

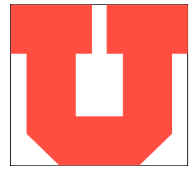


Auger latest results

Miguel Mostafá

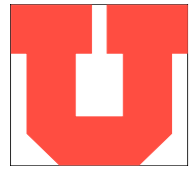
UC Davis Physics Colloquium
April 21, 2008





Outline

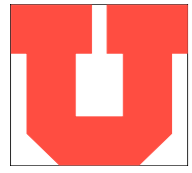
- Brief **history** of UHECRs
- Intro to *Particle Astrophysics*
- Observation **techniques**
- **The Pierre Auger Observatory**
 - Latest **results**
 - **Current** analysis
- Conclusions and **Prospects**



History

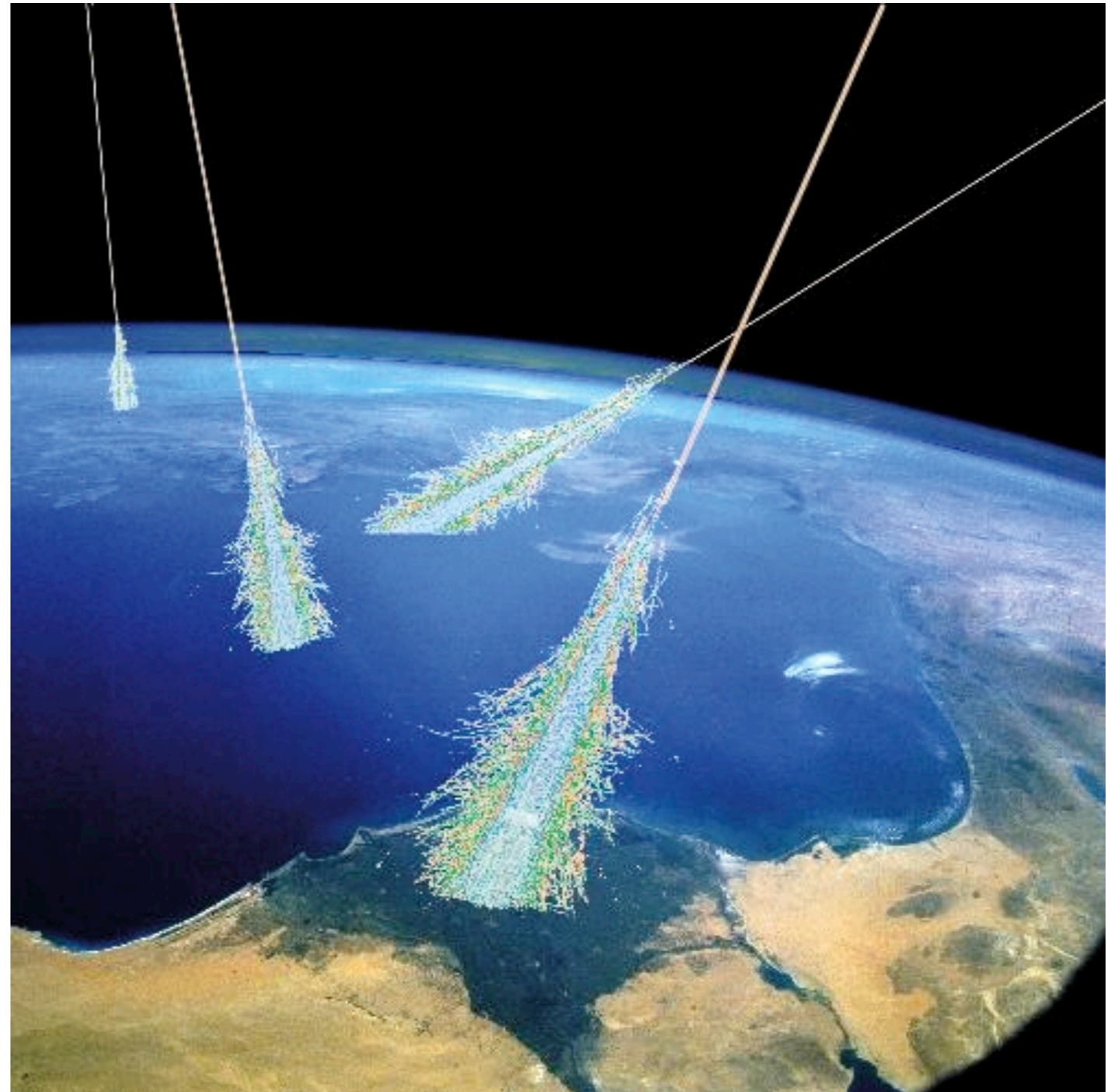
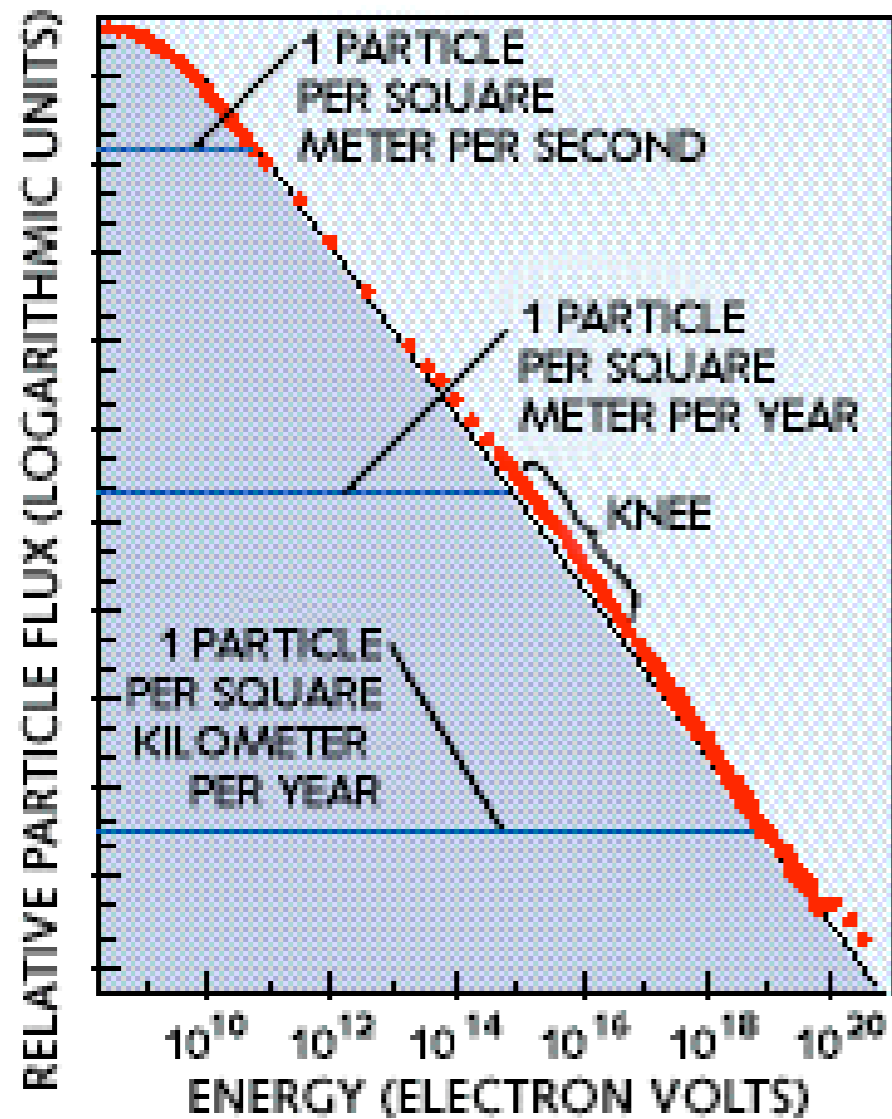
- 1912: **Victor Hess** discovers cosmic rays

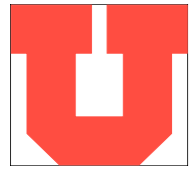




History

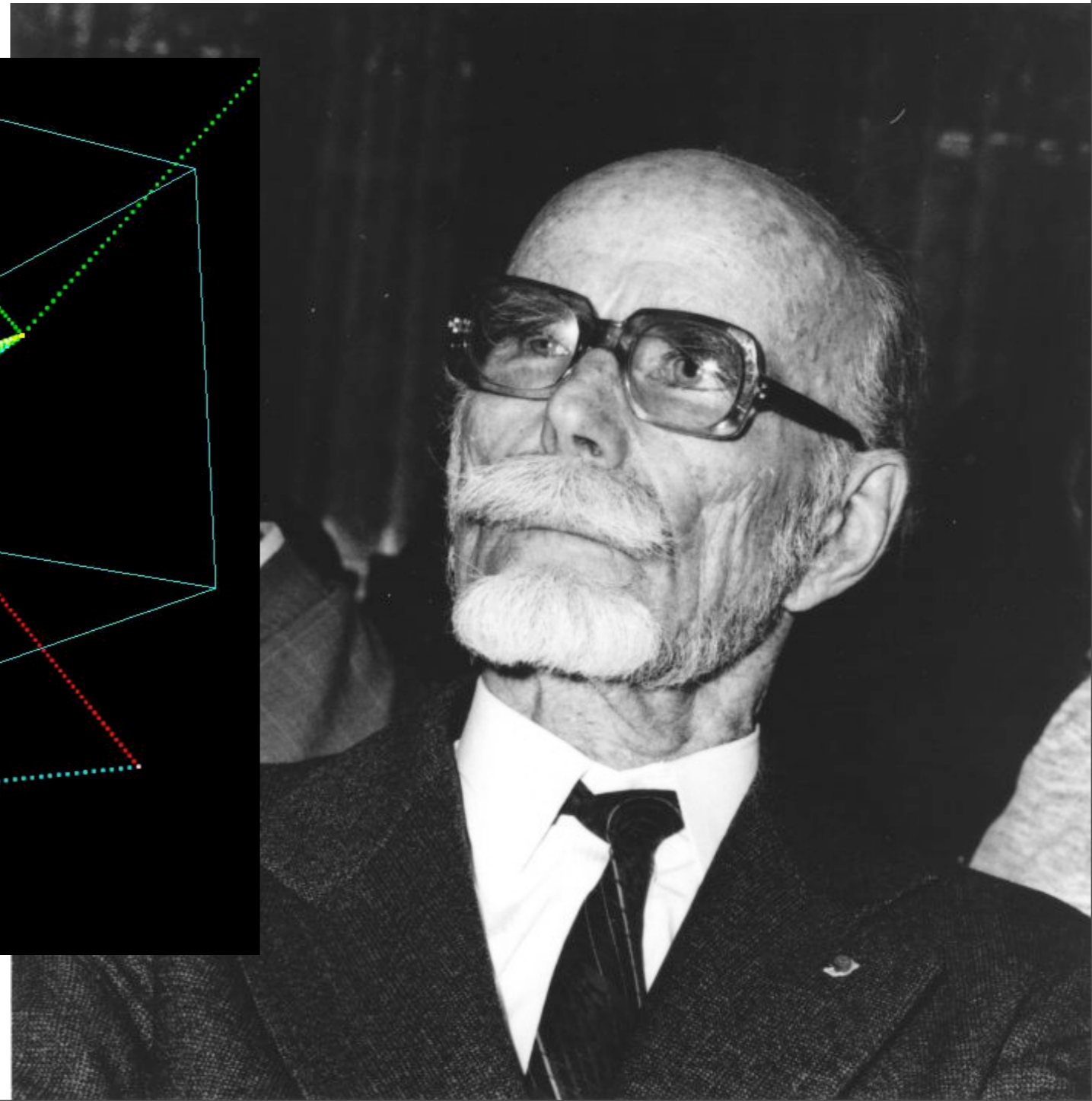
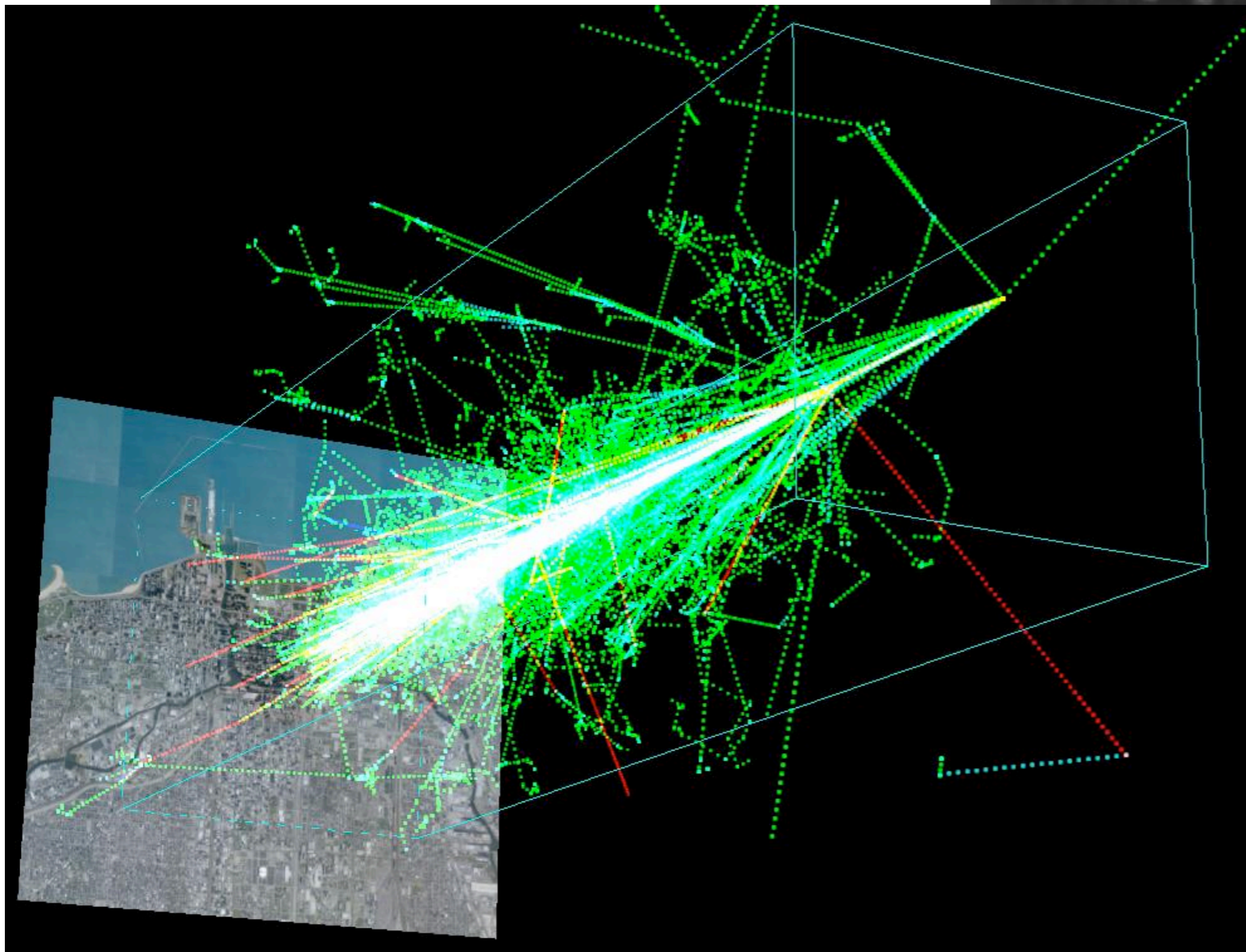
- What are Cosmic Rays?

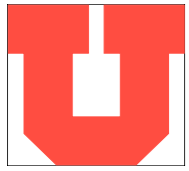




History

- 1938: **Pierre Auger** saw Extensive Air Showers

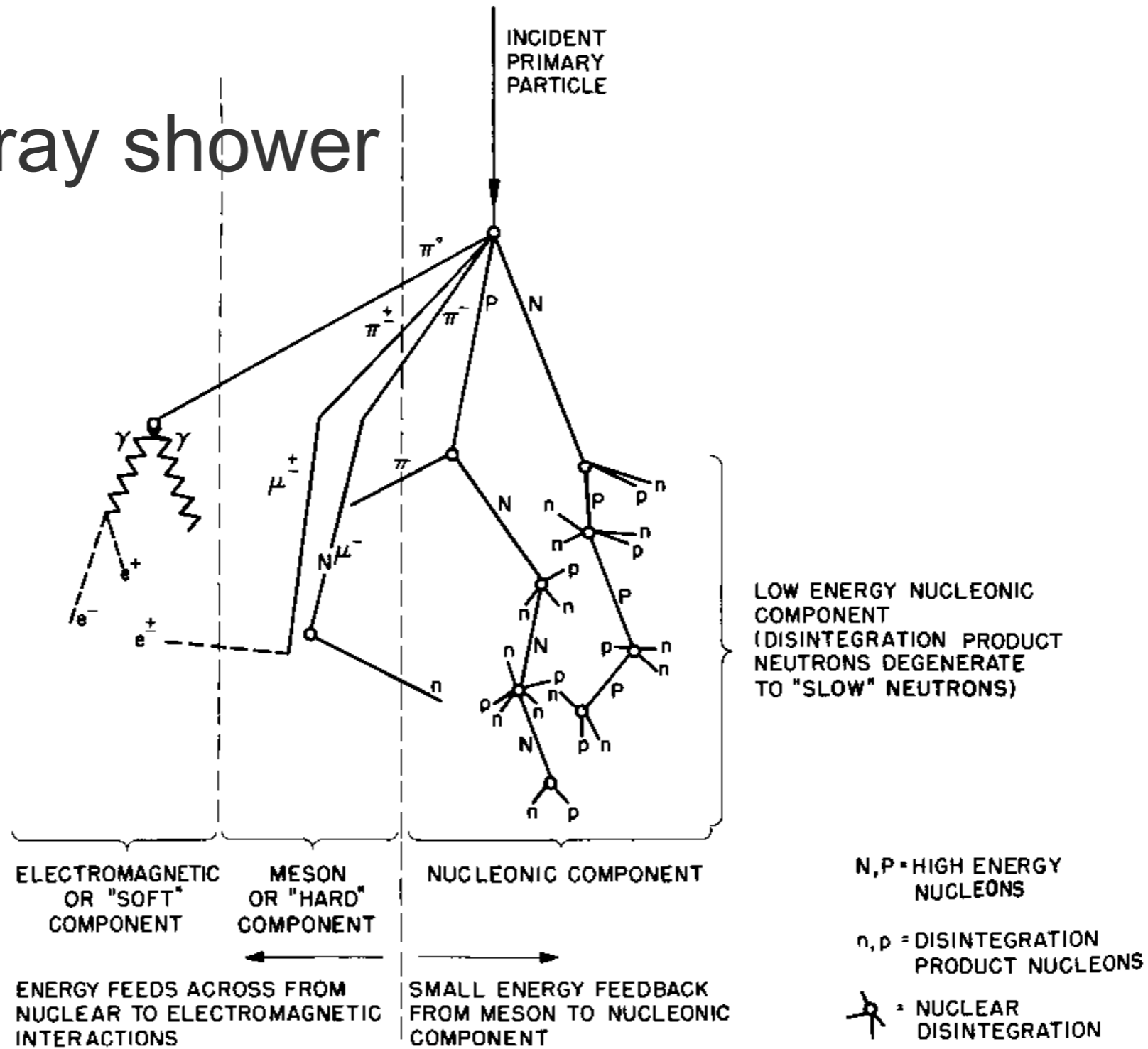




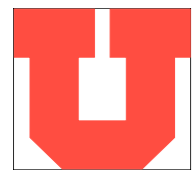
History - Science

■ Cosmic ray shower

Top of the at



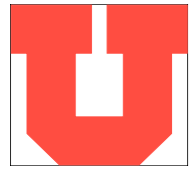
Schematic Diagram of Cosmic Ray Shower



History

- 1946: **Rossi & Zatsepin** build *first* array

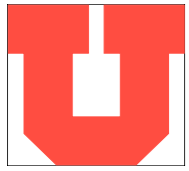




History

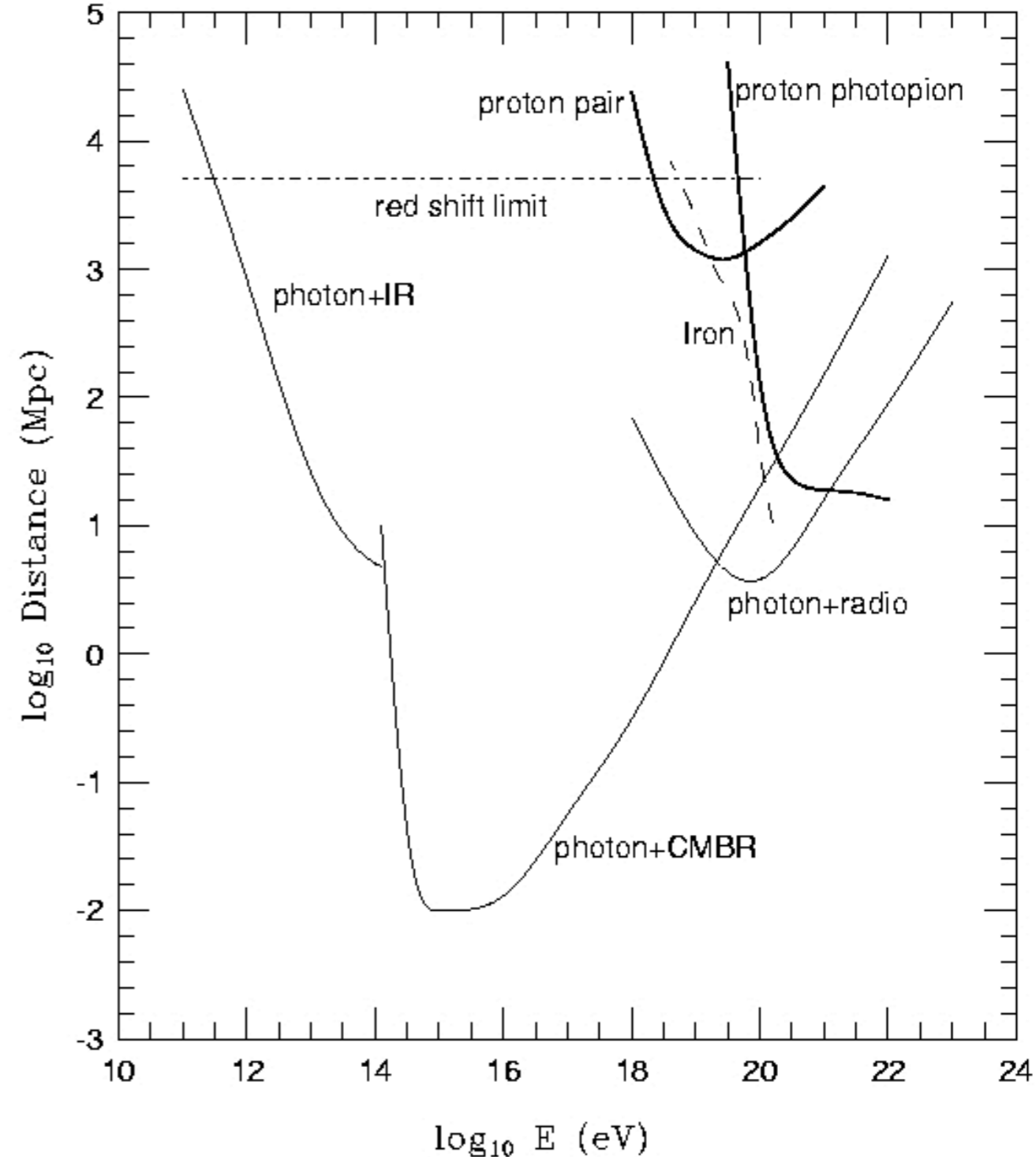
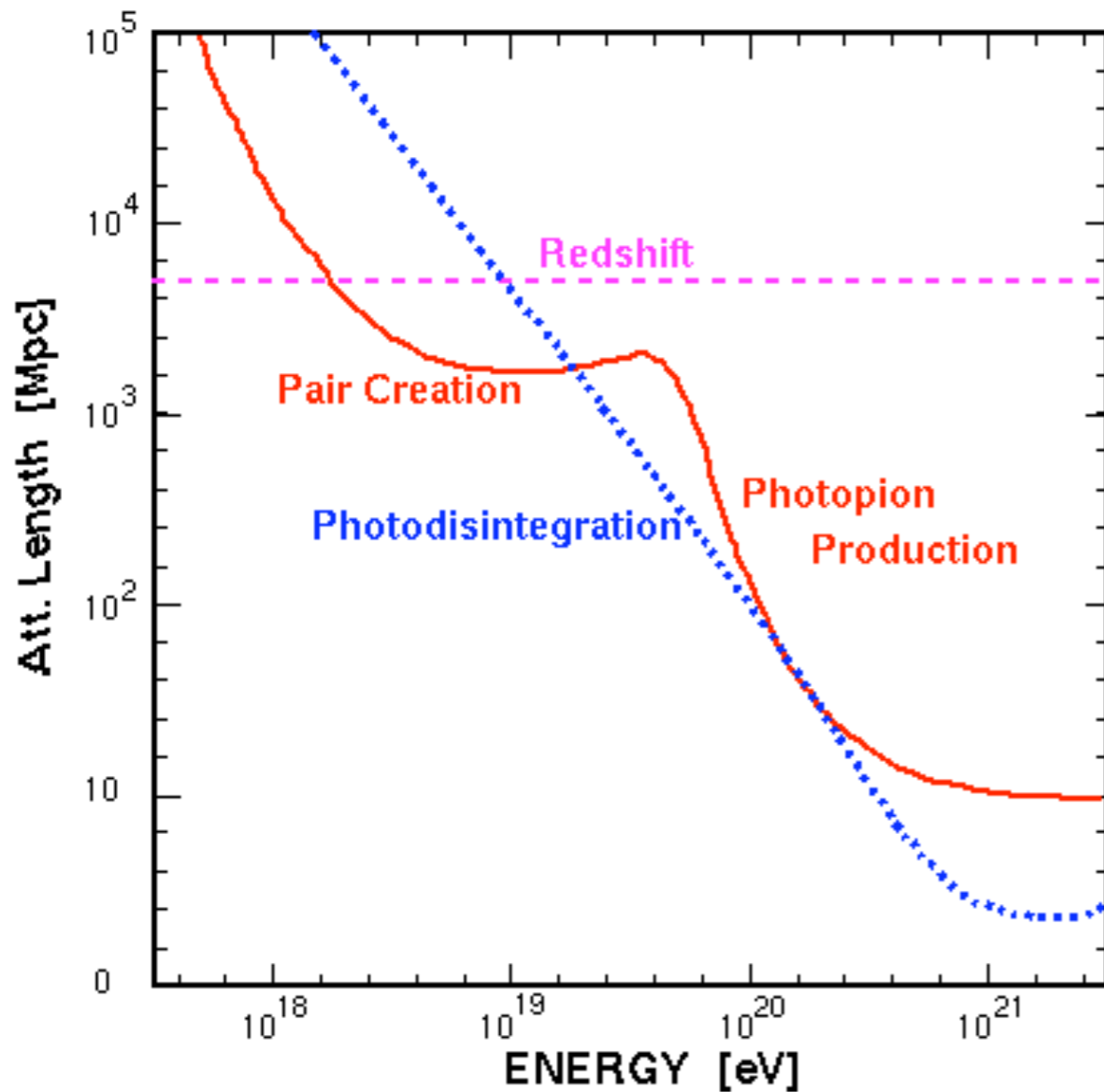
- 1962: *Linsley et al.* see 1st event $E > 10^{20}$ eV

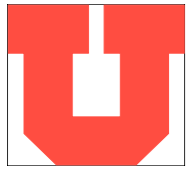




History - Science

- 1966: Greisen, Zatsepin, & Kuzmin predict the GZK suppression

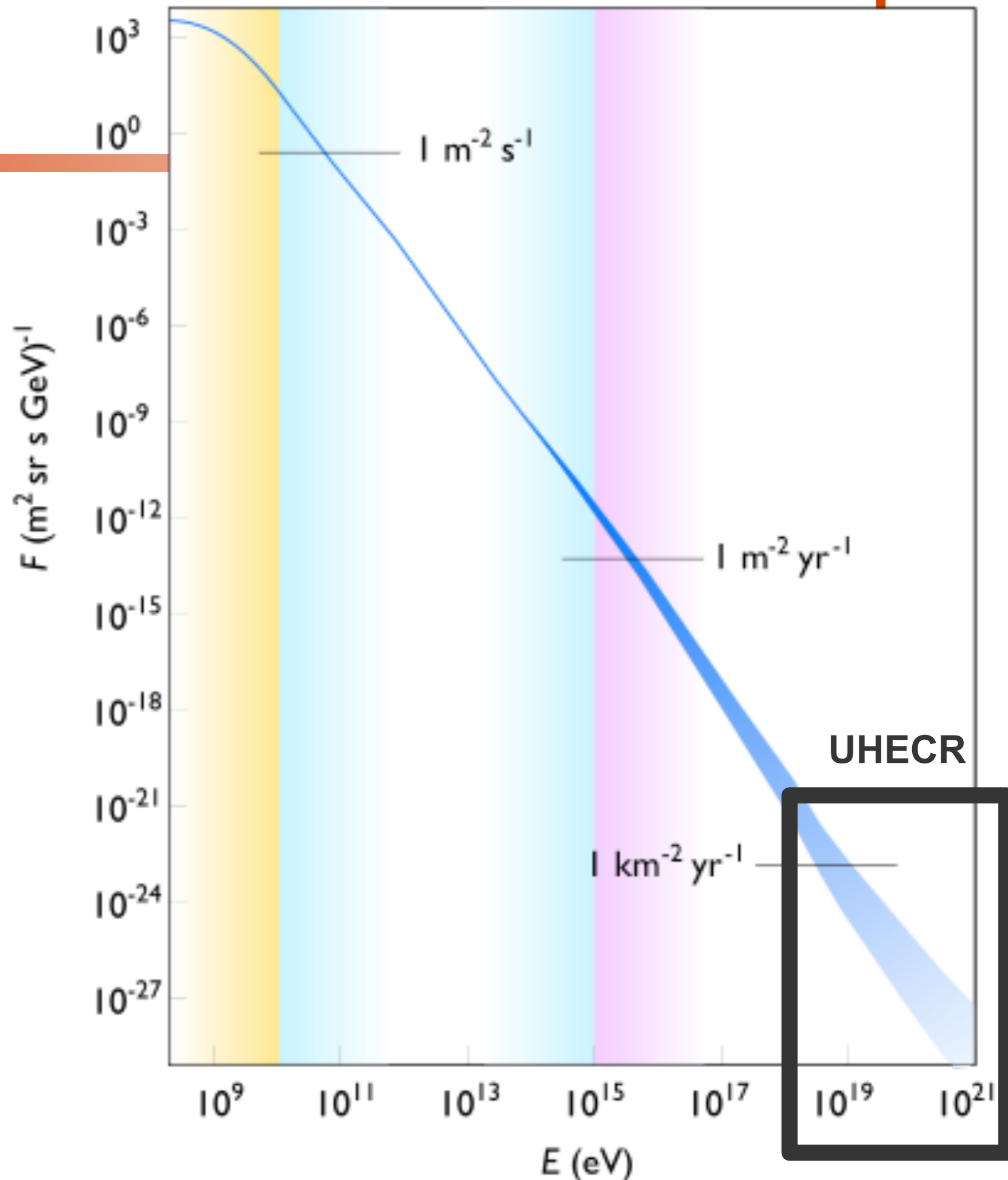


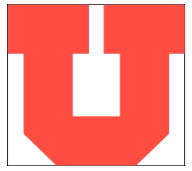


Science

the spectrum

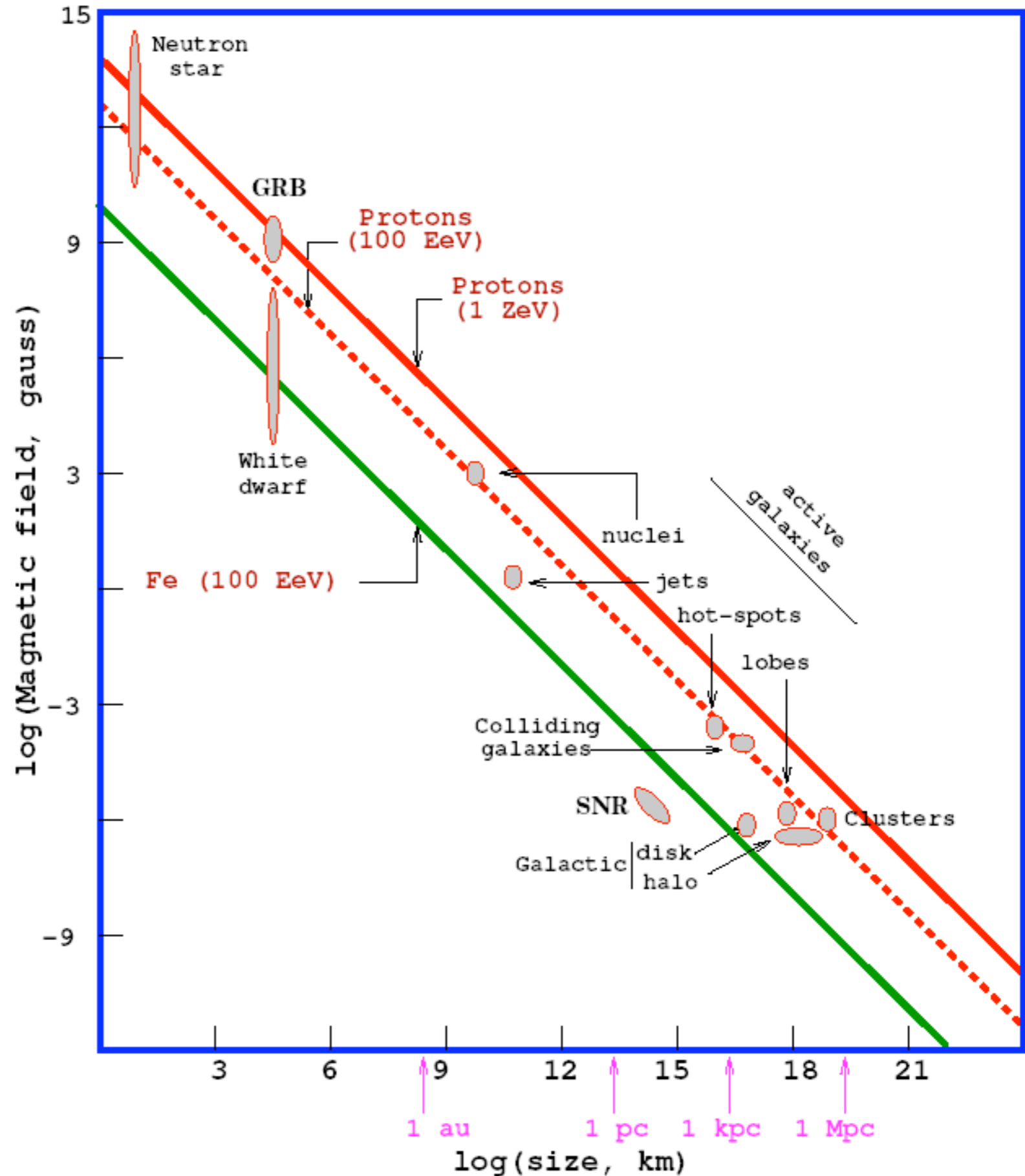
- Flux vs. Energy
- Flux per unit:
 - Area [m^2]
 - Solid Angle [sr]
 - Time [s]
 - Energy [GeV]

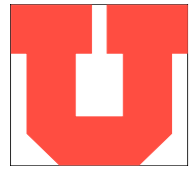




Science

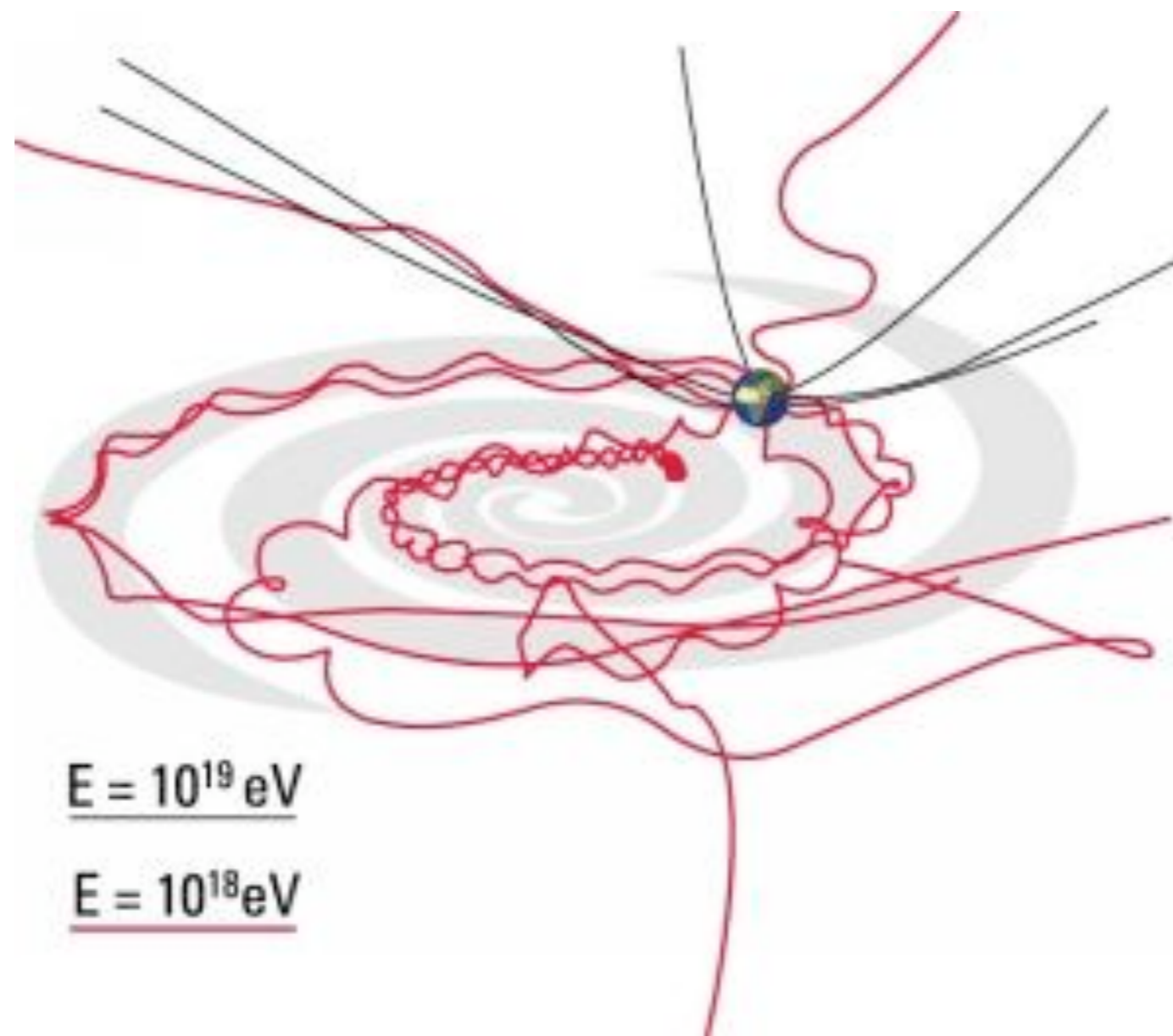
- acceleration mechanisms
- accelerator
- propagation
- composition

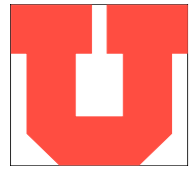




Science

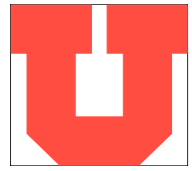
- account for deflection!





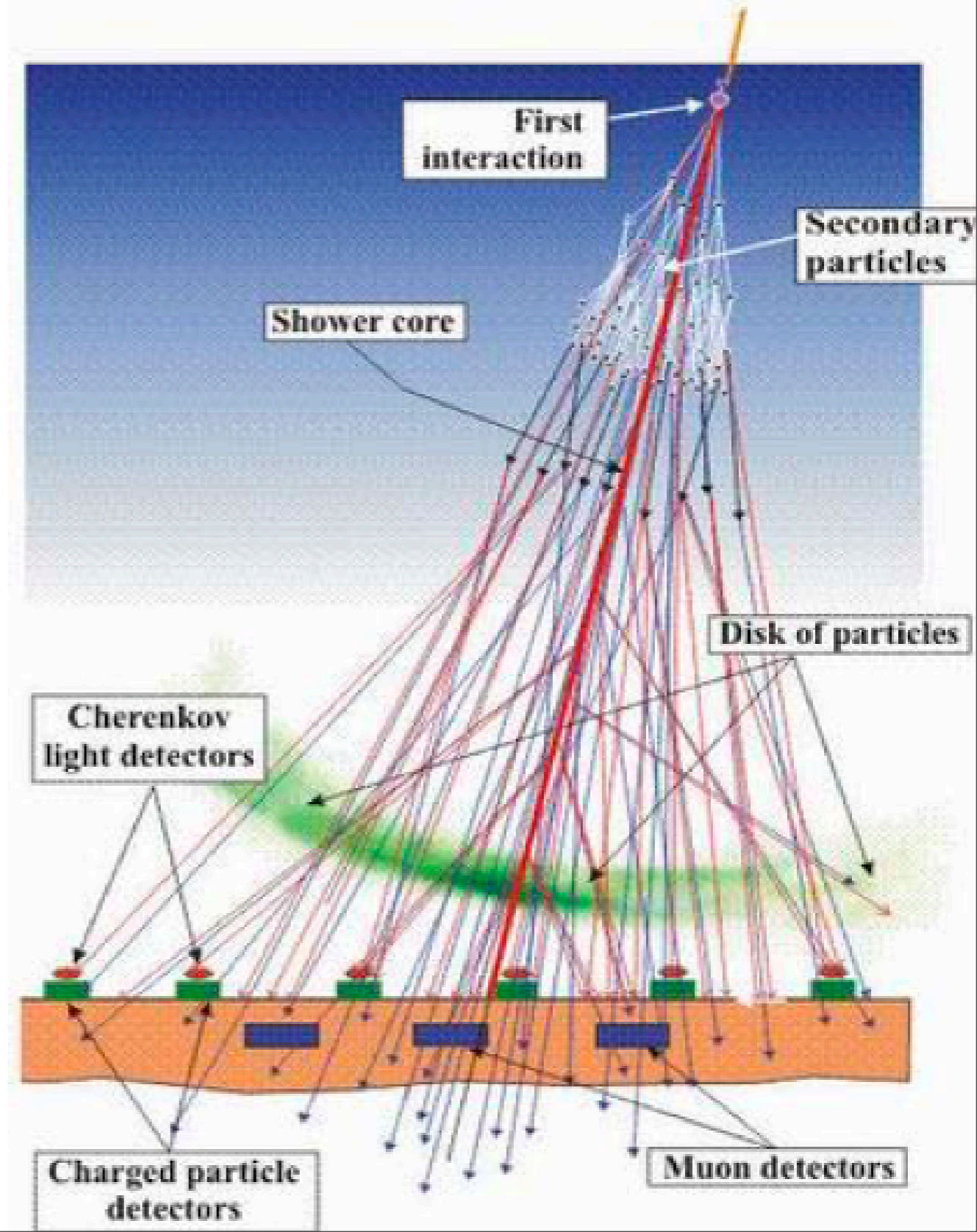
Science Conclusion

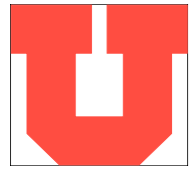
- We must address:
 - **Energy distribution**
 - GZK suppression?
 - Need for new physics?
 - **Directionality**
 - Known astrophysics?
 - New physics?
 - **Composition**
 - $p, \gamma, \text{Fe}, n, \nu, \dots$?



Techniques

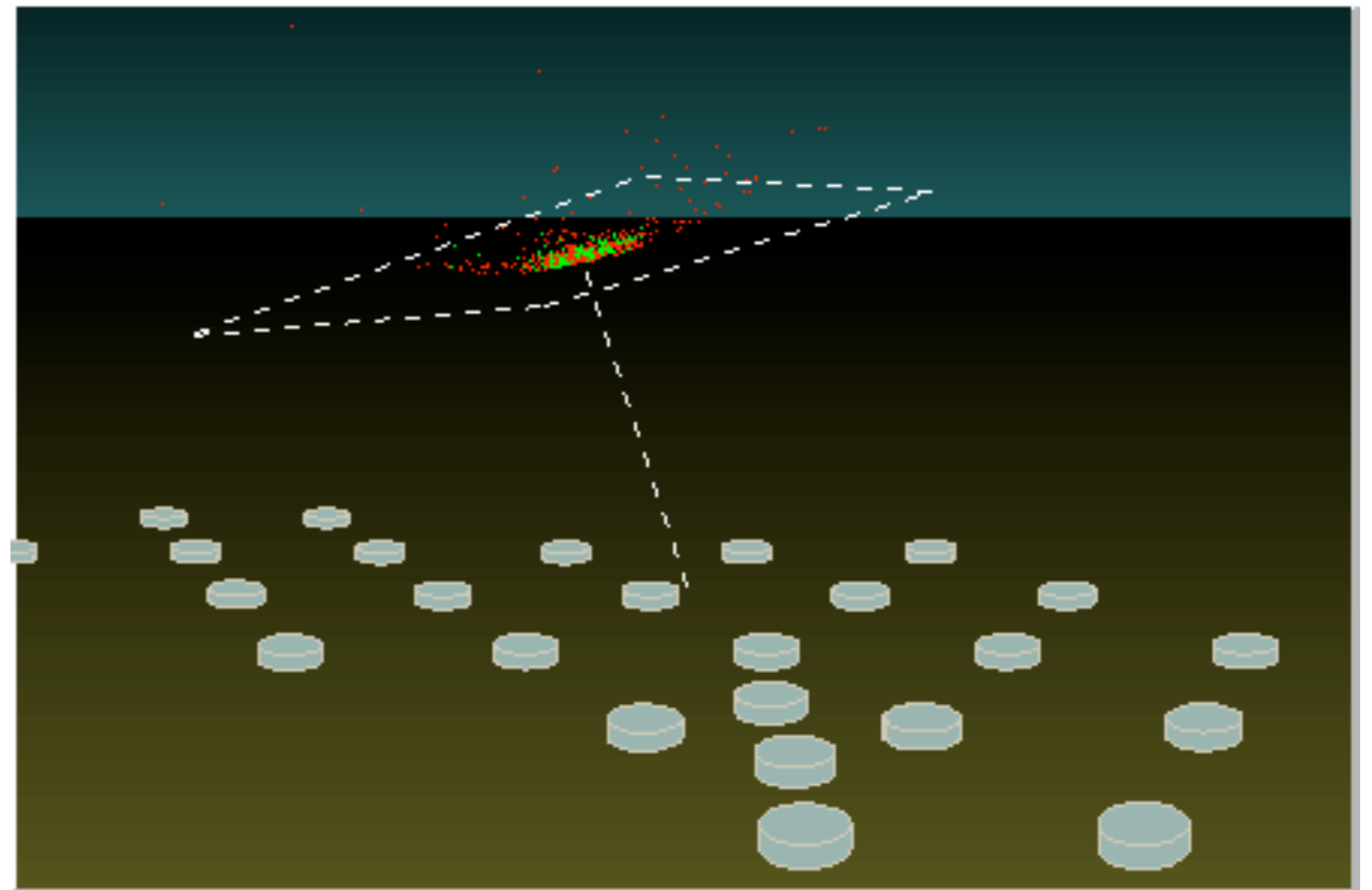
- @ UHE we can only measure the EAS (and *side effects*)

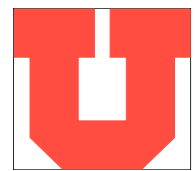




Detection techniques

- particle counters on the ground

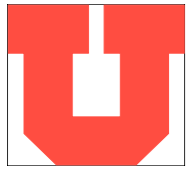




Techniques

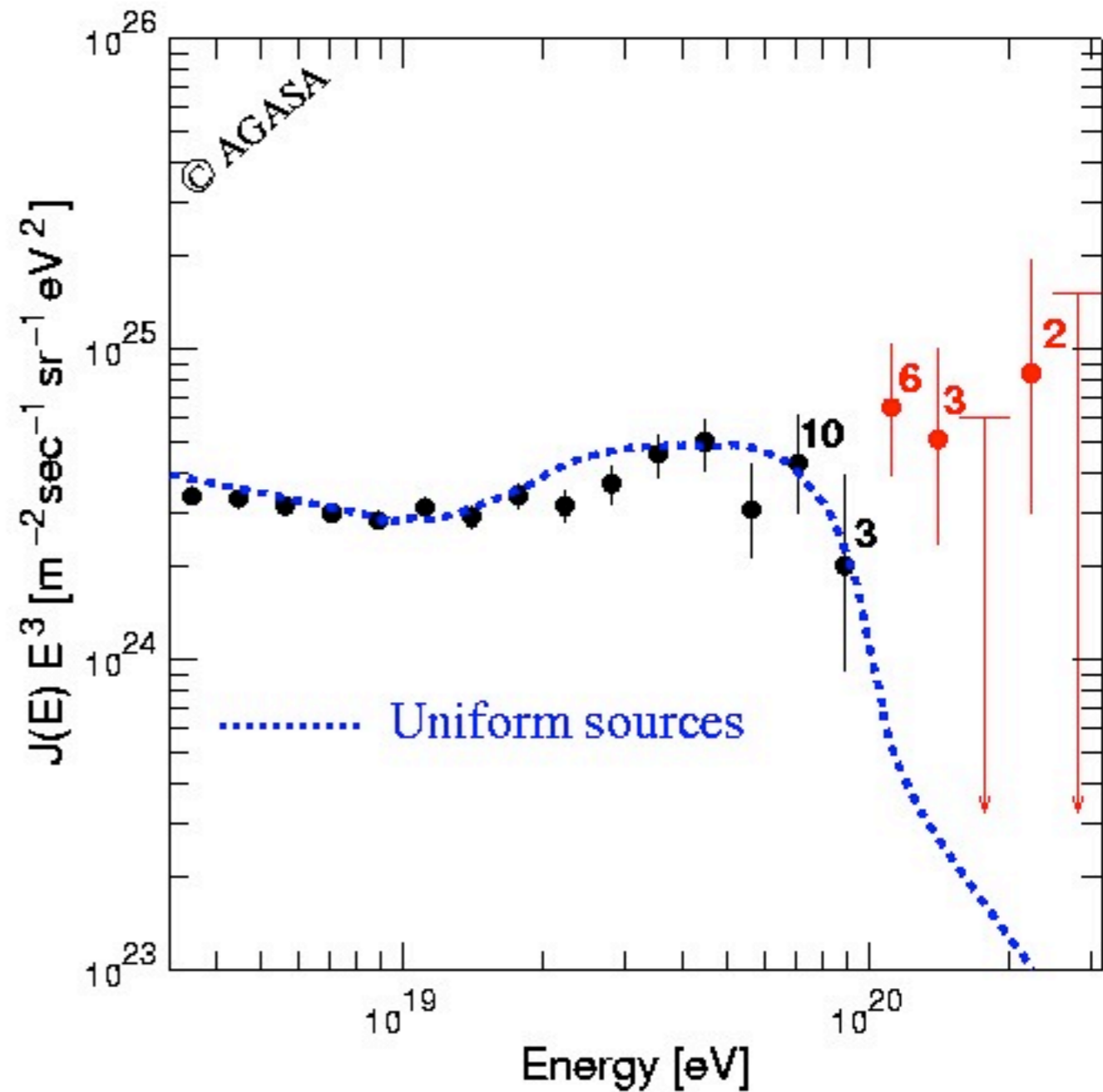
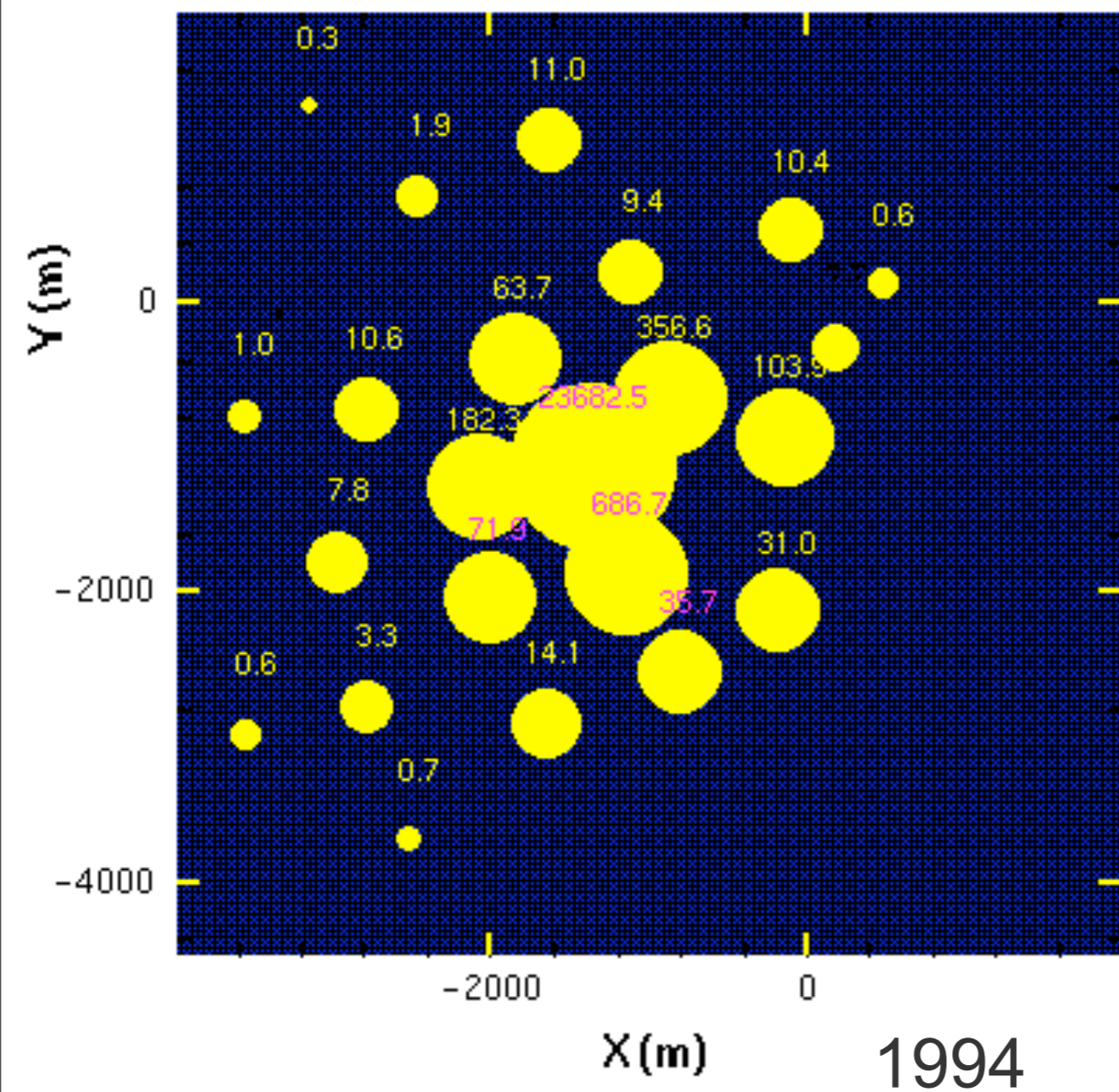
- AGASA
- 100 km² array
- plastic scintillators

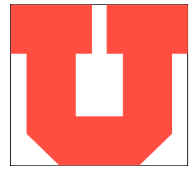




Techniques

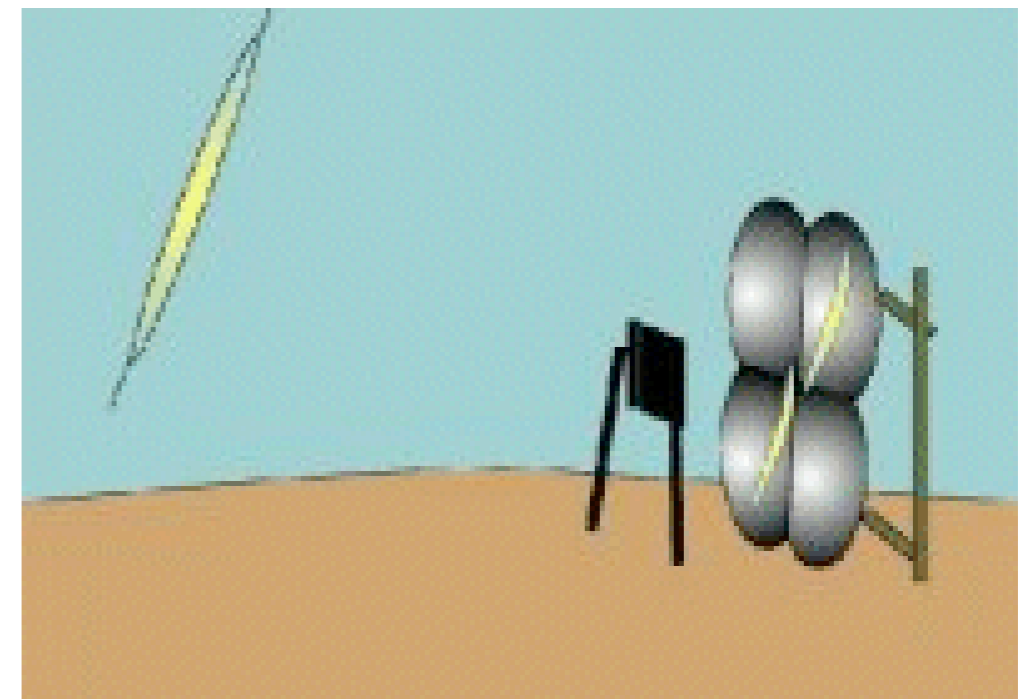
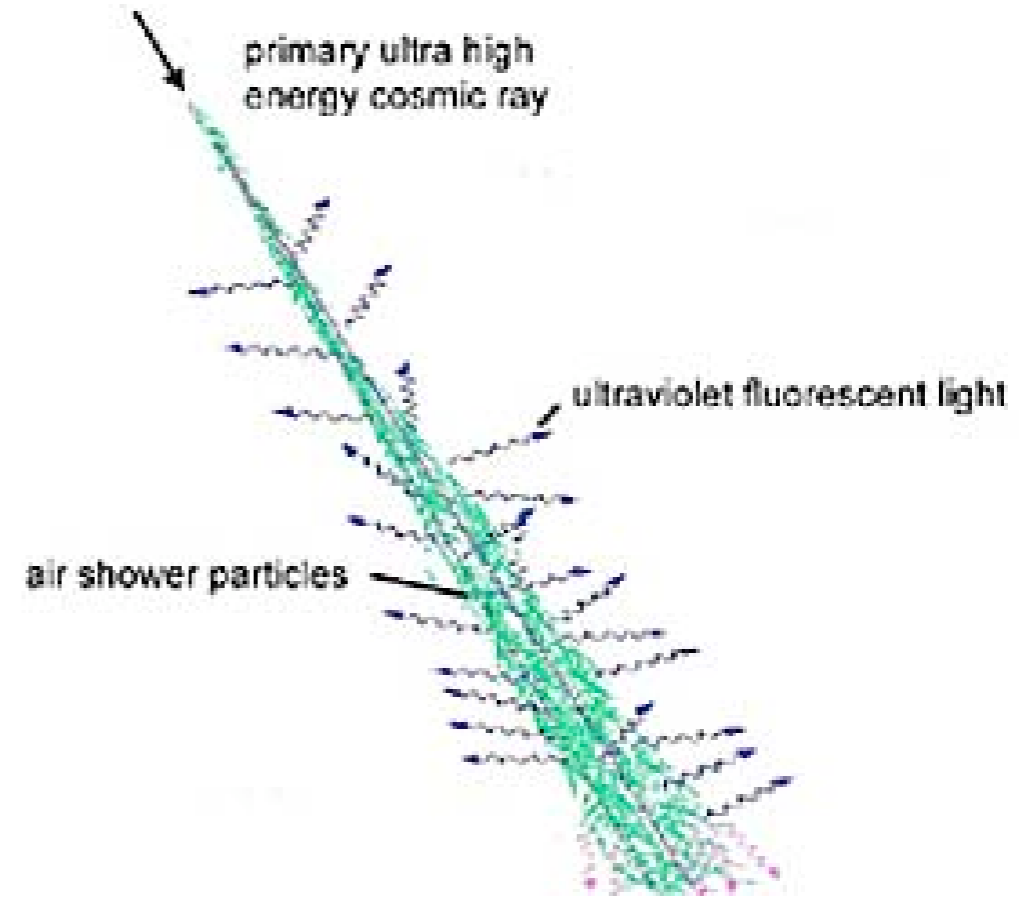
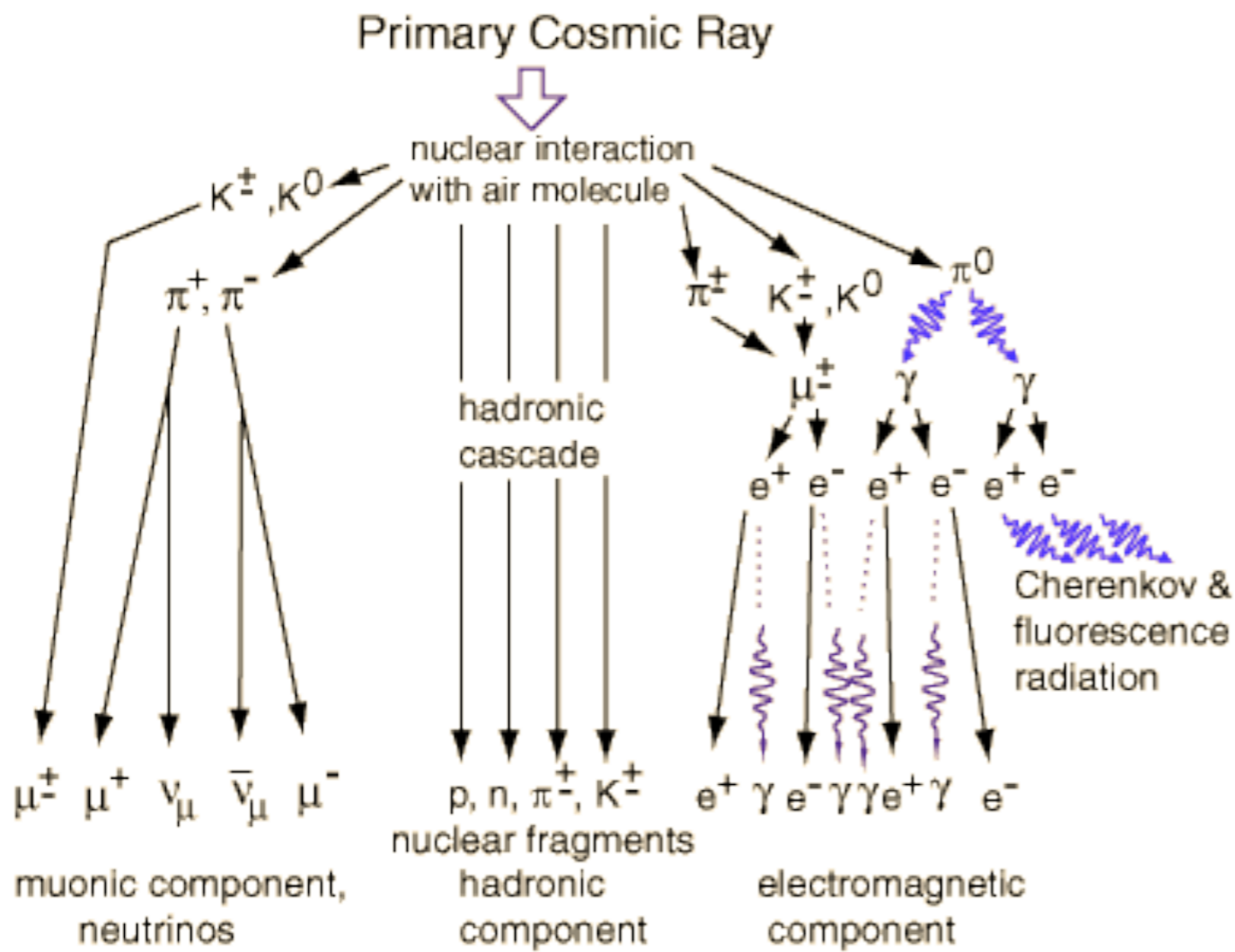
AGASA results

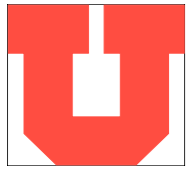




Detection Techniques

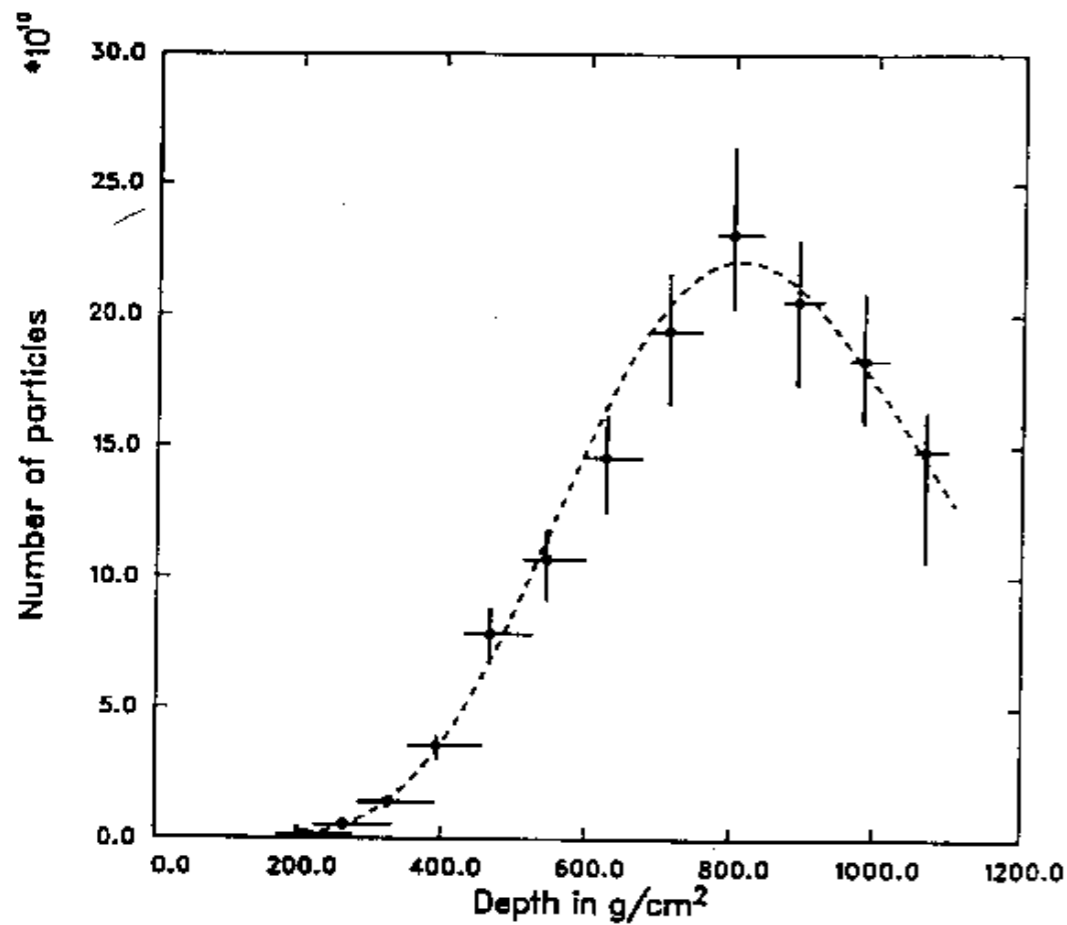
Fluorescence emissions





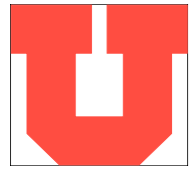
Techniques

the Fly's Eye



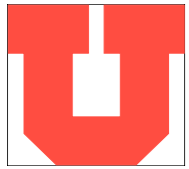
1991

The University of Utah



Techniques Summary

- Ground array
 - **sampling** method
 - 24/7
 - **lateral** distribution
- Fluorescence telescopes
 - **calorimetric** measurement
 - **10%** duty cycle
 - **longitudinal** profile

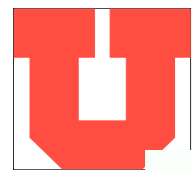


Auger

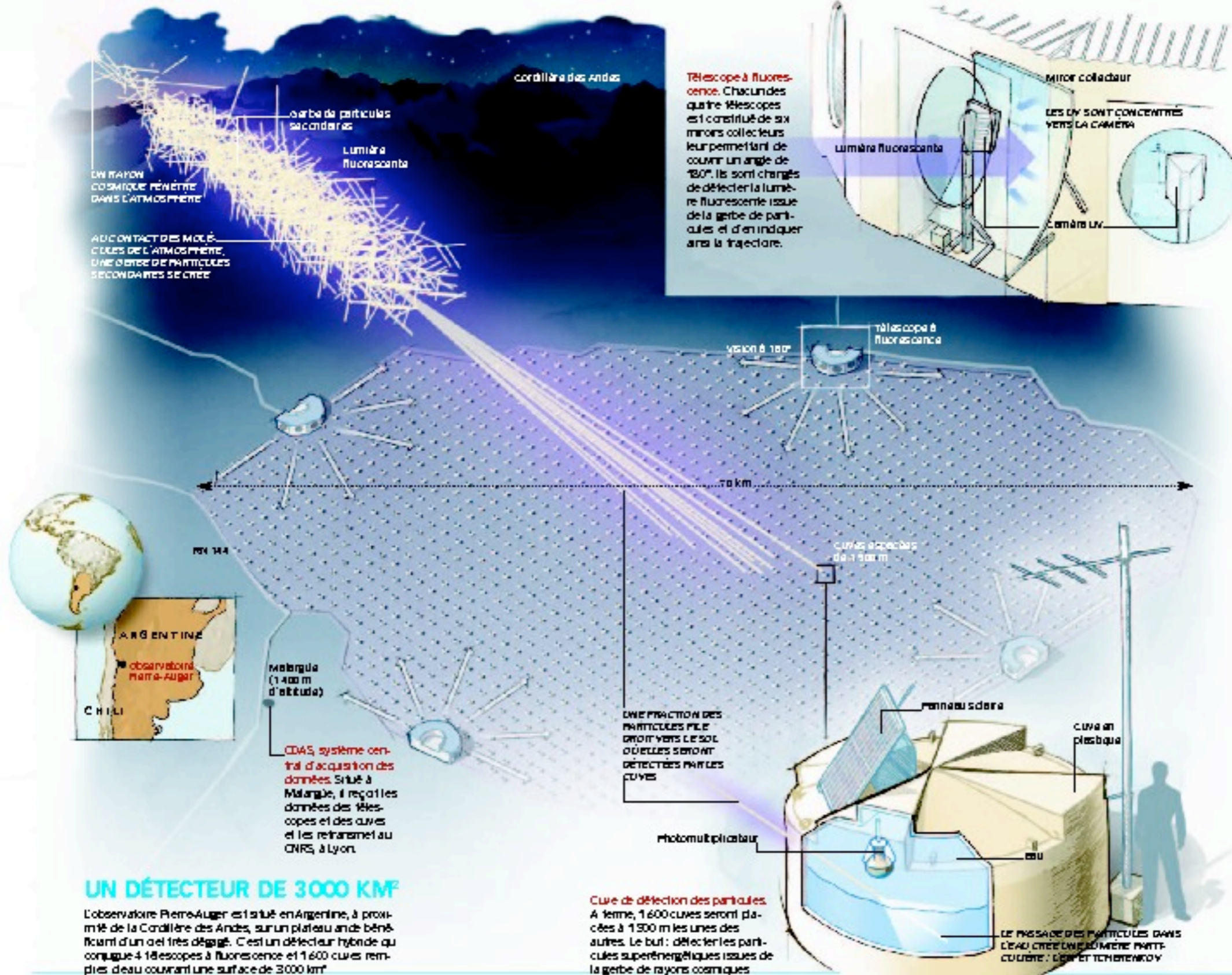


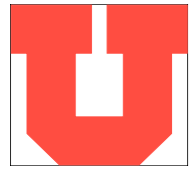
■ the Collaboration





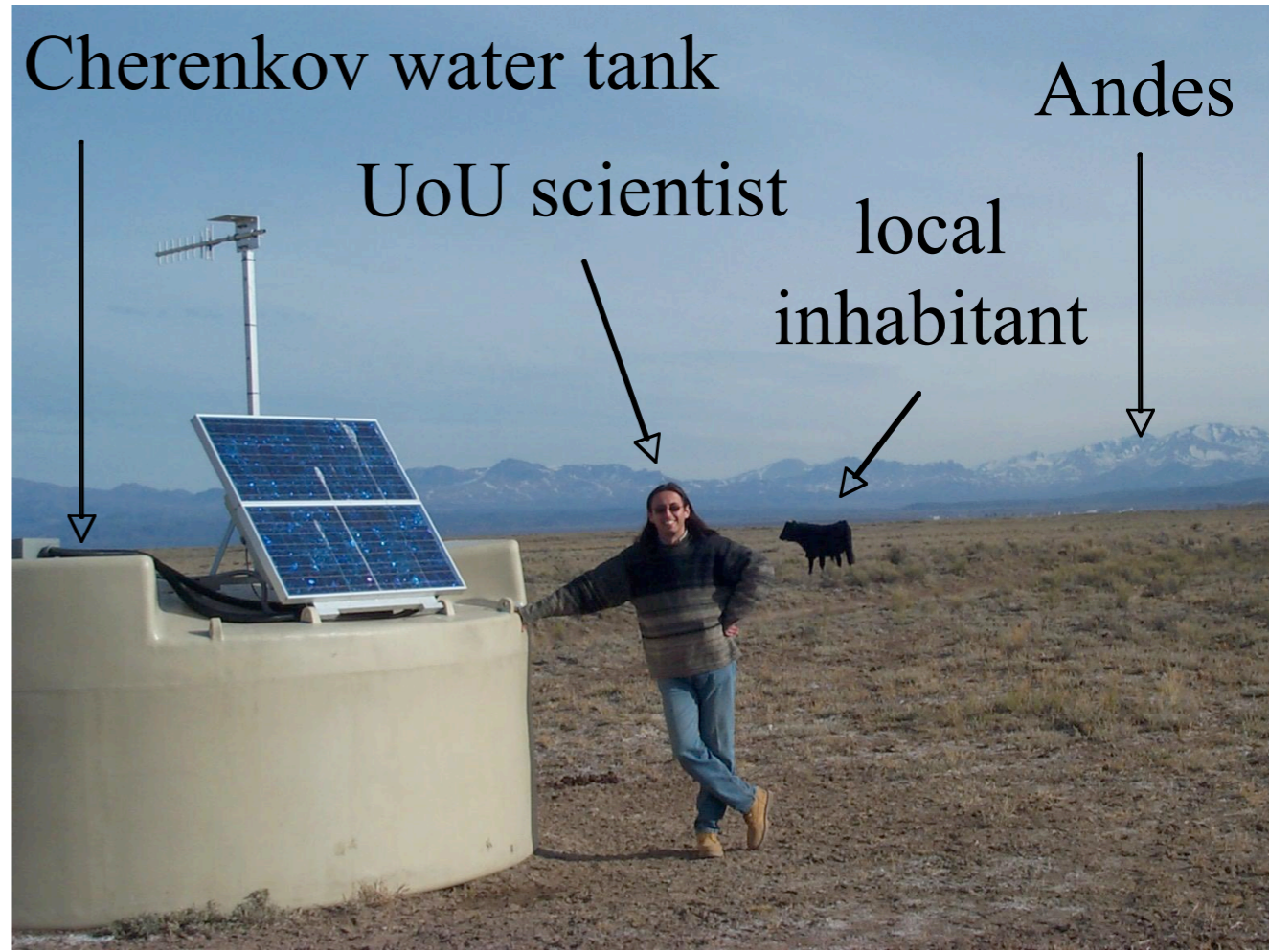
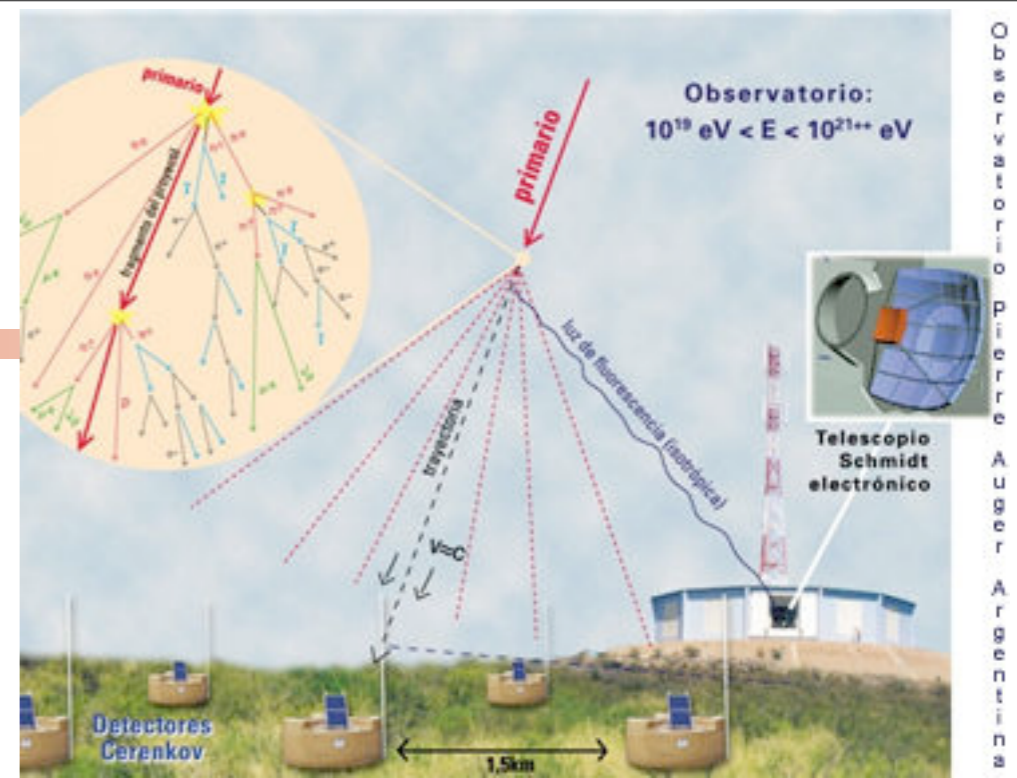
the hybrid concept

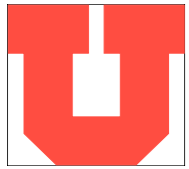




Auger

- the hybrid detector



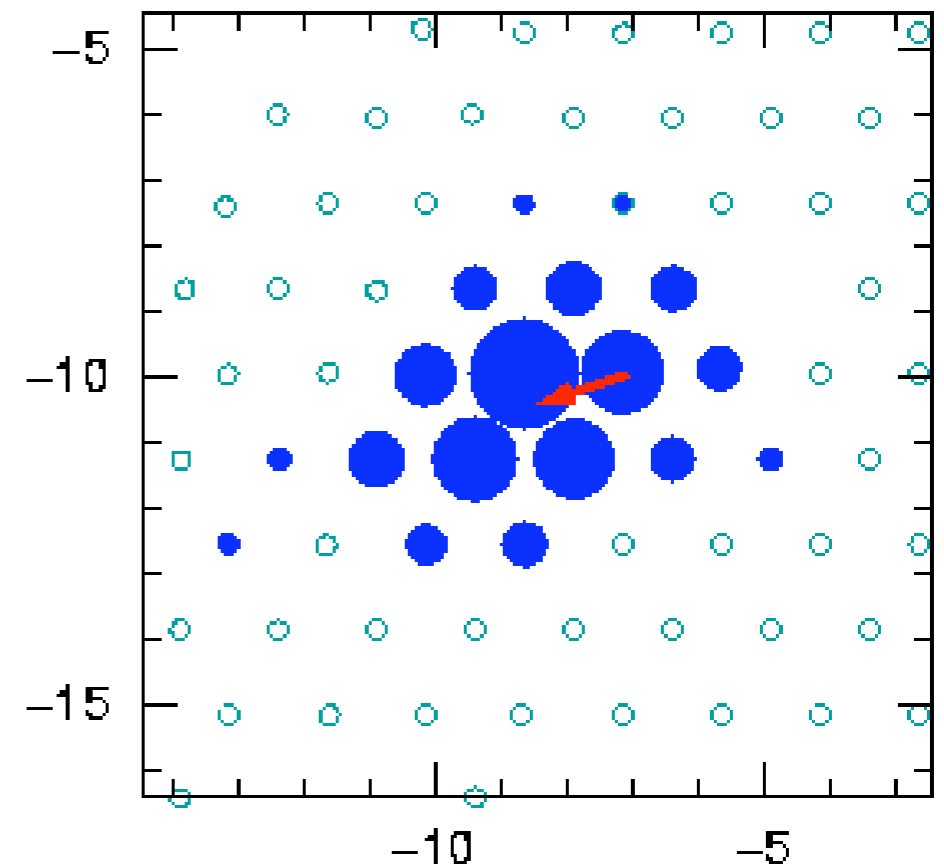


detecting UHECRs

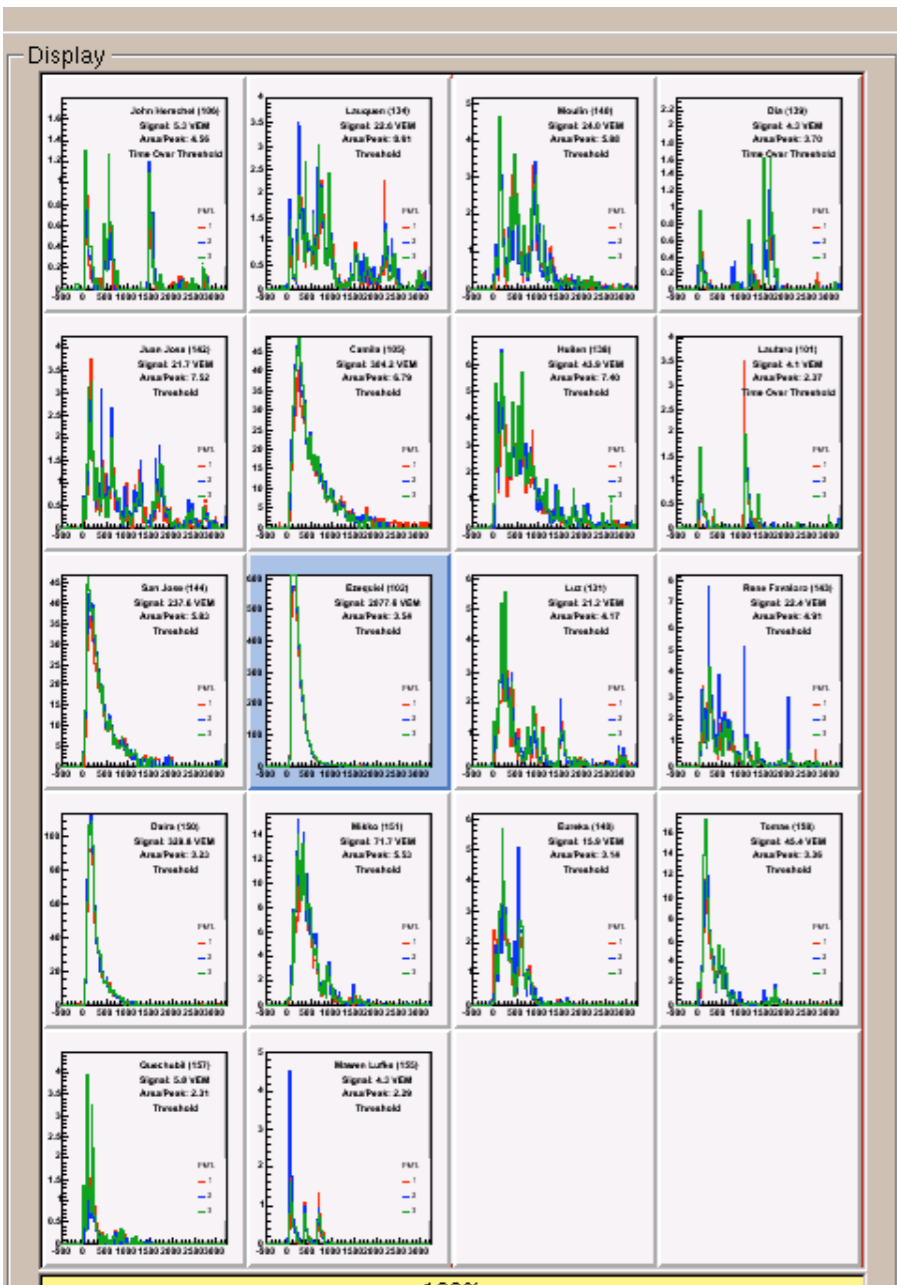
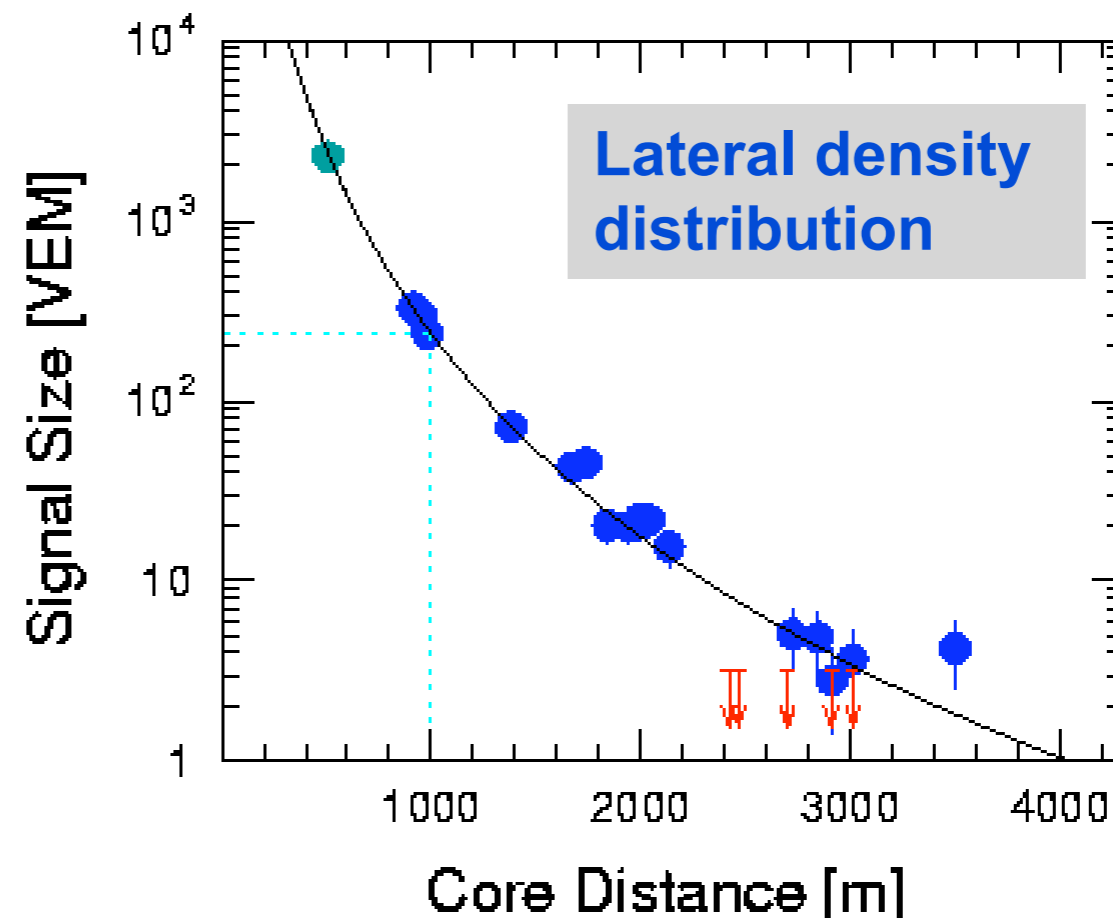
ID 762238

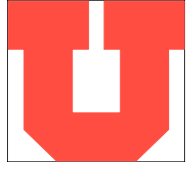
SD view

North [km]



ID 762238





Auger

- the fluorescence detector



aperture box

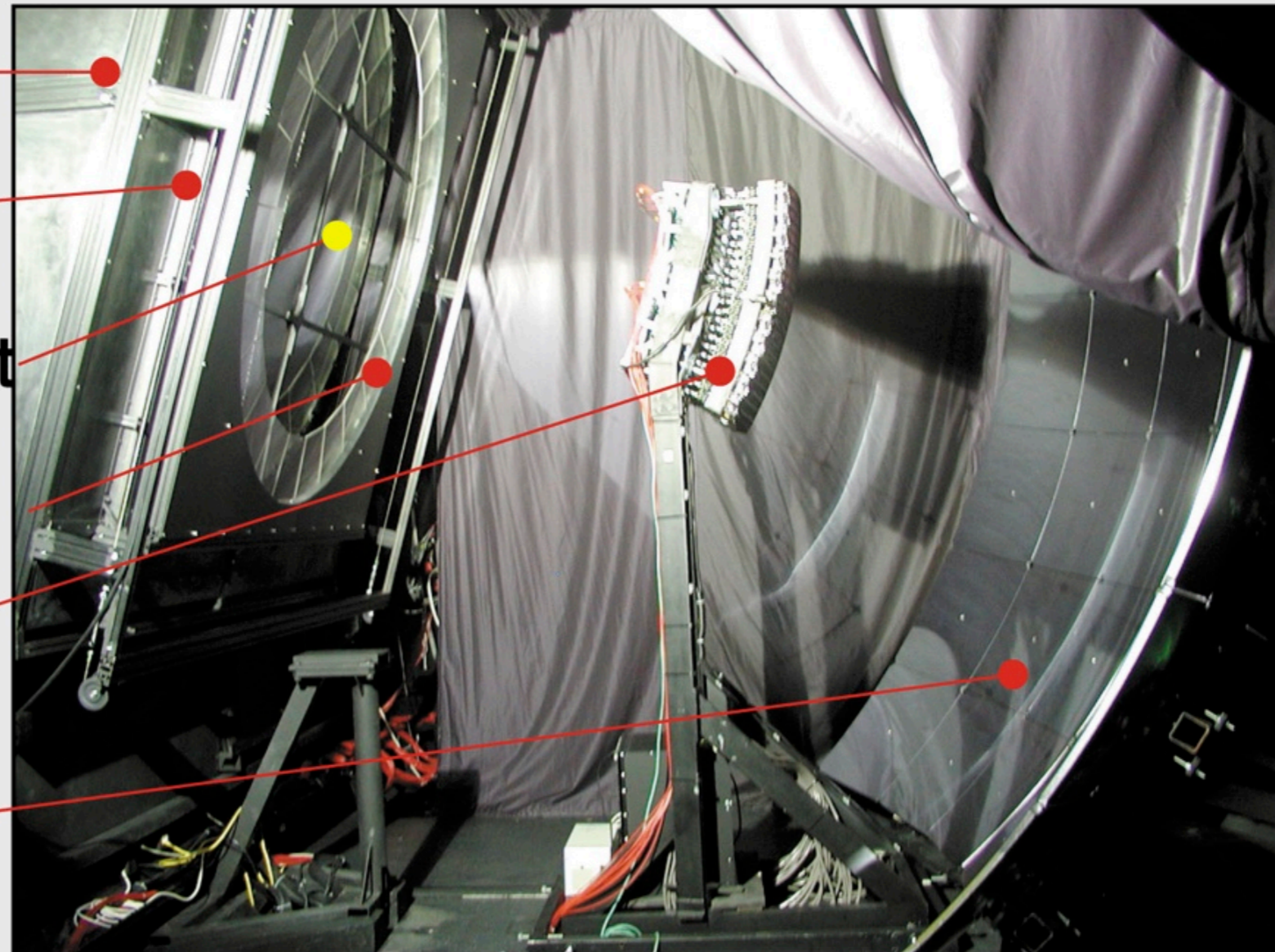
filter

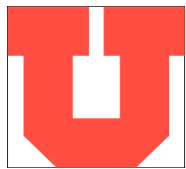
reference point

corrector ring

camera

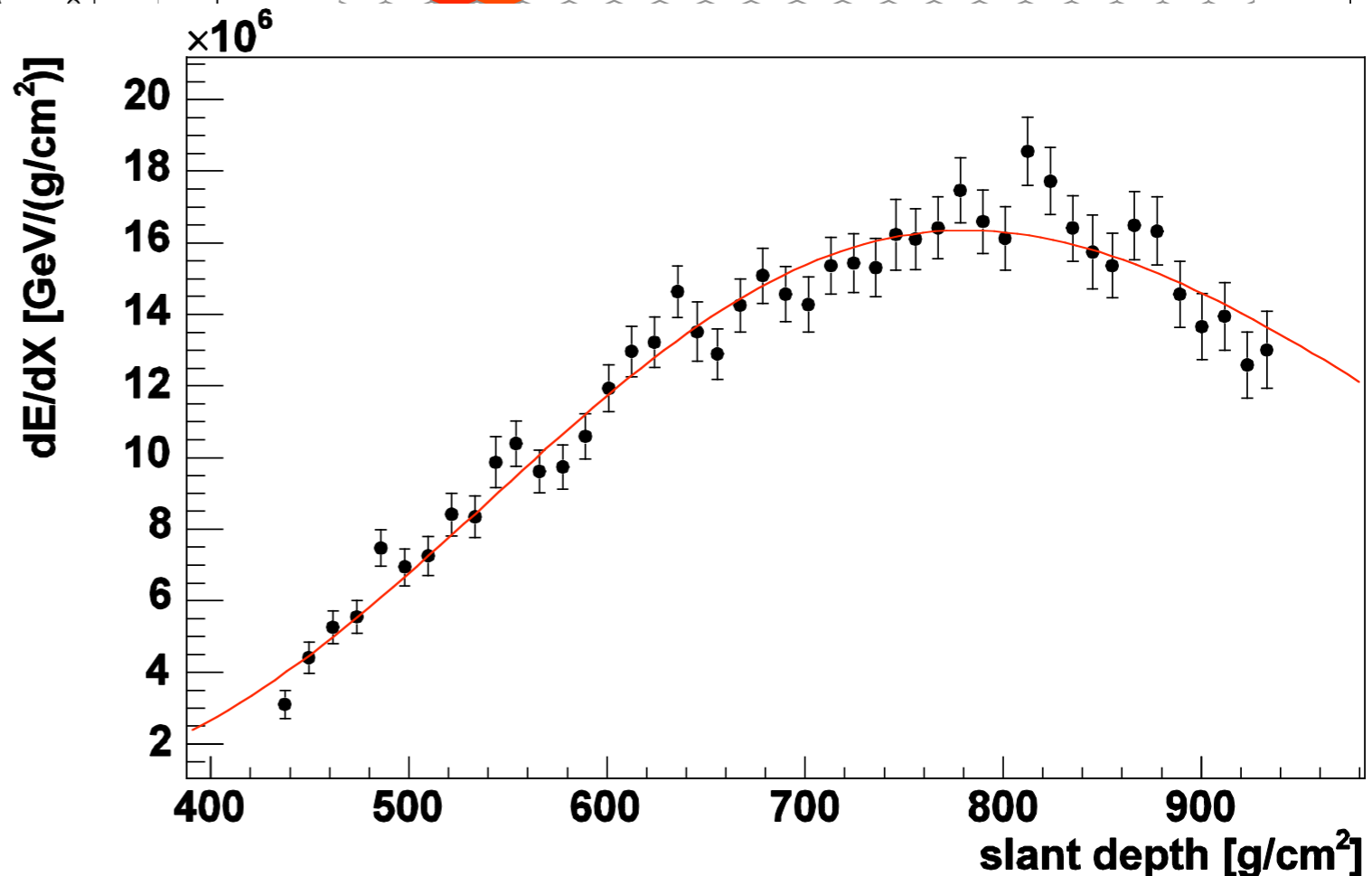
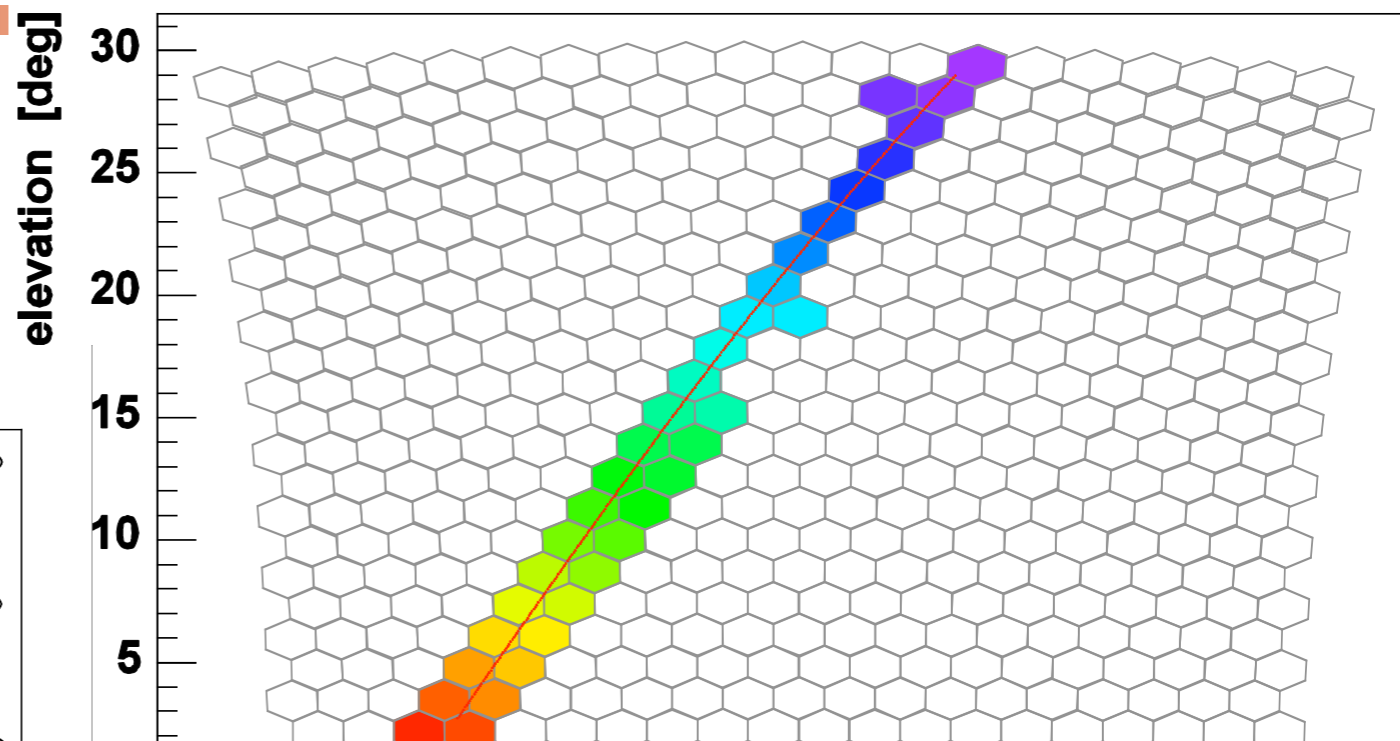
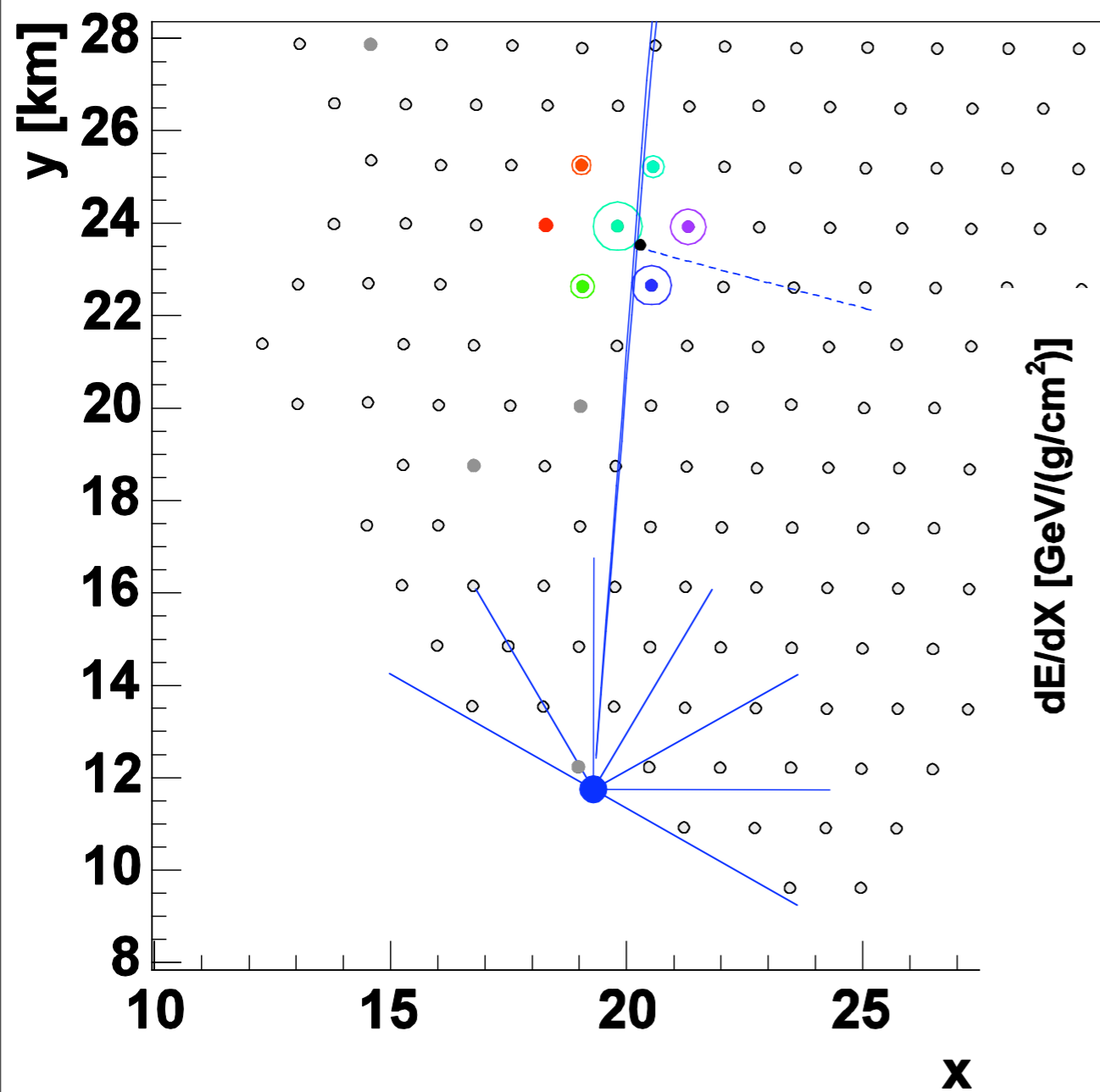
mirror system

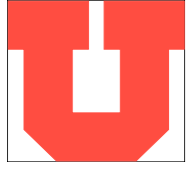




detecting UHECRs

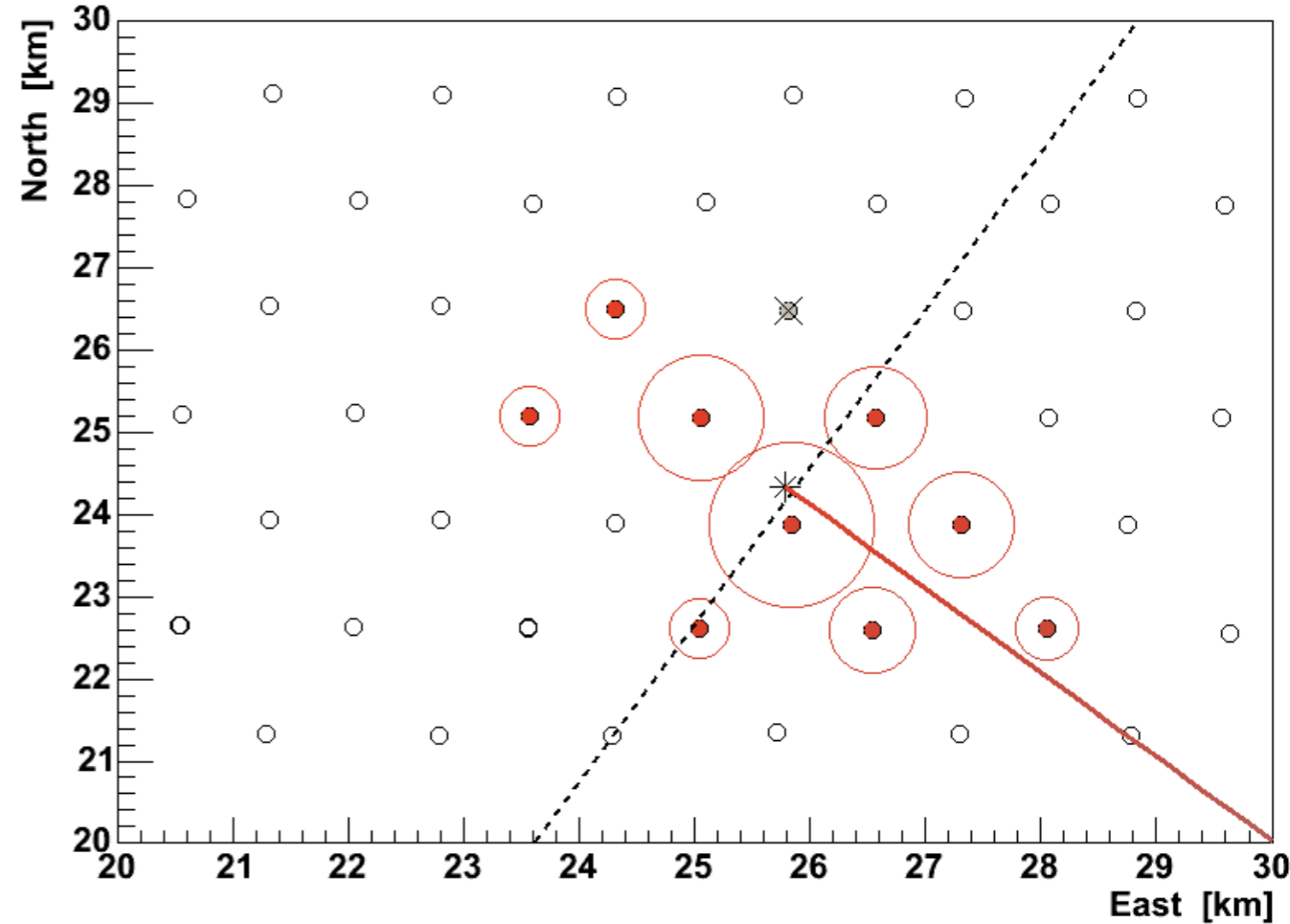
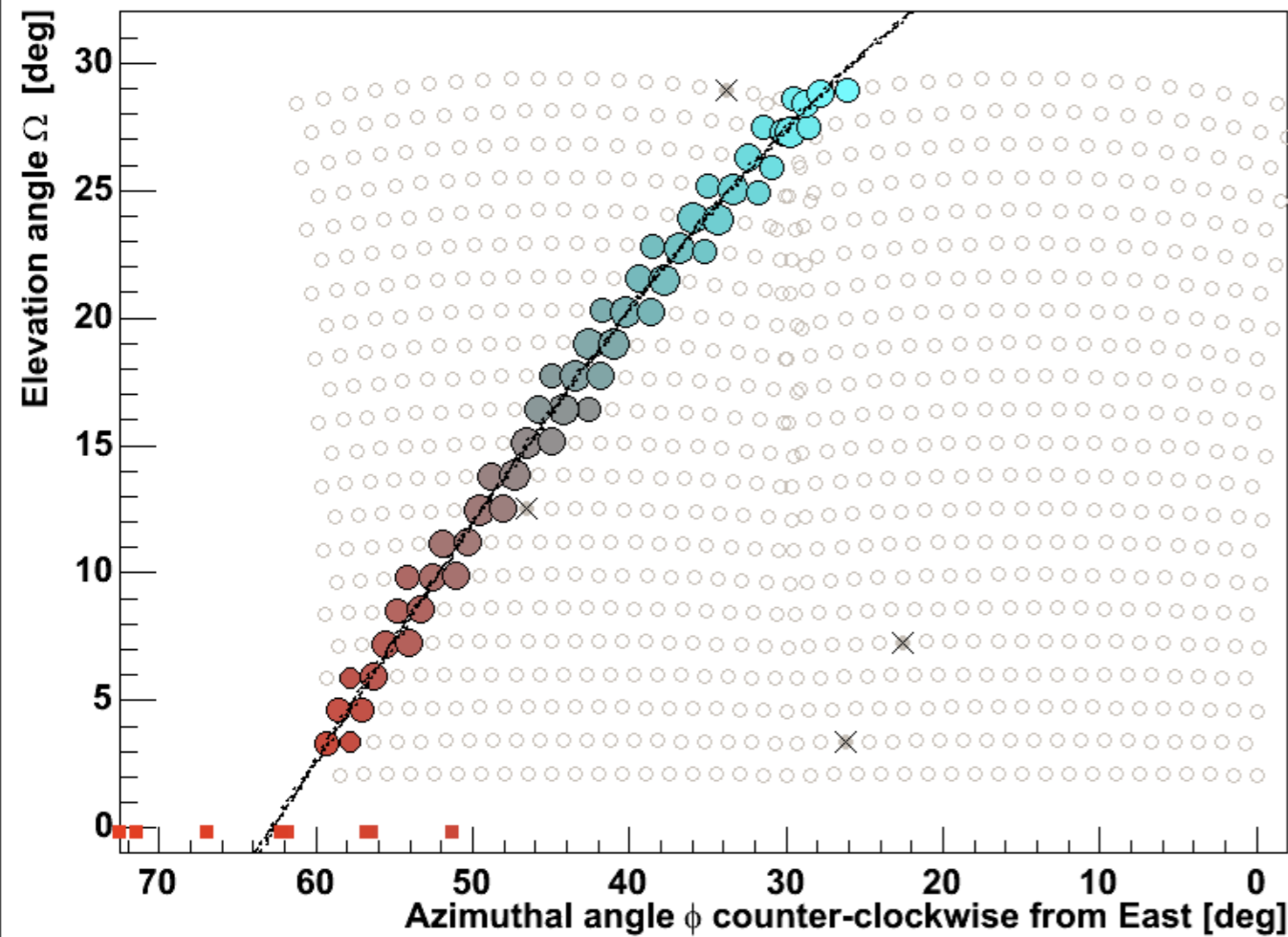
FD view

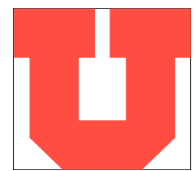




detecting UHECRs

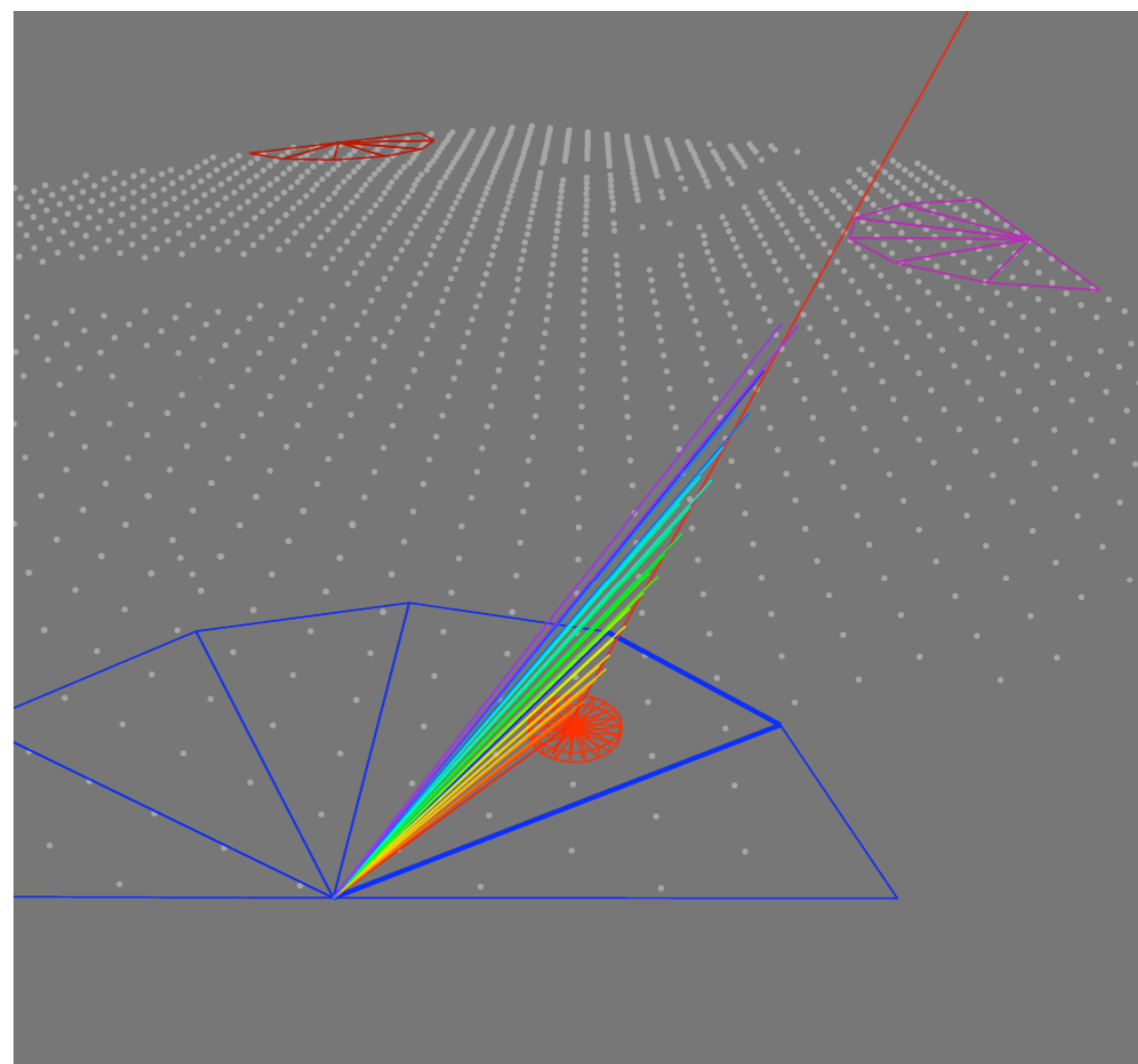
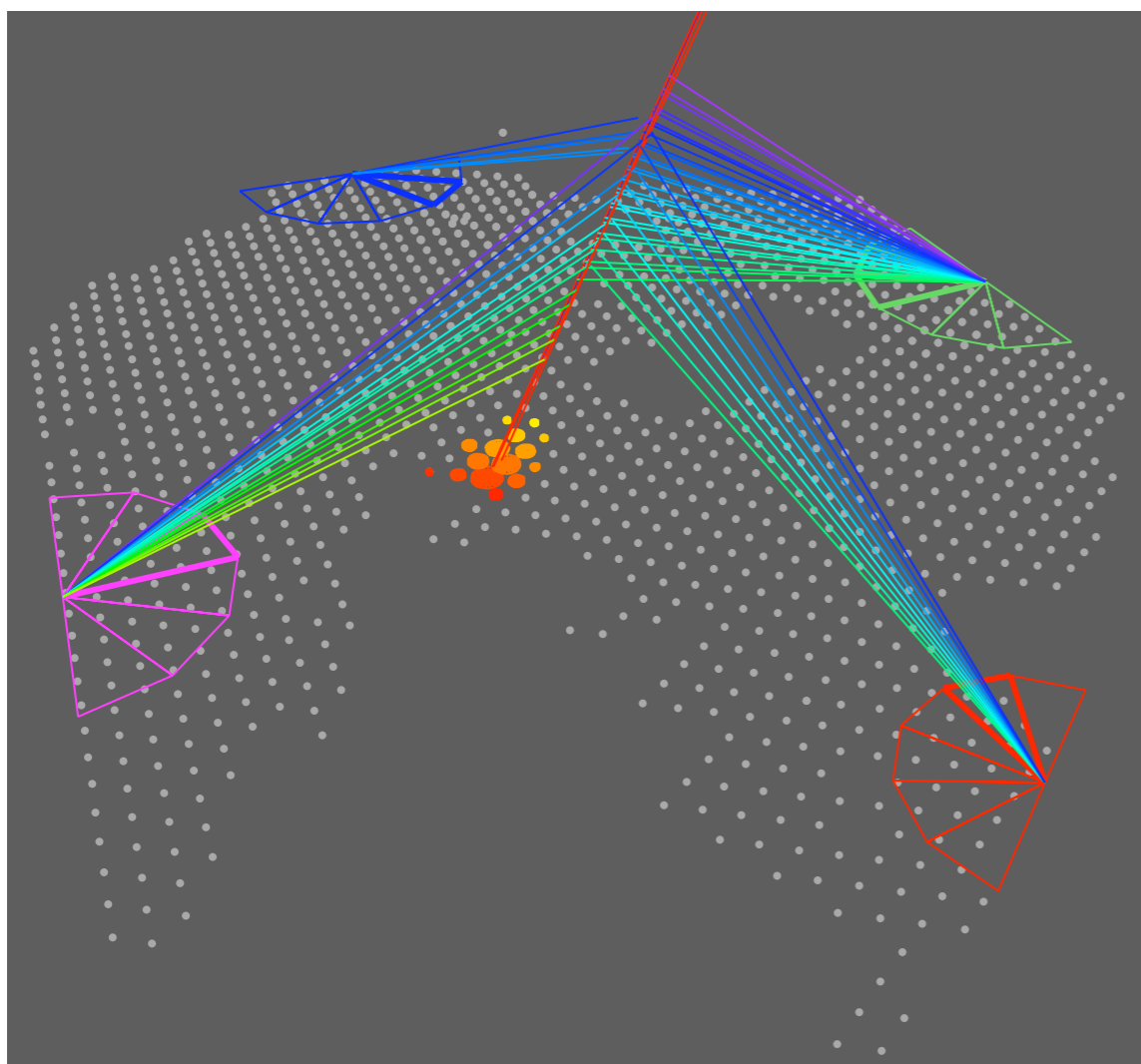
- *hybrid* reconst.: all avail **pixels** and **tanks**

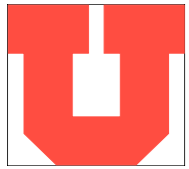




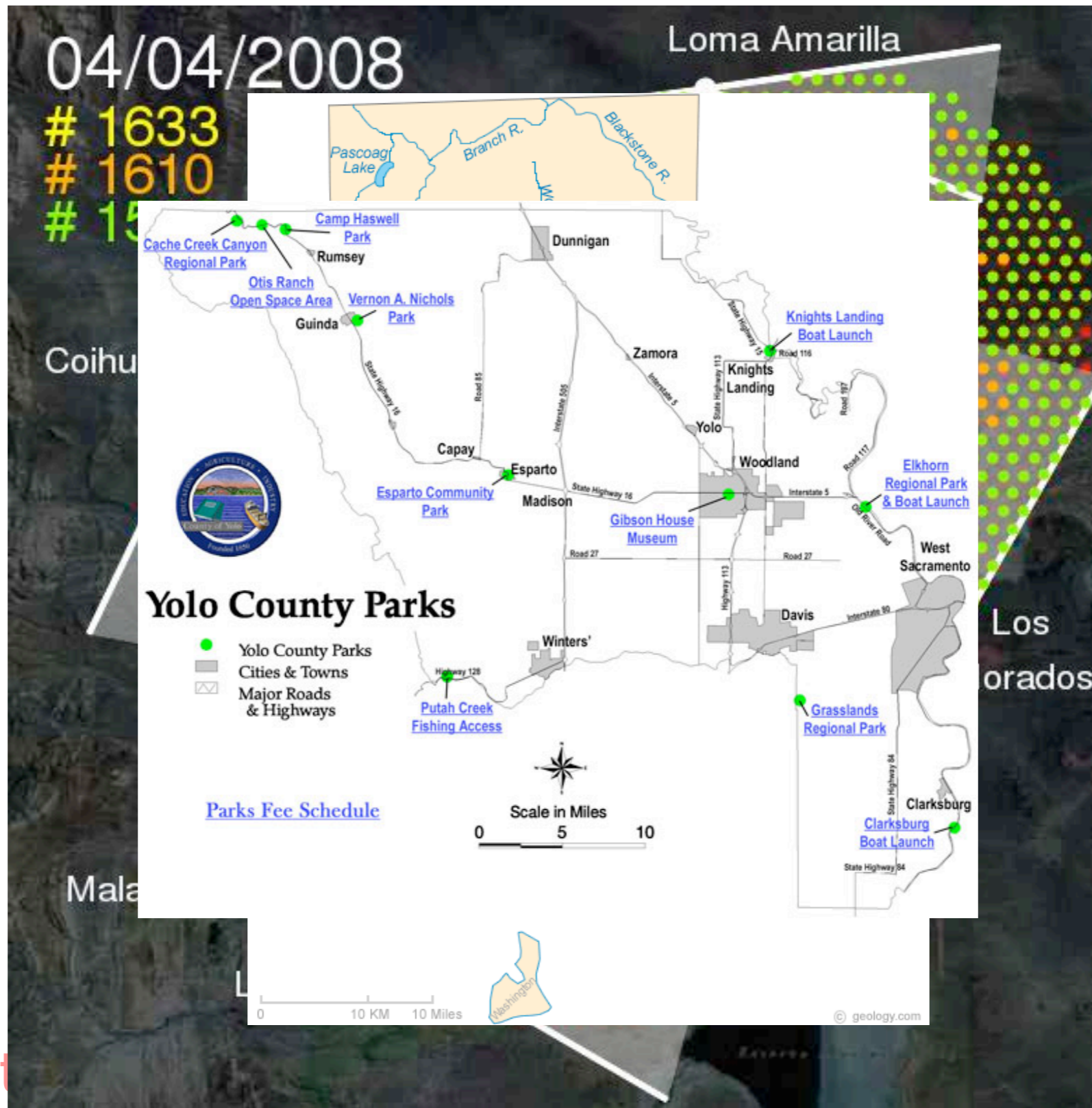
hybrid Reconstruction

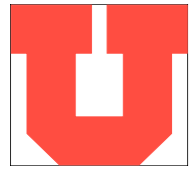
- reconstruct **golden** hybrids and **sub-threshold**



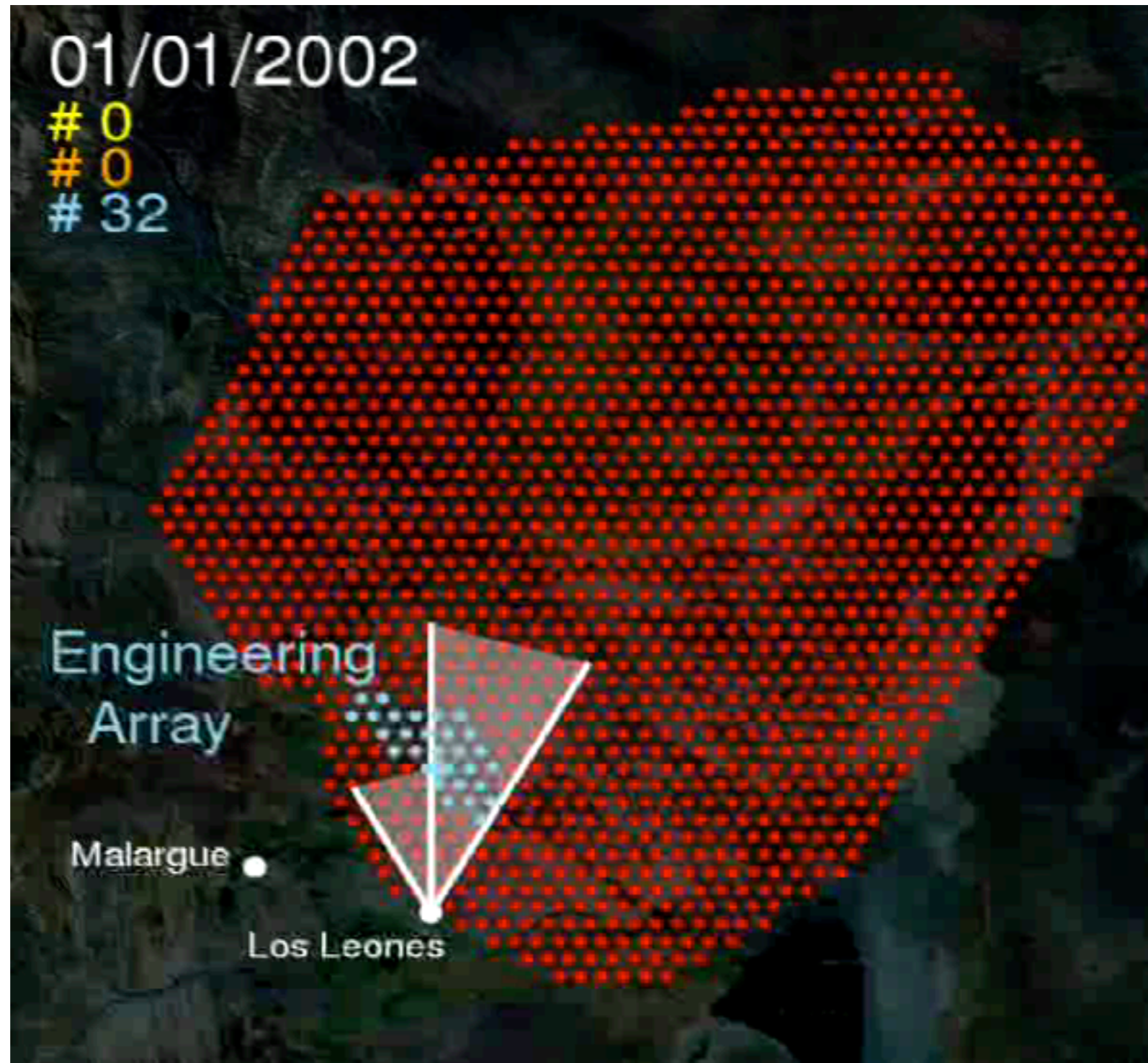


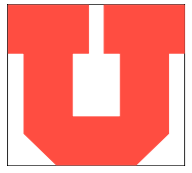
Auger status





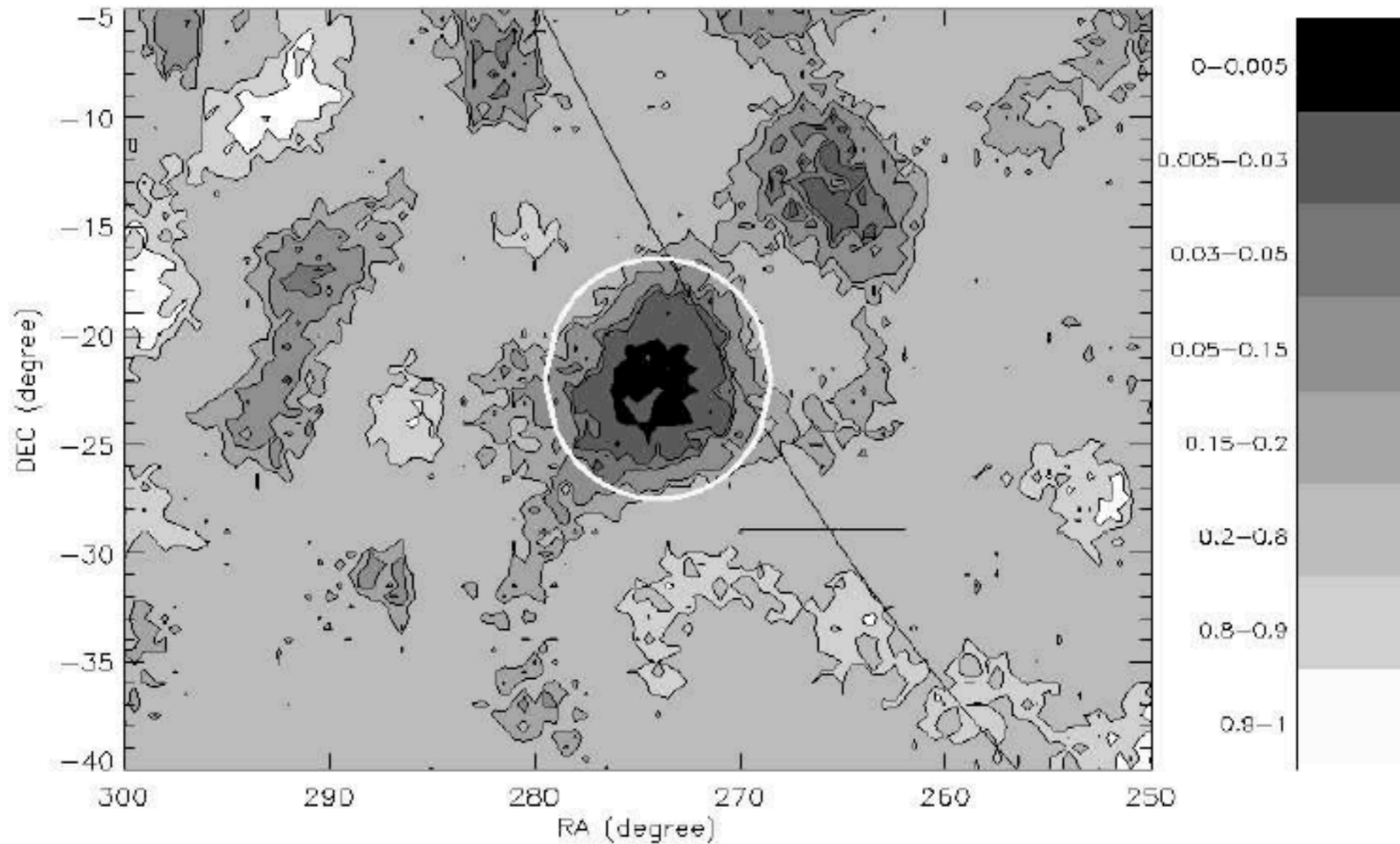
Auger status

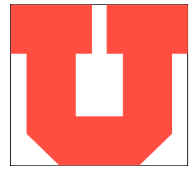




Results

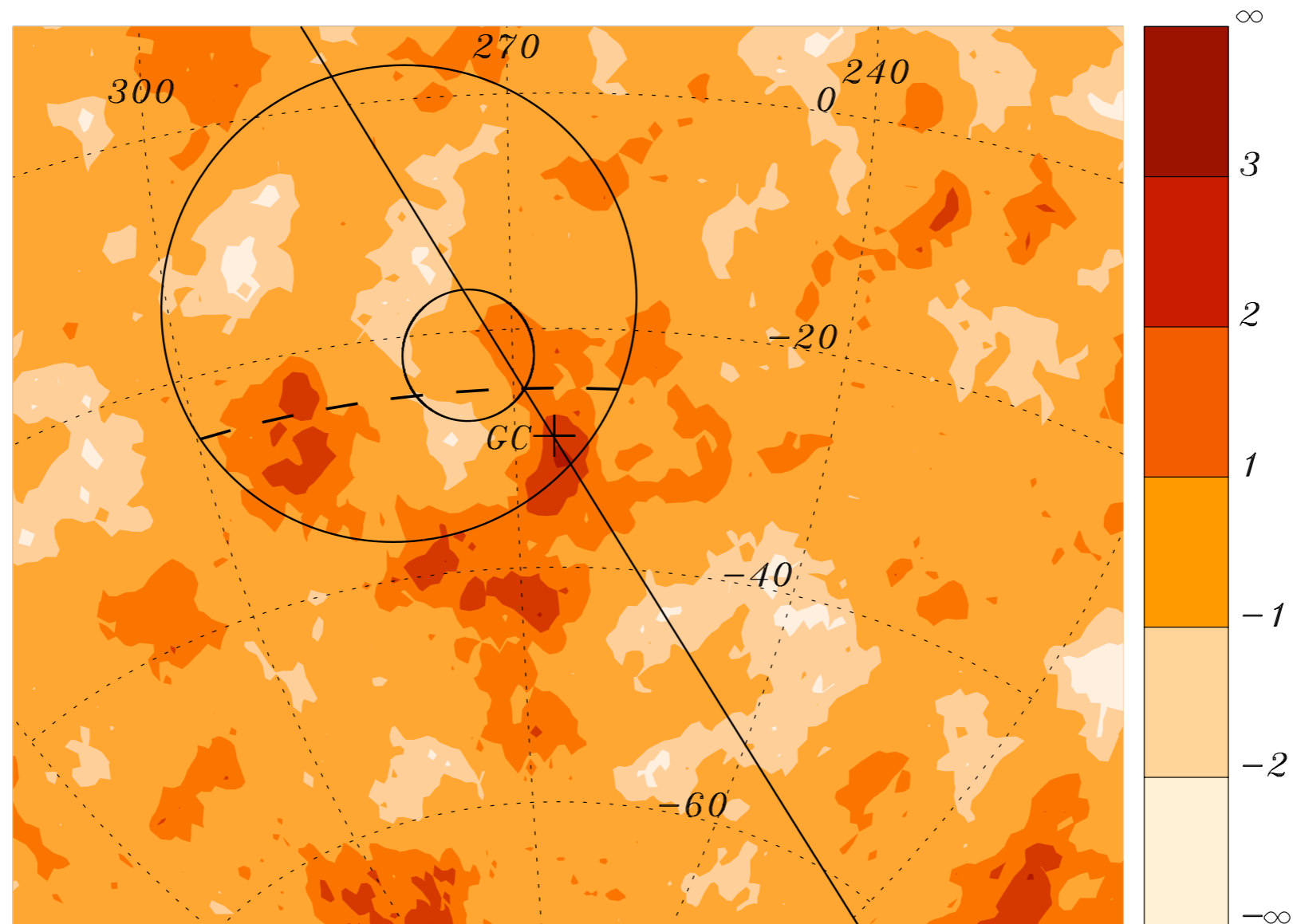
- Galactic Centre

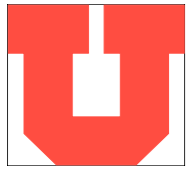




Auger Results

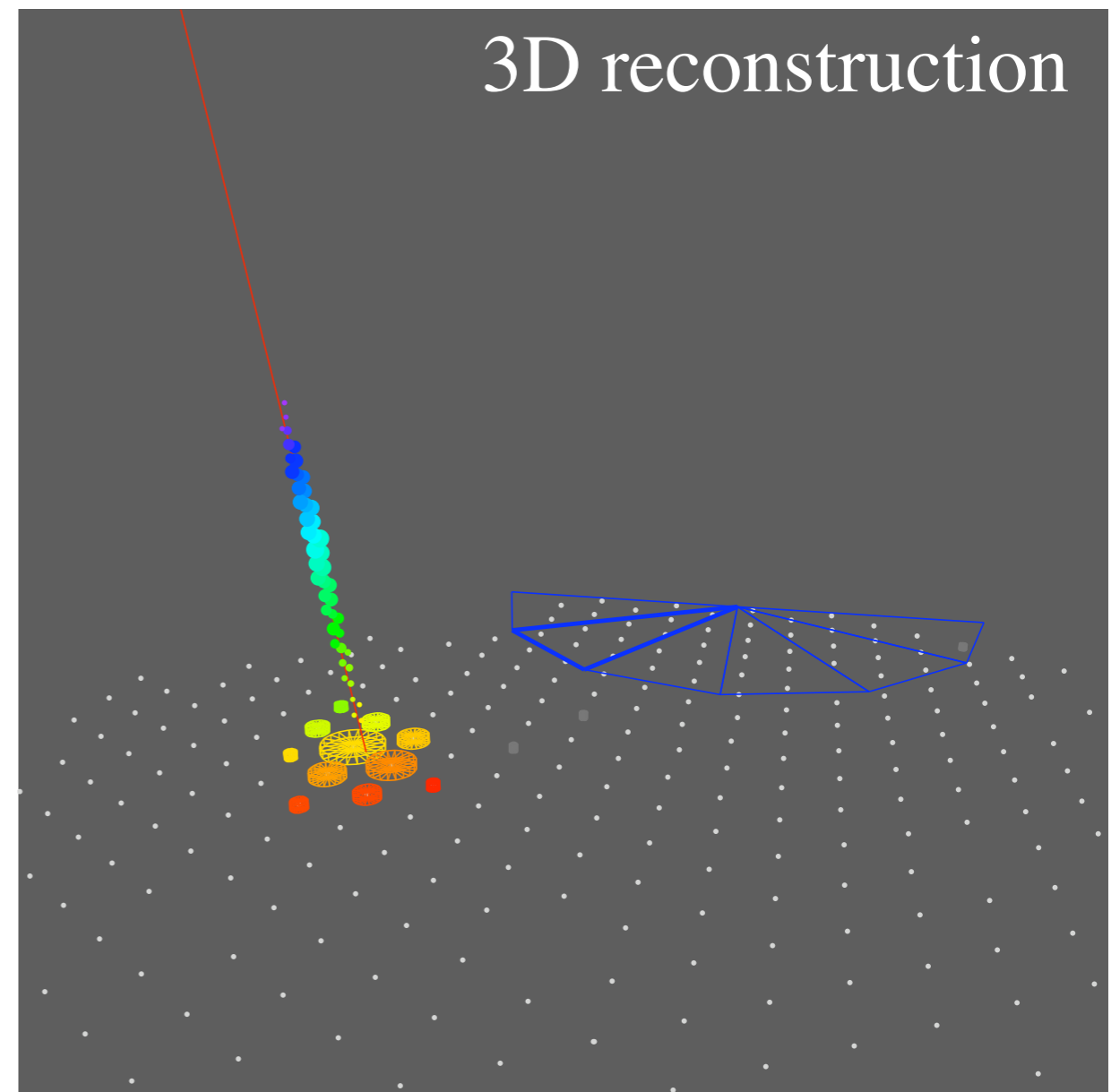
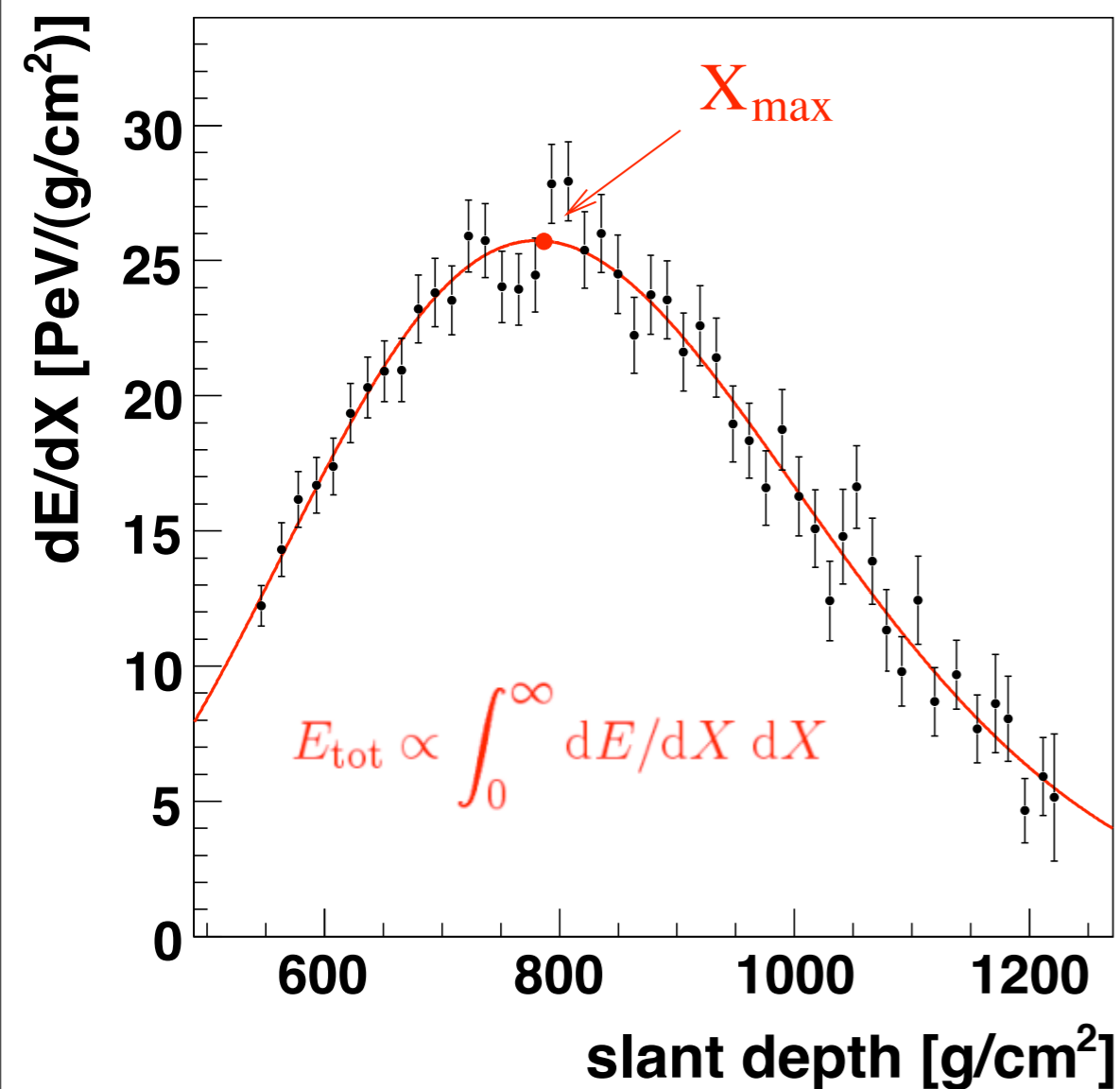
- Anisotropy around the GC at EeV energies

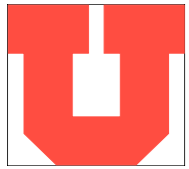




Auger Analysis

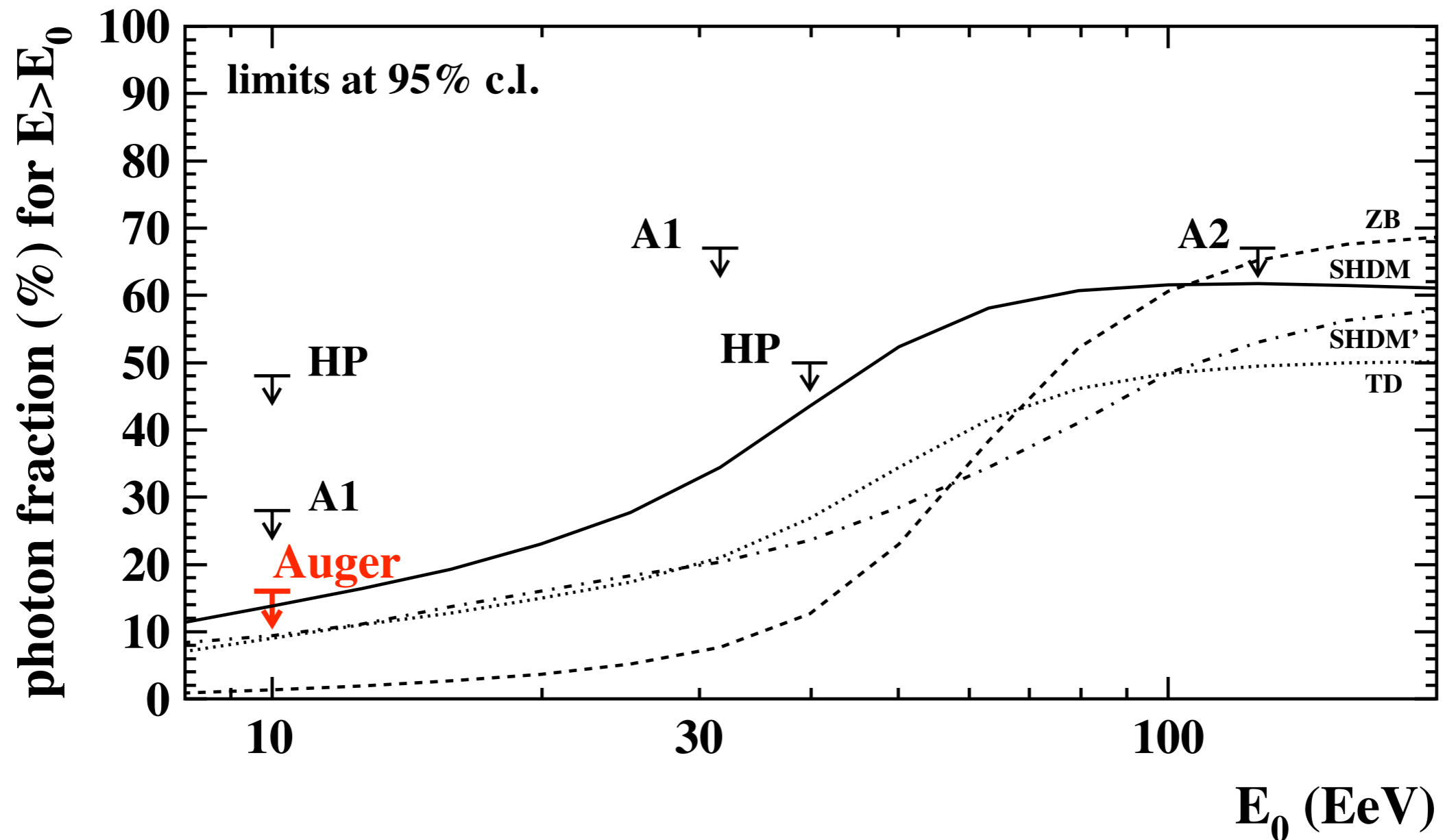
- longitudinal profile reconstruction

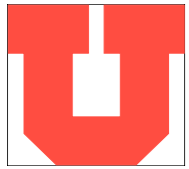




Auger Results

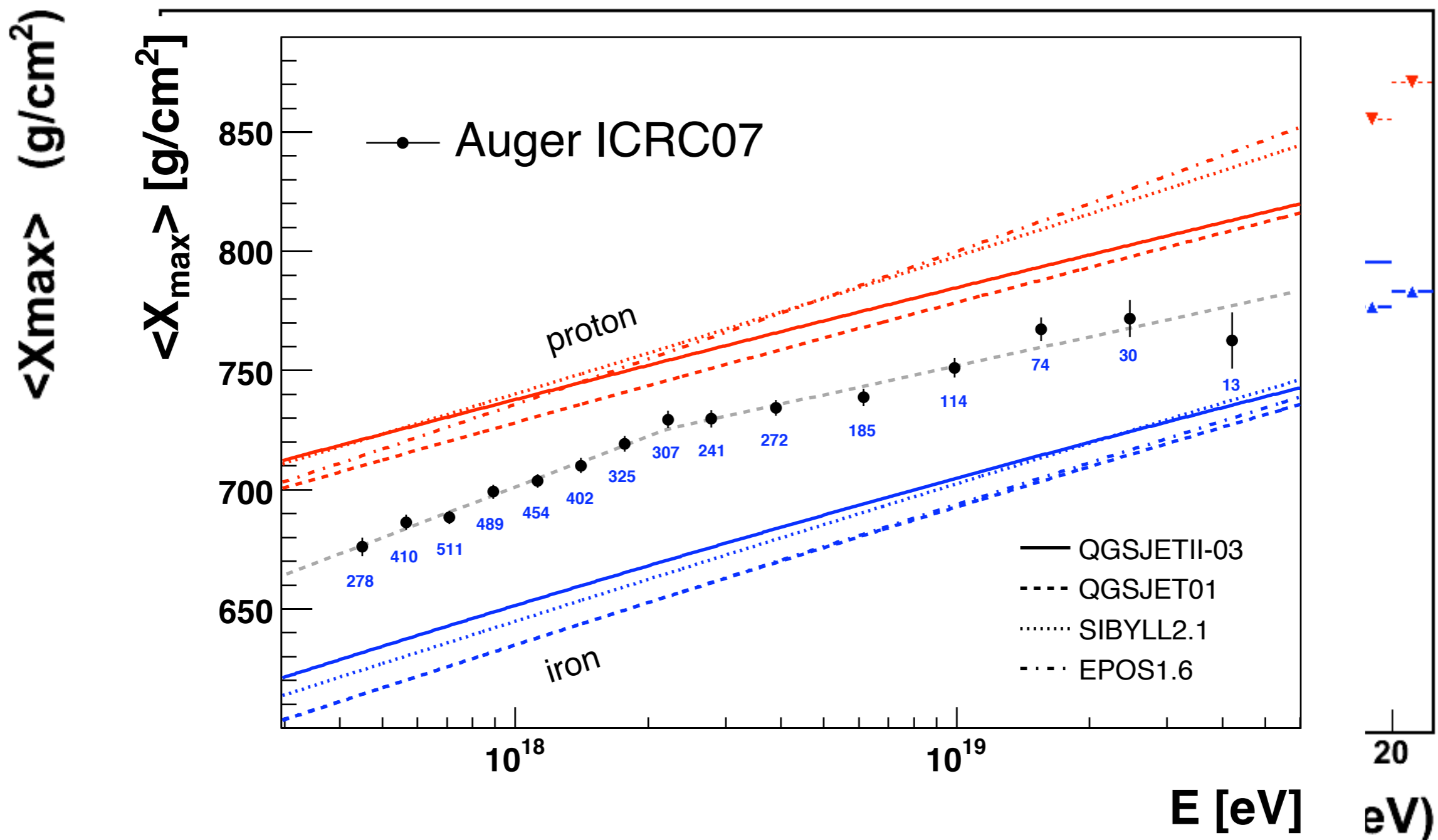
- Upper limit on *photon fraction* from **FD**

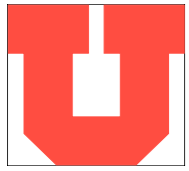




Auger Analysis

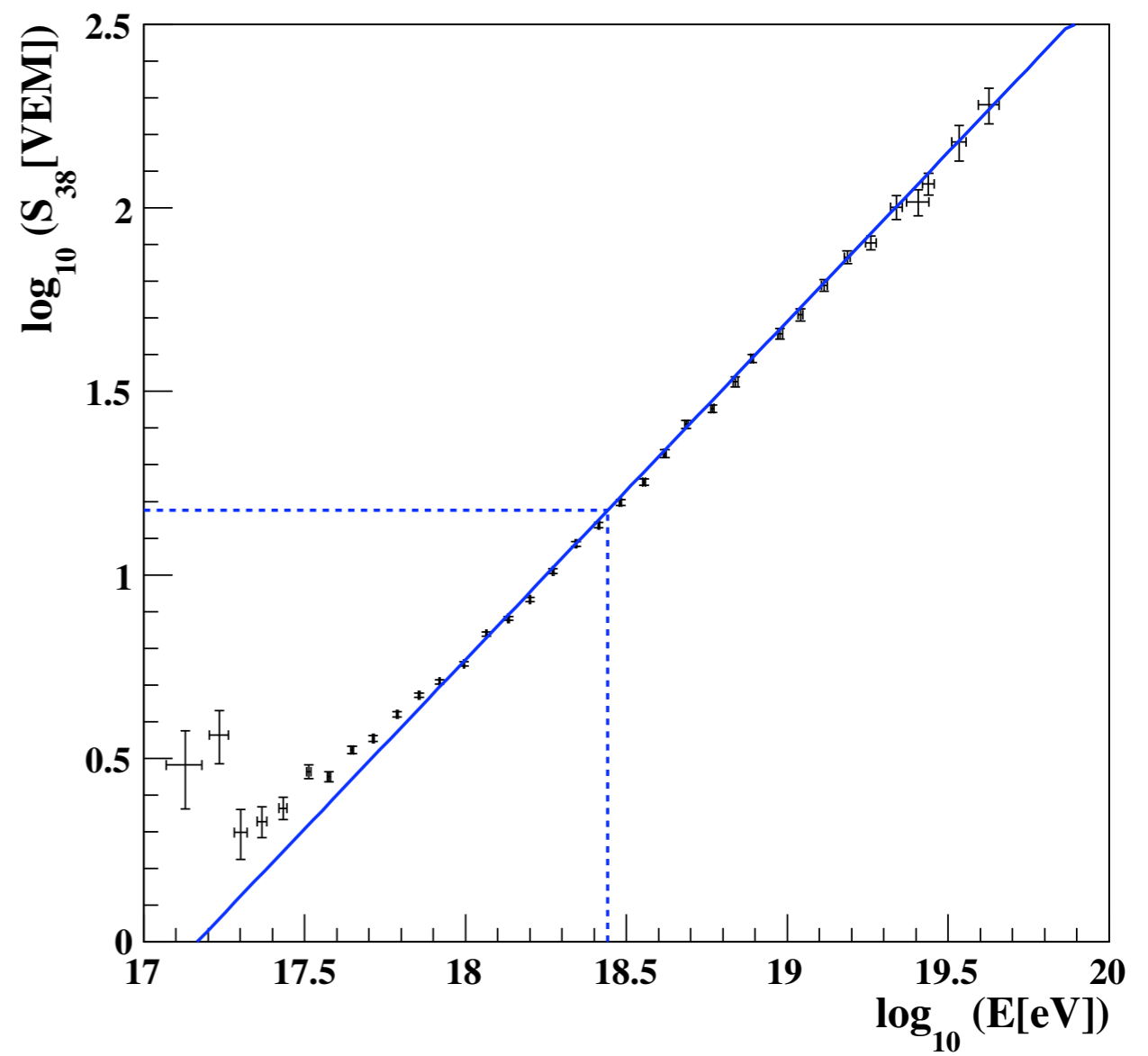
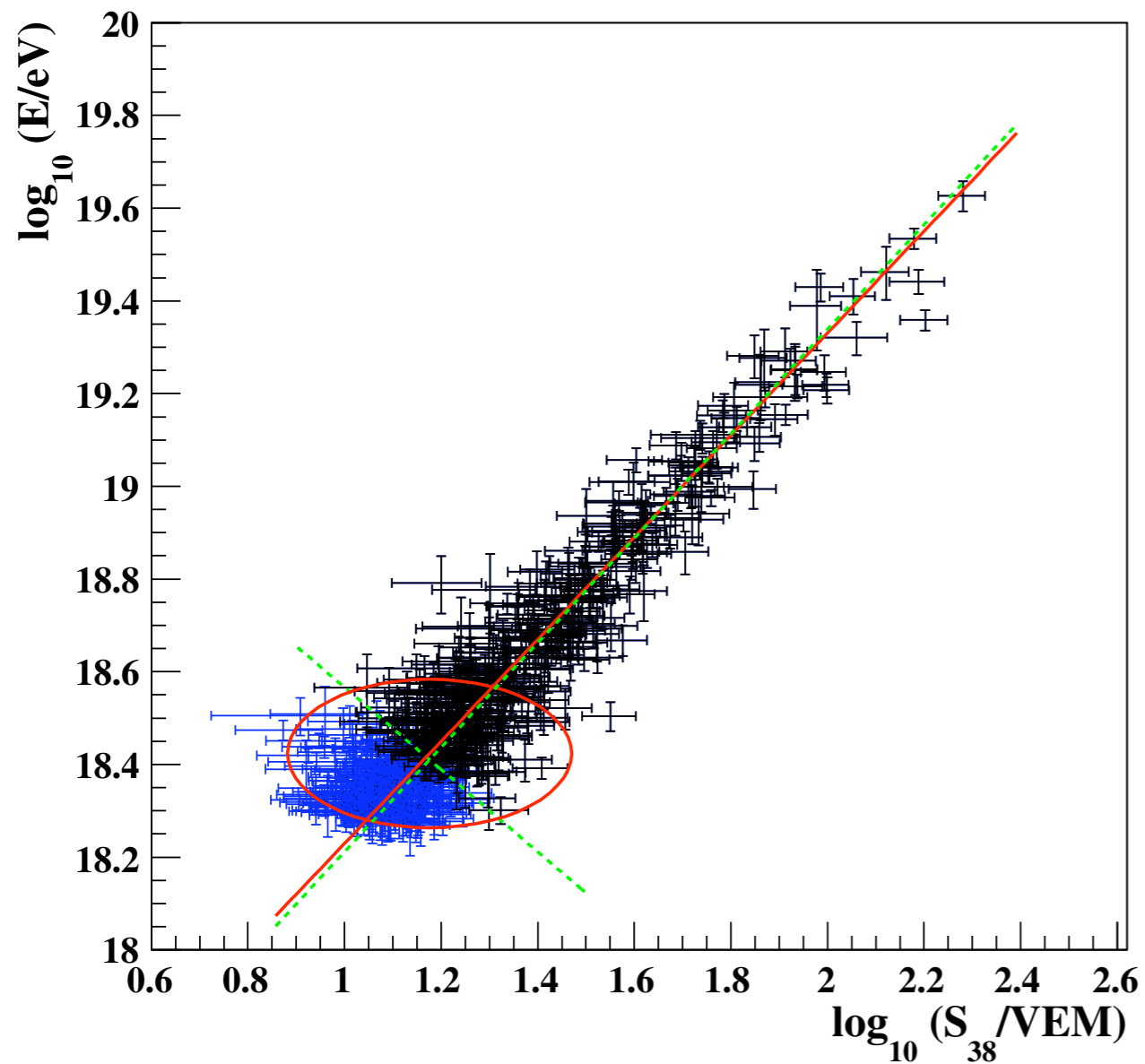
■ Elongation Rate

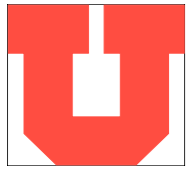




Auger Analysis

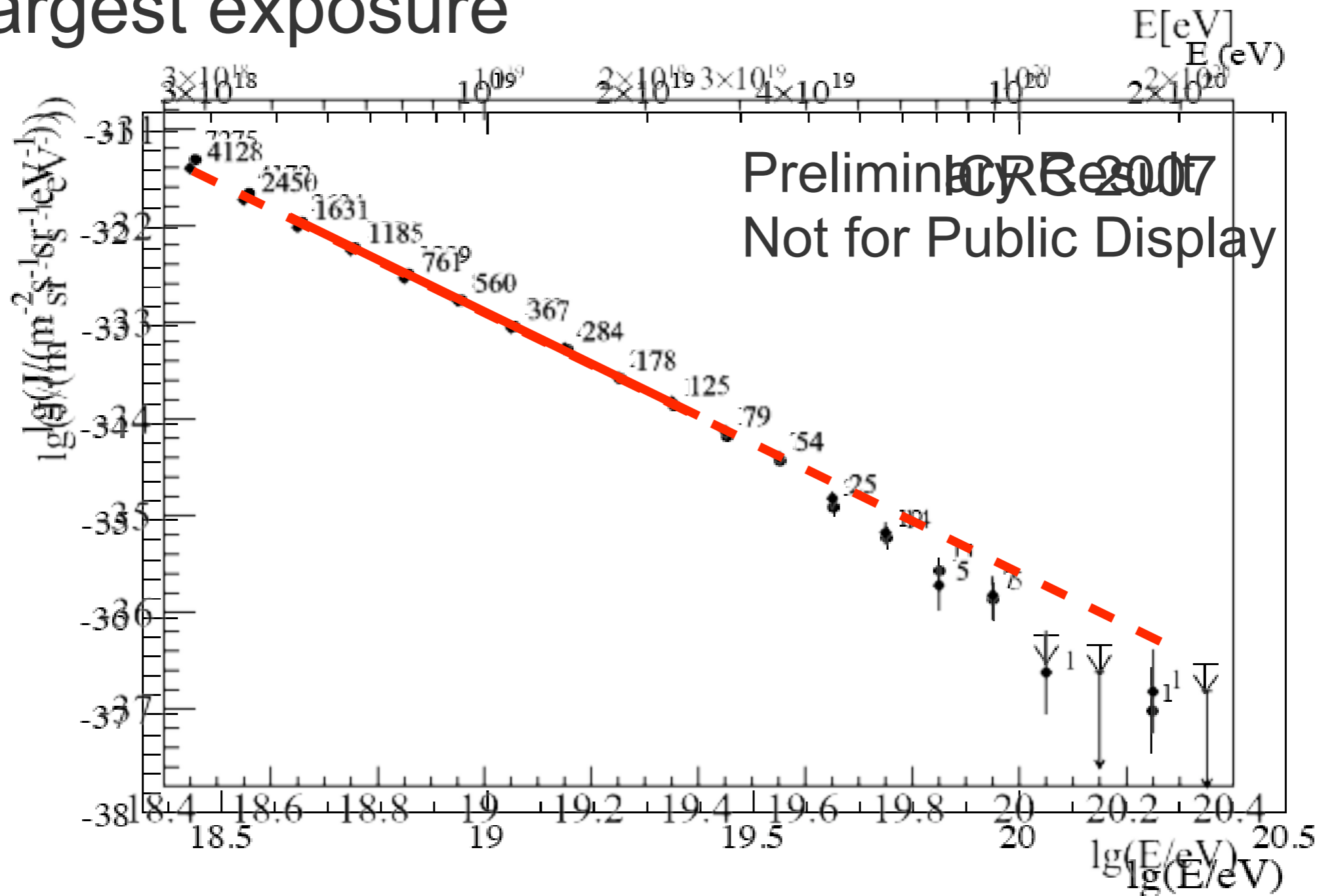
energy calibration

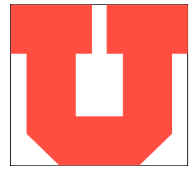




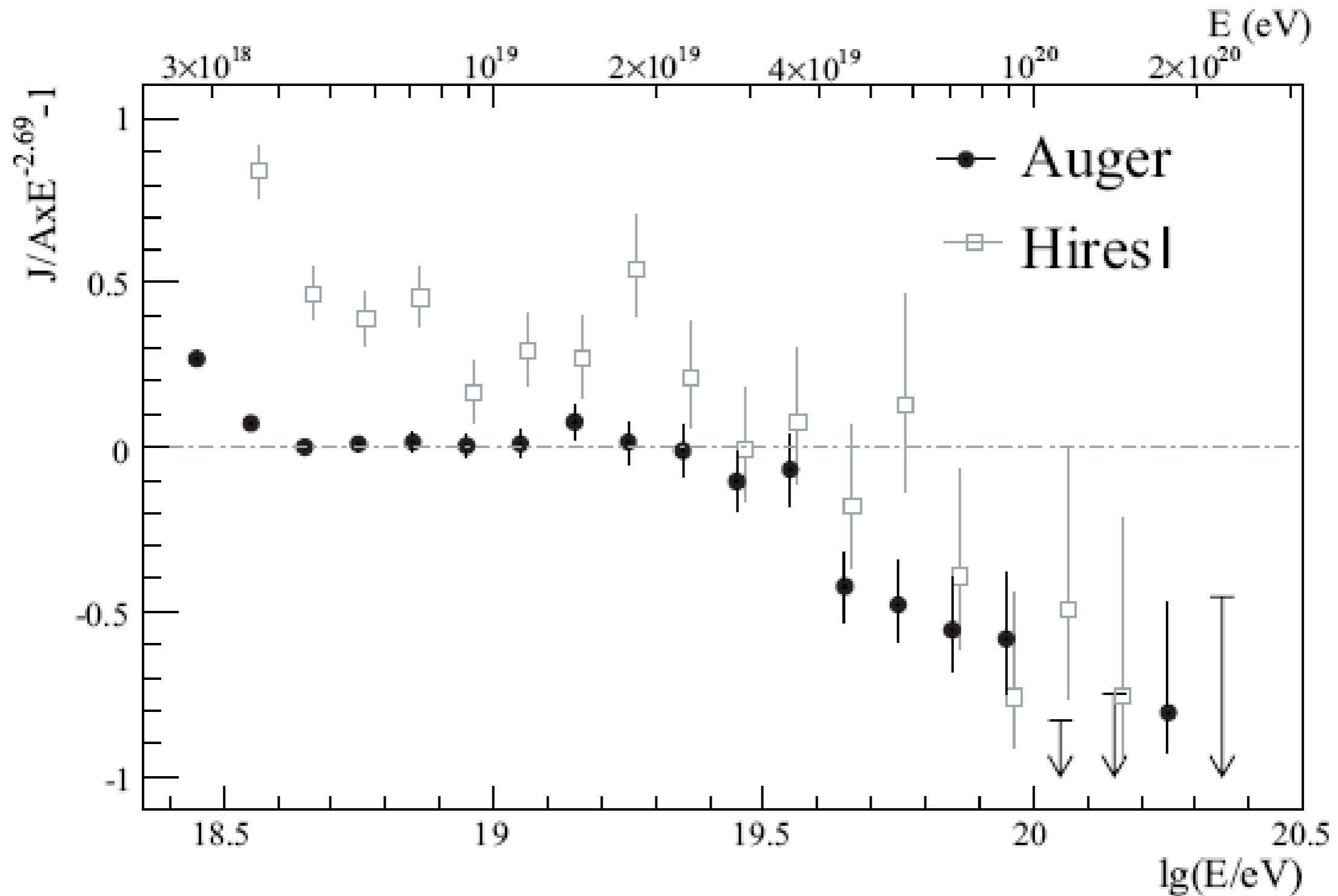
Auger Results

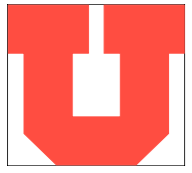
- largest exposure





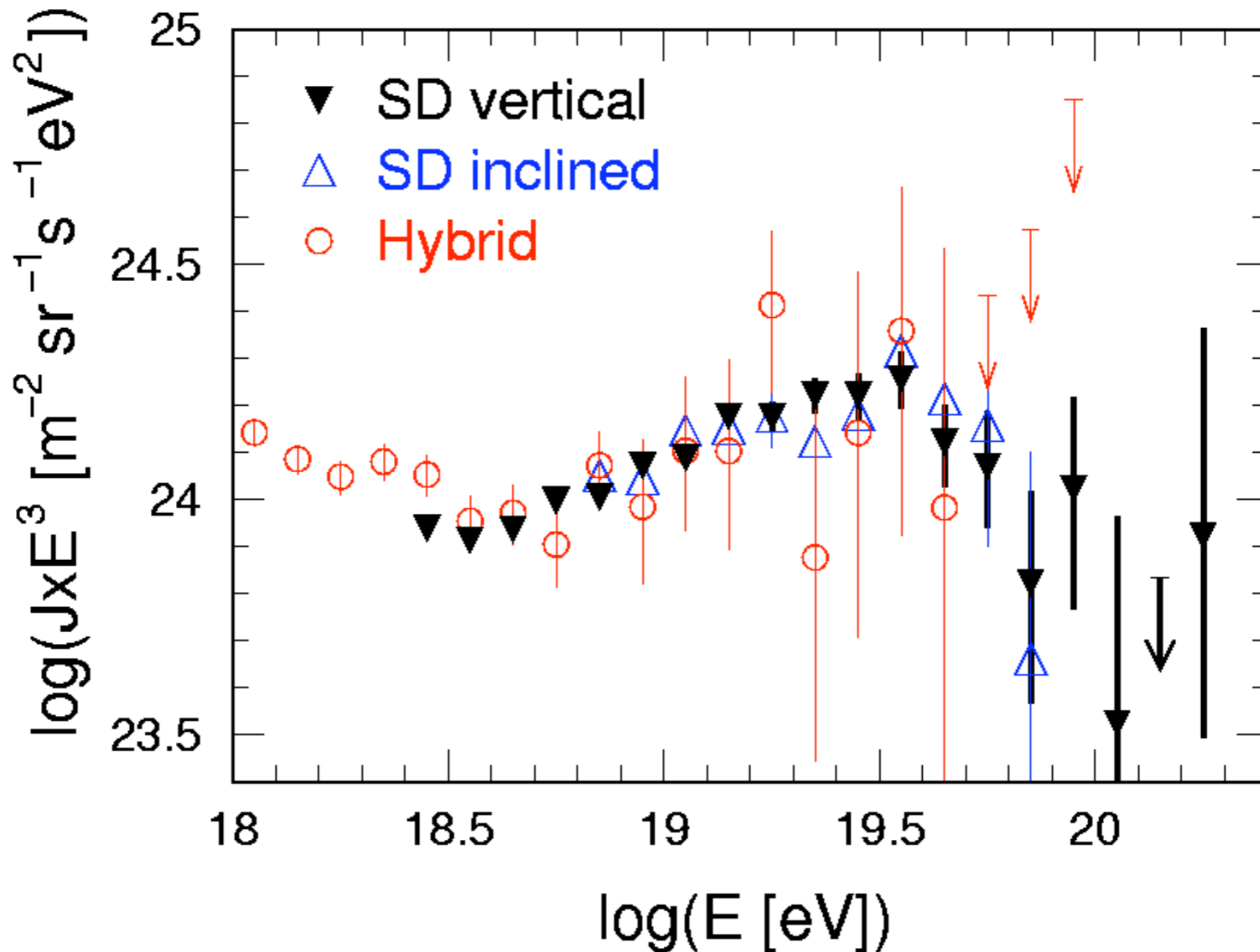
Auger Analysis

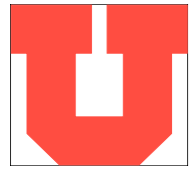




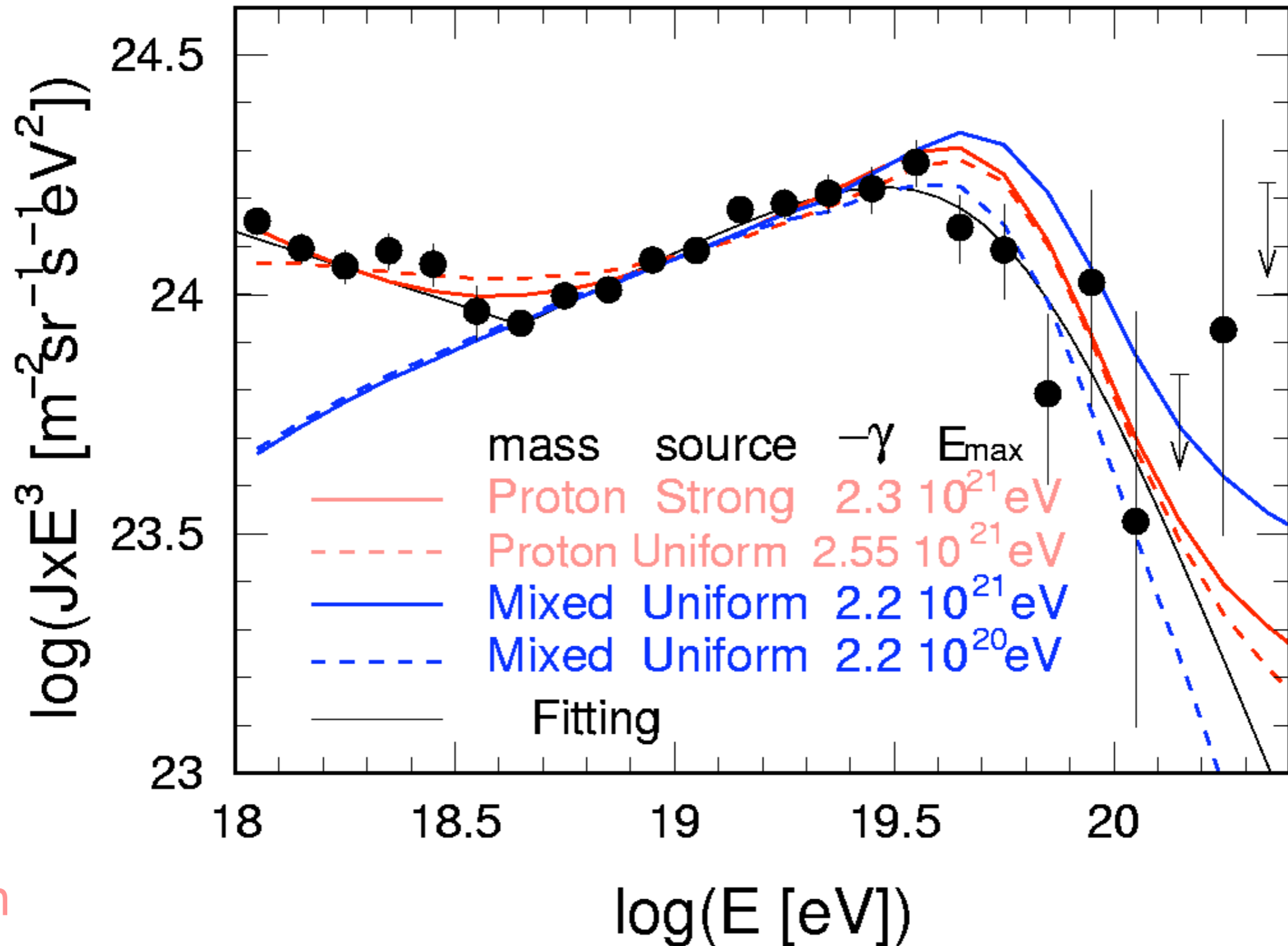
Auger Analysis

- hybrid extension of the spectrum



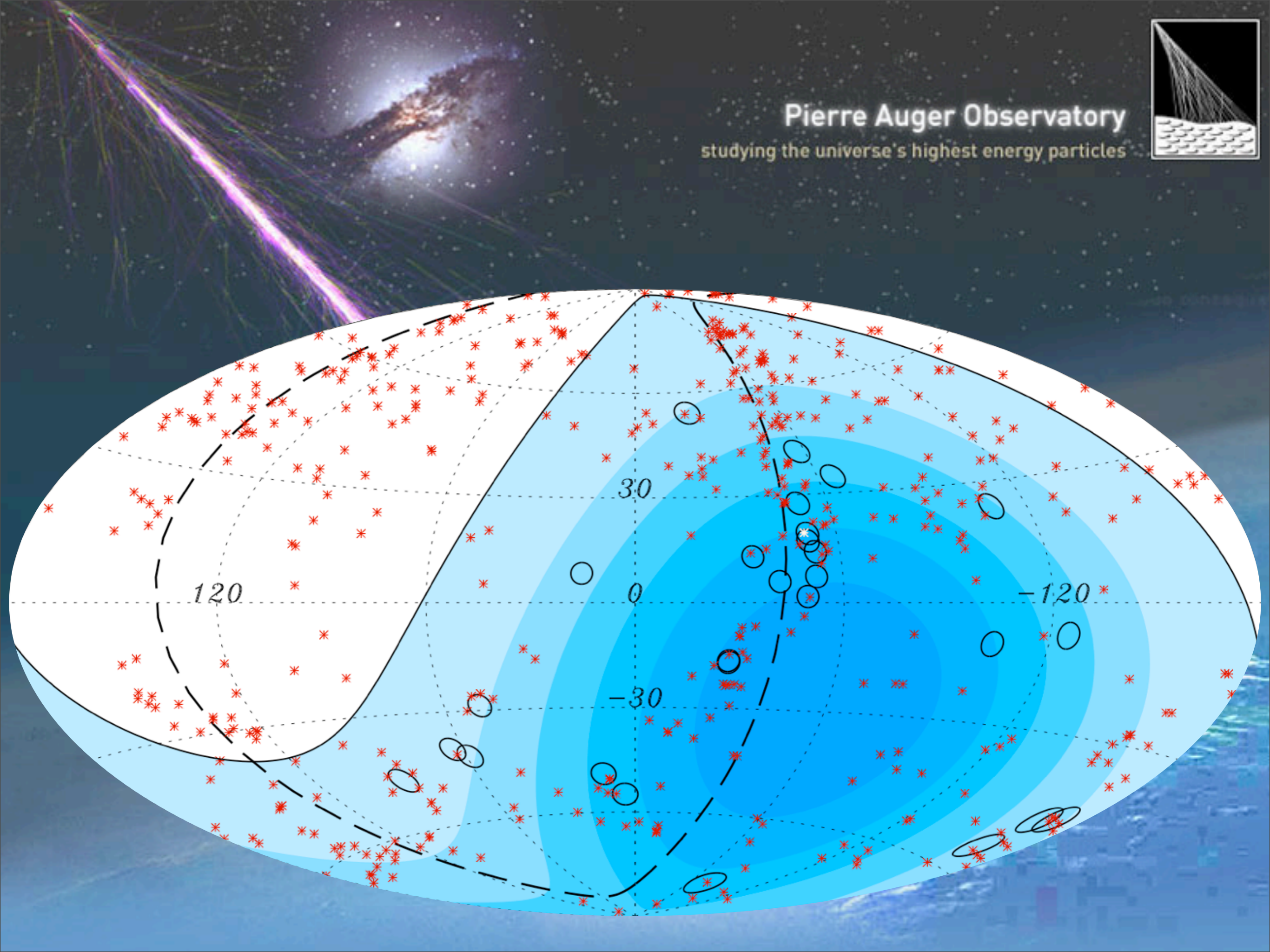


astroph implications



Pierre Auger Observatory

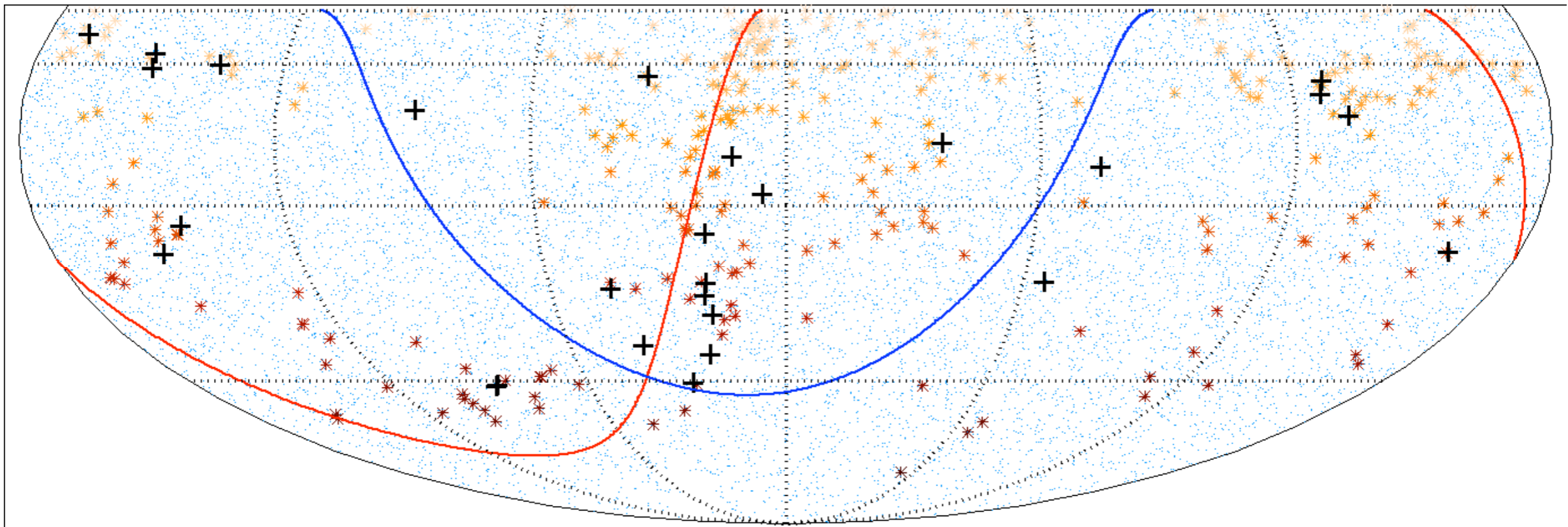
studying the universe's highest energy particles

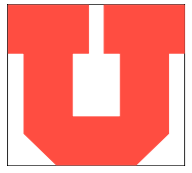




Auger Results

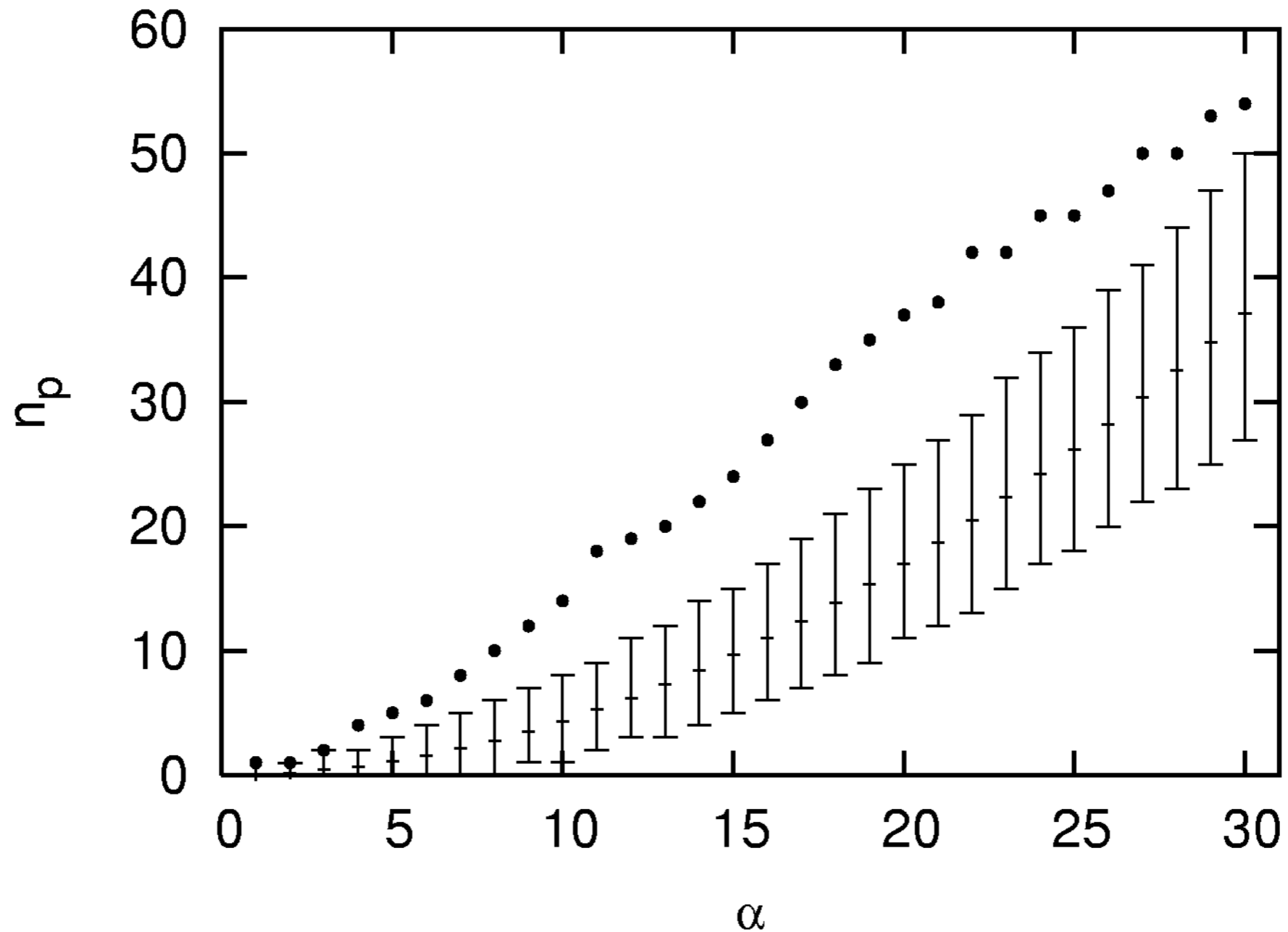
- an iso-exposure Mollweide map

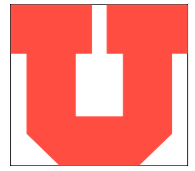




Auger Analysis

- auto-correlation

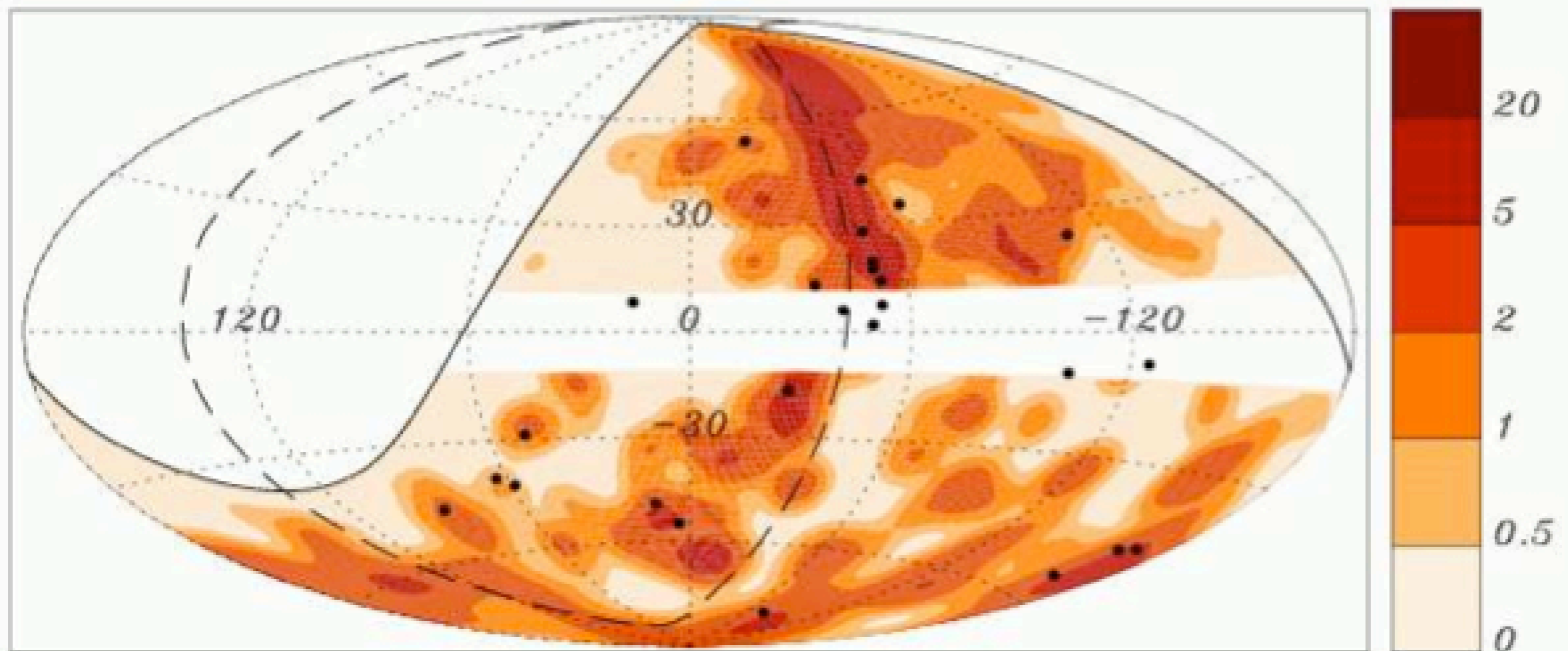


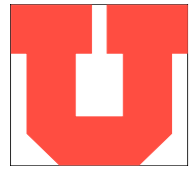


Source Studies

- 100 Mpc horizon maps

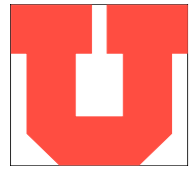
VC 4deg reference map





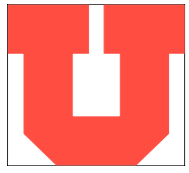
“AGN” conclusions

- Can we say anything about the sources?
 - They are **not Galactic**
 - Likely **astrophysical**
 - AGNs are interesting **plausible** sites
- More data are needed to identify and characterize the sources



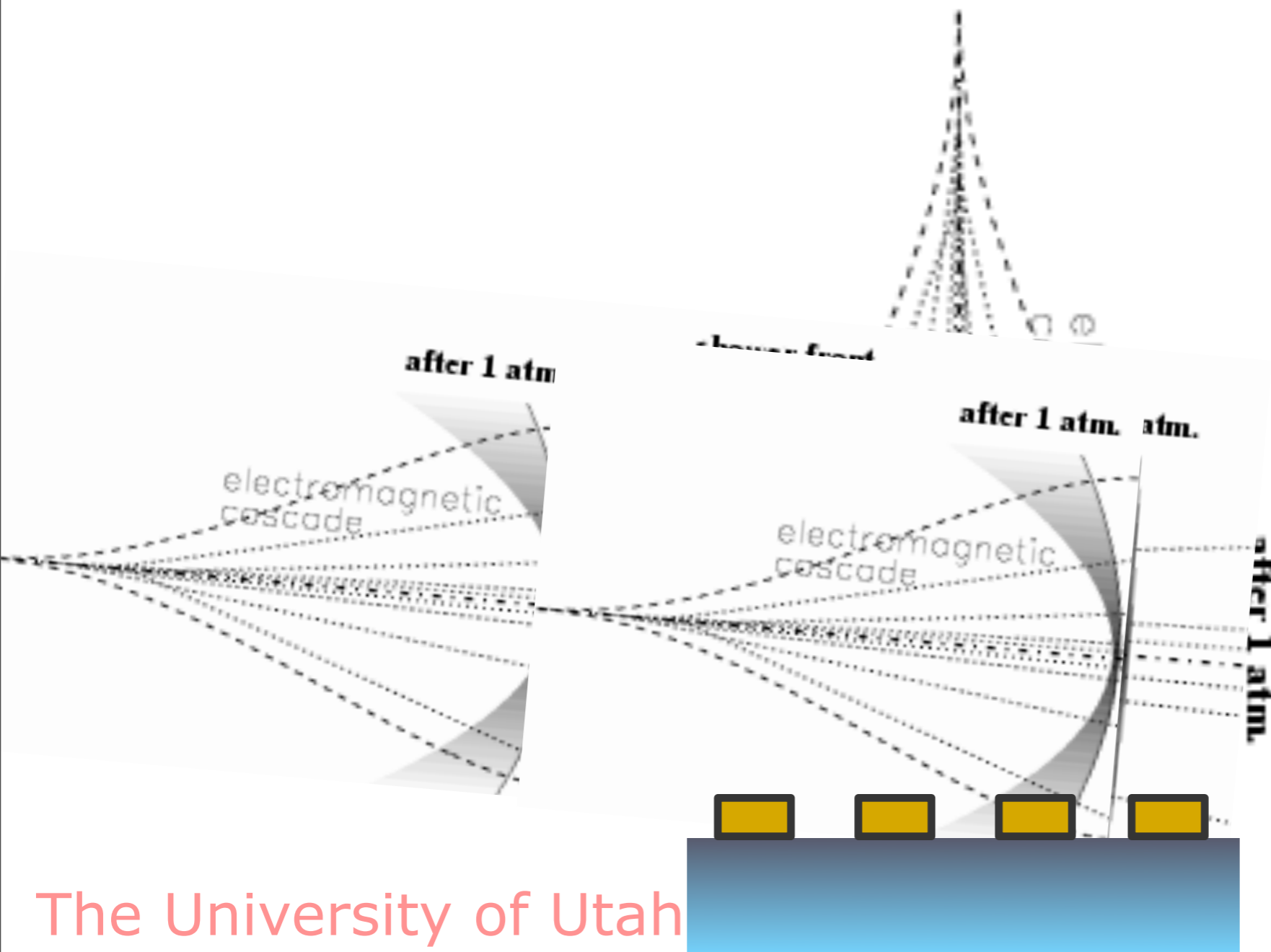
“AGN” conclusions

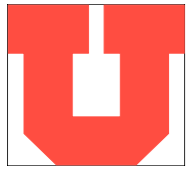
- Have we found the sources of EHECRs?
 - The results are certainly **interesting** if not (yet) *statistically compelling*
 - If/when our correlations are statistically compelling, we will have (arguably) the first experimental feedback on **magnetic deflections** of extra-galactic CRs
 - We will continue our analysis on the ever-**increasing** Auger data set



Auger Analysis

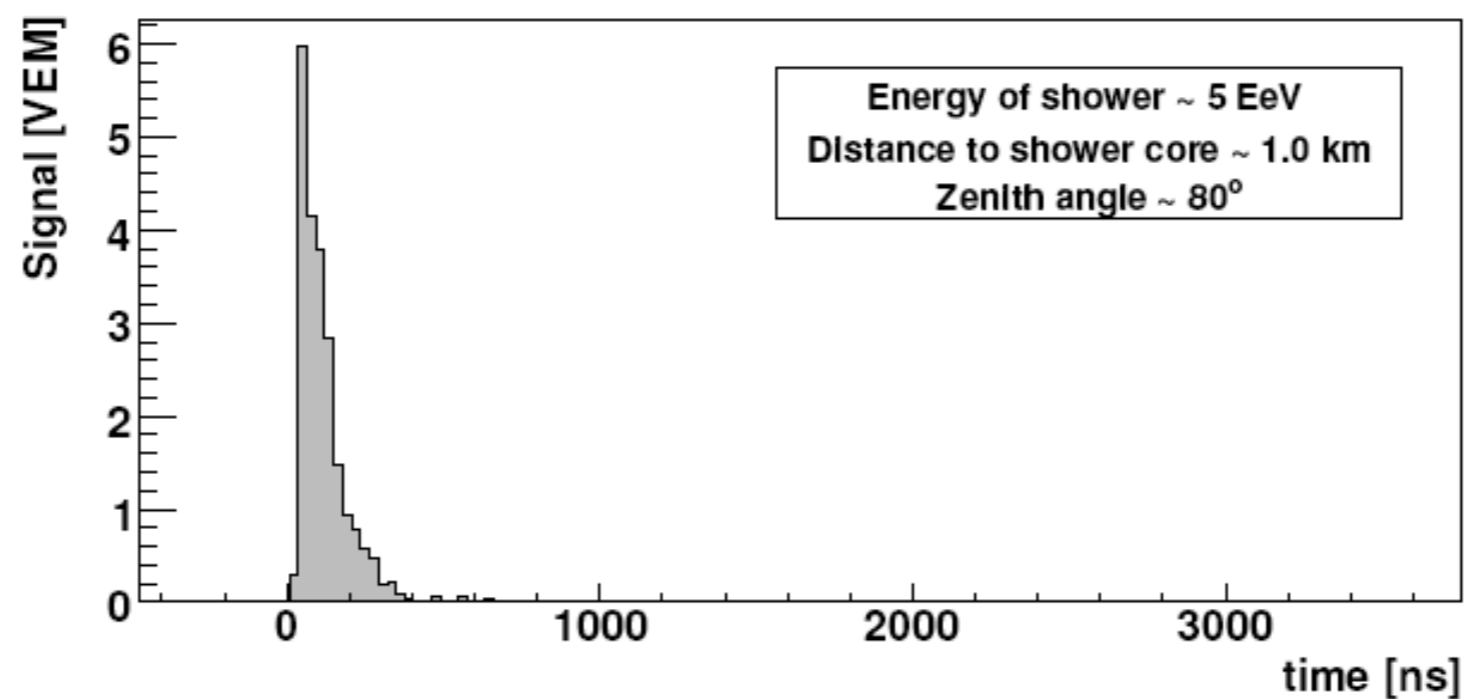
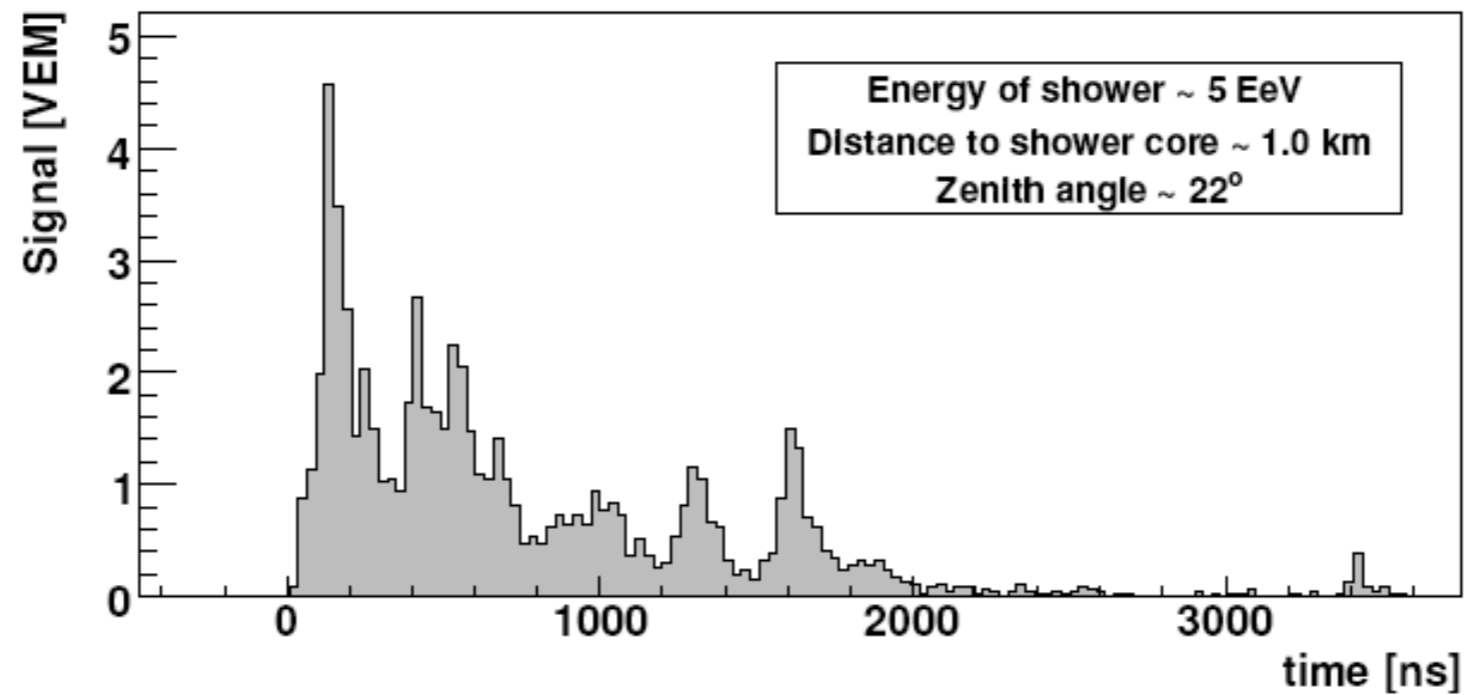
- neutrino detector?

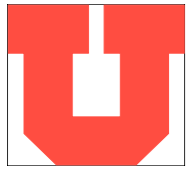




Auger Analysis

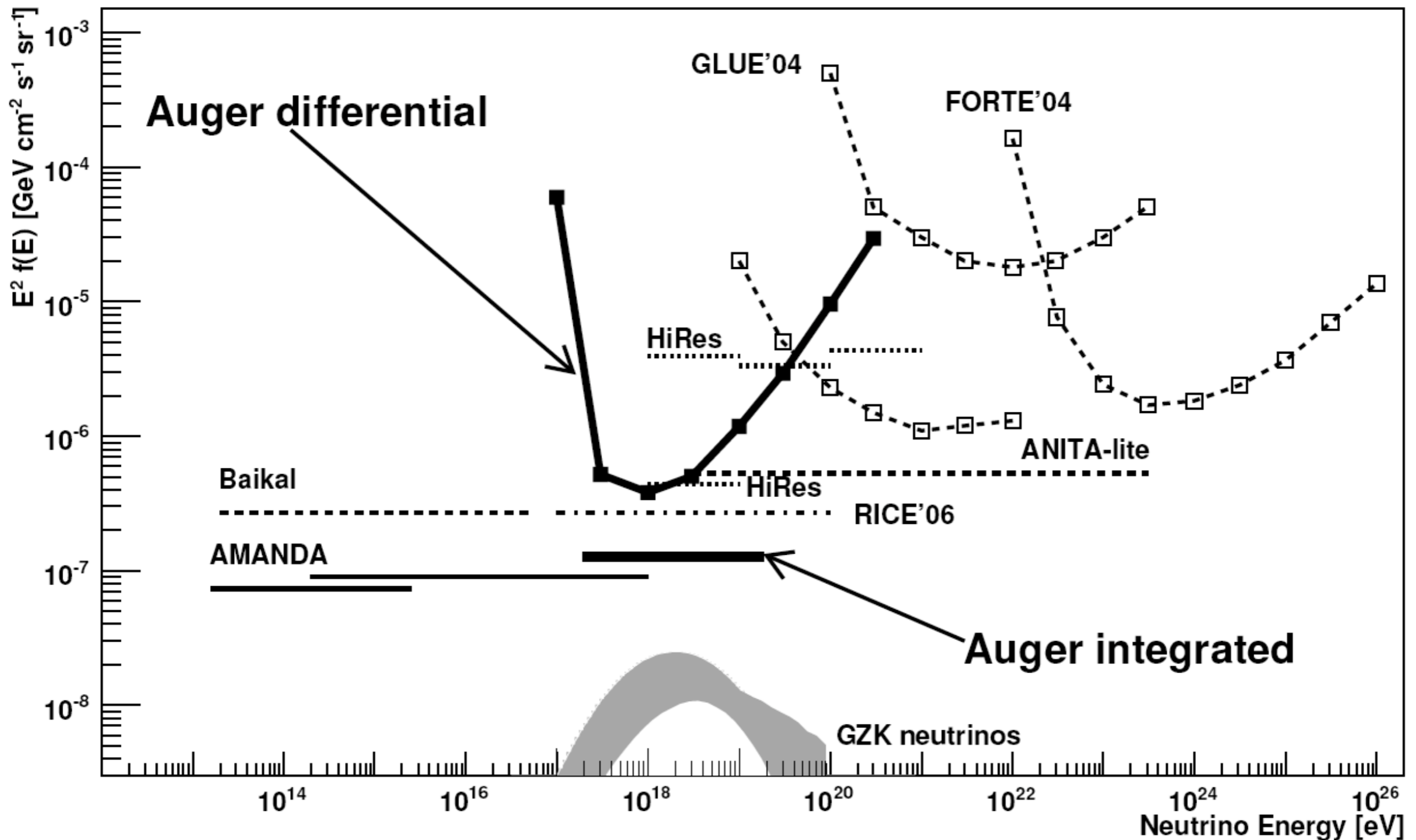
- vertical vs. horizontal showers

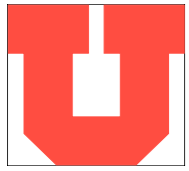




Auger Analysis

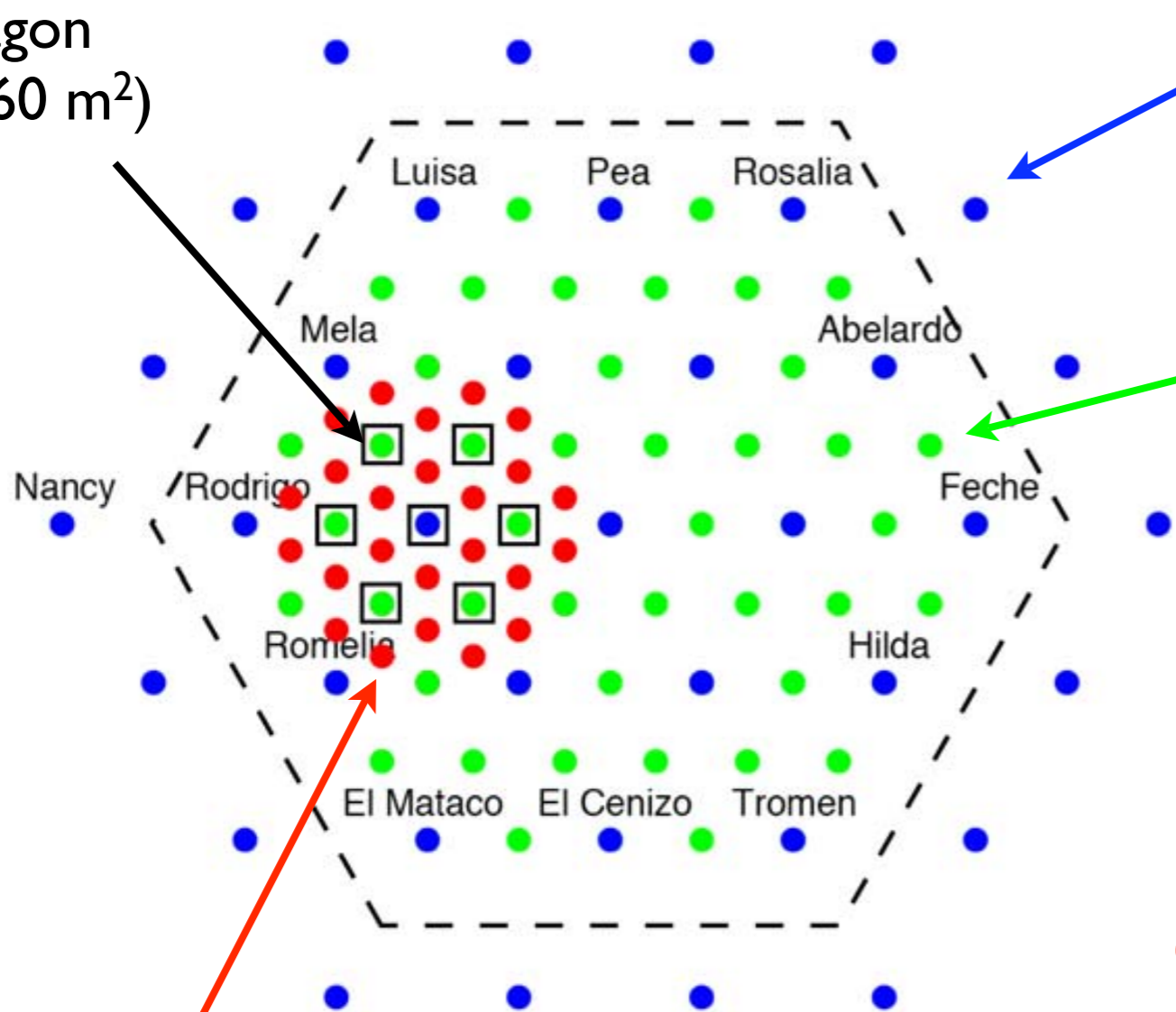
neutrino limits





Auger future - AMIGA

Hexagon
(7 x 60 m²)



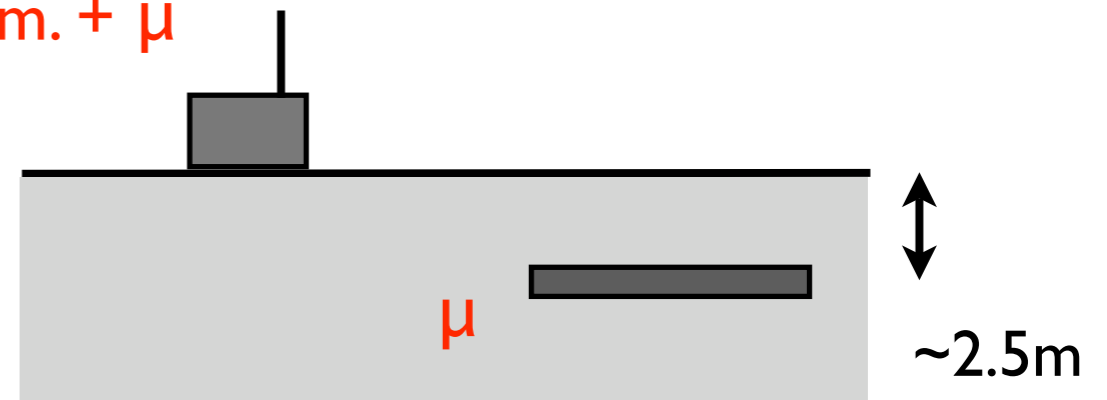
Existing tank array 1500m

Infill array 750m

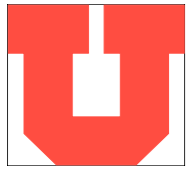
Muon detectors:
54 (30m²) + 7 (60m²)
Cherenkov tanks: 61
Area ~ 23 km²

Infill array 433m
Area ~ 5.9 km²

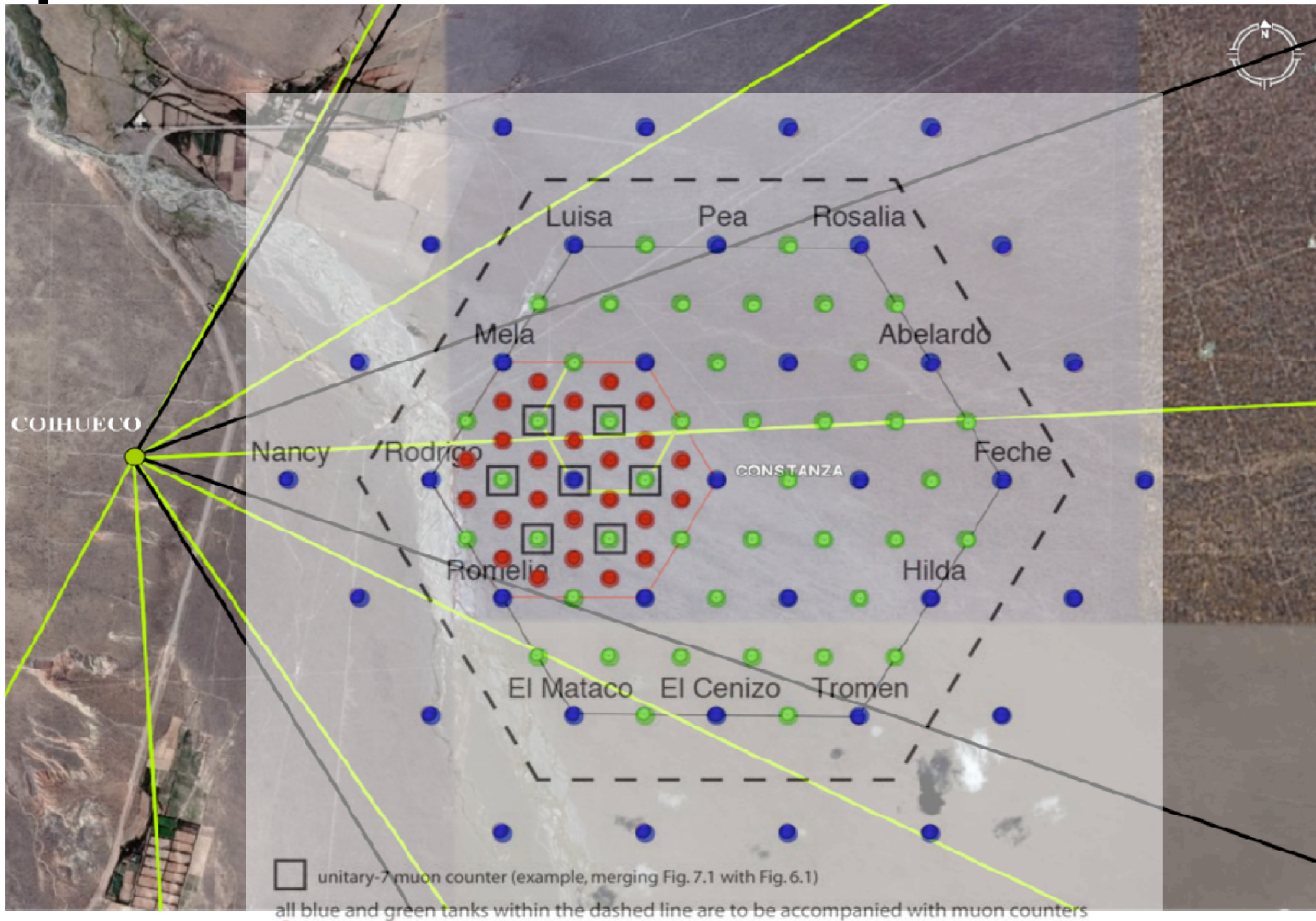
em. + μ

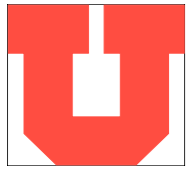


Detector pairs



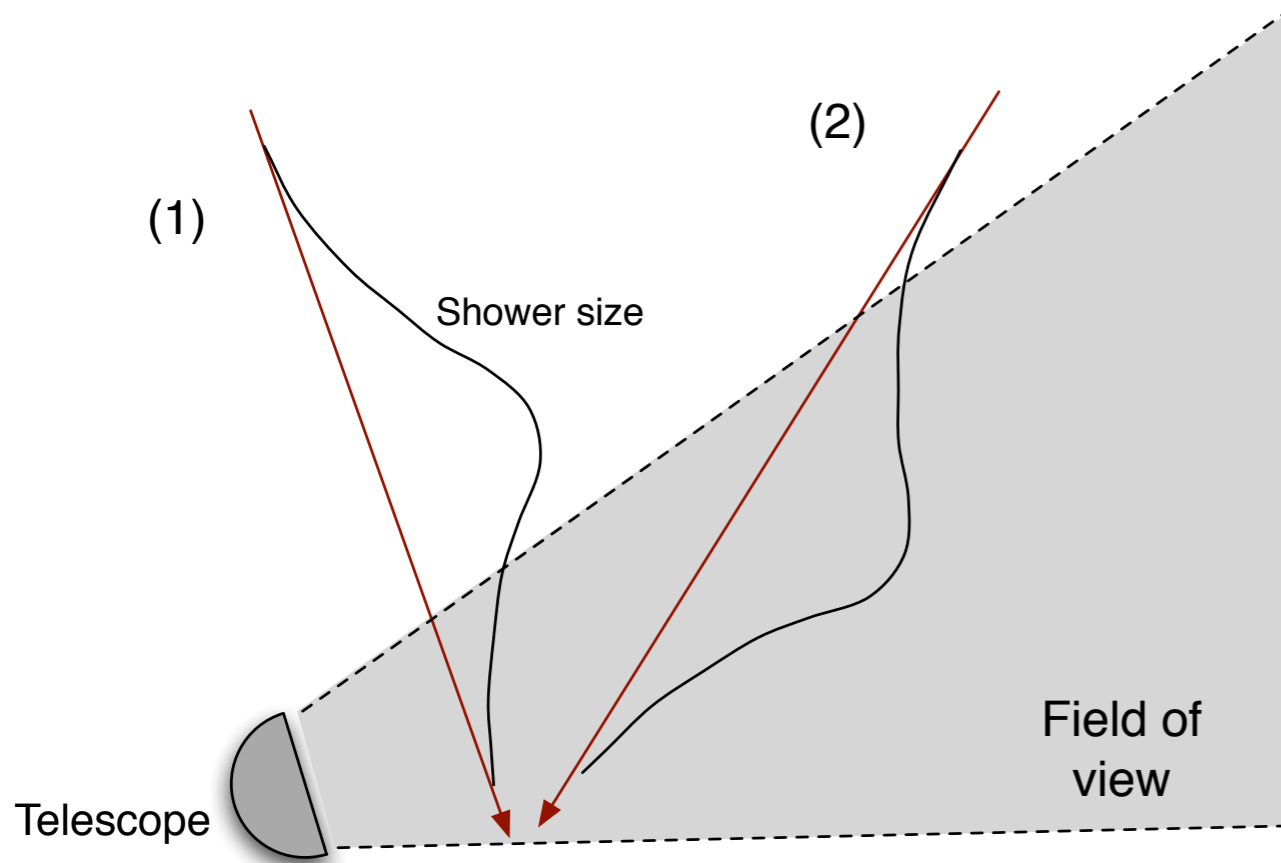
Auger future



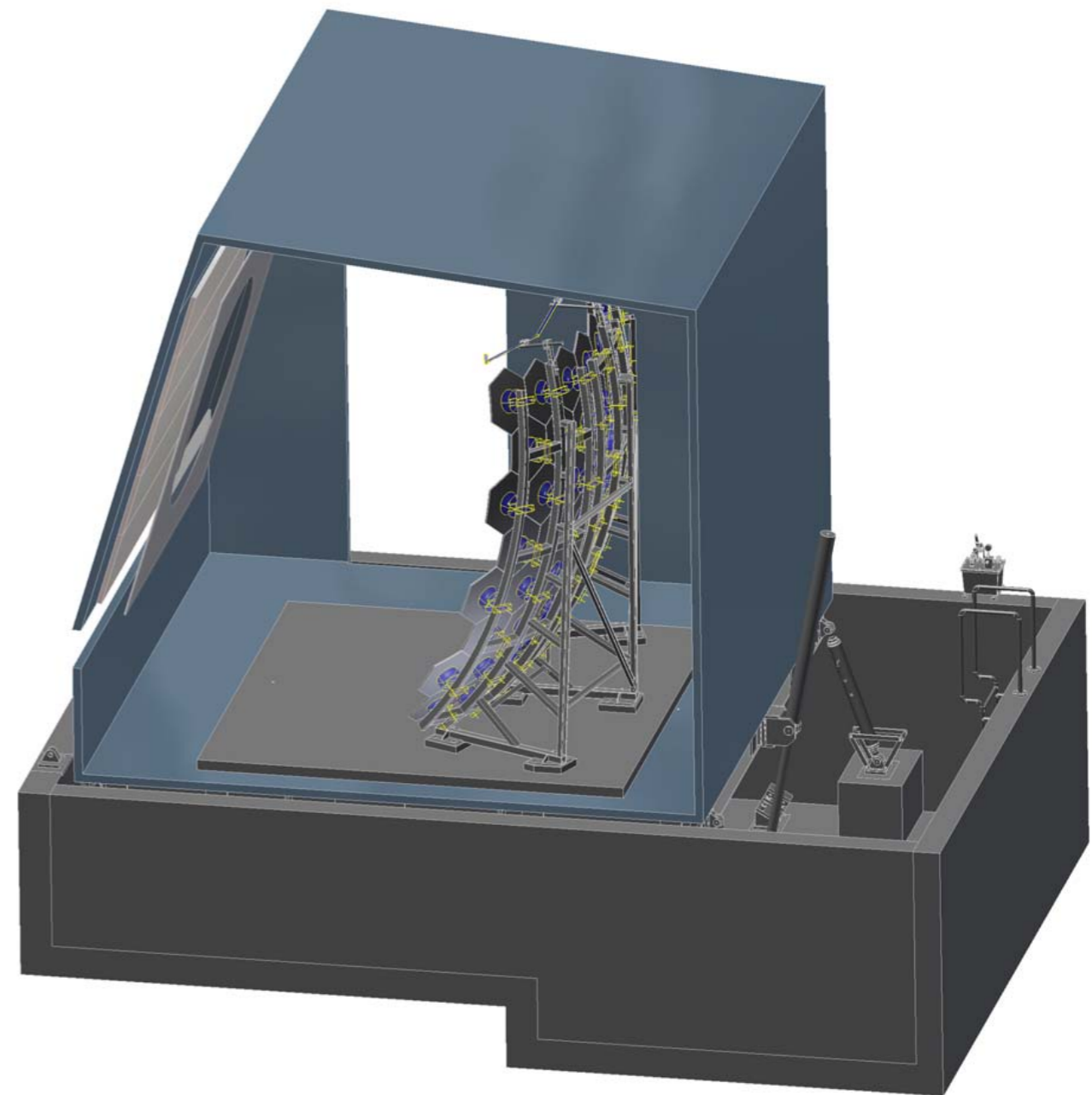


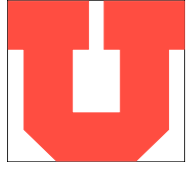
Auger future

High Elevation Auger Telescopes



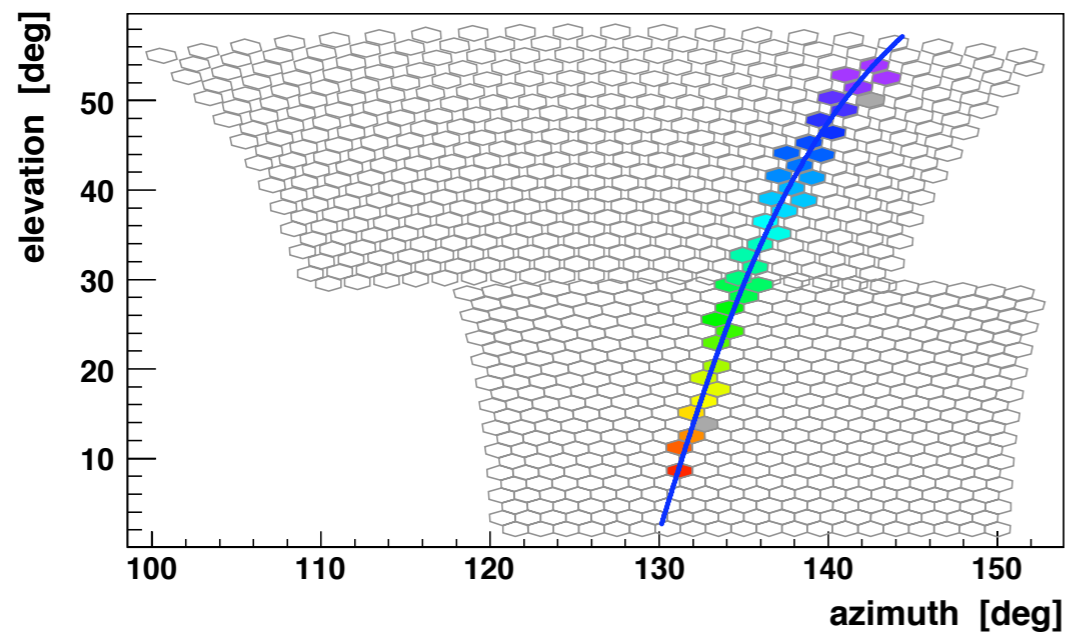
Auger fluorescence telescopes:
1 - 30° FoV (elevation angle)



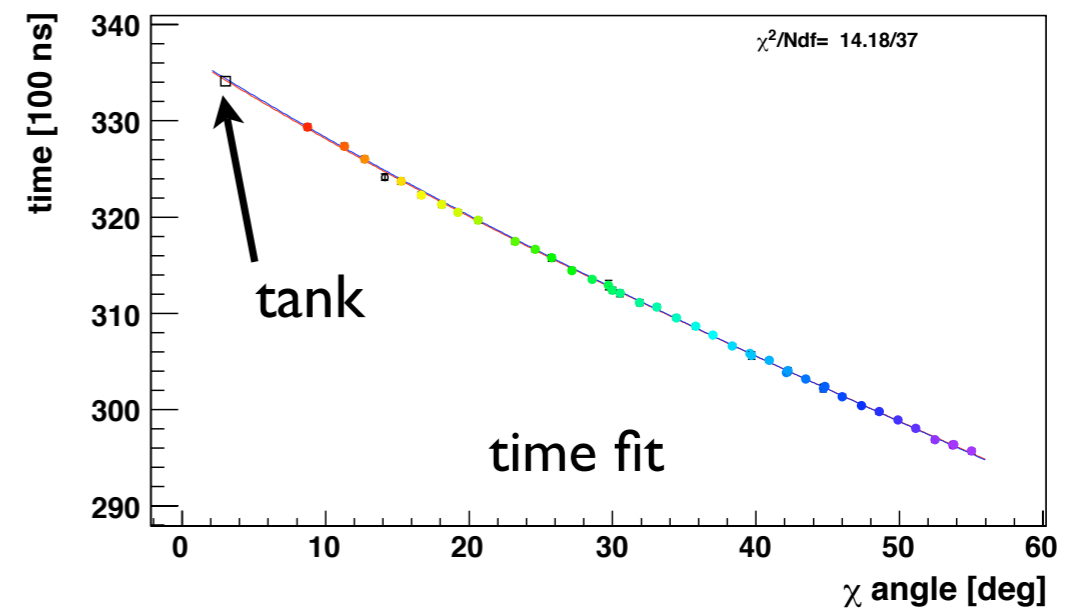
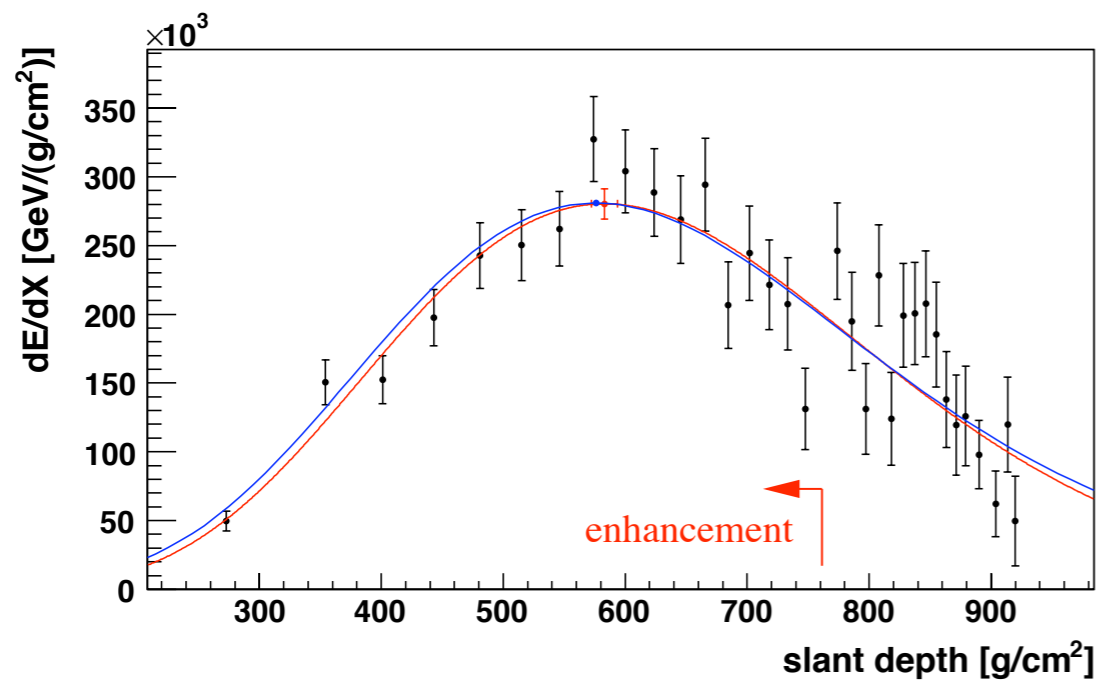


Auger future

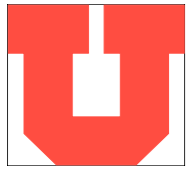
■ simulated nearby event



Simulated shower with core distance
 $R_p = 1.2 \text{ km}$, $E = 10^{17.25} \text{ eV}$

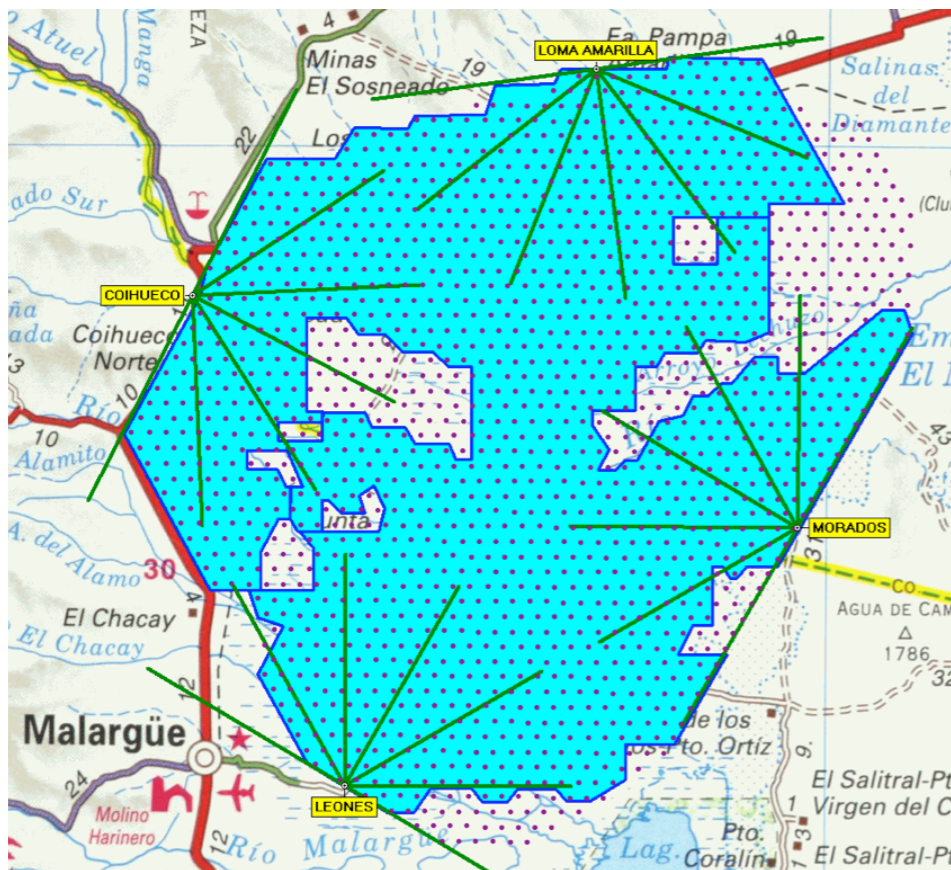


- simulated profile
- reconstructed profile



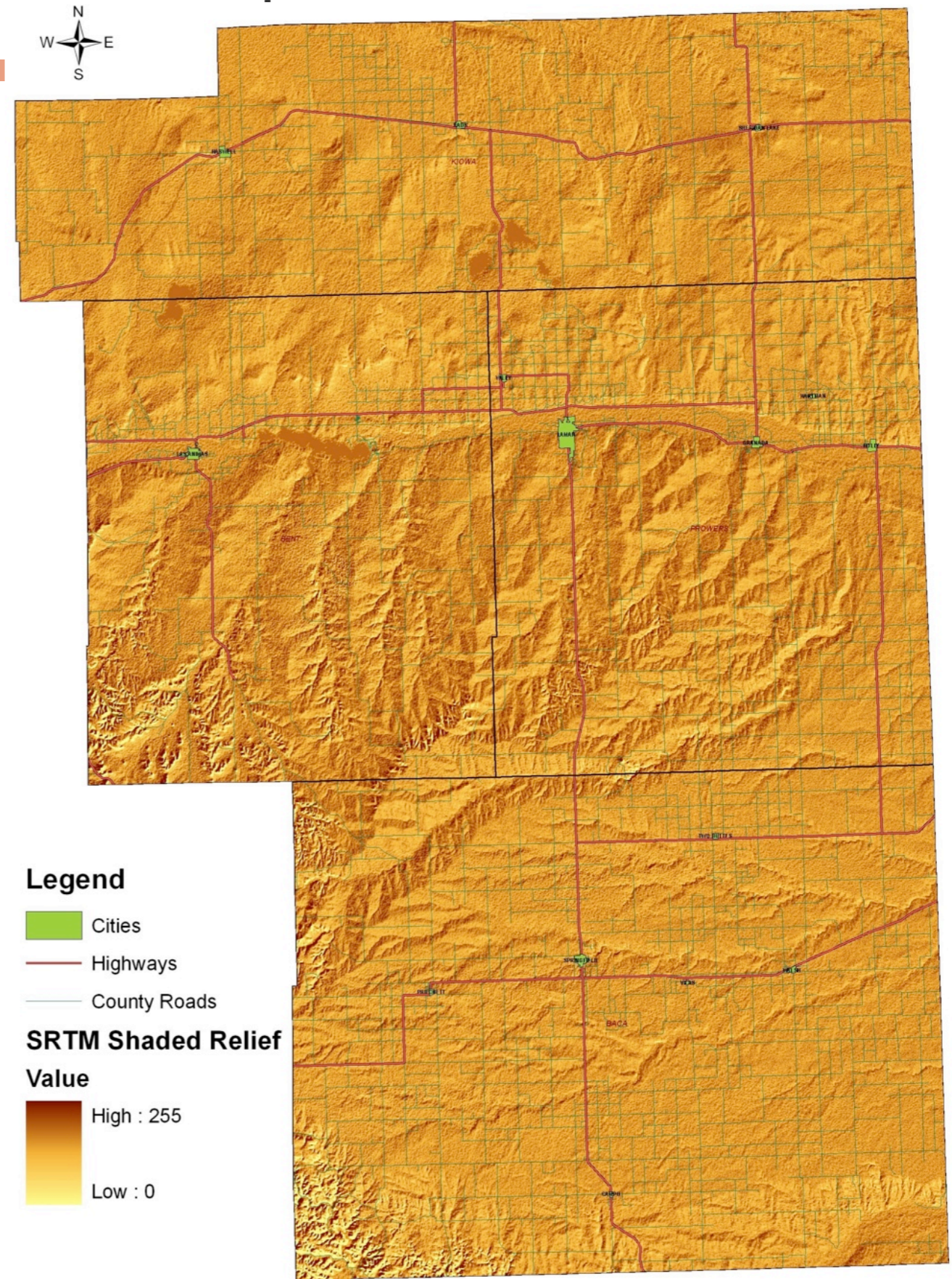
Auger future

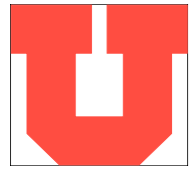
- Auger North (proposal in 2008)



Southern site

SOUTHEAST COLORADO TOPO MAP Proposed Northern site





Conclusions

- Summary
 - largest exposure
 - southern sky
 - interesting results
- Prospects
 - novel measurements
 - enhance the Southern Observatory
 - map sources in the North

Thank You!