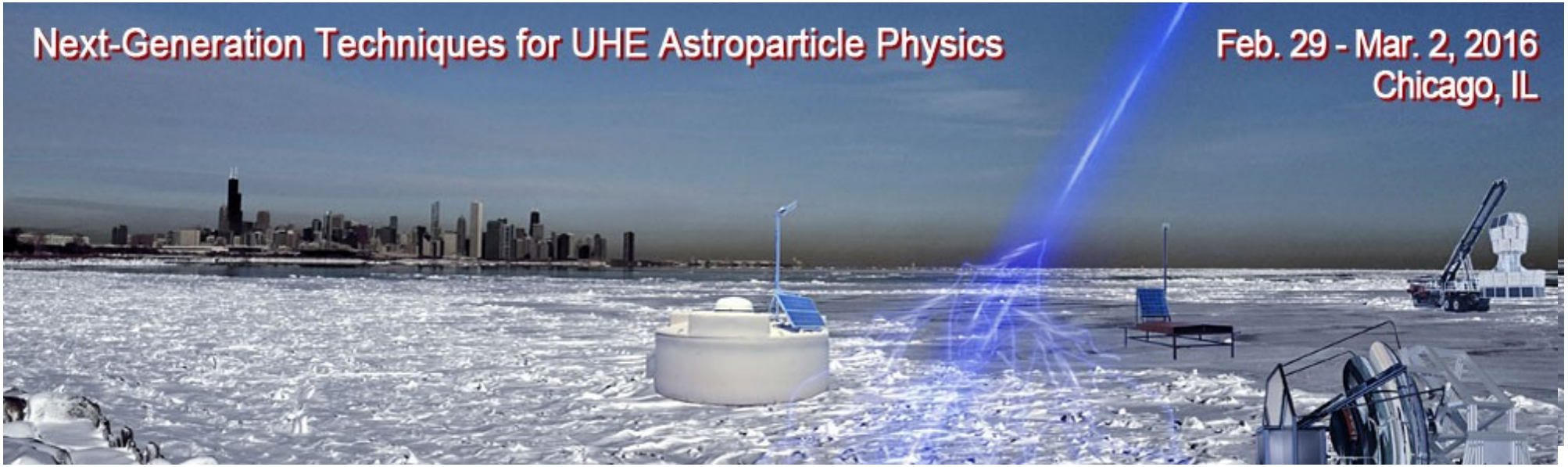
AugerPrime

Primary cosmic ray identification for the next 10 years



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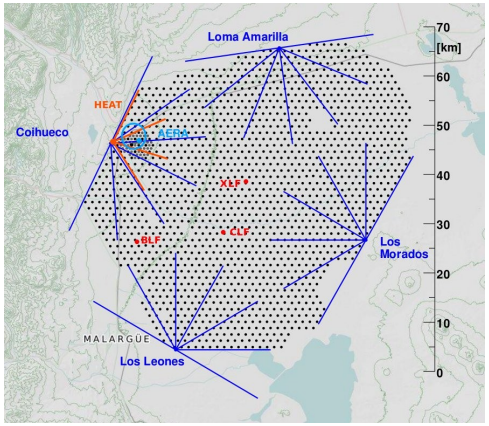
The Pierre Auger Observatory

The primary goal is to study the most energetic cosmic rays

Southern hemisphere, province Mendoza in Argentina

Flat semi-desert area of 3000 km^2 (1300 – 1500 m a.s.l.)

Construction started in 2004 and was finished in 2008.



The Auger observatory consists of

Surface detector (SD): 1660 stations

Fluorescence detector (FD): 24 telescopes

Extensions:

High Elevated Auger Telescopes (HEAT)

Underground muon detector (AMIGA)

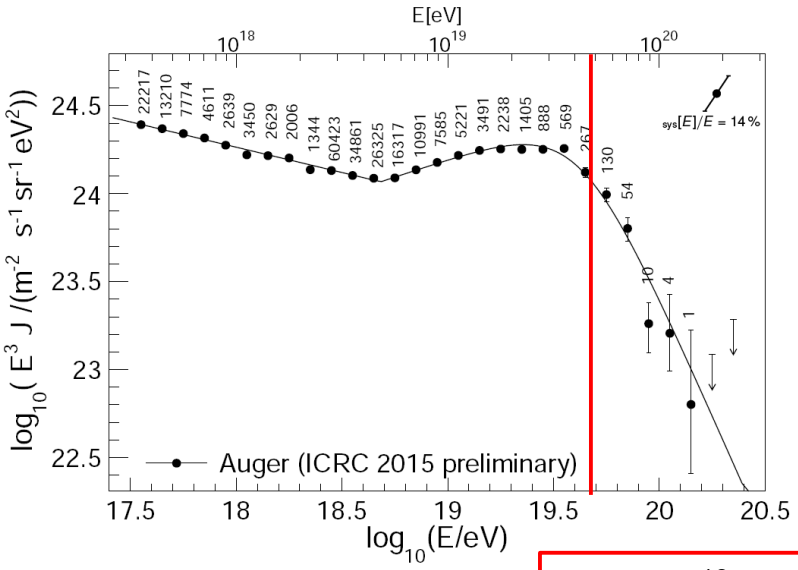
R&D activities: radio (AERA), GHz, etc.

Pierre Auger Coll., NIMA 798 (2015)

arXiv:1509.03732

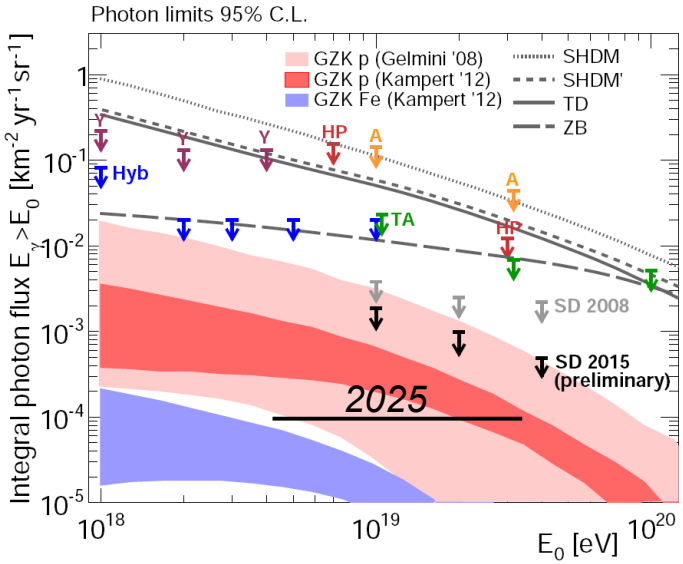
Results of the Auger Observatory

Very strong flux suppression above 5 x 10^{19} eV (caused by CR propagation or sources?)

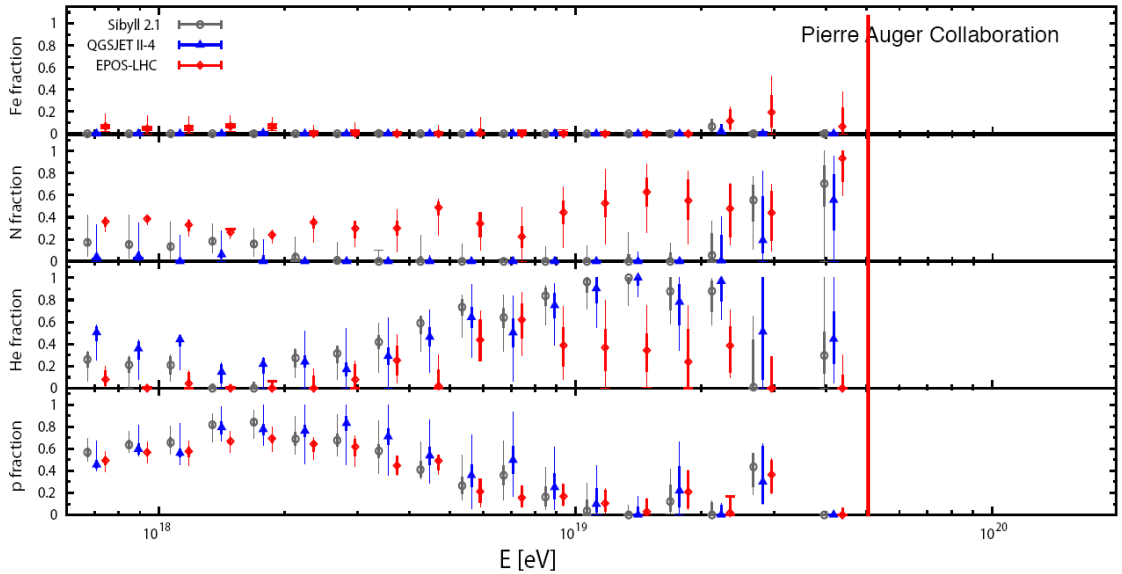


5 x 10^{19} eV

Photon and neutrino upper limits (top-down models are excluded)



Mass composition change (but no data above 5 x 10^{19} eV)



Deficit of muons

and many others...

Motivation for the upgrade

To provide additional measurements to allow us to address the following questions:

1. The origin of the flux suppression at the highest energies

   Measurement of the mass composition beyond the reach of the FD.

2. Proton contribution in the flux suppression region ($E > 5 \times 10^{19}$ eV)

   Search of point sources and estimate the physics potential of existing and future cosmic ray, neutrino, and gamma-ray detectors.

3. Fundamental particle physics at energies beyond reach of man-made accelerators

   Study extensive air showers and hadronic multiparticle production.

Mass composition measurement above 5×10^{19} eV
with a sensitivity to the proton flux as small as 10%.

How to do it?

Preliminary Design Report, arXiv:1509.03732

Measure with the Pierre Auger Observatory (designed 15 yrs ago) until the end of 2024. MOUs have been signed in Nov 2015.

Proposed upgrades:

1) Upgrade surface detector electronics & a small PMT

2) Scintillator SD (SSD) to measure the mass composition with 100% duty cycle

3) Finish AMIGA to have a direct muon measurement

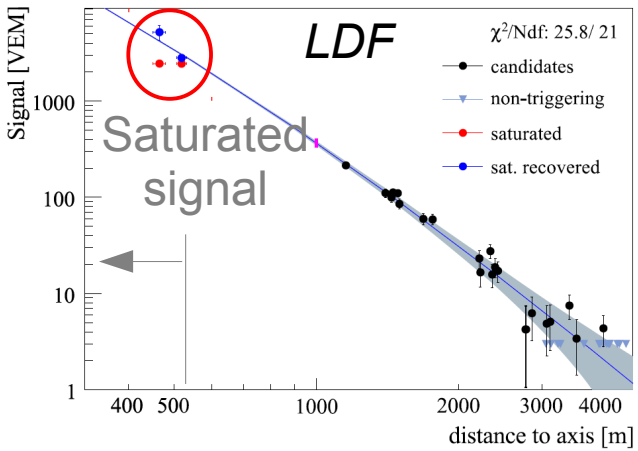
4) Extended FD operation

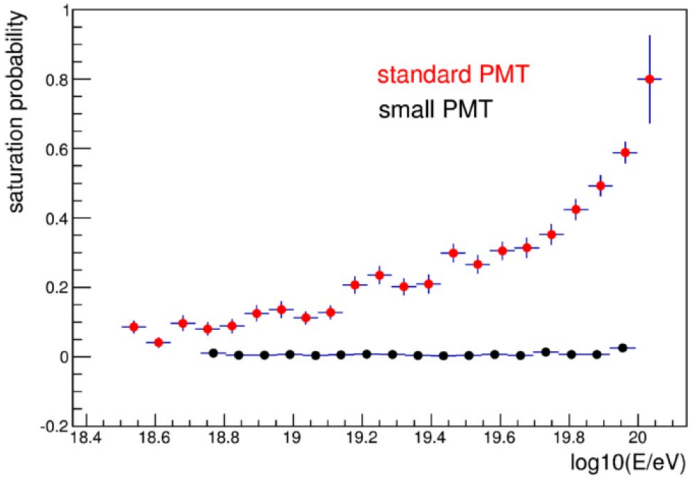
Event statistics will more than double compared with the existing data set, with the critical added advantage that every event will now have mass information.

$\log_{10}(E/\mathrm{eV})$	$\mathrm{d}N/\mathrm{d}t\|_{\mathrm{infill}}$ $[\mathrm{yr}^{-1}]$	$\mathrm{d}N/\mathrm{d}t\|_{\mathrm{SD}}$ $[\mathrm{yr}^{-1}]$	$N\|_{\mathrm{infill}}$ [2018-2024]	$N\|_{\mathrm{SD}}$ [2018-2024]
17.5	11500	-	80700	-
18.0	900	-	6400	-
18.5	80	12000	530	83200
19.0	8	1500	50	10200
19.5	$\sim$1	100	7	700
19.8	-	9	-	60
20.0	-	$\sim$1	-	$\sim$9

SD electronics and small PMT

1. Increase of the data quality (better timing, dynamic range and μ identification):
   a) faster sampling of ADC traces (40 → 120 MHz)
   b) more precise absolute timing accuracy (new GPS receiver)
   c) increase the dynamic range by adding a 1” PMT (SD PMTs are 9”)





Improved LDF fit

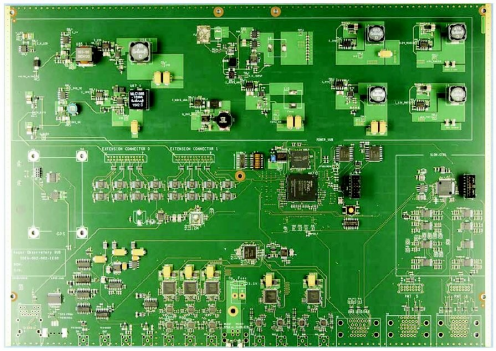
↓

Better SD-only X_{max} resolution

2. Faster data processing and more sophisticated local triggers (more powerful processor and FPGA)

3. Improved calibration and monitoring capabilities

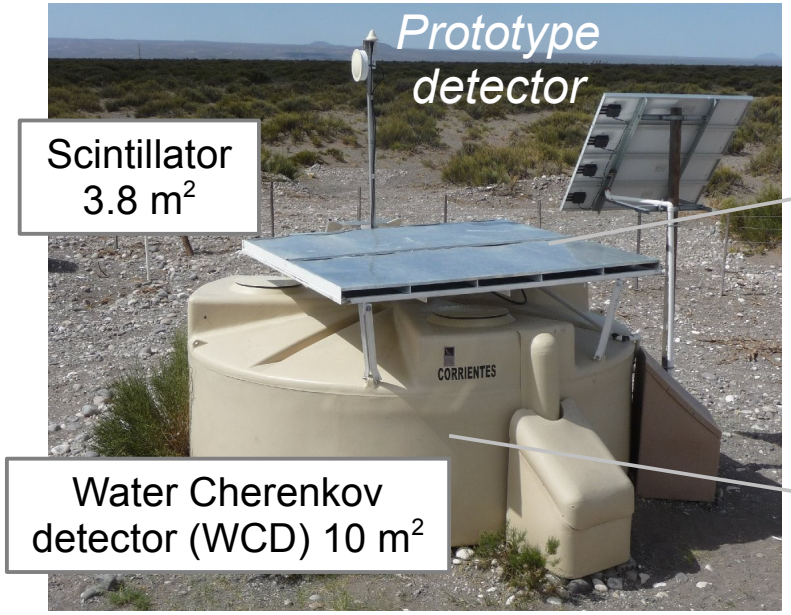
4. New components:
   a) Connection to the SSD and any additional (R&D) detectors
   b) Prolong lifetime and reduce failure rate

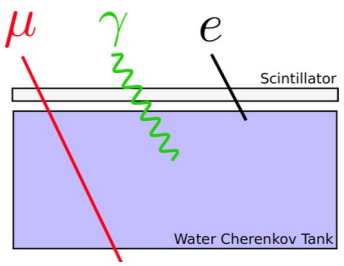


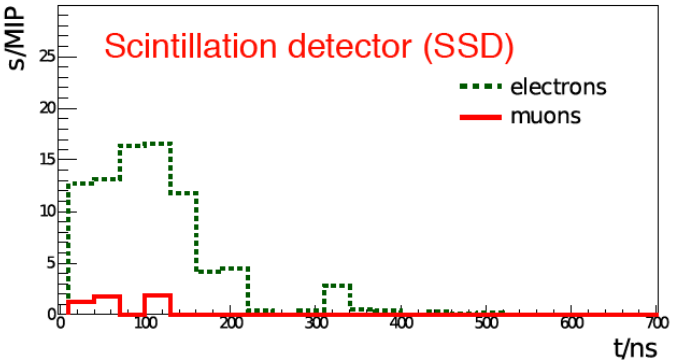
Prototype is being tested.

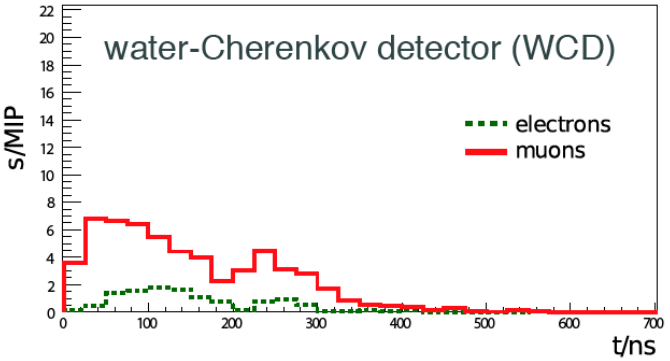
SSD measurement

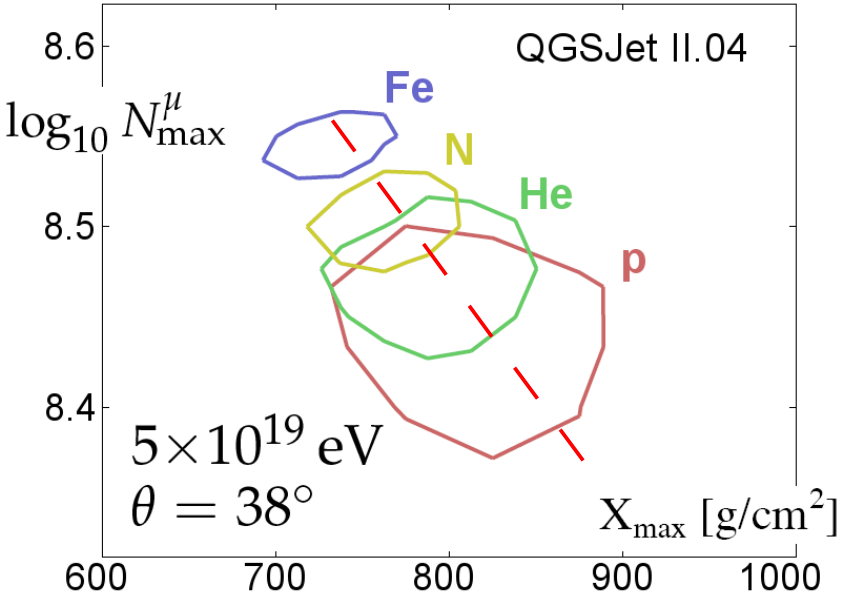
100% duty cycle









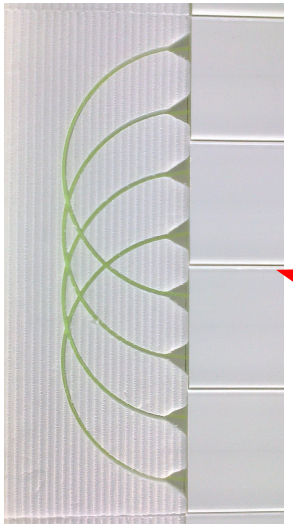


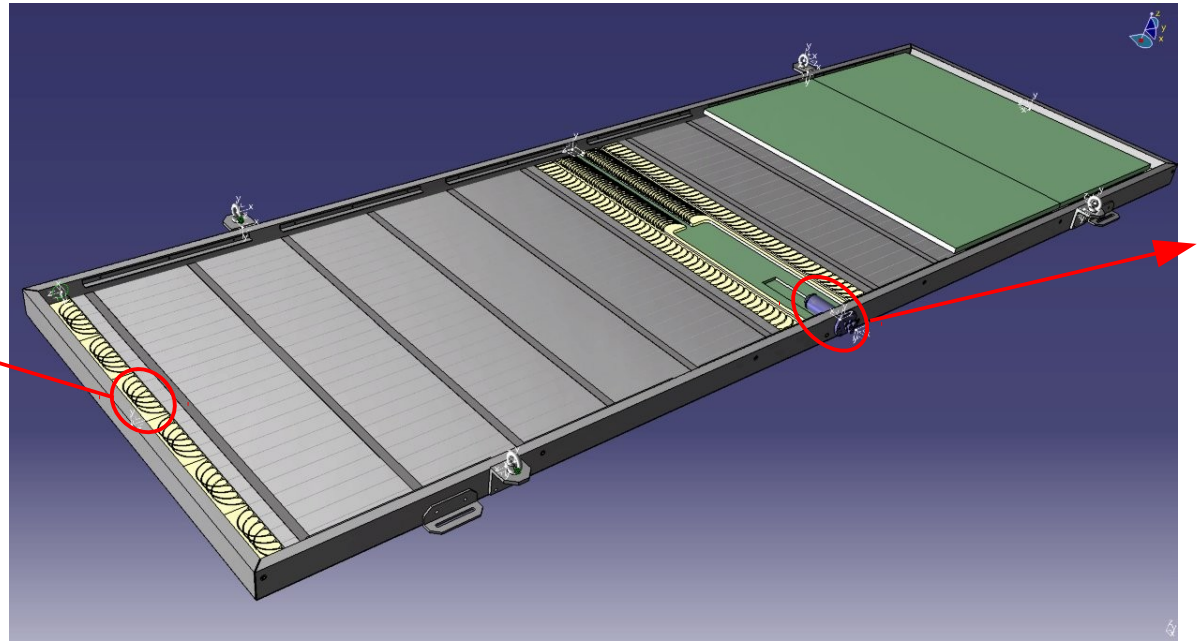
Complementarity of particle response used to discriminate electromagnetic and muonic components of air showers.

Both, N_{μ} and X_{max}, can be reconstructed from WCD and SSD.

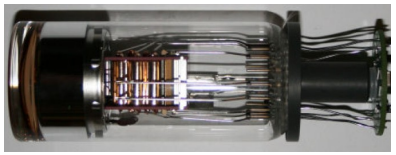
Scintillator detector

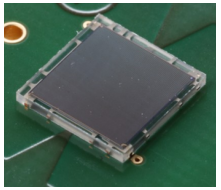
Fibers routing





PMT/SiPM



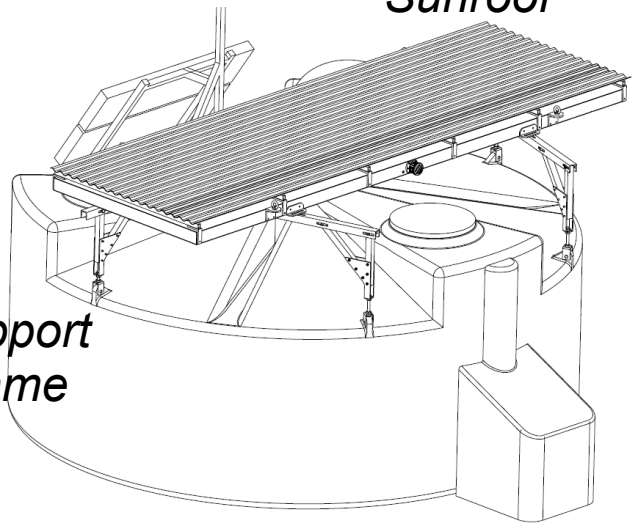


WLS fibers

Extruded scintillator bars (1600 x 50 x 10 mm)

Alu enclosure

Sunroof



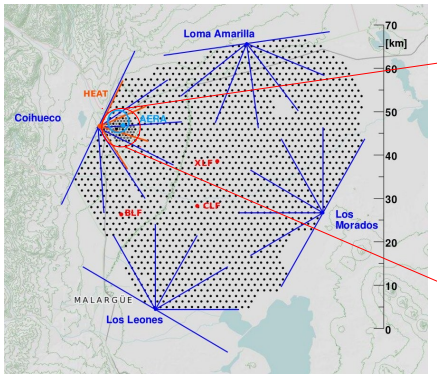
Support frame

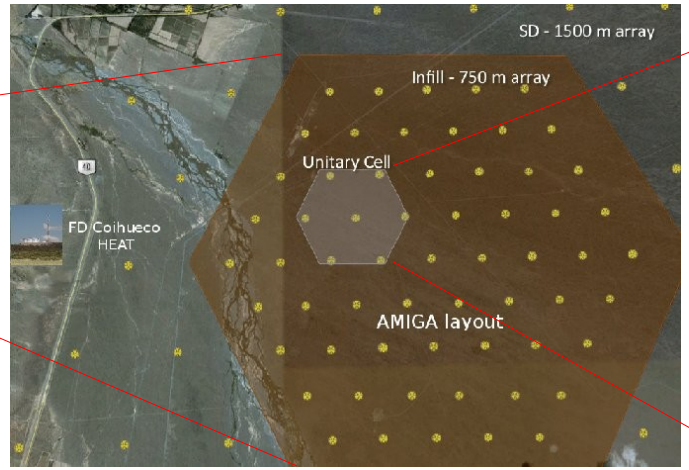
AMIGA

The underground muon detector

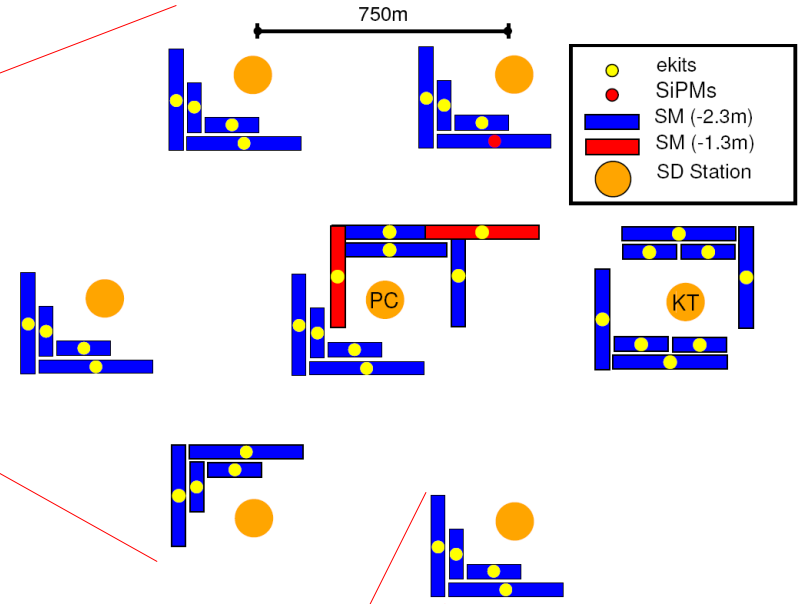
61 AMIGA muon detectors (30 m^2) are planned

Will be deployed on a 750m grid (a total area of 23.5 km^2)

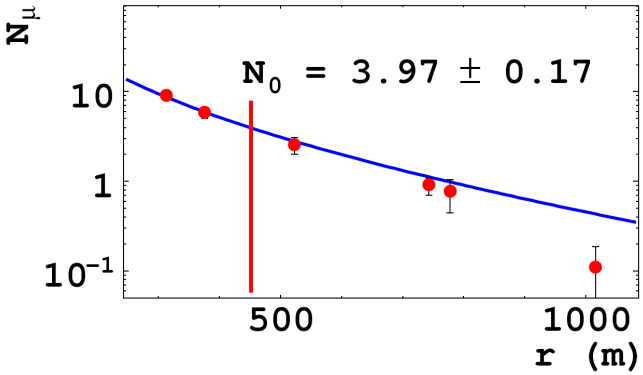


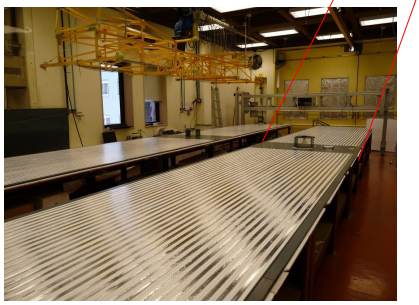


AMIGA Unitary cell (Feb 2015)



LDF, E = 2 x 10^{18} eV





Standard FD operation

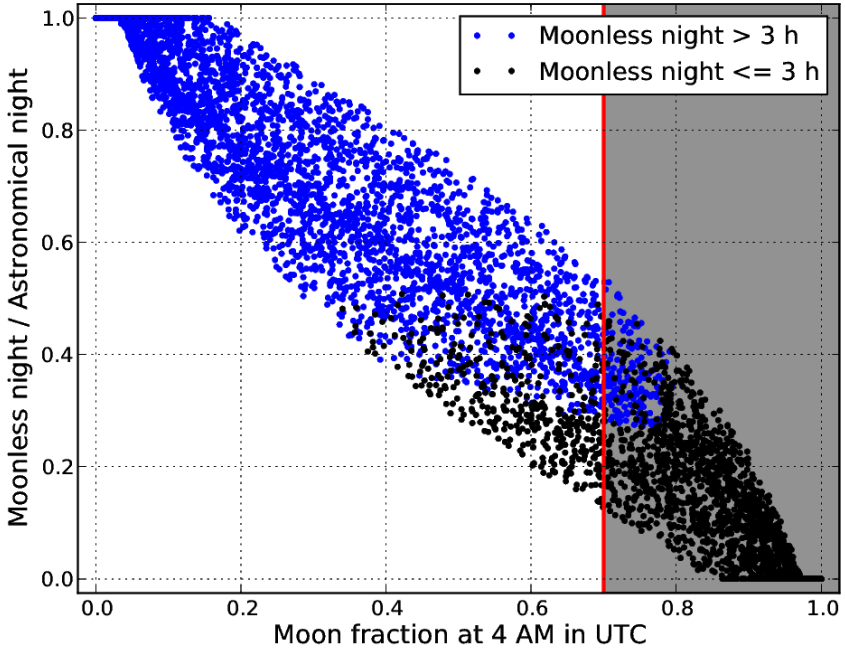
FD provides exceptional information (e.g. model-independent energy reconstruction & mass composition measurement).

The main limitation of the FD is its duty cycle (15% nowadays).

The current criteria for FD measurement:

1. *The sun more than 18° below the horizon*
2. *The moon remains below horizon for longer than 3 hours*
3. *The illuminated fraction of the moon must be below 70%*

Pierre Auger Coll., NIMA 798 (2015)



Measurement periods (~17 nights long), limit on the PMT illumination (i.e. no rapid aging), and the PMT response stays linear.

By relaxing criteria #2 and #3 the FD duty cycle <u>can be increased by 50%</u>, while keeping very high selection efficiency and reconstruction.

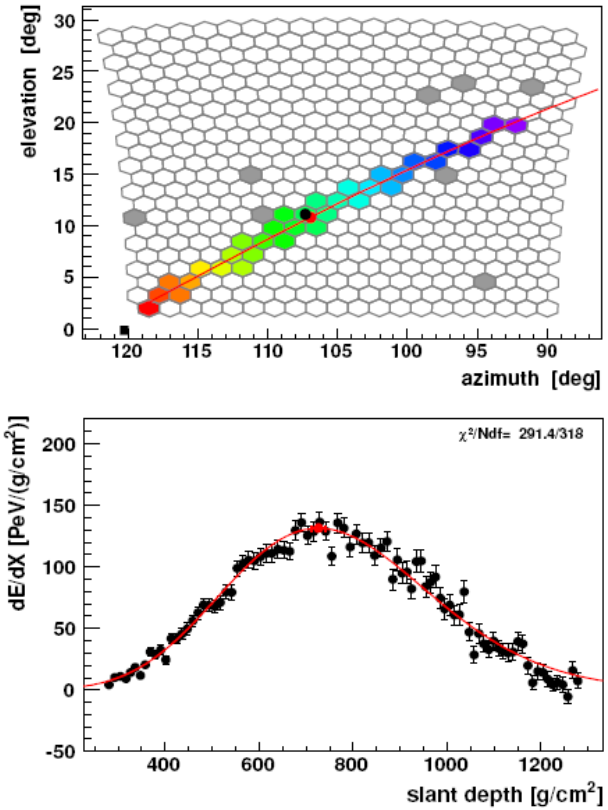
Extended FD operation

15% duty cycle

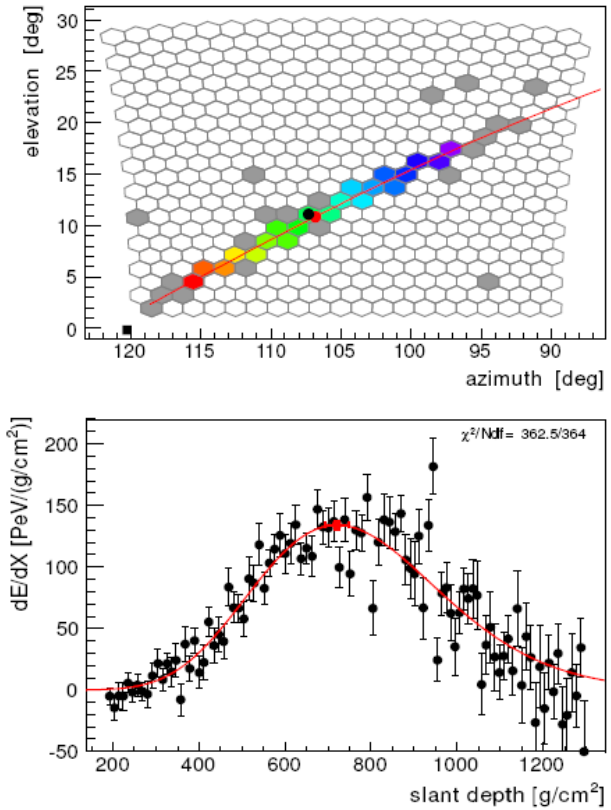
Increase by 50% by measurement during high night sky background

The moon and Jupiter above Los Leones in the morning on 4 Mar, 2015.

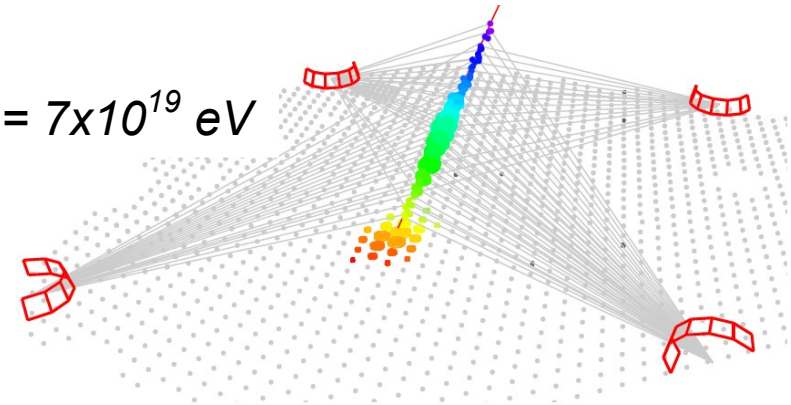
Clear sky, no moonlight



40 times higher NSB (90% moon)



$E = 7x10^{19}$ eV



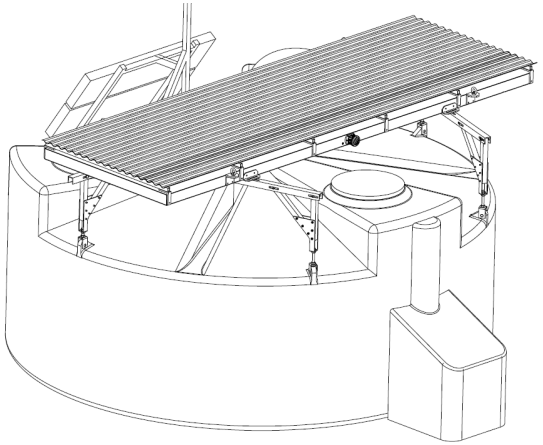
10x reduced PMT gain by reducing supplied HV.

Successful test has been done last year.

Conclusions and outlook

AugerPrime will allow a study of *mass composition above 5 x 10^{19} eV* and address:

1. Origin of the flux suppression (GZK energy loss vs. maximum energy of sources)
2. Proton contribution of more than 10% above 5 x 10^{19} eV?
   (particle astronomy, GZK γ and ν fluxes → future experiments)
3. New particle physics beyond the reach of LHC?



Timeline for new SDE and SSD:

Jul/Aug 2016: Engineering Array (12 stations)

Nov 2016: Evaluation of detectors

2017-2018: Deployment

Till Jan 2025: Data taking (up to 40,000 km^2 sr yr)

Similar event statistics as collected so far will be reached with upgraded detectors.

Mass composition info on event-by-event basis

Total cost: *about $12M* (w/o AMIGA)

The FD duty cycle extension will be evaluated after additional tests.