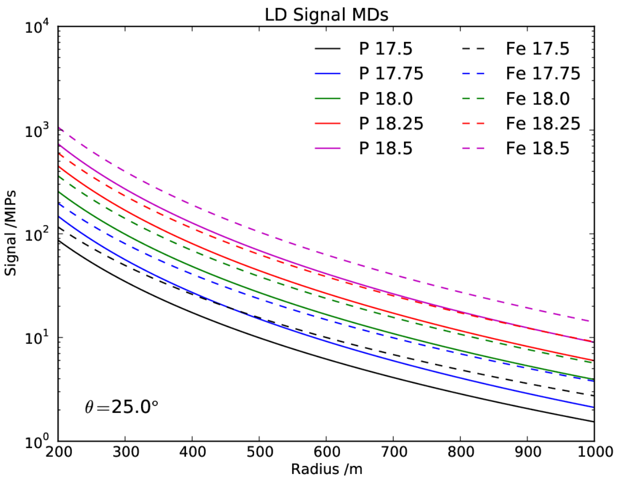
AMIGA-like Muon Detector Simulations

A prerequisite for composition studies and hadronic interaction tests

Mirko Scherer, Adviser Dr. M. Roth
IKP, KIT Karlsruhe

Obertrubach, 8.10.2012

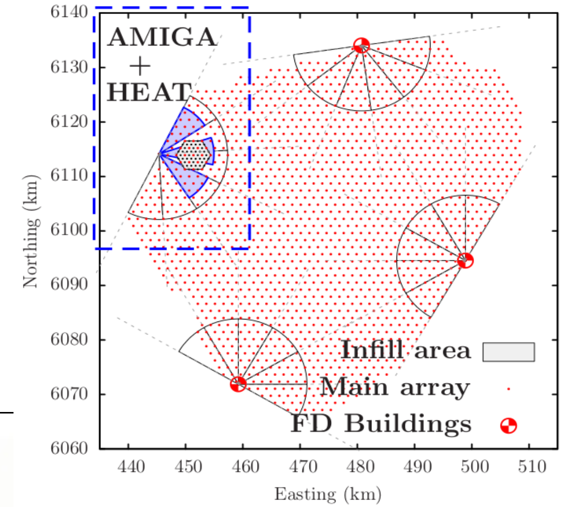


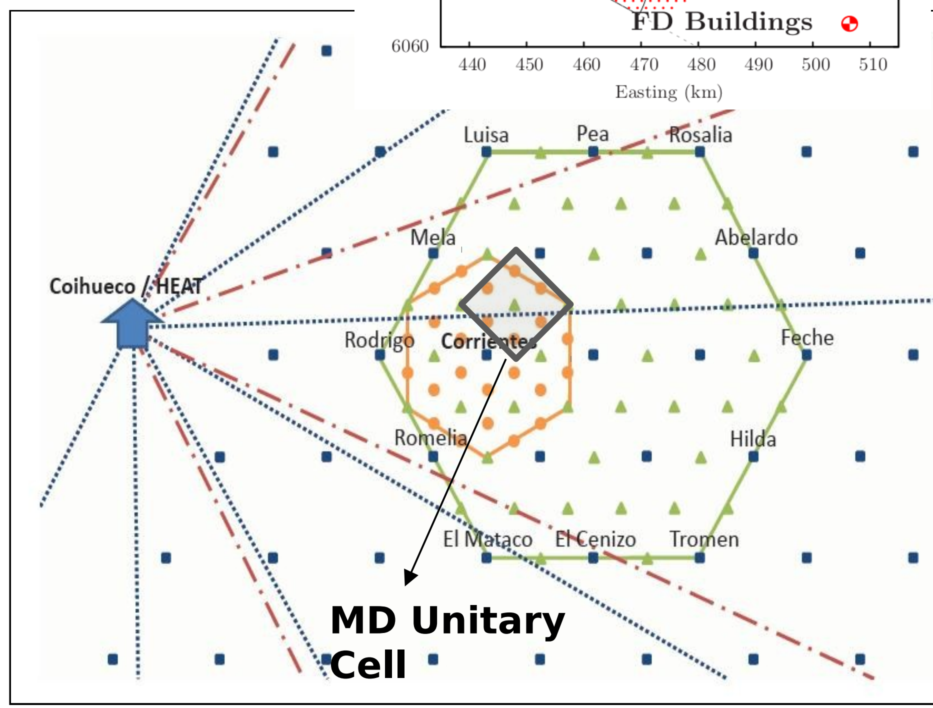
Pierre Auger Observatory

- Surface Detector Array (SD):
  ~1600 Water Cherenkov Detectors
  in a hexagonal grid with 1500 m spacing
  between stations covering 3000 km²
  + AMIGA Infill extension
    (61 stations in 750 m grid associated with
     buried scintillators (MD))

- Fluorescence Detector (FD):
  4 stations with 6 fluorescence
  telescopes each
  + HEAT extension
    (1 station with 3 telescopes)

- AERA radio antenna
  extension



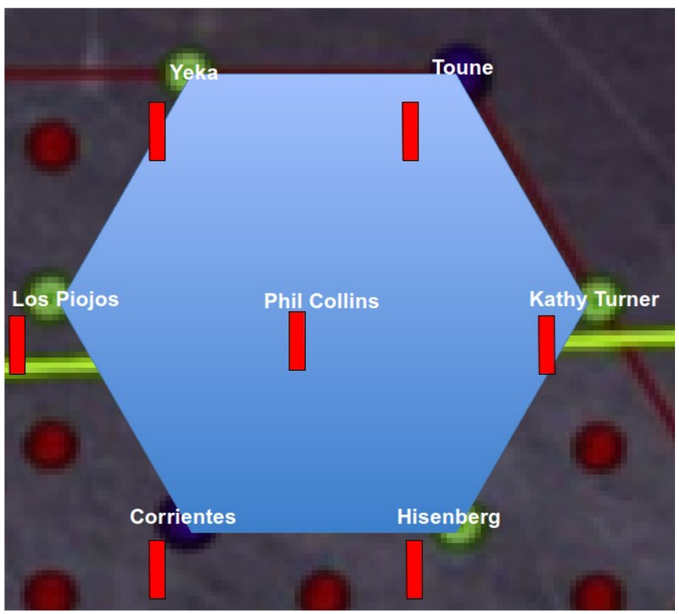


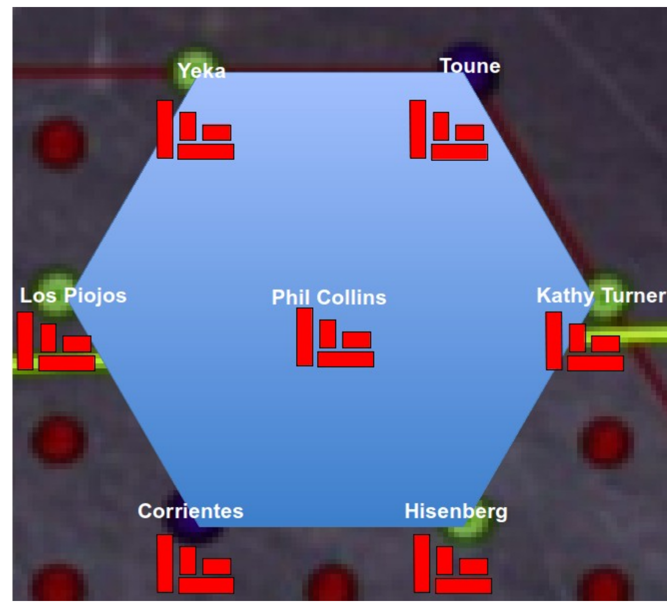
AMIGA Muon Detector (MD)

- *MD* currently in prototype phase called Unitary Cell (UC)

Deployed → *Pre-UC*
composed of seven 10 m² muon counter modules deployed in a hexagonal array with a position in the middle

Next Step → *UC*
will be constructed in the same array but with 30 m² of muon counters per station

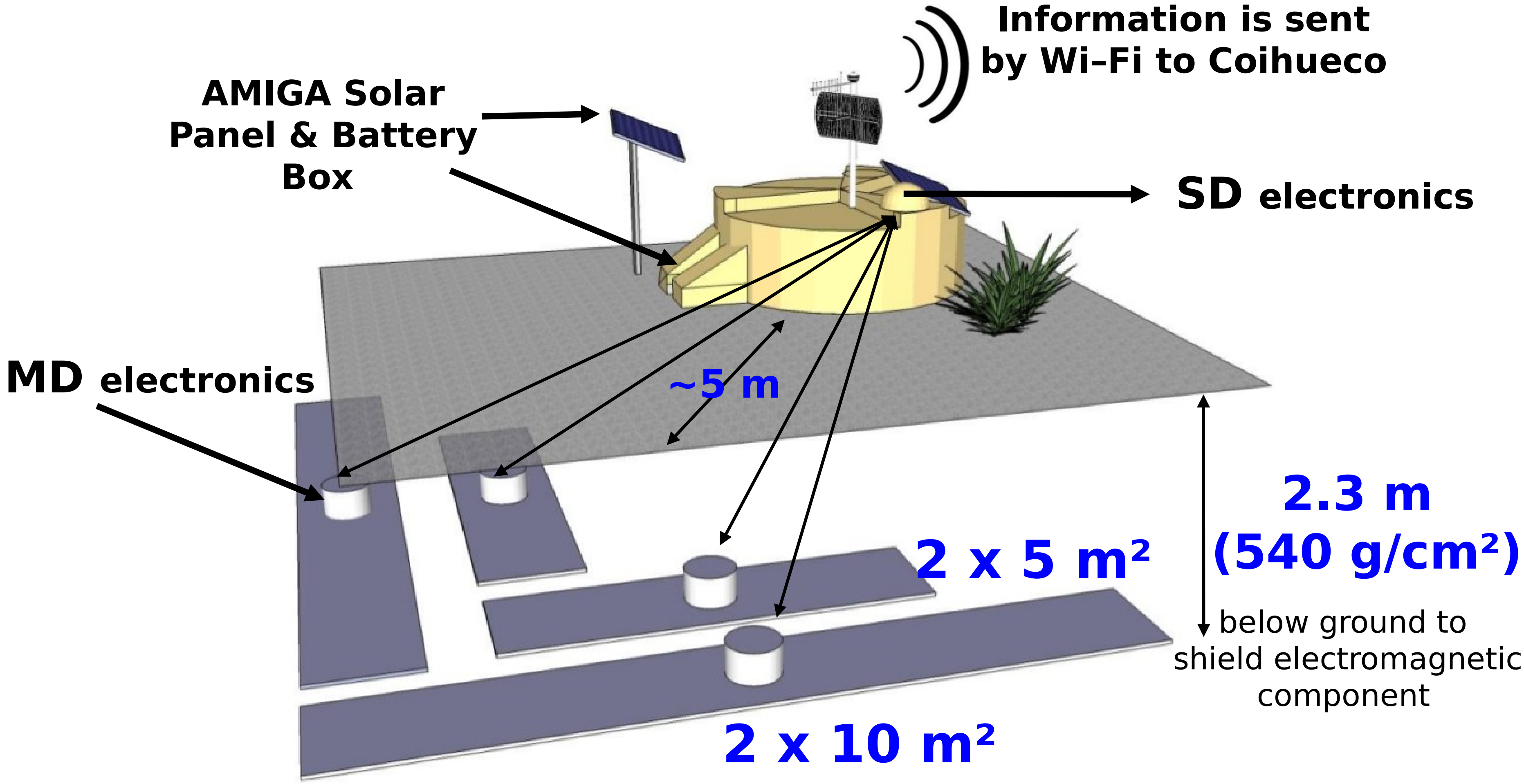




- Future → all of the 750 m Infill stations will have partner MD stations

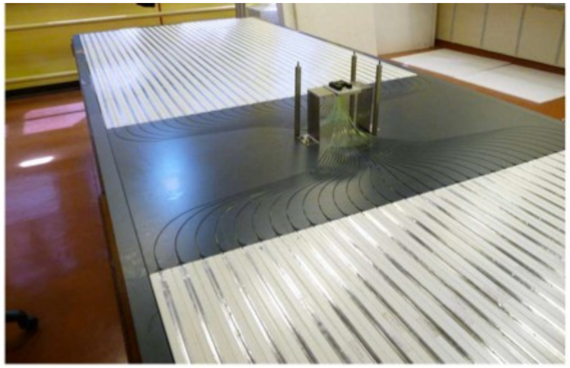
The Muon Detector

Each Muon Detector (MD) 30 m²



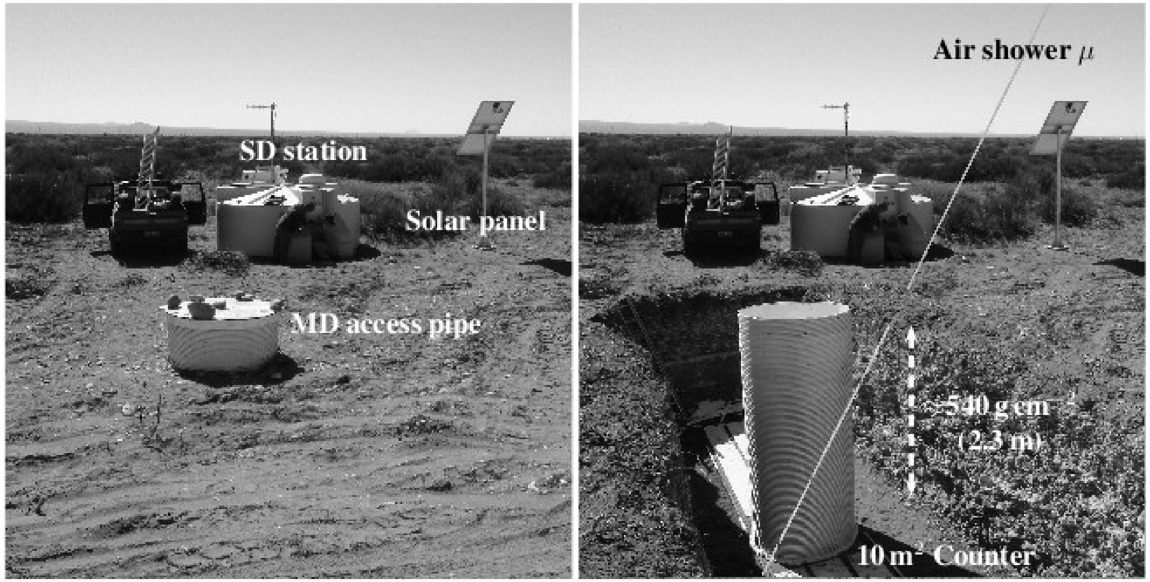
2 different sizes → to reduce saturation near core position
2 different angles → to reduce double counting

The Modules



64 scintillator strips per module + one PMT

muons with energy E ≥ 1 GeV reach the scintillator

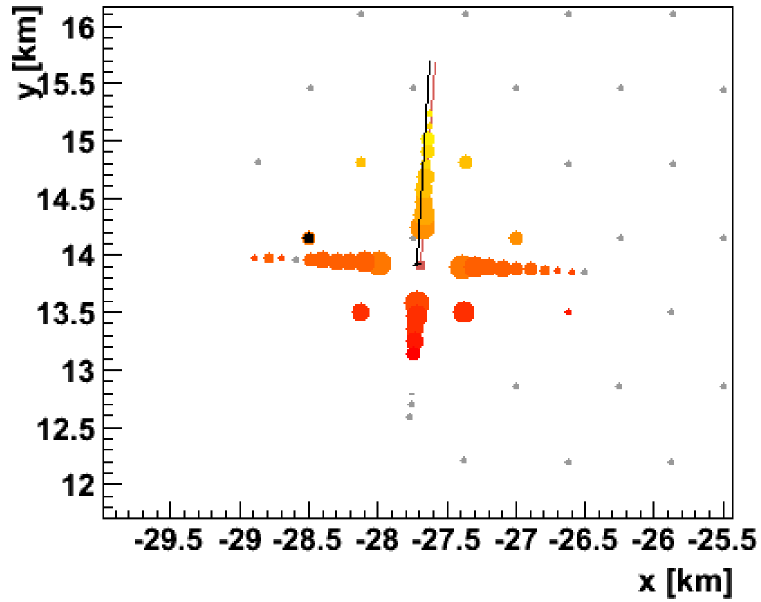


To maintain uniform shielding access tubes are filled with sand bags

← *photomontage*

MD Simulations

Simulated Event:
Log E /eV = 18
Zenith = 25 °
Proton



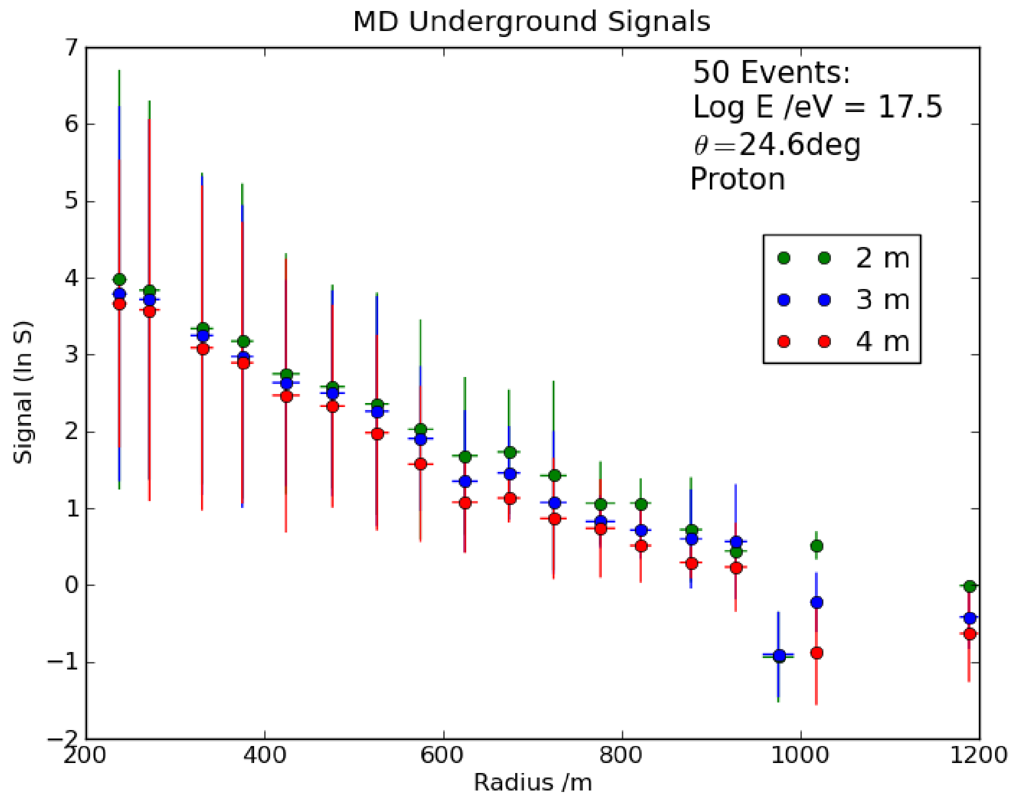
- CORSIKA showers used to run MC toy detector simulations

- Simulations include:
  - SD Stations of 750 m Infill array
  - ~30 m² muon counters at the same position as SD Stations
    → Scintillator signal can be read at several depths underground (2, 3, 4 m)
  - Furthermore Dense Stations have been added for SD and MD
    → located every 100 m between 300 m and 1200 m from the shower axis at four different azimuth angles

MD Underground Signals

- The signal difference for varying burial depths of the MDs is very small compared to the variance of the signals

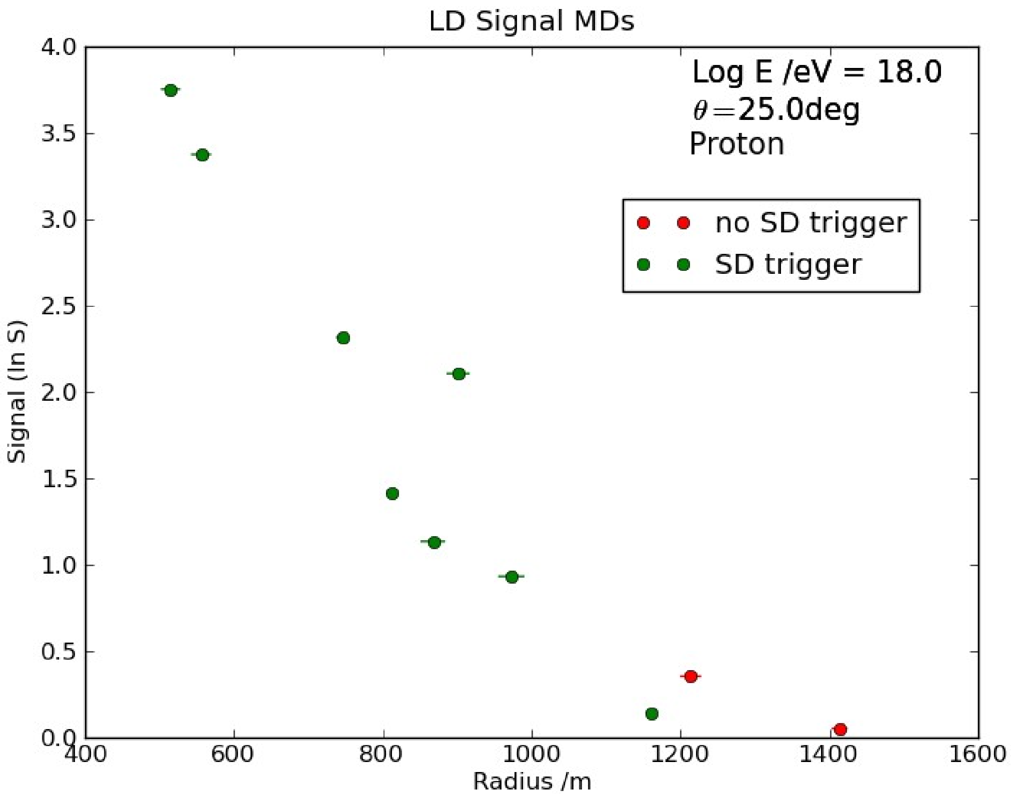
- In this presentation data taken from the MDs at 3 m depth is used



MD Trigger

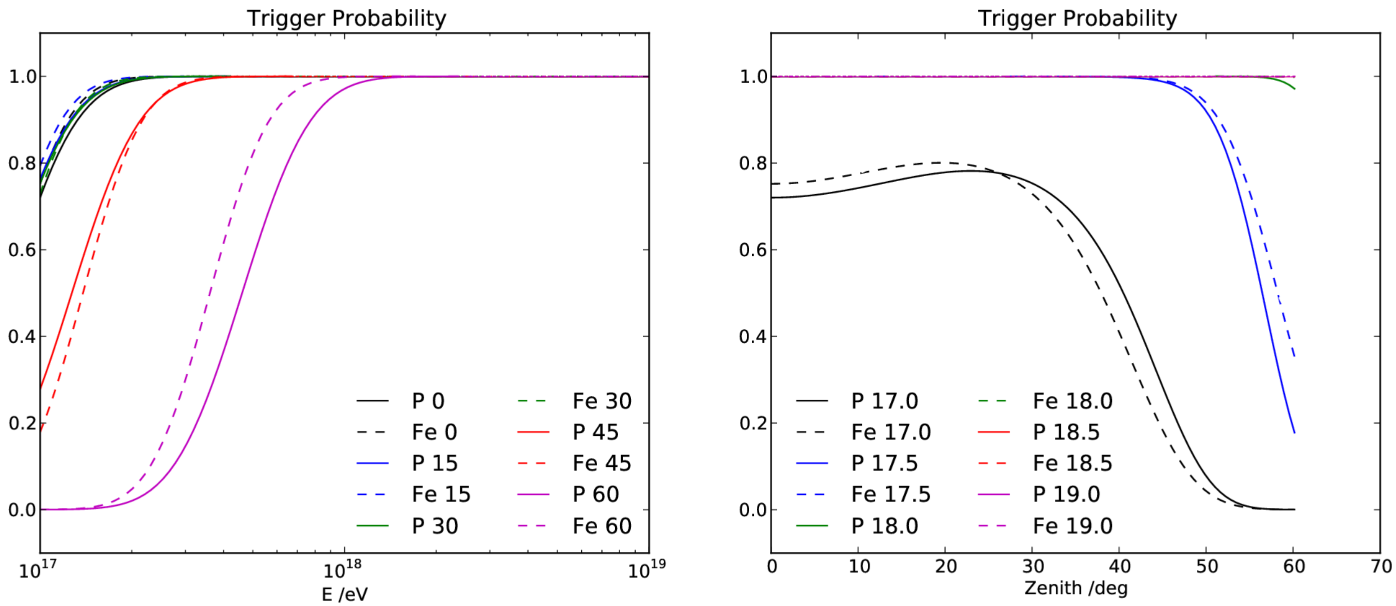
- MDs are triggered by their associated SD Stations
  → low level trigger T1 is passed locally

- SD has two independent T1 trigger modes:
  - TH-T1 → signal threshold discrimination (muons)
  - ToT-T1 → signal above threshold must be maintained more than 325 ns (electrons)



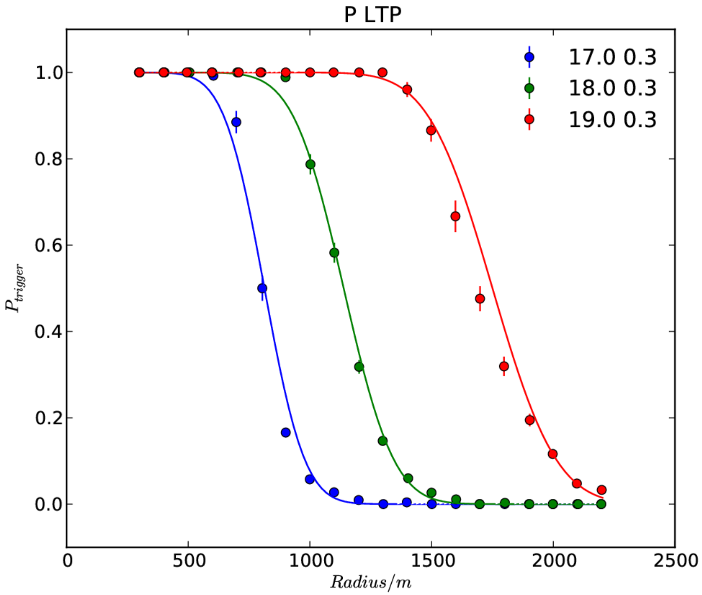
Efficiency (events)

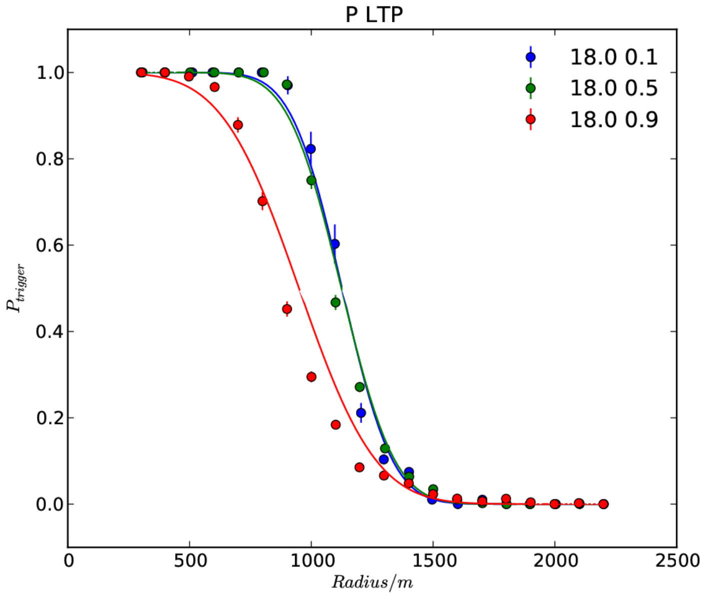
- Function fitted to describe T3-Trigger Probability of infill array (minimum of 3 triggered SD stations required for reconstruction)
- Events with Trigger Probability below 99% will be cut out



Efficiency (stations)

- Function fitted to describe Lateral Trigger Probability (LTP)
- Stations with LTP below 99% will be cut out



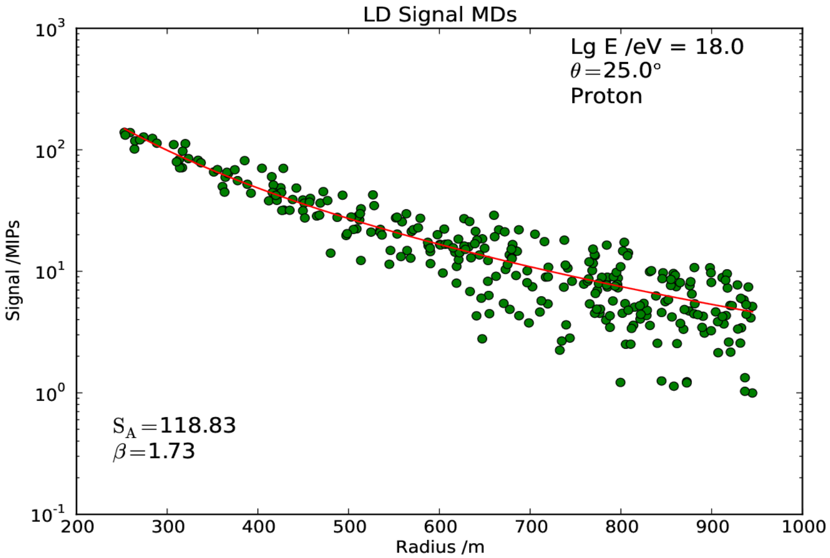


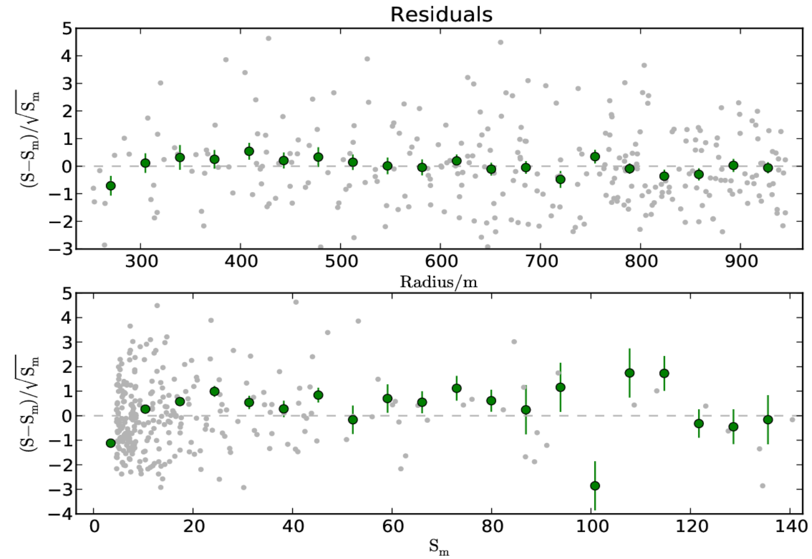
Lateral Distribution Function (LDF)

Ansatz:

$$S = S_A \cdot \left(\frac{r}{r_{450}}\right)^{\beta} \cdot \left(1 + \frac{r}{r_{450}}\right)^{\beta+\gamma}$$

- 1st step → fit LDF model to data of distinctive energy/zenith bins to get parameter dependencies
  (50-100 simulated events per bin)

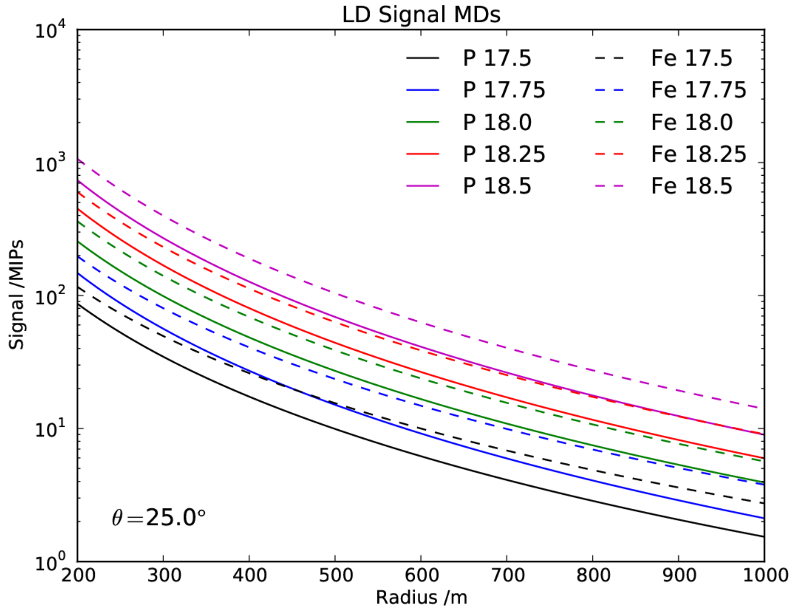




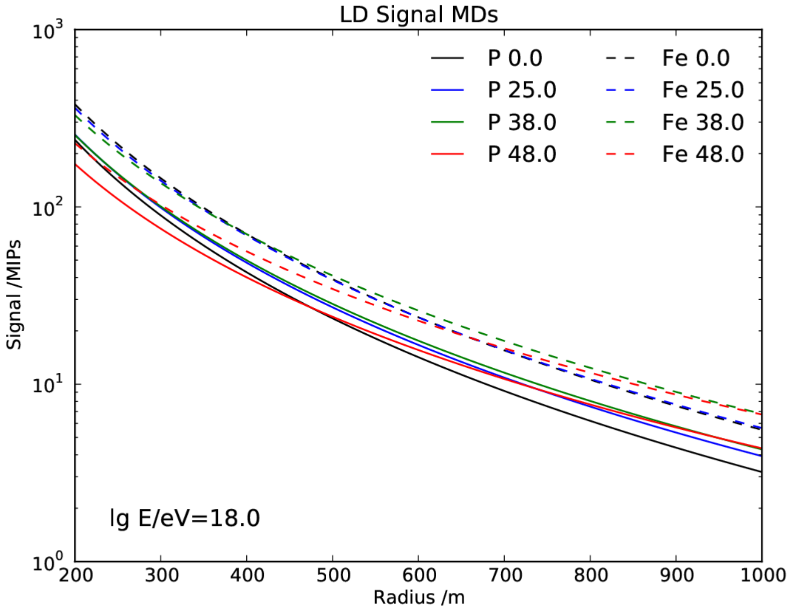
Mass, Energy, and Zenith Angle

- Fits for different energy/zenith bins plotted together

Mass and energy dependence clearly visible



Only slope shows zenith angle dependence



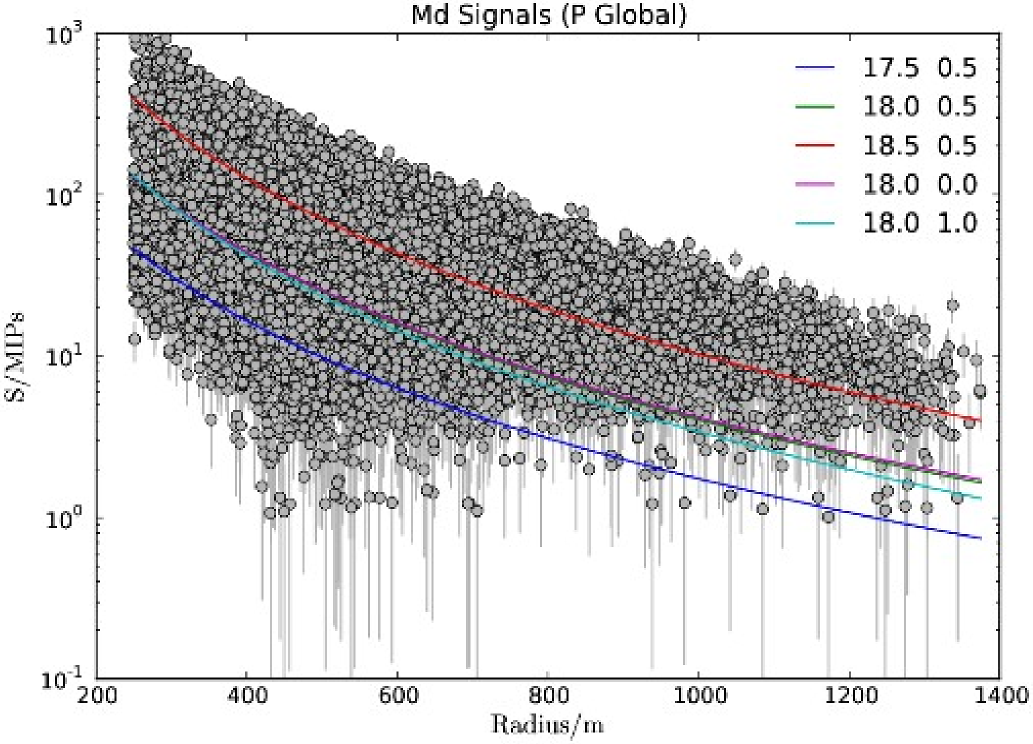
LDF (Global Fit)

- 2nd step → fit LDF model with energy/zenith dependent parameters to data from MC simulations with continuous CORSIKA shower library

$$17.0 < lgE < 19.0 \wedge 0 < \theta < 60$$

- Ansatz:

$$S_A = S_A(E)$$
$$\beta = \beta(lg(E), sec(\theta))$$
$$\gamma = 0$$



Next Steps

- Fine tuning of LDF parametrisation → $S_A = S_A(E)$
  $\beta = \beta(E, \theta)$
  $\gamma = \gamma(E, \theta)$
- Fit events with LDF to get Energy Estimator

Goal

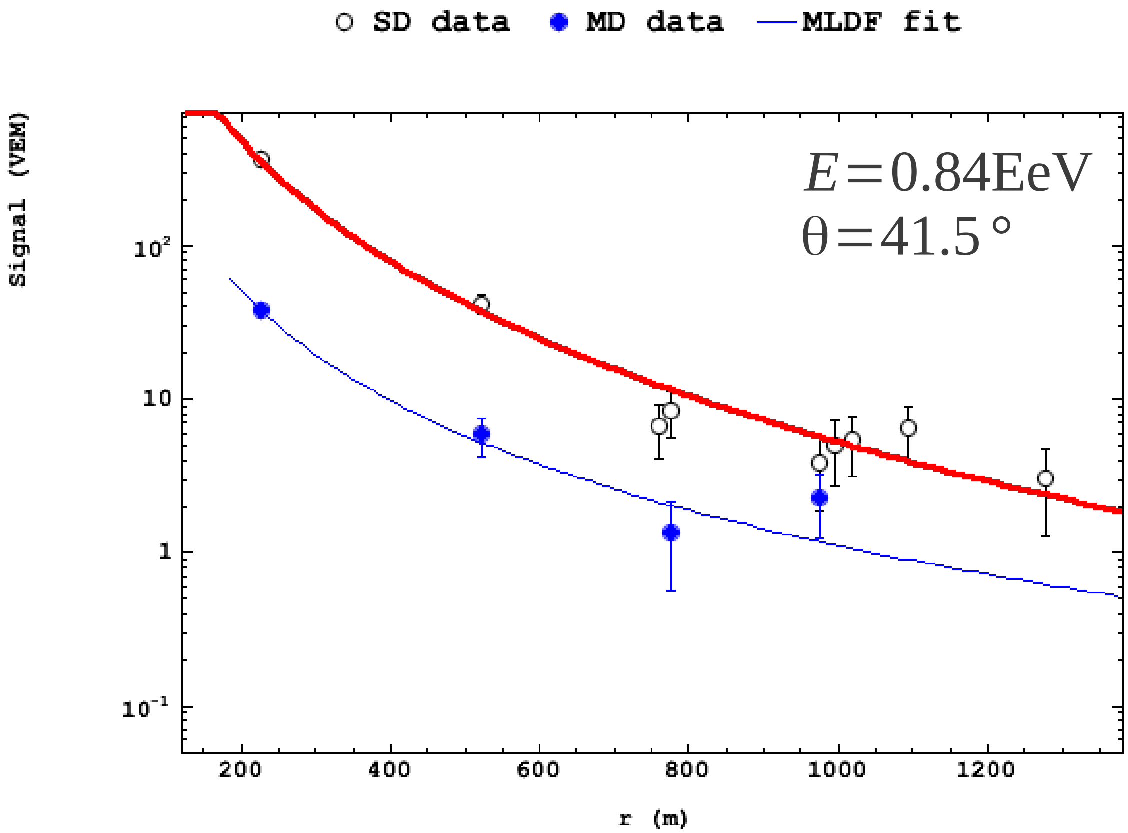
- Composition studies using hybrid events with SD, FD, and MD information
- With SD, FD, and MD Include hadronic interaction models

$$\underbrace{S_{450}, X_{max}, S_A}_{E, A} \longrightarrow \underbrace{S_{450}, X_{max}, S_A}_{E, A, N_\mu}$$

system over-determined!

Real Data

- 1st event detected by Pre-Unitary Cell
  (hybrid event also detected by SD and FD)



$$S = S_A \cdot \left(\frac{r}{r_{450}}\right)^{\beta}$$