
# The upgrade of the Pierre Auger Observatory with the Scintillator Surface Detector.

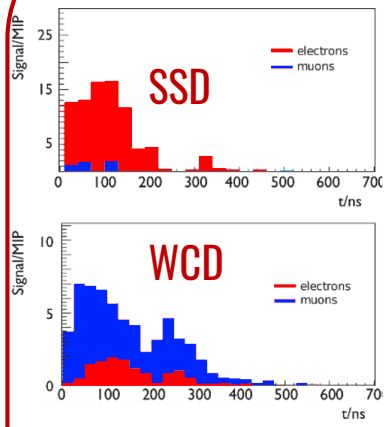
Gabriella Cataldi (INFN Lecce)
on behalf of the Pierre Auger Collaboration

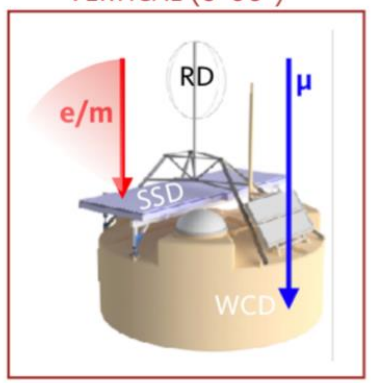
# The concept of the upgrade

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

Use complementary of response of detectors to discriminate muonic and em components on 3000 km$^2$

## Vertical showers




$S_{\mu,WCD} = a\, S_{WCD} + b\, S_{SSD}$

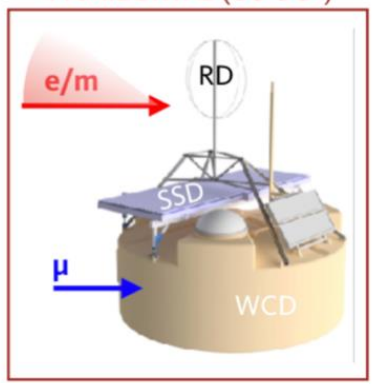
+

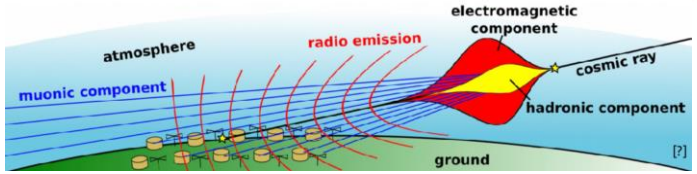
## Horizontal showers

F.Schlüter #1210
T. Fodran #1278

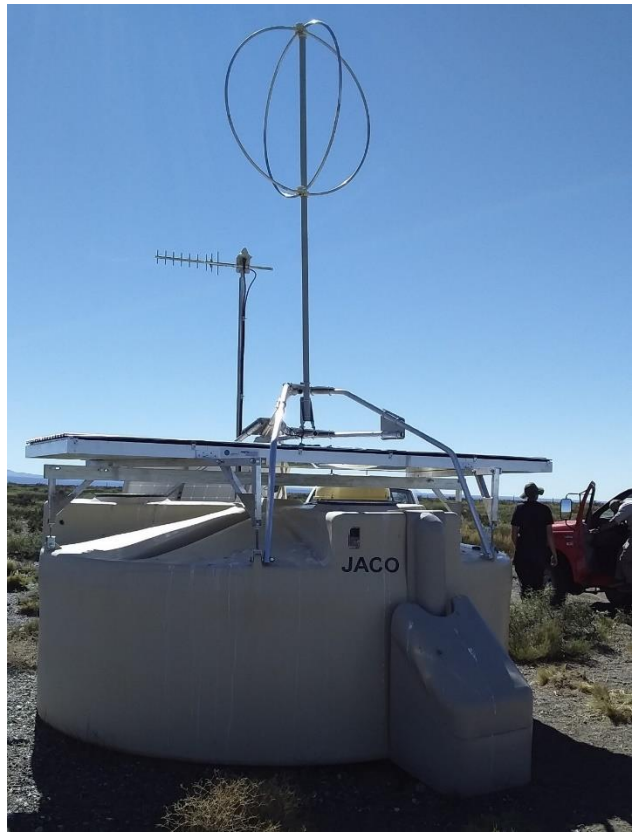
RADIO

Hybrid:
$E_{rad}$ from radio
muons from WCD




+




+

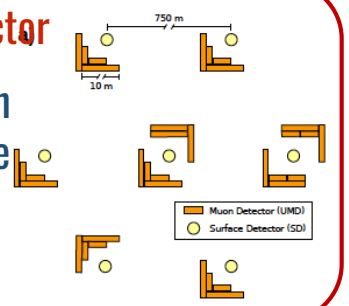
- ✓ New electronics (faster)
- ✓ Addition of a small PMT in the WCD (extension of dynamic range)

G. Marsella #746

+

## Underground Muon Detector

61 Underground Muon Detectors in coincidence with 750 m array



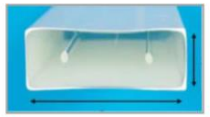

A.M. Botti #778

Extend operations to >2025, increasing the statistics

# The Scintillator Surface detector (SSD)

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

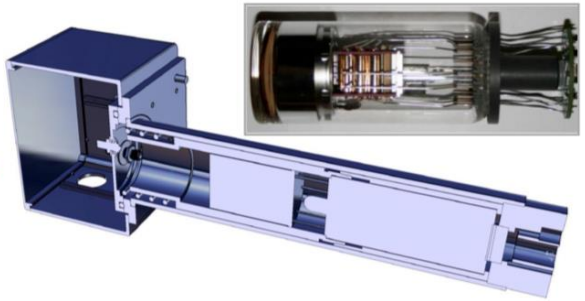
Extruded Scintillator bars with 2 holes




WLS fibers+routers

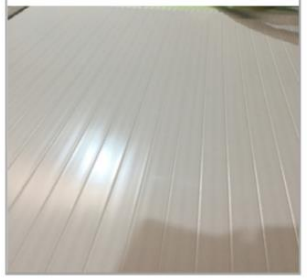


PMT



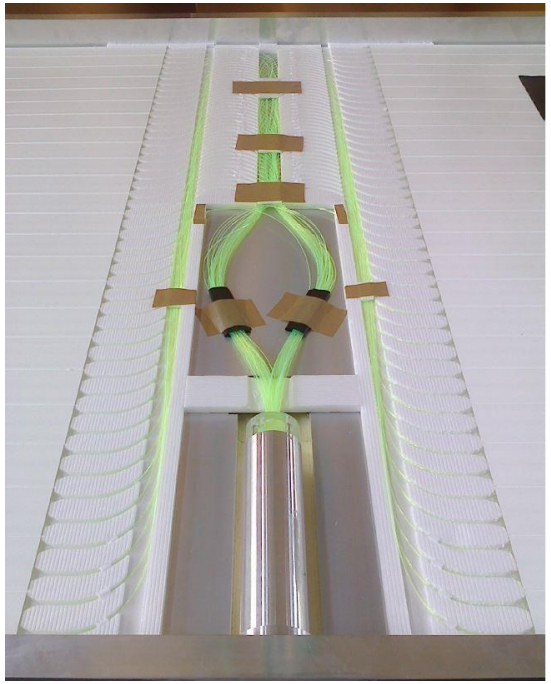
WLS fibers+routers

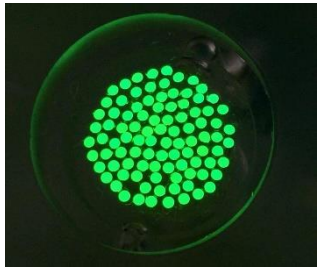
Extruded scintillator bars 160cm long




Alu Enclosure

Scintillator 3.8 $m^2$





# SSD Production


## SSD assembly and testing

NIKHEF Nijmegen
RWTH Aachen
LPSC Grenoble
IFJ PAN Kraków
KIT Karlsruhe
INFN Lecce

## PMT testing

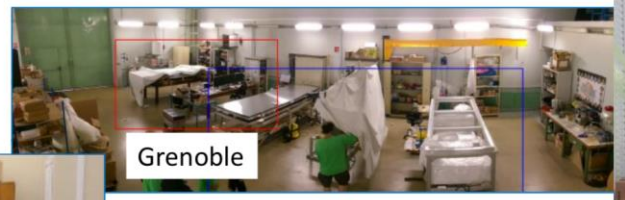
Bergische Universität Wuppertal
INFN Napoli

## UUB testing (electronics)

Prague

**Other institutions are helping in the procurement and preparation of the parts.**

**The large-scale production of the 1518 detectors is now completed**



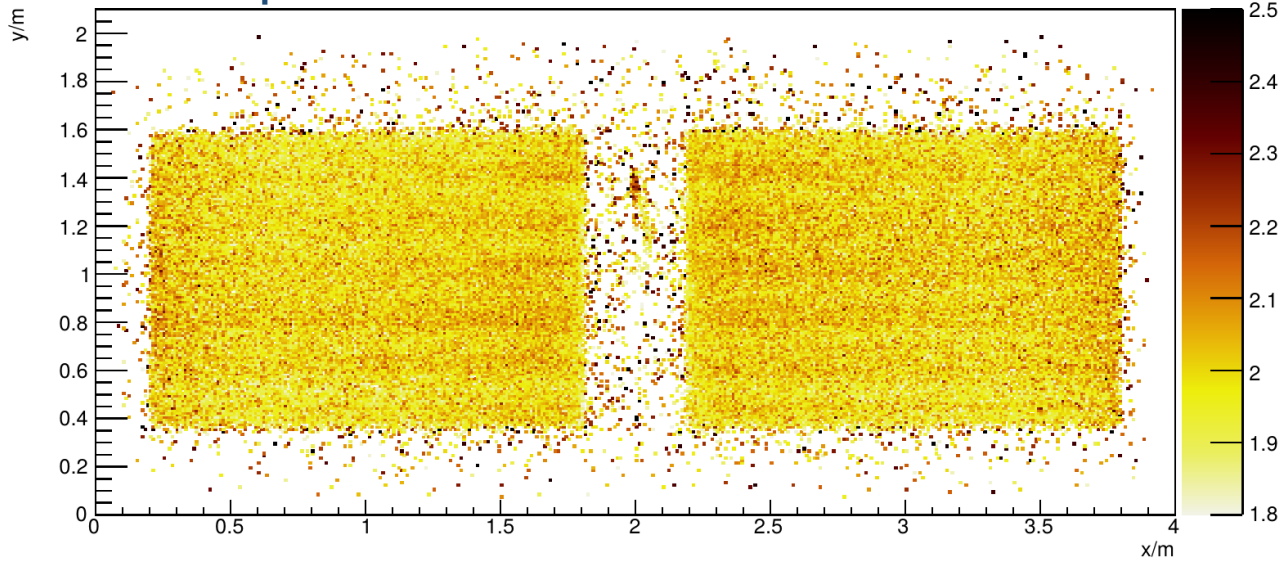





# SSD Production insight

Tests with cosmic ray muons:

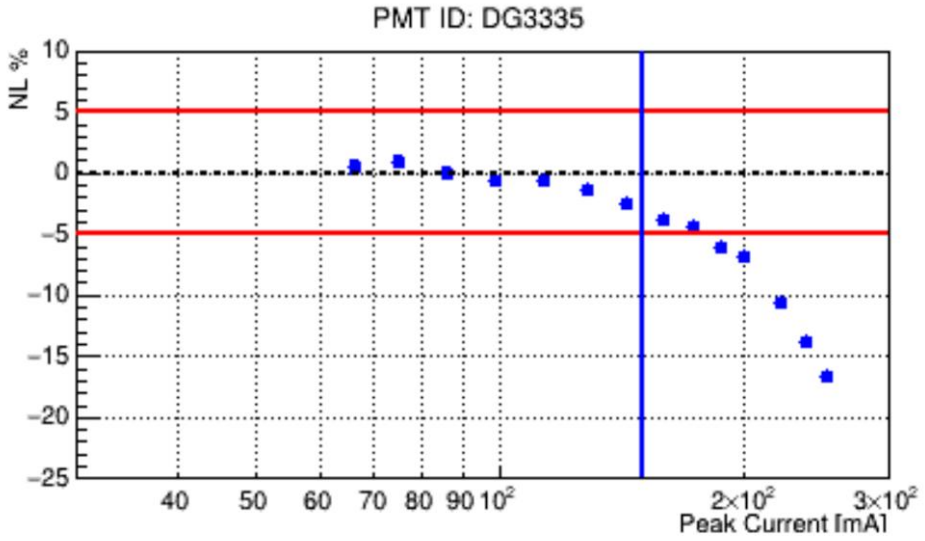
- Determination of SSD response to a reference MIP.
  - The ratio MIP/SPE is used check the quality of SSD.
  - The uniformity in the response of the SSD detectors can be measured via external trackers (e.g. planes of limited streamer tubes) on a muon tower setup.




Average logarithm of the deposited charges of the particles depending on the position of intersection with the scintillator planes in 1 cm x 1 cm bins for one of the SSD, as measured in a muon tower

The single PMT used in each SSD requires an excellent linearity.

Linearity curve for one of the SSD-PMT



# SSD Deployment: in the field

PIERRE AUGER OBSERVATORY

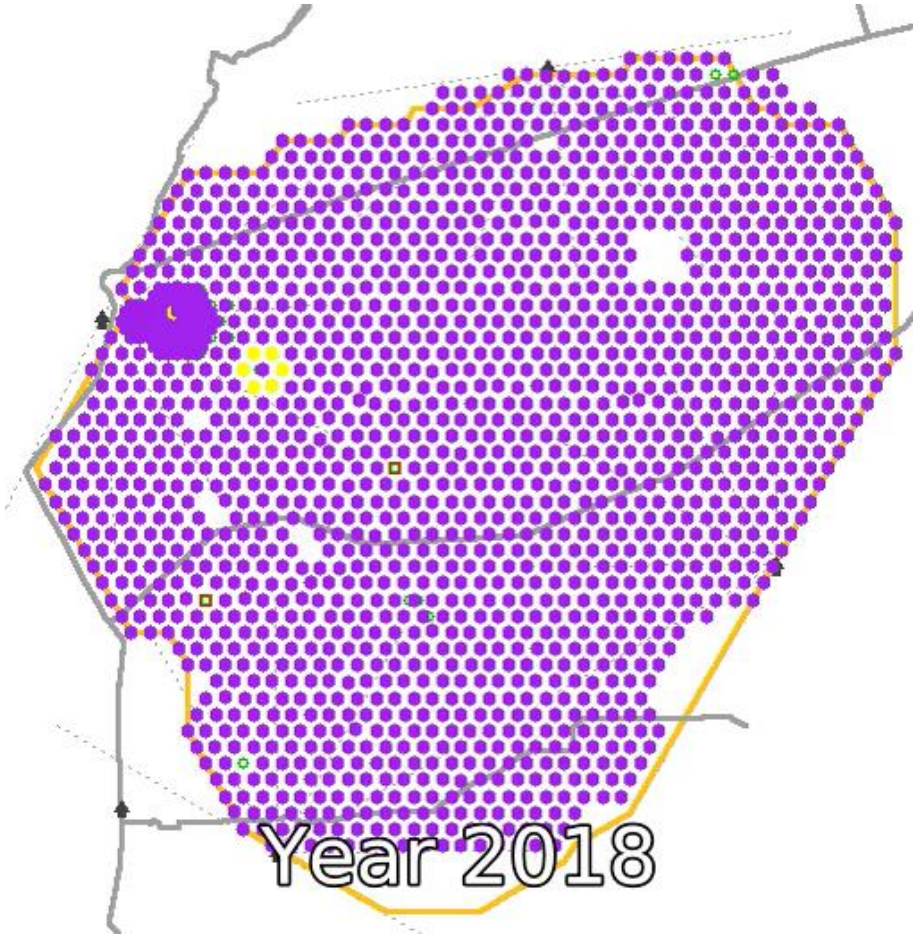
ONLINE ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany
37th International Cosmic Ray Conference
12–23 July 2021

# SSD Deployment: the status

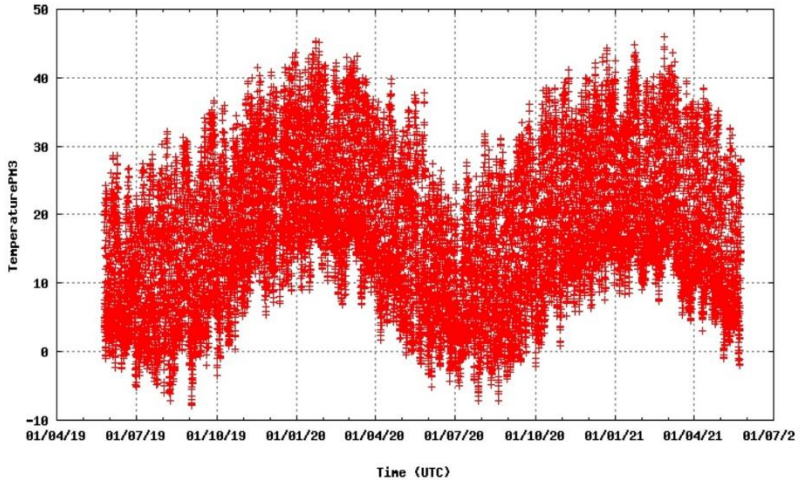
PIERRE AUGER OBSERVATORY
ONLINE
ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany
37th International Cosmic Ray Conference
12–23 July 2021

The online monitoring system, which overviews the operation and maintenance of the SD, includes the **status of the deployment** and the control of SSDs operation:

In March 2019 a preproduction array of 77 SSDs started data acquisition with an adapted version of non-upgraded electronics, it is collecting events.
Since December 2020, the upgraded electronics boards are being deployed in the field together with the photomultiplier tubes

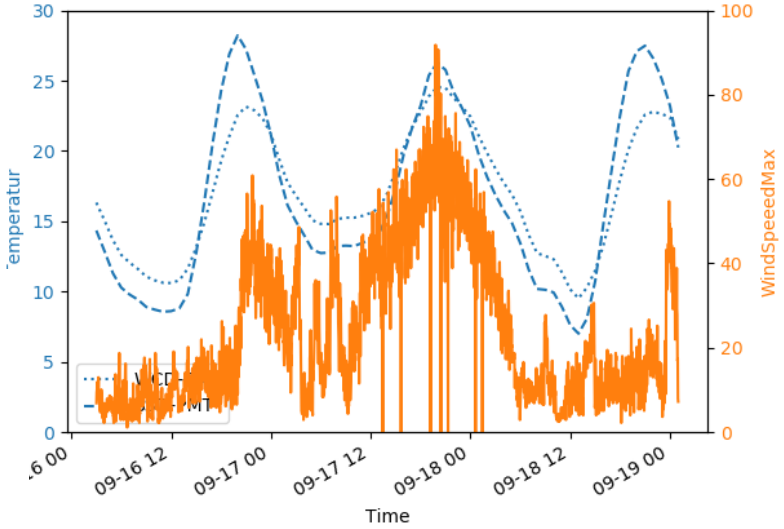


# SSD Deployment: temperature and wind

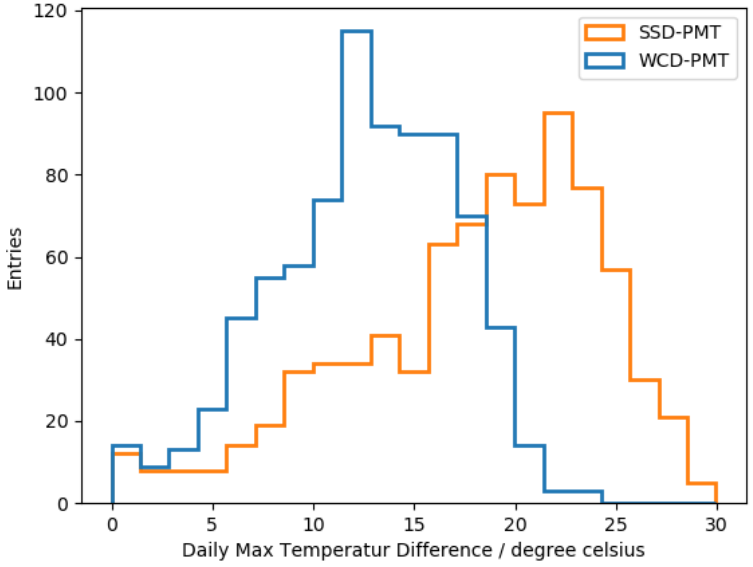


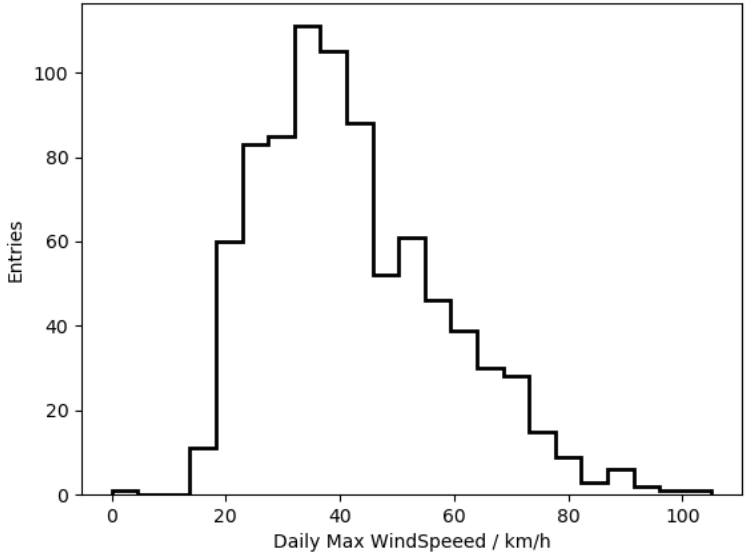

Temperature –spread giving the diurnal variation
General shape evidencing the seasonal effects

- Harsh environment



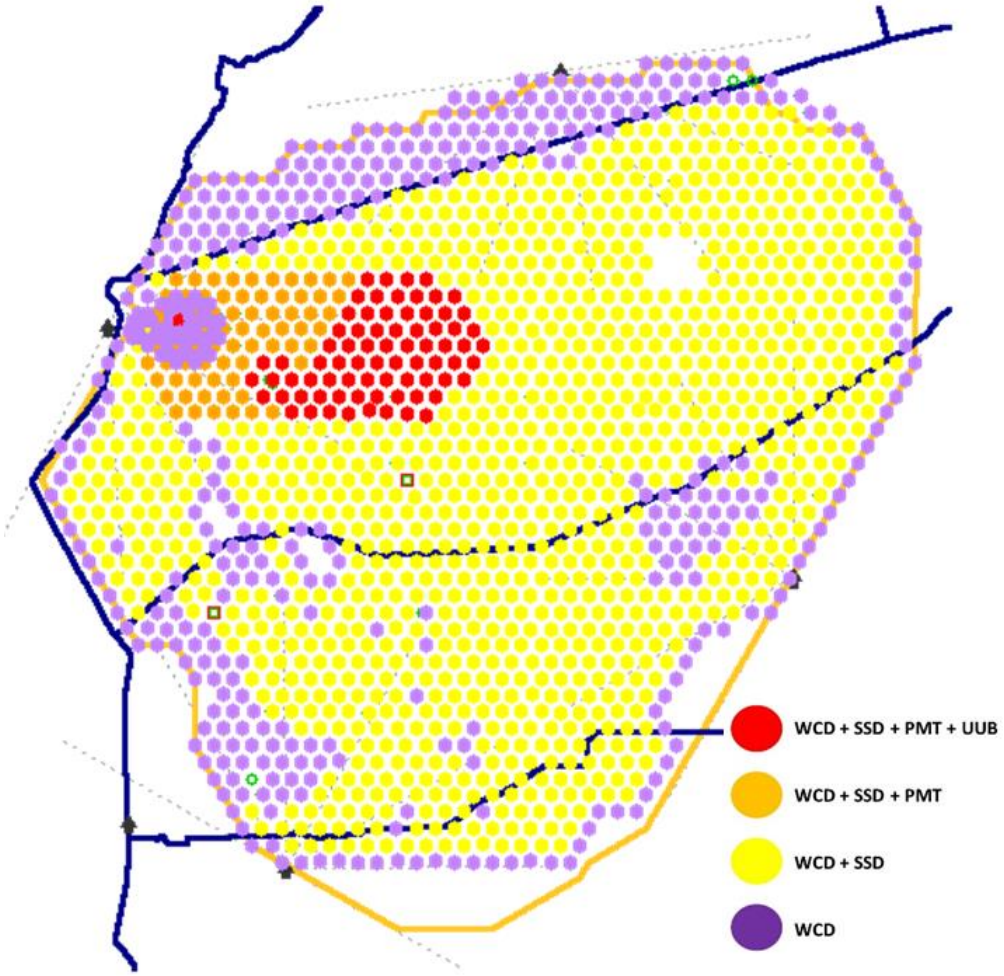

*Combine temperature and wind for a few days*



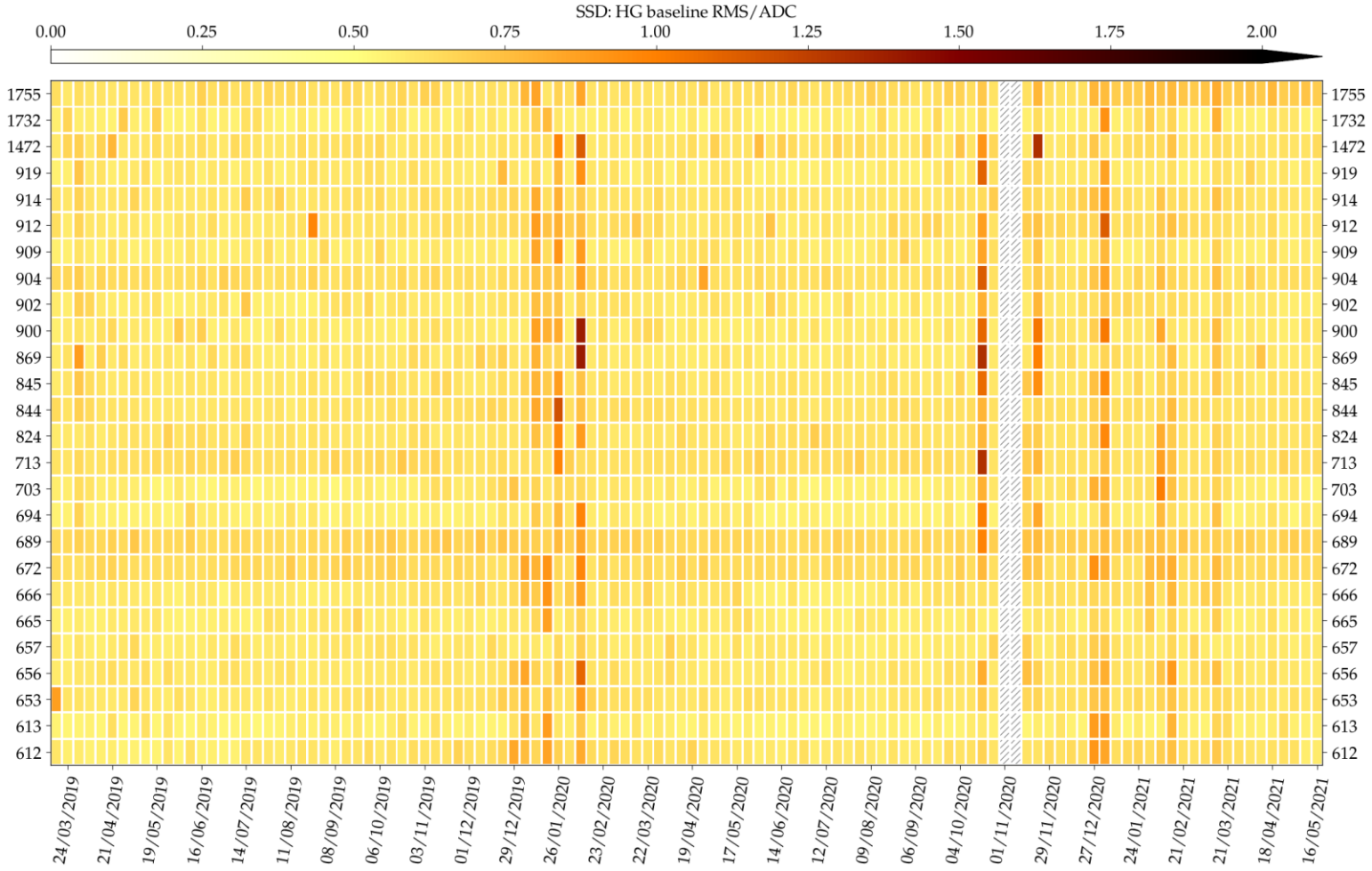

Temperature and Maximum Windspeed for the data acquisition period

# SSD Deployment: status map in june 2021




Around 1400 out of the total number of Auger surface detectors will be instrumented with SSD.
The remaining detectors will be used either as spares or on specific parts of the experimental region (e.g. on doublets that are detectors located few meters apart, or in the 750m sub-array where the SDs are more densely spaced).
The full array will contain the upgraded electronics and will be fully functional in trigger capabilities.

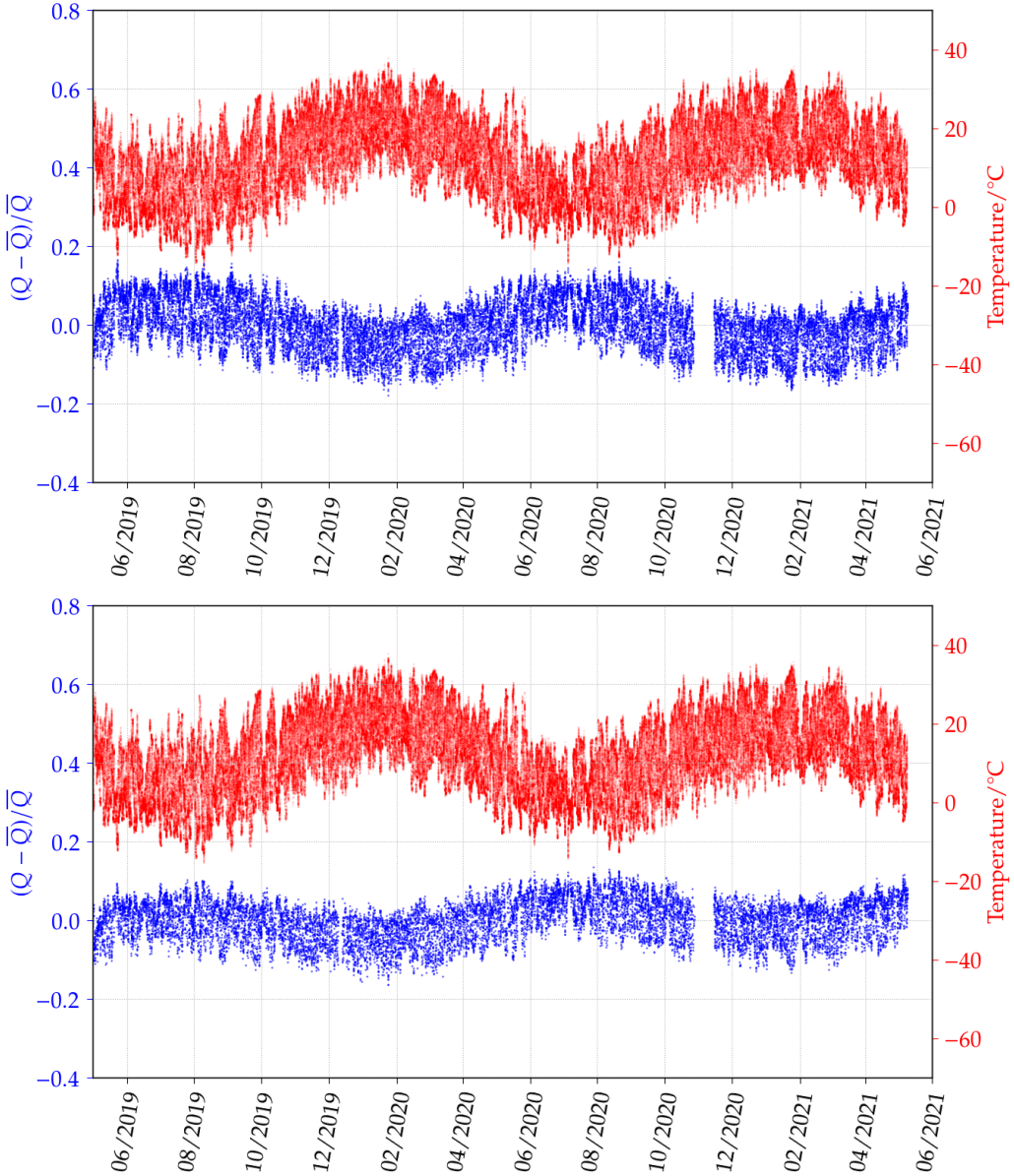
# Status of the array and stability of operations

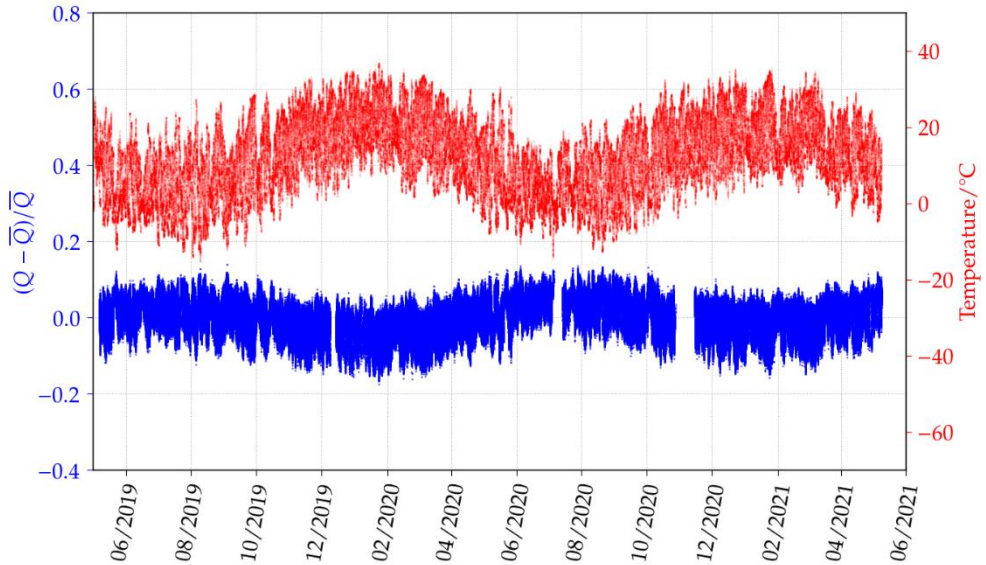



Evolution of the RMS in ADC counts for the PMTs trace (HG channel) for a subsample of SSD of the preproduction array.

In the vertical axis the identification number of the WCD are reported. The uniformity in horizontal rows, clearly shows the stability of the detectors, while the vertical patterns evidence the presence of thunderstorms or communication problems in the array.

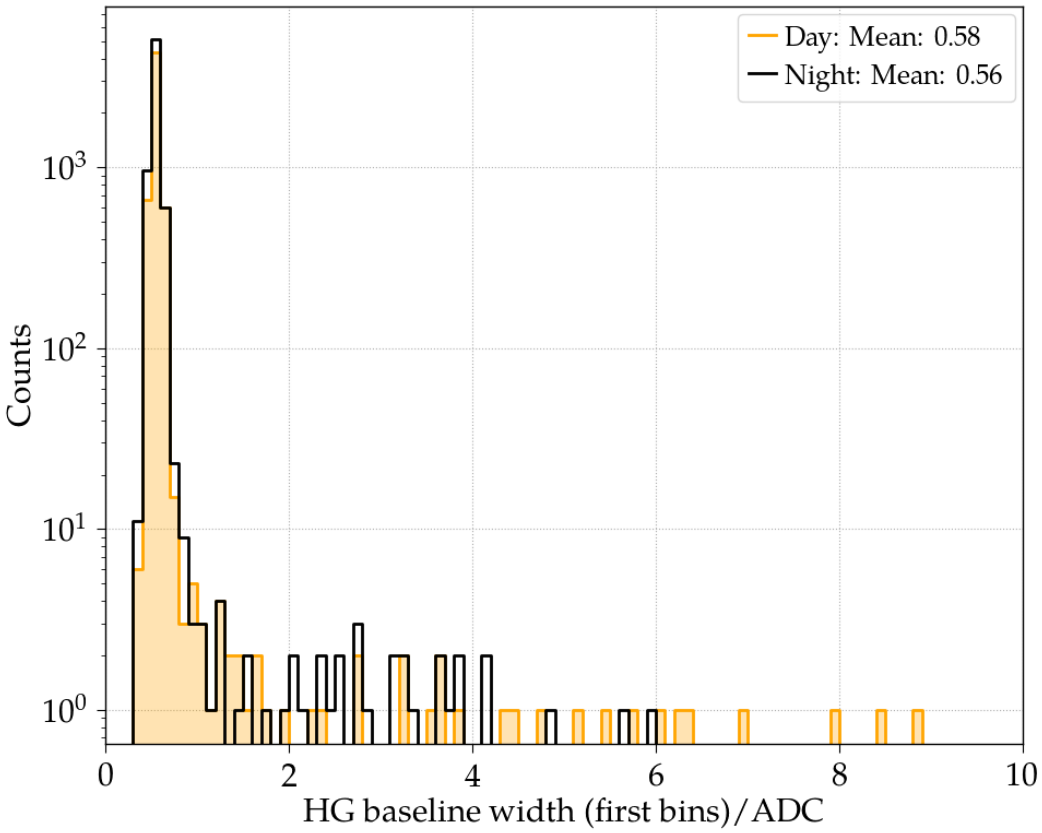
# MIP-Temperature effects

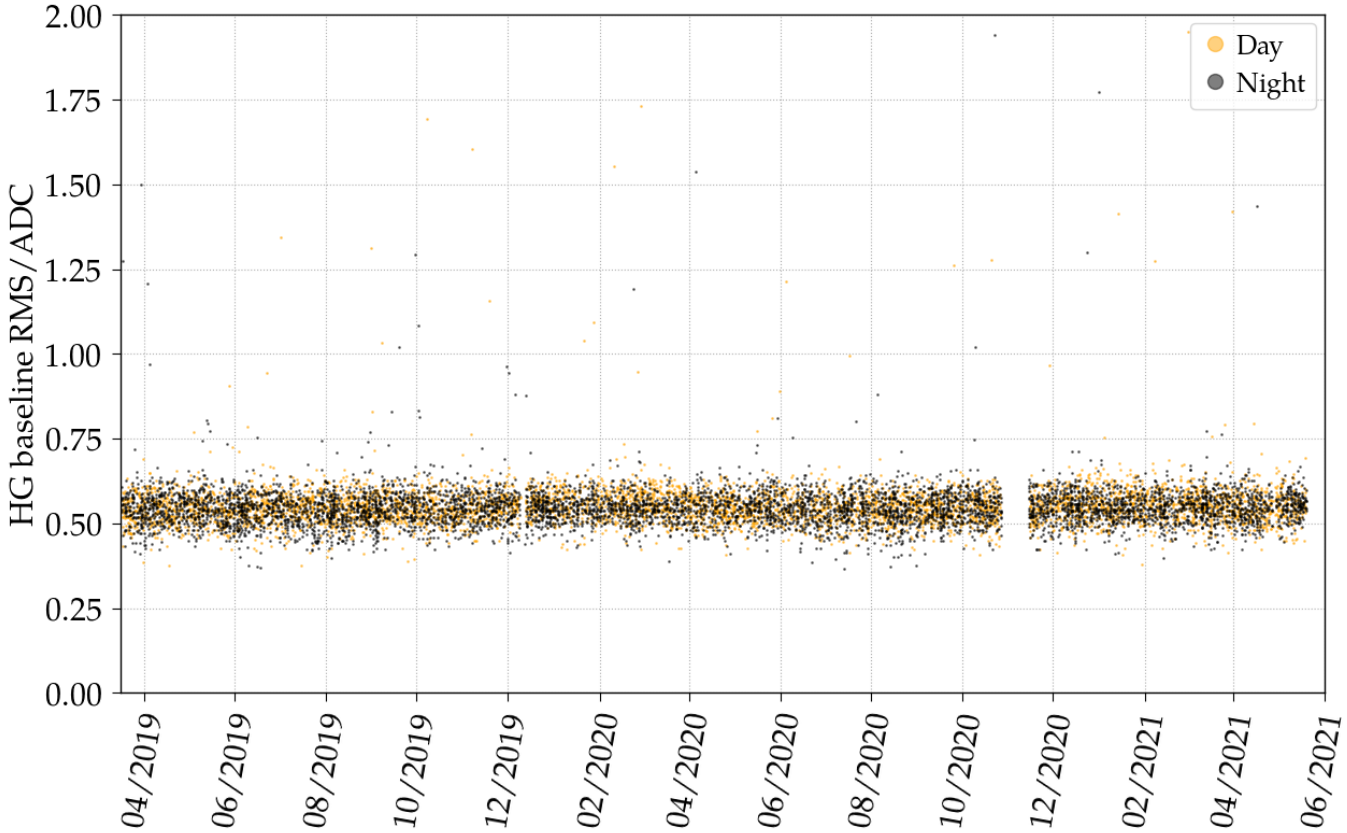



Evolution of the oscillation around an average MIP value (in blue) and evolution of the temperature (in red) for 3 SSDs of the Array.

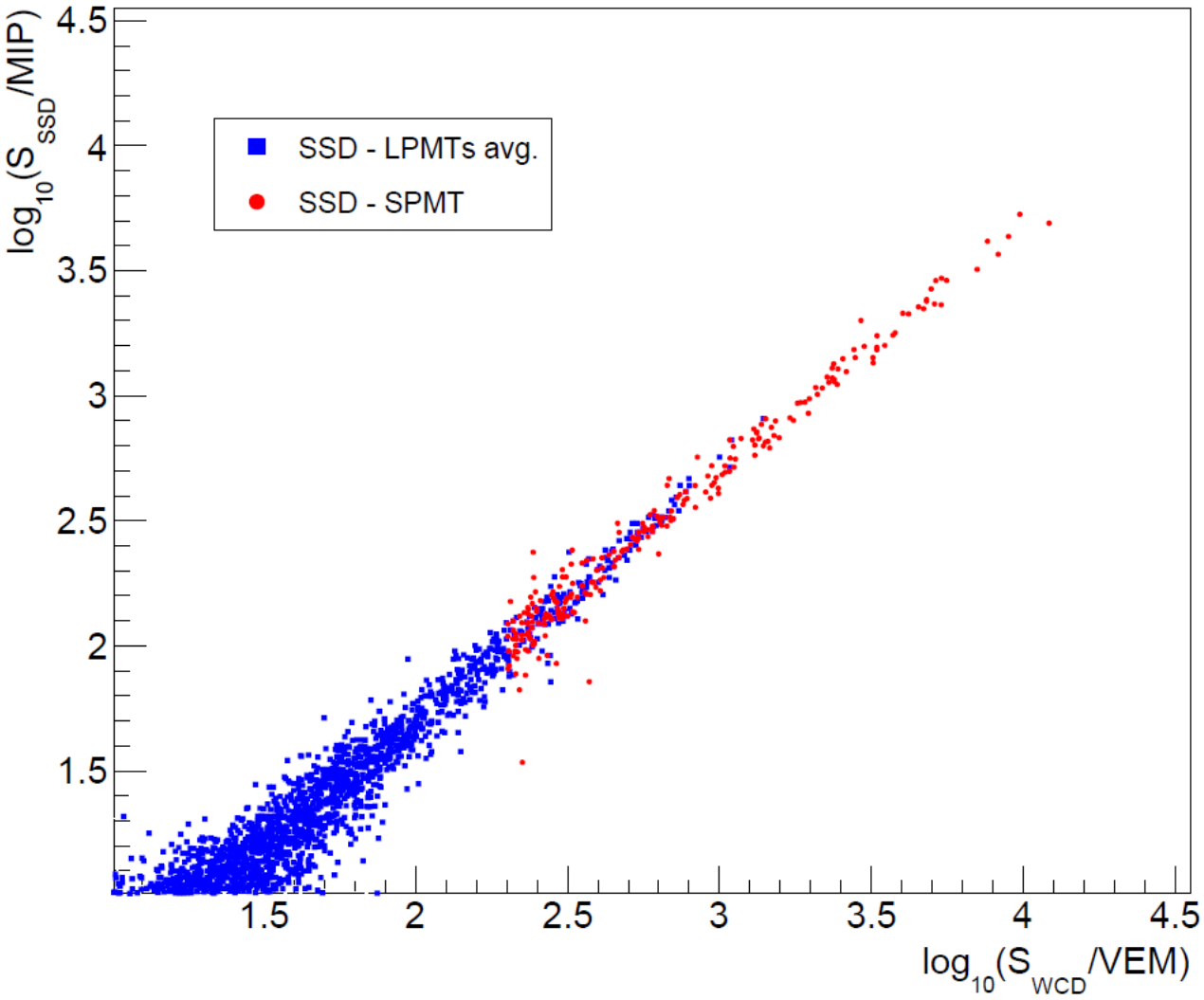
# Light tightness




Average Baseline width (RMS) and its evolution with time for one of the SSD of the array.

# Correlation between WCD and SSD




## Use of reconstructed events

The signals in the WCD are measured up to saturation ( around 700 VEM) by the large PMTs in the WCD tanks.
In the superposition region and above the saturation region, they are derived from the sPMT).

The non-saturated range of the WCD extends to more then 20000 VEM with the sPMT and by means of SSD has an additional measurement.

# Conclusions


- ✓The production of the SSD detectors of the Pierre Auger Observatory as well as their transportation to Argentina has been completed.
- ✓In spite of the Covid-19 pandemic, the deployment of the SSD in the full array will be completed before the end of 2021.
- ✓The PMTs are gradually being installed together with the new electronics that is now in production phase.
- ✓ All the SSDs deployed in the Observatory SD array are foreseen to be in data acquisition at the end of 2022.
- ✓The detectors operate smoothly and stably in agreement with the requirements.