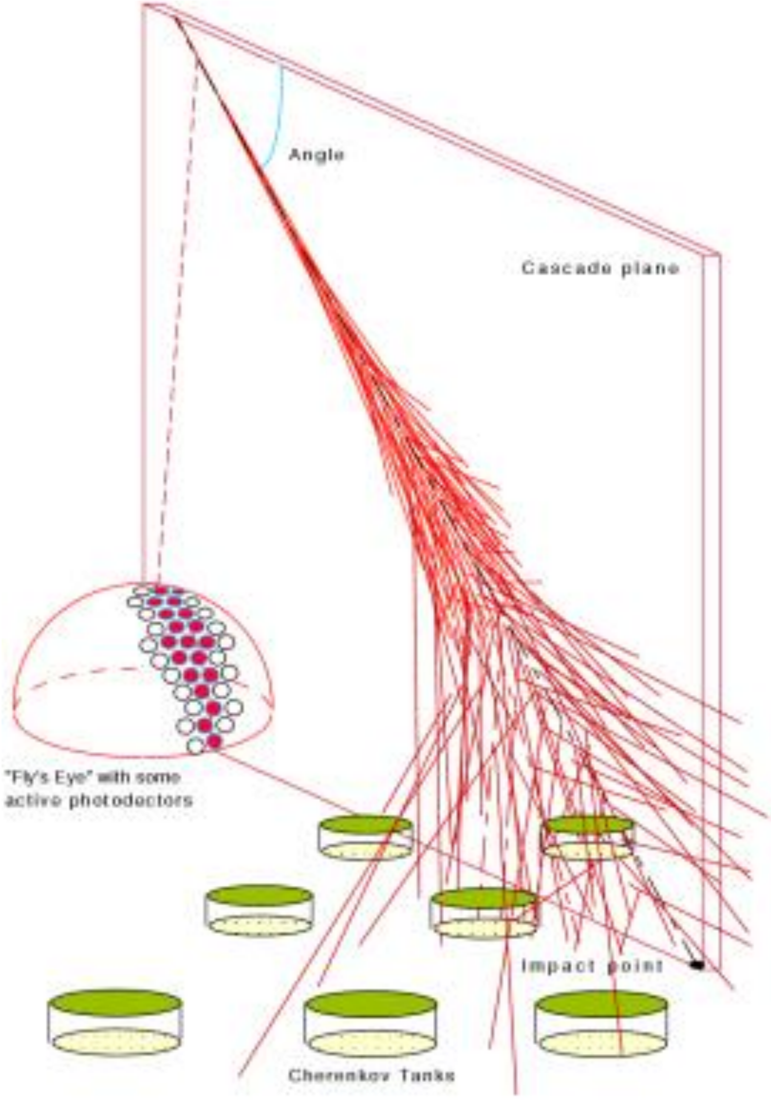
Towards a high-resolution fluorescence telescope

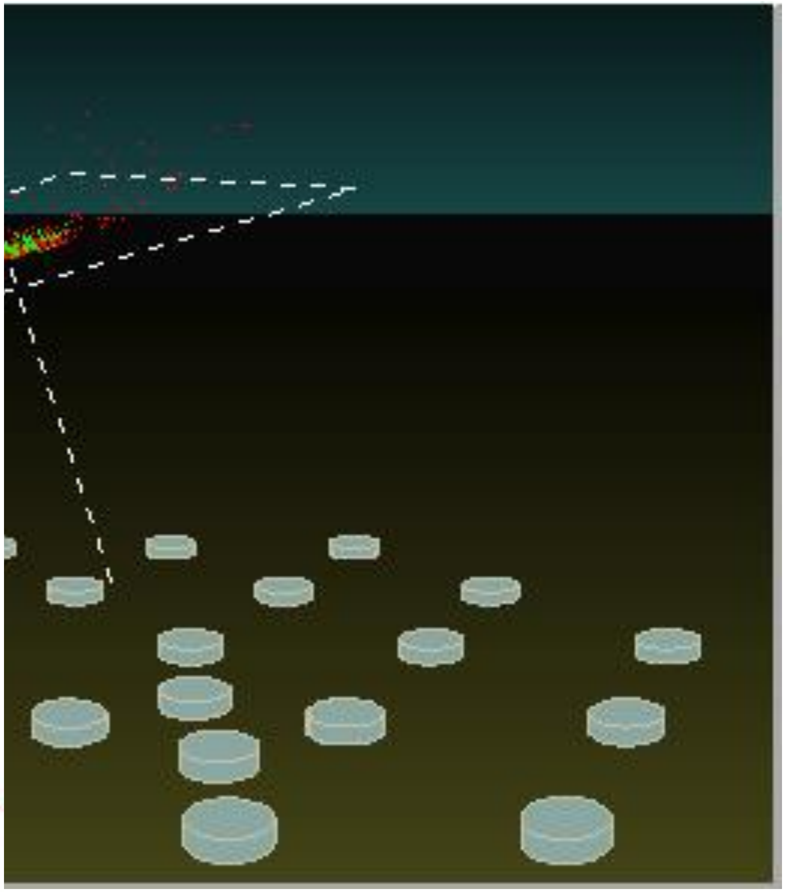
B. Tomé

(LIP)

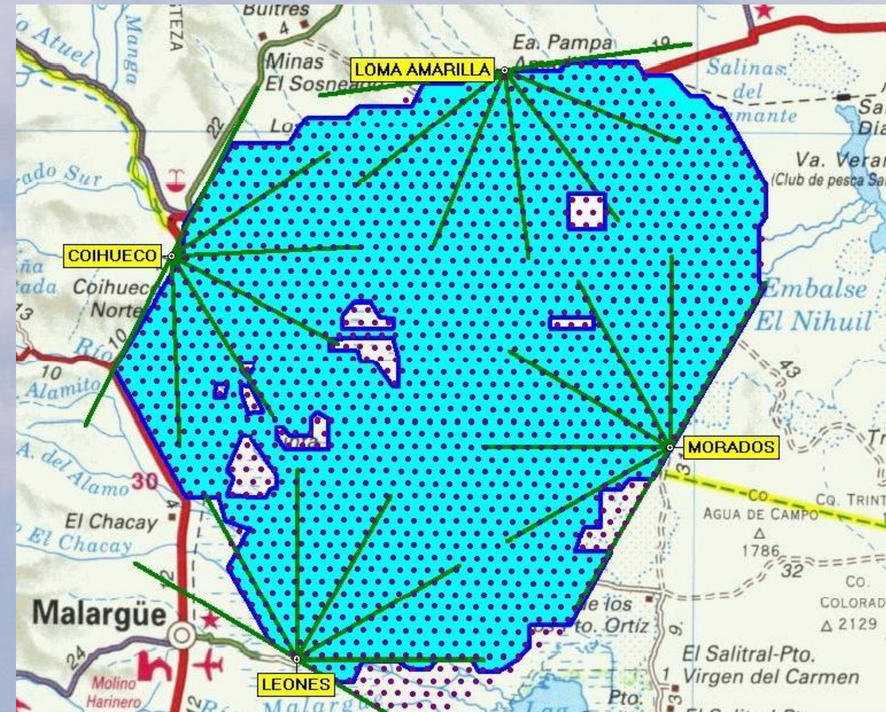
IDPASC School on Digital Counting Photosensors for Extreme Low Light Levels, Lisboa, 16-20 April, 2012

Extensive Air Showers (EAS)





Pierre Auger Observatory



Hybrid Detector

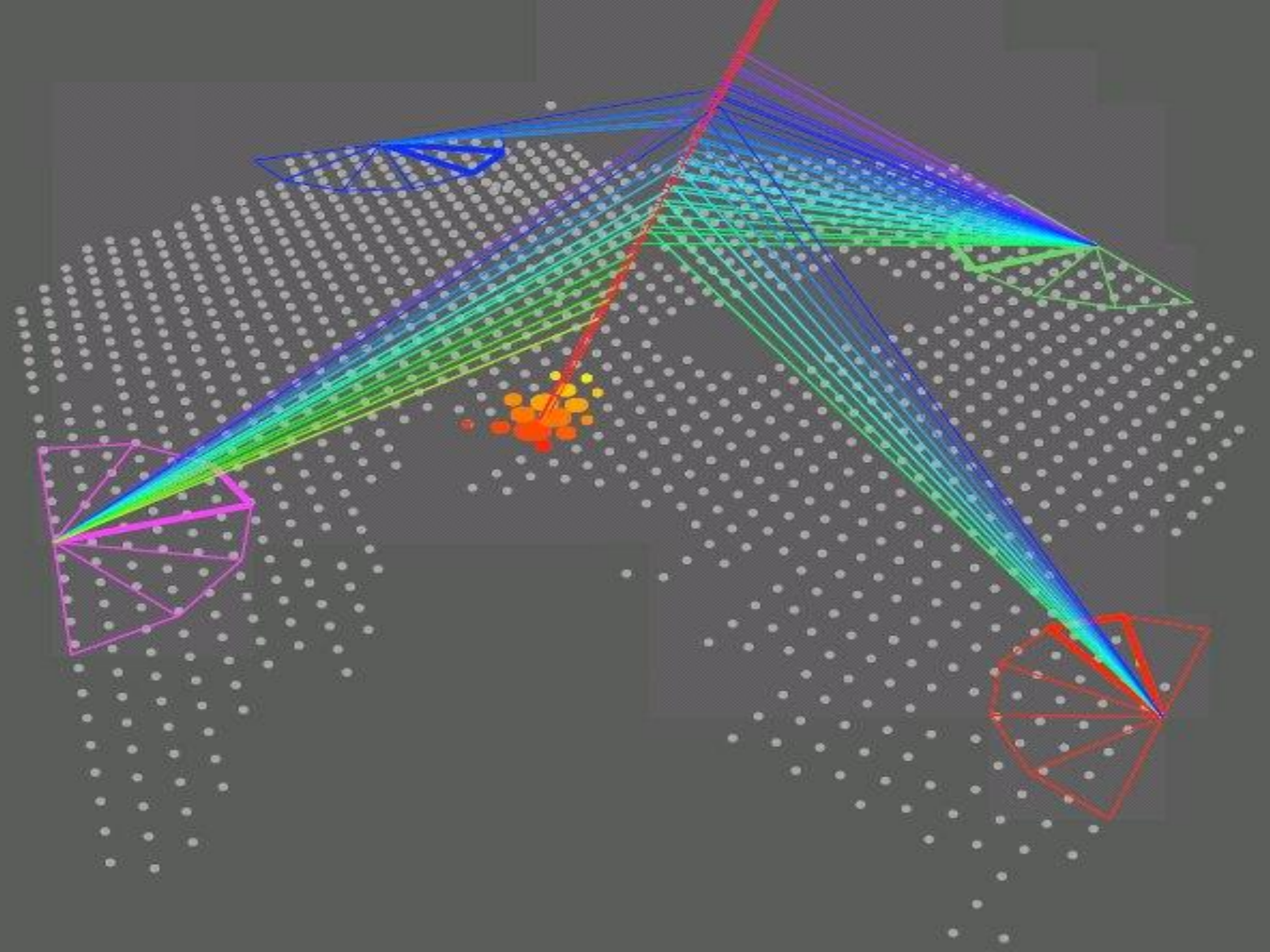
1600 Detectors

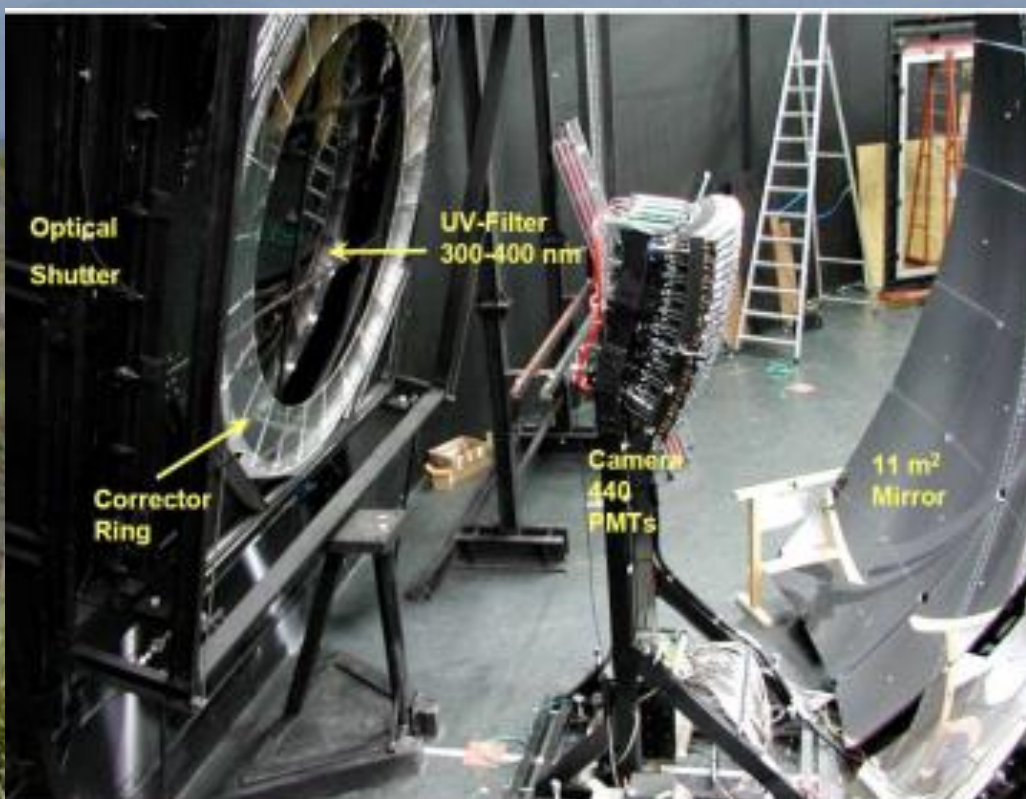
(Water tanks – Cherenkov)

In a 1500m grid

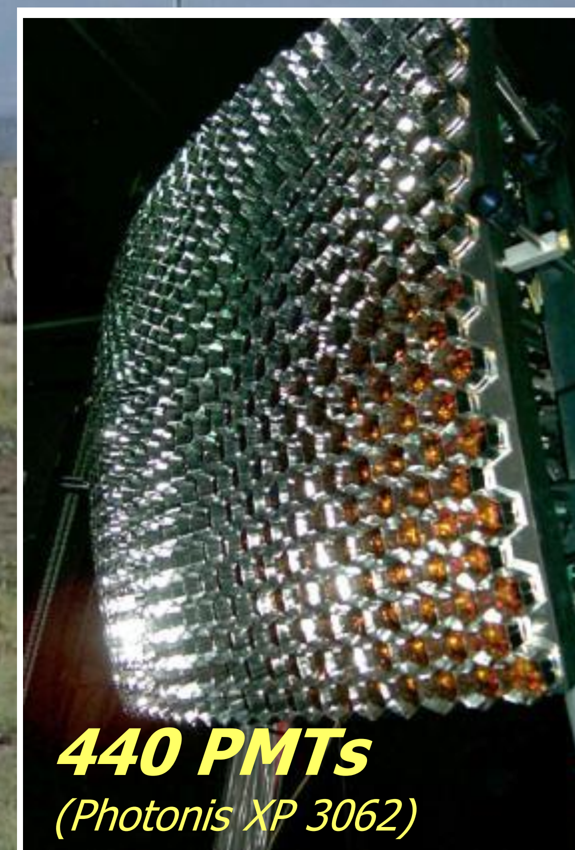
Covered area = 3000 km^2

27 (24+3) fluorescence telescope





Optical
Shutter
UV-Filter
300-400 nm
Corrector
Ring
Camera
440
PMTs
11 m²
Mirror

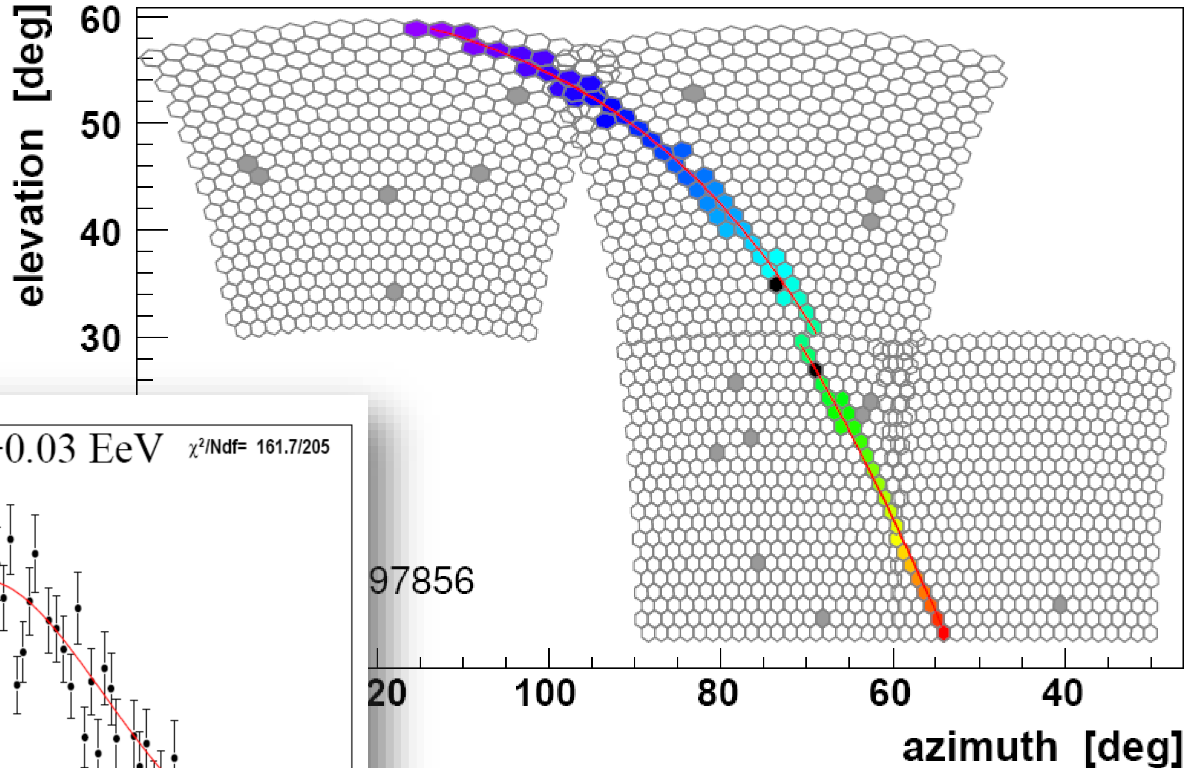


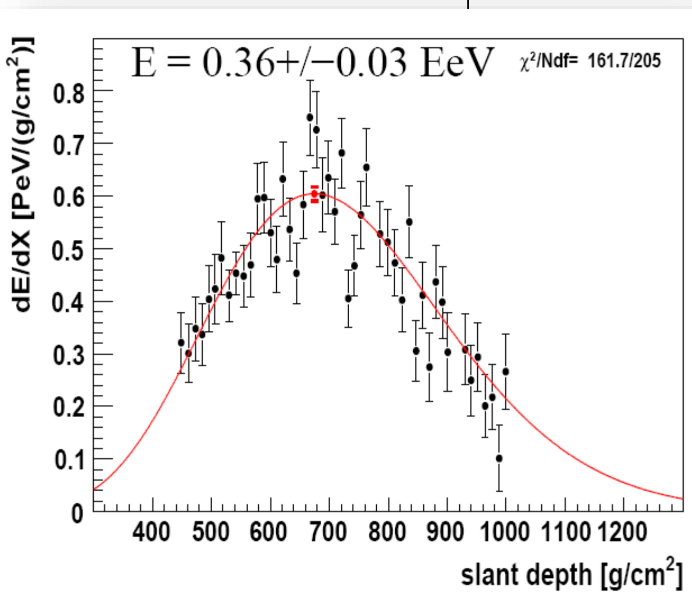
440 PMTs
(Photonis XP 3062)

HEAT – High-Elevation Auger Telescopes

- Upgrade of the FD; taking data since 2009
- Extend FoV of one FD eye (Coihueco) from 30^{o} to 60^{o} in elevation
- Same optics as other FD telescopes

Shower seen by HEAT and Coihueco





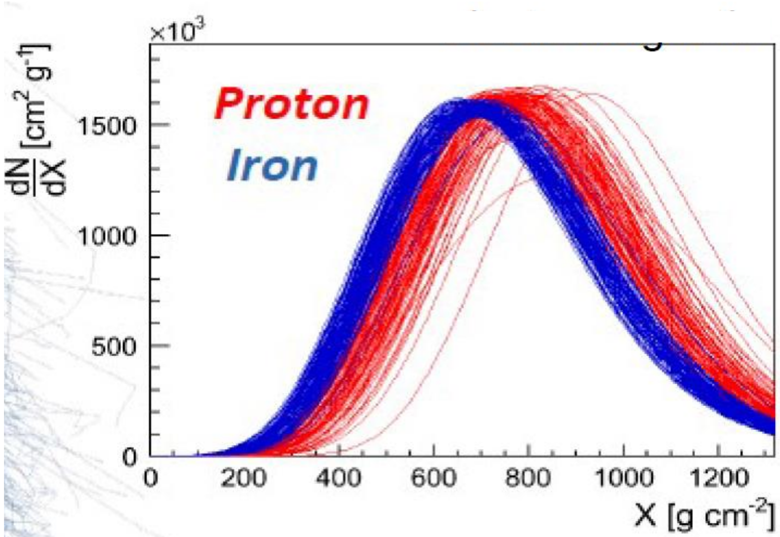
- Light profile converted to energy deposited in the atmosphere
- Shower profile gives information on:
  - energy of primary particle (integral of energy deposition)
  - type of primary particle and properties of high energy interactions in the atmosphere (X_{max}, position of shower maximum)

- Auger collaboration is planning an upgrade of the detectors (FD and SD) to run the observatory beyond 2015

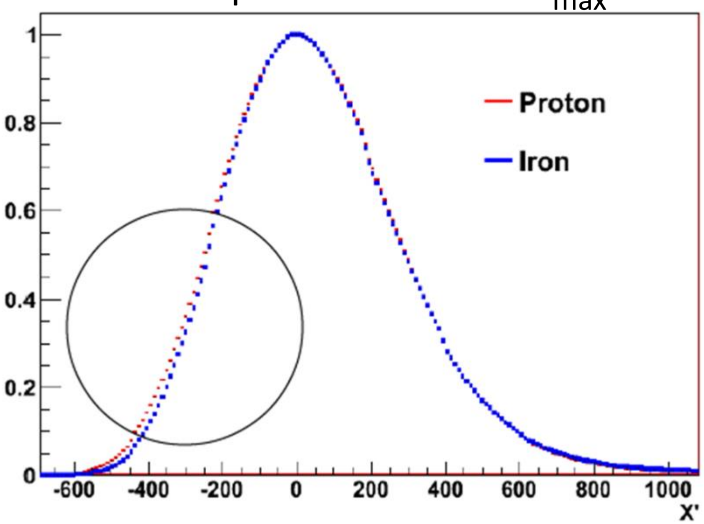
- Main physics goals:
  - Composition vs Hadronic interactions
  - Cross-section measurements
  - ...

- FD enhancements should be focused on:
  - increase of statistics
  - increase of FOV
  - improvement of shower measurement

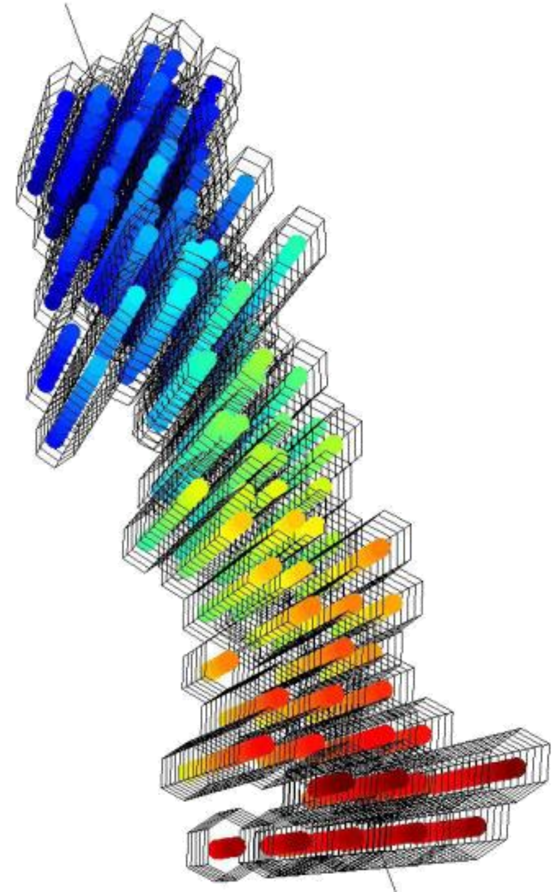
Detailed studies of EAS development



Universal shower profiles in $X' = X - X_{max}$ and $N' = N/N_{max}$



- Early part of normalized shower profile sensitive to composition and hadronic interactions
- Experimentaly challenging due to lower light level



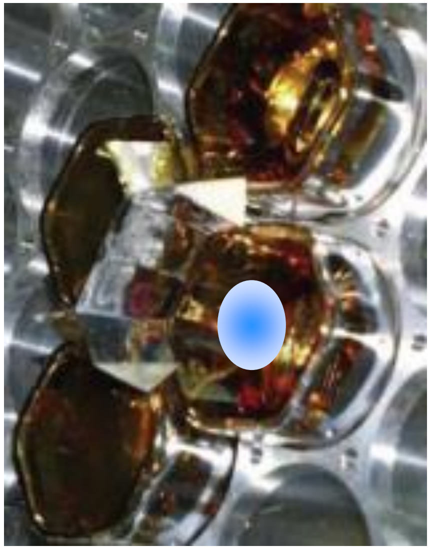
3D reconstruction of EAS

- Investigate sensitivity of shower transverse profile to first hadronic interactions

- Detailed studies of the shower profiles could benefit from:
  - Higher light collection efficiency
  - Higher resolution

- In addition a finer pixel would be better adapted to the telescope optics performance

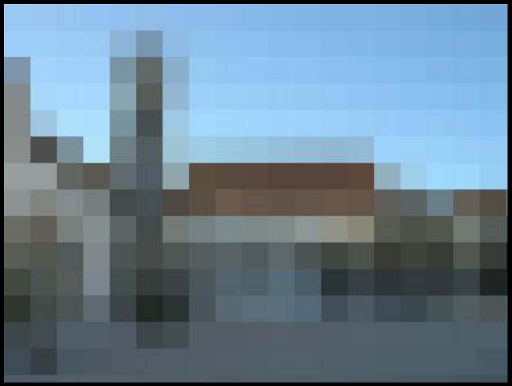
Optical spot smaller than pixel…

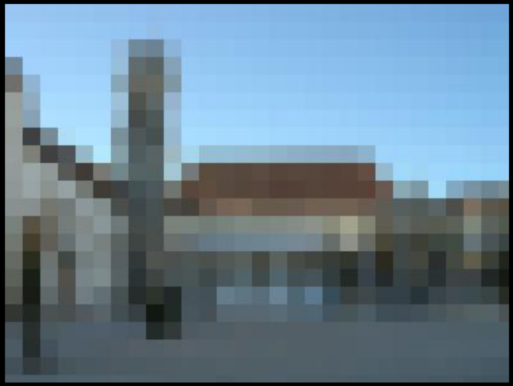


Improvements

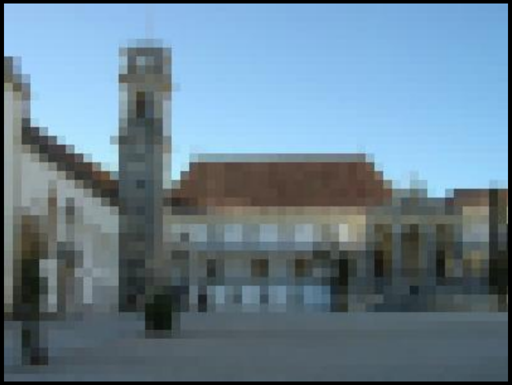
Credits to P. Assis

Improve efficiency





Increase resolution (Space & Time)



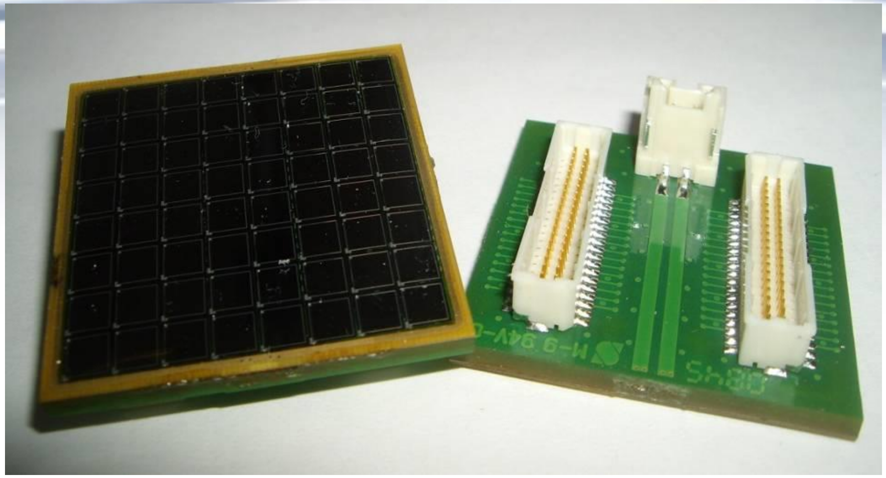
New Sensors: SiPM

...Upgrading the detector

Double the eficiency

Double resolution
(1/4 pixel area)

Reduce systematics in light collection



To have a focal surface built with SiPM
Use digital photon counting
Signals Digitized and time-tagged “as soon as possible”.
Data forward @ max bandwith using off-the-shelf links and boards.

Detector operated at low temperature

Performance

SiPM Pros:

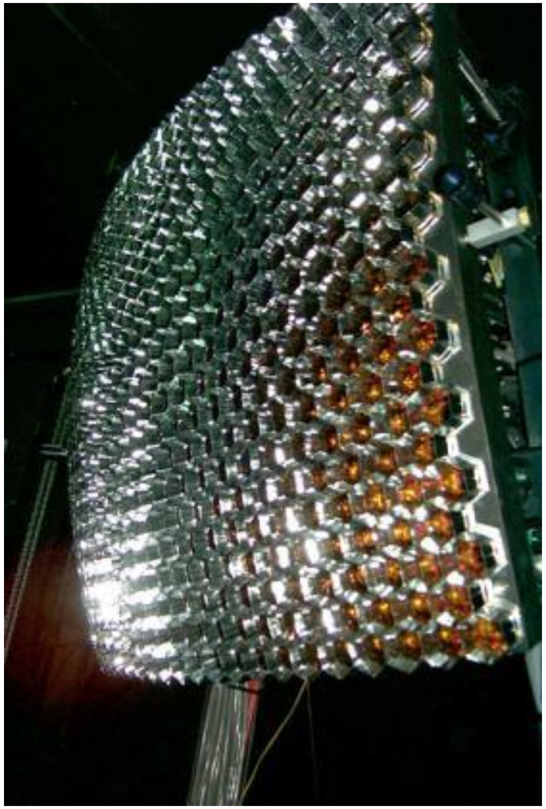
- Robust
- Fast
- Low operating voltage (30 V – 80 V)
- Small (1-10 mm^2)
- High PDE (devices with PDE ~ 60%)
- Gain: 10^5 - 10^6
- Photon counting capability
- Cheap (and expected to get cheaper)

SiPM Cons:

- Dependency with temperature
- Dark current,
- Afterpulse
- crosstalk

Great developments in SiPM.
Control Dark current, afterpulse, x-talk
Increase efficiency
Lower Price

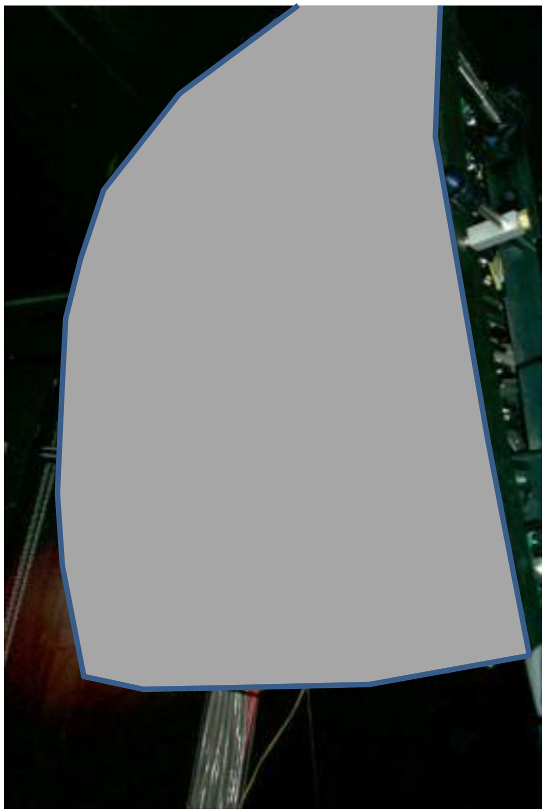
Replacing a FD camera

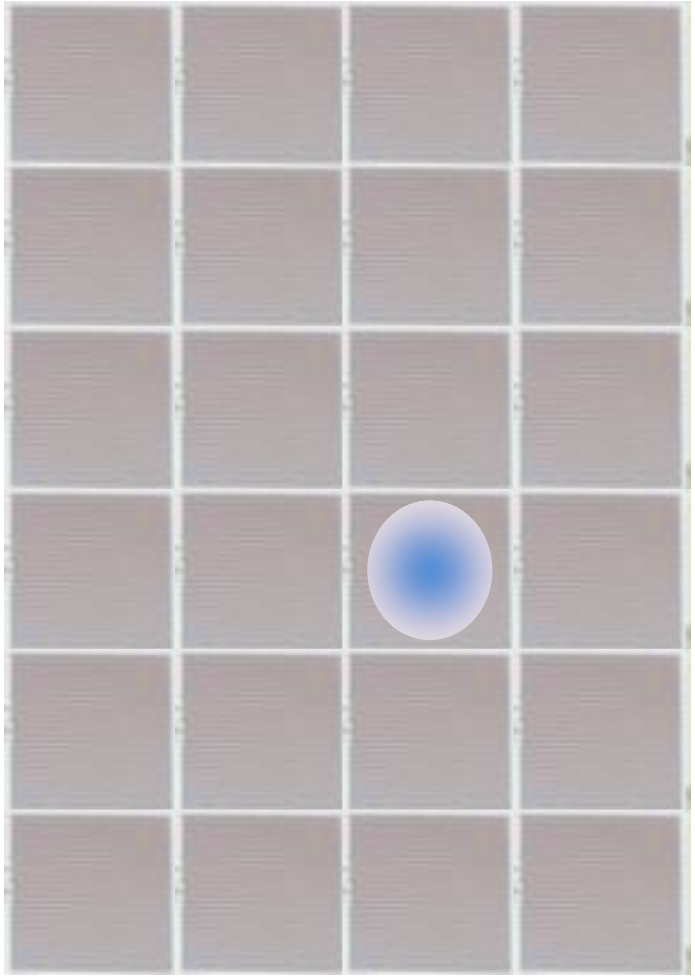


Pixel FOV	~ 1.5^o
Pixel Size	~ 4 cm
N Pixels	440

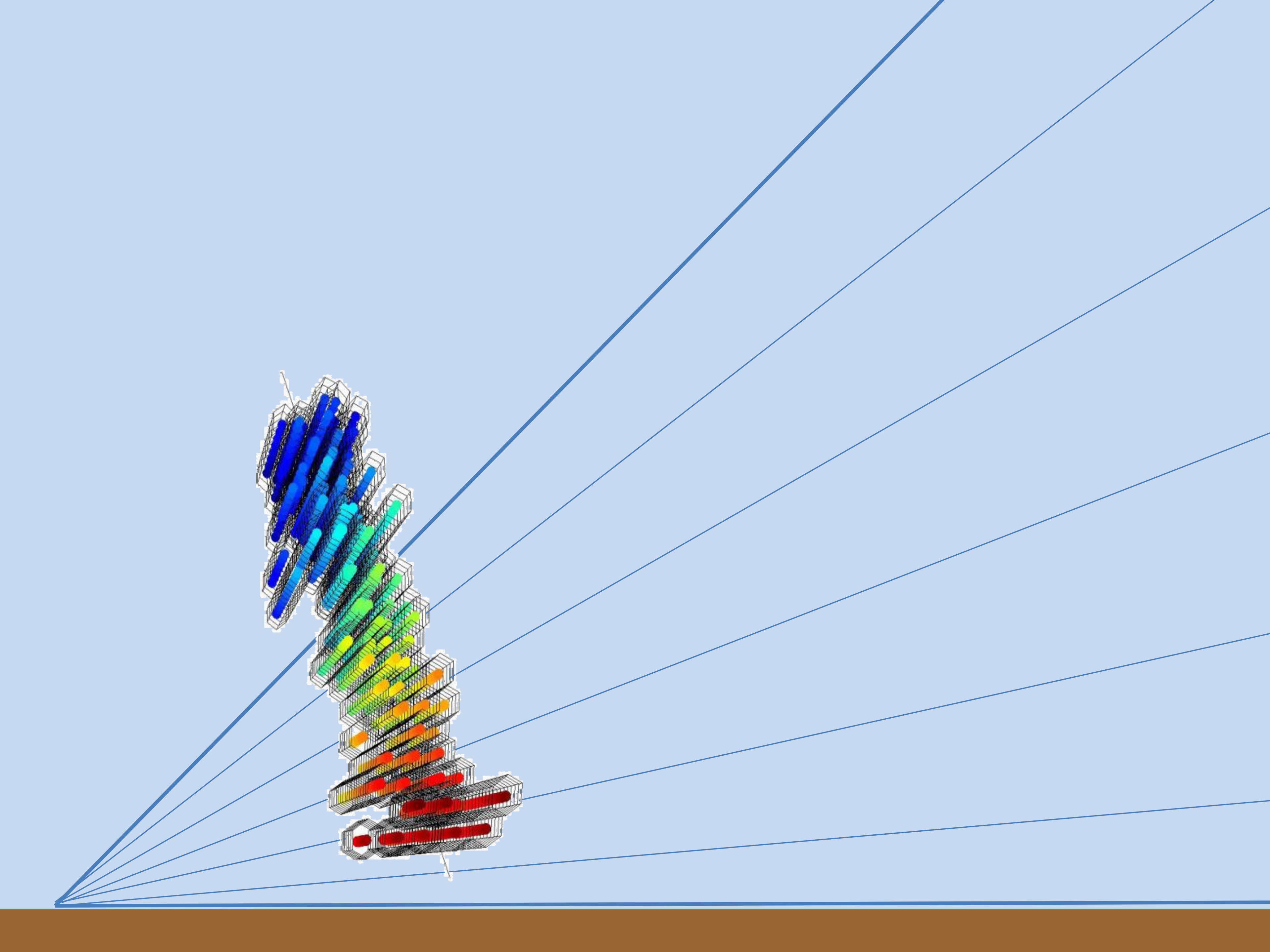
with SiPM...

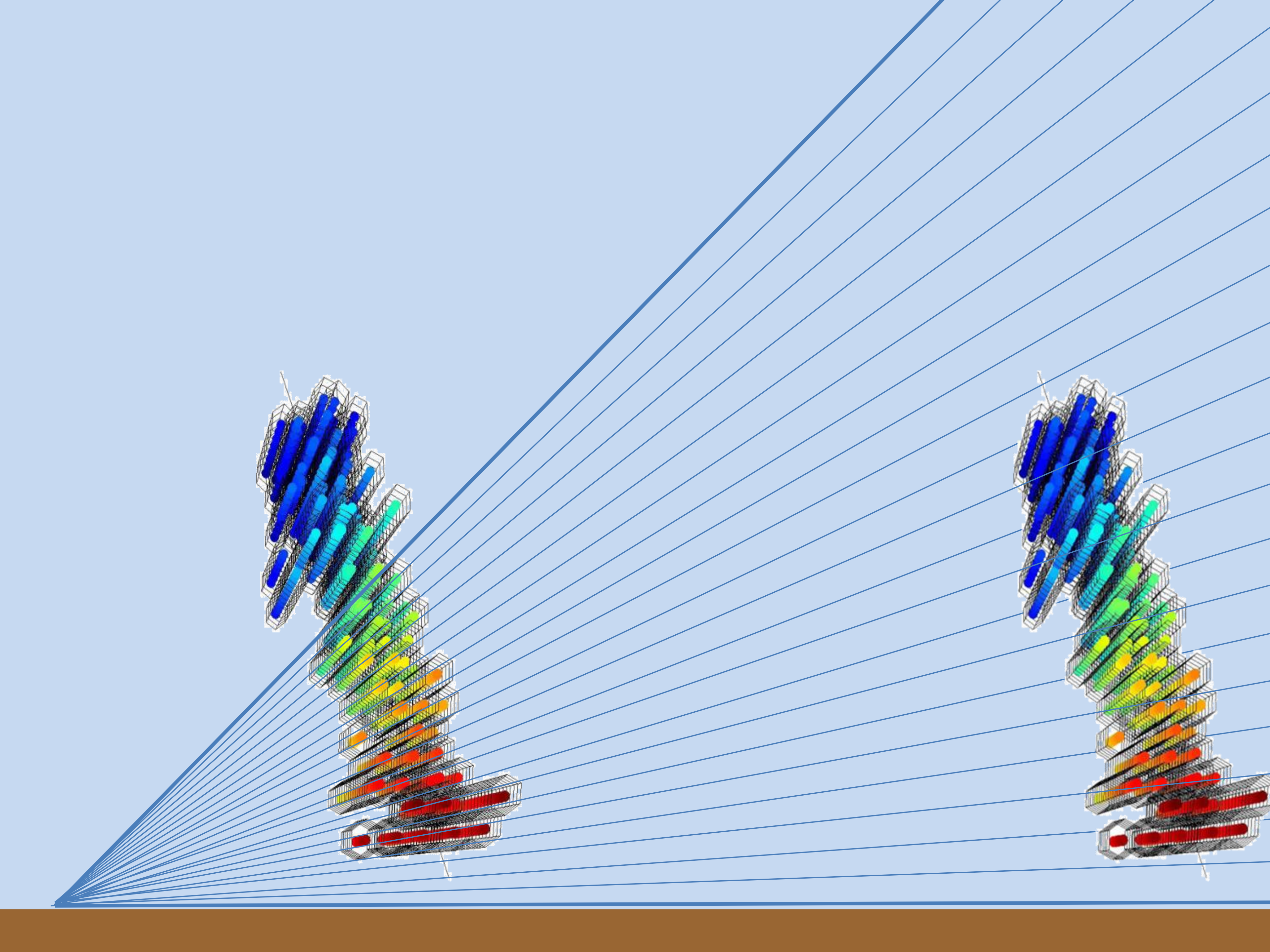
Replacing a FD camera





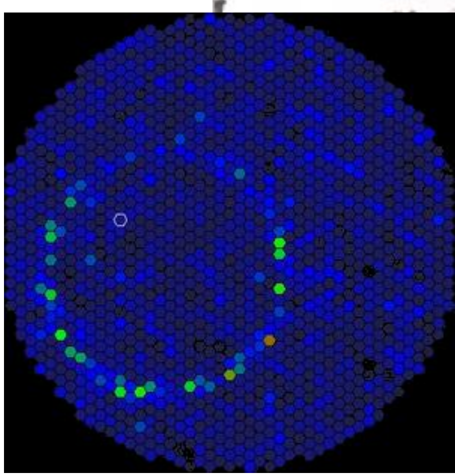
Advantages:
Resolution
Light detection efficiency
Light detection uniformity across camera surface





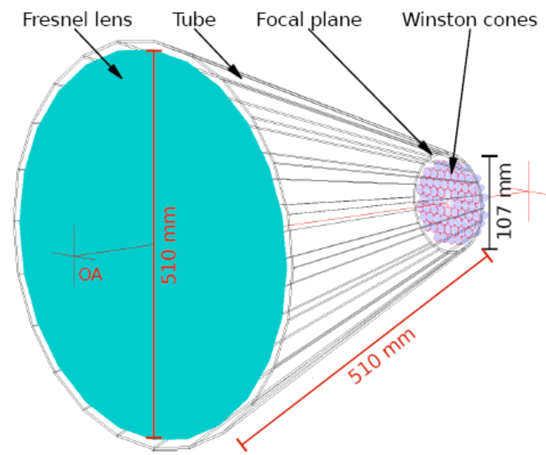
First Cameras

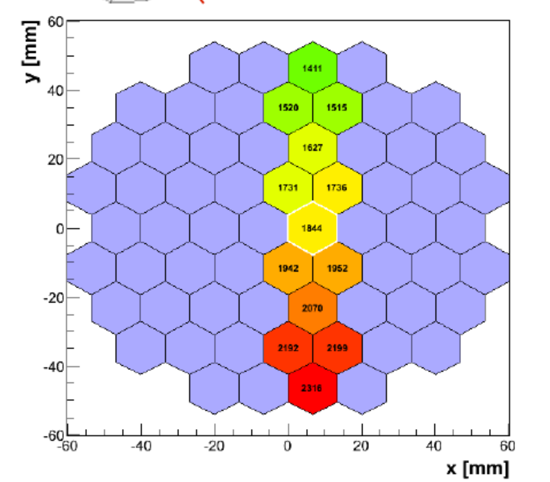
FACT First GAPD Cherenkov Telescope



FAMOUS

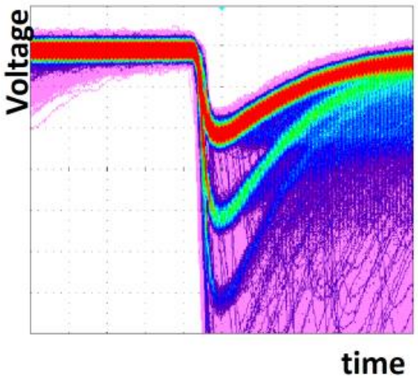
First Auger MPPC camera for the Observation of UHECR air Showers
(64 pixels)

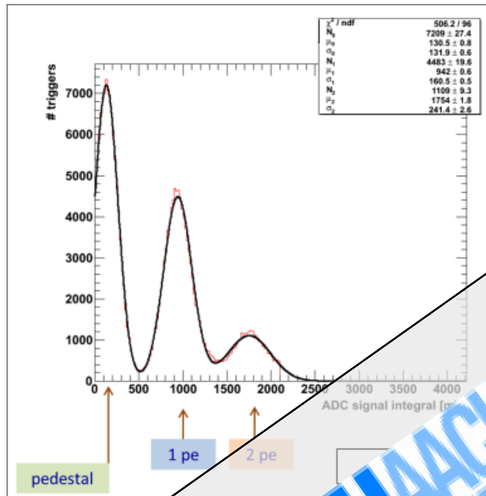


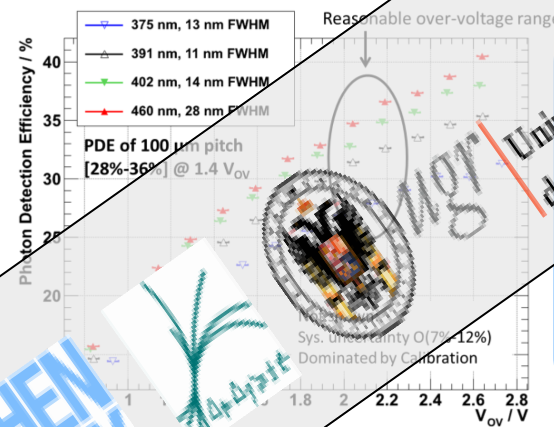


Towards a SiPM focal surface

SiPM characterisation





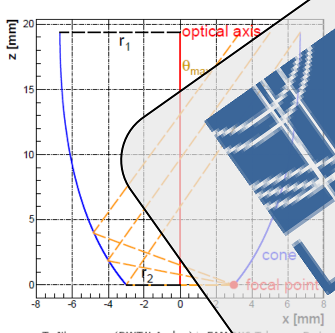


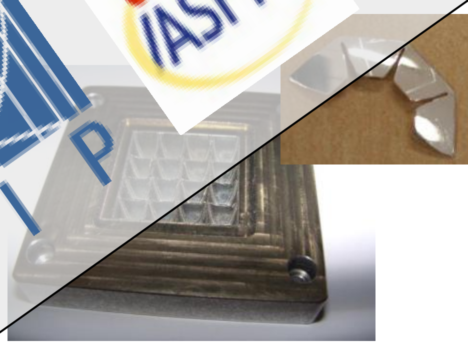
Main Parameters to control:

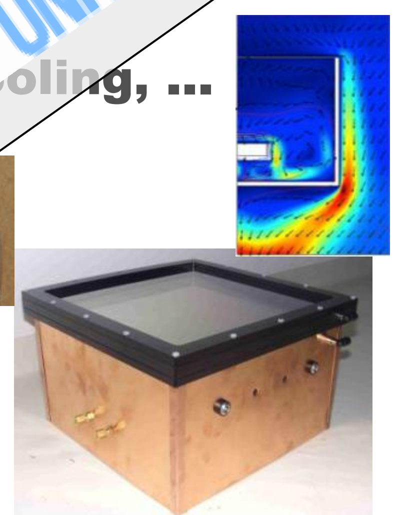
PDE
Gain
Darkcurrent

Afterpulses
Crosstalk
Temperature

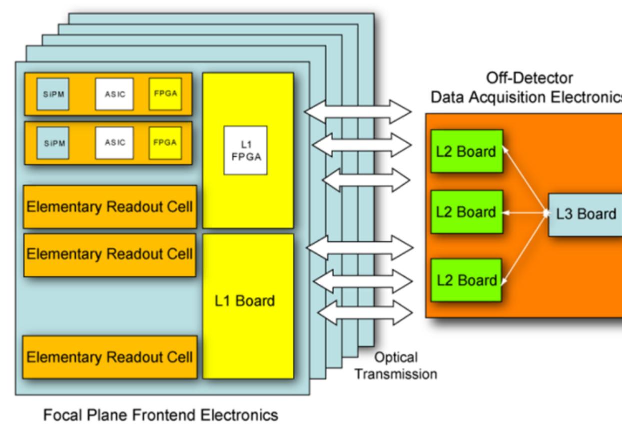
Solutions for light collection, cooling, ...







DAQ and Trigger



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