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

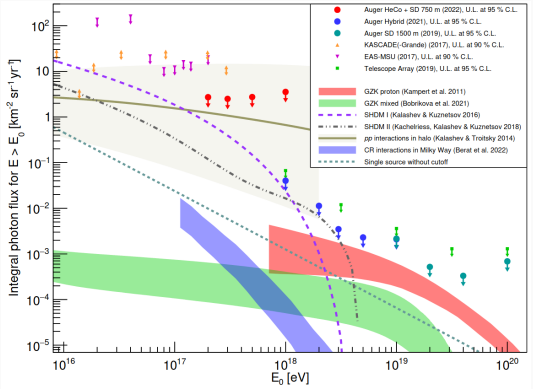
ARENA 2022

Jannis Pawlowsky for the Pierre Auger Collaboration

June 10, 2022

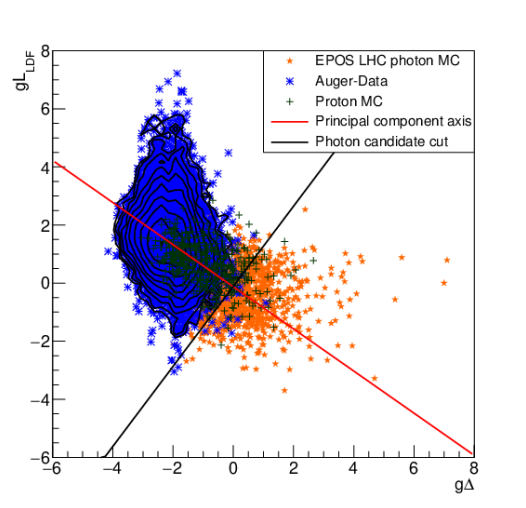
Motivation

- 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)



Motivation

- 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)
- Study indicates number of photon candidates cannot be explained by misinterpretation of hadrons.
- Main challenge: Photons have reduced particle footprint.



Radio and inclined photon showers - a good combination

BERGISCHE UNIVERSITÄT WUPPERTAL

Inclined photon showers with particle detectors:

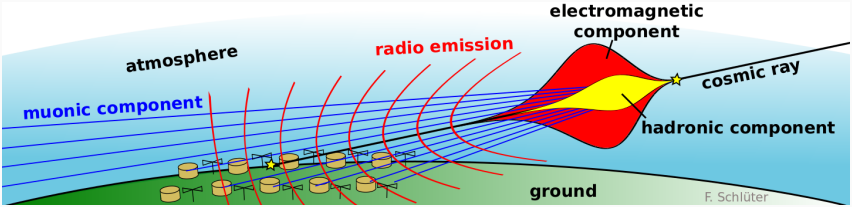
Small particle footprint as EM-part absorbed in the atmosphere

Challenge: Low detection probability and poor reconstruction!

With additional Radio Detector (RD):

Strong Radio signal

Feature: Discrimination from hadrons with their strong particle footprint.



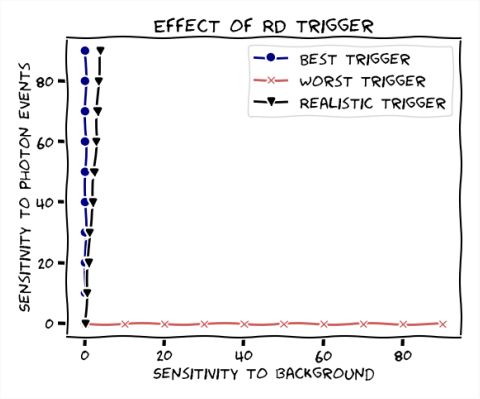
The Radio Detector

- Mounted on top of the Water Cherenkov Detector (WCD).
- Two polarizations (NS and EW).
- Current status: 10 fully installed stations.
- Detector response understood, simulations possible.
- At the moment: triggered by the WCD.

Requirement for a RD trigger

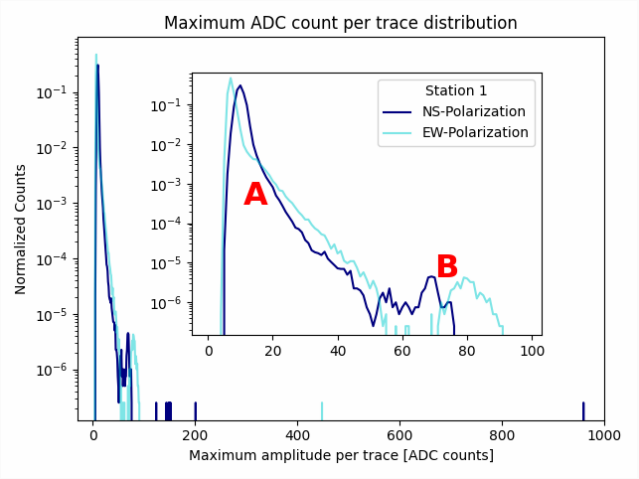
- Not sensitive to background (RFI and hadron events)
- Significant increase of photon trigger rate
- Compatible with limited bandwidth

$\Rightarrow$ Simple radio amplitude trigger for photons with threshold much larger than noise level.



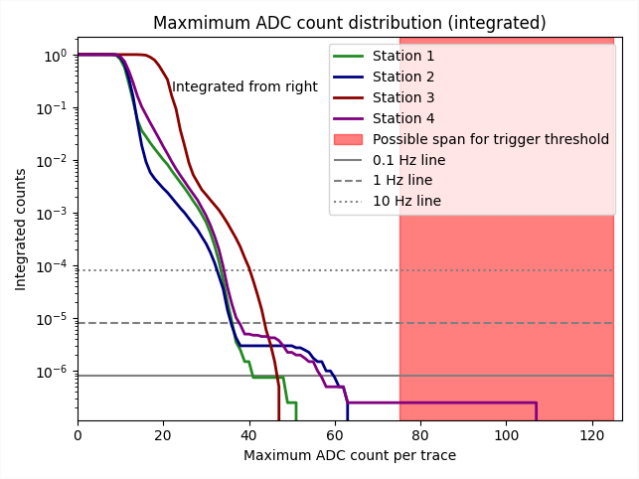
Noise level

- Measured periodically triggered noise.
- 32M traces with 8μs length $\Rightarrow$ in total 4 minutes
- Normal noise peaks (distr. A) mostly below 50 ADC counts.
- High RFI signals (distr. B, mostly CB radio) can be filtered on trigger level.



Noise level

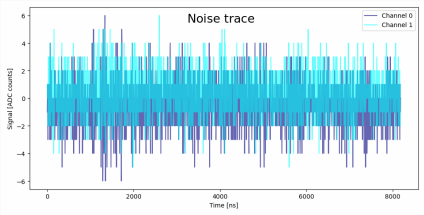
- Noise of stations comparable.
- Noise level not known for all positions in array.
- Trigger threshold larger than 60 ADC counts compatible with requirements.

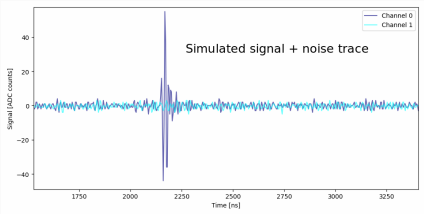


Used simulations for trigger study

BERGISCHE UNIVERSITÄT WUPPERTAL

- CoREAS simulations:
  CORSIKA 7.7410, Sybill 2.3d
  $\approx$ 1500 shower for photons and protons
  $\theta \in [65°, 85°]$, $\log E/\mathrm{eV} \in [18.4, 20.4]$
- Measured noise from RD added.
- Full detector simulation and reconstruction (WCD and RD).
- Radio threshold trigger on quadratic sum of both polarization.

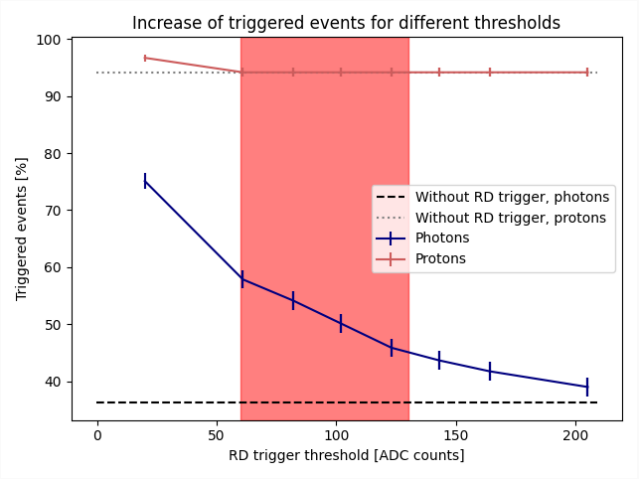




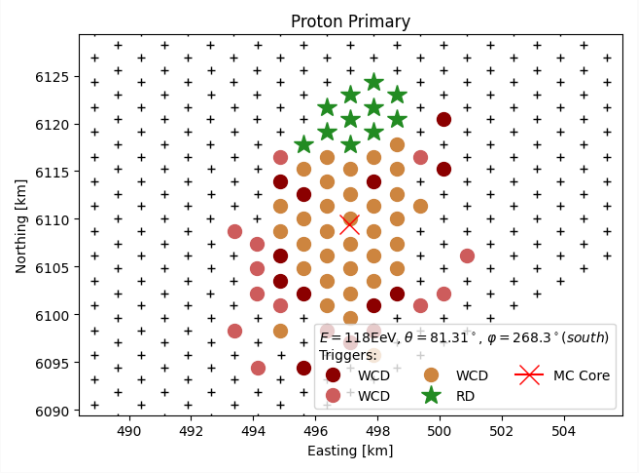
Event trigger rate for different thresholds

BERGISCHE UNIVERSITÄT WUPPERTAL

- RD trigger improves event trigger rate significantly.
- Red area marks ideal span for threshold.
- Event trigger rate improved by factor of 2 at lowest threshold.



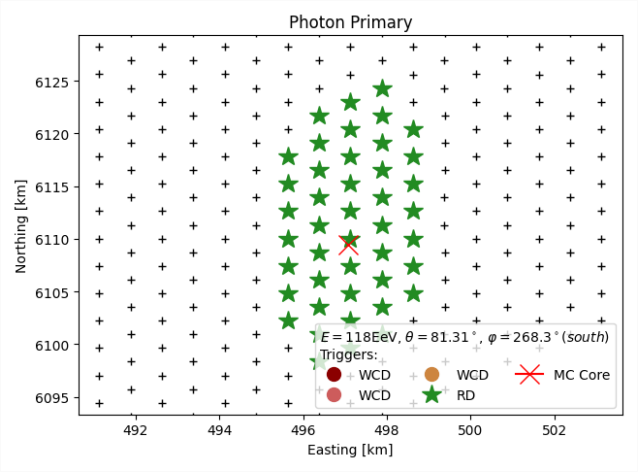
Typical proton simulation with Radio



Proton shower:

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

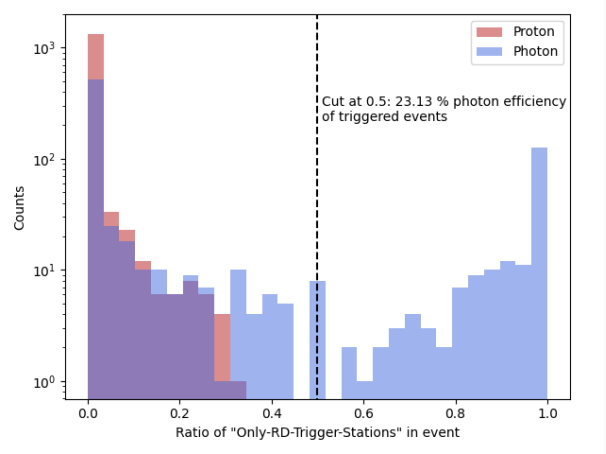
Typical photon simulation with Radio



Photon shower:

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

Discrimination on trigger level

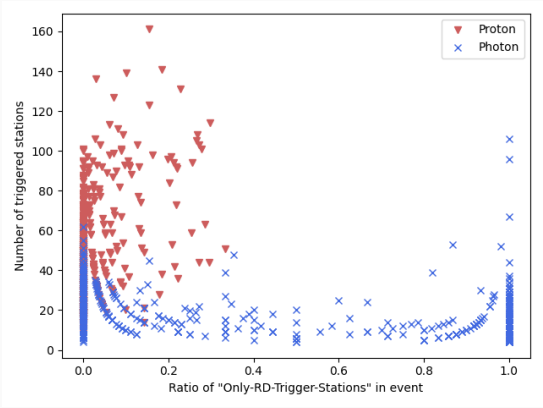


Trigger composition:

Many T3 events with only Radio triggers.

$\rightarrow$ Discrimination on trigger level!

Discrimination on reconstruction level

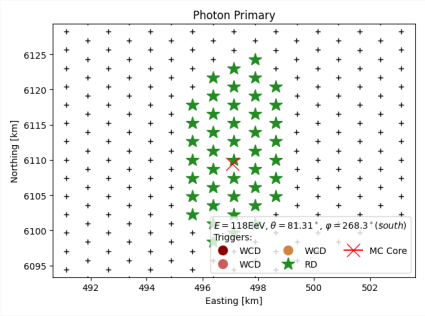


Discrimination improves with more parameters.

⇒ Combining parameters with multivariate analysis like e.g. Fisher-Discrimination and Decision Trees.

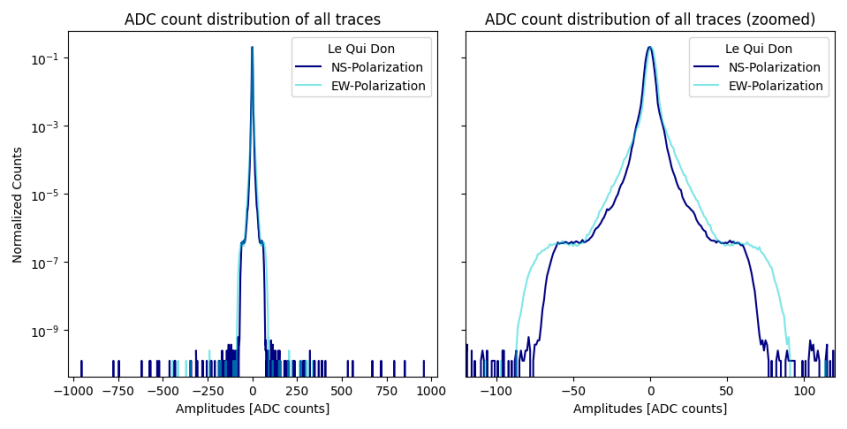
Summary and outlook

- Radio threshold trigger on inclined photons leads to significant increase in sensitivity.
- Combination of WCD and new RD yield strong discrimination.
- Further analysis for exact exposure and discrimination power.
- Calculation of expected upper flux limits after n years in work.
- Hardware implementation in preparation - promising.



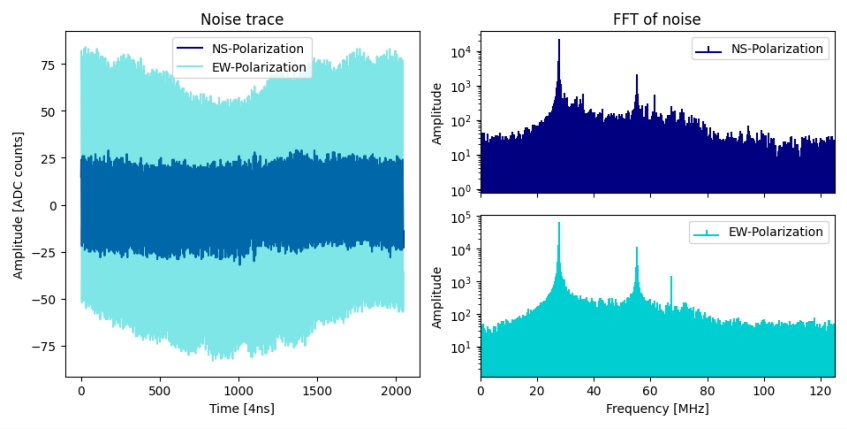
jannis.pawlowsky@uni-wuppertal.de

Noise distribution



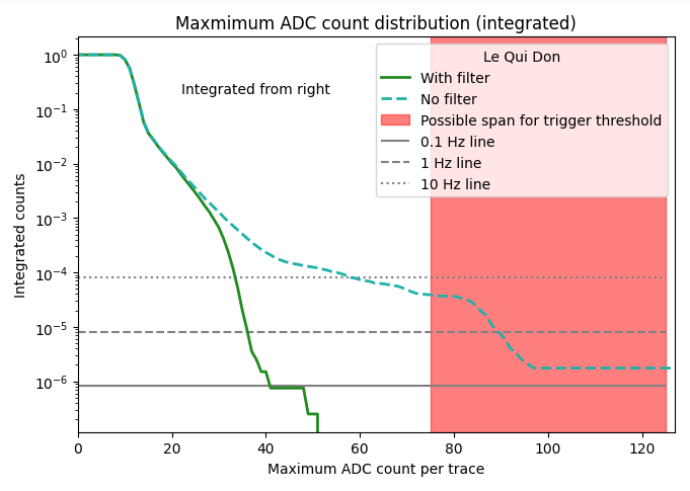
jannis.pawlowsky@uni-wuppertal.de

Artificial noise trace - periodic triggering



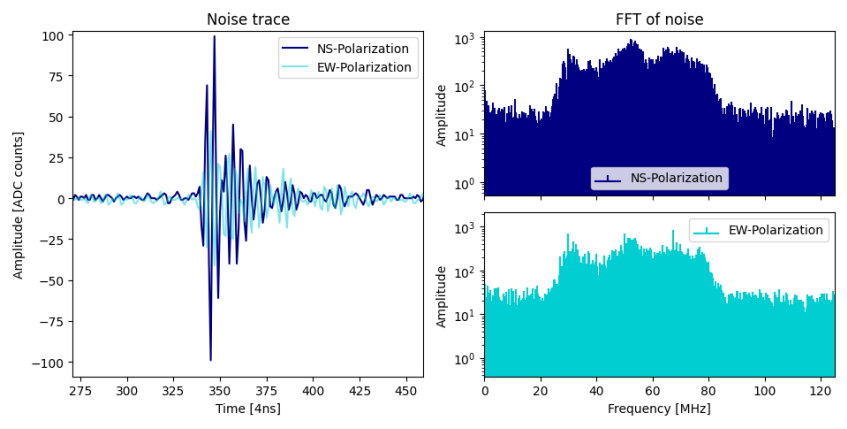
jannis.pawlowsky@uni-wuppertal.de

Filter effect



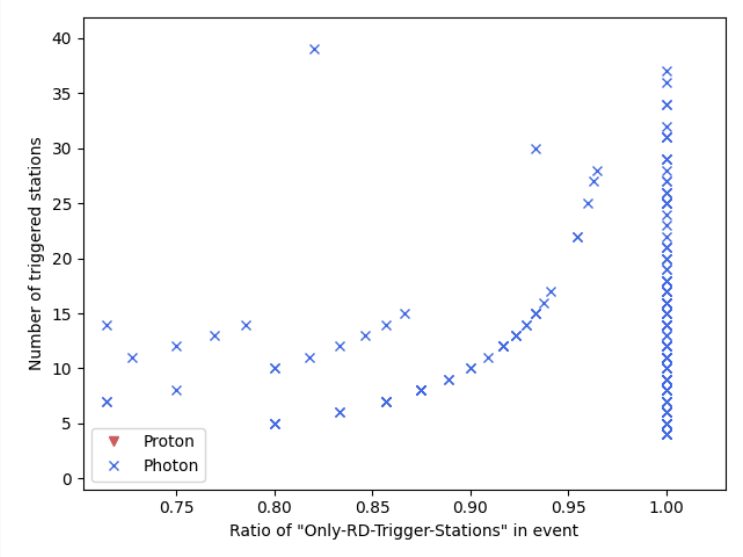
jannis.pawlowsky@uni-wuppertal.de

Triggered event



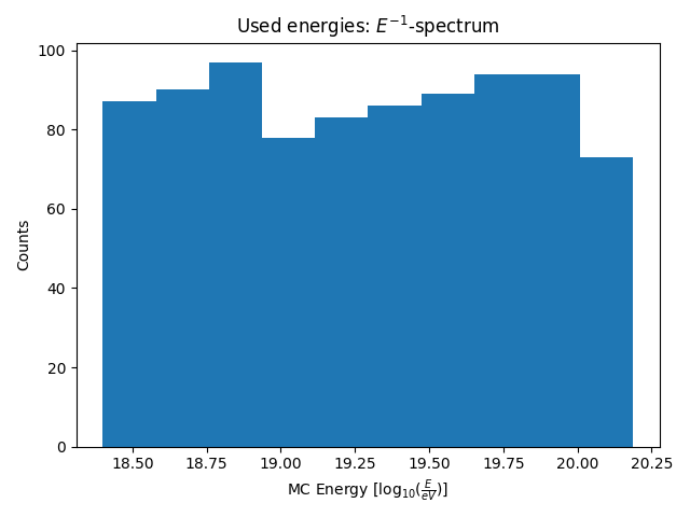
jannis.pawlowsky@uni-wuppertal.de

Discrimination



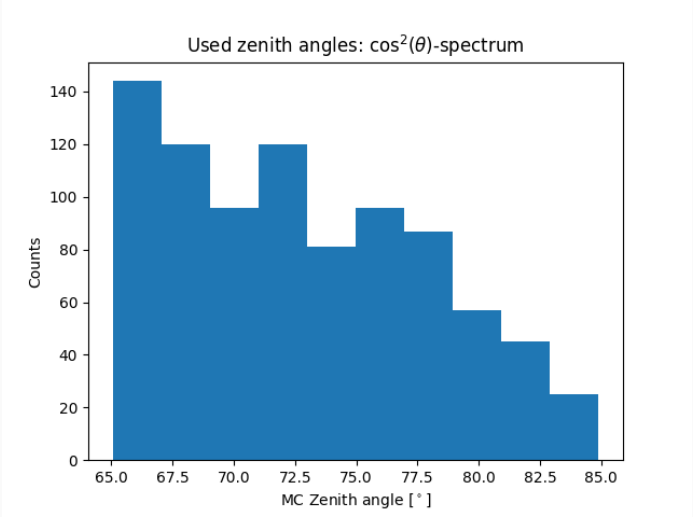
jannis.pawlowsky@uni-wuppertal.de

Used energy range



jannis.pawlowsky@uni-wuppertal.de

Used zenith range



jannis.pawlowsky@uni-wuppertal.de