Earth’s atmosphere

(Cosmic rays interactions in the Earth's atmosphere)

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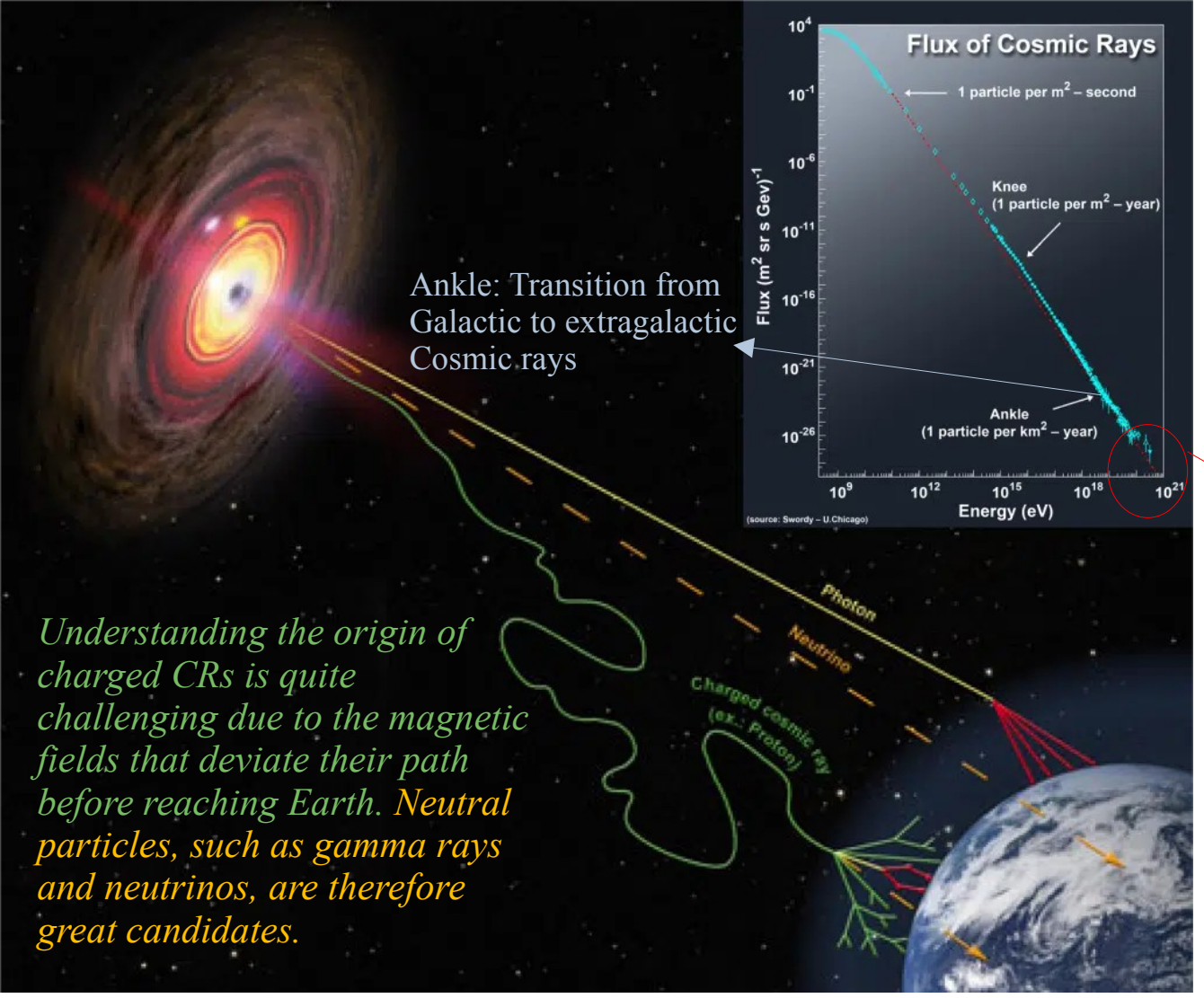
Cosmic rays (CRs)

- are charged particles, mainly protons and helium nuclei

- the flux spectrum exhibits a power law over several orders of magnitude, with several features.

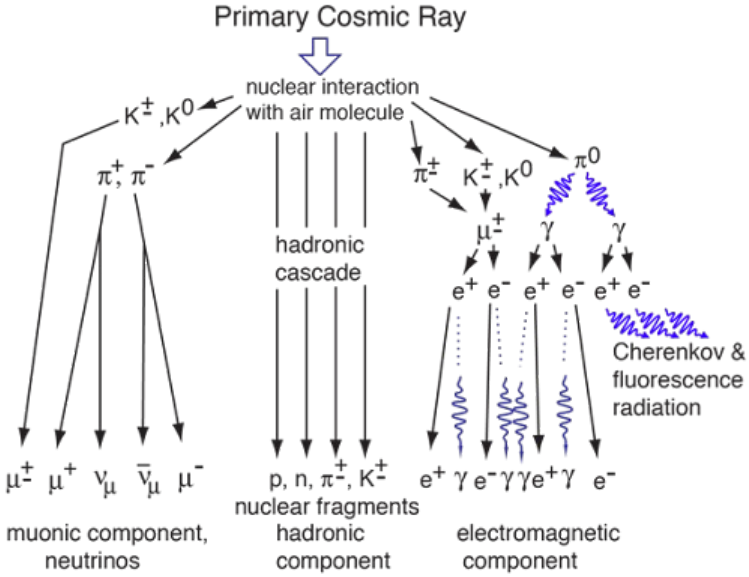
- the Earth's magnetic field acts as a shield, protecting us from CRs

- UHECRs have very low flux, are not isotropic, and are mostly heavy nuclei



Credit: HAP/A. Chantelauze

Where do the UHECRs come from?



PIERRE AUGER OBSERVATORY

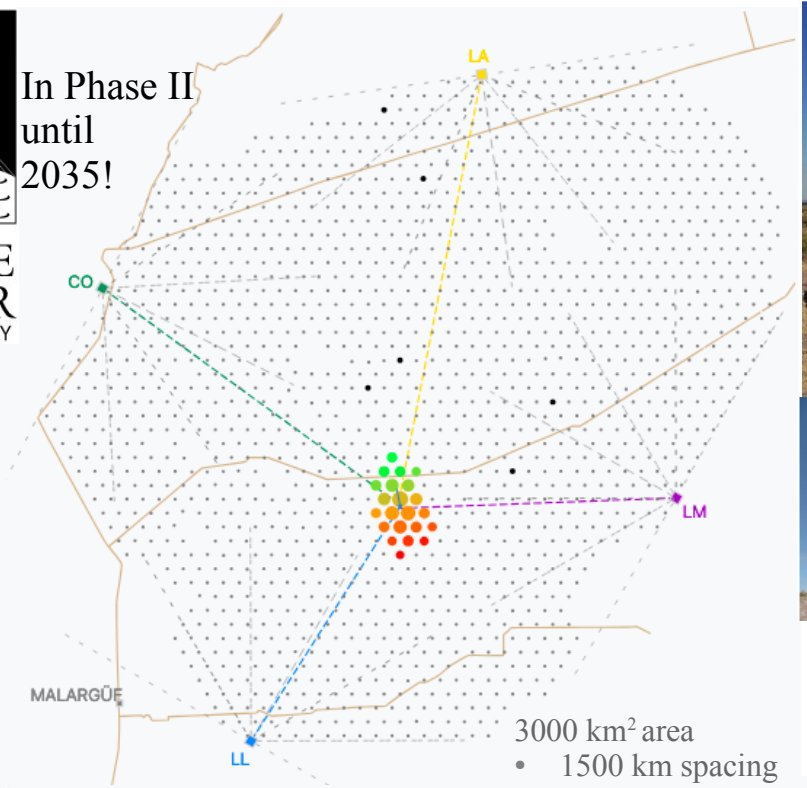
In Phase II until 2035!

SD #1600

FD: #27

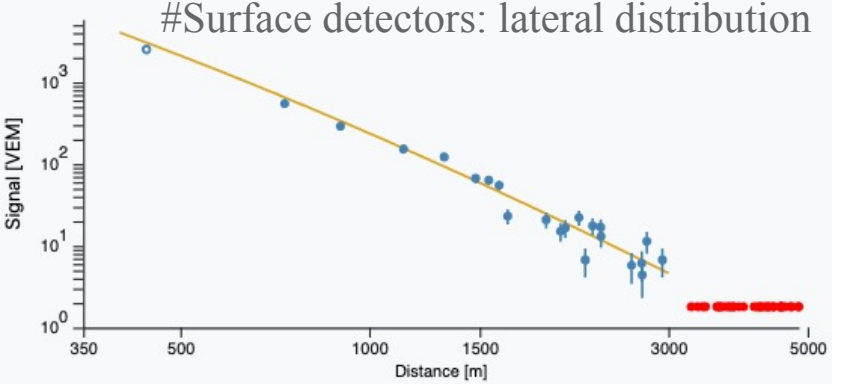
RD

Lidar

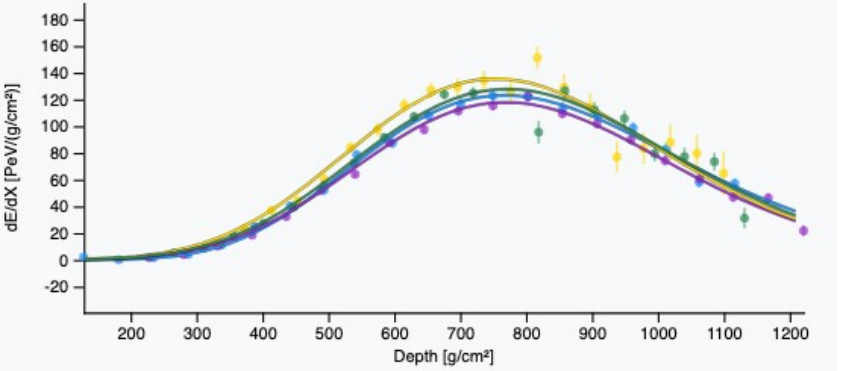


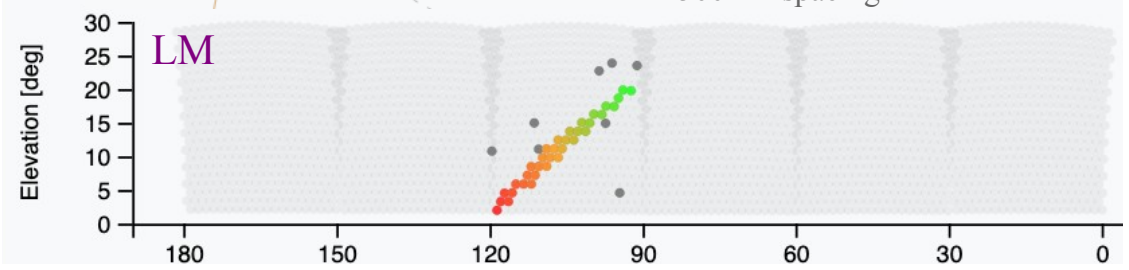
e.g. hybrid event
82±7 EeV | #22
53.8° θ |100.6° φ

#Surface detectors: lateral distribution



#Fluorescence detectors: longitudinal profiles





The Auger Open Data (30%) additionally include scaler data for low energy CRs (10^{10}-10^{12} eV), and atmospheric data, all in CSV format.
https://opendata.auger.org/catalog/

> Catalog of the Highest-Energy Cosmic Rays from Phase I, Pierre Auger Collaboration, *ApJS, 264, 50 (2023)*
> Studies of solar transient events and identification of modulations related to the solar cycle, *PoS(ICRC2019)1147*
> Studies on special ionospheric phenomena called ELVES, *Earth and Space Science, 7 (2020), PoS(ICRC2023)372*
> Study of the atmospheric effect on the FD measurements, *Astroparticle Physics 33 (2010) 108, PoS(ICRC2023)374*

Key messages

- The level of cosmic radiation rises with altitude, an important aspect for pilots and astronauts, and moreover for longer human space travels to e.g. Mars
- Cosmic rays help us to advance our knowledge in particle physics at energies far beyond those reached in the laboratories, and in astrophysical phenomena
- Modern international experiments for indirect measurements of UHECRs are great facilities nowadays for other observations like multi-messenger astronomy (CRs, γ-rays, ν, gravitational waves) and atmospheric monitoring, or space-weather
- Observing CRs induced air showers with increased statistics at the highest energies is the goal for the next decade, including the full sky coverage by space-based observations
  (e.g. JEM-EUSO for Extreme Universe Space Observatory, POEMMA for Extreme Multi-Messenger Astrophysics)

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Thank you!