大気ニュートリノフラックスの精密計算

2009年12月18日、本田守広
@ICRR共同利用研究成果発表研究会

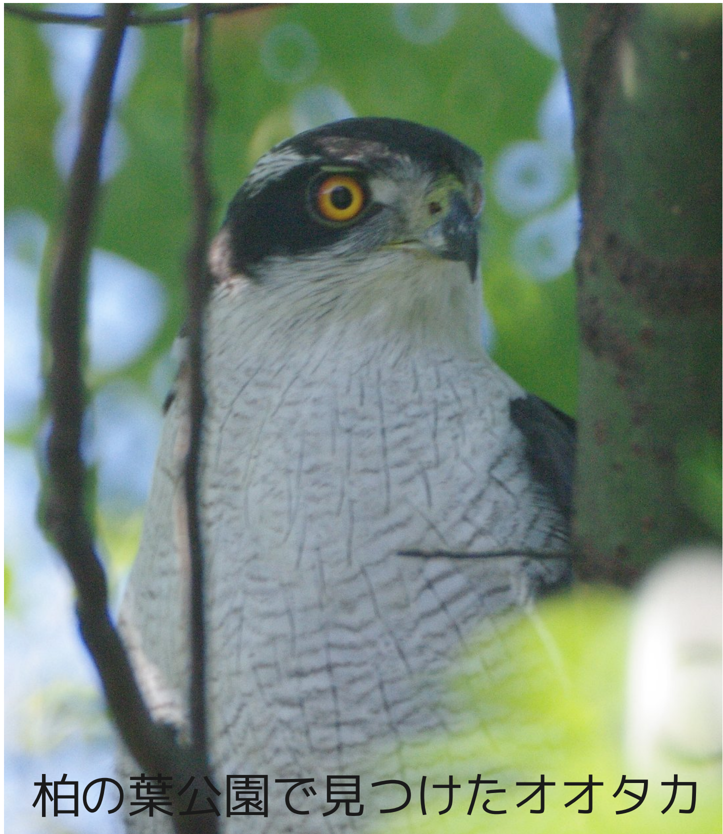
この一年の進展、

衛星軌道データを使ったcalibration (Not fully yet)

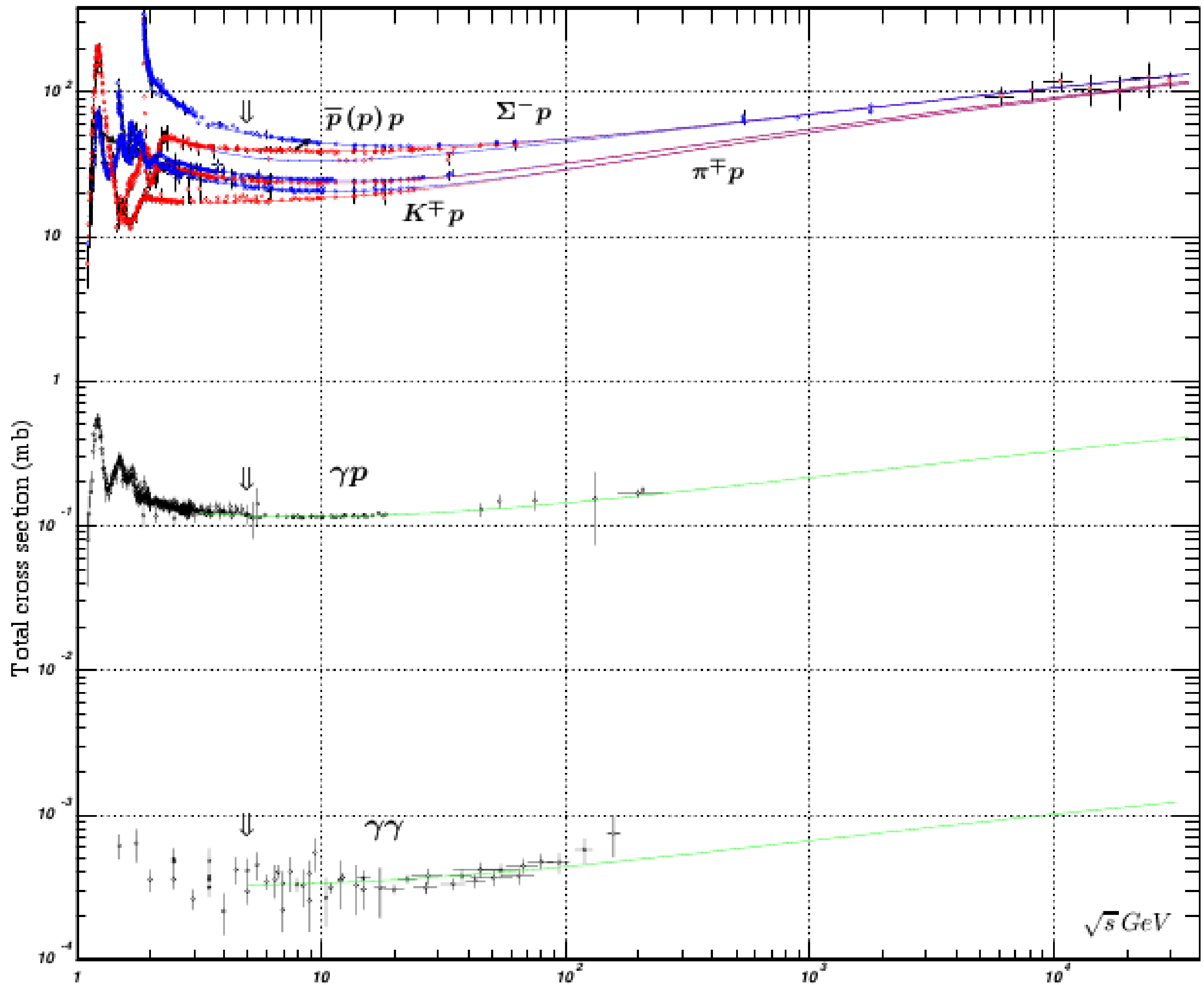
•Simulation のチューンアップ、
$\gamma + N \rightarrow \pi's$ の影響の見積り
誤差の見積りの再検討
3次元計算から1次元計算へ切り替えのエネルギーの再検討
目標：統計など、物理以外のエラーを ～3%に抑える。

•大気ニュートリノフラックスの計算（～70%完了）

査定金額：旅費４万円、
年度内に全額執行予定

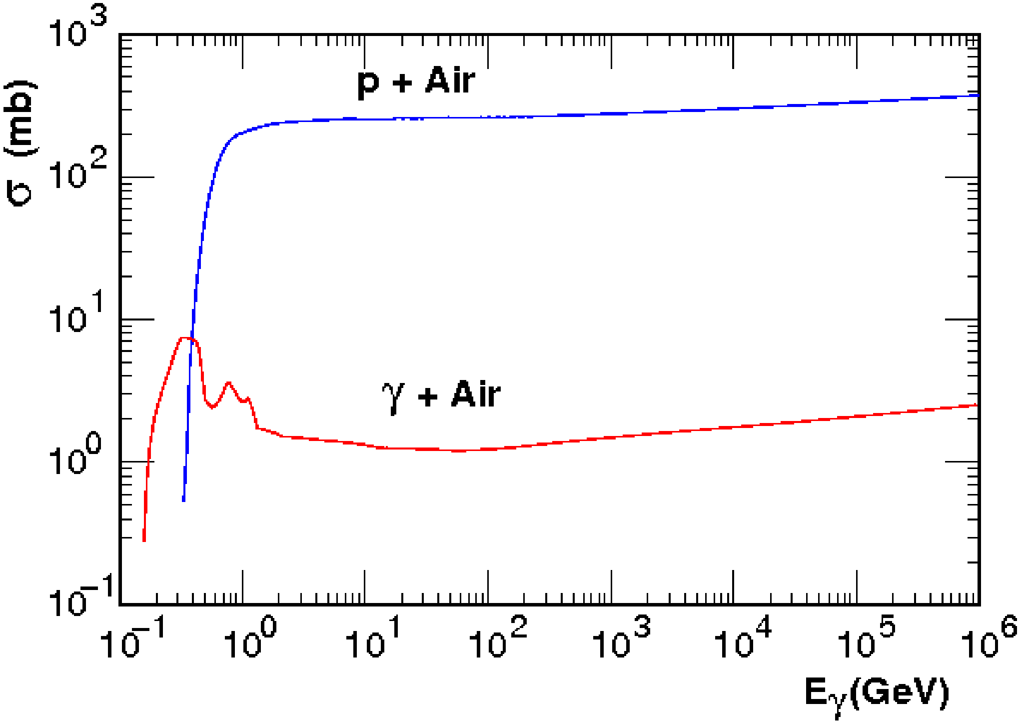

柏の葉公園で見つけたオオタカ

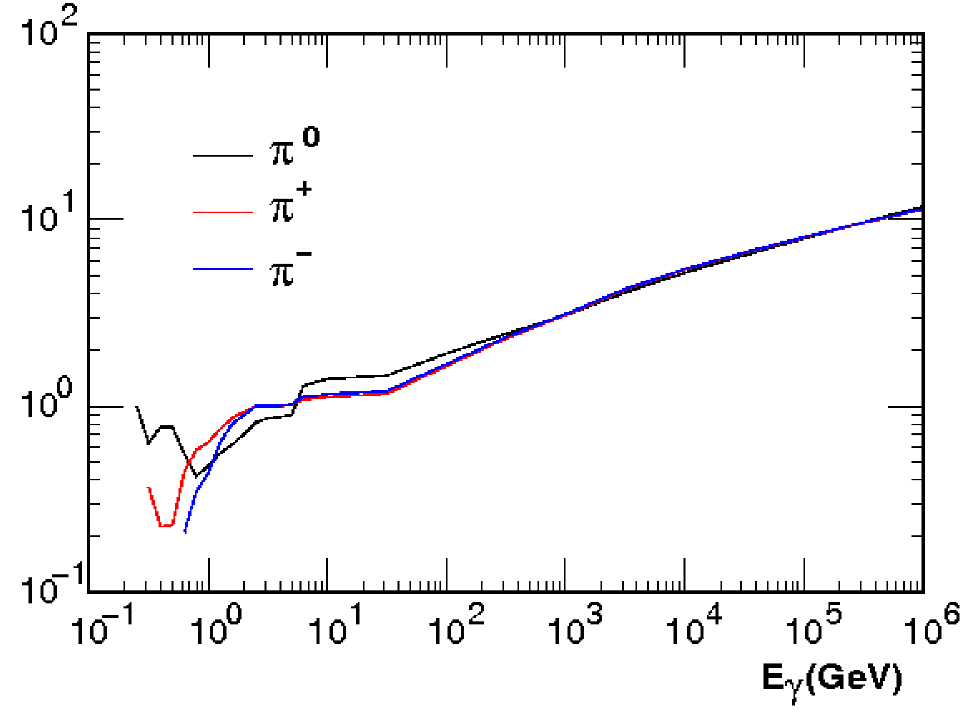
Estimation of the effect of gamma nucleus interaction



Small cross section but a large effect in AS.

The cross sections and the multiplicity

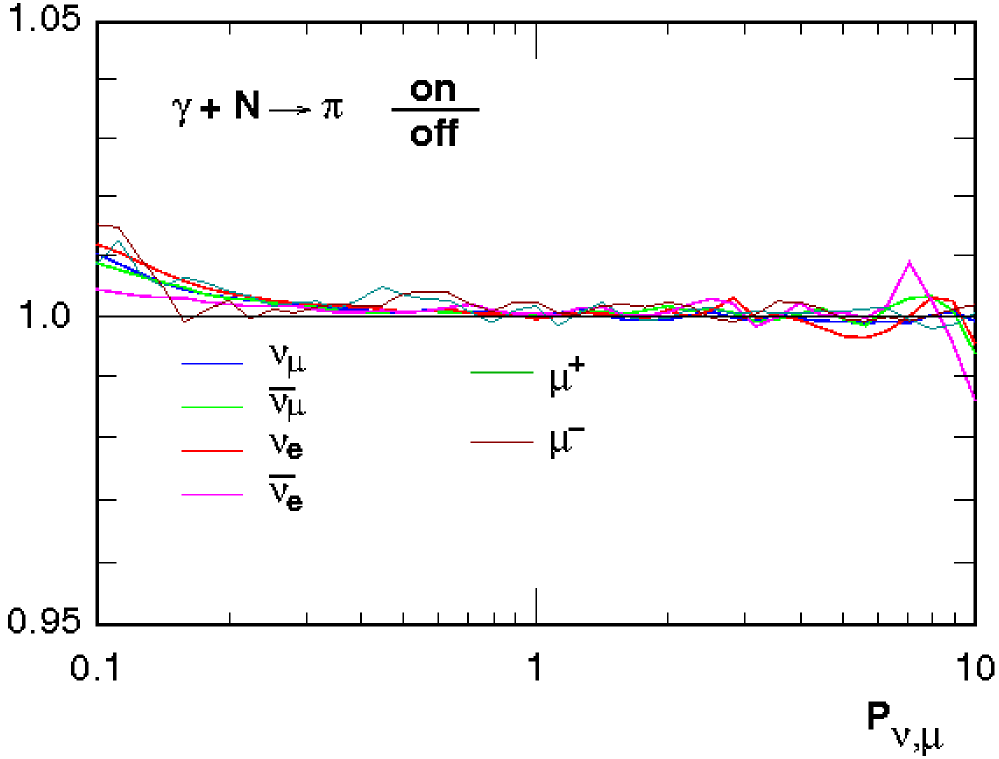




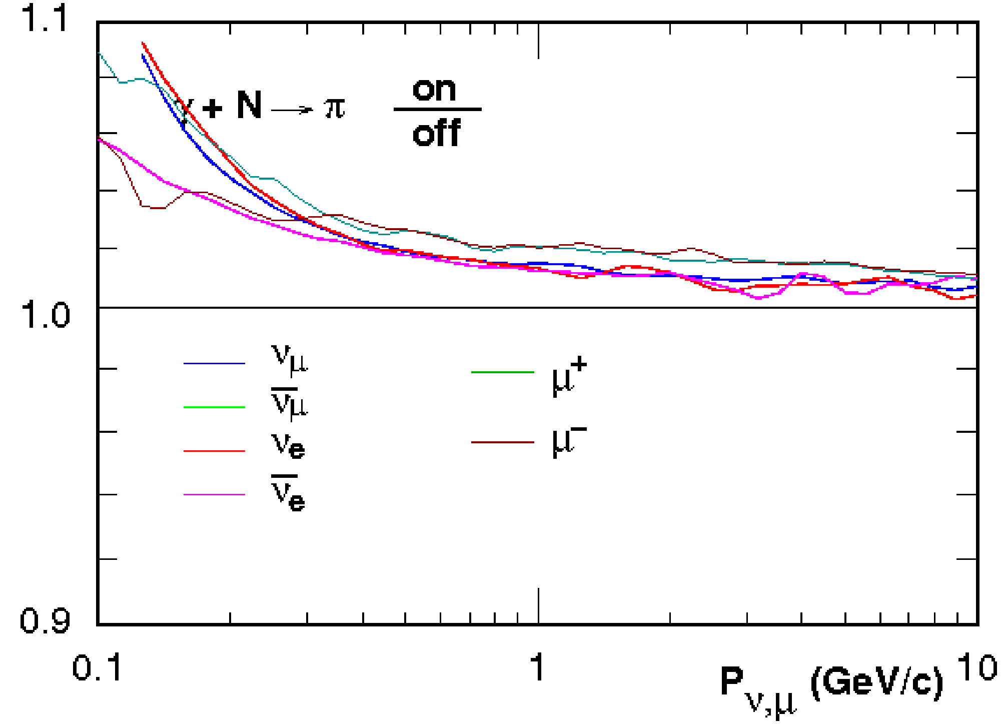
(Those are the same as Kasahara's COSMOS)

Calculation of neutrino and muon fluxes at Tsukuba

With all CR energies (>0.3GeV)



Limiting primary CR energy > 1TeV

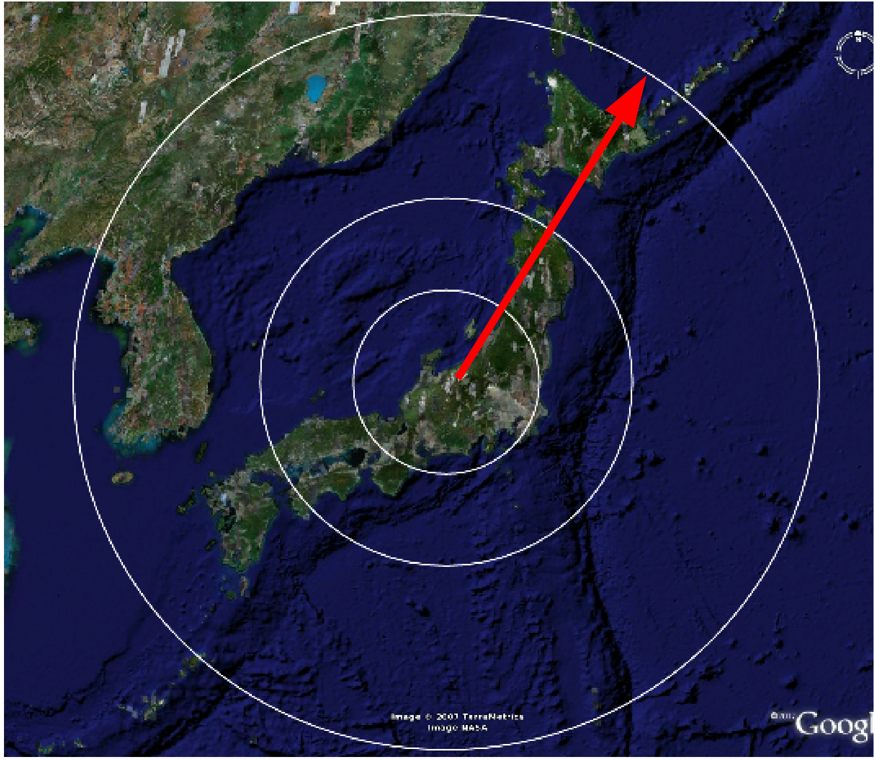


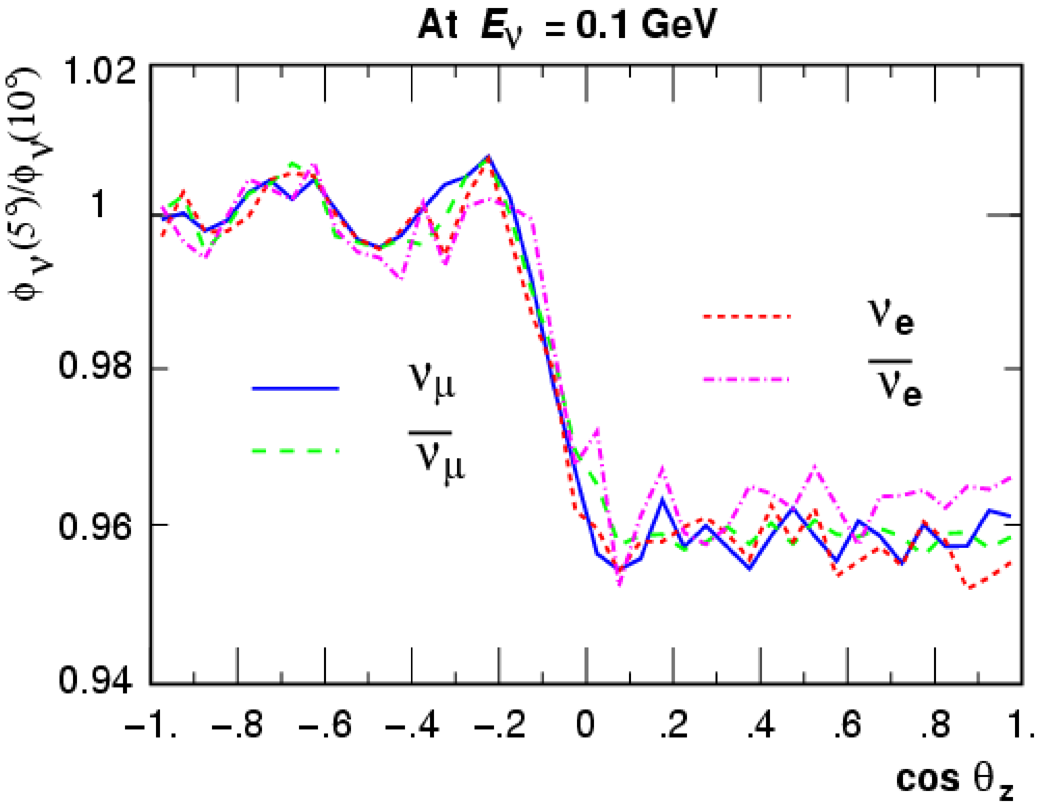
For time averaged neutrino and muon fluxes,
$\gamma + N \rightarrow \pi\,' s$ may safely be ignored

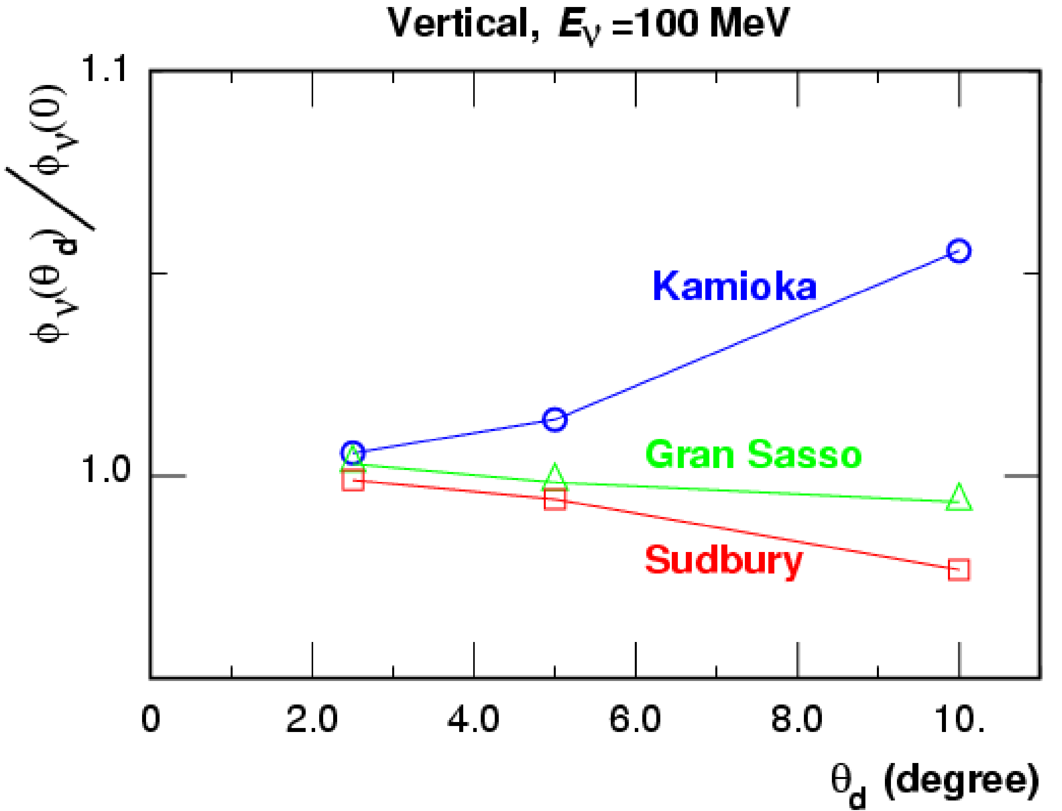
Error due to the radius of Virtual Detector

In HKKM06

$$\phi_\nu(0) \simeq -\frac{1}{3}\phi_\nu(10) + \frac{4}{3}\phi_\nu(5)$$





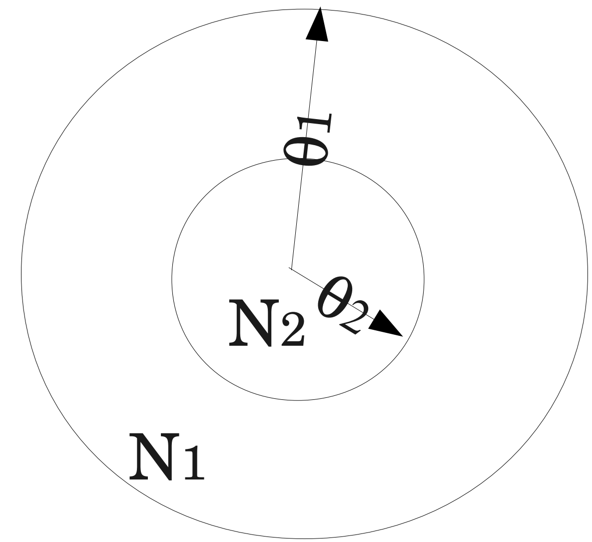


Optimization of size correction for virtual detector

Assume true flux value and average in the circle with radius θ1 and θ2 may be related as

$$\phi_1 = \phi_0 + \phi' \theta_1^2$$

$$\phi_2 = \phi_0 + \phi' \theta_2^2$$



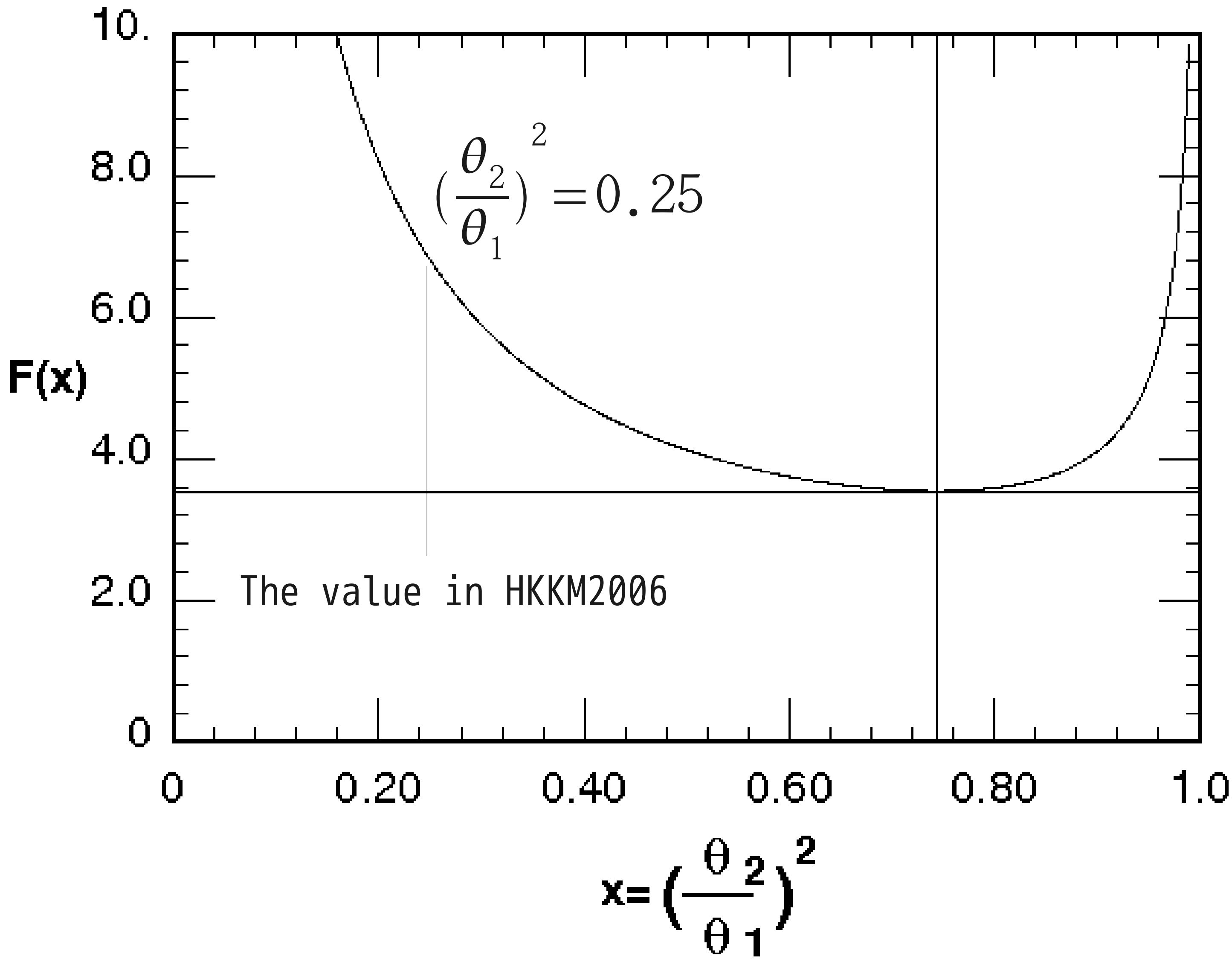
Therefore the true value is calculated from ϕ1 and ϕ2 as;

$$\phi_0 = \frac{\theta_1^2 \phi_2 - \theta_2^2 \phi_1}{\theta_1^2 - \theta_2^2} = \frac{\phi_2 - r^2 \phi_1}{1 - r^2} \qquad r = \left(\frac{\theta_2}{\theta_1}\right)^2, \ r < 1$$

In terms of the sampled number $N1$ in the circle θ < θ1, and $N2$ in θ < θ2, ϕ1 and ϕ2 are given as

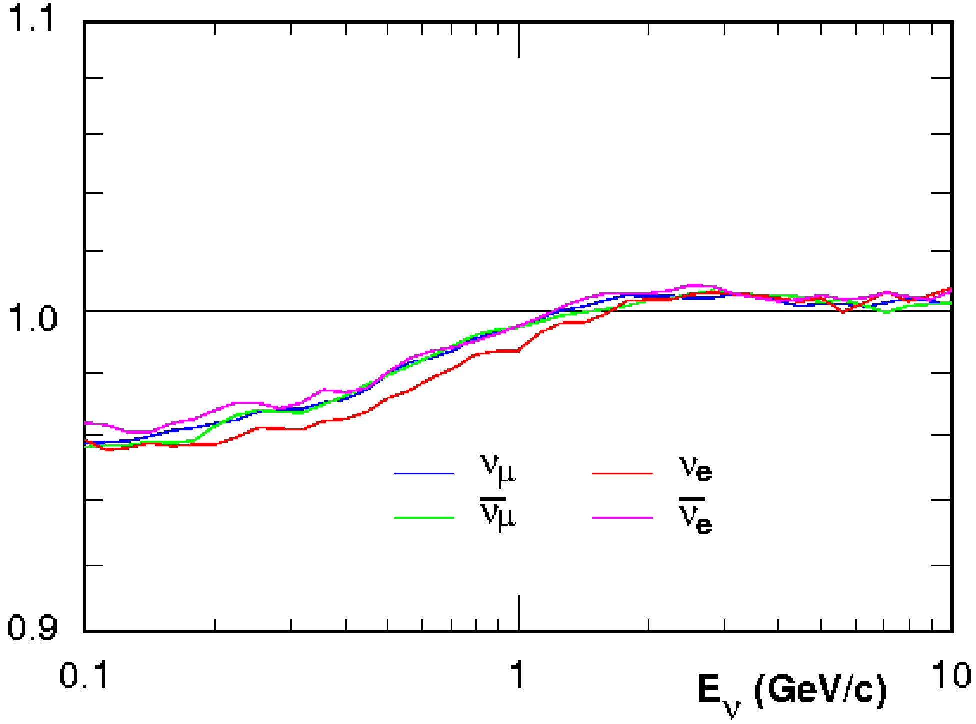
$$\phi_1 = \frac{N_1}{T \pi \theta_1^2}, \quad \phi_2 = \frac{N_2}{T \pi \theta_2^2}$$

$$\frac{\Delta\phi_0}{\phi_0} \approx F\left(\left(\frac{\theta_2}{\theta_1}\right)^2\right)\frac{1}{\sqrt{N_1}}$$

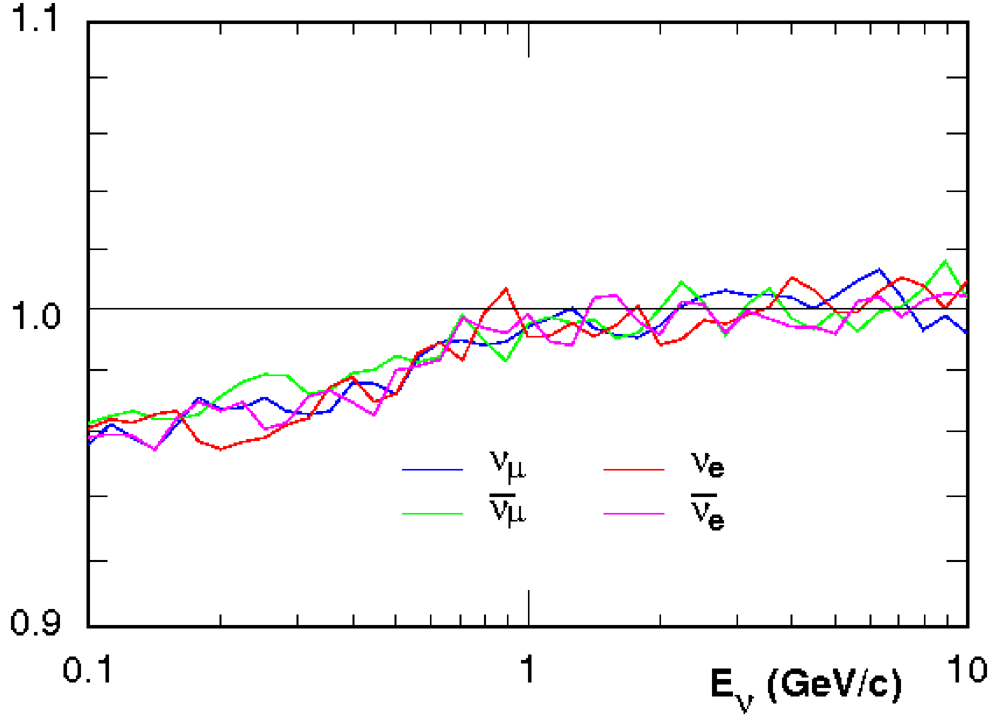


It has the minimum at r^2=0.7432676(r=0.8621297) and the ratio is 3.5428232097

After / Before the correction



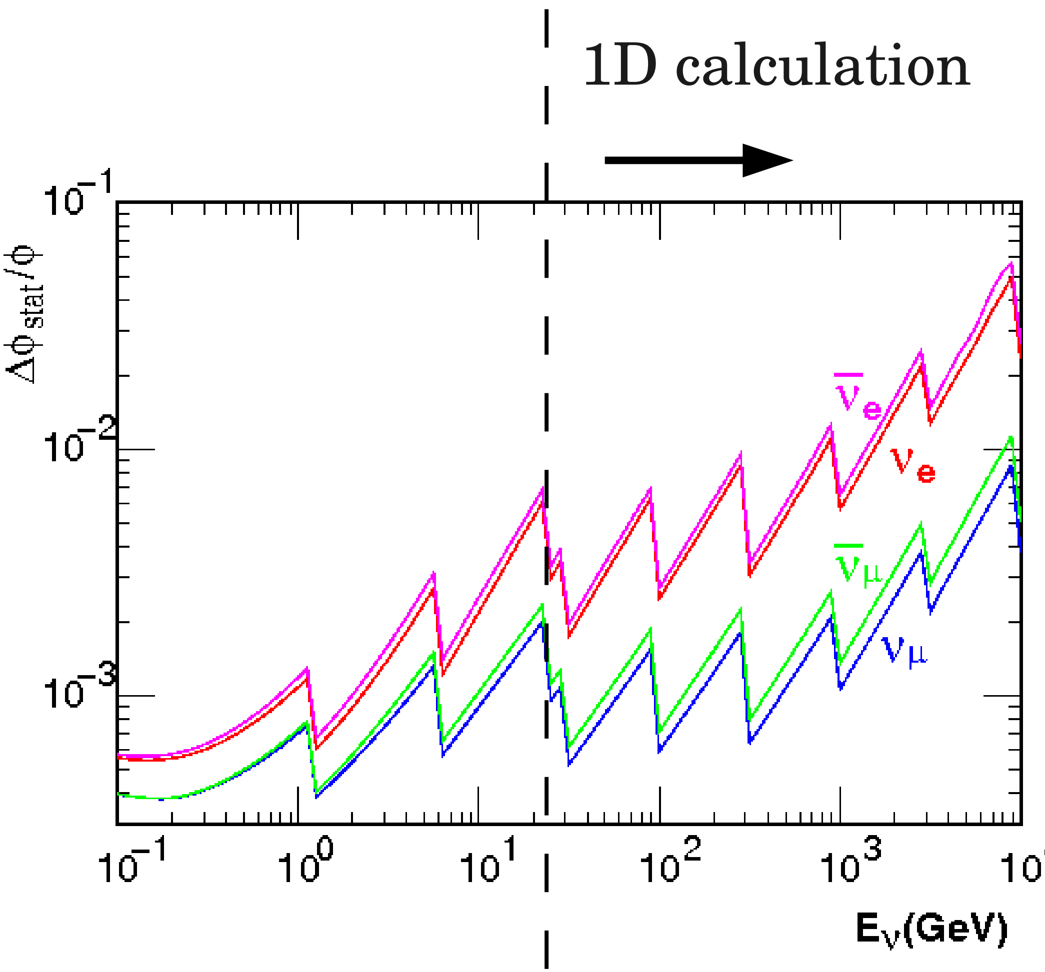
$0.95 < \cos\theta < 1.0$



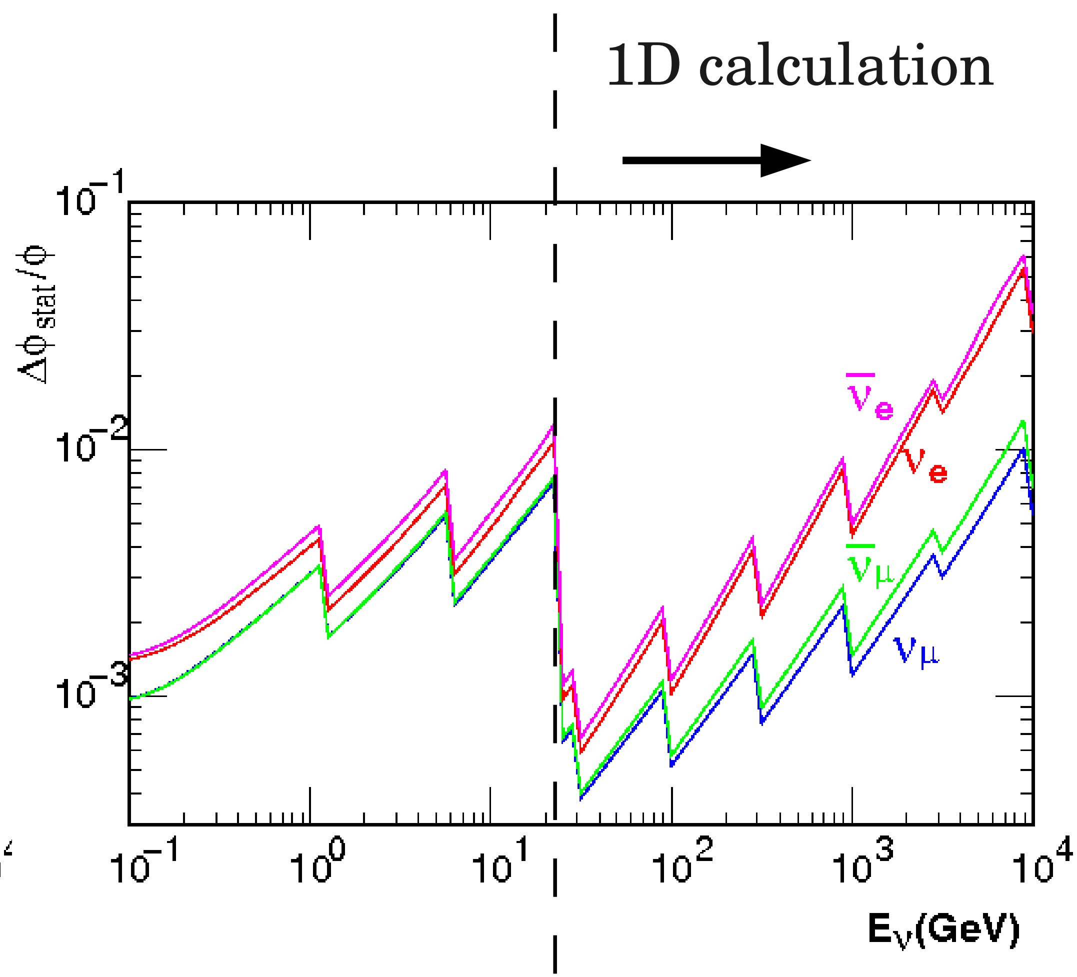
$0.0 < \cos\theta < 0.05$

At most ~4% of the corrections

Statistical Error (HKKM06)



$0.9 < \cos\theta < 1.0$

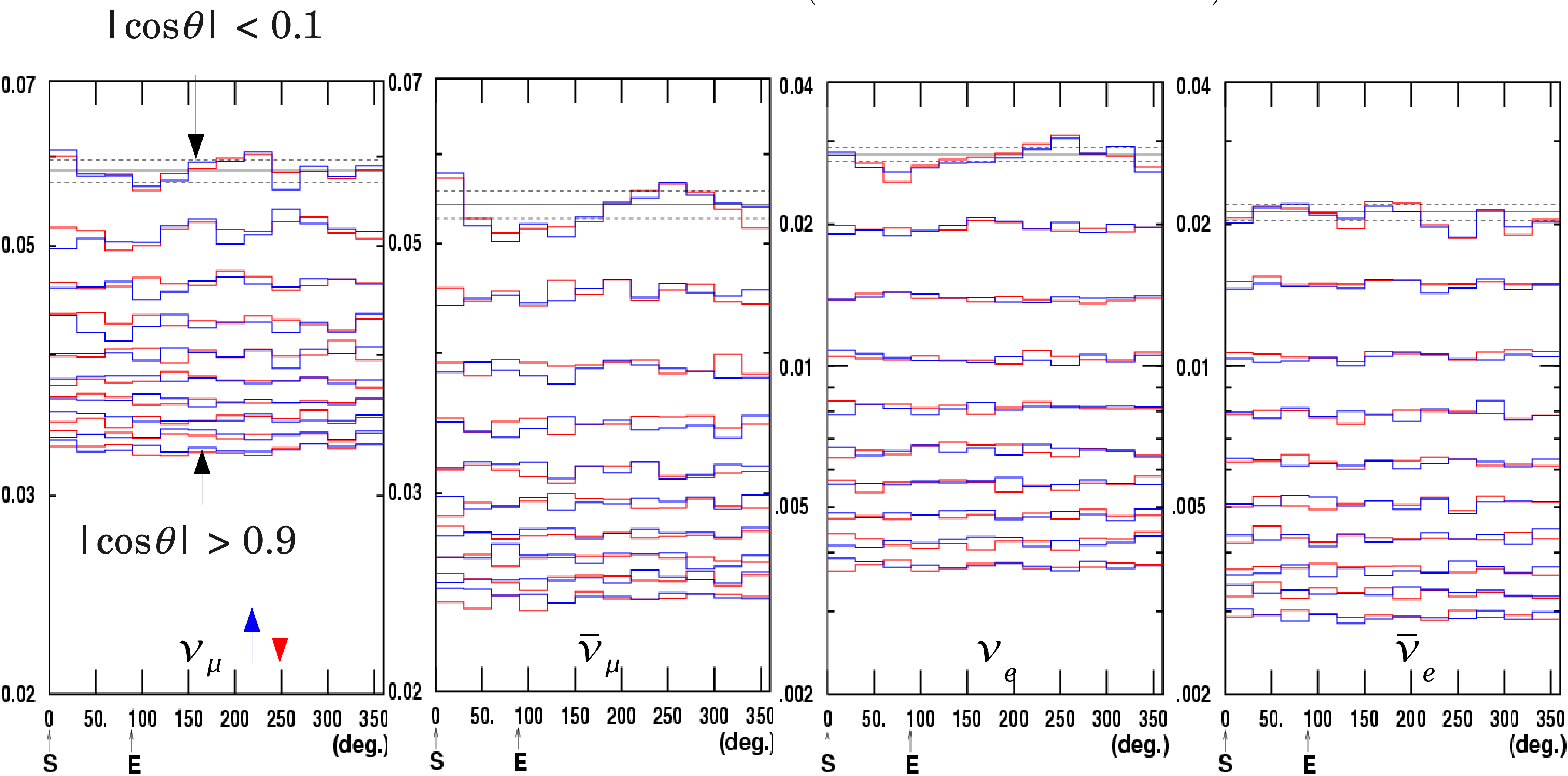


$0.0 < \cos\theta < 0.1$

Averaged over all azimuth directions.

Azimuth variation of ν flux at the switching energy
from 1D to 3D calculation. (HKKM06)

ν -flux at 20 GeV $(m^{-2}s^{-1}sr^{-1}GeV^{-1})$



Problem: Azimuth Variation of Atmospheric Neutrino

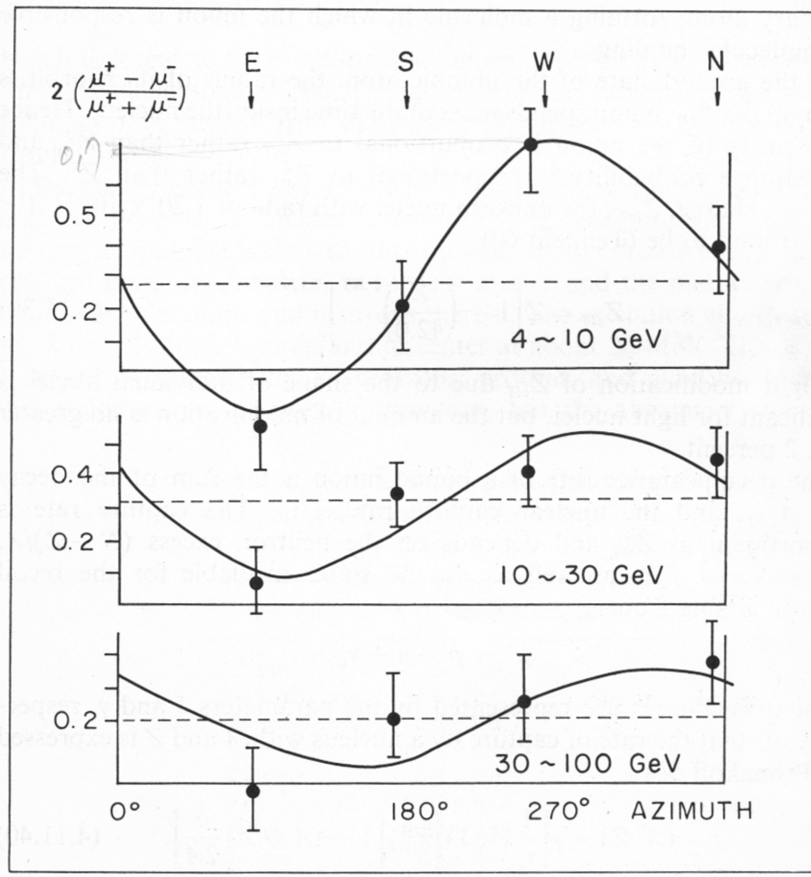
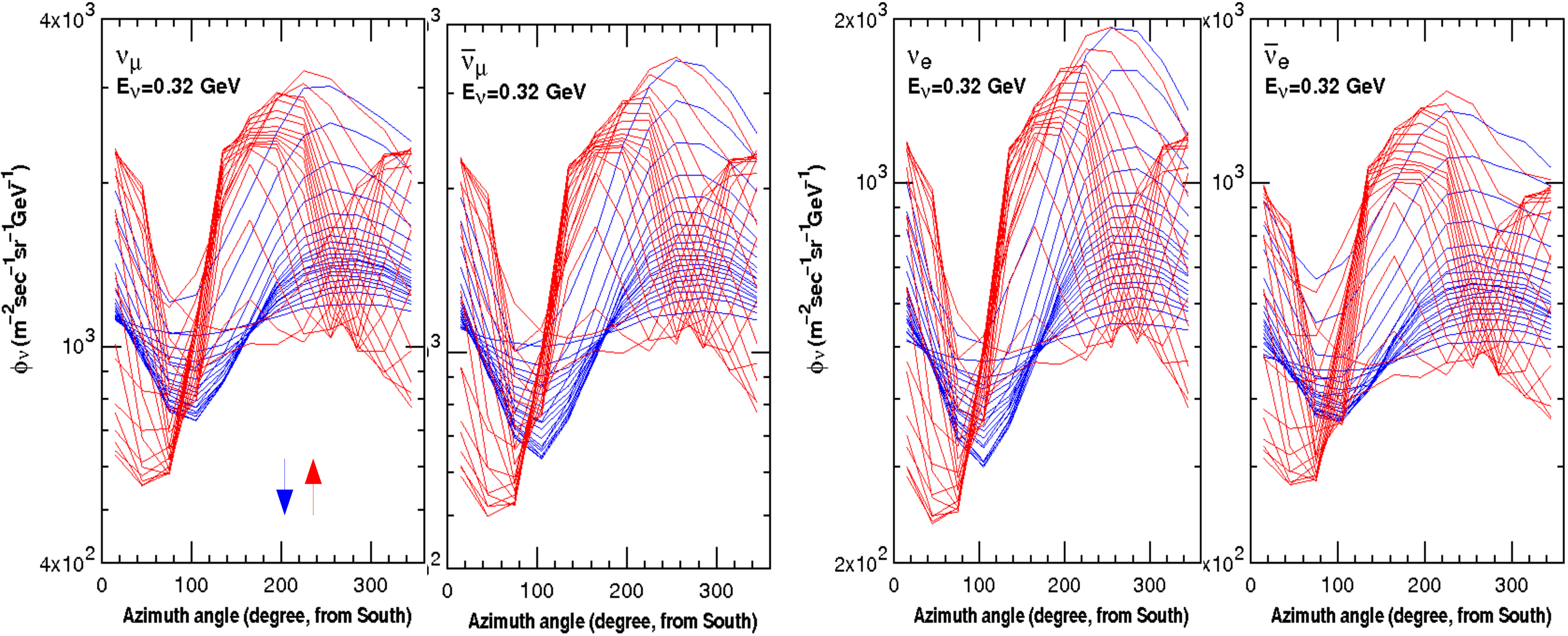


Fig. 4.27 Azimuth dependence of the positive excess of muons at zenith angle 78° at sea level. The energy intervals of sea-level muons are indicated (Kamiya 62).

Azimuth variation of muon

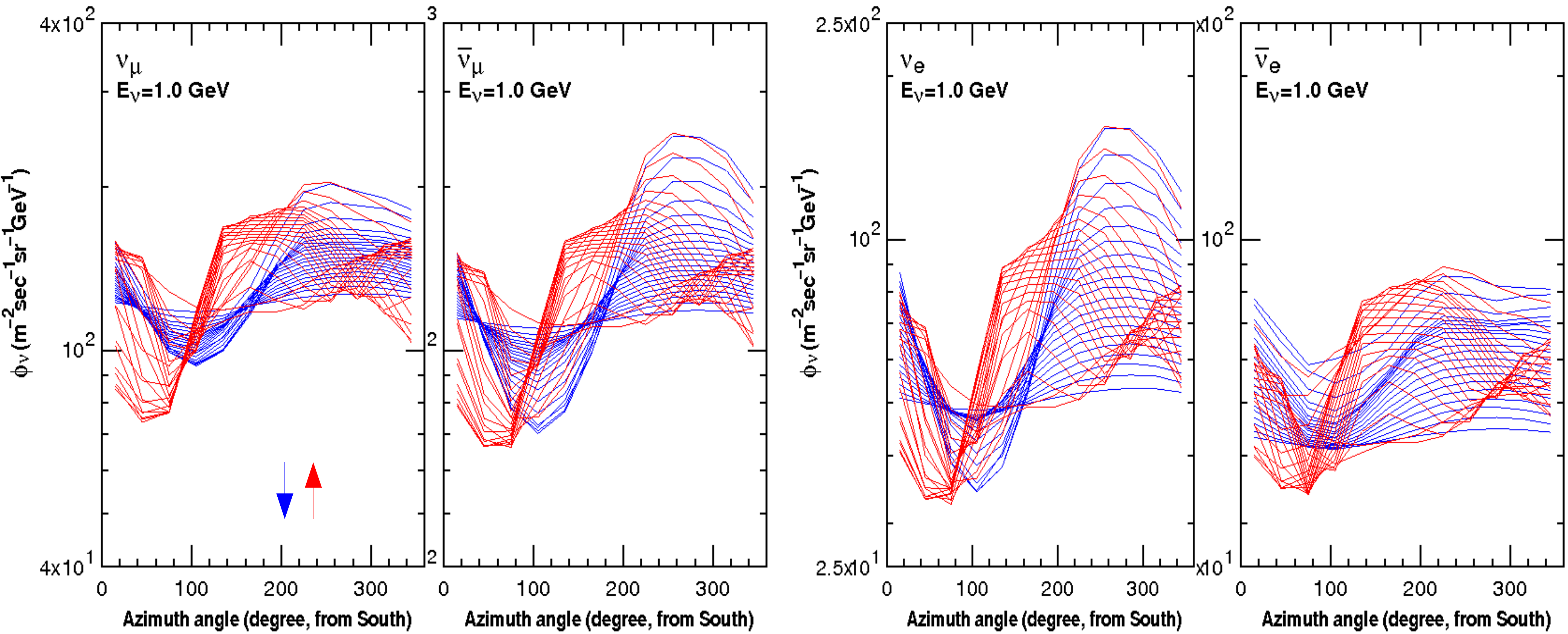
Azimuth variation of neutrino

$E\nu$=0.32 GeV



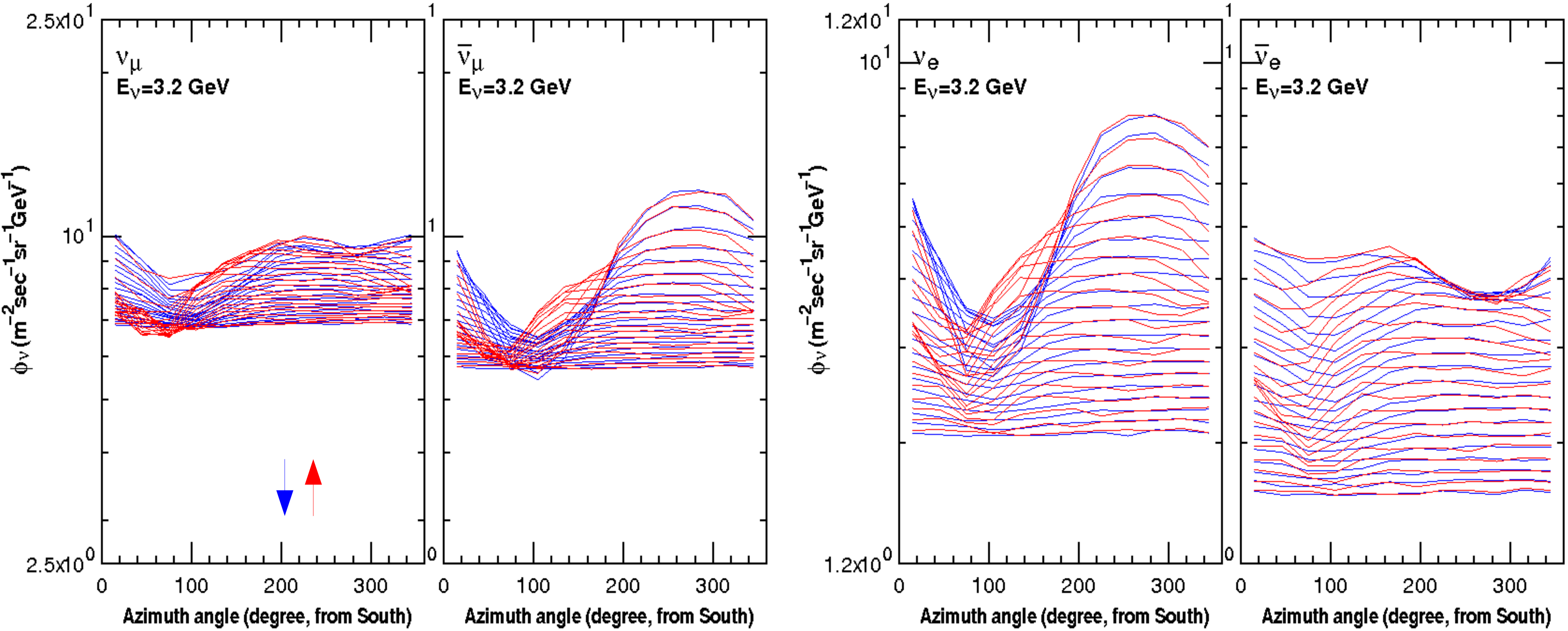
ν_μ $\bar{\nu}_\mu$ ν_e $\bar{\nu}_e$

$E\nu$=1.0 GeV



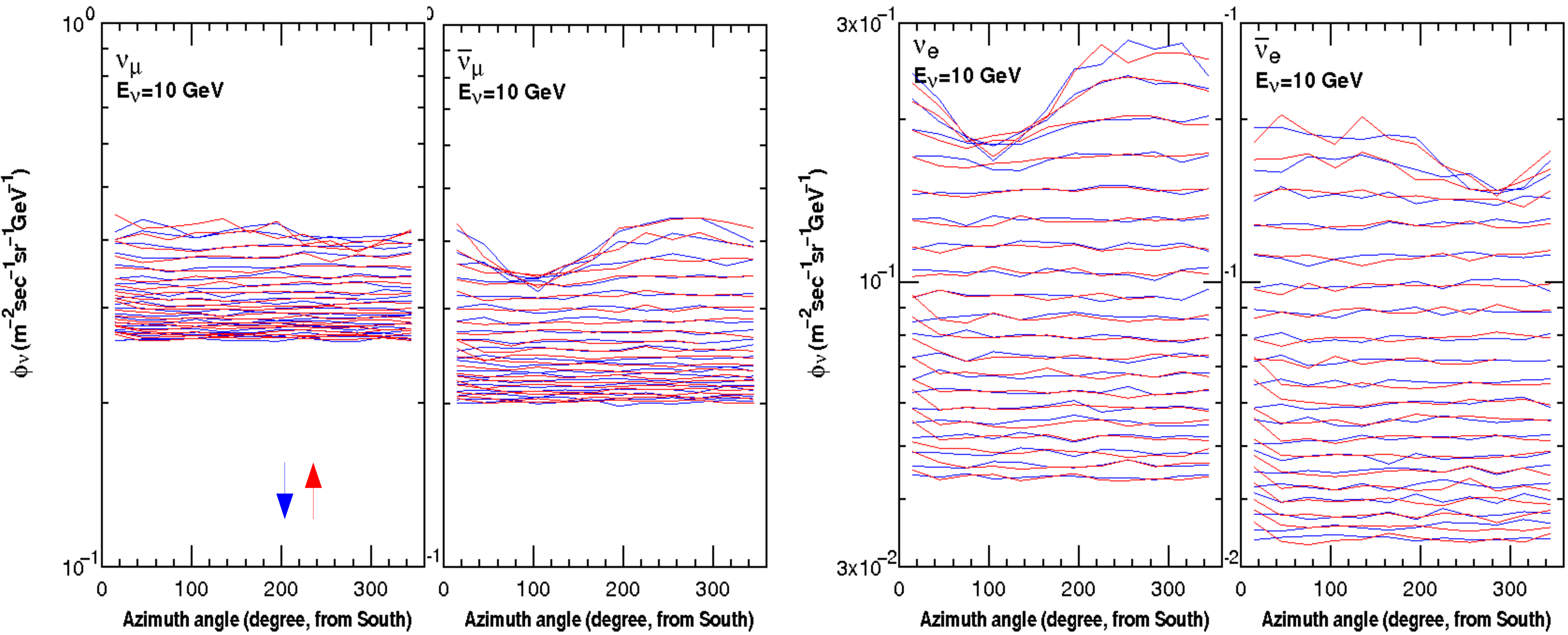
$\nu\mu$ $\bar{\nu}\mu$ νe $\bar{\nu}e$

Eν=3.2 GeV



ν_μ $\bar{\nu}_\mu$ ν_e $\bar{\nu}_e$

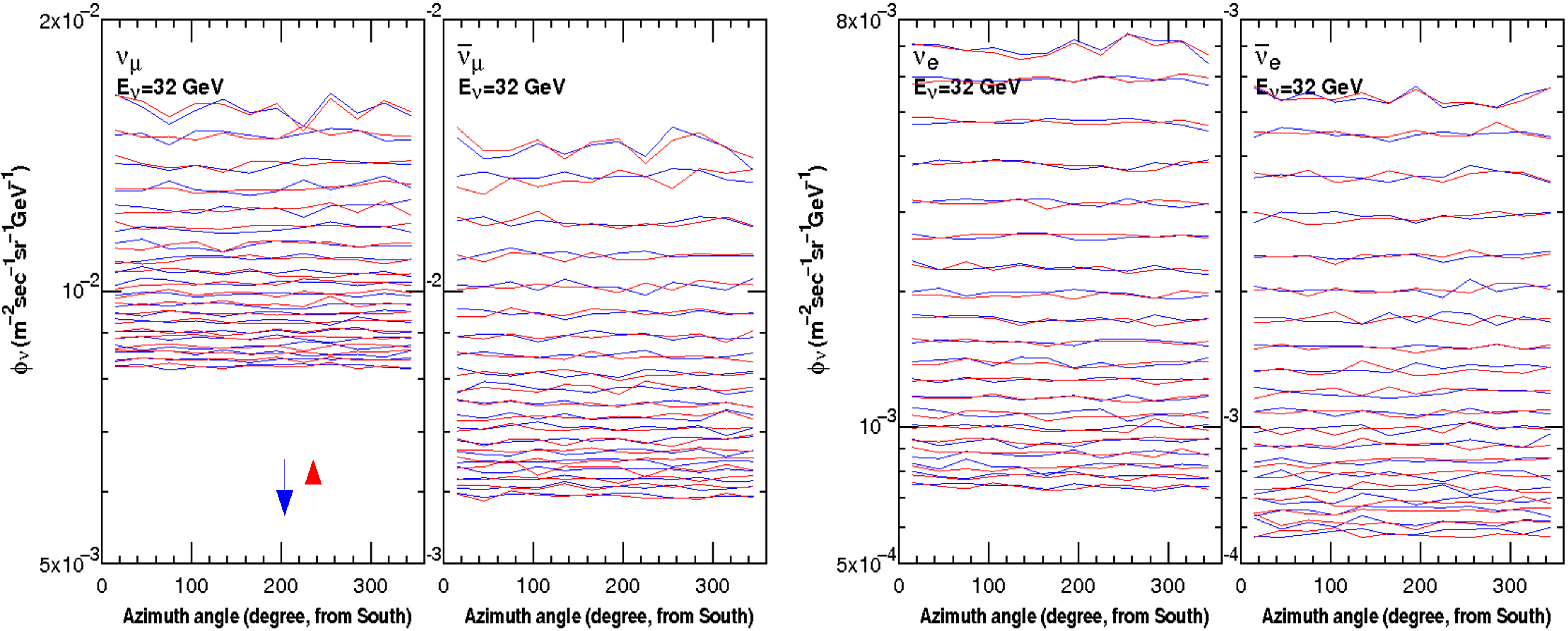
$E\nu$=10 GeV



ν_μ $\bar{\nu}_\mu$ ν_e $\bar{\nu}_e$

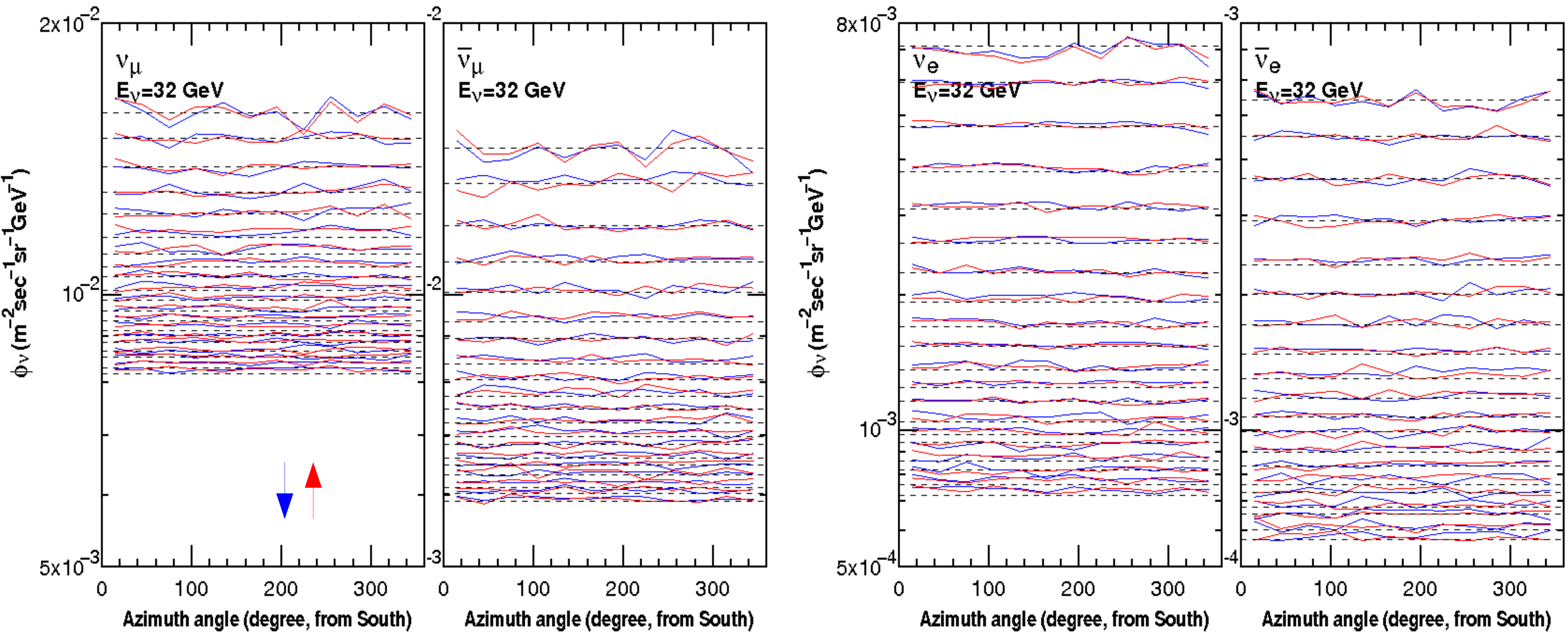
In the HKKM04, 1-dim calculation was used above 10 GeV
(This was known, but computer power is limited.)

Eν=32 GeV



ν_μ $\bar{\nu}_\mu$ ν_e $\bar{\nu}_e$

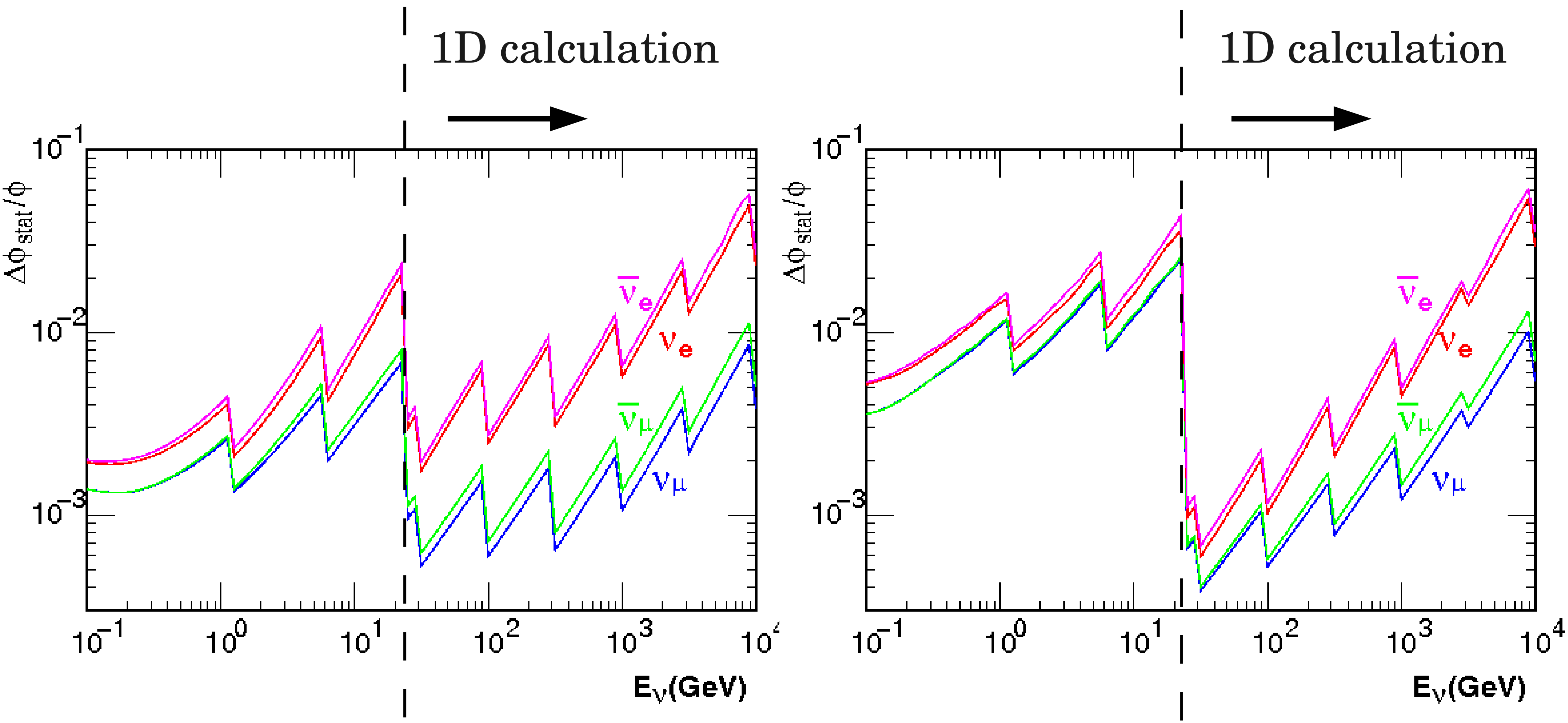
Eν=32 GeV



ν_μ $\bar{\nu}_\mu$ ν_e $\bar{\nu}_e$

Above this energy, the 1-dimensional calculation may be good

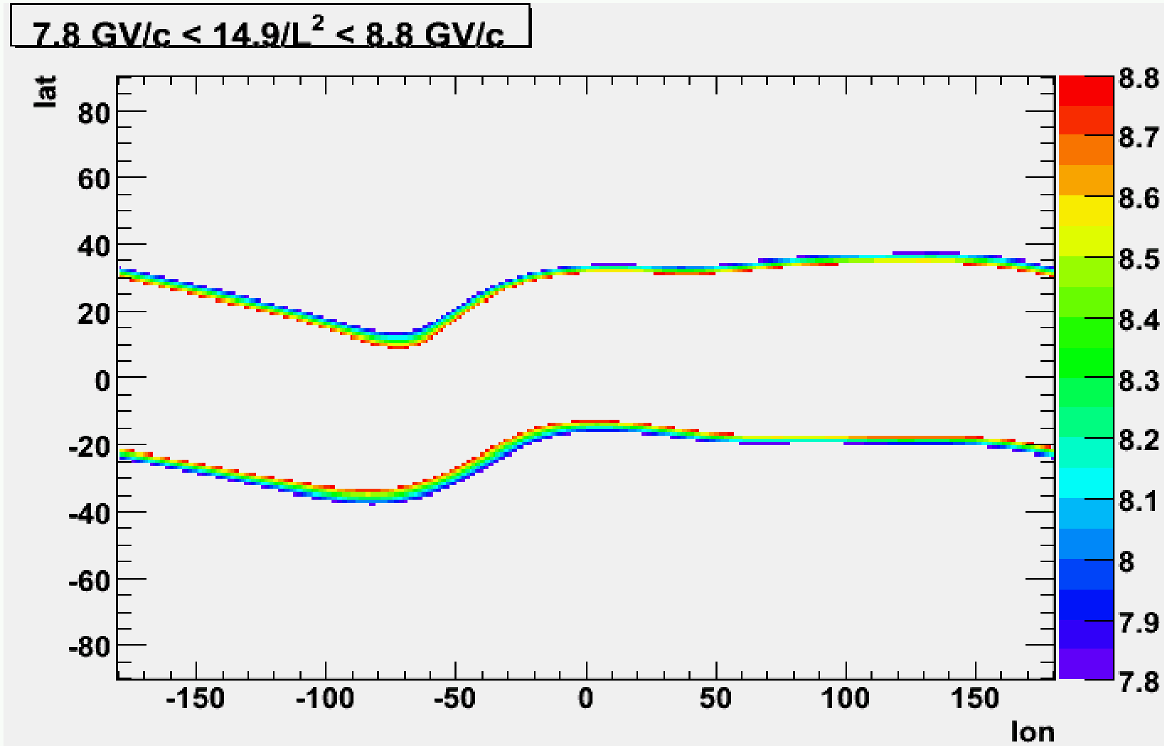
Statistical Error (HKKM06)



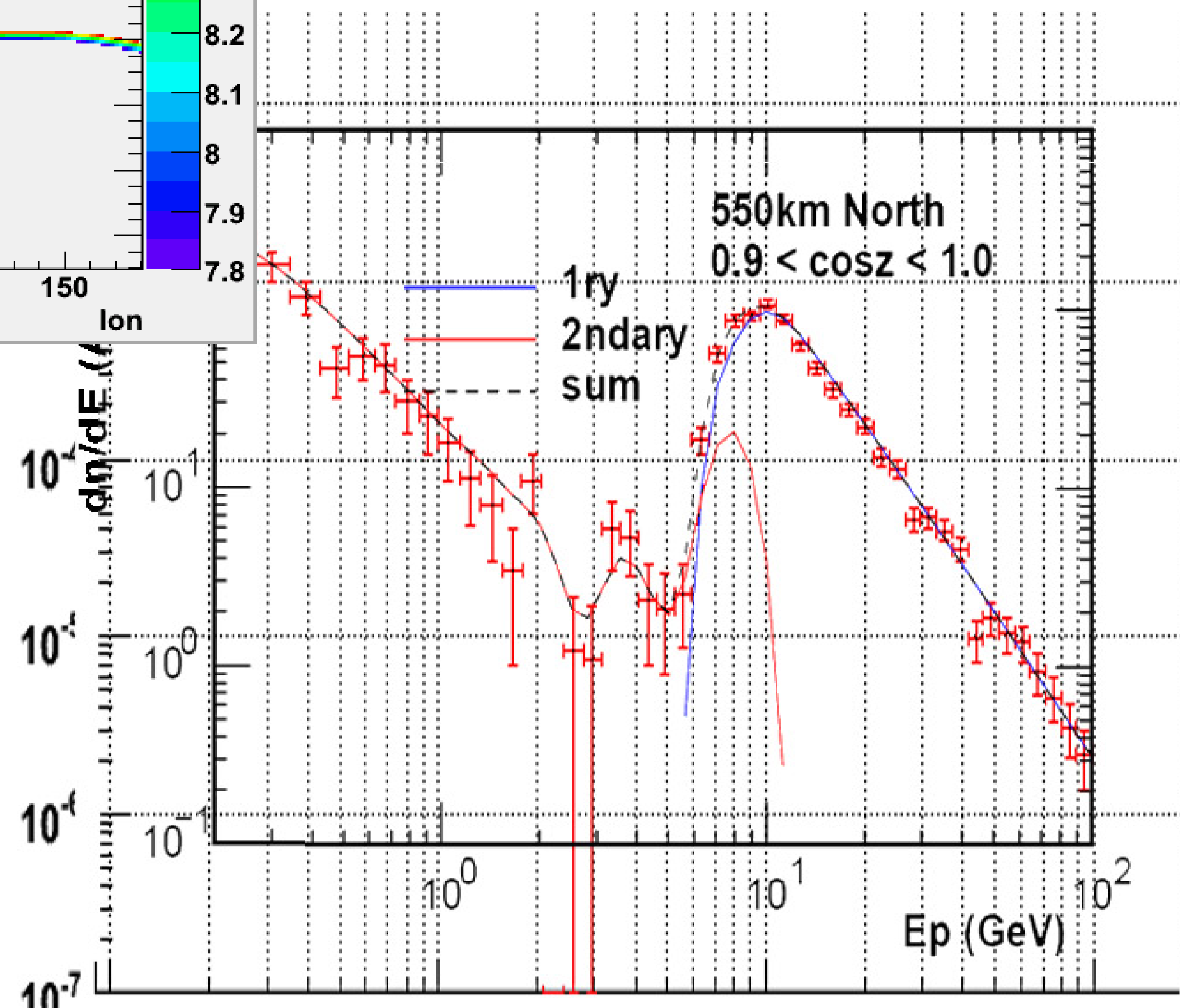
$0.9 < \cos\theta < 1.0$ $\qquad$ $0.0 < \cos\theta < 0.1$

For each azimuth direction.

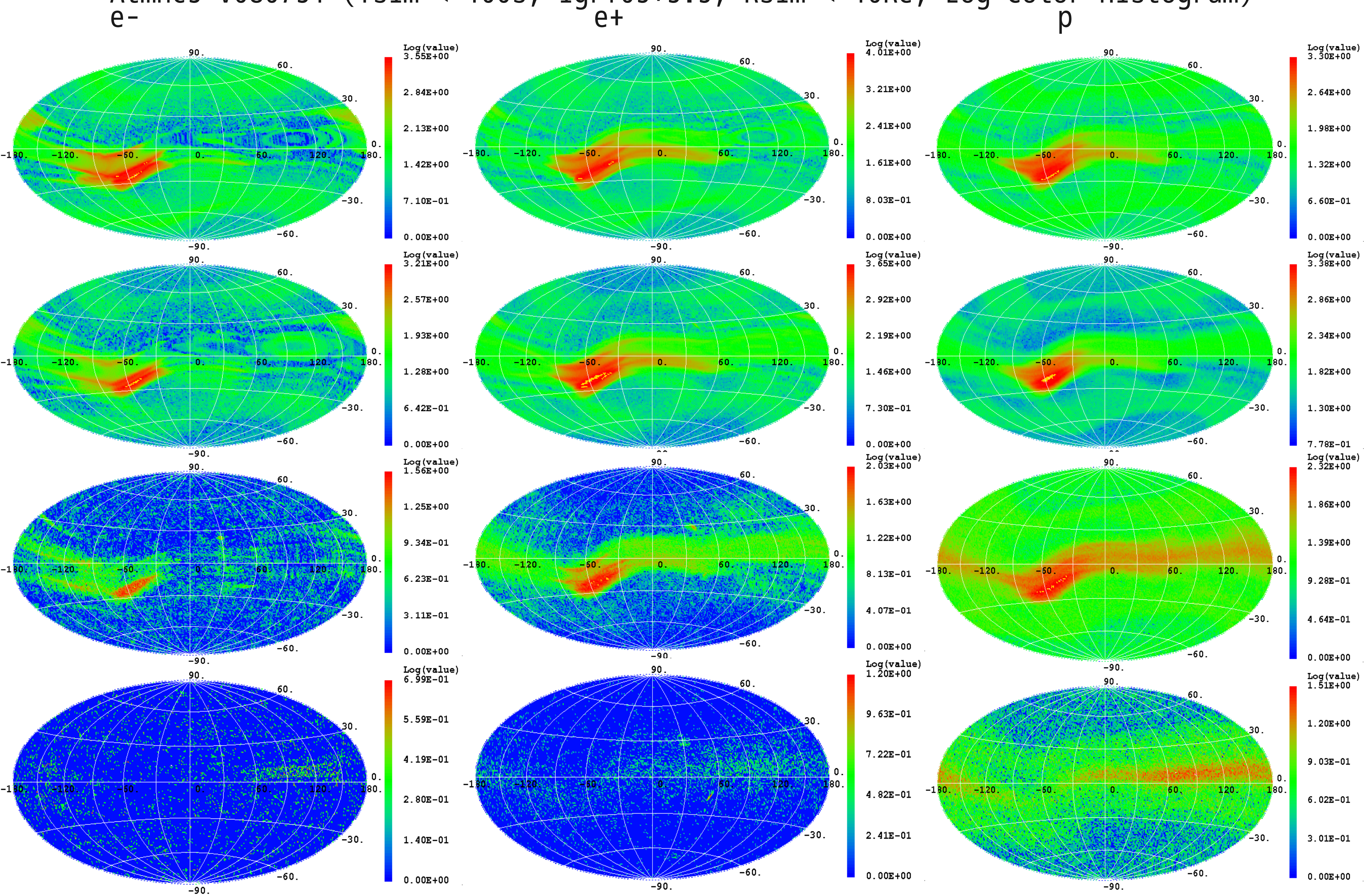
Comparison of Albedo Particle with Pamela



Compared region

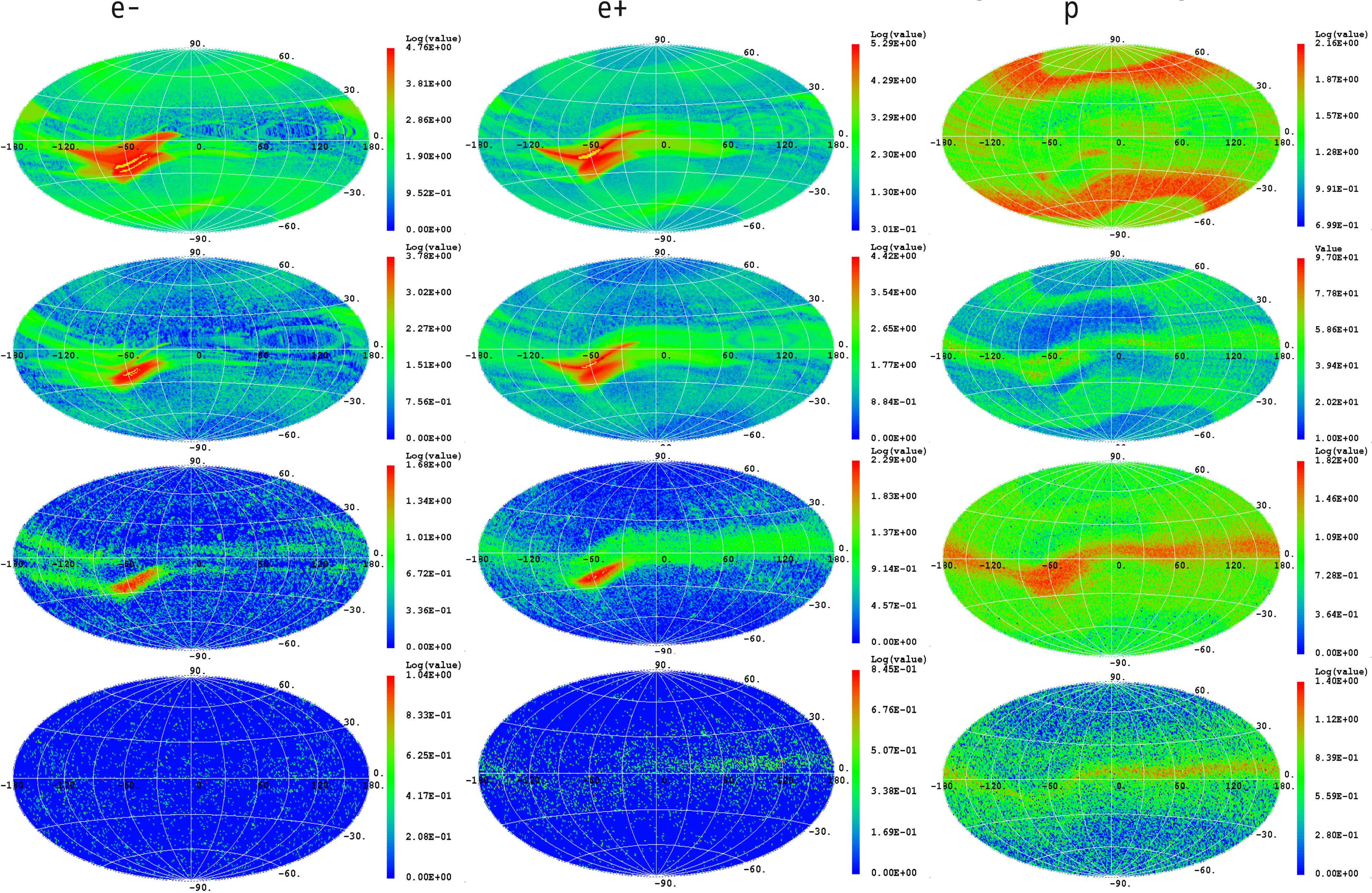


Atmnc3 v080731 (Tsim < 100s, igrf05+3.5, Rsim < 10Re, Log Color Histogram)



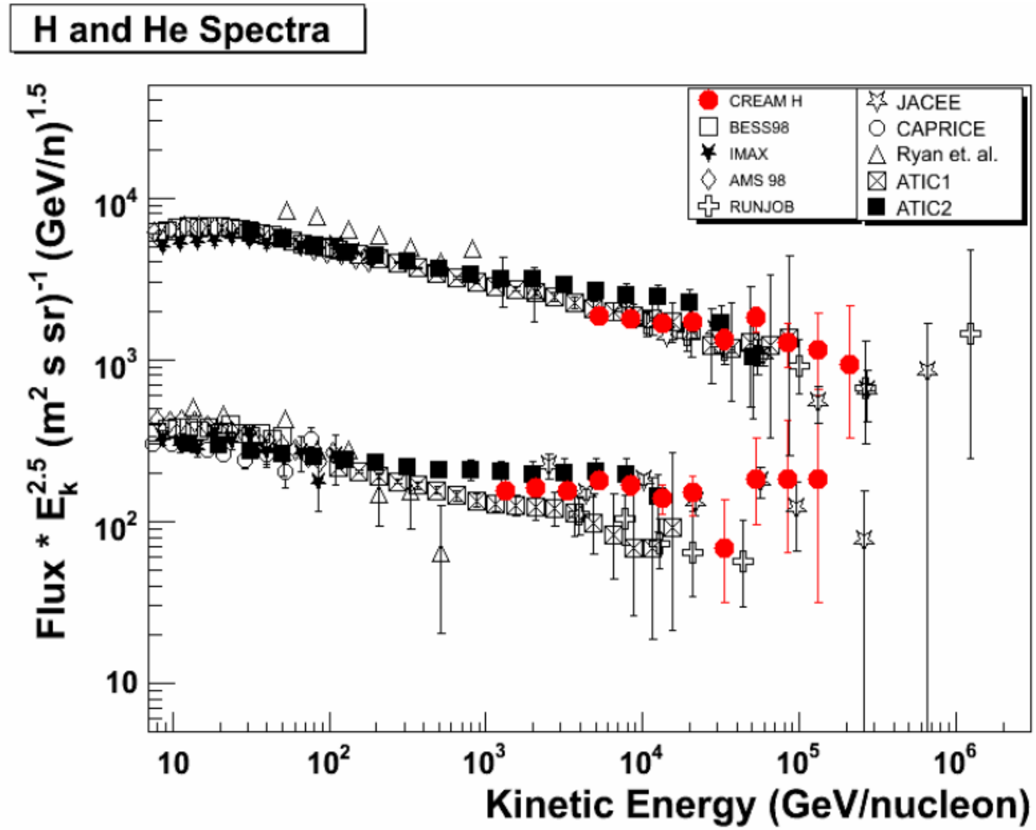
From top to bottom, 0.1 < Ek < 0.32 ⋯ 3.2 < Ek < 10 GeV

Atmnc3 v090711 (Tsim < 1000s, IGRF05+3.5, Rsim < 10Re, Log Color Histogram)



From top to bottom, 0.1 < Ek < 0.32 ⋯ 3.2 < Ek < 10 GeV

Interaction model and primary flux above 1TeV



CREAM

Soudan II

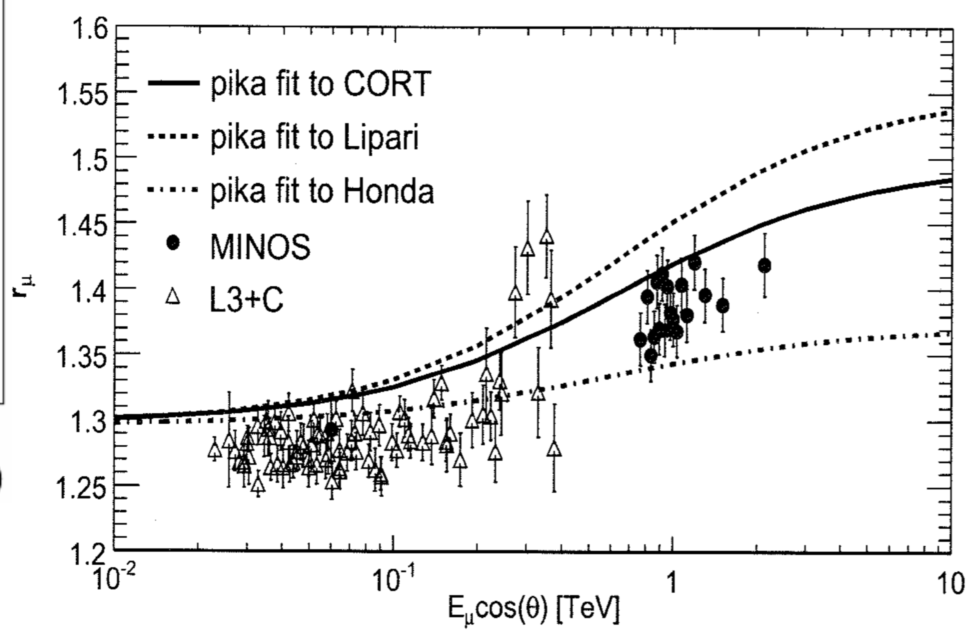


Figure 16: Fits of the pika formula to the three models of the charge ratio vs $E_\mu^{surface} \cos\theta$ compared to L3+C and MINOS data sets.

当面の目標

•現在のスキームの計算を完成させる。

近い将来の目標

•高エネルギー大気ニュートリノの再計算

EPOS2.? の導入
チャーム粒子の寄与の見積り
一次宇宙線のモデルの再検討

＝＞10TeV以上の大気ニュートリノフラックス

•人工衛星軌道上での粒子観測との精密な比較。