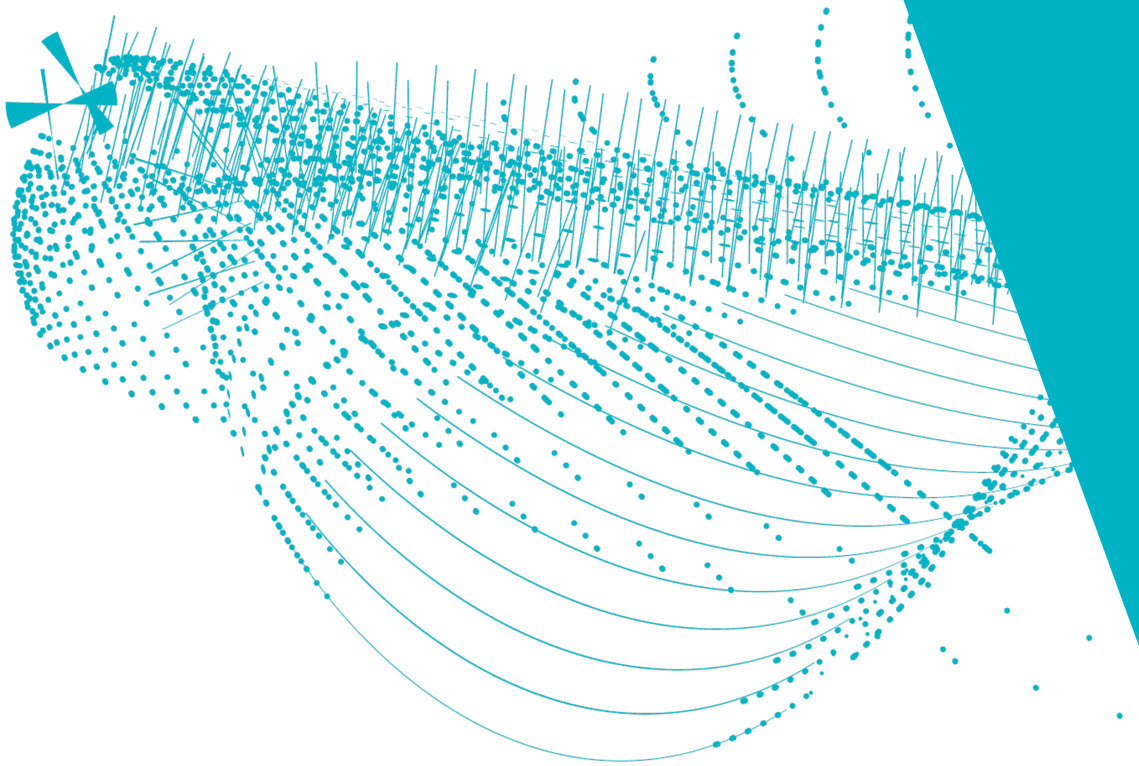
Nikhef

KASPER VAN DAM



HISPARC

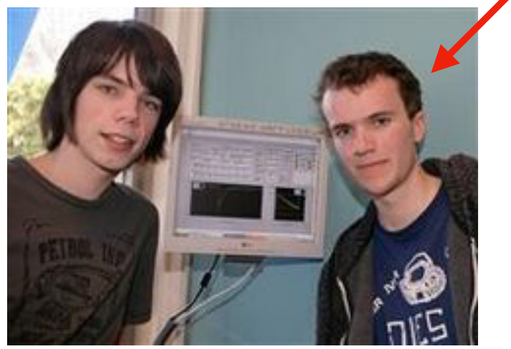
24th Symposium on APP in NL

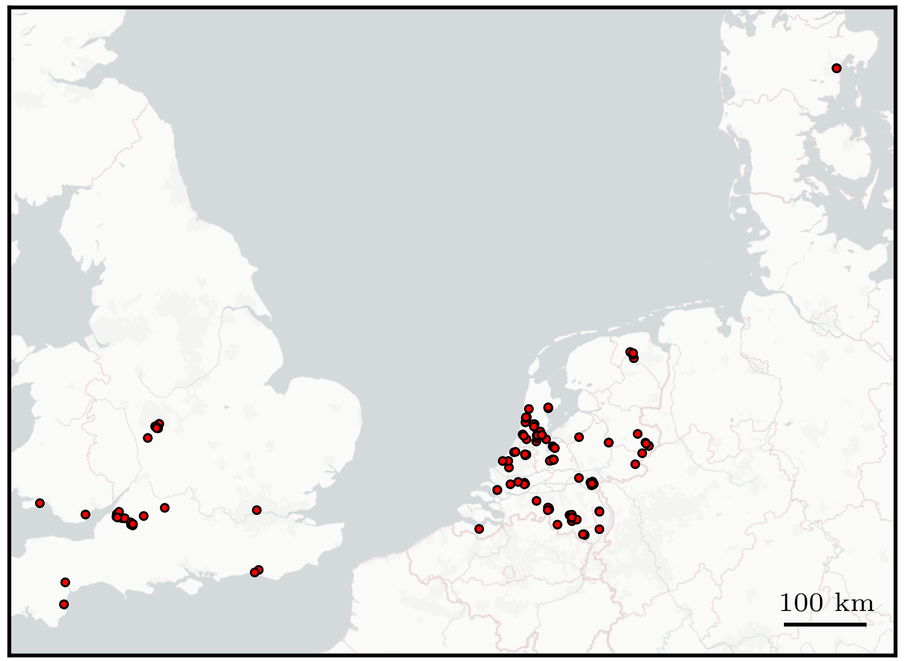
WHAT IS HISPARC?

HiSPARC

- High School Project on Astrophysics Research with Cosmics
- First and foremost an outreach project
- ~140 cosmic ray detection stations throughout NL, UK, DK, Namibia
- Large community of teachers

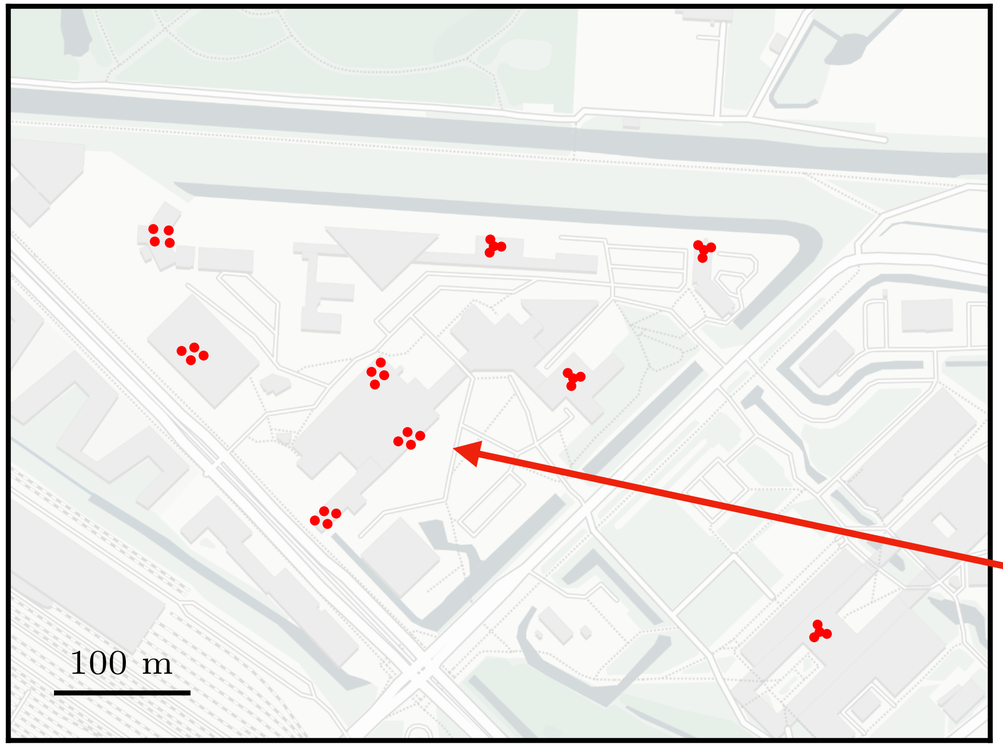
me in 2009:
CERN visit
(profielwerkstukprijs)

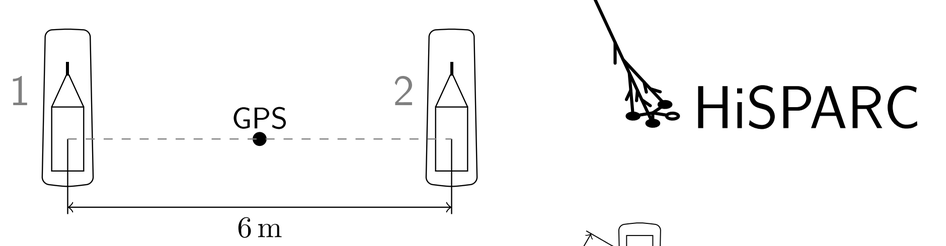


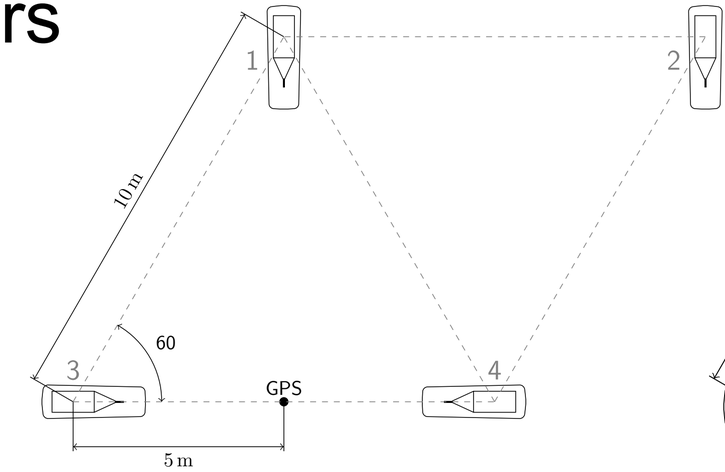


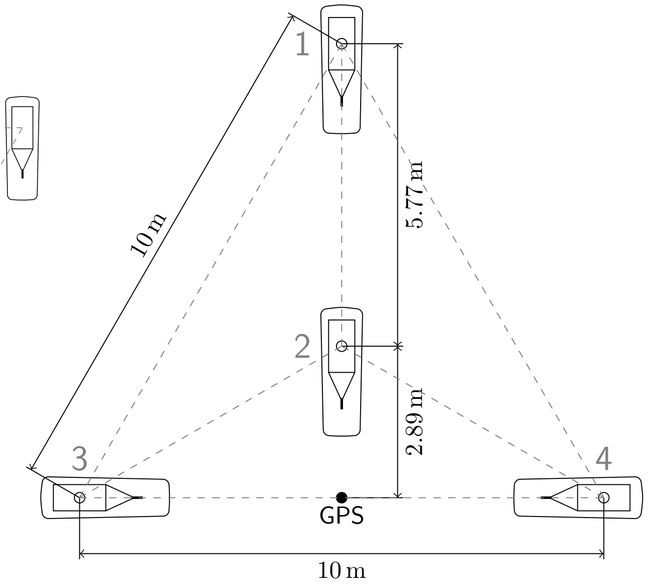
WHAT IS HISPARC?

- Station consists of 2 or 4 detectors
- Store coincidences







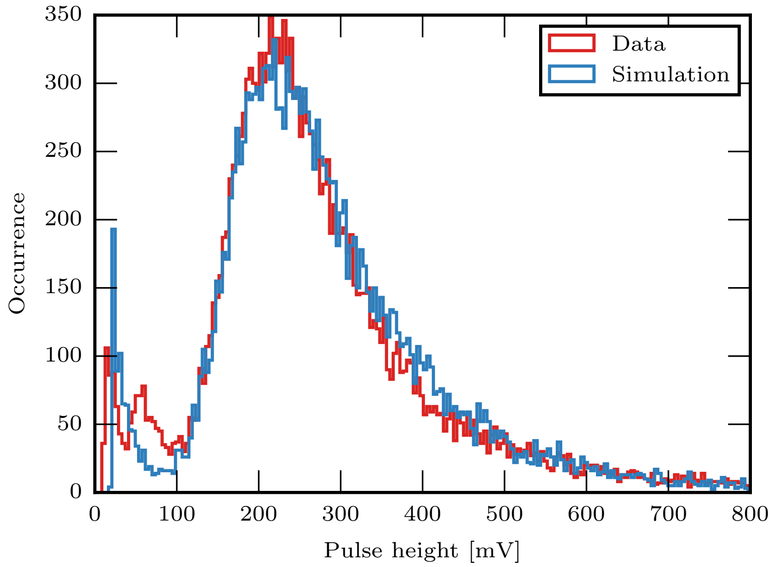


WHICH SCIENCE WITH HISPARC?

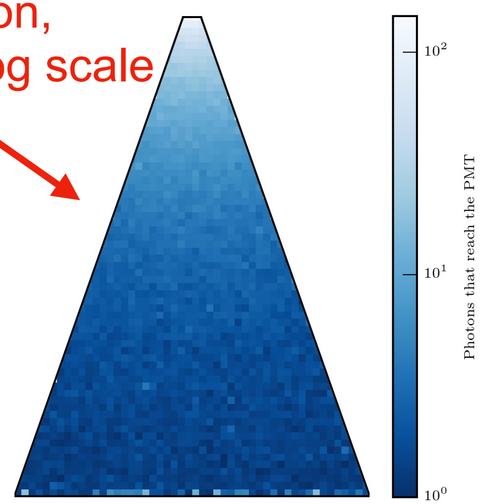
- Station
  - We cannot: reconstruct single EAS properties
  - We can: infer data from distributions ← this talk
  - Stations in special configurations
    - muon tomography / space weather (PhD student in Birmingham)
- Combination of stations
  - EAS reconstruction methods using machine learning techniques
- Network
  - Changes in atmosphere ← this talk
  - Correlated air showers

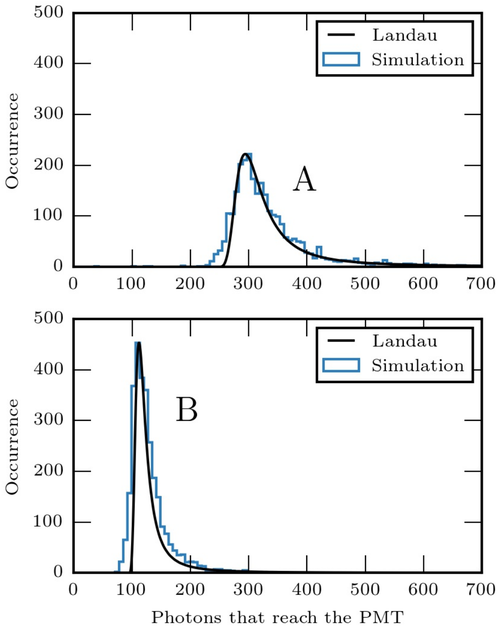
DETECTOR

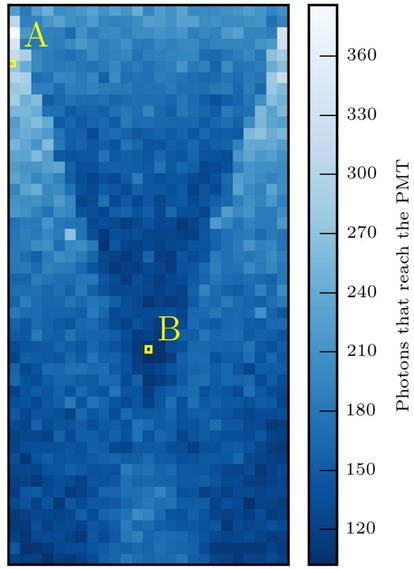
- Scintillator + light-guide + PMT
  - Cherenkov light in light-guide
  - Yield is position dependent
  - Simulations vs experiment

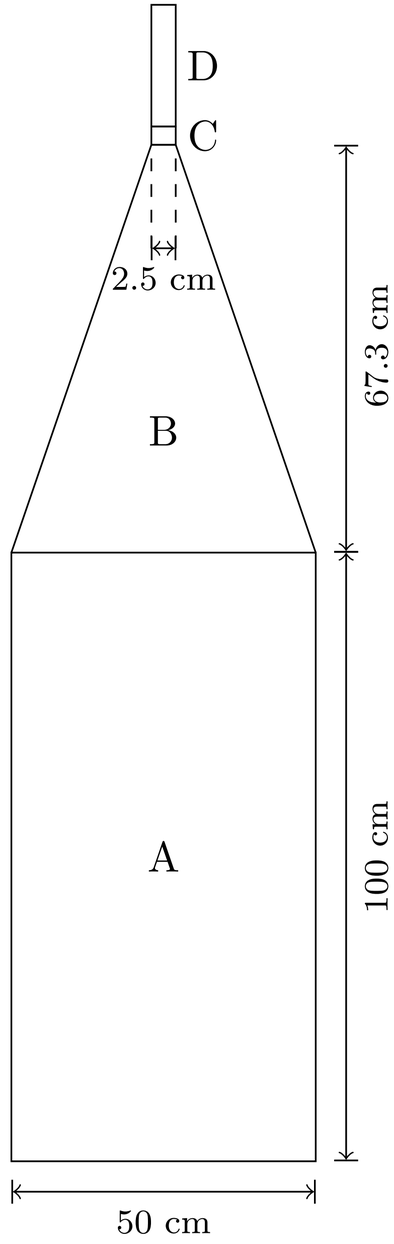


small contribution,
colours are in log scale



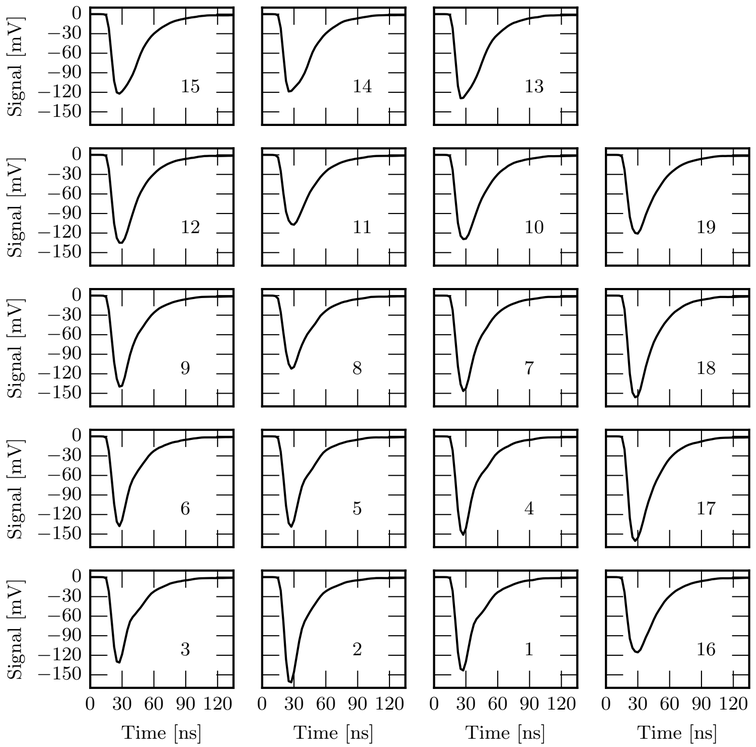


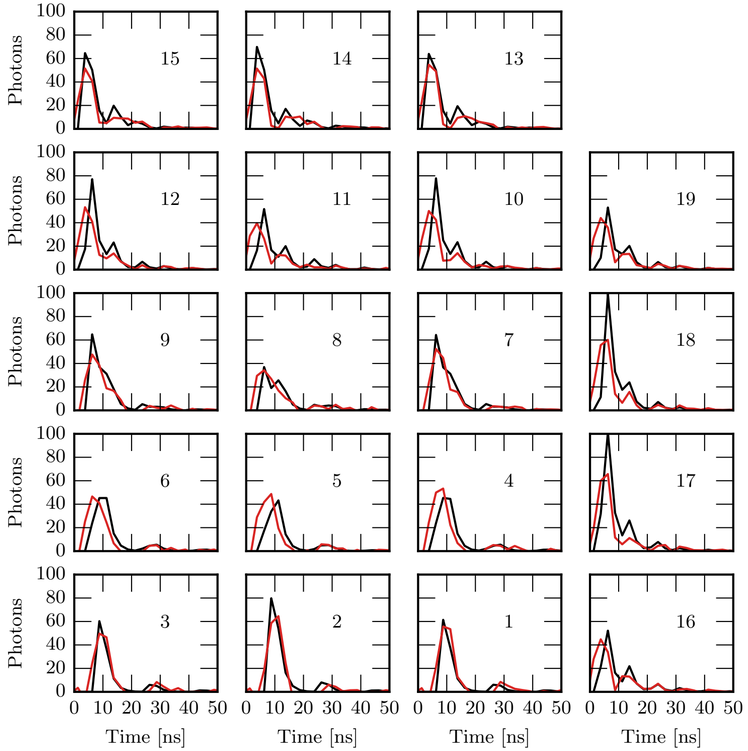


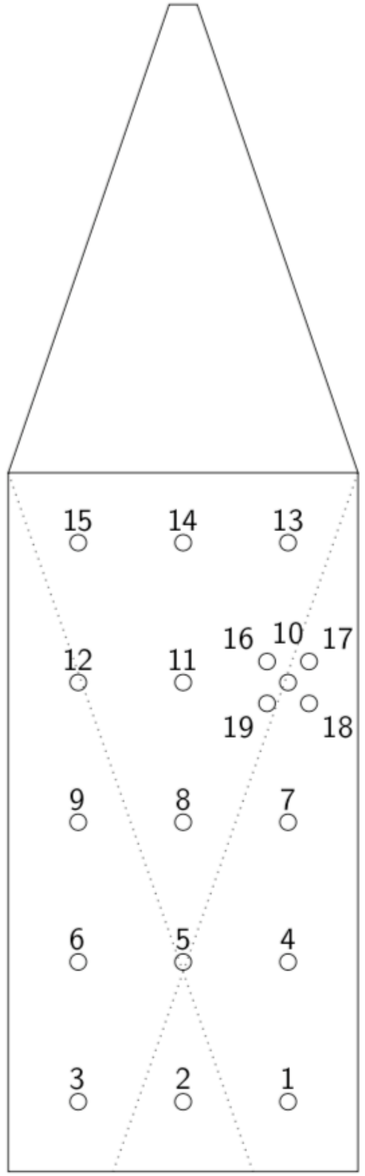


DETECTOR

- Deconvolution of single photo-electron pulse
- Arrival times of scintillation photons at PMT







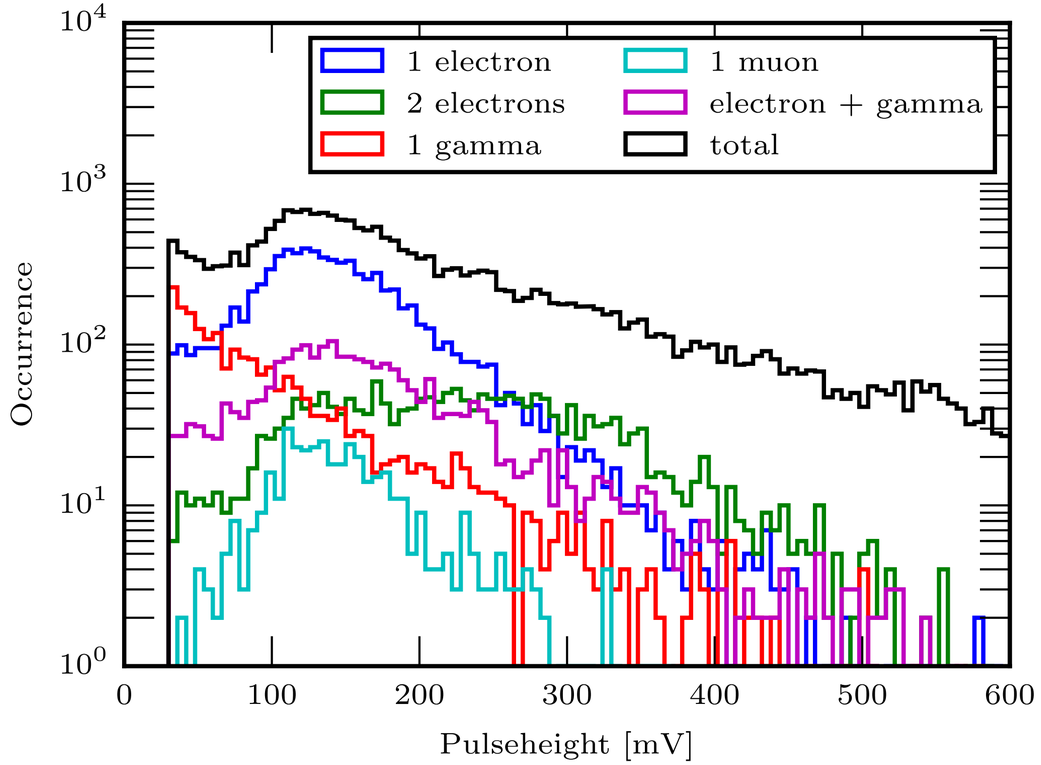
SIMULATION PIPELINE

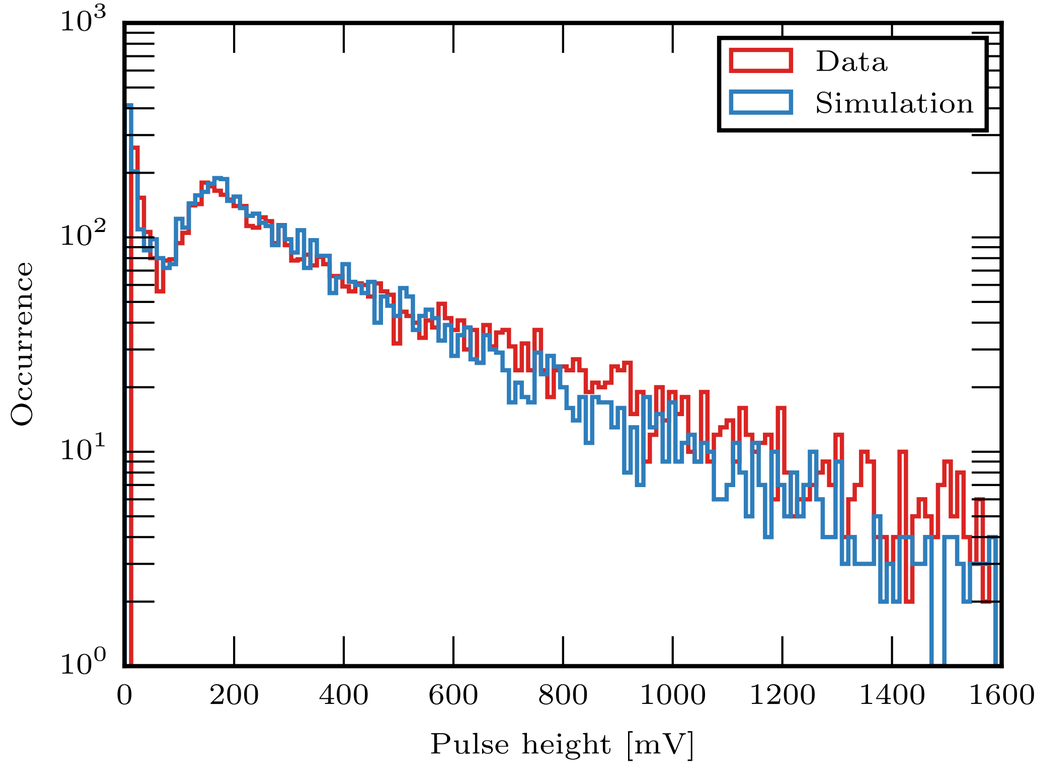
HiSPARC

- CORSIKA footprints (QGSJET-II, GHEISHA, EGS4)
  - large data set
  - $10^{12.5}$ to $10^{16.5}$ eV (4 days on Nikhef cluster)
  - 0 to 60 degrees in steps of 3.75
  - lowest energy cuts
  - no thinning
- GEANT4 detector simulation
  - station placement
- Scintillation photons + analytical description single photo-electron pulse
- Store in same data format as experimental data

SINGLE STATION: PULSE HEIGHT DISTRIBUTION

- Pulse height is a measure for the number of particles
- Agreement with experimental data 4-detector station

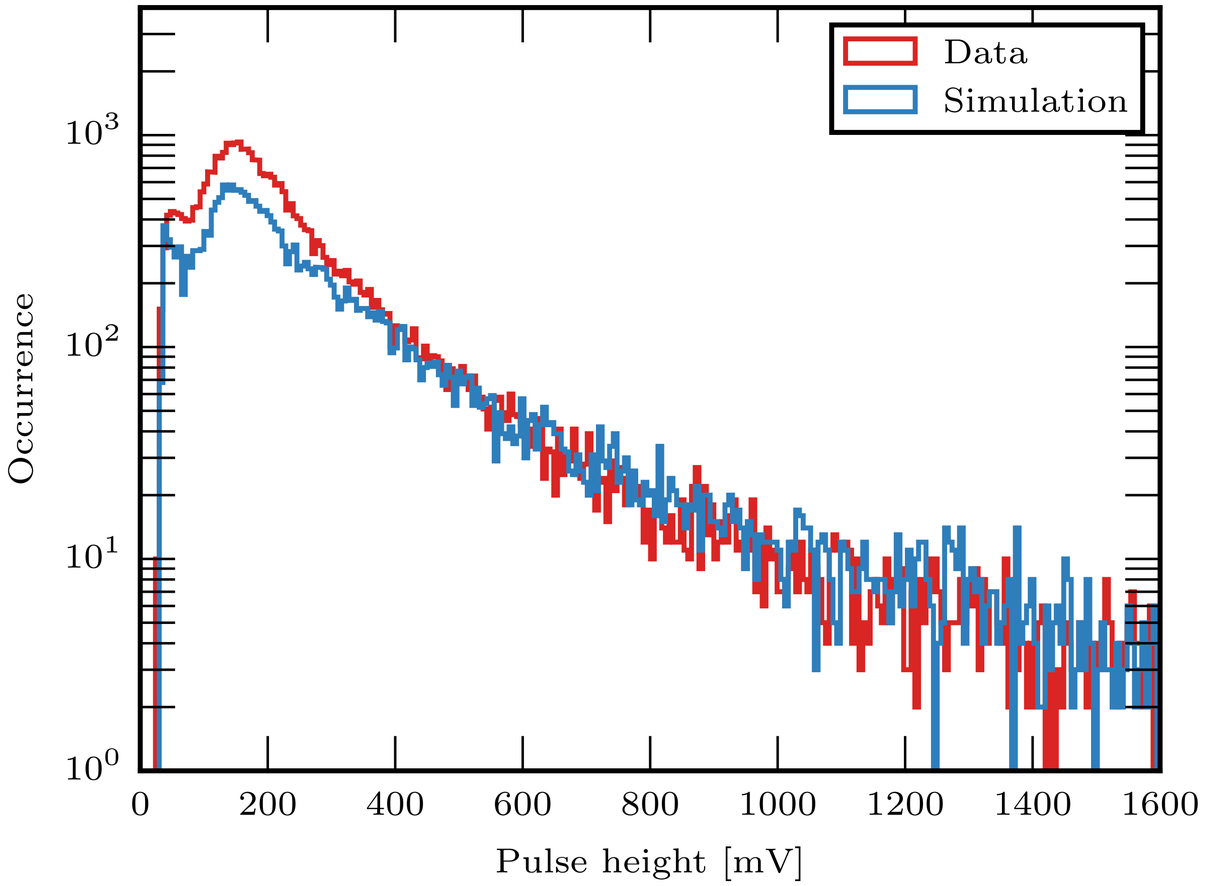




SINGLE STATION: PULSE HEIGHT DISTRIBUTION

- Discrepancy for 2-detector station
- We're missiong a lot of
  - single electrons
  - single gammas

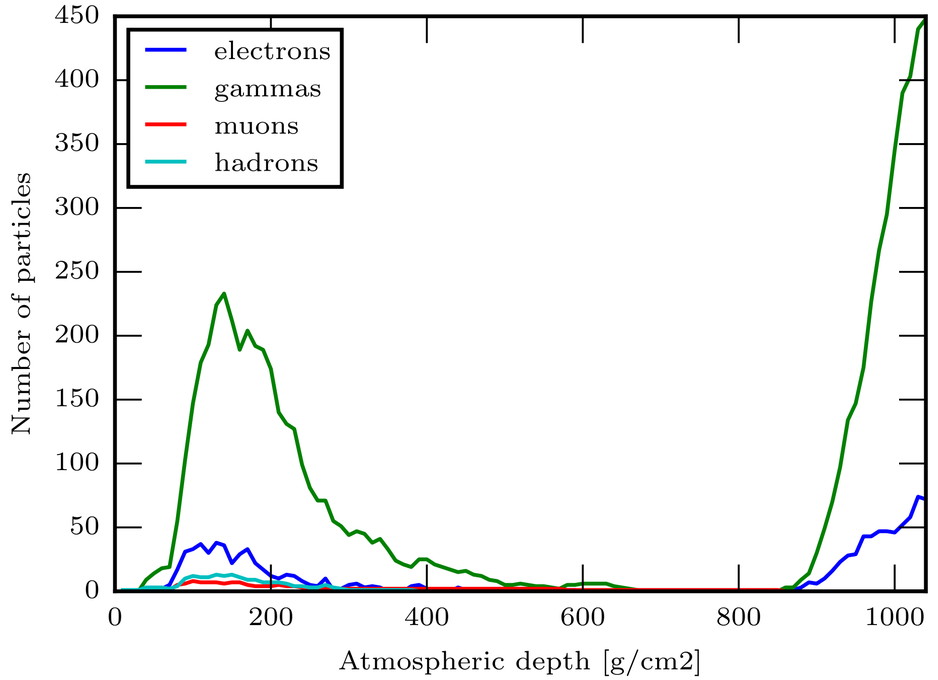
- Something that:
  - is not included in the simulation
  - only shows up at 2-detector events

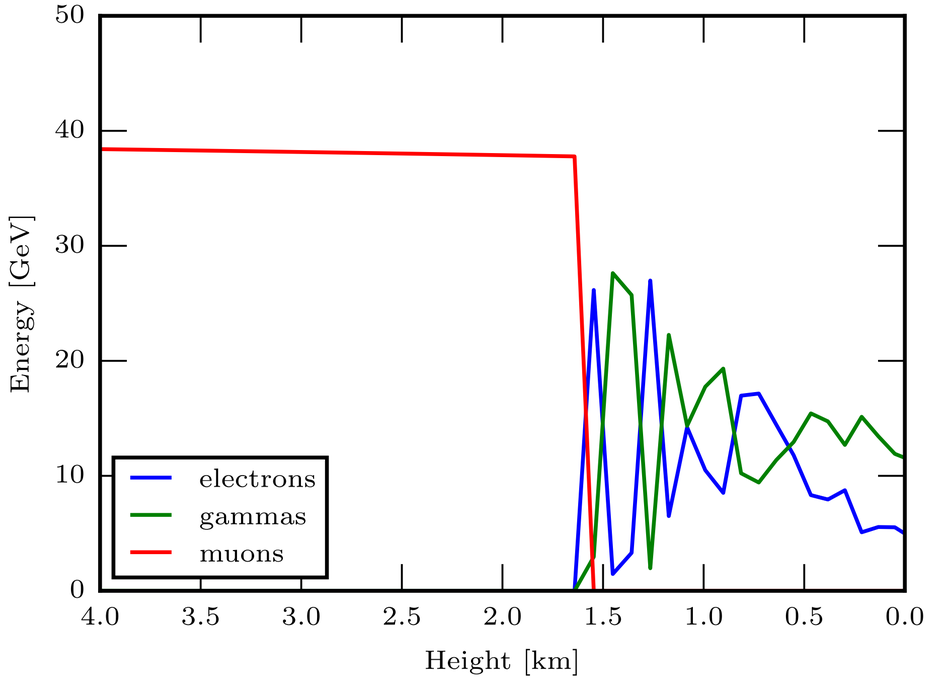


MINI-SHOWERS

- High energies: EAS
- Low energies: shower dies out, only muons at ground (10^{11} eV)

- What if energetic muon decays?
  - Electron initiates EM-shower

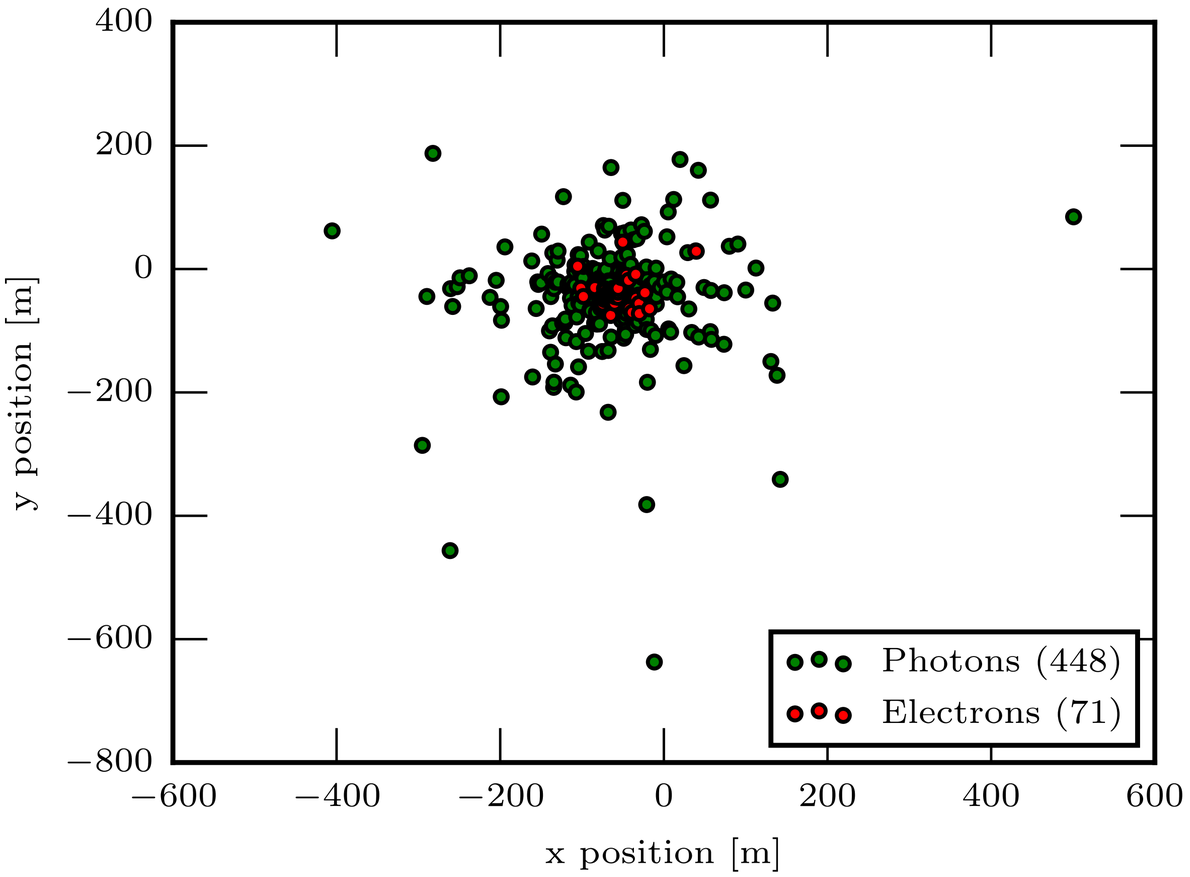




MINI-SHOWERS

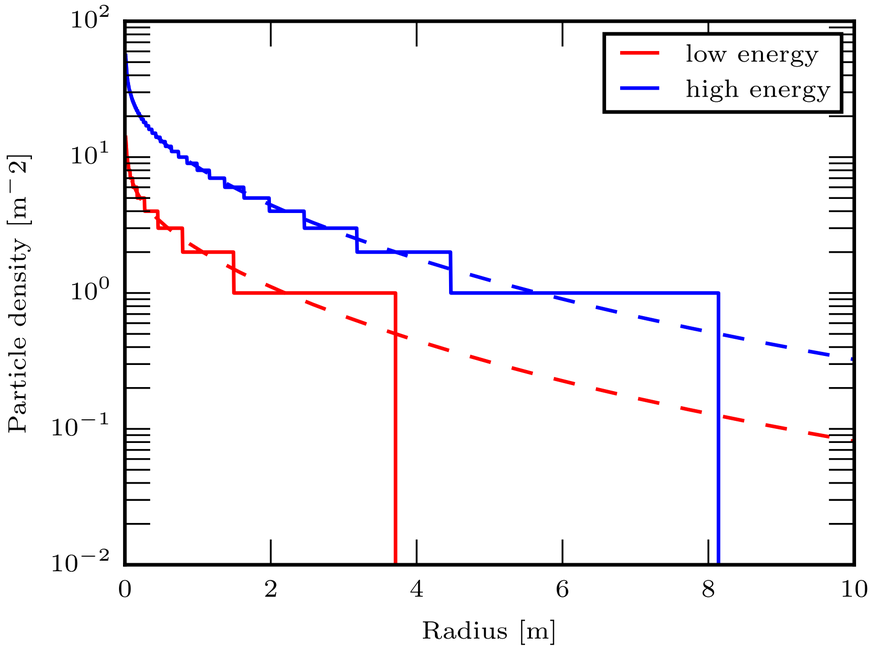
- Very low number densities at ground
  - probability for 4 detectors to sample mini-shower is negligible
  - 2 detectors is possible
  - only measure 1 electron or 1 gamma

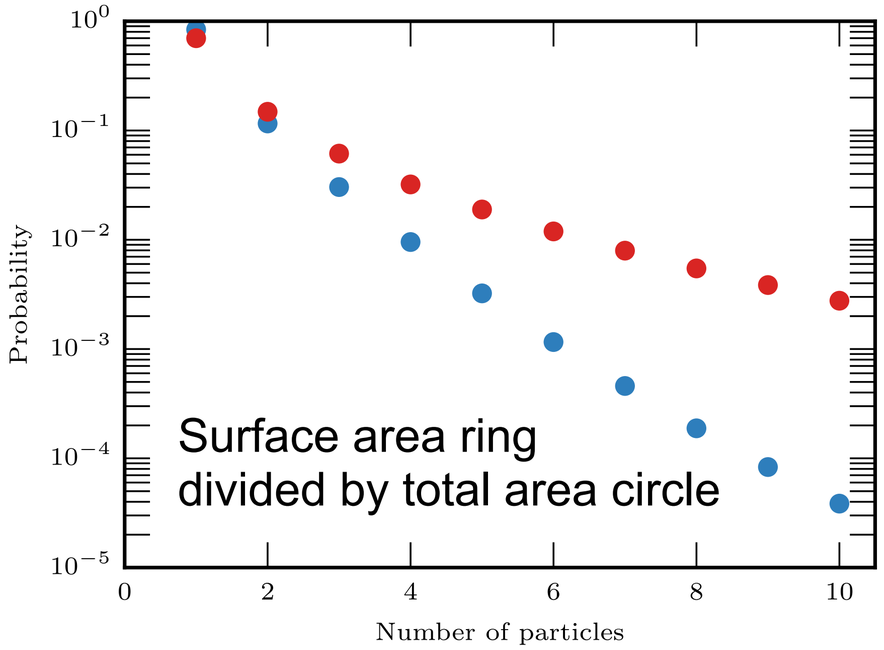
- Large number of single muons
  - large number of mini-showers

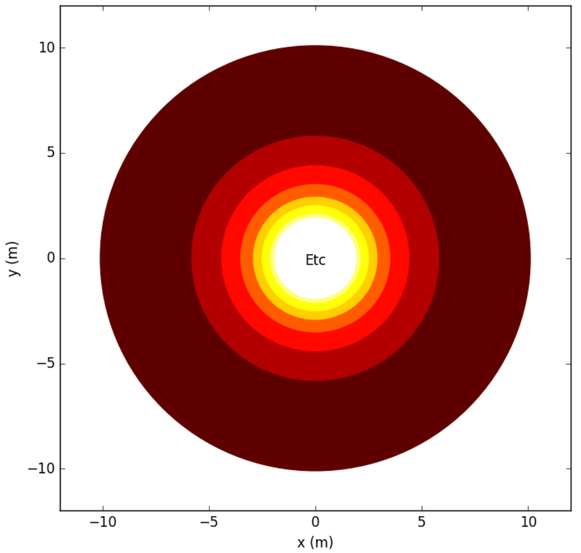


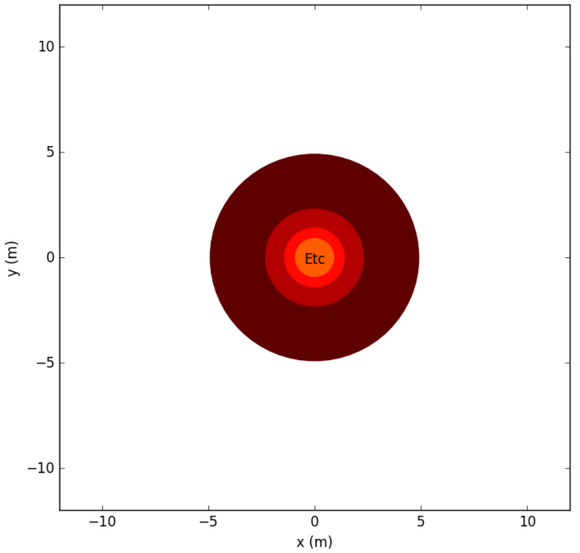
PULSE HEIGHT DISTRIBUTION: ENERGIES

- Let's have a closer look
- Simple representation of shower footprint:
  - Only discrete densities



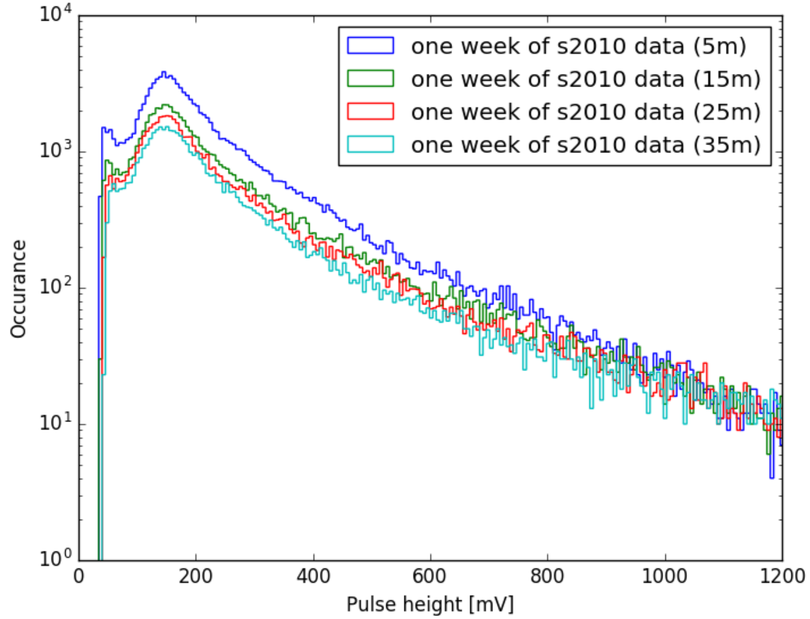


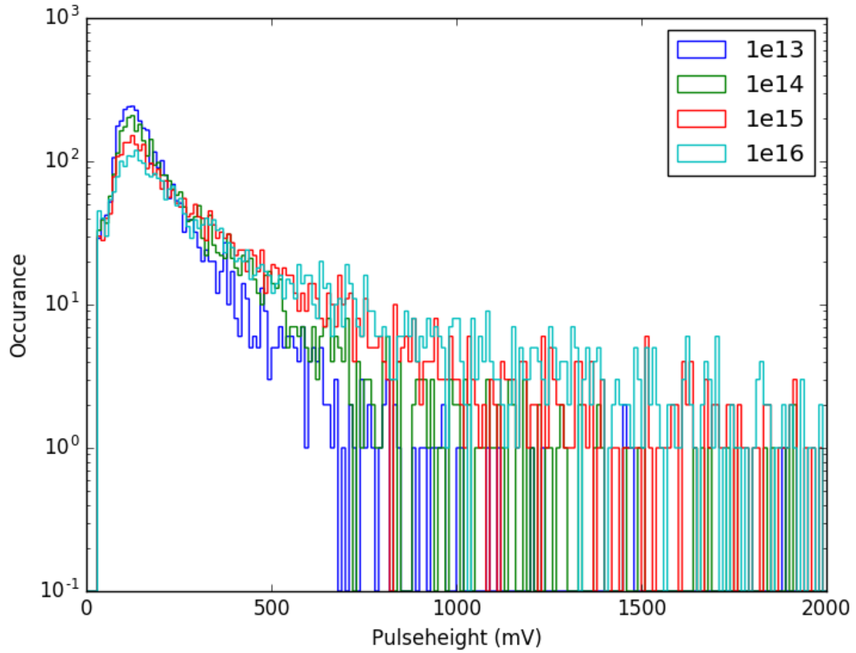


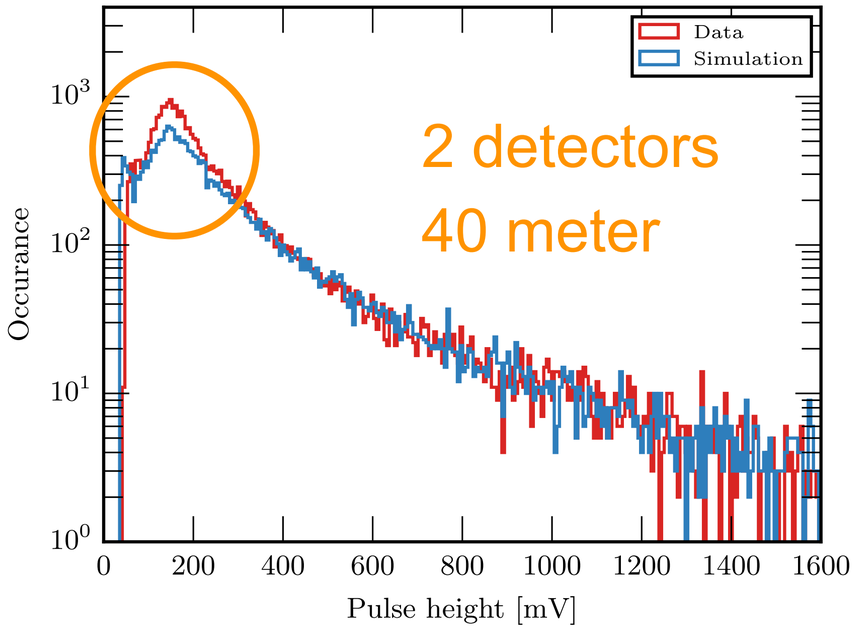


PULSE HEIGHT DISTRIBUTION: ENERGIES

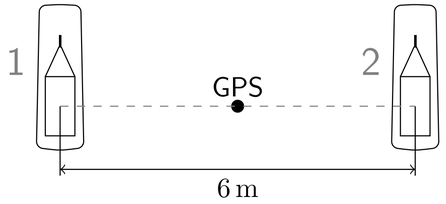
- Increase distance between both detectors
  - Less low energy showers
  - Change in pulse height distribution
- You can simulate this







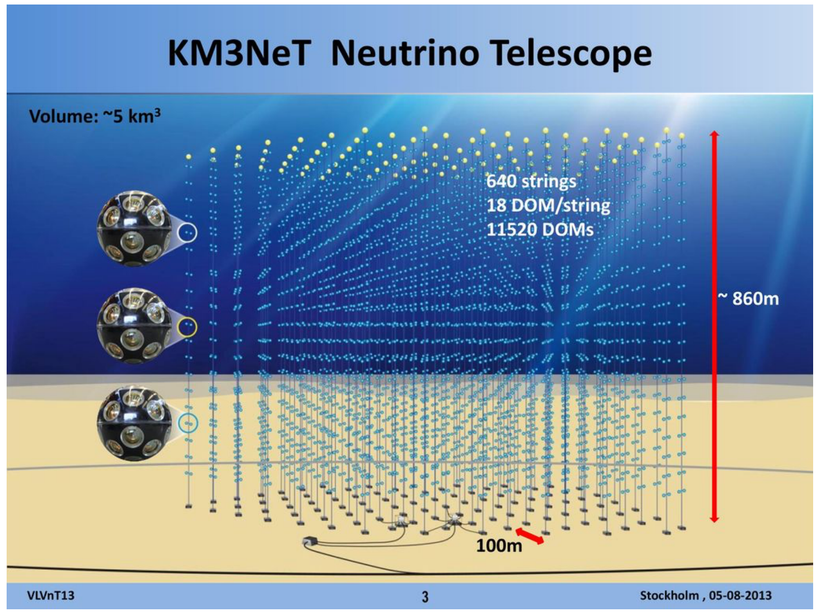
APPLICATIONS?



HiSPARC

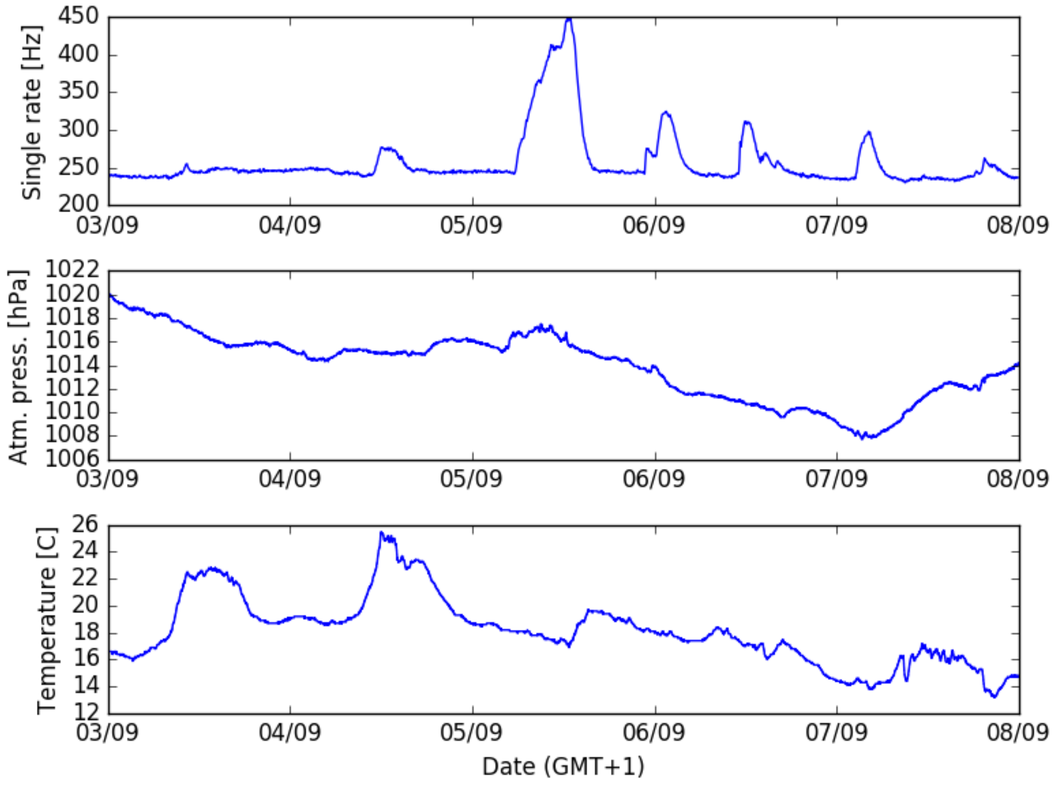
- Measure cosmic ray spectrum using 2 scintillators
  - fit simulated energy-components to measured pulse height distribution

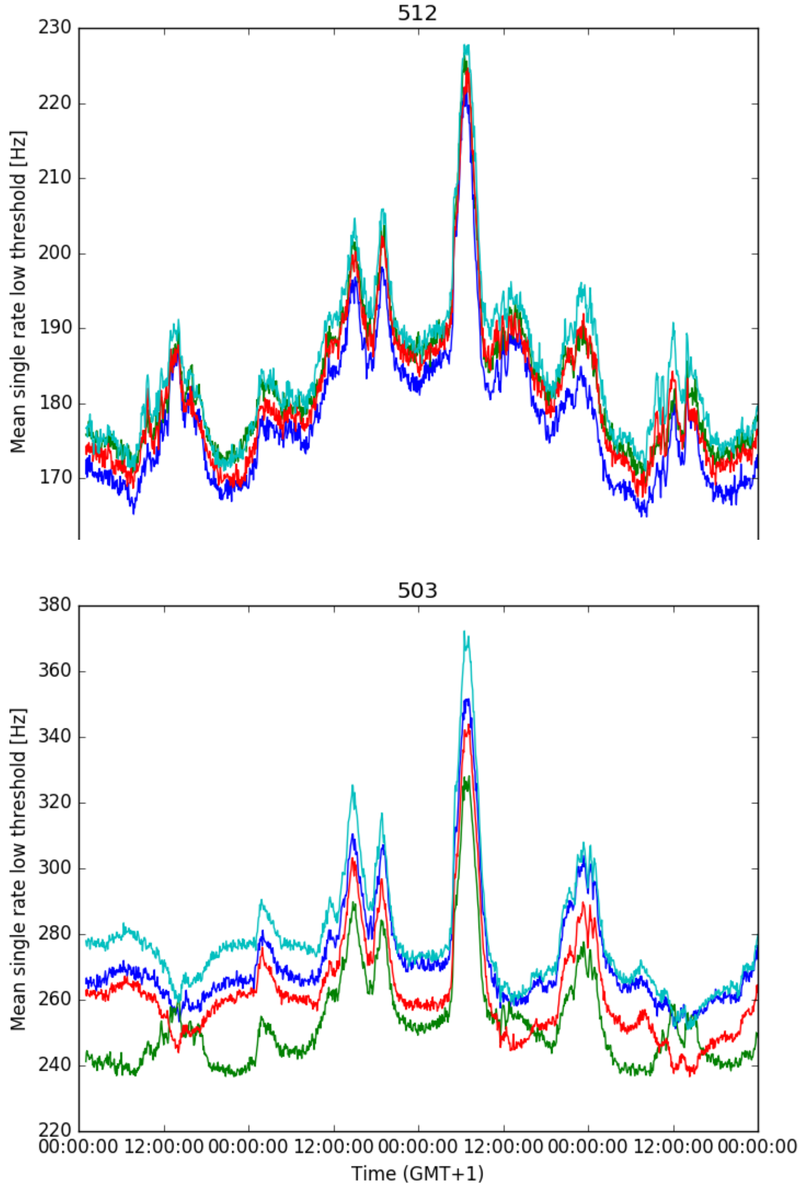
- Investigate high energy muons in combination with KM3NET?
  - Slope of pulse height distribution gives you EAS energies



HISPARC NETWORK

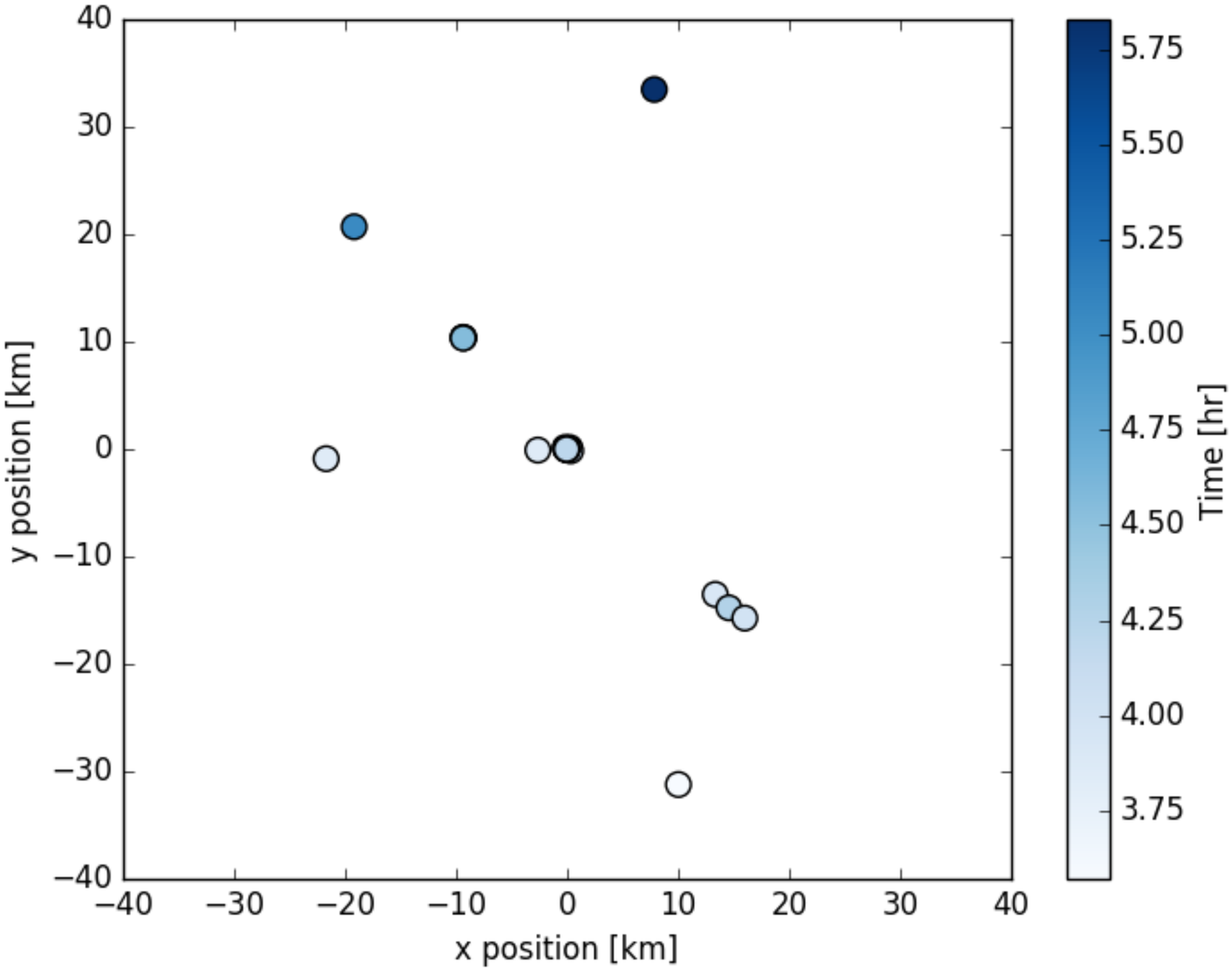
- Temporary increase in single rate
  - mainly single muons but also electrons / PMT noise





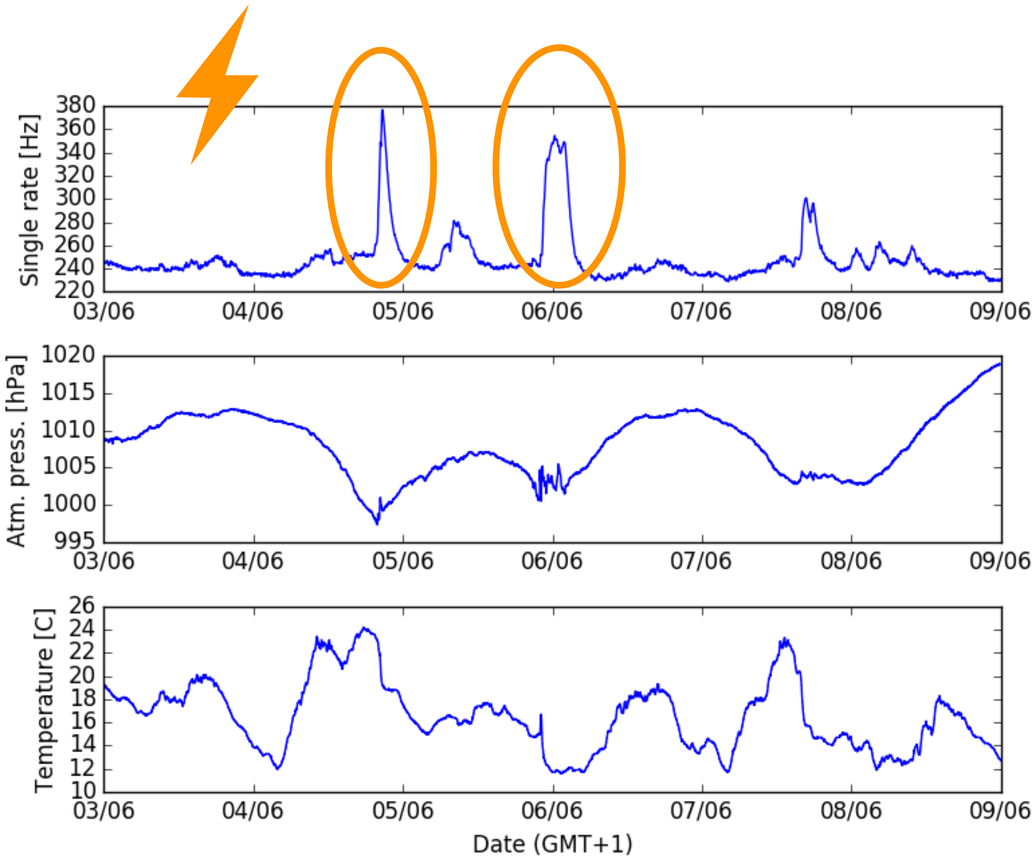
HISPARC NETWORK

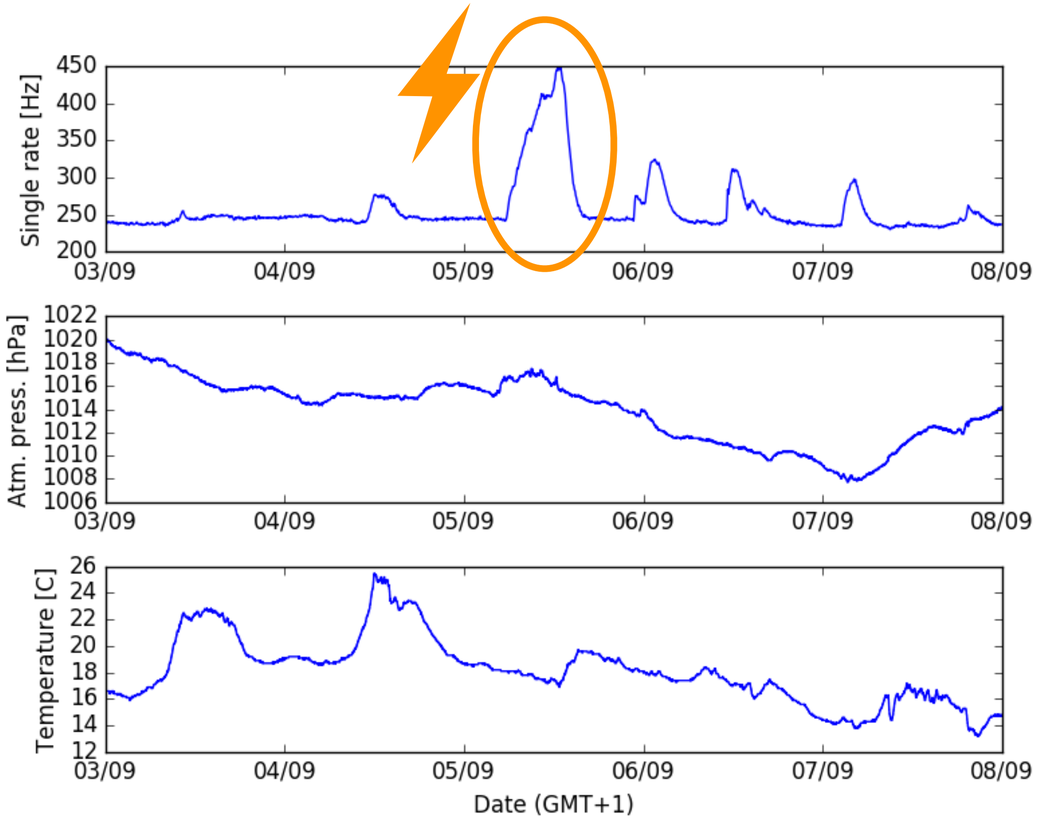
- Seen in many stations
- Moves like a weather front
  - Amsterdam region
  - position (0,0) is Science Park



INCREASE SINGLE RATES

- Related to thunderstorms
- But also during clear skies

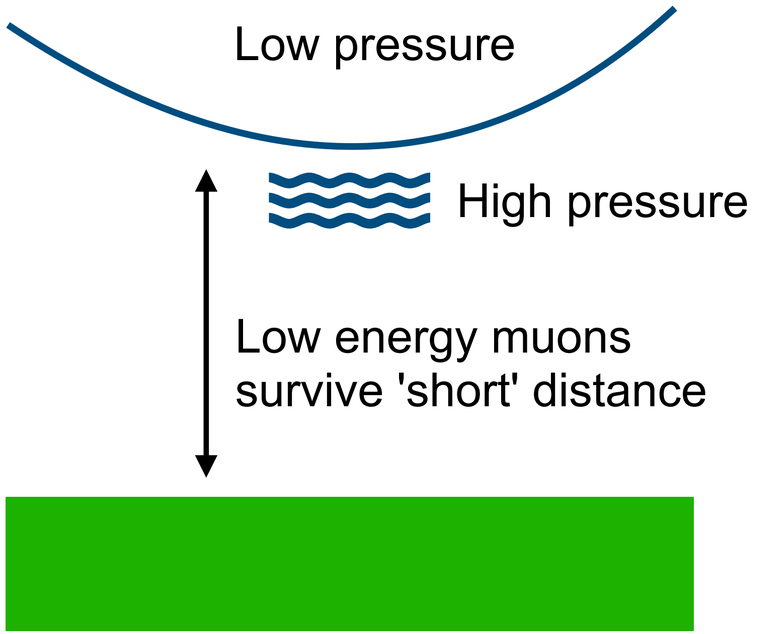




ATMOSPHERIC GRAVITY WAVES?

HiSPARC

- My favourite hypothesis
  - (not related to gravitational waves)
- Important for weather and climate modelling
  - hard to measure
  - hard to include in models (parameterisations)
- Gravity waves are related to lightning storms
  - Multiple mini-showers instead of rare EAS as initial "runaway breakdown"?
- In touch with KNMI
  - infra-sound / lidar measurements



CONCLUSION

- Outreach but you can do interesting stuff
- Good understanding of detector
  - arrival times scintillation photons
  - (training ML algorithms on simulated data works on real data)
- Look at distributions instead of reconstructing single EAS
  - mini-showers
  - pulse height distribution and EAS energies
- Increase single rates
  - relation thunderclouds
  - atmospheric gravity waves?