



DUMAND - Deep Underwater Muon and Neutrino Detector

*Transparencies of the DUMAND Presentation
before the HEPAP Subpanel on Major Detectors in
Non-Accelerator Physics*

March 20, 1989

Department of Energy

V. Z Peterson, V.J. Stenger, J.G. Learned and G. Wilkins

for the DUMAND Collaboration:

University of Aachen, University of Bern,
California Institute of Technology, University of Hawaii,
University of Kiel, Kinki University, Kobe University
Okayama University, Scripps Institution of Oceanography,
Institute for Cosmic Ray Research, University of Tokyo,
Vanderbilt University, University of Wisconsin

Hawaii DUMAND Center
University of Hawaii
2505 Correa Rd.
Honolulu, HI. 96822

*Transparencies of the DUMAND Presentation
before the HEPAP Subpanel on Major Detectors in
Non-Accelerator Physics*

March 20, 1989
Department of Energy

V. Z Peterson, V.J. Stenger, J.G. Learned and G. Wilkins

for the DUMAND Collaboration:

University of Aachen, University of Bern,
California Institute of Technology, University of Hawaii,
University of Kiel, Kinki University, Kobe University
Okayama University, Scripps Institution of Oceanography,
Institute for Cosmic Ray Research, University of Tokyo,
Vanderbilt University, University of Wisconsin

This report contains copies of the transparencies from the oral presentations on the DUMAND Stage II (Octagon Array) proposal before the Subpanel on Major Detectors in Non-Accelerator Physics. This subpanel of the High Energy Physics Advisory Panel (HEPAP) was chaired by R. Adair. The other members were: T. Fields, W.F. Fry, T. Gaisser, H. Gordon, R. Lanou, A. Melissinos, B. Sadoulet, M. Strovink, and T. Weeks. L. Voyvodic was the Executive Secretary. HEPAP advises both the U.S. Department of Energy and National Science Foundation on high energy physics. The meeting was held at the Department of Energy, Germantown, MD, on March 20, 1989. DUMAND made the first presentation, followed by GRANDE and Fly's Eye.

The enclosed transparencies are in the approximate order of presentation. Some contain notations that were added after the actual talks. A few additional figures that were not actually shown have been added for completeness. It is also to be noted that the presentation included a display of the Philips' photomultiplier tube and a ten minute video tape on deployment that included interviews with V. Anderson and F. Spiess of Scripps and C. Helsley of the Hawaii Institute of Geophysics. Also, sample fiber optic cables and the McDonnell-Douglas make-and-break single mode undersea fiber optic connector, were passed around for the Subpanel's information.

In addition to the speakers, the following DUMAND collaborators attended the meeting and contributed importantly to the discussions: P. Bosetti, H. Bradner, P. Grieder, R. March, C. Roos, and M. Webster. The speakers are grateful for their guidance and support, and wish to emphasize that everything presented represented the efforts of the full collaboration.

DUMAND-II — THE OCTAGON ARRAY

I. INTRODUCTION V. Peterson (6 min.)

Main features of proposal

Cost estimate, collaborators, time schedule

II. PHYSICS GOALS:

Neutrino astrophysics..... V. Stenger (15 min)

Cosmic ray physics..... V. Stenger (5 min)

Particle physics..... J. Learned (8 min)

III. DUMAND-I RESULTS; DESIGN OF DUMAND-II.

Short Prototype String J. Learned (10 min)

Octagon Array design..... J. Learned (10 min)

Deployment of array..... G. Wilkins (20 min)
(including videotape)

IV. ORGANIZATION, BUDGET..... V. Peterson (10 min)

Revised collaboration -- Representatives present
Cost estimate; group contributions
Time schedule

V. SUMMING UP..... J. Learned (6 min)

V.J. Stenger

March 20, 1989

Astro- and Cosmic Ray Physics

- What can we learn from the detection of very high energy neutrinos from astronomical sources?
- What are the possible sources?
- How can we estimate the expected neutrino fluxes?
- What are the capabilities of DUMAND for neutrino detection?
- What are the capabilities of DUMAND for "Muon Astronomy?"
- What are the capabilities of DUMAND for Cosmic Ray Physics?

What can we learn from the detection of very high energy neutrinos from astronomical sources?

■ Sites of cosmic ray acceleration

ν_μ 's result from hadronic processes

■ Properties of sources deep inside matter

Complements γ -ray observations

■ Properties of neutrinos

Example of SN1987a

■ The unexpected

New window on the universe

What are the possible sources?

- Binary systems with a neutron star

Cygnus X-3

Hercules X-1

LMC X-4

- Expanding supernova shells

Very high energy ν_μ 's

- Active galactic nuclei

Super-massive black hole?

Centaurus A seen in TeV γ -rays

- Center of galaxy

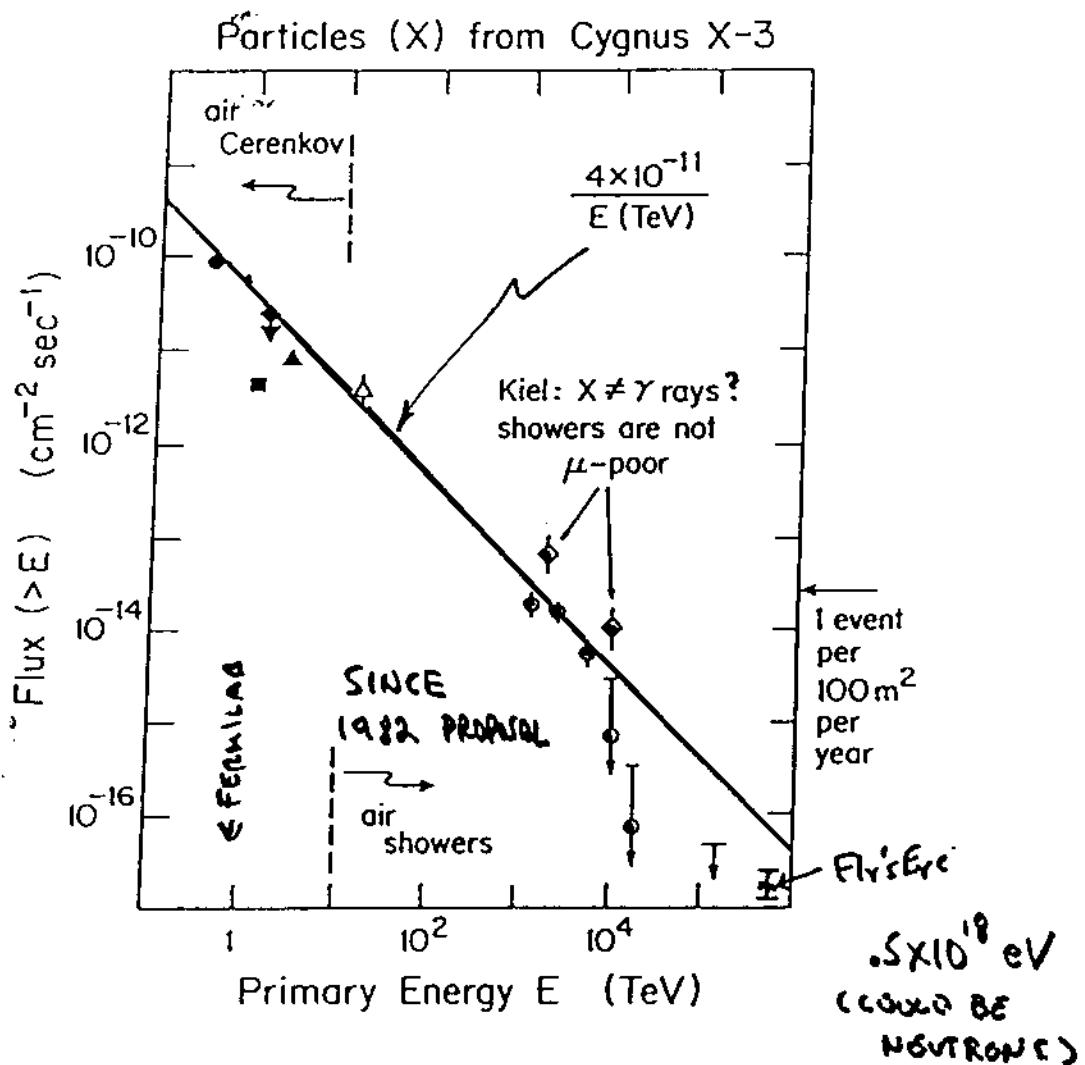
Interaction of cosmic rays

+

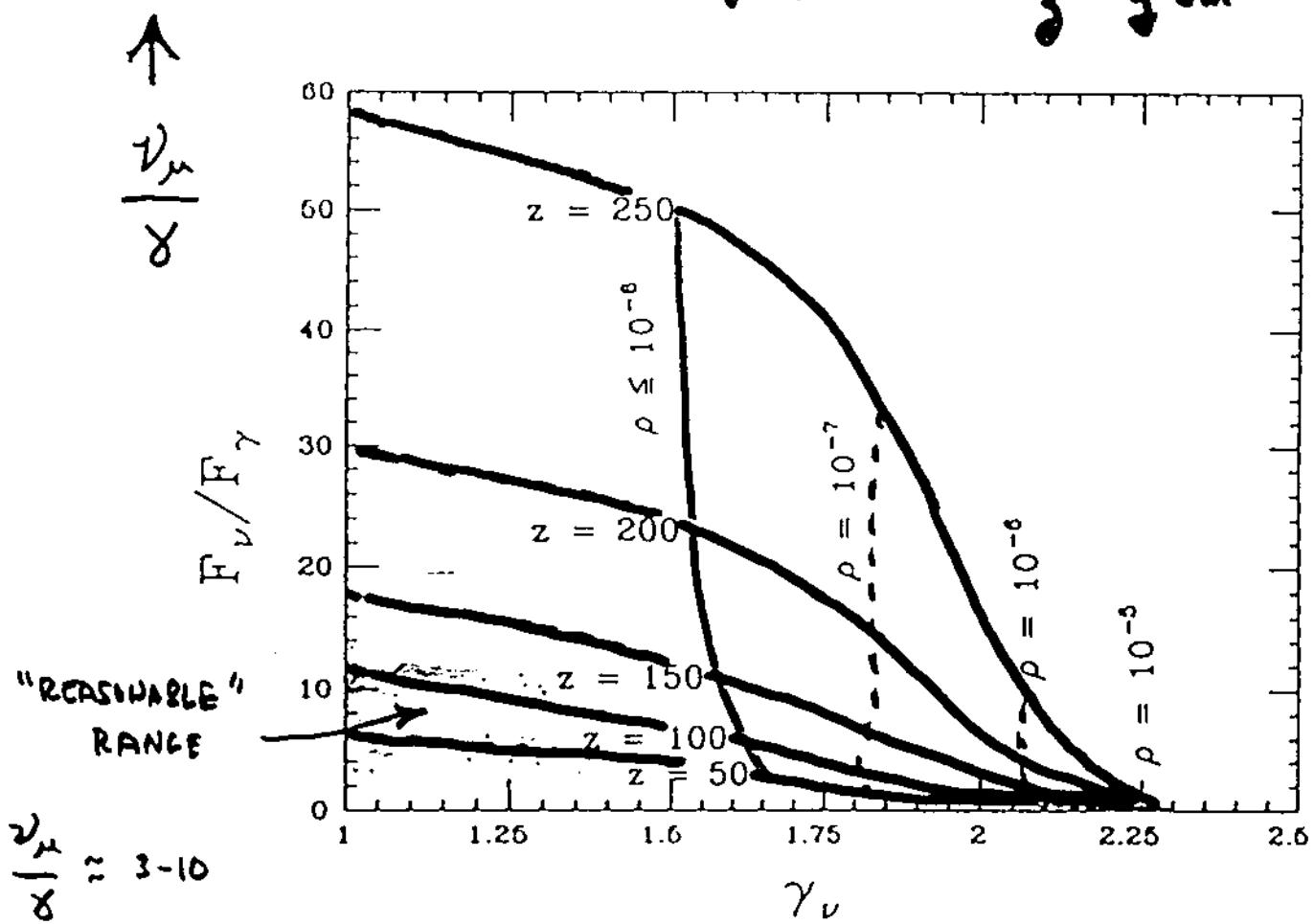
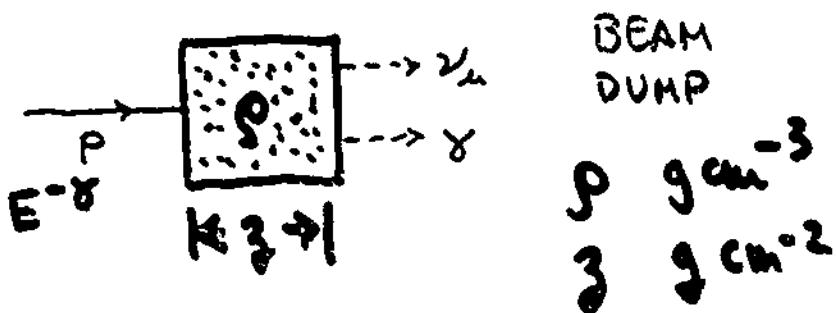
Observed γ -ray Fluxes from Cygnus X-3

VERY LIKELY HADRONIC - π^0 DECAY

π^\pm 's ν_μ 's



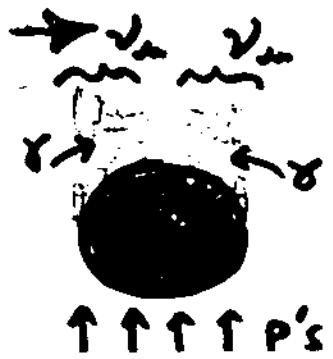
The Dependence of ν_μ/γ on Source Parameters



INTEGRAL SPECTRAL INDEX
OF NEUTRINOS

ADDITIONAL MULTIPLYING FACTOR:

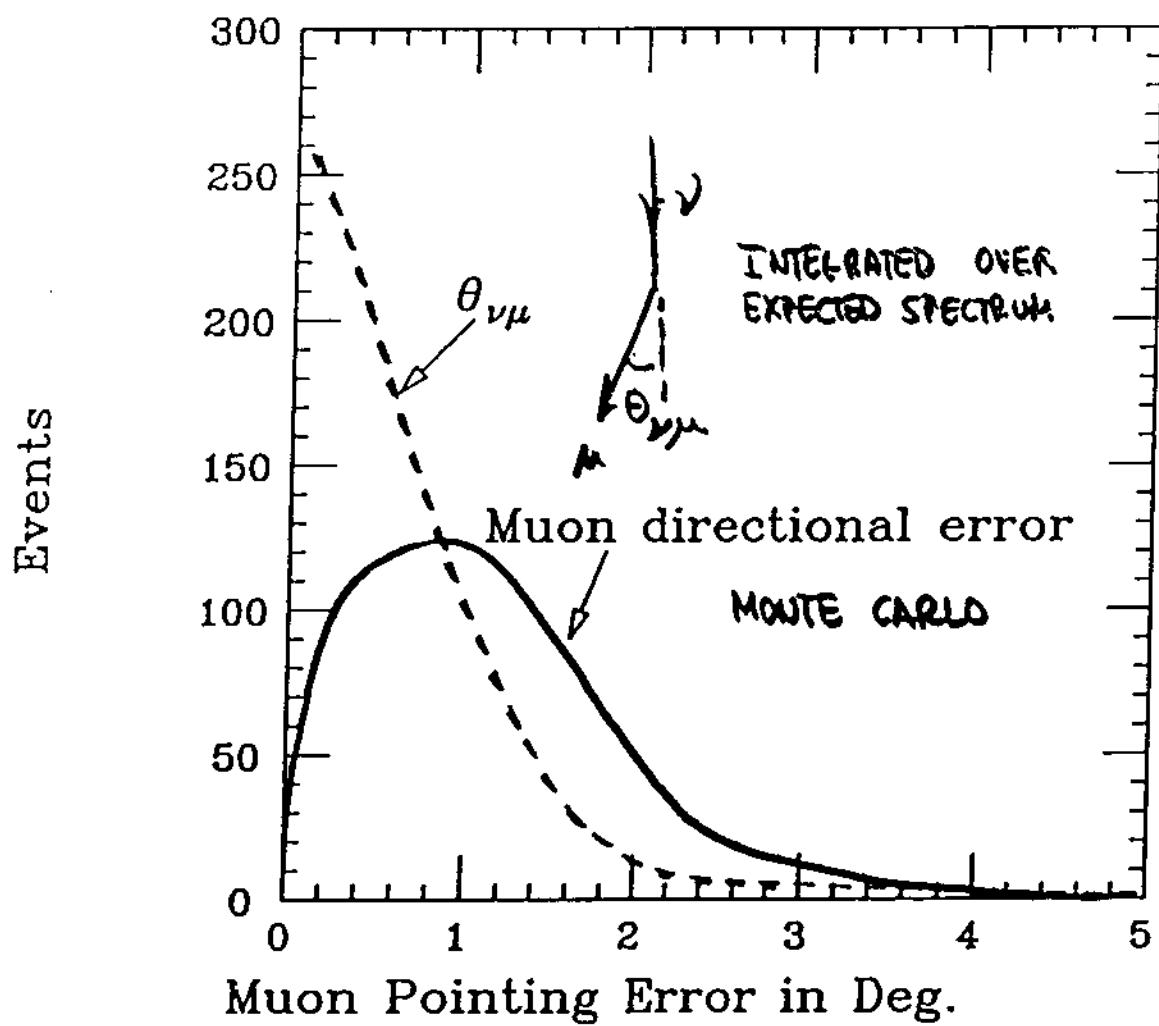
$$\frac{\text{DUTY FACTOR FOR } \nu_\mu}{\text{DUTY FACTOR FOR } \gamma} > 1$$



What are the capabilities of DUMAND for neutrino detection?

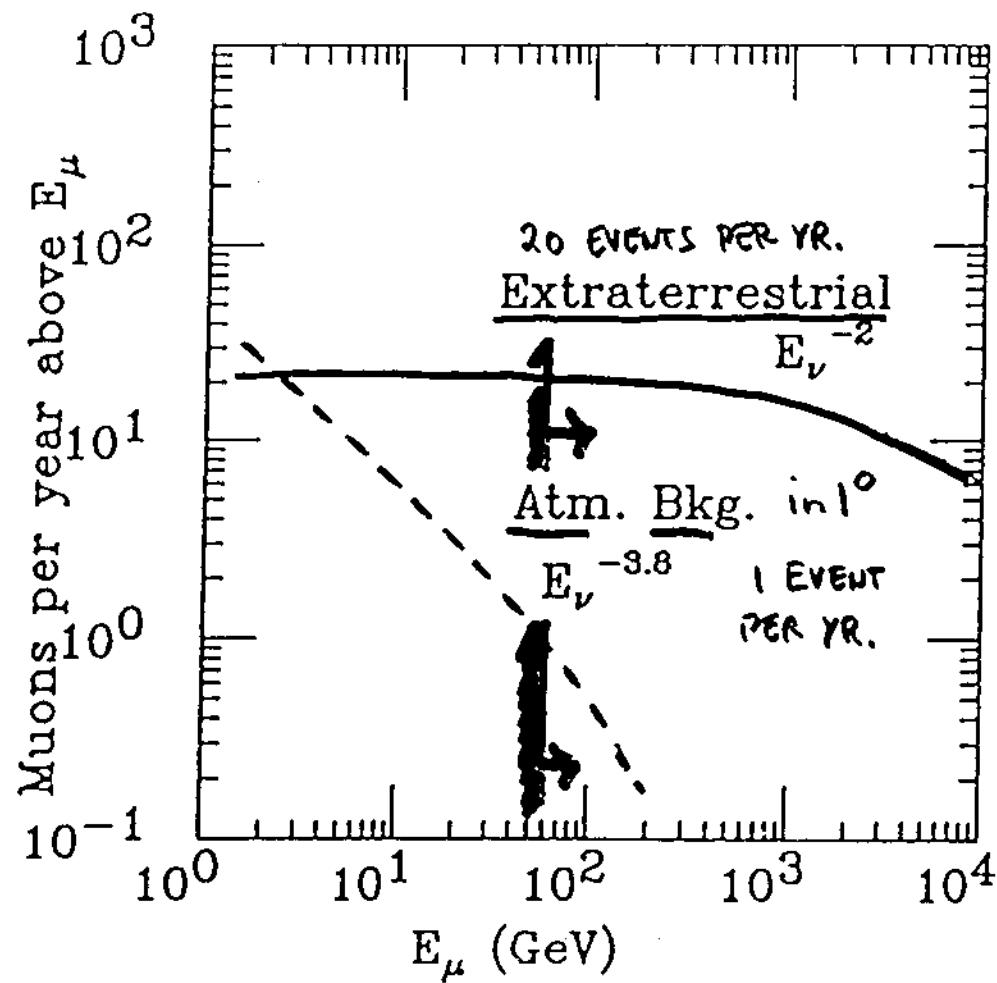
- Effective area: $20,000 \text{ m}^2$ $2.3\pi \text{ sr}$
 $(\text{IMB} = 400 \text{ m}^2)$ $145,000 \text{ m}^2 \text{ sr}$
- Angular resolution: 10°
- Spectral resolution: *some*
- Sky coverage: $\sim 100\%$
- Minimum detectable flux: $10 \text{ EVENTS PER YEAR}$
 $(4-7) \times 10^{-10} \text{ cm}^{-2} \text{ s}^{-1} > 1 \text{ TeV}$ $(\text{Bkg.} < 1 \text{ EVENT PER YEAR})$
 $\approx \text{OBSV} \text{D} \text{ X RAY FLUXES}$
- Events rates from possible sources:
 - Assuming $\nu_\mu/\gamma = 1$ **MIN**
 - At existing observational limits **MAX**
(models give $1 - 1000$)
- simulation of signal from galactic center **POSSIBILITY**

Determination of the Neutrino Direction



Comparison of Muon Spectra from Atmospheric and Extraterrestrial Neutrinos

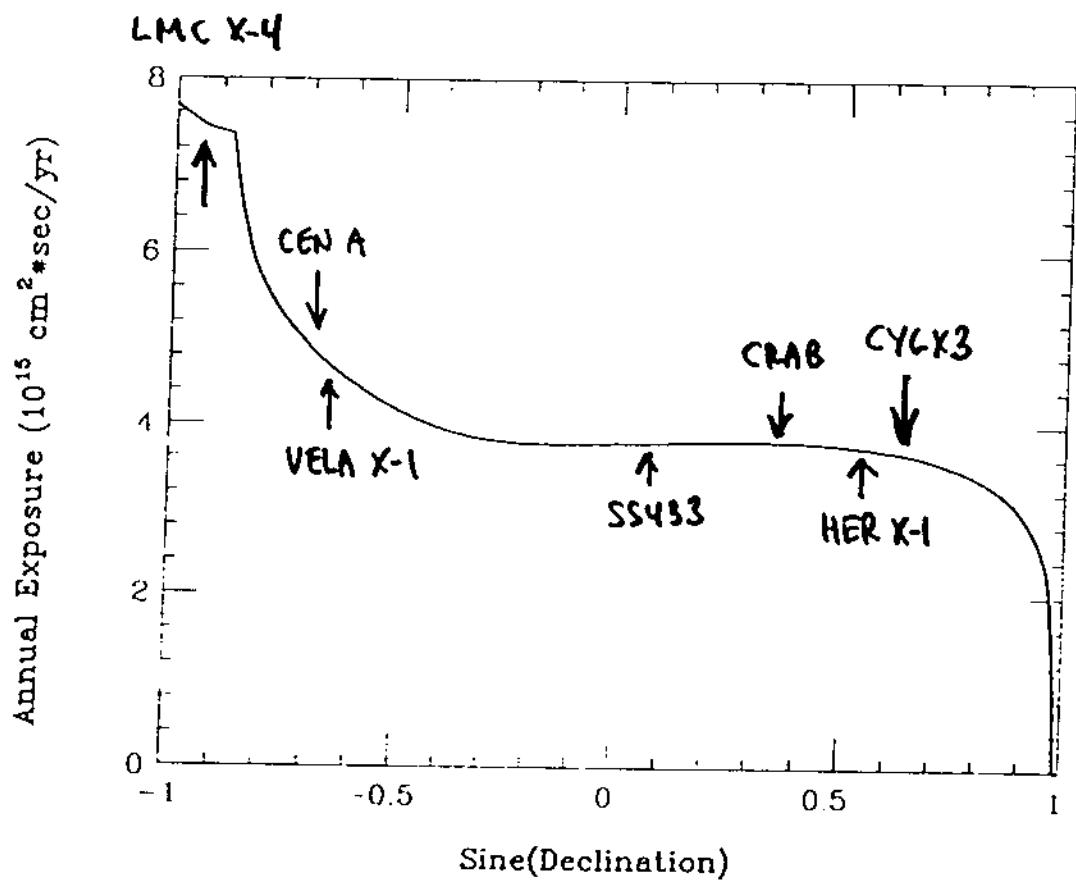
Integral Muon Spectrum



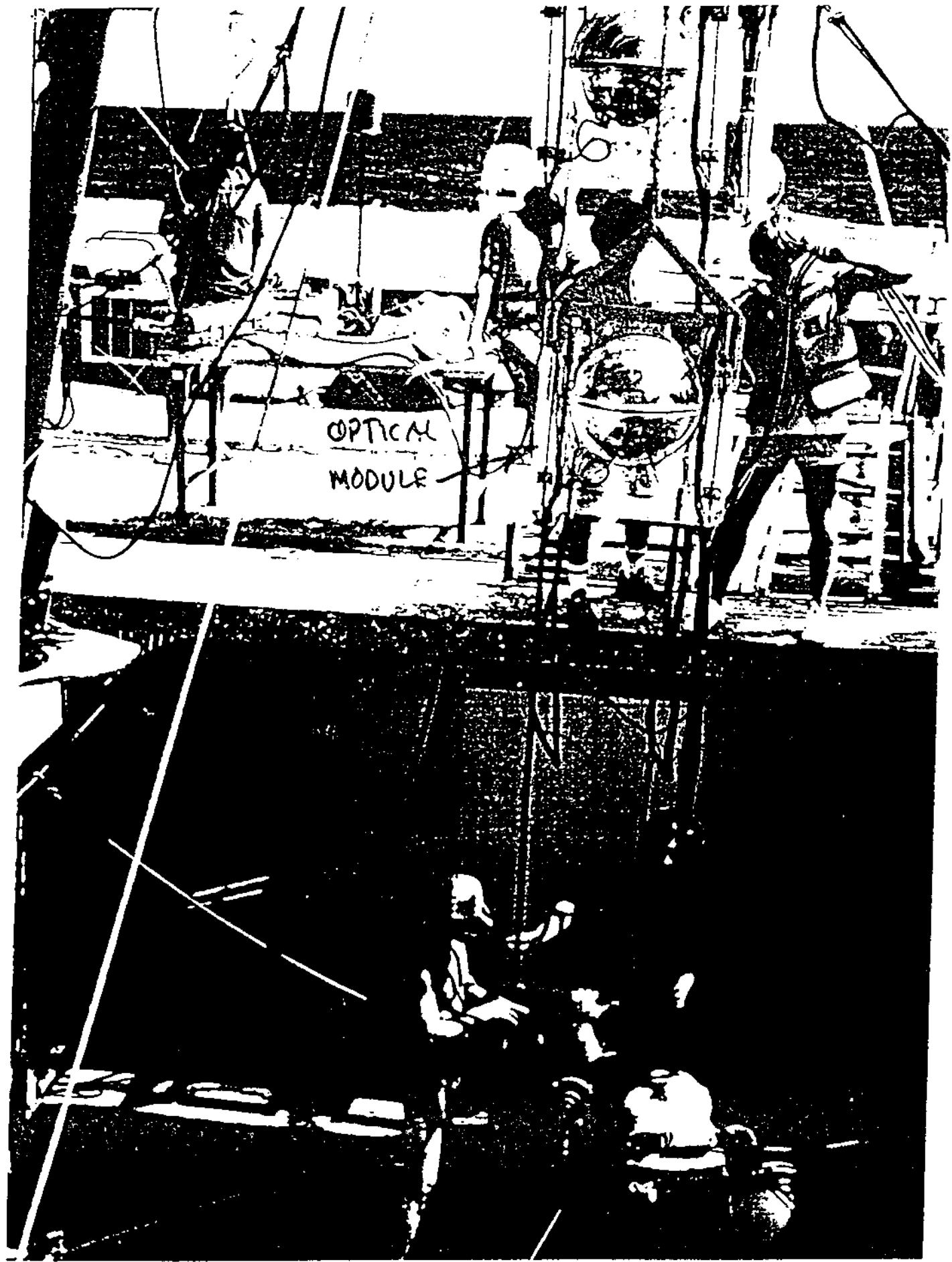
$E_{\mu} \geq 60 \text{ GeV TO TRIGGER}$

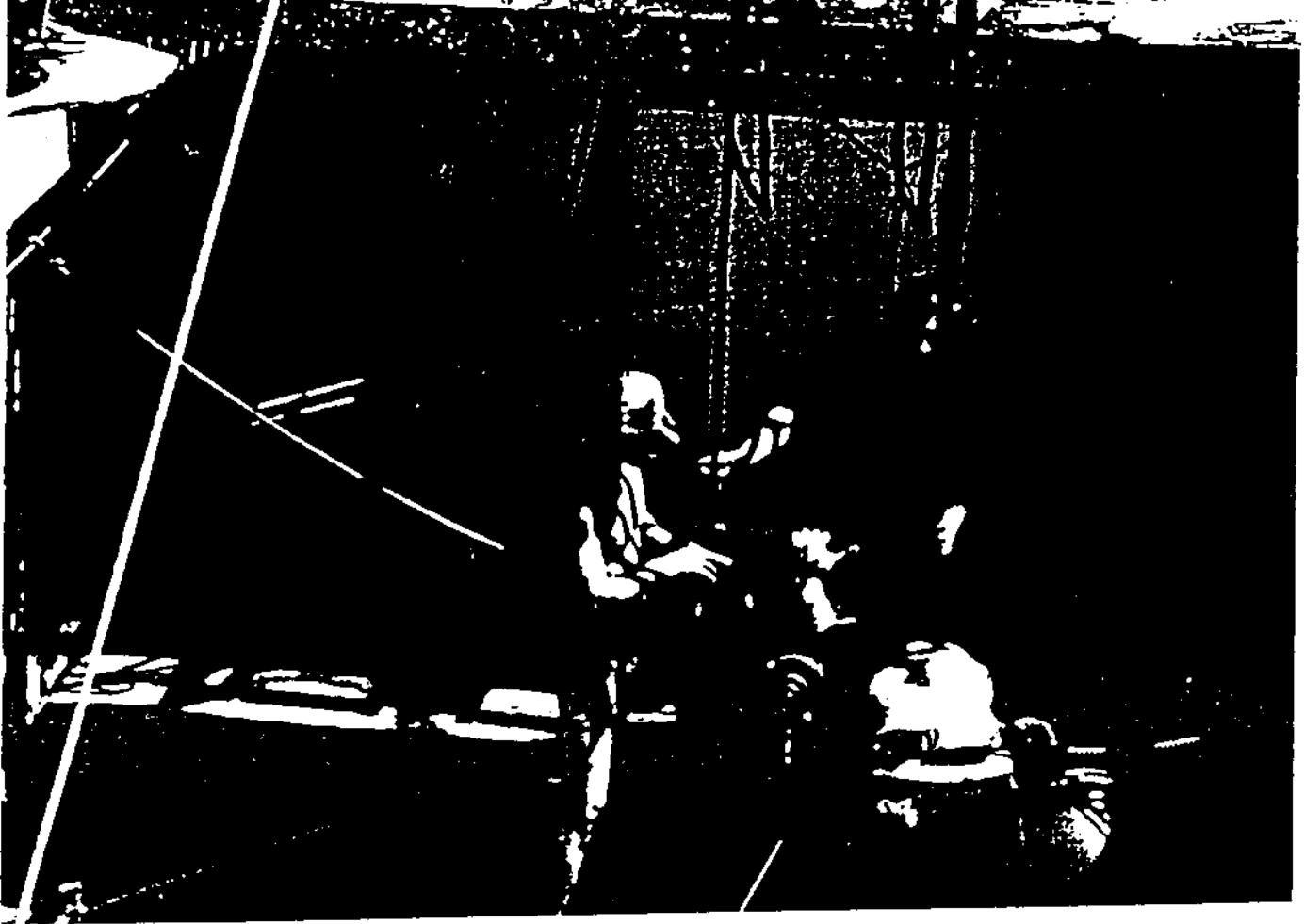
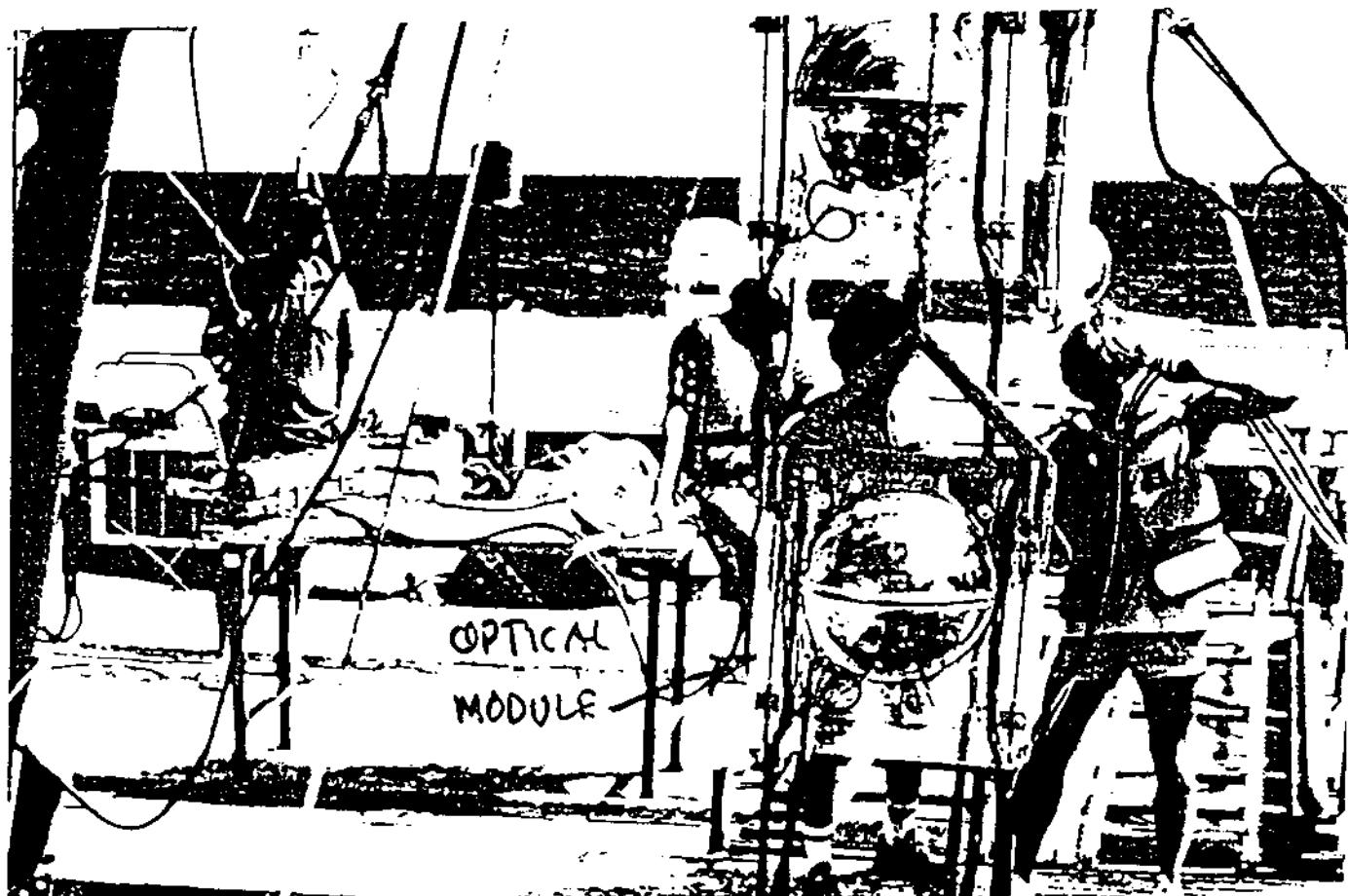
NOTE: NO LOSS OF SIGNAL

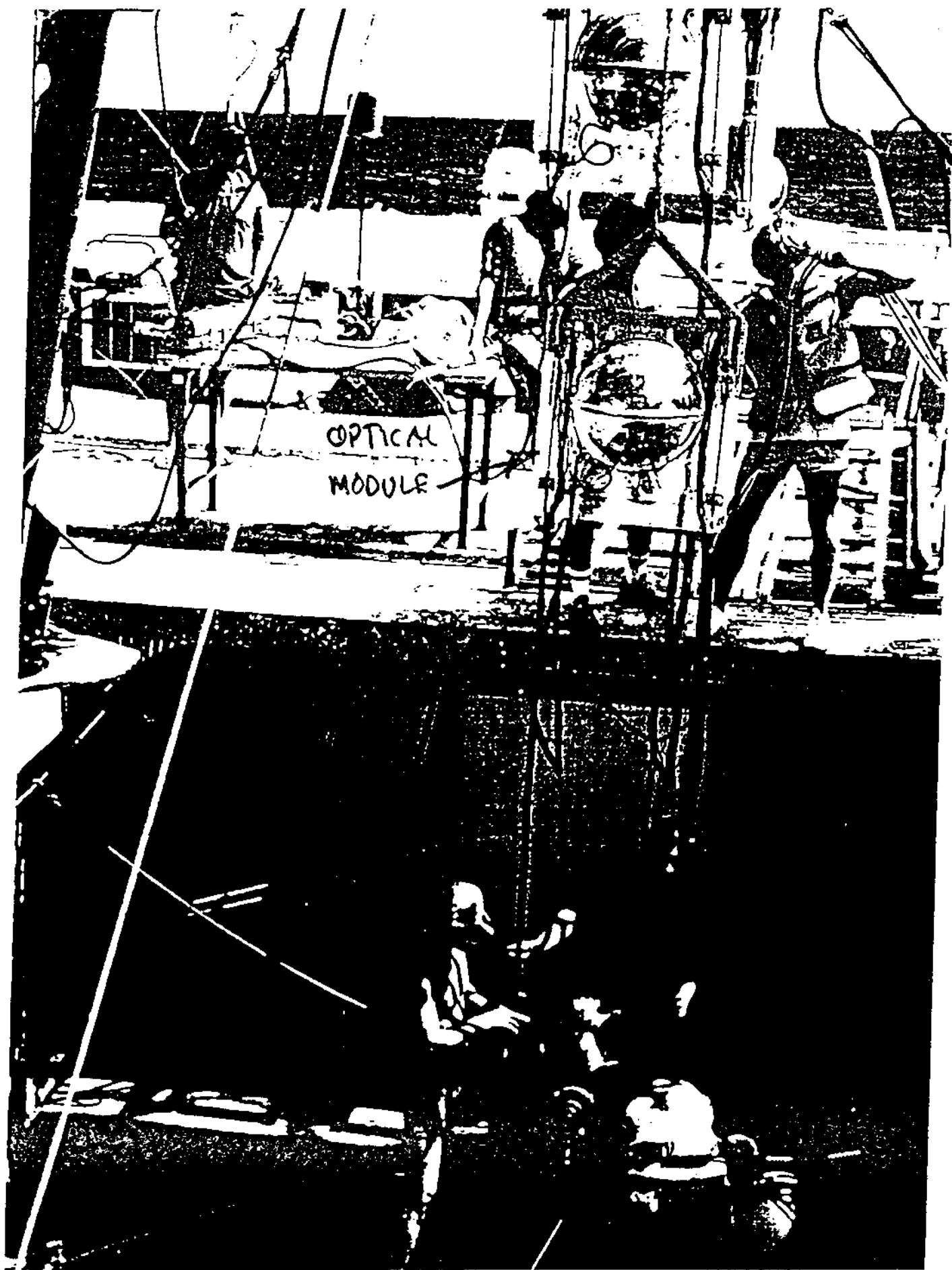
Sky Coverage of DUMAND



- CAN LOOK SOMEWHAT ABOVE HORIZON 10-20°
- LOCATED AT 20° LATITUDE



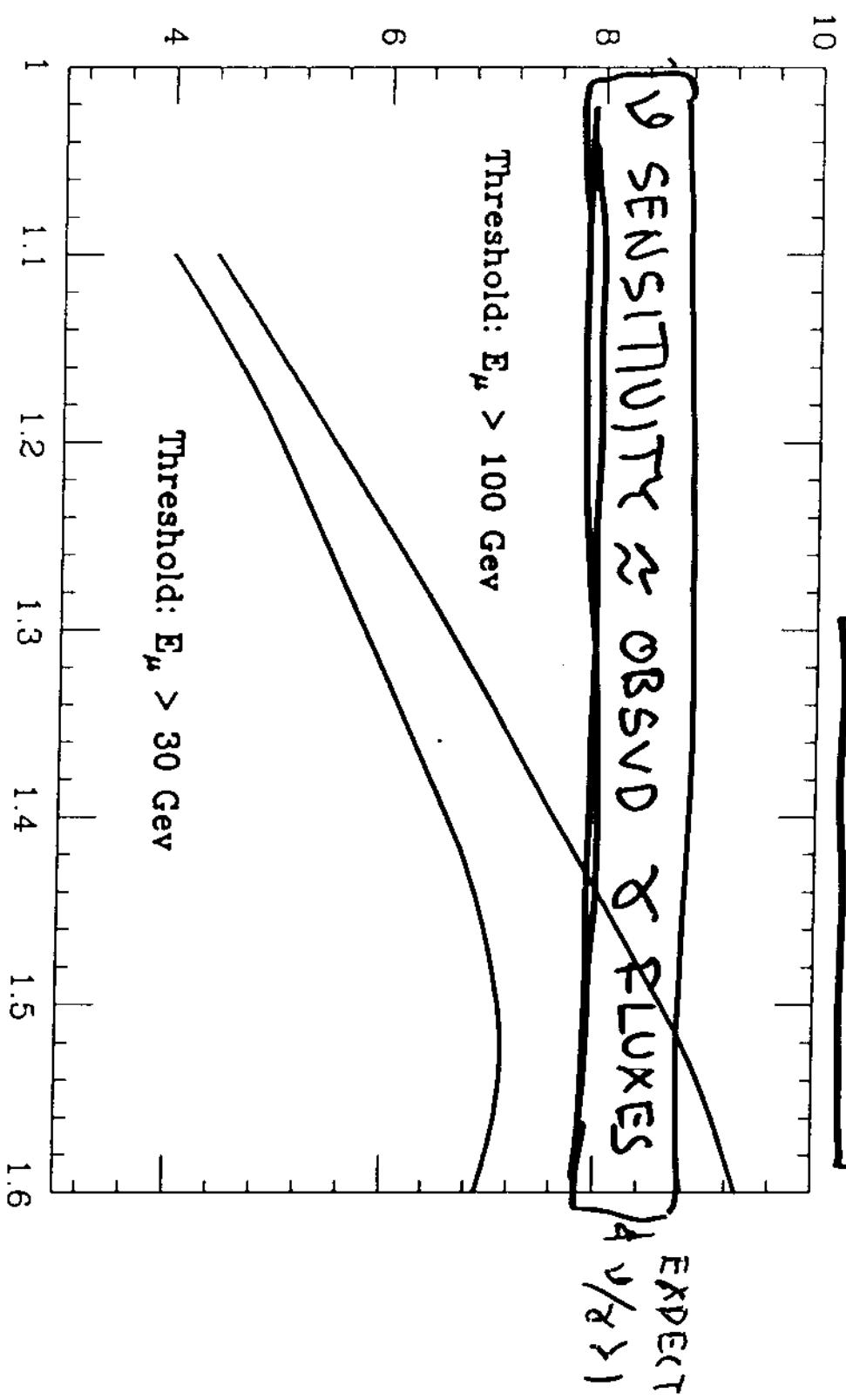




DUMAND II NIN DET FLUX $\sim 6 \times 10^{-19} / \text{cm}^2 \text{s}$ @ 1TeV

DUMAND Octagonal Array

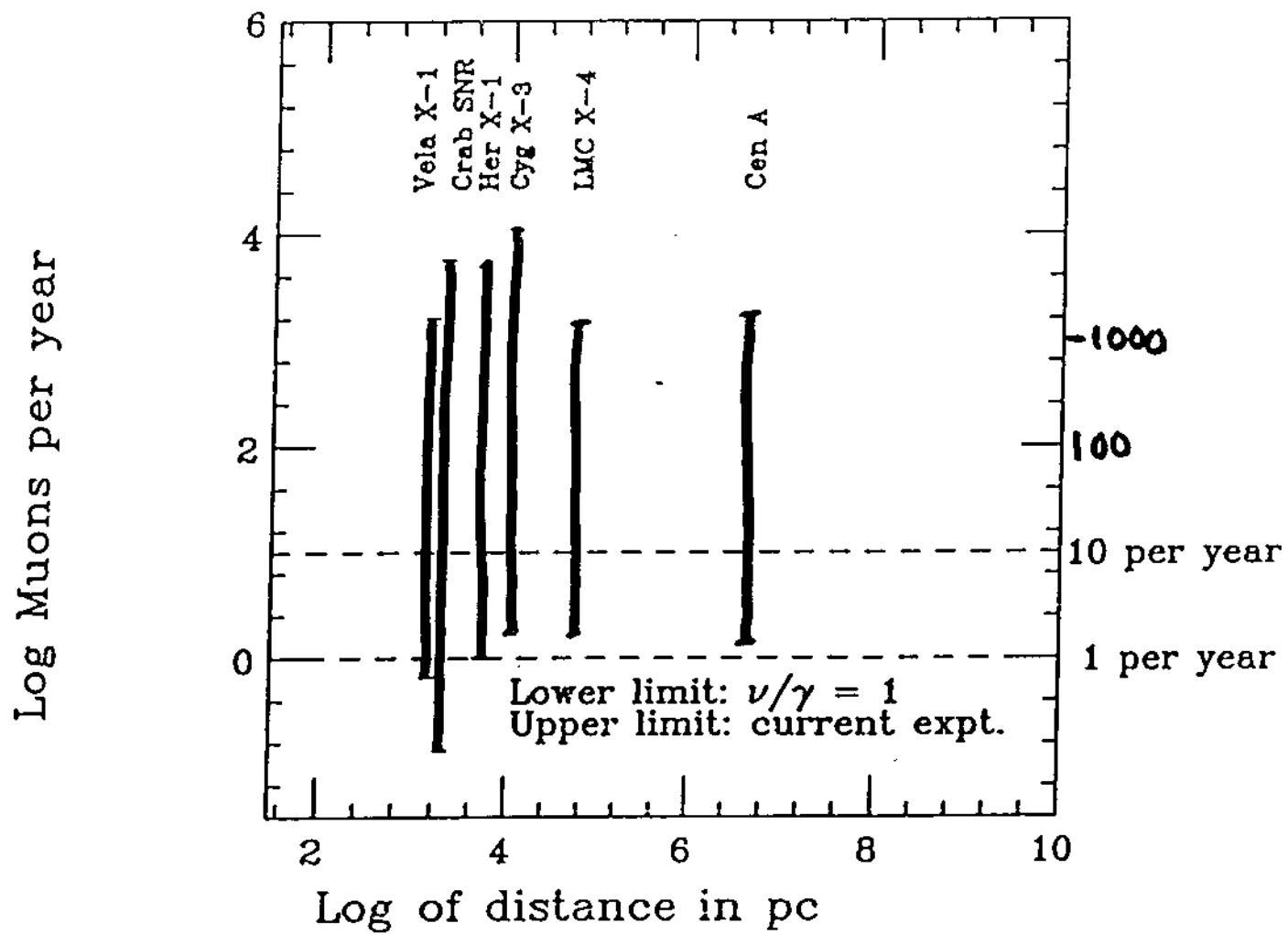
Minimum Detectable Flux



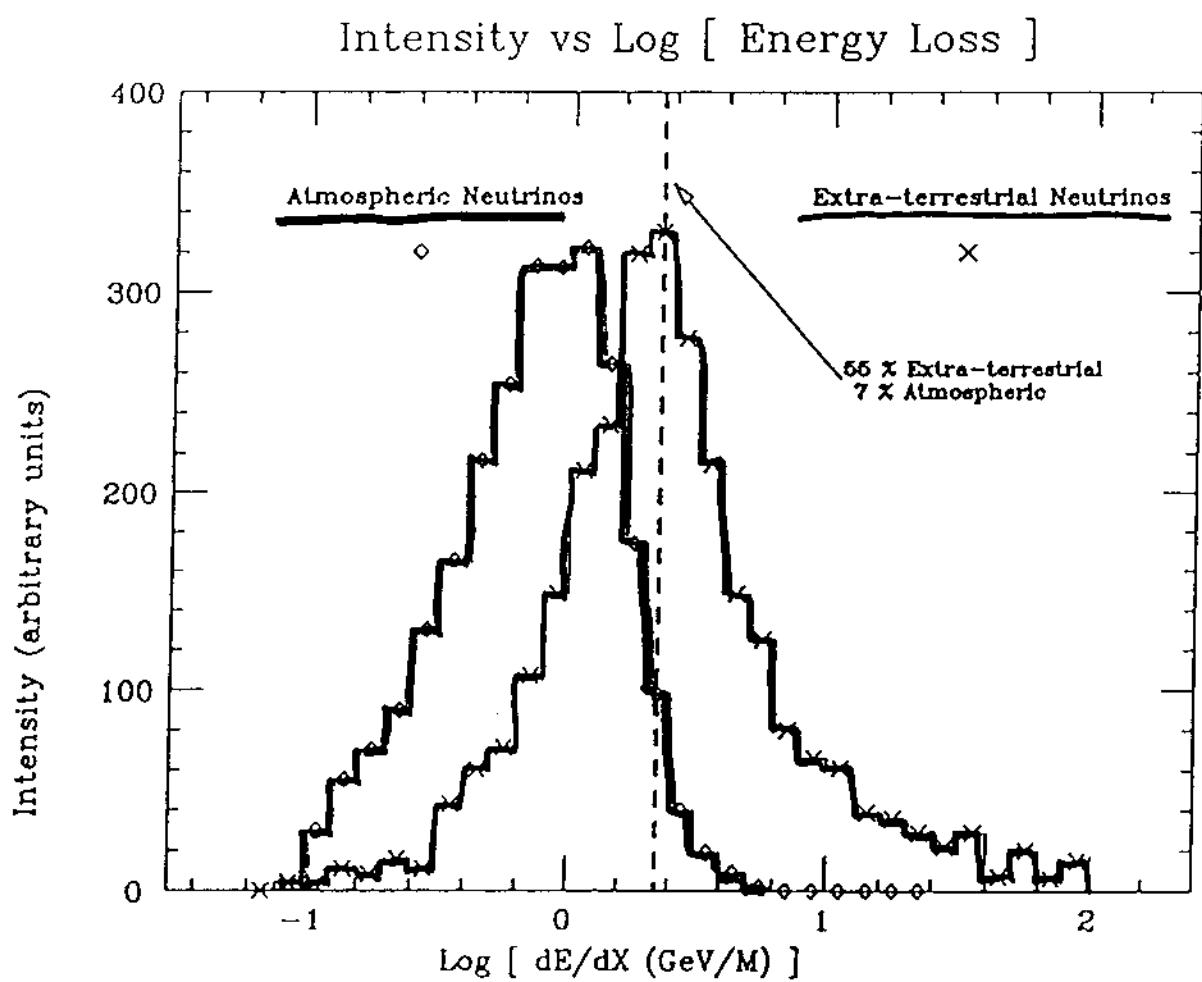
JCL 5/14/88

DET. CRITERIA $\left\{ \begin{array}{l} > 10 \text{ EVENTS} \\ > 4.5 \sigma \end{array} \right.$

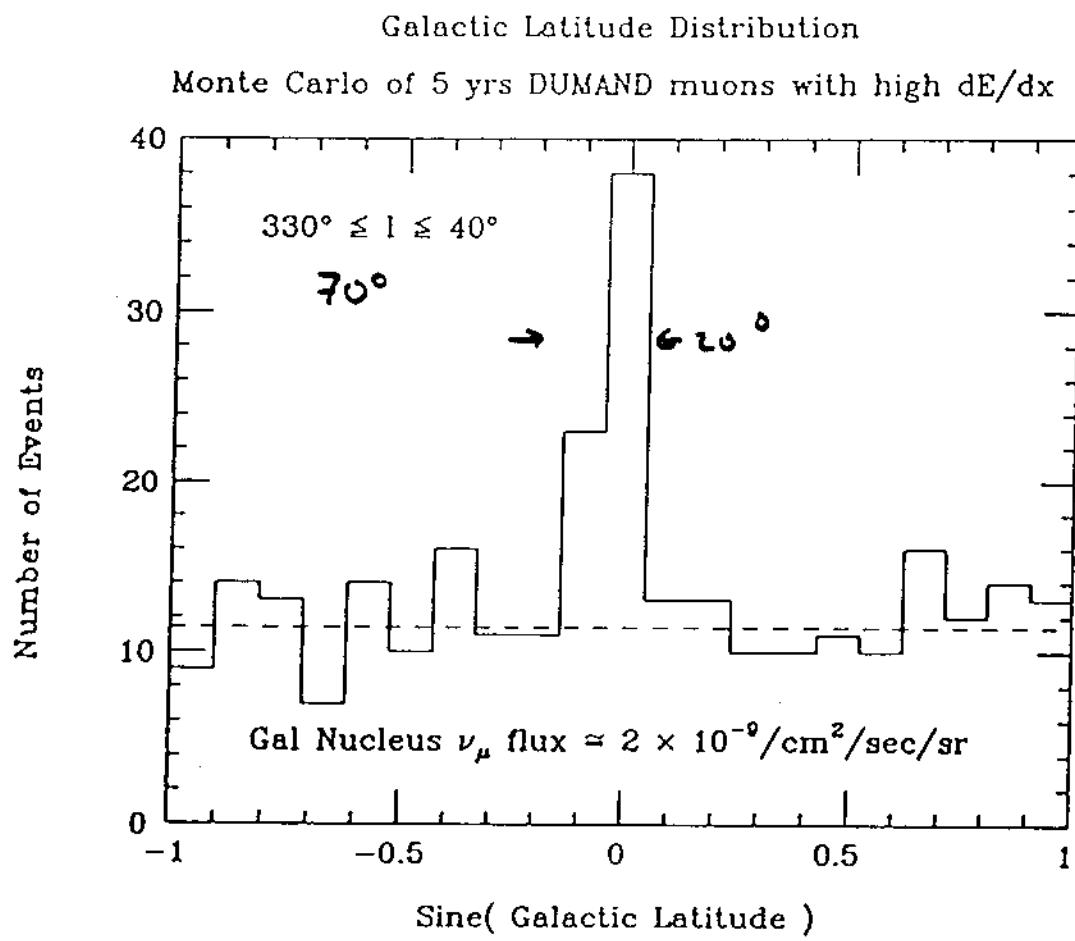
SOME
Possible Neutrino Signals
in the
DUMAND Octagon



Comparison of Simulated Measured Energy Loss for Muons from Atmospheric and Extraterrestrial Neutrinos



Simulated Observation of the Galactic Center (DIFFUSE SOURCE)



JCL 4/17/86

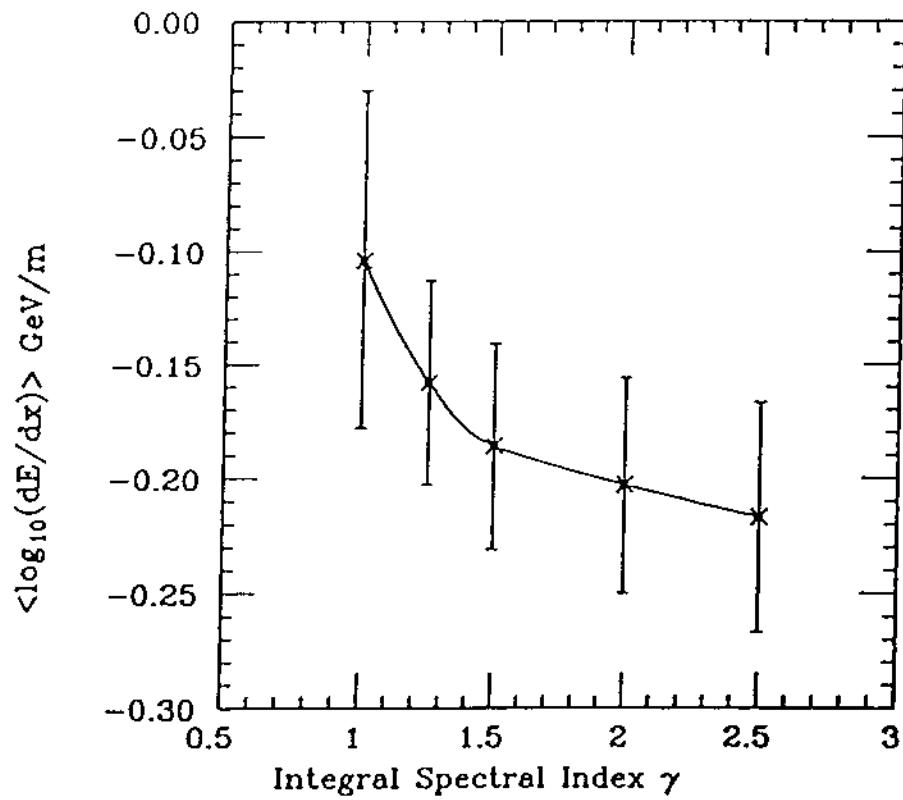
ASSUMED FLUX:

$10 \times$ Stecker (Calc.)

$\frac{1}{100} \times$ Turver (γ -RAY OBS.)

Determination of Spectral Index

FROM 20 EVENTS

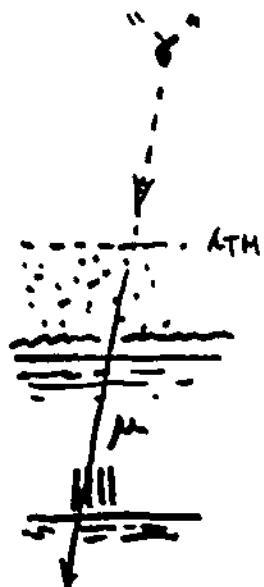


WITH EVEN A SMALL SIGNAL ONE
BEGINS TO EXTRACT "PHYSICS"

What are the capabilities of DUMAND for

"Muon Astronomy?"

- Assume muons produced in atmosphere by gamma rays or other neutral particles from an astronomical source have a flatter spectrum than cosmic ray muons
- The signal-to-noise ratio will be as much as 10^6 times greater at 4.5 km depth than at sea level



$$N_\mu = 10^3 \left(\frac{F_\mu}{F_\gamma} \right) \text{ PER YEAR} \quad \text{CYG X-3}$$

FEW % CONVENTIONAL PHYSICS

HIGHER RATIO SUGGESTED BY EAS
OBS. OF CYG X-3, IITER X-1

What are the capabilities of DUMAND for

Cosmic Ray Physics?

- Information on sea level spectrum
above 10 TeV 1000 EVENTS PER YEAR
- Widely-spaced multiple muons
 > 2 m HIGH p_T
- Search for anomalies in the muon
range-energy relation at very high
energies



Some Expected Event Rates

- "Upward" muons from atmospheric neutrinos:
 - ≤ 1 per year in 1° circle \Rightarrow NOT BACKGROUND
LIMITED FOR PT SOURCES
 - 3500 per year $80^\circ < \theta < 180^\circ$
- "Upward" muons from a detectable point source:
 - ≥ 10 events per year ?
- Contained atmospheric neutrino events above 1 TeV:
 - 50 per year
- Downward muons:
 - 16 per minute total
 - 1000 per year from sea level muons above 10 TeV
 - $10^3 F_\mu / F_\gamma$ per year from Cyg X-3 γ -rays
 - ONLY FEW % CONVENTIONAL PHYSICS
 - BUT ANOMALOUS PRODUCTION SUGGESTED FROM CYG X-3, HERX-1

J.G. Learned

task 3

HEP in the Deep Ocean

- heavenly accelerator environs
unattainable in lab
=> new phenomena?
>10¹⁷ eV hadron beams, 10¹² Gauss fields, GR effects, Strange matter, >10⁶ L_γ, photon-photon interactions, ...
- "tagged beams" from X-ray binaries
cyclic variations on 3 time scales observed
- are the 10¹⁵ eV "γ's" really photons?
Kiel, Los Alamos, Haverah Park, (Mt. Hopkins)
- search for exotic particles
massive WIMPS, dark matter quark globules, Rubakov monopoles, photinos, ...
- study direct production at UHE
muon angular variation, new flavors > 100 TeV
- check standard model *(if strong signal)*
weak interactions >100 TeV (linearly rising cross section?)
- study ν_μ oscillations in unique regime
 ν_μ disappearance in range suggested by Kamioka results
- future studies of different ν flavors

UPDATE ON EVIDENCE (?)

FOR ν OSC WITH CWS RAYS

JCL
12/9/88

87

KAMIOKANDE: DEFICIT OF μ EVENTS
(IMB : "T2 PROBLEM")

(HIRAIKA, ET AL;
PHYS. LETT. B205;
416, '88)

7/88

OBS - EXPECTED
EXPECTED

KAM

$28 \pm 7\%$ $\rightarrow ?$

FREJUS

$19 \pm 9\%$

(LONGUEMAINE,
GRAND SUD FUKUOKA
AU LES BAINS 4/88)

IMB

$8 \pm 11\%$

(GAJEWSKI AT
MUNICH 3/88)

INTERPRETATION: $\nu_\mu \rightarrow \bar{\nu}_e$?

/ LEARNED
PARVASA
WEILER

$\rightarrow \nu_\mu \rightarrow \bar{\nu}_\tau$

(HIRAIKA,
MONDA,
MINOURAWA, JAP)

$$S m^2 \sim 0.3 \text{ eV}^2$$

$$\sin^2 2\theta \sim 0.5 - 1.0$$

IMPLICATION: SEE EFFECT IN Δ DIST
OF UPCOMING μ 'S? MAYBE?

PROBLEM: - RESULTS OF LOW EN DEPEND ON M.C.'S

CRUDE ESTIMATE OF SENSITIVITY

FOR DOMAIN II

$$V_{\text{EFF}} = A_D \cdot R_M(\xi) \approx 2 \times 10^4 \text{ m}^3 \cdot 5 \times 10^3 \text{ n} @ 1 \text{ TJV}$$

$$\approx 10^8 \text{ m}^3 \approx 10^8 \text{ T}$$

$$A_{\nu \text{EFF}} = V_{\text{EFF}} \cdot N_A \cdot \sigma_{VN}$$

$$= 10^8 \text{ T} \cdot 6 \times 10^{29} \frac{\text{n}}{\text{T}} \cdot 1.7 \times 10^{-39} \text{ m}^2 \cdot \left(\frac{E_V}{1 \text{ TJV}} \right)$$

$$= 720 \text{ cm}^3$$

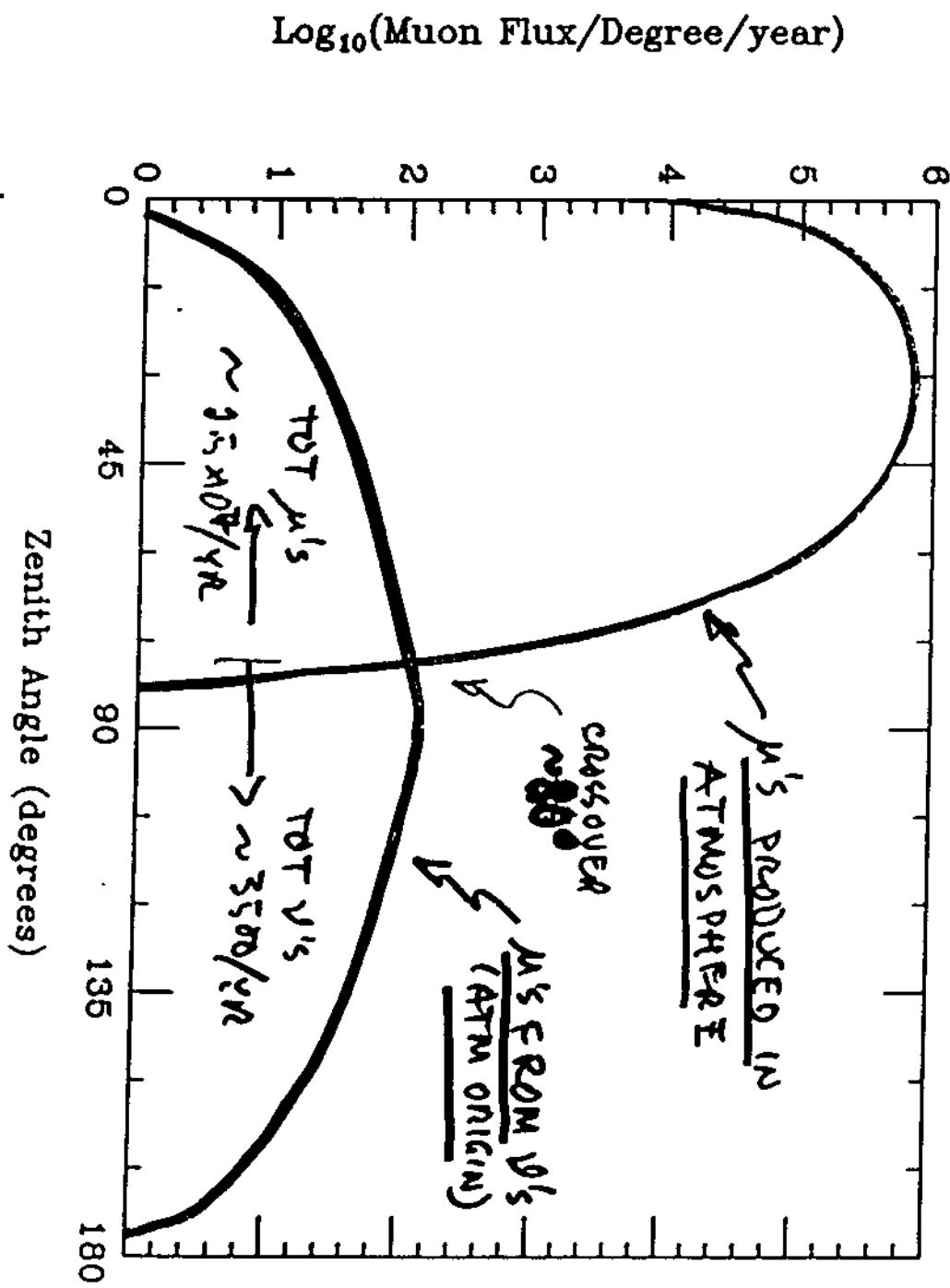
$$N_{\text{EVTS}} = \phi_\nu \cdot A_{\nu \text{EFF}} \cdot T$$

$$\phi_\nu^{\text{MIN}} = \frac{N_{\text{EVTS}}^{\text{MIN}}}{A_{\nu \text{EFF}} \cdot T} = \frac{10}{720 \text{ cm}^3 \cdot \pi \times 10^7 \text{ sec}} \left(\frac{T}{1 \text{ yr}} \right)^{-1}$$

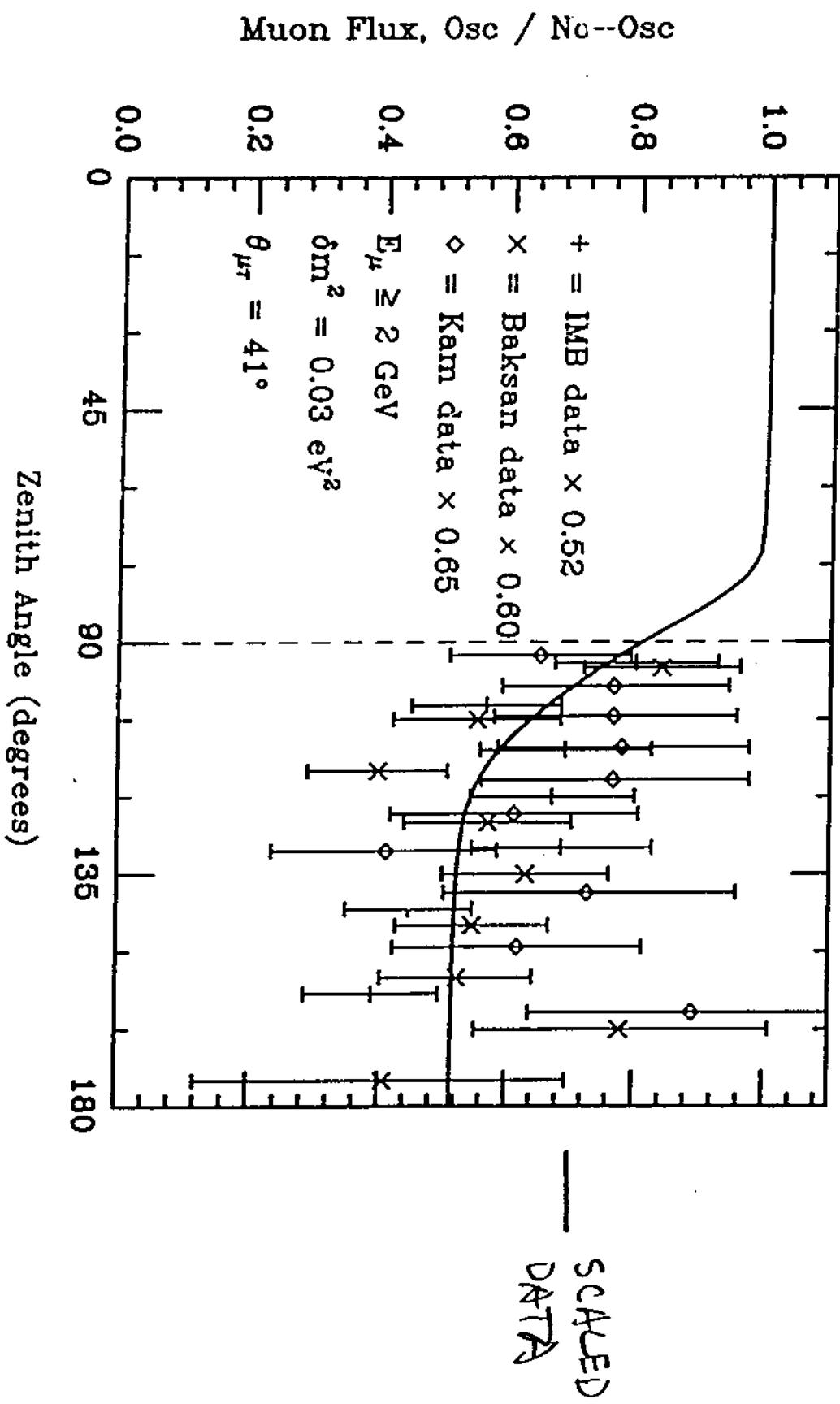
$$\phi_\nu^{\text{MIN}} \approx 5 \times 10^{-10} \left(\frac{1 \text{ yr}}{T} \right) \text{ /cm}^2 \cdot \text{s}$$

DETAILED MONTE CARLO'S YIELD ~ THIS VALUE
 (SLOW DEPENDANCE ON SOURCE SPECTRUM)

Muon Angular Distribution in DUMAND Octagonal Array
from Atmospheric Muons and Neutrino induced Muons

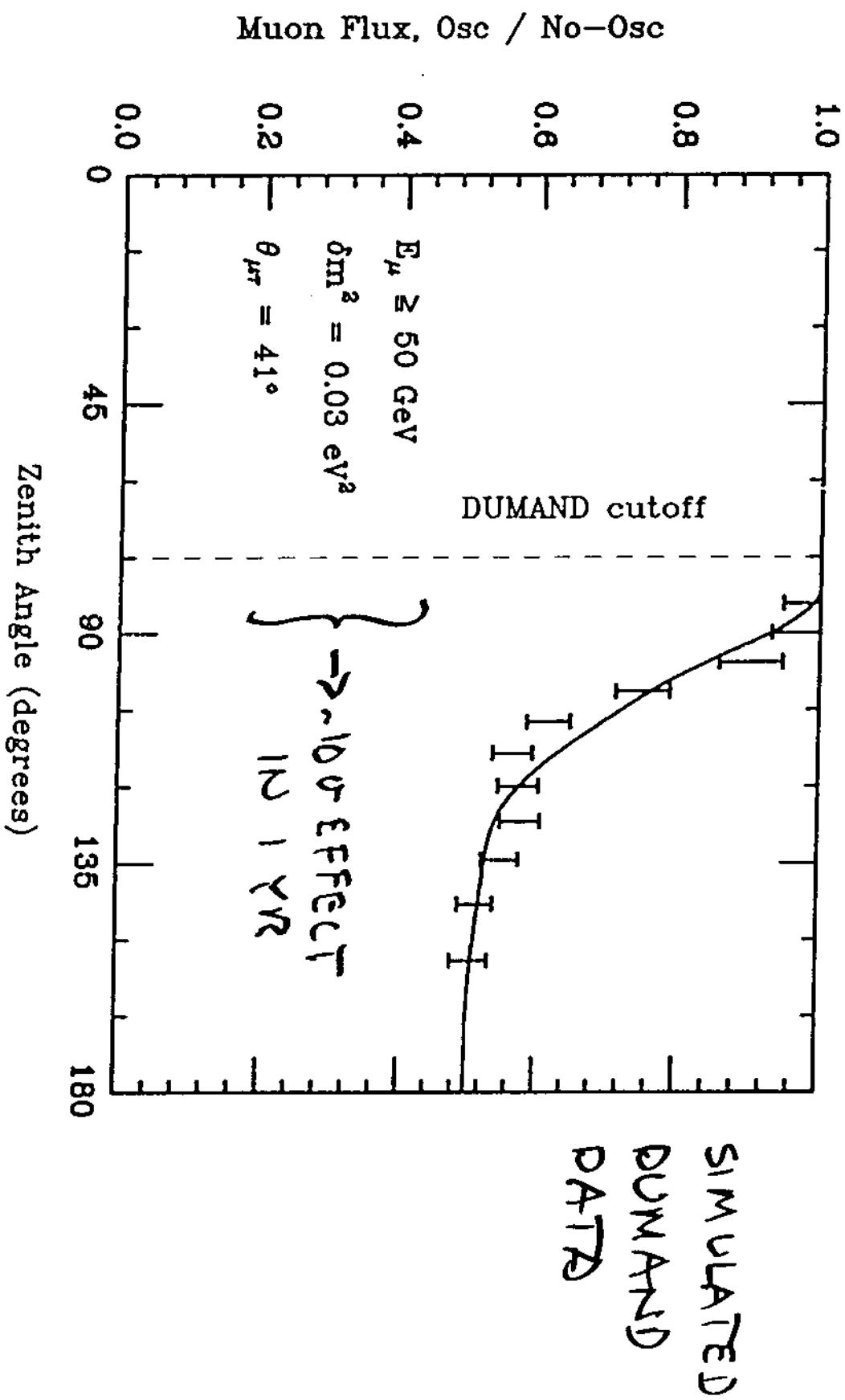


Effect of Muon-Tau Oscillations
on Deep Underearth Muons from Neutrinos

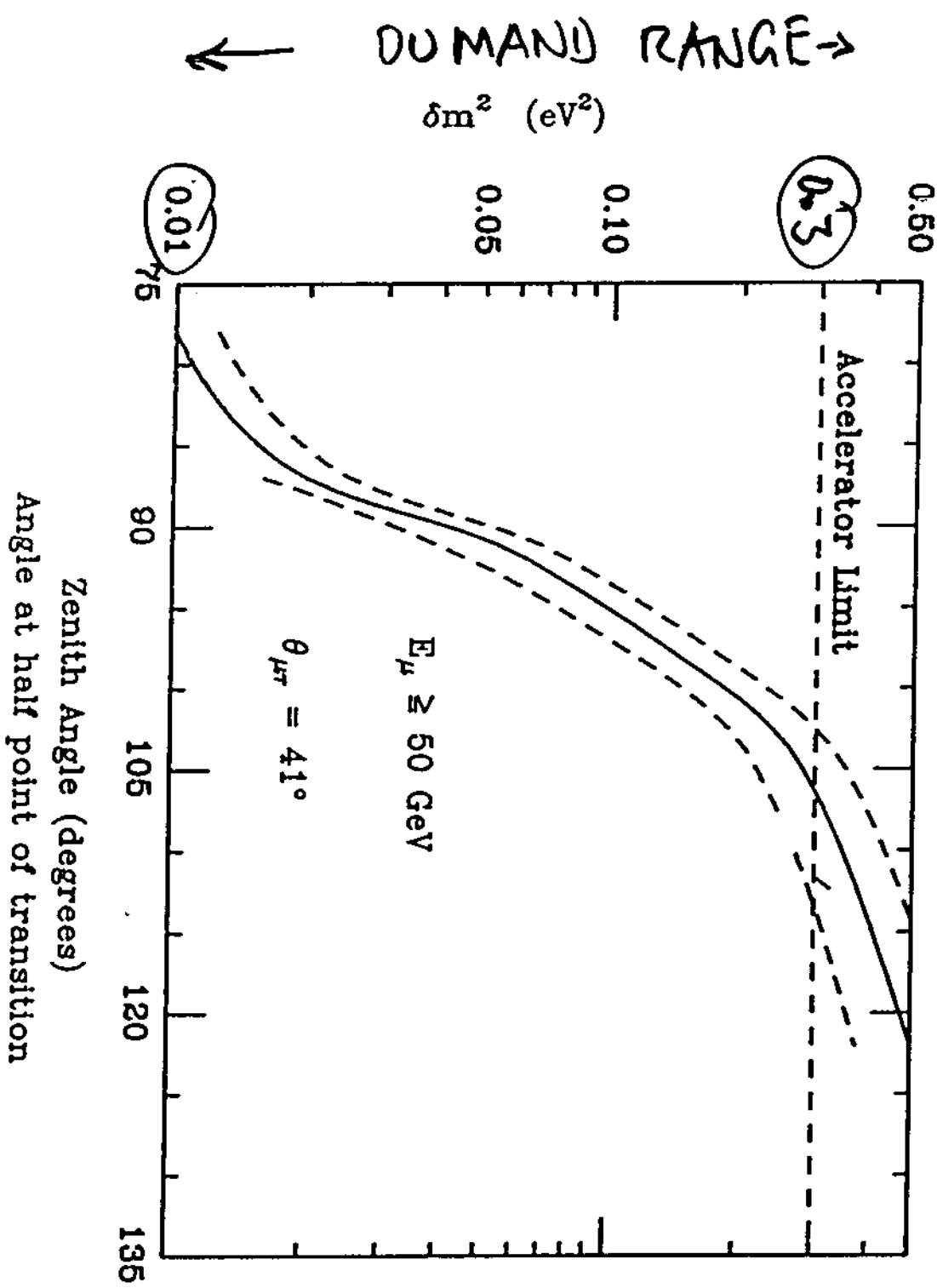


POINT: DIFFICULT FOR NINE EXPTS
TO RESOLVE THIS ISSUE

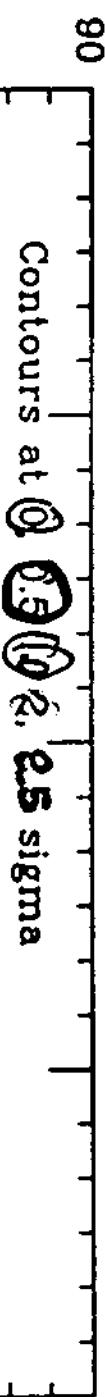
Effect of Muon-Tau Oscillations
on Deep Underearth Muons from Neutrinos



Effect of Muon-Tau Oscillations
on Deep Underearth Muons from Neutrinos



Upward Muon Excess Contours



RA in hrs

-90 0 45 90
0 6 12 18 24

Dec

3/89 MUB UPWARD MUON DATA (391 EVTS)

Cosmic Ray Muons in the Deep Ocean

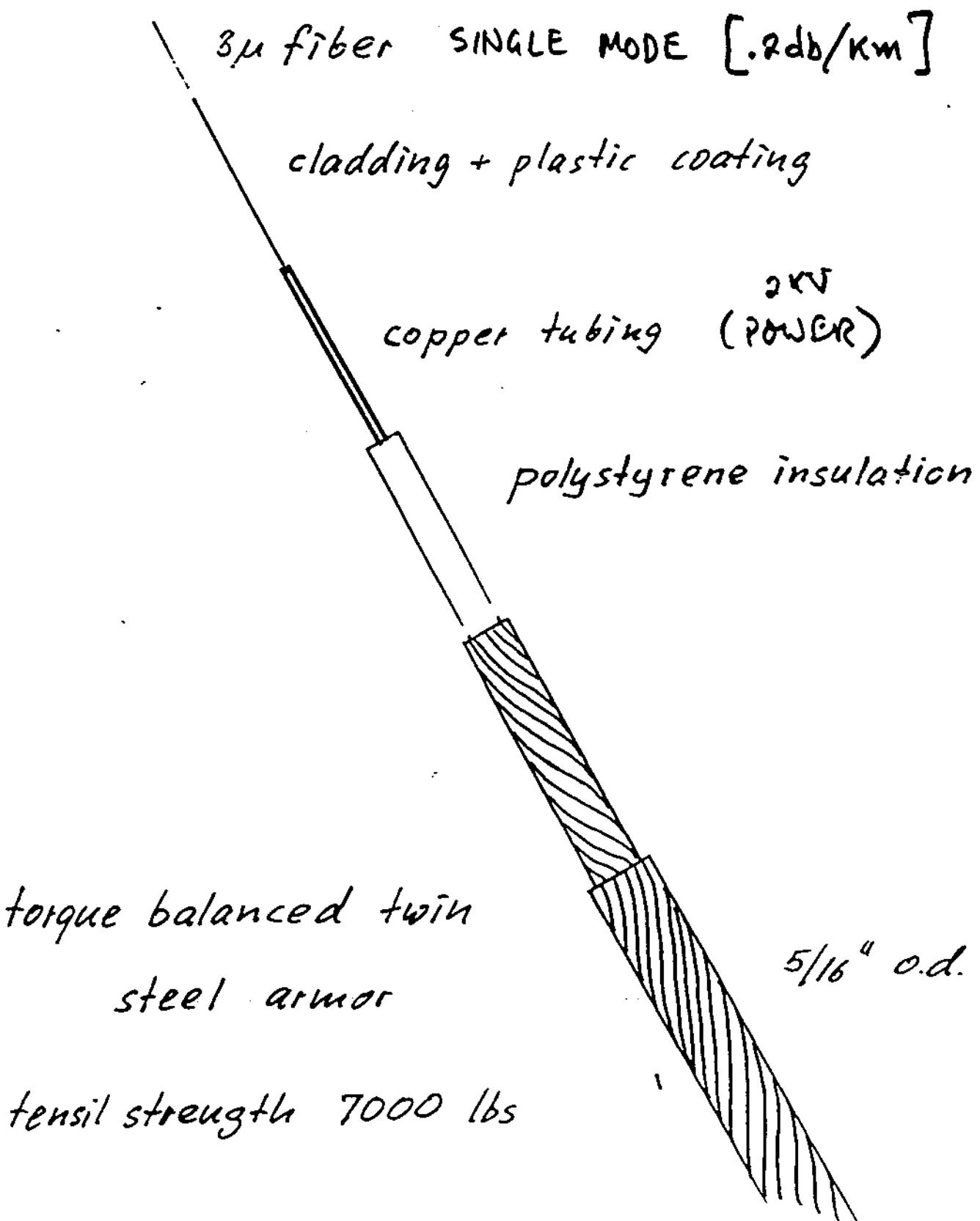
(DUMAND Collaboration)

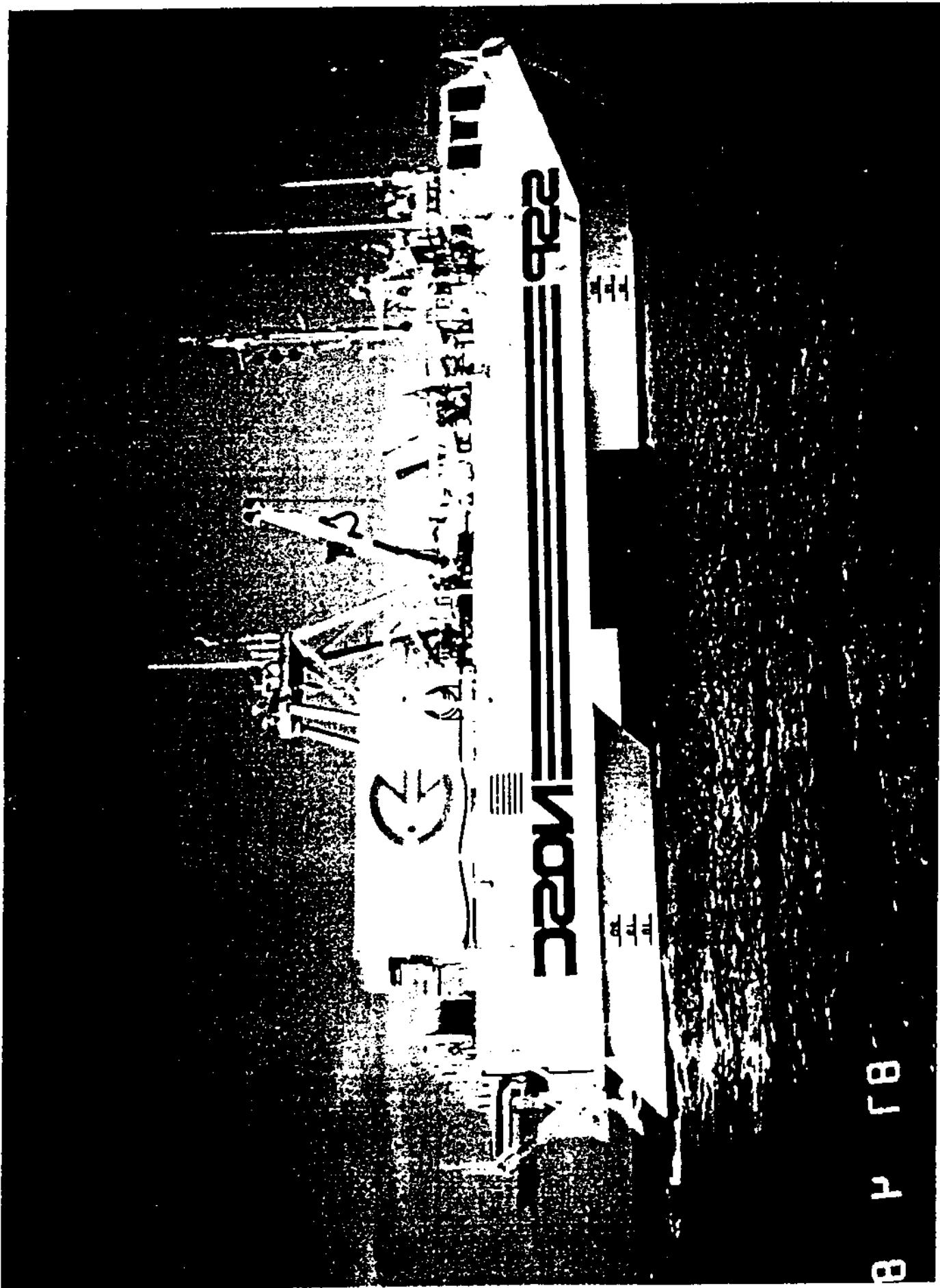
J. Babson⁵, B. Barish², R. Becker-Szendy⁵, H. Bradner⁴, R. Cady^{5*}
J. Clem⁸, S. Dye^{5**}, J. Gaidos⁶, P. Gorham^{5†}, P. K. F. Grieder¹
T. Kitamura^{7††}, W. Kropp³, J. G. Learned⁵, S. Matsuno⁵, R. March⁹
K. Mitsui⁷, D. O'Connor⁵, Y. Ohashi⁷, A. Okada⁷, V. Petersen⁵
L. Price³, F. Reines³, A. Roberts⁵, C. Roos⁸, H. Sobel³
V. J. Stenger⁵, M. Webster⁸, C. Wilson⁶

- 1 - University of Bern, Bern, Switzerland
- 2 - California Institute of Technology, Pasadena, CA 91125
- 3 - University of California at Irvine, Irvine, CA 92717
- 4 - University of California at San Diego, La Jolla, CA 92093
- 5 - Hawaii DUMAND Center, University of Hawaii,
Honolulu, HI 96822
- 6 - Purdue University, Lafayette, IN 47907
- 7 - Institute for Cosmic Ray Research, University of Tokyo,
Tokyo, Japan
- 8 - Vanderbilt University, Nashville, TN 37215
- 9 - University of Wisconsin, Madison, WI 53706

(to be submitted to Phys. Rev. D)

E/O Cable FOR SPS





8 4 7 8

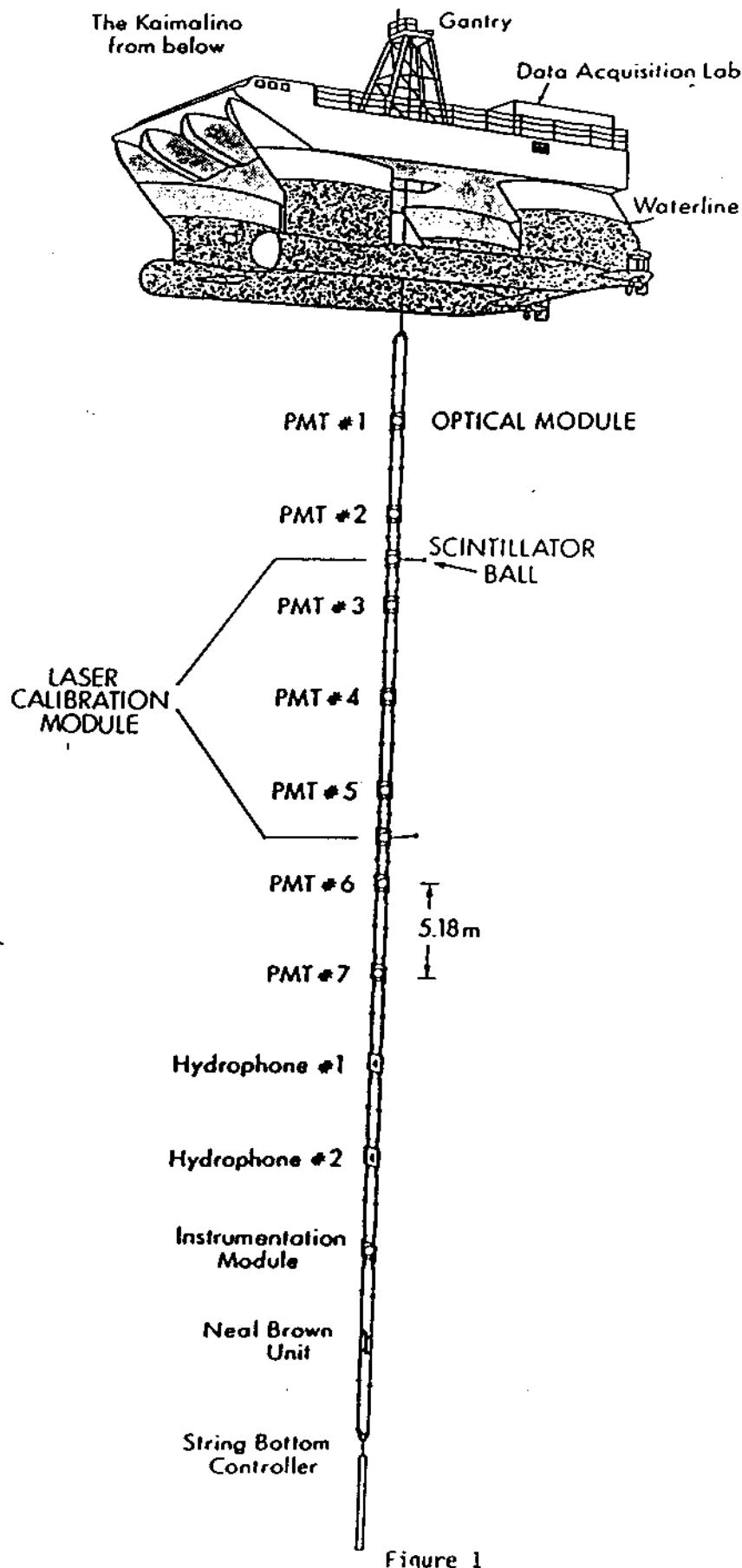


Figure 1

