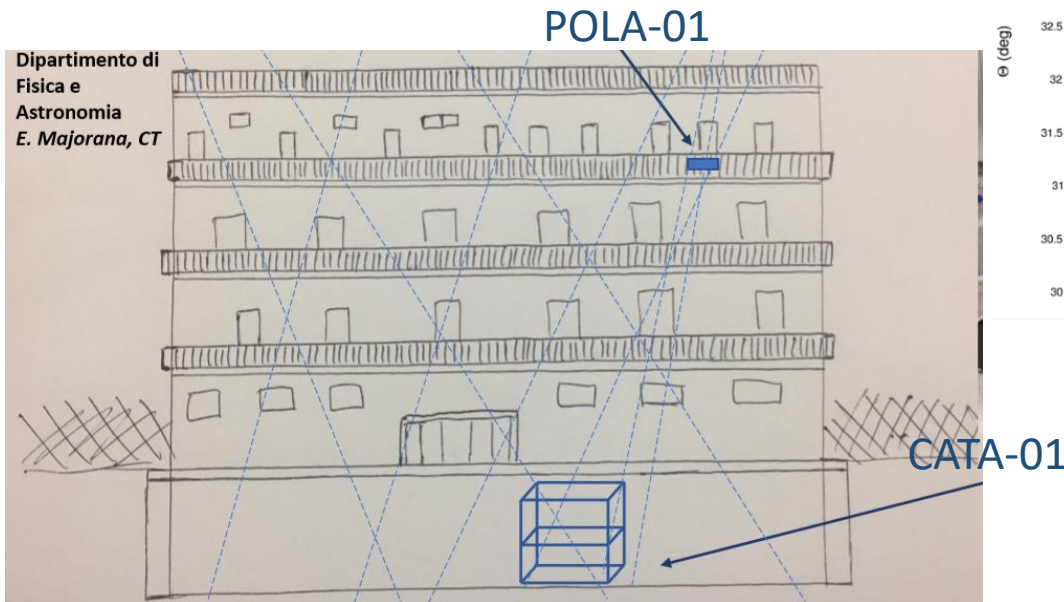
# CR flux vs latitude



CR flux as a function of latitude.  
Normalized to POLA-02 e POLA-03 to subtract  
seasonal effects

# More on POLA-01 trip...

During its trip the polar detector (POLA-01) visited Catania. Several vertical coincidences between POLA-01 and one EEE telescope in Catania University were measured.



Sensitivity at 2.5 m:

- few cm in 1 day data taking
- few mm in few months data taking

Such campaign of measurements allowed to demonstrate the capability of POLA-EEE telescopes to monitor the stability of civil structure on a long-time scale.

# PolarquEEEst2019@Ny Ålesund



# Installation at Ny Ålesund



The force Polar landed in Ny Ålesund

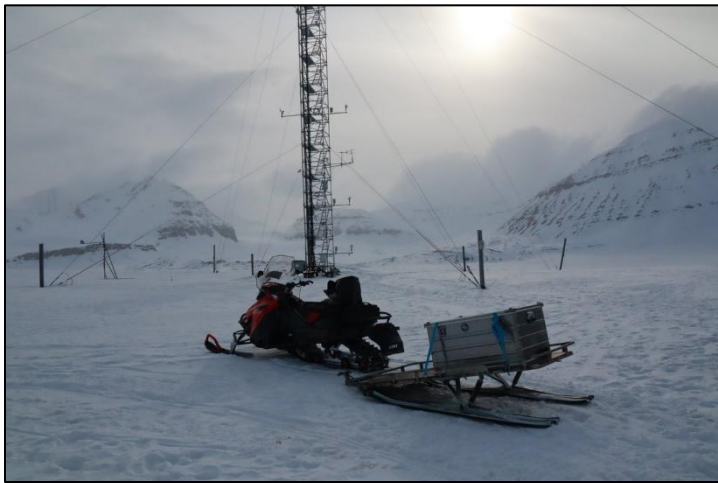


“Dirigibile Italia” station with CNR staff

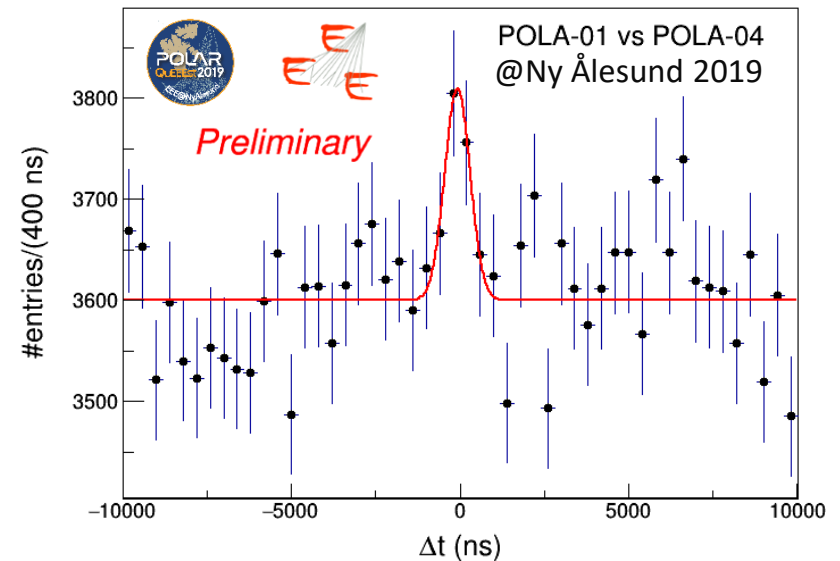
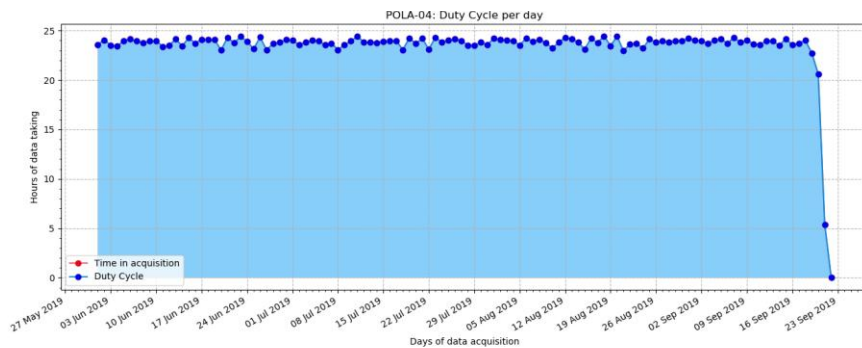
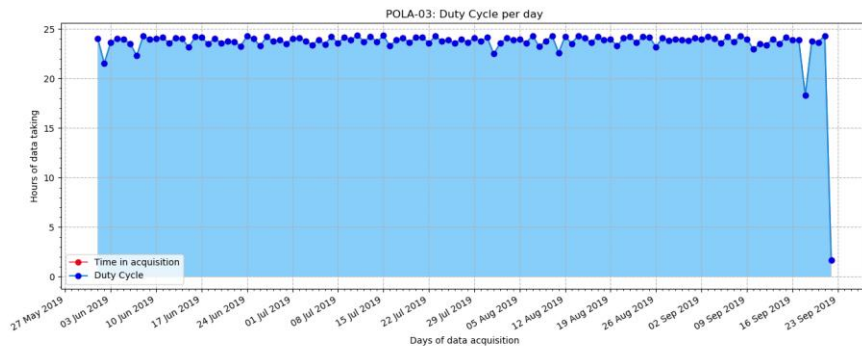
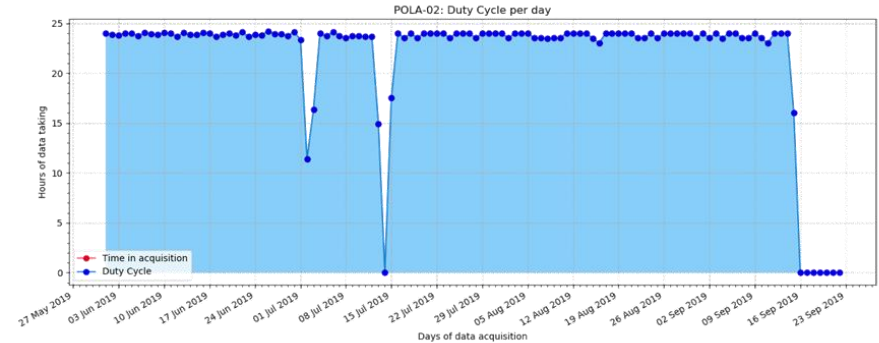
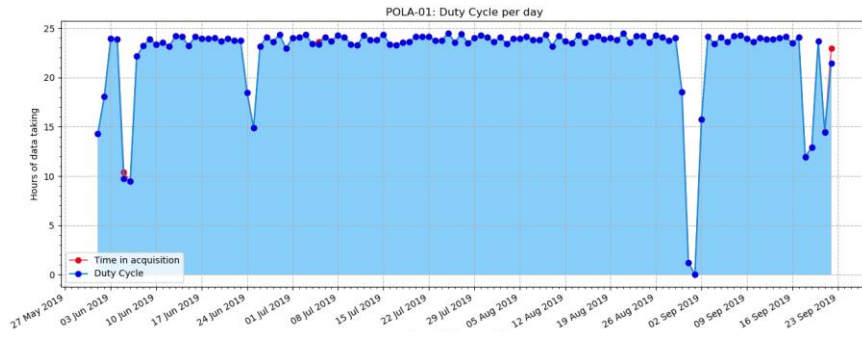


POLA-01 towards the “Climate Change Tower” CNR





# First 3 months of data taking



THANKS FOR YOUR ATTENTION!!!!

← POLA-01



MUSEO  
STORICO DELLA FISICA  
E  
CENTRO  
STUDI E RICERCHE  
ENRICO FERMI



# Recent publications

2019

- Panetta M.P. et. al. (EEE Collaboration), [\*The new trigger/GPS module for the EEE project\*](#), Nuclear Instruments and Methods in Physics Research A936 (2019) 376, doi: 10.1016/j.nima.2018.10.127.
- Abbrescia M. et. al. (EEE Collaboration), [\*The EEE MRPC telescopes as tracking tools to monitor building stability\*](#), Journal of Instrumentation 14 (2019) C05022, doi: 10.1088/17480221/14/06/P06035.
- Abbrescia M. et. al. (EEE Collaboration), [\*Performance of the Multi-gap Resistive Plate Chambers of the Extreme Energy Event experiment\*](#), Journal of Instrumentation 14 (2019) C05022, doi: 10.1088/1748-0221/14/05/C05022.

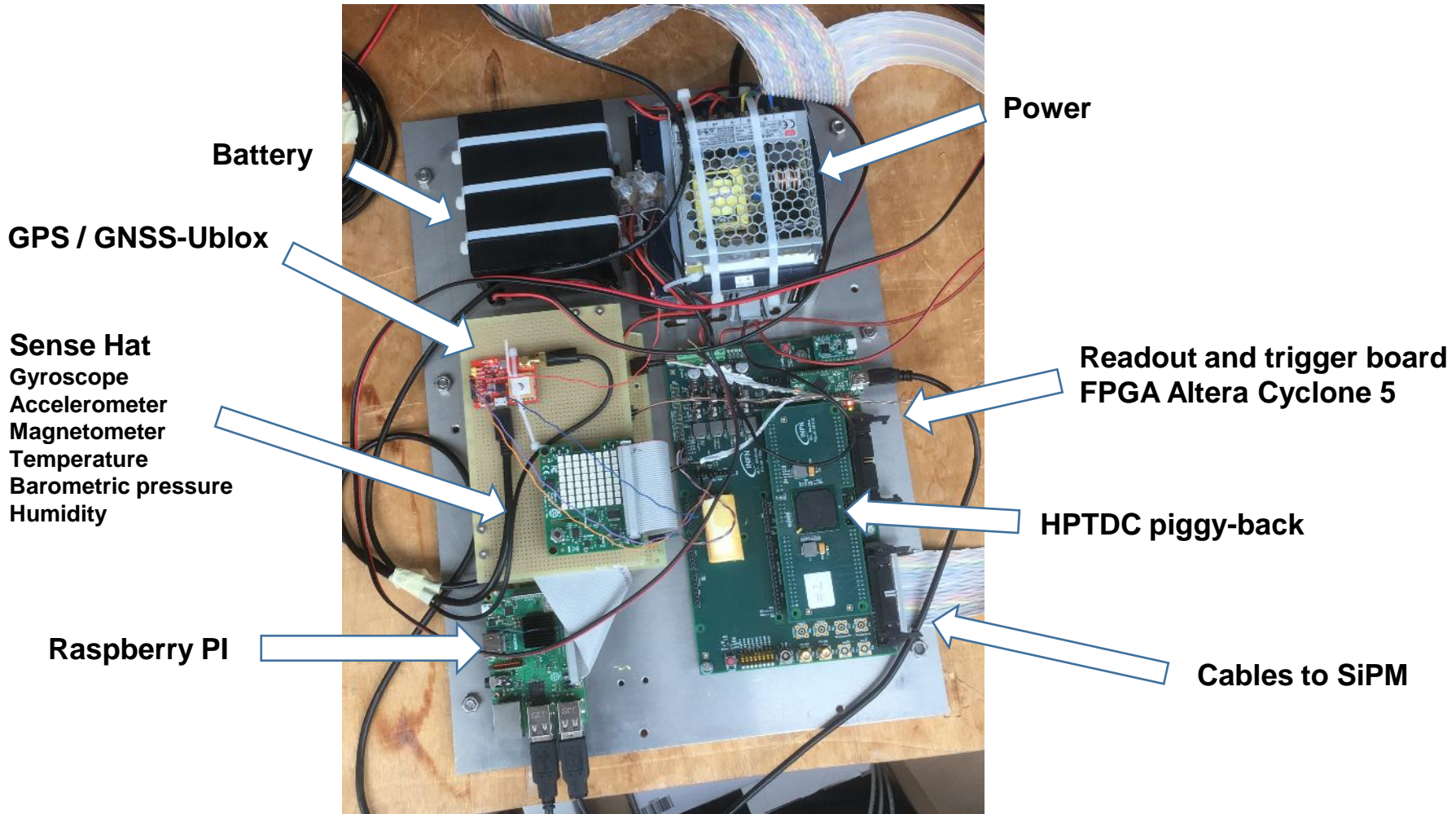
2018

- Nania R., Pinazza O. (EEE Collaboration), [\*Measuring cosmic ray showers near the North Pole with the Extreme Energy Events project\*](#), Il Nuovo Saggiatore - Bollettino della Società Italiana di Fisica, Nuova Serie Anno 34 • N. 5 Settembre-Ottobre 2018 • N. 6 Novembre-Dicembre 2018.
- EEE Collaboration, [\*Search for long distance correlations between extensive air showers detected by the EEE network\*](#), Eur. Phys. J. Plus (2018) 133: 34.

+ several contributions to conference proceedings

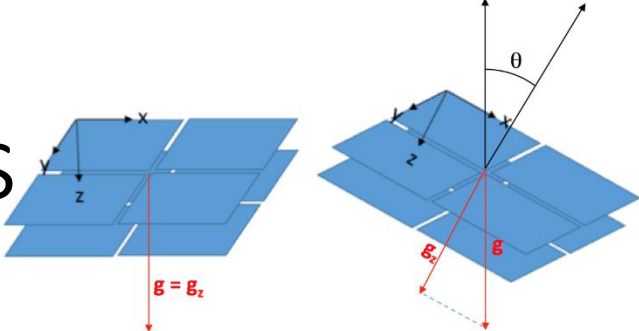
backup

# Electronics (readout, trigger)



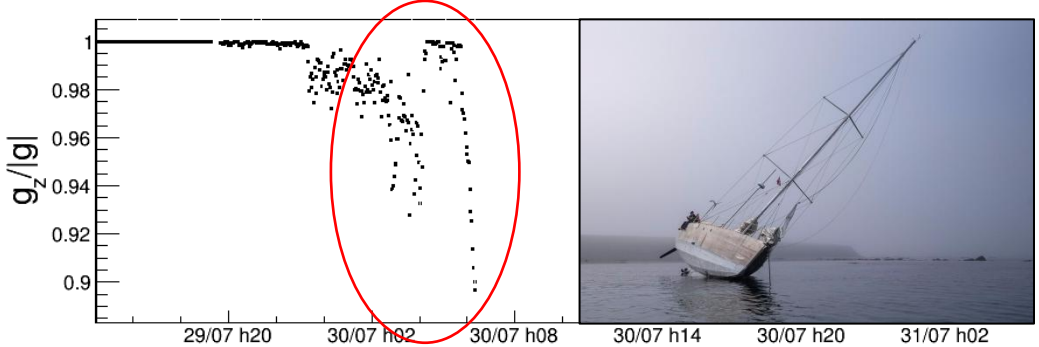
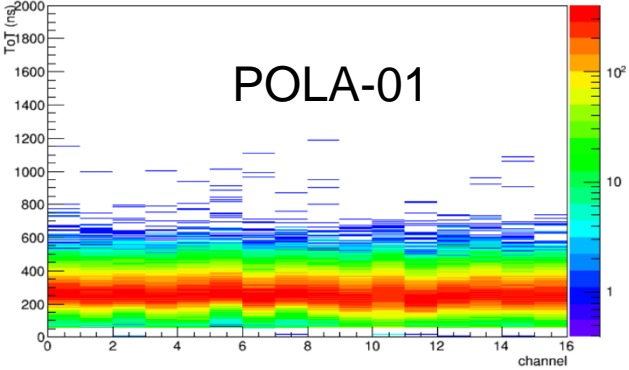
**Total power consumption ~ 12,5 W**

# Detector performances



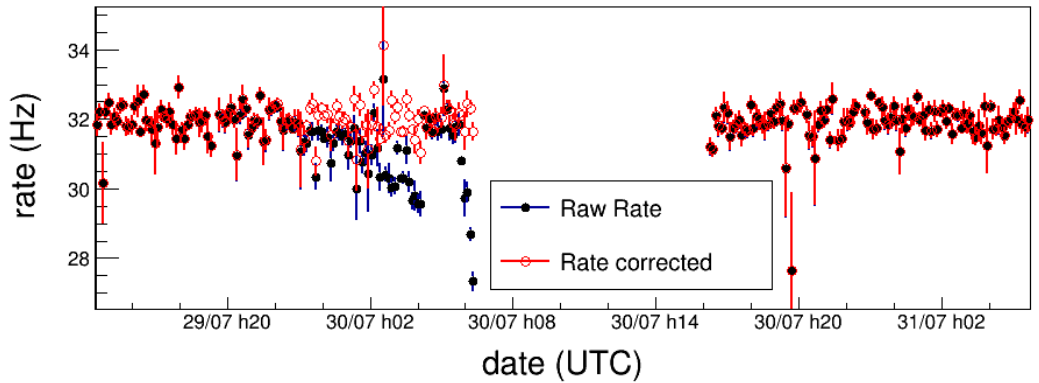
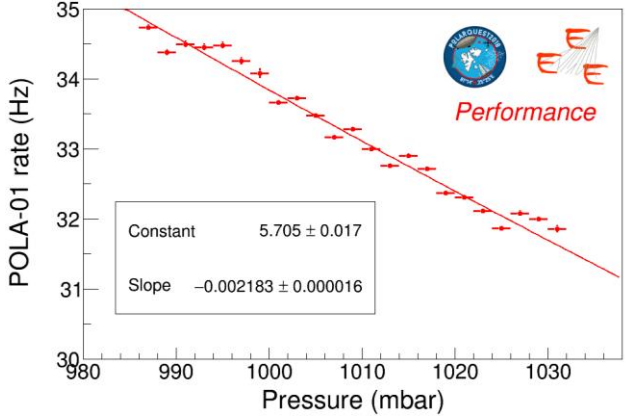
Correction for inclination (POLA-01)

Channel equalization



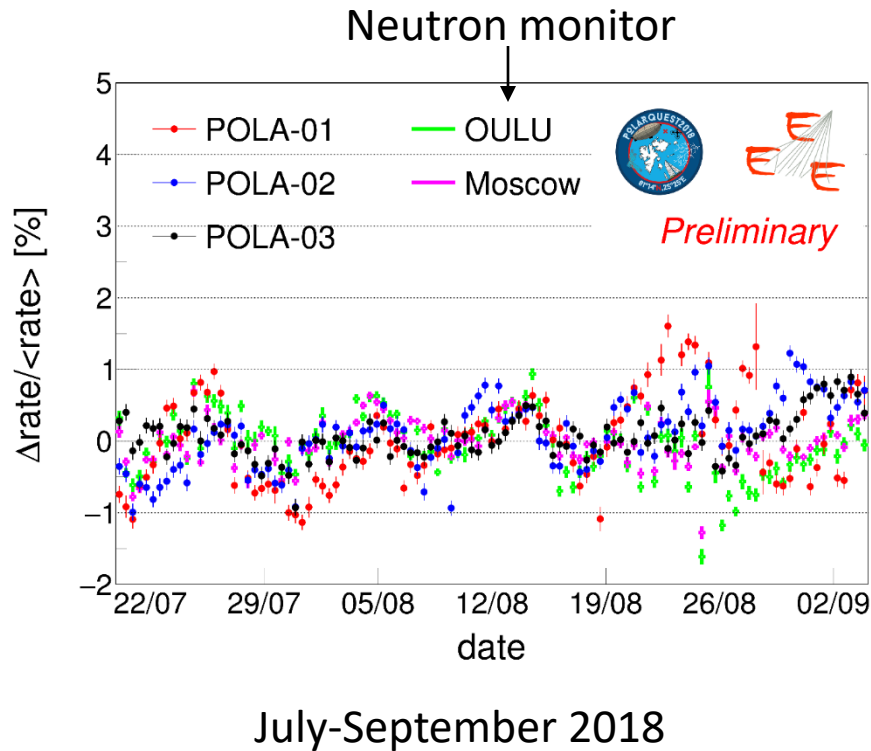
“calibration run” during low tide on 30/07/18

Pressure correction

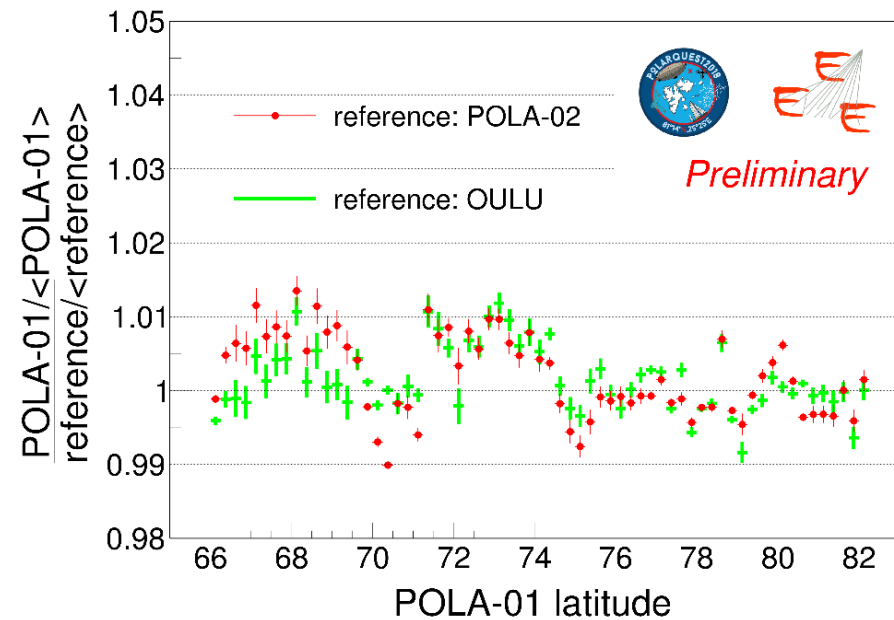




# PolarquEEEst2018



Constant flux from 66° to 82° N.

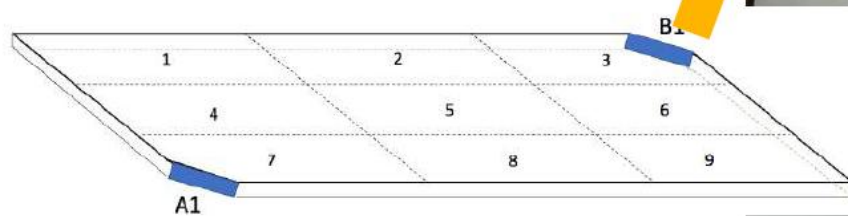
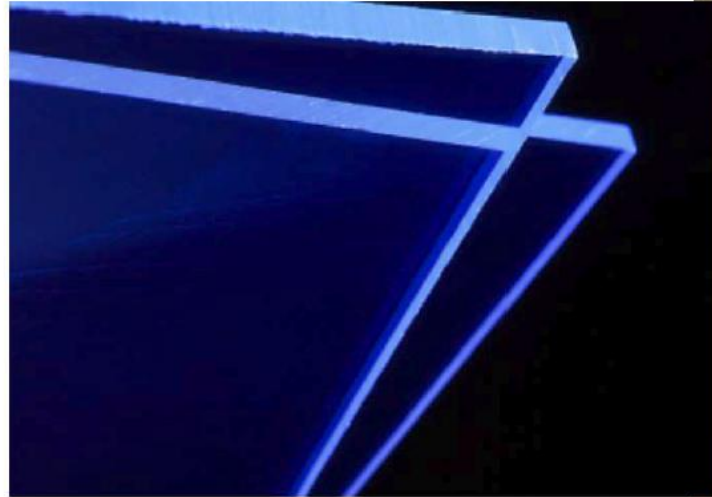
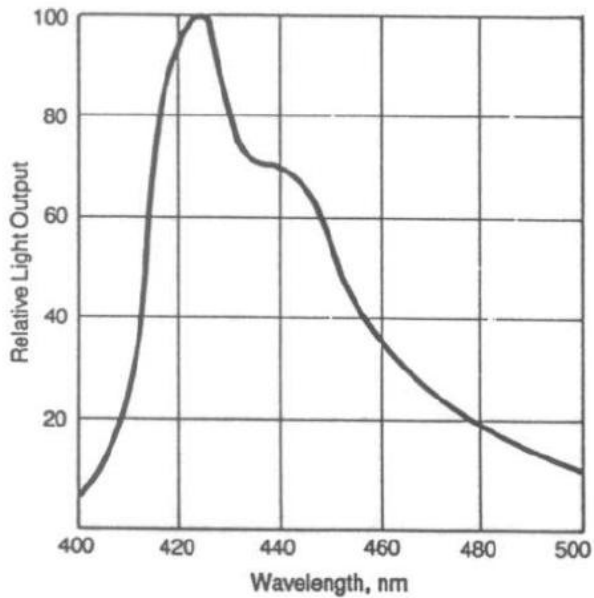




# Scintillators

SAINT GOBAIN BC-400  
20 cm x 30 cm x 1 cm

BC-400



# DAQ Control



## pola-01 DAQ Control

Start DAQ Stop DAQ

### Run Configuration

Parameter	Current value	New value
Number of buffers per run	50000	50000
Number of contiguous runs	1000000	1000000
Sensors sampling interval [seconds]	30	30
Maximum run time [seconds]	3600	3600
Trigger mask of the top plane	0	0
Trigger mask of the bottom plane	0	0
Enable the calibration run	0	0

Apply Reset

### Log

```
INFO | 2019-07-07 09:53:39 | Initial MET = 394883619.792
INFO | 2019-07-07 09:53:39 | Opening sensor run name Data/2019-07-07/POLA-01-2019-07-07-394883619_slo.txt
INFO | 2019-07-07 09:53:39 | Opening event run name Data/2019-07-07/POLA-01-2019-07-07-394883619.bin
INFO | 2019-07-07 09:53:39 | Check TRB Status : (0L,,0L,)
INFO | 2019-07-07 09:53:39 | btrc0: 0
INFO | 2019-07-07 09:53:39 | btrc1: 0
INFO | 2019-07-07 09:53:39 | current TRB SD card size = 0
INFO | 2019-07-07 09:57:02 | Now at event 5000 / 50000 Elapsed time 202.787508
INFO | 2019-07-07 10:00:28 | Now at event 10000 / 50000 Elapsed time 408.22112
```

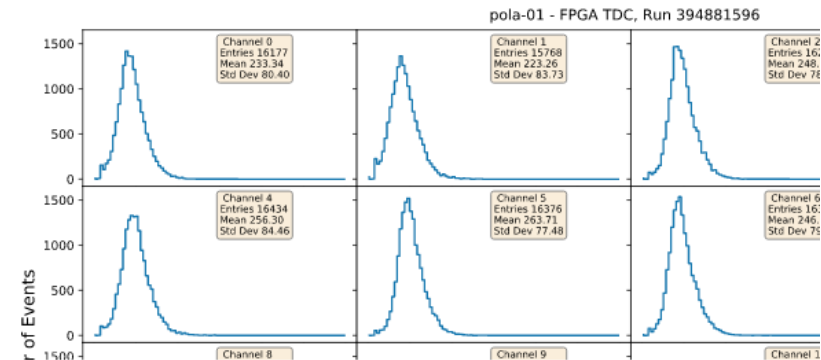


## pola-01 Monitor



Status: running  
 Since: Tue Jun 25 2019 11:28:22 GMT+0200 (Central European Summer Time)  
 Run start: Sun Jul 07 2019 11:53:39 GMT+0200 (Central European Summer Time)  
 Run duration: 446 seconds  
 Current file name: /home/pi/Polar/Data/2019-07-07/POLA-01-2019-07-07-394883619.bin   
 Current file buffer size: 1967824  
 Current file size: 0  
 Trigger rate: **35.42 Hz**  
 Approximate run completion:

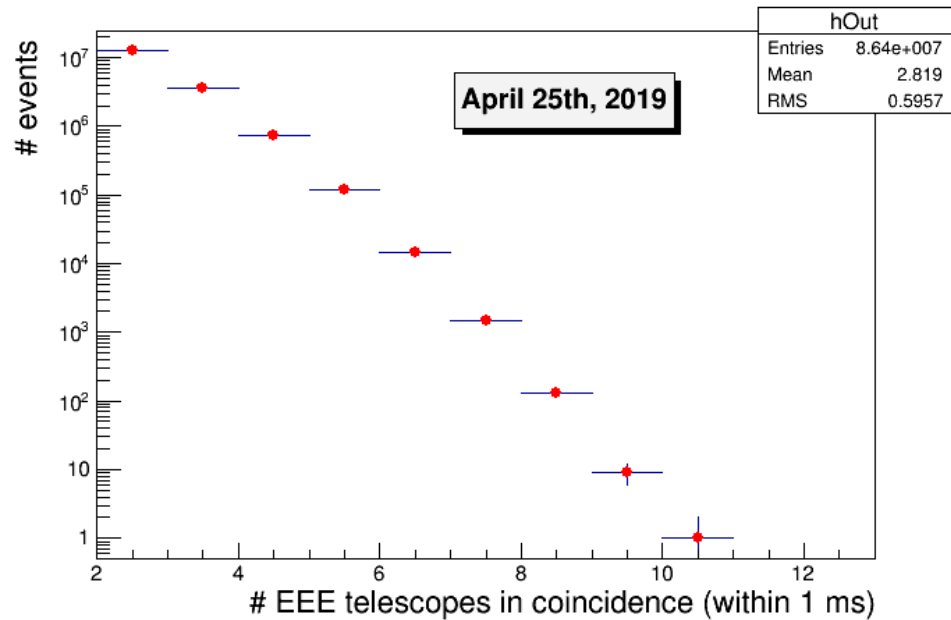
### Previous run plots



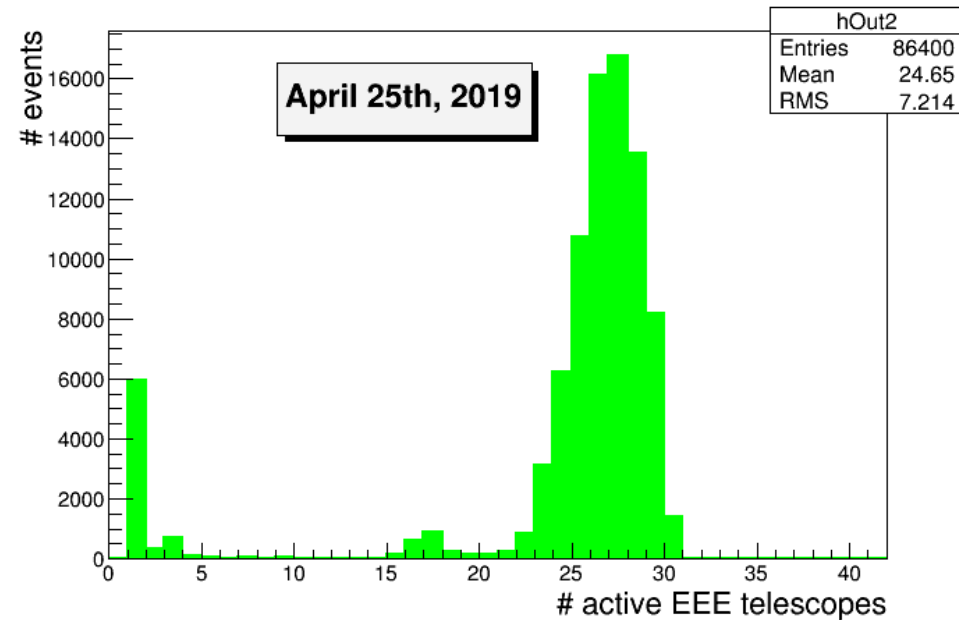
### Log

```
INFO | 2019-07-07 09:53:37 | Setting time 20190707 09:53:36 time.struct_time(tm_year=2019, tm_mon=7, tm_mday=7, tm_hour=9, tm_min=53, tm_sec=36, tm_wday=0, tm_yday=190)
INFO | 2019-07-07 09:53:36 | Sun Jul 7 09:53:36 UTC 2019
INFO | 2019-07-07 09:53:39 | 2019-07-07 09:53:39.791994
INFO | 2019-07-07 09:53:39 | Initial MET = 394883619.792
INFO | 2019-07-07 09:53:39 | Opening sensor run name Data/2019-07-07/POLA-01-2019-07-07-394883619_slo.txt
INFO | 2019-07-07 09:53:39 | Opening event run name Data/2019-07-07/POLA-01-2019-07-07-394883619.bin
```

# Neutrons stars fusion on 25th April 2019



Looking for anomalous signals in the EEE network



# Outreach

La Repubblica 06/03/2019



Video PolarQuEEEst2019 facebook Centro Fermi: <https://www.facebook.com/pg/centrofermi.it/videos/>

## Lab La scienza in classe

Il banco di prova  
Quel ragazzi a caccia di raggi cosmici

Gli studenti di un liceo scientifico di Cosenza sono al centro di un progetto che coinvolge centinaia di scuole in tutta Italia

Il ingresso del liceo scientifico "Scorza" di Cosenza è un luogo di incontro tra la scienza e la cultura. È qui che si svolge il progetto "PolarQuEEEst2019".

Il progetto "PolarQuEEEst2019" è un progetto di citizen science che coinvolge centinaia di scuole in tutta Italia.

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**Un telescopio per rilevare i muoni**  
I risultati condivisi in videoconferenza

**Il racconto del prof**  
Il nostro robot vive nella realtà aumentata per studiare la geografia

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45  
La Repubblica  
16 marzo 2019  
R  
SCUOLA

asimmetrie.it  
rivista dell'Istituto Nazionale di Fisica Nucleare

las] spazi  
Tre E in barca.  
<https://www.asimmetrie.it/as-spazi-tre-e-in-barca>

Video PolarQuEEEst2019 facebook Centro Fermi: <https://www.facebook.com/pg/centrofermi.it/videos/>

## Studiare i raggi cosmici dalla base di ricerca più a nord del mondo

Aldo ai confini della terra per fare ricerca sulle frasi della scienza. È qui che si svolge il progetto "PolarQuEEEst2019".

## EEE, PolarQuEEEst2019 e la Citizen Science

I ricercatori del progetto PolarQuEEEst2019 sono stati impegnati a più consueti. Il loro risultato è stato un computer, una estensione appogge per la raccolta di dati e un software per l'analisi dei dati.

## PolarQuEEEst2019

Il team di ricercatori del Centro Fermi ha provveduto all'installazione dei rivelatori a Ny-Alesund.