

# Simulation Study of the Detection of Inclined Photon Air Showers with the AugerPrime Radio Detector

Astroparticle School Obertrubach

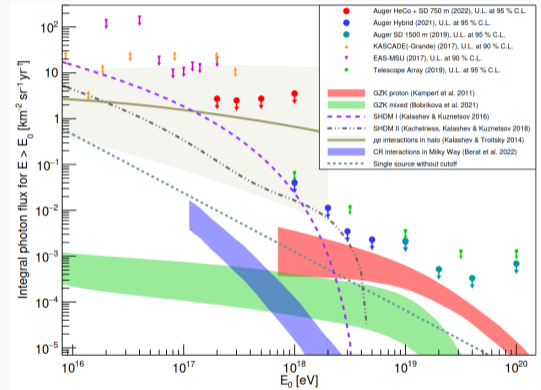
---

Jannis Pawlowsky

October 06, 2022



- Various photon analysis done by the Pierre Auger Collaboration, strongest upper limits on UHE photon flux set. (arXiv:2205.14864)
- Photon searches not background free, yield photon candidates in the data set. (PoS(ICRC2019)398)
- Main challenge: Photons have reduced particle footprint.



## Inclined photon showers with particle detectors:

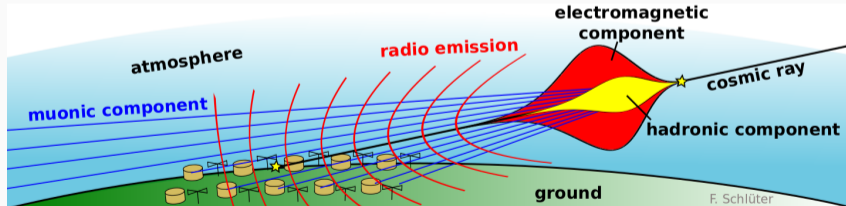
Small particle footprint as EM-part absorbed in the atmosphere

**Challenge:** Low detection probability and poor reconstruction!

## With additional Radio Detector (RD):

Strong Radio signal

**Feature:** Discrimination from hadrons with their strong particle footprint.

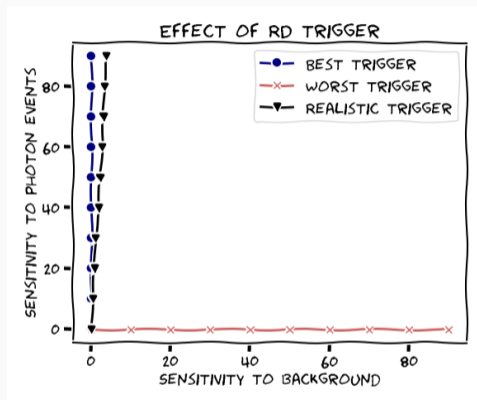


- Mounted on top of the Water Cherenkov Detector (WCD).
- Increase of exposure by one third ( $65\text{-}85^\circ$ ).
- Current status: 10 fully installed stations.
- Detector response understood, simulations possible.
- At the moment: triggered by the WCD.



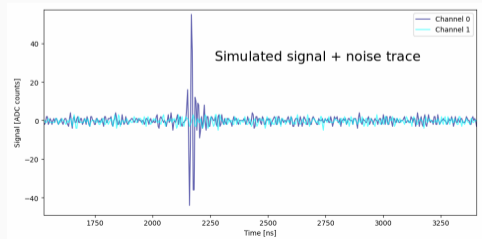
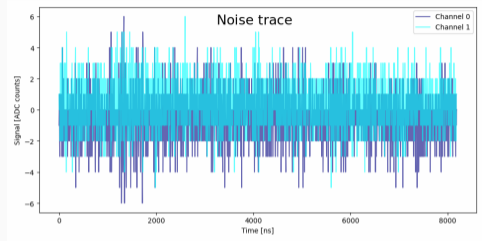
- Significant increase of photon trigger rate
- Not sensitive to background (RFI and hadron events)
- Compatible with limited bandwidth

⇒ Simple radio amplitude trigger for photons with threshold much larger than noise level.

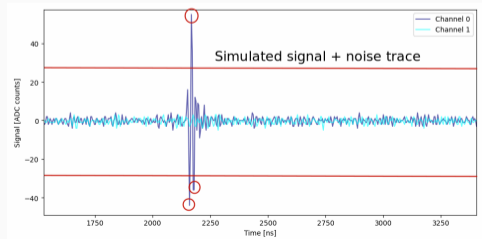
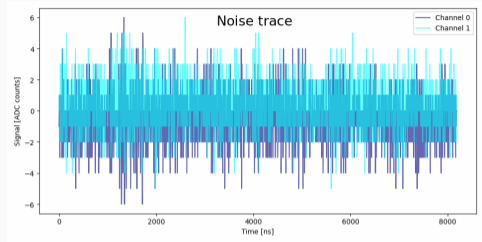


- Significant increase of photon trigger rate
- Not sensitive to background (RFI and hadron events)
- Compatible with limited bandwidth

⇒ Simple radio amplitude trigger for photons with threshold much larger than noise level.

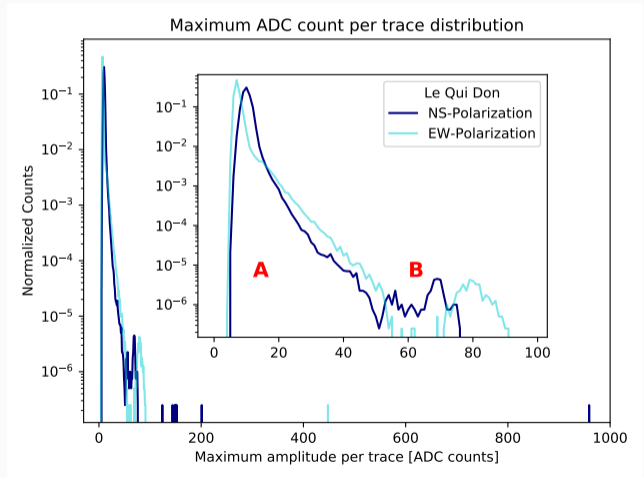


- Significant increase of photon trigger rate
  - Not sensitive to background (RFI and hadron events)
  - Compatible with limited bandwidth
- ⇒ Simple radio amplitude trigger for photons with threshold much larger than noise level.



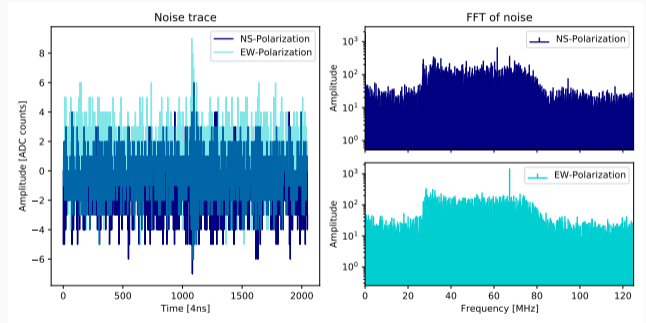
Is an RD trigger compatible with the noise level?

- 32M periodically triggered noise traces (4 minutes) of 4 stations
- Distribution of maximum trace amplitude yields trigger probability
- Majority of values low, strange distribution **B**

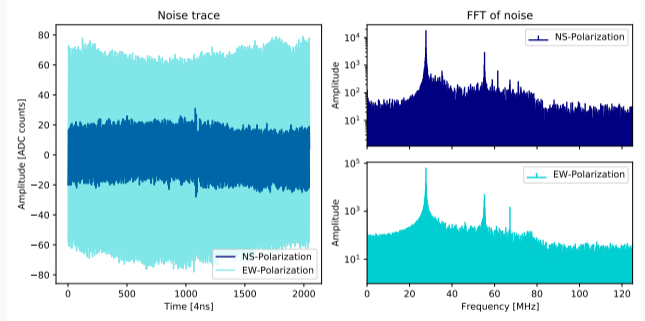




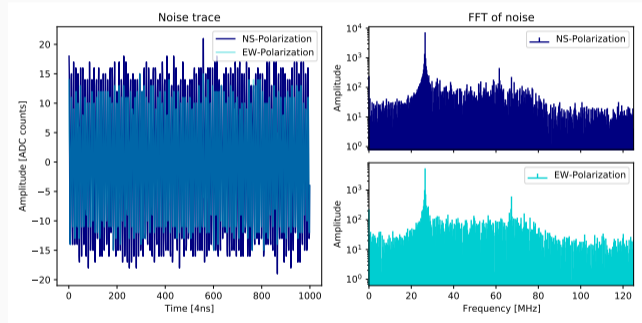
- Normal noise fluctuations in order of few ADC counts
  - No dominant frequency
- ⇒ No hurdle for RD trigger



- Large noise traces from CB radio frequencies (27 MHz)
- Traces consecutively with changing polarization: people walking around station with walkie-talkies
- Majority of noise by ourselves
- Noisiest traces can be filtered

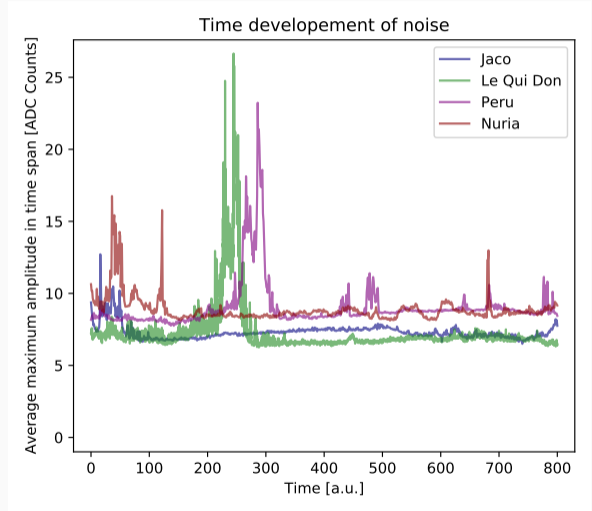


- Also CB radio with lower amplitudes (larger distance to station)
- Cannot be filtered without cutting on events
- But: Clearly time dependent, only when people around

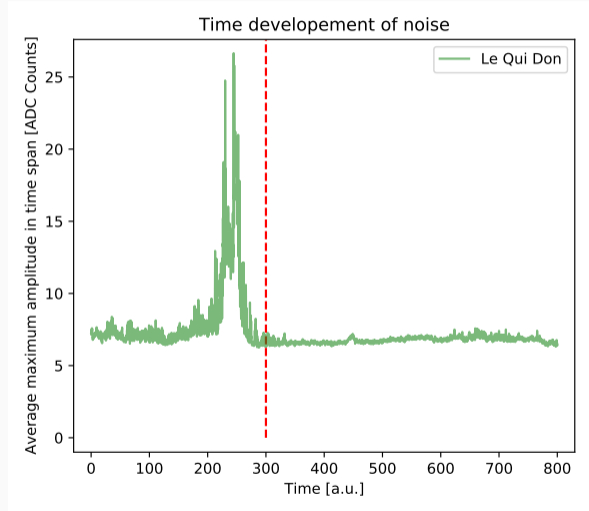


- Times with much higher noise amplitudes
- Worsening the overall noise distribution

⇒ Variable trigger threshold needed,  
constant trigger rate

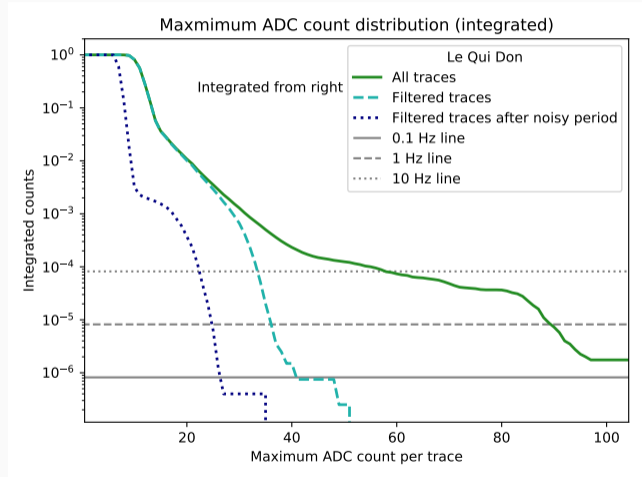


- Times with much higher noise amplitudes
  - Worsening the overall noise distribution
- ⇒ Variable trigger threshold needed, constant trigger rate



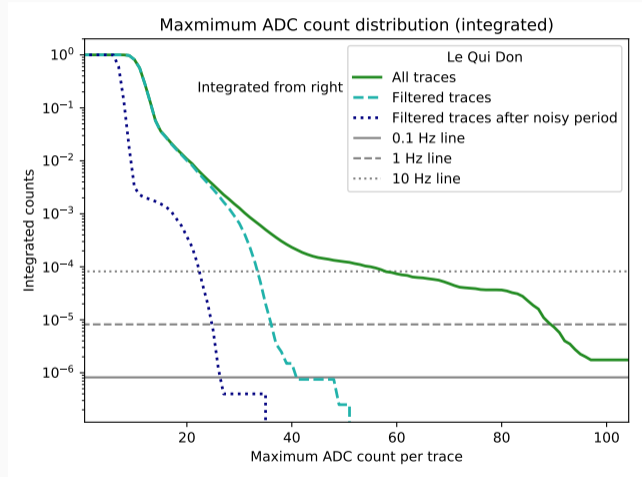
- Safe threshold at 60 ADC counts
- At times also 30 ADC counts or less applicable

Valid for the 4 stations, noise map needed!



- Safe threshold at 60 ADC counts
- At times also 30 ADC counts or less applicable

Valid for the 4 stations, noise map needed!

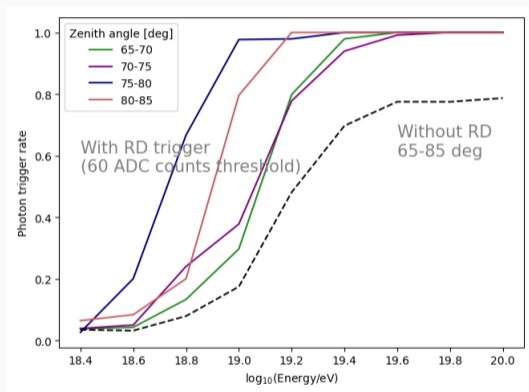


## Conservative - 60 ADC counts threshold:

- Doubling of photon trigger rate  
12%  $\rightarrow$  25%

## Optimistic - 25 ADC counts threshold:

- Quadrupling of photon trigger rate  
12%  $\rightarrow$  46%



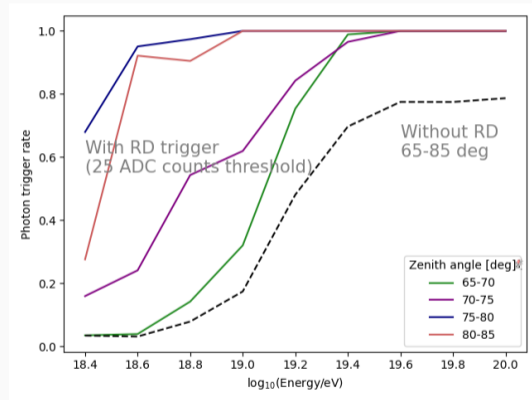


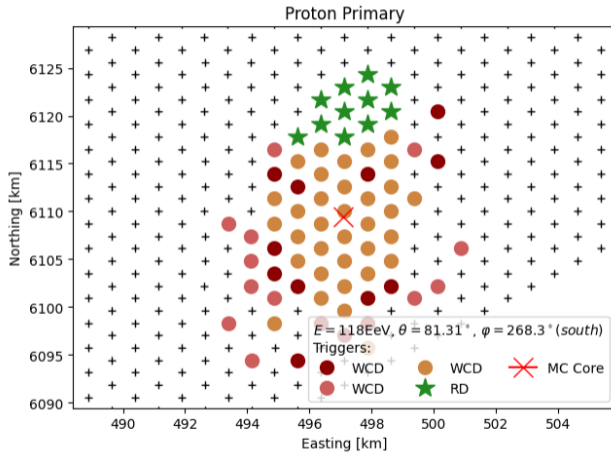
Conservative - 60 ADC counts threshold:

- Doubling of photon trigger rate  
12%  $\rightarrow$  25%

Optimistic - 25 ADC counts threshold:

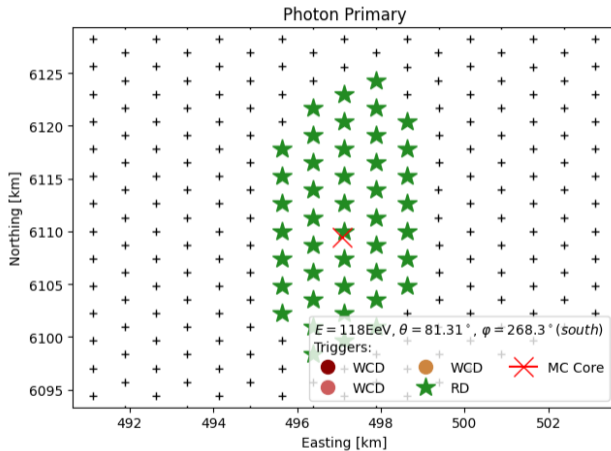
- Quadrupling of photon trigger rate  
12%  $\rightarrow$  46%





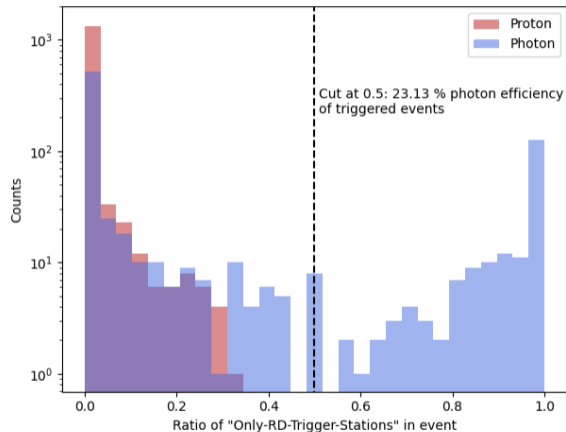
Proton shower:

- RD yields little benefit
- Extension of footprint
- Most stations anyways triggered by particles



Photon shower:

- RD yields large benefit
- No particle trigger at all
- Event only detected by RD



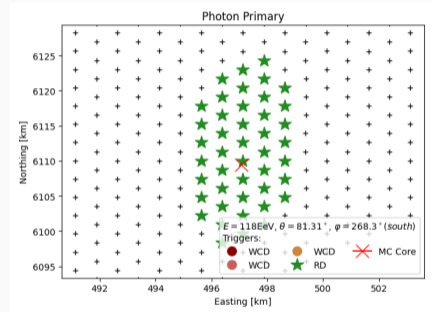
Trigger composition:

Many events with only Radio triggers.

→ Discrimination on trigger level!

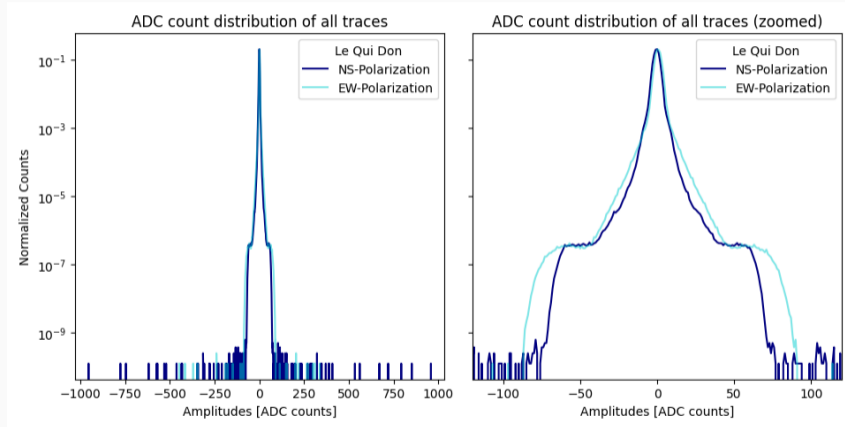
But in the future multivariate analysis.

- Radio threshold trigger on inclined photons leads to significant increase in sensitivity.
- Combination of WCD and new RD yield strong discrimination.
- Good knowledge about noise level.
- Further analysis for exact exposure and discrimination power.
- Hardware implementation in preparation - promising.

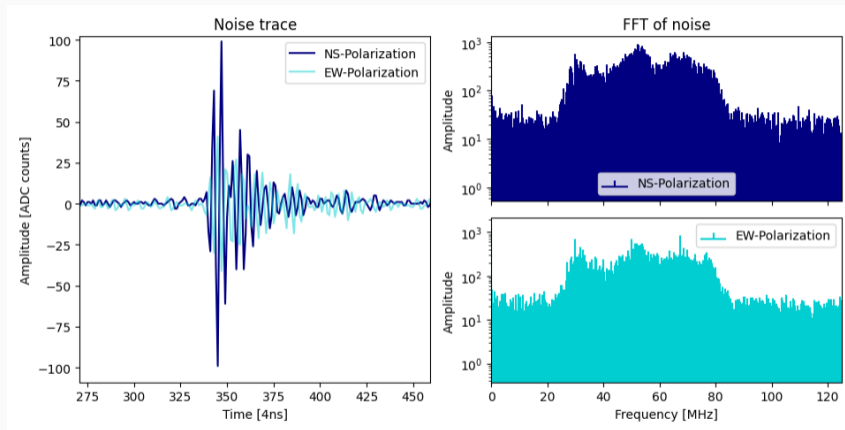




# Noise distribution

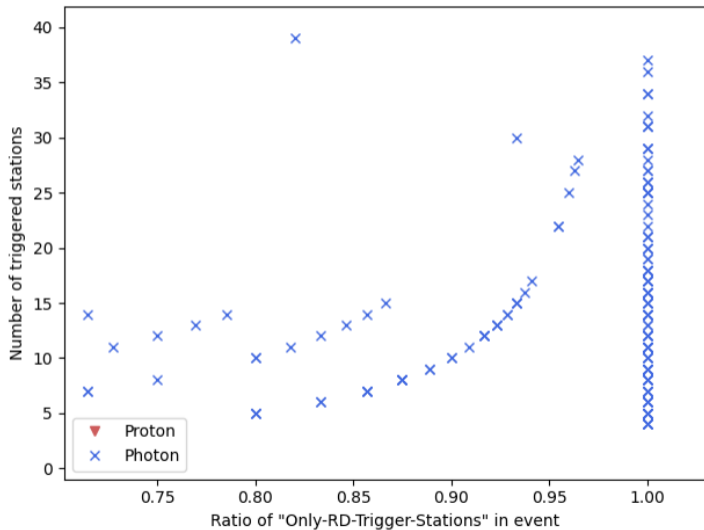


# Triggered event

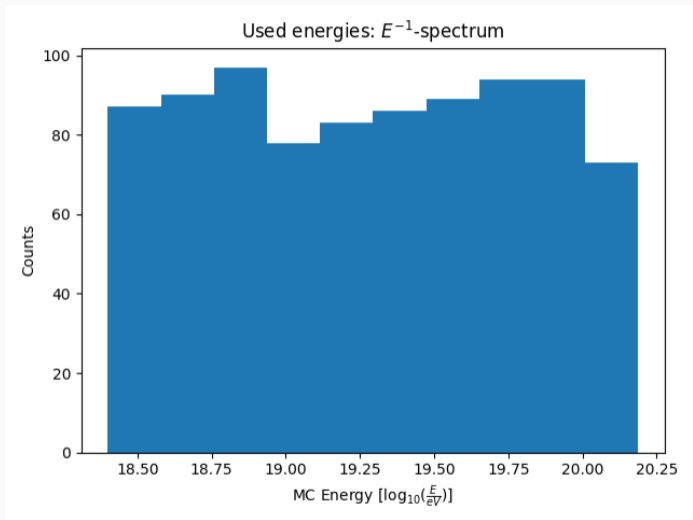




# Discrimination



# Used energy range



# Used zenith range

