

# *PolarQuEEEst, una misura del flusso di raggi cosmici al Polo Nord*





Umberto Nobile ed il dirigibile ITALIA - 1928



Antonio Pontremoli  
Finn Malmgren



František Běhounek



## La Preparazione e i Risultati Scientifici Della Spedizione Polare Dell' "Italia." , Umberto Nobile. Mondadori, Milano, 1938.

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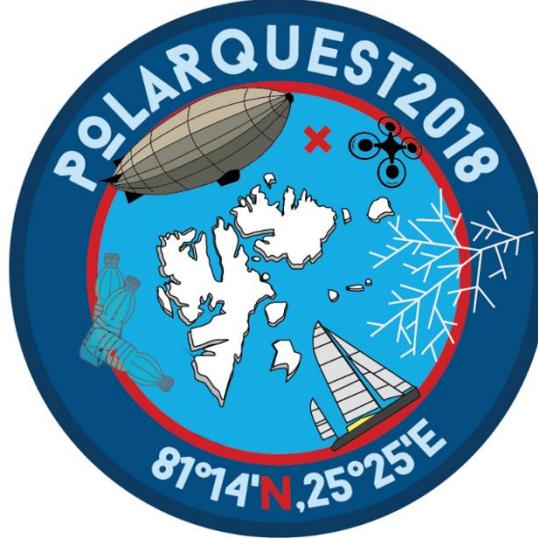
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# *PolarQuEEEst, una misura del flusso di raggi cosmici al Polo Nord*



*M. Garbini  
F. Noferini  
O. Pinazza*

# The E.E.E. Project

## Dual Role

- *Cosmic ray experiment*
- *Scientific Education*

**51** MRPC tracking telescopes  
in High Schools

+ **2** telescopes at CERN

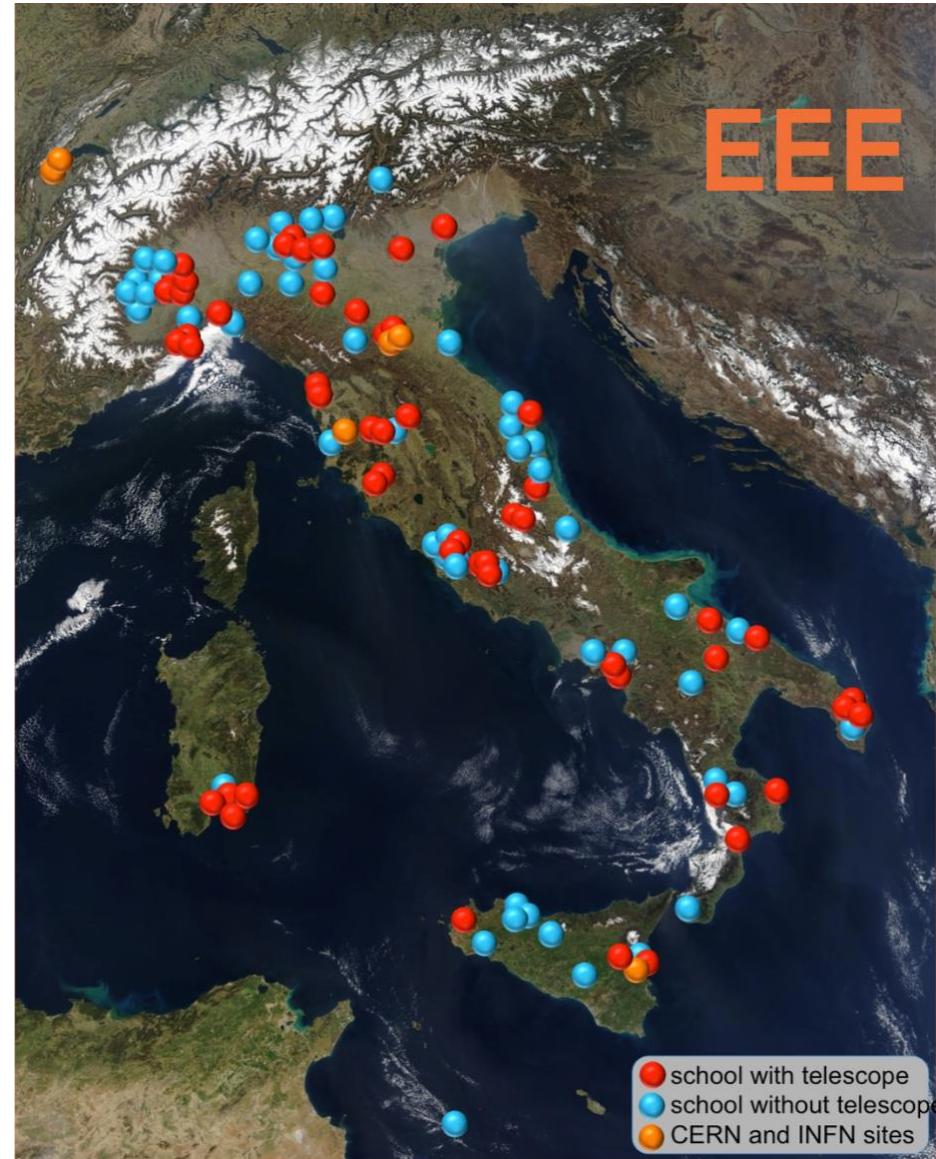
+ **6** telescopes in INFN Units

Total : **59 telescopes**

+ **54** High Schools participating  
without telescopes

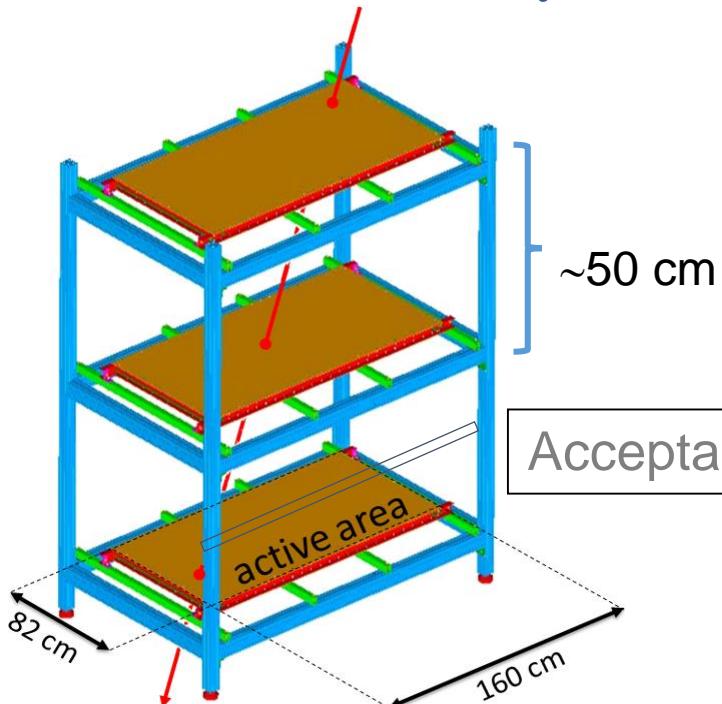


$\approx 0.5 \times 10^6 \text{ km}^2$   
 $\approx 10^\circ \text{ of latitude/longitude}$



# The E.E.E. Project

MRPC chambers are built by High School students at CERN (starting from 2004) and maintained by them under the supervision of EEE researchers

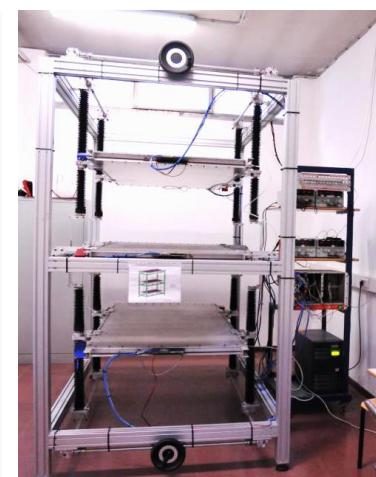


Acceptance  $\Omega = 1.6 \text{ sr}$



3 MRPC planes with 24 strips each read at both ends  $\rightarrow$  144 readout channels

- The trigger requires a hit signal on each end of the 3 MRPCs within a  $\pm 500 \text{ ns}$  window
- Cosmic muons are tracked & reconstructed



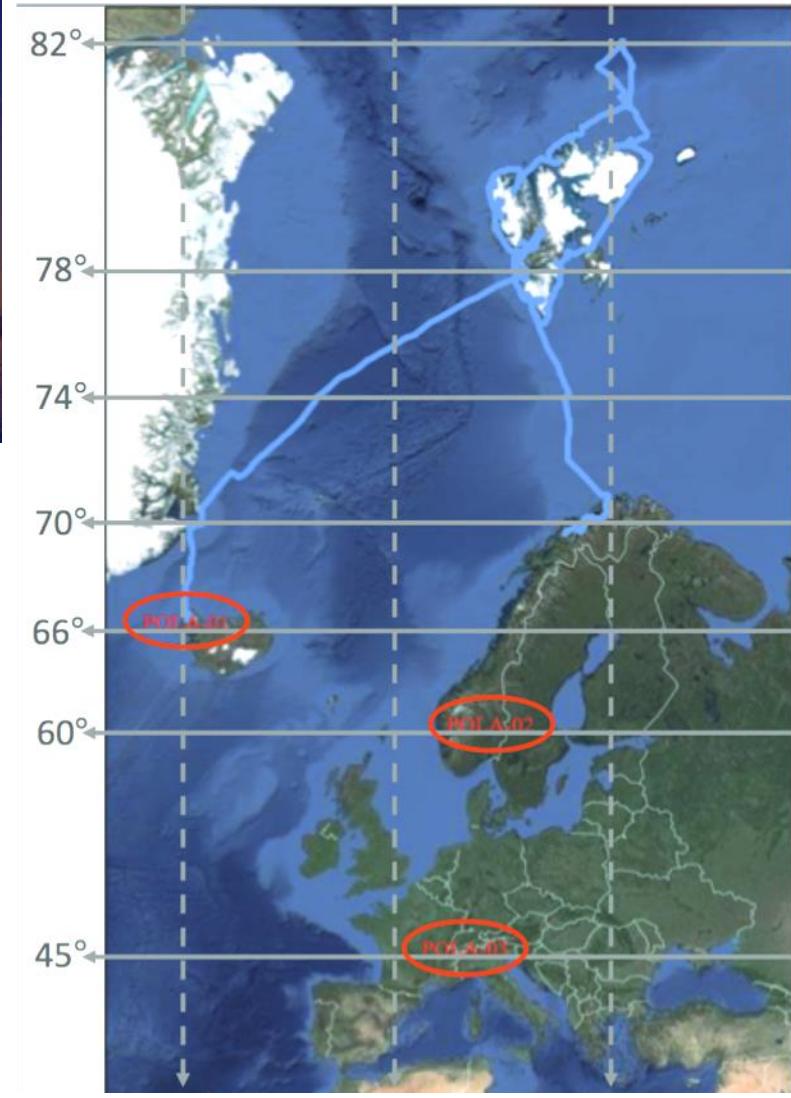
# Polar QuEEEst expedition



Polar QuEEESt 1928 – 2018

*Measure the Cosmic Rays flux with three detectors at different latitudes*  
<http://www.polarquest2018.org/>

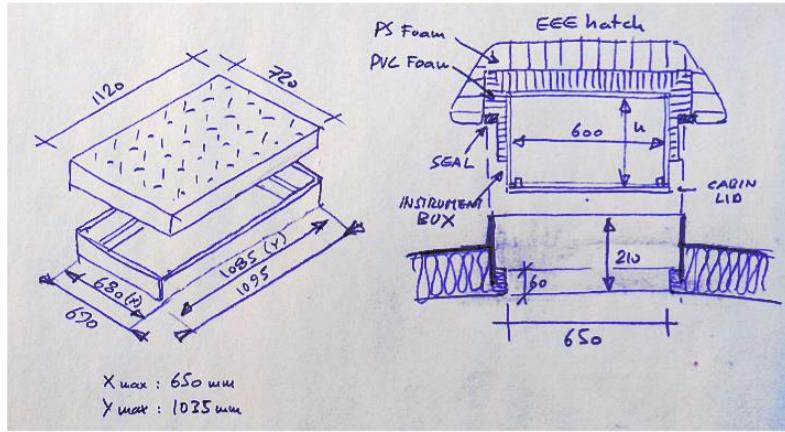
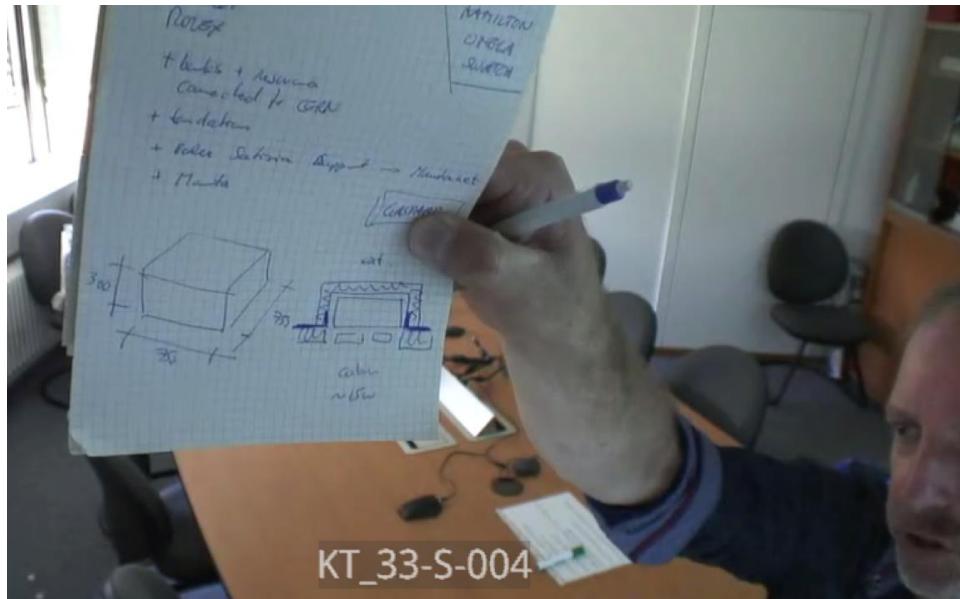
Institutions  
*Centro Fermi*  
*INFN (Bari, Bologna)*  
*Politecnico Torino*





## *The Polar QuEEEst Detector*

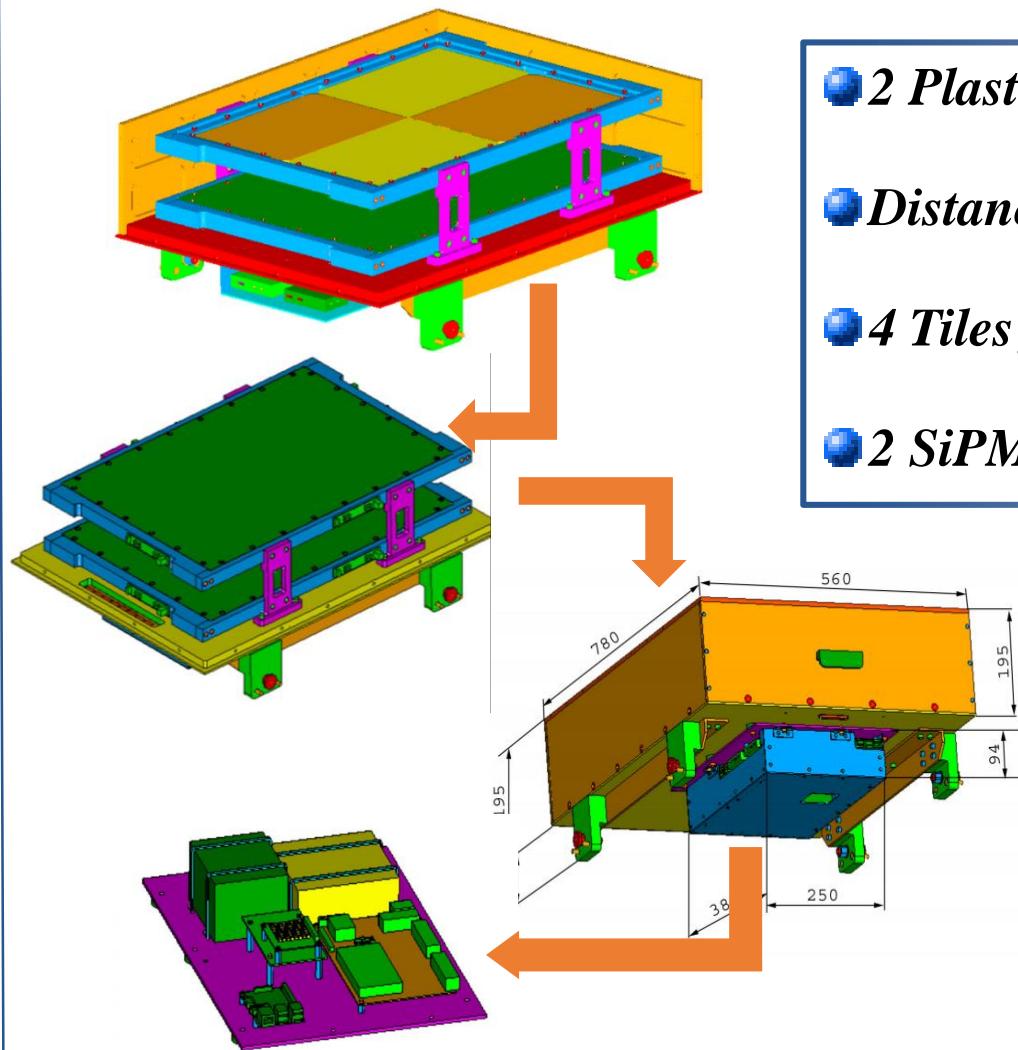
# Requirements



The Detector on the Polar Nanuq boat has been designed to fulfill the requests on

- Dimension
- Weight (~ 50 kg)
- power consumption (< 15 W)

# The Design

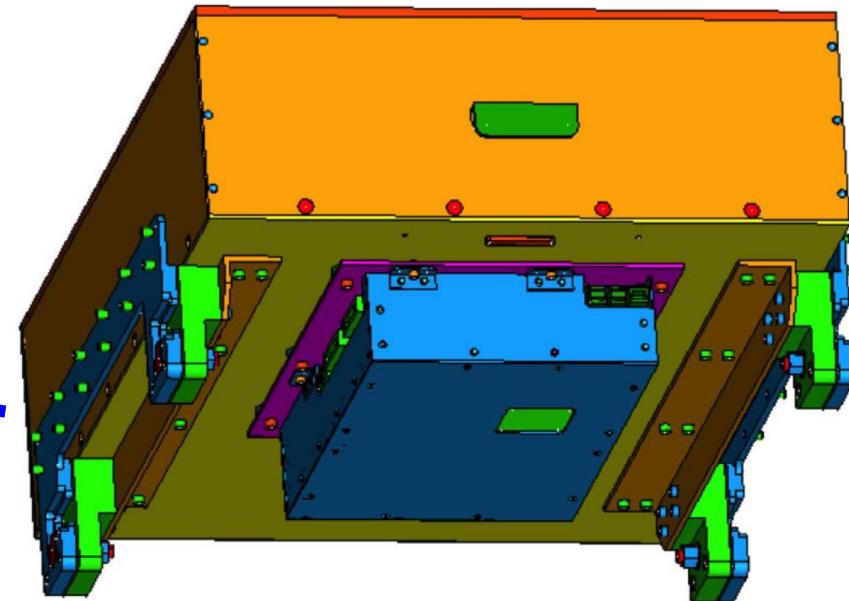
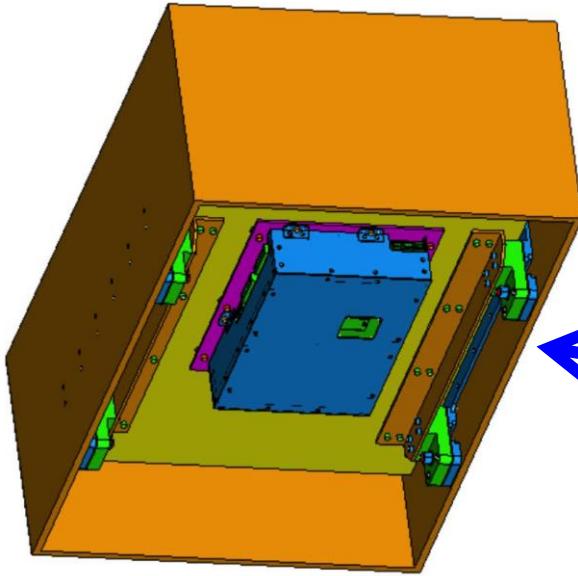


- 2 Plastic scintillator planes
- Distance between planes: 11 cm
- 4 Tiles for each plane: 30 cmx20 cm
- 2 SiPM per tile (16 SiPMs in total)

- Design developed together with INFN Bologna Technical Design Service
- Light Tight Box made of Black Delrin plates. All parts realized by INFN Bologna mechanical workshop

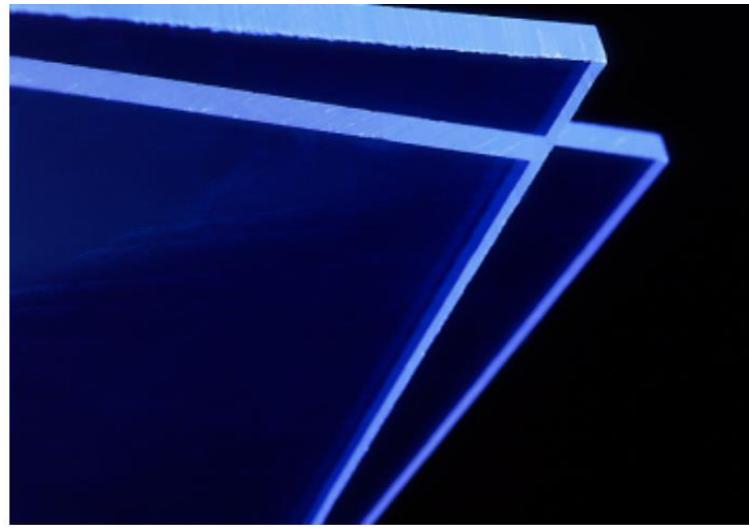
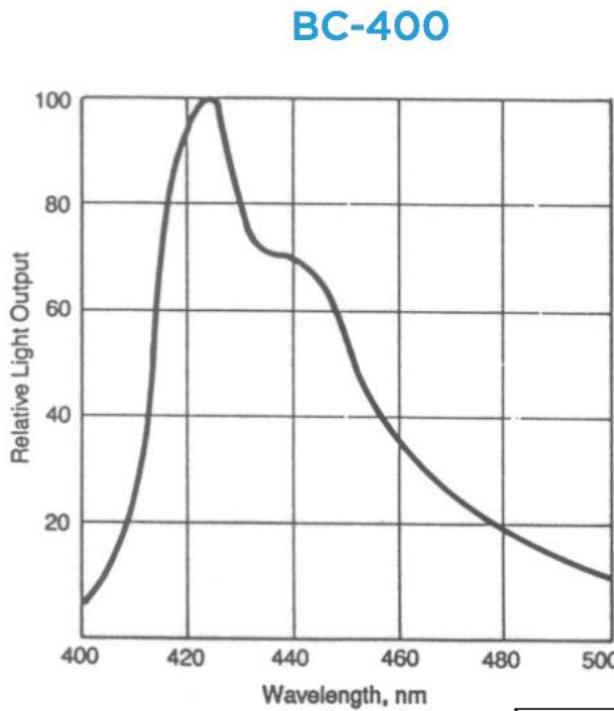
# Anchoring inside Nanuq

*Cosmic hatch and anchoring system*

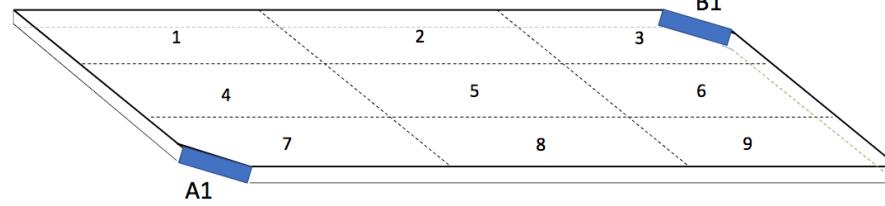


# The Scintillator

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



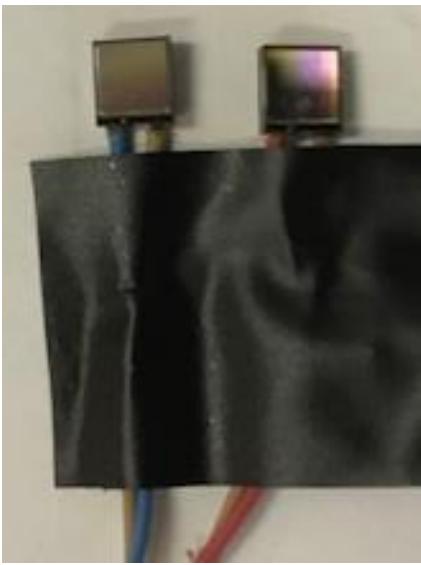
*Two corners of each tile  
have been milled to house  
SiPMs.*



# Preparing the Scintillators

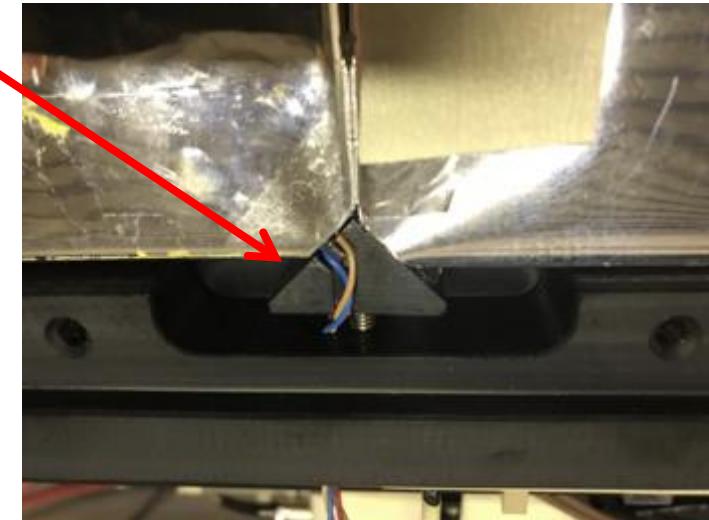
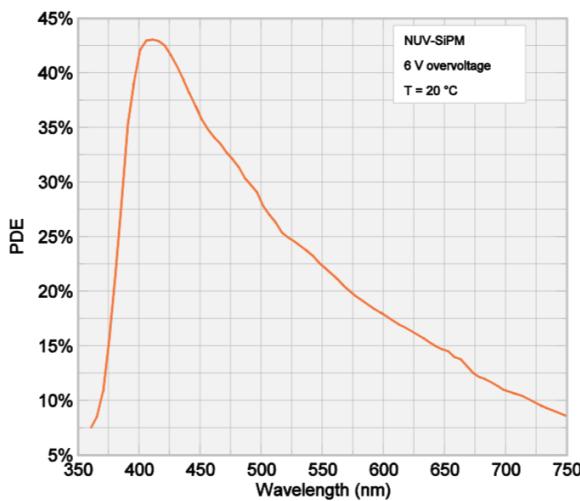


# The SiPMs

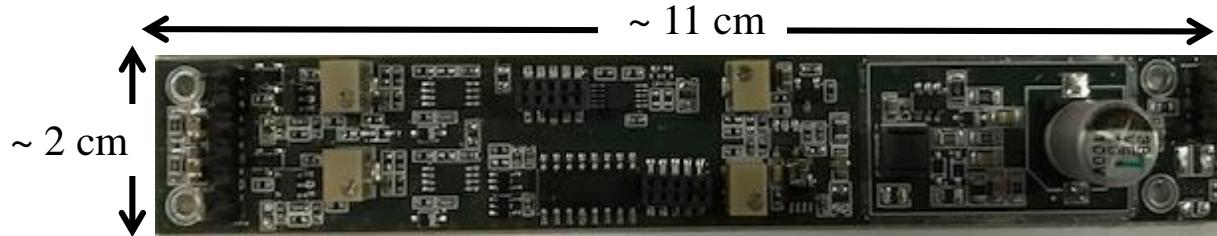
NUV SiPMs  
Chip Scale Package (CSP)

Symbol	Parameter	Product			
		ASD-NUV1S-P	ASD-NUV1C-P	ASD-NUV3S-P	ASD-NUV4S-P
AA	Effective active area	1×1 mm <sup>2</sup>	1.13 mm <sup>2</sup>	3×3 mm <sup>2</sup>	4×4 mm <sup>2</sup>
N	Cell count	625	673	5520	9340
CS	Cell size (pitch)	40 μm × 40 μm			

*Directly coupled to the scintillator*

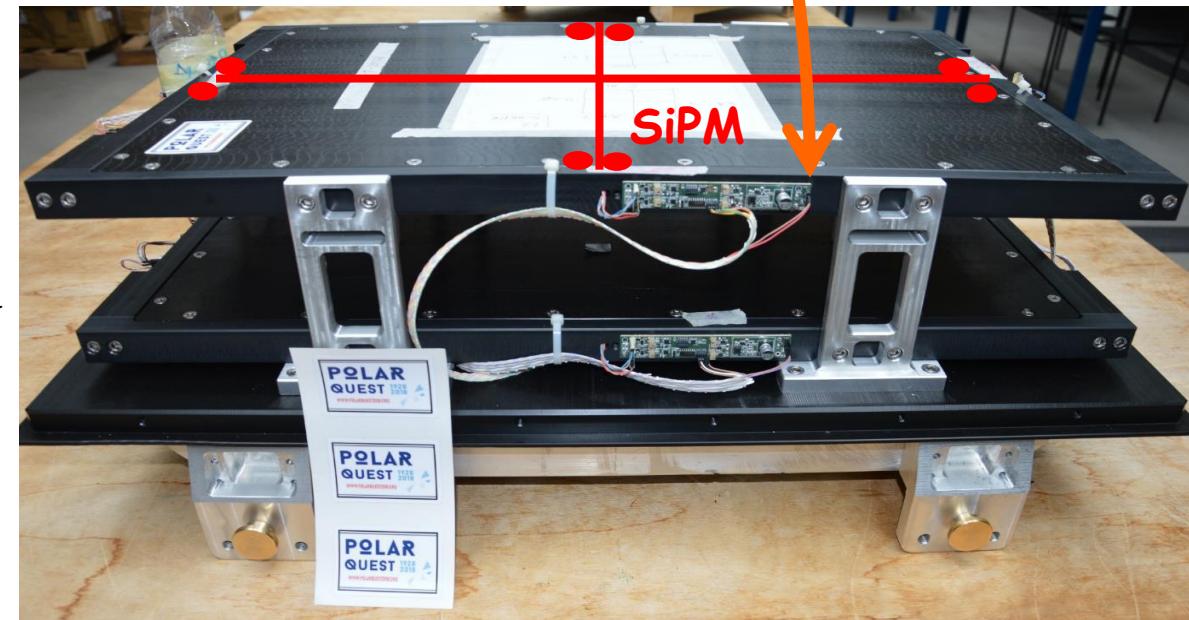


# Front End Electronics

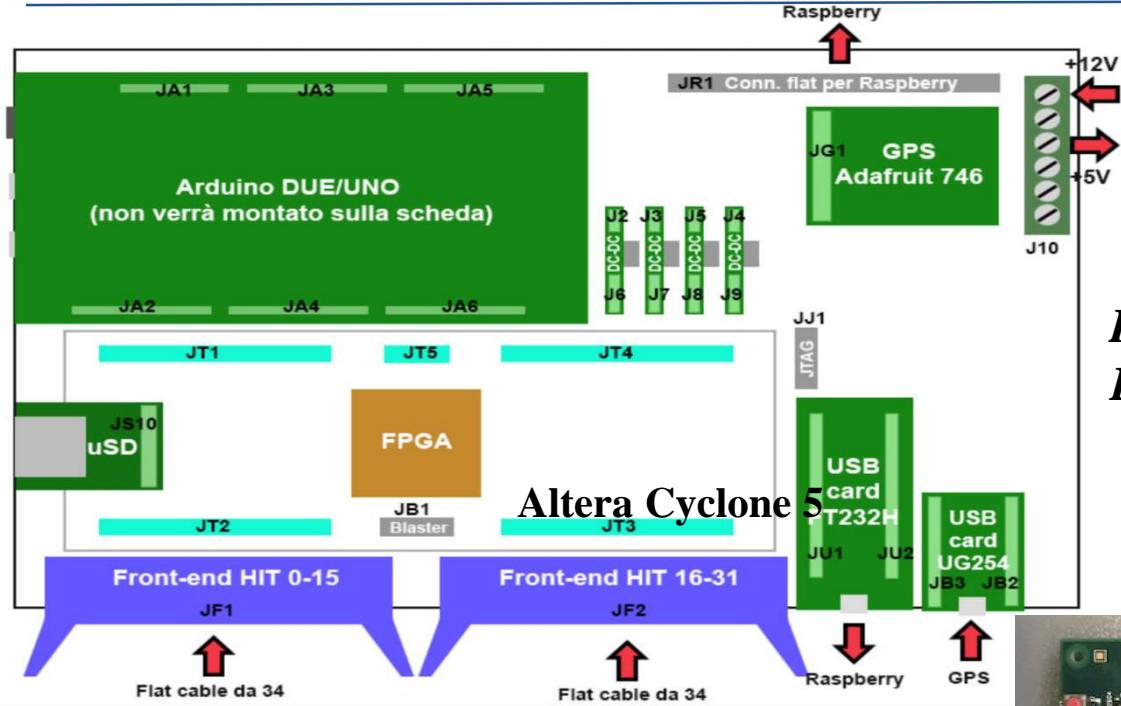


## Custom Front End Card serving 2 SiPMs

- SiPMs VBias(Temperature feedback)
- Signal Discrimination/Digitalization (LVDS standard)
- T.O.T (Charge) measurement



# Trigger & Read Out Board



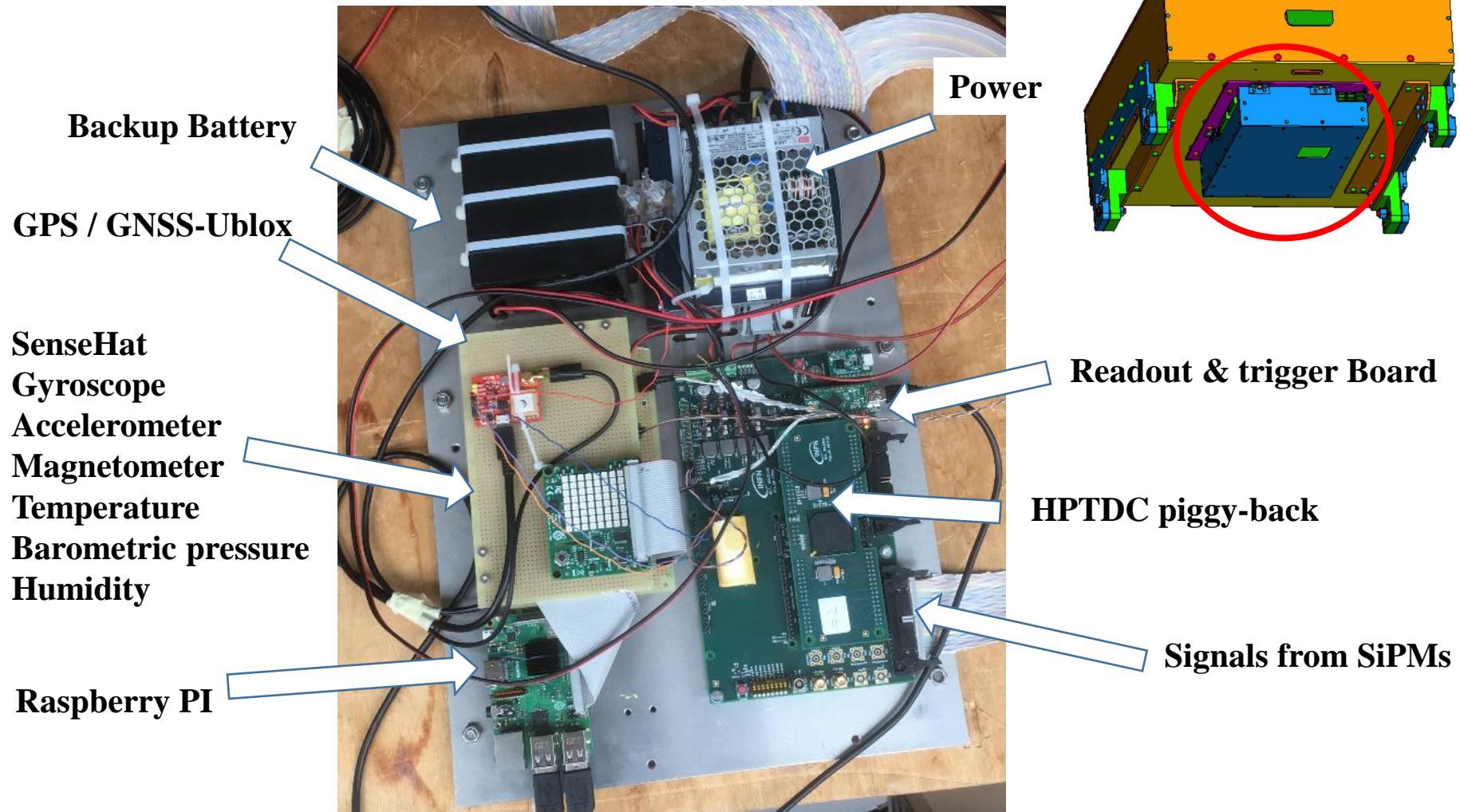
*Developed by  
INFN Bologna Electronic Service*



## Provides:

- Trigger logic
- TDC and TOT measurements (HPTDC & Internal)
- GPS time Stamp
- Data stream to Raspberry
- Supply Voltage for Raspberry PI

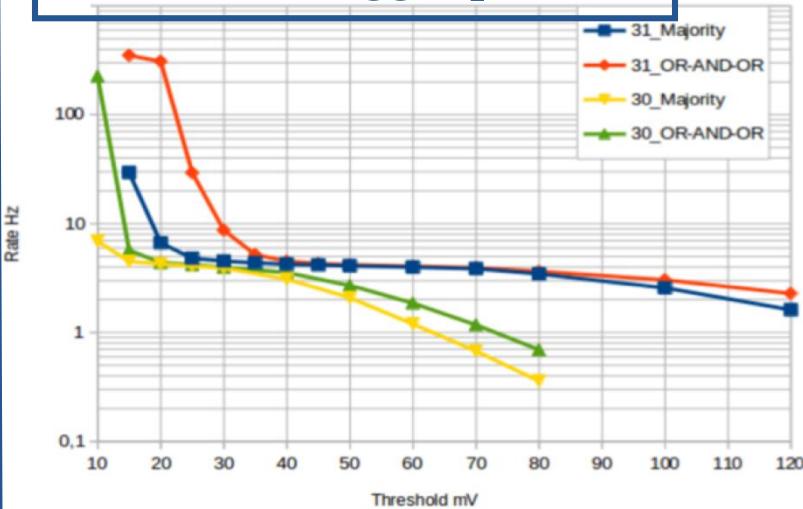
# The complete Electronics



*Total power consumption ~ 12.5 W*

# Some Tests

## Sensors & trigger pattern

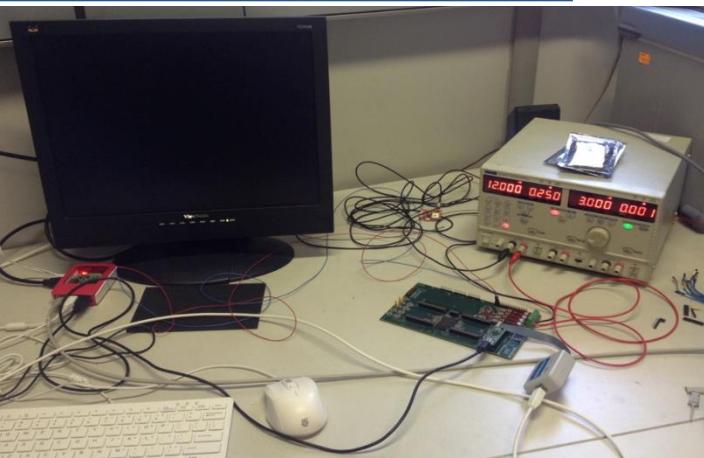


## Mechanics & Assembling



## First Prototype Ready

### Trigger&Readout Board

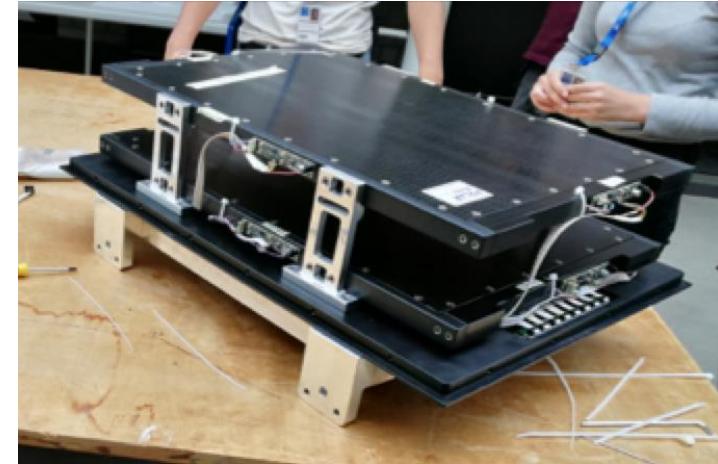
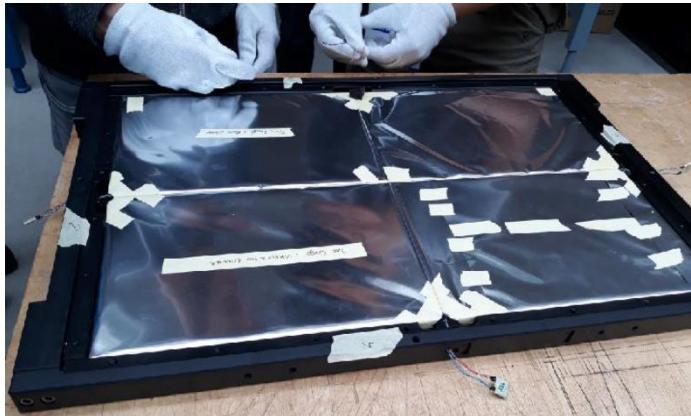


May 2018



# Assembling

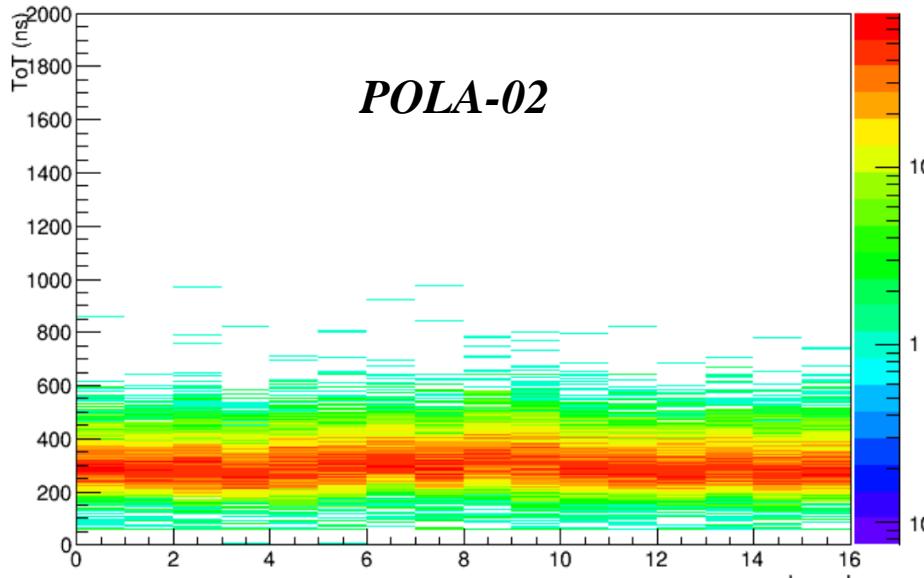
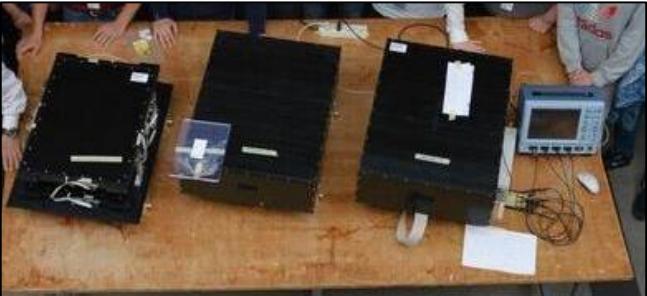
*Performed at CERN by high schools students from  
Italy, Switzerland and Norway*



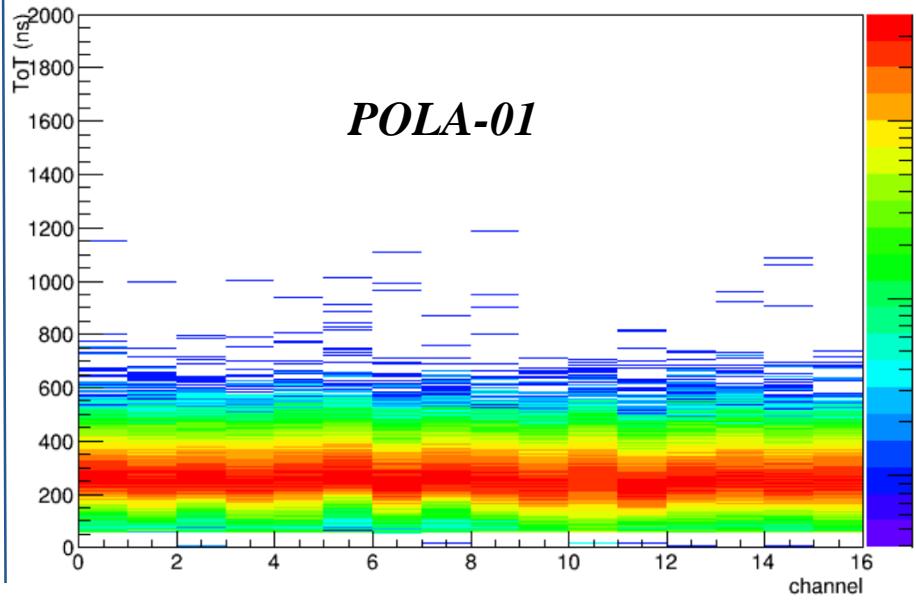
24 May 2018

# Calibration and Final tuning

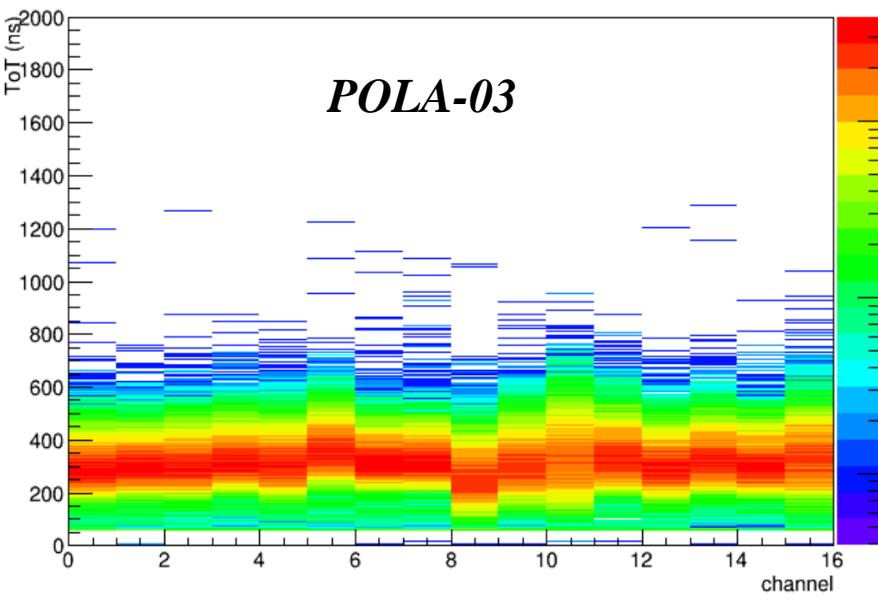
*Final calibration of the  
detectors at CERN using  
cosmic rays*



**POLA-01**



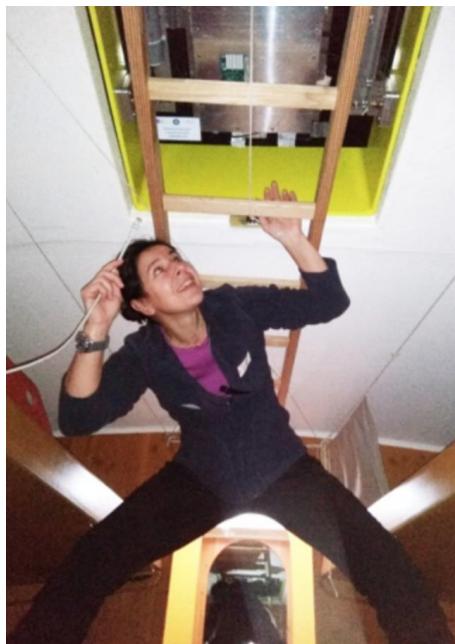
**POLA-03**



27 June 2018

# Installation

*All the detectors installed by the end of July 2018*



21 July 2018



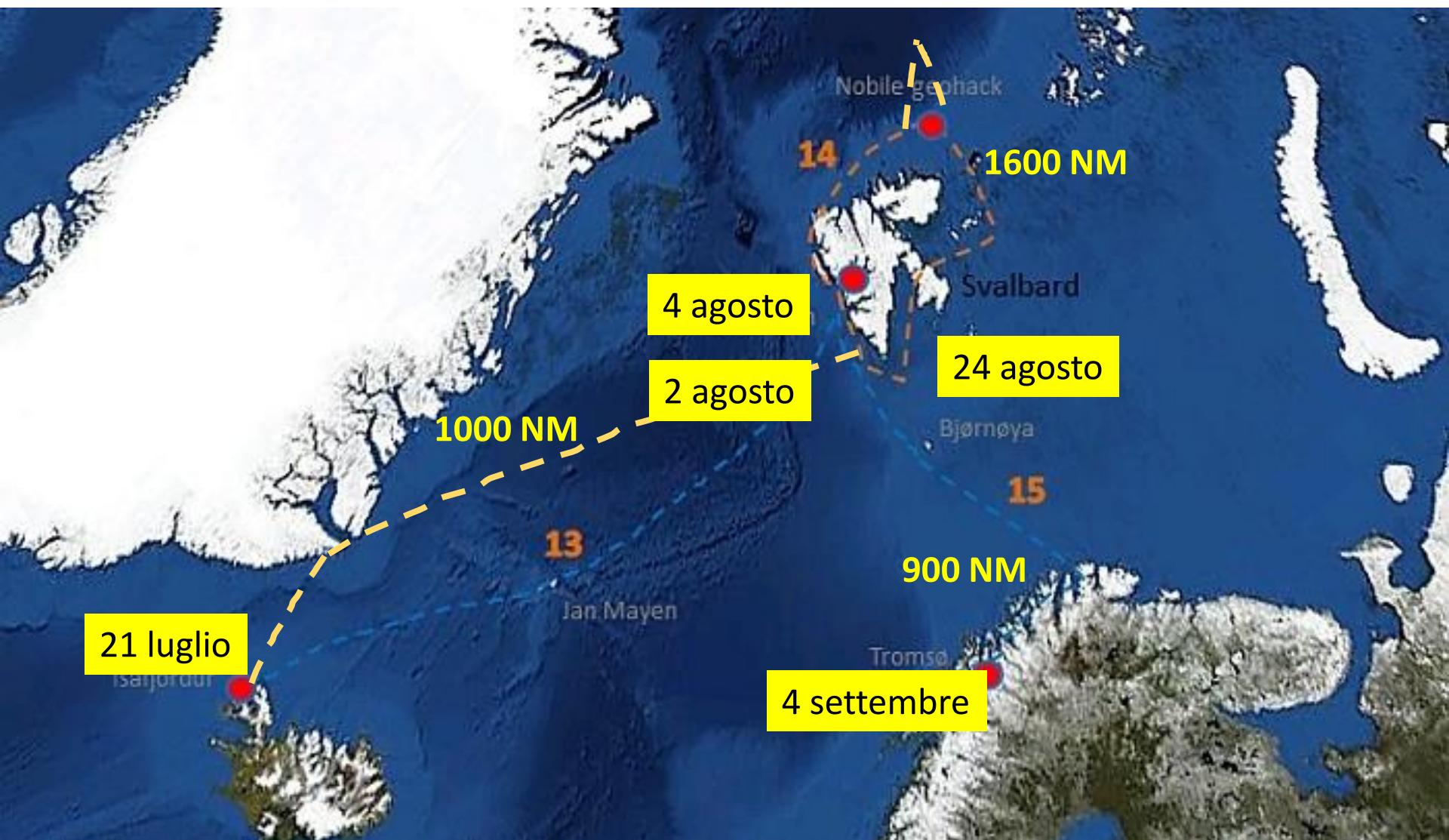
# PolarQuest2018

Ombretta Pinazza

on behalf of the PolarQuest team and the EEE collaboration



La rotta: Islanda, Groenlandia, Svalbard, polo Nord, Norvegia



# Il libro di bordo

Date 04/08/2018

Date \_\_\_\_\_

t: h. >5 bf. \_\_\_\_\_

tification CE \_\_\_\_\_

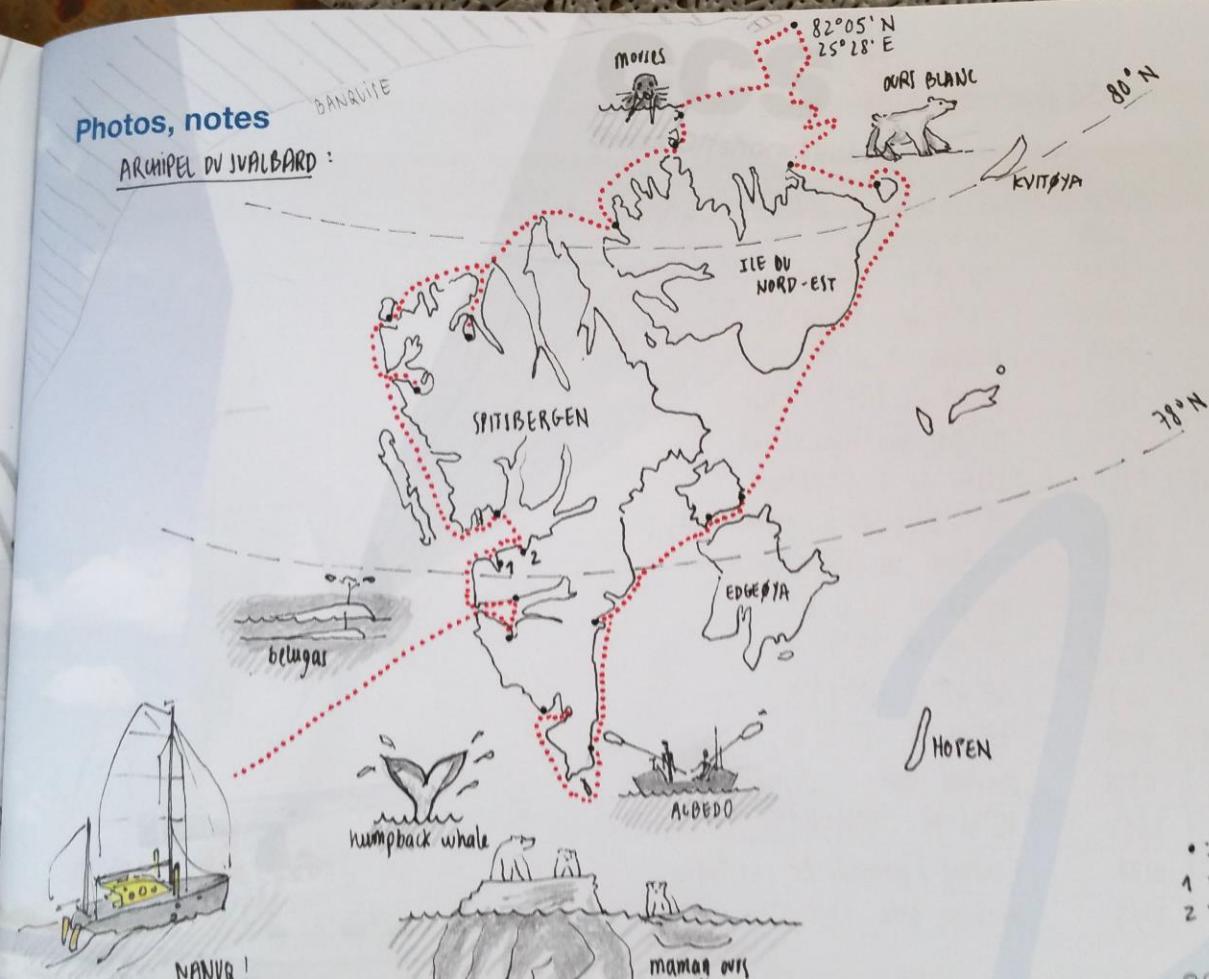
Moteur (kW) 65 kW

tache BALE

u SUISSE

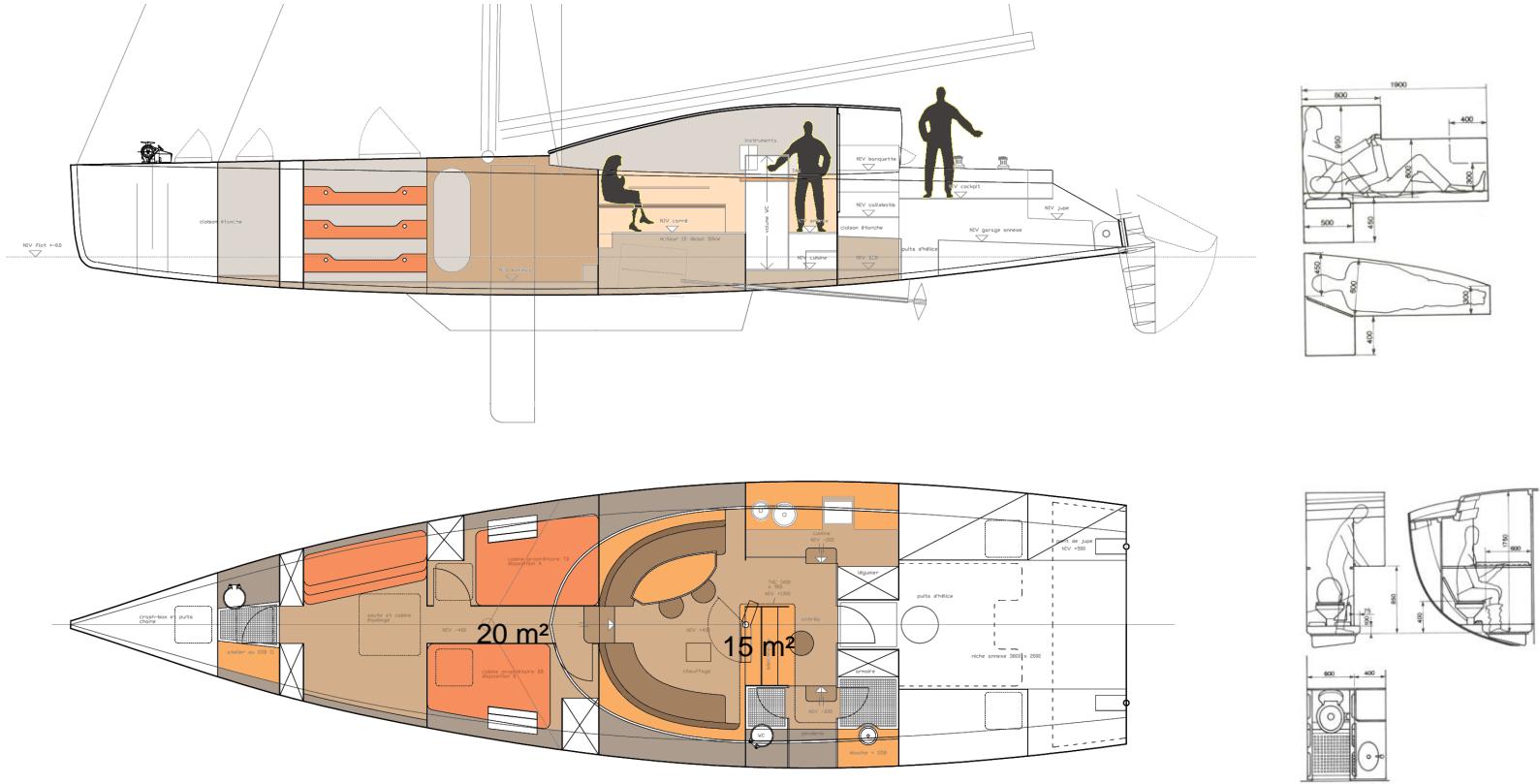
## Photos, notes

### ARCHIPEL DU SVALBARD :



- : arrêt / mouillage
- 1 : Barentsburg
- 2 : LONGYEARBYEN

# La barca: Nanuq, Integral 60, progettato e realizzato da Peter Gallinelli



# Inverno 2016-2017 in Groenlandia





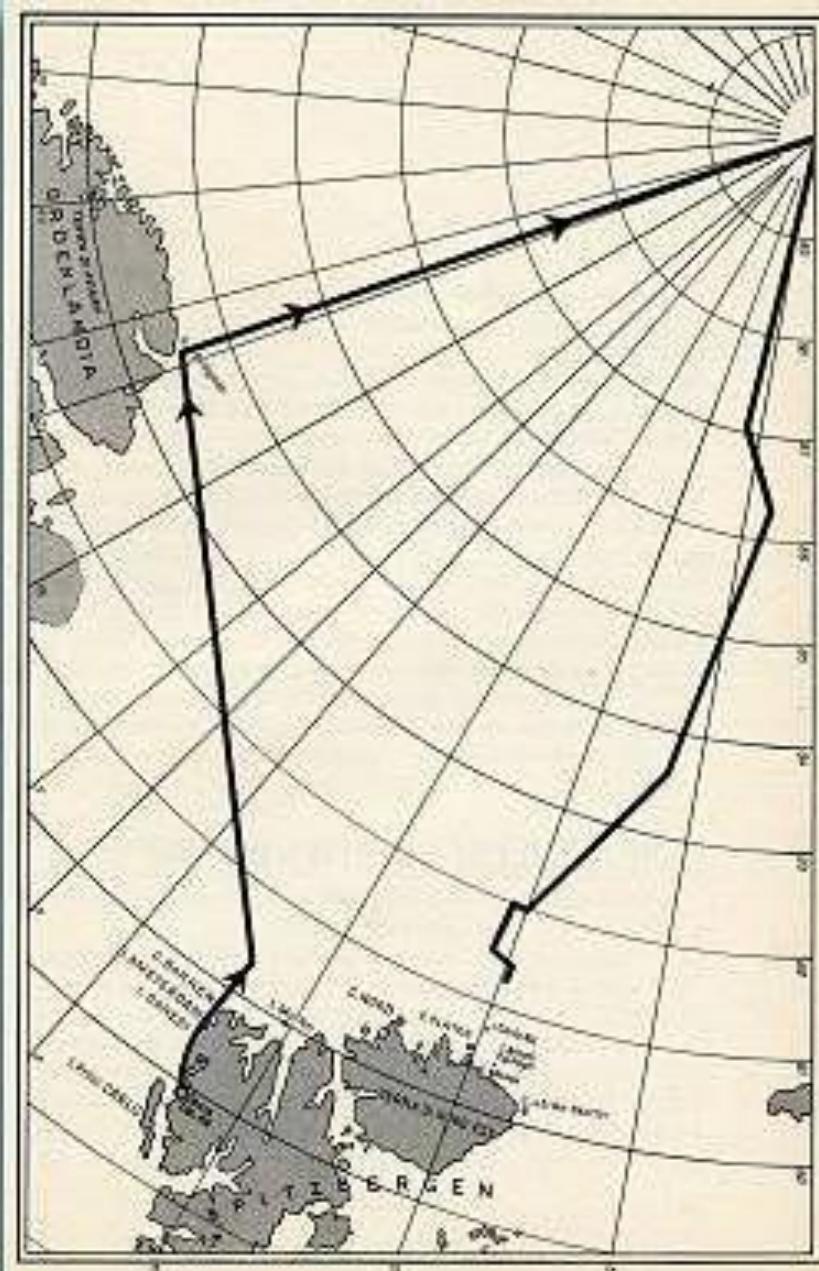
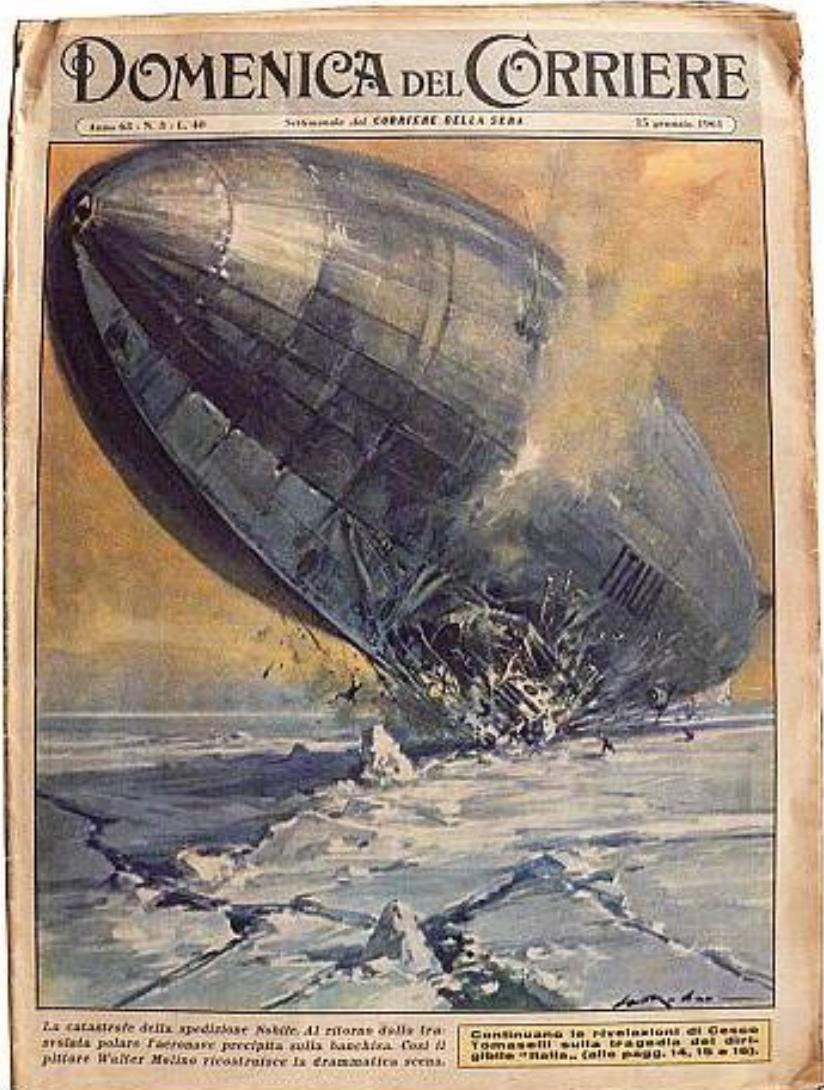
# A bordo di Nanuq



# Sulle tracce del dirigibile Italia



*Domenica del Corriere* - 15 gennaio 1961  
L'elenco



# Commemorazione dei caduti

Ny Ålesund



Crash point 81°14N 25°2



# Microplastiche, PCB, Mantanet

- Mantanet: 3 km, 0.1x0.7 m
- Bottiglia + filtri (10 l)
- PCB (Polychlorinate biphenyl)

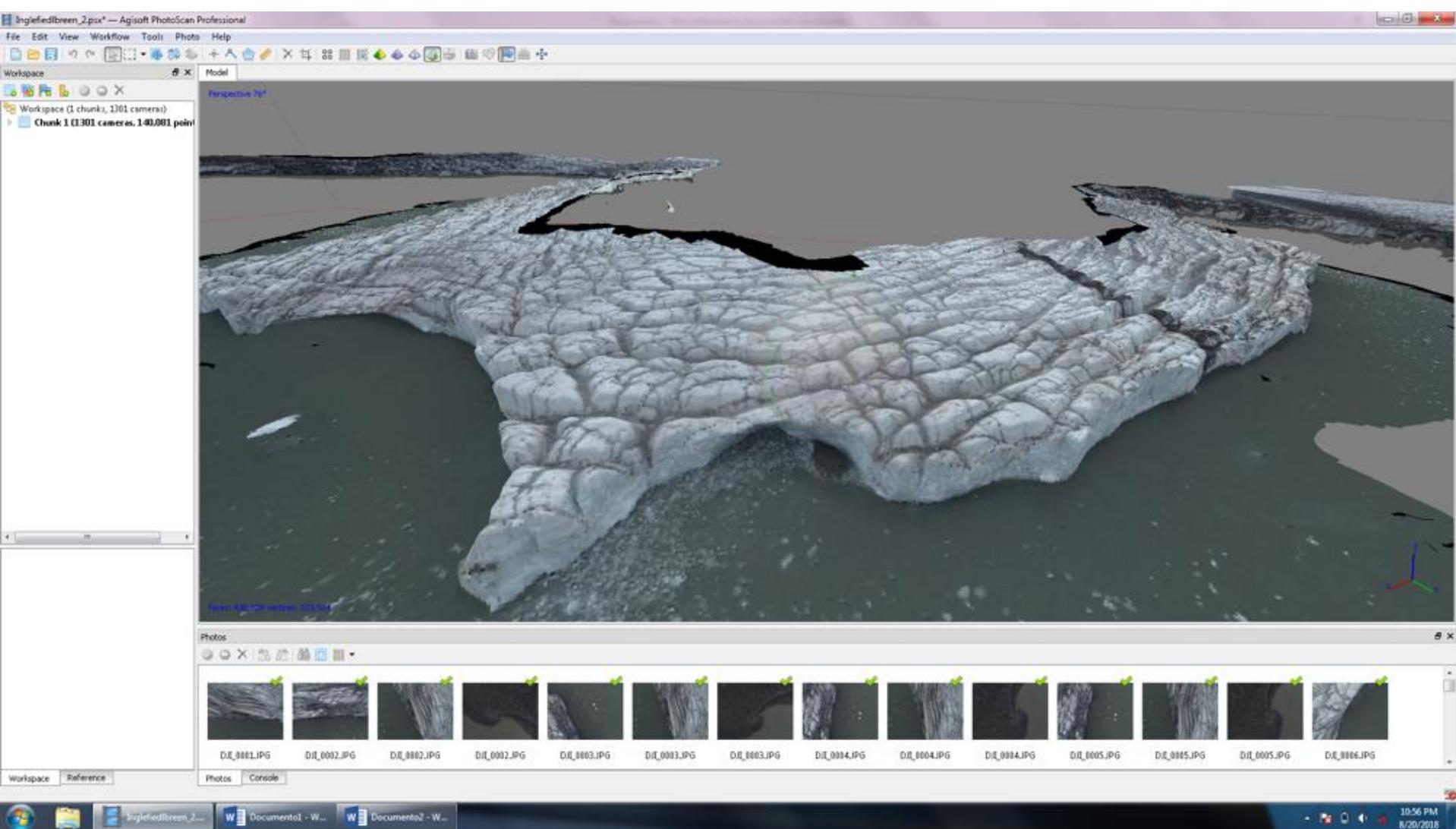


# Droni per cartografia e telerilevamento

- Progetto Aurora (Società Geografica Italiana)



# Modello 3D di Alpinøya

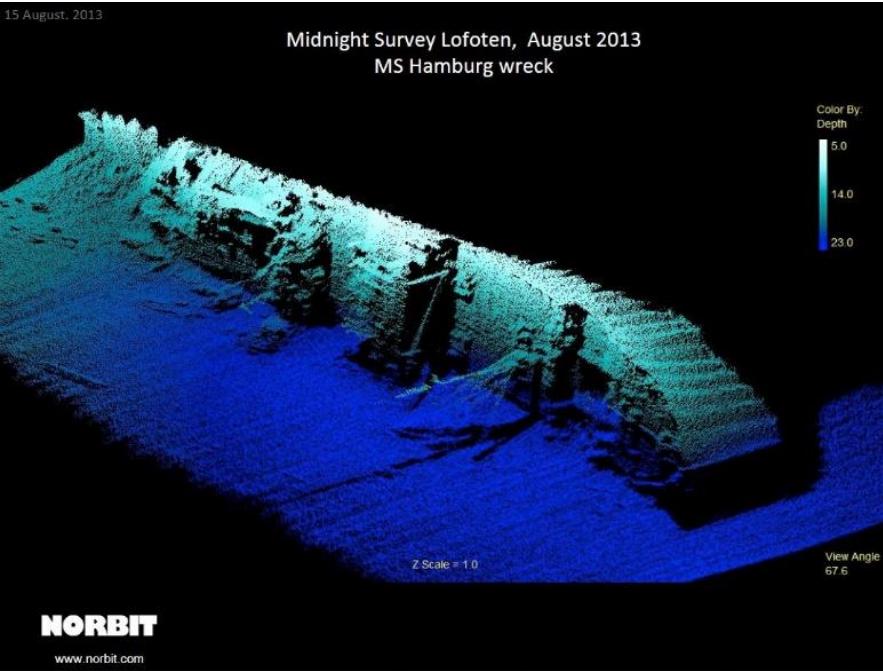


# Virgobay



# Scansione del fondale

Multibeamer scanner Norbit, fondali fino a 600 m



# Foto, video, media

Social media  
[www.polarquest2018.org](http://www.polarquest2018.org)

Esposizione foto

- CERN
- Festival di Genova

Documentari in  
preparazione:

- Addictive Milano
- Ushuaia TV (Francia)



Ombretta, che ne diresti di  
andare in barca al polo nord?

(Rosario Nania, autunno 2017)

Iceberg







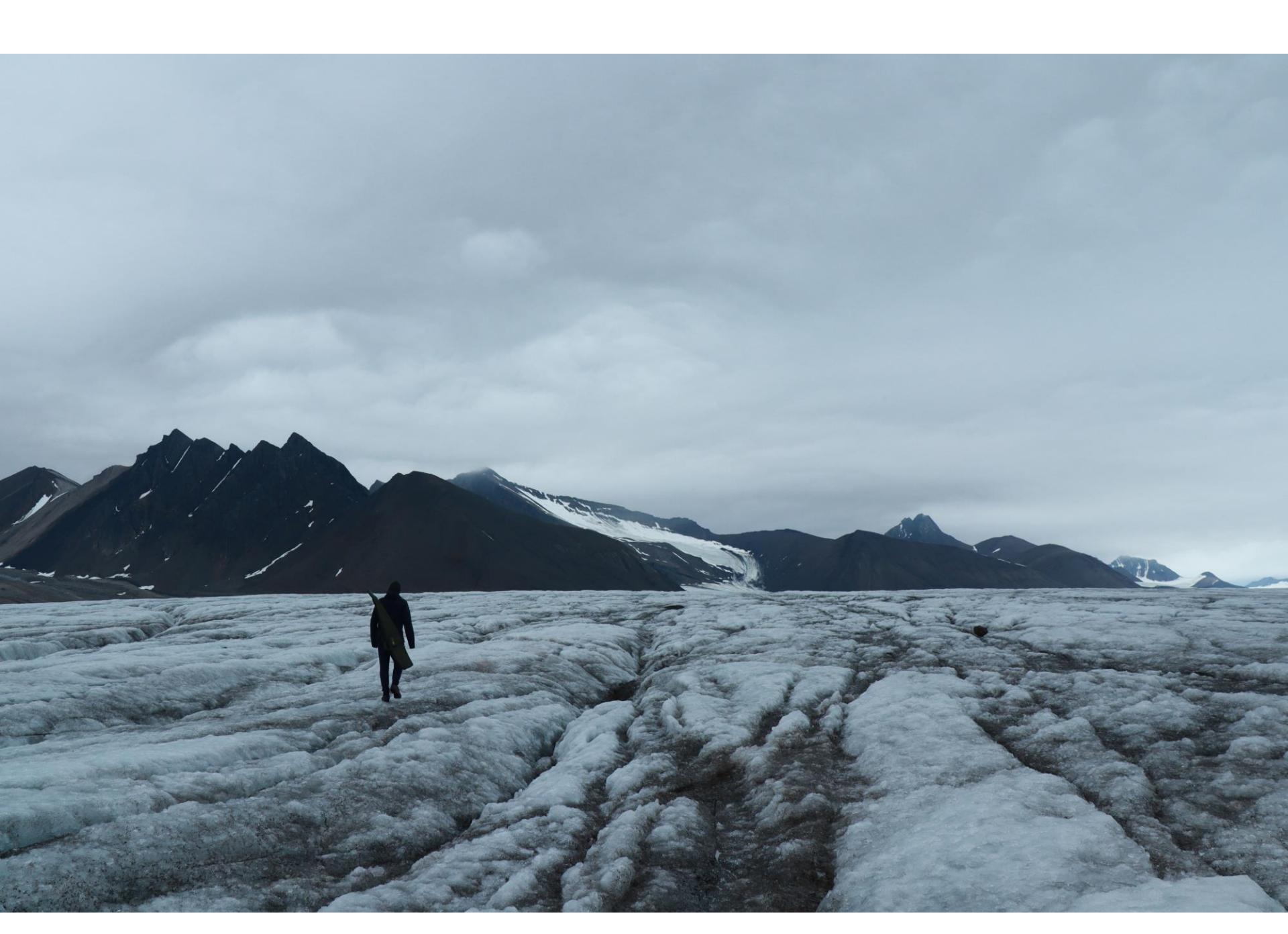






# Ghiacciai







# Luoghi abitati



... disabitati



... inquinati



# Luoghi storici





# Siti di importanza storica e scientifica





ITALIA







# Spiagge



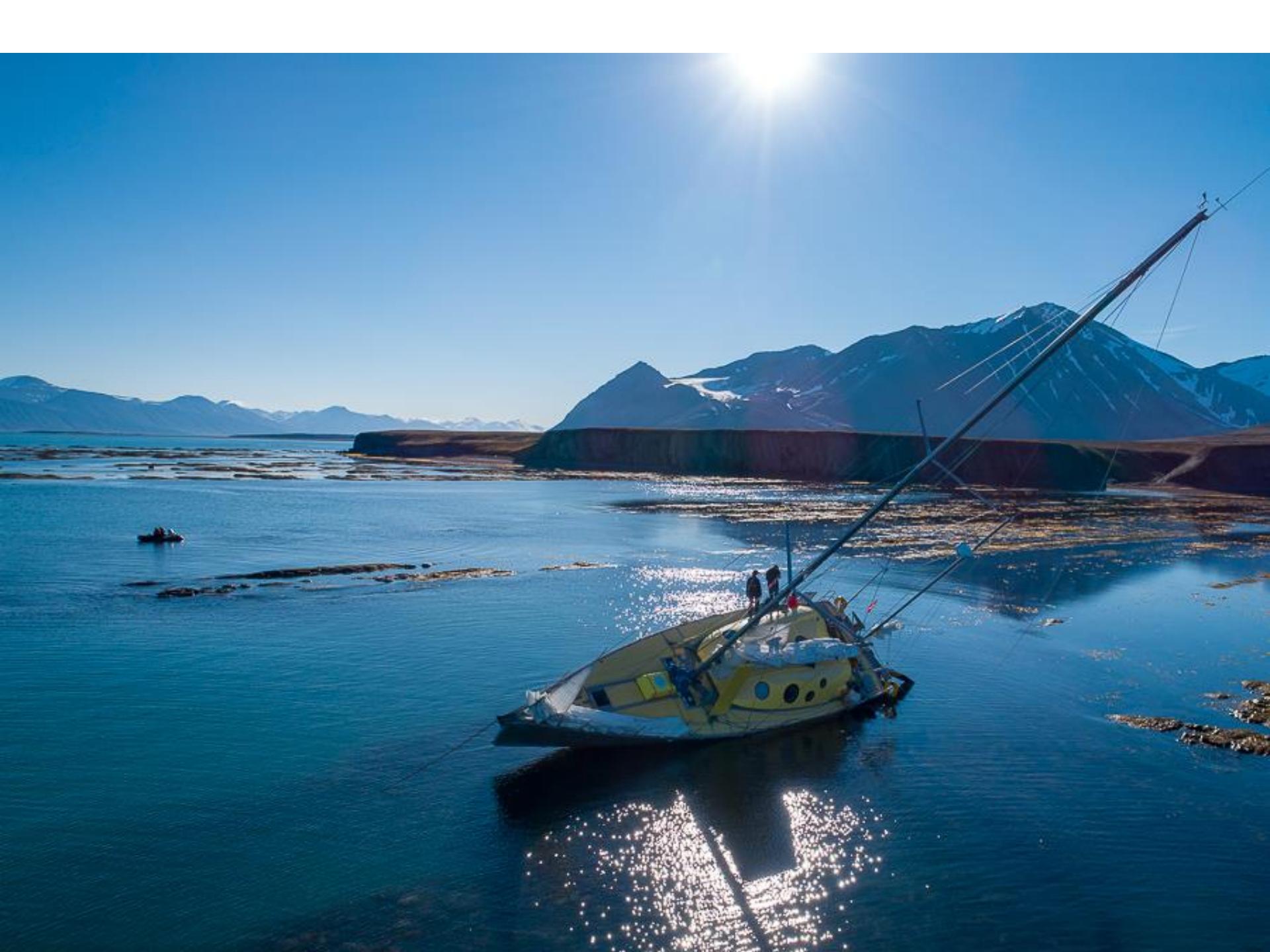


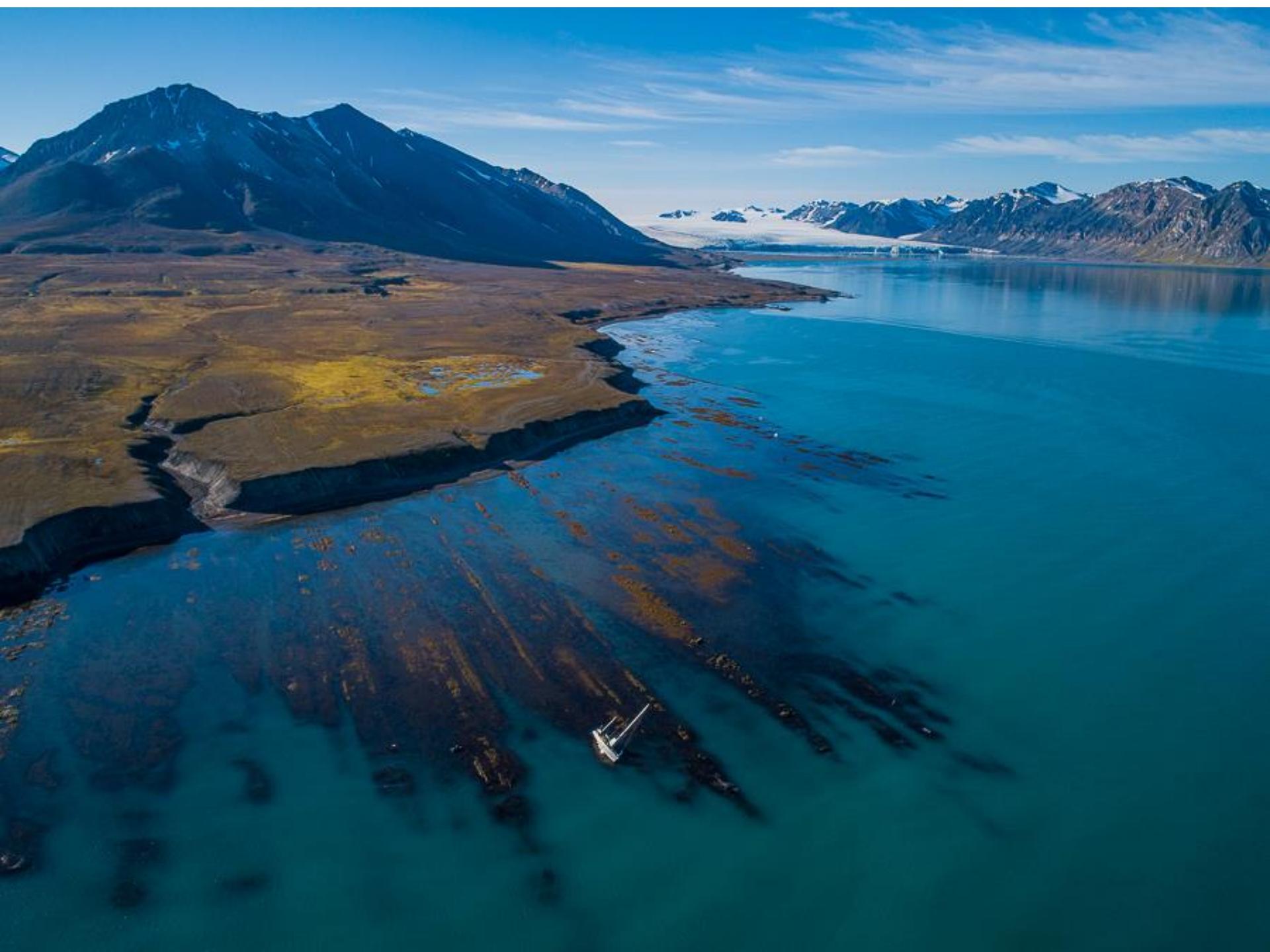












# Avventura







[rowaroundsvalbard.se](http://rowaroundsvalbard.se)

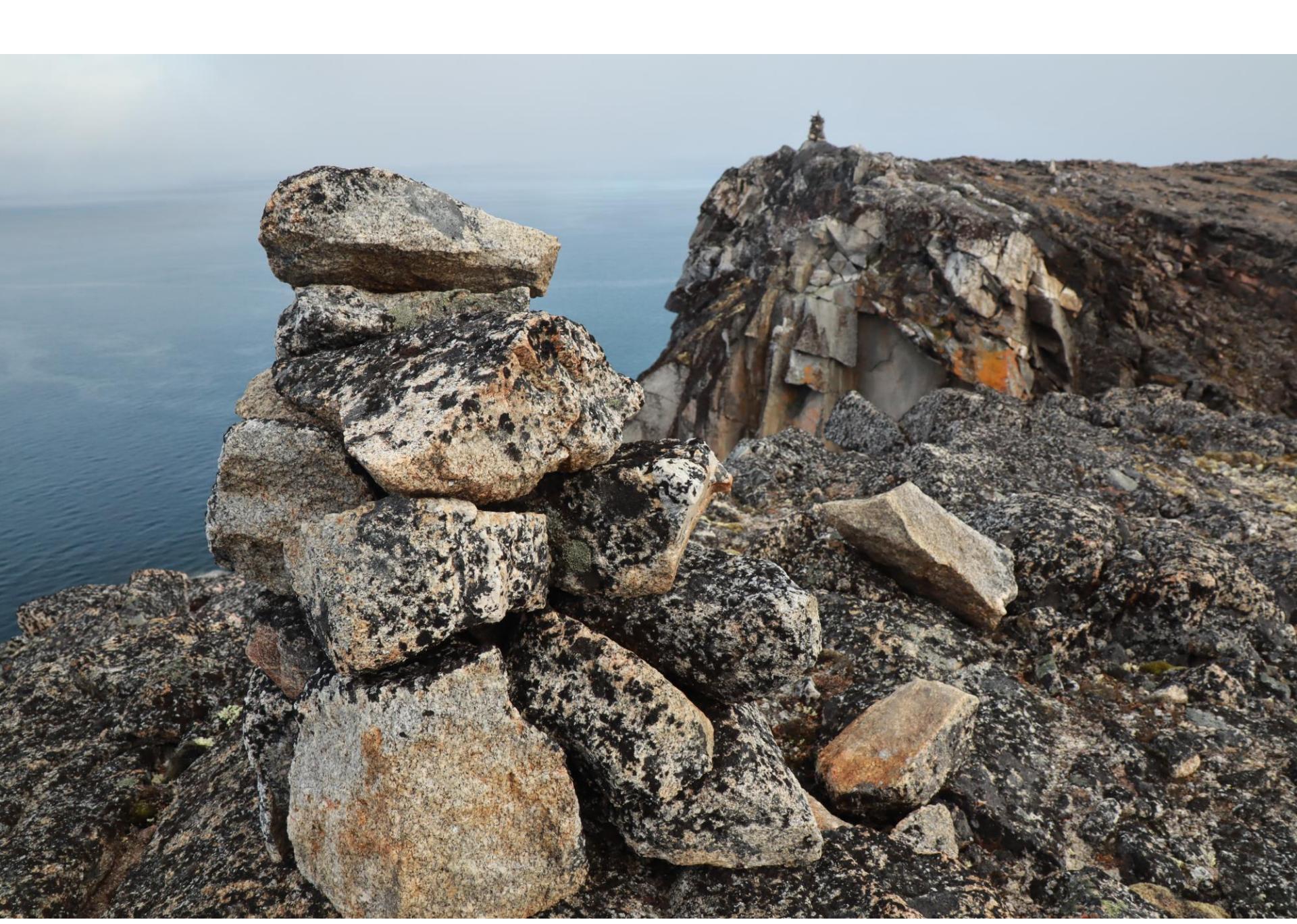
# Paesaggi e montagne







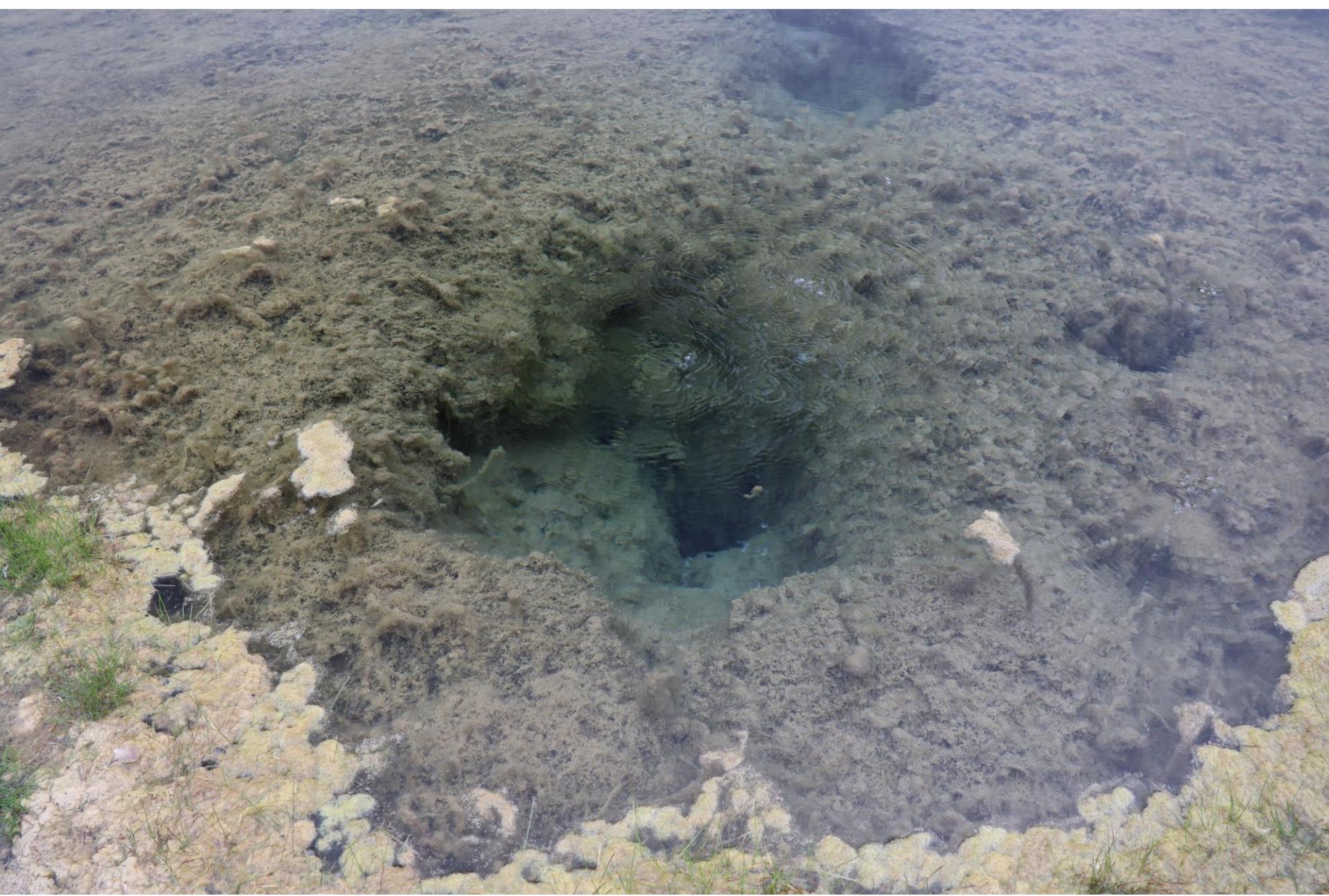






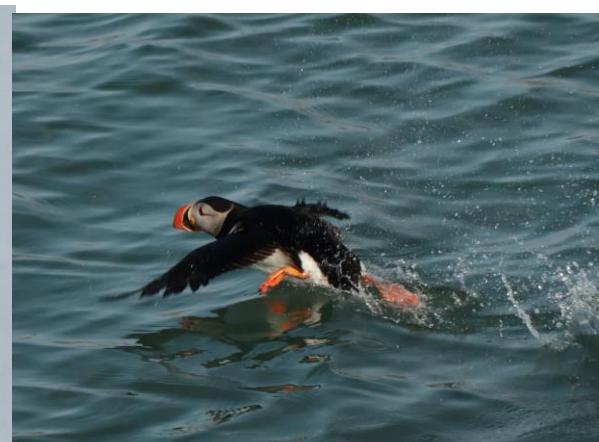
Natura













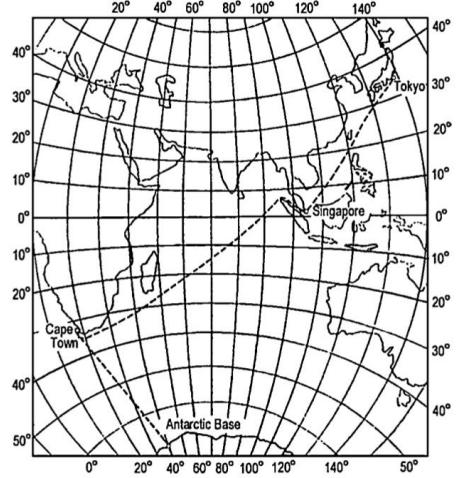
# Part-3

*Data Analysis*

# Previous measurements at sea level

*... vs latitude*

Soya Ship route, 1960



GEOGRAPHIC STUDY OF COSMIC RAYS

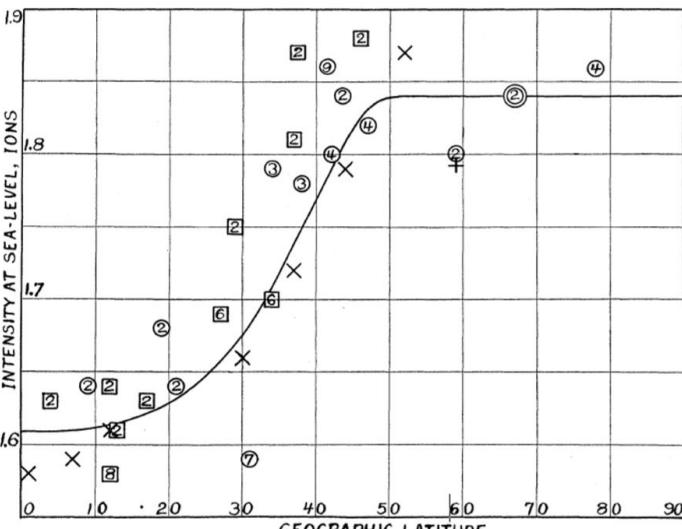
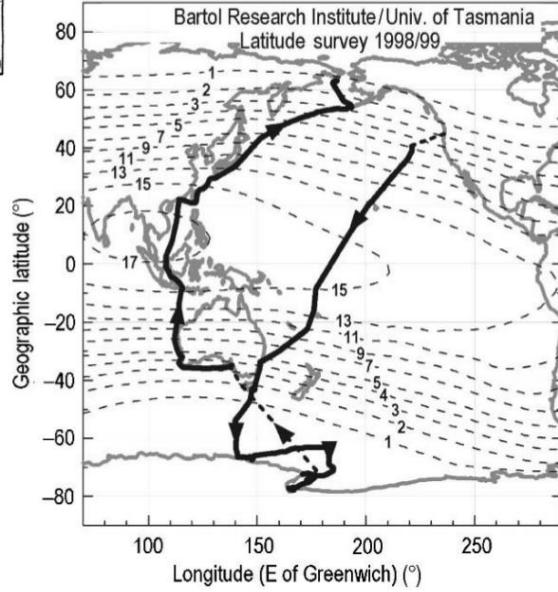


FIG. 8. Intensity vs. geographic latitude.

*... on boat*

A.H. Compton Phys. Rev.  
43 (1933) 387

Polar Ship Survey, 1999



# Time schedule

3 detector were assembled at CERN (POLA-01, POLA-02, POLA-03)

Two of them (POLA-02 and POLA-03) were supposed to be installed in two fixed location while POLA-01 was prepared for the expedition

Telescope ID	Time	Place	Text
POLA-01	23 October 2018	CERN	POLA-01 stopped. It will be sent to Bra
POLA-01	28 September 2018	CERN (bld 29)	POLA-01 back at building 29 --> 31 Hz
POLA-01	26 September 2018	CERN (R1)	POLA-01 moved at the photo exposition in R1 at 1 p.m. UTC time --> 25 Hz
POLA-01	24 September 2018	CERN (bld 29)	POLA-01 starts to take data at CERN --> 31 Hz
POLA-01	04 September 2018	NORWAY	Stop of the PolarQuEEEst expedition in tromso (Norway)
POLA-01	22 July 2018	ICELAND	Start of the PolarQuEEEst expedition
POLA-01	20 July 2018	Nanuq@Isafjordur	POLA-01 successfully installed on nanuq. It started to take data around 20.00 UTC --> 34 Hz
POLA-01	15 July 2018	Isafjordur (Iceland)	POLA-01 starts to acquire data in Isafjordur Harbor --> 28 Hz
POLA-01	28 June 2018	CERN	Last day of DAO@CERN before to send the telescope to Island
POLA-01	21 June 2018	CERN	POLA-01 is acquiring with the final setting --> 32 Hz in Building 29
POLA-01	28 May 2018	CERN	Start to acquire data at CERN

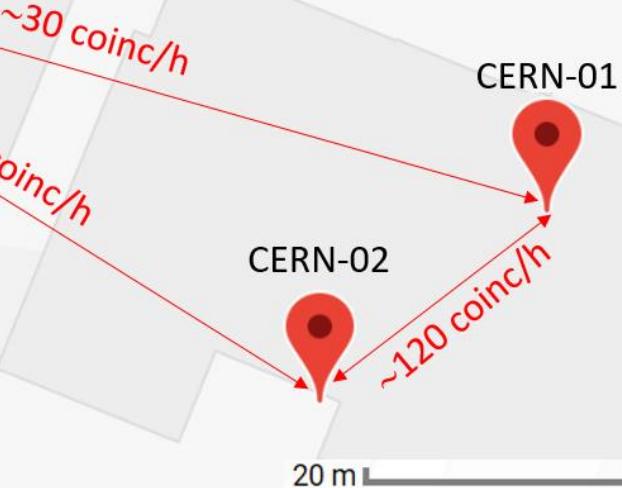
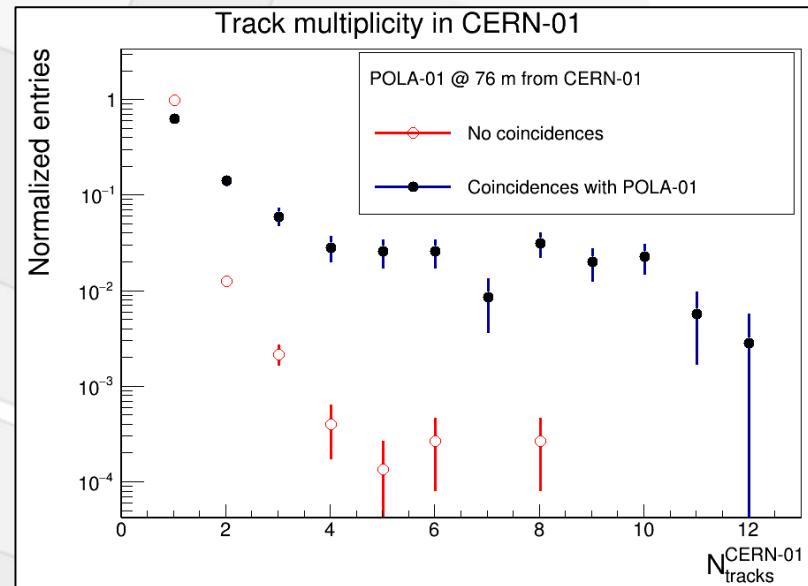
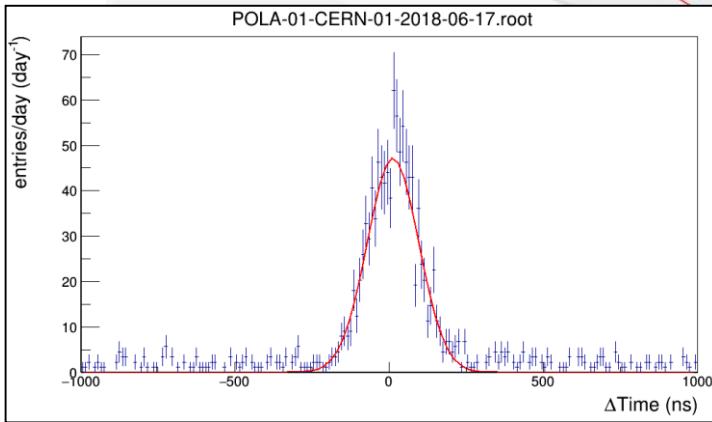
*Polar logbook*

## Part-3

**$\geq 3$  SiPMs coincidence required  
Single POLA rate  $\approx 30$  Hz**

POLA-01  
POLA-02  
POLA-03

$\sim 351$  coinc/h



## *Trip length*

Nanuq sailed for 45 days covering about **3500 NM**

## *Duty cycle*

The POLA-01 cosmic ray detector has taken data almost continuously for about **984 hours**

## *Detector efficiency*

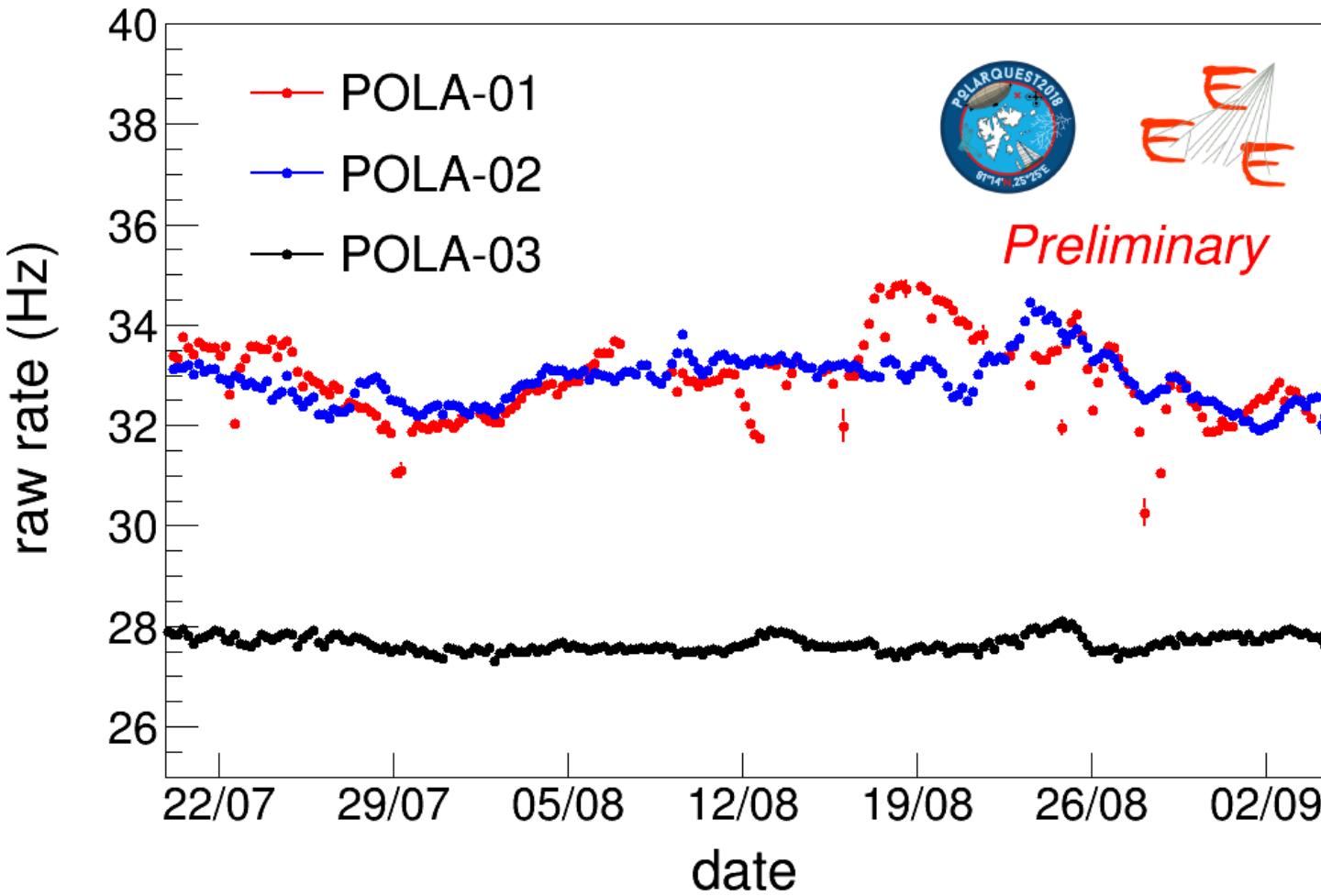
With a global efficiency for **POLA-01 of about 91%**, due to various reasons (main power down, difficult weather conditions, detector reset .... )

POLA-02 and POLA-03 were functioning during the whole period, with essentially 100% efficiency

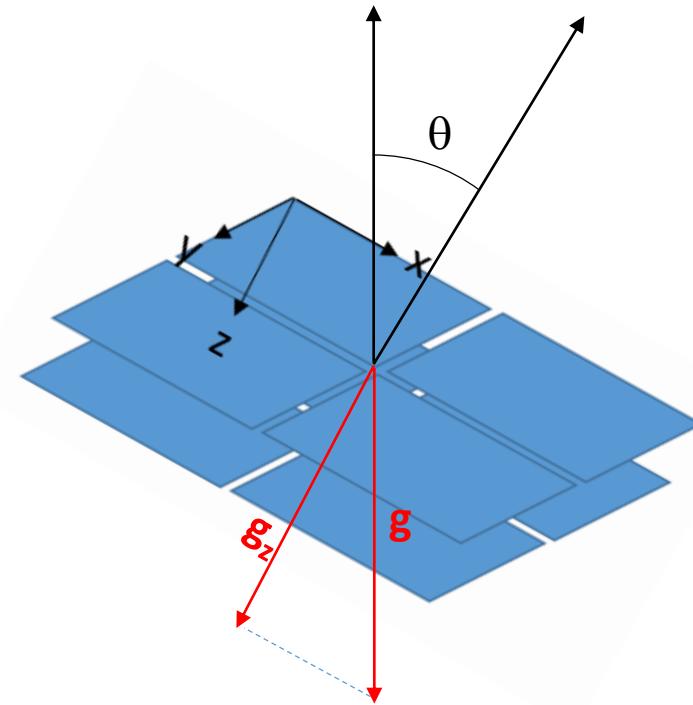
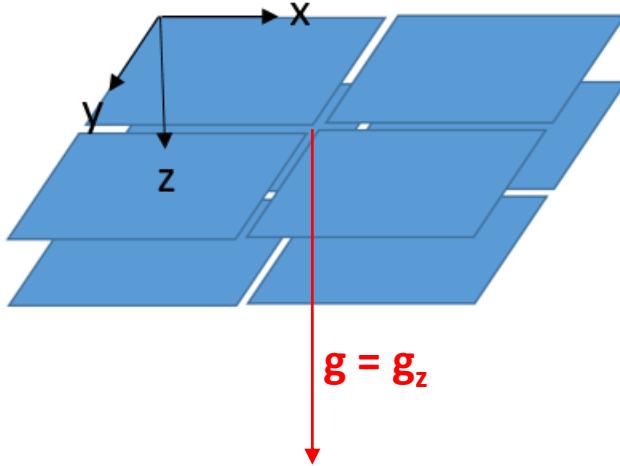
## *Collected muons*

In total, more than **100.000.000 tracks per detector** were collected

# Rate (*uncorrected*)

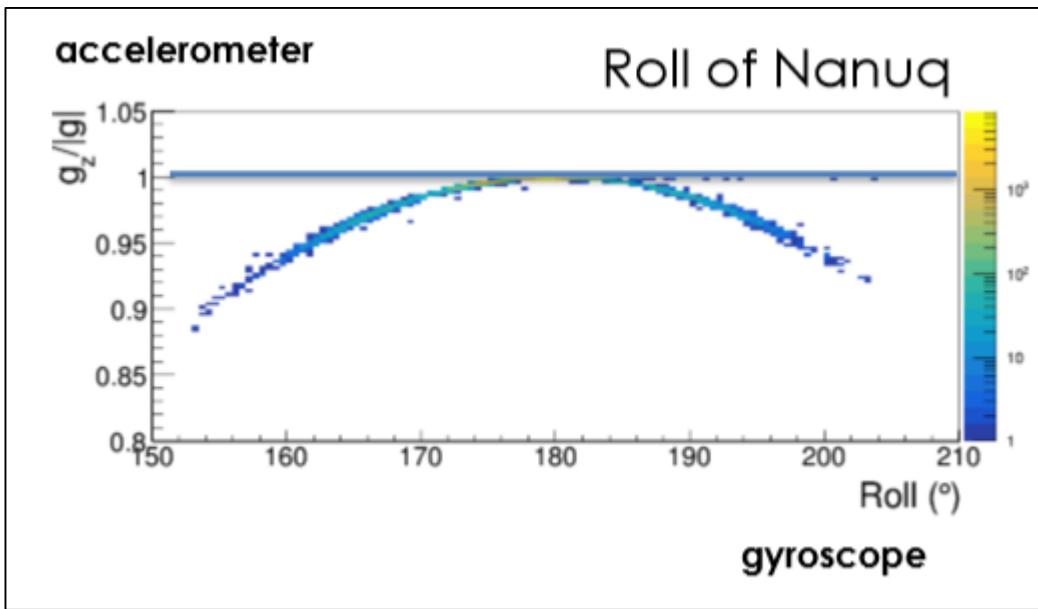


# Orientation of the telescope



The acceptance depends on the zenithal orientation of the detector. While sailing this orientation may change but it can be measured using the accelerometer on board and looking at the direction of the gravity acceleration in the local system  $\rightarrow \cos\theta = |\mathbf{g}_z|/\mathbf{g}$ . The max acceptance is expected to be at  $\cos\theta=1$  ( $\theta=0$ ) since the flux of secondaries has a maximum in the vertical direction.

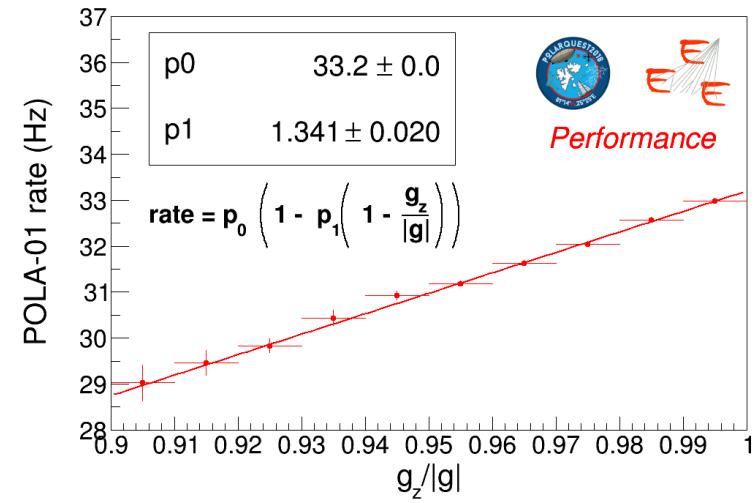
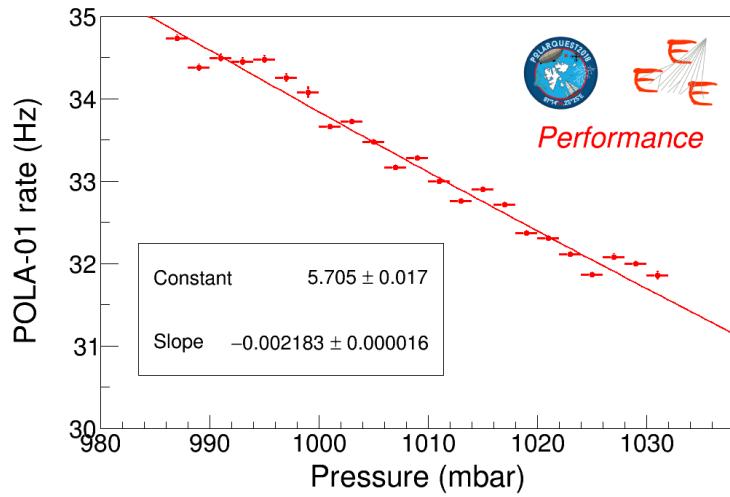
# Orientation of the telescope



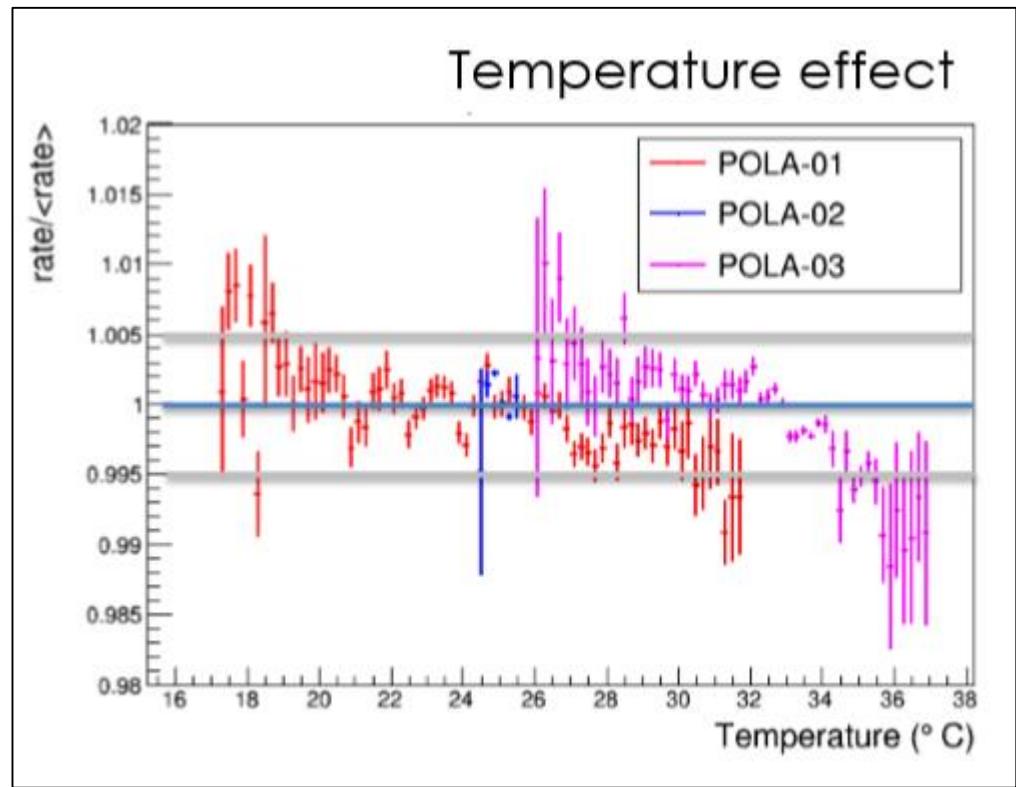
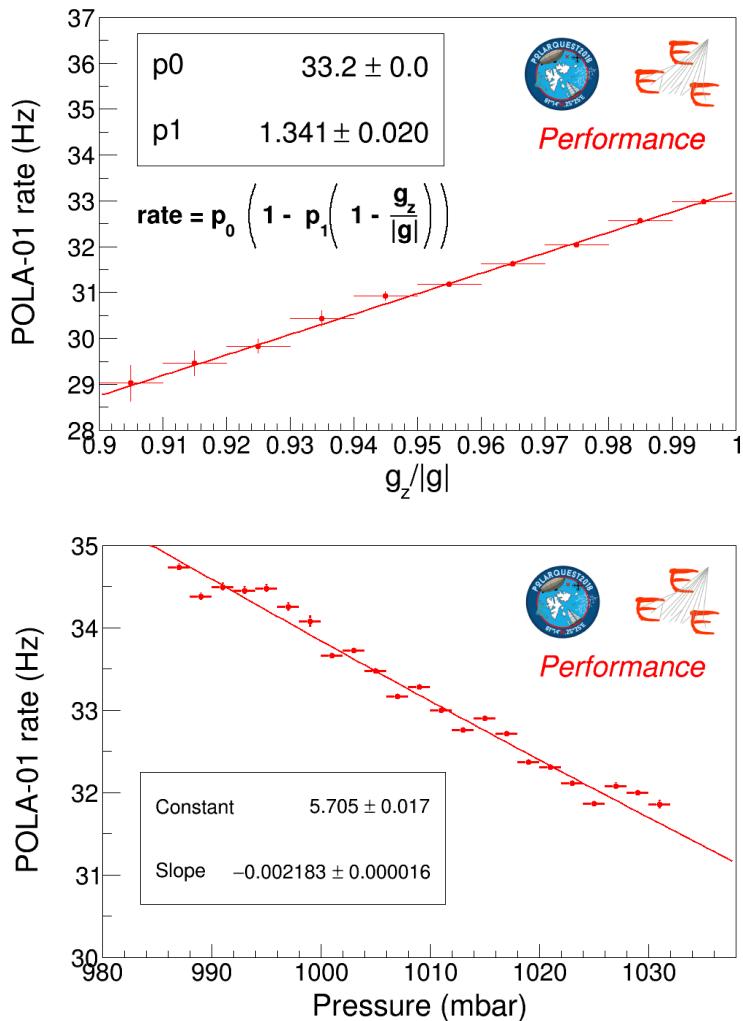
We checked also the correlation of the accelerometer with the gyroscope and we found a very good agreement.

The acceptance depends on the zenithal orientation of the detector. While sailing this orientation may change but it can be measured using the accelerometer on board and looking at the direction of the gravity acceleration in the local system  $\rightarrow \cos\theta = |g_z|/g$ . The max acceptance is expected to be at  $\cos\theta=1$  ( $\theta=0$ ) since the flux of secondaries has a maximum in the vertical direction.

1. Rates have to be corrected for the barometric effect since the absorption of secondaries (muons) increases with the amount of matter in the atmosphere, to which the pressure is proportional  
→ corrections obtained by fitting the rate dependence on the pressure for each detector separately during the full period
2. For POLA-01 also correction due to the detector orientation which may change when sailing (less relevant than pressure correction)  
→ corrections obtained by correlating the rate with the azimuthal angle using the accelerometer installed in the station (z-projection of the acceleration, 1 means vertical direction, i.e. gravity)



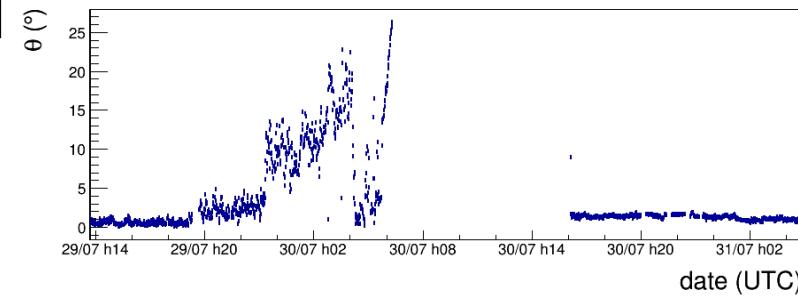
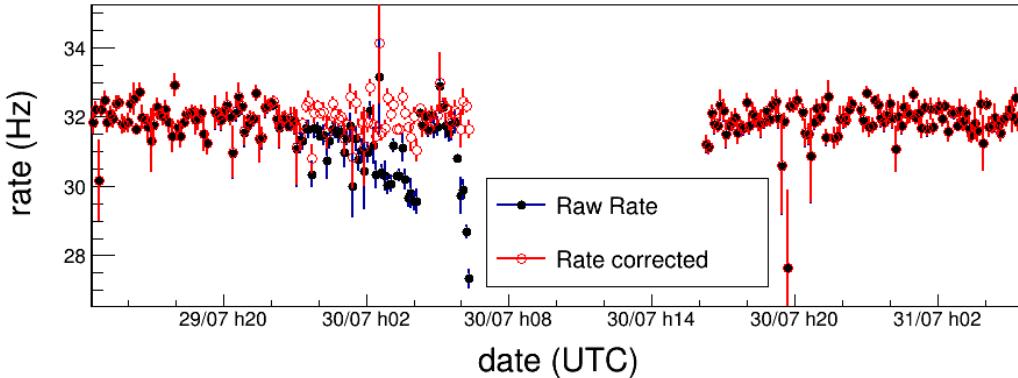
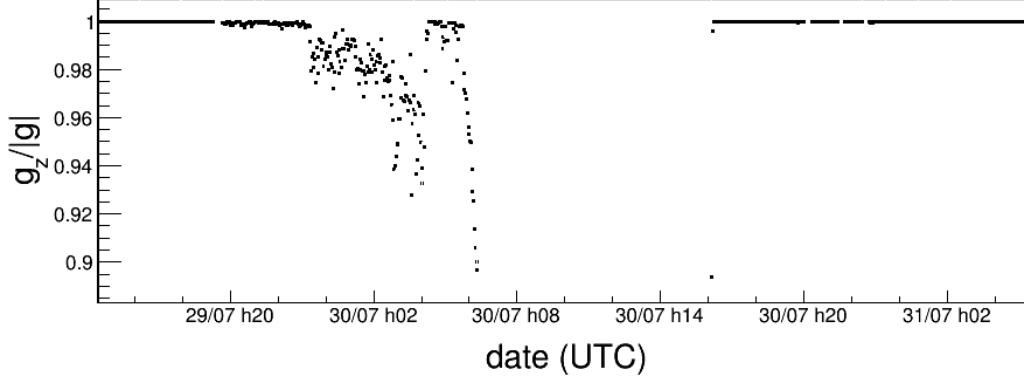
# Corrections



We checked also the rate temperature dependence and we found it negligible (compared to other effects)

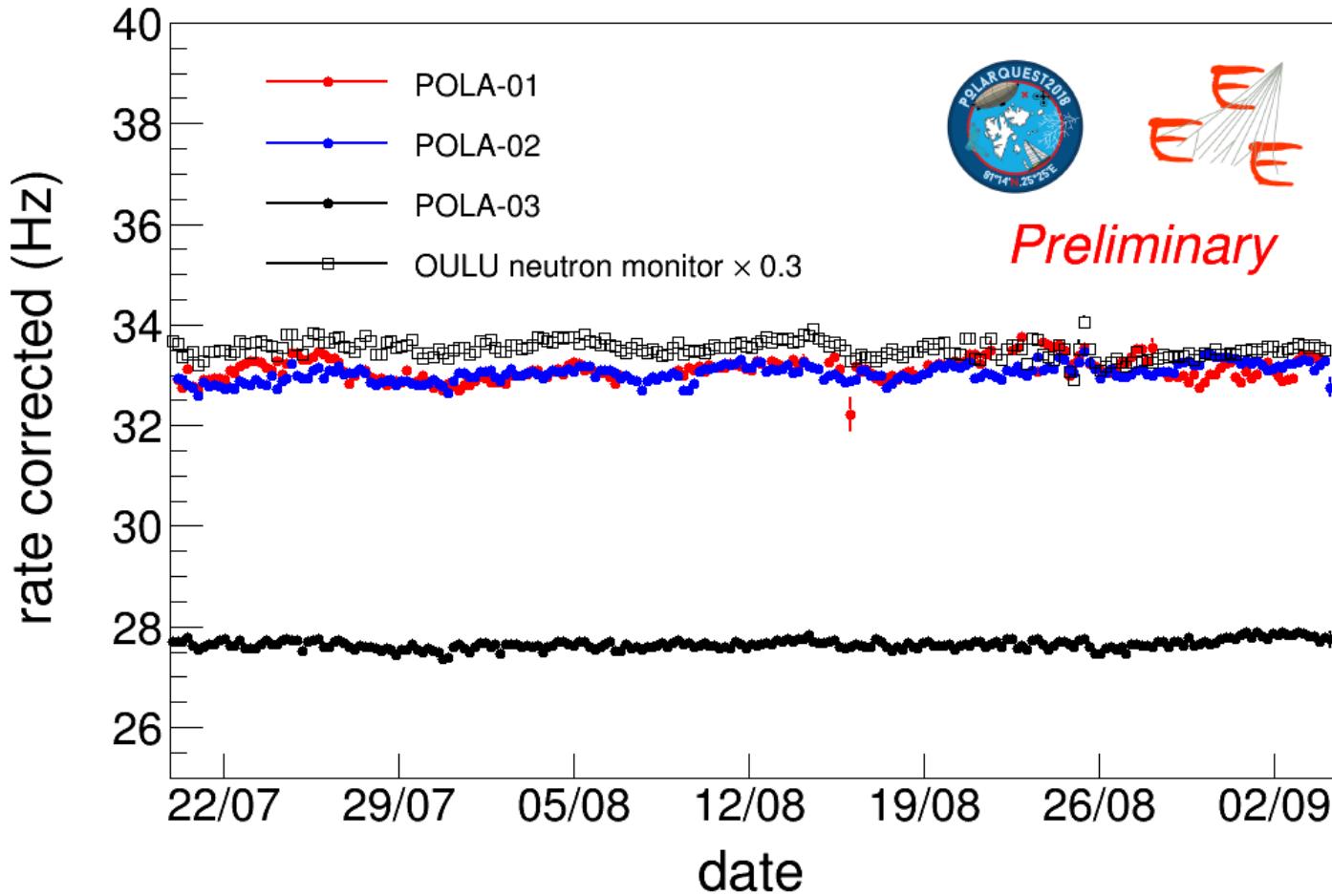
# Orientation correction

On 30 July a problem occurred for Nanuq (during low tide) ... Data were nevertheless collected before reaching this “exotic” position



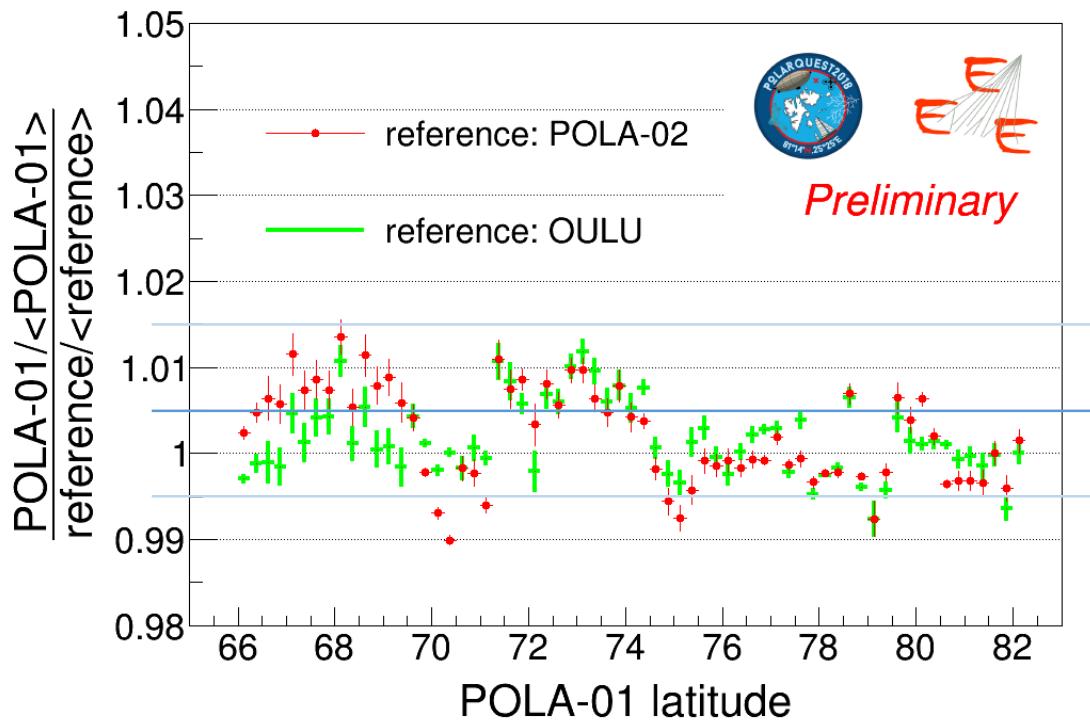
This special event allowed to verify the proper calibration of the orientation correction.

# Rate (corrected)



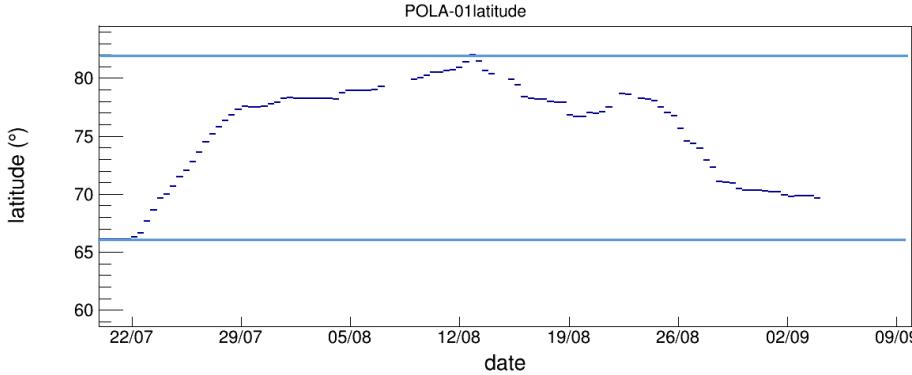
Three POLA detectors, corrected for pressure and rolling of the boat, compared with the OULU neutron monitor rate in the same period  
→ similar fluctuations related to primary cosmic rays flux variation

# Rate vs latitude



POLA-02 (in Oslo @ 59° N)  
used as reference since closer  
in latitude than POLA-03 (in  
Turin @ 45° N)

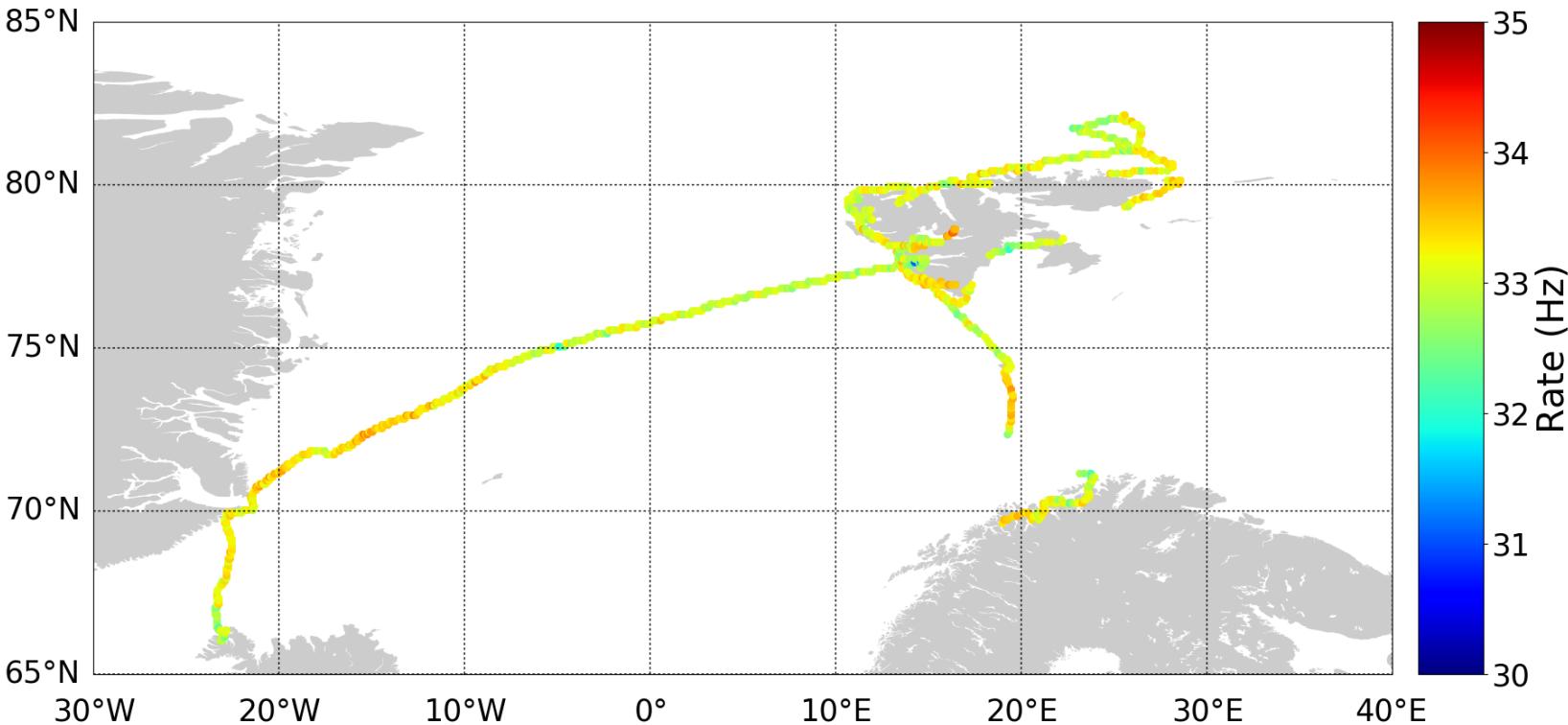
No significant effect observed  
→ Possible variation < 1%



**82°N (max) –North of Svalbard**  
**POLA-01 on Nanuq**  
**66°N (min) -Iceland**

# Rate along the Nanuq path

Aperitivo Scientifico, 26 Ottobre 2018, M. Garbini &amp; O. Pinazza &amp; F. Noferini



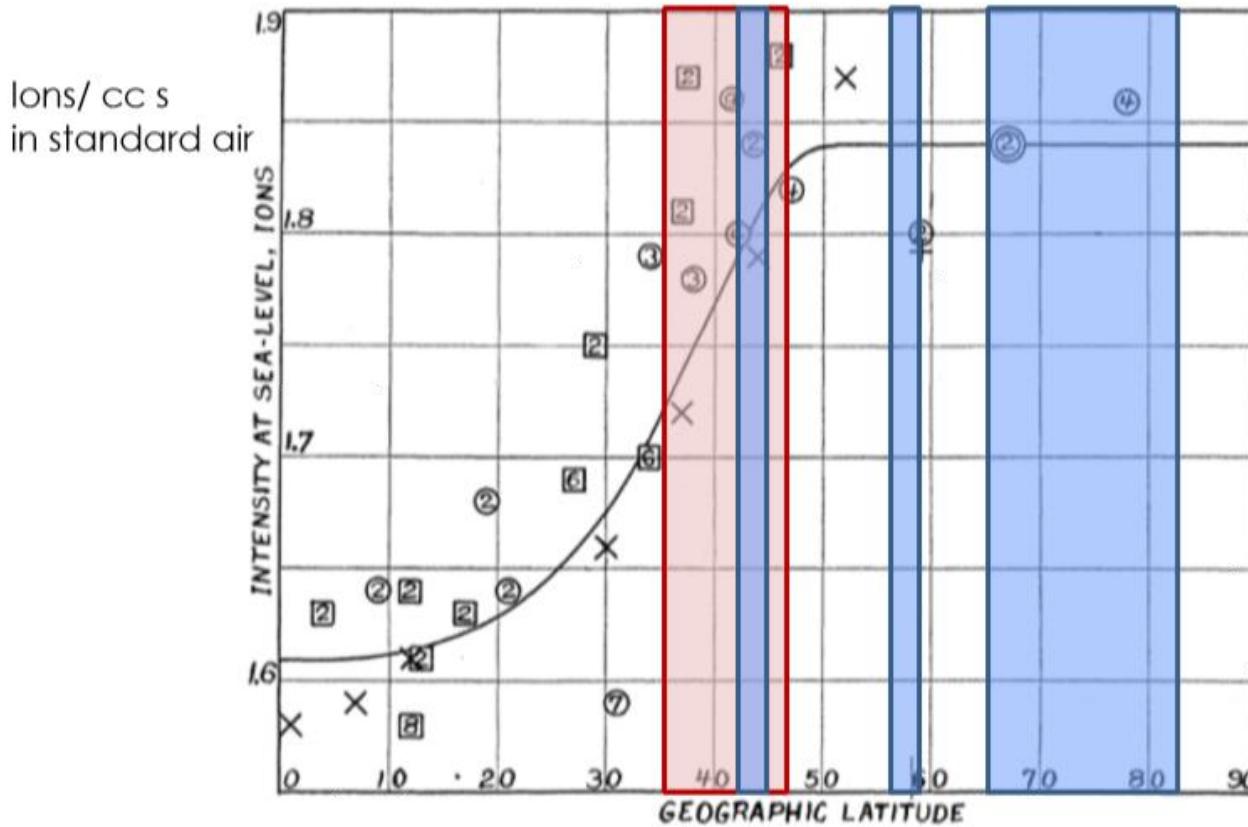


FIG. 8. Intensity vs. geographic latitude.



**PolarQuEEst latitude coverage**



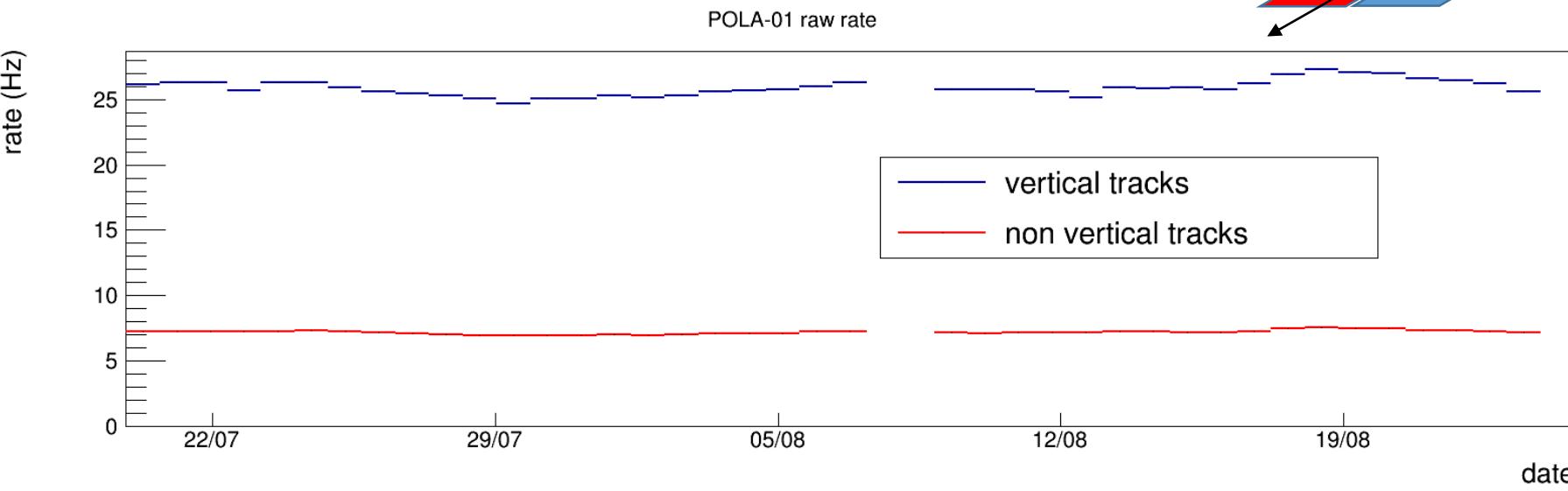
**EEE latitude coverage ( $36^\circ$  N –  $26^\circ$  N)  
and POLA-01 next measurements**

# Zenithal dependence

## Work in progress

We started to repeat the analysis splitting data in two different samples:

- vertical tracks → only events in two correspondent plates
- non vertical tracks -> only events in two non correspondent plates



We recalculated the corrections in the two sample (no relevant difference in the barometric coefficient but differences in the orientation correction)

# Many thanks to ...

M. Garbini & O. Pinazza & F. Noferini

Aperitivo Scientifico, 26 Ottobre 2018,

100



... to many people

