Feb. 23rd, 2001

神岡の新しい大気ニュートリノデータ2

（タウの探索）

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スーパーカミオカンデ共同実験

based on 79kt year of SK atmospheric neutrino data

1289 days

- A search for CC $\nu\tau$ events

Search for CC ν_τ

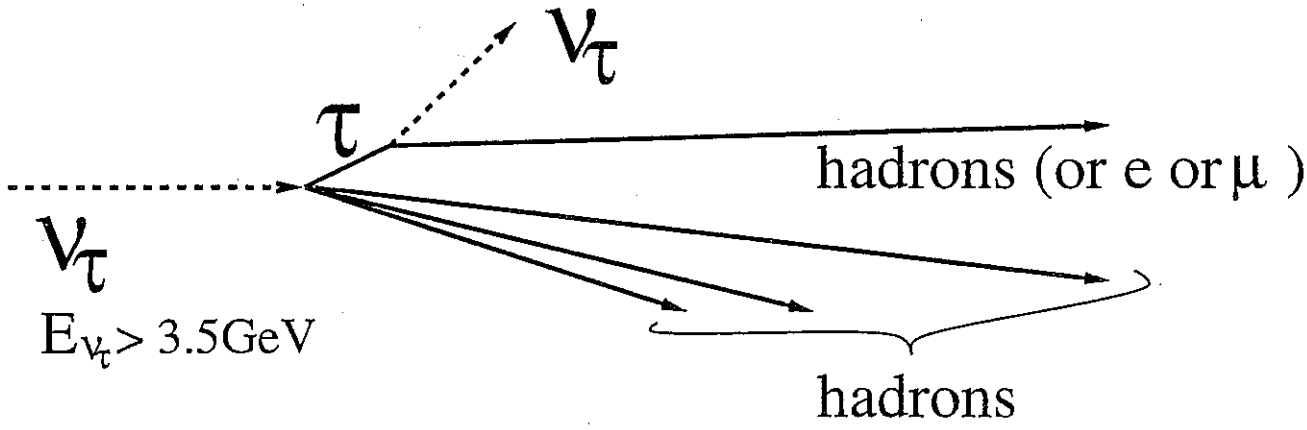
Assumption

$\nu_\mu \rightarrow \nu_\tau$ oscillation

at $\Delta m^2 = 3 \times 10^{-3} eV^2$ $\sin^2 2\theta = 1$

CC ν_τ ← ν_eCC, ν_μCC, NC

~20 events/year S/N ~ 0.7%



CC ν_τ events have large missing energy !

NC like

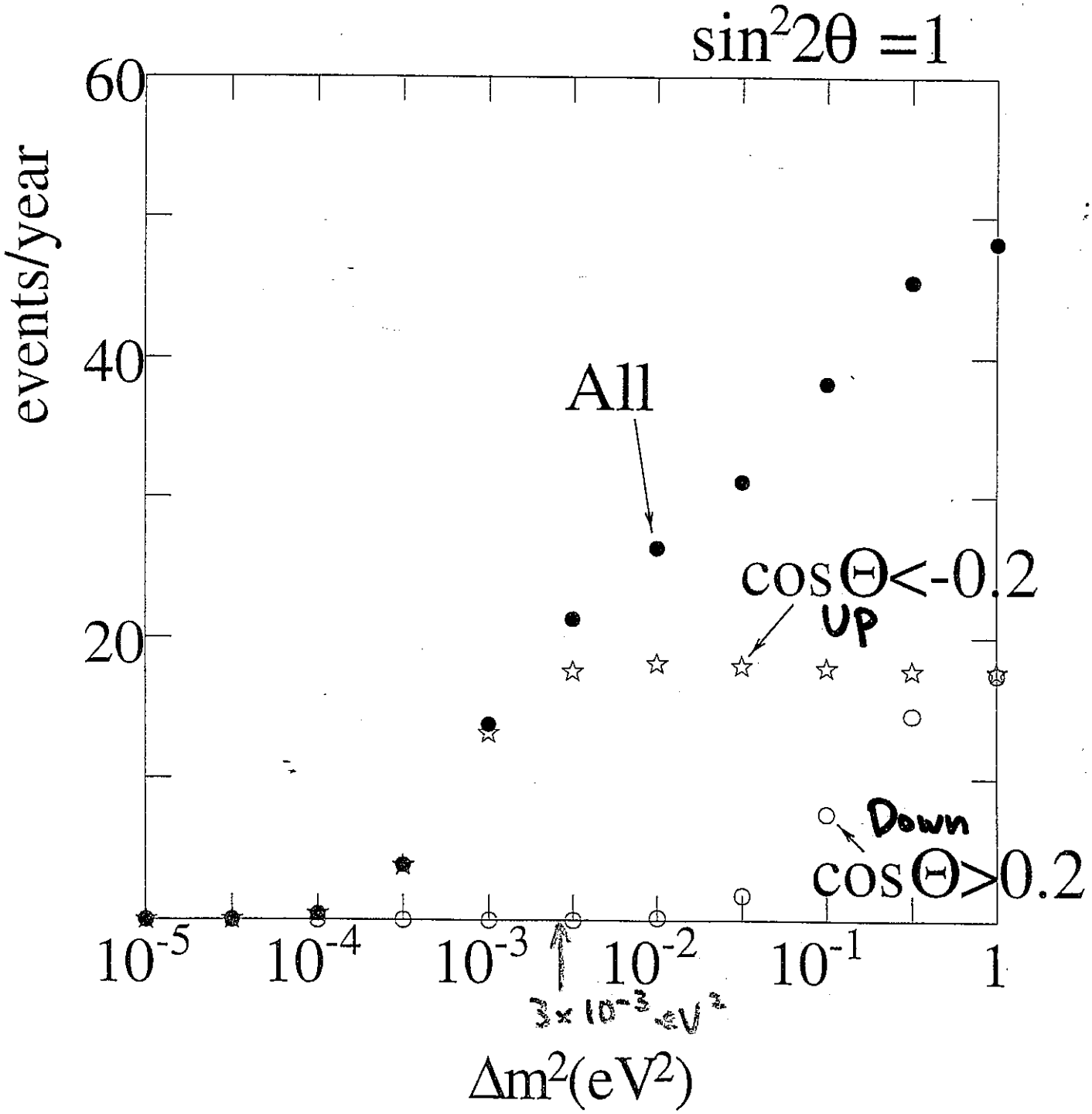
Three different analysis have done to enrich CC ν_τ .

1)likelihood method using "standard" SK variables such as Evis,# of rings,decay-e etc

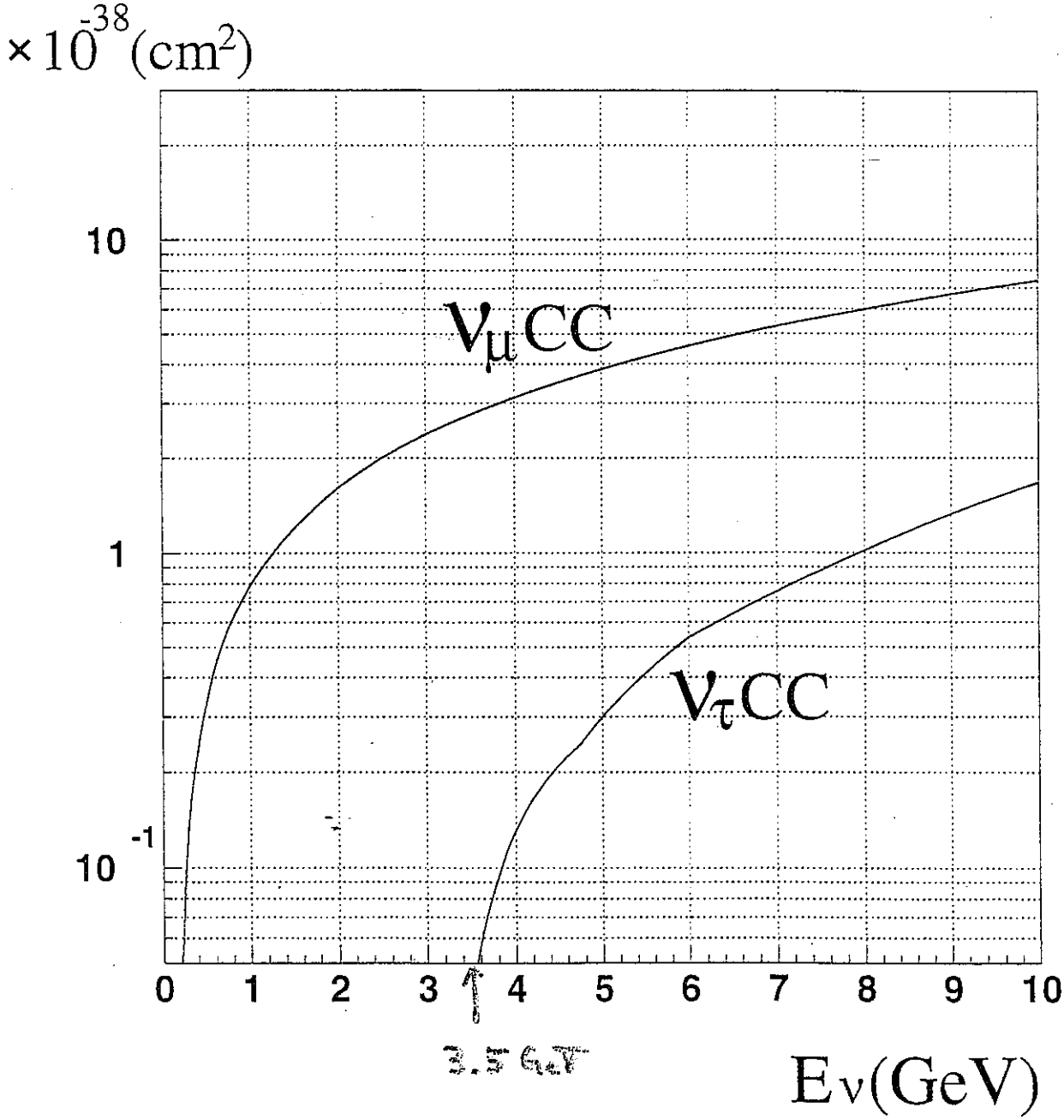
2)neural network method using "standard" SK veriables

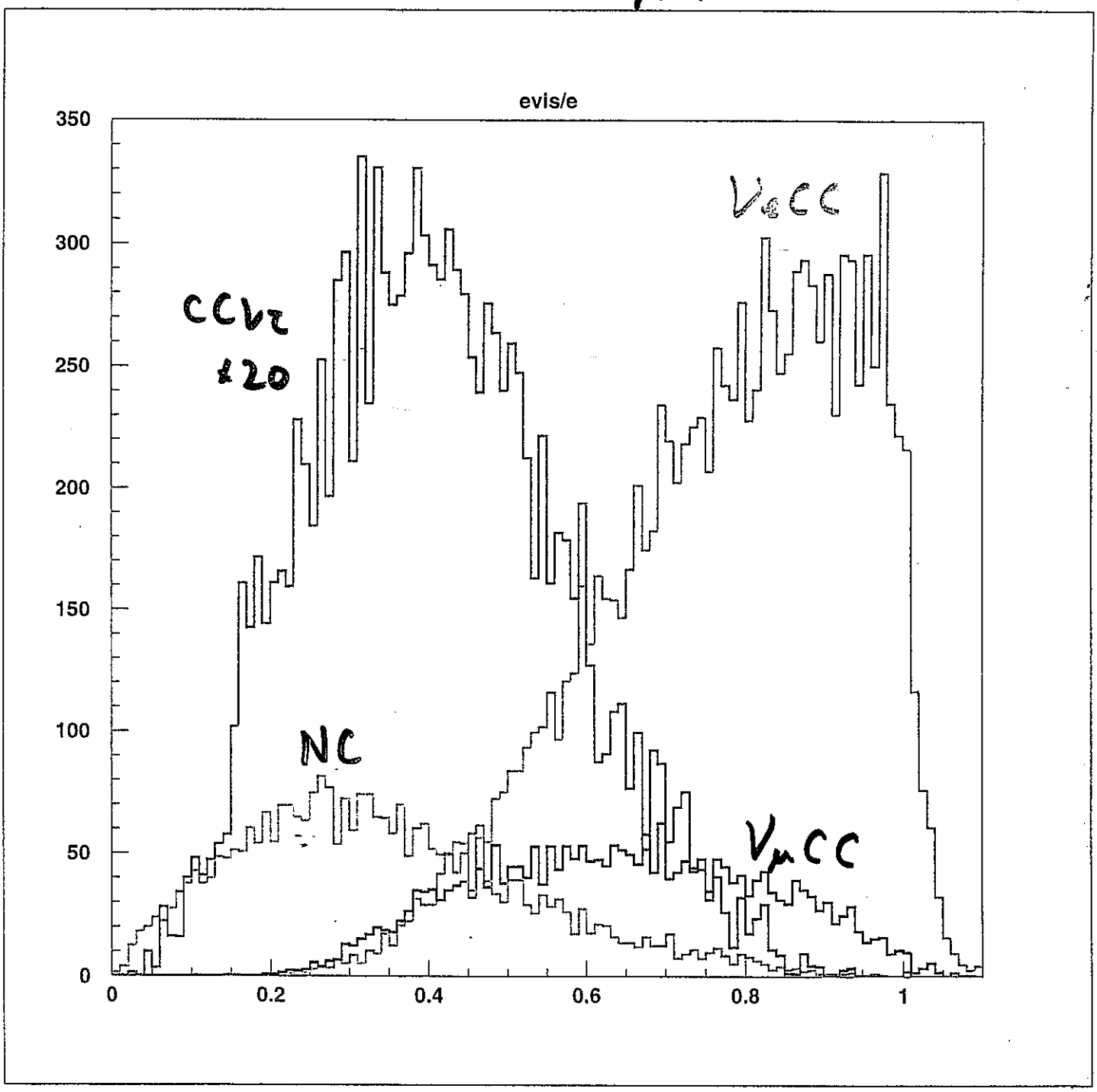
3)likelihood method using energy flow and event shape

Expected CC ν_τ events



Neutrino CC cross sections




evis/e
350
300
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
CCνt
×20
NC
νμCC
νeCC

analysis(1)

basic cuts;

FC,Evis>1.33GeV,most energetic=e-like

S/N ~ 3.5%

likelihood analysis with;

Evis

# of decay-e ← # of π ← E_ν } MissE

# of rings ↙

max(E of a ring)/Etot — reject ν_e CC

max d(1ry -> decay-e) — reject ν_μ CC

max P_μ — reject ν_μ CC

Pt — event shape

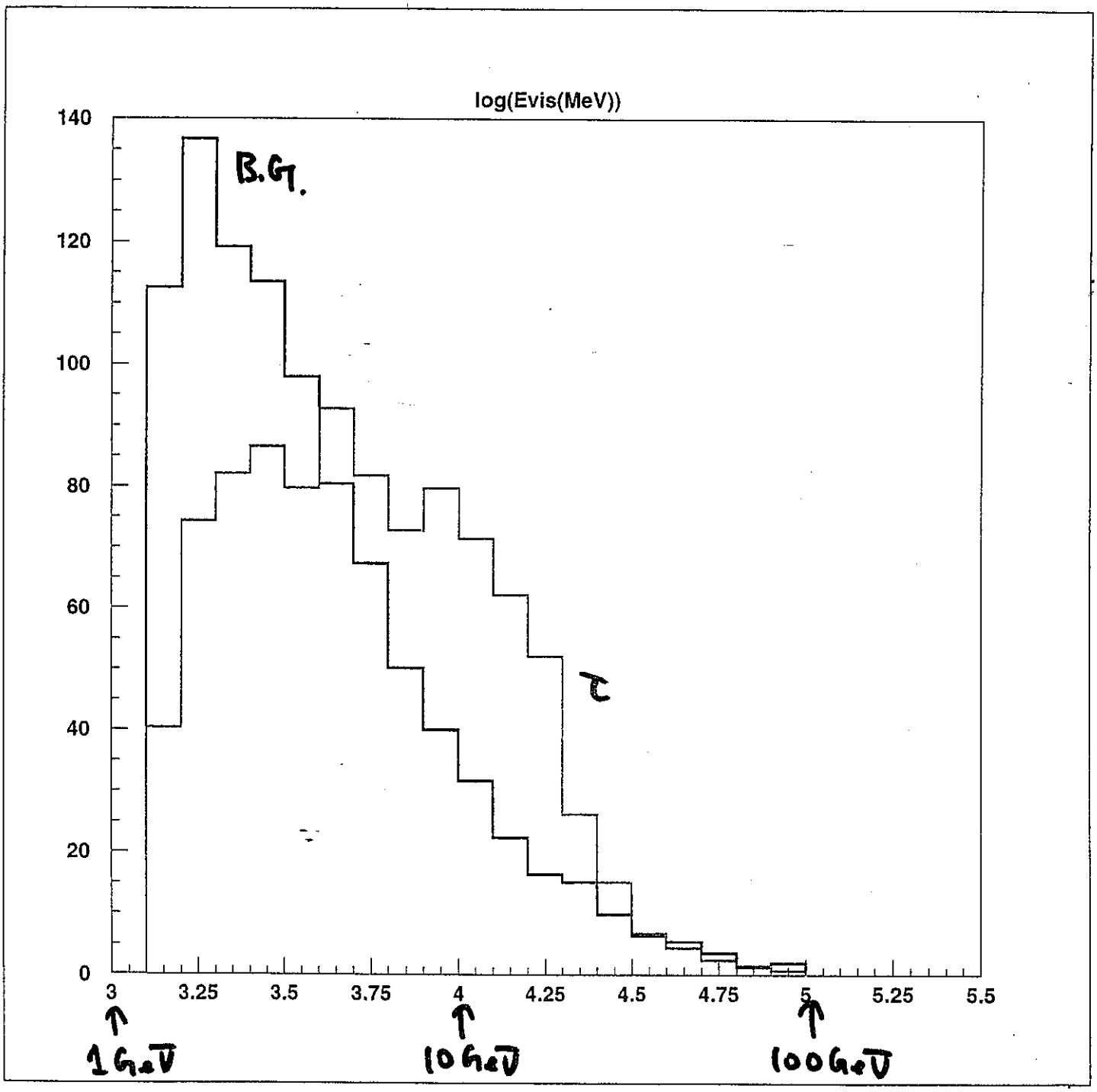
PID likelihood of most energetic ring — difference in shower structure

multi-ring + single-ring

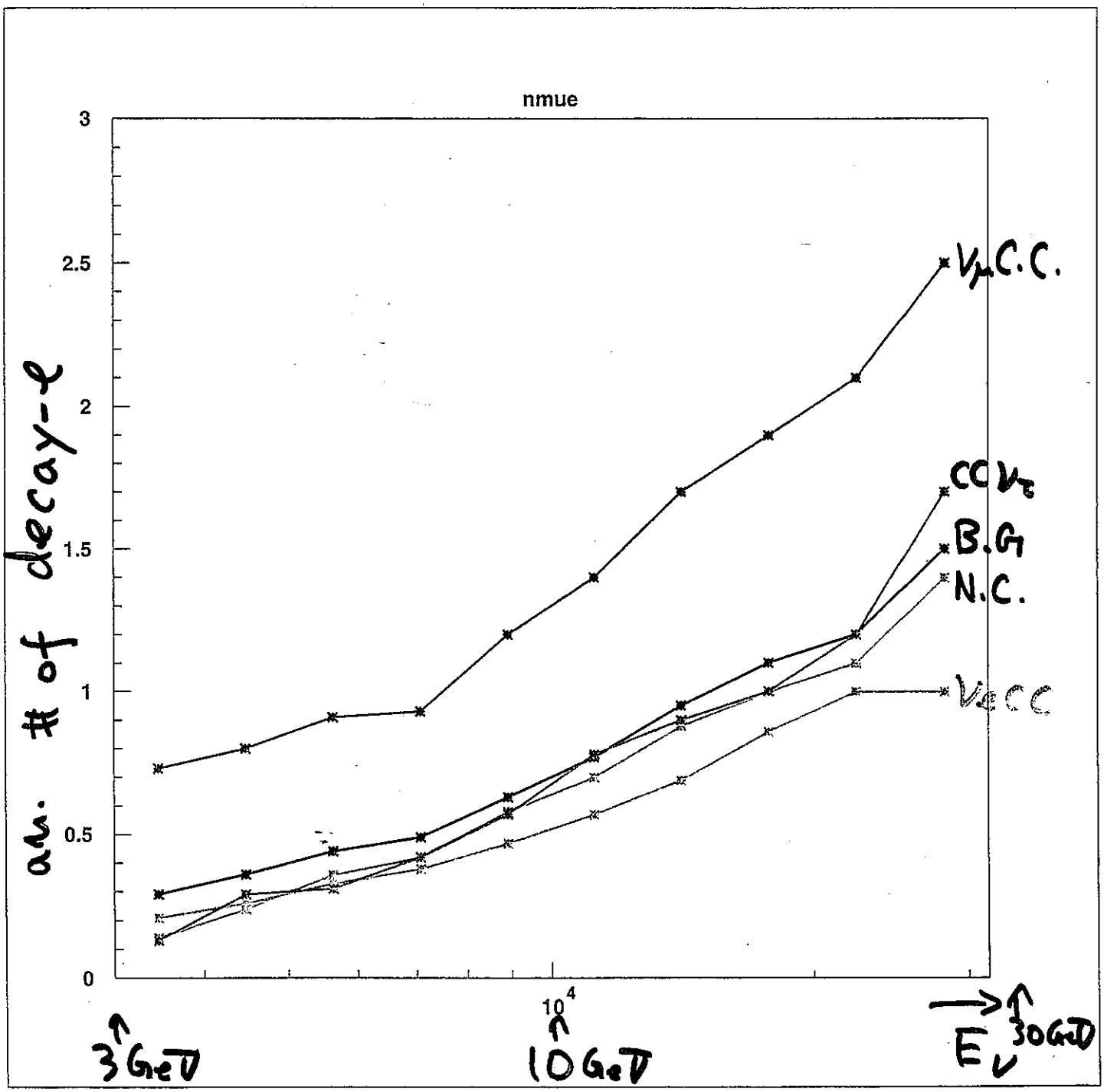
80% 20%

multi-ring

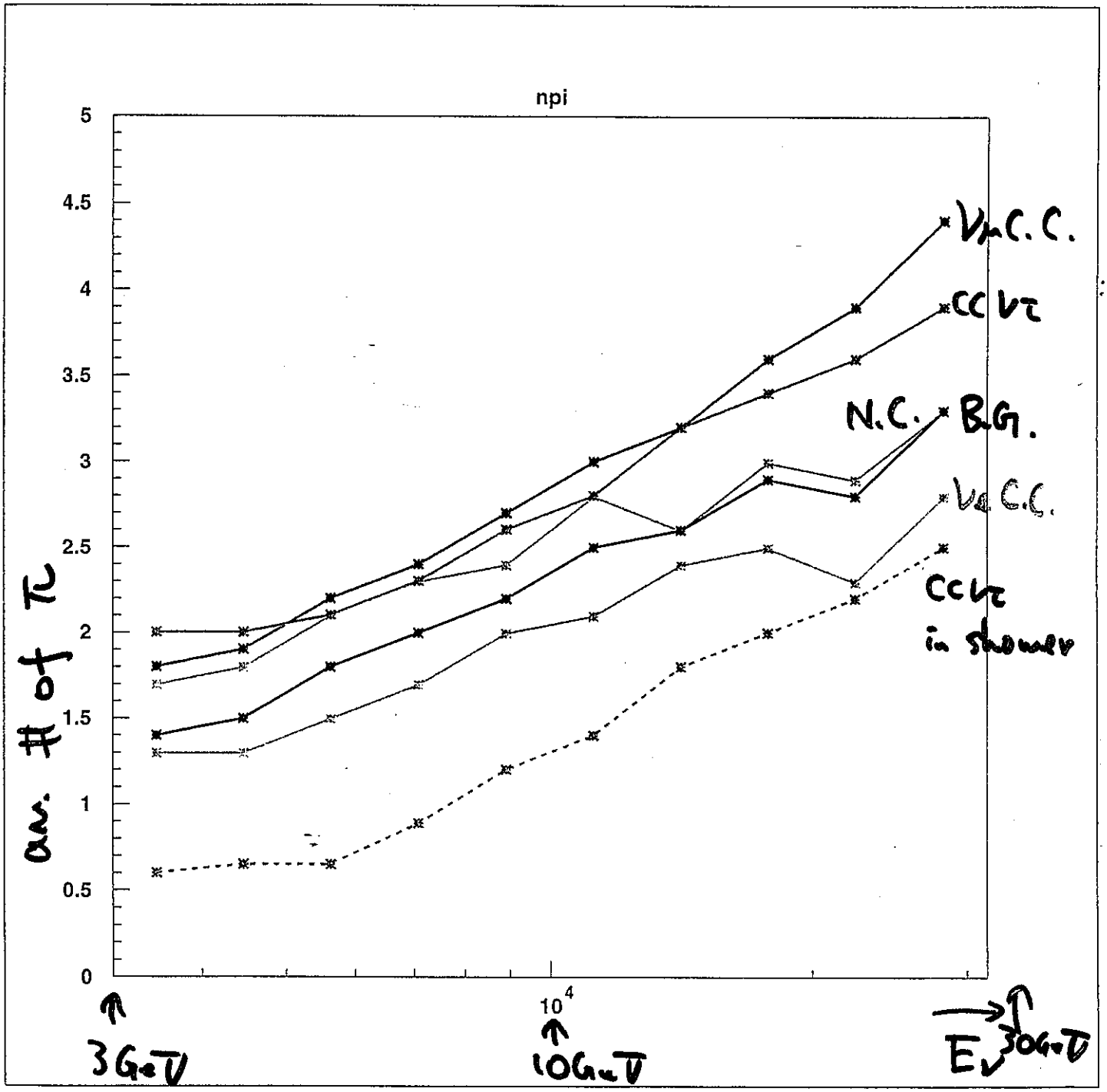
Evis



MC

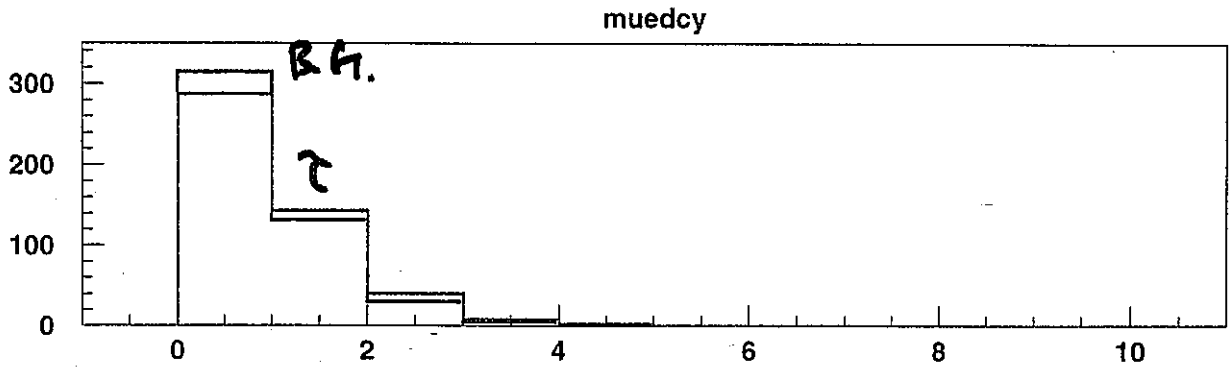

nmue
3
2.5
2
1.5
1
0.5
0
10^4
ν_μ C.C.
CC ν_τ
B.G
N.C.
ν_e CC
arb. # of decay-e
3GeV
10GeV
30GeV
E_ν

MC

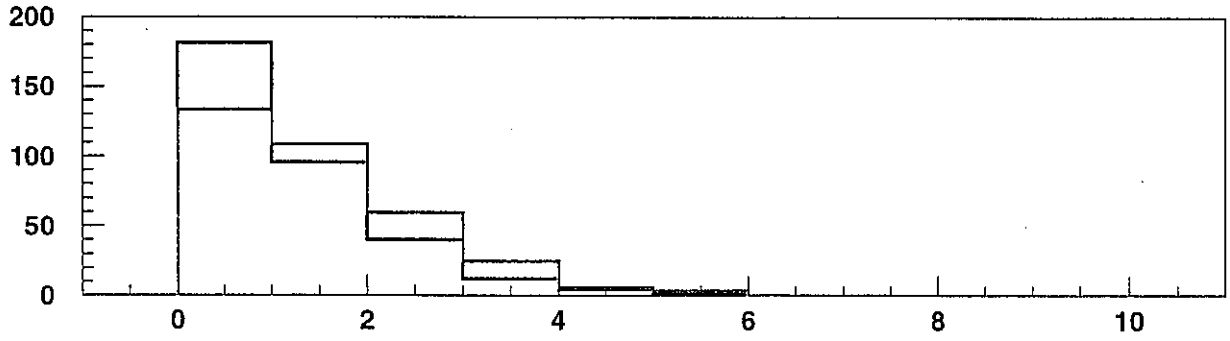

npi
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10^4
av. # of τ
3GeV
10GeV
E
30GeV
N.C. BG.
CC ντ
in shower

multi-ring

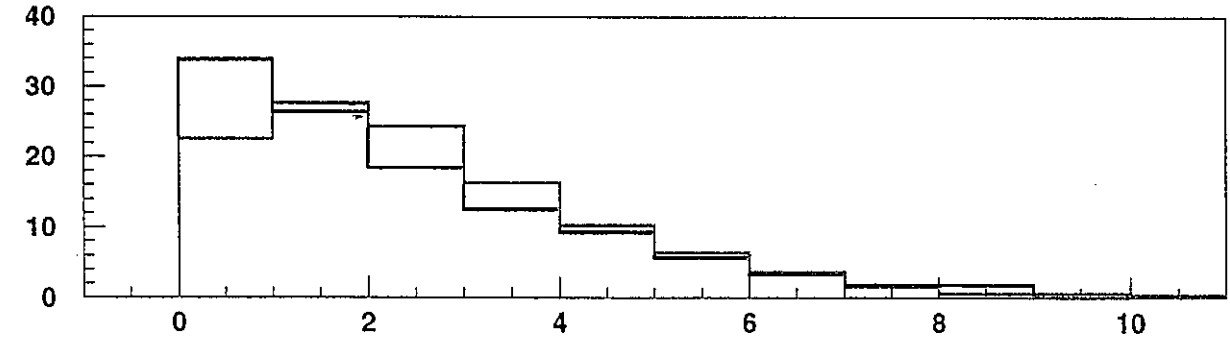
# of decay-e



1330<Evis(MeV)<3162

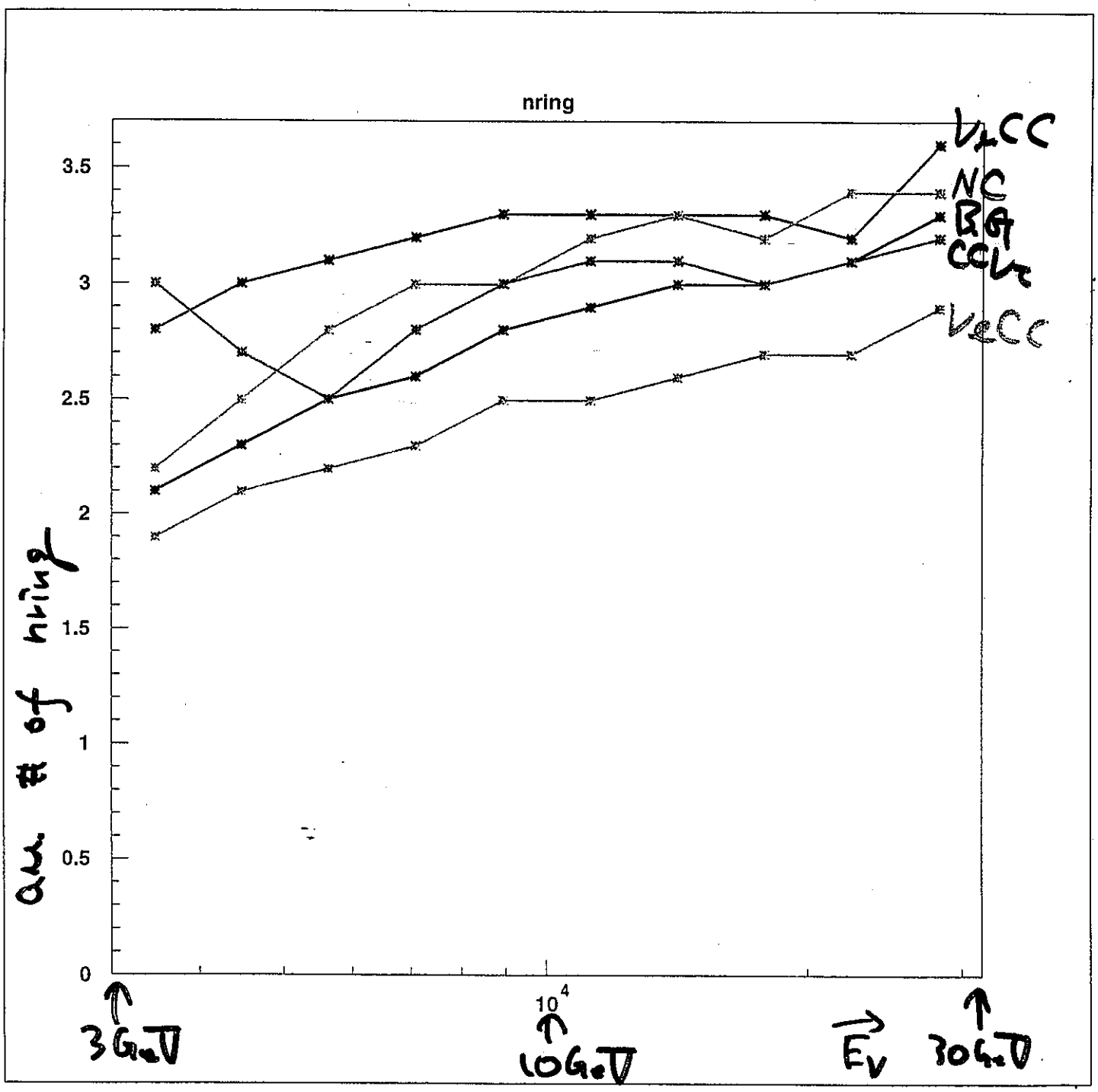


3162<Evis(MeV)<10000



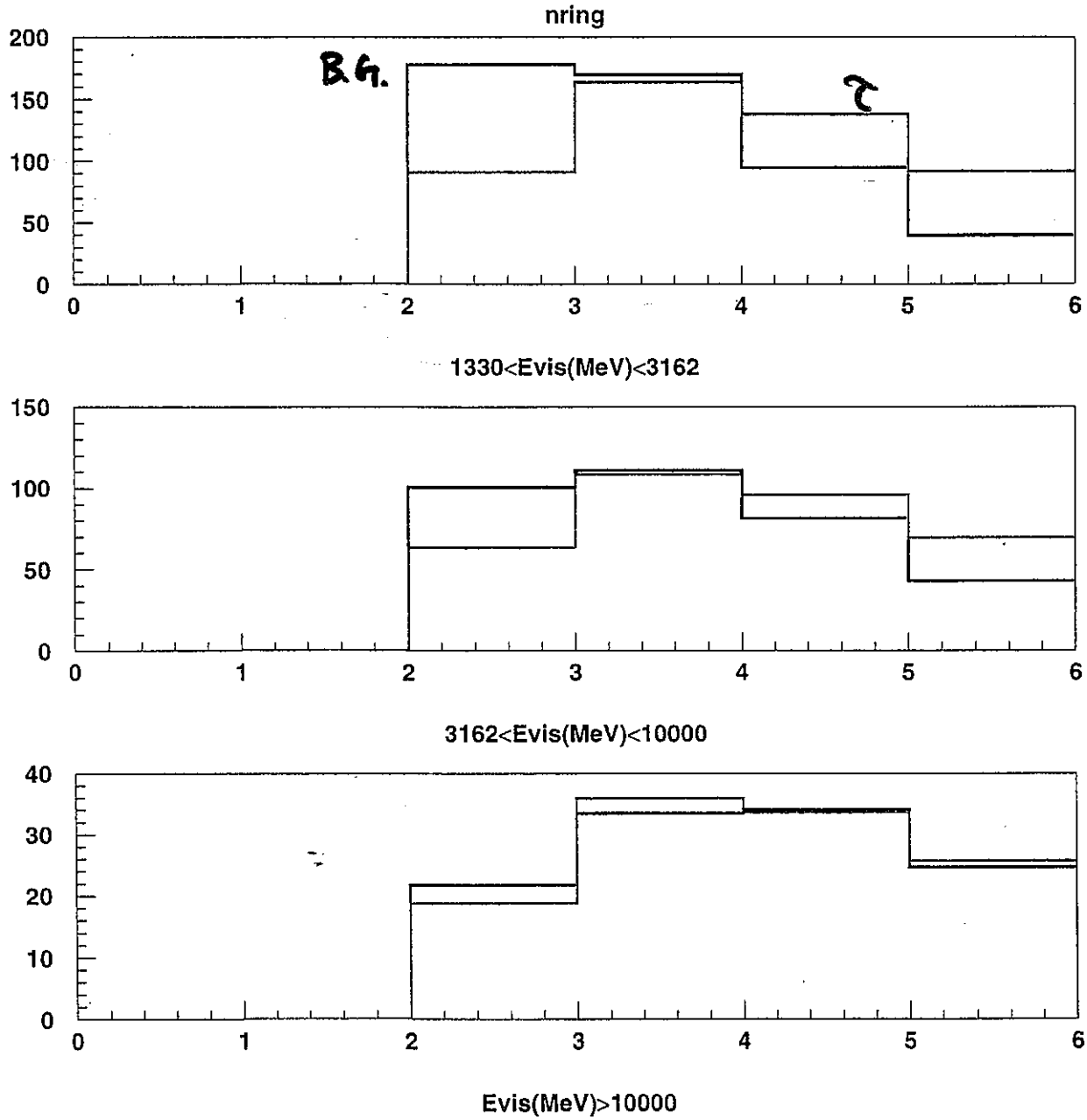
Evis(MeV)>10000

MC

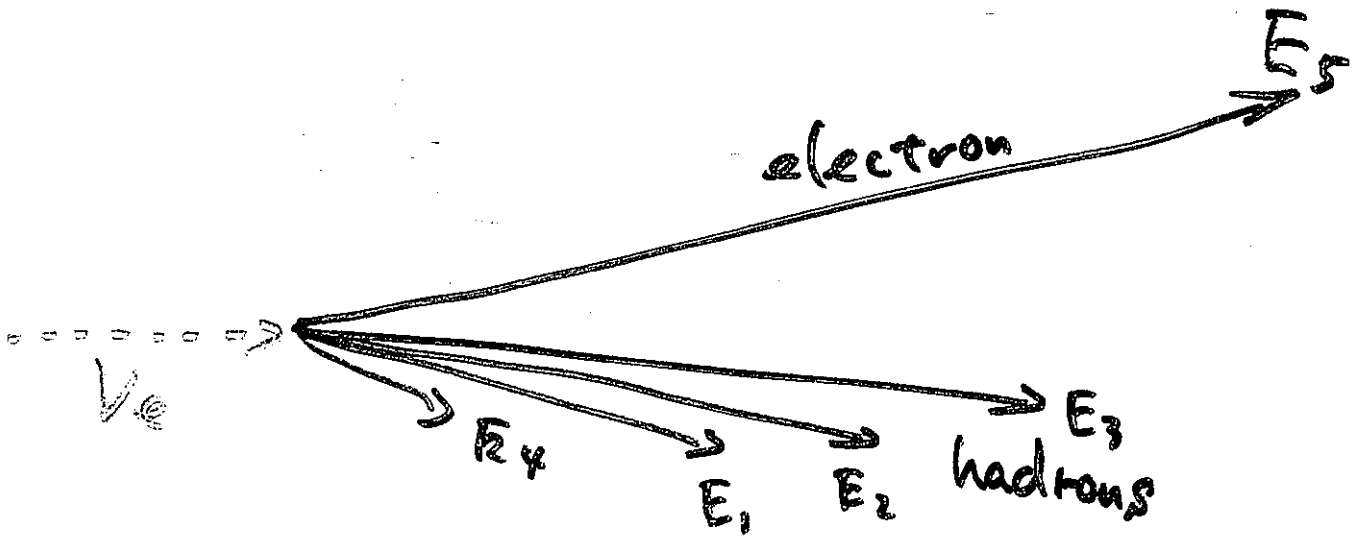

nring
3.5
3
2.5
2
1.5
1
0.5
0
Qu. # of hring
ν_μCC
NC
BG
CCν_τ
ν_eCC
3GeV
10^4
10GeV
E_ν
30GeV

multi-ring

# of rings



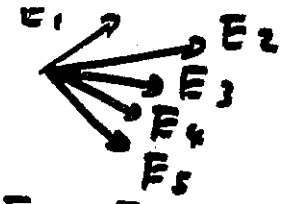
ν_e C.C.

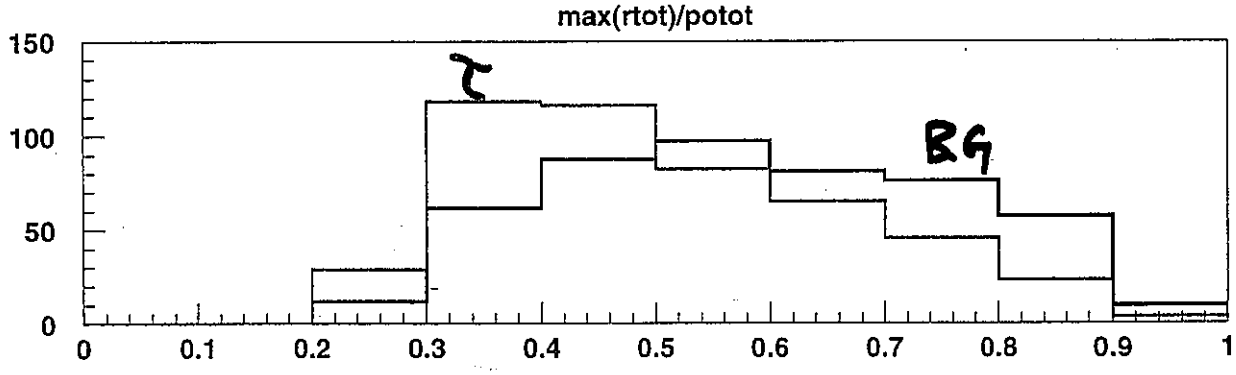


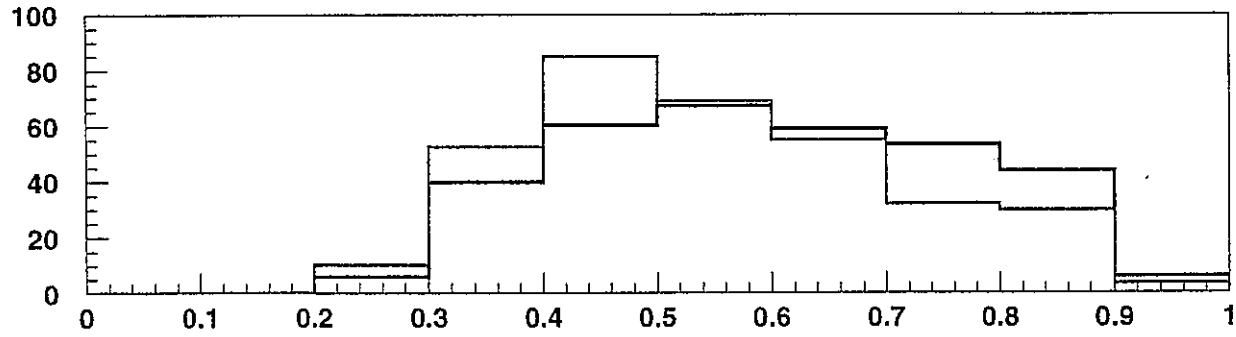
$\max(E_i) / \sum_i E_i$: large

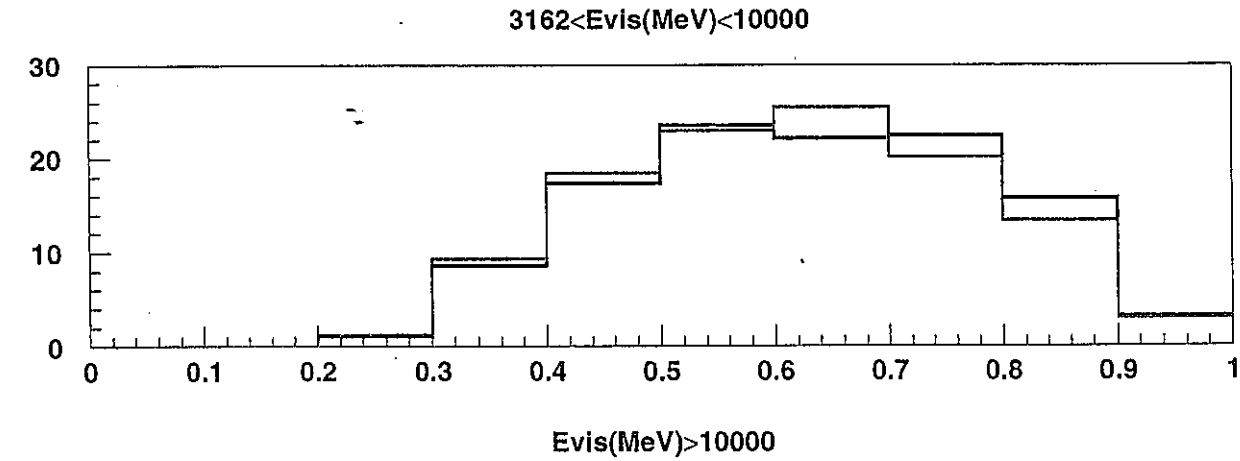
multi-ring

$$\max(E_1, E_2, E_3, E_4, E_5) / (E_1 + E_2 + E_3 + E_4 + E_5)$$

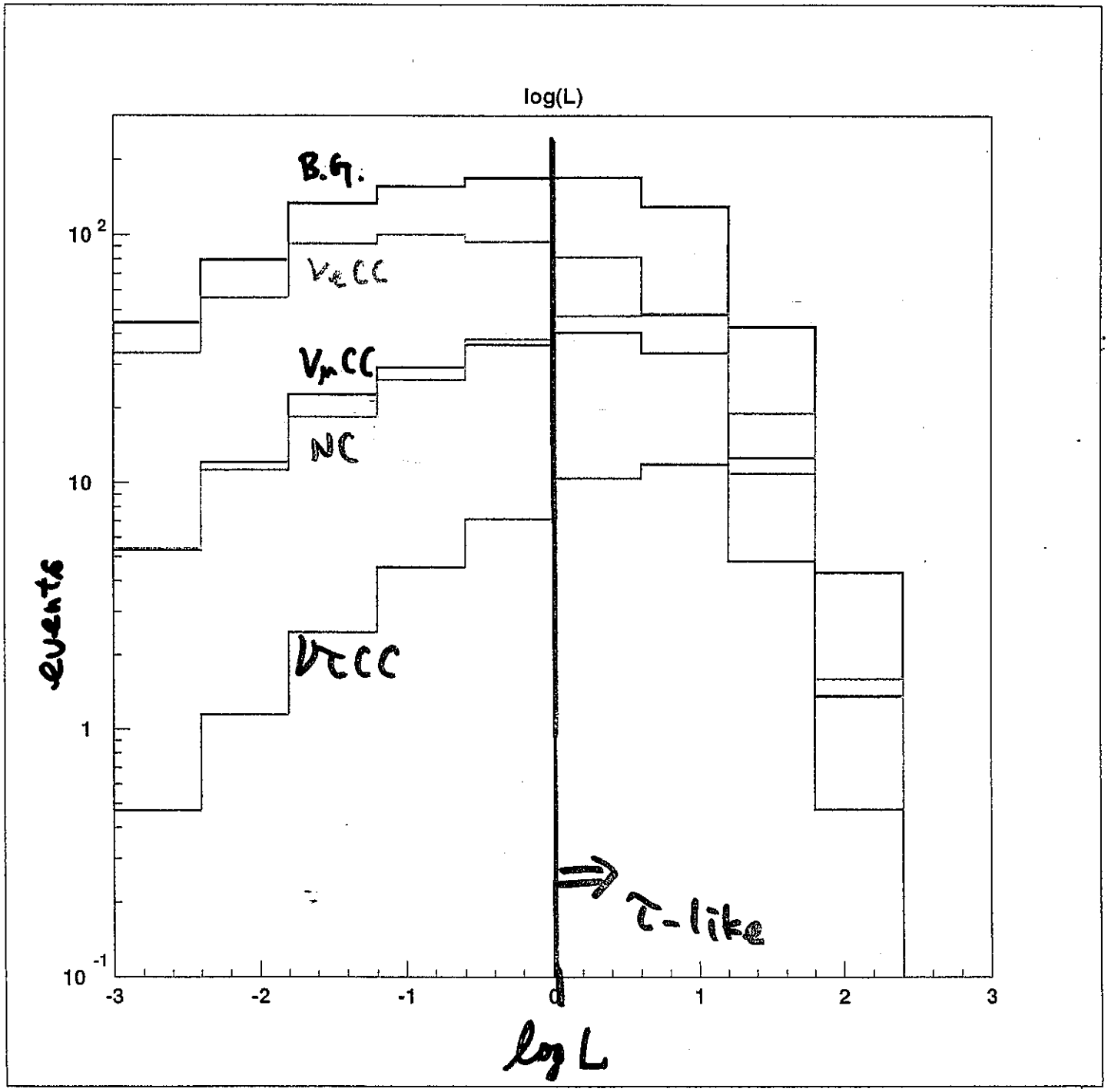








multi-ring



Normalized by livetime (1289 days)

-like
ν_τCC 31ev B.G. 387ev

ν_eCC 43%
ν_μCC 25%
NC 32%

S/N = 8%

ν_τ events appear as upward going events!

Analysis is optimized by MC

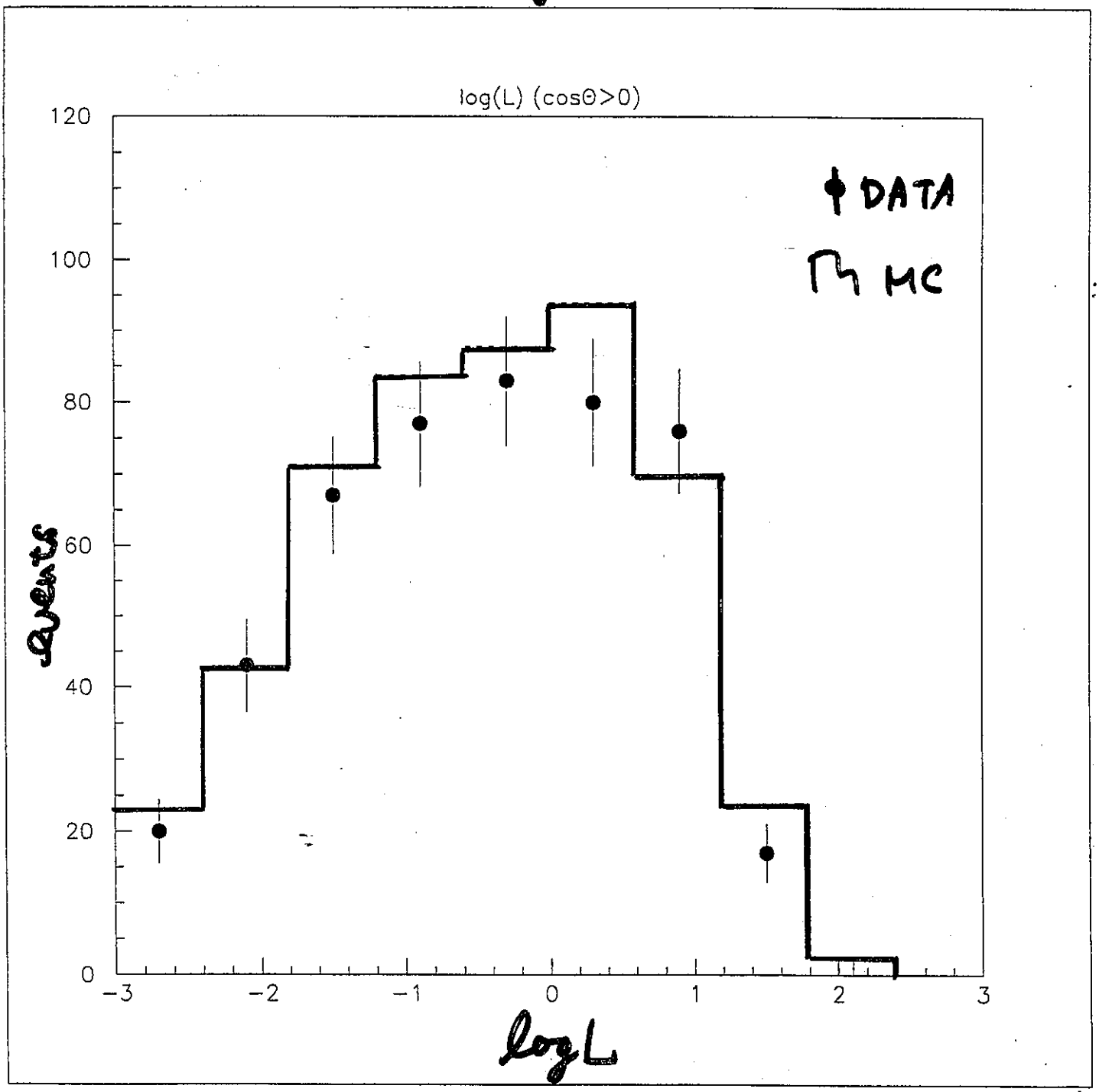
and looking at using only downward going events in data.

blind analysis!

Zenith angle fits are performed to obtain signal.

multi-ring

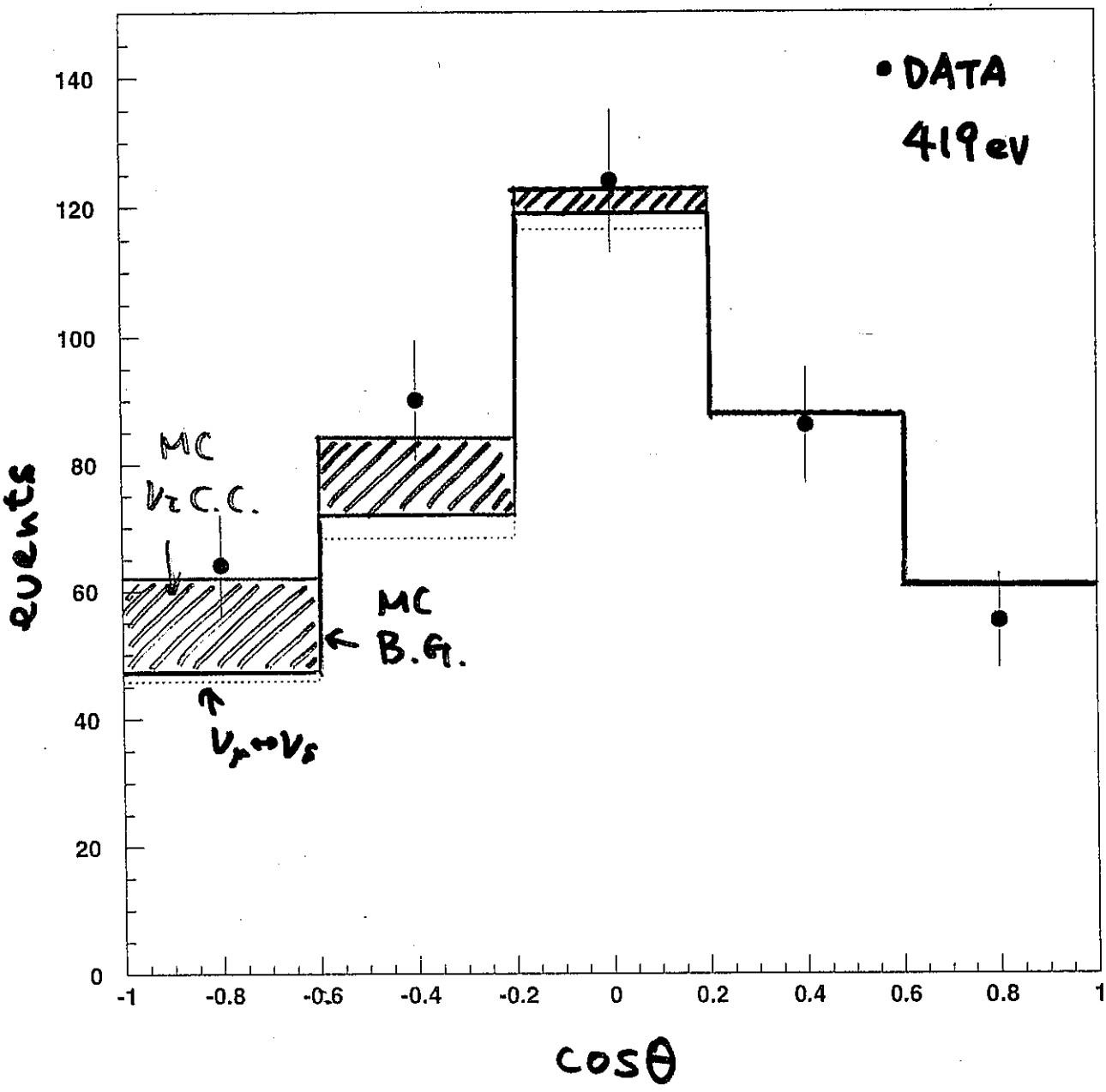
Downward going events



MC is normalized by livetime

Zenith angle distribution

τ - like



MC is normalized by livetime.

3×10^{-3} eV^2, $\sin^2 2\theta = 1$

ν_τ C.C. 31 ev

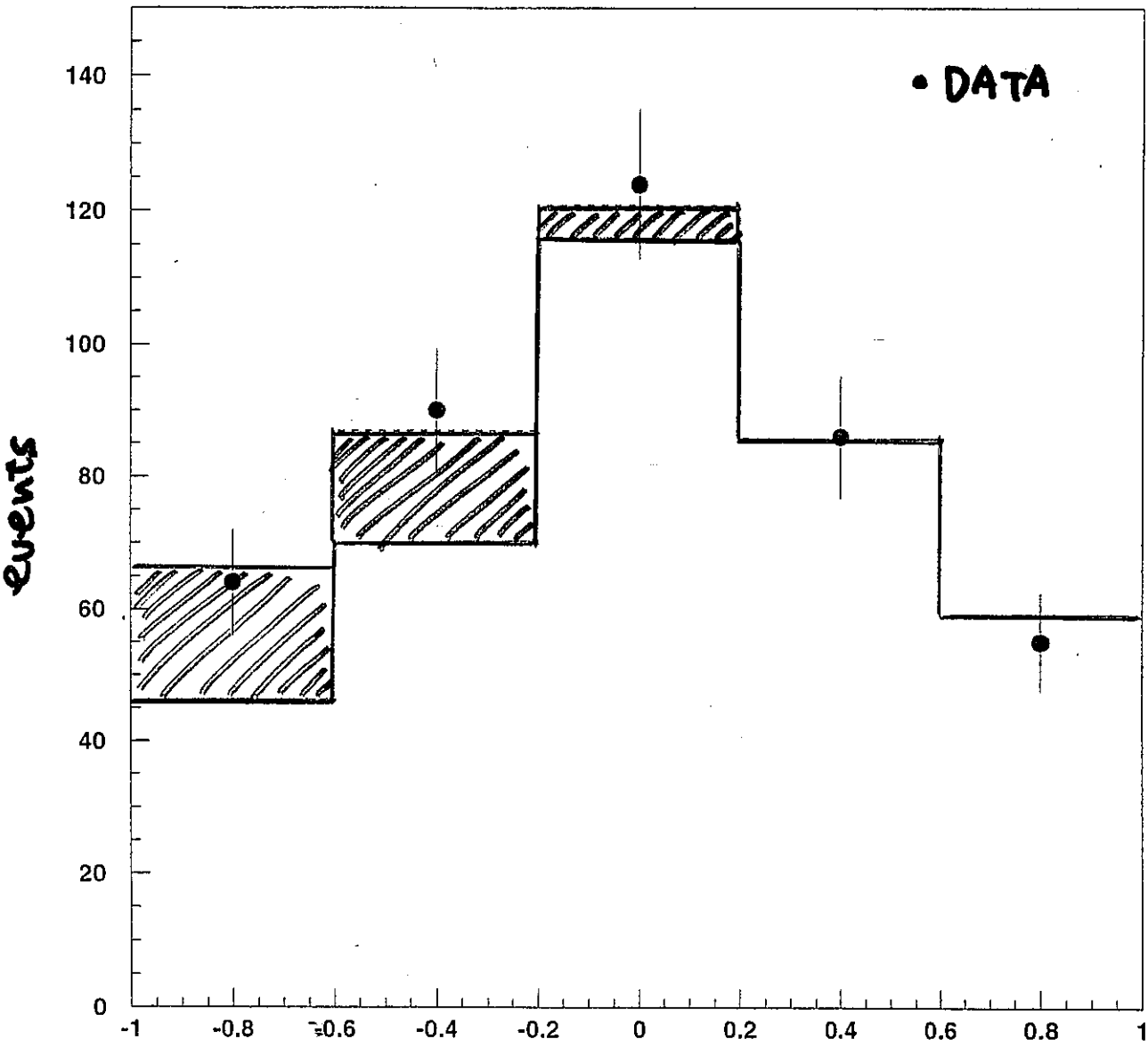
B.G. 387 ev

(ν_e C.C. 43 %
ν_μ C.C. 25 %
N.C. 32 %)

S/N = 8 %

Zenith angle distribution

τ - like



fit :

$$\chi^2 \equiv \sum_{\cos\Theta_i}^{5} \left(\frac{N_{data\,i} - (\alpha \cdot N^{\tau}_{MC\,i} + \beta \cdot N^{B.G.}_{MC\,i})}{\sigma_i} \right)^2$$

α, β free

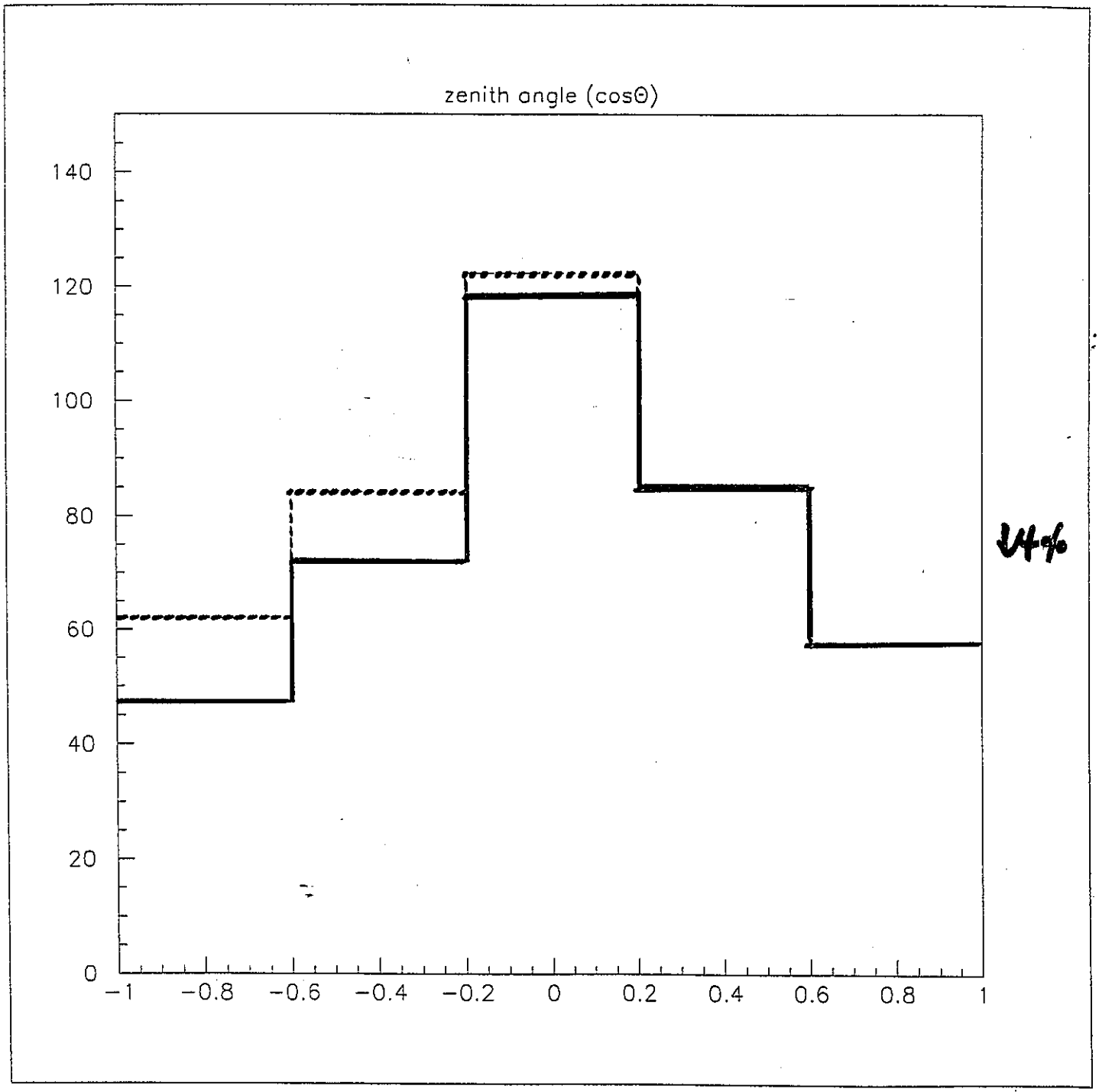
$\chi^2_{min.} = 0.54(d.o.f. = 3)$ at $\alpha = 1.39, \beta = 0.97$

$$\boxed{\begin{aligned} N^{obs.}_{\tau} &\equiv \alpha \cdot N^{\tau}_{MC} \\ &= 43 \pm 17^{+8}_{-11} \end{aligned}}$$

systematic errors for $N_\tau^{obs.}$

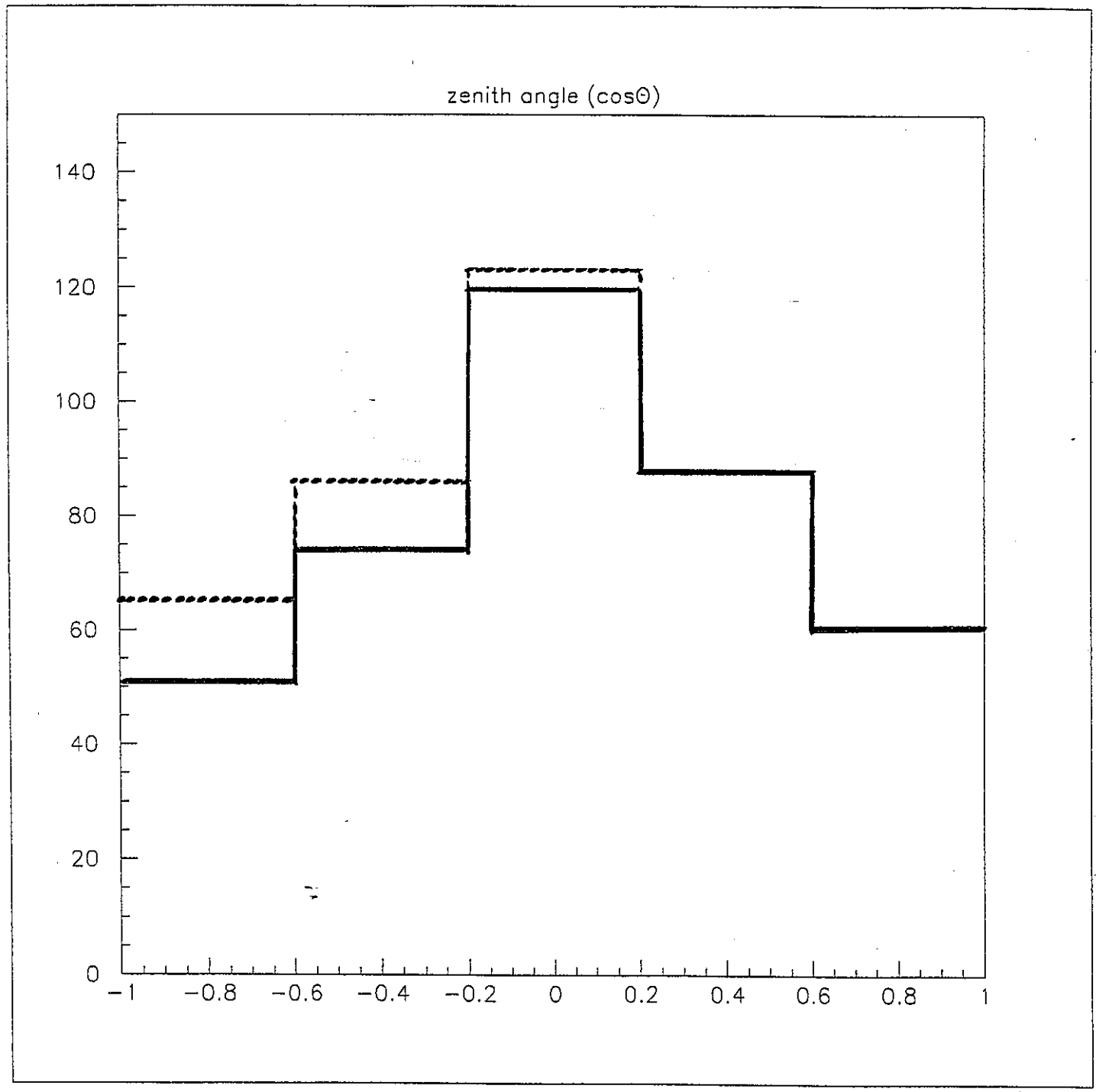
source	systematic error
$\frac{\sigma(N.C.)}{\sigma(C.C.)}$ (30%)	± 3
$\frac{\phi(\nu_e)}{\phi(\nu_\mu)}$ (10%)	0
'Mt Ikenoyama' effect	$^{+0}_{-3}$
$(\sin^2 2\theta, \Delta m^2(eV^2))$	± 7
$(1.0, 1.5 \times 10^{-3})$ **-7**	
$(0.9, 3.0 \times 10^{-3})$ **-2**	
$(1.0, 5.0 \times 10^{-3})$ **+7**	
$\sin^2 \theta_{13}$ (0.025)	$^{+0}_{-7}$

mountain 'Mt. Ikenoyama' effect



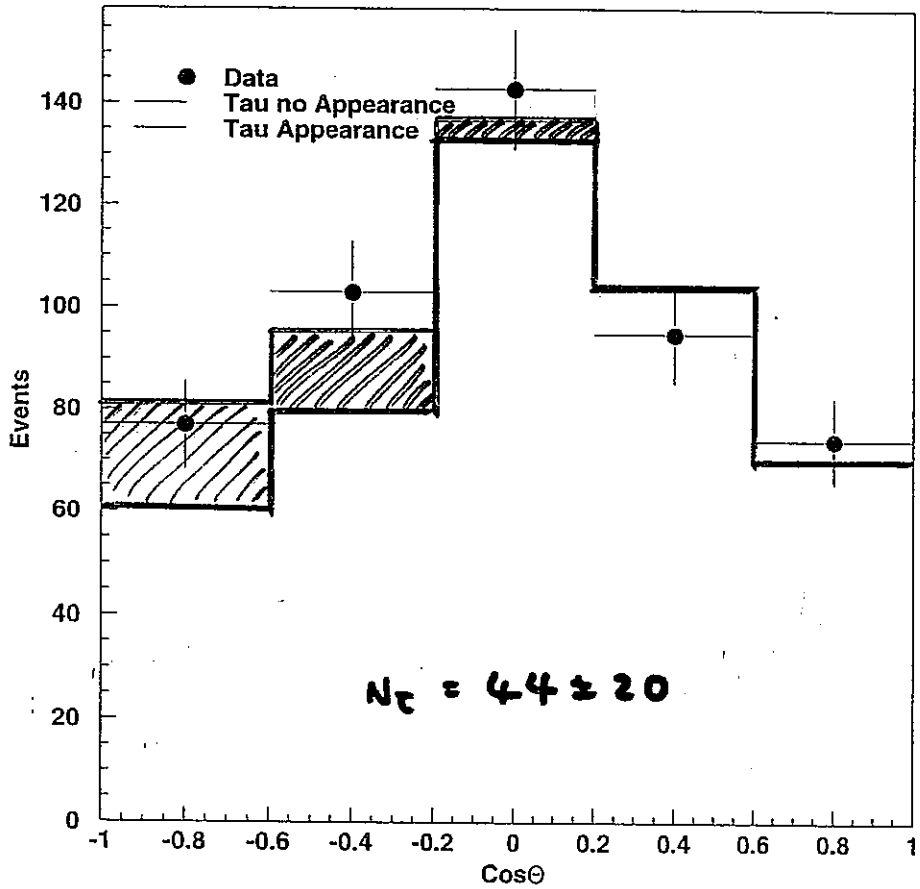
$\sin^2\theta_{13} = 0.025$

$\sin^2\theta_{13} = 0.025$

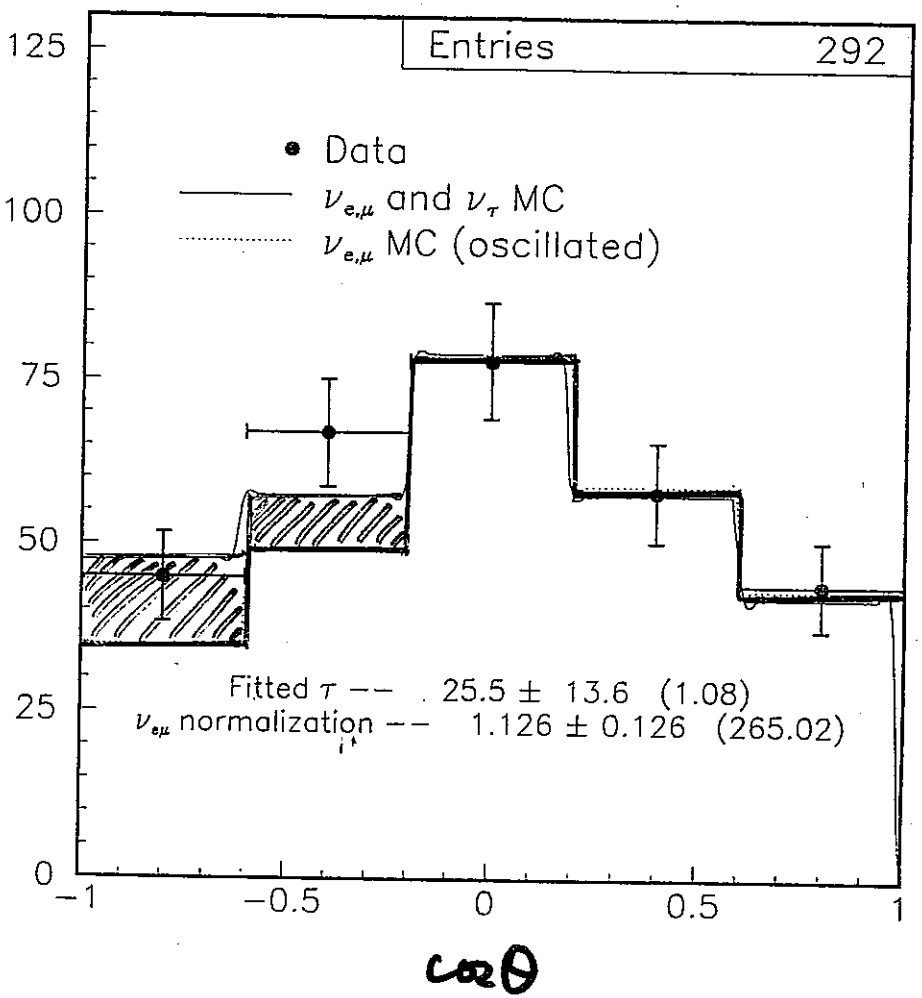


Zenith angle distribution

Analysis (2)



Analysis (3)



Results

	1)	2)	3)
Number of CC ν_τ (fitted excess)	$43 \pm 17^{+8}_{-11}$	$44 \pm 20^{+8}_{-12}$	25.5^{+14}_{-13}
Efficiency	42%	45%	32%
Number of CC ν_τ (efficiency corrected)	$103 \pm 41^{+18}_{-26}$	$98 \pm 44^{+18}_{-27}$	79^{+44}_{-40}

Consistent with ν_τ appearance.

74 CC ν_τ events are expected as FC so far.

Summary

79kt year of SK atmospheric neutrino data

- Search for CC $\nu\tau$

Three different analysis have done.

Consistent with ν_τ appearance

In future

Three analysis will be combined.
Estimation of selection efficiency
More statistics!

> 3 sigma signal with a few more years of data.