THE VIEW FROM AUGER

E. ZAS

RADHEP-2000
UCLA

PIERRE AUGER OBSERVATORIES

- 2 OBSERVATORIES { SOUTH Argentina (started)
  NORTH Utah (planned)

  FULL SKY COVERAGE

- 2 TECHNIQUES { Fluor. Det.
  Particle array: Water Čerenkov tanks

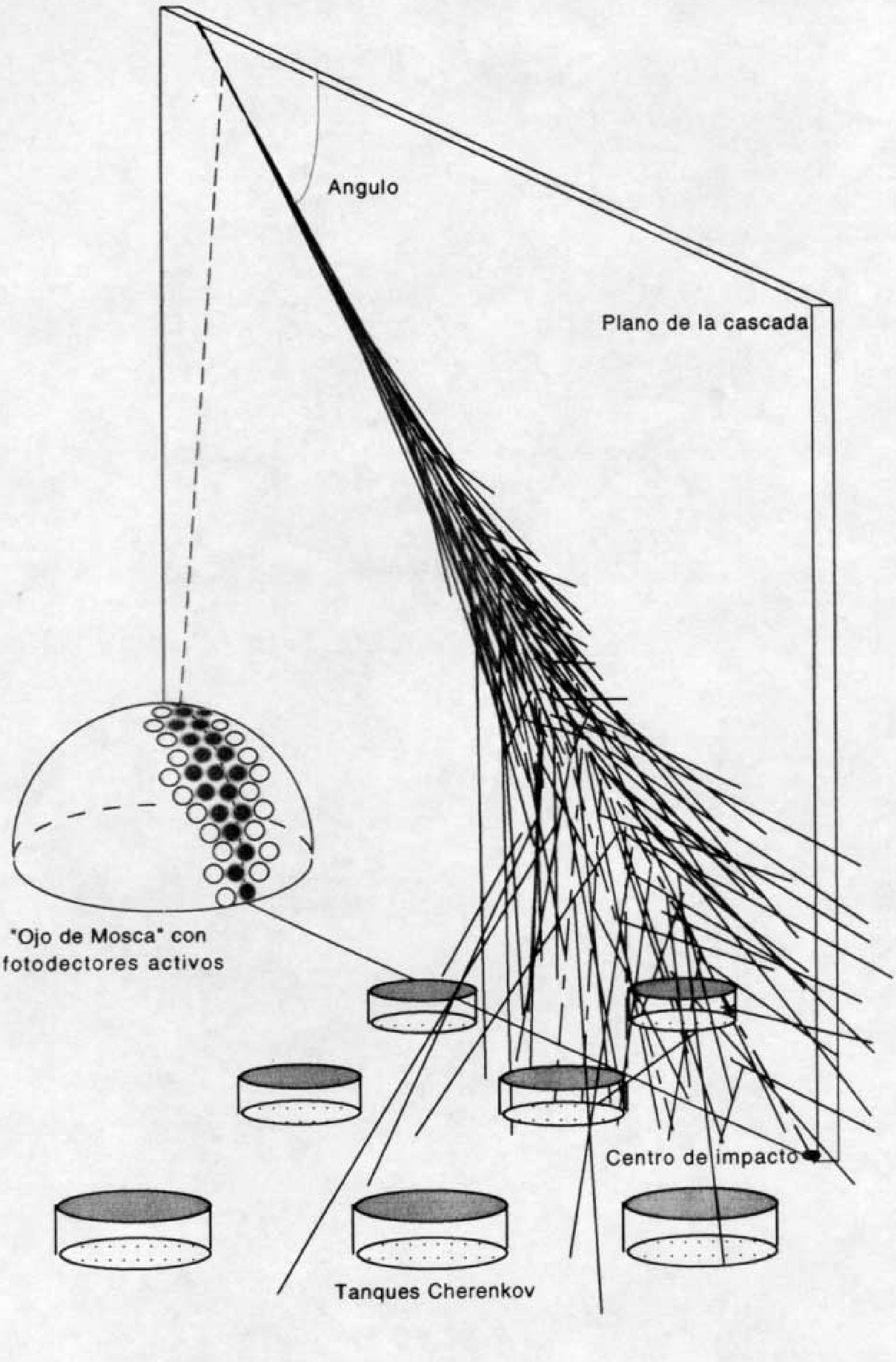
  CROSS CALLIBRATION

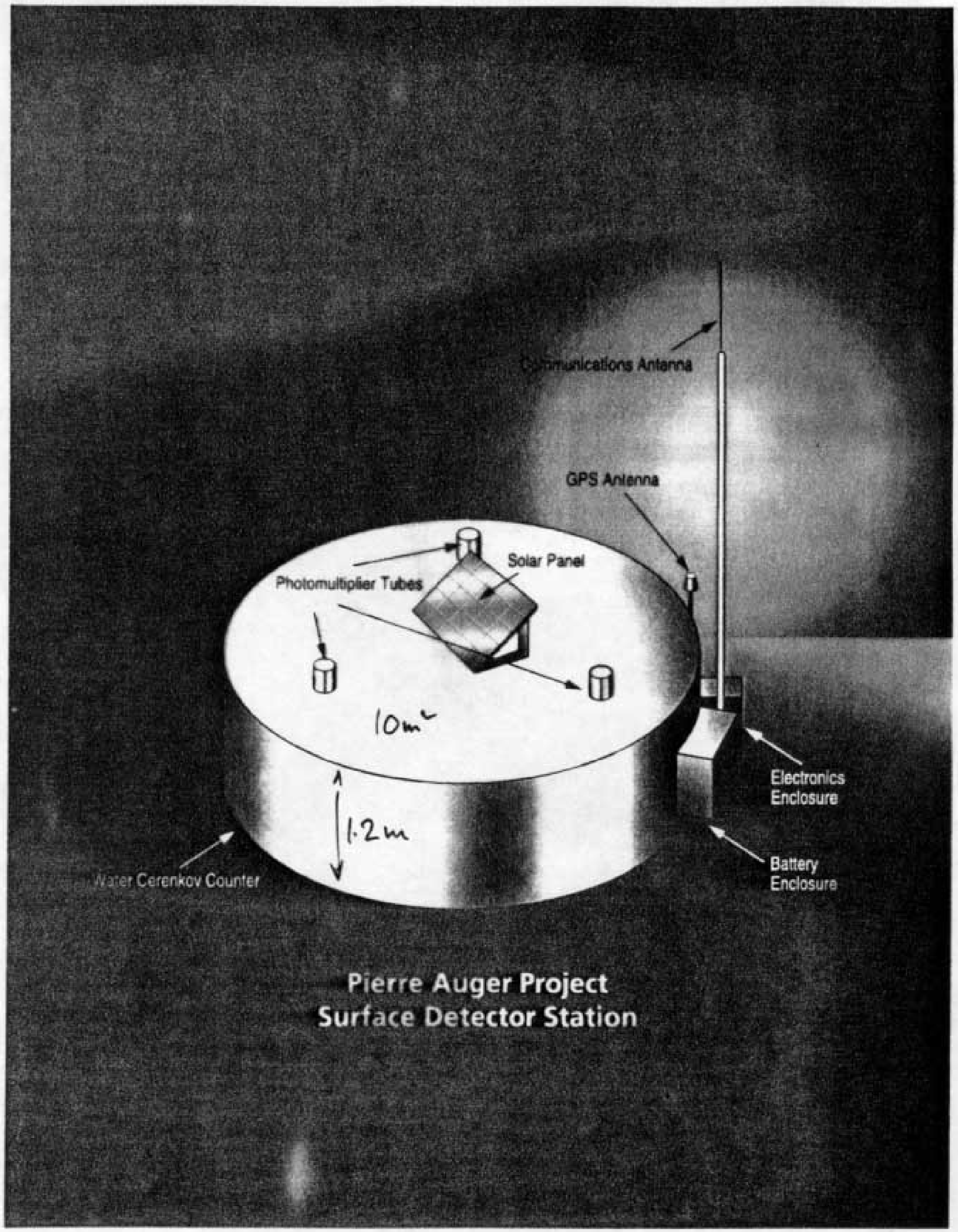
- 3000 km^2 AREA

- HEXAGONAL ARRAY 1.5 km SEPARATION

- FOUR FD "Eyes"

MEASURE CR EAS with $E \gtrsim 10^{19}$ eV


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


Communications Antenna
GPS Antenna
Solar Panel
Photomultiplier Tubes
10m²
1.2m
Electronics
Enclosure
Battery
Enclosure
Water Cerenkov Counter
Pierre Auger Project
Surface Detector Station

CONSTRUCTION HAS BEGUN !

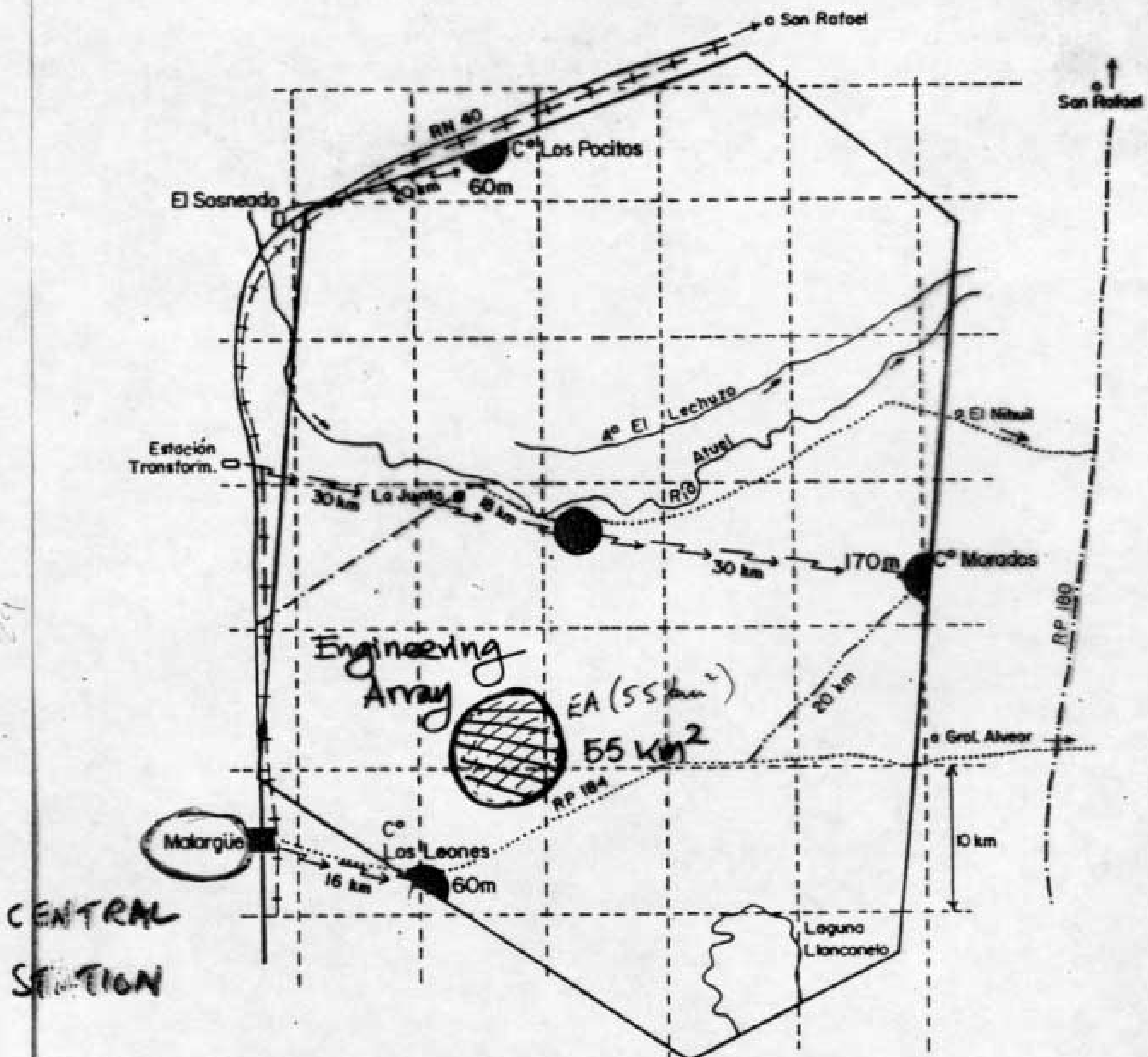
ENGINEERING ARRAY

55 km^2 40 tanks

Could be doing Physics Next Year

ESQUEMA DE DISTRIBUCION PROPUESTO

PARA EL AREA EL NIHUIL



REFERENCIAS

Detector de fluorescencia

Camino asfaltado

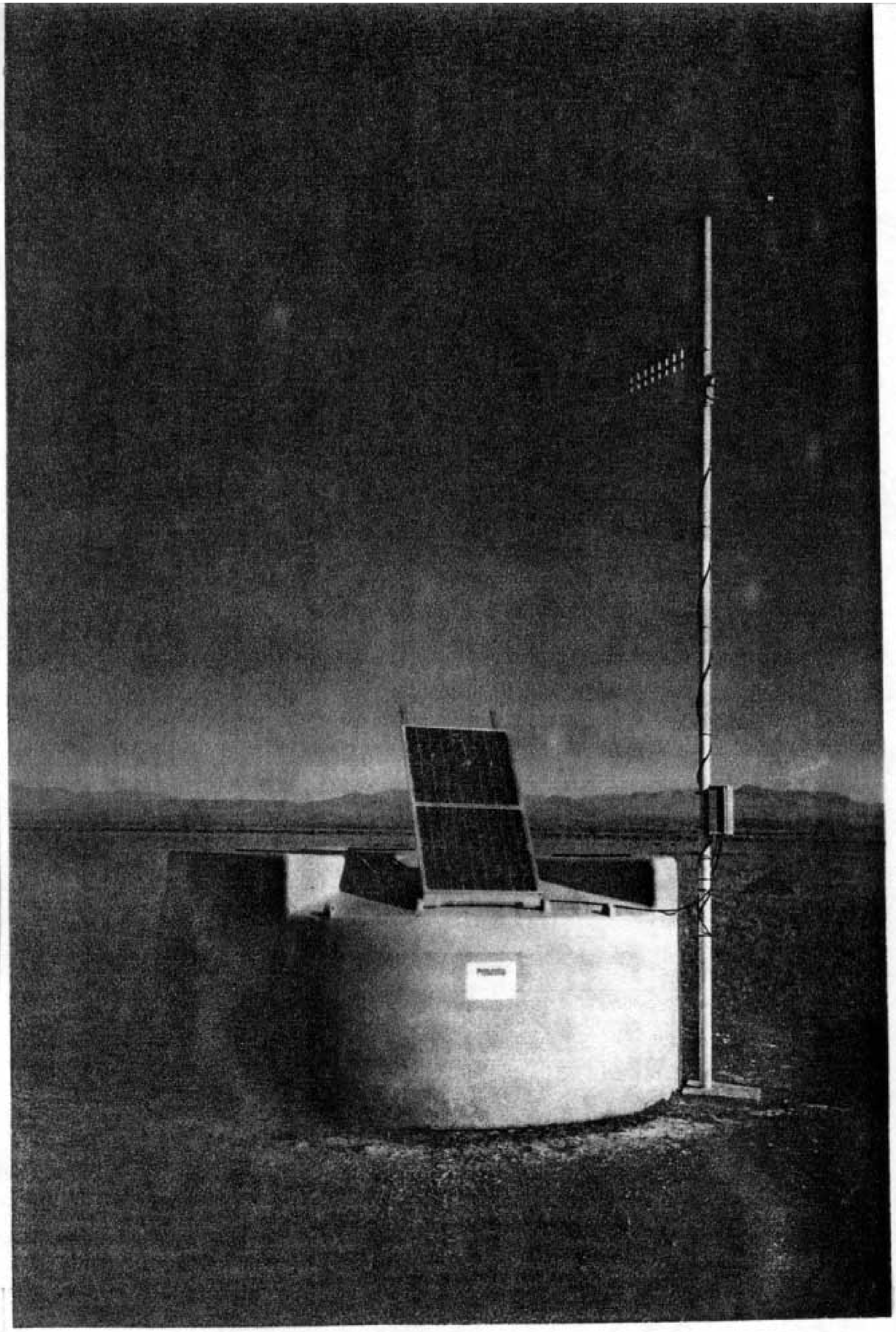
Camino consolidado

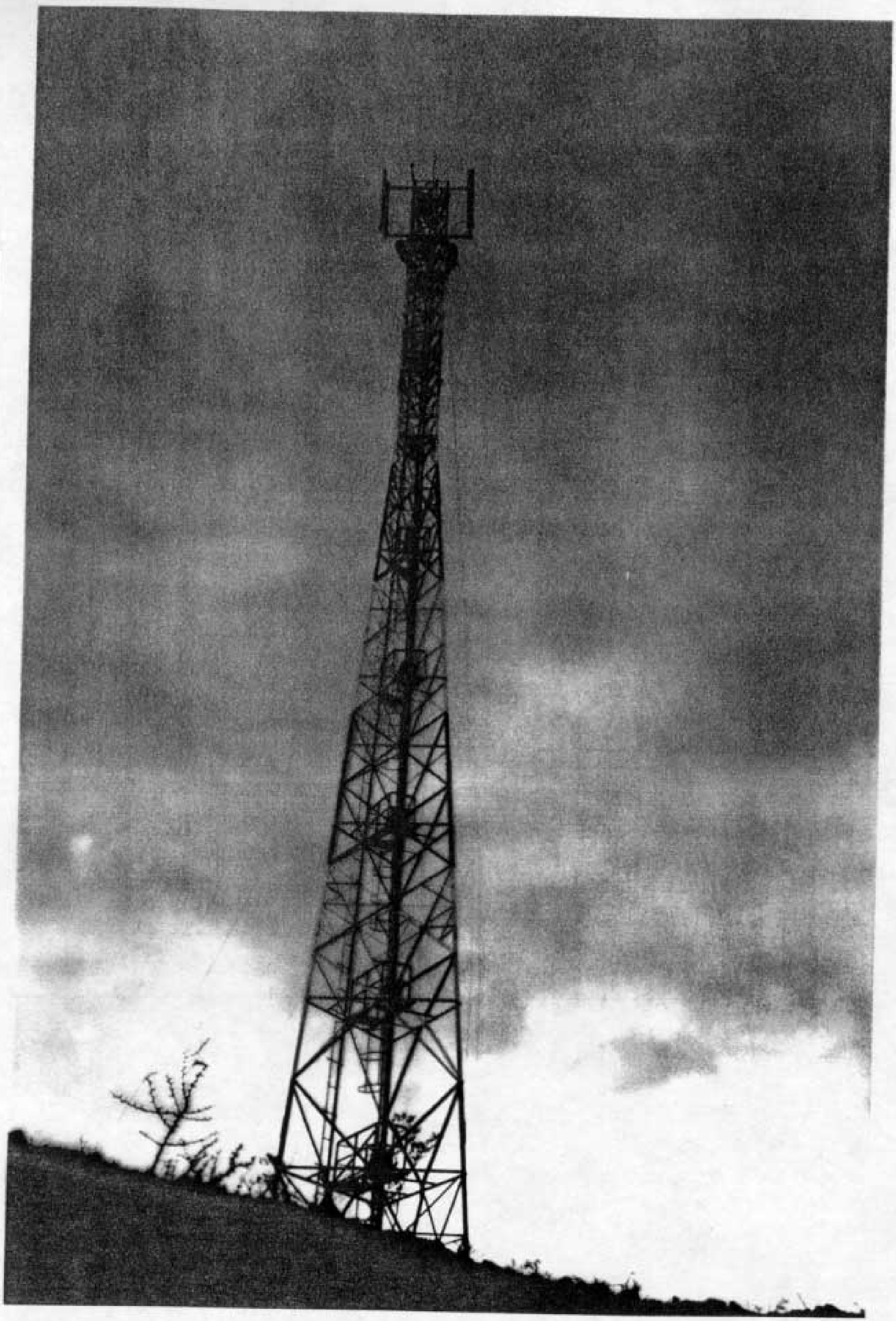
Línea de suministro eléctrico propuesto 33 Kv

Camino de huella

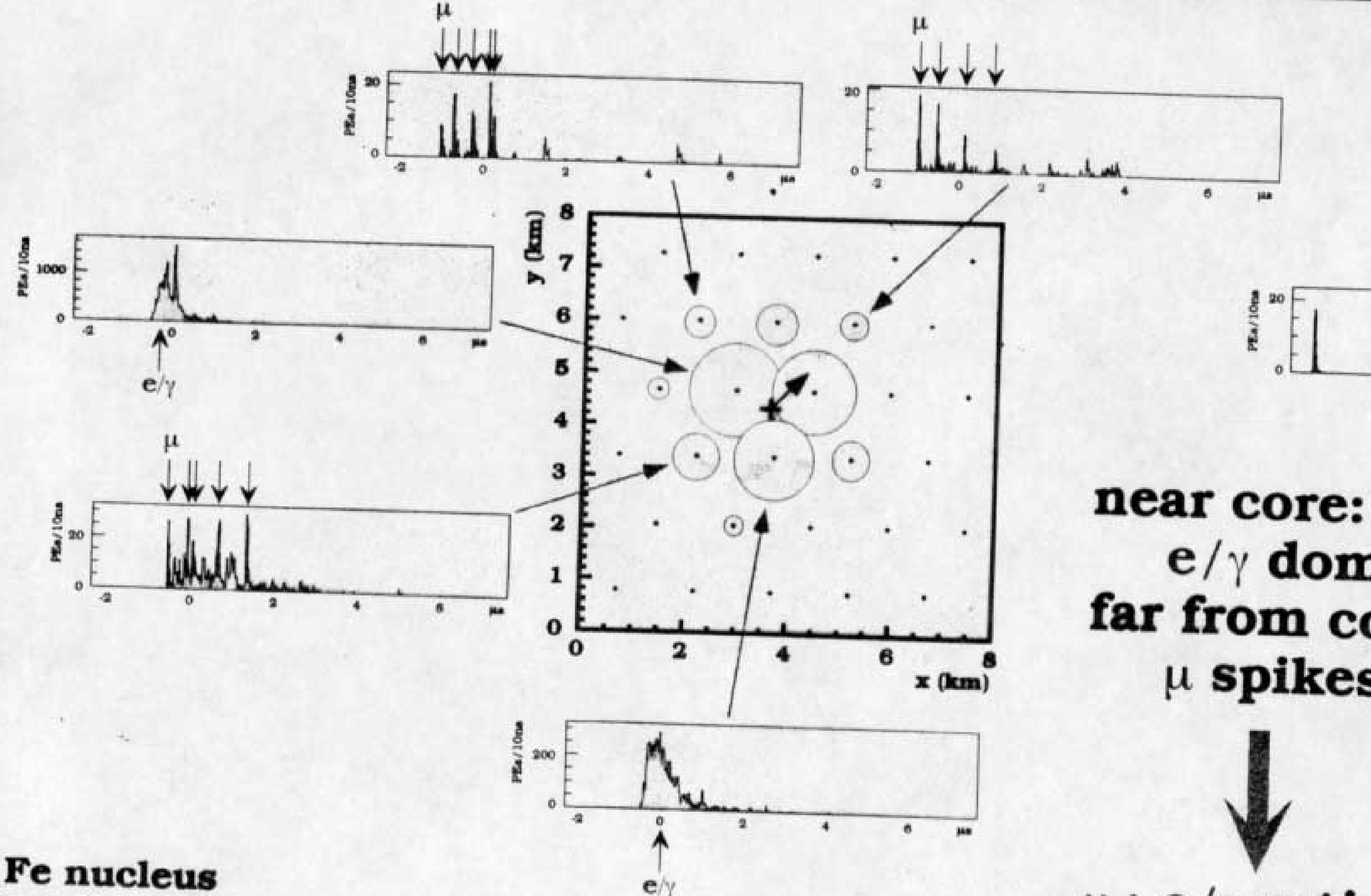
Camino consolidado a construir

Ferrocarril





Pulse Shapes in Water Ch. Detectors

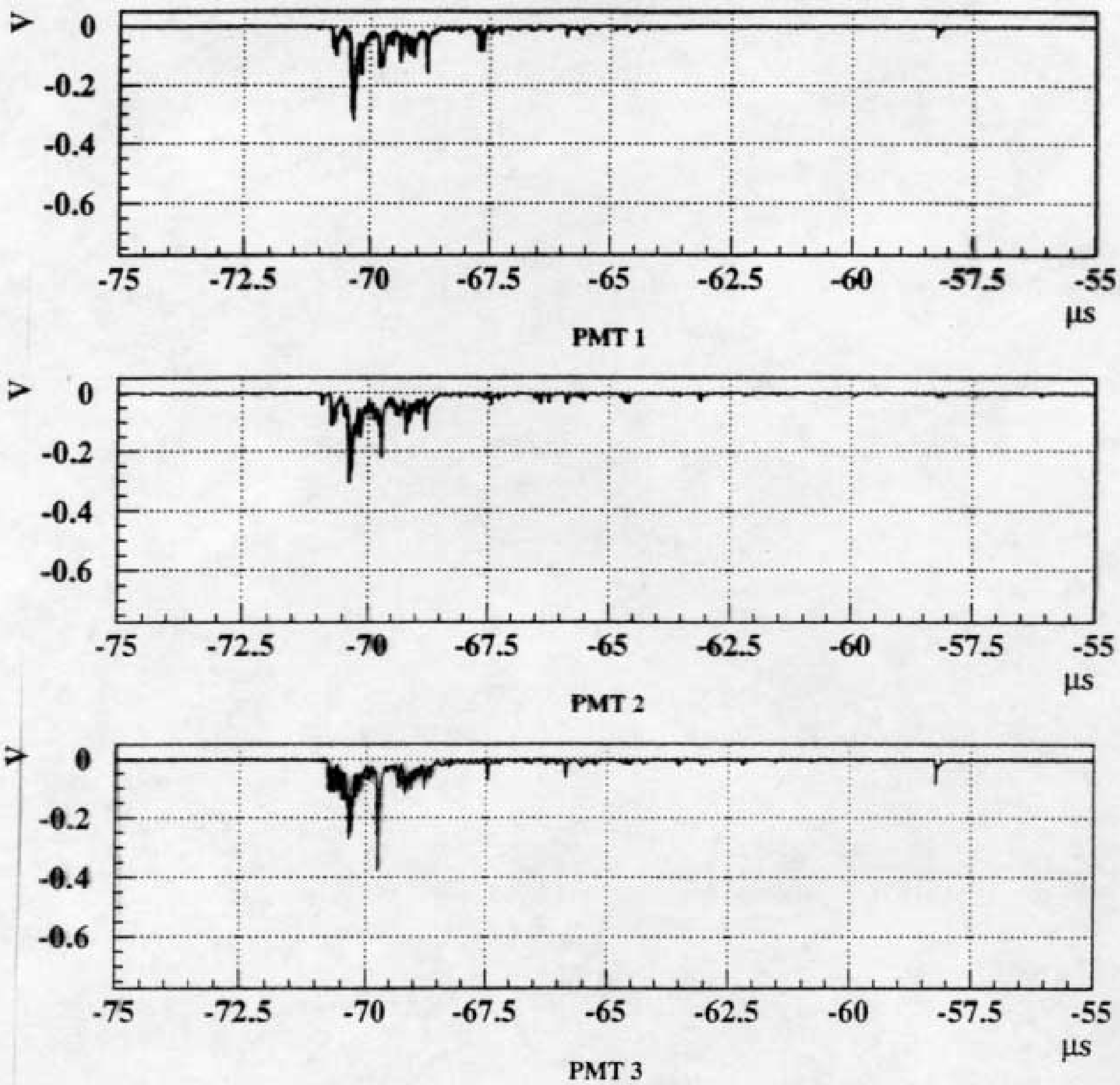


near core:
e/γ dominate
far from core:
μ spikes

$\mu : e/\gamma$ ratio
(mass sensitive)

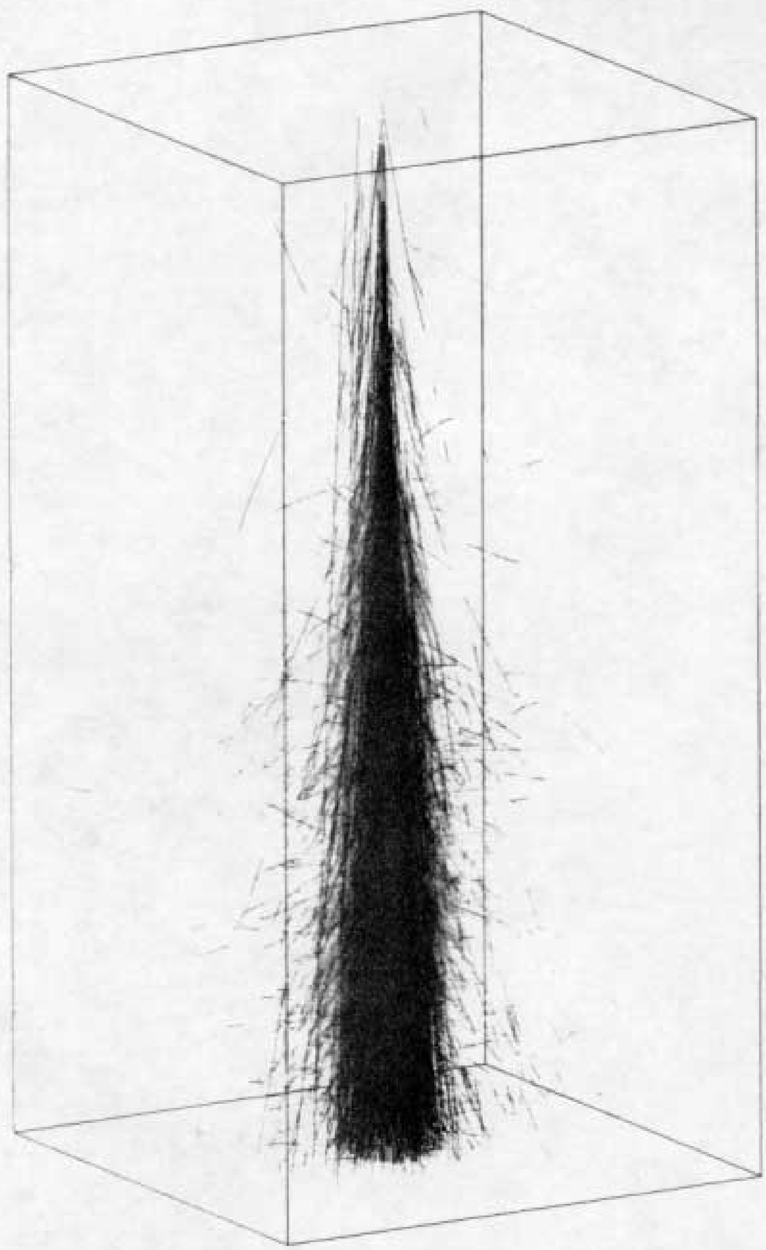
Fe nucleus
$E = 6 \times 10^{19}$ eV
$\Theta = 19^o$

961022.803



2 TANKS OPERATE IN AGASA (JAPAN) FOR 2 years

25 µs FADC



Simulation of a 10^{19} eV proton EAS using the MOCCA 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: γ green, e red, μ blue. *Drawn by Clem Pryke — University of Chicago*

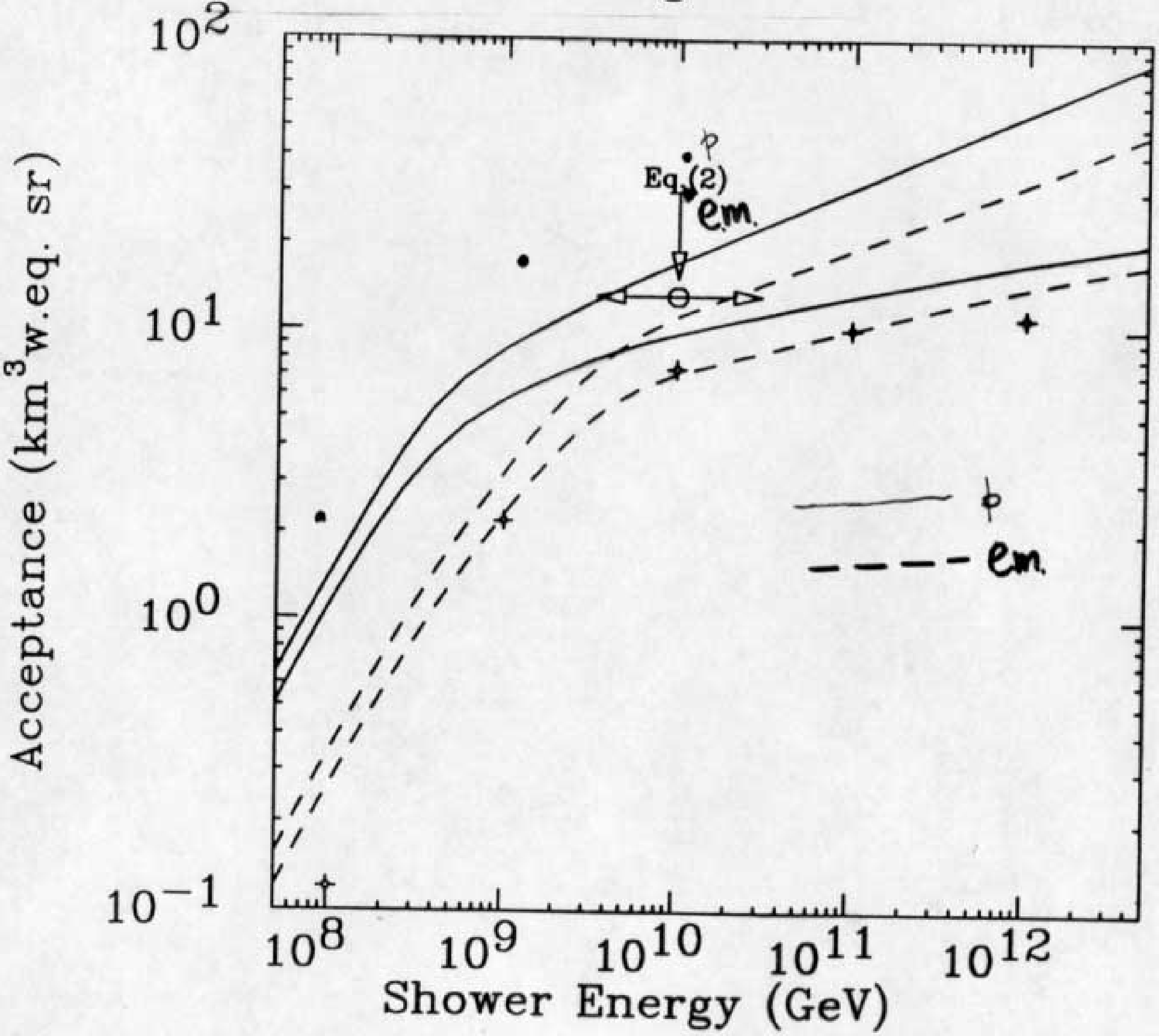
Hybrid Design....

Both the ground array technique and the FD technique have been used separately in the past. (eg Haverah Park, Fly's Eye)

The hybrid combination provides a ~10% sample of data with cross calibration of angular and energy reconstruction and shower development characteristics.

- ## Ground array features
  - Aperture well defined and large
  - 100 % duty cycle
  - Uniform right ascension exposure for anisotropy
  - direction by timing (energy by density and model)
  - muon/em ratio, shower front curvature and risetime
- ## FD features
  - Direct calorimetric energy estimator
  - good angular resolution, *improves* with gnd array
  - Xmax and longitudinal development measured
- ## Combination hybrid ....

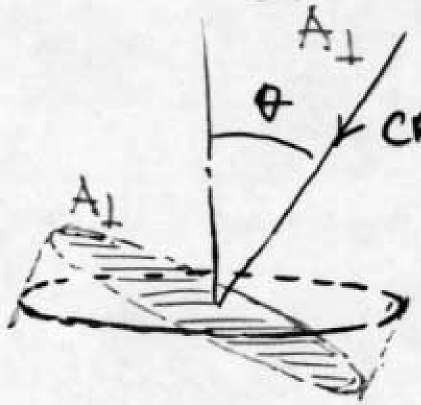
Fig. 2



G. Parente, E.Z. Venice (96) 345
K. Capelle, J.W. Cronin, G. Parente, E.Z.
Astrop. Phys. 8 (98?) 329

INCLINED SHOWERS

$$\mathcal{A} = \text{Acceptance} \simeq \int \underbrace{A \cos\theta}\, d(\sin\theta)\, d\phi = \pi A \left[1 - \cos^2\theta_{max}\right]$$



$A = 3000$ Km^2

typically $\theta < 45°$ to avoid large angle effects

$$\mathcal{A} = \frac{\pi A}{2} \simeq 4500 \text{ Km}^2\text{sr}$$

If $45 < \theta < 90°$ can be analysed

DOUBLE ACCEPTANCE !

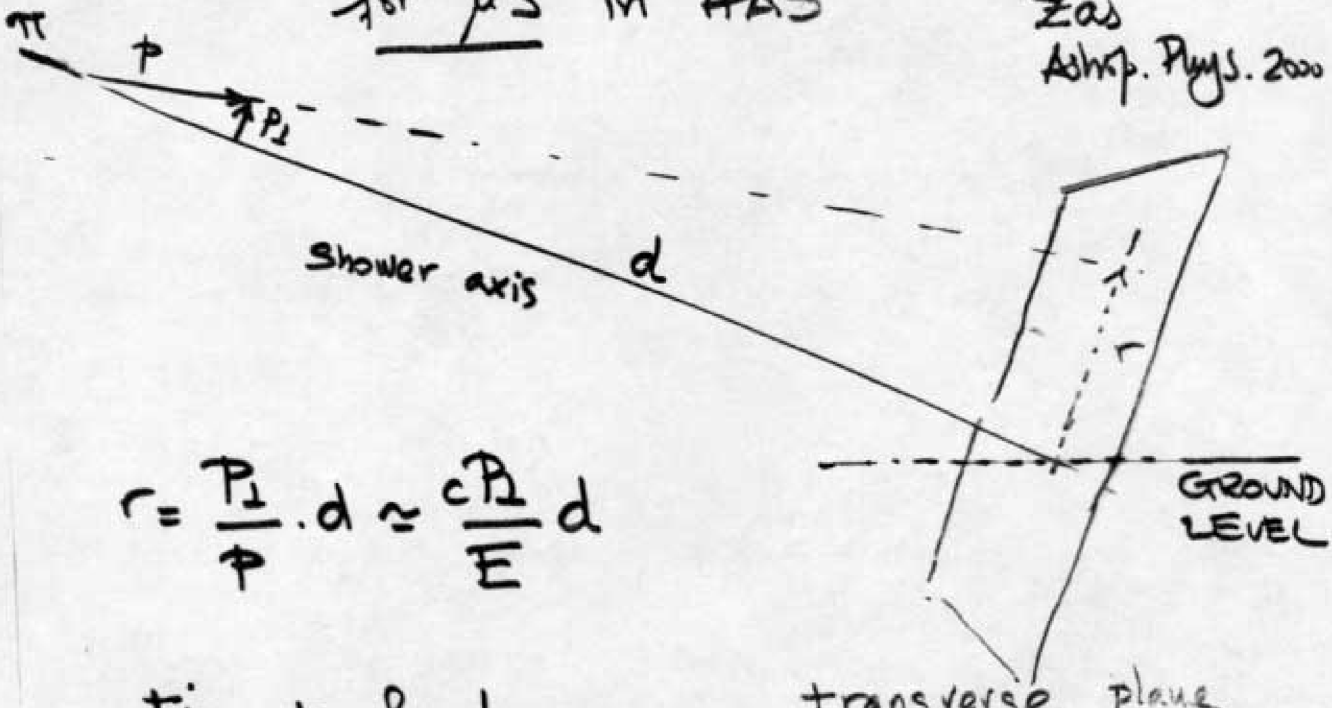
$$\mathcal{A} = 9000 \text{ Km}^2\text{sr}$$

(this started as a ν background study !)

TOY MODEL

for μ's in HAS

Ave
Vazquez
Zas
Astrop. Phys. 2000



$$r = \frac{p_\perp}{p} \cdot d \simeq \frac{c p_\perp}{E} d$$

Fix $p_\perp$ & d

μ Energy spectrum $\quad \frac{dN_\mu}{dE} = \Phi(E)$

ρ_μ lateral distribution specified $\quad \rho_\mu(r) = -\frac{\Phi(E)\,dE}{2\pi r\,dr} = \frac{c p_\perp d}{2\pi r^3}\Phi(E(r))$

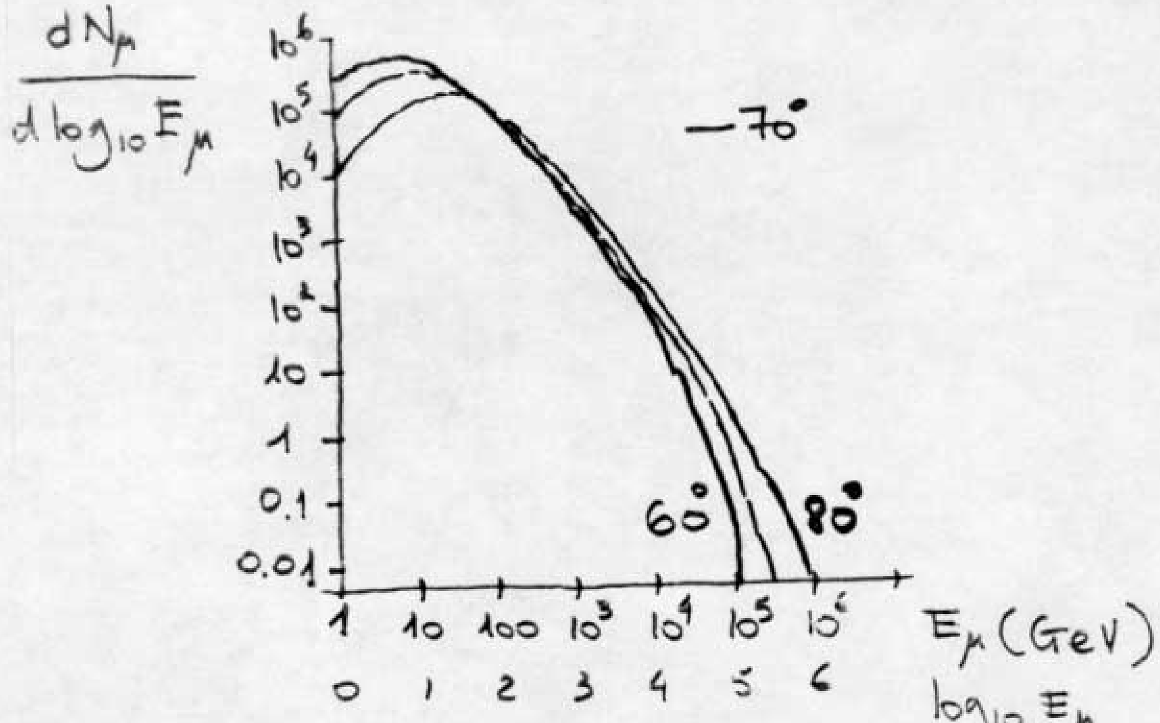
SIMULATIONS

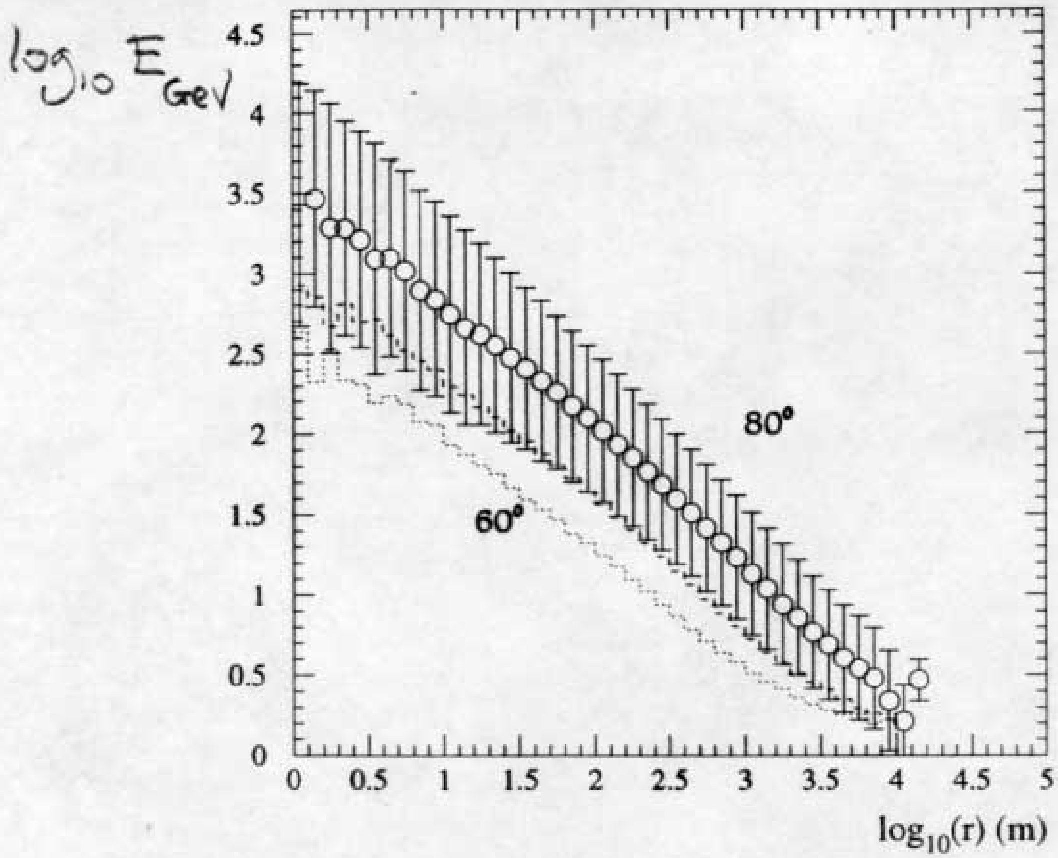
No B field 10^{19} p (100 showers)

AIRES

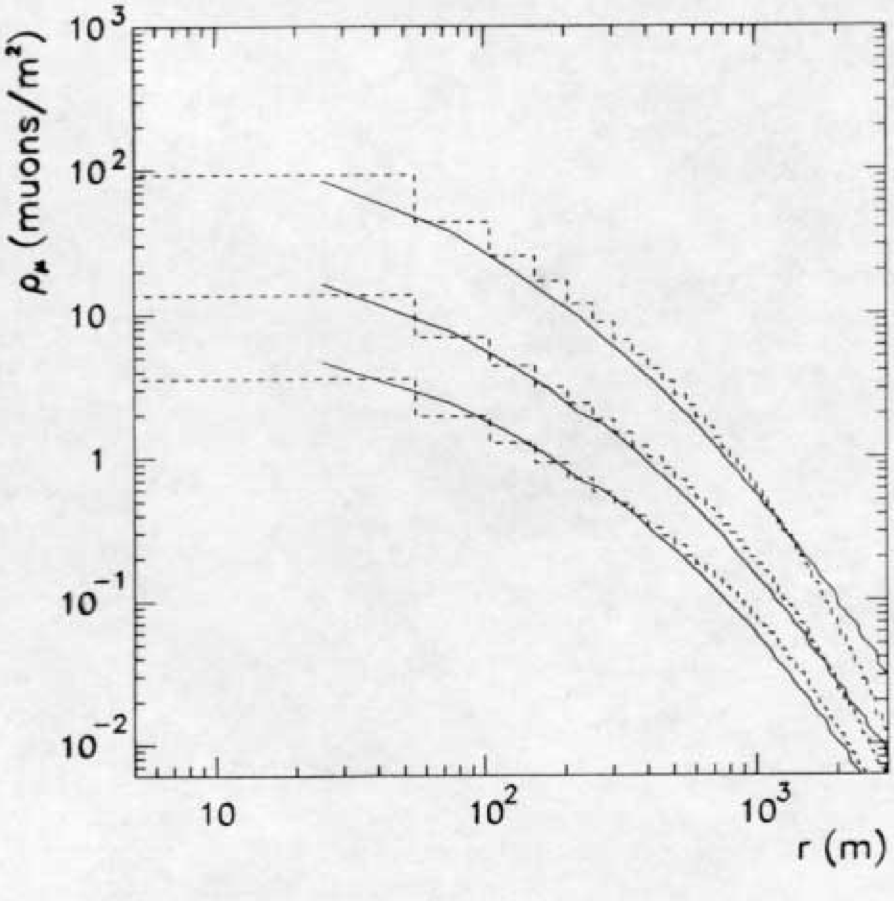
distribution of muons arriving at GROUND:

θ	d(km)	Δd	$\langle E_\mu \rangle$ at production
0°	4	2.8	8.1 GeV
60°	16	6.5	18.9 GeV
70°	32	10	32.9 GeV
80°	88	17	77 GeV
87°	276	31	204 GeV





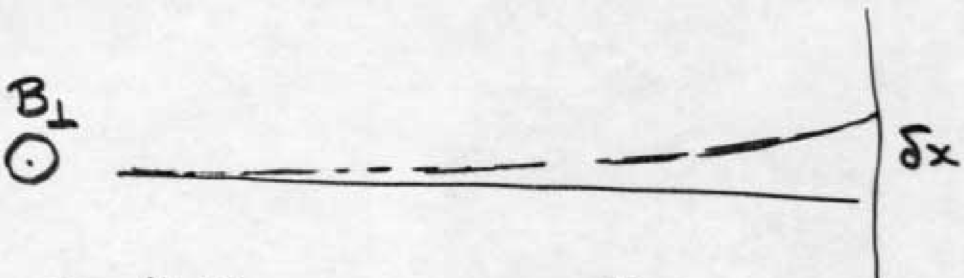
$\langle E_\mu \rangle \propto r^{-0.85}$



$p_\perp = 200\,\mathrm{MeV}$

$\langle d \rangle$, $\frac{dN_\mu}{dE_\mu}$ } from simulation

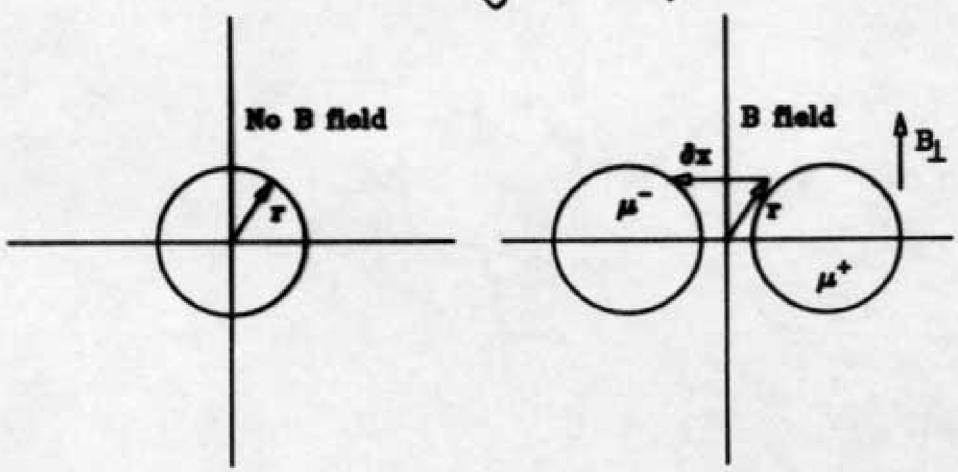
B EFFECTS



Small $\delta x \rightarrow$ $\quad \delta x \simeq \dfrac{d^2}{R \cdot 2} = \dfrac{e B_\perp d^2}{2p} = \underbrace{\dfrac{e B_\perp d}{2 p_\perp}}_{\text{constant}} r$

recalling $r = \dfrac{p_\perp}{p} d$

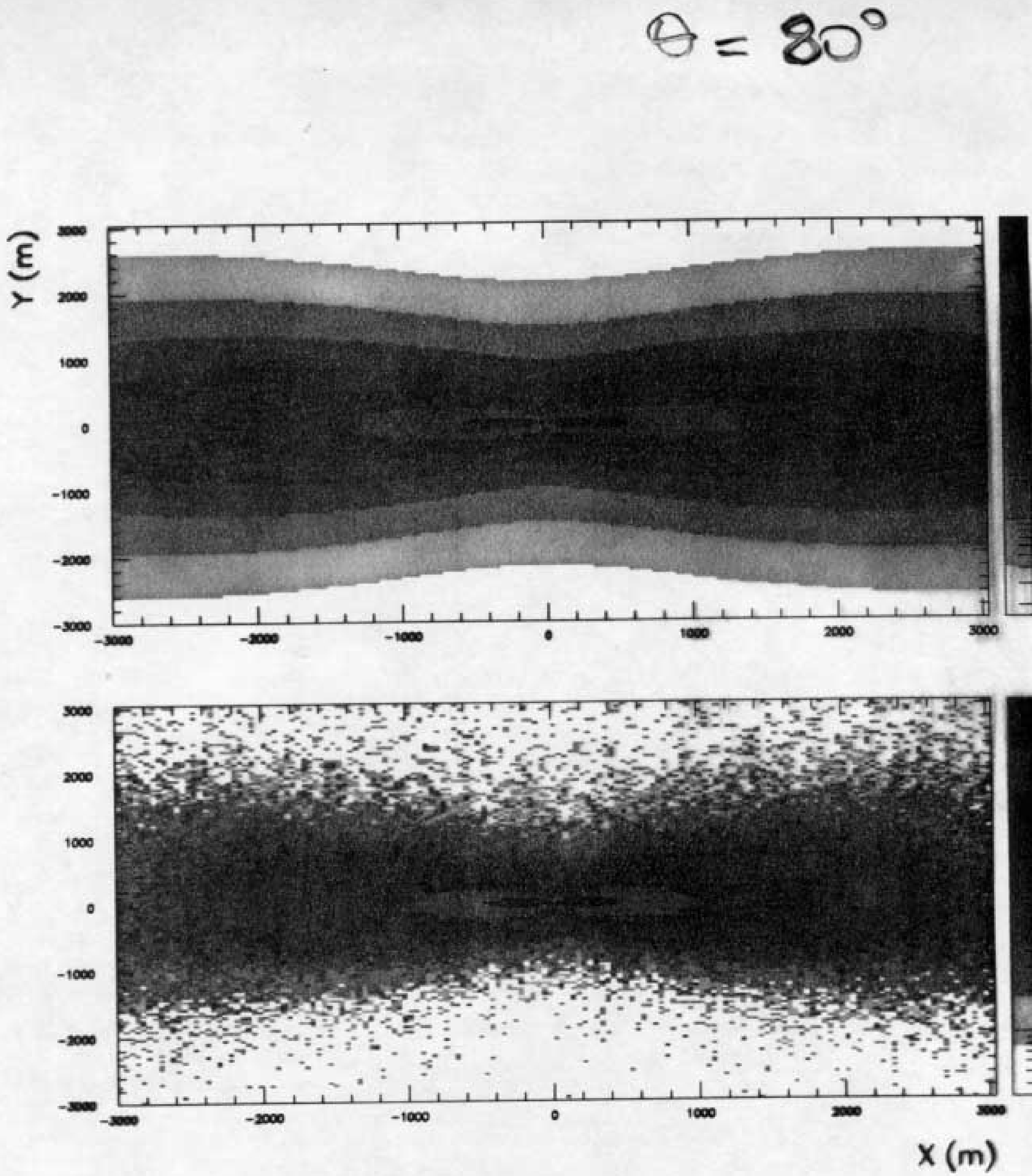
$\delta x = \alpha r$



can do transformation

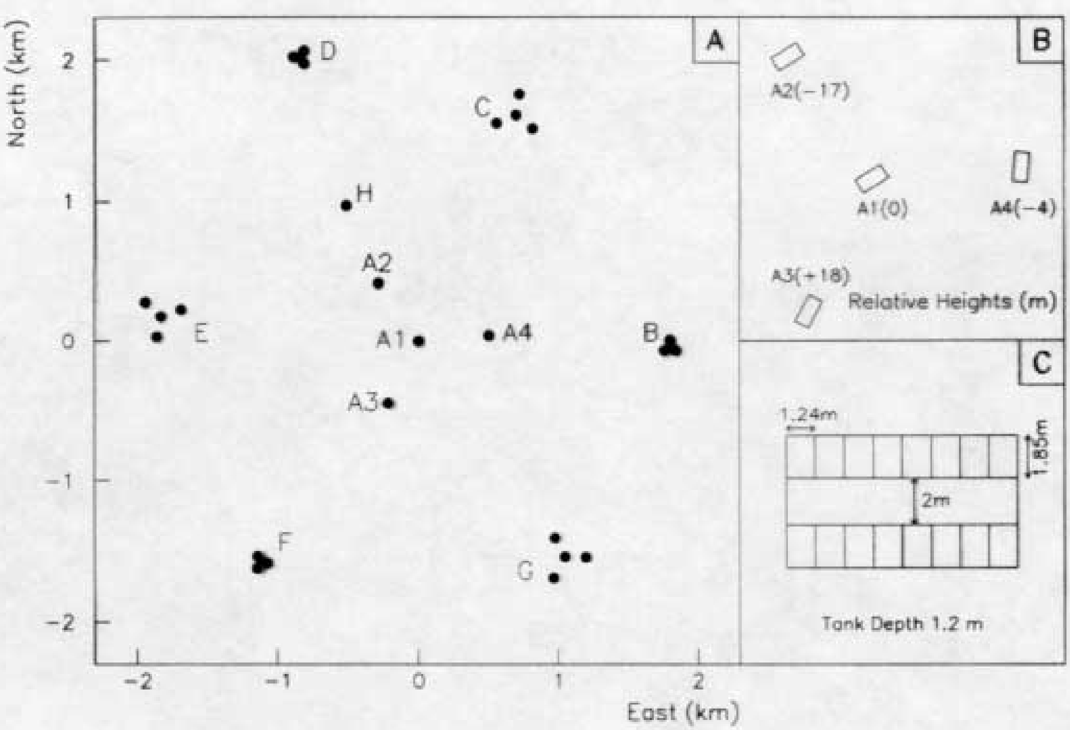
$$x = \bar{x} + \alpha \sqrt{\bar{x}^2 + \bar{y}^2} \qquad \text{No } \vec{B} \qquad \vec{B}$$

$$y = \bar{y} \qquad \Longrightarrow \bar{\rho}(\bar{x}, \bar{y}) \longrightarrow \rho(x, y)$$


θ = 80°
Y (m)
X (m)
3000
2000
1000
0
-1000
-2000
-3000
1
10^-1
10^-2

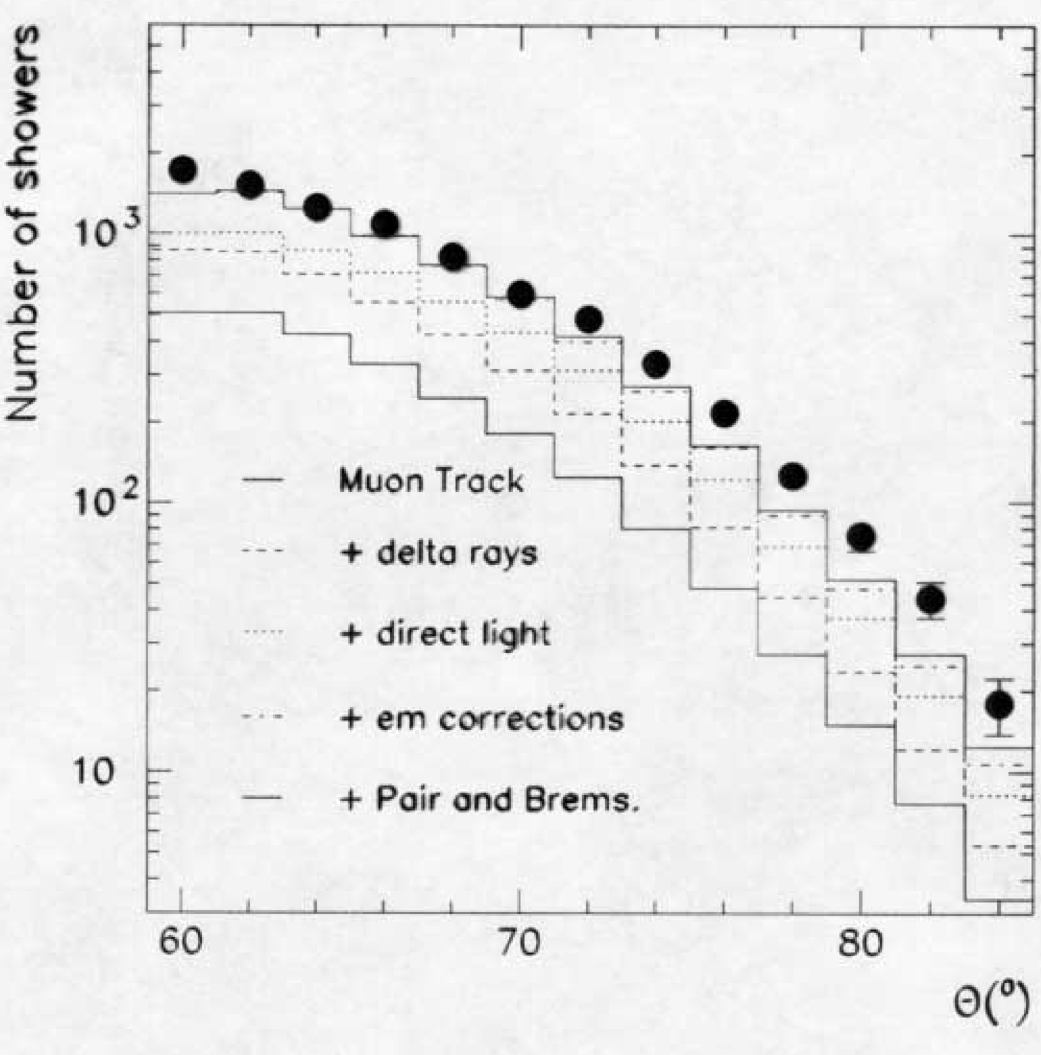
HAVERAH PARK

M. Ave
J.A. Hinton
R.A. Vazquez
A.A. Watson
E. Zas
Astrop. Phys 2000



RATE SIMULATION

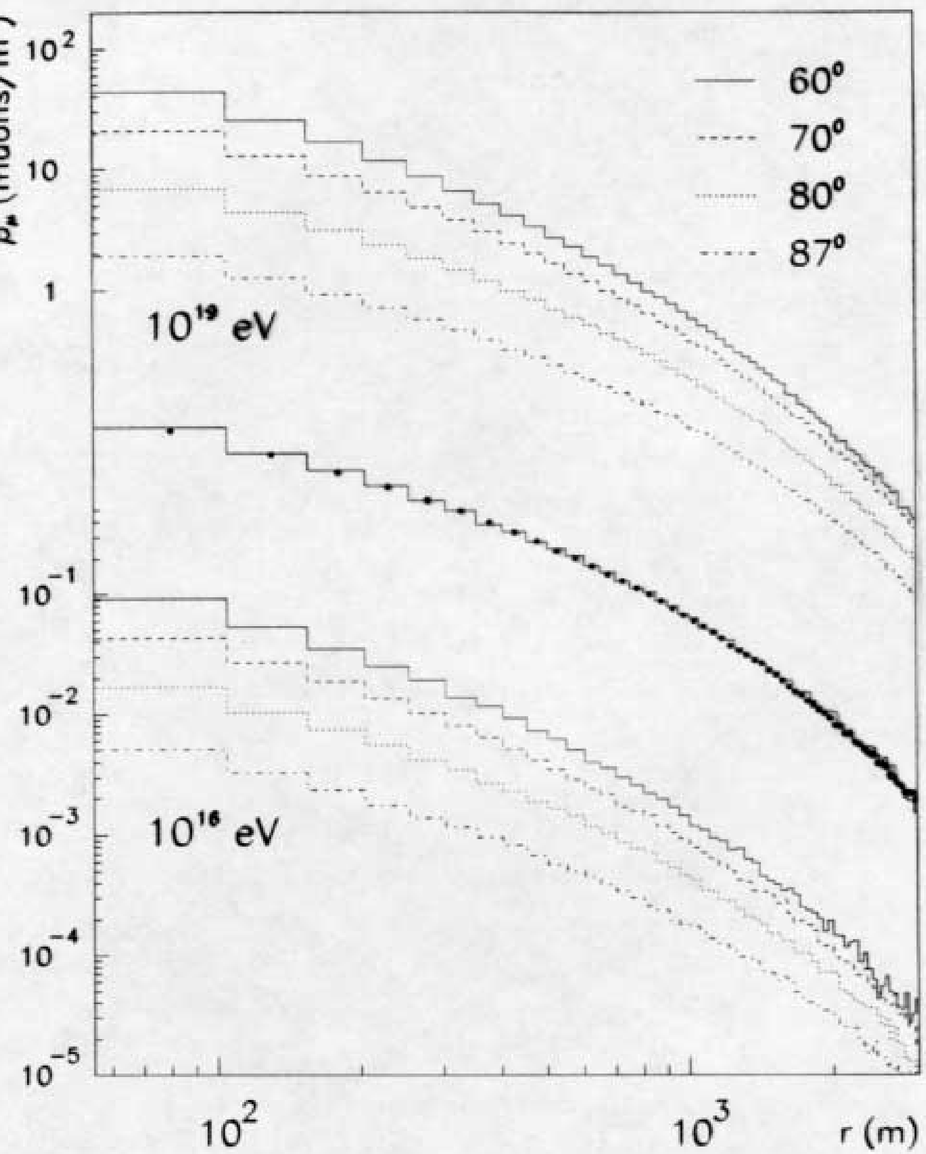
- GENERATE $\bar{N}_\mu$ MAPS
  - 40 E BINS $10^{16} - 10^{20}$ eV
  - 15 θ BINS 60° – 88°
  - 18 ϕ BINS
- SIMULATE IMPACT POINTS n r<d
  - n ~ 10.000
  - d ~ 8 Km
- READ $\bar{\rho}_\mu$ AT TRIGGER (±20% fluct)
- GENERATE TANK SIGNAL
  - corrections
- TEST TRIGGER CONDITION
- GET TRIGGERING PROBABILITY → Aeff
- CONVOLVE WITH CR FLUX (AKENO + H.P)
  - Nagano & Watson Rev Mod Phys 2000
- SMEAR WITH θ ERROR



Number of showers
10^3
10^2
10
60
70
80
Θ(°)
Muon Track
+ delta rays
+ direct light
+ em corrections
+ Pair and Brems.

also: $\frac{dN_\mu}{dr}$

100 Showers averages



Fluctuations: $\sigma_{N_\mu} \sim 20\% N_\mu$

n
tails

QUALITY CUTS

① distance < 2 Km

② χ^2 probability > 1%

③ $\Delta E_p < \frac{E_0}{2}$ (downward Energy error)

(No events $\theta > 80°$ left)

$$\Delta E_p = \sqrt{\Delta E_{fit}^2 + \Delta E_{\Delta\theta}^2}$$

$E_p > 10^{19}$	$E_p > 4\,10^{19}$	$E_p > 10^{20}$
46	7	2

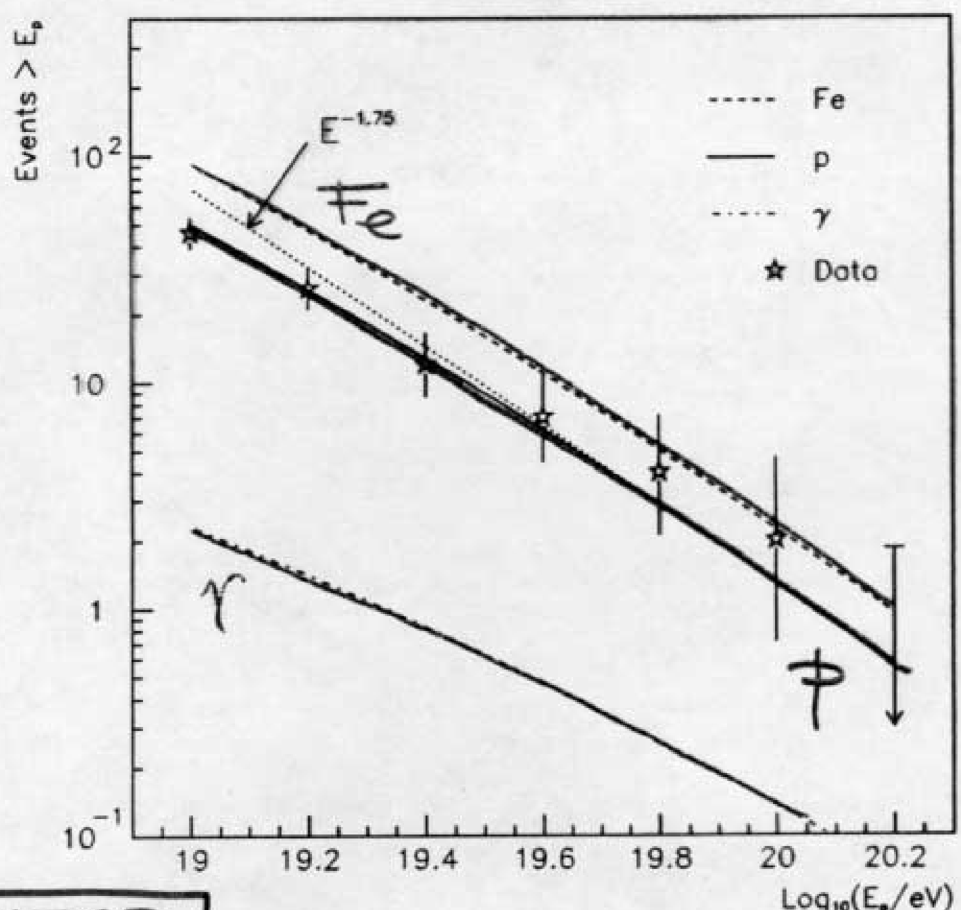
TABLES

MR	Zenith (°)		RA (°)	Dec. (°)	$\log_{10}(E_p/\mathrm{eV})$			χ^2/ν
14050050	65	±1.2	86.7	31.7	20.09	-0.15	+0.26	10.3/10
18731630	60	±2.3	318.3	3.0	20.06	-0.03	+0.03	45.8/43
14182627	70	±1.3	121.2	8.0	19.85	-0.26	+0.42	4.2/10
19167320	72	±1.3	152.5	25.9	19.82	-0.06	+0.04	48.4/40
15301069	74	±1.2	50.0	49.4	19.78	-0.05	+0.06	26.7/32
12753623	74	±2.1	304.9	17.1	19.75	-0.10	+0.06	17.1/11
12519070	70	±1.3	47.7	8.8	19.62	-0.08	+0.06	10.2/13

TABLE I. Zenith angle, arrival direction coordinates and shower energy (assuming proton primary) of selected showers with energy $> 4 \times 10^{19}$ eV. MR is the event record number. The reported χ^2 values refer to the energy fits.

M. Ave, J.H. Hinton, R.A. Vazquez, A.A. Watson, E.Z

Phys. Rev. Lett. 85 (2000) 2244

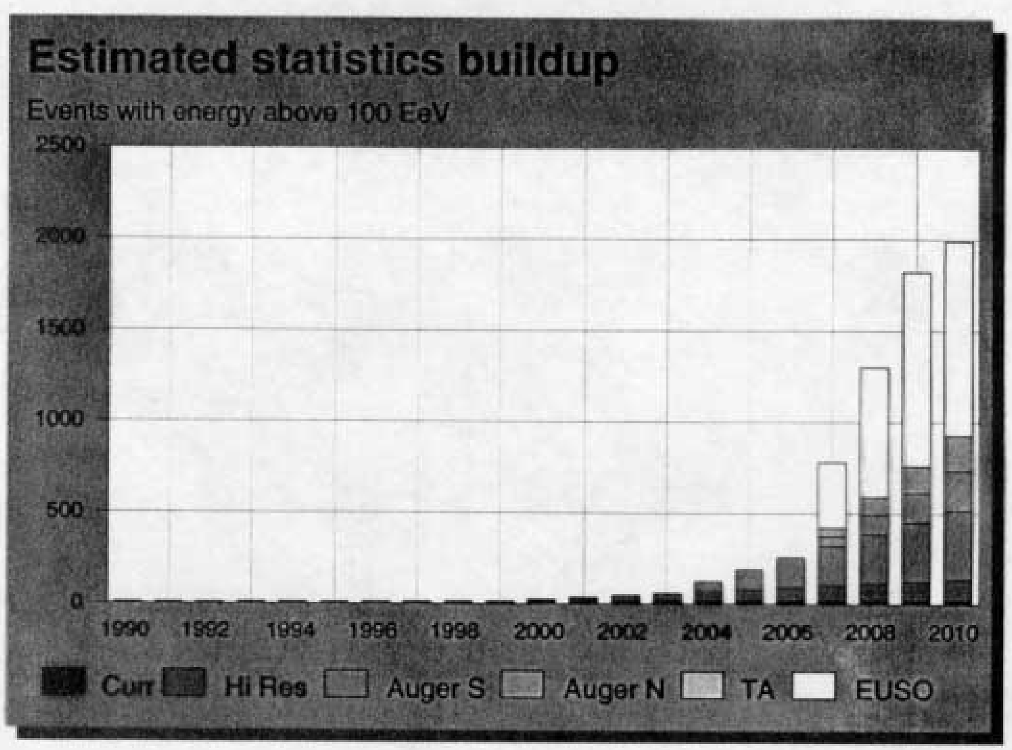


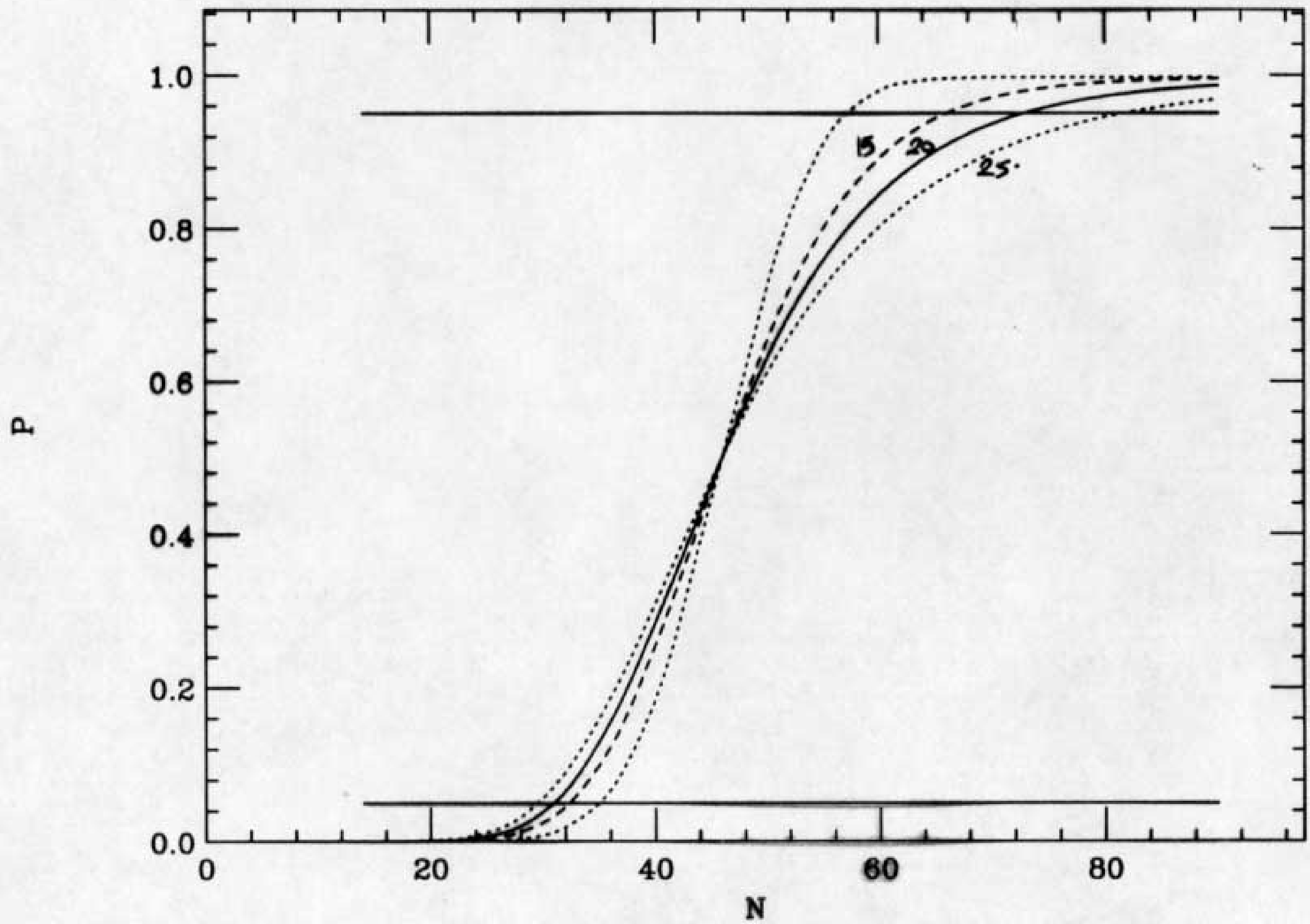
UHECR

CONCLUDE @ 95% C.L.

for $E > 10^{19}$ eV LESS THAN 41% of γ's

for $E > 4 \cdot 10^{19}$ eV LESS THAN 55% of γ's


Estimated statistics buildup
Events with energy above 100 EeV
2500
2000
1500
1000
500
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Curr
Hi Res
Auger S
Auger N
TA
EUSO


P
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
N
15
20
25