

DUMAND: DIR-9-82

REVISED MUON FLUX and MUON SPECTRA in the OCEAN

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The purpose of this note is to resolve the difference in the integral muon spectrum as calculated by JGL (see HDC note 80-28) and a calculation done in MUFLER.FOR by VJS.

VJS uses  $-dE/dx = a + bE$  to get

$$E = b^{-1}[(a + b E_0)e^{bL} - a]$$

where  $E_0$  is the muon energy at the depth of the detector, and  $E$  is the muon energy at the surface.  $a$  and  $b$  have a logarithmic dependence on  $E$  but are taken to be constants in this calculation:  $a = .268 \text{ Tev/km}$ ,  $b = .299/\text{km}$  (see ELBERT, DUMAND 78, vol. 2, p. 109). VJS uses muon flux:

$$dI/d\Omega = 520 E^{-28}/\cos\theta * s^{-1} \text{ km}^{-2} \text{ sr}^{-1} (\text{DUMAND 78, vol.1, p. 37, eqn.1})$$

For ease of comparison I have normalized everything in these calculations (after integrating over solid angle) to intensity in  $\text{m}^{-2}\text{s}^{-1}$ .

The first plot (fig 1.) is a calculation of the integral muon flux using VJS's program MUFLU.FOR. VJS employs JCL's subroutine RFMU to get the integral muon flux  $\text{sr}^{-1} \text{ m}^{-2} \text{ sec}^{-1}$  and integrates over solid angle in the main program to get the integral flux  $\text{m}^{-2} \text{ s}^{-1}$ . RFMU calculates underwater muon flux using the Miyake empirical formula. Figure 1 shows fits for 5 sets of constants supplied to Miyake's formula. These 5 sets of constants are the same as described by JGL in HDC note 80-28.

Figure 2 shows the agreement of integral muon flux as calculated by VJS in MUFLER.FOR compared with integral muon flux calculated by VJS in MUFLU.FOR using JGL's Miyake fit with Miyake parameters. The agreement is quite good.

Fig. 3 shows flux before algebraic corrections to JGL's RFMU and after.

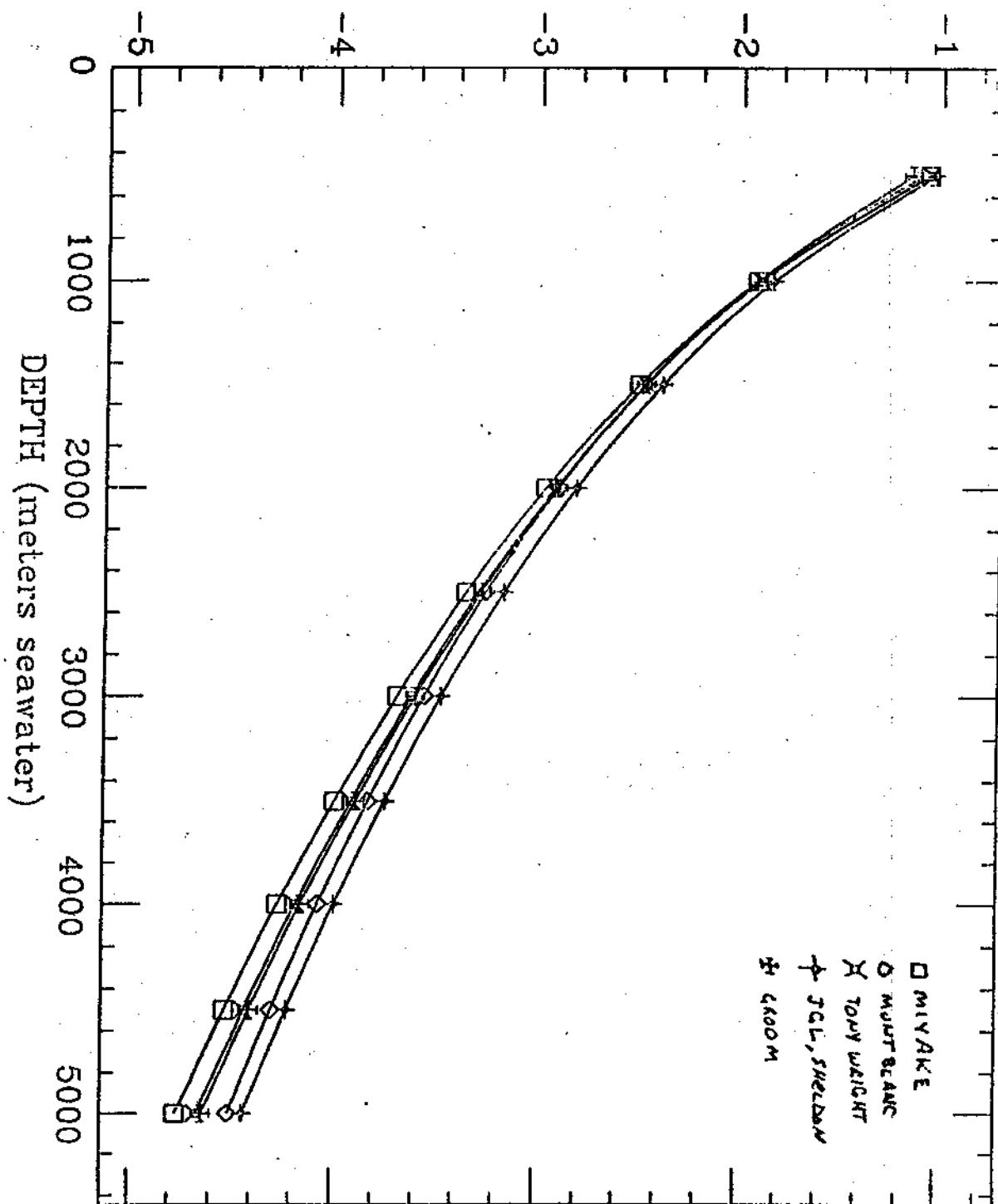
Fig. 4 shows integral muon flux vs. depth as calculated in MUFLER.FOR for energies at the array of .1, 1, 10 Tev.

Fig. 5 shows energy spectrum as calculated in MUFLER.FOR for various depths.

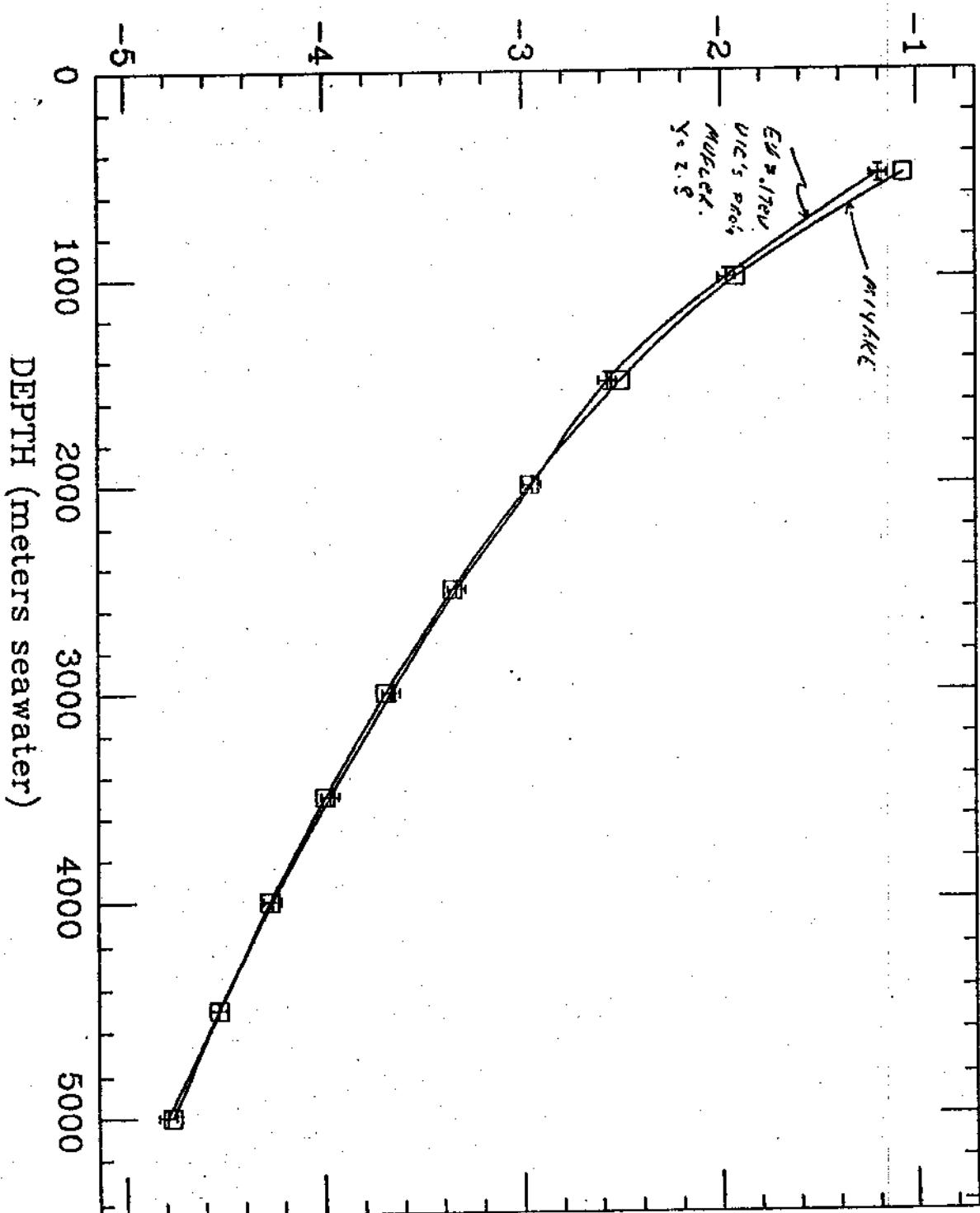
Figures 6 and 7 show angular distribution of muons as calculated in MUFLER.FOR. The flux at large angles is very small. Figure 6 show  $\log [dN/d\cos(\theta)]$  for zenith angles out to  $70^\circ$ . Fig. 7 show  $\log [dN/d\cos(\theta)]$  for a wider range of energies and to  $\theta = 85^\circ$ .

Figure 8 shows the geometry assumed in my calculations.

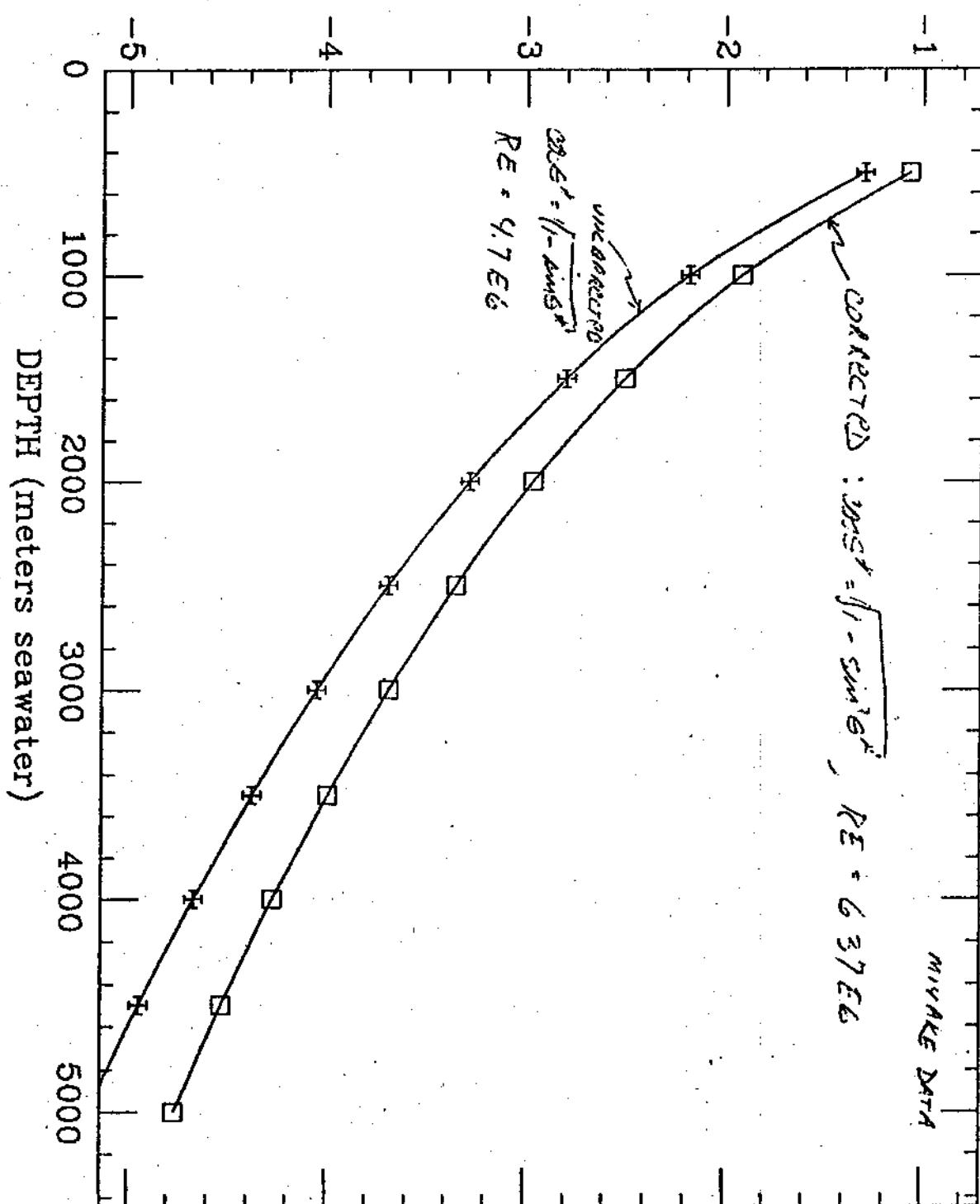
LOG INTEGRAL MUON FLUX (/M\*\*2/SEC)



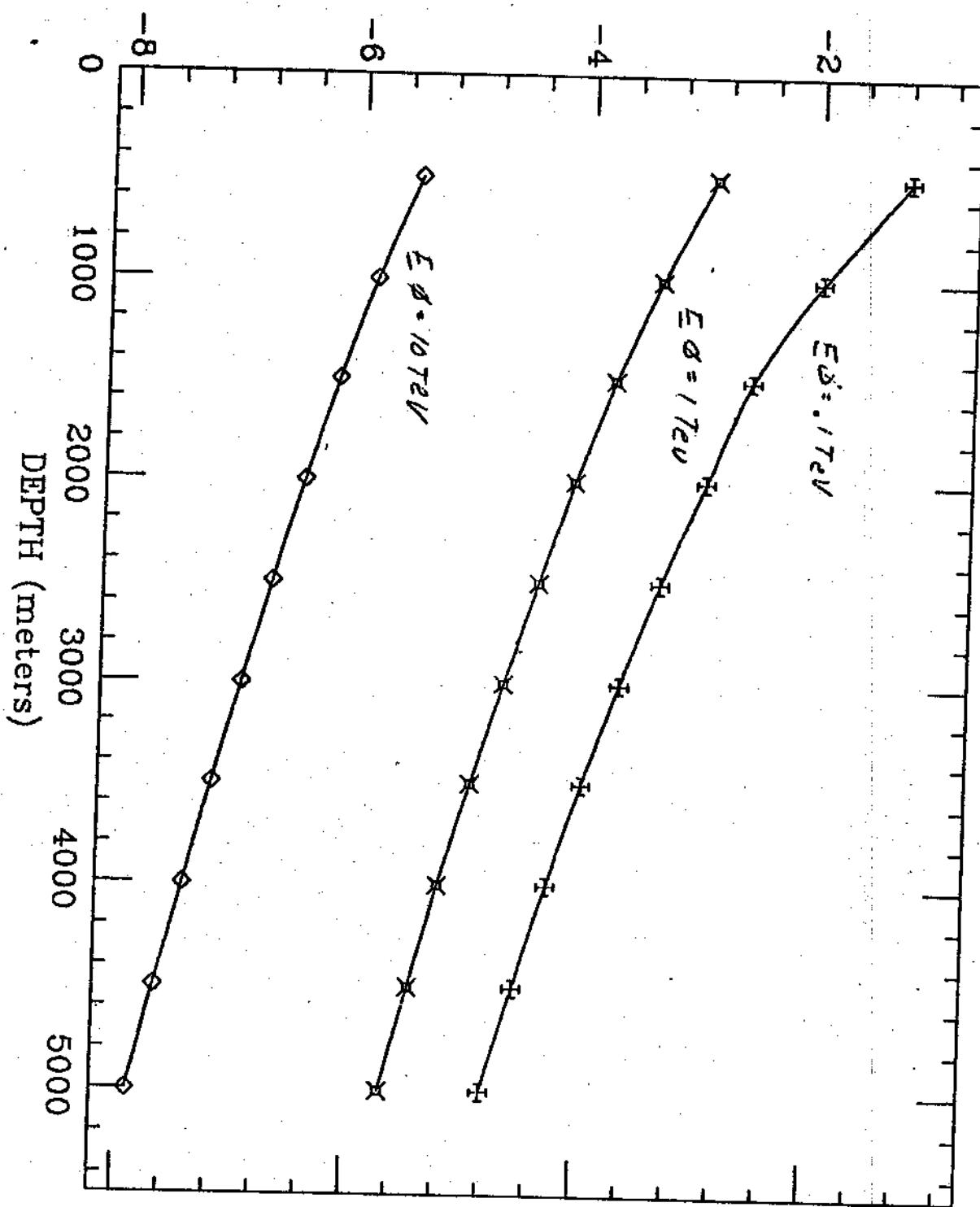
LOG INTEGRAL MUON FLUX (/M\*\*2/SEC)



LOG INTEGRAL MUON FLUX (/M\*\*2/SEC)

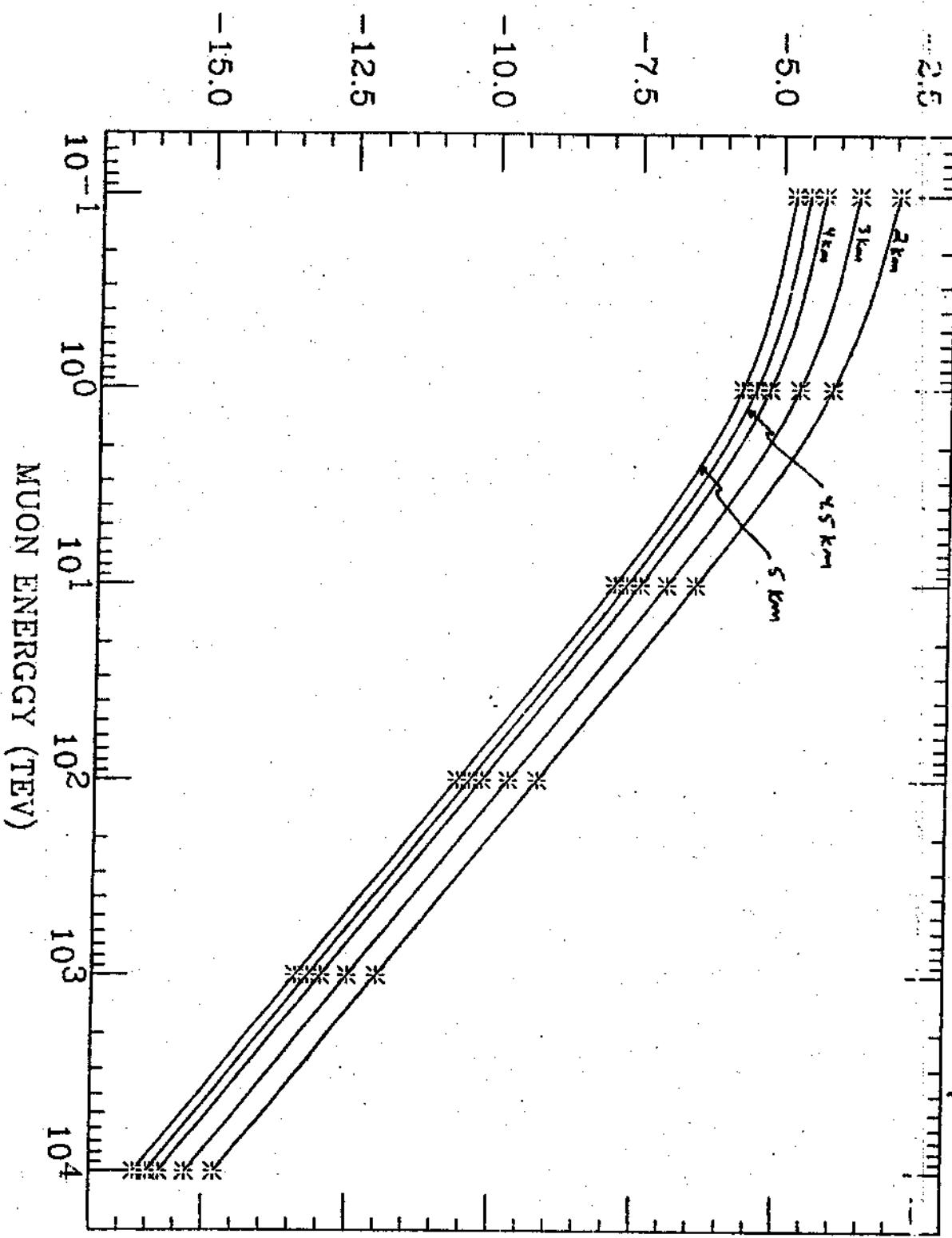


LOG INTEGRAL MUON FLUX (/M\*\*2/SEC)

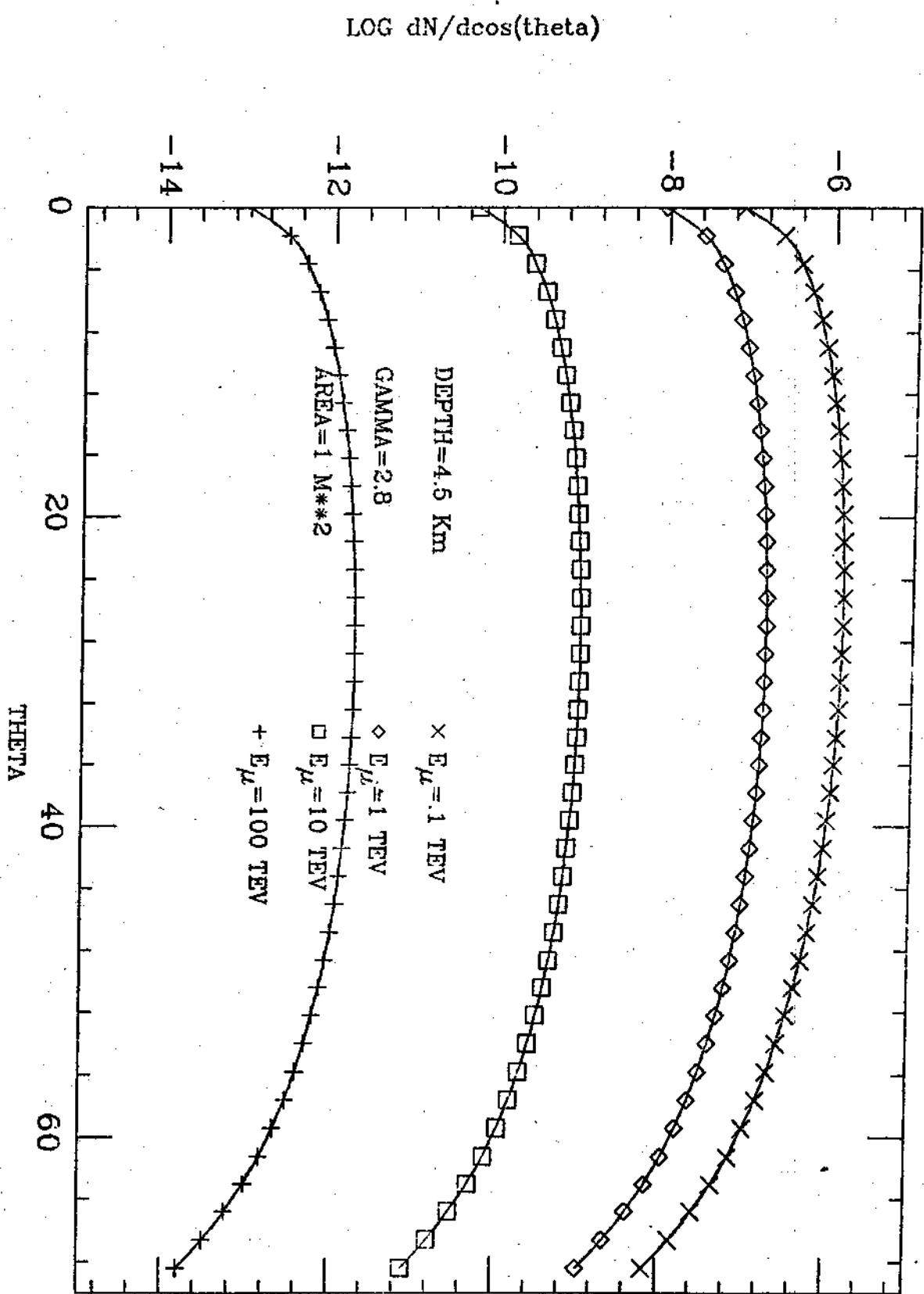


# MUON SPECTRUM AT ARRAY, 2, 3, 4, 4.5, 5 Km

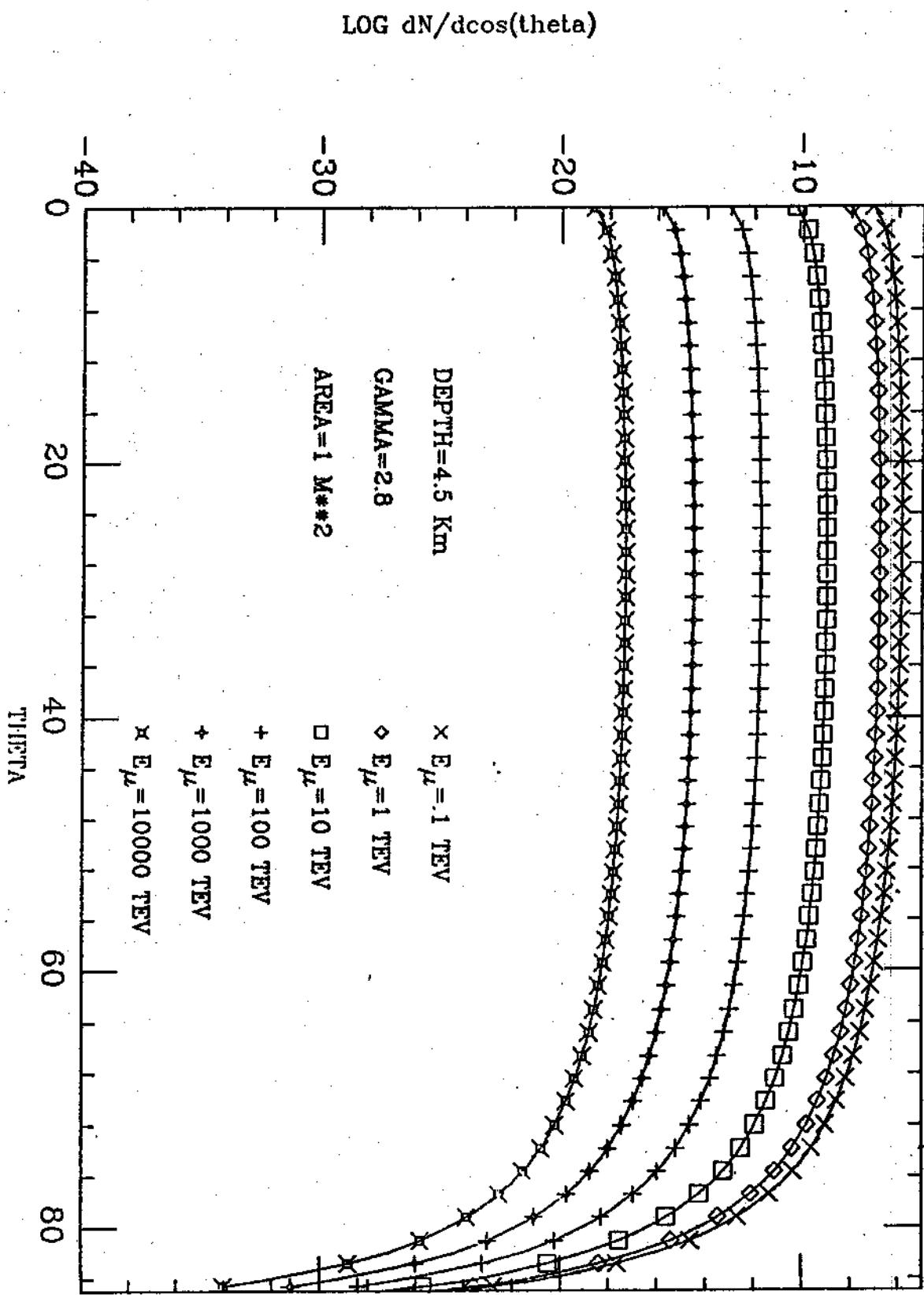
LOG INTEGRAL FLUX (/M\*\*2/SEC)



# ANGULAR DISTRIBUTION OF MUONS



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At is the atmospheric depth = 20 km.

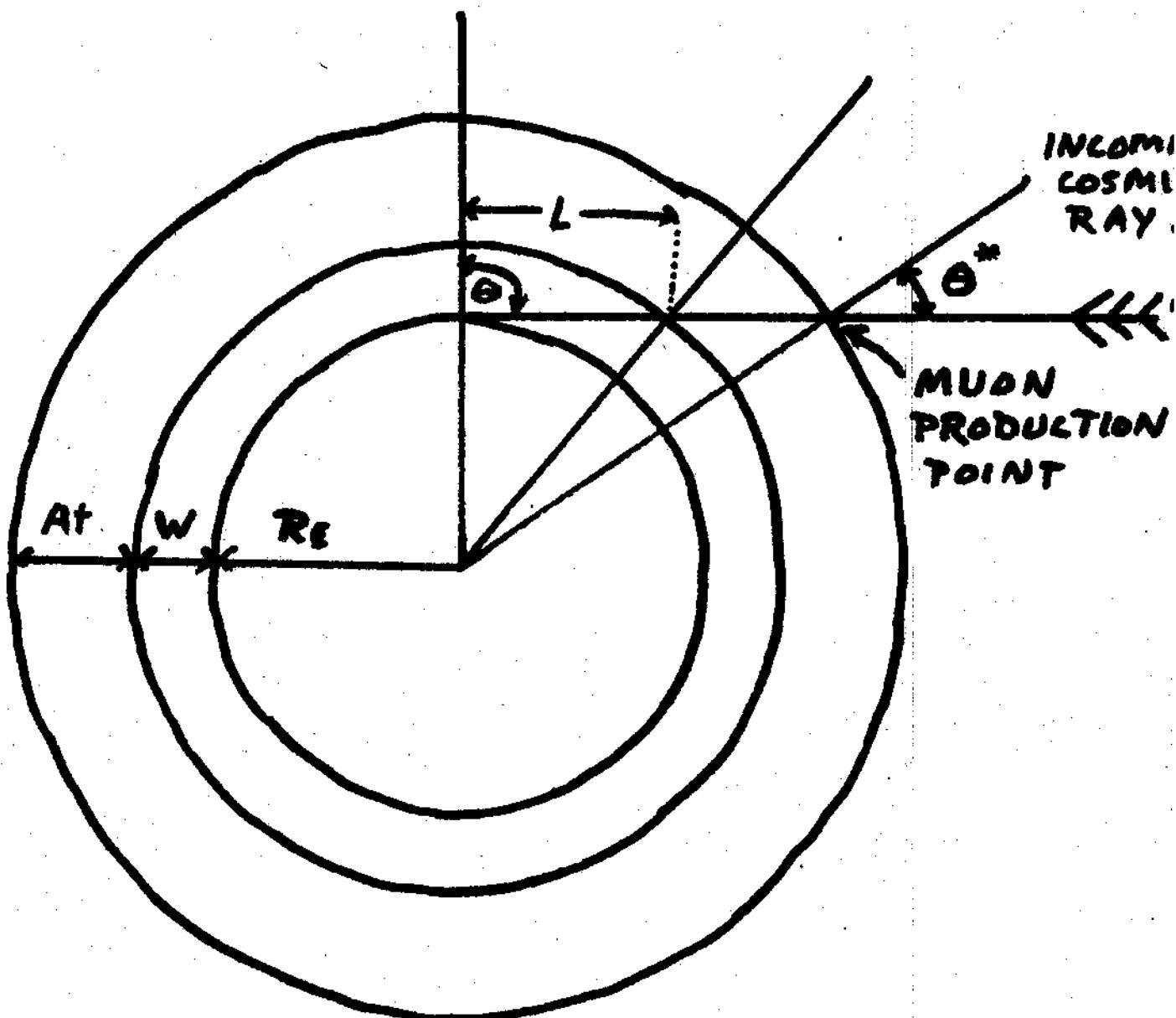
L is the path length the muon travels in water

$R_E$  is the radius of the earth

$$R = R_E + W + At$$

$$D = At + W$$

W is water depth = 4.5 km for typical DUMAND array



$$\sin \theta^* = \frac{R_E}{R_E + At + W} \sin \theta$$