10 June 2023

GCOS-Workshop Brussels: Radio Session

Session chair: Jörg Hörandel

Notes: Frank Schröder

**Conclusions:**

* Radio may serve as a calibration device for energy scale and long-term stability of SD; for this purpose partial coverage of the surface detector is likely sufficient
* While radio + muons in SD can provide per-event mass sensitivity for inclined showers, and SD can do for near-vertical showers, it will be challenging to reach overlap between both methods.
* Thus, it is not yet clear whether radio is useful for the full scale of GCOS and at all sites. This may depend on SD spacing and the specific radio detector design
	+ how many antennas per surface detector (e.g., one on top of or three around one SD)
	+ what antenna design, e.g., what frequency band
	+ is the time synchronization good enough for interferometry, or can Xmax be reconstructed in an alternative way for inclined showers

🡪 R&D and dedicated simulation studies required to assess zenith angle range of radio detector for inclined showers and contribution to GCOS science case for different designs.

**Summary on talks and discussions during the session:**

Slides by Tim Huege on general considerations about radio in GCOS

Independent calibration of absolute energy scale, electromagnetic energy within 10%, Xmax for inclined showers probably possible with interferometery. Interferometry requires 1 ns time synchronization and many antennas, i.e., a dense array. Is the next generation of GPS good enough for interferometry?

Radio footprint size increases rapidly with zenith angles. AugerPrime RD works on 1.5 km spacing, 2.0 km is stretching the potential of radio 🡪 could local radio clusters be an option?

2km grid for single antenna station can cover zenith range from 75-85 deg zenith, 1km spacing from about 65 deg, and 1.5 km from about 70 deg zenith angle onwards.

Higher frequencies (e.g., 150-300 MHz) will not help much as signal is only visible on Cherenkov ring.

Radio antenna on top of segmented tanks as an option? With sparse SD, this may be an option only for a denser in-fill array for cross-calibration.

Michael U.: radio needs to be tuned to science case.

Jörg: suggestion to study three antennas at ~50m distance to the tank.

Frank: this is similar to Gen2 surface design; in this case, local interferometry might improve threshold and zenith range a little bit.

Matthias Kleifges explains similarities to IceCube-Gen2 setup: can the same electronics be useful? Generally, trigger and buffer time are essential considerations for radio electronics.

Agreement in discussion that we need simulation studies to assess the feasibility of radio for GCOS and to determine what zenith range could be covered with radio.

Discussion about whether next generation GPS could be good enough for interferometry, either directly or if raw data are stored and later corrected. Nobody seems to know for sure whether 1ns timing can be achieved.

Slides by Bjarni about radio lessons from Hybrid and Calibration

Capability to measure energy and Xmax proven at Auger. Hybrid detection is important. Radio can provide calibration and cross-checks. Radio might be of particular value to ensure long-term stability as no aging is expected in radio, and no long-term effects are seen over several years of AERA operation.

Markus asks about largest areas that are radio quiet enough, which initiates a discussion about how necessary that is. For cosmic-ray hybrid detection with the water-Cherenkov tanks it is probably not necessary to be at a very radio-quiet site (external trigger, and events can be confirmed by particle detector). For radio self-triggering on very inclined photon showers (that don’t have a particle signal) the situation is different. If that works at all, likely a radio quiet site is required and/or a more sophisticated approach such as veto antennas. The situation on the self-trigger might improve with better communication and exploiting detailed knowledge on the radio signal. In summary, radio quietness seems to be less of a concern for cosmic-ray detection, but more for photon searches.

Frank suggests to optimize GCOS on cosmic rays and leave photon search to overlap site with GRAND (as GRAND does self-triggering and their site need to be suited for this by definition).

Some further discussion on how important the geomagnetic field is: according to Tim, it is not obvious whether a strong geomagnetic field is better for very inclined showers. Detailed studies and experience with Auger RD will be needed. At this moment, nobody has a convincing argument whether or not the geomagnetic field will be an important site constrain for a GCOS radio component.

Washington C. shows slides on radio footprint sizes

Confirms basically what Tim said: with wide spacing, only zenith angles larger than about 70 deg can be observed. Deep neutrino showers have smaller footprints which makes neutrino detection more difficult.

Conclusion: Need to do simulation studies what we could do with local clusters of few antennas vs. one antenna with a very wide bandwidth.