

Antoine Letessier-Selvon

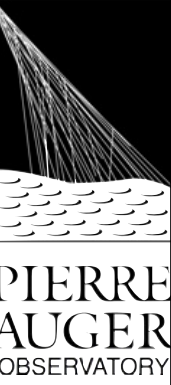
Laboratoire de Physique Nucléaire et des Hautes Énergies UPMC/IN2P3

The Pierre Auger Observatory

French contributions to :

- Construction
- Analysis
- Upgrades

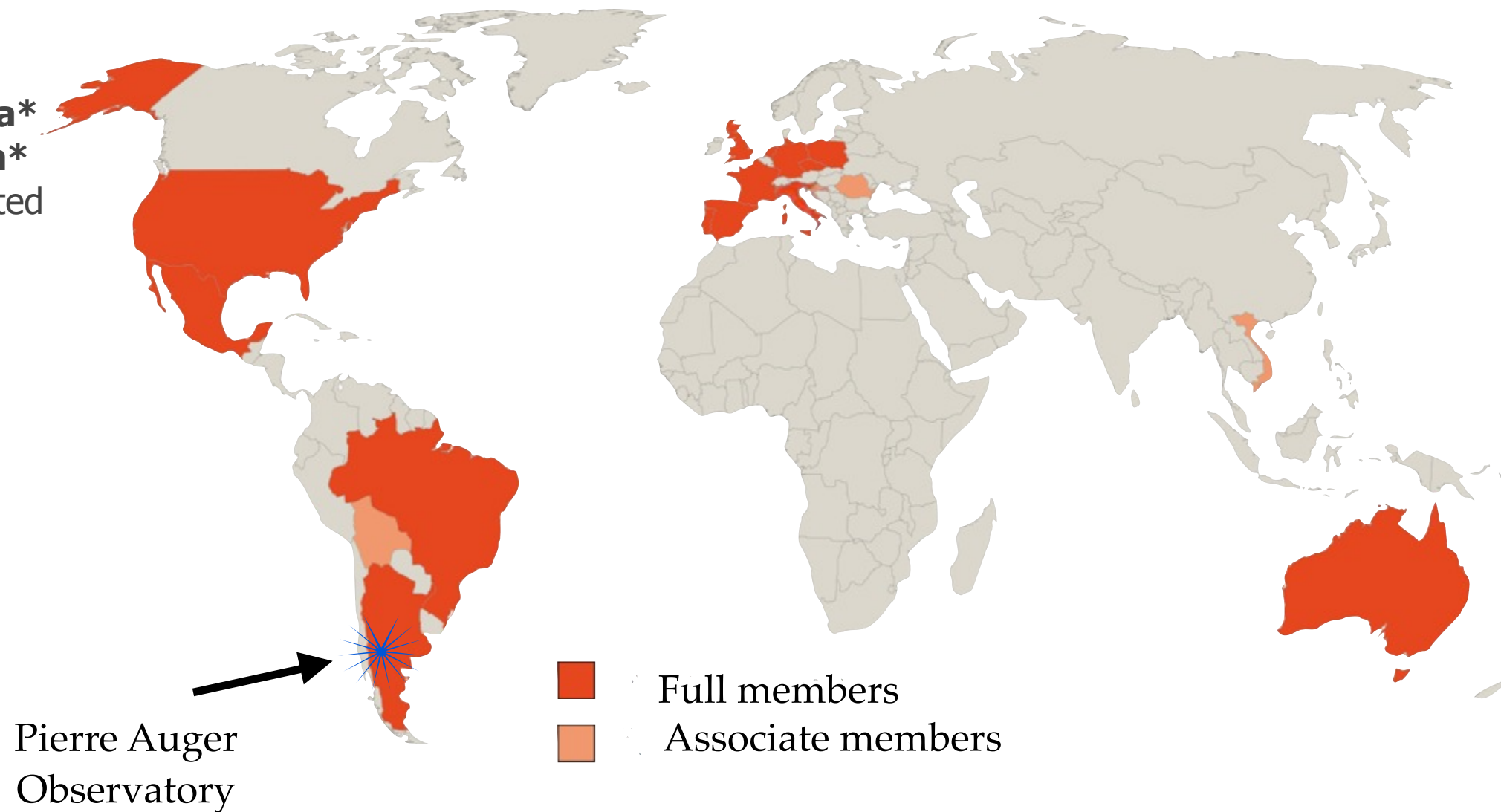
THE WORLD'S LARGEST COSMIC RAY OBSERVATORY



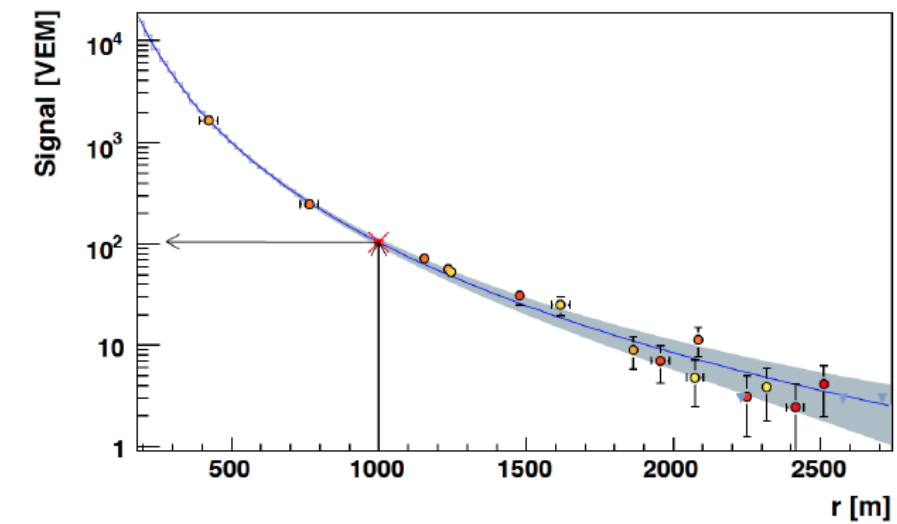
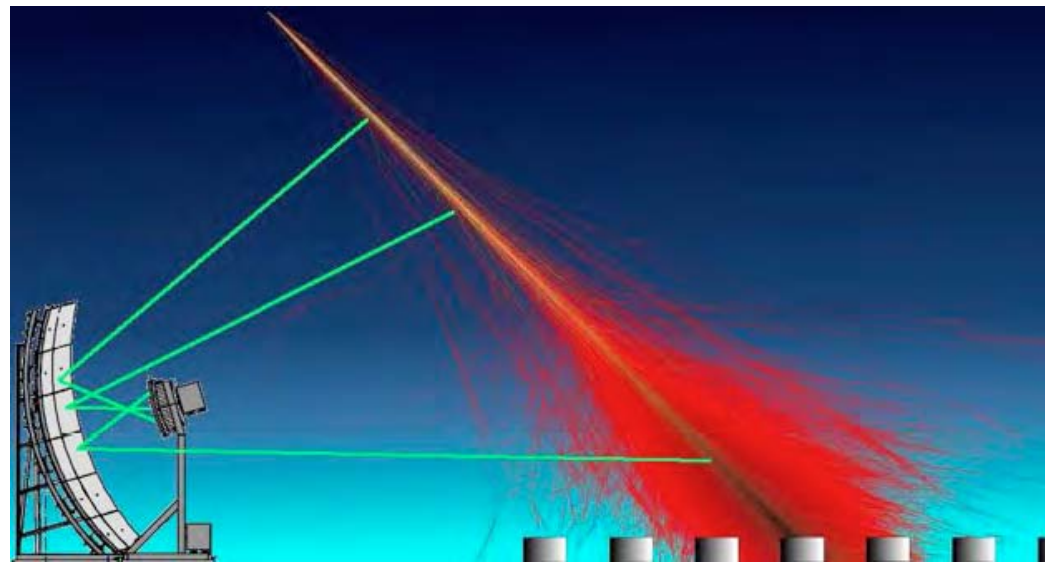
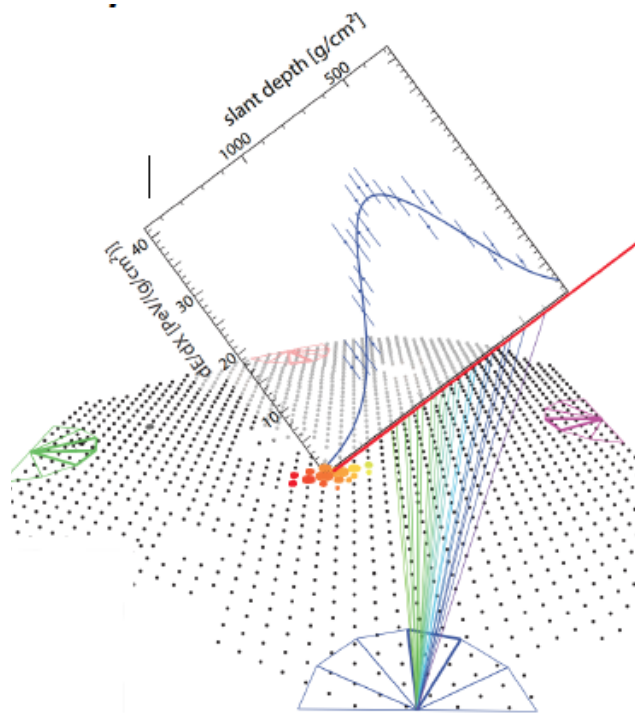
Collaboration : ~ 500 members & 19 countries

Argentina
Australia
Brazil
Croatia
Czech Republic
France
Germany
Italy
Mexico
Netherlands
Poland
Portugal
Slovenia
Spain
United Kingdom
USA

Bolivia*
Romania*
Vietnam*
*Associated

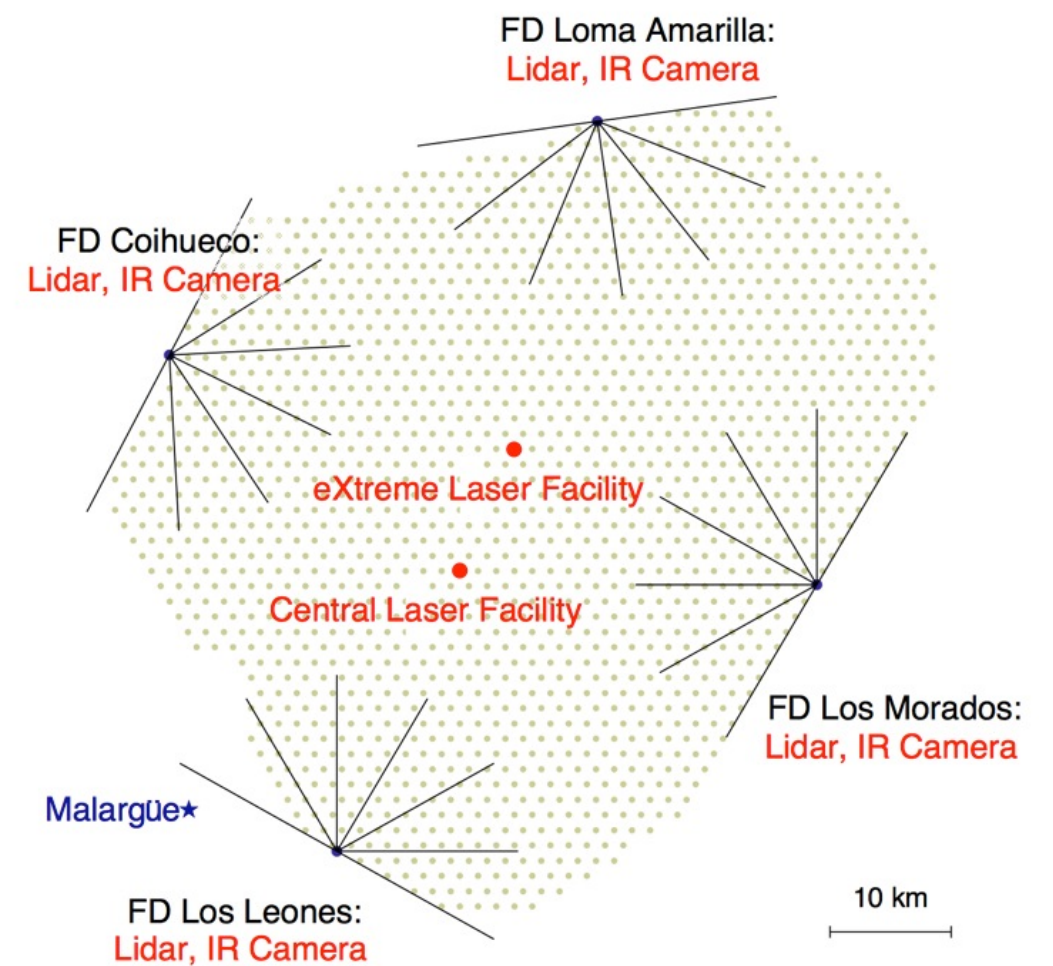
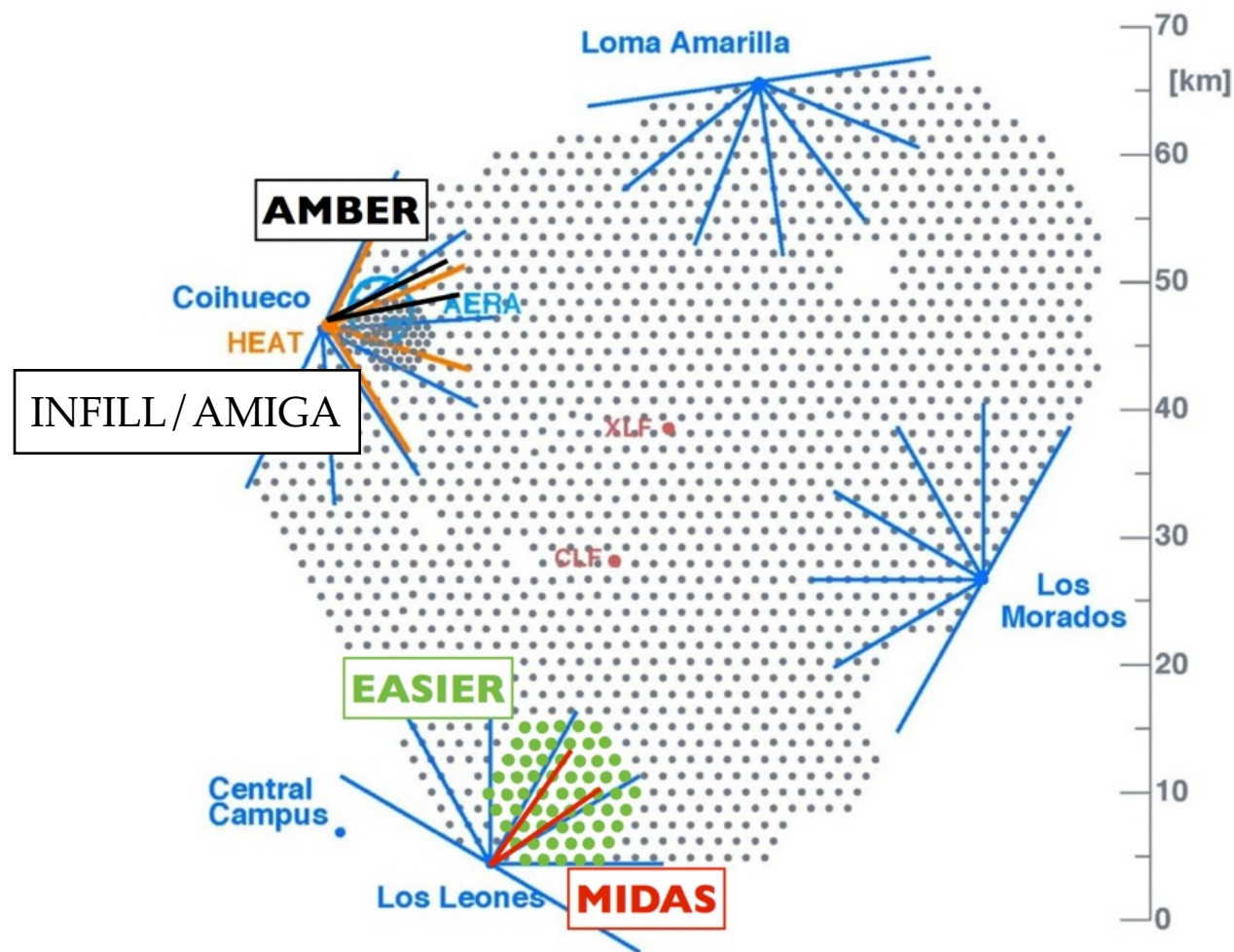


DETECTION PRINCIPLES



STATUS & PERFORMANCE

The world's largest cosmic ray observatory
In operation since 2004



STATUS & PERFORMANCE

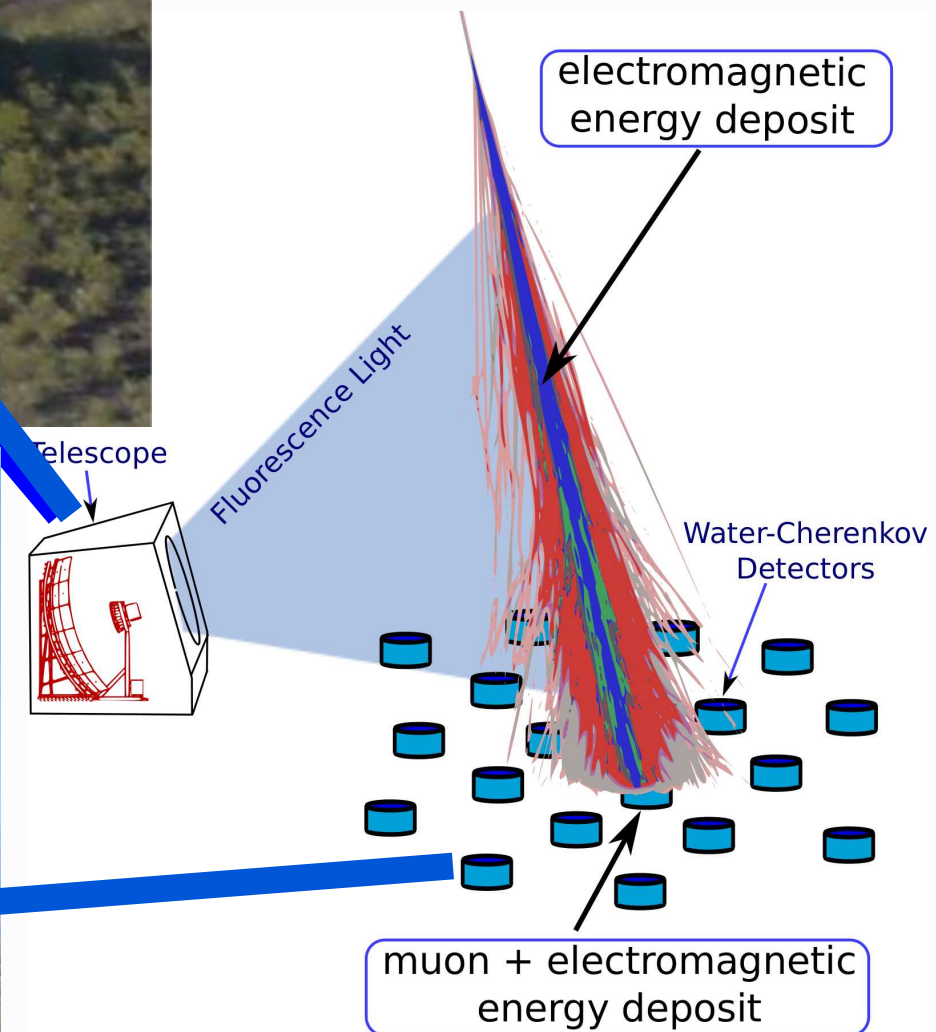
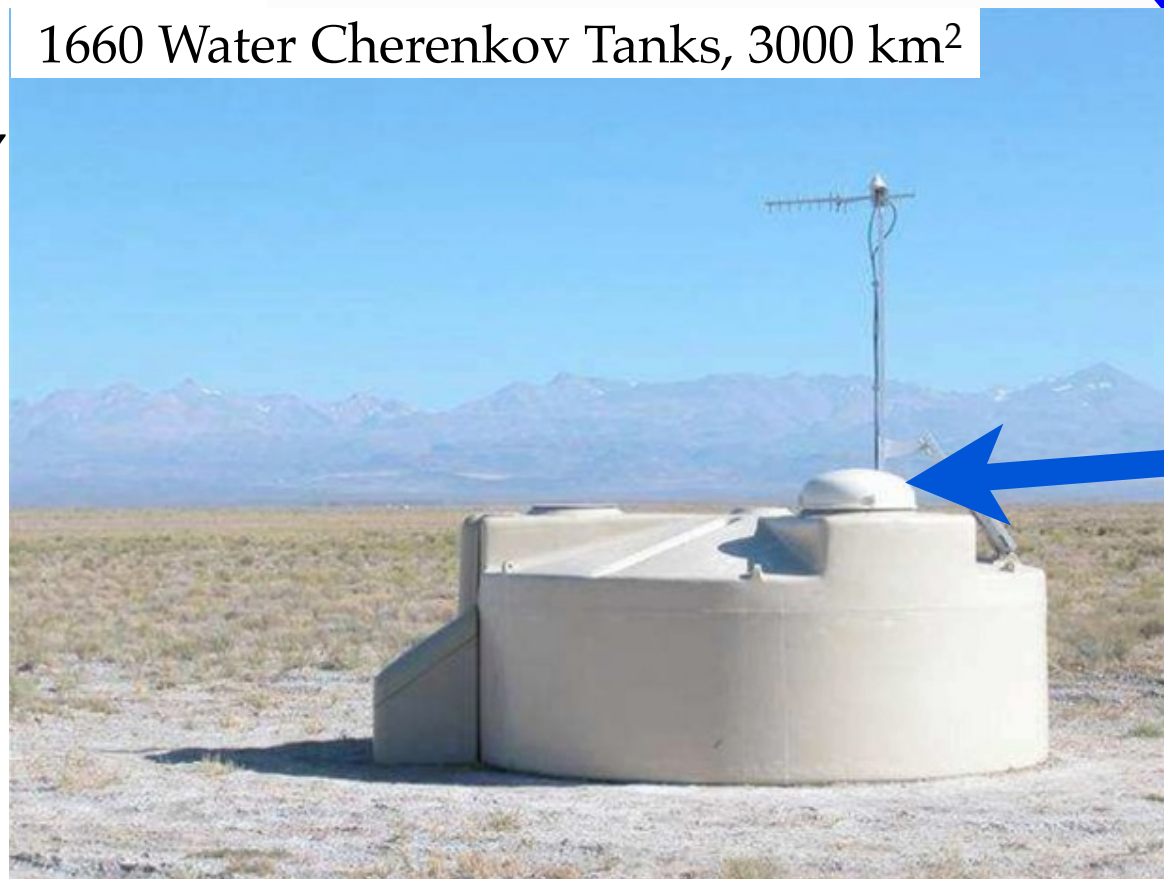
The world's largest cosmic ray observatory

**THE HYBRID
CONCEPT
ALLOWS FOR A
DATA-DRIVEN
CALIBRATION
OF THE ~100%
DUTY CYCLE
SURFACE ARRAY
USING THE
CALORIMETRIC
INFORMATION
FROM THE
FLUORESCENCE
TELESCOPES**

24+3 Telescopes, 4+1 sites



1660 Water Cherenkov Tanks, 3000 km²

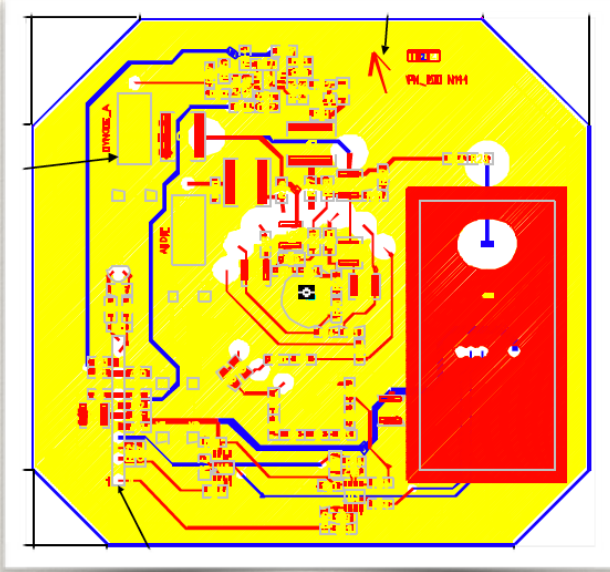


Technical contributions

Design and Site

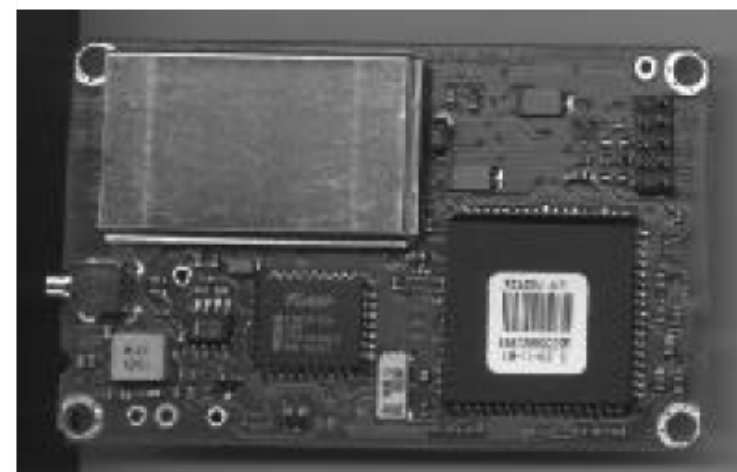
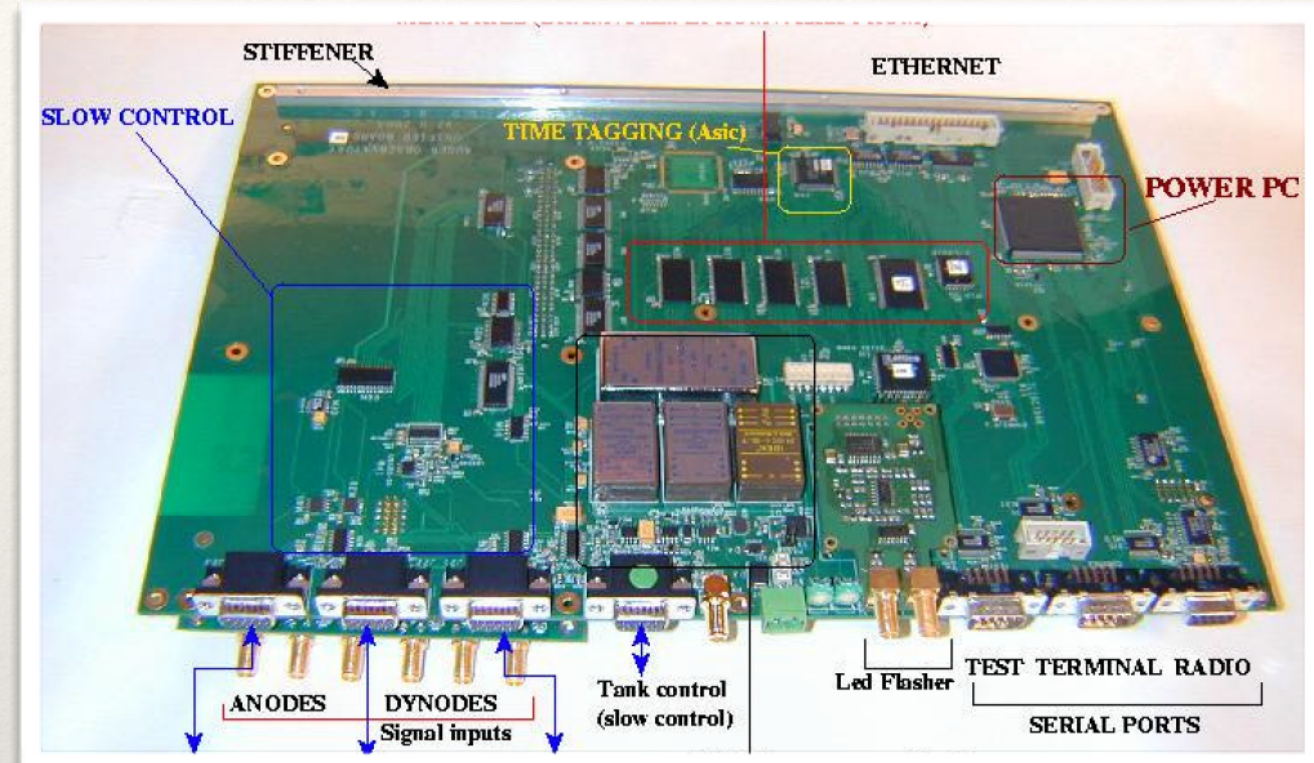
- ❖ Design phase 1992-1996
- ❖ Site search 1995-1997
- ❖ Money hunting (not only in France...) 1996-1999





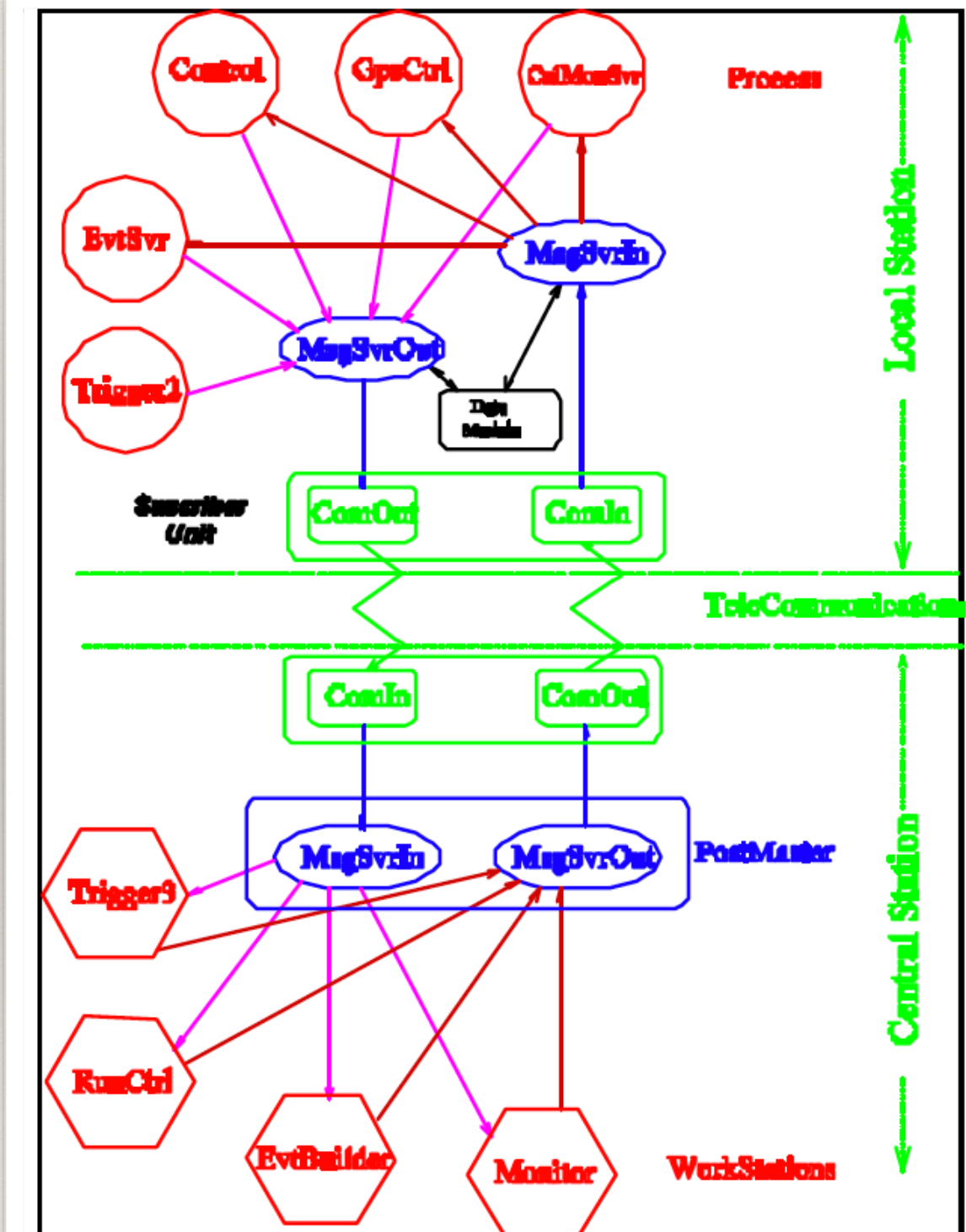
Electronics & Timing

- ❖ PMT bases
- ❖ Time tagging (10 ns resolution)
- ❖ Unified board



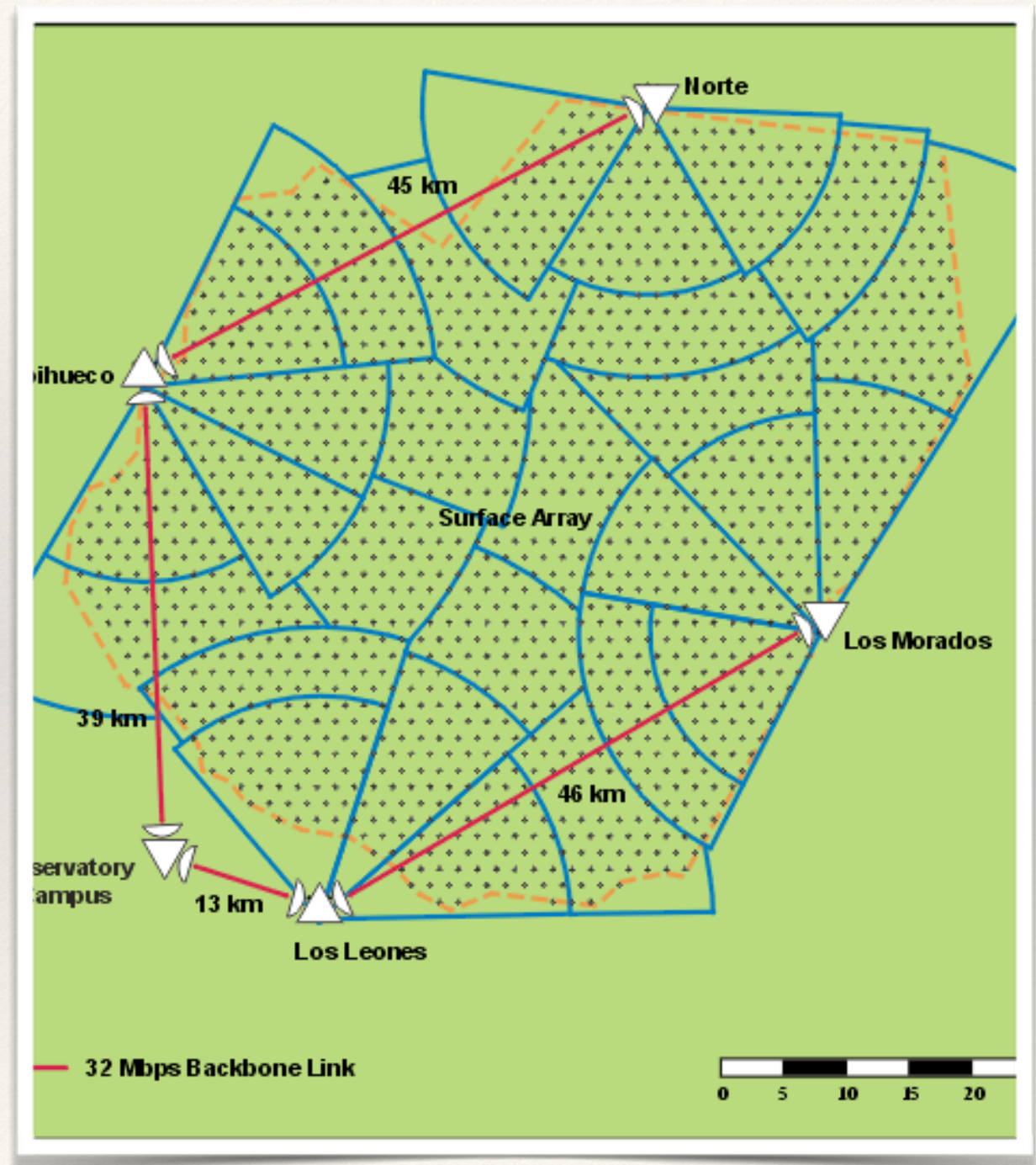
Local and Central DAQ

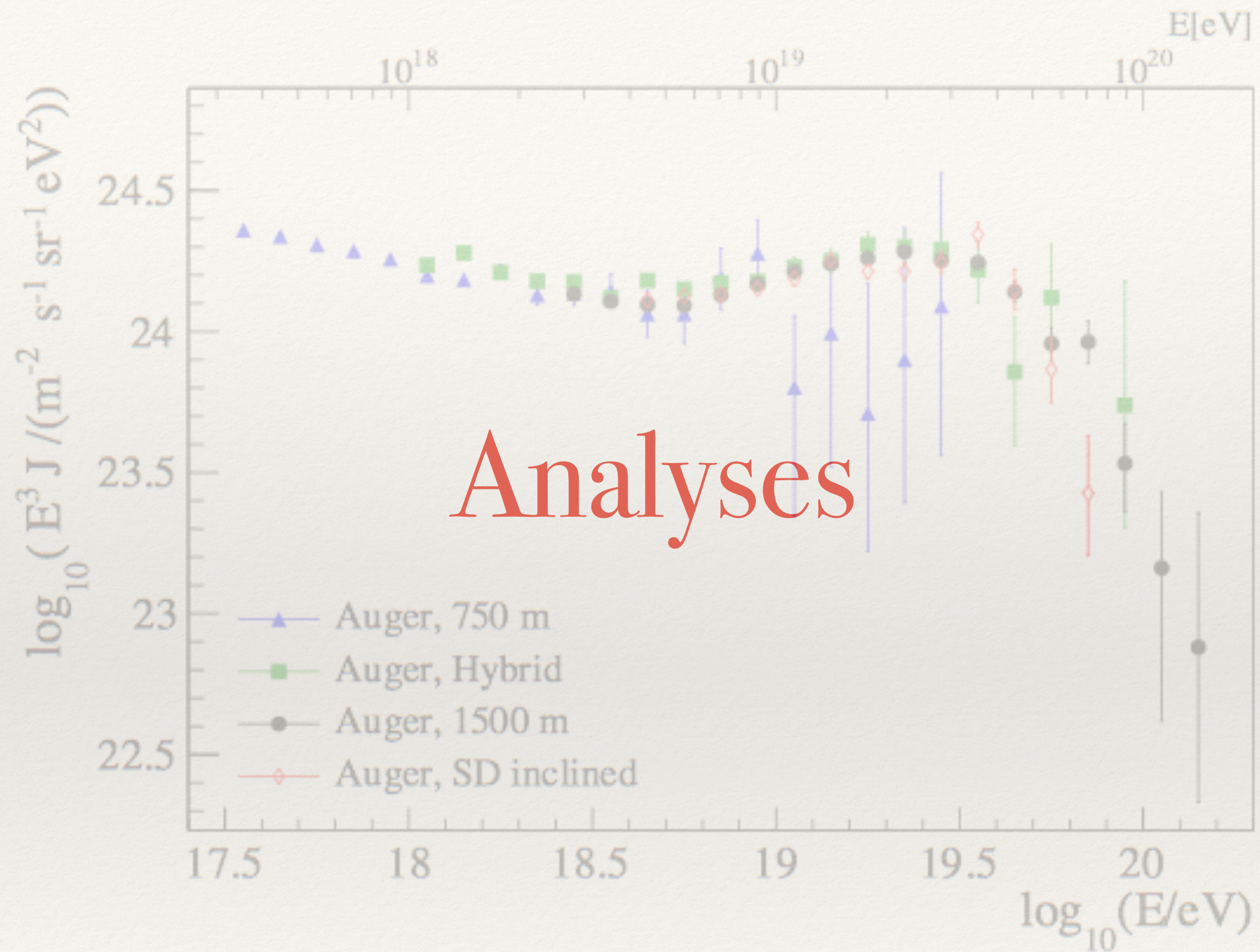
- ❖ Local station software
 - ❖ Acquisition
 - ❖ Monitoring
 - ❖ Calibration
 - ❖ Communication
- ❖ Central Acquisition CDAS
 - ❖ Trigger
 - ❖ Control
 - ❖ Event builder
 - ❖ Monitoring
 - ❖ Reconstruction/visualisation/Analysis tools

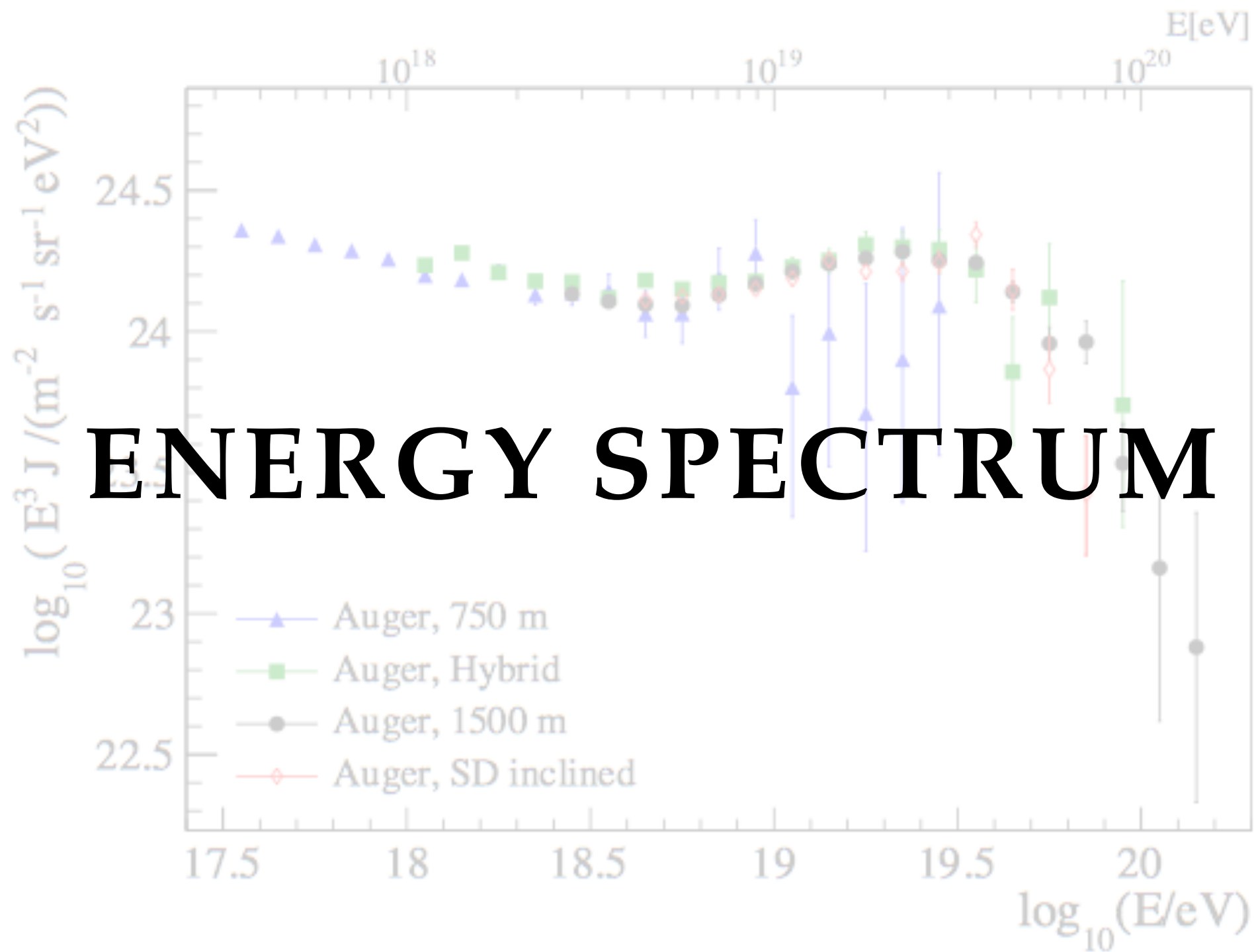


Network and Data distribution

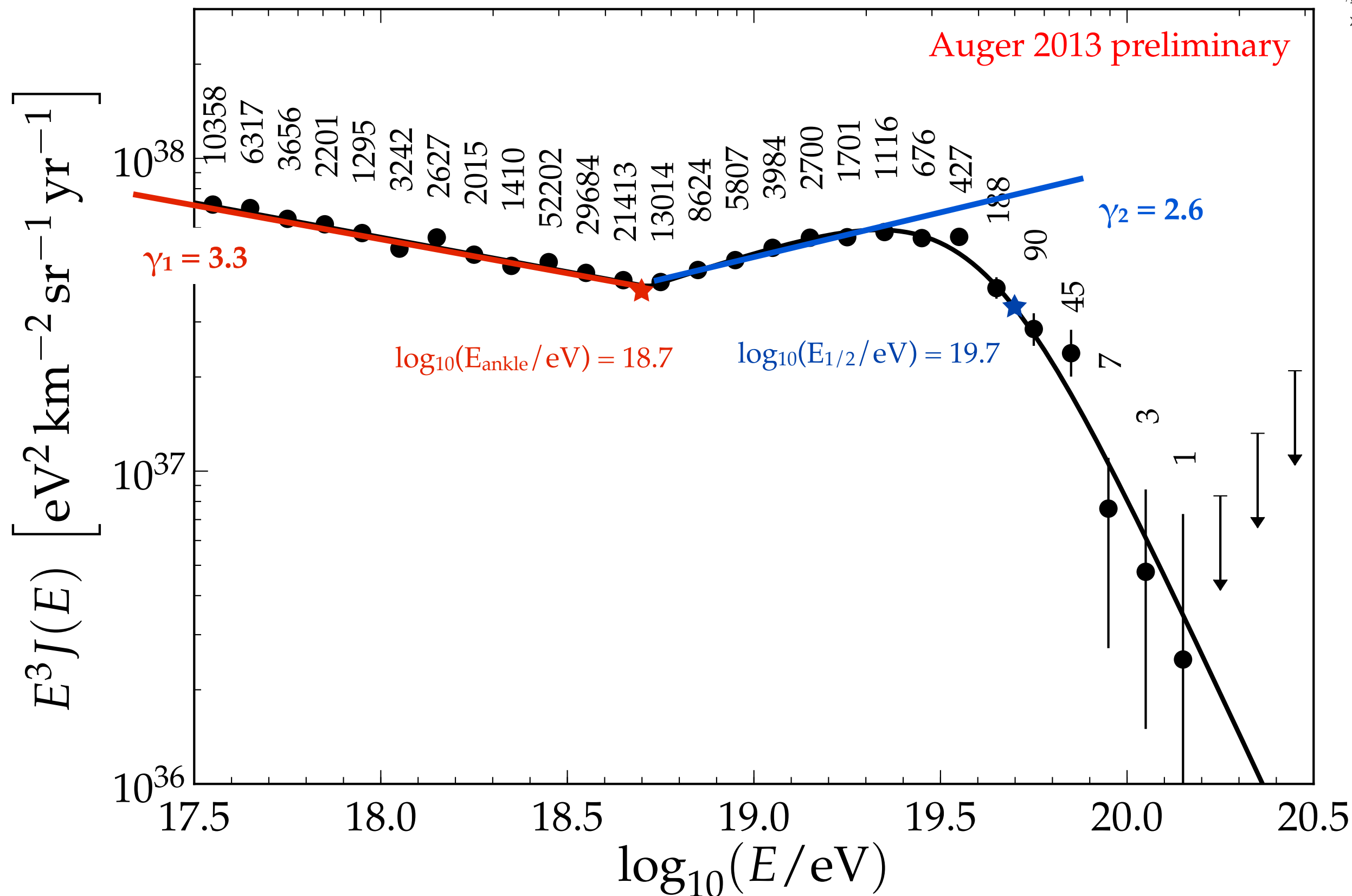
- ❖ Collection (backbone) Network
- ❖ Data Mirroring (CC-IN2P3)
- ❖ MC prod (GRID)
- ❖ Auger Access



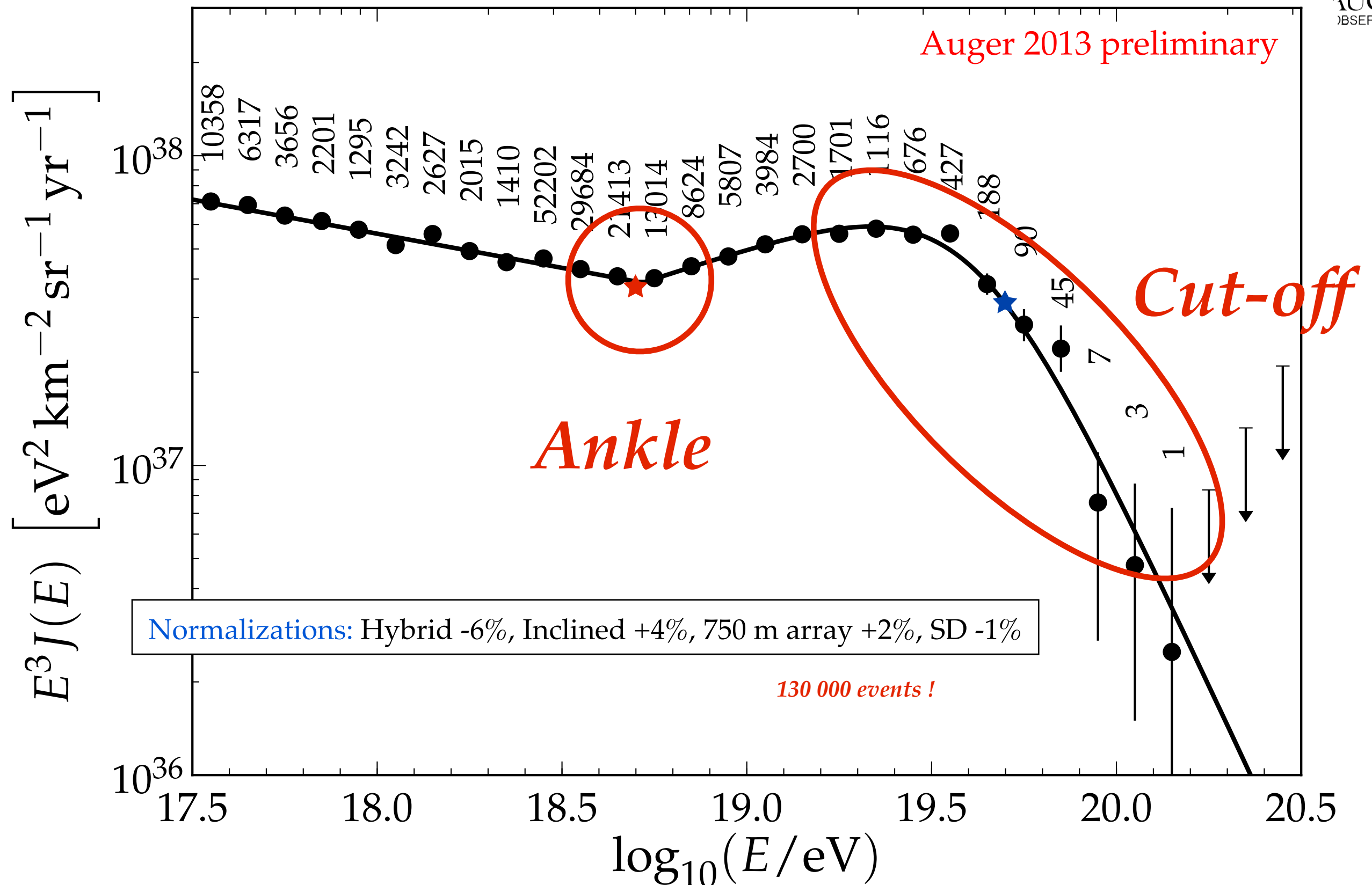
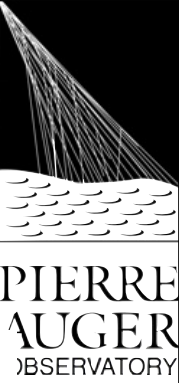




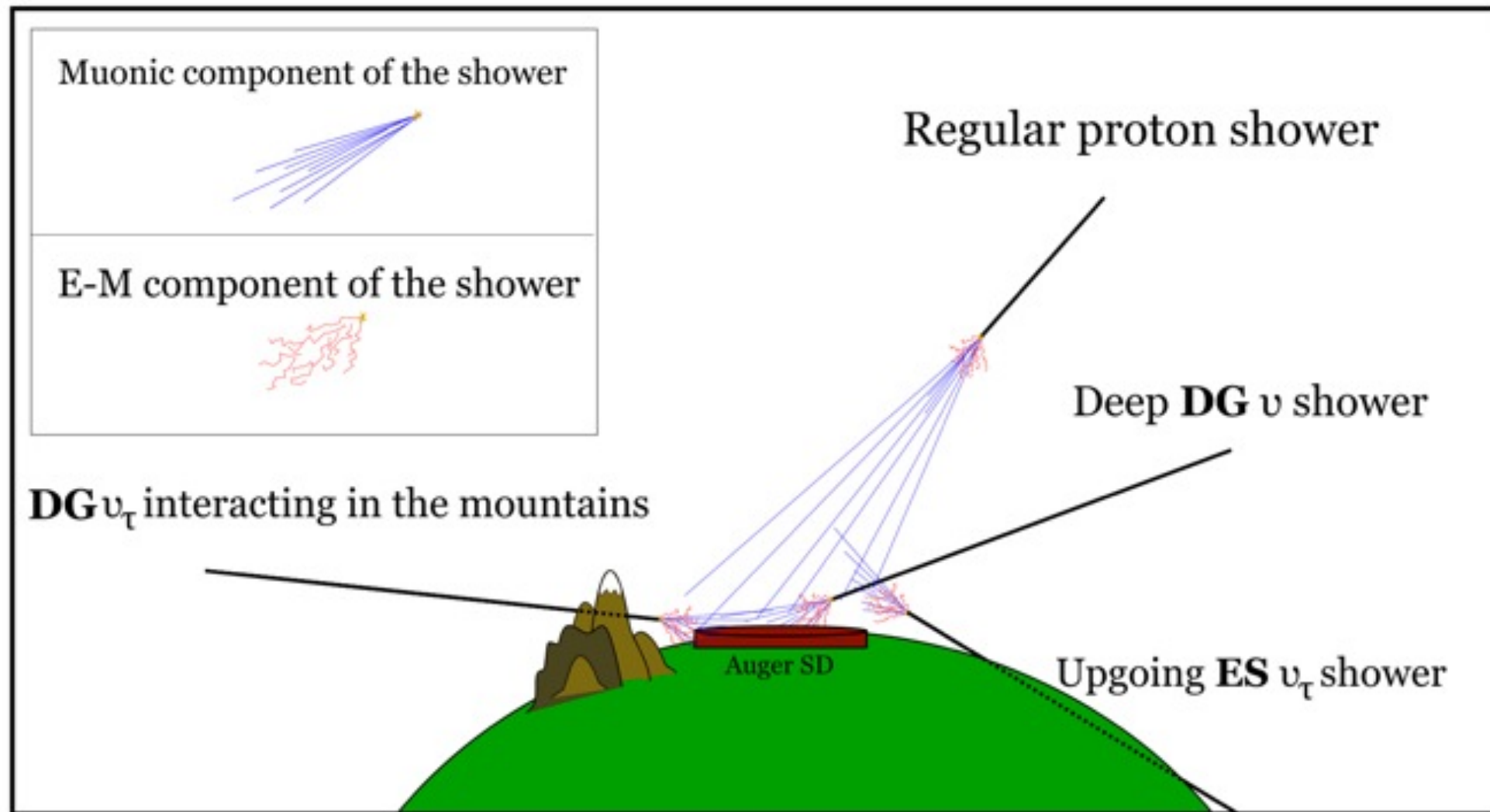
THE AUGER ALL-PARTICLE FLUX



THE AUGER ALL-PARTICLE FLUX



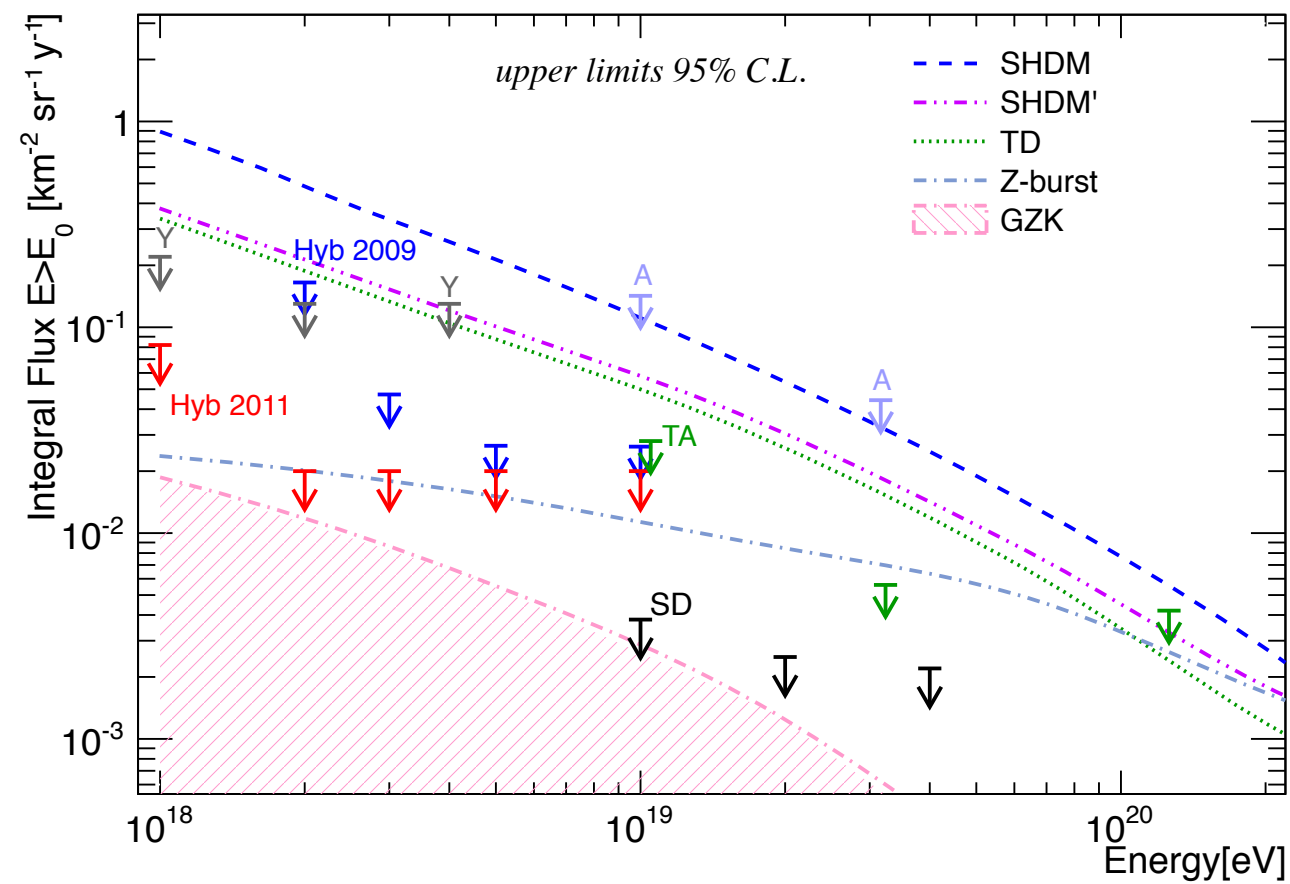
PHOTONS AND NEUTRINOS ?



Current Auger limits rule out top-down models as dominant production of UHECR

ES method paper (SAL) 170 citations

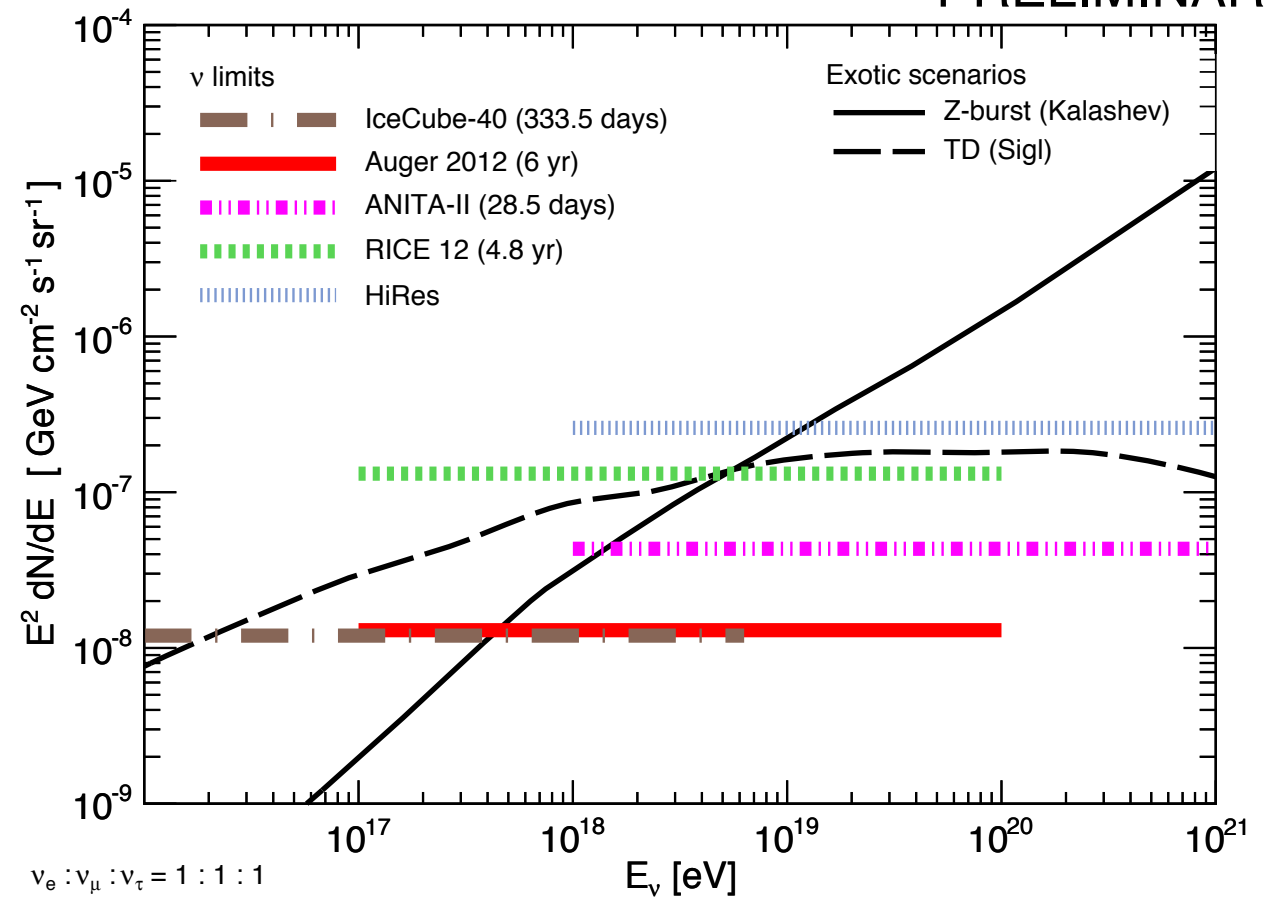
PHOTONS AND NEUTRINOS ?



130 cites

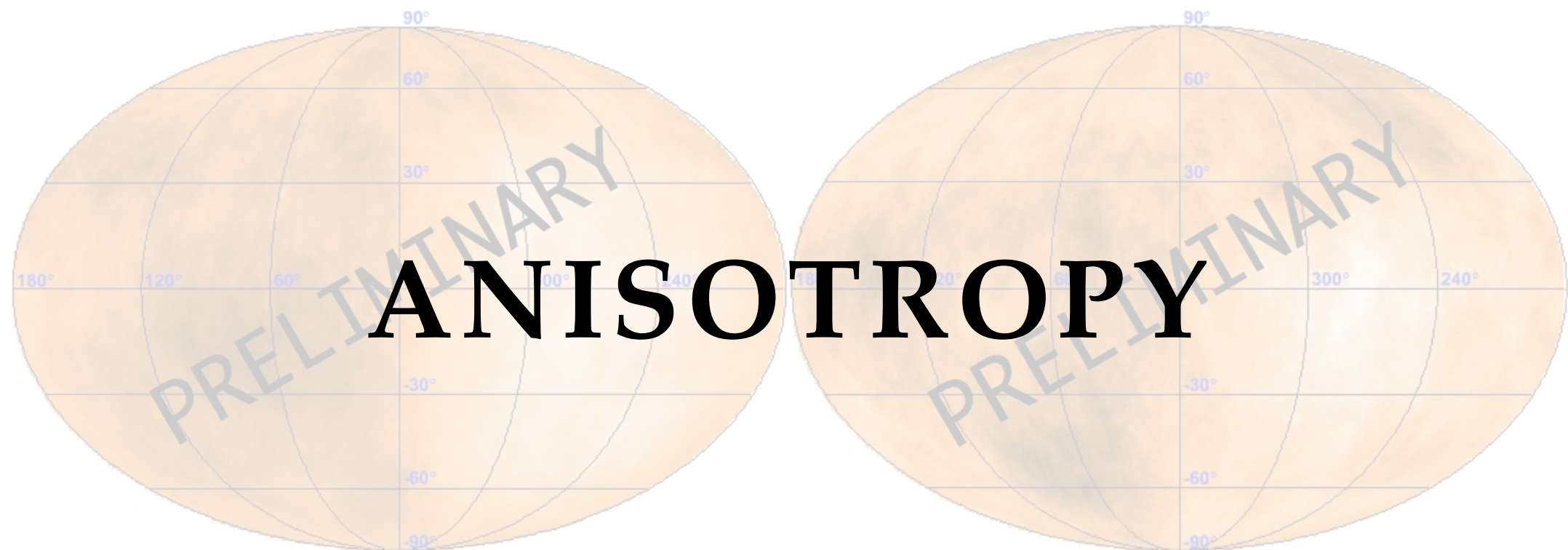
Single flavour (90% CL)

PRELIMINARY



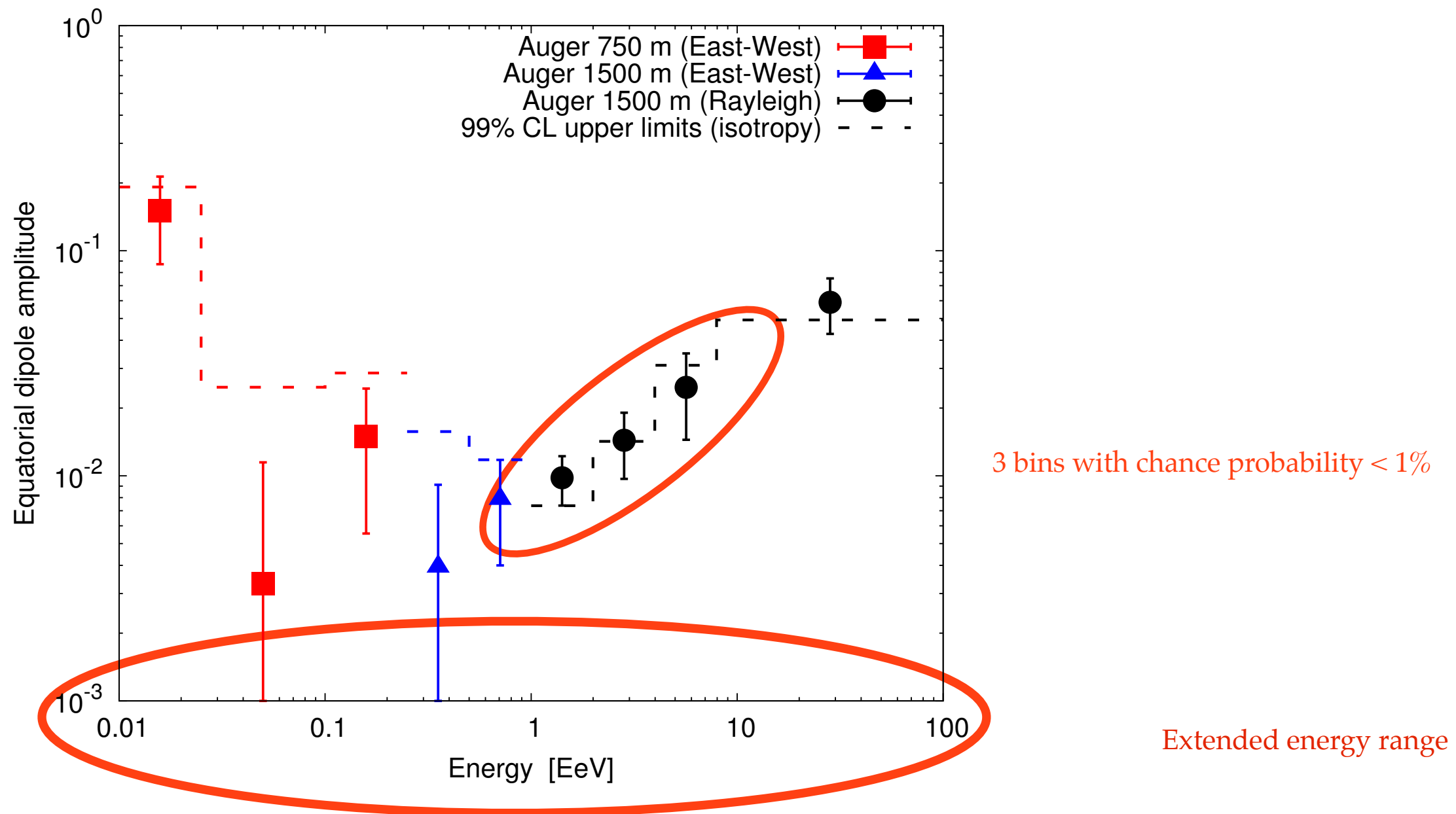
130 cites

Current Auger limits rule out top-down models as dominant production of UHECR



Large scale first harmonic analyses

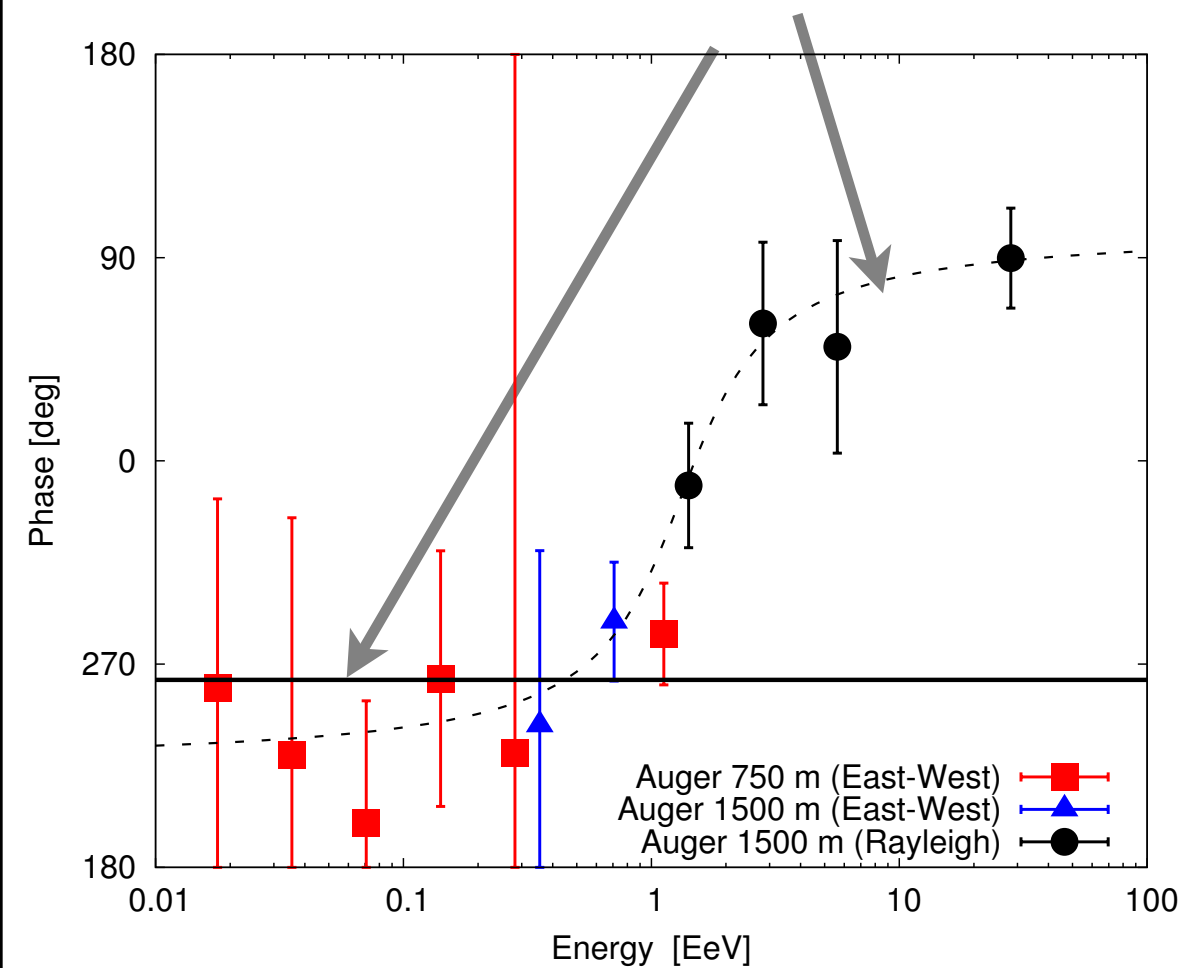
Data up to December 31st 2012



Large scale first harmonic analyses

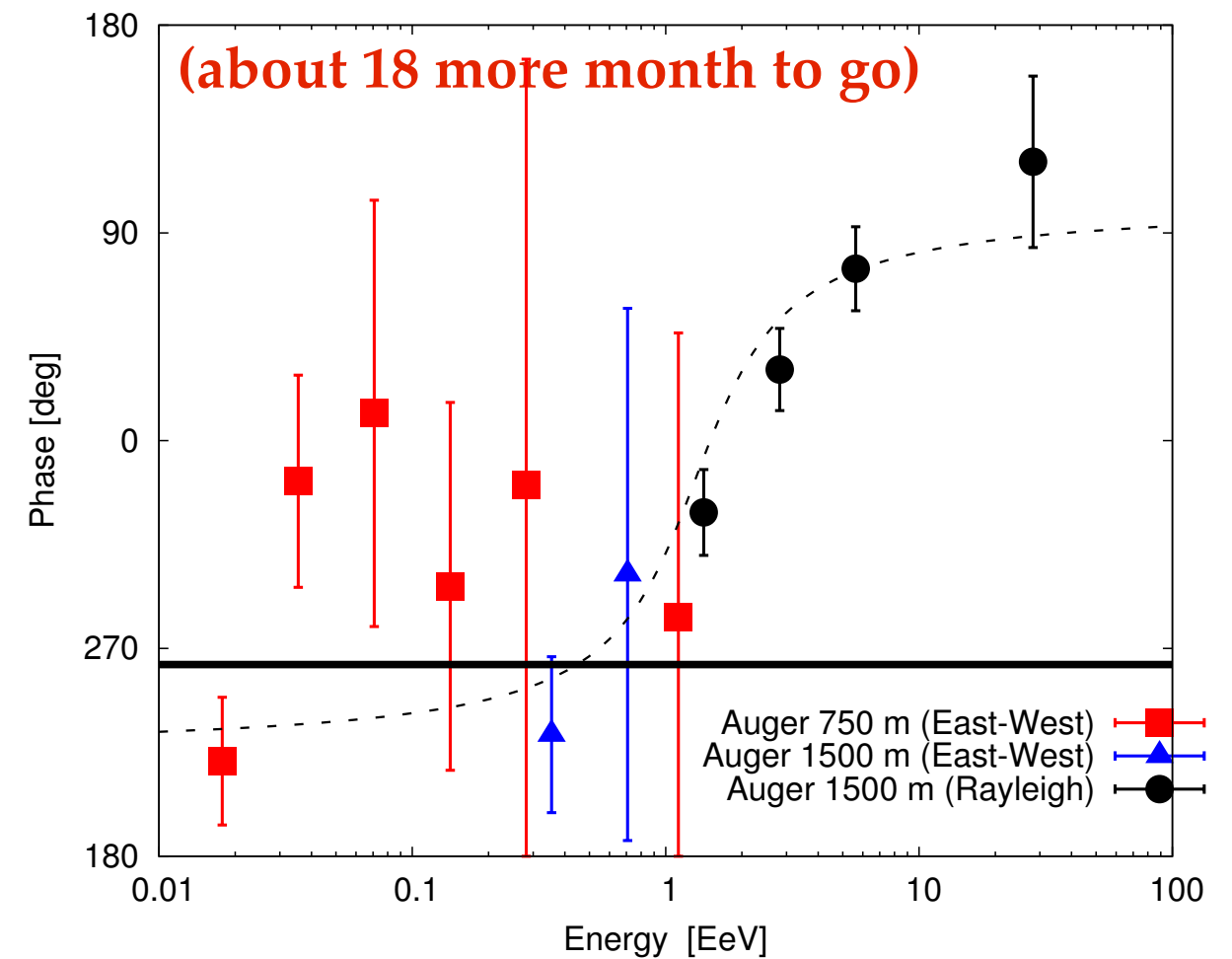
Data up to December 2010 (April 2011)

Prescription set

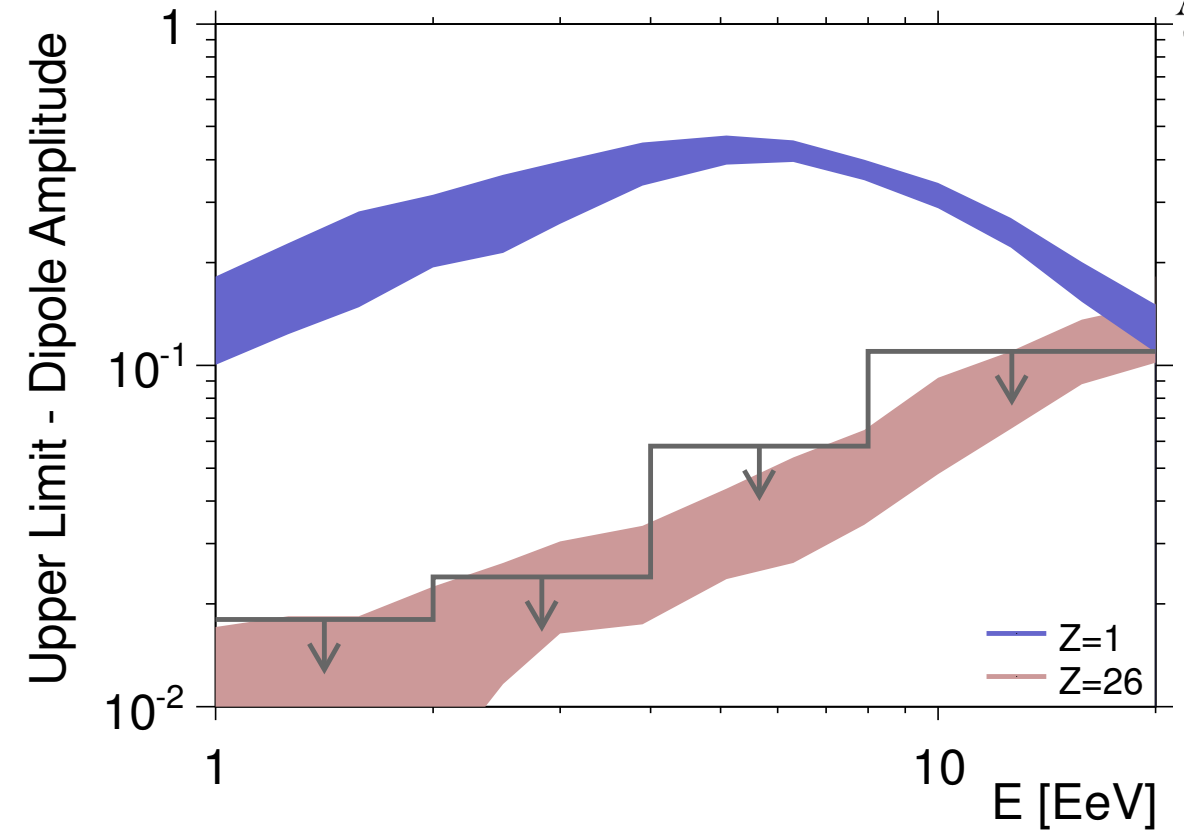
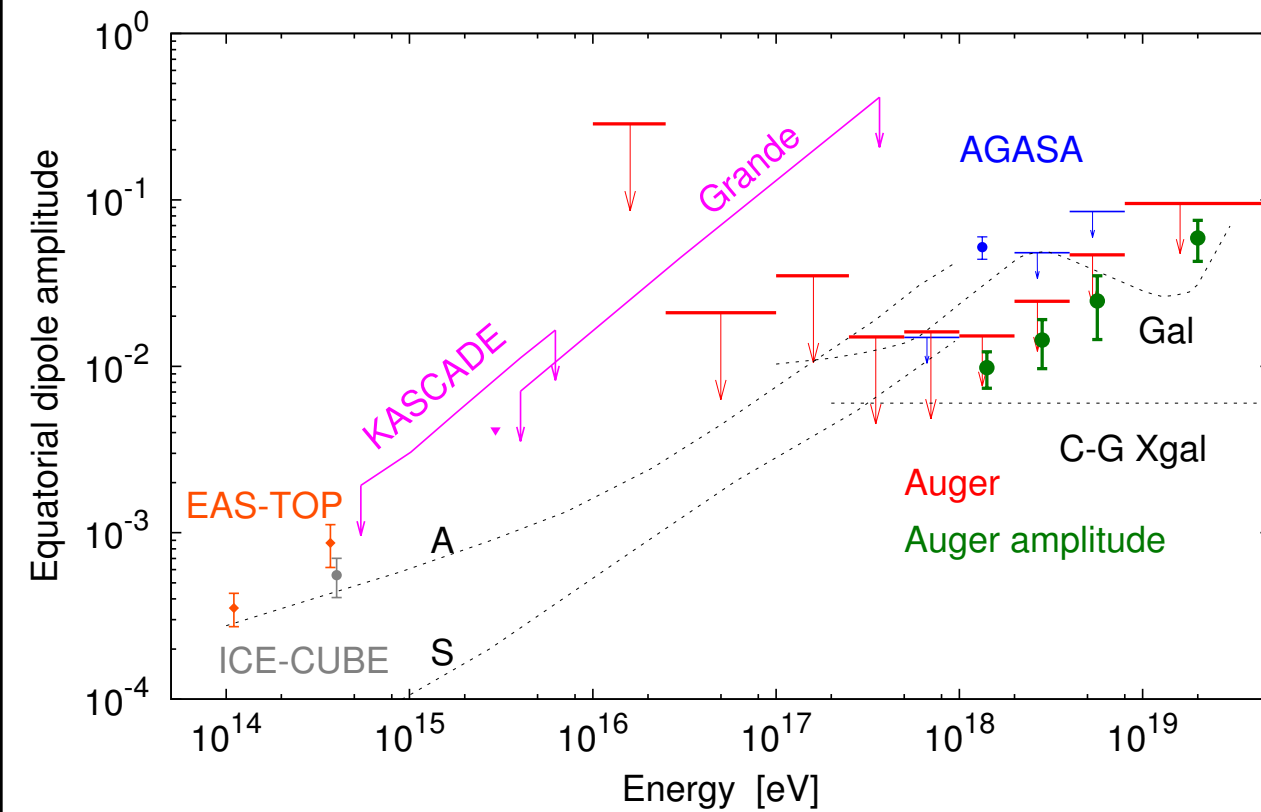


New data

Prescription status



Large scale analyses



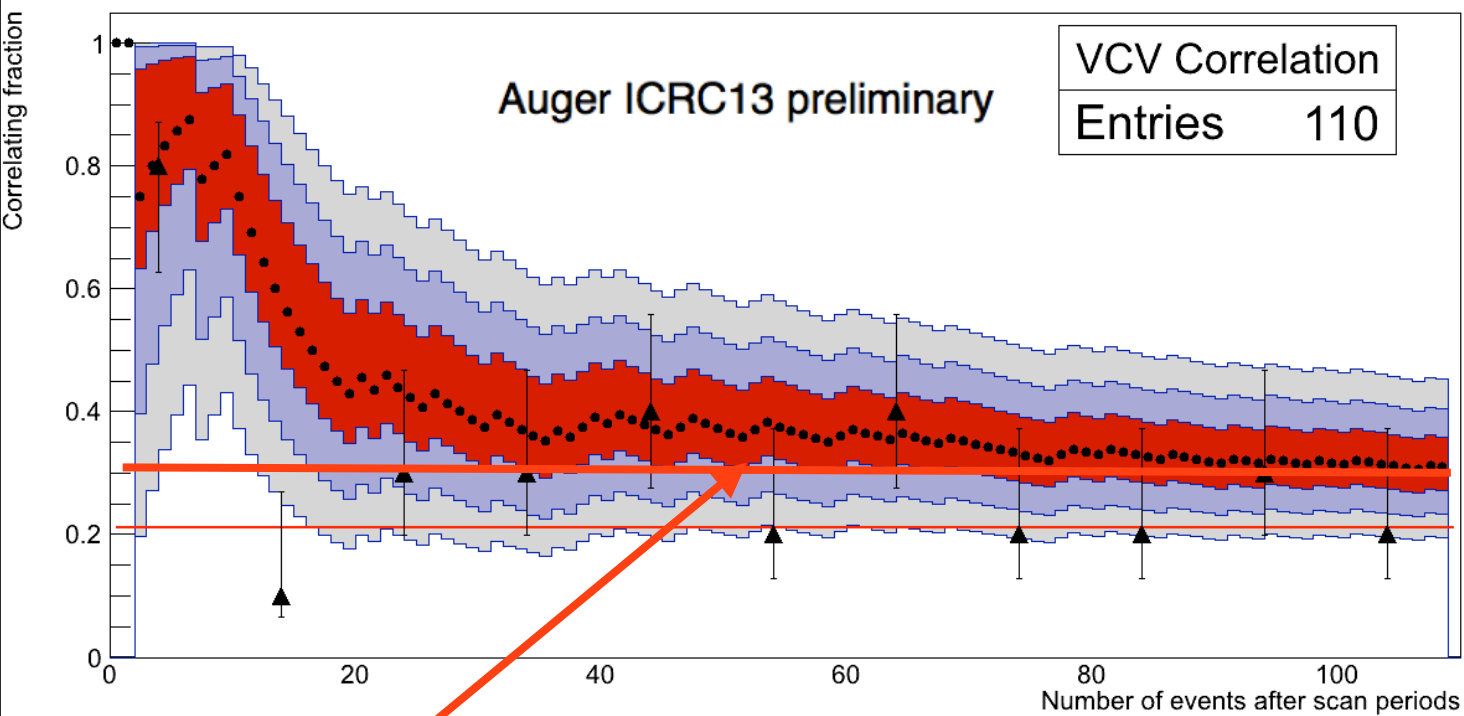
If protons dominate and if of Galactic origin,
anisotropies are remarkably small

*In this examples we exclude the hypothesis that the light
component of cosmic rays comes from stationary sources densely
distributed in the Galactic disk and emitting in all directions.*

VCV CORRELATION

Time ordered

VCV Correlation

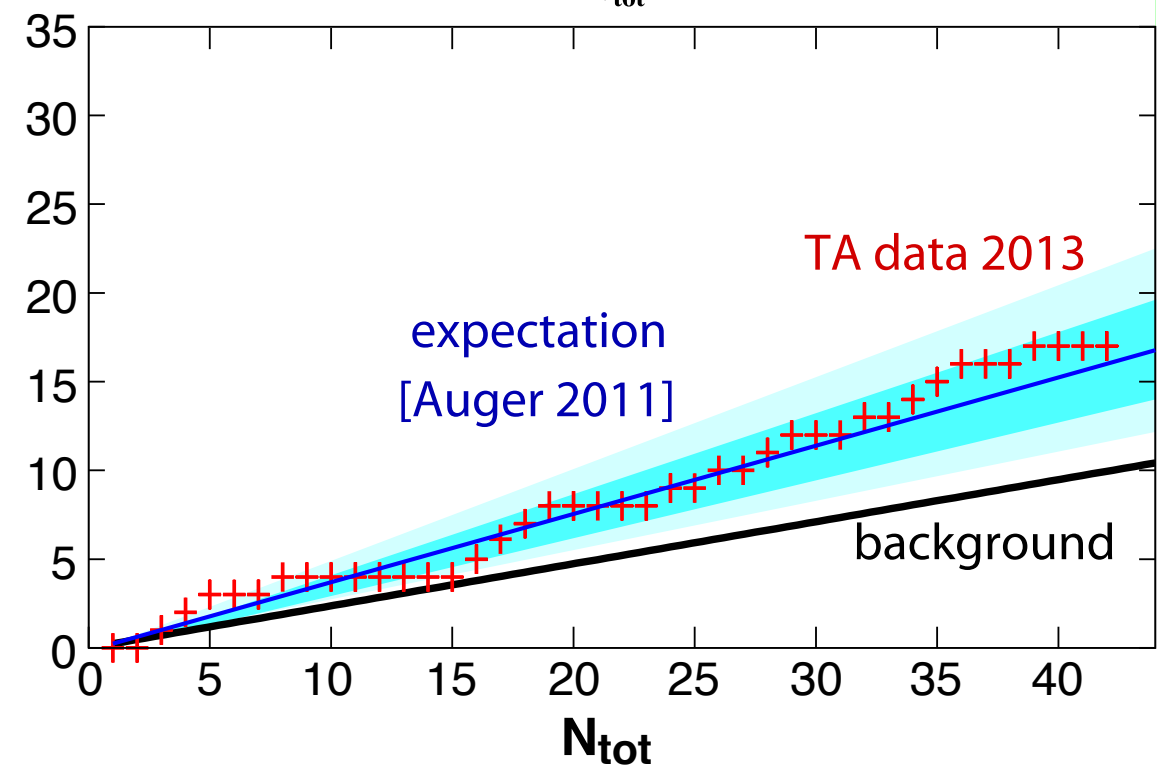
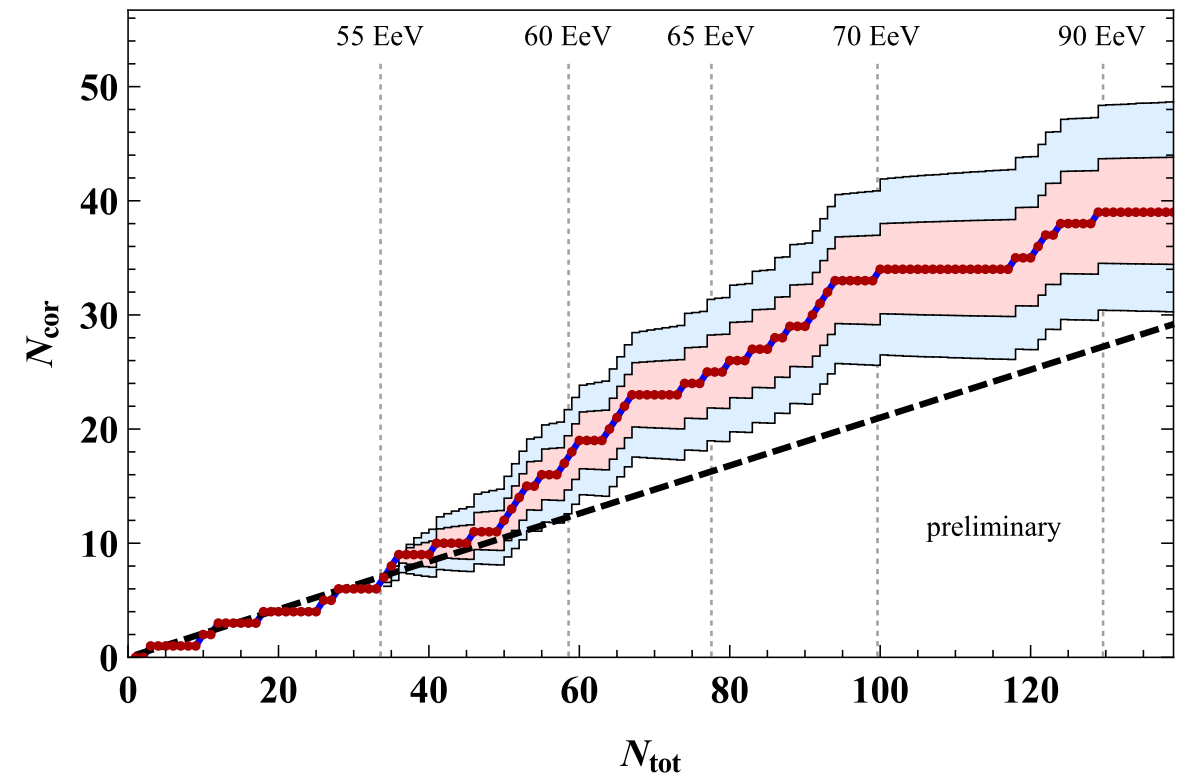


$\sim 30\%$ (e.g. : $80\% \times 0.21 + 20\% \times 0.7$)

440 cites

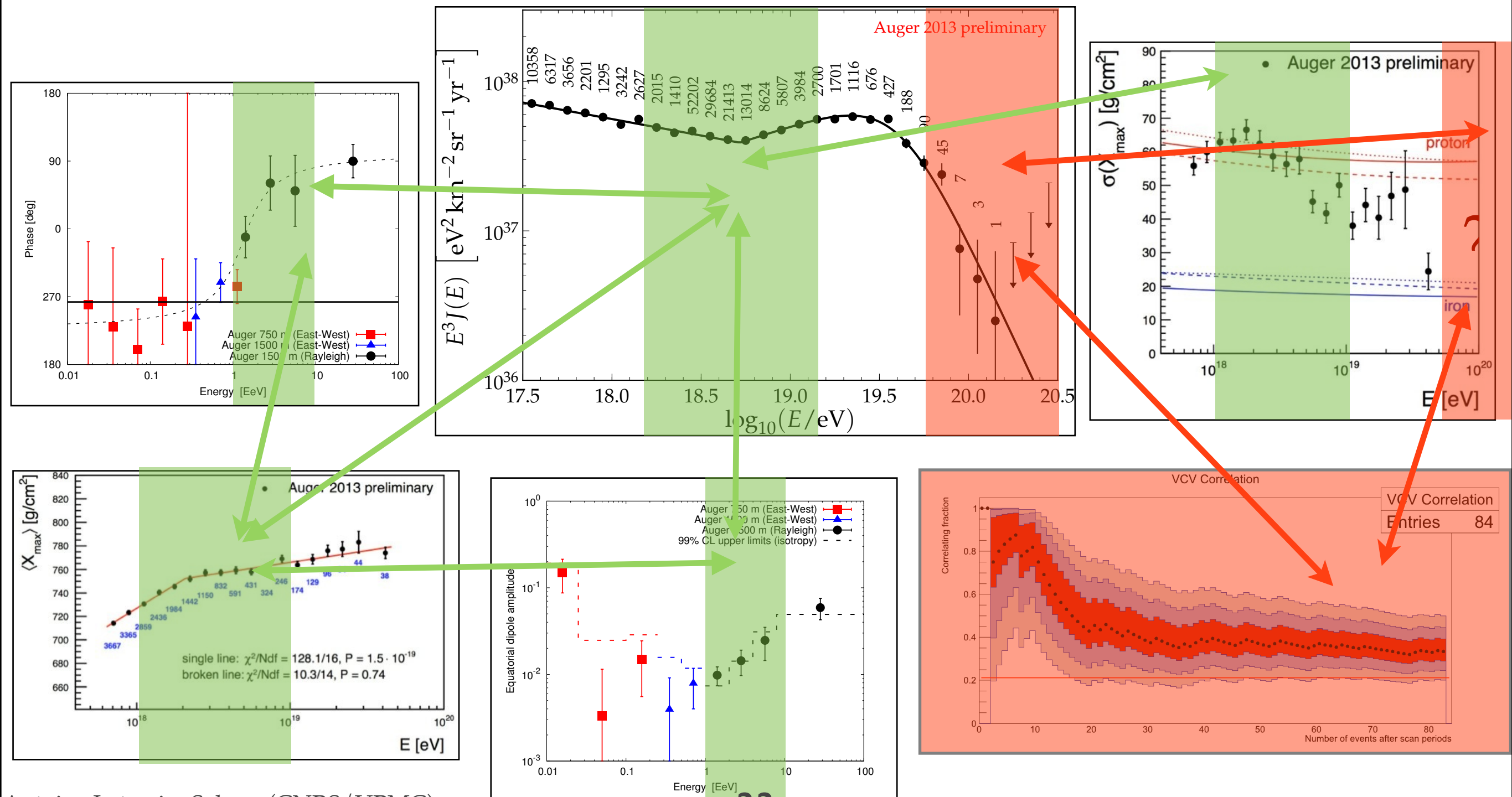
Consistent with a subdominant p fraction ($< 20\%$) at the highest energies

Energy ordered



SUMMARY

- AUGER PROVIDES A WEALTH OF HIGH QUALITY DATA
- WE OBSERVE A COHERENT BEHAVIOR OF OBSERVABLES



WHERE TO GO FROM HERE ?

Run Auger until 2023 (+10 years) with a detector upgrade that allows us to do mass composition analysis on an event by event basis

Elucidate the origin of the cut-off

this will allow for reliable estimates of neutrino and gamma fluxes

Search for a proton contribution in the cut-off

with a sensitivity to a fraction of 10% of proton

Prospect for proton astronomy with future detectors will be determined

Study of extensive air showers and hadronic multi-particle production

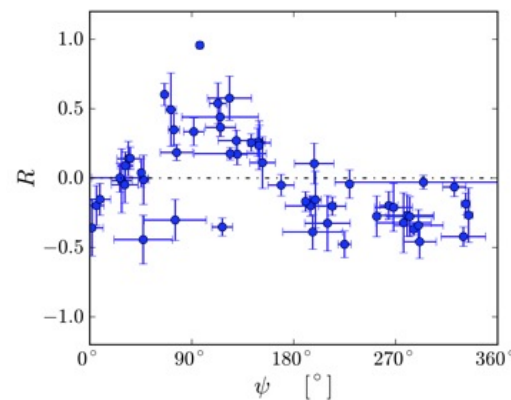
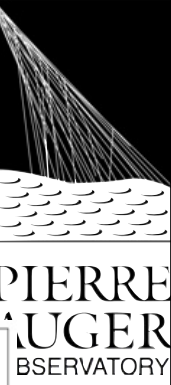
Includes search for new physics

Elucidate the origin of the Ankle

Search for cosmogenic photons

Huege (661), Schröder (899),
Gaïor (883)

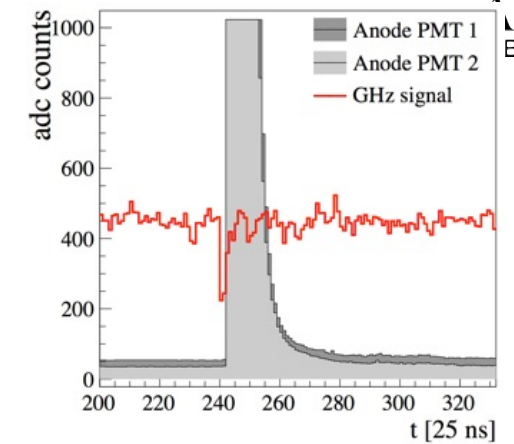
RADIO DETECTION



AMBER

AERA

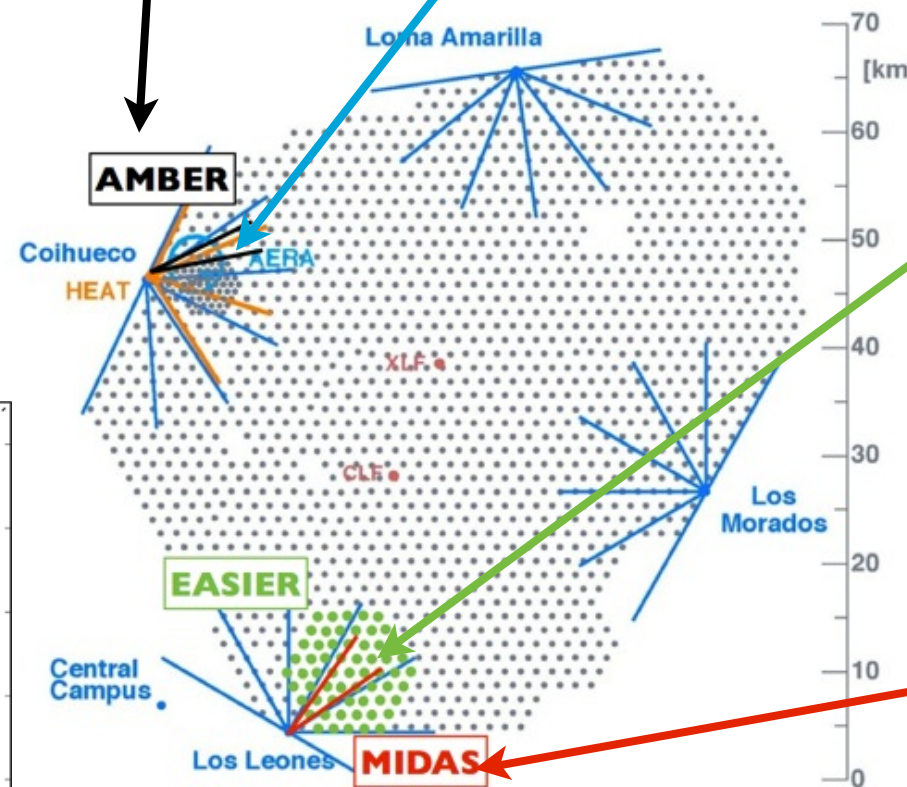
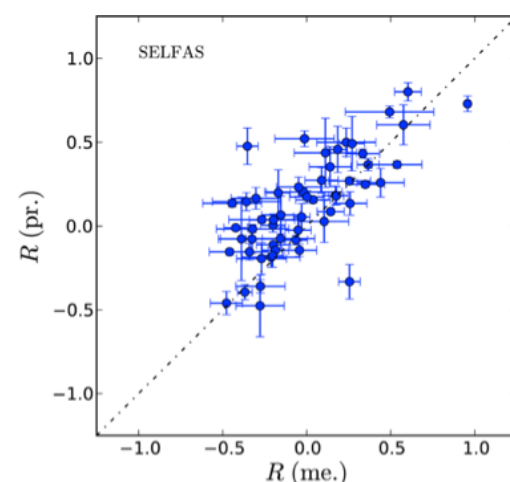
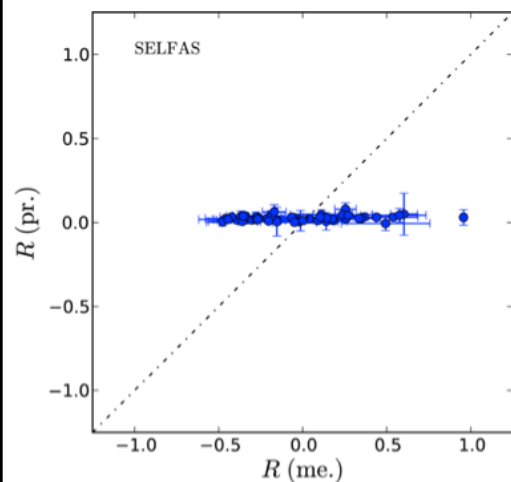
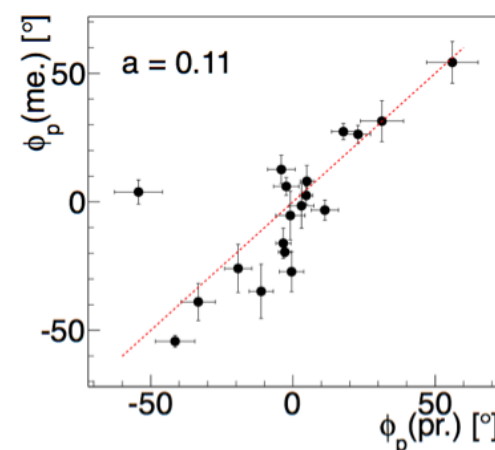
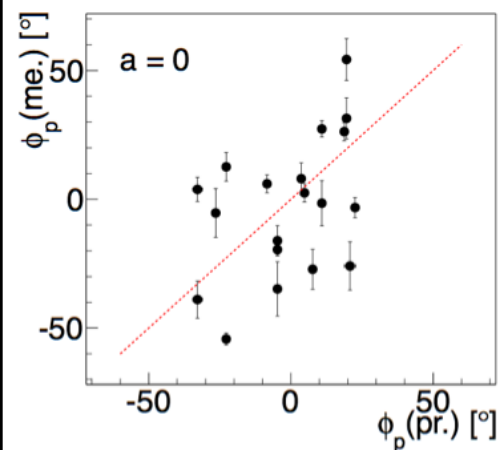
124 stations, 6 km²



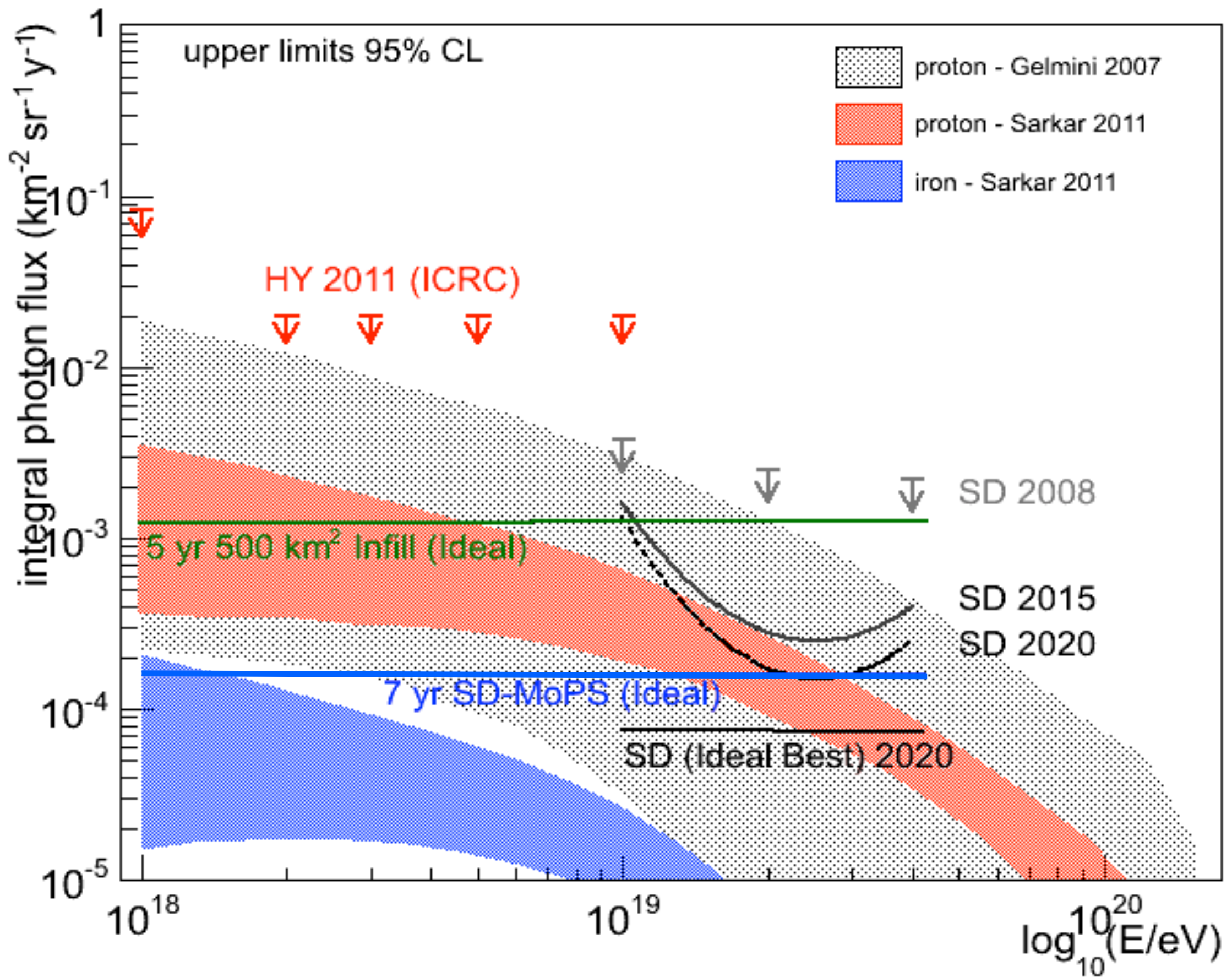
EASIER

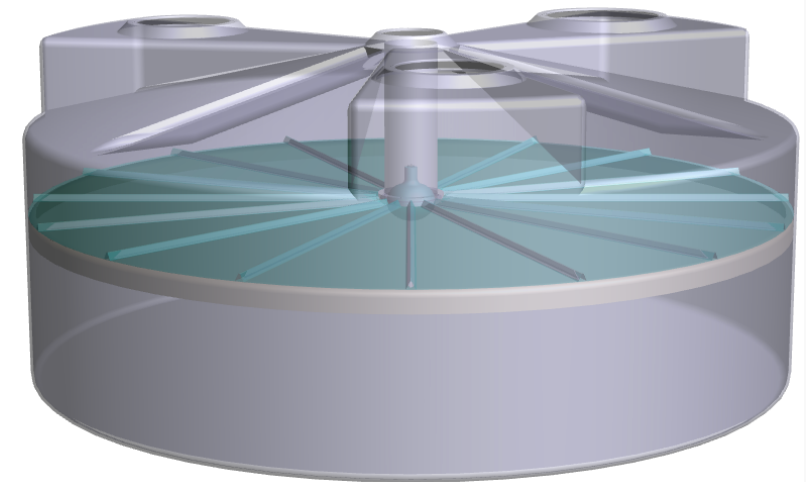
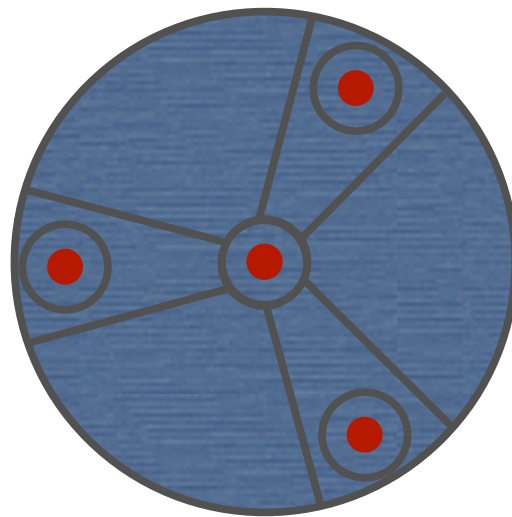
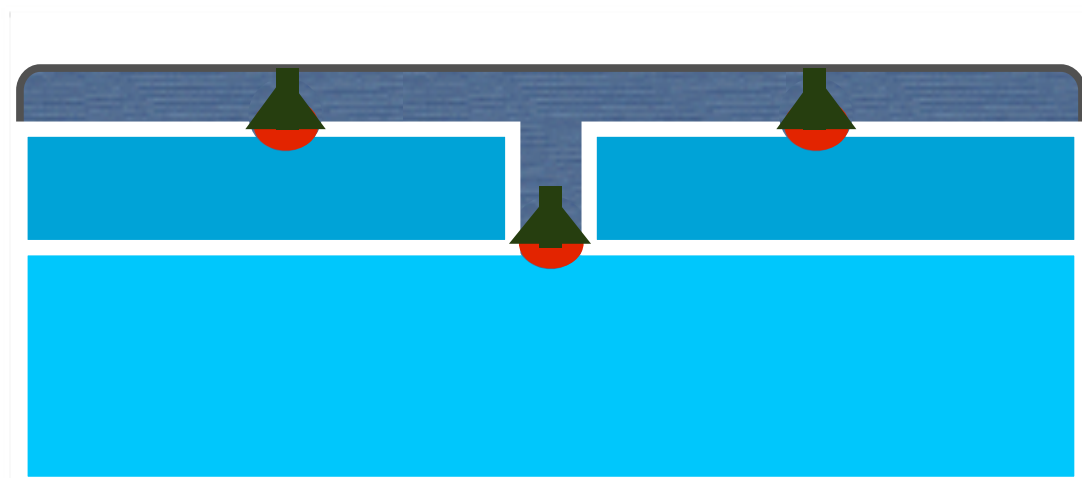
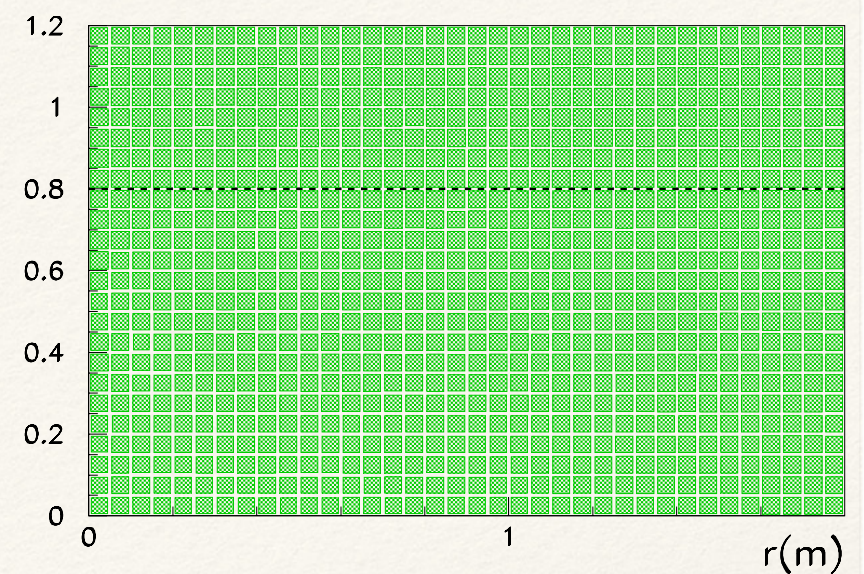
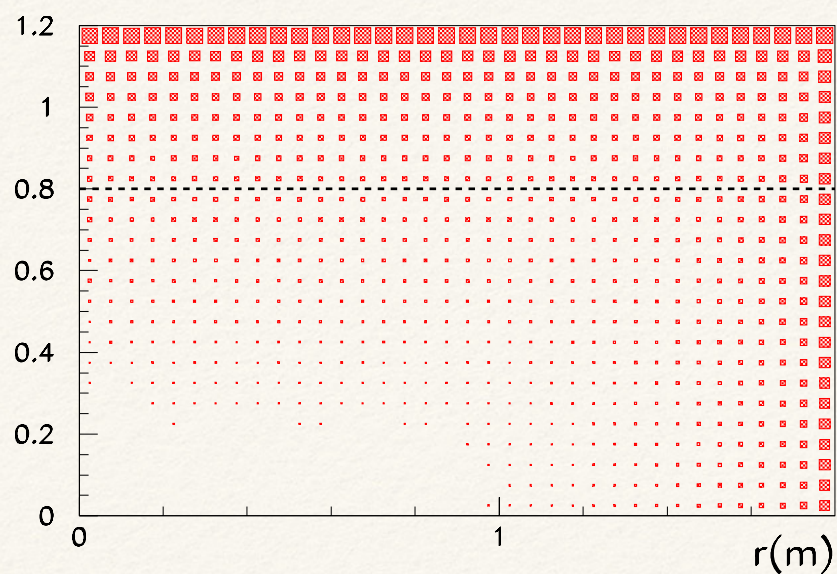
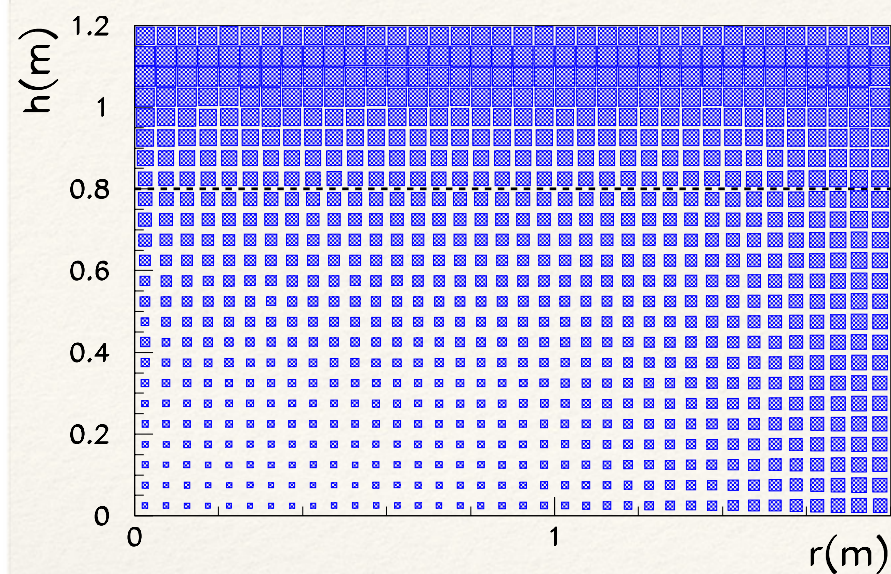


61 stations, 100 km²



MIDAS





LSD

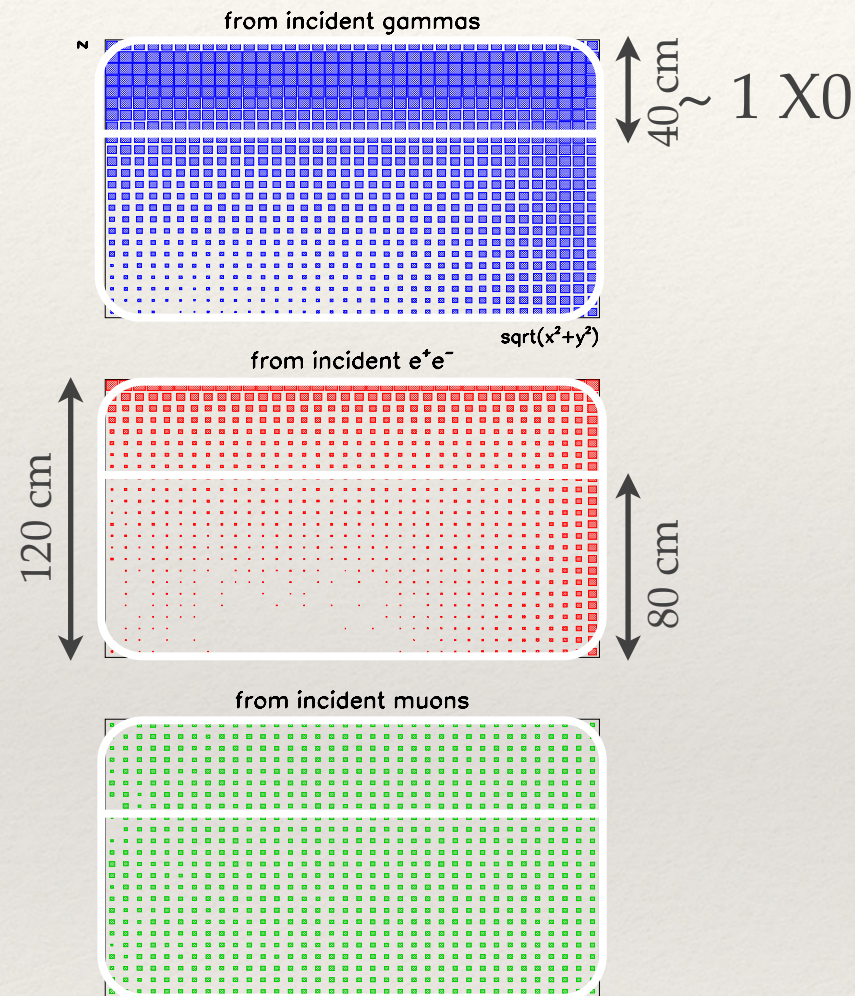
Principle & design

Distribution of the Cherenkov photons production point in a 1.2 m height and 1.6 m radius WCD. From left to right the contribution from the photons, e^+e^- and muon component of a 30 EeV EAS with 45° zenith angle is shown.

LSD design side, top and 3D view.

Principle

Simple - Universal - Robust
After segmentation



fraction a of e/γ p.e. are collected in the top segment

fraction b of μ p.e. are collected in the top segment

$$\begin{pmatrix} S_{top} \\ S_{bot} \end{pmatrix} = M \begin{pmatrix} S_{em} \\ S_{\mu} \end{pmatrix} = \begin{pmatrix} a & b \\ 1-a & 1-b \end{pmatrix} \begin{pmatrix} S_{em} \\ S_{\mu} \end{pmatrix}$$

For 40/80 cm $a=0.6$ and $b = 0.4$

Same after the matrix inversion to get EM and muonic LDFs

