STATUS OF THE AUGERPRIME UPGRADE OF THE PIERRE AUGER OBSERVATORY

Niraj Dhital* for the Pierre Auger Collaboration

*Institute of Nuclear Physics PAN, Krakow

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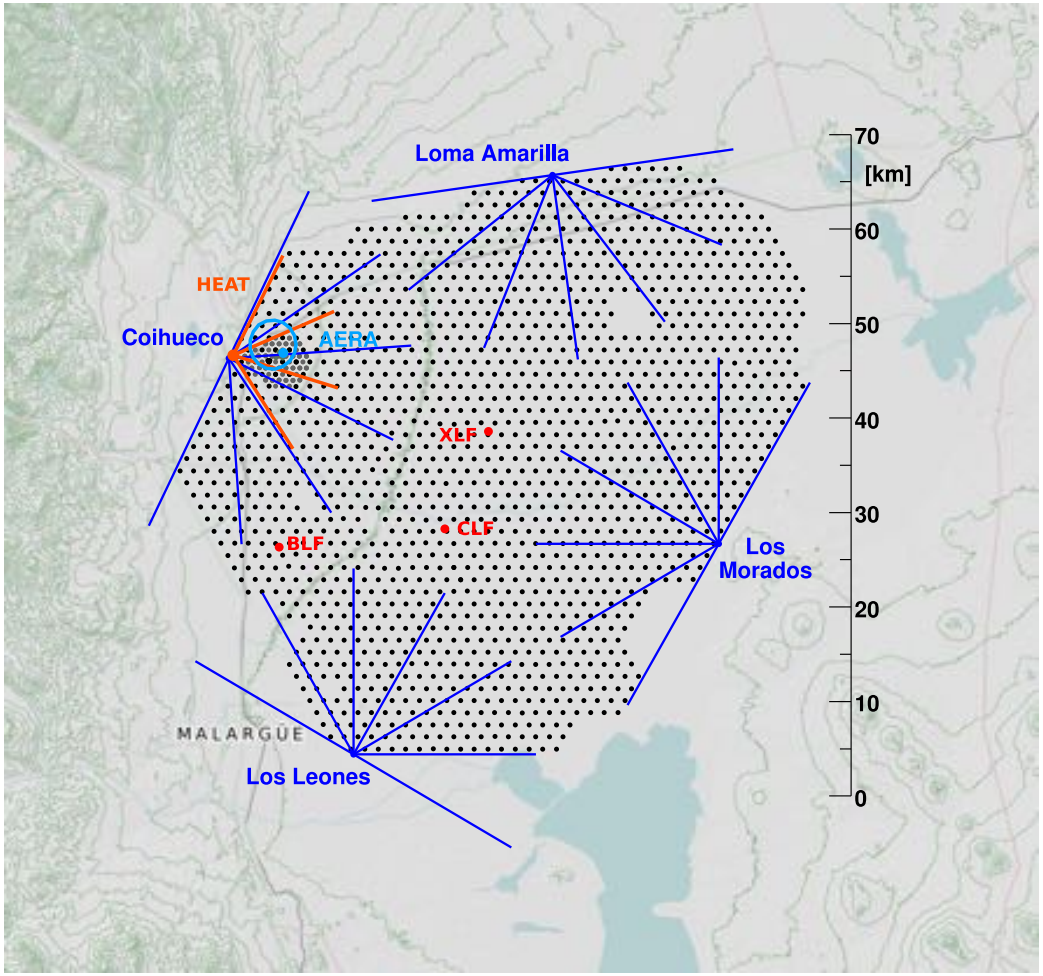
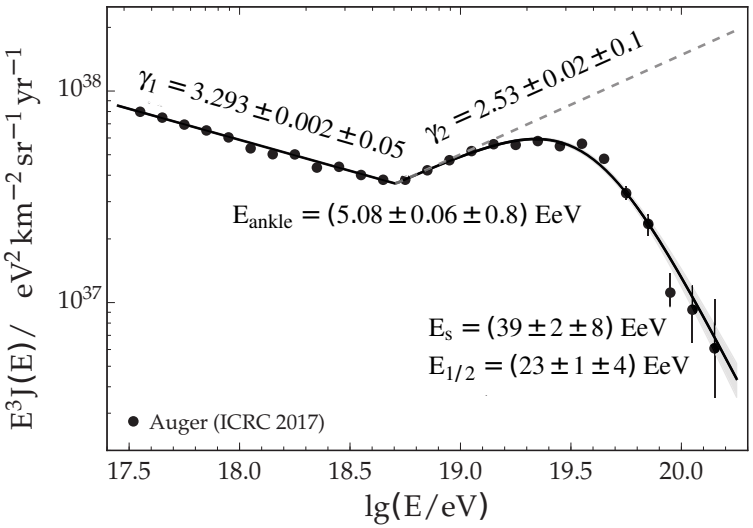
PIERRE AUGER OBSERVATORY

The Pierre Auger Observatory

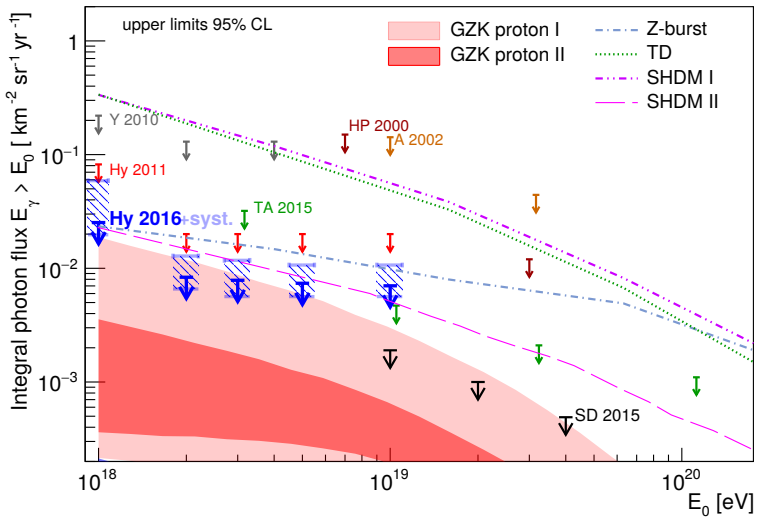


- SD array: 1660 WCD spread over 3000 km^2 with 1.5 km spacing.
- FD: 4 stations each enclosing 6 fluorescence telescopes.
- HEAT: 3 fluorescence telescopes with an elevated field of view.
- Infill Array: A denser array of WCDs (23.5 km^2 with 750 m spacing).
- Additional facilities for atmospheric monitoring.

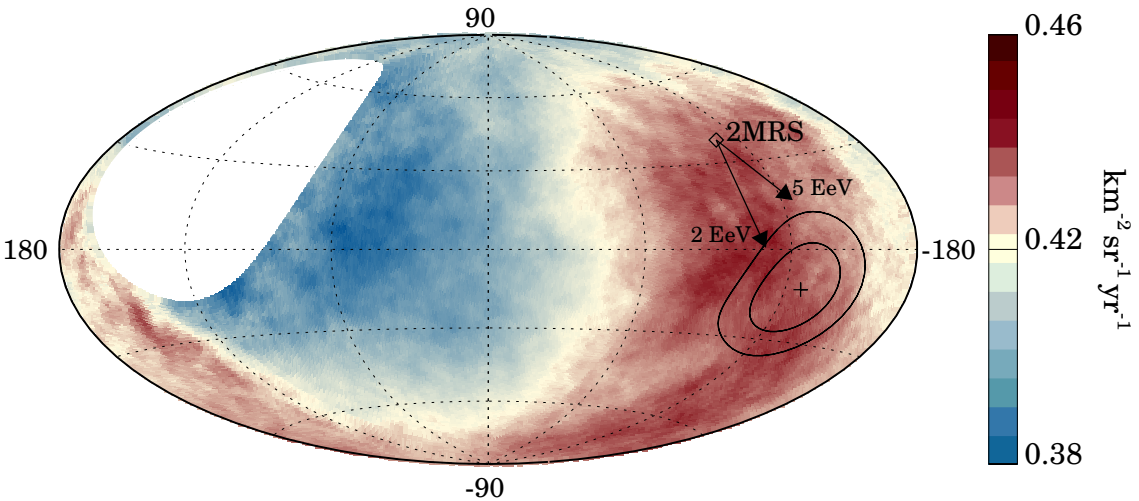
Major Science Results



Flux Suppression above 4×10^{19} eV

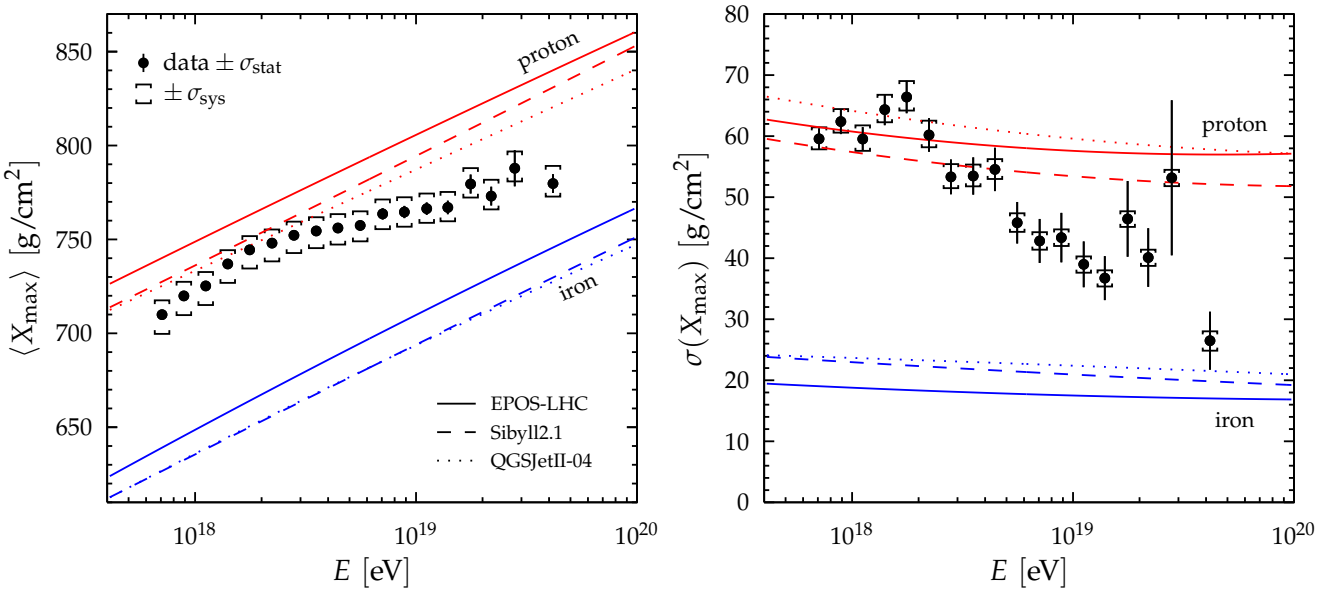


Stringent upper limits on UHE gamma and neutrino flux

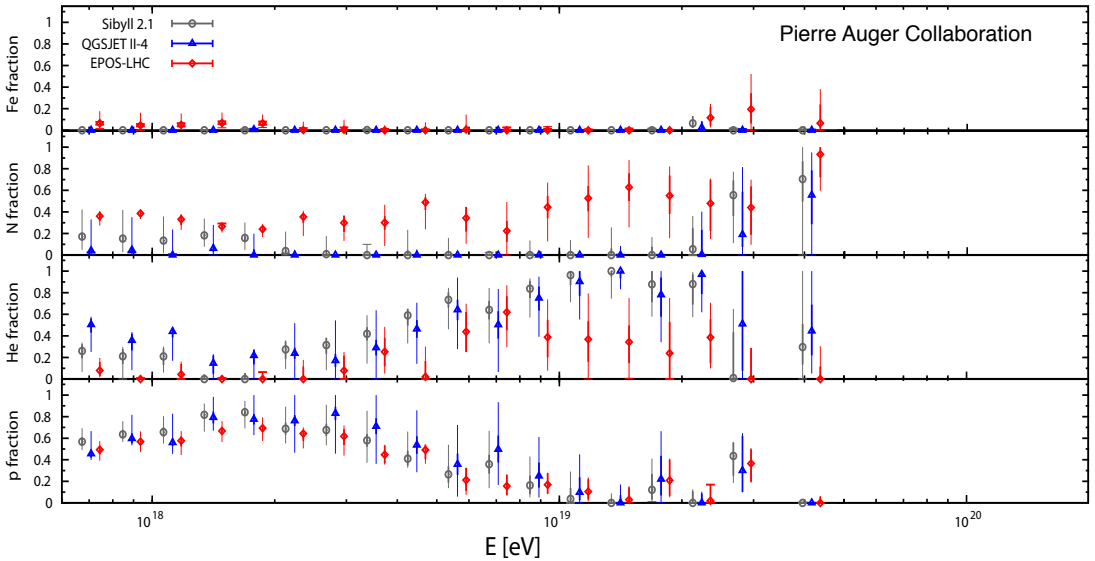


Observation of dipolar anisotropy above 8 EeV.

Major Science Results



Mean X_{max} and $\sigma(X_{max})$ as measured with the Pierre Auger Observatory.



Evolution of mass composition with energy.

Motivation for the AugerPrime Upgrade

Plans to operate the observatory until the end of 2024 $\Longrightarrow$ better statistics.

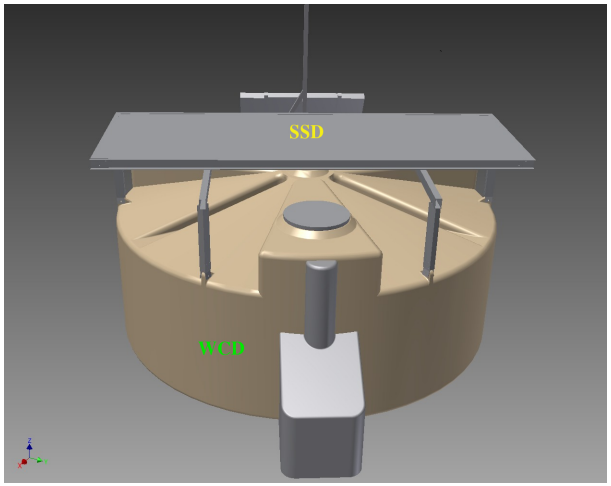
Upgrade necessary to ensure that the new data will provide additional information to allow us to address the following:

1. Elucidate the mass composition and the origin of the flux suppression at the highest energies.
   - Understanding the origin of the flux suppression will provide fundamental constraints on the astrophysical sources and will allow much more reliable estimates of neutrino and gamma-ray fluxes at UHE.
2. The search for a flux contribution of protons up to the highest energies.
   - Aim to reach a sensitivity to a contribution as small as 10% in the flux suppression region; prospects for proton astronomy.
3. Exploration of fundamental particle physics at energies beyond those accessible at man-made accelerators.
   - Understanding extensive air showers and hadronic interactions (muon deficit in sim. results), derivation of constraints on new physics phenomena.

The AugerPrime Strategy

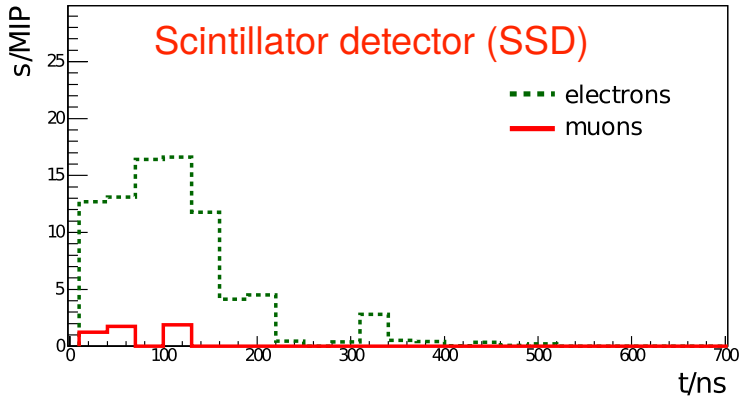
- Addition of a Surface Scintillator Detector (SSD) with an active area 3.84 m^2 atop each Water Cherenkov Detector(WCD) to perform a complementary measurement of the shower particles.
- Addition of a small PMT in each WCD to increase its dynamic range.
- Upgrade of Surface Detector Electronics to increase data quality, to enhance the local trigger and processing capabilities and to improve calibration and monitoring capabilities of the SD.
- Extension of operation mode of the FD, which will increase its current duty cycle by about 50% (to $\sim$ 23%).
- Installation of the AMIGA Underground Muon Detector for direct muon measurements.

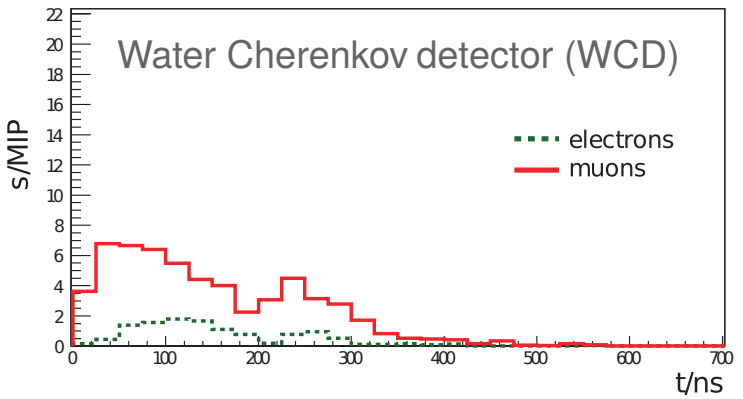
The Surface Scintillator Detector



- SSD provides a robust and well-understood technique for particle detection.

- Complementary to the water Cherenkov technique allowing a good measurement of muons.

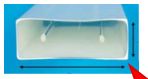




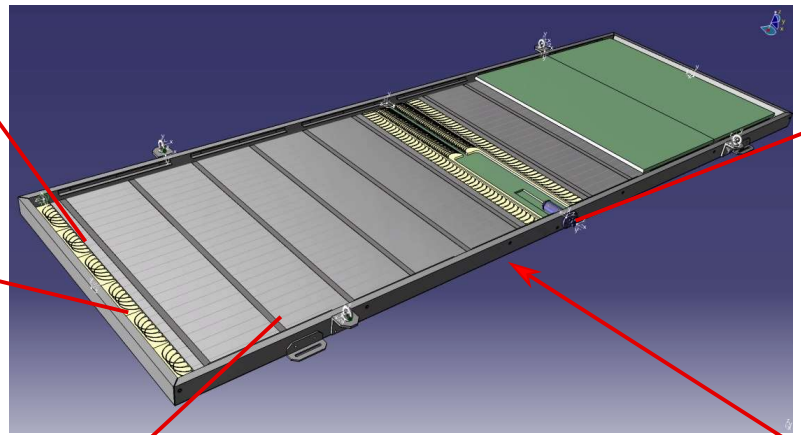
Detector response of electrons and muons for SSD and WCD
$\rightarrow$ primary mass composition on event-by-event basis

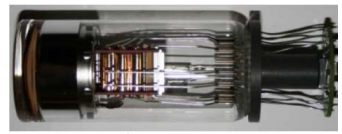
THE SURFACE SCINTILLATOR DETECTOR

side view of a scintillator bar



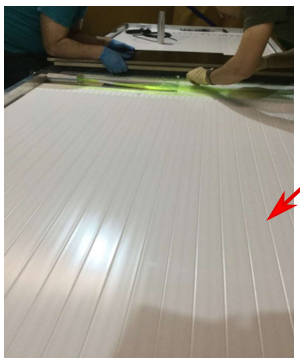
SSD





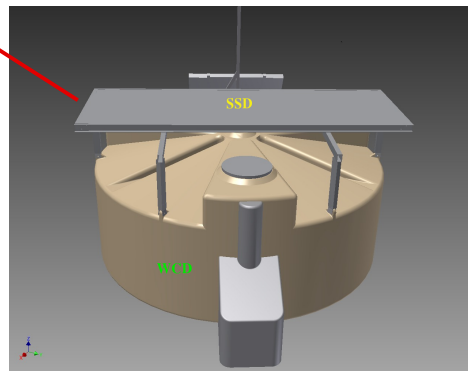
PMT

WLS fibers and fiber routers

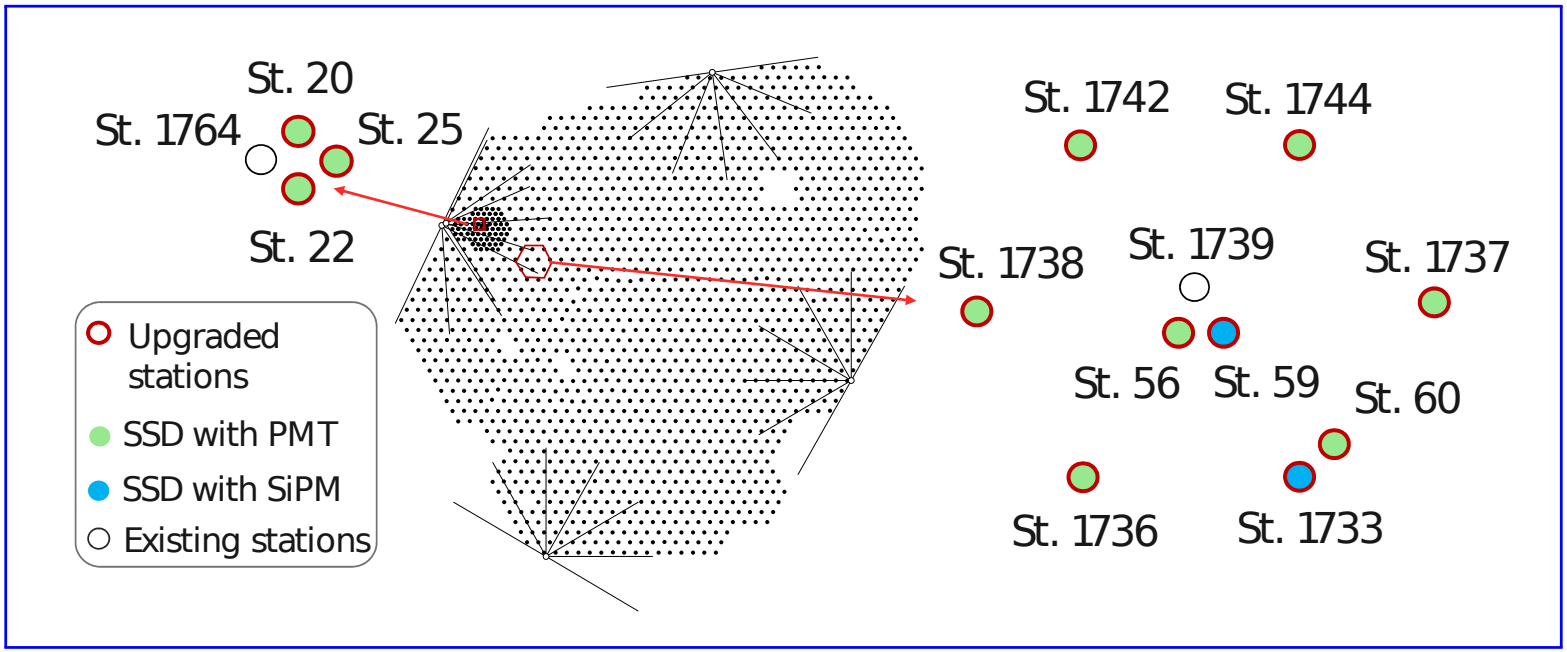


Scintillator bars 160x5x1cm

Al Enclosure

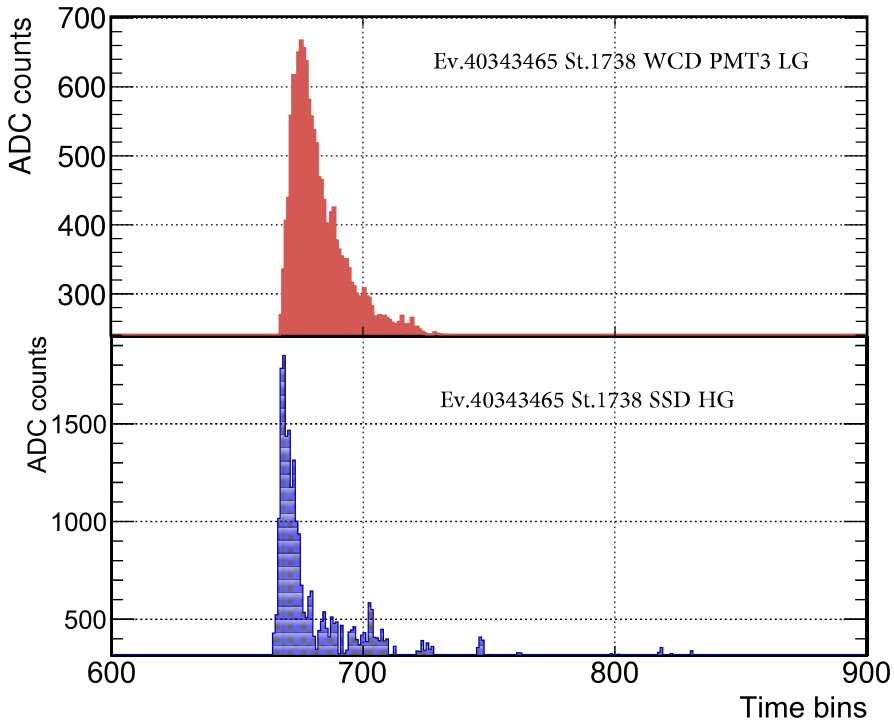


The Engineering Array

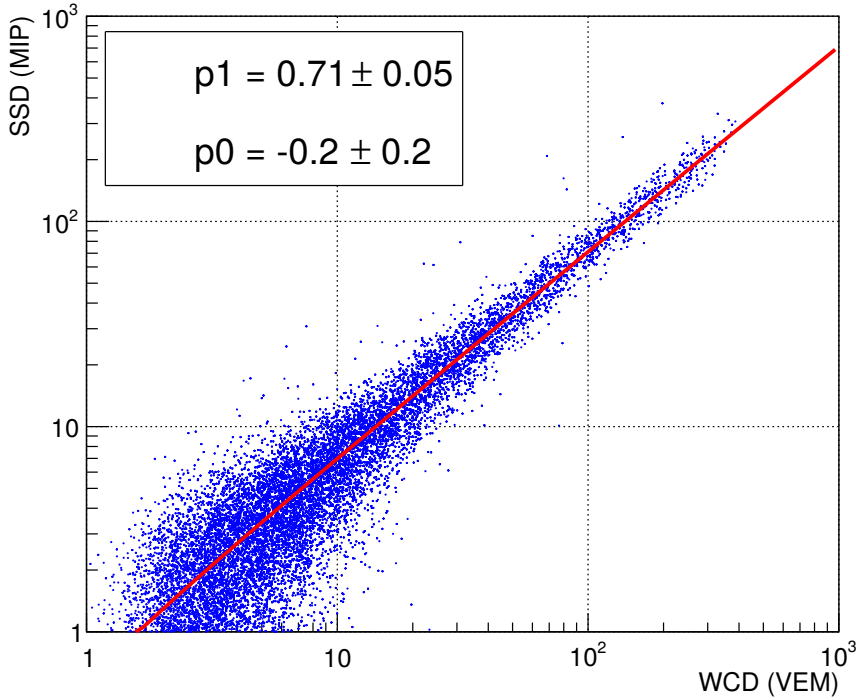


Engineering Array comprising 12 AugerPrime detectors operational since Oct 2016.

The Surface Scintillator Detector

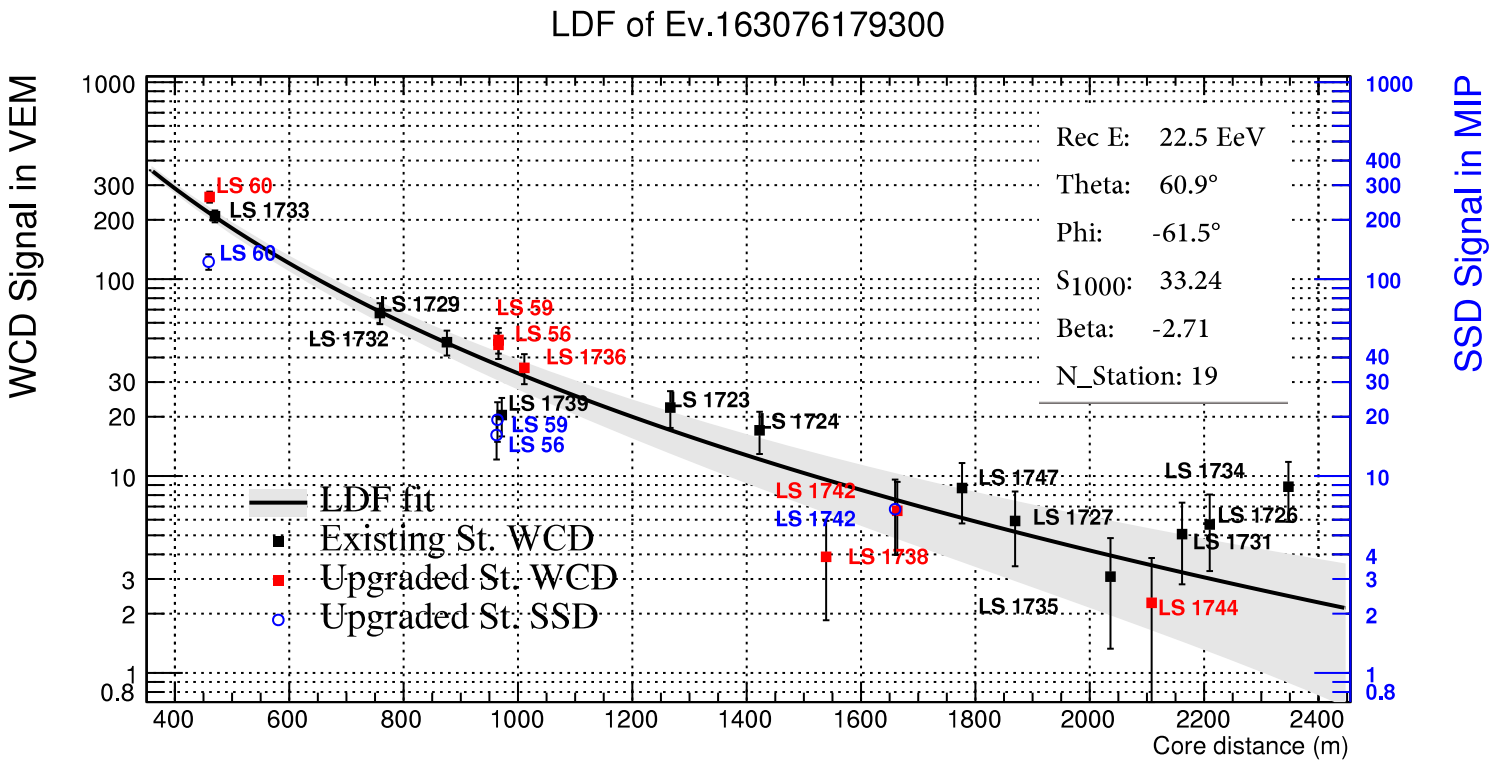


WCD and SSD signals in the same station for an event.



Correlation between the SSD and WCD signals.

The Surface Scintillator Detector

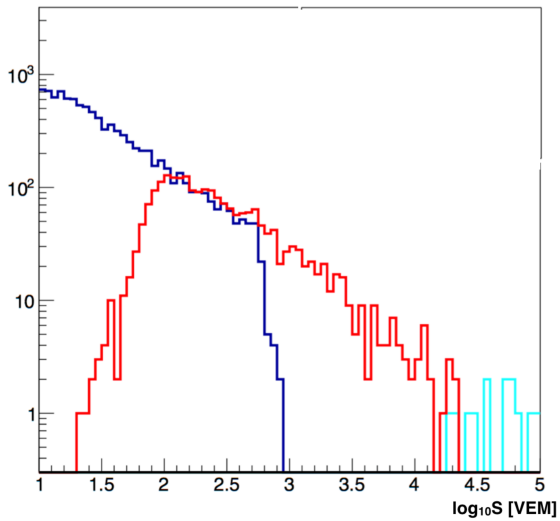


Signals in upgraded local stations (LS) from one event compared with its LDF reconstructed with regular 1500 m array.

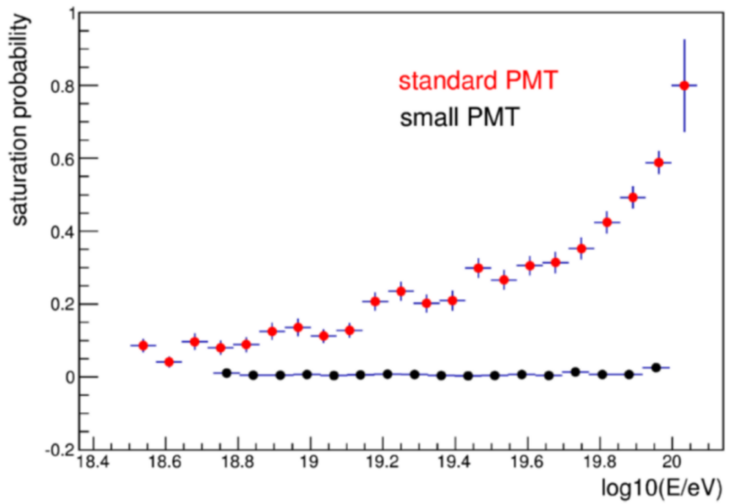
Small PMT in the WCD

Each WCD will have an additional 4th Small PMT (SPMT) with active area $\frac{1}{100}$ of standard PMT, which allows

- dynamic range from fractions of VEM to $>$ 20000 VEM.
- less than 2% saturated events at the highest energies.
- determination of particle densities down to $\sim$ 300 m from the shower core.



Logarithm of charge for single station measured by standard PMT (blue) and SPMT (red -unsaturated, cyan-saturated).



Probability of at least one saturated station/event.

SD Electronics Upgrade

The new electronics will process both WCD and SSD signals and will

- increase the data quality by providing

  faster sampling of ADC traces (40 MHz$\rightarrow$ 120 MHz) better suited for counting muons.

  better absolute timing accuracy from new GPS receivers.

- enhance the local trigger and processing capabilities (more powerful local station processor and FPGA).

- improve calibration and monitoring capabilities of the SD.

- provide a facility for interfacing not only the SSD but also any other additional detectors.

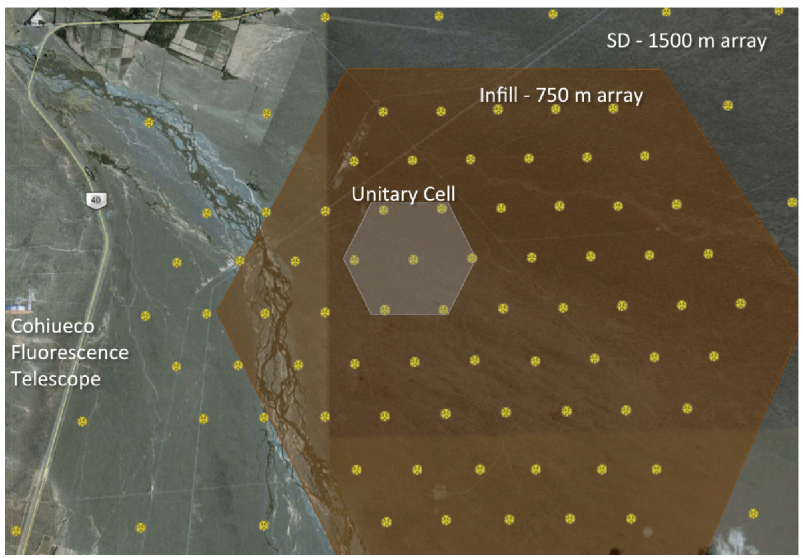
Backwards-compatibility with the current data-set will be maintained.
The deployment will have minimal impact on continuous data taking of the SD.

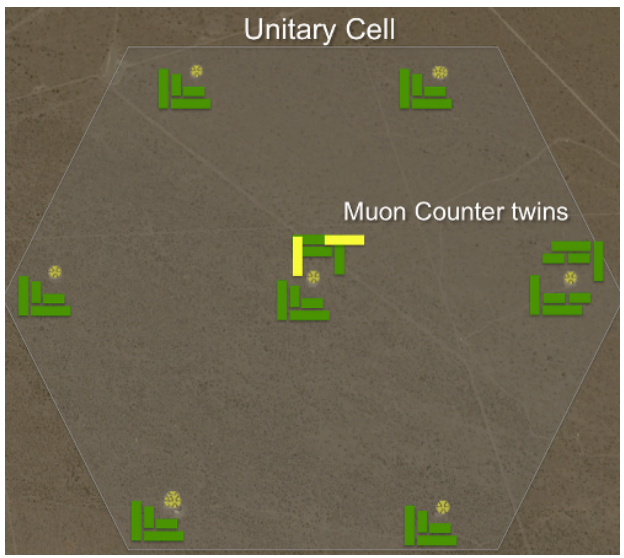
The Underground Muon Detector

UMD design objectives:

- provide direct muon measurement of a sub-sample of showers detected by upgraded SD.
- this serves for fine-tuning of different hadronic models and verification of the methods used to extract shower muon content using the SSD and WCD stations.

The UMD will consist of 61 AMIGA muon detectors (30 m^2) on a 750 m grid in infill array with a total area of 23.5 km^2.





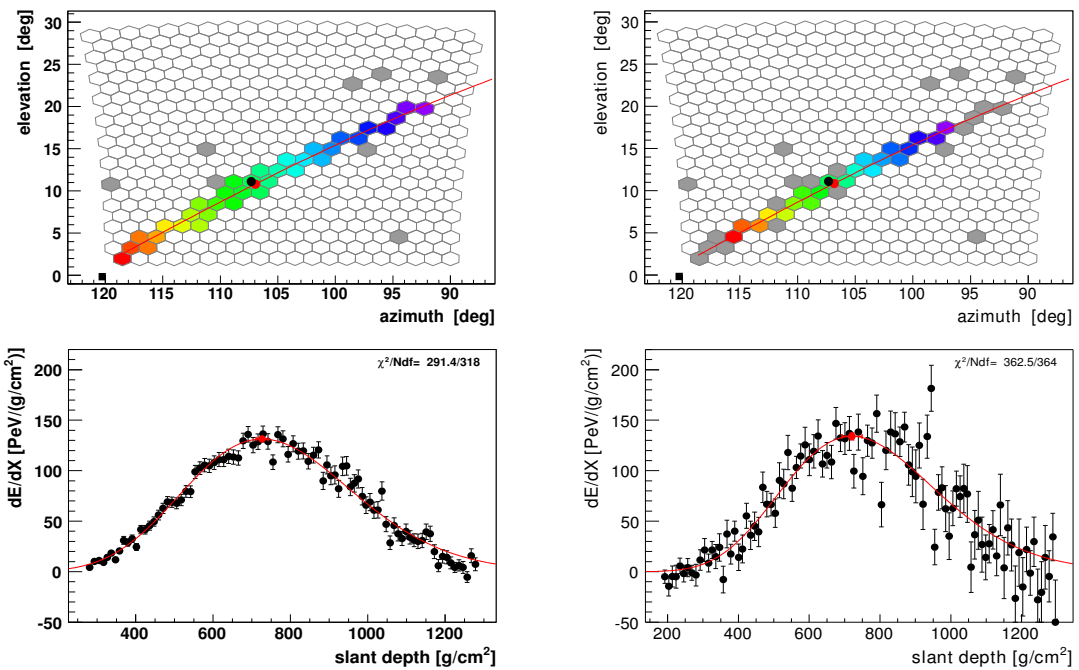
Duty Cycle Extension of the FD

The FD provides exceptional information about extensive air showers (model-independent energy reconstruction and direct measurement of the longitudinal development profiles).

Currently, its main limitation is the duty cycle ($\sim$ 15 %).

Extension of FD operation to the times with larger illuminated fraction of the moon is planned. This will increase the duty cycle to $\sim$ 23%.

Extension achievable by reducing the PMT gain by lowering the supplied HV for such times.



Real FD event with reconstructed energy 70 EeV (left) and the same event after adding random noise corresponding to 40 times higher night sky background.

Summary and Outlook

- The AugerPrime will allow us to
  - understand the origin of flux suppression and astrophysical scenarios of UHECR production/propagation.
  - get information on primary mass composition on an event-by-event basis.
  - determine the proton flux contribution (sensitivity to as small as 10%) at the highest energies, and achieve more accurate particle astronomy.
  - search for new physics at energies beyond the reach of the LHC.
- The AugerPrime Engineering Array is already operational (since Oct. 2016).
  - The upgraded stations with WCDs and SSDs operate with a good stability and signals from EA stations are as expected.
- SSDs are being assembled and tested at several sites. Deployment will begin soon.