AugerPrime:
the Upgrade of the Pierre Auger Observatory

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The Pierre Auger Observatory, Phase I

- See previous presentations by:
  Fabio Convenga
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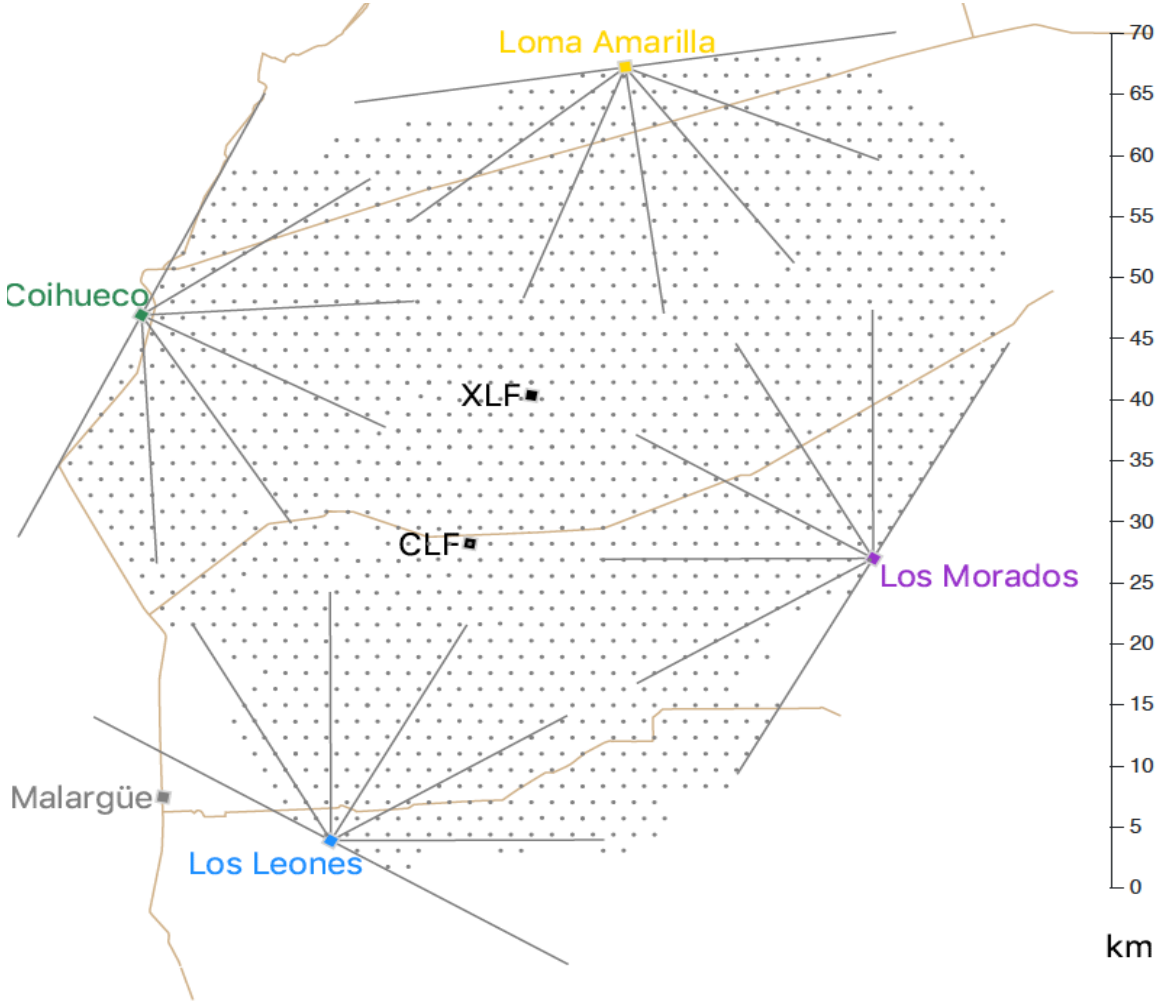
- Hybrid: FD + SD
- 1660 Water Cherenkov Detectors:
  1500 m spacing, 3000 km^2, E > $10^{18.5}$ eV
  750 m spacing, 23.5 km^2, E > $10^{17.5}$ eV
  433 m spacing, 1.9 km^2, E > 63 PeV
- 24 Fluorescence Telescopes
  30^o x 30^o FoV
  + 3 “HEAT” FD high elevation FoV
- Atmospheric monitoring



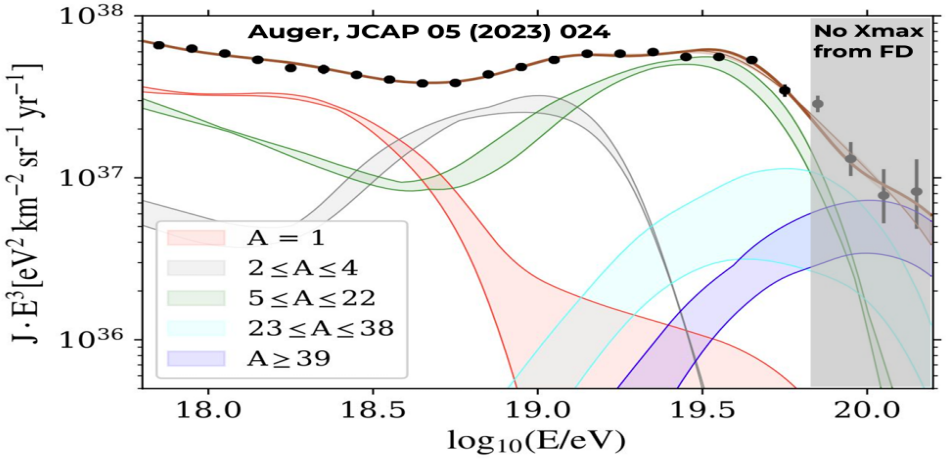
AugerPrime: goals of the Upgrade

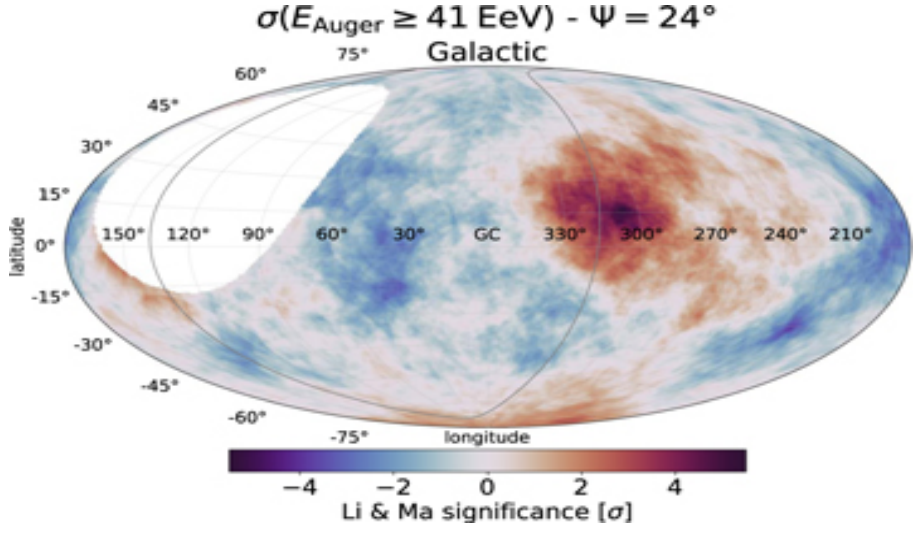
AugerPrime wants to address:

- Nature and origin of UHECRs
- Origin of the flux suppression at highest energies
- Search for UHE neutrinos and photons
- Hadronic interactions at high energies
- “Muon deficit” in simulations

- Increase composition sensitivity (event by event)
- Composition at the highest energies
- Composition-related anisotropies
- Search for fraction of light components
- Continue increasing statistics

- Assess potentiality of future instruments





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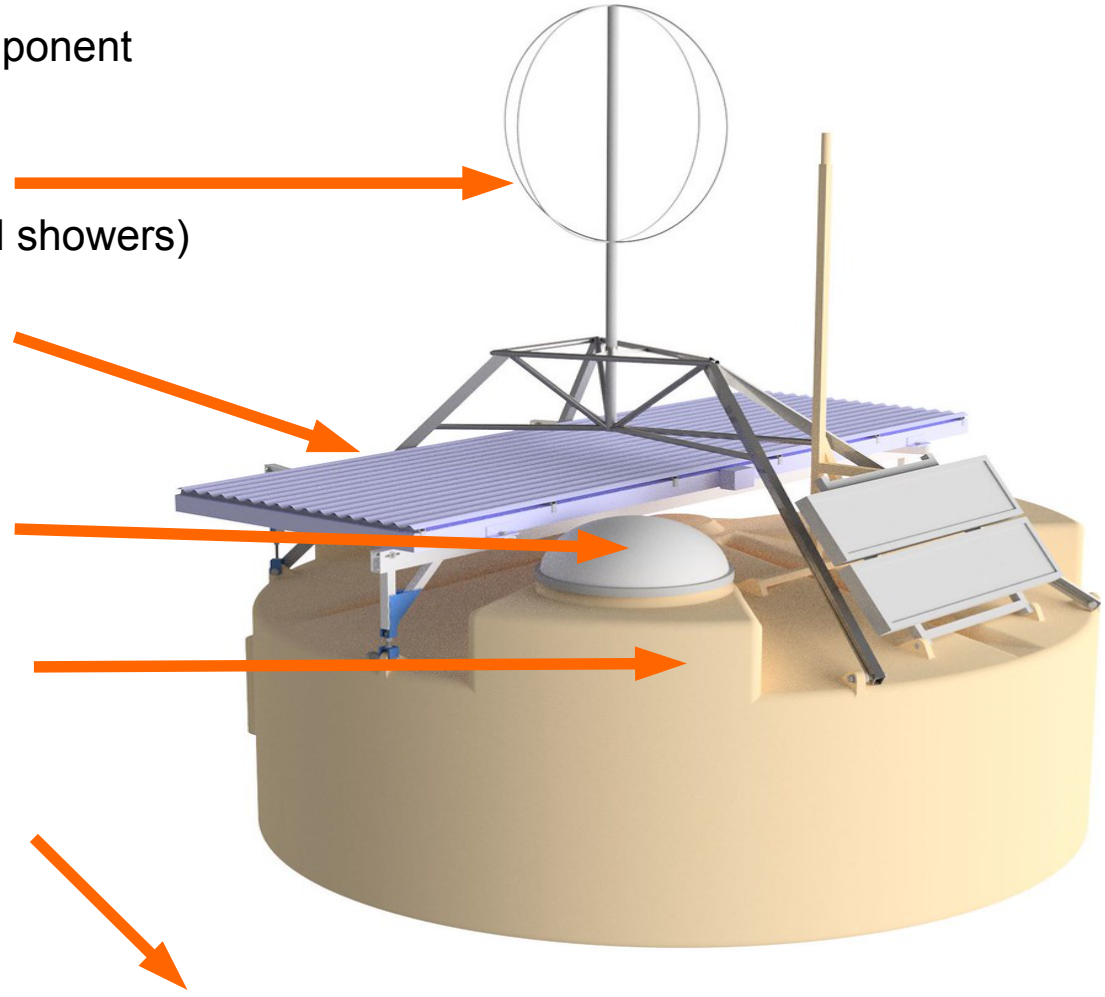
AugerPrime: the Upgrade

Different sensitivity to MUONS and EM component

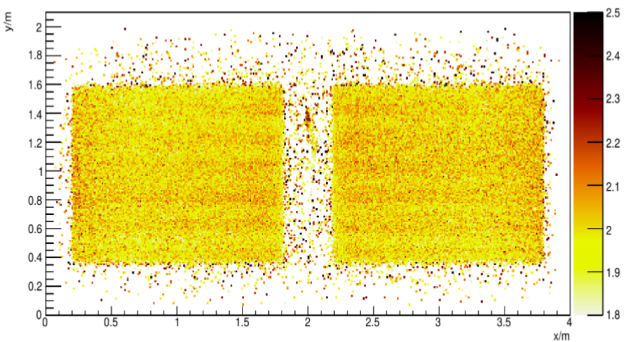
- RD:
  Radio Detectors (sensitive to EM, horizontal showers)
- SSD:
  Scintillation Surface Detectors
  (more sensitive to EM, vertical showers)
- UUB:
  New SD electronics
- SPMT:
  Small PMTs (increased dynamic range)
- UMD:
  Underground Muon Detectors
  (direct measurement of μ at lower E)

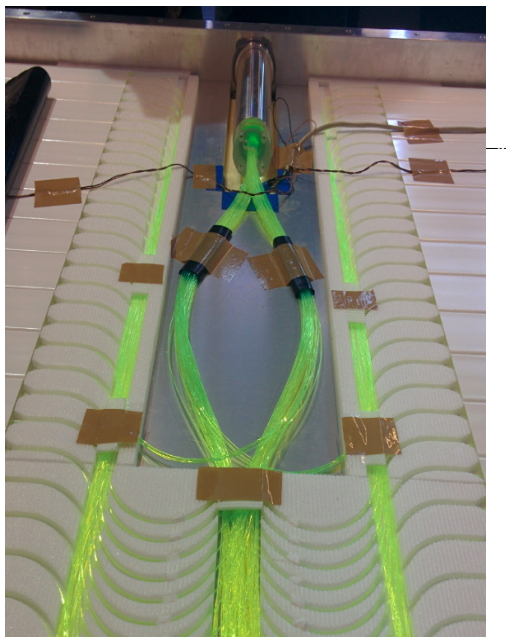


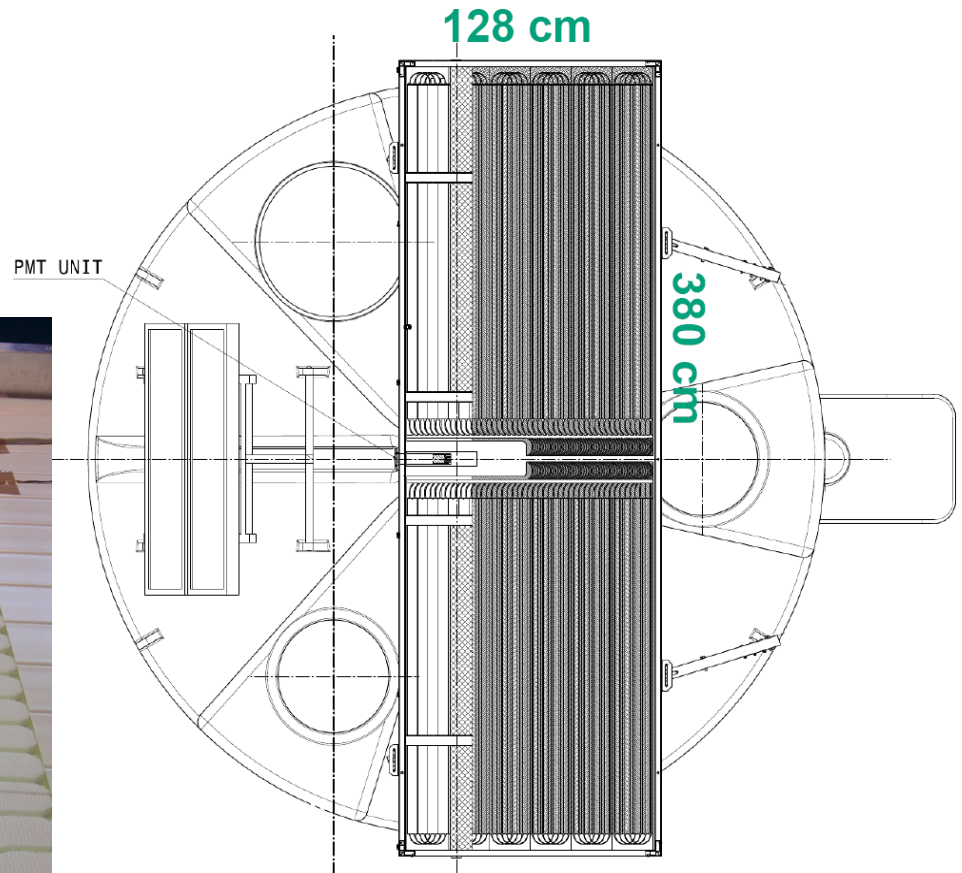
The Scintillation Surface Detector

- Plastic scintillator (extruded polystyrene w. 1% PPO + 0.03% POPOP)
- 2 panels x 24 scintillator bars
- 3.8 m^2 detector area
- 1 mm WLS fiber
- 1.5” PMT Hamamatsu R9420
- Al mechanical structure / support
- Corrugated Al sunroof

- Uniformity (muon hodoscope)
- Resistance to weather conditions

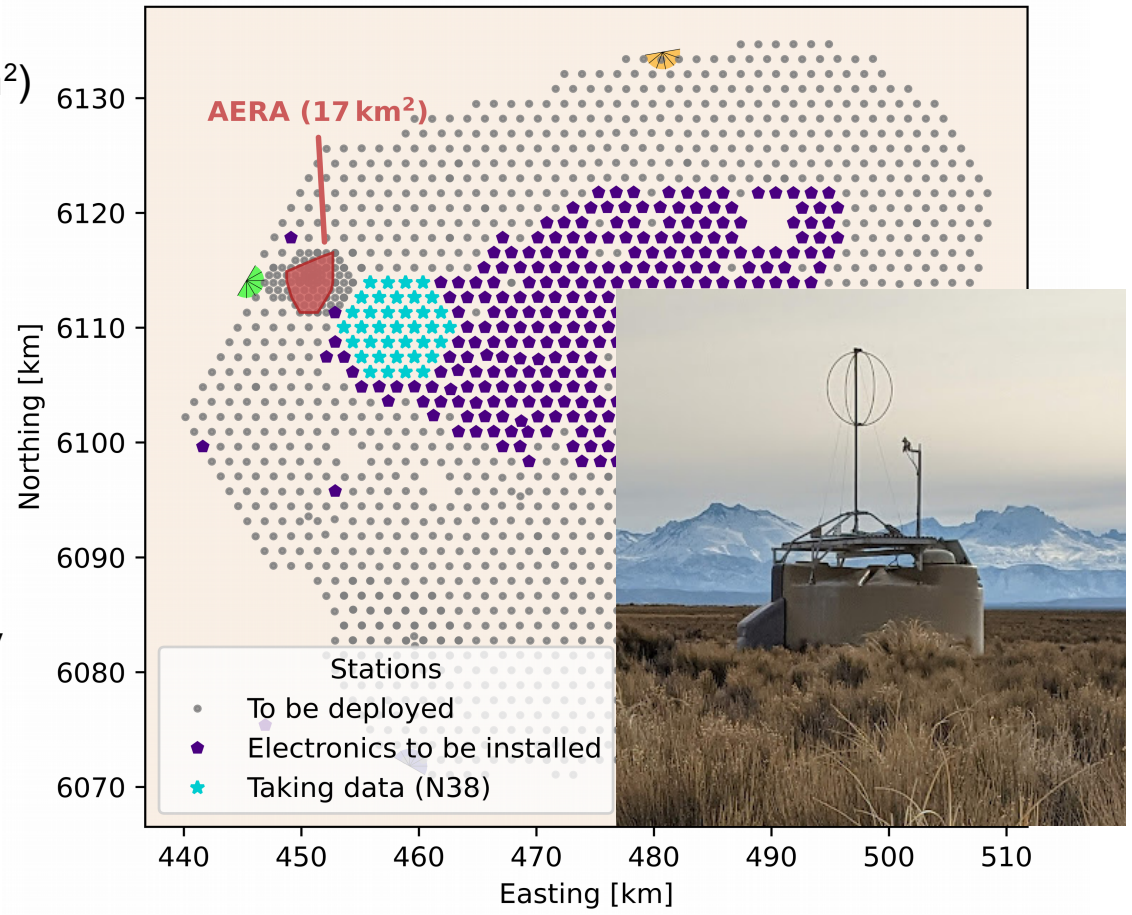






The Radio Detector

- Experience from AERA (150 antennas, 17 km^2)
- Loop antenna (SALLA)
  (short aperiodic loaded loop antenna)
- 30 – 80 MHz
- 2 polarizations
- Good EM component determination for inclined showers
- Expectation: >3000 showers above 10 EeV in 10 years



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The Underground Muon Detector

- Direct muon counting
- 2.3 m underground (540 g/cm^2)
- 3 modules x 10 m^2 per position
- 23 km^2
- Plastic scintillator + WLS fiber
- 64-SiPM array detectors
- Counter / Integrator mode

The Small PMT and Upgraded Electronics

- Small PMT in WCD

  1” Hamamatsu R8619
  20.000 VEM dynamic range
  (250 m for 6 x 10^{19} eV shower)

- New electronics (UUB)

  12 bit, 120 MHz FADC (AD9628)

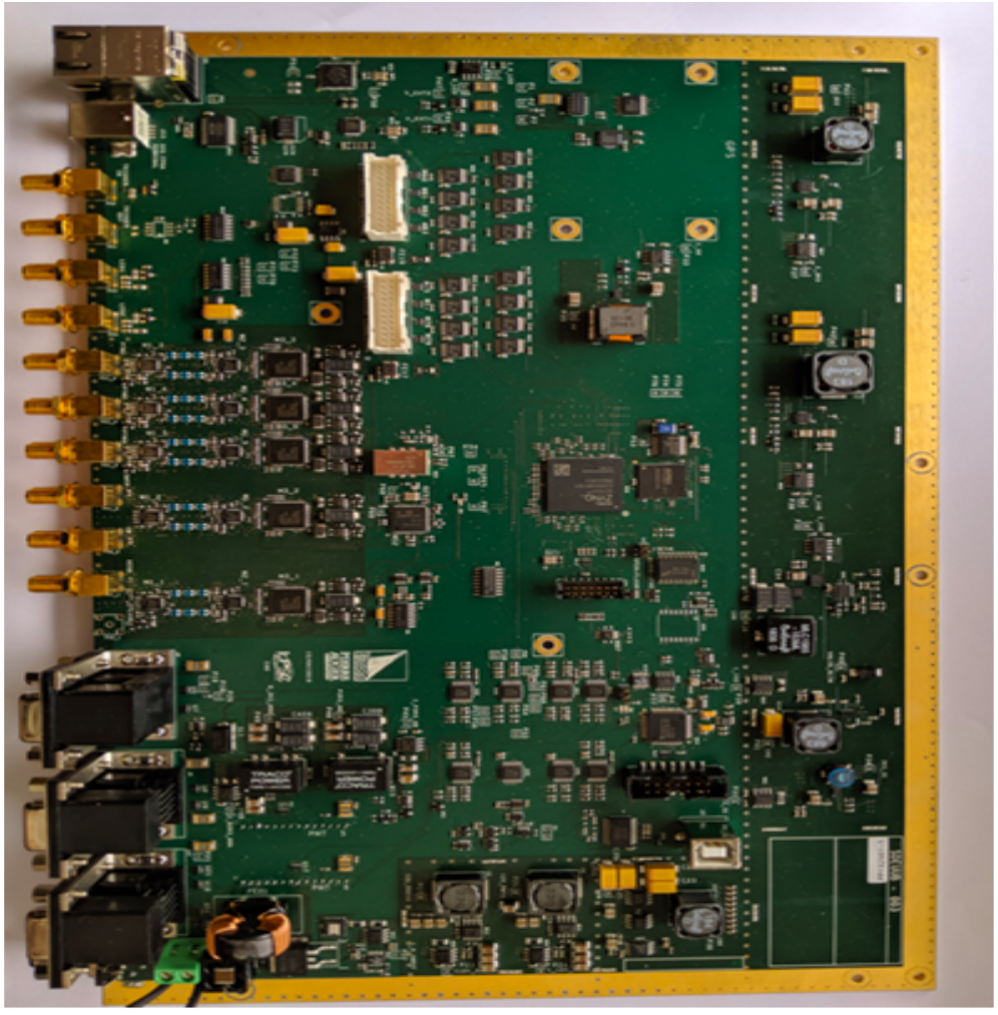
  Input: 3x WCD-PMT, 1x SSD-PMT, 1x SPMT, RD (digital), UMD (digital)

  FPGA Zynq 7020 (+ 2 ARM Cortex A9 processors)

  Old + new triggers

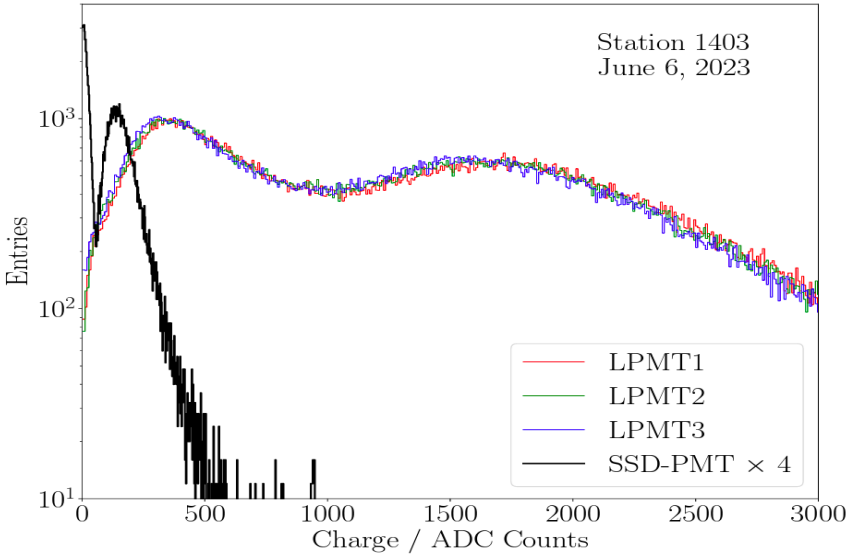
  Backwards compatibility

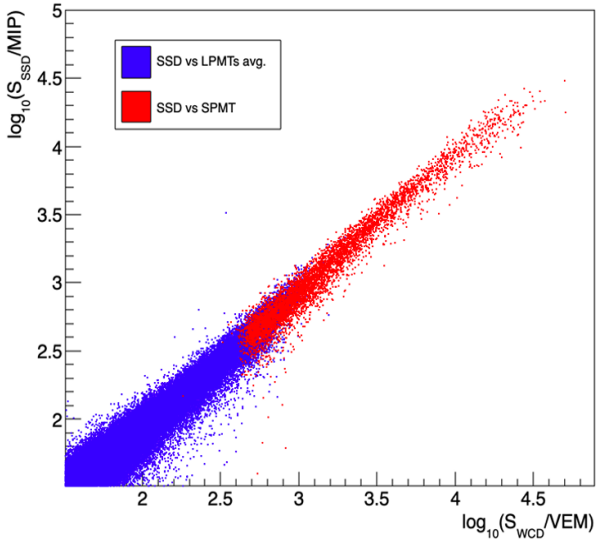
- New, more efficient solar panels

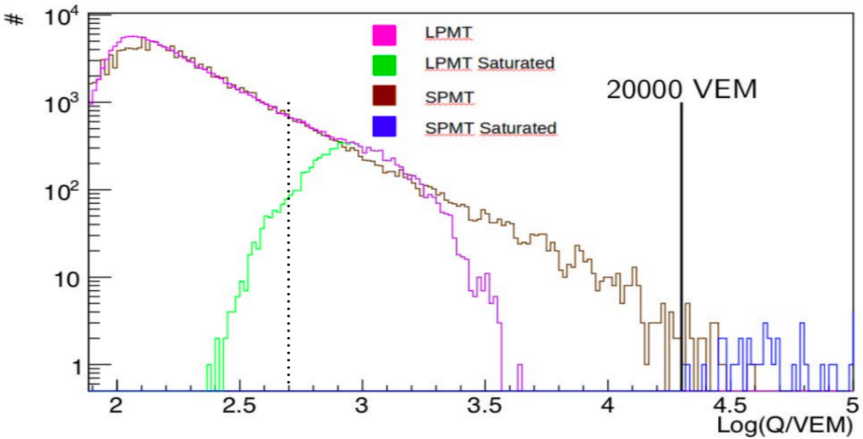


Calibration

- WCD: background muons, VEM charge histograms
  Test-WCD with external muon hodoscope
  Coincidences with SSD for ageing detectors
- SSD: MIP signal, triggered by WCD
- High gain – low gain (32x and 128x) by electronics
- SPMT: small showers in coincidence with large PMTs
- RD: simulations + WCD



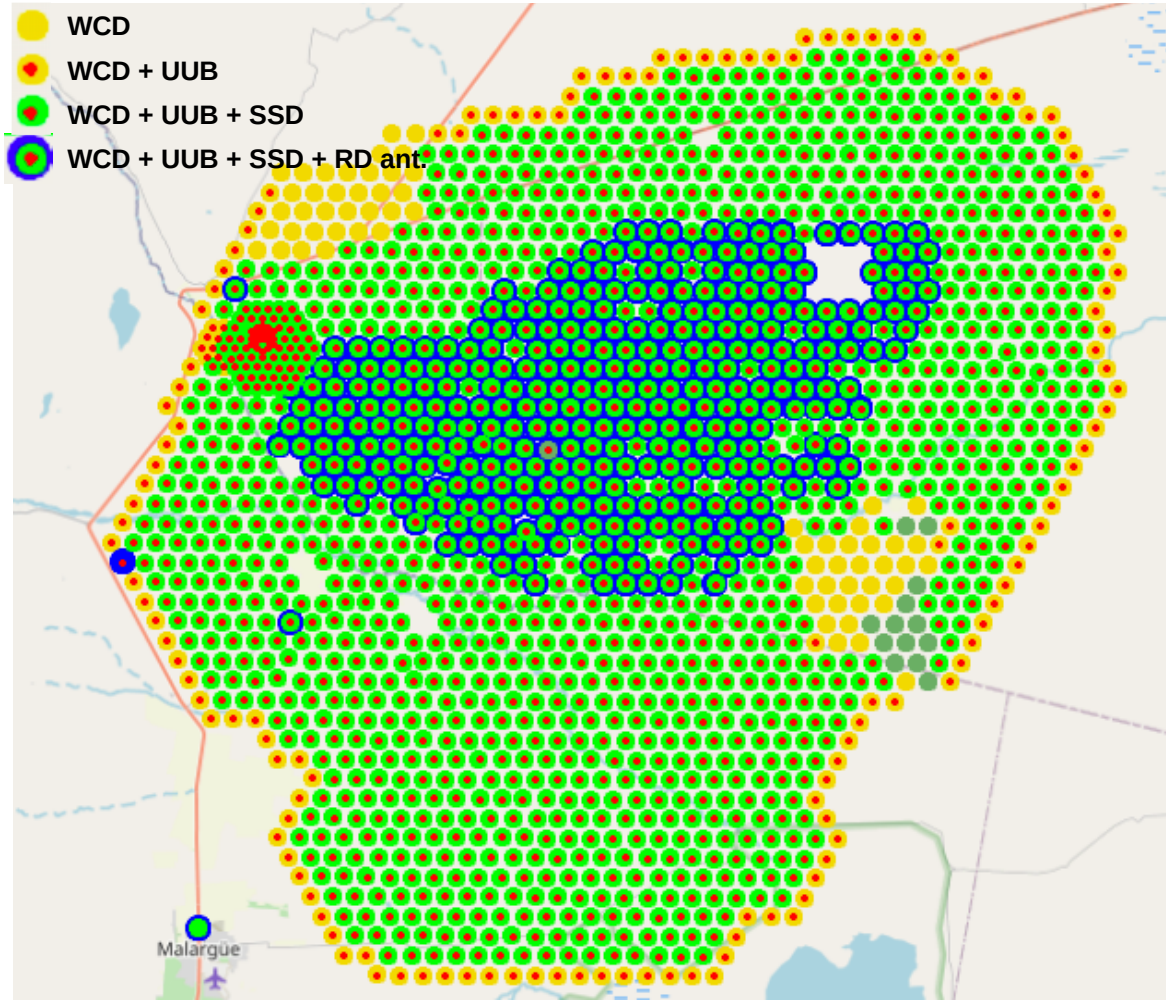




T. Suomijarvii TMEX 2023

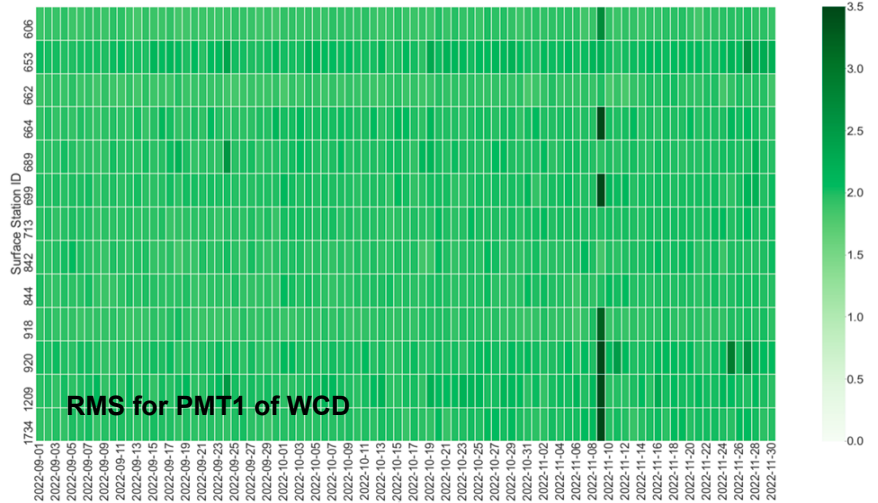
Status of the Upgrade

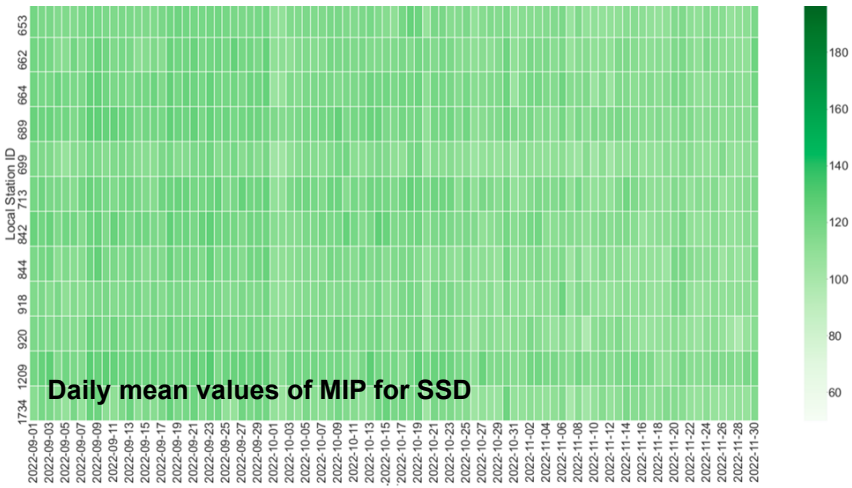
- 1572 UUBs installed
  (all accessible positions completed 6/2023)
- 1436 SSD installed
  (all accessible positions w.o. rim completed 2022)
- 1436 SPMT installed
  (all accessible positions w.o. rim completed 6/2023)
- Installation of RD ongoing (t.b.c. April 2024)
  340 RD antennas installed
  38 RD digitizers installed
- Installation of UMD ongoing (t.b.c. June 2024)
  38/73 UMD installed
- Commissioning studies underway



Commissioning

- Baseline RMS for WCD + SSD - noise levels
- VEM and MIP charges
- Small PMT x-calibration with LPMT signals
- Hexagon of twin detectors for compatibility studies
- Time resolution (twin tanks) ≈ 5 ns
- Lightning sensitivity
- New triggers
- Testing performance of RD digitizers





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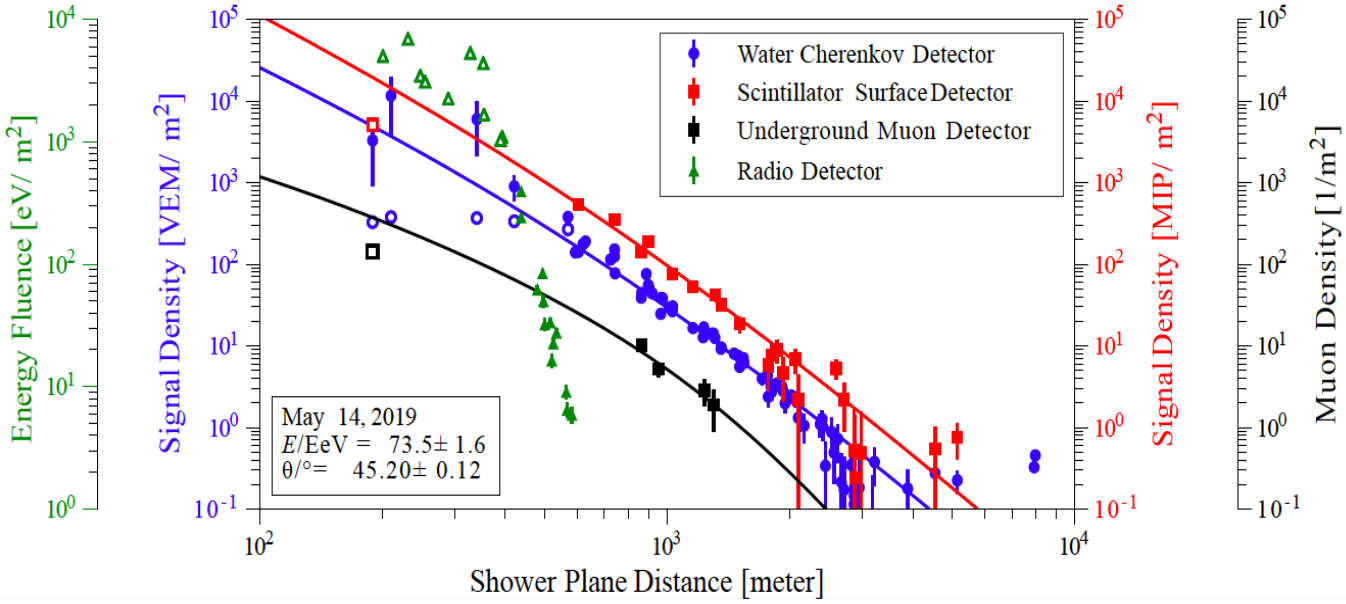
Conclusions and Outlook

- Construction nearly completed
- Data taking not interrupted during construction
- Commissioning underway
- Progress in understanding noise levels, triggers, failure modes
- Multi-hybrid detection
  (WCD + SSD + RD + UMD + FD)
- Expect 10 years of data taking
- Cosmo-geo studies ongoing
- Open access data
- Auger is an ideal platform
  for testing of instruments



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