A multi-channel trigger and acquisition board for TDC-based readout: application to the cosmic rays detector of the PolarQuEEEst 2018 project.

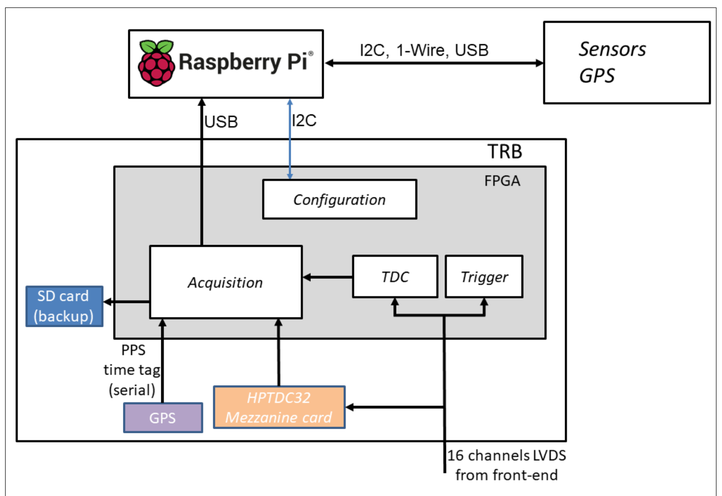
R. Travaglini [1], G. Balbi [1], D. Cavazza [1], D. Falchieri [1], M.Garbini [2], M.N. Mazziotta [3], S. Meneghini [1], F. Noferini [1], R.Nania [1], C. Pellegrino [2], O. Pinazza [1], G. Torromeo [1]
on behalf of the EEE Collaboration [4]

[1]INFN Bologna, [2]Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, [3]INFN Bari,
[4]https://eee.centrofermi.it/research/structure-of-the-eee-collaboration

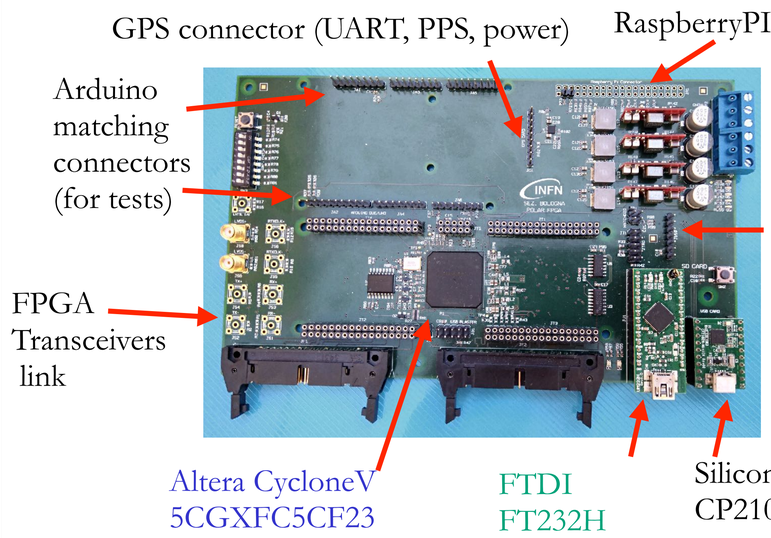
ABSTRACT

In the 2018 summer the **PolarQuEEEst experiment** accomplished a **measurement of cosmic rays flux in the Arctic**. The **detector**, installed on a sailboat, was **based on scintillation tiles read by a total of 16 SiPMs**. A **multi-channel board** (called TRB) has been designed to **process** the discriminated **SiPM signals providing self-trigger capability and time-to-digital conversion**. TDC conversion has been implemented in FPGA and in a HPTDC chip (as a backup). Hereinafter, the board is detailed, and the PolarQuEEEst project, including further measurement campaigns, is shown.

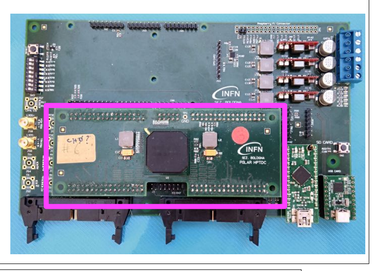
THE TRIGGER AND READOUT BOARD (TRB)

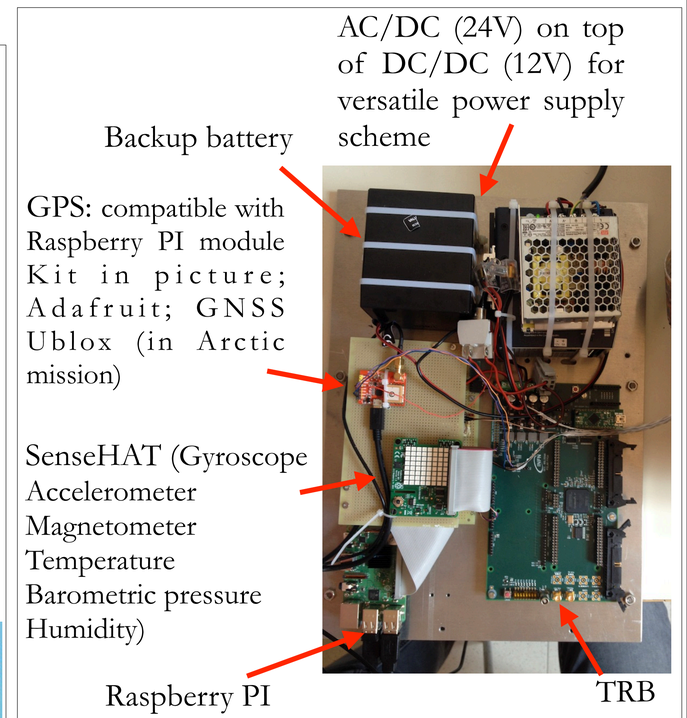


The main scheme
16 differential channels routed to the FPGA for trigger generation (configurable) and time-to-digital conversion. The same 16 channels plus 16 more are routed to a mezzanine card hosting a HPTDC which acts either as a backup or as an extension. GPS data are added to data and used to generate a 10 ns time-tagging. The trigger is configurable (auto-generated, external) and with 10 ns resolution.

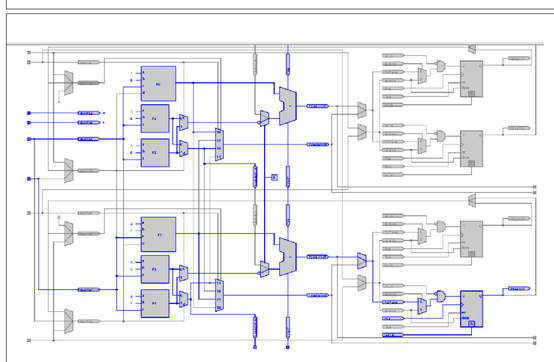


The PCB
Signals from the connectors are routed to the Altera FPGA and the HPTDC. FTDI USB card implements the 60 MB/s output data bus towards RaspberryPI. The HPTDC-based mezzanine board is plugged on top (**right**).



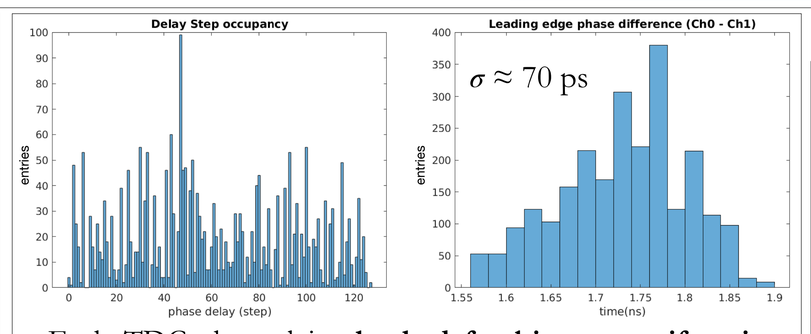


The portable Acquisition System has been designed for PolarQuEEEst project. TRB provides trigger and data acquisition. Raspberry PI configures and control runs, acquires environment sensors. Total power consumption **less than 13 W**.



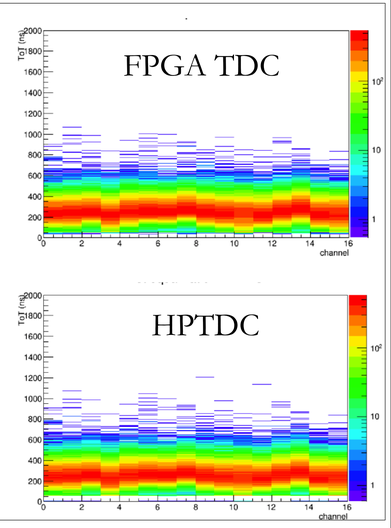
63% logic utilization

The FPGA and TDC implementation
Each TDC is implemented with a 512-length carry chain, sampling 1 out of 4 taps (**2 logic cells shown, left**) at 320 MHz. ~40 ps resolution is expected. Partitions are used to block TDC chains (**blue and orange cells, right**).



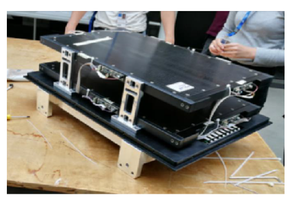
Each TDC channel is **checked for bin non-uniformity** (**left**). The resolution can be obtained by sending the same pulse to each channel and measuring the phase difference between every pair (**right**) which is the square sum of the single channel resolution. Therefore, **channel resolution** can be calculated by solving linear systems and **typical** achieved **values** range **from 40 to 90 ps.**

FPGA TDC vs HPTDC performance (TOT)
HPTDC has been set with 200 ps resolution (for low power consumption). **SiPM time-over-threshold cumulative histograms** for a typical cosmic run show very good agreement between FPGA TDC measurements (**upper**) and the HPTDC ones (**lower**).

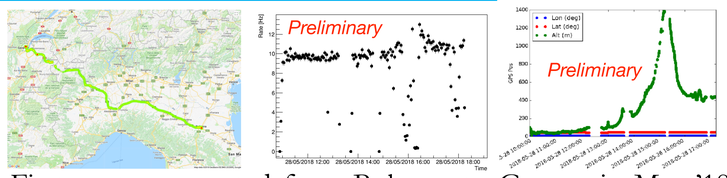


THE POLARQUEEEST PROJECT

Prototype and detector assembly



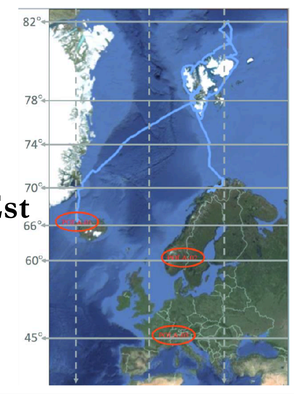
The detector (**left**) was built in 2018 and consists of 2 scintillation layers of 60x40 cm (4 tiles/layer), 2 SiPM per tile, for a total of 16 channels



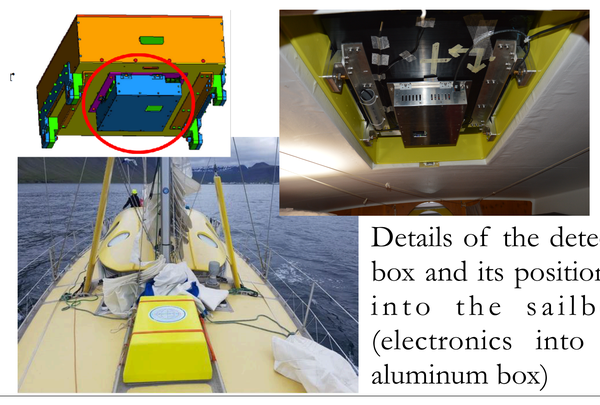
First prototype tested from Bologna to Geneva in May '18, acquiring cosmic rays and GPS info. Can you spot the Mont Blanc tunnel transit from rates and GPS data (**above**)?

Three detectors were assembled at Cern (**right**) by scholars: one for the Arctic campaign and two acting as reference (one put in Bra, near Turin, the other one in Oslo).

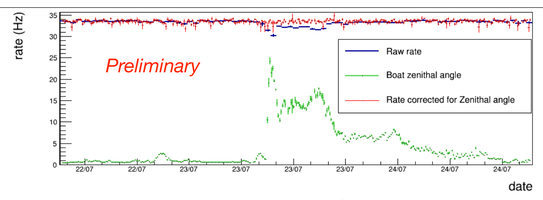
2018 Arctic PolarQuEEEst Mission



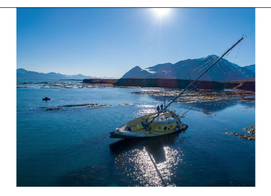
During the summer 2018 expedition, a sailboat circumnavigated the Svalbard archipelago equipped carrying one detector to perform cosmic rays flux measurement in the Arctic region up to 82°N lat.

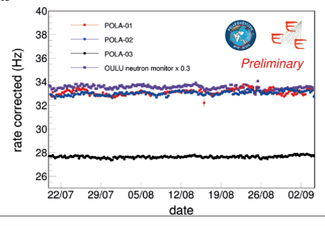


Details of the detector box and its positioning into the sailboat (electronics into the aluminum box)

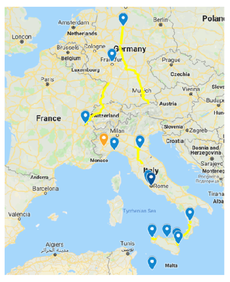


About 2 months of data were recorded with ~30 Hz trigger rate. Data have been corrected using environment sensors (**above**) and compared with reference detectors (**right**)

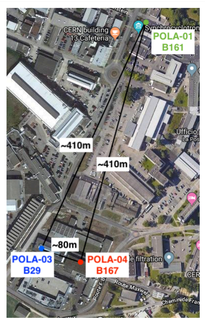




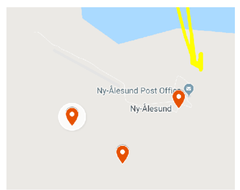
2019 Measurements campaign



From fall '18 to spring '19 the Arctic detector has been carried around Italy, Switzerland and Germany (**left**) to provide measurements at several latitudes. Its portability have been proved (**right**)



Three detectors reconvened at Cern in spring '19 to get proper cross-calibration. A new firmware allowed them to be synchronized with < 10 ns of absolute time reference to look for coincidences (**left**)



At the end of May 2019 three detectors were put back at the Svalbard islands, near Ny Alesund (**above left**), into barracks (**above right**). Measurements on going !

References

1) 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
2) http://www.polarquest2018.org
3) https://eee.centrofermi.it