BIRMINGHAM 1 OCTOBER 97

IOP PARTICLE PHYSICS

# THE PIERRE AUGER PROJECT

PHYSICS AND ASTROPHYSICS OF PARTICLES $\gtrsim 10^{19}$ eV.

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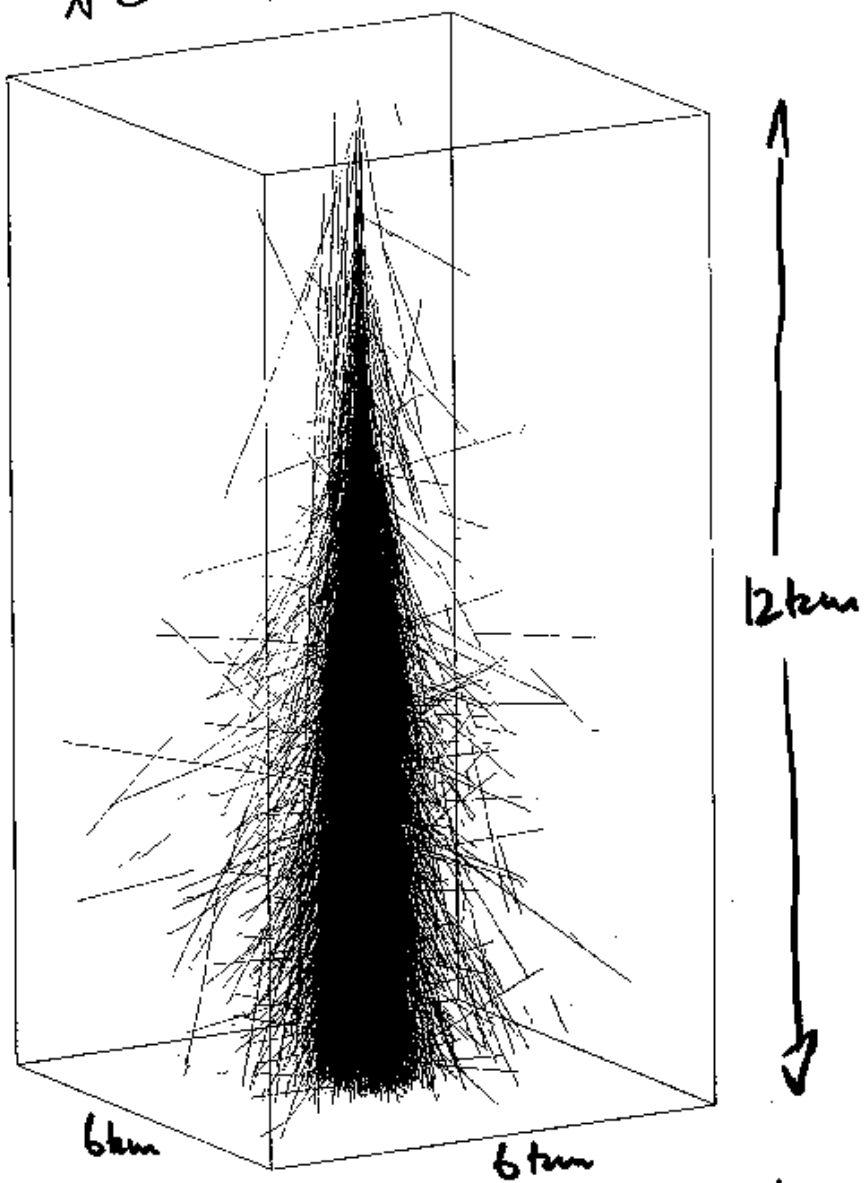
for AUGER COLLABORATION

J W CRONIN et al

~ 200

$10^{19}$ eV $\sqrt{S} = \sqrt{2} \cdot 10^{14}$ eV = 140 TeV (c




Simulation of a $10^{19}$ eV proton EAS using the MOCCA (HILLAS) program. A sample of tracks at > 300 m from the shower axis are shown. Frame box: $6 \times 6 \times 12$ km high. Color code: $\gamma$ green, $e$ red, $\mu$ blue. *Drawn by Clem Pryke — University of ~~Chicago~~* LEEDS

FLY's eye 3x10^20 eV event $X_m = 852^{+68}_{-100}$ g cm$^{-2}$

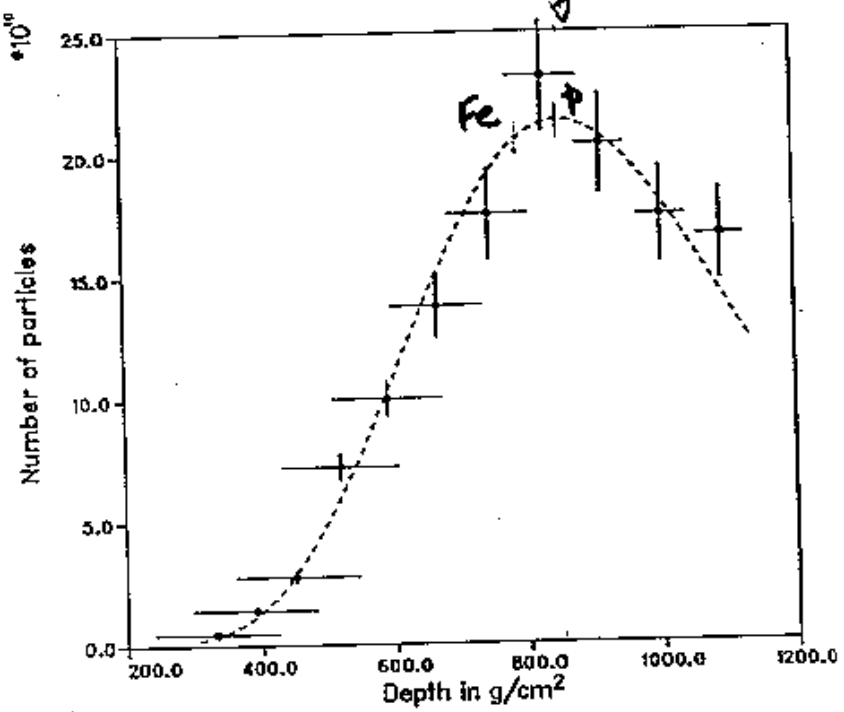



Figure 12: Shower profile for the most energetic event observed by the Fly's Eye

OCT 1991

Reported July 1993

Time (UT): Oct. 15, 1991, 7:34:16.443

$R_p$ (impact parameter): $12.06^{+1.11}_{-1.16}$ km

$\theta$ (zenith angle): $45.13^{+2.47}_{-1.73}$ degree

E (energy): $299.7^{+36.0}_{-41.0}$ EeV $E = 3^{+.4}_{-.5} \times 10^{20}$ eV

$X_m$ (depth of shower maximum): $852^{+68}_{-100}$ $g/cm^2$,

mean $X_m$ for proton: 850 $g/cm^2$; iron: 780 $g/cm^2$.

RA = 86.1 Dec = 44°

Figure out

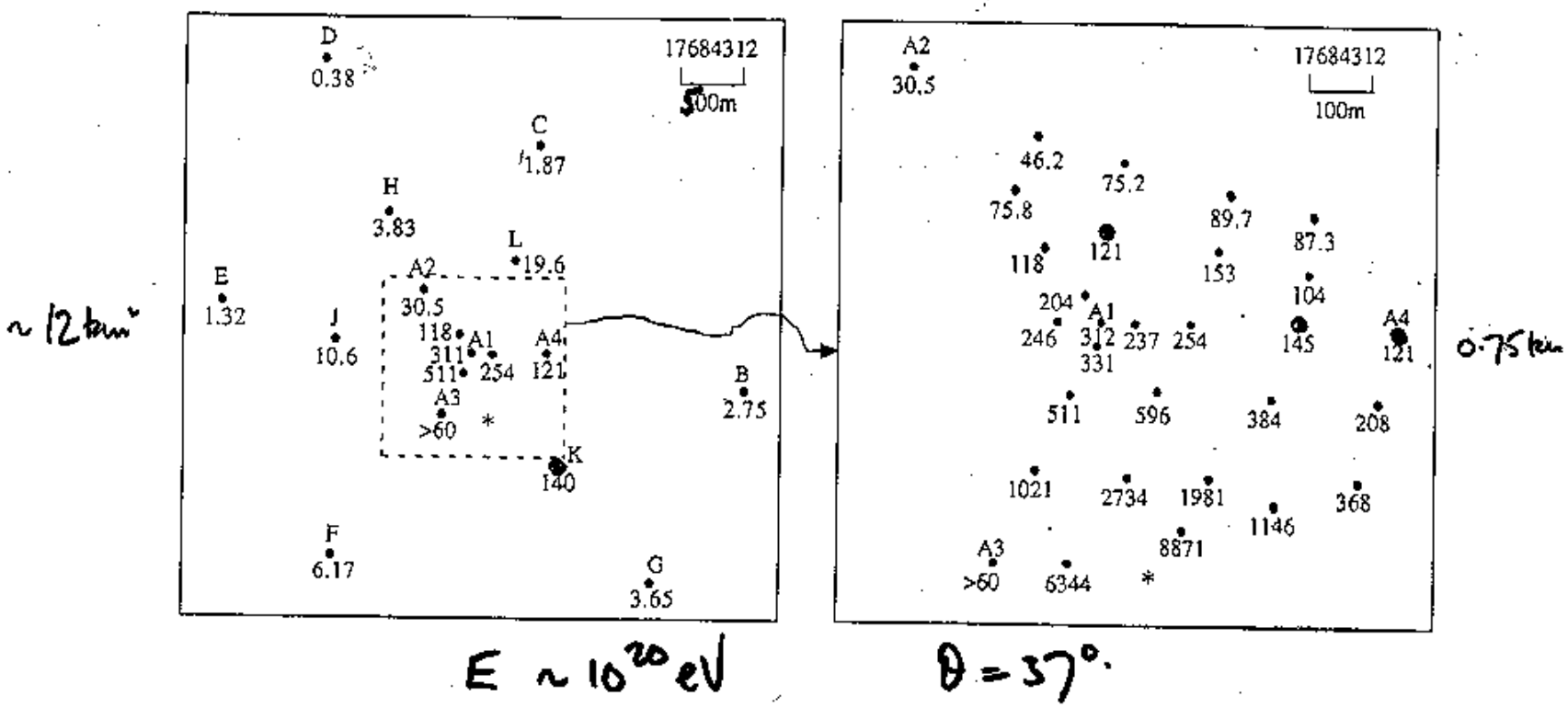
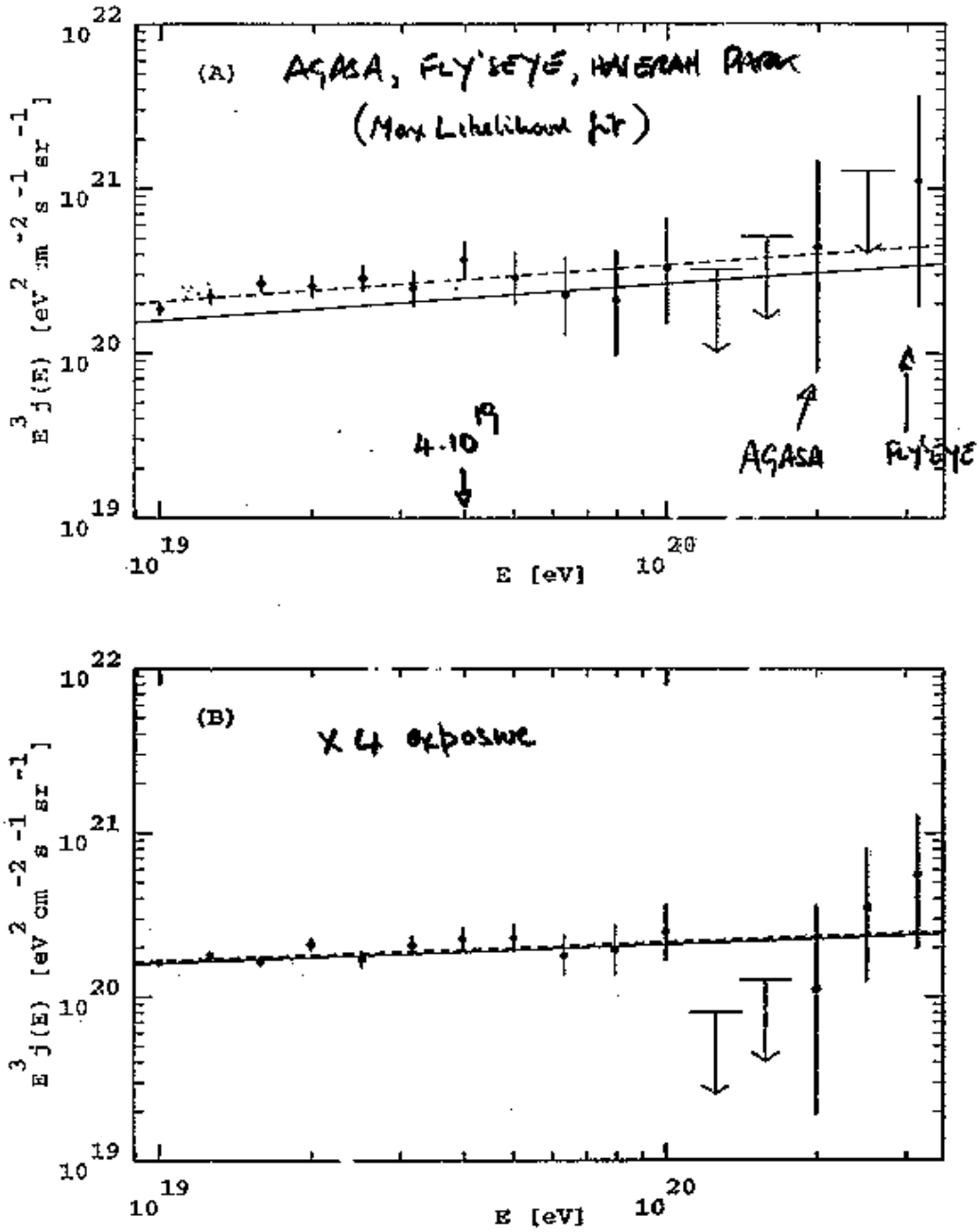



FIGURE 11

Density maps for event 17684312 recorded at Haverah Park[28]. The area enclosed by the dashed square in the left-hand map is enlarged on the right where the unlettered detectors are 1m² water-Cerenkov detectors. The enlarged area is approximately the shaded area of Figure 3. The core (left-hand map) is marked with a star.

Sigl et al Science 270 1923 1995



## IMPACT OF PARTICLE & NUCLEAR PHYSICS ON SPECTRUM

(i) $p + \gamma_{2.7K} \rightarrow \Delta^+ \rightarrow p + \pi^0$ ($\pi^0$ ← $\gamma$-Source)

$\rightarrow n + \pi^+$ ($\pi^+$ → $\nu_\mu$-Source)

$> 4 \times 10^{19}$ eV

(ii) $^{56}Fe + \gamma_{2.7K} \rightarrow {}^{55}Fe + n$

$> 4 \times 10^{9}$ eV

GREISEN – KUZMIN – ZATSEPIN 1966

(GKZ-effect)

BOTH PROCESSES SEVERELY LIMIT DISTANCES FROM WHICH UHECR CAN REACH US

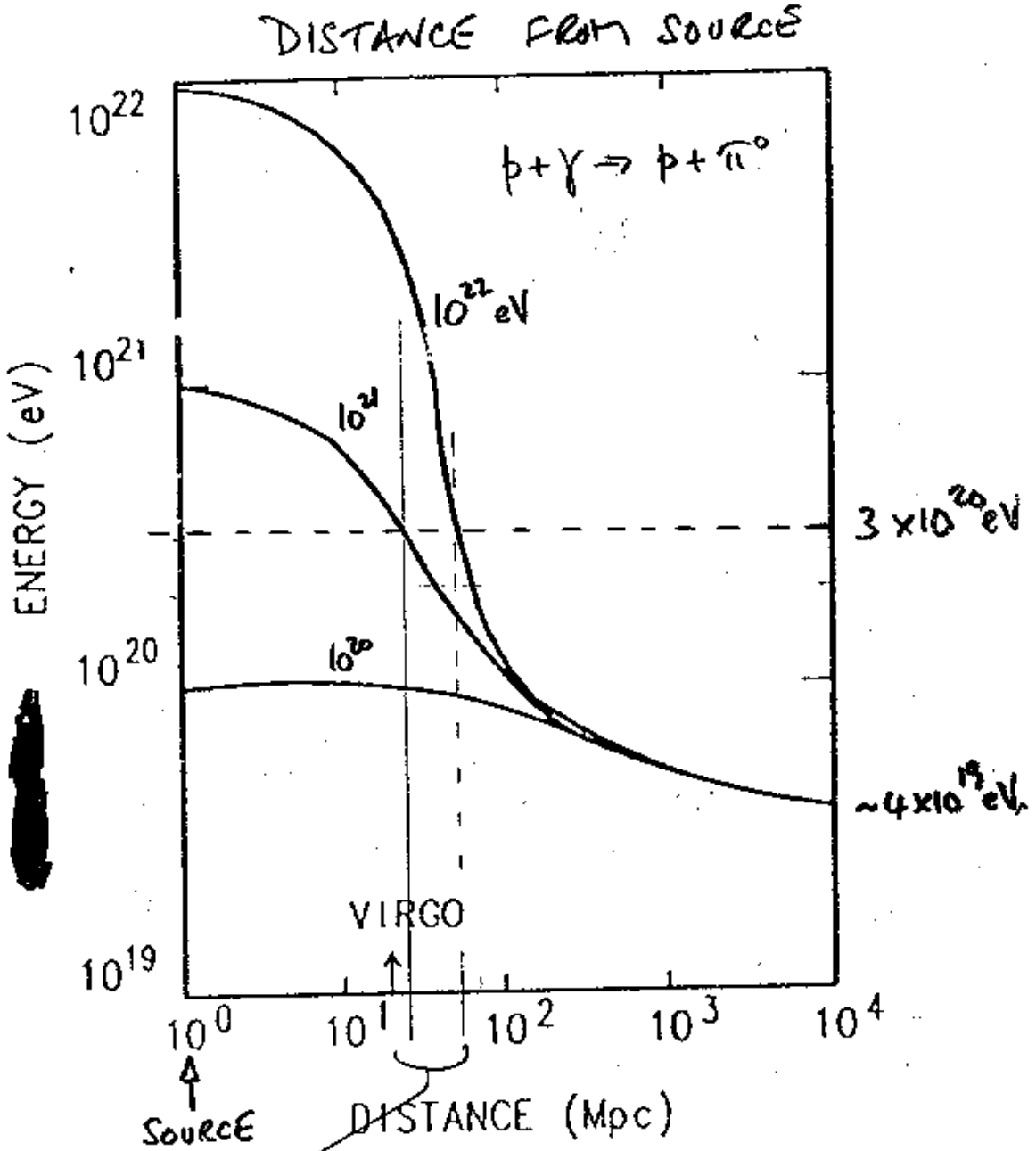



Fig. 2. Calculation of the mean energy of protons due to the interaction with the 2.7°K radiation as a function of distance for various initial energies.

+ FLUCTUATIONS
EVENTS MUST HAVE ORIGINATED CLOSE BY

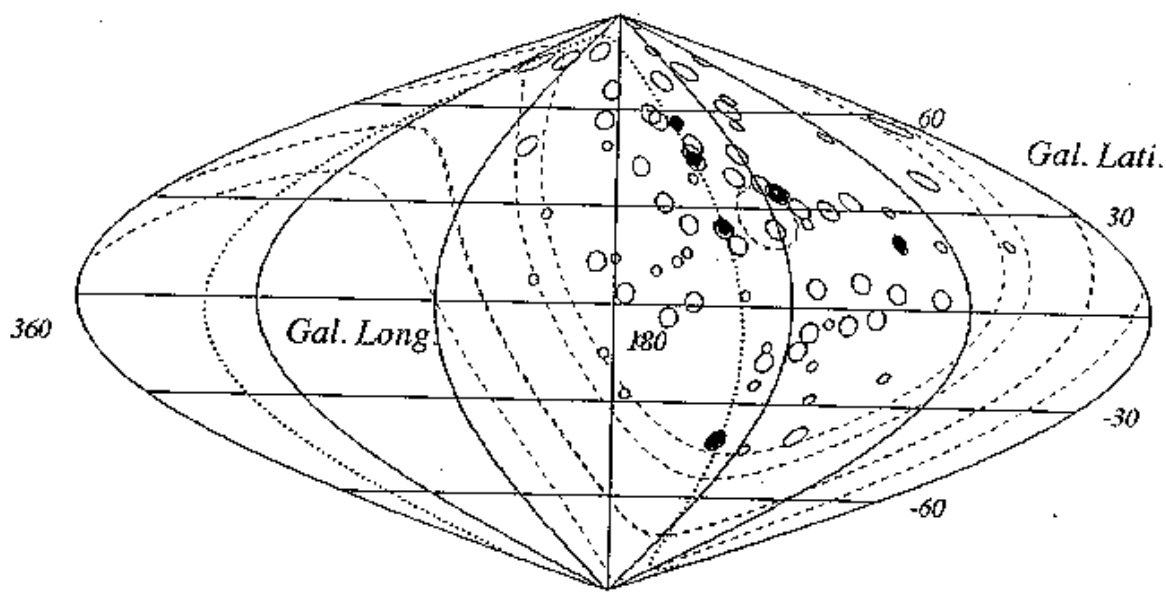
Keep out

## DEFLECTIONS

### $3 \times 10^{20}$ eV

| GALACTIC | EXTRAGALACTIC |
|---|---|
| $\sim 1$ kpc | $\sim 30$ Mpc |
| $3\mu$G | $\lesssim 10^{-9}$ G |
| $0.3^\circ$ | $\leq 6^\circ$ |
| | $\simeq 1^\circ$ (B-field in cells.) |

# Galactic Coordinates




*AGASA*
*Haverah Park*
*Yakutsk*
*Volcano Ranch*

*Super Galactic Plane*

- 5 'DOUBLES' (< 1.5°)
- 1 'TRIPLE'

| | | |
|---|---|---|
| PROTON | SEPARATION | 0.9° |
| He | | 3.2° (1.4°) |
| C | | 16.1° |

## ELECTROMAGNETIC ACCELERATION

- 'SINGLE SHOT' PULSAR

$$E_{max} = Ze\,BR\,\beta c$$

- SYNCHROTRON

$$E_{max} < Ze\,BR\,\beta c$$

- SHOCK ACCELERATION

$$E_{max} < \frac{3}{20}\,Ze\,BRU$$
$$= \frac{3}{20}\,Ze\,BR\,\beta c$$

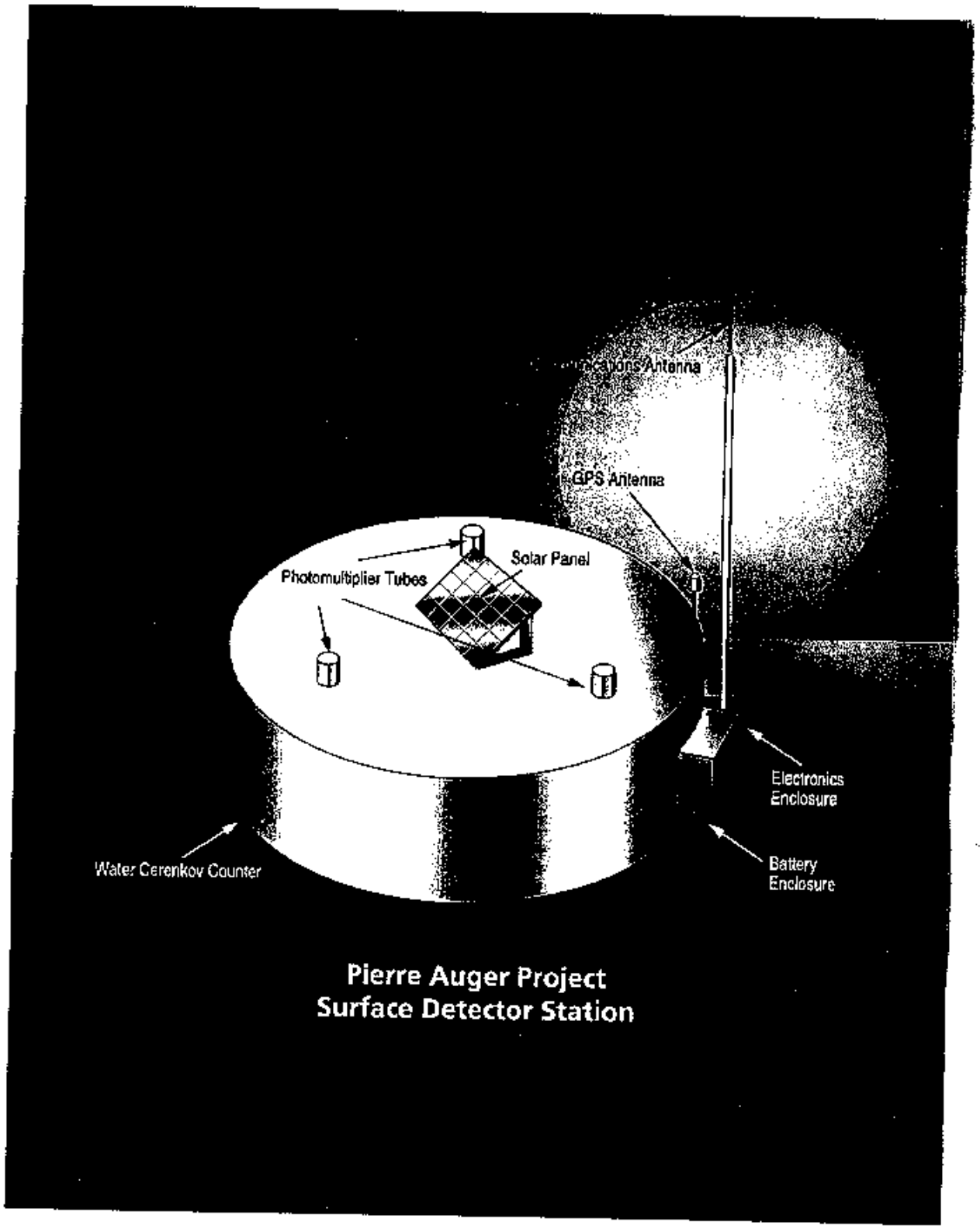
IN GENERAL

$$E_{max} < kZe\,BR\,\beta c$$

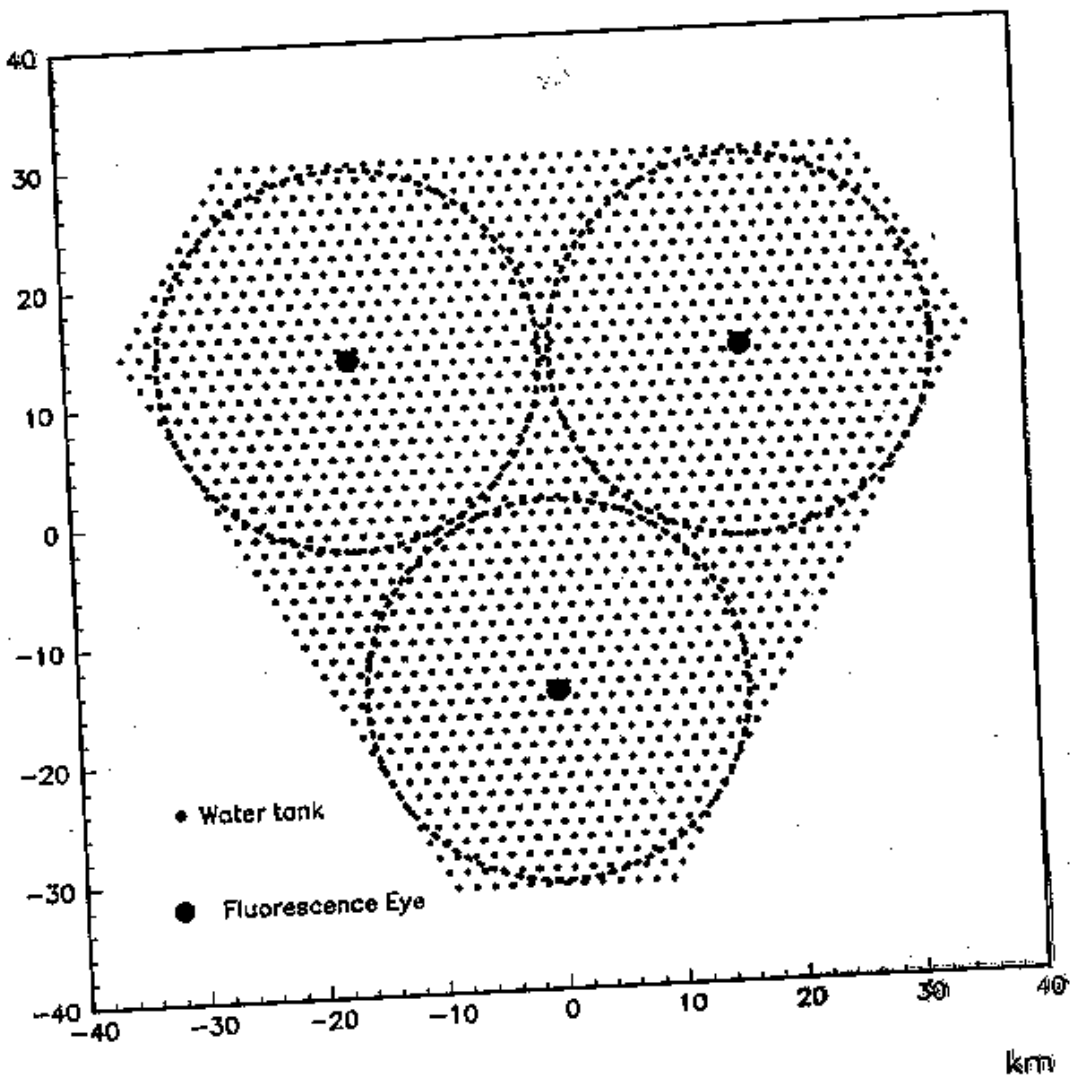
$k < 1$

DRURY CONT. PHYSICS 35, 232, 1994

$k = 3/20 \simeq \frac{1}{7}$

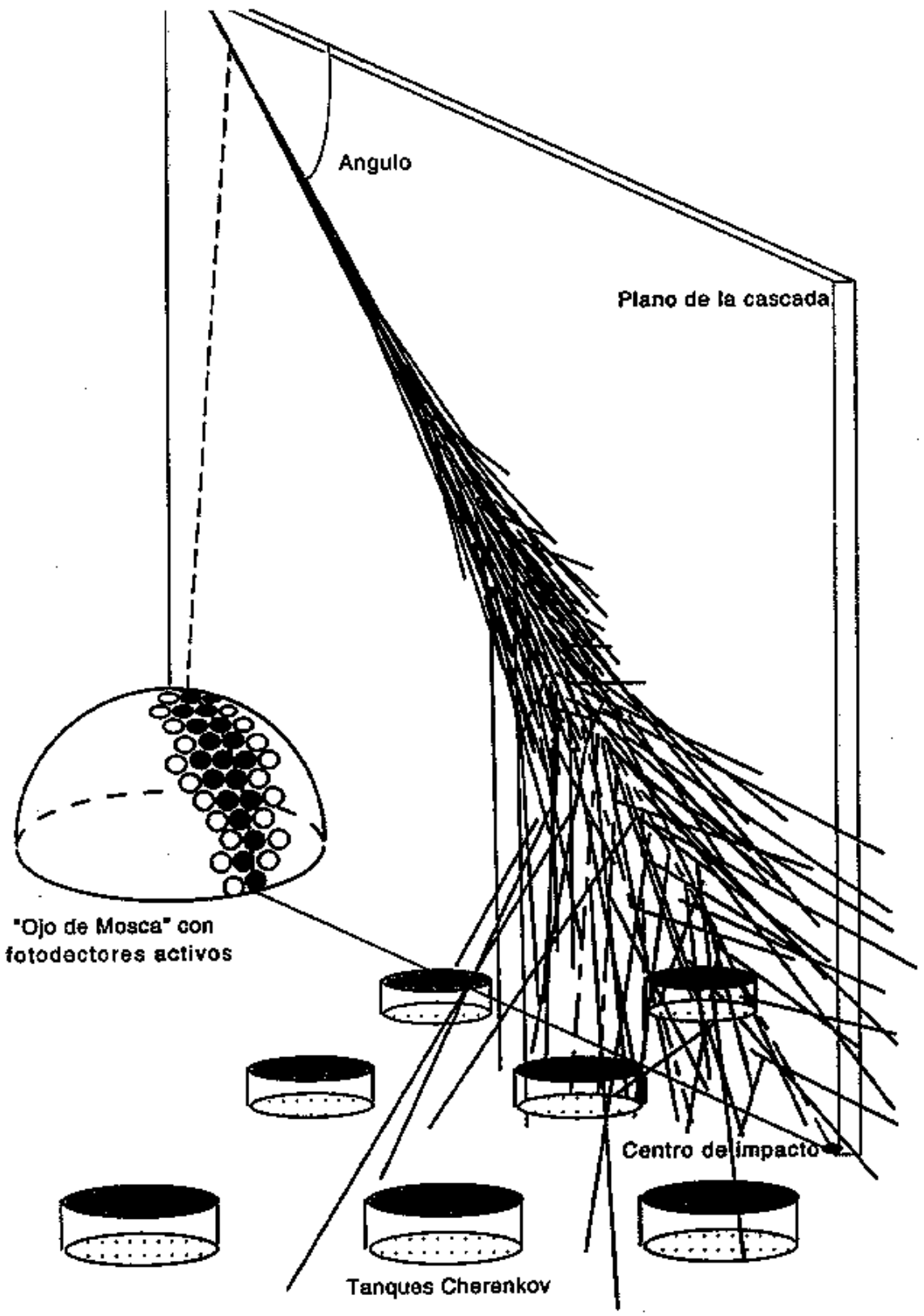

GPS Antenna
Solar Panel
Photomultiplier Tubes
Electronics Enclosure
Water Cerenkov Counter
Battery Enclosure
Pierre Auger Project
Surface Detector Station

Layout of the proposed Auger detector




DO IT BIGGER & BETTER THAN EVER BEFORE!

$2 \times 3000\ km^2$.


Angulo
Plano de la cascada
"Ojo de Mosca" con
fotodectores activos
Centro de impacto
Tanques Cherenkov

- 10 years × 2 × 3000 km² : 600–1000 $> 10^{20}$ eV

  if $E^{-2}$ then ~5 $> 10^{21}$ eV

THE HIGHER THE ENERGY, THE MORE INTRIGUING ARE THE THEORETICAL PROBLEMS

- N+S essential : ASYMMETRIC DISTRIBUTION OF 'CONVENTIONAL' SOURCES
- MASS FROM SEVERAL INDEPENDENT MEASURES
- IF SOURCES : PROTON PRIMARIES ?
  MAGNETIC FIELD TO 50 Mpc
  MUON CONTENT / DEPTH OF MAX
  → p-A INTERACTIONS
  MASS SPECTROMETRY
- ISOTROPIC : EXOTIC MODELS
  - TOPOLOGICAL DEFECTS
  - GRBs
- Estimates : $6 \times 10^5$ km² sr : few/year

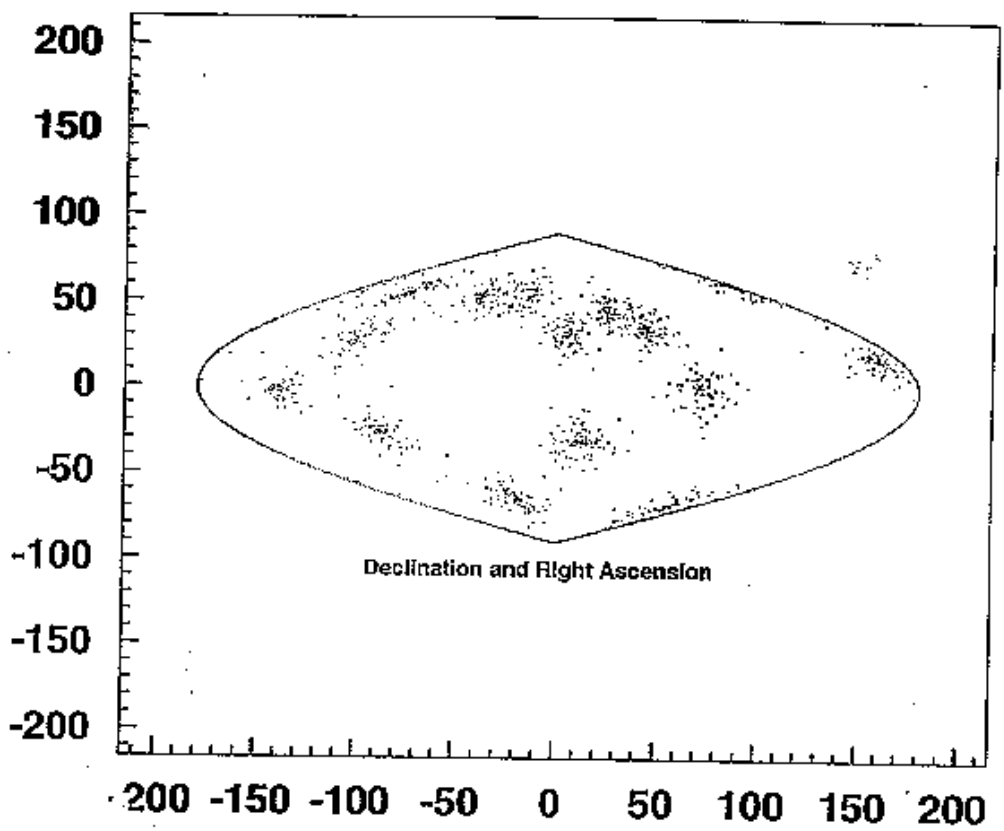
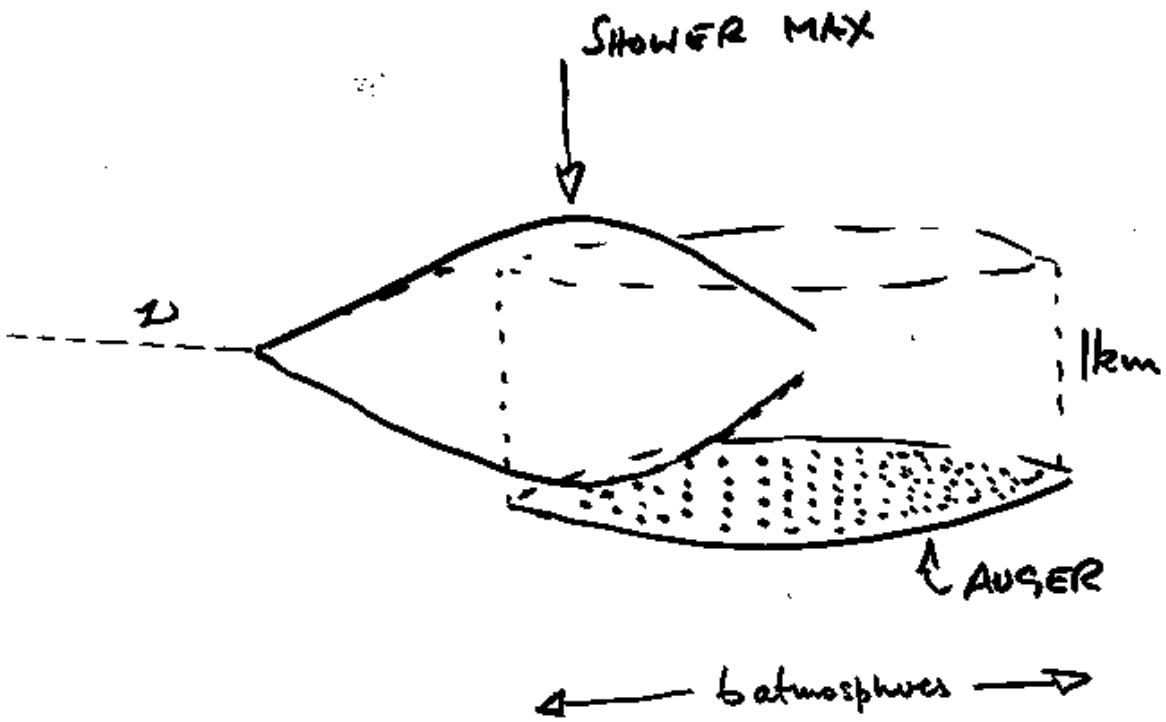



Figure 3.9: Simulation of the Auger sky for showers with energy greater than 40 EeV after 3 years (1165 showers expected). Positions for 15 point sources of approximately equal flux were chosen randomly. Each simulated source is smeared by sampling a Gaussian of 10° width.




RATES ($>10^9$ eV) ≃ a few per year.

## TASKS :-

- WATER TANKS — DETECTOR + ELECTRONICS
- FLUORESCENCE DETECTORS —— " ——
- COMMUNICATIONS (951 MHz)
- DAQ
- DATA ANALYSIS
- SIMULATIONS
- TIMING (GPS) - probably established (Lecam work)
- SOLAR POWER (< 10W)

TASKS NEEDING EFFORT ARE CIRCLED

## The AUGER COLLABORATION

| | | | | |
|---|---|---|---|---|
| *** | ARGENTINA | | CHILE | UK |
| | ARMENIA | | CHINA | ** USA |
| | AUSTRALIA | ** | FRANCE | VIETNAM |
| | BOLIVIA | * | JAPAN | * ITALY |
| * | BRAZIL | * | MEXICO | SPAIN |
| | GERMANY | | RUSSIA | |
| | GREECE | * | SLOVENIA | |

| TOTAL COST: $98M |
|---|

*** 5 year x $3M

** AGENCY APPLICATION MADE

* SERIOUS PROSPECT OF > $1M

Scientists from all these countries (and more) contributed to Design Studies