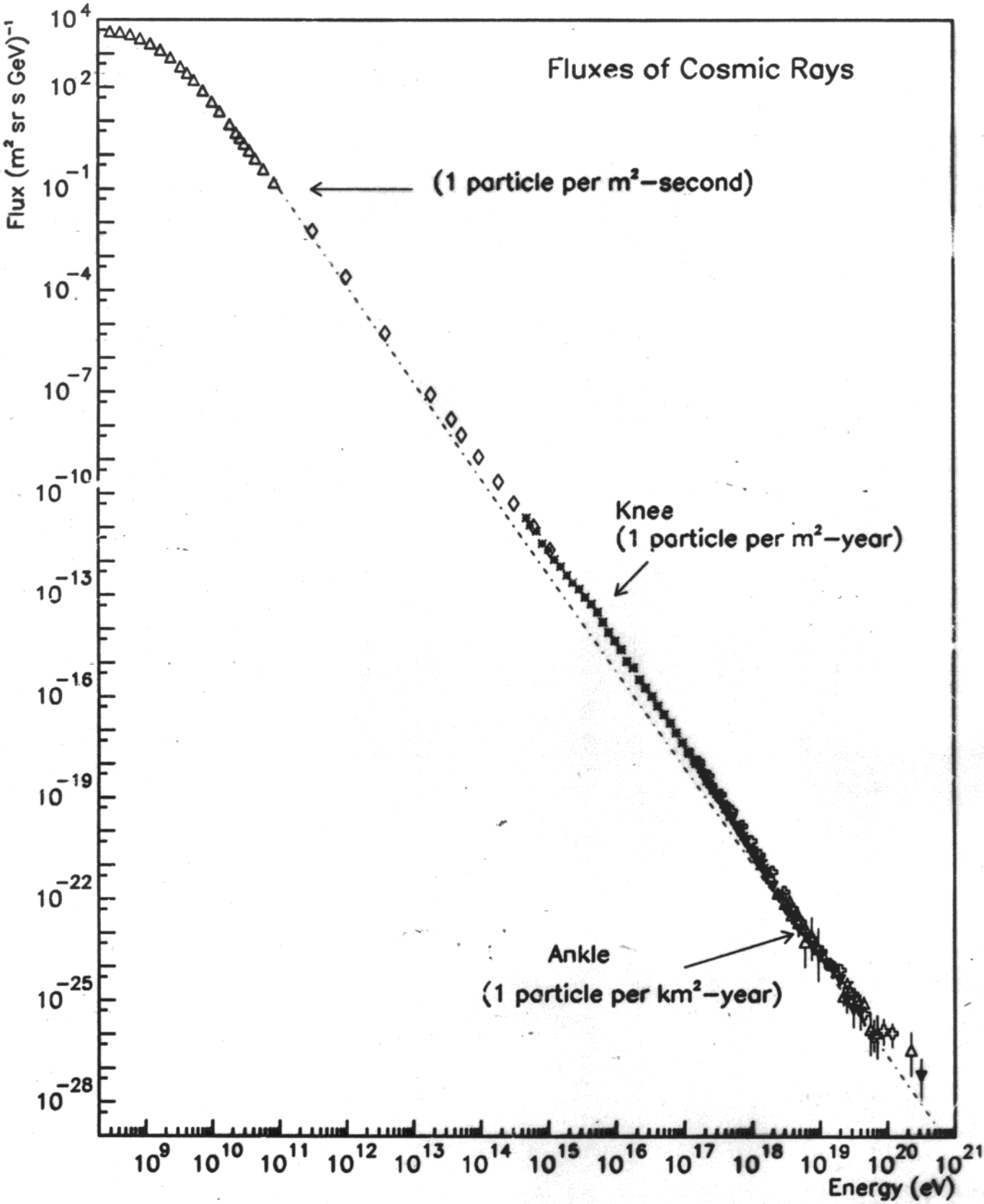


⇒ indirect (shower) measurements

particle exchanges have been considered by a number of authors. See, for example, R. Bryan, C. Dismukes, and W. Ramsay (to be published).

[3]R. Blankenbecler and M. L. Goldberger, Phys. Rev. 126, 766 (1962); G. F. Chew and S. C. Frautschi,

[5]M. Hull, K. Lassila, H. Ruppel, [illegible], G. Breit, Phys. Rev. 122, 1606 (1961).

[6]C. de Vries, R. Hofstadter, and R. Herman, Phys. Rev. Letters 8, 381 (1962).

[7]J. Ball and D. Wong (to be published).

GDF 15

B Rossi

EVIDENCE FOR A PRIMARY COSMIC-RAY PARTICLE WITH ENERGY 10^{20} eV†

John Linsley

Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts

(Received 10 January 1963)

"5×10[10] particles"

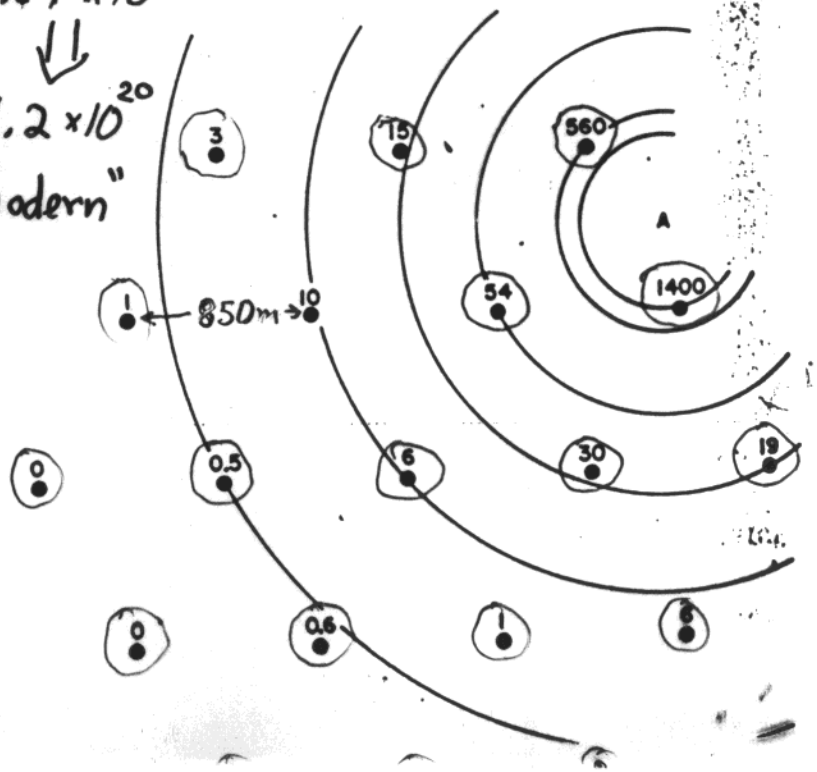
Analysis of a cosmic-ray air shower recorded at the MIT Volcano Ranch station in February 1962 indicates that the total number of particles in the shower (Serial No. 2-4834) was 5×10^{10}. The total energy of the primary particle which produced the shower was 1.0×10^{20} eV. The shower was about twice the size of the largest we had reported previously (No. 1-15832, recorded in March 1961).[1]

The existence of cosmic-ray particles having such a great energy is of importance to astrophysics because such particles (believed to be atomic nuclei) have very great magnetic rigidity. It is believed that the region in which such a particle originates must be large enough and possess a strong enough magnetic field so that $RH \gg (1/300) \times (E/Z)$, where R is the radius of the region (cm) and H is the intensity of the magnetic field (gauss). E is the total energy of the particle (eV) and Z is its charge. Recent evidence favors the choice $Z = 1$ (proton primaries) for the region of highest cosmic-ray energies.[2] For the present event one obtains the condition $RH \gg 3\times10^{17}$. This condition is not satisfied by our galaxy (for which $RH \approx 5$

point marked "*A*," assuming only (1) that shower particles are distributed symmetrically about an axis (the "core"), and (2) that the density of particles decreases monotonically with increasing distance from the axis. The observed densities

1.4×10^{20}

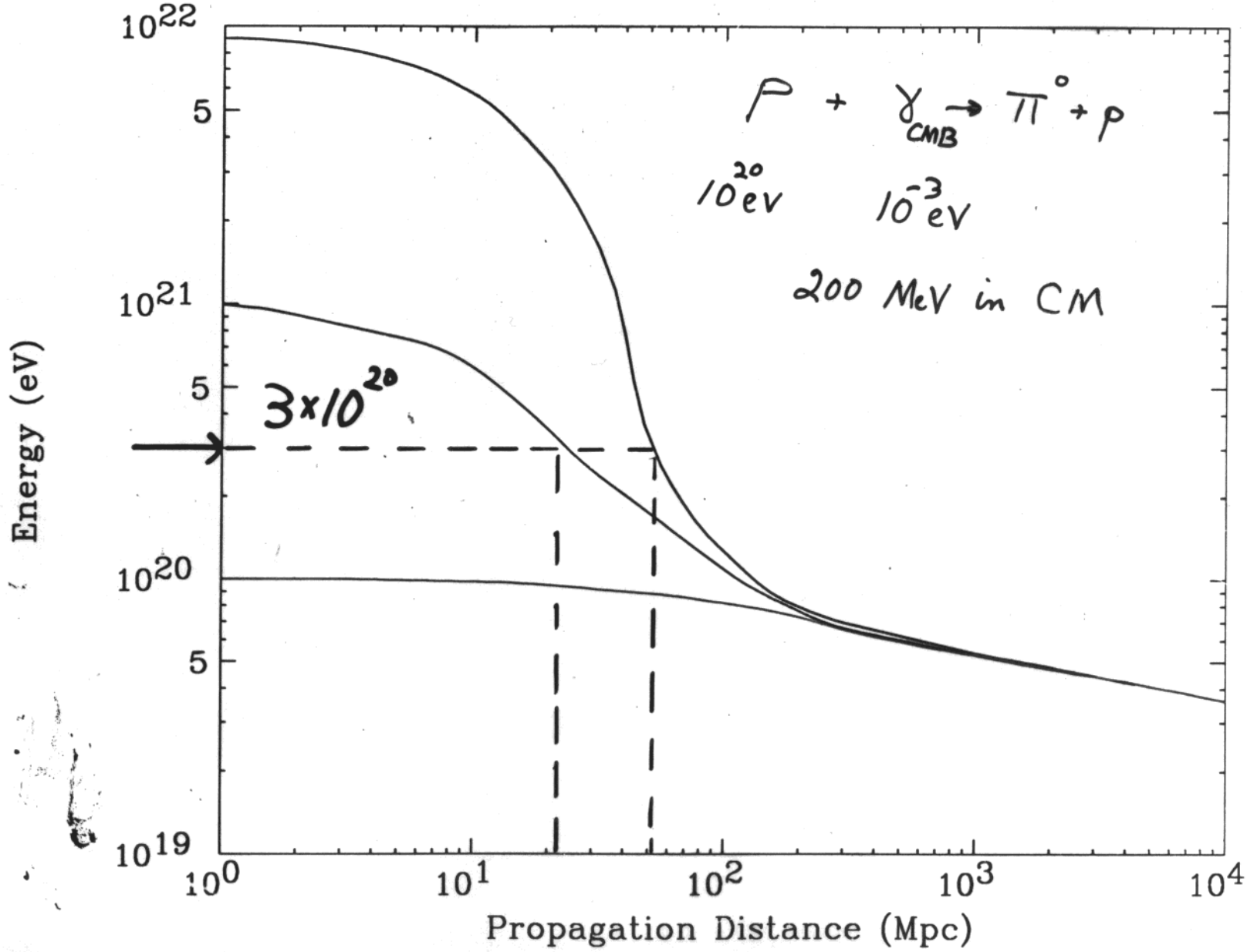
1.2×10^{20} "modern"



5

13

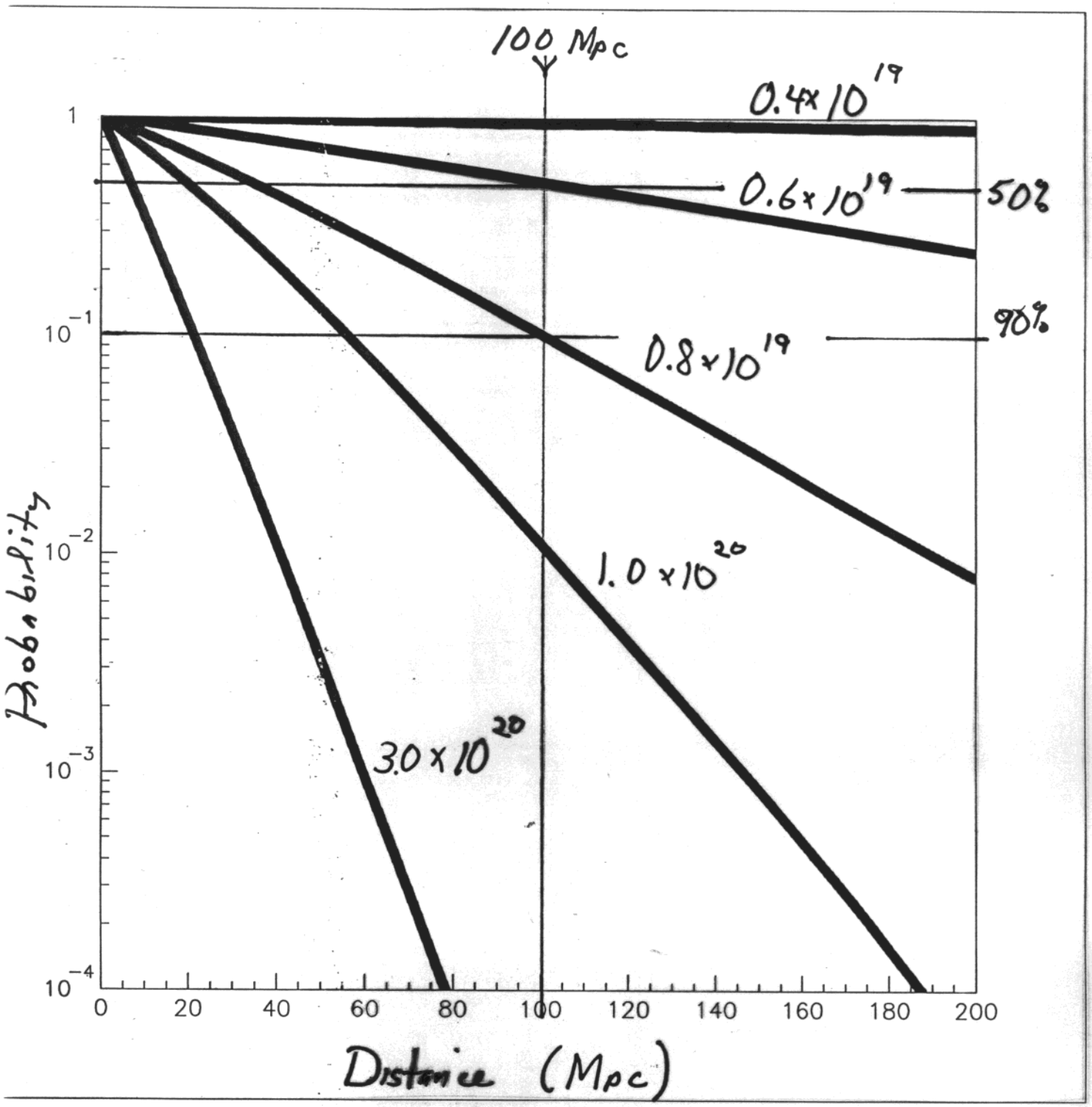
1 Mpc ≈ 3×10^6 light years



19

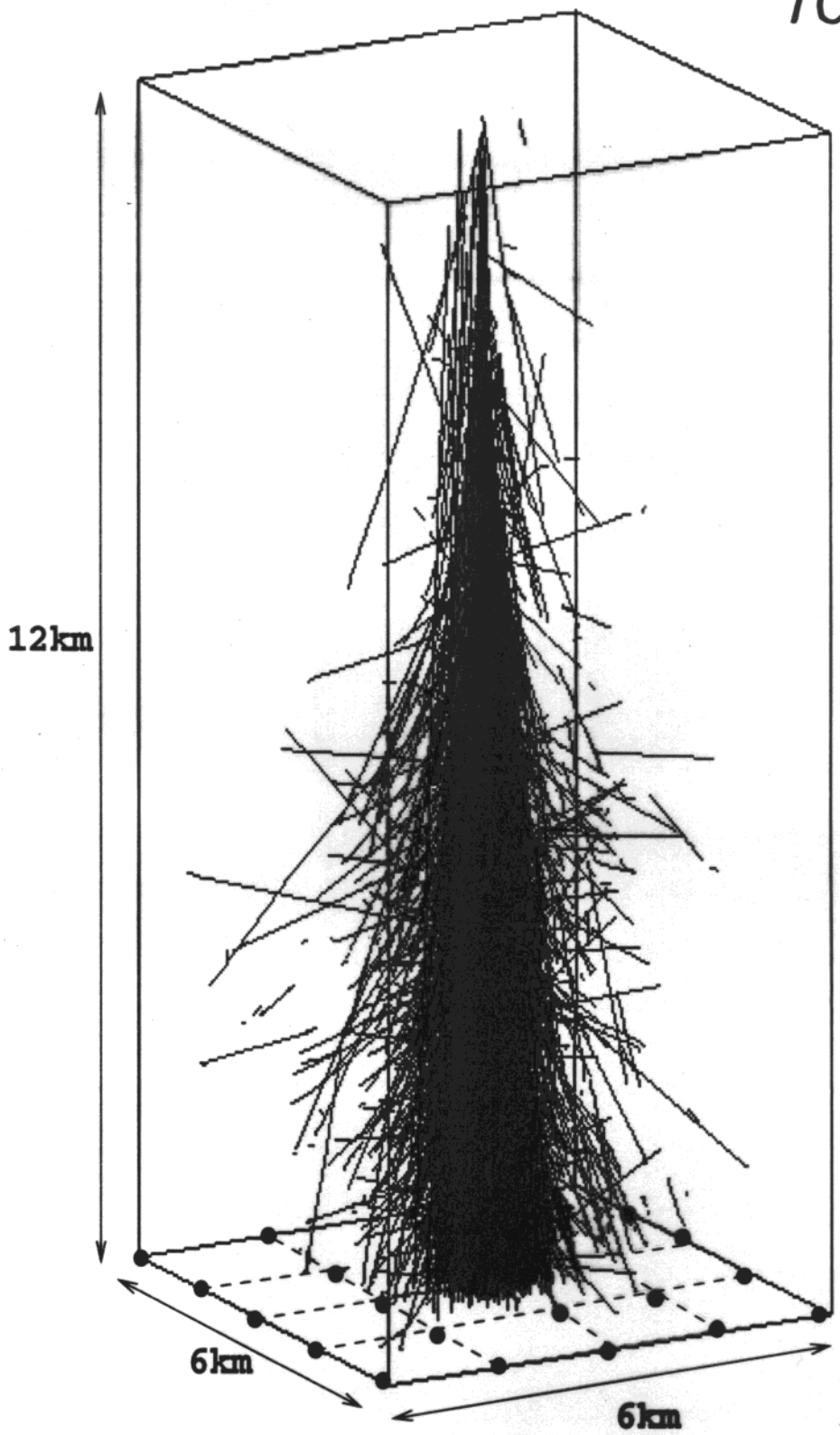
Source < 50 Mpc

Probability > d



Une "Gerbe Atmosphérique" de 10 EeV

10^{19} eV

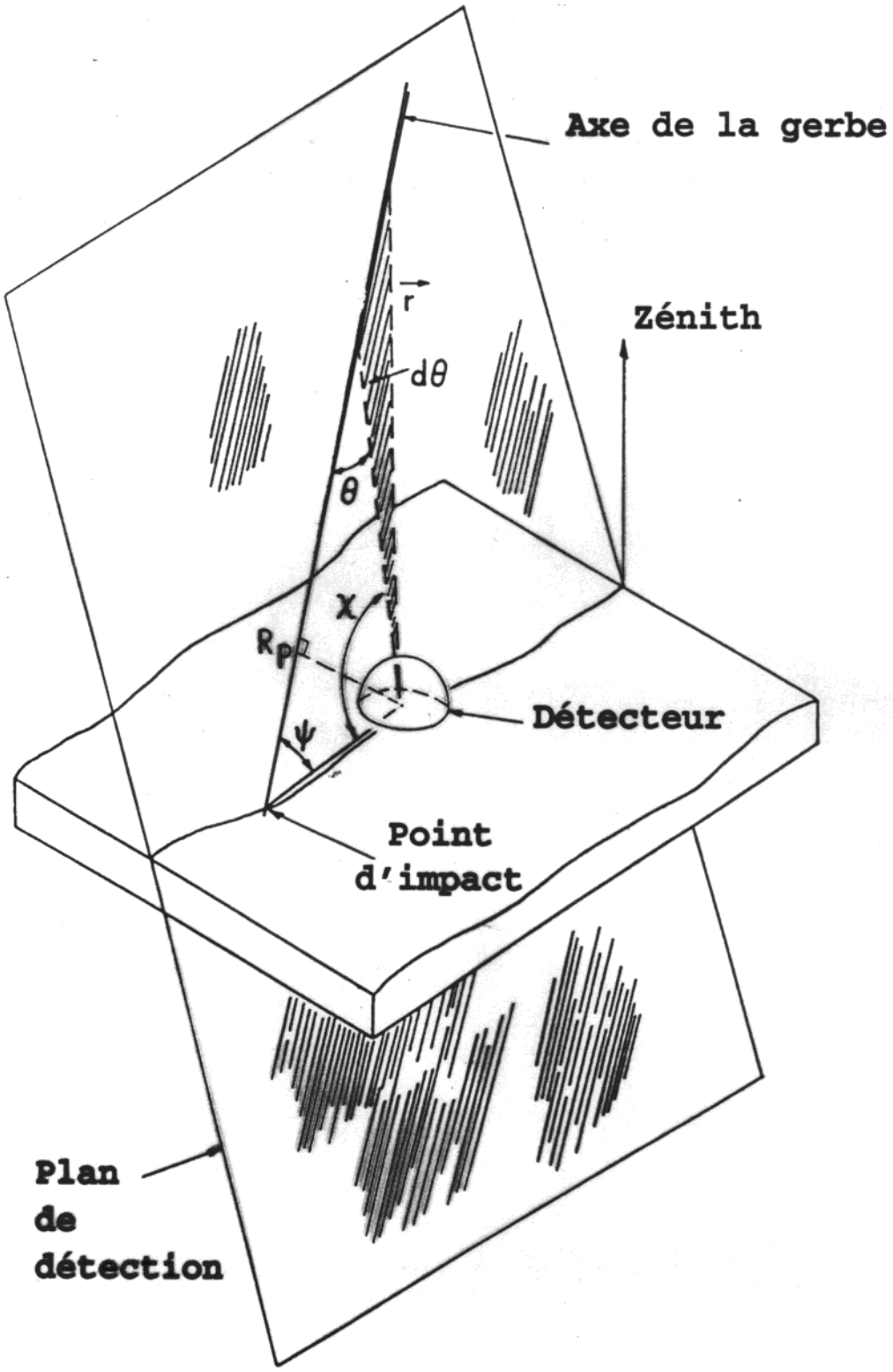


100 milliards de particles au niveau de la mer

photons, électrons (99%), muons (1%)

- **Réseau de détecteurs**

Principe de fonctionnement du "Fly's Eye"



FOUR IMPORTANT Five PAPERS

"Observation of a Very Energetic Cosmic Ray Well Beyond the Predicted 2.7K Cutoff in the Primary Energy Spectrum"

N. Hayashida et al. PRL 73, 3491 (1994)

"Detection of a Cosmic Ray with Measured Energy Well Beyond the Expected Spectral Cutoff Due to Cosmic Microwave Radiation"

D. J. Bird et al. Ap J. 441, 144 (1995)

"Possible Clustering of the Most Energetic Cosmic Rays within a Limited Space Angle Obeserved by the Akeno Giant Air Shower Array

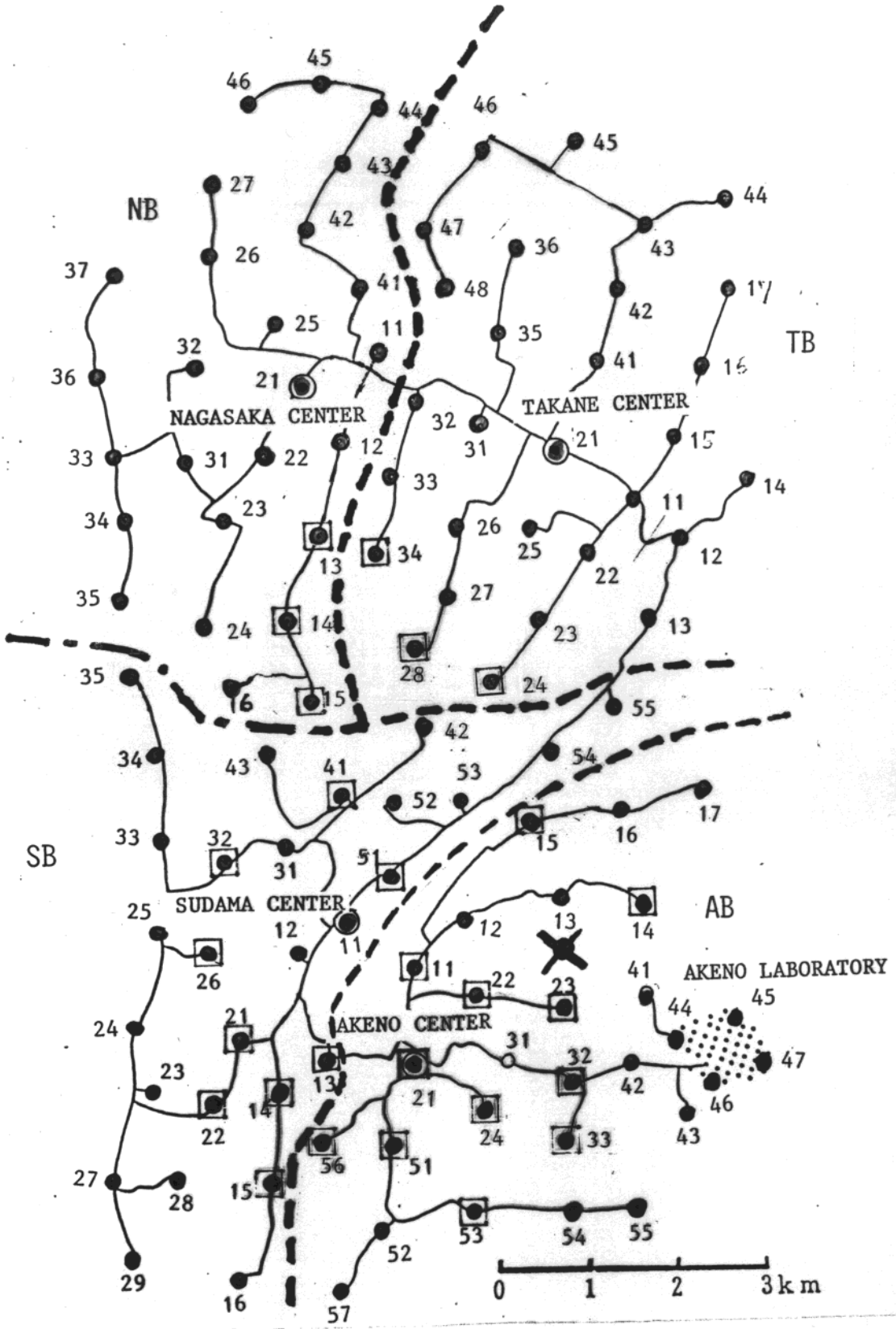
N Hayashida et al. PRL 77, 1000 (1996)

"Extension of the Cosmic Ray Spectrum beyond the Predicted Greisen-Zatsepen-Kuz'min Cutoff"

M. Takeda et al. PRL 81 1163 (1998)

"Small-scale anisotropy of cosmic rays above 10^{19} eV observed with the Akeno Giant Air Shower Array" M. Takeda et al
sub to Ap J. astro-ph 9902 239

10

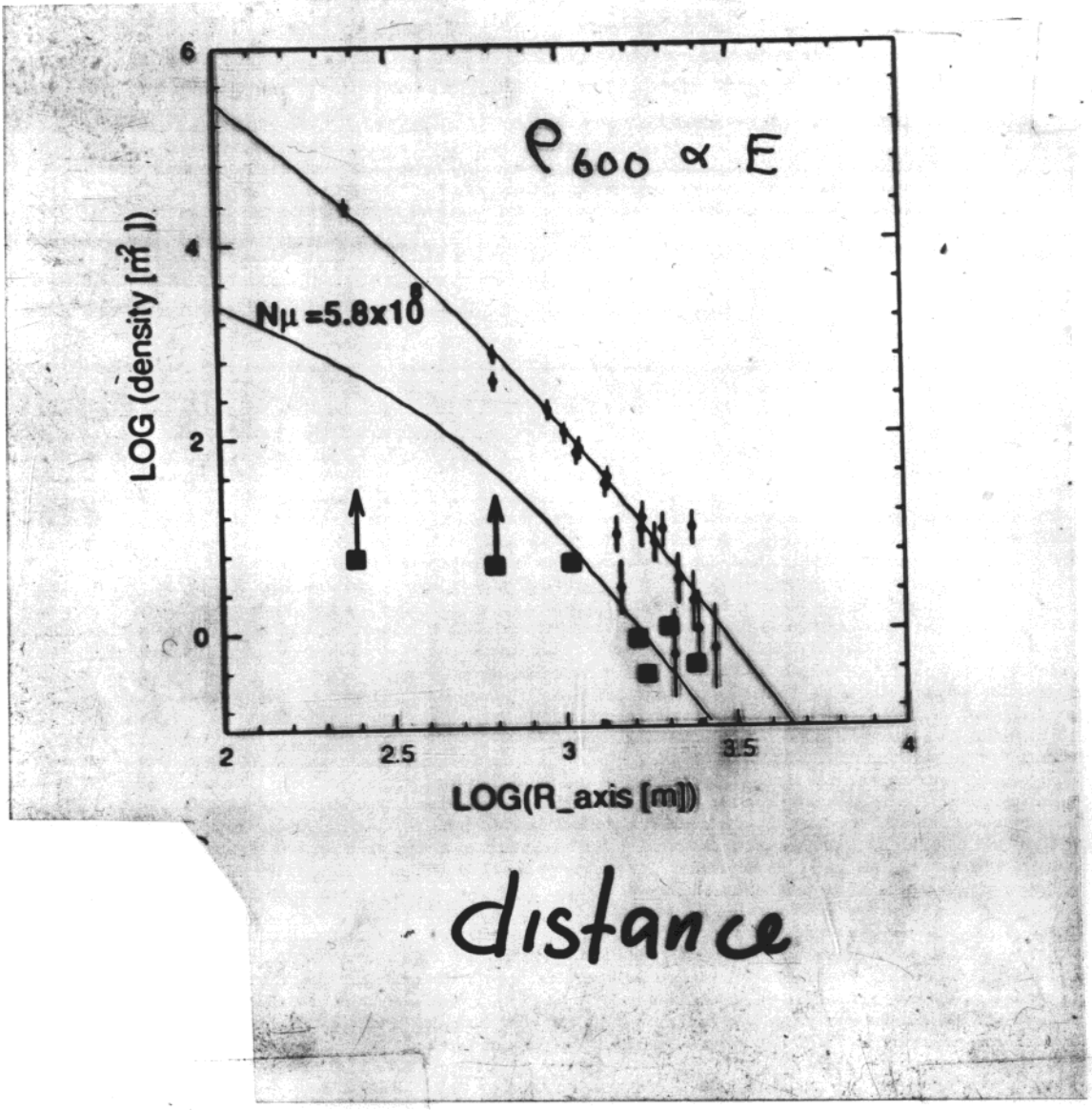

NB
TB
SB
AB
NAGASAKA CENTER
TAKANE CENTER
SUDAMA CENTER
AKENO CENTER
AKENO LABORATORY
0 1 2 3km

AGASA

AGASA

2×10^{20} eV (30 joules)

particles/m^2



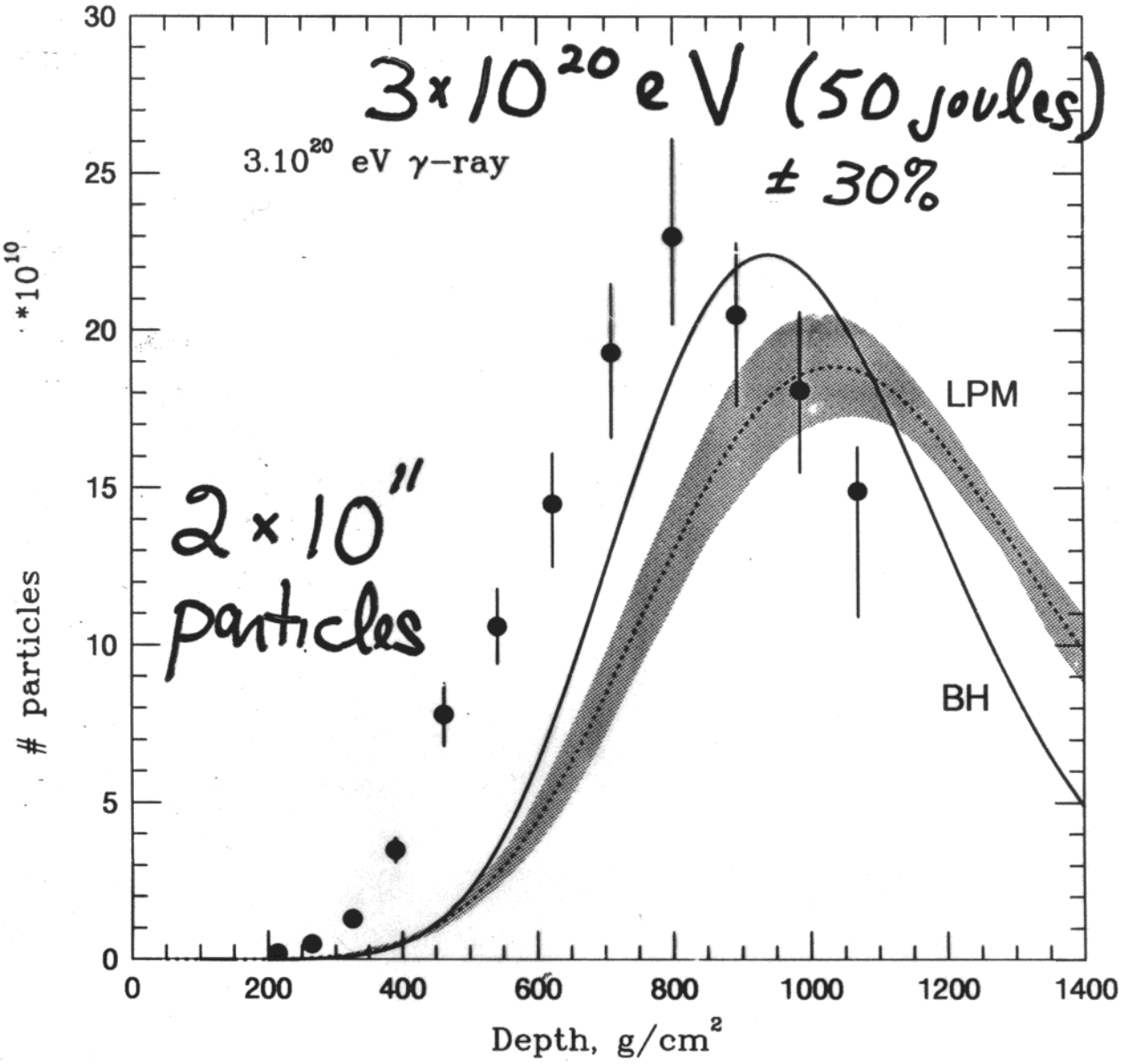
distance

2.4×10^4 particles/m^2 250m

1.0 " 3 km

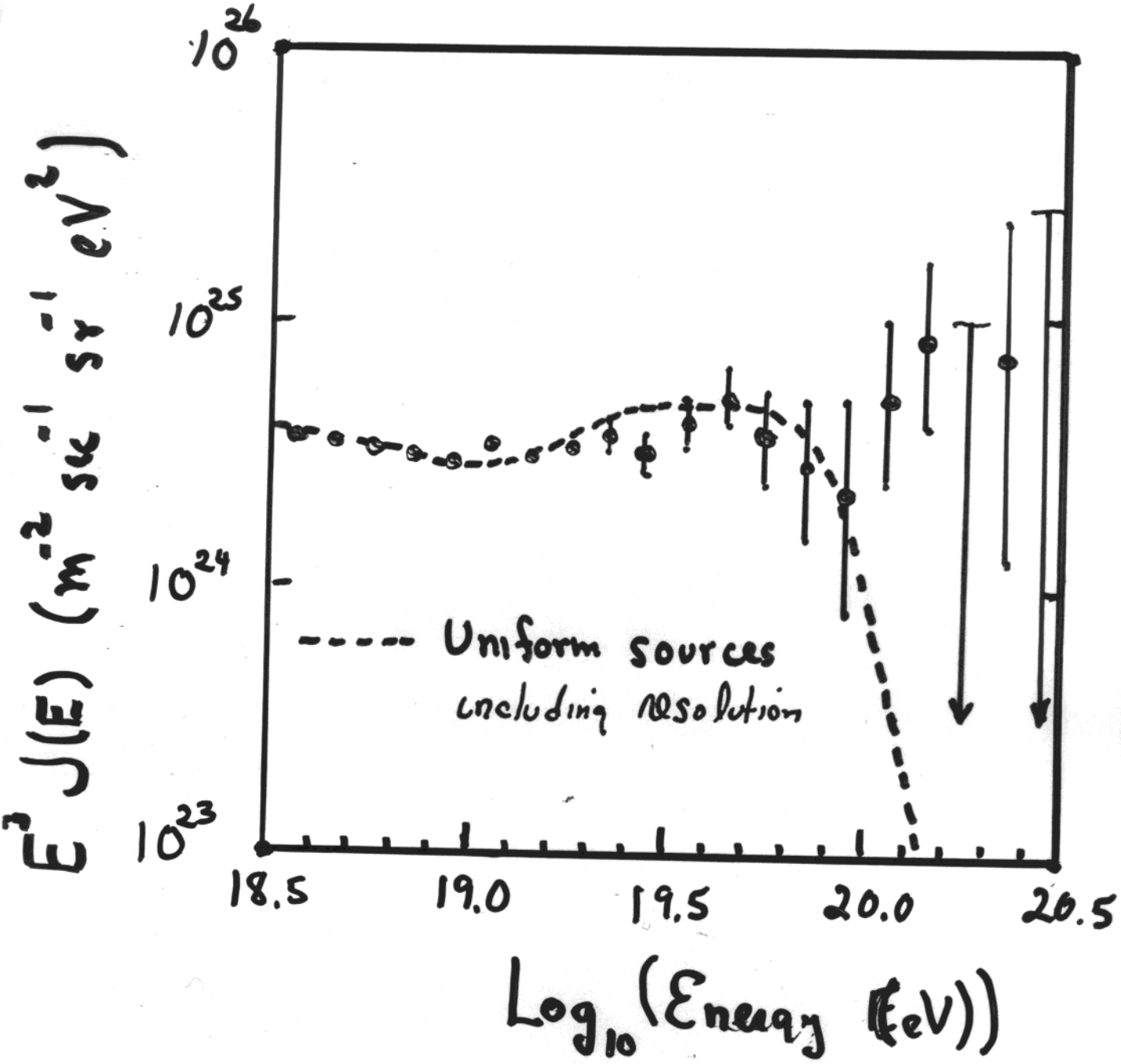
Fly's Eye Event

2×10^{11} particles at max



7 evt > 10^{20} eV

ASTRO-PH/99 02 239



AGASA

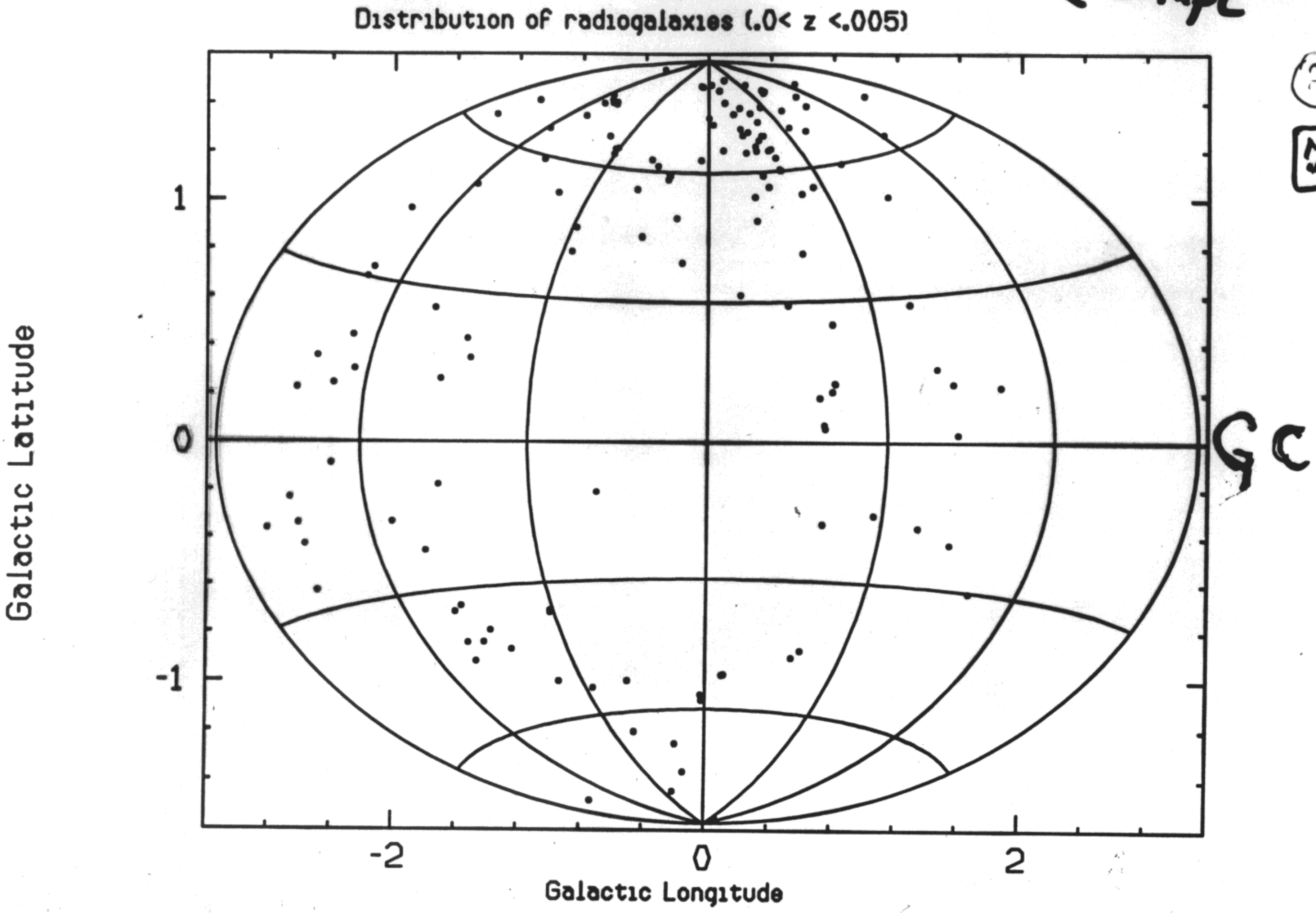
IPAC catalog

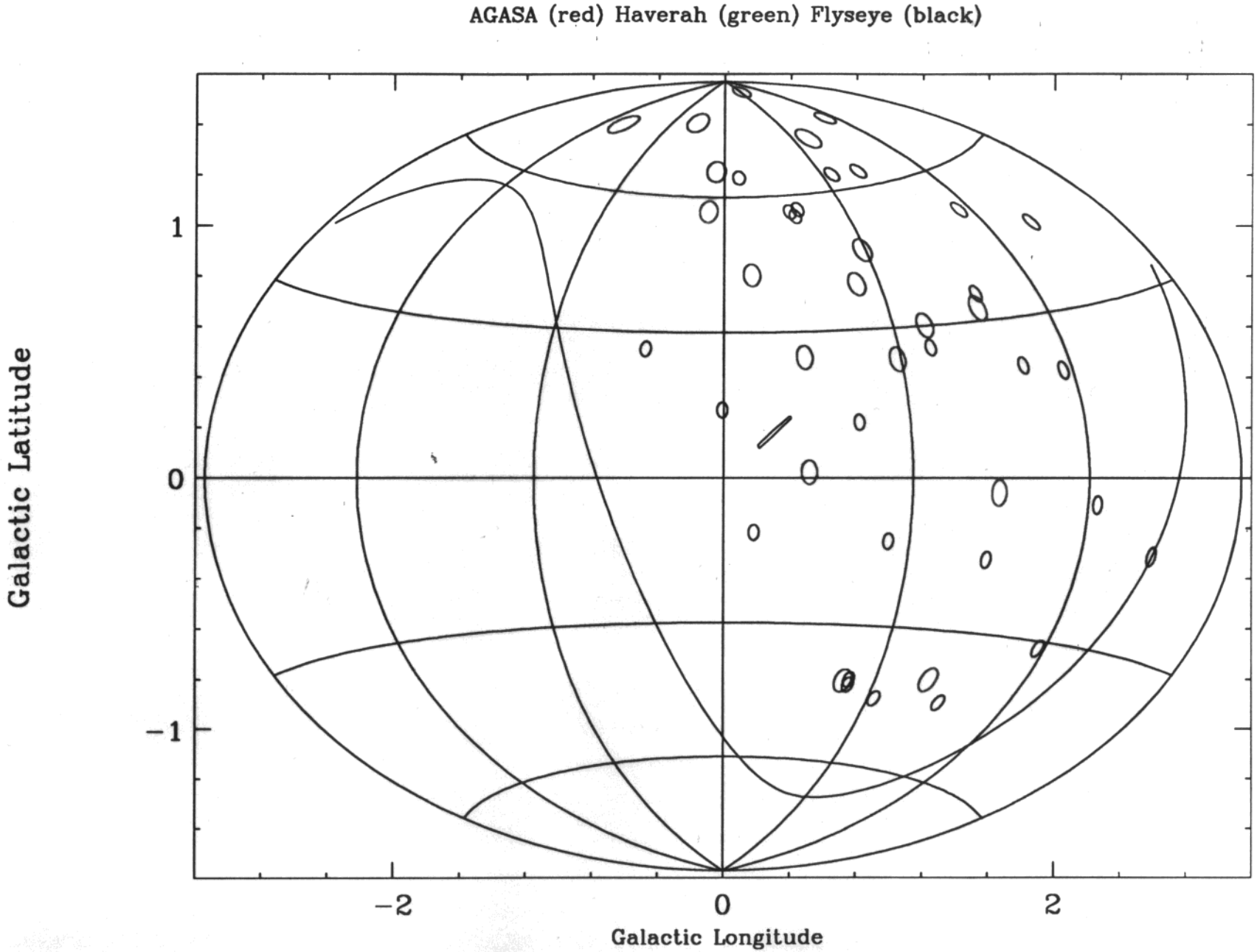
< 30 Mpc

13

22

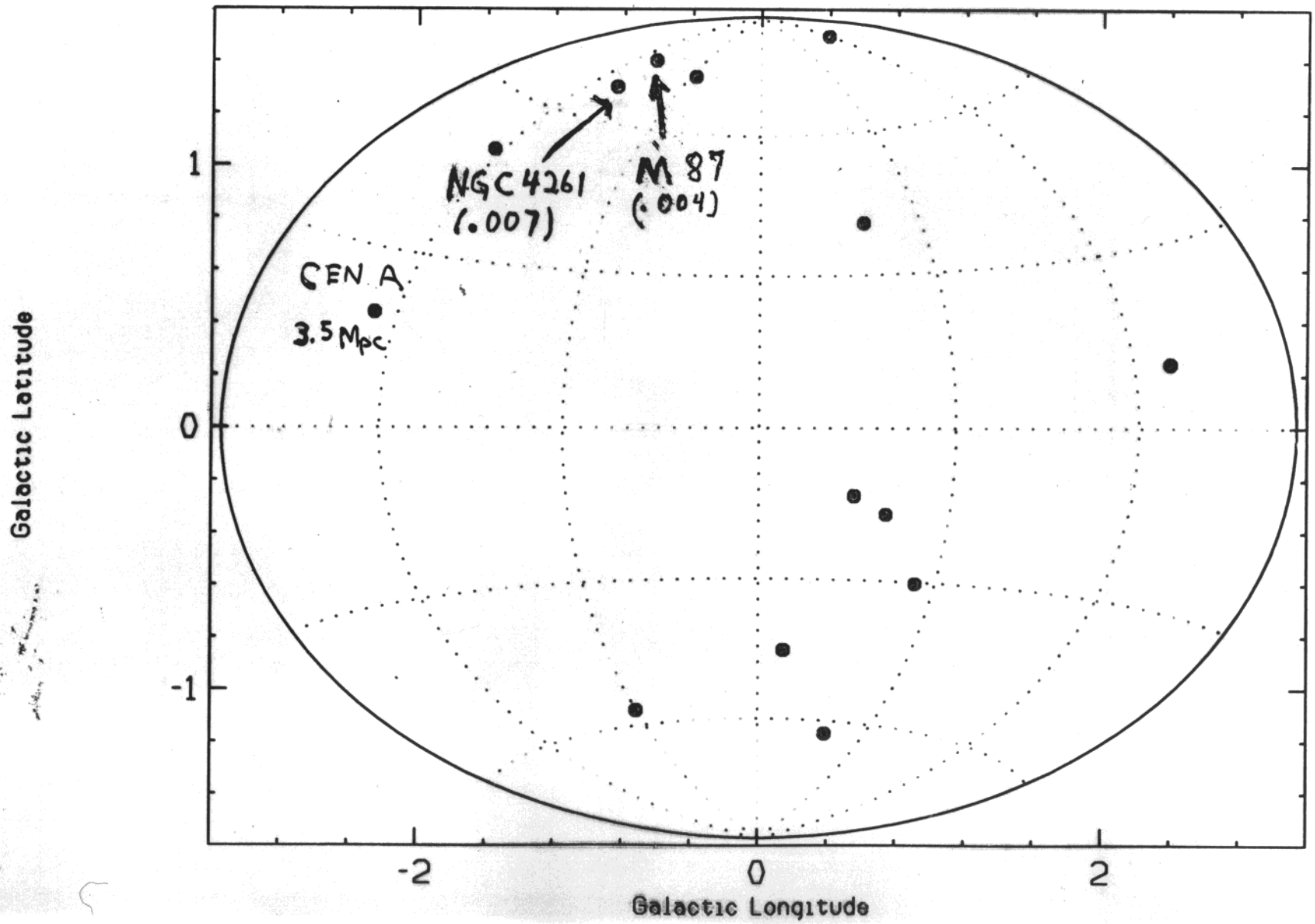
25



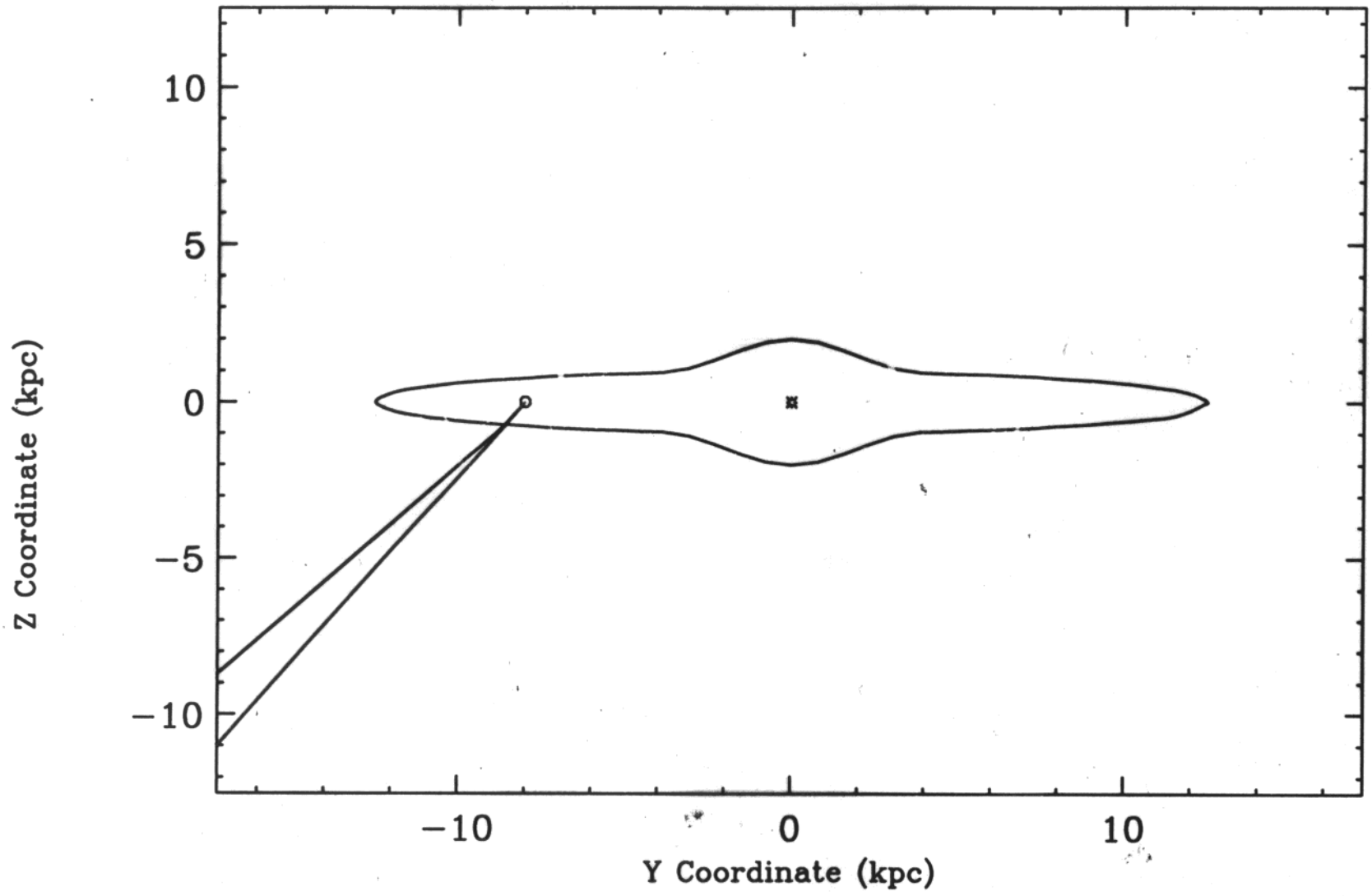


$E > 5 \times 10^{19}$ eV

$Z < .025$ > 10 jy at 400 Mhz

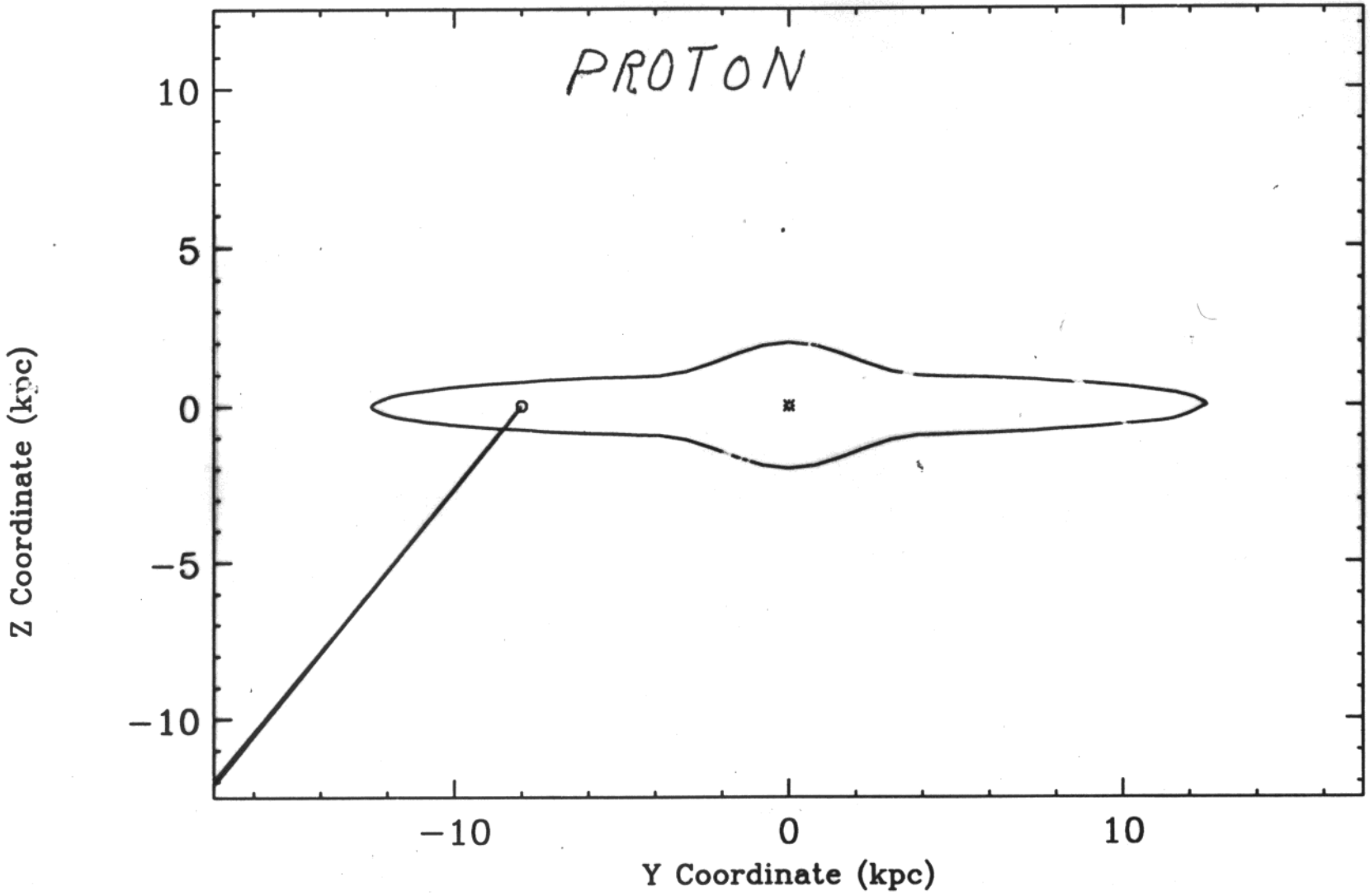


CARBON



— 2×10^{20} eV
— 5×10^{19} eV

Side view of our galaxy from AGASA



For in depth discussion see

V. Berezinsky Nucl Phys B (Proc Suppl) 70 (1999) 419

CONVENTIONAL

Radio Galaxies

AGN

Colliding Galaxies

sufficient sources nearby?

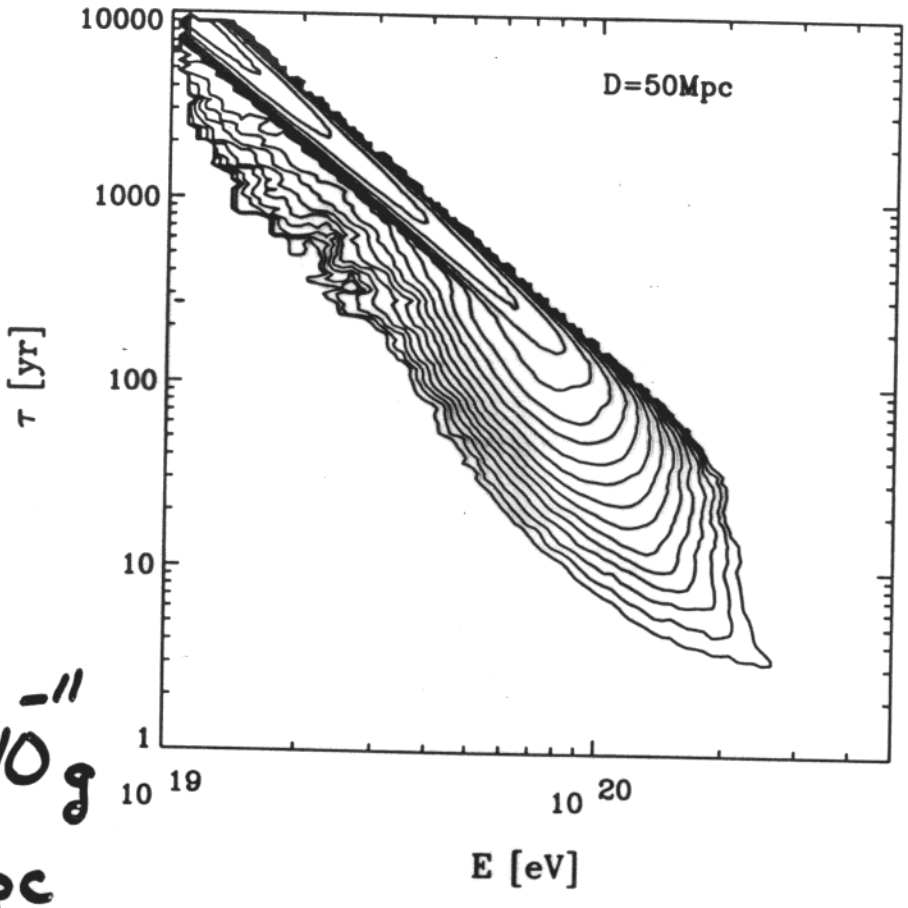
BURSTING SOURCES

GRB

Collapsars

time - energy correlation

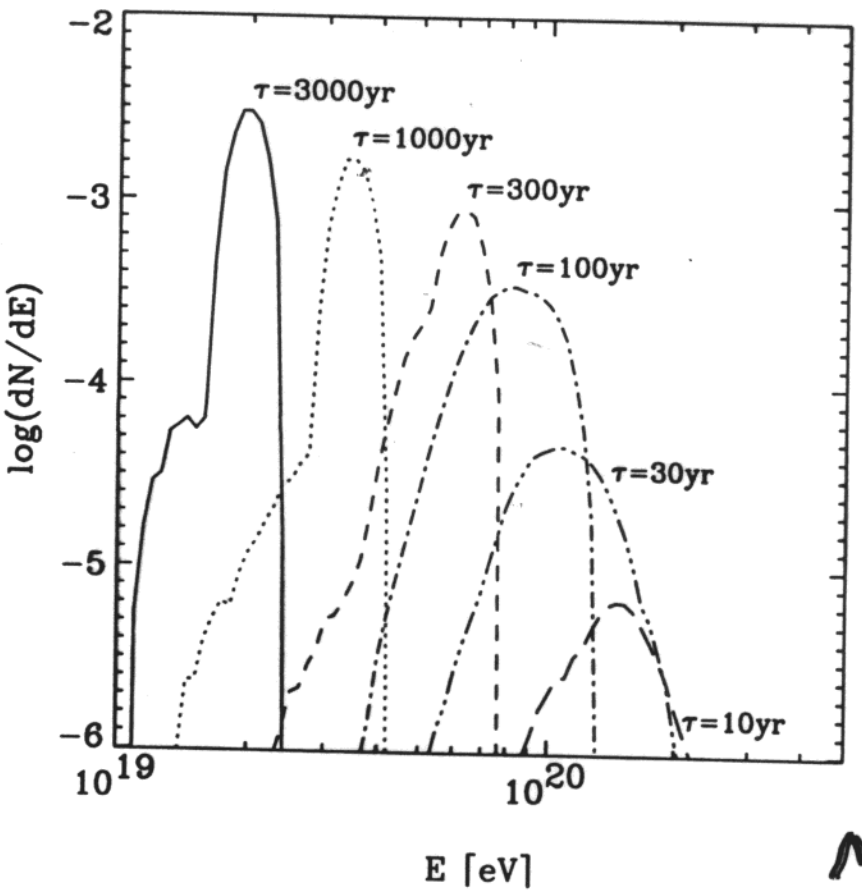
$\sim 1000 > 10^{19}$ eV on 3000 km^2



$B = 4 \times 10^{-11}$ g

$l = 1$ Mpc

time scale $\propto Bl$



Sigl, Lemoine, Olinto

Phys Rev D56, 4470 (1997)

M Lemoine U of C

TOPOLOGICAL DEFECT

Heavy Relic Particles

Expect neutrinos

photons *

protons

Excess towards galactic center

* high or low energy depends on distance and strength of magnetic field.

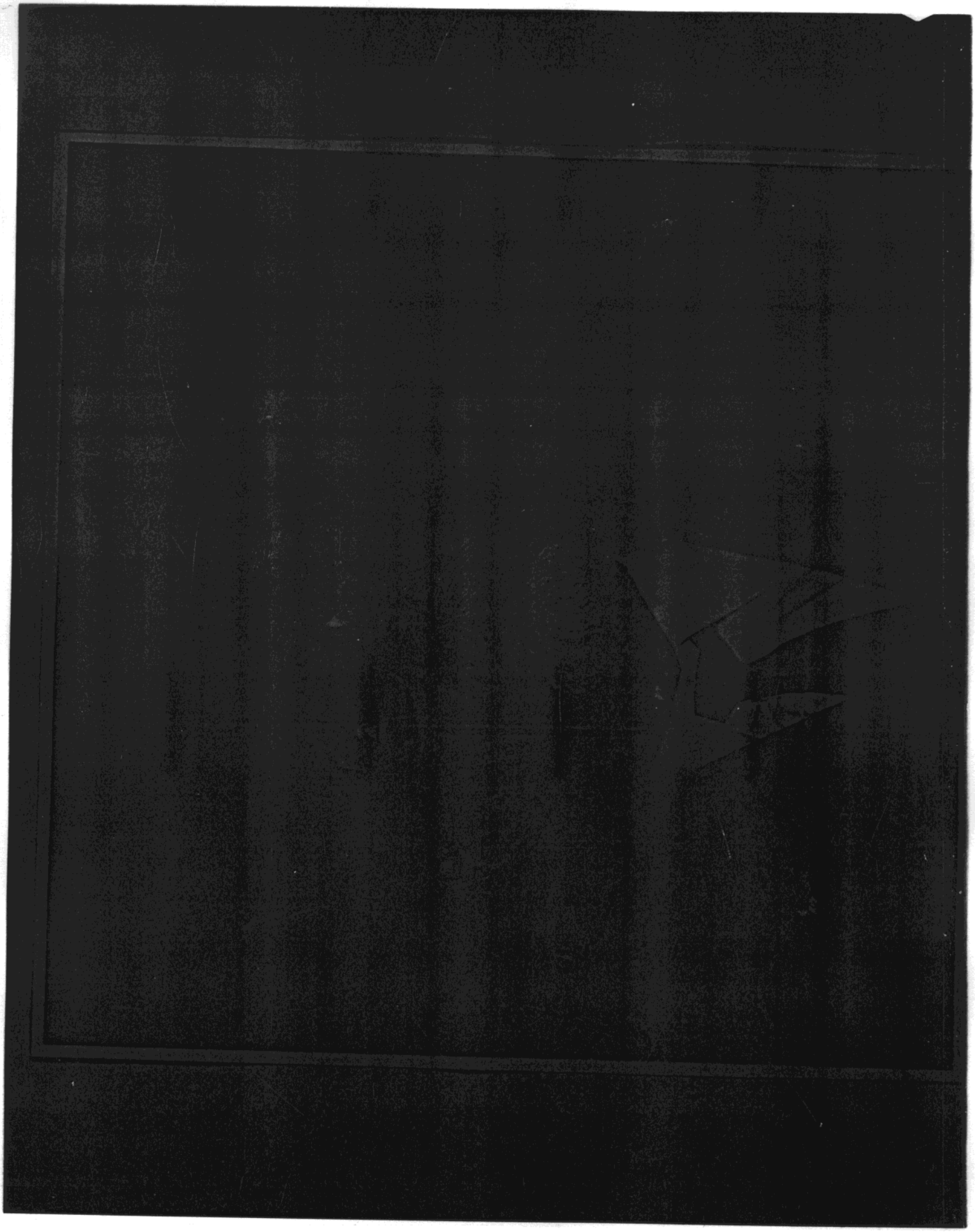
EVADE GZK CUTOFF

- Distant ($z \gtrsim 1$) Compact Radio Quasars – neutral (SUSY?) particle
  Bierman-Farrar
- Collisions of high energy ν with background ν.
  T. Wyler
- Breakdown of special relativity
  $\gamma \geq 10^{11}$
  $\mathcal{L}$ Mestres Coleman and Glashow
- exploit $m^2_{\nu_e} = -4.5\ eV^2$
  Enlich

look at xxx.lanl.gov

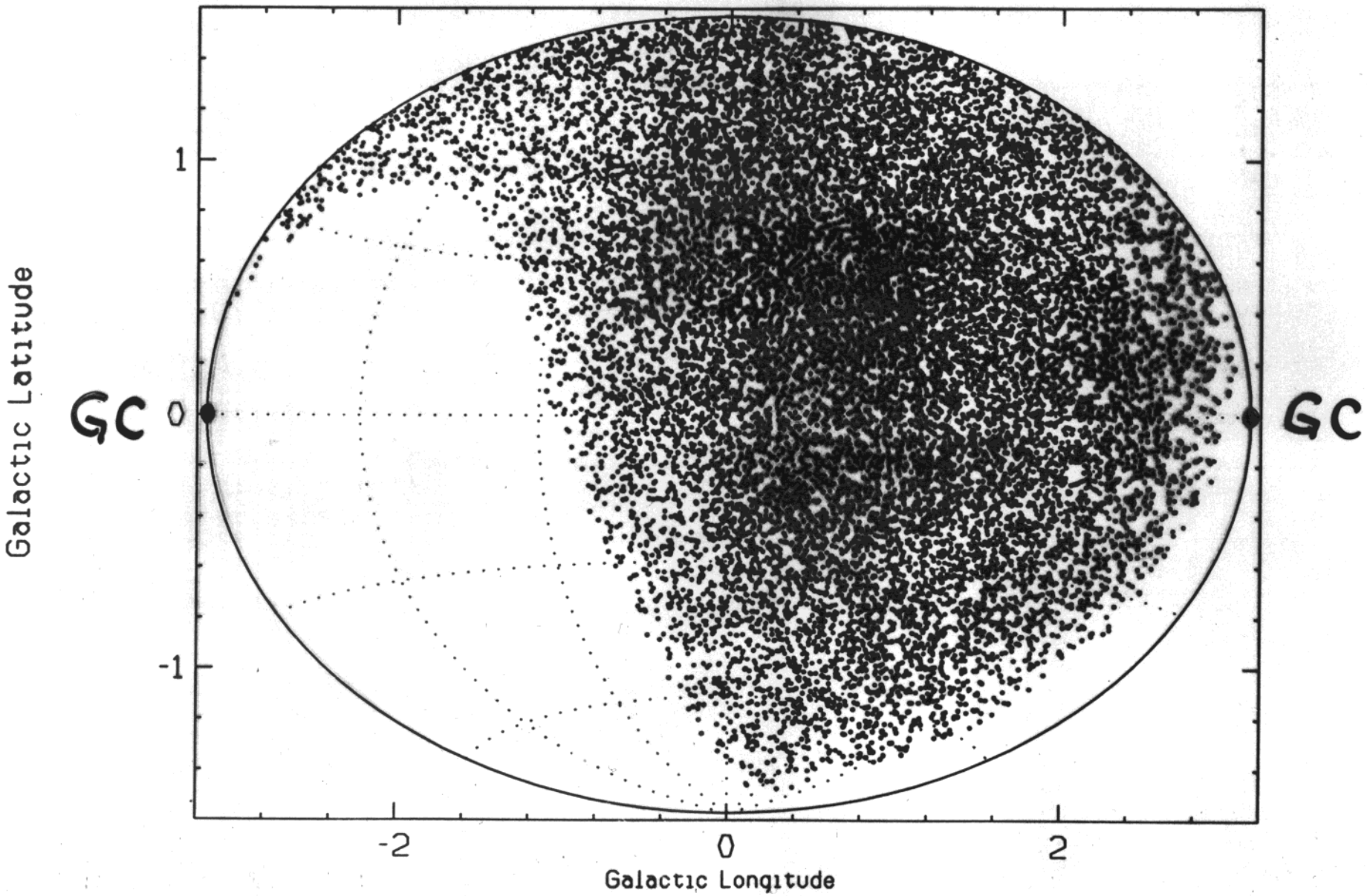
Motivation for the Pierre Auger Observatories

- **Protons in the cosmic radiation exist with energies $\geq 10^{20}$ eV. The most energetic has a kinetic energy of 3×10^{20} eV (50 joules).**
- **There is no understanding how known astrophysical objects can accelerate protons to energies $\geq 10^{20}$ eV**
- **There is mounting evidence that some of these protons come from point sources.**
- **Because of interaction with the 2.7K cosmic background radiation the sources must be close on a cosmological scale ($\leq$ 50 Mpc or 150 million light years).**
- **These protons are little affected by the magnetic field within and outside the Milky Way. They should point to their source giving a new form of astronomy.**
- **The prospect for the discovery of new physics or astrophysics is likely.**
- **The fluxes are low. Above 10^{19} eV the flux is $\sim$ 1/km^2/year. Above 10^{20} eV the flux is $\sim$ 1/km^2 per century.**
- **Two observatories of 3000 km^2 will be built in the southern and northern hemisphere respectively to scan the entire sky. They are called the Pierre Auger Observatories in honor of the French physicist who first observed in 1938 the existence of cosmic rays of extraordinary energy.**

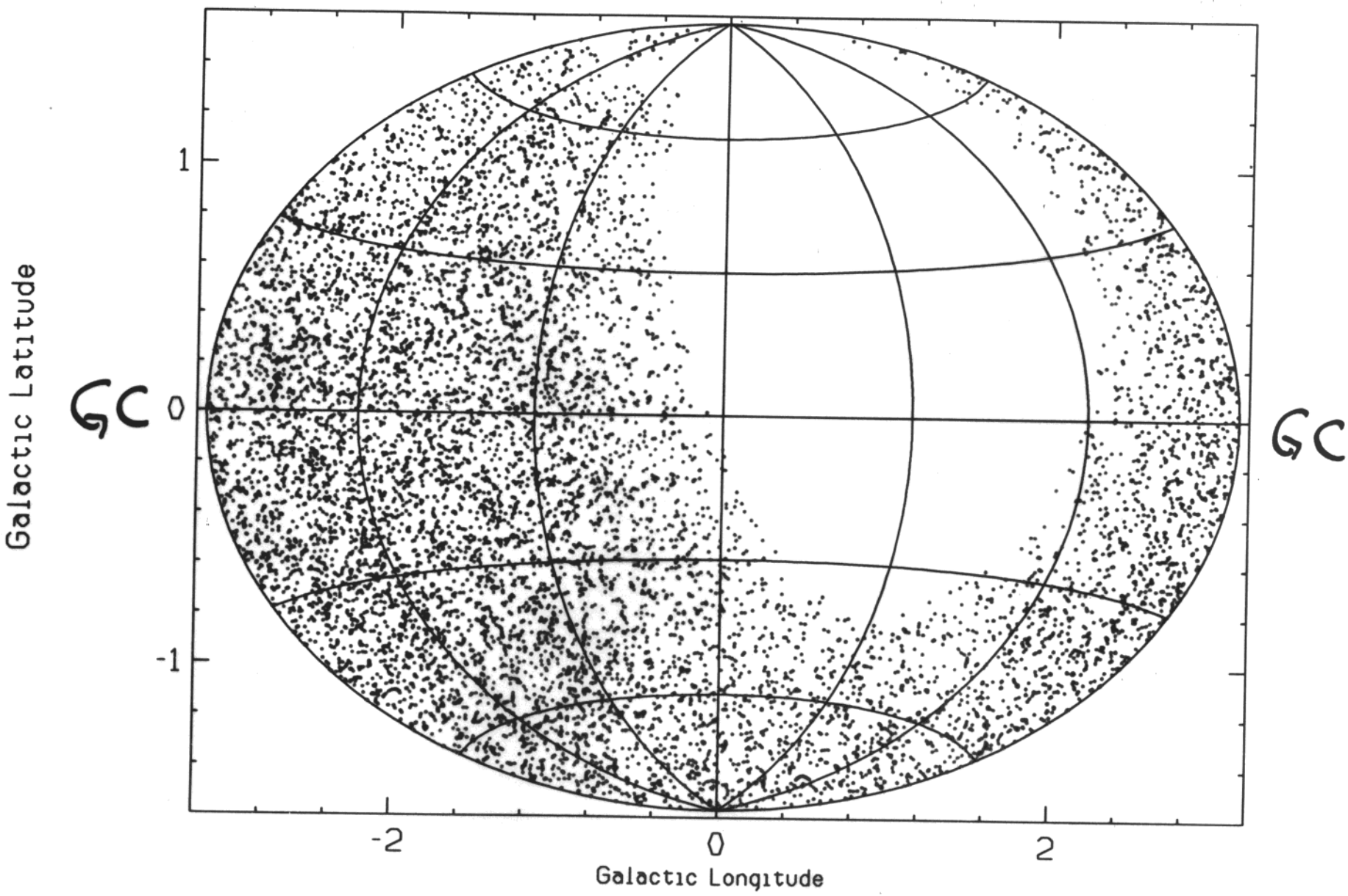


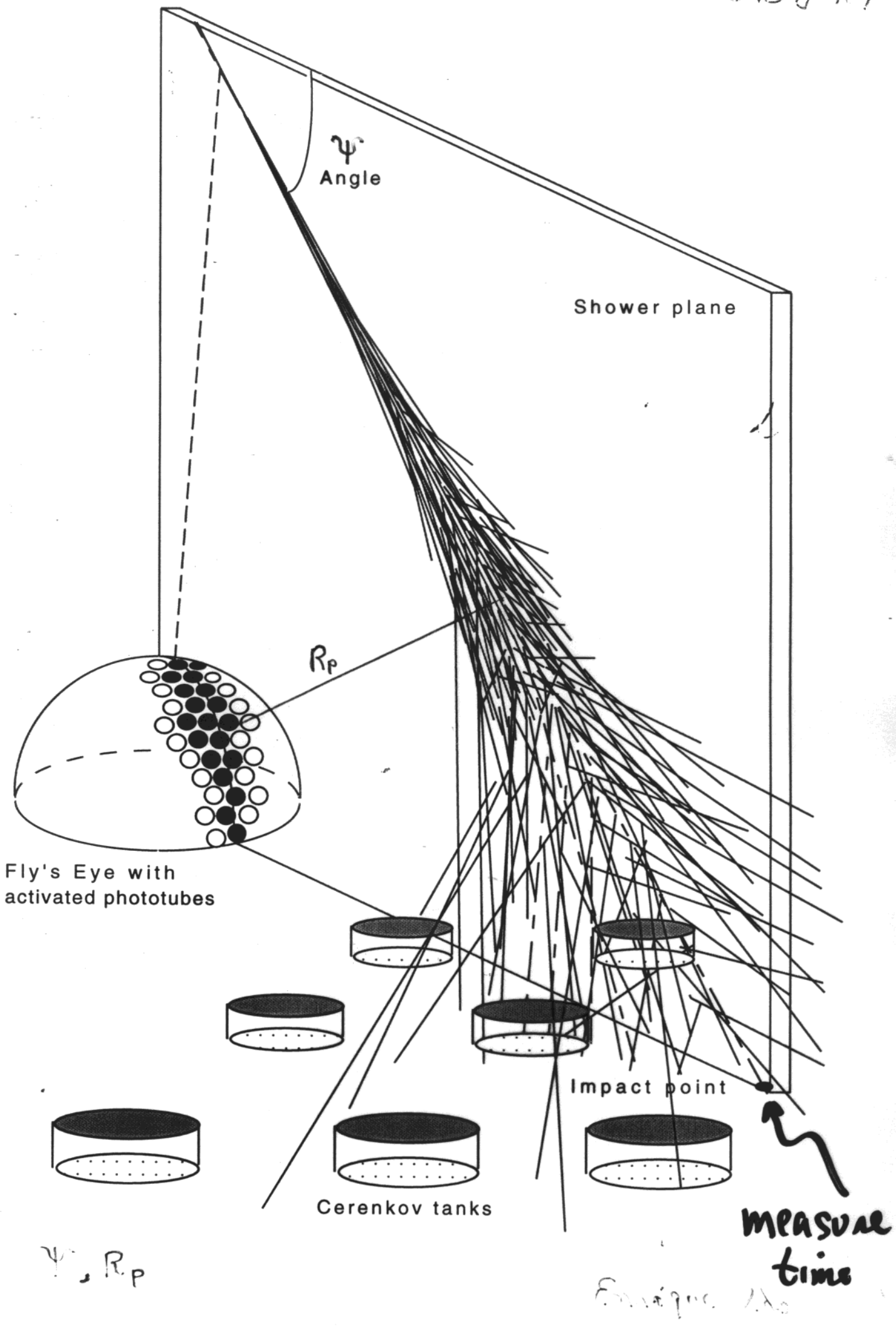
3 years NORTHERN SITE (UTAH)

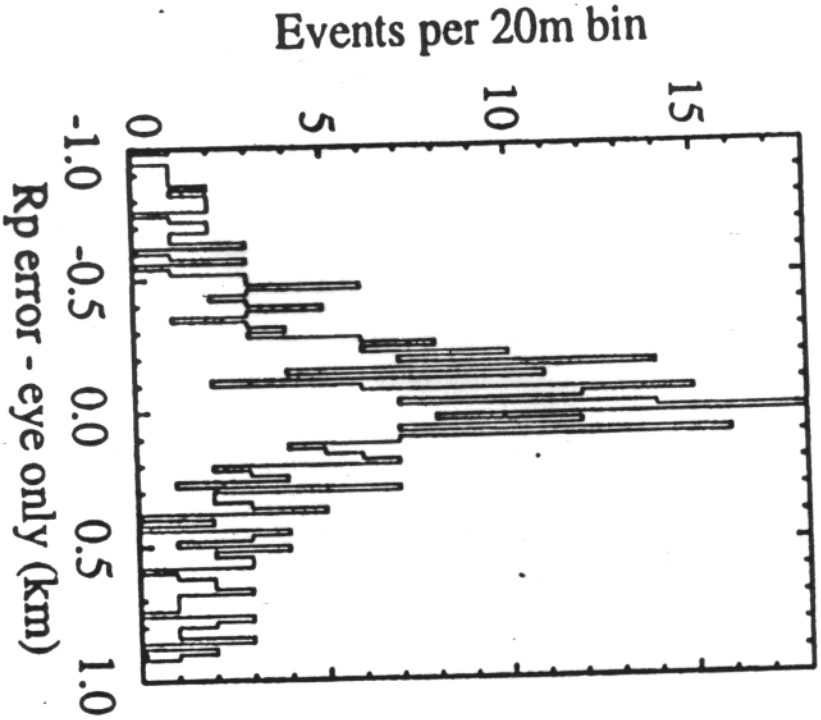
6

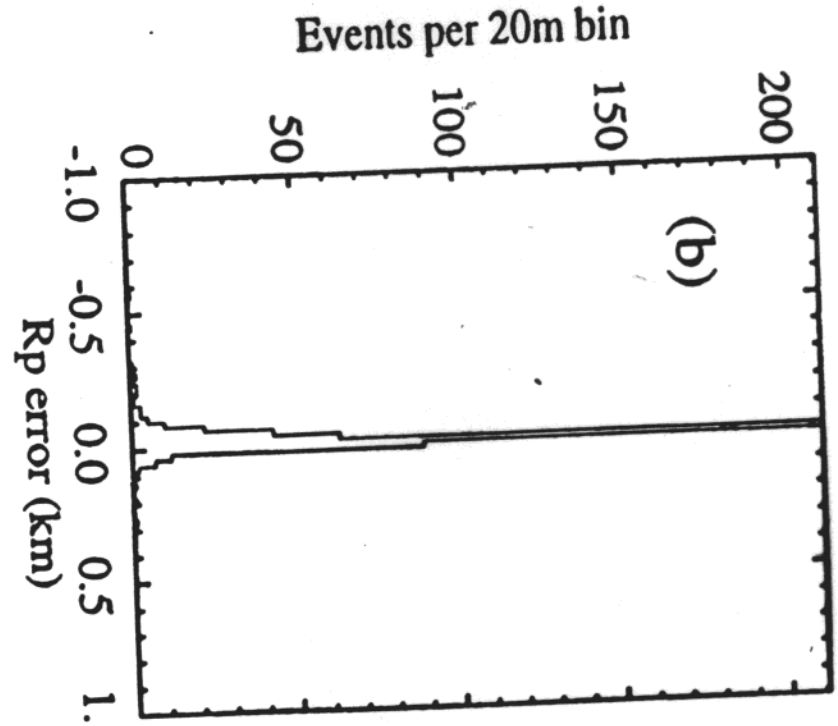


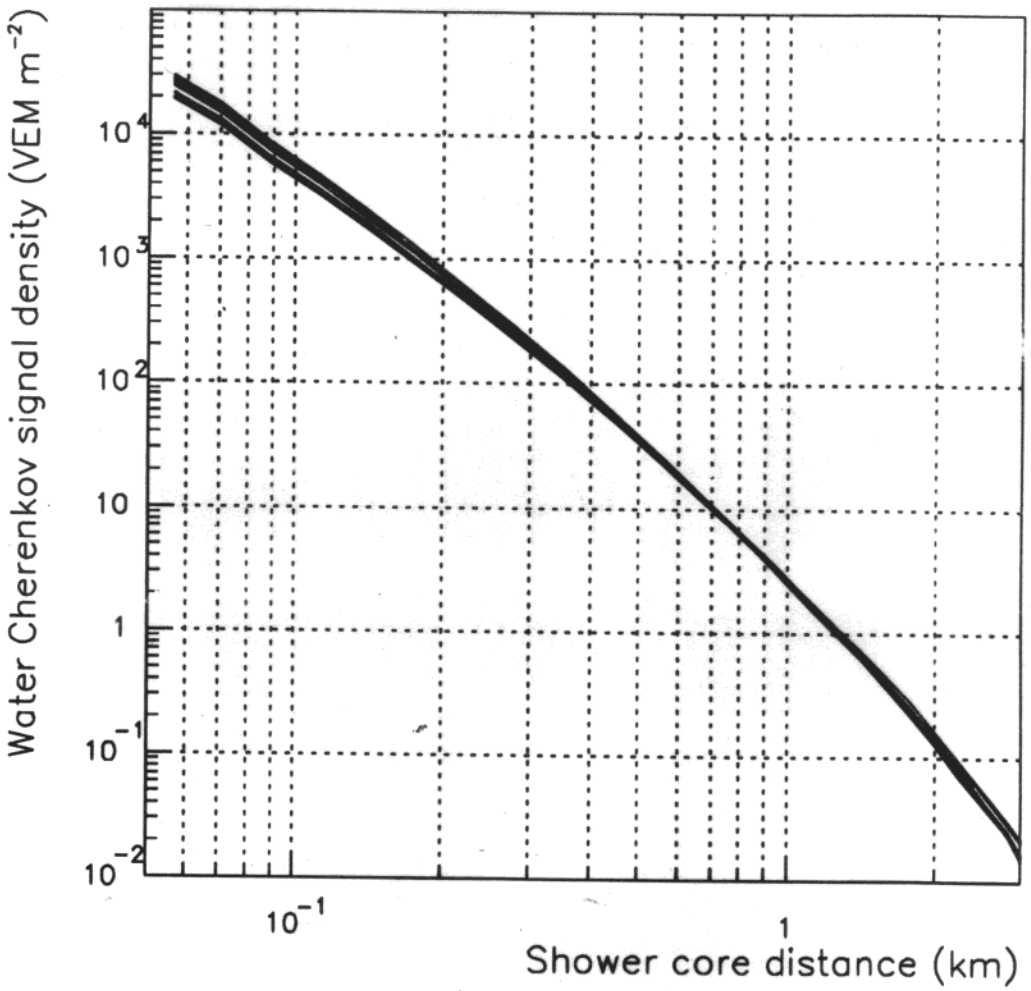
3 years Southern Site




ψ
Angle
Shower plane
R_P
Fly's Eye with
activated phototubes
Impact point
Cerenkov tanks
measure
time

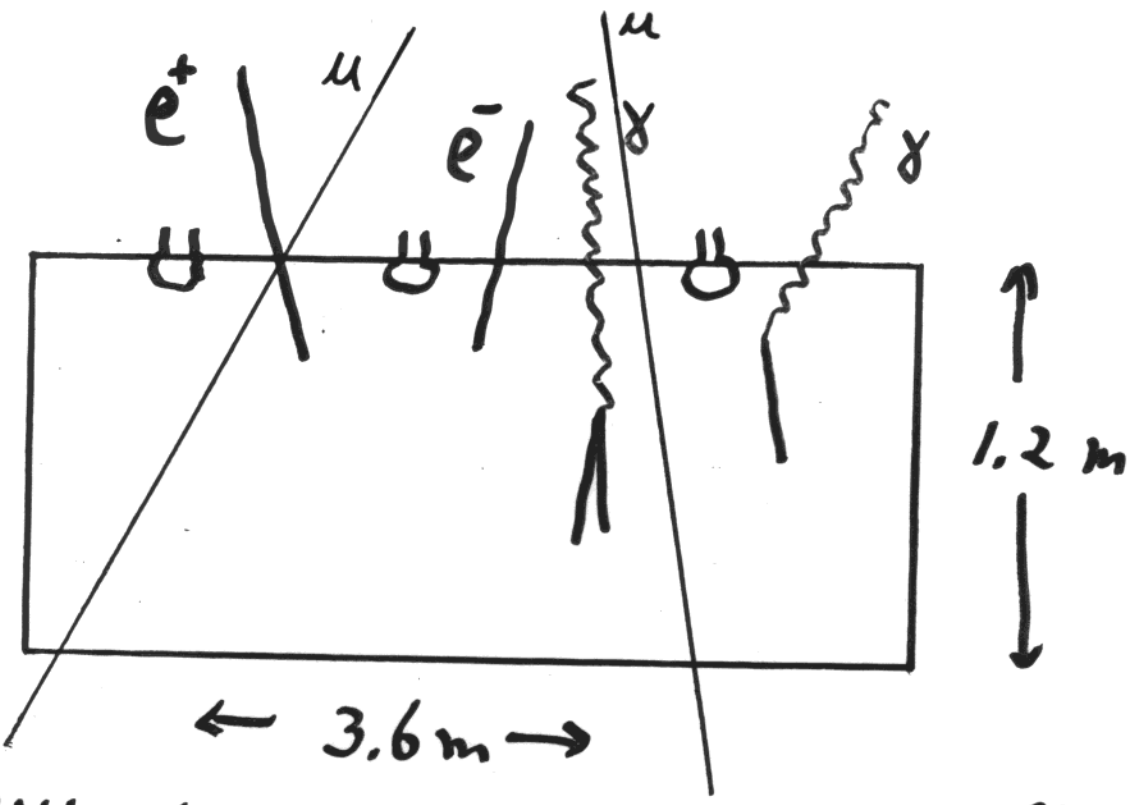

Events per 20m bin
0
5
10
15
-1.0
-0.5
0.0
0.5
1.0
Rp error - eye only (km)


Events per 20m bin
0
50
100
150
200
(b)
-1.0
-0.5
0.0
0.5
1.
Rp error (km)

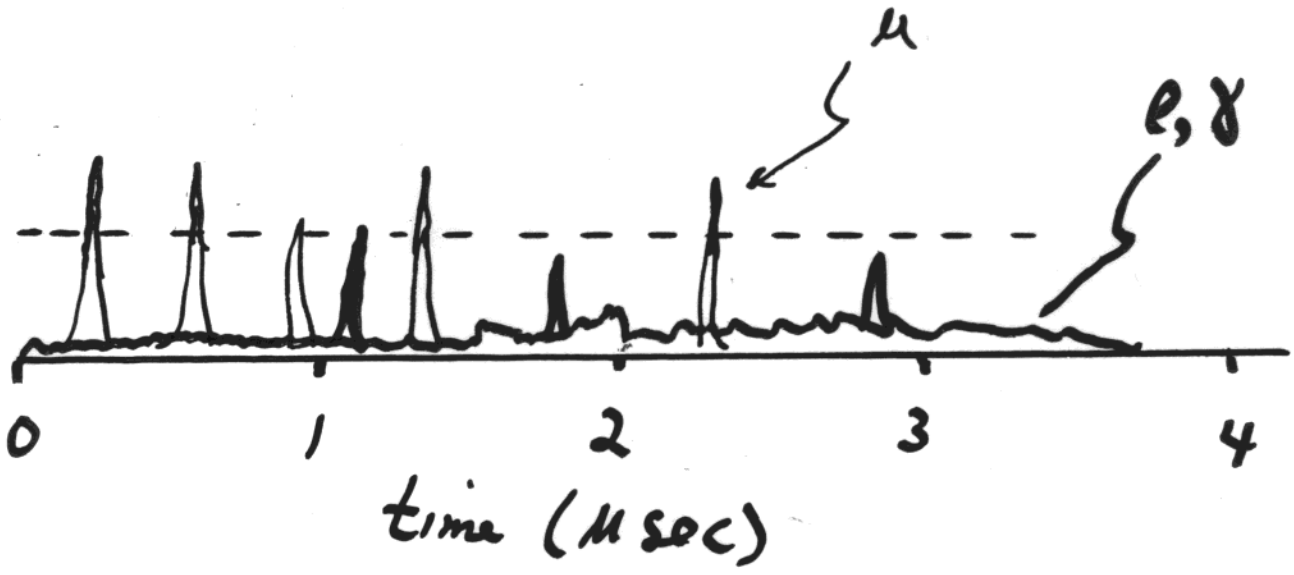

Water Cherenkov signal density (VEM m^{-2})
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-1}
1
Shower core distance (km)

M. Hillas

(36)

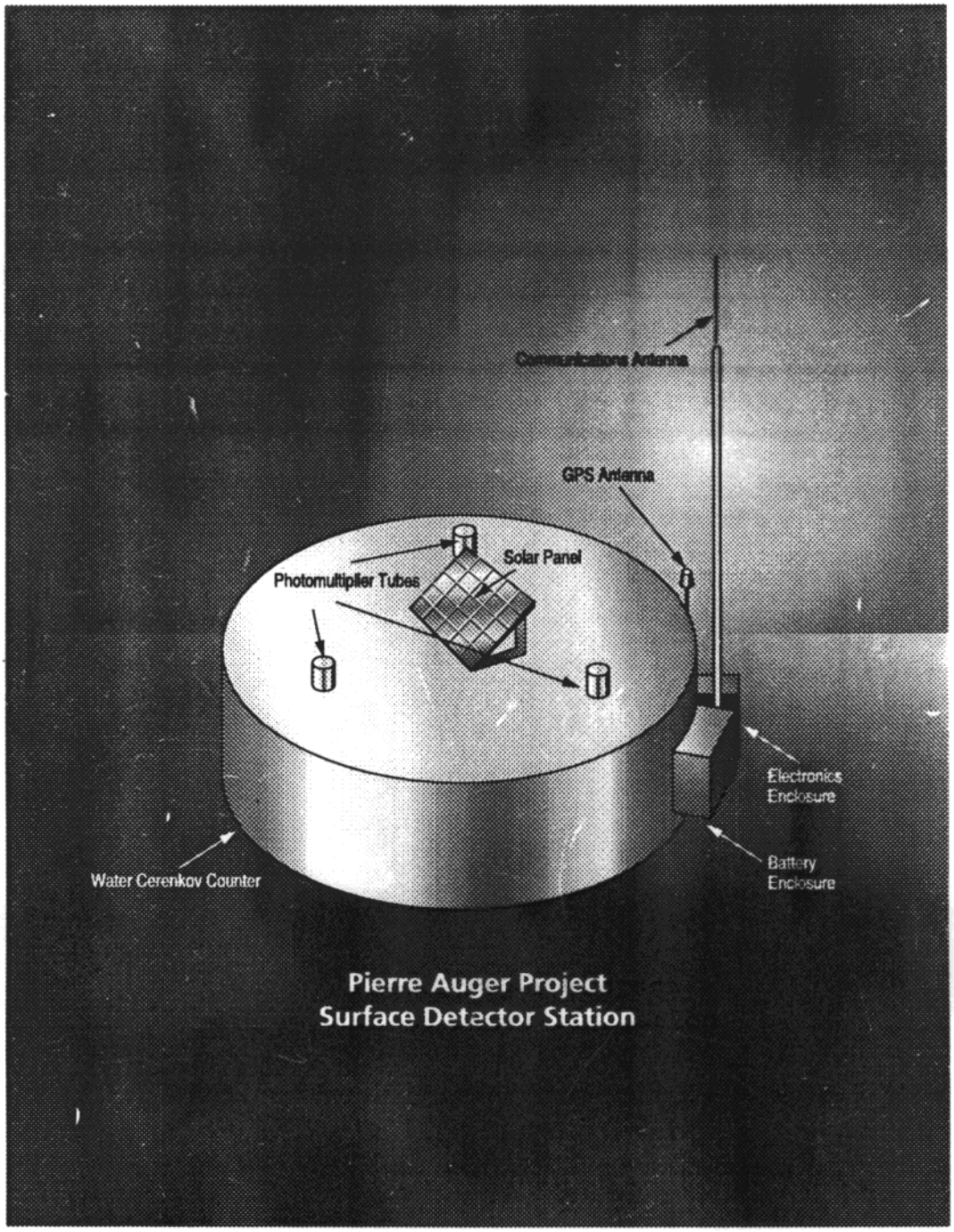


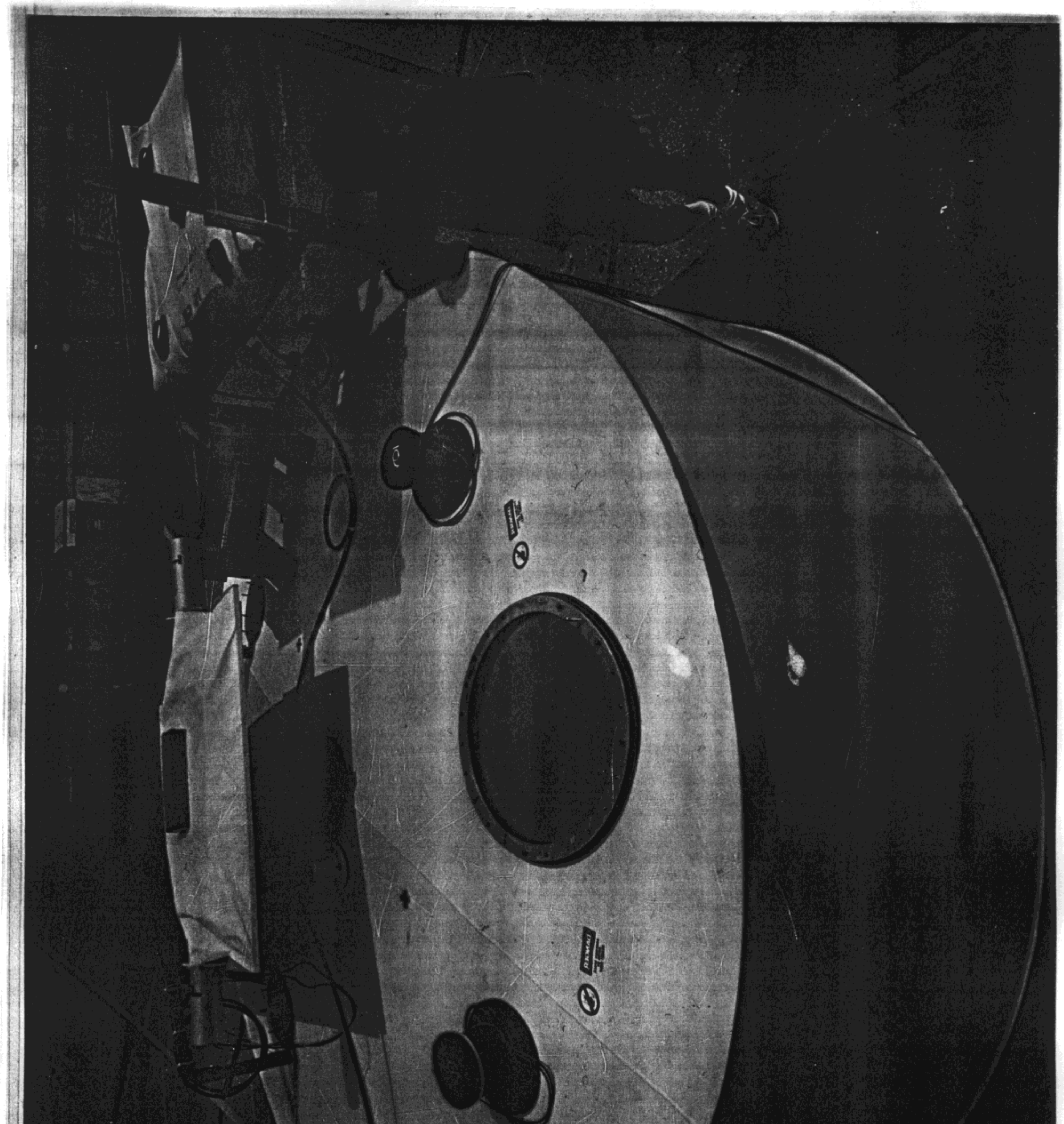
TANK lined with white diffuse reflector



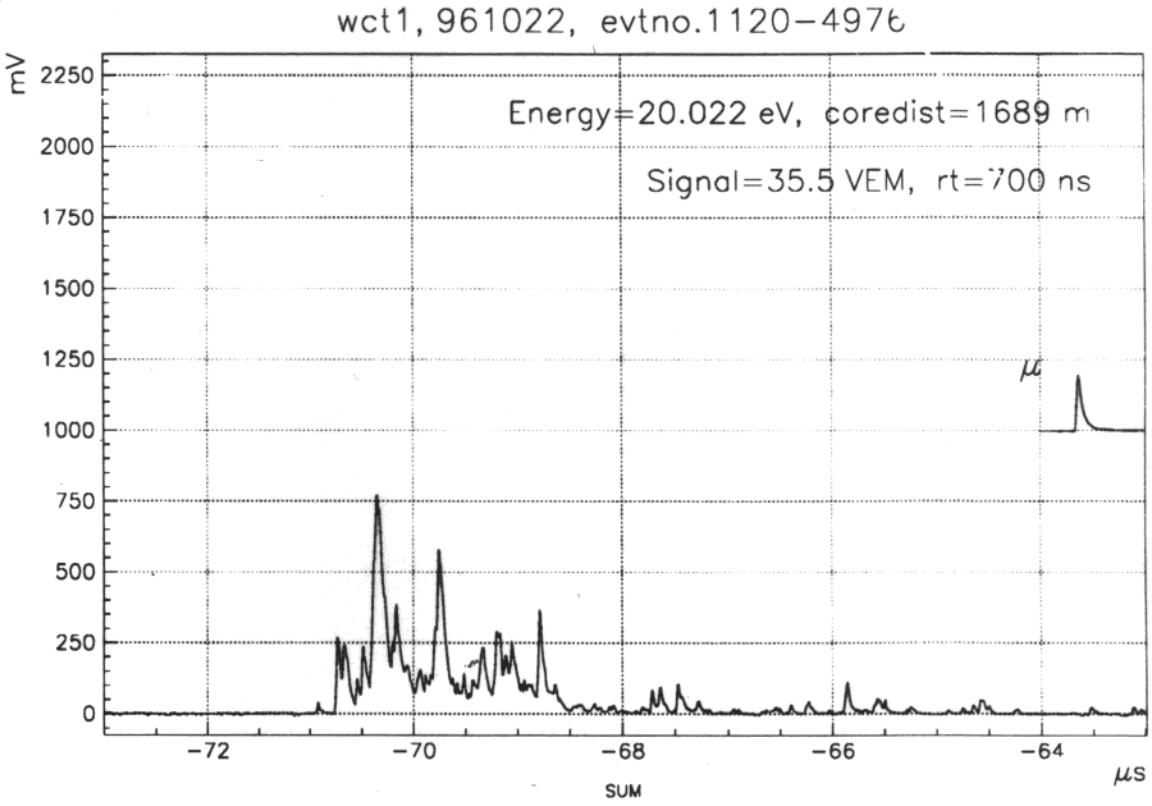
FADC trace

~ 1000 meters from core


Communications Antenna
GPS Antenna
Solar Panel
Photomultiplier Tubes
Electronics Enclosure
Battery Enclosure
Water Cerenkov Counter
Pierre Auger Project
Surface Detector Station



9


wct1, 961022, evtno.1120-4976
Energy=20.022 eV, coredist=1689 m
Signal=35.5 VEM, rt=700 ns
μ
mV
2250
2000
1750
1500
1250
1000
750
500
250
0
-72
-70
-68
-66
-64
μs
SUM

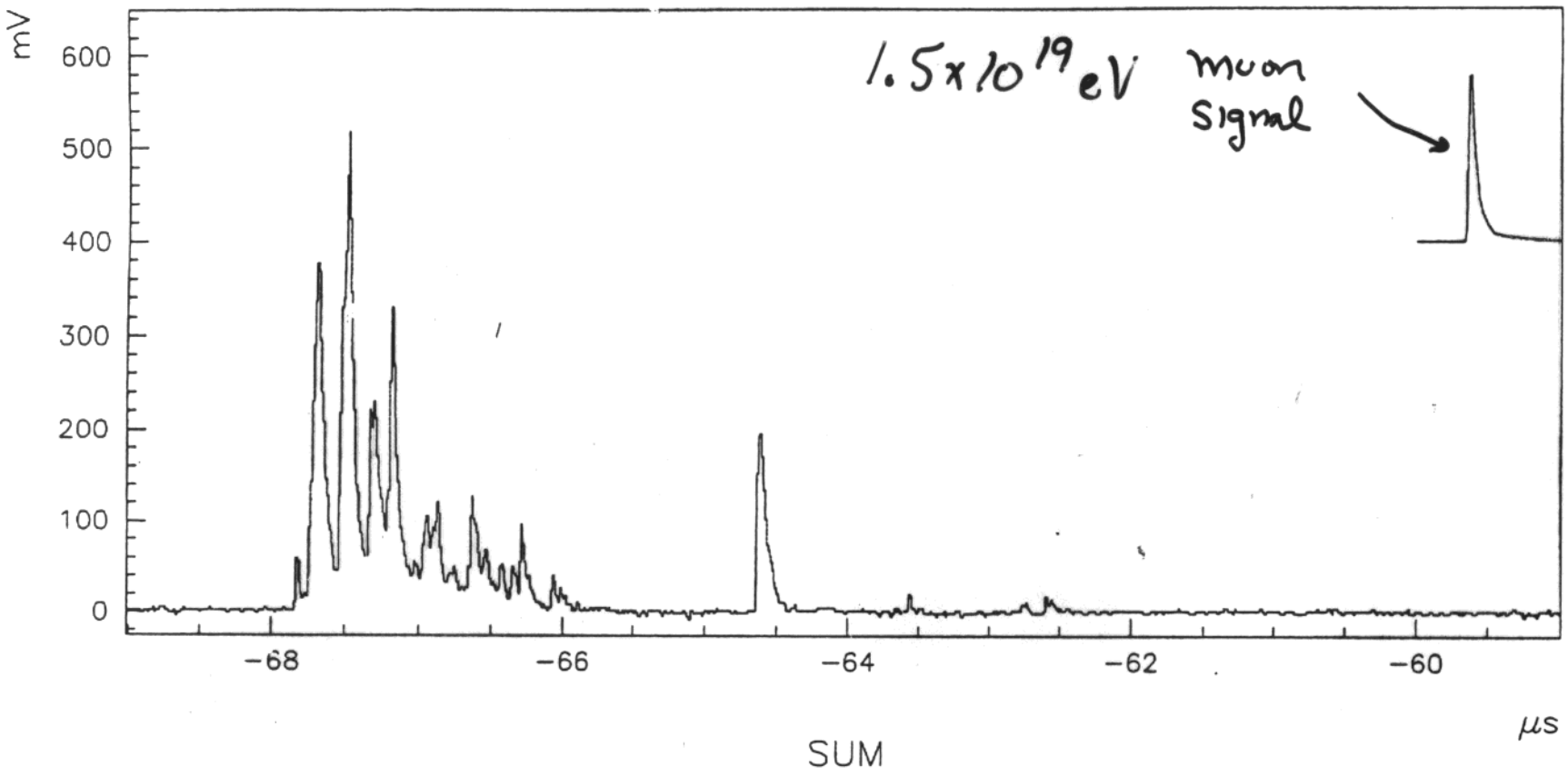
AGASA tank (data)

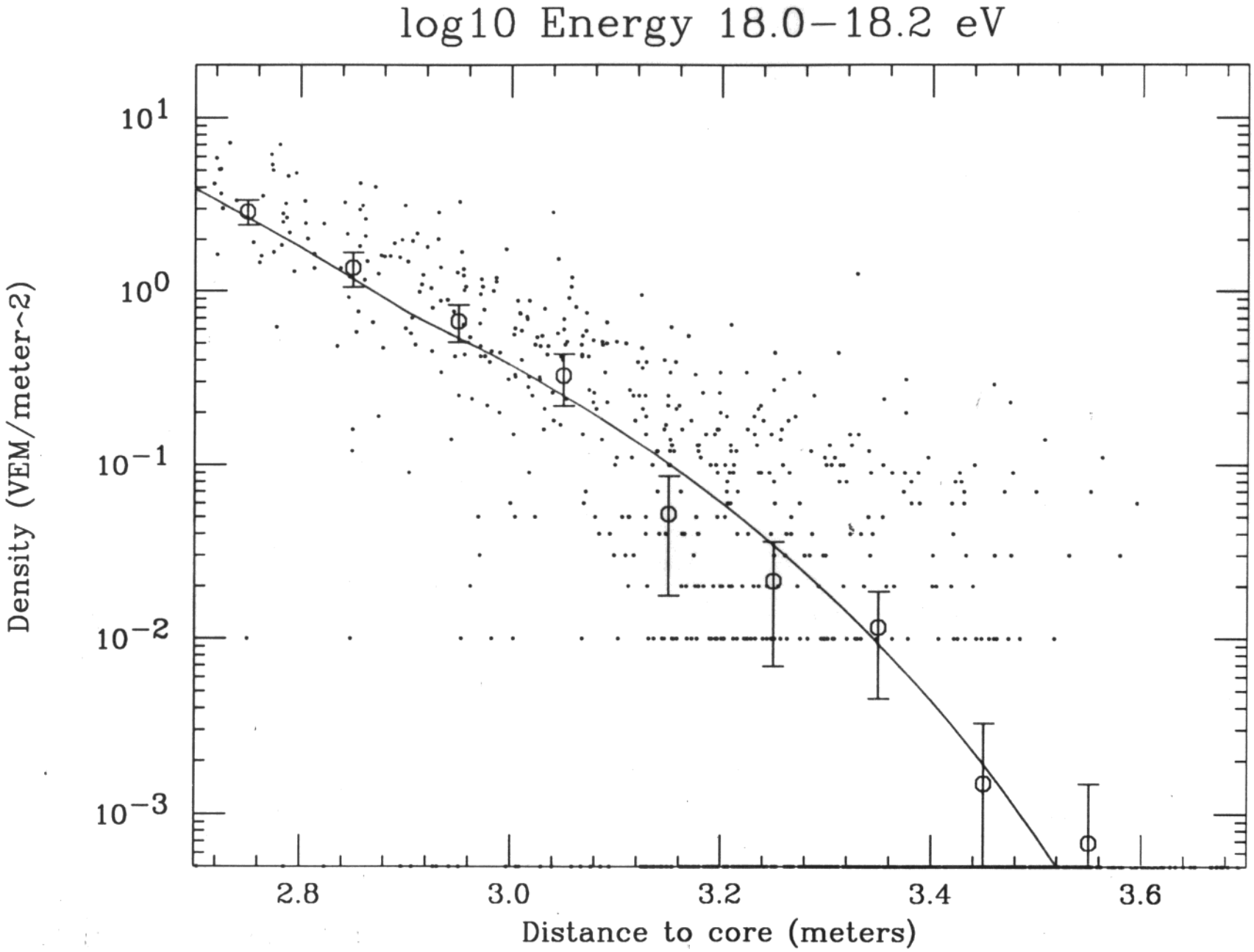
r = 1,32 km; E = $10^{17.10}$ eV

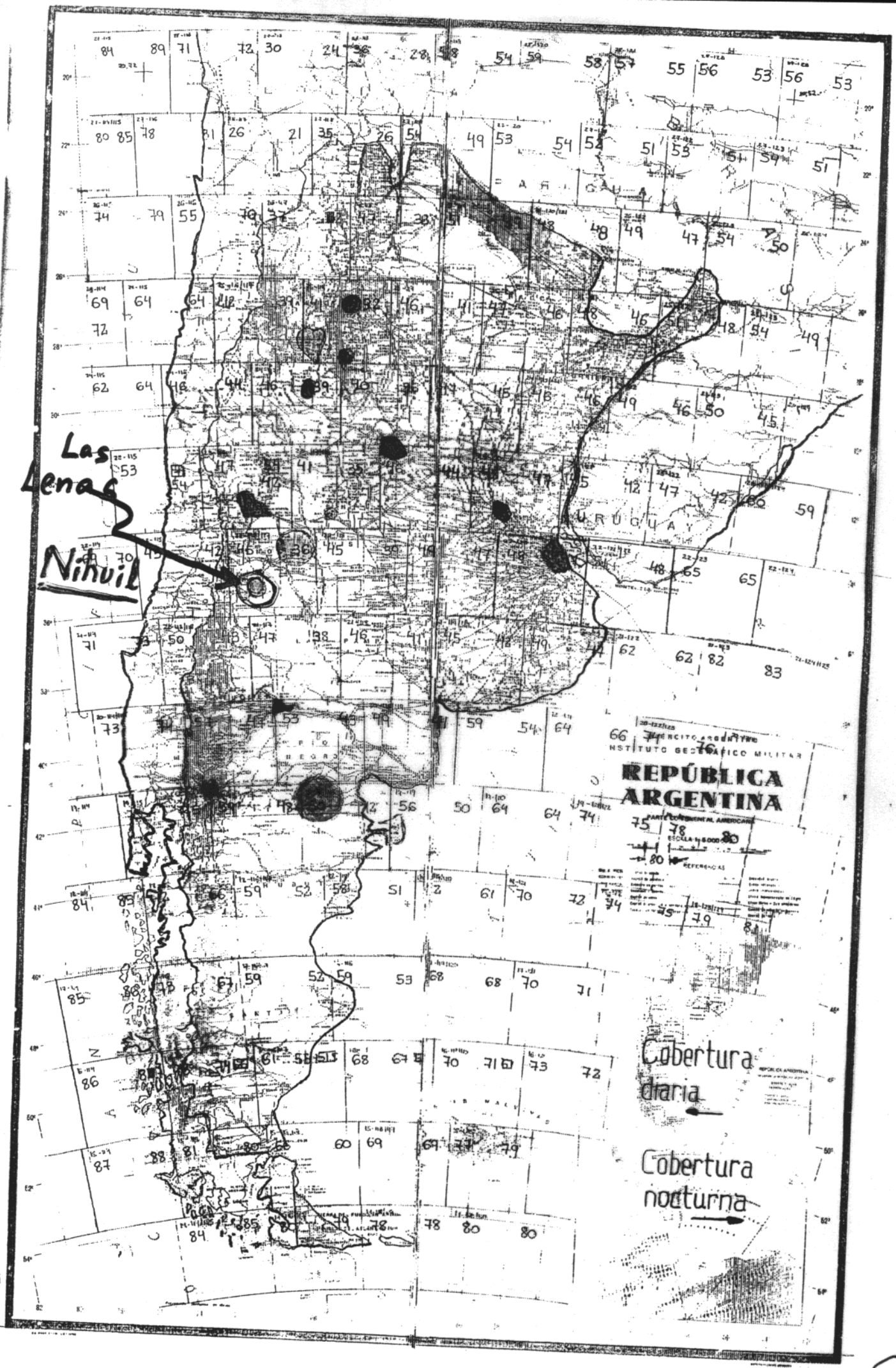
16 VEM

rt = 390 ns

970629, evtno.1850–4921

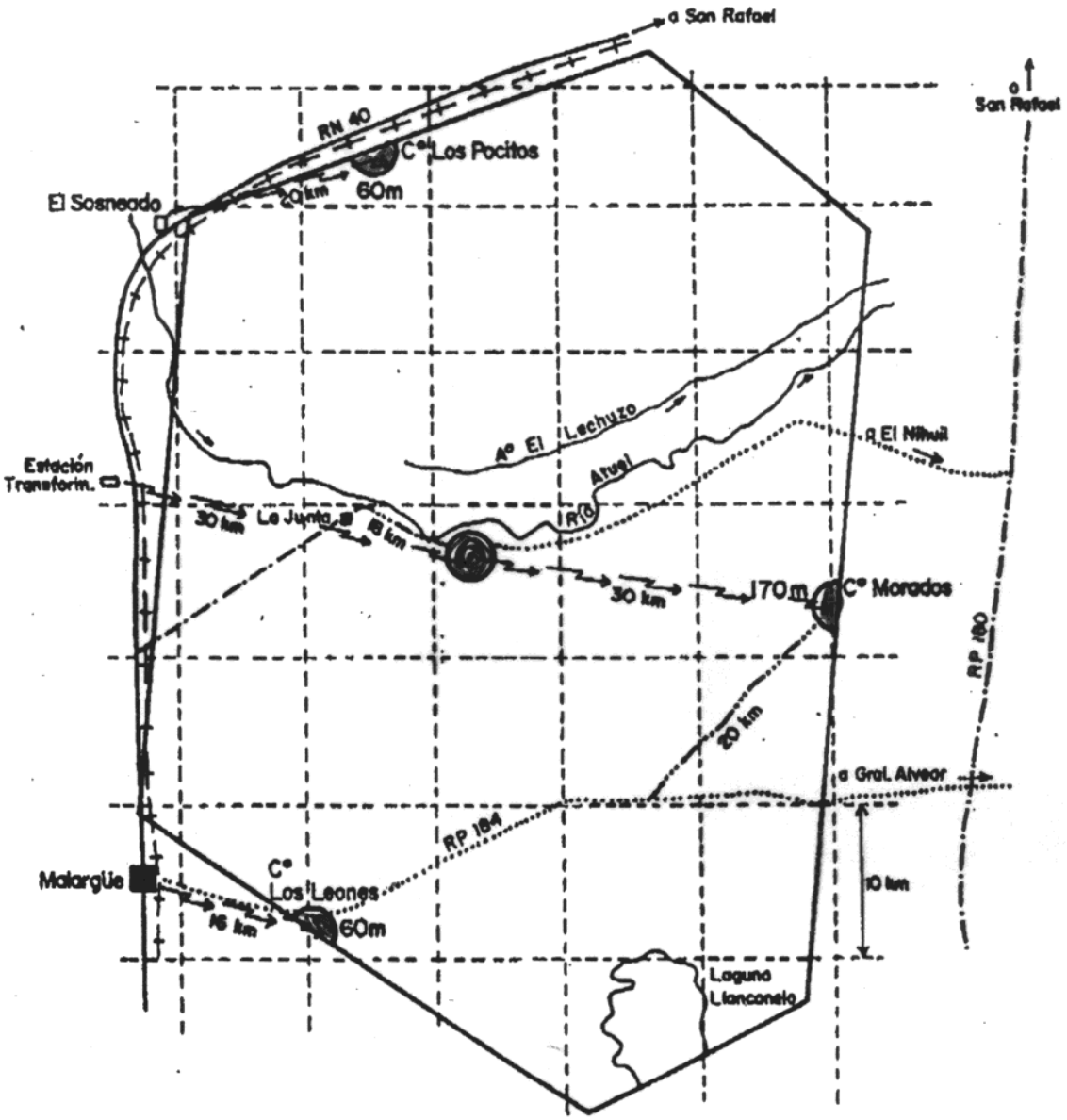



log10 Energy 18.0–18.2 eV
Density (VEM/meter^2)
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
2.8
3.0
3.2
3.4
3.6
Distance to core (meters)


Las Lenas
Nihuil
REPÚBLICA ARGENTINA
Cobertura diaria
Cobertura nocturna

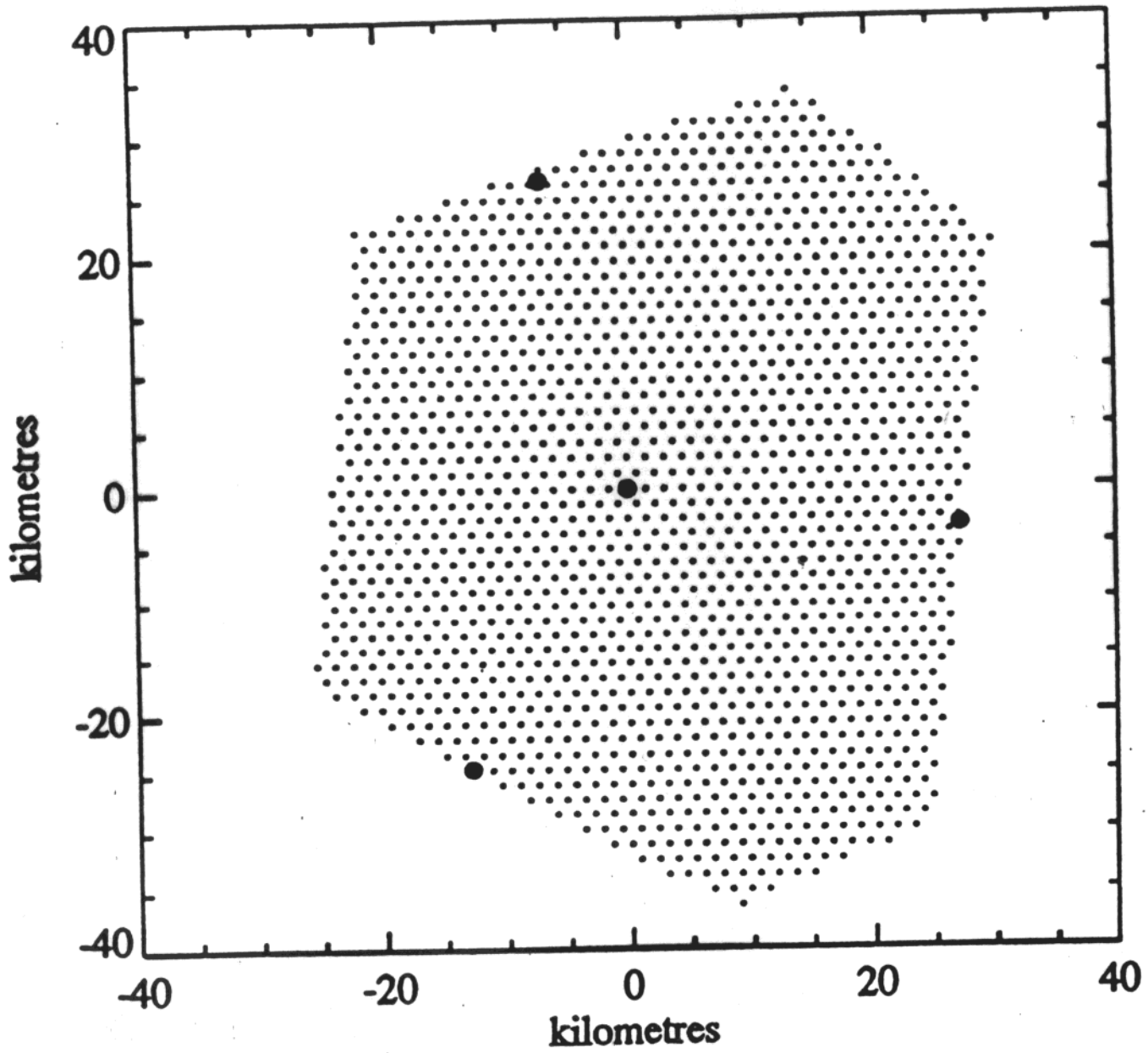
ESQUEMA DE DISTRIBUCION PROPUESTO

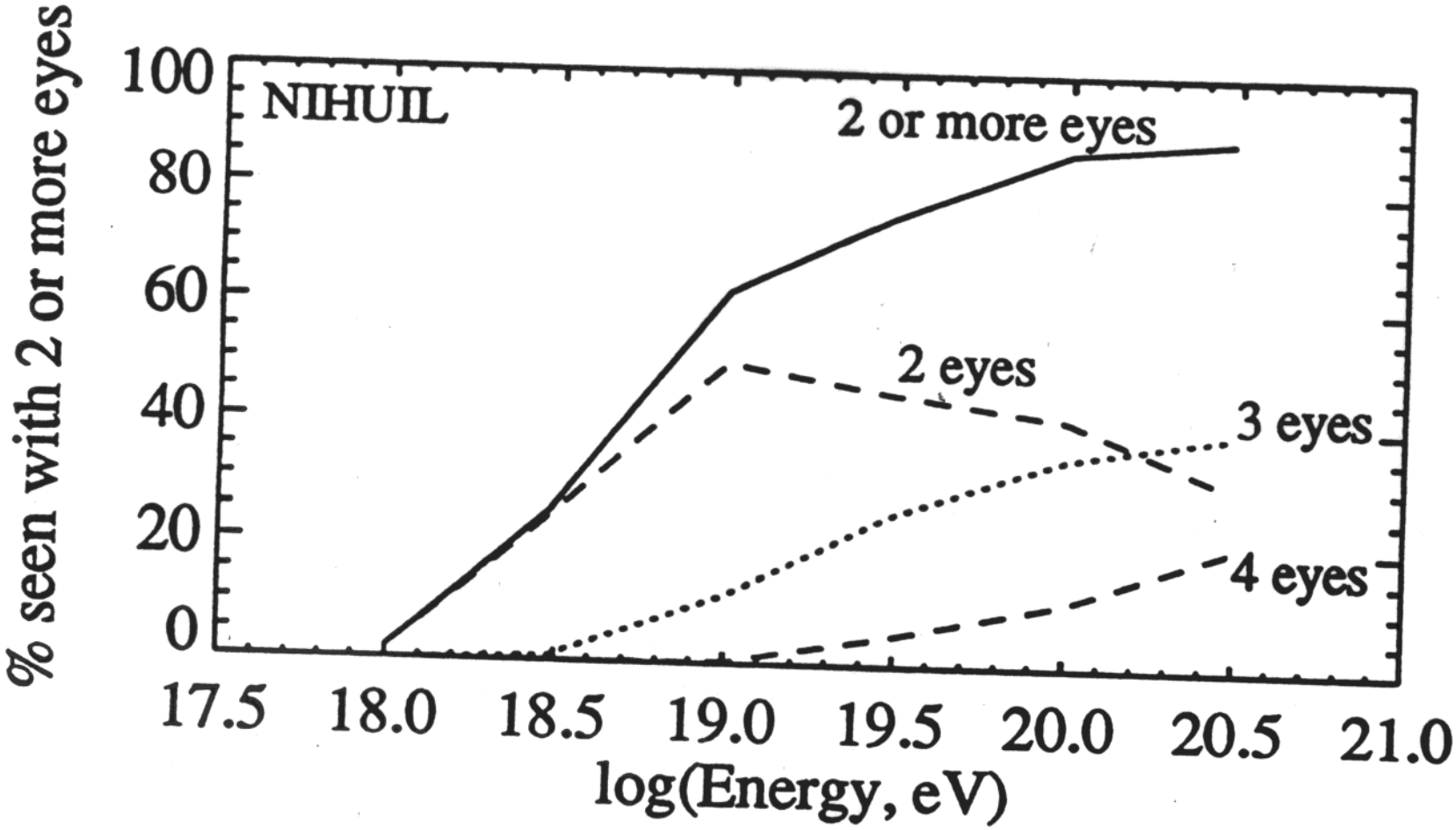
PARA EL AREA EL NIHUIL

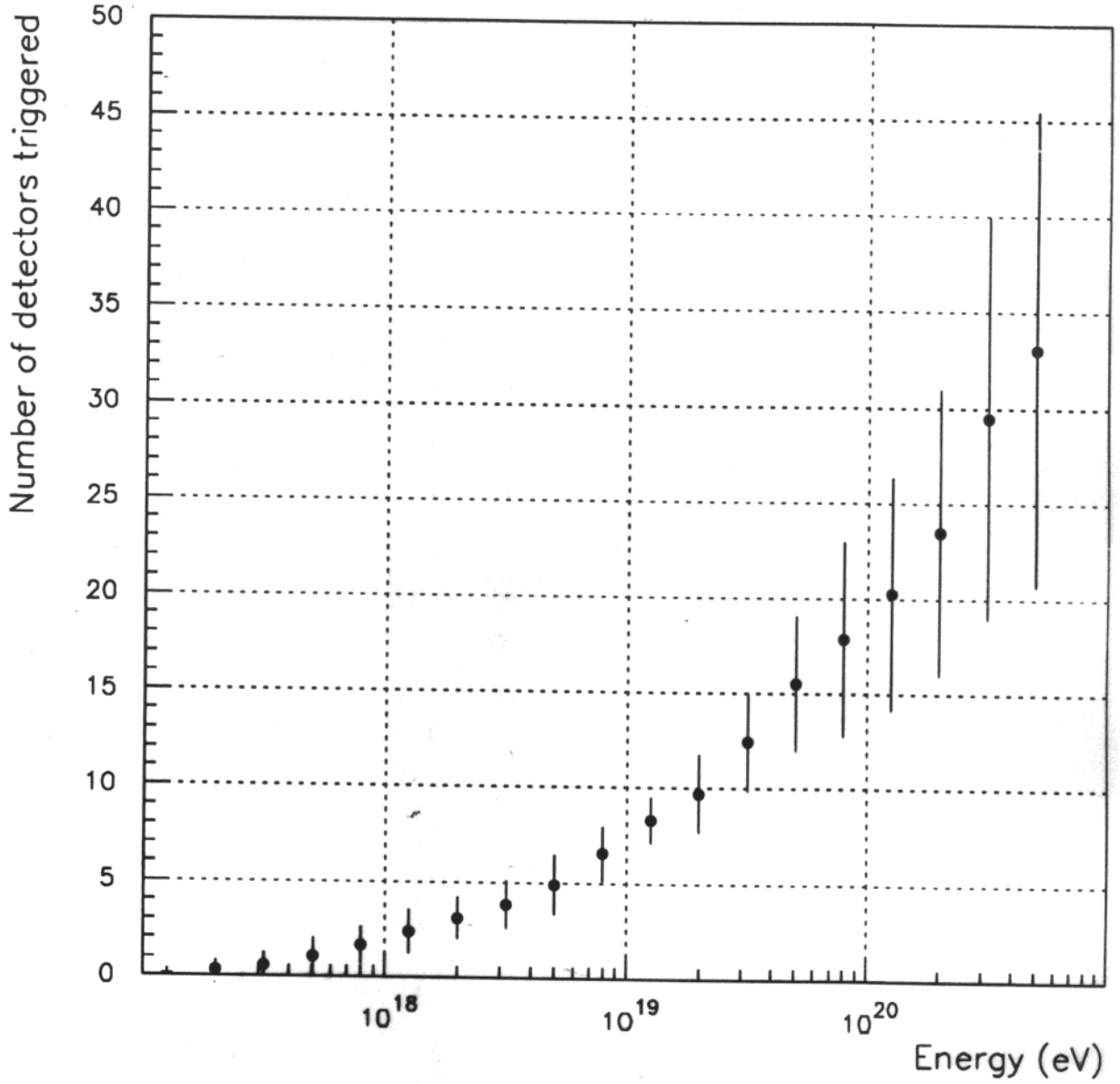


REFERENCIAS

- Detector de fluorescencia
- Camino de huella
- Camino asfaltado
- Camino consolidado a construir
- Camino consolidado
- Ferrocarril
- Línea de suministro eléctrico propuesto 33 Kv


40
20
0
-20
-40
kilometres
-40
-20
0
20
40
kilometres


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


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

Southern Site

$\theta_z \leq 60^\circ$

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

Energy	HiRes	Auger	Auger-Hybrid
≤ 10 *EeV*	~ 500	10000	~ 700
≥ 10 *EeV*	387	5150	515
≥ 20 *EeV*	170	1590	160
≥ 50 *EeV*	63	490	49
≥ 100 *EeV*	15	103	10
≥ 200 *EeV*	4	32	3
≥ 500 *EeV*	1.4	10	1

Is there an end to the spectrum?

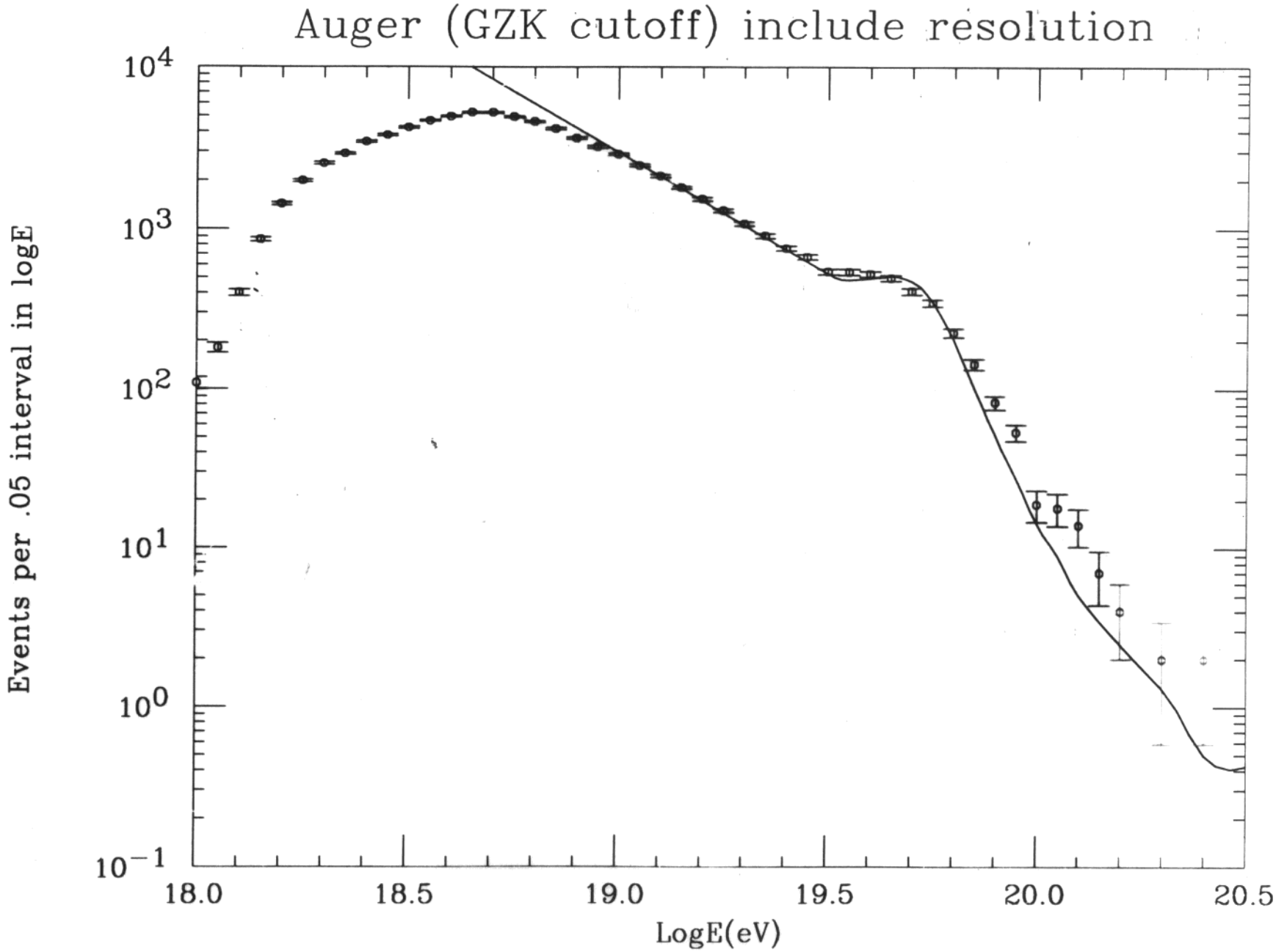
1500 evts/year $> 70^\circ$

ν's ?

Countries Participating in the Pierre Auger Collaboration

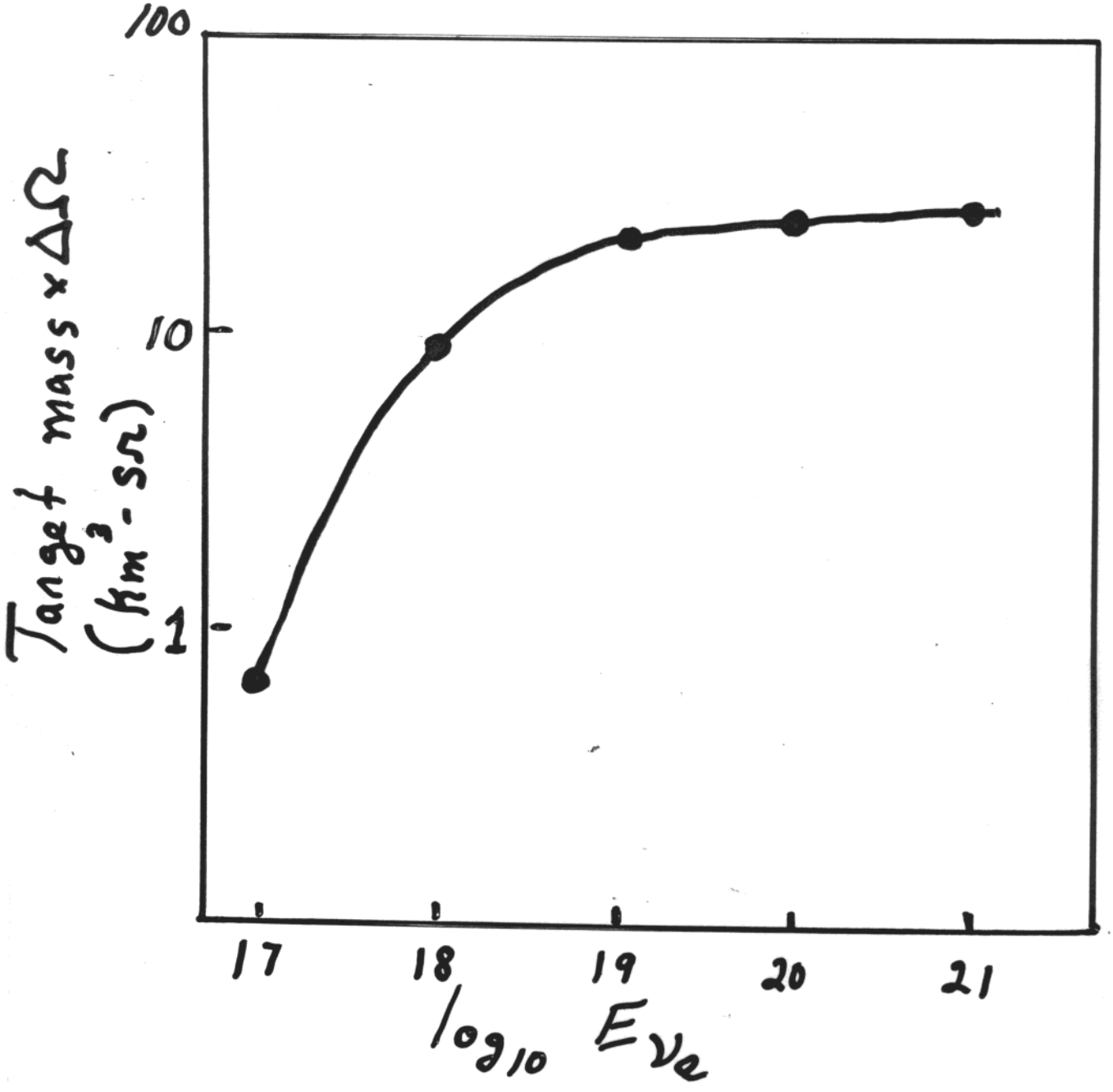
- Argentina
- Armenia
- Australia
- Brazil
- China
- Czech Republic
- France
- Germany
- Greece
- Italy
- Japan*
- Mexico
- Poland
- Russia
- Slovenia
- United Kingdom
- United States
- Vietnam

* Northern Site


Auger (GZK cutoff) include resolution
Events per .05 interval in logE
LogE(eV)
10^4
10^3
10^2
10^1
10^0
10^{-1}
18.0
18.5
19.0
19.5
20.0
20.5

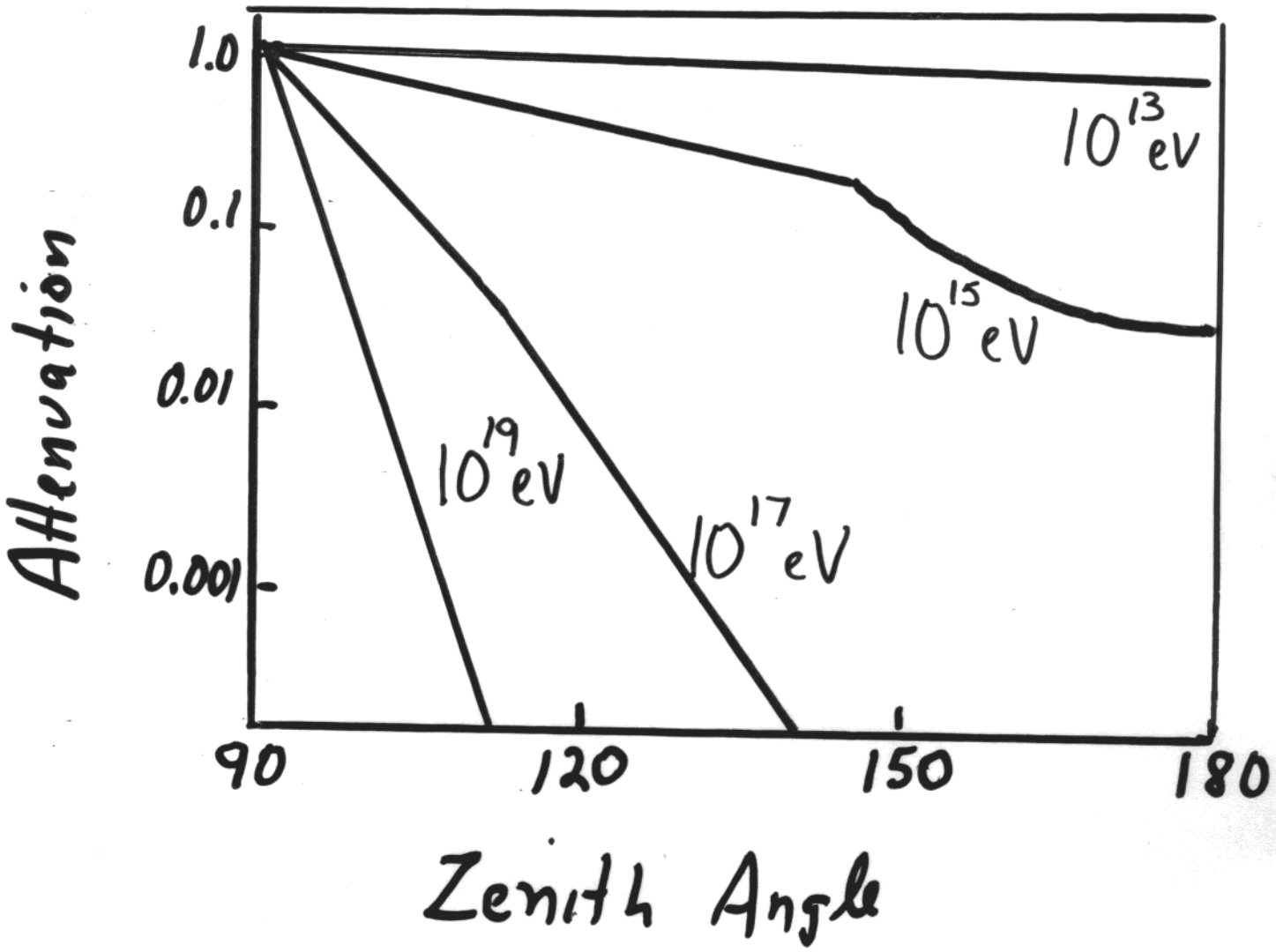
Pierre Billoir

GAP 97-49



(3000 km² surface array
Tanks 10 m² x 1.2 m high)

ν shadowing by earth



after T Kifune

Gobernador de Mendoza

Mr.....

The Governor of the Province of Mendoza, Argentina, Dr. Arturo Lafalla, has the pleasure to invite you to the Ground Breaking Ceremony of the Southern Pierre Auger Observatory to take place next March 17 in the City of Malargue, Province of Mendoza.

Mendoza, February 17, 1999

Dr. ARTURO PEDRO LAFALLA
GOBERNADOR DE MENDOZA