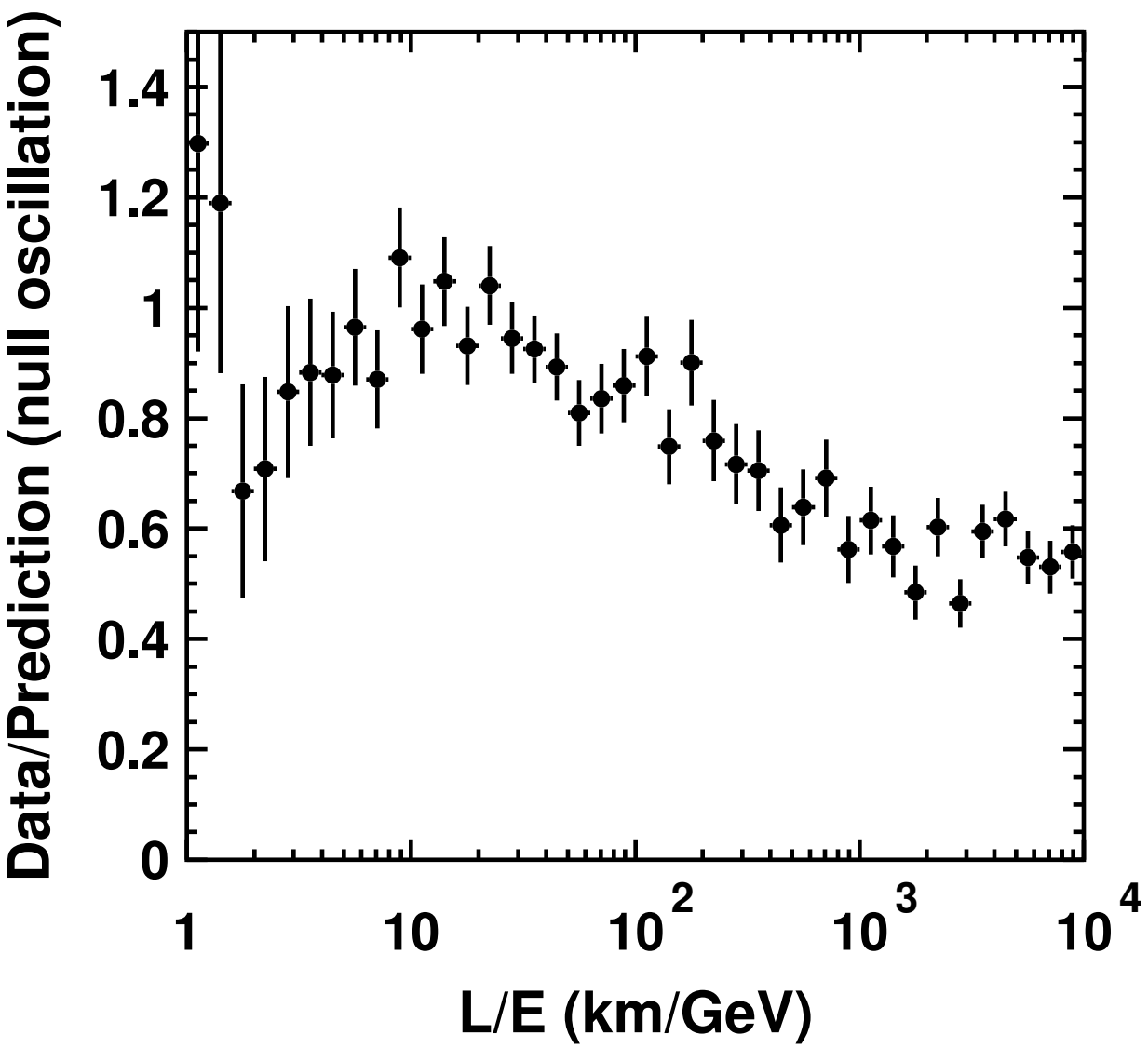
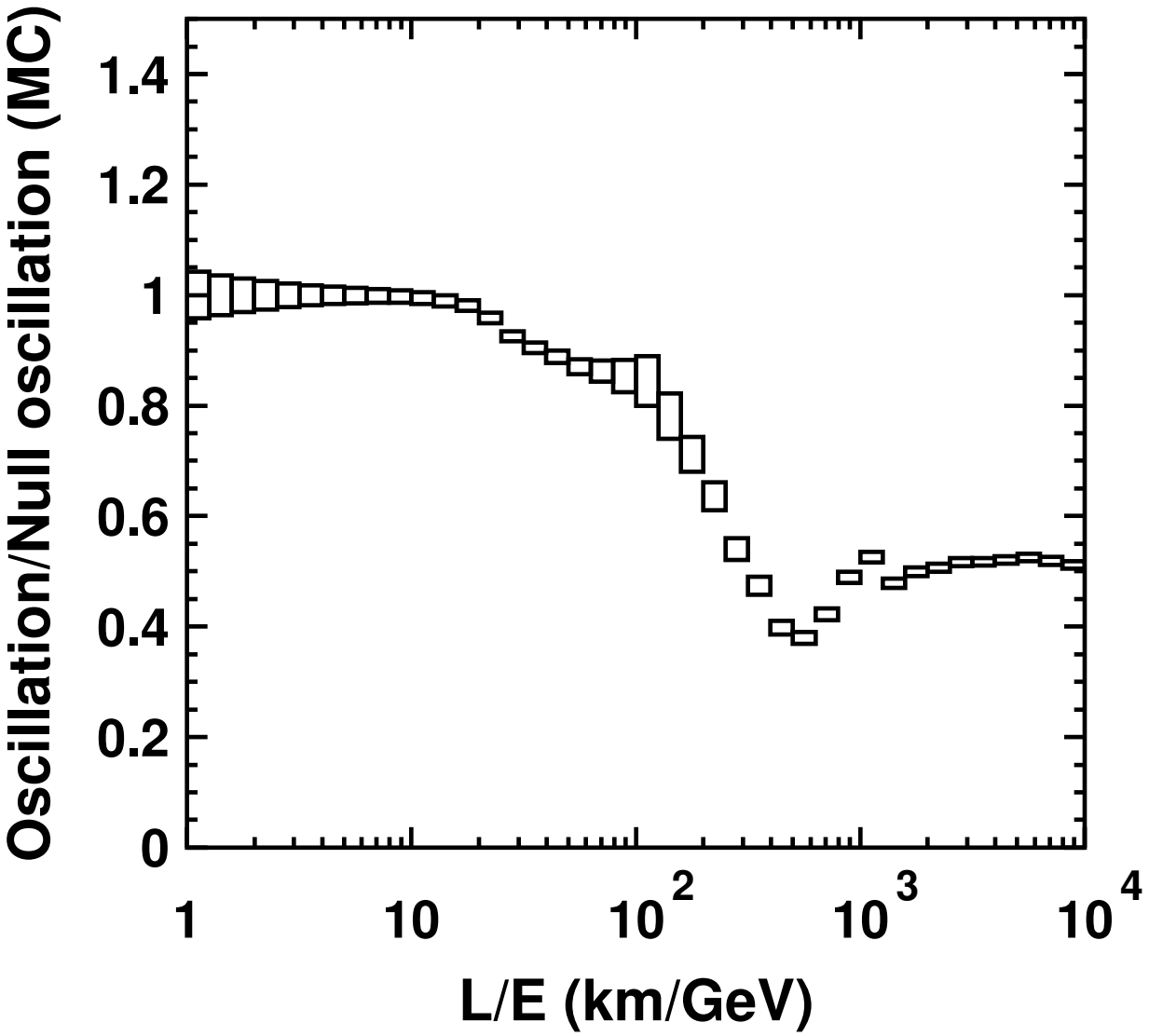
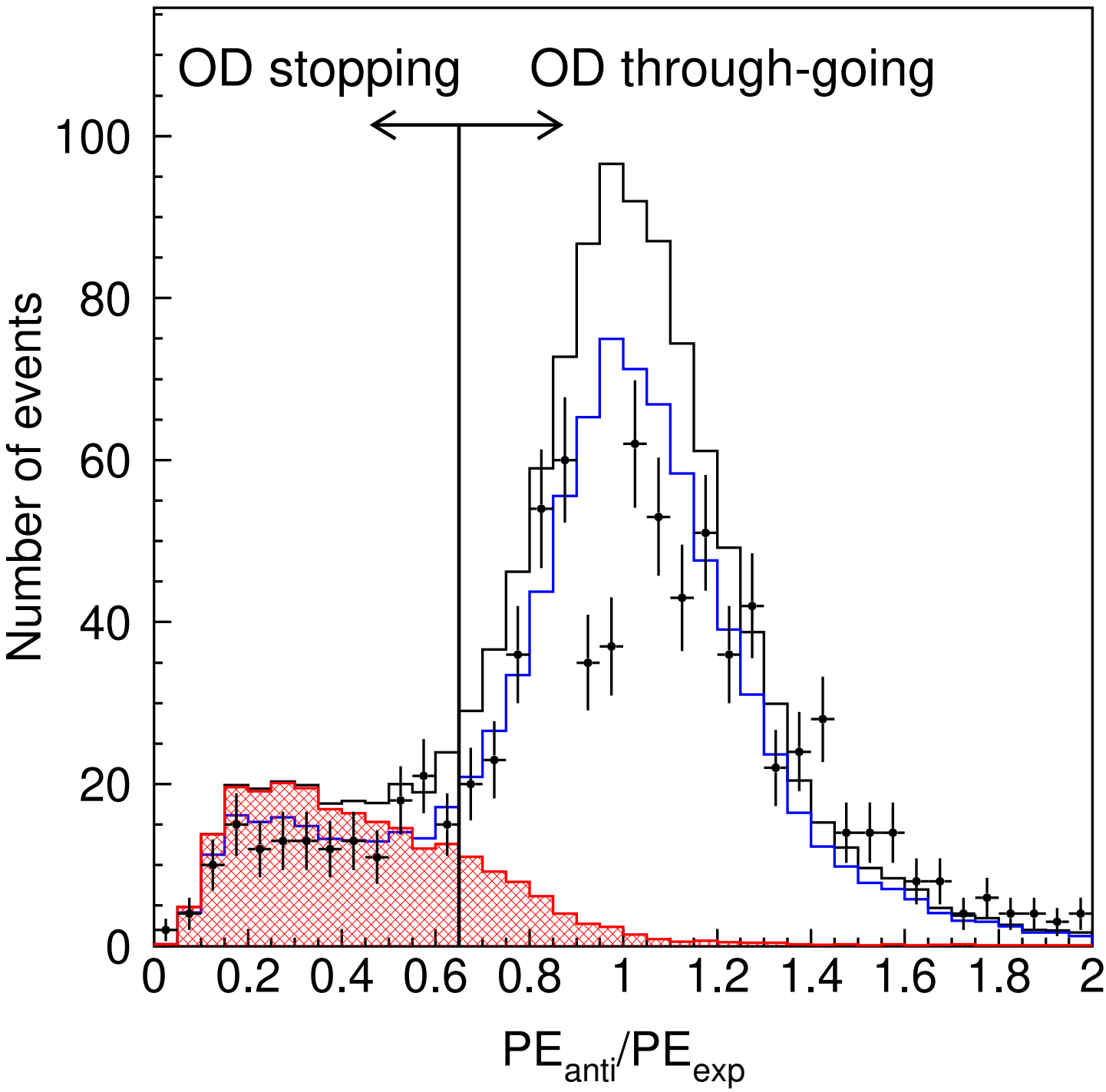
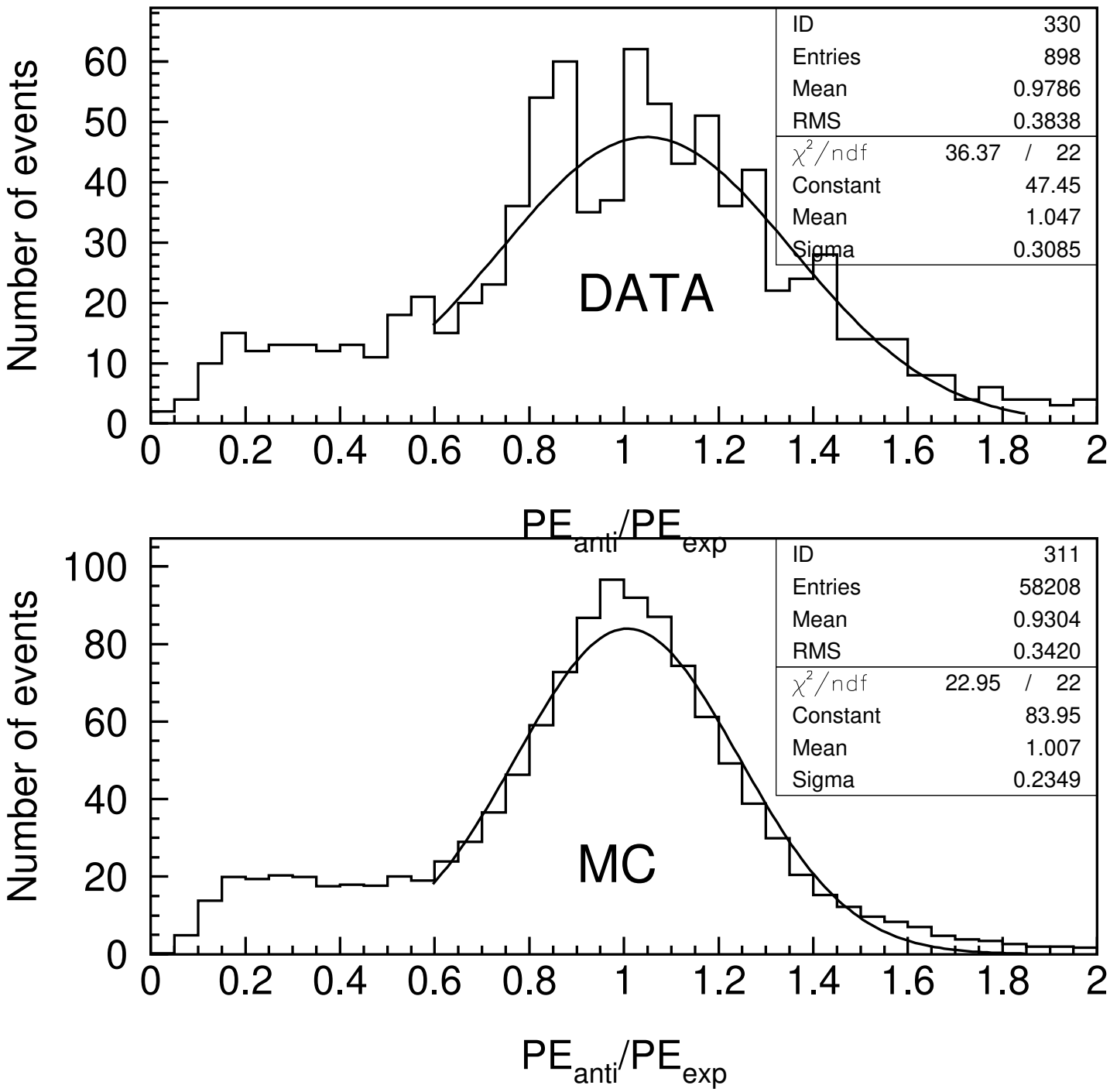
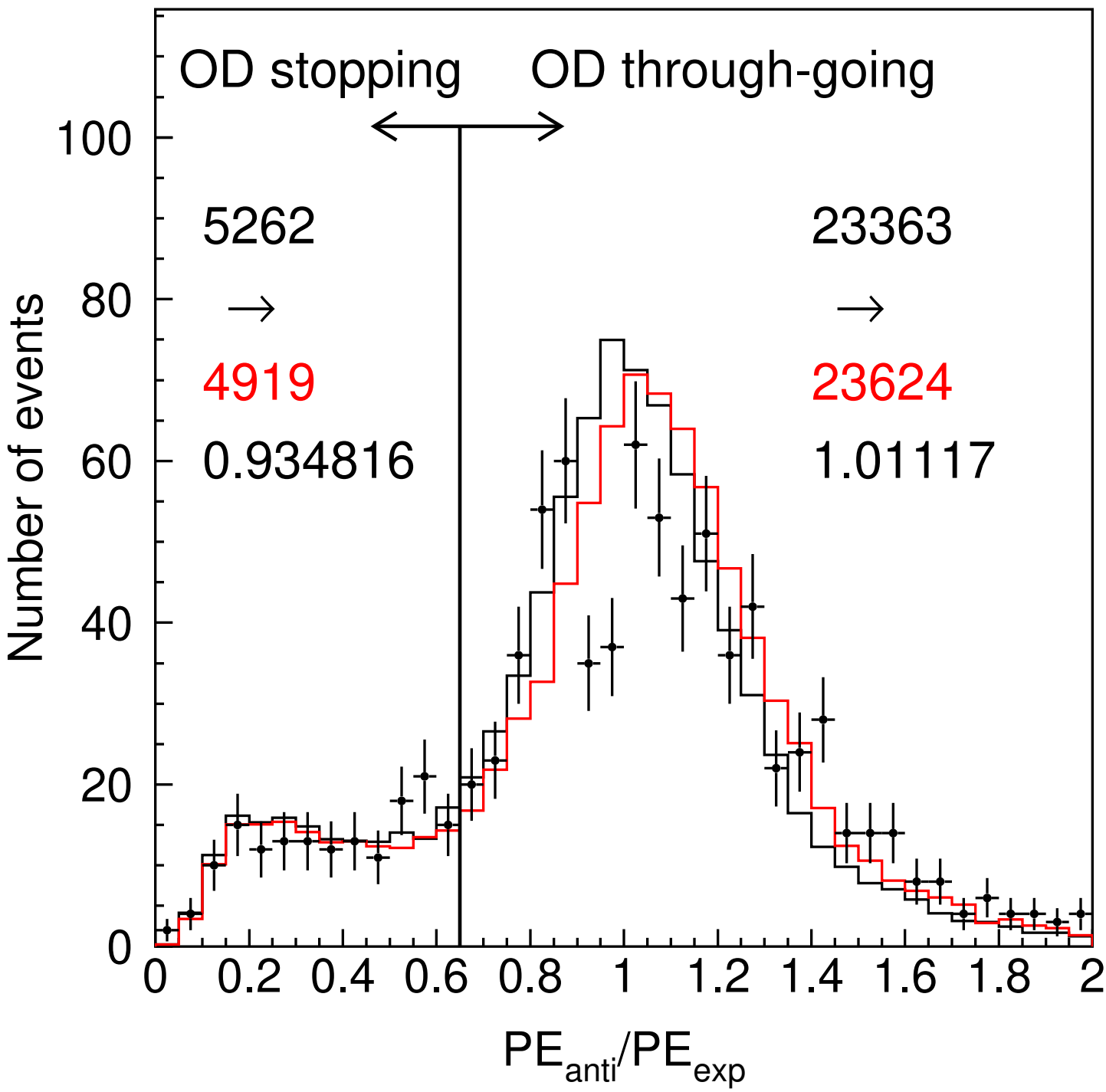
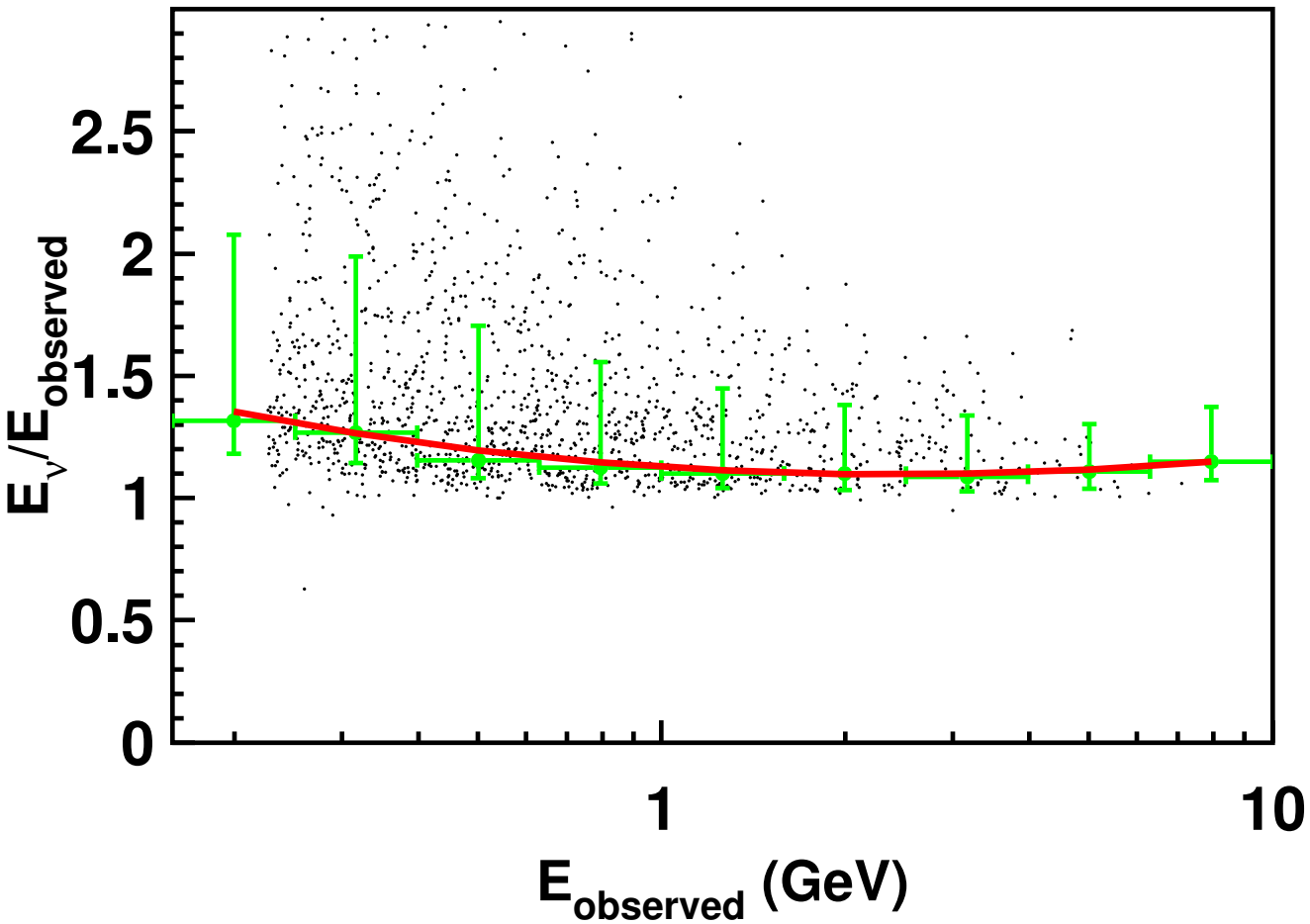

Data/Prediction (null oscillation)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1
10
10^2
10^3
10^4
L/E (km/GeV)

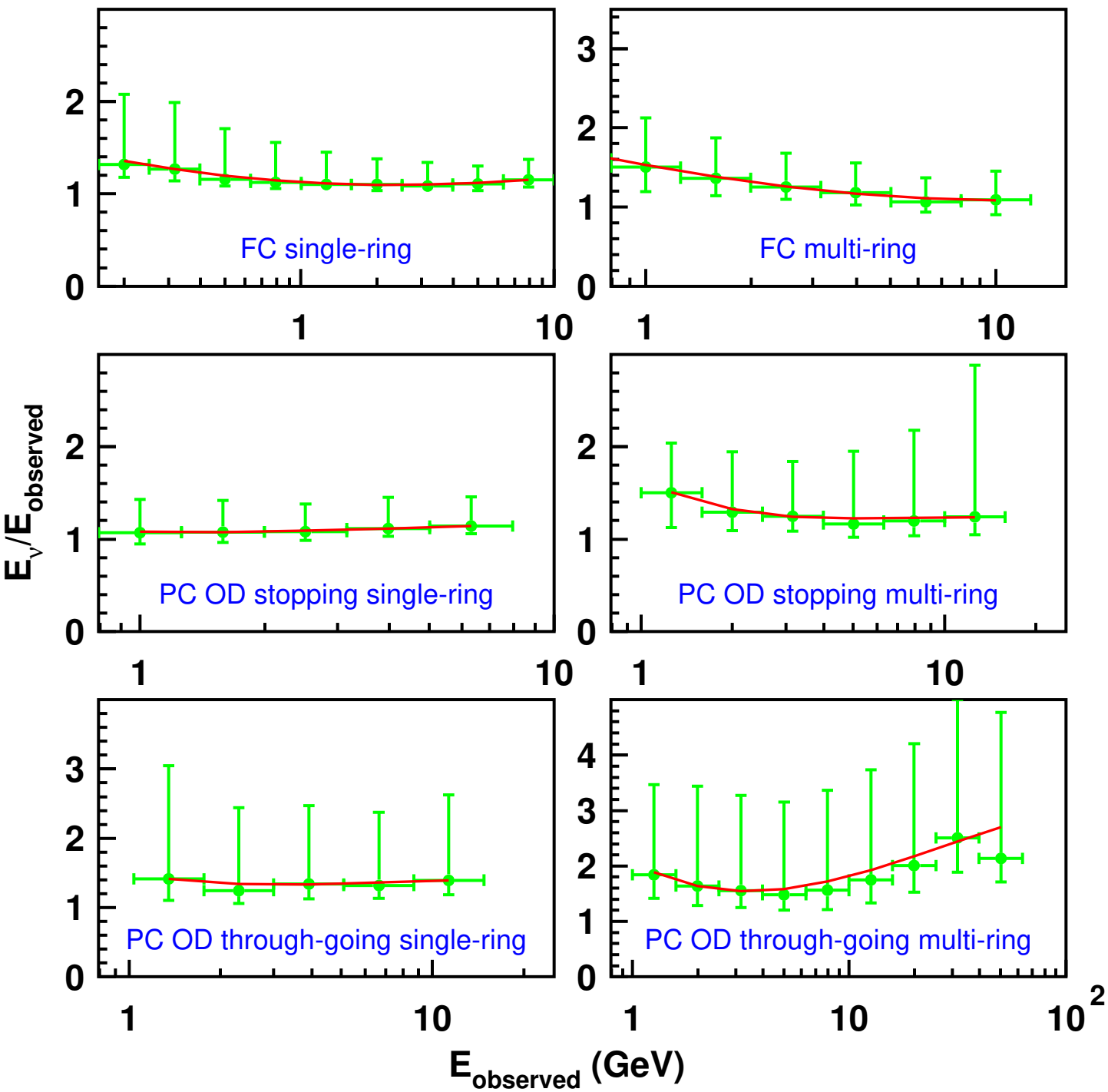

Oscillation/Null oscillation (MC)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10^2
10^3
10^4
L/E (km/GeV)

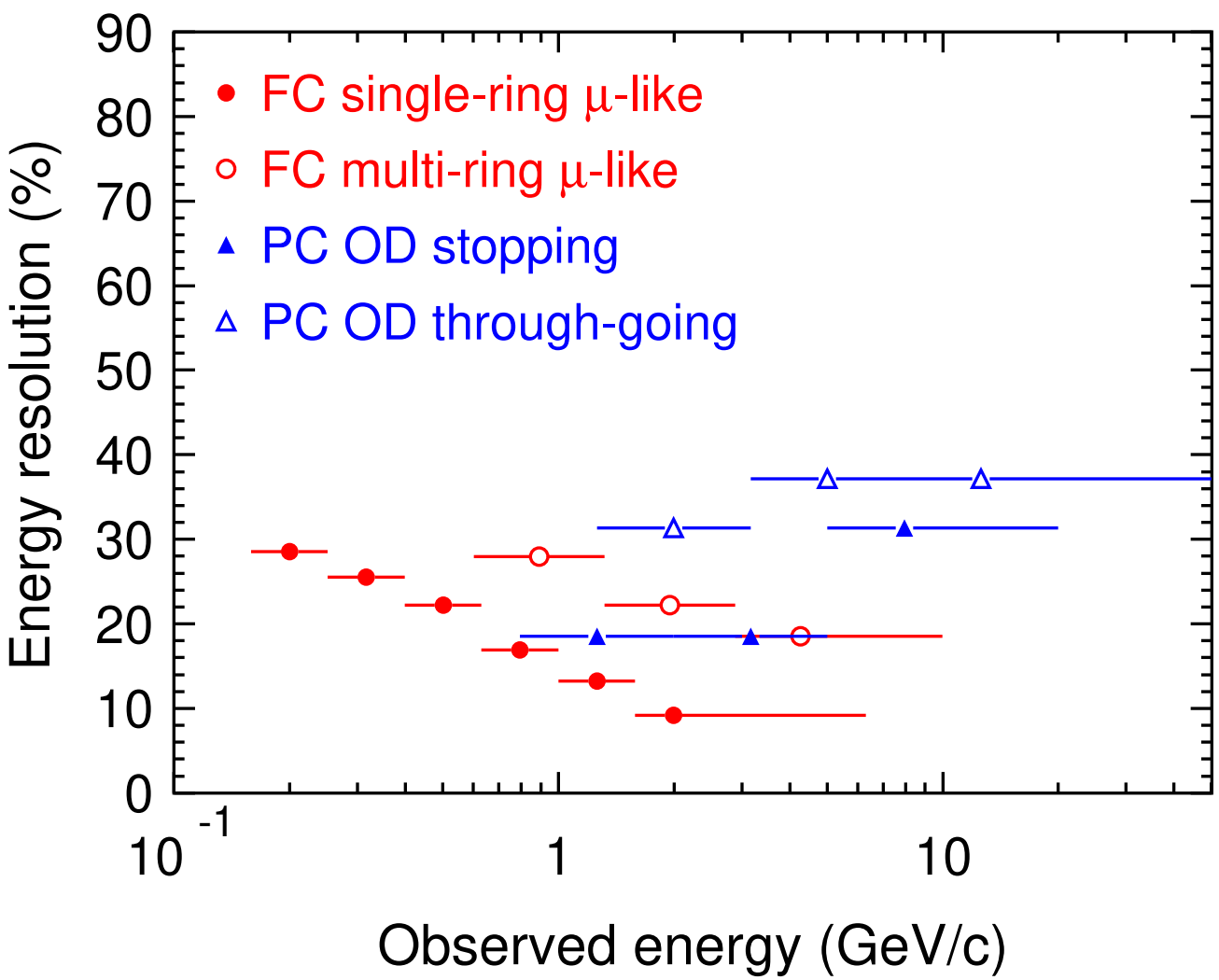

OD stopping
OD through-going
Number of events
0
20
40
60
80
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
PE_anti/PE_exp

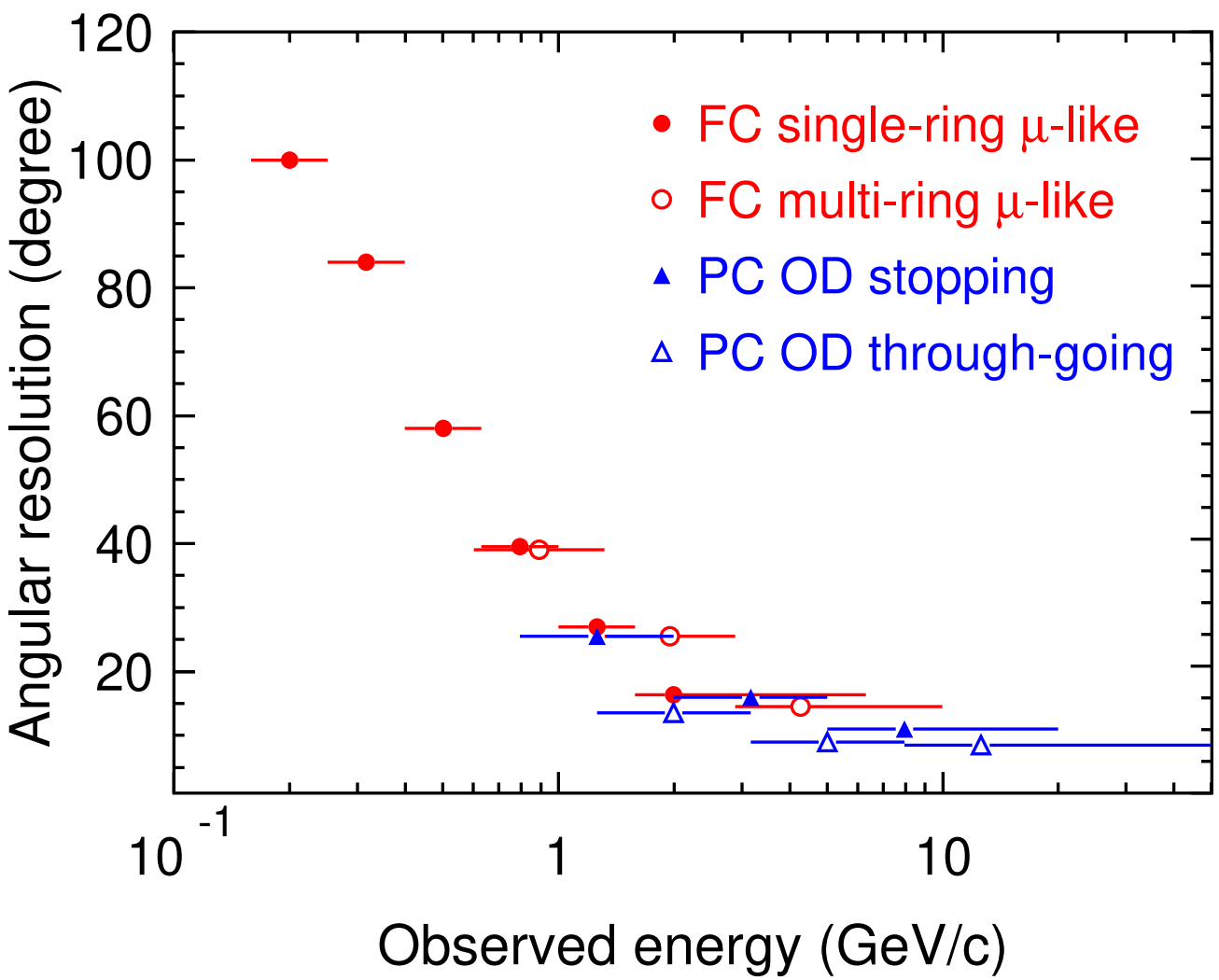

ID 330
Entries 898
Mean 0.9786
RMS 0.3838
χ²/ndf 36.37 / 22
Constant 47.45
Mean 1.047
Sigma 0.3085
DATA
Number of events
PE_anti/PE_exp
ID 311
Entries 58208
Mean 0.9304
RMS 0.3420
χ²/ndf 22.95 / 22
Constant 83.95
Mean 1.007
Sigma 0.2349
MC
Number of events
PE_anti/PE_exp

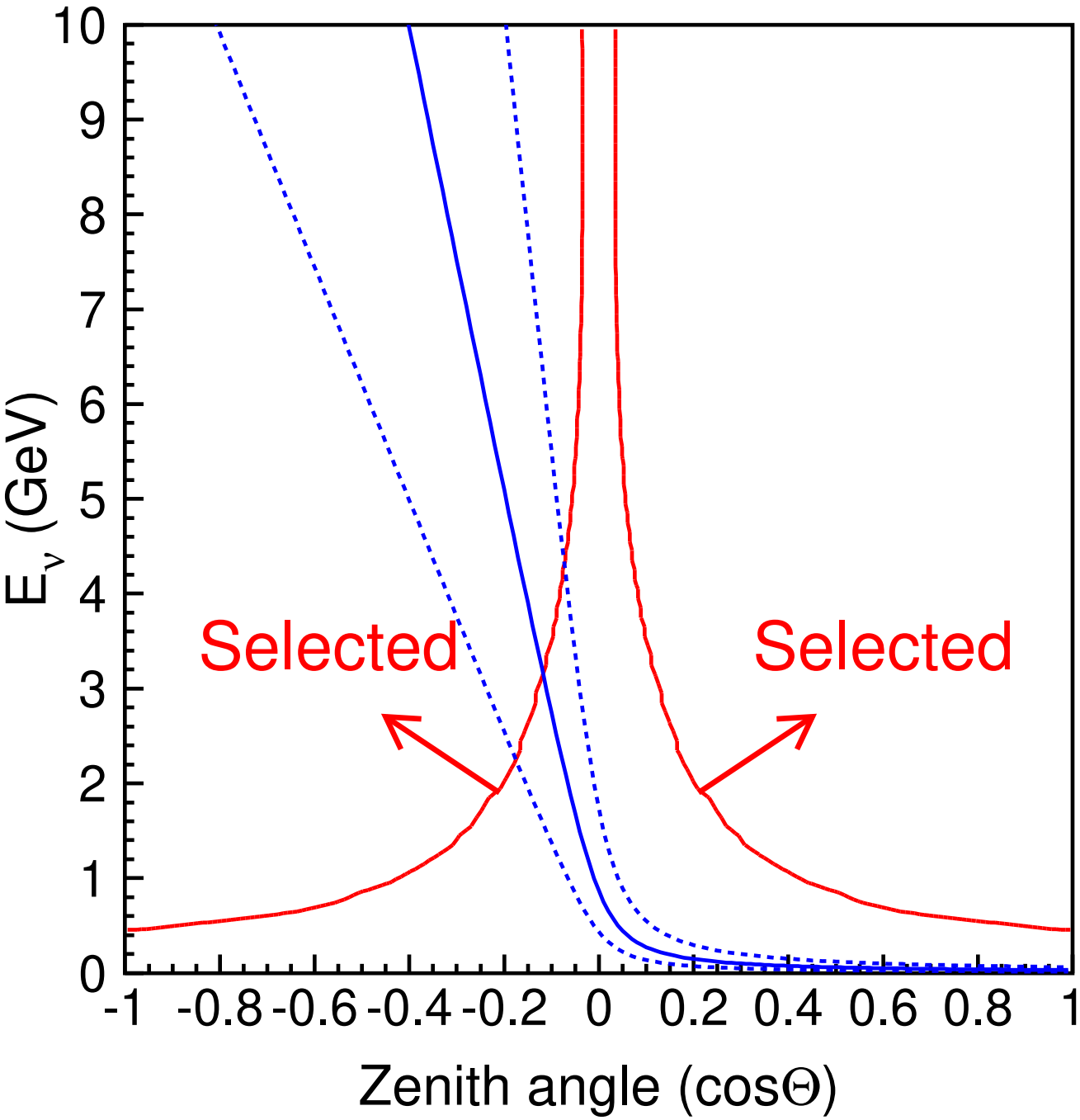

OD stopping
OD through-going
5262
→
4919
0.934816
23363
→
23624
1.01117
Number of events
0
20
40
60
80
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
PE_anti/PE_exp

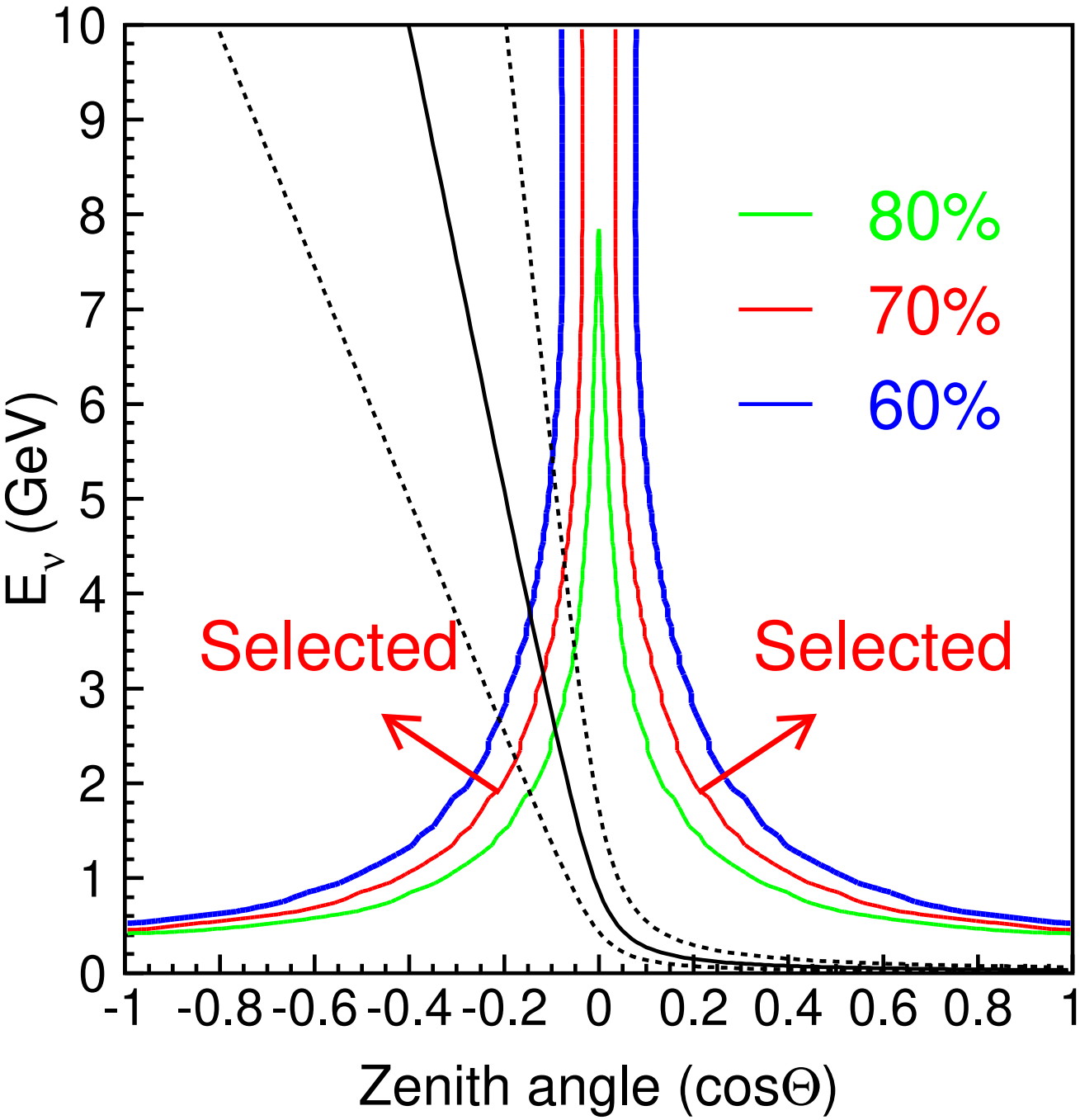

2.5
2
1.5
1
0.5
0
$E_\nu/E_{observed}$
1
10
$E_{observed}$ (GeV)

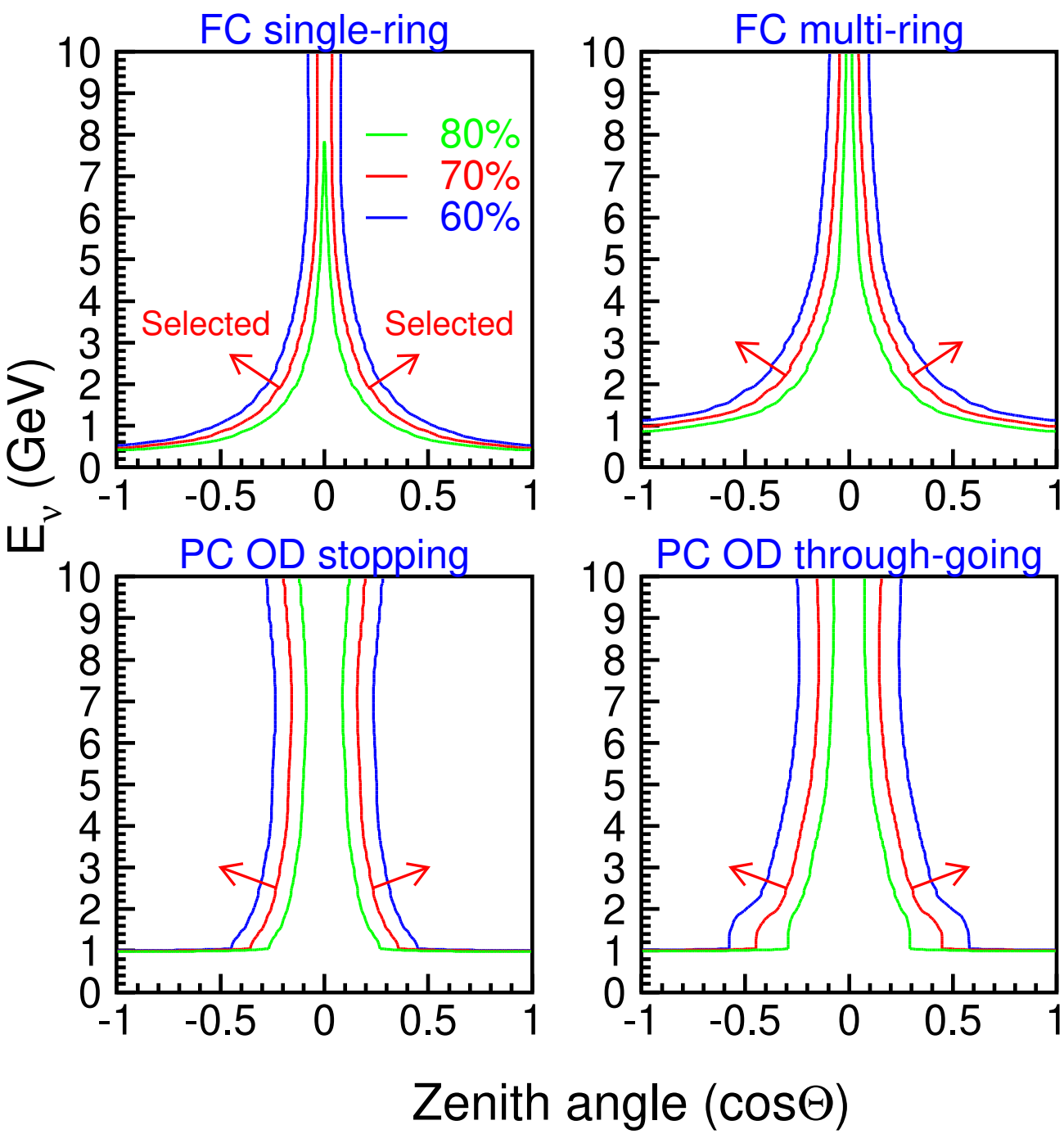

FC single-ring
FC multi-ring
PC OD stopping single-ring
PC OD stopping multi-ring
PC OD through-going single-ring
PC OD through-going multi-ring
$E_\nu/E_{observed}$
$E_{observed}$ (GeV)


FC single-ring μ-like
FC multi-ring μ-like
PC OD stopping
PC OD through-going
Energy resolution (%)
Observed energy (GeV/c)
0
10
20
30
40
50
60
70
80
90
10^-1
1
10


120
100
80
60
40
20
Angular resolution (degree)
10 -1
1
10
Observed energy (GeV/c)
FC single-ring μ-like
FC multi-ring μ-like
PC OD stopping
PC OD through-going


10
9
8
7
6
5
4
3
2
1
0
E_ν (GeV)
Selected
Selected
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Zenith angle (cosΘ)

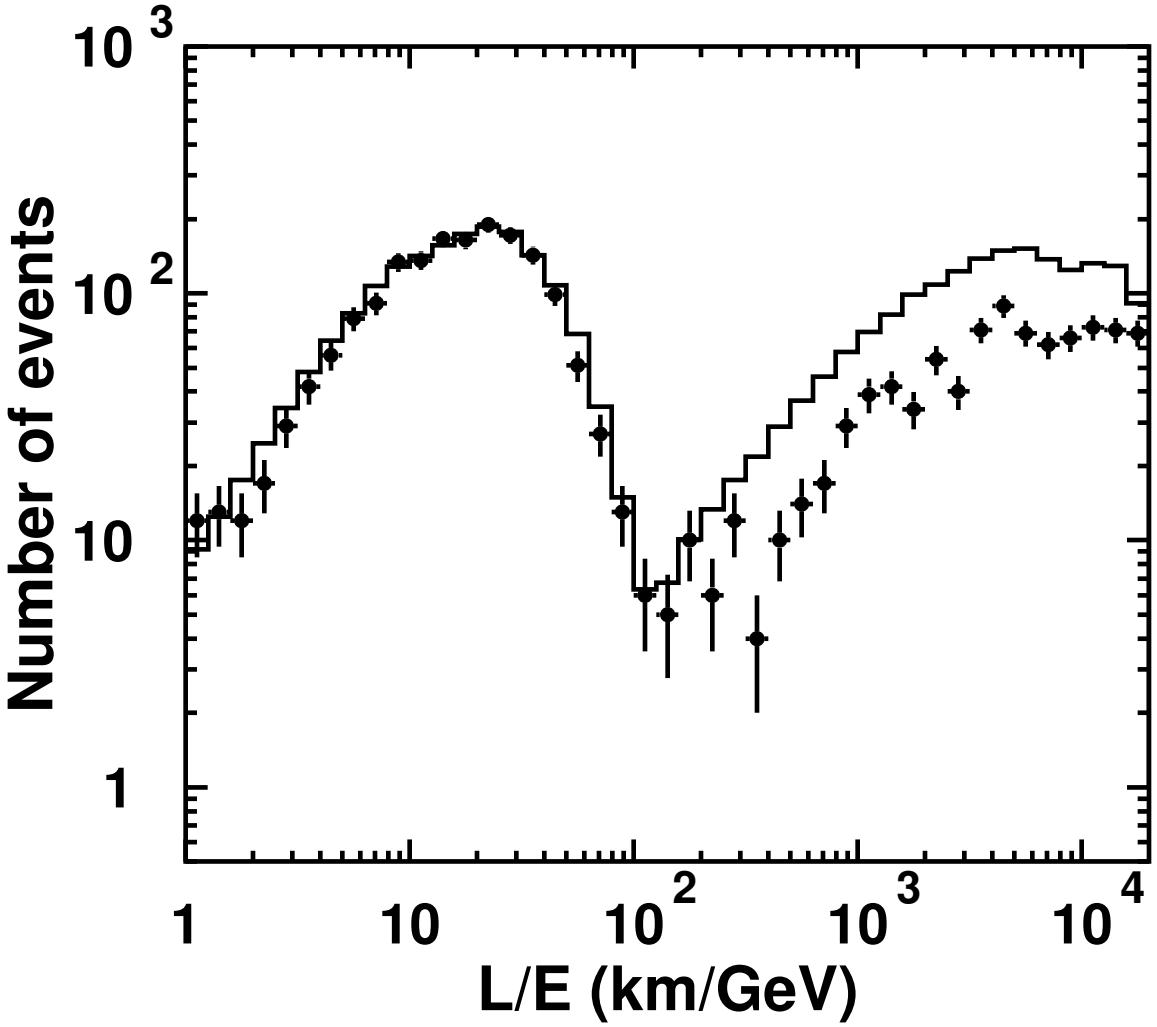

10
9
8
7
6
5
4
3
2
1
0
E_ν (GeV)
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Zenith angle (cosΘ)
80%
70%
60%
Selected
Selected

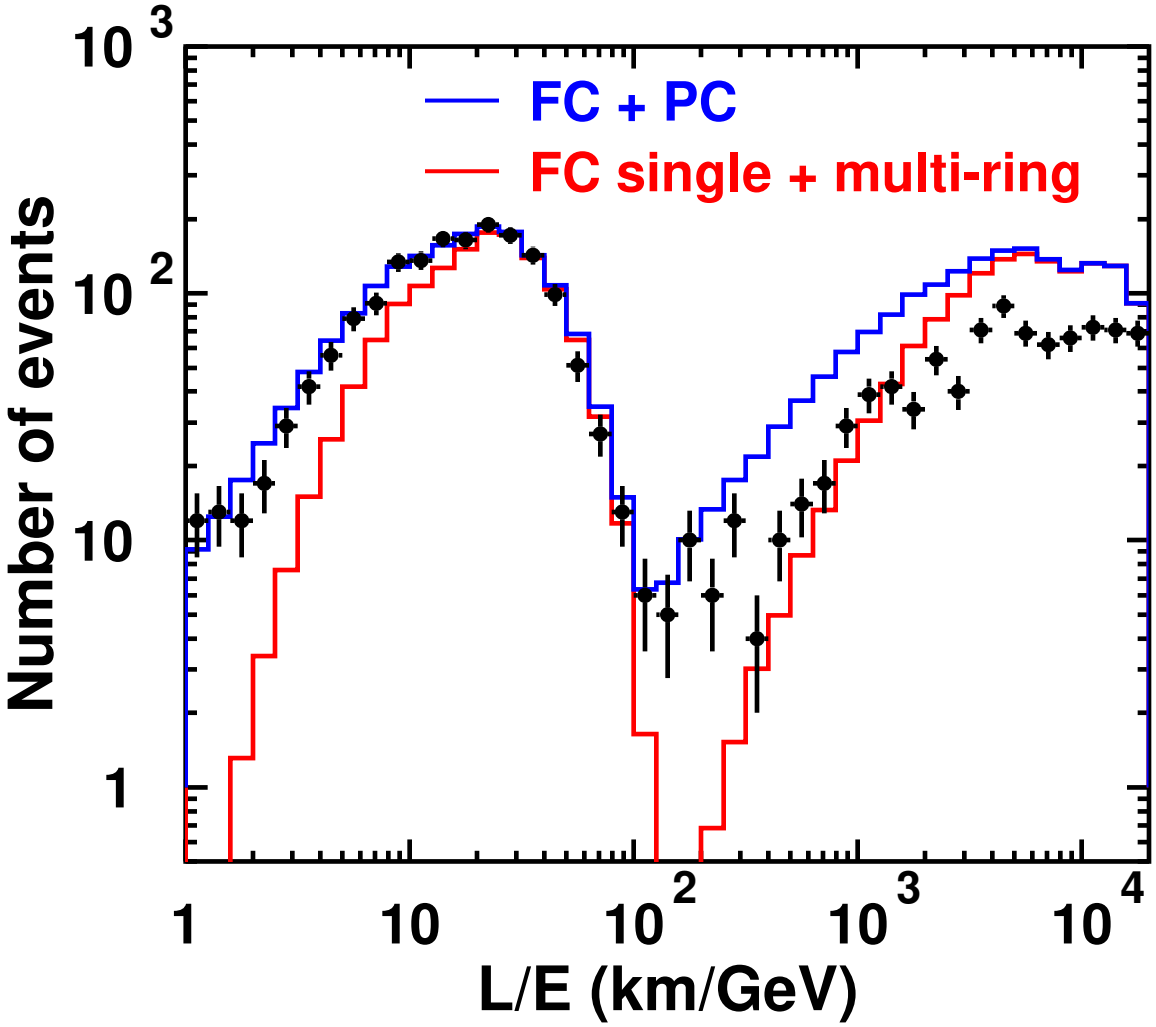

FC single-ring
FC multi-ring
PC OD stopping
PC OD through-going
80%
70%
60%
Selected
Selected
E_ν (GeV)
Zenith angle (cosΘ)

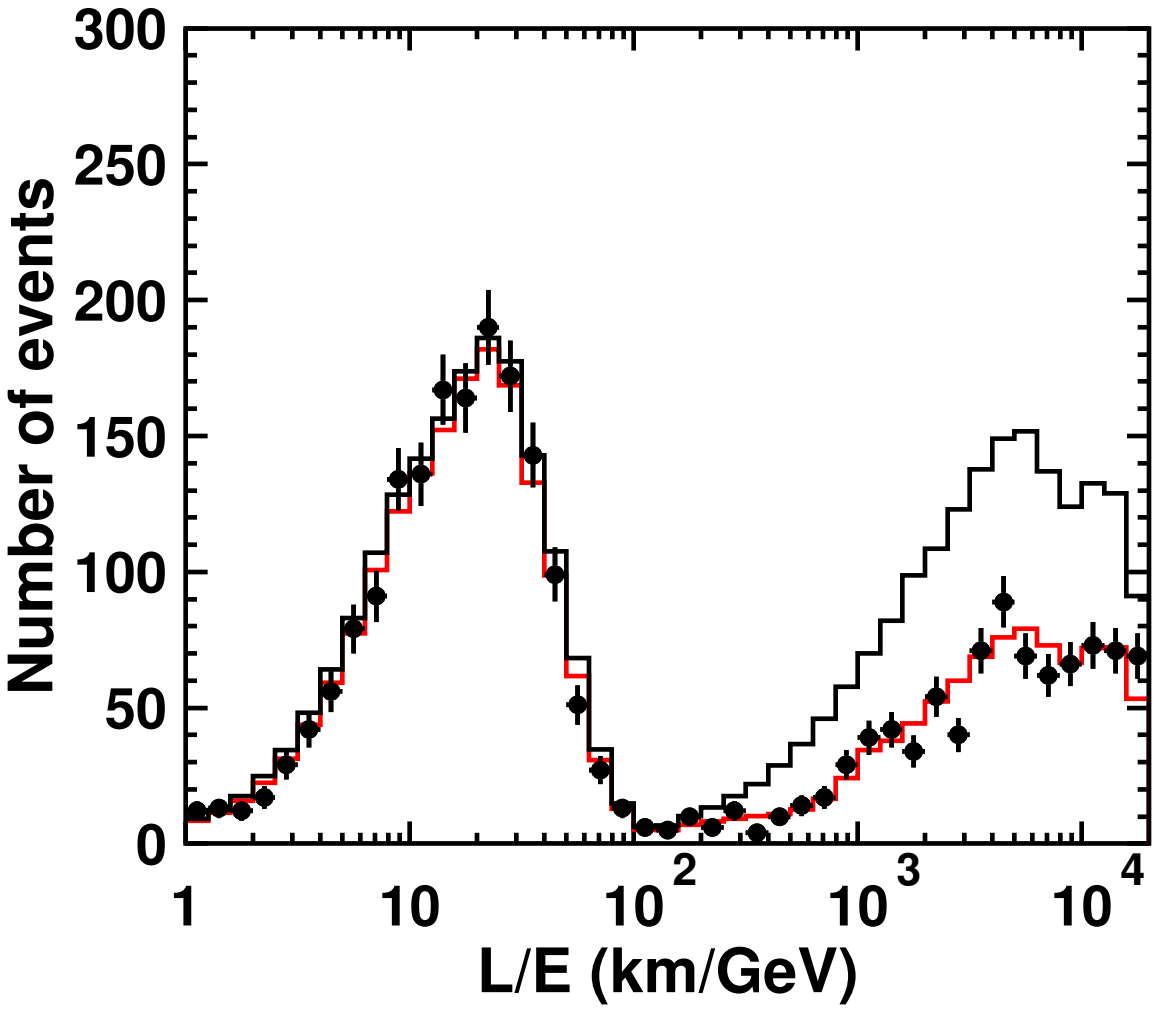
L/E event summary

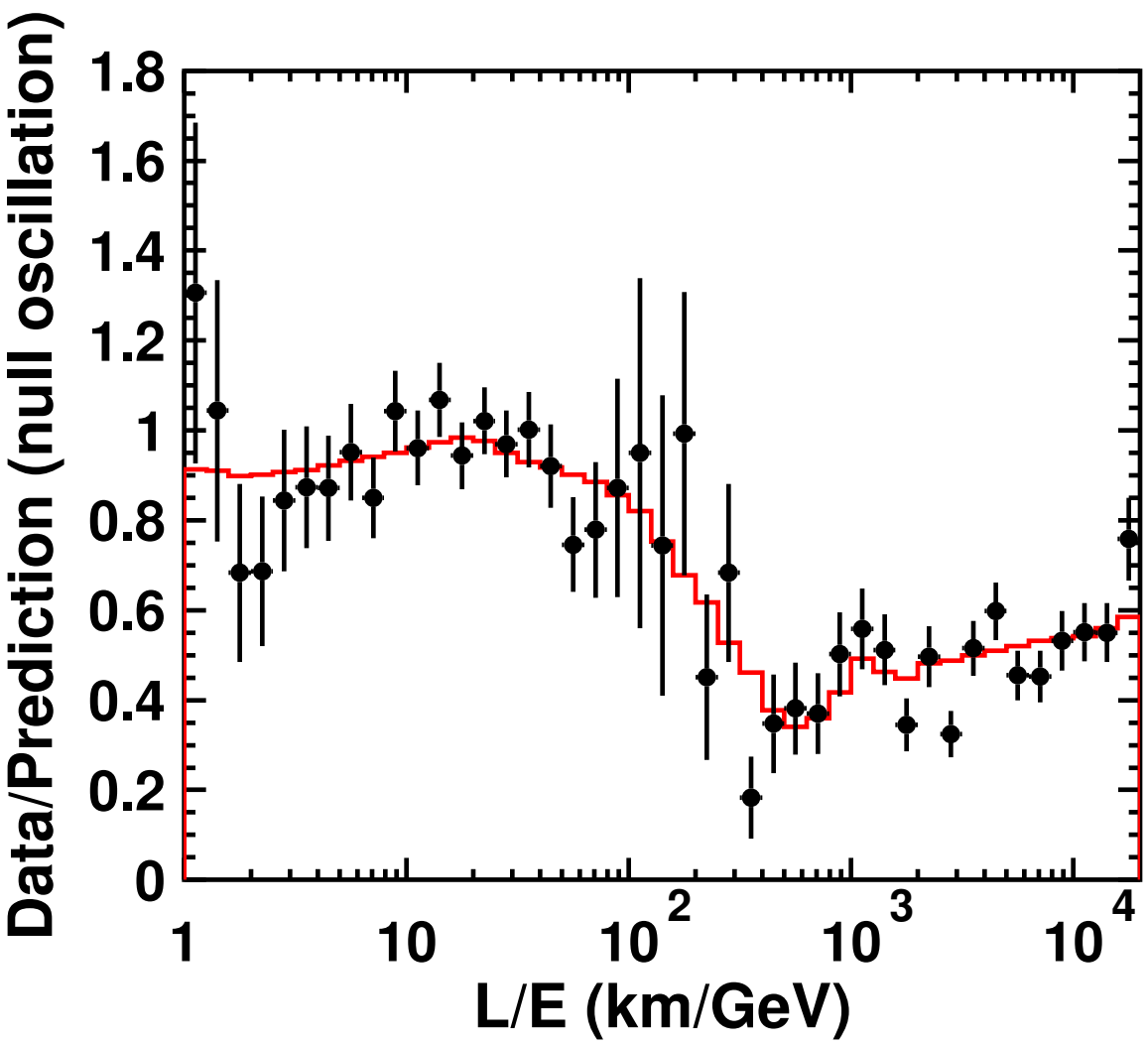
(ΔL/E < 70%)

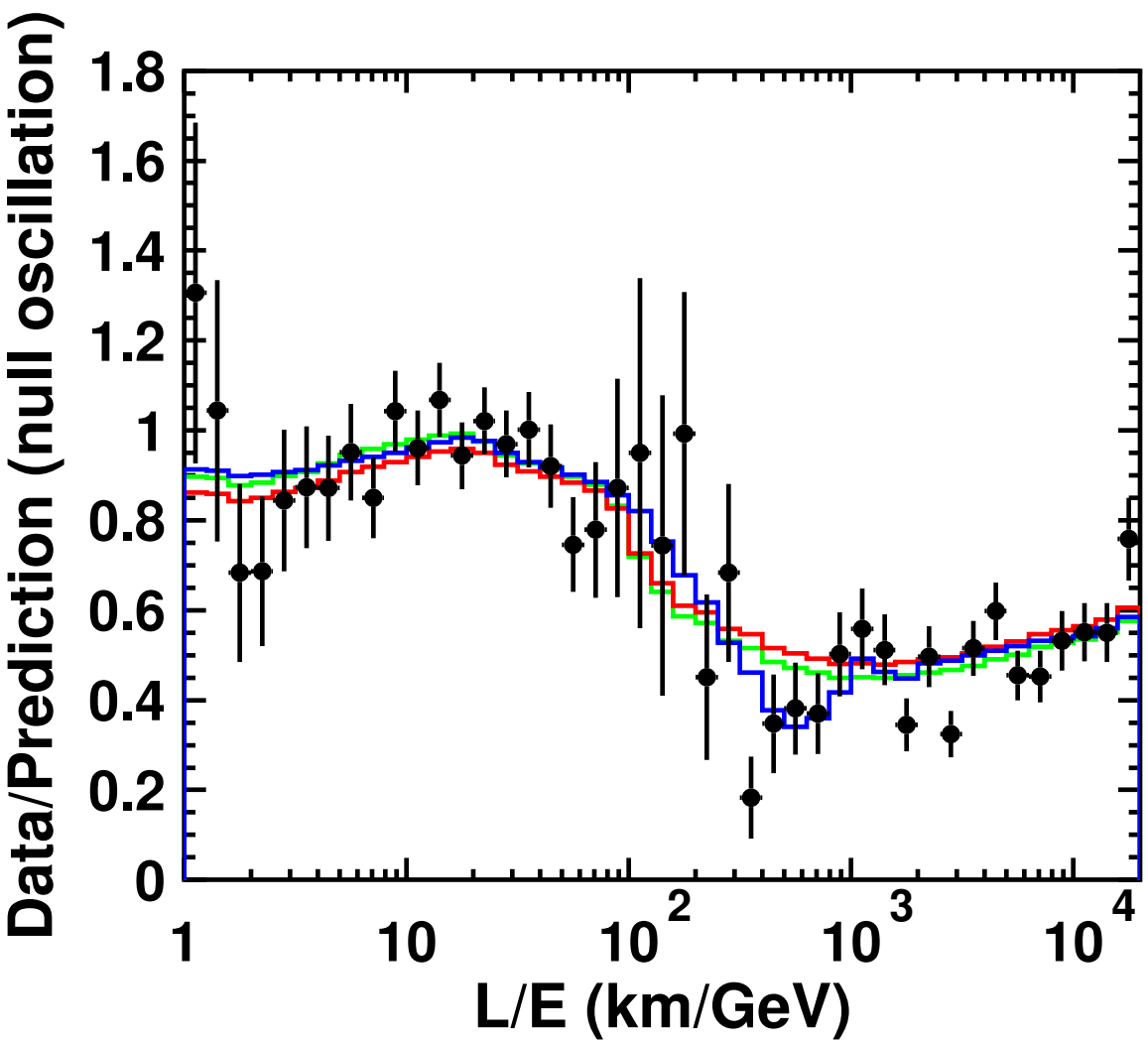
	DATA	MC	ν_μ CC
FC			
single-ring	1562	2093.6	(98.2%)
multi-ring	445	625.6	(93.5%)
PC			
OD stopping	100	148.5	(94.9%)
OD through-going	455	670.6	(99.3%)

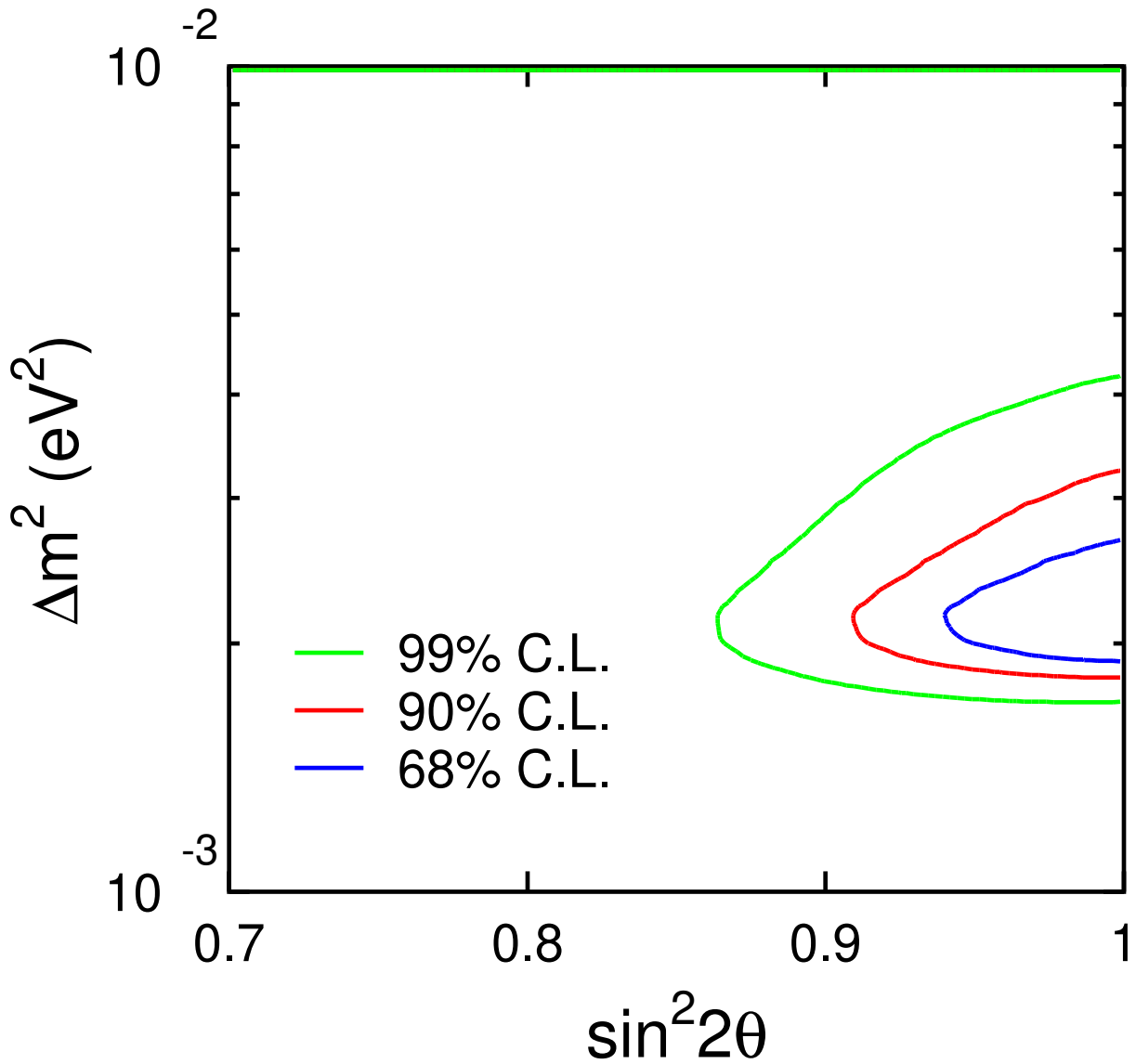

Number of events
10 3
10 2
10
1
1
10
10 2
10 3
10 4
L/E (km/GeV)

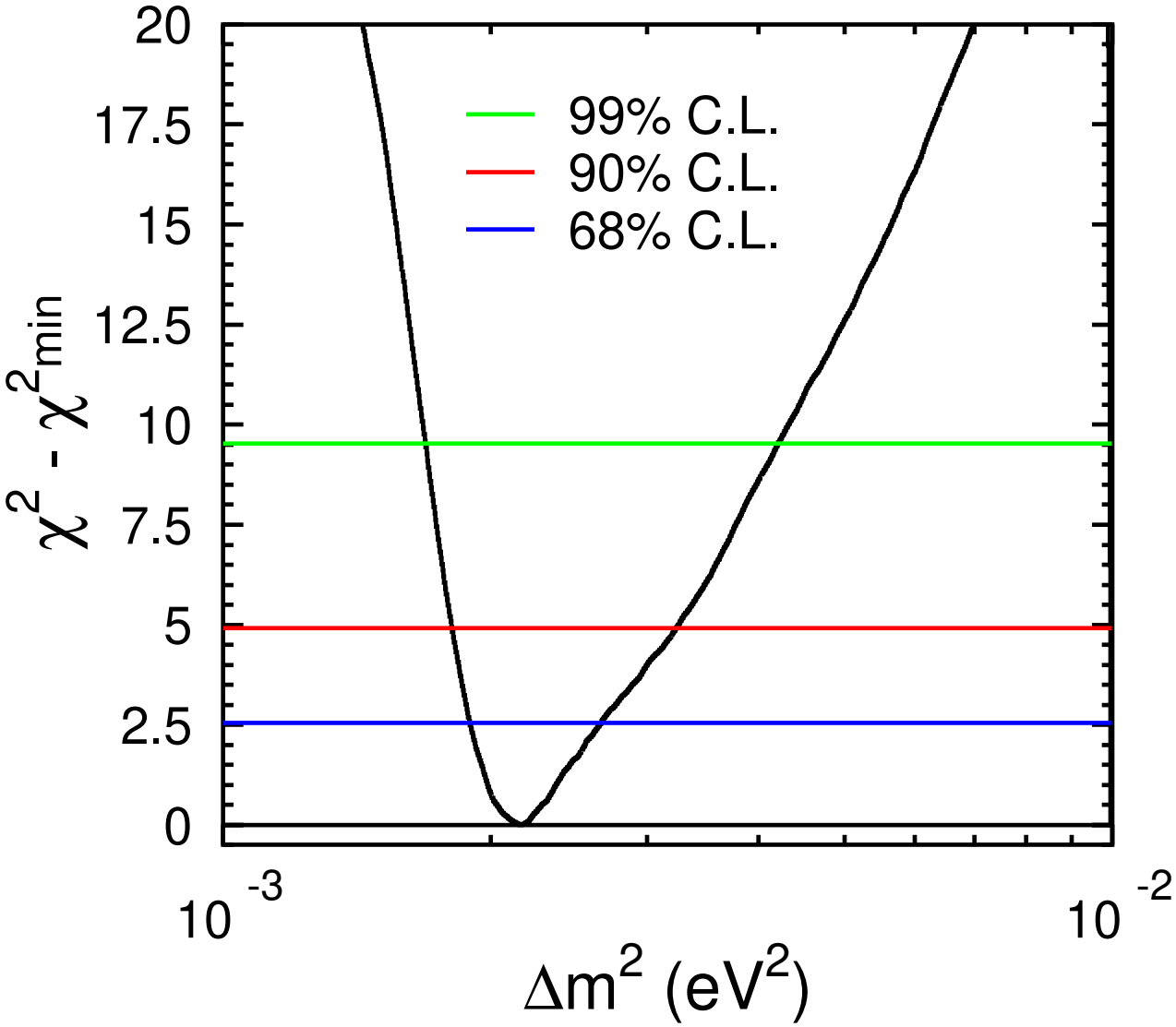

FC + PC
FC single + multi-ring
Number of events
L/E (km/GeV)
10 3
10 2
10
1
1
10
10 2
10 3
10 4

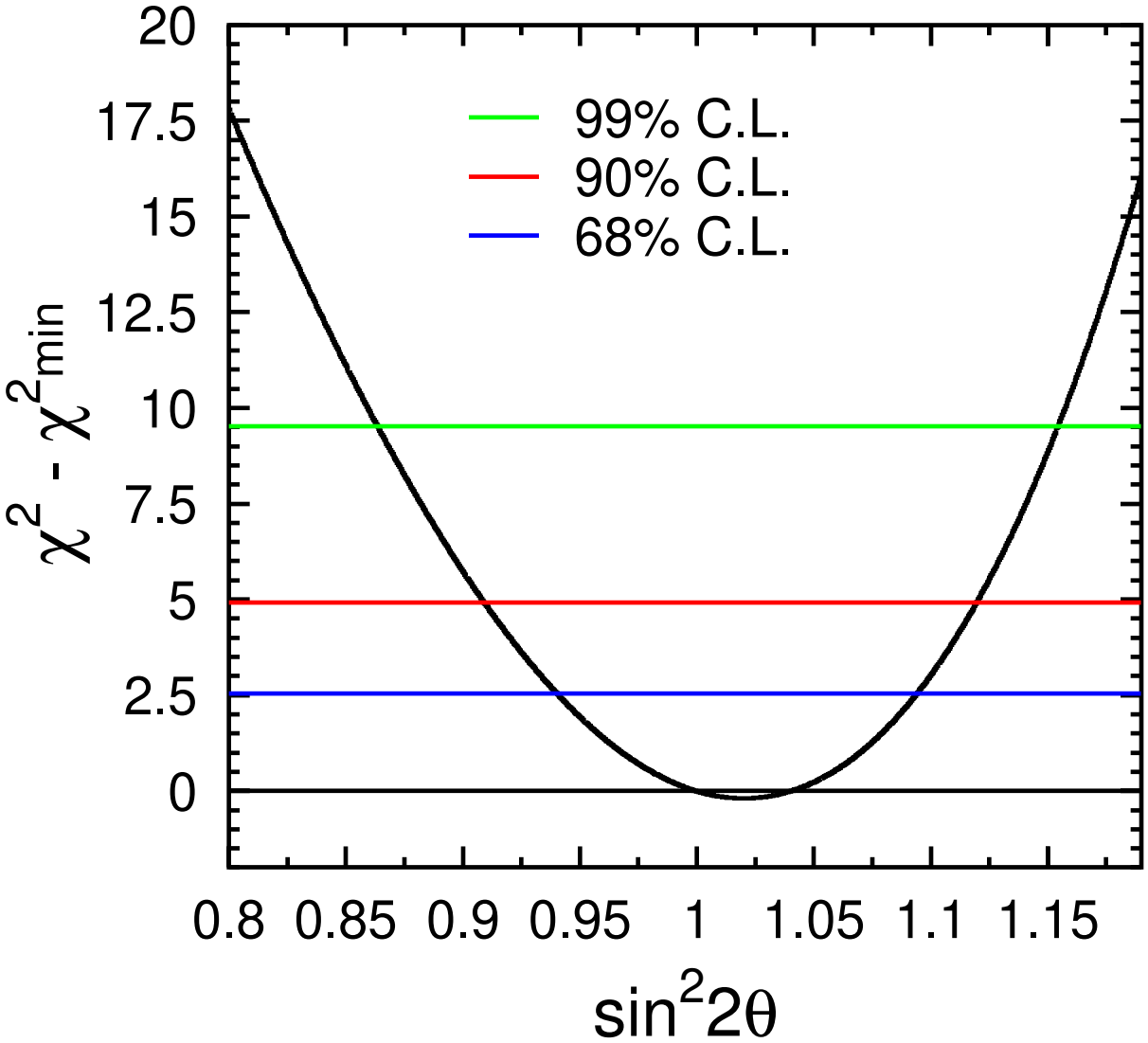

300
250
200
150
100
50
0
Number of events
1
10
10 2
10 3
10 4
L/E (km/GeV)

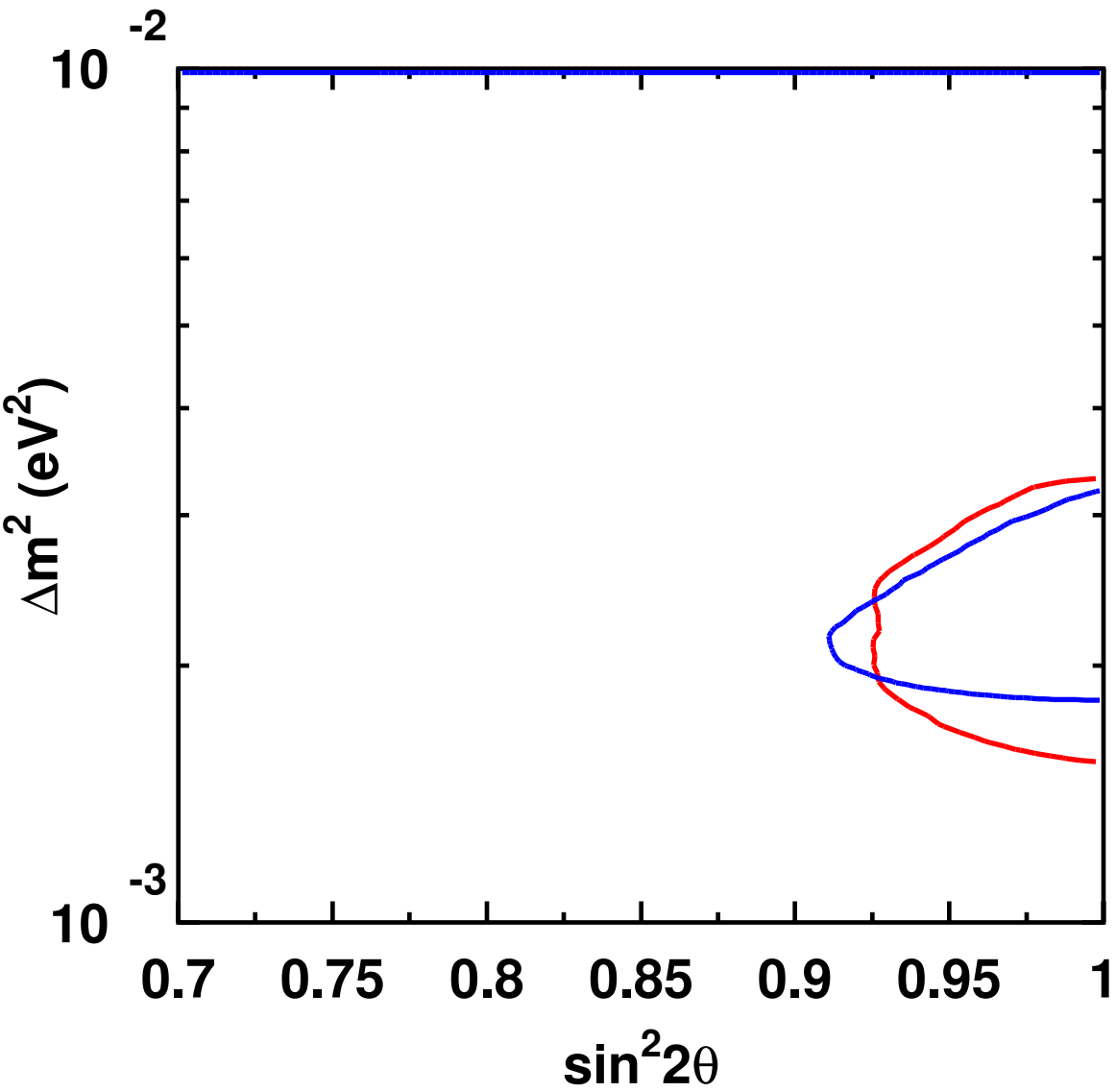

Data/Prediction (null oscillation)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10^2
10^3
10^4
L/E (km/GeV)

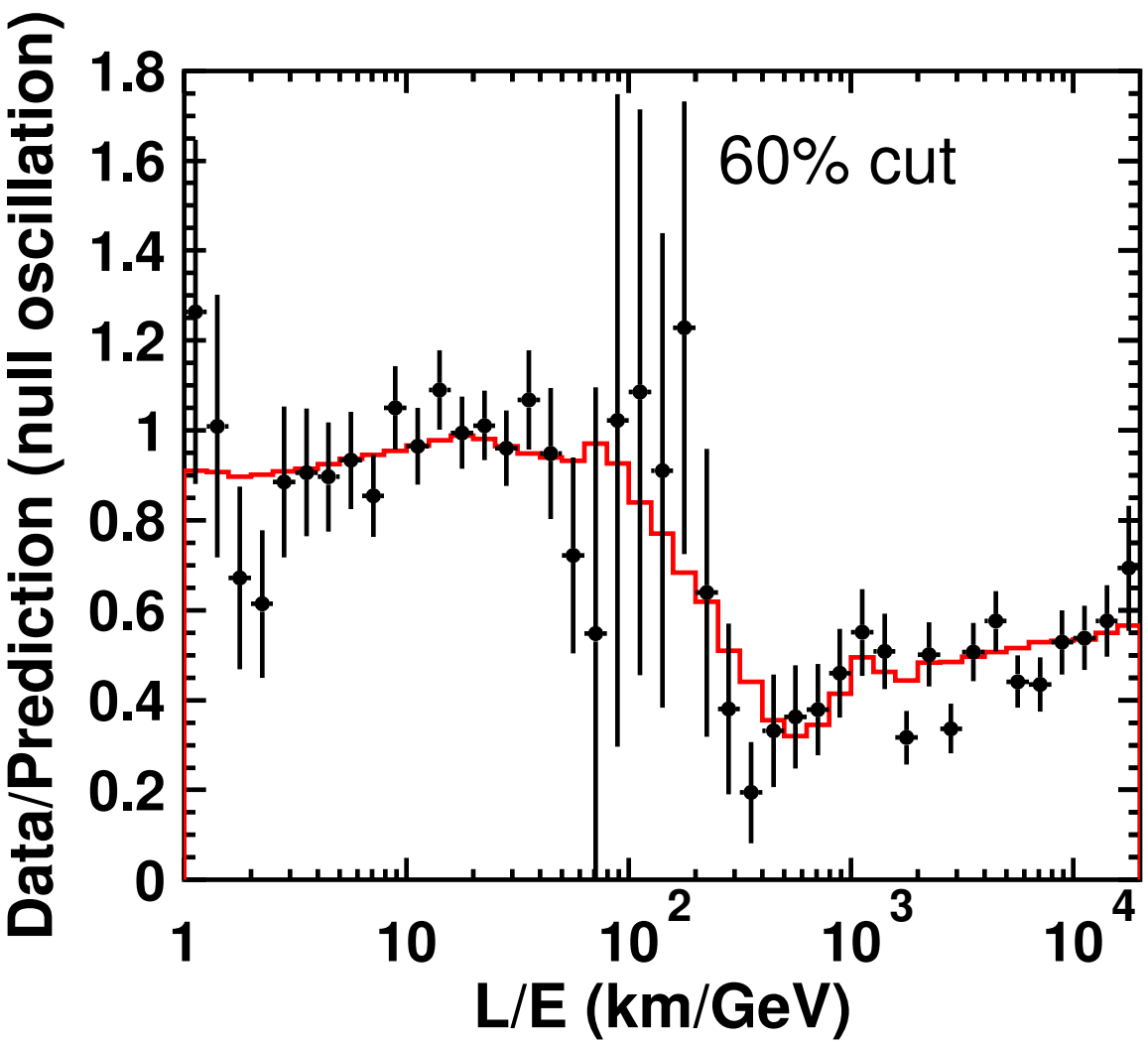

Data/Prediction (null oscillation)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10^2
10^3
10^4
L/E (km/GeV)

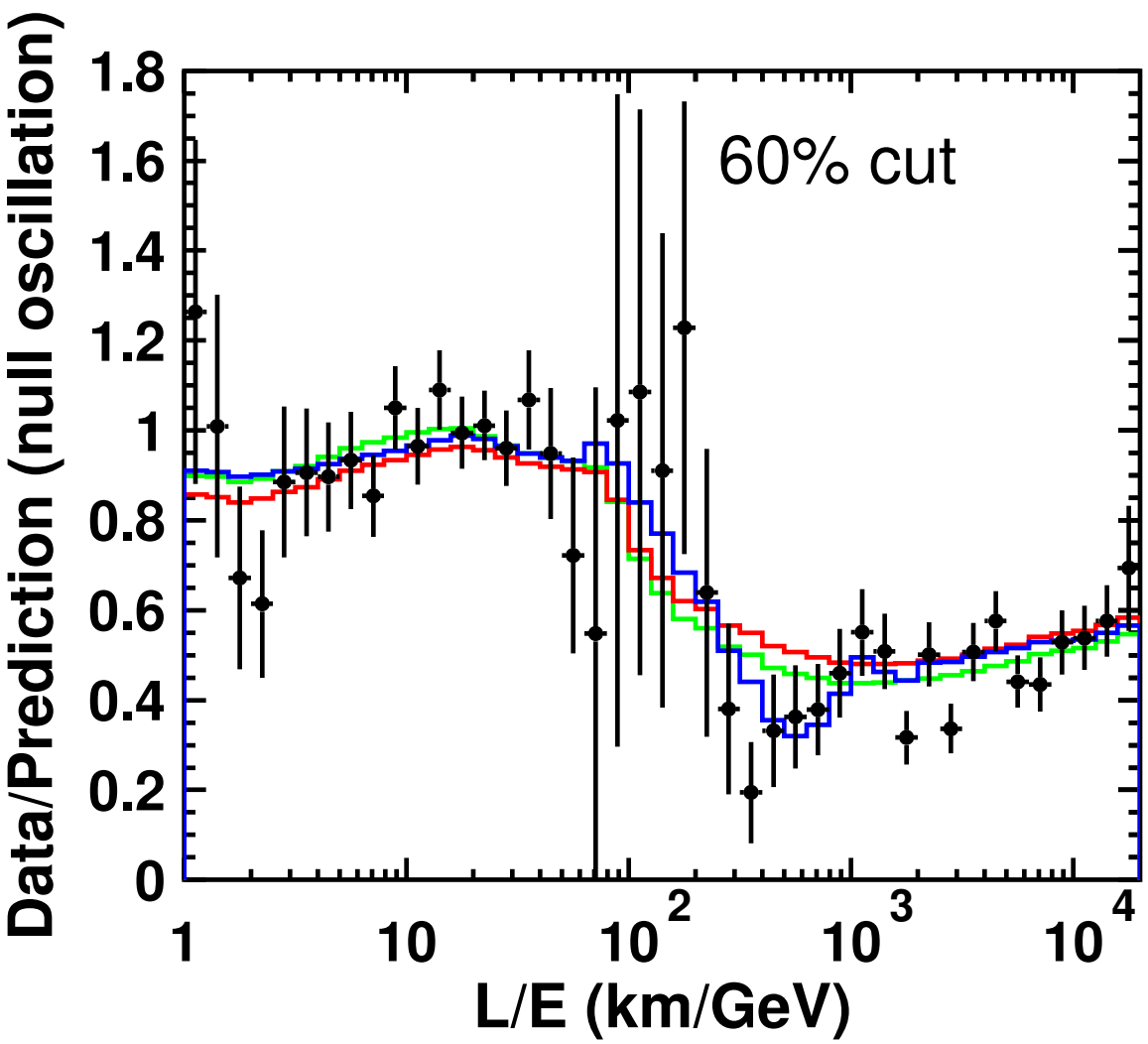

10^-2
10^-3
0.7
0.8
0.9
1
Δm^2 (eV^2)
sin^2 2θ
99% C.L.
90% C.L.
68% C.L.

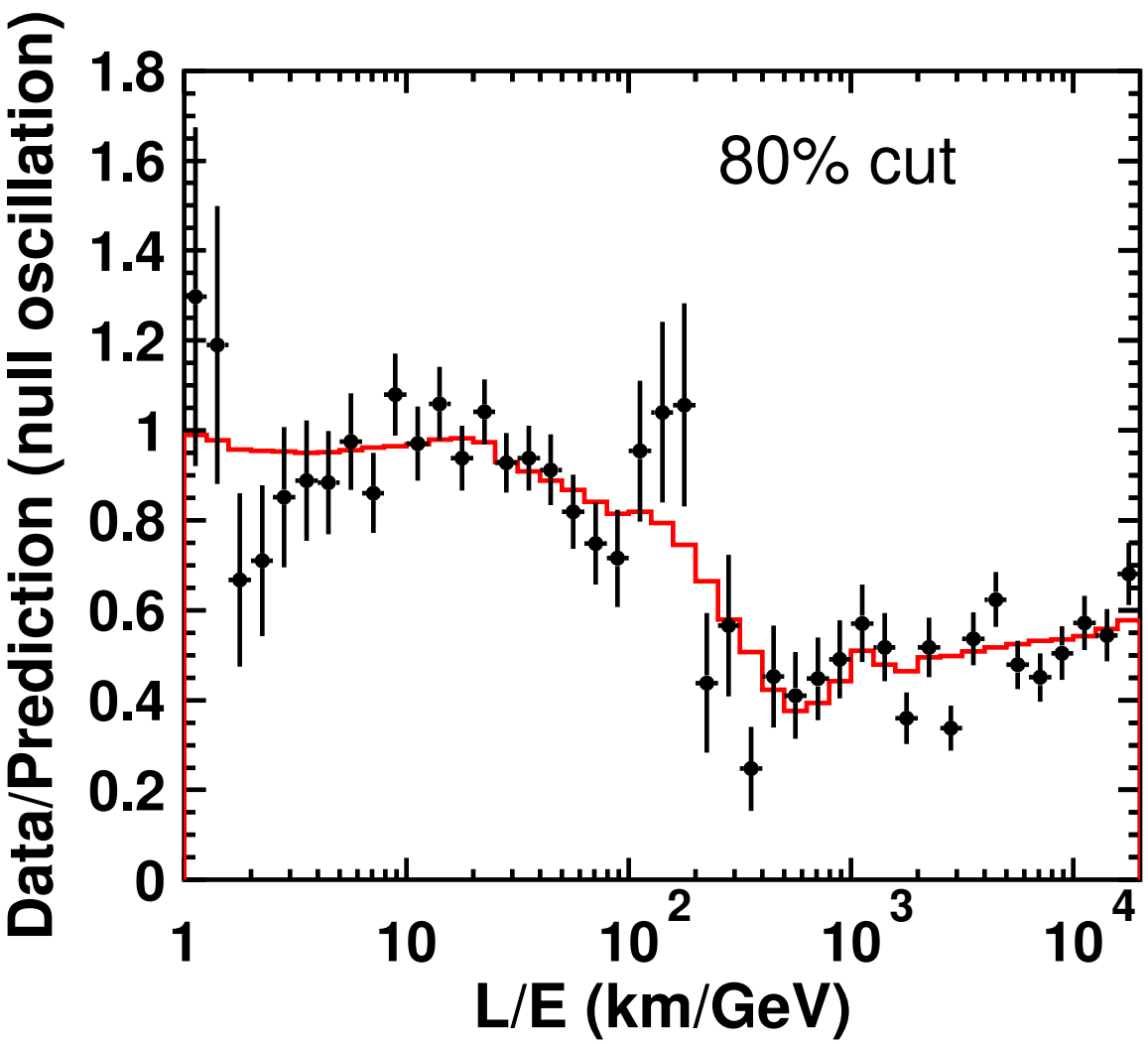

20
17.5
15
12.5
10
7.5
5
2.5
0
$\chi^2 - \chi^2_{min}$
99% C.L.
90% C.L.
68% C.L.
10^{-3}
10^{-2}
Δm^2 (eV^2)

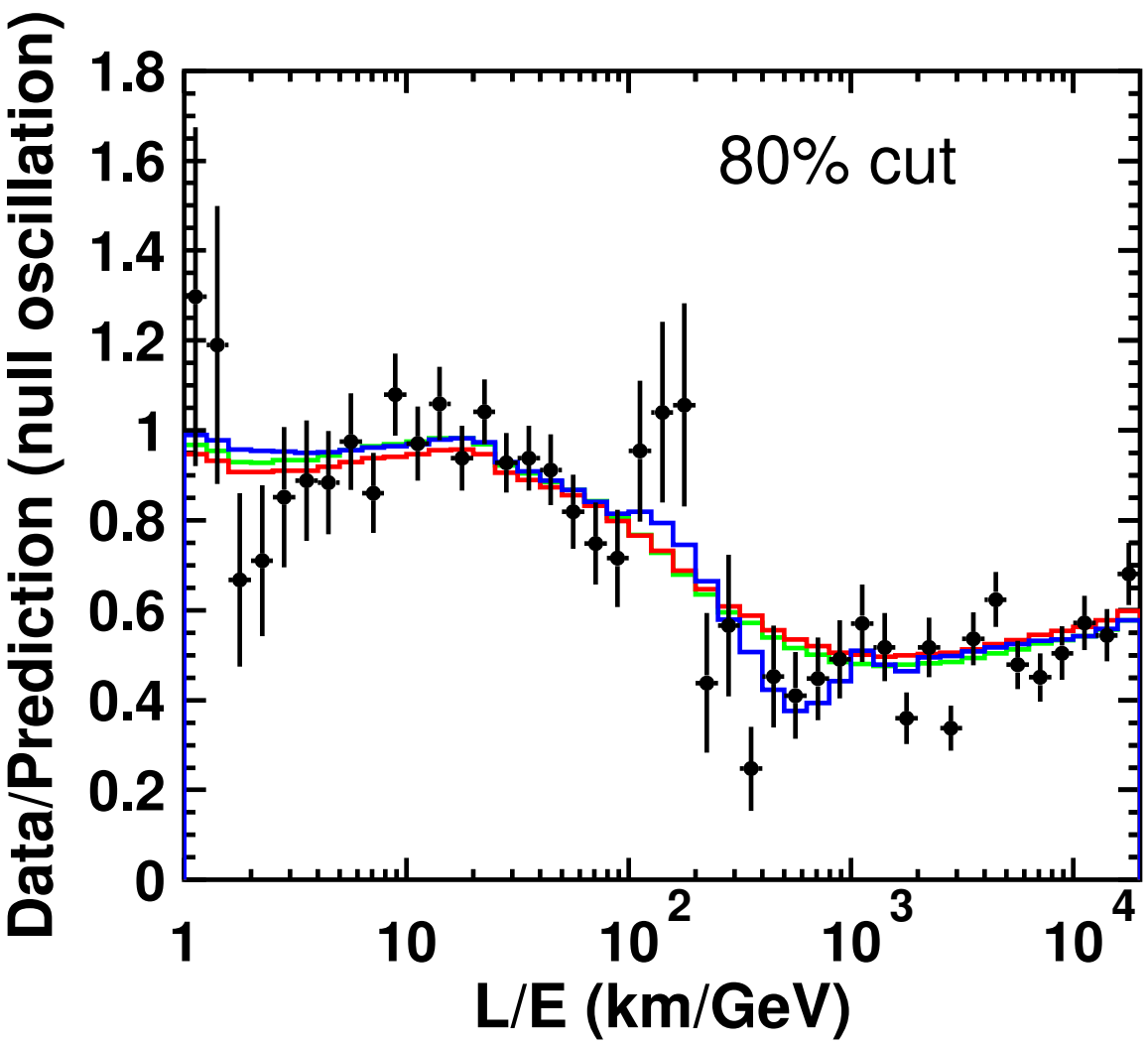

20
17.5
15
12.5
10
7.5
5
2.5
0
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
99% C.L.
90% C.L.
68% C.L.
$\chi^2 - \chi^2_{min}$
$\sin^2 2\theta$

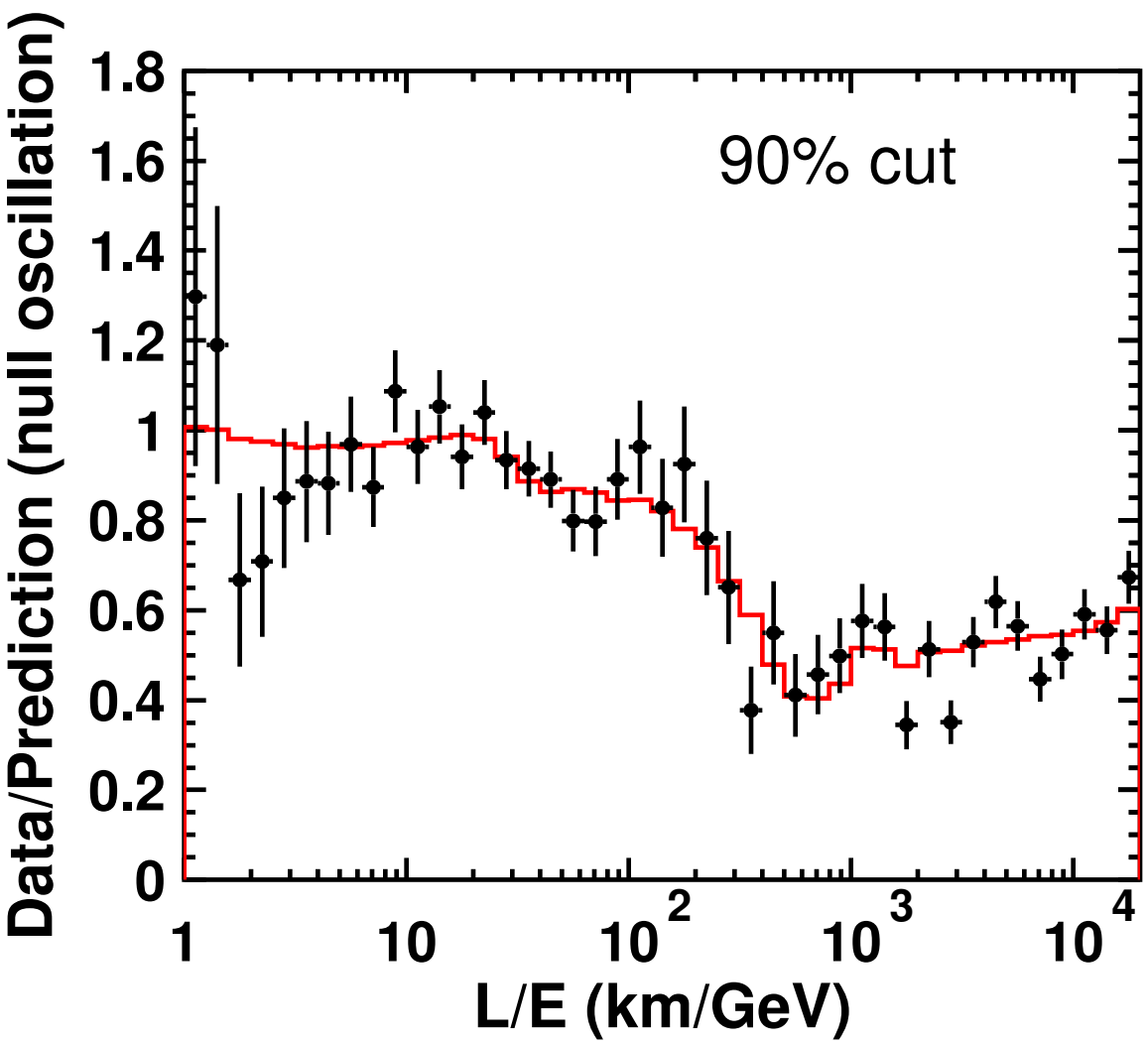

10^-2
10^-3
Δm^2 (eV^2)
0.7
0.75
0.8
0.85
0.9
0.95
1
sin^2 2θ

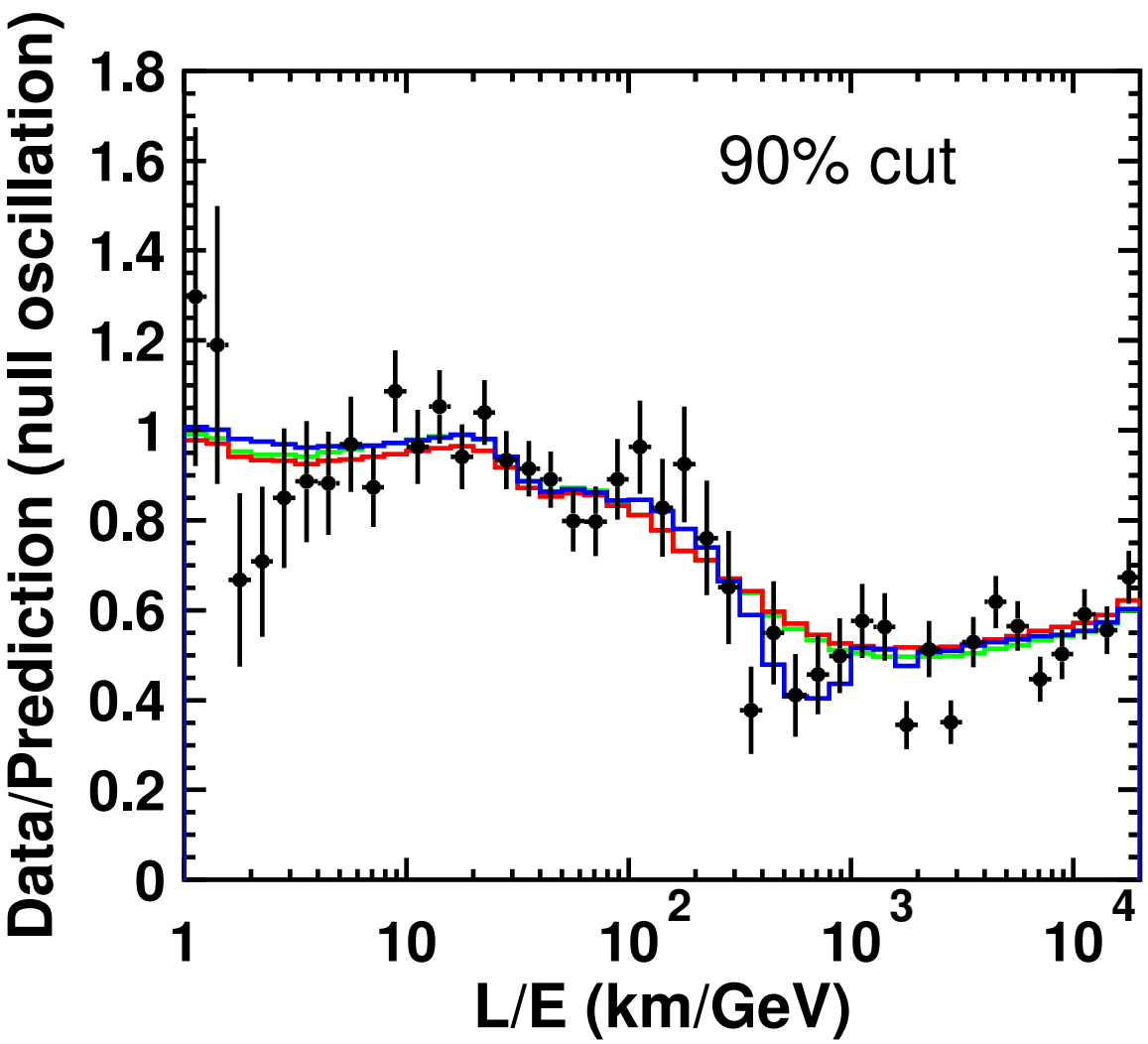

60% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4

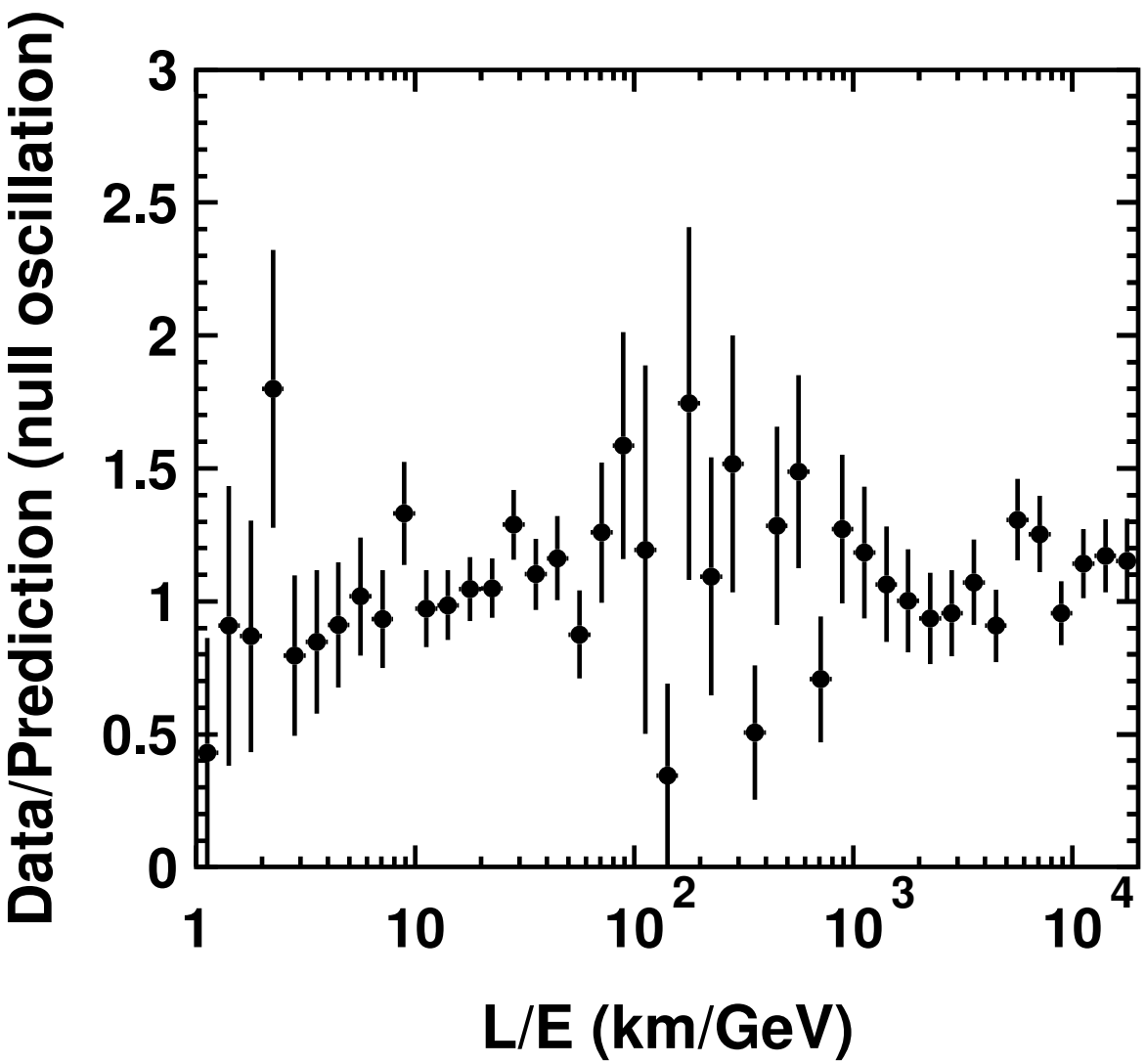

60% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4

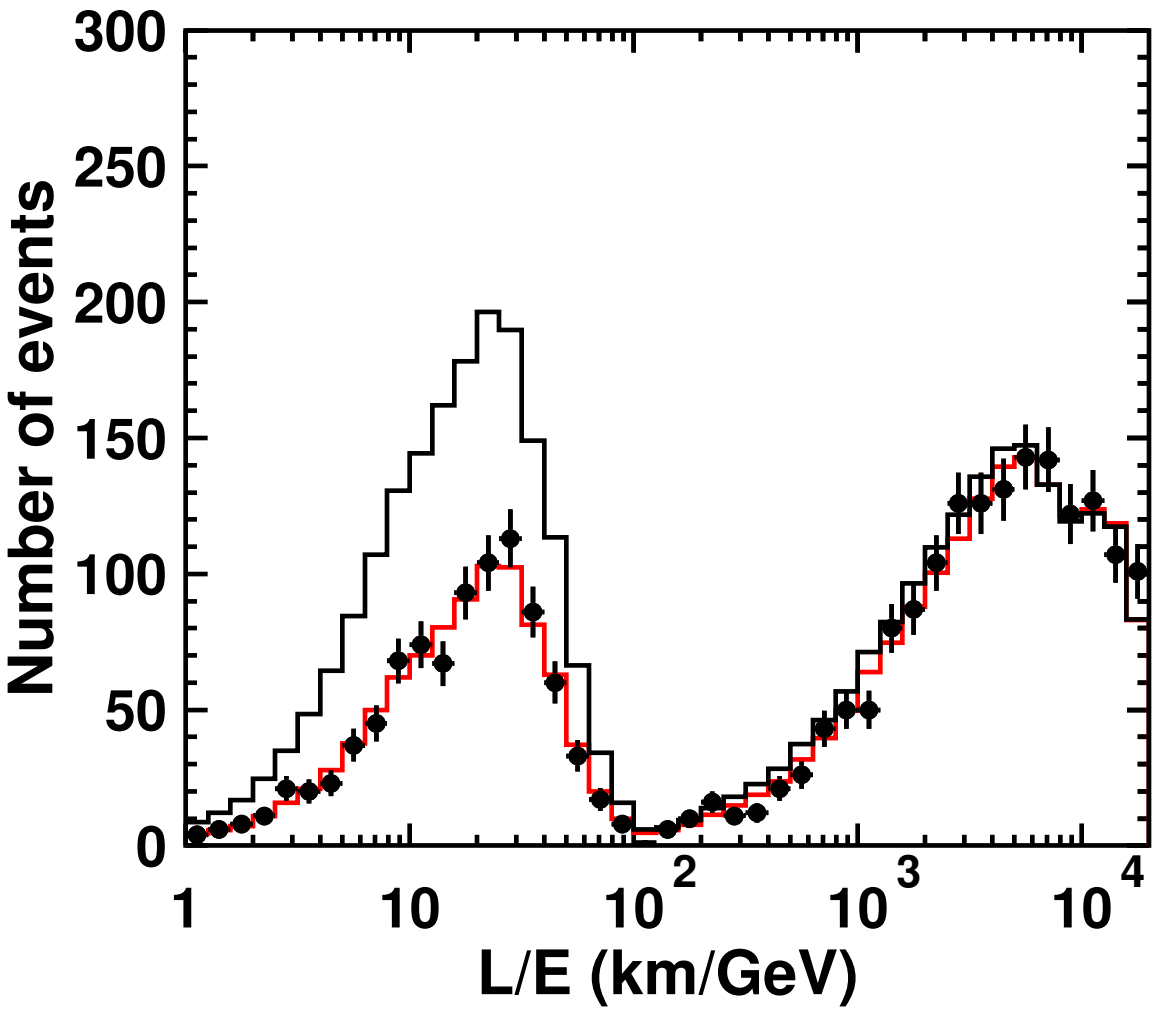

80% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4

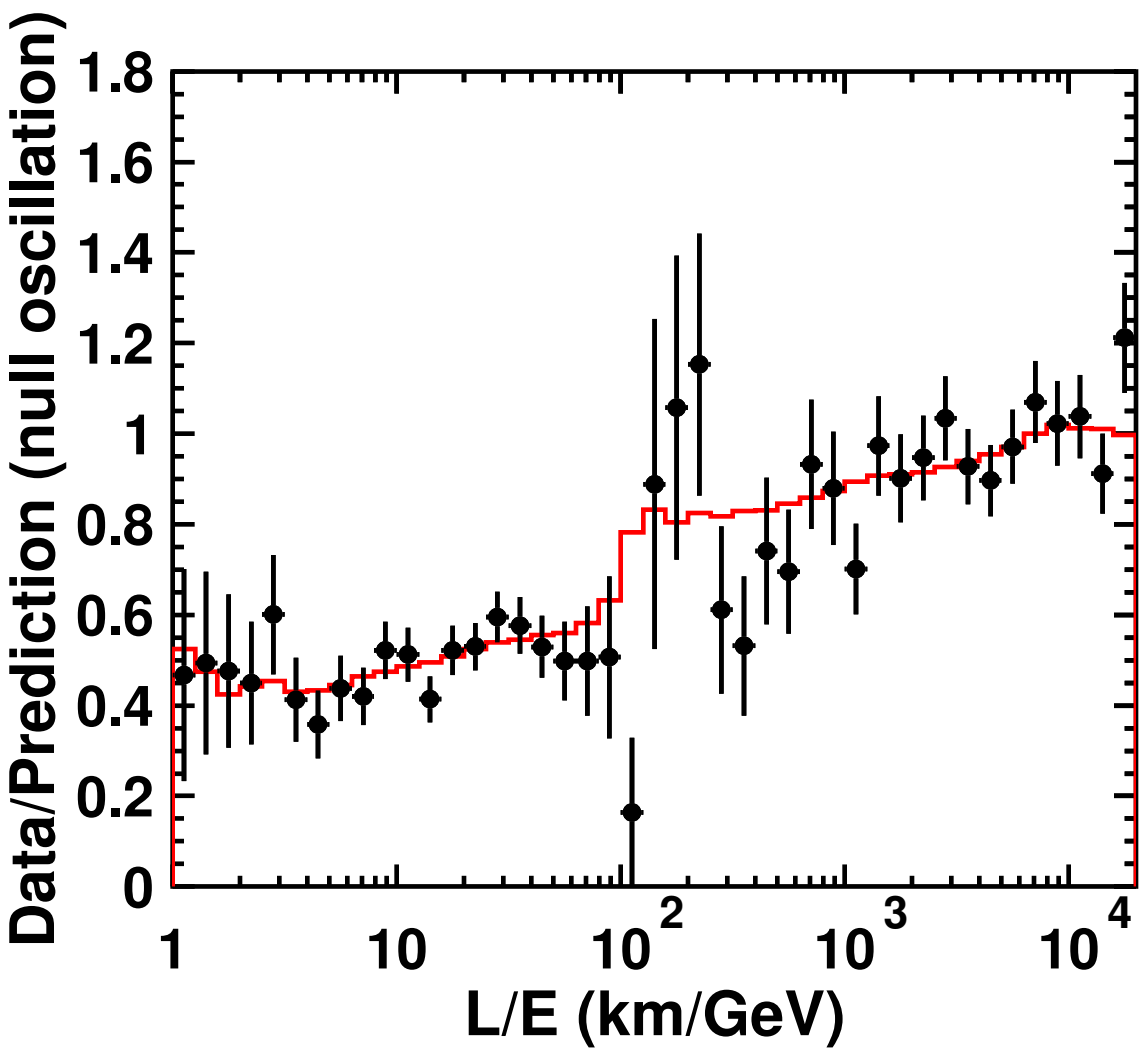

80% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4


90% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4


90% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4


Data/Prediction (null oscillation)
3
2.5
2
1.5
1
0.5
0
1
10
10^2
10^3
10^4
L/E (km/GeV)


Number of events
300
250
200
150
100
50
0
1
10
10 2
10 3
10 4
L/E (km/GeV)


Data/Prediction (null oscillation)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10 2
10 3
10 4
L/E (km/GeV)

List of Systematics for SK1

Sys ID	Sys value	Pull term	Best fit phys	Best fit
1	10.0000	0.0000	0.0013	0.0078
2	0.0060	0.0000	0.0000	0.0000
3	0.0600	0.0082	0.0054	0.0054
4	0.0100	0.0011	0.0003	-0.0002
5	0.0100	0.0130	0.0011	-0.0003
6	0.1000	0.0026	0.0051	0.0045
7	0.0500	0.0910	-0.0151	-0.0150
8	0.0500	0.1487	-0.0193	-0.0193
9	0.1000	0.4989	0.0706	0.0712
10	0.1000	0.0239	-0.0154	-0.0157
11	0.0500	0.0754	-0.0137	-0.0138
12	1.0000	0.0131	-0.1146	-0.1226
13	0.2000	0.0232	0.0305	0.0337
14	0.0020	0.0001	0.0000	0.0000
15	0.0240	0.0214	-0.0035	-0.0035
16	0.1000	0.0039	0.0063	0.0064
17	0.0100	0.0001	-0.0001	-0.0001
18	0.1000	0.0011	0.0033	0.0033
19	0.0110	0.0734	-0.0030	-0.0030
20	0.0060	0.1030	0.0019	0.0018
21	0.3000	0.0000	-0.0013	-0.0014
22	0.0100	0.0000	0.0000	0.0000
23	0.1500	0.0014	0.0057	0.0055
24	0.2000	0.0214	-0.0293	-0.0324
25	0.2000	0.8471	0.1841	0.1848
26	0.2000	0.0238	-0.0308	-0.0323
27	0.4000	0.0001	-0.0039	-0.0056
28	0.1130	0.0109	-0.0118	-0.0115
29	0.0740	0.0017	0.0031	0.0026

Results of L/E Analysis
(1489 days FC + PC)

- **Assuming $\nu_\mu \leftrightarrow \nu_\tau$ Oscillation**

  Best Fit:

  χ^2_{min} = 43.2 / 40 d.o.f

  at ($\sin^2 2\theta$, Δm^2) = (1.00 , 2.2E-03 eV^2)

  (including unphysical region)

  χ^2_{min} = 43.0 / 40 d.o.f

  at ($\sin^2 2\theta$, Δm^2) = (1.02 , 2.2E-03 eV^2)

  90% confidence level allowed region:

  $\sin^2(2\theta) > 0.91$

  $1.81\ '\times 10^{-3}\ eV^2 < \Delta m^2 < '3.24' \times 10^{-3}\ eV^2$,

- **Assuming Neutrino Decay**

  χ^2_{min} = 51.7 / 40 d.o.f

  $\Delta\chi^2$ = 8.5 / 40 d.o.f (2.9 standard deviations)

- **Assuming Neutrino Decoherence**

  χ^2_{min} = 55.9 / 40 d.o.f

  $\Delta\chi^2$ = 12.7 / 40 d.o.f (3.6 standard deviations)