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Exploring the Universe with high-energy neutrinos

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70th Workshop on Gravitational Waves and Numerical Relativity
APCTP

Oct 5, 2023

NSF

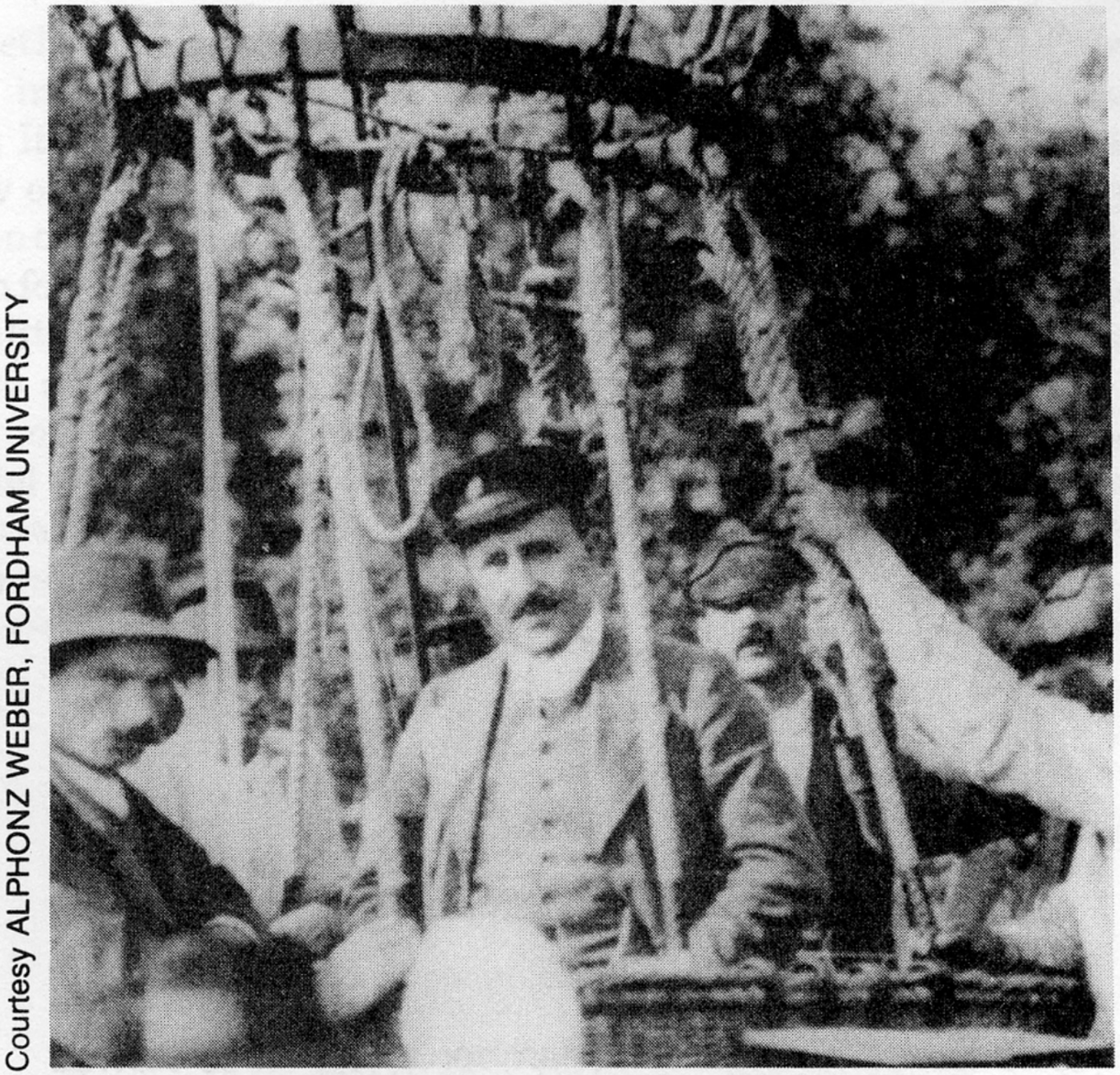
NRF
National Research Foundation of Korea

Outline

- Motivation
  - Cosmic ray mystery
- Neutrino Telescopes and IceCube
- Selected Results and Searches
  - Astrophysical Neutrino Search & Search for BSM Physics & Solar Atmospheric Neutrinos
- Outlook
  - IceCube Upgrade and overcoming the neutrino pointing challenge
  - An observatory for the next decades
- Conclusions

The Cosmic Ray Mystery

Victor Hess



Courtesy ALPHONZ WEBER, FORDHAM UNIVERSITY

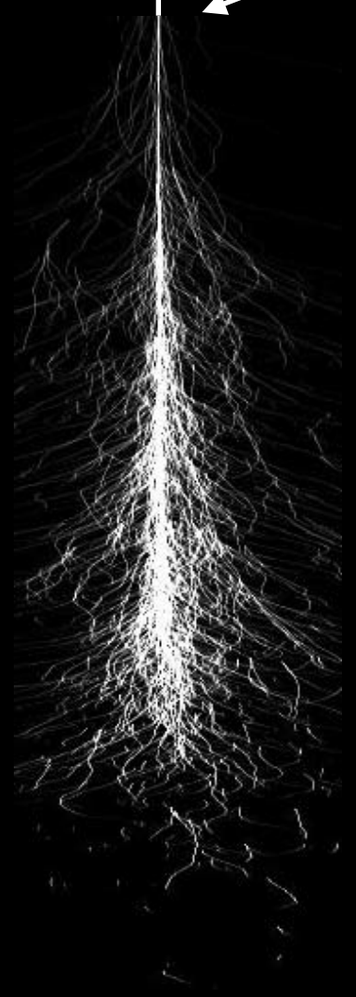
Victor Hess surrounded by Austrian peasants after landing from one of his ascensions a few weeks before his record breaking ascent in the Böhmen.

primary particle

stratospheric balloon

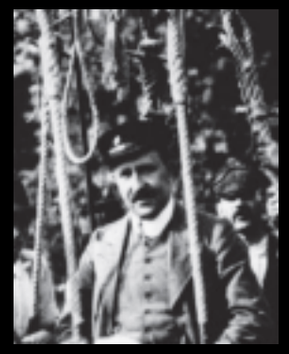
~40km

collision point of
primary particle



~20km altitude

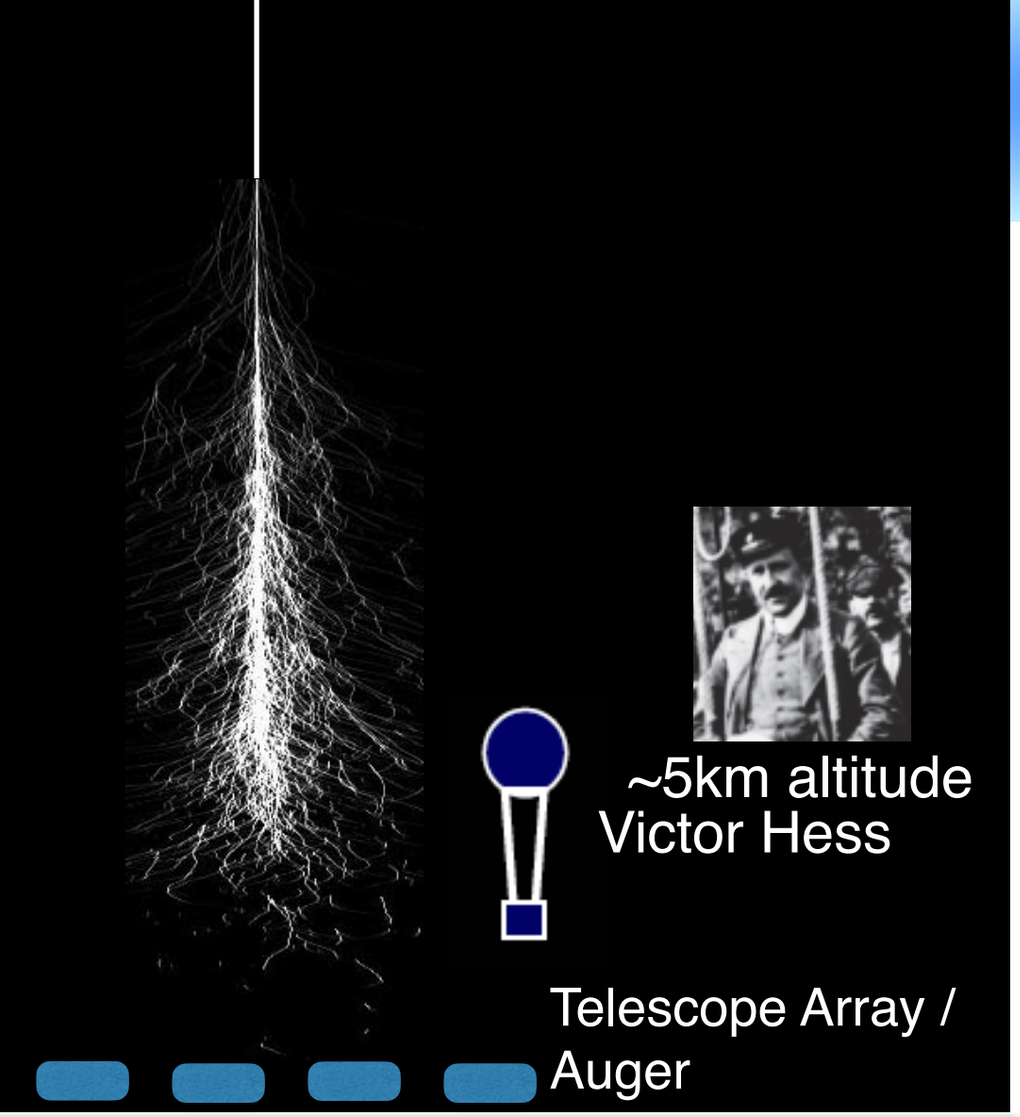
~5km altitude
Victor Hess



Victor Hess 1912

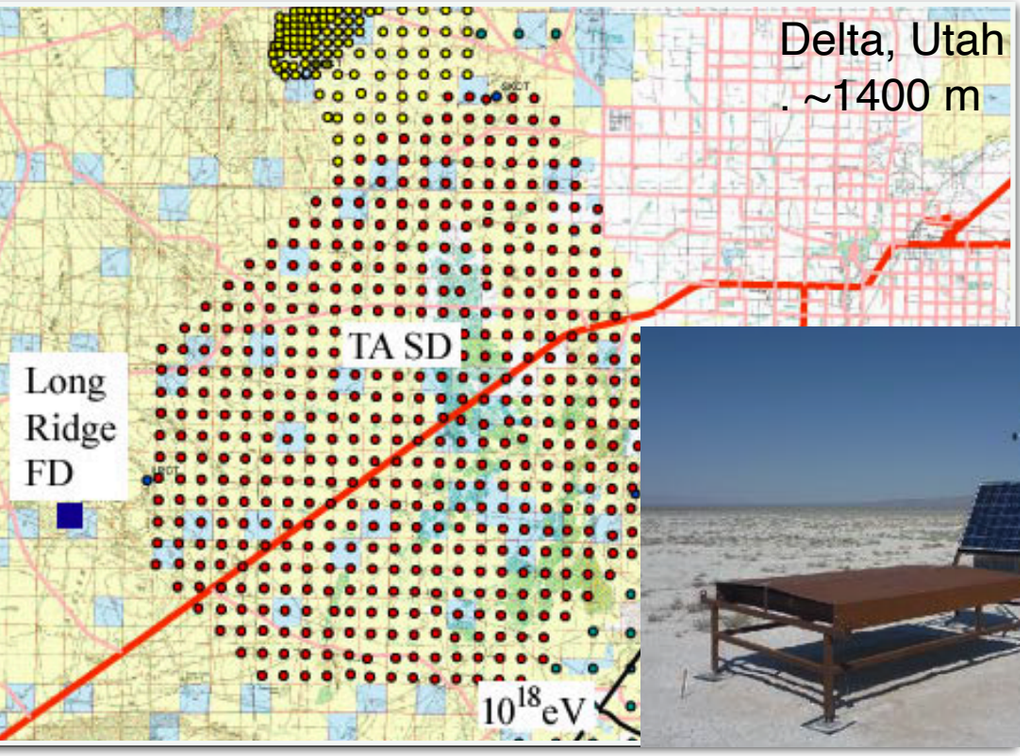
Surface of the Earth

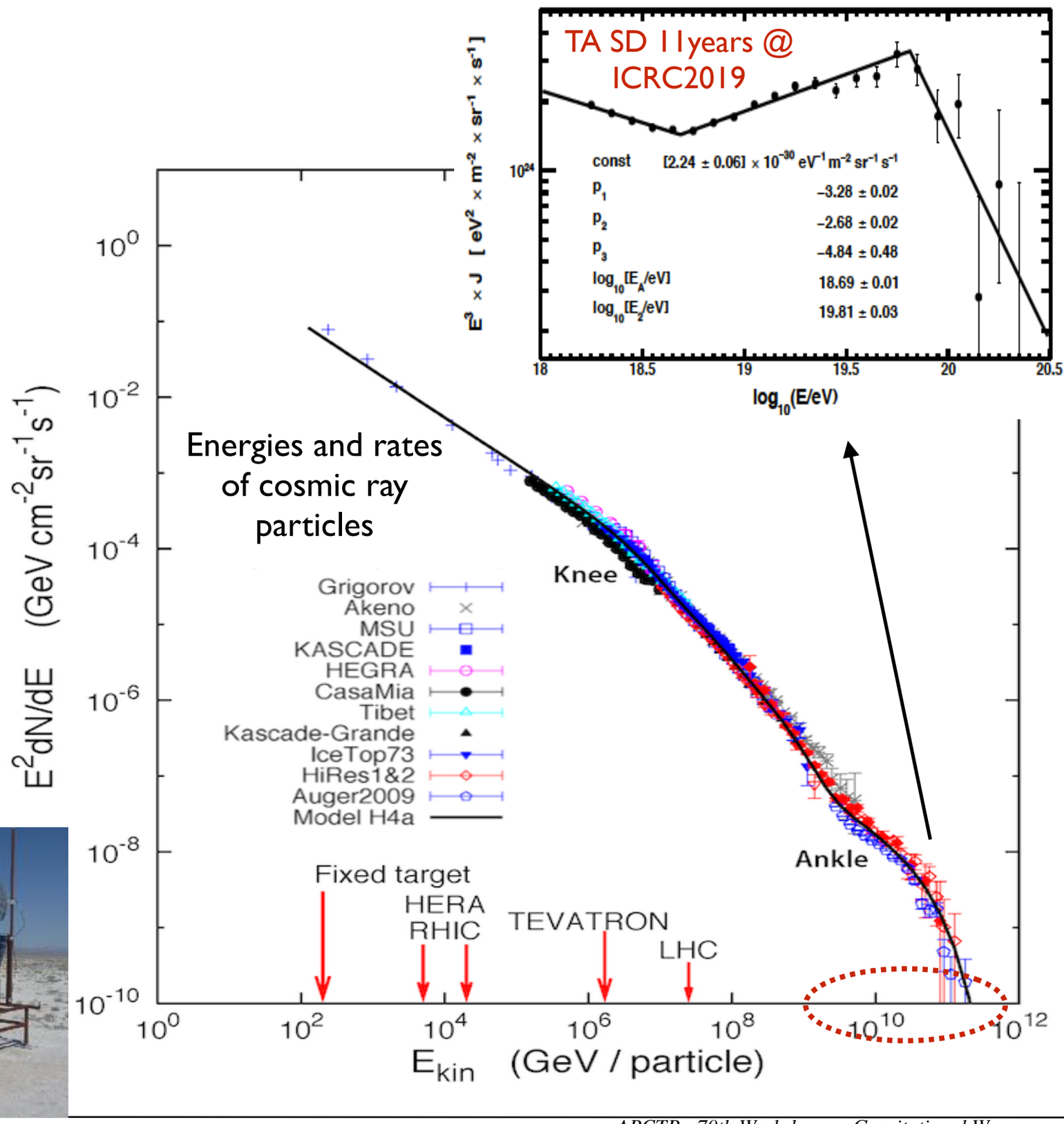
Cosmic Rays



~5km altitude
Victor Hess

Telescope Array / Auger

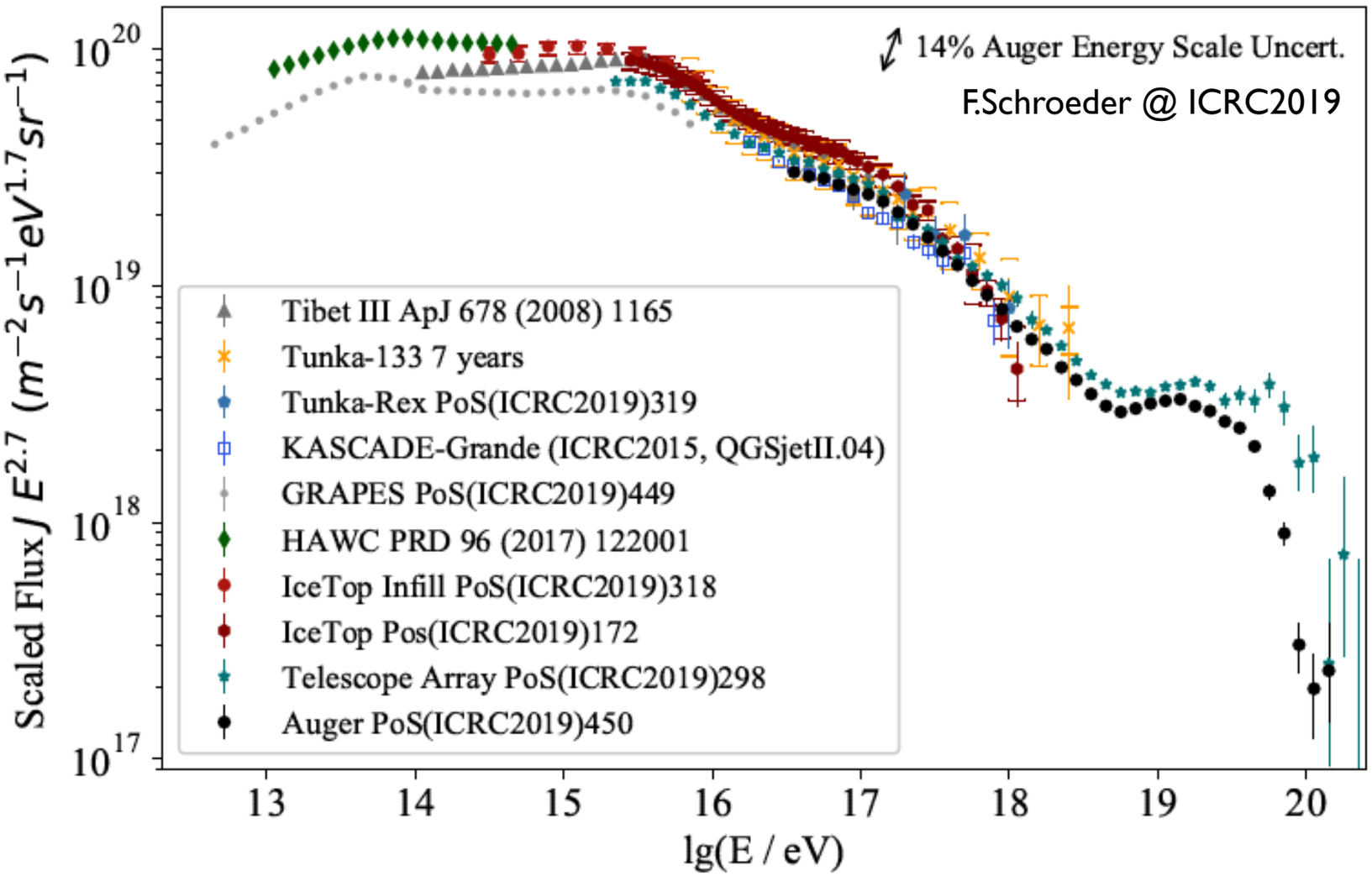




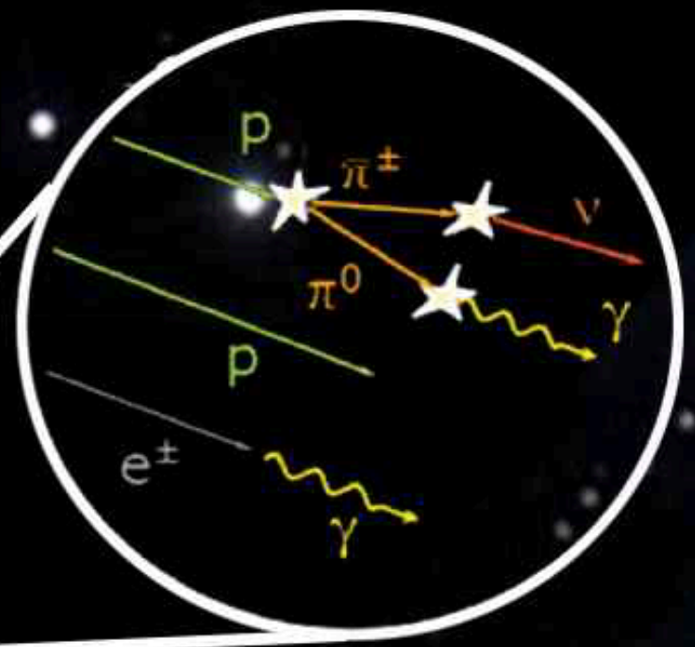
Cosmic Rays

Cosmic rays have been observed with energies up to 10^{20}eV (100EeV) or 10^7 LHC beam energies

- Cosmic ray spectrum extremely well measured (TA, Auger, …)
- Where are they coming from ?
- What cosmic sources accelerate these particles to energies well beyond that reached at LHC ?



cosmic rays
+ neutrinos



Cosmic Ray Sources
- Active Galactic Nuclei (AGN)
- Gamma Ray Bursts (GRB)
- Supernovae (SN)
- Galaxy Clusters
- Unknown

Victor Francis Hess

Discovery of cosmic-rays

1936

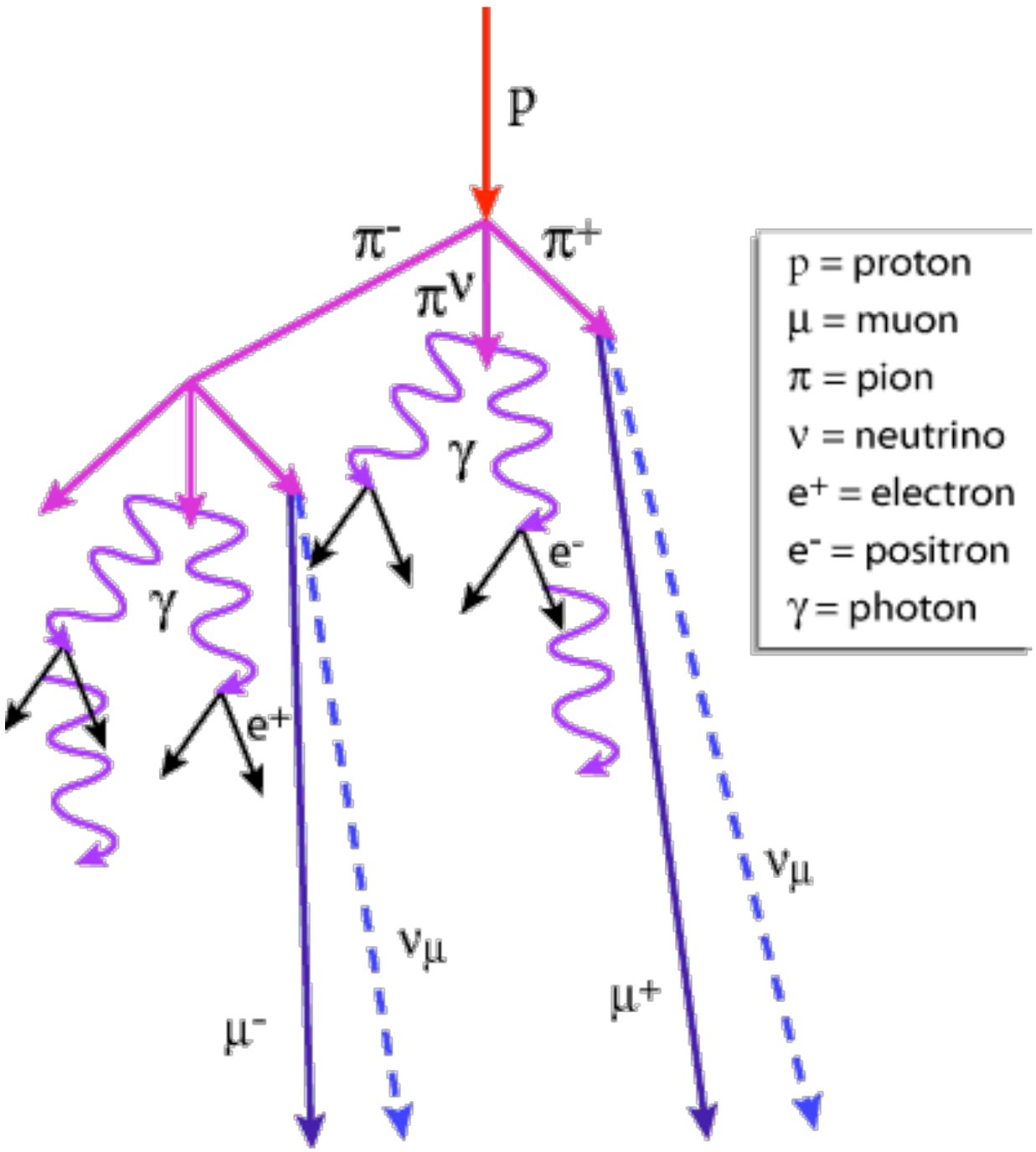
γ

ν

P

Astrophysical Messengers

Atmospheric Neutrinos



Cosmic rays interact in the upper atmosphere:

$p + A \rightarrow \pi^{\pm} (K^{\pm}) +$ other hadrons ...

$\pi^+ \rightarrow \mu^+ \nu_\mu \rightarrow e^+ \nu_e \nu_\mu \nu_\mu$

IceCube Collaboration Phys. Rev. Lett. 110 (2013) 151105 /1212.4760v2