CoMET

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

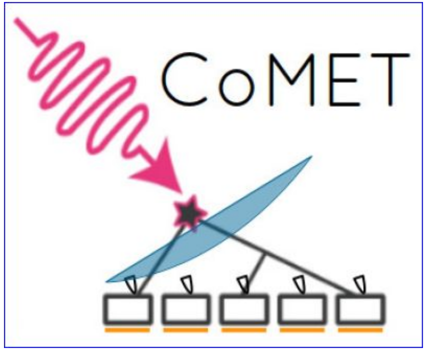
The CoMET multiperspective event tracker for wide field-of-view gamma-ray astronomy

Gašper Kukec Mezek[1] on behalf of the COMET collaboration

Yvonne Becherini[1], Michael Punch[1,2], Jean-Pierre Ernenwein[3], Satyendra Thoudam[4], Ahmed Saleh[4], Tomas Bylund[1], Mohanraj Senniappan[1], Patrizia Romano[5], Stefano Vercellone[5], Martin Tluczykont[6]

[1]Linnaeus University, Sweden, [2]Université de Paris, CNRS, Astroparticule et Cosmologie, France, [3]Aix Marseille Univ, CNRS/IN2P3, CPPM, France, [4]Khalifa University, United Arab Emirates, [5]INAF-Osservatorio Astronomico di Brera, Italy, [6]Universität Hamburg, Germany

CoMET: Introduction



ALTO: Particle detector array with 1242 detector units (water-Cherenkov and scintillation detector).

CoMET: Extension to the ALTO array by adding atmospheric Cherenkov Light Collectors (CLiC).

The CoMET R&D project is dedicated to observing very-high-energy extragalactic gamma-ray sources (200 GeV − 100 TeV).

CLiC

The key features of ALTO include,

- Regular monitoring → **Observations may be done 24h per day**
- Wide field-of-view → **~ 2 steradian**
- At high altitude (> 5 km) → **Low threshold E ≥ 200 GeV**
- Excellent timing accuracy → Improved angular resolution (~ 0.1° at few TeV)
- Modular design → Phased construction and easy maintenance
- Simple to construct → Minimize human intervention at high-altitude
- Long duration → Should operate for 30 years
- Open Observatory → Distribute data to the community

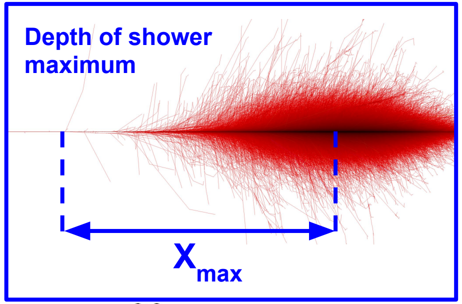
Atmospheric Cherenkov light observations only available during clear nights

Smaller field-of-view of CLiCs (~ 0.8 steradian)

Aim to further improve angular resolution

CoMET: Motivation

[1] FZKA 6019 (1998)



Accessing independent information (shower development):

- Extract X_{max} from atmospheric Cherenkov light information
- Better energy resolution and bias
- Improved gamma/hadron separation

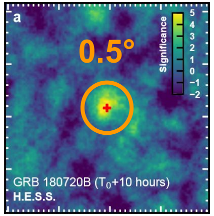
Better source localisation:

- Adding atmospheric Cherenkov light signals to particle signals

Better sensitivity:

- Energy range focus of CoMET: 200 GeV - 100 TeV (soft-spectrum sources)

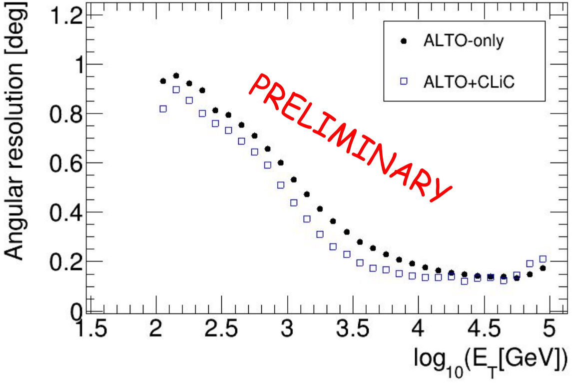
[3] arXiv:1911.08961

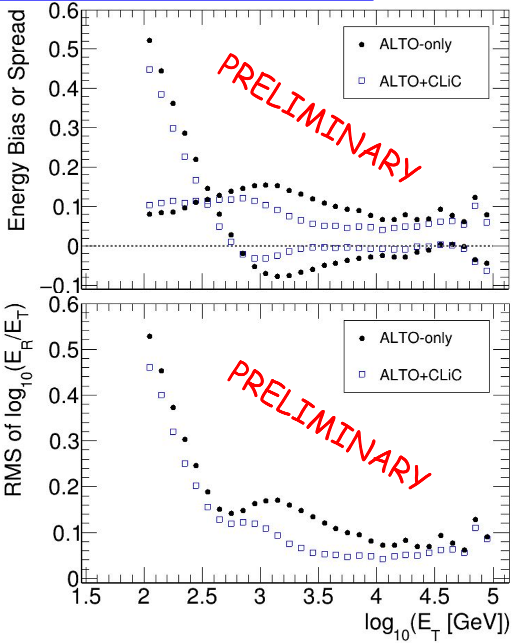


[2] M. Senniappan et al., at this conference

Current ALTO performance

Preliminary CoMET performance

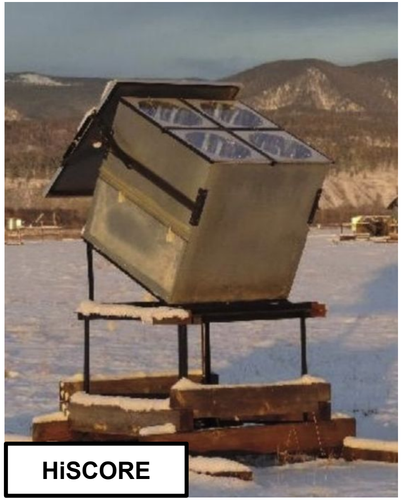




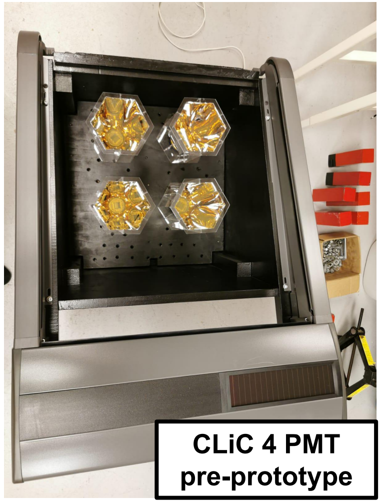
CoMET array (ALTO + CLiC)

- 1242 ALTO units + 414 CLiC detectors
- CLiC inspired by the HiSCORE wide field-of-view detector (four 8” PMTs → eight 3” PMTs)
- CLiC stations read-out by coincidence with particle detectors in corresponding cluster

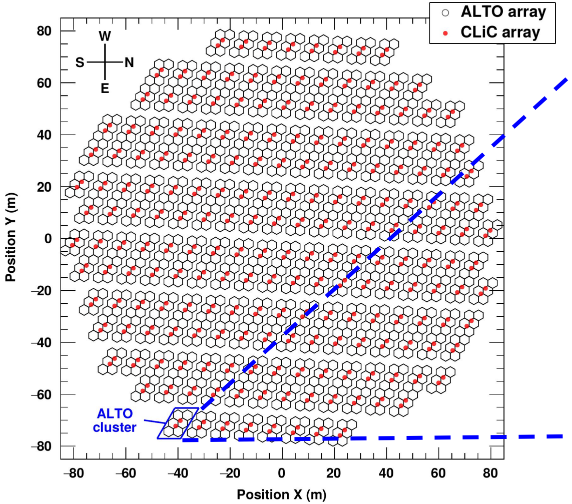
[4] doi:10.1016/j.nima.2016.08.031

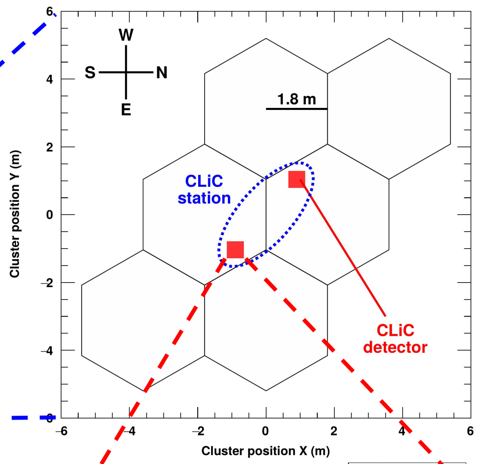


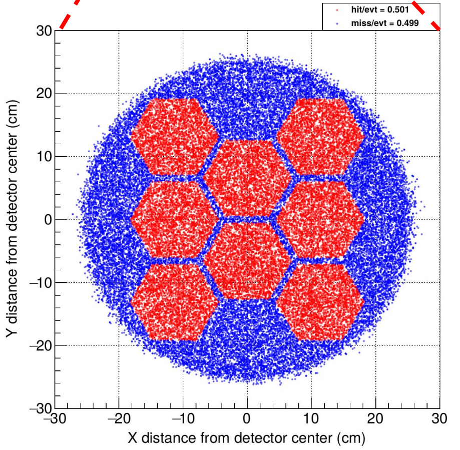
HiSCORE



CLiC 4 PMT pre-prototype







Multiple PMTs per CLiC detector, smaller PMTs: Increase sensitivity, reduce NSB contamination, no amplifier

Combining two CLiC detectors: Increase sensitivity and light collection area

Atmospheric Cherenkov light simulations

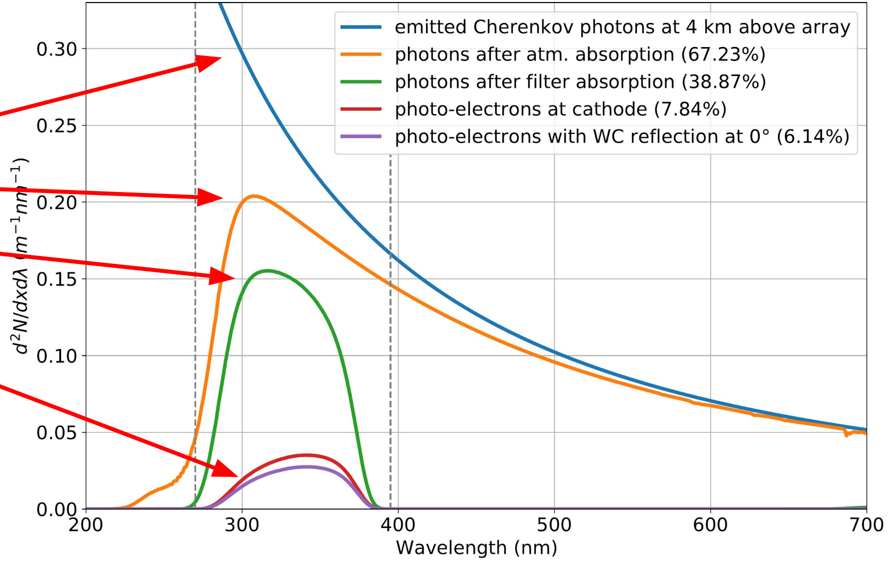
CORSIKA atmospheric shower simulations:

- Gamma-rays simulated with power-law index Γ = 2 and zenith angle of θ = 18°, diffuse protons with Γ = 2.7 and zenith angle of θ = 15° − 21°
- Simulated energy range between 100 GeV and 100 TeV

±3° from source position

CLiC detector response:

- Cherenkov light transmission and CLiC detector response simulations:
  1. Cherenkov spectrum random wavelength
  2. Atmospheric transmission
  3. UV filter transmission
  4. Winston Cone ray-tracing and reflection efficiency
  5. PMT quantum efficiency (Hamamatsu R6233)
  6. Conversion of p.e. waveform to signal
- Summation of CLiC detector signals connected to the same cluster

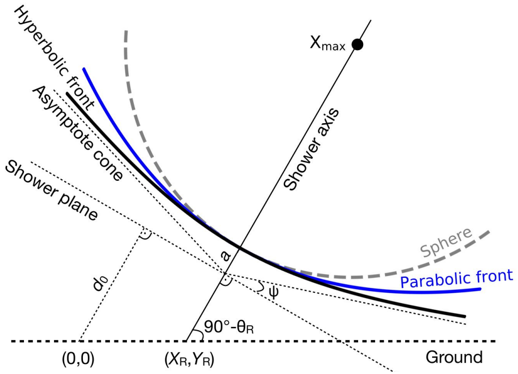


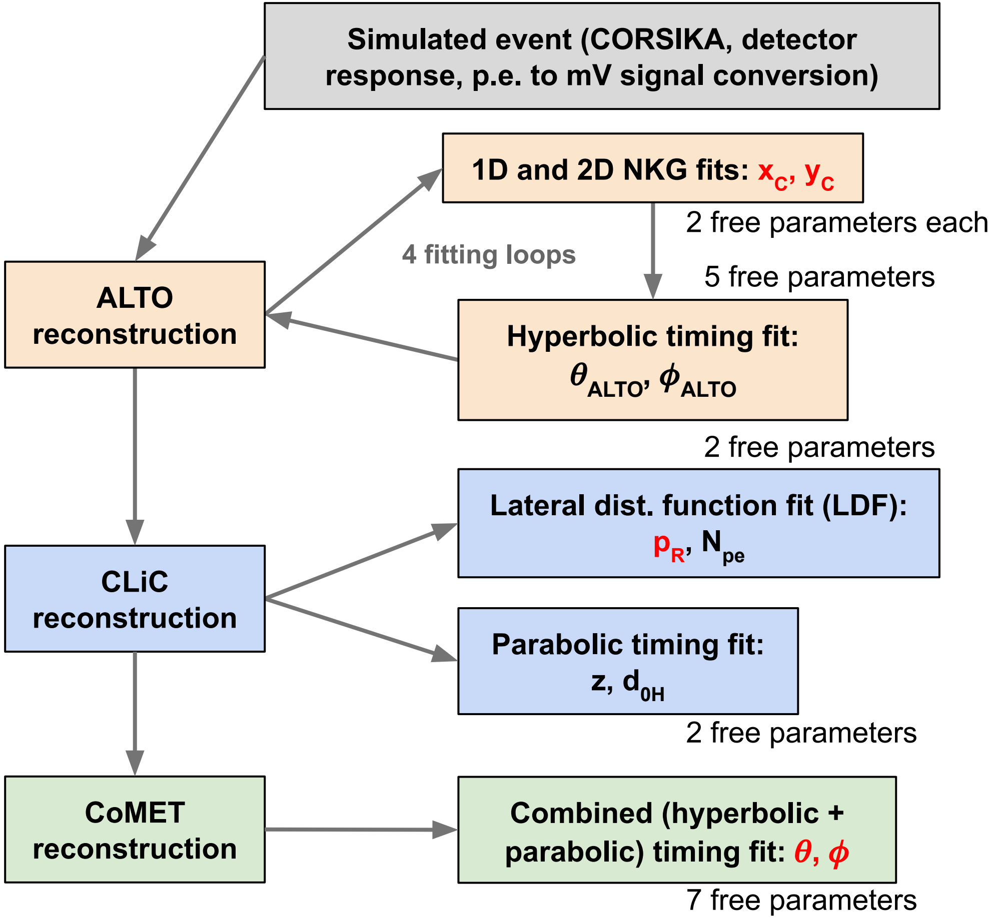
CoMET reconstruction strategy

ALTO reconstruction:
- Core position reconstruction (x_C, y_C)
- Initial estimation of arrival direction (θ_{ALTO}, ϕ_{ALTO})

CLiC reconstruction:
- Fixed core and arrival direction from ALTO
- Shower maximum estimator extraction (p_R)

CoMET reconstruction:
- Fixed core from ALTO
- Arrival direction reconstruction (θ, ϕ)



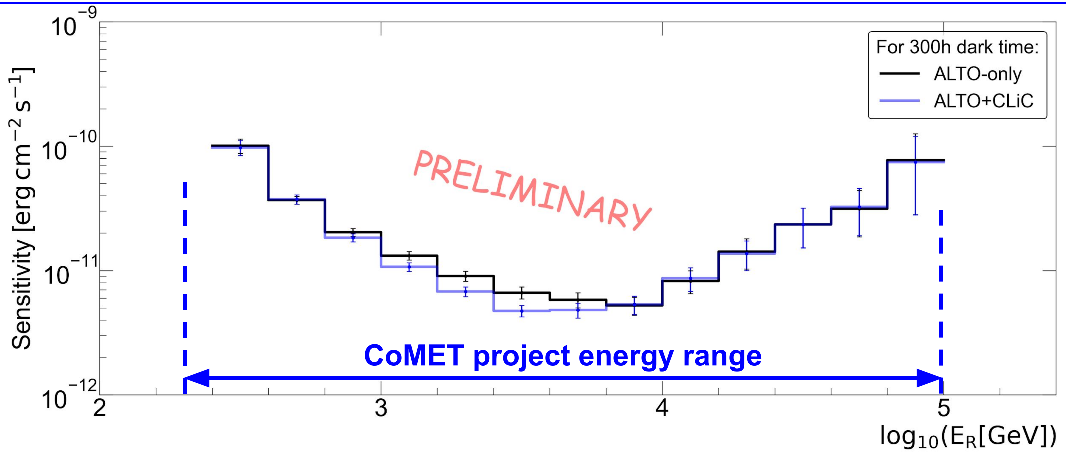


Preliminary SEMLA results for CoMET

[5] arXiv:2105.06728

Analysis performed with the SEMLA [5] procedure:

- Adding CLiC observables into the machine learning structure of SEMLA:
  - Stage B (cutting badly reconstructed events): Parabolic fit χ^2_{parab}, LDF slope p_R
  - Stage C (gamma/hadron separation): p_R, LDF value at 60 m p_{60}
  - Stage D (energy reconstruction): p_{60}, number of detected photo-electrons N_{pe}
- Improvement seen in all stages of SEMLA: 10% (angular resolution), 30% at 1 TeV (energy resolution), 12% less background, loss of only 1% of gamma-rays

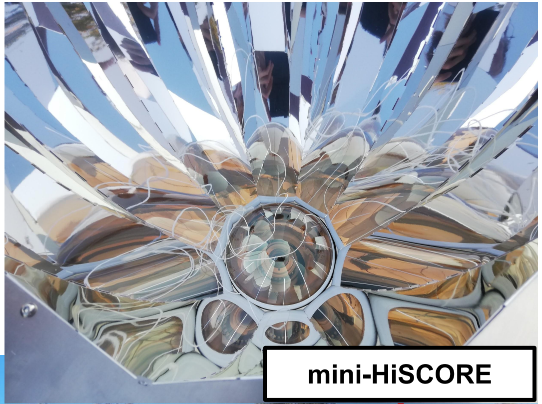


Prototype at Linnaeus University

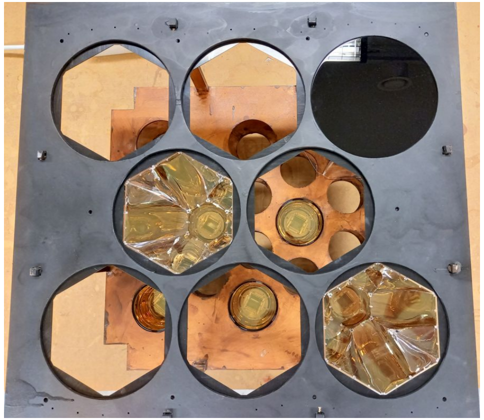
Atmospheric Cherenkov light prototypes:

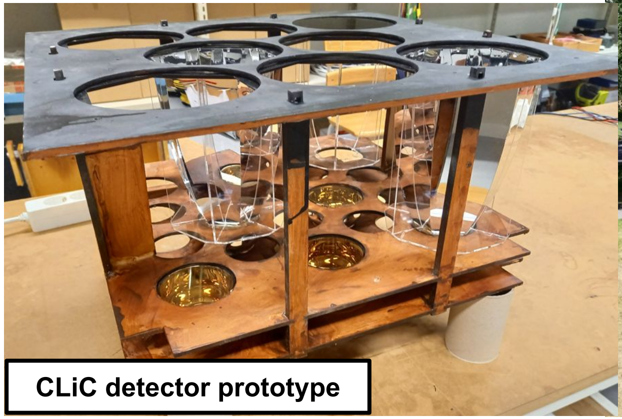
- 4 PMT CLiC pre-prototype, September 2020
- 1 PMT mini-HiSCORE (4 detectors), 2020 − 2021
- 8 PMT CLiC detector prototype, installation in Summer 2021

CLiC pre-prototype on top of WCD

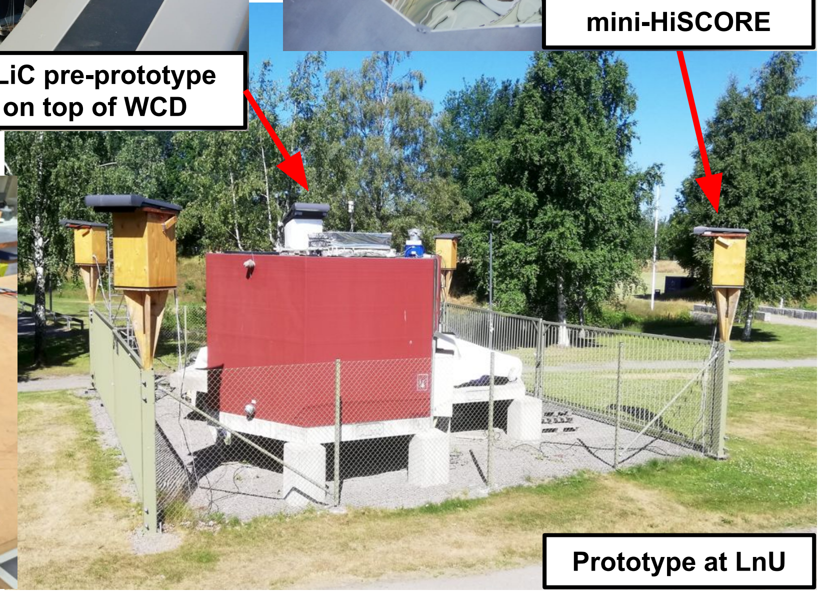


mini-HiSCORE





CLiC detector prototype

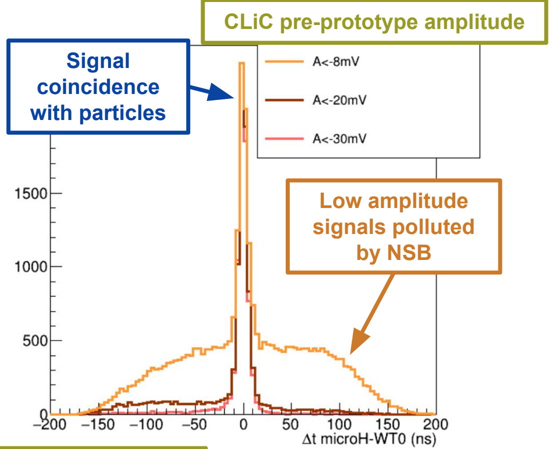


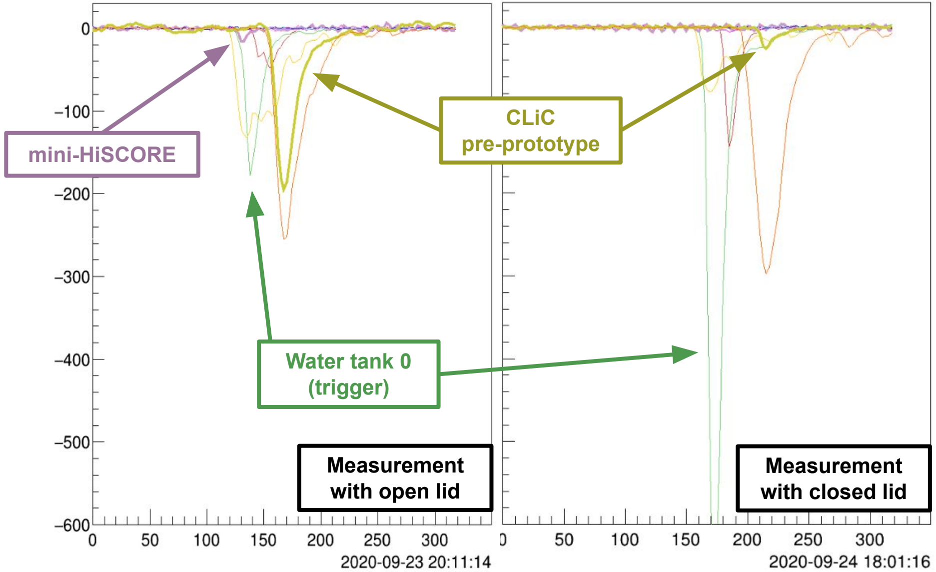
Prototype at LnU

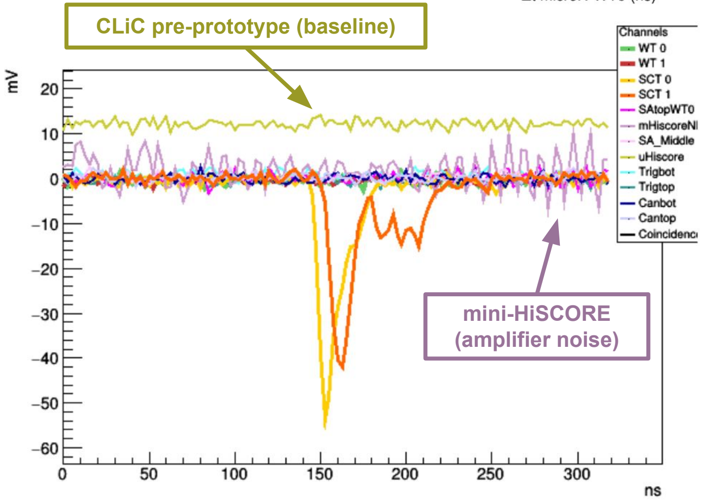
Prototype at Linnaeus University

First measurements with CLiC pre-prototype (23. and 24. Sep 2020):

- Signals correlated with water-Cherenkov particle detectors
- Improved gain and lower noise (compared to mini-HiSCORE)
- Closed vs. open lid measurements show particles passing through the filter and PMT glass (high sensitivity)







Conclusions

- CoMET dedicated to soft-spectrum sources, and sensitive in the energy range 200 GeV - 100 TeV
- **Key idea:** during darkness couple atmospheric Cherenkov light signals to particle detector signals from atmospheric showers for a better gamma/hadron separation and a better source localisation
- **Confirmation of the hypothesis** (preliminary results):
  - Adding four new CLiC observables improved all stages of the SEMLA analysis
  - Improvement to angular resolution, energy reconstruction and background suppression
  - Clear improvement at [600 GeV, 6 TeV]
- **Prototype activities:**
  - New CLiC design has good sensitivity and reduced night sky background (NSB)
  - Full CLiC detector prototype measurements to follow in Autumn-Winter 2021-2022

Thank you for your attention