Workshop on "Neutrino Telescopes"
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THE AUGER EXPERIMENT

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Design considerations:

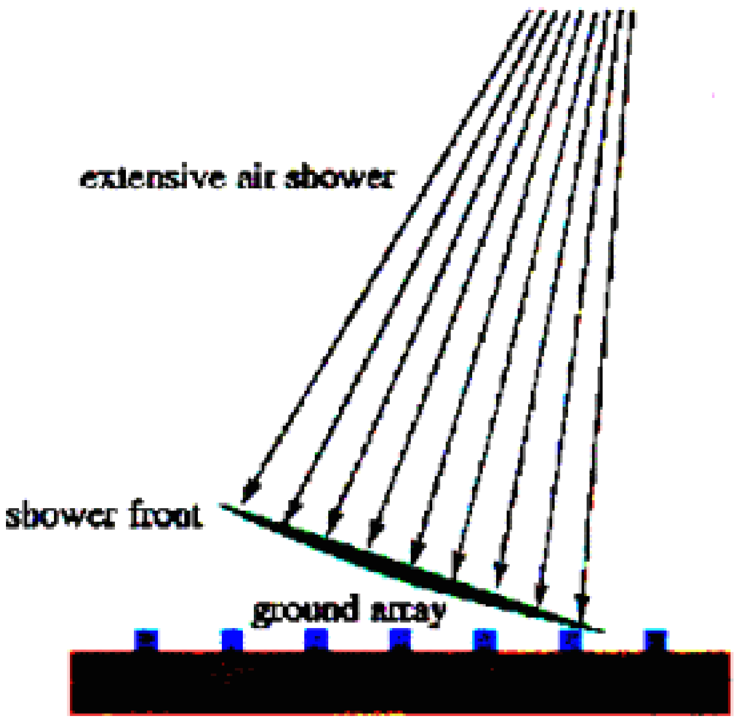
A new, high quality, generation of experiments to explore the cosmic ray spectrum above the GZK cutoff requires:

- Large acceptance: (expected rate, 1 per km^2 sterad century)
- Precise energy measurements and an accurate knowledge of the energy scale
- Redundant measurements of the shower parameters that carry information on the nature and origin of the primary particle (direction, μ/electrons ratio, position of shower maximum (XMAX))

Conventional techniques for earth based experiments:

Large Ground Arrays:

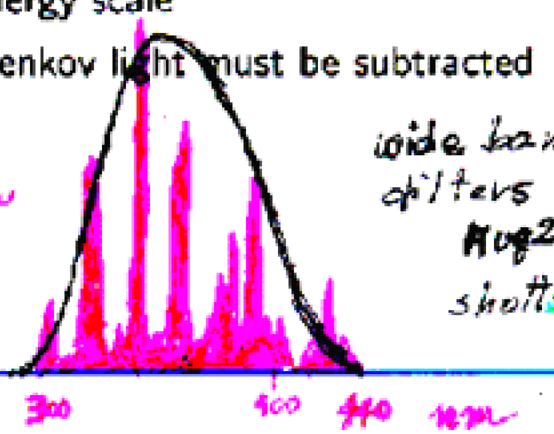
- ~100 % duty cycle
- Energy range accepted is determined by lattice spacing (E_{min}) and total area (E_{max})
- Modular, state of the art detectors
- Cost excalates with complexity
- All showers characteristics derived from projection at ground level



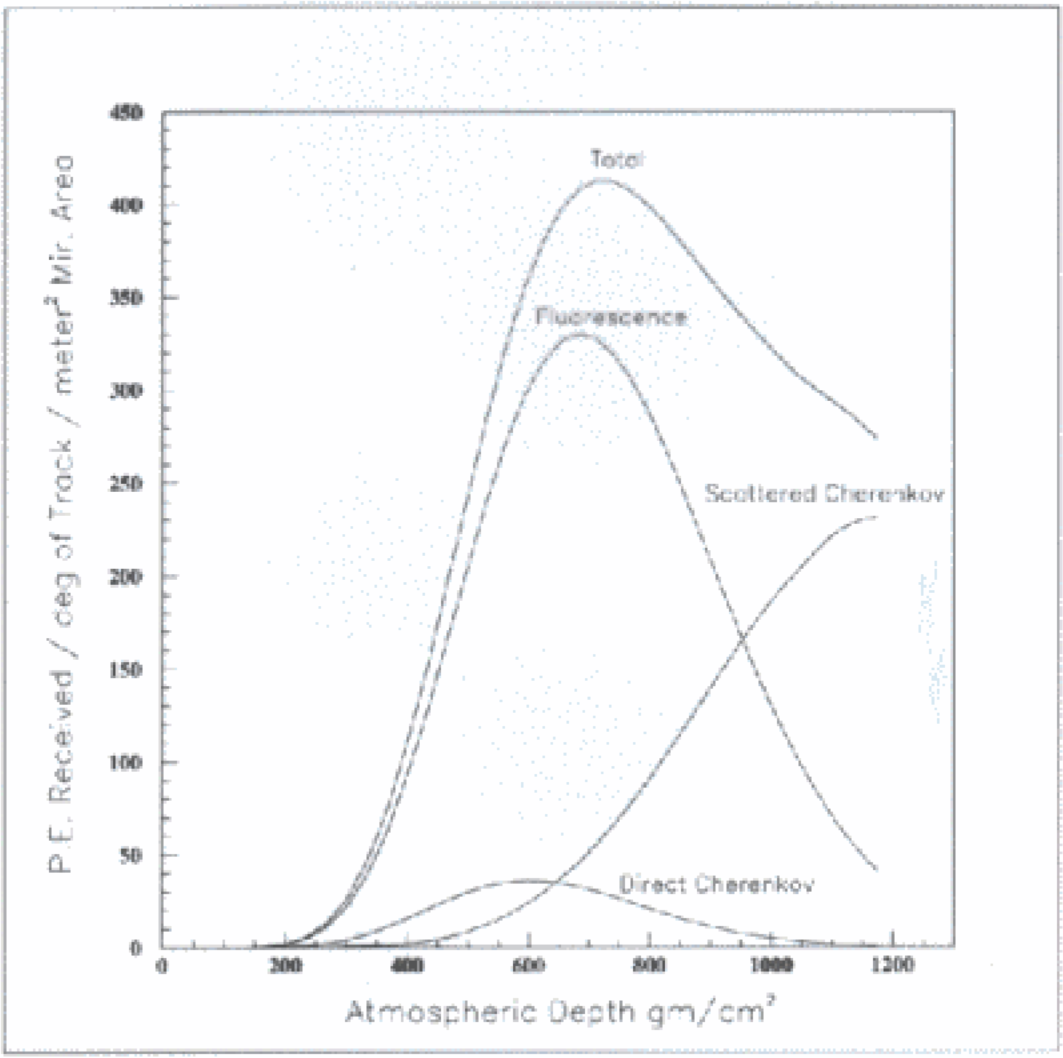
Fluorescence Fly's Eye detectors

- Few stations (eye's) overlook large areas
- Fluorescence light is emitted isotropically. The yield of light is proportional to track length and approximately independent from atmospheric depth
- The trajectory of the shower is mapped on a phototube (PM) array. The amplitude and time readout of PM signals allows a precise calorimetric determination of the energy and direction of the shower as it develops giving direct information on the shower profile
- The light is emitted in a restricted wave length range ($300 < \lambda < 440$ nm) allowing filtering out of night-sky background
- Small (10%÷ 20%) duty cycle
- The energy range is determined by the minimum size of detectable signals
- Requires excellent monitoring of atmosphere to understand energy scale
- Scattered Cerenkov light must be subtracted

Fluorescence spectrum



wide band glass filters
Kug2 - Kug6
Schott



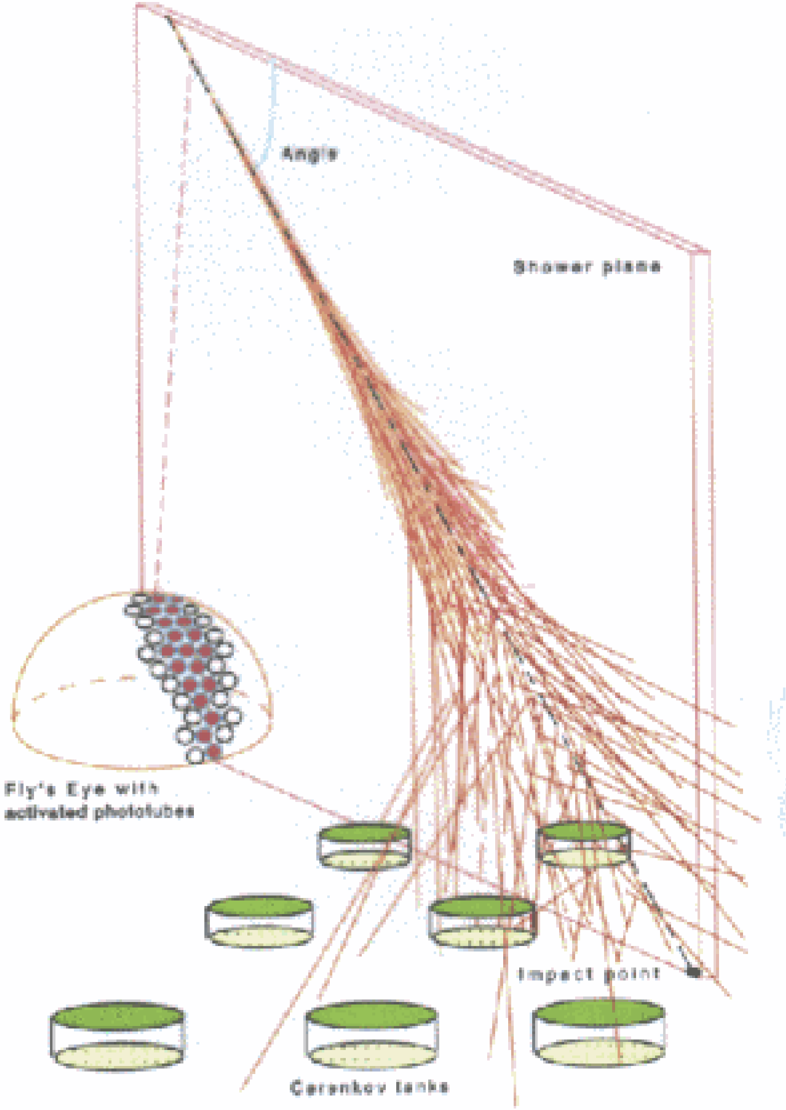
P.E. Received / deg of Track / meter² Mir. Area
450
400
350
300
250
200
150
100
50
0
Total
Fluorescence
Scattered Cherenkov
Direct Cherenkov
0
200
400
600
800
1000
1200
Atmospheric Depth gm/cm²

Auger hybrid system:

Two ground arrays, one in the northern and one in the southern hemisphere to achieve full sky coverage, each complemented by 4 Fly's Eye detectors providing.

- Large duty cycle
- Intercalibration of energy scale with the two detectors and redundant information on primary direction and mass on the subsample of golden events

Construction and deplojment in Southern site is well underway



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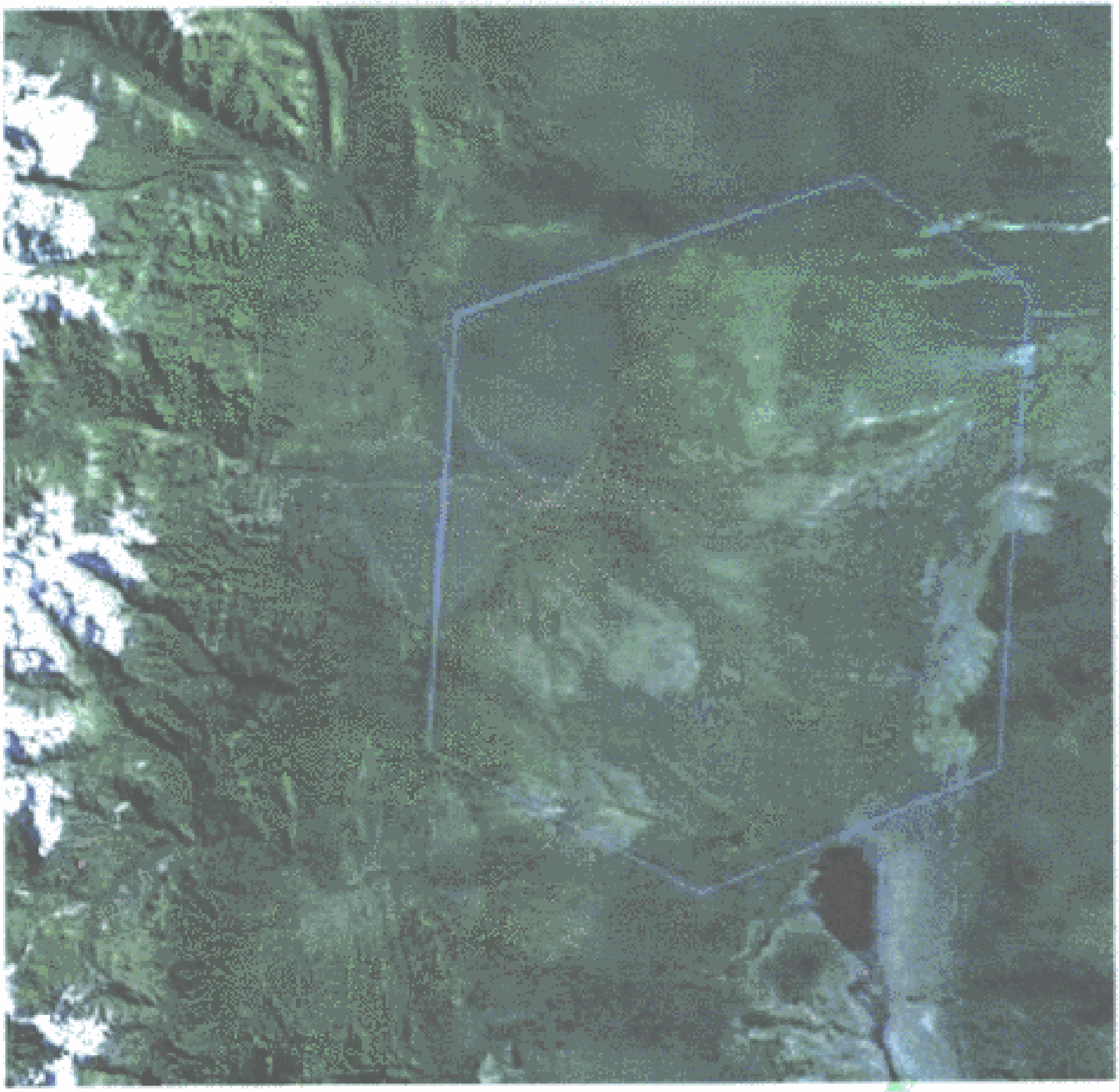
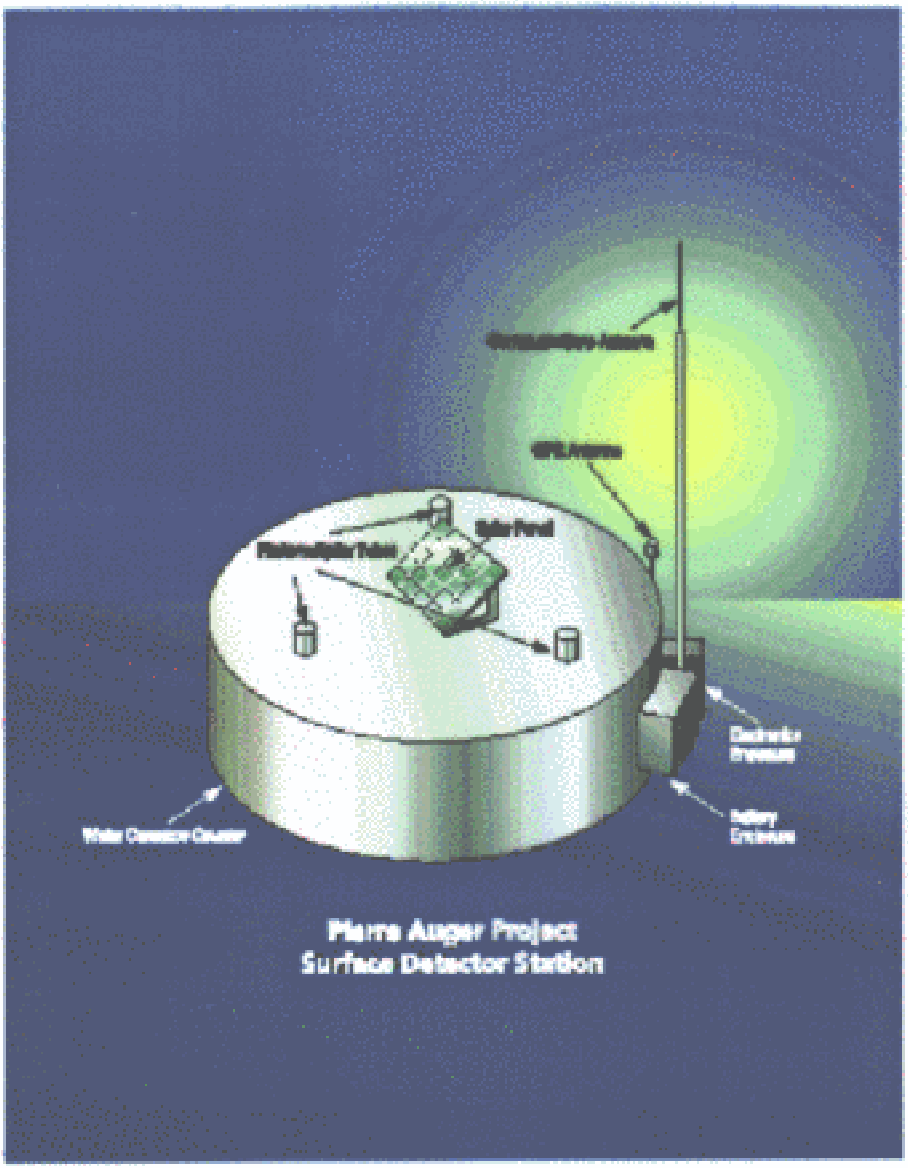


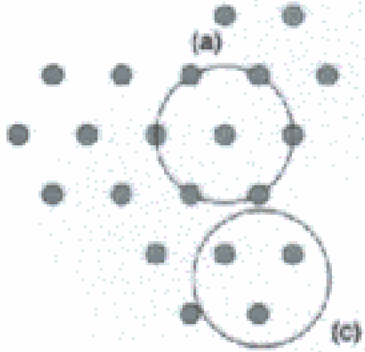
Auger Ground Arrays

- **Array dimensions**
  Area of each ground array: 3000 km^2 - expect $\sim$100 events above GZK cutoff per site per year
- **Arrays location**
  Northern site: Millard County- Utah
  Southern site: El Nihuil-Prov.of Mendoza-Argentina
  Desert areas with good sky quality; altitude $\sim$ 870 gr/cm^2, near shower maximum for vertical showers of energy $> 10^{19} eV$ (10 EeV).
- **Array configuration**
  1600 detectors positioned on an hexagonal lattice with 1.5 Km spacing; sets E_{min} = 10 EeV for vertical showers (100 % detection efficency for 3 module trigger)
- **Module definition**:
  Detection technique: **Cerenkov counters**; simple,low cost,stable,low maintenance.
  Units 1.2m high and of 10m^2 area, filled with purified H_2O. Cerenkov light emitted in H_2O by shower particles is seen by 3 PMT's. Each unit is powered by a solar panel. A GPS antenna on top of each unit allows synchronization of signals from different modules.

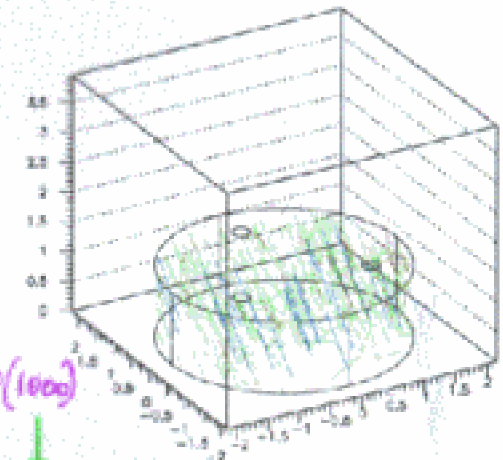


$d = 3.6\,m \Rightarrow A = 10\,m^2$

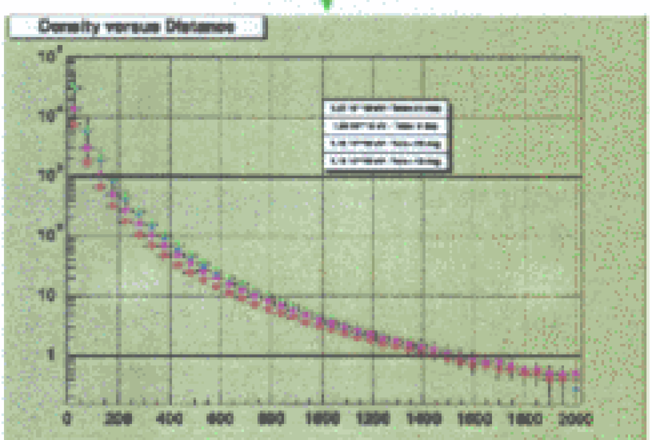
$h \approx 1.2\,m$



10 EeV vertical shower



S(1000)



Density of part.

distance from core impact point (m)

Event Reconstruction in Ground Array

- Each PM signal is processed to give time and amplitude data.
- Verification of module trigger conditions (T1) are performed.
- A communication network transmits informations to the central station.
- Event trigger (T_N) is generated if $>$ N modules have T1.
- Core impact point is reconstructed by triangulation and shower direction determined from signal amplitudes and time delays in the triggered modules
- $\rho(1000)$ a density function of energy and direction at 1000 m from the core is determined
- Through modeling and calibration $\rho(1000)$ allows determination of shower energy
- Signal shape and rise time measures μ/em ratio

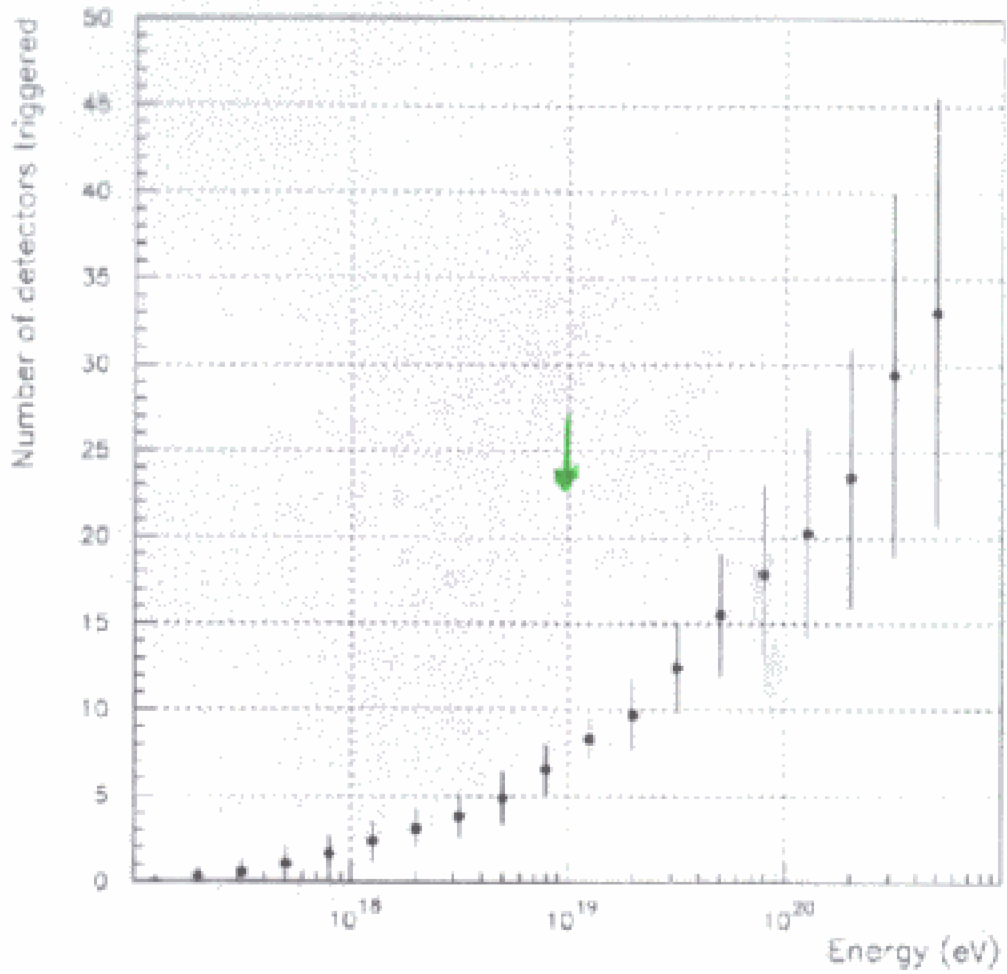

Number of detectors triggered
50
45
40
35
30
25
20
15
10
5
0
10^{18}
10^{19}
10^{20}
Energy (eV)

Table 1: Events per year. AGASA spectrum: PRL 81 1163.(1998)

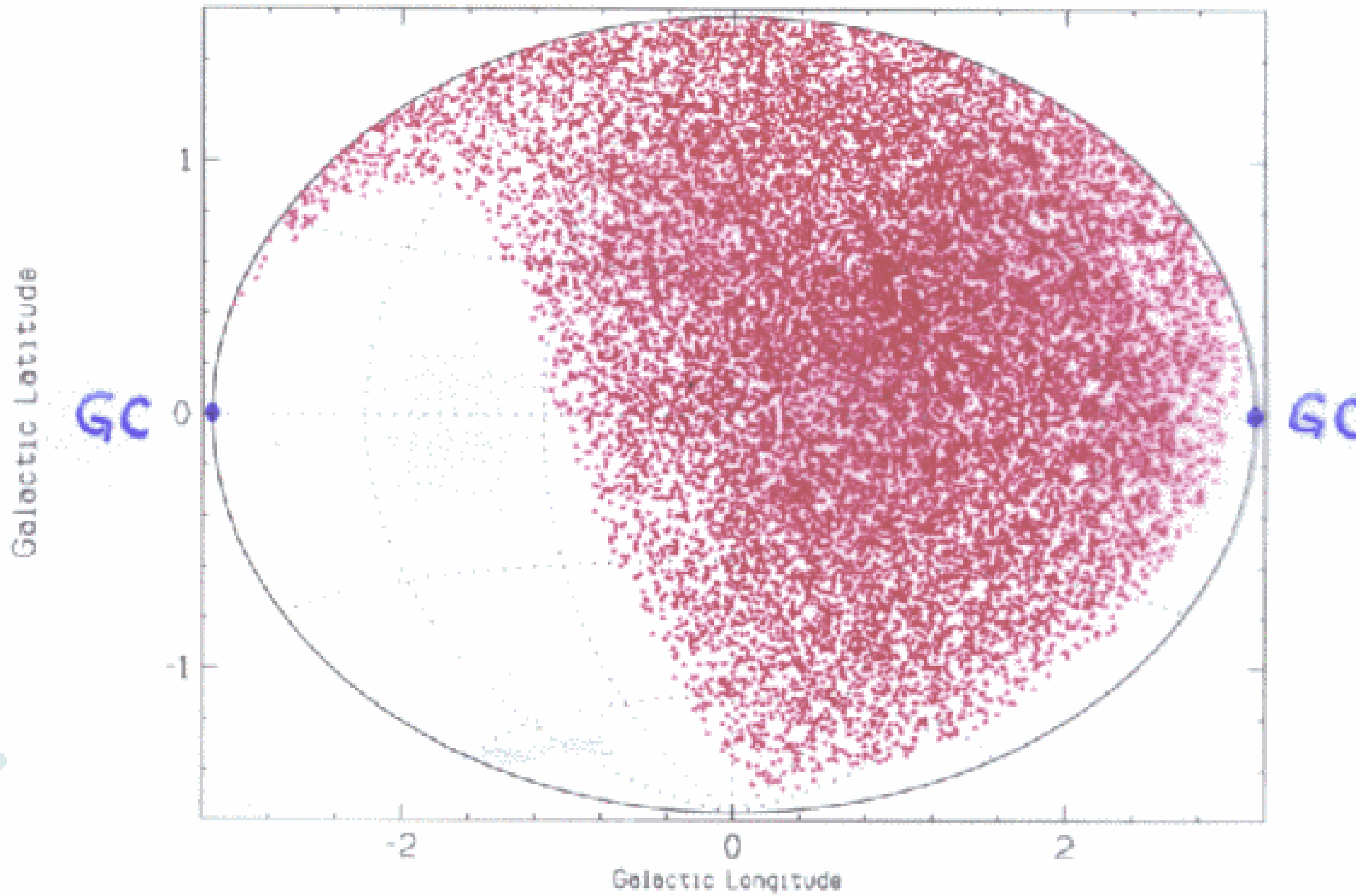
Energy	HiRes	Auger
$\leq 10\ EeV$	~ 500	10000
$\geq 10\ EeV$	387	5150
$\geq 20\ EeV$	170	1590
$\geq 50\ EeV$	63	490
$\geq 100\ EeV$	15	103
$\geq 200\ EeV$	4	32
$\geq 500\ EeV$	1.4	10

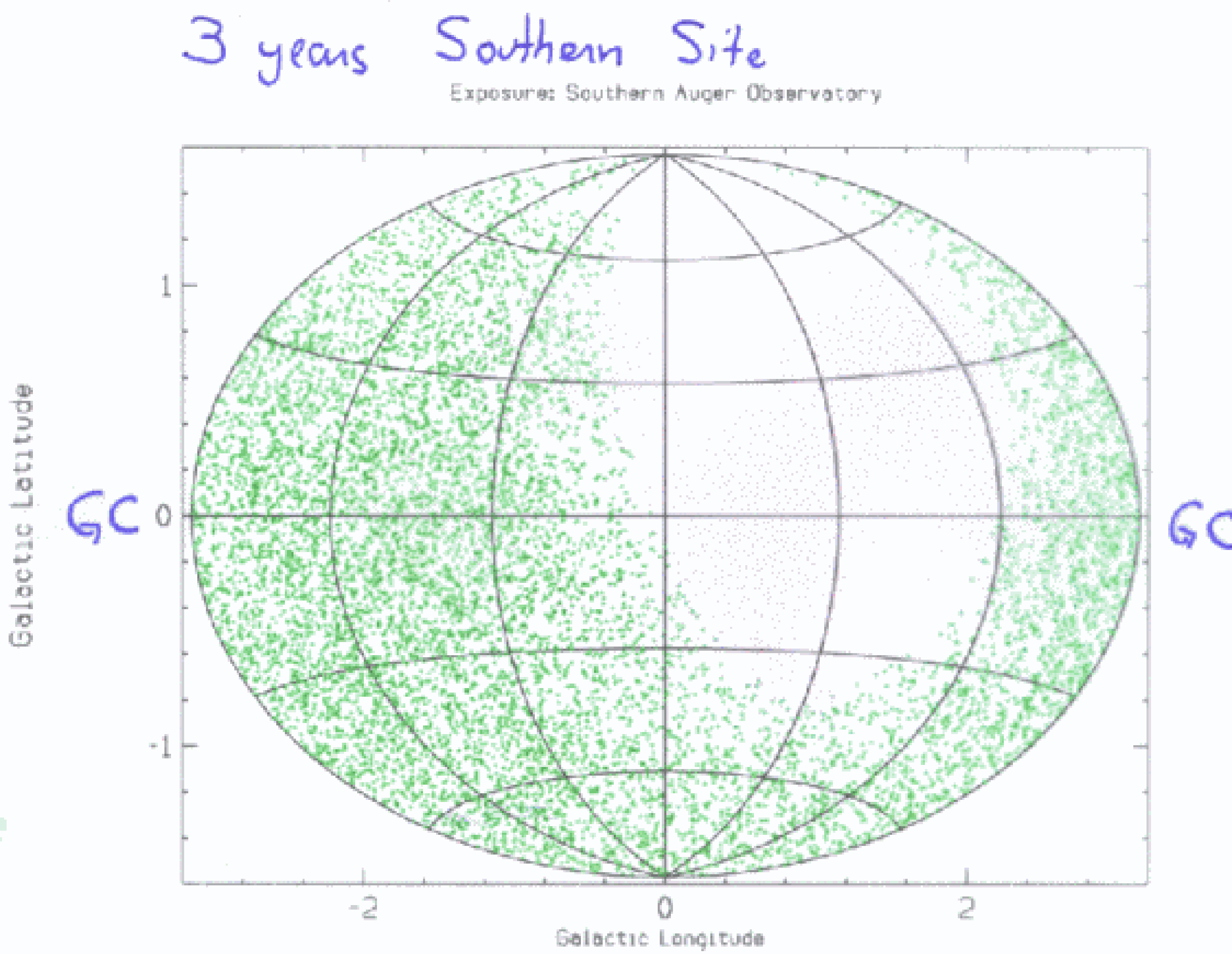
fully efficient

For showers with $\theta_Z \geq 60°$
add 50%

6

3 years (UTAH)




3 years Southern Site
Exposure: Southern Auger Observatory
Galactic Latitude
Galactic Longitude
GC
GC
1
0
-1
-2
0
2

Reconstruction Errors ($\theta_z \leq 60°$)

	RMS Energy	$\delta\theta$ (63%)
$< 10^{20}$ eV	12%	0.6°
$> 10^{20}$ eV	8%	0.4°
$\theta_z < 40°$	12%	0.8°
$\theta_z > 40°$	12%	0.4°

Systematic energy error 10-15 %

Auger Fluorescence detectors

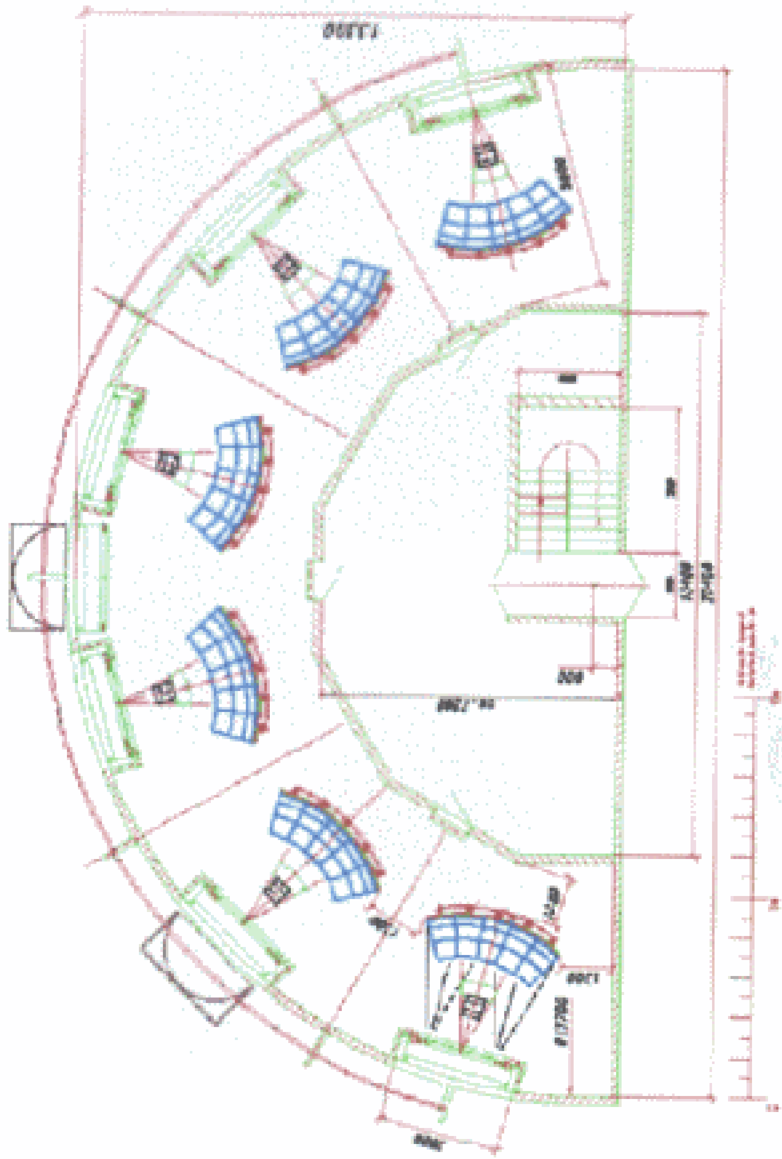
Terminology: 4 eye's ; each eye 12 or 6 telescopes housed in the same building

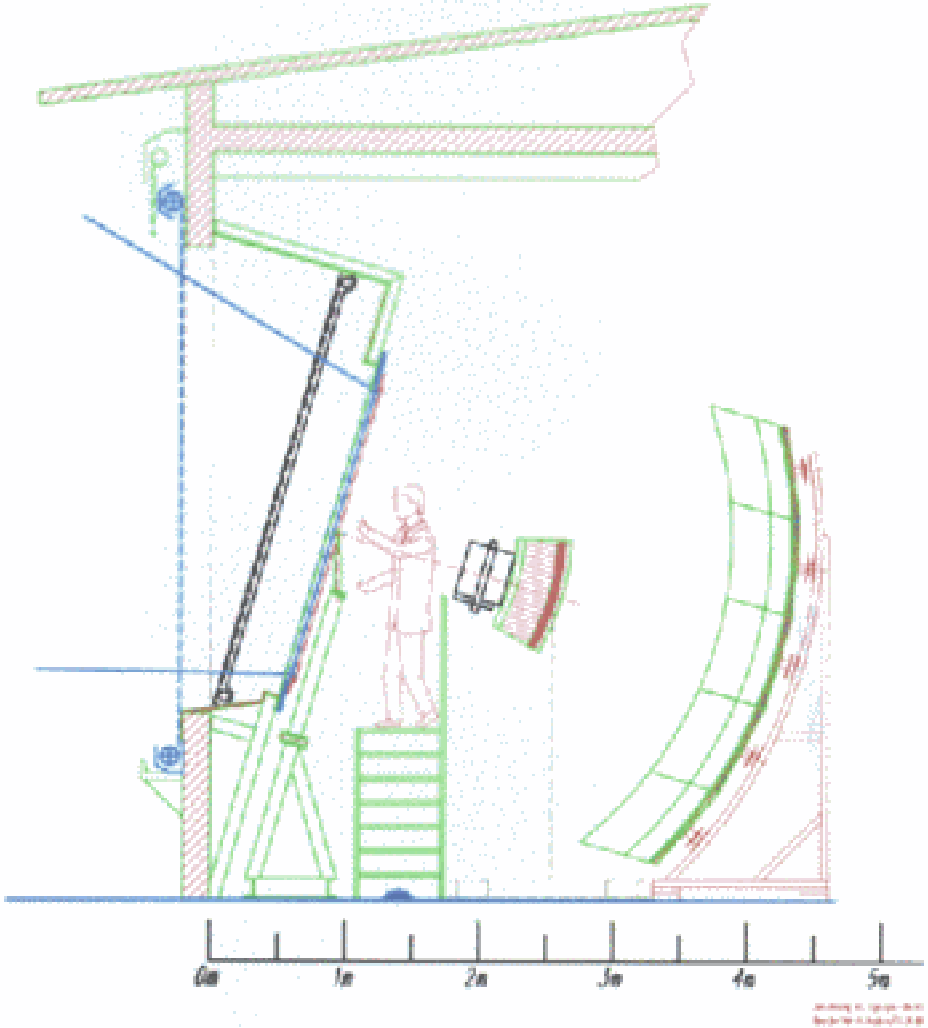
Telescope characteristics

- $30^0 \times 30^0$ acceptance; light collected by $\sim$12 m^2 mirrors of 3.4 m radius of curvature
- Schmidt optics to avoid coma aberration
- Optical filters to transmit preferentially N light
- detector: 440 PMT array
- pixel size $1.5^0 \times 1.5^0$, spot diameter d = 0.5^0 (spherical aberration)

Reconstruction by one telescope - mono events

- Front-end low noise electronics samples (in 100 ns slices) PMT signals.
- Trigger is based on identification of sequential pattern of pixels
- Shower detector plane can than be reconstructed
- From curvature of long tracks of pixels, shower direction in space can be reconstructed
- Shower profile (energy vs atmospheric depth) is reconstructed from signal amplitude along the track





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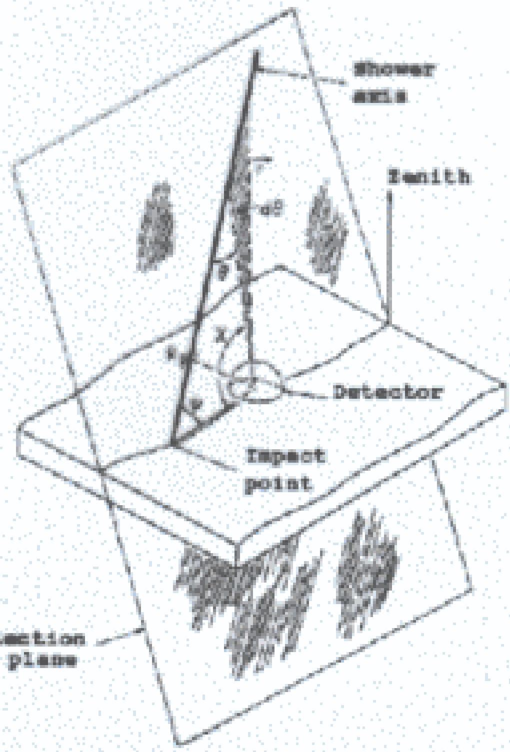
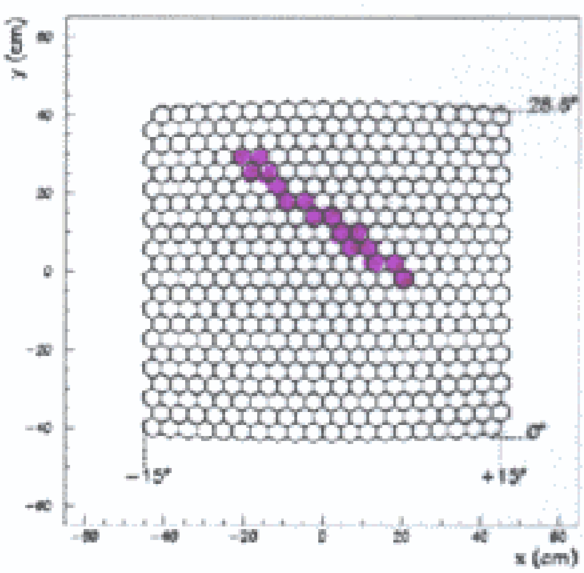


Shower axis
Zenith
Detector
Impact point
Detection plane



y (cm)
x (cm)
28.8°
0°
−15°
+15°

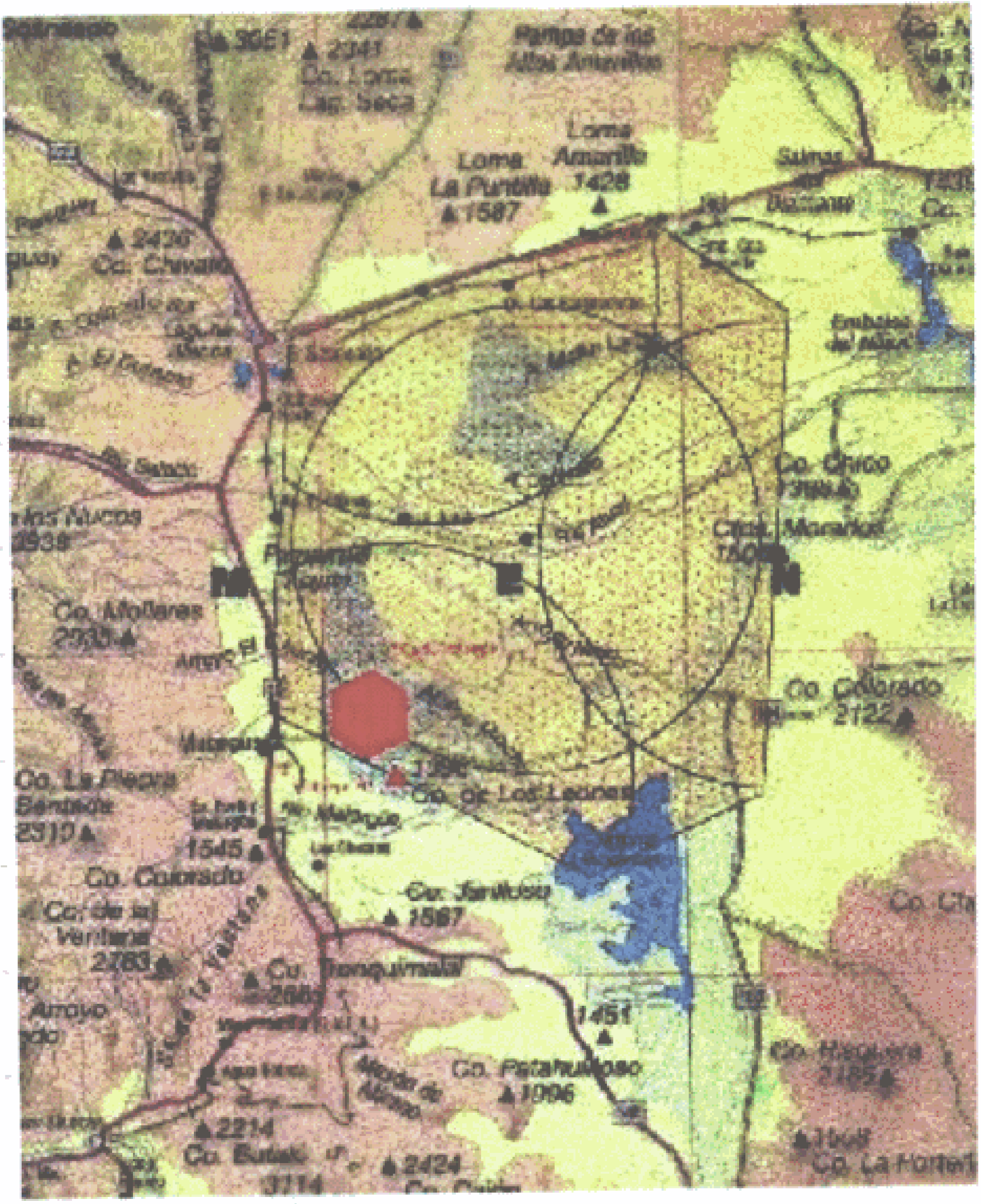
Stereo events

If an event seen by two or more telescopes the stereo views allow reconstruction of the direction of the shower and provide redundant information on shower profile and energy

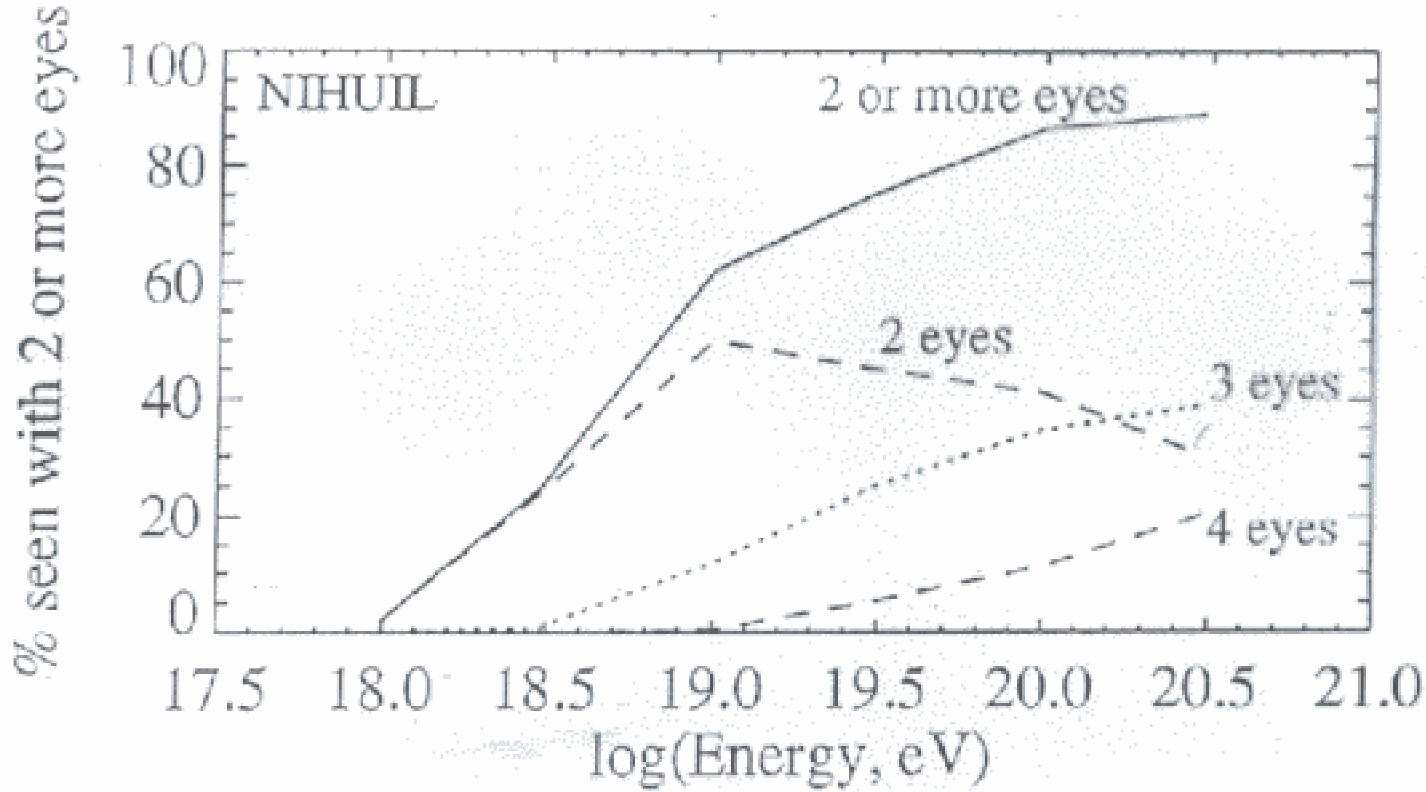
Hybrid reconstruction

Each year a good sample of events of energy above 10 EeV will be detected in the ground array and by at least one fluorescence detector.

- The direction of the shower will be accurately measured even for mono events adding the information on the core impact point (Ground Array)
- Independent measurements of energy with Ground Array and Fluorescence Detector(s) will allow improvement in precision and intercalibration
- Complementary indicators from the two type of detectors (Cerenkov and Fluorescence) will strengthen the determination of the primary composition
- E_{min} can be lowered by detecting events close to one eye with signals well above background in at least one tank



3061
2341
Loma Amarilla 1428
Loma La Puntilla
1587
2430
Co. Chico
Co. Colorado
2122
Co. La Piedra Sentada
2319
1545
Co. Colorado
2783
1451
2214
2424


NIHUIL
2 or more eyes
2 eyes
3 eyes
4 eyes
% seen with 2 or more eyes
100
80
60
40
20
0
17.5
18.0
18.5
19.0
19.5
20.0
20.5
21.0
log(Energy, eV)

Milestones and status report

Milstones

- 2001 - 2002
  Construction and test of Engeneering Array
- 2002 - 2004
  Continue deployment of experiment components
- 2005 →
  Detector completed and in data taking mode

Engeneering Array

A 40 tanks Ground Array + 2 Fluorescence ~~detectors~~ telescopes will start data taking at the end of the winter in Argentina

- Buildings and infrastructures available
- Deployment of tanks under way
- Fluorescence telescopes being assembled
- Communication network ready