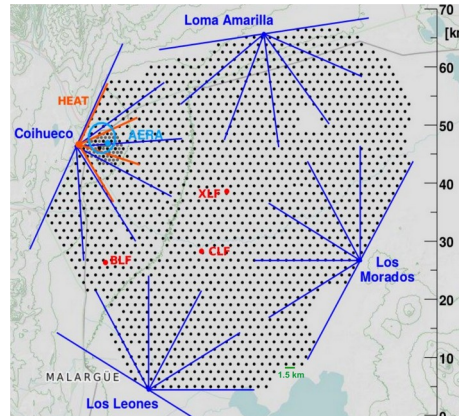# Terrestrial Gamma Ray Flahes at the Pierre Auger Observatory

Martin Schimassek for the Pierre Auger Collaboration
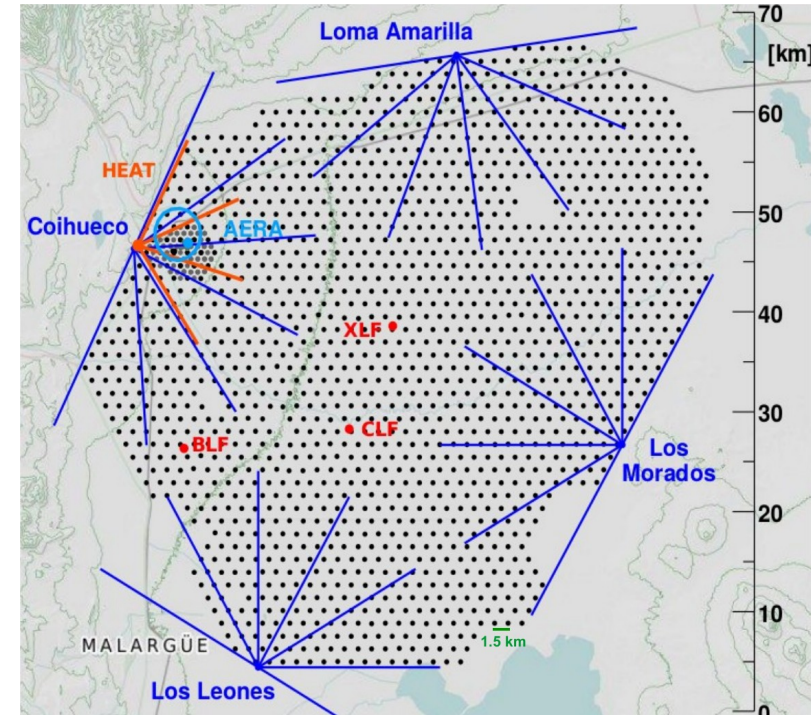
www.kit.edu

The Pierre Auger Observatory

- largest cosmic ray observatory in the world

- covers 3000 km² in Argentina
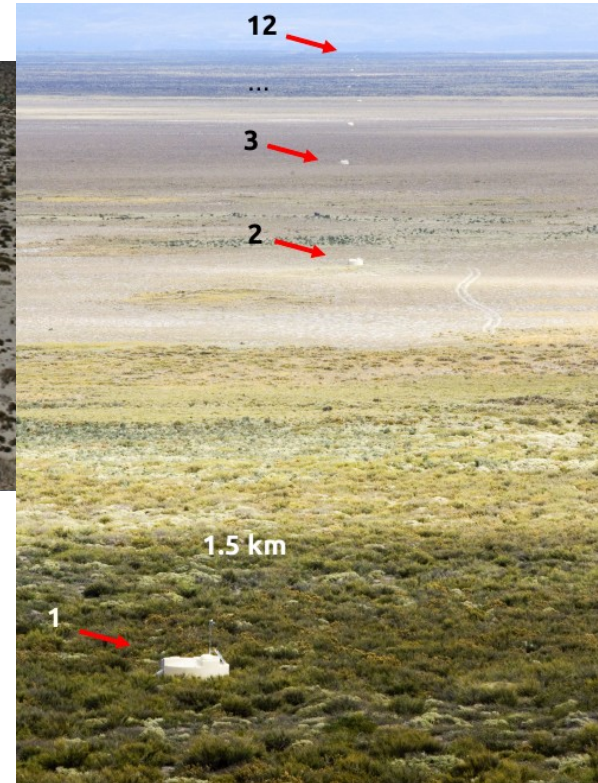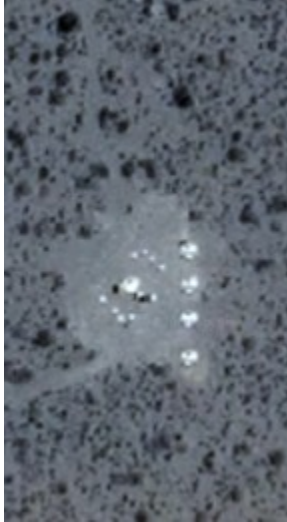
- hybrid detector approach

Pierre Auger Observatory
Province Mendoza, Argentina

Auger – Hybrid Detector

- Surface Detectors (SDs) deployed in triangular grid with 1.5 km spacing

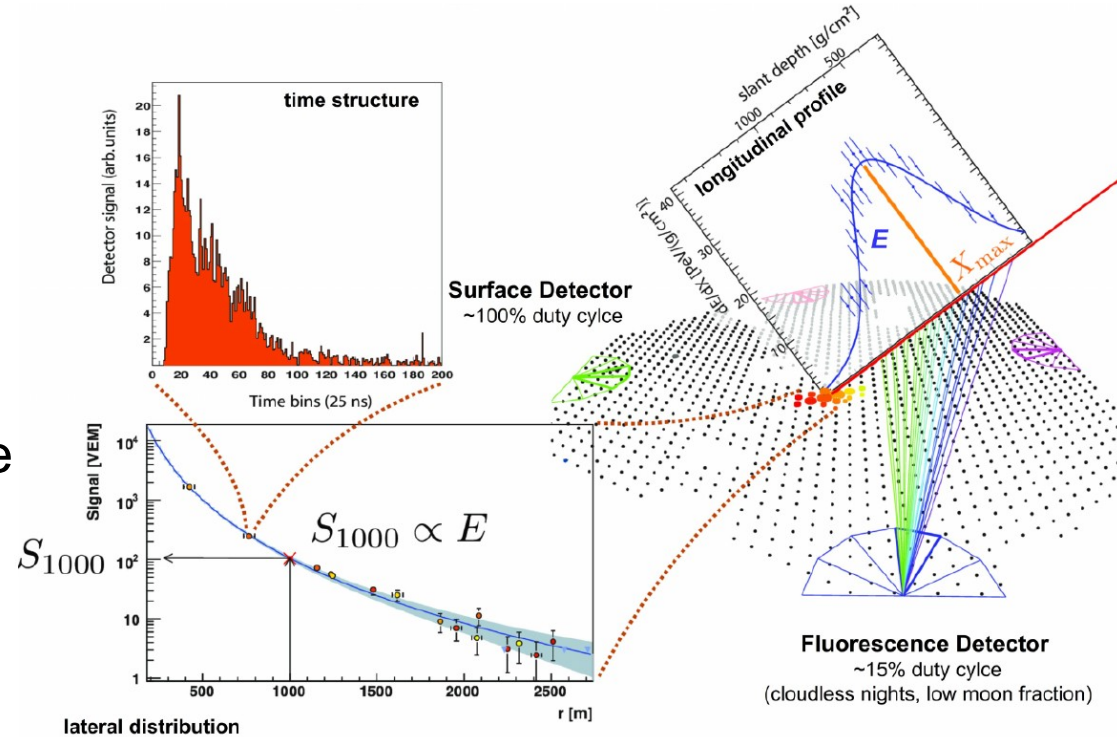- Fluorescence Detectors (FDs) in 4 sites

Auger – Surface Detector

17 km

1.5 km

triangular grid
with 1.5 km
spacing

Institute for Astroparticle Physics (IAP)

Cosmic Rays – the usual events

- short signals in SDs
  - order of 5 μs in length

- steeply falling lateral distribution

- randomly distributed in time with constant rate
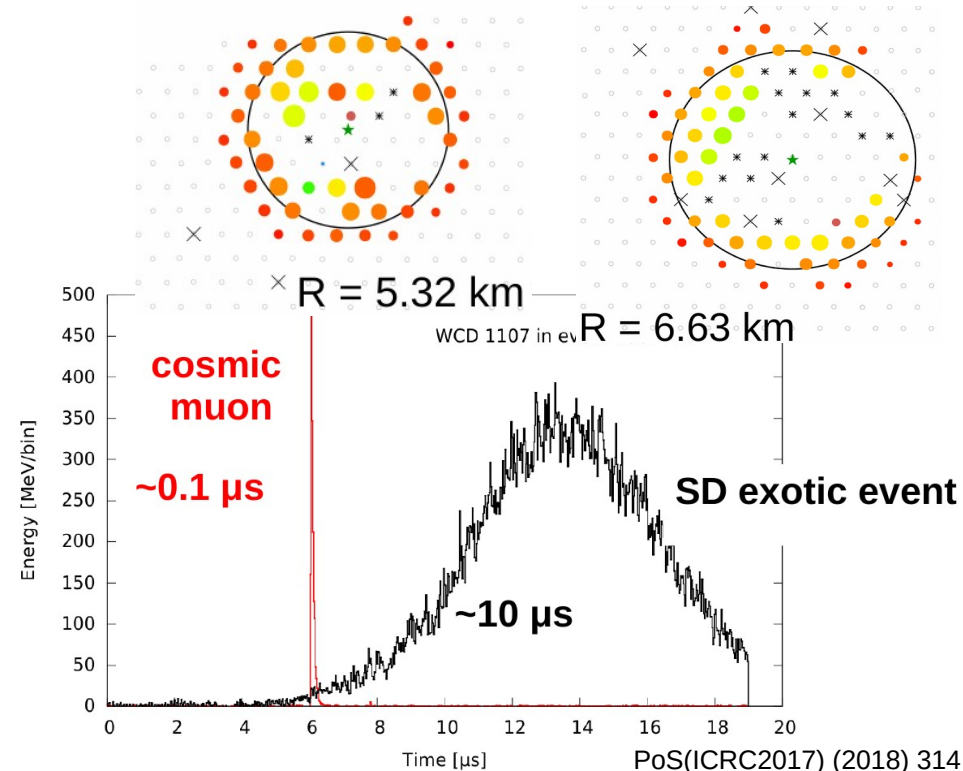

time structure

Surface Detector
~100% duty cylce

longitudinal profile

E X_{max}

$S_{1000} \propto E$

S_{1000}

lateral distribution

Fluorescence Detector
~15% duty cylce
(cloudless nights, low moon fraction)

Lightning Events – the usual 'exotics'

- high-frequency signals in many stations
  - usually visible across the whole recorded trace of 19.2 μs
  - RF pick-up in cables as cause

- footprints very variable but can be large

- usually clustered in time from repeated discharges

PoS(ICRC2017) (2018) 314
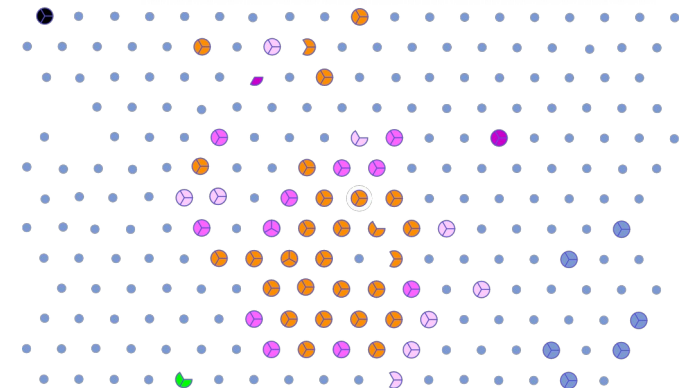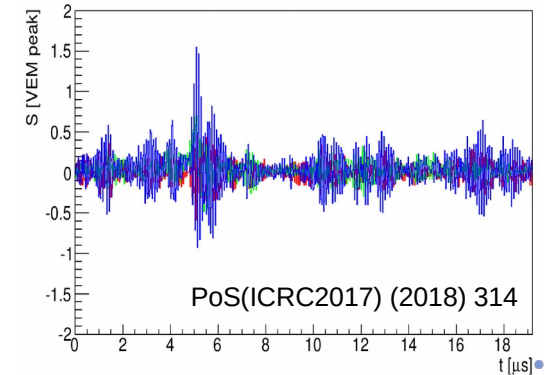
The true Exotics – TGFs?

- **very large signals**
  - often longer than the recorded trace

- **footprints variable but typically large and round**
  - some events: hole in the centre
  - some completely filled

- **indications of repeated events**

R = 5.32 km

R = 6.63 km

WCD 1107 in ev

cosmic muon

~0.1 µs

SD exotic event

~10 µs

Energy [MeV/bin]

Time [µs]

PoS(ICRC2017) (2018) 314

Are those real signals?

- different channels agree
  - cables with different orientation and length should have different pick-up, if it's only RF-noise

- all PMTs agree

  - different cables not symmetric

- large signals from particles within thunderstorms

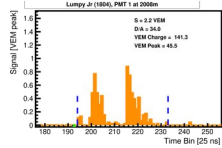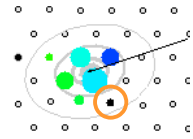 - TA has downwards TGFs (DOI: 10.1029/2019JD031940), these are similar

PoS(ICRC2017) (2018) 314
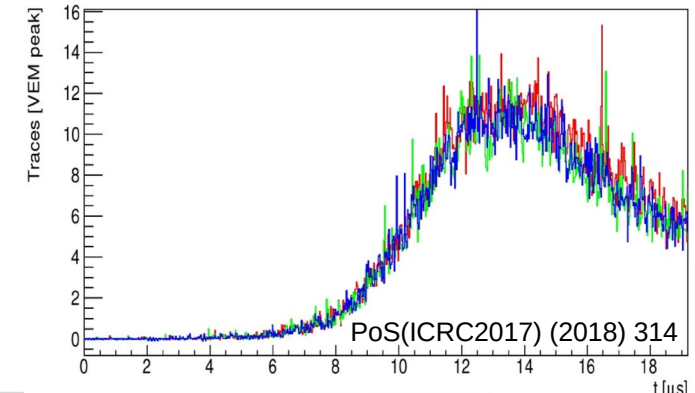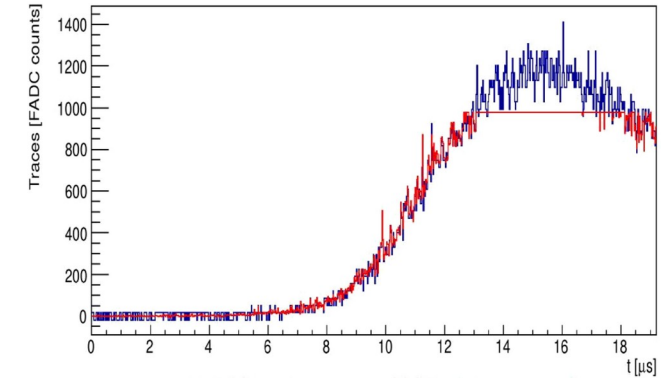
The Trigger Chain

signal trigger | station trigger

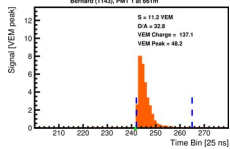| ToT | →promote→ | ToT |

'for EM-part'
13 bins
> 0.2 VEM

2 Hz

'for muons'
> 3.2 VEM

20 Hz
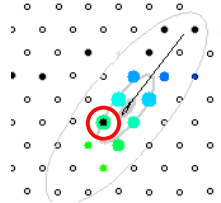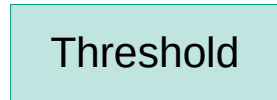
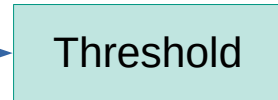| Threshold | →higher threshold→ | Threshold |

only trigger data

geometry

array trigger

timing

Usual Trigger Rates:
- 0.05 Hz
- background T2s:
  ~ 30 / ms

TGFs? – Current Limitations

- example event for representation

- DAQ optimised for UHE-CRs
  - event rate of about 0.05 Hz
  - about 4 triggers per CR event
  - ~1000 triggers for these events

- lightning strikes lead to
  many triggers and lost data

TGFs? – Current Limitations

14.07.2022   Martin Schimassek – TGFs at Auger?   Institute for Astroparticle Physics (IAP)
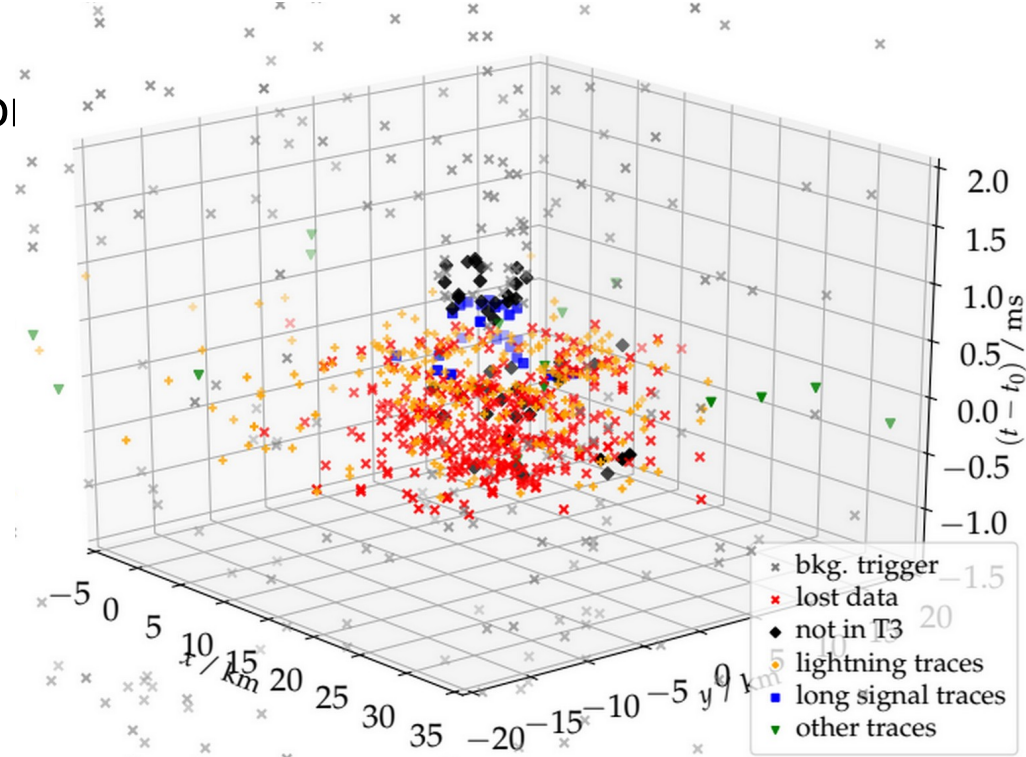
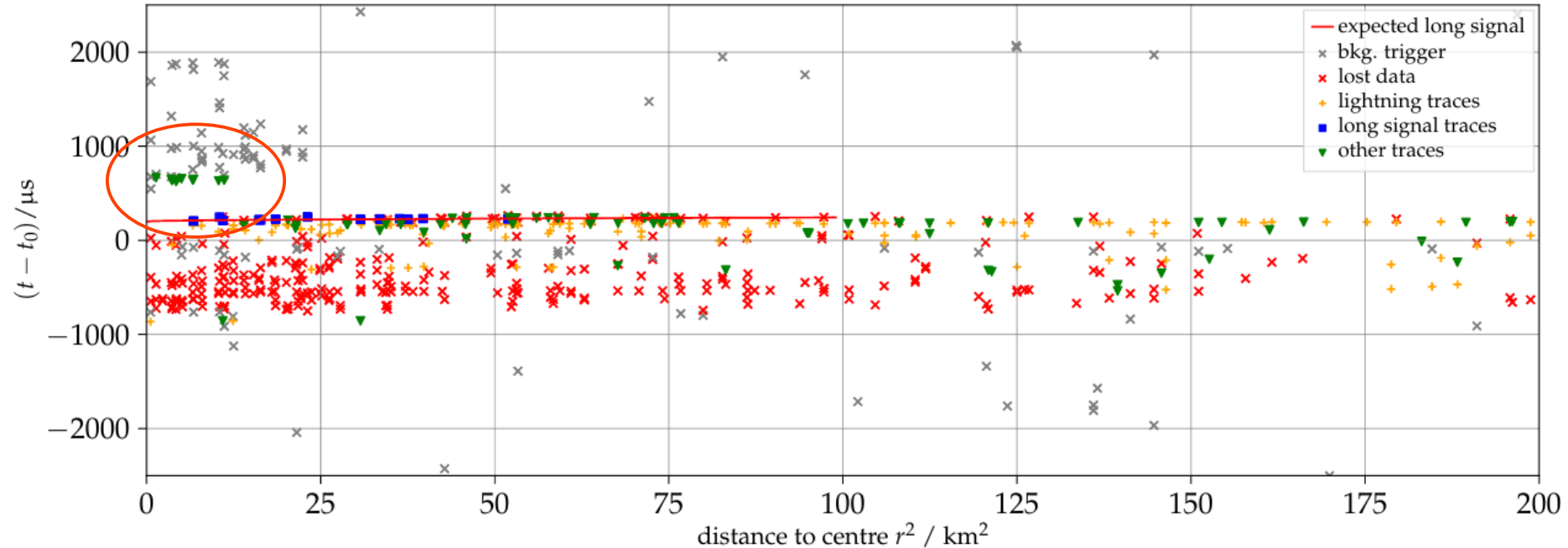# What did we learn about the ring structure?
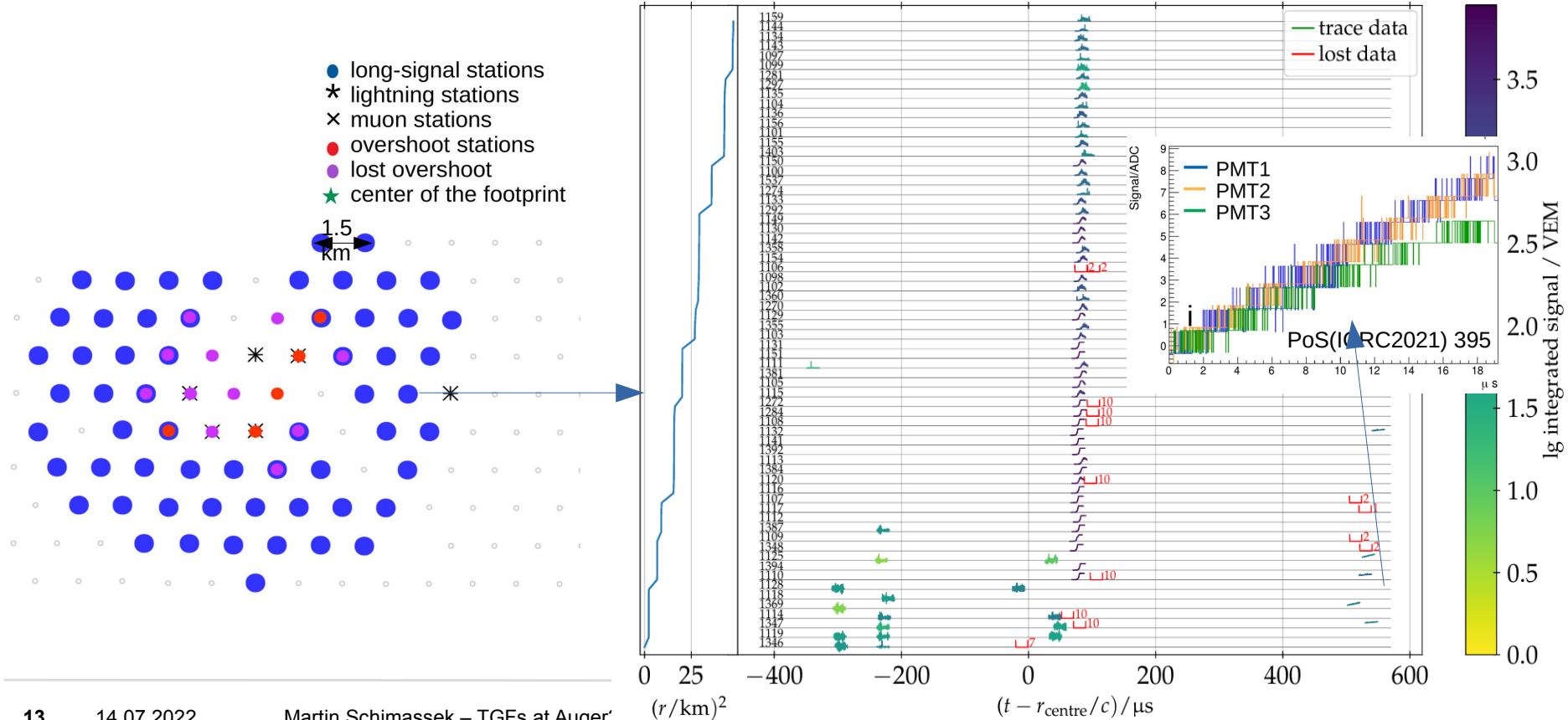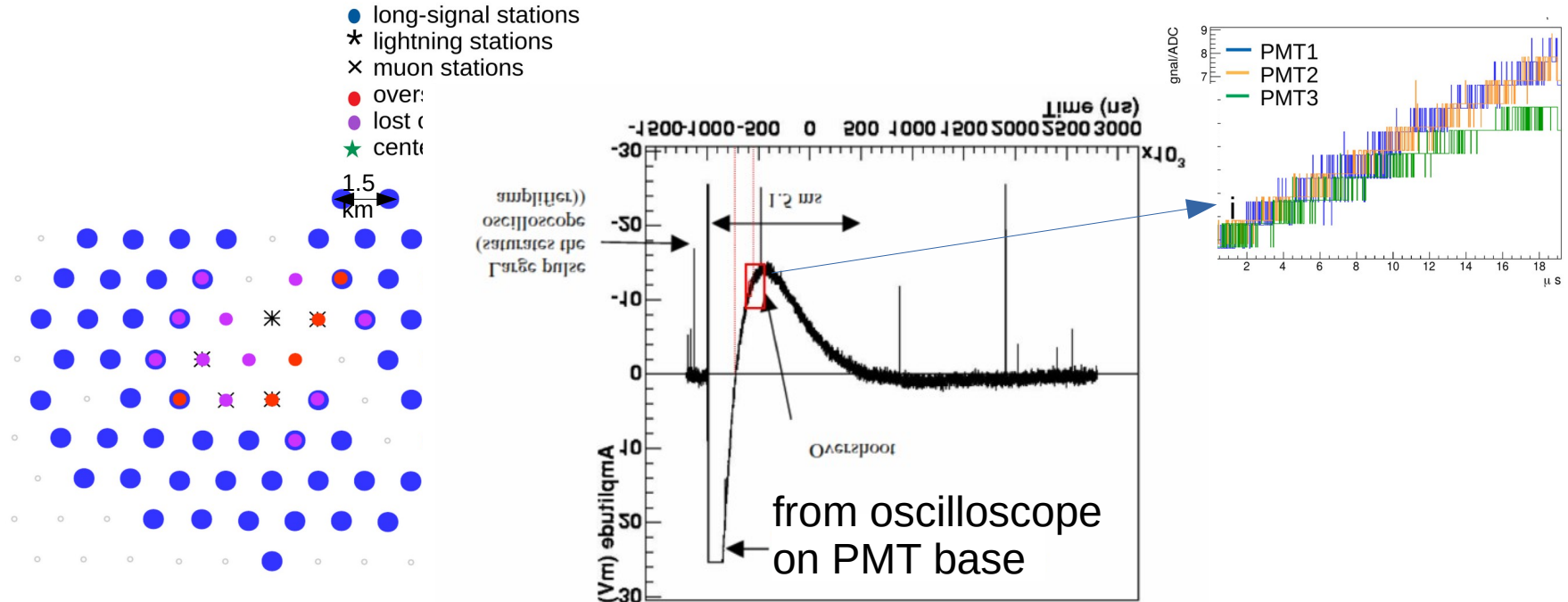
- careful re-analysis of data of previous events

- information available in other events close in time

- also information on 'lost' data can be valuable

Legend:
- ● long-signal stations
- ✳ lightning stations
- ✕ muon stations
- ● overshoot stations
- ● lost overshoot
- ★ center of the footprint

1.5 km

PoS(ICRC2021) 395
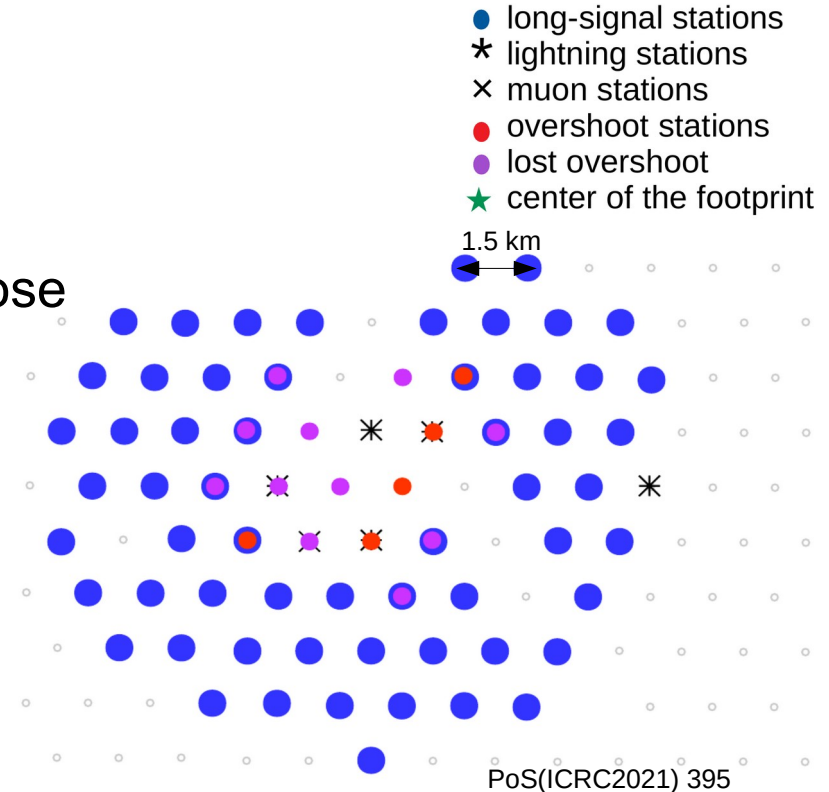
What did we learn about the ring structure?

What did we learn about the ring structure?

- • long-signal stations
- * lightning stations
- × muon stations
- • over...
- • lost ...
- ★ cent...

1.5 km

Time (µs)

1.5 ms

Late pulse (saturates the oscilloscope (amplitude))

Overshoot

from oscilloscope on PMT base

PMT1
PMT2
PMT3

Current Limitations – Reading out the Event

- DAQ optimised for UHE-CRs

- later events lost due to memory limitations of (old) hardware
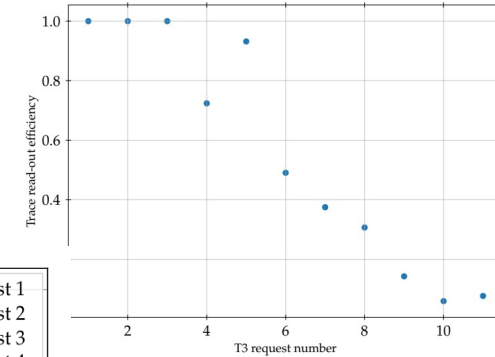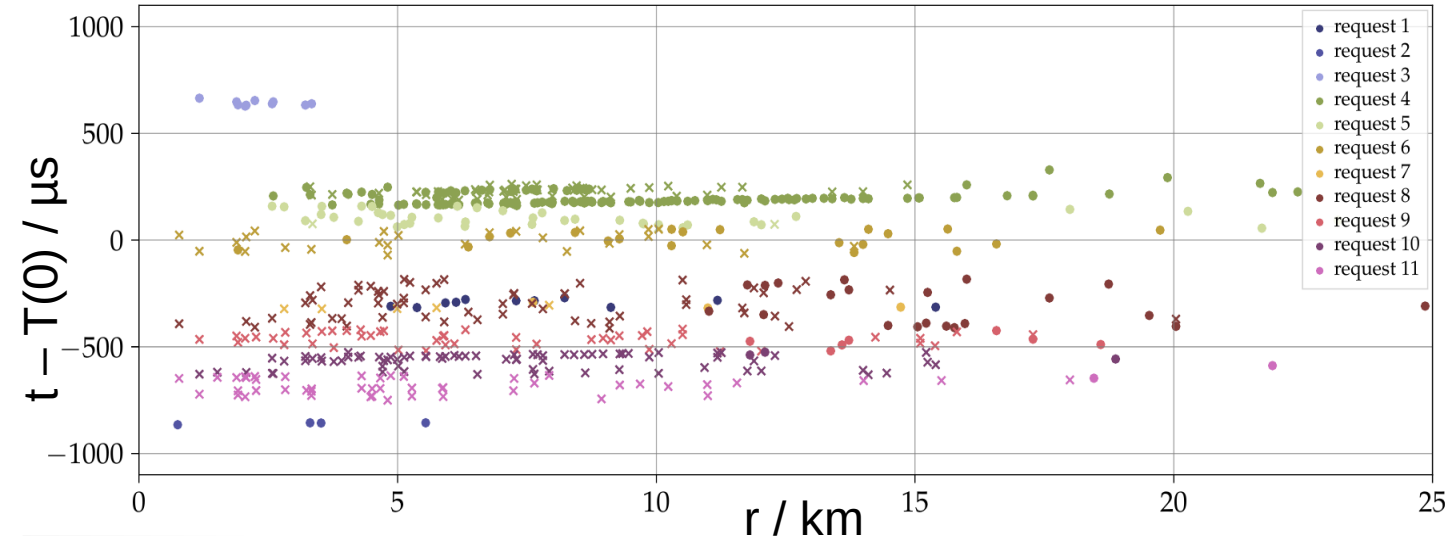
How to move forward?

Station
- full trace information
- limited CPU time

Communication
- 4 bits for trigger type
- only 2 in use

CDAS
- trigger bits only
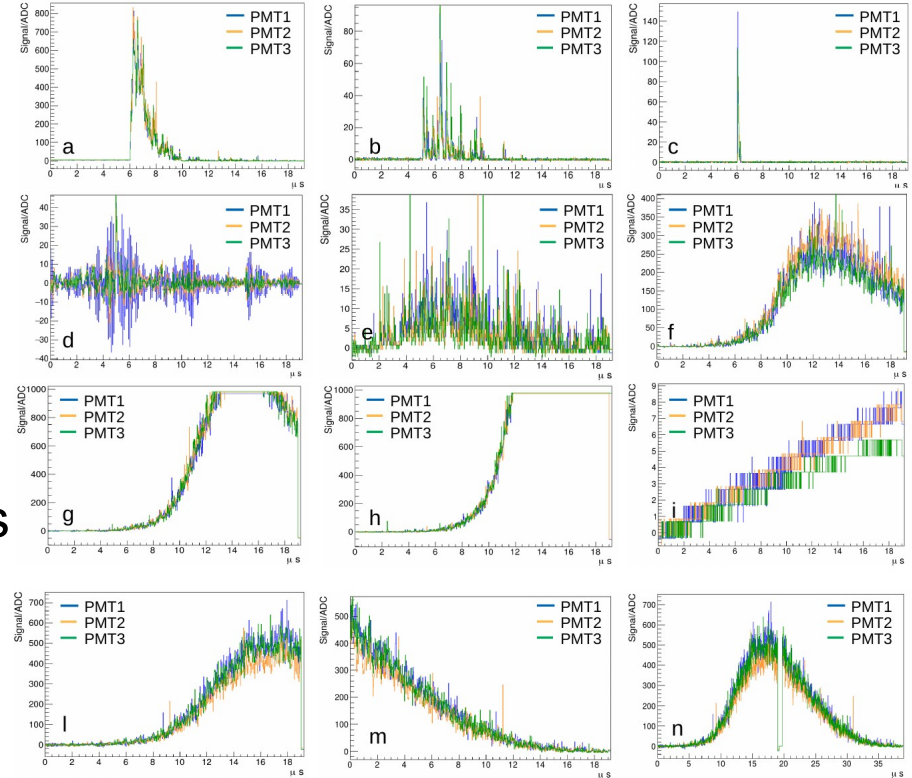- triggers from all stations

Station – New Algorithm

Idea:

- make use of full trace to send new trigger flag

- but needs simple algorithm

Concept

- build representative sample of traces

- test algorithm on recorded data
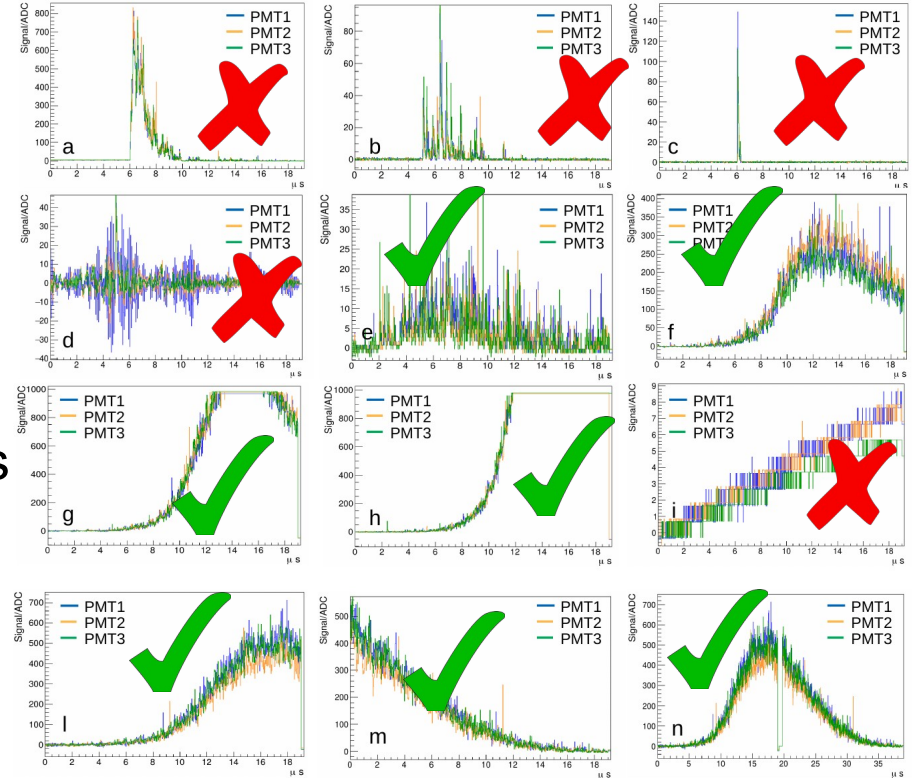

PoS(ICRC2021) 395

Station – New Algorithm

Idea:

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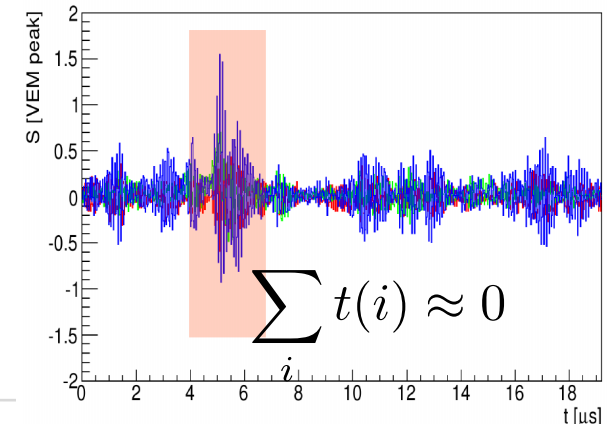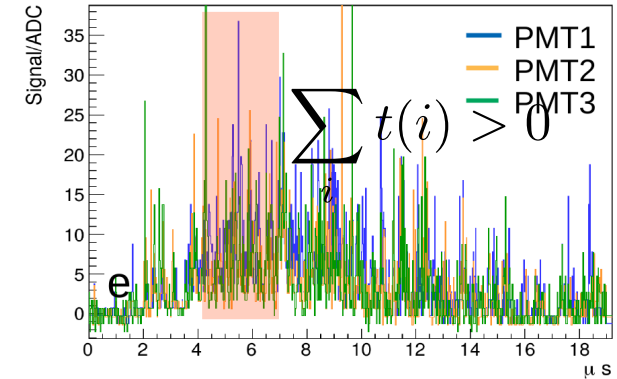
- labeled traces!

PoS(ICRC2021) 395

Concept of the Algorithm

Idea:

- integration of high frequency noise ~ 0

- integrating small but long signal increases signal to noise (w.r.t single bin)

  needs

- choice of window length

- baseline …?

$$\sum_i t(i) > 0$$
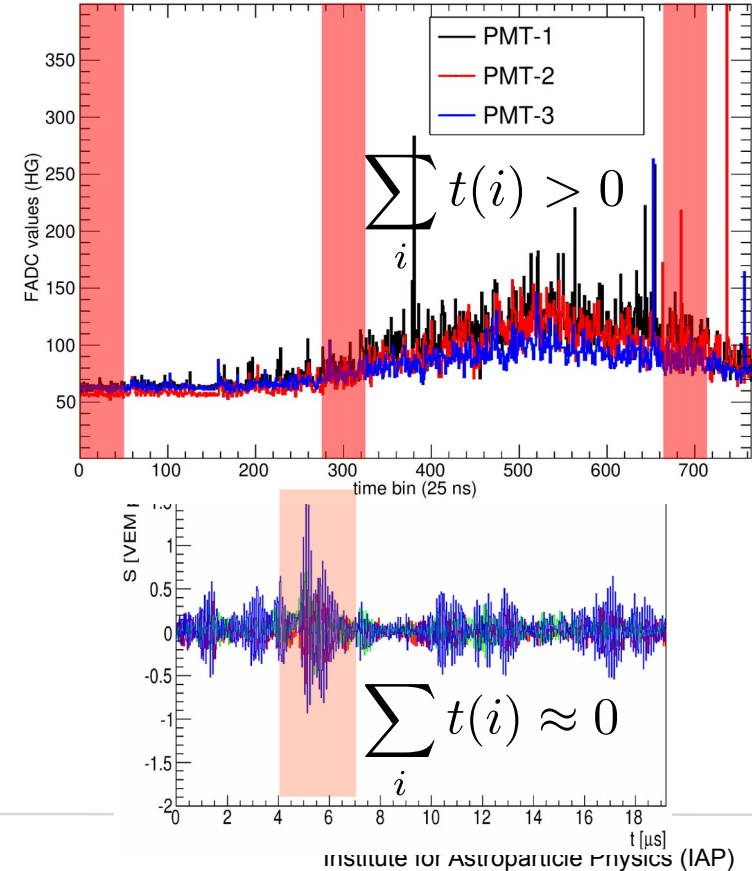
$$\sum_i t(i) \approx 0$$

Concept of the Algorithm

Idea – 2:

- differences of integrals are independent of baseline

- windows can be placed to optimise S/N

- threshold to be defined on test-sample

$$S_i = \sum_{j=a_i}^{b_i} t(j) \qquad \sum_{i=2}^{3} \left| S_i - S_1 \right| > x_{\text{thr}}$$

Choice of the windows

- make use of known trigger bin
- 'ending long-signals'
- we want to be insensitive to muons / small showers
  → we reach ~75% efficiency! (first estimate: <1 / 5h of lighting false pos.)
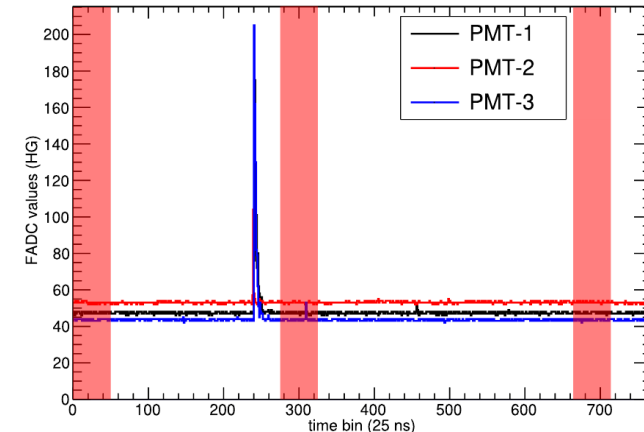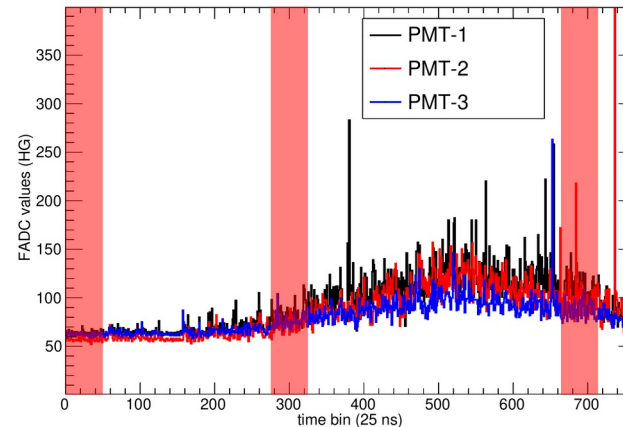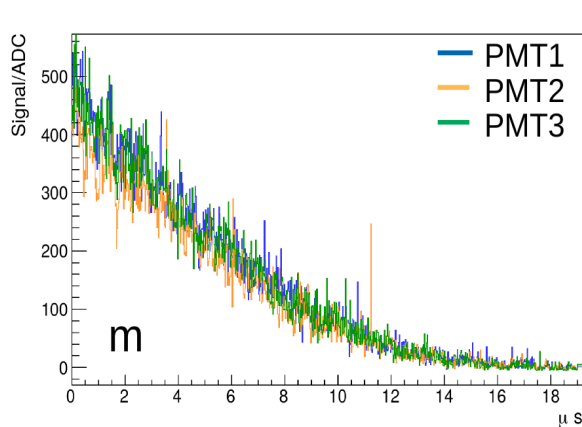
New Possibilities? – Auger Prime!

- Hardware changes
  - additional scintillators
  - **new electronics**
  - a small PMT
  - radio antennas
  - underground muon counters
  - enhanced duty cycle of FD

VERTICAL (0-60°)   HORIZONTAL (60-90°)

Composition sensitivity with 100% duty cycle
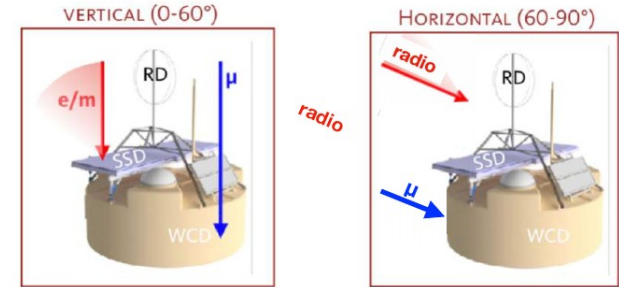
(AugerPrime design report 1604.03637)
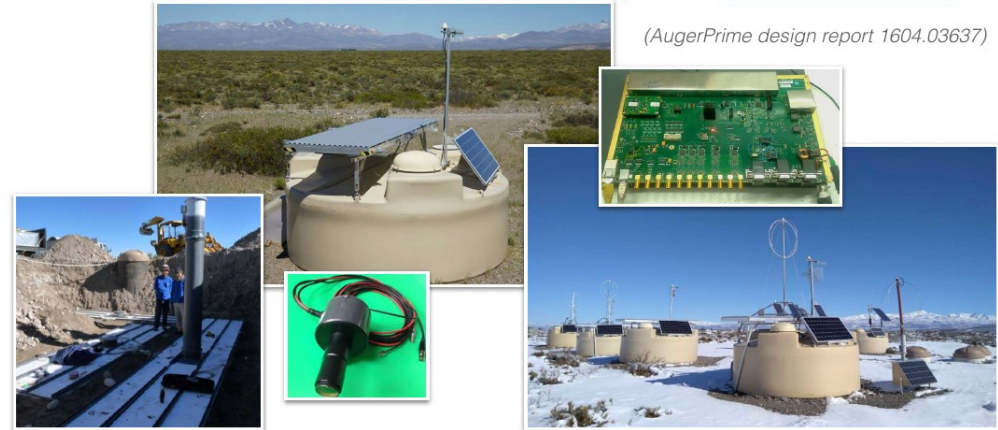
slide by R. Engel

Summary and Conclusion

- re-analysis of existing data shows interesting facts about TGF-candidates

- Auger 'SD-rings' are actually filled

- main reason for reduced event rate identified

- new software trigger in the field to enhance efficiency

14.07.2022   Martin Schimassek – TGFs at Auger?   Institute for Astroparticle Physics (IAP)

Backup

Martin Schimassek – TGFs at Auger?   Institute for Astroparticle Physics (IAP)

Backup

GPS antenna

Communications antenna

Electronics

3 photomultipliers

Solar panels

Battery

Plastic tank with 12 tons of clean water

Auger – Hybrid Detector

Radio antenna array
(153 antennas, 17 km²)

(UMD)

Underground muon
detectors (24+)

Sub-array of 750 m
(63 stations, 23.4 km²)

LIDARs and laser facilities

Pierre Auger Observatory
Province Mendoza, Argentina

High elevation telescopes (3)

4 fluorescence detectors
(24 telescopes up to 30°)

Central
Campus

**More than 400 members,
98 institutes, 17 countries**

**Southern hemisphere: Malargue,
Province Mendoza, Argentina**

1665 surface detectors:
water-Cherenkov tanks
(grid of 1.5 km, 3000 km²)

**Water-Cherenkov
detectors and**

**Fluorescence
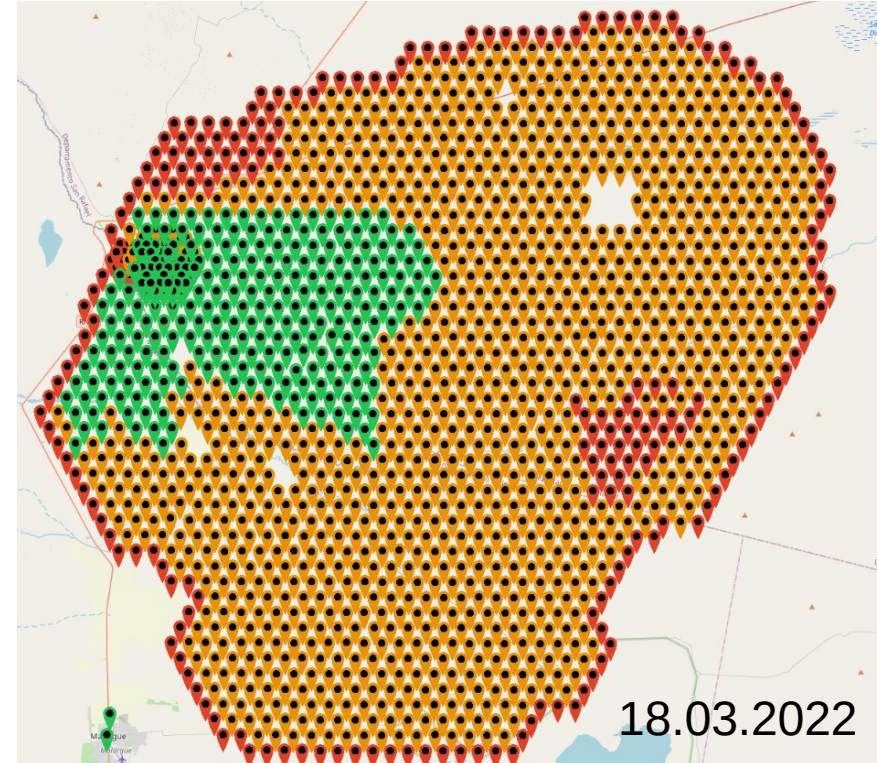telescopes**

slide by R. Engel

Current Status – Deployment

■ production of SSDs finished

■ deployment with 5-10 SSDs / day

■ almost finished

■ no deployment in border region

■ production of electronics well progressing

■ deployment of electronics well underway (~280 deployed)

18.03.2022

✓ SSD installed (1437 detectors)   ● with PMT (264 detectors) ✓   ● w/o PMT (1173 detectors) ✓   ✓ ● SSD not installed (230 detectors)