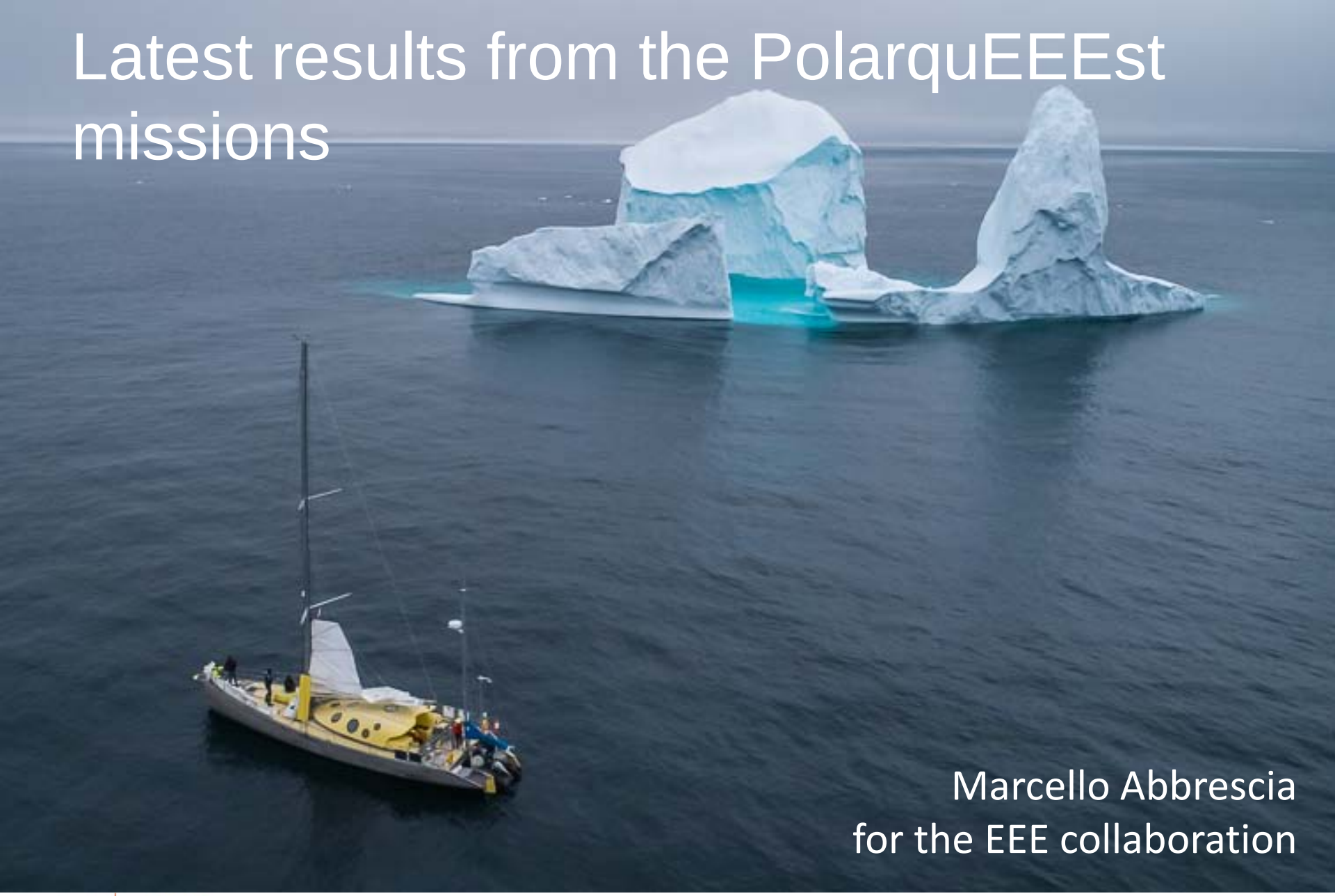
Latest results from the PolarquEEEst missions



Marcello Abbrescia
for the EEE collaboration

ONLINE ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany
37th International Cosmic Ray Conference
12–23 July 2021

Extreme Energy Events
Science inside Schools

POLARQUEST2018
POLAR QUEEEST 2019
EEE@NyAlesund

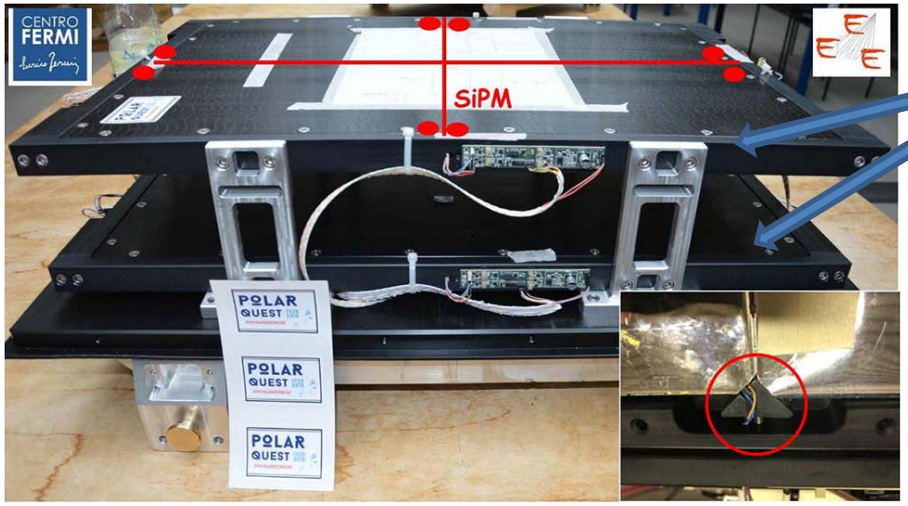
The Trip

The **Polarquest2018** expedition set sail on board the boat Nanuq on July 22, 2018 from Isafjordur and ended in Tromso on September 3.

Experiments hosted on board:
✓ Mapping of unchartered zones in north Svalbard archipelago.
✓ Measurements of the concentration of microplastics in the Polar Arctic sea water.
✓**Measurement of cosmic rays: PolarquEEEst2018.**

PolarquEEEst2018 included:
- **1 detector on board** Nanuq (POLA-01)
- **2 reference detectors** at Nessoden (Oslo) (POLA-02) and Bra (TO) (POLA-03)

The PolarquEEEst2018 detector

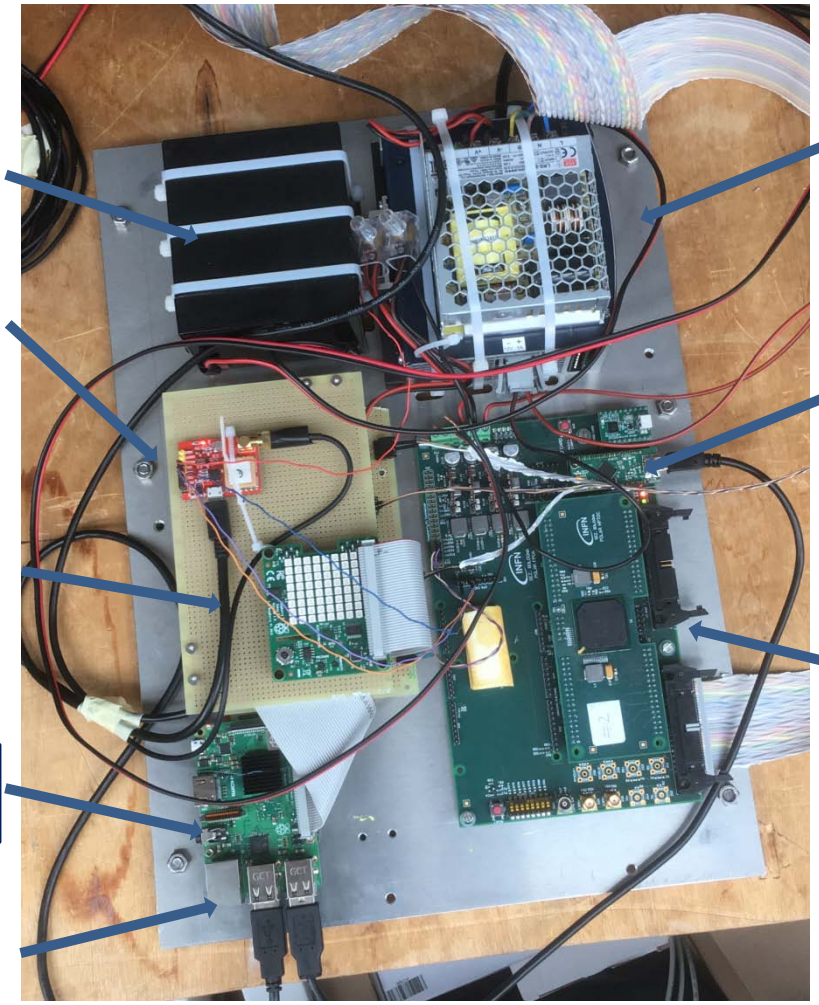


Two **scintillator planes**
- four 30 x 20 cm^2 tiles each;
- tiles read by **2 SiPMs each**;
- separated by 11 cm;
- at least coincidence of 3 SiPMs signals for triggering.

The detector on the sailboat Nanuq was designed to fulfill requests on:
- dimensions and weight ≈ 70 kg;
- **power consumption < 15 W**;
- **robustness and reliability;**
- efficiency > 90%;
- tag events at 20 ns precision (GPS).

The detector was positioned inside a tight light box and mounted on the deck of the Nanuq sailboat.

The PolarquEEEst detector electronics



Back-up Battery

GPS
GNSS-Ublox

Sense Hat
Gyroscope
Accelerometer
Magnetometer
Temperature
Barometric pressure
Humidity

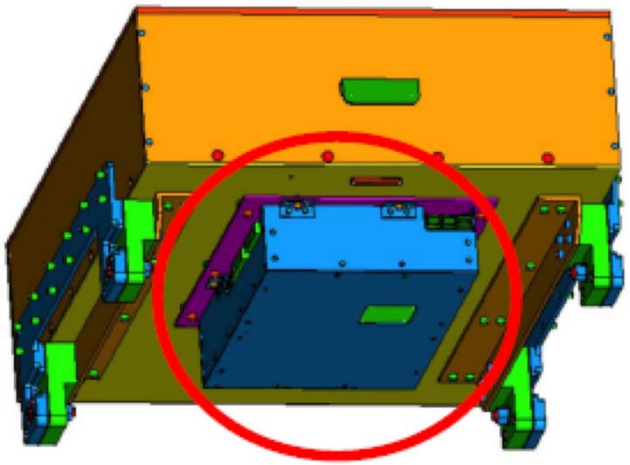
Raspberry PI
Control readout

GPS
GNSS-Ublox

Power box

Readout board
FPGA Altera Cyclone 5
For Trigger and TDC readout

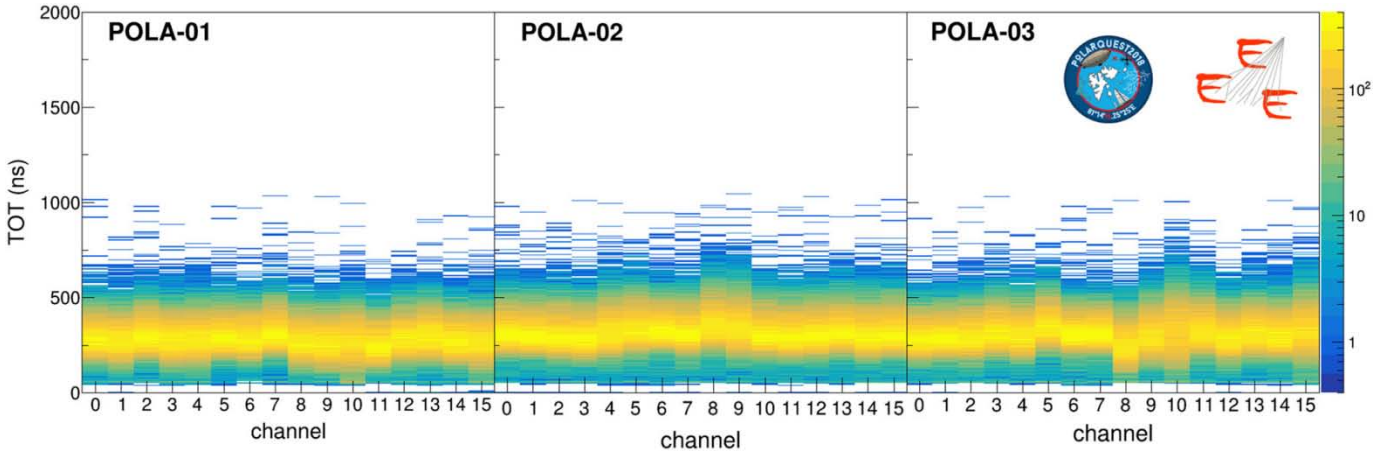
HPTDC piggy-back
for TDC readout



- ✓ Overall power **consumption:12-13 W**;
- ✓ data stored on SSD memory or transmitted via internet;
- ✓ electronics in an aluminum box below the detector.

Detector calibration and testing

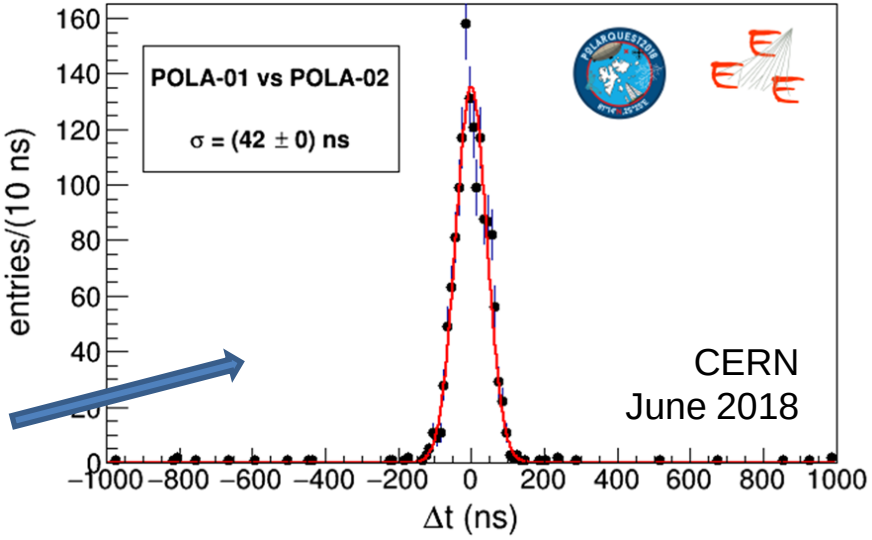
Before installation on the Nanuq, the POLA detectors were **calibrated** and extensively tested at CERN.



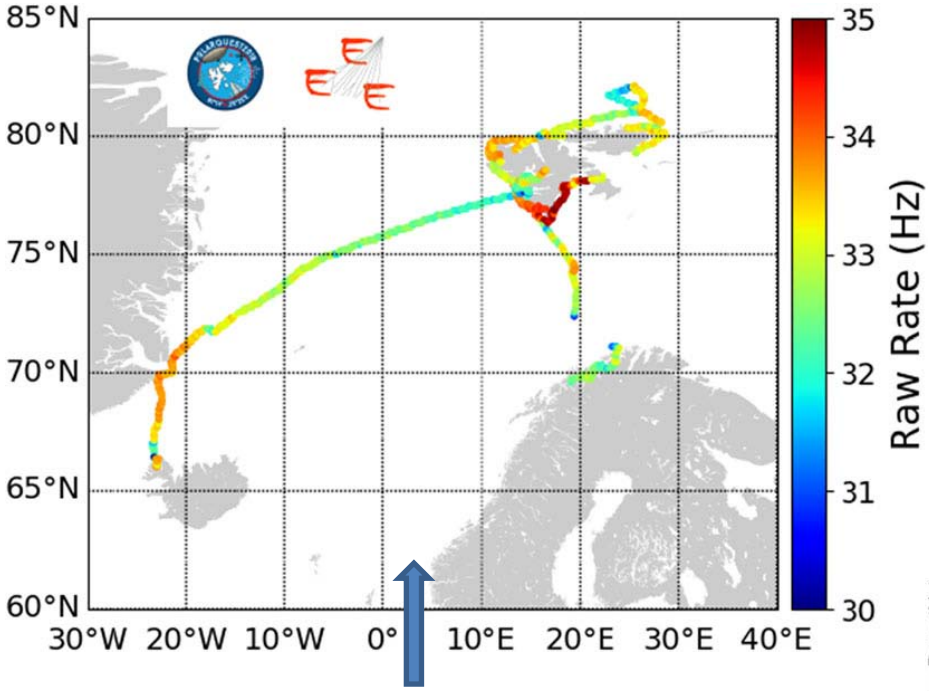
Time Over Threshold (TOT) distributions after equalization (each bin represents one SiPM)

Thanks to the GPS, the POLA detectors can be used, when located close to one another, to reveal small **Extensive Atmoshperic Showers**.

Time coincidences between POLA-01-POLA-02 (≈ 2 m apart), at CERN, during 11 hours data taking. Peak width due to **detector time resolution** and uncertainity in the **shower arrival direction**.



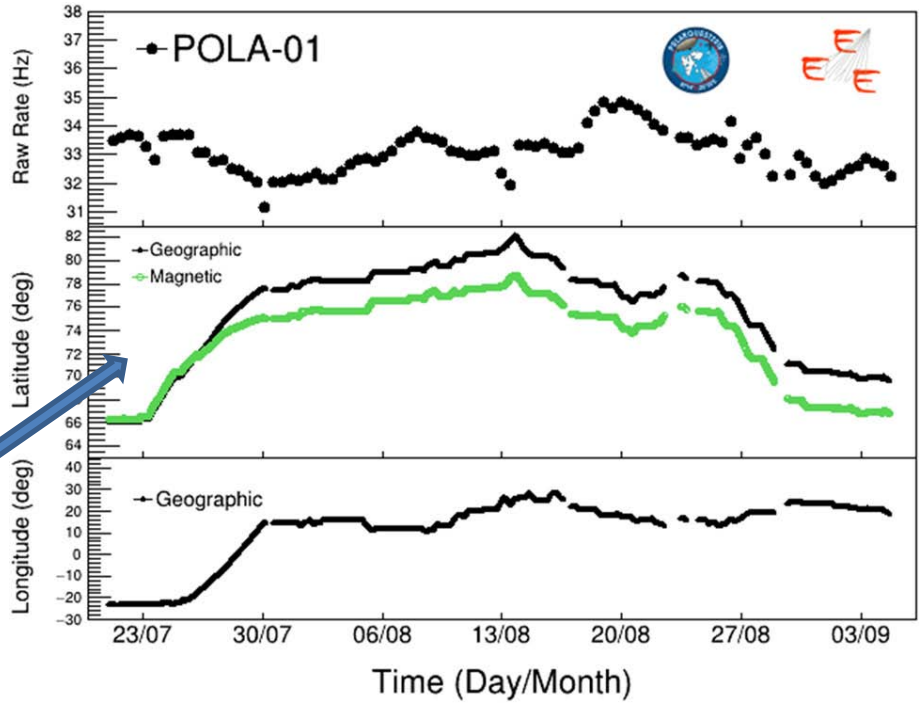
Data taking and raw results



POLA-01 raw rate on a chart: apparently a **rate increase** observed close to the **south shores** of the Svalbard archipelago.

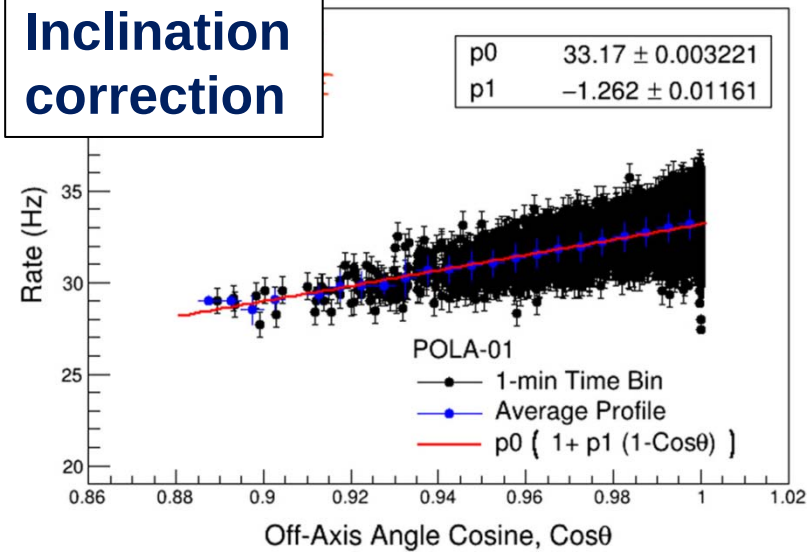
POLA-01 raw rate, geographic and magnetic latitude, vs. time: **no correlation** clearly evident.

- ✓ Nanuq sailed for 45 days. covering about **3500 nautical miles;**
- ✓ POLA-01 took data almost continuously for about **984 hours;**
- ✓ POLA-01 duty cycle**:** **≈ 91%** (difficult weather conditions leading to power down and detector reset):
- ✓ > **100.000.000 muon tracks** collected

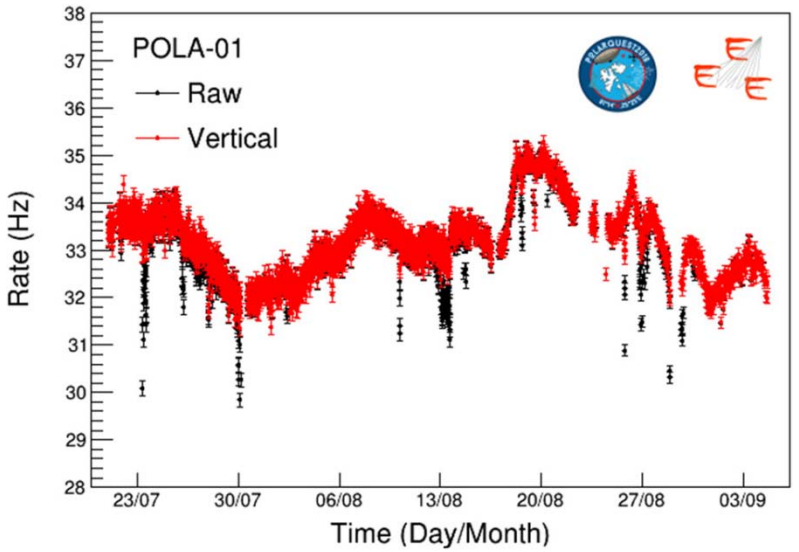


Corrections to the raw data

Inclination correction

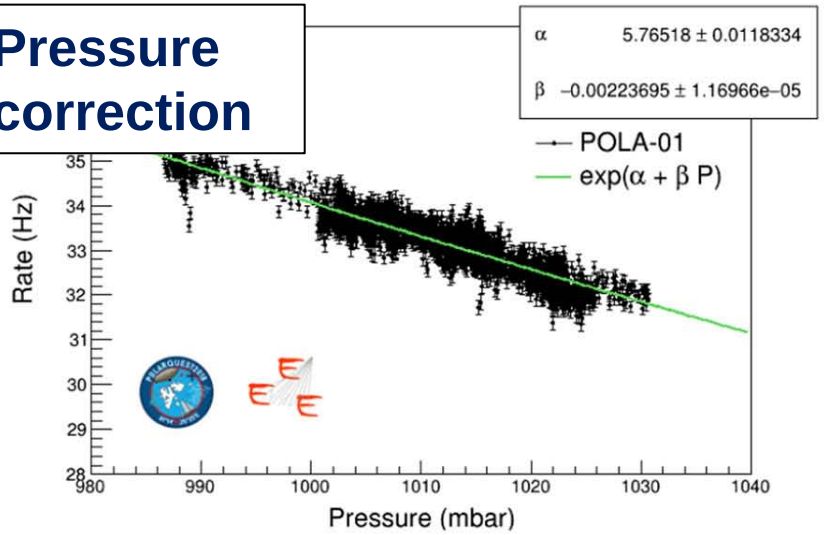


POLA-01 rate vs. wrt. vertical

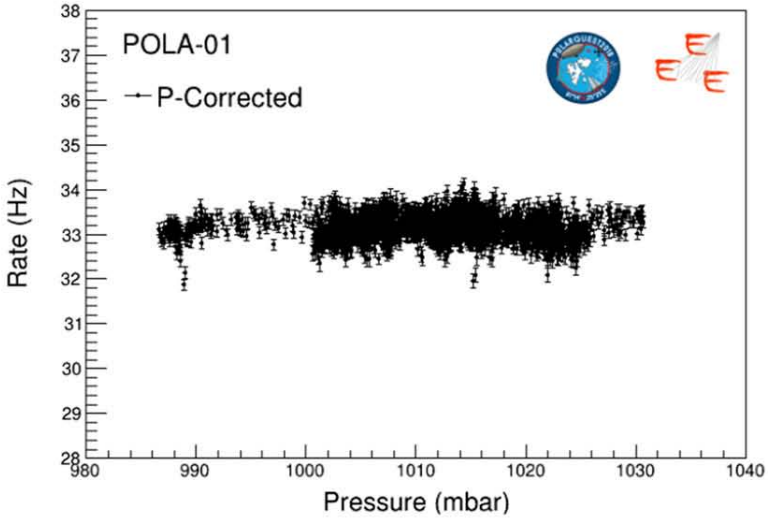


POLA-01 rate after inclination correction

Pressure correction



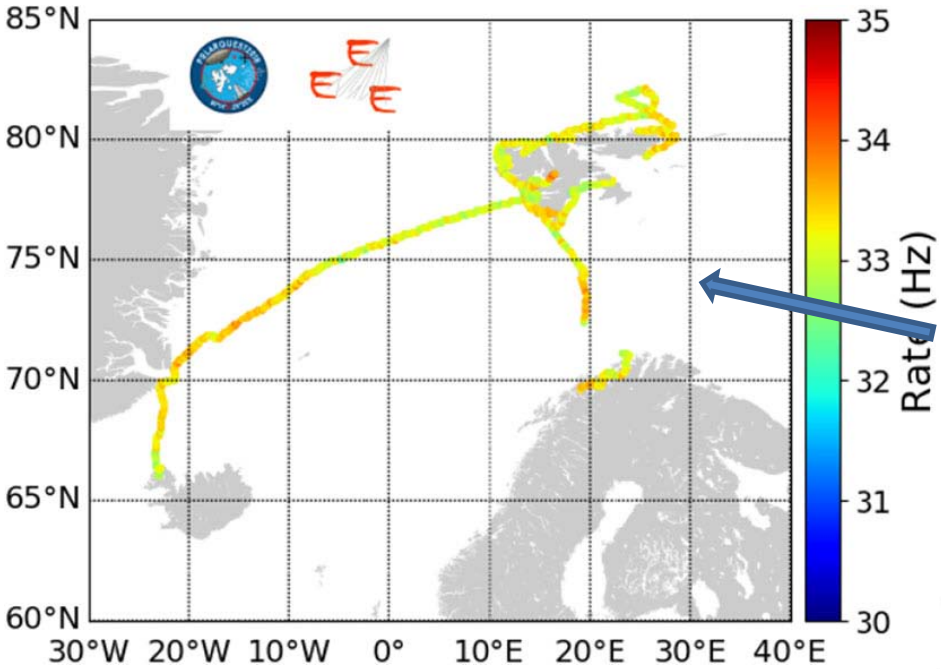
POLA-01 rate vs. atmospheric pressure



POLA-01 rate after pressure correction

Data from the whole data taking period

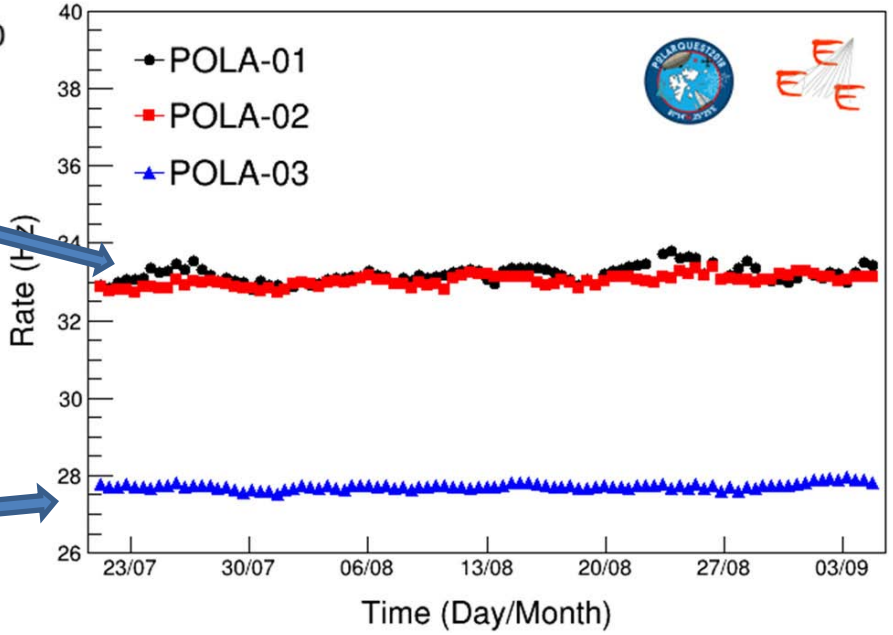
Results after corrections



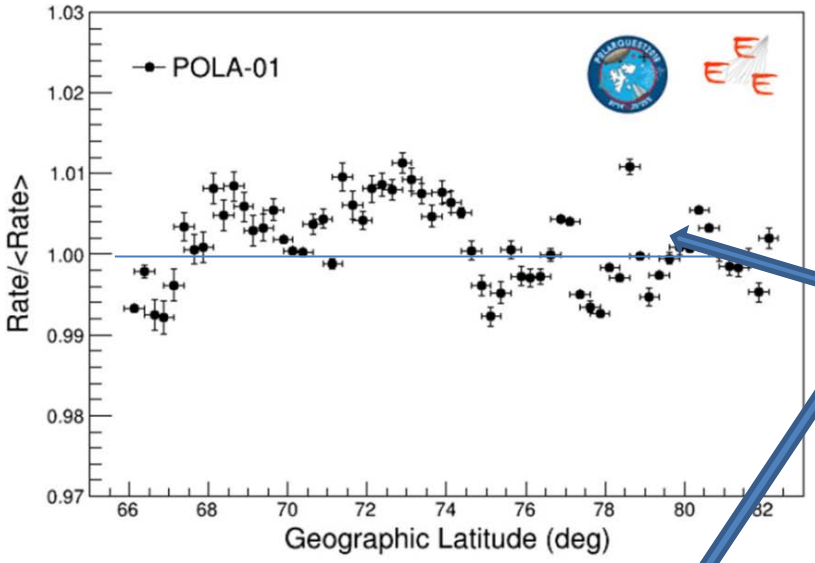
After applying correction for detector inclination and atmospheric pressure to the raw rate measured by POLA-01, the **"hot spot"** south of Spitzbergen **is absent.**

Comparison of POLA-01 rate with POLA-02 and POLA-03 rate show that they basically **remain stable** during the whole data taking.

Note: POLA-03 was in a building under a **thick roof of bricks** (and this caused a lower rate).

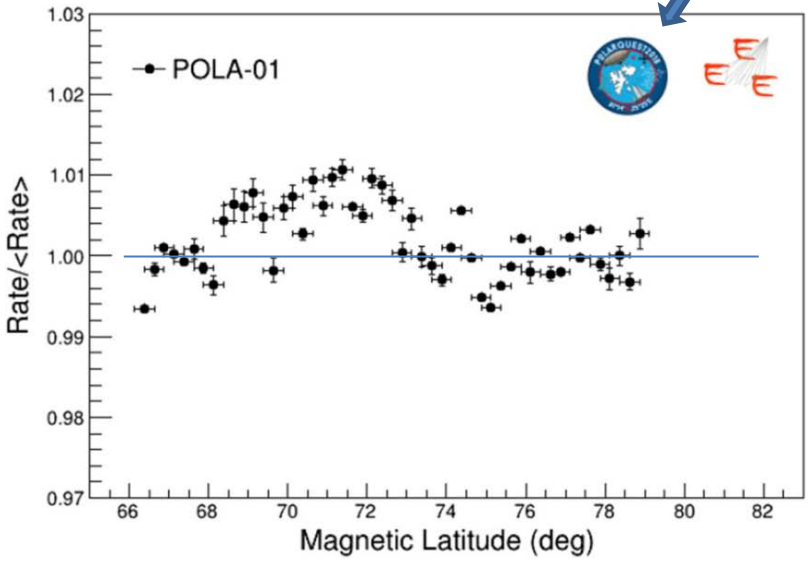


Results after corrections

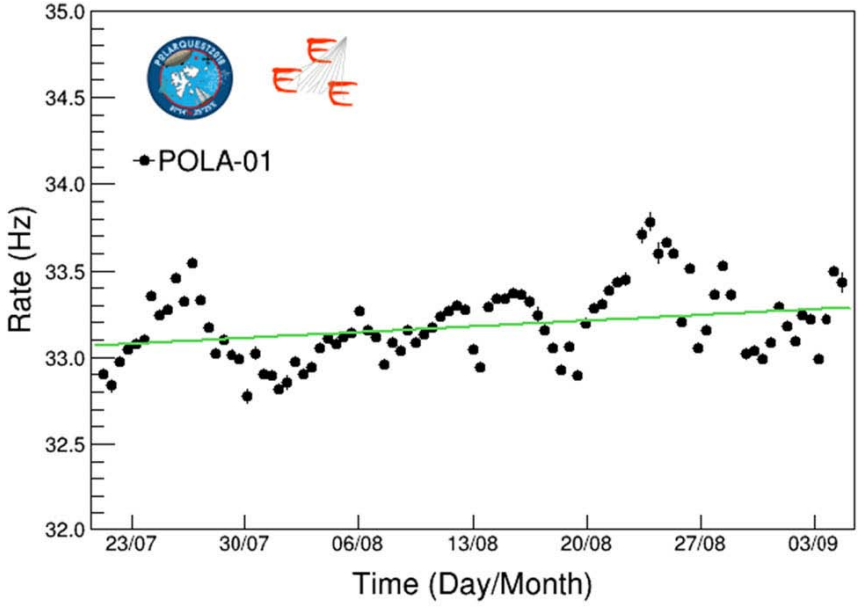


After pressure and inclination corrections are applied, POLA-01 rate **does not show any significant dependence** on both geographic and magnetic latitudes.

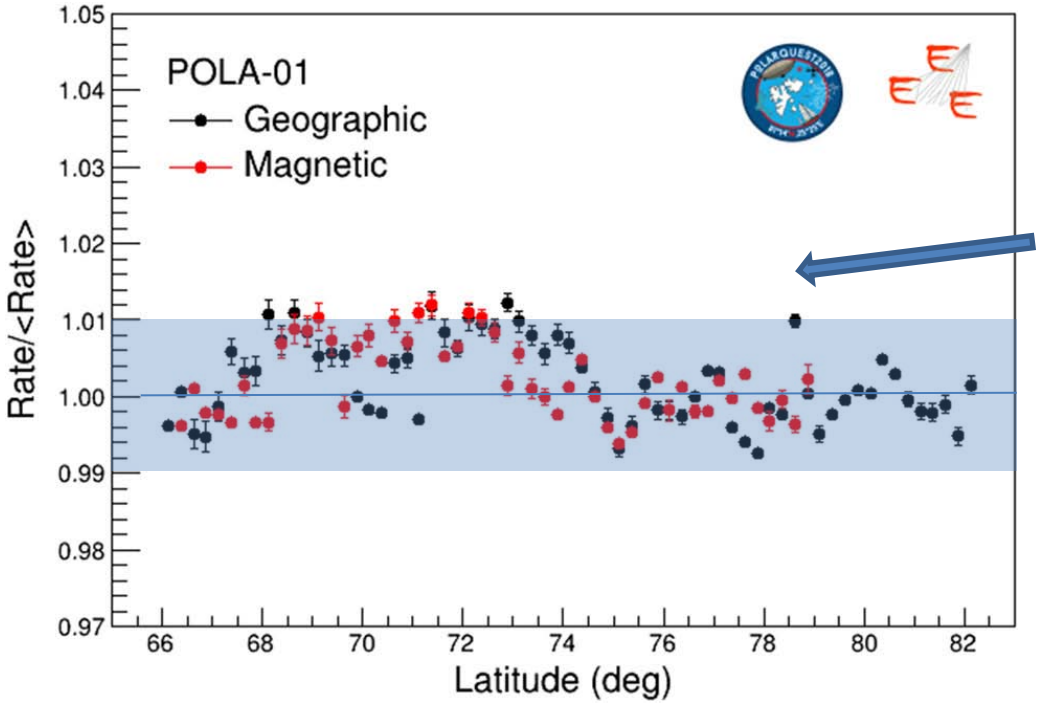
POLA-01 relative rate variations vs. latitudes.



However, a **long term seasonal shift** is observed (also in POLA-02 and POLA-03, not shown here).

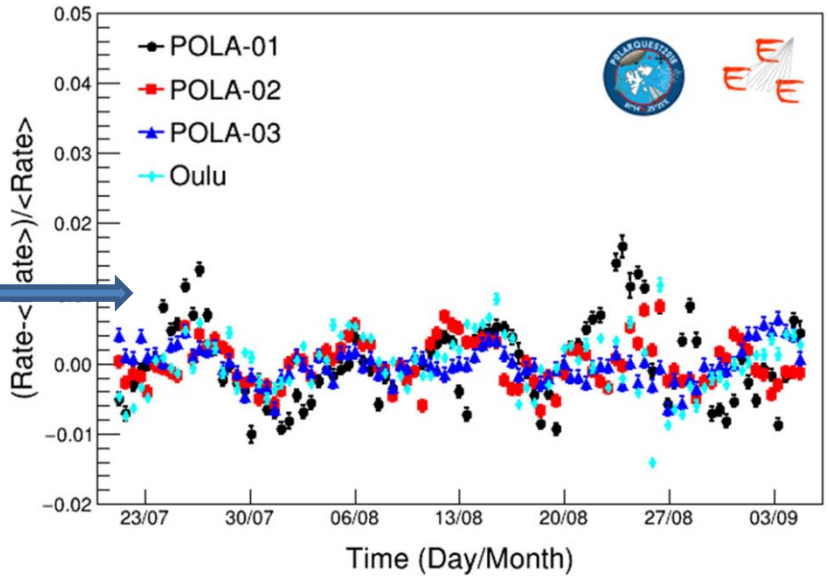


Final results



POLA-01 relative rate variations, vs. geographic and magnetic latitudes, after **all corrections** (including seasonal shift) have been applied.
The **rate remains stable** within ± 1% in the examined latitude range, **as expected**.

Also the **residual oscillations** in the rate vs. time observed by POLA-01 are **clearly correlated** with the ones observed with the reference detectors POLA-02 and POLA-03, and the Oulu Neutron Monitor.



The PolarquEEEst journey

At the end of 2018 and in 2019, the POLA-01 detector started another trip across Italy and Germany to **cover an increased range in latitude.**

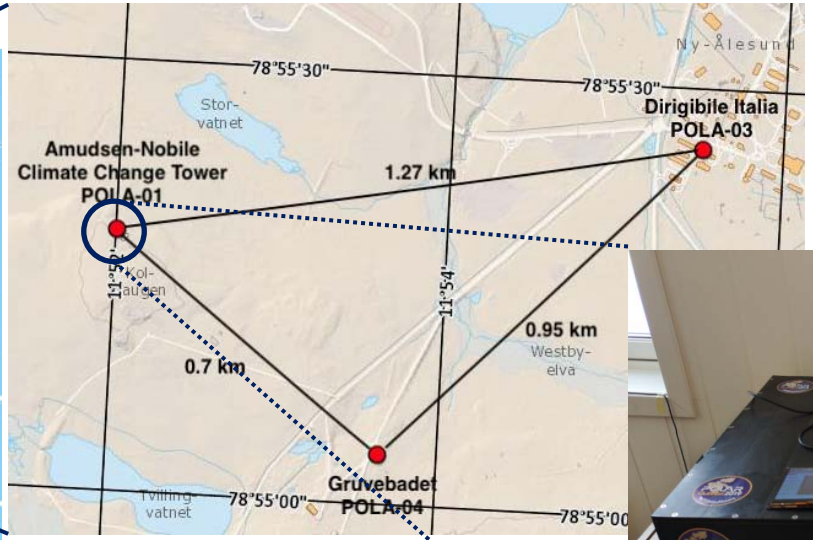
Location	Date	Latitude
Nanuq	Jul 22-Sep 4 2018	66°05′-82°06′
Genova	Oct 25 2018	44°24′
Vigna di Valle (Rome)	Nov 27 2018	42°04′
Cosenza	Dec 3-4 2018	39°18′
Messina	Dec 5 2018	38°11′
Cefalù (Palermo)	Dec 6 2018	38°02′
Erice (900m a.s.l., Trapani)	Dec 6-8 2018	38°02′
Catania-Etna (Catania, ≈ 2000 m a.s.l.)	Dec 12-Feb 15	37°30′
Lampedusa	Mar 6-15 2019	35°30′
Bologna	Apr 3-4 2019	44°29′
Munich	Apr 10 2019	48°08′
Hannover	Apr 10-11 2019	52°22′
Frankfurt am Main	Apr 11-12 2019	50°06′
CERN	Apr 12-May 2 2019	46°12′

Data analysis ongoing

PolarquEEEst 2019: EEE@NyAlesund

Long term study of the high energy cosmic ray flux with charged particles at sea level and at the northernmost latitudes.

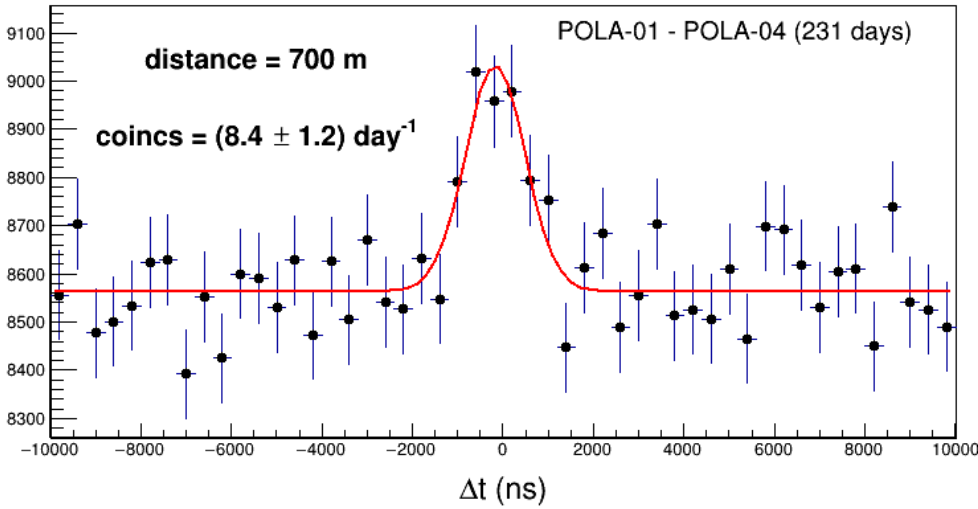
Three detectors installed at Ny Alesund (79N): **a mini-array** for Extensive Air Showers



- ✓ Cosmic ray physics **at high latitudes** (where very few measurements exist).
- ✓ Monitoring of the **Solar cycle**.
- ✓ Study of the correlations of cosmic rays flux with **environmental conditions**.
- ✓ Correlations with **measurements on atmosphere** performed at Ny Alesund.

PolarquEEEst 2019 laboratories

First coincidences (very preliminary!)



Conclusions

- ✓ Checked cosmic ray rate stability vs. latitude above 65N with **precision better than1%**
  - full analysis and results published on European Physical Journal C
- ✓ Additional data taking campaign to cover **latitude range > 35N**
  - data analysis ongoing
- ✓ Installation of a mini-array for EAS for **long term measurements at Ny Alesund**
  - almost one and half year of data already taken

Thanks for the attention!