New electronics for the surface detectors of the Pierre Auger Observatory

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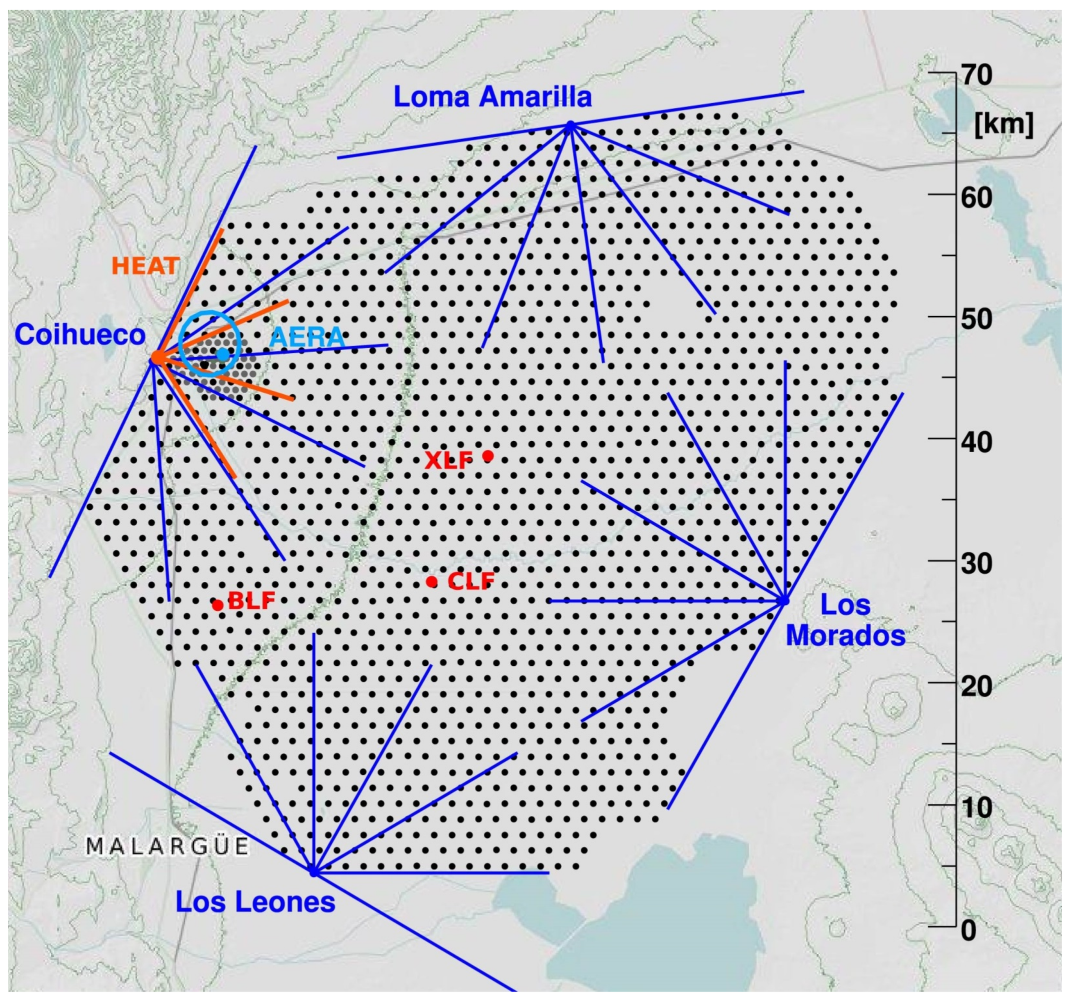


Layout of Pierre Auger Observatory :
dots: locations of WCD on 1.5 km grid
blue lines: FD telescopes field of view

The Pierre Auger Observatory [2]

- cosmic ray measurements for energies above 10^{17}eV
- consists of 1660 water Cherenkov detectors (WCD) and 27 fluorescence detectors (FD) measuring in hybrid mode
- covering > 3000 km^2 near Malargüe, Mendoza, Argentina
- main results published since completion in 2008 are :
  - o flux suppression at energies around 5 x 10^{19} eV [3,4]
  - o strong limits on photon and neutrino flux
  - o energy dependent composition deduced from depth of shower maximum with fluorescence telescope [5,6]
- results can be explained by several different models (see the energy spectrum fit (right))
- further progress in understanding requires determination of cosmic ray composition also at highest energies

→ additional detectors to determine air shower composition
→ upgrade of WCD with complementary scintillators (SSD)
→ upgrade of WCD electronics with new functions = UUB

Maximum rigidity scenario

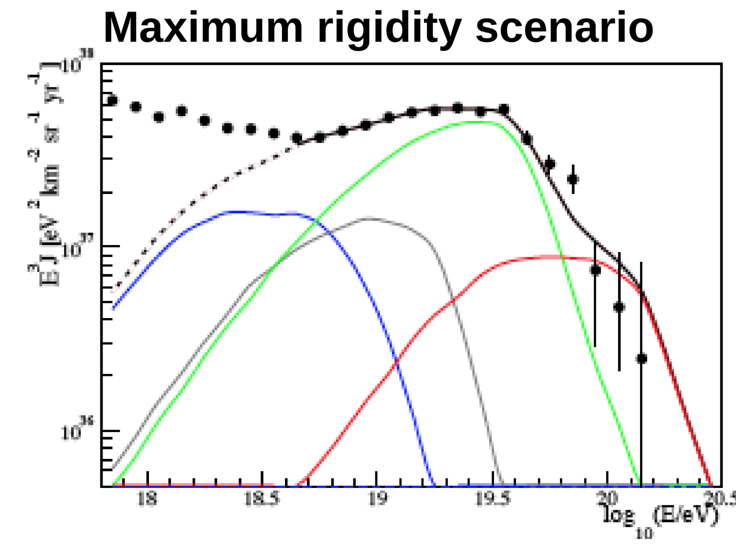
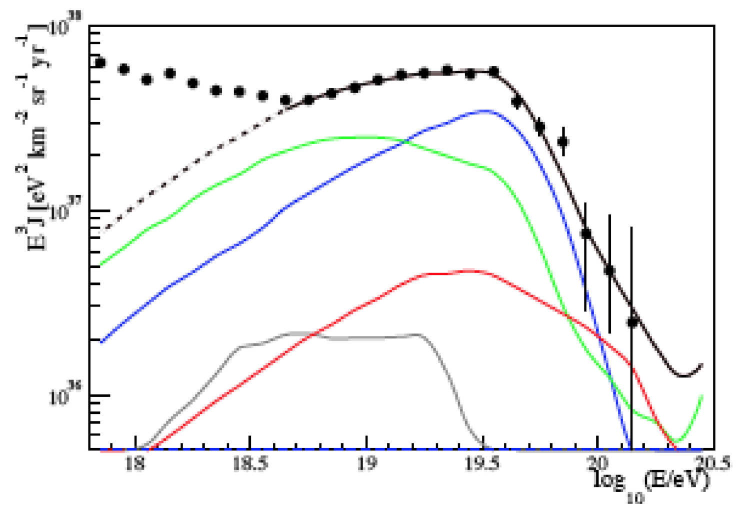
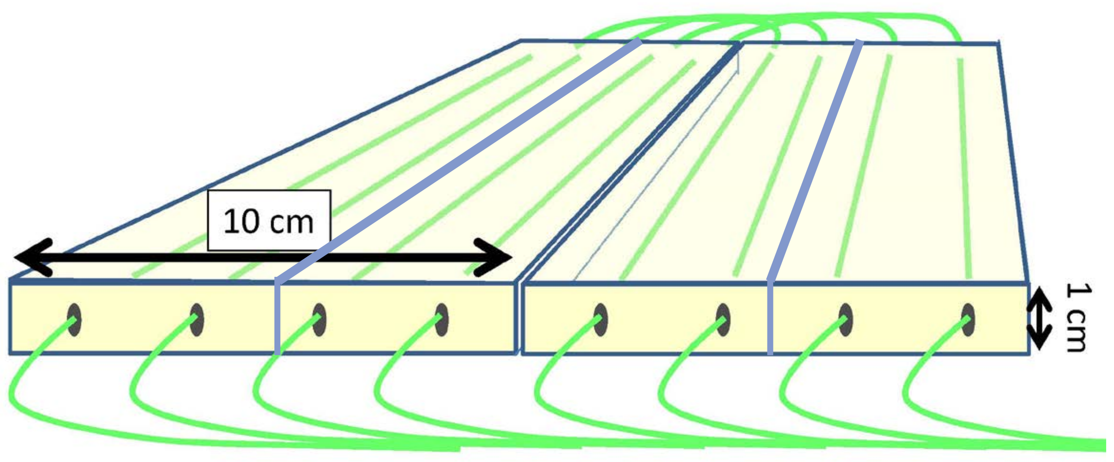


Photo-disintegration scenario



Flux contributions of different mass groups according to different scenarios:
color code: protons, helium, nitrogen, iron

Design of scintillator surface detector (SSD):

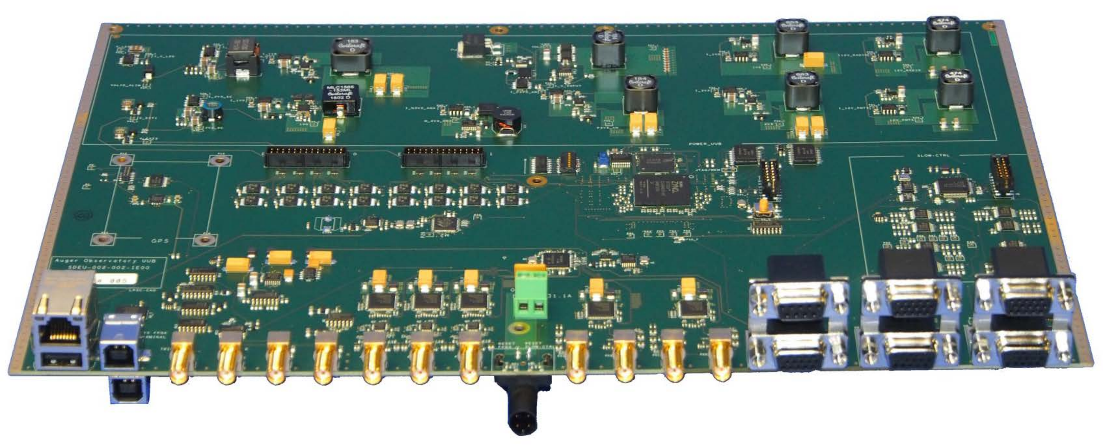


Sketch of scintillator module design:

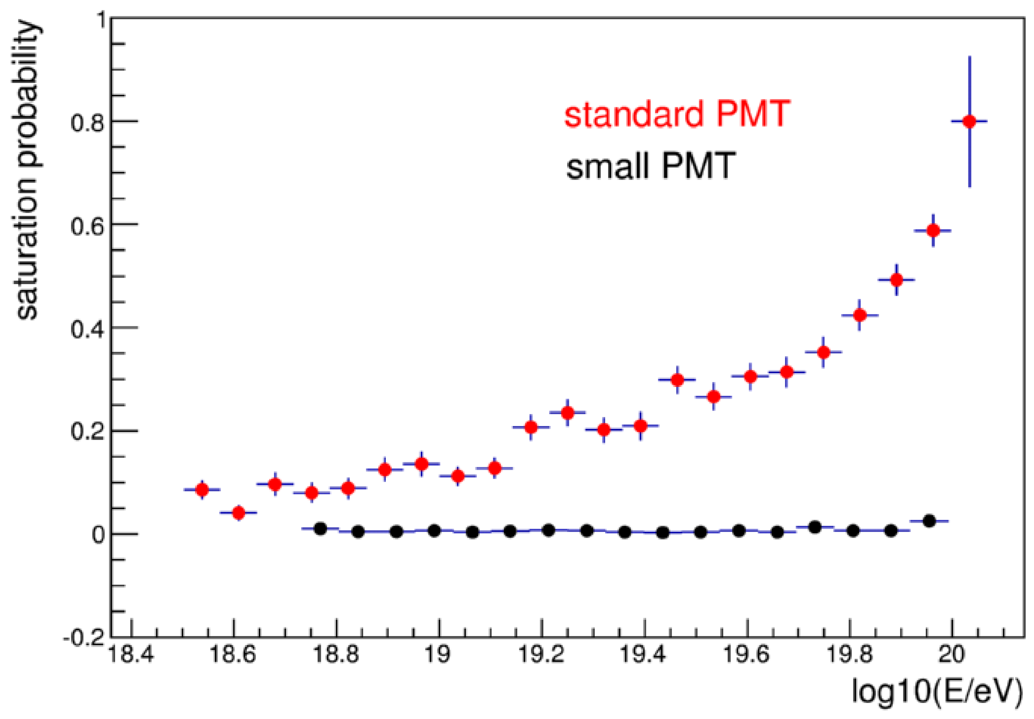
- 2 modules of 2 m^2, made of extruded polystyrene scintillators
- bars are about 1.6 m long, 5 cm wide and 1 cm thick
- readout by wavelength-shifting fibers of 1 mm diameter
- fibers inserted through holes in U shaped configuration for maximum light output and longitudinal uniform light response
- coupled to 8-stage 38 mm PMT (Hamamatsu R9420)
- first prototype detectors mounted on top of existing WCD
- verification of proof of principle and performance tests over > 1 year
- 10 prototypes with improved design will be deployed in spring 2016

WCD with scintillator prototype on top

New electronics in the upgraded unified board (UUB):



New prototype UUB electronics:



Fraction of saturated events vs. energy

- update of 15 year old electronics with present-day technology and seamless integration of SSD
- keep established 9“ PMT of WCD, photovoltaic system and communications
  → max. 10 W average power consumption and 1200 bit/s communications bandwidth per WCD
- dynamic range of 17 (19) bits using high-gain and low- gain channels for WCD (and SSD)
- 5-pole low-pass filter with 60 MHz cut-off; low noise of 440 µV and low power of 540 mW/chan.
- digitization of 10 channels with 12-bit 120 MHz FADC (current sampling is 10-bits and 40 MHz)
- global synchronization with I-Lotus M12M GPS receiver with 2 ns accuracy (after corrections)
- use of modern Xilinx Zynq FPGA with 2 embedded ARM Cortex A9 333 MHz micro-processors
- on board 4 Gbit LP-DDR2 memory and 2 Gbit flash memory
  → much higher processing power for improved and additional trigger algorithm
- MSP430 micro-controller for slow control functions and monitoring of PMT high voltages
  - o slow sampling of 64 analog input lines
  - o control of 16 logic I/O lines and 8 analog outputs
  - o in total 90 monitoring parameters, including temperature and supply voltages and currents
- WCD will be equipped with an additional extra small PMT to reduce fraction of saturated events
  → dynamic range of WCD is extended from about 600 to above 20 000 VEM
- 5 prototypes have been produced and are currently tested in various labs (see left photo)

References:

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[1] The complete Auger author list is found at
http://www.auger.org/archive/authors_2015_02.html
[2] Pierre Auger Collaboration, The Pierre Auger Cosmic Ray Observatory, to be published in Nucl. Instrum. Meth. A
[3] Pierre Auger Collaboration, Phys. Rev. Lett. 101 (2008) 061101
[4] Pierre Auger Collaboration, Phys. Lett. B 685 (2010) 239–-246.
[5] Pierre Auger Collaboration, Phys. Rev. D90 no. 12, (2014) 122005.
[6] Pierre Auger Collaboration, Phys. Rev. D90 no. 12, (2014) 122006..