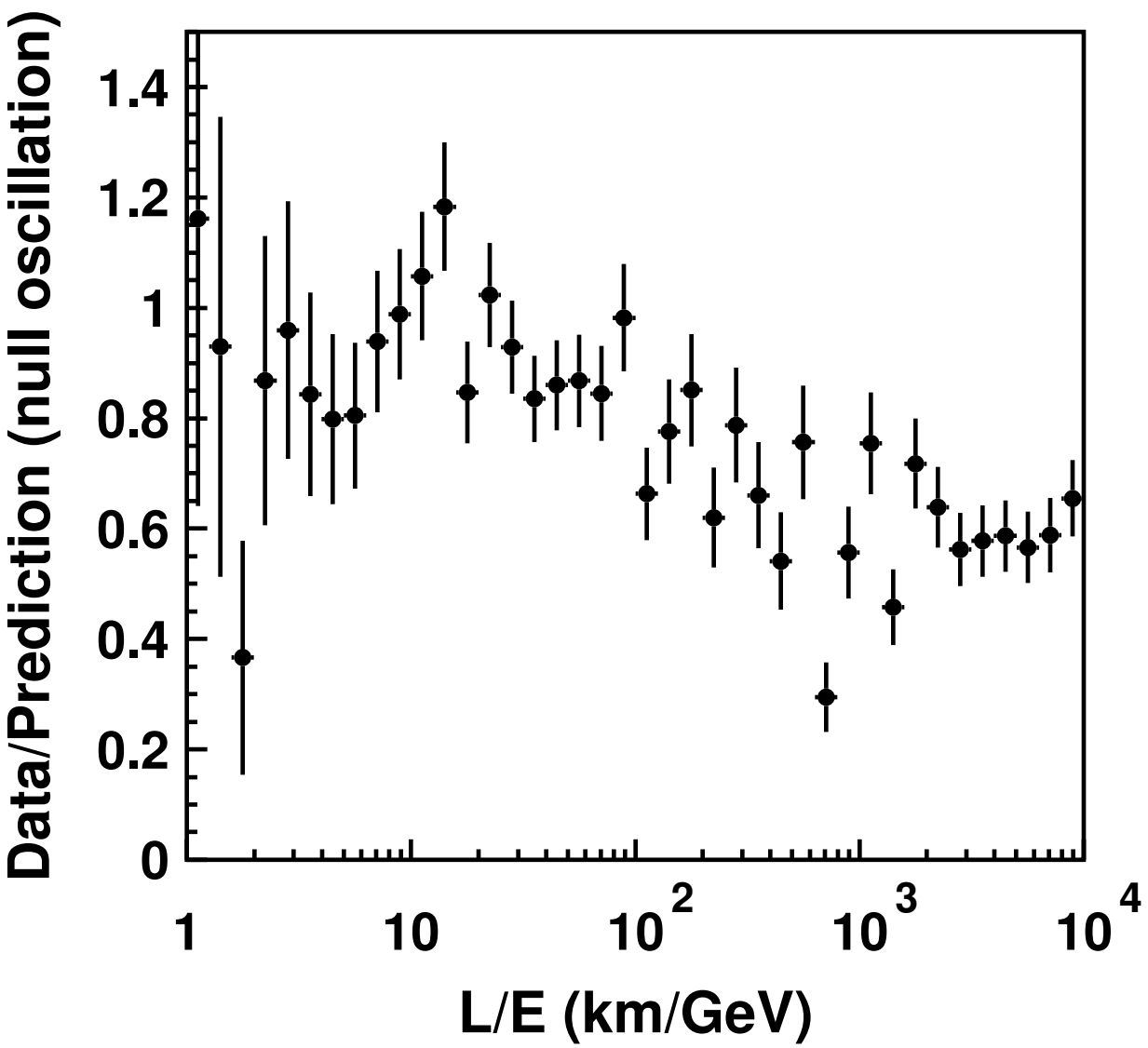
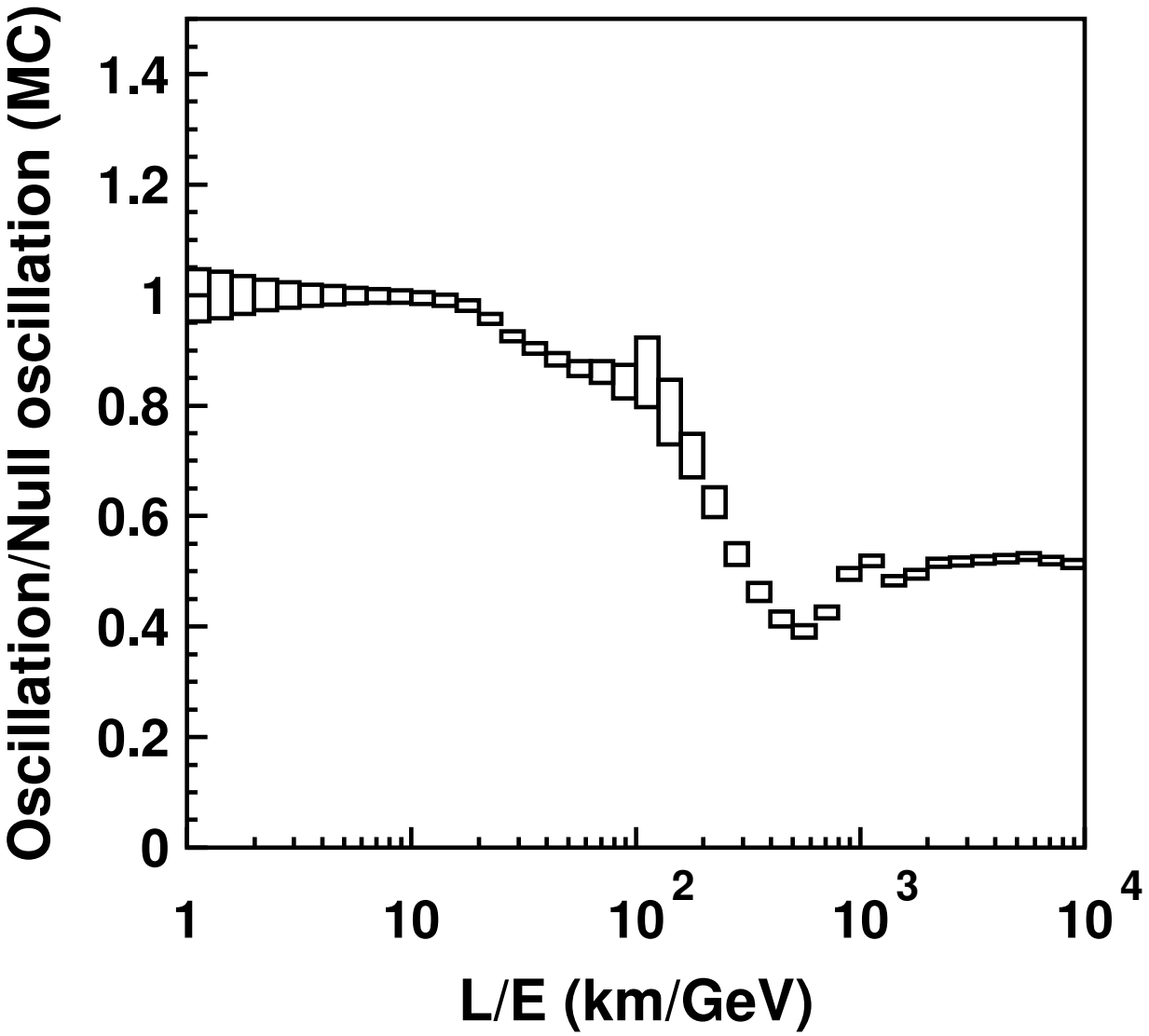
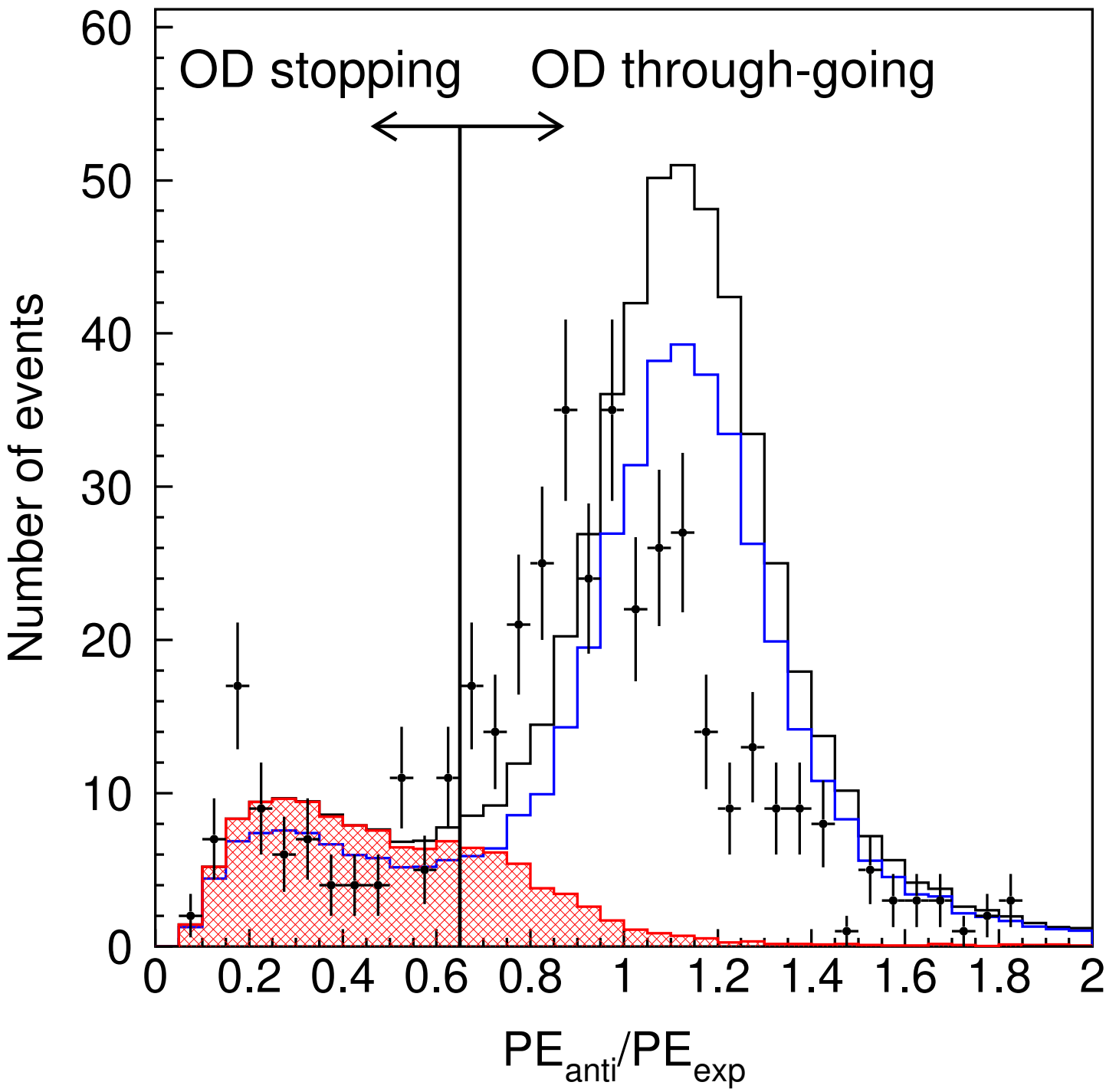
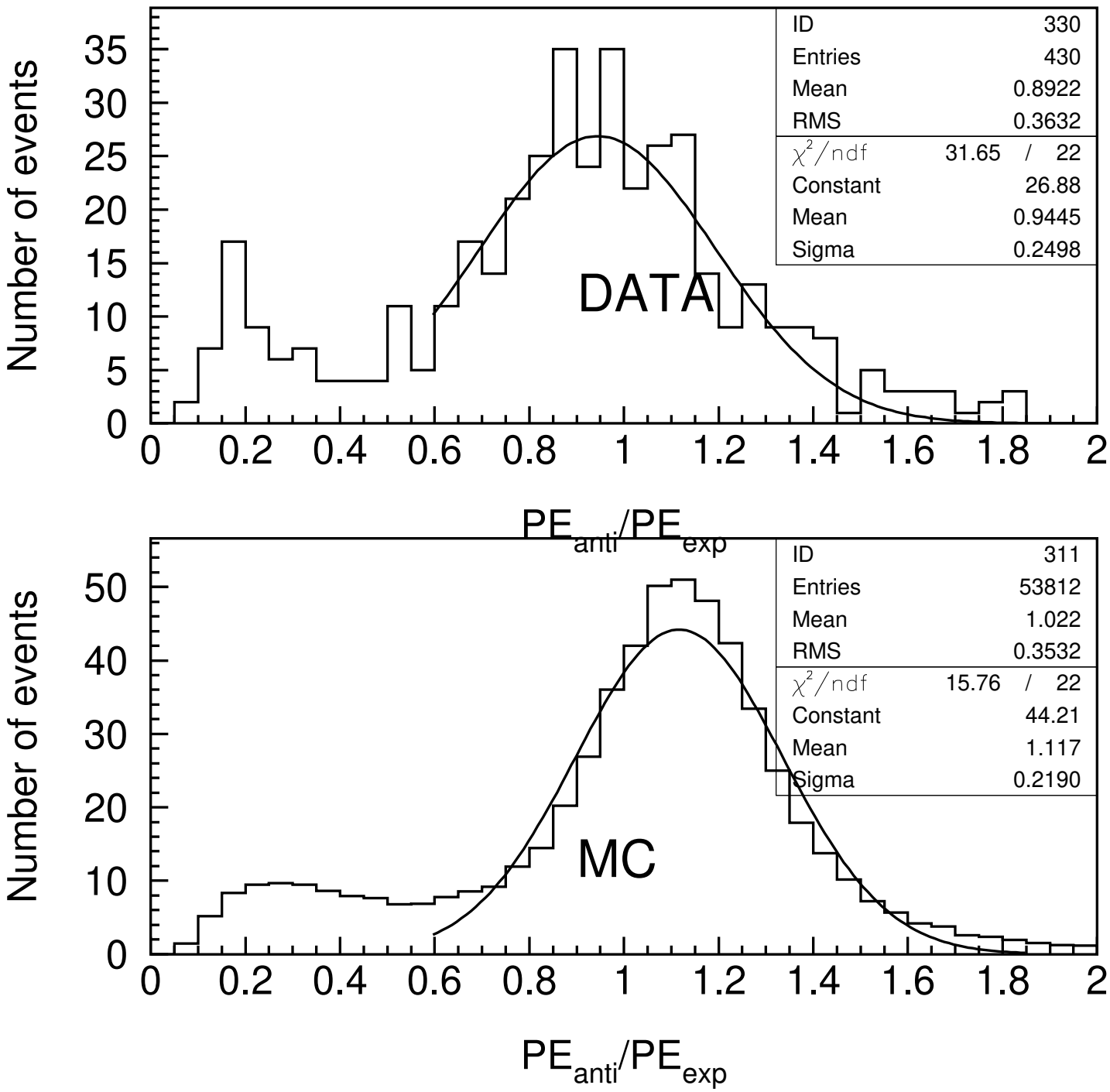
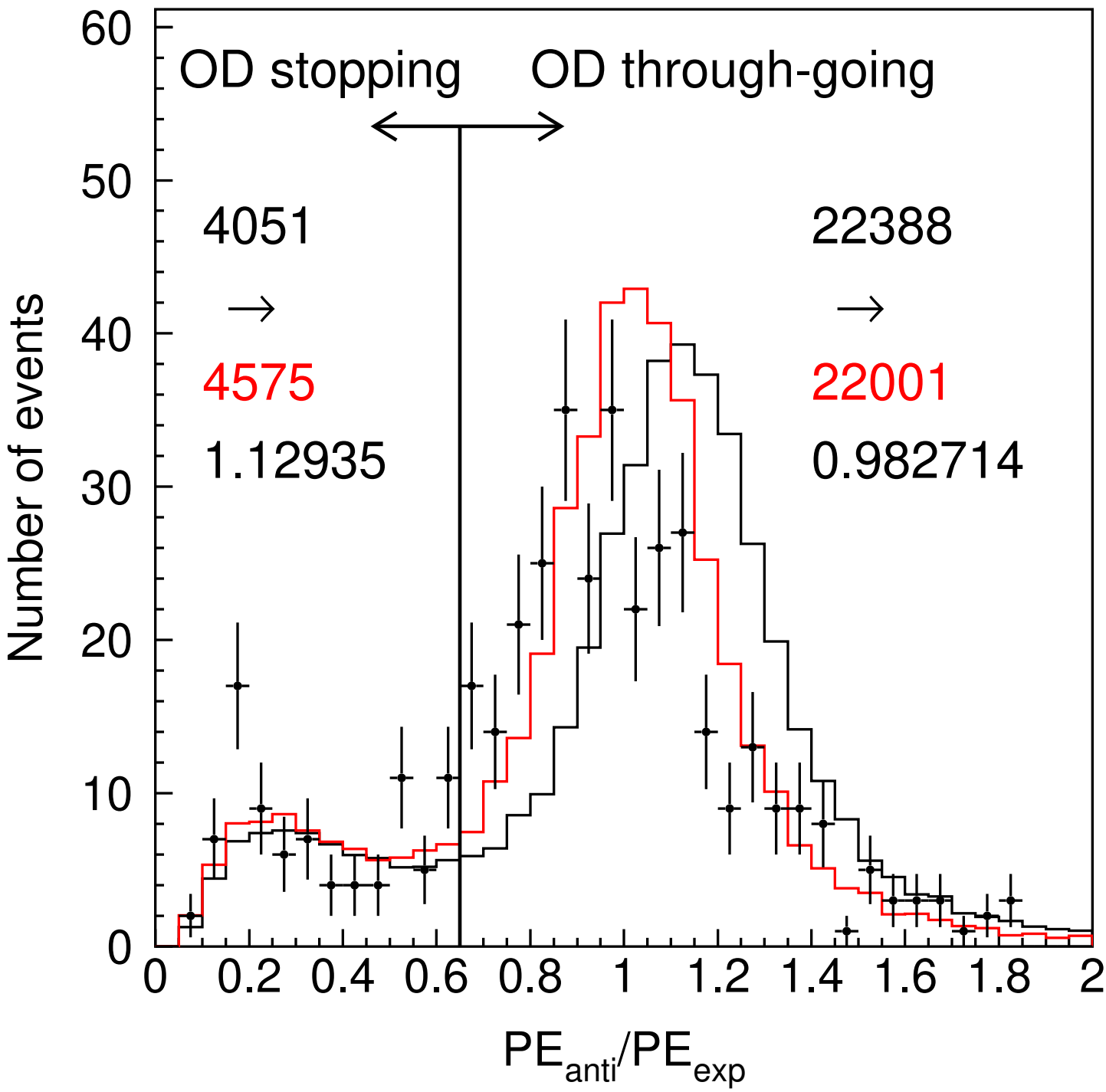
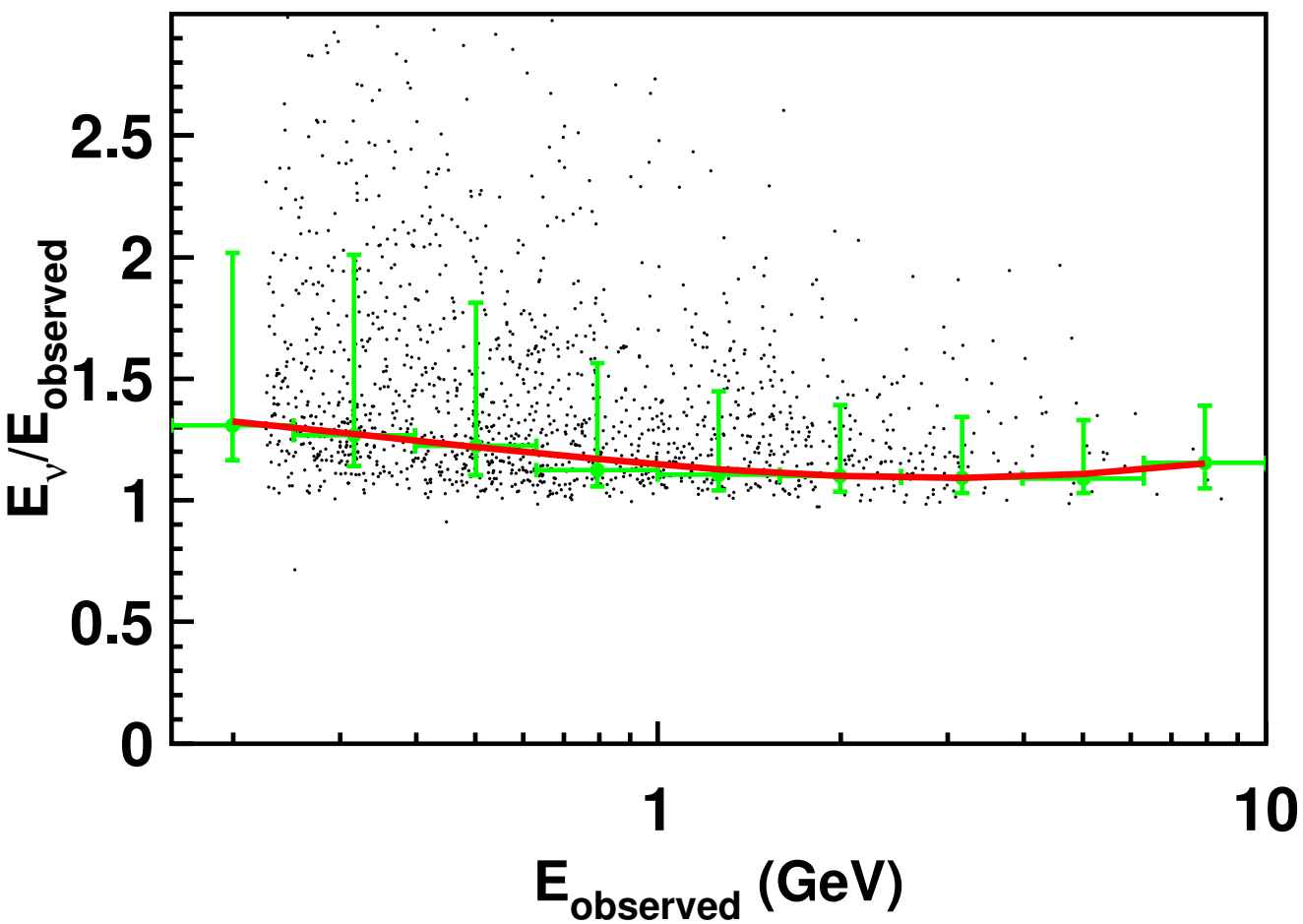

Data/Prediction (null oscillation)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10^2
10^3
10^4
L/E (km/GeV)

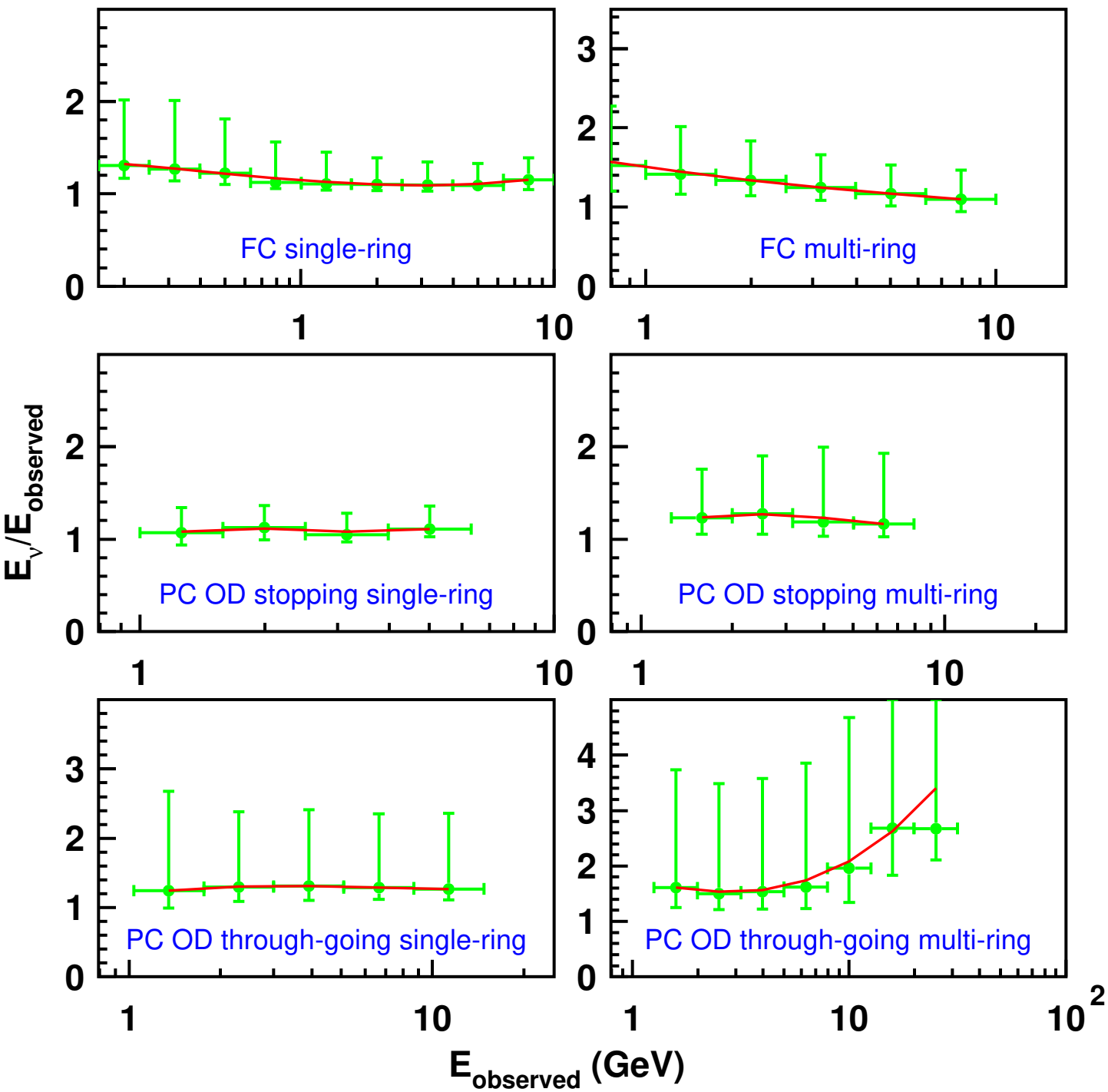

Oscillation/Null oscillation (MC)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10^2
10^3
10^4
L/E (km/GeV)

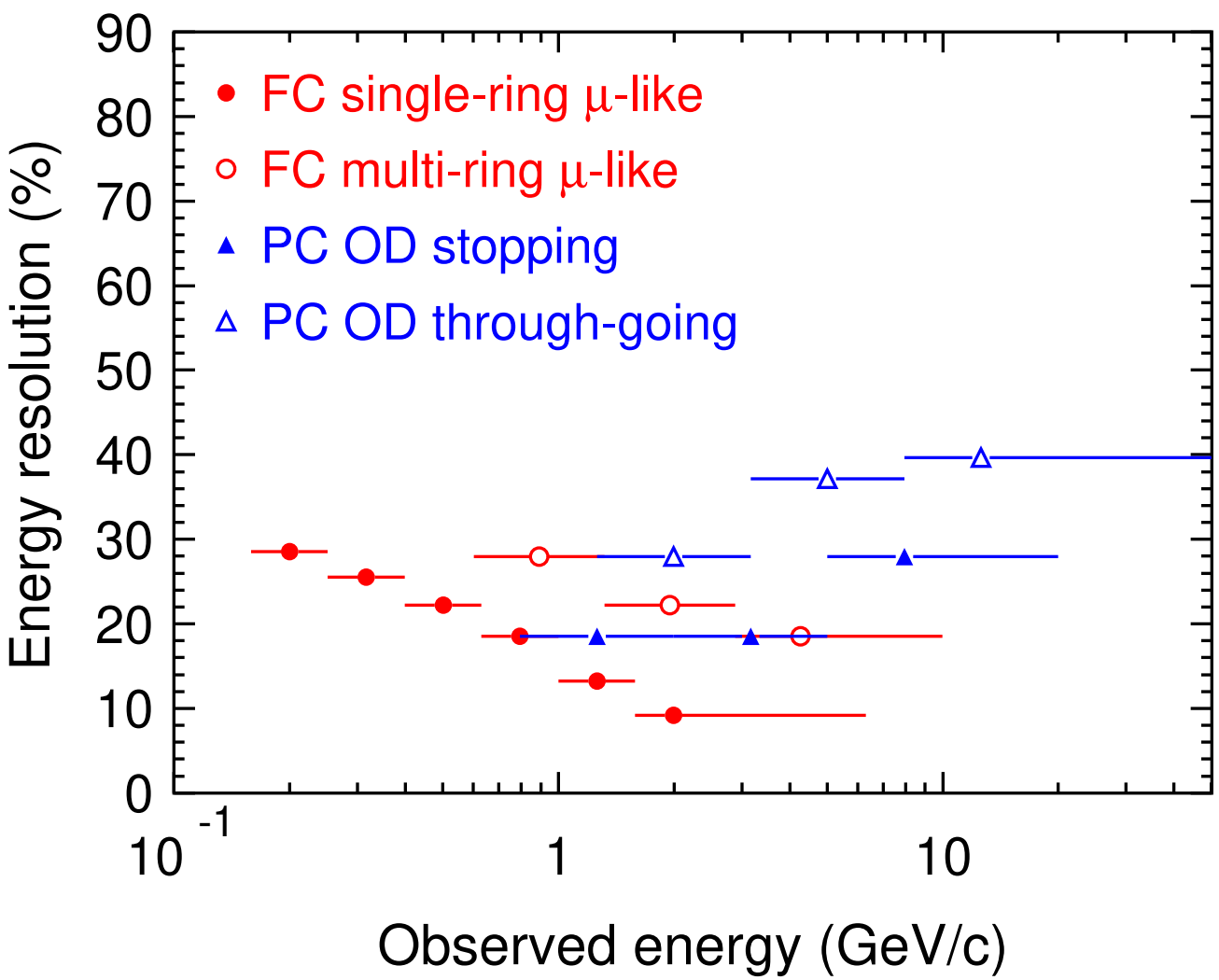

OD stopping
OD through-going
Number of events
0
10
20
30
40
50
60
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
PE_anti/PE_exp

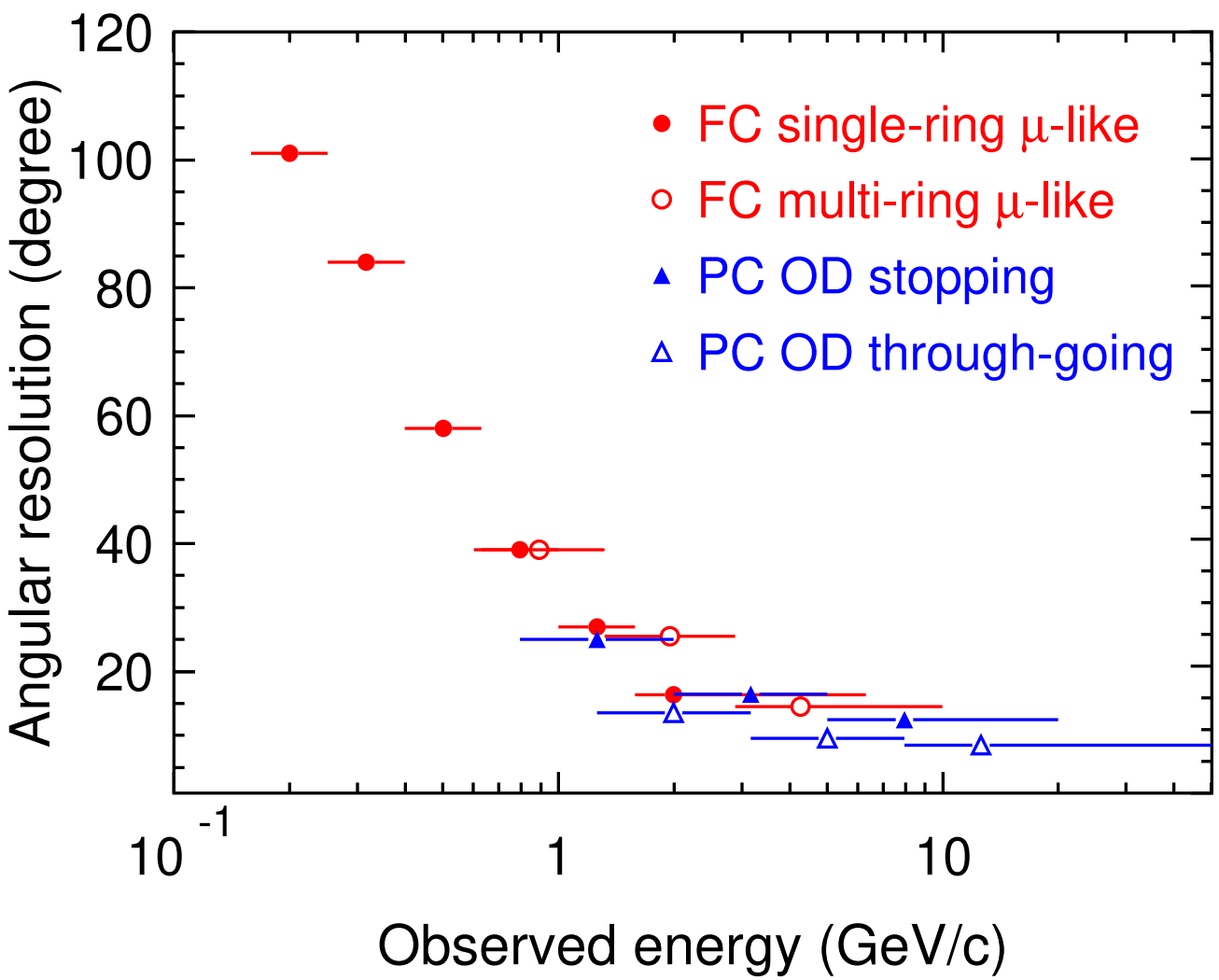

Number of events
DATA
ID 330
Entries 430
Mean 0.8922
RMS 0.3632
χ²/ndf 31.65 / 22
Constant 26.88
Mean 0.9445
Sigma 0.2498
PE_anti/PE_exp
Number of events
MC
ID 311
Entries 53812
Mean 1.022
RMS 0.3532
χ²/ndf 15.76 / 22
Constant 44.21
Mean 1.117
Sigma 0.2190
PE_anti/PE_exp

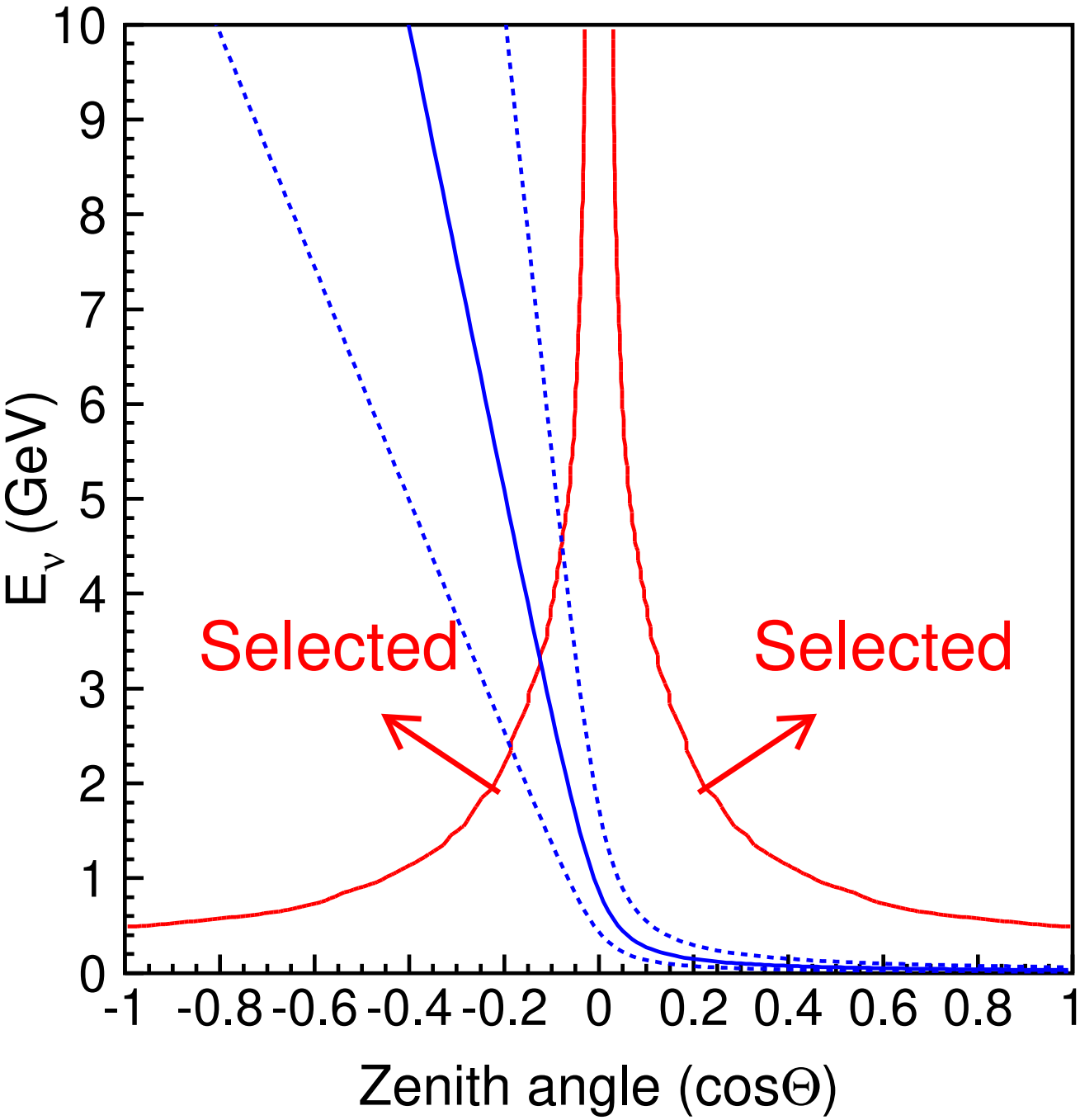

OD stopping
OD through-going
4051
22388
4575
22001
1.12935
0.982714
Number of events
PE_anti/PE_exp
0
10
20
30
40
50
60
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

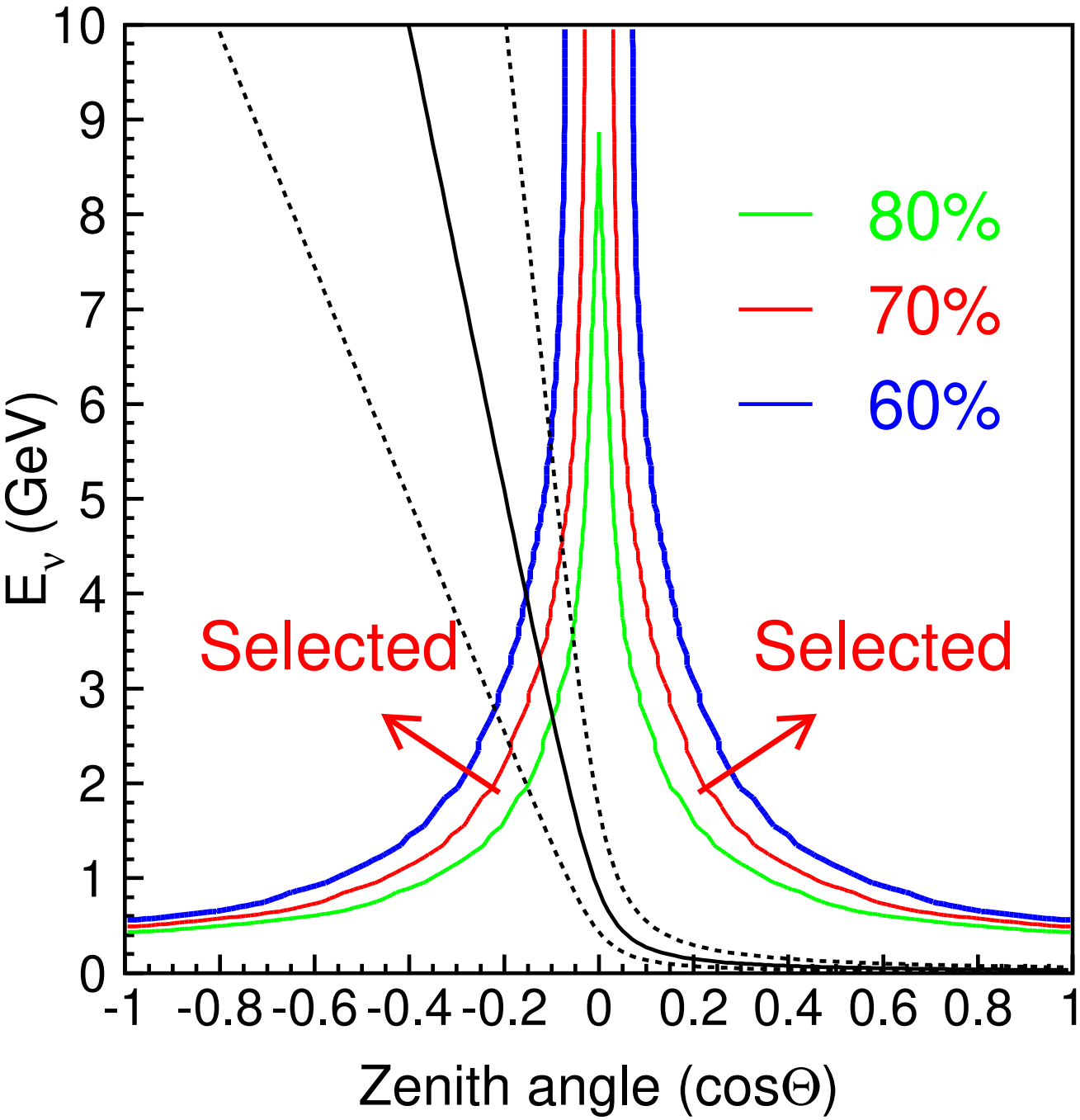

2.5
2
1.5
1
0.5
0
$E_\nu/E_{observed}$
1
10
$E_{observed}$ (GeV)

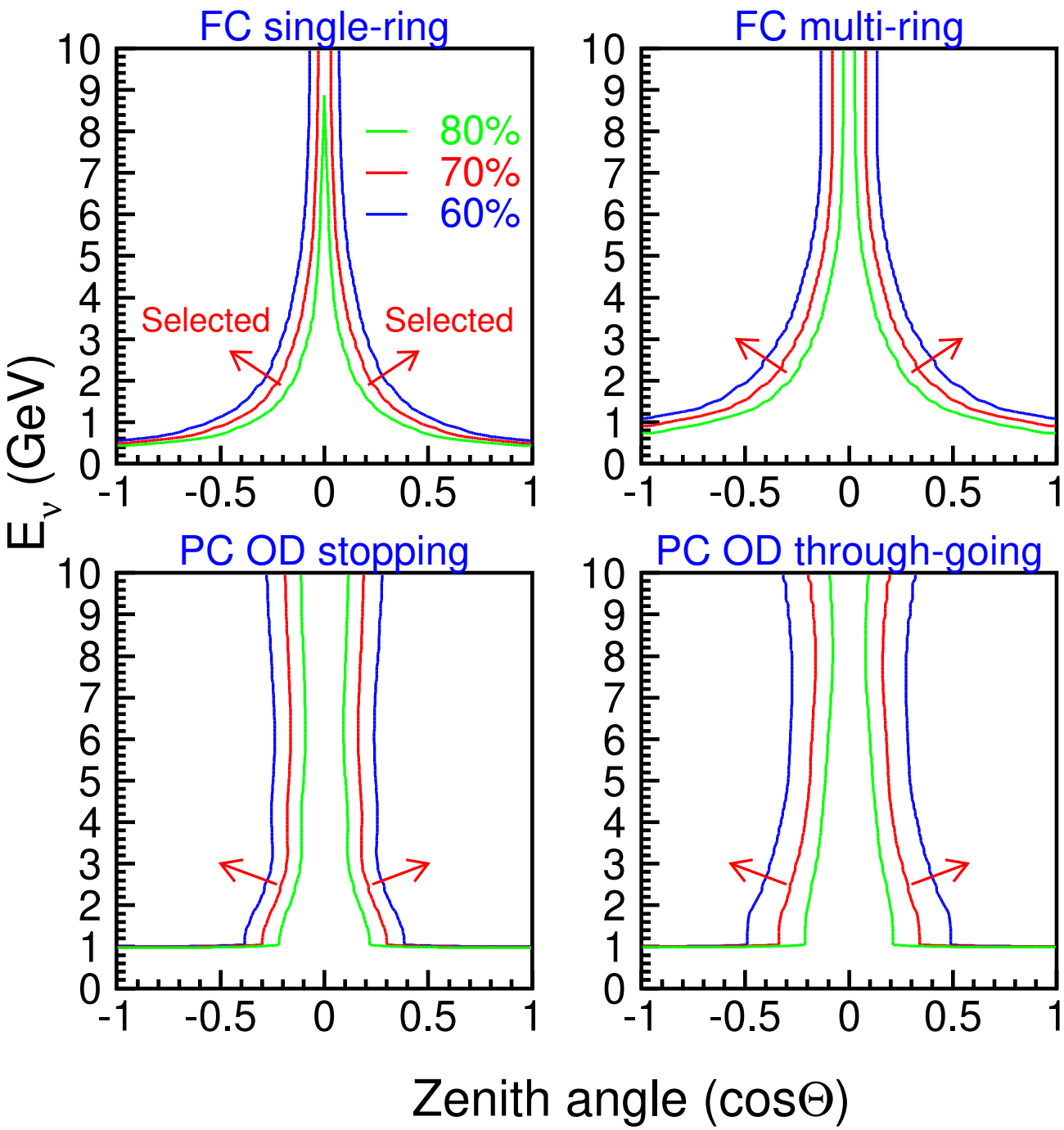

FC single-ring
FC multi-ring
PC OD stopping single-ring
PC OD stopping multi-ring
PC OD through-going single-ring
PC OD through-going multi-ring
$E_\nu/E_{observed}$
$E_{observed}$ (GeV)


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)

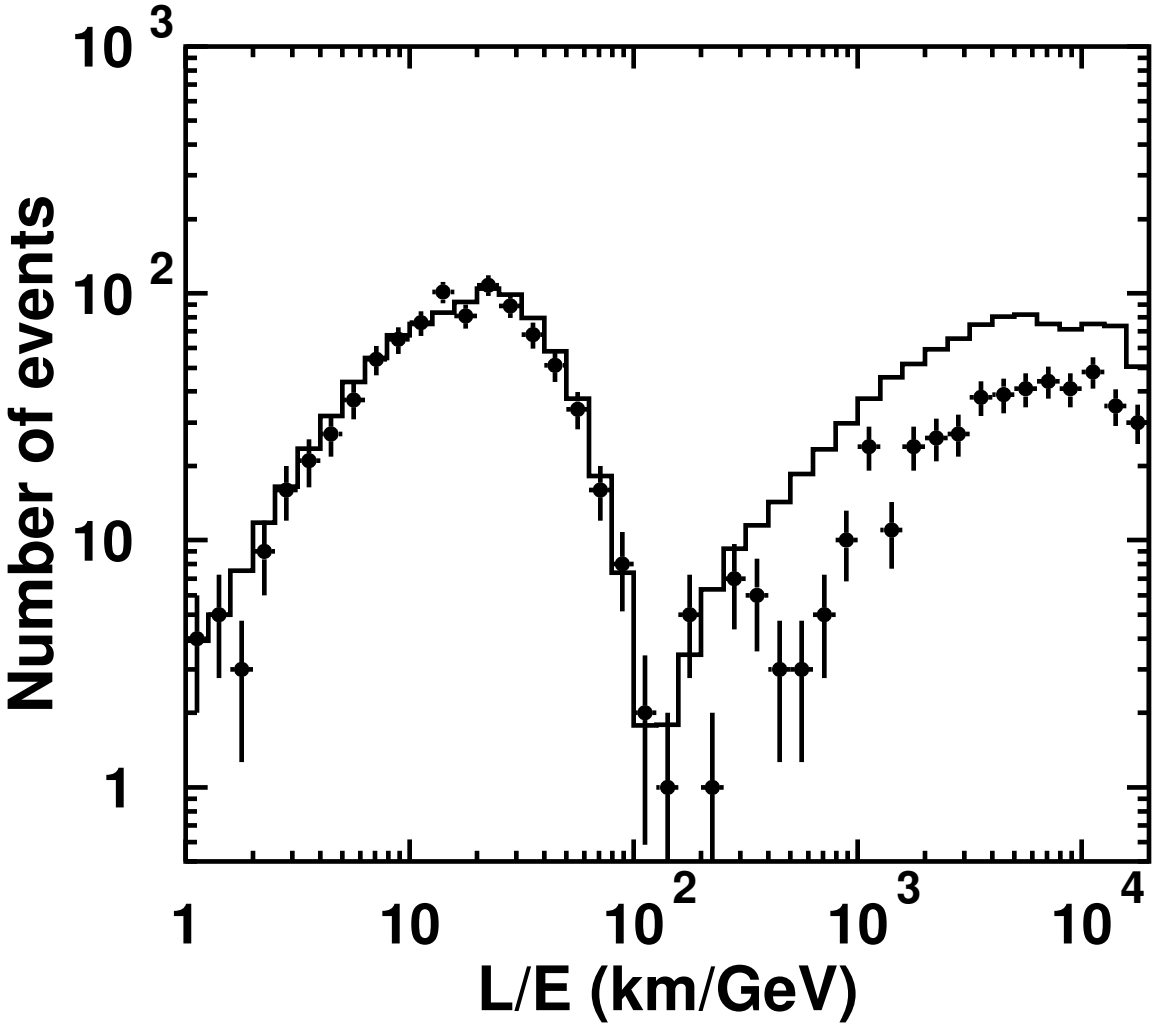

10
9
8
7
6
5
4
3
2
1
0
E_ν (GeV)
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Zenith angle (cosΘ)
80%
70%
60%
Selected
Selected

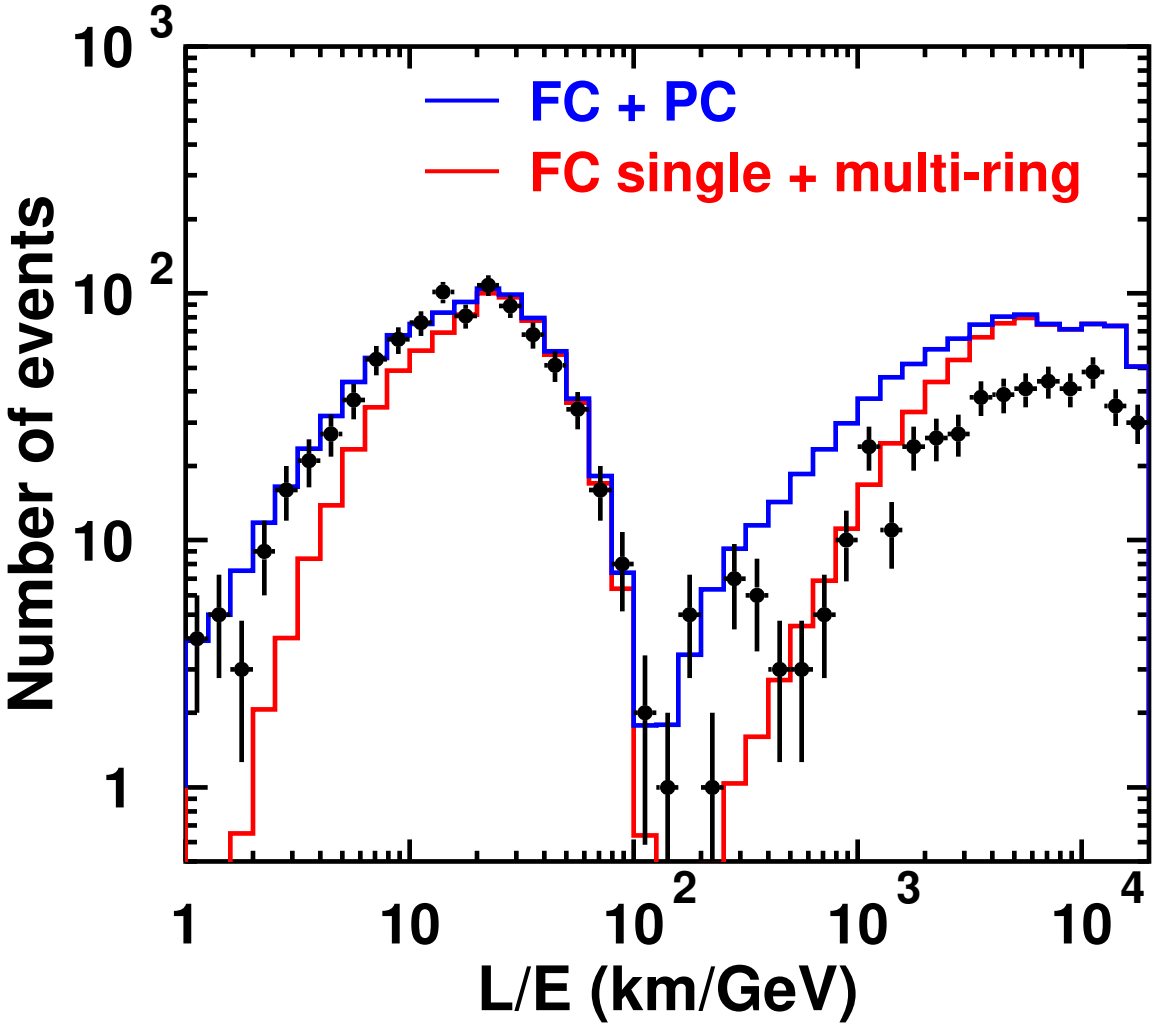

FC single-ring
FC multi-ring
PC OD stopping
PC OD through-going
80%
70%
60%
Selected
Selected
E_ν (GeV)
Zenith angle (cosΘ)

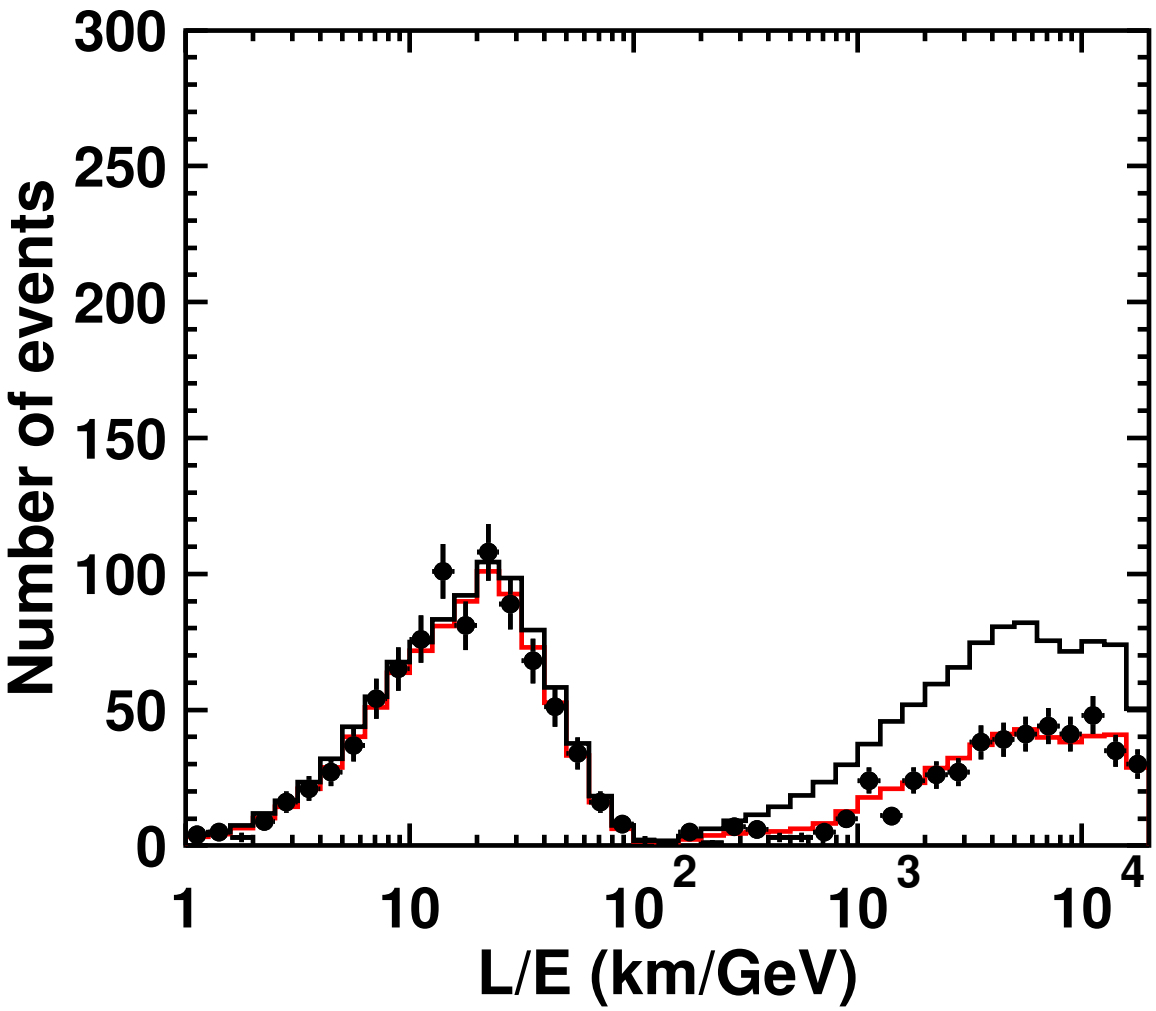
L/E event summary

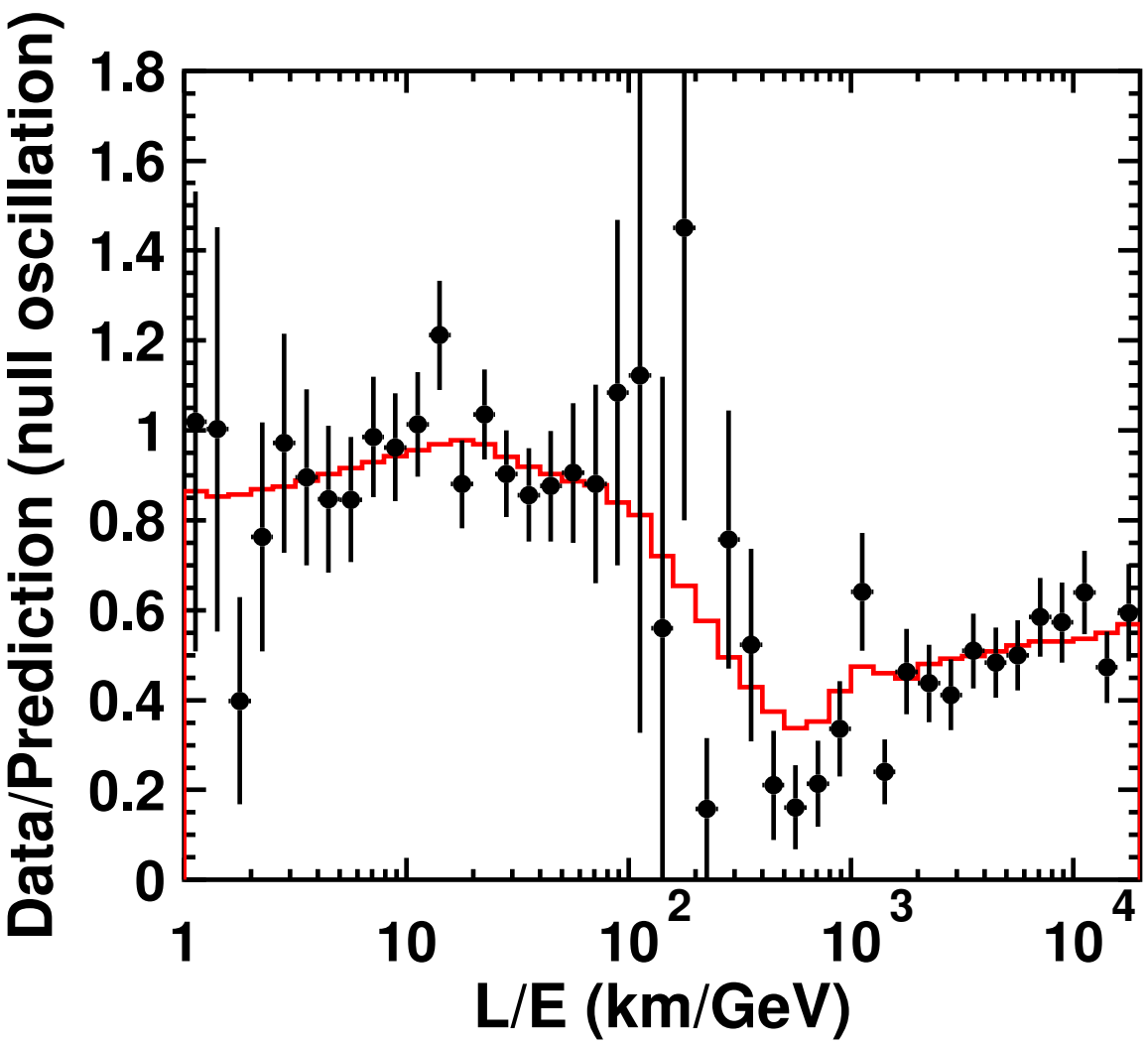
(ΔL/E < 70%)

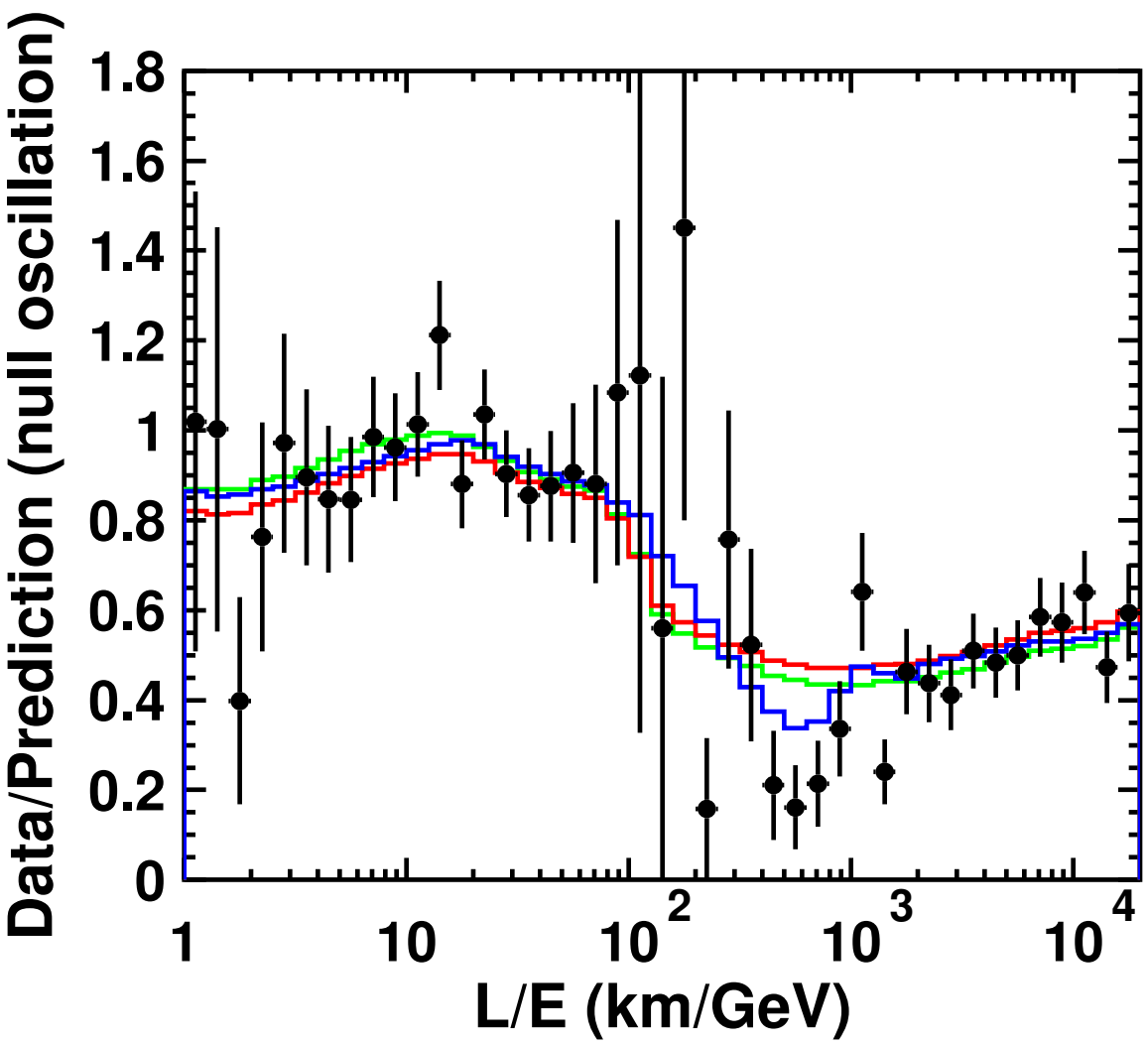
	DATA	MC	ν_μ CC
FC			
single-ring	855	1170.4	(98.2%)
multi-ring	246	333.4	(93.3%)
PC			
OD stopping	73	68.5	(94.2%)
OD through-going	191	321.7	(99.3%)

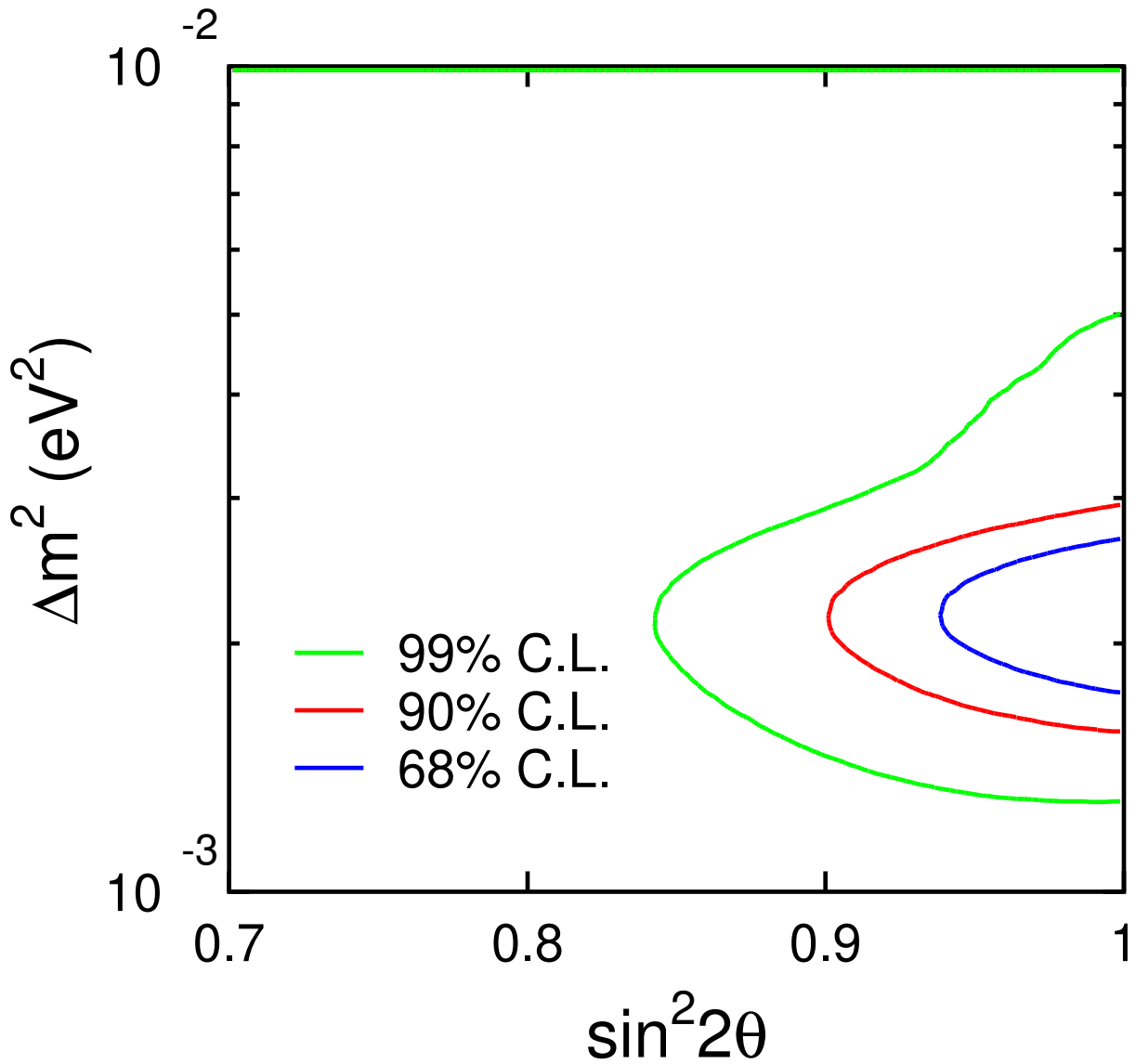

Number of events
10 3
10 2
10
1
1
10
10 2
10 3
10 4
L/E (km/GeV)

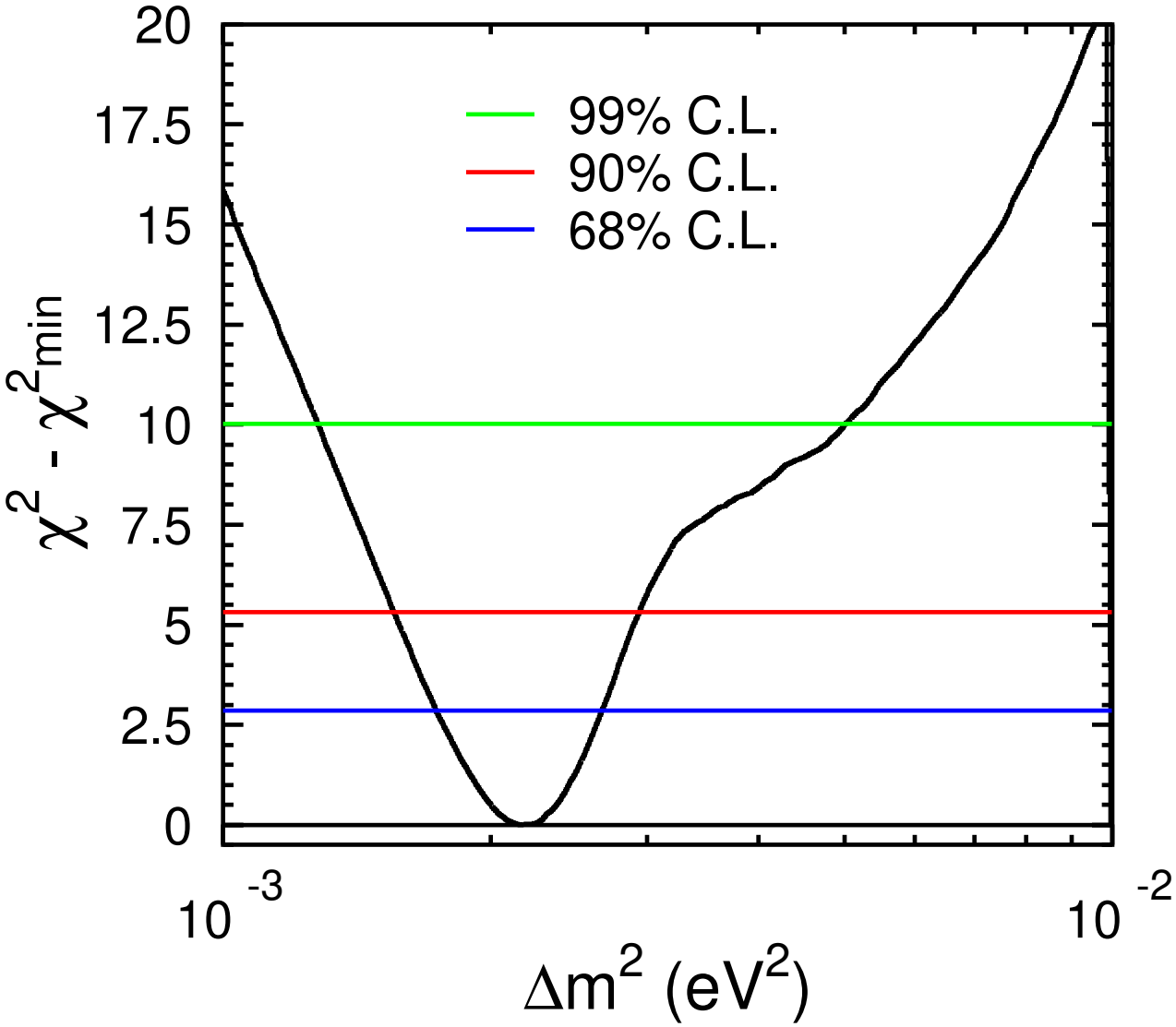

FC + PC
FC single + multi-ring
Number of events
L/E (km/GeV)
1
10
10 2
10 3
1
10
10 2
10 3
10 4

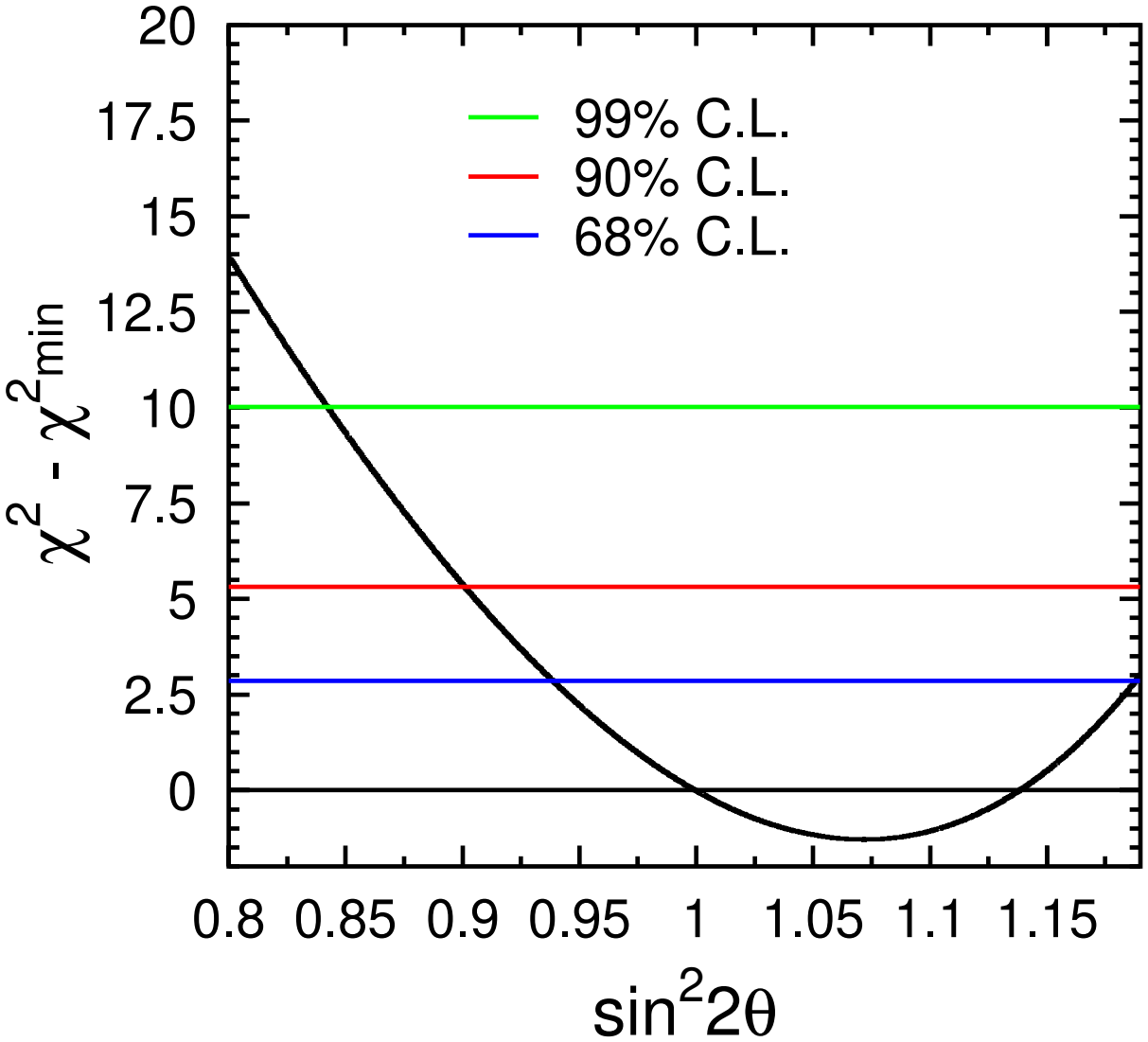

300
250
200
150
100
50
0
Number of events
1
10
10^2
10^3
10^4
L/E (km/GeV)

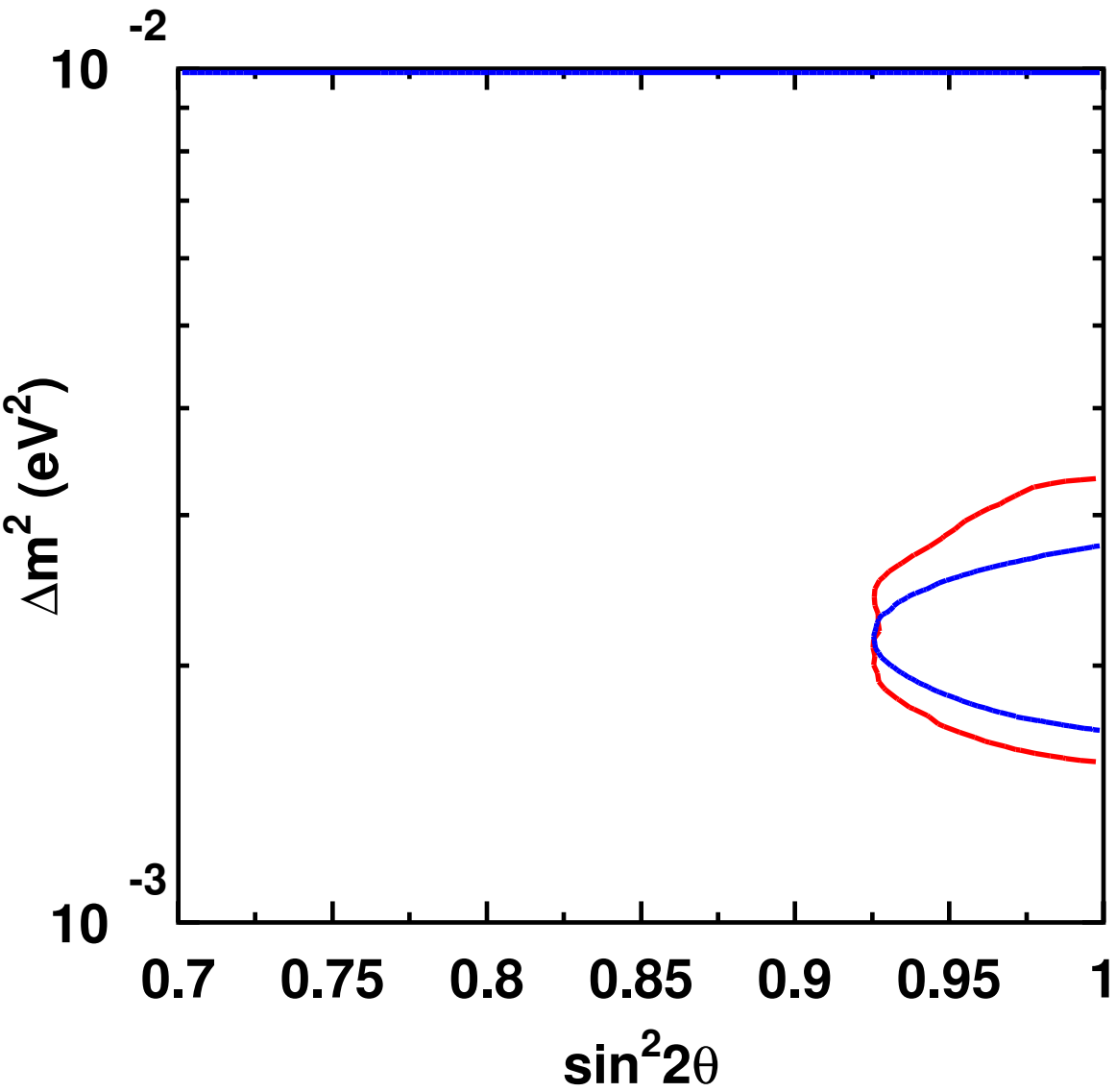

Data/Prediction (null oscillation)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10^2
10^3
10^4
L/E (km/GeV)

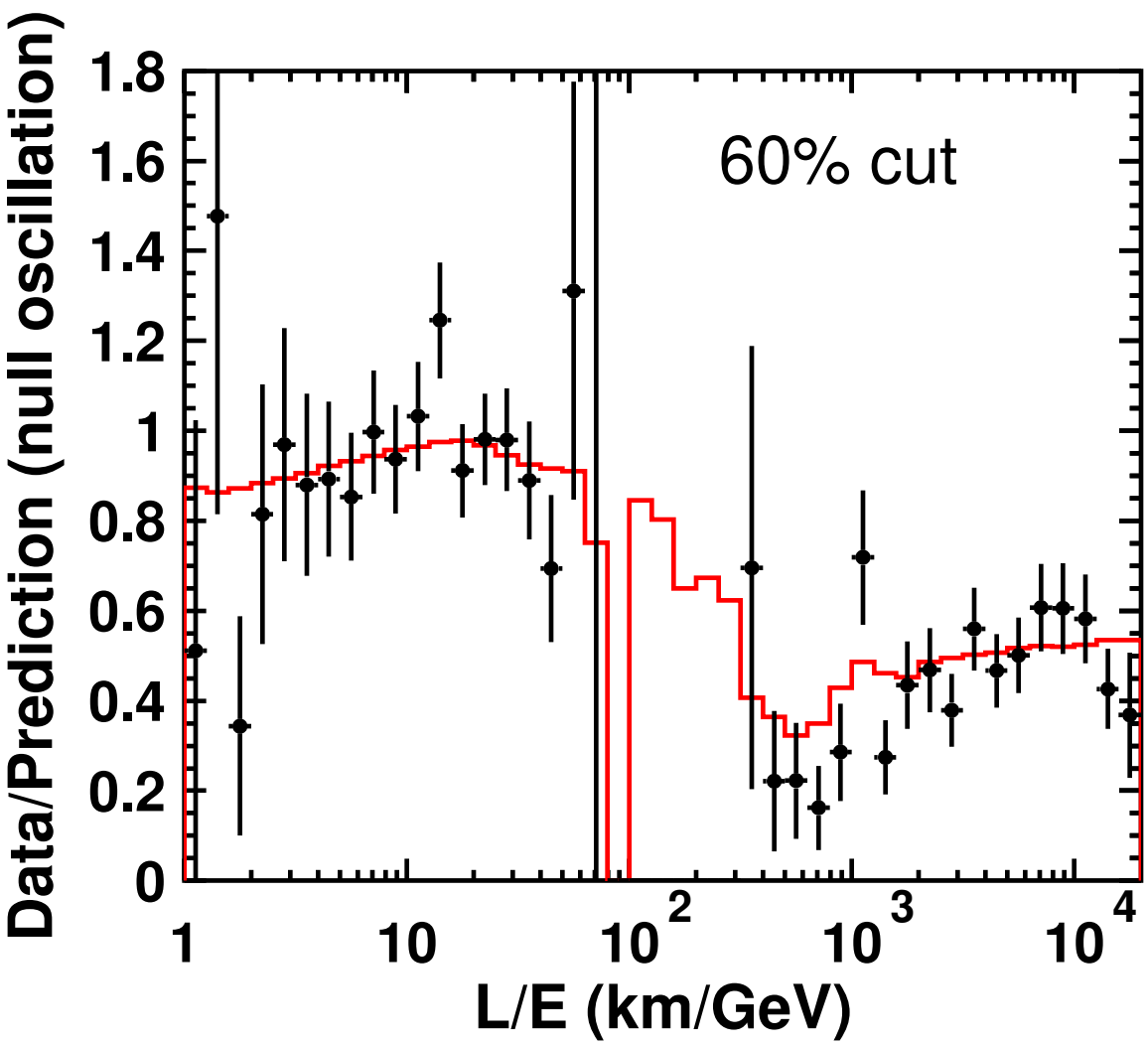

Data/Prediction (null oscillation)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
10^2
10^3
10^4
L/E (km/GeV)

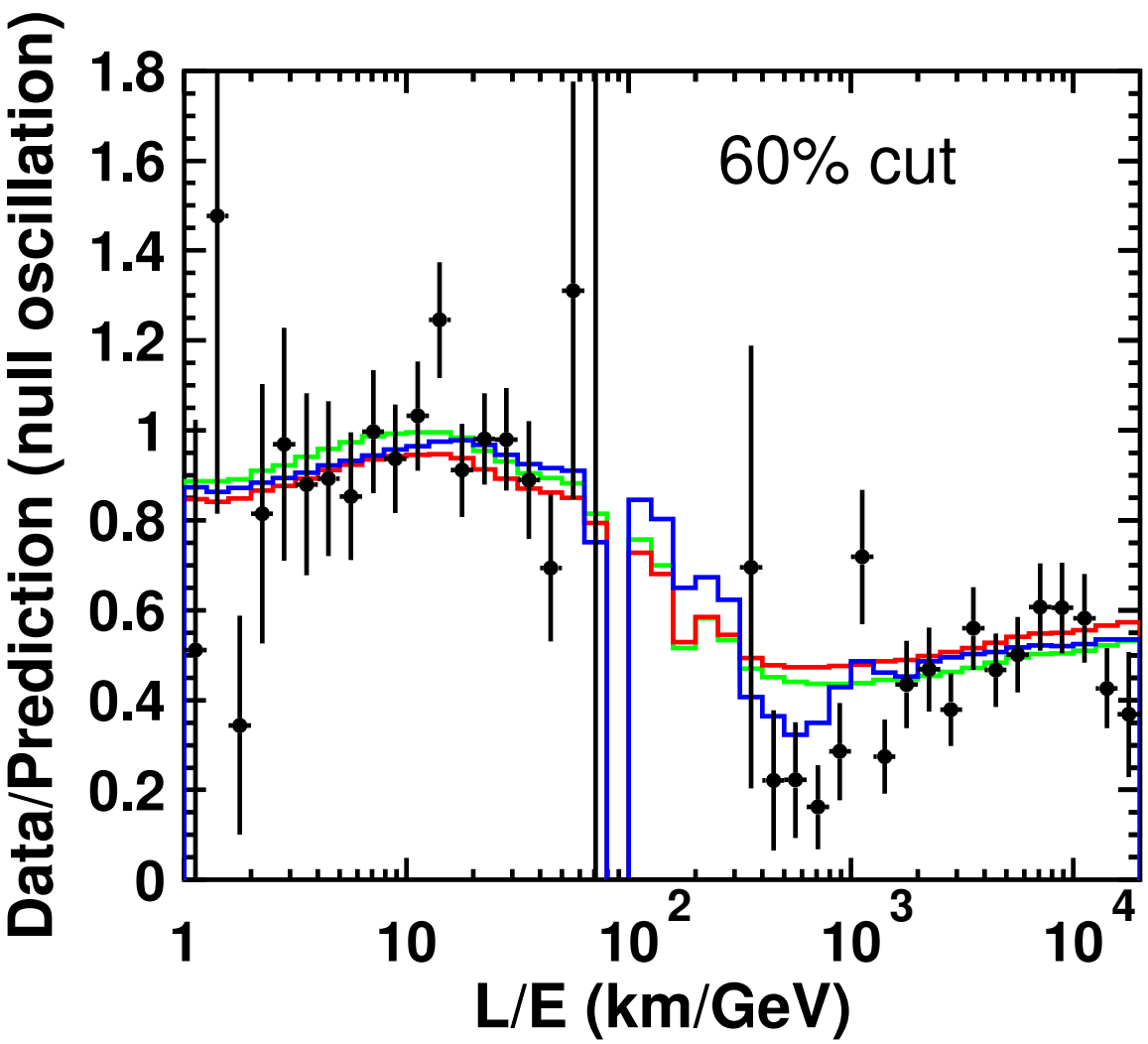

10^-2
10^-3
0.7
0.8
0.9
1
Δm^2 (eV^2)
sin^2 2θ
99% C.L.
90% C.L.
68% C.L.

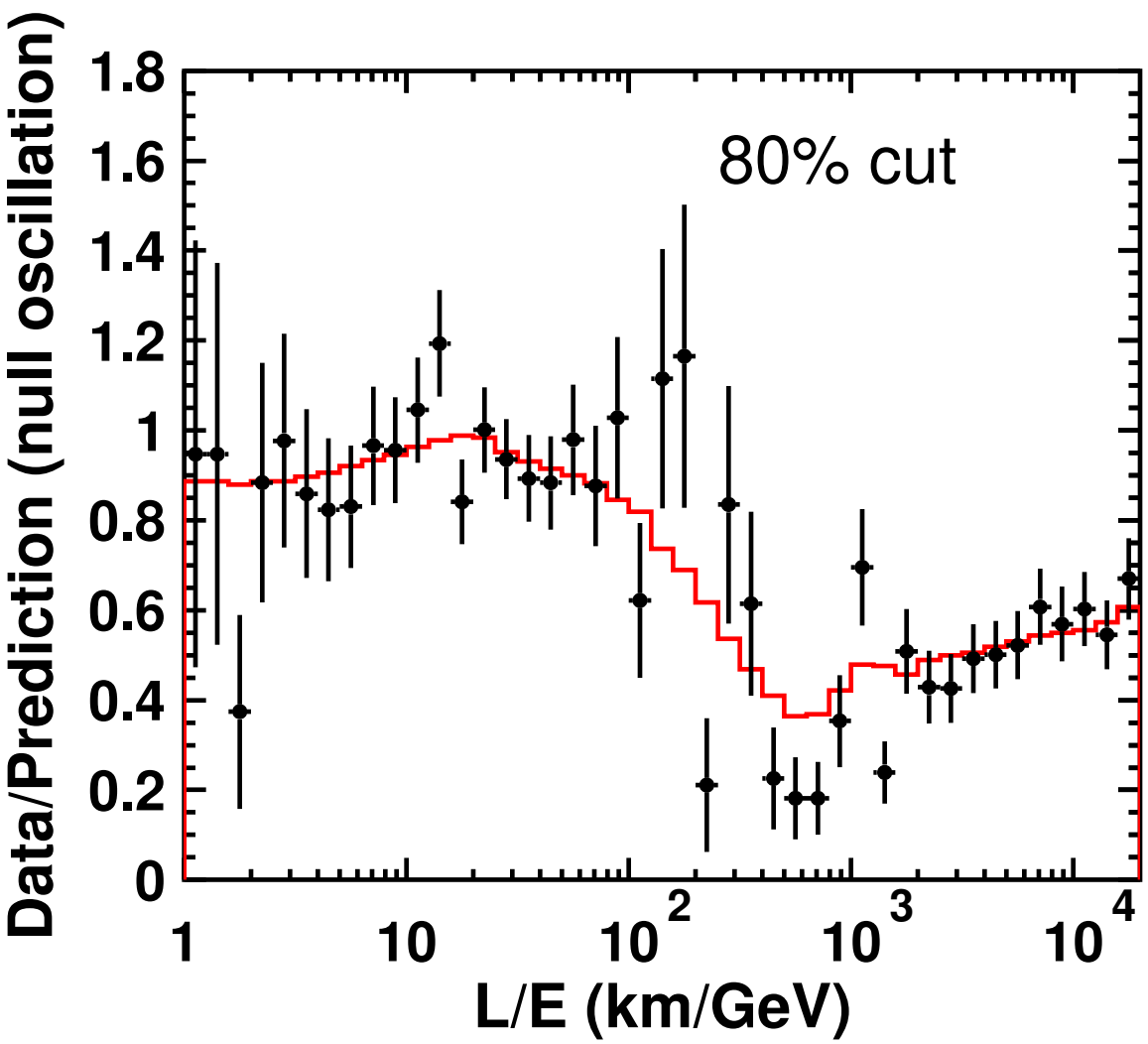

20
17.5
15
12.5
10
7.5
5
2.5
0
$\chi^2 - \chi^2_{min}$
99% C.L.
90% C.L.
68% C.L.
10^{-3}
10^{-2}
Δm^2 (eV^2)

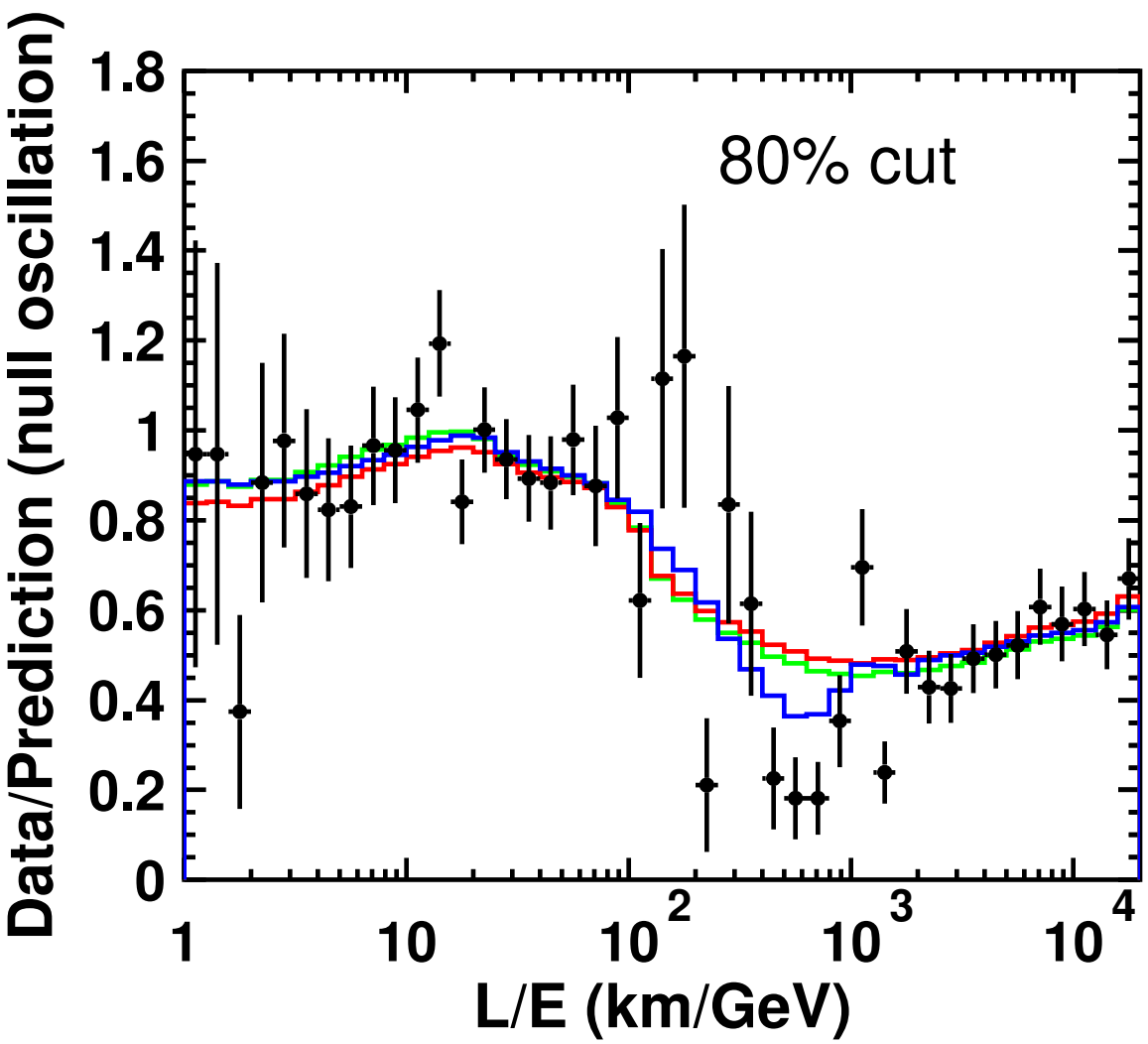

20
17.5
15
12.5
10
7.5
5
2.5
0
$\chi^2 - \chi^2_{min}$
99% C.L.
90% C.L.
68% C.L.
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
$\sin^2 2\theta$

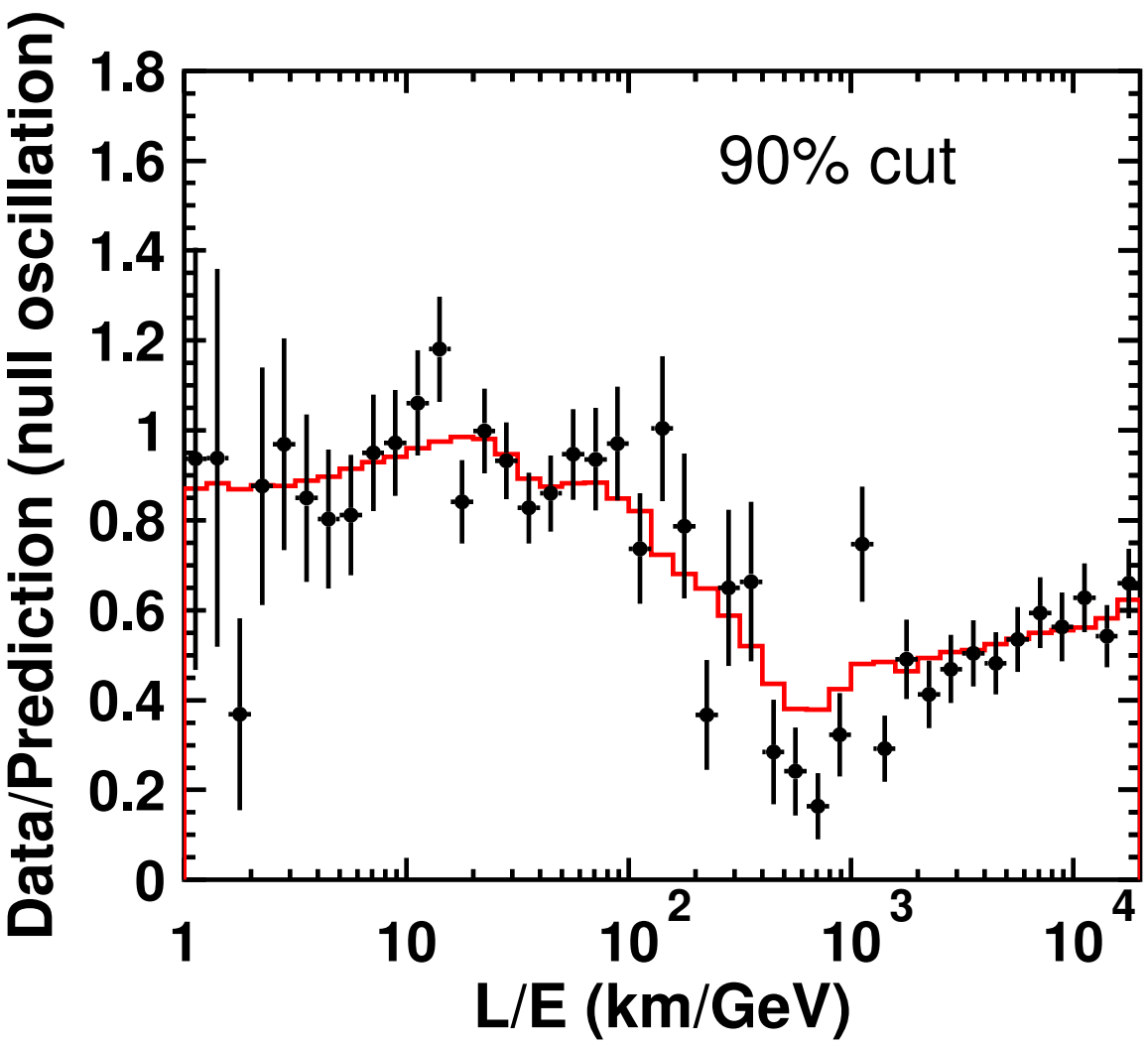

10^-2
10^-3
Δm^2 (eV^2)
0.7
0.75
0.8
0.85
0.9
0.95
1
sin^2 2θ

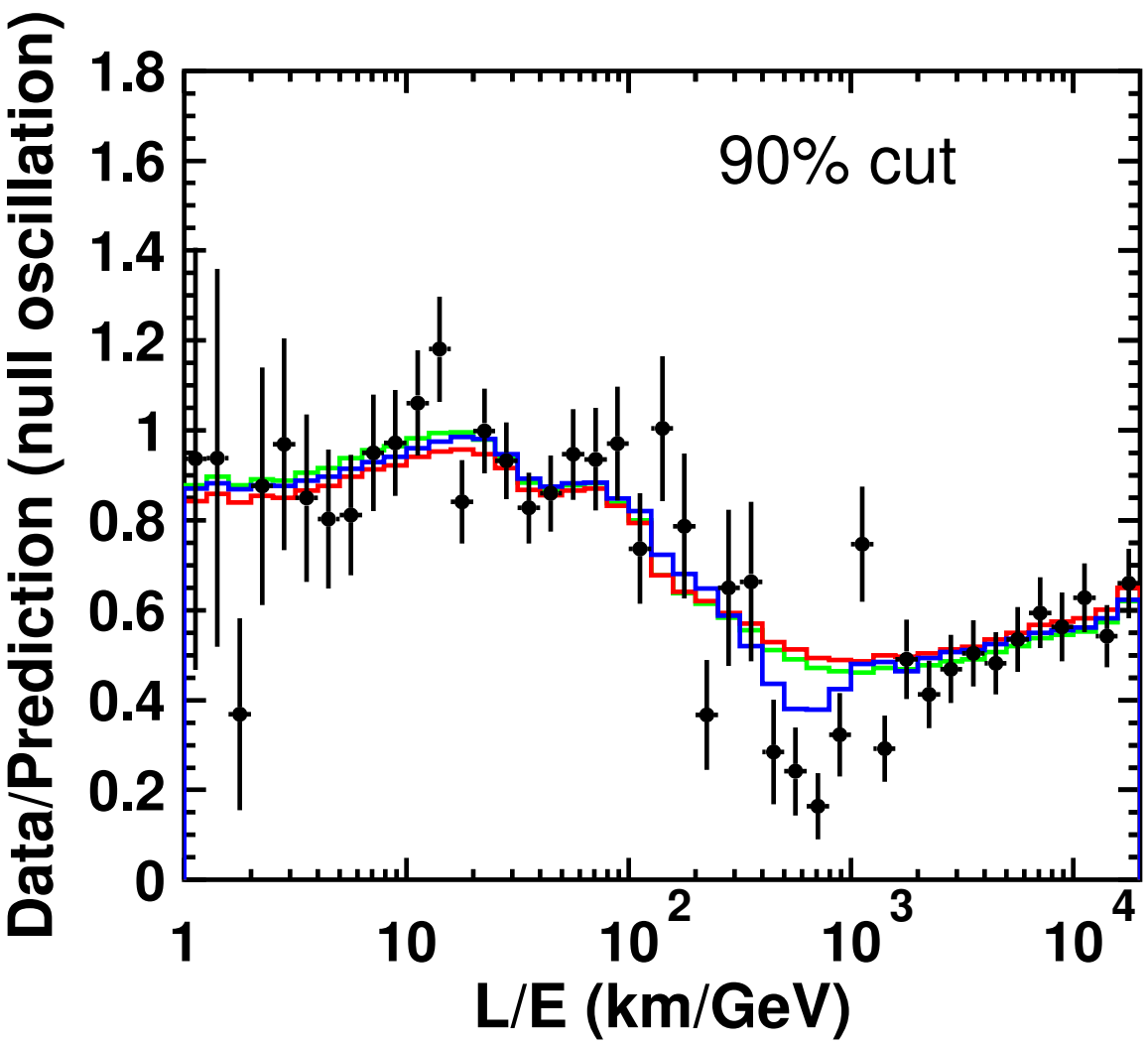

Data/Prediction (null oscillation)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
60% cut
1
10
10^2
10^3
10^4
L/E (km/GeV)

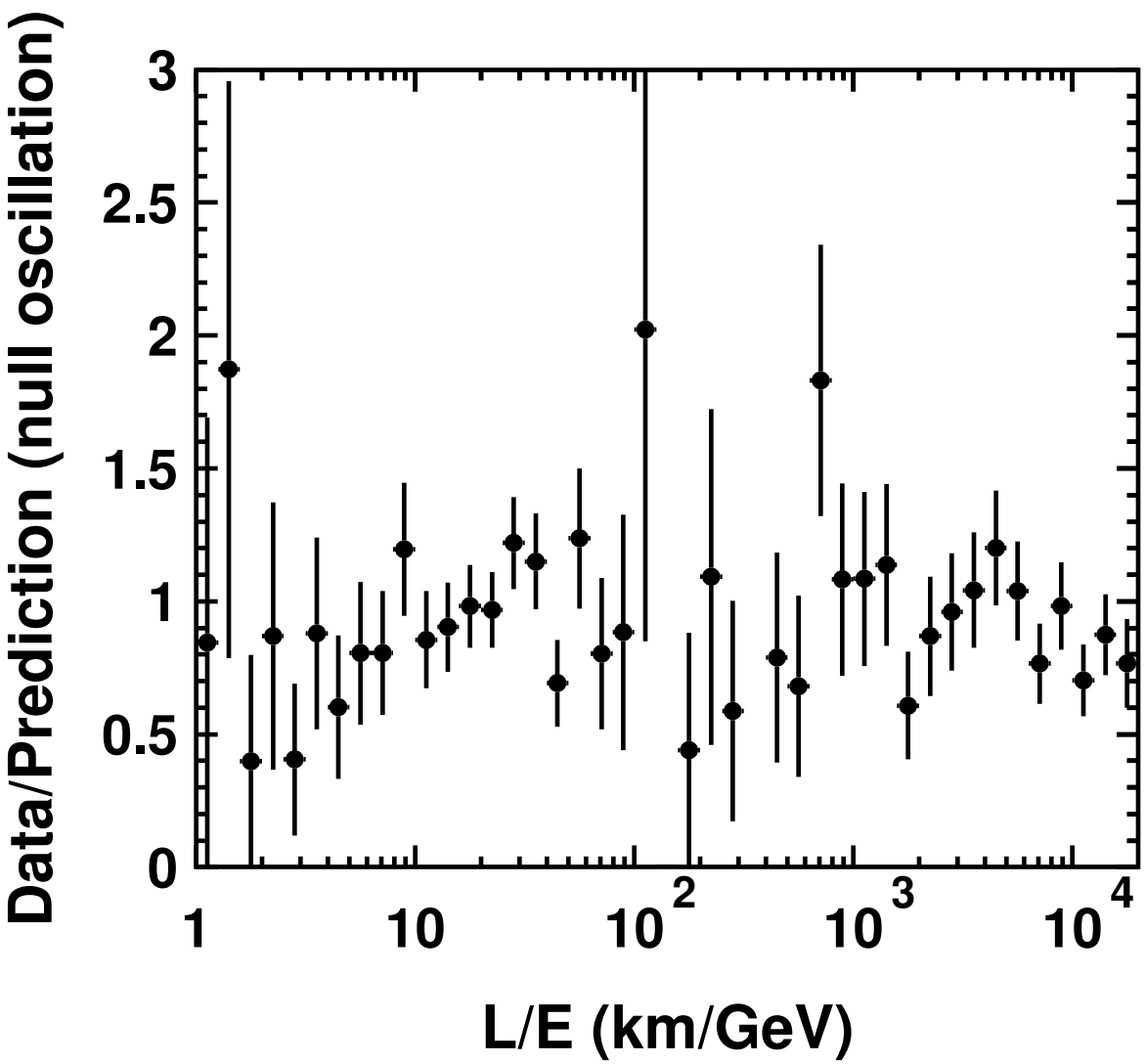

60% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4

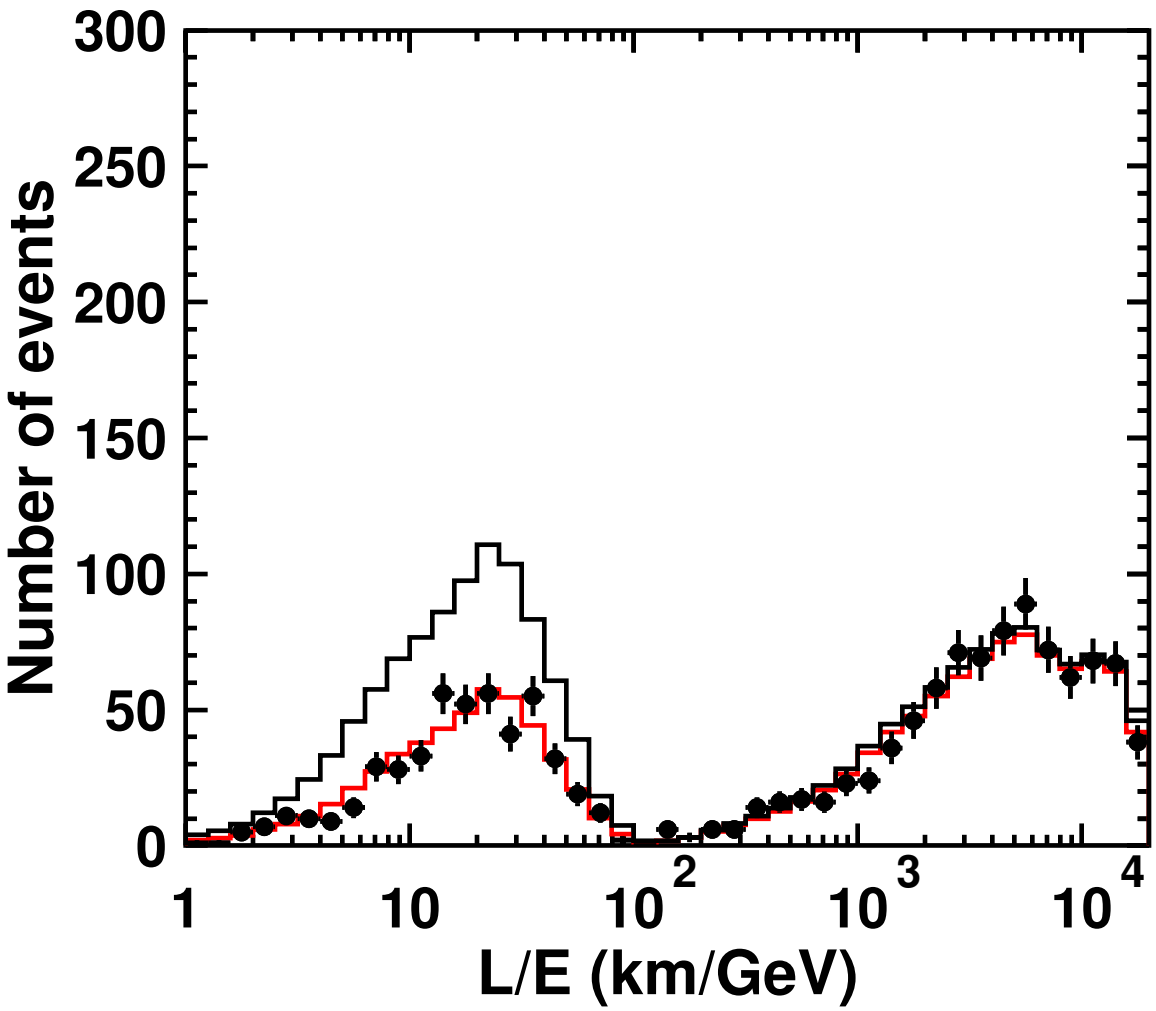

80% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4

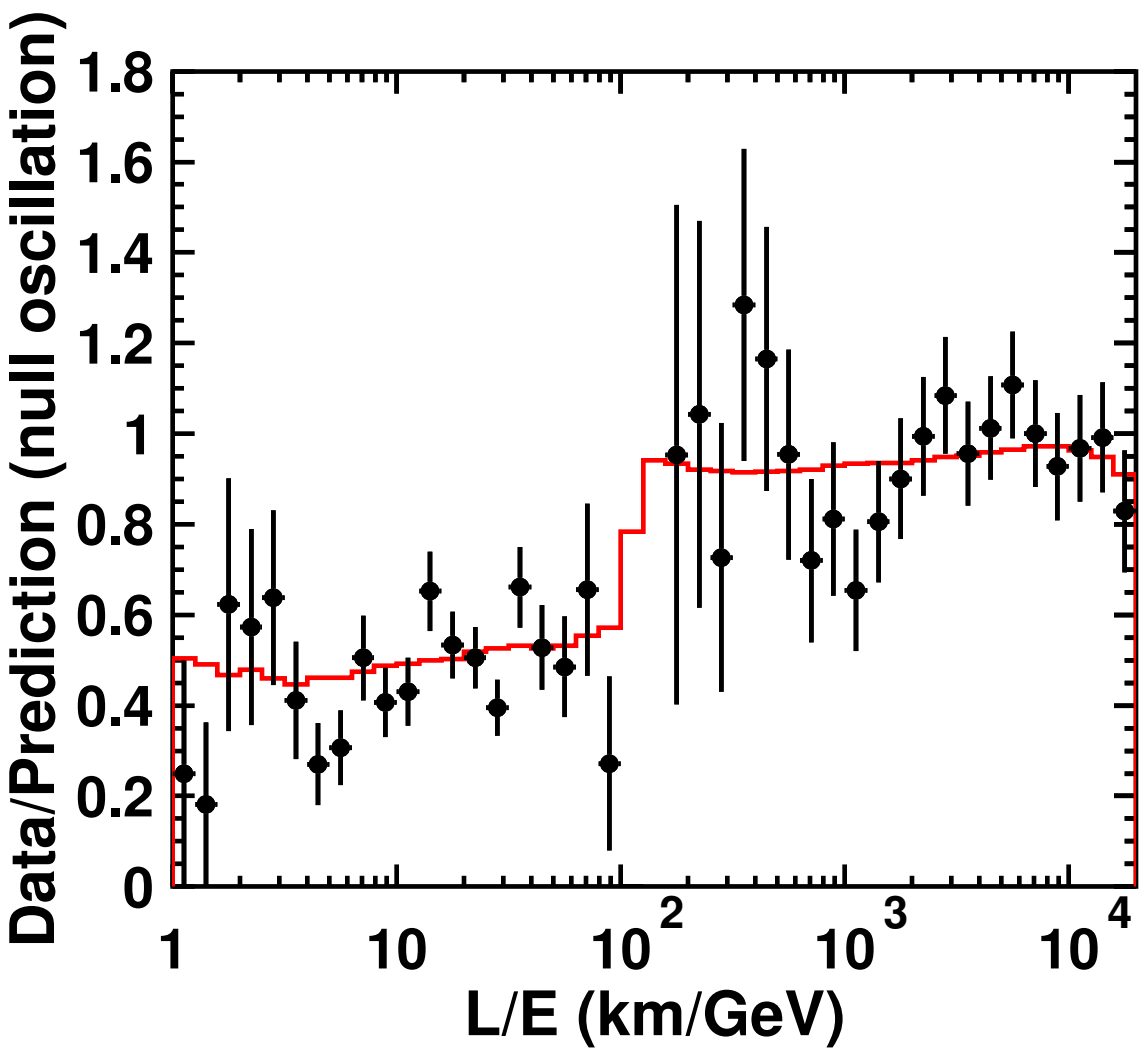

80% cut
Data/Prediction (null oscillation)
L/E (km/GeV)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1
10
10^2
10^3
10^4


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)


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)

List of Systematics for SK2

Sys ID	Sys value	Pull term	Best fit phys	Best fit
1	10.0000	0.0000	-0.0396	-0.0097
2	0.0050	0.0003	-0.0001	-0.0001
3	0.0600	0.0000	0.0004	0.0005
4	0.0100	0.0006	0.0002	-0.0007
5	0.0100	0.0240	0.0015	-0.0014
6	0.1000	0.0010	-0.0032	-0.0040
7	0.0500	0.0373	-0.0097	-0.0096
8	0.0500	0.0264	-0.0081	-0.0088
9	0.1000	0.3529	0.0594	0.0604
10	0.1000	0.0002	0.0014	-0.0007
11	0.0500	0.0968	-0.0156	-0.0152
12	1.0000	0.0196	0.1398	0.1003
13	0.2000	0.0008	-0.0057	0.0030
14	0.0020	0.0002	0.0000	0.0000
15	0.0480	0.1307	-0.0174	-0.0175
16	0.1000	0.0053	-0.0073	-0.0071
17	0.0100	0.0007	-0.0003	-0.0003
18	0.1000	0.0212	0.0146	0.0145
19	0.0170	0.0003	-0.0003	-0.0009
20	0.0060	0.0142	0.0007	0.0005
21	0.3000	0.0746	0.0819	0.0830
22	0.0100	0.0000	0.0000	0.0000
23	0.1900	0.0001	-0.0022	-0.0023
24	0.2000	0.1137	-0.0674	-0.0660
25	0.2000	0.8280	0.1820	0.1815
26	0.5000	0.0368	-0.0959	-0.1146
27	0.4000	0.0277	-0.0665	-0.0606
28	0.1800	0.0145	-0.0217	-0.0210
29	0.1400	0.0002	0.0021	0.0005

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

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

  Best Fit:

  χ^2_{min} = 36.7 / 40 d.o.f

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

  (including unphysical region)

  χ^2_{min} = 35.4 / 40 d.o.f

  at ($\sin^2 2\theta$, Δm^2) = (1.07 , 2.2E-03 eV^2)

  90% confidence level allowed region:

  $\sin^2(2\theta) > 0.9$

  $1.56\text{'}\times 10^{-3}\ eV^2 < \Delta m^2 < \text{'}2.94\text{'}\times 10^{-3}\ eV^2$,

- **Assuming Neutrino Decay**

  χ^2_{min} = 45.3 / 40 d.o.f

  $\Delta\chi^2$ = 8.6 / 40 d.o.f (2.9 standard deviations)

- **Assuming Neutrino Decoherence**

  χ^2_{min} = 49.2 / 40 d.o.f

  $\Delta\chi^2$ = 12.5 / 40 d.o.f (3.5 standard deviations)